GEOS-Chem Reference, Volume 3: "Core" Modules and Routines

GEOS-Chem Support Team

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Contents

1 Routine/Function Prologues

1.1 Fortran: Module Interface GEOS-Chem include files

Here follows a list of include files used by the GEOS-Chem modules and subroutines.

1.2 Fortran: Module Interface CMN_SIZE

CMN_SIZE contains size parameters for GEOS-Chem arrays.

INTERFACE:

```
      MODULE CMN_SIZE_MOD
```

USES:

```
      IMPLICIT NONE
      PUBLIC
```

DEFINED PARAMETERS:

```
      !=================================================================
      ! DISIZE = size (in degrees) of a longitude grid box
      ! DJSIZE = size (in degrees) of a latitude  grid box
      !=================================================================
#if   defined( GRID4x5 )
      REAL*8, PARAMETER :: DISIZE = 5.0d0
      REAL*8, PARAMETER :: DJSIZE = 4.0d0
#elif defined( GRID2x25 )
      REAL*8, PARAMETER :: DISIZE = 2.5d0
      REAL*8, PARAMETER :: DJSIZE = 2.0d0
#elif defined( GRID1x125 )
      REAL*8, PARAMETER :: DISIZE = 1.25d0
      REAL*8, PARAMETER :: DJSIZE = 1.0d0
#elif defined( GRID1x1 )
      REAL*8, PARAMETER :: DISIZE = 1.0d0
      REAL*8, PARAMETER :: DJSIZE = 1.0d0
#elif defined( GRID05x0666 )
      REAL*8, PARAMETER :: DISIZE = 2d0/3d0
      REAL*8, PARAMETER :: DJSIZE = 0.5d0
#elif defined( GRID025x03125)
      REAL*8, PARAMETER :: DISIZE = 0.3125d0
      REAL*8, PARAMETER :: DJSIZE = 0.25d0
#elif defined( EXTERNAL_GRID )
      REAL*8            :: DISIZE
      REAL*8            :: DJSIZE
#endif

      !=================================================================
      ! GRID SETTINGS #1: Necessary for the grid-independent GEOS-Chem
```

```
      !=================================================================
      INTEGER             :: I_LO         ! Minimum lon index on this CPU
      INTEGER             :: J_LO         ! Minimum lat index on this CPU
      INTEGER             :: I_HI         ! Maximum lon index on this CPU
      INTEGER             :: J_HI         ! Maximum lat index on this CPU
      INTEGER             :: IM_WORLD     ! # of lons in the whole global grid
      INTEGER             :: JM_WORLD     ! # of lats in the whole global grid
      INTEGER             :: LM_WORLD     ! # of levs in the whole global grid
      REAL*8, ALLOCATABLE :: DLON(:,:,:)  ! Array of delta-longitude [degrees]
      REAL*8, ALLOCATABLE :: DLAT(:,:,:)  ! Array of delta-latitude  [degrees]

      !=================================================================
      ! GRID SETTINGS #2: Mostly historical declarations (keep for now)
      ! IGLOB      = global longitude dimension
      ! JGLOB      = global latitude dimension
      ! LGLOB      = max number of sigma levels
      ! IIPAR      = window longitude dimension
      ! JJPAR      = window latitude dimension
      ! LLPAR      = window vertical dimension
      ! LLTROP     = maximum number of tropospheric levels for variable
      !              tropopause
      ! LLTROP_FIX = number of tropospheric levels for offline simulations
      ! PTOP       = model top pressure (mb)
      ! Most of the time, GEOS-CHEM is used for global simulations.
      ! In this case, then IIPAR=IGLOB, JJPAR=JGLOB, LLPAR=LGLOB.
      ! For nested grids, then IIPAR<IGLOB, JJPAR<JGLOB, LLPAR<LGLOB.
      !=================================================================
#if   defined( GCAP ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GCAP: 4 x 5
      !-----------------------------------------------------------------
      INTEGER             :: IGLOB      = 72
      INTEGER             :: JGLOB      = 45
      INTEGER             :: LGLOB      = 23
      INTEGER             :: IIPAR
      INTEGER             :: JJPAR
      INTEGER             :: LLPAR
      INTEGER, PARAMETER  :: LLTROP     = 12
      INTEGER, PARAMETER  :: LLTROP_FIX = LLTROP
      REAL*8,  PARAMETER  :: PTOP       = 0.002d0

#elif defined( GEOS_4 ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GEOS-4: 4 x 5
      !-----------------------------------------------------------------
      INTEGER             :: IGLOB      = 72
```

```
      INTEGER            :: JGLOB      = 46
      INTEGER            :: LGLOB      = 55
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 30        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP     = 22        !  -- 30 levels
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP     = 23        !  -- 55 levels
#endif
      INTEGER, PARAMETER :: LLTROP_FIX = 17
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_4 ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! GEOS-4: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 144
      INTEGER            :: JGLOB      = 91
      INTEGER            :: LGLOB      = 55
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 30        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP     = 22        !  -- 30 levels
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP     = 23        !  -- 55 levels
#endif
      INTEGER, PARAMETER :: LLTROP_FIX = 17
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_4 ) && defined( GRID1x125 )

      !-----------------------------------------------------------------
      ! GEOS-4: 1 x 1.2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 288
      INTEGER            :: JGLOB      = 181
      INTEGER            :: LGLOB      = 55
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 30        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP     = 22        !  -- 30 levels
#else
```

```
      INTEGER            :: LLPAR                 ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP     = 23       !  -- 55 levels
#endif
      INTEGER, PARAMETER :: LLTROP_FIX = 17
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GEOS-5: 4 x 5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 72
      INTEGER            :: JGLOB      = 46
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47       ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38       !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                 ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40       !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! GEOS-5: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 144
      INTEGER            :: JGLOB      = 91
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47       ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38       !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                 ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40       !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0
```

```
#elif defined( GEOS_5 ) && defined( GRID1x125 )
      !-----------------------------------------------------------------
      ! GEOS-5: 1 x 1.25
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 288
      INTEGER            :: JGLOB      = 181
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_5 ) && defined( GRID05x0666 )

      !-----------------------------------------------------------------
      ! GEOS-5: 0.5 x 0.666
      !-----------------------------------------------------------------
#if   defined( NESTED_CH )
      INTEGER            :: IGLOB      = 121       ! NESTED CHINA   0.5x0.666
      INTEGER            :: JGLOB      = 133
      INTEGER            :: LGLOB      = 72
#elif defined( NESTED_NA )
      INTEGER            :: IGLOB      = 151       ! NESTED N.AMER. 0.5x0.666
      INTEGER            :: JGLOB      = 121
      INTEGER            :: LGLOB      = 72
#elif defined( NESTED_EU )
      INTEGER            :: IGLOB      = 121       ! NESTED EUROPE  0.5x0.666
      INTEGER            :: JGLOB      = 81
      INTEGER            :: LGLOB      = 72
#endif
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
```

```
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( MERRA ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! MERRA: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 144
      INTEGER            :: JGLOB      = 91
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( MERRA ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! MERRA: 4 x 5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 72
      INTEGER            :: JGLOB      = 46
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_FP ) && defined( GRID025x03125 ) && defined( NESTED_CH )

      !-----------------------------------------------------------------
```

```
      ! GEOS-FP: Nested China Grid
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 225
      INTEGER            :: JGLOB      = 161
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR      = IGLOB
      INTEGER            :: JJPAR      = JGLOB
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_FP ) && defined( GRID025x03125 ) && defined( NESTED_NA)

      !-----------------------------------------------------------------
      ! GEOS-FP Nested NA Grid
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 225
      INTEGER            :: JGLOB      = 202
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_FP ) && defined( GRID2x25 )

      !-----------------------------------------------------------------
      ! GEOS-FP: 2 x 2.5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 144
      INTEGER            :: JGLOB      = 91
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
```

```
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined( GEOS_FP ) && defined( GRID4x5 )

      !-----------------------------------------------------------------
      ! GEOS-FP: 4 x 5
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB      = 72
      INTEGER            :: JGLOB      = 46
      INTEGER            :: LGLOB      = 72
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
#if   defined( GRIDREDUCED )
      INTEGER            :: LLPAR      = 47        ! Reduced vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 38        !  -- 47 levels
      INTEGER, PARAMETER :: LLTROP     = 38
#else
      INTEGER            :: LLPAR                  ! Full vertical grid
      INTEGER, PARAMETER :: LLTROP_FIX = 40        !  -- 72 levels
      INTEGER, PARAMETER :: LLTROP     = 40
#endif
      REAL*8,  PARAMETER :: PTOP       = 0.01d0

#elif defined ( EXTERNAL_GRID ) || defined( EXTERNAL_FORCING )
      !-----------------------------------------------------------------
      !     %%%%% CONNECTING TO GEOS-5 GCM via ESMF INTERFACE %%%%%
      ! We need to make all of these be variables rather than
      ! parameters, so that they can be defined directly from the
      ! ESMF interface. (bmy, 10/11/12)
      !-----------------------------------------------------------------
      INTEGER            :: IGLOB
      INTEGER            :: JGLOB
      INTEGER            :: LGLOB
      INTEGER            :: IIPAR
      INTEGER            :: JJPAR
      INTEGER            :: LLPAR
      INTEGER            :: LLTROP_FIX
      INTEGER            :: LLTROP
```

```
      REAL*8,  PARAMETER :: PTOP       = 0.01d0
#endif

      !-----------------------------------------------------------------
      ! For GEOS 1x1 files
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: I1x1       = 360
      INTEGER, PARAMETER :: J1x1       = 181

      !-----------------------------------------------------------------
      ! For GEOS 05x0666 files
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: I05x0666   = 540
      INTEGER, PARAMETER :: J05x0666   = 361

      !-----------------------------------------------------------------
      ! For GFED3
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: IGFED3     = 720
      INTEGER, PARAMETER :: JGFED3     = 360

      !=================================================================
      ! TRACER & EMISSION SPECIES PARAMETERS
      ! NNPAR   = max number of tracers
      ! NEMPARA = max number of anthropogenic emission species
      ! NEMPARB = max number of biogenic      emission species
      !=================================================================
      ! increase NNPAR and NEMPARA an extra amount (hotp 7/31/09)
#if   defined( TOMAS )
# if    defined( TOMAS40 )
      INTEGER, PARAMETER :: NNPAR   = 430   ! For TOMAS40 (sfarina 6/11/13)
# elif  defined( TOMAS15 )
      INTEGER, PARAMETER :: NNPAR   = 205   ! For TOMAS15 (sfarina 6/11/13)
# elif  defined( TOMAS12 )
      INTEGER, PARAMETER :: NNPAR   = 178   ! For TOMAS12 (sfarina 6/11/13)
# else
      INTEGER, PARAMETER :: NNPAR   = 340   ! For TOMAS (win, bmy, sfarina 6/11/13)
# endif
#elif defined( APM )
      INTEGER, PARAMETER :: NNPAR   = 154   ! For APM (G. Luo, 3/8/11)
#else
      INTEGER, PARAMETER :: NNPAR   = 125   ! For non-TOMAS simulations
#endif

      ! Nempara increased to 26. (fp, 2/8/10)
      ! new emissions HNO3 and O3 (phs)
      !  Add non-biogenic emission species:
      !  BENZ, TOLU, XYLE, C2H2, C2H4, GLYX, MGLY, GLYC, HAC. (tmf, 1/7/09)
```

```
      !INTEGER, PARAMETER :: NEMPARA = 21
      !  Add RCHO, HCOOH, ACTA
      !INTEGER, PARAMETER :: NEMPARA = 26
      INTEGER, PARAMETER :: NEMPARA = 29
      INTEGER, PARAMETER :: NEMPARB = 20

      !=================================================================
      ! OTHER PARAMETERS
      !=================================================================

      ! NVEGTYPE - Maximum number of surface types: 74 olson
      ! NTYPE    - Maximum number of veg types in a CTM grid box
      ! NPOLY    - Number of coefficients for polynomial fits
      INTEGER, PARAMETER :: NVEGTYPE = 74
#if defined( EXTERNAL_GRID ) || defined( EXTERNAL_TYPE )
      !-----------------------------------------------------------------
      !     %%%%% CONNECTING TO GEOS-5 GCM via ESMF INTERFACE %%%%%
      ! For testing the ESMF interface to GEOS-Chem with a grid that
      ! is smaller than the usual 72x46, increase NTYPE (bmy, 12/4/12)
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: NTYPE    = 50
#else
      !-----------------------------------------------------------------
      !              %%%%% TRADITIONAL GEOS-Chem %%%%%
      ! Current practice in the std GEOS-Chem is to set NTYPE to 25,
      ! which is large enough if using the Olson 2001 land map at
      ! 0.25 x 0.25 resolution. (bmy, 12/4/12)
      !-----------------------------------------------------------------
      INTEGER, PARAMETER :: NTYPE    = 25
#endif
      INTEGER, PARAMETER :: NPOLY    = 20

      ! NNSTA = max number of time series stations (in inptr.ctm)
      INTEGER, PARAMETER :: NNSTA = 800

      ! MAXIJ - Maximum number of 1st level grid boxes
      INTEGER :: MAXIJ

      ! LLCONVM - Max number of layers for convection
      INTEGER :: LLCONVM

      ! NOXLEVELS = Number of levels of anthro NOx emission
      !             (e.g. surface and 100m)
      ! NOXEXTENT = Highest sigma level that receives anthro NOx emission
      INTEGER, PARAMETER :: NOXLEVELS = 2
      INTEGER, PARAMETER :: NOXEXTENT = 2

      ! MAXFAM -- Max number of families for prod and loss output
```

```
      INTEGER, PARAMETER :: MAXFAM = 40

      ! MAXMEM is maximum number of families of prod and loss
      ! moved from input_mod and diag_pl_mod to here (hotp 7/31/09)
      ! MAXMEM also increased from 10 to 20 by FP
      ! MAXMEM increased from 20 to 22 for bromine (jpp, mpayer, 12/28/11)
      INTEGER, PARAMETER :: MAXMEM = 22

      ! MAXPL increased from 100 to 500 and moved from diag_pl_mod
      ! to here by FP (hotp 7/31/09)
      INTEGER, PARAMETER :: MAXPL = 500


      ! NDUST -- Number of FAST-J aerosol size bins (rvm, bmy, 11/15/01)
      INTEGER, PARAMETER :: NDUST = 7

      ! NAER -- number of other aerosol categories (rvm, bmy, 2/27/02)
      INTEGER, PARAMETER :: NAER = 5

      ! NRH -- number of relative humidity bins (rvm, bmy, 2/27/02)
      INTEGER, PARAMETER :: NRH = 5

      !NBIOMAX -- biomass burning
      ! increase NBIOMAX to 20 (hotp 7/31/09)
      ! increase NBIOMAX to 24 for dicarbonyls (ccc, 2/02/10)
      ! increase NBIOMAX to 25 fpr CH4 (kjw)
      ! SOAupdate: add 1 for naphthalene, now 26 (hotp 7/21/10)
      INTEGER, PARAMETER :: NBIOMAX = 26

#if   defined( TOMAS )
      INTEGER, PARAMETER :: TOMASSPEC = 8

# if  defined( TOMAS40 )
      INTEGER, PARAMETER :: NDSTBIN   = 40
      INTEGER, PARAMETER :: TOMASBIN  = 40
# elif  defined( TOMAS15 )
      INTEGER, PARAMETER :: NDSTBIN   = 15
      INTEGER, PARAMETER :: TOMASBIN  = 15
# elif  defined( TOMAS12 )
      INTEGER, PARAMETER :: NDSTBIN   = 12
      INTEGER, PARAMETER :: TOMASBIN  = 12
# else
      ! NDSTBIN -- redimensioned for TOMAS (dwest, bmy, 2/1/10)
      INTEGER, PARAMETER :: NDSTBIN   = 30
      INTEGER, PARAMETER :: TOMASBIN  = 30 ! Number of TOMAS bins
# endif

#else
```

```
      ! NDSTBIN -- number of dust size bins for transport (tdf, bmy, 3/31/04)
      INTEGER, PARAMETER :: NDSTBIN   = 4
#endif
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%% NOTE: THIS WAS MADE INTO A MODULE IN ORDER TO REMOVE COMMON BLOCKS  %%%
%%% WE WILL KEEP THIS FOR NOW.  EVENTUALLY WE MIGHT MIGRATE THESE DATA  %%%
%%% INTO A DERIVED TYPE OBJECT. (bmy, 12/3/12)                          %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
(1 ) Now set LLTROP = 20 for GEOS-3 (bmy, 4/12/01)
(2 ) Eliminated obsolete commented-out code (bmy, 4/20/01)
(3 ) Now set MAXFAM = 12 for more P-L families (bmy, 6/28/01)
(4 ) Comment out {IJL}GCMPAR -- these are obosolete (bmy, 9/24/01)
(5 ) Also set LLPAR = 30 for GEOS-3, will regrid online (bmy, 9/24/01)
(6 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(7 ) Removed NAIR, LAIREMS, these are now defined
      in "aircraft_nox_mod.f" (bmy, 2/14/02)
(8 ) Eliminated commented-out code from 2/14/02.  Also added NAER
      and NRH parameters for aerosols. (rvm, bmy, 2/27/02)
(9 ) Removed IM, JM, IMX, JMX to avoid namespace pollution.  This
      is needed to get the new TPCORE to work.  Also changed RCS
      ID tag comment character from "C" to "!" to allow freeform
      compilation. (bmy, 6/25/02)
(10) Removed obsolete code from 6/02 (bmy, 8/26/02)
(11) Added NUMDEP_SULF in a common block for sulfate dry deposition.
      Also set MAXDEP=31 and NNPAR=31 for coupled fullchem/sulfate
      simulations. (rjp, bdf, bmy, 11/15/02)
(12) Removed I0, J0; these are now superseded by "grid_mod.f"
      (bmy, 2/11/03)
(13) Added parameters for GEOS-4 (bmy, 6/18/03)
(14) Now defines both 55 level and 30 level GEOS-4 grids.  Also
      define LLTROP=19 for GEOS-4 grids.  Also remove obsolete
      GEOS-2 grid declarations. (bmy, 10/31/03)
(15) LLTROP should be 17 for GEOS-4...based on the ND55 diagnostic
      when computed for 2003 met fields (bmy, 2/18/04)
(16) Increase NNPAR from 31 to 39 for carbon & dust tracers.  Also
      declare NDSTBIN as # of dust bins. (rvm, tdf, bmy, 4/1/04)
(17) Increase NNPAR to 41 for seasalt tracers (rjp, bec, bmy, 4/20/04)
(18) Increase NNPAR to 50 for SOA tracers (rjp, bmy, 7/15/04)
(19) Now use NESTED_CH and NESTED_NA cpp switches to define
      parameters for 1x1 nested grids.  Also add parameters for
      the 1 x 1.25 global grid. (bmy, 12/1/04)
(20) Now add parameters for GCAP and GEOS-5 grids.  Remove references
      to obsolete LGEOSCO and FULLCHEM Cpp switches (bmy, 6/24/05)
```

```
(21) Now add I1x1 and J1x1 parameters for data on the 1x1 GEOS
     grid. (bmy, 10/24/05)
(22) Increase NNPAR to 52 (bmy, 12/6/05)
(23) Increase NNPAR to 54 (dkh, bmy, 5/22/06)
(24) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(25) Added variable tropopause case (bmy, phs, bdf, 8/21/06)
(26) Set LLTROP to level of first box entirely above 20km for GEOS-3
     and GEOS-4 (phS, 9/14/06)
(27) Bug fix: set LLTROP_FIX = LLPAR for GCAP (bmy, 11/29/06)
(28) Reset vertical coordinates for GEOS-5.  Also renamed GRID30LEV
     to GRIDREDUCED (bmy, 4/3/07)
(29) New parameters for GEOS-5 nested grid (yxw, dan, bmy, 11/6/08)
(30) NEMPARA set to 12 to emit O3 and HNO3 (phs, 4/3/08)
(31) Add tracers to NNPAR = 73. (tmf, 1/7/09)
(32) NEMPARA set to 21 to emit new tracers for GLYX chemistry
     (tmf, ccc, 3/2/09)
(33) NEMPARB set to 3 to emit MBO, MONX (tmf, ccc, 3/2/09)
(34) Added EUROPE grid parameters (amv, 10/19/09)
18 Dec 2009 - Aaron van D - Added NESTED_EU grid parameters
18 Dec 2009 - R. Yantosca - Added ProTeX headers
25 Jan 2010 - R. Yantosca - Set NNPAR=320 for TOMAS simulations
25 Jan 2010 - R. Yantosca - Define TOMASBIN and TOMASSPEC for TOMAS sims
08 Feb 2010 - F. Paulot   - Increase NNPAR, NEMPARA and NEMPARB
08 Feb 2010 - F. Paulot   - Move MAXMEM and MAXPL from diag_pl_mod.
30 Nov 2010 - R. Yantosca - Increase LLTROP (from 38 to 40) for GEOS-5 and
                            MERRA for the full 72-layer grids (i.e. when
                            the Cpp switch GRIDREDUCED is not set).
09 Mar 2011 - R. Yantosca - Updated NNPAR for APM (G. Luo)
23 Aug 2011 - M. Long     - Converted to Module from Header file
27 Dec 2011 - M. Payer    - Updated NNPAR, NEMPARB, MAXMEM for bromine
                            chemistry (J. Parrella)
10 Feb 2012 - R. Yantosca - Added #if blocks for GEOS-5.7.x nested CH grid
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
27 Mar 2012 - R. Yantosca - Increase NTYPE from 15 to 25 for Olson 2001 map
22 Oct 2012 - M. Payer    - Increase NNPAR to 100 for tagged Hg simulation
                            (E. Corbitt)
25 Oct 2012 - R. Yantosca - Now also set LLPAR, LLTROP, LLTROP_FIX to
                            LGLOB for grid-independent simulation
19 Nov 2012 - R. Yantosca - Renamed to INIT_CMN_SIZE, to better follow
                            adopted GEOS-Chem naming convention
27 Nov 2012 - R. Yantosca - Removed commented out code
05 Jun 2013 - R. Yantosca - Now define GEOS-5 0.25x0.3125 nested NA grid
13 Aug 2013 - M. Sulprizio- Increase NNPAR & NBIOMAX for updated SOA and
                            SOA + semivolatile POA simulations (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.2.1 init_cmn_size

Routine INIT_CMN_SIZE initializes the grid dimension values in module CMN_SIZE_mod.F.

INTERFACE:

```
 SUBROUTINE Init_CMN_SIZE( am_I_Root,      RC,
&                          value_I_LO,     value_J_LO,
&                          value_I_HI,     value_J_HI,
&                          value_IM,       value_JM,
&                          value_LM,       value_IM_WORLD,
&                          value_JM_WORLD, value_LM_WORLD  )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root        ! Are we on the root CPU?
INTEGER, OPTIONAL    :: value_I_LO       ! Lower lon index on this CPU
INTEGER, OPTIONAL    :: value_J_LO       ! Lower lat index on this CPU
INTEGER, OPTIONAL    :: value_I_HI       ! Upper lon index on this CPU
INTEGER, OPTIONAL    :: value_J_HI       ! Upper lat index on this CPU
INTEGER, OPTIONAL    :: value_IM         ! # of lons   on this CPU
INTEGER, OPTIONAL    :: value_JM         ! # of lats   on this CPU
INTEGER, OPTIONAL    :: value_LM         ! # of levels on this CPU
INTEGER, OPTIONAL    :: value_IM_WORLD   ! # of lons in the global grid
INTEGER, OPTIONAL    :: value_JM_WORLD   ! # of lats in the global grid
INTEGER, OPTIONAL    :: value_LM_WORLD   ! # of levs in the global grid
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
15 Oct 2012 - M. Long     - Initial version
15 Oct 2012 - R. Yantosca - Added ProTeX Headers, use F90 format/indents
22 Oct 2012 - R. Yantosca - Renamed to GIGC_Init_Dimensions
03 Dec 2012 - R. Yantosca - Rewritten for clarity.  Also pass optional
                            arguments to carry values from ESMF environment
03 Dec 2012 - R. Yantosca - Now allocate DLON, DLAT arrays here.
```

1.2.2 cleanup_cmn_size

Subroutine CLEANUP_CMN_SIZE deallocates all module arrays.

INTERFACE:

```
SUBROUTINE Cleanup_CMN_SIZE( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
3 Dec 2012 - R. Yantosca - Initial version
```

1.3 Fortran: Module Interface CMN_DIAG_mod

Module CMN_DIAG_mod contains size parameters and global variables for the GEOS-Chem diagnostic arrays. This is mostly historical baggage.

INTERFACE:

```
MODULE CMN_DIAG_MOD
```

USES:

```
USE CMN_SIZE_MOD

IMPLICIT NONE
PUBLIC
```

DEFINED PARAMETERS:

```
!=================================================================
! Maximum sizes of diagnostic arrays
! Changed PD66 to 6  (bmy, 9/8/00)
! Changed PD21 to 10 (bmy, 9/30/00)
! Changed PD67 to 18 (bmy, 10/11/00)
! Changed PD46 to 4  (bmy, 1/2/01)
! Changed PD29 to 5  (bmy, 1/2/01)
! Changed PD11 to 7  (bmy, 9/4/01)
! Changed PD32 to 0  (bmy, 2/14/02)
! Changed PD21 to 20 (bmy, 2/27/02)
! Changed PD43 to 4  (bmy, 3/4/02)
! Changed PD05 to 10 (bmy, 10/18/02)
! Changed PD44 to 30 (bmy, 11/19/02)
! Changed PD43 to 5
```

```
! Changed PD67 to 22 (bmy, 6/23/03)
! Changed PD66 to 5  (bmy, 6/23/03)
! Changed PD03 to 5  (bmy, 8/20/03)
! Changed PD37 to 10 (bmy, 1/21/04)
! Changed PD06 to NDSTBIN (bmy, 4/5/04)
! Changed PD07 to 7  (bmy, 4/5/04)
! Changed PD08 to 2  (bmy, 4/20/04)
! Changed PD07 to 12 (bmy, 7/15/04)
! Changed PD21 to 26 (bmy, 1/5/05)
! Removed PD03 -- now in "diag03_mod.f" (bmy, 1/21/05)
! Removed PD41 -- now in "diag41_mod.f" (bmy, 1/21/05)
! Now set PD09 to 6 (bmy, 6/27/05)
! Removed PD04 -- now in "diag04_mod.f" (bmy, 7/26/05)
! Now set PD30 to 1 (bmy, 8/18/05)
! Now set PD46 to 6 (tmf, 1/20/09)
! Now set PD10 to 20 (phs, 9/18/07)
! Changed PD17 to 8 (tmf, 1/7/09)
! Changed PD18 to 8 (tmf, 1/7/09)
! Changed PD22 to 8 (tmf, 1/7/09)
! Changed PD37 to 35 (tmf, 1/7/09)
! Changed PD38 to 35 (tmf, 1/7/09)
! Changed PD39 to 35 (tmf, 1/7/09)
! Changed PD44 to 41 (tmf, 1/7/09)
! Now set PD52 to 1 (jaegle 2/26/09)
! Increase PD46 from 6 to 13 (mpb, ccc, 11/19/09)
! increase PD21 from 20 to 27 (clh, 05/06/10)
! changed PD44 (drydep) to 53 (jpp, 6/13/09)
! changed PD39 (wetdep) to 38 (jpp, 7/08/09)
! Now set PD46 to 16 (jpp, 6/7/09)
! Changed PD11 from 7 to 5 (efischer, mpayer, 3/19/12)
! SOAupdate: PD46 increased from 16 to 20 (hotp 3/1/10)
!=================================================================
INTEGER, PARAMETER :: PD01=3
INTEGER, PARAMETER :: PD02=3
INTEGER, PARAMETER :: PD05=10
INTEGER, PARAMETER :: PD06=NDSTBIN
! +3 for SEAC4RS SOA tracers (jaf, 6/25/13)
INTEGER, PARAMETER :: PD07=15
INTEGER, PARAMETER :: PD08=2
INTEGER, PARAMETER :: PD09=6
INTEGER, PARAMETER :: PD10=20
INTEGER, PARAMETER :: PD11=5
INTEGER, PARAMETER :: PD12=0
INTEGER, PARAMETER :: PD13=1
INTEGER, PARAMETER :: PD14=NNPAR
INTEGER, PARAMETER :: PD15=NNPAR
INTEGER, PARAMETER :: PD16=2
INTEGER, PARAMETER :: PD17=8
```

```
      INTEGER, PARAMETER :: PD18=8
      INTEGER, PARAMETER :: PD19=0
      INTEGER, PARAMETER :: PD20=0
      INTEGER, PARAMETER :: PD21=27
      INTEGER, PARAMETER :: PD22=14      !jpp replaced 8, 4/24/2011... for Br.
      INTEGER, PARAMETER :: PD23=0
      INTEGER, PARAMETER :: PD24=NNPAR
      INTEGER, PARAMETER :: PD25=NNPAR
      INTEGER, PARAMETER :: PD26=NNPAR
      INTEGER, PARAMETER :: PD27=1
      INTEGER, PARAMETER :: PD28=0
      INTEGER, PARAMETER :: PD29=5
      INTEGER, PARAMETER :: PD30=1
      INTEGER, PARAMETER :: PD31=1
      INTEGER, PARAMETER :: PD32=1
      INTEGER, PARAMETER :: PD33=NNPAR
      INTEGER, PARAMETER :: PD34=2
      INTEGER, PARAMETER :: PD35=NNPAR
      INTEGER, PARAMETER :: PD36=NNPAR
      INTEGER, PARAMETER :: PD37=35
      INTEGER, PARAMETER :: PD38=35
      INTEGER, PARAMETER :: PD39=38      !jpp replaced 35
      INTEGER, PARAMETER :: PD40=4
      INTEGER, PARAMETER :: PD43=5
      INTEGER, PARAMETER :: PD44=53      !jpp replaced 41
      INTEGER, PARAMETER :: PD45=NNPAR+1
      INTEGER, PARAMETER :: PD46=20
      INTEGER, PARAMETER :: PD47=NNPAR+1
      INTEGER, PARAMETER :: PD48=2
      INTEGER, PARAMETER :: PD49=0
      INTEGER, PARAMETER :: PD50=0
      INTEGER, PARAMETER :: PD51=0
      INTEGER, PARAMETER :: PD52=1
      INTEGER, PARAMETER :: PD54=0
      INTEGER, PARAMETER :: PD55=3
      ! Potential temperature diagnostic (hotp 7/31/09)
      INTEGER, PARAMETER :: PD57=1
      INTEGER, PARAMETER :: PD58=12
#if   defined( TOMAS )
      ! Special settings for TOMAS aerosol microphysics (win, bmy, 1/22/10)
      INTEGER, PARAMETER :: PD59=TOMASBIN*TOMASSPEC
      INTEGER, PARAMETER :: PD60=TOMASBIN*TOMASSPEC
      INTEGER, PARAMETER :: PD61=2
#else
      ! Normal settings for non-TOMAS simulations
      INTEGER, PARAMETER :: PD59=0
      INTEGER, PARAMETER :: PD60=1
      INTEGER, PARAMETER :: PD61=0
```

```
#endif
      INTEGER, PARAMETER :: PD62=NNPAR
      INTEGER, PARAMETER :: PD63=0
      INTEGER, PARAMETER :: PD64=0
      INTEGER            :: PD65
      INTEGER, PARAMETER :: PD66=6
      INTEGER, PARAMETER :: PD67=23 ! (Lin, 31/03/09)
      INTEGER, PARAMETER :: PD68=4
      INTEGER, PARAMETER :: PD69=1
      INTEGER, PARAMETER :: PD70=0

      !=================================================================
      ! Variables for printing out selected tracers in diagnostic output
      !=================================================================
      INTEGER, PARAMETER :: MAX_DIAG   = 70
#if   defined( TOMAS )
      INTEGER, PARAMETER :: MAX_TRACER = NNPAR+1   ! For TOMAS (win, 1/25/10)
#elif defined( APM )
      INTEGER, PARAMETER :: MAX_TRACER = NNPAR+100 ! For APM (G. Luo 3/8/11)
#else
      INTEGER, PARAMETER :: MAX_TRACER = NNPAR+6   ! For non-TOMAS simulations
#endif
```

PUBLIC DATA MEMBERS:

```
      !=================================================================
      ! Diagnostic counters & time variables
      !=================================================================
      INTEGER :: KDA48, NJDAY(366)

      !=================================================================
      ! Variables for the number of levels in multi-level diagnostics
      ! Removed LD03 -- this is now in diag03_mod.f (bmy, 1/21/05)
      ! Added LD09 (bmy, 6/27/05)
      ! Added LD54 (phs, 9/22/06)
      ! Added LD10 (phs, 9/18/07)
      ! Added LD31 (bmy, 5/8/07)
      ! Added LD52 (jaegle, 02/26/09)
      ! Added LD59, LD60, LD61 (bmy, 1/22/10)
      ! Added LD57 (hotp 7/31/09)
      !=================================================================
      INTEGER :: LD12, LD13, LD14, LD15, LD16, LD17, LD18, LD21, LD22
      INTEGER :: LD24, LD25, LD26, LD37, LD38, LD39, LD43, LD45, LD47
      INTEGER :: LD54, LD64, LD65, LD66, LD68, LD01, LD02, LD05, LD07
      INTEGER :: LD09, LD10, LD31, LD52, LD19, LD57, LD58, LD59, LD60
      INTEGER :: LD61, LD62

      !=================================================================
```

```
! NDxx diagnostic flags
!=================================================================
INTEGER :: ND01, ND02, ND05, ND06, ND07, ND08, ND09, ND10, ND11
INTEGER :: ND12, ND13, ND14, ND15, ND16, ND17, ND18, ND19, ND20
INTEGER :: ND21, ND22, ND23, ND24, ND25, ND26, ND27, ND28, ND29
INTEGER :: ND30, ND31, ND32, ND33, ND34, ND35, ND36, ND37, ND38
INTEGER :: ND39, ND40, ND43, ND44, ND45, ND46, ND47, ND48, ND49
INTEGER :: ND50, ND51, ND52, ND54, ND55, ND57, ND58, ND59
INTEGER :: ND60, ND61, ND62, ND63, ND64, ND65, ND66, ND67, ND68
INTEGER :: ND69, ND70, ND71, ND72, ND73, ND74, ND75

!=================================================================
! Variables for printing out selected tracers in diagnostic output
!=================================================================
INTEGER :: TINDEX(MAX_DIAG,MAX_TRACER)
INTEGER :: TCOUNT(MAX_DIAG)
INTEGER :: TMAX(MAX_DIAG)

!=================================================================
! OH, J-Value, and 2-PM diagnostic arrays (bmy, 9/25/98)
! Move this here for now (bmy, 7/20/04)
! Removed HR1_NO and HR2_NO (mpayer, 11/8/13)
!=================================================================
REAL*8  :: HR1_JV, HR2_JV
REAL*8  :: HR1_OH, HR2_OH, HR1_OTH, HR2_OTH
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE IS DEPRECATED.  MANY OF THE QUANTITIES STORED  %%%
%%%  in CMN_DIAG_MOD ARE NOW INCLUDED IN THE INPUT OPTIONS OBJECT,    %%%
%%%  BASED ON THE DERIVED TYPE IN Headers/gigc_input_opt_mod.F90.     %%%
%%%  (bmy, 11/19/12)                                                 %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
(1 ) Changed RCS ID tag comment character from "C" to "!" to allow freeform
      compilation.  Also added & continuation characters in column 73
      to allow header files to be included in F90 freeform files.
      Also converted PARAMETER statements to F90 syntax. (bmy, 6/25/02)
(2 ) Add LD05 for sulfate prod/loss (rjp, bdf, bmy, 9/20/02)
(3 )  Removed obsolete variables NTAU0, IDAY0, JDATE0, JYEAR0, KDACC,
       KDADYN, KDACONV, KDASRCE, KDACHEM, KDA3FLDS, KDA6FLDS, KDI6FLDS,
       KDKZZFLDS (bmy, 2/11/03)
(4 ) Fix for LINUX - remove & from column 73 (bmy, 6/27/03)
(5 ) Added LD03 for Kr85 Prod/loss diagnostic (bmy, 8/20/03)
(6 ) Removed obsolete arrays (bmy, 1/21/05)
(7 ) Rename MAXDIAG to MAX_DIAG and MAXTRACER to MAX_TRACER in order to
```

```
      avoid name conflicts with "gamap_mod.f" (bmy, 5/3/05)
(8 ) Remove reference to TRCOFFSET (bmy, 5/16/06)
(9 ) Added multi level LD54 to common CDIAG1 (phs, 9/22/06)
(10) Added multi level LD10 to common CDIAG1. Set PD10 to 20.  Set
      PD66 to 6. (phs, 9/18/07)
(11) Added LD52 to common CDIAG1 (jaegle, 02/26/09)
(12) Add GLYX, MGLY, SOAG, SOAM, and a few other tracers to AD17, AD18
      for archiving rainout and washout fraction. (tmf, 1/7/09)
(13) Add GLYX, MGLY J value archive. (tmf, 1/7/09)
(14) Add GLYX, MGLY, SOAG, SOAM, and a few other tracers to AD37, AD38,
      AD39
      for archiving rainout and washout flux. (tmf, 1/7/09)
(15) Add GLYX, MGLY, GLYC, 6 PANs, SOAG, SOAM dry dep,
      PD44 = 41.(tmf, 1/7/09)
(16) Add biogenic C2H4 emission, PD46 = 6. (tmf, 1/20/09)
(17) Add one met field to ND67 (EFLUX). (ccc, 5/14/09)
(18) Add declarations for PD58 and PD60, LD19, LD58. (kjw,8/18/09)
(19) Redimension PD59, PD60, PD61 for TOMAS microphysics.  Added LD59, LD60,
      LD61 to common block.  Reset MAX_TRACER to NNPAR+1 for TOMAS.
      (win, bmy, 1/22/10)
(20) Add LD57 and PD57 (potential temperature) (hotp, 3/15/10)
03 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Aug 2010 - P. Kasibhatla & R. Yantosca - Now set MAX_TRACER to NNPAR+6
                                            to match ND09 diagnostic
09 Mar 2011 - R. Yantosca - Updated MAX_TRACER for APM (G. Luo)
03 Aug 2011 - M. Long     - Converted from Header file to Module
08 Nov 2013 - M. Sulprizio- Remove HR1_NO and HR2_NO. They are no longer
                            needed for ND43 because NO, NO2, and NO3 are now
                            tracers.
```

1.3.1 init_cmn_diag

Subroutine INIT_CMN_DIAG initializes quantities based on the grid-independent size parameters.

INTERFACE:

```
SUBROUTINE Init_CMN_DIAG( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
      INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    19 Nov 2012 - R. Yantosca - Added ProTeX headers
```

1.4 Fortran: Module Interface CMN_GCTM_mod

CMN_GCTM_mod contains GEOS-Chem specific PHYSICAL CONSTANTS and DERIVED QUANTITIES.

INTERFACE:

```
      MODULE CMN_GCTM_MOD
```

USES:

```
      IMPLICIT NONE
      PUBLIC
```

DEFINED PARAMETERS:

```
      ! AIRMW : Molecular weight of air [28.97 g/mole]
      REAL*8, PARAMETER :: AIRMW  =  28.97d0

      ! g0    : Gravity at Surface of Earth [9.8 m/s^2]
      REAL*8, PARAMETER :: g0     =   9.8d0

      ! PI    : Double-Precision value of PI
      REAL*8, PARAMETER :: PI     =   3.14159265358979323d0

      ! Re    : Radius of Earth [m]
      REAL*8, PARAMETER :: Re     =   6.375d6

      ! Rd    : Gas Constant (R) in Dry Air [287 J/K/kg]
      REAL*8, PARAMETER :: Rd     = 287.0d0

      ! g0_100 = 100.0 / g0
      REAL*8, PARAMETER :: g0_100 = 100d0 / g0

      ! PI_180 = PI    / 180.0
      REAL*8, PARAMETER :: PI_180 =    PI / 180d0

      ! Rdg0   = Rd    / g0
      REAL*8, PARAMETER :: Rdg0   =    Rd / g0

      ! Scale height of atmosphere (7.6 km = 7600m)
      REAL*8, PARAMETER :: SCALE_HEIGHT = 7600d0
```

REVISION HISTORY:

```
25 Jun 2002 - R. Yantosca - Initial version
23 Aug 2011 - M. Long     - Converted to Module from Header file
```

1.5 Fortran: Module Interface CMN_NOX_mod

CMN_NOX_mod is the module file for containing NOx from soils.

INTERFACE:

```
MODULE CMN_NOX_MOD
```

USES:

```
USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR

IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
! NOTE: Keep this for backwards compatibility for now (bmy, 10/2/07)
! GEMISNOX2 = Soil Nox [molec NOx/cm3/s]
REAL*8, PUBLIC, ALLOCATABLE :: GEMISNOX2(:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: Init_CMN_NOX
PUBLIC :: Cleanup_CMN_NOX
```

REMARKS:

```
!%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
!%%%  NOTE: THIS MODULE IS DEPRECATED.  WE WILL PROBABLY PLACE THE  %%%
!%%%  MODULE ARRAYS INTO A NEW DERIVED TYPE FOR THE GIGC EMISSIONS  %%%
!%%%  COMPONENT. (bmy, 11/19/12)                                    %%%
!%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
05 Mar 1998 - M. Schultz - Initial version
(1 ) Changed RCS ID tags from "C" to "!" to allow
      freeform compilation.  (bmy, 6/25/02)
(2 ) Moved BXHEIGHT to "dao_mod.f".  The fact that BXHEIGHT
      was in "CMN_NOX" is historical baggage. (bmy, 9/18/02)
(3 ) Now everything except GEMISNOX, GEMISNOX2 is in
      "lightning_mod.f" (bmy, 4/14/04)
(4 ) Remove GEMISNOX from common block (ltm, bmy, 10/2/07)
23 Aug 2011 - M. Long    - Converted to Module from Header file
```

```
  !-------------------------------------------------------------------------
  !BOC
       CONTAINS
  !EOC
  !-------------------------------------------------------------------------
  !                  GEOS-Chem Global Chemical Transport Model             !
  !-------------------------------------------------------------------------
%!////////////////////////////////////////////////////////////

\mbox{}\hrulefill\


  \subsubsection [init\_cmn\_nox] {init\_cmn\_nox}


  Subroutine INIT\_CMN\_NOX allocates all module arrays.
  \\
  \\{\bf INTERFACE:}
\begin{verbatim}       SUBROUTINE Init_CMN_NOX( am_I_Root, RC )
```

USES:

```
       USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
       LOGICAL, INTENT(IN)  :: am_I_Root ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
       INTEGER, INTENT(OUT) :: RC ! Success or failure?
```

REVISION HISTORY:

```
    19 Nov 2012 - R. Yantosca - Added ProTeX headers
```

1.5.1 cleanup_cmn_nox

Subroutine CLEANUP_CMN_NOX allocates all module arrays.

INTERFACE:

```
       SUBROUTINE Cleanup_CMN_NOX( am_I_Root, RC )
```

USES:

```
       USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
       LOGICAL,        INTENT(IN)  :: am_I_Root ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC ! Success or failure?
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Added ProTeX headers
```

1.6 Fortran: Module Interface CMN_O3_mod

Common blocks for anthro emissions (via SMVGEAR!)

INTERFACE:

```
MODULE CMN_O3_MOD
```

USES:

```
USE CMN_SIZE_MOD, ONLY : IIPAR,     JJPAR,     LLPAR
USE CMN_SIZE_MOD, ONLY : NEMPARA,   NEMPARB
USE CMN_SIZE_MOD, ONLY : NOXLEVELS, NOXEXTENT

IMPLICIT NONE
PUBLIC
```

PUBLIC DATA MEMBERS:

```
! Rural Emissions: EMISRN = NOx (1:NOXLEVELS), EMISR = all other tracers
! Total Emissions: EMISTN = NOx (1:NOXLEVELS), EMIST = all other tracers
REAL*8, ALLOCATABLE  :: EMISR(:,:,:)
REAL*8, ALLOCATABLE  :: EMISRN(:,:,:)
REAL*8, ALLOCATABLE  :: EMIST(:,:,:)
REAL*8, ALLOCATABLE  :: EMISTN(:,:,:)

! Rural Emissions:
! EMISRRN = NOx emissions into sigma levels L=1,NOXEXTENT
! EMISRR  = All other tracer emissions into sigma level L=1
REAL*8, ALLOCATABLE  :: EMISRR (:,:,:)
REAL*8, ALLOCATABLE  :: EMISRRN(:,:,:)

!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! New biogenic VOC emissions (mpb,2009)
! Now 19 species (dbm, 12/2012)
!     ---------------------------
!     Species            | Order
!     ---------------------------
!     Isoprene           = 1
!     Acetone            = 2
```

```
!     Propene            = 3
!     Total Monoterpenes = 4
!     MBO                = 5
!     Ethene             = 6
!     Alpha-Pinene       = 7
!     Beta-Pinene        = 8
!     Limonene           = 9
!     Sabinene           = 10
!     Mycrene            = 11
!     3-Carene           = 12
!     Ocimene            = 13
!     Formic acid        = 14
!     Acetic acid        = 15
!     Acetaldehyde       = 16
!     Other monoterpenes = 17
!     Methanol           = 18
!     Ethanol            = 19
!     ---------------------------
!     SOAupdate: Sesquiterpenes (hotp 3/1/10):
!     Farnesene          = 11
!     b-Caryophyllene    = 12
!     Other sesquiterp   = 13
!     Other monoterpenes = 14
!     ---------------------------

! Define common block
REAL*8, ALLOCATABLE  :: EMISS_BVOC(:,:,:)

!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Arrays to read emissions from updated merge file :
!        NOx, CO, PRPE, C3H8, ALK4, C2H6, ACET, MEK
! NOTE: ALD2 is not emitted in GEIA so we don't need an array for
!       it below...but it is emitted in EMEP.  It will be saved
!       into the EMISRR array for SMVGEAR. (bdf, bmy, 11/1/05)
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
REAL*4, ALLOCATABLE  :: EMISTNOX (:,:,:,:)
REAL*4, ALLOCATABLE  :: EMISTETHE(:,:)
REAL*4, ALLOCATABLE  :: EMISTCO  (:,:)
REAL*4, ALLOCATABLE  :: EMISTPRPE(:,:)
REAL*4, ALLOCATABLE  :: EMISTC3H8(:,:)
REAL*4, ALLOCATABLE  :: EMISTALK4(:,:)
REAL*4, ALLOCATABLE  :: EMISTC2H6(:,:)
REAL*4, ALLOCATABLE  :: EMISTSOX (:,:,:,:)
REAL*4, ALLOCATABLE  :: EMISTACET(:,:)
REAL*4, ALLOCATABLE  :: EMISTMEK (:,:)
REAL*4, ALLOCATABLE  :: EMISTBENZ(:,:)
REAL*4, ALLOCATABLE  :: EMISTTOLU(:,:)
REAL*4, ALLOCATABLE  :: EMISTXYLE(:,:)
```

```
      REAL*4, ALLOCATABLE  :: EMISTC2H4(:,:)
      REAL*4, ALLOCATABLE  :: EMISTC2H2(:,:)
      ! SOAupdate: Add EMISTNAP (hotp 7/21/10)
      REAL*4, ALLOCATABLE  :: EMISTNAP (:,:)


      ! Time of day and weekday/weekend scale factors
      ! NOTE: Now SCNR89 is (3,3) because of the weekday scale factor!!!
      REAL*8  :: TODH(6)
      REAL*8  :: TODN(6)
      REAL*8  :: TODB(6)
      REAL*8  :: SCNR89(3,3)


      ! IFSCLYR = Year to use for scaling fossil fuel emissions
      ! (1985 = no scaling        !)
      INTEGER :: FSCALYR


      ! FTOTCO2 = yearly scale factors based on Total  Fuel CO2 emissions
      ! FLIQCO2 = yearly scale factors based on Liquid Fuel CO2 emissions
      REAL*4, ALLOCATABLE  :: FTOTCO2(:,:)
      REAL*4, ALLOCATABLE  :: FLIQCO2(:,:)

      ! SAVEOH                   = array to save OH  fields
      ! SAVEHO2                  = array to save HO2 fields (rvm, bmy, 2/27/02)
      REAL*8, ALLOCATABLE ::   SAVEOH(:,:,:)
      REAL*8, ALLOCATABLE ::   SAVEHO2(:,:,:)
```

REMARKS:

```
NOTE: Now NEMPARA = max no. of anthropogenic emissions
          NEMPARB = max no. of biogenic emissions
```

.

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE IS NOW DEPRECATED.  IT WILL BE REMOVED WHEN  %%%
%%%  THE GEOS-CHEM EMISSIONS MODULE IS UPDATED (SOMETIME SOON)      %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
23 Aug 2011 - M. Long   - Converted to Module from Header file
29 Mar 2013 - M. Payer    - Removed FRACO3, FRACNO, FRACNO2, SAVENO, SAVENO2,
                            and SAVENO3. They are no longer needed because
                            O3, NO, NO2, and NO3 are now tracers.
13 Aug 2013 - M. Sulprizio- Increase last dimension of EMISS_BVOC to include
                            sesquiterpenes and add EMISTNAP for SOA +
                            semivolatile POA simulation (H. Pye)
```

1.6.1 init_cmn_o3

Subroutine INIT_CMN_O3 allocates all module arrays.

INTERFACE:

```
SUBROUTINE Init_CMN_O3( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Added ProTeX headers
01 Feb 2013 - R. Yantosca - Now allocate EMISS_BVOC to 19 emission species
29 Mar 2013 - M. Payer    - Removed FRACO3, FRACNO, FRACNO2, SAVENO, SAVENO2,
                            and SAVENO3. They are no longer needed because
                            O3, NO, NO2, and NO3 are now tracers.
13 Aug 2013 - M. Sulprizio- Increase last dimension of EMISS_BVOC to include
                            sesquiterpenes and add EMISTNAP for SOA +
                            semivolatile POA simulation (H. Pye)
```

1.6.2 cleanup_cmn_o3

Subroutine CLEANUP_CMN_O3 allocates all module arrays.

INTERFACE:

```
SUBROUTINE Cleanup_CMN_O3( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Added ProTeX headers
29 Mar 2013 - M. Payer    - Removed FRACO3, FRACNO, FRACNO2, SAVENO, SAVENO2,
                            and SAVENO3. They are no longer needed because
                            O3, NO, NO2, and NO3 are now tracers.
```

1.7 Fortran: Module Interface CMN_mod

Module CMN is the remnant of header file "CMN", which once held many global variables, but now is reduced to only a couple.

INTERFACE:

```
MODULE CMN_MOD
```

USES:

```
USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR

IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
! LPAUSE  stores the annual mean tropopause (bmy, 12/6/99)
INTEGER, PUBLIC, ALLOCATABLE :: LPAUSE(:,:)

! IFLX stores the flags for ND27 diagnostic (bmy, 12/6/99)
! This is mostly obsolete by now (bmy, 8/24/11)
INTEGER, PUBLIC, ALLOCATABLE :: IFLX(:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: Init_CMN
PUBLIC :: Cleanup_CMN
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%% NOTE: THIS MODULE IS DEPRECATED.  IT WILL BE REMOVED IN THE FUTURE  %%%
%%% COMBINE THESE ARRAYS INTO ANOTHER MODULE FILE.  FOR NOW, KEEP IT.   %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
23 Aug 2011 - M. Long   - Converted to Module from Header file
```

1.7.1 init_cmn

Subroutine INIT_CMN allocates all module arrays.

INTERFACE:

```
SUBROUTINE Init_CMN( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Added ProTeX headers
```

1.7.2 cleanup_cmn

Subroutine CLEANUP_CMN allocates all module arrays.

INTERFACE:

```
SUBROUTINE Cleanup_CMN( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Added ProTeX headers
```

1.8 Fortran: Module Interface cmn_fj_mod

Module cmn_fj_mod contains parameters and global variables used to interface between Harvard chemistry and UC-Irvine Fast-J photolysis programs.

INTERFACE:

```
MODULE CMN_FJ_MOD
```

USES:

```
USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR, LLPAR

IMPLICIT NONE
PUBLIC
```

DEFINED PARAMETERS:

```
! max # of photolysis rxns = 4 + IPHOT (see comode.h)
! FP increased JPMAX since IPHOT was increased (hotp 7/31/09)
INTEGER, PARAMETER :: JPMAX = 89
```

PUBLIC DATA MEMBERS:

```
! Variables for number of layers and number of photolysis rxns
INTEGER            :: JPNL, JPPJ

! Branches for photolysis species
INTEGER            :: BRANCH(JPMAX)

! Names of photolysis species
! FP increased length of RNAMES for species indistinguishable
! with only 4 characters (hotp 7/31/09)
! used in jv_index and rd_js.f
!CHARACTER (LEN=4)  :: RNAMES
CHARACTER (LEN=7)  :: RNAMES(JPMAX)

! Mapping array from Harvard species names to UCI species names
INTEGER            :: RINDEX(JPMAX)

! Output J-values
REAL*8, ALLOCATABLE :: ZPJ(:,:,:,:)
```

REMARKS:

Based on code from Oliver Wild (9 Jul 1999)

REVISION HISTORY:

(1) Uses Fortran 90 declarations for parameters and variables
(2) Pass CTM size parameters and preprocessor switches via CMN_SIZE.
(3) Update JPMAX for new chemistry mechanism (amf, bmy, 4/20/00)
(4) Return JPMAX to original setting (bmy, 9/25/00)
(5) Return JPMAX to 55 for peroxy recycling (again) (bmy, 12/20/00)
(6) Now need to use the window parameters IIPAR,JJPAR,LLPAR (bmy, 9/25/01)
(7) Changed RCS ID tag comment character from "C" to "!" to allow freeform compilation. (bmy, 6/25/02)
(8) Replaced ESIG array with ETAA and ETAB arrays for the hybrid pressure formulation. Also deleted PREST, since we don't need that anymore. (bmy, 8/23/02)
(9) Removed ETAA and ETAB arrays. We now compute PJ directly from the GET_PEDGE routine. (bmy, 10/30/07)
(10) Increase photolysis rxns JPMAX = 79 (tmf, 1/7/09)
(11) Increase photolysis rxns JPMAX = 89 for Isoprene (fp, 2/2/10)
(12) Increase species name length. (fp, 2/2/10)
23 Aug 2011 - M. Long - Converted to Module from Header file
10 Aug 2012 - R. Yantosca - Replace IPAR, JPAR, LPAR w/ IIPAR, JJPAR, LLPAR

1.8.1 init_cmn_fj

Subroutine INIT_CMN_FJ allocates all module arrays.

INTERFACE:

```
SUBROUTINE Init_CMN_FJ( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Added ProTeX headers
```

1.8.2 cleanup_cmn_fj

Subroutine CLEANUP_CMN_FJ deallocates all module arrays.

INTERFACE:

```
SUBROUTINE Cleanup_CMN_FJ( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Added ProTeX headers
```

1.9 Fortran: Module Interface commsoil_mod

Module COMMSOIL_MOD contains global variables for the soil NOx emissions routines. This has been updated to the new Soil NOx algorithm (2012).

INTERFACE:

```
MODULE COMMSOIL_MOD
```

USES:

```
USE CMN_SIZE_MOD, ONLY : IIPAR, JJPAR, MAXIJ

IMPLICIT NONE
PRIVATE
```

DEFINED PARAMETERS:

```
! The defined soil types (Olson soil types)
INTEGER, PUBLIC, PARAMETER :: NSOIL = 11

! Number of MODIS/Koppen biome types
INTEGER, PUBLIC, PARAMETER :: NSOILB = 24
```

PUBLIC DATA MEMBERS:

```
!=================================================================
! The following arrays depend on longitude & latitude
!=================================================================

! Soil NOx emissions [molec/cm2/s]
REAL*8,  PUBLIC, ALLOCATABLE :: SOILNOX      (:,:  )

! Soil fertilizer
REAL*8,  PUBLIC, ALLOCATABLE :: SOILFERT     (:,:,:)

! Fraction of arid (layer 1) and non-arid (layer 2) land
REAL*4,  PUBLIC, ALLOCATABLE :: CLIM         (:,:,:)

! MODIS landtype
REAL*4,  PUBLIC, ALLOCATABLE :: LAND2        (:,:,:)

! Dry period length
REAL*4,  PUBLIC, ALLOCATABLE :: DRYPERIOD    (:,:  )

! Pulse factors
REAL*4,  PUBLIC, ALLOCATABLE :: PFACTOR      (:,:  )
REAL*4,  PUBLIC, ALLOCATABLE :: GWET_PREV    (:,:  )

! Instantaneous soil NOx and fertilizer
REAL*8,  PUBLIC, ALLOCATABLE :: INST_SOIL    (:,:  )
```

```
      REAL*8,  PUBLIC, ALLOCATABLE :: INST_FERT    (:,:  )

      ! NOx in the canopy, used in dry deposition
      REAL*8,  PUBLIC, ALLOCATABLE :: CANOPYNOX    (:,:  )

      ! Soil NOx deposited N arrays
      REAL*8,  PUBLIC, ALLOCATABLE :: DRY_NO2      (:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: DRY_PAN      (:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: DRY_HNO3     (:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: DRY_NH3      (:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: DRY_NH4      (:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: DRY_NIT      (:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: DEP_RESERVOIR(:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: WET_HNO3     (:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: WET_NH3      (:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: WET_NH4      (:,:  )
      REAL*8,  PUBLIC, ALLOCATABLE :: WET_NIT      (:,:  )

      !=================================================================
      ! The following arrays do not depend on longitude & latitude
      !=================================================================

      REAL*8,  PUBLIC              :: SOILEXC      (NSOILB)

      ! MODIS/Koppen resistance values
      INTEGER, PUBLIC              :: SNIMODIS     (NSOILB)
      INTEGER, PUBLIC              :: SNIRI        (NSOILB)
      INTEGER, PUBLIC              :: SNIRLU       (NSOILB)
      INTEGER, PUBLIC              :: SNIRAC       (NSOILB)
      INTEGER, PUBLIC              :: SNIRGSS      (NSOILB)
      INTEGER, PUBLIC              :: SNIRGSO      (NSOILB)
      INTEGER, PUBLIC              :: SNIRCLS      (NSOILB)
      INTEGER, PUBLIC              :: SNIRCLO      (NSOILB)
      INTEGER, PUBLIC              :: SNIVSMAX     (NSOILB)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: Init_COMMSOIL
      PUBLIC :: Cleanup_COMMSOIL
```

REMARKS:

```
  Updated to new Soil NOx algorithm (2012).  See:
  http://wiki.seas.harvard.edu/geos-chem/index.php/Soil_NOx_Emissions

  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
  %%% NOTE: THIS MODULE IS DEPRECATED.  WE MAY END UP PLACING THE MODULE %%%
  %%% VARIABLES INTO A DERIVED TYPE FOR THE NEW EMISSIONS COMPONENT IN   %%%
  %%% THE NEAR FUTURE. (bmy, 11/19/12)                                   %%%
  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
(1 ) Be sure to force double precision with the DBLE function
     and the "D" exponent, wherever necessary (bmy, 10/6/99)
(2 ) Changed RCS ID tag comment character from "C" to "!" to allow
     freeform compilation.  Also added & continuation characters in
     column 73 to allow header files to be included in F90 freeform
     files. Updated comments, cosmetic changes. (bmy, 6/25/02)
(3 ) Now use cpp switches to define 1x1 parameters.  Also added
     space in the #ifdef block for the 1x125 grid (bmy, 12/1/04)
(4 ) Bug fix: 2681 should be 2861 in NLAND (bmy, 9/22/06)
(5 ) Set # of land boxes for GEOS-5 nested grids (yxw, dan, bmy, 11/6/08)
(6 ) Set # of land boxes for GEOS-5 EUROPE nested grid (amv, 10/19/09)
23 Aug 2011 - M. Long   - Converted to Module from Header file
30 Aug 2012 - J.D. Maasakkers - Removed all obsolete old soil NOx code data
30 Oct 2012 - R. Yantosca - Removed obsolete NLAND parameter, that cannot
                            be used with the Grid-Independent GEOS-Chem
30 Oct 2012 - R. Yantosca - Now make all arrays that depend on lon &
                            lat into ALLOCATABLE arrays (for GIGC code)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.9.1 init_commsoil

Routine INIT_COMMSOIL allocates all module arrays with the longitude and latitude values IIPAR and JJPAR.

INTERFACE:

```
SUBROUTINE Init_COMMSOIL( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure
```

REMARKS:

```
This is used for the Grid-Independent GEOS-Chem.  We cannot assume that
IIPAR and JJPAR will be fixed parameters, since these would be determined
from the interface to the external GCM.

May need to add better error checking
```

REVISION HISTORY:

```
30 Oct 2012 - R. Yantosca - Now allocate all arrays depending on lon & lat
30 Oct 2012 - R. Yantosca - Added ProTeX headers
```

1.9.2 cleanup_commsoil

Subroutine CLEANUP_COMMSOIL deallocates all module arrays.

INTERFACE:

```
SUBROUTINE Cleanup_COMMSOIL( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Return code
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Initial version
```

1.10 Fortran: Module Interface comode_loop_mod

Module file COMODE contains common blocks and variables for SMVGEAR II.

INTERFACE:

```
MODULE COMODE_LOOP_MOD
```

USES:

```
USE CMN_SIZE_MOD

IMPLICIT NONE
PUBLIC
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: Init_COMODE_LOOP
PUBLIC :: Cleanup_COMODE_LOOP
```

REMARKS:

```
       CCCCCCC  OOOOOOO  M     M  OOOOOOO  DDDDDD   EEEEEEE
       C        O     O  M M M M  O     O  D     D  E
       C        O     O  M  M  M  O     O  D     D  EEEEEEE
       C        O     O  M     M  O     O  D     D  E
       CCCCCCC  OOOOOOO  M     M  OOOOOOO  DDDDDD   EEEEEEE

      ******************************************************************
      * THIS IS THE COMMON BLOCK FOR "SMVGEAR" AND "MIE," TWO ORDINARY    *
      * DIFFERENTIAL EQUATION SOLVERS. THE REFERENCE FOR THE CODES IS     *
      *                                                                   *
      *   JACOBSON M. Z. AND TURCO R. P. (1993) SMVGEAER: A SPARSE-       *
      *    MATRIX, VECTORIZED GEAR CODE FOR ATMOSPHERIC MODELS.           *
      *    SUBMITTED TO ATMOSPHERIC ENVIRONMENT, PART A. MAY 20, 1993     *
      *                                                                   *
      * COMODE.H SETS PARAMETER VALUES AND SERVES AS A COMMON BLOCK FOR   *
      * ALL DIMENSIONED AND NON-DIMENSIONED VARIABLES. COMODE.H ALSO      *
      * DEFINES EACH PARAMETER, BUT DATA FILE DEFINE.DAT EXPLAINS NON-    *
      * DIMENSIONED VARIABLES. INDIVIDUAL SUBROUTINES DEFINE DIMENSIONED  *
      * VARIABLES.                                                        *
      ******************************************************************

      ******************************************************************
      *                        SET PARAMETERS                          *
      ******************************************************************

      ****************** COORDINATE-SYSTEM PARAMETERS *********************
      ILAT     = MAXIMUM NUMBER OF LATITUDE(ILAT)   GRID POINTS
      ILONG    = MAXIMUM NUMBER OF LONGITUDE(ILONG) GRID POINTS
      IMLOOP   = ILAT * ILONG - USED FOR MORE EFFICIENT ARRAYS
      IVERT    = MAXIMUM NUMBER OF LAYERS
      ILAYER   = MAXIMUM OF LAYER BOUNDARIES
      KBLOOP   = MAXIMUM NUMBER OF GRID POINTS IN A VECTORIZED BLOCK
                 SHOULD RANGE FROM 512 (BELOW WHICH VECTORIZATION DECREASES)
                 TO 1024 (ABOVE WHICH, ARRAY SPACE IS LIMITED)
      MXBLOCK  = MAXIMUM NUMBER OF GRID POINT BLOCKS
      MAXDAYS  = MAXIMUM NUMBER OF DAYS FOR THE MODEL TO RUN
```

REVISION HISTORY:

```
(M. Jacobson 1997; bdf, bmy, 4/23/03, 6/1/06)
(1 ) Removed many commented-out common blocks not needed for GEOS-CHEM.
     Also updated comments.  Also make sure that MAXGL3 is dimensioned
     for at least NNPAR tracers.  Add NNADDG and NKSPECG for DMS+OH+O2
     rxn.  COEF12 and QRM2 are now obsolete for SMVGEAR II. (bmy, 4/23/03)
(2 ) Added ICH4 to the /SPECIE2/ common block for interannual-varying
     CH4 concentration.  Added variables for latitude distribution of
     CH4 to the /SPECIE3/ common block. (bmy, 7/1/03)
(3 ) Added ITS_NOT_A_ND65_FAMILY to the /LPL/ common block for the ND65
     production/loss diagnostic.   Comment out counter variables, you can
```

```
      get the same info w/ a profiling run.  Updated comments, cosmetic
      changes. (bmy, 7/9/03)
(4 ) Removed the following variables from common blocks which are not needed
      for GEOS-CHEM: COLENG, AERSURF, VHMET1, VHMET, VMET3, CINIT, RHO3,
      GRIDVH, CSUMA1, XELRAT, T1BEG, T2BEG, T1FIN, T2FIN, DECLIN, RAGSUT,
      SINDEC, COSDEC, SIGMAL, PRESSL, RHOA, DSIG_SMV, TEMPL, VMET, SIGDIF,
      TMORN, PRESSC, XLAT, XLON, DMERIDUT, GRIDAREA, DSX, XLONUT, DSY,
      SINXLAT, COSXLAT, HMETT, HMET1, HMET2, RSET, RRIS, TZDIF, ZENRAT0,
      ZENRAT1, MLOPJ, REORDER_SAVE, RHO3K, GRIDVH3K, FIELDXY, FIELDYZ,
      FIELDXZ, RATMIX, GQSCHEM, C, QPRODA, QPRODB, QPRODC, QPRODD, QPROD,
      CINP, NUMSDT, NKSDT, PRATE.  MONTHP, KYEAR, LDMONTH, ININT, ICLO,
      JCLO, FIELD1, MZLO, MZLO2, MZHI0, MZHI1, KZLO1, KZLO2, KZHI0, KZHI1,
      IHIZ1, IHIZ2, IHIZ3, PRESS5KM, KGRP, IABOVK, MROTAT1, MINROT1,
      NUMSUBS, LSPECEMIS, MROTAT2, MINROT2, MAXPOS, NOGAINR, NOLOSSR,
      MAXSTEPS, YLOW, HMAXDAY, KPHT, KRDD, KMIX, KINS, KGCO, ABHSUMK, DX0,
      DY0, XU0, DTOUT, CONPSUR, DXLONG, DYLAT, SWLONDC, CONSTIM, SWLATDC,
      UTSECY, TOTSEC, FINHOUR, FINMIN, FINSEC, TFROMID, ZENFIXED, ZENITH,
      DENCONS, HALFDAY, GRAVC, FOURPI, TWOPI, REARTH, RPRIMB, AVOG1,
      HALF, THIRD, THRPI2, PID180, PID2, SCTWOPI, AMRGAS, TWPISC.
      This should free up more memory for runs. (bmy, 7/16/03)
(5 ) Split off NOCC into the /CHEM3B/ common block, since it doesn't need
      to be held THREADPRIVATE.  Removed /DKBLOOP/ and /DKBLOOP5/, since
      these contain variables which are used locally within either
      "calcrate.f" or "smvgear.f".  Cosmetic changes. (bmy, 7/28/03)
(6 ) Add NKN2O5 to /CHEM4/ common block to flag N2O5 hydrolysis rxn.
       (mje, bmy, 8/7/03)
(7 ) Eliminated SMALLCHEM cpp switch (bmy, 12/2/03)
(8 ) Now set MAXGL3 = NNPAR for new # of tracers (bmy, 4/6/04)
(9 ) Remove obsolete LGEOSCO and FULLCHEM Cpp switches (bmy, 6/24/05)
(10) For COMPAQ, put IRMA, IRMB in /INMTRATE2/ common block.  For COMPAQ,
      also declare /INMTRATE2/ THREADPRIVATE. (Q. Liang, bmy, 10/17/05)
(11) Now remove AVG, BOLTG, RGAS, SCDAY, BK, EIGHTDPI, RSTARG, WTAIR,
      ONEPI, CONSVAP, SMAL1, SMAL2, SMAL3 from common blocks and declare
      these as parameters. (bec, bmy, 3/29/06)
(12) Added ILISOPOH, the index of ISOP lost to OH (dkh, bmy, 6/1/06)
(13) Added NKHO2 to /CHEM4/ common block to flag HO2 aerosol uptake
      (jaegle 02/26/09)
(14) Add NNADDF and NNADDH to /CHEM4/ for HOC2H4O rxns
     Add NKHOROI and NKHOROJ to /CHEM4/ for HOC2H4O rxns in EP photolysis
     (tmf, 3/6/09)
(15) Added NKSPECF, NKSPECH to /IDICS/ for C2H4 chemistry (tmf, 3/6/09)
(16) Increase IGAS, MAXGL, MAXGL2, NMRATE, IPHOT (tmf, 3/6/09)
(17) Add RRATE_FOR_KPP variable to DKBLOOP2 common block (phs,ks,dhk, 09/15/09)
(18) PINP(20) increased to PINP(IMISC) (FP 2/10)
(19) Added NKO3PHOTH2 (bhh, jmao, eam, 7/18/11)
```

REVISION HISTORY:

```
23 Aug 2011 - M. Long     - Converted to Module from Header file
```

```
14 Aug 2012 - R. Yantosca - Add #include "define.h" to USES section
14 Aug 2012 - R. Yantosca - Now set KBLOOP=1 only if we are connecting to
                            an external GCM (i.e. triggered by switches
                            EXTERNAL_GRID or EXTERNAL_FORCING).
17 Oct 2012 - R. Yantosca - Do not define ILAYER if compiling w/ -DDEVEL
24 Oct 2012 - R. Yantosca - Rewrite GIGC #ifdef blocks for clarity
19 Nov 2012 - R. Yantosca - Now use funcitions INIT_COMODE_LOOP and
                            CLEANUP_COMODE_LOOP to allocate/free arrays
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.10.1 init_comode_loop

Subroutine INIT_COMODE_LOOP initializes size parameters with the geospatial values obtained from the ESMF interface.

INTERFACE:

```
SUBROUTINE Init_COMODE_LOOP( am_I_Root, Input_Opt, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
Need to add error-checking on the allocation statements, so that we
exit the code upon error.
```

REVISION HISTORY:

```
17 Oct 2012 - R. Yantosca - Need to also set NLAT, NLONG, etc.
17 Oct 2012 - R. Yantosca - Added ProTeX headers
22 Oct 2012 - R. Yantosca - Now references gigc_errcode_mod.F90
27 Nov 2012 - R. Yantosca - Now pass Input_Opt via the argument list
```

1.10.2 cleanup_comode_loop

Subroutine CLEANUP_COMODE_LOOP deallocates all module arrays.

INTERFACE:

```
SUBROUTINE Cleanup_COMODE_LOOP( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod

IMPLICIT NONE
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Initial version
```

1.11 Fortran: Module Interface ef_mgn20_mod

Module EF_MGN20 contains emission factors for 20 MEGAN species. The values in this file have to be in the same order as in SPC_MGN.EXT

INTERFACE:

```
MODULE EF_MGN20_MOD
```

USES:

```
IMPLICIT NONE
PUBLIC
```

DEFINED PARAMETERS:

```
! Number of categories
INTEGER, PARAMETER :: N_EF_SPC = 20
```

PUBLIC DATA MEMBERS:

```
 ! Speciation factor for broadleaf
 REAL*8 ::      EF_BT( N_EF_SPC )

 ! Speciation factor for needleleaf
 REAL*8 ::      EF_NT( N_EF_SPC )

 ! Speciation factor for shrub
 REAL*8 ::      EF_SB( N_EF_SPC )

 ! Speciation factor for herb/grass/crop
 REAL*8 ::      EF_HB( N_EF_SPC )

 DATA    EF_BT(  1)  , EF_NT(  1)  , EF_SB(  1)  , EF_HB(  1)
&      / 13000.00    , 2000.00     , 11000.00    , 400.00       /
 DATA    EF_BT(  2)  , EF_NT(  2)  , EF_SB(  2)  , EF_HB(  2)
&      / 20.00       , 75.00       , 22.00       , 0.30         /
 DATA    EF_BT(  3)  , EF_NT(  3)  , EF_SB(  3)  , EF_HB(  3)
&      / 45.00       , 70.00       , 50.00       , 0.70         /
 DATA    EF_BT(  4)  , EF_NT(  4)  , EF_SB(  4)  , EF_HB(  4)
&      / 45.00       , 100.00      , 52.00       , 0.70         /
 DATA    EF_BT(  5)  , EF_NT(  5)  , EF_SB(  5)  , EF_HB(  5)
&      / 18.00       , 160.00      , 25.00       , 0.30         /
 DATA    EF_BT(  6)  , EF_NT(  6)  , EF_SB(  6)  , EF_HB(  6)
&      / 90.00       , 60.00       , 85.00       , 1.00         /
 DATA    EF_BT(  7)  , EF_NT(  7)  , EF_SB(  7)  , EF_HB(  7)
&      / 90.00       , 300.00      , 100.00      , 1.50         /
 DATA    EF_BT(  8)  , EF_NT(  8)  , EF_SB(  8)  , EF_HB(  8)
&      / 180.00      , 450.00      , 200.00      , 2.00         /
 DATA    EF_BT(  9)  , EF_NT(  9)  , EF_SB(  9)  , EF_HB(  9)
&      / 90.00       , 180.00      , 110.00      , 4.80         /
 DATA    EF_BT( 10)  , EF_NT( 10)  , EF_SB( 10)  , EF_HB( 10)
&      / 35.00       , 30.00       , 30.00       , 0.50         /
 DATA    EF_BT( 11)  , EF_NT( 11)  , EF_SB( 11)  , EF_HB( 11)
&      / 30.00       , 60.00       , 45.00       , 0.90         /
 DATA    EF_BT( 12)  , EF_NT( 12)  , EF_SB( 12)  , EF_HB( 12)
&      / 75.00       , 110.00      , 85.00       , 1.4          /
 DATA    EF_BT( 13)  , EF_NT( 13)  , EF_SB( 13)  , EF_HB( 13)
&      / 0.10        , 100.00      , 1.00        , 0.01         /
 DATA    EF_BT( 14)  , EF_NT( 14)  , EF_SB( 14)  , EF_HB( 14)
&      / 800.00      , 800.00      , 800.00      , 800.00       /
 DATA    EF_BT( 15)  , EF_NT( 15)  , EF_SB( 15)  , EF_HB( 15)
&      / 240.00      , 240.00      , 240.00      , 80.00        /
 DATA    EF_BT( 16)  , EF_NT( 16)  , EF_SB( 16)  , EF_HB( 16)
&      / 30.00       , 30.00       , 30.00       , 30.00        /
 DATA    EF_BT( 17)  , EF_NT( 17)  , EF_SB( 17)  , EF_HB( 17)
&      / 5.00        , 6.00        , 30.00       , 70.00        /
 DATA    EF_BT( 18)  , EF_NT( 18)  , EF_SB( 18)  , EF_HB( 18)
&      / 240.00      , 240.00      , 240.00      , 80.00        /
```

```
      DATA    EF_BT( 19)  , EF_NT( 19)  , EF_SB( 19)  , EF_HB( 19)
     &      / 70.00       , 70.00       , 70.00       , 70.00       /
      DATA    EF_BT( 20)  , EF_NT( 20)  , EF_SB( 20)  , EF_HB( 20)
     &      / 1000.0      , 1000.0      , 1000.0      , 1000.0      /
```

REMARKS:

```
MEGAN v2.02
INPUT version 210
```

REVISION HISTORY:

```
Tan          12/02/06 - Creates this file
Guenther A.  08/11/07 - Creates this file again with updates and move
                        from v2.0 to v2.02
Havala Pye   07/26/10 - EFs now double precision (replace REAL with
                        REAL*8) (part of SOA + semivolatile POA)
15 Mar 2012 - M. Payer  - Converted to module from include file.
                          Added ProTeX headers.
```

1.12 Fortran: Module Interface gigc_errcode_mod.F90

Module GIGC_ERRCODE_MOD contains the error codes (i.e. that report success or failure) returned by routines of the Grid-Independent GEOS-Chem (aka "GIGC").

INTERFACE:

```
MODULE GIGC_ErrCode_Mod
```

USES:

```
IMPLICIT NONE
PRIVATE
```

DEFINED PARAMETERS:

```
INTEGER, PUBLIC, PARAMETER :: GIGC_SUCCESS =  0   ! Routine returns success
INTEGER, PUBLIC, PARAMETER :: GIGC_FAILURE = -1   ! Routine returns failure
```

REMARKS:

```
The error codes are returned by routines at various levels of the
Grid-Independent GEOS-Chem implementation.
```

REVISION HISTORY:

```
19 Oct 2012 - R. Yantosca - Initial version
```

1.13 Fortran: Module Interface gigc_state_chm_mod

Module GIGC_STATE_CHM_MOD contains the derived type used to define the Chemistry State object for the Grid-Independent GEOS-Chem implementation (abbreviated "GIGC").

This module also contains the routines that allocate and deallocate memory to the Chemistry State object. The chemistry state object is not defined in this module. It must be be declared as variable in the top-level driver routine, and then passed to lower-level routines as an argument.

INTERFACE:

```
MODULE GIGC_State_Chm_Mod
  USES:
  IMPLICIT NONE
  PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC :: Get_Indx
  PUBLIC :: Register_Species
  PUBLIC :: Register_Tracer
  PUBLIC :: Init_GIGC_State_Chm
  PUBLIC :: Cleanup_GIGC_State_Chm
```

PUBLIC DATA MEMBERS:

```
  !=========================================================================
  ! Derived type for Chemistry State
  !=========================================================================
  TYPE, PUBLIC :: ChmState

     ! Advected tracers
     INTEGER,           POINTER :: Trac_Id    (:      )  ! Tracer ID #'s
     CHARACTER(LEN=14), POINTER :: Trac_Name  (:      )  ! Tracer names
     REAL*8,            POINTER :: Tracers    (:,:,:,:)  ! Tracer conc [kg]
     REAL*8,            POINTER :: Trac_Tend  (:,:,:,:)  ! Tracer tendency
     REAL*8,            POINTER :: Trac_Btend (:,:,:,:)  ! Biomass tendency

     ! Chemical species
     INTEGER,           POINTER :: Spec_Id    (:      )  ! Species ID #
     CHARACTER(LEN=14), POINTER :: Spec_Name  (:      )  ! Species names
     REAL*8,            POINTER :: Species    (:,:,:,:)  ! Species [molec/cm3]

     ! Chemical rates & rate parameters
     REAL*8,            POINTER :: DepSav     (:,:,:  )  ! Drydep freq [1/s]

     ! Stratospheric chemistry
     INTEGER,           POINTER :: Schm_Id    (:      )  ! Strat Chem ID #'s
     CHARACTER(LEN=14), POINTER :: Schm_Name  (:      )  ! Strat Chem Names
```

```
  REAL*8,            POINTER :: Schm_P     (:,:,:,:)  ! Strat prod [v/v/s]
  REAL*8,            POINTER :: Schm_k     (:,:,:,:)  ! Strat loss [1/s]
  INTEGER,           POINTER :: Schm_BryId (:      )  ! Bry tracer #'s
  CHARACTER(LEN=14), POINTER :: Schm_BryNam(:      )  ! Bry Names
  REAL*8,            POINTER :: Schm_BryDay(:,:,:,:)  ! Bry, Day
  REAL*8,            POINTER :: Schm_BryNit(:,:,:,:)  ! Bry, Night

END TYPE ChmState
```

REMARKS:

```
-------------------------------------------------------------------------
 FULLCHEM Simulation Emissions
 Done | Units? | Routine
 Y/P  --> Yes or Partially(fix needed)
        good  --> Verifed that they are in Kg/s
-------------------------------------------------------------------------
 Y    |        | CALL COMPUTE_BIOMASS_EMISSIONS
 Y    |        | CALL EMISS_STREETS_ANTHRO_05x0666
 Y    |        | CALL EMISS_STREETS_ANTHRO
 Y    |        | CALL EMISS_EDGAR( YEAR, MONTH )
 Y    |  good  | CALL EMISS_RETRO
 Y    |  good* | CALL EMISS_EPA_NEI
 Y    |        | CALL EMISS_VISTAS_ANTHRO
 Y    |        | CALL EMISS_BRAVO
 Y    |        | CALL EMISS_EMEP_05x0666
 Y    |        | CALL EMISS_EMEP
 Y    |        | CALL EMISS_CAC_ANTHRO_05x0666
 Y    |        | CALL EMISS_CAC_ANTHRO
 Y    |        | CALL EMISS_EPA_NEI
 Y    |        | CALL EMISS_NEI2005_ANTHRO_05x0666
 Y    |        | CALL EMISS_NEI2005_ANTHRO
 Y    |        | CALL EMISS_ARCTAS_SHIP( YEAR )
 Y    |        | CALL EMISS_ICOADS_SHIP
      |        | CALL EMISSDR
 Y    |        | CALL EMISSSEASALT
 Y    |        | CALL EMISSSULFATE --> Be sure there's no PBL mixing
 Y    |        | CALL EMISSCARBON --> Be sure there's no PBL mixing
 Y    |        | CALL EMISSDUST --> Be sure there's no PBL mixing
 Y    |        | AIRCRAFT_NOX
 Y    |        | LIGHTNING_NOX
 Y    |        | SOIL_NOX
      |        | BIOFUEL_BURN (NOx and CO)
-------------------------------------------------------------------------
 Notes:
 LNLPBL Switch --> NEEDS TO BE ON (>=1)
               --> But, does VDIFF need to be turned off?
 NOT ALL EMISSIONS ARE JUST AT SFC, e.g. SO2
 LFUTURE --> How to deal with this? e.g. EDGAR emissions
```

```
 REGIONAL EMISSIONS OVERWRITE GLOBAL!!!!! DEAL WITH THIS!

 STT<-->CSPEC mapped in PARTITION

 KEEP EMISSIONS FROM UPDATING STT DIRECTLY

 NEI EMISSIONS: BIOFUEL EMISSIONS ARE NOT 'REALLY' BIOFUEL.
                AS IN THERE'S NO IDBF'SPEC' INDEX.

-----------------------------------------------------------------------
 FULLCHEM Simulation Chemistry Routines
 Done | Units? | Routine
 Y/P  --> Yes or Partially(fix needed)
         good  --> Verifed that they are in Kg
-----------------------------------------------------------------------
      |        | CALL CHEMDR
      |        | CALL CHEMSEASALT
      |        | CALL CHEMSULFATE
      |        | CALL DO_ISOROPIAII
      |        | CALL DO_RPMARES
      |        | CALL CHEMCARBON
      |        | CALL CHEMDUST
      |        | CALL DRYFLX
      |        | CALL DIAGOH
      |        | CALL OCEAN_SINK_ACET( STT(:,:,1,IDTACET) )
-----------------------------------------------------------------------
 Notes:
 (1) If STT IS TIGHTLY LINKED TO CHEM_STATE, THEN THE ONLY CHANGE
     NEEDED IN "DO_CHEMISTRY" IS TO PASS "CHEM_STATE" IN AND OUT
 (2) 1st PASS, WORKS ONLY WITH FULLCHEM, NOT APM OR ANY ADD-ON SIM
     OPTIONS.
-----------------------------------------------------------------------
```

REVISION HISTORY:

```
19 Oct 2012 - R. Yantosca - Initial version, based on "gc_type2_mod.F90"
26 Oct 2012 - R. Yantosca - Add fields for stratospheric chemistry
26 Feb 2013 - M. Long     - Add DEPSAV to derived type ChmState
07 Mar 2013 - R. Yantosca - Add Register_Tracer subroutine
07 Mar 2013 - R. Yantosca - Now make POSITION a locally SAVEd variable
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.13.1 get_indx

Function GET_INDX returns the index of an advected tracer or chemical species contained in the chemistry state object by name.

INTERFACE:

```
FUNCTION Get_Indx( name, allIds, allNames ) RESULT( Indx )
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(IN) :: name         ! Species or tracer name
CHARACTER(LEN=*), INTENT(IN) :: allNames(:)  ! List of species/tracer names
INTEGER,          INTENT(IN) :: allIDs(:)    ! List of species/tracer IDs
```

RETURN VALUE:

```
INTEGER                      :: Indx         ! Index of this species
```

REVISION HISTORY:

```
09 Oct 2012 - M. Long     - Initial version, based on gc_esmf_utils_mod.F90
```

1.13.2 register_species

Routine REGISTER_SPECIES stores the names of GEOS-Chem chemical species in fields of the Chemistry State (aka State_Chm) object.

INTERFACE:

```
SUBROUTINE Register_Species( Name, Id, State_Chm, Status )
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(IN)    :: Name       ! Name of desired species
INTEGER,          INTENT(IN)    :: Id         ! ID flag of desired species
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState),   INTENT(INOUT) :: State_Chm  ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,          INTENT(OUT)   :: Status     ! Success or failure
```

REMARKS:

```
This routine is called from SETTRACE in tracerid_mod.F.
```

REVISION HISTORY:

```
15 Oct 2012 - M. Long     - Initial version, based on gc_esmf_type_mod.F90
07 Mar 2013 - R. Yantosca - Now make POSITION a locally saved variable
```

1.13.3 Register_Tracer

Routine REGISTER_TRACER stores the names of GEOS-Chem advected tracers in fields of the Chemistry State (aka State_Chm) object.

INTERFACE:

```
SUBROUTINE Register_Tracer( Name, Id, State_Chm, Status )
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(IN)    :: Name       ! Name of desired tracer
INTEGER,          INTENT(IN)    :: Id         ! ID flag of desired tracer
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState),   INTENT(INOUT) :: State_Chm  ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,          INTENT(OUT)   :: Status     ! Success or failure
```

REVISION HISTORY:

```
7 Mar 2013 - R. Yantosca - Initial version, based on Register_SPecies
```

1.13.4 init_gigc_state_chm

Routine INIT_GIGC_STATE_CHM allocates and initializes the pointer fields of the chemistry state object.

INTERFACE:

```
SUBROUTINE Init_GIGC_State_Chm( am_I_Root, IM,        JM,        LM,     &
                                nTracers,  nBioMax,   nSpecies,  nSchm,  &
                                nSchmBry,  Input_Opt, State_Chm, RC      )
```

USES:

```
USE GIGC_ErrCode_Mod                        ! Error codes
USE GIGC_Input_Opt_Mod, ONLY   : OptInput   ! Derived type
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
INTEGER,        INTENT(IN)    :: IM          ! # longitudes on this PET
INTEGER,        INTENT(IN)    :: JM          ! # longitudes on this PET
INTEGER,        INTENT(IN)    :: LM          ! # longitudes on this PET
INTEGER,        INTENT(IN)    :: nTracers    ! # advected tracers
INTEGER,        INTENT(IN)    :: nBioMax     ! # biomass burning tracers
INTEGER,        INTENT(IN)    :: nSpecies    ! # chemical species
INTEGER,        INTENT(IN)    :: nSchm       ! # of strat chem species
INTEGER,        INTENT(IN)    :: nSchmBry    ! # of Bry species, strat chm
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Return code
```

REMARKS:

```
In the near future we will put some error trapping on the allocations
so that we can stop the simulation if the allocations cannot be made.
```

REVISION HISTORY:

```
19 Oct 2012 - R. Yantosca - Renamed from gc_type2_mod.F90
19 Oct 2012 - R. Yantosca - Now pass all dimensions as arguments
26 Oct 2012 - R. Yantosca - Now allocate Strat_P, Strat_k fields
26 Oct 2012 - R. Yantosca - Add nSchem, nSchemBry as arguments
01 Nov 2012 - R. Yantosca - Don't allocate strat chem fields if nSchm=0
                            and nSchmBry=0 (i.e. strat chem is turned off)
26 Feb 2013 - M. Long     - Now pass Input_Opt via the argument list
26 Feb 2013 - M. Long     - Now allocate the State_Chm%DEPSAV field
```

1.13.5 cleanup_gigc_state_chm

Routine CLEANUP_GIGC_STATE_CHM deallocates the fields of the chemistry state object.

INTERFACE:

```
SUBROUTINE Cleanup_GIGC_State_Chm( am_I_Root, State_Chm, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root    ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm    ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC           ! Return code
```

REMARKS:

```
For now the am_I_Root and RC arguments are not used.  We include these
for consistency and also to facilitate future expansion. (bmy, 10/16/12)
```

REVISION HISTORY:

```
15 Oct 2012 - R. Yantosca - Initial version
26 Oct 2012 - R. Yantosca - Now deallocate Strat_P, Strat_k fields
26 Feb 2013 - M. Long     - Now deallocate State_Chm%DEPSAV
```

1.14 Fortran: Module Interface gigc_state_met_mod

Module GIGC_STATE_MET_MOD contains the derived type used to define the Meteorology State object for the Grid-Independent GEOS-Chem implementation (abbreviated "GIGC").

This module also contains the routines that allocate and deallocate memory to the Meteorology State object. The Meteorology State object is not defined in this module. It must be be declared as variable in the top-level driver routine, and then passed to lower-level routines as an argument.

INTERFACE:

```
MODULE GIGC_State_Met_Mod
  USES:
  IMPLICIT NONE
  PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC :: Init_GIGC_State_Met
  PUBLIC :: Cleanup_GIGC_State_Met
```

PUBLIC DATA MEMBERS:

```
  !=========================================================================
  ! Derived type for Meteorology State
  !=========================================================================
  TYPE, PUBLIC :: MetState

     !---------------------------------------------------------------------
     ! Surface fields
     !---------------------------------------------------------------------
     REAL*8,  POINTER :: ALBD      (:,:  )  ! Visible surface albedo [1]
     REAL*8,  POINTER :: CLDFRC    (:,:  )  ! Column cloud fraction [1]
     INTEGER, POINTER :: CLDTOPS   (:,:  )  ! Max cloud top height [levels]
     REAL*8,  POINTER :: EFLUX     (:,:  )  ! Latent heat flux [W/m2]
     REAL*8,  POINTER :: EVAP      (:,:  )  ! Surface evap [kg/m2/s]
     REAL*8,  POINTER :: FRCLND    (:,:  )  ! Olson land fraction [1]
     REAL*8,  POINTER :: FRLAKE    (:,:  )  ! Fraction of lake [1]
     REAL*8,  POINTER :: FRLAND    (:,:  )  ! Fraction of land [1]
     REAL*8,  POINTER :: FRLANDIC  (:,:  )  ! Fraction of land ice [1]
     REAL*8,  POINTER :: FROCEAN   (:,:  )  ! Fraction of ocean [1]
     REAL*8,  POINTER :: FRSEAICE  (:,:  )  ! Sfc sea ice fraction
```

```
      REAL*8,  POINTER :: FRSNO     (:,:  )  ! Sfc snow fraction
      REAL*8,  POINTER :: GRN       (:,:  )  ! Greenness fraction
      REAL*8,  POINTER :: GWETROOT  (:,:  )  ! Root soil wetness [1]
      REAL*8,  POINTER :: GWETTOP   (:,:  )  ! Top soil moisture [1]
      REAL*8,  POINTER :: HFLUX     (:,:  )  ! Sensible heat flux [W/m2]
      REAL*8,  POINTER :: LAI       (:,:  )  ! Leaf area index [m2/m2]
      REAL*8,  POINTER :: LWI       (:,:  )  ! Land/water indices [1]
      REAL*8,  POINTER :: LWI_GISS  (:,:  )  ! Land fraction [1]
      REAL*8,  POINTER :: MOLENGTH  (:,:  )  ! Monin-Obhukov length [m]
      REAL*8,  POINTER :: OICE      (:,:  )  ! Fraction of ocean ice [1]
      REAL*8,  POINTER :: PARDR     (:,:  )  ! Direct  photsyn active rad [W/m2]
      REAL*8,  POINTER :: PARDF     (:,:  )  ! Diffuse photsyn active rad [W/m2]
      REAL*8,  POINTER :: PBLH      (:,:  )  ! PBL height [m]
      REAL*8,  POINTER :: PHIS      (:,:  )  ! Sfc geopotential height [m2/s2]
      REAL*8,  POINTER :: PRECANV   (:,:  )  ! Anvil previp @ ground [kg/m2/s]
      REAL*8,  POINTER :: PRECCON   (:,:  )  ! Conv  precip @ ground [kg/m2/s]
      REAL*8,  POINTER :: PRECTOT   (:,:  )  ! Total precip @ ground [kg/m2/s]
      REAL*8,  POINTER :: PRECLSC   (:,:  )  ! LS precip @ ground [kg/m2/s]
      REAL*8,  POINTER :: PRECSNO   (:,:  )  ! Snow precip [kg/m2/s]
      REAL*8,  POINTER :: PS1       (:,:  )  ! Sfc press at timestep start[hPa]
      REAL*8,  POINTER :: PS2       (:,:  )  ! Sfc press at timestep end [hPa]
      REAL*8,  POINTER :: PSC2      (:,:  )  ! Interpolated sfc pressure [hPa]
      REAL*8,  POINTER :: RADLWG    (:,:  )  ! Net LW radiation @ ground [W/m2]
      REAL*8,  POINTER :: RADSWG    (:,:  )  ! Solar radiation @ ground [W/m2]
      REAL*8,  POINTER :: SEAICE00  (:,:  )  ! Sea ice coverage 00-10%
      REAL*8,  POINTER :: SEAICE10  (:,:  )  ! Sea ice coverage 10-20%
      REAL*8,  POINTER :: SEAICE20  (:,:  )  !  Sea ice coverage 20-30%
      REAL*8,  POINTER :: SEAICE30  (:,:  )  ! Sea ice coverage 30-40%
      REAL*8,  POINTER :: SEAICE40  (:,:  )  ! Sea ice coverage 40-50%
      REAL*8,  POINTER :: SEAICE50  (:,:  )  ! Sea ice coverage 50-60%
      REAL*8,  POINTER :: SEAICE60  (:,:  )  ! Sea ice coverage 60-70%
      REAL*8,  POINTER :: SEAICE70  (:,:  )  ! Sea ice coverage 70-80%
      REAL*8,  POINTER :: SEAICE80  (:,:  )  ! Sea ice coverage 80-90%
      REAL*8,  POINTER :: SEAICE90  (:,:  )  ! Sea ice coverage 90-100%
      REAL*8,  POINTER :: SLP       (:,:  )  ! Sea level pressure [hPa]
      REAL*8,  POINTER :: SNICE     (:,:  )  ! Fraction of snow/ice [1]
      REAL*8,  POINTER :: SNODP     (:,:  )  ! Snow depth [m]
      REAL*8,  POINTER :: SNOMAS    (:,:  )  ! Snow mass [kg/m2]
      REAL*8,  POINTER :: SNOW      (:,:  )  ! Snow depth (H2O equiv) [mm H2O]
      REAL*8,  POINTER :: SST       (:,:  )  ! Sea surface temperature [K]
      REAL*8,  POINTER :: SUNCOS    (:,:  )  ! COS(SZA), current time
      REAL*8,  POINTER :: SUNCOSmid (:,:  )  ! COS(SZA), midpt of chem timestep
      REAL*8,  POINTER :: SUNCOSmid5(:,:  )  ! COS(SZA), midpt of chem timestep
                                             !  5 hrs ago (for PARANOX)
      REAL*8,  POINTER :: TO3       (:,:  )  ! Total overhead O3 column [DU]
      REAL*8,  POINTER :: TO31      (:,:  )  ! Total O3 at timestep start [DU]
      REAL*8,  POINTER :: TO32      (:,:  )  ! Total O3 at timestep end [DU]
      REAL*8,  POINTER :: TROPP     (:,:  )  ! Tropopause pressure [hPa]
```

```
REAL*8,  POINTER :: TROPP1    (:,:  )  ! Trop P at timestep start [hPa]
REAL*8,  POINTER :: TROPP2    (:,:  )  ! Trop P at timestep end [hPa]
REAL*8,  POINTER :: TS        (:,:  )  ! Surface temperature [K]
REAL*8,  POINTER :: TSKIN     (:,:  )  ! Surface skin temperature [K]
REAL*8,  POINTER :: TTO3      (:,:  )  ! Tropospheric ozone column [DU]
REAL*8,  POINTER :: U10M      (:,:  )  ! E/W wind speed @ 10m height [m/s]
REAL*8,  POINTER :: USTAR     (:,:  )  ! Friction velocity [m/s]
REAL*8,  POINTER :: UVALBEDO  (:,:  )  ! UV surface albedo [1]
REAL*8,  POINTER :: V10M      (:,:  )  ! N/S wind speed @ 10m height [m/s]
REAL*8,  POINTER :: Z0        (:,:  )  ! Surface roughness height [m]

!-----------------------------------------------------------------------
! 3-D Fields
!-----------------------------------------------------------------------
REAL*8,  POINTER :: AD        (:,:,:)  ! Air mass [kg]
REAL*8,  POINTER :: AIRDEN    (:,:,:)  ! Air density [kg/m3]
REAL*8,  POINTER :: AIRVOL    (:,:,:)  ! Grid box volume [m3]
REAL*8,  POINTER :: AREA_M2   (:,:,:)  ! Grid box surface area [cm2]
REAL*8,  POINTER :: AVGW      (:,:,:)  ! Mixing ratio of water vapor
REAL*8,  POINTER :: BXHEIGHT  (:,:,:)  ! Grid box height [m]
REAL*8,  POINTER :: CLDF      (:,:,:)  ! 3-D cloud fraction [1]
REAL*8,  POINTER :: CMFMC     (:,:,:)  ! Cloud mass flux [kg/m2/s]
REAL*8,  POINTER :: DELP      (:,:,:)  ! Delta-P extent  of a grid box [mb]
REAL*8,  POINTER :: DETRAINE  (:,:,:)  ! Detrainment (entrain plume)[Pa/s]
REAL*8,  POINTER :: DETRAINN  (:,:,:)  ! Detrainment (non-entr plume)[Pa/s]
REAL*8,  POINTER :: DNDE      (:,:,:)  ! Downdraft (entr plume) [Pa/s]
REAL*8,  POINTER :: DNDN      (:,:,:)  ! Downdraft (non-entr plume) [Pa/s]
REAL*8,  POINTER :: DQRCU     (:,:,:)  ! Conv precip prod rate [kg/kg/s]
REAL*8,  POINTER :: DQRLSAN   (:,:,:)  ! LS precip prod rate [kg/kg/s]
REAL*8,  POINTER :: DQIDTMST  (:,:,:)  ! Ice tendency, mst proc [kg/kg/s]
REAL*8,  POINTER :: DQLDTMST  (:,:,:)  ! H2O tendency, mst proc [kg/kg/s]
REAL*8,  POINTER :: DQVDTMST  (:,:,:)  ! Vapor tendency, mst proc [kg/kg/s]
REAL*8,  POINTER :: DTRAIN    (:,:,:)  ! Detrainment flux [kg/m2/s]
REAL*8,  POINTER :: ENTRAIN   (:,:,:)  ! GCAP entrainment [Pa/s]
REAL*8,  POINTER :: HKBETA    (:,:,:)  ! Hack overshoot parameter [1]
REAL*8,  POINTER :: HKETA     (:,:,:)  ! Hack conv mass flux [kg/m2/s]
REAL*8,  POINTER :: MOISTQ    (:,:,:)  ! Tendency in sp. humidity [kg/kg/s]
REAL*8,  POINTER :: OPTD      (:,:,:)  ! Visible optical depth [1]
REAL*8,  POINTER :: OPTDEP    (:,:,:)  ! Visible optical depth [1]
REAL*8,  POINTER :: PEDGE     (:,:,:)  ! Pressure @ level edges [Pa]
REAL*8,  POINTER :: PMID      (:,:,:)  ! Pressure @ level centers [Pa]
REAL*8,  POINTER :: PFICU     (:,:,:)  ! Dwn flux ice prec:conv [kg/m2/s]
REAL*8,  POINTER :: PFILSAN   (:,:,:)  ! Dwn flux ice prec:LS+anv [kg/m2/s]
REAL*8,  POINTER :: PFLCU     (:,:,:)  ! Dwn flux liq prec:conv [kg/m2/s]
REAL*8,  POINTER :: PFLLSAN   (:,:,:)  ! Dwn flux ice prec:LS+anv [kg/m2/s]
REAL*8,  POINTER :: PV        (:,:,:)  ! Potential vort [kg*m2/kg/s]
REAL*8,  POINTER :: QI        (:,:,:)  ! Ice mixing ratio [kg/kg]
REAL*8,  POINTER :: QL        (:,:,:)  ! Water mixing ratio [kg/kg]
```

```
      REAL*8,  POINTER :: REEVAPCN  (:,:,:)  ! Evap of precip conv [kg/kg/s]
      REAL*8,  POINTER :: REEVAPLS  (:,:,:)  ! Evap of precip LS+anvil [kg/kg/s]
      REAL*8,  POINTER :: RH        (:,:,:)  ! Relative humidity [%]
      REAL*8,  POINTER :: RH1       (:,:,:)  ! RH at timestep start [%]
      REAL*8,  POINTER :: RH2       (:,:,:)  ! RH at timestep end [%]
      REAL*8,  POINTER :: SPHU      (:,:,:)  ! Specific humidity [kg/kg]
      REAL*8,  POINTER :: SPHU1     (:,:,:)  ! Spec hum at timestep start [kg/kg]
      REAL*8,  POINTER :: SPHU2     (:,:,:)  ! Spec hum at timestep end [kg/kg]
      REAL*8,  POINTER :: T         (:,:,:)  ! Temperature [K]
      REAL*8,  POINTER :: TAUCLI    (:,:,:)  ! Opt depth of ice clouds [1]
      REAL*8,  POINTER :: TAUCLW    (:,:,:)  ! Opt depth of H2O clouds [1]
      REAL*8,  POINTER :: TMPU1     (:,:,:)  ! Temperature at timestep start [K]
      REAL*8,  POINTER :: TMPU2     (:,:,:)  ! Temperature at timestep end [K]
      REAL*8,  POINTER :: U         (:,:,:)  ! E/W component of wind [m s-1]
      REAL*8,  POINTER :: UPDE      (:,:,:)  ! Updraft (entraining plume) [Pa/s]
      REAL*8,  POINTER :: UPDN      (:,:,:)  ! Updraft (non-entr'n plume) [Pa/s]
      REAL*8,  POINTER :: V         (:,:,:)  ! N/S component of wind [m s-1]
      REAL*8,  POINTER :: ZMEU      (:,:,:)  ! Z/M updraft entrainment [Pa/s]
      REAL*8,  POINTER :: ZMMD      (:,:,:)  ! Z/M downdraft mass flux [Pa/s]
      REAL*8,  POINTER :: ZMMU      (:,:,:)  ! Z/M updraft   mass flux [Pa/s]

      !-----------------------------------------------------------------
      ! Land type and leaf area index (LAI) fields for dry deposition
      !-----------------------------------------------------------------
      INTEGER, POINTER :: IREG      (:,:  )  ! # of landtypes in grid box (I,J)
      INTEGER, POINTER :: ILAND     (:,:,:)  ! Land type at (I,J); 1..IREG(I,J)
      INTEGER, POINTER :: IUSE      (:,:,:)  ! Fraction (per mil) of grid box
                                             !  (I,J) occupied by each land type
      REAL*8,  POINTER :: XLAI      (:,:,:)  ! LAI per land type, this month
      REAL*8,  POINTER :: XLAI2     (:,:,:)  ! LAI per land type, next month

   END TYPE MetState
```

REVISION HISTORY:

```
   19 Oct 2012 - R. Yantosca - Initial version, split off from gc_type_mod.F90
   23 Oct 2012 - R. Yantosca - Added QI, QL met fields to the derived type
   15 Nov 2012 - M. Payer    - Added all remaining met fields
   12 Dec 2012 - R. Yantosca - Add IREG, ILAND, IUSE fields for dry deposition
   13 Dec 2012 - R. Yantosca - Add XLAI, XLAI2 fields for dry deposition
   20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
   15 Nov 2013 - R. Yantosca - Now denote that RH fields have units of [%]
```

1.14.1 init_gigc_state_met

Subroutine INIT_GIGC_STATE_MET allocates all fields of the Grid-Indpendent GEOS-Chem (aka "GIGC") Meteorology State object.

INTERFACE:

```
SUBROUTINE Init_GIGC_State_Met( am_I_Root, IM, JM, LM, State_Met, RC )
```

USES:

```
USE GIGC_ErrCode_Mod                          ! Error codes
USE CMN_SIZE_MOD,    ONLY : NTYPE             ! # of land types
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
INTEGER,        INTENT(IN)    :: IM          ! # longitudes on this PET
INTEGER,        INTENT(IN)    :: JM          ! # longitudes on this PET
INTEGER,        INTENT(IN)    :: LM          ! # longitudes on this PET
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Obj for meteorology state
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Return code
```

REMARKS:

```
For consistency, maybe this should be moved to a different module.
```

REVISION HISTORY:

```
19 Oct 2012 - R. Yantosca - Initial version, based on gc_environment_mod.F90
19 Oct 2012 - R. Yantosca - Now pass all dimensions as arguments
23 Oct 2012 - R. Yantosca - Now allocate QI, QL fields
15 Nov 2012 - M. Payer    - Added all remaining met fields
16 Nov 2012 - R. Yantosca - Now zero all fields after allocating
27 Nov 2012 - R. Yantosca - Now allocate SUNCOS fields (IM,JM)
12 Dec 2012 - R. Yantosca - Now allocate the IREG, ILAND, IUSE fields
13 Dec 2012 - R. Yantosca - Now allocate the XLAI, XLAI2 fields
07 Mar 2013 - R. Yantosca - Now allocate PF*LSAN, PF*CU fields properly
                            for GEOS-5.7.x met (they are edged)
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.14.2 cleanup_gigc_state_met

Subroutine CLEANUP_GIGC_STATE_MET allocates all fields of the Grid-Independent GEOS-Chem (aka "GIGC") Meteorology State object.

INTERFACE:

```
SUBROUTINE Cleanup_GIGC_State_Met( am_I_Root, State_Met, RC )
```

USES:

```
USE GIGC_ErrCode_Mod                          ! Error codes
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root    ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met    ! Obj for meteorology state
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC           ! Return code
```

REVISION HISTORY:

```
19 Oct 2012 - R. Yantosca - Initial version, based on gc_environment_mod.F90
23 Oct 2012 - R. Yantosca - Now deallocate QI, QL fields
15 Nov 2012 - M. Payer    - Added all remaining met fields
19 Nov 2012 - R. Yantosca - Segregate DEALLOCATE statements w/ #ifdefs
                            for each met field data product type
27 Nov 2012 - R. Yantosca - Now deallocate the SUNCOS fields
12 Dec 2012 - R. Yantosca - Now deallocate the IREG, ILAND, IUSE fields
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.15 Fortran: Module Interface jv_cmn_mod

Module jv_cmn_mod contains global variables (formerly in common blocks) for the FAST-J code (cf. Wild/Prather 7/99).

INTERFACE:

```
      MODULE JV_CMN_MOD
```

USES:

```
      USE CMN_SIZE_MOD,      ONLY : IIPAR, JJPAR, LLPAR
      USE CMN_SIZE_MOD,      ONLY : NDUST, NAER, NRH
      USE CMN_FJ_MOD,        ONLY : JPMAX
      USE SMV_DIMENSION_MOD, ONLY : MAX_COLUMN

      IMPLICIT NONE
      PUBLIC
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: Init_JV_CMN
      PUBLIC :: Cleanup_JV_CMN
  !DEFINED PARAMETERS
      ! NB  Number of levels in CTM plus one for above model top
```

```
! NC  Number of levels in the fundamental Fast-J grid
! NS  Maximum number of species which require J-values calculating
! NW  Maximum number of wavelength bins that can be used
! NP  Maximum number of aerosol/cloud types that can be used
! MX  Number of aerosol/cloud types supplied from CTM
! NOTE: MAX_COLUMN is set to 47L for GRIDREDUCED or 72L otherwise
! This is kludge to let us test the DEVEL code (bmy, mlong, 8/10/12)
INTEGER, PARAMETER :: NB      = MAX_COLUMN+1
INTEGER, PARAMETER :: NC      = 2*NB
INTEGER, PARAMETER :: NS      = 51
INTEGER, PARAMETER :: NW      = 15
INTEGER, PARAMETER :: NP      = 56
INTEGER, PARAMETER :: MX      = 35

REAL*8,  PARAMETER :: RAD     = 6375.d5
REAL*8,  PARAMETER :: ZZHT    = 5.d5
REAL*8,  PARAMETER :: dtaumax = 1.d0
REAL*8,  PARAMETER :: dtausub = 1.d0
REAL*8,  PARAMETER :: dsubdiv = 10.d0
REAL*8,  PARAMETER :: szamax  = 98.0d0
```

PUBLIC DATA MEMBERS:

```
! Character variables
CHARACTER*20 TITLEA(NP)
CHARACTER*78 TITLE0
CHARACTER*7  TITLEJ(3,NS), jlabel(JPMAX)

!-----------------------------------------------------------------------
! These common blocks MUST NOT be held local (bmy, 5/2/00)

REAL*8  :: WBIN(NW+1),WL(NW),FL(NW),QO2(NW,3),QO3(NW,3)
REAL*8  :: Q1D(NW,3),QQQ(NW,2,NS-3),QRAYL(NW),TQQ(3,NS)
REAL*8  :: WAA(4,NP),QAA(4,NP)
REAL*8  :: PAA(8,4,NP),RAA(4,NP),SSA(4,NP),QBC(NW)

INTEGER :: NJVAL,NW1,NW2,NAA,NLBATM

REAL*8  :: WAA_AOD(NP),QAA_AOD(NP),PAA_AOD(8,NP)
REAL*8  :: RAA_AOD(NP),SSA_AOD(NP)

REAL*8  :: TREF(51,18,12),OREF(51,18,12),BREF(51)
REAL*8, ALLOCATABLE  :: ODMDUST(:,:,:,:)
REAL*8, ALLOCATABLE  :: ODAER(:,:,:,:)

REAL*8  :: jfacta(JPMAX),zpdep(NW,7)
INTEGER :: npdep,jpdep(NS),jind(JPMAX)

INTEGER :: MIEDX(MX)
```

```
      !-----------------------------------------------------------------------
      ! Split off GLYX-chemistry specific arrays into separate common blocks
      ! (ccarouge, bmy, 8/20/09)
      INTEGER :: PDEPF(7)

      REAL*8  :: MGLYPDEP(NW, 3)

      !-----------------------------------------------------------------------
      ! These common blocks MUST be held local for the parallelization
      ! (bmy, 5/2/00)
      REAL*8   :: TJ(NB),PJ(NB+1),DM(NB),DO3(NB),DBC(NB),Z(NB)
      REAL*8   :: AER(MX,NB),AMF(NB,NB),RFLECT,SZA,U0,TANHT
      REAL*8   :: zj(NB,JPMAX)
      REAL*8   :: FFF(NW,NB),VALJ(NS)
      INTEGER  :: jadsub(NC)

$OMP THREADPRIVATE( TJ, PJ, DM, DO3, DBC, Z)
$OMP THREADPRIVATE( AER, AMF, RFLECT, SZA, U0, TANHT)
$OMP THREADPRIVATE( zj )
$OMP THREADPRIVATE( FFF, VALJ )
$OMP THREADPRIVATE( jadsub )
```

REMARKS:

```
    NOTES for CTM Interface (bmy, 10/27/99, 3/23/03)
    ================================================================
    (1) Change JPNL and JPPJ from parameters to variables, which are
        set in "inphot.f".  This allows the user to switch the number
        of levels at run-time via the CTM inputs.

    (2) Now make RAD, ZZHT, DTAUMAX, DTAUSUB, DSUBDIV, SZAMAX into
        parameters instead of holding them in common blocks.

    (3) Create new common blocks /WLLOC/ and /JVLOC/ to hold certain
        quantities -Xlocal for parallel code (ppm, 4/98, bmy, 9/21/99)

    (4) The common blocks that must be held -Xlocal are:
           /ATMOS/, /JVSUB/, /WLLOC/, /JVLOC/

    (4a) Declare the above commons THREADPRIVATE for the Compaq
         Alpha platform (bmy, 7/10/01)

    (5) Break MIEDX off from the WLLOC common block, since it must
        not be declared LOCAL for the parallelization. (bmy, 5/2/00)

    (6) For including aerosol optical depths: (rvm, bmy, 9/30/00)
        (a) Increase MX from 3 to 10 .
```

```
      (c) Add ODMDUST(IIPAR,JJPAR,LLPAR,NDUST) to common block /CLIM/
                                                                             .
  (7) Move NDUST to CMN_SIZE to avoid conflicts (bmy, 11/15/01)
                                                                             .
  (8) For updating aerosol optical depths again (rvm, bmy, 2/27/02):
      (a) Change NP from 21 to 56
      (b) Change MX from 10 to 35
      (c) Add ODAER(IIPAR,JJPAR,LLPAR,NAER*NRH) to common block /CLIM/
                                                                             .
  (9) Changed RCS ID tag comment character from "C" to "!" to allow freeform
       compilation.  Also added & continuation characters in column 73
       to allow header files to be included in F90 freeform files.
       Also changed comment character from "C" to "!" to allow this
       file to be inlined into freeform source code. (bmy, 6/25/02)
                                                                             .
  (10) Renamed cpp switch from DEC_COMPAQ to COMPAQ.  Also declare common
        blocks ATMOS, JVLOC, WLLOC, JVSUB as !$OMP THREADPRIVATE for
        all platforms. (bmy, 3/23/03)
                                                                             .
  (11) Added new pressure denpendencies algorithm parameters
         for MGLY. (tmf, 1/7/09)
                                                                             .
  (12) Added 'pdepf' as pressure dependancy function selector. (tmf, 1/31/06)
                                                                             .
  (13) Split off PDEPF and MGLYPDEP into separate common blocks to avoid
        warnings on IFORT 9 (ccarouge, bmy, 8/20/09)
                                                                             .
  (14) Add new optical variables for AOD calculation (clh, 05/06/10)
```

REVISION HISTORY:

```
  23 Aug 2011 - M. Long   - Converted to Module from Header file
  19 Nov 2012 - R. Yantosca - Now use INIT_JV_CMN to allocate arrays and
                              CLEANUP_JV_CMN to deallocate arrays
```

1.15.1 init_comode_loop

Subroutine INIT_COMODE_LOOP initializes size parameters with the geospatial values obtained from the ESMF interface.

INTERFACE:

```
      SUBROUTINE Init_JV_CMN( am_I_Root, RC )
```

USES:

```
      USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
Need to add error-checking on the allocation statements, so that we
exit the code upon error.
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Added ProTeX headers
```

1.15.2 cleanup_comode_loop

Subroutine CLEANUP_COMODE_LOOP deallocates all module arrays.

INTERFACE:

```
SUBROUTINE Cleanup_JV_CMN( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Initial version
```

1.16 Fortran: Module Interface jv_mie_mod.F

This include file contains physical constants for the GEOS-Chem column chemistry code.

INTERFACE:

```
MODULE JV_MIE_MOD
```

USES:

```
      IMPLICIT NONE
      PUBLIC
```

DEFINED PARAMETERS:

```
      ! NL    Maximum number of levels after insertion of extra Mie levels
      ! N__   Number of levels in Mie grid: 2*(2*lpar+2+jaddto(1))+3
      ! M__   Number of Gauss points used
 ------------------------------------------------------------------------
      NL=1500 was too small for dicarbonyls, so we upped it to 2000.
      Uncomment this line to restore the previous definition (phs, 10/9/09)
       INTEGER, PARAMETER :: NL  = 1500
 ------------------------------------------------------------------------
      INTEGER, PARAMETER :: NL  = 2000
      INTEGER, PARAMETER :: N__ = 2*NL
      INTEGER, PARAMETER :: M__ = 4
```

PUBLIC DATA MEMBERS:

```
      ! Arrays
      REAL*8  :: A(M__),           B(M__,M__),   C1(M__)
      REAL*8  :: H(M__),           AA(M__,M__),  CC(M__,M__)
      REAL*8  :: S(M__,M__),       W(M__,M__),   U1(M__,M__)
      REAL*8  :: V1(M__),          WT(M__),      EMU(M__)
      REAL*8  :: PM(M__,2*M__),    PM0(2*M__),   POMEGA(2*M__,N__)
      REAL*8  :: ZTAU(N__),        FZ(N__),      FJ(N__)
      REAL*8  :: DD(M__,M__,N__),  RR(M__,N__)
      REAL*8  :: ZREFL,            ZFLUX

      ! Scalars
      REAL*8  :: RADIUS,           ZU0
      INTEGER :: ND,               N
      INTEGER :: M,                MFIT

      !=================================================================
      ! Declare the following global variables as THREADPRIVATE for the
      ! OpenMP parallelization on all platforms (bmy, 3/23/03)
      !=================================================================
$OMP THREADPRIVATE( A,B,C1,H,AA,CC,S,W,U1,V1,WT,EMU,PM,PM0,POMEGA )
$OMP THREADPRIVATE( ZTAU,FZ,FJ,DD,RR,ZREFL,ZFLUX,RADIUS,ZU0 )
$OMP THREADPRIVATE( ND,N,M,MFIT )
```

REMARKS:

```
  Keep increasing NL if necessary.  This will avoid the "too many levels
  in photolysis" error.
```

REVISION HISTORY:

```
  (1 ) Changed RCS ID tags to by adding a ! comment character to allow
       freeform compilation.  Also added & continuation characters in
```

```
         column 73 to allow header files to be included in F90 freeform files.
         Also changed comment character from "C" to "!", to allow this
         file to be inlined into freeform source code. (bmy, 6/25/02)
   (2 ) Now declare common blocks /MIEBLK/ and /MINDEX/ as THREADPRIVATE for
         all platforms (bmy, 3/23/03)
   (3 ) Set NL to 1000 to avoid SMVGEAR crash with GEOS-5.2.0 on Sept 1st 2008
   03 Aug 2011 - M. Long     - Converted from Header file to Module
```

1.17 Fortran: Module Interface smv_dimension_mod

This include file contains the various placeholder parameters that are required to replace references to GEOS-Chem grid parameters. This is necessary because several quantities in the FAST-J and SMVGEAR codes are contained in common blocks, and we need to have these parameters for sizing those arrays properly.

INTERFACE:

```
      MODULE SMV_DIMENSION_MOD
```

USES:

```
      IMPLICIT NONE
      PUBLIC
```

DEFINED PARAMETERS:

```
      ! Locally defined replacement for GEOS-Chem parameter "LLPAR"
      ! This is used to set the "NB" value in jv_cmn_mod.F
#if defined( GCAP )

      !----------------------------------------
      ! GCAP vertical grid
      !----------------------------------------
      INTEGER, PARAMETER :: MAX_COLUMN   = 23

#elif defined( GEOS_4 )

      !----------------------------------------
      ! GEOS-4 vertical grid
      !----------------------------------------
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: MAX_COLUMN   = 30   ! Reduced GEOS-4 vertical grid
#else
      INTEGER, PARAMETER :: MAX_COLUMN   = 55   ! Full GEOS-4 vertical grid
#endif

#else
```

```
      !---------------------------------------
      ! GEOS-5, MERRA, GEOS-FP vertical grids
      !---------------------------------------
#if   defined( GRIDREDUCED )
      INTEGER, PARAMETER :: MAX_COLUMN   = 47   ! Reduced GEOS-5 vertical grid
#else
      INTEGER, PARAMETER :: MAX_COLUMN   = 72   ! Full GEOS-5 vertical grid
#endif

#endif

      ! Locally defined replacement for GEOS-Chem parameters "IIPAR" & "JJPAR"
      INTEGER, PARAMETER :: MAX_LAT      = 47   !
      INTEGER, PARAMETER :: MAX_LON      = 47   !

      ! Locally defined replacement for GEOS-Chem parameter "NNPAR"
      INTEGER, PARAMETER :: MAX_TRACERS = 100

      ! Locally defined replacement for "comode.h" parameter "IGAS"
      INTEGER, PARAMETER :: MAX_SPECIES = 125
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE WAS ORIGINALLY DEVELOPED FOR THE COLUMN CODE.  %%%
%%%  THE PARAMETERS HERE CAN BE COMBINED INTO A SINGLE MODULE WITH    %%%
%%%  DECLARED SIZE PARAMETERS (IN THE NEAR FUTURE).                   %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
24 Mar 2009 - R. Yantosca - Initial version
16 Apr 2010 - R. Yantosca - Added MAX_SPECIES = 125
03 Aug 2011 - M. Long     - Converted from Header file to Module
10 Aug 2012 - R. Yantosca - Now define MAX_COLUMN=47 for GRIDREDUCED or
                            =72 otherwise.  Kludge for testing DEVEL code.
02 Jul 2013 - R. Yantosca - Set MAX_COLUMN properly for GCAP grid
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
28 Oct 2013 - R. Yantosca - Bug fix: add GEOS-4 info
```

1.18 Fortran: Module Interface smv_physconst_mod

This include file contains physical constants for the GEOS-Chem column chemistry code.

INTERFACE:

```
      MODULE SMV_PHYSCONST_MOD
```

USES:

```
IMPLICIT NONE
PUBLIC
```

DEFINED PARAMETERS:

```
! Molecular weight of air [28.97e-3 kg/mol]
REAL*8, PARAMETER :: MW_AIR       = 28.97d-3

! Avogadro's # [#/mol]
REAL*8, PARAMETER :: AVO          = 6.022d23

! g0    : Gravity at Surface of Earth [9.8 m/s^2]
REAL*8, PARAMETER :: g0           = 9.8d0

! PI    : Double-Precision value of PI
REAL*8, PARAMETER :: PI           = 3.14159265358979323d0

! Re    : Radius of Earth [m]
REAL*8, PARAMETER :: Re           = 6.375d6

! Rd    : Gas Constant (R) in Dry Air [287 J/K/kg]
REAL*8, PARAMETER :: Rd           = 287.0d0

! g0_100 = 100.0 / g0
REAL*8, PARAMETER :: g0_100       = 100d0 / g0

! PI_180 = PI    / 180.0
REAL*8, PARAMETER :: PI_180       = PI / 180d0

! Rdg0   = Rd    / g0
REAL*8, PARAMETER :: Rdg0         = Rd / g0

! Scale height of atmosphere (7.6 km = 7600m)
REAL*8, PARAMETER :: SCALE_HEIGHT = 7600d0

! Cp = 1000 J / kg / K = specific heat of air at constant P
REAL*8, PARAMETER :: Cp           = 1000.0d0

! Von Karman's constant
REAL*8, PARAMETER :: VON_KARMAN   = 0.4d0
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE WAS ORIGINALLY DEVELOPED FOR THE COLUMN CODE.  %%%
%%%  THE PARAMETERS HERE CAN BE COMBINED INTO A SINGLE MODULE WITH    %%%
%%%  DECLARED PHYSICAL CONSTANTS (IN THE NEAR FUTURE).                %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

In older sections of code, AIRMW may be replaced by (MW_AIR*1d3).
```

REVISION HISTORY:

```
14 Dec 2009 - R. Yantosca - Initial version, adapted from CMN_GCTM
03 Aug 2011 - M. Long     - Converted from Header file to Module
```

1.19 Fortran: Module Interface geos_chem

Program GEOS_CHEM is the main level driver program for the GEOS-Chem model of atmospheric chemistry and composition.

INTERFACE:

```
PROGRAM GEOS_CHEM
```

USES:

```
!-----------------------------------------------------------------
! Basic GEOS-Chem modules
!-----------------------------------------------------------------
USE CMN_SIZE_MOD          ! Size parameters
USE CMN_GCTM_MOD          ! Physical constants
USE COMMSOIL_MOD          ! Soil NOx emissions header file
USE ERROR_MOD             ! For error checking
USE FILE_MOD              ! For file I/O
USE INPUT_MOD             ! For reading settings from "input.geos"
USE LOGICAL_MOD           ! Logical flags to toggle G-C options
USE MAPPING_MOD           ! For regridding MODIS LAI
USE OLSON_LANDMAP_MOD     ! Computes IREG, ILAND, IUSE from Olson map
USE PRESSURE_MOD          ! For computing pressure at grid boxes
USE RESTART_MOD           ! For restart file I/O
USE TIME_MOD              ! For computing date & time
USE TRACERID_MOD          ! Flags for G-C tracers & chemical species
USE TRACER_MOD, ONLY : N_MEMBERS
USE TRACER_MOD, ONLY : CHECK_STT
USE TRACER_MOD, ONLY : CHECK_STT_05x0666
USE TRACER_MOD, ONLY : CHECK_STT_025x03125

!-----------------------------------------------------------------
! GEOS-Chem chemistry modules
!-----------------------------------------------------------------
USE CARBON_MOD            ! For SOA simulation
USE CHEMISTRY_MOD         ! Driver routines for chemistry
USE COMODE_MOD            ! Allocatable arrays for SMVGEAR solver
USE COMODE_LOOP_MOD       ! Formerly common-block arrays for SMVGEAR
USE GCKPP_COMODE_MOD      ! For the KPP chemical solver
USE GLOBAL_CH4_MOD        ! For offline CH4 simulation
USE MERCURY_MOD           ! For offline Hg simulation (driver)
USE OCEAN_MERCURY_MOD     ! For offline Hg simulation (ocean model)
```

```
      USE STRAT_CHEM_MOD        ! For linearized stratospheric chemistry
      USE TOMS_MOD              ! For overhead O3 columns (for FAST-J)
      USE UVALBEDO_MOD          ! For reading UV albedoes (for FAST-J)

      !-----------------------------------------------------------------
      ! GEOS-Chem deposition modules
      !-----------------------------------------------------------------
      USE DEPO_MERCURY_MOD      ! Deposition for offline Hg simulation
      USE DRYDEP_MOD            ! For dry deposition
      USE WETSCAV_MOD           ! For wet deposition (rainout & washout)

      !-----------------------------------------------------------------
      ! GEOS-Chem diagnostics modules
      !-----------------------------------------------------------------
      USE BENCHMARK_MOD         ! For the 1-month benchmark simulations
      USE CMN_DIAG_MOD          ! Logical switches for G-C diagnostics
      USE DIAG_MOD              ! G-C diagnostic arrays & counters
      USE DIAG41_MOD            ! For ND41  (afternoon PBL       ) diag
      USE DIAG42_MOD            ! For ND42  (SOA products        ) diag
      USE DIAG48_MOD            ! For ND48  (station timeseries  ) diag
      USE DIAG49_MOD            ! For ND49  (inst. timeseries    ) diag
      USE DIAG50_MOD            ! For ND50  (24h avg timeseries  ) diag
      USE DIAG51_MOD            ! For ND51  (satellite timeseries) diag
      USE DIAG51b_MOD           ! For ND51b (satellite timeseries) diag
      USE DIAG63_MOD            ! For ND63  (PARANOX timeseries  ) diag
      USE DIAG_OH_MOD           ! For ND43  (OH,HO2,etc. prod    ) diag
      USE PLANEFLIGHT_MOD       ! For ND40  (plane flight track  ) diag

      !-----------------------------------------------------------------
      ! GEOS-Chem dynamics modules
      !-----------------------------------------------------------------
      USE CONVECTION_MOD        ! For deep cloud convection
      USE LINOZ_MOD             ! For LINOX linear strat chemistry
      USE PBL_MIX_MOD           ! For full PBL mixing (TURBDAY)
      USE TPCORE_BC_MOD         ! For nested-grid boundary conditions
      USE TRANSPORT_MOD         ! Driver routines for advection
      USE TROPOPAUSE_MOD        ! For the dynamic tropopause
      USE VDIFF_MOD             ! For non-local PBL mixing (J. Lin)

      !-----------------------------------------------------------------
      ! GEOS-Chem emissions modules
      !-----------------------------------------------------------------
      USE EMISSIONS_MOD         ! Driver routines for emissions
      USE MODIS_LAI_MOD         ! For MODIS leaf area indices (replacement)
      USE LIGHTNING_NOX_MOD     ! For lightning NOx emissions
      USE MEGAN_MOD             ! For biogenic emissions
      USE SOILNOX_RESTART_MOD   ! For reading and writing soil NOx restart
      USE BROMOCARB_MOD         ! For setting CH3Br concentrations in PBL, jpp
```

```
      !-----------------------------------------------------------------
      ! GEOS-Chem met field I/O modules
      !-----------------------------------------------------------------
      USE DAO_MOD               ! Met field definitions
      USE GCAP_READ_MOD         ! For reading GCAP met data
      USE GEOSFP_READ_MOD       ! For reading GEOS-FP data
      USE MERRA_A1_MOD          ! For reading MERRA A1 data
      USE MERRA_A3_MOD          ! For reading MERRA A3 data
      USE MERRA_CN_MOD          ! For reading MERRA CN data
      USE MERRA_I6_MOD          ! For reading MERRA I6 data
      USE A3_READ_MOD           ! For reading A3 data (all other met)
      USE A6_READ_MOD           ! For reading A6 data (all other met)
      USE I6_READ_MOD           ! For reading I6 data (all other met)

      !-----------------------------------------------------------------
      ! Modules for the Grid-Independent GEOS-Chem (aka "GIGC")
      !-----------------------------------------------------------------
      USE GIGC_ErrCode_Mod      ! Error codes for success or failure
      USE GIGC_Environment_Mod  ! For allocating objects
      USE GIGC_Input_Opt_Mod    ! Derived type for Input Options
      USE GIGC_State_Chm_Mod    ! Derived type for Chemistry State object
      USE GIGC_State_Met_Mod    ! Derived type for Meteorology State object

      IMPLICIT NONE
```

REMARKS:

```
      .
       GGGGGG  EEEEEEE  OOOOO  SSSSSSS       CCCCCC H     H EEEEEEE M     M
      G        E       O     O S           C       H     H E       M M M M
      G   GGG  EEEEEE  O     O SSSSSSS     C       HHHHHHH EEEEEE  M  M  M
      G     G  E       O     O       S     C       H     H E       M     M
       GGGGGG  EEEEEEE  OOOOO  SSSSSSS       CCCCCC H     H EEEEEEE M     M
      .
      .
                  (formerly known as the Harvard-GEOS model)
            for 4 x 5, 2 x 2.5 global grids and hi-res nested grids
      .
        Contact: GEOS-Chem Support Team (geos-chem-support@as.harvard.edu)

      .
   See the GEOS-Chem Web Site:
      .
      http://acmg.seas.harvard.edu/geos/
      .
   and the GEOS-Chem User's Guide:
      .
      http://acmg.seas.harvard.edu/geos/doc/man/
```

```
.
and the GEOS-Chem wiki:
.
   http://wiki.seas.harvard.edu/geos-chem/
.
for the most up-to-date GEOS-Chem documentation on the following topics:
.
   - installation, compilation, and execution
   - coding practice and style
   - input files and met field data files
   - horizontal and vertical resolution
   - modification history
```

REVISION HISTORY:

```
13 Aug 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2010 - R. Yantosca - Add modifications for MERRA (treat like GEOS-5)
19 Aug 2010 - R. Yantosca - Now call MERRA met field reader routines
02 Feb 2011 - S. Kim      - Call Compute_OD after wet deposition
05 Oct 2011 - R. Yantosca - Now get SUNCOS30 array from routine COSSZA
07 Oct 2011 - R. Yantosca - Rename SUNCOS30 to SUNCOS_MID, which is the
                            cos(SZA) at the midpt of the chemistry timestep
02 Feb 2012 - R. Yantosca - Added modifications for GEOS-5.7.x met fields
06 Feb 2012 - R. Yantosca - Reorganize USE statements for clarity
06 Feb 2012 - R. Yantosca - Renamed NN to NNN to avoid name confusion
07 Feb 2012 - R. Yantosca - Split off met field I/O into internal routines
                            READ_INITIAL_MET_FIELDS and READ_MET_FIELDS
07 Feb 2012 - M. Payer    - Replace call to COSSZA with GET_COSINE_SZA
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
06 Mar 2012 - R. Yantosca - Now call READ_TOMS every month (this was
                            formerly done within routine "fast_j.F")
06 Mar 2012 - R. Yantosca - Add subroutine GET_OVERHEAD_O3_FOR_FASTJ
                            which calls COMPUTE_OVERHEAD_O3 (in toms_mod.F)
                            to pre-compute the overhead O3 columsn for
                            FAST-J photolysis.  This removes code from
                            "set_prof.F" to facilitate the GI model.
19 Mar 2012 - R. Yantosca - Now call routines from olson_landmap_mod.F90
                            to read the Olson land map data
04 Apr 2012 - R. Yantosca - Now call updated LAI routines from new module
                            modis_lai_mod.F90.  Retire routine RDLAI.
05 Apr 2012 - R. Yantosca - Removed reference to LXTRA, it's obsolete
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F90
11 Apr 2012 - R. Yantosca - Now call INIT_MODIS_LAI (in modis_lai_mod.F90)
                            here so that we don't have to call it from
                            megan_mod.F and mercury_mod.F separately.
17 Apr 2012 - R. Yantosca - Need to set the mapping variable to NULL()
10 Jun 2012 - L. Murray   - Remove references to UPBDFLX_MOD.F
31 Jul 2012 - R. Yantosca - Now pass am_I_Root variable to lower-level
                            routines in order to allow PRINT and WRITE
```

```
                            statements to execute on the root CPU.  This
                            is needed for compatibility w/ the GEOS-5 GCM.
    13 Aug 2012 - R. Yantosca - Now call FILL_CHEM_STATE_IDs to populate
                            the CHEM_STATE object ID and name fields
    18 Oct 2012 - R. Yantosca - Rename LOCAL_MET object to State_Met
    18 Oct 2012 - R. Yantosca - Rename CHEM_STATE object to State_Chm
    18 Oct 2012 - R. Yantosca - Now pass am_I_Root, RC arguments to routines
                            ALLOCATE_ALL, INIT_ALL when using -DDEVEL
    19 Oct 2012 - R. Yantosca - Now reference gigc_state_chm_mod.F90
    19 Oct 2012 - R. Yantosca - Now reference gigc_state_met_mod.F90
    25 Oct 2012 - R. Yantosca - Define logical doDebugPrt for ND70 output
    25 Oct 2012 - R. Yantosca - Add descriptive comments for DEVEL #ifdefs
    25 Oct 2012 - R. Yantosca - Now reference gigc_errcode_mod.F90
    01 Nov 2012 - R. Yantosca - Now read soil NOx restart file
    01 Nov 2012 - R. Yantosca - Now reference gigc_input_opt_mod.F90
    08 Nov 2012 - R. Yantosca - Now pass Input_Opt as an arg to DO_CHEMISTRY
    01 Nov 2012 - R. Yantosca - Now read soil NOx restart file
    14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
                            to various subroutines
    15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
    15 Nov 2012 - R. Yantosca - Bring Input_Opt out of the DEVEL tags
    26 Feb 2013 - R. Yantosca - Add placeholder tag for Input_Opt%MAX_DEP
    05 Mar 2013 - R. Yantosca - Now pass am_I_Root, Input_Opt, RC to routine
                            DO_PBL_MIX_2 (for non-local PBL mixing)
    15 Mar 2013 - R. Yantosca - Now set Input_Opt%LINOZ_N* fields here
    29 Mar 2013 - R. Yantosca - Bring code out of DEVEL blocks
    30 May 2013 - R. Yantosca - Now pass Input_Opt object to STDRUN routine
    03 Jun 2013 - R. Yantosca - Use routines from updated mercury_mod.F
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
    23 Oct 2013 - R. Yantosca - Now pass am_I_root, Input_Opt, RC to INIT_DAO
    13 Dec 2013 - M. Sulprizio- Now set USE_O3_FROM_MET logical flag during
                            initialization stage
```

1.19.1 display_grid_and_model

Internal Subroutine DISPLAY_GRID_AND_MODEL displays the appropriate messages for the given model grid and machine type. It also prints the starting time and date (local time) of the GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE DISPLAY_GRID_AND_MODEL
```

REVISION HISTORY:

```
02 Dec 2003 - R. Yantosca - Initial version
```

```
13 Aug 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2010 - R. Yantosca - Added extra output
02 Feb 2012 - R. Yantosca - Added output for GEOS-5.7.x met fields
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
19 Mar 2012 - R. Yantosca - Now echo info for 0.25 x 0.3125 runs
19 Mar 2012 - R. Yantosca - Now echo info if ISORROPIA is turned off
22 Oct 2012 - R. Yantosca - Now echo info if -DDEVEL is used
```

1.19.2 ctm_flush

Internal subroutine CTM_FLUSH flushes certain diagnostic file buffers to disk.

CTM_FLUSH should normally be called after each diagnostic output, so that in case the run dies, the output files from the last diagnostic timestep will not be lost.

FLUSH is an intrinsic FORTRAN subroutine and takes as input the unit number of the file to be flushed to disk.

INTERFACE:

```
SUBROUTINE CTM_FLUSH
```

REVISION HISTORY:

```
31 Aug 2000 - R. Yantosca - Initial version
13 Aug 2010 - R. Yantosca - Added ProTeX headers
06 Aug 2012 - R. Yantosca - IU_BPCH is only global file LUN still needed
```

1.19.3 display_end_time

Internal subroutine DISPLAY_END_TIME prints the ending time of the GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE DISPLAY_END_TIME
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
13 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.19.4 read_initial_met_fields

Internal subroutine READ_INITIAL_MET_FIELDS calls the various routines to read met fields at the beginning of a GEOS-Chem simulation. This code was moved out of the main routine for clarity, due to the many #if defined() blocks that are required.

INTERFACE:

```
SUBROUTINE READ_INITIAL_MET_FIELDS()
```

REMARKS:

```
All variables used in this routine are declared above in the main
program, and as such, are visible here.

Also calls the following routines:
(1) AVGPOLE   (average pressure @ poles) when I3 or I6 fields are read
(2) LIGHTNING (lightning NOx emissions)  when A3 or A6 fields are read
```

REVISION HISTORY:

```
07 Feb 2012 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
23 Oct 2013 - R. Yantosca - Now pass Input_Opt to GET_A6_FIELDS
23 Oct 2013 - R. Yantosca - Now pass Input_Opt to GET_MERRA_A3_FIELDS
```

1.19.5 read_met_fields

Internal subroutine READ_MET_FIELDS calls the various routines to read met fields in the main GEOS-Chem timestepping loop. This code was moved out of the main routine for clarity, due to the many #if defined() blocks that are required.

INTERFACE:

```
SUBROUTINE READ_MET_FIELDS()
```

REMARKS:

```
All variables used in this routine are declared above in the main
program, and as such, are visible here.

Also calls the following routines:
(1) AVGPOLE   (average pressure @ poles) when I3 or I6 fields are read
(2) LIGHTNING (lightning NOx emissions)  when A3 or A6 fields are read
```

REVISION HISTORY:

```
07 Feb 2012 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
04 Jan 2013 - M. Payer    - Call UPDATE_T_DAY for MERRA and GEOS-5.7.2 (tmf)
23 Oct 2013 - R. Yantosca - Now pass Input_Opt to GET_A6_FIELDS
```

1.19.6 get_overhead_o3_for_fastj

Internal subroutine GET_OVERHEAD_O3_FOR_FASTJ

INTERFACE:

```
SUBROUTINE GET_OVERHEAD_O3_FOR_FASTJ()
```

REMARKS:

```
This routine makes use of variables declared in above in the main program
(which are visible in all sub-programs below the CONTAINS statement).

.

The original code was done in FAST-J routine "set_prof.F", but has been
split off to facilitate development of the grid-independent model.
```

REVISION HISTORY:

```
07 Mar 2012 - R. Yantosca - Initial version
14 Nov 2013 - R. Yantosca - For GEOS-FP, read O3 from met field files
13 Dec 2013 - M. Sulprizio- Moved USE_O3_FROM_MET to the Input_Opt object and
                            set in initialization stage of GEOS_CHEM
```

1.20 Fortran: Module Interface a3_read_mod

Module A3_READ_MOD contains routines that unzip, open, and read the GEOS-Chem A3 (avg 3-hour) met fields from disk.

INTERFACE:

```
MODULE A3_READ_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
PUBLIC  :: ARCHIVE_ND67_1D
PUBLIC  :: GET_A3_FIELDS
PUBLIC  :: OPEN_A3_FIELDS
PUBLIC  :: UNZIP_A3_FIELDS
!PRIVATE DATA MEMBERS:
PRIVATE :: A3_CHECK
PRIVATE :: CHECK_TIME
PRIVATE :: DO_OPEN_A3
PRIVATE :: GET_N_A3
PRIVATE :: READ_A3
```

REMARKS:

```
This module reads GEOS-4, GEOS-5, and GCAP met fields
MERRA met fields are read in routines merra_*_mod.F
GEOS-FP met fields are read in geosfp_read_mod.F
```

REVISION HISTORY:

```
23 Jun 2003 - R. Yantosca - Initial version
(1 ) Adapted from "dao_read_mod.f" (bmy, 6/23/03)
(2 ) Now can read from either zipped or unzipped files. (bmy, 12/11/03)
(3 ) Now skips past the GEOS-4 met field ident string (bmy, 12/12/03)
(4 ) Now references "unix_cmds_mod.f", "directory_mod.f", and
      "logical_mod.f" (bmy, 7/20/04)
(5 ) Now references FILE_EXISTS from "file_mod.f" (bmy, 3/23/05)
(6 ) Now modified for GEOS-5 and GCAP met fields (bmy, 5/25/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Fixed typos for GCAP fields and ND67 diagnostics (bmy, 2/9/06)
(9 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(10) Now read PARDF, PARDR for GCAP met fields (swu, bmy, 10/4/06)
(11) Extra modifications for GEOS-5 met fields (bmy, 1/17/07)
(12) Now get the # of A-3 fields from the file ident string (bmy, 10/7/08)
(13) Remove references to IN_CLOUD_OD (bmy, 10/15/09)
21 Sep 2010 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
03 Aug 2012 - R. Yantosca - Now make IU_A3 a private module variable
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.20.1 unzip_a3_fields

Subroutine UNZIP_A3_FIELDS invokes a FORTRAN system call to uncompress GEOS-Chem A3 met field files and store the uncompressed data in a temporary directory, where GEOS-CHEM can read them. The original data files are not disturbed.

INTERFACE:

```
SUBROUTINE UNZIP_A3_FIELDS( Input_Opt, OPTION, NYMD )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE CMN_SIZE_MOD
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE ERROR_MOD,          ONLY : ERROR_STOP
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*),  INTENT(IN) :: OPTION    ! Unzip option
INTEGER, OPTIONAL, INTENT(IN) :: NYMD      ! YYYY/MM/DD of file to unzip
TYPE(OptInput),    INTENT(IN) :: Input_Opt ! Input Options object
```

REVISION HISTORY:

```
15 Jun 1998 - R. Yantosca - Initial version
(1 ) Adapted from UNZIP_MET_FIELDS of "dao_read_mod.f" (bmy, 6/23/03)
(2 ) Directory information YYYY/MM or YYYYMM is now contained w/in
     GEOS_1_DIR, GEOS_S_DIR, GEOS_3_DIR, GEOS_4_DIR (bmy, 12/11/03)
(3 ) Now reference "directory_mod.f" and "unix_cmds_mod.f". Now prevent
     EXPAND_DATE from overwriting directory paths with Y/M/D tokens in
     them (bmy, 7/20/04)
(4 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
21 Sep 2010 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.20.2 do_open_a3

Function DO_OPEN_A3 returns TRUE if is time to open the A3 met field file or FALSE otherwise. This prevents us from opening a file which has already been opened.

INTERFACE:

```
FUNCTION DO_OPEN_A3( NYMD, NHMS, RESET ) RESULT( DO_OPEN )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)            :: NYMD    ! YYYY/MM/DD date
INTEGER, INTENT(IN)            :: NHMS    ! hh:mm:ss time
LOGICAL, INTENT(IN),  OPTIONAL :: RESET   ! Reset first-time flag?
```

REVISION HISTORY:

```
23 Jun 2003 - R. Yantosca - Initial version
(1 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
21 Sep 2010 - R. Yantosca - Added ProTeX headers
21 Sep 2010 - R. Yantosca - Bug fix: If we are using MEGAN (which reads many
                            days of A3 data @ start of run), then reset the
                            first-time flag.  This will prevent an error if
                            if the start time is not 00 GMT.
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.20.3 open_a3_fields

Subroutine OPEN_A3_FIELDS opens the A3 met fields file for date NYMD and time NHMS.

INTERFACE:

```
SUBROUTINE OPEN_A3_FIELDS( NYMD, NHMS, Input_Opt, RESET, IUNIT )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE CMN_SIZE_MOD                         ! Size parameters
USE ERROR_MOD,          ONLY : ERROR_STOP
USE FILE_MOD,           ONLY : IOERROR,    FILE_EXISTS
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)            :: Input_Opt  ! Input_Options
INTEGER,        INTENT(IN)            :: NYMD       ! YYYY/MM/dd and
INTEGER,        INTENT(IN)            :: NHMS       !  hh:mm:ss of data
LOGICAL,        INTENT(IN),  OPTIONAL :: RESET      ! Reset first flag?
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT), OPTIONAL :: IUNIT      ! Returns IU_A1
```

REVISION HISTORY:

```
15 Jun 1998 - R. Yantosca - Initial version
(1 ) Adapted from OPEN_MET_FIELDS of "dao_read_mod.f" (bmy, 6/13/03)
(2 ) Now opens either zipped or unzipped files (bmy, 12/11/03)
(3 ) Now skips past the GEOS-4 ident string (bmy, 12/12/03)
(4 ) Now references "directory_mod.f" instead of CMN_SETUP.  Also now
     references LUNZIP from "logical_mod.f".  Also now prevents EXPAND_DATE
     from overwriting Y/M/D tokens in directory paths. (bmy, 7/20/04)
(5 ) Now use FILE_EXISTS from "file_mod.f" to determine if file unit IU_A3
     refers to a valid file on disk (bmy, 3/23/05)
(6 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(9 ) Now get the # of A-3 fields from the file ident string (bmy, 10/7/08)
21 Sep 2010 - R. Yantosca - Added ProTeX headers
21 Sep 2010 - R. Yantosca - Now pass RESET flag to DO_OPEN_A3
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
03 Aug 2012 - R. Yantosca - Now use findFreeLUN to define IU_A3 locally
06 Aug 2012 - R. Yantosca - Add IUNIT to pass IU_A3 to calling routine
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
11 Apr 2013 - R. Yantosca - Now pass Input_Opt object
```

1.20.4 get_a3_fields

Subroutine GET_A3_FIELDS is a wrapper for routine READ_A3. GET_A3_FIELDS calls READ_A3 properly for reading GEOS-3, GEOS-4, GEOS-5, or GCAP met data sets.

INTERFACE:

```
SUBROUTINE GET_A3_FIELDS( NYMD, NHMS, State_Met )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD   ! YYYY/MM/DD
INTEGER, INTENT(IN) :: NHMS   !  and hh:mm:ss of desired data
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
23 Jun 2003 - R. Yantosca - Initial version
(1 ) Now save RADSWG to the RADSWG array (instead of RADIAT).  Now save
     CLDFRC to the CLDFRC array (instead of CFRAC).  Now get RADLWG,
     SNOW arrays.  Also updated comments. (bmy, 12/9/03)
(2 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(3 ) Bug fix: replace RADSWG in call to READ_A3 for GCAP met fields.
     (bmy, 2/9/06)
(4 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(5 ) Now read PARDF, PARDR for GCAP met fields (swu, bmy, 10/4/06)
(6 ) Now read SNOW and GETWETTOP for GCAP met fields (swu, phs, 11/15/06)
(7 ) Now read extra fields for GEOS-5 (bmy, 1/17/07)
(8 ) Now read EFLUX field for non-local PBL scheme (only GEOS5).
     (ccc, 5/14/09)
(9 ) Now read FRLAND, FROCEAN, FRLANDIC and FRLAKE for methane
     (kjw, 8/18/09)
21 Sep 2010 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
02 Jul 2013 - R. Yantosca - For GCAP, PBL is now State_Met%PBLH (similarly
                            for State_Met%PRECCON and State_Met%PRECTOT)
13 Aug 2013 - R. Yantosca - For GEOS-4, PBL is now State_Met%PBLH (similarly
                            for State_Met%PRECCON and State_Met%PRECTOT)
```

1.20.5 get_n_a3

Function GET_N_A3 returns the number of A3 fields per met data set.

INTERFACE:

```
FUNCTION GET_N_A3( NYMD ) RESULT( N_A3 )
```

USES:

```
USE CMN_SIZE_MOD              ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD   ! YYYY/MM/DD date
```

RETURN VALUE:

```
INTEGER             :: N_A3   ! Number of A3 fields in file
```

REMARKS:

REVISION HISTORY:

```
23 Jun 2003 - R. Yantosca - Initial version
(1 ) GEOS-4/fvDAS now has 19 A-3 fields; we added LAI, RADLWG, SNOW.
     (bmy, 12/9/03)
(2 ) Now modified for GEOS-5 and GCAP met fields (bmy, 5/25/05)
(3 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(4 ) Increase # of fields for GCAP from 12 to 16 (swu, bmy, 10/4/06)
(5 ) Increase # of fields for GEOS-5 to 25 (bmy, 1/17/07)
(6 ) Increase # of fields for GEOS-5 to 26 (EFLUX) (ccc, 5/21/09)
21 Sep 2010 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.20.6 check_time

Function CHECK_TIME checks to see if the timestamp of the A3 field just read from disk matches the current time. If so, then it's time to return the A3 field to the calling program.

INTERFACE:

```
FUNCTION CHECK_TIME( XYMD, XHMS, NYMD, NHMS ) RESULT( ITS_TIME )
```

USES:

```
USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: XYMD       ! YYYY/MM/DD and hh:mm:ss
      INTEGER, INTENT(IN) :: XHMS       !  timestamp of A3 data in file
      INTEGER, INTENT(IN) :: NYMD       ! YYYY/MM/DD and hh:mm:ss
      INTEGER, INTENT(IN) :: NHMS       !  timestamp for desired data
```

RETURN VALUE:

```
      LOGICAL             :: ITS_TIME   ! =T if XYMD & XHMS match NYMD & NHMS
```

REVISION HISTORY:

```
    23 Jun 2003 - R. Yantosca - Initial version
    (1 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
    21 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.20.7 read_a3

Subroutine READ_A3 reads GEOS A-3 (3-hr avg) fields from disk.

INTERFACE:

```
      SUBROUTINE READ_A3( NYMD,    NHMS,
     &                    ALBEDO,  CLDFRC, EVAP,   GRN,      GWETROOT,
     &                    GWETTOP, HFLUX,  LAI,    MOLENGTH, OICE,
     &                    PARDF,   PARDR,  PBL,    PREACC,   PRECON,
     &                    PRECSNO, RADLWG, RADSWG, RADSWT,   SNICE,
     &                    SNODP,   SNOMAS, SNOW,   TROPP,    TS,
     &                    TSKIN,   U10M,   USTAR,  V10M,     Z0,
     &                    EFLUX,   FRLAND, FRLAKE, FROCEAN,  FRLANDIC )
```

USES:

```
      USE DIAG_MOD,     ONLY : AD67
      USE FILE_MOD,     ONLY : IOERROR
      USE TIME_MOD,     ONLY : SET_CT_A3
      USE TIME_MOD,     ONLY : TIMESTAMP_STRING
      USE TRANSFER_MOD, ONLY : TRANSFER_2D
      USE TRANSFER_MOD, ONLY : TRANSFER_TO_1D

      USE CMN_SIZE_MOD                      ! Size parameters
      USE CMN_DIAG_MOD                      ! ND67
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: NYMD   ! YYYYMMDD
      INTEGER, INTENT(IN)           :: NHMS   !  and hhmmss of desired data
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT), OPTIONAL :: ALBEDO  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: CLDFRC  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: EVAP    (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: GRN     (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: GWETROOT(IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: GWETTOP (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: HFLUX   (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: LAI     (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: MOLENGTH(IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: OICE    (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: PARDF   (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: PARDR   (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: PBL     (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: PREACC  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: PRECON  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: PRECSNO (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: RADLWG  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: RADSWG  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: RADSWT  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: SNICE   (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: SNODP   (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: SNOMAS  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: SNOW    (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: TROPP   (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: TS      (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: TSKIN   (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: U10M    (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: USTAR   (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: V10M    (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: Z0      (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: EFLUX   (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: FRLAND  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: FRLAKE  (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: FROCEAN (IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: FRLANDIC(IIPAR,JJPAR)
```

REMARKS:

```
(1 ) ALBEDO   : (2-D) GMAO surface albedo at 10 m           [unitless]
(2 ) CLDFRC   : (2-D) GMAO column cloud fraction @ ground   [unitless]
(3 ) EVAP     : (2-D) GMAO evapotranspiration flux
(4 ) GRN      : (2-D) GMAO greenness index
(5 ) GWETROOT : (2-D) GMAO root soil wetness                [unitless]
(6 ) GWETTOP  : (2-D) GMAO topsoil wetness                  [unitless]
(7 ) HFLUX    : (2-D) GMAO sensible heat flux               [W/m2]
(8 ) LAI      : (2-D) GMAO leaf area index                  [m2/m2]
(9 ) MOLENGTH : (2-D) GCAP Monin-Obhukov length             [m]
(10) OICE     : (2-D) GCAP fraction of ocean ice            [unitless]
(11) PARDF    : (2-D) GMAO photosyn active diffuse radiation [W/m2]
```

```
(12) PARDR    : (2-D) GMAO photosyn active direct radiation  [W/m2]
(13) PBL      : (2-D) GMAO planetary boundary layer depth    [mb]
(14) PREACC   : (2-D) GMAO accumulated precip @ ground       [mm H2O/day]
(15) PRECON   : (2-D) GMAO convective  precip @ ground       [mm H2O/day]
(16) PRECSNO  : (2-D) GMAO "snow" precip @ ground
(17) RADLWG   : (2-D) GMAO upward LW flux @ ground           [W/m2]
(18) RADSWG   : (2-D) GMAO downward SW flux @ ground         [W/m2]
(19) RADSWT   : (2-D) GMAO downward SW flux @ atm top        [W/m2]
(20) SNICE    : (2-D) GCAP fraction of snow/ice              [unitless]
(21) SNODP    : (2-D) GMAO GEOS-5 geometric snow depth       [m]
(22) SNOMAS   : (2-D) GMAO GEOS-5 H2O equiv snow depth       [m]
(23) SNOW     : (2-D) GMAO snow depth (H2O equivalent)       [mm H2O]
(24) TROPP    : (2-D) GMAO tropopause pressure               [hPa]
(25) TS       : (2-D) GMAO surface air temperature           [K]
(26) TSKIN    : (2-D) GMAO radiance temperature              [K]
(27) USTAR    : (2-D) GMAO friction velocity                 [m/s]
(28) U10M     : (2-D) GMAO U-wind at 10 m                    [m/s]
(29) V10M     : (2-D) GMAO V-wind at 10 m                    [m/s]
(30) Z0       : (2-D) GMAO roughness height                  [m]
(31) EFLUX    : (2-D) GMAO latent heat flux                  [W/m2]
(32) FRLAND   : (2-D) GMAO fraction of land                  [unitless]
(33) FROCEAN  : (2-D) GMAO fraction of ocean                 [unitless]
(34) FRLANDIC : (2-D) GMAO fraction of land ice              [unitless]
(35) FRLAKE   : (2-D) GMAO fraction of lake water            [unitless]
```

REVISION HISTORY:

```
08 May 1998 - R. Yantosca - Initial version
(1 ) Now use function TIMESTAMP_STRING from "time_mod.f" for formatted
     date/time output. (bmy, 10/28/03)
(2 ) RADSWG, CLDFRC, USTAR, and Z0. are now 2-D arrays.  Also added RADLWG
     and SNOW arrays via the arg list.  Now skip over LAI. (bmy, 12/9/03)
(3 ) Now modified for GEOS-5 and GCAP met fields.  Added GCAP MOLENGTH,
     SNICE, OICE optional arguments. (swu, bmy, 5/25/05)
(4 ) Fixed typo in the ND67 diagnostic for RADSWG (swu, bmy, 2/9/06)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(6 ) Add "PARDIF", "PARDIR" to case statement for GCAP (swu, bmy, 10/4/06)
(7 ) Add EVAP, GRN, GWETROOT, LAI, PRECSNO, SNODP, SNOMAS, and TROPP as
     optional arguments.  Also update the CASE statement accordingly for
     GEOS-5 fields.  Convert GEOS-5 PRECTOT and PRECCON fields from
     [kg/m2/s] to [mm/day] for backwards compatibility. (bmy, 1/17/07)
(8 ) Now get the # of A-3 fields from the file ident string (bmy, 10/7/08)
(9 ) Now read EFLUX for non-local PBL scheme for GEOS5 (ccc, 5/14/09)
(10) Now read FRLAND, FROCEAN, FRLANDIC, FRLAKE for methane (kjw, 8/18/09)
(11) Remove reference to IN_CLOUD_OD (bmy, 10/15/09)
21 Sep 2010 - R. Yantosca - Added ProTeX headers
08 Jun 2012 - S. Philip   - Correction for GEOS_5 boundary layer height
03 Aug 2012 - R. Yantosca - Now use locally-defined IU_A3 file LUN
```

```
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
```

1.20.8 archive_nd67_1d

Subroutine ARCHIVE_ND67_1D saves 1-D arrays for the ND67 diagnostic.

INTERFACE:

```
SUBROUTINE ARCHIVE_ND67_1D( FIELD, N )
```

USES:

```
USE DIAG_MOD, ONLY : AD67             ! ND67 diagnostic array

USE CMN_SIZE_MOD                      ! Size parameters
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: FIELD(MAXIJ)   ! Array to be archived in ND67
INTEGER, INTENT(IN) :: N              ! ND67 index in which to store data
```

REVISION HISTORY:

```
23 Jun 2003 - R. Yantosca - Initial version
21 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.20.9 a3_check

Subroutine A3_CHECK prints an error message if not all of the A-3 met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE A3_CHECK( NFOUND, N_A3 )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! Number of A3 fields found in file
INTEGER, INTENT(IN) :: N_A3     ! Expected number of A3 fields
```

REVISION HISTORY:

```
27 Oct 2000 - R. Yantosca - Initial version
(1 ) Adapted from DAO_CHECK from "dao_read_mod.f" (bmy, 6/23/03)
21 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.21 Fortran: Module Interface a6_read_mod

Module A6_READ_MOD contains subroutines that unzip, open, and read GEOS-CHEM A-6 (avg 6-hour) met fields from disk.

INTERFACE:

```
MODULE A6_READ_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
PUBLIC :: GET_A6_FIELDS
PUBLIC :: OPEN_A6_FIELDS
PUBLIC :: UNZIP_A6_FIELDS
```

REMARKS:

```
This module reads GEOS-4, GEOS-5, and GCAP met fields
MERRA met fields are read in routines merra_*_mod.F
GEOS-FP met fields are read in geosfp_read_mod.F
```

REVISION HISTORY:

```
19 Jun 2003 - R. Yantosca - Initial version
(1 ) Adapted from "dao_read_mod.f" (bmy, 6/19/03)
(2 ) Now use TIMESTAMP_STRING for formatted output (bmy, 10/28/03)
(3 ) CLDFRC is now a 2-D array in MAKE_CLDFRC< GET_A6_FIELDS.  Also now
     read from either zipped or unzipped files. (bmy, 12/9/03)
(4 ) Now skips past the GEOS-4 ident string (bmy, 12/12/03)
(5 ) Bug fix: need to determine CLDTOPS for GEOS-4.  (bmy, 3/4/04)
(6 ) Now modified for GEOS-4 "a_llk_03" and "a_llk_04" data (bmy, 3/4/04)
(7 ) Now references "unix_cmds_mod.f", "directory_mod.f" and
     "logical_mod.f" (bmy, 7/20/04)
(8 ) Now references FILE_EXISTS from "file_mod.f" (bmy, 3/23/05)
(9 ) Now modified for GEOS-5 and GCAP met fields.  Added MAKE_GCAP_CLDFRC
     routine. (swu, bmy, 5/25/05)
(10) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(11) Bug fix in ND66 diagnostic for ZMMU (bmy, 2/1/06)
(12) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(13) Now set negative Q (i.e. SPHU)to a small positive # (bmy, 9/8/06)
(14) Now read extra fields for GEOS-5.  Bug fix: we must convert RH from
     unitless to % to be compatible w/ present drydep etc. algorithms.
     (phs, bmy, 3/28/08)
(15) Now get the # of A-6 fields from the file ident string (bmy, 10/7/08)
(16) Remove references to IN_CLOUD_OD (bmy, 10/15/09)
```

```
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
03 Aug 2012 - R. Yantosca - Now make IU_A6 a private module variable
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.21.1 unzip_a6_fields

Subroutine UNZIP_A6_FIELDS invokes a FORTRAN system call to uncompress GEOS-Chem A6 met field files and store the uncompressed data in a temporary directory, where GEOS-CHEM can read them. The original data files are not disturbed.

INTERFACE:

```
SUBROUTINE UNZIP_A6_FIELDS( Input_Opt, OPTION, NYMD )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*),  INTENT(IN) :: OPTION    ! Unzip option
INTEGER, OPTIONAL, INTENT(IN) :: NYMD      ! YYYY/MM/DD of file to unzip
TYPE(OptInput),    INTENT(IN) :: Input_Opt ! Input Options object
```

REVISION HISTORY:

```
15 Jun 1998 - R. Yantosca - Initial version
(1 ) Adapted from UNZIP_MET_FIELDS of "dao_read_mod.f" (bmy, 6/19/03)
(2 ) Directory information YYYY/MM or YYYYMM is now contained w/in
     GEOS_1_DIR, GEOS_S_DIR, GEOS_3_DIR, GEOS_4_DIR (bmy, 12/11/03)
(3 ) Now reference "directory_mod.f" and "unix_cmds_mod.f". Now prevent
     EXPAND_DATE from overwriting directory paths with Y/M/D tokens in
     them (bmy, 7/20/04)
(4 ) Removed code for GEOS-4 a_llk_03 data.  Also modified for GEOS-5
     and GCAP met fields. (bmy, 5/25/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
11 Apr 2013 - R. Yantosca - Now replace directory_mod.F and unix_cmds_mod.F
                            with the Input_Opt derived type object
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.21.2 do_open_a6

Function DO_OPEN_A6 returns TRUE if is time to open the A6 met field file or FALSE otherwise. This prevents us from opening a file which has already been opened.

INTERFACE:

```
FUNCTION DO_OPEN_A6( NYMD, NHMS ) RESULT( DO_OPEN )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD    ! YYYY/MM/DD date
INTEGER, INTENT(IN) :: NHMS     ! hh:mm:ss time
```

REVISION HISTORY:

```
19 Jun 2003 - R. Yantosca - Initial version
(1 ) Now modified for GEOS-4 "a_llk_03" or "a_llk_04" data (bmy, 3/22/04)
(2 ) Remove code for obsolete GEOS-4 a_llk_03 data.  Also modified for
     GEOS-5 and GCAP met fields. (swu, bmy, 5/25/05)
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.21.3 open_a6_fields

Subroutine OPEN_A6_FIELDS opens the A6 met fields file for date NYMD and time NHMS.

INTERFACE:

```
SUBROUTINE OPEN_A6_FIELDS( NYMD, NHMS, Input_Opt )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ERROR_STOP
USE FILE_MOD,           ONLY : IOERROR, FILE_EXISTS
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN) :: Input_Opt  ! Input_Options
INTEGER,        INTENT(IN) :: NYMD       ! YYYY/MM/dd and
INTEGER,        INTENT(IN) :: NHMS       !  hh:mm:ss of data
```

REVISION HISTORY:

```
15 Jun 1998 - R. Yantosca - Initial version
(1 ) Adapted from OPEN_MET_FIELDS of "dao_read_mod.f" (bmy, 6/19/03)
(2 ) Now opens either zipped or unzipped files (bmy, 12/11/03)
```

```
(3 ) Now skips past the GEOS-4 ident string (bmy, 12/12/03)
(4 ) Now references "directory_mod.f" instead of CMN_SETUP.  Also now
     references LUNZIP from "logical_mod.f".  Also now prevents EXPAND_DATE
     from overwriting Y/M/D tokens in directory paths. (bmy, 7/20/04)
(5 ) Now use FILE_EXISTS from "file_mod.f" to determine if file unit IU_A6
     refers to a valid file on disk (bmy, 3/23/05)
(6 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(9 ) Now get the # of A-3 fields from the file ident string (bmy, 10/7/08)
(10) Set N_A6_FIELDS=21 for GEOS-5 and IN_CLOUD_OD (jmao, bmy, 2/12/09)
(11) Remove references to IN_CLOUD_OD (bmy, 10/15/09)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
03 Aug 2012 - R. Yantosca - Now use findFreeLUN to define IU_A6 locally
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.21.4 get_a6_fields

Subroutine GET_A6_FIELDS is a wrapper for routine READ_A6. GET_A6_FIELDS calls READ_A6 properly for reading A-6 fields from GEOS-1, GEOS-STRAT, GEOS-3, GEO b S-4, GEOS-5, or GCAP met data sets.

INTERFACE:

```
SUBROUTINE GET_A6_FIELDS( NYMD, NHMS, Input_Opt, State_Met )
```

USES:

```
USE CMN_SIZE_MOD
USE DAO_MOD,            ONLY : T_FULLGRID
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
! Arguments
INTEGER,        INTENT(IN)    :: NYMD      ! YYYY/MM/DD
INTEGER,        INTENT(IN)    :: NHMS      !  and hh:mm:ss of desired data
TYPE(OptInput), INTENT(IN)    :: Input_Opt ! Input_Options
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met ! Meteorology State object
```

REVISION HISTORY:

```
19 Jun 2003 - R. Yantosca - Initial version
(1 ) CFRAC has been removed from CMN_DEP.  Now use CLDFRC(I,J) from
     "dao_mod.f" (bmy, 12/9/03)
(2 ) Now pass CLDTOPS to READ_A6 for GEOS-4 (bmy, 3/4/04)
(3 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(4 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(5 ) Now read CMFMC, DQIDTMST, DQLDTMST, DQRCON, DQRLSC, DQVDTMST, MFXC,
     MFYC, MFZ, PV, QI, QL, RH, TAUCLI, TAUCLW for GEOS-5
     (bmy, 10/30/07)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
19 Oct 2012 - R. Yantosca - Now reference gigc_state_met_mod.F90
23 Oct 2012 - R. Yantosca - Add QI, QL to the State_Met object
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
14 Mar 2013 - M. Payer    - Now read T_FULLGRID for vertical regridding of
                            OH for offline simulations (C. Holmes)
02 Jul 2013 - R. Yantosca - Now use State_Met%U and State_Met%V to hold
                            the GCAP U and V wind fields
02 Jul 2013 - R. Yantosca - Now use State_Met%U and State_Met%V to hold
                            the GEOS-4 U and V wind fields
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.21.5 make_gcap_cldfrc

Subroutine MAKE_CLDFRC constructs the GCAP CLDFRC field from the 3-D cloud fraction field.

INTERFACE:

```
SUBROUTINE MAKE_GCAP_CLDFRC( CLDF, CLDFRC )
```

USES:

```
USE CMN_SIZE_MOD   ! Size parameters
USE CMN_DIAG_MOD   ! ND67
USE DIAG_MOD, ONLY : AD67
```

INPUT PARAMETERS:

```
! GCAP 3-D cloud fraction field [unitless]
REAL*8, INTENT(IN)  :: CLDF(LLPAR,IIPAR,JJPAR)
```

OUTPUT PARAMETERS:

```
! GCAP column cloud fraction field [unitless]
REAL*8, INTENT(OUT) :: CLDFRC(IIPAR,JJPAR)
```

REVISION HISTORY:

```
25 May 2005 - R. Yantosca - Initial version
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.21.6 get_n_a6

Function GET_N_A6 returns the number of A6 fields per met data set.

INTERFACE:

```
FUNCTION GET_N_A6() RESULT( N_A6 )
```

USES:

```
USE CMN_SIZE_MOD
```

RETURN VALUE:

```
INTEGER :: N_A6
```

REVISION HISTORY:

```
19 Jun 2003 - R. Yantosca - Initial version
(1 ) Now modified for GCAP and GEOS-5 met fields (swu, bmy, 5/25/05)
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(3 ) Increase number of A-6 fields for GEOS-5 to 21 (bmy, 5/15/07)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.21.7 check_time

Function CHECK_TIME checks to see if the timestamp of the A6 field just read from disk matches the current time. If so, then it's time to return the A6 field to the calling program.

INTERFACE:

```
FUNCTION CHECK_TIME( XYMD, XHMS, NYMD, NHMS ) RESULT( ITS_TIME )
```

USES:

```
USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: XYMD       ! YYYY/MM/DD and hh:mm:ss
INTEGER, INTENT(IN) :: XHMS       !  timestamp of A6 data in file
INTEGER, INTENT(IN) :: NYMD       ! YYYY/MM/DD and hh:mm:ss
INTEGER, INTENT(IN) :: NHMS       !  timestamp for desired data
```

RETURN VALUE:

```
      LOGICAL             :: ITS_TIME   ! =T if XYMD & XHMS match NYMD & NHMS
```

REVISION HISTORY:

```
19 Jun 2003 - R. Yantosca - Initial version
(1 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.21.8 read_a6

Subroutine READ_A6 reads GEOS A-6 (6-hr avg) fields from disk.

INTERFACE:

```
      SUBROUTINE READ_A6( NYMD,      NHMS,
     &                    CLDF,      CLDMAS,    CLDTOPS,   CMFMC,
     &                    DETRAINE,  DETRAINN,  DNDE,      DNDN,
     &                    DQIDTMST,  DQLDTMST,  DQRCON,    DQRLSC,
     &                    DQVDTMST,  DTRAIN,    ENTRAIN,   HKBETA,
     &                    HKETA,     MFXC,      MFYC,      MFZ,
     &                    MOISTQ,    OPTDEPTH,  PLE,       PV,
     &                    Q,         QI,        QL,        RH,
     &                    T,         TAUCLI,    TAUCLW,    U,
     &                    UPDE,      UPDN,      V,         ZMEU,
     &                    ZMMD,      ZMMU,      T_FULLGRID )
```

USES:

```
      USE CMN_SIZE_MOD
      USE CMN_DIAG_MOD
      USE CMN_GCTM_MOD
      USE DIAG_MOD,     ONLY : AD66,        AD67
      USE FILE_MOD,     ONLY : IOERROR
      USE TIME_MOD,     ONLY : SET_CT_A6,   TIMESTAMP_STRING
      USE TRANSFER_MOD, ONLY : TRANSFER_A6, TRANSFER_3D_Lp1
      USE TRANSFER_MOD, ONLY : TRANSFER_3D, TRANSFER_G5_PLE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)            :: NYMD   ! YYYYMMDD
      INTEGER, INTENT(IN)            :: NHMS   !  and hhmmss of desired data
```

OUTPUT PARAMETERS:

```
      INTEGER, INTENT(OUT), OPTIONAL :: CLDTOPS(IIPAR,JJPAR)
      REAL*8,  INTENT(OUT), OPTIONAL :: CLDF(LLPAR,IIPAR,JJPAR)
      REAL*8,  INTENT(OUT), OPTIONAL :: CLDMAS(IIPAR,JJPAR,LLPAR)
      REAL*8,  INTENT(OUT), OPTIONAL :: CMFMC(IIPAR,JJPAR,LLPAR+1)
      REAL*8,  INTENT(OUT), OPTIONAL :: DETRAINE(IIPAR,JJPAR,LLPAR)
      REAL*8,  INTENT(OUT), OPTIONAL :: DETRAINN(IIPAR,JJPAR,LLPAR)
```

```
REAL*8,  INTENT(OUT), OPTIONAL :: DNDE(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: DNDN(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: DQIDTMST(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: DQLDTMST(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: DQRCON(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: DQRLSC(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: DQVDTMST(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: DTRAIN(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: ENTRAIN(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: HKBETA(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: HKETA(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: MFXC(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: MFYC(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: MFZ(IIPAR,JJPAR,LLPAR+1)
REAL*8,  INTENT(OUT), OPTIONAL :: MOISTQ(LLPAR,IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: OPTDEPTH(LLPAR,IIPAR,JJPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: PLE(IIPAR,JJPAR,LLPAR+1)
REAL*8,  INTENT(OUT), OPTIONAL :: PV(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: Q(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: QI(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: QL(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: RH(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: T(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: TAUCLI(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: TAUCLW(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: U(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: UPDE(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: UPDN(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: V(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: ZMEU(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: ZMMD(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: ZMMU(IIPAR,JJPAR,LLPAR)
REAL*8,  INTENT(OUT), OPTIONAL :: T_FULLGRID(IIPAR,JJPAR,LGLOB)
```

REMARKS:

```
(3 ) CLDF     : (3-D) Total cloud fractions                [unitless]
(4 ) CLDMAS   : (3-D) Cloud mass flux field                [kg/m2/600s]
(5 ) CLDTOPS  : (2-D) CTM Level in which cloud top occurs  [unitless]
(6 ) CMFMC    : (3-D) GEOS-5 cloud mass flux               [kg/m2/s]
(7 ) DETRAINE : (3-D) GCAP detrainment (entraining plume)  [kg/m2/s]
(8 ) DETRAINN : (3-D) GCAP detrainment (non-entr'n plume)
(9 ) DNDE     : (3-D) GCAP downdraft   (entraining plume)
(10) DNDN     : (3-D) GCAP downdraft   (non-entr'n plume)
(11) DQIDTMST : (3-D) GEOS-5 ice tendency in moist proc    [kg/kg/s]
(12) DQLDTMST : (3-D) GEOS-5 liquid tendency in moist proc [kg/kg/s]
(13) DQRCON   : (3-D) GEOS-5 precip formation rate / conv
(14) DQRLSC   : (3-D) GEOS-5 precip formation rate / lg scl
```

```
(15) DQVDTMST : (3-D) GEOS-5 vapor tendency in moist proc   [kg/kg/s]
(16) DTRAIN   : (3-D) Detrainment field                     [kg/m2/s]
(17) ENTRAIN  : (3-D) GCAP entrainment
(18) HKBETA   : (3-D) Hack overshoot parameter              [unitless]
(19) HKETA    : (3-D) Hack convective mass flux             [kg/m2/s]
(20) MFXC     : (3-D) GEOS-5 E-W mass flux                  [Pa*m2/s]
(21) MFYC     : (3-D) GEOS-5 N-S mass flux                  [Pa*m2/s]
(22) MFZ      : (3-D) GEOS-5 up/down mass flux              [kg/m2/s]
(23) MOISTQ   : (3-D) DAO water vapor tendency d            [g/kg/day]
(24) OPTDEPTH : (3-D) GEOS grid box optical depth           [unitless]
(25) PLE      : (3-D) GEOS-5 pressure edges                 [hPa]
(26) PV       : (3-D) GEOS-5 potential vorticity            [kg*m2/kg/s]
(27) Q        : (3-D) Specific humidity                     [g H2O/kg air]
(28) T        : (3-D) Temperature                           [K]
(29) TAUCLI   : (3-D) GEOS ice path optical depth           [unitless]
(30) TAUCLW   : (3-D) GEOS water path optical depth         [unitless]
(31) U        : (3-D) Zonal winds                           [m/s]
(32) UPDE     : (3-D) GCAP updraft (entraining plume)
(33) UPDN     : (3-D) GCAP updraft (non-entr'n plume)
(34) V        : (3-D) Meridional winds                      [m/s]
(35) ZMEU     : (3-D) Zhang/McFarlane updraft entrainment   [Pa/s]
(36) ZMMD     : (3-D) Zhang/McFarlane downdraft mass flux   [Pa/s]
(37) ZMMU     : (3-D) Zhang/McFarlane updraft mass flux     [Pa/s]
```

REVISION HISTORY:

```
05 Jun 1998 - R. Yantosca - Initial version
(1 ) Adapted from READ_A6 of "dao_read_mod.f" (bmy, 6/19/03)
(2 ) Now use function TIMESTAMP_STRING from "time_mod.f" for formatted
     date/time output. (bmy, 10/28/03)
(3 ) Now compute CLDTOPS using ZMMU for GEOS-4 (bmy, 3/4/04)
(4 ) Now modified for GEOS-5 and GCAP fields.  Added DETRAINE,
     DETRAINN, DNDE, DNDN, ENTRAIN, UPDE, UPDN as optional arguments.
     Now references "CMN_DIAG". (swu, bmy, 5/25/05)
(5 ) Bug fix in ND66 diagnostic for GEOS-4 (bmy, 2/1/06)
(6 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(7 ) Now set negative SPHU to a small positive # (1d-32) instead of zero,
     so as not to blow up logarithms (bmy, 9/8/06)
(8 ) Add CMFMC, DQIDTMST, DQLDTMST, DQRCON, DQRLSC, DQVDTMST, MFXC, MFYC,
     MFZ, PLE, PV, RH, TAUCLI, and TAUCLW as optional arguments.  Also
     update the CASE statement accordingly for GEOS-5 met fields.
     Now reference TRANSFER_3D_Lp1 from "transfer_mod.f".  Now convert
     GEOS-5 specific humidity from [kg/kg] to [g/kg] for compatibility
     with existing routines.  Also recognize EPV, which is an alternate
     name for PV.  Bug fix: convert GEOS-5 RH from unitless to %.
     (phs, bmy, 3/28/08)
(8 ) Now get the # of A-6 fields from the file ident string (bmy, 10/7/08)
(9 ) Remove references to IN_CLOUD_OD (bmy, 10/15/09)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

```
03 Aug 2012 - R. Yantosca - Now use locally-defined IU_A3 file LUN
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
14 Mar 2013 - M. Payer    - Added T_FULLGRID as optional argument
29 Oct 2013 - R. Yantosca - Remove reference to TRANSFER_3D_NOLUMP
07 Nov 2013 - R. Yantosca - Now replace any NaN's in the MOISTQ field
                            with zeroes.  NaN's have occured near t-pause.
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.21.9 a6_check

Subroutine A6_CHECK prints an error message if not all of the A-6 met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE A6_CHECK( NFOUND, N_A6 )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! Number of A6 fields found in file
INTEGER, INTENT(IN) :: N_A6     ! Expected number of A6 fields
```

REVISION HISTORY:

```
27 Oct 2000 - R. Yantosca - Initial version
(1 ) Adapted from DAO_CHECK from "dao_read_mod.f" (bmy, 6/19/03)
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.22 Fortran: Module Interface acetone_mod

Module ACETONE_MOD contains subroutines to emit the biogenic flux of acetone into the full chemistry simulation.

INTERFACE:

```
MODULE ACETONE_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_ACETONE
      PUBLIC :: EMISS_BIOACET
      PUBLIC :: OCEAN_SOURCE_ACET
      PUBLIC :: OCEAN_SINK_ACET
```

REMARKS:

```
References:
============================================================================
(1 ) Jacob, D.J., B.D. Field, E. Jin, I. Bey, Q. Li, J.A. Logan, and
      R.M. Yantosca, "Atmospheric budget of acetone", Geophys. Res. Lett.,
      107(D11), 4100, 2002.
(2 ) Nightingale et al [2000a], J. Geophys. Res, 14, 373-387
(3 ) Nightingale et al [2000b], Geophys. Res. Lett, 27, 2117-2120
```

REVISION HISTORY:

```
NOTES:
18 Sep 2001 - B. Field, R. Yantosca - Initial version
(1 ) Added changes from bdf and updated comments (bmy, 9/5/01)
(2 ) Updated comments (bmy, 9/12/01)
(3 ) Removed VERBOSE flag and all "print-to-log-file" diagnostics.  The
      ND11 diagnostic produces the same totals. (bdf, bmy, 9/18/01)
(4 ) Now cal GET_TAU0 w/ 3 arguments instead of 2.  Also minor bug
      fix in READ_RESP (bmy, 11/15/01)
(5 ) Implemented fix for ocean source/sink from Mat Evans.  Also deleted
      obsolete code from 11/01. (bmy, 11/26/01)
(6 ) Eliminated more obsolete code from 11/01 (bmy, 2/27/02)
(7 ) Removed duplicate variable definitions (bmy, 3/20/02)
(8 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
      MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(9 ) Bug fix: Now apply true exponential loss in OCEAN_SINK_ACET, instead
      of just the 1st order approximation. (bdf, bmy, 7/11/02)
(10) Scale the ocean source of acetone for GEOS-3 meteorology in order to
      match the total listed in Jacob et al 2002. (bdf, bmy, 9/16/02)
(11) Now references "error_mod.f" (bmy, 10/15/02)
(12) Minor modifications to READ_JO1D, READ_RESP (bmy, 3/14/03)
(13) Add surface area scale factor for ocean source for 1x1 nested
      grids.  (yxw, bmy, 5/16/03)
(14) Scale ACET ocean source to Jacob et al 2002 for GEOS-4, and now
      account for surface area ratio for all GEOS grids. (bmy, 3/15/04)
(15) Now references "directory_mod.f" (bmy, 7/19/04)
(16) Now can read data from GEOS and GCAP grids.  Also now use Nightingale
      et al 2000b formulation for piston velocity KL. (swu, bmy, 8/16/05)
(17) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(18) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(19) Updates for nested EU and NA grids (amv, bmy, 12/18/09)
(20) Updates for GEOS-4 1 x 1.25 grid (lok, bmy, 1/13/10)
13 Aug 2010 - R. Yantosca - Add modifications for MERRA (treat like GEOS-5)
```

```
04 Nov 2010 - R. Yantosca - Added ProTeX headers
06 Dec 2011 - E. Fischer  - Updated Ocean exchange, MEGAN biogenic emiss.
                            Removed obsolete code.
19 Mar 2012 - M. Payer    - Removed obsolete subroutines READ_JO1D and
                            READ_RESP (E. Fischer)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.22.1 ocean_source_acet

Subroutine OCEAN_SOURCE_ACET specifies the ocean source of acetone.

INTERFACE:

```
SUBROUTINE OCEAN_SOURCE_ACET( I, J, ACETONE, State_Met )
```

USES:

```
USE ERROR_MOD,          ONLY : CHECK_VALUE
USE DIAG_MOD,           ONLY : AD11
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE TIME_MOD,           ONLY : GET_TS_EMIS

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_DIAG_MOD             ! ND11
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: I           ! GEOS-Chem longitude index
INTEGER,        INTENT(IN)    :: J           ! GEOS-Chem latitude index
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,         INTENT(INOUT) :: ACETONE     ! Acetone emiss [atoms C/s]
```

REMARKS:

REVISION HISTORY:

```
14 Sep 2001 - B. Field    - Initial version
(1 ) Now compute u = SQRT( U10M^2 + V10M^2 ) as SQRT( SFCWINDSQR(I,J) ).
      This is necessary since U10M and V10M are missing for 1996, and
      need to be computed from UWND and VWND.  (bmy, 9/5/01)
(2 ) Bug fixes: multiply kg by 360000 and use exponent to the -0.5 power
      in the expression for Kl.  Also update value of the OCEAN_SCALE
      factor to 3.63e11.  Also updated comments. (bdf, bmy, 9/5/01)
(3 ) Bug fix: ACETONE has units of [atoms C/box/s], to match those of
      EMISRR.  This involves an extra division by DTSRCE. (bmy, 9/14/01)
```

```
(4 ) Removed diagnostic variable OCEAN_SOURCE (bmy, 9/18/01)
(5 ) JO1D(IREF,JREF) is now JO1D(I,J).  Bug fix: Zero the ocean source
     of acetone in grid boxes that are covered by less than 50% ocean.
     Bug fix: make sure -5 <= TC <= 30, in order to prevent the power
     series for Schmidt # from going negative.  Also eliminate IREF,
     JREF, we don't need them anymore. (mje, rvm, bmy, 11/26/01)
(6 ) Eliminated obsolete code from 11/01 (bmy, 2/27/02)
(7 ) Scale the ocean source of acetone for GEOS-3 meteorology in order to
     match the total listed in Jacob et al 2002. (bdf, bmy, 9/16/02)
(8 ) Now use function GET_AREA_CM2 of "grid_mod.f" to return the
     grid box area in cm2.  Use function GET_TS_EMIS from "time_mod.f".
     Remove reference to CMN header file. (bmy, 2/11/03)
(9 ) Apply surface area scale factor for 1x1 nested grids, in order to
     make the total ocean source the same as for 4x5. (yxw, bmy, 5/16/03)
(10) Scale the ocean source to Jacob et al 2002 for GEOS-4.  Also account
     for surface area ratio for all GEOS grids. (bmy, 3/15/04)
(11) Added space in #ifdef block for GEOS-4 x 1x125 grid (bmy, 12/1/04)
(12) Now use Nightingale et al 2000b formulation for piston velocity KL.
     (swu, bmy, 8/16/05)
(13) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(14) Adjust SCALE_FACTOR for 0.5 x 0.667 grid (dan, bmy, 11/6/08)
(15) Additional scale factors for NESTED_NA and NESTED_EU calculated and
     included (amv, bmy, 12/18/09)
(16) Added scale factor for GEOS-4 1 x 1.25 grid (lok, bmy, 1/13/10)
13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
04 Nov 2010 - R. Yantosca - Added ProTeX headers
04 Nov 2010 - R. Yantosca - Cleaned up #if statements for clarity
06 Dec 2011 - E. Fischer  - Updated ocean source and sink terms to be
                            different than Jacob et al. [2002]. Ocean mixed
                            layer is now set to a constant concentration of
                            acetone (15 nM). Fluxes are now calculated
                            using a direct application of the standard
                            two-film model described by Liss and Slater
                            [1974]. The fluxes are calculated using an
                            updated Henry's law coefficient and transfer
                            velocities have been updated following Johnson
                            [2010]. The model now reproduces aircraft
                            measurements over the remote oceans well.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.22.2 ocean_sink_acet

Subroutine OCEAN_SINK_ACET applies the ocean sink to global acetone concentrations.

INTERFACE:

```
      SUBROUTINE OCEAN_SINK_ACET( ACETONE, State_Met )
```

USES:

```
      USE CMN_SIZE_MOD
      USE CMN_DIAG_MOD
      USE DIAG_MOD,           ONLY : AD11
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE TIME_MOD,           ONLY : GET_TS_CHEM
```

INPUT PARAMETERS:

```
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,         INTENT(INOUT) :: ACETONE(IIPAR,JJPAR) ! Acet mass [kg C]
```

REVISION HISTORY:

```
    14 Sep 2001 - B. Field    - Initial version
    (1 ) Remove references to CMN_UV10M and CMN_LWI -- these are now
         obsolete in GEOS-CHEM versions 4.18 and higher (bmy, 9/5/01)
    (2 ) Now compute u = SQRT( U10M^2 + V10M^2 ) as SQRT( SFCWINDSQR(I,J) ).
         This is necessary since U10M and V10M are missing for 1996, and
         need to be computed from UWND and VWND.  (bmy, 8/2/01)
    (3 ) Now declare OCEANSINK_SCALE = 0.15 as a parameter.  This is the
         optimized value of BETA from Emily Jin's analysis.  Also updated
         comments. (bdf, bmy, 9/5/01)
    (4 ) Updated comments.  Also parallellized DO loops. (bmy, 9/14/01)
    (5 ) Removed diagnostic variable OCEAN_LOSS (bmy, 9/18/01)
    (6 ) Bug fix: Zero the ocean sink of acetone in grid boxes where there
         is less than 50% of ocean, and where there is ice on the surface.
         Bug fix: Make sure -5 <= TC <= 30, in order to prevent the power
         series for Schmidt # from going negative.  Also eliminate IREF,
         JREF, we don't need them. (mje, rvm, bmy, 11/26/01)
    (7 ) Eliminated obsolete code from 11/01 (bmy, 2/27/02)
    (8 ) Bug fix: now use true exponential for loss instead of just 1st
         order term.  Also added PRE_ACET variable to save previous acetone
         mass for diagnostic, before applying loss.  (bdf, bmy, 7/11/02)
    (9 ) Now use function GET_AREA_CM2 of "grid_mod.f" to return the
         grid box area in cm2.  Now use function GET_TS_CHEM from
         "time_mod.f".  Remove reference to CMN header file. (bmy, 2/11/03)
    (12) Now use Nightingale et al 2000b formulation for piston velocity KL.
         (swu, bmy, 8/16/05)
    04 Nov 2010 - R. Yantosca - Added ProTeX headers
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
    02 Aug 2012 - R. Yantosca - Add error trap for acetone under DEVEL tag
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
```

1.22.3 emiss_bioacet

Subroutine EMISS_BIOACET computes the biogenic emissions of ACETONE from monoterpenes, isoprene, methyl butenol, dry leaf matter, and grasslands.

INTERFACE:

```
  evf, edits to use MEGAN biogenic acetone emissions (5/25/2011)
       SUBROUTINE EMISS_BIOACET( I,    J,    TMMP,  EMMO, SUNCOS, Q_DIR,
      &                          Q_DIFF, XNUMOL_C, EMIS, EMMB, GRASS,
      &                          ACETONE )
```

USES:

```
       USE DIAG_MOD, ONLY : AD11
       USE GRID_MOD, ONLY : GET_AREA_M2
       USE GRID_MOD, ONLY : GET_XMID
       USE GRID_MOD, ONLY : GET_YMID
       USE TIME_MOD, ONLY : GET_TS_EMIS
  !(evf, 5/25/2011)
       USE MEGAN_MOD, ONLY : GET_EMACET_MEGAN

       USE CMN_SIZE_MOD                 ! Size parameters
       USE CMN_DIAG_MOD                 ! ND11
```

INPUT PARAMETERS:

```
       INTEGER, INTENT(IN)    :: I         ! Grid box longitude index
       INTEGER, INTENT(IN)    :: J         ! Grid box latitude index
       REAL*8,  INTENT(IN)    :: TMMP      ! Local Surface Air temperature [K]
       REAL*8,  INTENT(IN)    :: EMMO      ! Monoterpene emission [atoms C]
       REAL*8,  INTENT(IN)    :: EMIS      ! Isoprene emission [atoms C]
       REAL*8,  INTENT(IN)    :: EMMB      ! Methylbutenol emission  [atoms C]
       REAL*8,  INTENT(IN)    :: GRASS     ! Isoprene from grasslands [atoms C]
  evf, edits to use MEGAN biogenic acetone emissions (5/25/2011)
       REAL*8,  INTENT(IN)    :: SUNCOS    ! Cosine of Solar Zenith Angle
       REAL*8,  INTENT(IN)    :: Q_DIR     ! Flux of direct PAR above canopy
       REAL*8,  INTENT(IN)    :: Q_DIFF    ! Flux of diffuse PAR above canopy
       REAL*8,  INTENT(IN)    :: XNUMOL_C  ! Number of atoms C / kg C
```

INPUT/OUTPUT PARAMETERS:

```
       REAL*8,  INTENT(INOUT) :: ACETONE   ! Biogenic acetone [atoms C/s]
```

REVISION HISTORY:

```
    18 Sep 2001 - B. Field    - Initial version
    (1 ) Now pass acetone array (e.g. from STT) thru the argument list, since
         this avoids dependence on IDTACET in this program (bmy, 8/1/01)
    (2 ) Updated scale factors (bdf, bmy, 9/5/01)
```

```
(3 ) Updated comments (bmy, 9/14/01)
(4 ) Removed diagnostic variables: MONOTERPENES, ISOPRENE, ISOP_TOTAL,
     MONO_TOTAL, NA_TOT, RESP_TOT, GRASS_TOT.  These have now been
     supplanted by the ND11 acetone source diagnostic. (bdf, bmy, 9/18/01)
(5 ) XRESP(I+I0,J+J0) is now XRESP(I,J) (bmy, 11/26/01)
(6 ) Eliminated obsolete code from 11/01 (bmy, 2/27/02)
(7 ) Removed duplicate definitions of EMMB and GRASS (bmy, 3/20/02)
(8 ) Now use functions from "grid_mod.f" to get surface area, lon, and
     lat of grid box (I,J).   Use function GET_AREA_M2 to get the grid
     box surface area in m2, then convert to cm2.   Now use function
     GET_TS_EMIS from "time_mod.f".  Remove reference to CMN header
     file. (bmy, 2/11/03)
04 Nov 2010 - R. Yantosca - Added ProTeX headers
06 Dec 2011 - E. Fischer  - Direct biogenic emissions of acetone from
                            metabolism and decay are now calculated using
                            the MEGAN biogenic emission model [Guenther et
                            al., 2006]. The code assumes the fraction of
                            emissions that are light-independent is 0.20,
                            and the temperature response factor (beta) is
                            0.10 as recommended by Alex Guenther. The
                            dependency on GEIA has been removed.
08 Dec 2011 - M. Payer    - Remove use of obsolete CMN_MONOT_MOD
01 Mar 2012 - R. Yantosca - Use new grid routines from grid_mod.F90
```

1.22.4 cleanup_acetone

Subroutine CLEANUP_ACETONE deallocates module arrays

INTERFACE:

```
SUBROUTINE CLEANUP_ACETONE
```

REVISION HISTORY:

```
14 Sep 2001 - R. Yantosca - Initial version
04 Nov 2010 - R. Yantosca - Added ProTeX headers
19 Mar 2012 - M. Payer    - Removed deallocation of JO1D and XRESP. They
                            are obsolete after removal of READ_JO1D and
                            READ_RESP routines.
```

1.23 Fortran: Module Interface aeic_mod

Module AEIC_MOD contains variables and routines for aircraft flight emissions into the chemistry and transport grids. (sde, 12/14/12)

INTERFACE:

```
      MODULE AEIC_MOD
```

USES:

```
      IMPLICIT NONE
#     include "netcdf.inc" ! Needed for netCDF libraries
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC EMIT_AEIC
      PUBLIC CLEANUP_AEIC
```

REMARKS:

```
    The AEIC fields are stored on 1x1 grids.
    These fields will be interpolated onto the current horizontal grid.
                                                                             .
    References:
    ============================================================================
    (1) Stettler, M.E.J., S. Eastham, S.R.H. Barrett, Air quality and public
         health impacts of UK airports. Part I: Emissions, Atmos. Env., 2011.
         DOI: 10.1016/j.atmosenv.2011.07.012
```

REVISION HISTORY:

```
    14 Dec 2012 - S. Eastham  - Adapted from AIRCRAFT_NOX_MOD. Now emits
                                aircraft NOx, CO, HC, SO2, SO4, OC and BC
    01 Aug 2013 - M. Sulprizio- Added ProTeX headers
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.23.1 read_aeic_file

Subroutine READ_AEIC_FILE reads fuel burn and emissions from AEIC netCDF files (monthly average). (sde, 12/14/12)

INTERFACE:

```
      SUBROUTINE READ_AEIC_FILE( INMONTH, State_Met )
```

USES:

```
      ! NcdfUtil modules for netCDF I/O
      USE m_netcdf_io_open         ! netCDF open
      USE m_netcdf_io_get_dimlen   ! netCDF dimension queries
      USE m_netcdf_io_read         ! netCDF data reads
      USE m_netcdf_io_close        ! netCDF close

      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
```

```
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_State_Met_Mod, ONLY : MetState
USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
USE TIME_MOD,           ONLY : EXPAND_DATE
USE PRESSURE_MOD,       ONLY : GET_AP, GET_BP

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_GCTM_MOD,       ONLY : Rdg0
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: INMONTH     ! Current month number (1-12)
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
14 Dec 2012 - S. Eastham  - Adapted from READ_NONERUP_VOLC
31 Jul 2013 - M. Sulprizio- Now pass met fields using State_Met
01 Aug 2013 - M. Sulprizio- Update to read emissions from netCDF file
                            created by Christoph Keller. He combined original
                            monthly files into one file and made file
                            COARDS compliant.
26 Aug 2013 - R. Yantosca - Avoid array temporaries in call to NcRd
```

1.23.2 emit_aeic

Subroutine EMIT_AEIC interpolates AEIC aircraft emissions from the native grid onto the given GEOS-CHEM grid. (sde, 12/14/12)

INTERFACE:

```
SUBROUTINE EMIT_AEIC( Input_Opt, State_Met, State_Chm )
```

USES:

```
USE DIAG_MOD,           ONLY   : AD32_ac,     AD13_SO2_ac
USE GIGC_Input_Opt_Mod, ONLY   : OptInput
USE GIGC_State_Chm_Mod, ONLY   : ChmState
USE GIGC_State_Met_Mod, ONLY   : MetState
USE GRID_MOD,           ONLY   : GET_XOFFSET, GET_YOFFSET
USE GRID_MOD,           ONLY   : GET_AREA_CM2
USE PRESSURE_MOD,       ONLY   : GET_AP,      GET_BP
USE TIME_MOD,           ONLY   : GET_MONTH,   GET_TS_EMIS
USE TRACERID_MOD
USE TROPOPAUSE_MOD,     ONLY   : GET_TPAUSE_LEVEL

USE CMN_SIZE_MOD               ! Size parameters
USE CMN_DIAG_MOD               ! Diagnostic switches
USE CMN_MOD                    ! PTOP, SIGE, AVP
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
31 Jul 2013 - M. Sulprizio- Now add aircraft NOx and SO2 emissions to
                            AD32 and AD13 arrays for diagnostics
01 Aug 2013 - M. Sulprizio- Added ProTeX headers
13 Dec 2013 - M. Sulprizio- Only add SO2 aircraft emissions to AD13_SO2_ac
                            if level is <= LD13 in order to avoid array-
                            out-of-bounds error (J. Fisher)
```

1.23.3 init_aeic

Subroutine INIT_AEIC allocates and initializes module variables. (sde, 12/16/12)

INTERFACE:

```
SUBROUTINE INIT_AEIC
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
01 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.23.4 cleanup_aeic

Subroutine CLEANUP_AEIC deallocates module variables. (sde, 12/16/12)

INTERFACE:

```
SUBROUTINE CLEANUP_AEIC
```

REVISION HISTORY:

```
01 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.24 Fortran: Module Interface aerosol_mod

Module AEROSOL_MOD contains variables and routines for computing optical properties for aerosols which are needed for both the FAST-J photolysis and ND21 optical depth diagnostics. (bmy, 7/20/04, 2/10/09)

INTERFACE:

```
MODULE AEROSOL_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: AEROSOL_CONC
PUBLIC :: AEROSOL_RURALBOX
PUBLIC :: CLEANUP_AEROSOL
PUBLIC :: INIT_AEROSOL
PUBLIC :: RDAER
```

PUBLIC DATA MEMBERS:

```
PUBLIC :: SOILDUST
```

REMARKS:

```
References:
============================================================================
(1 ) Pye, H.O.T., and J.H. Seinfeld, "A global perspective on aerosol from
      low-volatility organic compounds", Atmos. Chem. & Phys., Vol 10, pp
      4377-4401, 2010.
```

REVISION HISTORY:

```
(1 ) Added AEROSOL_RURALBOX routine (bmy, 9/28/04)
(2 ) Now convert ABSHUM from absolute humidity to relative humidity in
       AEROSOL_RURALBOX, using the same algorithm as in "gasconc.f".
       (bmy, 1/27/05)
(3 ) Now references "tropopause_mod.f" (bmy, 8/22/05)
(4 ) Now add contribution of SOA4 into Hydrophilic OC (dkh, bmy, 5/18/06)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(6 ) Add support for variable tropopause (bdf, phs, 9/14/06)
(7 ) Now set OCF=2.1 in AEROSOL_CONC for consistency w/ carbon_mod.f
     (tmf, 2/10/09)
(8 ) Add WTAREA and WERADIUS for dicarbonyl SOA production.
     WTAREA is the same as TAREA, but excludes dry dust, BCPO and OCPO;
     use same units as TAREA.
     WERADIUS is same as ERADIUS, but excludes dry dust, BCPO and OCPO;
```

```
     use same units as ERADIUS. (tmf, 3/2/09)
(9 ) Add SOAG and SOAM species. (tmf, ccc, 3/2/09)
(10) Modify AOD output to wavelength specified in jv_spec_aod.dat
     (clh, 05/07/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
05 Mar 2013 - R. Yantosca - Now make INIT_AEROSOL a public routine
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.24.1 aerosol_ruralbox

! DESCRIPTION: Subroutine AEROSOL_RURALBOX computes quantities that are needed by RDAER. This mimics the call to RURALBOX, which is only done for fullchem runs. (bmy, 9/28/04, 9/14/06)

INTERFACE:

```
      SUBROUTINE AEROSOL_RURALBOX( N_TROP,    am_I_Root,
     &                             Input_Opt, State_Met )
```

USES:

```
      USE COMODE_MOD,         ONLY : ABSHUM, AIRDENS, IXSAVE
      USE COMODE_MOD,         ONLY : IYSAVE, IZSAVE,  JLOP
      USE DAO_MOD,            ONLY : MAKE_AVGW
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_TROP

      USE CMN_SIZE_MOD             ! Size parameters
      USE COMODE_LOOP_MOD          ! AD, AVG, WTAIR, etc.
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root ! Is this the root CPU?
```

INPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(IN)    :: Input_Opt ! Input Options object
      TYPE(MetState), INTENT(INOUT) :: State_Met ! Meteorology State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: N_TROP    ! # tropospheric boxes
```

REVISION HISTORY:

```
(1 ) Now convert ABSHUM from absolute humidity to relative humidity in
     AEROSOL_RURALBOX, using the same algorithm as in "gasconc.f".
     (bmy, 1/27/05)
(2 ) Now references ITS_IN_THE_TROP from "tropopause_mod.f" to diagnose
     boxes w/in the troposphere. (bmy, 8/22/05)
```

```
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Modified for variable tropopause (phs, bdf, 9/14/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
08 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.24.2 aerosol_conc

Subroutine AEROSOL_CONC computes aerosol concentrations in kg/m3 from the tracer mass in kg in the STT array. These are needed to compute optical properties for photolysis and for the optical depth diagnostics. (bmy, 7/20/04, 2/10/09)

INTERFACE:

```
 SUBROUTINE AEROSOL_CONC( am_I_Root, Input_Opt,
&                         State_Met, State_Chm, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACERID_MOD,       ONLY : IDTBCPI, IDTBCPO, IDTDST1, IDTDST2
USE TRACERID_MOD,       ONLY : IDTDST3, IDTDST4, IDTNH4,  IDTNIT
USE TRACERID_MOD,       ONLY : IDTOCPO, IDTOCPI, IDTSALA, IDTSALC
USE TRACERID_MOD,       ONLY : IDTSO4,   IDTSOAG, IDTSOAM
! SOAupdate: update SOA tracers (hotp 7/25/10)
USE TRACERID_MOD,       ONLY : IDTPOA1,  IDTPOA2
USE TRACERID_MOD,       ONLY : IDTOPOA1, IDTOPOA2
! SOAupdate: new mtp replaces SOA1-4 (hotp 5/20/10
USE TRACERID_MOD,       ONLY : IDTTSOA1, IDTTSOA2
USE TRACERID_MOD,       ONLY : IDTTSOA3, IDTTSOA0
USE TRACERID_MOD,       ONLY : IDTISOA1, IDTISOA2, IDTISOA3
! SOAupdate: replace SOA5 with lumped aromatic (hotp 5/12/10)
USE TRACERID_MOD,       ONLY : IDTASOAN, IDTASOA1
USE TRACERID_MOD,       ONLY : IDTASOA2, IDTASOA3
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REMARKS:

```
    This code was originally included in "chemdr.f", but the same computation
    also needs to be done for offline aerosol simulations.  Therefore, we have
    split this code off into a separate subroutine which can be called by both
    fullchem and offline aerosol simulations.
```

REVISION HISTORY:

```
    (1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (2 ) Now add contribution from SOA4 into Hydrophilic OC (dkh, bmy, 5/18/06)
    (3 ) Now set OCF=2.1 to be consistent w/ "carbon_mod.f" (tmf, 2/10/09)
    22 Dec 2011 - M. Payer    - Added ProTeX headers
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    13 Nov 2012 - R. Yantosca - Now pass am_I_Root, Input_Opt, RC as arguments
    15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    05 Mar 2013 - R. Yantosca - Remove call to INIT_AEROSOL, this is now done
                                in the initialization stage
    25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
    13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                                semivolatile POA simulations (H. Pye)
```

1.24.3 rdaer

Subroutine RDAER reads global aerosol concentrations as determined by Mian Chin. Calculates optical depth at each level for "set_prof.f". Also calculates surface area for heterogeneous chemistry. It uses aerosol parameters in FAST-J input file "jv_spec.dat" for these calculations. (rvm, rjp, tdf, bmy, 11/04/01, 7/20/04)

INTERFACE:

```
      SUBROUTINE RDAER( am_I_Root, Input_Opt, State_Met,  RC,
     &                  MONTH,     YEAR,      WAVELENGTH      )
```

USES:

```
      USE CMN_FJ_MOD,         ONLY : JPMAX
      USE CMN_FJ_MOD,         ONLY : JPPJ
      USE CMN_SIZE_MOD
      USE CMN_DIAG_MOD
      USE COMODE_LOOP_MOD
      USE BPCH2_MOD,          ONLY : GET_NAME_EXT
      USE BPCH2_MOD,          ONLY : GET_RES_EXT
      USE BPCH2_MOD,          ONLY : GET_TAU0
```

```
      USE BPCH2_MOD,          ONLY : READ_BPCH2
      USE COMODE_MOD,         ONLY : ABSHUM
      USE COMODE_MOD,         ONLY : ERADIUS
      USE COMODE_MOD,         ONLY : IXSAVE
      USE COMODE_MOD,         ONLY : IYSAVE
      USE COMODE_MOD,         ONLY : IZSAVE
      USE COMODE_MOD,         ONLY : TAREA
      USE COMODE_MOD,         ONLY : WTAREA
      USE COMODE_MOD,         ONLY : WERADIUS
      USE DIAG_MOD,           ONLY : AD21
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE JV_CMN_MOD
      USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH
      USE TRANSFER_MOD,       ONLY : TRANSFER_3D

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)  :: am_I_Root     ! Are we on root CPU?
      TYPE(MetState), INTENT(IN)  :: State_Met     ! Meteorology State
      INTEGER,        OPTIONAL    :: MONTH         ! # of current month
      INTEGER,        OPTIONAL    :: YEAR          ! 4-digit year
      INTEGER,        OPTIONAL    :: WAVELENGTH    ! Logical indicator
                                                   !  = 0: AOD computed
                                                   !       at 999 nm
                                                   !  = 1: AOD computed
                                                   !       at wavelength
                                                   !       in jv_spec_aod.dat
      TYPE(OptInput), INTENT(IN)  :: Input_Opt     ! Input Options object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT) :: RC            ! Success or failure?
```

REVISION HISTORY:

```
    (1 ) At the point in which "rdaer.f" is called, ABSHUM is actually
         absolute humidity and not relative humidity (rvm, bmy, 2/28/02)
    (2 ) Now force double-precision arithmetic by using the "D" exponent.
         (bmy, 2/28/02)
    (3 ) At present aerosol growth is capped at 90% RH.  The data
         in jv_spec.dat could be used to allow a particle to grow to
         99% RH if desired. (rvm, 3/15/02)
    (4 ) Bug fix: TEMP2 needs to be sized (IIPAR,JJPAR,LLPAR) (bmy, 5/30/02)
    (5 ) Now reference BXHEIGHT from "dao_mod.f".  Also references ERROR_STOP
         from "error_mod.f".  Delete local declaration of TIME, since that
```

```
      is also declared w/in comode.h -- this causes compile-time errors
      on the ALPHA platform. (gcc, bmy, 11/6/02)
(6 ) Now use the online SO4, NH4, NIT aerosol, taken from the STT array,
      and passed via SO4_NH4_NIT argument if sulfate chemistry is turned on.
      Otherwise, read monthly mean sulfate from disk.  (rjp, bmy, 3/23/03)
(7 ) Now call READ_BPCH2 with QUIET=.TRUE., which prevents info from being
      printed to stdout.  Also made cosmetic changes. (bmy, 3/27/03)
(8 ) Add BCPI, BCPO, OCPI, OCPO to the arg list.  Bug fix: for online
      sulfate & carbon aerosol tracers, now make sure these get updated
      every timestep.  Now references "time_mod.f".  Now echo info about
      which online/offline aerosols we are using.  Updated comments.
      (bmy, 4/9/04)
(9 ) Add SALA, SALC to the arg list (rjp, bec, bmy, 4/20/04)
(10) Now references DATA_DIR from "directory_mod.f".  Now references LSULF,
      LCARB, LSSALT from "logical_mod.f".  Added minor bug fix for
      conducting the appropriate scaling for optical depth for ND21
      diagnostic.  Now make MONTH and YEAR optional arguments.  Now bundled
      into "aerosol_mod.f".  (rvm, aad, clh, bmy, 7/20/04)
(11) Now remove FWET from extinction efficiency computation (avd, 8/3/10)
(12) Include third input argument to determine the wavelength at which
      the AOD should be computed. This will set the optical properties
      that are used for the calculation of the AOD. The ND21 diagnostic
      should only be updated when WAVELENGTH = 1. (skim, 02/03/11)
09 Mar 2011 - R. Yantosca - Set MSDENS(2) = 1800 for APM (G. Luo)
22 Dec 2011 - M. Payer    - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
13 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC arguments for GIGC
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.24.4 init_aerosol

Subroutine INIT_AEROSOL allocates and zeroes module arrays

INTERFACE:

```
SUBROUTINE INIT_AEROSOL( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
22 Dec 2011 - M. Payer    - Added ProTeX headers
05 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC arguments
```

1.24.5 cleanup_aerosol

Subroutine CLEANUP_AEROSOL deallocates all module arrays (bmy, 7/20/04)

INTERFACE:

```
SUBROUTINE CLEANUP_AEROSOL
```

REVISION HISTORY:

```
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.25 Fortran: Module Interface arctas_ship_emiss_mod

Module ARCTAS_SHIP_EMISS_MOD contains variables and routines to read the Arctas Ship emissions.

INTERFACE:

```
MODULE ARCTAS_SHIP_EMISS_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_ARCTAS_SHIP
PUBLIC  :: EMISS_ARCTAS_SHIP
PUBLIC  :: GET_ARCTAS_SHIP
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: INIT_ARCTAS_SHIP
      PRIVATE :: READ_ARCTAS_SHIP
      PRIVATE :: TOTAL_EMISS_TG
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
31 Aug 2010 - R. Yantosca - Updated comments
01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use the new function
                            GET_AREA_CM2( I, J, L ) from grid_mod.F90
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

REMARKS:

```
(1) Part of the ARCTAS pre-campaign composite inventory distributed by
     David Streets.
(2) Only SO2 differs from existing EDGAR inventory. All other
     species are disregarded for now, except CO2 that we did not have
     before.
(3) The ship emission is based on the work by Eyring et al., JGR 2005,
    which estimates the total international ship emissions for 1985, 1990,
    2001, and 2020 (projection). The ship emission for each individual year
    is interpreted based on the above years, and the spatial pattern
    (gridded) is mapped based on the EDGAR gridded ship emission for 2000
    (total amount from EDGAR is scaled to Eyring-based number).
    If you want to reference the work on publication or website, you may
    either mention "Diehl et al., manuscript in preparation, 2009" or
    refer to the AeroCom readme document for hindcast emissions for ship
    (prepared by Diehl):
    http://www-lscedods.cea.fr/aerocom/AEROCOM_HC/readme_ship/.
    If you have further questions, please contact Thomas directly
    (thomas.diehl@nasa.gov).
```

1.25.1 get_arctas_ship

Function GET_ARCTAS_SHIP returns the ARCTAS_SHIP emission for GEOS-Chem grid box (I,J) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s].

INTERFACE:

```
      FUNCTION GET_ARCTAS_SHIP( I, J, N, MOLEC_CM2_S, KG_S )
     &     RESULT( VALUE )
```

USES:

```
      USE GRID_MOD,     ONLY : GET_AREA_CM2
      USE TRACER_MOD,   ONLY : ITS_A_CO2_SIM
      USE TRACER_MOD,   ONLY : XNUMOL
      USE TRACERID_MOD, ONLY : IDTSO2
```

INPUT PARAMETERS:

```
! Longitude, latitude, and tracer indices
INTEGER, INTENT(IN)           :: I, J, N

! OPTIONAL -- return emissions in [molec/cm2/s]
LOGICAL, INTENT(IN), OPTIONAL :: MOLEC_CM2_S

! OPTIONAL -- return emissions in [kg/s]
LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
! Emissions output
REAL*8                        :: VALUE
```

REVISION HISTORY:

28 Jan 2009 - P. Le Sager - Initial Version

1.25.2 emiss_arctas_ship

Subroutine EMISS_ARCTAS_SHIP reads the ARCTAS_SHIP emissions from disk.

INTERFACE:

```
SUBROUTINE EMISS_ARCTAS_SHIP( am_I_Root, YEAR,
&                             Input_Opt, State_Chm, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACERID_MOD,       ONLY : IDTSO2
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
INTEGER,        INTENT(IN)    :: YEAR        ! Year of data to read
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

28 Jan 2009 - P. Le Sager - Initial Version

1.25.3 read_arctas_ship

Subroutine READ_ARCTAS_SHIP reads data from one ARCTAS_SHIP data file from disk, at GENERIC 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
 SUBROUTINE READ_ARCTAS_SHIP( FILENAME, CATEGORY,
&                             TRACERN,  ARR,      YEAR )
```

USES:

```
USE BPCH2_MOD,         ONLY : GET_TAU0,      READ_BPCH2
USE REGRID_A2A_MOD,    ONLY : DO_REGRID_A2A
USE DIRECTORY_MOD,     ONLY : DATA_DIR_1x1
USE SCALE_ANTHRO_MOD, ONLY : GET_ANNUAL_SCALAR

USE CMN_SIZE_MOD           ! Size parameters
```

INPUT PARAMETERS:

```
! Year of data to read
INTEGER,          INTENT(IN)    :: YEAR

! Tracer number
INTEGER,          INTENT(IN)    :: TRACERN

! Filename & category under which data is stored in bpch file
CHARACTER(LEN=*), INTENT(IN)    :: FILENAME, CATEGORY
```

INPUT/OUTPUT PARAMETERS:

```
! Array containing output data
REAL*8,           INTENT(INOUT) :: ARR(IIPAR,JJPAR)
```

REMARKS:

```
(1) Even though the inventory was prepared for Arctas 2008 campaign, CO2
    base year is 2000, and SO2 base year is 2006. Input YEAR is used to
    scale SO2 into 1985-2005
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
14 May 2012 - R. Yantosca - Bug fix: SC should be defined w/ IIPAR,JJPAR
24 May 2012 - R. Yantosca - Fix minor bugs in map_a2a implementation
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.25.4 TOTAL_EMISS_TG

Subroutine TOTAL_EMISS_TG prints the totals for the anthropogenic or biomass emissions.

INTERFACE:

```
SUBROUTINE TOTAL_EMISS_TG( Input_Opt )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.25.5 INIT_ARCTAS_SHIP

Subroutine INIT_ARCTAS_SHIP allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_ARCTAS_SHIP( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Remove A_CM2 array
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.25.6 CLEANUP_ARCTAS_SHIP

Subroutine CLEANUP_ARCTAS_SHIP deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_ARCTAS_SHIP
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.26 Fortran: Module Interface benchmark_mod

Module BENCHMARK_MOD contains routines to save out initial and final tracer masses which are needed for GEOS-Chem 1-month benchmark simulations

INTERFACE:

```
MODULE BENCHMARK_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: STDRUN
```

PUBLIC DATA MEMBERS:

```
CHARACTER(LEN=255), PUBLIC :: INITIAL_FILE ! File w/ initial tracer mass
CHARACTER(LEN=255), PUBLIC :: FINAL_FILE   ! File w/ final   tracer mass
```

REVISION HISTORY:

```
(1 ) Now expand date & time tokens in filenames (bmy, 1/31/05)
(2 ) Now modified for GCAP grid (swu, bmy, 6/28/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.26.1 stdrun

Subroutine STDRUN dumps the mass of either O3 [kg] or 222Rn, 210Pb, and 7Be [kg] at the start & end of each run. This is necessary for GEOS-CHEM benchmarking.

INTERFACE:

```
SUBROUTINE STDRUN( Input_Opt, State_Chm, LBEGIN )
```

USES:

```
USE BPCH2_MOD,          ONLY : BPCH2
USE BPCH2_MOD,          ONLY : OPEN_BPCH2_FOR_WRITE
USE BPCH2_MOD,          ONLY : GET_HALFPOLAR
USE BPCH2_MOD,          ONLY : GET_MODELNAME
USE CMN_SIZE_MOD
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE inquireMod,         ONLY : findFreeLUN
USE TIME_MOD,           ONLY : EXPAND_DATE
USE TIME_MOD,           ONLY : GET_NYMD
USE TIME_MOD,           ONLY : GET_NHMS
USE TIME_MOD,           ONLY : GET_TAU
USE TRACERID_MOD,       ONLY : IDTO3
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
TYPE(ChmState), INTENT(IN) :: State_Chm   ! Chemistry State object
LOGICAL,        INTENT(IN) :: LBEGIN      ! =T denotes start of run
                                          ! =F denotes end of run
```

REVISION HISTORY:

```
12 Aug 2002 - R. Yantosca - Initial version
03 Aug 2012 - R. Yantosca - Added ProTeX headers
(1 ) Changed name from STDRUN_Ox to STDRUN, since we now can also save out
     Rn/Pb/Be for NSRCX==1.  Also deleted obsolete code from 6/02.  Added
     LBEGIN as an argument to determine if this is the start or end of the
     run.  (bmy, 8/12/02)
(2 ) Bundled into "benchmark_mod.f" (bmy, 7/20/04)
(3 ) Now expand date tokens in the filename (bmy, 1/31/05)
(4 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
     value for GEOS or GCAP grids .  Also removed references to CMN_DIAG
     and TRCOFFSET. (bmy, 6/28/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
03 Aug 2012 - R. Yantosca - Now use findFreeLUN to obtain file unit #'s
14 Mar 2013 - M. Payer    - Replace Ox with O3 as part of removal of
                            NOx-Ox partitioning
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
30 May 2013 - R. Yantosca - Now pass Input_Opt object via the arg list
```

1.27 Fortran: Module Interface bravo_mod

Overview

Module BRAVO_MOD contains variables and routines to read the BRAVO Mexican anthropogenic emission inventory for NOx, CO, and SO2. (rjp, kfb, bmy, 6/22/06, 1/30/09)

References

1. Kuhns, H., M. Green, and Etyemezian, V, *Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study Emissions Inventory*, Desert Research Institute, 2003.

INTERFACE:

```
MODULE BRAVO_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_BRAVO
PUBLIC  :: EMISS_BRAVO
PUBLIC  :: GET_BRAVO_MASK
PUBLIC  :: GET_BRAVO_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: BRAVO_SCALE_FUTURE
PRIVATE :: INIT_BRAVO
PRIVATE :: READ_BRAVO_MASK
```

REVISION HISTORY:

```
(1 ) Now pass the unit string to DO_REGRID_G2G_1x1 (bmy, 8/9/06)
(2 ) Now scale emissions using int-annual scale factors (amv, 08/24/07)
(3 ) Now accounts for FSCLYR (phs, 3/17/08)
(4 ) Added ProTeX headers (bmy, 1/30/09)
31 Aug 2010 - R. Yantosca - Updated comments
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.27.1 get_bravo_mask

Function GET_BRAVO_MASK returns the value of the Mexico mask for BRAVO emissions at grid box (I,J). MASK=1 if (I,J) is in the BRAVO Mexican region, or MASK=0 otherwise.

INTERFACE:

```
FUNCTION GET_BRAVO_MASK( I, J ) RESULT( MASK )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I        ! Longitude index
INTEGER, INTENT(IN) :: J        ! Latitude  index
```

RETURN VALUE:

```
      REAL*8              :: MASK     ! Returns the mask value @ (I,J)
```

REVISION HISTORY:

```
    22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
```

1.27.2 get_bravo_anthro

Function GET_BRAVO_ANTHRO returns the BRAVO emission for GEOS-Chem grid box (I,J) and tracer N. Units are [molec/cm2/s].

INTERFACE:

```
      FUNCTION GET_BRAVO_ANTHRO( I, J, N ) RESULT( BRAVO )
```

USES:

```
      USE TRACERID_MOD, ONLY : IDTNO, IDTCO, IDTSO2
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I       ! Longitude index
      INTEGER, INTENT(IN) :: J       ! Latitude index
      INTEGER, INTENT(IN) :: N       ! Tracer number
  RETURN VALUE:

      REAL*8              :: BRAVO   ! Returns emissions at (I,J)
```

REVISION HISTORY:

```
    22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
    (1 ) added SOx, SOx ship and NH3 emissions, plus optional kg/s output
         (amv, 06/2008)
    (2 ) Now returns ship emissions if requested (phs, 6/08)
    (3 ) Added checks to avoid calling unavailable ship emissions (phs, 6/08)
    14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                                of removal of NOx-Ox partitioning
```

1.27.3 emiss_bravo

Subroutine EMISS_BRAVO reads the BRAVO emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
      SUBROUTINE EMISS_BRAVO( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR
      USE TIME_MOD,           ONLY : GET_YEAR
      USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A

      USE CMN_SIZE_MOD           ! Size parameters
      USE CMN_O3_MOD             !

#if defined( DEVEL )
      USE TRACERID_MOD, ONLY : IDTNO, IDTCO, IDTSO2
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
    (1 ) Now pass the unit string to DO_REGRID_G2G_1x1 (bmy, 8/9/06)
    13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
    24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
    24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
    03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
    25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.27.4 bravo_scale_future

Subroutine BRAVO_SCALE_FUTURE applies the IPCC future scale factors to the BRAVO anthropogenic emissions.

INTERFACE:

```
      SUBROUTINE BRAVO_SCALE_FUTURE
```

USES:

```
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff

      USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
    30 May 2006 - S. Wu & R. Yantosca - Initial version
```

1.27.5 total_anthro_Tg

Subroutine TOTAL_ANTHRO_TG prints the amount of BRAVO anthropogenic emissions that are emitted each year.

INTERFACE:

```
      SUBROUTINE TOTAL_ANTHRO_TG( YEAR )
```

USES:

```
      ! References to F90 modules
      USE GRID_MOD,     ONLY : GET_AREA_CM2
      USE TRACERID_MOD, ONLY : IDTNO, IDTCO, IDTSO2

      USE CMN_SIZE_MOD     ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: YEAR
```

REVISION HISTORY:

```
    22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
    (1 ) Now YEAR is input to reflect scaling factors applied (phs, 3/17/08)
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                                of removal of NOx-Ox partitioning
```

1.27.6 read_bravo_mask

Subroutine READ_BRAVO_MASK reads the Mexico mask from disk. The Mexico mask is the fraction of the grid box (I,J) which lies w/in the BRAVO Mexican emissions region.

INTERFACE:

```
      SUBROUTINE READ_BRAVO_MASK
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE TRANSFER_MOD,   ONLY : TRANSFER_2D

USE CMN_SIZE_MOD         ! Size parameters
```

REVISION HISTORY:

```
22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
(1 ) Now pass UNIT to DO_REGRID_G2G_1x1 (bmy, 8/9/06)
06 Apr 2012 - M. Payer    - Changed regrid algorithm to map_a2a (M. Cooper)
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
15 Aug 2012 - M. Payer    - Set mask to 1 if greater than 0 (L. Murray)
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.27.7 init_bravo

Subroutine INIT_BRAVO allocates and zeroes BRAVO module arrays, and also creates the mask which defines the Mexico region

INTERFACE:

```
SUBROUTINE INIT_BRAVO( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_XMID, GET_YMID
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.27.8 CLEANUP_BRAVO

Subroutine CLEANUP_BRAVO deallocates all BRAVO module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_BRAVO
```

REVISION HISTORY:

```
22 Jun 2006 - R. Park, F. Boersma, R. Yantosca - Initial version
```

1.28 Fortran: Module Interface bromocarb_mod

Module BROMOCARB_MOD contains variables and routines for the GEOS-CHEM bromocarbon simulation.

INTERFACE:

```
MODULE BROMOCARB_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: EMIS_CHBr3
PUBLIC :: EMIS_CH2Br2
PUBLIC :: SET_CH3Br
PUBLIC :: SET_BrO
PUBLIC :: SEA_SURFACE
PUBLIC :: INIT_BROMOCARB
PUBLIC :: CLEANUP_BROMOCARB
```

PUBLIC DATA MEMBERS:

```
! For scaling bromine emissions (mpayer, 5/15/12)
REAL*8, PUBLIC :: Br_SCALING
```

REVISION HISTORY:

```
13 Aug 2007 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
27 Aug 2012 - M. Payer    - Now parallelize DO loops
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.28.1 emiss_ch3br

Function EMIS_CHBr3 is the emissions driver for very short lived bromocarbon (VSLB) species and the one long-lived compound, methyl bromide (CH3Br).

INTERFACE:

```
FUNCTION EMIS_CHBr3( I, J, State_Met ) RESULT( E_R_CHBr3 )
```

USES:

```
USE LOGICAL_MOD,        ONLY : LWARWICK_VSLS
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_YMID
USE TIME_MOD,           ONLY : GET_MONTH

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_DIAG_MOD             ! ND57 -- diagnostics
USE COMODE_LOOP_MOD          ! Avogadro's #, called 'AVG' = 6.02252d+23
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I           ! Longitude index
INTEGER,        INTENT(IN)  :: J           ! Latitude  index
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
REAL*8                      :: E_R_CHBr3
```

REMARKS:

```
only ocean emissions for all bromocarbons
plan: (1) Bromoform: 400 Gg CHBr3/yr emitted from ocean, broken into
             latitudinal bands: 75% between 20deg south and 20deg north
                25% between 20deg and 50deg north and south
             - This emission scheme follows the work of
               Warwick et al. (2006) Global Modeling of Bromocarbons
                  --> scheme A (eventually, should try B as well,
                      with coastal and shelf emissions...)
               & Yang et al. (2005) Tropospheric Bromine Chemistry
      (2) Dibromomethane:
             - Warwick et al. use same spatial scheme as used for
               bromoform in scenario 3 (lat bands above...)
                  --> schemes A & B: 113 Gg CH2Br2/yr global flux
             - they say they require higher emissions than some previous
               lit probably because they center emissions in the tropics,
               yielding shorter lifetimes for bromocarbons...
```

REVISION HISTORY:

```
23 Aug 2007 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
```

1.28.2 emis_ch2br2

Function EMIS_CH2Br2 is the emissions driver for very short lived bromocarbon (VSLB) species and the one long-lived compound, dibromomethane (CH2Br2)

INTERFACE:

```
FUNCTION EMIS_CH2Br2( I, J ) RESULT( E_R_CH2Br2 )
```

USES:

```
USE LOGICAL_MOD,   ONLY : LWARWICK_VSLS

USE CMN_SIZE_MOD        ! Size parameters
USE CMN_DIAG_MOD        ! ND57 -- diagnostics
USE COMODE_LOOP_MOD     ! Avogadro's #, called 'AVG' = 6.02252d+23
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: I        ! Longitude index
INTEGER, INTENT(IN)    :: J        ! Latitude  index
```

RETURN VALUE:

```
REAL*8                 :: E_R_CH2Br2
```

REMARKS:

```
only ocean emissions for all bromocarbons
plan: (1) Bromoform: 400 Gg CHBr3/yr emitted from ocean, broken into
            latitudinal bands: 75% between 20deg south and 20deg north
               25% between 20deg and 50deg north and south
            - This emission scheme follows the work of
              Warwick et al. (2006) Global Modeling of Bromocarbons
                 --> scheme A (eventually, should try B as well,
                     with coastal and shelf emissions...)
              & Yang et al. (2005) Tropospheric Bromine Chemistry
      (2) Dibromomethane:
            - Warwick et al. use same spatial scheme as used for
              bromoform in scenario 3 (lat bands above...)
                 --> schemes A & B: 113 Gg CH2Br2/yr global flux
            - they say they require higher emissions than some previous
              lit probably because they center emissions in the tropics,
              yielding shorter lifetimes for bromocarbons...
```

REVISION HISTORY:

```
23 Aug 2007 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
```

1.28.3 sea_surface

Subroutine SEA_SURFACE calculates the total sea surface area within two specified regions: (1) total area between 20S and 20N (2) total area between 20 and 50 degrees, North + South These surface area values are used to set the emission fluxes for each of the aforementioned regions.

INTERFACE:

```
SUBROUTINE SEA_SURFACE( State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_M2, GET_YEDGE

USE CMN_SIZE_MOD      ! Size parameters
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
16 Aug 2007 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
27 Aug 2012 - M. Payer    - Added parallel DO loop
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.28.4 set_ch3br

Subroutine SET_CH3Br set CH3Br Concentrations in the planetary boundary layer. Based on latitude bands (1) 90-55N, (2) 55N-0, (3) 0-55S, (4) 55-90S. Values for setting pbl flux were determined by surface measurements from NOAA 2006 data.

INTERFACE:

```
SUBROUTINE SET_CH3Br( N_TRACERS, TCVV, STT, unit_flag, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_YMID
USE LOGICAL_MOD,        ONLY : LWARWICK_VSLS
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE TRACER_MOD,         ONLY : TRACER_NAME

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: unit_flag
INTEGER,        INTENT(IN)    :: N_TRACERS
REAL*8,         INTENT(IN)    :: TCVV(N_TRACERS) ! [Air MW / Tracer MW]
TYPE(MetState), INTENT(IN)    :: State_Met       ! Met State object
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,         INTENT(INOUT) :: STT(IIPAR,JJPAR,LLPAR,N_TRACERS)
```

REMARKS:

```
1) STT is converted back and forth between units of [kg] and
   [v/v]. Placement of the call to SET_CH3Br in main.f (it's
   with the emissions) means that it should be in [kg].
```

REVISION HISTORY:

```
12 Feb 2008 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
27 Aug 2012 - M. Payer    - Added parallel DO loop
28 Aug 2012 - M. Payer    - Add error check for CH3Br to avoid OOB error
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.28.5 set_bro

Subroutine SET_BRO sets BrO concentrations in the planetary boundary layer. Based on latitude bands (1) 90-55N, (2) 55N-0, (3) 0-55S, (4) 55-90S. Values for setting pbl flux were determined by surface measurements from NOAA 2006 data.

INTERFACE:

```
SUBROUTINE SET_BRO( N_TRACERS, TCVV, STT, unit_flag, State_Met )
```

USES:

```
USE DAO_MOD,            ONLY : IS_WATER
USE GIGC_State_Met_Mod, ONLY : MetState
USE LOGICAL_MOD,        ONLY : LFIX_PBL_BRO
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE TRACER_MOD,         ONLY : TRACER_NAME

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: unit_flag
INTEGER,        INTENT(IN)    :: N_TRACERS
REAL*8,         INTENT(IN)    :: TCVV(N_TRACERS)  ! [Air MW / Tracer MW]
TYPE(MetState), INTENT(IN)    :: State_Met        ! Met State object
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,         INTENT(INOUT) :: STT(IIPAR,JJPAR,LLPAR,N_TRACERS)
```

REMARKS:

```
1) STT is converted back and forth between units of [kg] and
   [v/v]. Placement of the call to SET_Bro in main.f (it's
   with the emissions) means that it should be in [kg].
```

REVISION HISTORY:

```
12 Feb 2008 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
27 Aug 2012 - M. Payer    - Added parallel DO loop
28 Aug 2012 - M. Payer    - Add error check for BrO to avoid OOB error
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
27 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
```

1.28.6 init_bromocarb

Subroutine INIT_BROMOCARB allocates and zeroes BROMOCARB module arrays.

INTERFACE:

```
SUBROUTINE INIT_BROMOCARB( State_Met )
```

USES:

```
USE DIRECTORY_MOD,      ONLY : DATA_DIR, DATA_DIR_1x1
USE ERROR_MOD,          ONLY : ALLOC_ERR, DEBUG_MSG
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_M2
USE LOGICAL_MOD,        ONLY : LPRT,      LWARWICK_VSLS
USE REGRID_A2A_MOD

USE CMN_SIZE_MOD             ! Size parameters
USE COMODE_LOOP_MOD          ! Avogadro's #, called 'AVG' = 6.02252d+23

USE m_netcdf_io_open
USE m_netcdf_io_read
USE m_netcdf_io_close
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
13 Aug 2007 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
27 Aug 2012 - M. Payer    - Added parallel DO loop
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
05 Jun 2013 - R. Yantosca - Add st2d, ct2d arrays to avoid having the
                            code create array temporaries in call to NcRd
```

1.28.7 cleanup_bromocarb

Subroutine CLEANUP_BROMOCARB deallocates all BROMOCARB module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_BROMOCARB
```

REVISION HISTORY:

```
13 Aug 2007 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
```

1.29 Fortran: Module Interface c2h6_mod

Module C2H6_MOD contains variables and routines used for the tagged C2H6 (ethane) simulation. (xyp, qli, bmy, 7/28/01, 4/5/06)

INTERFACE:

```
MODULE C2H6_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: GET_C2H6_ANTHRO
PUBLIC  :: EMISSC2H6
PUBLIC  :: CHEMC2H6
PUBLIC  :: CLEANUP_C2H6
PRIVATE DATA MEMBERS:
PRIVATE :: NGASC2H6
PRIVATE :: FMOL_C2H6
PRIVATE :: XNUMOL_C2H6
```

REMARKS:

```
Setting LSPLIT = T in "input.geos" will run with the following tracers:
   (1) Total C2H6
   (2) C2H6 from biomass burning
   (3) C2H6 from biofuel burning
   (4) C2H6 from natural gas leaking/venting (e.g. "anthro" C2H6)

Setting LSPLIT = F in "input.geos" will run w/ the following tracers:
   (1) Total C2H6
```

REVISION HISTORY:

```
(1 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
(2 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
      MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(3 ) Now reference BXHEIGHT and T from "dao_mod.f".  Also references
      "error_mod.f".  Removed obsolete code.  Now references F90 module
       tracerid_mod.f". (bmy, 11/15/02)
(4 ) Now references "grid_mod.f" and the new "time_mod.f" (bmy, 2/11/03)
(5 ) Now references "directory_mod.f", "logical_mod.f", and "tracer_mod.f".
      (bmy, 7/20/04)
(6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(7 ) Now modified
22 Mar 2012 - M. Payer    - Add function GET_C2H6_ANTHRO
22 Mar 2012 - M. Payer    - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.29.1 emissc2h6

Subroutine EMISSC2H6 reads in C2H6 emissions for the Tagged C2H6 run. (xyp, qli, bmy, 7/21/00, 4/5/06)

INTERFACE:

```
      SUBROUTINE EMISSC2H6( am_I_Root, Input_Opt,
     &                      State_Met, State_Chm, RC )
```

USES:

```
      USE BIOMASS_MOD,        ONLY : BIOMASS
      USE BIOFUEL_MOD,        ONLY : BIOFUEL, BIOFUEL_BURN
      USE DIAG_MOD,           ONLY : AD36
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE GEIA_MOD,           ONLY : READ_C3H8_C2H6_NGAS
      USE GEIA_MOD,           ONLY : TOTAL_FOSSIL_TG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
```

```
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE TIME_MOD,           ONLY : GET_MONTH, GET_TS_EMIS
      USE TRACERID_MOD,       ONLY : IDBC2H6
      USE TRACERID_MOD,       ONLY : IDBFC2H6, IDEC2H6, IDTC2H6
      USE TRANSFER_MOD,       ONLY : TRANSFER_2D

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_O3_MOD               ! EMISTC2H6
      USE CMN_DIAG_MOD             ! Diagnostic arrays & switches
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) BURNEMIS and BIOFUEL are now dimensioned with IIPAR,JJPAR instead of
     IIPAR,JJPAR.  Remove BXHEIGHT from the arg list, since ND28 and ND36
     diags are archived in BIOBURN and BIOFUEL_BURN.  Now use routine
     TRANSFER_2D from "transfer_mod.f" to cast from REAL*4 to REAL*8.
     Now print emission totals for C2H6 emissions to stdout. (bmy, 1/25/02)
(2 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
(3 ) Now references IDBC2H6 etc from "tracerid_mod.f".  Now make FIRSTEMISS
     a local SAVEd variable instead of an argument. (bmy, 11/15/02)
(4 ) Now use GET_AREA_CM2 from "grid_mod.f" to get grid box surface
     area in cm2.  Remove references to DXYP.  Use routines GET_MONTH
     and GET_TS_EMIS from "time_mod.f".  Remove MONTH from call to
     BIOBURN. (bmy, 2/11/03)
(5 ) Now replace CMN_SETUP w/ references from "logical_mod.f" and
     "directory_mod.f".  Now references STT from "tracer_mod.f".
     Replace LFOSSIL with LANTHRO (bmy, 7/20/04)
(6 ) Now make sure all USE statements are USE, ONLY.  Also eliminate
     reference to BPCH2_MOD, it's obsolete. (bmy, 10/3/05)
(7 ) Now modified for new "biomass_mod.f" (bmy, 4/5/06)
(8 ) BIOMASS(:,:,IDBCO) from "biomass_mod.f" is now in units of
     [atoms C/cm2/s].  Adjust unit conversion accordingly. (bmy, 9/27/06)
(9 ) Now IDBC2H6 is defined in TRACERID_MOD. (fp, hotp , 7/31/09)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
22 Mar 2012 - M. Payer    - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.29.2 chemc2h6

Subroutine CHEMC2H6 performs C2H6 chemistry. Loss of C2H6 is via reaction with OH. (xyp, qli, bmy, 10/19/99, 7/20/04)

INTERFACE:

```
      SUBROUTINE CHEMC2H6( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_OH_MOD,      ONLY : OH,        GET_GLOBAL_OH
      USE TIME_MOD,           ONLY : GET_MONTH, GET_TS_CHEM
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    (1 ) Now do chemistry all the way to the model top.
    (2 ) Use monthly mean OH fields for oxidation -- reference the monthly
         mean OH array and the routine which reads it from disk in
        "global_oh_mod.f" (bmy, 1/25/02)
    (3 ) Now reference T from "dao_mod.f".  Also make FIRSTCHEM a local SAVEd
         variable. (bmy, 11/15/02)
    (4 ) Now use functions GET_MONTH and GET_TS_CHEM from "time_mod.f".
    (5 ) Now reference STT & N_TRACERS from "tracer_mod.f".  Now reference
         LSPLIT from "logical_mod.f" (bmy, 7/20/04)
    22 Mar 2012 - M. Payer    - Added ProTeX headers
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
    23 Oct 2013 - R. Yantosca - Now pass objects to GET_GLOBAL_OH routine
```

1.29.3 get_c2h6_anthro

Function GET_C2H6_ANTHRO returns the monthly average anthropogenic C2H6 emissions at GEOS-Chem grid box (I,J). Data will be returned in units of [atoms C/cm2/s].

INTERFACE:

```
FUNCTION GET_C2H6_ANTHRO( I, J, N ) RESULT( C2H6_ANTHRO )
```

USES:

```
USE TRACERID_MOD, ONLY : IDTC2H6
USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)   :: I   ! GEOS-Chem longitude index
INTEGER, INTENT(IN)   :: J   ! GEOS-Chem latitude index
INTEGER, INTENT(IN)   :: N   ! GEOS-Chem tracer index
```

RETURN VALUE:

```
REAL*8                :: C2H6_ANTHRO
```

REVISION HISTORY:

```
22 Mar 2012 - M. Payer    - Initial version adapted from GET_RETRO_ANTHRO
```

1.29.4 init_c2h6

Subroutine INIT_C2H6 allocates and zeroes the NGASC2H6 array, which holds global monthly mean natural gas C2H6 emissions. (qli, bmy, 1/1/01, 10/15/02)

INTERFACE:

```
SUBROUTINE INIT_C2H6
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
22 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.29.5 cleanup_c2h6

Subroutine CLEANUP_C2H6 deallocates the natural gas C2H6 emission array.

INTERFACE:

```
SUBROUTINE CLEANUP_C2H6
```

REVISION HISTORY:

```
22 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.30 Fortran: Module Interface cac_anthro_mod

Module CAC_ANTHRO_MOD contains variables and routines to read the Criteria Air Contaminant Canadian anthropogenic emissions (amv, phs, 1/28/2009)

INTERFACE:

```
MODULE CAC_ANTHRO_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CLEANUP_CAC_ANTHRO
PUBLIC :: EMISS_CAC_ANTHRO
PUBLIC :: EMISS_CAC_ANTHRO_05x0666
PUBLIC :: GET_CANADA_MASK
PUBLIC :: GET_CAC_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: CAC_SCALE_FUTURE
PRIVATE :: READ_CANADA_MASK
PRIVATE :: READ_CANADA_MASK_05x0666
PRIVATE :: INIT_CAC_ANTHRO
PRIVATE :: TOTAL_ANTHRO_TG
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
18 Dec 2009 - Aaron van D - Added EMISS_CAC_ANTHRO_05x0666 routine
18 Dec 2009 - Aaron van D - Added READ_CANADA_MASK_05x0666 routine
01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use the new function
                            GET_AREA_CM2( I, J, L ) from grid_mod.F90
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.30.1 get_canada_mask

Function GET_CANADA_MASK returns the value of the Canadian geographic mask at grid box (I,J). MASK=1 if (I,J) is within Canada, MASK=0 otherwise. (amv, phs, 1/28/09)

INTERFACE:

```
FUNCTION GET_CANADA_MASK( I, J ) RESULT( THISMASK )
```

INPUT PARAMETERS:

```
! Longitude and latitude indices
INTEGER, INTENT(IN) :: I, J
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.30.2 get_cac_anthro

Function GET_CAC_ANTHRO returns the Critical Air Contaminants emission for GEOS-Chem grid box (I,J) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s]. (amv, phs, 1/28/09)

INTERFACE:

```
FUNCTION GET_CAC_ANTHRO( I,    J,     N,
&                        MOLEC_CM2_S, KG_S ) RESULT( VALUE )
```

USES:

```
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : XNUMOL
USE TRACERID_MOD, ONLY : IDTNO, IDTCO, IDTSO2, IDTNH3, IDTNO2
```

INPUT PARAMETERS:

```
! Longitude, latitude, and tracer indices
INTEGER, INTENT(IN)           :: I, J, N

! OPTIONAL -- return emissions in [molec/cm2/s]
LOGICAL, INTENT(IN), OPTIONAL :: MOLEC_CM2_S

! OPTIONAL -- return emissions in [kg/s]
LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
! Emissions output
REAL*8                        :: VALUE
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
```

1.30.3 emiss_cac_anthro

Subroutine EMISS_CAC_ANTHRO reads the Critical Air Contaminants emission fields at 1x1 resolution and regrids them to the current model resolution. (amv, phs, 1/28/2009)

INTERFACE:

```
      SUBROUTINE EMISS_CAC_ANTHRO( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TIME_MOD,           ONLY : GET_YEAR,  GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_1x1
      USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
      USE CMN_SIZE_MOD
      USE CMN_O3_MOD

#if defined( DEVEL )
      USE TRACERID_MOD,       ONLY : IDTNO, IDTCO, IDTSO2, IDTNH3
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?!
```

REVISION HISTORY:

```
   28 Jan 2009 - P. Le Sager - Initial Version
```

REMARKS:

```
   (1 ) Emissions are read for a year b/w 2002-2005, and scaled
        (except NH3) between 1985-2003 if needed (phs, 3/10/08)
   (2 ) Now accounts for FSCALYR (phs, 3/17/08)
   18 Dec 2009 - Aaron van D - Use 2005 scale factors for years beyond 2005
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bug in map_a2a implementation
   24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
   03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
   16 Jul 2013 - M. Payer    - Bug fix: Prevent negative emissions when scaling
                               between 2002 and 2005 (C. Keller)
```

1.30.4 emiss_cac_anthro_05x0666

Subroutine EMISS_CAC_ANTHRO_05x0666 reads the Critical Air Contaminants emission fields at nested NA resolution (1/2 x 2/3) (amv, phs, 11/03/2009)

INTERFACE:

```
      SUBROUTINE EMISS_CAC_ANTHRO_05x0666( am_I_Root, Input_Opt,
     &                                     State_Chm, RC         )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TIME_MOD,           ONLY : GET_YEAR,  GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_05x0666_NESTED
      USE CMN_SIZE_MOD
      USE CMN_O3_MOD

#if defined( DEVEL )
      USE TRACERID_MOD,       ONLY : IDTNO, IDTCO, IDTSO2, IDTNH3
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   03 Nov 2009 - A. van Donkelaar - Initial Version
```

REMARKS:

```
   (1 ) Emissions are read for a year b/w 2002-2005, and scaled
        (except NH3) between 1985-2003 if needed (phs, 3/10/08)
   (2 ) Now accounts for FSCALYR (phs, 3/17/08)
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
   16 Jul 2013 - M. Payer    - Bug fix: Prevent negative emissions when scaling
                               between 2002 and 2005 (C. Keller)
```

1.30.5 cac_scale_future

Subroutine CAC_SCALE_FUTURE applies the IPCC future scale factors to the Criteria Air Contaminant anthropogenic emissions. (amv, phs, 1/28/09)

INTERFACE:

```
SUBROUTINE CAC_SCALE_FUTURE
```

USES:

```
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NH3an
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff

USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
```

1.30.6 total_anthro_tg

Subroutine TOTAL_ANTHRO_TG prints the totals for the anthropogenic emissions of NOx, CO, SO2 and NH3. (amv, phs, 1/28/09)

INTERFACE:

```
SUBROUTINE TOTAL_ANTHRO_TG( YEAR )
```

USES:

```
USE CMN_SIZE_MOD            ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: YEAR   ! Year of data to compute totals
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
```

1.30.7 read_canada_mask

Subroutine READ_CANADA_MASK reads and regrids the Canadian geographic mask from disk. (amv, phs, 1/28/09)

INTERFACE:

```
SUBROUTINE READ_CANADA_MASK
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_TAU0, READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

USE CMN_SIZE_MOD         ! Size parameters
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
07 Jun 2012 - M. Payer    - Fixed minor bugs in map_a2a implementation
15 Aug 2012 - M. Payer    - Fixed minor bugs in regridding of mask; Also set
                            mask to 1 if greater than 0 (L. Murray)
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.30.8 read_canada_mask_05x0666

Subroutine READ_CANADA_MASK_05x0666 reads the Canadian geographic mask from disk. (amv, phs, 1/28/09)

INTERFACE:

```
SUBROUTINE READ_CANADA_MASK_05x0666
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_TAU0, READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR


USE CMN_SIZE_MOD       ! Size parameters
```

REVISION HISTORY:

```
11 Nov 2009 - A. van Donkelaar - Initial Version
```

1.30.9 init_cac_anthro

Subroutine INIT_CAC_ANTHRO allocates and zeroes all module arrays. (phs, 1/28/09)

INTERFACE:

```
SUBROUTINE INIT_CAC_ANTHRO( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE ERROR_MOD,          ONLY : ALLOC_ERR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT) :: RC          ! Success or failure?!
```

REVISION HISTORY:

```
    28 Jan 2009 - P. Le Sager - Initial Version
    01 Mar 2012 - R. Yantosca - Delete the A_CM2 array, we will now just
                                use the function directly
    25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.30.10 cleanup_cac_anthro

Subroutine CLEANUP_CAC_ANTHRO deallocates all module arrays. (phs, 1/28/09)

INTERFACE:

```
      SUBROUTINE CLEANUP_CAC_ANTHRO
```

REVISION HISTORY:

```
    28 Jan 2009 - P. Le Sager - Initial Version
```

1.31 Fortran: Module Interface canopy_nox_mod

Module CANOPY_NOX_MOD contains routines for computing the bulk surface resistance of the canopy to NOx. This quantity is needed by GEOS-Chem soil emissions routine "soilcrf.f".

INTERFACE:

```
      MODULE CANOPY_NOX_MOD
   !USES
      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: GET_CANOPY_NOX
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: DIFFG
```

REMARKS:

```
This computation was originally done in legacy routine DEPVEL (located in
"drydep\_mod.f"), and the bulk surface resistance was stored in common block
array CANOPYNOX (in "commsoil.h").  However, the legacy code caused an ugly
dependency.  Drydep routine DEPVEL had to be called BEFORE the soil NOx
emissions routines.  Routine GET\_CANOPY\_NOX in this module performs the
same computation of NOx from tree canopies independent of "drydep\_mod.f",
thus allowing for a totally clean separation between dry deposition routines
and emisisons routines.

References:
============================================================================
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(2 ) Brutsaert, W., "Evaporation into the Atmosphere", Reidel, 1982.
(3 ) Businger, J.A., et al., "Flux-profile relationships in the atmospheric
      surface layer", J. Atmos. Sci., 28, 181-189, 1971.
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(5 ) Guenther, A., and 15 others, A global model of natural volatile
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(9 ) Levine, I.N., "Physical Chemistry, 3rd ed.", McGraw-Hill,
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(11) Walcek, C.J., R.A. Brost, J.S. Chang, and M.L. Wesely, "SO2, sulfate,
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      meteorological data", Atmos. Environ., 20, 949-964, 1986.
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(13) Wesely, M.L, "Improved parameterizations for surface resistance to
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      Environmental Protection Agency Report EPA/600/3-88/025,
      Research Triangle Park (NC), 1988.
(14) Wesely, M. L., Parameterization of surface resistance to gaseous dry
      deposition in regional-scale numerical models.  Atmos. Environ., 23
```

1293-1304, 1989.
(15) Price, H., L. Jaegl, A. Rice, P. Quay, P.C. Novelli, R. Gammon,
Global Budget of Molecular Hydrogen and its Deuterium Content:
Constraints from Ground Station, Cruise, and Aircraft Observations,
submitted to J. Geophys. Res., 2007.

REVISION HISTORY:

22 Jun 2009 - R. Yantosca - Split off from "drydep_mod.f"

1.31.1 get_canopy_nox

Subroutine GET_CANOPY_NOX computes the bulk surface resistance of the canopy to NOx. This computation was originally done within legacy routine DEPVEL (in "drydep_mod.f"). Moving this computation to GET_CANOPY_NOX now allows for a totally clean separation between dry deposition routines and emissions routines in GEOS-Chem.

INTERFACE:

```
SUBROUTINE GET_CANOPY_NOX( State_Met )
```

USES:

```
USE DRYDEP_MOD,         ONLY : DRYCOEFF !todo
USE GIGC_State_Met_Mod, ONLY : MetState
USE MODIS_LAI_MOD

USE COMMSOIL_MOD
USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

REMARKS:

```
For backwards compatibility, the bulk surface resistance is stored
in common block array CANOPYNOX in "commsoil.h".  Leave it like this
for the time being...we'll clean it up when we fix all of the soil
NOx routines.
```

REVISION HISTORY:

```
22 Jun 2009 - R. Yantosca     - Split off from "drydep_mod.f"
14 Jun 2012 - J.D. Maasakkers - Rewritten as a function of the
                                MODIS/Koppen biometype
09 Nov 2012 - M. Payer        - Replaced all met field arrays with State_Met
                                derived type object
13 Dec 2012 - R. Yantosca     - Removed ref to obsolete CMN_DEP_mod.F
```

1.31.2 diffg

Function DIFFG calculates the molecular diffusivity [m2/s] in air for a gas X of molecular weight XM [kg] at temperature TK [K] and pressure PRESS [Pa].

INTERFACE:

```
FUNCTION DIFFG( TK, PRESS, XM ) RESULT( DIFF_G )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: TK      ! Temperature [K]
REAL*8, INTENT(IN) :: PRESS   ! Pressure [hPa]
REAL*8, INTENT(IN) :: XM      ! Molecular weight of gas [kg]
```

RETURN VALUE:

```
REAL*8             :: DIFF_G  ! Molecular diffusivity [m2/s]
```

REMARKS:

```
We specify the molecular weight of air (XMAIR) and the hard-sphere molecular
radii of air (RADAIR) and of the diffusing gas (RADX).  The molecular
radius of air is given in a Table on p. 479 of Levine [1988].  The Table
also gives radii for some other molecules.  Rather than requesting the user
to supply a molecular radius we specify here a generic value of 2.E-10 m for
all molecules, which is good enough in terms of calculating the diffusivity
as long as molecule is not too big.
```

REVISION HISTORY:

```
22 Jun 2009 - R. Yantosca - Copied from "drydep_mod.f"
```

1.32 Fortran: Module Interface carbon_mod

Module CARBON_MOD contains arrays and routines for performing a carbonaceous aerosol simulation. Original code taken from Mian Chin's GOCART model and modified accordingly. (rjp, bmy, 4/2/04, 6/30/10)

INTERFACE:

```
MODULE CARBON_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CHEMCARBON
      PUBLIC :: CLEANUP_CARBON
      PUBLIC :: EMISSCARBON
      PUBLIC :: INIT_CARBON
```

PUBLIC DATA MEMBERS:

```
      ! SOAupdate: for branching ratio diagnostic (hotp 5/24/10)
      PUBLIC :: BETANOSAVE
```

REMARKS:

```
    4 Aerosol species : Organic and Black carbon
                      : hydrophilic (soluble) and hydrophobic of each
                                                                             .
    For secondary organic aerosol (SOA) simulation orginal code developed
    by Chung and Seinfeld [2002] and Hong Liao from John Seinfeld's group
    at Caltech was taken and further modified accordingly (rjp, bmy, 7/15/04)
                                                                             .
    SOAupdate: Traditional SOA simulation updated by hotp 7/2010
      New code treats semivolatile or nonvolatile POA, aerosol from IVOCs,
        and has updated biogenic SOA
      For more detailes on the updated SOA/POA simulation, see comments
        in SOA_CHEMISTRY, Pye and Seinfeld ACP 2010, Pye et al. in prep
        for ACP 2010
      Note that modifications were made throughout the code for SOAupdate
                                                                             .
    References:
    ============================================================================
    (1 ) Bond, T.C., E. Bhardwaj, R. Dong, R. Jogani, S. Jung, C. Roden, D.G.
          Streets, and N.M. Trautmann, "Historical emissions of black and
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          Seinfeld, "Secondary orgainc aerosol formation from photooxidation of
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          Vol 9, 3049-3060, doi:10.5194/acp-9-3049-2009, 2009.
    (3 ) Chung, S.H., and J.H. Seinfeld. "Global distribution and climate
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```

Geophys. Res., 104(D3), 3555-3567, 1999.

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(10) Ng, N.L., P.S. Chhabra, A.W.H. Chan, J.D. Surratt, J.H. Kroll, A.J. Kwan, D.C. McCabe, P.O. Wennberg, A. Sorooshian, S.M. Murphy, N.F. Dalleska, R.C. Flagan, and J.H. Seinfeld, "Effect of NOx level on secondary orgainc aerosol (SOA) formation from the photooxidation of terpenes", Atmos. Chem. Phys., Vol 7, 5159-5174, doi:10.5194/acp-7-5195-2007, 2007a.

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110, 11053-11063, doi:10.1021/Jp06286f, 2006.

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Base Year is 2000. More at http://www.hiwater.org

REVISION HISTORY:

(1) Added code from the Caltech group for SOA chemistry (rjp, bmy, 7/15/04)
(2) Now references "directory_mod.f", "logical_mod.f", "tracer_mod.f". (bmy, 7/20/04)
(3) Now read data from carbon_200411/ subdir of DATA_DIR. Also added some extra debug output. Now read T. Bond yearly emissions as default, but overwrite N. America with the monthly Cooke/RJP emissions. Added module variables I1_NA, I2_NA, J1_NA, J2_NA. (rjp, bmy, 12/1/04)
(4) Now can read seasonal or interannual BCPO, OCPO biomass emissions. Also parallelize loop in OHNO3TIME. (rjp, bmy, 1/18/05)
(5) Now references "pbl_mix_mod.f". Bug fix: now make sure only to save up to LD07 levels for the ND07 diagnostic in SOA_LUMP. (bmy, 3/4/05)
(6) Now can read data for both GEOS and GCAP grids (bmy, 8/16/05)
(7) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8) Now references "megan_mod.f". Also now references XNUMOL and XNUMOLAIR from "tracer_mod.f" (tmf, bmy, 10/25/05)
(9) Bug fix for GCAP in BIOGENIC_OC (bmy, 4/11/06)
(10) Updated for SOA production from ISOP (dkh, bmy, 5/22/06)
(11) Updated for IPCC future emission scale factors. Also added function GET_DOH to return ISOP that has reacted w/ OH. (swu, dkh, bmy, 6/1/06)
(12) Now add SOG condensation onto SO4, NH4, NIT (rjp, bmy, 8/3/06)
(13) Minor fix for 20 carbon tracers. (phs, 9/14/06)
(14) Now remove reading of biomass emissions from "carbon_mod.f", since they are better done in gc_biomass_mod.f. This will allow us to standardize treatment of GFED2 or default BB emissions. Also applied a typo fix in SOA_LUMP. (tmf, bmy, 10/16/06)
(15) Prevent seg fault error in BIOMASS_CARB_GEOS (bmy, 11/3/06)
(16) Corrected typos in SOA_LUMP. Now also save GPROD and APROD to disk for each new diagnostic interval. (dkh, tmv, havala, bmy, 2/6/07)
(17) Modifications for 0.5 x 0.666 nested grids (yxw, dan, bmy, 11/6/08)
(18) Now account for various GFED2 products (yc, phs, 12/23/08)
(19) Now add future scaling to BIOMASS_CARB_GEOS (hotp, swu, 2/19/09)
(20) Added SOA production from dicarbonyls (tmf, 3/2/09)
(21) Bugfix: cleanup ORVC_TERP and ORVC_SESQ (tmf, 3/2/09)
(22) Replace USE_MONTHLY_BIOB with USE_BOND_BIOBURN, since this hardwired flag is a switc b/w annual Bond biomass burning emissions, and default GC source, which can be monthly/8 days/3hr.
Implement changes for reading new Bond files (eml, phs, 5/18/09)
(23) Add option for non-local PBL scheme (lin, 06/09/08)
(24) Now added NESTED_EU grid. Updated formulation of SOG condensation onto OC aerosol, according to recommendations of Aerosol Working Group. (amv, clh, bmy, 12/21/09)
(25) Bug fix for EMIS_SAVE in EMITHIGH (bmy, 1/11/10)

```
(26) Modifications for TOMAS (win, bmy, 1/25/10)
(27) Bug fix: call SOA_PARA_INIT (ensberg, bmy, 6/30/10)
(28) Modified to include GFED3 (psk, 1/5/11)
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
30 Jul 2012 - R. Yantosca - Modifications for grid-independence
28 Nov 2012 - R. Yantosca - Replace SUNCOS array with State_Met%SUNCOS and
                            SUNCOS_MID array with State_Met%SUNCOSmid
04 Mar 2013 - R. Yantosca - Now call INIT_CARBON from the init stage
                            which facilitates connection to GEOS-5 GCM
05 Mar 2013 - R. Yantosca - Remove reference to LNLPBL from logical_mod.F
                            and replace with Input_Opt%LNLPBL
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.32.1 chemcarbon

Subroutine CHEMCARBON is the interface between the GEOS-Chem main program and the carbon aerosol chemistry routines that calculates dry deposition, chemical conversion between hydrophilic and hydrophobic, and SOA production.

INTERFACE:

```
      SUBROUTINE CHEMCARBON( am_I_Root, Input_Opt,
     &                       State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_OH_MOD,      ONLY : GET_GLOBAL_OH
      USE GLOBAL_NO3_MOD,     ONLY : GET_GLOBAL_NO3
      USE GLOBAL_O3_MOD,      ONLY : GET_GLOBAL_O3
      USE TIME_MOD,           ONLY : GET_MONTH
      USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH
      USE TRACERID_MOD,       ONLY : IDTBCPI,  IDTBCPO
      USE TRACERID_MOD,       ONLY : IDTOCPI,  IDTOCPO
      USE TRACERID_MOD,       ONLY : IDTSOAG,  IDTSOAM
      ! Add lumped arom/IVOC (hotp 5/14/10)
      USE TRACERID_MOD,       ONLY : IDTASOAN
      USE TRACERID_MOD,       ONLY : IDTASOA1, IDTASOG1
      USE TRACERID_MOD,       ONLY : IDTASOA2, IDTASOG2
```

```
      USE TRACERID_MOD,       ONLY : IDTASOA3, IDTASOG3
      ! 1 and 2 POA (hotp 10/11/09)
      USE TRACERID_MOD,       ONLY : IDTPOA1,  IDTOPOA1
      USE TRACERID_MOD,       ONLY : IDTPOA2,  IDTOPOA2
      USE TRACERID_MOD,       ONLY : IDTPOG1,  IDTOPOG1
      USE TRACERID_MOD,       ONLY : IDTPOG2,  IDTOPOG2
      ! need isoprene semivols for offline sim (hotp 5/20/10)
      USE TRACERID_MOD,       ONLY : IDTISOA1, IDTISOG1
      USE TRACERID_MOD,       ONLY : IDTISOA2, IDTISOG2
      USE TRACERID_MOD,       ONLY : IDTISOA3, IDTISOG3
#if   defined( TOMAS )
      USE TRACERID_MOD,       ONLY : IDTECIL1, IDTECOB1          !(win, 1/25/10)
      USE TRACERID_MOD,       ONLY : IDTOCIL1, IDTOCOB1, IDTNK1  !(win, 1/25/10)
      USE TOMAS_MOD,          ONLY : IBINS                       !(win, 1/25/10)
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

REVISION HISTORY:

```
    01 Apr 1994 - R. Park - Initial version
    (1 ) Added code from the Caltech group for SOA chemistry.  Also now
         reference "global_oh_mod.f", "global_o3_mod.f", "global_no3_mod.f".
         (rjp, bmy, 7/8/04)
    (2 ) Now reference LSOA and LEMIS from CMN_SETUP.  Now only call OHNO3TIME
         if it hasn't been done before w/in EMISSCARBON. (rjp, bmy, 7/15/04)
    (3 ) Now reference LSOA, LEMIS, LPRT from "logical_mod.f".  Now reference
         STT and ITS_AN_AEROSOL_SIM from "tracer_mod.f" (bmy, 7/20/04)
    (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (5 ) Now updated for SOA production from ISOP. (dkh, bmy, 6/1/06)
    (6 ) Bug fix for aerosol sim w/ 20 tracers (phs, 9/14/06)
    (7 ) Add subroutine call AGING_CARB for converting H-phobic 30-bin EC or OC
         to H-philic EC or OC. (win, 1/25/10)
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
```

```
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
15 Nov 2012 - R. Yantosca - Added ProTeX headers
04 Mar 2013 - R. Yantosca - Remove call to INIT_CARBON
04 Mar 2013 - R. Yantosca - Now pass Input_Opt to SOA_CHEMISTRY
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
23 Oct 2013 - R. Yantosca - Now pass objects to GET_GLOBAL_OH routine
```

1.32.2 chem_bcpo

Subroutine CHEM_BCPO converts hydrophobic BC to hydrophilic BC and calculates the dry deposition of hydrophobic BC.

INTERFACE:

```
SUBROUTINE CHEM_BCPO( am_I_Root, Input_Opt, TC, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD44, AD07_BC
USE DRYDEP_MOD,         ONLY : DEPSAV
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE TRACERID_MOD,       ONLY : IDTBCPO
USE TIME_MOD,           ONLY : GET_TS_CHEM
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root             ! Root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt             ! Input Options
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! H-phobic BC [kg]
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC                    ! Success?
```

REMARKS:

REVISION HISTORY:

```
01 Apr 2004 - R. Park - Initial version
(1 ) Remove reference to "CMN", it's obsolete (bmy, 7/20/04)
(2 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP
      from "pbl_mix_mod.f" (bmy, 2/17/05)
(3 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(4 ) Add option for non-local PBL scheme (lin, 06/09/08)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
26 Nov 2012 - R. Yantosca - Added ProTeX headers
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%XNUMOL(1:N_TRACERS)
```

1.32.3 chem_bcpi

Subroutine CHEM_BCPI calculates dry deposition of hydrophilic BC.

INTERFACE:

```
SUBROUTINE CHEM_BCPI( am_I_Root, Input_Opt, TC, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD44
USE DRYDEP_MOD,         ONLY : DEPSAV
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE TRACERID_MOD,       ONLY : IDTBCPI
USE TIME_MOD,           ONLY : GET_TS_CHEM
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root             ! Root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt             ! Input Options
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! H-philic BC [kg]
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC                    ! Success?
```

REMARKS:

REVISION HISTORY:

```
01 Apr 2004 - R. Park - Initial version
(1 ) Remove reference to "CMN", it's obsolete (bmy, 7/20/04)
(2 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
      "pbl_mix_mod.f" (bmy, 2/17/05)
(3 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
26 Nov 2012 - R. Yantosca - Added ProTeX Headers
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%XNUMOL(1:N_TRACERS)
```

1.32.4 chem_ocpo

Subroutine CHEM_OCPO converts hydrophobic OC to hydrophilic OC and calculates the dry deposition of hydrophobic OC.

INTERFACE:

```
SUBROUTINE CHEM_OCPO( am_I_Root, Input_Opt, TC, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD44
USE DIAG_MOD,           ONLY : AD07_OC
USE DRYDEP_MOD,         ONLY : DEPSAV
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE TRACERID_MOD,       ONLY : IDTOCPO
USE TIME_MOD,           ONLY : GET_TS_CHEM
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root             ! Root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt             ! Input Options
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! H-phobic OC [kg]
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC                    ! Success?
```

REMARKS:

REVISION HISTORY:

```
01 Apr 2004 - R. Park - Initial version
(1 ) Remove reference to "CMN", it's obsolete (bmy, 7/20/04)
(2 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
     "pbl_mix_mod.f" (bmy, 2/17/05)
(3 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
26 Nov 2012 - R. Yantosca - Added ProTeX headers
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%XNUMOL(1:N_TRACERS)
```

1.32.5 chem_ocpi

Subroutine CHEM_BCPI calculates dry deposition of hydrophilic OC.

INTERFACE:

```
SUBROUTINE CHEM_OCPI( am_I_Root, Input_Opt, TC, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD44
USE DRYDEP_MOD,         ONLY : DEPSAV
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE TRACERID_MOD,       ONLY : IDTOCPI
USE TIME_MOD,           ONLY : GET_TS_CHEM
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root             ! Root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt             ! Input Options
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! H-philic OC [kg]
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC                    ! Success?
```

REMARKS:

REVISION HISTORY:

```
01 Apr 2004 - R. Park - Initial version
(1 ) Remove reference to "CMN", it's obsolete (bmy, 7/20/04)
(2 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
      "pbl_mix_mod.f" (bmy, 2/17/05)
(3 ) Bug fix: add BL_FRAC to the PRIVATE list (mak, bmy, 10/3/05)
(4 ) Now refrerences XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
26 Nov 2012 - R. Yantosca - Added ProTeX headers
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%XNUMOL(1:N_TRACERS)
```

1.32.6 aging_carb

Subroutine AGING_CARB converts the size-resolved hydrophobic EC or OC to hydrophilic EC or OC with an assumed e-folding time. (win, 9/11/07)

INTERFACE:

```
SUBROUTINE AGING_CARB( MIL, MOB )
```

USES:

```
USE CMN_SIZE_MOD
USE TIME_MOD,     ONLY : GET_TS_CHEM    ! [=] minute
USE TOMAS_MOD,    ONLY : IBINS
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,  INTENT(INOUT) :: MIL(IIPAR,JJPAR,LLPAR, IBINS)
REAL*8,  INTENT(INOUT) :: MOB(IIPAR,JJPAR,LLPAR, IBINS)
```

REMARKS:

```
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.7 soa_liggio_diff

Subroutine SOAG_LIGGIO_DIFF produces SOA on aqueous aerosol surfaces from GLYX following the uptake model used for N2O5, and the gamma from Liggio et al. [2005]. (tmf, 5/30/06)

INTERFACE:

```
 SUBROUTINE SOAG_LIGGIO_DIFF( am_I_Root, Input_Opt,
&                             State_Met, State_Chm, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_O3_MOD
USE CMN_SIZE_MOD
USE COMODE_MOD,         ONLY : WTAREA, WERADIUS
USE COMODE_MOD,         ONLY : AIRDENS, JLOP
USE COMODE_LOOP_MOD
USE DIAG_MOD,           ONLY : AD07_SOAGM
USE ERROR_MOD,          ONLY : DEBUG_MSG
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TIME_MOD,           ONLY : GET_TS_CHEM, GET_MONTH
USE TRACERID_MOD,       ONLY : IDTGLYX, IDTSOAG
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
(1 ) SOAG (SOA product of GLYX is produced at existing hydrophilic aerosol
     surface.
```

REVISION HISTORY:

```
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.8 soam_liggio_diff

Subroutine SOAM_LIGGIO_DIFF produces SOA on aqueous aerosol surfaces from GLYX following the uptake model used for N2O5, and the gamma from Liggio et al. [2005]. (tmf, 5/30/06)

INTERFACE:

```
      SUBROUTINE SOAM_LIGGIO_DIFF( am_I_Root, Input_Opt,
     &                             State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_O3_MOD
      USE CMN_SIZE_MOD
      USE COMODE_MOD,         ONLY : WTAREA, WERADIUS
      USE COMODE_MOD,         ONLY : AIRDENS, JLOP
      USE COMODE_LOOP_MOD
      USE DIAG_MOD,           ONLY : AD07_SOAGM
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TIME_MOD,           ONLY : GET_TS_CHEM, GET_MONTH
      USE TRACERID_MOD,       ONLY : IDTMGLY, IDTSOAM
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    (1 ) SOAM (SOA product of MGLY) is produced at existing hydrophilic aerosol
         surface.
```

REVISION HISTORY:

```
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
     5 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt arguments
    25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
    20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.9 soa_chemistry

Subroutine SOA_CHEMISTRY performs SOA formation. This code is from the Caltech group (Hong Liao, Serena Chung, et al) and was modified for GEOS-CHEM. (rjp, bmy, 7/8/04, 12/21/09)

INTERFACE:

```
      SUBROUTINE SOA_CHEMISTRY( am_I_Root, Input_Opt,
     &                          State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_O3_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD07_HC
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TIME_MOD,           ONLY : GET_TS_CHEM,      GET_MONTH
      USE TIME_MOD,           ONLY : ITS_TIME_FOR_BPCH
      ! new mtp formulation (hotp 5/20/10)
      USE TRACERID_MOD,       ONLY : IDTOCPI,  IDTOCPO
      USE TRACERID_MOD,       ONLY : IDTMTPA,  IDTLIMO, IDTMTPO
      ! mono+sesq products
      USE TRACERID_MOD,       ONLY : IDTTSOA1, IDTTSOG1
      USE TRACERID_MOD,       ONLY : IDTTSOA2, IDTTSOG2
      USE TRACERID_MOD,       ONLY : IDTTSOA3, IDTTSOG3
      USE TRACERID_MOD,       ONLY : IDTTSOA0, IDTTSOG0
      ! isoprene products
      USE TRACERID_MOD,       ONLY : IDTISOA1, IDTISOG1
      USE TRACERID_MOD,       ONLY : IDTISOA2, IDTISOG2
      USE TRACERID_MOD,       ONLY : IDTISOA3, IDTISOG3
      ! semivolpoa: add POA (hotp 2/26/09)
      USE TRACERID_MOD,       ONLY : IDTPOA1,IDTPOA2
      USE TRACERID_MOD,       ONLY : IDTPOG1, IDTPOG2
      ! semivolpoa4opoa: add OPOA, OPOG (hotp 3/18/09)
      USE TRACERID_MOD,       ONLY : IDTOPOA1, IDTOPOG1
      USE TRACERID_MOD,       ONLY : IDTOPOA2, IDTOPOG2
      ! lumped arom/IVOC (hotp 5/14/10)
      USE TRACERID_MOD,       ONLY : IDTASOAN
      USE TRACERID_MOD,       ONLY : IDTASOA1, IDTASOG1
      USE TRACERID_MOD,       ONLY : IDTASOA2, IDTASOG2
      USE TRACERID_MOD,       ONLY : IDTASOA3, IDTASOG3
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    Procedure:
    ============================================================================
    (1 ) Read in NO3, O3, OH in CHEM_SOA
    (2 ) Scales these fields using OHNO3TIME in sulfate_mod.f (see GET_OH)
    (3 ) Calculate reaction rates (Serena's OCHEMPARAETER)
    (4 ) CALCULATE DELHC
    (5 ) get TOM gas products
    (6 ) equilibrium calculation
                                                                             .
    As of 5/20/10: Havala's New formulation
                                                                             .
    ========================================
    FOR SEMIVOLATILE POA and IVOC simulations:
    ========================================
    GEOS-Chem treats formation of aerosol from 11 parent hydrocarbons
    and oxidation by OH, O3, and NO3:
                                                                             .
    The parent hydrocarbons are lumped into 5 semivolatile systems:
    TSOA/G: the lumped semivolatile oxidation products of
            monoterpene and sesquiterpene oxidation
    ISOA/G: the lumped semivolatile oxidation products of isoprene ox
    ASOA/G: the lumped semivolatile (and nonvolatile) products of
            benzene, toluene, xylene, and naphthalene (IVOC surrogate)
            oxidation
    POA/G : the lumped primary semivolatile emissions
    OPOA/G: the lumped products of primary semivolatile oxidation
                                                                             .
    Parent HC      Oxidized by       Products
    =============  ================  ==================================
    MTPA           OH, O3, NO3       TSOA/G0-3
    LIMO           OH, O3, NO3       TSOA/G1-3
    MTPO           OH, O3, NO3       TSOA/G0-3
    SESQ           OH, O3, NO3       TSOA/G1-3
    ISOP           OH, NO3           ISOA/G1-3
    BENZ           OH, (+NO,HO2)     ASOAN, ASOA/G1-3
```

```
TOLU            OH, (+NO,HO2)     ASOAN, ASOA/G1-3
XYLE            OH, (+NO,HO2)     ASOAN, ASOA/G1-3
SVOC/POA        OH                POA/G1-2
O-SVOC/OPOA     OH                OPOA/G1-2
NAP             OH, (+NO,HO2)     ASOAN, ASOA/G1-3

Tracers that must be defined in input.geos (in addition to standard
full chem tracers) (34 additional):
TSOA1       TSOG1       ISOA1       ISOG1       ASOA1       ASOG1
TSOA2       TSOG2       ISOA2       ISOG2       ASOA2       ASOG2
TSOA3       TSOG3       ISOA3       ISOG3       ASOA3       ASOG3
ASOAN       TSOA0       TSOG0
BENZ        TOLU        XYLE        MTPA        LIMO        MTPO
NAP
POA1        POG1        POA2        POG2
OPOA1       OPOG1       OPOA2       OPOG2

The following should NOT be defined for semivol POA: OCPI, OCPO

============================================================
FOR NON-VOLATILE TRADITIONAL POA (and no IVOCs) simulations:
============================================================
GEOS-Chem treats formation of aerosol from 8 parent hydrocarbons
and oxidation by OH, O3, and NO3:

Two non-volatile,traditional primary OC species exist:
OCPO: hydrophobic POA
OCPI: hydrophillic POA

The parent hydrocarbons are lumped into 3 semivolatile systems:
TSOA/G: the lumped semivolatile oxidation products of
        monoterpene and sesquiterpene oxidation
ISOA/G: the lumped semivolatile oxidation products of isoprene ox
ASOA/G: the lumped semivolatile (and nonvolatile) products of
        benzene, toluene, and xylene oxidation

Parent HC       Oxidized by       Products
=============  ================  ==================================
MTPA            OH, O3, NO3       TSOA/G0-3
LIMO            OH, O3, NO3       TSOA/G1-3
MTPO            OH, O3, NO3       TSOA/G0-3
SESQ            OH, O3, NO3       TSOA/G1-3
ISOP            OH, NO3           ISOA/G1-3
BENZ            OH, (+NO,HO2)     ASOAN, ASOA/G1-3
TOLU            OH, (+NO,HO2)     ASOAN, ASOA/G1-3
XYLE            OH, (+NO,HO2)     ASOAN, ASOA/G1-3

Tracers that must be defined in input.geos (in addition to standard
```

```
full chem tracers) (25 additional):
TSOA1      TSOG1      ISOA1      ISOG1      ASOA1      ASOG1
TSOA2      TSOG2      ISOA2      ISOG2      ASOA2      ASOG2
TSOA3      TSOG3      ISOA3      ISOG3      ASOA3      ASOG3
ASOAN      TSOA0      TSOG0
BENZ       TOLU       XYLE       MTPA       LIMO       MTPO
                                                                    .
The following should NOT be defined for traditional POA:
   NAP, POA/G OPOA/G
                                                                    .
References (see above for full citations):
=========================================================================
Monoterpenes and sesquiterpenes:
  Experimental Data:
    Griffin et al. 1999 JGR      (sesquiterps low NOx)
    Shilling et al. 2008 ACP     (a-pinene ozonolysis for MTPO/MTPA)
    Zhang et al. 2006 JPhysChemA (limonene ozonolysis)
    Ng et al. 2007 ACP           (data for NOx effect on sesq aerosol)
  Modeling:
    Chung and Seinfeld 2002 JGR  (original formulation in GEOS-Chem)
    Liao et al. 2007 JGR         (comparison to measurements)
    Pye et al. in prep 2010      (new lumping scheme, NOx effect)
Isoprene
    Kroll et al. 2006 ES&T       (low NOx experiments)
    Ng et al. 2008 ACP           (isoprene + NO3 experiments)
    Henze et al. 2006 GRL        (low NOx isoprene modeling in GEOS-Chem)
    Pye et al. in prep 2010      (new lumping scheme and isop+no3 modeling)
Aromatics: benz, tolu, xyle
    Ng et al. 2007 ACP           (experiments)
    Henze et al. 2008 ACP        (global modeling)
POA/OPOA
    Shrivastava et al. 2006 ES&T (POA experiments)
    Grieshop et al. 2009 ACP     (POA/SVOC oxidation experiments)
    Pye and Seinfeld 2010 ACP    (global modeling)
IVOC/Naphthalene
    Chan et al. 2009 ACP         (experiments)
    Pye and Seinfeld 2010 ACP    (global modeling)
```

REVISION HISTORY:

```
(1 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
(2 ) Now modified for SOG4, SOA4 -- products of oxidation by isoprene.
      (dkh, bmy, 6/1/06)
(3 ) Now consider SOG condensation onto SO4, NH4, NIT aerosols (if SO4,
      NH4, NIT are defined as tracers). (rjp, bmy, 8/3/06)
(4 ) Updated formulation of SOG condensation onto OC aerosol, according
      to recommendations of Aerosol Working Group (clh, bmy, 12/21/09)
(5 ) Now only print out debug info when LPRT=T (bmy, 4/21/10)
```

```
(6 ) Bug fix: call SOA_PARA_INIT (ensberg, bmy, 6/30/10)
05 Oct 2011 - R. Yantosca - SUNCOS is not needed, so remove
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
05 Mar 2013 - R. Yantosca - Now pass Input_Opt to SOA_DEPO
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LPRT
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.10 soa_equil

Function SOA_EQUIL solves SOAeqn=0 to determine Mnew (= mass) See Eqn (27) on page 70 of notes. Originally written by Serena Chung at Caltech, and modified for inclusion into GEOS-CHEM. (rjp, bmy, 7/8/04)

INTERFACE:

```
      FUNCTION SOA_EQUIL( MASS, MPOC, AEROSOL, GAS, KOM )
     &         RESULT( SOA_MASS )
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8, INTENT(IN) :: MASS                ! Pre-existing aer mass [ug/m3]
      REAL*8, INTENT(IN) :: MPOC                ! POA Mass [ug/m3]
      REAL*8, INTENT(IN) :: AEROSOL(MPROD,MSV)  ! Aerosol concentration [ug/m3]
      REAL*8, INTENT(IN) :: GAS(MPROD,MSV)      ! Gas-phase conc [ug/m3]
      REAL*8, INTENT(IN) :: KOM(MPROD,MSV)      ! Equilibrium gas-aerosol
                                                !  partition coeff. [m3/ug]
```

RETURN VALUE:

```
      REAL*8             :: SOA_MASS
```

REMARKS:

```
    This version does NOT assume that the gas and aerosol phases are in
    equilibrium before chemistry; therefore, gas phase concentrations are
    needed explicitly.  The gas and aerosol phases are assumed to be in
    equilibrium after chemistry.

                                                                             .
    Note: Unlike FUNCTION SOA, this function assumes no reactions.  It only
    considers the partitioning of existing products of VOC oxidation.

                                                                             .
    HC_JHC + OXID_IOXID - >
      alpha(1,IOXID,JHC) [SOAprod_gas(1,IOXID,JHC)+SOAprod(1,IOXID,JHC)]+
```

```
  alpha(2,IOXID,JHC) [SOAprod_gas(2,IOXID,JHC)+SOAprod(2,IOXID,JHC)]

                                                                              .
SOAprod_gas(IPR,IOXID,JHC) <--> SOAprod(IPR,IOXID,JHC)
                                          (aerosol phase)
                                                                              .
w/ equilibrium partitioning:
                                                                              .
                                  SOAprod(IPR,IOXID,JHC)
  SOAprod_gas(IPR,IOXID,JHC) = ------------------------
                                    Kom(IPR,IOXID,JHC)
NOTES:
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.11 zeroin

Function ZEROIN computes a zero of the function f(x) in the interval ax,bx.

INTERFACE:

```
 ------------------------------------------------------------------------------

    FUNCTION ZEROIN(AX,BX,TOL,MPOC,AEROSOL,GAS,KOM) RESULT( MNEW )
```

INPUT PARAMETERS:

```
    REAL*8, INTENT(IN) :: ax
    REAL*8, INTENT(IN) :: bx
    REAL*8, INTENT(IN) :: tol
    REAL*8, INTENT(IN) :: Mpoc
    REAL*8, INTENT(IN) :: Aerosol(MPROD,MSV)
    REAL*8, INTENT(IN) :: Gas(MPROD,MSV)
    REAL*8, INTENT(IN) :: Kom(MPROD,MSV)
```

RETURN VALUE:

```
    REAL*8             :: MNEW
```

REMARKS:

```
  NOTE: This function may be problematic -- it uses GOTO's, which are not
  good for parallelization. (bmy, 7/8/04)
                                                                              .
  shc I got this code from http://www.netlib.org
                                                                              .
       a zero of the function  f(x)  is computed in the interval ax,bx .
                                                                              .
   input..
```

```
.
ax     left endpoint of initial interval
bx     right endpoint of initial interval
f      function subprogram which evaluates f(x) for any x in
       the interval  ax,bx
tol    desired length of the interval of uncertainty of the
       final result ( .ge. 0.0d0)
.
output..
.
zeroin abcissa approximating a zero of  f  in the interval ax,bx
.
    it is assumed  that   f(ax)   and   f(bx)   have  opposite  signs
without  a  check.  zeroin  returns a zero  x  in the given interval
ax,bx  to within a tolerance  4*macheps*abs(x) + tol, where macheps
is the relative machine precision.
    this function subprogram is a slightly  modified  translation  of
the algol 60 procedure  zero  given in  richard brent, algorithms for
minimization without derivatives, prentice - hall, inc. (1973).
```

REVISION HISTORY:

```
(1 ) Change dabs to ABS and dsign to SIGN, in order to avoid conflicts
      with intrinsic function names on the PGI compiler. (bmy, 12/2/04)
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.12 rtbis

Function RTBIS finds the root of the function SOA_EQUIL via the bisection method. Original algorithm from "Numerical Recipes" by Press et al, Cambridge UP, 1986. Modified for inclusion into GEOS-CHEM. (bmy, 7/8/04)

INTERFACE:

```
      FUNCTION RTBIS( X1,   X2,      XACC,
     &                MPOC, AEROSOL, GAS, KOM ) RESULT( ROOT )
```

USES:

```
      USE ERROR_MOD, ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
      REAL*8, INTENT(IN) :: X1                ! Endpoint #1
      REAL*8, INTENT(IN) :: X2                ! Endpoint #2
      REAL*8, INTENT(IN) :: XACC              ! Desired accuracy of solution
      REAL*8, INTENT(IN) :: MPOC              ! POA mass [ug/m3]
```

```
      REAL*8, INTENT(IN) :: AEROSOL(MPROD,MSV) ! Aerosol concentration [ug/m3]
      REAL*8, INTENT(IN) :: GAS(MPROD,MSV)     ! Gas-phase concentration [ug/m3]
      REAL*8, INTENT(IN) :: KOM(MPROD,MSV)     ! Equilibrium gas-aerosol
                                               !  partition coeff. [m3/ug]
```

RETURN VALUE:

```
      REAL*8             :: ROOT
```

REVISION HISTORY:

```
    13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                                semivolatile POA simulations (H. Pye)
    20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.13 soa_para

Subroutine SOA_PARA gves mass-based stoichiometric coefficients for semi-volatile products from the oxidation of hydrocarbons. It calculates secondary organic aerosol yield parameters. Temperature effects are included. Original code from the CALTECH group and modified for inclusion to GEOS-CHEM. (rjp, bmy, 7/8/04, 6/30/08)

INTERFACE:

```
      SUBROUTINE SOA_PARA( TEMP, KO3, KOH, KNO3,   KOM,
     &                     II,   JJ,  LL,  KRO2NO, KRO2HO2, State_Met )
```

USES:

```
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_TROP
```

INPUT PARAMETERS:

```
      ! Arguments
      INTEGER,         INTENT(IN)  :: II              ! Longitude index
      INTEGER,         INTENT(IN)  :: JJ              ! Latitude index
      INTEGER,         INTENT(IN)  :: LL              ! Altitude index
      REAL*8,          INTENT(IN)  :: TEMP            ! Temperature [k]
      TYPE(MetState), INTENT(IN)  :: State_Met       ! Meteorology State object
```

OUTPUT PARAMETERS:

```
      REAL*8,          INTENT(OUT) :: KO3(MHC)        ! Rxn rate for HC oxidation
                                                      !  by O3 [cm3/molec/s]
      REAL*8,          INTENT(OUT) :: KOH(MHC)        ! Rxn rate for HC oxidation
                                                      !  by OH [cm3/molec/s]
      REAL*8,          INTENT(OUT) :: KNO3(MHC)       ! Rxn rate for HC oxidation
                                                      !  by NO3 [cm3/molec/s]
      REAL*8,          INTENT(OUT) :: KOM(MPROD,MSV)  ! Equilibrium gas-aerosol
                                                      !  partition coeff [m3/ug]
```

```
      ! RO2+NO,HO2 rate constants (hotp 5/7/10)
      REAL*8,         INTENT(OUT) :: KRO2NO          ! RO2+NO  rate constant
      REAL*8,         INTENT(OUT) :: KRO2HO2         ! RO2+HO2 rate constant
```

REMARKS:

```
References:
============================================================================
PHOTO-OXIDATION RATE CONSTANTS OF ORGANICS come from:
(1 ) Atkinson, el al., Int. J. Chem.Kinet., 27: 941-955 (1995)
(2 ) Shu and Atkinson, JGR 100: 7275-7281 (1995)
(3 ) Atkinson, J. Phys. Chem. Ref. Data 26: 215-290 (1997)
(4 ) Some are reproduced in Table 1 of Griffin, et al., JGR 104: 3555-3567
(5 ) Chung and Seinfeld (2002)
                                                                             .
ACTIVATION ENERGIES come from:
(6 ) Atkinson, R. (1994) Gas-Phase Tropospheric Chemistry of Organic
      Compounds.  J. Phys. Chem. Ref. Data, Monograph No.2, 1-216.
(7 ) They are also reproduced in Tables B.9 and B.10 of Seinfeld and
      Pandis (1988).
                                                                             .
PARAMETERS FOR ISOPRENE:
(8 ) Kroll et al., GRL, 109, L18808 (2005)
(9 ) Kroll et al., Environ Sci Tech, in press (2006)
(10) Henze and Seinfeld, GRL, submitted (2006)
```

REVISION HISTORY:

```
(1 ) Now use temporary variables TMP1, TMP2, TMP3 to pre-store the values
      of exponential terms outside of DO-loops (bmy, 7/8/04)
(2 ) Add parameters for isoprene.  Now include grid cell location in
      subroutine arguments.  Define a reference temperature at 295.
      Now use ITS_IN_THE_TROP to determine if we are in a tropospheric
      grid box.  Now pass II, JJ, LL via the argument list.
      (dkh, bmy, 5/22/06)
(3 ) Corrected confusing documentation. (clh, bmy, 6/30/08)
(4 ) Add paramters for aromtics. Add high NOx low NOx index to every
      parameter, NNOX (dkh, 10/29/06)
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.14 soa_para_init

Subroutine SOA_PARA_INIT initializes the ALPHAS and KOMS, the latter at their reference temperature. It is faster to define these seperately as it only needs to be done once.

(dkh, 11/12/06)

INTERFACE:

```
SUBROUTINE SOA_PARA_INIT( Input_Opt )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

REMARKS:

```
NOTE: REFT for KOM_REF depends on hydrocarbon.
```

REVISION HISTORY:

```
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.15 chem_nvoc

Subroutine CHEM_NVOC computes the oxidation of Hydrocarbon by O3, OH, and NO3. This comes from the Caltech group (Hong Liao, Serena Chung, et al) and was incorporated into GEOS-CHEM. (rjp, bmy, 7/6/04,6/1/06)

INTERFACE:

```
SUBROUTINE CHEM_NVOC( I,         J,         L,
&                     KO3,       KOH,       KNO3,
&                     GMO,       KNO,       KHO2,
&                     Input_Opt, State_Met, State_Chm, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
! semivolpoa4: oxidation diagnostic for POG (hotp 3/28/09)
USE DIAG_MOD,           ONLY : AD07_HC
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TIME_MOD,           ONLY : GET_TS_CHEM, GET_MONTH
! new mtp (hotp 5/34/10)
USE TRACERID_MOD,       ONLY : IDTMTPA, IDTLIMO, IDTMTPO
USE TRACERID_MOD,       ONLY : IDTNAP,  IDTPOA1
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN)    :: I             ! Longitude index
      INTEGER,        INTENT(IN)    :: J             ! Latitude index
      INTEGER,        INTENT(IN)    :: L             ! Altitude index
      REAL*8,         INTENT(IN)    :: KO3(MHC)      ! Rxn rate for HC oxidation
                                                     !  by O3 [cm3/molec/s]
      REAL*8,         INTENT(IN)    :: KOH(MHC)      ! Rxn rate for HC oxidation
                                                     !  by OH [cm3/molec/s]
      REAL*8,         INTENT(IN)    :: KNO3(MHC)     ! Rxn rate for HC oxidation
                                                     !  by NO3 [cm3/molec/s]
      ! RO2+NO, RO2+HO2 rate constants (hotp 5/7/10)
      REAL*8,         INTENT(IN)    :: KNO           ! RO2+NO  rate constant
      REAL*8,         INTENT(IN)    :: KHO2          ! RO2+HO2 rate constant
      TYPE(OptInput), INTENT(IN)    :: Input_Opt     ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met     ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,         INTENT(INOUT) :: GM0(MPROD,MSV)! Gas mass for HCs and
                                                     !  oxidation products [kg]
      TYPE(ChmState), INTENT(INOUT) :: State_Chm     ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC            ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
(2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(3 ) Updated for SOA from isoprene.  Now calls GET_DOH. (dkh, bmy, 6/1/06)
(4 ) Updated for SOA from aromatics. (dkh, 10/29/06)
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.16 soa_partition

Subroutine SOA_PARTITION partitions the mass of gas and aerosol tracers according to five Hydrocarbon species and three oxidants. (rjp, bmy, 7/7/04, 5/22/06)

Revised purpose: SOA_PARTITION assigns the mass in the STT array to the GM0 and AM0 arrays (hotp 5/13/10)

INTERFACE:

```
      SUBROUTINE SOA_PARTITION( I, J, L, GM0, AM0, State_Chm )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_State_Chm_Mod, ONLY : ChmState
! new mtp (hotp 5/24/10)
USE TRACERID_MOD,       ONLY : IDTTSOG1, IDTTSOG2, IDTTSOG3
USE TRACERID_MOD,       ONLY : IDTTSOA1, IDTTSOA2, IDTTSOA3
USE TRACERID_MOD,       ONLY : IDTTSOA0, IDTTSOG0
USE TRACERID_MOD,       ONLY : IDTISOG1, IDTISOG2, IDTISOG3
USE TRACERID_MOD,       ONLY : IDTISOA1, IDTISOA2, IDTISOA3
! semivolpoa2: add POG, POA (hotp 3/2/09)
USE TRACERID_MOD,       ONLY : IDTPOA1, IDTPOG1
USE TRACERID_MOD,       ONLY : IDTPOA2, IDTPOG2
! semivolpoa4: add OPOA, OPOG (hotp 3/27/09)
USE TRACERID_MOD,       ONLY : IDTOPOA1, IDTOPOG1
USE TRACERID_MOD,       ONLY : IDTOPOA2, IDTOPOG2
! Lumped aromatic/IVOC tracers (hotp 5/13/10)
USE TRACERID_MOD,       ONLY : IDTASOAN, IDTASOA1
USE TRACERID_MOD,       ONLY : IDTASOA2, IDTASOA3
USE TRACERID_MOD,       ONLY : IDTASOG1, IDTASOG2, IDTASOG3
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: I              ! Longitude index
INTEGER,        INTENT(IN)    :: J              ! Latitude index
INTEGER,        INTENT(IN)    :: L              ! Altitude index
```

OUTPUT PARAMETERS:

```
REAL*8,         INTENT(OUT)   :: GM0(MPROD,MSV) ! Gas mass for HCs and
                                                !  oxidation products [kg]
REAL*8,         INTENT(OUT)   :: AM0(MPROD,MSV) ! Aer mass for HCs and
                                                !  oxidation products [kg]
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm      ! Chemistry State object
```

REMARKS:

```
NOTE: GPROD and APROD are mass ratios of individual oxidation
      products of gas/aerosol to the sum of all.
```

REVISION HISTORY:

```
(1 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
(2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(3 ) Updated for SOG4, SOA4 (bmy, 5/22/06)
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.17 soa_lump

Subroutine SOA_LUMP returns the organic gas and aerosol back to the STT array. (rjp, bmy, 7/7/04, 2/6/07)

INTERFACE:

```
SUBROUTINE SOA_LUMP( I, J, L, GM0, AM0, State_Chm )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD07_HC
USE GIGC_State_Chm_Mod, ONLY : ChmState
! new mtp (hotp 5/24/10)
USE TRACERID_MOD,       ONLY : IDTTSOA1, IDTTSOA2, IDTTSOA3
USE TRACERID_MOD,       ONLY : IDTTSOG1, IDTTSOG2, IDTTSOG3
USE TRACERID_MOD,       ONLY : IDTTSOA0, IDTTSOG0
USE TRACERID_MOD,       ONLY : IDTISOA1, IDTISOA2, IDTISOA3
USE TRACERID_MOD,       ONLY : IDTISOG1, IDTISOG2, IDTISOG3
! semivolpoa2: add POA,POG (hotp 3/2/09)
USE TRACERID_MOD,       ONLY : IDTPOA1, IDTPOG1
USE TRACERID_MOD,       ONLY : IDTPOA2, IDTPOG2
! semivolpoa4: add OPOA, OPOG (hotp 3/27/09)
USE TRACERID_MOD,       ONLY : IDTOPOA1, IDTOPOG1
USE TRACERID_MOD,       ONLY : IDTOPOA2, IDTOPOG2
! Lumped aromatic/IVOC aerosol (hotp 5/13/10)
USE TRACERID_MOD,       ONLY : IDTASOAN, IDTASOA1
USE TRACERID_MOD,       ONLY : IDTASOA2, IDTASOA3
USE TRACERID_MOD,       ONLY : IDTASOG1, IDTASOG2, IDTASOG3
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: I              ! Longitude index
INTEGER,        INTENT(IN)    :: J              ! Latitude index
INTEGER,        INTENT(IN)    :: L              ! Altitude index
REAL*8,         INTENT(IN)    :: GM0(MPROD,MSV) ! Gas mass for HCs and
                                                !  oxidation products [kg]
REAL*8,         INTENT(IN)    :: AM0(MPROD,MSV) ! Aer mass for HCs and
                                                !  oxidation products [kg]
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm      ! Chemistry State object
```

REVISION HISTORY:

```
(1 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
(2 ) Bug fix: make sure L <= LD07 before saving into AD07 array, or else
     we will get an out-of-bounds error. (bmy, 3/4/05)
```

```
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Updated for SOG4, SOA4 (dkh, bmy, 5/22/06)
(5 ) Typo fix: GPROD should be APROD in a couple places (tmf, bmy, 10/16/06)
(6 ) Bug fix: For SOA4, GPROD and APROD should have default values of 0.5,
      instead of 1.0 (dkh, bmy, 2/6/07)
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.18 soa_depo

Subroutine SOA_DEPO computes dry-deposition of a particular SOA species. (rjp, bmy, 7/8/04, 10/25/05)

INTERFACE:

```
      SUBROUTINE SOA_DEPO( TC, DEPID, TRID, Input_Opt )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
      USE TIME_MOD,           ONLY : GET_TS_CHEM
  !INPUT PARAMTERS:
      INTEGER,        INTENT(IN)    :: DEPID                ! Drydep ID #
      INTEGER,        INTENT(IN)    :: TRID                 ! Tracer ID #
      TYPE(OptInput), INTENT(IN)    :: Input_Opt            ! Input Options
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Tracer [kg]
```

REVISION HISTORY:

```
(1 ) Remove reference to CMN, it's obsolete (bmy, 7/20/04)
(2 ) Replace PBLFRAC from "drydep_mod.f" with  GET_FRAC_UNDER_PBLTOP from
      "pbl_mix_mod.f" (bmy, 2/17/05)
(3 ) Bug fix: Add BL_FRAC to the PRIVATE list (mak, bmy, 10/3/05)
(4 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(5 ) Add non-local PBL scheme option for dry deposition (lin, 06/09/08)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.19 emisscarbon

Subroutine EMISSCARBON is the interface between the GEOS-CHEM model and the CARBONACEOUS AEROSOL emissions (rjp, bmy, 1/24/02, 9/25/06)

INTERFACE:

```
      SUBROUTINE EMISSCARBON( am_I_Root, Input_Opt,
     &                        State_Met, State_Chm, RC )
```

USES:

```
      ! References to F90 modules
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD07
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE GFED2_BIOMASS_MOD,  ONLY : GFED2_IS_NEW
      USE GFED3_BIOMASS_MOD,  ONLY : GFED3_IS_NEW
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TIME_MOD,           ONLY : GET_MONTH, ITS_A_NEW_MONTH
      ! Emissions are semivol if IDTPOA is defined (hotp 8/24/09)
      USE TRACERID_MOD,       ONLY : IDTPOA1
#if defined( TOMAS )
      USE PRESSURE_MOD,       ONLY : GET_PCENTER
      USE DIAG_MOD,           ONLY : AD59_ECIL, AD59_ECOB
      USE DIAG_MOD,           ONLY : AD59_OCIL, AD59_OCOB
      USE DIAG_MOD,           ONLY : AD59_NUMB
      USE TOMAS_MOD,          ONLY : IBINS,     AVGMASS, SOACOND
      USE TOMAS_MOD,          ONLY : ICOMP,     IDIAG
      USE TRACERID_MOD,       ONLY : IDTECIL1,  IDTECOB1, IDTNK1
      USE TRACERID_MOD,       ONLY : IDTOCIL1,  IDTOCOB1
#endif
#if defined( DEVEL )
      USE TRACERID_MOD,       ONLY : IDTBCPI, IDTBCPO, IDTOCPI, IDTOCPO
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
For  semivolpoa: do not distinguish between hyrophobic and
hydrophilic emissions  (hotp 2/13/09)
```

REVISION HISTORY:

```
(1 ) Now references LSOA from "CMN_SETUP".  Also now call OHNO3TIME since
     biogenic emissions also have a diurnal variation. (rjp, bmy, 7/15/04)
(2 ) Now references LSOA and LPRT from "logical_mod.f".  Now references
     STT from "tracer_mod.f" (bmy, 7/20/04)
(3 ) Bug fix: removed "," from FORMAT 111.  Also added extra DEBUG_MSG
     output after calling emissions routines. (bmy, 11/19/04)
(4 ) Now always call ANTHRO_CARB_TBOND and ANTHRO_CARB_COOKE.  This will
     read the T. Bond et al [2004] emissions but overwrite the North
     America region with monthly-mean emissions from Cooke et al [1999]
     with imposed seasonality from R. Park [2003].  (bmy, 12/1/04)
(5 ) Now remove THISMONTH from the arg list to BIOMASS_CARB_GEOS
     (bmy, 9/25/06)
(6 ) Now check that GFED2 has been updated if we do not use the annual
     Bond Biomass emission (phs, yc, 12/18/08)
(7 ) Now reads monthly (eml, phs, 5/18/09)
(8 ) New array for 30bin EC and OC source EC30SRC and OC30SRC and refer to
     IBINS (size bin parameters) and refer to LCARB30 (win, 9/4/07)
(9 ) Condensing SOA (when LSOA = F) onto existing aerosol by SOACOND
     (win, 9/25/07)
(10) Convert OC emitted to OM using a factor of 1.8 and note that now
     OCIL and OCOB are actually OM mass.  I might have to rename these
     arrays later. (win, 2/26/08)
(11) Correct the biogenic mass input to SOA condensation from mass OC to
     mass OM using the OC2OM factor. (win, 9/20/08)
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
04 Mar 2013 - R. Yantosca - Remove call to INIT_CARBON
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
22 Jul 2013 - M. Sulprizio- Now copy LRCP from Input_Opt
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
18 Oct 2013 - M. Sulprizio- Do not call ANTHRO_CARB_TBOND when LRCP is true.
                            RCP emissions include biofuel. (C. Heald)
28 Jan 2014 - R. Yantosca - Avoid array temporary in calls to EMITSGC
```

1.32.20 emitsgc

Subroutine EMITSGC calculates sub-grid coagulation for the size distribution of emission. (win, 10/6/07)

INTERFACE:

```
      SUBROUTINE EMITSGC( EMISMASS,  CTYPE,
     &                    Input_Opt, State_Met, State_Chm )
```

USES:

```
      USE CMN_SIZE_MOD
      USE CMN_DIAG_MOD             ! ND59
      USE DIAG_MOD,           ONLY : AD59_ECIL,   AD59_ECOB
      USE DIAG_MOD,           ONLY : AD59_OCIL,   AD59_OCOB
      USE DIAG_MOD,           ONLY : AD59_NUMB
      USE ERROR_MOD,          ONLY : IT_IS_NAN
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL,  GET_PBL_MAX_L
      USE PRESSURE_MOD,       ONLY : GET_PCENTER
      USE TRACERID_MOD,       ONLY : IDTECIL1, IDTECOB1
      USE TRACERID_MOD,       ONLY : IDTOCIL1, IDTOCOB1, IDTNK1
      USE TRACERID_MOD,       ONLY : IDTNH4,   IDTAW1
      USE TOMAS_MOD,          ONLY : IBINS,    AVGMASS,  ICOMP,   IDIAG
      USE TOMAS_MOD,          ONLY : SRTECIL,  SRTECOB,  SRTOCIL
      USE TOMAS_MOD,          ONLY : SRTOCOB,  SRTSO4,   SRTNH4
      USE TOMAS_MOD,          ONLY : SRTH2O,   MNFIX
      USE TOMAS_MOD,          ONLY : SUBGRIDCOAG
      USE TOMAS_MOD,          ONLY : NH4BULKTOBIN
```

INPUT PARAMETERS:

```
      REAL*8,         INTENT(IN)    :: EMISMASS(IIPAR, JJPAR, IBINS)
      INTEGER,        INTENT(IN)    :: CTYPE       ! 1 = EC and 2 = OC
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.21 scalecarb

Function SCALECARB split the carbonaceous emission from each source into the TOMAS aerosol size bins using different mass distribution for fossil fuel and biomass burning+biofuel. The mass size distributions are different for EC and OC. (win, 9/4/07)

INTERFACE:

```
FUNCTION SCALECARB( BULKEMIS, STYPE, CTYPE ) RESULT( VALUE )
```

USES:

```
USE CMN_SIZE_MOD
USE TOMAS_MOD,   ONLY : IBINS
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: BULKEMIS(IIPAR, JJPAR)
INTEGER, INTENT(IN) :: STYPE,  CTYPE
```

RETURN VALUE:

```
REAL*8              :: VALUE(IIPAR, JJPAR, IBINS)
```

REMARKS:

```
STYPE (source type): 1 = Fossil fule
                     2 = Biofuel
                     3 = Biomass burning
CTYPE (carbon type): 1 = EC
                     2 = OC

.
Array ECSCALE30 and OCSCALE100 specify how mass is distributed into bins
for a 30 nm number peak and a 100 nm peak.  Similary for OC size split.

.
This function is adapted from emisOCbond.f and emisBCbond.f by Jeff Pierce
(Jan, 2007) used in GISS GCM-II'.  Introduced to GEOS-Chem by Win T.(9/4/07)
```

REVISION HISTORY:

```
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.22 biogenic_oc

Subroutine BIOGENIC_OC emits secondary organic carbon aerosols. Also modified for SOA tracers. (rjp, bmy, 4/1/04, 1/24/08)

INTERFACE:

```
SUBROUTINE BIOGENIC_OC( Input_Opt, State_Met )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_NAME_EXT_2D,  GET_RES_EXT
      USE BPCH2_MOD,          ONLY : GET_TAU0,         READ_BPCH2
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE MEGAN_MOD,          ONLY : GET_EMMONOT_MEGAN
      ! Speciated MEGAN monoterpenes (hotp 3/10/10)
      USE MEGAN_MOD,          ONLY : GET_EMTERP_MEGAN
      USE MEGANUT_MOD,        ONLY : XLTMMP
      USE TIME_MOD,           ONLY : GET_MONTH,        GET_TS_CHEM
      USE TIME_MOD,           ONLY : GET_TS_EMIS,      ITS_A_NEW_MONTH
      USE TRANSFER_MOD,       ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REMARKS:

```
    Terpene emissions as a source of OC:  TERP.GEIA90.a1.2x2.5.*
    Assuming 10% yield of OC(hydrophilic) from terpene emission.
```

REVISION HISTORY:

```
    (1 ) Now separate computation for FULLCHEM and OFFLINE runs (bmy, 7/8/04)
    (2 ) Now references DATA_DIR from "directory_mod.f".  Now references LSOA
         from "logical_mod.f". (bmy, 7/20/04)
    (3 ) Now reads data from "carbon_200411" subdir of DATA_DIR (bmy, 11/15/04)
    (4 ) Now can use MEGAN biogenic emissions (tmf, bmy, 10/20/05)
    (5 ) For GCAP, need to use GET_NAME_EXT_2D in NVOC file name (bmy, 4/11/06)
    (6 ) Bug fix: add MEGAN emissions to TERP_ORGC when SOA emissions are
         turned on (dkh, bmy, 1/24/08)
    (7 ) Change LMEGAN switch to LMEGANMONO switch (ccc, 3/2/09)
    (8 ) Update MEGAN calculations to MEGAN v2.1 (mpb, ccc, 11/19/09)
    (9 ) Use speciated information from MEGAN v2.1 (hotp, 3/16/10)
    05 Oct 2011 - R. Yantosca - Now use SUNCOS30, which is the cos(SZA)
                                computed @ 30 mins after each GMT hour
    07 Oct 2011 - R. Yantosca - Rename SUNCOS30 to SUNCOS_MID, which is the
                                cos(SZA) at the midpt of the chemistry timestep
    08 Dec 2011 - M. Payer    - Remove GEIA biogenic emissions option
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    28 Nov 2012 - R. Yantosca - Replace SUNCOS_MID with State_Met%SUNCOSmid
    13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                                semivolatile POA simulations (H. Pye)
    20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.23 anthro_carb_tbond

Subroutine ANTHRO_CARB_TBOND reads monthly mean anthropogenic and biofuel emissions of BLACK CARBON (aka ELEMENTAL CARBON) and ORGANIC CARBON. It also separates these into HYDROPHILIC and HYDROPHOBIC fractions. (eml 4/17/09, rjp, bmy, 4/2/04, 5/30/06)

INTERFACE:

```
SUBROUTINE ANTHRO_CARB_TBOND( THISMONTH, Input_Opt )
```

USES:

```
USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,        ONLY : DATA_DIR,        DATA_DIR_1x1
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_BCbf
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_BCff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_OCbf
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_OCff
USE GIGC_Input_Opt_Mod,   ONLY : OptInput
USE REGRID_A2A_MOD,       ONLY : DO_REGRID_A2A
USE TIME_MOD,             ONLY : GET_TS_EMIS
USE TIME_MOD,             ONLY : GET_HISTYR
USE TRANSFER_MOD,         ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: THISMONTH   ! Current month
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

REMARKS:

```
Emissions data comes from Bond et al [GBC, 2007] inventory and has units
of [kg C/yr], which is converted to [kg C/timestep] below. Seasonality is
applied over the US as in Park [2003].

We also assume that 20% of BC and 50% of OC from anthropogenic
emissions are hydrophilic (soluble) and the rest are hydrophobic.
```

REVISION HISTORY:

```
(1 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(2 ) Now read data from "carbon_200411" subdir of DATA_DIR (bmy, 11/15/04)
(3 ) Now can read data for both GEOS and GCAP grids (bmy, 8/16/05)
(4 ) Now compute future emissions of BC,OC if necessary. (swu, bmy, 5/30/06)
(5 ) Now reads in monthly data from Bond et al [2007] (eml, 4/17/09)
08 Mar 2012 - M. Payer    - Added modifications for historical emissions of
                            BC/POA (E. Leibensperger)
03 Jan 2013 - M. Payer    - Use MAP_A2A regridding for historical emissions
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

```
19 Feb 2013 - M. Payer    - Add calculation of XTAU under LBIOFUEL. Otherwise
                            XTAU will not be set if LANTHRO=F (C.L. Heald)
25 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.24 anthro_carb_cooke

Subroutine ANTHRO_CARB_COOKE computes monthly mean anthropogenic and biofuel emissions of BLACK CARBON (aka ELEMENTAL CARBON) and ORGANIC CARBON. It also separates these into HYDROPHILIC and HYDROPHOBIC fractions. (rjp, bmy, 4/2/04, 5/30/06)

INTERFACE:

```
      SUBROUTINE ANTHRO_CARB_COOKE( THISMONTH, Input_Opt )
```

USES:

```
      USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD,        ONLY : DATA_DIR
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_BCbf
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_BCff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_OCbf
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_OCff
      USE GIGC_Input_Opt_Mod,   ONLY : OptInput
      USE TIME_MOD,             ONLY : GET_TS_EMIS
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D
   !INPUT PARAMETERS
      INTEGER,        INTENT(IN)    :: THISMONTH   ! Current month
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

REMARKS:

```
Emissions data comes from the Cooke et al. [1999] inventory and
seasonality imposed by Park et al. [2003].  The data has units of
[kg C/month].  This will be converted to [kg C/timestep] below.

We also assume that 20% of BC and 50% of OC from anthropogenic
emissions are hydrophilic (soluble) and the rest are hydrophobic.
```

REVISION HISTORY:

```
(1 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(2 ) Now read data from "carbon_200411" subdir of DATA_DIR.  Now only apply
     Cooke/RJP emissions over the North American region (i.e. the region
     bounded by indices I1_NA, J1_NA, I2_NA, J2_NA).  (rjp, bmy, 12/1/04)
(3 ) Now can read data from both GEOS and GCAP grids (bmy, 8/16/05)
```

```
(4 ) Now compute future emissions of BC,OC if necessary. (swu, bmy, 5/30/06)
25 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.25 anthro_carb_rcp

Subroutine ANTHRO_CARB_RCP reads monthly mean anthropogenic and biofuel emissions of BLACK CARBON (aka ELEMENTAL CARBON) and ORGANIC CARBON. (cdh, 1/2/2013)

INTERFACE:

```
SUBROUTINE ANTHRO_CARB_RCP( THISMONTH )
```

USES:

```
USE CMN_SIZE_MOD
USE GRID_MOD,             ONLY : GET_AREA_CM2
USE RCP_MOD,              ONLY : GET_RCP_EMISSION
USE TIME_MOD,             ONLY : GET_TS_EMIS
USE TRACERID_MOD,         ONLY : IDTBCPO, IDTOCPO
USE TRACER_MOD,           ONLY : XNUMOL
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)           :: THISMONTH   ! Current month
```

REMARKS:

```
This function also separates these into HYDROPHILIC and HYDROPHOBIC
fractions using the same fractions as the Bond et al. (2007) global
inventory.

We also assume that 20% of BC and 50% of OC from anthropogenic
emissions are hydrophilic (soluble) and the rest are hydrophobic.
```

REVISION HISTORY:

```
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.26 biomass_carb_tbond

Subroutine BIOMASS_CARB_TBOND computes annual mean biomass burning emissions of BLACK CARBON (aka ELEMENTAL CARBON) and ORGANIC CARBON. It also separates these into HYDROPHILIC and HYDROPHOBIC fractions. (rjp, bmy, 4/2/04, 5/30/06)

INTERFACE:

```
SUBROUTINE BIOMASS_CARB_TBOND( Input_Opt )
```

USES:

```
USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,        ONLY : DATA_DIR
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_BCbb
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_OCbb
USE GIGC_Input_Opt_Mod,   ONLY : OptInput
USE TIME_MOD,             ONLY : GET_TS_EMIS
USE TRANSFER_MOD,         ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

REMARKS:

```
Emissions data comes from the Bond et al [2004] inventory and has units
of [kg C/yr].  This will be converted to [kg C/timestep] below.

We also assume that 20% of BC and 50% of OC from anthropogenic
emissions are hydrophilic (soluble) and the rest are hydrophobic.
```

REVISION HISTORY:

```
(1 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(2 ) Now read data from "carbon_200411" subdir of DATA_DIR (bmy, 11/15/04)
(3 ) Now can read from both GEOS and GCAP grids (bmy, 8/16/05)
(4 ) Now compute future emissions of BC,OC if necessary (swu, bmy, 5/30/06)
25 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.27 biomass_carb_geos

Subroutine BIOMASS_CARB_GEOS computes monthly mean biomass burning emissions of BLACK CARBON (aka ELEMENTAL CARBON) and ORGANIC CARBON. It also separates these into HYDROPHILIC and HYDROPHOBIC fractions. (rjp, bmy, 4/2/04, 2/19/09)

INTERFACE:

```
SUBROUTINE BIOMASS_CARB_GEOS( Input_Opt )
```

USES:

```
USE BIOMASS_MOD,          ONLY : BIOMASS
USE CMN_SIZE_MOD
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_OCbb
```

```
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_BCbb
      USE GRID_MOD,             ONLY : GET_AREA_CM2
      USE GIGC_Input_Opt_Mod,   ONLY : OptInput
      USE TIME_MOD,             ONLY : GET_TS_EMIS
      USE TRACERID_MOD,         ONLY : IDBBC,   IDBOC
      USE TRACERID_MOD,         ONLY : IDTBCPO, IDTOCPO
      ! semivolpoa: add POA (hotp 2/26/09)
      USE TRACERID_MOD,         ONLY : IDTPOA1
```

INPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

REMARKS:

```
Emissions are contained in the BIOMASS array of "biomass_mod.f", and will
contain biomass emissions from either the Duncan et al [2001] inventory or
the GFED2 inventory, depending on the option selected at runtime startup.
BIOMASS has units of [atoms C/cm3/s].  Units will be converted to
[kg C/timestep] below.

We also assume that 20% of BC and 50% of OC from anthropogenic
emissions are hydrophilic (soluble) and the rest are hydrophobic.
```

REVISION HISTORY:

```
(1 ) Now references DATA_DIR from "directory_mod.f".  Also removed CMN,
     it's obsolete. (bmy, 7/20/04)
(2 ) Now read data from "carbon_200411" subdir of DATA_DIR (bmy, 11/15/04)
(3 ) Now read BCPO, OCPO biomass burning data directly from files instead
     of computing from emission factors. (rjp, bmy, 1/11/05)
(4 ) Now can read data for both GEOS and GCAP grids (bmy, 8/16/05)
(5 ) Now compute future emissions of BC,OC if necessary (swu, bmy, 5/30/06)
(6 ) Now get biomass emissions from the BIOMASS array of "biomass_mod.f",
     which will contain either GFED2 or default emissions.  Also move
     file-reading code to gc_biomass_mod.f. (bmy, 9/25/06)
(7 ) Prevent seg fault error when LBIOMASS=F (bmy, 11/3/06)
(8 ) Now apply future emissions if necessary (hotp, swu, bmy, 2/19/09)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
25 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
13 Aug 2013 - M. Sulprizio- Add modifications for SOA + semivolatile POA
                            simulation (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.28 emithigh

Subroutine EMITHIGH mixes tracer completely from the surface to the PBL top. (rjp, bmy, 4/2/04, 1/11/10)

INTERFACE:

```
SUBROUTINE EMITHIGH( BCSRC, OCSRC, Input_Opt, State_Chm )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL,  GET_PBL_MAX_L
USE TRACERID_MOD,       ONLY : IDTBCPI, IDTBCPO, IDTOCPI, IDTOCPO
USE TRACERID_MOD,       ONLY : IDTMTPA, IDTLIMO, IDTMTPO ! hotp 5/20/10
! Add POA treatment (hotp 8/24/09)
USE TRACERID_MOD,       ONLY : IDTPOA1
USE VDIFF_PRE_MOD,      ONLY : EMIS_SAVE ! (Lin, 03/31/09)
```

INPUT PARAMETERS:

```
REAL*8,         INTENT(IN)    :: BCSRC(IIPAR,JJPAR,2) ! Total BC [kg]
REAL*8,         INTENT(IN)    :: OCSRC(IIPAR,JJPAR,2) ! Total OC [kg]
TYPE(OptInput), INTENT(IN)    :: Input_Opt            ! Input Options
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
(1 ) Now also mix ALPH, LIMO, ALCO tracers (rjp, bmy, 7/8/04)
(2 ) Now reference STT from "tracer_mod.f" (bmy, 7/20/04)
(3 ) Remove references to "dao_mod.f", "pressure_mod.f", and "error_mod.f".
     Rewrote for computational expediency using routines from
     "pbl_mix_mod.f".  (bmy, 2/17/05)
(4 ) Add emis_save to save surface emissions for non-local PBL scheme.
     (lin, 5/29/09)
(5 ) Bug fix: EMIS_SAVE should be EMIS_SAVE(I,J,...) instead of
     EMIS_SAVE(:,:,...) since we are in a parallel loop (bmy, 1/11/10)
25 Mar 2013 - R. Yantosca - Now accept Input_Opt, State_Chm, args
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.29 emithigh2

Subroutine EMITHIGH2 mixes tracer completely from the surface to the PBL top. This is a copy of subroutine EMITHIGH modified to work with 30-bin EC and OC mass and also aerosol number. (win, 9/4/07)

INTERFACE:

```
SUBROUTINE EMITHIGH2( BCSRC, OCSRC, NUMBSRC,
&                     Input_Opt, State_Chm )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL,  GET_PBL_MAX_L
USE TRACERID_MOD,       ONLY : IDTECIL1, IDTECOB1
USE TRACERID_MOD,       ONLY : IDTOCIL1, IDTOCOB1, IDTNK1
USE TOMAS_MOD,          ONLY : IBINS
USE VDIFF_PRE_MOD,      ONLY : EMIS_SAVE
```

INPUT PARAMETERS:

```
REAL*8,         INTENT(IN)  :: BCSRC(IIPAR,JJPAR,IBINS, 2) ! Total BC [kg]
REAL*8,         INTENT(IN)  :: OCSRC(IIPAR,JJPAR,IBINS, 2) ! Total OC [kg]
REAL*8,         INTENT(IN)  :: NUMBSRC(IIPAR,JJPAR,IBINS)
TYPE(OptInput), INTENT(IN)  :: Input_Opt                   ! Input Options
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
(1 ) Now also mix ALPH, LIMO, ALCO tracers (rjp, bmy, 7/8/04)
(2 ) Now reference STT from "tracer_mod.f" (bmy, 7/20/04)
(3 ) Remove references to "dao_mod.f", "pressure_mod.f", and "error_mod.f".
     Rewrote for computational expediency using routines from
     "pbl_mix_mod.f".  (bmy, 2/17/05)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.30 ohno3time

Subroutine OHNO3TIME computes the sum of cosine of the solar zenith angle over a 24 hour day, as well as the total length of daylight. This is needed to scale the offline OH and NO3 concentrations. (rjp, bmy, 12/16/02, 1/18/05)

INTERFACE:

```
SUBROUTINE OHNO3TIME
```

USES:

```
USE CMN_GCTM_MOD
USE CMN_SIZE_MOD
USE GRID_MOD, ONLY : GET_XMID,    GET_YMID_R
USE TIME_MOD, ONLY : GET_NHMSb,   GET_ELAPSED_SEC
USE TIME_MOD, ONLY : GET_TS_CHEM, GET_DAY_OF_YEAR, GET_GMT
```

REVISION HISTORY:

```
(1 ) Copy code from COSSZA directly for now, so that we don't get NaN
     values.  Figure this out later (rjp, bmy, 1/10/03)
(2 ) Now replace XMID(I) with routine GET_XMID from "grid_mod.f".
     Now replace RLAT(J) with routine GET_YMID_R from "grid_mod.f".
     Removed NTIME, NHMSb from the arg list.  Now use GET_NHMSb,
     GET_ELAPSED_SEC, GET_TS_CHEM, GET_DAY_OF_YEAR, GET_GMT from
     "time_mod.f". (bmy, 3/27/03)
(3 ) Now store the peak SUNCOS value for each surface grid box (I,J) in
     the COSZM array. (rjp, bmy, 3/30/04)
(4 ) Also added parallel loop over grid boxes (bmy, 1/18/05)
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R(I,J,L) from grid_mod.F90
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.31 get_oh

Function GET_OH returns OH from SMVGEAR's CSPEC array (for coupled runs) or monthly mean OH (for offline runs). Imposes a diurnal variation on OH for offline simulations. (bmy, 7/9/04)

INTERFACE:

```
      FUNCTION GET_OH( I, J, L, Input_Opt, State_Met )
     &         RESULT( OH_MOLEC_CM3 )
```

USES:

```
      USE CMN_SIZE_MOD
      USE COMODE_MOD,          ONLY : CSPEC, JLOP
      USE ERROR_MOD,           ONLY : ERROR_STOP
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_OH_MOD,       ONLY : OH
      USE TIME_MOD,            ONLY : GET_TS_CHEM
      USE TRACERID_MOD,        ONLY : IDOH
```

INPUT PARAMETERS:

```
      INTEGER,         INTENT(IN)  :: I           ! Longitude index
      INTEGER,         INTENT(IN)  :: J           ! Latitude index
      INTEGER,         INTENT(IN)  :: L           ! Altitude index
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
      REAL*8                       :: OH_MOLEC_CM3
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDOH (bmy, 11/1/02)
(2 ) Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference inquiry functions from "tracer_mod.f" (bmy, 7/20/04)
28 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
28 Nov 2012 - R. Yantosca - Add State_Met to the argument list
 4 Mar 2013 - R. Yantosca - Add Input_Opt to the argument list
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.32 get_no3

Function GET_NO3 returns NO3 from SMVGEAR's CSPEC array (for coupled runs) or monthly mean OH (for offline runs). For offline runs, the concentration of NO3 is set to zero during the day. (rjp, bmy, 12/16/02, 7/20/04)

INTERFACE:

```
      FUNCTION GET_NO3( I, J, L, Input_Opt, State_Met )
     &         RESULT( NO3_MOLEC_CM3 )
```

USES:

```
      USE CMN_SIZE_MOD
      USE CMN_MOD                  ! NSRCX
      USE COMODE_MOD,          ONLY : CSPEC, JLOP
      USE ERROR_MOD,           ONLY : ERROR_STOP
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_NO3_MOD,      ONLY : NO3
      USE TRACERID_MOD,        ONLY : IDNO3
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN)  :: I           ! Longitude index
      INTEGER,        INTENT(IN)  :: J           ! Latitude index
      INTEGER,        INTENT(IN)  :: L           ! Altitude index
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
      REAL*8                      :: NO3_MOLEC_CM3
```

REVISION HISTORY:

```
(1 ) Now references ERROR_STOP from "error_mod.f".  We also assume that
     SETTRACE has been called to define IDNO3.  Now also set NO3 to
     zero during the day. (rjp, bmy, 12/16/02)
```

```
(2 ) Now reference inquiry functions from "tracer_mod.f" (bmy, 7/20/04)
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
28 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
04 Mar 2013 - R. Yantosca - Add Input_Opt to the argument list
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.33 get_o3

Function GET_O3 returns monthly mean O3 for offline sulfate aerosol simulations. (bmy, 12/16/02, 7/20/04)

INTERFACE:

```
      FUNCTION GET_O3( I, J, L, Input_Opt, State_Met )
     &         RESULT( O3_MOLEC_CM3 )
```

USES:

```
      USE CMN_SIZE_MOD
      USE COMODE_MOD,          ONLY : CSPEC, JLOP, VOLUME
      USE ERROR_MOD,           ONLY : ERROR_STOP
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_O3_MOD,       ONLY : O3
      USE TIME_MOD,            ONLY : GET_TS_CHEM
      USE TRACER_MOD,          ONLY : XNUMOLAIR
      USE TRACERID_MOD,        ONLY : IDO3
```

INPUT PARAMETERS:

```
      INTEGER,         INTENT(IN)  :: I           ! Longitude index
      INTEGER,         INTENT(IN)  :: J           ! Latitude index
      INTEGER,         INTENT(IN)  :: L           ! Altitude index
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
      REAL*8                      :: O3_MOLEC_CM3
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDO3. (bmy, 12/16/02)
(2 ) Now reference inquiry functions from "tracer_mod.f" (bmy, 7/20/04)
(3 ) Now reference XNUMOLAIR from "tracer_mod.f" (bmy, 10/20/05)
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
28 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
04 Mar 2013 - R. Yantosca - Add Input_Opt to the argument list
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.34 get_daro2

Function GET_DARO2 returns the amount of aromatic peroxy radical that reacted with HO2 or NO during the last chemistry timestep. (dkh, 11/10/06)

INTERFACE:

```
FUNCTION GET_DARO2( I, J, L, NOX, JHC, Input_Opt ) RESULT( DARO2 )
```

USES:

```
USE CMN_O3_MOD
USE CMN_SIZE_MOD
USE COMODE_LOOP_MOD
USE COMODE_MOD,         ONLY : CSPEC, JLOP, VOLUME
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TRACERID_MOD,       ONLY : IDTBENZ, IDTTOLU, IDTXYLE
! NAPSOA: add IVOC surrogate (NAP) (hotp 7/22/09)
USE TRACERID_MOD,       ONLY : IDTNAP
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I           ! Longitude index
INTEGER,        INTENT(IN)  :: J           ! Latitude index
INTEGER,        INTENT(IN)  :: L           ! Altitude index
INTEGER,        INTENT(IN)  :: NOX
INTEGER,        INTENT(IN)  :: JHC
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

RETURN VALUE:

```
REAL*8                      :: DARO2
```

REVISION HISTORY:

```
04 Mar 2013 - R. Yantosca - Add Input_Opt to the argument list
13 Aug 2013 - M. Sulprizio- Add NAP for SOA + semivolatile POA (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.35 get_doh

Function GET_DOH returns the amount of isoprene [kg] that has reacted with OH during the last chemistry time step. (dkh, bmy, 6/01/06)

INTERFACE:

```
FUNCTION GET_DOH( I, J, L, Input_Opt ) RESULT( DOH )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_LOOP_MOD
USE COMODE_MOD,         ONLY : CSPEC, JLOP, VOLUME
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TRACERID_MOD,       ONLY : IDTISOP
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I           ! Longitude index
INTEGER,        INTENT(IN)  :: J           ! Latitude index
INTEGER,        INTENT(IN)  :: L           ! Altitude index
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

RETURN VALUE:

```
REAL*8                      :: DOH
```

REVISION HISTORY:

```
04 Mar 2013 - R. Yantosca - Now use fields from Input_Opt object
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.36 get_vcldf

Subroutine GET_VCLDF computes the volume cloud fraction for SO2 chemistry. (rjp, bdf, bmy, 9/23/02)

INTERFACE:

```
SUBROUTINE GET_VCLDF( State_Met )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_State_Met_Mod, ONLY : MetState
USE PRESSURE_MOD,       ONLY : GET_PCENTER, GET_PEDGE
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REMARKS:

```
References:
============================================================================
(1) Sundqvist et al. [1989]
```

REVISION HISTORY:

```
(1 ) Copied from 'sulfate_mod.f' for cloud uptake of GLYX and MGLY (tmf,
     2/26/07)
14 Jan 2011 - R. Yantosca - Return if VCLDF is not allocated
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.37 get_lwc

Function GET_LWC returns the cloud liquid water content [g H2O/m3 air] at a GEOS-CHEM grid box as a function of temperature. (rjp, bmy, 10/31/02, 1/14/03)

INTERFACE:

```
FUNCTION GET_LWC( T ) RESULT( LWC )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: T     ! Temperature [K]
```

RETURN VALUE:

```
REAL*8             :: LWC   ! Cloud liquid water content [g H2O/m3 air]
```

REVISION HISTORY:

```
(1 ) Copied from 'sulfate_mod.f' for cloud uptake of GLYX and MGLY (tmf, 2/26/07)
18 Jan 2011 - R. Yantosca - Updated comments
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.38 soag_cloud

Subroutine SOAG_CLOUD produces SOAG from GLYX during a cloud event. Mimics the SO2 -¿ SO4 process from 'sulfate_mod.f'. (tmf, 2/26/07)

INTERFACE:

```
SUBROUTINE SOAG_CLOUD( State_Met, State_Chm )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DAO_MOD,             ONLY : IS_LAND
USE DIAG_MOD,            ONLY : AD07_SOAGM
USE GIGC_State_Met_Mod, ONLY : MetState
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TIME_MOD,            ONLY : GET_TS_CHEM
USE TROPOPAUSE_MOD,      ONLY : ITS_IN_THE_STRAT
USE TRACERID_MOD,        ONLY : IDTGLYX, IDTSOAG
```

INPUT PARAMETERS:

```
! Arguments
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
(1 ) SOAG (SOA product of GLYX is produced at existing hydrophilic aerosol
     surface. (tmf, 2/26/07)
(2 ) Assume marine and continental cloud droplet size (tmf, 2/26/07)
14 Jan 2011 - R. Yantosca - Now compute cloud fraction and liquid water
                            content directly from GEOS-5 & MERRA met fields
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.32.39 soam_cloud

Subroutine SOAM_CLOUD produces SOAM from MGLY during a cloud event. Mimics the SO2 -¿ SO4 process from 'sulfate_mod.f'. (tmf, 2/26/07)

INTERFACE:

```
SUBROUTINE SOAM_CLOUD( State_Met, State_Chm )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DAO_MOD,            ONLY : IS_LAND
USE DIAG_MOD,           ONLY : AD07_SOAGM
USE GIGC_State_Met_Mod, ONLY : MetState
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TIME_MOD,           ONLY : GET_TS_CHEM
USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
USE TRACERID_MOD,       ONLY : IDTMGLY, IDTSOAM
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
(1 ) SOAM (SOA product of MGLY is produced at existing hydrophilic aerosol
     surface. (tmf, 2/26/07)
(2 ) Assume typical marine and continental cloud droplet size (tmf, 2/26/07)
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.40 check_eqlb

Subroutine CHECK_EQLB makes sure aerosols are at equilibrium (checks SOA=SOG*KOM*Mo). Called inside SOA_SVPOA_CHEMISTRY I, J, L loop after SOA_SVPOA_LUMP. Created by Havala Pye (5/18/10).

INTERFACE:

```
 SUBROUTINE CHECK_EQLB( I,   J,   L, KOMIJL, CONVFAC, MSOACHEM,
&                       LOW, TOL, ASOANGAS, ASOANAER, OCPIOCPO,
&                       State_Chm )
```

USES:

```
 USE GIGC_State_Chm_Mod, ONLY : ChmState
 USE TRACERID_MOD,       ONLY : IDTASOAN
 USE TRACERID_MOD,       ONLY : IDTASOA1, IDTASOA2, IDTASOA3
 USE TRACERID_MOD,       ONLY : IDTASOG1, IDTASOG2, IDTASOG3
 USE TRACERID_MOD,       ONLY : IDTPOA1,  IDTPOG1
 USE TRACERID_MOD,       ONLY : IDTPOA2,  IDTPOG2
 USE TRACERID_MOD,       ONLY : IDTOPOA1, IDTOPOG1
 USE TRACERID_MOD,       ONLY : IDTOPOA2, IDTOPOG2
 USE TRACERID_MOD,       ONLY : IDTOCPI,  IDTOCPO
 USE TRACERID_MOD,       ONLY : IDTTSOA1, IDTTSOA2, IDTTSOA3
 USE TRACERID_MOD,       ONLY : IDTTSOG1, IDTTSOG2, IDTTSOG3
 USE TRACERID_MOD,       ONLY : IDTTSOA0, IDTTSOG0
 USE TRACERID_MOD,       ONLY : IDTISOA1, IDTISOA2, IDTISOA3
 USE TRACERID_MOD,       ONLY : IDTISOG1, IDTISOG2, IDTISOG3
```

INPUT PARAMETERS:

```
 INTEGER,        INTENT(IN)  :: I           ! Longitude index
 INTEGER,        INTENT(IN)  :: J           ! Latitude index
 INTEGER,        INTENT(IN)  :: L           ! Altitude index
 REAL*8,         INTENT(IN)  :: KOMIJL(MPROD,MSV) ! KOM at grid box (adj T)
 REAL*8,         INTENT(IN)  :: CONVFAC     ! Conversion factor kg to ug/m3
 REAL*8,         INTENT(IN)  :: OCPIOCPO    ! POA mass [ug/m3]

 ! Arguments for debugging
 REAL*8,         INTENT(IN)  :: MSOACHEM    ! MNEW from calling prog
 REAL*8,         INTENT(IN)  :: LOW         ! Lower bound on soln
 REAL*8,         INTENT(IN)  :: TOL         ! Tolerance on soln
 REAL*8,         INTENT(IN)  :: ASOANGAS    ! Gas phase ASOAN (should =0)
 REAL*8,         INTENT(IN)  :: ASOANAER    ! Aer phase ASOAN [ug/m3]

 TYPE(ChmState), INTENT(IN)  :: State_Chm   ! Chemistry State object
```

REMARKS:

```
 Note: There are some deviations from equilibrium due to the fact
```

```
that ASOAN is supposed to be nonvolatile, but is modeled with a KOM of
10^6. An adjustment is made in SOA_CHEMISTRY to force all ASOAN to
the aerosol phase. This was found to lead to error up to 1e-5 ug/m3
in Mo. This error is small, but the effects can be investigated
here if you're interested!

As of 6/2010, KOM for ASOAN was increased and the error in Mo reduced.
```

REVISION HISTORY:

```
(1)  Updated for TSOA and ISOA (hotp 5/24/10)
(2)  Add OCPIOCPO and remove NOX (hotp 6/9/10)
(3)  Add TSOA0 (hotp 6/12/10)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.41 save_oaginit

Subroutine SAVE_OAGINIT saves total SOA+SOG before partitioning for diagnostic purposes. Units are the same as the STT array ([kg] or [kgC per box]). created hotp 5/17/10

INTERFACE:

```
SUBROUTINE SAVE_OAGINIT( State_Chm )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACERID_MOD,       ONLY : IDTASOAN
USE TRACERID_MOD,       ONLY : IDTASOA1, IDTASOA2, IDTASOA3
USE TRACERID_MOD,       ONLY : IDTASOG1, IDTASOG2, IDTASOG3
USE TRACERID_MOD,       ONLY : IDTPOA1,  IDTPOG1
USE TRACERID_MOD,       ONLY : IDTPOA2,  IDTPOG2
USE TRACERID_MOD,       ONLY : IDTOPOA1, IDTOPOG1
USE TRACERID_MOD,       ONLY : IDTOPOA2, IDTOPOG2
USE TRACERID_MOD,       ONLY : IDTTSOA1, IDTTSOA2, IDTTSOA3
USE TRACERID_MOD,       ONLY : IDTTSOG1, IDTTSOG2, IDTTSOG3
USE TRACERID_MOD,       ONLY : IDTTSOA0, IDTTSOG0
USE TRACERID_MOD,       ONLY : IDTISOA1, IDTISOA2, IDTISOA3
USE TRACERID_MOD,       ONLY : IDTISOG1, IDTISOG2, IDTISOG3
```

INPUT PARAMETERS:

```
TYPE(ChmState), INTENT(IN)  :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
(1) added TSOA and ISOA (hotp 5/24/10)
(2) OAGINITSAVE dimensions changes from (I,J,L,NOx,NPROD,JSV) to
    (I,J,L,NPROD,JSV)
(3) Add compatability with non-vol sim (hotp 6/7/10)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.42 check_mb

Subroutine CHECK_MB checks total SOA+SOG mass balance for diagnostic/debugging purposes. Units are the same as the STT array ([kg] or [kgC per box]). Routine also prints helpful budget info. Created by Havala Pye (5/18/10).

INTERFACE:

```
SUBROUTINE CHECK_MB( am_I_Root, Input_Opt, State_Met, State_Chm )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACERID_MOD,       ONLY : IDTASOAN
USE TRACERID_MOD,       ONLY : IDTASOA1, IDTASOA2, IDTASOA3
USE TRACERID_MOD,       ONLY : IDTASOG1, IDTASOG2, IDTASOG3
USE TRACERID_MOD,       ONLY : IDTPOA1, IDTPOG1
USE TRACERID_MOD,       ONLY : IDTPOA2, IDTPOG2
USE TRACERID_MOD,       ONLY : IDTOPOA1, IDTOPOG1
USE TRACERID_MOD,       ONLY : IDTOPOA2, IDTOPOG2
USE TRACERID_MOD,       ONLY : IDTTSOA1, IDTTSOA2, IDTTSOA3
USE TRACERID_MOD,       ONLY : IDTTSOG1, IDTTSOG2, IDTTSOG3
USE TRACERID_MOD,       ONLY : IDTTSOA0, IDTTSOG0
USE TRACERID_MOD,       ONLY : IDTISOA1, IDTISOA2, IDTISOA3
USE TRACERID_MOD,       ONLY : IDTISOG1, IDTISOG2, IDTISOG3
! for debug:
USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
TYPE(ChmState), INTENT(IN)  :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
(1) added monoterpene, sesq, isoprene SOA (hotp 5/24/10)
(2) updated OAGINITSAVE dimensions (hotp 5/24/10)
(3) keeps track and prints to screen amount of parent HC reacted
    with each oxidant cumulative (hotp 5/24/10)
(4) Add non-volatile compatability (hotp 6/9/10)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.43 get_no

Function GET_NO returns NO from SMVGEAR's CSPEC array (for coupled runs). (hotp 5/7/2010)

INTERFACE:

```
      FUNCTION GET_NO( I, J, L ) RESULT( NO_MOLEC_CM3 )
```

USES:

```
      USE CMN_SIZE_MOD
      USE COMODE_MOD,    ONLY : CSPEC, JLOP
      USE ERROR_MOD,     ONLY : ERROR_STOP
      USE TRACER_MOD,    ONLY : ITS_A_FULLCHEM_SIM
      USE TRACERID_MOD,  ONLY : IDNO
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: I    ! Longitude index
      INTEGER, INTENT(IN)    :: J    ! Latitude index
      INTEGER, INTENT(IN)    :: L    ! Altitude index
  !RETURN VALUE
      REAL*8                 :: NO_MOLEC_CM3
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDNO (bmy, 11/1/02)
(3 ) Now reference inquiry functions from "tracer_mod.f" (bmy, 7/20/04)
(4 ) Based on GET_OH (hotp 5/7/2010)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.44 get_ho2

Function GET_HO2 returns HO2 from SMVGEAR's CSPEC array (for coupled runs). Created by Havala Pye (5/7/2010).

INTERFACE:

```
      FUNCTION GET_HO2( I, J, L ) RESULT( HO2_MOLEC_CM3 )
```

USES:

```
      USE CMN_SIZE_MOD
      USE COMODE_MOD,    ONLY : CSPEC, JLOP
      USE ERROR_MOD,     ONLY : ERROR_STOP
      USE TRACER_MOD,    ONLY : ITS_A_FULLCHEM_SIM
      USE TRACERID_MOD,  ONLY : IDHO2
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: I    ! Longitude index
      INTEGER, INTENT(IN)    :: J    ! Latitude index
      INTEGER, INTENT(IN)    :: L    ! Altitude index
  !RETURN VALUE
      REAL*8                 :: HO2_MOLEC_CM3
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDHO2 (bmy, 11/1/02)
(3 ) Now reference inquiry functions from "tracer_mod.f" (bmy, 7/20/04)
(4 ) Based on GET_OH (hotp 5/6/2010)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.45 get_isopno3

Modification of GET_DOH that returns the amount of isoprene [kgC] that has reacted with NO3 during the last chemistry time step. (hotp 5/22/10)

INTERFACE:

```
FUNCTION GET_ISOPNO3( I, J, L ) RESULT( ISOPNO3 )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_LOOP_MOD     ! ILISOPNO3
USE COMODE_MOD,    ONLY : CSPEC, JLOP, VOLUME
USE ERROR_MOD,     ONLY : ERROR_STOP
USE TRACER_MOD,    ONLY : ITS_A_FULLCHEM_SIM, ITS_AN_AEROSOL_SIM
USE TRACER_MOD,    ONLY : XNUMOL,             TRACER_COEFF
USE TRACERID_MOD,  ONLY : IDTISOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: I        ! Longitude index
INTEGER, INTENT(IN)    :: J        ! Latitude index
INTEGER, INTENT(IN)    :: L        ! Altitude index
!RETURN VALUE
REAL*8                 :: ISOPNO3  ! Isoprene replaced with NO3 [kg C]
```

REVISION HISTORY:

```
(1) IDLISOPNO3 is declared in tracerid_mod.f and initialized by SETTRACE
    in tracerid_mod (called in chemdr). Before each chemistry call,
    CSPEC(JLOOP,IDLISOPNO3) is zeroed so that the CSPEC array only stores
    the parent HC reacted during that timestep. (hotp 6/1/10)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.32.46 init_carbon

Subroutine INIT_CARBON initializes all module arrays. (rjp, bmy, 4/1/04, 12/19/09)

INTERFACE:

```
SUBROUTINE INIT_CARBON( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR, ERROR_STOP
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_BOUNDING_BOX
USE TIME_MOD,           ONLY : GET_NYMDb, GET_NHMSb, GET_TAUb
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure
```

REVISION HISTORY:

```
(1 ) Also added arrays for secondary organic aerosols (rjp, bmy, 7/8/04)
(2 ) Remove reference to CMN, it's obsolete (bmy, 7/20/04)
(3 ) Now reference LSOA from "logical_mod.f" not CMN_SETUP.  Now call
     GET_BOUNDING_BOX from "grid_mod.f" to compute the indices I1_NA,
     I2_NA, J1_NA, J2_NA which define the N. America region. (bmy, 12/1/04)
(4 ) Now call READ_GPROD_APROD to read GPROD & APROD from disk.
     (tmf, havala, bmy, 2/6/07)
(5 ) Now set I1_NA, I2_NA, J1_NA, J2_NA appropriately for both 1 x 1 and
     0.5 x 0.666 nested grids (yxw, dan, bmy, 11/6/08)
(6 ) Now set parameters for NESTED_EU grid (amv, bmy, 12/19/09)
14 Jan 2011 - R. Yantosca - If we are using GEOS-5 or MERRA met, then get
                            the cloud fraction directly from the met fields.
01 Mar 2012 - R. Yantosca - Now use GET_BOUNDING_BOX from grid_mod.F90
04 Mar 2013 - R. Yantosca - Now take am_I_Root, Input_Opt, RC as arguments
04 Mar 2013 - R. Yantosca - Now search for drydep flags here
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LSOA
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
26 Sep 2013 - R. Yantosca - Removed SEAC4RS Cpp switch, this is supplanted
                            by NESTED_NA
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.32.47 cleanup_carbon

Subroutine CLEANUP_CARBON deallocates all module arrays (rjp, bmy, 4/1/04, 7/8/04)

INTERFACE:

```
SUBROUTINE CLEANUP_CARBON
```

REVISION HISTORY:

```
(1 ) Now deallocate arrays for secondary organic aerosols (rjp, bmy, 7/8/04)
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - M. Sulprizio- Added ProTeX headers
```

1.33 Fortran: Module Interface chemistry_mod

Module CHEMISTRY_MOD is used to call the proper chemistry subroutine for the various GEOS-Chem simulations.

INTERFACE:

```
MODULE CHEMISTRY_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: DO_CHEMISTRY
PUBLIC :: GCKPP_DRIVER
PUBLIC :: RECOMPUTE_OD
```

REVISION HISTORY:

```
(1 ) Bug fix in DO_CHEMISTRY (bnd, bmy, 4/14/03)
(2 ) Now references DEBUG_MSG from "error_mod.f" (bmy, 8/7/03)
(3 ) Now references "tagged_ox_mod.f"(bmy, 8/18/03)
(4 ) Now references "Kr85_mod.f" (jsw, bmy, 8/20/03)
(5 ) Bug fix: Now also call OPTDEPTH for GEOS-4 (bmy, 1/27/04)
(6 ) Now references "carbon_mod.f" and "dust_mod.f" (rjp, tdf, bmy, 4/5/04)
(7 ) Now references "seasalt_mod.f" (rjp, bec, bmy, 4/20/04)
(8 ) Now references "logical_mod.f", "tracer_mod.f", "diag20_mod.f", and
     "diag65_mod.f", and "aerosol_mod." (bmy, 7/20/04)
(9 ) Now references "mercury_mod.f" (bmy, 12/7/04)
(10) Updated for SO4s, NITs chemistry (bec, bmy, 4/13/05)
(11) Now call CHEM_HCN_CH3CN from "hcn_ch3cn_mod.f".  Also remove all
     references to the obsolete CO-OH param simulation. (xyp, bmy, 6/24/05)
(12) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(13) Now call MAKE_RH from "main.f" (bmy, 3/16/06)
(14) Updated for SOA from isoprene (dkh, bmy, 6/1/06)
(15) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(16) For now, replace use RPMARES instead of ISORROPIA. (bmy, 4/2/08)
(17) Added KPP chemistry driver subroutine (phs,ks,dhk, 09/15/09)
(18) Added public member function recompute_OD (skim, 02/03/11)
```

```
17 Dec 2009 - R. Yantosca - Added ProTeX headers
28 Jan 2010 - C. Carouge, R. Yantosca - Modified for ISORROPIA II
08 Aug 2012 - R. Yantosca - Now align IF statements better
10 Aug 2012 - R. Yantosca - Cosmetic changes
25 Mar 2013 - M. Payer    - Now pass State_Chm to several routines
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.33.1 do_chemistry

Subroutine DO_CHEMISTRY is the driver routine which calls the appropriate chemistry subroutine for the various GEOS-Chem simulations.

INTERFACE:

```
      SUBROUTINE DO_CHEMISTRY( am_I_Root, Input_Opt,
     &                         State_Chm, State_Met, RC )
```

USES:

```
      USE ACETONE_MOD,         ONLY : OCEAN_SINK_ACET
      USE AEROSOL_MOD,         ONLY : AEROSOL_CONC
      USE AEROSOL_MOD,         ONLY : AEROSOL_RURALBOX
      USE AEROSOL_MOD,         ONLY : RDAER
      USE AEROSOL_MOD,         ONLY : SOILDUST
      USE C2H6_MOD,            ONLY : CHEMC2H6
      USE CARBON_MOD,          ONLY : CHEMCARBON
      USE CH3I_MOD,            ONLY : CHEMCH3I
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE COMODE_LOOP_MOD
      USE DRYDEP_MOD,          ONLY : DRYFLX
      USE DRYDEP_MOD,          ONLY : DRYFLXRnPbBe
      USE DRYDEP_MOD,          ONLY : DRYFLXH2HD
      USE DUST_MOD,            ONLY : CHEMDUST
      USE DUST_MOD,            ONLY : RDUST_ONLINE
      USE ERROR_MOD,           ONLY : DEBUG_MSG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_CH4_MOD,      ONLY : CHEMCH4
      USE H2_HD_MOD,           ONLY : CHEM_H2_HD
      USE HCN_CH3CN_MOD,       ONLY : CHEM_HCN_CH3CN
      USE ISOROPIAII_MOD,      ONLY : DO_ISOROPIAII
      USE MERCURY_MOD,         ONLY : CHEMMERCURY
      USE OPTDEPTH_MOD,        ONLY : OPTDEPTH
      USE POPS_MOD,            ONLY : CHEMPOPS
      USE RnPbBe_MOD,          ONLY : CHEMRnPbBe
```

```
      USE RPMARES_MOD,        ONLY : DO_RPMARES
      USE SEASALT_MOD,        ONLY : CHEMSEASALT
      USE SULFATE_MOD,        ONLY : CHEMSULFATE
      USE STRAT_CHEM_MOD,     ONLY : DO_STRAT_CHEM
      USE TAGGED_CO_MOD,      ONLY : CHEM_TAGGED_CO
      USE TAGGED_OX_MOD,      ONLY : CHEM_TAGGED_OX
      USE TIME_MOD,           ONLY : GET_ELAPSED_MIN
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TRACERID_MOD,       ONLY : IDTACET
      USE TRACERID_MOD,       ONLY : IDTISOP
      USE TRACERID_MOD,       ONLY : IDTDST1
#if   defined( TOMAS )
      USE TOMAS_MOD,          ONLY : DO_TOMAS  !(win, 7/14/09)
      USE TRACERID_MOD,       ONLY : IDTNK1    !(win, 7/14/09)
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REMARKS:

```
(1) State_Chm%TRACERS needs to enter this routine w/ units of [kg].
(2) State_Chm%SPECIES needs to enter this routine w/ units of [molec/cm3].
(3) As of 25 Oct 2012, we have not replaced the met-field arrays from
     dao_mod.F with the fields in State_Met.  This will be done in a
     piecemeal fashion so as not to disrupt the existing G-C workflow.
```

REVISION HISTORY:

```
(1 ) Now reference DELP, T from "dao_mod.f" since we need to pass this
      to OPTDEPTH for GEOS-1 or GEOS-STRAT met fields (bnd, bmy, 4/14/03)
(2 ) Now references DEBUG_MSG from "error_mod.f" (bmy, 8/7/03)
(3 ) Removed call to CHEMO3, it's obsolete.  Now calls CHEM_TAGGED_OX !
      from "tagged_ox_mod.f" when NSRCX==6.  Now calls Kr85 chemistry if
      NSRCX == 12 (jsw, bmy, 8/20/03)
(4 ) Bug fix: added GEOS-4 to the #if block in the call to OPTDEPTH.
      (bmy, 1/27/04)
(5 ) Now calls CHEMCARBON and CHEMDUST to do carbon aerosol & dust
      aerosol chemistry (rjp, tdf, bmy, 4/2/04)
(6 ) Now calls CHEMSEASALT to do seasalt aerosol chemistry
      (rjp, bec, bmy, 4/20/04)
```

```
(7 ) Now references "logical_mod.f" & "tracer_mod.f".  Now references
     AEROSOL_CONC, AEROSOL_RURALBOX, and RDAER from "aerosol_mod.f".
     Now includes "CMN_DIAG" and "comode.h".  Also call READER, READCHEM,
     and INPHOT to initialize the FAST-J arrays so that we can save out !
     AOD's to the ND21 diagnostic for offline runs. (bmy, 7/20/04)
(8 ) Now call routine CHEMMERCURY from "mercury_mod.f" for an offline
     Hg0/Hg2/HgP simulation. (eck, bmy, 12/7/04)
(9 ) Now do not call DO_RPMARES if we are doing an offline aerosol run
     with crystalline sulfur & aqueous tracers (cas, bmy, 1/7/05)
(10) Now use ISOROPIA for aer thermodyn equilibrium if we have seasalt
     tracers defined, or RPMARES if not.  Now call CHEMSEASALT before
     CHEMSULFATE.  Now do aerosol thermodynamic equilibrium before
     aerosol chemistry for offline aerosol runs.  Now also reference
     CLDF from "dao_mod.f" (bec, bmy, 4/20/05)
(11) Now modified for GCAP met fields.  Now call CHEM_HCN_CH3CN from
     "hcn_ch3cn_mod.f".  Also remove allreferences to the obsolete
      CO-OH param simulation. (xyp, bmy, 6/23/05)
(12) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(13) Now call MAKE_RH from "main.f" (bmy, 3/16/06)
(14) Removed ISOP_PRIOR as a local variable (dkh, bmy, 6/1/06)
(15) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(16) Now use DRYFLXH2HD and CHEM_H2_HD for H2/HD sim (lyj, phs, 9/18/07)
(17) Bug fix: now hardwired to use RPMARES since ISORROPIA can return very
     unphysical values at low RH.  Wait for ISORROPIA II. (bmy, 4/2/08)
(18) The dry deposition diagnostic (ND44) is done in vdiff_mod if using non-
     local PBL (lin, ccc, 5/29/09)
(19) Now calls CHEMPOPS from "pops_mod.f" for an offline POPs simulation
    (eck, 9/20/10)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
25 Jan 2010 - R. Yantosca - Now call DO_TOMAS for TOMAS microphysics
28 Jan 2010 - C. Carouge, R. Yantosca - Modified for ISORROPIA II
19 Mar 2012 - R. Yantosca - Add C-preprocessor switch to shut off
                            ISORROPIA to facilitate debugging
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument, and pass
                            this down to lower-level chem routines for GIGC
08 Aug 2012 - R. Yantosca - Now align IF statements better
10 Aug 2012 - R. Yantosca - Cosmetic changes
18 Oct 2012 - R. Yantosca - Rename GC_MET argument to State_Met
18 Oct 2012 - R. Yantosca - Rename CHEM_STATE argument to State_Chem
19 Oct 2012 - R. Yantosca - Now reference gigc_state_chm_mod.F90
19 Oct 2012 - R. Yantosca - Now reference gigc_state_met_mod.F90
25 Oct 2012 - R. Yantosca - Add comments for GIGC #ifdefs
25 Oct 2012 - R. Yantosca - Add the RC output argument for the GIGC
08 Nov 2012 - R. Yantosca - Now pass Input_Opt argument for the GIGC and
                            use fields of Input_Opt to replace logicals
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
26 Nov 2012 - R. Yantosca - Now pass Input_Opt, State_Chm, RC to routine
```

```
                            DO_STRAT_CHEM (in GeosCore/strat_chem_mod.F90)
11 Dec 2012 - R. Yantosca - Remove NI, NJ, NL, NCNST arguments; these are
                            now obtained either from CMN_SIZE_mod.F or
                            from the Input_Opt object
05 Mar 2013 - R. Yantosca - Now pass am_I_Root, Input_Opt, RC to DRYFLX
31 May 2013 - R. Yantosca - Now pass Input_Opt, State_Chm to DO_TOMAS
```

1.33.2 gckpp_driver

Subroutine GCKPP_DRIVER is the driver routine to perform integration with the full KPP chemistry mechanism.

INTERFACE:

```
SUBROUTINE GCKPP_DRIVER( KTLOOP, JLOOPLO, R_KPP, NSPEC_GC )
```

USES:

```
USE COMODE_MOD,           ONLY : JLOP,   CSPEC
USE COMODE_MOD,           ONLY : IXSAVE, IYSAVE,    IZSAVE
USE GCKPP_COMODE_MOD,     ONLY : HSAVE_KPP
USE TIME_MOD,             ONLY : GET_TS_CHEM
USE GCKPP_UTIL,           ONLY : SHUFFLE_KPP2USER
USE GCKPP_INITIALIZE,     ONLY : INITIALIZE
USE GCKPP_MODEL
USE GCKPP_GLOBAL
USE GCKPP_RATES,          ONLY : UPDATE_RCONST
USE GCKPP_MONITOR,        ONLY : SPC_NAMES
USE GCKPP_FUNCTION
USE ERROR_MOD,            ONLY : ERROR_STOP
USE GCKPP_INTEGRATOR,     ONLY : NHNEW, NHEXIT, INTEGRATE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: KTLOOP       ! Local loop index
INTEGER, INTENT(IN) :: JLOOPLO      ! JLOOPLO + KLOOP = JLOOP
REAL*8,  INTENT(IN) :: R_KPP(:,:)   ! Array of reaction rates
INTEGER, INTENT(IN) :: NSPEC_GC     ! # of active chemical species
```

REMARKS:

```
Variables used to pass the last/first step size b/w call

.

For Rosenbrock:
---------------
    Nhexit=2, Nhnew = 3
OUT
    RSTATUS(2)  -> Hexit, last accepted step before exit
    RSTATUS(3)  -> Hnew, last predicted step (not yet taken)
```

```
      For multiple restarts, use Hnew as Hstart in the subsequent run
   IN
      RCNTRL(3)   -> Hstart, starting value for the integration step size
                                                                          .
                                                                          .
   For LSODE:
   ------------
   OUT
      RSTATUS(1)  -> Texit, the time corresponding to the
                     computed Y upon return
      RSTATUS(2)  -> Hexit, last predicted step before exit
      For multiple restarts, use Hexit as Hstart in the following run
   IN
      RCNTRL(3)  -> Hstart, starting value for the integration step size
                                                                          .
                                                                          .
   For RADAU5:
   ------------
   OUT
      RSTATUS(1)  -> final time
   IN
      RCNTRL(3)   -> not used
                                                                          .
                                                                          .
  For RUNGE-KUTTA
  ---------------
  OUT
     same as Rosenbrock
```

REVISION HISTORY:

```
 24 Jan 2008 - Kumaresh    - Based on Daven Henze's GCKPP_DRIVER.
 16 Sep 2009 - R. Yantosca - Commented, and updated to call various
 03 Dec 2009 - C. Carouge  - Use CSPEC instead of CSPEC_FOR_KPP
                             to save memory space
 17 Dec 2009 - R. Yantosca - Added ProTeX headers
 20 Jan 2010 - C. Carouge  - Now call GCKPP_DRIVER from physproc.f to save
                             memory.
 20 Jan 2010 - C. Carouge  - Now use the # of active species from GC to
                             update CSPEC and not the of variable species
                             from KPP.
 12 Apr 2013 - R. Yantosca - If -DDEVEL is used, when the chemistry can't
                             converge, we shall increase the tolerances
                             by a factor of 2 and try again.  This is often
                             needed to run GEOS-Chem in the GEOS-5 GCM.
```

1.33.3 recompute_od

Subroutine RECOMPUTE_OD will update the optical depth values before accumulating or writing the diagnostics.

INTERFACE:

```
SUBROUTINE RECOMPUTE_OD( am_I_Root, Input_Opt,
&                        State_Met, State_Chm, RC )
```

USES:

```
! References to F90 modules
USE AEROSOL_MOD,         ONLY : AEROSOL_CONC
USE AEROSOL_MOD,         ONLY : RDAER
USE AEROSOL_MOD,         ONLY : SOILDUST
USE DUST_MOD,            ONLY : RDUST_ONLINE
USE DUST_MOD,            ONLY : RDUST_OFFLINE
USE ERROR_MOD,           ONLY : DEBUG_MSG
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,            ONLY : GET_MONTH
USE TIME_MOD,            ONLY : GET_YEAR
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
03 Fev 2011 - Adapted from chemdr.f by skim
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
13 Nov 2012 - R. Yantosca - Now pass Input_Opt and RC arguments for GIGC
15 Nov 2012 - M. Payer    - Now pass all met fields via State_Met
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.34 Fortran: Module Interface co2_mod

Module CO2_MOD contains variables and routines used for the CO2 simulation. A tagged CO2 simulation capability has now been added.

References:

- Andres, R.J, G. Marland, I. Fung, and E. Matthews, *A 1x1 distribution of carbon dioxide emissions from fossil fuel consumption and cement manufacture*, Glob. Biogeochem. Cycles, **10**, 419-429, 1996.
- Corbett and Koehler (2003) *Updated emissions from ocean shipping*, J. Geophys. Res., **108**, D20, 4650.
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INTERFACE:

```
MODULE CO2_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_CO2
PUBLIC  :: EMISSCO2
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: READ_CHEMCO2
PRIVATE :: READ_FOSSILCO2
PRIVATE :: CHEM_SURF
PRIVATE :: AVIATION_DOM_CORR
PRIVATE :: READ_OCEANCO2
PRIVATE :: READ_ANNUAL_BIOFUELCO2
PRIVATE :: READ_SHIPCO2_EDGAR
PRIVATE :: READ_SHIPCO2_ICOADS
PRIVATE :: READ_AVIATION_CO2
PRIVATE :: READ_ANNUAL_BIONET_CO2
PRIVATE :: READ_BBIO_DAILYAVERAGE
PRIVATE :: READ_BBIO_DIURNALCYCLE
PRIVATE :: TOTAL_BIOMASS_TG
PRIVATE :: DEF_BIOSPH_CO2_REGIONS_F
PRIVATE :: DEF_OCEAN_CO2_REGIONS_F
PRIVATE :: DEF_FOSSIL_CO2_REGIONS_F
PRIVATE :: INIT_CO2
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

.

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam - Initial version
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Now references biomass_mod.f (bmy, 9/27/06)
(3 ) Tagged CO2 capability developed (dbj)
(4 ) Implemented monthly and annual fossil fuel inventories
      (R.Nassar 2009-03-10)
(5 ) Implemented CO2 emissions from shipping and aviation (R.Nassar 2010)
(6 ) Implemented monthly CO2 chemical production and surface correction
      (R.Nassar 2010)
25 Feb 2011 - R. Nassar  - Now read updated CDIAC CO2 emissions data
07 Sep 2011 - P. Kasibhatla - Modified to include GFED3
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.34.1 emissco2

Subroutine EMISSCO2 is the driver routine for CO2 emissions.

INTERFACE:

```
      SUBROUTINE EMISSCO2( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE BIOMASS_MOD,        ONLY : BIOMASS
      USE CMN_SIZE_MOD
      USE DIAG04_MOD,         ONLY : AD04, ND04
      USE DIAG04_MOD,         ONLY : AD04_plane,    AD04_chem
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE TIME_MOD,           ONLY : GET_DAY,       GET_DAY_OF_YEAR
      USE TIME_MOD,           ONLY : GET_HOUR,      GET_MONTH
      USE TIME_MOD,           ONLY : GET_YEAR,      GET_TS_CHEM
      USE TIME_MOD,           ONLY : GET_TS_EMIS
      USE TIME_MOD,           ONLY : ITS_A_NEW_DAY, ITS_A_NEW_MONTH
      USE TRACERID_MOD,       ONLY : IDBCO2
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
The initial condition for CO2 has to be at least 50 ppm or higher or else
the balanced biosphere fluxes will make STT negative. (pns, bmy, 8/16/05)
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam - Initial version
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) We now get CO2 biomass emissions from biomass_mod.f.  This allows us
     to use either GFED2 or default Duncan et al biomass emissions.
     (bmy, 9/27/06)
(3 ) Tagged tracer capability added. This requires the editable region
     files Regions_land.dat and Regions_ocean.dat in the run directory
     (rnassar,dbj, 2009)
(4 ) New tracers for emissions from international and domestic shipping,
     international and domestic aviation, and the chemical CO2 source
     from the oxidation of CO, CH4, and other organics (rnassar,dbj, 2009)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.34.2 read_chemco2

Reads the chemical source of CO2 [molec/cm3/s] from disk.

INTERFACE:

```
SUBROUTINE READ_CHEMCO2
```

USES:

```
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE BPCH2_MOD,     ONLY : GET_MODELNAME, GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0,   READ_BPCH2
      USE TIME_MOD,      ONLY : GET_MONTH,  GET_YEAR

      USE CMN_SIZE_MOD      ! Size parameters
```

REMARKS:

REVISION HISTORY:

```
    18 May 2010 - R. Nassar, D. Jones - Initial version
```

1.34.3 read_fossilco2

Subroutine READ_FOSSILCO2 reads in fossil fuel CO2 emissions from a bpch file.

INTERFACE:

```
      SUBROUTINE READ_FOSSILCO2( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE BPCH2_MOD,          ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,          ONLY : GET_TAU0,        READ_BPCH2
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE TRANSFER_MOD,       ONLY : TRANSFER_2D
      USE TIME_MOD,           ONLY : GET_YEAR, GET_MONTH
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    Original data provided by Robert Andres (CDIAC), personal communication

    If GENFF=T, then annual data for 1995 are read (but tau is for 1985)
    If ANNFF=T, then annual data for a given year (1985-2006) are read
    If MONFF=T, then annual data for a given month (198501-200612) are read

    ANNFF and MONFF for 2007-2009 were developed based on scaling using
```

```
preliminary data on the CDIAC website for 2007-2008 and LeQuere et al.
(2009) for 2009

    -- Ray Nassar 2010-03-10
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
25 Feb 2011 - R. Nassar           - Now point to annual_v2010 and
                                    monthly_v2010 directories, which
                                    contain updated CO2 data from CDIAC
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.34.4 chem_surf

This subroutine reads the fossil fuel distribution from file to be used for part of the spatial distribution of the CO2 surface correction, based on a value of 4.89Suntharalingam et al. (2005).

INTERFACE:

```
SUBROUTINE CHEM_SURF( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE BPCH2_MOD,          ONLY : GET_TAU0,   READ_BPCH2
USE BPCH2_MOD,          ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE DIRECTORY_MOD,      ONLY : DATA_DIR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TRANSFER_MOD,       ONLY : TRANSFER_2D
USE TIME_MOD,           ONLY : GET_YEAR,GET_MONTH
USE GRID_MOD,           ONLY : GET_AREA_CM2
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
Methane source distribution are read for the same purpose from 2004 data
provided by Kevin Wecht.

Monoterpenes and Isoprene are read and treated as representative NMVOCs.

   -- Ray Nassar 2010-03-27
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
25 Feb 2011 - R. Nassar           - Now point to annual_v2010 and
                                    monthly_v2010 directories, which
                                    contain updated CO2 data from CDIAC
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.34.5 aviation_dom_corr

This subroutine downscales national fossil fuels emissions for the CO2 which is atttibuted to domestic aviation based on Kim et al. (2005,2007). It should only be used when the aviation emissions are turned on since these emissions will instead be emitted throughout the troposphere.

INTERFACE:

```
SUBROUTINE AVIATION_DOM_CORR( am_I_Root, Input_Opt, EMFOSS, RC )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_TAU0,        READ_BPCH2
USE BPCH2_MOD,          ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : DATA_DIR,        DATA_DIR_1x1
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TRANSFER_MOD,       ONLY : TRANSFER_2D
USE TIME_MOD,           ONLY : GET_YEAR,        ITS_A_LEAPYEAR
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options objec
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,         INTENT(INOUT) :: EMFOSS(IIPAR,JJPAR)  ! Fuel to be scaled
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

INPUT PARAMETERS:

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
25 Feb 2011 - R. Nassar           - Now point to annual_v2010 and
                                    monthly_v2010 directories, which
                                    contain updated CO2 data from CDIAC
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
05 Mar 2012 - M. Payer    - Add modifications for nested-grid CO2
                            (Yuxuan Wang, lmw)
06 Apr 2012 - M. Payer    - Changed regrid algorithm to map_a2a (M. Cooper)
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.34.6 read_oceanco2

Subroutine READ_OCEANCO2 reads in either

- Annual mean oceanic CO2 exchange from Takahashi 1997
- Annual mean oceanic CO2 exchange from Takahashi 2009
- Aonthly mean oceanic CO2 exchange from Takahashi 2009

from a binary punch file.

INTERFACE:

```
SUBROUTINE READ_OCEANCO2( am_I_Root, Input_Opt, RC )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,          ONLY : GET_TAU0,        READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : DATA_DIR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : GET_MONTH
USE TRANSFER_MOD,       ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
See References Above
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
25 Feb 2011 - R. Nassar           - Now point to annual_v2010 and
                                    monthly_v2010 directories, which
                                    contain updated CO2 data from CDIAC
25 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
```

1.34.7 read_annual_biofuelco2

Subroutine READ_ANNUAL_BIOFUELCO2 reads in annual mean biofuel CO2 emissions from a binary punch file.

INTERFACE:

```
SUBROUTINE READ_ANNUAL_BIOFUELCO2
```

USES:

```
! References to F90 modules
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR,        DATA_DIR_1x1  !(lmw,05/16/11)
USE TRANSFER_MOD,   ONLY : TRANSFER_2D
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

USE CMN_SIZE_MOD         ! Size parameters
```

REMARKS:

```
References:
(1 ) Yevich and Logan 2001 gridded (1x1) dataset in combination with
      emission factors for CO2 per kg drymatter burned
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
05 Mar 2012 - M. Payer            - Add modifications for nested-grid CO2
                                    (Yuxuan Wang, lmw)
06 Apr 2012 - M. Payer            - Changed regrid algorithm to map_a2a
                                    (M. Cooper)
24 May 2012 - R. Yantosca         - Fixed minor bugs in map_a2a calls
24 Aug 2012 - R. Yantosca         - DO_REGRID_A2A now reads netCDF input
03 Jan 2013 - M. Payer            - Renamed PERAREA to IS_MASS in
                                    DO_REGRID_A2A
```

1.34.8 read_shipco2_edgar

Subroutine READ_SHIPCO2_EDGAR reads in annual mean ship CO2 emissions from a binary punch file. Scaling is based on Endresen et al. (2007).

INTERFACE:

```
SUBROUTINE READ_SHIPCO2_EDGAR
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR, DATA_DIR_1x1
USE TRANSFER_MOD,   ONLY : TRANSFER_2D
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE GRID_MOD,       ONLY : GET_AREA_CM2
USE TIME_MOD,       ONLY : GET_YEAR

USE CMN_SIZE_MOD         ! Size parameters
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a impelementation
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.34.9 read_shipco2_icoads

Subroutine READ_SHIPCO2_ICOADS reads in ICOADS monthly ship CO2 emissions

INTERFACE:

```
SUBROUTINE READ_SHIPCO2_ICOADS
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR, DATA_DIR_1x1
USE TRANSFER_MOD,   ONLY : TRANSFER_2D
USE FILE_MOD,       ONLY : IOERROR
USE TIME_MOD,       ONLY : GET_YEAR, GET_MONTH
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

USE CMN_SIZE_MOD         ! Size parameters
```

REMARKS:

```
This subroutine reads from bpch files at GEOS 1x1 (half-polar) resolution
although the original data are provided as 0.1 deg x 0.1 deg. Regridding to
the current resolution is carried out in the code.
                                                                             .
References:
(1) Corbett and Koehler (2003) "Updated emissions from ocean shipping",
     JGR 108, D20, 4650.
(2) Corbett and Koehler (2004) "Considering alternative input parameters in
     an activity-based ship fuel consumption and emissions model: Reply ..."
     JGR, 109, D23303.
(3) Endresen et al. (2007) "A historical reconstruction of ships fuel
     consumption and emissions", JGR, 112, D12301.
                                                                             .
NOTE: The Corbett website values do not sum to the values in any Corbett
et al. or Wang (2008) papers. It is not clear if this relates to the
ongoing dispute between Corbett et al.(2003,2004) and Endresen et al.
(2003,2004,2007)
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.34.10 read_aviation_co2

Subroutine READ_AVIATION_CO2 reads monthly mean aircraft fuel emissions and converts them to CO2 emissions.

INTERFACE:

```
SUBROUTINE READ_AVIATION_CO2( State_Met )
```

USES:

```
! Reference to F90 modules
USE BPCH2_MOD,          ONLY : GET_RES_EXT, GET_TAU0, READ_BPCH2
USE DIRECTORY_MOD,      ONLY : DATA_DIR
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_MONTH, GET_YEAR

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REMARKS:

```
    This is a modified version of READ_AIRCRAFT_SO2 from:
                                            rjp, bdf, bmy, 9/18/02, 10/3/05
                                                                            .
    The sulfate data are based on an inventory by the Atmospheric Effects of
    Aviation Project (AEAP) for the year 1992.
                                                                            .
    CO2 emission factor of 3155 g/kg fuel was taken from
    (1) Kim et al. (2005) System for assessing Aviation's Global Emissions
         (SAGE) Federal Aviation Administration Office of Environment and
         Energy Version 1.5 (FAA-EE-2005-02), Global Aviation Emissions
         Inventories for 2000 through 2004.
    (2) Kim et al. (2007) System for assessing Aviation's Global Emissions
         (SAGE) Part 1: Model description and inventory results
```

REVISION HISTORY:

```
    (1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
    (2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
    (3 ) Now read files from "sulfate_sim_200508/".  Now read data for both
          GCAP and GEOS grids (bmy, 8/16/05)
    (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (6 ) Reading of GlobPTot values from input.geos has not yet been implemented
    18 May 2010 - R. Nassar, D. Jones - Initial version
    01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
    03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
```

1.34.11 read_annual_bionet_co2

Subroutine READ_ANNUAL_BIONET_CO2 reads in annual mean values of for Net Terrestrial exchange from a binary punch file.

INTERFACE:

```
      SUBROUTINE READ_ANNUAL_BIONET_CO2( am_I_Root, Input_Opt, RC )
```

USES:

```
      ! References to F90 modules
      USE BPCH2_MOD,          ONLY : GET_NAME_EXT_2D,   GET_RES_EXT
      USE BPCH2_MOD,          ONLY : GET_TAU0,          READ_BPCH2
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD,      ONLY : DATA_DIR,          DATA_DIR_1x1
```

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE FILE_MOD,           ONLY : IOERROR
USE TRANSFER_MOD,       ONLY : TRANSFER_2D
USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
The two choices are:
(1 ) Old Net Terrestrial Exchange for Year 2000 from David Baker
      (pers. comm.) from undocumented Transcom 3 inversion results
(2 ) New Baker et al [2006] Transcom 3 climatology 1991-2000 minus
     GFEDv2 climatology 1997-2007.

References:
(1 ) Baker et al. (2006), Transcom3 inversion intercomparison: Impact of
      Transport model errors on the interannual vaiability of regional CO2
      fluxes, 1988-2003, Glob. Biogeochem. Cycles, 20, GB1002.
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
05 Mar 2012 - M. Payer            - Add modifications for nested-grid CO2
                                    (Yuxuan Wang, lmw)
06 Apr 2012 - M. Payer            - Changed regrid algorithm to map_a2a
                                    (M. Cooper)
24 May 2012 - R. Yantosca         - Fix minor bugs in map_a2a calls
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
 2 Oct 2012 - R. Yantosca - Bug fix, the terrestrial exchange file is
                            placed on the generic grid, not geos grid
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.34.12 read_bbio_dailyaverage

Subroutine READ_DAILY_BBIO_CO2 reads in daily values for balanced biospheric exchange from a binary punch file.

INTERFACE:

```
SUBROUTINE READ_BBIO_DAILYAVERAGE( MONTH, DAY, DOY )
```

USES:

```
! References to F90 modules
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
USE TIME_MOD,      ONLY : GET_YEAR,        ITS_A_LEAPYEAR

USE CMN_SIZE_MOD      ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: MONTH   ! Current month (1-12)
INTEGER, INTENT(IN) :: DAY     ! Current day (1-31)
INTEGER, INTENT(IN) :: DOY     ! Current day of year (0-366)
```

REMARKS:

```
Data Source: CASA gridded (1x1) dataset for from M. Thompson
Monthly values interpolated to daily values : 365 daily files
NB : These files DO NOT have the diurnal cycle in daily emissions
See routine ' ' to read in files with diurnal cycle imposed
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Added fixes for leapyears
```

1.34.13 read_bbio_diurnalcycle

Subroutine READ_BBIO_DIURNALCYCLE reads CASA daily Net Ecosystem Production (NEP) fluxes but with a diurnal cycle imposed.

INTERFACE:

```
SUBROUTINE READ_BBIO_DIURNALCYCLE( MONTH, DAY, HOUR, DOY )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
USE TIME_MOD,      ONLY : GET_YEAR, ITS_A_LEAPYEAR

USE CMN_SIZE_MOD      ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: MONTH   ! Current month (1-12)
INTEGER, INTENT(IN) :: DAY     ! Current day (1-31)
INTEGER, INTENT(IN) :: HOUR    ! Current hour (0-23)
INTEGER, INTENT(IN) :: DOY     ! Current day of year (0-365)
```

REMARKS:

```
References
(1 ) Olsen and Randerson (2004), Differences between surface and column
      atmospheric CO2 and implications for carbon cycle research, J.
      Geophys. Res., 109, D02301,
(2 ) Potter et al. (1993), terrestrial Ecosystem Production: A process
      model based on global satellite and surface data, Glob. Biogeochem.
      Cycles, 7(4), 811-841.
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Added fixes for leapyears
```

1.34.14 total_biomass_tg

Subroutine TOTAL_BIOMASS_Tg prints the amount of biomass burning emissions that are emitted each month in Tg or Tg

INTERFACE:

```
SUBROUTINE TOTAL_BIOMASS_Tg( BBARRAY, MOLWT, NAME )
```

USES:

```
USE GRID_MOD, ONLY : GET_AREA_CM2

USE CMN_SIZE_MOD  ! Size parameters
```

INPUT PARAMETERS:

```
REAL*8,           INTENT(IN) :: MOLWT                ! Mol wt [kg/mole]
CHARACTER(LEN=*), INTENT(IN) :: NAME                 ! Species name
REAL*8,           INTENT(IN) :: BBARRAY(IIPAR,JJPAR) ! BB Emissions
                                                     ! [molec/cm2/month]
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Updated
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.34.15 def_biosph_co2_regions_f

Subroutine DEF_BIOSPH_CO2_REGIONS defines the land biospheric and ocean CO2 exchange regions.

INTERFACE:

```
SUBROUTINE DEF_BIOSPH_CO2_REGIONS_F( REGION )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IOERROR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD      ! Size parameters
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT)   :: REGION(IIPAR,JJPAR)
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%!
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

1.34.16 def_ocean_co2_regions_f

Subroutine DEF_OCEAN_CO2_REGIONS defines CO2 regions for ocean exchange.

INTERFACE:

```
SUBROUTINE DEF_OCEAN_CO2_REGIONS_F( REGION )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IOERROR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD      ! Size parameters
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT)  :: REGION(IIPAR,JJPAR)
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%!
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

1.34.17 def_fossil_co2_regions_f

Subroutine DEF_FOSSIL_CO2_REGIONS defines CO2 regions for anthropogenic emissions

INTERFACE:

```
SUBROUTINE DEF_FOSSIL_CO2_REGIONS_F( REGION )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IOERROR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD      ! Size parameters
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT)   :: REGION(IIPAR,JJPAR)
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%!
```

REVISION HISTORY:

```
18 May 2010 - R. Nassar, D. Jones - Initial version
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

1.34.18 init_co2

Subroutine INIT_CO2 allocates memory to module arrays and reads in annual mean emissions.

INTERFACE:

```
SUBROUTINE INIT_CO2( am_I_Root, Input_Opt, RC )
```

USES:

```
! References to F90 modules
USE CMN_SIZE_MOD
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE ERROR_MOD,          ONLY : ALLOC_ERR
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
25 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
```

1.34.19 cleanup_co2

Subroutine CLEANUP_CO2 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_CO2
```

REVISION HISTORY:

```
16 Aug 2005 - P. Suntharalingam   - Initial version
18 May 2010 - R. Nassar, D. Jones - Updated
```

1.35 Fortran: Module Interface comode_mod

Module COMODE_MOD contains allocatable arrays for SMVGEAR that were previously contained in common blocks in header file "comode.h".

INTERFACE:

```
MODULE COMODE_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
!=========================================================================
! ABSHUM    : array for absolute humidity [H2O molec/cm3]
! AIRDENS   : array for air density [molec/cm3]
! CSPEC     : array of chemical species concentration [molec/cm3]
! CSPEC_FULL: array of chemical species for full potential troposphere
! CSUMA     : array for time of sunrise/sunset, from midnight [s]
! CSUMC     : array for temporary storage
! ERADIUS   : array for aerosol or dust radii [cm]
! ERRMX2    : array for storing stiffness values
! IXSAVE    : array of grid box longitude indices
! IYSAVE    : array of grid box latitude indices
! IZSAVE    : array of grid box altitude indices
! JLOP      : array of 1-D grid box indices
! PRESS3    : array for grid box pressure [mb]
! REMIS     : array for emissions from GEOS-CHEM [molec/cm3]
! T3        : array for grid box temperature [K]
! TAREA     : array for surface area of aerosol or dust [cm2/cm3]
! VOLUME    : array for grid box volume [cm3]
!=========================================================================
REAL*8,  ALLOCATABLE, PUBLIC :: ABSHUM(:)
REAL*8,  ALLOCATABLE, PUBLIC :: AIRDENS(:)
REAL*8,  ALLOCATABLE, PUBLIC :: CSPEC(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: CSUMA(:)
REAL*8,  ALLOCATABLE, PUBLIC :: CSUMC(:)
REAL*8,  ALLOCATABLE, PUBLIC :: ERADIUS(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: ERRMX2(:)
INTEGER, ALLOCATABLE, PUBLIC :: IXSAVE(:)
INTEGER, ALLOCATABLE, PUBLIC :: IYSAVE(:)
INTEGER, ALLOCATABLE, PUBLIC :: IZSAVE(:)
INTEGER, ALLOCATABLE, PUBLIC :: JLOP(:,:,:)
INTEGER, ALLOCATABLE, PUBLIC :: JLOP_PREVIOUS(:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: PRESS3(:)
REAL*8,  ALLOCATABLE, PUBLIC :: REMIS(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: T3(:)
```

```
REAL*8,  ALLOCATABLE, PUBLIC :: TAREA(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: VOLUME(:)
REAL*8,  ALLOCATABLE, PUBLIC :: WTAREA(:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: WERADIUS(:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CLEANUP_COMODE
PUBLIC :: INIT_COMODE
```

REMARKS:

```
In case you were wondering, "comode" stands for:
   "COMmon blocks: Ordinary Differential Equations"
```

REVISION HISTORY:

```
31 Aug 2000 - R. Yantosca - Initial version
(1 ) Now zero CSPEC after allocating memory (bmy, 9/8/00)
(2 ) Now declare more SMVGEAR arrays allocatable (bmy, 10/19/00)
(3 ) Updated comments (bmy, 9/4/01)
(4 ) Now make ERADIUS, TAREA 2-D arrays, for het chem (bmy, 11/15/01)
(5 ) DARSFCA is now obsolete, remove it.  Now allocate ERADIUS and
      TAREA arrays to be of size (ITLOOP,NDUST+NAER).  (rvm, bmy, 2/27/02)
(5 ) Removed obsolete code from 2/02 (bmy, 4/15/02)
(6 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
      MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(7 ) Now references "error_mod.f" (bmy, 10/15/02)
(8 ) Now add CSUMA, CSUMC, ERRMX2 arrays for SMVGEAR II (bmy, 7/18/03)
(9 ) Now also references "tracer_mod.f" (bmy, 9/28/04)
(10) Add WTAREA and WERADIUS variables.
     For SOA production from reactive uptake of dicarbonyls,
     archived WTAREA and WERADIUS should include dusts,
     but excludes BCPO and OCPO (tmf, ccc, 1/7/09)
(11) Added 3 *_KPP arrays (phs,ks,dhk, 09/15/09)
(12) Removed 3 *_KPP arrays (phs, 09/16/09)
21 Dec 2010 - R. Yantosca - Added ProTeX headers
04 Apr 2013 - R. Yantosca - Removed CSPEC_FULL (now in State_Chm)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.35.1 init_comode

Subroutine INIT_COMODE allocates memory for allocatable arrays that were previously contained in common blocks in "comode.h".

INTERFACE:

```
SUBROUTINE INIT_COMODE( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_LOOP_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
31 Aug 2000 - R. Yantosca - Initial version
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
(2 ) Cosmetic chagnes (bmy, 2/27/03)
(3 ) Now allocate CSUMA, CSUMC, ERRMX2; cosmetic changes (bmy, 7/18/03)
(4 ) Now allocate certain arrays for offline aerosol sim (bmy, 9/28/04)
21 Dec 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
13 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC arguments for GIGC
04 Apr 2013 - R. Yantosca - Removed CSPEC_FULL (now in State_Chm)
```

1.35.2 cleanup_comode

Subroutine CLEANUP_COMODE deallocates memory from allocatable arrays that were previously contained in common blocks in "comode.h"

INTERFACE:

```
SUBROUTINE CLEANUP_COMODE()
```

REVISION HISTORY:

```
31 Aug 2000 - R. Yantosca - Initial version
(1 ) Now deallocate CSPEC, CSUMA, ERRMX2; cosmetic changes (bmy, 7/18/03)
21 Dec 2010 - R. Yantosca - Added ProTeX headers
13 Nov 2012 - R. Yantosca - Cosmetic changes
 4 Apr 2013 - R. Yantosca - Removed CSPEC_FULL (now in State_Chm)
```

1.36 Fortran: Module Interface convection_mod

Module CONVECTION_MOD contains routines which select the proper convection code for GEOS-3, GEOS-4, GEOS-5, MERRA, or GCAP met field data sets.

INTERFACE:

```
MODULE CONVECTION_MOD
```

USES:

```
USE GC_TYPE_MOD
USE GIGC_ERRCODE_MOD
USE SMV_PHYSCONST_MOD

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: DO_CONVECTION
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: DO_GEOS4_CONVECT
PRIVATE :: DO_GCAP_CONVECT
PRIVATE :: NFCLDMX
PRIVATE :: DO_MERRA_CONVECTION
```

REVISION HISTORY:

```
27 Jan 2004 - R. Yantosca - Initial version
(1 ) Contains new updates for GEOS-4/fvDAS convection.  Also now references
     "error_mod.f".  Now make F in routine NFCLDMX a 4-D array to avoid
     memory problems on the Altix. (bmy, 1/27/04)
(2 ) Bug fix: Now pass NTRACE elements of TCVV to FVDAS_CONVECT in routine
     DO_CONVECTION (bmy, 2/23/04)
(3 ) Now references "logical_mod.f" and "tracer_mod.f" (bmy, 7/20/04)
(4 ) Now also references "ocean_mercury_mod.f" and "tracerid_mod.f"
     (sas, bmy, 1/19/05)
(5 ) Now added routines DO_GEOS4_CONVECT and DO_GCAP_CONVECT by breaking
     off code from DO_CONVECTION, in order to implement GCAP convection
     in a much cleaner way. (swu, bmy, 5/25/05)
(6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(7 ) Shut off scavenging in shallow convection for GCAP (swu, bmy, 11/1/05)
(8 ) Modified for tagged Hg simulation (cdh, bmy, 1/6/06)
(9 ) Bug fix: now only call ADD_Hg2_WD if LDYNOCEAN=T (phs, 2/8/07)
(10) Fix for GEOS-5 met fields in routine NFCLDMX (swu, 8/15/07)
(11) Resize DTCSUM array in NFCLDMX to save memory (bmy, 1/31/08)
13 Aug 2010 - R. Yantosca - Added ProTeX headers
```

```
    13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as for GEOS-5
    29 Sep 2010 - R. Yantosca - Added modifications for MERRA
    05 Oct 2010 - R. Yantosca - Added ND14 and ND38 diagnostics to
                                DO_MERRA_CONVECTION routine
    16 Aug 2011 - J. Fisher   - Minor bug fixes in DO_MERRA_CONVECTION
    15 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
    28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
    02 Mar 2012 - R. Yantosca - Now reference the new grid_mod.F90
    22 Oct 2012 - R. Yantosca - Now reference Headers/gigc_errcode_mod.F90
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.36.1 do_convection

Subroutine DO_CONVECTION calls the appropriate convection driver program for different met field data sets.

INTERFACE:

```
      SUBROUTINE DO_CONVECTION( am_I_Root, Input_Opt,
     &                          State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : CONVFLUP
      USE DIAG_MOD,           ONLY : AD38
      USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_M2
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE TRACERID_MOD,       ONLY : IDTHg2
      USE TRACERID_MOD,       ONLY : IDTHgP
      USE TIME_MOD,           ONLY : GET_TS_DYN
      USE WETSCAV_MOD,        ONLY : COMPUTE_F
      USE WETSCAV_MOD,        ONLY : H2O2s
      USE WETSCAV_MOD,        ONLY : SO2s
#if   defined( APM )
      USE TRACER_MOD,         ONLY : N_APMTRA
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
25 May 2005 - S. Wu       - Initial version
08 Feb 2007 - R. Yantosca - Now reference "CMN_SIZE".  Now references
                            CLDMAS, CMFMC, DTRAIN from "dao_mod.f" so that
                            we can pass either GEOS-5 or GEOS-3 meteorology
                            to NFCLDMX.
13 Aug 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as for GEOS-5
29 Sep 2010 - R. Yantosca - Now call DO_MERRA_CONVECTION for MERRA met
05 Oct 2010 - R. Yantosca - Now attach diagnostics to MERRA conv routine
06 Oct 2010 - R. Yantosca - Parallelized call to DO_MERRA_CONVECTION
15 Oct 2010 - H. Amos     - Now get BXHEIGHT, T from dao_mod.f
15 Oct 2010 - R. Yantosca - Now get LDYNOCEAN from logical_mod.f
15 Oct 2010 - R. Yantosca - Now get ITS_A_MERCURY_SIM from tracer_mod.f
15 Oct 2010 - R. Yantosca - Now get IDTHg2, IDTHgP from tracerid_mod.f
15 Oct 2010 - R. Yantosca - Now get H2O2s, SO2s from wetscav_mod.f
15 Oct 2010 - H. Amos     - Now pass BXHEIGHT, T, to DO_MERRA_CONVECTION
15 Oct 2010 - R. Yantosca - Now pass H2O2s, SO2s to DO_MERRA_CONVECTION
15 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
29 Aug 2011 - R. Yantosca - Bug fix: reposition #if defined(APM) statement
09 Feb 2012 - R. Yantosca - For GEOS-5.7, PFICU and PFLCU fields are
                            defined on level edges.  Pass the top edge
                            of each level to DO_MERRA_CONVECTION
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
21 Jun 2012 - R. Yantosca - Now use poiners to pass array slices to routines
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
04 Feb 2013 - S. Kim      - Bug fix: H2O2s, SO2s, STT are not in State_Met
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
31 May 2013 - R. Yantosca - Now pass objects to NFCLDMX
03 Jun 2013 - R. Yantosca - Bug fix: pass State_Chm to DO_MERRA_CONVECTION
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.36.2 do_geos4_convect

Subroutine DO_GEOS4_CONVECT is a wrapper for the GEOS-4/fvDAS convection code. This was broken off from the old DO_CONVECTION routine above.

INTERFACE:

```
      SUBROUTINE DO_GEOS4_CONVECT( am_I_Root, Input_Opt,
     &                             State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD37
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE FVDAS_CONVECT_MOD,  ONLY : INIT_FVDAS_CONVECT, FVDAS_CONVECT
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE TIME_MOD,           ONLY : GET_TS_CONV
      USE WETSCAV_MOD,        ONLY : COMPUTE_F
#if   defined( APM )
      USE TRACER_MOD,         ONLY : N_APMTRA
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   25 May 2005 - S. Wu       - Initial version
   (1 ) Now use array masks to flip arrays vertically in call to FVDAS_CONVECT
        (bmy, 5/25/05)
   (2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (3 ) Add a check to set negative values in STT to TINY (ccc, 4/15/09)
   13 Aug 2010 - R. Yantosca - Added ProTeX headers
   15 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
   09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                               derived type object
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.36.3 do_gcap_convect

Subroutine DO_GCAP_CONVECT is a wrapper for the GCAP convection code. This was broken off from the old DO_CONVECTION routine above.

INTERFACE:

```
      SUBROUTINE DO_GCAP_CONVECT( am_I_Root, Input_Opt,
     &                            State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD37
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE GCAP_CONVECT_MOD,   ONLY : GCAP_CONVECT
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PRESSURE_MOD,       ONLY : GET_PEDGE, GET_PCENTER
      USE TIME_MOD,           ONLY : GET_TS_CONV
      USE WETSCAV_MOD,        ONLY : COMPUTE_F
#if   defined( APM )
      USE TRACER_MOD,         ONLY : N_APMTRA
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   25 May 2005 - S. Wu       - Initial version
   (1 ) Now use array masks to flip arrays vertically in call to GCAP_CONVECT
        (bmy, 5/25/05)
   (2 ) Shut off scavenging in shallow convection for GCAP below 700 hPa
        (swu, bmy, 11/1/05)
   (3 ) Add a check to set negative values in STT to TINY (ccc, 4/15/09)
   13 Aug 2010 - R. Yantosca - Added ProTeX headers
   15 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
```

```
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
04 Nov 2013 - M. Sulprizio- Now use pointer variables to flip met fields in
                            the vertical
```

1.36.4 nfcldmx

Subroutine NFCLDMX is S-J Lin's cumulus transport module for 3D GSFC-CTM, modified for the GEOS-Chem model. The "NF" stands for "no flipping", and denotes that you don't have to flip the tracer array Q in the main program before passing it to NFCLDMX.

NOTE: NFCLDMX can be used with GEOS-1, GEOS-STRAT, and GEOS-3 met fields. For GEOS-4/fVDAS, you must use the routines in "fvdas_convect_mod.f"

INTERFACE:

```
      SUBROUTINE NFCLDMX( am_I_Root, Input_Opt, CLDMAS,
     &                    DTRN,      State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DEPO_MERCURY_MOD,   ONLY : ADD_Hg2_WD
      USE DEPO_MERCURY_MOD,   ONLY : ADD_HgP_WD
      USE DEPO_MERCURY_MOD,   ONLY : ADD_Hg2_SNOWPACK
      USE DIAG_MOD,           ONLY : AD37
      USE DIAG_MOD,           ONLY : AD38
      USE DIAG_MOD,           ONLY : CONVFLUP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_M2
      USE PRESSURE_MOD,       ONLY : GET_BP
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE TIME_MOD,           ONLY : GET_TS_CONV
      USE TRACER_MOD,         ONLY : ITS_A_MERCURY_SIM
      USE TRACERID_MOD,       ONLY : IS_Hg2
      USE TRACERID_MOD,       ONLY : IS_HgP
      USE WETSCAV_MOD,        ONLY : COMPUTE_F
      USE ERROR_MOD,          ONLY : ALLOC_ERR

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
! Are we on the root CPU
LOGICAL,        INTENT(IN)    :: am_I_Root

! CLDMAS : Cloud mass flux (at upper edges of each level) [kg/m2/s]
REAL*8,         INTENT(IN)    :: CLDMAS(IIPAR,JJPAR,LLPAR)

! Detrainment mass flux [kg/m2/s]
REAL*8,         INTENT(IN)    :: DTRN(IIPAR,JJPAR,LLPAR)

TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REMARKS:

```
(1) The "NF" stands for "no flipping", and denotes that you don't have to
flip the tracer array Q in the main program before passing it to NFCLDMX.
(bmy, 2/12/97, 1/31/08)
(2) This version has been customized to work with GEOS-5 met fields.
Reference:
============================================================================
Lin, SJ.  "Description of the parameterization of cumulus transport
   in the 3D Goddard Chemistry Transport Model, NASA/GSFC, 1996.
Vertical indexing:
============================================================================
The indexing of the vertical sigma levels has been changed from
SJ-Lin's original code:
              Old Method          New Method
               (SJ Lin)
             ------------------------------------ Top of Atm.
                k = 1               k = NLAY
             ==================================== Max Extent
                k = 2               k = NLAY-1      of Clouds
             ------------------------------------


                 ...                 ...
             ------------------------------------
                k = NLAY-3          k = 4
             ------------------------------------
                k = NLAY-2          k = 3
             ------------------------------------ Cloud base
                k = NLAY-1          k = 2
```

```
            -    -    -    -    -    -    -    -
               k = NLAY            k = 1
            ==================================== Ground
    which means that:
                Old Method                      New Method
                 (SJ Lin)
          k-1      ^                     k+1      ^
          ---------|---------             ---------|---------
                   |                               |
                 CMFMC(k)                        CMFMC(k)

                                 becomes
          k     DTRAIN(k),                k     DTRAIN(k),
                QC(k), Q(k)                     QC(k), Q(k)

                   ^                               ^
          ---------|---------             ---------|---------
                   |                               |
          k+1   CMFMC(k+1)                k-1   CMFMC(k-1)
    i.e., the lowest level    used to be  NLAY  but is now  1
          the level below k   used to be  k+1   but is now  k-1.
          the level above k   used to be  k-1   but is now  k+1
          the top of the atm. used to be  1     but is now  NLAY.
The old method required that the vertical dimensions of the CMFMC, DTRAIN,
and Q arrays had to be flipped before and after calling CLDMX.  Also,
diagnostic arrays generated within CLDMX also had to be flipped.  The new
indexing eliminates this requirement (and also saves on array operations).
Major Modifications:
=============================================================================
Original Author:   Shian-Jiann Lin, Code 910.3, NASA/GSFC
Original Release:  12 February 1997
                   Version 3, Detrainment and Entrainment are considered.
                   The algorithm reduces to that of version 2 if Dtrn = 0.
                                                                             .
Modified By:       Bob Yantosca, for Harvard Atmospheric Sciences
Modified Release:  27 January 1998
                   Version 3.11, contains features of V.3 but also
                   scavenges soluble tracer in wet convective updrafts.
                                                                             .
                   28 April 1998
                   Version 3.12, now includes mass flux diagnostic
                                                                             .
                   11 November 1999
                   Added mass-flux diagnostics
                                                                             .
                   04 January 2000
                   Updated scavenging constant AS2
                                                                             .
```

```
14 March 2000
Added new wet scavenging code and diagnostics
based on the GMI algorithm

02 May 2000
Added parallel loop over tracers!
```

REVISION HISTORY:

```
12 Feb 1997 - M. Prather  - Initial version
(1 ) NFCLDMX is written in Fixed-Form Fortran 90.
(2 ) Added TCVV to the argument list.  Also cleaned up argument
     and local variable declarations. (bey, bmy, 11/10/99)
(3 ) AD38 and CONVFLUP are now declared allocatable in "diag_mod.f".
     (bmy, 11/29/99)
(4 ) Bug fix for tagged CO tracer run (bey, bmy, 1/4/00)
(5 ) Add new routines for computing scavenging coefficients,
     as well as adding the AD37 diagnostic array. (bmy, 3/14/00)
(6 ) Updated comments (bmy, 10/2/01)
(7 ) Now print a header to stdout on the first call, to confirm that
     NFCLDMX has been called (bmy, 4/15/02)
(8 ) Remove PZ from the arg list -- it isn't used! (bmy, 8/22/02)
(9 ) Fixed ND38 diagnostic so that it now reports correctly (must divide
     by DNS).  Updatec comments, cosmetic changes. (bmy, 1/27/03)
(10) Bug fix: remove duplicate K from PRIVATE declaration (bmy, 3/23/03)
(11) Now removed all arguments except NC, TCVV, Q from the arg list -- the
     other arguments can be supplied via F90 modules.  Now references
     "dao_mod.f", "grid_mod.f", "pressure_mod.f", and "time_mod.f".
     (bmy, 3/27/03)
(12) Bundled into "convection_mod.f" (bmy, 6/26/03)
(13) Make sure K does not go out of bounds in ND38 diagnostic.  Now make
     F a 4-D array in order to avoid memory problems on the Altix.
     (bmy, 1/27/04)
(14) Now references both "ocean_mercury_mod.f" and "tracerid_mod.f".
     Now call ADD_Hg2_WD from "ocean_mercury_mod.f" to pass the amt of Hg2
     lost by wet scavenging (sas, bmy, 1/19/05)
(15) Now references IS_Hg2 from "tracerid_mod.f".  Now pass tracer # IC
     to ADD_Hg2_WD. (cdh, bmy, 1/6/06)
(16) Bug fix: now only call ADD_Hg2_WD if LDYNOCEAN=T (phs, 2/8/07)
(17) Now make CLDMAS, DTRN as arguments, so that we can pass either
     GEOS-3 or GEOS-3 met data.  Redimension DTCSUM with NC instead of
     NNPAR.  In many cases, NC is less than NNPAR and this will help to
     save memory especially when running at 2x25 or greater resolution
     (bmy, 1/31/08)
(18) Add a check to set negative values in Q to TINY (ccc, 4/15/09)
(19) Updates for mercury simulation (ccc, 5/17/10)
13 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

```
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
29 May 2013 - R. Yantosca - Now set TINY = 1d-60 only for TOMAS code
31 May 2013 - R. Yantosca - Now pass State_Chm and then have Q point to
                            State_Chm%Tracers.  This is for TOMAS.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
04 Feb 2014 - R. Yantosca - Bug fix for TOMAS: call COMPUTE_F In its own
                            separate parallel loop.  Also save the values
                            of ISOL in the ISOL_SAVE array so that we can
                            pass them to the parallel tracer loop.
```

1.36.5 do_merra_convection

Subroutine DO_MERRA_CONVECTION (formerly called NFCLDMX) is S-J Lin's cumulus transport module for 3D GSFC-CTM, modified for the GEOS-Chem model.

INTERFACE:

```
 SUBROUTINE DO_MERRA_CONVECTION( IDENT,    DIMINFO,  COEF,
&                                IDT,      OPTIONS,  AD,
&                                AREA_M2,  BXHEIGHT, CMFMC,
&                                DQRCU,    DTRAIN,   F,
&                                PEDGE,    PFICU,    PFLCU,
&                                REEVAPCN, T,        TS_DYN,
&                                Q,        DIAG14,   DIAG38,
&                                H2O2s,    SO2s,     I,
&                                J,        RC,       State_Met,
&                                State_Chm                     )
```

USES:

```
USE DEPO_MERCURY_MOD,   ONLY : ADD_Hg2_SNOWPACK
USE DEPO_MERCURY_MOD,   ONLY : ADD_Hg2_WD
USE DEPO_MERCURY_MOD,   ONLY : ADD_HgP_WD
USE ERROR_MOD,          ONLY : IT_IS_NAN, IT_IS_FINITE
USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP  ! hma Nov 3, debug
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE TRACERID_MOD,       ONLY : IS_Hg2
USE TRACERID_MOD,       ONLY : IS_HgP
USE WETSCAV_MOD,        ONLY : WASHOUT
USE WETSCAV_MOD,        ONLY : LS_K_RAIN
USE WETSCAV_MOD,        ONLY : LS_F_PRIME
```

INPUT PARAMETERS:

```
TYPE(SPEC_2_TRAC), INTENT(IN) :: COEF        ! Obj w/ spec <-> trac map
```

```
      TYPE(GC_DIMS),     INTENT(IN) :: DIMINFO     ! Obj w/ array dimensions
      TYPE(ID_TRAC),     INTENT(IN) :: IDT         ! Obj w/ tracer ID flags
      TYPE(GC_OPTIONS),  INTENT(IN) :: OPTIONS     ! Obj w/ logical switches
      TYPE(MetState),    INTENT(IN) :: State_Met   ! Meteorology State object
      REAL*8,            INTENT(IN) :: AD(:)       ! Air mass [kg]
      REAL*8,            INTENT(IN) :: AREA_M2     ! Surface area [m2]
      REAL*8,            INTENT(IN) :: BXHEIGHT(:) ! Box height [m]
      REAL*8,            INTENT(IN) :: CMFMC(:)    ! Cloud mass flux [kg/m2/s]
      REAL*8,            INTENT(IN) :: DQRCU(:)    ! Precip production rate:
                                                   !  convective [kg/kg/s]
      REAL*8,            INTENT(IN) :: DTRAIN(:)   ! Detrainment flux [kg/m2/s]
      REAL*8,            INTENT(IN) :: F(:,:)      ! Fraction of soluble tracer
                                                   !  for updraft scavenging
                                                   !  [unitless].  ! This is
                                                   !  computed by routine
                                                   !  COMPUTE_UPDRAFT_FSOL
      REAL*8,            INTENT(IN) :: PEDGE(:)    ! P @ level box edges [hPa]
      REAL*8,            INTENT(IN) :: PFICU(:)    ! Dwnwd flux of convective
                                                   !  ice precip [kg/m2/s]
      REAL*8,            INTENT(IN) :: PFLCU(:)    ! Dwnwd flux of convective
                                                   !  liquid precip [kg/m2/s]
      REAL*8,            INTENT(IN) :: REEVAPCN(:) ! Evap of precip'ing conv.
                                                   !  condensate [kg/kg/s]
      REAL*8,            INTENT(IN) :: T(:)        ! air temperature [K]
      REAL*8,            INTENT(IN) :: TS_DYN      ! Dynamic timestep [min]
      INTEGER,           INTENT(IN) :: I, J        ! Lon & lat indices
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
      TYPE(GC_IDENT), INTENT(INOUT) :: IDENT       ! Obj w/ info from ESMF etc.
      REAL*8,         INTENT(INOUT) :: H2O2s(:)
      REAL*8,         INTENT(INOUT) :: SO2s(:)
      REAL*8,         INTENT(INOUT) :: Q(:,:)      ! Tracer conc. [mol/mol]
```

OUTPUT PARAMETERS:

```
      REAL*8,           INTENT(OUT) :: DIAG14(:,:) ! Array for ND14 diagnostic
      REAL*8,           INTENT(OUT) :: DIAG38(:,:) ! Array for ND38 diagnostic
      INTEGER,          INTENT(OUT) :: RC          ! Return code
```

REMARKS:

```
    Reference:
    ============================================================================
    Lin, SJ.  "Description of the parameterization of cumulus transport
       in the 3D Goddard Chemistry Transport Model, NASA/GSFC, 1996.
```

.

```
Unit conversion for BMASS:
    Ps - Pt (mb)| P2 - P1 | 100 Pa |  s^2  | 1  |  1 kg        kg
   -------------+---------+--------+-------+----+--------  =  -----
                | Ps - Pt |   mb   | 9.8 m | Pa | m^2 s^2      m^2

NOTE: We are passing I & J down to this routine so that it can call the
proper code from "mercury_mod.f".  Normally, we wouldn't pass I & J as
arguments to columnized code.  This prevents rewriting the mercury_mod.f
routines ADD_Hg2_
```

REVISION HISTORY:

```
15 Jul 2009 - R. Yantosca - Columnized and cleaned up.
                          - CLDMAS renamed to CMFMC and DTRN renamed
                            to DTRAIN for consistency w/ GEOS-5.
17 Jul 2009 - R. Yantosca - Now do unit conversion of Q array from
                            [kg] --> [v/v] and vice versa internally
14 Dec 2009 - R. Yantosca - Now remove internal unit conversion, since
                            Q now comes in as [mol/mol] (=[v/v]) from the
                            calling routine.
14 Dec 2009 - R. Yantosca - Remove COEF from the argument list
06 May 2010 - R. Yantosca - Now add IDENT via the argument list
29 Sep 2010 - R. Yantosca - Modified for MERRA met fields
05 Oct 2010 - R. Yantosca - Now pass COEF via the argument list
05 Oct 2010 - R. Yantosca - Attach ND14 and ND38 diagnostics
15 Oct 2010 - H. Amos     - Added BXHEIGHT and T as arguments
15 Oct 2010 - R. Yantosca - Added I, J, H2O2s and SO2s as arguments
15 Oct 2010 - H. Amos     - Added scavenging below cloud base
06 Apr 2011 - M.Fu, H.Amos- Bug fix: make sure washout adheres to the same
                            algorithm as in the wet deposition code.
27 Jul 2011 - R. Yantosca - Declare CLDBASE as INTEGER to avoid PGI errors
16 Aug 2011 - J. Fisher   - Bug fix: use IS_Hg2() and IS_HgP to test if
                            a tracer is Hg2 or HgP (for tagged species)
16 Aug 2011 - J. Fisher   - Now use WETLOSS instead of TO_SUM in the ND38
                            diagnostic below the cloud.  Using TO_SUM leads
                            us to over-count the tracer scavenged out of
                            the column.
22 Oct 2012 - R. Yantosca - Now reference Headers/gigc_errcode_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
31 May 2013 - R. Yantosca - Now pass State_Chm to WASHOUT
05 Sep 2013 - R. Yantosca - Bug fix: DT is apparently undefined, but still
                            passed to WASHOUT.  Use SDT instead.  This
                            avoids a floating-point error.
```

1.37 Fortran: Module Interface dao_mod

Module DAO_MOD contains both arrays that hold DAO met fields, as well as subroutines that compute, interpolate, or otherwise process DAO met field data.

INTERFACE:

```
MODULE DAO_MOD
```

USES:

```
USE CMN_SIZE_MOD          ! Size parameters
USE CMN_GCTM_MOD          ! Physical constants

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: AVGPOLE
PUBLIC  :: AIRQNT
PUBLIC  :: AIRQNT_FULLGRID
PUBLIC  :: CLEANUP_DAO
PUBLIC  :: CONVERT_UNITS
PUBLIC  :: COPY_I3_I6_FIELDS
PUBLIC  :: GET_COSINE_SZA
PUBLIC  :: GET_OBK
PUBLIC  :: INTERP
PUBLIC  :: INIT_DAO
PUBLIC  :: IS_LAND
PUBLIC  :: IS_WATER
PUBLIC  :: IS_ICE
PUBLIC  :: IS_NEAR
PUBLIC  :: MAKE_AVGW
PUBLIC  :: MAKE_RH
```

PUBLIC DATA MEMBERS:

```
! Arrays AIRDEN_FULLGRID and T_FULLGRID are used to correct vertical
! regridding of OH for offline simulations (mpayer, 3/14/13)
REAL*8,  ALLOCATABLE, PUBLIC :: AIRDEN_FULLGRID(:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: T_FULLGRID     (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: T_FULLGRID_1   (:,:,:)
REAL*8,  ALLOCATABLE, PUBLIC :: T_FULLGRID_2   (:,:,:)
```

REVISION HISTORY:

```
26 Jun 2010 - R. Yantosca - Initial version
(1 ) Added sea level pressure (SLP) met field for GEOS-3 (bmy, 10/10/00)
(2 ) Moved MAKE_QQ to "wetscav_mod.f" (bmy, 10/12/00)
(3 ) Now get LWI from ALBEDO for GEOS-3 in routines IS_LAND and
      IS_WATER (bmy, 4/4/01)
```

```
(4 ) Define OPTDEP allocatable array for GEOS-3 -- this is the grid
     box optical depth and is now stored as a met field (bmy, 8/15/01)
(5 ) Updated comments (bmy, 9/4/01)
(6 ) Now make AVGW an allocatable module array.  Also replace obsolete
     parameters {IJL}GCMPAR with IIPAR,JJPAR,LLPAR. (bmy, 9/27/01)
(7 ) Remove arguments LMAKEPW, PW, and LM from AIRQNT (bmy, 10/3/01)
(8 ) Remove obsolete code from 9/01 (bmy, 10/23/01)
(9 ) Bug fixes in IS_LAND and IS_WATER.  Also cosmetic changes and
     updated some comments. (mje, bmy, 1/9/02)
(10) Now add additional array PSC2 in order to pass to TPCORE, which will
     fix the mixing ratio bug.  Compute PSC2 in subroutine INTERP.
     Now bundle "convert_units.f" into "dao_mod.f".  Updated comments.
     (bmy, 3/27/02)
(11) Updated comments (bmy, 5/28/02)
(12) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(13) Eliminated PS, PSC arrays.  Now reference "pressure_mod.f".  Also
     updated AIRQNT for hybrid grid.  Added routine MAKE_RH to this
     module. (dsa, bdf, bmy, 8/27/02)
(14) Added arrays AD, BXHEIGHT, and T to "dao_mod.f".  Also removed
     obsolete code from 8/02 from several module routines.  Now
     references "error_mod.f".  Remove all references to QQ, it is now
     declared in "wetscav_mod.f".  (bmy, 11/8/02)
(15) Now references "grid_mod.f".  Also added PHIS field, which was
     formerly stored as PALTD in "CMN".  Added bug fix in routine
     AVGPOLE for 1x1 nested grid. (bmy, 3/11/03)
(16) Added SUNCOSB array for SMVGEAR II.  Also removed KZZ array, since
     that is now obsolete. (bmy, 4/28/03)
(17) Now moved MAKE_CLDFRC into "a6_read_mod.f".  Added HKBETA, HKETA,
     TSKIN, GWETTOP, ZMEU, ZMMD, ZMMU, PARDF, PARDR fields for
     GEOS-4/fvDAS. (bmy, 6/25/03)
(18) Added CLDFRC, RADSWG, RADLWG, SNOW arrays (bmy, 12/9/03)
(19) Added routine COPY_I6_FIELDS w/ parallel DO-loops (bmy, 4/13/04)
(20) Now also allocate AVGW for offline aerosol simulation (bmy, 9/28/04)
(21) AVGPOLE now uses NESTED_CH and NESTED_NA cpp switches (bmy, 12/1/04)
(22) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(23) Now allocate SNOW and GWET for GCAP (bmy, 8/17/05)
(24) Now also add TSKIN for GEOS-3 (tmf, bmy, 10/20/05)
(25) Modifications for near-land formulation (ltm, bmy, 5/16/06)
(26) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(27) Modified for variable tropopause (phs, bdf, 9/14/06)
(28) Add in extra fields for GEOS-5.  Updated COSSZA.  Now cap var trop
     at 200hPa near poles in INTERP (bmy, phs, 9/18/07)
(29) Bug fix in INIT_DAO for CMFMC array (bmy, jaf, 6/11/08)
(30) Add heat flux EFLUX for GEOS5. (lin, ccc, 5/29/09)
(31) Add fractions of land and water, FRLAND, FROCEAN, FRLANDIC, FRLAKE
     for methane (kjw, 8/18/09)
(32) Bug fix in AVGPOLE (bmy, 12/18/09)
```

```
(33) Remove obsolete SUNCOSB array (bmy, 4/28/10)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
18 Aug 2010 - R. Yantosca - Added modifications for MERRA data
18 Aug 2010 - R. Yantosca - Move CMN_SIZE, CMN_DIAG to top of module
25 Aug 2010 - R. Yantosca - Now read LWI (land/water/ice) for MERRA met
05 Oct 2011 - R. Yantosca - Add SUNCOS_30 array to hold the cos(SZA)
                            computed @ 30 mins after each GMT hour.
07 Oct 2011 - R. Yantosca - Rename SUNCOS30 to SUNCOS_MID, which is the
                            cos(SZA) at the midpt of the chemistry timestep
06 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met fields
06 Feb 2012 - R. Yantosca - Split up INIT_DAO into several routines
07 Feb 2012 - M. Payer    - Add subroutine GET_COSINE_SZA to compute sun
                            angles at the current time and 5 hours prior to
                            the current time (for the PARANOX ship emissions
                            plume model) (R. Yantosca)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now references the new grid_mod.F90
06 Mar 2012 - R. Yantosca - Now allocate TO3 for all met fields
21 Nov 2012 - R. Yantosca - Removed met fields now contained in State_met
21 Nov 2012 - R. Yantosca - Remove functions INIT_DAO_GCAP, INIT_DAO_GEOS4,
                            INIT_DAO_GEOS5, INIT_DAO_GEOS57, INIT_DAO_MERRA
27 Nov 2012 - R. Yantosca - Removed obsolete AIRQNT_FULLGRID routine and
                            obsolete arrays AIRDEN_FULLGRID, T_FULLGRID
28 Nov 2012 - R. Yantosca - Removed SUNCOS, SUNCOS_MID, SUNCOS_MID_5hr
28 Nov 2012 - R. Yantosca - Removed routines INIT_DAO, INIT_DAO_DERIVED, and
                            CLEANUP_DAO; we have no more allocatable arrays
14 Mar 2013 - M. Payer    - Restored routines AIRQNT_FULLGRID, INIT_DAO,
                            CLEANUP_DAO and arrays AIRDEN_FULLGRID and
                            T_FULLGRID. They are required to correct vertical
                            regridding of OH for offline simulations.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.37.1 avgpole

Subroutine AVGPOLE computes average quantity near polar caps, defined by (J = 1, 2) and (J = JJPAR-1, JJPAR).

INTERFACE:

```
SUBROUTINE AVGPOLE( Z )
```

USES:

```
USE GRID_MOD, ONLY : GET_AREA_M2
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8, INTENT(INOUT) :: Z(IIPAR,JJPAR)   ! Quantity to be averaged
                                          !  over the pole (usually PS)
```

REVISION HISTORY:

```
30 Jan 1998 - R. Yantosca - Initial version
(1 ) AVGPOLE is written in Fixed-Form Fortran 90.  Use F90 syntax
      for declarations, etc (bmy, 4/14/99)
(2 ) MAIN now passes the Harvard CTM variable for surface area of
      a gridbox, DXYP(JJPAR), to AVGPOLE.  Use window offset
      J+J0 when accessing DXYP.  Add JJPAR to the parameter list.
(3 ) Added this routine to "dao_mod.f" (bmy, 6/27/00)
(4 ) Updated comments (bmy, 4/4/01)
(5 ) Now replaced DXYP(J) with routine GET_AREA_M2 of "grid_mod.f"
      Now also return immediately if GRID1x1 is selected. (bmy, 3/11/03)
(6 ) Now use cpp switches NESTED_CH and NESTED_NA to denote nested
      grids...GRID1x1 can now also denote a global grid (bmy, 12/1/04)
(7 ) Also need to RETURN for 0.5 x 0.666 nested grid simulations
      (mpb, bmy, 12/18/09)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
26 Sep 2013 - R. Yantosca - Remove SEAC4RS C-preprocessor switch
```

1.37.2 airqnt

Subroutine AIRQNT calculates the volume [m$\hat{3}$ and cm$\hat{3}$], mass [kg], density, [kg/m$\hat{3}$], and pressure thickness [hPa] of air for each grid box (I,J,L). The quantity (surface pressure - PTOP) [hPa] at each surface grid box (I,J) is also computed.

INTERFACE:

```
SUBROUTINE AIRQNT( State_Met )
```

USES:

```
USE GIGC_State_Met_Mod,   ONLY : MetState
USE GRID_MOD,             ONLY : GET_AREA_M2
USE PRESSURE_MOD,         ONLY : GET_BP, GET_PEDGE
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Obj for met fields
```

REMARKS:

```
DAO met fields updated by AIRQNT:
============================================================================
(1 ) BXHEIGHT (REAL*8 ) : Vertical extent of a grid box   [m       ]
(2 ) DELP     (REAL*8 ) : Delta-P extent  of a grid box   [mb      ]
(3 ) AIRVOL   (REAL*8 ) : Volume  of air  in a grid box   [m^3     ]
(4 ) AD       (REAL*8 ) : Mass    of air  in a grid box   [kg      ]
(5 ) AIRDEN   (REAL*8 ) : Density of air  in a grid box   [kg/m^3  ]
```

REVISION HISTORY:

```
30 Jan 1998 - R. Yantosca - Initial version
(1 ) AIRQNT is written in Fixed-Form Fortran 90.  Use F90 syntax
     for declarations etc. (bmy, 4/14/99)
(2 ) AIRQNT can now compute PW from PS (if LMAKEPW=T) or PS from PW.
(3 ) AIRQNT should also be called after TPCORE, since TPCORE changes
     the PW values.  AIRQNT must then be called to compute the post-TPCORE
     values of AD, BXHEIGHT, AIRVOL, and AIRDEN.
(4 ) The AIRDEN and DELP arrays are now dimensioned as (LLPAR,IIPAR,JJPAR)
     for better efficiency when processing a whole (I,J) column layer by
     layer.  In FORTRAN, the best efficiency is obtained when the leftmost
     array index corresponds to the innermost loop.
(5 ) Remove PTOP from the arg list.  PTOP is now a parameter in
    "CMN_SIZE".  Also updated comments. (bmy, 2/22/00)
(6 ) Replace IM, JM, LM with IIPAR, JJPAR, LLPAR as loop boundaries.
     This ensures that all quantities get defined up to the top of
     the atmosphere. (bmy, 6/15/00)
(7 ) Added to "dao_mod.f" (bmy, 6/26/00)
(8 ) Updated comments (bmy, 4/4/01)
(9 ) P(IREF,JREF) is now P(I,J).  T(IREF,JREF,L) is now T(I,J,L).  Also
     removed LM from the arg list, it is obsolete.  Also updated
     comments. (bmy, 9/26/01)
(10) Remove PW -- it is now obsolete.  Also make PW a local variable,
     we need to preserve the way it computes P so as to avoid numerical
     drift. (bmy, 10/4/01)
(11) Removed obsolete code from 9/01 and 10/01 (bmy, 10/23/01)
(12) Removed LMAKEPW from arg list.  Added parallel DO loops (bmy, 11/15/01)
(13) Removed obsolete code from 11/01 (bmy, 1/9/02)
(14) Now rename G_SIGE to SIGE, and dimension it (1:LLPAR+1).  Updated
     comments, cosmetic changes. (bmy, 4/4/02)
(15) Removed obsolete, commented-out code (bmy, 6/25/02)
(16) Removed PS, P, SIGE from the arg list for hybrid grid.  Now reference
     routines GET_PEDGE and GET_BP from "pressure_mod.f".  Removed
     obsolete, commented-out code. (dsa, bdf, bmy, 8/27/02)
(17) Now only pass DXYP via the arg list -- the other arguments are actually
     are already contained within "dao_mod.f" (bmy, 11/15/02)
(18) Now replace DXYP(JREF) with routine GET_AREA_M2 of "grid_mod.f".
     (bmy, 3/11/03)
(19) Now move computation of DELP into main loop.  Also remove P, LOGP,
     JREF, DSIG variables -- these are obsolete for fvDAS.  (bmy, 6/19/03)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
22 Oct 2012 - R. Yantosca - Now reference gigc_state_met_mod.F90
22 Oct 2012 - R. Yantosca - Renamed LOCAL_MET argument to State_Met
09 Nov 2012 - M. Payer    - Copy met field arrays to the State_Met derived
                            type object
```

1.37.3 airqnt_fullgrid

Subroutine AIRQNT_FULLGRID calculates the same quantities as AIRQNT, but for the full, unlumped vertical grid of the GEOS GCM.

INTERFACE:

```
SUBROUTINE AIRQNT_FULLGRID( am_I_Root, Input_Opt, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_AREA_M2
USE PRESSURE_MOD,       ONLY : GET_PEDGE_FULLGRID
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
DAO met fields updated by AIRQNT_FULLGRID:
============================================================================
(1 ) AIRDEN_FULLGRID (REAL*8 ) : Density of air  in a grid box   [kg/m^3  ]
NOTES:
(1 ) Modified from AIRQNT in DAO_MOD (cdh, 1/22/09)
05 Sep 2013 - R. Yantosca - Prevent an out-of-bounds error in the call
                            to GET_AREA_CM2.
23 Oct 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC arguments
```

1.37.4 interp

Subroutine INTERP linearly interpolates GEOS-Chem I6 fields (winds, surface pressure, temperature, surface albedo, specific humidity etc.) to the current dynamic timestep.

INTERFACE:

```
SUBROUTINE INTERP( NTIME0, NTIME1, NTDT, Input_Opt, State_Met )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_YEDGE
USE LOGICAL_MOD,        ONLY : LVARTROP
```

INPUT PARAMETERS:

```
INTEGER,         INTENT(IN)    :: NTIME0     ! Elapsed time [s] at
                                             !  start of outer time step
INTEGER,         INTENT(IN)    :: NTIME1     ! Elapsed time [s] at
                                             !  current time
INTEGER,         INTENT(IN)    :: NTDT       ! Dynamic timestep [s]
TYPE(OptInput), INTENT(IN)     :: Input_Opt  ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

REMARKS:

Different met fields are archived at I6 (instantaneous 6-hr) time resolution depending on the specific product. For example, relative humidity is an instantaneous 6hr field in MERRA and a 6-hr time averaged field in GEOS-5.

REVISION HISTORY:

30 Jan 1998 - R. Yantosca - Initial version
(1) INTERP is written in Fixed-Form Fortran 90.
(2) Subtract PINT from PSC since the only subroutine that uses PSC is TPCORE. This prevents having to subtract and add PINT to PSC before and after each call of TPCORE.
(3) Pass the Harvard CTM temperature variable T(IGCMPAR,JGCMPAR,LGCMPAR) to INTERP via the argument list (instead of including file CMN). It is computationally inefficient to keep two large arrays for the same quantity. Use the proper window offsets with T.
(4) Added to "dao_mod.f" (bmy, 6/26/00)
(5) Updated comments (bmy, 4/4/01)
(6) Replaced {IJL}GCMPAR w/ IIPAR,JJPAR,LLPAR. Also now use parallel DO-loop for interpolation. Updated comments. (bmy, 9/26/01)
(7) Removed obsolete code from 9/01 (bmy, 10/23/01)
(8) Add PSC2 as the surface pressure at the end of the dynamic timestep. This needs to be passed to TPCORE and AIRQNT so that the mixing ratio can be converted to mass properly. Removed PINT from the arg list, since we don't need it anymore. Also updated comments and made some cosmetic changes. (bmy, 3/27/02)
(9) Removed obsolete, commented-out code (bmy, 6/25/02)
(10) Eliminated PS, PSC from the arg list, for floating-pressure fix. (dsa, bdf, bmy, 8/27/02)
(11) Met field arrays are module variables, so we don't need to pass them as arguments. (bmy, 11/20/02)
(12) Removed NDT from the arg list since that is always 21600. For GEOS-4 met fields, only interpolate PSC2; the other fields are 6-h averages. Eliminate TC variable, it's obsolete. Now use double precision to compute TM and TC2 values. Renamed NTIME to NTIME1 and NTIME1 to

```
      NTIME0.  Updated comments. (bmy, 6/19/03)
(13) Now modified for GEOS-5 and GCAP met fields. (swu, bmy, 5/25/05)
(14) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(15) Now interpolate TROPP, only if variable tropopause is used
      (phs, 9/12/06)
(16) Don't interpolate TROPP for GEOS-5 (bmy, 1/17/07)
(17) Now limit tropopause pressure to 200 mbar at latitudes above 60deg
      (phs, 9/18/07)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
18 Aug 2010 - R. Yantosca - Rewrite #if block logic for clarity
06 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met fields
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_YEDGE(I,J,L) from new grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
29 Oct 2013 - R. Yantosca - Now interpolate T_FULLGRID field for GEOS-FP met
```

1.37.5 is_land

Function IS_LAND returns TRUE if surface grid box (I,J) is a land box.

INTERFACE:

```
FUNCTION IS_LAND( I, J, State_Met ) RESULT ( LAND )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_YEAR
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I           ! Longitude index of grid box
INTEGER,        INTENT(IN)  :: J           ! Latitude  index of grid box
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
LOGICAL                     :: LAND        ! =T if it is a land box
```

REVISION HISTORY:

```
26 Jun 2000 - R. Yantosca - Initial version
(1 ) Now use ALBEDO field to determine land or land ice boxes for GEOS-3.
      (bmy, 4/4/01)
(2 ) For 4x5 data, regridded albedo field can cause small inaccuracies
      near the poles (bmy, 4/4/01)
(3 ) Add references to CMN_SIZE and CMN, so that we can use the JYEAR
```

```
      variable to get the current year.  Also, for 1998, we need to compute
      if is a land box or not from the surface albedo, since for this
      year the LWI/SURFTYPE field is not given.  For other years than 1998,
      we use LWI(I,J) < 50 as our land box criterion.  Deleted obsolete
      code and updated comments.(mje, bmy, 1/9/02)
(4 ) Deleted GEOS-2 #ifdef statement.  GEOS-2 met fields never really
     materialized, we use GEOS-3 instead. (bmy, 9/18/02)
(5 ) Now uses function GET_YEAR from "time_mod.f".  Removed reference
     to CMN header file. (bmy, 3/11/03)
(6 ) Added code to determine land boxes for GEOS-4 (bmy, 6/18/03)
(7 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(8 ) Now return TRUE only for land boxes (w/ no ice) (bmy, 8/10/05)
(9 ) Now use NINT to round LWI for GEOS-4/GEOS-5 (ltm, bmy, 5/9/06)
(10) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
06 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA/GEOS-5
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.37.6 is_water

Function IS_WATER returns TRUE if surface grid box (I,J) is an ocean or an ocean-ice box.

INTERFACE:

```
FUNCTION IS_WATER( I, J, State_Met ) RESULT ( WATER )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_YEAR
```

INPUT PARAMETERS:

```
INTEGER,         INTENT(IN) :: I           ! Longitude index of grid box
INTEGER,         INTENT(IN) :: J           ! Latitude  index of grid box
TYPE(MetState),  INTENT(IN) :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
LOGICAL                     :: WATER       ! =T if this is a water box
```

REVISION HISTORY:

```
30 Jan 1998 - R. Yantosca - Initial version
(1 ) Now use ALBEDO field to determine water or water ice boxes for GEOS-3.
     (bmy, 4/4/01)
```

```
(2 ) For 4x5 data, regridded albedo field can cause small inaccuracies
     near the poles (bmy, 4/4/01)
(3 ) Add references to CMN_SIZE and CMN, so that we can use the JYEAR
     variable to get the current year.  Also, for 1998, we need to compute
     if is an ocean box or not from the surface albedo, since for this
     year the LWI/SURFTYPE field is not given.  For other years than 1998,
     we use LWI(I,J) >= 50 as our ocean box criterion.  Deleted obsolete
     code and updated comments. (mje, bmy, 1/9/02)
(4 ) Deleted GEOS-2 #ifdef statement.  GEOS-2 met fields never really
     materialized, we use GEOS-3 instead. (bmy, 9/18/02)
(5 ) Now uses function GET_YEAR from "time_mod.f".  Removed reference
     to CMN header file. (bmy, 3/11/03)
(6 ) Added code to determine water boxes for GEOS-4 (bmy, 6/18/03)
(7 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(8 ) Now remove test for sea ice (bmy, 8/10/05)
(9 ) Now use NINT to round LWI for GEOS-4/GEOS-5 (ltm, bmy, 5/9/06)
(10) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06
16 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
06 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA/GEOS-5
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.37.7 is_ice

Function IS_ICE returns TRUE if surface grid box (I,J) contains either land-ice or sea-ice.

INTERFACE:

```
FUNCTION IS_ICE( I, J, State_Met ) RESULT ( ICE )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_YEAR
```

INPUT PARAMETERS:

```
INTEGER,         INTENT(IN) :: I           ! Longitude index of grid box
INTEGER,         INTENT(IN) :: J           ! Latitude  index of grid box
TYPE(MetState),  INTENT(IN) :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
LOGICAL                     :: ICE         ! =T if this is an ice box
```

REVISION HISTORY:

```
09 Aug 2005 - R. Yantosca - Initial version
(1 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
06 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA/GEOS-5
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
```

1.37.8 is_near

Function IS_NEAR returns TRUE if surface grid box (I,J) contains any land above a certain threshold (THRESH) or any of the adjacent boxes up to NEIGHBOR boxes away contain land.

INTERFACE:

```
      FUNCTION IS_NEAR( I, J, THRESH, NEIGHBOR, State_Met )
     &   RESULT ( NEAR )
```

USES:

```
      USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
      ! Arguments
      INTEGER,        INTENT(IN) :: I, J       ! Lon & lat grid box indices
      INTEGER,        INTENT(IN) :: NEIGHBOR   ! # of neighbor boxes to consider
      REAL*8,         INTENT(IN) :: THRESH     ! LWI threshold for near-land
      TYPE(MetState), INTENT(IN) :: State_Met  ! Meteorology State object
```

RETURN VALUE:

```
      LOGICAL                    :: NEAR       ! # of near land boxes
```

REMARKS:

```
Typical values for:
   GCAP   : THRESH =  0.2, NEIGHBOR = 1
   GEOS-3 : THRESH = 80.0, NEIGHBOR = 1
   GEOS-4 : THRESH =  0.2, NEIGHBOR = 1
   GEOS-5 : THRESH =  0.2, NEIGHBOR = 1

NOTE: This routine is mostly obsolete now.
```

REVISION HISTORY:

```
09 May 2006 - R. Yantosca - Initial version
(1 ) Modified for GCAP and GEOS-3 met fields (bmy, 5/16/06)
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
```

```
19 Aug 2010 - R. Yantosca - Rewrote logic of #if block for clarity
25 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
06 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA/GEOS-5
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.37.9 make_avgw

Subroutine MAKE_AVGW converts DAO specific humidity SPHU to AVGW, which is the mixing ratio of water vapor.

INTERFACE:

```
SUBROUTINE MAKE_AVGW( State_Met )
```

USES:

```
USE GIGC_State_Met_Mod,   ONLY : MetState
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
30 Jan 1998 - R. Yantosca - Initial version
(1 ) AVGW was originally indexed by (L,I,J).  Reorder the indexing to
      (I,J,L) to take advantage of the way FORTRAN stores by columns.
      An (L,I,J) ordering can lead to excessive disk swapping.
(2 ) Now dimension AVGW as (IIPAR,JJPAR,LLPAR).  Also use parallel
      DO-loop to compute AVGW.  Updated comments. (bmy, 9/24/01)
(3 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(4 ) SPHU and AVGW are declared w/in "dao_mod.f", so we don't need to pass
      these as arguments anymore (bmy, 11/15/02)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.37.10 make_rh

Subroutine MAKE_RH computes relative humidity from specific humidity and temperature.

INTERFACE:

```
SUBROUTINE MAKE_RH( State_Met )
```

USES:

```
      USE GIGC_State_Met_Mod,   ONLY : MetState
      USE PRESSURE_MOD,         ONLY : GET_PCENTER
```

INPUT PARAMETERS:

```
      TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REMARKS:

```
    Module variables used:
    ============================================================================
    (1 ) SPHU (REAL*8) : Array containing 3-D specific humidity [g H2O/kg air]
    (2 ) TMPU (REAL*8) : Array containing 3-D temperature field [K]
    (3 ) RH   (REAL*8) : Output array for relative humidity     [%]
```

REVISION HISTORY:

```
    13 Oct 1999 - R. Yantosca - Initial version
    (1 ) Use F90 syntax for declarations, etc.
    (2 ) Cosmetic changes (bmy, 10/12/99)
    (3 ) Now use GET_PCENTER from "pressure_mod.f" to compute the pressure
         at the midpoint of grid box (I,J,L).  Updated comments, cosmetic
         changes.  Added parallel DO-loops.  Remove reference to "CMN"
         header file.  Added to "dao_mod.f" (dsa, bdf, bmy, 8/27/02)
    (4 ) Removed obsolete code from 8/02 (bmy, 9/18/02)
    (5 ) Now remove SPHU, TMPU, RH from the arg list, since these are now
         all contained w/in this dao_mod.f as module variables. (bmy, 9/23/02)
    16 Aug 2010 - R. Yantosca - Added ProTeX headers
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
```

1.37.11 get_obk

Function GET_OBK returns the Monin-Obhukov length at a grid box (I,J).

INTERFACE:

```
      FUNCTION GET_OBK( I, J, State_Met ) RESULT( OBK )
```

USES:

```
      USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
      INTEGER,         INTENT(IN) :: I           ! Longitude index
      INTEGER,         INTENT(IN) :: J           ! Latitude  index
      TYPE(MetState),  INTENT(IN) :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
      REAL*8                        :: OBK         ! Monin-Obhukhov length
```

REMARKS:

REVISION HISTORY:

```
    25 May 2005 - R. Yantosca - Initial version
    16 Aug 2010 - R. Yantosca - Added ProTeX headers
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
```

1.37.12 get_cosine_sza

Routine GET_COSINE_SZA is a driver for calling the COSSZA routine from dao_mod.F. This routine calls COSSZA twice. The first call computes the sun angles at the current time and midpoint of the current chemistry time step. The second call computes the sun angles 5 hours prior to the current time (for the PARANOX ship emissions plume model).

INTERFACE:

```
      SUBROUTINE GET_COSINE_SZA( am_I_Root, Input_Opt, State_Met, RC  )
  USES:
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE JULDAY_MOD,         ONLY : JULDAY
      USE TIME_MOD,           ONLY : GET_DAY_OF_YEAR
      USE TIME_MOD,           ONLY : GET_DAY
      USE TIME_MOD,           ONLY : GET_GMT
      USE TIME_MOD,           ONLY : GET_HOUR
      USE TIME_MOD,           ONLY : GET_MINUTE
      USE TIME_MOD,           ONLY : GET_MONTH
      USE TIME_MOD,           ONLY : GET_YEAR
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
07 Feb 2012 - R. Yantosca - Initial version
27 Nov 2012 - R. Yantosca - Add am_I_root, Input_Opt, State_Met, RC args
27 Nov 2012 - R. Yantosca - Now pass State_Met to COSSZA so that the
                            SUNCOS fields may be updated
28 Nov 2012 - R. Yantosca - Removed references to 1-D SUNCOS arrays
```

1.37.13 cossza

COSSZA computes the cosine of the solar zenith angle, given the day of the year and GMT hour. The cosine of the solar zenith angle is returned at both the current time and at the midpoint of the chemistry timestep (i.e. for the centralized chemistry timestep option).

INTERFACE:

```
SUBROUTINE COSSZA( DOY, GMT_HOUR, DO_5hr_AGO, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_YMID_R
USE TIME_MOD,           ONLY : GET_MINUTE
USE TIME_MOD,           ONLY : GET_LOCALTIME
USE TIME_MOD,           ONLY : GET_TS_CHEM
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: DOY          ! Day of the year
INTEGER,        INTENT(IN)    :: GMT_HOUR     ! Hour of day
LOGICAL,        INTENT(IN)    :: DO_5hr_AGO   ! Compute 5h ago?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met    ! Meteorology State
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: The SUNCOS arrays of dimension MAXIJ are now deprecated.  We  %%%
%%%  are replacing them with the SUNCOS fields of the State_Met object,  %%%
%%%  which are of dimensions (IIPAR,JJPAR).   During the transition we   %%%
%%%  will keep the old arrays. (bmy, 11/27/12)                           %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                                                          .
Hour angle (AHR) is a function of longitude.  AHR is zero at solar noon,
and increases by 15 deg for every hour before or after solar noon.  Hour
angle can be thought of as the time in hours since the sun last passed
the meridian (i.e. the time since the last local noon).
                                                                          .
The cosine of the solar zenith angle (SZA) is given by:
                                                                          .
```

```
   cos(SZA) = sin(LAT)*sin(DEC) + cos(LAT)*cos(DEC)*cos(AHR)

where LAT = the latitude angle,
      DEC = the solar declination angle,
      AHR = the hour angle, all in radians.

If SUNCOS < 0, then the sun is below the horizon, and therefore does not
contribute to any solar heating.
```

REVISION HISTORY:

```
21 Jan 1998 - R. Yantosca - Initial version
(1 ) COSSZA is written in Fixed-Form Fortran 90.
(2 ) Use IMPLICIT NONE
(3 ) Use C-preprocessor #include statement to include CMN_SIZE, which
      has IIPAR, JJPAR, LLPAR, IIPAR, JJPAR, LGLOB.
(4 ) Use IM and JM (in CMN_SIZE) as loop limits.
(5 ) Include Harvard CTM common blocks and rename variables where needed.
(6 ) Use SUNCOS(MAXIJ) instead of a 2D array, in order for compatibility
      with the Harvard CTM subroutines.  SUNCOS loops over J, then I.
(7 ) Added DO WHILE loops to reduce TIMLOC into the range 0h - 24h.
(8 ) Cosmetic changes.  Also use F90 declaration statements (bmy, 6/5/00)
(9 ) Added to "dao_mod.f".  Also updated comments. (bmy, 9/27/01)
(10) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
      to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(11) Deleted obsolete code from 6/02 (bmy, 8/21/02)
(12) Removed RLAT and XLON from the arg list.  Now compute these using
      functions from "grid_mod.f" (bmy, 2/3/03)
(13) Now uses GET_LOCALTIME from "time_mod.f" to get the local time.
      Added parallel DO loop. Removed NHMSb, NSEC arguments. (bmy, 2/13/07)
(14) Now compute SUNCOS at the midpoint of the relevant time interval
      (i.e. the chemistry timestep).   Also make the A and B coefficients
      parameters instead of variables. (bmy, 4/27/10)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
05 Oct 2011 - R. Yantosca - Now also return the cosine of the solar
                            zenith angle at 30m after the GMT hour.
07 Oct 2011 - R. Yantosca - Now return SUNCOS_MID, the cos(SZA) at the
                            midpt of the chem step (not always at 00:30).
07 Feb 2012 - R. Yantosca - Now add GMT_HOUR as a new argument, which !
                            will facilitate computing sun angles 5h ago
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90
27 Nov 2012 - R. Yantosca - Update SUNCOS fields of the State_Met object
```

1.37.14 convert_units

Subroutine CONVERT_UNITS converts the units of STT from [kg] to [v/v] mixing ratio, or vice versa.

INTERFACE:

```
      SUBROUTINE CONVERT_UNITS( IFLAG, N_TRACERS, TCVV, AD, STT )
```

USES:

```
      USE ERROR_MOD,  ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
      ! =1 then convert from [kg ] --> [v/v]
      ! =2 then convert from [v/v] --> [kg ]
      INTEGER, INTENT(IN)    :: IFLAG

      ! Number of tracers
      INTEGER, INTENT(IN)    :: N_TRACERS

      ! Array containing [Air MW / Tracer MW] for tracers
      REAL*8,  INTENT(IN)    :: TCVV(N_TRACERS)

      ! Array containing grid box air masses
      REAL*8,  INTENT(IN)    :: AD(IIPAR,JJPAR,LLPAR)
```

OUTPUT PARAMETERS:

```
      !  Array containing tracer conc. [kg] or [v/v]
      REAL*8,  INTENT(INOUT) :: STT(IIPAR,JJPAR,LLPAR,N_TRACERS)
   !REMARKS
    Most of the GEOS-Chem subroutines require the tracer array STT to be in
    units of [kg].  However, the cloud convection, PBL mixing, and transport
    routines require STT to be in volume mixing ratio [v/v].

    Therefore, we need to call CONVERT_UNITS to convert STT from [kg] to [v/v]
    before calling convection, PBL mixing, or transport.  We also need to
    call CONVERT_UNITS after these routines to make the inverse conversion
    from [v/v] to [kg].
```

REVISION HISTORY:

```
    15 Jun 1998 - R. Yantosca - Initial version
    (1 ) CONVERT_UNITS is written in Fixed-Form Fortran 90.
    (2 ) Cosmetic changes, updated comments (bmy, 4/19/00)
    (3 ) Now use SELECT CASE statement.  Also added parallel DO-loops
         with the new Open-MP compiler directives. (bmy, 4/27/00)
    (4 ) Bundled into "dao_mod.f".  Now pass NTRACE, TCVV, AD, STT as args.
         Now use explicit DO-loops for I-J-L w/in parallel loops.  Updated
         comments, cosmetic changes. (bmy, 3/29/02)
    (5 ) Removed obsolete, commented-out code.  Also now use F90 intrinsic
         REPEAT to write a line of "="'s to the screen. (bmy, 6/25/02)
```

```
(6 ) Updated comments.  Now reference ERROR_STOP from "error_mod.f"
     (bmy, 10/15/02)
(7 ) Renamed NTRACE to N_TRACERS for consistency (bmy, 7/19/04)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.37.15 copy_i3_i6_fields

Subroutine COPY_I3_I6_FIELDS copies the I-6 fields at the end of a 6-hr timestep. The I-6 fields at the end of a given 6-hr timestep become the fields at the beginning of the next 6-hr timestep.

INTERFACE:

```
SUBROUTINE COPY_I3_I6_FIELDS( State_Met )
```

USES:

```
USE GIGC_State_Met_Mod,   ONLY : MetState
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
13 Apr 2004 - R. Yantosca - Initial version
(1 ) Added parallel DO-loops (bmy, 4/13/04)
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(3 ) Added TROPP (phs 11/10/06)
(4 ) Don't copy TROPP2 to TROPP1 for GEOS-5 (bmy, 1/17/07)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
20 Aug 2010 - R. Yantosca - Rewrite #if block for clarity
20 Aug 2010 - R. Yantosca - Added #if block for MERRA met fields
06 Feb 2012 - R. Yantosca - Added #if block for GEOS-5.7.x met fields
07 Feb 2012 - R. Yantosca - Renamed to COPY_I3_I6_FIELDS
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.37.16 init_dao

Subroutine INIT_DAO allocates memory for all allocatable module arrays.

INTERFACE:

```
SUBROUTINE INIT_DAO( am_I_Root, Input_Opt, RC )
```

USES:

```
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
26 Jun 2000 - R. Yantosca - Initial version
(1 ) Now allocate AVGW for either NSRCX == 3 or NSRCX == 5 (bmy, 9/24/01)
(2 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(3 ) Add PSC2 array for TPCORE mixing ratio fix.   (bmy, 3/27/02)
(4 ) Elimintated PS, PSC arrays for floating-pressure fix.
      (dsa, bdf, bmy, 8/20/02)
(5 ) Added AD, BXHEIGHT, T to "dao_mod.f" as allocatable arrays, to remove
      historical baggage and centralize variables.  Also remove GEOS_2
      flag from C-preprocessor statements.  Also allocate RH array
      but only if we are doing a sulfate simulation.  Now references
      ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
(6 ) Now allocate PHIS array (bmy, 3/11/03)
(7 ) Now allocate SUNCOSB array for SMVGEAR II.  Also removed KZZ array,
      that is now obsolete. (bdf, bmy, 4/28/03)
(8 ) Now order all arrays in alphabetical order.  Also added new fields
      for GEOS-4/fvDAS: HKBETA, HKETA, ZMEU, ZMMD, ZMMU, TSKIN, PARDF,
      and PARDR. (bmy, 6/25/03)
(9 ) Now allocate CLDFRC, RADLWG, RADSWG, SNOW arrays.  USTAR, CLDFRC,
      and Z0 and RADSWG are now 2-D arrays. (bmy, 12/9/03)
(10) Allocate RADLWG and SNOW for both GEOS-3 & GEOS-4 (bmy, 4/2/04)
(11) Now reference inquiry functions from "tracer_mod.f".  Now reference
      LWETD, LDRYD, LCHEM from "logical_mod.f".  Now allocate RH regardless
      of simulation. (bmy, 7/20/04)
(12) Now also allocate AVGW for offline aerosol simulations (bmy, 9/27/04)
(13) Now modified for GCAP met fields.  Removed references to CO-OH param
      simulation.  Now allocate AVGW only for fullchem or offline aerosol
      simulations. (bmy, 6/24/05)
(14) Now allocate SNOW and GWETTOP for GCAP (bmy, 8/17/05)
(15) Now also add TSKIN for GEOS-3 (bmy, 10/20/05)
(16) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(17) Reorganized for GEOS-5 met fields (bmy, 1/17/07)
(18) Bug fix: should be CMFMC=0 after allocating CMFMC (jaf, bmy, 6/11/08)
(19) Remove obsolete SUNCOSB array (bmy, 4/28/10)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
```

```
18 Aug 2010 - R. Yantosca - Now allocate met fields for MERRA
20 Aug 2010 - R. Yantosca - Bug fix, now allocate REEVAPCN
14 Mar 2013 - M. Payer    - Now allocate AIRDEN_FULLGRID and T_FULLGRID
                            arrays used to correct vertical regridding of OH
                            for offline simulations (C. Holmes)
23 Oct 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC arguments
23 Oct 2013 - R. Yantosca - Now only allocate T_FULLGRID and AIRDEN_FULLGRID
                            if we are using an offline (non-fullchem) sim
23 Oct 2013 - R. Yantosca - Also allocate T_FULLGRID_1 and T_FULLGRID_2
                            which are needed for GEOS-FP met only
```

1.37.17 cleanup_dao

Subroutine CLEANUP_DAO deallocates all met field arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DAO
```

REVISION HISTORY:

```
26 Jun 2000 - R. Yantosca - Initial version
(1 ) Now deallocate SLP met field for GEOS-3 (bmy, 10/10/00)
(2 ) Now deallocate OPTDEP met field for GEOS-3 (bmy, 8/15/01)
(3 ) Now deallocate AVGW (bmy, 9/24/01)
(4 ) Remove TAUCLD deallocation -- it's obsolete (bmy, 10/23/01)
(5 ) Add call to deallocate PSC2 array (bmy, 3/27/02)
(6 ) Elimintated PS, PSC arrays for floating-pressure fix.
     (dsa, bdf, bmy, 8/20/02)
(7 ) Now deallocate AD, BXHEIGHT, and T arrays (bmy, 9/18/02)
(8 ) Now deallocate PHIS array (bmy, 3/11/03)
(9 ) Now deallocate SUNCOSB array.  Remove reference to KZZ, since
     that is now obsolete. (bmy, 4/28/03)
(10) Now list all arrays in order.  Now also deallocate new arrays
     for GEOS-4/fvDAS. (bmy, 6/25/03)
(11) Now deallocate CLDFRC, RADLWG, RADSWG, SNOW arrays (bmy, 12/9/03)
(12) Now deallocate GCAP met fields (bmy, 5/25/05)
(13) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(14) Deallocate additional arrays for GEOS-5 (bmy, 1/17/07)
(15) Remove obsolete SUNCOSB (bmy, 4/28/10)
16 Aug 2010 - R. Yantosca - Added ProTeX headers
18 Aug 2010 - R. Yantosca - Now deallocate MERRA met field arrays
05 Oct 2011 - R. Yantosca - Now deallocate SUNCOS_MID
14 Mar 2013 - M. Payer    - Now deallocate AIRDEN_FULLGRID and T_FULLGRID
                            arrays used to correct vertical regridding of OH
                            for offline simulations (C. Holmes)
```

1.38 Fortran: Module Interface depo_mercury_mod

Module DEPO_MERCURY_MOD contains routines to handle deposition fluxes for mercury.

INTERFACE:

```
      MODULE DEPO_MERCURY_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: ADD_Hg2_DD
      PUBLIC :: ADD_Hg2_WD
      PUBLIC :: ADD_HgP_DD
      PUBLIC :: ADD_HgP_WD
      PUBLIC :: ADD_HG2_SNOWPACK
      PUBLIC :: RESET_HG_DEP_ARRAYS
      PUBLIC :: CHECK_DIMENSIONS
      PUBLIC :: READ_GTMM_RESTART
      PUBLIC :: MAKE_GTMM_RESTART
      PUBLIC :: UPDATE_DEP
      PUBLIC :: INIT_DEPO_MERCURY
      PUBLIC :: CLEANUP_DEPO_MERCURY
```

PUBLIC DATA MEMBERS:

```
      PUBLIC :: DD_HG2, DD_HGP, WD_HG2, WD_HGP
      PUBLIC :: HG2mth_wd, HG0mth_dd, HG2mth_dd
      PUBLIC :: SNOW_HG
      PUBLIC :: LHGSNOW
      REAL*8,  ALLOCATABLE :: DD_Hg2(:,:,:)
      REAL*8,  ALLOCATABLE :: DD_HgP(:,:,:)
      REAL*8,  ALLOCATABLE :: WD_Hg2(:,:,:)
      REAL*8,  ALLOCATABLE :: WD_HgP(:,:,:)
      REAL*8,  ALLOCATABLE :: HG0mth_dd(:,:)
      REAL*8,  ALLOCATABLE :: HG2mth_dd(:,:)
      REAL*8,  ALLOCATABLE :: HG2mth_wd(:,:)
      REAL*8,  ALLOCATABLE :: SNOW_HG(:,:,:) !CDH Hg stored in snow+ice
      REAL*8,  ALLOCATABLE :: Hg0dryGEOS(:,:), HgIIdryGEOS(:,:),
     &                        HgIIwetGEOS(:,:)
   !PRIVATE DATA MEMBERS:
      CHARACTER(LEN=255)   :: GTMM_RST_FILE
      LOGICAL              :: LHGSNOW
```

REVISION HISTORY:

```
   23 Apr 2010 - C. Carouge  - Initial version
   12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
   08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met
   20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.38.1 add_Hg2_dd

Subroutine ADD_Hg2_DD computes the amount of Hg(II) dry deposited out of the atmosphere into the column array DD_Hg2.

INTERFACE:

```
      SUBROUTINE ADD_Hg2_DD( I, J, N, DRY_Hg2)
   !USES
      USE TRACERID_MOD, ONLY : GET_Hg2_CAT
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I, J, N   ! GEOS-Chem long, lat and tracer index
      REAL*8,  INTENT(IN)   :: DRY_Hg2   ! Hg(II) dry deposited out of the
                                         ! atmosphere [kg]
```

REVISION HISTORY:

```
    19 Jan 2005 - S. Strode, C. Holmes - Initial version
    (1 ) DD_Hg2 is now a 3-D array.  Also pass N via the argument list. Now
         call GET_Hg2_CAT to return the Hg category #. (cdh, bmy, 3/28/06)
    23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                                depo_mercury_mod.f
```

1.38.2 add_Hg2_wd

Subroutine ADD_Hg2_WD computes the amount of Hg(II) wet scavenged out of the atmosphere into the column array WD_Hg2.

INTERFACE:

```
      SUBROUTINE ADD_Hg2_WD( I, J, N, WET_Hg2 )
   !USES
      USE TRACERID_MOD, ONLY : GET_Hg2_CAT
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I, J, N   ! GEOS-Chem long, lat and tracer index
      REAL*8,  INTENT(IN)   :: WET_Hg2   ! Hg(II) scavenged out of the
                                         ! atmosphere [kg]
```

REVISION HISTORY:

```
    19 Jan 2005 - S. Strode, C. Holmes - Initial version
    (1 ) WD_Hg2 is now a 3-D array.  Also pass N via the argument list. Now
         call GET_Hg2_CAT to return the Hg category #. (cdh, bmy, 3/28/06)
    23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                                depo_mercury_mod.f
```

1.38.3 add_HgP_dd

Subroutine ADD_HgP_DD computes the amount of HgP dry deposited out of the atmosphere into the column array DD_HgP.

INTERFACE:

```
      SUBROUTINE ADD_HgP_DD( I, J, N, DRY_HgP )
   !USES
      USE TRACERID_MOD, ONLY : GET_HgP_CAT
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I, J, N   ! GEOS-Chem long, lat and tracer index
      REAL*8,  INTENT(IN)   :: DRY_HgP   ! HgP dry deposited out of the
                                         ! atmosphere [kg]
```

REVISION HISTORY:

```
    19 Jan 2005 - S. Strode, C. Holmes - Initial version
    (1 ) DD_HgP is now a 3-D array.  Also pass N via the argument list. Now
         call GET_HgP_CAT to return the Hg category #. (cdh, bmy, 3/28/06)
    23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                                depo_mercury_mod.f
```

1.38.4 add_HgP_wd

Subroutine ADD_HgP_WD computes the amount of HgP wet scavenged out of the atmosphere into the column array WD_HgP.

INTERFACE:

```
      SUBROUTINE ADD_HgP_WD( I, J, N, WET_HgP )
   !USES
      USE TRACERID_MOD, ONLY : GET_HgP_CAT
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)   :: I, J, N   ! GEOS-Chem long, lat and tracer index
      REAL*8,  INTENT(IN)   :: WET_HgP   ! HgP scavenged out of the
                                         ! atmosphere [kg]
```

REVISION HISTORY:

```
    19 Jan 2005 - S. Strode, C. Holmes - Initial version
    (1 ) WD_HgP is now a 3-D array.  Also pass N via the argument list. Now
         call GET_HgP_CAT to return the Hg category #. (cdh, bmy, 3/28/06)
    23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                                depo_mercury_mod.f
```

1.38.5 add_hg2_snowpack

Subroutine ADD_Hg2_SNOWPACKS adds Hg2 deposition to snowpack.

INTERFACE:

```
SUBROUTINE ADD_HG2_SNOWPACK( I, J, N, DEP_Hg2, State_Met )
```

USES:

```
USE DAO_MOD,            ONLY : IS_ICE, IS_LAND
USE GIGC_State_Met_Mod, ONLY : MetState
USE TRACERID_MOD,       ONLY : GET_Hg2_CAT, GET_HgP_CAT
USE TRACERID_MOD,       ONLY : IS_Hg2,      IS_HgP
```

INPUT PARAMETERS:

```
! Arguments as input
INTEGER,        INTENT(IN)  :: I, J, N
REAL*8,         INTENT(IN)  :: Dep_Hg2
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
02 Sep 2008 - C. Holmes   - Initial version
23 Apr 2010 - C. Carouge  - Moved from mercury_mod.f to depo_mercury_mod.f
25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
26 Apr 2011 - J. Fisher   - Use MERRA land fraction information
12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
13 Apr 2011 - R. Yantosca - Bug fix: reference IS_LAND from dao_mod.f
 8 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.38.6 reset_hg_dep_arrays

Subroutine RESET_Hg_DEP_ARRAYS resets the wet and dry deposition arrays for Hg(II) and Hg(p) to zero. This allows us to call OCEAN_MERCURY_FLUX and LAND_MERCURY_FLUX in any order in MERCURY_MOD.

INTERFACE:

```
SUBROUTINE RESET_HG_DEP_ARRAYS
```

REVISION HISTORY:

```
02 Sep 2008 - C. Holmes   - Initial version
23 Apr 2010 - C. Carouge  - Moved from ocean_mercury_mod.f to
                            depo_mercury_mod.f
```

1.38.7 make_gtmm_restart

MAKE_GTMM_RESTART writes a GTMM restart file with deposition fluxes and store deposition fluxes for continuous runs.

INTERFACE:

```
SUBROUTINE MAKE_GTMM_RESTART( NYMD, NHMS, TAU )
```

USES:

```
USE BPCH2_MOD
USE DIAG_MOD,      ONLY : AD39, AD44, AD38
USE DIRECTORY_MOD, ONLY : RUN_DIR
USE GRID_MOD,      ONLY : GET_XOFFSET, GET_YOFFSET
USE TIME_MOD,      ONLY : EXPAND_DATE
USE TRACERID_MOD,  ONLY : ID_Hg0, ID_Hg2, ID_Hg_tot
USE TIME_MOD,      ONLY : GET_CT_DYN, GET_CT_CHEM
USE inquireMod,    ONLY : findFreeLUN
USE CMN_SIZE_MOD                ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)   :: NYMD    ! Year-Month-Date
INTEGER, INTENT(IN)   :: NHMS    ! and Hour-Min-Sec for which to create
                                 ! a restart file
REAL*8,  INTENT(IN)   :: TAU     ! GEOS-CHEM TAU value corresponding to
                                 ! NYMD, NHMS
```

REVISION HISTORY:

```
15 Sep 2009 - C. Carouge  - Initial version
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
```

1.38.8 read_gtmm_restart

Subroutine READ_GTMM_RESTART reads dry and wet deposition for mercury from GTMM restart.

INTERFACE:

```
SUBROUTINE READ_GTMM_RESTART( YYYYMMDD, HHMMSS,
&                             Hg0dryGEOS, HgIIdryGEOS, HgIIwetGEOS )
```

USES:

```
USE BPCH2_MOD,     ONLY : OPEN_BPCH2_FOR_READ
USE DIRECTORY_MOD, ONLY : RUN_DIR
```

```
USE ERROR_MOD,     ONLY : DEBUG_MSG
USE FILE_MOD,      ONLY : IOERROR
USE inquireMod,    ONLY : findFreeLun
USE TIME_MOD,      ONLY : EXPAND_DATE
USE TRACER_MOD,    ONLY : TRACER_NAME, TRACER_MW_G
USE TRACERID_MOD,  ONLY : GET_Hg0_CAT, GET_Hg2_CAT, N_Hg_CATS
USE TRACERID_MOD,  ONLY : ID_Hg0,      ID_Hg2

USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)   :: YYYYMMDD, HHMMSS
```

OUTPUT PARAMETERS:

```
REAL*8, DIMENSION(IIPAR, JJPAR)   :: Hg0dryGEOS
REAL*8, DIMENSION(IIPAR, JJPAR)   :: HgIIdryGEOS
REAL*8, DIMENSION(IIPAR, JJPAR)   :: HgIIwetGEOS
```

REVISION HISTORY:

```
15 Sep 2009 - C. Carouge - Initial version
```

1.38.9 update_dep

Subroutine UPDATE_DEP update the monthly average for wet and dry deposition of Hg0 and Hg2 for mercury from GTMM restart.

INTERFACE:

```
SUBROUTINE UPDATE_DEP( NN )
```

USES:

```
USE DIAG_MOD,     ONLY : AD38,   AD39,   AD44
USE LOGICAL_MOD,  ONLY : LGTMM
USE TIME_MOD,     ONLY : GET_CT_DYN,  GET_CT_CHEM
USE TRACERID_MOD, ONLY : IDTHg0, IDTHg2
```

INPUT PARAMETERS:

```
INTEGER :: NN    ! Hg2 ID for wet deposition
```

REVISION HISTORY:

```
04 June 2010  - C. Carouge  - Initial version
```

1.38.10 check_dimensions

Subroutine CHECK_DIMENSIONS makes sure that the dimensions of the Hg restart file extend to cover the entire grid.

INTERFACE:

```
      SUBROUTINE CHECK_DIMENSIONS( NI, NJ, NL )
```

USES:

```
      USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
      USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: NI, NJ, NL
```

REVISION HISTORY:

```
   30 Aug 2010 - S. Strode, C. Holmes - Initial version
```

1.38.11 init_depo_mercury

Subroutine INIT_DEPO_MERCURY initialize deposition arrays for mercury.

INTERFACE:

```
      SUBROUTINE INIT_DEPO_MERCURY( THIS_Hg_RST_FILE )
  !USES
      USE ERROR_MOD,    ONLY : ALLOC_ERR
      USE LOGICAL_MOD,  ONLY : LGTMM
      USE TRACERID_MOD, ONLY : N_Hg_CATS

      USE CMN_SIZE_MOD     ! Size parameters
```

INPUT PARAMETERS:

```
      ! Name of the GTMM restart file
      CHARACTER(LEN=*), INTENT(IN) :: THIS_Hg_RST_FILE
```

REVISION HISTORY:

```
   23 Apr 2010 - C. Carouge   - Moved arrays allocation from
                                ocean_mercury_mod.f
```

1.38.12 cleanup_depo_mercury

Subroutine CLEANUP_DEPO_MERCURY deallocate all arrays

INTERFACE:

```
SUBROUTINE CLEANUP_DEPO_MERCURY
```

REVISION HISTORY:

```
23 Apr 2010 - C. Carouge - Moved from ocean_mercury_mod.f
```

1.39 Fortran: Module Interface diag03_mod

Module DIAG03_MOD contains arrays and routines for archiving the ND03 diagnostic – Hg emissions, mass, and production.

INTERFACE:

```
MODULE DIAG03_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

DEFINED PARAMETERS:

```
INTEGER, PUBLIC, PARAMETER   :: PD03    = 18         ! Dim of AD03 array
INTEGER, PUBLIC, PARAMETER   :: PD03_PL = 10         ! # of PL-HG2 diags
```

PUBLIC DATA MEMBERS:

```
! Scalars
INTEGER, PUBLIC              :: ND03                 ! ND03 on/off flag
INTEGER, PUBLIC              :: LD03                 ! # of levels

! Arrays
 REAL*4,  PUBLIC, ALLOCATABLE :: AD03(:,:,:)          ! Diagnostic arrays
 REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_Hg0(:,:,:)  !  for the prod/loss
 REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_Br(:,:,:)   !  and mass of
 REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_OH(:,:,:)   !  various Hg
 REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_O3(:,:,:)   !  species
 REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_SS(:,:,:)   !
 REAL*4,  PUBLIC, ALLOCATABLE :: AD03_nat(:,:,:)      !
 REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_SSR(:,:)    !
- eds 8/31/10 -----------------------------------------------------
REAL*4,  PUBLIC, ALLOCATABLE :: AD03(:,:,:,:)
REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_Hg0(:,:,:,:)
REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_Br(:,:,:,:)
```

```
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_OH(:,:,:,:)
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_O3(:,:,:,:)
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_SS(:,:,:)
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_nat(:,:,:)
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Hg2_SSR(:,:,:)
 ------------------------------------------------------------------------
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_Br(:,:,:,:)     !
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_RGM(:,:,:)      !
      REAL*4,  PUBLIC, ALLOCATABLE :: AD03_PBM(:,:,:)      !
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: ZERO_DIAG03
      PUBLIC :: WRITE_DIAG03
      PUBLIC :: INIT_DIAG03
      PUBLIC :: CLEANUP_DIAG03
```

REMARKS:

```
    Nomenclature:
    ============================================================================
    (1 ) Hg(0)  a.k.a. Hg0     : Elemental   mercury
    (2 ) Hg(II) a.k.a. Hg2     : Divalent    mercury
    (3 ) RGM a.k.a. Hg(II)gas  : Reactive (oxidized) gaseous mercury
    (4 ) PBM a.k.a. Hg(II)P    : Reactive (oxidized) particulate mercury
```

REVISION HISTORY:

```
    21 Jan 2005 - R. Yantosca - Initial version
    (1 ) Updated for GCAP grid (bmy, 6/28/05)
    (2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (3 ) Add 2 extra diagnostics to ND03. Set PD03=15.  (cdh, bmy, 12/15/05)
    (4 ) Add loss of Hg2 by sea salt (eck, bmy, 4/6/06)
    (5 ) Replace TINY(1d0) w/ 1d-32 to avoid problems on SUN 4100 platform
         (bmy, 9/5/06)
    (6 ) Updates to mercury simulation (ccc, 5/17/10)
    (7 ) Added mercury tagged tracers (eds 9/2/10)
    02 Dec 2010 - R. Yantosca - Added ProTeX headers
    07 Feb 2012 - E. Corbitt  - Added new diagnostics for tagged simulation.
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.39.1 zero_diag03

Subroutine ZERO_DIAG03 zeroes all module arrays.

INTERFACE:

```
      SUBROUTINE ZERO_DIAG03
```

USES:

```
! References to F90 modules
USE TRACERID_MOD, ONLY : N_Hg_CATS

USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
21 Jan 2005 - R. Yantosca - Initial version
(1 ) Now references N_Hg_CATS from "tracerid_mod.f".  Now zero AD03_Hg2_SS
     array. (bmy, 4/6/06)
(2 ) Now use broadcast assignment and double precision 0D0 to zero arrays,
     rather than nested DO loops and single precision 0E0. (cdh, 8/14/08)
(3 ) Now zeros RGM and PBM diagnostics. (hma 20100219)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.39.2 write_diag03

Subroutine WRITE_DIAG03 writes the ND03 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG03
```

USES:

```
USE BPCH2_MOD,    ONLY : BPCH2
USE BPCH2_MOD,    ONLY : GET_MODELNAME
USE BPCH2_MOD,    ONLY : GET_HALFPOLAR
USE FILE_MOD,     ONLY : IU_BPCH
USE GRID_MOD,     ONLY : GET_XOFFSET
USE GRID_MOD,     ONLY : GET_YOFFSET
USE TIME_MOD,     ONLY : GET_CT_EMIS
USE TIME_MOD,     ONLY : GET_DIAGb
USE TIME_MOD,     ONLY : GET_DIAGe
USE TIME_MOD,     ONLY : GET_CT_CHEM
USE TRACERID_MOD, ONLY : N_Hg_CATS
USE TIME_MOD,     ONLY : GET_CT_DIAG, GET_Hg2_DIAG !H Amos, 20100218
USE LOGICAL_MOD,  ONLY : LSPLIT !eds 9/7/10

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! TINDEX
```

REMARKS:

```
 # : Field    : Description                    : Units    : Scale factor
---------------------------------------------------------------------------
```

```
The following list is outdated and not reliable (cdh, 7/5/11)
(1 ) HG-SRCE  : Anthropogenic HG0 emission      : kg       : 1
(2 ) HG-SRCE  : Total mass of oceanic Hg0       : kg       : 1
(3 ) HG-SRCE  : Oceanic Hg0 emission            : kg       : 1
(4 ) HG-SRCE  : Land reemission                 : kg       : 1
(5 ) HG-SRCE  : Land natural emission           : kg       : 1
(6 ) HG-SRCE  : Anthropogenic Hg2 emission      : kg       : 1
(7 ) HG-SRCE  : Total mass of oceanic Hg2       : kg       : 1
(8 ) HG-SRCE  : Mass of Hg2 sunk in the ocean   : kg       : 1
(9 ) HG-SRCE  : Anthropogenic HgP emission      : kg       : 1
(10) HG-SRCE  : Henry's law piston velocity Kw  : cm/h     : em timesteps  (anls, redo)
(11) HG-SRCE  : Mass of Hg(P)                   : kg       : 1
(12) HG-SRCE  : Converted to Particulate        : kg       : 1
(13) HG-SRCE  : Biomass burning emissions       : kg       : 1
(14) HG-SRCE  : Emissions from vegetation       : kg       : 1
(15) HG-SRCE  : Emissions from soils            : kg       : 1
(16) HG-SRCE  : Flux-up Hg0 volat from ocean    : kg       : 1
(17) HG-SRCE  : Flux-down Hg0 dry dep to ocean  : kg       : 1
(18) PL-HG2-$ : Production of Hg2 from Hg0      : kg       : 1
(19) PL-HG2-$ : Production of Hg2 from rxn w/OH : kg       : 1
(20) PL-HG2-$ : Production of Hg2 from rxn w/O3 : kg       : 1
(21) PL-HG2-$ : Loss of Hg2 from rxn w/ seasalt : kg       : 1
(22) PL-HG2-$ : Prod of Hg2 form rxn w/ Br      : kg       : 1
(23) PL-HG2-$ : Br concentration                : molec/cm3: 1
(24) PL-HG2-$ : Br concentration                : molec/cm3: 1
(27) PL-HG2-$ : Reactive gaseous mercury        : pptv     : 1
(28) PL-HG2-$ : Reactice particule mercury      : pptv     : 1
NOTES:
```

REVISION HISTORY:

```
21 Jan 2005 - R. Yantosca - Initial version
(1 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
     value for GEOS or GCAP grids. (bmy, 6/28/05)
(2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(3 ) Add HgC ocean mass and converted to colloidal to ND03 diagnostic.
     The units of the Kw and conversion terms in ND03 should be kg
     and not divided by the scale factor. (cdh, sas, bmy, 2/26/02)
(4 ) Replace TINY(1d0) w/ 1d-32 to avoid problems on SUN 4100 platform
     (bmy, 9/5/06)
(5 ) Fixed tracer numbers (NN) for 'PL-HG2-$' diagnostic quantities.
     (cdh, 8/13/08)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.39.3 init_diag03

Subroutine INIT_DIAG03 allocates all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DIAG03
```

USES:

```
USE ERROR_MOD,    ONLY : ALLOC_ERR
USE TRACERID_MOD, ONLY : N_Hg_CATS

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
21 Jan 2005 - R. Yantosca - Initial version
(1 ) Now allocates AD03_Hg2_SS (eck, bmy, 4/6/06)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
(3 ) Adapted for tagged tracers (eds 2/7/12)
```

1.39.4 cleanup_diag03

Subroutine CLEANUP_DIAG03 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG03
```

REVISION HISTORY:

```
21 Jan 2005 - R. Yantosca - Initial version
(1 ) Now deallocates AD03_Hg2_SS (eck, bmy, 4/6/06)
(2 ) Now deallocates AD03_PBM, AD03_RGM (hma 20100216)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.40 Fortran: Module Interface diag04_mod

Module DIAG04_MOD contains arrays and routines for archiving the ND04 diagnostic – CO2 emissions and fluxes.

INTERFACE:

```
MODULE DIAG04_MOD
```

USES:

```
IMPLICIT NONE
PUBLIC
```

PUBLIC DATA MEMBERS:

```
! Scalars
INTEGER              :: ND04, LD04
INTEGER, PARAMETER   :: PD04 = 10

! Arrays
REAL*4,  ALLOCATABLE :: AD04(:,:,:)
REAL*4,  ALLOCATABLE :: AD04_plane(:,:,:)
REAL*4,  ALLOCATABLE :: AD04_chem(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CLEANUP_DIAG04
PUBLIC :: INIT_DIAG04
PUBLIC :: WRITE_DIAG04
PUBLIC :: ZERO_DIAG04
```

PRIVATE MEMBER FUNCTIONS:

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%   BUYER BEWARE! Tagged CO2 tracers only work for 2 x 2.5 grid!   %%%
%%%   Someone will have to make this more general later on...        %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

.

REVISION HISTORY:

```
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
      (bmy, 9/5/06)
(3 ) Modified for ship emissions (2-D), aircraft emissions (3-D) and
     chemical source for CO2 (3-D) (RayNassar, 2009-12-23)
20 May 2010 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.40.1 zero_diag04

Subroutine ZERO_DIAG04 zeroes the ND04 diagnostic array.

INTERFACE:

```
SUBROUTINE ZERO_DIAG04
```

USES:

```
USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
26 Jul 2005 - R. Yantosca - Initial version
18 May 2010 - R. Nassar   - Also zero AD04_PLANE, AD04_CHEM arrays
18 May 2010 - R. Yantosca - Added ProTeX headers
```

1.40.2 write_diag04

Subroutine WRITE_DIAG04 writes the ND04 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG04
```

USES:

```
USE BPCH2_MOD, ONLY : BPCH2, GET_MODELNAME, GET_HALFPOLAR
USE FILE_MOD,  ONLY : IU_BPCH
USE GRID_MOD,  ONLY : GET_XOFFSET, GET_YOFFSET
USE TIME_MOD,  ONLY : GET_CT_EMIS, GET_DIAGb,  GET_DIAGe

USE CMN_SIZE_MOD  ! Size parameters
USE CMN_DIAG_MOD  ! TINDEX
```

REMARKS:

```
 # : Field     : Description                  : Units       : Scale factor
-----------------------------------------------------------------------------
(1 ) CO2-SRCE  : CO2 fossil fuel emissions    : molec/cm2/s : SCALE
(2 ) CO2-SRCE  : CO2 ocean emissions          : molec/cm2/s : SCALE
(3 ) CO2-SRCE  : CO2 balanced biosphere       : molec/cm2/s : SCALE
(4 ) CO2-SRCE  : CO2 biomass emissions        : molec/cm2/s : SCALE
(5 ) CO2-SRCE  : CO2 biofuel emissions        : molec/cm2/s : SCALE
(6 ) CO2-SRCE  : CO2 net terrestrial exchange : molec/cm2/s : SCALE
(7 ) CO2-SRCE  : CO2 ship emissions           : molec/cm2/s : SCALE
(8 ) CO2-SRCE  : CO2 aircraft emissions (3-D) : molec/cm2/s : SCALE
(9 ) CO2-SRCE  : CO2 chemical source (3-D)    : molec/cm2/s : SCALE
(10) CO2-SRCE  : CO2 chem source surf correct : molec/cm2/s : SCALE!
```

REVISION HISTORY:

```
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
18 May 2010 - R. Nassar   - Now write out AD04_PLANE, AD04_CHEM
18 May 2010 - R. Yantosca - Added ProTeX headers
```

1.40.3 init_diag04

Subroutine INIT_DIAG04 allocates all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DIAG04
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
26 Jul 2005 - R. Yantosca - Initial version
18 May 2010 - R. Nassar   - Now initialize AD04_PLANE, AD04_CHEM
18 May 2010 - R. Yantosca - Added ProTeX headers
```

1.40.4 cleanup_diag04

Subroutine CLEANUP_DIAG04 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG04
```

REVISION HISTORY:

```
26 Jul 2005 - R. Yantosca - Initial version
18 May 2010 - R. Nassar   - Now ce
18 May 2010 - R. Yantosca - Added ProTeX headers
```

1.41 Fortran: Module Interface diag41_mod

Module DIAG41_MOD contains arrays and routines for archiving the ND41 diagnostic – Afternoon PBL heights.

INTERFACE:

```
MODULE DIAG41_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
INTEGER, PUBLIC            :: ND41
INTEGER, PUBLIC, PARAMETER :: PD41 = 2
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: ZERO_DIAG41
PUBLIC :: WRITE_DIAG41
PUBLIC :: DIAG41
PUBLIC :: INIT_DIAG41
PUBLIC :: CLEANUP_DIAG41
```

REVISION HISTORY:

```
17 Feb 2005 - R. Yantosca - Initial version
(1 ) Updated for GCAP grid (bmy, 6/28/05)
(2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(3 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
     (bmy, 9/5/06)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Use updated GET_LOCALTIME from time_mod.F
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.41.1 zero_diag41

Subroutine ZERO_DIAG41 zeroes the ND41 diagnostic arrays.

INTERFACE:

```
SUBROUTINE ZERO_DIAG41
```

USES:

```
USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
17 Feb 2005 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.41.2 write_diag41

Subroutine WRITE_DIAG41 writes the ND41 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG41
```

USES:

```
      USE BPCH2_MOD, ONLY : BPCH2
      USE BPCH2_MOD, ONLY : GET_HALFPOLAR
      USE BPCH2_MOD, ONLY : GET_MODELNAME
      USE FILE_MOD,  ONLY : IU_BPCH
      USE GRID_MOD,  ONLY : GET_XOFFSET
      USE GRID_MOD,  ONLY : GET_YOFFSET
      USE TIME_MOD,  ONLY : GET_CT_EMIS
      USE TIME_MOD,  ONLY : GET_DIAGb
      USE TIME_MOD,  ONLY : GET_DIAGe

      USE CMN_SIZE_MOD  ! Size parameters
      USE CMN_DIAG_MOD  ! TINDEX
```

REMARKS:

```
    ND41: Afternoon PBL depth (between 1200 and 1600 Local Time)

     #  Field    : Description             : Units  : Scale factor
    ---------------------------------------------------------------
    (1) PBLDEPTH : Afternoon PBL heights   : m      : GOOD_CT
```

REVISION HISTORY:

```
    17 Feb 2005 - R. Yantosca - Initial version
    (1 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
         value for GEOS or GCAP grids. (bmy, 6/28/05)
    (2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (3 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
         (bmy, 9/5/06)
    02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.41.3 diag41

Subroutine DIAG41 produces monthly mean boundary layer height in meters between 1200-1600 local time for the U.S. geographical domain.

INTERFACE:

```
      SUBROUTINE DIAG41
```

USES:

```
      USE PBL_MIX_MOD, ONLY : GET_PBL_TOP_L
      USE PBL_MIX_MOD, ONLY : GET_PBL_TOP_m
      USE TIME_MOD,    ONLY : GET_LOCALTIME

      USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
18 Nov 1999 - A. Fiore, S. Wu - Initial version
(1 ) DIAG41 is written in Fixed-Format F90.
(2 ) XTRA2 must be computed by turning TURBDAY on first.  Also,
      XTRA2 is a global-size array, so use window offsets IREF, JREF
      to index it correctly. (bmy, 11/18/99)
(3 ) Do a little rewriting so that the DO-loops get executed
      in the correct order (J first, then I). (bmy, 11/18/99)
(4 ) AD41 is now declared allocatable in "diag_mod.f". (bmy, 12/6/99)
(5 ) AFTTOT is now declared allocatable in "diag_mod.f". (bmy, 3/17/00)
(6 ) Remove NYMD from the argument list -- it wasn't used (bmy, 6/22/00)
(7 ) XTRA2(IREF,JREF,5) is now XTRA2(I,J).  Also updated comments.
      (bmy, 9/25/01)
(8 ) Removed obsolete code from 9/01 (bmy, 10/23/01)
(9 ) Now reference BXHEIGHT from "dao_mod.f".  Also removed obsolete
      code. (bmy, 9/18/02)
(10) Now use function GET_LOCALTIME from "dao_mod.f" (bmy, 2/11/03)
(11) Bug fix in DO-loop for calculating local time (bmy, 7/9/03)
(12) For GEOS-4, PBL depth is already in meters, so we only have to
      multiply that by the GOOD array.  Also now references PBL array
      from "dao_mod.f".  Bug fix: now use barometric law to compute PBL
      height in meters for GEOS-1, GEOS-STRAT, GEOS-3.  This eliminates an
      overprediction of the PBL height. (swu, bmy, 11/6/03)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90
```

1.41.4 init_diag41

Subroutine CLEANUP_DIAG41 allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DIAG41
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
17 Feb 2005 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.41.5 cleanup_diag41

Subroutine CLEANUP_DIAG41 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG41
```

REVISION HISTORY:

```
17 Feb 2005 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.42 Fortran: Module Interface diag42_mod

Module DIAG42_MOD contains arrays and routines for archiving the ND42 diagnostic – secondary organic aerosols [ug/m3].

INTERFACE:

```
MODULE DIAG42_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

DEFINED PARAMETERS:

```
! Maximum number of output:
! SOA1, SOA2, SOA3, SOA4, SOA5, SUM(SOA1-3), SUM(SOA1-4), SUM(SOA1-5),
! SUM(SOA1-5+OC), SUM(SOA1-5+OC), SUM(SOA1-5+OC), OC, BC, SOA4, NH4, NIT,
! SSALT, SUM(aerosols), SOAG, SOAM, SUM(SOA1-5+SOAG+SOAM),
! SUM(SOA1-5+SOAG+SOAM+OC), SUM(SOA1-5+SOAG+SOAM),
! SUM(SOA1-5+SOAG+SOAM+OC)
INTEGER, PUBLIC, PARAMETER   :: PD42 = 24
```

PUBLIC DATA MEMBERS:

```
INTEGER, PUBLIC              :: ND42            ! ND42 on/off flag
INTEGER, PUBLIC              :: LD42            ! # of levels for ND42

! SOAupdate: ratio of OM/OC (hotp 6/12/09)
REAL*8, PARAMETER    :: OCFPOA  = 1.4d0
REAL*8, PARAMETER    :: OCFOPOA = 1.4d0*1.5d0  ! 2.1

! Arrays
REAL*4,  PUBLIC, ALLOCATABLE :: AD42(:,:,:,:)   ! Array for SOA [ug/m3]
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: DIAG42
PUBLIC :: ZERO_DIAG42
PUBLIC :: WRITE_DIAG42
PUBLIC :: INIT_DIAG42
PUBLIC :: CLEANUP_DIAG42
```

REVISION HISTORY:

```
22 May 2006 - D. Henze, R. Yantosca - Initial version
(1 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
     (bmy, 9/5/06)
(2 ) Now use ratio of 2.1 instead of 1.4 for SOA4 (dkh, bmy, 3/29/07)
(3 ) Add diagnostics for SOAG and SOAM (tmf, 1/7/09)
(4 ) Increase PD42 to 24. (fp, hotp, 2/3/10)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.42.1 diag42

Subroutine DIAG42 archives SOA concentrations [ug/m3] for the ND42 diagnostic.

INTERFACE:

```
SUBROUTINE DIAG42( Input_Opt, State_Met, State_Chm )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE PRESSURE_MOD,       ONLY : GET_PCENTER
USE TRACERID_MOD,       ONLY : IDTOCPI, IDTOCPO
USE TRACERID_MOD,       ONLY : IDTSOAG, IDTSOAM
USE TRACERID_MOD,       ONLY : IDTSO4,  IDTNIT, IDTNH4
USE TRACERID_MOD,       ONLY : IDTSALA, IDTSALC
USE TRACERID_MOD,       ONLY : IDTBCPI, IDTBCPO
! SOAupdate: consider additional species (hotp 10/26/07) MERGE1
! semivolpoa: replace OCPO and OCPI with POA (hotp 2/17/09)
USE TRACERID_MOD,       ONLY : IDTPOA1,  IDTPOA2
! semivolpoa4: add OPOA (hotp 3/27/09)
USE TRACERID_MOD,       ONLY : IDTOPOA1, IDTOPOA2
! add lumped arom/ivoc (hotp 5/15/10)
USE TRACERID_MOD,       ONLY : IDTASOAN, IDTASOA1
USE TRACERID_MOD,       ONLY : IDTASOA2, IDTASOA3
! monoterpene + sesquiterpene SOA (hotp 5/24/10)
USE TRACERID_MOD,       ONLY : IDTTSOA1, IDTTSOA2
```

```
      USE TRACERID_MOD,       ONLY : IDTTSOA3, IDTTSOA0
      ! isoprene SOA (hotp 5/24/10)
      USE TRACERID_MOD,       ONLY : IDTISOA1, IDTISOA2, IDTISOA3
      ! NO branching ratio diagnostic (hotp 5/24/10)
      USE CARBON_MOD,         ONLY : BETANOSAVE

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! NDxx flags
```

INPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(IN)  :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
    22 May 2006 - D. Henze, R. Yantosca - Initial version
    (1 ) Now use ratio of 2.1 instead of 1.4 for SOA4 (dkh, bmy, 3/29/07)
    02 Dec 2010 - R. Yantosca - Added ProTeX headers
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
    13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                                semivolatile POA simulations (H. Pye)
```

1.42.2 zero_diag42

Subroutine ZERO_DIAG42 zeroes all module arrays.

INTERFACE:

```
      SUBROUTINE ZERO_DIAG42
```

REVISION HISTORY:

```
    22 May 2006 - D. Henze, R. Yantosca - Initial version
    02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.42.3 write_diag42

Subroutine WRITE_DIAG42 writes the ND42 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
      SUBROUTINE WRITE_DIAG42( Input_Opt )
```

USES:

```
      USE BPCH2_MOD,          ONLY : BPCH2
      USE BPCH2_MOD,          ONLY : GET_MODELNAME
      USE BPCH2_MOD,          ONLY : GET_HALFPOLAR
      !USE DIAG_MOD,          ONLY : CTOTH
      USE FILE_MOD,           ONLY : IU_BPCH
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GRID_MOD,           ONLY : GET_XOFFSET
      USE GRID_MOD,           ONLY : GET_YOFFSET
      USE TIME_MOD,           ONLY : GET_CT_DIAG
      USE TIME_MOD,           ONLY : GET_DIAGb
      USE TIME_MOD,           ONLY : GET_DIAGe

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! TINDEX
```

INPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

REMARKS:

```
     # : Field    : Description                 : Units    : Scale factor
    ---------------------------------------------------------------------
    (1 ) IJ-SOA-$ : SOA1                        : ug/m3    : SCALE_OTH
    (2 ) IJ-SOA-$ : SOA2                        : ug/m3    : SCALE_OTH
    (3 ) IJ-SOA-$ : SOA3                        : ug/m3    : SCALE_OTH
    (4 ) IJ-SOA-$ : SOA4                        : ug/m3    : SCALE_OTH
    (5 ) IJ-SOA-$ : SOA1 + SOA2 + SOA3          : ug/m3    : SCALE_OTH
    (6 ) IJ-SOA-$ : SOA1 + SOA2 + SOA3 + SOA4   : ug/m3    : SCALE_OTH
    (7 ) IJ-SOA-$ : Sum of all Org Carbon       : ug C/m3  : SCALE_OTH
    (8 ) IJ-SOA-$ : Sum of all Org Carbon @ STP : ug C/sm3 : SCALE_OTH
```

REVISION HISTORY:

```
    22 May 2006 - D. Henze, R. Yantosca - Initial version
    (1 ) Replace TINY(1d0) with 1d-32 to avoid problems  on SUN 4100 platform
         (bmy, 9/5/06)
    (2 ) Use TS_DIAG for scaling instead of TS_DYN. (ccc, 8/18/09)
    02 Dec 2010 - R. Yantosca - Added ProTeX headers
    13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                                semivolatile POA simulations (H. Pye)
```

1.42.4 init_diag42

Subroutine INIT_DIAG42 allocates all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DIAG42
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE LOGICAL_MOD, ONLY : LSOA

USE CMN_SIZE_MOD    ! Size parameters
```

REVISION HISTORY:

```
22 May 2006 - D. Henze, R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.42.5 cleanup_diag42

Subroutine CLEANUP_DIAG42 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG42
```

REVISION HISTORY:

```
22 May 2006 - D. Henze, R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.43 Fortran: Module Interface diag49_mod

Module DIAG49_MOD contains variables and routines to save out 3-D instantaneous time-series output to disk.

INTERFACE:

```
MODULE DIAG49_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
LOGICAL, PUBLIC :: DO_SAVE_DIAG49
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: DIAG49
PUBLIC  :: ITS_TIME_FOR_DIAG49
PUBLIC  :: INIT_DIAG49
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: ITS_TIME_TO_CLOSE_FILE
PRIVATE :: GET_I
```

REMARKS:

ND49 tracer numbers:

1 - N_TRACERS	: GEOS-CHEM transported tracers	[v/v]
61	: Soil NOx	[molec/cm2/s]
62	: Fertilizer NOx	[molec/cm2/s]
63	: Dry Period	[hours]
64	: PFactor	[unitless]
65	: Soil Moisture	[unitless]
76	: OH concentration	[molec/cm3]
77	: NO2 concentration	[v/v]
78	: PBL heights	[m]
79	: PBL heights	[levels]
80	: Air density	[molec/cm3]
81	: 3-D Cloud fractions	[unitless]
82	: Column optical depths	[unitless]
83	: Cloud top heights	[hPa]
84	: Sulfate aerosol optical depth	[unitless]
85	: Black carbon aerosol optical depth	[unitless]
86	: Organic carbon aerosol optical depth	[unitless]
87	: Accumulation mode seasalt optical depth	[unitless]
88	: Coarse mode seasalt optical depth	[unitless]
89	: Total dust optical depth	[unitless]
90	: Total seasalt tracer concentration	[unitless]
91	: Pure O3 (not Ox) concentration	[v/v]
92	: NO concentration	[v/v]
93	: NOy concentration	[v/v]
94	: Grid box heights	[m]
95	: Relative Humidity	[%]
96	: Sea level pressure	[hPa]
97	: Zonal wind (a.k.a. U-wind)	[m/s]
98	: Meridional wind (a.k.a. V-wind)	[m/s]
99	: PEDGE-$ (Pressure @ level edges	[hPa]
100	: Temperature	[K]
101	: PAR direct	[hPa]
102	: PAR diffuse	[hPa]
103	: Daily LAI	[hPa]
104	: Temperature at 2m	[K]
105	: Isoprene emissions	[atomC/cm2/s]
106	: Total Monoterpene emissions	[atomC/cm2/s]
107	: Methyl Butanol emissions	[atomC/cm2/s]
108	: Alpha-Pinene emissions	[atomC/cm2/s]
109	: Beta-Pinene emissions	[atomC/cm2/s]

```
110           : Limonene emissions                        [atomC/cm2/s]
111           : Sabinene emissions                        [atomC/cm2/s]
112           : Myrcene emissions                         [atomC/cm2/s]
113           : 3-Carene emissions                        [atomC/cm2/s]
114           : Ocimene emissions                         [atomC/cm2/s]
115           : Farnesene emissions                       [atomC/cm2/s]
116-122       : size resolved dust optical depth          [unitless   ]
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Bug fix: get I0, J0 properly for nested grids (bmy, 11/9/04)
(2 ) Now references "pbl_mix_mod.f" (bmy, 2/16/05)
(3 ) Now saves 3-D cld frac & grid box height (bmy, 4/20/05)
(4 ) Remove TRCOFFSET since it's always zero  Also now get HALFPOLAR for
      both GCAP and GEOS grids.  (bmy, 6/28/05)
(5 ) Bug fix: do not save SLP if it's not allocated (bmy, 8/2/05)
(6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(7 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(8 ) Modified INIT_DIAG49 to save out transects (cdh, bmy, 11/30/06)
(9 ) Bug fix: accumulate into Q(X,Y,K) for dust OD (qli, bmy, 4/30/07)
(10) Minor bug fixes in DIAG49 (cdh, bmy, 2/11/08)
(11) Bug fix: replace "PS-PTOP" with "PEDGE-$"
(12) Modified to archive O3, NO, NOy as tracers 89, 90, 91  (tmf, 9/26/07)
(13) Bug fix DIAG49 for diagnostic output of SLP (tai, bmy, 10/13/09)
(14) Modify AOD output to wavelength specified in jv_spec_aod.dat
     (clh, 05/07/10)
(15) Bug fix in ITS_TIME_TO_CLOSE: compare HR1 to 00 not 24. (ccc, 11/11/10)
(16) Now do not scale AOD output (recalculated in RDAER AND DUST_MOD)
     (skim, 02/02/11)
12 Nov 2010 - R. Yantosca - Changed tracer 99 to be PEDGE-$ (pressure at
                            level edges) instead of Psurface-PTOP.
02 Dec 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2013 - M. Sulprizio- Add farnesene emissions for updated SOA (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.43.1 diag49

Subroutine DIAG49 produces time series (instantaneous fields) for a geographical domain from the information read in timeseries.dat. Output will be in binary punch (BPCH) format.

INTERFACE:

```
      SUBROUTINE DIAG49( am_I_Root, Input_Opt,
     &                   State_Met, State_Chm, RC )
```

USES:

```
      USE BPCH2_MOD,          ONLY : BPCH2,   OPEN_BPCH2_FOR_WRITE
      USE MODIS_LAI_MOD,      ONLY : ISOLAI => GC_LAI
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_XOFFSET,        GET_YOFFSET
      USE inquireMod,         ONLY : findFreeLun
      USE TIME_MOD,           ONLY : EXPAND_DATE
      USE TIME_MOD,           ONLY : GET_NYMD,           GET_NHMS
      USE TIME_MOD,           ONLY : GET_NYMD_DIAG,      GET_TS_DIAG
      USE TIME_MOD,           ONLY : GET_TAU,            GET_HOUR
      USE TIME_MOD,           ONLY : ITS_A_NEW_DAY
      USE TIME_MOD,           ONLY : TIMESTAMP_STRING
      USE PBL_MIX_MOD,        ONLY : GET_PBL_TOP_L,      GET_PBL_TOP_m
      USE TRACER_MOD,         ONLY : XNUMOLAIR
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE TRACERID_MOD,       ONLY : IDTHNO3, IDTHNO4, IDTN2O5, IDTNO
      USE TRACERID_MOD,       ONLY : IDTPAN,  IDTPMN,  IDTPPN,  IDTO3
      USE TRACERID_MOD,       ONLY : IDTR4N2, IDTSALA, IDTSALC, IDTNO2

      USE CMN_FJ_MOD,         ONLY : JPMAX,   JPPJ     ! FAST-J stuff
      USE JV_CMN_MOD               ! ODAER, QAA, QAA_AOD (clh)
      USE CMN_O3_MOD             ! SAVEOH
      USE CMN_GCTM_MOD             ! XTRA2
      USE COMMSOIL_MOD
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    09 Apr 1999 - I. Bey, R. Martin, R. Yantosca - Initial version
    (1 ) Now bundled into "diag49_mod.f".  Now reference STT from
         "tracer_mod.f".  Now scale aerosol & dust OD's to 400 nm.
         (bmy, rvm, aad, 7/9/04)
    (2 ) Updated tracer # for NO2 (bmy, 10/25/04)
    (3 ) Remove reference to "CMN".  Also now get PBL heights in meters and
         model layers from GET_PBL_TOP_m and GET_PBL_TOP_L of "pbl_mix_mod.f".
         (bmy, 2/16/05)
```

```
(4 ) Now reference CLDF and BXHEIGHT from "dao_mod.f".  Now save 3-D cloud
     fraction as tracer #79 and box height as tracer #93.  Now remove
     reference to PBL from "dao_mod.f"(bmy, 4/20/05)
(5 ) Remove references to TRCOFFSET because it is always zero (bmy, 6/24/05)
(6 ) Now do not save SLP data if it is not allocated (bmy, 8/2/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Now references XNUMOLAIR from "tracer_mod.f".  Bug fix: now must sum
     aerosol OD's over all RH bins.  Also zero Q array. (bmy, 11/1/05)
(9 ) Bug fix: accumulate into Q(X,Y,K) for dust OD (qli, bmy, 4/30/07)
(10) Bug fix: UNIT should be "levels" for tracer 77.  Also RH should be
     tracer #17 under "TIME-SER" category. (cdh, bmy, 2/11/08)
(11) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, phs, 10/7/08)
(12) Change the new day condition to open a new file. (ccc, 8/12/09)
(13) Change the timestamp for the filename when closing (ccc, 8/12/09)
(14) Add outputs for EMISS_BVOC (10 tracers), TS, PARDR, PARDF and ISOLAI
     (mpb, 11/19/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
14 Mar 2013 - M. Payer    - Replace NOx and Ox with NO, NO2, and O3 as part
                            of removal of NOx-Ox partitioning
13 Aug 2013 - M. Sulprizio- Add farnesene emissions for updated SOA (H. Pye)
```

1.43.2 its_time_to_close_file

Function ITS_TIME_TO_CLOSE_FILE returns TRUE if it's time to close the ND49 bpch file before the end of the day.

INTERFACE:

```
FUNCTION ITS_TIME_TO_CLOSE_FILE() RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD, ONLY : GET_HOUR
USE TIME_MOD, ONLY : GET_MINUTE
```

RETURN VALUE:

```
LOGICAL :: ITS_TIME
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) The time is already updated to the next time step (ccc, 8/12/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.43.3 its_time_for_diag49

Function ITS_TIME_FOR_DIAG49 returns TRUE if ND49 is turned on and it is time to call DIAG49 – or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_DIAG49() RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD,  ONLY : GET_ELAPSED_MIN
USE TIME_MOD,  ONLY : GET_TS_DIAG
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

RETURN VALUE:

```
LOGICAL :: ITS_TIME
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Add a check on the output frequency for validity compared to time
     steps used. (ccc, 5/21/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.43.4 get_i

Function GET_I returns the absolute longitude index (I), given the relative longitude index (X).

INTERFACE:

```
FUNCTION GET_I( X ) RESULT( I )
```

USES:

```
USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: X   ! Relative longitude index (used by Q array)
```

RETURN VALUE:

```
INTEGER             :: I   ! Absolute longitude index
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.43.5 init_diag49

Subroutine INIT_DIAG49 allocates and zeroes all module arrays. It also gets values for module variables from "input_mod.f".

INTERFACE:

```
 SUBROUTINE INIT_DIAG49( DO_ND49, N_ND49, TRACERS, IMIN,
&                        IMAX,    JMIN,   JMAX,    LMIN,
&                        LMAX,    FREQ,   FILE )
```

USES:

```
USE BPCH2_MOD, ONLY : GET_MODELNAME
USE BPCH2_MOD, ONLY : GET_HALFPOLAR
USE GRID_MOD,  ONLY : GET_XOFFSET
USE GRID_MOD,  ONLY : GET_YOFFSET
USE GRID_MOD,  ONLY : ITS_A_NESTED_GRID
USE ERROR_MOD, ONLY : ERROR_STOP

USE CMN_SIZE_MOD ! Size parameters
```

INPUT PARAMETERS:

```
! DO_ND49 : Switch to turn on ND49 timeseries diagnostic
! N_ND50  : Number of ND49 read by "input_mod.f"
! TRACERS : Array w/ ND49 tracer #'s read by "input_mod.f"
! IMIN    : Min longitude index read by "input_mod.f"
! IMAX    : Max longitude index read by "input_mod.f"
! JMIN    : Min latitude index read by "input_mod.f"
! JMAX    : Min latitude index read by "input_mod.f"
! LMIN    : Min level index read by "input_mod.f"
! LMAX    : Min level index read by "input_mod.f"
! FREQ    : Frequency for saving to disk [min]
! FILE    : ND49 output file name read by "input_mod.f"
LOGICAL,             INTENT(IN) :: DO_ND49
INTEGER,             INTENT(IN) :: N_ND49, TRACERS(100)
INTEGER,             INTENT(IN) :: IMIN,   IMAX
INTEGER,             INTENT(IN) :: JMIN,   JMAX
INTEGER,             INTENT(IN) :: LMIN,   LMAX
INTEGER,             INTENT(IN) :: FREQ
CHARACTER(LEN=255), INTENT(IN) :: FILE
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now get I0 and J0 correctly for nested grid simulations (bmy, 11/9/04)
(2 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
     value for GEOS or GCAP grids. (bmy, 6/28/05)
(3 ) Now allow ND49_IMIN to be equal to ND49_IMAX and ND49_JMIN to be
```

```
      equal to ND49_JMAX.  This will allow us to save out longitude
      or latitude transects.  (cdh, bmy, 11/30/06)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.44 Fortran: Module Interface diag50_mod

Module DIAG50_MOD contains variables and routines to generate 24-hour average time-series data.

INTERFACE:

```
MODULE DIAG50_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
LOGICAL, PUBLIC :: DO_SAVE_DIAG50    ! On/off flag for ND50 diagnostic
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_DIAG50
PUBLIC  :: DIAG50
PUBLIC  :: INIT_DIAG50
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: ACCUMULATE_DIAG50
PRIVATE :: ITS_TIME_FOR_WRITE_DIAG50
PRIVATE :: WRITE_DIAG50
PRIVATE :: GET_I
```

REMARKS:

```
ND50 tracer numbers:
============================================================================
1 - N_TRACERS : GEOS-CHEM transported tracers           [v/v      ]
76            : OH concentration                        [molec/cm3]
77            : NO2 concentration                       [v/v      ]
78            : PBL heights                             [m        ]
79            : PBL heights                             [levels   ]
80            : Air density                             [molec/cm3]
81            : 3-D Cloud fractions                     [unitless ]
82            : Column optical depths                   [unitless ]
83            : Cloud top heights                       [hPa      ]
84            : Sulfate aerosol optical depth           [unitless ]
85            : Black carbon aerosol optical depth      [unitless ]
86            : Organic carbon aerosol optical depth    [unitless ]
```

```
87            : Accumulation mode seasalt optical depth  [unitless ]
88            : Coarse mode seasalt optical depth        [unitless ]
89            : Total dust optical depth                 [unitless ]
90            : Total seasalt tracer concentration       [unitless ]
91            : Pure O3 (not Ox) concentration           [v/v      ]
92            : NO concentration                         [v/v      ]
93            : NOy concentration                        [v/v      ]
94            : Grid box height                          [m        ]
95            : Relative humidity                        [%        ]
96            : Sea level pressure                       [hPa      ]
97            : Zonal wind (a.k.a. U-wind)               [m/s      ]
98            : Meridional wind (a.k.a. V-wind)          [m/s      ]
99            : P(surface) - PTOP                        [hPa      ]
100           : Temperature                              [K        ]
115-121       : size resolved dust optical depth         [unitless ]
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Rewritten for clarity and to save extra quantities (bmy, 7/20/04)
(2 ) Added COUNT_CHEM to count the chemistry timesteps per day, since some
     quantities are only archived after a fullchem call (bmy, 10/25/04)
(3 ) Bug fix: Now get I0 and J0 properly for nested grids (bmy, 11/9/04)
(4 ) Now only archive AOD's once per chemistry timestep (bmy, 1/14/05)
(5 ) Now references "pbl_mix_mod.f" (bmy, 2/16/05)
(6 ) Now save cloud fractions & grid box heights (bmy, 4/20/05)
(7 ) Remove TRCOFFSET since it's always zero.  Also now get HALFPOLAR for
     both GCAP and GEOS grids. (bmy, 6/24/05)
(8 ) Bug fix: don't save SLP unless it is allocated (bmy, 8/2/05)
(9 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(10) Modified INIT_DIAG49 to save out transects (cdh, bmy, 11/30/06)
(11) Now use 3D timestep counter for full chem in the trop (phs, 1/24/07)
(12) Renumber RH diagnostic in WRITE_DIAG50 (bmy, 2/11/08)
(13) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, 10/7/08)
(14) Modified to archive O3, NO, NOy as tracers 89, 90, 91  (tmf, 9/26/07)
(15) Updates & bug fixes in WRITE_DIAG50 (ccc, tai, bmy, 10/13/09)
(16) Updates to AOD output.  Also have the option to write to HDF
     (amv, bmy, 12/21/09)
(17) Modify AOD output to wavelength specified in jv_spec_aod.dat
     (clh, 05/07/10)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
02 Dec 2010 - R. Yantosca - Added ProTeX headers
03 Feb 2011 - S. Kim      - Now do not scale the AOD output
                            (recalculated in RDAER AND DUST_MOD)
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
06 Aug 2012 - R. Yantosca - Now make IU_ND50 a local module variable
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.44.1 DIAG50

Subroutine DIAG50 generates 24hr average time series. Output is to binary punch file format or HDF5 file.

INTERFACE:

```
SUBROUTINE DIAG50( am_I_Root, Input_Opt, State_Met, State_Chm, RC)
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GIGC_State_Met_Mod, ONLY : MetState
USE LOGICAL_MOD,        ONLY : DO_DIAG_WRITE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.44.2 accumulate_diag50

Subroutine ACCUMULATE_DIAG50 accumulates tracers into the Q array.

INTERFACE:

```
 SUBROUTINE ACCUMULATE_DIAG50( am_I_Root, Input_Opt,
&                              State_Met, State_Chm, RC )
```

USES:

```
      USE COMODE_MOD,         ONLY : JLOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PBL_MIX_MOD,        ONLY : GET_PBL_TOP_L, GET_PBL_TOP_m
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE TIME_MOD,           ONLY : GET_ELAPSED_MIN, GET_TS_CHEM
      USE TIME_MOD,           ONLY : TIMESTAMP_STRING
      USE TRACER_MOD,         ONLY : XNUMOLAIR
      USE TRACERID_MOD,       ONLY : IDTHNO3, IDTHNO4, IDTN2O5, IDTNO
      USE TRACERID_MOD,       ONLY : IDTPAN,  IDTPMN,  IDTPPN,  IDTO3
      USE TRACERID_MOD,       ONLY : IDTR4N2, IDTSALA, IDTSALC, IDTNO2

      USE CMN_FJ_MOD,         ONLY : JPMAX, JPPJ      ! includes F77_CMN_SIZE
      USE JV_CMN_MOD               ! ODAER,   QAA,    QAA_OUT
      USE COMODE_LOOP_MOD          ! NPVERT
      USE CMN_O3_MOD               ! SAVEOH
      USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Rewrote to remove hardwiring and for better efficiency.  Added extra
         diagnostics and updated numbering scheme.  Now scale aerosol & dust
         optical depths to 400 nm. (rvm, aad, bmy, 7/20/04)
    (2 ) Now reference GET_ELAPSED_MIN and GET_TS_CHEM from "time_mod.f".
         Also now use extra counter COUNT_CHEM to count the number of
         chemistry timesteps since NO, NO2, OH, O3 only when a full-chemistry
         timestep happens. (bmy, 10/25/04)
    (3 ) Only archive AOD's when it is a chem timestep (bmy, 1/14/05)
    (4 ) Remove reference to "CMN".  Also now get PBL heights in meters and
         model layers from GET_PBL_TOP_m and GET_PBL_TOP_L of "pbl_mix_mod.f".
         (bmy, 2/16/05)
    (5 ) Now reference CLDF and BXHEIGHT from "dao_mod.f".  Now save 3-D
         cloud fraction as tracer #79 and box height as tracer #93.  Now
         remove references to CLMOSW, CLROSW, and PBL from "dao_mod.f".
```

```
      (bmy, 4/20/05)
(6 ) Remove references to TRCOFFSET because it's always zero (bmy, 6/24/05)
(7 ) Now do not save SLP data if it is not allocated (bmy, 8/2/05)
(8 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(9 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(10) Now account for time spent in the trop for non-tracers (phs, 1/24/07)
(11) IS_CHEM check is not appropriate anymore. Keep COUNT_CHEM3D for
     species known in troposphere only (ccc, 8/12/09)
(12) Output AOD at 3rd jv_spec.dat row wavelength.  Include all seven dust
      bin's individual AOD (amv, bmy, 12/21/09)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
02 Dec 2010 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
14 Mar 2013 - M. Payer    - Replace NOx and Ox with NO, NO2, and O3 as part
                            of removal of NOx-Ox partitioning
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.44.3 its_time_for_write_diag50

Function ITS_TIME_FOR_WRITE_DIAG50 returns TRUE if it's time to write the ND50 bpch file to disk. We test the time at the next dynamic timestep, so that we can close the file before the end of the run properly.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_WRITE_DIAG50() RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD, ONLY : GET_HOUR
USE TIME_MOD, ONLY : GET_MINUTE
USE TIME_MOD, ONLY : GET_TS_DYN
```

RETURN VALUE:

```
LOGICAL :: ITS_TIME
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) The time is already updated to the next time step in main.f
      (ccc, 8/12/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.44.4 write_diag50

Subroutine WRITE_DIAG50 computes the 24-hr time-average of quantities and saves to bpch file format.

INTERFACE:

```
      SUBROUTINE WRITE_DIAG50( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE BPCH2_MOD,          ONLY : BPCH2
      USE BPCH2_MOD,          ONLY : GET_MODELNAME
      USE BPCH2_MOD,          ONLY : GET_HALFPOLAR
      USE BPCH2_MOD,          ONLY : OPEN_BPCH2_FOR_WRITE
      USE ERROR_MOD,          ONLY : ALLOC_ERR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GRID_MOD,           ONLY : GET_XOFFSET
      USE GRID_MOD,           ONLY : GET_YOFFSET
      USE inquireMod,         ONLY : findFreeLUN
      USE TIME_MOD,           ONLY : EXPAND_DATE
      USE TIME_MOD,           ONLY : GET_NYMD_DIAG
      USE TIME_MOD,           ONLY : GET_NHMS
      USE TIME_MOD,           ONLY : GET_TAU
      USE TIME_MOD,           ONLY : GET_TS_DYN
      USE TIME_MOD,           ONLY : TIMESTAMP_STRING

#if   defined( USE_HDF5 )
      ! Only include this if we are linking to HDF5 library (bmy, 12/21/09)
      USE HDF_MOD,            ONLY : OPEN_HDF
      USE HDF_MOD,            ONLY : CLOSE_HDF
      USE HDF_MOD,            ONLY : WRITE_HDF
      USE HDF5,               ONLY : HID_T
      INTEGER(HID_T)              :: IU_ND50_HDF
#endif

      USE CMN_SIZE_MOD  ! Size Parameters
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?!
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Rewrote to remove hardwiring and for better efficiency.  Added extra
```

```
      diagnostics and updated numbering scheme. (bmy, 7/20/04)
(2 ) Now only archive NO, NO2, OH, O3 on every chemistry timestep (i.e.
      only when fullchem is called).  Also remove reference to FIRST.
      (bmy, 10/25/04)
(3 ) Now divide tracers 82-87 (i.e. various AOD's) by GOOD_CT_CHEM since
      these are only updated once per chemistry timestep (bmy, 1/14/05)
(4 ) Now save grid box heights as tracer #93.  Now save 3-D cloud fraction
      as tracer #79. (bmy, 4/20/05)
(5 ) Remove references to TRCOFFSET because it's always zero (bmy, 6/24/05)
(6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(7 ) DIVISOR is now a 3-D array.  Now zero COUNT_CHEM3D.  Now zero Q
      array with array assignment statement. (phs, 1/24/07)
(8 ) RH should be tracer #17 under "TIME-SER" category (bmy, 2/11/08)
(9 ) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, 10/7/08)
(10) Change timestamp for filename.  Now save SLP under tracer #18 in
      "DAO-FLDS".  Also set unit to 'K' for temperature field.
      (ccc, tai, bmy, 10/13/09)
(11) Now have the option of saving out to HDF5 format.  NOTE: we have to
      bracket HDF-specific code with an #ifdef statement to avoid problems
      if the HDF5 libraries are not installed. (amv, bmy, 12/21/09)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
02 Dec 2010 - R. Yantosca - Added ProTeX headers
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC args
```

1.44.5 get_i

Function GET_I returns the absolute longitude index (I), given the relative longitude index (X).

INTERFACE:

```
FUNCTION GET_I( X ) RESULT( I )
```

USES:

```
USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: X   ! Relative longitude index
```

RETURN VALUE:

```
INTEGER             :: I   ! Absolute longitude index
```

REMARKS:

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.44.6 init_diag50

Subroutine INIT_DIAG50 allocates and zeroes all module arrays. It also gets values for module variables from "input_mod.f".

INTERFACE:

```
  SUBROUTINE INIT_DIAG50( DO_ND50, N_ND50, TRACERS, IMIN, IMAX,
 &                        JMIN,    JMAX,   LMIN,    LMAX, FILE )
```

USES:

```
  USE BPCH2_MOD,  ONLY : GET_MODELNAME
  USE BPCH2_MOD,  ONLY : GET_HALFPOLAR
  USE ERROR_MOD,  ONLY : ALLOC_ERR
  USE ERROR_MOD,  ONLY : ERROR_STOP
  USE GRID_MOD,   ONLY : GET_XOFFSET
  USE GRID_MOD,   ONLY : GET_YOFFSET
  USE GRID_MOD,   ONLY : ITS_A_NESTED_GRID
  USE TIME_MOD,   ONLY : GET_TAUb
  USE TRACER_MOD, ONLY : N_TRACERS

  USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
  ! DO_ND50 : Switch to turn on ND50 timeseries diagnostic
  ! N_ND50  : Number of ND50 read by "input_mod.f"
  ! TRACERS : Array w/ ND50 tracer #'s read by "input_mod.f"
  ! IMIN    : Min longitude index read by "input_mod.f"
  ! IMAX    : Max longitude index read by "input_mod.f"
  ! JMIN    : Min latitude index read by "input_mod.f"
  ! JMAX    : Min latitude index read by "input_mod.f"
  ! LMIN    : Min level index read by "input_mod.f"
  ! LMAX    : Min level index read by "input_mod.f"
  ! FILE    : ND50 output file name read by "input_mod.f"
  LOGICAL,            INTENT(IN) :: DO_ND50
  INTEGER,            INTENT(IN) :: N_ND50, TRACERS(100)
  INTEGER,            INTENT(IN) :: IMIN,   IMAX
  INTEGER,            INTENT(IN) :: JMIN,   JMAX
  INTEGER,            INTENT(IN) :: LMIN,   LMAX
  CHARACTER(LEN=255), INTENT(IN) :: FILE
```

REMARKS:

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now get I0 and J0 correctly for nested grid simulations (bmy, 11/9/04)
(2 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
      value for GEOS or GCAP grids. (bmy, 6/28/05)
(3 ) Now allow ND50_IMIN to be equal to ND50_IMAX and ND50_JMIN to be
      equal to ND50_JMAX.  This will allow us to save out longitude
      or latitude transects.  Now allocate COUNT_CHEM3D array.
      (cdh, phs, 1/24/07)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.44.7 cleanup_diag50

Subroutine CLEANUP_DIAG50 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG50
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now deallocate COUNT_CHEM3D (phs, 1/24/07)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.45 Fortran: Module Interface diag51b_mod

Module DIAG51b_MOD contains variables and routines to generate save timeseries data where the local time is between two user-defined limits. This facilitates comparisons with morning or afternoon-passing satellites such as GOME.

INTERFACE:

```
MODULE DIAG51b_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
LOGICAL, PUBLIC :: DO_SAVE_DIAG51b   ! On/off switch for ND51b diagnostic
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_DIAG51b
PUBLIC  :: DIAG51b
PUBLIC  :: INIT_DIAG51b
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: ACCUMULATE_DIAG51
PRIVATE :: GET_LOCAL_TIME
PRIVATE :: ITS_TIME_FOR_WRITE_DIAG51
PRIVATE :: WRITE_DIAG51
```

REMARKS:

ND51b tracer numbers:

1 - N_TRACERS	GEOS-CHEM transported tracers	[v/v]
76	OH concentration	[molec/cm3]
77	NO2 concentration	[v/v]
78	PBL heights	[m]
79	PBL heights	[levels]
80	Air density	[molec/cm3]
81	3-D Cloud fractions	[unitless]
82	Column optical depths	[unitless]
83	Cloud top heights	[hPa]
84	Sulfate aerosol optical depth	[unitless]
85	Black carbon aerosol optical depth	[unitless]
86	Organic carbon aerosol optical depth	[unitless]
87	Accumulation mode seasalt optical depth	[unitless]
88	Coarse mode seasalt optical depth	[unitless]
89	Total dust optical depth	[unitless]
90	Total seasalt tracer concentration	[unitless]
91	Pure O3 (not Ox) concentration	[v/v]
92	NO concentration	[v/v]
93	NOy concentration	[v/v]
94	Grid box heights	[m]
95	Relative Humidity	[%]
96	Sea level pressure	[hPa]
97	Zonal wind (a.k.a. U-wind)	[m/s]
98	Meridional wind (a.k.a. V-wind)	[m/s]
99	P(surface) - PTOP	[hPa]
100	Temperature	[K]
101	PAR direct	[hPa]
102	PAR diffuse	[hPa]
103	Daily LAI	[hPa]
104	Temperature at 2m	[K]
105	Isoprene emissions	[atomC/cm2/s]
106	Total Monoterpene emissions	[atomC/cm2/s]
107	Methyl Butanol emissions	[atomC/cm2/s]

```
108           : Alpha-Pinene emissions                    [atomC/cm2/s]
109           : Beta-Pinene emissions                     [atomC/cm2/s]
110           : Limonene emissions                        [atomC/cm2/s]
111           : Sabinene emissions                        [atomC/cm2/s]
112           : Myrcene emissions                         [atomC/cm2/s]
113           : 3-Carene emissions                        [atomC/cm2/s]
114           : Ocimene emissions                         [atomC/cm2/s]
115-121       : size resolved dust optical depth          [unitless   ]
```

REVISION HISTORY:

```
(1 ) Rewritten for clarity (bmy, 7/20/04)
(2 ) Added extra counters for NO, NO2, OH, O3.  Also all diagnostic counter
     arrays are 1-D since they only depend on longitude. (bmy, 10/25/04)
(3 ) Bug fix: Now get I0 and J0 properly for nested grids (bmy, 11/9/04)
(4 ) Now only archive AOD's once per chemistry timestep (bmy, 1/14/05)
(5 ) Now references "pbl_mix_mod.f" (bmy, 2/16/05)
(6 ) Now save cld frac and grid box heights (bmy, 4/20/05)
(7 ) Remove TRCOFFSET since it's always zero  Also now get HALFPOLAR for
     both GCAP and GEOS grids.  (bmy, 6/28/05)
(8 ) Bug fix: do not save SLP if it's not allocated (bmy, 8/2/05)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(10) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(11) Modified INIT_DIAG51 to save out transects (cdh, bmy, 11/30/06)
(12) Now use 3D timestep counter for full chem in the trop (phs, 1/24/07)
(13) Renumber RH in WRITE_DIAG50 (bmy, 2/11/08)
(14) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, phs, 10/7/08)
(15) Bug fix in GET_LOCAL_TIME (ccc, 12/10/08)
(16) Modified to archive O3, NO, NOy as tracers 89, 90, 91  (tmf, 9/26/07)
(17) Updates in WRITE_DIAG51b (ccc, tai, bmy, 10/13/09)
(18) Updates to AOD output.  Also have the option to write to HDF
     (amv, bmy, 12/21/09)
(19) Added MEGAN species (mpb, bmy, 12/21/09)
(20) Modify AOD output to wavelength specified in jv_spec_aod.dat
     (clh, 05/07/10)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
03 Feb 2011 - S. Kim      - Now do not scale the AOD output
                            (recalculated in RDAER AND DUST_MOD)
01 Mar 2012 - R. Yantosca - Use updated GET_LOCALTIME from time_mod.F
06 Aug 2012 - R. Yantosca - Now make IU_ND51b a local module variable
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.45.1 diag51b

Subroutine DIAG51 generates time series (averages from ! 10am - 12pm LT or 1pm - 4pm LT) for the US grid area. Output is to binary punch files or HDF5 files.

INTERFACE:

```
SUBROUTINE DIAG51b( am_I_Root, Input_Opt,
&                   State_Met, State_Chm, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Rewritten for clarity (bmy, 7/20/04)
(2 ) Added TAU_W as a local variable (bmy, 9/28/04)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.45.2 get_local_time

Subroutine GET_LOCAL_TIME computes the local time and returns an array of points where the local time is between two user-defined limits.

INTERFACE:

```
SUBROUTINE GET_LOCAL_TIME
```

USES:

```
USE TIME_MOD, ONLY : GET_LOCALTIME
USE TIME_MOD, ONLY : GET_TS_DYN

USE CMN_SIZE_MOD   ! Size parameters
```

REMARKS:

```
For now use GET_LOCALTIME( I, 1, 1 ) which will be independent of J and L
for a pure cartesian grid.  This may need to be revisited once G-C is
interfaced into a GCM.
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) The 1d-3 in the computation of XLOCTM is to remove roundoff ambiguity
      if a the local time should fall exactly on an hour boundary.
      (bmy, 11/29/00)
(2 ) Bug fix: XMID(I) should be XMID(II).  Also updated comments.
      (bmy, 7/6/01)
(3 ) Updated comments (rvm, bmy, 2/27/02)
(4 ) Now uses function GET_LOCALTIME of "time_mod.f" (bmy, 3/27/03)
(5 ) Removed reference to CMN (bmy, 7/20/04)
(6 ) Bug fix: LT should be REAL*8 and not INTEGER (ccarouge, 12/10/08)
(7 ) We need to substract TS_DYN to the time to get the local time at
      the beginning of previous time step. (ccc, 8/11/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90
```

1.45.3 accumulate_diag51

Subroutine ACCUMULATE_DIAG51 accumulates tracers into the Q array.

INTERFACE:

```
      SUBROUTINE ACCUMULATE_DIAG51( am_I_Root, Input_Opt,
     &                              State_Met, State_Chm, RC )
```

USES:

```
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE MODIS_LAI_MOD,      ONLY : ISOLAI => GC_LAI
      USE PBL_MIX_MOD,        ONLY : GET_PBL_TOP_L,    GET_PBL_TOP_m
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE TIME_MOD,           ONLY : GET_ELAPSED_MIN,  GET_TS_CHEM
      USE TIME_MOD,           ONLY : TIMESTAMP_STRING, GET_TS_DYN
      USE TIME_MOD,           ONLY : GET_TS_DIAG,      GET_TS_EMIS
      USE TRACER_MOD,         ONLY : XNUMOLAIR
      USE TRACERID_MOD,       ONLY : IDTHNO3, IDTHNO4, IDTN2O5, IDTNO
      USE TRACERID_MOD,       ONLY : IDTPAN,  IDTPMN,  IDTPPN,  IDTO3
      USE TRACERID_MOD,       ONLY : IDTR4N2, IDTSALA, IDTSALC, IDTNO2
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_TROP
```

```
      USE CMN_FJ_MOD,         ONLY : JPMAX, JPPJ      ! includes F77_CMN_SIZE
      USE JV_CMN_MOD                ! ODAER,   QAA,    QAA_AOD
      USE CMN_O3_MOD                ! SAVEOH
      USE CMN_GCTM_MOD              ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Rewrote to remove hardwiring and for better efficiency.  Added extra
         diagnostics and updated numbering scheme.  Now scale optical depths
         to 400 nm (which is usually what QAA(2,*) is.  (bmy, 7/20/04)
    (2 ) Now reference GET_ELAPSED_MIN and GET_TS_CHEM from "time_mod.f".
         Also now all diagnostic counters are 1-D since they only depend on
         longitude. Now only archive NO, NO2, OH, O3 on every chemistry
         timestep (i.e. only when fullchem is called). (bmy, 10/25/04)
    (3 ) Only archive AOD's when it is a chem timestep (bmy, 1/14/05)
    (4 ) Remove reference to "CMN".  Also now get PBL heights in meters and
         model layers from GET_PBL_TOP_m and GET_PBL_TOP_L of "pbl_mix_mod.f".
         (bmy, 2/16/05)
    (5 ) Now reference CLDF and BXHEIGHT from "dao_mod.f".  Now save 3-D cloud
         fraction as tracer #79 and box height as tracer #93.  Now remove
         references to CLMOSW, CLROSW, and PBL from "dao_mod.f". (bmy, 4/20/05)
    (6 ) Remove TRCOFFSET since it's always zero  Also now get HALFPOLAR for
         both GCAP and GEOS grids.  (bmy, 6/28/05)
    (7 ) Now do not save SLP data if it is not allocated (bmy, 8/2/05)
    (8 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (9 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
    (10) Now account for time spent in the trop for non-tracers (phs, 1/24/07)
    (11) We determine points corresponding to the time window at each timestep.
         But accumulate only when it's time for diagnostic (longest t.s.)
         (ccc, 8/12/09)
    (12) Add outputs ("DAO-FLDS" and "BIOGSRCE" categories). Add GOOD_EMIS and
         GOOD_CT_EMIS to manage emission outputs. (ccc, 11/20/09)
    (13) Output AOD at 3rd jv_spec.dat row wavelength.  Include all seven dust
         bin's individual AOD (amv, bmy, 12/21/09)
```

```
(12) Added MEGAN species (mpb, bmy, 12/21/09)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
14 Mar 2013 - M. Payer    - Replace NOx and Ox with NO, NO2, and O3 as part
                            of removal of NOx-Ox partitioning
```

1.45.4 its_time_for_write_diag51

Function ITS_TIME_FOR_WRITE_DIAG51 returns TRUE if it's time to write the ND51 bpch file to disk. We test the time at the next dynamic timestep so that we can write to disk properly.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_WRITE_DIAG51( TAU_W ) RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD,  ONLY : GET_HOUR
USE TIME_MOD,  ONLY : GET_MINUTE
USE TIME_MOD,  ONLY : GET_TAU
USE TIME_MOD,  ONLY : GET_TAUb
USE TIME_MOD,  ONLY : GET_TAUe
USE TIME_MOD,  ONLY : GET_TS_DYN
USE TIME_MOD,  ONLY : GET_TS_DIAG
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

OUTPUT PARAMETERS:

```
REAL*8, INTENT(OUT) :: TAU_W   ! TAU at time of disk write
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Added TAU_W so to make sure the timestamp is accurate. (bmy, 9/28/04)
(2 ) Add check with TS_DIAG. (ccc, 7/21/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.45.5 write_diag51

Subroutine WRITE_DIAG51 computes the time-average of quantities between local time limits ND51_HR1 and ND51_HR2 and writes them to a bpch file or HDF5 file. Arrays and counters are also zeroed for the next diagnostic interval.

INTERFACE:

```
      SUBROUTINE WRITE_DIAG51( am_I_Root, Input_Opt, TAU_W, RC )
```

USES:

```
      USE BPCH2_MOD,          ONLY : BPCH2
      USE BPCH2_MOD,          ONLY : OPEN_BPCH2_FOR_WRITE
      USE ERROR_MOD,          ONLY : ALLOC_ERR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE inquireMod,         ONLY : findFreeLUN
      USE TIME_MOD,           ONLY : EXPAND_DATE
      USE TIME_MOD,           ONLY : GET_NYMD_DIAG
      USE TIME_MOD,           ONLY : GET_NHMS
      USE TIME_MOD,           ONLY : GET_TAU
      USE TIME_MOD,           ONLY : TIMESTAMP_STRING
      USE TIME_MOD,           ONLY : GET_TS_DYN

#if   defined( USE_HDF5 )
      ! Only include this if we are linking to HDF5 library (bmy, 12/21/09)
      USE HDF_MOD,            ONLY : OPEN_HDF
      USE HDF_MOD,            ONLY : CLOSE_HDF
      USE HDF_MOD,            ONLY : WRITE_HDF
      USE HDF5,               ONLY : HID_T
      INTEGER(HID_T)              :: IU_ND51b_HDF
#endif

      USE CMN_SIZE_MOD   ! Size Parameters
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
      REAL*8,         INTENT(IN)  :: TAU_W       ! TAU value at time of write
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
   Arguments as Input:
   ============================================================================
   (1 ) TAU_W (REAL*8) : TAU value at time of writing to disk
   NOTES:
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Rewrote to‘ remove hardwiring and for better efficiency.  Added extra
        diagnostics and updated numbering scheme. (bmy, 7/20/04)
   (2 ) Added TAU_W to the arg list.  Now use TAU_W to set TAU0 and TAU0.
        Also now all diagnostic counters are 1-D since they only depend on
        longitude.  Now only archive NO, NO2, OH, O3 on every chemistry
        timestep (i.e. only when fullchem is called).  Also remove reference
```

```
      to FIRST. (bmy, 10/25/04)
(3 ) Now divide tracers 82-87 (i.e. various AOD's) by GOOD_CT_CHEM since
      these are only updated once per chemistry timestep (bmy, 1/14/05)
(4 ) Now save grid box heights as tracer #93.  Now save 3-D cloud fraction
      as tracer #79 (bmy, 4/20/05)
(5 ) Remove references to TRCOFFSET because it's always zero (bmy, 6/24/05)
(6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(7 ) DIVISOR is now a 3-D array.  Now zero COUNT_CHEM3D.  Now use CASE
      statement instead of IF statements.  Now zero counter arrays with
      array broadcast assignments. (phs, 1/24/07)
(8 ) RH should be tracer #17 under "TIME-SER" category (bmy, 2/11/08)
(9 ) Bug fix: replace "PS-PTOP" with "PEDGE-$" (bmy, phs, 10/7/08)
(10) Change timestamp used for filename.  Now save SLP under tracer #18 in
     "DAO-FLDS". (ccc, tai, bmy, 10/13/09)
(11) Now have the option of saving out to HDF5 format.  NOTE: we have to
      bracket HDF-specific code with an #ifdef statement to avoid problems
      if the HDF5 libraries are not installed. (amv, bmy, 12/21/09)
(12) Add outputs ("DAO-FLDS" and "BIOGSRCE" categories). Add GOOD_EMIS and
     GOOD_CT_EMIS to manage emission outputs. (ccc, 11/20/09)
(13) Added MEGAN species (mpb, bmy, 12/21/09)
12 Nov 2010 - R. Yantosca - Now save out PEDGE-$ (pressure at level edges)
                            rather than Psurface - PTOP
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.45.6 get_i

Function GET_I returns the absolute longitude index (I), given the relative longitude index (X).

INTERFACE:

```
FUNCTION GET_I( X ) RESULT( I )
```

USES:

```
USE CMN_SIZE_MOD   ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: X   ! Relative longitude index
```

RETURN VALUE:

```
INTEGER             :: I   ! Absolute longitude index
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.45.7 init_diag51

Subroutine INIT_DIAG51b allocates and zeroes all module arrays. It also gets values for module variables from "input_mod.f".

INTERFACE:

```
 SUBROUTINE INIT_DIAG51b( DO_ND51, N_ND51, TRACERS, HR_WRITE,
&                         HR1,     HR2,    IMIN,    IMAX,
&                         JMIN,    JMAX,   LMIN,    LMAX,  FILE )
```

USES:

```
USE BPCH2_MOD,  ONLY : GET_MODELNAME
USE BPCH2_MOD,  ONLY : GET_HALFPOLAR
USE ERROR_MOD,  ONLY : ALLOC_ERR
USE ERROR_MOD,  ONLY : ERROR_STOP
USE GRID_MOD,   ONLY : GET_XOFFSET
USE GRID_MOD,   ONLY : GET_YOFFSET
USE GRID_MOD,   ONLY : ITS_A_NESTED_GRID
USE TIME_MOD,   ONLY : GET_TAUb
USE TRACER_MOD, ONLY : N_TRACERS

USE CMN_SIZE_MOD   ! Size parameters
```

INPUT PARAMETERS:

```
! DO_ND51 : Switch to turn on ND51 timeseries diagnostic
! N_ND51  : Number of ND51 read by "input_mod.f"
! TRACERS : Array w/ ND51 tracer #'s read by "input_mod.f"
! HR_WRITE: GMT hour of day at which to write bpch file
! HR1     : Lower limit of local time averaging bin
! HR2     : Upper limit of local time averaging bin
! IMIN    : Min longitude index read by "input_mod.f"
! IMAX    : Max longitude index read by "input_mod.f"
! JMIN    : Min latitude index read by "input_mod.f"
! JMAX    : Min latitude index read by "input_mod.f"
! LMIN    : Min level index read by "input_mod.f"
! LMAX    : Min level index read by "input_mod.f"
! FILE    : ND51 output file name read by "input_mod.f"
LOGICAL,            INTENT(IN) :: DO_ND51
INTEGER,            INTENT(IN) :: N_ND51, TRACERS(100)
INTEGER,            INTENT(IN) :: IMIN,   IMAX
INTEGER,            INTENT(IN) :: JMIN,   JMAX
INTEGER,            INTENT(IN) :: LMIN,   LMAX
REAL*8,             INTENT(IN) :: HR1,    HR2
REAL*8,             INTENT(IN) :: HR_WRITE
CHARACTER(LEN=255), INTENT(IN) :: FILE
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Diagnostic counter arrays are now only 1-D.  Also add GOOD_CT_CHEM
      which is the counter array of "good" boxes at each chemistry
      timesteps.  Now allocate GOOD_CT_CHEM. (bmy, 10/25/04)
(2 ) Now get I0 and J0 correctly for nested grid simulations (bmy, 11/9/04)
(3 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
      value for GEOS or GCAP grids. (bmy, 6/28/05)
(4 ) Now allow ND51_IMIN to be equal to ND51_IMAX and ND51_JMIN to be
      equal to ND51_JMAX.  This will allow us to save out longitude or
      latitude transects.  Allocate COUNT_CHEM3D. (cdh, bmy, phs, 1/24/07)
(5 ) Allocate GOOD_EMIS and GOOD_CT_EMIS (ccc, 12/12/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.45.8 cleanup_diag51

Subroutine CLEANUP_DIAG51 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG51b
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now deallocate GOOD_CT_CHEM (bmy, 10/25/04)
(2 ) Also deallocate COUNT_CHEM3D (phs, 1/24/07)
(5 ) Also deallocate Allocate GOOD_EMIS and GOOD_CT_EMIS (ccc, 12/12/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.46 Fortran: Module Interface diag53_mod

Module DIAG53_MOD contains arrays and routines for archiving the ND53 diagnostic – POPS emissions, mass, and production. (eck 9/20/10)

INTERFACE:

```
MODULE DIAG53_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

DEFINED PARAMETERS:

```
INTEGER, PUBLIC, PARAMETER   :: PD53 = 11  ! # of AD53 diags
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: ZERO_DIAG53
PUBLIC :: WRITE_DIAG53
PUBLIC :: INIT_DIAG53
PUBLIC :: CLEANUP_DIAG53
```

PUBLIC DATA MEMBERS:

```
! Scalars
INTEGER, PUBLIC              :: ND53  ! ND53 on/off flag
INTEGER, PUBLIC              :: LD53  ! # of levels

! Arrays
REAL*4,  PUBLIC, ALLOCATABLE :: AD53(:,:,:)
REAL*4,  PUBLIC, ALLOCATABLE :: AD53_PG_OC_NEG(:,:,:)
REAL*4,  PUBLIC, ALLOCATABLE :: AD53_PG_OC_POS(:,:,:)
REAL*4,  PUBLIC, ALLOCATABLE :: AD53_PG_BC_NEG(:,:,:)
REAL*4,  PUBLIC, ALLOCATABLE :: AD53_PG_BC_POS(:,:,:)
REAL*4,  PUBLIC, ALLOCATABLE :: AD53_POPG_OH(:,:,:)
REAL*4,  PUBLIC, ALLOCATABLE :: AD53_POPP_OC_O3(:,:,:)
REAL*4,  PUBLIC, ALLOCATABLE :: AD53_POPP_BC_O3(:,:,:)

 REAL*4,  PUBLIC, ALLOCATABLE :: AD53_POPG_NO3(:,:,:)
 REAL*4,  PUBLIC, ALLOCATABLE :: AD53_POPG_OX(:,:,:)
```

REMARKS:

```
Nomenclature:
============================================================================
(1 ) POPG                  : Gas phase POP
(2 ) POPP                  : PARTICULATE PHASE POP
```

REVISION HISTORY:

```
20 Sep 2010 - N.E. Selin  - Initial Version based on DIAG03_MOD
27 Nov 2012 - M. Payer    - Added ProTeX headers
```

1.46.1 zero_diag53

Subroutine ZERO_DIAG53 zeroes all module arrays.

INTERFACE:

```
SUBROUTINE ZERO_DIAG53
```

USES:

```
USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
20 Sep 2010 - N.E. Selin  - Initial Version
27 Nov 2012 - M. Payer    - Added ProTeX headers
```

1.46.2 write_diag53

Subroutine WRITE_DIAG53 writes the ND53 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG53
```

USES:

```
USE BPCH2_MOD,    ONLY : BPCH2, GET_MODELNAME, GET_HALFPOLAR
USE FILE_MOD,     ONLY : IU_BPCH
USE GRID_MOD,     ONLY : GET_XOFFSET, GET_YOFFSET
USE TIME_MOD,     ONLY : GET_CT_EMIS, GET_DIAGb,  GET_DIAGe
USE TIME_MOD,     ONLY : GET_CT_CHEM ! CDH for sea salt loss rate

USE CMN_SIZE_MOD       ! Size parameters
USE CMN_DIAG_MOD       ! TINDEX
```

REMARKS:

```
 # : Field    : Description                    : Units    : Scale factor
-------------------------------------------------------------------------
(1 ) PG-SRCE  : POP emissions                  : kg       : 1
(2 ) PG-PP-$  : Gas phase POP reacted with OH  : kg       : 1
                or partitioned
```

REVISION HISTORY:

```
20 Sep 2010 - N.E. Selin  - Initial Version
27 Nov 2012 - M. Payer    - Added ProTeX headers
```

1.46.3 init_diag53

Subroutine INIT_DIAG53 allocates all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DIAG53
```

USES:

```
      USE ERROR_MOD,    ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
    20 Sep 2010 - N.E. Selin  - Initial Version
    27 Nov 2012 - M. Payer    - Added ProTeX headers
```

1.46.4 cleanup_diag53

Subroutine CLEANUP_DIAG53 deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_DIAG53
```

REVISION HISTORY:

```
    20 Sep 2010 - N.E. Selin  - Initial Version
    27 Nov 2012 - M. Payer    - Added ProTeX headers
```

1.47 Fortran: Module Interface diag56_mod.f

Module DIAG56_MOD contains arrays and routines for archiving the ND56 diagnostic – lightning flash rates.

INTERFACE:

```
      MODULE DIAG56_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_DIAG56
      PUBLIC :: INIT_DIAG56
      PUBLIC :: WRITE_DIAG56
      PUBLIC :: ZERO_DIAG56
```

PUBLIC DATA MEMBERS:

```
      ! Scalars
      INTEGER,              PUBLIC :: ND56
      INTEGER, PARAMETER,   PUBLIC :: PD56 = 3

      ! Arrays
      REAL*4,  ALLOCATABLE, PUBLIC :: AD56(:,:,:)
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
(1 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
      (bmy, 9/5/06)
(2 ) Now divide AD56 by the # of A-6 timesteps (ltm, bmy, 3/7/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.47.1 zero_diag56

Subroutine ZERO_DIAG03 zeroes the ND03 diagnostic arrays.

INTERFACE:

```
SUBROUTINE ZERO_DIAG56
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.47.2 write_diag56

Subroutine WRITE_DIAG56 writes the ND03 diagnostic arrays to the binary punch file at the proper time.

INTERFACE:

```
SUBROUTINE WRITE_DIAG56
```

USES:

```
USE BPCH2_MOD,    ONLY : BPCH2, GET_MODELNAME, GET_HALFPOLAR
USE FILE_MOD,     ONLY : IU_BPCH
USE GRID_MOD,     ONLY : GET_XOFFSET, GET_YOFFSET
USE TIME_MOD,     ONLY : GET_CT_A6, GET_CT_A3, GET_CT_I3
USE TIME_MOD,     ONLY : GET_DIAGb,  GET_DIAGe

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! TINDEX
```

REMARKS:

```
 # : Field    : Description              : Units          : Scale factor
-----------------------------------------------------------------------
(1 ) LFLASH-$ : Lightning flash rate     : flashes/min/km2 : SCALE_A6
(2 ) LFLASH-$ : Intra-cloud flash rate   : flashes/min/km2 : SCALE_A6
(3 ) LFLASH-$ : Cloud-ground flash rate  : flashes/min/km2 : SCALE_A6
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
(1 ) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
      (bmy, 9/5/06)
(2 ) Now scale AD56 by the # of A-6 timesteps (ltm, bmy, 3/7/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.47.3 init_diag56

Subroutine INIT_DIAG56 allocates all module arrays, 5/11/06)

INTERFACE:

```
SUBROUTINE INIT_DIAG56
```

USES:

```
USE ERROR_MOD,    ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.47.4 cleanup_diag56

Subroutine CLEANUP_DIAG56 deallocates all module arrays

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG56
```

REVISION HISTORY:

```
11 May 2006 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.48 Fortran: Module Interface diag63_mod

Module DIAG63_MOD contains variables and routines to save out the fraction of NOx remaining and integrated OPE to disk (gvinken, 25/02/11)

INTERFACE:

```
MODULE DIAG63_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
LOGICAL, PUBLIC :: DO_SAVE_DIAG63
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: DIAG63
PUBLIC :: ITS_TIME_FOR_DIAG63
PUBLIC :: INIT_DIAG63
```

REMARKS:

```
ND63 tracer numbers:
============================================================================
1  : Fraction of NOx remaining  [unitless]
2  : Integrated OPE             [molec O3 produced / molec NOx lost]
```

REVISION HISTORY:

```
25 Feb 2011 - G. Vinken   - Initial version based on the orig. diag49_mod.f
07 Feb 2012 - M. Payer    - Added ProTeX headers
24 Feb 2012 - M. Payer    - Rename module from diag59_mod to diag63_mod.
                            Diag59 is used by TOMAS. Fix this throughout.
06 Aug 2012 - R. Yantosca - Now make IU_ND63 a local module variable
```

1.48.1 diag63

Subroutine DIAG63 produces time series (instantaneous fields) for a geographical domain from the information read in timeseries.dat. Output will be in binary punch (BPCH) format.

INTERFACE:

```
SUBROUTINE DIAG63
```

USES:

```
USE BPCH2_MOD,    ONLY : BPCH2,   OPEN_BPCH2_FOR_WRITE
USE GRID_MOD,     ONLY : GET_XOFFSET,        GET_YOFFSET
USE inquireMod,   ONLY : findFreeLUN
USE TIME_MOD,     ONLY : EXPAND_DATE
USE TIME_MOD,     ONLY : GET_NYMD,           GET_NHMS
USE TIME_MOD,     ONLY : GET_NYMD_DIAG,      GET_TS_DIAG
USE TIME_MOD,     ONLY : GET_TAU,            GET_HOUR
USE TIME_MOD,     ONLY : ITS_A_NEW_DAY,      TIMESTAMP_STRING
USE TIME_MOD,     ONLY : GET_TAUb
```

```
USE PBL_MIX_MOD,  ONLY : GET_PBL_TOP_L,      GET_PBL_TOP_m
USE PRESSURE_MOD, ONLY : GET_PEDGE
USE DIAG_MOD,     ONLY : AD63,    AD63_COUNT
USE ERROR_MOD,    ONLY : SAFE_DIV

USE CMN_FJ_MOD         ! FAST-J stuff, includes CMN_SIZE
USE JV_CMN_MOD         ! ODAER, QAA, QAA_AOD (clh)
USE CMN_O3_MOD      ! Pure O3, SAVENO2
USE CMN_GCTM_MOD       ! XTRA2
```

REVISION HISTORY:

```
25 Feb 2011 - G. Vinken   - Initial version based on DIAG49
07 Feb 2012 - M. Payer    - Added ProTeX headers
11 Apr 2012 - R. Yantosca - Remove reference to lai_mod.F, it's not needed
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

1.48.2 its_time_to_close_file

Function ITS_TIME_TO_CLOSE_FILE returns TRUE if it's time to close the ND63 bpch file before the end of the day.

INTERFACE:

```
FUNCTION ITS_TIME_TO_CLOSE_FILE() RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD, ONLY : GET_HOUR
USE TIME_MOD, ONLY : GET_MINUTE
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) The time is already updated to the next time step (ccc, 8/12/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.48.3 its_time_for_diag63

Function ITS_TIME_FOR_DIAG63 returns TRUE if ND63 is turned on and it is time to call DIAG63 – or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_DIAG63() RESULT( ITS_TIME )
```

USES:

```
      USE TIME_MOD,  ONLY : GET_ELAPSED_MIN
      USE TIME_MOD,  ONLY : GET_TS_DIAG
      USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

RETURN VALUE:

```
      LOGICAL :: ITS_TIME
```

REVISION HISTORY:

```
   25 Feb 2011 - G. Vinken   - Initial version based on ITS_TIME_FOR_DIAG49
   07 Feb 2012 - M. Payer    - Added ProTeX headers
```

1.48.4 get_i

Function GET_I returns the absolute longitude index (I), given the relative longitude index (X).

INTERFACE:

```
      FUNCTION GET_I( X ) RESULT( I )
```

USES:

```
      USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: X   ! Relative longitude index (used by Q array)
```

RETURN VALUE:

```
      INTEGER             :: I   ! Absolute longitude index
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.48.5 init_diag63

Subroutine INIT_DIAG63 allocates and zeroes all module arrays. It also gets values for module variables from "input_mod.f".

INTERFACE:

```
      SUBROUTINE INIT_DIAG63( DO_ND63, N_ND63, TRACERS, IMIN,
     &                        IMAX,    JMIN,   JMAX,    FREQ,
     &                        FILE )
```

USES:

```
USE BPCH2_MOD, ONLY : GET_MODELNAME
USE BPCH2_MOD, ONLY : GET_HALFPOLAR
USE GRID_MOD,  ONLY : GET_XOFFSET
USE GRID_MOD,  ONLY : GET_YOFFSET
USE GRID_MOD,  ONLY : ITS_A_NESTED_GRID
USE ERROR_MOD, ONLY : ERROR_STOP

USE CMN_SIZE_MOD    ! Size parameters
```

INPUT PARAMETERS:

```
! DO_ND63 : Switch to turn on ND63 timeseries diagnostic
! N_ND63  : Number of ND63 read by "input_mod.f"
! TRACERS : Array w/ ND63 tracer #'s read by "input_mod.f"
! IMIN    : Min longitude index read by "input_mod.f"
! IMAX    : Max longitude index read by "input_mod.f"
! JMIN    : Min latitude index read by "input_mod.f"
! JMAX    : Min latitude index read by "input_mod.f"
! FREQ    : Frequency for saving to disk [min]
! FILE    : ND63 output file name read by "input_mod.f"
LOGICAL,            INTENT(IN) :: DO_ND63
INTEGER,            INTENT(IN) :: N_ND63, TRACERS(100)
INTEGER,            INTENT(IN) :: IMIN,   IMAX
INTEGER,            INTENT(IN) :: JMIN,   JMAX
INTEGER,            INTENT(IN) :: FREQ
CHARACTER(LEN=255), INTENT(IN) :: FILE
```

REVISION HISTORY:

```
25 Feb 2011 - G. Vinken   - Initial version based on INIT_DIAG49
07 Feb 2012 - M. Payer    - Added ProTeX headers
```

1.49 Fortran: Module Interface diag_pl_mod

Module DIAG_PL_MOD contains variables and routines which are used to compute the production and loss of chemical families in the "full chemistry" (NOx-Ox-Hydrocarbon-aerosol) mechanism.

INTERFACE:

```
MODULE DIAG_PL_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
      ! Scalars
      LOGICAL,           PUBLIC              :: DO_SAVE_PL
      INTEGER,           PUBLIC              :: TAGO3_PL_YEAR

      ! Arrays
      REAL*4,            PUBLIC, ALLOCATABLE :: AD65  (:,:,:,:)
      REAL*8,            PUBLIC, ALLOCATABLE :: FAM_PL(:,:,:,:)
      CHARACTER(LEN=14), PUBLIC, ALLOCATABLE :: FAM_NAME(:)
#if   defined( TOMAS )
      REAL*8,            PUBLIC, ALLOCATABLE :: H2SO4RATE(:,:,:)
#endif
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: DO_DIAG_PL
      PUBLIC  :: CLEANUP_DIAG_PL
      PUBLIC  :: GET_FAM_MWT
      PUBLIC  :: GET_FAM_NAME
      PUBLIC  :: GET_NFAM
      PUBLIC  :: INIT_DIAG_PL
      PUBLIC  :: SETJFAM
      PUBLIC  :: SETPL
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: DIAG20
      PRIVATE :: ITS_TIME_FOR_WRITE20
      PRIVATE :: WRITE20
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Add TAUe as a module variable.  Bug fixes: Make sure WRITE20 uses the
        global FILENAME, and also write to disk on the last timestep before
        the end of the simulation. (bmy, 11/15/04)
   (2 ) Added routine ITS_TIME_FOR_WRITE20 (bmy, 3/3/05)
   (3 ) Added functions GET_NFAM, GET_FAM_MWT, GET_FAM_NAME (bmy, 5/2/05)
   (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (5 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
   (6 ) Bug fix in DIAG20 (phs, 1/22/07)
   (7 ) Now use LD65 as the vertical dimension instead of LLTROP or LLTROP_FIX
        in DO_DIAG_PL, DIAG20, and WRITE20 (phs, bmy, 12/4/07)
   (8 ) Now make COUNT a 3-D array (phs, 11/18/08)
   (9 ) Minor fix in DIAG20 (dbj, bmy, 10/26/09)
   (10) Make public FAM_NAME and H2SO4RATE (win, 1/25/10)
   16 Sep 2010 - R. Yantosca - Added ProTeX headers
   06 Aug 2012 - R. Yantosca - Make IU_ND20 a local module variable
```

1.49.1 setjfam

Subroutine SETJFAM stores info into SMVGEAR arrays for the ND65 prod/loss diagnostic.

INTERFACE:

```
SUBROUTINE SETJFAM( NACTIVE, NINAC, am_I_Root )
```

USES:

```
USE CMN_SIZE_MOD                    ! Size parameters
USE COMODE_LOOP_MOD                 ! SMVGEAR II arrays
```

INPUT/OUTPUT PARAMETERS:

```
INTEGER, INTENT(INOUT) :: NACTIVE     ! # of active chemical species
INTEGER, INTENT(INOUT) :: NINAC       ! # of inactive chemical species
LOGICAL, INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

REMARKS:

```
At present, the ND65 diagnostic works only with SMVGEAR and not with
KPP.  KPP is generated automatically and lacks the code to keep track of
the production/loss of chemical families. (bmy, 9/16/10)
```

REVISION HISTORY:

```
01 Feb 1999- L. Mickley, I. Bey, R. Yantosca - Initial version
(1 ) Replace NAMESPEC with NAMEGAS for SMVGEAR II.  Added comment header
      and updated comments.  Now references IU_FILE and IOERROR from
      F90 module "file_mod.f".  Now trap I/O errors using routine IOERROR.
      Make DEFMR a parameter for safety's sake.   Need to increment NACTIVE
      for SMVGEAR II or else the last species will be overwritten w/ the
      first ND65 family.  Set NCS = NCSURBAN, since we have defined our
      GEOS-CHEM mechanism in the urban slot of SMVGEAR II.(bmy, 4/21/03)
(2 ) Bundled into "diag65_mod.f" (bmy, 7/20/04)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument, even when
                            called from the traditional driver main.F
```

1.49.2 setpl

Subroutine SETPL flags the reactions and species which contribute to production or loss for a given ND65 prodloss diagnostic family.

INTERFACE:

```
SUBROUTINE SETPL( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_LOOP_MOD
USE ERROR_MOD,          ONLY : ERROR_STOP, GEOS_CHEM_STOP
USE ERROR_MOD,          ONLY : DEBUG_MSG
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_MOd, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
At present, the ND65 diagnostic works only with SMVGEAR and not with
KPP.  KPP is generated automatically and lacks the code to keep track of
the production/loss of chemical families. (bmy, 9/16/10)
```

REVISION HISTORY:

```
01 Feb 1999- L. Mickley, I. Bey, R. Yantosca - Initial version
(1 ) Now references "file_mod.f" and "error_mod.f".  Also now use IOERROR
     to trap I/O errors, and ERROR_STOP to stop the run and deallocate
     all module arrays.  NAMESPEC is now NAMEGAS for SMVGEAR II. Now
     uses F90 declaration syntax.  Set NCS = NCSURBAN for now, since we
     have defined our GEOS-CHEM mechanism in the urban slot of SMVGEAR II
     Updated comments.  (bmy, 5/1/03)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument, even when
                            called from the traditional driver main.F
05 Mar 2013 - R. Yantosca - Now accept Input_Opt, RC arguments
```

1.49.3 do_diag_pl

Subroutine DO_DIAG_PL saves info on production and loss of families into the FAM_PL diagnostic array.

INTERFACE:

```
SUBROUTINE DO_DIAG_PL( am_I_Root, Input_Opt,
&                      State_Met, State_Chm, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE COMODE_MOD,          ONLY : CSPEC, JLOP
USE COMODE_LOOP_MOD
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
16 Mar 2000 - I. Bey      - Initial version
(1 ) Now bundled into "prod_loss_diag_mod.f" (bmy, 7/20/04)
(2 ) Now only loop up thru LD65 levels (bmy, 12/4/07)
(3 ) Set FAM_PL to zero in the stratosphere (phs, 11/17/08)
(4 ) Add calcuation for H2SO4RATE (win, 8/4/09)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.49.4 diag20

Subroutine DIAG20 computes production and loss rates of O3, and then calls subroutine WRITE20 to save the these rates to disk. By saving the production and loss rates from a full-chemistry run, a user can use these archived rates to perform a quick O3 chemistry run at a later time.

INTERFACE:

```
SUBROUTINE DIAG20( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE COMODE_MOD,          ONLY : JLOP
      USE DIRECTORY_MOD,       ONLY : O3PL_DIR
      USE ERROR_MOD,           ONLY : ERROR_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TIME_MOD,            ONLY : EXPAND_DATE,   GET_NYMD
      USE TIME_MOD,            ONLY : GET_TAU,       GET_TAUb
      USE TIME_MOD,            ONLY : ITS_A_NEW_DAY, TIMESTAMP_STRING
      USE TRACERID_MOD,        ONLY : IDTO3
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    DIAG20 assumes that ND65 (P-L diagnostics) have been turned on.
```

REVISION HISTORY:

```
    09 Jun 1999 - I. Bey      - Initial version
    (1 ) Now bundled into "diag20_mod.f" (bmy, 7/20/04)
    (2 ) Now also write to disk when it is the last timestep before the end of
         the run.  Now references GET_TAUE from "time_mod.f". (bmy, 11/15/04)
    (3 ) Now call function ITS_TIME_FOR_WRITE20 to determine if the next
         chemistry timestep is the start of a new day.  Remove reference
         to GET_TAUe and GET_TS_CHEM.  Now archive P(Ox) and L(Ox) first
         and then test if we have to save the file to disk. (bmy, 3/3/05)
    (4 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
    (5 ) Now use LLTROP_FIX instead of LLTROP (phs, 1/22/07)
    (6 ) Now use LD65 instead of LLTROP_FIX (phs, bmy, 12/4/07)
    (7 ) Now take care of boxes that switch b/w stratospheric and tropospheric
         regimes (phs, 11/17/08)
    (8 ) Bug fix: Now just zero arrays w/o loop indices (dbj, bmy, 10/26/09)
    15 Sep 2010 - R. Yantosca - Added ProTeX headers
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    14 Mar 2013 - M. Payer    - Replace Ox with O3 as part of removal of
                                NOx-Ox partitioning
    25 Mar 2013 - M. Payer    - Now pass State_Chm object + RC via the arg list
    04 Apr 2013 - R. Yantosca - Now pass the Input_Opt object
```

1.49.5 write20

Subroutine WRITE20 saves production and loss rates to disk, where they will be later read by subroutine CHEMO3.

INTERFACE:

```
SUBROUTINE WRITE20
```

USES:

```
USE BPCH2_MOD,  ONLY : BPCH2,         GET_HALFPOLAR
USE BPCH2_MOD,  ONLY : GET_MODELNAME, OPEN_BPCH2_FOR_WRITE
USE GRID_MOD,   ONLY : GET_XOFFSET,   GET_YOFFSET
USE inquireMod, ONLY : findFreeLUN

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! LD65
```

REVISION HISTORY:

```
09 Jun 1999 - I. Bey      - Initial version
(1 ) Now bundled into "diag20_mod.f" (bmy, 7/20/04)
(2 ) Bug fix: remove declaration of FILENAME which masked the global
     declaration (bmy, 11/15/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now only write up to LD65 levels (phs, bmy, 12/4/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

1.49.6 its_time_for_write20

Function ITS_TIME_FOR_WRITE20 returns TRUE if it's time to write the ND20 ozone P/L rate file to disk. We test the time at the next chemistry timestep so that we can write to disk properly.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_WRITE20( TAU_W ) RESULT( ITS_TIME )
```

USES:

```
USE TIME_MOD, ONLY : GET_HOUR, GET_MINUTE, GET_TAU
USE TIME_MOD, ONLY : GET_TAUb, GET_TAUe,   GET_TS_CHEM, GET_TS_DYN
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: TAU_W      ! TAU value @ time of writing to disk
```

RETURN VALUE:

```
LOGICAL              :: ITS_TIME   ! =T if its time to write to disk
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.49.7 get_nfam

Function GET_NFAM returns the number of defined P/L families.

INTERFACE:

```
FUNCTION GET_NFAM() RESULT( N_FAM )
```

RETURN VALUE:

```
INTEGER :: N_FAM    ! Number of defined P/L families
```

REVISION HISTORY:

```
02 May 2005 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.49.8 get_fam_name

Function GET_FAM_NAME returns the name of the Nth P/L family.

INTERFACE:

```
FUNCTION GET_FAM_NAME( N ) RESULT( NAME )
```

USES:

```
USE ERROR_MOD, ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: N      ! Family # for desired molecular weight
```

RETURN VALUE:

```
CHARACTER(LEN=255)   :: NAME   ! Name of Nth P/L family
```

REVISION HISTORY:

```
02 May 2005 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.49.9 get_fam_mwt

Function GET_FAM_MWT returns the molecular weight of the Nth P/L family.

INTERFACE:

```
FUNCTION GET_FAM_MWT( N ) RESULT( MWT )
```

USES:

```
USE CHARPAK_MOD, ONLY : TRANUC
USE ERROR_MOD,   ONLY : ERROR_STOP
USE TRACER_MOD,  ONLY : N_TRACERS, TRACER_MW_KG, TRACER_NAME
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: N     ! Family # for desired molecular weight
```

RETURN VALUE:

```
REAL*8               :: MWT   ! Molecular weight
```

REVISION HISTORY:

```
02 May 2005 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.49.10 init_diag_pl

Subroutine INIT_DIAG_PL takes values read from the GEOS-Chem input file and saves to module variables w/in "diag_pl_mod.f"

INTERFACE:

```
SUBROUTINE INIT_DIAG_PL( DOPL, SAVEO3, N_FAM, NAME,
&                        TYPE, NMEM,   MEMB,  COEF )
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE TRACER_MOD,  ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD      ! Size parameters
USE COMODE_LOOP_MOD   ! LFAMILY, NFAMILIES
USE CMN_DIAG_MOD      ! ND65,    LD65
```

INPUT PARAMETERS:

```
! Turn on P/L diagnostic?
LOGICAL,           INTENT(IN) :: DOPL

! Save out P(Ox), L(Ox) for future tagged Ox simulation?
```

```
LOGICAL,           INTENT(IN) :: SAVEO3

! Number of prod/loss families
INTEGER,           INTENT(IN) :: N_FAM

! Number of members w/in the prod/loss family
INTEGER,           INTENT(IN) :: NMEM(MAXFAM)

! Coefficients for each prod/loss family member
REAL*8,            INTENT(IN) :: COEF(MAXMEM,MAXFAM)

! Prod/loss family name
CHARACTER(LEN=14), INTENT(IN) :: NAME(MAXFAM)

! Prod/loss family type
CHARACTER(LEN=14), INTENT(IN) :: TYPE(MAXFAM)

! Names for each prod/loss family member
CHARACTER(LEN=14), INTENT(IN) :: MEMB(MAXMEM,MAXFAM)
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now allocate arrays up to LD65 levels (phs, bmy, 12/4/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
26 Apr 2013 - R. Yantosca - Removed LTOMAS; we now use #if defined( TOMAS )
```

1.49.11 cleanup_diag_pl

Subroutine CLEANUP_DIAG_PL deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG_PL
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.50 Fortran: Module Interface diag_oh_mod

Module DIAG_OH_MOD contains routines and variables to archive OH mass and air mass concentrations. These are then used to print out the mass-weighted mean OH concentration in 1e5 molec/cm3. This is a metric of how certain chemisry simulations are performing.

INTERFACE:

```
MODULE DIAG_OH_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_DIAG_OH
PUBLIC  :: DO_DIAG_OH
PUBLIC  :: DO_DIAG_OH_CH4
PUBLIC  :: INIT_DIAG_OH
PUBLIC  :: PRINT_DIAG_OH
```

REVISION HISTORY:

```
(1 ) Remove code for obsolete CO-OH simulation (bmy, 6/24/05)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.50.1 do_diag_oh

Subroutine DO_DIAG_OH sums the OH and air mass (from SMVGEAR arrays) for the mean OH concentration diagnostic.

INTERFACE:

```
SUBROUTINE DO_DIAG_OH
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_MOD,     ONLY : AIRDENS, CSPEC, JLOP, T3, VOLUME
USE COMODE_LOOP_MOD
USE TRACERID_MOD,   ONLY : IDOH
```

REVISION HISTORY:

```
07 Jul 2004 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.50.2 do_diag_oh_ch4

Subroutine DO_DIAG_OH_CH4 passes the OH loss, OH mass, and air mass terms from "global_ch4_mod.f" to "diag_oh_mod.f"

INTERFACE:

```
 SUBROUTINE DO_DIAG_OH_CH4( I, J, L, XOHMASS, XAIRMASS, XLOSS,
&                   XCH4LOSS, XCH4TROPMASS, XCH4EMIS, XCH4MASS )
```

USES:

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I          ! Longitude index
INTEGER, INTENT(IN) :: J          ! Latitude index
INTEGER, INTENT(IN) :: L          ! Level index
REAL*8,  INTENT(IN) :: XOHMASS    ! OH Mass  (from global_ch4_mod.f)
REAL*8,  INTENT(IN) :: XAIRMASS   ! Air mass (from global_ch4_mod.f)
REAL*8,  INTENT(IN) :: XLOSS      ! Loss of ch3ccl3 by OH
REAL*8,  INTENT(IN) :: XCH4LOSS   ! Loss of ch4 by OH
REAL*8,  INTENT(IN) :: XCH4MASS   ! CH4 Mass  (from global_ch4_mod.f)
REAL*8,  INTENT(IN) :: XCH4TROPMASS   ! CH4 Mass  (from global_ch4_mod.f)
REAL*8,  INTENT(IN) :: XCH4EMIS   ! CH4 emissions
```

REVISION HISTORY:

```
07 Jul 2004 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.50.3 print_diag_oh

Subroutine PRINT_DIAG_OH prints the mass-weighted OH concentration at the end of a simulation.

INTERFACE:

```
SUBROUTINE PRINT_DIAG_OH
```

USES:

```
USE TRACER_MOD, ONLY : ITS_A_CH4_SIM
```

REVISION HISTORY:

```
21 Oct 2003 - R. Yantosca - Initial version
15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.50.4 init_diag_oh

Subroutine INIT_DIAG_OH initializes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DIAG_OH(am_I_Root)
```

USES:

```
      USE ERROR_MOD,   ONLY : ALLOC_ERR
      USE LOGICAL_MOD, ONLY : LCHEM
      USE TRACER_MOD,  ONLY : ITS_A_FULLCHEM_SIM, ITS_A_CH4_SIM

      USE CMN_SIZE_MOD    ! Size parameters

  !INPUT VARIABLES:

      LOGICAL, INTENT(IN) :: am_I_Root
```

REVISION HISTORY:

```
    07 Jul 2004 - R. Yantosca - Initial version
    (1 ) Remove references to CO-OH simulation and to CMN_DIAG (bmy, 6/24/05)
    15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.50.5 cleanup_diag_oh

Subroutine CLEANUP_DIAG_OH deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_DIAG_OH
```

REVISION HISTORY:

```
    07 Jul 2004 - R. Yantosca - Initial version
    15 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.51 Fortran: Module Interface diag_mod

Module DIAG_MOD contains declarations for allocatable arrays for use with GEOS-CHEM diagnostics.

INTERFACE:

```
      MODULE DIAG_MOD
```

USES:

```
      IMPLICIT NONE
      PUBLIC
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_DIAG
```

PUBLIC DATA MEMBERS:

```
      ! For ND01 -- Rn, Pb, Be emissions
      REAL*4,  ALLOCATABLE :: AD01(:,:,:,:)

      ! For ND02 -- Rn, Pb, Be decay
      REAL*4,  ALLOCATABLE :: AD02(:,:,:,:)

      !------------------------------------------
      !! For ND03 -- Kr85 prod/loss
      !REAL*4,  ALLOCATABLE :: AD03(:,:,:,:)
      !------------------------------------------

      ! For ND05 -- Sulfate prod/loss diagnostics
      REAL*4,  ALLOCATABLE :: AD05(:,:,:,:)

      ! For ND06 -- Dust aerosol emission
      REAL*4,  ALLOCATABLE :: AD06(:,:,:)

      ! For ND07 -- Carbon aerosol emission
      REAL*4,  ALLOCATABLE :: AD07(:,:,:)
      REAL*4,  ALLOCATABLE :: AD07_BC(:,:,:)
      REAL*4,  ALLOCATABLE :: AD07_OC(:,:,:)
      REAL*4,  ALLOCATABLE :: AD07_HC(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD07_SOAGM(:,:,:,:)

#if   defined( APM )
      REAL*4,  ALLOCATABLE :: AD07_OM(:,:)
#endif

      ! For ND08 -- seasalt emission
      REAL*4,  ALLOCATABLE :: AD08(:,:,:)

      ! For ND09 -- HCN / CH3CN simulation
      REAL*4,  ALLOCATABLE :: AD09(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD09_em(:,:,:)

      ! For ND10 -- H2/HD prod, loss, & emiss diagnostics
      REAL*4,  ALLOCATABLE :: AD10(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD10em(:,:,:)

      ! For ND12 -- boundary layer multiplication factor
      REAL*4,  ALLOCATABLE :: AD11(:,:,:)

      ! For ND12 -- boundary layer multiplication factor
      REAL*4,  ALLOCATABLE :: AD12(:,:,:)
```

```
! For ND13 -- Sulfur emissions
REAL*4,  ALLOCATABLE :: AD13_DMS(:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_ac(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_an(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_bb(:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_bf(:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_nv(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_ev(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_SO2_sh(:,:)
REAL*4,  ALLOCATABLE :: AD13_SO4_an(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_SO4_bf(:,:)
REAL*4,  ALLOCATABLE :: AD13_NH3_an(:,:,:)
REAL*4,  ALLOCATABLE :: AD13_NH3_na(:,:)
REAL*4,  ALLOCATABLE :: AD13_NH3_bb(:,:)
REAL*4,  ALLOCATABLE :: AD13_NH3_bf(:,:)

! For ND14 -- wet convection mass flux diagnostic
REAL*8,  ALLOCATABLE :: CONVFLUP(:,:,:,:)

! For ND15 -- BL mixing mass flux diagnostic
REAL*8,  ALLOCATABLE :: TURBFLUP(:,:,:,:)

! For ND16 -- Fraction of grid box that is precipitating
REAL*4,  ALLOCATABLE :: AD16(:,:,:,:)
INTEGER, ALLOCATABLE :: CT16(:,:,:,:)

! For ND17 -- Fraction of tracer lost to rainout
REAL*4,  ALLOCATABLE :: AD17(:,:,:,:,:)
INTEGER, ALLOCATABLE :: CT17(:,:,:,:)

! For ND18 -- Fraction of tracer lost to washout
REAL*4,  ALLOCATABLE :: AD18(:,:,:,:,:)
INTEGER, ALLOCATABLE :: CT18(:,:,:,:)

! For ND21 -- Optical Depth diagnostic
REAL*4,  ALLOCATABLE :: AD21(:,:,:,:)
REAL*4,  ALLOCATABLE :: AD21_cr(:,:,:)

! For ND22 -- J-value diagnostic
REAL*4,  ALLOCATABLE :: AD22(:,:,:,:)
INTEGER, ALLOCATABLE :: LTJV(:,:)
INTEGER, ALLOCATABLE :: CTJV(:,:)

! For ND23 -- CH3CCl3 lifetime diagnostic
REAL*8,  ALLOCATABLE :: DIAGCHLORO(:,:,:,:)

! For ND24 -- E/W transport mass flux diagnostic
REAL*8,  ALLOCATABLE :: MASSFLEW(:,:,:,:)
```

```
! For ND25 -- N/S transport mass flux diagnostic
REAL*8,  ALLOCATABLE :: MASSFLNS(:,:,:,:)

! For ND26 -- UP/DOWN transport mass flux diagnostic
REAL*8,  ALLOCATABLE :: MASSFLUP(:,:,:,:)

! For ND28 -- Biomass burning diagnostic
REAL*4,  ALLOCATABLE :: AD28(:,:,:)

! For ND29 -- CO source diagnostic
REAL*4,  ALLOCATABLE :: AD29(:,:,:)

! For ND30 -- land / water / ice flags
REAL*4,  ALLOCATABLE :: AD30(:,:)

! For ND31 -- surface pressures
REAL*4,  ALLOCATABLE :: AD31(:,:,:)

! For ND32 -- NOx sources
REAL*4,  ALLOCATABLE :: AD32_ac(:,:,:)
REAL*4,  ALLOCATABLE :: AD32_an(:,:,:)
REAL*4,  ALLOCATABLE :: AD32_bb(:,:)
REAL*4,  ALLOCATABLE :: AD32_bf(:,:)
REAL*4,  ALLOCATABLE :: AD32_fe(:,:)
REAL*4,  ALLOCATABLE :: AD32_li(:,:,:)
REAL*4,  ALLOCATABLE :: AD32_so(:,:)
REAL*4,  ALLOCATABLE :: AD32_ub(:,:)
REAL*4,  ALLOCATABLE :: AD32_ship(:,:)
INTEGER              :: AD32_ship_count

! For ND33 -- tropopsheric sum of tracer
REAL*4,  ALLOCATABLE :: AD33(:,:,:)

! For ND34 -- biofuel emissions
REAL*4,  ALLOCATABLE :: AD34(:,:,:)

! For ND35 -- 500 mb tracer
REAL*4,  ALLOCATABLE :: AD35(:,:,:)

! For ND36 -- Anthropogenic source diagnostic
REAL*4,  ALLOCATABLE :: AD36(:,:,:)
REAL*4,  ALLOCATABLE :: AD36_SHIP(:,:,:)
INTEGER              :: AD36_SHIP_COUNT

! For ND37 -- Fraction of tracer scavenged in cloud updrafts
REAL*4,  ALLOCATABLE :: AD37(:,:,:,:)
```

```
! For ND38 -- Rainout in moist convection diagnostic
REAL*4,  ALLOCATABLE :: AD38(:,:,:,:)

! For ND39 -- Washout in aerosol wet deposition diagnostic
REAL*4,  ALLOCATABLE :: AD39(:,:,:,:)

! For ND43 -- OH and HO2 chemical diagnostics
REAL*4,  ALLOCATABLE :: AD43(:,:,:,:)
INTEGER, ALLOCATABLE :: LTOH(:,:)
INTEGER, ALLOCATABLE :: CTOH(:,:,:)
INTEGER, ALLOCATABLE :: LTHO2(:,:)
INTEGER, ALLOCATABLE :: CTHO2(:,:,:)
! update for arom (dkh, 06/21/07)
INTEGER, ALLOCATABLE :: CTLBRO2H(:,:,:)
INTEGER, ALLOCATABLE :: CTLBRO2N(:,:,:)
INTEGER, ALLOCATABLE :: CTLTRO2H(:,:,:)
INTEGER, ALLOCATABLE :: CTLTRO2N(:,:,:)
INTEGER, ALLOCATABLE :: CTLXRO2H(:,:,:)
INTEGER, ALLOCATABLE :: CTLXRO2N(:,:,:)
INTEGER, ALLOCATABLE :: LTLBRO2H(:,:)
INTEGER, ALLOCATABLE :: LTLBRO2N(:,:)
INTEGER, ALLOCATABLE :: LTLTRO2H(:,:)
INTEGER, ALLOCATABLE :: LTLTRO2N(:,:)
INTEGER, ALLOCATABLE :: LTLXRO2H(:,:)
INTEGER, ALLOCATABLE :: LTLXRO2N(:,:)

! For ND44 -- Dry deposition fluxes & velocities
REAL*4,  ALLOCATABLE :: AD44(:,:,:,:)

! For ND45 -- Tracer concentration diagnostic
REAL*4,  ALLOCATABLE :: AD45(:,:,:,:)
INTEGER, ALLOCATABLE :: LTOTH(:,:)
INTEGER, ALLOCATABLE :: CTOTH(:,:)

! For ND46 -- Tracer concentration diagnostic
REAL*4,  ALLOCATABLE :: AD46(:,:,:)

! For ND47 -- 24-h tracer concentration diagnostic
REAL*4,  ALLOCATABLE :: AD47(:,:,:,:)

! For ND47(O3) / ND65 -- 24-h tracer diagnostic
INTEGER, ALLOCATABLE :: CTO3_24h(:,:,:)

! Dynamically allocatable array -- local only to DIAG50.F
REAL*8,  ALLOCATABLE :: STT_TEMPO2(:,:,:,:)

! For ND52 -- gamma HO2 diagnostic
REAL*4,  ALLOCATABLE :: AD52(:,:,:)
```

```
      ! For ND54 -- tropopause diagnostics
      REAL*4,  ALLOCATABLE :: AD54(:,:,:)

      ! For ND55 -- tropopause diagnostics
      REAL*4,  ALLOCATABLE :: AD55(:,:,:)

      ! For ND57 -- theta, potential temp (FP 6/2009)
      REAL*4,  ALLOCATABLE :: AD57(:,:,:)

      ! -- for methane simulation diagnostics
      REAL*4,  ALLOCATABLE :: AD19(:,:,:)
      REAL*4,  ALLOCATABLE :: AD58(:,:,:)
      REAL*4,  ALLOCATABLE :: AD60(:,:)

#if   defined( TOMAS )
      ! For ND59 -- Size-resolved primary aerosol emissions
      REAL*4,  ALLOCATABLE :: AD59_NUMB(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD59_SULF(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD59_SALT(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD59_ECIL(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD59_ECOB(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD59_OCIL(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD59_OCOB(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD59_DUST(:,:,:,:)

      ! For ND60 -- TOMAS condensation rate diagnostic
      REAL*4,  ALLOCATABLE :: AD60_COND(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD60_COAG(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD60_NUCL(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD60_AQOX(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD60_ERROR(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD60_SOA(:,:,:,:)

      ! For ND61 -- 3D TOMAS rate diagnostic
      REAL*4,  ALLOCATABLE :: AD61(:,:,:,:)
      REAL*4,  ALLOCATABLE :: AD61_inst(:,:,:,:)
#endif

      ! For ND63 -- fraction of NOx remaining and Integrated OPE
      REAL*4,  ALLOCATABLE :: AD63(:,:,:)
      INTEGER, ALLOCATABLE :: AD63_COUNT

      ! For ND66 -- I-6 fields diagnostic
      REAL*4,  ALLOCATABLE :: AD66(:,:,:,:)

      ! For ND67 -- DAO surface fields diagnostic
      REAL*4,  ALLOCATABLE :: AD67(:,:,:)
```

```
      ! For ND68 -- BXHEIGHT, AD, AVGW diagnostic
      REAL*4,  ALLOCATABLE :: AD68(:,:,:,:)

      ! For ND69 -- DXYP diagnostic
      REAL*4,  ALLOCATABLE :: AD69(:,:,:)
```

REVISION HISTORY:

```
    30 Nov 1999 - A. Fiore - Initial version
    (1 ) DIAG_MOD is written in Fixed-Format F90.
    (2 ) Call subroutine CLEANUP at the end of the MAIN program to deallocate
         the memory before the run stops.  It is always good style to free
         any memory we have dynamically allocated when we don't need it
         anymoren
    (3 ) Added ND13 arrays for sulfur emissions (bmy, 6/6/00)
    (4 ) Moved ND51 arrays to "diag51_mod.f" (bmy, 11/29/00)
    (5 ) Added AD34 array for biofuel burning emissions (bmy, 3/15/01)
    (6 ) Eliminated old commented-out code (bmy, 4/20/01)
    (7 ) Added AD12 array for boundary layer emissions in routine "setemis.f".
         (bdf, bmy, 6/15/01)
    (8 ) Added CHEML24, DRYDL24, CTCHDD for archiving daily mean chemical
         and drydep loss in chemo3 and chemo3.f (amf, bmy, 7/2/01)
    (9 ) Add ND43 arrays LTNO2, CTNO2, LTHO2, CTHO2 (rvm, bmy, 2/27/02)
    (10) Add AD01, AD02 arrays for Rn-Pb-Be simulation (hyl, bmy, 8/7/02)
    (11) Add AD05 array for sulfate P-L diagnostic (rjp, bdf, bmy, 9/20/02)
    (12) Added subroutine CLEANUP_DIAG...moved code here from "cleanup.f",
         so that it is internal to "diag_mod.f".  Added arrays AD13_NH3_bb,
         AD13_NH3_bf, AD13_NH3_an for NH3 emissons in ND13.  Deleted obsolete
         allocatable arrays CHEML24, DRYDL24, CTCHDD.  Now also added LTNO3
         and CTNO3 arrays for ND43 diagnostic.  Added AD13_SO2_bf array for
         SO2 biofuel. (bmy, 1/16/03)
    (13) Added array AD13_NH3_na for ND13 diagnostic (rjp, bmy, 3/23/03)
    (14) Removed P24H and L24H -- these are now defined w/in "tagged_ox_mod.f"
         Also added AD03 array for Kr85 prod/loss diag. (jsw, bmy, 8/20/03)
    (15) Added ND06 (dust emission) and ND07 (carbon aerosol emission)
         diagnostic arrays (rjp, tdf, bmy, 4/5/04)
    (16) Added AD13_SO2_sh diagnostic array for ND13 (bec, bmy, 5/20/04)
    (17) Added AD07_HC diagnostic array for ND07 (rjp, bmy, 7/13/04)
    (18) Moved AD65 & FAMPL to "diag65_mod.f" (bmy, 7/20/04)
    (19) Added array AD13_SO4_bf (bmy, 11/17/04)!
    (20) Added extra arrays for ND03 mercury diagnostics (eck, bmy, 12/7/04)
    (21) Added extra ND21 array for crystalline sulfur tracers.  Also remove
         ND03 and ND48 arrays; they are obsolete (bmy, 1/21/05)
    (22) Removed AD41 and AFTTOT arrays; they're obsolete (bmy, 2/17/05)
    (23) Added AD09, AD09_em arrays for HCN/CH3CN simulation (xyp, bmy, 6/27/05)
    (24) Added AD30 array for land/water/ice output (bmy, 8/18/05)
    (25) Added AD54 array for time spend in the troposphere (phs, 9/22/06)
    (26) Added CTO3 counter. Convert ND43 counter arrays from 2D to 3D, for
```

```
      the variable tropopause. (phs, 1/19/07)
(27) Added AD10 and AD10em arrays for ND10 H2-HD-sim diag (phs, 9/18/07)
(28) Added CTO3_24h to account for time in the troposphere for O3 in
      ND47 (phs, 11/17/08)
(29) Added AD52 for Gamma HO2 diagnostic. (jaegle, ccc, 2/26/09)
(30) Updated to save out GLYX production of SOAG in ND07.
     (tmf, 3/6/09)
(31) Add LTO3 for ND45 diag. (ccc, 7/20/09)
(32) Add AD19, AD58, AD60 for CH4 (kjw, 8/18/09)
(33) AD13_NH3_an is 3D now (phs, 10/22/09)
(34) Add AD59_NUMB, AD59_SULF, AD59_SALT, AD59_ECOB, AD59_ECIL, AD59_OCOB,
      AD59_OCIL, and AD59_DUST for size-resolved emission  (win, 1/25/10)
(35) Add AD60_COND, AD60_COAG, AD60_NUCL, AD60_AQOX, AD60_SOA, and
      AD60_ERROR for TOMAS process rate diagnostics (win, 1/25/10)
(36) Add AD61 and AD61_INST for saving 3-D TOMAS rate (win, 1/25/10)
(37) Add counter for aromatics SOA and add AD57 diagnostic for potential
     temperature. (fp, 2/3/10)
26 Aug 2010 - R. Yantosca - Added ProTeX headers
02 Apr 2013 - M. Payer    - Removed *NO, *NO2, and *NO3 arrays for ND43
                            diagnostic. These are no longer needed because
                            NO, NO2, and NO3 are now tracers.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
08 Nov 2013 - M. Sulprizio- Removed CTO3 and LTO3. They are no longer used
                            because O3 is now a tracer.
```

1.51.1 cleanup_diag

Subroutine CLEANUP_DIAG deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_DIAG
```

REVISION HISTORY:

```
13 Dec 2002 - R. Yantosca - Initial version
(1 ) Now also deallocate AD13_NH3_an, AD13_NH3_bb, AD13_NH3_bf arrays
      for the ND13 diagnostic.  (bmy, 12/13/02)
(2 ) Now also deallocate AD13_NH3_na array for ND13 (rjp, bmy, 3/23/03)
(3 ) Removed P24H and L24H, these are now defined within "tagged_ox_mod.f".
     Now also deallocate AD03 array for Kr85 prod/loss (jsw, bmy, 8/20/03)
(4 ) Now also deallocate AD06 and AD07* arrays (rjp, bdf, bmy, 4/5/04)
(5 ) Now also deallocate AD08 array (rjp, bec, bmy, 4/20/04)
(6 ) Now also deallocaes AD13_SO2_sh array (bec, bmy, 5/20/04)
(7 ) Now also deallocates AD07_HC array (rjp, bmy, 7/13/04)
(8 ) Now also deallocate AD13_SO4_bf array (bmy, 11/17/04)
(9 ) Now deallocate extra arrays for ND03 diagnostics (eck, bmy, 12/7/04)
(10) Now deallocates AD21_cr array.  Remove reference to arrays for ND03
```

```
      and ND48 diagnostics, they're obsolete. (cas, sas, bmy, 1/21/05)
(11) Removed AD41 and AFTTOT arrays; they're obsolete (bmy, 2/17/05)
(12) Now also deallocate AD09 and AD09_em (bmy, 6/27/05)
(13) Now deallocate AD30 (bmy, 8/18/05)
(14) Now deallocate CTO3, AD10, AD10em arrays (phs, 9/18/07)
(15) Now deallocate TOMAS related arrays (win, bmy, 1/25/10)
15 Feb 2011 - R. Yantosca - Add modifications for APM microphysics
```

1.52 Fortran: Module Interface drydep_mod

Module DRYDEP_MOD contains variables and routines for the GEOS-Chem dry deposition scheme.

INTERFACE:

```
      MODULE DRYDEP_MOD
```

USES:

```
      USE CMN_SIZE_MOD                          ! Size parameters
      USE CMN_DIAG_MOD                          ! Diag counters & flags
      USE CMN_GCTM_MOD                          ! Physical constants
      USE COMMSOIL_MOD                          ! Soil wetness variables
      USE COMODE_MOD                            ! Large arrays for SMVGEAR
      USE COMODE_LOOP_MOD                       ! Formerly "comode.h"
      USE DAO_MOD                               ! Met field subroutines
      USE DIAG_MOD,       ONLY : AD44           ! Diagnostic arrays
      USE DIRECTORY_MOD                         ! Data directory paths
      USE ERROR_MOD                             ! Error handling routines
      USE GET_POPSINFO_MOD                      ! For POPs simulation
      USE GRID_MOD,       ONLY : GET_AREA_CM2   ! Grid box surface areas [cm2]
      USE LOGICAL_MOD                           ! GEOS-Chem logical switches
      USE PBL_MIX_MOD                           ! Boundary layer quantities
      USE PRESSURE_MOD,   ONLY : GET_PEDGE      ! Pressure @ level edges
      USE TIME_MOD,       ONLY : GET_TS_CHEM    ! Chemistry timestep
      USE TRACERID_MOD                          ! Tracer ID flags
#if   defined( TOMAS )
      USE TOMAS_MOD                             ! For TOMAS microphysics
#endif

      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_DRYDEP
      PUBLIC :: DO_DRYDEP
```

```
PUBLIC :: DRYFLX
PUBLIC :: DRYFLXH2HD
PUBLIC :: DRYFLXRnPbBe
PUBLIC :: DVZ_MINVAL
PUBLIC :: INIT_DRYDEP
PUBLIC :: INIT_WEIGHTSS
```

PUBLIC DATA MEMBERS:

```
PUBLIC :: DEPNAME
PUBLIC :: DEPSAV
PUBLIC :: SHIPO3DEP
PUBLIC :: MAXDEP
PUBLIC :: NUMDEP
PUBLIC :: NTRAIND
PUBLIC :: DRYHg0, DRYHg2, DryHgP    !CDH
PUBLIC :: DRYPOPG, DRYPOPP_OC, DRYPOPP_BC
PUBLIC :: IDEP,   IRGSS,  IRAC, IRCLS
PUBLIC :: IRGSO,  IRLU,   IRI,  IRCLO, DRYCOEFF
PUBLIC :: NDVZIND ! MSL -> For MPI broadcasting in GIGC
```

REMARKS:

```
References:
============================================================================
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      MacMillan, 1957.
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       organic compound emissions, J. Geophys. Res., 100, 8873-8892, 1995.
(6 ) Hicks, B.B., and P.S. Liss, "Transfer of SO2 and other reactive
      gases across the air-sea interface", Tellus, 28, 348-354, 1976.
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      hydrocarbons, and ozone over the Amazon forest during the wet season",
      J.  Geophys. Res., 95, 16737-16754, 1990.
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      97, 16473-16479, 1992.
(9 ) Levine, I.N., "Physical Chemistry, 3rd ed.", McGraw-Hill,
      New York, 1988.
(10) Munger, J.W., et al, "Atmospheric deposition of reactive nitrogen
      oxides and ozone in a temperate deciduous forest and a sub-arctic
      woodland", J. Geophys. Res., in press, 1996.
(11) Walcek, C.J., R.A. Brost, J.S. Chang, and M.L. Wesely, "SO2, sulfate,
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and HNO3 deposition velocities computed using regional landuse and meteorological data", Atmos. Environ., 20, 949-964, 1986.
(12) Wang, Y.H., paper in preparation, 1996.
(13) Wesely, M.L, "Improved parameterizations for surface resistance to gaseous dry deposition in regional-scale numerical models", Environmental Protection Agency Report EPA/600/3-88/025, Research Triangle Park (NC), 1988.
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(15) Price, H., L. Jaegl, A. Rice, P. Quay, P.C. Novelli, R. Gammon, Global Budget of Molecular Hydrogen and its Deuterium Content: Constraints from Ground Station, Cruise, and Aircraft Observations, submitted to J. Geophys. Res., 2007.
(16) Karl, T., Harley, P., Emmons, L., Thornton, B., Guenther, A., Basu, C., Turnipseed, A., and Jardine, K.: Efficient Atmospheric Cleansing of Oxidized Organic Trace Gases by Vegetation, Science, 330, 816-819, 10.1126/science.1192534, 2010.

REVISION HISTORY:

27 Jan 2003 - R. Yantosca - Moved standalone routines into this module
(1) Bug fix: Do not assume NO2 is the 2nd drydep species. This causes a mis-indexing for CANOPYNOX. Now archive ND44 diagnostic in kg for Radon runs in routine DRYFLXRnPbBe; convert to kg/s in diag3.f (bmy, 1/27/03)
(2) Now references "grid_mod.f" and the new "time_mod.f". Renamed DRYDEP routine to DO_DRYDEP for consistency w/ other drivers called from the MAIN program. (bmy, 2/11/03)
(3) Added error check in DRYFLX for SMVGEAR II (bmy, 4/28/03)
(4) Added drydep of N2O5. Now added PBLFRAC array, which is the fraction of each level below the PBL top. Also now compute drydep throughout the entire PBL, in order to prevent short-lived species such as HNO3 from being depleted in the shallow GEOS-3 surface layer. (rjp, bmy, 7/21/03)
(5) Bug fix for GEOS-4 in DRYFLXRnPbBe (bmy, 12/2/03)
(6) Now made CFRAC, RADIAT local variables in DO_DRYDEP (bmy, 12/9/03)
(7) Now enclose AD44 in !$OMP CRITICAL block for drydep flux (bmy, 3/24/04)
(8) Now handle extra carbon & dust tracers (rjp, tdf, bmy, 4/1/04)
(9) Added routines AERO_SFCRS1, AERO_SFCRSII. Increased MAXDEP to 25. Now handles extra carbon & dust tracers. (rjp, tdf, bmy, 4/1/04)
(10) Increased MAXDEP to 26. Added A_RADI and A_DEN module variables. Other modifications for size-resolved drydep. (rjp, bec, bmy, 4/20/04)
(11) Increased MAXDEP to 35 and handle extra SOA tracers (rjp, bmy, 7/13/04)
(12) Now references "logical_mod.f", "directory_mod.f", and "tracer_mod.f" (bmy, 7/20/04)
(13) Add Hg2, HgP as drydep tracers (eck, bmy, 12/8/04)
(14) Updated for AS, AHS, LET, NH4aq, SO4aq (cas, bmy, 1/6/05)
(15) Now references "pbl_mix_mod.f". Removed PBLFRAC array. (bmy, 2/22/05)

```
(16) Now include SO4s, NITs tracers.  Now accounts for hygroscopic growth
     of seasalt aerosols when computing aerodynamic resistances.
     (bec, bmy, 4/13/05)
(17) Now modified for GEOS-5 and GCAP met fields (bmy, 5/25/05)
(18) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(19) Now change Reynold's # criterion from 1 to 0.1 in DEPVEL.  Also
     change Henry's law constant for Hg2.  Also increase MAXDEP from
     35 to 37. (eck, djj, bmy, 2/1/06)
(20) Bug fix in INIT_DRYDEP (bmy, 4/17/06)
(21) Now bundle function DIFFG into "drydep_mod.f".  Also updated for SOG4
     and SOA4 tracers.  Bug fix in INIT_DRYDEP. (dkh, bmy, 5/24/06)
(22) Fix typo in INIT_DRYDEP (dkh, bmy, 6/23/06)
(23) Add H2 and HD as drydep tracers. Added subroutine DRYFLXH2HD for H2HD
     offline sim (phs, 9/18/07)
(24) Extra error check for small RH in AERO_SFCRII (phs, 6/11/08)
(25) Added 15 more dry deposition species (tmf, 7/31/08)
(26) Modify dry depostion to follow the non-local PBL scheme.
     (lin, ccc, 5/29/09)
(27) Minor bug fix in mol wts for ALPH, LIMO (bmy, 10/19/09)
(28) Change MAXDEP from 50 to 81 (win, 7/14/09)
(28a) modified to use Zhang 2001 for all non-size resolved aerosols (hotp)
(29) Add aromatics SOA (dkh)
(30) Add new species. Some tracers give 2 deposition species: ISOPN-> ISOPNB
    and ISOPND. (fp)
(31) Updates for mercury simulation (ccc, 5/17/10)
(32) Add POPs (eck, 9/20/10)
(33) Increase MAXDEP to 51 for dicarbonyls simulation. (ccc, 10/8/10)
01 Aug 2011 - J. Fisher - Set aerosol dry deposition velocity to 0.03 cm/s
                          over snow and ice based on Nilsson & Rannik, 2001
21 Dec 2011 - M. Payer  - Updates for sea salt (jaegle 5/11/11)
22 Dec 2011 - M. Payer  - Added ProTeX headers
10 Jan 2012 - M. Payer  - Update to use local surface pressure
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
26 Mar 2012 - R. Yantosca - Now reference CMN_SIZE_MOD at the top of module
26 Mar 2012 - R. Yantosca - Replace NNTYPE, NNPOLY, NNVEGTYPE w/ the
                            values NTYPE, NPOLY, NVEGTYPE from CMN_SIZE
26 Mar 2012 - R. Yantosca - Now retire MODIN and RDDRYCF; read drydep inputs
                            from a netCDF file w/ routine READ_DRYDEP_INPUTS
26 Mar 2012 - R. Yantosca - Reorganize module USE statements for clarity
09 Apr 2012 - R. Yantosca - Now replace IJREG, IJLAND, IJUSE, XYLAI arrays
                            with IREG, ILAND, IUSE, XLAI.
31 Jul 2012 - R. Yantosca - Modifications for grid-independence
11 Dec 2012 - M. Long     - Now call READ_DRYDEP_INPUTS from INIT_DRYDEP
11 Dec 2012 - R. Yantosca - Now call INIT_WEIGHTSS from INIT_DRYDEP
13 Dec 2012 - R. Yantosca - Remove reference to obsolete CMN_DEP_mod.F
26 Feb 2013 - R. Yantosca - Now use Input_Opt fields where possible
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
```

```
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
29 Jan 2014 - R. Yantosca - Now set MAXDEP=105 for all simulations.  For
                            TOMAS we had MAXDEP=100; this is close enough.
```

1.52.1 do_drydep

Subroutine DO_DRYDEP is the driver for the GEOS-CHEM dry deposition scheme. DO_DRYDEP calls DEPVEL to compute deposition velocities [m/s], which are then converted to [cm/s]. Drydep frequencies are also computed. (lwh, gmg, djj, 1989, 1994; bmy, 2/11/03, 5/25/05)

INTERFACE:

```
SUBROUTINE DO_DRYDEP( am_I_Root, Input_Opt,
&                     State_Met, State_Chm, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
NOTE: Modeled aerosol dry deposition velocities over snow and ice surfaces
in the Arctic are much higher than estimated from measured values (e.g.,
Ibrahim et al. [1983]; Duan et al. [1988]; Nilsson and Rannik [2001]).
We will impose a dry deposition velocity of 0.03 cm/s for all aerosols
over snow and ice surfaces. (Jenny Fisher, 01 Aug 2011)
References (see full citations above):
============================================================================
(1 ) Wesely, M. L., 1989
(2 ) Jacob, D.J., and S.C. Wofsy, 1990
```

REVISION HISTORY:

```
(1 ) Remove SUNCOS, USTAR, AZO, OBK from the arg list; now reference these
     as well as AD and T from "dao_mod.f".  Cleaned up code and updated
     comments.  Now only order tracer numbers into NTRAIND on the first
     call.  Now force double-precision with "D" exponents.  Now also
     reference IDTNOX, IDTOX, etc. from "tracerid_mod.f".  Bundled into
     "drydep_mod.f" (bmy, 11/19/02)
(2 ) Now make sure that the PBL depth (THIK) is greater than or equal to
     the thickness of the first layer.  Now initialize PBLFRAC array on
     each call. (rjp, bmy, 7/21/03)
(3 ) Now declare CFRAC, RADIAT, AZO, USTAR as local variables, which are
     returned by METERO.  CFRAC and RADIAT have also been deleted from
     "CMN_DEP". (bmy, 12/9/03)
(4 ) Now use explicit formula for IJLOOP to allow parallelization.
     Also reference LPRT from "logical_mod.f" (bmy, 7/20/04)
(5 ) Now use routines from "pbl_mix_mod.f" to get PBL quantities, instead
     of re-computing them here.  Removed PBLFRAC array.  Removed reference
     to "pressure_mod.f".  Removed reference to header file CMN.
     Parallelize DO-loops. (bmy, 2/22/05)
(6 ) Now define RHB as a local array, which is defined in METERO and then
     passed to DEPVEL. (bec, bmy, 4/13/05)
(7 ) Now dimension AZO for GEOS or GCAP met fields.  Remove obsolete
     variables. (swu, bmy, 5/25/05)
(8 ) Remove reference to TRACERID_MOD, it's not needed (bmy, 10/3/05)
01 Aug 2011 - J. Fisher - Set aerosol dry deposition velocity to 0.03 cm/s
                          over snow and ice based on Nilsson & Rannik, 2001
15 Aug 2011 - R. Yantosca - Now reference IDTxxx flags from tracerid_mod.f
07 Oct 2011 - R. Yantosca - Rename SUNCOS30 to SUNCOS_MID, which is the
                            cos(SZA) at the midpt of the chemistry timestep
22 Dec 2011 - M. Payer    - Added ProTeX headers
10 Jan 2012 - M. Payer    - Added local surface pressure
26 Mar 2012 - R. Yantosca - Now read drydep inputs from a netCDF file
                            via routine READ_DRYDEP_INPUTS
26 Mar 2012 - R. Yantosca - Remove calls to obsolete MODIN, RDDRYCF routines
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
28 Nov 2012 - R. Yantosca - Now make SUNCOS_MID a local array of size
                            MAXIJ, populated from State_Met%SUNCOSmid
11 Dec 2012 - R. Yantosca - Now do not call READ_DRYDEP_INPUTS and
                            INIT_WEIGHTSS when using the ESMF environment
11 Dec 2012 - R. Yantosca - Remove FIRST variable, as we now read inputs
                            from disk in routine INIT_DRYDEP
12 Dec 2012 - R. Yantosca - Now pass State_Met to DEPVEL
26 Feb 2013 - R. Yantosca - Now use Input_Opt fields where possible.  This
                            facilitates connection to the GEOS-5 GCM.
31 May 2013 - R. Yantosca - Now pass Input_Opt & State_Chm to DEPVEL
```

1.52.2 dvz_minval

Function DVZ_MINVAL sets minimum values for drydep velocities for SULFATE TRACERS, according to Mian Chin's GOCART model. (rjp, bmy, 11/21/02, 10/3/05)

INTERFACE:

```
FUNCTION DVZ_MINVAL( N, LSNOW, DVZ ) RESULT( NEWDVZ )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: N      ! Tracer number
LOGICAL, INTENT(IN) :: LSNOW  ! Flag for denoting snow/ice
REAL*8,  INTENT(IN) :: DVZ    ! Deposition velocity [cm/s]
```

RETURN VALUE:

```
REAL*8              :: NEWDVZ
```

REVISION HISTORY:

```
(1 ) Don't put a min drydep value on H2O2 for offline run (rjp, bmy,3/31/03)
(2 ) Remove reference to CMN, it's obsolete (bmy, 7/20/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.52.3 metero

Subroutine METERO calculates meteorological constants needed for the dry deposition velocity module. (lwh, gmg, djj, 1989, 1994; bmy, 10/3/05)

INTERFACE:

```
SUBROUTINE METERO( State_Met, CZ1,    TCO,  OBK,       CFRAC,
&                  RADIAT,    AZO,    USTR, ZH,        LSNOW,
&                  RHB,       PRESSU, W10,  SUNCOS_MID        )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
LOGICAL, INTENT(OUT) :: LSNOW (MAXIJ)  ! Flag for denoting snow/ice
REAL*8,  INTENT(OUT) :: CZ1   (MAXIJ)  ! Midpt ht of 1st model level [m]
REAL*8,  INTENT(OUT) :: TCO   (MAXIJ)  ! Grid box sfc temperature [K]
```

```
      REAL*8,  INTENT(OUT) :: OBK   (MAXIJ)  ! Monin-Obhukov length [m]
      REAL*8,  INTENT(OUT) :: CFRAC (MAXIJ)  ! Column cloud fraction [unitless]
      REAL*8,  INTENT(OUT) :: RADIAT(MAXIJ)  ! Solar radiation @ ground [W/m2]
      REAL*8,  INTENT(OUT) :: RHB   (MAXIJ)  ! Rel humidity at sfc [unitless]
      REAL*8,  INTENT(OUT) :: USTR  (MAXIJ)  ! Friction velocity [m/s]
      REAL*8,  INTENT(OUT) :: ZH    (MAXIJ)  ! PBL height [m]
      REAL*8,  INTENT(OUT) :: PRESSU(MAXIJ)  ! Local surface pressure [Pa]
      REAL*8,  INTENT(OUT) :: W10   (MAXIJ)  ! 10 meter windspeed [m/s]
      REAL*8,  INTENT(OUT) :: SUNCOS_MID(MAXIJ)  ! COS(SZA) @ midpt of current
                                                 !  chemistry timestep

      ! Dimension AZO for GCAP or GEOS met fields (swu, bmy, 5/25/05)
#if   defined( GCAP )
      REAL*8, INTENT(OUT)  :: AZO(NTYPE)     ! Roughness heights, by landtype
#else
      REAL*8, INTENT(OUT)  :: AZO(MAXIJ)     ! Roughness heights, by grid box
#endif
```

REMARKS:

```
   NOTE: We save into arrays of dimension MAXIJ=IIPAR*JJPAR for compatibility
   with the legacy drydep routine DEPVEL.
                                                                             .
   References (see full citations above):
   ========================================================================
   (1 ) Wesely, M. L., 1989.
   (2 ) Jacob, D.J., and S.C. Wofsy, 1990
```

REVISION HISTORY:

```
   (1 ) Now reference GET_PEDGE from "pressure_mod.f".  Now reference T from
        "dao_mod.f".  Removed obsolete code & comments, and added new
         documentation header.  Now force double precision with "D"
         exponents.  Now compute OBK here as well.  Bundled into F90 module
         "drydep_mod.f" (bmy, 11/20/02)
   (2 ) Now reference CLDFRC, RADSWG, ZO, USTAR from "dao_mod.f".  Also now
         pass CFRAC, RADIAT, AZO, USTR back to the calling routine
         via the arg list. (bmy, 12/9/03)
   (3 ) Now use explicit formula for IJLOOP to allow parallelization
        (bmy, 7/20/04)
   (4 ) Now compute ZH and LSNOW here instead of w/in DO_DRYDEP.  Parallelize
        DO-loops.  Now use BXHEIGHT from "dao_mod.f" instead of computing
        the thickness of the 1st level here.  Remove reference to
        "pressure_mod.f".  Remove reference to T from "dao_mod.f".  Now
        reference ALBD from "dao_mod.f" (bmy, 2/22/05)
   (5 ) Now references RH from "dao_mod.f".  Now passes relative humidity
        from the surface layer back via RHB argument. (bec, bmy, 4/13/05)
   (6 ) Now call GET_OBK from "dao_mod.f" to get the M-O length for both
        GEOS or GCAP met fields.  Remove local computation of M-O length
```

```
      here.  Also now dimension AZO appropriately for GCAP or GEOS met
      fields.  Remove obsolete variables. (swu, bmy, 5/25/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Move XLTMMP function to module MEGANUT_MOD. (ccc, 11/20/09)
(9 ) Add sea level pressure and 10m windspeed as arguments (jaegle 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
10 Jan 2012 - M. Payer    - Added local surface pressure
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
28 Nov 2012 - R. Yantosca - Add SUNCOS_MID to the argument list and
                            populate that with State_Met%SUNCOSmid
21 Oct 2013 - R. Yantosca - Bug fix: need to hold SP private in OMP loop
```

1.52.4 dryflx

Subroutine DRYFLX sets up the dry deposition flux diagnostic for tracers which are part of the SMVGEAR mechanism. (bmy, bdf, 4/20/99, 3/24/04)

INTERFACE:

```
SUBROUTINE DRYFLX( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE CMN_DIAG_MOD
USE COMMSOIL_MOD
USE COMODE_MOD
USE GET_NDEP_MOD,       ONLY : SOIL_DRYDEP
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TRACERID_MOD,       ONLY : IDTHNO3
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
DRYFLX is not called if non-local PBL mixing is done (i.e. when LNLPBL=F).
If using non-local PBL mixing, the drydep fluxes are archived in routine
VDIFF (GeosCore/vdiff_mod.F90).
```

REVISION HISTORY:

```
(1 ) Bug fix -- now skip tracers for which NTDEP(N) is zero, in order
     to avoid array-out-of-bounds errors. (bmy, 5/2/00)
(2 ) Now reference the CSPEC array from "comode_mod.f" instead of from
     common block header "comode.h". (bmy, 7/11/00)
(3 ) Also reference JLOP and VOLUME from "comode_mod.f" (bmy, 10/19/00)
(4 ) Updated comments, cosmetic changes (bmy, 3/14/02)
(5 ) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(6 ) Removed reference to "comtrid.h", "CMN_SAV", "CMN_DEP", and "CMN_O3",
     these are not used in this routine.  Also bundled into "drydep_mod.f"
     for more convenient packaging. (bmy, 11/19/02)
(7 ) Replaced DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid"mod.f".
     Also removed references to JREF and FLUXRUL.  Now use function
     GET_TS_CHEM from "time_mod.f". (bmy, 2/11/03)
(8 ) Now references ERROR_STOP from "error_mod.f" (bmy, 4/28/03)
(9 ) Now sum drydep fluxes throughout the entire PBL.  Added L variable.
     AREA_CM2 has now been made into a lookup table. Now implement a
     parallel DO loop for efficiency. (rjp, bmy, 7/21/03)
(10) Now bracket AD44 with a !$OMP CRITICAL block in order to avoid
     multiple threads writing to the same element (bmy, 3/24/04)
(11) Now reference GET_FRAC_UNDER_PBLTOP and GET_PBL_MAX_L from
     "pbl_mix_mod.f".  Remove reference to CMN. (bmy, 2/22/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
31 Jul 2012 - R. Yantosca - Now loop from 1..LLPAR for GIGC compatibility
05 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC arguments
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LSOILNOX and Input_Opt%NUMDEP
30 Oct 2013 - M. Sulprizio- Bug fix: Hold AREA_CM2 private in !$OMP loop
```

1.52.5 dryflxRnPbBe

Subroutine DRYFLXRnPbBe removes dry deposition losses from the STT tracer array and archives deposition fluxes to the ND44 diagnostic. (hyl, bmy, bdf, 4/2/99, 5/25/05)

INTERFACE:

```
SUBROUTINE DRYFLXRnPbBe( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Now eliminate DEPFLUX from CMN_SAV, in order to save memory.
     DEPFLUX is now a local variable (bdf, 4/2/99)
(2 ) Now make DEPFLUX of dimension (IIPAR,JJPAR,MAXDEP) (bmy, 4/2/99)
(3 ) Now use an allocatable array for the ND44 diagnostic.
     Also made cosmetic changes, updated comments. (bmy, 3/16/00)
(4 ) Eliminate obsolete code and ND63 diagnostic (bmy, 4/12/00)
(5 ) Added to module "RnPbBe_mod.f".  Also made cosmetic changes
     and updated comments (bmy, 6/14/01)
(6 ) Updated comments (bmy, 3/29/02)
(7 ) Replace all instances of IM, JM, IMX, JMX, with IIPAR, JJPAR, IIPAR,
     and JJPAR.  Now replaced DEPFLUX array w/ AMT_LOST scalar
     variable.  Also make sure that the amount of tracer lost to drydep
     is now accurately accounted in the ND44 diagnostic. (bmy, 8/7/02)
(8 ) Now call GEOS_CHEM_STOP or ERROR_STOP (from "error_mod.f") when
     stopping the run w/ an error condition. (bmy, 10/15/02)
(9 ) Now moved from "RnPbBe_mod.f" to "drydep_mod.f".  (bmy, 1/27/03)
(10) Now use function GET_TS_CHEM from "time_mod.f" (bmy, 2/11/03)
(11) Now compute drydep fluxes throughout the entire PBL.  Now references
     PBLFRAC.  Added L_PBLTOP variable. (bmy, 7/21/03)
(12) Now follow GEOS-3 algorithm for GEOS-4 model (bmy, 12/2/03)
(13) Now reference STT from "tracer_mod.f" and LDRYD from "logical_mod.f"
     (bmy, 7/20/04)
(14) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.52.6 dryflxh2hd

Subroutine DRYFLXH2HD removes dry deposition losses from the tracer array and archives deposition fluxes AND VELOCITY to the ND44 diagnostic. (adapted from DRYFLX v5-05, jaegle 11/02/2005).

INTERFACE:

```
SUBROUTINE DRYFLXH2HD( State_Met, State_Chm )
```

USES:

```
      USE DIAG_MOD,           ONLY : AD44
      USE ERROR_MOD,          ONLY : ERROR_STOP, GEOS_CHEM_STOP
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE GRID_MOD,           ONLY : GET_XOFFSET, GET_YOFFSET
      USE LOGICAL_MOD,        ONLY : LDRYD
      USE PBL_MIX_MOD,        ONLY : GET_PBL_TOP_m
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
      USE PBL_MIX_MOD,        ONLY : GET_PBL_MAX_L
      USE TIME_MOD,           ONLY : GET_TS_CHEM

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! Diagnostic switches & arrays
      USE COMMSOIL_MOD             ! Soil wetness variables
```

INPUT PARAMETERS:

```
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%% NOTE: THIS ROUTINE SHOULD BE REWRITTEN FOR THE NEW SOIL NOX SCHEME. %%%
%%% We have commented out the obsolete INDEXSOIL and NLAND variables,   %%%
%%% which were different depending on which horizontal grid was used.   %%%
%%% The grid-independent GEOS-Chem cannot know a-priori what the size   %%%
%%% of the horizontal grid is, since it will be told that by the        %%%
%%% interface to the external GEOS-Chem.  Therefore, we cannot use      %%%
%%% fixed parameters to define the horizontal (and vertical) grids that %%%
%%% are used in GEOS-Chem.  (bmy, 10/30/12)                             %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
(1) Now deposit through the PBL. Commented but kept code related to soil
    temperature (phs, 5/16/07)
(2) Move XLTMMP to module MEGANUT_MOD (ccc, 11/20/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
09 Apr 2012 - R. Yantosca - Replace IJLAND, IJUSE arrays w/ ILAND, IUSE
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.52.7 depvel

Subroutine DEPVEL computes the dry deposition velocities using a resistance-in-series model.

INTERFACE:

```
      SUBROUTINE DEPVEL( Input_Opt, State_Met, State_Chm, NPTS,
     &                   RADIAT,    TEMP,      SUNCOS,    F0,
     &                   HSTAR,     XMW,       AIROSOL,   USTAR,
     &                   CZ1,       OBK,       CFRAC,     ZH,
     &                   LSNOW,     DVEL,      ZO,        RHB,
     &                   PRESSU,    W10                           )
```

USES:

```
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(IN) :: Input_Opt ! Input Options object
      TYPE(MetState), INTENT(IN) :: State_Met ! Meteorology state object

      INTEGER, INTENT(IN) :: NPTS             ! # of grid boxes = IIPAR*JJPAR
      REAL*8,  INTENT(IN) :: RADIAT (MAXIJ )  ! Solar radiation [W/m2]
      REAL*8,  INTENT(IN) :: TEMP   (MAXIJ )  ! Temperature [K]
      REAL*8,  INTENT(IN) :: SUNCOS (MAXIJ )  ! Cosine of solar zenith angle
      LOGICAL, INTENT(IN) :: AIROSOL(MAXDEP)  ! =T denotes aerosol species
      REAL*8,  INTENT(IN) :: F0     (MAXDEP)  ! Reactivity factor for oxidation
                                              !  of biological substances
      REAL*8,  INTENT(IN) :: HSTAR  (MAXDEP)  ! Henry's law constant
      REAL*8,  INTENT(IN) :: XMW    (MAXDEP)  ! Molecular weight [kg/mol]
      REAL*8,  INTENT(IN) :: USTAR  (MAXIJ )  ! Friction velocity [m/s]
      REAL*8,  INTENT(IN) :: CZ1    (MAXIJ )  ! Alt @ which Vd is computed [m]
      REAL*8,  INTENT(IN) :: OBK    (MAXIJ )  ! Monin-Obhukov length [m]
      REAL*8,  INTENT(IN) :: CFRAC  (MAXIJ )  ! Surface cloud fraction
      REAL*8,  INTENT(IN) :: ZH     (MAXIJ )  ! Roughness height [m]
      REAL*8,  INTENT(IN) :: RHB    (MAXIJ )  ! Relative humidity [%]
      REAL*8,  INTENT(IN) :: PRESSU (MAXIJ )  ! Surface pressure [hPa]
      REAL*8,  INTENT(IN) :: W10    (MAXIJ )  ! Wind speed @ 10m altitude [m/s]
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      REAL*8, INTENT(OUT) :: DVEL(MAXIJ,MAXDEP)   ! Drydep velocity [m/s]
```

REMARKS:

```
Need as landtype input for each grid square (I,J); see CMN_DEP_mod.F
   IREG(I,J)       - # of landtypes in grid square
   ILAND(I,J,LDT)  - Land type ID for element LDT =1, IREG(I,J)
                     (could be from any source - mapped to deposition
                     surface ID in input unit 65)
   IJUSE(I,J,LDT) - Fraction ((per mil) of gridbox area occupied by
                    land type element LDT
                                                                      .
Need as leaf area index; see CMN_DEP_mod.F
   XLAI(I,J,LDT)  - Leaf Area Index of land type element LDT
                                                                      .
Need as meteorological input for each grid square(I,J) (passed):
   RADIAT(IJLOOP) - Solar radiation in W m-2
   TEMP(IJLOOP)   - Surface air temperature in K
   SUNCOS(IJLOOP) - Cosine of solar zenith angle
   LSNOW(IJLOOP)  - Logical for snow and sea ice
   RHB(IJLOOP)    - Relative humidity at the surface
   PRESSU(IJLOOP) - Local surface pressure
   W10(IJLOOP)    - 10m wind speed
                                                                      .
Need as input for each species K (passed):
   F0(K)          - reactivity factor for oxidation of biological substances
   HSTAR(K)       - Henry's Law constant
   XMW(K)         - Molecular weight (kg/mole) of species K
                    (used to calculate molecular diffusivities)
   AIROSOL(K)     - LOGICAL flag (T = aerosol species;
                                  F = gas-phase species)
                                                                      .
Also need to call the following subroutines to read drydep input data:
   READ_DRYDEP_INPUTS    - (in this module) Reads in Olson land type
                           indices, dry deposition land type indices,
                           default roughness heights, and polynomial
                           coefficients.  (This supersedes MODIN, RDDRYCF)
   COMPUTE_OLSON_LANDMAP - (in olson_landmap_mod.F90).  Reads in the
                           Olson land types at native resolution and re-bins
                           them on-the-fly to the GEOS-Chem grid resolution.
                           (This supersedes RDLAND)
   "rdlai.f"             - reads Leaf Area Indices from files "lai**.global"
                                                                      .
Some variables used in the subroutine (passed):
   LRGERA(IJLOOP) T -> stable atmosphere; a high aerodynamic resistance
                       (RA=1.E4 m s-1) is imposed; else RA is calculated
   USTAR(IJLOOP)  - Friction velocity (m s-1)
   CZ1(IJLOOP)    - Altitude (m) at which deposition velocity is computed
   OBK(IJLOOP)    - Monin-Obukhov length (m): set to 1.E5 m under neutral
                    conditions
   CFRAC(IJLOOP)  - Fractional cloud cover
   ZH(IJLOOP)     - Mixing depth (m)
```

```
                                                                             .
    Some variables used in the subroutine:
       MAXDEP         - the maximum number of species for which the dry
                        deposition calculation is done
       ZO(LDT)        - Roughness height (m) for specific surface type indexed
                        by LDT
       RSURFC(K,LDT)  - Bulk surface resistance (s m-1) for species K to
                        surface LDT
       C1X(K)         - Total resistance to deposition (s m-1) for species K
                                                                             .
    Returned:
       DVEL(IJLOOP,K) - Deposition velocity (m s-1) of species K
                                                                             .
    References:
    ===========================================================================
       Baldocchi, D.D., B.B. Hicks, and P. Camara, A canopy stomatal
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         J.  Geophys. Res., 95, 16737-16754, 1990.
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         J. Geophys. Res., 97, 16473-16479, 1992.
       Levine, I.N., Physical Chemistry, 3rd ed., McGraw-Hill, New York, 1988.
       Munger, J.W., and 8 others, Atmospheric deposition of reactive
         nitrogen oxides and ozone in a temperate deciduous forest and a
         sub-arctic woodland, J. Geophys. Res., in press, 1996.
       Walcek, C.J., R.A. Brost, J.S. Chang, and M.L. Wesely, SO2, sulfate, and
         HNO3 deposition velocities computed using regional landuse and
         meteorological data, Atmos. Environ., 20, 949-964, 1986.
       Wang, Y.H., paper in preparation, 1996.
       Wesely, M.L, Improved parameterizations for surface resistance to
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         Research Triangle Park (NC), 1988.
       Wesely, M.L., same title, Atmos. Environ., 23, 1293-1304, 1989.
```

REVISION HISTORY:

```
** Contact: D.J. Jacob, Harvard U. (djj@io.harvard.edu)
```

```
** Modularized by G.M. Gardner, Harvard U.
** Version 3.2:   5/27/97
** Version 3.2.1: 3/4/99   -- bug fix in expression for RT
** Version 3.2.2: 3/26/99  -- bug fix: specify a large Ra for aerosols
** Version 3.2.3: 11/12/99 -- change Reynolds # criterion from 10 to 1
                            -- force double precision w/ "D" exponents
** Version 3.3:   5/8/00   -- bug fixes, cleanup, updated comments.
** Version 3.4:   1/22/03  -- remove hardwire for CANOPYNOX
** Version 3.5    7/21/03  -- Remove cap of surface resistance in RLUXX
** Version 3.6    4/01/04  -- Now do drydep of DUST aerosol tracers
** Version 3.7    4/20/04  -- Now also do drydep of SEASALT aerosol tracers
** Version 3.8    4/13/05  -- Accounts for hygroscopic growth of SEASALT
**                            aerosol tracers.  DUST aerosol tracers do
**                            not grow hygroscopically.  Added RHB as
**                            an input argument.
** Version 3.9    5/25/05  -- Now restore GISS-specific code for GCAP model
** Version 3.9.1  11/17/05 -- change Reynolds # criterion from 1 to 0.1
  11 May 2011 - L. Jaegle   - Updated to use actual Sea level pressure instead
                              of 1000 hPa
                            - Modified to used Slinn & Slinn (1980) over Ocean
                              surfaces
  22 Dec 2011 - M. Payer    - Added ProTeX headers
  10 Jan 2012 - M. Payer    - Updated to use local surface pressure
  09 Apr 2012 - R. Yantosca - Remove IJREG, IJLAND, IJUSE, XYLAI arrays and
                              replace w/ IREG, ILAND, IUSE, XLAI
  09 Apr 2012 - R. Yantosca - Remove reference to CMN_VEL_mod.F
  09 Apr 2012 - R. Yantosca - Now use INTENT(IN), INTENT(OUT) for arguments
  30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                              running with the traditional driver main.F
  12 Dec 2012 - R. Yantosca - Now get ILAND, IUSE, IREG from State_Met
  13 Dec 2012 - R. Yantosca - Now get XLAI from State_Met
  31 May 2013 - R. Yantosca - Now pass State_Chm, for TOMAS
  14 Jun 2013 - R. Yantosca - Now use Input_Opt%ITS_A_POPS_SIM
  29 Aug 2013 - R. Yantosca - Bug fix: Skip to the next species if unless
                              HSTAR>0 and XMW>0, or AIROSOL=t.  This avoids
                              a floating-point invalid condition.
  28 Jan 2014 - R. Yantosca - For TOMAS, don't hold A_RADI and A_DEN PRIVATE
!-----------------------------------------------------------------------
!  Changes from Version 3.2 to Version 3.3:                           ***
!  * We now suppress dry deposition over aerodynamically smooth       ***
!    surfaces.  The previous algorithm yielded negative numbers       ***
!    when u* was very small (due to the logarithm going negative).    ***
!    See the comments below for more information.                     ***
!  * Now eliminate obsolete variables ZLMO and SIH from the code.     ***
!  * Obsolete comments have been updated or removed.                  ***
!-----------------------------------------------------------------------
!  Changes from version 3.1 to version 3.2:                           ***
!  * In unstable atmospheres with |ZLMO| < ZO, as can happen          ***
```

```
     occasionally under very low wind conditions with tall canopies, ***
     application of Monin-Obukhov similarity yields negative values  ***
     for RA.  This was a problem in version 3.1.  In fact,           ***
     Monin-Obukhov similarity does not apply under such conditions,  ***
     so we now set RA to zero and let the boundary                   ***
     resistance RB define the overall aerodynamic resistance.  Since ***
     RB varies inversely with U* it will impose a large aerodynamic  ***
     resistance under very low wind conditions.                      ***
    * The range of applicability of stability correction functions   ***
     to Monin-Obukhov similarity has been extended to                ***
     -2.5 < z/zMO < 1.5, based on Figure 2 of Businger et al. [1971].***
     The range used to be -1 < z/zMO < 1 in version 3.1.             ***
 ************************************************************************
```

1.52.8 diffg

Subroutine DIFFG calculates the molecular diffusivity [m2/s] in air for a gas X of molecular weight XM [kg] at temperature TK [K] and pressure PRESS [Pa]. (bmy, 5/16/06)

INTERFACE:

```
      FUNCTION DIFFG( TK, PRESS, XM ) RESULT( DIFF_G )
```

USES:

INPUT PARAMETERS:

```
      REAL*8, INTENT(IN) :: TK     ! Temperature [K]
      REAL*8, INTENT(IN) :: PRESS  ! Pressure [Pa]
      REAL*8, INTENT(IN) :: XM     ! Molecular weight of gas [kg]
```

REMARKS:

```
We specify the molecular weight of air (XMAIR) and the hard-sphere molecular
radii of air (RADAIR) and of the diffusing gas (RADX).  The molecular
radius of air is given in a Table on p. 479 of Levine [1988].  The Table
also gives radii for some other molecules.  Rather than requesting the user
to supply a molecular radius we specify here a generic value of 2.E-10 m for
all molecules, which is good enough in terms of calculating the diffusivity
as long as molecule is not too big.
```

REVISION HISTORY:

```
(1 ) Originally was a standalone function; now bundled into drydep_mod.f.
     Also now force REAL*8 precision with D exponents.  Now use F90
     style syntax and updated comments. (bmy, 5/16/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.52.9 read_drydep_inputs

Subroutine READ_DRYDEP_INPUTS reads inputs for the dry deposition module corresponding to either the Olson 1992 (GEOS-Chem default) or Olson 2001 (planned replacement for Olson 1992) land map.

INTERFACE:

```
      SUBROUTINE READ_DRYDEP_INPUTS( am_I_Root, DRYCOEFF, IOLSON,
     &                               IDEP,      IWATER,   NWATER,
     &                               IZO,       IDRYDEP,  IRI,
     &                               IRLU,      IRAC,     IRGSS,
     &                               IRGSO,     IRCLS,    IRCLO,
     &                               IVSMAX,    Data_Dir_1x1      )
```

USES:

```
      ! Modules for netCDF read
      USE m_netcdf_io_open
      USE m_netcdf_io_get_dimlen
      USE m_netcdf_io_read
      USE m_netcdf_io_readattr
      USE m_netcdf_io_close

#     include "netcdf.inc"
```

INPUT PARAMETERS:

```
      LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
      CHARACTER(LEN=255), INTENT(IN) :: Data_Dir_1x1
```

OUTPUT PARAMETERS:

```
      !-----------------------------------------------------------------------
      ! DRYCOEFF : Baldocchi polynomial coeffs
      ! IOLSON   : Olson land type indices (+1)
      ! IDEP     : Mapping: Olson ==> drydep ID
      ! IWATER   : Olson types that represent water
      ! NWATER   : Number of Olson types that are water
      ! IZO      : Default Z0 (routgness height) for each Olson land type
      ! IDRYDEP  : Dry deposition land type indices
      ! IRI      : RI   resistance for drydep
      ! IRLU     : RLU  resistance for drydep
      ! IRAC     : RAC  resistance for drydep
      ! IRGSS    : RGSS resistance for drydep
      ! IRGSO    : RGSO resistance for drydep
      ! IRCLS    : RCLS resistance for drydep
      ! IRCLO    : RCLO resistance for drydep
      ! IVSMAX   : Max drydep velocity (for aerosol) perr drydep land type
      !-----------------------------------------------------------------------
      REAL*8,  INTENT(OUT) :: DRYCOEFF(NPOLY    )
```

```
      INTEGER, INTENT(OUT) :: IOLSON  (NVEGTYPE )
      INTEGER, INTENT(OUT) :: IDEP    (NVEGTYPE )
      INTEGER, INTENT(OUT) :: IWATER  (NVEGTYPE )
      INTEGER, INTENT(OUT) :: NWATER
      INTEGER, INTENT(OUT) :: IZO     (NVEGTYPE )
      INTEGER, INTENT(OUT) :: IDRYDEP (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRI     (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRLU    (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRAC    (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRGSS   (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRGSO   (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRCLS   (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IRCLO   (NDRYDTYPE)
      INTEGER, INTENT(OUT) :: IVSMAX  (NDRYDTYPE)
```

REMARKS:

```
    Routine READ_DRYDEP_INPUTS replaces routines MODIN (which read the ASCII
    file "drydep.table") and RDDRYCF (which read the ASCII file "drydep.coef").
                                                                             .
    READ_DRYDEP_INPUTS was generated from the Perl script "ncCodeRead", which
    is part of the NcdfUtilities package (with subsequent hand-editing).
                                                                             .
    Assumes that you have:
    (1) A netCDF library (either v3 or v4) installed on your system
    (2) The NcdfUtilities package (from Bob Yantosca) source code
```

REVISION HISTORY:

```
    26 Mar 2012 - R. Yantosca - Initial version
```

1.52.10 aero_sfcrsii

Function AERO_SFCRSII computes the aerodynamic resistance of seasalt aerosol tracers according to Zhang et al 2001. We account for hygroscopic growth of the seasalt aerosol particles. (rjp, tdf, bec, bmy, 4/1/04, 6/11/08)

INTERFACE:

```
      FUNCTION AERO_SFCRSII( K, II, PRESS, TEMP, USTAR, RHB,
     &                       W10, Input_Opt ) RESULT(RS)
```

USES:

```
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN) :: K     ! Drydep tracer index (range: 1-NUMDEP)
      INTEGER,        INTENT(IN) :: II    ! Surface type index of GEOS-CHEM
```

```
REAL*8,         INTENT(IN) :: PRESS ! Pressure [kPa] (1 mb=100 Pa=0.1 kPa)
REAL*8,         INTENT(IN) :: TEMP  ! Temperature [K]
REAL*8,         INTENT(IN) :: USTAR ! Friction velocity [m/s]
REAL*8,         INTENT(IN) :: RHB   ! Relative humidity (fraction)
REAL*8,         INTENT(IN) :: W10   ! 10 m windspeed [m/s]
TYPE(OptInput), INTENT(IN) :: Input_Opt  ! Input Options object
```

RETURN VALUE:

```
REAL*8              :: RS    ! Surface resistance for particles [s/m]
```

REVISION HISTORY:

```
(1 ) Updated comments.  Also now force double precision w/ "D" exponents.
     (bmy, 4/1/04)
(2 ) Now limit relative humidity to [tiny(real*8),0.99] range for DLOG
      argument (phs, 6/11/08)
(3 ) Bug fixes to the Gerber (1985) growth function (jaegle 5/11/11)
(4)  Update growth function to Lewis and Schwartz (2006) and density
     calculation based on Tang et al. (1997) (bec, jaegle 5/11/11)
(5 ) Updates of sea salt deposition over water to follow the Slinn & Slinn
     (1980) formulation over water surface. Described in Jaegle et al. (ACP,
     11, 2011) (jaegle 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
14 Jun 2013 - R. Yantosca - Now pass Input_Opt via the arg list
```

1.52.11 init_weightss

Subroutine INIT_WEIGHTSS calculates the volume size distribution of sea-salt. This only has to be done once. We assume that sea-salt is the combination of a coarse mode and accumulation model log-normal distribution functions. The resulting arrays are: DMID = diameter of bin and SALT_V = dV/dln(D) [in um3]. (jaegle 5/11/11)

INTERFACE:

```
SUBROUTINE INIT_WEIGHTSS( Input_Opt )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN) :: Input_Opt
```

REVISION HISTORY:

```
11 May 2011 - L. Jaegle   - Initial version
22 Dec 2011 - M. Payer    - Added ProTeX headers
14 Jun 2013 - R. Yantosca - Now accept Input_Opt via tha argument list
```

1.52.12 dust_sfcrsi

Function DUST_SFCRSI computes the aerodynamic resistance of dust aerosol tracers according to Seinfeld et al 96. We do not consider hygroscopic growth of the dust aerosol particles. (rjp, tdf, bmy, bec, 4/1/04, 4/15/05)

INTERFACE:

```
FUNCTION DUST_SFCRSI( K, II, PRESS, TEMP, USTAR ) RESULT( RS )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: K       ! Drydep species (range: 1-NUMDEP)
INTEGER, INTENT(IN) :: II      ! Surface type index of GEOS-CHEM
REAL*8,  INTENT(IN) :: PRESS   ! Pressure [kPa]
REAL*8,  INTENT(IN) :: TEMP    ! Temperature [K]
REAL*8,  INTENT(IN) :: USTAR   ! Friction velocity [m/s]
```

RETURN VALUE:

```
REAL*8              :: RS      ! Surface resistance for particles [s/m]
```

REVISION HISTORY:

```
(1 ) Updated comments.  Also now force double precision w/ "D" exponents.
     (bmy, 4/1/04)
(2 ) Renamed to DUST_SFCRSII, since this will only be used to compute
     aerodynamic resistance of dust aerosols.  (bec, bmy, 4/15/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.52.13 adust_sfcrsii

Function ADUST_SFCRSII computes the aerodynamic resistance of non-size resolved aerosol according to Zhang et al 2001. We do not consider the hygroscopic growth of the aerosol particles. (rjp, tdf, bec, bmy, 4/1/04, 4/15/05)

This routine is used for all aerosols except dust, sulfate, and seasalt (hotp 7/31/09)

INTERFACE:

```
FUNCTION ADUST_SFCRSII( K, II, PRESS, TEMP, USTAR ) RESULT( RS )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: K     ! Drydep tracer index (range: 1-NUMDEP)
INTEGER, INTENT(IN) :: II    ! Surface type index of GEOS-CHEM
REAL*8,  INTENT(IN) :: PRESS ! Pressure [kPa] (1 mb = 100 Pa = 0.1 kPa)
REAL*8,  INTENT(IN) :: TEMP  ! Temperature [K]
REAL*8,  INTENT(IN) :: USTAR ! Friction velocity [m/s]
```

RETURN VALUE:

```
      REAL*8              :: RS    ! Surface resistance for particles [s/m]
```

REVISION HISTORY:

```
(1 ) Updated comments.  Also now force double precision w/ "D" exponents.
     (bmy, 4/1/04)
(2 ) Renamed to DUST_SFCRSII, since this will only be used to compute
     aerodynamic resistance of dust aerosols.  (bec, bmy, 4/15/05)
(3 ) Modified hotp for non size resolved aerosols. This is just DUST_SFCRSII
     renamed and the diameter and density fixed. (hotp 7/12/07)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.52.14 dust_sfcrsii

Function DUST_SFCRSII computes the aerodynamic resistance of dust aerosol tracers according to Zhang et al 2001. We do not consider the hygroscopic growth of the aerosol particles. (rjp, tdf, bec, bmy, 4/1/04, 4/15/05)

INTERFACE:

```
      FUNCTION DUST_SFCRSII( K, II, PRESS, TEMP, USTAR, DIAM, DEN )
     & RESULT( RS )
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: K       ! Drydep tracer index (range: 1-NUMDEP)
      INTEGER, INTENT(IN) :: II      ! Surface type index of GEOS-CHEM
      REAL*8,  INTENT(IN) :: PRESS   ! Pressure [kPa]
      REAL*8,  INTENT(IN) :: TEMP    ! Temperature [K]
      REAL*8,  INTENT(IN) :: USTAR   ! Friction velocity [m/s]
      REAL*8,  INTENT(IN) :: DIAM    ! Particle diameter [m]
      REAL*8,  INTENT(IN) :: DEN     ! Particle density [kg/m3]
```

RETURN VALUE:

```
      REAL*8              :: RS      ! Surface resistance for particles [s/m]
```

REVISION HISTORY:

```
(1 ) Updated comments.  Also now force double precision w/ "D" exponents.
     (bmy, 4/1/04)
(2 ) Renamed to DUST_SFCRSII, since this will only be used to compute
     aerodynamic resistance of dust aerosols.  (bec, bmy, 4/15/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
31 Jan 2014 - R. Yantosca - Now pass DIAM and DEN as arguments so as to
                            avoid parallelization errors when using
                            the TOMAS microphysics package.
```

1.52.15 init_drydep

Subroutine INIT_DRYDEP initializes certain variables for the GEOS-CHEM dry deposition subroutines. (bmy, 11/19/02, 10/19/09)

INTERFACE:

```
SUBROUTINE INIT_DRYDEP( am_I_Root, Input_Opt, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?!
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
(1 ) Added N2O5 as a drydep tracer, w/ the same drydep velocity as
     HNO3.  Now initialize PBLFRAC array. (rjp, bmy, 7/21/03)
(2 ) Added extra carbon & dust aerosol tracers (rjp, tdf, bmy, 4/1/04)
(3 ) Added seasalt aerosol tracers.  Now use A_RADI and A_DEN to store
     radius & density of size-resolved tracers.  Also added fancy
     output. (bec, rjp, bmy, 4/26/04)
(3 ) Now handles extra SOA tracers (rjp, bmy, 7/13/04)
(4 ) Now references LDRYD from "logical_mod.f" and N_TRACERS,
     SALA_REDGE_um, and SALC_REDGE_um from "tracer_mod.f" (bmy, 7/20/04)
(5 ) Included Hg2, HgP tracers (eck, bmy, 12/14/04)
(6 ) Included AS, AHS, LET, NH4aq, SO4aq tracers (cas, bmy, 1/6/05)
(7 ) Remove reference to PBLFRAC array -- it's obsolete (bmy, 2/22/05)
(8 ) Included SO4s, NITs tracers (bec, bmy, 4/13/05)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(10) Now set Henry's law constant to 1.0d+14 for Hg2.  Now use ID_Hg2,
     ID_HgP, and ID_Hg_tot from "tracerid_mod.f".  Bug fix: split up
     compound IF statements into separate 2 IF statements for ID_Hg2,
     ID_HgP to avoid seg faults. (eck, cdh, bmy, 4/17/06)
(11) Now also initialize SOG4, SOA4 drydep species.  Bug fix: Remove 2nd
     "IF ( IS_Hg ) THEN" statement. (dkh, bmy, 5/24/06)
(12) Bug fix: fix TYPO in IF block for IDTSOA4 (dkh, bmy, 6/23/06)
(13) Included H2/HD tracers for offline H2-HD sim (phs, 9/18/07)
(14) Add dicarbonyl chemistry species (tmf, ccc, 3/6/09)
```

```
(15) Minor bug fix: ALPH, LIMO should have molwt = 136.23, not 136 even
     (bmy, 10/19/09)
(16) Add TOMAS aerosol NK1-NK30 and H2SO4 to drydep list (win, 7/14/09)
15 Dec 2011 - M. Payer    - Update OVOC drydep according to Karl et al. 2010
                            and add drydep for MVK and MACR. (J. Mao)
21 Dec 2011 - M. Payer    - Add allocation for size distribution of sea salt
                            SALT_V and DMID (jaegle, 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
14 Mar 2013 - M. Payer    - Replace NOx and Ox with NO2 and O3 as part
                            of removal of NOx-Ox partitioning
12 Jun 2013 - R. Yantosca - Bug fix: now only copy NUMDEP values to
                            Input_Opt%NDVZIND and Input_Opt%DEPNAME
14 Jun 2013 - R. Yantosca - Now replace fields from tracer_mod.F
                            with fields from Input_Opt
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
29 Aug 2013 - R. Yantosca - Assign XMW=118d-3 to RIP and IEPOX.  This now
                            prevents XMW=0d0 from being passed to function
                            DIFFG, where it is in the denominator.
04 Sep 2013 - R. Yantosca - Improve printout of drydep species
```

1.52.16 cleanup_drydep

Subroutine CLEANUP_DRYDEP deallocates all module arrays. (bmy, 2/27/03, 2/22/05)

INTERFACE:

```
SUBROUTINE CLEANUP_DRYDEP
```

REVISION HISTORY:

```
(1 ) Remove reference to PBLFRAC array; it's obsolete (bmy, 2/22/05)
(2 ) Added SALT_V and DMID (jaegle, 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.53 Fortran: Module Interface dust_mod

Module DUST_MOD contains routines for computing dust aerosol emissions, chemistry, and optical depths.

INTERFACE:

```
MODULE DUST_MOD
```

USES:

```
      USE inquireMod, ONLY : findFreeLUN

      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CHEMDUST
#if   defined( TOMAS )
      PUBLIC  :: SETTLEDUST
#endif
      PUBLIC  :: EMISSDUST
      PUBLIC  :: RDUST_ONLINE
      PUBLIC  :: RDUST_OFFLINE
      PUBLIC  :: INIT_DUST
      PUBLIC  :: CLEANUP_DUST
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: DRY_SETTLING
      PRIVATE :: DRY_DEPOSITION
      PRIVATE :: SRC_DUST_DEAD
      PRIVATE :: SRC_DUST_GINOUX
```

REVISION HISTORY:

```
   30 Mar 2004 - T. D. Fairlie - Initial version
   (1 ) Bug fix in SRC_DUST_DEAD (bmy, 4/14/04)
   (2 ) Now references "logical_mod.f", "directory_mod.f", and "tracer_mod.f"
        Added comments. (bmy, 7/2/04)
   (3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (4 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
   (5 ) Bug fix in snow height computation (bmy, 11/18/05)
   (6 ) Now only do drydep if LDRYD=T (bmy, 5/23/06)
   (7 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
   (8 ) Updated output print statement in SRC_DUST_DEAD (bmy, 1/23/07)
   (9 ) Modifications for GEOS-5 (bmy, 1/24/07)
   (10) Modified to archive only hydrophilic aerosol/aqueous dust surface area
        (excluding BCPO and OCPO) for aqueous chemistry calculations
        Dust surfaces are considered aqueous only when RH > 35% (tmf, 3/6/09)
   (11) Add AOD output for all dust size bins (clh, 5/7/10)
   (12) Modify AOD output to wavelength specified in jv_spec_aod.dat
        (clh, 05/07/10)
   25 Aug 2010 - R. Yantosca - Added ProTeX headers
   03 Sep 2010 - R. Yantosca - Bug fix in SRC_DUST_DEAD
   08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x
   01 Mar 2012 - R. Yantosca - Now reference the new grid_mod.F90
   01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
   03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

```
14 Nov 2012 - R. Yantosca - Add modifications for GIGC
04 Mar 2013 - R. Yantosca - Now call INIT_DUST from the init stage
                            which facilitates connection to GEOS-5 GCM
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.53.1 chemdust

Subroutine CHEMDUST is the interface between the GEOS-Chem main program and the dust chemistry routines that mostly calculates dust dry deposition.

INTERFACE:

```
  SUBROUTINE CHEMDUST( am_I_Root, Input_Opt,
 &                     State_Met, State_Chm, RC )
```

USES:

```
  USE CMN_SIZE_MOD
  USE ERROR_MOD,          ONLY : DEBUG_MSG
  USE ERROR_MOD,          ONLY : ERROR_STOP
  USE GIGC_ErrCode_Mod
  USE GIGC_Input_Opt_Mod, ONLY : OptInput
  USE GIGC_State_Met_Mod, ONLY : MetState
  USE GIGC_State_Chm_Mod, ONLY : ChmState
  USE TRACERID_MOD,       ONLY : IDTDST1
  USE TRACERID_MOD,       ONLY : IDTDST2
  USE TRACERID_MOD,       ONLY : IDTDST3
  USE TRACERID_MOD,       ONLY : IDTDST4
```

INPUT PARAMETERS:

```
  LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
  TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
  TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
  TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
  INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
30 Mar 2004 - T. D. Fairlie - Initial version
(1 ) Now references STT from "tracer_mod.f" and LDUST from "logical_mod.f"
     (bmy, 7/20/04)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Now only do dry deposition if LDRYD = T (bmy, 5/23/06)
```

```
25 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Now pass State_Met as an argument
05 Mar 2013 - R. Yantosca - Add ND70 debug print output
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.53.2 settledust

Subroutine SETTLEDUST is the interface between the size-resolved dry deposition subroutine AERO_DRYDEP and the dust module. This is to call only gravitational settling and deals with removal of aerosol number with the dust mass. (win, 7/17/09)

INTERFACE:

```
  SUBROUTINE SETTLEDUST( am_I_Root, Input_Opt,
 &                       State_Met, State_Chm, RC )
```

USES:

```
  USE DIAG_MOD,           ONLY : AD44
  USE DRYDEP_MOD,         ONLY : NUMDEP, NTRAIND
  USE ERROR_MOD,          ONLY : ERROR_STOP
  USE GIGC_ErrCode_Mod
  USE GIGC_Input_Opt_Mod, ONLY : OptInput
  USE GIGC_State_Chm_Mod, ONLY : ChmState
  USE GIGC_State_Met_Mod, ONLY : MetState
  USE GRID_MOD,           ONLY : GET_AREA_CM2
  USE TIME_MOD,           ONLY : GET_TS_CHEM
  USE TOMAS_MOD,          ONLY : IBINS, Xk, SRTDUST
  USE TRACERID_MOD,       ONLY : IDTDUST1, IDTNK1

  USE CMN_SIZE_MOD             ! Size parameters
  USE CMN_DIAG_MOD             ! ND44
```

INPUT PARAMETERS:

```
  LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
  TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
  TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
  TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
  INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
  17 Jul 2009 - W. Trivitayanurak - Initial version
  01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
  13 Dec 2012 - M. Payer    - Add am_I_Root, Input_Opt, RC as arguments
  31 May 2013 - R. Yantosca - Now pass State_Chm via the arg list
------------------------------------------------------------------------------
BOC
```

LOCAL VARIABLES:

```
      ! SAVEd scalars
      LOGICAL, SAVE :: FIRST = .TRUE.

      ! Non-SAVEd scalars
      INTEGER       :: N, BIN, I, J, L, NN
      REAL*8        :: DUO(IIPAR,JJPAR,LLPAR,IBINS)
      REAL*8        :: DIF, FLUXN, FLUXD
      REAL*8        :: DT_SETTL, AREA_CM2

      !debug
      integer       :: ii, jj , ix, jx, bb
      data ii,jj, ix, jx, bb /37, 24, 58, 34, 30 /

      ! For values from Input_Opt
      INTEGER         :: N_TRACERS
      REAL*8          :: XNUMOL(Input_Opt%N_TRACERS)

      ! Pointers
      ! We need to define local arrays to hold corresponding values
      ! from the Chemistry State (State_Chm) object. (mpayer, 12/6/12)
      REAL*8, POINTER   :: STT(:,:,:,:)

      !=================================================================
      ! SETTLEDUST begins here!
      !=================================================================

      ! Assume success
      RC        = GIGC_SUCCESS

      ! Copy values from Input_Opt
      N_TRACERS = Input_Opt%N_TRACERS
      XNUMOL    = Input_Opt%XNUMOL(1:N_TRACERS)

      ! Initialize GEOS-Chem tracer array [kg] from Chemistry State object
      ! (mpayer, 12/6/12)
      STT       => State_Chm%Tracers

      !=================================================================
```

```
      ! Do dust settling & deposition
      !=================================================================

      ! Dust settling timestep [s]
      DT_SETTL = GET_TS_CHEM() * 60d0

      ! Save initial dust mass
      DO BIN = 1, IBINS
      DO L = 1, LLPAR
      DO J = 1, JJPAR
      DO I = 1, IIPAR
         DUO(I,J,L,BIN) = STT(I,J,L,IDTDUST1-1+BIN)
      ENDDO
      ENDDO
      ENDDO
      ENDDO

      ! Dust settling
      CALL DRY_SETTLING( am_I_Root,
     &                   Input_Opt,
     &                   State_Met,
     &                   STT(:,:,:,IDTDUST1:IDTDUST1-1+IBINS),
     &                   RC )

      ! Calculate change in number to correspond with dust redistribution
      ! by gravitational settling
      DO BIN = 1, IBINS
      NN = NUMDEP + (SRTDUST-1)*IBINS + BIN

      DO J = 1, JJPAR
         DO I = 1, IIPAR

            ! Surface area [cm2]
            AREA_CM2 = GET_AREA_CM2( I, J, 1 )

            FLUXD = 0d0
            FLUXN = 0d0
debug             if(i==ii .and. j==jj .and. bin==bb)
     &           print *,'L    DUO(',I,J,L,BIN,')   DIF    ',
     &            'FLUXD  AD44'
             if(i==ix .and. j==jx .and. bin==bb)
     &           print *,'L    DUO(',I,J,L,BIN,')   DIF    ',
     &            'FLUXD  AD44'
debug-----
            DO L = 1, LLPAR
               DIF = DUO(I,J,L,BIN) - STT(I,J,L,IDTDUST1-1+BIN)

               STT(I,J,L,IDTNK1-1+BIN) = STT(I,J,L,IDTNK1-1+BIN) -
```

```
     &                                DIF/(SQRT( Xk(BIN)*Xk(BIN+1)))

                ! Convert flux from [kg/s] to [molec/cm2/s]
                FLUXD = FLUXD +
     &               DIF / DT_SETTL * XNUMOL(IDTDUST1-1+BIN) / AREA_CM2
                FLUXN = FLUXN + DIF/(SQRT( Xk(BIN)*Xk(BIN+1))) /
     &                       DT_SETTL * XNUMOL(IDTNK1-1+BIN) / AREA_CM2

  debug               if(i==ii .and. j==jj .and. bin==bb) then
                     print *,L, DU0(I,J,L,BIN), DIF , FLUXD, AD44(I,J,NN,1)
                   endif
                   if(i==ix .and. j==jx .and. bin==bb) then
                     print *,L, DU0(I,J,L,BIN), DIF , FLUXD, AD44(I,J,NN,1)
                   endif
  debug-----
              ENDDO
           !=========================================================
           ! ND44: Dry deposition diagnostic [#/cm2/s]
           !=========================================================
              IF ( ND44 > 0 ) THEN
                 AD44(I,J,Input_Opt%IDDEP(BIN),1) =
     &           AD44(I,J,Input_Opt%IDDEP(BIN),1) + FLUXN
                 AD44(I,J,NN,1) = AD44(I,J,NN,1) + FLUXD
              ENDIF

           ENDDO
        ENDDO
        ENDDO

        ! Free pointer memory
        NULLIFY( STT )

        END SUBROUTINE SETTLEDUST
  EOC
 #endif
  !-----------------------------------------------------------------------------
                    GEOS-Chem Global Chemical Transport Model                  !
  !-----------------------------------------------------------------------------
%//////////////////////////////////////////////////////////

\mbox{}\hrulefill\


  \subsubsection [dry\_settling] {dry\_settling }


  Subroutine DRY\_SETTLING computes the dry settling of
    dust tracers.
```

```
  \\
  \\{\bf INTERFACE:}
\begin{verbatim}       SUBROUTINE DRY_SETTLING( am_I_Root, Input_Opt, State_Met, TC, RC )
```

USES:

```
      USE CMN_GCTM_MOD
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PRESSURE_MOD,       ONLY : GET_PCENTER
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TRACERID_MOD,       ONLY : IDTDST1
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)   :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)   :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)   :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,        INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NDSTBIN) ! Dust [kg]
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)  :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    30 Mar 2004 - T. D. Fairlie - Initial version
    (1 ) Updated comments, cosmetic changes (bmy, 3/30/04)
    (2 ) Remove reference to CMN, it's not needed (bmy, 7/20/04)
    (3 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
    25 Aug 2010 - R. Yantosca - Added ProTeX headers
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
    15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    19 Mar 2013 - R. Yantosca - Now copy Input_Opt%XNUMOL(1:N_TRACERS)
```

1.53.3 dry_deposition

Subroutine DRY_DEPOSITION computes the loss of dust due to dry deposition at the surface using an implicit method.

INTERFACE:

```
      SUBROUTINE DRY_DEPOSITION( am_I_Root, Input_Opt, TC, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TRACERID_MOD,       ONLY : IDTDST1
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,       INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NDSTBIN)  ! Dust [kg]
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    30 Mar 2004 - T. D. Fairlie - Initial version
    (1 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
    25 Aug 2010 - R. Yantosca - Added ProTeX headers
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
    19 Mar 2013 - R. Yantosca - Now copy Input_Opt%XNUMOL(1:N_TRACERS)
```

1.53.4 emissdust

Subroutine EMISSDUST is the driver routine for the dust emission module. You may call either the GINOUX or the DEAD dust source function.

INTERFACE:

```
      SUBROUTINE EMISSDUST( am_I_Root, Input_Opt,
     &                      State_Met, State_Chm, RC )
```

USES:

```
#if   defined( TOMAS )
      USE CMN_DIAG_MOD             ! ND59
#endif
```

```
      USE CMN_SIZE_MOD             ! Size parameters
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TRACERID_MOD,       ONLY : IDTDST1
      USE TRACERID_MOD,       ONLY : IDTDST2
      USE TRACERID_MOD,       ONLY : IDTDST3
      USE TRACERID_MOD,       ONLY : IDTDST4
      USE TIME_MOD,           ONLY : GET_TS_EMIS
#if   defined( TOMAS )
      USE TRACERID_MOD,       ONLY : IDTDUST1, IDTNK1      !(win, 7/17/09)
      USE TOMAS_MOD,          ONLY : IBINS, XK             !(win, 7/17/09)
      USE DIAG_MOD,           ONLY : AD59_DUST, AD59_NUMB  !(win, 7/17/09)
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   30 Mar 2004 - T. D. Fairlie - Initial version
   (1 ) Now reference LDEAD, LDUST, LPRT from "logical_mod.f".  Now reference!
        STT from "tracer_mod.f" (bmy, 7/20/04)
   (2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (3 ) Add if condition for selecting between emitting 4-bin or 30-bin
        dust.  Add emission diagnostic calculation for 30bin dust(win, 7/17/09)
   25 Aug 2010 - R. Yantosca - Added ProTeX headers
   26 Nov 2012 - R. Yantosca - Now pass am_I_Root, Input_Opt, State_Met as args
   26 Feb 2013 - R. Yantosca - Now pass Input_Opt to SRC_DUST_GINOUX
   26 Feb 2013 - R. Yantosca - Changed INPUT_OPT to INTENT(IN), since we are
                               now no longer calling INIT_DUST from here,
                               it is now called in the init stage
```

1.53.5 src_dust_dead

Subroutine SRC_DUST_DEAD is the DEAD model dust emission scheme, alternative to Ginoux scheme. Increments the TC array with emissions from the DEAD model.

INTERFACE:

```
SUBROUTINE SRC_DUST_DEAD( TC, State_Met )
```

USES:

```
USE DIAG_MOD,           ONLY : AD06
USE DIRECTORY_MOD,      ONLY : DATA_DIR
USE DUST_DEAD_MOD,      ONLY : GET_TIME_INVARIANT_DATA, GET_ORO
USE DUST_DEAD_MOD,      ONLY : GET_MONTHLY_DATA,        DST_MBL
USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_YMID_R
USE PRESSURE_MOD,       ONLY : GET_PEDGE,       GET_PCENTER
USE TIME_MOD,           ONLY : GET_TS_EMIS,     GET_MONTH
USE TIME_MOD,           ONLY : GET_DAY_OF_YEAR, ITS_A_NEW_MONTH
USE TRANSFER_MOD,       ONLY : TRANSFER_2D

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_DIAG_MOD             ! ND06
USE CMN_GCTM_MOD             ! g0
```

INPUT PARAMETERS:

```
! Meteorology State object
TYPE(MetState), INTENT(IN)    :: State_Met
```

INPUT/OUTPUT PARAMETERS:

```
! Dust mass [kg]
REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NDSTBIN)
```

REMARKS:

```
Input:
       SRCE_FUNK Source function                                  (-)
       for 1: Sand, 2: Silt, 3: Clay
       DUSTDEN   Dust density                                     (kg/m3)
       DUSTREFF  Effective radius                                 (um)
       AD        Air mass for each grid box                       (kg)
       NTDT      Time step                                        (s)
       W10M      Velocity at the anemometer level (10meters)      (m/s)
       GWET      Surface wetness                                  (-)

                                                                              .
Parameters used in GEOS-CHEM
                                                                              .
```

```
Longitude: IIPAR
Latitude : JJPAR
Levels   : LLPAR  =  20 (GEOS-1), 26 (GEOS-strat), 30 (GEOS-terra)
Size bins: NDSTBIN  =   4

Dust properties used in GOCART

Size classes: 01-1, 1-1.8, 1.8-3, 3-6 (um)
Radius: 0.7, 1.5, 2.5, 4  (um)
Density: 2500, 2650, 2650, 2650 (kg/m3)!
```

REVISION HISTORY:

```
08 Apr 2004 - T. D. Fairlie - Initial version
(1 ) Added OpenMP parallelization, added comments (bmy, 4/8/04)
(2 ) Bug fix: DSRC needs to be held PRIVATE (bmy, 4/14/04)
(3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Bug fix: It should be SNOW/1d3 not SNOW*1d3 (tdf, bmy, 11/18/05)
(6 ) Updated output statement (bmy, 1/23/07)
(7 ) Use SNOMAS (m H2O) for GEOS-5 (bmy, 1/24/07)
25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as for GEOS-5
25 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Sep 2010 - R. Yantosca - Bug fix, SNOMAS was mislabled in GEOS-5
                            and has units of mm H2O instead of m H2O
                            so we need to convert to m H2O.
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R(I,J,L) from grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.53.6 src_dust_ginoux

Paul GINOUX dust source function. This subroutine updates the surface mixing ratio of dust aerosols for NDSTBIN size bins. The uplifting of dust depends in space on the source function, and in time and space on the soil moisture and surface wind speed (10 meters). Dust is uplifted if the wind speed is greater than a threshold velocity which is calculated with the formula of Marticorena et al. (JGR, v.102, pp 23277-23287, 1997). To run this subroutine you need the source function which can be obtained by contacting Paul Ginoux at ginoux@rondo.gsfc.nasa.gov/ If you are not using GEOS DAS met fields, you will most likely need to adapt the adjusting parameter.

INTERFACE:

```
SUBROUTINE SRC_DUST_GINOUX( TC, State_Met, Input_Opt )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_RES_EXT
      USE DIAG_MOD,           ONLY : AD06
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE FILE_MOD,           ONLY : IOERROR
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_M2
      USE TIME_MOD,           ONLY : GET_TS_EMIS
      USE ERROR_MOD,          ONLY : ERROR_STOP
#if   defined ( TOMAS )
      USE TOMAS_MOD,          ONLY : IBINS, Xk
#endif

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! ND19, LD13 (for now)
      USE CMN_GCTM_MOD             ! g0
```

INPUT PARAMETERS:

```
      ! Meteorology State object
      TYPE(MetState), INTENT(IN)    :: State_Met
      TYPE(OptInput), INTENT(IN)    :: Input_Opt
```

INPUT/OUTPUT PARAMETERS:

```
      ! Dust mass [kg]
      REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NDSTBIN)
```

REMARKS:

```
    Input:
      SRCE_FUNK Source function                                (-)
                for 1: Sand, 2: Silt, 3: Clay

      DUSTDEN   Dust density                                   (kg/m3)
      DUSTREFF  Effective radius                               (um)
      AD        Air mass for each grid box                     (kg)
      NTDT      Time step                                      (s)
      W10m      Velocity at the anemometer level (10meters)    (m/s)
      GWET      Surface wetness                                (-)

    Parameters used in GEOS-CHEM

    Longitude: IIPAR
    Latitude : JJPAR
    Levels   : LLPAR  =  20 (GEOS-1), 26 (GEOS-strat), 30 (GEOS-terra)
    Size bins: NDSTBIN  =   4

    Dust properties used in GOCART
```

```
Size classes: 01-1, 1-1.8, 1.8-3, 3-6 (um)
Radius: 0.7, 1.5, 2.5, 4  (um)
Density: 2500, 2650, 2650, 2650 (kg/m3)
                                                                             .
References:
============================================================================
(1 ) Ginoux, P., M. Chin, I. Tegen, J. Prospero, B. Hoben, O. Dubovik,
      and S.-J. Lin, "Sources and distributions of dust aerosols simulated
      with the GOCART model", J. Geophys. Res., 2001
(2 ) Chin, M., P. Ginoux, S. Kinne, B. Holben, B. Duncan, R. Martin,
      J. Logan, A. Higurashi, and T. Nakajima, "Tropospheric aerosol
      optical thickness from the GOCART model and comparisons with
      satellite and sunphotometers measurements", J. Atmos Sci., 2001.
                                                                             .
Contact: Paul Ginoux (ginoux@rondo.gsfc.nasa.gov)
```

REVISION HISTORY:

```
08 Apr 2004 - T. D. Fairlie - Initial version
(1 ) Added OpenMP parallelization (bmy, 4/8/04)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
26 Feb 2013 - R. Yantosca - Now accept Input_Opt via the arg list
```

1.53.7 rdust_online

Subroutine RDUST_ONLINE reads global mineral dust concentrations as determined by P. Ginoux. Calculates dust optical depth at each level for the FAST-J routine "set_prof.f".

INTERFACE:

```
SUBROUTINE RDUST_ONLINE( DUST, WAVELENGTH, State_Met )
```

USES:

```
USE CMN_SIZE_MOD
USE CMN_DIAG_MOD
USE COMODE_MOD,         ONLY : ERADIUS, IXSAVE, IYSAVE
USE COMODE_MOD,         ONLY : IZSAVE,  JLOP,   TAREA
USE COMODE_MOD,         ONLY : WTAREA, WERADIUS
USE COMODE_LOOP_MOD
USE DIAG_MOD,           ONLY : AD21
```

```
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE JV_CMN_MOD
      USE TRANSFER_MOD,       ONLY : TRANSFER_3D
```

INPUT PARAMETERS:

```
      REAL*8,         INTENT(IN) :: DUST(IIPAR,JJPAR,LLPAR,NDUST) ! Dust [kg/m3]
      INTEGER,        INTENT(IN) :: WAVELENGTH
      TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
    01 Apr 2004 - R. Martin, R. Park - Initial version
    (1 ) Bundled into "dust_mod.f" (bmy, 4/1/04)
    (2 ) Now references DATA_DIR from "directory_mod.f".  Now parallelize over
         the L-dimension for ND21 diagnostics. (bmy, 7/20/04)
    (3 ) Archive only hydrophilic aerosol/aqueous dust surface area
         (excluding BCPO and OCPO), WTAREA and WERADIUS. (tmf, 3/6/09)
    25 Aug 2010 - R. Yantosca - Added ProTeX headers
    03 Feb 2011 - S. Kim.     - Include wavelength argument to determine the
                                wavelength at which the AOD should be computed.
                                This will set the optical properties that are
                                used for the calculation of the AOD. The ND21
                                diagnostic should only be updated when
                                WAVELENGTH = 1. (skim, 02/03/11)
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
```

1.53.8 rdust_offline

Subroutine RDUST_OFFLINE reads global mineral dust concentrations as determined by P. Ginoux. Calculates dust optical depth at each level for the FAST-J routine "set_prof.f".

INTERFACE:

```
      SUBROUTINE RDUST_OFFLINE( THISMONTH, THISYEAR, WAVELENGTH,
     &                          am_I_Root, State_Met )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_NAME_EXT, GET_RES_EXT
      USE BPCH2_MOD,          ONLY : GET_TAU0,     READ_BPCH2
      USE CMN_FJ_MOD,         ONLY : JPMAX, JPPJ
      USE COMODE_MOD,         ONLY : ERADIUS, IXSAVE, IYSAVE
      USE COMODE_MOD,         ONLY : IZSAVE,  JLOP,   TAREA
      USE COMODE_MOD,         ONLY : WTAREA, WERADIUS
```

```
      USE COMODE_LOOP_MOD
      USE CMN_DIAG_MOD
      USE DIAG_MOD,           ONLY : AD21
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE JV_CMN_MOD,         ONLY : ODMDUST, QAA, RAA, RAA_AOD, QAA_AOD
      USE TRANSFER_MOD,       ONLY : TRANSFER_3D

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN) :: THISMONTH   ! Current month (1-12)
      INTEGER,        INTENT(IN) :: THISYEAR    ! Current year  (YYYY format)
      INTEGER,        INTENT(IN) :: WAVELENGTH  ! Determine which wavelength to
                                                !  use for optical properties
      LOGICAL,        INTENT(IN) :: am_I_Root   ! Is this the root CPU?
      TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
(1 ) RDUST was patterned after rdaerosol.f (rvm, 9/30/00)
(2 ) Don't worry about rewinding the binary file...reading from
     binary files is pretty fast.  And it's only done once a month.
(3 ) Now references punch file utility routines from F90 module
     "bpch2_mod.f".  Also reference variable DATA_DIR from the
      header file "CMN_SETUP". (bmy, 9/30/00)
(4 ) Now selects proper GEOS-STRAT dust field for 1996 or 1997.
     Also need to pass THISYEAR thru the arg list. (rvm, bmy, 11/21/00)
(5 ) CONC is now declared as REAL*8 (rvm, bmy, 12/15/00)
(6 ) Removed obsolete code from 12/15/00 (bmy, 12/21/00)
(7 ) CONC(IIPAR,JJPAR,LGLOB,NDUST) is now CONC(IIPAR,JJPAR,LLPAR,NDUST).
     Now use routine TRANSFER_3D from "transfer_mod.f" to cast from REAL*4
     to REAL*8 and also to convert from {IJL}GLOB to IIPAR,JJPAR,LLPAR
     space.  Use 3 arguments in call to GET_TAU0.  Updated comments.
     (bmy, 9/26/01)
(8 ) Removed obsolete code from 9/01 (bmy, 10/24/01)
(9 ) Now reference ERADIUS, IXSAVE, IYSAVE, IZSAVE, TAREA from
     "comode_mod.f".  Compute ERADIUS and TAREA for the NDUST dust
     size bins from FAST-J.  Renamed CONC to DUST to avoid conflicts.
     Also reference NTTLOOP from "comode.h".  Also added parallel
     DO-loops.  Also renamed MONTH and YEAR to THISMONTH and THISYEAR
     to avoid conflicts w/ other variables. (bmy, 11/15/01)
(10) Bug fix: Make sure to use 1996 dust data for Dec 1995 for the
     GEOS-STRAT met field dataset.  Set off CASE statement with an
     #if defined( GEOS_STRAT ) block. (rvm, bmy, 1/2/02)
(11) Eliminate obsolete code from 1/02 (bmy, 2/27/02)
(12) Now report dust optical depths in ND21 diagnostic at 400 nm.  Now
```

```
      report dust optical depths as one combined diagnostic field instead
       of 7 separate fields.  Now reference JLOP from "comode_mod.f".
       Now save aerosol surface areas as tracer #5 of the ND21 diagnostic.
       (rvm, bmy, 2/28/02)
(13) Remove declaration for TIME, since that is also defined in the
      header file "comode.h" (bmy, 3/20/02)
(14) Now read mineral dust files directly from the DATA_DIR/dust_200203/
      subdirectory (bmy, 4/2/02)
(15) Now reference BXHEIGHT from "dao_mod.f".  Also reference ERROR_STOP
      from "error_mod.f". (bmy, 10/15/02)
(16) Now call READ_BPCH2 with QUIET=TRUE to suppress extra informational
      output from being printed.  Added cosmetic changes. (bmy, 3/14/03)
(17) Since December 1997 dust data does not exist, use November 1997 dust
      data as a proxy. (bnd, bmy, 6/30/03)
(18) Bundled into "dust_mod.f" and renamed to RDUST_OFFLINE. (bmy, 4/1/04)
(19) Now references DATA_DIR from "directory_mod.f".  Now parallelize over
      the L-dimension for ND21 diagnostic. (bmy, 7/20/04)
(20) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(21) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(22) Archive only hydrophilic aerosol/aqueous dust surface area
     (excluding BCPO and OCPO), WTAREA and WERADIUS. (tmf, 3/6/09)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Feb 2011 - S. Kim      - Include third input argument to determine the
                            wavelength at which the AOD should be computed.
                            This will set the optical properties that are
                            used for the calculation of the AOD.  The ND21
                            diagnostic should only be updated when
                            WAVELENGTH = 1.
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.53.9 init_dust

Subroutine INIT_DUST allocates all module arrays.

INTERFACE:

```
SUBROUTINE INIT_DUST( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE DRYDEP_MOD,         ONLY : NTRAIND
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
```

```
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
#if   defined( TOMAS )
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE TOMAS_MOD,          ONLY : IBINS, Xk
      USE TRACERID_MOD,       ONLY : IDTNK1
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input Options object
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   30 Mar 2004 - R. Yantosca - Initial version
   (1 ) Now references LDEAD from "logical_mod.f" (bmy, 7/20/04)
   (2 ) Modify to work with 30bin dust. Reference to IBINS from tomas_mod
        for number of total bi}n = 30 bins.  (win, 7/17/09)
   25 Aug 2010 - R. Yantosca - Added ProTeX headers
   14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
   26 Feb 2013 - M. Long     - Now use fields from Input_Opt
```

1.53.10 cleanup_dust

Subroutine CLEANUP_DUST deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_DUST
```

REVISION HISTORY:

```
   30 Mar 2004 - R. Yantosca - Initial version
   25 Aug 2010 - R. Yantosca - Added ProTeX headers
   26 Feb 2013 - R. Yantosca - Now use Input_Opt instead of local arrays
```

1.54 Fortran: Module Interface emep_mod

Overview

Module EMEP_MOD contains variables and routines to read the EMEP European anthropogenic emission inventory for CO, NOz, and some NMVOCs. The EMEP files come from Marion Auvray and Isabelle Bey at EPFL. (bdf, bmy, amv, phs, 11/1/05, 1/28/09)

References

1. Vestreng, V., and H. Klein (2002), *Emission data reported to UNECE/EMEP: Quality insurance and trend analysis and presentation of Web-Dab*, MSC-W Status Rep. 2002:, 101 pp., Norw. Meteorol. Inst., Oslo, Norway. This paper is on the EMEP web site:

   http://www.emep.int/mscw/mscw_publications.html
   http://www.emep.int/publ/reports/2002/mscw_note_1_2002.pdf

2. Auvray, M., and I. Bey, *Long-Range Transport to Europe: Seasonal Variations and Implications for the European Ozone Budget*, J. Geophys. Res., **110**, D11303, doi: 10.1029/2004JD005503, 2005.

INTERFACE:

```
MODULE EMEP_MOD
```

USES:

```
USE ERROR_MOD, ONLY: ALLOC_ERR

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: EMISS_EMEP
PUBLIC  :: EMISS_EMEP_05x0666
PUBLIC  :: CLEANUP_EMEP
PUBLIC  :: GET_EUROPE_MASK
PUBLIC  :: GET_EMEP_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: EMEP_SCALE_FUTURE
PRIVATE :: READ_EMEP_UPDATED
PRIVATE :: READ_EMEP_UPDATED_05x0666
PRIVATE :: READ_EUROPE_MASK
PRIVATE :: READ_EUROPE_MASK_05x0666
PRIVATE :: INIT_EMEP
```

REVISION HISTORY:

```
01 Nov 2005 - B. Field, R. Yantosca - Initial version
(1 ) Now only print totals for defined tracers (bmy, 2/6/06)
(2 ) Now modified for IPCC future emissions (swu, bmy, 5/30/06)
(3 ) Now yearly scale factors can be applied (phs, amv, 3/17/08)
(4 ) Now include emep SOx and emep emissions to 2005 (amv, 06/08)
(5 ) Modify to access SHIP emissions from outside (phs, 06/08)
```

```
(6 ) Account for monthly variations (amv, 12/9/08)
18 Dec 2009 - Aaron van D - Created routine EMISS_EMEP_05x0666
18 Dec 2009 - Aaron van D - Created routine READ_EMEP_UPDATED_05x0666
18 Dec 2009 - Aaron van D - Created routine READ_EUROPE_MASK_05x0666
11 Jan 2010 - Aaron van D - Max scale year is now 2007, for consistency
11 Jan 2010 - Aaron van D - Extend 1x1 emission files to 2007.  Routine
                            READ_EMEP_UPDATED now mimics routine
                            READ_EMEP_UPDATED_05x0666.
26 Jan 2010 - R. Yantosca - Minor bug fix in INIT_EMEP
31 Aug 2010 - R. Yantosca - Updated comments
24 Nov 2010 - G. Vinken   - Updated EMEP mask file
13 Mar 2012 - M. Cooper   - Changed gridding algorithm to map_a2a
22 Mar 2012 - M. Payer    - C2H6 emissions are too low. Use Yaping
                            Xiao's C2H6 emissions instead.
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.54.1 get_europe_mask

Function GET_EUROPE_MASK returns the value of the EUROPE mask for EMEP emissions at grid box (I,J). MASK=1 if (I,J) is in the European region, or MASK=0 otherwise.

INTERFACE:

```
FUNCTION GET_EUROPE_MASK( I, J ) RESULT( EUROPE )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I        ! Longitude index
INTEGER, INTENT(IN) :: J        ! Latitude  index
```

RETURN VALUE:

```
REAL*8              :: EUROPE   ! Returns the mask value @ (I,J)
```

REVISION HISTORY:

```
01 Nov 2005 - B. Field, R. Yantosca - Initial version
```

1.54.2 get_emep_anthro

Function GET_EMEP_ANTHRO returns the EMEP emission for GEOS-CHEM grid box (I,J) and tracer N.

INTERFACE:

```
FUNCTION GET_EMEP_ANTHRO( I, J, N, KG_S, SHIP ) RESULT( EMEP )
```

USES:

```
      USE TRACERID_MOD, ONLY : IDTNO,   IDTCO,   IDTALK4, IDTMEK
      USE TRACERID_MOD, ONLY : IDTALD2, IDTPRPE, IDTC2H6, IDTSO2
      USE TRACERID_MOD, ONLY : IDTNH3,  IDTNO2
      USE GRID_MOD,     ONLY : GET_AREA_CM2
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: I       ! Longitude index
      INTEGER, INTENT(IN)           :: J       ! Latitude index
      INTEGER, INTENT(IN)           :: N       ! Tracer number
      LOGICAL, INTENT(IN), OPTIONAL :: KG_S    ! Return emissions in [kg/s]
      LOGICAL, INTENT(IN), OPTIONAL :: SHIP    ! Return ship emissions
  RETURN VALUE:

      REAL*8                        :: EMEP    ! Returns emissions at (I,J)
```

REVISION HISTORY:

```
    01 Nov 2005 - B. Field, R. Yantosca - Initial version
    (1 ) added SOx, SOx ship and NH3 emissions, plus optional kg/s output
         (amv, 06/2008)
    (2 ) Now returns ship emissions if requested (phs, 6/08)
    (3 ) Added checks to avoid calling unavailable ship emissions (phs, 6/08)
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    22 Mar 2012 - M. Payer    - C2H6 emissions are too low. Use Yaping
                                Xiao's C2H6 emissions instead.
    14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                                of removal of NOx-Ox partitioning
```

1.54.3 emiss_emep

Subroutine EMISS_EMEP reads the EMEP emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
      SUBROUTINE EMISS_EMEP( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0, OPEN_BPCH2_FOR_READ
      USE CMN_O3_MOD
      USE CMN_SIZE_MOD
      USE FILE_MOD,           ONLY : IOERROR
      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
```

```
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE inquireMod,         ONLY : findFreeLUN
      USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
      USE TIME_MOD,           ONLY : EXPAND_DATE,  GET_YEAR
      USE TIME_MOD,           ONLY : GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR
#if defined( DEVEL )
      USE TRACERID_MOD,       ONLY : IDTNO2,  IDTCO,   IDTALK4, IDTMEK
      USE TRACERID_MOD,       ONLY : IDTALD2, IDTPRPE, IDTC2H6, IDTSO2
      USE TRACERID_MOD,       ONLY : IDTNH3,  IDTNO
      USE GRID_MOD,           ONLY : GET_AREA_CM2
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    01 Nov 2005 - B. Field, R. Yantosca - Initial version
    (1 ) Modified for IPCC future emissions.  Now references LFUTURE from
         "logical_mod.f". (bmy, 5/30/06)
    13 Mar 2012 - M. Cooper   - Changed gridding algorithm to map_a2a
    24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
    03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
    07 Aug 2012 - R. Yantosca - Now print LUN used to open file
    24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
    03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
    14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                                of removal of NOx-Ox partitioning
    25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.54.4 emiss_emep_05x0666

Subroutine EMISS_EMEP reads the EMEP emission fields at 05x0666 resolution and regrids them to the current model resolution.

INTERFACE:

```
      SUBROUTINE EMISS_EMEP_05x0666( am_I_Root, Input_Opt,
     &                               State_Chm, RC         )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,     READ_BPCH2
      USE CMN_O3_MOD
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TIME_MOD,           ONLY : EXPAND_DATE,  GET_YEAR
      USE TIME_MOD,           ONLY : GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_05x0666_NESTED
#if defined( DEVEL )
      USE TRACERID_MOD,       ONLY : IDTNO2,  IDTCO,   IDTALK4, IDTMEK
      USE TRACERID_MOD,       ONLY : IDTALD2, IDTPRPE, IDTC2H6, IDTSO2
      USE TRACERID_MOD,       ONLY : IDTNH3,  IDTNO
      USE GRID_MOD,           ONLY : GET_AREA_CM2
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   23 Oct 2006 - A. v. Donkelaar - Initial version, modified from EMISS_EMEP
   14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                               of removal of NOx-Ox partitioning
```

1.54.5 emep_scale_future

Subroutine EMEP_SCALE_FUTURE applies the IPCC future scale factors to the EMEP anthropogenic emissions.

INTERFACE:

```
      SUBROUTINE EMEP_SCALE_FUTURE
```

USES:

```
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_ALK4ff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_C2H6ff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_PRPEff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_TONEff
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_VOCff

      USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
    30 May 2006 - S. Wu & R. Yantosca - Initial version
```

1.54.6 total_anthro_Tg

Subroutine TOTAL_ANTHRO_TG prints the amount of EMEP anthropogenic emissions that are emitted each month in Tg or Tg C.

INTERFACE:

```
      SUBROUTINE TOTAL_ANTHRO_TG( EMEP_YEAR,  EMISS_YEAR,
     &                            EMEP_MONTH, Input_Opt )
```

USES:

```
      USE CMN_SIZE_MOD
      USE GRID_MOD,            ONLY : GET_AREA_CM2
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE TIME_MOD,            ONLY : ITS_A_LEAPYEAR
      USE TRACERID_MOD,        ONLY : IDTNO,   IDTCO,   IDTALK4, IDTMEK
      USE TRACERID_MOD,        ONLY : IDTALD2, IDTPRPE, IDTC2H6, IDTSO2
      USE TRACERID_MOD,        ONLY : IDTNH3
```

INPUT PARAMETERS:

```
      INTEGER,         INTENT(IN) :: EMEP_YEAR    ! EMEP base year
      INTEGER,         INTENT(IN) :: EMISS_YEAR   ! Current simulated year
      INTEGER,         INTENT(IN) :: EMEP_MONTH   ! Current simulated month
      TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
    10 Nov 2004 - R. Hudman, R. Yantosca - Initial version
    (1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (2 ) Now replace FMOL with TRACER_MW_KG (bmy, 10/25/05)
    (3 ) Now only print totals of defined tracers; other totals will be
         printed as zeroes. (bmy, 2/6/06)
    (4 ) Now emissions and base year are arguments. Output in Tg/month
         since this is called monthly (phs, 12/9/08)
```

```
(5 ) Bug fix, now print out correct monthly EMEP totals (bmy, 1/30/09)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
22 Mar 2012 - M. Payer    - Remove print for C2H6 emissions.
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
```

1.54.7 read_europe_mask

Subroutine READ_EUROPE_MASK reads and regrids the Europe mask for the EMEP anthropogenic emissions.

INTERFACE:

```
SUBROUTINE READ_EUROPE_MASK
```

USES:

```
USE BPCH2_MOD,      ONLY : READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE CMN_SIZE_MOD         ! Size parameters
```

REVISION HISTORY:

```
18 Oct 2006 - R. Yantosca - Initial version
(1 ) Now read the Europe mask from a disk file instead of defining it as
     a rectangular box (bmy, 10/18/06)
(2 ) Updated the mask file to correspond with the 200911 EMEP emissions
     (gvinken, 11/24/10)
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
15 Aug 2012 - M. Payer    - Fixed minor bugs in regridding of mask; Also set
                            mask to 1 if greater than 0 (L. Murray)
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.54.8 read_europe_mask_05x0666

Subroutine READ_EUROPE_MASK reads and regrids the Europe mask for the EMEP anthropogenic emissions.

INTERFACE:

```
SUBROUTINE READ_EUROPE_MASK_05x0666
```

USES:

```
      USE BPCH2_MOD,      ONLY : READ_BPCH2
      USE DIRECTORY_MOD,  ONLY : DATA_DIR

      USE CMN_SIZE_MOD       ! Size parameters
```

REVISION HISTORY:

```
    18 Oct 2006 - R. Yantosca - Initial version
    (1 ) Now read the Europe mask from a disk file instead of defining it as
         a rectangular box (bmy, 10/18/06)
```

1.54.9 read_emep_updated

Subroutine READ_EMEP_UPDATED reads updated EMEP emissions from the year 1990 including SOx emissions. These are regridded to the simulation resolution. Ship emissions can also be included.

INTERFACE:

```
      SUBROUTINE READ_EMEP_UPDATED( TRACER, EMEP_YEAR, ARRAY, wSHIP )
```

USES:

```
      USE BPCH2_MOD,      ONLY : READ_BPCH2, GET_TAU0
      USE TIME_MOD,       ONLY : EXPAND_DATE, GET_MONTH
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
      USE GRID_MOD,       ONLY : GET_AREA_CM2
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

      USE CMN_SIZE_MOD         ! Size parameters
      USE CMN_O3_MOD           ! SCALEYEAR
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: TRACER             ! Tracer number
      INTEGER, INTENT(IN)  :: EMEP_YEAR          ! Year of emissions to read
      INTEGER, INTENT(IN)  :: wSHIP              ! Use ground, ship, or both?
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: ARRAY(IIPAR,JJPAR)  ! Output array
```

REVISION HISTORY:

```
    28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial version
    28 Jan 2009 - P. Le Sager - Now account for LEMEPSHIP
    29 Oct 2009 - Added multi-species seasonality (amv)
    04 Jan 2010 - Extended to 2007, changed input format (amv)
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
    24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
    24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
    03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.54.10 read_emep_updated_05x0666

Subroutine READ_EMEP_UPDATED reads updated EMEP emissions from the year 1990 including SOx emissions. These are regridded to the simulation resolution. Ship emissions can also be included.

INTERFACE:

```
SUBROUTINE READ_EMEP_UPDATED_05x0666( TRACER, EMEP_YEAR, ARRAY,
&                   wSHIP )
```

USES:

```
USE BPCH2_MOD,      ONLY : READ_BPCH2, GET_TAU0
USE TIME_MOD,       ONLY : EXPAND_DATE, GET_MONTH
USE DIRECTORY_MOD,  ONLY : DATA_DIR
USE GRID_MOD,       ONLY : GET_AREA_CM2

USE CMN_SIZE_MOD
USE CMN_O3_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: TRACER              ! Tracer number
INTEGER, INTENT(IN)  :: EMEP_YEAR           ! Year of emissions to read
INTEGER, INTENT(IN)  :: wSHIP               ! Use ground, ship, or both?
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: ARRAY(IIPAR,JJPAR)  ! Output array
```

REVISION HISTORY:

```
28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial version
28 Jan 2009 - P. Le Sager - Now account for LEMEPSHIP
29 Oct 2009 - Added multi-species seasonality (amv)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.54.11 init_emep

Subroutine INIT_EMEP allocates and zeroes EMEP module arrays, and also creates the mask which defines the European region.

INTERFACE:

```
SUBROUTINE INIT_EMEP( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GRID_MOD,           ONLY : GET_XMID, GET_YMID
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    01 Nov 2005 - B. Field, R. Yantosca - Initial version
    (1 ) Now call READ_EUROPE_MASK to read & regrid EUROPE_MASK from disk
         instead of just defining it as a rectangular box. (bmy, 10/18/06)
    26 Jan 2010 - R. Yantosca - Fixed cut-n-paste error.  Now make sure to zero
                                EMEP_CO_SHIP and EMEP_NOx_SHIP.
    25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
    04 Apr 2013 - R. Yantosca - Now allocate a shadow variable of XNUMOL
```

1.54.12 cleanup_emep

Subroutine CLEANUP_EMEP deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_EMEP
```

REVISION HISTORY:

```
    1 Nov 2005 - R. Yantosca - Initial Version
```

1.55 Fortran: Module Interface emissions_mod

Module EMISSIONS_MOD is used to call the proper emissions subroutines for the various GEOS-Chem simulations.

INTERFACE:

```
      MODULE EMISSIONS_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: DO_EMISSIONS
   !PUBLIC MEMBER DATA:
      !FP_ISOP (6/2009)
      PUBLIC :: ISOP_SCALING,NOx_SCALING
```

REVISION HISTORY:

```
11 Feb 2003 - R. Yantosca - Initial version
(1 ) Now references DEBUG_MSG from "error_mod.f"
(2 ) Now references "Kr85_mod.f" (jsw, bmy, 8/20/03)
(3 ) Now references "carbon_mod.f" and "dust_mod.f" (rjp, tdf, bmy, 4/2/04)
(4 ) Now references "seasalt_mod.f" (rjp, bmy, bec, 4/20/04)
(5 ) Now references "logical_mod" & "tracer_mod.f" (bmy, 7/20/04)
(6 ) Now references "epa_nei_mod.f" and "time_mod.f" (bmy, 11/5/04)
(7 ) Now references "emissions_mod.f" (bmy, 12/7/04)
(8 ) Now calls EMISSSULFATE if LCRYST=T.  Also read EPA/NEI emissions for
     the offline aerosol simulation. (bmy, 1/11/05)
(9 ) Remove code for the obsolete CO-OH param simulation (bmy, 6/24/05)
(10) Now references "co2_mod.f" (pns, bmy, 7/25/05)
(11) Now references "emep_mod.f" (bdf, bmy, 10/1/05)
(12) Now references "gfed2_biomass_mod.f" (bmy, 3/30/06)
(13) Now references "bravo_mod.f" (rjp, kfb, bmy, 6/26/06)
(14) Now references "edgar_mod.f" (avd, bmy, 7/6/06)
(15) Now references "streets_anthro_mod.f" (yxw, bmy, 8/18/06)
(16) Now references "h2_hd_mod.f" (lyj, phs, 9/18/07)
(17) Now calls EMISSDR for tagged CO simulation (jaf, mak, bmy, 2/14/08)
(18) Now references "cac_anthro_mod.f" (amv, phs, 03/11/08)
(19) Now references "vistas_anthro_mod.f" (amv, 12/02/08)
(20) Bug fixe : add specific calls for Streets for the grid 0.5x0.666.
     (dan, ccc, 3/11/09)
18 Dec 2009 - Aaron van D - Added emissions for nested grids @ 0.5 x 0.666
26 Fev 2010 - Fabien P.   - Add scaling for isoprene and Nox emissions
01 Feb 2011 - C Friedman  - Added POP emissions
07 Feb 2011 - R. Yantosca - Now use EPA/NEI99 biofuel emissions when
                            EPA/NEI05 anthro emissions are selected.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.55.1 do_emissions

Subroutine DO_EMISSIONS is the driver routine which calls the appropriate emissions subroutine for the various GEOS-CHEM simulations.

INTERFACE:

```
      SUBROUTINE DO_EMISSIONS( am_I_Root, Input_Opt,
     &                         State_Met, State_Chm, RC )
```

USES:

```
      USE ARCTAS_SHIP_EMISS_MOD,  ONLY : EMISS_ARCTAS_SHIP
      USE BIOMASS_MOD,            ONLY : COMPUTE_BIOMASS_EMISSIONS
      USE BRAVO_MOD,              ONLY : EMISS_BRAVO
      USE C2H6_MOD,               ONLY : EMISSC2H6
```

```
      USE CAC_ANTHRO_MOD,         ONLY : EMISS_CAC_ANTHRO
      USE CAC_ANTHRO_MOD,         ONLY : EMISS_CAC_ANTHRO_05x0666
      USE CARBON_MOD,             ONLY : EMISSCARBON
      USE CH3I_MOD,               ONLY : EMISSCH3I
      USE CMN_O3_MOD
      USE CMN_SIZE_MOD
      USE CO2_MOD,                ONLY : EMISSCO2
      USE DUST_MOD,               ONLY : EMISSDUST
      USE EDGAR_MOD,              ONLY : EMISS_EDGAR
      USE EMEP_MOD,               ONLY : EMISS_EMEP
      USE EMEP_MOD,               ONLY : EMISS_EMEP_05x0666
      USE EPA_NEI_MOD,            ONLY : EMISS_EPA_NEI
      USE ERROR_MOD,              ONLY : DEBUG_MSG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod,     ONLY : OptInput
      USE GIGC_State_Chm_Mod,     ONLY : ChmState
      USE GIGC_State_Met_Mod,     ONLY : MetState
      USE GLOBAL_CH4_MOD,         ONLY : EMISSCH4
      USE H2_HD_MOD,              ONLY : EMISS_H2_HD
      USE HCN_CH3CN_MOD,          ONLY : EMISS_HCN_CH3CN
      USE ICOADS_SHIP_MOD,        ONLY : EMISS_ICOADS_SHIP
      USE MERCURY_MOD,            ONLY : EMISSMERCURY
      USE NEI2005_ANTHRO_MOD,     ONLY : EMISS_NEI2005_ANTHRO
      USE NEI2005_ANTHRO_MOD,     ONLY : EMISS_NEI2005_ANTHRO_05x0666
      USE PARANOX_MOD,            ONLY : READ_PARANOX_LUT
      USE POPS_MOD,               ONLY : EMISSPOPS  !(clf, 2/1/2011)
      USE RCP_MOD,                ONLY : LOAD_RCP_EMISSIONS !cdh
      USE RETRO_MOD,              ONLY : EMISS_RETRO
      USE RnPbBe_MOD,             ONLY : EMISSRnPbBe
      USE SEASALT_MOD,            ONLY : EMISSSEASALT
      USE SSA_BROMINE_MOD,        ONLY : EMIT_Br2
      USE STREETS_ANTHRO_MOD,     ONLY : EMISS_STREETS_ANTHRO
      USE STREETS_ANTHRO_MOD,     ONLY : EMISS_STREETS_ANTHRO_05x0666
      USE SULFATE_MOD,            ONLY : EMISSSULFATE
      USE TAGGED_CO_MOD,          ONLY : EMISS_TAGGED_CO
      USE TIME_MOD,               ONLY : GET_MONTH
      USE TIME_MOD,               ONLY : GET_YEAR
      USE TIME_MOD,               ONLY : ITS_A_NEW_MONTH
      USE TIME_MOD,               ONLY : ITS_A_NEW_YEAR
      USE TRACERID_MOD,           ONLY : IDTSO2, IDTC2H6
      USE VISTAS_ANTHRO_MOD,      ONLY : EMISS_VISTAS_ANTHRO

#if   defined( TOMAS )
      USE TRACERID_MOD,           ONLY : IDTSS1           ! (win, 1/25/10)
      USE TRACERID_MOD,           ONLY : IDTSF1           ! (win, 1/25/10)
      USE TRACERID_MOD,           ONLY : IDTECIL1         ! (win, 1/25/10)
      USE TRACERID_MOD,           ONLY : IDTOCIL1         ! (win, 1/25/10)
      USE TRACERID_MOD,           ONLY : IDTECOB1         ! (win, 1/25/10)
```

```
      USE TRACERID_MOD,           ONLY : IDTOCOB1         ! (win, 1/25/10)
      USE TRACERID_MOD,           ONLY : IDTDUST1         ! (win, 1/25/10)
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object!
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Now references DEBUG_MSG from "error_mod.f" (bmy, 8/7/03)
(2 ) Now calls Kr85 emissions if NSRCX == 12 (jsw, bmy, 8/20/03)
(3 ) Now calls EMISSCARBON and EMISSDUST for carbon aerosol and dust
     aerosol chemistry (rjp, tdf, bmy, 4/2/04)
(4 ) Now calls EMISSSEASALT for seasalt emissions (rjp, bec, bmy, 4/20/04)
(5 ) Now use inquiry functions from "tracer_mod.f".  Now references
     "logical_mod.f" (bmy, 7/20/04)
(6 ) Now references ITS_A_NEW_MONTH from "time_mod.f".  Now references
     EMISS_EPA_NEI from "epa_nei_mod.f" (bmy, 11/5/04)
(7 ) Now calls EMISSMERCURY from "mercury_mod.f" (eck, bmy, 12/7/04)
(8 ) Now calls EMISSSULFATE if LCRYST=T.  Also read EPA/NEI emissions for
     the offline sulfate simulation.  Also call EMISS_EPA_NEI for the
     tagged CO simulation. (cas, bmy, stu, 1/10/05).
(9 ) Now call EMISSSEASALT before EMISSSULFATE (bec, bmy, 4/13/05)
(10) Now call EMISS_HCN_CH3CN from "hcn_ch3cn_mod.f".   Also remove all
     references to the obsolete CO-OH param simulation. (xyp, bmy, 6/23/05)
(11) Now call EMISSCO2 from "co2_mod.f" (pns, bmy, 7/25/05)
(12) Now references EMISS_EMEP from "emep_mod.f" (bdf, bmy, 11/1/05)
(13) Now call GFED2_COMPUTE_BIOMASS to read 1x1 biomass emissions and
     regrid to the model resolution once per month. (bmy, 3/30/06)
(14) Now references EMISS_BRAVO from "bravo_mod.f" (rjp, kfb, bmy, 6/26/06)
(15) Now references EMISS_EDGAR from "edgar_mod.f" (avd, bmy, 7/6/06)
(16) Now references EMISS_STREETS_ANTHRO from "streets_anthro_mod.f"
     (yxw, bmy, 8/17/06)
(17) Now calls EMISSDR for tagged CO simulation (jaf, mak, bmy, 2/18/08)
(18) Now references EMISS_CAC_ANTHRO from "cac_anthro_mod.f"
     (amv, phs, 3/11/08)
(19) Now references EMISS_ARCTAS_SHIP from "arctas_ship_emiss_mod.f"
     (phs, 5/12/08)
(20) Now references EMISS_VISTAS_ANTHR from "vistas_anthro_mod.f". Call
     EMEP, and Streets every month (amv, 12/2/08)
```

```
(21) Now references EMISS_NEI2005_ANTHRO from "nei2005_anthro_mod.f"
     (amv, 10/19/09)
(22) Reference to TRACERID_MOd for IDTDUST1 for calling EMISSDUST (Win, 7/17/09)
18 Dec 2009 - Aaron van D - Added emissions for nested grids @ 0.5 x 0.666
08 Feb 2010 - NBIOMAX is now in CMN_SIZE
01 Feb 2011 - CFriedman   - Added emissions for POPs
07 Feb 2011 - R. Yantosca - Use NEI99 biofuels when useing NEI05 anthro
17 Aug 2011 - R. Yantosca - Added call to RETRO anthro emissions
07 Feb 2012 - M. Payer    - Added call to read PARANOX look up tables
22 Mar 2012 - M. Payer    - Added call to EMISSC2H6
19 Oct 2012 - R. Yantosca - Now reference gigc_state_chm_mod.F90
19 Oct 2012 - R. Yantosca - Now reference gigc_state_met_mod.F90
19 Oct 2012 - R. Yantosca - Rename CHEM_STATE argument to State_Chm
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Now pass all met fields via State_Met object
26 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
27 Mar 2013 - R. Yantosca - Now remove DEVEL tags; pass objects to routines
22 Jul 2013 - M. Sulprizio- Now copy LRCP, LRCPSHIP, LRCPAIR from Input_Opt
15 Oct 2013 - R. Yantosca - Remove calls to PARANOX for simulations other
                            than full-chemistry (they don't carry NO, O3)
```

1.56 Fortran: Module Interface fjx_acet_mod

Overview

This module contains functions used for the new acetone pressure dependency calculation in JRATET.f introduced in FAST-JX version 6.4 The temperature interpolation factors and the Xsect are different for both acetone photolysis reactions and interdependant. See use in JRATET.f

Reference

Blitz, M. A., D. E. Heard, M. J. Pilling, S. R. Arnold, M. P. Chipperfield 2004: *Pressure and temperature-dependent quantum yields for the photodissociation of acetone between 279 and 327.5 nm*, GRL, **31**, 9, L09104.

INTERFACE:

```
MODULE FJX_ACET_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: QQ2_F
PUBLIC :: QQ1_F
```

```
      PUBLIC :: TFACA_F
      PUBLIC :: TFAC0_F
      PUBLIC :: TFAC_F
```

AUTHOR:

```
  Original code from Michael Prather.
  Implemented into GEOS-Chem by Claire Carouge (ccarouge@seas.harvard.edu)
```

REVISION HISTORY:

```
   20 Apr 2009 - C. Carouge - Created the module from fastJX64.f code.
   20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.56.1 tfaca_f

Calculates temperature interpolation factors for acetone

INTERFACE:

```
      FUNCTION TFACA_F(TTT, IV)
  !USES
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
      ! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
      INTEGER :: IV

      ! Temperature in 1 grid box
      REAL*8  :: TTT
  !OUTPUT VALUE:
      ! Temperature interpolation factor
      REAL*8  :: TFACA_F
                                with the "D" double-precision exponent.
```

1.56.2 tfac0_f

Calculates temperature interpolation factors for acetone

INTERFACE:

```
      FUNCTION TFAC0_F(TTT, IV)
```

USES:

```
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
      ! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
      INTEGER :: IV

      ! Temperature in 1 grid box
      REAL*8  :: TTT
  !OUTPUT VALUE:
      ! Temperature interpolation factor
      REAL*8  :: TFAC0_F
```

1.56.3 tfac_f

Calculates temperature interpolation factors for acetone

INTERFACE:

```
      FUNCTION TFAC_F(TTT, IV)
```

USES:

```
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
      ! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
      INTEGER :: IV

      ! Temperature in 1 grid box
      REAL*8  :: TTT

  !OUTPUT VALUE:
      ! Temperature interpolation factor
      REAL*8  :: TFAC_F
```

1.56.4 qq2_f

This routine computes the cross-section for acetone.

INTERFACE:

```
      FUNCTION QQ2_F(TFAC0, IV, K, TTT)
```

USES:

```
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
      ! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
      INTEGER :: IV

      ! Wavelength
      INTEGER :: K

      ! Temperature in 1 grid box
      REAL*8  :: TTT

      ! Temperature interpolation factor from TFAC0_F function
      REAL*8  :: TFAC0
  !OUTPUT VALUE:
      ! Xsect (total abs) for Acetone
      REAL*8  :: QQ2_F
  !NOTES:
   (1 ) We use IV-3 and not IV because there is no QQQ values for O2, O3
        and O1-D. (ccc, 4/20/19)
```

1.56.5 qq1_f

This routine computes the cross-section for acetone.

INTERFACE:

```
      FUNCTION QQ1_F(TFAC, IV, K)
```

USES:

```
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD
```

INPUT PARAMETERS:

```
      ! Index of the specie in jv_spec.dat (should be between 4 and NJVAL)
      INTEGER :: IV

      ! Wavelength
      INTEGER :: K

      ! Temperature interpolation factor from TFAC_F function
      REAL*8  :: TFAC
  !OUTPUT VALUE:
      ! Xsect (total abs) for Acetone
      REAL*8  :: QQ1_F
  !NOTES:
   (1 ) We use IV-3 and not IV because there is no QQQ values for O2, O3
        and O1-D. (ccc, 4/20/19)
```

1.57 Fortran: Module Interface gamap_mod

Module GAMAP_MOD contains routines to create GAMAP "tracerinfo.dat" and "diaginfo.dat" files which are customized to each particular GEOS-Chem simulation.

INTERFACE:

```
MODULE GAMAP_MOD
```

USES:

```
USE CMN_SIZE_MOD                    ! Dimensions of arrays
USE CMN_DIAG_MOD                    ! Diagnostic parameters
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: DO_GAMAP
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: CREATE_DINFO
PRIVATE :: CREATE_TINFO
PRIVATE :: WRITE_TINFO
PRIVATE :: WRITE_SEPARATOR
PRIVATE :: INIT_DIAGINFO
PRIVATE :: INIT_TRACERINFO
PRIVATE :: INIT_GAMAP
PRIVATE :: CLEANUP_GAMAP
```

REMARKS:

```
For more information, please see the GAMAP Online Users' Manual:
 http://acmg.seas.harvard.edu/gamap/doc/index.html
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
(1 ) Minor bug fix for Rn/Pb/Be simulations (bmy, 5/11/05)
(2 ) Added ND09 diagnostic for HCN/CH3CN simulation. (bmy, 6/30/05)
(3 ) Added ND04 diagnostic for CO2 simulation (bmy, 7/25/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Add MBO to ND46 diagnostic (tmf, bmy, 10/20/05)
(6 ) Updated for tagged Hg simulation (cdh, bmy, 4/6/06)
(7 ) Updated for ND56 lightning flash diagnostics (ltm, bmy, 5/5/06)
(8 ) Updated for ND42 SOA concentration diagnostics (dkh, bmy, 5/22/06)
(9 ) Updated for ND36 CH3I simulation diagnostics (bmy, 7/25/06)
(10) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
```

```
(11) Add routines INIT_DIAGINFO, INIT_TRACERINFO for clarity.  Added new
     entries for biomass burning (ND28) and time in tropopshere (ND54)
     in INIT_DIAGINFO and INIT_TRACERINFO. (phs, bmy, 10/17/06)
(12) Now write GPROD & APROD info to diaginfo.dat, tracerinfo.dat files,
     for the SOA restart files (tmf, havala, bmy, 2/6/07)
(13) Added ND10 diagnostic for H2/HD simulation. (phs, 9/18/07)
(14) Change category name for ND31 diagnostic (bmy, 11/16/07)
(15) Add to tracerinfo.dat file for timeseries and Rn-Pb-Be (bmy, 2/22/08)
(16) Added ND52 diagnostic for gamma HO2 (jaegle 02/26/09)
(17) Add gamap info for dicarbonyl simulation (tmf, 3/10/09)
(18) Add C2H4 in ND46 (ccc, 3/10/09)
(19) Add EFLUX to ND67 (lin, ccc, 5/29/09)
(20) Minor bug fixes (bmy, phs, 10/9/09)
(20) Minor bug fixes (dkh, bmy, 11/19/09)
(21) Include second satellite overpass diagnostic.  Adjust AOD name to 550
     nm from 400 nm.  Add additional dust AOD bins.  Output values to
     hdf_mod. (amv, bmy, 12/1/09)
(22) Increase MAXTRACER from 120 to 325 (win, 6/25/09)
03 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Aug 2010 - R. Yantosca - Now move the #include "CMN_SIZE" and
                            #include "CMN_DIAG" to the top of module
13 Aug 2010 - R. Yantosca - Added modifications for MERRA
21 Sep 2010 - R. Yantosca - Removed duplicates in INIT_DIAGINFO
21 Oct 2010 - R. Yantosca - Bug fix in INIT_DIAGINFO
09 Dec 2010 - C. Carouge  - Modify MAXTRACER definition to account for
07 Feb 2012 - E. Corbitt  - Added diagnostic info for tagged Hg simulation.
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.57.1 do_gamap

Subroutine DO_GAMAP is the driver program for creating the customized GAMAP files "diaginfo.dat" and "tracerinfo.dat".

INTERFACE:

```
SUBROUTINE DO_GAMAP( am_I_Root, Input_Opt, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : SYSTEM_TIMESTAMP
USE TRACER_MOD,         ONLY : GET_SIM_NAME
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
03 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.57.2 create_dinfo

Subroutine CREATE_DINFO writes information about diagnostic categories to a customized "diaginfo.dat" file. (bmy, 5/3/05)

INTERFACE:

```
SUBROUTINE CREATE_DINFO
```

USES:

```
USE FILE_MOD, ONLY : IOERROR
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
03 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

1.57.3 create_tinfo

Subroutine CREATE_TINFO writes information about tracers to a customized tracer-info.dat" file.

INTERFACE:

```
SUBROUTINE CREATE_TINFO( am_I_Root, Input_Opt, RC )
```

USES:

```
USE FILE_MOD,    ONLY : IOERROR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,         INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,         INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
21 Apr 2005 - R. Yantosca - Initial version
(1 ) Now write out tracers in ug/m3 (dkh, bmy, 5/22/06)
(2 ) Now write out GPROD & APROD info (tmf, havala, bmy, 2/6/07)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
31 Oct 2012 - R. Yantosca - Now save out info about soil NOx restart file
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.57.4 write_tinfo

Subroutine WRITE_TINFO writes one line to the customized "tracerinfo.dat" file.

INTERFACE:

```
SUBROUTINE WRITE_TINFO( IU_FILE, NAME, FNAME,
&                       MWT, MOLC, SCALE, UNIT, N )
```

USES:

```
USE FILE_MOD, ONLY : IOERROR
```

INPUT PARAMETERS:

```
INTEGER,          INTENT(IN) :: IU_FILE ! Logical unit number
CHARACTER(LEN=*), INTENT(IN) :: NAME    ! GAMAP short tracer name
CHARACTER(LEN=*), INTENT(IN) :: FNAME   ! GAMAP long tracer name
REAL*4,           INTENT(IN) :: MWT     ! Molecular weight [kg/mole]
INTEGER,          INTENT(IN) :: MOLC    ! Moles C/mole tracer (for HC's)
INTEGER,          INTENT(IN) :: N       ! Tracer number
REAL*4,           INTENT(IN) :: SCALE   ! GAMAP scale factor
CHARACTER(LEN=*), INTENT(IN) :: UNIT    ! Unit string
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
03 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.57.5 write_separator

Subroutine WRITE_SEPARATOR writes a separator block to the customized "tracerinfo.dat" file.

INTERFACE:

```
SUBROUTINE WRITE_SEPARATOR( IU_FILE, DIAG )
```

USES:

```
USE FILE_MOD, ONLY : IOERROR
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: IU_FILE
INTEGER, INTENT(IN) :: DIAG   ! GEOS-Chem diagnostic number
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
06 Feb 2007 - R. Yantosca - Added new header for GPROD & APROD info
03 Aug 2010 - R. Yantosca - Added ProTeX headers
31 Oct 2012 - R. Yantosca - Add write statement for soil NOx restart file
```

1.57.6 init_diaginfo

Subroutine INIT_DIAGINFO initializes the CATEGORY, DESCRIPT, and OFFSET variables, which are used to define the "diaginfo.dat" file for GAMAP.

INTERFACE:

```
SUBROUTINE INIT_DIAGINFO
```

REVISION HISTORY:

```
17 Oct 1996 - R. Yantosca - Initial version
(1 ) Split this code off from INIT_GAMAP, for clarity.  Now declare biomass
     burning emissions w/ offset of 45000.  Now declare time in the
     troposphere diagnostic with offset of 46000. (phs, bmy, 10/17/06)
(2 ) Now add IJ-GPROD & IJ-APROD w/ offset of SPACING*6, for the SOA
     GPROD & APROD restart file. (tmf, havala, bmy, 2/6/07)
(3 ) Now declare H2-HD sources w/ offset of 48000. Now declare H2-HD
     production/loss w/ offset of 47000. (phs, 9/18/07)
(4 ) Change diagnostic category for ND31 diagnostic from "PS-PTOP"
     to "PEDGE-$" (bmy, 11/16/07)
(5 ) Add categories CH4-LOSS, CH4-EMISS and WET-FRAC (kjw, 8/18/09)
(6 ) Add potential temperature category. (fp, 2/26/10)
21 May 2010 - C. Carouge  - Add diagnostic for mercury simulation
```

```
    03 Aug 2010 - R. Yantosca - Added ProTeX headers
    21 Sep 2010 - R. Yantosca - Remove duplicate definitions of CV-FLX-$,
                                TURBMC-$, EW-FLX-$, NS-FLX-$, UP-FLX-$
    21 Oct 2010 - R. Yantosca - Bug fix: MC-FRC-$ should have an offset of
                                SPACING*3 since it has units of kg/s.
    31 Oct 2012 - R. Yantosca - Save soil NOx restart quantities as SPACING*60
    14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                                of removal of NOx-Ox partitioning
    13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                                semivolatile POA simulations (H. Pye)
    03 Sep 2013 - R. Yantosca - Restored PS-PTOP to avoid issues when using
                                diaginfo.dat, tracerinfo.dat w/ REGRIDH_RESTART
    30 Jan 2014 - R. Yantosca - Add ND60 TOMAS diagnostic catetories
```

1.57.7 init_tracerinfo

Subroutine INIT_TRACERINFO initializes the NAME, FNAME, MWT, MOLC, INDEX, MOLC, UNIT arrays which are used to define the "tracerinfo.dat" file.

INTERFACE:

```
      SUBROUTINE INIT_TRACERINFO( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE DIAG03_MOD,         ONLY : ND03, PD03, PD03_PL
      USE DIAG04_MOD,         ONLY : ND04
      USE DIAG41_MOD,         ONLY : ND41
      USE DIAG42_MOD,         ONLY : ND42
      USE DIAG48_MOD,         ONLY : DO_SAVE_DIAG48
      USE DIAG49_MOD,         ONLY : DO_SAVE_DIAG49
      USE DIAG50_MOD,         ONLY : DO_SAVE_DIAG50
      USE DIAG51_MOD,         ONLY : DO_SAVE_DIAG51
      USE DIAG51b_MOD,        ONLY : DO_SAVE_DIAG51b
      USE DIAG53_MOD,         ONLY : ND53, PD53
      USE DIAG56_MOD,         ONLY : ND56
      USE DIAG63_MOD,         ONLY:  DO_SAVE_DIAG63
      USE DIAG_PL_MOD,        ONLY : DO_SAVE_PL,  GET_NFAM
      USE DIAG_PL_MOD,        ONLY : GET_FAM_MWT, GET_FAM_NAME
      USE DRYDEP_MOD,         ONLY : DEPNAME,     NUMDEP,    NTRAIND
      USE GET_POPSINFO_MOD,   ONLY : GET_POP_XMW
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE TRACERID_MOD
      USE WETSCAV_MOD,        ONLY : GET_WETDEP_IDWETD
      USE WETSCAV_MOD,        ONLY : GET_WETDEP_NSOL
#if   defined( TOMAS )
      USE TOMAS_MOD,          ONLY : IBINS, ICOMP,   IDIAG  !(win, 7/14/09)
```

```
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    17 Oct 1996 - R. Yantosca & P. Le Sager - Initial version
    (1 ) Split this code off from INIT_GAMAP, for clarity.  Also now declare
         biomass burning emissions w/ offset of 45000.  Bug fix: write out
         26 tracers for ND48, ND49, ND50, ND51 timeseries.  Also define
         ND54 diagnostic with offset of 46000. (bmy, 10/17/06)
    (2 ) Modifications for H2/HD in ND10, ND44 diagnostics (phs, 9/18/07)
    (3 ) Now write out PBLDEPTH diagnostic information to "tracerinfo.dat" if
         any of ND41, ND48, ND49, ND50, ND51 are turned on.  Also set the
         unit to "kg/s" for the Rn-Pb-Be ND44 drydep diag. (cdh, bmy, 2/22/08)
    (4 ) Added C2H4 in ND46 (ccc, 2/2/09)
    (5 ) Add EFLUX to ND67 (lin, ccc, 5/29/08)
    (6 ) Bug fix in ND28: ALD2 should have 2 carbons, not 3.  Also bug fix
         in ND66 to print out the name of ZMMU correctly. (dbm, bmy, 10/9/09)
    (7 ) Previous bug fix was erroneous; now corrected (dkh, bmy, 11/19/09)
    (8 ) Include second satellite overpass diagnostic.  Adjust AOD name to 550
         nm from 400 nm.  Add additional dust AOD bins (amv, bmy, 12/18/09)
    (9 ) Add iniformation for ND61 (win, 7/9/09)
    (10) Manually add info for ND44 when TOMAS aerosols dry deposition because
         only numbers are real drydep species while the mass species just
         tag along but we need them to show up in diagnostic too.  Reference
         to TOMAS_MOD and use IDTNK1 from TRACERID_MOD (win, 7/14/09)
    20 Jul 2010 - C. Carouge  - Modifications to ND03 for mercury.
    03 Aug 2010 - R. Yantosca - Added ProTeX headers
    13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
    02 Sep 2010 - R. Yantosca - In ND28: Omit SOA tracers if LSOA = .FALSE.
    09-Dec-2010 - H. Amos     - Added RGM and PBM  tracers for the
                                mercury simulation
    09-Dec-2010 - H. Amos     - fix spacing and #s for PL-HG2-$ diagnostics
    12 Nov 2010 - R. Yantosca - Need to save out surface pressure line to
                                tracerinfo.dat for the timeseries diagnostics
    22 Mar 2011 - C. Friedman - Added POPs
    24 Jan 2012 - M. Payer    - Change scale factors for Rn-Pb-Be simulation so
                                units are in mBq/SCM
    08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
    19 Mar 2012 - M. Payer    - Remove ACETdl and ACETgr from ND11 diagnostic.
                                Acetone from dry leaf matter and grasses is now
```

```
                            included in the direct emissions (ACETbg).
                            (E. Fischer)
   14 Mar 2013 - M. Payer    - Replace NOx and Ox with NO and O3 as part of
                            removal of NOx-Ox partitioning. Removed code for
                            storing pure O3 as N_TRACERS+1.
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
   13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
   04 Sep 2013 - R. Yantosca - Fix ND44 tracer listing
   04 Sep 2013 - R. Yantosca - Now also reference everything in tracerid_mod.F
   04 Sep 2013 - R. Yantosca - Bug fix: # of ND46 tracers should be 20
   26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
   31 Jan 2014 - R. Yantosca - Now save out tracerinfo.dat properly for TOMAS
```

1.57.8 init_gamap

Subroutine INIT_GAMAP allocates and initializes all module variables.

INTERFACE:

```
SUBROUTINE INIT_GAMAP( am_I_Root, Input_Opt, RC )
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE TIME_MOD,    ONLY : EXPAND_DATE, GET_NHMSb, GET_NYMDb
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE HDF_MOD,     ONLY : INIT_HDF
USE HDF_MOD,     ONLY : HDFCATEGORY
USE HDF_MOD,     ONLY : HDFDESCRIPT
USE HDF_MOD,     ONLY : HDFNAME
USE HDF_MOD,     ONLY : HDFFNAME
USE HDF_MOD,     ONLY : HDFUNIT
USE HDF_MOD,     ONLY : HDFMOLC
USE HDF_MOD,     ONLY : HDFMWT
USE HDF_MOD,     ONLY : HDFSCALE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
22 Apr 2005 - R. Yantosca - Initial version
(1 ) Now add proper UNIT & SCALE for Rn/Pb/Be simulations (bmy, 5/11/05)
(2 ) Added HCN & CH3CN source & sink info for ND09 (bmy, 6/27/05)
(3 ) Bug fix: removed duplicate category names.  Updated for CO2-SRCE
     diagnostic.  Now references ND04 from "diag04_mod.f.
     (pns, bmy, 7/25/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now save MBO as tracer #5 for ND46 (tmf, bmy, 10/20/05)
(6 ) Now add categories CV-FLX-$, TURBMC-$, EW-FLX-$, NS-FLX-$, UP-FLX-$
     which had been inadvertently omitted.  Also add OCEAN-HG category.
     Rewrote do loop and case statement to add new diagnostics to ND03.
     Now make units of Hg tracers "pptv", not "ppbv".  Now remove
     restriction on printing out cloud mass flux in GEOS-4 for the ND66
     diagnostic.  Added new sea salt category. (cdh, eck, bmy, 4/6/06)
(7 ) Now references ND56 from "diag56_mod.f" (ltm, bmy, 5/5/06)
(8 ) Now references ND42 from "diag42_mod.f".  Also updated for extra SOA
     tracers in ND07 diagnostic. (dkh, bmy, 5/22/06)
(9 ) Updated ND36 for CH3I simulation (bmy, 7/25/06)
(10) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(11) Split into INIT_DIAGINFO, INIT_TRACERINFO for clarity (bmy, 9/28/06)
(12) Save output to HDF_MOD (amv, bmy, 12/18/09)
03 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.57.9 cleanup_gamap

Subroutine CLEANUP_GAMAP deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GAMAP
```

REVISION HISTORY:

```
25 Apr 2005 - R. Yantosca - Initial version
03 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.58 Fortran: Module Interface gcap_read_mod.f

Module GCAP_READ_MOD contains file unit numbers, as well as file I/O routines for GEOS-Chem. FILE_MOD keeps all of the I/O unit numbers in a single location for convenient access.

INTERFACE:

```
MODULE GCAP_READ_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: CHECK_TIME
PRIVATE :: READ_GCAP
PRIVATE :: GCAP_CHECK
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: GET_GCAP_FIELDS
PUBLIC :: OPEN_GCAP_FIELDS
PUBLIC :: UNZIP_GCAP_FIELDS
```

REVISION HISTORY:

```
(1 ) Adapted from the obsolete "phis_read_mod.f" (bmy, 2/1/06)
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
06 Aug 2012 - R. Yantosca - Now make IU_PH a local variable
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.58.1 unzip_gcap_fields

Subroutine UNZIP_GCAP_FIELDS invokes a FORTRAN system call to uncompress GCAP PHIS met field files and store the uncompressed data in a temporary directory, where GEOS-CHEM can read them. The original data files are not disturbed.

INTERFACE:

```
SUBROUTINE UNZIP_GCAP_FIELDS( Input_Opt, OPTION )
```

USES:

```
USE CMN_SIZE_MOD
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
TYPE(OptInput),    INTENT(IN) :: Input_Opt   ! Input Options object
CHARACTER(LEN=*),  INTENT(IN) :: OPTION      ! Unzipping option
```

REVISION HISTORY:

```
15 Jun 1998 - R. Yantosca - Initial version
(1 ) Adapted from UNZIP_MET_FIELDS of "dao_read_mod.f" (bmy, 6/16/03)
(2 ) Directory information YYYY/MM or YYYYMM is now contained w/in
     GEOS_1_DIR, GEOS_S_DIR, GEOS_3_DIR, GEOS_4_DIR (bmy, 12/11/03)
(3 ) Now reference "directory_mod.f" and "unix_cmds_mod.f". Now prevent
     EXPAND_DATE from overwriting directory paths with Y/M/D tokens in
     them (bmy, 7/20/04)
(4 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
06 Aug 2012 - R. Yantosca - Added ProTeX headers
11 Apr 2013 - R. Yantosca - Now pass fields via Input_Opt
```

1.58.2 open_gcap_fields

Subroutine OPEN_GCAP_FIELDS opens the PHIS and LWI met fields file.

INTERFACE:

```
SUBROUTINE OPEN_GCAP_FIELDS( Input_Opt )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ERROR_STOP
USE FILE_MOD,           ONLY : IOERROR, FILE_EXISTS
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
01 Feb 2006 - S. Wu        - Initial version
(1 ) Adapted from OPEN_MET_FIELDS of "dao_read_mod.f" (bmy, 6/13/03)
(2 ) Now opens either zipped or unzipped files (bmy, 12/11/03)
(3 ) Now skips past the GEOS-4 ident string (bmy, 12/12/04)
(4 ) Now references "directory_mod.f" instead of CMN_SETUP.  Also now
     references LUNZIP from "logical_mod.f".  Also now prevents EXPAND_DATE
     from overwriting Y/M/D tokens in directory paths. (bmy, 7/20/04)
(5 ) Now use FILE_EXISTS from "file_mod.f" to determine if file unit IU_PH
     refers to a valid file on disk (bmy, 3/23/05)
(6 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
06 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
06 Aug 2012 - R. Yantosca - Added ProTeX headers
```

1.58.3 get_gcap_fields

Subroutine GET_GCAP_FIELDS calls READ_GCAP to read GCAP fields from disk at the start of a GEOS-Chem run.

INTERFACE:

```
SUBROUTINE GET_GCAP_FIELDS( Input_Opt, State_Met )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
01 Feb 2006 - S. Wu       - Initial version
(1 ) Now also read LWI_GISS for GCAP met fields (swu, bmy, 5/25/05)
06 Aug 2012 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
```

1.58.4 check_time

Function CHECK_TIME checks to see if the timestamp of the GCAP field just read from disk matches the current time. If so, then it's time to return the GCAP field to the calling program. (bmy, 6/16/03)

INTERFACE:

```
FUNCTION CHECK_TIME( XYMD, XHMS, NYMD, NHMS ) RESULT( ITS_TIME )
```

USES:

```
USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: XYMD       ! Date stamp in file (YYYYMMDD)
INTEGER, INTENT(IN) :: XHMS       ! Time stamp in file (hhmmss)
INTEGER, INTENT(IN) :: NYMD       ! Current model date (YYYYMMDD)
INTEGER, INTENT(IN) :: NHMS       ! Current model time (hhmmss)
```

RETURN VALUE:

```
! Function value
LOGICAL             :: ITS_TIME   ! = T is time to return fields
```

REVISION HISTORY:

```
16 Jun 2003 - R. Yantosca - Initial version
06 Aug 2012 - R. Yantosca - Added ProTeX headers
```

1.58.5 read_gcap

Subroutine READ_GCAP reads the PHIS (surface geopotential heights) field from disk. PHIS is an I-6 field, but is time-independent. Thus READ_GCAP only needs to be called once at the beginning of the model run.

INTERFACE:

```
SUBROUTINE READ_GCAP( NYMD, NHMS, PHIS, LWI )
```

USES:

```
USE DIAG_MOD,     ONLY : AD67
USE FILE_MOD,     ONLY : IOERROR
USE TIME_MOD,     ONLY : TIMESTAMP_STRING
USE TRANSFER_MOD, ONLY : TRANSFER_2D

USE CMN_SIZE_MOD                                    ! Size parameters
USE CMN_DIAG_MOD                                    ! ND67
USE CMN_GCTM_MOD                                    ! g0
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)            :: NYMD              ! YYYYMMDD date
INTEGER, INTENT(IN)            :: NHMS              ! hhmmss time
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT)           :: PHIS(IIPAR,JJPAR)  ! PHIS [m2/s2]
REAL*8,  INTENT(OUT), OPTIONAL :: LWI(IIPAR,JJPAR)   ! LWI flags
```

REVISION HISTORY:

```
01 Feb 2006 - S. Wu       - Initial version
(1 ) Adapted from READ_PHIS from "dao_read_mod.f" (bmy, 6/16/03)
(2 ) Now use function TIMESTAMP_STRING from "time_mod.f" for formatted
     date/time output. (bmy, 10/28/03)
(3 ) Now also read LWI_GISS for GCAP met fields.  Added optional variable
     LWI to the arg list. (swu, bmy, 5/25/05)
06 Aug 2012 - R. Yantosca - Added ProTeX headers
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
```

1.58.6 gcap_check

Subroutine GCAP_CHECK prints an error message if not all of the GCAP met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE GCAP_CHECK( NFOUND, N_PHIS )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! # of fields read from disk
INTEGER, INTENT(IN) :: N_PHIS   ! # of of fields expected to be found
```

REMARKS:

REVISION HISTORY:

```
15 Jun 1998 - R. Yantosca - Initial version
(1 ) Adapted from DAO_CHECK from "dao_read_mod.f" (bmy, 6/16/03)
06 Aug 2012 - R. Yantosca - Added ProTeX headers
```

1.59 Fortran: Module Interface get_ndep_mod

Module GET_NDEP_MOD contains routines for computing the nitrogen dry and wet deposition. This quantity is needed by GEOS-Chem soil emissions "FERT_AW"

INTERFACE:

```
MODULE GET_NDEP_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: SOIL_DRYDEP
PUBLIC  :: SOIL_WETDEP
PUBLIC  :: GET_DEP_N
```

REVISION HISTORY:

```
23 Oct 2012 - M. Payer    - Added ProTeX headers
```

1.59.1 soil_drydep

Subroutine SOIL_DRY_DEP holds dry deposited species [molec/cm2/s]. This is called from dry_dep_mod.F.

INTERFACE:

```
SUBROUTINE SOIL_DRYDEP( I, J, L, NN, TDRYFX )
```

USES:

```
USE TRACERID_MOD, ONLY : IDTNH4,    IDTNIT, IDTNH4aq
USE TRACERID_MOD, ONLY : IDTHNO3,   IDTNH3, IDTNITs
USE TRACERID_MOD, ONLY : IDTNO2,     IDTPAN
USE COMMSOIL_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)   :: I          ! I
INTEGER, INTENT(IN)   :: J          ! J
INTEGER, INTENT(IN)   :: L          ! Level
INTEGER, INTENT(IN)   :: NN         ! Dry Dep Tracer #
REAL*8 , INTENT(IN)   :: TDRYFX     ! Dry dep flux [molec/cm2/s]
```

REVISION HISTORY:

```
23 Oct 2012 - M. Payer    - Added ProTeX headers
14 Mar 2013 - M. Payer    - Replace NOx with NO2 as part of removal of
                            NOx-Ox partitioning
```

1.59.2 soil_wetdep

Subroutine SOIL_WETDEP holds wet deposited species [molec/cm2/s]. This is called from wetscav_mod.F.

INTERFACE:

```
SUBROUTINE SOIL_WETDEP( I, J, L, NN, TWETFX )
```

USES:

```
USE TRACERID_MOD, ONLY : IDTNH4,    IDTNIT, IDTNH4aq
USE TRACERID_MOD, ONLY : IDTHNO3,   IDTNH3, IDTNITs
USE COMMSOIL_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)   :: I          ! I
INTEGER, INTENT(IN)   :: J          ! J
INTEGER, INTENT(IN)   :: L          ! Level
INTEGER, INTENT(IN)   :: NN         ! Wet Dep Tracer #
REAL*8 , INTENT(IN)   :: TWETFX     ! Wet dep flux [kg/s]
```

REVISION HISTORY:

```
23 Oct 2012 - M. Payer    - Added ProTeX headers
```

1.59.3 get_dep_N

Subroutine GET_DEP_N sums dry and wet deposition since prev. timestep and calculates contribution to fertilizer N source.

INTERFACE:

```
SUBROUTINE GET_DEP_N ( I, J, TS_EMIS, DEP_FERT )
```

USES:

```
USE COMMSOIL_MOD
```

INPUT PARAMETERS:

```
INTEGER,  INTENT(IN)  :: I
INTEGER,  INTENT(IN)  :: J
REAL*8 ,  INTENT(IN)  :: TS_EMIS     ! Emission timestep [min]
```

INPUT/OUTPUT PARAMETERS:

```
! Dep emitted as Fert [ng N/m2/s]
REAL*8 ,  INTENT(INOUT) :: DEP_FERT
```

REVISION HISTORY:

```
23 Oct 2012 - M. Payer    - Added ProTeX headers
```

1.59.4 source_dryN

Subroutine SOURCE_DRYN gets dry deposited Nitrogen since last emission time step, converts to ng N/m2/s.

INTERFACE:

```
FUNCTION SOURCE_DRYN( I, J  ) RESULT( DRYN )
```

USES:

```
USE COMMSOIL_MOD
USE CMN_DIAG_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: I
INTEGER, INTENT(IN)  :: J
```

RETURN VALUE:

```
REAL*8               :: DRYN         !Dry dep. N since prev timestep
```

REVISION HISTORY:

```
23 Oct 2012 - M. Payer    - Added ProTeX headers
```

1.59.5 source_wetN

Subroutine SOURCE_WETN gets wet deposited Nitrogen since last emission time step, converts to ng N/m2/s.

INTERFACE:

```
FUNCTION SOURCE_WETN( I, J  ) RESULT(WETN )
```

USES:

```
USE TIME_MOD,     ONLY : GET_TS_EMIS
USE TIME_MOD,     ONLY : GET_TS_DYN
USE GRID_MOD,     ONLY : GET_AREA_M2
USE COMMSOIL_MOD
USE CMN_DIAG_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: I
INTEGER, INTENT(IN)  :: J
```

RETURN VALUE:

```
REAL*8               :: WETN         !Dry dep. N since prev timestep
```

REVISION HISTORY:

```
23 Oct 2012 - M. Payer    - Added ProTeX headers
```

1.60 Fortran: Module Interface gigc_environment_mod

Module GIGC_ENVIRONMENT_MOD establishes the runtime environment for the Grid-Independent GEOS-Chem (aka "GIGC") model. It is designed to receive model parameter and geophysical environment information and allocate memory based upon it.

It provides routines to do the following:

- Allocate geo-spatial arrays
- Initialize met. field derived type.
- Initialize Chemistry, Metorology, Emissions, and Physics States

INTERFACE:

```
MODULE GIGC_Environment_Mod
  !USES

  IMPLICIT NONE
  PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: GIGC_Allocate_All
PUBLIC  :: GIGC_Init_All
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: Get_nSchm_nSchmBry
```

REMARKS:

```
For consistency, we should probably move the met state initialization
to the same module where the met state derived type is contained.
```

REVISION HISTORY:

```
26 Jan 2012 - M. Long     - Created module file
13 Aug 2012 - R. Yantosca - Added ProTeX headers
19 Oct 2012 - R. Yantosca - Removed routine INIT_LOCAL_MET, this is now
                            handled in Headers/gigc_state_met_mod.F90
22 Oct 2012 - R. Yantosca - Renamed to gigc_environment_mod.F90
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.60.1 gigc_allocate_all

Subroutine GIGC_ALLOCATE_ALL allocates all LAT/LON ALLOCATABLE arrays for global use by the GEOS-Chem either as a standalone program or module.

INTERFACE:

```
SUBROUTINE GIGC_Allocate_All( am_I_Root,       Input_Opt,       &
                              RC,              value_I_LO,      &
                              value_J_LO,      value_I_HI,      &
                              value_J_HI,      value_IM,        &
                              value_JM,        value_LM,        &
                              value_IM_WORLD,  value_JM_WORLD,  &
                              value_LM_WORLD )
```

USES:

```
 USE CMN_Mod,            ONLY : Init_CMN
 USE CMN_DIAG_Mod,       ONLY : Init_CMN_DIAG
 USE CMN_FJ_Mod,         ONLY : Init_CMN_FJ
 USE CMN_NOX_Mod,        ONLY : Init_CMN_NOX
 USE CMN_O3_Mod,         ONLY : Init_CMN_O3
 USE CMN_SIZE_Mod,       ONLY : Init_CMN_SIZE
 USE COMODE_LOOP_Mod,    ONLY : Init_COMODE_LOOP
 USE COMMSOIL_Mod,       ONLY : Init_COMMSOIL
 USE GIGC_ErrCode_Mod
 USE GIGC_Input_Opt_Mod
```

```
USE JV_CMN_Mod,         ONLY : Init_JV_CMN
USE VDIFF_PRE_Mod,      ONLY : Init_VDIFF_PRE

IMPLICIT NONE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root        ! Are we on the root CPU?
INTEGER,        OPTIONAL      :: value_I_LO       ! Min local lon index
INTEGER,        OPTIONAL      :: value_J_LO       ! Min local lat index
INTEGER,        OPTIONAL      :: value_I_HI       ! Max local lon index
INTEGER,        OPTIONAL      :: value_J_HI       ! Max local lat index
INTEGER,        OPTIONAL      :: value_IM         ! Local # of lons
INTEGER,        OPTIONAL      :: value_JM         ! Local # of lats
INTEGER,        OPTIONAL      :: value_LM         ! Local # of levels
INTEGER,        OPTIONAL      :: value_IM_WORLD   ! Global # of lons
INTEGER,        OPTIONAL      :: value_JM_WORLD   ! Global # of lats
INTEGER,        OPTIONAL      :: value_LM_WORLD   ! Global # of levels
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt        ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC               ! Success or failure?
```

REMARKS:

```
For error checking, return up to the main routine w/ an error code.
This can be improved upon later.
```

REVISION HISTORY:

```
26 Jan 2012 - M. Long     - Initial version
13 Aug 2012 - R. Yantosca - Added ProTeX headers
17 Oct 2012 - R. Yantosca - Add am_I_Root, RC as arguments
22 Oct 2012 - R. Yantosca - Renamed to GIGC_Allocate_All
30 Oct 2012 - R. Yantosca - Now pass am_I_Root, RC to SET_COMMSOIL_MOD
01 Nov 2012 - R. Yantosca - Now zero the fields of the Input Options object
16 Nov 2012 - R. Yantosca - Remove this routine from the #ifdef DEVEL block
27 Nov 2012 - R. Yantosca - Now pass Input_Opt to INIT_COMODE_LOOP
03 Dec 2012 - R. Yantosca - Now pass am_I_Root, RC to INIT_CMN_SIZE
03 Dec 2012 - R. Yantosca - Add optional arguments to accept dimension
                            size information from the ESMF interface
13 Dec 2012 - R. Yantosca - Remove reference to obsolete CMN_DEP_mod.F
```

1.60.2 gigc_init_all

Subroutine GIGC_INIT_ALL initializes the top-level data structures that are either passed to/from GC or between GC components (emis-¿transport-¿chem-¿etc)

INTERFACE:

```
SUBROUTINE GIGC_Init_All( am_I_Root, Input_Opt, State_Chm, State_Met, RC )
```

USES:

```
USE CMN_Size_Mod,       ONLY : IIPAR, JJPAR, LLPAR, NBIOMAX
USE Comode_Loop_Mod,    ONLY : IGAS
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod
USE GIGC_State_Chm_Mod
USE GIGC_State_Met_Mod
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REMARKS:

```
Need to add better error checking, currently we just return upon error.
```

REVISION HISTORY:

```
26 Jan 2012 - M. Long     - Initial version
13 Aug 2012 - R. Yantosca - Added ProTeX headers
16 Oct 2012 - R. Yantosca - Renamed LOCAL_MET argument to State_Met
16 Oct 2012 - R. Yantosca - Renamed GC_STATE  argument to State_Chm
16 Oct 2012 - R. Yantosca - Call Init_Chemistry_State (in gc_type2_mod.F90,
                            which was renamed from INIT_CHEMSTATE)
19 Oct 2012 - R. Yantosca - Now reference gigc_state_met_mod.F90
19 Oct 2012 - R. Yantosca - Now reference gigc_state_chm_mod.F90
19 Oct 2012 - R. Yantosca - Now reference gigc_errcode_mod.F90
19 Oct 2012 - R. Yantosca - Now reference IGAS in Headers/comode_loop_mod.F
22 Oct 2012 - R. Yantosca - Renamed to GIGC_Init_All
26 Oct 2012 - R. Yantosca - Now call Get_nSchm, nSchmBry to find out the
                            number of strat chem species and Bry species
01 Nov 2012 - R. Yantosca - Now use LSCHEM from logical_mod.F
09 Nov 2012 - R. Yantosca - Now pass Input Options object for GIGC
26 Feb 2013 - R. Yantosca - Now pass Input_Opt to Init_GIGC_State_Chm
```

1.60.3 get_nSchm_nSchmBry

Subroutine Get_nSchm_nSchmBry finds out the # of stratospheric chemistry tracers and bromine tracers so that we can allocate the various Schm_* fields in the Chemistry State object.

INTERFACE:

```
SUBROUTINE Get_nSchm_nSchmBry( am_I_Root, nSchm, nSchmBry, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_ErrCode_Mod
USE LOGICAL_MOD,       ONLY : LLINOZ
USE TRACER_MOD,        ONLY : N_TRACERS, TRACER_NAME
USE TIME_MOD,          ONLY : GET_TAU, GET_NYMD, GET_NHMS, GET_TS_CHEM
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Is this the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: nSchm       ! # of strat chem species
INTEGER, INTENT(OUT) :: nSchmBry    ! # of strat chem Bry species
INTEGER, INTENT(OUT) :: RC          ! Success or failure
```

REVISION HISTORY:

```
01 Feb 2011 - L. Murray   - Initial version
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
26 Oct 2012 - R. Yantosca - Now pass Chemistry State object for GIGC
```

1.61 Fortran: Module Interface gc_type_mod.f

Module GC_TYPE_MOD contains derived type definitions for GEOS-Chem. These definitions are used to create objects for:

- ID flags for chemical species
- ID flags for advected tracers
- Coefficients & other quantities that translate between chemical species and advected tracers
- ID flags for advected tracers that dry deposit
- Logical flags for selecting the various GEOS-Chem options
- GEOS-Chem columnized meteorological fields and related quantities

- Error traceback output

INTERFACE:

```
    MODULE GC_TYPE_MOD
USES:
    IMPLICIT NONE
    PUBLIC
```

PUBLIC TYPES:

```
    !-----------------------------------------------------------------
    ! ID flags for advected tracers
    ! NOTE: This is a holdover from the column code and is presently
    ! only used in convection_mod.F (bmy, 10/22/12)
    !-----------------------------------------------------------------
    TYPE :: ID_TRAC
       INTEGER          :: NOx,     Ox,      PAN,     CO,      ALK4
       INTEGER          :: ISOP,    HNO3,    H2O2,    ACET,    MEK
       INTEGER          :: ALD2,    RCHO,    MVK,     MACR,    PMN
       INTEGER          :: PPN,     R4N2,    PRPE,    C3H8,    CH2O
       INTEGER          :: C2H6,    N2O5,    HNO4,    MP,      DMS
       INTEGER          :: SO2,     SO4,     SO4s,    MSA,     NH3
       INTEGER          :: NH4,     NIT,     NITs,    BCPI,    BCPO
       INTEGER          :: OCPI,    OCPO,    ALPH,    LIMO,    ALCO
       INTEGER          :: SOG1,    SOG2,    SOG3,    SOG4,    SOA1
       INTEGER          :: SOA2,    SOA3,    SOA4,    DST1,    DST2
       INTEGER          :: DST3,    DST4,    SALA,    SALC
       INTEGER          :: Hg0,     Hg2,     HgP
    END TYPE ID_TRAC

    !-----------------------------------------------------------------
    ! Coefficients & arrays that link species & tracers
    !-----------------------------------------------------------------
    TYPE :: SPEC_2_TRAC
       REAL*8,  POINTER :: SPEC_COEF(:,:)
       INTEGER, POINTER :: SPEC_ID(:,:)
       INTEGER, POINTER :: SPEC_EMITTED(:)
       INTEGER, POINTER :: SPEC_PER_TRAC(:)
       REAL*8,  POINTER :: TRAC_COEF(:)
       REAL*8,  POINTER :: MOLWT_KG(:)
       REAL*8,  POINTER :: XNUMOL(:)
    END TYPE SPEC_2_TRAC

    !-----------------------------------------------------------------
    ! Logical flags that turn various options on/off
    !-----------------------------------------------------------------
    TYPE :: GC_OPTIONS
       LOGICAL          :: USE_ANTHRO
```

```
   LOGICAL          :: USE_ANTHRO_BRAVO
   LOGICAL          :: USE_ANTHRO_CAC
   LOGICAL          :: USE_ANTHRO_EDGAR
   LOGICAL          :: USE_ANTHRO_EPA
   LOGICAL          :: USE_ANTHRO_VISTAS
   LOGICAL          :: USE_ANTHRO_EMEP
   LOGICAL          :: USE_BIOGENIC
   LOGICAL          :: USE_BIOMASS
   LOGICAL          :: USE_BIOMASS_GFED2
   LOGICAL          :: USE_CARBON_AEROSOLS
   LOGICAL          :: USE_CHEMISTRY
   LOGICAL          :: USE_CONVECTION
   LOGICAL          :: USE_DEAD_DUST
   LOGICAL          :: USE_DEBUG_PRINT
   LOGICAL          :: USE_DRYDEP
   LOGICAL          :: USE_DUST_AEROSOLS
   LOGICAL          :: USE_EMISSIONS
   LOGICAL          :: USE_NOx_AIRCRAFT
   LOGICAL          :: USE_NOx_LIGHTNING
   LOGICAL          :: USE_NOx_SOIL
   LOGICAL          :: USE_PBL_MIXING
   LOGICAL          :: USE_SEC_ORG_AEROSOLS
   LOGICAL          :: USE_SHIP_ARCTAS
   LOGICAL          :: USE_SEASALT_AEROSOLS
   LOGICAL          :: USE_SULFATE_AEROSOLS
   LOGICAL          :: USE_WETDEP
   LOGICAL          :: USE_Hg
   LOGICAL          :: USE_Hg_DYNOCEAN
   LOGICAL          :: USE_DIAG14
   LOGICAL          :: USE_DIAG38
END TYPE GC_OPTIONS

!-----------------------------------------------------------------
! Time & date values
!-----------------------------------------------------------------
TYPE :: GC_TIME
   INTEGER          :: YEAR         ! Current year (YYYY)
   INTEGER          :: MONTH        ! Current month (1-12)
   INTEGER          :: DAY          ! Current day (1-31)
   INTEGER          :: DOY          ! Day of year (0-365/366)
   INTEGER          :: HOUR         ! Current hour (0-23)
   INTEGER          :: MINUTE       ! Current minute (0-59)
   LOGICAL          :: FIRST_TIME   ! Is it the first timestep?
   REAL*8           :: T_ELAPSED    ! Elapsed simulation time [min]
   REAL*8           :: TS_DYN       ! Dynamic timestep [min]
   REAL*8           :: TS_CHEM      ! Chemistry timestep [min]
END TYPE GC_TIME
```

```
!-----------------------------------------------------------------
! Geographic location
!-----------------------------------------------------------------
TYPE :: GC_GEOLOC
   REAL*8           :: LON          ! Longitude [degrees]
   REAL*8           :: LAT          ! Latitude  [degrees]
   REAL*8           :: LOCALTIME    ! Local solar time [hrs]
END TYPE GC_GEOLOC

!-----------------------------------------------------------------
! Dimension information
!-----------------------------------------------------------------
TYPE :: GC_DIMS
   INTEGER          :: L_COLUMN     ! # of boxes in the vertical column
   INTEGER          :: J_LAT        ! # of lat boxes
   INTEGER          :: I_LON        ! # of lon boxes
   INTEGER          :: N_AER        ! # of aerosol tracers
   INTEGER          :: N_DRYDEP     ! # of dry deposited tracers
   INTEGER          :: N_DUST       ! # of dust tracers
   INTEGER          :: N_JV         ! # of J-value reactions
   INTEGER          :: N_MEMBERS    ! Max # of species per family tracer
   INTEGER          :: N_RH         ! # of RH bins for photolysis
   INTEGER          :: N_REACTIONS  ! # of chemical reactons
   INTEGER          :: N_SOA_HC     ! # of SOA HC classes and products
   INTEGER          :: N_SOA_PROD   !   (dimensions of GPROD/APROD)
   INTEGER          :: N_SPECIES    ! # of chemical species
   INTEGER          :: N_TRACERS    ! # of advected tracers
   INTEGER          :: N_WETDEP     ! # of wet deposited tracers
END TYPE GC_DIMS

!-----------------------------------------------------------------
! Derived type to pass ID information to GEOS-Chem routines
!-----------------------------------------------------------------
TYPE :: GC_IDENT
   INTEGER            :: PET          ! # of the CPU we are on
   INTEGER            :: STDOUT_LUN   ! LUN for stdout redirect
   CHARACTER(LEN=255) :: STDOUT_FILE  ! Filename for stdout redirect
   INTEGER            :: LEV          ! Stack pointer
   CHARACTER(LEN=40)  :: I_AM(20)     ! Stack for routine names
   CHARACTER(LEN=999) :: ERRMSG       ! Error message to display
   LOGICAL            :: VERBOSE      ! Should we print out debug info?
END TYPE GC_IDENT
```

REVISION HISTORY:

```
24 Mar 2009 - R. Yantosca - Initial version
21 Apr 2009 - R. Yantosca - Renamed from "id_type_mod.f" to
                            "gc_type_mod.f"; added type GC_OPTIONS
05 Jun 2009 - R. Yantosca - added LISOPOH to ID_SPEC
```

```
                          - added MOLWT, XNUMOL to SPEC_2_TRAC
  08 Jul 2009 - R. Yantosca - Added USE_CONVECTION, USE_PBL_MIXING,
                              USE_WETDEP, USE_EMISSIONS flags to GC_OPTIONS
  24 Aug 2009 - R. Yantosca - Added GC_TIME type
  30 Oct 2008 - R. Yantosca - Added GC_GEOLOC type
  05 Nov 2009 - R. Yantosca - Added GC_MET_LOCAL type
  13 Apr 2010 - R. Yantosca - Added N_MEMBERS to GC_DIMS type
  16 Apr 2010 - R. Yantosca - Added all chemical species to ID_SPEC
  16 Apr 2010 - R. Yantosca - Added N_SPECIES, N_JV to GC_DIMS
  23 Apr 2010 - R. Yantosca - Added GC_IDENT object
  29 Apr 2010 - R. Yantosca - Added TO3, FRCLND to GC_MET_LOCAL object
  30 Apr 2010 - R. Yantosca - Change character lengths in GC_IDENT
  13 May 2010 - R. Yantosca - Updated comments
  17 May 2010 - R. Yantosca - Added L_COLUMN to DIMINFO
  02 Jun 2010 - R. Yantosca - Added VERBOSE to GC_IDENT
  02 Jun 2010 - R. Yantosca - Added TAUCLI, TAUCLW to GC_MET_LOCAL
  02 Jun 2010 - R. Yantosca - Added DQ*DTMST fields to GC_MET_LOCAL
  02 Jun 2010 - R. Yantosca - Moved type SCOX_1d here from schem_mod.F
  22 Oct 2012 - R. Yantosca - Comment out obsolete type definitions
  20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.62 Fortran: Module Interface geosfp_read_mod

Module GEOSFP_READ_MOD contains subroutines for reading the GEOS-FP data from disk (in netCDF format).

INTERFACE:

```
MODULE GeosFp_Read_Mod
```

USES:

```
  ! NcdfUtil modules for netCDF I/O
  USE m_netcdf_io_open                    ! netCDF open
  USE m_netcdf_io_get_dimlen              ! netCDF dimension queries
  USE m_netcdf_io_read                    ! netCDF data reads
  USE m_netcdf_io_close                   ! netCDF close

  ! GEOS-Chem modules
  USE CMN_SIZE_MOD                        ! Size parameters
  USE CMN_GCTM_MOD                        ! Physical constants
  USE CMN_DIAG_MOD                        ! Diagnostic arrays & counters
  USE DIAG_MOD,      ONLY : AD66          ! Array for ND66 diagnostic
  USE DIAG_MOD,      ONLY : AD67          ! Array for ND67 diagnostic
  USE ERROR_MOD,     ONLY : ERROR_STOP    ! Stop w/ error message
  USE TIME_MOD                            ! Date & time routines
  USE TRANSFER_MOD                        ! Routines for casting
```

```
  IMPLICIT NONE
  PRIVATE

# include "netcdf.inc"                    ! Include file for netCDF library
```

PRIVATE MEMBER FUNCTIONS:

```
  PRIVATE :: Check_Dimensions
  PRIVATE :: GeosFp_Read_A3cld
  PRIVATE :: GeosFp_Read_A3dyn
  PRIVATE :: GeosFp_Read_A3mstC
  PRIVATE :: GeosFp_Read_A3mstE
  PRIVATE :: Get_Resolution_String
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC  :: GeosFp_Read_CN
  PUBLIC  :: GeosFp_Read_A1
  PUBLIC  :: GeosFp_Read_A3
  PUBLIC  :: GeosFp_Read_I3_1
  PUBLIC  :: GeosFp_Read_I3_2
```

REMARKS:

```
  Assumes that you have a netCDF library (either v3 or v4) installed on
  your system.
```

REVISION HISTORY:

```
  30 Jan 2012 - R. Yantosca - Initial version
  03 Feb 2012 - R. Yantosca - Add Geos57_Read_A3 wrapper function
  07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
  10 Feb 2012 - R. Yantosca - Add function Get_Resolution_String
  05 Apr 2012 - R. Yantosca - Convert units for specific humidity properly
  15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
  11 Apr 2013 - R. Yantosca - Now pass directory fields via Input_Opt
  26 Sep 2013 - R. Yantosca - Renamed to geosfp_read_mod.F90
  14 Jan 2014 - R. Yantosca - Remove "define GEOS572_FILES #ifdef blocks
```

1.62.1 get_resolution_string

Function Get_Resolution_String returns the proper filename extension for the GEOS-Chem horizontal grid resolution. This is used to construct the various file names.

INTERFACE:

```
  FUNCTION Get_Resolution_String() RESULT( resString )
```

RETURN VALUE:

```
   CHARACTER(LEN=255) :: resString
```

REVISION HISTORY:

```
10 Feb 2012 - R. Yantosca - Initial version
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Remove SEAC4RS C-preprocssor switch
14 Jan 2014 - R. Yantosca - Now add NESTED_SE option
```

1.62.2 check_dimensions

Subroutine CHECK_DIMENSIONS checks to see if dimensions read from the netCDF file match the defined GEOS-Chem dimensions. If not, then it will stop the GEOS-Chem simulation with an error message.

INTERFACE:

```
SUBROUTINE Check_Dimensions( lon, lat, lev, time, time_expected, caller )
```

INPUT PARAMETERS:

```
 INTEGER,          OPTIONAL, INTENT(IN)  :: lon            ! Lon dimension
 INTEGER,          OPTIONAL, INTENT(IN)  :: lat            ! Lat dimension
 INTEGER,          OPTIONAL, INTENT(IN)  :: lev            ! Alt dimension
 INTEGER,          OPTIONAL, INTENT(IN)  :: time           ! Time dimension
 INTEGER,          OPTIONAL, INTENT(IN)  :: time_expected  ! Expected # of
                                                           !  time slots
 CHARACTER(LEN=*), OPTIONAL, INTENT(IN)  :: caller         ! Name of caller
                                                           !  routine
```

REMARKS:

```
Call this routine with keyword arguments, e.g
   CALL CHECK_DIMENSION( lon=X,  lat=Y,           lev=Z,         &
                         time=T, time_expected=8, caller=caller )
```

REVISION HISTORY:

```
02 Feb 2012 - R. Yantosca - Initial version
03 Feb 2012 - R. Yantosca - Now pass the caller routine name as an argument
```

1.62.3 geosfp_read_cn

Routine to read variables and attributes from a GEOS-FP met fields file containing constant (CN) data.

INTERFACE:

```
SUBROUTINE GeosFp_Read_CN( Input_Opt, State_Met )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

                                                                             .
Even though the netCDF file is self-describing, the GEOS-FP data,
dimensions, and units are pre-specified according to the GMAO GEOS-FP
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
26 Sep 2013 - R. Yantosca - Renamed to GeosFp_Read_CN
```

1.62.4 geosfp_read_a1

Routine to read variables and attributes from a GEOS-FP met fields file containing 1-hr time-averaged (A1) data.

INTERFACE:

```
SUBROUTINE GeosFp_Read_A1( YYYYMMDD, HHMMSS, Input_Opt, State_Met )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: YYYYMMDD   ! GMT date in YYYY/MM/DD format
INTEGER,        INTENT(IN)    :: HHMMSS     ! GMT time in hh:mm:ss   format
TYPE(OptInput), INTENT(IN)    :: Input_Opt  ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

.

Even though the netCDF file is self-describing, the GEOS-FP data,
dimensions, and units are pre-specified according to the GMAO GEOS-FP
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.

.

Special handling for surface precipitation fields:
------------------------------------------------------------------------
In GEOS-FP (and in MERRA), the PRECTOT etc. surface precipitation
met fields fields have units of [kg/m2/s].  In all other GEOS
versions, PREACC and PRECON have units of [mm/day].

.

Therefore, for backwards compatibility with existing code, apply
the following unit conversion to the GEOS-5 PRECTOT and PRECCON
fields:

.

    kg  |    m3    | 86400 s | 1000 mm
  ------+----------+---------+--------- = 86400
   m2 s |  1000 kg |  day    |   m
             ^
             |
      1 / density of water
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
04 Jan 2013 - M. Payer    - Bug fix: Use State_Met%TSKIN for ND67 surface
                            skin temperature diagnostic, not State_MET%TS
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
02 Dec 2013 - S. Philip   - Correction for GEOS-FP boundary layer height
04 Dec 2013 - R. Yantosca - Now comment out GEOS-FP BL height correction
```

1.62.5 geosfp_read_a3

Convenience wrapper for the following routines which read 3-hour time averaged data from disk:

- GeosFp_Read_A3cld
- GeosFp_Read_A3dyn
- GeosFp_Read_A3mstC
- GeosFp_Read_A3mstE

INTERFACE:

```
SUBROUTINE GeosFp_Read_A3( YYYYMMDD, HHMMSS, Input_Opt, State_Met )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: YYYYMMDD   ! GMT date in YYYY/MM/DD format
INTEGER,        INTENT(IN)    :: HHMMSS     ! GMT time in hh:mm:ss   format
TYPE(OptInput), INTENT(IN)    :: Input_Opt  ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
26 Sep 2013 - R. Yantosca - Renamed to GeosFp_Read_A3
```

1.62.6 geosfp_read_a3cld

Routine to read variables and attributes from a GEOS-FP met fields file containing 3-hr time-averaged (A3) data (cloud fields).

INTERFACE:

```
SUBROUTINE GeosFp_Read_A3cld( YYYYMMDD, HHMMSS, Input_Opt, State_Met )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: YYYYMMDD   ! GMT date in YYYY/MM/DD format
INTEGER,        INTENT(IN)    :: HHMMSS     ! GMT time in hh:mm:ss   format
TYPE(OptInput), INTENT(IN)    :: Input_Opt  ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

.

Even though the netCDF file is self-describing, the GEOS-FP data,
dimensions, and units are pre-specified according to the GMAO GEOS-FP
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
05 Apr 2012 - R. Yantosca - Fixed bug: TAUCLI was overwritten w/ TAUCLW
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
26 Sep 2013 - R. Yantosca - Renamed to GeosFp_Read_A3Cld
```

1.62.7 geosfp_read_a3dyn

Routine to read variables and attributes from a GEOS-FP met fields file containing 3-hr time-averaged (A3) data (dynamics fields).

INTERFACE:

```
SUBROUTINE GeosFp_Read_A3dyn( YYYYMMDD, HHMMSS, Input_Opt, State_Met )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: YYYYMMDD   ! GMT date in YYYY/MM/DD format
INTEGER,        INTENT(IN)    :: HHMMSS     ! GMT time in hh:mm:ss   format
TYPE(OptInput), INTENT(IN)    :: Input_Opt  ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

.

Even though the netCDF file is self-describing, the GEOS-FP data,
dimensions, and units are pre-specified according to the GMAO GEOS-FP
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
11 Apr 2013 - R. Yantosca - Now pass directories with Input_Opt
26 Sep 2013 - R. Yantosca - Renamed to GeosFp_Read_A3dyn
15 Nov 2013 - R. Yantosca - Now convert RH from [1] to [%], in order
                            to be consistent with GEOS-Chem convention
```

1.62.8 geosfp_read_a3mstc

Routine to read variables and attributes from a GEOS-FP met fields file containing 3-hr time-averaged (A3) data (moist fields, saved on level centers).

INTERFACE:

```
SUBROUTINE GeosFp_Read_A3mstC( YYYYMMDD, HHMMSS, Input_Opt, State_Met )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: YYYYMMDD   ! GMT date in YYYY/MM/DD format
INTEGER,        INTENT(IN)    :: HHMMSS     ! GMT time in hh:mm:ss   format
TYPE(OptInput), INTENT(IN)    :: Input_Opt  ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

.

Even though the netCDF file is self-describing, the GEOS-FP data,
dimensions, and units are pre-specified according to the GMAO GEOS-FP
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
26 Sep 2013 - R. Yantosca - Renamed to GeosFp_Read_A3mstC
```

1.62.9 geosfp_read_a3mste

Routine to read variables and attributes from a GEOS-FP met fields file containing 3-hr time-averaged (A3) data (moist fields, saved on level edges).

INTERFACE:

```
SUBROUTINE GeosFp_read_A3mstE( YYYYMMDD, HHMMSS, Input_Opt, State_Met )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: YYYYMMDD   ! GMT date in YYYY/MM/DD format
INTEGER,        INTENT(IN)    :: HHMMSS     ! GMT time in hh:mm:ss   format
TYPE(OptInput), INTENT(IN)    :: Input_Opt  ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

                                                                             .
Even though the netCDF file is self-describing, the GEOS-FP data,
dimensions, and units are pre-specified according to the GMAO GEOS-FP
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
```

```
                              object
    15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
    11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
    26 Sep 2013 - R. Yantosca - Renamed to GeosFp_Read_A3mstE
    26 Sep 2013 - R. Yantosca - Now read CMFMC from GEOSFP*.nc files
```

1.62.10 geosfp_read_I3_1

Routine to read variables and attributes from a GEOS-FP met fields file containing 3-hr instantaneous (I3) data.

INTERFACE:

```
SUBROUTINE GeosFp_Read_I3_1( YYYYMMDD, HHMMSS, Input_Opt, State_Met )
```

USES:

```
USE DAO_MOD,            ONLY : T_FULLGRID
USE DAO_MOD,            ONLY : T_FULLGRID_1
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: YYYYMMDD   ! GMT date in YYYY/MM/DD format
INTEGER,        INTENT(IN)    :: HHMMSS     ! GMT time in hh:mm:ss   format
TYPE(OptInput), INTENT(IN)    :: Input_Opt  ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

                                                                       .
Even though the netCDF file is self-describing, the GEOS-FP data,
dimensions, and units are pre-specified according to the GMAO GEOS-FP
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
05 Apr 2012 - R. Yantosca - Now convert QV1 from [kg/kg] to [g/kg]
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
```

```
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
06 Sep 2013 - R. Yantosca - Bug fix: we need to initialize State_Met%T
                            with State_Met%TMPU1 to avoid errors.  The
                            State_Met%T field will be set again in INTERP.
26 Sep 2013 - R. Yantosca - Renamed to GeosFp_Read_I3_1
29 Oct 2013 - R. Yantosca - Now read T_FULLGRID_1 for offline simulations
```

1.62.11 geosfp_read_I3_2

Routine to read variables and attributes from a GEOS-FP met fields file containing 3-hr instantaneous (I3) data.

INTERFACE:

```
SUBROUTINE GeosFp_Read_I3_2( YYYYMMDD, HHMMSS, Input_Opt, State_Met )
```

USES:

```
USE DAO_MOD,            ONLY : T_FULLGRID_2
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: YYYYMMDD   ! GMT date in YYYY/MM/DD format
INTEGER,        INTENT(IN)    :: HHMMSS     ! GMT time in hh:mm:ss   format
TYPE(OptInput), INTENT(IN)    :: Input_Opt  ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

REMARKS:

```
This routine was automatically generated by the Perl script ncCodeRead,
and was subsequently hand-edited for compatibility with GEOS-Chem.

                                                                             .
Even though the netCDF file is self-describing, the GEOS-FP data,
dimensions, and units are pre-specified according to the GMAO GEOS-FP
file specification.  Therefore we can "cheat" a little bit and not have
to read netCDF attributes to find what these values are.
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
07 Feb 2012 - R. Yantosca - Now echo info after reading fields from disk
10 Feb 2012 - R. Yantosca - Now get a string for the model resolution
05 Apr 2012 - R. Yantosca - Now convert QV2 from [kg/kg] to [g/kg]
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
26 Sep 2013 - R. Yantosca - Rename to GeosFp_Read_I3_2
29 Oct 2013 - R. Yantosca - Now read T_FULLGRID_2 for offline simulations
```

1.63 Fortran: Module Interface get_popsinfo_mod

Module GET_POPSINFO_MOD contains variables and routines for the GEOS-Chem persistent organic pollutants (POPs) simulation.

INTERFACE:

```
MODULE GET_POPSINFO_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: GET_POP_TYPE
PUBLIC :: GET_EMISSFILE
PUBLIC :: GET_POP_XMW
PUBLIC :: GET_POP_HSTAR
PUBLIC :: GET_POP_DEL_Hw
PUBLIC :: GET_POP_DEL_H
PUBLIC :: GET_POP_KBC
PUBLIC :: GET_POP_K_POPP_O3A
PUBLIC :: GET_POP_K_POPP_O3B
PUBLIC :: GET_POP_K_POPG_OH
PUBLIC :: GET_POP_KOA
PUBLIC :: INIT_POP_PARAMS
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.1 get_pop_type

Function GET_POP_TYPE is used to retrieve type of POP.

INTERFACE:

```
FUNCTION GET_POP_TYPE( IN_TYPE )
```

INPUT PARAMETERS:

```
CHARACTER(LEN=3), INTENT(IN) :: IN_TYPE
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.2 get_pop_xmw

Function GET_POP_XMW returns POP molecular weight in kg/mol.

INTERFACE:

```
FUNCTION GET_POP_XMW( IN_XMW )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: IN_XMW
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.3 get_pop_koa

Function GET_POP_KOA returns the POP octanol-water partition coefficient [unitless].

INTERFACE:

```
FUNCTION GET_POP_KOA( IN_KOA )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: IN_KOA
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.4 get_pop_kbc

Function GET_POP_KBC returns the POP black carbon-air partition coefficient [unitless].

INTERFACE:

```
FUNCTION GET_POP_KBC( IN_KBC )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: IN_KBC
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.5 get_pop_k_popg_oh

Function GET_POP_K_POPG_OH returns the POP reaction rate constant for reaction of gas phase POP with hydroxyl radical [cm3/molecule/s]

INTERFACE:

```
FUNCTION GET_POP_K_POPG_OH( IN_K_POPG_OH )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: IN_K_POPG_OH
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.6 get_pop_k_popp_o3a

Function GET_POP_K_POPP_O3A returns the POP reaction rate constant for reaction of particle phase POP with ozone [sˆ1].

INTERFACE:

```
FUNCTION GET_POP_K_POPP_O3A( IN_K_POPP_O3A )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: IN_K_POPP_O3A
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.7 get_pop_k_popp_o3b

Function GET_POP_K_POPP_O3B returns the POP reaction rate constant for reaction of particle phase POP with ozone [molec/cm3].

INTERFACE:

```
FUNCTION GET_POP_K_POPP_O3B( IN_K_POPP_O3B )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: IN_K_POPP_O3B
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.8 get_pop_hstar

Function GET_POP_HSTAR returns the POP Henry's Law constant in atm/M/K.

INTERFACE:

```
FUNCTION GET_POP_HSTAR( IN_HSTAR )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: IN_HSTAR
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.9 get_pop_del_H

Function GET_POP_DEL_H returns the enthalpy of air-water exchange (K).

INTERFACE:

```
FUNCTION GET_POP_DEL_H( IN_DEL_H )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: IN_DEL_H
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.10 get_pop_del_Hw

Function GET_POP_DEL_Hw returns the enthalpy of phase transfer from gas phaseto particle phase.

INTERFACE:

```
FUNCTION GET_POP_DEL_Hw( IN_DEL_Hw )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: IN_DEL_Hw
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.11 init_pop_params

Subroutine INIT_POP_PARAMS initalizes POP parameters.

INTERFACE:

```
 SUBROUTINE INIT_POP_PARAMS( POP_XMW,        POP_KOA,
&                            POP_KBC,        POP_K_POPG_OH,
&                            POP_K_POPP_O3A, POP_K_POPP_O3B,
&                            POP_HSTAR,      POP_DEL_H,
&                            POP_DEL_Hw      )
```

INPUT/OUTPUT PARAMETERS:

```
 REAL*8 :: POP_XMW,        POP_KOA
 REAL*8 :: POP_KBC,        POP_K_POPG_OH
 REAL*8 :: POP_K_POPP_O3A, POP_K_POPP_O3B
 REAL*8 :: POP_HSTAR,      POP_DEL_H
 REAL*8 :: POP_DEL_Hw
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.63.12 get_emissfile

Function GET_EMISSFILE returns the emissions file for particular POP.

INTERFACE:

```
 FUNCTION GET_EMISSFILE( IN_FILE )
```

INPUT PARAMETERS:

```
 CHARACTER, INTENT(IN)    :: IN_FILE
```

REVISION HISTORY:

```
30 Sep 2012 - C. Pike Thackray - Initial version
```

1.64 Fortran: Module Interface gfed3_biomass_mod

Module GFED3_BIOMASS_MOD contains routines and variables used to incorporate GFED3 emissions into GEOS-Chem

INTERFACE:

```
 MODULE GFED3_BIOMASS_MOD
```

USES:

```
      USE inquireMod, ONLY : findFreeLUN

      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: GFED3_COMPUTE_BIOMASS
      PUBLIC  :: CLEANUP_GFED3_BIOMASS
      PUBLIC  :: GFED3_IS_NEW
  PRIVATE MEMBER FUNCTIONS:
      PRIVATE :: CHECK_GFED3
      PRIVATE :: GFED3_AVAILABLE
      PRIVATE :: GFED3_SCALE_FUTURE
      PRIVATE :: GFED3_TOTAL_Tg
      PRIVATE :: INIT_GFED3_BIOMASS
      PRIVATE :: REARRANGE_BIOM
      PRIVATE :: READ_BPCH2_GFED3
```

REMARKS:

```
    Monthly emissions of DM are read from disk,
    multiplied by daily and 3hourly fractions (if necessary), and then
    multiplied by the appropriate emission factors to produce biomass
    burning emissions on the GFED3 0.5x0.5 degree grid  The emissions are
    then regridded to the current GEOS-Chem or GCAP grid (1x1, 2x25, or 4x5).
                                                                             .
    GFED3 biomass burning emissions are computed for the following gas-phase
    and aerosol-phase species:
                                                                             .
       (1 ) NOx  [  molec/cm2/s]     (13) BC   [atoms C/cm2/s]
       (2 ) CO   [  molec/cm2/s]     (14) OC   [atoms C/cm2/s]
       (3 ) ALK4 [atoms C/cm2/s]     (15) GLYX [  molec/cm2/s]
       (4 ) ACET [atoms C/cm2/s]     (16) MGLY [  molec/cm2/s]
       (5 ) MEK  [atoms C/cm2/s]     (17) BENZ [atoms C/cm2/s]
       (6 ) ALD2 [atoms C/cm2/s]     (18) TOLU [atoms C/cm2/s]
       (7 ) PRPE [atoms C/cm2/s]     (19) XYLE [atoms C/cm2/s]
       (8 ) C3H8 [atoms C/cm2/s]     (20) C2H4 [atoms C/cm2/s]
       (9 ) CH2O [  molec/cm2/s]     (21) C2H2 [atoms C/cm2/s]
       (10) C2H6 [atoms C/cm2/s]     (22) GLYC [  molec/cm2/s]
       (11) SO2  [  molec/cm2/s]     (23) HAC  [  molec/cm2/s]
       (12) NH3  [  molec/cm2/s]     (24) CO2  [  molec/cm2/s]
                                                                             .
    References:
    ============================================================================
    (1 ) Original GFED3 database from Guido van der Werf
         http://www.falw.vu/~gwerf/GFED/GFED3/emissions/
    (2 ) Giglio, L., Randerson, J. T., van der Werf, G. R., Kasibhatla, P. S.,
```

Collatz, G. J., Morton, D. C., and DeFries, R. S.: Assessing variability and long-term trends in burned area by merging multiple satellite fire products, Biogeosciences, 7, 1171-1186, doi:10.5194/bg-7-1171-2010, 2010.

(3) van der Werf, G. R., Randerson, J. T., Giglio, L., Collatz, G. J., Mu, M., Kasibhatla, P. S., Morton, D. C., DeFries, R. S., Jin, Y., and van Leeuwen, T. T.: Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (19972009), Atmos. Chem. Phys., 10, 11707-11735, doi:10.5194/acp-10-11707-2010, 2010.

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
14 Feb 2012 - M. Payer      - Add modifications for CH4 (K. Wecht)
01 Mar 2012 - R. Yantosca   - Now reference new grid_mod.F90
06 Mar 2012 - P. Kasibhatla - Final version
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.64.1 gfed3_is_new

Function GFED3_IS_NEW returns TRUE if GFED3 emissions have been updated.

INTERFACE:

```
FUNCTION GFED3_IS_NEW( ) RESULT( IS_UPDATED )
```

RETURN VALUE:

```
LOGICAL :: IS_UPDATED    ! =T if GFED3 is updated; =F otherwise
```

REMARKS:

```
Called from carbon_mod.f and sulfate_mod.f
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.64.2 check_gfed3

Subroutine CHECK_GFED3 checks if we entered a new GFED period since last emission timestep (ie, last call). The result depends on the emissions time step, and the GFED time period used, as well as MMDDHH at beginning of the GEOS-Chem run

INTERFACE:

```
SUBROUTINE CHECK_GFED3( DOY, HH )
```

USES:

```
USE LOGICAL_MOD, ONLY : LDAYBB3
USE LOGICAL_MOD, ONLY : L3HRBB3
USE TIME_MOD,    ONLY : ITS_A_NEW_MONTH
USE TIME_MOD,    ONLY : ITS_A_NEW_DAY
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: DOY   ! Day of year (0-365 or 0-366 leap years)
INTEGER, INTENT(IN) :: HH    ! Hour of day (0-23)
```

REMARKS:

```
The routine computes the DOY (resp. HOUR) at start of the 1-day (resp.
3-hour) period we are in, if the 1-day (resp. 3-hr ) GFED3
option is on. Result is compared to previous value to indicate if new
data should be read.
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
06 Mar 2012 - P. Kasibhatla - final GFED3 version
```

1.64.3 gfed3_available

Function GFED3_AVAILABLE checks an input YYYY year and MM month against the available data dates. If the requested YYYY and MM lie outside of the valid range of dates, then GFED3_AVAILABLE will return the last valid YYYY and MM.

INTERFACE:

```
SUBROUTINE GFED3_AVAILABLE( YYYY, YMIN, YMAX, MM, MMIN, MMAX )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)              :: YMIN, YMAX   ! Min & max years
INTEGER, INTENT(IN),    OPTIONAL :: MMIN, MMAX   ! Min & max months
```

INPUT/OUTPUT PARAMETERS:

```
INTEGER, INTENT(INOUT)           :: YYYY         ! Year of GFED3 data
INTEGER, INTENT(INOUT), OPTIONAL :: MM           ! Month of GFED3 data
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.64.4 gfed3_compute_biomass

Subroutine GFED3_COMPUTE_BIOMASS computes the monthly GFED3 biomass burning emissions for a given year and month.

INTERFACE:

```
SUBROUTINE GFED3_COMPUTE_BIOMASS( THIS_YYYY, THIS_MM, BIOM_OUT )
```

USES:

```
USE BPCH2_MOD,        ONLY : GET_TAU0
USE DIRECTORY_MOD,    ONLY : DATA_DIR_NATIVE => DATA_DIR_1x1
USE JULDAY_MOD,       ONLY : JULDAY
USE JULDAY_MOD,       ONLY : CALDATE
USE LOGICAL_MOD,      ONLY : LFUTURE
USE LOGICAL_MOD,      ONLY : LDAYBB3
USE LOGICAL_MOD,      ONLY : L3HRBB3
USE LOGICAL_MOD,      ONLY : LGFED3BB
USE TIME_MOD,         ONLY : EXPAND_DATE
USE TIME_MOD,         ONLY : TIMESTAMP_STRING
USE TIME_MOD,         ONLY : GET_DAY
USE TIME_MOD,         ONLY : GET_HOUR
USE TIME_MOD,         ONLY : GET_DAY_OF_YEAR
USE TIME_MOD,         ONLY : ITS_A_LEAPYEAR
USE GLOBAL_GRID_MOD, ONLY : GET_XEDGE_G
USE GLOBAL_GRID_MOD, ONLY : GET_YEDGE_G
USE GRID_MOD,         ONLY : GET_XEDGE
USE GRID_MOD,         ONLY : GET_YEDGE
USE GRID_MOD,         ONLY : GET_XOFFSET
USE GRID_MOD,         ONLY : GET_YOFFSET
USE ERROR_MOD,        ONLY : ALLOC_ERR
USE REGRID_A2A_MOD,   ONLY : MAP_A2A

USE CMN_SIZE_MOD                                        ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: THIS_YYYY                       ! Current year
INTEGER, INTENT(IN)  :: THIS_MM                         ! Current month
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: BIOM_OUT(IIPAR,JJPAR,NBIOMAX)  ! BB emissions
                                                       ! [molec/cm2/s]
```

REMARKS:

```
This routine has to be called on EVERY emissions-timestep if you use one
of the GFED3 options.
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
03 May 2012 - M. Payer      - Now use 3D indices for grid_mod.F90 routines
                              GET_XEDGE and GET_YEDGE. Nested grids still
                              use 1D indices for routines GET_XEDGE_G and
                              GET_YEDGE_G found in global_grid_mod.90. This
                              will maintain grid-independent functionality.
06 Jun 2013 - M. Payer      - Set TAU0 to first of month for 3-hr emissions
                              to match time stamp of data file (C. Keller)
02 Jul 2013 - M. Payer      - Update GFED3 emissions to 2011 (P. Kasibhatla)
```

1.64.5 gfed3_scale_future

Subroutine GFED3_SCALE_FUTURE applies the IPCC future emissions scale factors to the GFED3 biomass burning emisisons in order to compute the future emissions of biomass burning for NOx, CO, and VOC's.

INTERFACE:

```
SUBROUTINE GFED3_SCALE_FUTURE( BB )
```

USES:

```
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_BCbb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_CObb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_NH3bb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_NOxbb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_OCbb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_SO2bb
USE FUTURE_EMISSIONS_MOD,   ONLY : GET_FUTURE_SCALE_VOCbb
USE TRACER_MOD,             ONLY : ITS_A_CO2_SIM
USE TRACER_MOD,             ONLY : ITS_A_CH4_SIM
USE TRACERID_MOD,           ONLY : IDBNO,   IDBCO,   IDBSO2
USE TRACERID_MOD,           ONLY : IDBNH3,  IDBBC,   IDBOC

USE CMN_SIZE_MOD                 ! Size parameters
```

OUTPUT PARAMETERS:

```
!  Array w/ biomass burning emisisons [molec/cm2]
REAL*8, INTENT(INOUT) :: BB(IIPAR,JJPAR,N_SPEC)
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
14 Mar 2013 - M. Payer      - Replace NOx emissions with NO emissions as part
                              of removal of NOx-Ox partitioning
```

1.64.6 gfed3_total_Tg

Subroutine GFED3_TOTAL_Tg prints the amount of biomass burning emissions that are emitted each month/day/3-hr in Tg or Tg C.

INTERFACE:

```
SUBROUTINE GFED3_TOTAL_Tg
```

USES:

```
USE GRID_MOD,    ONLY : GET_AREA_CM2

USE CMN_SIZE_MOD      ! Size parameters
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.64.7 init_gfed3_biomass

Subroutine INIT_GFED3_BIOMASS allocates all module arrays. It also reads the emission factors at the start of a GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE INIT_GFED3_BIOMASS
```

USES:

```
USE DIRECTORY_MOD,   ONLY : DATA_DIR_NATIVE => DATA_DIR_1x1
USE ERROR_MOD,       ONLY : ALLOC_ERR
USE FILE_MOD,        ONLY : IOERROR
USE LOGICAL_MOD,     ONLY : LDICARB
```

```
USE LOGICAL_MOD,     ONLY : LDAYBB3
USE LOGICAL_MOD,     ONLY : L3HRBB3
USE TRACERID_MOD,    ONLY : IDBNO,  IDBCO,   IDBALK4
USE TRACERID_MOD,    ONLY : IDBACET, IDBMEK,  IDBALD2
USE TRACERID_MOD,    ONLY : IDBPRPE, IDBC3H8, IDBCH2O
USE TRACERID_MOD,    ONLY : IDBC2H6, IDBBC,   IDBOC
USE TRACERID_MOD,    ONLY : IDBSO2,  IDBNH3,  IDBCO2
USE TRACERID_MOD,    ONLY : IDBGLYX, IDBMGLY, IDBBENZ
USE TRACERID_MOD,    ONLY : IDBTOLU, IDBXYLE, IDBC2H4
USE TRACERID_MOD,    ONLY : IDBC2H2, IDBGLYC, IDBHAC
USE TRACERID_MOD,    ONLY : IDBCH4   !kjw
USE GLOBAL_GRID_MOD, ONLY : GET_IIIPAR
USE GLOBAL_GRID_MOD, ONLY : GET_JJJPAR
USE CMN_SIZE_MOD           ! Size parameters
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
```

1.64.8 rearrange_biom

Subroutine REARRANGE_BIOM takes GFED3 emissions (which have their own, unique ID numbers and associates them with the IDBxxxs of tracerid_mod.F.

INTERFACE:

```
SUBROUTINE REARRANGE_BIOM( BIOM_OUT, BIOM_OUTM )
```

USES:

```
USE CMN_SIZE_MOD     ! Size parameters
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN)  :: BIOM_OUT (IIPAR,JJPAR,N_SPEC)
```

OUTPUT PARAMETERS:

```
REAL*8, INTENT(OUT) :: BIOM_OUTM(IIPAR,JJPAR,NBIOMAX) !+1 from CO2
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.64.9 cleanup_gfed3_biomass

Subroutine CLEANUP_GFED3_BIOMASS deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GFED3_BIOMASS
```

REVISION HISTORY:

```
07 Sep 2011 - P. Kasibhatla - Initial version, based on GFED2
07 Sep 2011 - R. Yantosca   - Added ProTeX headers
```

1.64.10 read_bpch2_gfed3

Subroutine READ_BPCH2_GFED3 reads GFED3 DM burnt and and humid tropical forest map files

INTERFACE:

```
 SUBROUTINE READ_BPCH2_GFED3( FILENAME, CATEGORY_IN, TRACER_IN,
&                             TAU0_IN,  IX,          JX,
&                             LX,       ARRAY,       QUIET )
```

USES:

```
USE ERROR_MOD, ONLY : ERROR_STOP
USE FILE_MOD,  ONLY : IOERROR
USE BPCH2_MOD, ONLY : OPEN_BPCH2_FOR_READ
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*),  INTENT(IN)  :: FILENAME         ! Bpch file to read
CHARACTER(LEN=*),  INTENT(IN)  :: CATEGORY_IN      ! Diag. category name
INTEGER,           INTENT(IN)  :: TRACER_IN        ! Tracer index #
REAL*8,            INTENT(IN)  :: TAU0_IN          ! TAU timestamp
INTEGER,           INTENT(IN)  :: IX, JX, LX       ! Dimensions of ARRAY
LOGICAL, OPTIONAL, INTENT(IN)  :: QUIET            ! Don't print output
```

OUTPUT PARAMETERS:

```
REAL*4,            INTENT(OUT) :: ARRAY(IX,JX,LX)  ! Data array from file
```

REVISION HISTORY:

```
(1 ) Adapted from READ_BPCH2 to facilitate reading of 0.5x0.5 GFED3 files (psk, 2/7/12)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.65 Fortran: Module Interface global_bc_mod

Module GLOBAL_BC_MOD contains variables and routines for reading the global monthly mean OC concentration from disk. Based on module GLOBAL_OH_MOD. (clf, 1/19/2011).

INTERFACE:

```
MODULE GLOBAL_BC_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: GET_GLOBAL_BC
PUBLIC :: CLEANUP_GLOBAL_BC
```

PUBLIC DATA MEMBERS:

```
PUBLIC :: BC
```

REVISION HISTORY:

```
19 January 2011 - C.L. Friedman - Initial Version
```

1.65.1 get_global_bc

Subroutine GET_GLOBAL_BC reads global BC from binary punch files stored on disk. BC data is needed for partitioning of gas phase organics onto BC particles (e.g., POPs). (clf, 1/19/2011)

INTERFACE:

```
SUBROUTINE GET_GLOBAL_BC( THISMONTH, THISYEAR )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D

USE CMN_SIZE_MOD        ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: THISMONTH, THISYEAR
```

REVISION HISTORY:

```
19 January 2011 - C.L. Friedman - Initial Version
```

1.65.2 init_global_bc

Subroutine INIT_GLOBAL_BC allocates and zeroes the BC array, which holds global monthly mean BC concentrations. (clf, 1/19/2011)

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_BC
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
19 January 2011 - C.L. Friedman - Initial Version
```

1.65.3 cleanup_global_bc

Subroutine CLEANUP_GLOBAL_BC deallocates the BC array. (clf, 1/19/2011)

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_BC
```

REVISION HISTORY:

```
19 January 2011 - C.L. Friedman - Initial Version
```

1.66 Fortran: Module Interface global_Br_mod

Module GLOBAL_Br_MOD contains variables and routines for reading the global monthly mean Br concentration from disk.

INTERFACE:

```
MODULE GLOBAL_Br_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
! Array to store global monthly mean BR field
REAL*8, PUBLIC, ALLOCATABLE :: BR_TROP(:,:,:)
REAL*8, PUBLIC, ALLOCATABLE :: BR_STRAT(:,:,:)
REAL*8, PUBLIC, ALLOCATABLE :: BR_MERGE(:,:,:)
```

```
      ! Array to store global monthly mean BrO field
      REAL*8, PUBLIC, ALLOCATABLE :: BRO_TROP(:,:,:)
      REAL*8, PUBLIC, ALLOCATABLE :: BRO_STRAT(:,:,:)
      REAL*8, PUBLIC, ALLOCATABLE :: BRO_MERGE(:,:,:)

      ! Array to store global monthly J-BrO field
      REAL*8, PUBLIC, ALLOCATABLE :: J_BRO(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      ! Remove obsolete routine
      !PUBLIC :: GET_GLOBAL_Br_NEW
      PUBLIC :: GET_GLOBAL_Br
      PUBLIC :: INIT_GLOBAL_Br
      PUBLIC :: CLEANUP_GLOBAL_Br

   !REFERENCES
    (1 ) Holmes, C. D., et al. (2006), Global lifetime of elemental mercury
         against oxidation by atomic bromine in the free troposphere, Geophys.
         Res. Lett., 33(20).
    (2 ) Holmes, C.D., et al. (2010) Global atmospheric model for mercury
         including oxidation by bromine atoms, AC&P, 10, 12,037-12,057.
    (3 ) Parrella, J. et al. (2012), Tropospheric bromine chemistry:
         implications for present and pre-industrial ozone and mercury, ACP.
```

REVISION HISTORY:

```
    05 Jul 2006 - C. Holmes   - Copied from "global_oh_mod.f"
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
    19 Apr 2012 - E.S. Corbitt - Added LGCBROMINE to use GEOS-Chem bromine.
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.66.1 get_global_Br

Subroutine GET_GLOBAL_Br reads global Br from binary punch files stored in the /data/ctm/GEOS_MEAN directory. This Br data is needed as oxidant for mercury chemistry.

INTERFACE:

```
      SUBROUTINE GET_GLOBAL_Br( THISMONTH, State_Met )
```

USES:

```
      !USE LOGICAL_MOD,    ONLY : LVARTROP     ! Comment this out for now
      USE BPCH2_MOD,          ONLY : GET_NAME_EXT
      USE BPCH2_MOD,          ONLY : GET_RES_EXT
      USE BPCH2_MOD,          ONLY : GET_TAU0
      USE BPCH2_MOD,          ONLY : READ_BPCH2
```

```
      USE DIRECTORY_MOD,      ONLY : DATA_DIR ! cdh
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TRANSFER_MOD,       ONLY : TRANSFER_3D
      USE TRANSFER_MOD,       ONLY : TRANSFER_3D_TROP
      USE TROPOPAUSE_MOD,     ONLY : GET_TPAUSE_LEVEL
      USE OCEAN_MERCURY_MOD,  ONLY : LGCBROMINE     !eds 4/19/12

      USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN)  :: THISMONTH   ! Current month
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REMARKS:

```
    THIS IS A NEW VERSION OF THIS SUBROUTINE WHICH COMBINES Br CONCENTRATIONS
    FROM MULTIPLE DATA SOURCES
```

REVISION HISTORY:

```
    05 Jul 2006 - C. Holmes   - Copied from "global_oh_mod.f"
    (1 ) GET_GLOBAL_BR assumes that we are reading global BR data that occupies
          all CTM levels.  Contact Bob Yantosca (bmy@io.harvard.edu) for IDL
          regridding code which will produce the appropriate BR files.
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.66.2 init_global_Br

Subroutine INIT_GLOBAL_Br allocates and zeroes all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_GLOBAL_Br
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
    05 Jul 2006 - C. Holmes   - Copied from "global_oh_mod.f"
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.66.3 cleanup_global_Br

Subroutine CLEANUP_GLOBAL_Br deallocates module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_Br
```

REVISION HISTORY:

```
05 Jul 2006 - C. Holmes   - Copied from "global_oh_mod.f"
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.67 Fortran: Module Interface global_ch4_mod

Module GLOBAL_CH4_MOD contains variables and routines for simulating CH4 chemistry in the troposphere.

INTERFACE:

```
MODULE GLOBAL_CH4_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%% Normally we will not save out the CH4_BUDGET diagnostics (esp. when
%%% using the nested grid simulations) in order to save memory.  If you
%%% want to use CH4_BUDGET, then uncomment the following line of code:
%%% (kjw, bmy, 2/12/14)
#define USE_CH4_BUDGET_DIAG 1
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CH4_AVGTP
PUBLIC :: EMISSCH4
PUBLIC :: CHEMCH4
PUBLIC :: INIT_GLOBAL_CH4
PUBLIC :: CLEANUP_GLOBAL_CH4
```

PUBLIC DATA MEMBERS:

```
REAL*8, PARAMETER,   PUBLIC :: XNUMOL_CH4 = 6.0221d23 / 16d-3

#if defined( USE_CH4_BUDGET_DIAG )
```

```
      REAL*8, ALLOCATABLE, PUBLIC :: TCH4(:,:,:,:)
#endif
```

REVISION HISTORY:

```
17 Jan 2001- J. Wang, B. Duncan, R. Yantosca -- Initial version
(1 ) Merged routines from jsw's CH4 code  into "global_ch4_mod.f"
     (bmy, 1/16/01)
(2 ) XNUMOL_CH4 and TCH4 have to be public - all other variables can
     be made private, so as not to conflict with other common-block
     definitions (bmy, 1/17/01)
(3 ) Minor fixes from jsw added (jsw, bmy, 2/17/01)
(4 ) Removed some F90 module references from EMISSCH4 (bmy, 3/20/01)
(5 ) Eliminate obsolete commented-out code (bmy, 4/20/01)
(6 ) Updated comments (bmy, 9/4/01)
(7 ) Fixes for binary punch file in READ_COPROD (bmy, 9/26/01)
(8 ) Removed obsolete code from READ_COPROD (bmy, 10/24/01)
(9 ) Minor bug fixes for compilation on ALPHA (bmy, 11/15/01)
(10) Eliminate obsolete code from 11/01 (bmy, 2/27/02)
(11) Now eliminate PS from the arg list to CH4_AVGTP (4/11/02)
(12) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
     MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(13) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(14) Now reference "file_mod.f".  Also removed obsolete code. (bmy, 6/27/02)
(15) Now references "pressure_mod.f" (bmy, 8/21/02)
(16) Now reference AD and T from "dao_mod.f".  Now reference "error_mod.f".
     Remove obsolete code from various routines.  Remove reference to
     header file "comtrid.h" -- it's not used. (bmy, 11/6/02)
(17) Minor bug fix in FORMAT statements (bmy, 3/23/03)
(18) Now references "grid_mod.f" and "time_mod.f" (bmy, 3/27/03)
(19) Updates to GET_GLOBAL_CH4 (bmy, 7/1/03)
(20) Now references "directory_mod.f", "tracer_mod.f", and "diag_oh_mod.f"
     (bmy, 7/20/04)
(21) Now can read data for both GEOS and GCAP grids (bmy, 8/16/05)
(22) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(23) Updated CH4 simulation (kjw, cph, ccarouge, 10/1/09)
(24) Added modifications for MERRA (bmy, 8/13/10)
08 Feb 2012 - R. Yantosca - Added modifications for GEOS-5.7.x
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
07 Mar 2012 - M. Payer    - Added ProTeX headers
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
12 Feb 2014 - K. Wecht    - Add modifications for 0.25 x 0.3125 NA grid
12 Feb 2014 - K. Wecht    - Disable CH4 budget diagnostic (bracket the
                            code out with #ifdef blocks so it can be used)
```

1.67.1 ch4_avgtp

Subroutine CH4_AVGTP gets the 24-h average surface pressure and temperature needed for the CH4 simulation. (jsw, bnd, bmy, 1/16/01, 7/20/04)

INTERFACE:

```
SUBROUTINE CH4_AVGTP( State_Met )
```

USES:

```
USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
USE GIGC_State_Met_Mod, ONLY : MetState
USE PRESSURE_MOD,       ONLY : GET_PCENTER
USE TIME_MOD,           ONLY : GET_TS_DYN, GET_TS_CHEM
USE TIME_MOD,           ONLY : GET_ELAPSED_MIN

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry and
     placed into module "global_ch4_mod.f" by Bob Yantosca. (bmy, 1/16/01)
(2 ) CH4_AVGTP is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
     (bmy, 1/16/01)
(3 ) Removed duplicate definition for NTDT, NMIN (bmy, 11/15/01)
(4 ) Removed PS from argument list.  Now use P(I,J)+PTOP instead of
     PS, this ensures that we have consistency between P and AD.
     (bmy, 4/11/02)
(5 ) Removed obsolete code (bmy, 6/27/02)
(6 ) Now uses GET_PCENTER from "pressure_mod.f" to return the pressure
     at the midpoint of the box (I,J,L).  Also added parallel DO-loops.
     Updated comments. (dsa, bdf, bmy, 8/21/02)
(7 ) Now reference T from "dao_mod.f".  Now reference GEOS_CHEM_STOP from
     "error_mod.f" (bmy, 10/15/02)
(8 ) Removed NTDT, NMIN from the arg list.  Now uses functions GET_TS_DYN,
     GET_TS_CHEM, and GET_ELAPSED_MIN from "time_mod.f" (bmy, 3/27/03)
(9 ) Remove reference to CMN, it's not needed (bmy, 7/20/04)
07 Mar 2012 - M. Payer    - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.67.2 emissch4

Subroutine EMISSCH4 places emissions of CH4 [kg] into the STT array. (jsw, bnd, bey, bmy, 1/16/01, 10/3/05)

INTERFACE:

```
      SUBROUTINE EMISSCH4( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH, ITS_A_NEW_YEAR
      USE TIME_MOD,           ONLY : GET_MONTH,       GET_YEAR
      USE TIME_MOD,           ONLY : GET_TS_EMIS,     ITS_A_NEW_DAY
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2,    GET_XOFFSET
      USE GRID_MOD,           ONLY : GET_YOFFSET
      USE DIAG_MOD,           ONLY : AD58
      USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP, IT_IS_NAN
      USE VDIFF_PRE_MOD,      ONLY : EMIS_SAVE ! (ccc, 08/31/09)
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    WARNING: Soil absorption has to be the 11th field in CH4_EMIS
```

REVISION HISTORY:

```
    (1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
         James Wang (7/00).  Inserted into module "global_ch4_mod.f"
         by Bob Yantosca. (bmy, 1/16/01)
    (2 ) EMISSCH4 is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
         (bmy, 1/16/01)
    (3 ) GLOBASEAEMIS, GLOBSEAEMIS are diagnostics by jsw.
    (4 ) Do not multiply CO emissions by 1.28 anymore (jsw, bmy, 2/12/01)
    (5 ) Renamed input files to CH4_monthly.geos.{RES} and
```

```
      CH4_aseasonal.geos.{RES}. (bmy, 2/12/01)
(6 ) Add reference to "CMN_SETUP" for the DATA_DIR variable (bmy, 2/13/01)
(7 ) Removed references to "biofuel_mod.f" and "biomass_mod.f"; these
      weren't necessary (bmy, 3/20/01)
(8 ) Now reference IU_FILE and IOERROR from "file_mod.f".  Now use IU_FILE
      instead of IUNIT as the file unit #. (bmy, 6/27/02)
(9 ) Now reference BXHEIGHT and SUNCOS from "dao_mod.f".  Remove reference
      to header file "comtrid.h" -- it's not used.  Make FIRSTEMISS a local
      SAVEd variable.  Also use MONTH from "CMN" instead of the variable
      LMN. (bmy, 11/15/02)
(10) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f".
      Now use function GET_MONTH and GET_TS_EMIS from "time_mod.f".
      Now use functions GET_XOFFSET and GET_YOFFSET from "grid_mod.f".
      I0 and J0 are now local variables. (bmy, 3/27/03)
(11) Now reference STT from "tracer_mod.f".  Now reference DATA_DIR from
      "directory_mod.f". (bmy, 7/20/04)
(12) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(13) Add non-local PBL capability (ccc, 8/31/09)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
07 Mar 2012 - M. Payer    - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.67.3 wetland_emis

Subroutine WETLAND_EMIS calculates emissions of CH4 [kg] by Wetland. For a description of the GEOS-Chem wetland CH4 emission routine, see a paper titled, "Magnitude and trends of wetland methane emissions from the Hudson Bay Lowlands (Canada)" by C. Pickett-Heaps

INTERFACE:

```
SUBROUTINE WETLAND_EMIS( State_Met )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT,  GET_MODELNAME
USE BPCH2_MOD,          ONLY : GET_TAU0,     READ_BPCH2
USE BPCH2_MOD,          ONLY : GET_NAME_EXT, GET_NAME_EXT_2D
USE DIRECTORY_MOD,      ONLY : DATA_DIR
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_M2
USE TIME_MOD,           ONLY : GET_MONTH,       GET_YEAR
USE TIME_MOD,           ONLY : GET_TS_EMIS
USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH, ITS_A_NEW_YEAR
USE TRANSFER_MOD,       ONLY : TRANSFER_2D
USE DIAG_MOD,           ONLY : AD60, AD58
```

```
      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! Diagnostic switches
```

INPUT PARAMETERS:

```
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
    (1 ) Adapted by Jrme Drevet (3/06) from the BIOME-TG Wetland-Methane
         scheme provided by Jed O. Kaplan.
    (2 ) CH4 Emissions from Wetland depend on:
   a - Soil Carbon content.
   b - Vegetation type
   c - Wetland area (%)
   d - Soil moisture.
         a, b, c are taken from the LPJ, a vegetation model. Data are provided
   by J.O.Kaplan. Soil moisture is read from GEOS Met input files.
    (3 ) Corrected order of DO loops (bmy, 10/1/09)
    08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
    07 Mar 2012 - M. Payer    - Added ProTeX headers
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
    23 Jan 2014 - M. Sulprizio- Now zero wetland emissions if snow covers the
                                ground. Also updated MOIST_SCALE and EMIT_FACT.
                                (K. Wecht, C. Pickett-Heaps)
    12 Feb 2014 - K. Wecht    - Updated for 0.25 x 0.3125 NA grid
```

1.67.4 bioburn_emis

Subroutine BIOBURN_EMIS calculates CH4 emissions from GFED2 or GFED3 biomass burning. (kjw, 6/03/09)

INTERFACE:

```
      SUBROUTINE BIOBURN_EMIS( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE BIOMASS_MOD,        ONLY : BIOMASS
      USE CMN_SIZE_MOD,       ONLY : IIPAR, JJPAR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE TRACERID_MOD,       ONLY : IDBCH4
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
03 Jun 2009 - K. Wecht    - The code used to read, scale & regrid emissions
                            is from SUBROUTINE GFED2_COMPUTE_BIOMASS in
                            gfed2_biomass_mod.f
14 Feb 2012 - M. Payer    - Now obtain emissions from BIOMASS array. Also
                            update for GFED3 (K. Wecht)
07 Mar 2012 - M. Payer    - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.67.5 rice_emis

Subroutine RICE_EMIS calculates CH4 emissions from rice and places CH4 [kg] into the STT array. (kjw, 6/03/09)

INTERFACE:

```
SUBROUTINE RICE_EMIS( am_I_Root, Input_Opt, RC )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT,  GET_MODELNAME
USE BPCH2_MOD,          ONLY : GET_TAU0,     READ_BPCH2
USE BPCH2_MOD,          ONLY : GET_NAME_EXT, GET_NAME_EXT_2D
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : DATA_DIR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE TIME_MOD,           ONLY : GET_MONTH,    GET_YEAR
USE TRANSFER_MOD,       ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

LOCAL VARIABLES:

REMARKS:

```
Rice Emissions are scaled to GEOS soil wetness.  Scaling sceme developed
   and implemented by Jerome Drevet.
Wetland emissions are modified by the presence of rice emissions.  Sceme
   developed by Jerome Drevet.
```

REVISION HISTORY:

```
(1 ) CH4 emissions from rice calculated with a routine created by Jerome
     Drevet.  Adapted as its own subroutine by Kevin Wecht (6/03/09)
(2 ) Corrected ordering of DO loops (bmy, 10/1/09)
07 Mar 2012 - M. Payer    - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.67.6 aseasonal_anthro_emis

Subroutine ASEASONAL_ANTHRO_EMIS reads CH4 emissions from anthropogenic sources. (kjw, 6/03/09)

INTERFACE:

```
SUBROUTINE ASEASONAL_ANTHRO_EMIS( am_I_Root, Input_Opt, RC )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT,  GET_MODELNAME
USE BPCH2_MOD,          ONLY : GET_NAME_EXT_2D
USE BPCH2_MOD,          ONLY : GET_TAU0,     READ_BPCH2
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : DATA_DIR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : GET_YEAR
USE TRANSFER_MOD,       ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
Aseasonal anthropogenic emissions currently include EDGAR v4 categories
that are not called in their own subroutines.  Current emission categories
read in this subroutine are: gas & oil, coal, livestock, waste, and other
anthropogenic sources.
```

REVISION HISTORY:

```
07 Mar 2012 - M. Payer    - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
12 Feb 2014 - K. Wecht    - Add modifications for 0.25 x 0.3125 NA grid
12 Feb 2014 - K. Wecht    - Disable CH4 budget diagnostic (bracket the
                            code out with #ifdef blocks so it can be used)
```

1.67.7 aseasonal_natural_emis

Subroutine ASEASONAL_NATURAL_EMIS reads CH4 emissions from natural sources. (kjw, 6/03/09)

INTERFACE:

```
SUBROUTINE ASEASONAL_NATURAL_EMIS( am_I_Root, Input_Opt, RC )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT,    GET_MODELNAME
USE BPCH2_MOD,          ONLY : GET_NAME_EXT_2D
USE BPCH2_MOD,          ONLY : GET_TAU0,       READ_BPCH2
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : DATA_DIR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : GET_YEAR
USE TRANSFER_MOD,       ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
Aseasonal natural emissions currently include termites (Fung et. al. 1991)
and soil absorption (Fung et. al. 1991).  Future additions may include
emissions from permafrost, clathrates, thermokarst lakes, or
geothermal vents.
```

REVISION HISTORY:

```
07 Mar 2012 - M. Payer    - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
12 Feb 2014 - K. Wecht    - Add modifications for 0.25 x 0.3125 NA grid
```

1.67.8 chemch4

Subroutine CHEMCH4 computes the chemical loss of CH4 (sources - sinks). (jsw, bnd, bmy, 6/8/00, 10/3/05)

INTERFACE:

```
      SUBROUTINE CHEMCH4( am_I_Root, Input_Opt,
     &                    State_Met, State_Chm, RC )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0, READ_BPCH2, GET_MODELNAME
      USE BPCH2_MOD,          ONLY : GET_NAME_EXT, GET_RES_EXT
      USE CMN_MOD
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD43
      USE DIRECTORY_MOD,      ONLY : DATA_DIR, OH_DIR
      USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
      USE ERROR_MOD,          ONLY : IT_IS_NAN, IT_IS_FINITE
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_OH_MOD,      ONLY : GET_GLOBAL_OH, OH
      USE TIME_MOD,           ONLY : GET_DAY,   GET_MONTH
      USE TIME_MOD,           ONLY : GET_NYMDb, GET_NYMDe
      USE TIME_MOD,           ONLY : GET_TAU,   GET_YEAR
      USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH
      USE TRANSFER_MOD,       ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
CH4 SOURCES
============================================================================
(1 ) Oxidation of methane, isoprene and monoterpenes (SRCO_fromHCs).
(2 ) Direct emissions of CO from fossil fuel combustion, biomass
      burning and wood (for fuel) burning (SR SETEMIS).
(3 ) Emissions.
                                                                            .
CH4 SINKS:
============================================================================
(1 ) Removal of CO by OH (SR OHparam & CO_decay).
(2 ) CO uptake by soils (neglected).
(3 ) Transport of CO to stratosphere from troposphere
      (in dynamical subroutines).
(4 ) Removal by OH (Clarissa's OH--climatol_OH.f and CO_decay.f)
(5 ) Transport of CH4 between troposphere and stratosphere, and
      destruction in strat (CH4_strat.f).
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
      James Wang (6/8/00).  Inserted into module "global_ch4_mod.f"
      by Bob Yantosca. (bmy, 1/16/01)
(2 ) CHEMCH4 is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) Updated comments (jsw, bmy, 2/12/01)
(4 ) LD43 is already declared in CMN_DIAG; don't redefine it (bmy, 11/15/01)
(5 ) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
      to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(6 ) Now reference AD from "dao_mod.f".  Now reference GEOS_CHEM_STOP from
      "error_mod.f"  Now make FIRSTCHEM a local SAVEd variable.  Now
      reference ALBD from "dao_mod.f".  Now use MONTH and JDATE from "CMN"
      instead of LMN and LDY. (bmy, 11/15/02)
(7 ) Remove NYMDb, NYMDe from the arg list.  Now use functions GET_MONTH,
      GET_NYMDb, GET_NYMDe, GET_MONTH, GET_DAY from the new "time_mod.f"
      (bmy, 3/27/03)
(8 ) Now reference DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(9 ) Remove reference to BPCH2_MOD, it's not needed (bmy, 10/3/05)
07 Mar 2012 - M. Payer    - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
23 Oct 2013 - R. Yantosca - Now pass objects to GET_GLOBAL_OH routine
12 Feb 2014 - K. Wecht    - Disable CH4 budget diagnostic (bracket the
                            code out with #ifdef blocks so it can be used)
```

1.67.9 read_coprod

Subroutine READ_COPROD reads production and destruction rates for CO in the stratosphere. CO destruction rate is assumed equal to CH4 production rate for the GEOS-Chem CH4 simulation. (bnd, bmy, 1/17/01, 10/3/05)

INTERFACE:

```
SUBROUTINE READ_COPROD
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE BPCH2_MOD,     ONLY : GET_NAME_EXT,    GET_MODELNAME
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_ZONAL

USE CMN_SIZE_MOD        ! Size parameters

IMPLICIT NONE
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
     James Wang (6/8/00).  Inserted into module "global_ch4_mod.f"
     by Bob Yantosca. (bmy, 1/16/01)
(2 ) READ_COPROD is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
     (bmy, 1/16/01)
(3 ) ARRAY needs to be dimensioned (1,JJPAR,LGLOB) (bmy, 9/26/01)
(4 ) Remove obsolete code from 9/01 (bmy, 10/24/01)
(5 ) Now reference DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(6 ) Now reads data for both GEOS and GCAP grids (bmy, 8/16/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Treat MERRA in the same way as for GEOS-5 (bmy, 8/13/10)
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
07 Mar 2012 - M. Payer    - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.67.10 read_ch4loss

Subroutine READ_CH4LOSS reads CH4 loss frequencies in the stratosphere. These values constitute a linearized stratospheric CH4 chemistry scheme. Loss frequencies from 4x5 degree output from the GMI model. Thanks to Lee Murray for the ch4 loss frequencies. (kjw, 11/19/2011)

INTERFACE:

```
SUBROUTINE READ_CH4LOSS
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE BPCH2_MOD,     ONLY : GET_NAME_EXT,    GET_MODELNAME
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D
USE TIME_MOD,      ONLY : GET_MONTH

USE CMN_SIZE_MOD        ! Size parameters

IMPLICIT NONE
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
     James Wang (6/8/00).  Inserted into module "global_ch4_mod.f"
     by Bob Yantosca. (bmy, 1/16/01)
(2 ) READ_CH4LOSS is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
     (bmy, 1/16/01)
(3 ) ARRAY needs to be dimensioned (1,JJPAR,LGLOB) (bmy, 9/26/01)
(4 ) Remove obsolete code from 9/01 (bmy, 10/24/01)
(5 ) Now reference DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(6 ) Now reads data for both GEOS and GCAP grids (bmy, 8/16/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Treat MERRA in the same way as for GEOS-5 (bmy, 8/13/10)
07 Mar 2012 - M. Payer    - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
12 Feb 2014 - K. Wecht    - Add modifications for 0.25 x 0.3125 NA grid
```

1.67.11 ch4_decay

Subroutine CH4_DECAY calculates the decay rate of CH4 by OH. OH is the only sink for CH4 considered here. (jsw, bnd, bmy, 1/16/01, 7/20/04)

INTERFACE:

```
SUBROUTINE CH4_DECAY( State_Met, State_Chm )
```

USES:

```
USE DIAG_MOD,           ONLY : AD19
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_TS_CHEM, ITS_A_NEW_YEAR
```

```
      USE TIME_MOD,           ONLY : GET_MONTH
      USE GIGC_State_Chm_Mod, ONLY : ChmState

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! ND19
      USE CMN_MOD                  ! LPAUSE
```

INPUT PARAMETERS:

```
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REMARKS:

```
    The annual mean tropopause is stored in the LPAUSE array
    (from header file "CMN").  LPAUSE is defined such that:

                                                                             .
    Levels            1 <= L <= LPAUSE(I,J) - 1 are tropospheric
           LPAUSE(I,J) <= L <= LLPAR            are stratospheric
                                                                             .
    We now use LPAUSE instead of NSKIPL to denote the strat/trop boundary.
    (bmy, 4/18/00)
                                                                             .
    Monthly loss of CH4 is summed in TCH4(3)
       TCH4(3)  = CH4 sink by OH
```

REVISION HISTORY:

```
    (1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
         James Wang (7/00).  Inserted into module "global_ch4_mod.f"
         by Bob Yantosca. (bmy, 1/16/01)
    (2 ) CH4_DECAY is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
         (bmy, 1/16/01)
    (3 ) Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
    (4 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
    07 Mar 2012 - M. Payer    - Added ProTeX headers
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    12 Feb 2014 - K. Wecht    - Disable CH4 budget diagnostic (bracket the
                                code out with #ifdef blocks so it can be used)
```

1.67.12 ch4_ohsave

Subroutine CH4_OHSAVE archives the CH3CCl3 lifetime from the OH used in the CH4 simulation. (bnd, jsw, bmy, 1/16/01, 7/20/04)

INTERFACE:

```
SUBROUTINE CH4_OHSAVE( State_Met, State_Chm )
```

USES:

```
! References to F90 modules
USE DIAG_OH_MOD,        ONLY : DO_DIAG_OH_CH4
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE TIME_MOD,           ONLY : GET_MONTH

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_MOD                  ! LPAUSE
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
TYPE(ChmState), INTENT(IN)  :: State_Chm   ! Chemistry State object
```

REMARKS:

```
The annual mean tropopause is stored in the LPAUSE array
(from header file "CMN").  LPAUSE is defined such that:

Levels            1 <= L <= LPAUSE(I,J) - 1 are tropospheric
        LPAUSE(I,J) <= L <= LLPAR           are stratospheric
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
      James Wang (7/00).  Inserted into module "global_ch4_mod.f"
      by Bob Yantosca. (bmy, 1/16/01)
(2 ) CH4_OHSAVE is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) Now call DO_DIAG_OH_CH4 to pass OH diagnostic info to the
      "diag_oh_mod.f" (bmy, 7/20/04)
07 Mar 2012 - M. Payer    - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.67.13 ch4_strat

Subroutine CH4_STRAT calculates uses production rates for CH4 to calculate loss of CH4 in above the tropopause. (jsw, bnd, bmy, 1/16/01, 7/20/04)

INTERFACE:

```
SUBROUTINE CH4_STRAT( State_Met, State_Chm )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_MONTH, GET_TS_CHEM
USE TRACER_MOD,         ONLY : CHECK_STT
USE GIGC_State_Chm_Mod, ONLY : ChmState

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_MOD                  ! LPAUSE
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REMARKS:

```
Production (mixing ratio/sec) rate provided by Dylan Jones.
Only production by CH4 + OH is considered.

The annual mean tropopause is stored in the LPAUSE array
(from header file "CMN").  LPAUSE is defined such that:

Levels           1 <= L <= LPAUSE(I,J) - 1 are tropospheric
       LPAUSE(I,J) <= L <= LLPAR           are stratospheric (bmy, 4/18/00)
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
      James Wang (7/00).  Inserted into module "global_ch4_mod.f"
      by Bob Yantosca. (bmy, 1/16/01)
(2 ) CH4_STRAT is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
      (bmy, 1/16/01)
(3 ) Removed LMN from the arg list and made it a local variable.  Now use
      functions GET_MONTH and GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(4 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
07 Mar 2012 - M. Payer    - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.67.14 ch4_budget

Subroutine CH4_BUDGET calculates the budget of CH4. This SR only works for monthly averages, so be sure to start on the first of the month and run to another first of the month! (jsw, bnd, bmy, 1/16/01, 10/3/05)
Disable CH4 Budget for SEAC4RS code to save memory kjw, 2/3/2014

INTERFACE:

```
      SUBROUTINE CH4_BUDGET( State_Chm )
```

USES:

```
      USE BPCH2_MOD,  ONLY : BPCH2,       BPCH2_HDR,   GET_MODELNAME
      USE GRID_MOD,   ONLY : GET_XOFFSET, GET_YOFFSET
      USE TIME_MOD,   ONLY : GET_MONTH,   GET_YEAR
      USE TIME_MOD,   ONLY : GET_DIAGb,   GET_CT_DYN
      USE GIGC_State_Chm_Mod, ONLY : ChmState

      USE CMN_SIZE_MOD     ! Size parameters
```

INPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(IN)  :: State_Chm   ! Chemistry State object
```

REMARKS:

```
    Store the sources/sinks of CH4 in TCH4 in total molecules
             ( 1) = Initial burden
             ( 2) = Final burden
    SINKS
             ( 3) = Tropospheric CH4 sink by OH
    SOURCES
             ( 4) = Total Sources
             ( 5) = Industrial  ( Gas + Oil + Mine )
             ( 6) = Agriculture ( Enteric fermentation + Manure + Rice + Waste
                                + Waste water )
             ( 7) = Biomass burning
             ( 8) = Termites
             ( 9) = Wetland
             (10) = Soil absorption
             (11) = Interhemispheric Exchange (+ = northward)
```

REVISION HISTORY:

```
    (1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
         James Wang (7/00).  Inserted into module "global_ch4_mod.f"
         by Bob Yantosca. (bmy, 1/16/01)
    (2 ) CH4_BUDGET is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
         (bmy, 1/16/01)
    (3 ) Updated comments (jsw, bmy, 2/13/01)
    (4 ) Renamed XLABEL to LABEL so as not to conflict w/ "CMN"
    (5 ) Now use functions GET_MONTH, GET_YEAR, GET_DIAGb, and GET_CT_DYN from
         "time_mod.f".  Removed LMN from the arg list and made it a local
         variable.  Use functions GET_XOFFSET and GET_YOFFSET from
         "grid_mod.f".  (bmy, 3/27/03)
    (6 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
    (7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (8 ) Modified for the run with new emissions (j drevet, 03/06)
    07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.67.15 sum_ch4

Function SUM_CH4 sums a section of the TCH4 array bounded by the input variables I1, I2, J1, J2, L1, L2, K1, K2. SUM_CH4 is called by module subroutine CH4_BUDGET. (jsw, bnd, bmy, 1/16/01)
Disable CH4 Budget for SEAC4RS code to save memory kjw, 2/3/2014

INTERFACE:

```
REAL*8 FUNCTION SUM_CH4( I1, I2, J1, J2, L1, L2, K1, K2, UPDOWN )
```

USES:

```
USE CMN_SIZE_MOD     ! Size parameters
USE CMN_MOD          ! LPAUSE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I1, I2 ! Min/max longitude indices of TCH4 to sum
INTEGER, INTENT(IN) :: J1, J2 ! Min/max latitude  indices of TCH4 to sum
INTEGER, INTENT(IN) :: L1, L2 ! Min/max altitude  indices of TCH4 to sum
INTEGER, INTENT(IN) :: K1, K2 ! Min/max tracer    indices of TCH4 to sum
INTEGER, INTENT(IN) :: UPDOWN ! Sum in trop (=1) or in strat (=0)
```

REMARKS:

```
Store the sources/sinks of CH4 in TCH4 in total molecules
         ( 1) = Initial burden
         ( 2) = Final burden
SINKS
         ( 3) = Tropospheric CH4 sink by OH
SOURCES
         ( 4) = Total Source
         ( 5) = Industral
         ( 6) = Agriculture
         ( 7) = Biomass Burning
         ( 8) = Termites
         ( 9) = Wetland
         (10) = Soil absorption
         (11) = Interhemispheric Exchange (+ = northward)
         (12) = ...
                                                                              .
Levels            1 <= L <= LPAUSE(I,J) - 1 are tropospheric
        LPAUSE(I,J) <= L <= LLPAR           are stratospheric (bmy, 4/17/00)
```

REVISION HISTORY:

```
(1 ) Created by Bryan Duncan (1/99).  Adapted for CH4 chemistry by
     James Wang (7/00).  Inserted into module "global_ch4_mod.f"
     by Bob Yantosca. (bmy, 1/16/01)
(2 ) CH4_BUDGET is independent of "CMN_OH", "CMN_CO", and "CMN_CO_BUDGET".
     (bmy, 1/16/01)
(3 ) Updated comments (jsw, bmy, 2/12/01)
07 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.67.16 ch4_distrib

Subroutine CH4_DISTRIB allocates the chemistry sink to different emission tracers. (ccc, 10/2/09)

INTERFACE:

```
SUBROUTINE CH4_DISTRIB( PREVCH4, Input_Opt, State_Chm )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE ERROR_MOD,          ONLY : SAFE_DIV

IMPLICIT NONE
```

INPUT PARAMETERS:

```
REAL*8                         :: PREVCH4(IIPAR,JJPAR,LLPAR)! CH4 bef chem
TYPE(OptInput), INTENT(IN)     :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
07 Mar 2012 - M. Payer    - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept Input_Opt, State_Chm args
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.67.17 init_global_ch4

Subroutine INIT_GLOBAL_CH4 allocates and zeroes module arrays. (bmy, 1/16/01, 10/15/02)

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_CH4
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
USE CMN_DIAG_MOD
```

REVISION HISTORY:

```
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
07 Mar 2012 - M. Payer    - Added ProTeX headers
12 Feb 2014 - K. Wecht    - Disable CH4 budget diagnostic (bracket the
                            code out with #ifdef blocks so it can be used)
```

1.67.18 cleanup_global_ch4

Subroutine CLEANUP_GLOBAL_CH4 deallocates module arrays. (bmy, 1/16/01)

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_CH4
```

REVISION HISTORY:

```
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
07 Mar 2012 - M. Payer    - Added ProTeX headers
12 Feb 2014 - K. Wecht    - Disable CH4 budget diagnostic (bracket the
                            code out with #ifdef blocks so it can be used)
```

1.68 Fortran: Module Interface global_hno3_mod

Module GLOBAL_HNO3_MOD contains variables and routines for reading the global monthly mean HNO3 fields from disk. (bmy, 10/15/02, 2/7/07)

INTERFACE:

```
MODULE GLOBAL_HNO3_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: GET_HNO3_UGM3
PUBLIC :: GET_HNO3_VV
PUBLIC :: GET_GLOBAL_HNO3
PUBLIC :: CLEANUP_GLOBAL_HNO3
```

REVISION HISTORY:

```
(1 ) Minor bug fix in FORMAT statement (bmy, 3/23/03)
(2 ) Cosmetic changes (bmy, 3/27/03)
(3 ) Now references "directory_mod.f" & "tracer_mod.f" (bmy, 7/20/04)
(4 ) Now suppress output from READ_BPCH2 with QUIET=T (bmy, 1/14/05)
(5 ) Now read total gas + aerosol HNO3 data (bec, bmy, 4/13/05)
(6 ) Now read files from "sulfate_sim_200508/offline" dir (bmy, 8/1/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
 8 Feb 2012 - R. Yantosca - Add modifications for GEOS_5.7.x
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
05 Sep 2013 - M. Sulprizio- Added ProTeX headers
```

1.68.1 get_hno3_ugm3

Function GET_HNO3_UGM3 converts monthly mean HNO3 mixing ratio from [v/v] to [ug/m3]. This is necessary for the RPMARES code. We allow HNO3 concentrations to evolve but relax back to the monthly mean value every 3 hours. (bmy, 10/15/02, 7/20/04)

INTERFACE:

```
FUNCTION GET_HNO3_UGM3( I, J, L, State_Met ) RESULT( HNO3_UGM3 )
```

USES:

```
USE CMN_SIZE_MOD             ! Size parameters
USE GIGC_State_Met_Mod, ONLY : MetState
USE TRACER_MOD,         ONLY : TCVV
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I, J, L     ! Lon, lat, alt indices
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
REAL*8                      :: HNO3_UGM3
```

REVISION HISTORY:

```
(1 ) Now references TCVV from "tracer_mod.f" (bmy, 7/20/04)
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
05 Sep 2013 - M. Sulprizio- Added ProTeX headers
```

1.68.2 get_hno3_vv

Function GET_HNO3_VV returns HNO3 concentrations in units of v/v (bec, 12/23/11)

INTERFACE:

```
FUNCTION GET_HNO3_VV( I, J, L ) RESULT( HNO3_VV )
```

USES:

```
USE CMN_SIZE_MOD      ! Size parameters
USE TRACER_MOD,  ONLY : TCVV
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L     ! Lon, lat, alt indices
```

RETURN VALUE:

```
REAL*8              :: HNO3_VV
```

REVISION HISTORY:

```
(1 ) Now references TCVV from "tracer_mod.f" (bmy, 7/20/04)
05 Sep 2013 - M. Sulprizio- Added ProTeX headers
```

1.68.3 get_global_hno3

Subroutine GET_GLOBAL_HNO3 reads global OH from binary punch files stored in the data directory. This is needed for the offline sulfate simulation. (bmy, 10/3/02, 2/7/07)

INTERFACE:

```
SUBROUTINE GET_GLOBAL_HNO3( THISMONTH )
```

USES:

```
USE CMN_SIZE_MOD
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE ERROR_MOD,     ONLY : ERROR_STOP
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D,  TRANSFER_3D
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Bug fix in FORMAT statement: Replace missing commas (bmy, 3/23/03)
(2 ) Cosmetic changes (bmy, 3/27/03)
(3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(4 ) Now suppress output from READ_BPCH2 with QUIET=T (bmy, 1/14/05)
(5 ) Now read total gas + aerosol HNO3 data (bec, bmy, 4/13/05)
(6 ) GEOS-3 and GEOS-4 data comes from model runs w/ 30 layers.  Also now
     read from "sulfate_sim_200508/offline" directory (bmy, 8/1/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
```

```
(8 ) Renamed GRID30LEV to GRIDREDUCED (bmy, 2/7/07)
(9 ) Treat MERRA in the same way as for GEOS-5 (bmy, 8/13/10)
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
05 Sep 2013 - M. Sulprizio- Added ProTeX headers
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.68.4 init_global_hno3

Subroutine INIT_GLOBAL_HNO3 allocates and zeroes the HNO3 array (bmy, 10/15/02)

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_HNO3
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,    ONLY : ALLOC_ERR
```

REVISION HISTORY:

```
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
(2 ) Now dimension HNO3 as (IIPAR,JJPAR,LLPAR) (bmy, 8/1/05)
05 Sep 2013 - M. Sulprizio- Added ProTeX headers
```

1.68.5 cleanup_global_hno3

Subroutine CLEANUP_GLOBAL_HNO3 deallocates the HNO3 array. (bmy, 10/15/02)

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_HNO3
```

REVISION HISTORY:

```
05 Sep 2013 - M. Sulprizio- Added ProTeX headers
```

1.69 Fortran: Module Interface global_NO3_mod

Module GLOBAL_NO3_MOD contains variables and routines for reading the global monthly mean NO3 concentration from disk. These are needed for the offline sulfate/aerosol simulation.

INTERFACE:

```
MODULE GLOBAL_NO3_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
! Array to store global monthly mean OH field
REAL*8, PUBLIC, ALLOCATABLE :: NO3(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: GET_GLOBAL_NO3
PUBLIC  :: CLEANUP_GLOBAL_NO3
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: INIT_GLOBAL_NO3
```

REVISION HISTORY:

```
15 Oct 2002 - R. Yantosca - Initial version
(1 ) Adapted from "global_oh_mod.f" (bmy, 10/3/02)
(2 ) Minor bug fix in FORMAT statements (bmy, 3/23/03)
(3 ) Cosmetic changes (bmy, 3/27/03)
(4 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(5 ) Now suppress output from READ_BPCH2 with QUIET=T (bmy, 1/14/05)
(6 ) Now read from "sulfate_sim_200508/offline" directory (bmy, 8/1/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Bug fix: now zero ARRAY (phs, 1/22/07)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.69.1 get_global_NO3

Subroutine GET_GLOBAL_NO3 reads monthly mean NO3 data fields. These are needed for simulations such as offline sulfate/aerosol.

INTERFACE:

```
SUBROUTINE GET_GLOBAL_NO3( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0
USE BPCH2_MOD,     ONLY : READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D_TROP

USE CMN_SIZE_MOD                 ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
15 Oct 2002 - R. Yantosca - Initial version
(1 ) Minor bug fix in FORMAT statements (bmy, 3/23/03)
(2 ) Cosmetic changes (bmy, 3/27/03)
(3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(4 ) Now suppress output from READ_BPCH2 with QUIET=T (bmy, 1/14/05)
(5 ) GEOS-3 & GEOS-4 data comes from model runs w/ 30 levels.  Also now
     read from "sulfate_sim_200508/offline" directory.  Also now read
     up to LLTROP levels.  Now reference TRANSFER_3D_TROP from
     "transfer_mod.f". (bmy, 8/1/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Now zero local variable ARRAY (phs, 1/22/07)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.69.2 init_global_NO3

Subroutine INIT_GLOBAL_NO3 allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_NO3
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
15 Oct 2002 - R. Yantosca - Initial version
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
(2 ) Now allocate NO3 array up to LLTROP levels (bmy, 8/1/05)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.69.3 cleanup_global_no3

Subroutine CLEANUP_GLOBAL_NO3 deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_NO3
```

REVISION HISTORY:

```
15 Oct 2002 - R. Yantosca - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.70 Fortran: Module Interface global_NOx_mod

Module GLOBAL_NOx_MOD contains variables and routines for reading the global monthly mean NOx concentration from disk.

INTERFACE:

```
MODULE GLOBAL_NOX_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
! Array to store global monthly mean BNOX field
REAL*8, PUBLIC, ALLOCATABLE :: BNOX(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CLEANUP_GLOBAL_NOx
PUBLIC :: GET_GLOBAL_NOx
PUBLIC :: INIT_GLOBAL_NOx
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) Updated comments, made cosmetic changes (bmy, 6/13/01)
(2 ) Updated comments (bmy, 9/4/01)
(3 ) Now regrid BNOX array from 48L to 30L for GEOS-3 if necessary.
     (bmy, 1/14/02)
(4 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
(5 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
     MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(6 ) Now references "error_mod.f" (bmy, 10/15/02)
(7 ) Minor bug fix in FORMAT statements (bmy, 3/23/03)
(8 ) Cosmetic changes to improve output (bmy, 3/27/03)
(9 ) Now references "directory_mod.f" and "unix_cmds_mod.f" (bmy, 7/20/04)
(10) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.70.1 get_global_nox

Subroutine GET_GLOBAL_NOx reads global NOx from binary punch files from a full chemistry run. This NOx data is needed to calculate the CO yield from isoprene oxidation.

INTERFACE:

```
SUBROUTINE GET_GLOBAL_NOx( THISMONTH, Input_Opt )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_NAME_EXT
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE BPCH2_MOD,          ONLY : GET_TAU0
USE BPCH2_MOD,          ONLY : READ_BPCH2
USE CMN_SIZE_MOD
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TRANSFER_MOD,       ONLY : TRANSFER_3D
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: THISMONTH   ! Current month
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) Now use version of GET_TAU0 with 3 arguments.  Now call READ_BPCH2
     with IIPAR,JJPAR,LGLOB.  Call TRANSFER_3D to cast from REAL*4 to
     REAL*8 and to regrid to 30 levels for GEOS-3 (if necessary).  ARRAY
     should now be of size (IIPAR,JJPAR,LGLOB). (bmy, 1/14/02)
(2 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
(3 ) Bug fix in FORMAT statement: replace missing commas.  Also make sure
     to define FILENAME before printing it (bmy, 4/28/03)
(4 ) Now references TEMP_DIR, DATA_DIR from "directory_mod.f".  Also
     references Unix unzipping commands from "unix_cmds_mod.f".
     (bmy, 7/20/04)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
11 Apr 2013 - R. Yantosca - Now pass directory fields etc with Input_Opt
```

1.70.2 init_global_NOx

Subroutine INIT_GLOBAL_NOx allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_NOX
```

USES:

```
      USE ERROR_MOD, ONLY : ALLOC_ERR

      USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
    28 Jul 2000 - R. Yantosca - Initial version
    (1 ) BNOX now needs to be sized (IIPAR,JJPAR,LLPAR) (bmy, 1/14/02)
    (2 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
    (3 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.70.3 cleanup_global_nox

Subroutine CLEANUP_GLOBAL_NOx deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_GLOBAL_NOX
```

REVISION HISTORY:

```
    28 Jul 2000 - R. Yantosca - Initial version
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.71 Fortran: Module Interface global_o1d_mod

Module GLOBAL_O1D_MOD contains variables and routines for reading the global monthly mean O1D stratospheric concentration from disk. This is used in the H2/HD simulation. The O1D fields were obtained from Gabriele Curci GEOS-Chem simulation in the stratosphere (v5.03).

INTERFACE:

```
      MODULE GLOBAL_O1D_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      ! Array to store global monthly mean O1D field
      REAL*8, PUBLIC, ALLOCATABLE :: O1D(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_GLOBAL_O1D
      PUBLIC :: GET_GLOBAL_O1D
      PUBLIC :: INIT_GLOBAL_O1D
```

REVISION HISTORY:

```
    18 Sep 2007 - H. U. Price, P. Le Sager - Initial version
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.71.1 get_global_O1D

Subroutine GET_GLOBAL_O1D reads global O1D from binary punch files stored in the /data/ctm/GEOS_MEAN directory. This O1D data is needed for the H2/HD mechanisms in Tagged H2.

INTERFACE:

```
      SUBROUTINE GET_GLOBAL_O1D( THISMONTH )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT
      USE BPCH2_MOD,     ONLY : GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0
      USE BPCH2_MOD,     ONLY : READ_BPCH2
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TRANSFER_MOD,  ONLY : TRANSFER_3D

      USE CMN_SIZE_MOD                  ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
    18 Sep 2007 - H. U. Price, P. Le Sager - Initial version
    (1 ) GET_GLOBAL_O1D assumes that we are reading global O1D data that
         occupies all CTM levels.  Contact Bob Yantosca (bmy@io.harvard.edu)
         for IDL regridding code which will produce the appropriate O1D files.
    (2 ) ARRAY should now be of size (IIPAR,JJPAR,LGLOB). (bmy, 1/11/02)
    (3 ) Now point to new O1D files in the ??? subdirectory.
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.71.2 init_global_o1d

Subroutine INIT_GLOBAL_O1D allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_O1D
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
18 Sep 2007 - H. U. Price, P. Le Sager - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.71.3 cleanup_global_O1D

Subroutine CLEANUP_GLOBAL_O1D deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_O1D
```

REVISION HISTORY:

```
18 Sep 2007 - H. U. Price, P. Le Sager - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.72 Fortran: Module Interface global_o3_mod

Module GLOBAL_O3_MOD contains variables and routines for reading the global monthly mean O3 concentration from disk. These are needed for the offline sulfate/aerosol simulation.

INTERFACE:

```
MODULE GLOBAL_O3_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC              :: CLEANUP_GLOBAL_O3
PUBLIC              :: GET_GLOBAL_O3
```

PUBLIC DATA MEMBERS:

```
PUBLIC              :: O3
REAL*8, ALLOCATABLE :: O3(:,:,:)        ! Global monthly mean OH field
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE             :: INIT_GLOBAL_O3
```

REVISION HISTORY:

```
(1 ) Now references "directory_mod.f" (bmy, 7/20/04)
(2 ) Now reads O3 data from "sulfate_sim_200508/offline" dir (bmy, 8/30/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Bug fixes in GET_GLOBAL_O3 (bmy, 12/1/05)
(5 ) Now reads O3 from MERGE files, which include stratospheric O3 from
     COMBO, for GEOS-3 and GEOS-4 met fields (phs, 1/19/07)
(6 ) Bug fix in GET_GLOBAL_O3 (bmy, 1/14/09)
13 Aug 2010 - R. Yantosca - Added modifications for MERRA
13 Aug 2010 - R. Yantosca - Added ProTeX headers
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.72.1 get_global_o3

Subroutine GET_GLOBAL_O3 reads monthly mean O3 data fields. These are needed for simulations such as offline sulfate/aerosol.

INTERFACE:

```
SUBROUTINE GET_GLOBAL_O3( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D

USE CMN_SIZE_MOD                       ! Size parameters
IMPLICIT NONE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: THISMONTH       ! Current month
```

REVISION HISTORY:

```
23 Mar 2003 - R. Yantosca - Initial version
(1 ) Minor bug fix in FORMAT statements (bmy, 3/23/03)
(2 ) Cosmetic changes (bmy, 3/27/03)
(3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(4 ) Now reads O3 data from "sulfate_sim_200508/offline" dir (bmy, 8/30/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Tracer number for O3 is now 51.  Also need to call TRANSFER_3D_TROP
     since the new O3 data file only goes up to LLTROP. (bmy, 11/18/05)
(7 ) Modified to include stratospheric O3 -- Requires access to new
     MERGE.O3* files. (phs, 1/19/07)
(8 ) Renamed GRID30LEV to GRIDREDUCED (bmy, 2/7/07)
(9 ) Bug fix: don't call TRANSFER_3D if you use GRIDREDUCED (bmy, 1/14/09)
13 Aug 2010 - R. Yantosca - Rewrote logic more cleanly
13 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
08 Dec 2009 - R. Yantosca - Added ProTeX headers
19 Aug 2010 - R. Yantosca - Removed hardwiring of data directory
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.72.2 init_global_o3

Subroutine INIT_GLOBAL_O3 allocates the O3 module array.

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_O3
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
13 Jul 2004 - R. Yantosca - Initial version
(1 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 7/13/04)
(2 ) Now dimension O3 with LLTROP (bmy, 12/1/05)
(3 ) Now dimension O3 with LLPAR (phs, 1/19/07)
13 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.72.3 cleanup_global_o3

Subroutine CLEANUP_GLOBAL_O3 deallocates the O3 array.

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_O3
```

REVISION HISTORY:

```
13 Jul 2004 - R. Yantosca - Initial version
13 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.73 Fortran: Module Interface global_oc_mod

Module GLOBAL_OC_MOD contains variables and routines for reading the global monthly mean OC concentration from disk. Based on module GLOBAL_OH_MOD. (clf, 1/19/2011).

INTERFACE:

```
MODULE GLOBAL_OC_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: GET_GLOBAL_OC
PUBLIC :: CLEANUP_GLOBAL_OC
```

PUBLIC DATA MEMBERS:

```
PUBLIC :: OC
```

REVISION HISTORY:

```
19 January 2011 - C.L. Friedman - Initial Version
```

1.73.1 get_global_oc

GET_GLOBAL_OC reads global OC from binary punch files stored on disk. OC data is needed for partitioning of gas phase organics into OC particles (e.g., POPs). (clf, 1/19/2011)

INTERFACE:

```
SUBROUTINE GET_GLOBAL_OC( THISMONTH, THISYEAR )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D

USE CMN_SIZE_MOD        ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: THISMONTH, THISYEAR
```

REVISION HISTORY:

```
19 January 2011 - C.L. Friedman - Initial Version
```

1.73.2 init_global_oc

Subroutine INIT_GLOBAL_OC allocates and zeroes the OC array, which holds global monthly mean OC concentrations. (clf, 1/19/2011)

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_OC
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
19 January 2011 - C.L. Friedman - Initial Version
```

1.73.3 cleanup_global_oc

Subroutine CLEANUP_GLOBAL_OC deallocates the OC array. (clf, 1/19/2011)

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_OC
```

REVISION HISTORY:

```
19 January 2011 - C.L. Friedman - Initial Version
```

1.74 Fortran: Module Interface global_oh_mod

Module GLOBAL_OH_MOD contains variables and routines for reading the global monthly mean OH concentration from disk.

INTERFACE:

```
MODULE GLOBAL_OH_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC DATA MEMBERS:

```
      ! Array to store global monthly mean OH field [molec/cm3]
      REAL*8, PUBLIC, ALLOCATABLE :: OH(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_GLOBAL_OH
      PUBLIC :: GET_GLOBAL_OH
      PUBLIC :: INIT_GLOBAL_OH
```

REVISION HISTORY:

```
    28 Jul 2000 - R. Yantosca - Initial version
    (1 ) Updated comments (bmy, 9/4/01)
    (2 ) Now use routines from "transfer_mod.f" to regrid OH to 30 levels
         for reduced GEOS-3 grid.  Also size OH array properly. (bmy, 1/14/02)
    (3 ) Eliminate obsolete code from 11/01 (bmy, 2/27/02)
    (4 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
         MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
    (5 ) Now use updated OH fields (bmy, 10/2/02)
    (6 ) Now references "error_mod.f" (bmy, 10/15/02)
    (7 ) Minor bug fixes in FORMAT statements (bmy, 3/23/03)
    (8 ) Cosmetic changes to simplify output (bmy, 3/27/03)
    (9 ) Bug fix: OH should be (IIPAR,JJPAR,LLPAR) (bmy, 5/4/04)
    (10) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    01 Dec 2010 - R. Yantosca - Added ProTeX headers
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.74.1 get_global_oh

Subroutine GET_GLOBAL_OH reads global OH from binary punch files stored in the /data/ctm/GEOS_MEAN directory. This OH data is needed as oxidant for various offline chemistry mechanisms.

INTERFACE:

```
      SUBROUTINE GET_GLOBAL_OH( am_I_Root, Input_Opt,
     &                          State_Met, THISMONTH, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE BPCH2_MOD,            ONLY : GET_NAME_EXT
      USE BPCH2_MOD,            ONLY : GET_RES_EXT
      USE BPCH2_MOD,            ONLY : GET_TAU0
      USE BPCH2_MOD,            ONLY : READ_BPCH2
```

```
USE DAO_MOD,              ONLY : AIRDEN_FULLGRID
USE DAO_MOD,              ONLY : AIRQNT_FULLGRID
USE DIRECTORY_MOD,        ONLY : OH_DIR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod,   ONLY : OptInput
USE GIGC_State_Met_Mod,   ONLY : MetState
USE TRANSFER_MOD,         ONLY : TRANSFER_3D
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Obj for input options
TYPE(MetState), INTENT(IN)    :: State_Met   ! Obj for met fields
INTEGER,        INTENT(IN)    :: THISMONTH   ! Current month
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) GET_GLOBAL_OH assumes that we are reading global OH data that occupies
     all CTM levels.  Contact Bob Yantosca (bmy@io.harvard.edu) for IDL
     regridding code which will produce the appropriate OH files.
(2 ) Now use version of GET_TAU0 with 3 arguments.  Now call READ_BPCH2
     with IIPAR,JJPAR,LGLOB.  Call TRANSFER_3D to cast from REAL*4 to
     REAL*8 and to regrid to 30 levels for GEOS-3 (if necessary).
     ARRAY should now be of size (IIPAR,JJPAR,LGLOB). (bmy, 1/11/02)
(3 ) Now point to new OH files in the v4-26 subdirectory.  Also eliminated
     obsolete code from 11/01. (bmy, 2/27/02)
(4 ) Now point to OH files in the v4-33 subdirectory. (bmy, 10/2/02)
(5 ) Replace missing commas in the FORMAT statement (bmy, 3/23/03)
(6 ) Cosmetic changes to simplify output (bmy, 3/27/03)
(7 ) Add Mat's OH as an option.  Also read bpch file quietly (bmy, 5/4/04)
(8 ) Now use OH_DIR from "directory_mod.f" (bmy, 7/20/04)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
23 Oct 2013 - R. Yantosca - Now accept Input_Opt argument
29 Oct 2013 - R. Yantosca - Remove TRANSFER_3D_NOLUMP routine, we can just
                            instead do a direct cast assignment
```

1.74.2 init_global_oh

Subroutine INIT_GLOBAL_OH allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_GLOBAL_OH
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
(1 ) OH array now needs to be sized (IIPAR,JJPAR,LGLOB) (bmy, 1/14/02)
(2 ) Also eliminated obsolete code from 11/01 (bmy, 2/27/02)
(3 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
(4 ) OH should be (IIPAR,JJPAR,LLPAR): avoid subscript errors (bmy, 5/4/04)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.74.3 cleanup_global_oh

Subroutine CLEANUP_GLOBAL_OH deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_GLOBAL_OH
```

REVISION HISTORY:

```
28 Jul 2000 - R. Yantosca - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.75 Fortran: Module Interface

Module H2_HD_MOD contains variables and routines used for the geographically tagged H2-HD simulation.

INTERFACE:

```
MODULE H2_HD_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CHEM_H2_HD
PUBLIC  :: CLEANUP_H2_HD
PUBLIC  :: EMISS_H2_HD
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: INIT_H2_HD
PRIVATE :: READ_OCEAN_H2
PRIVATE :: READ_H2YIELD
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
07 Sep 2011 - P. Kasibhatla - Modified to include GFED3 (psk, 1/5/11)
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.75.1 emiss_h2_hd

Subroutine EMISS_H2_HD reads in emissions for the H2/HD simulation.

INTERFACE:

```
SUBROUTINE EMISS_H2_HD( am_I_Root, Input_Opt,
&                       State_Met, State_Chm, RC )
```

USES:

```
USE BIOFUEL_MOD,         ONLY : BIOFUEL,     BIOFUEL_BURN
USE BIOMASS_MOD,         ONLY : BIOMASS
USE CMN_DIAG_MOD
USE CMN_O3_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,            ONLY : AD29,        AD46,         AD10em
USE GEIA_MOD,            ONLY : GET_IHOUR,   GET_DAY_INDEX
USE GEIA_MOD,            ONLY : READ_GEIA,   READ_TODX
USE GEIA_MOD,            ONLY : READ_LIQCO2, READ_TOTCO2
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,            ONLY : GET_XOFFSET, GET_YOFFSET
USE GRID_MOD,            ONLY : GET_AREA_CM2
USE MEGANUT_MOD,         ONLY : XLTMMP
USE MEGAN_MOD,           ONLY : GET_EMMONOT_MEGAN
USE MEGAN_MOD,           ONLY : GET_EMISOP_MEGAN
USE TRACERID_MOD,        ONLY : IDBCO
USE TIME_MOD,            ONLY : GET_MONTH,   GET_TAU
USE TIME_MOD,            ONLY : GET_YEAR,    GET_TS_EMIS
USE TRACERID_MOD,        ONLY : IDBFCO,      IDTH2,        IDTHD
USE TAGGED_CO_MOD,       ONLY : INIT_TAGGED_CO
USE TAGGED_CO_MOD,       ONLY : READ_ACETONE,  EMACET
USE SCALE_ANTHRO_MOD,    ONLY : GET_ANNUAL_SCALAR
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
(1 ) Now references GET_ANNUAL_SCALAR (phs, 3/11/08)
(2 ) Move XLTMMP to module MEGANUT_MOD (ccc, 11/20/09)
(3 ) IDBCO is in TRACERID_MOD now (hotp 7/31/09)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
08 Dec 2011 - M. Payer    - Remove obsolete GEIA biogenic emissions and add
                            MEGAN biogenic emissions.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
27 Nov 2012 - R. Yantosca - Replace SUNCOS_MID with State_Met%SUNCOS_MID
```

1.75.2 chem_h2_hd

Subroutine CHEM_H2_HD performs H2 and HD chemistry. Chemical production is by oxidation of BVOC and CH4. Loss is via reaction with OH and uptake by soils. In the stratosphere, H2 is also lost by reaction with O(1D). For HD, we include the fractionation from photochemical oxidation (162 permil), and loss by OH and soil uptake.

INTERFACE:

```
SUBROUTINE CHEM_H2_HD( am_I_Root, Input_Opt,
&                      State_Met, State_Chm, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD10
USE ERROR_MOD,          ONLY : CHECK_VALUE
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
```

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE GLOBAL_OH_MOD,      ONLY : GET_GLOBAL_OH,   OH
USE GLOBAL_O1D_MOD,     ONLY : GET_GLOBAL_O1D, O1D
USE GLOBAL_NOX_MOD,     ONLY : GET_GLOBAL_NOX,  BNOX
USE GRID_MOD,           ONLY : GET_YMID, GET_AREA_M2, GET_AREA_CM2
USE PRESSURE_MOD,       ONLY : GET_PCENTER, GET_PEDGE
USE TIME_MOD,           ONLY : GET_TS_CHEM,     GET_MONTH
USE TIME_MOD,           ONLY : GET_YEAR
USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH, ITS_A_NEW_YEAR
USE DRYDEP_MOD,         ONLY : DEPSAV
USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
USE TRACERID_MOD,       ONLY : IDTH2, IDTHD
USE TAGGED_CO_MOD,      ONLY : GET_ALPHA_ISOP
USE TAGGED_CO_MOD,      ONLY : READ_PCO_LCO_STRAT
USE TAGGED_CO_MOD,      ONLY : GET_PCO_LCO_STRAT
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
11 Apr 2013 - R. Yantosca - Now pass Input_Opt to GET_GLOBAL_NOx
10 Jun 2013 - R. Yantosca - Avoid array temporaries in CHECK_VALUE
```

1.75.3 read_ocean_h2

Subroutine READ_OCEAN_H2 reads in oceanic H2 emissions from nitrogen fixation.

INTERFACE:

```
SUBROUTINE READ_OCEAN_H2( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD  ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Current month
```

REMARKS:

```
Ocean H2 emissions are based on the N2 oceanic fixation rates
determined by Curtis Deutsch (University of Washington) by
assimilating observed nutrient distributions in the oceans:
"Spatial coupling of nitrogen inputs and losses in the ocean",
Deutsch et al., Nature 445, 163-167 (2007).

The oceanic N2 fixation rates are read in and then scaled to
obtain a total ocean H2 source of 6 TgH2/yr. This source is
assumed to be constant and does not vary annually.
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.75.4 read_h2yield

Subroutine READ_H2YIELD reads in the relative H2/CO yield from photochemical production. This has been archived monthly (PH2/PCO using the PRODLOSS diagnostic and turning H2 on as an active species) from a full chemistry simulation at 4x5, v7-03-03, year 2001, GEOS-3 met fields.

INTERFACE:

```
SUBROUTINE READ_H2YIELD( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE TRANSFER_MOD,  ONLY : TRANSFER_3D
USE DIRECTORY_MOD, ONLY : DATA_DIR
 USE GRID_MOD,      ONLY : GET_YMID

USE CMN_SIZE_MOD                ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.75.5 init_h2_hd

Subroutine INIT_H2_HD allocates memory to module arrays.

INTERFACE:

```
SUBROUTINE INIT_H2_HD
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.75.6 cleanup_h2_hd

Subroutine CLEANUP_H2_HD deallocates memory from previously allocated module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_H2_HD
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager -- Initial version
02 Dec 2010 - R. Yantosca - Added ProTeX headers
```

1.76 Fortran: Module Interface i6_read_mod

Module I6_READ_MOD contains routines that unzip, open, and read the GEOS-Chem I6 (instantaneous 6-hour) met fields from disk.

INTERFACE:

```
MODULE I6_READ_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
PUBLIC :: GET_I6_FIELDS_1
PUBLIC :: GET_I6_FIELDS_2
PUBLIC :: OPEN_I6_FIELDS
PUBLIC :: UNZIP_I6_FIELDS
```

REMARKS:

```
This module reads GEOS-4, GEOS-5, and GCAP met fields
MERRA met fields are read in routines merra_*_mod.F
GEOS-FP met fields are read in geosfp_read_mod.F
```

REVISION HISTORY:

```
23 Jun 2003 - R. Yantosca - Initial version
(1 ) Adapted from "dao_read_mod.f" (bmy, 6/23/03)
(2 ) Now use TIMESTAMP_STRING for formatted date/time output (bmy, 10/28/03)
(3 ) Now reads either zipped or unzipped files (bmy, 12/11/03)
(4 ) Now skips past the GEOS-4 ident string (bmy, 12/12/03)
(5 ) Now references "directory_mod.f", "unix_cmds_mod.f", and
      "logical_mod.f" (bmy, 7/20/04)
(6 ) Now references FILE_EXISTS from "file_mod.f" (bmy, 3/23/05)
(7 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(8 ) Now account for GEOS-4 coastal boxes in LWI properly (bmy, 8/10/05)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(10) Now make LWI REAL*8 for near-land formulation (ltm, bmy, 5/9/06)
(11) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(12) Now set negative SPHU to a very small positive # (bmy, 9/8/06)
(13) Now read TROPP files for GEOS-4, and check tropopause level
     in case of a variable tropopause (phs, bmy, bdf, 9/14/06)
(14) Now get the # of A-3 fields from the file ident string (bmy, 10/7/08)
(15) Remove references to IN_CLOUD_OD (bmy, 10/15/09)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
03 Aug 2012 - R. Yantosca - Now make IU_I6 a private module variable
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.76.1 unzip_i6_fields

Subroutine UNZIP_I6_FIELDS invokes a FORTRAN system call to uncompress GEOS-Chem I-6 met field files and store the uncompressed data in a temporary directory, where GEOS-CHEM can read them. The original data files are not disturbed.

INTERFACE:

```
SUBROUTINE UNZIP_I6_FIELDS( Input_Opt, OPTION, NYMD )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*),  INTENT(IN) :: OPTION    ! Unzip option
INTEGER, OPTIONAL, INTENT(IN) :: NYMD      ! YYYY/MM/DD of file to unzip
TYPE(OptInput),    INTENT(IN) :: Input_Opt ! Input Options object
```

REVISION HISTORY:

```
15 Jun 1998 - R. Yantosca - Initial version
(1 ) Adapted from UNZIP_MET_FIELDS of "dao_read_mod.f" (bmy, 6/23/03)
(2 ) Directory information YYYY/MM or YYYYMM is now contained w/in
     GEOS_1_DIR, GEOS_S_DIR, GEOS_3_DIR, GEOS_4_DIR (bmy, 12/11/03)
(3 ) Now reference "directory_mod.f" and "unix_cmds_mod.f". Now prevent
     EXPAND_DATE from overwriting directory paths with Y/M/D tokens in
     them (bmy, 7/20/04)
(4 ) Now modified for GEOS-5 and GCAP met fields
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
11 Apr 2013 - R. Yantosca - Now pass fields via Input_Opt
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.76.2 open_i6_fields

Subroutine OPEN_I6_FIELDS opens the I-6 met fields file for date NYMD and time NHMS.

INTERFACE:

```
SUBROUTINE OPEN_I6_FIELDS( NYMD, NHMS, Input_Opt )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE CMN_SIZE_MOD             ! Size parameters
USE ERROR_MOD,          ONLY : ERROR_STOP
USE FILE_MOD,           ONLY : IOERROR, FILE_EXISTS
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
INTEGER,        INTENT(IN) :: NYMD        ! YYYY/MM/dd and
INTEGER,        INTENT(IN) :: NHMS        !  hh:mm:ss of data
```

REVISION HISTORY:

```
15 Jun 1998 - R. Yantosca - Initial version
(1 ) Adapted from OPEN_MET_FIELDS of "dao_read_mod.f" (bmy, 6/13/03)
(2 ) Now opens either zipped or unzipped files (bmy, 12/11/03)
(3 ) Now skips past the GEOS-4 ident string (bmy, 12/12/03)
(4 ) Now references "directory_mod.f" instead of CMN_SETUP.  Also now
     references LUNZIP from "logical_mod.f".  Also now prevents EXPAND_DATE
     from overwriting Y/M/D tokens in directory paths. (bmy, 7/20/04)
(5 ) Now use FILE_EXISTS from "file_mod.f" to determine if file unit IU_I6
     refers to a valid file on disk (bmy, 3/23/05
(6 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(9 ) Updated for variable tropopause (phs, bmy, 9/14/06)
(10) Now get the # of A-3 fields from the file ident string (bmy, 10/7/08)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
03 Aug 2012 - R. Yantosca - Now use findFreeLUN to define IU_I6 locally
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
11 Apr 2013 - R. Yantosca - Now pass fields via Input_Opt
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.76.3 get_i6_fields_1

Subroutine GET_I6_FIELDS_1 is a wrapper for routine READ_I6. This routine calls READ_I6 properly for reading I-6 fields from GEOS-3, GEOS-4, GEOS-5, or GCAP met data sets at the START of a GEOS-CHEM run.

INTERFACE:

```
SUBROUTINE GET_I6_FIELDS_1( NYMD, NHMS, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: NYMD    ! YYYY/MM/DD
INTEGER,        INTENT(IN)    :: NHMS    !  and hh:mm:ss of desired data
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
23 Jun 2003 - R. Yantosca - Initial version
(1 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(3 ) Now also read TO3 and TTO3 for GEOS-5 (bmy, 1/16/07)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.76.4 get_i6_fields_2

Subroutine GET_I6_FIELDS_2 is a wrapper for routine READ_I6. This routine calls READ_I6 properly for reading I-6 fields from GEOS-3, GEOS-4, GEOS-5, or GCAP met data sets every 6 hours during a GEOS-CHEM run.

INTERFACE:

```
SUBROUTINE GET_I6_FIELDS_2( NYMD, NHMS, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: NYMD    ! YYYY/MM/DD
INTEGER,        INTENT(IN)    :: NHMS    !  and hh:mm:ss of desired data
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
23 Jun 2003 - R. Yantosca - Initial version
(1 ) Now modified for GEOS-5 and GCAP met fields
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(3 ) Now read TO3 and TTO3 for GEOS-5 (bmy, 1/16/07)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.76.5 get_n_i6

Function GET_N_I6 returns the number of I-6 fields per met data set.

INTERFACE:

```
FUNCTION GET_N_I6( NYMD ) RESULT( N_I6 )
```

USES:

```
USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD   ! YYYY/MM/DD date
```

RETURN VALUE:

```
INTEGER             :: N_I6   ! Number of I-6 fields in file
```

REVISION HISTORY:

```
(1 ) Now modified for GCAP and GEOS-5 met fields (swu, bmy, 5/25/05)
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(3 ) Increase # of I-6 fields to 5 for GEOS-5 (bmy, 1/17/06)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.76.6 check_time

Function CHECK_TIME checks to see if the timestamp of the I6 field just read from disk matches the current time. If so, then it's time to return the I6 field to the calling program.

INTERFACE:

```
FUNCTION CHECK_TIME( XYMD, XHMS, NYMD, NHMS ) RESULT( ITS_TIME )
```

USES:

```
      USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: XYMD       ! YYYY/MM/DD and hh:mm:ss
      INTEGER, INTENT(IN) :: XHMS       !  timestamp of I6 data in file
      INTEGER, INTENT(IN) :: NYMD       ! YYYY/MM/DD and hh:mm:ss
      INTEGER, INTENT(IN) :: NHMS       !  timestamp for desired data
```

RETURN VALUE:

```
      LOGICAL             :: ITS_TIME   ! =T if XYMD & XHMS match NYMD & NHMS
```

REVISION HISTORY:

```
    23 Jun 2003 - R. Yantosca - Initial version
    (1 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
    25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.76.7 read_i6

Subroutine READ_I6 reads GEOS I-6 (inst. 6-hr) met fields from disk.

INTERFACE:

```
      SUBROUTINE READ_I6( NYMD, NHMS,
     &                    ALBD, LWI,   PS,   SLP,  SPHU, TMPU,
     &                    TO3,  TROPP, TTO3, UWND, VWND         )
```

USES:

```
      USE DIAG_MOD,       ONLY : AD66,            AD67
      USE FILE_MOD,       ONLY : IOERROR
      USE LOGICAL_MOD,    ONLY : LVARTROP
      USE TIME_MOD,       ONLY : SET_CT_I6,       TIMESTAMP_STRING
      USE TRANSFER_MOD,   ONLY : TRANSFER_2D,     TRANSFER_3D

      USE CMN_SIZE_MOD         ! Size parameters
      USE CMN_DIAG_MOD         ! NDxx flags
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)            :: NYMD   ! YYYYMMDD
      INTEGER, INTENT(IN)            :: NHMS   !  and hhmmss of desired data
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT), OPTIONAL :: ALBD (IIPAR,JJPAR      )
      REAL*8,  INTENT(OUT), OPTIONAL :: LWI  (IIPAR,JJPAR      )
      REAL*8,  INTENT(OUT), OPTIONAL :: PS   (IIPAR,JJPAR      )
      REAL*8,  INTENT(OUT), OPTIONAL :: SLP  (IIPAR,JJPAR      )
```

```
      REAL*8,  INTENT(OUT), OPTIONAL :: SPHU (IIPAR,JJPAR,LLPAR)
      REAL*8,  INTENT(OUT), OPTIONAL :: TMPU (IIPAR,JJPAR,LLPAR)
      REAL*8,  INTENT(OUT), OPTIONAL :: TO3  (IIPAR,JJPAR      )
      REAL*8,  INTENT(OUT), OPTIONAL :: TROPP(IIPAR,JJPAR      )
      REAL*8,  INTENT(OUT), OPTIONAL :: TTO3 (IIPAR,JJPAR      )
      REAL*8,  INTENT(OUT), OPTIONAL :: UWND (IIPAR,JJPAR,LLPAR)
      REAL*8,  INTENT(OUT), OPTIONAL :: VWND (IIPAR,JJPAR,LLPAR)
```

REMARKS:

```
(3 ) ALBD  : (2-D) GMAO Surface albedo            [unitless]
(4 ) LWI   : (2-D) GMAO Land-water indices        [unitless]
(5 ) PS    : (2-D) GMAO Surface pressure          [hPa]
(6 ) SLP   : (2-D) GMAO Sea-level pressures       [hPa]
(7 ) SPHU  : (3-D) GMAO Specific humidity field   [g H2O/kg air]
(8 ) TMPU  : (3-D) GMAO Temperature field         [K]
(9 ) TO3   : (2-D) GMAO GEOS-5 column ozone       [DU]
(10) TROPP : (2-D) GMAO tropopause pressure pressures     [hPa]
(11) TTO3  : (2-D) GMAO GEOS-5 trop column ozone  [DU]
(12) UWND  : (3-D) GMAO U-wind (zonal wind)       [m/s]
(13) VWND  : (3-D) GMAO V-wind (meridional wind)  [m/s]
```

REVISION HISTORY:

```
08 May 1998 - R. Yantosca - Initial version
(1 ) Adapted from "READ_I6" of "dao_read_mod.f" (bmy, 6/23/03)
(2 ) Now use function TIMESTAMP_STRING from "time_mod.f" for formatted
     date/time output. (bmy, 10/28/03)
(3 ) Round up to account for GEOS-4 coastal boxes properly (bmy, 8/10/05)
(4 ) For near-land formulation: (a) make LWI a REAL*8 and (b) do not round
     up LWI for GEOS-4 meteorology (ltm, bmy, 5/9/06)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(6 ) Now set negative SPHU to a small positive number (1d-32) instead of
     zero, so as not to blow up logarithms (bmy, 9/8/06)
(7 ) Now read TROPP files for GEOS-4 (phs, bmy, bdf, 9/12/06)
(8 ) Now read TO3 and TTO3 for GEOS-5 (bmy, 1/16/07)
(9 ) Now get the # of A-3 fields from the file ident string (bmy, 10/7/08)
(10) Remove references to IN_CLOUD_OD (bmy, 10/15/09)
03 Aug 2012 - R. Yantosca - Now use locally-defined IU_I6, IU_TP file LUNs
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.76.8 i6_check

Subroutine I6_CHECK prints an error message if not all of the I-6 met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE I6_CHECK( NFOUND, N_I6 )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! Number of I-6 fields found in file
INTEGER, INTENT(IN) :: N_I6     ! Expected number of I-6 fields
```

REVISION HISTORY:

```
27 Oct 2000 - R. Yantosca - Initial version
(1 ) Adapted from DAO_CHECK from "dao_read_mod.f" (bmy, 6/23/03)
25 Feb 2014 - M. Sulprizio- Added ProTeX headers
```

1.77 Fortran: Module Interface icoads_ship_mod

Module ICOADS_SHIP_MOD contains variables and routines to read the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) ship emissions. Base year is 2002.

INTERFACE:

```
MODULE ICOADS_SHIP_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_ICOADS_SHIP
PUBLIC  :: EMISS_ICOADS_SHIP
PUBLIC  :: GET_ICOADS_SHIP
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: ICOADS_SCALE_FUTURE
PRIVATE :: INIT_ICOADS_SHIP
PRIVATE :: TOTAL_ICOADS_SHIP_TG
```

REMARKS:

```
Source: ICOADS Emissions data for NOx, SOx, and CO were downloaded from
http://coast.cms.udel.edu/GlobalShipEmissions/Inventories/
Reference: Wang, C., J. J. Corbett, and J. Firestone, \emph{Improving
Spatial representation of Global Ship Emissions Inventories},
Environ. Sci. Technol., 42, (1), 193-199, 2008.
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use GET_AREA_CM2 instead
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.77.1 get_icoads_ship

Function GET_ICOADS_SHIP returns the ICOADS ship emissions for GEOS-Chem grid box (I,J) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s].

INTERFACE:

```
  FUNCTION GET_ICOADS_SHIP( I,    J,     N,
 &                          MOLEC_CM2_S, KG_S ) RESULT( VALUE )
```

USES:

```
  USE GRID_MOD,     ONLY : GET_AREA_CM2
  USE TRACER_MOD,   ONLY : XNUMOL
  USE TRACERID_MOD, ONLY : IDTNO, IDTCO, IDTSO2, IDTNH3, IDTNO2
  USE TIME_MOD,     ONLY : GET_YEAR, GET_MONTH
```

INPUT PARAMETERS:

```
  ! Longitude, latitude, and tracer indices
  INTEGER, INTENT(IN)           :: I, J, N

  ! OPTIONAL -- return emissions in [molec/cm2/s]
  LOGICAL, INTENT(IN), OPTIONAL :: MOLEC_CM2_S

  ! OPTIONAL -- return emissions in [kg/s]
  LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
  ! Emissions output
  REAL*8                        :: VALUE
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
```

1.77.2 emiss_icoads_ship

Subroutine EMISS_ICOADS_SHIP reads the ICOADS emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
      SUBROUTINE EMISS_ICOADS_SHIP( am_I_Root, Input_Opt,
     &                              State_Chm, RC         )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TIME_MOD,           ONLY : GET_YEAR,      GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_1x1
      USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
      USE CMN_SIZE_MOD
      USE CMN_O3_MOD
#if defined( DEVEL )
      USE TRACERID_MOD,       ONLY : IDTNO, IDTCO, IDTSO2, IDTNH3
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a algorithm
   24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
   03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
   28 Feb 2013 - C. Holmes & G. Vinken - Bug fix for molecular weight of NOx
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.77.3 icoads_scale_future

applies the IPCC future scale factors

INTERFACE:

```
SUBROUTINE ICOADS_SCALE_FUTURE
```

USES:

```
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff

USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
```

1.77.4 total_icoads_ship_Tg

Subroutine TOTAL_ICOADS_SHIP_TG prints the totals for ship emissions of NOx, CO, and SO2.

INTERFACE:

```
SUBROUTINE TOTAL_ICOADS_SHIP_TG( MONTH )
```

USES:

```
USE CMN_SIZE_MOD            ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: MONTH   ! Month of data to compute totals
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
```

1.77.5 init_icoads_ship

Subroutine INIT_ICOADS_SHIP allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_ICOADS_SHIP( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
02 Mar 2012 - R. Yantosca - Remove A_CM2 array
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.77.6 cleanup_icoads_ship

Subroutine CLEANUP_ICOADS_SHIP deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_ICOADS_SHIP
```

REVISION HISTORY:

```
21 Jul 2009 - Chulkyu Lee & P. Le Sager - Initial Version
```

1.78 Fortran: Module Interface input_mod

Module INPUT_MOD contains routines that read the GEOS-Chem input file at the start of the run and pass the information to several other GEOS-Chem F90 modules.

INTERFACE:

```
MODULE INPUT_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: INITIALIZE_GEOS_GRID
      PUBLIC  :: READ_INPUT_FILE
      PUBLIC  :: GIGC_Init_Extra
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: READ_ONE_LINE
      PRIVATE :: SPLIT_ONE_LINE
      PRIVATE :: READ_SIMULATION_MENU
      PRIVATE :: READ_TRACER_MENU
      PRIVATE :: READ_AEROSOL_MENU
      PRIVATE :: READ_EMISSIONS_MENU
      PRIVATE :: READ_FUTURE_MENU
      PRIVATE :: READ_CHEMISTRY_MENU
      PRIVATE :: READ_TRANSPORT_MENU
      PRIVATE :: READ_CONVECTION_MENU
      PRIVATE :: READ_DEPOSITION_MENU
      PRIVATE :: READ_OUTPUT_MENU
      PRIVATE :: READ_DIAGNOSTIC_MENU
      PRIVATE :: SET_TINDEX
      PRIVATE :: READ_ND49_MENU
      PRIVATE :: READ_ND50_MENU
      PRIVATE :: READ_ND51_MENU
      PRIVATE :: READ_ND51b_MENU
      PRIVATE :: READ_ND63_MENU
      PRIVATE :: READ_PROD_LOSS_MENU
      PRIVATE :: READ_UNIX_CMDS_MENU
      PRIVATE :: READ_NESTED_GRID_MENU
      PRIVATE :: READ_ARCHIVED_OH_MENU
      PRIVATE :: READ_O3PL_MENU
      PRIVATE :: READ_BENCHMARK_MENU
      PRIVATE :: READ_CH4_MENU
      PRIVATE :: VALIDATE_DIRECTORIES
      PRIVATE :: CHECK_DIRECTORY
      PRIVATE :: CHECK_TIME_STEPS
      PRIVATE :: IS_LAST_DAY_GOOD
      PRIVATE :: INIT_INPUT
#if defined( TOMAS )
      PRIVATE :: INIT_TOMAS_MICROPHYSICS
#endif
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Now references LSOA in READ_AEROSOL_MENU (bmy, 9/28/04)
   (2 ) Fixed error checks and assign LSPLIT for tagged Hg.  Also now
        refernces LAVHRRLAI from "logical_mod.f" (eck, bmy, 12/20/04)
```

```
(3 ) Updated for crystalline/aqueous aerosol tracers.  Also moved routine
     IS_LAST_DAY_GOOD here from "main.f".  Also now references
     "ocean_mercury_mod.f".  Also now open the bpch file for output in
     READ_DIAGNOSTIC_MENU instead of in "main.f".  (cas, sas, bmy, 2/3/05)
(4 ) Now references "diag03_mod.f" and "diag41_mod.f".  Fixed minor
     bugs.  Now references FILE_EXISTS from "file_mod.f".  Updated
     comments. (bmy, 3/28/05)
(5 ) Now modified for GEOS-5 and GCAP met fields.  Also now set LSPLIT
     correctly for HCN/CH3CN simulation. (swu, xyp, bmy, 6/30/05)
(6 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(7 ) Now read LMEGAN switch for MEGAN biogenics.  Now read variable
     DATA_DIR_1x1 for 1x1 emissions files, etc.  Now reference XNUMOL and
     XNUMOLAIR from "tracer_mod.f" (tmf, bmy, 10/25/05)
(8 ) Now read LEMEP switch for EMEP emissions (bdf, bmy, 11/1/05)
(9 ) Now added MERCURY MENU section.  Also fixed bug in READ_ND48_MENU.
     (eck, cdh, bmy, 3/6/06)
(10) Now read LGFED2BB switch for GFED2 biomass emissions (bmy, 4/5/06)
(11) Bug fix for GCAP in IS_LAST_DAY_GOOD.  Also now read LCTH, LMFLUX,
     LPRECON in READ_EMISSIONS_MENU. (bmy, 5/10/06)
(12) Updated for ND42 SOA concentration diagnostic (dkh, bmy, 5/22/06)
(13) Modified for future emissions (swu, bmy, 6/1/06)
(14) Modified for BRAVO emissions (rjp, kfb, bmy, 6/26/06)
(15) Remove support for GEOS-1 and GEOS-STRAT met fields.  Also modified
     for David Streets' emissions. (bmy, 8/17/06)
(16) Modified for variable tropopause.  Also set dimension of ND28 diag
     for GFED2 or default biomass burning.  Now read if Time Spent in
     Troposphere is wanted (phs, bmy, 10/17/06)
(17) Now modified for OTD-LIS local redistribution.  Remove references
     to GEOS-1 and GEOS-STRAT run dirs. (bmy, 11/5/07)
(18) New error traps for OTD-LIS scaling, dependent on met field type.
     Bug fix, create string variables for ERROR_STOP.  Bug fix: use ND52
     in call to SET_TINDEX in READ_DIAGNOSTIC_MENU. (ltm, bmy, 2/11/08)
(19) Bug fix: use (0,0) in call to INIT_TRANSFER (phs, 6/17/08)
(20) Minor fix in READ_TRANSPORT_MENU (cdh, bmy, 7/7/08)
(21) Fixed typo READ_EMISSIONS_MENU for GEOS-3 (bmy, 10/30/08)
(22) Set upper limit on dynamic timestep for 0.5 x 0.666 nested
     grids (yxw, bmy, dan, 11/6/08)
(23) Now read LCAC switch for CAC emissions (amv, 1/09/2008)
(24) Move the call to NDXX_SETUP (phs, 11/18/08)
(25) Minor bug fix in READ_DIAGNOSTIC_MENU (tmf, 2/10/09)
(26) Add LMEGANMONO switch in emission menu (ccc, 3/2/09)
(27) Add LDICARB switch in aerosol menu (ccc, tmf, 3/10/09)
(28) Now read LCOOKE in aerosol menu (phs, 5/18/09)
(29) Add CH4_MENU in input.geos (kjw, 8/18/09)
(30) Corrected typos in CHECK_TIME_STEPS (bmy, 8/21/09)
(31) Now read LLINOZ in READ_SIMULATION_MENU (dbm, bmy, 10/16/09)
(32) Remove reference to obsolete embedded chemistry stuff (bmy, 2/25/10)
(33) Remove depreciated lightning options (ltm, bmy, 1/24/11)
```

```
25 Aug 2010 - R. Yantosca - Added modifications for MERRA
27 Aug 2010 - R. Yantosca - Added ProTeX headers
16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
29 Jul 2011 - R. Yantosca - Bug fix in READ_EMISSIONS_MENU for nested NA
07 Sep 2011 - P. Kasibhatla - Modified to include monthly GFED3
17 Jan 2012 - P. Kasibhatla - Modified to include daily and 3-hourly GFED3
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met data
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
30 Jul 2012 - R. Yantosca - READ_INPUT_FILE now accepts am_I_Root from
                            both the ESMF interface and main.F
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
03 Aug 2012 - R. Yantosca - Now make IU_GEOS a global module variable
                            so that we can define it with findFreeLun
02 Nov 2012 - R. Yantosca - Now pass the Input Options object to routines;
                            this will eventually replace logical_mod, etc.
26 Feb 2013 - M. Long     - Now make INITIALIZE_GEOS_GRID a public routine
04 Mar 2013 - R. Yantosca - Add routine GIGC_Init_Extra to move some init
                            calls out of the run stage when using ESMF
23 Apr 2013 - R. Yantosca - For TOMAS, rename READ_MICROPHYSICS_MENU to
                            INIT_TOMAS_MICROPHYSICS
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
17 Sep 2013 - R. Yantosca - Increase MAXDIM from 255 to 500 for more tracers
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP everywhere
26 Sep 2013 - R. Yantosca - Now read GEOS_FP_DIR from Input_Opt everywhere
```

1.78.1 read_input_file

Subroutine READ_INPUT_FILE is the driver program for reading the GEOS-Chem input file "input.geos" from disk.

INTERFACE:

```
SUBROUTINE READ_INPUT_FILE( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE CHARPAK_MOD,        ONLY : STRREPL
USE FILE_MOD,           ONLY : IOERROR
USE GAMAP_MOD,          ONLY : DO_GAMAP
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE SEASALT_MOD,        ONLY : INIT_SEASALT
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now call DO_GAMAP from "gamap_mod.f" to create "diaginfo.dat" and
     "tracerinfo.dat" files after all diagnostic menus have been read in
(2 ) Now call NDXX_setup from this routine (phs, 11/18/08)
(3 ) Now call READ_ND51b_MENU (amv, bmy, 12/18/09)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root from main.F, so that we
                            can get rid of duplicate code in DEVEL blocks
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
03 Aug 2012 - R. Yantosca - Now make IU_GEOS a global module variable
                            so that we can define it with findFreeLun
15 Oct 2012 - R. Yantosca - Add EXTERNAL_GRID, XTERNAL_FORCING to #ifdef
16 Oct 2012 - R. Yantosca - Don't call CHECK_TIME_STEPS if we are calling
                            READ_INPUT_FILE from the ESMF interface
09 Nov 2012 - R. Yantosca - Now pass Input_Opt to lower-level routines
06 Dec 2012 - R. Yantosca - Now call CHECK_TIME_STEPS when we are connecting
                            to the GEOS-5 GCM via the ESMF environment,
19 Mar 2013 - R. Yantosca - When using ESMF interface to GEOS-5, append
                            ".rc" to input.geos (instead of ___.rc)
04 Apr 2013 - R. Yantosca - Now pass objects to DO_GAMAP routine
```

1.78.2 read_one_line

Subroutine READ_ONE_LINE reads a line from the input file. If the global variable VERBOSE is set, the line will be printed to stdout. READ_ONE_LINE can trap an unexpected EOF if LOCATION is passed. Otherwise, it will pass a logical flag back to the calling routine, where the error trapping will be done.

INTERFACE:

```
FUNCTION READ_ONE_LINE( EOF, LOCATION ) RESULT( LINE )
```

USES:

```
USE FILE_MOD, ONLY : IOERROR
```

INPUT PARAMETERS:

```
    CHARACTER(LEN=*), INTENT(IN), OPTIONAL :: LOCATION    ! Msg to display
```

OUTPUT PARAMETERS:

```
    LOGICAL,          INTENT(OUT)          :: EOF         ! Denotes EOF
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
03 Aug 2012 - R. Yantosca - Now make IU_GEOS a global module variable
                            so that we can define it with findFreeLun
17 Sep 2013 - R. Yantosca - Extend line length to read in more tracers
```

1.78.3 split_one_line

Subroutine SPLIT_ONE_LINE reads a line from the input file (via routine READ_ONE_LINE), and separates it into substrings.

SPLIT_ONE_LINE also checks to see if the number of substrings found is equal to the number of substrings that we expected to find. However, if you don't know a-priori how many substrings to expect a-priori, you can skip the error check.

INTERFACE:

```
    SUBROUTINE SPLIT_ONE_LINE( SUBSTRS, N_SUBSTRS, N_EXP, LOCATION )
```

USES:

```
    USE CHARPAK_MOD, ONLY: STRSPLIT
```

INPUT PARAMETERS:

```
    ! Number of substrings we expect to find
    INTEGER,            INTENT(IN)  :: N_EXP

    ! Name of routine that called SPLIT_ONE_LINE
    CHARACTER(LEN=*),   INTENT(IN)  :: LOCATION
```

OUTPUT PARAMETERS:

```
    ! Array of substrings (separated by " ")
    CHARACTER(LEN=255), INTENT(OUT) :: SUBSTRS(MAXDIM)

    ! Number of substrings actually found
    INTEGER,            INTENT(OUT) :: N_SUBSTRS
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
17 Sep 2013 - R. Yantosca - Extend LINE to 500 chars to allow more tracers
```

1.78.4 read_simulation_menu

Subroutine READ_SIMULATION_MENU reads the SIMULATION MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_SIMULATION_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD,      ONLY : DATA_DIR,    DATA_DIR_1x1, GCAP_DIR
      USE DIRECTORY_MOD,      ONLY : GEOS_4_DIR,  GEOS_5_DIR
      USE DIRECTORY_MOD,      ONLY : MERRA_DIR,   GEOS_FP_DIR
      USE DIRECTORY_MOD,      ONLY : RUN_DIR
      USE DIRECTORY_MOD,      ONLY : TEMP_DIR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GRID_MOD,           ONLY : SET_XOFFSET, SET_YOFFSET
      USE LOGICAL_MOD,        ONLY : LSVGLB,      LUNZIP,       LWAIT
      USE LOGICAL_MOD,        ONLY : LVARTROP
      USE RESTART_MOD,        ONLY : SET_RESTART
      USE TIME_MOD,           ONLY : SET_BEGIN_TIME,   SET_END_TIME
      USE TIME_MOD,           ONLY : SET_CURRENT_TIME, SET_DIAGb
      USE TIME_MOD,           ONLY : SET_NDIAGTIME,    GET_TAU
      USE TRANSFER_MOD,       ONLY : INIT_TRANSFER
#if defined( EXTERNAL_GRID ) || defined( EXTERNAL_FORCING )
      USE TIME_MOD,           ONLY : Accept_External_Date_Time
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Bug fix: Read LSVGLB w/ the * format and not w/ '(a)'. (bmy, 2/23/05)
    (2 ) Now read GEOS_5_DIR and GCAP_DIR from input.geos (swu, bmy, 5/25/05)
    (3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (4 ) Now references DATA_DIR_1x1 for 1x1 emissions files (bmy, 10/24/05)
    (5 ) Now read switch for using variable tropopause or not (phs, 9/14/06)
```

```
(6 ) Remove references to GEOS-1 and GEOS-STRAT run dirs.  Now calls
     INIT_TRANSFER (bmy, 11/5/07)
(7 ) Fix typo in "print to screen" section  (phs, 6/1/08)
(8 ) Call INIT_TRANSFER w/ (0,0) instead of (I0,J0) (phs, 6/17/08)
(10) Now read LLINOZ switch from input.geos file (dbm, bmy, 10/16/09)
13 Aug 2010 - R. Yantosca - Now read MERRA_DIR
19 Aug 2010 - R. Yantosca - Set LUNZIP=F for MERRA met fields.
27 Aug 2010 - R. Yantosca - Added ProTeX headers
01 Feb 2012 - R. Yantosca - Now read GEOS_57_DIR for GEOS-5.7.x met
08 Feb 2012 - R. Yantosca - Set LUNZIP=F for GEOS-5.7.x met fields
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now call routine INITIALIZE_GEOS_GRID to
                            initialize horizontal grid parameters
10 Jun 2012 - L. Murray   - Move Linoz to chemistry menu
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
06 Dec 2012 - R. Yantosca - Now get NYMDb, NHMSb, NYMDe, NHMSe from the ESMF
                            environment when connecting to the GEOS-5 GCM
11 Dec 2012 - R. Yantosca - ACCEPT_DATE_TIME_FROM_ESMF has now been renamed
                            to ACCEPT_EXTERNAL_DATE_TIME
```

1.78.5 initialize_geos_grid

Subroutine INITIALIZE_GEOS_GRID calls routines from grid_mod.F90 to initialize the horizontal grid parameters.

INTERFACE:

```
SUBROUTINE INITIALIZE_GEOS_GRID( am_I_Root, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE GLOBAL_GRID_MOD, ONLY : COMPUTE_GLOBAL_GRID
USE GRID_MOD,        ONLY : COMPUTE_GRID
USE GRID_MOD,        ONLY : INIT_GRID
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root    ! Is this the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC           ! Success or failure?
```

REMARKS:

```
The module grid_mod.F90 has been modified to save grid parameters in 3D
format, which will facilitate interfacing GEOS-Chem to a GCM.
```

.

The module global_grid_mod.F90 contains several of the global grid arrays (*_g) originally in grid_mod.F. These arrays are used in regridding GFED3 biomass emissions, which are available on a 0.5x0.5 global grid. The global arrays may need to be used in the future for regridding other emissions for nested grids.

.

REVISION HISTORY:

```
01 Mar 2012 - R. Yantosca - Initial version
01 May 2012 - M. Payer    - Add call to COMPUTE_GLOBAL_GRID for nested grids
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
30 Nov 2012 - R. Yantosca - Accept external DLON, DLAT from ESMF interface
26 Feb 2013 - R. Yantosca - Now pass I_LO, J_LO to COMPUTE_GRID
28 Feb 2013 - R. Yantosca - Bug fix for GEOS-5 interface: Now call
                            Compute_Grid with 1..IIPAR, I..JJPAR
01 Jul 2013 - R. Yantosca - Don't use 1/2 sized polar boxes for GCAP
```

1.78.6 read_tracer_menu

Subroutine READ_TRACER_MENU reads the TRACER MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_TRACER_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CHARPAK_MOD,  ONLY : ISDIGIT
USE BIOFUEL_MOD,  ONLY : SET_BFTRACE
USE BIOMASS_MOD,  ONLY : SET_BIOTRCE
USE ERROR_MOD,    ONLY : ALLOC_ERR, ERROR_STOP
USE LOGICAL_MOD,  ONLY : LSPLIT
USE TRACER_MOD,   ONLY : ID_EMITTED,     ID_TRACER
USE TRACER_MOD,   ONLY : SIM_TYPE,       N_TRACERS
USE TRACER_MOD,   ONLY : TCVV,           TRACER_COEFF
USE TRACER_MOD,   ONLY : TRACER_CONST,   TRACER_MW_G
USE TRACER_MOD,   ONLY : TRACER_MW_KG,   TRACER_N_CONST
USE TRACER_MOD,   ONLY : TRACER_NAME,    INIT_TRACER
USE TRACER_MOD,   ONLY : XNUMOL,         XNUMOLAIR
USE TRACER_MOD,   ONLY : ITS_A_FULLCHEM_SIM
USE TRACER_MOD,   ONLY : ITS_A_HCN_SIM
USE TRACER_MOD,   ONLY : ITS_A_MERCURY_SIM
USE TRACERID_MOD, ONLY : TRACERID
```

```
USE CMN_SIZE_MOD                    ! Size parameters
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now set LSPLIT correctly for Tagged Hg simulation (eck, bmy, 12/13/04)
(2 ) Now initialize ocean mercury module (sas, bmy, 1/20/05)
(3 ) Now set LSPLIT correctly for Tagged HCN/CH3CN sim (xyp, bmy, 6/30/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now reference XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(6 ) Now move call to INIT_OCEAN_MERCURY to READ_MERCURY_MENU (bmy, 2/24/06)
(7 ) Now do not call SET_BIOTRCE anymore; it's obsolete (bmy, 4/5/06)
(8 ) Add SET_BIOTRCE to initialize IDBxxxs. (fp, 2/26/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2012 - R. Yantosca - Now pass CHEM_STATE as an argument (DEVEL only)
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
07 Nov 2012 - R. Yantosca - Now define Input_Opt%ITS_A_*_SIM fields
28 Oct 2013 - R. Yantosca - Set Input_Opt%ITS_A_SPECIALTY_SIM = .FALSE.
                            when running GEOS-Chem in an ESMF environment
```

1.78.7 read_aerosol_menu

Subroutine READ_AEROSOL_MENU reads the AEROSOL MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_AEROSOL_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE ERROR_MOD,    ONLY : ERROR_STOP
USE LOGICAL_MOD,  ONLY : LSULF, LCARB, LSOA,   LSVPOA
USE LOGICAL_MOD,  ONLY : LDUST, LDEAD, LSSALT, LCRYST
USE LOGICAL_MOD,  ONLY : LDICARB
```

```
      USE TRACER_MOD,   ONLY : N_TRACERS
      USE TRACER_MOD,   ONLY : SALA_REDGE_um,      SALC_REDGE_um
      USE TRACER_MOD,   ONLY : ITS_AN_AEROSOL_SIM, ITS_A_FULLCHEM_SIM
      USE TRACERID_MOD, ONLY : IDTDMS,   IDTSO2,   IDTSO4,  IDTSO4s
      USE TRACERID_MOD, ONLY : IDTMSA,   IDTNH3,   IDTNH4,  IDTNITs
      USE TRACERID_MOD, ONLY : IDTAS,    IDTAHS,   IDTLET,  IDTNH4aq
      USE TRACERID_MOD, ONLY : IDTSO4aq, IDTBCPO,  IDTBCPI, IDTOCPO
      USE TRACERID_MOD, ONLY : IDTOCPI
      USE TRACERID_MOD, ONLY : IDTDST1,  IDTDST2,  IDTDST3, IDTDST4
      USE TRACERID_MOD, ONLY : IDTSALA,  IDTSALC
      USE TRACERID_MOD, ONLY : IDTSOAG,  IDTSOAM
      ! SOAupdate: remove old tracers and add new mtp (hotp 5/24/10)
      USE TRACERID_MOD, ONLY : IDTMTPA,  IDTLIMO,  IDTMTPO
      USE TRACERID_MOD, ONLY : IDTBENZ,  IDTTOLU,  IDTXYLE
      USE TRACERID_MOD, ONLY : IDTTSOA1, IDTTSOA2, IDTTSOA3
      USE TRACERID_MOD, ONLY : IDTISOA1, IDTISOA2, IDTISOA3
      USE TRACERID_MOD, ONLY : IDTASOA1, IDTASOA2, IDTASOA3, IDTASOAN
      ! semivolpoa : add POA (hotp 8/23/09)
      ! POA now 1 and 2 (hotp 10/11/09), and NAP (hotp 7/28/10)
      USE TRACERID_MOD, ONLY : IDTPOA1,  IDTPOA2,  IDTPOG1,  IDTPOG2
      USE TRACERID_MOD, ONLY : IDTOPOA1, IDTOPOA2, IDTOPOG1, IDTOPOG2
      USE TRACERID_MOD, ONLY : IDTNAP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Now reference LSOA (bmy, 9/28/04)
    (2 ) Now stop run if LSOA=T and SOA tracers are undefined (bmy, 11/19/04)
    (3 ) Now reference LCRYST from "logical_mod.f".  Also now check to make
         prevent aerosol tracers from being undefined if the corresponding
         logical switch is set. (cas, bmy, 1/14/05)
    (4 ) Now also require LSSALT=T when LSULF=T, since we now compute the
         production of SO4 and NIT w/in the seasalt aerosol (bec, bmy, 4/13/05)
    (5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (6 ) Now update error check for SOG4, SOA4 (dkh, bmy, 6/1/06)
    (7 ) Add LDICARB switch to cancel SOG condensation onto OC aerosols.
```

```
    (ccc, tmf, 3/10/09)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
```

1.78.8 init_tomas_microphys

Subroutine INIT_TOMAS_MICROPHYS will initialize the TOMAS microphysics package. This replaces the former subroutine READ_MICROPHYSICS_MENU.

INTERFACE:

```
SUBROUTINE INIT_TOMAS_MICROPHYSICS( am_I_Root, Input_Opt, RC )
```

USES:

```
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TOMAS_MOD,          ONLY : INIT_TOMAS
USE TRACERID_MOD,       ONLY : IDTNK1
USE TRACERID_MOD,       ONLY : IDTSF1
USE TRACERID_MOD,       ONLY : IDTSS1
USE TRACERID_MOD,       ONLY : IDTECOB1, IDTECIL1, IDTOCOB1
USE TRACERID_MOD,       ONLY : IDTOCIL1, IDTH2SO4, IDTDUST1
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REMARKS:

```
We now invoke TOMAS by compiling GEOS-Chem and setting either the TOMAS=yes
(30 bins, default) or TOMAS40=yes (40 bins, optional) switches.  The old
LTOMAS logical switch is now obsolete because all of the TOMAS code is
segregated from the rest of GEOS-Chem with #ifdef blocks.  Therefore,
we no longer need to read the microphysics menu, but we still need to
apply some error checks and then call INIT_TOMAS. (bmy, 4/23/13)
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now read LNEI99 -- switch for EPA/NEI99 emissions (bmy, 11/5/04)
(2 ) Now read LAVHRRLAI-switch for using AVHRR-derived LAI (bmy, 12/20/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now read LMEGAN -- switch for MEGAN biogenics (tmf, bmy, 10/20/05)
(5 ) Now read LEMEP -- switch for EMEP emissions (bdf, bmy, 11/1/05)
(6 ) Now read LGFED2BB -- switch for GFED2 biomass emissions (bmy, 4/5/06)
(7 ) Now read LOTDLIS, LCTH, LMFLUX, LPRECON for lightning options
     (bmy, 5/10/06)
(8 ) Now read LBRAVO for BRAVO Mexican emissions (rjp, kfb, bmy, 6/26/06)
(9 ) Now read LEDGAR for EDGAR emissions (avd, bmy, 7/11/06)
(10) Now read LSTREETS for David Streets' emissions (bmy, 8/17/06)
(11) Kludge: Reset LMFLUX or LPRECON to LCTH, as the MFLUX and PRECON
     lightning schemes have not yet been implemented.  Rename LOTDLIS
     to LOTDREG.  Also read LOTDLOC for the OTD-LIS local redistribution
     of lightning flashes (cf B. Sauvage).  Make sure LOTDREG and
     LOTDLOC are not both turned on at the same time. (bmy, 1/31/07)
(12) Add LOTDSCALE to the list of LNOx options (ltm, bmy, 9/24/07)
(13) Add new error traps for OTD-LIS options, dependent on met field type
     (ltm, bmy, 11/29/07)
(14) Bug fix, create string variables for ERROR_STOP (bmy, 1/24/08)
(15) Now read LCAC for CAC emissions (amv, 1/09/2008)
(16) Now read LEDGARSHIP, LARCSHIP and LEMEPSHIP (phs, 12/5/08)
(17) Fixed typo in message for GEOS-3 (bmy, 10/30/08)
(18) Now read LVISTAS (amv, 12/2/08)
(19) Now read L8DAYBB, L3HRBB and LSYNOPBB for GFED2 8-days and 3hr
     emissions, and LICARTT for corrected EPA (phs, yc, 12/17/08)
(20) Add a specific switch for MEGAN emissions for monoterpenes and MBO
     (ccc, 2/2/09)
(21) Now read LICOADSSHIP (cklee, 6/30/09)
(22) Bug fix: for now, if LEMEPSHIP is turned on but LEMEP is turned off,
     just turn off LEMEPSHIP and print a warning msg. (mak, bmy, 10/18/09)
(23) Now accounts for NEI2005 (amv, phs, 10/9/09)
(24) Included optional flag for using MODIS LAI data (mpb,2009).
(25) Included optional flag for using PCEEA model (mpb, 2009)
(26) Now force settings for EU, NA, CC nested grids (amv, bmy, 12/18/09)
(27) Now force MEGAN to use MODIS LAI (ccarouge, bmy, 2/24/10)
(28) Add separate switch for NOx fertilizer. (fp, 2/29/10)
(29) Add scaling for isoprene and NOx emissions. (fp, 2/29/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
23 Apr 2013 - R. Yantosca - Renamed to INIT_TOMAS_MICROPHYS
30 Jan 2014 - R. Yantosca - INIT_TOMAS accepts am_I_Root, Input_Opt, RC
```

1.78.9 read_emissions_menu

Subroutine READ_EMISSIONS_MENU reads the EMISSIONS MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_EMISSIONS_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE BROMOCARB_MOD,      ONLY : Br_SCALING
USE CMN_O3_MOD               ! FSCALYR
USE CMN_SIZE_MOD             ! Size parameters
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE EMISSIONS_MOD,      ONLY : ISOP_SCALING
USE EMISSIONS_MOD,      ONLY : NOx_SCALING
USE ERROR_MOD,          ONLY : ERROR_STOP
USE LOGICAL_MOD
USE MODIS_LAI_MOD,      ONLY : INIT_MODIS_LAI
USE RCP_MOD,            ONLY : RCPNAME, RCPYEAR
USE TIME_MOD,           ONLY : SET_HISTYR
USE TRACER_MOD,         ONLY : ITS_A_FULLCHEM_SIM
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now read LNEI99 -- switch for EPA/NEI99 emissions (bmy, 11/5/04)
(2 ) Now read LAVHRRLAI-switch for using AVHRR-derived LAI (bmy, 12/20/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now read LMEGAN -- switch for MEGAN biogenics (tmf, bmy, 10/20/05)
(5 ) Now read LEMEP -- switch for EMEP emissions (bdf, bmy, 11/1/05)
(6 ) Now read LGFED2BB -- switch for GFED2 biomass emissions (bmy, 4/5/06)
(7 ) Now read LOTDLIS, LCTH, LMFLUX, LPRECON for lightning options
      (bmy, 5/10/06)
(8 ) Now read LBRAVO for BRAVO Mexican emissions (rjp, kfb, bmy, 6/26/06)
(9 ) Now read LEDGAR for EDGAR emissions (avd, bmy, 7/11/06)
(10) Now read LSTREETS for David Streets' emissions (bmy, 8/17/06)
```

```
(11) Kludge: Reset LMFLUX or LPRECON to LCTH, as the MFLUX and PRECON
     lightning schemes have not yet been implemented.  Rename LOTDLIS
     to LOTDREG.  Also read LOTDLOC for the OTD-LIS local redistribution
     of lightning flashes (cf B. Sauvage).  Make sure LOTDREG and
     LOTDLOC are not both turned on at the same time. (bmy, 1/31/07)
(12) Add LOTDSCALE to the list of LNOx options (ltm, bmy, 9/24/07)
(13) Add new error traps for OTD-LIS options, dependent on met field type
     (ltm, bmy, 11/29/07)
(14) Bug fix, create string variables for ERROR_STOP (bmy, 1/24/08)
(15) Now read LCAC for CAC emissions (amv, 1/09/2008)
(16) Now read LEDGARSHIP, LARCSHIP and LEMEPSHIP (phs, 12/5/08)
(17) Fixed typo in message for GEOS-3 (bmy, 10/30/08)
(18) Now read LVISTAS (amv, 12/2/08)
(19) Now read L8DAYBB, L3HRBB and LSYNOPBB for GFED2 8-days and 3hr
     emissions, and LICARTT for corrected EPA (phs, yc, 12/17/08)
(20) Add a specific switch for MEGAN emissions for monoterpenes and MBO
     (ccc, 2/2/09)
(21) Now read LICOADSSHIP (cklee, 6/30/09)
(22) Bug fix: for now, if LEMEPSHIP is turned on but LEMEP is turned off,
     just turn off LEMEPSHIP and print a warning msg. (mak, bmy, 10/18/09)
(23) Now accounts for NEI2005 (amv, phs, 10/9/09)
(24) Included optional flag for using MODIS LAI data (mpb,2009).
(25) Included optional flag for using PCEEA model (mpb, 2009)
(26) Now force settings for EU, NA, CC nested grids (amv, bmy, 12/18/09)
(27) Now force MEGAN to use MODIS LAI (ccarouge, bmy, 2/24/10)
(28) Add separate switch for NOx fertilizer. (fp, 2/29/10)
(29) Add scaling for isoprene and NOx emissions. (fp, 2/29/10)
(30) Remove depreciated lightning options. (ltm, 1/25,11)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
27 Aug 2010 - R. Yantosca - Added warning msg for MERRA
29 Jul 2011 - L. Zhang    - Fix bug that turns off CAC/BRAVO emissions
                            inadvertently during nested NA simulations
11 Aug 2011 - E. Leibensperger - Added flag for historical emissions and
                                 base year
07 Sep 2011 - P. Kasibhatla - Add modifications for GFED3
14 Feb 2012 - R. Yantosca - Reorganize error checks for logical switches
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
05 Apr 2012 - R. Yantosca - Now call INIT_MODIS_LAI
05 Apr 2012 - R. Yantosca - Reorganized USE statements for clarity
10 Apr 2012 - R. Yantosca - Bug fix: do not turn off LAVHRRLAI or LMODISLAI
                            when emissions are turned off.  LAI is used
                            in other areas of the code.
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
22 Jul 2013 - M. Sulprizio- Now copy LRCP, LRCPSHIP, LRCPAIR to Input_Opt
31 Jul 2013 - M. Sulprizio- Now copy LAEIC to Input_Opt; Add check to
                            make sure LAEIC and LRCPAIR are not both on
```

```
22 Aug 2013 - R. Yantosca - Now read path for soil NOx restart file
26 Sep 2013 - R. Yantosca - Remove SEAC4RS C-preprocessor switch
03 Oct 2013 - M. Sulprizio- Removed obsolete options for LAVHRRLAI and
                            LMODISLAI. MODIS LAI data are now read from
                            netCDF files.
```

1.78.10 read_co2_sim_menu

Subroutine READ_CO2_SIM_MENU reads the CO2 SIM MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_CO2_SIM_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE LOGICAL_MOD
USE ERROR_MOD,   ONLY : ERROR_STOP
USE TRACER_MOD,  ONLY : ITS_A_CO2_SIM

USE CMN_SIZE_MOD                  ! Size parameters
USE CMN_O3_MOD                    ! FSCALYR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
02 Mar 2009 - R. Nassar   - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
07 Sep 2011 - P. Kasibhatla - Modified for GFED3
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.11 read_future_menu

Subroutine READ_FUTURE_MENU reads the FUTURE MENU section of the GEOS-Chem input file; this defines IPCC future emissions options.

INTERFACE:

```
SUBROUTINE READ_FUTURE_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE FUTURE_EMISSIONS_MOD, ONLY : DO_FUTURE_EMISSIONS
USE LOGICAL_MOD,          ONLY : LFUTURE

USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
01 Jun 2006 - S. Wu       - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.78.12 read_chemistry_menu

Subroutine READ_CHEMISTRY_MENU reads the CHEMISTRY MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_CHEMISTRY_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE LOGICAL_MOD,        ONLY : LCHEM, LSCHEM, LLINOZ
      USE LOGICAL_MOD,        ONLY : LSVCSPEC, LKPP
      USE TIME_MOD,           ONLY : SET_CT_CHEM
      USE TRACER_MOD,         ONLY : N_TRACERS
#if defined( EXTERNAL_GRID ) || defined( EXTERNAL_FORCING )
      USE TIME_MOD,           ONLY : Accept_External_Date_Time
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1) added optional test on KPPTRACER (phs, 6/17/09)
   (2) Remove reference to obsolete embedded chemistry stuff in "CMN"
       (bmy, 2/25/10)
   27 Aug 2010 - R. Yantosca - Added ProTeX headers
   10 Jun 2012 - L. Murray   - Move all strat chemistry switches here
   30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                               running with the traditional driver main.F
   01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
   06 Dec 2012 - R. Yantosca - Now get TS_CHEM from the ESMF environment
                               when we are connecting to the GEOS-5 GCM
   11 Dec 2012 - R. Yantosca - ACCEPT_DATE_TIME_FROM_ESMF has now been renamed
                               to ACCEPT_EXTERNAL_DATE_TIME
   22 May 2013 - M. Payer    - Now read in GAMMA_HO2. Recommended value is 0.2
                               based on Jacon et al (2000) and Mao et al (2013).
   22 Aug 2013 - R. Yantosca - Now read in path for species restart file
```

1.78.13 read_transport_menu

Subroutine READ_TRANSPORT_MENU reads the TRANSPORT MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_TRANSPORT_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE LOGICAL_MOD,        ONLY : LFILL
      USE LOGICAL_MOD,        ONLY : LTRAN
      USE TRACER_MOD,         ONLY : ITS_A_FULLCHEM_SIM
      USE TRACER_MOD,         ONLY : ITS_A_TAGOX_SIM
#if defined( EXTERNAL_GRID ) || defined( EXTERNAL_FORCING )
      USE TIME_MOD,           ONLY : Accept_External_Date_Time
#endif
#if !defined( ESMF_ )
      USE TRANSPORT_MOD,      ONLY : SET_TRANSPORT
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Now define MAX_DYN for 1 x 1.25 grid (bmy, 12/1/04)
    (2 ) Update text in error message (bmy, 2/23/05)
    (3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
    (4 ) Don't stop run if TS_DYN > MAX_DYN but transport is turned off
         (cdh, bmy, 7/7/08)
    (5 ) Set MAX_DYN for the 0.5 x 0.666 nested grid (yxw, dan, bmy, 11/6/08)
    27 Aug 2010 - R. Yantosca - Added ProTeX headers
    10 Jun 2012 - L. Murray - Move strat to chemistry menu
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
    06 Dec 2012 - R. Yantosca - Now get TS_DYN from the ESMF environment, if
                                we are connecting to the GEOS-5 GCM
    11 Dec 2012 - R. Yantosca - ACCEPT_DATE_TIME_FROM_ESMF has now been renamed
                                to ACCEPT_EXTERNAL_DATE_TIME
    03 Oct 2013 - M. Sulprizio- Removed obsolete option for flux correction. This
                                was used for GEOS-3, which has been retired.
```

1.78.14 read_convection_menu

Subroutine READ_CONVECTION_MENU reads the CONVECTION MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_CONVECTION_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE LOGICAL_MOD,        ONLY : LCONV, LTURB
      USE LOGICAL_MOD,        ONLY : LNLPBL        ! (Lin, 03/31/09)
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
#if defined( EXTERNAL_GRID ) || defined( EXTERNAL_FORCING )
      USE TIME_MOD,           ONLY : Accept_External_Date_Time
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Add option for new non-local PBL scheme. And a check on GEOS-5,
        LNLPBL turned to false if GEOS-5 is not used (lin, ccc 5/13/09)
   27 Aug 2010 - R. Yantosca - Now allow non-local PBL for MERRA met data
   27 Aug 2010 - R. Yantosca - Added ProTeX headers
   02 Feb 2012 - R. Yantosca - Added modifications for MERRA met data
   13 Apr 2012 - R. Yantosca - Fixed typo ( defined( GEOS_FP ) should have
                               been !defined( GEOS_FP ) )
   30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                               running with the traditional driver main.F
   01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
   01 Mar 2013 - R. Yantosca - Now set TS_CONV to the same value as TS_DYN
                               when connecting to the GEOS-5 GCM.
```

1.78.15 read_deposition_menu

Subroutine READ_DEPOSITION_MENU reads the DEPOSITION MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_DEPOSITION_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE ERROR_MOD,   ONLY : ERROR_STOP
      USE DRYDEP_MOD,  ONLY : INIT_DRYDEP
      USE LOGICAL_MOD, ONLY : LCONV,             LDRYD
      USE LOGICAL_MOD, ONLY : LWETD,             LSPLIT
      USE LOGICAL_MOD, ONLY : USE_OLSON_2001
      USE TRACER_MOD,  ONLY : ITS_A_C2H6_SIM,    ITS_A_CH3I_SIM
      USE TRACER_MOD,  ONLY : ITS_A_CH4_SIM,     ITS_A_HCN_SIM
      USE TRACER_MOD,  ONLY : ITS_A_MERCURY_SIM, ITS_A_TAGCO_SIM
      USE TRACER_MOD,  ONLY : ITS_A_TAGOX_SIM
      USE WETSCAV_MOD, ONLY : WETDEPID
#if   defined( APM )
      USE APM_WETS_MOD, ONLY : WETDEPBINID
#endif
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   (1 ) Now print an informational message for tagged Hg (bmy, 12/15/04)
   (2 ) We need to call WETDEPID for both wetdep and cloud convection
        since this sets up the list of soluble tracers (bmy, 3/1/05)
   (3 ) Remove references to obsolete CO_OH simulation (bmy, 6/24/05)
   (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   27 Aug 2010 - R. Yantosca - Added ProTeX headers
   16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
   31 Jul 2012 - R. Yantosca - Now pass am_I_Root to INIT_DRYDEP
   30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
```

```
                              running with the traditional driver main.F
    01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
    26 Feb 2013 - R. Yantosca - Now call INIT_DUST jere to facilitate
                              connecting to the GEOS-5 GCM
```

1.78.16 read_gamap_menu

Subroutine READ_GAMAP_MENU reads the GAMAP MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_GAMAP_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
25 Apr 2005 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.17 read_output_menu

Subroutine READ_OUTPUT_MENU reads the OUTPUT MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_OUTPUT_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE FILE_MOD, ONLY : IOERROR

USE CMN_SIZE_MOD   ! Size parameters
USE CMN_DIAG_MOD   ! NJDAY
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
03 Aug 2012 - R. Yantosca - IU_GEOS is now a global module variable
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
28 Feb 2013 - R. Yantosca - Don't call IS_LAST_DAY_GOOD when using ESMF
```

1.78.18 read_diagnostic_menu

Subroutine READ_DIAGNOSTIC_MENU reads the DIAGNOSTIC MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_DIAGNOSTIC_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE BIOFUEL_MOD,  ONLY : NBFTRACE
USE BPCH2_MOD,    ONLY : OPEN_BPCH2_FOR_WRITE
USE DIAG03_MOD,   ONLY : ND03,      PD03,      INIT_DIAG03
USE DIAG03_MOD,   ONLY : PD03_PL    !eds 9/9/10
USE DIAG04_MOD,   ONLY : ND04,      PD04,      INIT_DIAG04
USE DIAG41_MOD,   ONLY : ND41,      PD41,      INIT_DIAG41
USE DIAG42_MOD,   ONLY : ND42,      PD42,      INIT_DIAG42
USE DIAG53_MOD,   ONLY : ND53,      PD53,      INIT_DIAG53
USE DIAG56_MOD,   ONLY : ND56,      PD56,      INIT_DIAG56
USE DIAG_OH_MOD,  ONLY : INIT_DIAG_OH
```

```
      USE DRYDEP_MOD,   ONLY : NUMDEP
      USE ERROR_MOD,    ONLY : ERROR_STOP
      USE FILE_MOD,     ONLY : IU_BPCH
      USE LOGICAL_MOD,  ONLY : LBIOMASS,  LBIOFUEL,  LCARB, LCONV
      USE LOGICAL_MOD,  ONLY : LDRYD,     LDUST,     LPRT,  LSULF
      USE LOGICAL_MOD,  ONLY : LSSALT,    LTURB,     LWETD, LGFED2BB
      USE LOGICAL_MOD,  ONLY : LGFED3BB
      USE TIME_MOD,     ONLY : GET_NYMDb, GET_NHMSb, EXPAND_DATE
      USE TRACER_MOD,   ONLY : N_TRACERS
      USE TRACER_MOD,   ONLY : ITS_A_CO2_SIM,        ITS_A_FULLCHEM_SIM
      USE TRACER_MOD,   ONLY : ITS_A_MERCURY_SIM,    ITS_A_RnPbBe_SIM
      USE TRACER_MOD,   ONLY : ITS_A_TAGOX_SIM,      ITS_A_CH3I_SIM
      USE TRACER_MOD,   ONLY : SALA_REDGE_um,        ITS_A_CH4_SIM
      USE TRACER_MOD,   ONLY : ITS_A_POPS_SIM
      USE TRACERID_MOD, ONLY : NEMANTHRO
      USE WETSCAV_MOD,  ONLY : GET_WETDEP_NMAX

      USE CMN_SIZE_MOD       ! Size parameters
      USE CMN_DIAG_MOD       ! NDxx flags
 ------------------------------------------------------------------------------
  Prior to 2/3/14:
  NOTE: These variables are in Headers/CMN_DIAG_mod.F, so we don't need
  to reference these.  Lee Murray says that this causes the code to choke
  when compiling GEOS-Chem on Mac. (bmy, 2/3/14)
       USE DIAG_MOD,           ONLY: TINDEX
       USE DIAG_MOD,           ONLY: TCOUNT
       USE DIAG_MOD,           ONLY: TMAX
 ------------------------------------------------------------------------------
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Now reference IU_BPCH from "file_mod.f" and OPEN_BPCH2_FOR_WRITE
         from "bpch2_mod.f".  Now opens the bpch file for output here
         instead of w/in "main.f" (bmy, 2/3/05)
    (2 ) Now references "diag03_mod.f" and "diag41_mod.f".  Now turn off ND38
         when both LWETD=F and LCONV=F.  Now calls EXPAND_DATE to replace
```

```
      YYYYMMDD and HHMMSS tokens in the bpch file name with the actual
      starting date & time of the run. (bmy, 3/25/05)
(3 ) Now get diag info for ND09 for HCN/CH3CN sim (bmy, 6/27/05)
(4 ) Now references "diag04_mod.f" (bmy, 7/26/05)
(5 ) Now make sure all USE statements are USE, ONLY.  Also remove reference
      to DIAG_MOD, it's not needed. (bmy, 10/3/05)
(6 ) Now remove reference to NBIOTRCE; Replace w/ NBIOMAX. (bmy, 4/5/06)
(7 ) Now reference ND56, PD56, INIT_DIAG56 from "diag56_mod.f"
      (bmy, 5/10/06)
(8 ) Now reference ND42, PD42, INIT_DIAG42 from "diag42_mod.f"
      (dkh, bmy, 5/22/06)
(9 ) Now set max dimension for GFED2 or default biomass (bmy, 9/22/06)
(10) Bug fix: Should use ND52 in call to SET_TINDEX (cdh, bmy, 2/11/08)
(11) Remove call to NDXX_SETUP; this is now called in READ_INPUT_FILE.
      (phs, 11/18/08)
(12) Now set TINDEX with PD45=NNPAR+1 tracers instead of N_TRACERS.
      (tmf, 2/10/09)
(13) NBIOMAX now in CMN_SIZE (fp, 6/2009)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
26 May 2011 - R. Yantosca - For ND17, ND18, ND37, ND38, ND39, we need to
                            set N_TMP = N_TRACERS, or else wetdep tracers
                            with indices higher than #32 won't print out.
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
08 Nov 2013 - M. Sulprizio- Remove HR1_NO, and HR2_NO from ND43 diagnostic.
03 Feb 2014 - R. Yantosca - Remove references to TINDEX, TCOUNT, and TMAX
                            from diag_mod.  They are in CMN_SIZE_mod.F.
                            Lee Murray reports this causes the compilation
                            to choke on Macintosh platforms.
```

1.78.19 set_tindex

Subroutine SET_TINDEX sets the TINDEX and TMAX arrays, which determine how many tracers to print to the punch file.

INTERFACE:

```
      SUBROUTINE SET_TINDEX( am_I_Root,
     &                       N_DIAG, L_DIAG, SUBSTRS, N, NMAX )
```

USES:

```
#if   defined( TOMAS )
      USE CHARPAK_MOD, ONLY : TXTEXT   ! (win, 7/14/09)
#endif

      USE CMN_SIZE_MOD                              ! Size parameters
```

```
USE CMN_DIAG_MOD                                ! TMAX, TINDEX
```

INPUT PARAMETERS:

```
INTEGER,            INTENT(IN) :: N_DIAG      ! GEOS-Chem diagnostic #
INTEGER,            INTENT(IN) :: N           ! # of valid substrs passed
INTEGER,            INTENT(IN) :: NMAX        ! Max # of tracers allowed
INTEGER,            INTENT(IN) :: L_DIAG      ! # of levels to save
CHARACTER(LEN=255), INTENT(IN) :: SUBSTRS(N)  ! Substrs passed from
                                              !  READ_DIAGNOSTIC_MENU
LOGICAL,            INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Bug fix: now do not drop the last tracer number if "all" is not
      explicitly specified (tmf, bmy, 11/15/04)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.78.20 read_planeflight_menu

Subroutine READ_PLANEFLIGHT_MENU reads the PLANEFLIGHT MENU section of the GEOS-Chem input file. This turns on the ND40 flight track diagnostic.

INTERFACE:

```
SUBROUTINE READ_PLANEFLIGHT_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE ERROR_MOD,       ONLY : ERROR_STOP
USE PLANEFLIGHT_MOD, ONLY : SET_PLANEFLIGHT

USE CMN_SIZE_MOD                  ! MAXFAM
USE CMN_DIAG_MOD                  ! ND40
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.21 read_nd48_menu

Subroutine READ_ND48_MENU reads the ND48 MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ND48_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE DIAG48_MOD, ONLY : INIT_DIAG48, ND48_MAX_STATIONS
USE ERROR_MOD,  ONLY : ERROR_STOP
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Bug fix: ND48 stations should now be read correctly. (bmy, 3/6/06)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.22 read_nd49_menu

Subroutine READ_ND49_MENU reads the ND49 MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ND49_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE DIAG49_MOD, ONLY : INIT_DIAG49
USE ERROR_MOD,  ONLY : ERROR_STOP

USE CMN_SIZE_MOD     ! Size parameters
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.23 read_nd50_menu

Subroutine READ_ND50_MENU reads the ND50 MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ND50_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE DIAG50_MOD,  ONLY : INIT_DIAG50
USE ERROR_MOD,   ONLY : ERROR_STOP
USE LOGICAL_MOD, ONLY : LND50_HDF
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now include option to save ND51 diagnostic to HDF5 file format
     (amv, bmy, 12/21/09)
(2 ) Increase tracer number to 121. (ccc, 4/20/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.24 read_nd51_menu

Subroutine READ_ND51_MENU reads the ND51 MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ND51_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE DIAG51_MOD,  ONLY : INIT_DIAG51
USE ERROR_MOD,   ONLY : ERROR_STOP
USE LOGICAL_MOD, ONLY : LND51_HDF

USE CMN_SIZE_MOD      ! Size parameters
USE CMN_DIAG_MOD      ! NDxx flags
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now include option to save ND51 diagnostic to HDF5 file format
     (amv, bmy, 12/21/09)
(2 ) Increase # of tracers to 121 (ccc, 4/20/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.25 read_nd51b_menu

Subroutine READ_ND51b_MENU reads the ND51 MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ND51b_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE DIAG51b_MOD, ONLY : INIT_DIAG51b
USE ERROR_MOD,   ONLY : ERROR_STOP
USE LOGICAL_MOD, ONLY : LND51b_HDF

USE CMN_SIZE_MOD      ! Size parameters
USE CMN_DIAG_MOD      ! NDxx flags
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
21 Dec 2009 - Aaron van D - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.26 read_nd63_menu

Subroutine READ_ND63_MENU reads the ND63 MENU section of the GEOS-Chem input file. (gvinken, 02/25/11)

INTERFACE:

```
SUBROUTINE READ_ND63_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE DIAG63_MOD, ONLY : INIT_DIAG63
USE ERROR_MOD,  ONLY : ERROR_STOP

USE CMN_SIZE_MOD     ! Size parameters
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
25 Feb 2011 - G. Vinken   - Initial version
07 Feb 2012 - M. Payer    - Added ProTeX headers
24 Feb 2012 - M. Payer    - Renamed routine from READ_ND59_MENU to
                            READ_ND63 MENU. ND59 is used by TOMAS.
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.27 read_prod_loss_menu

Subroutine READ_PROD_LOSS_MENU reads the PROD AND LOSS MENU section of the GEOS-Chem input file

INTERFACE:

```
SUBROUTINE READ_PROD_LOSS_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CHARPAK_MOD, ONLY : ISDIGIT,         STRSPLIT
USE DIAG_PL_MOD, ONLY : INIT_DIAG_PL
USE ERROR_MOD,   ONLY : ERROR_STOP
USE TRACER_MOD,  ONLY : N_TRACERS,       ITS_A_TAGCO_SIM
USE TRACER_MOD,  ONLY : ITS_A_TAGOX_SIM, ITS_AN_AEROSOL_SIM
USE LOGICAL_MOD, ONLY : LKPP

USE CMN_SIZE_MOD      ! MAXFAM
USE CMN_DIAG_MOD      ! ND65
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Bug fixes.  Only error check # of prod/loss families for TagOx and
     TagCO runs if DO_SAVE_PL=T.  Also turn off this diagnostic for
     the offline aerosol run. (bmy, 10/29/04)
(2 ) Add error trap is P/L families are asked when using KPP. (ccc, 3/10/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
08 Nov 2012 - R. Yantosca - Now save fields to the Input_Opt object
```

1.78.28 read_unix_cmds_menu

Subroutine READ_UNIX_CMDS_MENU reads the UNIX CMDS MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_UNIX_CMDS_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CHARPAK_MOD,   ONLY : STRSQUEEZE
USE UNIX_CMDS_MOD, ONLY : BACKGROUND, REDIRECT,  REMOVE_CMD
USE UNIX_CMDS_MOD, ONLY : SEPARATOR,  SPACE,     UNZIP_CMD
USE UNIX_CMDS_MOD, ONLY : WILD_CARD,  ZIP_SUFFIX
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.29 read_nested_grid_menu

Subroutine READ_NESTED_GRID_MENU reads the NESTED GRID MENU section of the GEOS-CHEM input file.

INTERFACE:

```
SUBROUTINE READ_NESTED_GRID_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE DIRECTORY_MOD, ONLY : TPBC_DIR
USE DIRECTORY_MOD, ONLY : TPBC_DIR_NA, TPBC_DIR_EU, TPBC_DIR_CH
USE DIRECTORY_MOD, ONLY : TPBC_DIR_SE
USE LOGICAL_MOD,   ONLY : LWINDO,      LWINDO2x25,  LWINDO_CU
USE LOGICAL_MOD,   ONLY : LWINDO_NA,   LWINDO_EU,   LWINDO_CH
USE LOGICAL_MOD,   ONLY : LWINDO_SE
USE TPCORE_BC_MOD, ONLY : INIT_TPCORE_BC
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    (1 ) Now give user the option of saving out nested grid boundary conditions
         at 2 x 2.5 resolution for the EU, CH, or NA grids (amv, bmy, 12/18/09)
    27 Aug 2010 - R. Yantosca - Added ProTeX headers
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.30 read_benchmark_menu

Subroutine READ_BENCHMARK_MENU reads the BENCHMARK MENU section of the GEOS-Chem input file.

INTERFACE:

```
      SUBROUTINE READ_BENCHMARK_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE BENCHMARK_MOD, ONLY : INITIAL_FILE, FINAL_FILE
      USE LOGICAL_MOD,   ONLY : LSTDRUN
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
    20 Jul 2004 - R. Yantosca - Initial version
    27 Aug 2010 - R. Yantosca - Added ProTeX headers
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.31 read_archived_oh_menu(am_I_Root)

Subroutine READ_ARCHIVED_OH_MENU reads the ARCHIVED OH MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_ARCHIVED_OH_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE DIRECTORY_MOD, ONLY : OH_DIR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.32 read_o3pl_menu

Subroutine READ_O3PL_MENU reads the O3 P/L MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_O3PL_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE DIRECTORY_MOD, ONLY : O3PL_DIR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
   20 Jul 2004 - R. Yantosca - Initial version
   27 Aug 2010 - R. Yantosca - Added ProTeX headers
   01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
------------------------------------------------------------------------------
BOC
```

LOCAL VARIABLES:

```
      INTEGER            :: N
      CHARACTER(LEN=255) :: SUBSTRS(MAXDIM)

      !=================================================================
      ! READ_O3PL_MENU begins here!
      !=================================================================

      ! Directory where archived P(O3) and L(O3) files are stored
      CALL SPLIT_ONE_LINE( SUBSTRS, N, 1, 'read_archived_oh_menu:1' )
      READ( SUBSTRS(1:N), '(a)' ) O3PL_DIR

      ! Separator line
      CALL SPLIT_ONE_LINE( SUBSTRS, N, 1, 'read_archived_oh_menu:2' )

      !=================================================================
      ! Set fields of Input Options object
      !=================================================================
      Input_Opt%O3PL_DIR = O3PL_DIR

      ! Return success
      RC = GIGC_SUCCESS

      !=================================================================
      ! Print to screen
      !=================================================================
      IF ( am_I_Root ) THEN
         WRITE( 6, '(/,a)' ) 'ARCHIVED O3PL MENU'
         WRITE( 6, '(  a)' ) '--------------------'
         WRITE( 6, 100     ) 'Dir w/ archived O3 P/L files: ',
     &                       TRIM( O3PL_DIR )
```

```
      ENDIF

      ! FORMAT statements
  100 FORMAT( A, A )

      END SUBROUTINE READ_O3PL_MENU
  EOC
  ------------------------------------------------------------------------------
                   GEOS-Chem Global Chemical Transport Model                  !
  ------------------------------------------------------------------------------
%//////////////////////////////////////////////////////////////

\mbox{}\hrulefill\


  \subsubsection [read\_mercury\_menu] {read\_mercury\_menu}


  Subroutine READ\_MERCURY\_MENU reads the BENCHMARK MENU
    section of the GEOS-Chem input file.
  \\
  \\{\bf INTERFACE:}
\begin{verbatim}      SUBROUTINE READ_MERCURY_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
      ! References to F90 modules
      USE LOGICAL_MOD,       ONLY : LDYNOCEAN, LPREINDHG, LGTMM
      USE MERCURY_MOD,       ONLY : INIT_MERCURY
      USE OCEAN_MERCURY_MOD, ONLY : INIT_OCEAN_MERCURY
      USE DEPO_MERCURY_MOD,  ONLY : INIT_DEPO_MERCURY
      USE LAND_MERCURY_MOD,  ONLY : INIT_LAND_MERCURY
      USE TRACER_MOD,        ONLY : ITS_A_MERCURY_SIM
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
24 Feb 2006 - R. Yantosca - Initial version
( 1) Update for Chris Holmes's mercury version. (ccc, 5/6/10)
( 2) Add options to use GTMM for mercury soil emissions (ccc, 9/16/09)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
```

1.78.33 read_ch4_menu

Subroutine READ_CH4_MENU reads the CH4 MENU section of the GEOS-Chem input file; this defines emissions options for CH4 tagged simulations.

INTERFACE:

```
SUBROUTINE READ_CH4_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
! References to F90 modules
USE LOGICAL_MOD, ONLY : LGAO,    LCOL,    LLIV,   LWAST
USE LOGICAL_MOD, ONLY : LBFCH4,  LBMCH4,  LWETL,  LRICE
USE LOGICAL_MOD, ONLY : LOTANT,  LSOABS,  LOTNAT
USE LOGICAL_MOD, ONLY : LCH4BUD
! kjw
USE LOGICAL_MOD, ONLY : LBIOMASS
USE LOGICAL_MOD, ONLY : LGFED3BB, LDAYBB3
USE LOGICAL_MOD, ONLY : LGFED2BB, L8DAYBB
USE ERROR_MOD,   ONLY : ERROR_STOP
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
03 Aug 2009 - K. Wecht, C. Pickett-Heaps - Initial version
27 Aug 2010 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
```

```
01 Nov 2012 - R. Yantosca - Now pass Input_Opt, RC as arguments
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
19 Feb 2014 - R. Yantosca - Add warning for CH4 budget (which is now
                            controlled by an #ifdef in global_ch4_mod.F)
```

1.78.34 read_pops_menu

Subroutine READ_POPS_MENU reads the POPS MENU section of the GEOS-Chem input file; this defines emissions options for POPs simulations.

INTERFACE:

```
SUBROUTINE READ_POPS_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE GET_POPSINFO_MOD,     ONLY : GET_POP_TYPE
USE POPS_MOD,             ONLY : INIT_POPS
USE DIRECTORY_MOD,        ONLY : POP_EMISDIR
USE TRACER_MOD,           ONLY : ITS_A_POPS_SIM
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod,   ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)           :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
01 Oct 2012 - C. Friedman - Initial version
26 Nov 2012 - M. Payer    - Added ProTeX headers
29 Nov 2012 - M. Payer    - Now pass Input_Opt, RC as arguments
26 Mar 2013 - R. Yantosca - Now pass Input_Opt to INIT_POPS
```

1.78.35 read_apm_menu

Subroutine READ_APM_MENU reads the APM MENU section of the GEOS-Chem input file.

INTERFACE:

```
SUBROUTINE READ_APM_MENU( am_I_Root, Input_Opt, RC )
```

USES:

```
USE APM_INIT_MOD,       ONLY : APMTRACER_MW_G
USE APM_INIT_MOD,       ONLY : APMTRACER_MW_Kg
USE APM_INIT_MOD,       ONLY : IFNUCL
USE APM_INIT_MOD,       ONLY : FE0
USE APM_INIT_MOD,       ONLY : LAPM
USE CHARPAK_MOD,        ONLY : STRREPL
USE ERROR_MOD,          ONLY : ERROR_STOP
USE FILE_MOD,           ONLY : IOERROR
USE GAMAP_MOD,          ONLY : DO_GAMAP
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TRACER_MOD,         ONLY : N_APMTRA
USE TRACER_MOD,         ONLY : N_TRACERS
USE TRACER_MOD,         ONLY : TCVV
USE TRACER_MOD,         ONLY : XNUMOL
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input options
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REMARKS:

```
This subroutine is only compiled when you build GEOS-Chem with the
APM=yes makefile option.
```

REVISION HISTORY:

```
30 Sep 2008 - G. Luo, F. Yu - Initial version
16 Feb 2011 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
```

1.78.36 validate_directories

Subroutine VALIDATE_DIRECTORIES makes sure that each of the directories that we have read from the GEOS-Chem input file are valid. Also, trailing separator characters will be added.

INTERFACE:

```
SUBROUTINE VALIDATE_DIRECTORIES
```

USES:

```
USE DIRECTORY_MOD
USE GRID_MOD,      ONLY : ITS_A_NESTED_GRID
USE LOGICAL_MOD,   ONLY : LWINDO_CU,   LUNZIP
USE LOGICAL_MOD,   ONLY : LWINDO_NA,   LWINDO_EU,    LWINDO_CH
USE LOGICAL_MOD,   ONLY : LWINDO_SE
USE TIME_MOD,      ONLY : EXPAND_DATE, GET_NYMDb,    GET_NYMDe
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now make sure all USE statements are USE, ONLY.  Now also validate
     GCAP and GEOS-5 directories. (bmy, 10/3/05)
(2 ) Now references DATA_DIR_1x1 from directory_mod.f (bmy, 10/24/05)
(3 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(4 ) Now check TPBC_DIR_NA, TPBC_DIR_CH, TPBC_DIR_EU (amv, bmy, 12/18/09)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
27 Aug 2010 - R. Yantosca -  Now check MERRA directory
08 Feb 2012 - R. Yantosca - Now check GEOS-5.7.x directory
09 Feb 2012 - R. Yantosca - Rewrote USE statements for clarity
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.78.37 check_directory

Subroutine CHECK_DIRECTORY makes sure that the given directory is valid. Also a trailing slash character will be added if necessary.

INTERFACE:

```
SUBROUTINE CHECK_DIRECTORY( DIR )
```

USES:

```
! References to F90 modules
USE ERROR_MOD,     ONLY : ERROR_STOP
USE FILE_MOD,      ONLY : FILE_EXISTS
USE UNIX_CMDS_MOD, ONLY : SEPARATOR
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(INOUT) :: DIR    ! Directory to be checked
```

REVISION HISTORY:

```
20 Mar 2003 - R. Yantosca - Initial version
(1 ) Now references FILE_EXISTS from "file_mod.f" (bmy, 3/23/05)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.78.38 check_time_steps

Subroutine CHECK_TIME_STEPS computes the smallest dynamic time step for the model, based on which operation are turned on. This is called from routine READ_INPUT_FILE, after all of the timesteps and logical flags have been read from "input.geos".

INTERFACE:

```
SUBROUTINE CHECK_TIME_STEPS( am_I_Root )
```

USES:

```
USE LOGICAL_MOD, ONLY : LCONV, LCHEM, LDRYD
USE LOGICAL_MOD, ONLY : LEMIS, LTRAN, LTURB
USE TIME_MOD,    ONLY : SET_TIMESTEPS
USE ERROR_MOD,   ONLY : GEOS_CHEM_STOP
USE TRACER_MOD,  ONLY : ITS_A_CH4_SIM
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Add TS_DIAG, the largest time steps used for diagnostics.
      And test that all time steps are multiple of the smallest one.
      (ccc, 5/13/09)
(3 ) Corrected typos -99999 instead of -999999 (phs, bmy, 8/21/09)
(4 ) Now compute TS_SUN_2 which is 1/2 of the chemistry timestep (or
      smallest timestep if LCHEM=LEMIS=LDRYD=F).  This is used to compute
      SUNCOS at the midpoint of the timestep instead of the beginning.
      (bmy, 4/27/10)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
07 Oct 2011 - R. Yantosca - Add extra error checks for centralizing
                            chemistry timestep algorithm
07 Oct 2011 - R. Yantosca - Remove TS_SUN_2 from call to SET_TIMESTEPS
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
```

1.78.39 is_last_day_good

Suborutine IS_LAST_DAY_GOOD tests to see if there is output scheduled on the last day of the run.

INTERFACE:

```
SUBROUTINE IS_LAST_DAY_GOOD
```

USES:

```
USE ERROR_MOD,  ONLY : ERROR_STOP
USE JULDAY_MOD, ONLY : JULDAY
USE TIME_MOD,   ONLY : GET_NYMDe, ITS_A_LEAPYEAR, YMD_EXTRACT

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! NJDAY
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Moved to "input_mod.f" from "main.f" (bmy, 1/11/05)
(2 ) Now call ITS_A_LEAPYEAR with FORCE=.TRUE. to always return whether
     the year Y would be a leap year, regardless of met field type.
     (swu, bmy, 4/24/06)
27 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.78.40 gigc_init_extra

Suborutine GIGC_INIT_EXTRA initializes other GEOS-Chem modules that have not been initialized in either GIGC_Allocate_All or GIGC_Init_all.

INTERFACE:

```
SUBROUTINE GIGC_Init_Extra( am_I_Root, Input_Opt, RC )
```

USES:

```
USE Aerosol_Mod,        ONLY : Init_Aerosol
USE Carbon_Mod,         ONLY : Init_Carbon
USE Drydep_Mod,         ONLY : Init_Drydep
USE Dust_Mod,           ONLY : Init_Dust
USE Error_Mod,          ONLY : Debug_Msg
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE Linoz_Mod,          ONLY : Init_Linoz
USE Seasalt_Mod,        ONLY : Init_SeaSalt
USE Sulfate_Mod,        ONLY : Init_Sulfate
USE Tropopause_Mod,     ONLY : Init_Tropopause
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
Several of the INIT routines now called within GIGC_Init_Extra had
originally been called from the Run method.  We now gather these INIT
routines here so that they may be called from the Initialization method.
This is necessary when connecting GEOS-Chem to the GEOS-5 GCM via ESMF.

GIGC_Init_Extra should be called after the call to DO_DRYDEP, since
these routines depend on dry deposition parameters being set up first.
```

REVISION HISTORY:

```
04 Mar 2013 - R. Yantosca - Initial revision
05 Mar 2013 - R. Yantosca - Now call INIT_AEROSOL (GeosCore/aerosol_mod.F)
15 Mar 2013 - R. Yantosca - Now call INIT_LINOZ (GeosCore/linoz_mod.F)
29 Mar 2013 - R. Yantosca - Now call INIT_TROPOPAUSE (so that we can pass
                            a LVARTROP from Input_Opt and not logical_mod.F)
```

1.78.41 init_input

Subroutine INIT_INPUT initializes all variables from "directory_mod.f" and "logical_mod.f" for safety's sake.

INTERFACE:

```
SUBROUTINE INIT_INPUT
```

USES:

```
USE DIRECTORY_MOD
USE LOGICAL_MOD
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
(1 ) Now also initialize LNEI99 from "logical_mod.f" (bmy, 11/5/04)
(2 ) Now also initialize LAVHRRLAI from "logical_mod.f" (bmy, 12/20/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now also initialize LMEGAN switch (tmf, bmy, 10/20/05)
```

```
(5 ) Now also initialize LEMEP, LGFED2BB switches and DATA_DIR_1x1
     directory (bmy, 4/5/06)
(6 ) Now also intitialize LFUTURE (swu, bmy, 6/1/06)
(7 ) Now reference the EDGAR logical switches from "logical_mod.f"
     (avd, bmy, 7/11/06)
(8 ) Now initialize the LVARTROP switch (phs, 9/14/06)
(9 ) Now initialize LOTDREG, LOTDLOC, LCTH, LMFLUX, LPRECON (bmy, 1/31/07)
(10) Now initialize LOTDSCALE (ltm, bmy, 9/24/07)
(11) Add MEGAN Monoterpenes switch (ccc, 2/2/09)
16 Oct 2009 - R. Yantosca - Now initialize LLINOZ
19 Nov 2009 - C. Carouge  - Initialize LMODISLAI and LPECCA
01 Dec 2009 - C. Carouge  - Initialize LNEI05
27 Aug 2010 - R. Yantosca - Added ProTeX headers
07 Sep 2011 - P. Kasibhatla - Modified for GFED3
17 Jan 2012 - P. Kasibhatla - Modified for GFED3
 8 Feb 2012 - R. Yantosca - Rewrote USE statements for clarity
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
26 Mar 2012 - R. Yantosca - Now turn off switch USE_OLSON_2001 by default
                            (except for GEOS-5.7.2 met)
27 Mar 2012 - R. Yantosca - Cosmetic changes
13 Aug 2013 - M. Sulprizio- Add modifications for SOA + semivolatile POA
                            simulation (H. Pye)
```

1.79 Fortran: Module Interface isoropiaii_mod

Module ISOROPIAII_MOD contains the routines that provide the interface between ISORROPIA II and GEOS-Chem.

The actual ISORROPIA II code which performs Na-SO4-NH3-NO3-Cl-(Ca-K-Mg) aerosol thermodynamic equilibrium is in `isoropiaIIcode.f`.

INTERFACE:

```
MODULE ISOROPIAII_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_ISOROPIAII
PUBLIC  :: DO_ISOROPIAII
PUBLIC  :: GET_GNO3
PUBLIC  :: GET_ISRINFO
```

PRIVATE MEMBER FUNCTIONS:

```
   PRIVATE :: GET_HNO3
   PRIVATE :: INIT_ISOROPIAII
   PRIVATE :: SAFELOG10
   PRIVATE :: SET_HNO3
```

REMARKS:

```
Original Author:
*** COPYRIGHT 1996-2006, UNIVERSITY OF MIAMI, CARNEGIE MELLON UNIVERSITY,
*** GEORGIA INSTITUTE OF TECHNOLOGY
*** WRITTEN BY ATHANASIOS NENES
*** UPDATED BY CHRISTOS FOUNTOUKIS

Original v1.3 isoropia implementation into GEOS-Chem by
Becky Alexander and Bob Yantosca (bec, bmy, 4/12/05, 11/2/05)

For Ca,K,Mg = 0, ISOROPIA II performs exactly like ISOROPIAv1.7
Ca, K, Mg, Na from dust is not currently considered

To implement ISOROPIA II into GEOS-Chem:
  * cleanup_isoropiaII needs to be called from cleanup.f
  * DO_ISOROPIA needs to be replaced with DO_ISOROPIAII in chemistry_mod.f
  * Change ISOROPIA to ISOROPIAII in sulfate_mod.f
  * add isoropiaII_mod.f, isoropiaIIcode.f, and irspia.inc to Makefile

ISOROPIA II implementation notes by Havala O.T. Pye:
(1) The original isoropia code from T.Nenes is left as unmodified as
     possible. Original isoropia code can be found in isoropiaIIcode.f
     and common blocks can be found in isrpia.inc. For future upgrades
     to isoropia, replace isrpia.inc and isoropiaIIcode.f with the new
     version of isoropia and modify the call to ISOROPIA in this module.
     Please let the original author know of any changes made to ISOROPIA.
(2) As of Nov 2007, routines using non-zero Ca, K, and Mg do not always
     conserve mass. Ca, K, and Mg are set to zero.

NOTE: ISORROPIA is Greek for "equilibrium", in case you were wondering.
```

REVISION HISTORY:

```
06 Jul 2007 - H. O. T. Pye - Initial version
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
21 Apr 2010 - R. Yantosca  - Bug fix in DO_ISOROPIAII for offline aerosol
16 Feb 2011 - R. Yantosca  - Add modifications for APM from G. Luo
20 Aug 2013 - R. Yantosca  - Removed "define.h", this is now obsolete
```

1.79.1 do_isoropiaii

Subroutine DO_ISOROPIAII is the interface between the GEOS-Chem model and the aerosol thermodynamical equilibrium routine ISORROPIA II.

INTERFACE:

```
      SUBROUTINE DO_ISOROPIAII( am_I_Root, Input_Opt,
     &                          State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE ERROR_MOD,          ONLY : SAFE_DIV
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_HNO3_MOD,    ONLY : GET_GLOBAL_HNO3
      USE TIME_MOD,           ONLY : GET_MONTH
      USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TRACERID_MOD,       ONLY : IDTHNO3
      USE TRACERID_MOD,       ONLY : IDTNIT
      USE TRACERID_MOD,       ONLY : IDTNH4
      USE TRACERID_MOD,       ONLY : IDTNH3
      USE TRACERID_MOD,       ONLY : IDTSALA
      USE TRACERID_MOD,       ONLY : IDTSO4
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
#if   defined( APM )
      USE APM_INIT_MOD,       ONLY : NSO4
      USE APM_INIT_MOD,       ONLY : IDTSO4BIN1
      USE APM_INIT_MOD,       ONLY : IDTCTSEA
      USE APM_INIT_MOD,       ONLY : IDTCTBCOC
      USE APM_INIT_MOD,       ONLY : IDTCTDST
      USE APM_INIT_MOD,       ONLY : IDTCTSO4
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
   Original isoropia v1.3 implmentation: (rjp, bec, bmy, 12/17/01, 8/22/05)
```

REVISION HISTORY:

```
24 Aug 2007 - H. O. T. Pye - Initial version, in ISORROPIA II
18 Dec 2009 - H. O. T. Pye - Added division checks
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
21 Apr 2010 - E. Sofen     - Prevent out-of-bounds errors for offline
                             aerosol simulations where HNO3 is undefined
23 Jul 2010 - R. Yantosca  - Bug fix: corrected typo in ND42 diag section
30 Jul 2012 - R. Yantosca  - Now accept am_I_Root as an argument when
                             running with the traditional driver main.F
31 Jul 2012 - R. Yantosca  - Now loop from 1..LLPAR for GIGC compatibilit
14 Nov 2012 - R. Yantosca  - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer     - Replaced all met field arrays with State_Met
                             derived type object
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.79.2 safelog10

Calculates the LOG (base 10) of a number X. Returns a minimum value if X is too small, in order to avoid NaN or Infinity problems.

INTERFACE:

```
FUNCTION SAFELOG10( X ) RESULT ( SAFLOG )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: X        ! Argument for LOG10 function
```

RETURN VALUE:

```
REAL*8             :: SAFLOG   ! LOG10 output --
```

REVISION HISTORY:

```
11 Aug 2009 - H. O. T. Pye - Initial version, in ISORROPIA II
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.79.3 get_isrinfo

Subroutine GET_ISRINFO returns information related to aerosol pH.

INTERFACE:

```
FUNCTION GET_ISRINFO( I, J, L, N ) RESULT ( RETURNVALUE )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I   ! GEOS-Chem longitude index
INTEGER, INTENT(IN) :: J   ! GEOS-Chem latitude index
INTEGER, INTENT(IN) :: L   ! GEOS-Chem level index
INTEGER, INTENT(IN) :: N   ! Flag for which information is desired
```

RETURN VALUE:

```
REAL*8              :: RETURNVALUE
```

REVISION HISTORY:

```
11 Aug 2009 - H. O. T. Pye - Initial version
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.79.4 get_hno3

Subroutine GET_HNO3 allows the HNO3 concentrations to evolve with time, but relaxes back to the monthly mean concentrations every 3 hours.

INTERFACE:

```
FUNCTION GET_HNO3( I, J, L, State_Met ) RESULT ( HNO3_UGM3 )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE GLOBAL_HNO3_MOD,    ONLY : GET_HNO3_UGM3
USE TIME_MOD,           ONLY : GET_ELAPSED_MIN
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I           ! GEOS-Chem longitude index
INTEGER,        INTENT(IN)  :: J           ! GEOS-Chem latitude index
INTEGER,        INTENT(IN)  :: L           ! GEOS-Chem level index
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
16 Dec 2002 - R. Yantosca  - Initial version, in ISORROPIA I
24 Mar 2003 - R. Yantosca  - Now use function GET_ELAPSED_MIN() from the
                             new "time_mod.f" to get the elapsed minutes
                             since the start of run.
06 Jul 2007 - H. O. T. Pye - Initial version, in ISORROPIA II
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.79.5 set_hno3

Subroutine SET_HNO3 stores the modified HNO3 value back into the HNO3_sav array for the next timestep.

INTERFACE:

```
SUBROUTINE SET_HNO3( I, J, L, HNO3_UGM3 )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I           ! GEOS-Chem longitude index
INTEGER, INTENT(IN) :: J           ! GEOS-Chem longitude index
INTEGER, INTENT(IN) :: L           ! GEOS-Chem longitude index
REAL*8,  INTENT(IN) :: HNO3_UGM3   ! HNO3 concentration [ug/m3]
```

REVISION HISTORY:

```
16 Dec 2002 - R. Yantosca  - Initial version, in ISORROPIA I
06 Jul 2007 - H. O. T. Pye - Initial version, in ISORROPIA II
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.79.6 get_gno3

Function GET_GNO3 returns the gas-phase HNO3 [v/v] for calculation of sea-salt chemistry in sulfate_mod (SEASALT_CHEM).

INTERFACE:

```
SUBROUTINE GET_GNO3( I, J, L, HNO3_kg, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: I          ! GEOS-Chem longitude index
INTEGER,        INTENT(IN)    :: J          ! GEOS-Chem latitude index
INTEGER,        INTENT(IN)    :: L          ! GEOS-Chem level index
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met  ! Meteorology State object
```

OUTPUT PARAMETERS:

```
REAL*8,          INTENT(OUT)  :: HNO3_kg    ! Gas-phase HNO3 [kg]
```

REVISION HISTORY:

```
15 Apr 2005 - B. Alexander - Initial version, in ISORROPIA I
06 Jul 2007 - H. O. T. Pye - Initial version, in ISORROPIA II
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
09 Nov 2012 - M. Payer     - Replaced all met field arrays with State_Met
                             derived type object
```

1.79.7 init_isoropiaII

Subroutine INIT_ISOROPIAII initializes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_ISOROPIAII
```

USES:

```
USE ERROR_MOD,   ONLY : ALLOC_ERR
USE CMN_SIZE_MOD                  ! Size parameters
```

REVISION HISTORY:

```
06 Jul 2007 - H. O. T. Pye - Initial version
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
31 Jul 2012 - R. Yantosca  - Declare diag arrays w/ LLPAR (not LLTROP)
```

1.79.8 cleanup_isoropiaII

Subroutine CLEANUP_ISOROPIAII deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_ISOROPIAII
```

REVISION HISTORY:

```
06 Jul 2007 - H. O. T. Pye - Initial version
29 Jan 2010 - R. Yantosca  - Added ProTeX headers
```

1.80 Fortran: Module Interface land_mercury_mod

Module LAND_MERCURY_MOD contains variables and routines for the land emissions for the GEOS-Chem mercury simulation.

INTERFACE:

```
MODULE LAND_MERCURY_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: BIOMASSHG
PUBLIC :: VEGEMIS
PUBLIC :: SOILEMIS
PUBLIC :: LAND_MERCURY_FLUX
PUBLIC :: GTMM_DR
PUBLIC :: SNOWPACK_MERCURY_FLUX
PUBLIC :: INIT_LAND_MERCURY
PUBLIC :: CLEANUP_LAND_MERCURY
```

REVISION HISTORY:

```
02 Jun 2010 - N. E. Selin, C. Carouge - Initial version
02 Jun 2010 - C. Carouge  - Group all land emissions routine for mercury
                            into this new module.
13 Aug 2010 - R. Yantosca - Added modifications for MERRA
25 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
30 Aug 2010 - R. Yantosca - Added more ProTeX headers
12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
11 Apr 2012 - R. Yantosca - Now reference new modis_lai_mod.F90
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.80.1 land_mercury_flux

Subroutine LAND_MERCURY_FLUX calculates emissions of Hg(0) from prompt recycling of previously deposited mercury to land, in [kg/s].

INTERFACE:

```
SUBROUTINE LAND_MERCURY_FLUX( LFLUX, LHGSNOW, State_Met )
```

USES:

```
USE DAO_MOD,             ONLY : IS_ICE, IS_LAND
USE DEPO_MERCURY_MOD,    ONLY : WD_HGP, WD_HG2, DD_HGP, DD_HG2
USE GIGC_State_Met_Mod, ONLY : MetState
USE LOGICAL_MOD,         ONLY : LSPLIT
USE TIME_MOD,            ONLY : GET_TS_EMIS
USE TRACERID_MOD,        ONLY : ID_Hg0,          N_Hg_CATS

USE CMN_SIZE_MOD              ! Size parameters
```

INPUT PARAMETERS:

```
LOGICAL,         INTENT(IN)  :: LHGSNOW     ! Use Hg0 from snow?
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
REAL*8,          INTENT(OUT) :: LFLUX(IIPAR,JJPAR,N_Hg_CATS) ! Hg0 flux
                                                             !  [kg/s]
```

REVISION HISTORY:

```
30 Aug 2010 - N. E. Selin, C. Holmes, B. Corbitt - Initial version
(1 ) Now uses SNOWMAS from DAO_MOD for compatibility with GEOS-5.
     (eds 7/30/08)
(2 ) Now includes REEMFRAC in parallelization; previous versions may have
     overwritten variable. (cdh, eds 7/30/08)
(3 ) Now also reemit Hg(0) from ice surfaces, including sea ice
     (cdh, 8/19/08)
13 Aug 2010 - R. Yantosca - Add modifications for MERRA
25 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
26 Apr 2011 - J. Fisher   - Use MERRA land fraction information
12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.80.2 biomasshg

Subroutine BIOMASSHG is the subroutine for Hg(0) emissions from biomass burning. These emissions are active only for present day simulations and not for preindustrial simulations.

INTERFACE:

```
SUBROUTINE BIOMASSHG( EHg0_bb )
```

USES:

```
USE BIOMASS_MOD,  ONLY : BIOMASS
USE TRACERID_MOD, ONLY : IDBCO
USE LOGICAL_MOD,  ONLY : LBIOMASS, LPREINDHG
USE TIME_MOD,     ONLY : GET_TS_EMIS
USE GRID_MOD,     ONLY : GET_AREA_CM2

USE CMN_SIZE_MOD     ! Size parameters
USE CMN_DIAG_MOD     ! Diagnostic arrays & switches
```

OUTPUT PARAMETERS:

```
REAL*8, DIMENSION(:,:),INTENT(OUT) :: EHg0_bb
```

REMARKS:

```
Emissions are based on an inventory of CO emissions from biomass burning
(Duncan et al. J Geophys Res 2003), multiplied by a Hg/CO ratio in BB
plumes from Franz Slemr (Poster, EGU 2006).

Slemr surveyed emission factors from measurements worldwide. Although his
best estimate was 1.5e-7 mol Hg/ mol CO, we chose the highest value
(2.1e-7 mol Hg/ mol CO) in the range because the simulations shown in
Selin et al. (GBC 2008) required large Hg(0) emissions to sustain
reasonable atmospheric Hg(0) concentrations. (eck, 11/13/2008)
```

REVISION HISTORY:

```
30 Jul 2008 - N. E. Selin, C. Holmes, B. Corbitt - Initial version
12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.80.3 vegemis

Subroutine VEGEMIS is the subroutine for Hg(0) emissions from vegetation by evapotranspiration.

INTERFACE:

```
! Bug fix: VEGEMIS shouldn't be tied to GCAP emissions
! (jaf, eds, 4/1/11)
SUBROUTINE VEGEMIS( LVEGEMIS, EHg0_dist, EHg0_vg, State_Met )
```

USES:

```
USE DAO_MOD,            ONLY : IS_LAND
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_M2
USE TIME_MOD,           ONLY : GET_MONTH, ITS_A_NEW_MONTH
USE TIME_MOD,           ONLY : GET_TS_EMIS

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
LOGICAL,                INTENT(IN)  :: LVEGEMIS
REAL*8, DIMENSION(:,:), INTENT(IN)  :: EHg0_dist
TYPE(MetState),         INTENT(IN)  :: State_Met   ! Met State object
```

OUTPUT PARAMETERS:

```
REAL*8, DIMENSION(:,:), INTENT(OUT) :: EHg0_vg
```

REMARKS:

```
Vegetation emissions are proportional to the evapotranspiration rate and the
soil water mercury content. We assume a constant concentration of mercury
in soil matter, based on the preindustrial and present-day simulations
described in Selin et al. (GBC 2008) and in SOILEMIS subroutine. From the
soil matter Hg concentration, we calculate a soil water Hg concentration in
equilibrium (Allison and Allison, 2005).
NASA provides a climatology of evapotranspiration based on a water budget
model (Mintz and Walker, 1993).
Calculate vegetation emissions following Xu et al (1999)
   Fc = Ec Cw
   Fc is Hg0 flux (ng m-2 s-1)
   Ec is canopy transpiration (m s-1)
   Cw is conc of Hg0 in surface soil water (ng m-3)
Calculate Cw from the Allison and Allison (2005) equilibrium formula
   Cw = Cs / Kd
   Cs is the concentration of Hg is surface soil solids, ng/g
   Kd is the equilibrium constant = [sorbed]/[dissolved]
      log Kd = 3.8 L/kg -> Kd = 6310 L /kg = 6.31D-3 m3/g
We assume a global mean Cs = 45 ng/g for the preindustrial period. In
iterative simulations we redistribute this according to the deposition
pattern while maintining the global mean. The scaling factor, EHg0_dist,
also accounts for the anthropogenic enhancement of soil Hg in the present
day.
```

REVISION HISTORY:

```
30 Aug 2010 - N. Eckley, C. Holmes, B. Corbitt - Initial version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
```

1.80.4 soilemis

Subroutine SOILEMIS is the subroutine for Hg(0) emissions from soils.

INTERFACE:

```
SUBROUTINE SOILEMIS( EHg0_dist, EHg0_so, State_Met )
```

USES:

```
USE DAO_MOD,             ONLY : IS_LAND
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,            ONLY : GET_AREA_M2
USE MODIS_LAI_MOD,       ONLY : ISOLAI  => GC_LAI
USE TIME_MOD,            ONLY : GET_MONTH, ITS_A_NEW_MONTH
USE TIME_MOD,            ONLY : GET_TS_EMIS

USE CMN_SIZE_MOD              ! Size parameters
```

INPUT PARAMETERS:

```
REAL*8, DIMENSION(:,:), INTENT(IN)  :: EHg0_dist
TYPE(MetState),         INTENT(IN)  :: State_Met   ! Met State object
```

OUTPUT PARAMETERS:

```
REAL*8, DIMENSION(:,:), INTENT(OUT) :: EHg0_so
```

REMARKS:

```
Soil emissions are a function of solar radiation at ground level
(accounting for attenuation by leaf canopy) and surface temperature.
The radiation dependence from Zhang et al. (2000) is multiplied by the
temperature dependence from Poissant and Casimir (1998).
Finally, this emission factor is multiplied by the soil mercury
concentration and scaled to meet the global emission total.
Comments on soil Hg concentration:
---------------------------------
We chose the preindustrial value of 45 ng Hg /g dry soil as the mean of
the range quoted in Selin et al. (GBC 2008): 20-70 ng/g (Andersson, 1967;
Shacklette et al., 1971; Richardson et al., 2003; Frescholtz and Gustin,
2004). Present-day soil concentrations are thought to be 15% greater than
preindustrial (Mason and Sheu 2002), but such a difference is much less
than the range of concentrations found today, so not well constrained.
We calculate the present-day soil Hg distribution by adding a global mean
6.75 ng/g (=0.15 * 45 ng/g) according to present-day Hg deposition.
(eck, 11/13/08)
```

REVISION HISTORY:

```
30 Aug 2010 - N. Eckley, B. Corbitt - Initial version
(1 ) Added comments. (cdh, eds, 7/30/08)
(2 ) Now include light attenuation by the canopy after sunset. Emissions
     change by < 1% in high-emission areas  (cdh, 8/13/2008)
(3 ) Removed FRCLND for consistency with other Hg emissions (cdh, 8/19/08)
2 June 2010 - C. Carouge  - Solve
13 Aug 2010 - R. Yantosca - Added modifications for MERRA
25 Aug 2010 - R. Yantosca - Treat MERRA in same way as GEOS-5
26 Apr 2011 - J. Fisher   - Use MERRA land fraction information
12 Apr 2011 - J. Fisher   - Bug fixes, add missing code from Holmes 2010
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
10 Feb 2012 - R. Yantosca - Extend #if statement for SOIL_EMIS_FAC in order
                            to get the code to compile w/o error.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
28 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.80.5 read_nasa_transp

Subroutine READ_NASA_TRANSP reads monthly average transpiration [m/s] from NASA: for input into the vegetation emissions.

INTERFACE:

```
SUBROUTINE READ_NASA_TRANSP
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_TAU0,   READ_BPCH2
USE BPCH2_MOD,      ONLY : GET_RES_EXT
USE DIRECTORY_MOD,  ONLY : DATA_DIR
USE TIME_MOD,       ONLY : GET_MONTH,  ITS_A_NEW_MONTH
USE TRANSFER_MOD,   ONLY : TRANSFER_2D

USE CMN_SIZE_MOD       ! Size parameters
```

REMARKS:

```
Data source:
 http://gcmd.nasa.gov/records/GCMD_MINTZ_WALKER_SOIL_AND_EVAPO.html
References:
-----------
Mintz, Y and G.K. Walker (1993). "Global fields of soil moisture
 and land surface evapotranspiration derived from observed
 precipitation and surface air temperature." J. Appl. Meteorol. 32 (8),
1305-1334.
```

REVISION HISTORY:

```
15 Sep 2006 - N. E. Selin - Initial version
30 Aug 2010 - R. Yantosca - Added ProTeX headers
```

1.80.6 snowpack_mercury_flux

Subroutine SNOWPACK_MERCURY_FLUX calculates emission of Hg(0) from snow and ice.

INTERFACE:

```
SUBROUTINE SNOWPACK_MERCURY_FLUX( FLUX, LHGSNOW, State_Met )
```

USES:

```
USE DEPO_MERCURY_MOD,   ONLY : SNOW_HG
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_TS_EMIS
USE TRACERID_MOD,       ONLY : N_Hg_CATS

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: LHGSNOW     ! Use Hg from snow?
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
REAL*8,         INTENT(OUT) :: FLUX(IIPAR,JJPAR,N_Hg_CATS)  ! Hg0 flux
                                                            !  [kg/s]
```

REMARKS:

```
Emissions are a linear function of Hg mass stored in the snowpack. The
Hg lifetime in snow is assumed to be 180 d when T< 270K and 7 d when T>270K
   E = k * SNOW_HG     : k = 6D-8 if T<270K, 1.6D-6 otherwise
These time constants reflect the time scales of emission observed in the
Arctic and in field studies. Holmes et al 2010
```

REVISION HISTORY:

```
15 Sep 2009 - C. Holmes, S. Carouge - Initial version
30 Aug 2010 - R. Yantosca - Added ProTex headers
12 Apr 2011 - J. Fisher   - Add missing code from Holmes 2010
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
28 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
```

1.80.7 gtmm_dr

GTMM_DR is a driver to call GTMM from GEOS-Chem.

INTERFACE:

```
SUBROUTINE GTMM_DR( Hg0gtm, State_Met )
```

USES:

```
USE BPCH2_MOD
USE DAO_MOD,             ONLY : IS_LAND
USE DEPO_MERCURY_MOD,    ONLY : CHECK_DIMENSIONS
USE DEPO_MERCURY_MOD,    ONLY : WD_Hg2, WD_HgP, DD_HgP, DD_Hg2
USE DEPO_MERCURY_MOD,    ONLY : READ_GTMM_RESTART
USE DIRECTORY_MOD,       ONLY : DATA_DIR
USE FILE_MOD,            ONLY : IOERROR
USE GIGC_State_Met_Mod, ONLY : MetState
USE inquireMod,          ONLY : findFreeLun
USE TIME_MOD,            ONLY : EXPAND_DATE, YMD_EXTRACT
USE TIME_MOD,            ONLY : GET_NYMD, GET_NHMS

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
! Meteorology State object
TYPE(MetState), INTENT(IN)  :: State_Met
```

OUTPUT PARAMETERS:

```
! Emission of Hg0 calculated by GTMM for the month [kg/s]
REAL*8,         INTENT(OUT) :: Hg0gtm(IIPAR, JJPAR)
```

REVISION HISTORY:

```
15 Sep 2009 - C. Carouge  - Initial version
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

1.80.8 init_land_mercury

Subroutine INIT_LAND_MERCURY allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_LAND_MERCURY
```

USES:

```
USE ERROR_MOD,    ONLY : ALLOC_ERR
USE TRACERID_MOD, ONLY : N_Hg_CATS

USE CMN_SIZE_MOD     ! Size parameters
```

REVISION HISTORY:

```
14 Sep 2009 - C. Carouge  - Initial version
```

1.80.9 cleanup_land_mercury

Subroutine CLEANUP_LAND_MERCURY deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_LAND_MERCURY
```

REVISION HISTORY:

```
14 Sep 2009 - C. Carouge  - Initial version
```

1.81 Fortran: Module Interface lightning_nox_mod

Module LIGHTNING_NOx_MOD contains variables and routines for emitting NOx from lightning into the atmosphere. Original code comes from the old GISS-II CTM's of Yuhang Wang, Gerry Gardner, & Larry Horowitz.

INTERFACE:

```
MODULE LIGHTNING_NOx_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: LIGHTNING
PUBLIC  :: EMLIGHTNING
PUBLIC  :: CLEANUP_LIGHTNING_NOX
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: LIGHTDIST
PRIVATE :: FLASHES_CTH
PRIVATE :: GET_IC_CG_RATIO
PRIVATE :: READ_LOCAL_REDIST
PRIVATE :: GET_OTD_LIS_SCALE
PRIVATE :: INIT_LIGHTNING_NOX
```

PUBLIC DATA MEMBERS:

```
! Lightning NOx emissions [molec/cm3/s]
REAL*8, ALLOCATABLE, PUBLIC :: EMIS_LI_NOx(:,:,:)
```

REMARKS:

```
(1) MFLUX and PRECON methods are now deprecated (ltm, bmy, 7/9/09)
(2) Starting w/ GEOS-Chem v9-02, we read OTD-LIS local redistribution
     data files contained in subdirectory lightning_NOx_201311/.
                                                                             .
References:
============================================================================
(1 ) Price & Rind (1992), JGR, vol. 97, 9919-9933.
(2 ) Price & Rind (1994), M. Weather Rev, vol. 122, 1930-1939.
(3 ) Allen & Pickering (2002), JGR, 107, D23, 4711, doi:10.1029/2002JD002066
(4 ) Hudman et al (2007), JGR, 112, D12S05, doi:10.1029/2006JD007912
(5 ) Sauvage et al, 2007, ACP,
      http://www.atmos-chem-phys.net/7/815/2007/acp-7-815-2007.pdf
(6 ) Ott et al., (2010), JGR
(7 ) Allen et al., (2010), JGR
(8 ) Murray et al., (2011), in prep.
```

REVISION HISTORY:

```
14 Apr 2004 - L. Murray, R. Hudman - Initial version
(1 ) Based on "lightning_nox_mod.f", but updated for near-land formulation
     and for CTH, MFLUX, PRECON parameterizations (ltm, bmy, 5/10/06)
(2 ) Now move computation of IC/CG flash ratio out of routines FLASHES_CTH,
     FLASHES_MFLUX, FLASHES_PRECON, and into routine GET_IC_CG_RATIO.
     Added a fix in LIGHTDIST for pathological grid boxes.  Set E_IC_CG=1
     according to Allen & Pickering [2002].  Rename OTDSCALE array to
     OTD_REG_REDIST, and also add OTD_LOC_REDIST array.  Now scale
     lightning to 6 Tg N/yr for both 2x25 and 4x5.  Rename routine
     GET_OTD_LIS_REDIST to GET_REGIONAL_REDIST.  Add similar routine
     GET_LOCAL_REDIST.  Removed GET_OTD_LOCp AL_REDIST.  Bug fix: divide
     A_M2 by 1d6 to get A_KM2. (rch, ltm, bmy, 2/22/07)
(3 ) Rewritten for separate treatment of LNOx emissions at tropics &
     midlatitudes, based on Hudman et al 2007.  Removed obsolete
     variable E_IC_CG. (rch, ltm, bmy, 3/27/07)
(4 ) Changes implemented in this version (ltm, bmy, 10/3/07)
     * Revert to not classifying near-land as land
     * Eliminate NOx emisisons per path length entirely
     * Scale tropics to 260 mol/fl constraint from Randall Martin's
       4.4 Tg and OTD-LIS avg ann flash rate
     * Remove top-down scaling (remove the three functions)
     * Allow option of mid-level scaling to match global avg ann flash
       rate between G-C and OTD-LIS 11-year climatology (new function)
     * Local Redist now a la Murray et al, 2007 in preparation (monthly)
     * Replace GEMISNOX (from CMN_NOX) with module variable EMIS_LI_NOx
(5 ) Added MFLUX, PRECON redistribution options (ltm, bmy, 11/29/07)
(6 ) Updated OTD/LIS scaling for GEOS-5 to get more realistic totals
     (ltm, bmy, 2/20/08)
(7 ) Now add the proper scale factors for the GEOS-5 0.5 x 0.666 grid
     and the GEOS-3 1x1 nested N. America grid in routine
     GET_OTD_LIS_SCALE. (yxw, dan, ltm, bmy, 11/14/08)
(8 ) Added quick fix for GEOS-5 reprocessed met fields (ltm, bmy, 2/18/09)
(9 ) Added quick fix for GEOS-5 years 2004, 2005, 2008 (ltm, bmy, 4/29/09)
(10) Updated OTD/LIS scaling for GEOS-5 reprocessed data (ltm, bmy, 7/10/09)
(11) Updated for GEOS-4 1 x 1.25 grid (lok, ltm, bmy, 1/13/10)
(12) Reprocessed for CLDTOPS calculation error; Updated Ott vertical
     profiles; Removal of depreciated options, e.g., MFLUX and PRECON;
     GEOS5 5.1.0 vs. 5.2.0 special treatment; MERRA; Other changes.
     Please see PDF on wiki page for full description of lightning
     changes to v9-01-01. (ltm, 1/25/11)
13 Aug 2010 - R. Yantosca - Add modifications for MERRA
10 Nov 2010 - L. Murray   - Updated OTD/LIS local scaling for MERRA 4x5
10 Nov 2010 - R. Yantosca - Added ProTeX headers
02 Feb 2012 - R. Yantosca - Added modifications for GEOS-5.7.x met fields
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

```
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.81.1 lightning

Subroutine LIGHTNING uses Price & Rind's formulation for computing NOx emission from lightning (with various updates).

INTERFACE:

```
SUBROUTINE LIGHTNING( State_Met )
```

USES:

```
USE DIAG56_MOD,         ONLY : AD56,      ND56
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_YMID,  GET_XMID,   GET_AREA_M2
USE LOGICAL_MOD,        ONLY : LOTDLOC
USE PRESSURE_MOD,       ONLY : GET_PEDGE, GET_PCENTER
USE TIME_MOD,           ONLY : GET_MONTH, GET_YEAR

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_GCTM_MOD             ! Physical constants
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REMARKS:

```
Output Lightning NOX [molec/cm3/s] is stored in the EMIS_NOX_LI array.
```

REVISION HISTORY:

```
10 May 2006 - L. Murray - Initial version
(1 ) Now recompute the cold cloud thickness according to updated formula
     from Lee Murray.  Rearranged argument lists to routines FLASHES_CTH,
     FLASHES_MFLUX, FLASHES_PRECON.  Now call READ_REGIONAL_REDIST and
     READ_LOCAL_REDIST. Updated comments accordingly.  Now apply
     FLASH_SCALE to scale the total lightning NOx to 6 Tg N/yr.  Now apply
     OTD/LIS regional or local redistribution (cf. B. Sauvage) to the ND56
     diagnostic. lightning redistribution to the ND56 diag.  Renamed
     REGSCALE variable to REDIST.  Bug fix: divide A_M2 by 1d6 to get
     A_KM2. (rch, ltm, bmy, 2/14/07)
(2 ) Rewritten for separate treatment of LNOx emissions at tropics &
     midlatitudes (rch, ltm, bmy, 3/27/07)
(3 ) Remove path-length algorithm.  Renamed from LIGHTNING_NL to LIGHTNING.
     Other improvements. (ltm, bmy, 9/24/07)
(4 ) Remove depreciated options; Update to new Ott et al vertical profiles;
     Reprocessed for bug in CLDTOPS calculation. See PDF on wiki for
```

```
      full description of changes for v9-01-01. (ltm, bmy, 1/25,11)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.81.2 lightdist

Subroutine LIGHTDIST reads in the CDF used to partition the column lightning NOx into the GEOS-Chem vertical layers.

INTERFACE:

```
      SUBROUTINE LIGHTDIST( I, J, LTOP, H0, XLAT, TOTAL, VERTPROF,
     &                      State_Met )
```

USES:

```
      USE DAO_MOD,             ONLY : IS_LAND,  IS_WATER
      USE DIRECTORY_MOD,       ONLY : DATA_DIR
      USE ERROR_MOD,           ONLY : GEOS_CHEM_STOP
      USE FILE_MOD,            ONLY : IOERROR
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,            ONLY : GET_YMID
      USE TIME_MOD,            ONLY : GET_MONTH

      USE CMN_SIZE_MOD              ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER,         INTENT(IN)  :: I          ! Longitude index
      INTEGER,         INTENT(IN)  :: J          ! Latitude index
      INTEGER,         INTENT(IN)  :: LTOP       ! Level of conv cloud top
      REAL*8,          INTENT(IN)  :: H0         ! Conv cloud top height [m]
      REAL*8,          INTENT(IN)  :: XLAT       ! Latitude value [degrees]
      REAL*8,          INTENT(IN)  :: TOTAL      ! Column Total # of LNOx molec
      TYPE(MetState), INTENT(IN)  :: State_Met  ! Meteorology State object
```

OUTPUT PARAMETERS:

```
      REAL*8,          INTENT(OUT) :: VERTPROF(LLPAR) ! Vertical profile of LNOx
```

REMARKS:

```
    References:
    ============================================================================
    (1 ) Pickering et al., JGR 103, 31,203 - 31,316, 1998.
    (2 ) Ott et al., JGR, 2010
    (3 ) Allen et al., JGR, 2010
```

REVISION HISTORY:

```
18 Sep 2002 - M. Evans - Initial version (based on Yuhang Wang's code)
(1 ) Use functions IS_LAND and IS_WATER to determine if the given grid
     box is over land or water.  These functions work for all DAO met
     field data sets. (bmy, 4/2/02)
(2 ) Renamed M2 to LTOP and THEIGHT to H0 for consistency w/ variable names
     w/in "lightning.f".  Now read the "light_dist.dat.geos3" file for
     GEOS-3 directly from the DATA_DIR/lightning_NOx_200203/ subdirectory.
     Now read the "light_dist.dat" file for GEOS-1, GEOS-STRAT directly
     from the DATA_DIR/lightning_NOx_200203/ subdirectory.  Added
     descriptive comment header.  Now trap I/O errors across all
     platforms with subroutine "ioerror.f".  Updated comments, cosmetic
     changes.  Redimension FRAC(NNLIGHT) to FRAC(LLPAR). (bmy, 4/2/02)
(3 ) Deleted obsolete code from April 2002.  Now reference IU_FILE and
     IOERROR from "file_mod.f".  Now use IU_FILE instead of IUNIT as the
     file unit number. (bmy, 6/27/02)
(4 ) Now reference BXHEIGHT from "dao_mod.f" (bmy, 9/18/02)
(5 ) Bug fix: add GEOS_4 to the #if block (bmy, 3/4/04)
(6 ) Now bundled into "lightning_mod.f".  CDF's are now read w/in
     routine INIT_LIGHTNING to allow parallelization (bmy, 4/14/04)
(7 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(8 ) Now uses near-land formulation (ltm, bmy, 5/10/06)
(9 ) Added extra safety check for pathological boxes (bmy, 12/11/06)
(10) Remove the near-land formulation, except for PRECON (ltm, bmy, 9/24/07)
(11) Now use the Ott et al. [2010] profiles, and apply consistently with
     GMI model [Allen et al., 2010] (ltm, bmy, 1/25/11).
10 Nov 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
15 Jun 2012 - Nielsen - INQUIRE finds free logical unit number for IU_FILE
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.81.3 flashes_cth

Subroutine FLASHES_CTH determines the rate of lightning flashes per minute based on the height of convective cloud tops, and the intra-cloud to cloud-ground strike ratio.

INTERFACE:

```
SUBROUTINE FLASHES_CTH( I, J, HEIGHT, FLASHRATE, State_Met )
```

USES:

```
USE DAO_MOD,            ONLY : IS_ICE
USE DAO_MOD,            ONLY : IS_LAND
USE DAO_MOD,            ONLY : IS_WATER
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,         INTENT(IN)  :: I           ! Longitude index
INTEGER,         INTENT(IN)  :: J           ! Latitude index
REAL*8,          INTENT(IN)  :: HEIGHT      ! Height of conv cloud top [m]
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
REAL*8,          INTENT(OUT) :: FLASHRATE   ! Lightning flast rate
                                            !  [flashes/min]
```

REVISION HISTORY:

```
10 May 2006 - L. Murray - Initial version
(1  ) Subroutine renamed from FLASHES (ltm, bmy, 5/10/06)
(2  ) Remove CCTHICK, IC_CG_RATIO as arguments.  Remove computation of
      IC_CG_RATIO and move that to GET_IC_CG_RATIO. (ltm, bmy, 12/11/06)
(3  ) Remove the near-land formulation (i.e. use function IS_LAND
      instead of IS_NEAR).(ltm, bmy, 9/24/07)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.81.4 get_ic_cg_ratio

Function GET_IC_CG_RATIO calculates the Intra-Cloud (IC) and Cloud-to-Ground (CG) lightning flash ratio based on the method of Price and Rind 1993, which is calculated from the cold-cloud depth (CCTHICK).

INTERFACE:

```
FUNCTION GET_IC_CG_RATIO( CCTHICK ) RESULT( IC_CG_RATIO )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN)  :: CCTHICK       ! Cold cloud thickness [m]
```

RETURN VALUE:

```
REAL*8               :: IC_CG_RATIO   ! Intra-cloud/cloud-ground ratio
```

REVISION HISTORY:

```
11 Dec 2006 - R. Yantosca - Initial version
(1 ) Split off from FLASHES_CTH, FLASHES_MFLUX, FLASHES_PRECON into this
     separate function (ltm, bmy, 12/11/06)
(2 ) Bug fix for XLF compiler (morin, bmy, 7/8/09)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
```

1.81.5 read_local_redist

Subroutine READ_LOCAL_REDIST reads in seasonal factors in order to redistribute GEOS-Chem flash rates according the "local redistribution" method of Bastien Sauvage. This helps to make sure that the lightning flashes occur according to the distribution of observed convection.

INTERFACE:

```
SUBROUTINE READ_LOCAL_REDIST( MONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT
USE BPCH2_MOD,     ONLY : GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0
USE BPCH2_MOD,     ONLY : READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE ERROR_MOD,     ONLY : ALLOC_ERR
USE TIME_MOD,      ONLY : GET_TAU
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD               ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: MONTH   ! Current month
```

REVISION HISTORY:

```
26 Jan 2007 - B. Sauvage - Initial version
(1 ) Change from seasonal to monthly.  Rename all filenames from "v2"
     to "v3". (ltm, bmy, 9/24/07)
(2 ) Change all filenames from "v2" to "v3".  Also now read from the
     directory lightning_NOx_200709. (ltm, bmy, 9/24/07)
(3 ) Added "quick fix" for reprocessed GEOS-5 met fields to be used when
     the IN_CLOUD_OD switch is turned on. (ltm, bmy, 2/18/09)
(4 ) Now read from lightning_NOx_200907 directory for GEOS-4 and
     GEOS-5 CTH parameterizations.  Updated OTD/LIS for GEOS-5 based on
     4+ years of data; removed temporary fixes. (ltm, bmy, 7/10/09)
(5 ) Remove depreciated options and update to v5 of redist files in
     new data directory. Special handling for GEOS5.1.0 and 5.2.0 added.
     (ltm, bmy, 1/25/11)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
02 Feb 2012 - R. Yantosca - Added modifications for GEOS-5.7.x met
18 Apr 2013 - R. Yantosca - Bug fix, prefix DATA_DIR to GEOS-5.7.x file
26 Sep 2013 - R. Yantosca - Remove SEAC4RS C-preprocessor switch
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
07 Nov 2013 - R. Yantosca - Now read files from lightning_NOx_201311 dir
```

1.81.6 emlightning

Subroutine EMLIGHTNING converts lightning emissions to [molec/cm3/s] and stores them in the GEMISNOX array, which gets passed to SMVGEAR.

INTERFACE:

```
SUBROUTINE EMLIGHTNING( State_Met, State_Chm )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD32_li
USE GIGC_State_Met_Mod, ONLY : MetState
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACERID_MOD,       ONLY : IDTNO
USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
09 Oct 1997 - R. Yantosca - Initial version
(1 ) Remove IOFF, JOFF from the argument list.  Also remove references
     to header files "CMN_O3" and "comtrid.h" (bmy, 3/16/00)
(2 ) Now use allocatable array for ND32 diagnostic (bmy, 3/16/00)
(3 ) Now reference BXHEIGHT from "dao_mod.f".  Updated comments, cosmetic
     changes.  Replace LCONVM with the parameter LLCONVM. (bmy, 9/18/02)
(4 ) Removed obsolete reference to "CMN".  Now bundled into
     "lightning_mod.f" (bmy, 4/14/04)
(5 ) Renamed from EMLIGHTNING_NL to EMLIGHTNING.  Now replace GEMISNOX
     (from CMN_NOX) with module variable EMIS_LI_NOx. (ltm, bmy, 10/3/07)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - R. Yantosca - Now accept State_Chm
```

1.81.7 get_otd_lis_scale

Function GET_OTD_LIS_SCALE returns a met-field dependent scale factor which is to be applied to the lightning flash rate to bring the annual average flash rate to match that

of the OTD-LIS climatology (45.9 flashes/sec). Computed by running the model over the 11-year OTD-LIS campaign window and comparing the average flash rates, or as many years as are available.

INTERFACE:

```
FUNCTION GET_OTD_LIS_SCALE() RESULT( BETA )
```

USES:

```
USE BPCH2_MOD,   ONLY : GET_TAU0
USE ERROR_MOD,   ONLY : GEOS_CHEM_STOP
USE TIME_MOD,    ONLY : GET_TAU, GET_MONTH, GET_YEAR
```

RETURN VALUE:

```
REAL*8 :: BETA    ! Scale factor
```

REMARKS:

```
(1) Starting in G-C v9-02, we now read data from lightning_NOx_201311.
```

REVISION HISTORY:

```
24 Sep 2007 - L. Murray - Initial version
(1 ) Added MFLUX, PRECON scaling for GEOS-4.  Also write messages for met
     field types/grids where scaling is not defined. (ltm, bmy, 11/29/07)
(2 ) Now use different divisor for local redist (ltm, bmy, 2/20/08)
(3 ) Now compute the proper scale factor for GEOS-5 0.5 x 0.666 grids
     and the GEOS-3 1x1 nested NA grid (yxw, dan, ltm, bmy, 11/14/08)
(4 ) Added "quick fix" for reprocessed GEOS-5 met fields to be used when
     the IN_CLOUD_OD switch is turned on. (ltm, bmy, 2/18/09)
(5 ) Added "quick fix" for 2004, 2005, 2008 OTD/LIS (ltm, bmy, 4/29/09)
(6 ) Updated scale factors for GEOS-5 based on 4+ years of data.  Remove
     temporary fixes. (bmy, 7/10/09)
(7 ) Modification for GEOS-4 1 x 1.25 grid (lok, ltm, bmy, 1/13/10)
(8 ) Reprocessed for error in CLDTOPS field; Updated for GEOS
     5.1.0 vs. 5.2.0; MERRA added; (ltm, bmy, 1/25/11)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
02 Feb 2012 - R. Yantosca - Compute BETA for MERRA 2 x 2.5
02 Feb 2012 - R. Yantosca - Compute BETA for GEOS-5.7.x
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.81.8 init_lightning_NOx

Subroutine INIT_LIGHTNING_NOx allocates all module arrays. It also reads the lightning CDF data from disk before the first lightning timestep.

INTERFACE:

```
SUBROUTINE INIT_LIGHTNING_NOx
```

USES:

```
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE ERROR_MOD,     ONLY : ALLOC_ERR
USE FILE_MOD,      ONLY : IOERROR
USE GRID_MOD,      ONLY : GET_AREA_M2
USE LOGICAL_MOD,   ONLY : LOTDLOC

USE CMN_SIZE_MOD      ! Size parameters
```

REVISION HISTORY:

```
14 Apr 2004 - R. Yantosca - Initial version
(1 ) Now reference DATA_DIR from "directory_mod.f"
(2 ) Now call GET_MET_FIELD_SCALE to initialize the scale factor for
     each met field type and grid resolution (bmy, 8/25/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now get the box area at 30N for MFLUX, PRECON (lth, bmy, 5/10/06)
(5 ) Rename OTDSCALE to OTD_REG_REDIST.  Also add similar array
     OTD_LOC_REDIST.  Now call GET_FLASH_SCALE_CTH, GET_FLASH_SCALE_MFLUX,
     GET_FLASH_SCALE_PRECON depending on the type of lightning param used.
     Updated comments.  (ltm, bmy, 1/31/07)
(6 ) Removed near-land stuff.  Renamed from INIT_LIGHTNING_NOX_NL to
     INIT_LIGHTNING_NOX.  Now allocate EMIS_LI_NOx. (ltm, bmy, 10/3/07)
(7 ) Also update location of PDF file to lightning_NOx_200709 directory.
     (bmy, 1/24/08)
(8 ) Read in new Ott profiles from lightning_NOx_201101. Remove
     depreciated options. (ltm, bmy, 1/25/11)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Removed reference to GET_YEDGE
```

1.81.9 cleanup_lightning_NOx

Subroutine CLEANUP_LIGHTNING_NOx deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_LIGHTNING_NOx
```

REVISION HISTORY:

```
14 Apr 2004 - R. Yantosca - Initial version
(1 ) Now deallocates OTDSCALE (ltm, bmy, 5/10/06)
(2 ) Rename OTDSCALE to OTD_REG_REDIST.  Now deallocate OTD_LOC_REDIST.
     (bmy, 1/31/07)
```

```
(3 ) Renamed from CLEANUP_LIGHTNING_NOX_NL to CLEANUP_LIGHTNING_NOX.
      Now deallocate EMIS_LI_NOx. (ltm, bmy, 10/3/07)
(4 ) Remove depreciated options. (ltm, bmy, 1/25/11)
10 Nov 2010 - R. Yantosca - Added ProTeX headers
```

1.82 Fortran: Module Interface linoz_mod

Module LINOZ_MOD contains routines to perform the Linoz stratospheric ozone chemistry.

INTERFACE:

```
      MODULE LINOZ_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
   !PRIVATE DATA MEMBERS:
      REAL*8, ALLOCATABLE :: TLSTT(:,:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_LINOZ
      PUBLIC  :: DO_LINOZ
      PUBLIC  :: INIT_LINOZ
      PUBLIC  :: LINOZ_READ
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: LINOZ_CHEM3
      PRIVATE :: LINOZ_STRATL
      PRIVATE :: LINOZ_STRT2M
      PRIVATE :: LINOZ_SOMLFQ
      PRIVATE :: LINOZ_INTPL
```

REMARKS:

```
LINOZ Climatology:
============================================================================
The LINOZ stratospheric chemistry tables for ozone consist of:
                                                                            .
7 tables, each a function of:
  12 months,
  18 latitudes (-85 to 85 in 10 deg. increments)
  25 altitudes ( z*=10-58 km in 2 km increments)
                                                                            .
The 7 data fields are:
  1- ozone (Logan climatology), v/v
  2- Temperature climatology, K
  3- Column ozone climatology, Logan ozone integrated above box, DU
```

```
  4- ozone (P-L) for climatological ozone, v/v/s
  5- d(P-L) / dO3, 1/s
  6- d(P-L) / dT, v/v/s/K
  7- d(P-L) / d(column O3), v/v/s/DU
                                                                             .
 Implementation notes:
 ============================================================================
 Dylan Jones (dbj@atmosp.physics.utoronto.ca) wrote:
                                                                             .
   Testing this code [in v8-02-04] was more difficult that I thought.
   I began by trying to compare the output of v8-02-04 with our previous
   runs with v8-02-01.  I accounted for the changes in the transport_mod.f
   and I tried to undo the changes in when the diagnostics are archived in
   v8-02-04, but I was still getting large differences between v8-02-04
   and v8-02-01. I finally gave up on this since I may have made a mistake
   in reverting to the old way of doing the diagnostics in v8-02-04.  In
   the end I took the new linoz code from v8-02-04 and used it in v8-02-01.
   I ran two GEOS-5 full chemistry simulations for 2007 and the output
   were consistent over the full year.
                                                                             .
   I think that it is safe to release [Linoz in v8-02-04].  However, we
   should acknowledge that it was [only] tested in v8-02-01, since I was
   not able to assess the quality of the output in v8-02-04.
                                                                             .
 Bob Yantosca (yantosca@seas.harvard.edu) wrote:
                                                                             .
    We have also modified the code for use within the GEOS-5 GCM.  We now
    declare the TPARM array as part of the Input_Opt object.  The LINOZ
    climatology ASCII file is now read on the root CPU and MPI-broadcasted
    to the non-root CPUs.  Also, the INIT_LINOZ routine is now called
    not on the first chemistry timestep but rather in the initialization
    phase at the start of the run. (bmy, 3/18/13)

 REVISION HISTORY:
  23 Mar 2000 - P. Cameron-Smith    - Initial version adapted heavily
                                      from McLinden's original file.
  24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
  28 May 2009 - D. Jones            - Further modifications
  18 Nov 2009 - D. Jones            - Further modifications
  01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
  01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
  15 Mar 2013 - R. Yantosca - Now use fields from Input_Opt and made other
                              modifications for GIGC interface to GEOS-5 GCM
  18 Mar 2013 - R. Yantosca - Comment out STRAT_INIT, it's not called
  20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.82.1 do_linoz

Subroutine DO_LINOZ is the main driver for the Linoz stratospheric Ozone chemistry package.

INTERFACE:

```
      SUBROUTINE DO_LINOZ( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TIME_MOD,           ONLY : GET_MONTH
      USE TIME_MOD,           ONLY : GET_TS_CHEM
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
    10 Jun 2012 - L. Murray - Move call to DO_LINOZ from transport code to
                  chemistry code, so the use of DT_TS_CHEM is now correct.
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    18 Mar 2013 - R. Yantosca - Now accept Input_Opt, RC as arguments
    25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.82.2 linoz_chem3

Subroutine LINOZ_CHEM3 applies linearized chemistry based on tables from PRATMO model using climatological T, O3, time of year

INTERFACE:

```
      SUBROUTINE LINOZ_CHEM3( DTCHEM,    am_I_Root, Input_Opt,
     &                        State_Met, State_Chm, RC         )
```

USES:

```
      USE CMN_SIZE_MOD
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE TRACERID_MOD
      USE TROPOPAUSE_MOD,     ONLY : GET_TPAUSE_LEVEL
      USE TROPOPAUSE_MOD,     ONLY : GET_MAX_TPAUSE_LEVEL
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE PRESSURE_MOD,       ONLY : GET_PCENTER
```

INPUT PARAMETERS:

```
      REAL*8,         INTENT(IN)    :: DTCHEM      ! Time step [seconds]
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
   !OUTPUT PARAMETERS
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    Replace fields from tracer_mod.f with fields from Input_Opt.  When we
    use GEOS-Chem within the GEOS-5 GCM, the fields within Input_Opt will
    be read on the root CPU and MPI-broadcasted to all other CPUs.
```

REVISION HISTORY:

```
    24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
    18 Nov 2009 - D. Jones            - For now, set tagged stratospheric
                                        tracer to total O3 in the overworld
                                        to avoid issues with spin ups
    08 Feb 2010 - R. Yantosca         - Deleted obsolete local variables
    22 Oct 2010 - R. Yantosca         - Added OMP parallel loop
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    14 Mar 2013 - M. Payer    - Replace Ox with O3 as part of removal of NOx-Ox
                                partitioning
    18 Mar 2013 - R. Yantosca - Now accept Input_Opt, RC as arguments
```

```
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%TCVV(1:N_TRACERS)
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
06 Nov 2013 - R. Yantosca - Now activate the parallel loop.  Unit testing
                            revealed that this no longer causes errors.
```

1.82.3 linoz_stratl

Subroutine LINOZ_STRATL performs a monthly fixup of chemistry parameters for the Linoz stratospheric ozone chemistry.

INTERFACE:

```
SUBROUTINE LINOZ_STRATL( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_YMID
USE TIME_MOD,           ONLY : GET_MONTH
USE PRESSURE_MOD
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
Replace size fields NLAT_LINOZ etc. with fields from Input_Opt.  When we
use GEOS-Chem within the GEOS-5 GCM, the fields within Input_Opt will
be read on the root CPU and MPI-broadcasted to all other CPUs.

The LINOZ climatology array is Input_Opt%LINOZ_TPARM(25,18,12,N),
which has the following dimensions
  * 25 layers from 58 km to 10 km by 2 km intervals
  * 18 latitudes (85S, 75S, ...85N)
  * 12 months
  *  N fields (currently N=7)
```

REVISION HISTORY:

```
24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
18 Mar 2013 - R. Yantosca - Accept Input_Opt, RC arguments.  Use fields
                            from Input_Opt to facilitate GC/GEOS-5 interface
18 Mar 2013 - R. Yantosca - Cosmetic changes, updated comments
```

1.82.4 linoz_strt2m

Subroutine LINOZ_STRT2M interpolates quantities from the LINOZ vertical grid to the GEOS-Chem vertical grid. It also computes the 1st & 2nd moments of the distribution.

INTERFACE:

```
      SUBROUTINE LINOZ_STRT2M( am_I_Root, Input_Opt, NSTRT,
     &                         STRTX,     POL,       STRT0L,
     &                         STRT1L,    STRT2L,    RC      )
```

USES:

```
      USE CMN_SIZE_MOD
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      !-----------------------------------------------------------------
      ! am_I_Root : Are we on the root CPU?
      ! Input_Opt : Input Options object
      ! NSTRT     : # of levels in the GEOS-Chem grid (= LLPAR)
      ! STRTX     : Quantity on the LINOZ vertical grid
      !             (i.e. fields #1-7 of the LINOZ climatology)
      ! POL       : Pressure edges on the GEOS-Chem grid
      !-----------------------------------------------------------------
      LOGICAL,        INTENT(IN)  :: am_I_Root
      TYPE(OptInput), INTENT(IN)  :: Input_Opt
      INTEGER,        INTENT(IN)  :: NSTRT
      REAL*8,         INTENT(IN)  :: STRTX(Input_Opt%LINOZ_NLEVELS)
      REAL*8,         INTENT(IN)  :: POL(LLPAR+1)
```

OUTPUT PARAMETERS:

```
      !-----------------------------------------------------------------
      ! STRT0L    : 0th moment of distribution, on GEOS-Chem grid edges
      ! STRT1L    : 1st moment of distribution, on GEOS-Chem grid edges
      ! STRT2L    : 2nd moment of distribution, on GEOS-Chem grid edges
      ! RC        : Success or failure?
      !-----------------------------------------------------------------
      REAL*8,         INTENT(OUT) :: STRT0L(LLPAR+1)
      REAL*8,         INTENT(OUT) :: STRT1L(LLPAR+1)
      REAL*8,         INTENT(OUT) :: STRT2L(LLPAR+1)
      INTEGER,        INTENT(OUT) :: RC
```

REMARKS:

```
    Comments from Chris McLinden to Peter Cameron-Smith:
    ============================================================================
```

```
CALL SOMLFQ(P1,P2,F0,F1,F2,PS,F,NL)
- P1,P2 are the pressure EDGES for the CTM layer onto which the
  coefficients will be mapped. [P1>P2 I believe {PJC}]
- F0,F1,F2 are the CTM layer vertical moments determined in SOMLFQ
- PS are the pressure layer edges of the original [ie Linox] grid
- F is the column of coefficients (on the original grid); note
  F is flipped relative to STRTX and since the coefficients begin
  at z*=10, F(1)=F(2)=...=F(5)=0
- NL is 30; size of F()

 The box model calculations were performed at z*=10km, 12km, ... and
 so these would represent the centres with the corresponding edges at
 9,11km ; 11,13km; ...
 PS() represents the edges (although PS(1) is set to 1000mb).
 The first few values are:
   PS(1)=1000
   PS(2)=874.947105    (note PS(2) is not quite 1000 exp(-1/16) as the
   PS(3)=656.117767     the average pressure is used - not the pressure
   PS(4)=492.018914     at the average z*)
   PS(5)=368.96213
   PS(6)=276.68257
   PS(7)=207.48266
   ...
   PS(30)=0.276682568
   PS(31)=0.0

   F(1) spans PS(1)-PS(2)
   F(2) spans PS(2)-PS(3)
   ...
   F(30) spans PS(30)-PS(31)
```

REVISION HISTORY:

```
24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
18 Mar 2013 - R. Yantosca - Now pass am_I_root, Input_Opt, RC arguments
18 Mar 2013 - R. Yantosca - Rearrange argument list so that inputs are
                            all listed before outputs
18 Mar 2013 - R. Yantosca - Now make NL a local varable and set its
                            value from Input_Opt%LINOZ_NLEVELS
```

1.82.5 linoz_somlfq

subroutine LINOZ_SOMLFQ calculates loss freq moments from a set of loss frequencies at std z*, given a CTM model interval pressure range: P1 ¿ P2 (decreasing up)

INTERFACE:

```
      SUBROUTINE LINOZ_SOMLFQ(P1,P2,F0,F1,F2,PS,F,NL)
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)  :: NL
      REAL*8,  INTENT(IN)  :: F(NL)
      REAL*8,  INTENT(IN)  :: PS(NL+1)
      REAL*8,  INTENT(IN)  :: P1
      REAL*8,  INTENT(IN)  :: P2
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: F0
      REAL*8,  INTENT(OUT) :: F1
      REAL*8,  INTENT(OUT) :: F2
  REMARKS:
  The pressure levels BETWEEN z* values are:
       PS(i) > PS(i+1) bounds z*(i)

  NL:  z* levels, ==> PS(NL+1) = 0  (extrapolate chemical loss to top)
       Z1 = 16.D0*LOG10(1000.D0/P1)
       Z2 = 16.D0*LOG10(1000.D0/P2)

  The MOMENTS for a square-wave or 'bar': F(x)=f0  b<=x<=c, =0.0 else
       S0 =   f0 (x)                      [from x=b to x=c]
       S1 = 3 f0 (x^2 - x)                [from x=b to x=c]
       S2 = 5 f0 (2x^3 - 3x^2 + x)        [from x=b to x=c]
```

REVISION HISTORY:

```
   24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
   19 Mar 2013 - R. Yantosca - P1, P2 are now declared as INTENT(IN)
```

1.82.6 linoz_read

Subroutine LINOZ_READ reads the input data file for the Linoz stratospheric ozone chemistry.

INTERFACE:

```
      SUBROUTINE LINOZ_READ( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE FILE_MOD,           ONLY : IOERROR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE InquireMod,         ONLY : findFreeLun
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(OptInput), INTENT(INOUT) :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
LINOZ_READ is called from "main.f" at the start of the simulation.
LINOZ_READ will also call INIT_LINOZ to initialize the arrays.
```

REVISION HISTORY:

```
24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
16 Oct 2009 - R. Yantosca         - Now use IU_FILE instead of IU_LINOZ
16 Oct 2009 - R. Yantosca         - Read file from DATA_DIR_1x1
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
15 Mar 2013 - R. Yantosca - Now call INIT_LINOZ from GIGC_Init_Extra
```

1.82.7 linoz_intpl

Subroutine LINOZ_INTPL does some kind of interpolation.

INTERFACE:

```
SUBROUTINE LINOZ_INTPL(KE,IE,ND,NE,XI,XN,YI,YN)
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: KE
INTEGER, INTENT(IN)  :: IE
INTEGER, INTENT(IN)  :: ND
INTEGER, INTENT(IN)  :: NE
REAL*8,  INTENT(IN)  :: XI(IE)
REAL*8,  INTENT(IN)  :: XN(ND)
REAL*8,  INTENT(IN)  :: YI(KE,IE)
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: YN(KE,ND)
```

REVISION HISTORY:

```
24 Jun 2003 - B. Field & D. Jones - Further updates for GEOS-Chem
```

1.82.8 init_linoz

Subroutine INIT_LINOZ allocates and zeroes the module arrays used in the Linoz stratospheric ozone algorithm.

INTERFACE:

```
SUBROUTINE INIT_LINOZ( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
16 Oct 2009 - R. Yantosca - Initial version
18 Mar 2013 - R. Yantosca - Remove TPARM array since that is now carried
                            within the Input_Opt object.
18 Mar 2013 - R. Yantosca - Accept am_I_Root, Input_Opt, RC arguments
14 Mar 2013 - M. Payer    - Replace Ox with O3 for full-chemistry simulation
```

1.82.9 cleanup_linoz

Subroutine CLEANUP_LINOZ deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_LINOZ
```

REVISION HISTORY:

```
16 Oct 2009 - R. Yantosca - Initial version
```

1.83 Fortran: Module Interface logical_mod.f

Module LOGICAL_MOD contains all of the logical switches used by GEOS-Chem.

INTERFACE:

```
MODULE LOGICAL_MOD
```

USES:

```
IMPLICIT NONE
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: THIS MODULE IS NOW OBSOLETE AND IS SLATED TO BE REMOVED!   %%%
%%%  WE NOW USE THE LOGICALS FROM Input_Opt INSTEAD OF FROM HERE.     %%%
%%%     -- Bob Yantosca, 20 Aug 2013                                  %%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
05 Nov 2004 - R. Yantosca - Added LNEI99 switch to toggle EPA/NEI emissions
20 Dec 2004 - R. Yantosca - Added LAVHRRLAI switch for AVHRR LAI fields
20 Oct 2005 - T-M Fu.     - Added LMEGAN switch for MEGAN biogenics
01 Nov 2005 - B. Field    - Added LEMEP switch
26 Feb 2006 - R. Yantosca - Added LDYNOCEAN switch for online ocean Hg model
05 Apr 2006 - R. Yantosca - Added LGFED2BB switch for GFED2 BIOMASS BURNING
05 May 2006 - L. Murray   - Added LCTH, LMFLUX, LPRECON for lightning
30 May 2006 - S. Wu       - Added LFUTURE
26 Jun 2006 - R. Park     - Added LBRAVO
06 Jul 2006 - Aaron van D.- Added LEDGAR, LEDGARNOx, LEDGARCO, LEDGARSHIP,
                            LEDGARSOx switches for EDGAR emissions
17 Aug 2006 - R. Yantosca - Added LSTREETS for David Streets' emissions
21 Aug 2006 - P. Le Sager - Added LVARTROP for variable tropopause
31 Jan 2007 - L. Murray   - Added LOTDREG, LOTDLOC for regional or local
                            OTD-LIS redistribution of lightning flashes
31 Jan 2007 - L. Murray   - Added LOTDSCALE
08 Mar 2008 - Aaron van D.- Added LCAC, LARCSHIP, LEMEPSHIP
24 Nov 2008 - Aaron van D.- Added LVISTAS
16 Oct 2009 - Y. Chen     - Added L8DAYBB, L3HRBB and LSYNOPBB for
                            8-day and 3-hr GFED BB emissions
26 Jan 2009 - P. Le Sager - Added LICARTT to account for Hudman
                            corrections to EPA/NEI99
12 Feb 2009 - D. Henze    - Added LSVCSPEC
10 Mar 2009 - T-M Fu      - Added LMEGANMONO
10 Mar 2009 - T-M Fu      - Added LDICARB
29 May 2009 - J. Lin      - Add LNLPBL, LARPBLH and LDEPBCK (non-local PBL)
18 May 2009 - P. Le Sager - Added LCOOKE
28 May 2009 - P. Le Sager - Added LKPP
16 Oct 2009 - C. Lee      - Added LICOADSSHIP
18 Aug 2009 - K. Wecht    - Added switches for CH4 emissions & budget
16 Oct 2009 - R. Yantosca - Added LLINOZ switch for Linoz O3 strat chem
16 Oct 2009 - R. Yantosca - Added ProTeX header
30 Oct 2009 - Aaron van D - Added LNEI2005
19 Nov 2009 - M. Barkley  - Added LMODISLAI and LPECCA
```

```
 18 Dec 2009 - Aaron van D - Added HDF5 logical switches
 18 Dec 2009 - Aaron van D - Added logicals for NA, EU, CH, CU nested grids
 18 Dec 2009 - Aaron van D - Added logical for 2 x 2.5 TPCORE BC's
 29 Jan 2009 - F. Paulot   - Added LFERTILIZERNOX.
 22 Jan 2010 - R. Yantosca - Added LTOMAS switch
 26 Feb 2010 - R. Yantosca - Remove obsolete LEMBED flag
 18 May 2010 - R. Nassar   - Add logical flags for CO2 offline simulation
 20 Jul 2010 - C. Carouge  - Add LPREINDHG and LGTMM for updated mercury.
 24 Jan 2011 - L. Murray   - Remove LOTDREG, LCTH, LMFLUX, LPRECON,
                             and LOTDSCALE for lightning
 07 Sep 2011 - P. Kasibhatla - Modified to include GFED3
 26 Mar 2012 - R. Yantosca - Add USE_OLSON_2001 switch, which will use the
                             newer Olson 2001 land map & drydep inputs
 26 Apr 2013 - R. Yantosca - Remove LTOMAS; we now use #if defined( TOMAS )
 07 Aug 2013 - M. Sulprizio- Move NAPEMISS and POAEMISSSCALE for SOA + SVPOA
                             simulation to Headers/gigc_input_opt_mod.F90
 13 Aug 2013 - M. Sulprizio- Added LSVPOA switch for semivolatile POA (H. Pye)
 20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
 03 Oct 2013 - M. Sulprizio- Removed obsolete LMFCT for flux correction
 03 Oct 2013 - M. Sulprizio- Removed obsolete LAVHRRLAI and LMODISLAI
```

1.84 Fortran: Module Interface mapping_mod

Module MAPPING_MOD contains a derived-type object to compute and save the mapping weight (i.e. fraction of each "fine" grid box that fits into the "coarse" grid box") and areal mapping (i.e. the area of each "fine" grid box contained within a "coarse" grid box).

INTERFACE:

```
MODULE Mapping_Mod
```

USES:

```
  USE CMN_SIZE_MOD                  ! Size parameters
  USE ERROR_MOD                     ! Error handling routines
  USE LOGICAL_MOD                   ! Logical switches

  IMPLICIT NONE
  PRIVATE
```

PUBLIC DATA MEMBERS:

```
  PUBLIC :: MapWeight
  TYPE MapWeight
     INTEGER          :: count      ! # of "fine" boxes per "coarse" box
     INTEGER, POINTER :: II(:)      ! Longitude indices,  "fine"   grid
     INTEGER, POINTER :: JJ(:)      ! Latitude  indices,  "fine"   grid
     INTEGER, POINTER :: olson(:)   ! Olson land type,    "fine"   grid
```

```
    INTEGER, POINTER :: ordOlson(:)  ! Ordering of Olson land types
    REAL*4,  POINTER :: area(:)      ! Surface areas,      "fine"   grid
    REAL*4           :: sumarea      ! Total surface area, "coarse" grid
END TYPE MapWeight
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: Init_Mapping
PUBLIC  :: Get_Map_Wt
PUBLIC  :: Cleanup_Mapping
```

REMARKS:

The mapping weights and areal mapping are initialized when the Olson land map is read from disk (in olson_landmap_mod.F90). They are used again when the MODIS leaf area index data is prepared for input into GEOS-Chem's (legacy) dry deposition module.

Also, we do not define the mapping weight object within this module. This allows you to create more than one mapping weight object for different native grids (e.g. 0.5 x 0.5 and 0.25 x 0.25, etc.)

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
05 Apr 2012 - R. Yantosca - Comment out mapwt field of MapWeight type,
                            leave this for future expansion
17 Apr 2012 - R. Yantosca - Rename pointer object "map" to "mapping,
                            to remove confusion w/ F90 intrinsic
```

1.84.1 init_mapping

Subroutine INIT_MAPPING allocates and initializes a derived-type object containing grid mapping information.

INTERFACE:

```
SUBROUTINE Init_Mapping( I_FINE, J_FINE, I_COARSE, J_COARSE, mapping )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I_FINE    ! # of longitudes on the "fine" grid
INTEGER, INTENT(IN) :: J_FINE    ! # of latitudes  on the,"fine" grid
INTEGER, INTENT(IN) :: I_COARSE  ! # of longitudes on the "coarse" grid
INTEGER, INTENT(IN) :: J_COARSE  ! # of latitudes  on the "coarse" grid
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MapWeight), POINTER, INTENT(INOUT) :: mapping(:,:) !"fine" -> "coarse"
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
10 Apr 2012 - R. Yantosca - Now add a different # to FINE_PER_COARSE
                            depending on which Olson map we are using
17 Apr 2012 - R. Yantosca - Rename to "map" to "mapping" to avoid confusion
                            with a F90 intrinsic function
17 Apr 2012 - R. Yantosca - Add error check for mapping object
18 Apr 2012 - R. Yantosca - Improve error check for sub-fields of mapping
                            object so as not to interfere w/ parallel loop
```

1.84.2 get_map_wt

Subroutine GET_MAP_Wt returns the "mapping weight", that is, the fraction that each "fine" grid box fits into each "coarse" grid box.

INTERFACE:

```
SUBROUTINE Get_Map_Wt( xedge_w, xedge_e, xedgeC_w, xedgeC_e,   &
                       yedge_s, yedge_n, yedgeC_s, yedgeC_n,   &
                       mapWt                                  )
```

INPUT PARAMETERS:

```
REAL*4, INTENT(IN)  :: xedge_w,  xedge_e    ! Lon edges, fine grid
REAL*4, INTENT(IN)  :: xedgeC_w, xedgeC_e   ! Lon edges, coarse grid
REAL*4, INTENT(IN)  :: yedge_s,  yedge_n    ! Lat edges, fine grid
REAL*4, INTENT(IN)  :: yedgeC_s, yedgeC_n   ! Lat edges, coarse grid
REAL*4, INTENT(OUT) :: mapWt                ! Mapping weight
```

REMARKS:

```
Follows the algorithm from GAMAP routine ctm_getweight.pro
```

REVISION HISTORY:

```
30 Jan 2012 - R. Yantosca - Initial version
21 Mar 2012 - R. Yantosca - Typo: set xOverLap to zero if it is out of the
                            range of 0-1.  (We had set yOverLap=0 before)
21 Mar 2012 - R. Yantosca - Now use REAL*4 for computations to avoid
                            roundoff errors at hi-res grids
03 Apr 2012 - R. Yantosca - Moved from "olson_landmap_mod.F90" to here;
                            renamed "Get_Mapping"
```

1.84.3 cleanup_mapping

Subroutine CLEANUP_MAPPING deallocates memory from a derived-type object containing mapping information.

INTERFACE:

```
SUBROUTINE Cleanup_Mapping( mapping )
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MapWeight), POINTER, INTENT(INOUT) :: mapping(:,:)
```

REVISION HISTORY:

```
03 Mar 2012 - R. Yantosca - Initial version
17 Apr 2012 - R. Yantosca - Rename to "map" to "mapping to avoid name
                            confusion with a F90 intrinsic function
```

1.85 Fortran: Module Interface megan_mod

Module MEGAN_MOD contains variables and routines specifying the algorithms that control the MEGAN inventory of biogenic emissions.

References:

- Guenther, A., et al., *A global model of natural volatile organic compound emissions*, J.Geophys. Res., **100**, 8873-8892, 1995.
- Wang, Y., D. J. Jacob, and J. A. Logan, *Global simulation of tropospheric O3-Nox-hydrocarbon chemistry: 1. Model formulation*, J. Geophys. Res., **103**, D9, 10713-10726, 1998.
- Guenther, A., B. Baugh, G. Brasseur, J. Greenberg, P. Harley, L. Klinger, D. Serca, and L. Vierling, *Isoprene emission estimates and uncertanties for the Central African EXPRESSO study domain*, J. Geophys. Res., **104**, 30,625-30,639, 1999.
- Guenther, A. C., T. Pierce, B. Lamb, P. Harley, and R. Fall, *Natural emissions of non-methane volatile organic compounds, carbon monoxide, and oxides of nitrogen from North America*, Atmos. Environ., **34**, 2205-2230, 2000.
- Guenther, A., and C. Wiedinmyer, *User's guide to Model of Emissions of Gases and Aerosols from Nature*. http://cdp.ucar.edu. (Nov. 3, 2004)
- Guenther, A., *AEF for methyl butenol*, personal commucation. (Nov, 2004)
- Sakulyanontvittaya, T., T. Duhl, C. Wiedinmyer, D. Helmig, S. Matsunaga, M. Potosnak, J. Milford, and A. Guenther, *Monoterpene and sesquiterpene emission estimates for the United States*, Environ. Sci. Technol, **42**, 1623-1629, 2008.

INTERFACE:

```
MODULE MEGAN_MOD
```

USES:

```
      USE CMN_SIZE_MOD                                  ! Size parameters
      USE CMN_GCTM_MOD                                  ! Physical constants
      USE ERROR_MOD                                     ! Error trapping

      IMPLICIT NONE
      PRIVATE
```

DEFINED PARAMETERS:

```
      ! Scalars
#if   defined( MERRA ) || defined( GEOS_FP )
      INTEGER, PARAMETER  :: DAY_DIM        = 24       ! # of 1-hr periods/day
#else
      INTEGER, PARAMETER  :: DAY_DIM        = 8        ! # of 3-hr periods/day
#endif
      INTEGER, PARAMETER  :: NUM_DAYS       = 10       ! # of days to avg
      REAL*8,  PARAMETER  :: WM2_TO_UMOLM2S = 4.766d0  ! W/m2 -> umol/m2/s

      REAL*8, PARAMETER   :: D2RAD =  PI_180           ! Degrees to radians
      REAL*8, PARAMETER   :: RAD2D =  1d0 / PI_180     ! Radians to degrees

      ! SOAupdate: Megan group IDs (from MEGAN CDP) (hotp 3/1/10)
      ! Used to locate species within EF and AEF_GEN arrays
      INTEGER, PARAMETER  :: IDMGFARN = 10  ! farnesene
      INTEGER, PARAMETER  :: IDMGBCAR = 11  ! beta-caryophyllene
      INTEGER, PARAMETER  :: IDMGOSQT = 12  ! other sesquiterpenes
      INTEGER, PARAMETER  :: IDMGOMTP = 9   ! other monoterpenes
```

PRIVATE TYPES:

```
      ! Past light & temperature conditions (mpb,2009)
      ! (1) Temperature at 2m (TS):
      REAL*8, ALLOCATABLE :: T_DAILY(:,:)       ! Daily averaged sfc temp
      REAL*8, ALLOCATABLE :: T_DAY(:,:,:)       ! Holds 1 day of sfc temp data
      REAL*8, ALLOCATABLE :: T_15(:,:,:)        ! Holds 15 days of daily avg T
      REAL*8, ALLOCATABLE :: T_15_AVG(:,:)      ! Sfc temp avg'd over NUM_DAYS

      ! (2) PAR Direct:
      REAL*8, ALLOCATABLE :: PARDR_DAILY(:,:)   ! Average daily PARDR
      REAL*8, ALLOCATABLE :: PARDR_DAY(:,:,:)   ! Holds 1 day of PARDR data
      REAL*8, ALLOCATABLE :: PARDR_15(:,:,:)    ! 10 days of daily avg'd PARDR
      REAL*8, ALLOCATABLE :: PARDR_15_AVG(:,:)  ! PARDR averaged over NUM_DAYS

      ! (3) PAR Diffuse:
      REAL*8, ALLOCATABLE :: PARDF_DAILY(:,:)   ! Average daily PARDR
      REAL*8, ALLOCATABLE :: PARDF_DAY(:,:,:)   ! Holds 1-day of PARDR data
      REAL*8, ALLOCATABLE :: PARDF_15(:,:,:)    ! 10 days of daily avg'd PARDR
      REAL*8, ALLOCATABLE :: PARDF_15_AVG(:,:)  ! PARDF averaged over NUM_DAYS
```

```
! Annual emission factor arrays (mpb,2009)
REAL*8, ALLOCATABLE :: AEF_ISOP(:,:)      ! Isoprene
REAL*8, ALLOCATABLE :: AEF_MONOT(:,:)     ! Total monoterpenes
REAL*8, ALLOCATABLE :: AEF_MBO(:,:)       ! Methyl butenol
REAL*8, ALLOCATABLE :: AEF_OVOC(:,:)      ! Other biogenic VOC's
REAL*8, ALLOCATABLE :: AEF_APINE(:,:)     ! Alpha-pinene
REAL*8, ALLOCATABLE :: AEF_BPINE(:,:)     ! Beta-pinene
REAL*8, ALLOCATABLE :: AEF_LIMON(:,:)     ! Limonene
REAL*8, ALLOCATABLE :: AEF_SABIN(:,:)     ! Sabine
REAL*8, ALLOCATABLE :: AEF_MYRCN(:,:)     ! Myrcene
REAL*8, ALLOCATABLE :: AEF_CAREN(:,:)     ! 3-Carene
REAL*8, ALLOCATABLE :: AEF_OCIMN(:,:)     ! Ocimene
REAL*8, ALLOCATABLE :: AEF_ACET(:,:)      ! Acetone
REAL*8, ALLOCATABLE :: AEF_GEN(:,:,:)     ! Generic (all 20 MEGAN groups)

! SOAupdate: Plant functional types (hotp 2/26/10)
REAL*8, ALLOCATABLE :: PFT_BT(:,:)        ! broadleaf trees
REAL*8, ALLOCATABLE :: PFT_NT(:,:)        ! needleleaf trees
REAL*8, ALLOCATABLE :: PFT_SH(:,:)        ! shrubs
REAL*8, ALLOCATABLE :: PFT_GR(:,:)        ! grasses
REAL*8, ALLOCATABLE :: PFT_CR(:,:)        ! crops

! Path to MEGAN emission factors
CHARACTER(LEN=20)   :: MEGAN_SUBDIR = 'MEGAN_200909/'
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: ACTIVITY_FACTORS
PUBLIC  :: CLEANUP_MEGAN
PUBLIC  :: GET_EMACET_MEGAN
PUBLIC  :: GET_EMISOP_MEGAN
PUBLIC  :: GET_EMMBO_MEGAN
SOAudpate: renamed, includes SESQ (hotp 3/2/10)
PUBLIC  :: GET_EMTERP_MEGAN
PUBLIC  :: GET_EMMONOT_MEGAN
PUBLIC  :: GET_AEF
PUBLIC  :: GET_AEF_05x0666
PUBLIC  :: INIT_MEGAN
PUBLIC  :: UPDATE_T_DAY
PUBLIC  :: UPDATE_T_15_AVG
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: GET_GAMMA_LAI
PRIVATE :: GET_GAMMA_LEAF_AGE
PRIVATE :: GET_GAMMA_P
PRIVATE :: GET_GAMMA_T_ISOP
PRIVATE :: GET_GAMMA_T_NISOP
PRIVATE :: GET_GAMMA_P_PECCA
```

```
      PRIVATE :: SOLAR_ANGLE
```

REVISION HISTORY:

```
(1 ) Original code (biogen_em_mod.f) by Dorian Abbot (6/2003).  Updated to
     latest algorithm and modified for the standard code by May Fu
     (11/2004).
(2 ) All emission are currently calculated using TS from DAO met field.
     TS is the surface air temperature, which should be carefully
     distinguished from TSKIN. (tmf, 11/20/2004)
(3 ) In GEOS4, the TS used here are the T2M in the A3 files, read in
     'a3_read_mod.f'.
(4 ) Bug fix: change #if block to also cover GCAP met fields (bmy, 12/6/05)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(6 ) Bug fix: Skip Feb 29th if GCAP in INIT_MEGAN (phs, 9/18/07)
(7 ) Added routine GET_AEF_05x0666 to read hi-res AEF data for the GEOS-5
     0.5 x 0.666 nested grid simulations (yxw, dan, bmy, 11/6/08)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
09 Mar 2010 - R. Yantosca - Minor bug fix in GET_EMMONOT_MEGAN
17 Mar 2010 - H. Pye      - AEF_SPARE must be a scalar local variable
                            in GET_EMMONOT_MEGAN for parallelization.
20 Aug 2010 - R. Yantosca - Move CMN_SIZE to top of module
20 Aug 2010 - R. Yantosca - Now set DAY_DIM = 24 for MERRA, since the
                            surface temperature is now an hourly field.
01 Sep 2010 - R. Yantosca - Bug fix in INIT_MEGAN: now only read in
                            NUM_DAYS (instead of 15) days of sfc temp data
22 Nov 2011 - R. Yantosca - Do not use erroneous AEF's for nested grids
06 Dec 2011 - E. Fischer  - Added Acetone emissions
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
01 Mar 2012 - R. Yantosca - Use updated GET_LOCALTIME from time_mod.F
11 Apr 2012 - R. Yantosca - Replace lai_mod.F with modis_lai_mod.F90
13 Aug 2013 - M. Sulprizio- Modifications for updated SOA sim (H. Pye):
                             Add sesquiterpenes to MEGAN group;
                             Add plant functional types (PFT_xx);
                             Rename GET_EMMONOG_MEGAN to GET_EMTERP_MEGAN;
                             Add routines READ_PFT and GET_AEF_GEN
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.85.1 get_emisop_megan

Subroutine GET_EMISOP_MEGAN computes isoprene emissions in units of [atoms C/box] using the MEGAN inventory.

INTERFACE:

```
      FUNCTION GET_EMISOP_MEGAN( I,  J,     SUNCOS,
     &                           TS, Q_DIR, Q_DIFF, XNUMOL )
     &         RESULT( EMISOP )
```

USES:

```
      USE LOGICAL_MOD,   ONLY : LPECCA                     ! Use PCEEA model?
      USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI       ! Daily LAI
      USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM    ! Prev month's LAI
      USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM    ! Curr month's LAI
      USE MODIS_LAI_MOD, ONLY : NMISOLAI   => GC_LAI_NM    ! Next month's LAI
      USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I, J     ! GEOS-Chem lon & lat indices
      REAL*8,  INTENT(IN) :: SUNCOS   ! Solar zenith angle [unitless]
      REAL*8,  INTENT(IN) :: TS       ! Surface temperature [K]
      REAL*8,  INTENT(IN) :: Q_DIR    ! Flux of direct PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: Q_DIFF   ! Flux of diffuse PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: XNUMOL   ! Number of atoms C / kg C
```

RETURN VALUE:

```
      REAL*8              :: EMISOP   ! Isoprene emissions [atoms C/box]
```

REMARKS:

```
    References (see above for full citations):
    ============================================================================
    (1 ) Guenther et al, 1995, 1999, 2000, 2004, 2006
    (2 ) Wang,    et al, 1998
    (3 ) Guenther et al, 2007, MEGAN v2.1 User mannual
```

REVISION HISTORY:

```
    (1 ) Original code by Dorian Abbot (9/2003).  Updated to the latest
         algorithm and modified for the standard code by May Fu (11/20/04)
    (2 ) All MEGAN biogenic emission are currently calculated using TS from DAO
         met field. TS is the surface air temperature, which should be
         carefully distinguished from TSKIN. (tmf, 11/20/04)
    (3 ) Restructing of function & implementation of activity factors (mpb,2009)
    17 Dec 2009 - R. Yantosca - Added ProTeX headers
    11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
    11 Apr 2012 - R. Yantosca - Cosmetic changes
```

1.85.2 get_emmbo_megan

Subroutine GET_EMMBO_MEGAN computes methylbutenol emissions in units of [atoms C/box] using the MEGAN inventory.

INTERFACE:

```
      FUNCTION GET_EMMBO_MEGAN( I,  J,      SUNCOS,
     &                          TS, Q_DIR,  Q_DIFF, XNUMOL )
     &         RESULT( EMMBO )
```

USES:

```
      USE LOGICAL_MOD,   ONLY : LPECCA                     ! Use PCEEA model?
      USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI       ! Daily LAI
      USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM    ! Prev month's LAI
      USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM    ! Curr month's LAI
      USE MODIS_LAI_MOD, ONLY : NMISOLAI   => GC_LAI_NM    ! Next month's LAI
      USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I, J    ! GEOS-Chem lon & lat indices
      REAL*8,  INTENT(IN) :: SUNCOS  ! Solar zenith angle [unitless]
      REAL*8,  INTENT(IN) :: TS      ! Surface temperature [K]
      REAL*8,  INTENT(IN) :: Q_DIR   ! Flux of direct PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: Q_DIFF  ! Flux of diffuse PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: XNUMOL  ! Number of atoms C / kg C
```

RETURN VALUE:

```
      REAL*8              :: EMMBO   ! Methylbutenol emissions [atoms C/box]
```

REMARKS:

```
    References (see above for full citations):
    ============================================================================
    (1 ) Guenther et al, 1995, 1999, 2000, 2004, 2006
    (2 ) Wang,    et al, 1998
    (3 ) Guenther et al, 2007, MEGAN v2.1 User mannual
```

REVISION HISTORY:

```
    (1 ) Original code by Dorian Abbot (9/2003).  Updated to the latest
         algorithm and modified for the standard code by May Fu (11/20/04)
    (2 ) All MEGAN biogenic emission are currently calculated using TS from DAO
         met field. TS is the surface air temperature, which should be
         carefully distinguished from TSKIN. (tmf, 11/20/04)
    (3 ) Restructing of function & implementation of activity factors (mpb,2009)
    17 Dec 2009 - R. Yantosca - Added ProTeX headers
    11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
```

1.85.3 get_emterp_megan

Function GET_EMTERP_MEGAN computes monoterpene and sesquiterpene emissions for individual species in units of [atoms C/box] using the MEGAN v2.1 inventory.

INTERFACE:

```
      FUNCTION GET_EMTERP_MEGAN( I,     J,      SUNCOS, TS,
     &                           Q_DIR, Q_DIFF, XNUMOL, TERP_SPECIES )
     &            RESULT( EMTERP )
```

USES:

```
      USE LOGICAL_MOD,   ONLY : LPECCA                     ! Use PCEEA model?
      USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI       ! Daily LAI
      USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM    ! Prev month's LAI
      USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM    ! Curr month's LAI
      USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval

      USE CMN_SIZE_MOD      ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER,          INTENT(IN) :: I, J          ! Lon & lat indices
      REAL*8,           INTENT(IN) :: SUNCOS        ! Cos(solar zenith angle)
      REAL*8,           INTENT(IN) :: TS            ! Surface temperature [K]
      REAL*8,           INTENT(IN) :: Q_DIR         ! Direct PAR [W/m2]
      REAL*8,           INTENT(IN) :: Q_DIFF        ! Diffuse PAR [W/m2]
      REAL*8,           INTENT(IN) :: XNUMOL        ! Number of atoms C / kg C
      CHARACTER(LEN=5), INTENT(IN) :: TERP_SPECIES  ! Terpene species name
```

RETURN VALUE:

```
      ! SOAupdate: Add terpene emissions
      REAL*8                       :: EMTERP        ! Emissions [atoms C/box]
```

REMARKS:

```
    References (see above for full citations):
    ============================================================================
    (1 ) Guenther et al, 1995, 1999, 2004, 2006
    (2 ) Guenther et al, 2007, MEGAN v2.1 User Manual
    (3 ) Sakulyanontvittaya et al, 2008
```

REVISION HISTORY:

```
    (1 ) Written by Michael Barkley (2008), based on old monoterpene code by
         dsa,tmf.
    (2 ) Uses gamma factors instead of exchange factors, this includes
          calling of a new temperature algorithm which use a beta factor.
          (mpb,2008)
    17 Dec 2009 - R. Yantosca - Added ProTeX headers
    11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
    13 Aug 2013 - M. Sulprizio- Renamed from GET_EMMONOG_MEGAN and added
                                sesquiterpenes (H. Pye)
```

1.85.4 get_emacet_megan

Subroutine GET_EMACET_MEGAN computes acetone emissions in units of [atomsC/box] using the MEGAN inventory.

INTERFACE:

```
      FUNCTION GET_EMACET_MEGAN( I,     J ,     SUNCOS , TS,
     &                           Q_DIR, Q_DIFF, XNUMOL )
     &            RESULT( EMACET )
```

USES:

```
      USE LOGICAL_MOD,   ONLY : LMEGAN                    ! Is MEGAN used?
      USE LOGICAL_MOD,   ONLY : LPECCA                    ! Use PCEEA model?
      USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI      ! Daily LAI
      USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM   ! Prev month's LAI
      USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM   ! Curr month's LAI
      USE MODIS_LAI_MOD, ONLY : NMISOLAI   => GC_LAI_NM   ! Next month's LAI
      USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: I,  J   ! GEOS-Chem lon & lat indices
      REAL*8,  INTENT(IN) :: SUNCOS  ! Solar zenith angle [unitless]
      REAL*8,  INTENT(IN) :: TS      ! Surface temperature [K]
      REAL*8,  INTENT(IN) :: Q_DIR   ! Flux of direct PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: Q_DIFF  ! Flux of diffuse PAR above canopy [W/m2]
      REAL*8,  INTENT(IN) :: XNUMOL  ! Number of atoms C / kg C
```

RETURN VALUE:

```
      REAL*8              :: EMACET  ! Acetone emissions [atoms C/box]
```

REMARKS:

```
    References (see above for full citations):
    ============================================================================
    (1 ) Guenther et al, 1995, 1999, 2004, 2006
    (2 ) Guenther et al, 2007, MEGAN v2.1 User Manual
```

REVISION HISTORY:

```
    (1 ) Written by Michael Barkley (2008), based on old monoterpene code by
         dsa,tmf.
    (2 ) Uses gamma factors instead of exchange factors, this includes
          calling of a new temperature algorithm which use a beta factor.
          (mpb,2008)
    24 May 2011 - E. Fischer  - Modified for acetone. Function GET_EMACET_MEGAN
                                is called from "acetone_mod.f"
    06 Dec 2011 - M. Payer    - Added ProTeX headers
    27 Mar 2012 - R. Yantosca - Avoid segfault errors if LMEGAN=.FALSE.
    11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
```

1.85.5 get_emmonot_megan

Subroutine GET_EMMONOT_MEGAN computes the total monoterpene emissions in units of [atoms C/box] using the MEGAN v2.1 inventory.

INTERFACE:

```
 FUNCTION GET_EMMONOT_MEGAN( I,  J,     SUNCOS,
&                            TS, Q_DIR, Q_DIFF, XNUMOL )
&            RESULT( EMMONOT )
```

INPUT PARAMETERS:

```
 INTEGER, INTENT(IN) :: I, J      ! Lon & lat indices
 REAL*8,  INTENT(IN) :: SUNCOS    ! Cos( solar zenith angle )
 REAL*8,  INTENT(IN) :: TS        ! Local surface air temperature [K]
 REAL*8,  INTENT(IN) :: Q_DIR     ! Direct PAR above canopy [W/m2]
 REAL*8,  INTENT(IN) :: Q_DIFF    ! Diffuse PAR above canopy [W/m2]
 REAL*8,  INTENT(IN) :: XNUMOL    ! Number of atoms C / kg C
```

RETURN VALUE:

```
 REAL*8              :: EMMONOT   ! Monoterpene emissions [atoms C/box]
```

REMARKS:

```
References (see above for full citations):
=============================================================================
(1 ) Guenther et al, 1995, 1999, 2000, 2006
(2 ) Guenther et al, 2007, MEGAN v2.1 User Manual
```

REVISION HISTORY:

```
(1 ) Original code by Michael Barkley (mpb,2009).
17 Dec 2009 - R. Yantosca - Added ProTeX headers
09 Mar 2010 - H.O.T. Pye  - Change order of arguments in call to
                            routine GET_EMMONOG_MEGAN
11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
```

1.85.6 activity_factors

Subroutine ACTIVITY_FACTORS computes the gamma activity factors which adjust the emission factors to the current weather and vegetation conditions. Here they are calculated by (default) for isoprene.

INTERFACE:

```
 SUBROUTINE ACTIVITY_FACTORS( I,              J,       TS,
&                             SUNCOS,         Q_DIR,   Q_DIFF,
&                             XNUMOL,         SPECIES, GAMMA_LAI,
&                             GAMMA_LEAF_AGE, GAMMA_P, GAMMA_T,
&                             GAMMA_SM )
```

USES:

```
USE LOGICAL_MOD,   ONLY : LPECCA                    ! Use PCEEA model?
USE MODIS_LAI_MOD, ONLY : ISOLAI     => GC_LAI      ! Daily LAI
USE MODIS_LAI_MOD, ONLY : PMISOLAI   => GC_LAI_PM   ! Prev month's LAI
USE MODIS_LAI_MOD, ONLY : MISOLAI    => GC_LAI_CM   ! Curr month's LAI
USE MODIS_LAI_MOD, ONLY : NMISOLAI   => GC_LAI_NM   ! Next month's LAI
USE MODIS_LAI_MOD, ONLY : DAYS_BTW_M => DAYS_BTW_MON ! LAI month interval
```

INPUT PARAMETERS:

```
INTEGER,          INTENT(IN)   :: I, J     ! Lon & lat indices
REAL*8,           INTENT(IN)   :: SUNCOS   ! Cos( solar zenith angle )
REAL*8,           INTENT(IN)   :: TS       ! Surface air temperature [K]
REAL*8,           INTENT(IN)   :: XNUMOL   ! Number of atoms C / kg C
REAL*8,           INTENT(IN)   :: Q_DIR    ! Direct PAR [W/m2]
REAL*8,           INTENT(IN)   :: Q_DIFF   ! Diffuse PAR [W/m2]
CHARACTER(LEN=4), INTENT(IN)   :: SPECIES  ! Species (ISOP,MONO,MBOT)
```

OUTPUT PARAMETERS:

```
! GAMMA factors for:
REAL*8,           INTENT(OUT)  :: GAMMA_LAI       ! LAI
REAL*8,           INTENT(OUT)  :: GAMMA_LEAF_AGE  ! Leaf age
REAL*8,           INTENT(OUT)  :: GAMMA_P         ! Light
REAL*8,           INTENT(OUT)  :: GAMMA_T         ! Temperature
REAL*8,           INTENT(OUT)  :: GAMMA_SM        ! Soil moisture
```

REVISION HISTORY:

```
(1 ) Original code written by Michael Barkley (mpb,2009).
17 Dec 2009 - R. Yantosca - Added ProTeX headers
11 Apr 2012 - R. Yantosca - Now use data from modis_lai_mod.F90
```

1.85.7 get_gamma_p_pecca

Computes the PECCA gamma activity factor with sensitivity to LIGHT.

INTERFACE:

```
 FUNCTION GET_GAMMA_P_PECCA( I , J , Q_DIR_2, Q_DIFF_2 ,
&                            PARDR_AVG_SIM ,  PARDF_AVG_SIM  )
&              RESULT( GAMMA_P_PECCA )
```

USES:

```
 USE TIME_MOD,   ONLY : GET_DAY_OF_YEAR
 USE TIME_MOD,   ONLY : GET_LOCALTIME
 USE GRID_MOD,   ONLY : GET_YMID
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I,  J             ! Lon & lat indices
REAL*8,  INTENT(IN) :: PARDR_AVG_SIM     ! Average direct PAR [W/m2]
REAL*8,  INTENT(IN) :: PARDF_AVG_SIM     ! Average diffuse PAR [W/m2]
REAL*8,  INTENT(IN) :: Q_DIR_2           ! Direct PAR [umol/m2/s]
REAL*8,  INTENT(IN) :: Q_DIFF_2          ! Diffuse PAR [umol/m2/s]
```

RETURN VALUE:

```
REAL*8             :: GAMMA_P_PECCA     ! GAMMA factor for light
```

REMARKS:

```
References (see above for full citations):
==============================================================================
(1 ) Guenther et al, 2006
(2 ) Guenther et al, 2007, MEGAN v2.1 user guide
```

REVISION HISTORY:

```
(1 ) Here PAR*_AVG_SIM is the average light conditions over the simulation
     period. I've set this = 10 days to be consistent with temperature & as
     outlined in Guenther et al, 2006. (mpb,2009)
(2 ) Code was taken & adapted directly from the MEGAN v2.1 source code.
     (mpb,2009)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90
```

1.85.8 solar_angle

Function SOLAR_ANGLE computes the local solar angle for a given day of year, latitude and longitude (or local time). Called from routine GAMMA_P_PECCA.

INTERFACE:

```
FUNCTION SOLAR_ANGLE( DOY, SHOUR, LAT ) RESULT( SINbeta )
```

INPUT PARAMETERS:

```
! Arguments
INTEGER, INTENT(IN) :: DOY       ! Day of year
REAL*8,  INTENT(IN) :: SHOUR     ! Local time
REAL*8,  INTENT(IN) :: LAT       ! Latitude
```

RETURN VALUE:

```
REAL*8             :: SINbeta   ! Sin of the local solar angle
```

REMARKS:

```
References (see above for full citations):
(1 ) Guenther et al, 2006
(2 ) Guenther et al, MEGAN v2.1 user mannual 2007-09
```

REVISION HISTORY:

```
(1 ) This code was taken directly from the MEGAN v2.1 source code.(mpb,2009)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.85.9 get_gamma_t_isop

Function GET_GAMMA_T_ISOP computes the temperature sensitivity for ISOPRENE ONLY.

INTERFACE:

```
FUNCTION GET_GAMMA_T_ISOP( T, PT_15, PT_1 ) RESULT( GAMMA_T )
```

INPUT PARAMETERS:

```
! Current leaf temperature, the surface air temperature field (TS)
! is assumed equivalent to the leaf temperature over forests.
REAL*8,  INTENT(IN) :: T


! Average leaf temperature over the past 15 days
REAL*8,  INTENT(IN) :: PT_15

! Average leaf temperature over the past arbitray day(s).
! This is not used at present (but might be soon!).
REAL*8,  INTENT(IN) :: PT_1
```

RETURN VALUE:

```
! GAMMA factor for temperature (isoprene only)
REAL*8              :: GAMMA_T
```

REMARKS:

```
References (see above for full citations):
=============================================================================
(1 ) Guenther et al, 1995
(2 ) Guenther et al, 2006
(3 ) Guenther et al, MEGAN v2.1 user mannual 2007-08
```

REVISION HISTORY:

```
(1 ) Includes the latest MEGAN v2.1 temperature algorithm (mpb, 2009).
     Note, this temp-dependence is the same for the PECCA & hybrid models.
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.85.10 get_gamma_t_nisop

Function GET_GAMMA_T_NISOP computes the temperature activity factor (GAMMA_T) for BVOCs OTHER than isoprene. Called from routines GET_EMMONOG_MEGAN and GET_EMMBO_MEGAN.

INTERFACE:

```
FUNCTION GET_GAMMA_T_NISOP( T, BETA ) RESULT( GAMMA_T )
```

INPUT PARAMETERS:

```
! Current leaf temperature [K], the surface air temperature field (TS)
! is assumed equivalent to the leaf temperature over forests.
REAL*8, INTENT(IN) :: T

! Temperature factor per species (from MEGAN user manual).
! Beta = 0.09 for MBO and for monoterpene species (APINE, BPINE, LIMON,
! SABIN, MYRCN, CAREN, OCIMN). Pass as an argument in case this changes.
REAL*8, INTENT(IN) :: BETA
```

RETURN VALUE:

```
REAL*8             :: GAMMA_T  !
```

REMARKS:

```
GAMMA_T =  exp[BETA*(T-Ts)]

                                                                              .
           where BETA   = temperature dependent parameter
                 Ts     = standard temperature (normally 303K, 30C)
                                                                              .
References (see above for full citations):
================================================================================
(1 ) Guenther et al, 2006
(2 ) Guenther et al, MEGAN user mannual 2007-08
```

REVISION HISTORY:

```
(1 ) Original code by Michael Barkley (2009).
     Note: If T = Ts  (i.e. standard conditions) then GAMMA_T = 1
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.85.11 get_gamma_p

Function GET_GAMMA_P computes the gamma activity factor with sensitivity to LIGHT (aka 'PAR'). Called by the functions ! GET_EMISOP_MEGAN, GET_EMMBO_MEGAN, and GET_EMMONOG_MEGAN.

INTERFACE:

```
      FUNCTION GET_GAMMA_P( LAI, SUNCOS1, Q_DIR_2, Q_DIFF_2 )
     &              RESULT( GAMMA_P )
```

INPUT PARAMETERS:

```
      REAL*8,  INTENT(IN) :: LAI        ! Cumulative leaf area index
      REAL*8,  INTENT(IN) :: SUNCOS1    ! Cosine of solar zenith angle
      REAL*8,  INTENT(IN) :: Q_DIR_2    ! Direct PAR above canopy [umol/m2/s]
      REAL*8,  INTENT(IN) :: Q_DIFF_2   ! Diffuse PAR above canopy [umol/m2/s]
```

RETURN VALUE:

```
      REAL*8              :: GAMMA_P    ! Gamma activity factor w/r/t light
```

REMARKS:

```
    *** REVAMPED FUNCTION ***
                                                                             .
    C_PPFD: Effect of increasing PPFD up to a saturation point, where emission
            level off, based on Eq 4abc from Guenther et al. (1999)
            In addition, a 5 layered canopy model based on Eqs 12-16
            from Guenther et al. (1995) is included to correct for light
            attenuation in the canopy.
                                                                             .
    References (see above for full citations):
    ============================================================================
    (1 ) Guenther et al, 1995
    (2 ) Wang     et al, 1998
    (3 ) Guenther et al, 1999
    (5 ) Guenther et al, 2004
```

REVISION HISTORY:

```
    (1 ) Original code by Dorian Abbot and by May Fu.
    (2 ) This code was extracted from the previous GET_HEA_TL function.
         (mpb,2009)
    17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.85.12 get_gamma_leaf_age

Function GET_GAMMA_LEAF_AGE computes the gamma exchange activity factor which is sensitive to leaf age (= GAMMA_LEAF_AGE). Called from GET_EMISOP_MEGAN, GET_EMMBO_MEGAN, and GET_EMMONOG_MEGAN.

INTERFACE:

```
      FUNCTION GET_GAMMA_LEAF_AGE( CMLAI, PMLAI, T, SPECIES, TT )
     &         RESULT( GAMMA_LEAF_AGE )
```

INPUT PARAMETERS:

```
      REAL*8,           INTENT(IN) :: T        ! Number of days between
                                               !  current and previous LAI.
      REAL*8,           INTENT(IN) :: CMLAI    ! Current month's LAI [cm2/cm2]
      REAL*8,           INTENT(IN) :: PMLAI    ! Previous months LAI [cm2/cm2]
      CHARACTER(LEN=4), INTENT(IN) :: SPECIES  ! BVOC species name
      REAL*8,           INTENT(IN) :: TT       ! Daily average temperature [K]
```

RETURN VALUE:

```
      REAL*8                       :: GAMMA_LEAF_AGE   ! Activity factor
```

REMARKS:

```
    References (see above for full citations):
    ==========================================================================
    (3 ) Guenther et al, 2006
    (5 ) Guenther et al, MEGAN user mannual 2007-08
```

REVISION HISTORY:

```
    (1 ) Original code by Dorian Abbot (9/2003). Modified for the standard
         code by May Fu (11/2004)
    (2 ) Update to publically released (as of 11/2004) MEGAN algorithm and
         modified for the standard code by May Fu (11/2004).
    (3 ) Algorithm is based on the latest User's Guide (tmf, 11/19/04)
    (4 ) Renamed & now includes specific relative emission activity factors for
         each BVOC based on MEGAN v2.1 algorithm (mpb,2008)
    (5 ) Now calculate TI (number of days after budbreak required to induce
         iso. em.) and TM (number of days after budbreak required to reach
         peak iso. em. rates) using the daily average temperature, instead
         of using fixed values (mpb,2008)
         NOTE: Can create 20% increases in tropics (Guenther et al 2006)
    (6 ) Implemented change for the calculation of FGRO if ( CMLAI > PMLAI ),
         i.e. if LAI has increased with time, and used new values for
         all foilage fractions if ( CMLAI = PMLAI ). Also removed TG variable
         as not now needed. (mpb,2000)
    17 Dec 2009 - R. Yantosca - Added ProTeX headers
    13 Aug 2013 - M. Sulprizio- Updated for sesquiterpenes (H. Pye)
```

1.85.13 get_gamma_lai

Function GET_GAMMA_LAI computes the gamma exchange activity factor which is sensitive to leaf area (= GAMMA_LAI). Called from GET_EMISOP_MEGAN, GET_EMMBO_MEGAN, and GET_EMMONOG_MEGAN.

INTERFACE:

```
      FUNCTION GET_GAMMA_LAI( CMLAI ) RESULT( GAMMA_LAI )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN)  :: CMLAI       ! Current month's LAI [cm2/cm2]
```

RETURN VALUE:

```
REAL*8              :: GAMMA_LAI
```

REMARKS:

```
References (see above for full citations):
=============================================================================
(1 ) Guenther et al, 2006
(2 ) Guenther et al, MEGAN user mannual 2007-08
```

REVISION HISTORY:

```
(1 ) Original code by Dorian Abbot (9/2003).  Modified for the standard
     code by May Fu (11/2004)
(2 ) Update to publically released (as of 11/2004) MEGAN algorithm and
     modified for the standard code by May Fu (11/2004).
(3 ) Algorithm is based on the latest MEGAN v2.1 User's Guide (mpb,2009)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.85.14 get_aef

Subroutine GET_AEF reads Annual Emission Factor for all biogenic VOC species from disk. Called from GET_AEF is called from "main.f".

INTERFACE:

```
SUBROUTINE GET_AEF
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_RES_EXT, READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE TIME_MOD,       ONLY : GET_TS_EMIS
USE GRID_MOD,       ONLY : GET_AREA_M2
```

REMARKS:

```
Reference: (5 ) Guenther et al, 2004
```

REVISION HISTORY:

```
(1 ) Original code by Dorian Abbot (9/2003).  Modified for the standard
     code by May Fu (11/2004)
(2 ) AEF detailed in the latest MEGAN User's Guide (tmf, 11/19/04)
```

```
(3 ) Bug fix (tmf, 11/30/04)
(4 ) Now reads 1x1 files and regrids to current resolution (bmy, 10/24/05)
(5 ) Uses new v2.1 emission factors maps for isoprene, MBO and 7 monoterpene
      species, download in 2009. (mpb,2009)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.85.15 get_aef_05x0666

Subroutine GET_AEF_05x0666 reads Annual Emission Factor for all biogenic VOC species from disk. Called from "main.f". Specially constructed to read 0.5 x 0.666 nested grid data for the GEOS-5 nested grid simulations.

INTERFACE:

```
SUBROUTINE GET_AEF_05x0666
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_RES_EXT, READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE TIME_MOD,       ONLY : GET_TS_EMIS
USE GRID_MOD,       ONLY : GET_AREA_M2
USE DIRECTORY_MOD,  ONLY : DATA_DIR
```

REMARKS:

```
Reference: (5 ) Guenther et al, 2004
```

REVISION HISTORY:

```
(1) Specially constructed to read 0.5 x 0.666 nested grid data for the
    GEOS-5 nested grid simulations. (yxw, dan, bmy, 11/6/08)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
02 Jul 2012 - R. Yantosca - Rename the input file latlon_nested.txt to
                            latlon_geos05x0666.txt to avoid confusion
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Bug fix for regridding. Changed to PERAREA=0
                            since data is in ug C/m2/hr.
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.85.16 update_t_day

Subroutine UPDATE_T_DAY must be called every time the A-3 fields are updated. Each 3h TS value for each gridbox is moved up one spot in the matrix and the current value is put in the last spot.

INTERFACE:

```
SUBROUTINE UPDATE_T_DAY( State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE MEGANUT_MOD              ! We use all functions from the module
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
(1 ) All MEGAN biogenic emission are currently calculated using TS from DAO
     met field. TS is the surface air temperature, which should be
     carefully distinguished from TSKIN. (tmf, 11/20/04)
(2 ) In GEOS4, TS are originally T2M in the A3 files, read in
     'a3_read_mod.f'.
17 Dec 2009 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.85.17 update_t_15_avg

Subroutine UPDATE_T_15_AVG should be called at the beginning of each day. It loops through the gridboxes doing the following:

1. Average T_DAY over the 8 TS values during the day.
2. Push the daily average TS values through T_15, throwing out the oldest and putting the newest (the T_DAY average) in the last spot
3. Get T_15_AVG by averaging T_15 over the 15 day period.

INTERFACE:

```
SUBROUTINE UPDATE_T_15_AVG
```

REVISION HISTORY:

```
01 Oct 1995 - M. Prather  - Initial version
(1 ) All MEGAN biogenic emission are currently calculated using TS from DAO
      met field. TS is the surface air temperature, which should be
      carefully distinguished from TSKIN. (tmf, 11/20/04)
(2 ) In GEOS4, TS are originally T2M in the A3 files, read in
      'a3_read_mod.f'.
17 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.85.18 read_pft

Subroutine READ_PFT reads the MEGAN v2.1 plant functional type coverage from file for year 2001. Regridding from 1x1 to the simulation resolution is also done here. (hotp 2/25/10)

INTERFACE:

```
SUBROUTINE READ_PFT
```

USES:

```
USE BPCH2_MOD,      ONLY : READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

USE CMN_SIZE_MOD         ! Size parameters
```

REMARKS:

```
References:
============================================================================
(1 ) MEGAN PFT data originally from:
     http://cdp.ucar.edu (search for MEGAN)
     MEGAN_V2.0/Input/NETCDF_30min/PFT/PFT21.tar
     PFT files dated 3 Feb 2009, downloaded 26 February 2010 by hotp
                                                                            .
Notes:
============================================================================
(1 ) From the MEGAN Community Data Portal Documentation:
     http://acd.ucar.edu/~guenther/MEGAN/MEGAN.htm
     PFT: fraction of a grid covered by a plant functional type for the year
     2001. The units are non-dimensional. Note that the PFTS do not
     necessarily add up to one since part of the grid may not have
     vegetation! (e.g. barren,rock, ice, water).
     Version 2.0 has 6 PFTs and is described in Guenther et al. 2006:
        BTR: broadleaf trees
        FTD: fineleaf deciduous trees
        FTE: fineleaf evergreen trees
        CRP: crops
```

```
        GRS: grass
        SHR: shrub
     This GEOS-Chem code actually uses v2.1.
     Version 2.1 combines FTD ands FTE into a single category (NTR=
     needleleaftrees) It is an input for determining PFT weighted emission
     factors PFT21 contains
        btr200121: fraction of grid covered by broadleaf trees
        ntr200121: fraction of grid covered by needleleaf trees
        grs200121: fraction of grid covered by grass
        crp200121: fraction of grid covered by crops
        shr200121: fraction of grid covered by shrubs
(2 ) 30min x 30min netcdf files from the MEGAN CDP are regridded and
     converted from % to fraction and saved as geos 1x1 binary punch
     files using make_pft.pro based on Dylan Millet's
     make_aef_ald2.pro (hotp 2/25/10)
(3 ) PFTs from file are in units of m2/m2 (unitless) (hotp 2/27/10)
```

REVISION HISTORY:

```
25 Feb 2010 - H.O.T. Pye  - Wrote original code
13 Jul 2011 - M. Payer    - Added ProTeX headers
13 Aug 2013 - M. Sulprizio- Now regrid using MAP_A2A algorithm
```

1.85.19 get_aef_gen

Subroutine GET_AEF_GEN creates AEFs for species without global explicit georeferenced emission factor maps. This includes sesquiterpenes (isoprene, MBO, and monoterpenes all have global AEF maps available).

INTERFACE:

```
SUBROUTINE GET_AEF_GEN
```

USES:

```
USE TIME_MOD,    ONLY : GET_TS_EMIS
USE GRID_MOD,    ONLY : GET_AREA_M2

USE CMN_SIZE_MOD      ! Size parameters
USE EF_MGN20_MOD      ! EF_MGN20.EXT from MEGAN CDP, EFs
```

REMARKS:

```
References:
============================================================================
(1 ) MEGAN CDP: MEGAN EFs originally from:
     http://cdp.ucar.edu (search for MEGAN)
     MEGAN_v2.04/src/MECHCONV/INCDIR/EF_MGN20.EXT
     Files dated: 23 Aug 2007
```

```
Notes:
=============================================================================
(1 ) EFs are from EF_MGN20.EXT from the MEGAN CDP
```

REVISION HISTORY:

```
25 Feb 2010 - H.O.T. Pye  - Wrote original code
13 Jul 2011 - M. Payer    - Added ProTeX headers
```

1.85.20 init_megan

Subroutine INIT_MEGAN allocates and initializes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_MEGAN( Input_Opt, State_Met )
```

USES:

```
USE A3_READ_MOD
USE GEOSFP_READ_MOD,    ONLY : GEOSFP_READ_A1
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE inquireMod,         ONLY : findFreeLUN
USE MERRA_A1_MOD
USE JULDAY_MOD,         ONLY : CALDATE
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE TIME_MOD,           ONLY : GET_FIRST_A3_TIME
USE TIME_MOD,           ONLY : GET_JD
USE TIME_MOD,           ONLY : ITS_A_LEAPYEAR
USE TIME_MOD,           ONLY : YMD_EXTRACT
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
(1 ) Change the logic in the #if block for G4AHEAD. (bmy, 12/6/05)
(2 ) Bug fix: skip Feb 29th if GCAP (phs, 9/18/07)
(3 ) Now call GET_AEF_05x0666 for GEOS-5 nested grids (yxw,dan,bmy, 11/6/08)
17 Dec 2009 - R. Yantosca - Added ProTeX headers
26 Aug 2010 - R. Yantosca - Now reference merra_a1_mod.f
01 Sep 2010 - R. Yantosca - Now read in NUM_DAYS of sfc temp data (this had
                            been hardwired to 15 days previously)
07 Feb 2011 - R. Yantosca - Fix typos: make sure to zero out the proper
```

```
                              PARDF_* and PARDR_* arrays after allocation
   22 Nov 2011 - R. Yantosca - Do not use erroneous AEF's for nested grids
   08 Feb 2012 - R. Yantosca - Now read surface temperature for GEOS-5.7.x
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
   11 Apr 2012 - R. Yantosca - Now remove the call to INIT_LAI; we shall
                              initialize the LAI arrays from main.F
   03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
   11 Apr 2013 - R. Yantosca - Now pass directory info with Input_Opt
   13 Aug 2013 - M. Sulprizio- Add modifications for sesquiterpenes and PFTs
                              (H. Pye)
   26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
   26 Sep 2013 - R. Yantosca - Now use GEOSFP_READ_A1 from geosfp_read_mod.F90
```

1.85.21 cleanup_megan

Subroutine CLEANUP_MEGAN deallocates all allocated arrays at the end of a GEOS-Chem model run.

INTERFACE:

```
      SUBROUTINE CLEANUP_MEGAN
```

REVISION HISTORY:

```
   17 Dec 2009 - R. Yantosca - Added ProTeX headers
   13 Aug 2013 - M. Sulprizio- Add modifications for sesquiterpenes and PFTs
                              (H. Pye)
```

1.86 Fortran: Module Interface meganut_mod

Module MEGANUT_MOD contains functions used by MEGAN.

INTERFACE:

```
      MODULE MEGANUT_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: XLTMMP
      PUBLIC :: XLPARDF
      PUBLIC :: XLPARDR
  !REVISION HISTORY
   20 Nov 2009 - C. Carouge  - Create the module with xltmmp, xlpardf and
                              xlpardr functions.
   20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.86.1 xltmmp

Function XLTMMP passes the value of the DAO meterological field TS(IIPAR,JJPAR) back to the calling subroutine. This preserves the functionality of the H/G/I CTM function XLTMMP. XLTMMP is written in Fixed-Form Fortran 90. I, J are the long/lat indices of the grid box. IJLOOP is passed in order to maintain compatibility with the H/G/I subroutines, but is not used.

INTERFACE:

```
      FUNCTION XLTMMP( I, J, TS, IJLOOP ) RESULT( VALUE )
```

USES:

```
      USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: I, J
      REAL*8,  INTENT(IN)           :: TS(IIPAR,JJPAR)
      INTEGER, INTENT(IN), OPTIONAL :: IJLOOP
```

RETURN VALUE:

```
      REAL*8                        :: VALUE
```

REVISION HISTORY:

```
                              Use C-preprocessor #include statement to
                              include CMN_SIZE, which has IIPAR, JJPAR,
                              LLPAR, IIPAR, JJPAR, LGLOB.
   23 Jun 2000 - R. Yantosca - Now reference TS from "dao_mod.f" instead of
                              from common block header file "CMN_TS".
   31 Aug 2000 - R. Yantosca - Eliminated obsolete code from 6/23/00
   26 Sep 2001 - R. Yantosca - Now declare XLTMMP as REAL*8 w/in program body.
                              Also updated comments.
   24 Oct 2001 - R. Yantosca - Remove obsolete commented out code from 9/01
   20 Jul 2004 - R. Yantosca - IJLOOP is now not declared optional...this
                              facilitates compiling with -C on Altix
   04 Aug 2005 - R. Yantosca - Now make IJLOOP an optional argument; it's only
                              kept for backwards compatibility w/ older code
 ------------------------------------------------------------------------------
 BOC
      VALUE = TS(I,J)

      END FUNCTION XLTMMP
 EOC
 ------------------------------------------------------------------------------
                   GEOS-Chem Global Chemical Transport Model                  !
```

```
  ------------------------------------------------------------------------
%//////////////////////////////////////////////////////////

\mbox{}\hrulefill\


  \subsubsection{xlpardr }


  Function XLPARDR passes the value of the DAO meterological
    field PARDR(IIPAR,JJPAR) back to the calling subroutine.  This preserves
    the functionality of the H/G/I CTM function PARDR.  I, J are the long/lat
    indices of the grid box. IJLOOP is passed in order to maintain compatibility
    with the H/G/I subroutines, but is not used.
  \\
  \\{\bf INTERFACE:}
\begin{verbatim}       FUNCTION XLPARDR( I, J, PARDR, IJLOOP ) RESULT( VALUE )
   !USES

       USE CMN_SIZE_MOD
   !INPUT PARAMETERS
       INTEGER, INTENT(IN)           :: I, J
       REAL*8,  INTENT(IN)           :: PARDR(IIPAR,JJPAR)
       INTEGER, INTENT(IN), OPTIONAL :: IJLOOP
```

RETURN VALUE:

```
       REAL*8                        :: VALUE
   !REVISION HISTORY
   20 Nov 2009 - M. Barkley - Original version
```

1.86.2 xlpardf

Function XLPARDF passes the value of the DAO meterological field PARDF(IIPAR,JJPAR) back to the calling subroutine. This preserves the functionality of the H/G/I CTM function PARDF. I, J are the long/lat indices of the grid box. IJLOOP is passed in order to maintain compatibility with the H/G/I subroutines, but is not used.

INTERFACE:

```
       FUNCTION XLPARDF( I, J, PARDF, IJLOOP ) RESULT( VALUE )
   !USES
       USE CMN_SIZE_MOD
   !INPUT PARAMETERS
       INTEGER, INTENT(IN)           :: I, J
       REAL*8,  INTENT(IN)           :: PARDF(IIPAR,JJPAR)
       INTEGER, INTENT(IN), OPTIONAL :: IJLOOP
```

RETURN VALUE:

```
       REAL*8                         :: VALUE

   !REVISION HISTORY
    20 Nov 2009 - M. Barkley - Original version
  !EOP
  ------------------------------------------------------------------------------
  BOC
       VALUE = PARDF(I,J)

       END FUNCTION XLPARDF
  EOC
       END MODULE MEGANUT_MOD
\markboth{Left}{Source File: merra\_a1\_mod.F,  Date: Tue Feb 25 15:45:31 EST 2014
}


  ------------------------------------------------------------------------------
                   GEOS-Chem Global Chemical Transport Model                  !
  ------------------------------------------------------------------------------
%//////////////////////////////////////////////////////////////

\mbox{}\hrulefill\


  \subsection{Fortran:  Module Interface merra\_a1\_mod }


  Module MERRA\_A1\_MOD contains subroutines for reading the
    1-hour time averaged (aka "A1") fields from the MERRA data archive.
  \\
  \\{\bf INTERFACE:}
\begin{verbatim}       MODULE MERRA_A1_MOD
```

USES:

```
       USE inquireMod, ONLY : findFreeLUN

       IMPLICIT NONE
       PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
       PUBLIC  :: GET_MERRA_A1_FIELDS
       PUBLIC  :: OPEN_MERRA_A1_FIELDS
```

PRIVATE MEMBER FUNCTIONS:

```
       PRIVATE :: A1_CHECK
       PRIVATE :: DO_OPEN_A1
       PRIVATE :: READ_A1
```

REMARKS:

```
Don't bother with the file unzipping anymore.
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
03 Aug 2012 - R. Yantosca - Now make IU_A1 a private module variable
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.86.3 do_open_a1

Function DO_OPEN_A1 returns TRUE if is time to open the A1 met field file or FALSE otherwise. This prevents us from opening a file which has already been opened.

INTERFACE:

```
FUNCTION DO_OPEN_A1( NYMD, NHMS, RESET ) RESULT( DO_OPEN )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)           :: NYMD     ! YYYYMMDD and hhmmss to test
INTEGER, INTENT(IN)           :: NHMS     !  if it's time to open file
LOGICAL, INTENT(IN), OPTIONAL :: RESET    ! Reset the
```

RETURN VALUE:

```
LOGICAL                       :: DO_OPEN  ! =T if it's time to open file
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
21 Sep 2010 - R. Yantosca - Add RESET via the argument list to reset
                            the FIRST flag if so desired.
```

1.86.4 open_merra_a1_fields

Subroutine OPEN_MERRA_A1_FIELDS opens the A1 met fields file for date NYMD and time NHMS.

INTERFACE:

```
  SUBROUTINE OPEN_MERRA_A1_FIELDS( NYMD,  NHMS, Input_Opt,
 &                                 RESET, IUNIT            )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE ERROR_MOD,          ONLY : ERROR_STOP
USE FILE_MOD,           ONLY : FILE_EXISTS
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)            :: NYMD      ! YYYYMMDD date
INTEGER,        INTENT(IN)            :: NHMS      ! hhmmss time
TYPE(OptInput), INTENT(IN)            :: Input_Opt ! Input Options
LOGICAL,        INTENT(IN),  OPTIONAL :: RESET     ! Reset first A1 flag?
```

INPUT/OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT), OPTIONAL :: IUNIT     ! Returns IU_A1
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
03 Aug 2012 - R. Yantosca - Now use findFreeLUN to define IU_A1 locally
06 Aug 2012 - R. Yantosca - Add optional IUNIT to pass LUN to calling routine
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
```

1.86.5 get_merra_a1_fields

Subroutine GET_MERRA_A1_FIELDS is a wrapper for routine READ_A1.

INTERFACE:

```
SUBROUTINE GET_MERRA_A1_FIELDS( NYMD, NHMS, State_Met )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: NYMD        ! YYYYMMDD and
INTEGER,        INTENT(IN)    :: NHMS        !  hhmmss of data to read
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
25 Aug 2010 - R. Yantosca - Now pass LWI down to READ_A1
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Remove reference to dao_mod.F module arrays
```

1.86.6 read_a1

Subroutine READ_A1 reads MERRA 1-hour time averaged ("A1") met fields from disk.

INTERFACE:

```
 SUBROUTINE READ_A1( NYMD,     NHMS,
&                    ALBEDO,   CLDTOT,   EFLUX,    EVAP,
&                    FRSEAICE, FRSNO,    GRN,      GWETROOT,
&                    GWETTOP,  HFLUX,    LAI,      LWGNT,
&                    LWI,      PARDF,    PARDR,    PBLH,
&                    PRECANV,  PRECTOT,  PRECCON,  PRECLSC,
&                    PRECSNO,  SEAICE00, SEAICE10, SEAICE20,
&                    SEAICE30, SEAICE40, SEAICE50, SEAICE60,
&                    SEAICE70, SEAICE80, SEAICE90, SLP,
&                    SNODP,    SNOMAS,   SWGNT,    TROPPT,
&                    T2M,      TS,       U10M,     USTAR,
&                    V10M,     ZOM                           )
```

USES:

```
USE DIAG_MOD,     ONLY : AD67
USE FILE_MOD,     ONLY : IOERROR
USE TIME_MOD,     ONLY : SET_CT_A1
USE TIME_MOD,     ONLY : TIMESTAMP_STRING
USE TRANSFER_MOD, ONLY : TRANSFER_2D
USE TRANSFER_MOD, ONLY : TRANSFER_TO_1D

USE CMN_SIZE_MOD                          ! Size parameters
USE CMN_DIAG_MOD                          ! ND67 flag
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: NYMD                ! YYYYMMDD and hhmmss
INTEGER, INTENT(IN)  :: NHMS                !  of data to read
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: ALBEDO  (IIPAR,JJPAR)  ! Sfc albedo [unitless]
REAL*8,  INTENT(OUT) :: CLDTOT  (IIPAR,JJPAR)  ! Column cld fraction
REAL*8,  INTENT(OUT) :: EFLUX   (IIPAR,JJPAR)  ! Latent heat flux [W/m2]
REAL*8,  INTENT(OUT) :: EVAP    (IIPAR,JJPAR)  ! Surface evap [kg/m2/s]
REAL*8,  INTENT(OUT) :: FRSEAICE(IIPAR,JJPAR)  ! Sfc sea ice fraction
```

```
      REAL*8,  INTENT(OUT) :: FRSNO   (IIPAR,JJPAR)  ! Sfc snow fraction
      REAL*8,  INTENT(OUT) :: GRN     (IIPAR,JJPAR)  ! Greenness fraction
      REAL*8,  INTENT(OUT) :: GWETROOT(IIPAR,JJPAR)  ! Root soil wetness [frac]
      REAL*8,  INTENT(OUT) :: GWETTOP (IIPAR,JJPAR)  ! Topsoil wetness [frac]
      REAL*8,  INTENT(OUT) :: HFLUX   (IIPAR,JJPAR)  ! Sensible H-flux [W/m2]
      REAL*8,  INTENT(OUT) :: LAI     (IIPAR,JJPAR)  ! Leaf area index [m2/m2]
      REAL*8,  INTENT(OUT) :: LWI     (IIPAR,JJPAR)  ! Leaf area index [m2/m2]
      REAL*8,  INTENT(OUT) :: LWGNT   (IIPAR,JJPAR)  ! Net LW rad @ sfc [W/m2]
      REAL*8,  INTENT(OUT) :: PARDF   (IIPAR,JJPAR)  ! Diffuse PAR [W/m2]
      REAL*8,  INTENT(OUT) :: PARDR   (IIPAR,JJPAR)  ! Direct PAR [W/m2]
      REAL*8,  INTENT(OUT) :: PBLH    (IIPAR,JJPAR)  ! PBL height [m]
      REAL*8,  INTENT(OUT) :: PRECANV (IIPAR,JJPAR)  ! Anv prec @ sfc [kg/m2/s]
      REAL*8,  INTENT(OUT) :: PRECTOT (IIPAR,JJPAR)  ! Tot prec @ sfc [kg/m2/s]
      REAL*8,  INTENT(OUT) :: PRECCON (IIPAR,JJPAR)  ! CV prec @ sfc [kg/m2/s]
      REAL*8,  INTENT(OUT) :: PRECLSC (IIPAR,JJPAR)  ! LS prec @ sfc [kg/m2/s]
      REAL*8,  INTENT(OUT) :: PRECSNO (IIPAR,JJPAR)  ! Snow precip [kg/m2/s]
      REAL*8,  INTENT(OUT) :: SEAICE00(IIPAR,JJPAR)  ! Sea ice coverage 00-10%
      REAL*8,  INTENT(OUT) :: SEAICE10(IIPAR,JJPAR)  ! Sea ice coverage 10-20%
      REAL*8,  INTENT(OUT) :: SEAICE20(IIPAR,JJPAR)  ! Sea ice coverage 20-30%
      REAL*8,  INTENT(OUT) :: SEAICE30(IIPAR,JJPAR)  ! Sea ice coverage 30-40%
      REAL*8,  INTENT(OUT) :: SEAICE40(IIPAR,JJPAR)  ! Sea ice coverage 40-50%
      REAL*8,  INTENT(OUT) :: SEAICE50(IIPAR,JJPAR)  ! Sea ice coverage 50-60%
      REAL*8,  INTENT(OUT) :: SEAICE60(IIPAR,JJPAR)  ! Sea ice coverage 60-70%
      REAL*8,  INTENT(OUT) :: SEAICE70(IIPAR,JJPAR)  ! Sea ice coverage 70-80%
      REAL*8,  INTENT(OUT) :: SEAICE80(IIPAR,JJPAR)  ! Sea ice coverage 80-90%
      REAL*8,  INTENT(OUT) :: SEAICE90(IIPAR,JJPAR)  ! Sea ice coverage 90-100%
      REAL*8,  INTENT(OUT) :: SLP     (IIPAR,JJPAR)  ! Sea level pressure [hPa]
      REAL*8,  INTENT(OUT) :: SNODP   (IIPAR,JJPAR)  ! Snow depth [m]
      REAL*8,  INTENT(OUT) :: SNOMAS  (IIPAR,JJPAR)  ! Snow mass [kg/m2]
      REAL*8,  INTENT(OUT) :: SWGNT   (IIPAR,JJPAR)  ! SW rad @ sfc [W/m2]
      REAL*8,  INTENT(OUT) :: TROPPT  (IIPAR,JJPAR)  ! T'pause pressure [hPa]
      REAL*8,  INTENT(OUT) :: T2M     (IIPAR,JJPAR)  ! T @ 2m height [K]
      REAL*8,  INTENT(OUT) :: TS      (IIPAR,JJPAR)  ! Sfc skin T [K]
      REAL*8,  INTENT(OUT) :: U10M    (IIPAR,JJPAR)  ! U-wind @ 10m [m/s]
      REAL*8,  INTENT(OUT) :: USTAR   (IIPAR,JJPAR)  ! Friction velocity [m/s]
      REAL*8,  INTENT(OUT) :: V10M    (IIPAR,JJPAR)  ! V-wind @ 10m [m/s]
      REAL*8,  INTENT(OUT) :: Z0M     (IIPAR,JJPAR)  ! Roughness height [m]
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
25 Aug 2010 - R. Yantosca - Now read LWI (land/water/ice) from disk
15 Aug 2011 - R. Yantosca - Now save SWGDN in 2nd slot of ND67 diagnostic
25 Mar 2011 - R. Yantosca - Bug fix: make local SWGDN array for ND67 diag
08 Jun 2012 - S. Philip   - Correction for MERRA boundary layer height
03 Aug 2012 - R. Yantosca - Now use locally-defined IU_A1 file LUN
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
```

1.86.7 a1_check

Subroutine A1_CHECK prints an error message if not all of the A-3 met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE A1_CHECK( NFOUND, N_A1 )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! Number of met fields read in from disk
INTEGER, INTENT(IN) :: N_A1     ! Number of expected met fields
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
```

1.87 Fortran: Module Interface merra_a3_mod

Module MERRA_A3_MOD contains subroutines for reading the 3-hour time averaged (aka "A3") fields from the MERRA data archive.

INTERFACE:

```
MODULE MERRA_A3_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: GET_MERRA_A3_FIELDS
PUBLIC  :: OPEN_MERRA_A3_FIELDS
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: A3_CHECK
PRIVATE :: DO_OPEN_A3
PRIVATE :: READ_A3
```

REMARKS:

```
Don't bother with the file unzipping anymore.
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
03 Aug 2012 - R. Yantosca - Now make IU_A3 a private module variable
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.87.1 do_open_a3

unction DO_OPEN_A3 returns TRUE if is time to open the A3 met field file or FALSE otherwise. This prevents us from opening a file which has already been opened.

INTERFACE:

```
FUNCTION DO_OPEN_A3( NYMD, NHMS ) RESULT( DO_OPEN )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NYMD      ! YYYYMMDD and hhmmss to be tested
INTEGER, INTENT(IN) :: NHMS      !  to see if it's time to open A3 file
```

RETURN VALUE:

```
LOGICAL             :: DO_OPEN   ! = T if it is time to open the file
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
```

1.87.2 open_merra_a3_fields

Subroutine OPEN_MERRA_A3_FIELDS opens the A3 met fields file for date NYMD and time NHMS.

INTERFACE:

```
SUBROUTINE OPEN_MERRA_A3_FIELDS( NYMD, NHMS, Input_Opt )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ERROR_STOP
USE FILE_MOD,           ONLY : FILE_EXISTS
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN) :: NYMD        ! YYYYMMDD and hhmmss
INTEGER,        INTENT(IN) :: NHMS        !  to test for A3 file open
TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a6_read_mod.f
03 Aug 2012 - R. Yantosca - Now use findFreeLUN to define IU_A3 locally
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
11 Apr 2013 - R. Yantosca - Now pass fields with Input_Opt
```

1.87.3 get_merra_a3_fields

Subroutine GET_MERRA_A3_FIELDS is a wrapper for routine READ_A3.

INTERFACE:

```
SUBROUTINE GET_MERRA_A3_FIELDS( NYMD, NHMS, Input_Opt, State_Met )
```

USES:

```
USE CMN_SIZE_MOD
USE DAO_MOD,             ONLY : T_FULLGRID
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: NYMD        ! YYYYMMDD and
INTEGER,        INTENT(IN)    :: NHMS        !  hhmmss of desired data
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_met
23 Oct 2013 - R. Yantosca - Now accept Input_Opt as an argument
23 Oct 2013 - R. Yantosca - Now read T_FULLGRID for specialty (offline) sims
```

1.87.4 read_a3

Subroutine READ_A3 reads the MERRA 3-hour time-averaged (aka "A3") met fields from disk.

INTERFACE:

```
 SUBROUTINE READ_A3( NYMD,     NHMS,
&                    CLOUD,    CLDTOPS,   CMFMC,    DQRCU,
&                    DQRLSAN,  DQIDTMST,  DQLDTMST, DQVDTMST,
&                    DTRAIN,   MOISTQ,    OPTDEPTH, PFICU,
&                    PFILSAN,  PFLCU,     PFLLSAN,  QI,
&                    QL,       QV,        REEVAPCN, REEVAPLS,
&                    T,        TAUCLI,    TAUCLW,   U,
&                    V,        T_FULLGRID                     )
```

USES:

```
USE CMN_SIZE_MOD
USE CMN_DIAG_MOD
USE DIAG_MOD,     ONLY : AD66
USE DIAG_MOD,     ONLY : AD67
USE FILE_MOD,     ONLY : IOERROR
USE TIME_MOD,     ONLY : SET_CT_A3
USE TIME_MOD,     ONLY : TIMESTAMP_STRING
USE TRANSFER_MOD, ONLY : TRANSFER_A6
USE TRANSFER_MOD, ONLY : TRANSFER_3D_Lp1
USE TRANSFER_MOD, ONLY : TRANSFER_3D
USE TRANSFER_MOD, ONLY : TRANSFER_G5_PLE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: NYMD                          ! YYYYMMDD & hhmmss
INTEGER, INTENT(IN)  :: NHMS                          !  of desired data
```

OUTPUT PARAMETERS:

```
! Fields dimensioed as (I,J)
INTEGER, INTENT(OUT) :: CLDTOPS   (IIPAR,JJPAR       )

! Fields dimensioned as (I,J,L)
REAL*8,  INTENT(OUT) :: CMFMC     (IIPAR,JJPAR,LLPAR+1)
REAL*8,  INTENT(OUT) :: DQRCU     (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: DQRLSAN   (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: DQIDTMST  (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: DQLDTMST  (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: DQVDTMST  (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: DTRAIN    (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: PFICU     (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: PFILSAN   (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: PFLCU     (IIPAR,JJPAR,LLPAR  )
```

```
REAL*8,  INTENT(OUT) :: PFLLSAN   (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: QI        (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: QL        (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: QV        (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: REEVAPCN  (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: REEVAPLS  (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: T         (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: TAUCLI    (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: TAUCLW    (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: U         (IIPAR,JJPAR,LLPAR  )
REAL*8,  INTENT(OUT) :: V         (IIPAR,JJPAR,LLPAR  )

! Fields dimensioned as (L,I,J)
REAL*8,  INTENT(OUT) :: CLOUD     (LLPAR,IIPAR,JJPAR  )
REAL*8,  INTENT(OUT) :: MOISTQ    (LLPAR,IIPAR,JJPAR  )
REAL*8,  INTENT(OUT) :: OPTDEPTH  (LLPAR,IIPAR,JJPAR  )

! Optional arguments
REAL*8,  OPTIONAL    :: T_FULLGRID(IIPAR,JJPAR,LGLOB  )
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a3_read_mod.f
20 Aug 2010 - R. Yantosca - Now save CLDTOPS to ND67 diagnostic
03 Aug 2012 - R. Yantosca - Now use locally-defined IU_A3 file LUN
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
05 Sep 2013 - R. Yantosca - Set negatives in QI, QL to zero
28 Oct 2013 - R. Yantosca - Add optional T_FULLGRID argument for the
                            offline "specialty" simulations
```

1.87.5 a3_check

Subroutine A3_CHECK prints an error message if not all of the A-6 met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE A3_CHECK( NFOUND, N_A3 )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! # of fields found in file
INTEGER, INTENT(IN) :: N_A3     ! # of expected fields
```

REVISION HISTORY:

```
20 Aug 2010 - R. Yantosca - Initial version, based on a6_read_mod.f
```

1.88 Fortran: Module Interface merra_cn_mod

Module MERRA_CN_MOD contains subroutines for reading the constant (aka "CN") fields from the MERRA data archive.

INTERFACE:

```
MODULE MERRA_CN_MOD
```

USES:

```
USE CMN_SIZE_MOD                    ! Size parameters
USE CMN_DIAG_MOD                    ! NDxx flags
USE CMN_GCTM_MOD                    ! g0
USE inquireMod, ONLY : findFreeLUN  ! Routine to find free LUNs

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: GET_MERRA_CN_FIELDS
PUBLIC  :: OPEN_MERRA_CN_FIELDS
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: CN_CHECK
PRIVATE :: READ_CN
```

REMARKS:

```
Don't bother with the file unzipping anymore.
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
20 Aug 2010 - R. Yantosca - Moved include files to top of module
03 Aug 2012 - R. Yantosca - Now make IU_A3 a private module variable
09 Nov 2012 - R. Yantosca - Now get met fields from State_Met object
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.88.1 open_merra_cn_fields

Subroutine OPEN_MERRA_CN_FIELDS opens the MERRA "CN" met fields file for date NYMD and time NHMS.

INTERFACE:

```
SUBROUTINE OPEN_MERRA_CN_FIELDS( NYMD, NHMS, Input_Opt )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE ERROR_MOD,          ONLY : ERROR_STOP
USE FILE_MOD,           ONLY : FILE_EXISTS
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN) :: NYMD   ! YYYYMMDD date
INTEGER,        INTENT(IN) :: NHMS   ! hhmmss time
TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
03 Aug 2012 - R. Yantosca - Now use findFreeLUN to define IU_CN locally
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
11 Apr 2013 - R. Yantosca - Now pass directory fields via Input_Opt
```

1.88.2 get_merra_cn_fields

Subroutine GET_MERRA_CN_FIELDS is a wrapper for routine READ_CN.

INTERFACE:

```
SUBROUTINE GET_MERRA_CN_FIELDS( NYMD, NHMS, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: NYMD    ! YYYYMMDD date
INTEGER,        INTENT(IN)    :: NHMS    ! hhmmss time of desired data
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
```

1.88.3 read_cn

Subroutine READ_CN reads the MERRA CN (constant) fields from disk.

INTERFACE:

```
SUBROUTINE READ_CN( NYMD,   NHMS,
&                   FRLAKE, FRLAND, FRLANDIC, FROCEAN, PHIS )
```

USES:

```
USE DIAG_MOD,     ONLY : AD67
USE FILE_MOD,     ONLY : IOERROR
USE TIME_MOD,     ONLY : TIMESTAMP_STRING
USE TRANSFER_MOD, ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: NYMD   ! YYYYMMDD and
INTEGER, INTENT(IN)  :: NHMS   !  hhmmss time of desired data
```

OUTPUT PARAMETERS:

```
! Fraction of grid box covered by lakes [unitless]
REAL*8,  INTENT(OUT) :: FRLAKE  (IIPAR,JJPAR)

! Fraction of grid box covered by land ice [unitless]
REAL*8,  INTENT(OUT) :: FRLAND  (IIPAR,JJPAR)

! Fraction of grid box covered by land ice [unitless]
REAL*8,  INTENT(OUT) :: FRLANDIC(IIPAR,JJPAR)

! Fraction of grid box covered by ocean [unitless]
REAL*8,  INTENT(OUT) :: FROCEAN (IIPAR,JJPAR)

! Surface geopotential height [m2/s2]
REAL*8,  INTENT(OUT) :: PHIS    (IIPAR,JJPAR)
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
03 Aug 2012 - R. Yantosca - Now use locally-defined IU_CN file LUN
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
```

1.88.4 cn_check

Subroutine CN_CHECK prints an error message if not all of the CN met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE CN_CHECK( NFOUND, N_CN )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! Number of met fields read in from disk
INTEGER, INTENT(IN) :: N_CN     ! Number of expected met fields
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.89 Fortran: Module Interface merra_i6_mod

Module MERRA_I6_MOD contains subroutines for reading the 6-hour instantaneous (aka "I6") fields from the MERRA data archive.

INTERFACE:

```
MODULE MERRA_I6_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: GET_MERRA_I6_FIELDS_1
PUBLIC  :: GET_MERRA_I6_FIELDS_2
PUBLIC  :: OPEN_MERRA_I6_FIELDS
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: I6_CHECK
PRIVATE :: READ_I6
```

REMARKS:

```
Don't bother with the file unzipping anymore.
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
03 Aug 2012 - R. Yantosca - Now make IU_I6 a private module variable
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.89.1 open_merra_i6_fields

Subroutine OPEN_MERRA_I6_FIELDS opens the MERRA "I6" met fields file for date NYMD and time NHMS.

INTERFACE:

```
SUBROUTINE OPEN_MERRA_I6_FIELDS( NYMD, NHMS, Input_Opt )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE ERROR_MOD,          ONLY : ERROR_STOP
USE FILE_MOD,           ONLY : FILE_EXISTS
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN) :: NYMD        ! YYYYMMDD date
INTEGER,        INTENT(IN) :: NHMS        ! hhmmss time
TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
03 Aug 2012 - R. Yantosca - Now use findFreeLUN to define IU_I6 locally
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
11 Apr 2013 - R. Yantosca - Now pass directory fields with Input_Opt
```

1.89.2 get_merra_i6_fields_1

Subroutine GET_MERRA_I6_FIELDS_1 is a wrapper for routine READ_I6. It reads the initial data at the start of a GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE GET_MERRA_I6_FIELDS_1( NYMD, NHMS, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: NYMD   ! YYYYMMDD date
INTEGER,        INTENT(IN)    :: NHMS   ! hhmmss time of desired data
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
15 Nov 2012 - R. Yantosca - Now replace dao_mod.F arrays with State_Met
```

1.89.3 get_merra_i6_fields_2

Subroutine GET_MERRA_I6_FIELDS_2 is a wrapper for routine READ_I6. It reads the data every 6 hours during a GEOS-Chem simulation.

INTERFACE:

```
SUBROUTINE GET_MERRA_I6_FIELDS_2( NYMD, NHMS, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: NYMD   ! YYYYMMDD date
INTEGER,        INTENT(IN)    :: NHMS   ! hhmmss time of desired data
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
09 Nov 2012 - M. Payer    - Copy all met fields to the State_Met derived type
                            object
```

1.89.4 read_i6

Subroutine READ_I6 reads GEOS-Chem I-6 (instantaneous 6-hour) met fields from disk.

INTERFACE:

```
SUBROUTINE READ_I6( NYMD, NHMS, PS, RH )
```

USES:

```
USE FILE_MOD,     ONLY : IOERROR
USE TIME_MOD,     ONLY : SET_CT_I6
USE TIME_MOD,     ONLY : TIMESTAMP_STRING
USE TRANSFER_MOD, ONLY : TRANSFER_2D
USE TRANSFER_MOD, ONLY : TRANSFER_3D

USE CMN_SIZE_MOD                              ! Size parameters
USE CMN_DIAG_MOD                              ! NDxx flags
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: NYMD                  ! YYYYMMDD and hhmmss
INTEGER, INTENT(IN)  :: NHMS                  !  time of desired data
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: PS(IIPAR,JJPAR      )  ! Surface pressure [hPa]
REAL*8,  INTENT(OUT) :: RH(IIPAR,JJPAR,LLPAR)  ! Rel. humidity    [1]
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
03 Aug 2012 - R. Yantosca - Now use locally-defined IU_I6 file LUN
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
15 Nov 2013 - R. Yantosca - Now convert RH from [1] to [%], in order
                            to be consistent with GEOS-Chem convention
```

1.89.5 i6_check

Subroutine I6_CHECK prints an error message if not all of the I6 met fields are found. The run is also terminated.

INTERFACE:

```
SUBROUTINE I6_CHECK( NFOUND, N_I6 )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NFOUND   ! Number of met fields read in from disk
INTEGER, INTENT(IN) :: N_I6     ! Number of expected met fields
```

REVISION HISTORY:

```
19 Aug 2010 - R. Yantosca - Initial version, based on i6_read_mod.f
```

1.90 Fortran: Module Interface modis_lai_mod

Module MODIS_LAI_MOD reads the MODIS LAI data at native resolution (either 0.25 x 0.25 or 0.5 x 0.5, in netCDF format) and rebins it to the proper GEOS-Chem LAI arrays. This module eliminates the need for the following GEOS-Chem modules, routines, and data files:

- lai_mod.F
- readlai.F

- rdlai.F
- findmon.F
- The `lai*.global` input files
- CMN_VEL_mod.F

INTERFACE:

```
MODULE Modis_Lai_Mod
```

USES:

```
  USE CMN_SIZE_Mod                                ! Size parameters
  USE Directory_Mod                               ! Disk directory paths
  USE Error_Mod                                   ! Error checking routines
  USE Logical_Mod                                 ! Logical switches
  USE Mapping_Mod                                 ! Mapping weights & areas
  USE Time_Mod                                    ! EXPAND_DATE

  IMPLICIT NONE
  PRIVATE
```

PUBLIC DATA MEMBERS:

```
  INTEGER, PUBLIC              :: DAYS_BTW_MON    ! Days btw LAI midmonths
  REAL*8,  PUBLIC, ALLOCATABLE :: GC_LAI   (:,:)  ! Daily        LAI, G-C grid
  REAL*8,  PUBLIC, ALLOCATABLE :: GC_LAI_PM(:,:)  ! Prev month's LAI, G-C grid
  REAL*8,  PUBLIC, ALLOCATABLE :: GC_LAI_CM(:,:)  ! Curr month's LAI, G-C grid
  REAL*8,  PUBLIC, ALLOCATABLE :: GC_LAI_NM(:,:)  ! Next month's LAI, G-C grid
```

PUBLIC MEMBER FUNCTIONS:

```
  PUBLIC  :: Compute_Modis_Lai
  PUBLIC  :: Read_Modis_Lai
  PUBLIC  :: Find_Lai_Month
  PUBLIC  :: Init_Modis_Lai
  PUBLIC  :: Cleanup_Modis_Lai
```

PRIVATE MEMBER FUNCTIONS:

```
  PRIVATE :: RoundOff
```

REMARKS:

```
   Functionality of this module:
   ============================================================================
   If you are using the Olson 1992 land map, then this module will pick the
   MODIS LAI data at 0.5 x 0.5 native resolution.  This is because the legacy
   code assumed a direct correspondence between the Olson 1992 land map and
   the MODIS LAI data.  Similarly, if you are using the Olson 2001 land map,
   then this module will pick the MODIS LAI data at 0.25 x 0.25 resolution.
```

```
.
Follows the same algorithm as in the IDL codes used to regrid MODIS LAI
data (regridmodis_lai_v5.pro; contact GEOS-Chem Support team).
.
.
Historical background of how LAI data have been used in GEOS-Chem:
=============================================================================
Note that GEOS-Chem (as of April 2012) uses LAI data from two separate
sources.  The dry deposition and soil NOx modules rely on the data from
"lai*.global" ASCII files.  These files (which are pre-processed offline
by IDL codes) are generated for each specific GEOS-Chem grid configuration
(e.g. 4x5, 2x25, 0.5x0.666 nested grids).  These files are read from disk
by routine RDLAI, which saves the LAI data into the XLAI and XYLAI arrays.
XLAI and XYLAI store the leaf area index as a function of Olson land type
(cf Olson 1992 land map).
.
However, the MEGAN biogenic emissions code relies on LAI data stored at
1x1 resolution stored in bpch format.  These binary files are read by
routine RDISOLAI (and other underlying routines in lai_mod.F), and are
regridded on-the-fly to the current GEOS-Chem grid resolution.
.
Therefore, these two sources of LAI data present an inconsistency that
should be resolved.  Also, for the Grid-Indpendent GEOS-Chem project,
we must move away from ASCII files (which prevent interfacing with
external GCMs).  We also cannot assume any particular horizontal grid,
since that is now to be specified at the start of the simulation.
.
Also, to facilitate simulations at ultra-fine horizontal resolution, we
will eventually adopt the Olson 2001 land map, which has a native
resolution of 0.25 x 0.25 degrees, and likewise use an updated version
of the MODIS LAI data at 0.25 x 0.25 resolution.
.
To resolve these issues, we have created a new module (modis_lai_mod.F90)
which reads from the MODIS LAI data in netCDF format at the native
resolution and then regrids the LAI data to GEOS-Chem resolution on-the-
fly.  The XLAI array is populated for backwards compatibility with the
existing legacy codes.  The LAI arrays used for MEGAN (ISOLAI, PMISOLAI,
MISOLAI, and NMISOLAI) are now replaced by arrays GC_LAI, GC_LAI_PM,
GC_LAI_CM, and GC_LAI_NM) from modis_lai_mod.F.
.
We have validated that the new scheme generates identical XLAI arrays
w/r/t the old scheme.  The arrays GC_LAI etc. differ from the ISOLAI etc.
arrays slightly (but generally agree to within 0.001).  This is due to
the fact that the ISOLAI arrays were regridded from 1 x 1 native
resolution, but now we are regridding from much finer resolution
(either 0.5 x 0.5 or 0.25 x 0.25).
.
NOTES:
```

```
(1) At the present time, we have removed all references to the obsolete
    XYLAI array and its parent module CMN_VEL_mod.F.
(2) At the present time, we have not yet disabled the RDISOLAI function.
    We will do so in the future, and will validate this with a separate
    benchmark.
(3) As of December 2012, XLAI and XLAI2 have been moved out of obsolete
    module Headers/CMN_DEP_mod.F and are now carried as part of the
    Meteorology State object (State_Met).  This modification was made
    to facilitate the Grid-Independent GEOS-Chem (GIGC) project.

    -- Bob Yantosca (geos-chem-support@as.harvard.edu), 13 Dec 2012
                                                                             .
                                                                             .
LAI arrays and where they are (or will be) used in GEOS-Chem:
=============================================================================
(1) State_Met%XLAI  --> Used in dry deposition routine DEPVEL
(2) State_Met%XLAI2 --> Used to compute XLAI
(3) XYLAI           --> %%% OBSOLETE: REMOVED, NOW REPLACED BY XLAI %%%
(4) GC_LAI          --> Intended replacement for ISOLAI   (from lai_mod.F)
(5) GC_LAI_PM       --> Intended replacement for PMISOLAI (from lai_mod.F)
(6) GC_LAI_CM       --> Intended replacement for MISOLAI  (from lai_mod.F)
(7) GC_LAI_NM       --> Intended replacement for NMISOLAI (from lai_mod.F)
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
05 Apr 2012 - R. Yantosca - Added descriptive comments
09 Apr 2012 - R. Yantosca - Fixed error in ROUNDOFF function that caused
                            numbers to be rounded up incorrectly.
09 Apr 2012 - R. Yantosca - Changed variables to REAL*8
09 Apr 2012 - R. Yantosca - Now set MODIS_START and MODIS_END depending
                            on which version of MODIS LAI we are using
13 Dec 2012 - R. Yantosca - Remove reference to obsolete CMN_DEP_mod.F;
                            XLAI, XLAI2 now are carried in State_Met
```

1.90.1 compute_modis_lai

Subroutine COMPUTE_MODIS_LAI computes the daily MODIS leaf area indices for GEOS-Chem directly from the native grid resolution (0.25 x 0.25 or 0.5 x 0.5). The XLAI array (used in the legacy soil NOx and dry deposition routines) are populated accordingly. The XYLAI array is now obsolete and has been replaced by XLAI.

INTERFACE:

```
SUBROUTINE Compute_Modis_Lai( am_I_Root, State_Met,    doy, mm,  &
                              mapping,   wasModisRead, RC       )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
LOGICAL,         INTENT(IN)  :: am_I_Root     ! Are we on the root CPU?
TYPE(MetState),  INTENT(IN)  :: State_Met     ! Meteorology State object
INTEGER,         INTENT(IN)  :: doy           ! Day of year
INTEGER,         INTENT(IN)  :: mm            ! Month for LAI data
TYPE(MapWeight), POINTER     :: mapping(:,:)  ! "fine" -> "coarse" grid map
LOGICAL,         INTENT(IN)  :: wasModisRead  ! Was LAI data just read in?
```

OUTPUT PARAMETERS:

```
INTEGER,         INTENT(OUT) :: RC            ! Success or failure?
```

REMARKS:

```
Uses same algorithm as RDISOLAI in the existing lai_mod.F.
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
05 Apr 2012 - R. Yantosca - Renamed arg "doMonthly" to "wasModisRead"
09 Apr 2012 - R. Yantosca - Changed variables to REAL*8
09 Apr 2012 - R. Yantosca - Now follows same algorithm as rdlai.F for
                            populating XLAI array
09 Apr 2012 - R. Yantosca - Remove refs to CMN_VEL_mod.F and XYLAI array;
                            these are now obsolete
17 Apr 2012 - R. Yantosca - Now rename "map" object to "mapping" to avoid
                            name confusion w/ an F90 intrinsic function
13 Dec 2012 - R. Yantosca - Add am_I_Root, State_Met, RC arguments
13 Dec 2012 - R. Yantosca - XLAI, XLAI2 are now carried in State_Met
                            instead of in obsolete Headers/CMN_DEP_mod.F
```

1.90.2 read_modis_lai

Subroutine READ_MODIS_LAI reads the MODIS LAI from disk (in netCDF format) for the current month, and for next month.

INTERFACE:

```
SUBROUTINE Read_Modis_Lai( yyyy, mm, wasModisRead )
```

USES:

```
USE m_netcdf_io_open                    ! netCDF file open
USE m_netcdf_io_read                    ! netCDF read
USE m_netcdf_io_readattr                ! netCDF attribute reads
USE m_netcdf_io_close                   ! netCDF file close

#include "netcdf.inc"                   ! netCDF settings & parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: yyyy              ! Year for LAI data
INTEGER, INTENT(IN)  :: mm                ! Month for LAI data
```

OUTPUT PARAMETERS:

```
LOGICAL, INTENT(OUT) :: wasModisRead      ! Was LAI data just read in?
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
05 Apr 2012 - R. Yantosca - Renamed arg "doMonthly" to "wasModisRead"
05 Jun 2013 - R. Yantosca - Bug fix, use "mm" for current month index
```

1.90.3 find_lai_month

Function FIND_LAI_MONTH returns the corresponding LAI month and year for the current calendar date. Note that the LAI data starts at mid-month.

INTERFACE:

```
SUBROUTINE Find_Lai_Month( doy, month, year, mm, yyyy )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: doy       ! Current day of year
INTEGER, INTENT(IN)  :: month     ! Current month
INTEGER, INTENT(IN)  :: year      ! Current year
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: mm        ! Output month for LAI data
INTEGER, INTENT(OUT) :: yyyy      ! Output year  for LAI data
```

REVISION HISTORY:

```
05 Jan 1994 - Y. H. Wang, G.M. Gardner, D. Jacob - Initial version
(1 ) Updated comments, cosmetic changes (bmy, 4/4/03)
(2 ) Add the current simulation year as input & the current LAI as output.
     This is necessary for reading in MODIS LAI (mpb,2009).
08 Dec 2009 - R. Yantosca - Added ProTeX headers
03 Apr 2012 - R. Yantosca - Renamed to FIND_LAI_MONTH; made PUBLIC
```

1.90.4 RoundOff

Rounds a number X to N decimal places of precision.

INTERFACE:

```
FUNCTION RoundOff( X, N ) RESULT( Y )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: X   ! Number to be rounded
INTEGER, INTENT(IN) :: N   ! Number of decimal places to keep
```

RETURN VALUE:

```
REAL*8              :: Y   ! Number rounded to N decimal places
```

REMARKS:

```
The algorithm to round X to N decimal places is as follows:
(1) Multiply X by 10**(N+1)
(2) If X < 0, then add -5 to X; otherwise add 5 to X
(3) Take the integer part of X
(4) Divide X by 10**(N+1)
(5) Truncate X to N decimal places: INT( X * 10**N ) / 10**N

Rounding algorithm from: Hultquist, P.F, "Numerical Methods for Engineers
 and Computer Scientists", Benjamin/Cummings, Menlo Park CA, 1988, p. 20.

Truncation algorithm from: http://en.wikipedia.org/wiki/Truncation

The two algorithms have been merged together for efficiency.
```

REVISION HISTORY:

```
06 Apr 2012 - R. Yantosca - Initial version
09 Apr 2012 - R. Yantosca - Changed all variables & arguments to REAL*8
```

1.90.5 init_modis

Subroutine INIT_MODIS_LAI initializes and allocates all module variables.

INTERFACE:

```
SUBROUTINE Init_Modis_Lai()
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
```

1.90.6 cleanup_modis_lai

Subroutine CLEANUP_MODIS_LAI deallocates all previously-allocated module variables.

INTERFACE:

```
SUBROUTINE Cleanup_Modis_Lai
```

REVISION HISTORY:

```
03 Apr 2012 - R. Yantosca - Initial version
```

1.91 Fortran: Module Interface nei2005_anthro_mod

Module NEI2005_ANTHRO_MOD contains variables and routines to read the NEI2005 anthropogenic emissions.

INTERFACE:

```
MODULE NEI2005_ANTHRO_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
REAL*8, PUBLIC, ALLOCATABLE :: USA_MASK(:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_NEI2005_ANTHRO
PUBLIC  :: EMISS_NEI2005_ANTHRO
PUBLIC  :: EMISS_NEI2005_ANTHRO_05x0666
PUBLIC  :: GET_NEI2005_ANTHRO
!-------------------------------------
! Leave for future use (bmy, 12/3/09)
!PUBLIC  :: GET_NEI2005_MASK
!-------------------------------------
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: NEI2005_SCALE_FUTURE
PRIVATE :: INIT_NEI2005_ANTHRO
PRIVATE :: TOTAL_ANTHRO_TG
PRIVATE :: READ_NEI2005_MASK
PRIVATE :: GET_NEI99_SEASON
PRIVATE :: GET_NEI99_SEASON_05x0666
PRIVATE :: GET_VISTAS_SEASON
PRIVATE :: GET_VISTAS_SEASON_05x0666
PRIVATE :: GET_NEI99_WKSCALE
PRIVATE :: GET_NEI99_WKSCALE_05x0666
```

REMARKS:

```
(1) NIT is available in the data file but not read here (it is not
    emitted in GEOS-Chem).
(2) The algorithms in routines EMISS_NEI2005_ANTHRO and
    EMISS_NEI2005_ANTHRO_05x0666 may cause the code to die
    when running offline simulations.  We will add a fix later.
```

REVISION HISTORY:

```
07 Oct 2009 - A. van Donkelaar - initial version
20 Oct 2009 - P. Le Sager - added handling of VOC & masks
02 Nov 2009 - A. van Donkelaar - added seasonality, weekday factors
02 Dec 2009 - R. Yantosca - Added GET_NEI2005_MASK function
02 Dec 2009 - R. Yantosca - Updated comments etc.
10 Dec 2009 - D. Millet - Fix scaling, which is by ozone season
11 Dec 2009 - L. Zhang, A. Van Donkelaar - Add seasonality for NH3
21 Dec 2009 - R. Yantosca - Added support for 0.5 x 0.666 nested grids
13 Aug 2010 - R. Yantosca - Add modifications for MERRA (treat like GEOS-5)
27 Jul 2011 - R. Yantosca - Removed typo in EMISS_NEI2005_ANTHRO_05x0666
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
 2 Mar 2012 - R. Yantosca - Remove A_CM2 array, use GET_AREA_CM2 instead
22 Mar 2012 - M. Payer    - C2H6 emissions are too low. Use Yaping
                            Xiao's C2H6 emissions instead.
24 May 2012 - R. Yantosca - Make all module arrays targets for pointers
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.91.1 get_nei2005_anthro

Function GET_NEI2005_ANTHRO returns the NEI2005 emission for GEOS-Chem grid box (I,J,L) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s].

INTERFACE:

```
  FUNCTION GET_NEI2005_ANTHRO( I,    J,     L, N, WEEKDAY,
 &                          MOLEC_CM2_S, KG_S ) RESULT( VALUE )
```

USES:

```
  USE GRID_MOD,     ONLY : GET_AREA_CM2
  USE TRACER_MOD,   ONLY : XNUMOL
  USE TRACERID_MOD, ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
  USE TRACERID_MOD, ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
  USE TRACERID_MOD, ONLY : IDTNO,   IDTCO,   IDTSO2,  IDTNH3
  USE TRACERID_MOD, ONLY : IDTSO4,  IDTNO2
```

INPUT PARAMETERS:

```
! Longitude, latitude, and tracer indices
INTEGER, INTENT(IN)           :: I, J, L, N

! OPTIONAL -- return emissions in [molec/cm2/s]
LOGICAL, INTENT(IN), OPTIONAL :: WEEKDAY, MOLEC_CM2_S

! OPTIONAL -- return emissions in [kg/s] or [kg C/s]
LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
! Emissions output
REAL*8                        :: VALUE
```

REVISION HISTORY:

```
07 Oct 2009 - A. van Donkelaar - initial version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use GET_AREA_CM2 instead
22 Mar 2012 - M. Payer    - C2H6 emissions are too low. Use Yaping
                            Xiao's C2H6 emissions instead.
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
```

1.91.2 emiss_nei2005_anthro

Subroutine EMISS_NEI2005_ANTHRO reads the NEI2005 emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
SUBROUTINE EMISS_NEI2005_ANTHRO( am_I_Root, Input_Opt,
&                                State_Chm, RC         )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
USE CMN_O3_MOD
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
USE TIME_MOD,           ONLY : GET_YEAR, GET_MONTH
USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_1x1
USE TRACER_MOD,         ONLY : ITS_A_FULLCHEM_SIM
USE TRACERID_MOD,       ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
```

```
      USE TRACERID_MOD,       ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
      USE TRACERID_MOD,       ONLY : IDTNO,   IDTCO,   IDTSO2,  IDTNH3
      ! added POA (jje 8/19/10)
      USE TRACERID_MOD,       ONLY : IDTSO4,  IDTOCPI, IDTBCPI, IDTPOA1
#if defined( DEVEL )
      USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK_LT
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?!
```

REVISION HISTORY:

```
   07 Oct 2009 - A. van Donkelaar - initial version
   20 Oct 2009 - P. Le Sager - added VOC, account for mask to get better total
   12 Jul 2010 - R. Yantosca - Now point to NEI2005_201007 directory, to read
                               in updated files (by Aaron van Donkelaar) to
                               fix a problem in the VOC emissions.
   13 Aug 2010 - R. Yantosca - Treat MERRA like GEOS-5
   08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
   24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
   03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
   14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                               of removal of NOx-Ox partitioning
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
   14 Jun 2013 - R. Yantosca - Now determine weekday/weekend with respect to
                               the local time at each grid box.  (Formerly,
                               this had been done w/r/t the GMT time).
   13 Aug 2013 - M. Sulprizio- Re-define SPECIES_ID for semivolatile POA (H.Pye
   26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP)
```

1.91.3 emiss_nei2005_anthro_05x0666

Subroutine EMISS_NEI2005_ANTHRO reads the NEI2005 emission fields at 1/2 x 2.3 resolution

INTERFACE:

```
      SUBROUTINE EMISS_NEI2005_ANTHRO_05x0666( am_I_Root, Input_Opt,
     &                                         State_Chm, RC         )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE CMN_O3_MOD
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TIME_MOD,           ONLY : GET_YEAR, GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_05x0666_NESTED
      USE TRACER_MOD,         ONLY : ITS_A_FULLCHEM_SIM
      USE TRACERID_MOD,       ONLY : IDTACET, IDTALK4, IDTC2H6, IDTC3H8
      USE TRACERID_MOD,       ONLY : IDTALD2, IDTCH2O, IDTPRPE, IDTMEK
      USE TRACERID_MOD,       ONLY : IDTNO,   IDTCO,   IDTSO2,  IDTNH3
      ! added POA (jje 8/19/10)
      USE TRACERID_MOD,       ONLY : IDTSO4,  IDTOCPI, IDTBCPI, IDTPOA1
#if defined( DEVEL )
      USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK_LT
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   03 Nov 2009 - A. van Donkelaar - initial version
   12 Jul 2010 - R. Yantosca - Now point to NEI2005_201007 directory, to read
                               in updated files (by Aaron van Donkelaar) to
                               fix a problem in the VOC emissions.
   13 Aug 2010 - R. Yantosca - Treat MERRA like GEOS-5 (leave for future use)
   27 Jul 2011 - R. Yantosca - Fixed typo: now *really* point to the NEI2005
                               data directory NEI2005_101007/
   08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x like MERRA
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
   13 Aug 2013 - M. Sulprizio- Re-define SPECIES_ID for semivolatile POA (H.Pye)
   26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.91.4 get_nei99_season

Subroutine GET_NEI99_SEASON returns monthly scale factors from EPA 1999

INTERFACE:

```
SUBROUTINE GET_NEI99_SEASON( TRACER, AS )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_TAU0,    READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1
USE TIME_MOD,      ONLY : GET_MONTH

USE CMN_SIZE_MOD                         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: TRACER   ! Tracer number
```

INPUT/OUTPUT PARAMETERS:

```
REAL*4,  INTENT(OUT)   :: AS(I1x1,J1x1,5)  ! Scale factor array
```

REVISION HISTORY:

```
30 Oct 2009 - A. van Donkelaar - Initial Version
 3 Nov 2009 - P. Le Sager      - update handling of boxes w/ zero emissions
10 Dec 2009 - D. Millet        - Now scale to August, not an annual average
11 Dec 2009 - L. Zhang, A. van Donkelaar - Add seasonality for NH3
12 Jun 2013 - M. Payer         - Update  NH3 seasonal scaling factors over
                                 the US (L. Zhang)
```

1.91.5 get_nei99_season_05x0666

Subroutine GET_NEI_SEASON returns monthly scale factors from EPA 1999, for the 0.5 x 0.666 nested grids.

INTERFACE:

```
SUBROUTINE GET_NEI99_SEASON_05x0666( TRACER, AS )
```

USES:

```
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)     :: TRACER   ! Tracer number
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*4,  INTENT(INOUT)  :: AS(IIPAR,JJPAR,5)  ! Scale factor array
```

REVISION HISTORY:

```
    30 Oct 2009 - A. van Donkelaar - Initial Version
    13 Mar 2012 - M. Cooper        - Changed regrid algorithm to map_a2a
    07 Jun 2012 - M. Payer         - Fix minor bugs in map_a2a implementation
    24 Aug 2012 - R. Yantosca      - DO_REGRID_A2A now reads netCDF input file
    03 Jan 2013 - M. Payer         - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.91.6 get_vistas_season

Subroutine GET_VISTAS_SEASON returns monthly scale factors to account for monthly variations in NOx emissions on 1x1 resolution grid (amv, 11/02/09)

INTERFACE:

```
      SUBROUTINE GET_VISTAS_SEASON( AS )
```

USES:

```
      USE BPCH2_MOD,         ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,     ONLY : DATA_DIR_1x1
      USE TIME_MOD,          ONLY : GET_MONTH,     GET_YEAR

      USE CMN_SIZE_MOD                          ! Size parameters
      USE CMN_O3_MOD           ! FSCALYR
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*4,  INTENT(INOUT) :: AS(I1x1,J1x1,5)  ! Scale factor array
```

REVISION HISTORY:

```
    30 Oct 2009 - A. van Donkelaar - Initial Version
     3 Nov 2009 - P. Le Sager      - update handling of boxes w/ zero emissions
    10 Dec 2009 - D. Millet        - Now scale to August, not an annual average
```

1.91.7 get_vistas_season_05x0666

Subroutine GET_VISTAS_SEASON_05x0666 returns monthly scale factors to account for monthly variations in NOx emissions for the 0.5 x 0.666 nested grids. (amv, 11/02/09)

INTERFACE:

```
      SUBROUTINE GET_VISTAS_SEASON_05x0666( AS )
```

USES:

```
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1

      USE CMN_SIZE_MOD         ! Size parameters
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*4,  INTENT(INOUT)  :: AS(IIPAR,JJPAR,5)  ! Scale factor array
```

REVISION HISTORY:

```
    03 Nov 2009 - A. van Donkelaar - Initial Version
    13 Mar 2012 - M. Cooper        - Changed regrid algorithm to map_a2a
    07 Jun 2012 - M. Payer         - Fix minor bugs in map_a2a implementation
    24 Aug 2012 - R. Yantosca      - DO_REGRID_A2A now reads netCDF input file
    03 Jan 2013 - M. Payer         - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.91.8 get_nei99_wkscale

Subroutine GET_NEI99_WKSCALE returns the scale factors to convert weekday to weekend emissions based on the NEI99.

INTERFACE:

```
      SUBROUTINE GET_NEI99_WKSCALE( TRACER, AS )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
      USE TIME_MOD,           ONLY : GET_MONTH

      USE CMN_SIZE_MOD                          ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)       :: TRACER   ! Tracer number
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*4,  INTENT(INOUT) :: AS(I1x1,J1x1,5)  ! Scale factor array
```

REVISION HISTORY:

```
    30 Oct 2009 - A. van Donkelaar - Initial Version
     3 Nov 2009 - P. Le Sager - update handling of boxes w/ zero emissions
```

1.91.9 get_nei99_wkscale_05x0666

Subroutine GET_NEI99_WKSCALE_05x0666 returns the scale factors (for 0.5 x 0.666 nested grids) to convert weekday to weekend emissions based on the NEI99.

INTERFACE:

```
SUBROUTINE GET_NEI99_WKSCALE_05x0666( TRACER, AS )
```

USES:

```
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)     :: TRACER   ! Tracer number
```

INPUT/OUTPUT PARAMETERS:

```
REAL*4,  INTENT(INOUT)  :: AS(IIPAR,JJPAR,5)  ! Scale factor array
```

REVISION HISTORY:

```
30 Oct 2009 - A. van Donkelaar - Initial Version
13 Mar 2012 - M. Cooper        - Changed regrid algorithm to map_a2a
07 Jun 2012 - M. Payer         - Fix minor bugs in map_a2a implementation
24 Aug 2012 - R. Yantosca      - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer         - Bug fix for regridding. Changed to
                                 PERAREA=0 since scale factors are unitless.
03 Jan 2013 - M. Payer         - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.91.10 read_nei2005_mask

Subroutine READ_NEI2005_MASK reads the mask for NEI data

INTERFACE:

```
SUBROUTINE READ_NEI2005_MASK
```

USES:

```
! Reference to F90 modules
USE BPCH2_MOD,      ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,      ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE TRANSFER_MOD,   ONLY : TRANSFER_2D

USE CMN_SIZE_MOD         ! Size parameters
```

REMARKS:

```
temporary mask: same as EPA 99
```

REVISION HISTORY:

```
20 Oct 2009 - P. Le Sager - init
26 Oct 2009 - P. Le Sager - new masks
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
15 Aug 2012 - M. Payer    - Fixed minor bugs in regridding of mask; Also
                            set mask to 1 if greater than 0 (L. Murray)
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.91.11 nei2005_scale_future

Subroutine NEI2005_SCALE_FUTURE applies the IPCC future scale factors to the NEI2005 anthropogenic emissions.

INTERFACE:

```
SUBROUTINE NEI2005_SCALE_FUTURE
```

USES:

```
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_COff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NH3an
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_OCff
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_BCff

USE CMN_SIZE_MOD             ! Size parameters
```

REMARKS:

```
VOC are not scaled, however scale factors are available (see
 epa_nei_mod.f for procedure)
```

REVISION HISTORY:

```
 7 Oct 2009 - A. van Donkelaar - initial version
20 Oct 2009 - P. Le Sager - set L OpenMP private, put L loop first
```

1.91.12 total_anthro_Tg

Subroutine TOTAL_ANTHRO_TG prints the totals for the anthropogenic emissions of NOx, CO, SO2 and NH3.

INTERFACE:

```
SUBROUTINE TOTAL_ANTHRO_TG( YEAR )
```

USES:

```
USE CMN_SIZE_MOD            ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: YEAR   ! Year of data to compute totals
```

REVISION HISTORY:

```
 7 Oct 2009 - A. van Donkelaar - initial version
22 Mar 2012 - M. Payer         - Remove print for C2H6 emissions.
14 Mar 2013 - M. Payer         - Replace NOx emissions with NO emissions as
                                 part of removal of NOx-Ox partitioning
```

1.91.13 init_nei2005_anthro

Subroutine INIT_NEI2005_ANTHRO allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_NEI2005_ANTHRO( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
02 Mar 2012 - R. Yantosca - Remove A_CM2 array
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt,  RC
```

1.91.14 cleanup_nei2005_anthro

Subroutine CLEANUP_NEI2005_ANTHRO deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_NEI2005_ANTHRO
```

REVISION HISTORY:

```
01 Mar 2012 - R. Yantosca - Remove reference to A_CM2 array
```

1.92 Fortran: Module Interface olson_landmap_mod

Module OLSON_LANDMAP_MOD reads the Olson land map and computes the IREG, ILAND, and IUSE arrays. This module was written to facilitate Grid-Independent GEOS-Chem development while still keeping backwards compatibility with existing legacy code. It replaces the old routine rdland.F.

INTERFACE:

```
MODULE Olson_LandMap_Mod
```

USES:

```
USE CMN_GCTM_MOD                    ! Physical constants
USE CMN_SIZE_MOD                    ! Size parameters
USE DIRECTORY_MOD                   ! Disk directory paths
USE ERROR_MOD                       ! Error checking routines
USE GRID_MOD                        ! Horizontal grid definition
USE LOGICAL_MOD                     ! Logical switches
USE MAPPING_MOD                     ! Mapping weights & areas

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: Init_Olson_Landmap
PUBLIC  :: Compute_Olson_Landmap
PUBLIC  :: Cleanup_Olson_LandMap
```

REMARKS:

```
The Olson land types are as follows:
============================================================================
 0 Water              25 Deciduous           50 Desert
 1 Urban              26 Deciduous           51 Desert
 2 Shrub              27 Conifer             52 Steppe
 3 ---                28 Dwarf forest        53 Tundra
 4 ---                29 Trop. broadleaf     54 rainforest
```

```
 5 ---                30 Agricultural        55 mixed wood/open
 6 Trop. evergreen    31 Agricultural        56 mixed wood/open
 7 ---                32 Dec. woodland       57 mixed wood/open
 8 Desert             33 Trop. rainforest    58 mixed wood/open
 9 ---                34 ---                 59 mixed wood/open
10 ---                35 ---                 60 conifers
11 ---                36 Rice paddies        61 conifers
12 ---                37 agric               62 conifers
13 ---                38 agric               63 Wooded tundra
14 ---                39 agric.              64 Moor
15 ---                40 shrub/grass         65 coastal
16 Scrub              41 shrub/grass         66 coastal
17 Ice                42 shrub/grass         67 coastal
18 ---                43 shrub/grass         68 coastal
19 ---                44 shrub/grass         69 desert
20 Conifer            45 wetland             70 ice
21 Conifer            46 scrub               71 salt flats
22 Conifer            47 scrub               72 wetland
23 Conifer/Deciduous  48 scrub               73 water
24 Deciduous/Conifer  49 scrub
                                                                              .
                                                                              .
Arrays computed by olson_landmap_mod.F90
================================================================================
(1) IREG   (in CMN_DEP_mod.F): # of Olson land types per G-C grid box
(2) ILAND  (in CMN_DEP_mod.F): List of all Olson land types in G-C grid box
(3) IUSE   (in CMN_DEP_mod.F): Coverage of each Olson type in G-C grid box
(4) IJREG  (in CMN_VEL_mod.F): %%%%% OBSOLETE: NOW REPLACED BY IREG  %%%%%
(5) IJLAND (in CMN_VEL_mod.F): %%%%% OBSOLETE: NOW REPLACED BY ILAND %%%%%
(6) IJUSE  (in CMN_VEL_mod.F): %%%%% OBSOLETE: NOW REPLACED BY IUSE  %%%%%
(7) FRCLND (in CMN_DEP_mod.F): Fraction of G-C grid box that is not water
                                                                              .
NOTES:
(1) IREG,  ILAND,  IUSE  are used by the soil NOx emissions routines
(2) IJREG, IJLAND, IJUSE are used by the drydep routines (legacy code)
(3) FRCLND               is  used by various GEOS-Chem routines
                                                                              .
                                                                              .
BUG IN THE OLD "rdland.F" FOR 2 X 2.5 DEGREE RESOLUTION
================================================================================
This module ("olson_landmap_mod.F") replaces the old routine "rdland.F",
which previously read in the Olson landtype data from the ASCII format
file named "vegtype.global".  There used to be a different "vegtype.global"
file for each different horizontal grid resolution.
                                                                              .
The "vegtype.global" stored the following quantities, such that values
for a single grid box were saved on a single line:
                                                                              .
```

```
  I, J, IREG(I,J), ILAND(I,J,K), IUSE(I,J,K)  (where K=1,IREG(I,J))
```

.

Routine "rdland.F" reads these quantities from "vegtype.global" assuming there were 20 integer characters on a single line (i.e. using Fortran FORMAT '(20i4)'). However, ~ 12 lines of the 2 x 2.5 "vegtype.global" file contained more than 20 integer values. This caused "rdland.F", to read in the values from these lines improperly, which in turn caused the IREG, ILAND, IUSE, IJREG, IJLAND, IJUSE, and FRCLND arrays to be improperly initialized for the grid boxes corresponding to these lines in the "vegtype.global" file.

.

Bob Yantosca has validated that "olson_landmap_mod.F" returns results 100% identical to the "vegtype.global" file. Therefore, if you want to compare the output of model simulations using "olson_landmap_mod.F" the output of simulations using "rdland.F", you will see a slight difference in the MCL lifetime and tracer concentrations.

.

If you need to run a GEOS-Chem simulation with an older version of the code using "rdland.F", then this bug may be corrected by changing the line of code:

.

```
    101  FORMAT(20I4)
```

.

to:

.

```
   #if   defined( GRID2x25 )
    101  FORMAT(25I4)
   #else
    100  FORMAT(20I4)
   #endif
```

.

This is more or less a moot point, as "olson_landmap_mod.F" will be installed into GEOS-Chem v9-01-03 and higher versions.

.

.

NOTE FOR 0.5 x 0.666 grids

==========

As of 21 Mar 2012, the IUSE values computed by "olson_landmap_mod.F90" may slightly differ from those specified in the "vegtype.global" files for 0.5 x 0.666 nested grids. We attribute this to roundoff error caused by the the longitude spacing being an irrational number (0.6666666...). We are still investigating.

REVISION HISTORY:

13 Mar 2012 - R. Yantosca - Initial version
19 Mar 2012 - R. Yantosca - Minor last-minute bug fixes
21 Mar 2012 - R. Yantosca - Now use REAL*4 for computations
22 Mar 2012 - R. Yantosca - Now read surface area from the file

```
22 Mar 2012 - R. Yantosca - Now make lon, lat, OLSON, A_CM2 allocatable
22 Mar 2012 - R. Yantosca - Now define I_OLSON, J_OLSON, N_OLSON, D_LON,
                            and D_LAT in routine Init_Olson_LandMap
27 Mar 2012 - R. Yantosca - Now reference USE_OLSON_2001 from logical_mod.F
02 Apr 2012 - R. Yantosca - Now reference mapping_mod.F90
02 Apr 2012 - R. Yantosca - Moved routine GET_MAP_WT to mapping_mod.F90
02 Apr 2012 - R. Yantosca - Now Save mapping info for later use
09 Apr 2012 - R. Yantosca - Removed IJREG, IJUSE, IJLAND; these are now
                            replaced by IREG, IUSE, ILAND arrays
09 Apr 2012 - R. Yantosca - Removed reference to CMN_VEL_mod.F
```

1.92.1 compute_olson_landmap

Subroutine COMPUTE_OLSON_LANDMAP computes the GEOS-Chem arrays IREG, ILAND, IUSE (and corresponding 1-D arrays IJREG, IJLAND, IJUSE) on-the-fly from the Olson Land map file. This routine, which is intended to facilitate the Grid-Independent GEOS-Chem, replaces the old rdland.F, which read from pre-computed "vegtype.global" files.

INTERFACE:

```
SUBROUTINE Compute_Olson_LandMap( am_I_Root, mapping, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
LOGICAL,         INTENT(IN)    :: am_I_Root    ! Are we on the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MapWeight), POINTER       :: mapping(:,:) ! "fine" -> "coarse" mapping
TYPE(MetState),  INTENT(INOUT) :: State_Met    ! Meteorology State object
```

REMARKS:

```
This routine supplies arrays that are required for legacy code routines:
(1) IREG,  ILAND,  IUSE are used by the Soil NOx routines
(2) IJREG, IJLAND, IJUSE are used by the dry deposition routines
```

REVISION HISTORY:

```
13 Mar 2012 - R. Yantosca - Initial version
19 Mar 2012 - R. Yantosca - Reorder ILAND, IUSE, IJLAND, IJUSE to be
                            consistent w/ the leaf area indices
19 Mar 2012 - R. Yantosca - Compute the FRCLND array (from CMN_DEP_mod.F)
21 Mar 2012 - R. Yantosca - Now use REAL*4 for computation, to reduce
                            roundoff errors at high-resolution
22 Mar 2012 - R. Yantosca - Now get surface area directly from variable
```

```
                              A_CM2 (read from disk) instead of computing it
    02 Apr 2012 - R. Yantosca - Now pass MAP (mapping weight object) via the
                              arg list, to save the mapping info for later
    09 Apr 2012 - R. Yantosca - Remove IJLOOP variable
    09 Apr 2012 - R. Yantosca - Now do not compute IJREG, IJLAND, IJUSE; these
                              are replaced by IREG, ILAND, IUSE arrays
    17 Apr 2012 - R. Yantosca - Rename "map" object to "mapping" to avoid name
                              confusion with an F90 intrinsic function
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                              derived type object
    29 Nov 2012 - R. Yantosca - Added am_I_Root argument
    12 Dec 2012 - R. Yantosca - Now get IREG, ILAND, IUSE from State_Met
```

1.92.2 init_olson_landmap

Subroutine INIT_OLSON_LANDMAP reads Olson land map information from disk (in netCDF format).

INTERFACE:

```
   SUBROUTINE Init_Olson_LandMap( am_I_Root, DATA_DIR_1x1 )
```

USES:

```
     USE m_netcdf_io_open
     USE m_netcdf_io_read
     USE m_netcdf_io_readattr
     USE m_netcdf_io_close

     IMPLICIT NONE

 #   include "netcdf.inc"
```

INPUT PARAMETERS:

```
     LOGICAL,            INTENT(IN) :: am_I_Root
     CHARACTER(LEN=255), INTENT(IN) :: DATA_DIR_1x1
```

REMARKS:

```
    Assumes that you have:
    (1) A netCDF library (either v3 or v4) installed on your system
    (2) The NcdfUtilities package (from Bob Yantosca) source code
```

REVISION HISTORY:

```
    13 Mar 2012 - R. Yantosca - Initial version
    22 Mar 2012 - R. Yantosca - Also read in surface areas [m2] from file
    27 Mar 2012 - R. Yantosca - Now read the "units" attribute of each variable
    27 Mar 2012 - R. Yantosca - Now echo file I/O status info to stdout
```

```
27 Mar 2012 - R. Yantosca - Now can read Olson 1992 or Olson 2001 land map
29 Nov 2012 - R. Yantosca - Add am_I_Root to the argument list
26 Feb 2013 - M. Long     - Now pass DATA_DIR_1x1 via the argument list
```

1.92.3 cleanup_olson_landmap

Subroutine CLEANUP_OLSON_LANDMAP deallocates all allocated global module variables.

INTERFACE:

```
SUBROUTINE Cleanup_Olson_LandMap( am_I_Root )
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN) :: am_I_Root   ! Are we on the root CPU?
```

REVISION HISTORY:

```
22 Mar 2012 - R. Yantosca - Initial version
29 Nov 2012 - R. Yantosca - Add am_I_Root as an argument
```

1.93 Fortran: Module Interface optdepth_mod

Module OPTDEPTH_MOD contains routines to return optical depths and update the ND21 diagnostic.

INTERFACE:

```
MODULE OPTDEPTH_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
INTERFACE OPTDEPTH
   MODULE PROCEDURE OD_GEOS3_GEOS4
END INTERFACE

PUBLIC  :: OPTDEPTH
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: OD_GEOS3_GEOS4
```

REVISION HISTORY:

```
15 Aug 2001 - R. Yantosca - Initial version
(1 ) Now add parallel DO-loops (bmy, 8/15/01)
(2 ) Removed obsolete code from 9/01 (bmy, 10/24/01)
(3 ) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
     MODULE ROUTINES sections.  Also add MODULE INTERFACES section,
     since we have an interface here. (bmy, 5/28/02)
(4 ) Renamed OD_GEOS2_GEOS_3 to OD_GEOS3_GEOS4.  (bmy, 4/20/05)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
14 Sep 2010 - R. Yantosca - Added ProTeX headers
27 Nov 2012 - R. Yantosca - Added updates for GIGC
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.93.1 od_geos3_geos4

Subroutine OD_GEOS3_GEOS4 copies the DAO grid box optical depth from the OPTDEP met field array into the OPTD array. Diagnostics are also archived.

INTERFACE:

```
SUBROUTINE OD_GEOS3_GEOS4( am_I_Root, Input_Opt, State_Met, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY: AD21
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%  NOTE: This routine is somewhat obsolete now.  It would be better  %%%
%%%  to save the values into State_Met%OPTD in the routines that read  %%%
%%%  the met fields from disk.  Keep as-is for now for compatibility   %%%
%%%  with existing code. (bmy, 11/27/12)
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
.

The optical depths in the GEOS-5 met field archives are in-cloud optical
depths instead of grid-box optical depths (as was reported in the file
specification documents erroneously).
.

Also, the name "OD_GEOS3_GEOS4" is historical.  Once upon a time this was
used to denote the difference between the optical depths in GEOS-3 and
GEOS-4 (which come directly from the met fields) and GEOS-1 and GEOS-STRAT
(which were computed as functions of temperature).  The GEOS-5 and MERRA
optical depths are also provided in the met field archive, so the
algorithms in this routine are also equally applicable.
Original comments from the code:
  GEOS-3/GEOS-4 optical depth is stored in the OPTDEP array,
  which is read in routine "read_a6" of "dao_read_mod.f".
.

  OPTDEP is archived every 6 hours, nevertheless, each chemistry
  timestep we copy this into the OPTD array and archive for the
  ND21 diagnostic.  This way the ND21 diagnostic is consistent
  with GEOS-1/GEOS-STRAT.
.

  OPTDEP and OPTD are dimensioned (LLPAR,IIPAR,JJPAR) to maximize
  loop efficiency for processing an (I,J) column layer by layer.
.

  Now also save CLDTOT to the ND21 diagnostic (bmy, 4/20/05)
```

REVISION HISTORY:

```
15 Aug 2001 - R. Yantosca - Initial version
(1 ) Now parallelize I-J DO loops (bmy, 8/15/01)
(2 ) Renamed to OD_GEOS3_GEOS4.  Also now saves CLDF in AD21(I,J,L,2)
      for the ND21 diagnostic (bmy, 4/20/05)
14 Sep 2010 - R. Yantosca - Added ProTeX headers
27 Nov 2012 - R. Yantosca - Now pass am_I_Root, Input_Opt and State_Met args
```

1.94 Fortran: Module Interface paranox_mod

Module PARANOX_MOD contains subroutines for reading and interpolating look up tables necessary for the PARANOX (PARAmeterization of emitted NOX) ship plume model developed by G.C.M. Vinken.

INTERFACE:

```
MODULE PARANOX_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN
```

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: READ_PARANOX_LUT
 ###############################################
  Prior to 5/31/13:
  Comment out, this is not used (bmy, 5/31/13)
       PUBLIC  :: INTERPOLATE_LUT
 ###############################################
      PUBLIC  :: INTERPOLATE_LUT2
  !MODULE VARIABLES
      ! fracnox                 = look up table for fraction of NOx remaining
      !                           for ship emissions (gvinken, 6/6/10)
      ! intope                  = look up table for integrated Ozone Production
      !                           Efficiency for ship emiss (gvinken, 6/6/10)
      REAL*4 ::   fracnox(4,4,4,12,12,4,5)
      REAL*4 ::   intope(4,4,4,12,12,4,5)
  !REMARKS
   References:
   ============================================================================
   (1 ) Vinken, G.C.M., Boersma, K.F., Jacob, D.J., and Meijer, E.W.:
        Accounting for non-linear chemistry of ship plumes in the GEOS-Chem
        global chemistry transport model, Atmos. Chem. Phys., 11, 11707-11722,
        doi:10.5194/acp-11-11707-2011, 2011.
```

REVISION HISTORY:

```
   06 Feb 2012 - M. Payer    - Initial version
   01 Mar 2012 - R. Yantosca - Use updated GET_LOCALTIME from time_mod.F
   03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

1.94.1 read_paranox_lut

Subroutine READ_PARANOX_LUT reads look up tables for use in the PARANOX ship plume model (G.C.M. Vinken)

INTERFACE:

```
      SUBROUTINE READ_PARANOX_LUT
```

USES:

```
      USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1
      USE FILE_MOD,      ONLY : IOERROR
```

REVISION HISTORY:

```
06 Feb 2012 - M. Payer    - Initial version modified from code provided by
                            G.C.M. Vinken
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
```

1.94.2 interpolate_lut2

Subroutine INTERPOLATE_LUT2 returns FracNOx or IntOPE from the lookup tables (G.C.M. Vinken, KNMI, June 2010)

INTERFACE:

```
SUBROUTINE INTERPOLATE_LUT2( I, J, o3, no, no2, dens, JO1D, JNO2,
&                            fraction_nox, int_ope, State_Met )
```

USES:

```
USE TIME_MOD,           ONLY : GET_LOCALTIME
USE ERROR_MOD,          ONLY : ERROR_STOP
USE ERROR_MOD,          ONLY : SAFE_DIV
USE GIGC_State_Met_Mod, ONLY : MetState
USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I, J
REAL*8,         INTENT(IN)  :: o3, no, no2, dens, JNO2, JO1D
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
REAL*4,         INTENT(OUT) :: fraction_nox, int_ope
```

REVISION HISTORY:

```
   Jun 2010 - G.C.M. Vinken - Initial version
21 Feb 2011 - G.C.M. Vinken - Updated for NOx in LUT
06 Feb 2012 - M. Payer      - Moved from emissions_mod.F to paranox_mod.F;
                              Added ProTeX headers
15 Feb 2012 - M. Payer      - Add error trap to ensure 0 < fracnox < 1.
09 Nov 2012 - M. Payer      - Replaced all met field arrays with State_Met
                              derived type object
28 Nov 2012 - R. Yantosca   - Replace SUNCOS_MID w/ State_Met%SUNCOSmid
28 Nov 2012 - R. Yantosca   - Replace SUNCOS_MID_5hr w/ State_Met%SUNCOSmid5
17 Jun 2013 - R. Yantosca   - Bug fix: declare all REAL variables with
                              REAL*4 in order to avoid numerical precision
                              errors when compiling with OMP=yes.
23 Aug 2013 - R. Yantosca   - Avoid numerical instability when computing
                              the ratio JO1D/JNO2.  J-values go to zero
                              at night, which can lead to a div-by-zero.
```

1.95 Fortran: Module Interface pbl_mix_mod

Module PBL_MIX_MOD contains routines and variables used to compute the planetary boundary layer (PBL) height and to mix tracers underneath the PBL top.

INTERFACE:

```
      MODULE PBL_MIX_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: CLEANUP_PBL_MIX
      PUBLIC  :: DO_PBL_MIX
      PUBLIC  :: GET_FRAC_OF_PBL
      PUBLIC  :: GET_FRAC_UNDER_PBLTOP
      PUBLIC  :: GET_PBL_MAX_L
      PUBLIC  :: GET_PBL_TOP_hPa
      PUBLIC  :: GET_PBL_TOP_L
      PUBLIC  :: GET_PBL_TOP_m
      PUBLIC  :: GET_PBL_THICK
      PUBLIC  :: INIT_PBL_MIX
      PUBLIC  :: COMPUTE_PBL_HEIGHT

#if defined ( DEVEL )
      PUBLIC :: PBL_TOP_L, PBL_TOP_m
#endif
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: TURBDAY
```

REVISION HISTORY:

```
   11 Feb 2005 - R. Yantosca - Initial version
   (1 ) Now modified for GCAP and GEOS-5 met fields (bmy, 5/24/05)
   (2 ) Remove reference to "CMN" and XTRA2. (bmy, 8/30/05)
   (3 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
   (4 ) Add INIT_PBL_MIX and COMPUTE_PBL_HEIGHT as PUBLIC routines
        (lin, 5/29/09)
   (5 ) Extend tracers for APM simulation (GanLuo, 2010)
   28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
   28 Feb 2012 - R. Yantosca - Added ProTeX headers
   01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
   20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.95.1 do_pbl_mix

Subroutine DO_PBL_MIX is the driver routine for planetary boundary layer mixing. The PBL layer height and related quantities are always computed. Complete mixing of tracers underneath the PBL top is toggled by the DO_TURBDAY switch.

INTERFACE:

```
      SUBROUTINE DO_PBL_MIX( DO_TURBDAY, Input_Opt,
     &                       State_Met,  State_Chm  )
```

USES:

```
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GIGC_State_Chm_Mod, ONLY : ChmState
#if   defined( APM )
      USE TRACER_MOD,         ONLY : N_APMTRA
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: DO_TURBDAY  ! =T means call TURBDAY
                                                   !    for full PBL mixing
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
   11 Feb 2005 - R. Yantosca - Initial version
   07 Sep 2011 - G. Luo      - Add modifications for APM
   28 Feb 2012 - R. Yantosca - Added ProTeX headers
   25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.95.2 compute_pbl_height

Subroutine COMPUTE_PBL_HEIGHT computes the PBL height and other related quantities.

INTERFACE:

```
      SUBROUTINE COMPUTE_PBL_HEIGHT( State_Met )
```

USES:

```
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PRESSURE_MOD,       ONLY : GET_PEDGE

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_GCTM_MOD             ! Scale height
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
(1 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(2 ) Remove reference to "CMN" and XTRA2 -- they're obsolete.  Also do not
     force BLTOP, BLTHIK to minimum values for GEOS-STRAT met fields.
     (bmy, 8/30/05)
(3 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
28 Feb 2012 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.95.3 turbday

! Subroutine TURBDAY executes the GEOS-Chem boundary layer mixing algorithm (full PBL mixing).

INTERFACE:

```
SUBROUTINE TURBDAY( NTRC, TC, TCVV, State_Met )
```

USES:

```
USE DIAG_MOD,           ONLY : TURBFLUP
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_TS_CONV

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_DIAG_MOD             ! ND15
```

INPUT PARAMETERS:

```
! Number of tracers used in computation
INTEGER,        INTENT(IN)    :: NTRC

! MW air (g/mol) / MW tracer (g/mol)     [ unitless ]
REAL*8,         INTENT(IN)    :: TCVV(NTRC)

! Meteorology State object
TYPE(MetState), INTENT(IN)    :: State_Met
```

INPUT/OUTPUT PARAMETERS:

```
! Tracer concentration [v/v]
REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR,NTRC)
```

REMARKS:

```
Original subroutine by Dale Allen, Univ of MD.
```

REVISION HISTORY:

```
30 Jan 1998 - I. Bey, R. Yantosca - Initial version
(1 ) TURBDAY is written in Fixed-Form Fortran 90.  Also use F90
      syntax for declarations (bmy, 4/1/99).
(2 ) New tracer concentrations are returned in TC.
(3 ) PS(I,J) is ACTUAL surface pressure and not Psurface - PTOP
(4 ) Change in tracer in kg is now stored in DTC(I,J,L,N).  This makes
      it easier to compute diagnostic quantities.  The new mixing ratio
      is computed as TC(I,J,L,N) = TC(I,J,L,N) + DTC(I,J,L,N) / AD(I,J,L).
(5 ) XTRA2(*,*,5) is the height of the PBL in # of layers.  So if the
      PBL top is located in the middle of the 3rd sigma layer at (I,J)
      the value of XTRA2(I,J,5) would be 2.5.  The XTRA2 variable is
      used by the HCTM drydep subroutines...it really is a historical
      holdover.
(6 ) Restore the following NDxx diagnostics: (a) ND63 : Mass balance
      (CNVUPP) (b) ND15 : Mass change due to mixing in the boundary layer
(7 ) Now pass TCVV and NCONV for the mass flux diagnostics.  Also
      updated comments and cleaned up a few things. (bey, bmy, 11/10/99)
(8 ) Remove PTOP and XNUMOL from the arg list.  PTOP is now a parameter
      in "CMN_SIZE".  XNUMOL is no longer used in TURBDAY. (bmy, 2/10/00)
(9 ) Also removed obsolete ND63 diagnostics and updated comments.
      (bmy, 4/12/00)
(10) Now use NTRC instead of NNPAR to dimension variables TC, TCVV, DTC,
      and DTCSUM (bmy, 10/17/00).
(11) Removed obsolete code from 10/17/00 (bmy, 12/21/00)
(12) If the PBL depth is very small (or zero), then assume a PBL depth
      of 2 mb -- this prevents NaN's from propagating throughout the
      code.  Also updated comments & made cosmetic changes. (bmy, 3/9/01)
(13) DTCSUM was declared twice but wasn't used.  Elminate declarations
      to DTCSUM. (bmy, 7/16/01)
(14) XTRA2(IREF,JREF,5) is now XTRA2(I,J).  Also updated comments.
      Also remove IREF, JREF and some debug output. (bmy, 9/25/01)
(15) Removed obsolete commented out code from 9/01 (bmy, 10/24/01)
(16) Now takes in P=PS-PTOP instead of PS.  Redimension SIGE to
      (1:LLPAR+1).
(17) Renamed PS to PZ so as not to conflict w/ the existing P variable.
      Now pass P-PTOP thru PZ, in order to ensure that P and AD are
      consistent w/ each other.  Added parallel DO-loops. Updated comments,
      cosmetic changes.  Now print a header to stdout on the first call,
      to confirm that TURBDAY has been called. (bmy, 4/11/02)
(18) Now use GET_PEDGE from "pressure_mod.f" to compute the pressure
      at the bottom edge of grid box (I,J,L).  Deleted obsolete code from
      4/02.  Removed PZ, SIGE from the argument list, since we now compute
      pressure from GET_PEDGE. (dsa, bdf, bmy, 8/22/02)
```

```
(19) Now reference AD, PBL from "dao_mod.f".  Now removed DXYP from the
     arg list, use GET_AREA_M2 from "grid_mod.f" instead.  Now removed
     NCONV, ALPHA_d, ALPHA_n from the arg list.  Now no longer reference
     SUNCOS.  Now set A(:,:)=1 day & nite; we assume full mixing all the
     time regardless of SUNCOS.  Updated comments, cosmetic changes.
     (bmy, 2/11/03)
(20) Now can handle PBL field in meters for GEOS-4/fvDAS.  Also the
     atmospheric scale height from CMN_GCTM. (bmy, 6/23/03)
(21) Now bundled into "pbl_mix_mod.f".  Broke off the part which computes
     PBL height and related quantities into COMPUTE_PBL_HEIGHT.
     (bmy, 2/15/05)
28 Feb 2012 - R. Yantosca - Added ProTeX headers
 2 Mar 2012 - R. Yantosca - Remove reference to GET_AREA_M2
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.95.4 get_frac_of_pbl

Function GET_FRAC_OF_PBL returns the fraction of grid box (I,J,L) that lies within the planetary boundary layer.

INTERFACE:

```
FUNCTION GET_FRAC_OF_PBL( I, J, L ) RESULT( FRAC )
```

USES:

```
USE CMN_SIZE_MOD   ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L    ! Lon, lat, lev indices
```

RETURN VALUE:

```
REAL*8              :: FRAC       ! Fraction of box (I,J,L) in the PBL
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.95.5 get_frac_under_pbltop

Function GET_FRAC_UNDER_PBLTOP returns the fraction of grid box (I,J,L) that lies underneath the planetary boundary layer top.

INTERFACE:

```
FUNCTION GET_FRAC_UNDER_PBLTOP( I, J, L ) RESULT( FRAC )
```

USES:

```
USE CMN_SIZE_MOD                ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L   ! Lon, lat, level indices
```

RETURN VALUE:

```
REAL*8              :: FRAC      ! Fraction of box (I,J,L) below PBL top
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.95.6 get_pbl_max_l

Function GET_PBL_MAX_L returns the model level at the highest part of the planetary boundary layer.

INTERFACE:

```
FUNCTION GET_PBL_MAX_L() RESULT( TOP )
```

RETURN VALUE:

```
INTEGER  :: TOP   ! Highest extent of PBL [model levels]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.95.7 get_pbl_top_hpa

Function GET_PBL_TOP_hPa returns the planetary boundary layer top [hPa] at a given GEOS-Chem surface location (I,J).

INTERFACE:

```
FUNCTION GET_PBL_TOP_hPa( I, J ) RESULT( TOP )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J   ! Lon and lat indices
```

RETURN VALUE:

```
REAL*8              :: TOP    ! PBL top [hPa]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.95.8 get_pbl_top_l

Function GET_PBL_TOP_L returns the planetary boundary layer top [model levels] at a given GEOS-Chem surface location (I,J).

INTERFACE:

```
FUNCTION GET_PBL_TOP_L( I, J ) RESULT( TOP )
```

USES:

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J   ! Lon and lat indices
```

RETURN VALUE:

```
REAL*8              :: TOP    ! PBL top [model levels]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.95.9 get_pbl_top_m

Function GET_PBL_TOP_m returns the planetary boundary layer top [m] at a given GEOS-CHEM surface location (I,J).

INTERFACE:

```
FUNCTION GET_PBL_TOP_m( I, J ) RESULT( TOP )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J   ! Lon and lat indices
```

RETURN VALUE:

```
REAL*8              :: TOP    ! PBL top [m]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.95.10

Function GET_PBL_THICK returns the thickness of the PBL at a given surface location (I,J).

INTERFACE:

```
FUNCTION GET_PBL_THICK( I, J ) RESULT( THICK )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J    ! Lon and lat indices
```

RETURN VALUE:

```
REAL*8              :: THICK   ! PBL thickness [hPa]
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.95.11 init_pbl_mix

Subroutine INIT_PBL_MIX allocates and zeroes module arrays

INTERFACE:

```
SUBROUTINE INIT_PBL_MIX
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR
USE CMN_SIZE_MOD
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.95.12 cleanup_pbl_mix

Subroutine CLEANUP_PBL_MIX allocates and zeroes module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_PBL_MIX
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
28 Feb 2012 - R. Yantosca - Added ProTeX headers
```

1.96 Fortran: Module Interface Pjc_Pfix_Mod

Module Pjc_Pfix_Mod contains routines which implements the Philip Cameron-Smith pressure fixer for the new fvDAS transport scheme. (bdf, bmy, 5/8/03, 10/27/03)

INTERFACE:

```
MODULE Pjc_Pfix_Mod
```

USES:

```
IMPLICIT NONE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: Do_Pjc_Pfix
PUBLIC  :: Cleanup_Pjc_Pfix
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: Calc_Pressure
PRIVATE :: Calc_Advection_Factors
PRIVATE :: Adjust_Press
PRIVATE :: Init_Press_Fix
PRIVATE :: Do_Press_Fix_LLNL
PRIVATE :: Average_Press_Poles
PRIVATE :: Convert_Winds
PRIVATE :: Calc_Horiz_Mass_Flux
PRIVATE :: Calc_Divergence
PRIVATE :: Set_Press_Terms
PRIVATE :: Do_Divergence_Pole_Sum
PRIVATE :: Xpavg
PRIVATE :: Init_Pjc_Pfix
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
Brendan Field and Bob Yantosca (5/8/03)
Modified for new GMI TPCORE by Claire Carouge (ccarouge@seas.harvard.edu)
```

REVISION HISTORY:

```
(1 ) Bug fix for Linux/PGI compiler in routines ADJUST_PRESS and
     INIT_PRESS_FIX. (bmy, 6/23/03)
(2 ) Now make P1, P2 true surface pressure in DO_PJC_PFIX (bmy, 10/27/03)
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.96.1 Do_Pjc_Pfix

Subroutine Do_Pjc_Pfix is the driver routine for the Philip Cameron-Smith pressure fixer for the fvDAS transport scheme. (bdf, bmy, 5/8/03, 3/5/07)

We assume that the winds are on the A-GRID, since this is the input that the fvDAS transport scheme takes. (bdf, bmy, 5/8/03)

INTERFACE:

```
      SUBROUTINE Do_Pjc_Pfix( D_DYN, P1, P2, UWND, VWND, XMASS, YMASS )
```

USES:

```
      USE CMN_SIZE_MOD    ! Size parameters
      USE CMN_GCTM_MOD    ! Physical constants
```

INPUT PARAMETERS:

```
      ! Dynamic timestep [s]
      REAL*8,  INTENT(IN)  :: D_DYN

 ------------------------------------------------------------------------------
  Prior to 11/4/13:
  Eliminate array temporaries by accepting assumed-shape arguments into this
  routine. (mpayer, 11/4/13)
       ! True PSurface at middle of dynamic timestep [hPa]
       REAL*8,  INTENT(IN)  :: P1(IIPAR,JJPAR)
       ! True PSurface at end    of dynamic timestep [hPa]
       REAL*8,  INTENT(IN)  :: P2(IIPAR,JJPAR)
 ------------------------------------------------------------------------------
      ! True PSurface at middle of dynamic timestep [hPa]
      REAL*8,  INTENT(IN)  :: P1(:,:)

      ! True PSurface at end    of dynamic timestep [hPa]
      REAL*8,  INTENT(IN)  :: P2(:,:)

      ! Zonal (E-W) wind [m/s]
      REAL*8,  INTENT(IN)  :: UWND(IIPAR,JJPAR,LLPAR)

      ! Meridional (N-S) wind [m/s]
      REAL*8,  INTENT(IN)  :: VWND(IIPAR,JJPAR,LLPAR)
```

OUTPUT PARAMETERS:

```
      ! E-W mass fluxes [mixing ratio]
      REAL*8,  INTENT(OUT) :: XMASS(IIPAR,JJPAR,LLPAR)

      ! N-S mass fluxes [mixing ratio]
      REAL*8,  INTENT(OUT) :: YMASS(IIPAR,JJPAR,LLPAR)
```

AUTHOR:

```
Brendan Field and Bob Yantosca (5/8/03)
```

REMARKS:

```
(1 ) Now P1 and P2 are "true" surface pressures, and not PS-PTOP.  If using
     this P-fixer w/ GEOS-3 winds, pass true surface pressure to this
     routine. (bmy, 10/27/03)
(2 ) Now define P2_TMP array for passing to ADJUST_PRESS (yxw, bmy, 3/5/07)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
04 Nov 2013 - M. Sulprizio- Eliminate array temporaries by accepting assumed-
                            shape dummy arguments
```

1.96.2 Calc_Pressure

Subroutine Calc_Pressure recalculates the new surface pressure from the adjusted air masses XMASS and YMASS. This is useful for debugging purposes. (bdf, bmy, 5/8/03)

INTERFACE:

```
SUBROUTINE Calc_Pressure( XMASS, YMASS, RGW_FV, PS_NOW, PS_AFTER )
```

USES:

```
USE CMN_SIZE_MOD  ! Size parameters
USE CMN_MOD       ! NTRACE, LPRT, LWINDO
```

INPUT PARAMETERS:

```
! E-W mass flux from pressure fixer
REAL*8, INTENT(IN)  :: XMASS(IIPAR,JJPAR,LLPAR)

! N-S mass flux from pressure fixer
REAL*8, INTENT(IN)  :: YMASS(IIPAR,JJPAR,LLPAR)

! Surface pressure - PTOP at current time
REAL*8, INTENT(IN)  :: PS_NOW(IIPAR,JJPAR)

! 1 / ( SINE(J+1) - SINE(J) ) -- latitude factor
REAL*8, INTENT(IN)  :: RGW_FV(JJPAR)
```

OUTPUT PARAMETERS:

```
! Surface pressure - PTOP adjusted by P-fixer
REAL*8, INTENT(OUT) :: PS_AFTER(IIPAR,JJPAR)
```

AUTHOR:

```
Brendan Field and Bob Yantosca (5/8/03)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.96.3 Calc_Advection_Factors

Subroutine Calc_Advection_Factors calculates the relative area of each grid box, and the geometrical factors used by this modified version of TPCORE. These geomoetrical DO assume that the space is regularly gridded, but do not assume any link between the surface area and the linear dimensions.

INTERFACE:

```
      SUBROUTINE Calc_Advection_Factors
     &  (mcor, rel_area, geofac, geofac_pc)
```

USES:

```
      USE CMN_SIZE_MOD   ! Size parameters
      USE CMN_GCTM_MOD   ! Physical constants
```

INPUT PARAMETERS:

```
      ! Area of grid box (m^2)
      REAL*8, INTENT(IN)  :: mcor(i1_gl :i2_gl, ju1_gl:j2_gl)
```

OUTPUT PARAMETERS:

```
      ! relative surface area of grid box (fraction)
      REAL*8, INTENT(OUT) :: rel_area(i1_gl :i2_gl, ju1_gl:j2_gl)

      ! Geometrical factor for meridional advection; geofac uses
      ! correct spherical geometry, and replaces acosp as the
      ! meridional geometrical factor in tpcore
      REAL*8, INTENT(OUT) :: geofac(ju1_gl:j2_gl)

      ! Special geometrical factor (geofac) for Polar cap
      REAL*8, INTENT(OUT) :: geofac_pc
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REMARKS:

```
Now reference PI from "CMN_GCTM" for consistency.  Also force
double-precision with the "D" exponent. (bmy, 5/6/03)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.96.4 Adjust_Press

Subroutine Adjust_Press initializes and calls the pressure fixer code.

INTERFACE:

```
      SUBROUTINE Adjust_Press
     &  (metdata_name_org, do_timinterp_winds, new_met_rec,
     &   met_grid_type, advec_consrv_opt, pmet2_opt, press_fix_opt,
     &   tdt, geofac_pc, geofac, cose, cosp, rel_area, dap, dbk,
     &   pctm1, pctm2, pmet2, uu, vv, xmass, ymass)
```

INPUT PARAMETERS:

```
      ! First  part of metdata_name, e.g., "NCAR"
      CHARACTER(LEN=*) :: metdata_name_org

      ! Time interpolate wind fields?
      LOGICAL :: do_timinterp_winds

      ! New met record?
      LOGICAL :: new_met_rec

      ! Met grid type, A or C
      INTEGER :: met_grid_type

      ! Advection_conserve option
      INTEGER :: advec_consrv_opt

      ! pmet2 option
      INTEGER :: pmet2_opt

      ! pressure fixer option
      INTEGER :: press_fix_opt

      ! Model time step [s]
      REAL*8  :: tdt

      ! Special geometrical factor (geofac) for Polar cap
      REAL*8  :: geofac_pc

      ! Geometrical factor for meridional advection; geofac uses
      ! correct spherical geometry, and replaces acosp as the
```

```
! meridional geometrical factor in tpcore
REAL*8  :: geofac  (ju1_gl:j2_gl)

! Cosines of grid box edges and centers
REAL*8  :: cose    (ju1_gl:j2_gl)
REAL*8  :: cosp    (ju1_gl:j2_gl)

! Pressure difference across layer from (ai * pt) term [hPa]
REAL*8  :: dap     (k1:k2)

! Difference in bi across layer - the dSigma term
REAL*8  :: dbk     (k1:k2)

! Relative surface area of grid box (fraction)
REAL*8  :: rel_area( i1_gl:i2_gl,   ju1_gl:j2_gl)

! Metfield surface pressure at t1+tdt [hPa]
REAL*8  :: pmet2(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! CTM surface pressure at t1 [hPa]
REAL*8  :: pctm1(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! CTM surface pressure at t1+tdt [hPa]
REAL*8  :: pctm2(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! Wind velocity, x direction at t1+tdt/2 [m/s]
REAL*8  :: uu(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Wind velocity, y direction at t1+tdt/2 [m/s]
REAL*8  :: vv(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)
```

INPUT/OUTPUT PARAMETERS:

```
! Horizontal mass flux in E-W direction [hPa]
REAL*8  :: xmass(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Horizontal mass flux in N-S direction [hPa]
REAL*8  :: ymass(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)
```

AUTHOR:

Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)

REVISION HISTORY:

02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
Declare all REAL variables as REAL*8.

1.96.5 Init_Press_Fix

Subroutine Init_Press_Fix initializes the pressure fixer.

INTERFACE:

```
 SUBROUTINE Init_Press_Fix
&  (metdata_name_org, met_grid_type, tdt, geofac_pc, geofac,
&   cose, cosp, dap, dbk, dps, dps_ctm, rel_area, pctm1, pmet2,
&   uu, vv, xmass, ymass)
```

INPUT PARAMETERS:

```
 ! Model Time step [s]
 REAL*8 :: tdt

 ! First part of metdata_name, e.g., "NCAR"
 CHARACTER(LEN=*) :: metdata_name_org

 ! Met grid type, A or C
 INTEGER          :: met_grid_type

 ! Special geometrical factor (geofac) for Polar cap
 REAL*8           :: geofac_pc

 ! Cosine of grid box edges and centers
 REAL*8           :: cose(ju1_gl:j2_gl)
 REAL*8           :: cosp(ju1_gl:j2_gl)

 ! Geometrical factor for meridional advection; geofac uses
 ! correct spherical geometry, and replaces acosp as the
 ! meridional geometrical factor in tpcore
 REAL*8           :: geofac(ju1_gl:j2_gl)

 ! Pressure difference across layer from (ai * pt) term [hPa]
 REAL*8           :: dap(k1:k2)

 ! Difference in bi across layer - the dSigma term
 REAL*8           :: dbk(k1:k2)

 ! relative surface area of grid box (fraction)
 REAL*8           :: rel_area( i1_gl:i2_gl, ju1_gl:j2_gl)

 ! Metfield surface pressure at t1 [hPa]
 REAL*8           :: pmet2(ilo_gl:ihi_gl, julo_gl:jhi_gl)

 ! CTM surface pressure at t1 [hPa]
 REAL*8           :: pctm1(ilo_gl:ihi_gl, julo_gl:jhi_gl)

 ! CTM surface pressure at t1+tdt [hPa]
```

```
REAL*8           :: pctm2(ilo_gl:ihi_gl, julo_gl:jhi_gl)

! Wind velocity, x direction at t1+tdt/2 [m/s]
REAL*8           :: uu(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Wind velocity, y direction at t1+tdt/2 [m/s]
REAL*8           :: vv(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)
```

OUTPUT PARAMETERS:

```
! Horizontal mass flux in E-W direction [hPa]
REAL*8  :: xmass(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Horizontal mass flux in N-S direction [hPa]
REAL*8  :: ymass(ilo_gl:ihi_gl, julo_gl:jhi_gl, k1_gl:k2_gl)

! Change of surface pressure from met field pressure [hPa]
REAL*8  :: dps(i1_gl:i2_gl, ju1_gl:j2_gl)

! CTM surface pressure tendency [hPa]
REAL*8  :: dps_ctm(i1_gl:i2_gl, ju1_gl:j2_gl)
```

AUTHOR:

Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.96.6 Do_Press_Fix_Llnl

Subroutine Do_Press_Fix_Llnl fixes the mass fluxes to match the met field pressure tendency.

INTERFACE:

```
 SUBROUTINE Do_Press_Fix_Llnl
&  (geofac_pc, geofac, dbk, dps, dps_ctm, rel_area,
&   xmass, ymass, xmass_fixed, ymass_fixed)
```

INPUT PARAMETERS:

```
! Special geometrical factor (geofac) for Polar cap
REAL*8, INTENT(IN)   :: geofac_pc

! Geometrical factor for meridional advection; geofac uses
! correct spherical geometry, and replaces acosp as the
!  meridional geometrical factor in tpcore
```

```
      REAL*8, INTENT(IN)   :: geofac(ju1_gl:j2_gl)

      ! Difference in bi across layer - the dSigma term
      REAL*8, INTENT(IN)   :: dbk(k1:k2)

      ! Change of surface pressure from met field pressure [hPa]
      REAL*8, INTENT(IN)   :: dps(i1:i2, ju1:j2)

      ! Relative surface area of grid box (fraction)
      REAL*8, INTENT(IN)   :: rel_area(i1:i2, ju1:j2)

      ! Horizontal mass fluxes in E-W and N-S directions [hPa]
      REAL*8, INTENT(IN)   :: xmass(ilo:ihi, julo:jhi, k1:k2)
      REAL*8, INTENT(IN)   :: ymass(ilo:ihi, julo:jhi, k1:k2)
```

OUTPUT PARAMETERS:

```
      ! Sum over vertical of dpi calculated from original mass fluxes [hPa]
      REAL*8,  INTENT(OUT) :: dps_ctm(i1:i2, ju1:j2)

      ! Horizontal mass flux in E-W and N-S directions after fixing [hPa]
      REAL*8,  INTENT(OUT) :: xmass_fixed(ilo:ihi, julo:jhi, k1:k2)
      REAL*8,  INTENT(OUT) :: ymass_fixed(ilo:ihi, julo:jhi, k1:k2)
```

AUTHOR:

```
   Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
    02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                                Declare all REAL variables as REAL*8.
```

1.96.7 Average_Press_Poles

Subroutine Average_Press_Poles averages pressure at the Poles when the Polar cap is enlarged. It makes the last two latitudes equal.

INTERFACE:

```
      SUBROUTINE Average_Press_Poles
     &  (rel_area, press)
```

INPUT PARAMETERS:

```
      ! Relative surface area of grid box (fraction)
      REAL*8, INTENT(IN)    :: rel_area(i1:i2, ju1:j2)
```

OUTPUT PARAMETERS:

```
      ! Surface pressure [hPa]
      REAL*8, INTENT(INOUT) :: press   (ilo:ihi, julo:jhi)
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.96.8 Convert_Winds

Subroutine Convert_Winds converts winds on A or C grid to Courant # on C grid.

INTERFACE:

```
 SUBROUTINE Convert_Winds
&  (igd, tdt, cosp, crx, cry, uu, vv)
```

USES:

```
USE CMN_SIZE_MOD ! Size parameters
USE CMN_GCTM_MOD ! Re, PI
```

INPUT PARAMETERS:

```
! A or C grid
INTEGER, INTENT(IN)  :: igd

! Model time step [s]
REAL*8,  INTENT(IN)  :: tdt

! Cosine of grid box centers
REAL*8,  INTENT(IN)  :: cosp(ju1_gl:j2_gl)

! Wind velocity in E-W (UU) and N-S (VV) directions at t1+tdt/2 [m/s]
REAL*8,  INTENT(IN)  :: uu  (ilo:ihi, julo:jhi, k1:k2)
REAL*8,  INTENT(IN)  :: vv  (ilo:ihi, julo:jhi, k1:k2)
```

OUTPUT PARAMETERS:

```
! Courant number in E-W (CRX) and N-S (CRY) directions
REAL*8,  INTENT(OUT) :: crx (ilo:ihi, julo:jhi, k1:k2)
REAL*8,  INTENT(OUT) :: cry (ilo:ihi, julo:jhi, k1:k2)
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REMARKS:

```
Use GEOS-CHEM physical constants Re, PI to be consistent with other
usage everywhere (bmy, 5/5/03)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.96.9 Calc_Horiz_Mass_Flux

Subroutine Calc_Horiz_Mass_Flux calculates the horizontal mass flux for non-GISS met data.

INTERFACE:

```
SUBROUTINE Calc_Horiz_Mass_Flux
&  (cose, delpm, uu, vv, xmass, ymass, tdt, cosp)
```

USES:

```
USE CMN_SIZE_MOD ! Size parameters
USE CMN_GCTM_MOD ! Re, Pi
```

INPUT PARAMETERS:

```
! Timestep [s]
REAL*8, INTENT(IN)   :: tdt

! Cosine of grid box edges
REAL*8, INTENT(IN)   :: cose (ju1_gl:j2_gl)

! Cosine of grid box centers
REAL*8, INTENT(IN)   :: cosp (ju1_gl:j2_gl)

! Pressure thickness, the pseudo-density in a
! hdrostatic system  at t1+tdt/2 (approximate) [hPa]
REAL*8, INTENT(IN)   :: delpm(ilo:ihi, julo:jhi, k1:k2)

! E-W (UU) and N-S (VV) winds [m/s]
REAL*8, INTENT(IN)   :: uu  (ilo:ihi, julo:jhi, k1:k2)
REAL*8, INTENT(IN)   :: vv  (ilo:ihi, julo:jhi, k1:k2)
```

OUTPUT PARAMETERS:

```
! Horizontal mass flux in E-W and N-S directions [hPa]
REAL*8, INTENT(OUT)  :: xmass(ilo:ihi, julo:jhi, k1:k2)
REAL*8, INTENT(OUT)  :: ymass(ilo:ihi, julo:jhi, k1:k2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REMARKS:

```
Use GEOS-CHEM physical constants Re, PI to be consistent with other
usage everywhere (bmy, 5/5/03)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.96.10 Calc_Divergence

Subroutine Calc_Divergence calculates the divergence.

INTERFACE:

```
  SUBROUTINE Calc_Divergence
 &  (do_reduction, geofac_pc, geofac, dpi, xmass, ymass)
```

INPUT PARAMETERS:

```
! Set to F if called on Master; set to T if called by Slaves
! (NOTE: this doesn't seem to be used!)
LOGICAL, INTENT(IN)    :: do_reduction

! Special geometrical factor (geofac) for Polar cap
REAL*8,  INTENT(IN)    :: geofac_pc

! geometrical factor for meridional advection; geofac uses
! correct spherical geometry, and replaces acosp as the
! meridional geometrical factor in tpcore
REAL*8,  INTENT(IN)    :: geofac(ju1_gl:j2_gl)

! horizontal mass fluxes in E-W and N-S directions [hPa]
REAL*8,  INTENT(IN)    :: xmass (ilo:ihi, julo:jhi, k1:k2)
REAL*8,  INTENT(IN)    :: ymass (ilo:ihi, julo:jhi, k1:k2)
```

INPUT/OUTPUT PARAMETERS:

```
! Divergence at a grid point; used to calculate vertical motion [hPa]
REAL*8,  INTENT(INOUT) :: dpi   (i1:i2, ju1:j2, k1:k2)
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.96.11 Set_Press_Terms

Subroutine Set_Press_Terms sets the pressure terms.

INTERFACE:

```
      SUBROUTINE Set_Press_Terms
     &  (dap, dbk, pres1, pres2, delp1, delpm, pu)
```

INPUT PARAMETERS:

```
      ! Pressure difference across layer from (ai * pt) term [hPa]
      REAL*8, INTENT(IN)  :: dap  (k1:k2)

      ! Difference in bi across layer - the dSigma term
      REAL*8, INTENT(IN)  :: dbk  (k1:k2)

      ! Surface pressure at t1 [hPa]
      REAL*8, INTENT(IN)  :: pres1(ilo:ihi, julo:jhi)

      ! Surface pressure at t1+tdt [hPa]
      REAL*8, INTENT(IN)  :: pres2(ilo:ihi, julo:jhi)
```

OUTPUT PARAMETERS:

```
      ! Pressure thickness, the psudo-density in a
      ! hydrostatic system at t1 [hPa]
      REAL*8, INTENT(OUT) :: delp1(ilo:ihi, julo:jhi, k1:k2)

      ! Pressure thickness, the psudo-density in a
      ! hydrostatic system at t1+tdt/2 (approximate)  [hPa]
      REAL*8, INTENT(OUT) :: delpm(ilo:ihi, julo:jhi, k1:k2)

      ! Pressure at edges in "u" [hPa]
      REAL*8, INTENT(OUT) :: pu   (ilo:ihi, julo:jhi, k1:k2)
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.
```

1.96.12 Do_Divergence_Pole_Sum

Do_Divergence_Pole_Sum sets the divergence at the Poles.

INTERFACE:

```
      SUBROUTINE Do_Divergence_Pole_Sum
     &  (do_reduction, geofac_pc, dpi, ymass)
```

INPUT PARAMETERS:

```
      ! Set to T if called on Master; set to F if called by Slaves
      ! (NOTE: This does not seem to be used!)
      LOGICAL :: do_reduction

      ! Special geometrical factor (geofac) for Polar cap
      REAL*8  :: geofac_pc

      ! horizontal mass flux in N-S direction [hPa]
      REAL*8  :: ymass(ilo:ihi, julo:jhi, k1:k2)
```

OUTPUT PARAMETERS:

```
      ! Divergence at a grid point; used to calculate vertical motion [hPa]
      REAL*8  :: dpi  ( i1:i2,   ju1:j2,  k1:k2)
```

AUTHOR:

```
   Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
```

REVISION HISTORY:

```
    02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                                Declare all REAL variables as REAL*8.
```

1.96.13 Xpavg

!description: Subroutine Xpavg replaces each element of a vector with the average of the entire array. (bmy, 5/7/03)

INTERFACE:

```
      SUBROUTINE Xpavg( P, IM )
```

USES:

```
      ! References to F90 modules
      USE ERROR_MOD, ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
! Dimension of P
INTEGER, INTENT(IN)    :: IM
```

INPUT/OUTPUT PARAMETERS:

```
! 1-D vector to be averaged
REAL*8,  INTENT(INOUT) :: P(IM)
```

AUTHOR:

Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)

REVISION HISTORY:

02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
Now make all REAL variables REAL*8.

1.96.14 Init_Pjc_Pfix

Subroutine Init_Pjc_Pfix allocates and initializes module arrays and variables. GMI dimension variables will be used for compatibility with the Phil Cameron-Smith P-fixer. (bdf, bmy, 5/8/03)

INTERFACE:

```
SUBROUTINE Init_Pjc_Pfix
```

USES:

```
! References to F90 modules
USE GRID_MOD,     ONLY : GET_AREA_M2, GET_YMID_R
USE ERROR_MOD,    ONLY : ALLOC_ERR,   ERROR_STOP
USE PRESSURE_MOD, ONLY : GET_AP,      GET_BP

USE CMN_SIZE_MOD  ! Size parameters
USE CMN_GCTM_MOD  ! Re, PI, etc...
```

AUTHOR:

Brendan Field and Bob Yantosca (5/8/03)

REVISION HISTORY:

02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R(I,J,L) from grid_mod.F90

1.96.15 Cleanup_Pjc_Pfix

Subroutine Cleanup_Pjc_Pfix deallocates all module arrays (bmy, 5/8/03)

INTERFACE:

```
SUBROUTINE Cleanup_Pjc_Pfix
```

REVISION HISTORY:

```
02 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
```

1.97 Fortran: Module Interface planeflight_mod

Module PLANEFLIGHT_MOD contains variables and routines which are used to "fly" a plane through the GEOS-Chem model simulation. This is useful for comparing model results with aircraft observations.

INTERFACE:

```
MODULE PLANEFLIGHT_MOD
```

USES:

```
USE inquireMod, ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: ARCHIVE_RXNS_FOR_PF
PUBLIC  :: CLEANUP_PLANEFLIGHT
PUBLIC  :: PLANEFLIGHT
PUBLIC  :: SETUP_PLANEFLIGHT
PUBLIC  :: SET_PLANEFLIGHT
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: AN_SETUP
PRIVATE :: INIT_PLANEFLIGHT
PRIVATE :: NOY_SETUP
PRIVATE :: READ_VARIABLES
PRIVATE :: READ_POINTS
PRIVATE :: RO2_SETUP
PRIVATE :: TEST_VALID
PRIVATE :: WRITE_VARS_TO_FILE
```

REMARKS:

The quantities that are saved to disk by the planeflight diagnostic were requested by GEOS-Chem users. If you would like to save out a new quantity, then you will have to make your own modifications in this module.

REVISION HISTORY:

(1) Now references "pressure_mod.f" (dsa, bdf, bmy, 8/21/02)
(2) Now reference AD from "dao_mod.f". Now also references "error_mod.f". (bmy, 10/15/02)
(3) Bug fix: replace missing commas in FORMAT statement (bmy, 3/23/03)
(4) Now references "time_mod.f". (bmy, 3/27/03)
(5) Renamed PRATE to PRRATE to avoid conflict w/ SMVGEAR II (bmy, 4/1/03)
(6) Bug fix: use NAMEGAS instead of NAMESPEC (lyj, bmy, 7/9/03)
(7) Bug fix: avoid referencing JLOP for non-SMVGEAR runs (bmy, 7/18/03)
(8) Bug fix: Use T instead of T3 for GMAO temperature. Also replace NAMESPEC w/ NAMEGAS in RO2_SETUP. Now locate reordered rxn numbers for SMVGEAR II.(tdf, mje, bmy, 8/1/03)
(9) Now print out N2O5 hydrolysis rxn as a special case. Also rename output file. (bmy, 8/8/03)
(10) Changed "DAO" to "GMAO" for met field variable names. Now can save aerosol optical depths. Bug fix in TEST_VALID. (bmy, 4/23/03)
(11) Now references "tracer_mod.f" (bmy, 7/20/04)
(12) Bug fix in READ_VARIABLES (1/7/05)
(13) Modified the plane flight diagnostic so that it writes output files for each day where flight track files are defined. (bmy, 3/24/05)
(14) Minor bug fix in ARCHIVE_RXNS_FOR_PF (bmy, 5/20/05)
(15) Now split AOD's into column AOD's and AOD's below plane. Also scale AOD's to 400nm. (bmy, 10/25/05)
(16) Bug fixes in READ_VARIABLES (bmy, 10/16/06)
(17) Bug fix in PLANEFLIGHT (cdh, bmy, 12/12/06)
(18) Bug fix in RO2_SETUP (tmf, bmy, 4/23/07)
(19) Set very small values to zero. (tmf, 1/7/09)
(20) Add new RO2 species according to 'globchem.dat' (tmf, 1/7/09)
(21) Make sure we have 3 spaces in the exponential format (phs, 7/13/09)
(22) Output the grid cell indexes (kjw, 8/18/09)
(23) Add AN and NOy species. (fp, 3/10/10)
(24) Now scale AODs to wavelength specified in jv_spec_aod.dat(clh, 5/14/09)
29 Jul 2011 - R. Yantosca - Now also archive MERRA SEAICExx fields
29 Jul 2011 - R. Yantosca - Added ProTeX headers
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete

---

1.97.1 setup_planeflight

Subroutine SETUP_PLANEFLIGHT reads information from the input file in order to initialize the planeflight diagnostic. Also calls INIT_PLANEFLIGHT to allocate and zero module arrays.

INTERFACE:

```
SUBROUTINE SETUP_PLANEFLIGHT( am_I_Root )
```

USES:

```
USE FILE_MOD,   ONLY : FILE_EXISTS
USE FILE_MOD,   ONLY : IOERROR
USE TIME_MOD,   ONLY : EXPAND_DATE
USE TIME_MOD,   ONLY : GET_NYMD
USE TIME_MOD,   ONLY : GET_NHMS
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REMARKS:

```
For SMVGEAR or KPP simulations, the call to SETUP_PLANEFLIGHT is made from
routine "chemdr.f", after the "chem.dat" file is read.  This is necessary
since we have to reference the SMVGEAR rxn rate and species numbers.

For offline simulations, the call to SETUP_PLANEFLIGHT can be made
at the start of the GEOS-Chem run (in "ndxx_setup.f" or similar routine).
```

REVISION HISTORY:

```
30 Jul 2002 - M. Evans    - Initial version
(1 ) Rename from "plane.dat" to "plane.log", since "*.dat" implies an input
      file name. (bmy, 8/8/03)
(2 ) Add fancy output string (bmy, 4/26/04)
(3 ) Now references GET_NYMD, GET_NHMS, and EXPAND_DATE from "time_mod.f".
      Now also replaces date & time tokens in the filenames. (bmy, 7/20/04)
(4 ) Now references FILE_EXISTS from "file_mod.f".  Modified so that we
      check if a flight track file exists on each day.  Open file for
      output on each day and write header. (bmy, 3/25/05)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
06 Aug 2012 - R. Yantosca - Now use local IU_PLANE and not from file_mod.F
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
```

1.97.2 read_variables

Subroutine READ_VARIABLES reads the list of variables (SMVGEAR/KPP chemical species, SMVGEAR/KPP rxn rates, GMAO met fields, or GEOS-Chem tracers) to be printed out and sorts the information into the appropriate module variables.

INTERFACE:

```
SUBROUTINE READ_VARIABLES( IU_FILE, am_I_Root )
```

USES:

```
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP
USE FILE_MOD,   ONLY : IOERROR
USE TRACER_MOD, ONLY : N_TRACERS
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM
USE CMN_SIZE_MOD                  ! Size parameters
USE COMODE_LOOP_MOD               ! NAMEGAS, NSPEC
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: IU_FILE     ! Logical unit # for ASCII read
LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REVISION HISTORY:

```
30 Jul 2002 - M. Evans    - Initial version
(1 ) Now references GEOS_CHEM_STOP from "error_mod.f", which frees all
     allocated memory before stopping the run. (bmy, 10/15/02)
(2 ) Bug fix: replace missing commas in FORMAT statement (bmy, 3/23/03)
(3 ) Bug fix: replace NAMESPEC w/ NAMEGAS for SMVGEAR II (lyj, bmy, 7/9/09)
(4 ) Now locate reordered rxn numbers for SMVGEAR II. (mje, bmy, 8/1/03)
(5 ) Now flag N2O5 hydrolysis rxn as a special case (bmy, 8/8/03)
(6 ) Changed variable name prefix "DAO" to "GMAO".  Also added aerosol
     optical depths w/ tracer offset 2000. (bmy, 4/23/04)
(7 ) Now references N_TRACERS & ITS_A_FULLCHEM_SIM from "tracer_mod.f"
     (bmy, 7/20/04)
(8 ) Bug fix: extract tracer # when reading rxn rates (bmy, 1/7/05)
(9 ) Now computes column AOD's and AOD's below plane (bmy, 10/24/05)
(10) We need to trim NAMEGAS before comparing to LINE so that comparisons
     for species like "O3" will work.  Also set NCS=NCSURBAN at the top
     of the subroutine, to avoid out of bounds error. (dbm, bmy, 10/16/06)
(11) Add tracer TMS_?? for TOMAS microphysics rate diagnostic (win, 7/28/09)
29 Jul 2011 - R. Yantosca - Also search for MERRA SEAICExx met fields
29 Jul 2011 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
```

1.97.3 read_points

Subroutine READ_POINTS reads the information (ID, date, time, lat, lon, pressure) for each measurement listed in the input file, and sorts these into the appropriate module variables.

INTERFACE:

```
SUBROUTINE READ_POINTS( IU_FILE, am_I_Root )
```

USES:

```
USE BPCH2_MOD, ONLY : GET_TAU0
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
USE FILE_MOD,  ONLY : IOERROR
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REVISION HISTORY:

```
30 Jul 2002 - M. Evans    - Initial version
(1 ) Now references GEOS_CHEM_STOP from "error_mod.f", which frees all
     allocated memory before stopping the run. (bmy, 10/15/02)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
```

1.97.4 ro2_setup

Subroutine RO2_SETUP saves the SMVGEAR species indices of RO2 constituents in the PRO2 array. Also computes the count NPRO2.

INTERFACE:

```
SUBROUTINE RO2_SETUP
```

USES:

```
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD     ! Size parameters
USE COMODE_LOOP_MOD  ! NAMEGAS, NSPEC
```

REVISION HISTORY:

```
01 Aug 2003 - M. Evans    - Initial version
(1 ) Now references GEOS_CHEM_STOP from "error_mod.f", which frees all
     allocated memory before stopping the run. (bmy, 10/15/02)
(2 ) Now replace NAMESPEC w/ NAMEGAS for SMVGEAR II (bmy, 8/1/03)
(3 ) Now references ITS_A_FULLCHEM_SIM from "tracer_mod.f" (bmy, 7/20/04)
(4 ) Bug fix: PO3 should be PO2 (tmf, bmy, 4/23/07)
(5 ) NOTE: PO3 was a bug, that should have been PO2 (tmf, 2/10/09)
(6 ) Add new RO2 species according to 'globchem.dat' (tmf, 3/10/09)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.97.5 noy_setup

Subroutine NOY_SETUP saves the SMVGEAR species indices of NOy constituents in the PNOY array. Also computes the count NPNOY.

INTERFACE:

```
SUBROUTINE NOY_SETUP
```

USES:

```
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD   ! Size parameters
USE COMODE_LOOP_MOD       ! NSPEC, NAMEGAS, NCS
```

REVISION HISTORY:

```
01 Jun 2009 - F. Paulot   - Initial version
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.97.6 an_setup

Subroutine AN_SETUP saves the SMVGEAR species indices of AN constituents in the P_AN array. Also computes the count NPAN.

INTERFACE:

```
SUBROUTINE AN_SETUP
```

USES:

```
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP
USE TRACER_MOD, ONLY : ITS_A_FULLCHEM_SIM

USE CMN_SIZE_MOD   ! Size parameters
USE COMODE_LOOP_MOD       ! NSPEC, NAMEGAS, NCS
```

REVISION HISTORY:

```
04 Jan 2010 - F. Paulot   - Initial version
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.97.7 planeflight

Subroutine PLANEFLIGHT saves concentrations to disk at locations corresponding to a flight track.

INTERFACE:

```
      SUBROUTINE PLANEFLIGHT( am_I_Root, Input_Opt,
     &                        State_Met, State_Chm, RC )
```

USES:

```
      USE COMODE_MOD,         ONLY : AIRDENS,        CSPEC,       JLOP
      USE COMODE_MOD,         ONLY : T3,             VOLUME,      ABSHUM
      USE COMODE_MOD,         ONLY : TAREA
#if   defined( TOMAS )
      USE DIAG_MOD,           ONLY : AD61_INST   ! (win, 7/28/09)
#endif
      USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE TIME_MOD,           ONLY : GET_TAU,        GET_TS_DIAG
      USE OCEAN_MERCURY_MOD,  ONLY : Fp, Fg !eds 10/27/11

      USE JV_CMN_MOD               ! ODAER, QAA, QAA_AOD
      USE COMODE_LOOP_MOD          ! CSPEC, etc.
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   08 Jul 2002 - M. Evans    - Initial version
   (1 ) Now reference AD from "dao_mod.f".  Now references GEOS_CHEM_STOP from
        "error_mod.f", which frees memory before stopping. (bmy, 10/15/02)
   (2 ) Now uses functions GET_TAU, GET_TS_CHEM from "time_mod.f".
        (bmy, 3/27/03)
   (3 ) Updated comments, cosmetic changes (bmy, 7/18/03)
```

```
(4 ) Now references T from "dao_mod.f", so that we can save out temperature
     for non-SMVGEAR runs. (bmy, 8/1/03)
(5 ) Now references UWND and VWND from "dao_mod.f".  Now references
     GET_PEDGE from "pressure_mod.f".  Added CASEs for surface pressure,
     UWND, VWND to the CASE statement (bmy, 4/23/04)
(6 ) Now references STT & TCVV from "tracer_mod.f" (bmy, 7/20/04)
(7 ) Now return if DO_PF = .FALSE. (bmy, 3/24/05)
(8 ) Now compute column AOD's and AOD's below plane.  Also now scale
     AOD's to 400nm. (bmy, 10/24/05)
(9 ) Bug fix: exit if PTAU(M) == PTAUE, so that we write out on the next !
     planeflight timestep (cdh, bmy, 12/12/06)
(10) Change planeflight output time step. (ccc, 8/27/09)
(11) Add case matching for TOMAS rates (win, 7/28/09)
(12) Modify PTAUE calculation w/ ref to GET_TS_DYN  (win, 7/28/09)
(13) Now scale AOD's to jv_spec_aod.dat wavelength. (clh, 5/14/09)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
09 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.97.8 test_valid

Subroutine TEST_VALID tests to see if we are w/in the tropopause, which is where SMVGEAR chemistry is done.

INTERFACE:

```
SUBROUTINE TEST_VALID( IND, PCHEM, JLOOP, I, J, L )
```

USES:

```
USE COMODE_MOD,     ONLY : JLOP
USE PRESSURE_MOD,   ONLY : GET_PEDGE
USE TRACER_MOD,     ONLY : ITS_A_FULLCHEM_SIM
USE GRID_MOD,       ONLY : GET_XOFFSET
USE GRID_MOD,       ONLY : GET_YOFFSET

USE CMN_SIZE_MOD               ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: IND     ! # of the flight track point
```

OUTPUT PARAMETERS:

```
LOGICAL, INTENT(OUT) :: PCHEM   ! =T if chemistry is done here
INTEGER, INTENT(OUT) :: JLOOP   ! 1-D grid box index for SMVGEAR/KPP
```

```
      INTEGER, INTENT(OUT) :: I       ! GEOS-Chem longitude index
      INTEGER, INTENT(OUT) :: J       ! GEOS-Chem latitude index
      INTEGER, INTENT(OUT) :: L       ! GEOS-Chem level index
```

REVISION HISTORY:

```
08 Jul 2002 - M. Evans    - Initial version
(1 ) Now use GET_PEDGE of "pressure_mod.f" to return the pressure at the
      bottom edge of box (I,J,L), for hybrid grid. (dsa, bdf, bmy, 8/21/02)
(2 ) Since JLOP is not allocated for non-SMVGEAR runs, set PCHEM=F and
      JLOOP=0 even if we are in the troposphere. (bmy, 7/18/03)
(3 ) Bug fix: add 0.5 in expression for I so that the rounding will
      be done correctly.  Also make sure that I is computed correctly
for points near the date line.  (bmy, 4/23/04)
(4 ) Now references ITS_A_FULLCHEM_SIM from "tracer_mod.f" (bmy, 7/20/04)
(5 ) Now references ITS_IN_THE_TROP from "tropopause_mod.f" (bmy, 8/22/05)
(6 ) Reference GET_XOFFSET and GET_YOFFSET from "grid_mod.f" and also
      add for the case of nested-grid simulation (win, 7/28/09)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
08 Sep 2011 - L. Schiferl - Added correct definitions for I and J
                            based on nested regions
```

1.97.9 write_vars_to_file

Subroutine WRITE_VARS_TO_FILE writes the values of all the variables for a given flight track point to the output file.

INTERFACE:

```
      SUBROUTINE WRITE_VARS_TO_FILE( IND, VARI )
```

USES:

```
      USE FILE_MOD, ONLY : IOERROR
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: IND           ! # of the flight track point
      REAL*8,  INTENT(IN) :: VARI(NPVAR)   ! Values to print to file
```

REVISION HISTORY:

```
08 Jul 2002 - M. Evans    - Initial version
(1 ) The max line length for output seems to be 1024 characters.  Adjust
      MAXVARS accordingly so that we don't exceed this. (bmy, 7/8/02)
(2 ) Now do not write file header -- this is now done in subroutine
      SETUP_PLANEFLIGHT at the start of each day (bmy, 3/25/05)
(3 ) Bug fix: make sure we have 3 spaces in exponential (phs, 7/13/09)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.97.10 archive_rxns_for_PF

Subroutine ARCHIVE_RXNS_FOR_PF is called from "calcrate.f" to pass reaction rates from the SMVGEAR solver for the planeflight diagnostic.

INTERFACE:

```
SUBROUTINE ARCHIVE_RXNS_FOR_PF( JO1D, N2O5 )
```

USES:

```
USE COMODE_MOD, ONLY : IXSAVE
USE COMODE_MOD, ONLY : IYSAVE
USE COMODE_MOD, ONLY : IZSAVE
USE ERROR_MOD,  ONLY : GEOS_CHEM_STOP

USE CMN_SIZE_MOD                    ! Size parameters
USE COMODE_LOOP_MOD                 ! RRATE, JLOOPLO, KBLOOP
USE CMN_DIAG_MOD                    ! ND40 switch
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN)  :: JO1D(KBLOOP)  ! JO1D photolysis rate [1/s]
REAL*8, INTENT(IN)  :: N2O5(KBLOOP)  ! N2O5 hydrolysis rate [molec/cm3/s]
```

REVISION HISTORY:

```
08 Jul 2002 - M. Evans    - Initial version
(1 ) Now avoid overflow/underflow errors in PRATE (bmy, 7/8/02)
(2 ) Now reference GEOS_CHEM_STOP from "error_mod.f", which frees all
     allocated memory before stopping the run (bmy, 10/15/02)
(3 ) Renamed PRATE to PRRATE to avoid conflict w/ SMVGEAR II (bmy, 4/1/03)
(4 ) Now also pass N2O5 hydrolysis rxn rate array via the arg list.
     Also bug fix: replace TMP with RATE in under/overflow checking
     for JO1D and N2O5. (bmy, 8/8/03)
(5 ) Bug fix: Replace with DO_PF since this variable is reset to either T
     or F each day depending on whether there is plane flight data
     available (bmy, 5/20/05)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.97.11 set_planeflight

Subroutine SET_PLANEFLIGHT is used to pass values read in from the GEOS-Chem input file to "planeflight_mod.f".

INTERFACE:

```
SUBROUTINE SET_PLANEFLIGHT( PF, IN_FILE, OUT_FILE )
```

INPUT PARAMETERS:

```
LOGICAL,            INTENT(IN) :: PF         ! Turn on planeflight diag?
CHARACTER(LEN=255), INTENT(IN) :: IN_FILE    ! Input file to read
CHARACTER(LEN=255), INTENT(IN) :: OUT_FILE   ! Output file to write
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.97.12 init_planeflight

Subroutine INIT_PLANEFLIGHT reads the input file to compute the number of variables and flight track points to print out. Also allocates all module arrays.

INTERFACE:

```
SUBROUTINE INIT_PLANEFLIGHT( am_I_Root )
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
USE FILE_MOD,  ONLY : IOERROR
USE CMN_SIZE_MOD    ! Size Parameters
USE COMODE_LOOP_MOD ! ITLOOP
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REVISION HISTORY:

```
08 Jul 2002 - M. Evans    - Initial version
(1 ) Now reference GEOS_CHEM_STOP from "error_mod.f", which frees all
     allocated memory before stopping the run.  Also reference ALLOC_ERR
     from "error_mod.f" (bmy, 10/15/02)
(2 ) Renamed PRATE to PRRATE to avoid conflict w/ SMVGEAR II (bmy, 4/1/03)
(3 ) INIT_PLANEFLIGHT is now called each day but the arrays are only
     allocated once.  Arrays are now allocated to the maximum size.
     (bmy, 3/25/05)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
```

1.97.13 cleanup_planeflight

Subroutine CLEANUP_PLANEFLIGHT deallocates all allocatable module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_PLANEFLIGHT
```

REVISION HISTORY:

```
01 Jul 2001 - M. Evans    - Initial version
(1 ) Renamed PRATE to PRRATE to avoid conflict w/ SMVGEAR II (bmy, 4/1/03)
29 Jul 2011 - R. Yantosca - Added ProTeX headers
```

1.98 Fortran: Module Interface pops_mod

Module POPS_MOD contains variables and routines for the GEOS-Chem peristent organic pollutants (POPs) simulation.

INTERFACE:

```
MODULE POPS_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC TYPES:

```
PUBLIC :: EMISSPOPS
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CHEMPOPS
PUBLIC :: INIT_POPS
```

REMARKS:

```
POPs Tracers
=============================================================================
(1 ) POPG   : Gaseous POP - total tracer
(2 ) POPPOC : OC-sorbed POP  - total tracer
(3 ) POPPBC : BC-sorbed POP  - total tracer
```

REVISION HISTORY:

```
20 Sep 2010 - N.E. Selin    - Initial Version
04 Jan 2011 - C.L. Friedman - Expansion on initial version
```

1.98.1 chempops

Subroutine CHEMPOPS is the driver routine for POPs chemistry (eck, 9/20/10)

INTERFACE:

```
SUBROUTINE CHEMPOPS( am_I_Root, Input_Opt,
&                    State_Met, State_Chm, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE DRYDEP_MOD,         ONLY : DEPSAV
USE DRYDEP_MOD,         ONLY : DRYPOPG, DRYPOPP_OC, DRYPOPP_BC
USE ERROR_MOD,          ONLY : DEBUG_MSG
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GLOBAL_OH_MOD,      ONLY : GET_GLOBAL_OH
USE GLOBAL_O3_MOD,      ONLY : GET_GLOBAL_O3
USE GLOBAL_OC_MOD,      ONLY : GET_GLOBAL_OC
USE GLOBAL_BC_MOD,      ONLY : GET_GLOBAL_BC
USE PBL_MIX_MOD,        ONLY : GET_PBL_MAX_L
USE TIME_MOD,           ONLY : GET_MONTH, GET_YEAR
USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
20 September 2010 - N.E. Selin - Initial Version based on CHEMMERCURY
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
23 Oct 2013 - R. Yantosca - Now pass objects to GET_GLOBAL_OH routine
```

1.98.2 chem_popgp

Subroutine CHEM_POPGP is the chemistry subroutine for the oxidation, gas-particle partitioning, and deposition of POPs. (eck, clf, 1/4/2011)

INTERFACE:

```
      SUBROUTINE CHEM_POPGP ( V_DEP_G,   V_DEP_P_OC, V_DEP_P_BC,
     &                        Input_Opt, State_Met, State_Chm   )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE DIAG53_MOD,         ONLY : AD53_PG_OC_NEG
      USE DIAG53_MOD,         ONLY : AD53_PG_BC_NEG
      USE DIAG53_MOD,         ONLY : AD53_PG_OC_POS
      USE DIAG53_MOD,         ONLY : AD53_PG_BC_POS
      USE DIAG53_MOD,         ONLY : ND53, LD53
      USE DIAG53_MOD,         ONLY : AD53_POPG_OH
      USE DIAG53_MOD,         ONLY : AD53_POPP_OC_O3
      USE DIAG53_MOD,         ONLY : AD53_POPP_BC_O3
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE GET_POPSINFO_MOD,   ONLY : GET_POP_DEL_H
      USE GET_POPSINFO_MOD,   ONLY : GET_POP_KOA
      USE GET_POPSINFO_MOD,   ONLY : GET_POP_KBC
      USE GET_POPSINFO_MOD,   ONLY : GET_POP_K_POPG_OH
      USE GET_POPSINFO_MOD,   ONLY : GET_POP_K_POPP_O3A
      USE GET_POPSINFO_MOD,   ONLY : GET_POP_K_POPP_O3B
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TRACERID_MOD,       ONLY : IDTPOPG,    IDTPOPPOC,  IDTPOPPBC
```

INPUT PARAMETERS:

```
      ! Dry deposition frequency for gaseous POP [/s]
      REAL*8, INTENT(IN)            :: V_DEP_G(IIPAR,JJPAR)

      !  Dry deposition frequency for OC-POP [/s]
      REAL*8, INTENT(IN)            :: V_DEP_P_OC(IIPAR,JJPAR)

      ! Dry deposition frequency for BC-POP [/s]
      REAL*8, INTENT(IN)            :: V_DEP_P_BC(IIPAR,JJPAR)

      ! Input Options object
      TYPE(OptInput), INTENT(IN)    :: Input_Opt

      ! Meteorology State object
      TYPE(MetState), INTENT(IN)    :: State_Met
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REMARKS:

```
References:
============================================================================
(1 ) For OH rate constant: Brubaker & Hites. 1998. OH reaction kinetics of
PAHs and PCDD/Fs. J. Phys. Chem. A. 102:915-921.
```

REVISION HISTORY:

```
20 Sep 2010 - N.E. Selin  - Initial Version based on CHEM_HG0_HG2
29 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.98.3 rxn_ox_nodep

Subroutine RXN_OX_NODEP calculates new mass of POPG for given oxidation rates, without any deposition. This is for the free troposphere, or simulations with deposition turned off. (clf, 1/27/11, based on RXN_REDOX_NODEP in mercury_mod.f).

INTERFACE:

```
      SUBROUTINE RXN_OX_NODEP( OLD_POPG, K_OX, E_KOX_T,
     &                         NEW_POPG, GROSS_OX )
```

INPUT PARAMETERS:

```
      REAL*8,  INTENT(IN)  :: OLD_POPG
      REAL*8,  INTENT(IN)  :: K_OX
      REAL*8,  INTENT(IN)  :: E_KOX_T
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT) :: NEW_POPG,  GROSS_OX
```

REVISION HISTORY:

```
27 January 2011 - CL Friedman - Initial Version
```

1.98.4 rxn_ox_withdep

Subroutine RXN_OX_WITHDEP calculates new mass of POPG for given rates of oxidation and deposition. This is for the boundary layer. (clf, 1/27/11, based on RXN_REDOX_NODEP in mercury_mod.f).

INTERFACE:

```
      SUBROUTINE RXN_OX_WITHDEP( OLD_POPG, K_OX, K_DEPG, DT, E_KOX_T,
     &                           NEW_POPG, GROSS_OX, DEP_POPG )
  USES:
      USE ERROR_MOD,    ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN)  :: OLD_POPG,  DT
REAL*8,  INTENT(IN)  :: K_OX, K_DEPG
REAL*8,  INTENT(IN)  :: E_KOX_T
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: NEW_POPG,  GROSS_OX
REAL*8,  INTENT(OUT) :: DEP_POPG
```

REVISION HISTORY:

```
27 January 2011 - CL Friedman - Initial Version
```

1.98.5 no_rxn_withdep

Subroutine NO_RXN_WITHDEP calculates new mass of POPP for given rate of deposition. No oxidation of POPP. This is for the boundary layer. (clf, 2/9/11)

INTERFACE:

```
SUBROUTINE NO_RXN_WITHDEP( OLD_POPP, K_DEPP, DT,
&                          NEW_POPP, DEP_POPP )
```

USES:

```
USE ERROR_MOD,    ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN)  :: OLD_POPP
REAL*8,  INTENT(IN)  :: K_DEPP
REAL*8,  INTENT(IN)  :: DT
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: NEW_POPP
REAL*8,  INTENT(OUT) :: DEP_POPP
```

REVISION HISTORY:

```
9 February 2011 - CL Friedman - Initial Version
```

1.98.6 emisspops

This routine is the driver routine for POPs emissions

INTERFACE:

```
SUBROUTINE EMISSPOPS( am_I_Root, Input_Opt,
&                     State_Met, State_Chm, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE DIAG53_MOD,          ONLY : AD53, ND53
USE ERROR_MOD,           ONLY : DEBUG_MSG, ERROR_STOP
USE GET_POPSINFO_MOD,    ONLY : GET_POP_DEL_H
USE GET_POPSINFO_MOD,    ONLY : GET_POP_KOA
USE GET_POPSINFO_MOD,    ONLY : GET_POP_KBC
USE GET_POPSINFO_MOD,    ONLY : GET_POP_K_POPG_OH
USE GET_POPSINFO_MOD,    ONLY : GET_POP_K_POPP_O3A
USE GET_POPSINFO_MOD,    ONLY : GET_POP_K_POPP_O3B
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GLOBAL_BC_MOD,       ONLY : GET_GLOBAL_BC
USE GLOBAL_OC_MOD,       ONLY : GET_GLOBAL_OC
USE PBL_MIX_MOD,         ONLY : GET_FRAC_OF_PBL, GET_PBL_MAX_L
USE TIME_MOD,            ONLY : GET_MONTH, GET_YEAR
USE TIME_MOD,            ONLY : ITS_A_NEW_MONTH
USE TIME_MOD,            ONLY : GET_TS_EMIS
USE TRACERID_MOD,        ONLY : IDTPOPG, IDTPOPPOC,  IDTPOPPBC
USE VDIFF_PRE_MOD,       ONLY : EMIS_SAVE !cdh for LNLPBL
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
20 Sep 2010 - N.E. Selin  - Initial Version based on EMISSMERCURY
29 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
13 Dec 2012 - R. Yantosca - Remove reference to obsolete CMN_DEP_mod.F
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.98.7 emitpop

This routine directs emission either to STT directly or to EMIS_SAVE for use by the non-local PBL mixing. This is a programming convenience. (cdh, 08/27/09, modified for pops

by eck, 9/20/10)

INTERFACE:

```
SUBROUTINE EMITPOP( I, J, L, ID, E_POP, Input_Opt, State_Chm )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE VDIFF_PRE_MOD,ONLY : EMIS_SAVE
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: I, J, L     ! Grid box dimensions
INTEGER,        INTENT(IN)    :: ID          ! Tracer ID
REAL*8,         INTENT(IN)    :: E_POP       ! POP emissions [kg/s]
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
20 September 2010 - N.E. Selin - Initial Version based initially on EMITHG
```

REMARKS:

```
(1) Based initially on EMITHG from MERCURY_MOD (eck, 9/20/10)
25 Mar 2013 - R. Yantosca - Now accept Input_Opt, State_Chm arguments
```

1.98.8 pops_readyr

Subroutine POPS_READYR read the year-invariant emissions for POPs (PAHs) from all sources combined.

INTERFACE:

```
SUBROUTINE POPS_READYR
```

USES:

```
USE BPCH2_MOD,         ONLY : READ_BPCH2, GET_TAU0
USE DIRECTORY_MOD,     ONLY : DATA_DIR_1x1, POP_EMISDIR
USE REGRID_A2A_MOD,    ONLY : DO_REGRID_A2A
USE TIME_MOD,          ONLY : EXPAND_DATE
USE GET_POPSINFO_MOD,  ONLY : GET_EMISSFILE

USE CMN_SIZE_MOD             ! Size parameters
```

REMARKS:

```
References:
============================================================================
(1 ) Zhang, Y. and Tao, S. 2009. Global atmospheric emission inventory
of polycyclic aromatic hydrocarbons (PAHs) for 2004. Atm Env. 43:812-819.
```

REVISION HISTORY:

```
03 Feb 2011 - CL Friedman - Initial Version based on MERCURY_READYR
01 Oct 2013 - M. Sulprizio- Changed regrid algorithm to map_a2a
```

1.98.9 get_O3

Function GET_O3 returns monthly mean O3 for offline sulfate aerosol simulations. (bmy, 12/16/02)

INTERFACE:

```
FUNCTION GET_O3( I, J, L, State_Met ) RESULT( O3_MOLEC_CM3 )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE GLOBAL_O3_MOD,      ONLY : O3

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
! Grid box indices for lon, lat, vertical level
INTEGER, INTENT(IN)         :: I, J, L

! Meteorology State object
TYPE(MetState), INTENT(IN)  :: State_Met
```

RETURN VALUE:

```
REAL*8                      :: O3_MOLEC_CM3
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDO3. (bmy, 12/16/02)
(2 ) Now reference inquiry functions from "tracer_mod.f" (bmy, 7/20/04)
29 Nov 2012 - M. Payer   - Replaced all met field arrays with State_Met
                           derived type object
```

1.98.10 get_oh

Function GET_OH returns monthly mean OH and imposes a diurnal variation.

INTERFACE:

```
FUNCTION GET_OH( I, J, L, State_Met ) RESULT( OH_MOLEC_CM3 )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE GLOBAL_OH_MOD,      ONLY : OH
USE TIME_MOD,           ONLY : GET_TS_CHEM

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)         :: I, J, L

TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REMARKS:

```
Copied GET_OH function from mercury_mod.f - CLF
```

REVISION HISTORY:

```
03 Feb 2011 - CL Friedman - Initial Version
29 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.98.11 get_oc

Function GET_OC returns monthly mean organic carbon concentrations [kg/box]

INTERFACE:

```
FUNCTION GET_OC( I, J, L) RESULT( C_OC )
```

USES:

```
USE GLOBAL_OC_MOD, ONLY : OC
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L
```

REVISION HISTORY:

```
03 February 2011 - CL Friedman - Initial Version
```

1.98.12 get_bc

Function GET_BC returns monthly mean black carbon concentrations [kg/box]

INTERFACE:

```
FUNCTION GET_BC( I, J, L) RESULT( C_BC )
```

USES:

```
USE GLOBAL_BC_MOD, ONLY : BC
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L
```

REVISION HISTORY:

```
03 February 2011 - CL Friedman - Initial Version
```

1.98.13 ohno3time

Subroutine OHNO3TIME computes the sum of cosine of the solar zenith angle over a 24 hour day, as well as the total length of daylight. This is needed to scale the offline OH and NO3 concentrations. (rjp, bmy, 12/16/02, 12/8/04)

INTERFACE:

```
SUBROUTINE OHNO3TIME
```

USES:

```
USE GRID_MOD, ONLY : GET_XMID,    GET_YMID_R
USE TIME_MOD, ONLY : GET_NHMSb,   GET_ELAPSED_SEC
USE TIME_MOD, ONLY : GET_TS_CHEM, GET_DAY_OF_YEAR, GET_GMT

USE CMN_SIZE_MOD   ! Size parameters
USE CMN_GCTM_MOD   ! Physical constants
```

REVISION HISTORY:

```
20 September 2010 - N.E. Selin - Initial Version for POPS_MOD
```

1.98.14 init_pops

Subroutine INIT_POPS allocates and zeroes all module arrays.

INTERFACE:

```
 SUBROUTINE INIT_POPS(POP_XMW, POP_KOA, POP_KBC, POP_K_POPG_OH,
&                     POP_K_POPP_O3A, POP_K_POPP_O3B,
&                     POP_HSTAR, POP_DEL_H, POP_DEL_Hw, Input_Opt )
```

USES:

```
USE DRYDEP_MOD,          ONLY : DEPNAME,   NUMDEP
USE ERROR_MOD,           ONLY : ALLOC_ERR, ERROR_STOP
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE PBL_MIX_MOD,         ONLY : GET_PBL_MAX_L
USE GET_POPSINFO_MOD,    ONLY : INIT_POP_PARAMS

USE CMN_SIZE_MOD           ! Size parameters
USE CMN_DIAG_MOD           ! ND44
```

REVISION HISTORY:

```
20 Sep 2010 - N.E. Selin  - Initial Version based on INIT_MERCURY
25 Mar 2013 - R. Yantosca - Now accept Input_Opt argument
```

1.98.15 cleanup_pops

Subroutine CLEANUP_POPS deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_POPS
```

REVISION HISTORY:

```
20 September 2010 - N.E. Selin - Initial Version
```

1.99 Fortran: Module Interface rcp_mod

Module RCP_MOD provides access to the RCP emission inventories that were prepared for IPCC AR5. The inventory includes anthropogenic emissions from land, ships, and aircraft. Species include trace gases (NOx, CO, NH3, SO2, various VOCs) and aerosols (BC, OC). Land emissions include fossil fuel and biofuel use, energy production and distribution, residential and commercial combustion, industry, transportation, waste treatment and disposal, solvent production and use, agriculture, and agricultural waste burning. Data sources are documented in the data directories.

INTERFACE:

```
MODULE RCP_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
!NONE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CLEANUP_RCP
      PUBLIC :: LOAD_RCP_EMISSIONS
      PUBLIC :: GET_RCP_EMISSION
      PUBLIC :: RCPNAME, RCPYEAR
      PUBLIC :: RCP_AIREMISS
```

PUBLIC DATA MEMBERS:

```
      ! Array to pass aircraft NOx emissions to SMVGEAR
      REAL*8,  PUBLIC, ALLOCATABLE :: RCP_AC_NOx(:,:,:)
   !PRIVATE DATA MEMBERS:
      REAL*4, ALLOCATABLE :: RCP_LAND(:,:,:)
      REAL*4, ALLOCATABLE :: RCP_AIR(:,:,:,:)
      REAL*4, ALLOCATABLE :: RCP_SHIP(:,:,:)
      CHARACTER(LEN=20)   :: RCPNAME
      INTEGER             :: RCPYEAR
      INTEGER             :: IDTRCP_LAND(20), IDTRCP_SHIP(20),
     &     IDTRCP_AIR(3)
```

REVISION HISTORY:

```
 14 Jun 2012 - C. Holmes   - Initial version
 31 Jul 2013 - M. Sulprizio- Added new array RCP_AC_NOx to pass aircraft
                             emissions to SMVGEAR. The array EMIS_AC_NOx
                             was removed with the obsolete aircraft_nox_mod.F
                             when AEIC aircraft emissions were added.
```

1.99.1 load_rcp_emissions

Subroutine LOAD_RCP_EMISSIONS reads all RCP emissions at the beginning of each month. (cdh, 10/14/11)

INTERFACE:

```
      SUBROUTINE LOAD_RCP_EMISSIONS( Input_Opt )
```

USES:

```
      USE BPCH2_MOD,              ONLY : GET_TAU0, GET_RES_EXT
      USE DIRECTORY_MOD,          ONLY : DATA_DIR
      USE ERROR_MOD,              ONLY : GEOS_CHEM_STOP
      USE GIGC_Input_Opt_Mod,     ONLY : OptInput
      USE TIME_MOD,               ONLY : GET_MONTH
      USE TRACERID_MOD
      USE TRACER_MOD,             ONLY : TRACER_NAME
```

INPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
22 Jul 2013 - M. Sulprizio- Now copy LRCP, LRCPSHIP, LRCPAIR from Input_Opt
22 Jul 2013 - M. Sulprizio- Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.99.2 read_rcp_bpch

Subroutine READ_RCP_BPCH reads a BPCH file containing RCP data. (cdh, 10/14/11)

INTERFACE:

```
SUBROUTINE READ_RCP_BPCH( FILENAME, TYPE, TAU0 )
```

USES:

```
USE BPCH2_MOD,        ONLY : OPEN_BPCH2_FOR_READ
USE FILE_MOD,         ONLY : IU_FILE, IOERROR
USE TRANSFER_MOD,     ONLY : TRANSFER_2D
USE ERROR_MOD,        ONLY : ERROR_STOP
USE TRACERID_MOD           ! tracer ID numbers
USE CMN_SIZE_MOD           ! Size parameters
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(IN) :: FILENAME
INTEGER,          INTENT(IN) :: TYPE ! 1=LAND, 2=SHIP, 3=AIRCRAFT
REAL*8,OPTIONAL,  INTENT(IN) :: TAU0
```

REVISION HISTORY:

```
22 Jul 2013 - M. Sulprizio- Added ProTeX headers
```

1.99.3 rcp_airemiss

Subroutine RCP_AIREMISS populates EMIS_AC_NOx with aircraft NOx emissions. Also does diagnostics. (cdh, 10/14/11)

INTERFACE:

```
SUBROUTINE RCP_AIREMISS( State_Met )
```

USES:

```
USE DIAG_MOD,              ONLY : AD32_AC
USE ERROR_MOD,             ONLY : ERROR_STOP
USE GIGC_State_Met_Mod,    ONLY : MetState
USE TRACERID_MOD,          ONLY : IDTNO
USE CMN_DIAG_MOD                ! Diagnostic switches
USE CMN_SIZE_MOD                ! Size parameters
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
22 Jul 2013 - M. Sulprizio- Added ProTeX headers
```

1.99.4 total_anthro_rcp

Subroutine TOTAL_ANTHRO_RCP prints total RCP anthropogenic emissions each month. (cdh, 10/14/11)

INTERFACE:

```
SUBROUTINE TOTAL_ANTHRO_RCP( THISMONTH )
```

USES:

```
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : TRACER_MW_KG
USE TRACER_MOD,   ONLY : TRACER_NAME
USE ERROR_MOD,    ONLY : GEOS_CHEM_STOP

USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH
```

REVISION HISTORY:

```
22 Jul 2013 - M. Sulprizio- Added ProTeX headers
```

1.99.5 get_rcp_emission

Function GET_RCP_EMISSION retrieves the emissions of tracer N at grid location (I,J). Use LAND=.TRUE. or SHIP=.TRUE. or both to retrieve either land anthropogenic emissions, ship emissions, or their sum. "N" is the advected tracer index, i.e. the tracer index for STT. The function will return -1 if no emissions are found for that species. (cdh, 10/14/11)

INTERFACE:

```
FUNCTION GET_RCP_EMISSION( I, J, N, LAND, SHIP )
&         RESULT( EMISS )
```

USES:

```
USE TRACERID_MOD
USE ERROR_MOD,            ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)           :: I, J
INTEGER, INTENT(IN)           :: N     !GEOS-Chem advected tracer index
LOGICAL, INTENT(IN), OPTIONAL :: SHIP
LOGICAL, INTENT(IN), OPTIONAL :: LAND
```

REVISION HISTORY:

```
22 Jul 2013 - M. Sulprizio- Added ProTeX headers
```

1.99.6 init_rcp

Subroutine INIT_RCP allocates and zeroes all module arrays (cdh, 10/14/11)

INTERFACE:

```
SUBROUTINE INIT_RCP( Input_Opt )
```

USES:

```
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_Input_Opt_Mod, ONLY : OptInput

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
22 Jul 2013 - M. Sulprizio- Now copy LRCP, LRCPSHIP, LRCPAIR from Input_Opt
22 Jul 2013 - M. Sulprizio- Added ProTeX headers
```

1.99.7 cleanup_rcp

Subroutine CLEANUP_RCP deallocates all module arrays (cdh, 10/14/11)

INTERFACE:

```
SUBROUTINE CLEANUP_RCP
```

REVISION HISTORY:

```
22 Jul 2013 - M. Sulprizio- Added ProTeX headers
```

1.100 Fortran: Module Interface retro_mod

Module RETRO_MOD reads emissions from the RETRO emissions inventory

INTERFACE:

```
MODULE RETRO_MOD

IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
REAL*4, ALLOCATABLE :: RETRO_ALK4(:,:)
REAL*4, ALLOCATABLE :: RETRO_ACET(:,:)
REAL*4, ALLOCATABLE :: RETRO_MEK(:,:)
REAL*4, ALLOCATABLE :: RETRO_ALD2(:,:)
REAL*4, ALLOCATABLE :: RETRO_PRPE(:,:)
REAL*4, ALLOCATABLE :: RETRO_C3H8(:,:)
REAL*4, ALLOCATABLE :: RETRO_C2H6(:,:)
REAL*4, ALLOCATABLE :: RETRO_CH2O(:,:)
REAL*4, ALLOCATABLE :: RETRO_BENZ(:,:)
REAL*4, ALLOCATABLE :: RETRO_TOLU(:,:)
REAL*4, ALLOCATABLE :: RETRO_XYLE(:,:)
REAL*4, ALLOCATABLE :: RETRO_C2H4(:,:)
REAL*4, ALLOCATABLE :: RETRO_C2H2(:,:)
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_RETRO
PUBLIC  :: EMISS_RETRO
PUBLIC  :: GET_RETRO_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: INIT_RETRO
PRIVATE :: READ_RETRO
PRIVATE :: TOTAL_ANTHRO_Tg
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial version
18 Aug 2011 - D. Millet   - Partition ketones into 25% MEK and 75% ACET
18 Aug 2011 - D. Millet   - Remove call to GET_ANNUAL_SCALAR
22 Aug 2011 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
22 Mar 2012 - M. Payer    - RETRO C2H6 emissions are too low. Use
                            Yaping Xiao's C2H6 emissions instead.
```

1.100.1 read_retro

Subroutine READ_RETRO reads a BPCH file created from RETRO data. The data has units of [atoms C/cm2/s].

INTERFACE:

```
 SUBROUTINE READ_RETRO( FILENAME, ALK4, ACET, MEK,  ALD2, PRPE,
&                       C3H8,     C2H6, CH2O, BENZ, TOLU, XYLE,
&                       C2H4,     C2H2                          )
```

USES:

```
USE BPCH2_MOD,        ONLY : OPEN_BPCH2_FOR_READ
USE FILE_MOD,         ONLY : IOERROR
USE inquireMod,       ONLY : findFreeLUN
USE TRANSFER_MOD,     ONLY : TRANSFER_2D
USE SCALE_ANTHRO_MOD, ONLY : GET_ANNUAL_SCALAR
USE TIME_MOD,         ONLY : GET_YEAR
USE CMN_SIZE_MOD           ! Size parameters
USE CMN_O3_MOD             ! FSCLYR
```

INPUT PARAMETERS:

```
! Name of file to read
CHARACTER(LEN=*), INTENT(IN)    :: FILENAME
```

INPUT/OUTPUT PARAMETERS:

```
! RETRO emissions for various VOC species [molec/cm2/s]
REAL*4,           INTENT(INOUT) :: ALK4(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: ACET(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: MEK (IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: ALD2(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: PRPE(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: C3H8(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: CH2O(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: C2H6(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: BENZ(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: TOLU(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: XYLE(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: C2H4(IIPAR,JJPAR)
REAL*4,           INTENT(INOUT) :: C2H2(IIPAR,JJPAR)
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial Version
18 Aug 2011 - D. Millet   - Remove call to GET_ANNUAL_SCALAR
22 Aug 2011 - R. Yantosca - Added ProTeX headers
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
```

1.100.2 TOTAL_ANTHRO_Tg

Subroutine TOTAL_ANTHRO_Tg to print total RETRO anthropogenic VOC emissions each month in [Tg C].

INTERFACE:

```
SUBROUTINE TOTAL_ANTHRO_Tg( THISMONTH )
```

USES:

```
USE GRID_MOD,     ONLY : GET_AREA_CM2
USE TRACER_MOD,   ONLY : TRACER_MW_KG
USE TRACERID_MOD, ONLY : IDTALK4, IDTMEK,  IDTPRPE, IDTC3H8
USE TRACERID_MOD, ONLY : IDTCH2O, IDTC2H6, IDTBENZ, IDTTOLU
USE TRACERID_MOD, ONLY : IDTXYLE, IDTC2H4, IDTC2H2
USE TRACERID_MOD, ONLY : IDTACET, IDTALD2
USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Current month
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial Version
22 Aug 2011 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
22 Mar 2012 - M. Payer    - Remove print for C2H6 emissions
```

1.100.3 get_retro_anthro

Function GET_RETRO_ANTHRO returns the monthly average anthropogenic VOC emissions at GEOS-Chem grid box (I,J). Data will be returned in units of [atoms C/cm2/s].

INTERFACE:

```
FUNCTION GET_RETRO_ANTHRO( I, J, N ) RESULT( RETRO )
```

USES:

```
USE TRACERID_MOD, ONLY : IDTALK4, IDTMEK,  IDTPRPE, IDTC3H8
USE TRACERID_MOD, ONLY : IDTCH2O, IDTC2H6, IDTBENZ, IDTTOLU
USE TRACERID_MOD, ONLY : IDTXYLE, IDTC2H4, IDTC2H2
USE TRACERID_MOD, ONLY : IDTACET, IDTALD2
USE CMN_SIZE_MOD       ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I   ! GEOS-Chem longitude index
INTEGER, INTENT(IN) :: J   ! GEOS-Chem latitude index
INTEGER, INTENT(IN) :: N   ! GEOS-Chem tracer index
```

RETURN VALUE:

```
REAL*8              :: RETRO   ! RETRO emissions [mole
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial Version
18 Aug 2011 - D. Millet   - Partition RETRO ketones into 75% acetone
                            and 25% MEK
22 Mar 2012 - M. Payer    - RETRO C2H6 emissions are too low. Use
                            Yaping Xiao's C2H6 emissions instead.
```

1.100.4 init_retro

Subroutine INIT_RETRO allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_RETRO( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
08 Mar 2011 - W. Reinhart - Initial Version
22 Aug 2011 - R. Yantosca - Added ProTeX headers
```

1.100.5 cleanup_retro

Subroutine CLEANUP_RETRO deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_RETRO
```

REVISION HISTORY:

```
    08 Mar 2011 - W. Reinhart - Initial Version
    22 Aug 2011 - R. Yantosca - Added ProTeX headers
```

1.101 Fortran: Module Interface RnPbBe_mod

Module RnPbBe_MOD contains variables and routines used for the 222Rn-210Pb-7Be simulation. (hyl, swu, bmy, 6/14/01, 8/4/06)

INTERFACE:

```
      MODULE RnPbBe_MOD
```

USES:

```
      USE inquireMod, ONLY : findFreeLUN

      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC  :: EMISSRnPbBe
      PUBLIC  :: CHEMRnPbBe
      PUBLIC  :: SLQ
```

PRIVATE MEMBER FUNCTIONS:

```
      PRIVATE :: READ_7Be
      PRIVATE :: CORRECT_STE
```

REMARKS:

```
    References:
    ============================================================================
    (1 ) Liu,H., D.Jacob, I.Bey, and R.M.Yantosca, Constraints from 210Pb
         and 7Be on wet deposition and transport in a global three-dimensional
         chemical tracer model driven by assimilated meteorological fields,
         JGR, 106, D11, 12,109-12,128, 2001.
    (2 ) Jacob et al.,Evaluation and intercomparison of global atmospheric
         transport models using Rn-222 and other short-lived tracers,
         JGR, 1997 (102):5953-5970
    (3 ) Dorothy Koch, JGR 101, D13, 18651, 1996.
    (4 ) Lal, D., and B. Peters, Cosmic ray produced radioactivity on the
         Earth. Handbuch der Physik, 46/2, 551-612, edited by K. Sitte,
         Springer-Verlag, New York, 1967.
```

REVISION HISTORY:

```
14 Jun 2001 - H. Liu      - Initial version
(1 ) Added existing routines to this module (bmy, 6/14/01)
(2 ) Updated comments (bmy, 9/4/01)
(3 ) Eliminate AVGF; redimensioned XTRA2 (bmy, 9/25/01)
(4 ) Replace references to PW(I,J) with P(I,J) (bmy, 10/3/01)
(5 ) Remove obsolete code from 9/01 and 10/01 (bmy, 10/23/01)
(6 ) Removed duplicate variable declarations (bmy, 11/15/01)
(7 ) Now read files from DATA_DIR/RnPbBe_200203/ directory.
      Also updated comments. (bmy, 3/29/02)
(8 ) Incorporated latest changes from Hongyu Liu.  Also split off the
      code to read in the 7Be emissions into a separate routine.
      Add parallel DO-loops in several places.  Cleaned up DRYFLXRnPbBe,
      and now make sure ND44 accurately represents the drydep fluxes
      of 210Pb and 7Be. (hyl, bmy, 8/7/02)
(9 ) Now reference AD from "dao_mod.f".  Now references "error_mod.f".
      Moved routine DRYFLXRnPbBe into "drydep_mod.f".  (bmy, 1/27/03)
(10) Now references the new "time_mod.f" (bmy, 2/11/03)
(11) Bug fix in EMISSRnPbBe -- take abs( lat) for 7Be emiss. (bmy, 6/10/03)
(12) Bug fix in EMISSRnPbBe -- shut off 222Rn emissions in polar regions
      (swu, bmy, 10/28/03)
(13) Now references "directory_mod.f", "logical_mod.f", and "tracer_mod.f"
      (bmy, 7/20/04)
(14) Now modified for GCAP and GEOS-5 met fields (swu, bmy, 5/24/05)
(15) Now references "tropopause_mod.f"
(16) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
19 Nov 2010 - R. Yantosca - Added ProTeX headers
08 Nov 2011 - R. Yantosca - Prevent out-of-bounds errors in diagnostics
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use routines from the new grid_mod.F90
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.101.1 read_7Be

Subroutine READ_7Be reads the 7Be emissions from Lal & Peters on 33 pressure levels. This only needs to be done on the very first timestep.

INTERFACE:

```
SUBROUTINE READ_7BE
```

USES:

```
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE FILE_MOD,      ONLY : IOERROR
USE CMN_SIZE_MOD        ! Size parameters
```

REVISION HISTORY:

```
07 Aug 2002 - H. Liu - Initial version
(1 ) This code was split off from routine EMISSRnPbBe below. (bmy, 8/7/02)
(2 ) Now reference DATA_DIR from "directory_mod.f" (bmy, 7/19/04)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
```

1.101.2 correct_ste

Subroutine CORRECT_STE reduces the emission of 210Pb and/or 7Be in the stratosphere, to correct for too fast STE in the GEOS-CHEM model.

INTERFACE:

```
SUBROUTINE CORRECT_STE( EMISSION )
```

INPUT PARAMETERS:

```
! Arguments
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8, INTENT(INOUT) :: EMISSION   ! Emissions to be corrected [kg]
```

REVISION HISTORY:

```
07 Aug 2002 - H. Liu - Initial version
(1 ) Now updated for GCAP met fields (swu, bmy, 5/24/05)
(2 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.101.3 emissRnPbBe

Subroutine EMISSRnPbBe emits 222Rn and 7Be into the tracer array STT.

INTERFACE:

```
SUBROUTINE EMISSRnPbBe( am_I_Root, Input_Opt,
&                       State_Met, State_Chm, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD01
```

```
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE GRID_MOD,           ONLY : GET_YMID
      USE GRID_MOD,           ONLY : GET_YEDGE
      USE TIME_MOD,           ONLY : GET_TS_EMIS
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
      USE PRESSURE_MOD,       ONLY : GET_PCENTER
      USE VDIFF_PRE_MOD,      ONLY : EMIS_SAVE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    28 May 1999 - I. Bey - Initial version
    (1 ) Also added Hongyu's code for emission of Be7 (bmy, 3/22/99)
    (2 ) Now trap I/O errors with subroutine IOERROR (bmy, 5/28/99)
    (3 ) Eliminate obsolete code and ND63 diagnostic (bmy, 4/12/00)
    (4 ) Now reference TS from "dao_mod.f" instead of from common block
         header file "CMN_TS". (bmy, 6/23/00)
    (5 ) Cosmetic changes (bmy, 7/12/00)
    (6 ) Now use IOS /= 0 criterion to trap both I/O errors and EOF
         condition. (bmy, 9/13/00)
    (7 ) Added to module "RnPbBe_mod.f".  Also updated comments and made
         cosmetic changes. (bmy, 6/14/01)
    (8 ) Replace PW(I,J) with P(I,J) (bmy, 10/3/01)
    (9 ) Now reference DATA_DIR from "CMN_SETUP".  Added FILENAME variable.
         Now read "7Be.Lal" file from DATA_DIR/RnPbBe_200203/ directory.
         (bmy, 3/29/02)
    (10) Add diagnostics for Rn/Be emissions.  Also cleaned up some old code
         and added parallel DO-loops.  Correct for S-T exchange for 7Be
         emissions. Updated comments, cosmetic changes. (hyl, 8/6/02)
    (11) Now reference routine GET_PCENTER from "pressure_mod.f", which
         returns the correct "floating" pressure. (dsa, bdf, bmy, 8/20/02)
    (12) Now reference AD from "dao_mod.f".  Now make FIRSTEMISS a local SAVEd
         variable instead of an argument.  (bmy, 1/27/03)
```

```
(13) Now use routine GET_YMID from "grid_mod.f" instead of common block
     variable YLMID.  Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2
     of "grid_mod.f".  Now use routine GET_TS_EMIS from time_mod.
     (bmy, 2/11/03)
(14) Bug fix: take the absolute value of latitude -- this was a bug when
     implementing the GET_YMID function from v5-04. (bmy, 6/10/03)
(15) Now reference GET_YEDGE from "grid_mod.f".
(16) Bug fix: the Rn emission in antarctic area in the original code would
     lead to enormously hight Rn concentrations there, esp. after boundary
     layer mixing.  Now apply different emissions over land and water,
     and also shut off emissions poleward of 70 deg. (swu, bmy, 10/28/03)
(17) Now reference LEMIS from "logical_mod.f".  Now reference STT and
     N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
(18) Remove reference to CMN; it's obsolete.  Now use inquiry functions
     from "tropopause_mod.f" to diagnose strat boxes. (bmy, 8/15/05)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
08 Nov 2011 - R. Yantosca - Prevent out-of-bounds errors in diagnostics
01 Mar 2012 - R. Yantosca - Now use functions GET_AREA_CM2(I,J,L) and
                            GET_YEDGE(I,J,L) from the new grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
25 Mar 2013 - R. Yantosca - Now use fields from Input_Opt
01 Aug 2013 - R. Yantosca - Modified for use with non-local PBL mixing
```

1.101.4 chemRnPbBe

Subroutine CHEMRnPbBe performs loss chemistry on 222Rn, 210Pb, and 7Be.

INTERFACE:

```
SUBROUTINE CHEMRnPbBe( am_I_Root, Input_Opt,
&                      State_Met, State_Chm, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD01, AD02
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_TS_CHEM
USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
31 Oct 1999 - H. Liu - Initial version
(1 ) Now use F90 syntax (bmy, hyl, 3/22/99)
(2 ) Add FIRSTCHEM as an argument.  Only compute the exponential terms
      when FIRSTCHEM = .TRUE., and save the values for later use
      (bmy, 3/24/99)
(3 ) Cosmetic changes (bmy, 10/13/99)
(4 ) Eliminate obsolete code and ND63 diagnostic (bmy, 4/12/00)
(5 ) Cosmetic changes (bmy, 7/12/00)
(6 ) Added to module "RnPbBe_mod.f".  Also updated comments
      and made cosmetic changes. (bmy, 6/14/01)
(7 ) Add diagnostics for Rn/Be emissions.  Also cleaned up some old code
      and added parallel DO-loops.  Updated comments. (hyl, 8/6/02)
(8 ) Now make FIRSTCHEM a local SAVEd variable.  (bmy, 1/27/03)
(9 ) Now use function GET_TS_CHEM from "time_mod.f" (bmy, 2/11/03)
(10) Now references STT and N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
(11) Remove reference to CMN; it's obsolete.  Now use inquiry functions
      from "tropopause_mod.f" to diagnose strat boxes. (bmy, 8/15/05)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
08 Nov 2011 - R. Yantosca - Prevent out-of-bounds errors in diagnostics
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.101.5 slq

Subroutine SLQ is an interpolation subroutine from a Chinese reference book (says Hongyu Liu).

INTERFACE:

```
SUBROUTINE SLQ( X, Y, Z, N, M, U, V, W )
```

INPUT PARAMETERS:

```
INTEGER :: N        ! First dimension of Z
INTEGER :: M        ! Second dimension of Z
REAL*8  :: X(N)     ! X-axis coordinate on original grid
REAL*8  :: Y(M)     ! Y-axis coordinate on original grid
REAL*8  :: Z(N,M)   ! Array of data on original grid
REAL*8  :: U        ! X-axis coordinate for desired interpolated value
REAL*8  :: V        ! Y-axis coordinate for desired interpolated value
```

OUTPUT PARAMETERS:

```
REAL*8  :: W        ! Interpolated value of Z array, at coords (U,V)
```

REMARKS:

REVISION HISTORY:

```
17 Mar 1998 - H. Liu      - Initial version
(1 ) Added to "RnPbBe_mod.f" (bmy, 7/16/01)
(2 ) Removed duplicate definition of IQ.  Added comments. (bmy, 11/15/01)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.102 Fortran: Module Interface scale_anthro_mod

Module SCALE_ANTHRO_MOD contains routines to scale anthropogenic emissions from a base year to a simulation year.

INTERFACE:

```
MODULE SCALE_ANTHRO_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: GET_ANNUAL_SCALAR
PUBLIC  :: GET_ANNUAL_SCALAR_1x1
PUBLIC  :: GET_ANNUAL_SCALAR_05x0666_NESTED
```

REVISION HISTORY:

```
28 Jan 2009 - A. v. Donkelaar and P. Le Sager - Initial Version
```

REMARKS:

```
(1 ) Add GET_ANNUAL_SCALAR_05x0666_NESTED_CH for nested grid simulations
     over China. (tmf, 12/3/09)
(2 ) Renamed consistently variables: name depends on relation of variable
     to BASE or TARGET year. New data directory to account for updated
     scale factors for 1985-1989 (phs, 5/7/09)
(3 ) Adjusted GET_ANNUAL_SCALAR_05x0666_CH for new scalar format and
     renamed to GET_ANNUAL_SCALAR_05x0666 (amv, 10/29/2009)
18 Dec 2009 - Aaron van D - Updated scale factors thru 2006
18 Dec 2009 - Aaron van D - Updated routine GET_ANNUAL_SCALAR_05x0666_NESTED
10 Aug 2011 - D. Millet   - Now use updated scale factor file for CO, which
                            corrects a problem over Botswana/S. Africa
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.102.1 get_annual_scalar

Subroutine GET_ANNUAL_SCALAR returns annual scale factors to convert B_YEAR (base year) to T_YEAR (simulation year), on the current model resolution.

INTERFACE:

```
SUBROUTINE GET_ANNUAL_SCALAR( TRACER, B_YEAR, T_YEAR, AS )
```

USES:

```
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE FILE_MOD,       ONLY : IOERROR, IU_FILE
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1

USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)     :: TRACER           ! Tracer number
INTEGER, INTENT(IN)     :: B_YEAR           ! Base year of emissions
INTEGER, INTENT(IN)     :: T_YEAR           ! Target year of emissions
```

INPUT/OUTPUT PARAMETERS:

```
REAL*4,  INTENT(INOUT)  :: AS(IIPAR,JJPAR)  ! Scale factor array
```

REVISION HISTORY:

```
28 Jan 2009 - A. v. Donkelaar and P. Le Sager - Initial Version
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
07 Jun 2012 - M. Payer    - Fixed minor bugs in map_a2a calls (M. Cooper)
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.102.2 get_annual_scalar_1x1

Subroutine GET_ANNUAL_SCALAR_1x1 returns annual scale factors to convert B_YEAR (base year) to T_YEAR (target year), on the 1x1 GEOS-Chem grid.

INTERFACE:

```
SUBROUTINE GET_ANNUAL_SCALAR_1x1( TRACER, B_YEAR, T_YEAR, AS_1x1 )
```

USES:

```
USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1
USE BPCH2_MOD,     ONLY : GET_TAU0, READ_BPCH2

USE CMN_SIZE_MOD                          ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: TRACER            ! Tracer number
INTEGER, INTENT(IN)    :: B_YEAR            ! Base year of emissions
INTEGER, INTENT(IN)    :: T_YEAR            ! Target year of emissions
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8,   INTENT(OUT)  :: AS_1x1(I1x1,J1x1)  ! Scale factor array
```

REVISION HISTORY:

```
28 Jan 2009 - A. v. Donkelaar and P. Le Sager - Initial Version
```

REMARKS:

```
(1) Scaling factors are for years between 1985 and 2005, on the GEOS-Chem
     1x1 grid (phs, 3/10/08)
18 Dec 2009 - Aaron van D - Updated scale factors through 2006,
                            changed to new, directory, reset year limits
18 Dec 2009 - Aaron van D - Reformated scale factors to a single file for
                            all years, made necessary input changes
10 Aug 2011 - D. Millet   - Now use updated scale factor file for CO, which
                            corrects a problem over Botswana/S. Africa
25 Apr 2012 - M. Payer    - Add kludge to set TARG_YEAR=1985 for 1986 thru
                            1989 (B. Yantosca)
02 Jul 2013 - M. Payer    - Extend scale factors to 2010 for USA and Canada
                            (A. van Donkelaar)
```

1.102.3 get_annual_scalar_05x0666_nested

Subroutine GET_ANNUAL_SCALAR_05x0666_NESTED returns annual scale factors to convert B_YEAR (base year) to T_YEAR (target year), on the 0.5x0.666 GEOS-Chem grid for nested China domain.

INTERFACE:

```
      SUBROUTINE GET_ANNUAL_SCALAR_05x0666_NESTED
     &                     ( TRACER, B_YEAR, T_YEAR, AS )
```

USES:

```
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A

      USE CMN_SIZE_MOD         ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)     :: TRACER
      INTEGER, INTENT(IN)     :: B_YEAR
      INTEGER, INTENT(IN)     :: T_YEAR
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*4,   INTENT(INOUT) :: AS(IIPAR,JJPAR)
```

REVISION HISTORY:

```
    28 Jan 2009 - A. v. Donkelaar and P. Le Sager - Initial Version
    12 Mar 2009 - T-M. Fu     - Initial Version
    03 Nov 2009 - Aaron van D - rewritten to employ GET_ANNUAL_SCALAR_1x1
                                and regrid.
    18 Dec 2009 - Aaron van D - Renamed to GET_ANNUAL_SCALAR_05x0666_NESTED
    18 Dec 2009 - Aaron van D - Rewrote GET_ANNUAL_SCALAR_05x0666_NESTED to
                                retrieve and regrid scale factors by calling
                                GET_ANNUAL_SCALAR_1x1 and regridding on fly
    06 Apr 2012 - M. Payer    - Changed regrid algorithm to map_a2a (M. Cooper)
    07 Jun 2012 - M. Payer    - Fixed minor bugs in map_a2a calls (M. Cooper)
```

REMARKS:

```
    (1) Scaling factors are for years between 1985 and 2005, on the GEOS-Chem
        0.5x0.666 grid for China domain (tmf, 3/5/09)
    24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
    03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.103 Fortran: Module Interface seasalt_mod

Module SEASALT_MOD contains arrays and routines for performing either a coupled chemistry/aerosol run or an offline seasalt aerosol simulation. Original code taken from Mian Chin's GOCART model and modified accordingly. (bec, rjp, bmy, 6/22/00, 11/23/09)

INTERFACE:

```
      MODULE SEASALT_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: CHEMSEASALT
      PUBLIC :: EMISSSEASALT
      PUBLIC :: CLEANUP_SEASALT
      PUBLIC :: GET_ALK
      PUBLIC :: INIT_SEASALT
```

PUBLIC DATA MEMBERS:

```
      PUBLIC :: SALT_V
      PUBLIC :: DMID
```

REMARKS:

```
   Seasalt aerosol species: (1) Accumulation mode (usually 0.1 -  0.5 um)
                            (2) Coarse mode       (usually 0.5 - 10.0 um)
                                                                          .
   NOTE: You can change the bin sizes for accumulation mode and coarse
         mode seasalt in the "input.geos" file in v7-yy-zz and higher.
   References:
   ============================================================================
   (1 ) Chin, M., P. Ginoux, S. Kinne, B. Holben, B. Duncan, R. Martin,
         J. Logan, A. Higurashi, and T. Nakajima, "Tropospheric aerosol
         optical thickness from the GOCART model and comparisons with
         satellite and sunphotometers measurements", J. Atmos Sci., 2001.
   (2 ) Gong, S., L. Barrie, and J.-P. Blanchet, "Modeling sea-salt
         aerosols in the atmosphere. 1. Model development", J. Geophys. Res.,
         v. 102, 3805-3818, 1997.
```

REVISION HISTORY:

```
   (1 ) Now references "logical_mod.f" and "tracer_mod.f".  Comment out
         SS_SIZE, this has been replaced by SALA_REDGE_um and SALC_REDGE_um
         from "tracer_mod.f".  Increased NR_MAX to 200. (bmy, 7/20/04)
   (2 ) Added error check in EMISSSEASALT (bmy, 1/20/05)
   (3 ) Now references "pbl_mix_mod.f" (bmy, 2/22/05)
   (4 ) Added routine GET_ALK to account for alkalinity. (bec, bmy, 4/13/05)
   (5 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
   (6 ) Now only call dry deposition routine if LDRYD=T (bec, bmy, 5/23/06)
   (7 ) Remove unused variables from GET_ALK.  Also fixed variable declaration
         bug in WET_SETTLING. (bec, bmy, 9/5/06)
   (8 ) Extra error check for low RH in WET_SETTLING (phs, 6/11/08)
   (9 ) Bug fix to remove a double-substitution in GET_ALK (bec, bmy, 7/18/08)
   (10) Save surface emissions separately (emis_save) for non-local scheme.
         (ccc, 5/14/09)
   (11) Bug fixes in GET_ALK and SRCSALT (bec, lyj, bmy, 11/23/09)
   (12) Add size-resolved emission subroutine SRCSALT30 and reference to
```

```
      tomas_mod.f. (win, 7/17/09)
   22 Dec 2011 - M. Payer    - Added ProTeX headers
   16 Feb 2012 - R. Yantosca - Moved SRCSALT30 to end of module
   01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
   04 Mar 2013 - R. Yantosca - Now call INIT_SULFATE from the init stage
                               which facilitates connection to GEOS-5 GCM
   20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.103.1 chemseasalt

Subroutine CHEMSEASALT is the interface between the GEOS-CHEM main program and the seasalt chemistry routines that mostly calculates seasalt dry deposition (rjp, bmy, 1/24/02, 5/23/06)

INTERFACE:

```
      SUBROUTINE CHEMSEASALT( am_I_Root, Input_Opt,
     &                        State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE DRYDEP_MOD,         ONLY : DEPNAME
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE DRYDEP_MOD,         ONLY : NUMDEP
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TRACERID_MOD,       ONLY : IDTSALA
      USE TRACERID_MOD,       ONLY : IDTSALC
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Now reference STT from "tracer_mod.f".  Now references LPRT from
     "logical_mod.f" (bmy, 7/20/04)
(2 ) Now only call DRY_DEPOSITION if LDRYD=T (bec, bmy, 5/23/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
13 Nov 2012 - R. Yantosca - Now add Input_Opt, RC arguments for GIGC
15 Nov 2012 - M. Payer    - Now pass met fields via State_Met object
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.103.2 wet_settling

Subroutine WET_SETTLING performs wet settling of sea salt. (bec, rjp, bmy, 4/20/04, 6/11/08)

INTERFACE:

```
      SUBROUTINE WET_SETTLING( am_I_Root, Input_Opt, State_Met,
     &                         TC,        N,         RC         )
```

USES:

```
      USE CMN_GCTM_MOD
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PRESSURE_MOD,       ONLY : GET_PCENTER
      USE TRACERID_MOD,       ONLY : IDTSALA
      USE TRACERID_MOD,       ONLY : IDTSALC
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE GRID_MOD,           ONLY : GET_AREA_CM2
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN)    :: N                    ! 1=accum mode;
                                                            ! 2=coarse mode
      LOGICAL,        INTENT(IN)    :: am_I_Root            ! Root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt            ! Input Options
      TYPE(MetState), INTENT(IN)    :: State_Met            ! MeteorologyState
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Sea salt [kg]
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC                    ! Success/failure
```

REVISION HISTORY:

```
(1 ) Now references SALA_REDGE_um and SALC_REDGE_um from "tracer_mod.f"
     (bmy, 7/20/04)
(2 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(3 ) Bug fix: DTCHEM has to be REAL*8, not integer. (bmy, 9/7/06)
(4 ) Now limit relative humidity to [tiny(real*8),0.99] range for DLOG
      argument (phs, 5/1/08)
(5 ) Update sea salt density calculation using Tang et al. (1997) (bec,
     jaegle 5/11/11)
(6 ) Update hygroscopic growth for sea salt using Lewis and Schwartz (2006)
     and and density calculation based on Tang et al. (1997) (bec, jaegle
     5/11/11)
(7 ) Itegrate settling velocity over entire size distribution (jaegle
     5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%XNUMOL(1:N_TRACERS)
12 Jun 2013 - R. Yantosca - Bug fix: SALT_MASS needs to be !OMP PRIVATE
12 Jun 2013 - R. Yantosca - Reformatted some comments for clarity
```

1.103.3 dry_deposition

Subroutine DRY_DEPOSITION computes the loss of sea salt by dry deposition at the surface, using an implicit method (bec, rjp, bmy, 4/20/04)

INTERFACE:

```
SUBROUTINE DRY_DEPOSITION( am_I_Root, Input_Opt, TC, N, RC )
```

USES:

```
USE CMN_GCTM_MOD
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD44
USE DRYDEP_MOD,         ONLY : DEPSAV
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE TRACERID_MOD,       ONLY : IDTSALA
USE TRACERID_MOD,       ONLY : IDTSALC
```

```
      USE TIME_MOD,           ONLY : GET_MONTH
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE GRID_MOD,           ONLY : GET_AREA_CM2
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root             ! Is this root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt             ! Input Options
      INTEGER,        INTENT(IN)    :: N                     ! 1=accum; 2=coarse
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Sea salt [kg]
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC                    ! Success?
```

REVISION HISTORY:

```
    (1 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
    (2 ) Update to calculate the drydep throughout the entire PBL instead of
         just at the surface. This is more in line with what is done in
         dry_dep.f. This is only used if LNLPBL is turned off (or for GEOS-4 and
         prior met fields). (jaegle 5/11/11)
   22 Dec 2011 - M. Payer    - Added ProTeX headers
   01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
   20 Nov 2012 - R. Yantosca - Bug fix: use temp array to archive ND44 drydep
                               then save back to AD44 outside parallel loop
   20 Nov 2012 - R. Yantosca - Now loop from 1..LLPAR for GIGC.  Remove
                               references to GET_PBL_MAX_L.
   19 Mar 2013 - R. Yantosca - Now copy Input_Opt%XNUMOL(1:N_TRACERS)
```

1.103.4 emissseasalt

Subroutine EMISSSEASALT is the interface between the GEOS-Chem model and the SEASALT emissions routines in "seasalt_mod.f". (bec, rjp, bmy, 3/24/03, 2/22/05)

INTERFACE:

```
      SUBROUTINE EMISSSEASALT( am_I_Root, Input_Opt, State_Met,
     &                         State_Chm, RC,        SSA_Br2    )
```

USES:

```
      USE CMN_SIZE_MOD
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
```

```
      USE TRACERID_MOD,       ONLY : IDTSALA, IDTSALC
      USE VDIFF_PRE_MOD,      ONLY : emis_save ! (Lin, 03/31/09)
#if   defined( TOMAS )
      USE TRACERID_MOD,       ONLY : IDTNK1 ! (win, 7/17/09)
      USE TRACERID_MOD,       ONLY : IDTSS1 ! (win, 7/17/09)
      USE TOMAS_MOD,          ONLY : IBINS  ! (win, 7/17/09)
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,           INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput),    INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState),    INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState),    INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,           INTENT(OUT)   :: RC          ! Success or failure?
      REAL*8,  OPTIONAL, INTENT(OUT)   :: SSA_Br2(IIPAR, JJPAR)
```

REVISION HISTORY:

```
   (1 ) Now references LPRT from "logical_mod.f" and STT from "tracer_mod.f".
        (bmy, 7/20/04)
   (2 ) Now make sure IDTSALA, IDTSALC are nonzero before calling SRCSALT.
        (bmy, 1/26/05)
   (3 ) Remove reference to header file "CMN" (bmy, 2/22/05)
   (4 ) Now call INIT_SEASALT on the first timestep.  Also initialize ALK_EMIS
        and N_DENS on each timestep. (bec, bmy, 4/13/05)
   (5 ) Call SRCSALT30 for size-resolved sea-salt emission (win, 7/17/09)
   22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.103.5 srcsalt

Subroutine SRCSALT is based on the sea salt source function of Gong (2003) with the empirical sea surface temperature (SST) dependence of Jaegle et al. (2011). This SST dependence was derived based on comparisons to cruise observations of coarse mode sea salt mass concentrations.
Contact: Lyatt Jaegle (jaegle@uw.edu)

INTERFACE:

```
      SUBROUTINE SRCSALT( TC, SSA_Br2, N, State_Met )
```

USES:

```
      USE DAO_MOD,            ONLY : IS_WATER
      USE DIAG_MOD,           ONLY : AD08
      USE ERROR_MOD,          ONLY : DEBUG_MSG, ERROR_STOP
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_M2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
      USE SSA_BROMINE_MOD,    ONLY : EMISS_SSA_BROMINE
      USE TIME_MOD,           ONLY : GET_TS_EMIS
      USE TRACER_MOD,         ONLY : SALA_REDGE_um, SALC_REDGE_um
      USE TRACER_MOD,         ONLY : XNUMOL

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! ND44, ND08
      USE CMN_GCTM_MOD             ! PI

      !%%% NOTE: Keep this here as a placeholder, but we should
      !%%% eventually replace this with Input_Opt%LNLPBL
      USE LOGICAL_MOD,         ONLY : LNLPBL
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN)  :: N  ! N=1 is accum mode; N=2 is coarse mode
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,       INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Sea salt [v/v]
```

OUTPUT PARAMETERS:

```
      !jpp, 3/2/10
      REAL*8,       INTENT(OUT)   :: SSA_Br2(IIPAR,JJPAR)  ! Br2 sea salt emissions
```

REMARKS:

```
    References:
    ============================================================================
    (1 ) Chin, M., P. Ginoux, S. Kinne, B. Holben, B. Duncan, R. Martin,
         J. Logan, A. Higurashi, and T. Nakajima, "Tropospheric aerosol
         optical thickness from the GOCART model and comparisons with
         satellite and sunphotometers measurements", J. Atmos Sci., 2001.
    (2 ) Gong, S., L. Barrie, and J.-P. Blanchet, "Modeling sea-salt
         aerosols in the atmosphere. 1. Model development", J. Geophys. Res.,
         v. 102, 3805-3818, 1997.
    (3 ) Gong, S. L., "A parameterization of sea-salt aerosol source function
         for sub- and super-micron particles", Global Biogeochem.  Cy., 17(4),
         1097, doi:10.1029/2003GB002079, 2003.
    (4 ) Jaegle, L., P.K. Quinn, T.S. Bates, B. Alexander, J.-T. Lin, "Global
         distribution of sea salt aerosols: New constraints from in situ and
         remote sensing observations", Atmos. Chem. Phys., 11, 3137-3157,
         doi:10.5194/acp-11-3137-2011.
```

REVISION HISTORY:

```
(1 ) Now references SALA_REDGE_um and SALC_REDGE_um from "tracer_mod.f"
     (bmy, 7/20/04)
(2 ) Now references GET_FRAC_OF_PBL and GET_PBL_TOP_L from "pbl_mix_mod.f".
     Removed reference to header file CMN.  Removed reference to
     "pressure_mod.f".  (bmy, 2/22/05)
(3 ) Now also compute alkalinity and number density of seasalt emissions.
     (bec, bmy, 4/13/05)
(4 ) Now references XNUMOL & XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(5 ) The source function is for wet aerosol radius (RH=80%, with a radius
     twice the size of dry aerosols) so BETHA should be set to 2
     instead of 1.  Also now use LOG10 instead of LOG in the expressions
     for the seasalt base source, since we need the logarithm to the base
     10. (jaegle, bec, bmy, 11/23/09)
(6 ) Update to use the Gong (2003) source function (jaegle 5/11/11)
(7 ) Apply an empirical sea surface temperature dependence to Gong (2003)
    (jaegle 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.103.6 get_alk

Subroutine GET_ALK returns the seasalt alkalinity emitted at each timestep to sulfate_mod.f for chemistry on seasalt aerosols. (bec, 12/7/04, 11/23/09)

INTERFACE:

```
      SUBROUTINE GET_ALK( I, J, L, ALK1, ALK2, Kt1, Kt2, Kt1N, Kt2N,
     &                    State_Met )
```

USES:

```
      USE ERROR_MOD,          ONLY : IT_IS_NAN
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TRACER_MOD,         ONLY : SALA_REDGE_um, SALC_REDGE_um
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN)  :: I, J, L
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
      REAL*8, INTENT(OUT)  :: ALK1, ALK2           ! [kg]
      REAL*8, INTENT(OUT)  :: Kt1, Kt2, Kt1N, Kt2N ! [s-1]
```

REVISION HISTORY:

```
(1 ) Becky Alexander says we can remove AREA1, AREA2 (bec, bmy, 9/5/06)
(2 ) Bug fix to remove a double-substitution.  Replace code lines for
     TERM{123}A, TERM{123}B, TERM{123}AN, TERM{123}BN. (bec, bmy, 7/18/08)
(3 ) Updated hygroscopic growth parameters (bec, bmy, 11/23/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.103.7 init_seasalt

Subroutine INIT_SEASALT initializes and zeroes all module arrays (bmy, 4/26/04, 4/13/05)

INTERFACE:

```
SUBROUTINE INIT_SEASALT( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root
TYPE(OptInput), INTENT(IN)  :: Input_Opt
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC
```

REVISION HISTORY:

```
(1 ) Now exit if we have allocated arrays before.  Now also allocate
     ALK_EMIS & N_DENS.  Now reference CMN_SIZE. (bec, bmy, 4/13/05)
(2 ) Added SALT_V and DMID (jaegle 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
04 Mar 2013 - R. Yantosca - Now pass am_I_Root, Input_Opt, RC as arguments
 4 Mar 2013 - R. Yantosca - Now test for DEPSALA, DEPSALC here
```

1.103.8 cleanup_seasalt

Subroutine CLEANUP_SEASALT deallocates all module arrays (bmy, 4/26/04, 4/13/05)

INTERFACE:

```
SUBROUTINE CLEANUP_SEASALT
```

REVISION HISTORY:

```
(1 ) Now deallocates ALK_EMIS, N_DENS, SRC_N (bec, bmy, 4/13/05)
(2 ) Deallocated SALT_V and DMID (jaegle 5/11/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.103.9 srcsalt30

Subroutine SRCSALT30 emits sea-salt into the 30-bin sea-salt mass and aerosol number arrays. Sea-salt emission parameterization of Clarke et al. [2006] (win, 7/17/09)

INTERFACE:

```
SUBROUTINE SRCSALT30( TC1, TC2, State_Met )
```

USES:

```
USE CMN_SIZE_MOD             ! Size parameters
USE CMN_DIAG_MOD             ! ND59
USE DIAG_MOD,           ONLY : AD59_NUMB, AD59_SALT
USE ERROR_MOD,          ONLY : ERROR_STOP
USE ERROR_MOD,          ONLY : IT_IS_NAN
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_M2
USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
USE TIME_MOD,           ONLY : GET_TS_EMIS
USE TOMAS_MOD,          ONLY : IBINS, Xk
USE TRACERID_MOD             ! IDTNK1, IDTSS1
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
! TC1 : Aerosol number tracer array [no.]
! TC2 (REAL*8 ) : Sea salt tracer array [kg]
REAL*8,  INTENT(INOUT) :: TC1(IIPAR,JJPAR,LLPAR,IBINS)
REAL*8,  INTENT(INOUT) :: TC2(IIPAR,JJPAR,LLPAR,IBINS)
```

AUTHOR:

```
Contact: Win Trivitayanurak (win@cmu.edu)

Arguments as Input/Output:
============================================================================
```

REMARKS:

```
References:
============================================================================
(1 ) Clarke, A.D., Owens, S., Zhou, J. " An ultrafine sea-salt flux from
      breaking waves: Implications for CCN in the remote marine atmosphere"
      JGR, 2006
```

REVISION HISTORY:

```
(1 ) Originally from emisnaN3clarke.f in GISS GCM-II' (win, 7/18/07)
(2 ) Now partition emission throughout the PBL (win, 7/18/07)
(3 ) Add COEF to adjust emission in a 1x1 nested-grid (win, 4/27/08)
16 Feb 2012 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - A_M2 is now a scalar
```

1.104 Fortran: Module Interface soil_nox_mod

Module containing GEOS-Chem soil NOx emissions routines.

INTERFACE:

```
MODULE SOIL_NOx_MOD
```

USES:

```
USE CMN_SIZE_MOD

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: SOIL_NOX_EMISSION
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: SOILTEMP
PRIVATE :: SOILWET
PRIVATE :: SOILCRF
PRIVATE :: FERTADD
PRIVATE :: PULSING
```

AUTHOR:

```
Original codes from:
  HARVARD ATMOSPHERIC CHEMISTRY MODELING GROUP
  MODULE FOR SOIL NOX EMISSIONS
  by Yuhang Wang, Gerry Gardner, and Prof. Daniel Jacob
Updated model code:
  by  Rynda Hudman, Neil Moore, Randall Martin, and Bram Maasakkers
```

REMARKS:

```
The soil NOx code has been updated from the original implementation
of Yienger & Levy [1995] from  Wang et al., [1998] as summarized below.

Old:
ENOx   = f( T, biome, w/d)  x Pulse(precip) x canopy uptake + FERT

New:
ENOx   = f( T, biome, WFPS, Fert)  x Pulse(dryspell) x canopy uptake

1 - Update moisture treatment: soil moisture as a continuous variable
using WFPS rather than discrete wet/dry states and purely exponential
T impact (impact = -1. Tg N/yr)

2 - Update to Fertilizer:  new fertilizer maps including chemical and
manure fertilizer from Potter et al., [2010] distributed using MODIS EVI
seasonality, online-N deposition as a fertilizer source, and N-fertilizer
source subject to T, WFPS, and pulsing like other N (impact = +1.3 Tg N/yr)

3- Update Pulsing Scheme: Yan et al., [2005] (shorter, stronger pulses)
(impact = +1. Tg N/yr). Also added restart file containing dry spell
information to properly account for dry spell length in continuing runs.

References:
========================================================================
(1 ) Wang, Y., D.J. Jacob, and J.A. Logan,  Global simulation of
      tropospheric O3-NOx-hydrocarbon chemistry, 1. Model formulation,
      J. Geophys. Res., 103/D9, 10, 713-10,726, 1998.
(2 ) Yienger, J.J, and H. Levy, Empirical model of global soil-biogenic
      NOx emissions, J. Geophys. Res., 100, D6, 11,447-11464, June 20, 1995.
(3 ) Yan, X., T. Ohara, and H. Akimoto, Statistical modeling of global
      soil NOx emissions, Global Biogeochem. Cycles, 19, GB3019,
      doi:10.1029/2004GB002276, 2005.
(4 ) Potter, P., Ramankutty, N., Bennett, E., and Donner, S.:
      Characterizing the Spatial Patterns of Global Fertilizer Application
      and Manure Production, Earth Interactions, 14, 1-22,
      10.1175/2009EI288.1, 2010.
(5 ) Moore, N.E., Improving global bottom-up biogenic soil NOx inventories,
      Master's Thesis, Dalhousie University, 2007.
(6 ) Hudman, R.C., N.E. Moore, A.K. Mebust, R.V. Martin, A.R. Russell,
      L.C. Valin, and R.C Cohen, Steps toward a mechanistic model of global
      soil nitric oxide emissions: implementation and space
      based-constraints, Atmos. Chem. Phys., 12, 7779-7795,
      doi:10.5194/acp-12-7779-2012, 2012.
```

REVISION HISTORY:

```
17 Aug 2009 - R. Yantosca     - Columnized and cleaned up
```

```
17 Aug 2009 - R. Yantosca     - Added ProTeX headers
31 Jan 2011 - R. Hudman       - Added new code12259.perceus-ucb0
31 Jan 2011 - R. Hudman       - Updated headers
29 Aug 2012 - J.D. Maasakkers - Implemented Jacob and Bakwin CRF
29 Aug 2012 - J.D. Maasakkers - Adapted code to work with new (online
                                regridded) landfraction, climate and
                                fertilizer data
29 Aug 2012 - J.D. Maasakkers - Removed all unused Wang et al. code
                                (comments)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.104.1 soil_nox_emission

Subroutine SOIL_NOX_EMISSION computes the emission of soil and fertilizer NOx for the GEOS-Chem model.

INTERFACE:

```
      SUBROUTINE SOIL_NOx_EMISSION( TS_EMIS,   TK,
     &                              GWET,      SOILFRT,
     &                              GWET_PREV, DRYPERIOD,
     &                              PFACTOR,   SOILNOx,
     &                              DEPN,      FERTDIAG,
     &                              CLIM,      LANDFRAC,
     &                              RC,        SUNCOS,
     &                              U10M,      V10M,
     &     R_CANOPY,  LAI)
```

USES:

```
      USE GIGC_ERRCODE_MOD, ONLY : GIGC_SUCCESS
```

INPUT PARAMETERS:

```
      REAL*8,  INTENT(IN)  :: TS_EMIS     ! Emission timestep [min]
      REAL*8,  INTENT(IN)  :: TK          ! surface temperature [K]
      REAL*8,  INTENT(IN)  :: GWET        ! Top soil wetness [unitless]
      REAL*8,  INTENT(IN)  :: DEPN        ! Dry Dep Fert term [ng N/m2/s]
      REAL*8,  INTENT(IN)  :: SOILFRT     ! Fertilizer emissions [ng N/m2/s]
      REAL*4,  INTENT(IN)  :: CLIM(:)     ! CLIM(1), arid fraction
                                          ! CLIM(2), non-arid fraction
      REAL*4,  INTENT(IN)  :: LANDFRAC(:) ! Fraction of landtypes

      !Input parameters for the canopy reduction factor
      REAL*8,  INTENT(IN)  :: SUNCOS      ! Cosine of solar zenith angle
      REAL*8,  INTENT(IN)  :: U10M        ! E/W wind speed @ 10m altitude [m]
      REAL*8,  INTENT(IN)  :: V10M        ! N/S wind speed @ 10m altitude [m]
      REAL*8,  INTENT(IN)  :: R_CANOPY(:) ! Resist. of canopy to NOx [1/s]
      REAL*8,  INTENT(IN)  :: LAI         ! Leaf area indices [cm2/cm2]
```

OUTPUT PARAMETERS:

```
REAL*8,  INTENT(OUT) :: SOILNOx     ! Soil NOx emissions [molec/cm2/s]
REAL*4,  INTENT(OUT) :: GWET_PREV   ! Soil Moisture Prev timestep
REAL*4,  INTENT(OUT) :: DRYPERIOD   ! Dry period length in hours
REAL*4,  INTENT(OUT) :: PFACTOR     ! Pulsing Factor
REAL*8,  INTENT(OUT) :: FERTDIAG    ! Fert emissions [molec/cm2/s
INTEGER, INTENT(OUT) :: RC          ! Return code
```

REMARKS:

```
R_CANOPY is computed in routine GET_CANOPY_NOX of "canopy_nox_mod.f".
This was originally in the GEOS-Chem dry deposition code, but was split
off in order to avoid an ugly code dependency between the dry deposition
and soil NOx codes.

As of v9-02, this module uses the MODIS/Koppen biome types instead
of the Olson land type / biome type, making it different from the original
dry deposition code (J.D. Maasakkers)
```

REVISION HISTORY:

```
17 Aug 2009 - R. Yantosca - Columnized and cleaned up
17 Aug 2009 - R. Yantosca - Added ProTeX headers
31 Jan 2011 - R. Hudman   - New Model added
23 Oct 2012 - M. Payer    - Now reference Headers/gigc_errcode_mod.F90
```

1.104.2 soiltemp

Function SOILTEMP computes the temperature-dependent term of the soil NOx emissions in ng N/m2/s and converts to molec/cm2/s

INTERFACE:

```
FUNCTION SOILTEMP( NN, TC, GWET ) RESULT( SOIL_TEMP )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: NN           ! Soil biome type
REAL*8,  INTENT(IN) :: TC           ! Surface air temperature [C]
REAL*8,  INTENT(IN) :: GWET         ! Top soil moisture
```

RETURN VALUE:

```
REAL*8             :: SOIL_TEMP     ! Temperature-dependent term of
                                    ! soil NOx emissions [unitless]
```

REMARKS:

```
Based on Ormeci et al., [1999] and Otter et al., [1999]
there exists and entirely exponential relationship between
temperature and soil NOx emissions at constant soil moisture
Therefore we use the following relationship based
on Yienger and Levy et al., [1995] for temperatures 0-30C:


    f(T) =  exp( 0.103+/-0.04 * T )
      in ng N/m2/s


 where T is the temperature in degrees Celsius....Below
 0 C, we assume emissions are zero because they are insignificant
 for the purposes of this global source. ...

References:
========================================================================
(1 ) Ormeci, B., S. L. Sanin, and J. J. Pierce, Laboratory study of
      NO flux from agricultural soil: Effects of soil moisture, pH,
      and temperature, J. Geophys. Res., 104 ,16211629, 1999.
(2 ) Otter, L. B., W. X. Yang, M. C. Scholes, and F. X. Meixner,
      Nitric oxide emissions from a southern African savanna, J.
      Geophys. Res., 105 , 20,69720,706, 1999.
(3 ) Yienger, J.J, and H. Levy, Empirical model of global soil-biogenic
      NOx emissions, J. Geophys. Res., 100, D6, 11,447-11464, June 20, 1995.
```

REVISION HISTORY:

```
17 Aug 2009 - R. Yantosca - Initial Version
17 Aug 2009 - R. Yantosca - Added ProTeX headers
31 Jan 2011 - R. Hudman   - Added new soil T dependance
31 Jan 2011 - R. Hudman   - Updated headers
```

1.104.3 soilwet

Function SOILWET returns the soil moisture scaling of soil NOx emissions (values from 0-1).

INTERFACE:

```
FUNCTION SOILWET( GWET , CLIM) RESULT( WETSCALE )
```

INPUT PARAMETERS:

```
! Fraction of arid & non-arid soil in the gridbox
REAL*4, INTENT(IN) :: CLIM(:)

! Top soil wetness [unitless]
REAL*8, INTENT(IN) :: GWET
```

```
!RETURN_VALUE:

   ! A scaling term between 0-1 based on soil moisture
   REAL*8             :: WETSCALE
```

REMARKS:

```
Soil moisture and temperature and now decoupled, the temperature
term is scaled with a value from 0-1 based on water filled pore space
WFPS in top-soil.

From N.E. Moore thesis:
The response of SNOx is not monotonic to WFPS. SNOx are low for the
extreme values of WFPS (0 and 1). For low values, emissions are
substrate-limited. For high values, emissions are trapped and cannot
diffuse to the surface [Yan et al., 2005]. SNOx dependence on soil
moisture is best described as a Poisson function [Parsons et al., 1996;
Otter et al., 1999; Pierce and Aneja, 2000; Kirkman et al., 2001;
van Dijk and Meixner, 2001; van Dijk et al., 2002]:

   scaling = a*x*exp(-b*x^2)

where the values of a and b are chosen such that the maximum value
(unity) occurs for WFPS=0.3, which laboratory and field measurements have
found to be the optimal value for emissions in most soils. The typical
range of values are 0.2 (arid) up to 0.45 (floodplain)
[Yang and Meixner, 1997; Ormeci et al., 1999].

Rice paddies no longer have to be scaled as in the Yienger & Levy model.

References:
===============================================================================
(1 ) Galbally, I. E., and R. Roy, Loss of fixed nitrogen from soils
      by nitric oxide exhalation, Nature, 275 , 734735, 1978.
(2 ) Kirkman, G. A., W. X. Yang, and F. X. Meixner, Biogenic nitric
      oxide emissions upscaling: An approach for Zimbabwe, Global
      Biogeochemical Cycles, 15 ,1005 1020, 2001.
(3 ) Ormeci, B., S. L. Sanin, and J. J. Pierce, Laboratory study of NO
      flux from agricultural soil: Effects of soil moisture, pH, and
      temperature, J. Geophys. Res., 104 , 16211629, 1999.
(4 ) Otter, L. B., W. X. Yang, M. C. Scholes, and F. X. Meixner,
      Nitric oxide emissions from a southern African savanna, J.
      Geophys. Res., 105 , 20,69720,706, 1999.
(5 ) Parsons, D. A., M. C. Scholes, R. J. Scholes, and J. S. Levine,
      Biogenic NO emissions from savanna soils as a function of fire
      regime, soil type, soil nitrogen, and water status, J. Geophys.
      Res., 101 , 23,68323,688, 1996.
(6 ) Pierce, J. J., and V. P. Aneja, Nitric oxide emissions from
```

engineered soil systems, Journal of Environmental Engineering, pp. 225232, 2000.
(7) van Dijk, S. M., and J. H. Duyzer, Nitric oxide emissions from forest soils, J. Geophys. Res., 104 , 15,95515,961, 1999.
(8) van Dijk, S. M., and F. X. Meixner, Production and consumption of NO in forest and pasture soils from the Amazon basin, Water, Air, and Soil Pollution: Focus 1 , pp. 119130, 2001.
(9) Yang, W. X., and F. X. Meixner, Gaseous Nitrogen Emissions from Grasslands, CAB Int., Wallingford, UK, 1997, 67-71.

REVISION HISTORY:

17 Aug 2009 - R. Yantosca - Columnized and cleaned up
17 Aug 2009 - R. Yantosca - Added ProTeX headers
31 Jan 2011 - R. Hudman - Rewrote scaling scheme
31 Jan 2011 - R.Hudman - Updated ProTeX headers

1.104.4 soilcrf

Computes the canopy reduction factor for the soil NOx emissions according to Jacob % Bakwin [1991] (and as used in Wang et al [1998]).

INTERFACE:

```
      FUNCTION SOILCRF( K,        LAI,
     &                  CANOPYNOX, WINDSQR,
     &                  SUNCOS              ) RESULT( SOIL_CRF )
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: K          ! Soil biome type
      REAL*8,  INTENT(IN) :: LAI        ! Leaf area index [cm2/cm2]
      REAL*8,  INTENT(IN) :: CANOPYNOX  ! Bulk sfc resistance to NOx [1/s]
      REAL*8,  INTENT(IN) :: WINDSQR    ! Square of sfc wind speed [m2/s2]
      REAL*8,  INTENT(IN) :: SUNCOS     ! Cosine of solar zenith angle
   !RETURN_VALUE:

      REAL*8              :: SOIL_CRF   ! Canopy reduction factor (see below)
```

REMARKS:

Also note, CANOPYNOX (the bulk surface resistance to NOx) is computed in routine GET_CANOPY_NOx (in "canopy_nox_mod.f") and is passed here as an argument.

REVISION HISTORY:

17 Aug 2009 - R. Yantosca - Initial Version

1.104.5 fertadd

Function FERTADD computes fertilizer emissions

INTERFACE:

```
      FUNCTION FERTADD( SOILFERT, DEPN) RESULT( FERT_ADD )
```

INPUT PARAMETERS:

```
      REAL*8, INTENT(IN) :: DEPN      ! N emissions from deposition
      REAL*8, INTENT(IN) :: SOILFERT  ! N emissions from fertilizers
                                      !  read in from disk and passed
                                      !  here as an argument [ng N/m2/s]
  !RETURN_VALUE:

      REAL*8             :: FERT_ADD   ! Total Fert emissions

      REAL*8, PARAMETER :: SECPERYEAR = 86400.d0 * 365.
```

REMARKS:

```
    We use a new spatially explicit data set of chemical and manure fert
    (native resolution 0.5\B0x0.5\B0) from Potter et al., [2010]
    distributed using MODIS EVI seasonality as described in
    N.E. Moore thesis, and Hudman et al., in prep.

    In previous model, fertilizer emissions were emitted instantaneously as
    2.5% of applied fertilizer, independent of soil moisture/soil temperature,
    so that they were constant over the growing season.

    Similar to the YL  parameterization, we now treat fertilizer emissions
    as part of the Aw. If we treat the wet biome coefficient as a measure of
    available N multiplied by a mean emission rate, we can treat fertilizer
    N in the same manner.

    AW = SOILAW(BinewsoilAWS_08112011_emissonlyome) + N available in soil
         x mean emission rate

    Instead of choosing an emission rate for each box equivalent to 2.5%
    of applied N yearly as done in the YL scheme, we chose the mean emission
    rate so that the total global above canopy SNOx due to fertilizer matches
    observed estimates of fertilizer emissions of 1.8 Tg N yr-1 from Stehfest
    and Bouman [2006].  This treatment allows for interannual and daily
    variability in the strength  of response to temperature and precipitation.
    Note: this scaling must be set for each resolution.

    References:
    ===========================================================================
    (1 ) Potter, P., Ramankutty, N., Bennett, E.,  and Donner, S.:
```

Characterizing the Spatial Patterns of Global Fertilizer
Application and Manure Production, Earth Interactions,
in press, 2010.
(2) Stehfest, E. and L. Bouwman, N2O and NO emission from
agricultural fields and soils under natural vegetation:
summarizing available measurement data and modeling
of global annual emissions, Nutrient Cycling in Agroecosystems
(2006), 74:207-228 DOI 10.1007/s10705-006-9000-7.

REVISION HISTORY:

```
17 Aug 2009 - R. Yantosca - Columnized and cleaned up
17 Aug 2009 - R. Yantosca - Added ProTeX headers
31 Jan 2011 - R. Hudman   - Rewrote pulsing scheme
31 Jan 2011 - R. Hudman   - Updated ProTex headers
```

1.104.6 pulsing

Function PULSING calculates the increase (or "pulse") of soil NOx emission that happens after preciptiation falls on dry soil. . According to Yan et al., [2005] , this pulsing process is thought to be due to a release of inorganic nitrogen trapped on top of the dry soil and a subsequent reactivation of water-stressed bacteria, which then metabolize the excess nitrogen. This can happen in seasonally dry grasslands and savannahs or over freshly fertilized fields.

INTERFACE:

```
      FUNCTION PULSING( GWET,      TS_EMIS,
     &                  GWET_PREV, PFACTOR,
     &                  DRYPERIOD         ) RESULT( THE_PULSING )
```

INPUT PARAMETERS:

```
      REAL*8, INTENT(IN)    :: GWET        ! Soil Moisture
      REAL*8, INTENT(IN)    :: TS_EMIS     ! Emissions timestep [min]
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*4, INTENT(INOUT) :: GWET_PREV   ! soil moisture from prev. timestep
      REAL*4, INTENT(INOUT) :: PFACTOR     ! pulsing factor
      REAL*4, INTENT(INOUT) :: DRYPERIOD   ! dry period in # timesteps
```

RETURN VALUE:

```
      REAL*8                :: THE_PULSING ! Factor to multiply baseline
                                           ! emissions by to account for
                                           ! soil pulsing of all types
```

REMARKS:

```
Soil NOx emissions consist of baseline emissions plus discrete "pulsing"
episodes.  We follow thw Yan et al., [2005] algorithm, where the pulse
(relative to the flux prewetting) is determined by the antecedent dry
period, with a simple logarithmic relationship,

   PFACTOR = 13.01 ln ( DRYPERIOD ) -  53.6

where PFACTOR is the magnitude of peak flux relative to prewetting flux,
and DRYPERIOD  is the length of the antecedent dry period in hours.

The pulse decays with

   PFACTOR = PFACTOR * EXP( -0.068d0 * DTSRCE )

References:
============================================================================
(1 ) Yan, X., T. Ohara, and H. Akimoto (2005), Statistical modeling of
      global soil NOx emissions, Global Biogeochem. Cycles, 19, GB3019,
      doi:10.1029/2004GB002276.Section 2.3.3
```

REVISION HISTORY:

```
17 Aug 2009 - R. Yantosca - Columnized and cleaned up
17 Aug 2009 - R. Yantosca - Added ProTeX headers
31 Jan 2011 - R. Hudman   - Rewrote pulsing scheme
31 Jan 2011 - R. Hudman   - Updated ProTex header
28 Oct 2013 - R. Yantosca - Bug fix: prevent log(0) from happening
```

1.105 Fortran: Module Interface soilnox_restart_mod

Module SOILNOX_RESTART_MOD contains variables and routines used to read and write GEOS-CHEM Soil NOx restart files, which contain the following: DRYPERIOD - time since soil moisture increased by 0.01 (hours), PFACTOR - If soil pulsing, pulse factor from prev. timestep (unitless) This code was modified from restart_mod.F

INTERFACE:

```
MODULE SOILNOX_RESTART_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: MAKE_SOILNOX_RESTART
PUBLIC  :: READ_SOIL_RESTART
```

REVISION HISTORY:

```
23 Oct 2012 - M. Payer    - Added ProTeX headers
```

1.105.1 make_soilnox_restart

Subroutine MAKE_SOILNOX_RESTART creates GEOS-CHEM restart files of soilnox variables in binary punch file format. (rch, 10/15/2009)

INTERFACE:

```
  SUBROUTINE MAKE_SOILNOX_RESTART( am_I_Root, Input_Opt, YYYYMMDD,
 &                                 HHMMSS,    TAU,       RC        )
```

USES:

```
USE BPCH2_MOD,          ONLY : BPCH2
USE BPCH2_MOD,          ONLY : GET_HALFPOLAR
USE BPCH2_MOD,          ONLY : GET_MODELNAME
USE BPCH2_MOD,          ONLY : OPEN_BPCH2_FOR_WRITE
USE CMN_SIZE_MOD
USE COMMSOIL_MOD
USE ERROR_MOD,          ONLY : DEBUG_MSG
USE FILE_MOD,           ONLY : IOERROR
USE GRID_MOD,           ONLY : GET_XOFFSET
USE GRID_MOD,           ONLY : GET_YOFFSET
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE inquireMod,         ONLY : findfreeLUN
USE TIME_MOD,           ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
INTEGER,        INTENT(IN)  :: YYYYMMDD    ! Year-Month-Day
INTEGER,        INTENT(IN)  :: HHMMSS      ! Hour-Min-Sec
REAL*8,         INTENT(IN)  :: TAU         ! TAU value corresponding
                                           !  to YYYYMMDD, HHMMSS
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
23 Oct 2012 - M. Payer    - Added ProTeX headers
31 Oct 2012 - R. Yantosca - Now define a title string
22 Aug 2013 - R. Yantosca - Add am_I_Root, Input_Opt, RC arguments
22 Aug 2013 - R. Yantosca - Now get soil NOx file path from Input_Opt
```

1.105.2 read_soil_restart

Subroutine READ_SOIL_RESTART initializes GEOS-CHEM Soil NOx parameters (binary punch file format)

INTERFACE:

```
SUBROUTINE READ_SOIL_RESTART( am_I_Root, Input_Opt,
&                             YYYYMMDD,  HHMMSS,    RC )
```

USES:

```
USE BPCH2_MOD,          ONLY : OPEN_BPCH2_FOR_READ
USE CMN_SIZE_MOD
USE COMMSOIL_MOD
USE ERROR_MOD,          ONLY : DEBUG_MSG
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : EXPAND_DATE
USE inquireMod,         ONLY : findfreeLUN
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
INTEGER,        INTENT(IN)  :: YYYYMMDD    ! Year-Month-Day
INTEGER,        INTENT(IN)  :: HHMMSS      ! Hour-Min-Sec
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
23 Oct 2012 - M. Payer    - Added ProTeX headers
22 Aug 2013 - R. Yantosca - Add am_I_Root, Input_Opt, RC arguments
22 Aug 2013 - R. Yantosca - Now get soil NOx file path from Input_Opt
```

1.105.3 check_dimensions

Subroutine CHECK_DIMENSIONS makes sure that the dimensions of the restart file extend to cover the entire grid. (bmy, 6/25/02, 10/15/02)

INTERFACE:

```
SUBROUTINE CHECK_DIMENSIONS( NI, NJ )
```

USES:

```
      USE ERROR_MOD, ONLY : GEOS_CHEM_STOP
      USE CMN_SIZE_MOD
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN) :: NI ! Number of longitudes read from restart file
      INTEGER, INTENT(IN) :: NJ ! Number of latitudes  read from restart file
```

REVISION HISTORY:

```
    (1 ) Added to "restart_mod.f".  Now no longer allow initialization with
         less than a globally-sized data block. (bmy, 6/25/02)
    (2 ) Now reference GEOS_CHEM_STOP from "error_mod.f", which frees all
         allocated memory before stopping the run. (bmy, 10/15/02)
    23 Oct 2012 - M. Payer    - Added ProTeX headers
```

1.106 Fortran: Module Interface ssa_bromine_mod

Module SSA_BROMINE_MOD contains variables and routines for emissions of Br2.

INTERFACE:

```
      MODULE SSA_BROMINE_MOD
```

USES:

```
      IMPLICIT NONE
      PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
      PUBLIC :: EMISS_SSA_BROMINE
      PUBLIC :: EMIT_Br2
```

REVISION HISTORY:

```
    02 Mar 2010 - J. Parrella - Initial version
    22 May 2012 - M. Payer    - Added ProTeX headers
```

1.106.1 emiss_ssa_bromine

Subroutine EMISS_SSA_BROMINE calculates aerosol emissions of Br2.

INTERFACE:

```
      SUBROUTINE EMISS_SSA_BROMINE( ilat, rmid, p_kgsalt, br2_emiss_kg )
```

USES:

```
      USE TIME_MOD, ONLY : GET_MONTH
      USE GRID_MOD, ONLY : GET_YMID
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: ilat         ! Grid latitude index
REAL*8,  INTENT(IN) :: rmid         ! Dry radius of aerosol
REAL*8,  INTENT(IN) :: p_kgsalt     ! Seasalt aerosol production [kgNaCl]
```

OUTPUT PARAMETERS:

```
REAL*8, INTENT(OUT) :: br2_emiss_kg ! Br2 emissions [kg NaCl]
```

REMARKS:

```
References:
============================================================================
(1)  Parrella, J. P., Jacob, D. J., Liang, Q., Zhang, Y., Mickley, L. J.,
      Miller, B., Evans, M. J., Yang, X., Pyle, J. A., Theys, N., and Van
      Roozendael, M.: Tropospheric bromine chemistry: implications for
      present and pre-industrial ozone and mercury, Atmos. Chem. Phys., 12,
      6723-6740, doi:10.5194/acp-12-6723-2012, 2012.
(2 ) Yang, X., Cox, R. A., Warwick, N. J., Pyle, J. A., Carver, G. D.,
      OConnor, F. M., and Savage, N. H.: Tropospheric bromine chemistry and
      its impacts on ozone: A model study, J. Geophys. Res., 110, D23311,
      doi:10.1029/2005JD006244, 2005.
(2 ) Yang, X., Pyle, J. A., and Cox, R. A.: Sea salt aerosol production and
      bromine release: Role of snow on sea ice, Geophys. Res. Lett., 35,
      L16815, doi:10.1029/2008GL034536, 2008.
```

REVISION HISTORY:

```
02 Mar 2010 - J. Parrella - Initial version
22 May 2012 - M. Payer    - Added ProTeX headers
08 Aug 2012 - M. Payer    - Modified for size-dependent depletion factors
                            from Yang et al. (2008)
```

1.106.2 emit_br2

Subroutine EMIT_BR2 takes the mass flux of Br2 [kg] emitted from sea-salt and distributes it through the the boundary layer.

INTERFACE:

```
SUBROUTINE EMIT_BR2(SSA_Br2)
```

USES:

```
USE BROMOCARB_MOD,  ONLY : Br_SCALING
USE GRID_MOD,       ONLY : GET_AREA_M2
USE LOGICAL_MOD,    ONLY : LSSABr2
USE TRACERID_MOD,   ONLY : IDEBr2
```

```
      USE TIME_MOD,       ONLY : GET_TS_EMIS
      USE DIAG_MOD,       ONLY : AD46

      USE CMN_SIZE_MOD         ! Size parameters
      USE COMODE_LOOP_MOD      ! AVG(avagadro's #)
      USE CMN_DIAG_MOD         ! Diagnostic integers...
      USE CMN_O3_MOD           ! for EMISRR array
```

INPUT PARAMETERS:

```
      REAL*8, INTENT(INOUT)   :: SSA_Br2(IIPAR, JJPAR)
```

REVISION HISTORY:

```
    02 Mar 2010 - J. Parrella - Initial version
    22 May 2012 - M. Payer    - Added ProTeX headers
    27 Aug 2012 - M. Payer    - Now parallelize DO loop
    18 Dec 2012 - M. Payer    - Replace NLONG and NLAT with IIPAR and JJPAR
```

1.107 Fortran: Module Interface strat_chem_mod

Module STRAT_CHEM_MOD contains variables and routines for performing a simple linearized chemistry scheme in the stratosphere, using archived 3D monthly climatological production rates and loss frequencies are applied from the GMI combo model.
In the original schem code (schem.F), only the following species were destroyed by photolysis in the stratosphere: PAN, H2O2, ACET, MEK, ALD2, RCHO, MVK, MACR, R4N2, CH2O, N2O5, HNO4, MP and by reaction with OH: ALK4, ISOP, H2O2, ACET, MEK, ALD2, RCHO, MVK, MACR, PMN, R4N2, PRPE, C3H8, CH2O, C2H6, HNO4, MP
The updated code includes at least all of these, and many more. The code is flexible enough to automatically apply the rate to any new tracers for future simulations that share the name in tracer_mod with the GMI name. (See Documentation on wiki).

INTERFACE:

```
 MODULE STRAT_CHEM_MOD
```

USES:

```
   IMPLICIT NONE
   PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
   PUBLIC  :: Init_Strat_Chem
   PUBLIC  :: Do_Strat_Chem
   PUBLIC  :: Cleanup_Strat_Chem
   PUBLIC  :: Calc_STE
```

PRIVATE MEMBER FUNCTIONS:

```
  PRIVATE :: Get_Rates
  PRIVATE :: Get_Rates_Interp
  PRIVATE :: Do_Synoz
```

PUBLIC DATA MEMBERS:

REMARKS:

```
   References:
============================================================================
   (1 )
```

REVISION HISTORY:

```
   01 Feb 2011 - L. Murray   - Initial version
   20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
   20 Jul 2012 - R. Yantosca - Correct compilation error in GET_RATES_INTERP
   07 Aug 2012 - R. Yantosca - Fix parallelization problem in Bry do loop
   05 Oct 2012 - R. Yantosca - Add bug fix for IFORT 12 compiler in CALC_STE
   14 Mar 2013 - M. Payer    - Replace Ox with O3 as part of removal of NOx-Ox
                               partitioning
```

1.107.1 do_strat_chem

Function DO_STRAT_CHEM is the driver routine for computing the simple linearized stratospheric chemistry scheme.

INTERFACE:

```
  SUBROUTINE DO_STRAT_CHEM( am_I_Root, Input_Opt,          &
                            State_Met, State_Chm, errCode )
```

USES:

```
    USE CMN_SIZE_MOD
    USE DAO_MOD,             ONLY : CONVERT_UNITS
    USE ERROR_MOD,           ONLY : DEBUG_MSG
    USE ERROR_MOD,           ONLY : GEOS_CHEM_STOP
    USE GIGC_ErrCode_Mod
    USE GIGC_Input_Opt_Mod, ONLY : OptInput
    USE GIGC_State_Chm_Mod, ONLY : ChmState
    USE GIGC_State_Met_Mod, ONLY : MetState
    USE LINOZ_MOD,           ONLY : DO_LINOZ
    USE TIME_MOD,            ONLY : GET_MONTH
    USE TIME_MOD,            ONLY : TIMESTAMP_STRING
    USE TRACER_MOD,          ONLY : XNUMOLAIR
    USE TRACERID_MOD,        ONLY : IDTO3
    USE TRACERID_MOD,        ONLY : IDTCHBr3
```

```
    USE TRACERID_MOD,       ONLY : IDTCH2Br2
    USE TRACERID_MOD,       ONLY : IDTCH3Br
    USE TROPOPAUSE_MOD,     ONLY : GET_MIN_TPAUSE_LEVEL
    USE TROPOPAUSE_MOD,     ONLY : GET_TPAUSE_LEVEL
    USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_TROP

    IMPLICIT NONE
```

INPUT PARAMETERS:

```
    LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
    TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
    TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
    TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
    INTEGER,        INTENT(OUT)   :: errCode     ! Success or failure
  f
```

REMARKS:

REVISION HISTORY:

```
    01 Feb 2011 - L. Murray   - Initial version
    18 Jul 2012 - R. Yantosca - For compatibility w/ the GEOS-5/GCM, we cannot
                                assume a minimum tropopause level anymore
    18 Jul 2012 - R. Yantosca - Make sure I is the innermost DO loop
                                wherever expedient
    20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    07 Aug 2012 - R. Yantosca - Make BEFORE a local variable for parallel loop
    26 Oct 2012 - R. Yantosca - Now pass the Chemistry State object for GIGC
    09 Nov 2012 - R. Yantosca - Now pass the Input Options object for GIGC
    15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    27 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
    14 Mar 2013 - M. Payer    - Replace Ox with O3 as part of removal of NOx-Ox
                                partitioning
    18 Mar 2013 - R. Yantosca - Now pass Input_Opt via the arg list
    19 Mar 2013 - R. Yantosca - Now only copy Input_Opt%TCVV(1:N_TRACERS)
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.107.2 get_rates

Function GET_RATES reads from disk the chemical production and loss rates for the species of interest

INTERFACE:

```
SUBROUTINE GET_RATES( THISMONTH, Input_Opt, State_Chm, am_I_Root, RC )
```

USES:

```
! GEOS-Chem routines
USE BPCH2_MOD,          ONLY : GET_NAME_EXT
USE BPCH2_MOD,          ONLY : GET_RES_EXT
USE BPCH2_MOD,          ONLY : GET_TAU0
USE BPCH2_MOD,          ONLY : READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : DATA_DIR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TIME_MOD,           ONLY : GET_MONTH
USE TRANSFER_MOD,       ONLY : TRANSFER_3D

! netCDF routines
USE m_netcdf_io_open
USE m_netcdf_io_read
USE m_netcdf_io_close

IMPLICIT NONE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
INTEGER,        INTENT(IN)    :: THISMONTH   ! Current month
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
01 Feb 2011 - L. Murray   - Initial version
20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
26 Oct 2012 - R. Yantosca - Now pass Chemistry State object for GIGC
09 Nov 2012 - R. Yantosca - Now pass Input Options object for GIGC
12 Jun 2013 - R. Yantosca - Now pass st4d, ct4d arrays to NcRd routine.
                            This avoids array temporaries.
```

1.107.3 get_rates_interp

Function GET_RATES_INTERP reads from disk the chemical production and loss rates for the species of interest to resolutions finer than 2 x 2.5 (e.g., nested simluations) via simple nearest-neighbor mapping.

INTERFACE:

```
SUBROUTINE GET_RATES_INTERP( THISMONTH, am_I_Root )
```

USES:

```
! GEOS-Chem routines
USE BPCH2_MOD,       ONLY : GET_NAME_EXT
USE BPCH2_MOD,       ONLY : GET_RES_EXT
USE BPCH2_MOD,       ONLY : GET_TAU0
USE BPCH2_MOD,       ONLY : READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,   ONLY : DATA_DIR_1x1
USE GRID_MOD,        ONLY : GET_XMID
USE GRID_MOD,        ONLY : GET_YMID
USE LOGICAL_MOD,     ONLY : LLINOZ
USE TIME_MOD,        ONLY : GET_MONTH
USE TRACER_MOD,      ONLY : N_TRACERS, TRACER_NAME
USE TRANSFER_MOD,    ONLY : TRANSFER_3D
USE TRANSFER_MOD,    ONLY : TRANSFER_3D_Bry

! netCDF routines
USE m_netcdf_io_open
USE m_netcdf_io_read
USE m_netcdf_io_close

IMPLICIT NONE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Current month
LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REVISION HISTORY:

```
01 Feb 2011 - L. Murray   - Initial version
18 Jul 2012 - R. Yantosca - Make sure that I is the innermost DO loop
                            (wherever expedient)
20 Jul 2012 - R. Yantosca - Now call routine TRANSFER_3D_Bry, which takes
                            arrays of size (144,91,:) as input & output
20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
26 Aug 2013 - R. Yantosca - Avoid array temporaries
```

1.107.4 calc_ste

Subroutine CALC_STE estimates what the stratosphere-to- troposphere exchange flux must have been since the last time it was reset

INTERFACE:

```
SUBROUTINE Calc_STE( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TIME_MOD,   ONLY : GET_TAU, GET_NYMD, GET_NHMS, EXPAND_DATE

USE CMN_SIZE_MOD

IMPLICIT NONE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
28 Apr 2012 - L. Murray   - Initial version
18 Jul 2012 - R. Yantosca - Make sure I is the innermost DO loop
                            (wherever expedient)
20 Jul 2012 - R. Yantosca - Reorganized declarations for clarity
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
05 Oct 2012 - R. Yantosca - Bug fix for IFORT 12: extend the #if statement
                            to avoid including code for nested-grid sims
25 Mar 2013 - R. Yantosca - Now accept Input_Opt, State_Chm, RC arguments
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.107.5 init_strat_chem

Subroutine INIT_STRAT_CHEM allocates all module arrays. It also opens the necessary rate files.

INTERFACE:

```
SUBROUTINE INIT_STRAT_CHEM( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACERID_MOD,       ONLY : IDTCHBr3, IDTCH2Br2, IDTCH3Br
USE TRACERID_MOD,       ONLY : IDTBr2,   IDTBr,     IDTBrO
USE TRACERID_MOD,       ONLY : IDTHOBr,  IDTHBr,    IDTBrNO3
USE TIME_MOD,           ONLY : GET_TAU
USE TIME_MOD,           ONLY : GET_NYMD
USE TIME_MOD,           ONLY : GET_NHMS
USE TIME_MOD,           ONLY : GET_TS_CHEM

IMPLICIT NONE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure
```

REVISION HISTORY:

```
01 Feb 2011 - L. Murray   - Initial version
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
26 Oct 2012 - R. Yantosca - Now pass Chemistry State object for GIGC
09 Nov 2012 - R. Yantosca - Now pass Input Options object for GIGC
05 Nov 2013 - R. Yantosca - Now update tracer flags for tagOx simulation
```

1.107.6 cleanup_strat_chem

Subroutine CLEANUP_STRAT_CHEM deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_STRAT_CHEM
```

USES:

```
IMPLICIT NONE
```

REVISION HISTORY:

```
1 Feb 2011 - L. Murray - Initial version
```

1.107.7 do_synoz

Subroutine Do_Synoz establishes the flux boundary condition for Ozone coming down from the stratosphere, using the Synoz algorithm of McLinden et al, 2000.

INTERFACE:

```
SUBROUTINE Do_Synoz( am_I_Root, Input_Opt, State_Met, State_Chm, RC )
```

USES:

```
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE LOGICAL_MOD,        ONLY : LVARTROP
USE PRESSURE_MOD,       ONLY : GET_PEDGE,   GET_PCENTER
USE TAGGED_Ox_MOD,      ONLY : ADD_STRAT_POX
USE TIME_MOD,           ONLY : GET_TS_CHEM, GET_YEAR
USE TRACERID_MOD,       ONLY : IDTO3,       IDTO3Strt
USE TROPOPAUSE_MOD,     ONLY : GET_TPAUSE_LEVEL

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_GCTM_MOD             ! Rdg0

IMPLICIT NONE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
Reference:
============================================================================
C. A. McLinden, S. Olsen, B. Hannegan, O. Wild, M. J. Prather, and
J. Sundet, "Stratospheric Ozone in 3-D models: A simple chemistry
and the cross-tropopause flux".

                                                                           .
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%% NOTE: This SYNOZ scheme is now obsolete, replaced by LINOZ   %%%%
%%%% We keep this for backwards compatibility w/ older met fields %%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
13 Dec 1999 - Q. Li, R. Martin - Initial version
(1 ) The parameter Rdg0 from "CMN_GCTM" = R / g0 = 28.97.
(2 ) Pass PW = PS - PTOP to UPBDFLX via "CMN".
(3 ) Now pass IORD, JORD, KORD as arguments (bmy, 12/6/00)
(4 ) Now compute the proper value of PO3_vmr that will yield 475 Tg O3/yr
      for various settings of IORD, JORD, KORD (rvm, bey, bmy, 12/5/00)

                                                                           .
      ************************************************************
      ***** You must use this version of UPBDFLX_O3 if you are *****
      ***** using the Parallel Processor TPCORE v. 7.1         *****
      ************************************************************

                                                                           .
(5 ) Added to "upbdflx_mod.f".  Also updated comments and made some
      cosmetic changes. (bmy, 6/28/01)
(6 ) Now reference CMN_SETUP for LSPLIT.  Also store strat O3 into
      tracer #11 for multi-tracer Ox run. (amf, bmy, 7/3/01)
(7 ) Removed IREF, JREF -- these are obsolete.  Also T(IREF,JREF,L) is
      now T(I,J,L). (bmy, 9/27/01)
(8 ) Also replace PW(I,J) with P(I,J) (bmy, 10/3/01)
(9 ) Removed obsolete commented out code from 9/01 (bmy, 10/24/01)
(10) Removed obsolete commented out code from 7/01 (bmy, 11/26/01)
(11) Now write file names to stdout (bmy, 4/3/02)
(12) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
      to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(13) Now use GET_PEDGE and GET_PCENTER from "pressure_mod.f" to compute
      the pressure at the bottom edge and center of grid box (I,J,L).
      Also removed obsolete, commented-out code.  Removed G_SIG and
      G_SIGE from the arg list. (dsa, bdf, bmy, 8/21/02)
(14) Now reference BXHEIGHT and T from "dao_mod.f".  Also reference routine
      ERROR_STOP from "error_mod.f".  Now references IDTOX from F90 module
      "tracerid_mod.f" instead of from "comtrid.h". (bmy, 11/6/02)
(15) Now define J30S and J30N for 1x1 nested grid (bmy, 3/11/03)
(16) Make sure to pass AD via "dao_mod.f" for GEOS-1 (bnd, bmy, 4/14/03)
(17) On the first timestep, print how much O3 flux is coming down from the
      stratosphere in Tg/yr. (mje, bmy, 8/15/03)
```

```
(18) Change O3 flux to 500 Tg/yr for GEOS-3 (mje, bmy, 9/15/03)
(19) Now calls routine ADD_STRAT_POX from "tagged_ox_mod.f" in order to
     pass stratospheric flux of Ox to the proper tagged tracer w/o
     resorting to hardwiring w/in this routine. (bmy, 8/18/03)
(20) Add GEOS_4 to the #if defined block. (bmy, 1/29/04)
(21) Activated parallel DO-loops.  Now made STFLUX a local array
     in order to facilitate parallelization. (bmy, 4/15/04)
(22) Removed IORD, JORD, KORD from the arg list.  Now reference STT and
     ITS_A_TAGOX_SIM from "tracer_mod.f".  (bmy, 7/20/04)
(23) Use an #ifdef block to comment out an EXIT statement from w/in a
     parallel loop for COMPAQ compiler.  COMPAQ seems to have some
     problems with this.  Now supports 1x125 grid. (auvray, bmy, 12/1/04)
(24) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(25) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(26) Now set J30S and J30N for GEOS-5 nested grid (yxw, dan, bmy, 11/6/08)
(27) Remove support for COMPAQ compiler (bmy, 7/8/09)
(28) Now do not call ADD_STRAT_POx for tagged Ox (dbj, bmy, 10/16/09)
13 Aug 2010 - R. Yantosca - Treat MERRA like GEOS-5 (bmy, 8/13/10)
02 Dec 2010 - R. Yantosca - Added ProTeX headers
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.2 in the same way as MERRA
10 Feb 2012 - R. Yantosca - Modified for 0.25 x 0.3125 grids
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
28 Apr 2012 - L. Murray - Moved from upbdflx_mod.F to here, modified to
              F90, renamed from UPBDFLX_O3 to DO_SYNOZ. Use chem timestep
              now. Also, removed INIT_UPBDFLX, which was last used for
              GEOS-3.
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
04 Feb 2013 - M. Payer    - Replace all JJPAR with values for nested grids
                            since JJPAR is no longer a parameter
14 Mar 2013 - M. Payer    - Replace Ox with O3 as part of removal of NOx-Ox
                            partitioning
25 Mar 2013 - R. Yantosca - Now use explicit numbers for J30S, J30N
31 May 2013 - R. Yantosca - Now pass Input_Opt, RC as arguments
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Remove SEAC4RS C-preprocessor switch
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
05 Nov 2013 - R. Yantosca - Rename IDTOxStrt to IDTO3Strt
23 Jan 2014 - M. Sulprizio- Linoz does not call UPBDFLX_O3. Synoz does.
                            Now uncomment ADD_STRAT_POx (jtl,hyl,dbj,11/3/11)
```

1.107.8 upbdflx_hd

Subroutine UPBDFLX_HD establishes the flux boundary condition for HD coming down from the stratosphere. This is adapted from the UPBDFLX_O3 routine.

INTERFACE:

```
SUBROUTINE UPBDFLX_HD( State_Met, State_Chm )
```

USES:

```
USE ERROR_MOD,           ONLY : ERROR_STOP
USE PRESSURE_MOD,        ONLY : GET_PEDGE, GET_PCENTER
USE TIME_MOD,            ONLY : GET_TS_CHEM
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACERID_MOD,        ONLY : IDTHD, IDTH2
USE GIGC_State_Met_Mod, ONLY : MetState

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_GCTM_MOD             ! Rdg0
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REMARKS:

```
Instead of calculating the fractionation of H2 in the stratosphere
(where we would have to take into account fractionation of CH4),
we simply set the HD tracer concentrations in the stratosphere to
reproduce observed profiles in the UT/LS.

References:
============================================================================
(1) "Global Budget of Molecular Hydrogen and its Deuterium Content:
     Constraints from Ground Station, Cruise, and Aircraft Observations"
     Price, H., L. Jaegl, A. Rice, P. Quay, P.C. Novelli, R. Gammon,
     submitted to J. Geophys. Res., 2007.
```

REVISION HISTORY:

```
18 Sep 2007 - L. Jaegle, H. U. Price, P. Le Sager - Initial version
(1 ) First adapted from UPBDFLX_O3 (G-C v5-05-03) then merged w/ v7-04-12.
      Added parallel DO loops. (phs, 9/18/07)
(26) Now set J3OS and J3ON for GEOS-5 nested grid (yxw, dan, bmy, 11/6/08)
(27) Remove support for COMPAQ compiler (bmy, 7/8/09)
13 Aug 2010 - R. Yantosca - Treat MERRA like GEOS-5
02 Dec 2010 - R. Yantosca - Added ProTeX headers
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.2 in the same way as MERRA
10 Feb 2012 - R. Yantosca - Modified for 0.25 x 0.3125 grids
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
20 Jun 2012 - L. Murray   - Moved from upbdflx_mod.F to here.
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

```
04 Feb 2013 - M. Payer    - Replace all JJPAR with values for nested grids
                            since JJPAR is no longer a parameter
25 Mar 2013 - R. Yantosca - Now use explicit numbers for J3OS, J3ON
26 Sep 2013 - R. Yantosca - Remove SEAC4RS C-preprocessor switch
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.108 Fortran: Module Interface sulfate_mod

Module SULFATE_MOD contains arrays and routines for performing either a coupled chemistry/aerosol run or an offline sulfate aerosol simulation. Original code taken from Mian Chin's GOCART model and modified accordingly. (rjp, bdf, bmy, 6/22/00, 8/26/10)

INTERFACE:

```
MODULE SULFATE_MOD
```

USES:

```
USE VDIFF_PRE_MOD, ONLY : emis_save ! (Lin, 03/31/09)
USE inquireMod,    ONLY : findFreeLUN

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CHEMSULFATE
PUBLIC :: EMISSSULFATE
PUBLIC :: CLEANUP_SULFATE
PUBLIC :: INIT_SULFATE
```

REMARKS:

```
References:
============================================================================
(1 ) Andreae, M.O. & P. Merlet, "Emission of trace gases and aerosols from
      biomass burning", Global Biogeochem. Cycles, 15, 955-966, 2001.
(2 ) Nightingale et al [2000a], J. Geophys. Res, 14, 373-387
(3 ) Nightingale et al [2000b], Geophys. Res. Lett, 27, 2117-2120
(4 ) Wanninkhof, R., "Relation between wind speed and gas exchange over
      the ocean", J. Geophys. Res, 97, 7373-7382, 1992.
```

REVISION HISTORY:

```
(1 ) All module variables are declared PRIVATE (i.e., they can only
      be seen from within this module (bmy, 6/2/00)
(2 ) The routines in "sulfate_mod.f" assume that we are doing chemistry
      over the global region (e.g. IIPAR=IIPAR, JJPAR=JJPAR). (bmy, 6/8/00)
```

```
(3 ) Removed obsolete code from DRYDEP_SULFATE (bmy, 12/21/00)
(4 ) Removed obsolete commented-out code from module routines (bmy, 4/23/01)
(5 ) Now read data files from DATA_DIR/sulfate_sim_200106/ (bmy, 6/19/01)
(6 ) Updated comments (bmy, 9/4/01)
(7 ) XTRA2(IREF,JREF,5) is now XTRA2(I,J).  Now reference COSSZA from
     "dao_mod.f". (bmy, 9/27/01)
(8 ) Removed obsolete commented out code from 9/01 (bmy, 10/24/01)
(9 ) Minor fixes to facilitate compilation on ALPHA (bmy, 11/15/01)
(11) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
     MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(12) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(13) Now reference "file_mod.f" (bmy, 6/27/02)
(14) Now references GET_PEDGE from "pressure_mod.f", which computes P at
     the bottom edge of grid box (I,J,L).  Also deleted obsolete,
     commented-out code. (dsa, bdf, bmy, 8/21/02)
(15) Added updated code from Rokjin Park and Brendan Field, in order to
     perform coupled chemistry-aerosol simulations.  Also added parallel
     DO-loops in several subroutines.  Updated comments, cosmetic
     changes.  Now reference "error_mod.f" and "wetscav_mod.f".
     Now only do chemistry below the tropopause. (rjp, bdf, bmy, 12/6/02)
(16) Added ENH3_na array to hold natural source NH3 emissions.  Also now
     facilitate passing DMS, SO2, SO4, NH3 to SMVGEAR for fullchem
     simulations.  Added subroutine READ_NATURAL_NH3. (rjp, bmy, 3/23/03)
(17) Now references "grid_mod.f" and "time_mod.f".  Also made other minor
     cosmetic changes. (bmy, 3/27/03)
(18) Updated chemistry routines to apply drydep losses throughout the
     entire PBL. (rjp, bmy, 8/1/03)
(19) Now accounts for GEOS-4 PBL being in meters (bmy, 1/15/04)
(20) Fix ND44 diag so that we get same results for sp or mp (bmy, 3/24/04)
(21) Added COSZM array.  Now use diurnal varying JH2O2 in CHEM_H2O2.
     (rjp, bmy, 3/39/04)
(22) Added more parallel DO-loops (bmy, 4/14/04)
(23) Now add SO2 from ships (bec, bmy, 5/20/04)
(24) Now references "directory_mod.f", "logical_mod.f" and "tracer_mod.f".
     Now removed IJSURF. (bmy, 7/20/04)
(25) Can overwrite USA with EPA/NEI99 emissions (rjp, rch, bmy, 11/16/04)
(26) Modified for AS, AHS, LET, SO4aq, NH4aq (cas, bmy, 1/11/05)
(27) Now also references "pbl_mix_mod.f".  NOTE: Comment out phase
     transition  code for now since it is still under development and
     will take a while to be rewritten. (bmy, 3/15/05)
(28) Modified for SO4s, NITs chemistry (bec, 4/13/05)
(29) Now reads updated files for SST and offline chemistry.  Now read data
     for both GCAP and GEOS grids.  Now references "tropopause_mod.f".
     (bmy, 8/22/05)
(30) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(31) Now references XNUMOL & XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(32) Now read int'annual SST data on GEOS 1x1 grid (bmy, 11/17/05)
```

```
(33) Bug fix for offline aerosol sim in SEASALT_CHEM (bec, bmy, 3/29/06)
(34) Bug fix in INIT_DRYDEP (bmy, 5/23/06)
(35) Now references "bravo_mod.f" (rjp, kfb, bmy, 6/26/06)
(36) Now references "streets_anthro_mod.f" (yxw, bmy, 8/17/06)
(37) Now references "biomass_mod.f" (bmy, 9/27/06)
(38) Now prevent seg fault error in READ_BIOFUEL_SO2 (bmy, 11/3/06)
(39) Bug fix in SEASALT_CHEM (havala, bec, bmy, 12/8/06)
(40) Extra error check for low RH in GRAV_SETTLING (phs, 6/11/08)
(41) Now references "cac_anthro_mod.f".  And apply SO2 yearly scale factor
     to SO2 from GEIA (amv, phs, 3/11/08)
(41) Bug fixes in reading EDGAR data w/ the right tracer number,
     when we are doing offline or nonstd simulations (dkh, 10/31/08)
(42) Bug fix for AD13_SO2_sh in SRCSO2 (phs, 2/27/09)
(43) Bug fix: need to add CAC_AN to PRIVATE statements (bmy, 5/27/09)
(44) Constrain surface emissions to the first level and save them into
     emis_save (lin, 5/29/09)
(45) Last year of SST data is now 2008 (see READ_SST) (bmy, 7/13/09)
(46) Updated rxns in CHEM_DMS and CHEM_SO2 to JPL 2006 (jaf, bmy, 10/15/09)
(47) Added new volcanic emissions of SO2 (jaf, bmy, 10/15/09)
(48) Now accounts for NEI 2005 emissions, and multilevels SOxan emissions
     (amv, phs, 10/15/2009)
(49) Fixes in SRCSO2 for SunStudio compiler (bmy, 12/3/09)
(50) Add new subroutine SRCSF30 for emission to 30bin sulfate (win, 1/25/10)
(51) Add new array PSO4_SO2AQ for SO4 produced via aqueous chemistry of SO2
     excluding that from heterogeous reaction on sea-salt. (win, 1/25/10)
(52) Standardized patch in READ_ANTHRO_NH3 (dkh, bmy, 3/5/10)
(53) Use LWC from GEOS-5 met fields (jaf, bmy, 6/30/10)
(54) Add module parameters MNYEAR_VOLC and MXYEAR_VOLC to define the 1st
    and last year with data for volcanic emissions. (ccc, 9/30/10)
(55) Use updated volcanic emissions from 1979 to 2009
26 Aug 2010 - R. Yantosca   - Add modifications for MERRA
12 Nov 2010 - R. Yantosca   - Avoid div-by-zero when computing L2S, L3S
07 Sep 2011 - P. Kasibathla - Modified to include GFED3
22 Dec 2011 - M. Payer      - Added ProTeX headers
08 Feb 2012 - R. Yantosca   - Add modifications for GEOS-5.7.2 met
01 Mar 2012 - R. Yantosca   - Now reference new grid_mod.F90
13 Mar 2012 - M. Cooper     - Changed regrid algorithm to map_a2a
28 Nov 2012 - R. Yantosca   - Use SUNCOS fields from the State_Met object
04 Mar 2013 - R. Yantosca   - Now call INIT_SULFATE from the init stage
                              which facilitates connection to GEOS-5 GCM
05 Mar 2013 - R. Yantosca   - Now use Input_Opt%LNLPBL instead of LNLPBL
                              from logical_mod.F
13 Mar 2013 - R. Yantosca   - Bug fix: make sure we pass values to the
                              SOIL_DRYDEP routine even when ND44 is off
30 May 2013 - S. Farina     - Merged TOMAS code into sulfate_mod.F
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.108.1 get_vcldf

Subroutine GET_VCLDF computes the volume cloud fraction for SO2 chemistry. (rjp, bdf, bmy, 9/23/02)

INTERFACE:

```
SUBROUTINE GET_VCLDF( am_I_Root, State_Met, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_ErrCode_Mod
USE GIGC_State_Met_Mod, ONLY : MetState
USE PRESSURE_MOD,       ONLY : GET_PCENTER
USE PRESSURE_MOD,       ONLY : GET_PEDGE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
References:
============================================================================
(1) Sundqvist et al. [1989]
```

REVISION HISTORY:

```
14 Jan 2011 - R. Yantosca - Return if VCLDF is not allocated
22 Dec 2011 - M. Payer    - Added ProTeX headers
14 Nov 2012 - R. Yantosca - Added am_I_Root, RC arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.108.2 get_lwc

Function GET_LWC returns the cloud liquid water content [m3 H2O/m3 air] at a GEOS-CHEM grid box as a function of temperature. (rjp, bmy, 10/31/02, 1/14/03)

INTERFACE:

```
FUNCTION GET_LWC( T ) RESULT( LWC )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: T ! Temperature value at a GEOS-CHEM grid box [K]
```

RETURN VALUE:

```
REAL*8             :: LWC
```

REVISION HISTORY:

```
18 Jan 2011 - R. Yantosca - Updated comments
22 Dec 2011 - M. Payer    - Added ProTeX header
```

1.108.3 chemsulfate

Subroutine CHEMSULFATE is the interface between the GEOS-CHEM main program and the sulfate chemistry routines. The user has the option of running a coupled chemistry-aerosols simulation or an offline aerosol simulation. (rjp, bdf, bmy, 5/31/00, 3/16/06)

INTERFACE:

```
SUBROUTINE CHEMSULFATE( am_I_Root, Input_Opt,
&                       State_Met, State_Chm, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE DAO_MOD,            ONLY : CONVERT_UNITS
USE DRYDEP_MOD,         ONLY : DEPSAV
USE ERROR_MOD,          ONLY : DEBUG_MSG
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GLOBAL_OH_MOD,      ONLY : GET_GLOBAL_OH
USE GLOBAL_NO3_MOD,     ONLY : GET_GLOBAL_NO3
USE TIME_MOD,           ONLY : GET_MONTH
USE TIME_MOD,           ONLY : GET_TS_CHEM
USE TIME_MOD,           ONLY : GET_ELAPSED_SEC
USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH
USE TRACERID_MOD,       ONLY : IDTNITs
USE TRACERID_MOD,       ONLY : IDTSO4s
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Now reference all arguments except FIRSTCHEM and RH from either F90
     modules or from common block header files.  Updated comments,
     cosmetic changes.  Added NH3, NH4, NITRATE chemistry routines.
     Also call MAKE_RH and CONVERT_UNITS from "dao_mod.f".  Now references
     IDTDMS, IDTSO2 etc. from "tracerid_mod.f".  Now make FIRSTCHEM a
     local SAVEd variable.  Now reference DEPSAV from "drydep_mod.f".
     Also get rid of extraneous dimensions of DEPSAV.  Added NTIME,
     NHMSb arrays for OHNO3TIME.  (rjp, bdf, bmy, 12/16/02)
(2 ) CHEM_DMS is now only called for offline sulfate simulations.
     (rjp, bmy, 3/23/03)
(3 ) Now remove NTIME, NHMSb from the arg list and call to OHNO3TIME.
     Now references functions GET_MONTH, GET_TS_CHEM, and GET_ELAPSED_SEC
     from the new "time_mod.f". (bmy, 3/27/03)
(4 ) Now reference STT, TCVV, N_TRACERS, ITS_AN_AEROSOL_SIM from
     "tracer_mod.f".  Now reference ITS_A_NEW_MONTH from "time_mod.f".
     Now references LPRT from "logical_mod.f". (bmy, 7/20/04)
(5 ) Updated for AS, AHS, LET, SO4aq, NH4aq.  Now references LCRYST from
     logical_mod.f.  Now locate species in the DEPSAV array w/in
     INIT_SULFATE. (bmy, 12/21/04)
(6 ) Now handle gravitational settling of SO4s, NITs (bec, bmy, 4/13/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Remove reference to MAKE_RH, it's not needed here (bmy, 3/16/06)
(9 ) Reference to LTOMAS and add call CHEM_SO4_AQ using aqueous oxidation
     which is one of the TOMAS microphysics subroutine  (win, 1/25/10)
05 Oct 2011 - R. Yantosca - SUNCOS is no longer needed here
22 Dec 2011 - M. Payer    - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
14 Nov 2012 - R. Yantosca - Add Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
04 Mar 2013 - R. Yantosca - Remove call to INIT_SULFATE
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%TCVV(1:N_TRACERS)
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
23 Apr 2013 - R. Yantosca - Remove LTOMAS logical, since we now invoke TOMAS
                            with either TOMAS=yes or TOMAS40=yes
31 May 2013 - R. Yantosca - Now pass am_I_root, Input_Opt, State_Chm
                            and RC to TOMAS routine CHEM_SO4_AQ
23 Oct 2013 - R. Yantosca - Now pass objects to GET_GLOBAL_OH routine
```

1.108.4 grav_settling

Subroutine GRAV_SETTLING performs gravitational settling of sulfate and nitrate in coarse sea salt (SO4S and NITS). (bec, rjp, bmy, 4/20/04, 7/20/04, 10/25/05)

INTERFACE:

```
      SUBROUTINE GRAV_SETTLING( am_I_Root, Input_Opt, State_Met,
     &                          TC,        N,         RC         )
```

USES:

```
      USE CMN_GCTM_MOD
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PRESSURE_MOD,       ONLY : GET_PCENTER
      USE TRACERID_MOD,       ONLY : IDTSO4s
      USE TRACERID_MOD,       ONLY : IDTNITs
      USE TIME_MOD,           ONLY : GET_ELAPSED_SEC
      USE TIME_MOD,           ONLY : GET_TS_CHEM
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
      INTEGER,        INTENT(IN)    :: N           ! N=1 is SO4S; N=2 is NITS
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,         INTENT(INOUT) :: TC(IIPAR,JJPAR,LLPAR) ! Tracer [kg]
```

REVISION HISTORY:

```
(1 ) Now references SALA_REDGE_um and SALC_REDGE_um from "tracer_mod.f"
     (bmy, 7/20/04)
(2 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(3 ) Now limit relative humidity to [tiny(real*8),0.99] range for DLOG
     argument (phs, 5/1/08)
(4 ) Bug fixes to the Gerber hygroscopic growth for sea salt aerosols
     (jaegle, 5/5/11)
(5 ) Update hygroscopic growth to Lewis and Schwartz formulation (2006) and
     density calculation based on Tang et al. (1997) (bec, jaegle 5/5/11)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

```
14 Nov 2012 - R. Yantosca - Now pass am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.108.5 chem_dms

Subroutine CHEM_DMS is the DMS chemistry subroutine from Mian Chin's GOCART model, modified for use with the GEOS-CHEM model. (rjp, bdf, bmy, 5/31/00, 10/15/09)

INTERFACE:

```
      SUBROUTINE CHEM_DMS( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_GCTM_MOD
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD05
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TRACERID_MOD,       ONLY : IDTDMS
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    Reaction List (by Mian Chin, chin@rondo.gsfc.nasa.gov)
    ============================================================================
                                                                              .
    R1:    DMS + OH  -> a*SO2 + b*MSA                OH addition channel
           k1 = { 1.7e-42*exp(7810/T)*[O2] / (1+5.5e-31*exp(7460/T)*[O2] }
```

```
       a = 0.75, b = 0.25
                                                                             .
R2:    DMS + OH  ->   SO2 + ...                    OH abstraction channel
       k2 = 1.2e-11*exp(-260/T)
                                                                             .
       DMS_OH = DMS0 * exp(-(r1+r2)* NDT1)
       where DMS0 is the DMS concentration at the beginning,
       r1 = k1*[OH], r2 = k2*[OH].
                                                                             .
R3:    DMS + NO3 ->   SO2 + ...
       k3 = 1.9e-13*exp(500/T)
                                                                             .
       DMS = DMS_OH * exp(-r3*NDT1)
       where r3 = k3*[NO3].
                                                                             .
R4:    DMS + X   ->   SO2 + ...
       assume to be at the rate of DMS+OH and DMS+NO3 combined.
                                                                             .
The production of SO2 and MSA here, PSO2_DMS and PMSA_DMS, are saved
for use in CHEM_SO2 and CHEM_MSA subroutines as a source term.  They
are in unit of [v/v/timestep].
```

REVISION HISTORY:

```
(1 ) Now reference AD, AIRDEN, and SUNCOS from "dao_mod.f".  Added
     parallel DO-loops.  Also now extract OH and NO3 from SMVGEAR
     for coupled chemistry-aerosol runs. (rjp, bdf, bmy, 9/16/02)
(2 ) Bug fix: remove duplicate definition of RK3 (bmy, 3/23/03)
(3 ) Now use function GET_TS_CHEM from "time_mod.f".  (bmy, 3/27/03)
(4 ) Now reference STT and ITS_A_FULLCHEM_SIM from "tracer_mod.f"
     Now replace IJSURF w/ an analytic function. (bmy, 7/20/04)
(5 ) Shift rows 8,9 in AD05 to 9,10 in to make room for P(SO4) from O3
     oxidation in sea-salt aerosols (bec, bmy, 4/13/05)
(6 ) Now remove reference to CMN, it's obsolete.  Now reference
     ITS_IN_THE_STRAT from "tropopause_mod.f". (bmy, 8/22/05)
(7 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(8 ) Now correctly records P(SO2) from OH in AD05 (pjh)
(9 ) Update reaction rate to match JPL06 and full chem (jaf, bmy, 10/15/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
31 Jul 2012 - R. Yantosca - Now loop from 1..LLPAR for GIGC compatibility
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
28 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
```

1.108.6 chem_h2o2

Subroutine CHEM_H2O2 is the H2O2 chemistry subroutine for offline sulfate simulations. For coupled runs, H2O2 chemistry is already computed by the SMVGEAR module. (rjp, bmy, 11/26/02, 10/25/05)

INTERFACE:

```
      SUBROUTINE CHEM_H2O2( am_I_Root, Input_Opt,
     &                      State_Met, State_Chm, RC )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_NAME_EXT
      USE BPCH2_MOD,          ONLY : GET_RES_EXT
      USE BPCH2_MOD,          ONLY : GET_TAU0
      USE BPCH2_MOD,          ONLY : READ_BPCH2
      USE CMN_SIZE_MOD
      USE CMN_FJ_MOD,         ONLY : JPMAX, JPPJ
      USE CMN_DIAG_MOD
      USE CMN_GCTM_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
      USE TIME_MOD,           ONLY : GET_MONTH
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH
      USE TRACERID_MOD,       ONLY : IDTH2O2
      USE TRANSFER_MOD,       ONLY : TRANSFER_3D_TROP
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Bug fix: need to multiply DXYP by 1d4 for cm2 (bmy, 3/23/03)
(2 ) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
     Now use functions GET_MONTH and GET_TS_CHEM from "time_mod.f".
     (bmy, 3/27/03)
(3 ) Now references PBLFRAC from "drydep_mod.f".  Now apply dry deposition
     throughout the entire PBL.  Added FREQ variable. (bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
     sum into AD44 array.  This preents numerical differences when using
     multiple processors. (bmy, 3/24/04)
(5 ) Now use diurnally-varying JO1D.  Now use new unit conversion for
     the ND44 diagnostic. (rjp, bmy, 3/30/04)
(6 ) Now use parallel DO-loop to zero ND44_TMP.  Now uses ITS_A_NEW_MONTH
     from time_mod.f. (bmy, 4/14/04)
(7 ) Now reference STT & TCVV from "tracer_mod.f".  Also replace IJSURF
     with an analytic function.  Now references DATA_DIR from
     "directory_mod.f". (bmy, 7/20/04)
(8 ) Now suppress output from READ_BPCH with QUIET keyword (bmy, 1/25/05)
(9 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP
     from "pbl_mix_mod.f" (bmy, 2/22/05)
(10) Now read offline files from "sulfate_sim_200508/offline".  Now remove
     reference to CMN, it's obsolete.  Now reference ITS_IN_THE_STRAT from
     "tropopause_mod.f". (bmy, 8/22/05)
(11) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(12) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
31 Jul 2012 - R. Yantosca - Now loop from 1..LLPAR for GIGC compatibility
31 Jul 2012 - R. Yantosca - Declare temp drydep arrays w/ LLPAR (not LLTROP)
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
26 Nov 2012 - R. Yantosca - Dimension ND44_TMP array with LLPAR, not LLTROP
28 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%TCVV(1:N_TRACERS) and
                            Input_Opt%XNUMOL(1:N_TRACERS) -- avoid OOB errs
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.108.7 chem_so2

Subroutine CHEM_SO2 is the SO2 chemistry subroutine. (rjp, bmy, 11/26/02, 8/26/10)

INTERFACE:

```
      SUBROUTINE CHEM_SO2( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_GCTM_MOD
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DAO_MOD,            ONLY : IS_WATER
      USE DIAG_MOD,           ONLY : AD05
      USE DIAG_MOD,           ONLY : AD44
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE ERROR_MOD,          ONLY : IS_SAFE_EXP
      USE ERROR_MOD,          ONLY : SAFE_DIV
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_HNO3_MOD,    ONLY : GET_GLOBAL_HNO3
      USE GLOBAL_HNO3_MOD,    ONLY : GET_HNO3_VV
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
      USE PRESSURE_MOD,       ONLY : GET_PCENTER
      USE TIME_MOD,           ONLY : GET_TS_CHEM, GET_MONTH
      USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH
      USE TRACERID_MOD,       ONLY : IDTH2O2
      USE TRACERID_MOD,       ONLY : IDTSO2
      USE TRACERID_MOD,       ONLY : IDTSO4,  IDTNH3,  IDTNH4,  IDTHNO3
      USE TRACERID_MOD,       ONLY : IDTNIT,  IDTDST1, IDTDST2, IDTDST3
      USE TRACERID_MOD,       ONLY : IDTDST4, IDTSALA, IDTSALC
      USE SEASALT_MOD,        ONLY : GET_ALK
      USE WETSCAV_MOD,        ONLY : H2O2s
      USE WETSCAV_MOD,        ONLY : SO2s
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
Reaction List (by Rokjin Park, rjp@io.harvard.edu)
============================================================================
(1 ) SO2 production:
     DMS + OH, DMS + NO3 (saved in CHEM_DMS)

                                                                            .
(2 ) SO2 loss:
     (a) SO2 + OH  -> SO4
     (b) SO2       -> drydep
     (c) SO2 + H2O2 or O3 (aq) -> SO4

                                                                            .
(3 ) SO2 = SO2_0 * exp(-bt) +  PSO2_DMS/bt * [1-exp(-bt)]

                                                                            .
     where b is the sum of the reaction rate of SO2 + OH and the dry
     deposition rate of SO2, PSO2_DMS is SO2 production from DMS in
     MixingRatio/timestep.

                                                                            .
If there is cloud in the gridbox (fraction = fc), then the aqueous
phase chemistry also takes place in cloud. The amount of SO2 oxidized
by H2O2 in cloud is limited by the available H2O2; the rest may be
oxidized due to additional chemistry, e.g, reaction with O3 or O2
(catalyzed by trace metal).
```

REVISION HISTORY:

```
(1 ) Removed duplicate definition of Ki (bmy, 11/15/01)
(2 ) Eliminate duplicate HPLUS definition.  Make adjustments to facilitate
      SMVGEAR chemistry for fullchem runs (rjp, bmy, 3/23/03)
(3 ) Now replace DXYP(J+J0)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
      Now use function GET_TS_CHEM from "time_mod.f".
(4 ) Now apply dry deposition to entire PBL.  Now references PBLFRAC array
      from "drydep_mod.f". (bmy, 8/1/03)
(5 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
      sum into AD44 array.  This preents numerical differences when using
      multiple processors. (bmy, 3/24/04)
(6 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(7 ) Now reference STT, TCVV, & ITS_AN_AEROSOL_SIM from "tracer_mod.f".
      Now reference DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(8 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
      "pbl_mix_mod.f" (bmy, 2/22/05)
(9 ) Modified for SO4s, NITs.  Also modified for alkalinity w/in the
      seasalt chemistry. (bec, bmy, 4/13/05)
(10) Now remove reference to CMN, it's obsolete.  Now reference
      ITS_IN_THE_STRAT from "tropopause_mod.f" (bmy, 8/22/05)
(11) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(12) Updated to match JPL 2006 + full chem (jaf, bmy, 10/15/09)
(13) Now prevent floating-point exceptions when taking the exponential
      terms. (win, bmy, 1/4/10)
(14) Save aqueous production rate to PSO4_SO2AQ for TOMAS microphyics
```

```
      (win, 1/25/10)
(15) Added extra error checks to prevent negative L2S, L3S (bmy, 4/28/10)
(16) Use liq. water content from met fields in GEOS-5 (jaf, bmy, 6/30/10)
26 Aug 2010 - R. Yantosca - Use liquid water content from MERRA
12 Nov 2010 - R. Yantosca - Prevent div-by-zero when computing L2S and L3S
27 May 2011 - L. Zhang    - Divide LWC by cloud fraction for GEOS/MERRA
                            and adjust the L2S and L3S rates accordingly
22 Dec 2011 - M. Payer    - Added ProTeX headers
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.2 in the same way as MERRA
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
31 Jul 2012 - R. Yantosca - Now loop over 1..LLPAR for GIGC compatibility
31 Jul 2012 - R. Yantosca - Declare temp drydep arrays w/ LLPAR (not LLTROP)
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%TCVV(1:N_TRACERS) and
                            Input_Opt%XNUMOL(1:N_TRACERS) -- avoid OOB errs
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
05 Sep 2013 - M. Sulprizio- Add modifications for cloud pH (B. Alexander)
 6 Sep 2013 - M. Sulprizio- Bug fix: Prevent divide-by-zero if LWC=0. Only
                            do aqueous SO2 chemistry when LWC>0.
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
28 Jan 2014 - R. Yantosca - Bug fix for TOMAS. Set ALKdst=0 since TOMAS
                            carries its own dust tracers instead of DST1-4.
```

1.108.8 seasalt_chem

Subroutine SEASALT_CHEM computes SO4 formed from S(IV) + O3 on seasalt aerosols as a function of seasalt alkalinity. (bec, bmy, 4/13/05, 10/7/08)

INTERFACE:

```
      SUBROUTINE SEASALT_CHEM ( I,         J,         L,
     &                          ALK1,      ALK2,      SO2_cd,
     &                          Kt1,       Kt2,       Kt1N,
     &                          Kt2N,      SO2_ss,    PSO4E,
     &                          PSO4F,     am_I_Root, Input_Opt,
     &                          State_Met, State_Chm, RC )
```

USES:

```
      !-----------------------------------------------------------------
      ! DIAGNOSTICS -- leave commented out for now (bec, bmy, 4/13/05)
      !USE CMN_DIAG_MOD          ! ND19
      !USE DIAG_MOD,        ONLY : AD09
      !-----------------------------------------------------------------
      USE CMN_GCTM_MOD
```

```
      USE CMN_SIZE_MOD
      USE COMODE_MOD,          ONLY : CSPEC
      USE COMODE_MOD,          ONLY : JLOP
      USE COMODE_MOD,          ONLY : VOLUME
      USE ERROR_MOD,           ONLY : GEOS_CHEM_STOP
      USE ERROR_MOD,           ONLY : IT_IS_NAN
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GLOBAL_HNO3_MOD,     ONLY : GET_HNO3_UGM3
      USE TIME_MOD,            ONLY : GET_TS_CHEM
      USE TIME_MOD,            ONLY : GET_ELAPSED_SEC
      USE TIME_MOD,            ONLY : GET_MONTH
      USE TIME_MOD,            ONLY : ITS_A_NEW_MONTH
      USE TRACER_MOD,          ONLY : XNUMOLAIR
      USE TRACERID_MOD,        ONLY : IDTHNO3
      USE TRACERID_MOD,        ONLY : IDTNITs
      USE TRACERID_MOD,        ONLY : IDTSO2
      USE TRACERID_MOD,        ONLY : IDTSO4
      USE TRACERID_MOD,        ONLY : IDTSO4s
```

INPUT PARAMETERS:

```
      INTEGER,         INTENT(IN)   :: I, J, L    ! Grid box indices
      REAL*8,          INTENT(IN)   :: SO2_cd     ! SO2 mixing ratio [v/v] after
                                                  !  gas phase chemistry and
                                                  !  dry deposition
      REAL*8,          INTENT(IN)   :: Kt1, Kt2   ! Rate constant [s-1] for
                                                  !  sulfate formation on sea
                                                  !  salt aerosols from GET_ALK
                                                  !  (1=fine; 2=coarse)
      REAL*8,          INTENT(IN)   :: Kt1N, Kt2N
      REAL*8,          INTENT(IN)   :: ALK1, ALK2 ! Alkalinity [kg] from
                                                  !  seasalt_mod
      TYPE(MetState), INTENT(IN)    :: State_Met  ! Meteorology State object
      TYPE(OptInput), INTENT(IN)    :: Input_Opt  ! Input Options object
      LOGICAL,         INTENT(IN)   :: am_I_Root  ! Are we on the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      REAL*8,          INTENT(OUT)  :: SO2_ss     ! SO2 mixing ratio [v/v]
                                                  !  after sea salt chemistry
      REAL*8,          INTENT(OUT)  :: PSO4E      ! SO4E (sulfate produced by
                                                  !  S(IV)+O3 on fine seasalt)
                                                  !  mixing ratio [v/v]
```

```
      REAL*8,         INTENT(OUT)   :: PSO4F     ! SO4F (sulfate produced by
                                                 !  S(IV)+O3 on coarse seasalt)
      INTEGER,        INTENT(OUT)   :: RC        ! Success or failure?
```

REMARKS:

```
Chemical reactions:
============================================================================
(R1) SO2 + O3 + ALK => SO4 + O2
     Modeled after Chamedies and Stelson, 1992?
```

REVISION HISTORY:

```
(1 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(2 ) Bug fix: now avoid seg fault error if IDTHNO3 is zero, as it would
      be for an offline aerosol simulation. (bmy, 3/29/06)
(3 ) Fixed typo in FALK_A_SO2 equation: C_FLUX_C should be C_FLUX_A.
      (havala, bec, bmy, 12/8/06)
(4 ) Bug fix for mass balance, replace TITR_HNO3 w/ HNO3_SSC in the
      expression for HNO3_ss.  Bug fix: now do equivalent computation
      for GET_GNO3, which is now no longer called because it's in
      "isoropia_mod.f". (bec, bmy, 7/30/08)
22 Dec 2011 - M. Payer    - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.108.9 get_hplus

Subroutine GET_HPLUS computes H+ concentrations in cloud liquid water for pH dependent cloud chemistry. (bec, 4/11/11)

INTERFACE:

```
      SUBROUTINE GET_HPLUS( SO4nss, TNH3, TNO3, SO2,
     &                      T,      PRES, LWC,  iHPLUS, HPLUS )
```

USES:

```
      USE ERROR_MOD,       ONLY : IT_IS_NAN, GEOS_CHEM_STOP
```

INPUT PARAMETERS:

```
      REAL*8,  INTENT(IN)    :: SO4nss ! Total nss sulfate mixing ratio [M]
      REAL*8,  INTENT(IN)    :: TNO3   ! Total nitrate (gas+particulate) mixing
                                       ! ratio [v/v]
      REAL*8,  INTENT(IN)    :: TNH3   ! NH3 mixing ratio [v/v]
      REAL*8,  INTENT(IN)    :: SO2    ! SO2 mixing ratio [v/v]
      REAL*8,  INTENT(IN)    :: T      ! Temperature [K]
```

```
      REAL*8,  INTENT(IN)    :: PRES   ! Pressure [atm]
      REAL*8,  INTENT(IN)    :: LWC    ! Cloud liquid water content [m3/m3]
      REAL*8,  INTENT(IN)    :: iHPLUS ! Initial [H+] [M]
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(OUT)   :: HPLUS  ! Calculated [H+] [M]
```

REMARKS:

```
    Calculation:
    ============================================================================
    Solve the following electroneutrality equation:
    [H+] = 2[SO4]nss + [Cl] + [OH] + [HCO3] + 2[CO3] + [HSO3] + 2[SO3] + [NO3]
          - [Na] - 2[Ca] - [K] - 2[Mg] - [NH4]
    Aqueous concentrations of [Cl], [Na], [Ca], [K], and [Mg] come from
    ISORROPIA II
    Let concentrations of [HCO3], [CO3], [HSO3], [SO3], [NO3] and [NH4] evolve
    according to Henry's law equilibrium.
    Assume [S(VI)] = [SO4]nss (this applies for pH > 3)
```

REVISION HISTORY:

```
    25 Jan 2012 - M. Payer    - Added ProTeX headers
```

1.108.10 kCO21

Function kCO21

INTERFACE:

```
      FUNCTION kCO21 ( P, T, LWC, HPLUS ) RESULT ( KCO2p )
```

INPUT PARAMETERS:

```
      REAL*8,  INTENT(IN) :: T, P, LWC, HPLUS
```

OUTPUT PARAMETERS:

```
      REAL*8              :: KCO2p, KCO2p2
```

REVISION HISTORY:

```
    25 Jan 2012 - M. Payer    - Added ProTeX headers
```

1.108.11 kCO22

Function kCO22

INTERFACE:

```
FUNCTION kCO22 ( P, T, LWC, HPLUS ) RESULT ( KCO2p2 )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: T, P, LWC, HPLUS
```

OUTPUT PARAMETERS:

```
REAL*8              :: KCO2p, KCO2p2
```

REVISION HISTORY:

```
25 Jan 2012 - M. Payer    - Added ProTeX headers
```

1.108.12 kSO21

Function kSO21

INTERFACE:

```
FUNCTION kSO21 ( P, T, LWC, HPLUS, SO2 ) RESULT ( KSO2p )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: T, P, LWC, HPLUS, SO2
```

OUTPUT PARAMETERS:

```
REAL*8              :: KSO2p, KSO2p2
```

REVISION HISTORY:

```
25 Jan 2012 - M. Payer    - Added ProTeX headers
```

1.108.13 kSO22

Function kSO22

INTERFACE:

```
FUNCTION kSO22 ( P, T, LWC, HPLUS, SO2 ) RESULT ( KSO2p2 )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: T, P, LWC, HPLUS, SO2
```

OUTPUT PARAMETERS:

```
REAL*8              :: KSO2p, KSO2p2
```

REVISION HISTORY:

```
25 Jan 2012 - M. Payer    - Added ProTeX headers
```

1.108.14 kHNO3

Function kNO3

INTERFACE:

```
FUNCTION kHNO3 ( P, T, LWC, HPLUS, HNO3 ) RESULT ( KHNO3p )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: T, P, LWC, HPLUS, HNO3
```

OUTPUT PARAMETERS:

```
REAL*8              :: KHNO3p
```

REVISION HISTORY:

```
25 Jan 2012 - M. Payer    - Added ProTeX headers
```

1.108.15 kHCl

Function kHCl

INTERFACE:

```
FUNCTION kHCl ( P, T, LWC, HPLUS, Cl ) RESULT ( KHClp )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: T, P, LWC, HPLUS, Cl
```

OUTPUT PARAMETERS:

```
REAL*8              :: KHClp
```

REVISION HISTORY:

```
25 Jan 2012 - M. Payer    - Added ProTeX headers
```

1.108.16 kNH3

Function kNH3

INTERFACE:

```
FUNCTION kNH3 ( P, T, LWC, HPLUS, NH3, Kw ) RESULT ( KNH3p )
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: T, P, LWC, HPLUS, NH3, Kw
```

OUTPUT PARAMETERS:

```
REAL*8              :: KNH3p
```

REVISION HISTORY:

```
25 Jan 2012 - M. Payer    - Added ProTeX headers
```

1.108.17 cubic

Subroutine CUBIC finds the roots of a cubic equation / 3rd order polynomial

INTERFACE:

```
SUBROUTINE CUBIC( A2, A1, A0, NR, CRUTES )
```

USES:

```
USE ERROR_MOD, ONLY : GEOS_CHEM_STOP !ERROR_STOP
```

INPUT PARAMETERS:

```
INTEGER           :: NR
REAL*8            :: A2, A1, A0
REAL*8            :: CRUTES(3)
```

REMARKS:

```
Formulae can be found in numer. recip.  on page 145
  kiran  developed  this version on 25/4/1990
  Dr. Francis S. Binkowski modified the routine on 6/24/91, 8/7/97
***
*** modified 2/23/98 by fsb to incorporate Dr. Ingmar Ackermann's
    recommendations for setting a0, a1,a2 as real*8 variables.
Modified by Bob Yantosca (10/15/02)
- Now use upper case / white space
- force double precision with "D" exponents
- updated comments / cosmetic changes
- now call ERROR_STOP from "error_mod.f" to stop the run safely
```

REVISION HISTORY:

```
25 Jan 2012 - M. Payer    - Added ProTeX headers
```

1.108.18 aqchem_so2

Subroutine AQCHEM_SO2 computes the reaction rates for aqueous SO2 chemistry. (rjp, bmy, 10/31/02, 12/12/02)

INTERFACE:

```
SUBROUTINE AQCHEM_SO2( LWC, T,     P,       SO2, H2O2,
&                      O3,  Hplus, KaqH2O2, KaqO3 )
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN)  :: LWC     ! Liq water content [m3/m3]=1.E-6*L [g/m3]
REAL*8, INTENT(IN)  :: T       ! Temperature [K]
REAL*8, INTENT(IN)  :: P       ! Pressure [atm]
REAL*8, INTENT(IN)  :: SO2     ! SO2  mixing ratio [v/v]
REAL*8, INTENT(IN)  :: H2O2    ! H2O2 mixing ratio [v/v]
REAL*8, INTENT(IN)  :: O3      ! O3   mixing ratio [v/v]
REAL*8, INTENT(IN)  :: HPLUS   ! Concentration of H+ ion (i.e. pH) [v/v]
```

OUTPUT PARAMETERS:

```
      REAL*8, INTENT(OUT) :: KaqH2O2 ! Reaction rate for H2O2
      REAL*8, INTENT(OUT) :: KaqO3   ! Reaction rate for O3
```

REMARKS:

```
    Chemical Reactions:
    ============================================================================
    (R1) HSO3- + H2O2(aq) + H+ => SO4-- + 2H+ + H2O [Jacob, 1986]
                                                                              .
        d[S(VI)]/dt = k[H+][H2O2(aq)][HSO3-]/(1 + K[H+])
        [Seinfeld and Pandis, 1998, page 366]
                                                                              .
    (R2) SO2(aq) + O3(aq) =>
         HSO3-   + O3(aq) =>
         SO3--   + O3(aq) =>
         [Jacob, 1986; Jacobson, 1999]
                                                                              .
         d[S(VI)]/dt = (k0[SO2(aq)] + k1[HSO3-] + K2[SO3--])[O3(aq)]
         [Seinfeld and Pandis, 1998, page 363]
                                                                              .
    Reaction rates can be given as
         Ra     = k [H2O2(ag)] [S(IV)]  [mole/liter*s]  OR
         Krate  = Ra LWC R T / P        [1/s]
                                                                              .
    Where:
         LWC = Liquid water content(g/m3)*10-6 [m3(water)/m3(gas)]
         R   = 0.08205  (atm L / mol-K), Universal gas const.
         T   = Temperature (K)
         P   = Pressure (atm)
                                                                              .
    Procedure:
    ============================================================================
    (a ) Given [SO2] which is assumed to be total SO2 (gas+liquid) in
          equilibrium between gas and liquid phase.
                                                                              .
    (b ) We can compute SO2(g) using Henry's law
            P(so2(g)) = Xg * [SO2]
            Xg = 1/(1 + Faq), Fraction of SO2 in gas
         where:
            Faq   = Kheff * R * T * LWC,
            KHeff = Effective Henry's constant
                                                                              .
    (c ) Then Calculate Aquous phase, S[IV] concentrations
          S[IV] = Kheff * P(so2(g) in atm) [M]
                                                                              .
    (d ) The exact same procedure is applied to calculate H2O2(aq)
```

REVISION HISTORY:

```
(1 ) Updated by Rokjin Park (rjp, bmy, 12/12/02)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.108.19 het_drop_chem

Subroutine HET_DROP_CHEM estimates the in-cloud sulfate production rate in heterogeneous cloud droplets based on the Yuen et al., 1996 parameterization. (bec, 6/16/11)

INTERFACE:

```
SUBROUTINE HET_DROP_CHEM( I, J, L, LSTOT, SSCvv, aSO4, GNH3,
&                         SO2_sr, H2O2O, GNO3, SR, State_Met )
```

USES:

```
USE ERROR_MOD,          ONLY : IT_IS_FINITE, GEOS_CHEM_STOP
USE GIGC_State_Met_Mod, ONLY : MetState
USE TIME_MOD,           ONLY : GET_TS_CHEM
USE TRACER_MOD,         ONLY : TCVV
USE TRACERID_MOD,       ONLY : IDTSO4, IDTSALC
USE TRACERID_MOD,       ONLY : IDTDST2, IDTDST3, IDTDST4
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I, J, L
REAL*8,         INTENT(IN)  :: LSTOT
REAL*8,         INTENT(IN)  :: SSCvv
REAL*8,         INTENT(IN)  :: aSO4
REAL*8,         INTENT(IN)  :: GNH3
REAL*8,         INTENT(IN)  :: SO2_sr
REAL*8,         INTENT(IN)  :: H2O2O
REAL*8,         INTENT(IN)  :: GNO3
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

OUTPUT PARAMETERS:

```
REAL*8,         INTENT(OUT) :: SR ! Sulfate production rate
```

REVISION HISTORY:

```
25 Jan 2012 - M. Payer    - Added ProTeX headers
05 Sep 2013 - M. Sulprizio- Now pass met fields using the State_Met object
```

1.108.20 chem_so4

Subroutine CHEM_SO4 is the SO4 chemistry subroutine from Mian Chin's GOCART model, modified for the GEOS-CHEM model. Now also modified to account for production of crystalline and aqueous sulfur tracers. (rjp, bdf, cas, bmy, 5/31/00, 5/23/06)

INTERFACE:

```
      SUBROUTINE CHEM_SO4( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE CMN_DIAG_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TRACERID_MOD,       ONLY : IDTSO4
      USE TRACERID_MOD,       ONLY : IDTSO4s
      USE TRACERID_MOD,       ONLY : IDTAS
      USE TRACERID_MOD,       ONLY : IDTAHS
      USE TRACERID_MOD,       ONLY : IDTLET
      USE TRACERID_MOD,       ONLY : IDTSO4aq
      USE TRACERID_MOD,       ONLY : IDTNH4aq
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    Reaction List (by Mian Chin, chin@rondo.gsfc.nasa.gov)
    ============================================================================
    The Only production is from SO2 oxidation (save in CHEM_SO2), and the only
    loss is dry depsition here.  Wet deposition will be treated in "wetdep.f".
                                                                              .
    SO4 = SO4_0 * exp(-kt) + PSO4_SO2/kt * (1.-exp(-kt))
      where k = dry deposition.
                                                                              .
```

REVISION HISTORY:

```
(1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
     Updated comments, cosmetic changes. (rjp, bdf, bmy, 9/16/02)
(2 ) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
     Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
     to the entire PBL. (rjp, bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
     sum into AD44 array.  This preents numerical differences when using
     multiple processors. (bmy, 3/24/04)
(5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(6 ) Now reference STT & TCVV from "tracer_mod.f" (bmy, 7/20/04)
(7 ) Now references LCRYST from "logical_mod.f".  Modified for crystalline
     and aqueous sulfate2 tracers: AS, AHS, LET, SO4aq.  Also changed name
     of ND44_TMP to T44 to save space. (cas, bmy, 12/21/04)
(8 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
     "pbl_mix_mod.f" (bmy, 2/22/05)
(9 )  Now remove reference to CMN, it's obsolete.  Now reference
      ITS_IN_THE_STRAT from "tropopause_mod.f" (bmy, 8/22/05)
(10) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(11) Rearrange error check to avoid SEG FAULTS (bmy, 5/23/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
31 Jul 2012 - R. Yantosca - Now loop from 1..LLPAR for GIGC compatibility
31 Jul 2012 - R. Yantosca - Declare temp drydep arrays w/ LLPAR (not LLTROP)
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%TCVV(1:N_TRACERS) and
                            Input_Opt%XNUMOL(1:N_TRACERS) -- avoid OOB errs
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.108.21 chem_so4_aq

Subroutine CHEM_SO4_AQ takes the SO4 produced via aqueous chemistry of SO2 and distribute onto the size-resolved aerosol number and sulfate mass as a part of the TOMAS aerosol microphysics module (win, 1/25/10)

INTERFACE:

```
SUBROUTINE CHEM_SO4_AQ( am_I_Root, Input_Opt,
&                       State_Met, State_Chm, RC )
```

USES:

```
USE CMN_SIZE_MOD
```

```
USE DAO_MOD,            ONLY : CONVERT_UNITS
USE GIGC_Input_Opt_Mod, ONLY : OptINput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE TOMAS_MOD,          ONLY : AQOXID, GETACTBIN
USE TRACERID_MOD,       ONLY : IDTSO4, IDTNK10
USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
NOTE: This subroutine is ignored unless we compile for TOMAS microphysics.
```

REVISION HISTORY:

```
(1 ) As of now the SO4 produced via heterogeneous reaction on the 2-mode
     seasalt is not include in this treatment (win, 7/23/07)
(2 ) Change a fixed kmin = 8 (corresponding to the assumed activation dia.
     of 55nm to be varying with current chemical composition.  Take average
     of the activating bin for LS and CONV rains. (win, 9/25/07)
16 Feb 2012 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
31 May 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm
                            and RC arguments
31 May 2013 - R. Yantosca - Now pass State_Chm to TOMAS routines
```

1.108.22 chem_msa

Subroutine CHEM_MSA is the SO4 chemistry subroutine from Mian Chin's GOCART model, modified for the GEOS-CHEM model. (rjp, bdf, bmy, 5/31/00, 10/25/05)

INTERFACE:

```
 SUBROUTINE CHEM_MSA( am_I_Root, Input_Opt,
&                     State_Met, State_Chm, RC )
```

USES:

```
USE CMN_GCTM_MOD
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD44
USE DRYDEP_MOD,         ONLY : DEPSAV
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE PBL_MIX_MOD,        ONLY : GET_PBL_MAX_L
USE TIME_MOD,           ONLY : GET_TS_CHEM
USE TRACERID_MOD,       ONLY : IDTMSA
USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
Reaction List (by Mian Chin, chin@rondo.gsfc.nasa.gov)
============================================================================
The Only production is from DMS oxidation (saved in CHEM_DMS), and the only
loss is dry depsition here.  Wet deposition will be treated in "wetdep.f".
                                                                            .
MSA = MSA_0 * exp(-dt) + PMSA_DMS/kt * (1.-exp(-kt))
  where k = dry deposition.
```

REVISION HISTORY:

```
(1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
     Updated comments, cosmetic changes. (rjp, bmy, bdf, 9/16/02)
(2 ) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
     Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
     to the entire PBL. (rjp, bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
```

```
      sum into AD44 array.  This preents numerical differences when using
      multiple processors. (bmy, 3/24/04)
(5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(6 ) Now references STT & TCVV from "tracer_mod.f" (bmy, 7/20/04)
(7 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
      "pbl_mix_mod.f".  Also reference GET_PBL_MAX_L from "pbl_mix_mod.f"
      Vertical DO-loops can run up to PBL_MAX and not LLTROP.   Also
      remove reference to header file CMN. (bmy, 2/22/05)
(8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(9 ) Change loop back to over entire troposphere to correctly add production
      of MSA (PMSA_dms) to the MSA tracer array.
     Added reference USE_TROPOPAUSE_MOD, ONLY : ITS_IN_THE_STRAT
      as a precaution.  (pjh, 8/19/2009)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
31 Jul 2012 - R. Yantosca - Now loop from 1..LLPAR for GIGC compatibility
31 Jul 2012 - R. Yantosca - Declare temp drydep arrays w/ LLPAR (not LLTROP)
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%TCVV(1:N_TRACERS) and
                            Input_Opt%XNUMOL(1:N_TRACERS) -- avoid OOB errs
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.108.23 chem_nh3

Subroutine CHEM_NH3 removes NH3 from the surface via dry deposition. (rjp, bdf, bmy, 1/2/02, 10/25/05)

INTERFACE:

```
      SUBROUTINE CHEM_NH3( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE GET_NDEP_MOD,       ONLY : SOIL_DRYDEP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
```

```
      USE PBL_MIX_MOD,        ONLY : GET_PBL_MAX_L
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TRACERID_MOD,       ONLY : IDTNH3
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    If you are using the non-local PBL mixing scheme (VDIFF), then routine
    SOIL_DRYDEP and the ND44 diagnostic updating will be done there.
                                                                             .
    If you are using the full TURBDAY PBL mixing scheme, then we have to
    call the SOIL_DRYDEP and archive the ND44 diagnostics here.
                                                                             .
    Reaction List:
    ============================================================================
    (1 ) NH3 = NH3_0 * EXP( -dt )  where d = dry deposition rate [s-1]
```

REVISION HISTORY:

```
    (1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
         Updated comments, cosmetic changes. (rjp, bmy, bdf, 9/16/02)
    (2 ) Now replace DXYP(J+J0)*1d4 with routine GET_AREA_CM2 from "grid_mod.f"
         Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
    (3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
         to the entire PBL.  Added L and FREQ variables.  Recode to avoid
         underflow from the EXP() function. (rjp, bmy, 8/1/03)
    (4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
         sum into AD44 array.  This preents numerical differences when using
         multiple processors. (bmy, 3/24/04)
    (5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
    (6 ) Now references STT & TCVV from "tracer_mod.f" Also remove reference to
         CMN, it's not needed(bmy, 7/20/04)
    (7 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
         "pbl_mix_mod.f".  Also reference GET_PBL_MAX_L from "pbl_mix_mod.f"
         Vertical DO-loops can run up to PBL_MAX and not LLTROP. (bmy, 2/22/05)
    (8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
    22 Dec 2011 - M. Payer    - Added ProTeX headers
```

```
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
31 Jul 2012 - R. Yantosca - Now loop from 1..LLPAR for GIGC compatibility
31 Jul 2012 - R. Yantosca - Declare temp drydep arrays w/ LLPAR (not LLTROP)
14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
13 Mar 2013 - R. Yantosca - Bug fix: make sure we pass values to the
                            SOIL_DRYDEP routine even when ND44 is off
                            (this happens when LNLPBL = F)
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%TCVV(1:N_TRACERS) and
                            Input_Opt%XNUMOL(1:N_TRACERS) -- avoid OOB errs
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.108.24 chem_nh4

Subroutine CHEM_NH4 removes NH4 from the surface via dry deposition. (rjp, bdf, bmy, 1/2/02, 10/25/05)

INTERFACE:

```
SUBROUTINE CHEM_NH4( am_I_Root, Input_Opt,
&                    State_Met, State_Chm, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD44
USE DRYDEP_MOD,         ONLY : DEPSAV
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
USE PBL_MIX_MOD,        ONLY : GET_PBL_MAX_L
USE TIME_MOD,           ONLY : GET_TS_CHEM
USE TRACERID_MOD,       ONLY : IDTNH4
USE GET_NDEP_MOD,       ONLY : SOIL_DRYDEP
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
    If you are using the non-local PBL mixing scheme (VDIFF), then routine
    SOIL_DRYDEP and the ND44 diagnostic updating will be done there.
                                                                             .
    If you are using the full TURBDAY PBL mixing scheme, then we have to
    call the SOIL_DRYDEP and archive the ND44 diagnostics here.
                                                                             .
    Reaction List:
    ============================================================================
    (1 ) NH4 = NH4_0 * EXP( -dt )  where d = dry deposition rate [s-1]
```

REVISION HISTORY:

```
    (1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
         Updated comments, cosmetic changes. (rjp, bmy, bdf, 9/16/02)
    (2 ) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 of "grid_mod.f".
         Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
    (3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
         to the entire PBL.  Added L and FREQ variables.  Recode to avoid
         underflow from EXP(). (rjp, bmy, 8/1/03)
    (4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
         sum into AD44 array.  This preents numerical differences when using
         multiple processors. (bmy, 3/24/04)
    (5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
    (6 ) Now reference STT & TCVV from "tracer_mod.f".   Also remove reference
         to CMN, it's not needed (bmy, 7/20/04)
    (7 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
         "pbl_mix_mod.f".  Also reference GET_PBL_MAX_L from "pbl_mix_mod.f"
         Vertical DO-loops can run up to PBL_MAX and not LLTROP. (bmy, 2/22/05)
    (8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
    22 Dec 2011 - M. Payer    - Added ProTeX headers
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    31 Jul 2012 - R. Yantosca - Now loop from 1..LLPAR for GIGC compatibility
    31 Jul 2012 - R. Yantosca - Declare temp drydep arrays w/ LLPAR (not LLTROP)
    14 Nov 2012 - R. Yantosca - Add am_I_Root, Input_Opt, RC as arguments
    15 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
    13 Mar 2013 - R. Yantosca - Bug fix: make sure we pass values to the
                                SOIL_DRYDEP routine even when ND44 is off
                                (this happens when LNLPBL = F)
    19 Mar 2013 - R. Yantosca - Now copy Input_Opt%TCVV(1:N_TRACERS) and
                                Input_Opt%XNUMOL(1:N_TRACERS) -- avoid OOB errs
    25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.108.25 chem_nit

Subroutine CHEM_NIT removes SULFUR NITRATES (NIT) from the surface via dry deposition. (rjp, bdf, bmy, 1/2/02, 5/23/06)

INTERFACE:

```
      SUBROUTINE CHEM_NIT( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,           ONLY : AD44
      USE DRYDEP_MOD,         ONLY : DEPSAV
      USE GET_NDEP_MOD,       ONLY : SOIL_DRYDEP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
      USE PBL_MIX_MOD,        ONLY : GET_PBL_MAX_L
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TRACERID_MOD,       ONLY : IDTNIT
      USE TRACERID_MOD,       ONLY : IDTNITs
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
#endif

  If you are using the non-local PBL mixing scheme (VDIFF), then routine
  SOIL_DRYDEP and the ND44 diagnostic updating will be done there.

  If you are using the full TURBDAY PBL mixing scheme, then we have to
  call the SOIL_DRYDEP and archive the ND44 diagnostics here.
```

REMARKS:

```
Reaction List:
============================================================================
(1 ) NIT = NIT_0 * EXP( -dt )  where d = dry deposition rate [s-1]
```

REVISION HISTORY:

```
(1 ) Now reference AD from "dao_mod.f".  Added parallel DO-loops.
     Updated comments, cosmetic changes. (rjp, bmy, bdf, 9/20/02)
(2 ) Now replace DXYP(J+J0)*1d4 with routine GET_AREA_CM2 from "grid_mod.f".
     Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference PBLFRAC from "drydep_mod.f".  Now apply dry deposition
     to the entire PBL.  Added L and FREQ variables.  Recode to avoid
     underflow from EXP(). (rjp, bmy, 8/1/03)
(4 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
     sum into AD44 array.  This preents numerical differences when using
     multiple processors. (bmy, 3/24/04)
(5 ) Now use parallel DO-loop to zero ND44_TMP (bmy, 4/14/04)
(6 ) Now reference STT & TCVV from "tracer_mod.f".  Also remove reference
     to CMN, it's not needed anymore. (bmy, 7/20/04)
(7 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP from
     "pbl_mix_mod.f".  Also reference GET_PBL_MAX_L from "pbl_mix_mod.f"
     Vertical DO-loops can run up to PBL_MAX and not LLTROP. (bmy, 2/22/05)
(8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(9 ) Rearrange error check to avoid SEG FAULTS (bmy, 5/23/06)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
31 Jul 2012 - R. Yantosca - Now loop from 1..LLPAR for GIGC compatibility
31 Jul 2012 - R. Yantosca - Declare temp drydep arrays w/ LLPAR (not LLTROP)
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LNLPBL
13 Mar 2013 - R. Yantosca - Bug fix: make sure we pass values to the
                            SOIL_DRYDEP routine even when ND44 is off
                            (this happens when LNLPBL = F)
19 Mar 2013 - R. Yantosca - Now copy Input_Opt%TCVV(1:N_TRACERS) and
                            Input_Opt%XNUMOL(1:N_TRACERS) -- avoid OOB errs
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.108.26 emisssulfate

Subroutine EMISSSULFATE is the interface between the GEOS-CHEM model and the sulfate emissions routines in "sulfate_mod.f" (bmy, 6/7/00, 10/15/09)

INTERFACE:

```
      SUBROUTINE EMISSSULFATE( am_I_Root, Input_Opt,
     &                         State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE GFED2_BIOMASS_MOD,  ONLY : GFED2_IS_NEW
      USE GFED3_BIOMASS_MOD,  ONLY : GFED3_IS_NEW
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TIME_MOD,           ONLY : GET_SEASON, GET_MONTH
      USE TIME_MOD,           ONLY : GET_YEAR,   ITS_A_NEW_MONTH
      USE TIME_MOD,           ONLY : GET_DAY,    ITS_A_NEW_DAY
      USE TRACERID_MOD,       ONLY : IDTNITs,    IDTSO4s
      USE TRACERID_MOD,       ONLY : IDTDMS,     IDTSO2
      USE TRACERID_MOD,       ONLY : IDTSO4,     IDTNH3
#if   defined( TOMAS )
      USE TRACERID_MOD,       ONLY : IDTSF1,     IDTAW1,  IDTNH4
      USE TRACERID_MOD,       ONLY : IDTNK1
      USE TOMAS_MOD,          ONLY : IBINS,      ICOMP,   IDIAG
      USE TOMAS_MOD,          ONLY : NH4BULKTOBIN
      USE TOMAS_MOD,          ONLY : SRTNH4
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(MetState), INTENT(INOUT) :: State_Met   ! Meteorology State object
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) BXHEIGHT is now dimensioned IIPAR,JJPAR,LLPAR (bmy, 9/26/01)
(2 ) Removed obsolete commented out code from 9/01 (bmy, 10/24/01)
(3 ) Now reference all arguments except FIRSTEMISS, LENV, LEEV from
     header files or F90 modules.  Removed NSRCE,  MONTH, JDAY,
     LWI, BXHEIGHT, DXYP, AD, PTOP, SIGE, PS, PBL, XTRA2, STT, DATA_DIR,
     JYEAR from the arg list.  Now reference GET_PEDGE from F90 module
     "pressure_mod.f" to compute grid box edge pressures.  Now uses
     GET_SEASON from "time_mod.f" to get the season.  Now references
```

```
      IDTDMS, IDTSO2, etc from "tracerid_mod.f".  Now make FIRSTEMISS
      a local SAVEd variable.  Now call READ_BIOMASS_NH3 to read NH3
      biomass and biofuel emissions. (bmy, 12/13/02)
(4 ) Now call READ_NATURAL_NH3 to read the NH3 source from natural
      emissions. (rjp, bmy, 3/23/03)
(5 ) Now use functions GET_SEASON and GET_MONTH from the new "time_mod.f"
      (bmy, 3/27/03)
(6 ) Added first-time printout message (bmy, 4/6/04)
(7 ) Now references CMN_SETUP.  Now read ship SO2 if LSHIPSO2=T.  Also
      references ITS_A_NEW_MONTH from "time_mod.f". (bec, bmy, 5/20/04)
(8 ) Now references STT and ITS_AN_AEROSOL_SIM from "tracer_mod.f".
      Now references LSHIPSO2 from "logical_mod.f" (bmy, 7/20/04)
(9 ) Now references GET_YEAR from "time_mod.f". (bmy, 8/1/05)
(10) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(11) Now check if GFED2 has been updated (yc, phs, 12/23/08)
(12) Add LANTHRO switch to properly turn off the anthropogenic emissions,
      READ_AIRCRAFT_SO2, READ_ANTHRO_SOx, READ_ANTHRO_NH3 (ccc, 4/15/09)
(13) Now read new volcanic SO2 emissions daily (jaf, bmy, 10/15/09)
(14) Add LBIOFUEL switch to properly turn off the biofuel emissions,
     READ_BIOFUEL_SO2, READ_BIOFUEL_NH3. (ccc, 7/16/10)
(14a) Now call SRCSF30 to emit sulfate mass and aerosol number into the
      size-resolved TOMAS aerosol tracers. Reference to tracer IDs of
      the TOMAS aerosol from tracerid_mod  (win, 1/25/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
04 Mar 2013 - R. Yantosca - Remove call to INIT_SULFATE
31 Jul 2013 - M. Sulprizio- Now set SO2 aircraft emissions to zero if using
                            AEIC aircraft emissions (S. Eastham)
29 Jan 2014 - R. Yantosca - Avoid array temporaries in call to NH4BULKTOBIN
```

1.108.27 SULFATE_PBL_MIX

Subroutine SULFATE_PBL_MIX partitions the total anthro sulfate emissions thru the entire boundary layer. Emissions above the PBL are not used, and left in their level, regardless of the mixing scheme. For non-local mixing scheme, all emissions within the PBL are put in the first level.

INTERFACE:

```
      SUBROUTINE SULFATE_PBL_MIX ( EMISS, SULFATE, FRAC_OF_PBL,
     $                             PBL_TOP, IS_LOCAL )
```

USES:

```
      USE ERROR_MOD,    ONLY : ERROR_STOP
      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: PBL_TOP ! Top level of boundary layer
      LOGICAL, INTENT(IN)    :: IS_LOCAL ! mixing scheme
      REAL*8,  INTENT(IN)    :: FRAC_OF_PBL(:) !
      REAL*8,  INTENT(IN)    :: EMISS(:)
```

OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: SULFATE(:) ! partitioned emissions
```

REVISION HISTORY:

```
    27 Oct 2009 - P. Le Sager - initial
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.108.28 srcdms

Subroutine SRCDMS, from Mian Chin's GOCART model, add DMS emissions to the tracer array. Modified for use with the GEOS-CHEM model. (bmy, 6/2/00, 8/16/05)

INTERFACE:

```
      SUBROUTINE SRCDMS( am_I_Root, Input_Opt,
     &                   State_Met, State_Chm, RC )
```

USES:

```
      USE DIAG_MOD,           ONLY : AD13_DMS
      USE DAO_MOD,            ONLY : IS_WATER
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_M2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
      USE TIME_MOD,           ONLY : GET_TS_EMIS
      USE TRACERID_MOD,       ONLY : IDTDMS ! (Lin, 03/31/09)

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! ND13 (for now)
      USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Now reference NSRCE, LWI, DXYP, XTRA2 from either header files or
     F90 modules.  Now use routines from "pressure_mod.f" to compute
     grid box surface pressures. (bmy, 9/18/02)
(2 ) Now replace DXYP(J) with routine GET_AREA_M2 of "grid_mod.f"
     Now use routine GET_TS_EMIS from the new "time_mod.f". (bmy, 3/27/03)
(3 ) For GEOS-4, convert PBL from [m] to [hPa] w/ the hydrostatic law.
     Now references SCALE_HEIGHT from "CMN_GCTM".  Added BLTHIK variable
     for PBL thickness in [hPa]. (bmy, 1/15/04)
(4 ) Remove reference to "pressure_mod.f".  Now reference GET_FRAC_OF_PBL
     and GET_PBL_TOP_L from "pbl_mix_mod.f". (bmy, 2/22/05)
(5 ) Switch from Liss & Merlivat to Nightingale formulation for DMS
     emissions. (swu, bmy, 8/16/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.108.29 srcso2

Subroutine SRCSO2 (originally from Mian Chin) computes SO2 emissons from aircraft, biomass, and anthro sources. (rjp, bdf, bmy, 6/2/00, 12/3/09)

INTERFACE:

```
SUBROUTINE SRCSO2( am_I_Root, NSEASON, Input_Opt, State_Chm, RC )
```

USES:

```
USE BRAVO_MOD,      ONLY     : GET_BRAVO_ANTHRO, GET_BRAVO_MASK
USE CAC_ANTHRO_MOD, ONLY     : GET_CANADA_MASK,  GET_CAC_ANTHRO
USE DIAG_MOD,       ONLY     : AD13_SO2_an,      AD13_SO2_ac
USE DIAG_MOD,       ONLY     : AD13_SO2_bb,      AD13_SO2_nv
USE DIAG_MOD,       ONLY     : AD13_SO2_ev,      AD13_SO2_bf
USE DIAG_MOD,       ONLY     : AD13_SO2_sh
USE EPA_NEI_MOD,    ONLY     : GET_EPA_ANTHRO,   GET_EPA_BIOFUEL
USE EPA_NEI_MOD,    ONLY     : GET_USA_MASK
USE ERROR_MOD,      ONLY     : ERROR_STOP,       GEOS_CHEM_STOP
USE ERROR_MOD,      ONLY     : IS_SAFE_DIV
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GRID_MOD,       ONLY     : GET_AREA_CM2
USE GRID_MOD,       ONLY     : GET_XOFFSET, GET_YOFFSET
```

```
      USE NEI2005_ANTHRO_MOD, ONLY : GET_NEI2005_ANTHRO
      USE NEI2005_ANTHRO_MOD, ONLY : NEI05_MASK => USA_MASK
      USE PBL_MIX_MOD,    ONLY     : GET_FRAC_OF_PBL,  GET_PBL_TOP_L
      USE PRESSURE_MOD,   ONLY     : GET_PEDGE
      USE TIME_MOD,       ONLY     : GET_TS_EMIS,      GET_DAY_OF_YEAR
      USE TIME_MOD,       ONLY     : GET_DAY_OF_WEEK_LT
      USE TRACERID_MOD,   ONLY     : IDTSO2

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! ND13, LD13 (for now)
      USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      INTEGER,        INTENT(IN)    :: NSEASON     ! Season #: 1=DJF; 2=MAM;
                                                   !           3=JJA; 4=SON
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

(1) Now reference NSRCE, JDAY, PBL, XTRA2, BXHEIGHT from either header files or F90 modules. Also use routines from "pressure_mod.f" to compute grid box pressures. (bmy, 9/18/02)

(2) Now use routines GET_TS_EMIS and GET_DAY_OF_YEAR from the new "time_mod.f" (bmy, 3/27/03)

(3) For GEOS-4, convert PBL from [m] to [hPa] w/ the hydrostatic law. Now references SCALE_HEIGHT from "CMN_GCTM". Added BLTHIK variable to hold PBL thickness in [hPa]. (bmy, 1/15/04)

(4) Now references AD13_SO2_sh array from "diag_mod.f". Also references LSHIPSO2 from "CMN_SETUP" (bec, bmy, 5/20/04)

(5) Now references LSHIPSO2 from "logical_mod.f" (bmy, 7/20/04)

(6) Now references routines GET_EPA_ANTHRO and GET_USA_MASK from "epa_nei_mod.f". Now references GET_AREA_CM2 from "grid_mod.f". Now references GET_DAY_OF_WEEK from "time_mod.f" Now references LNEI99 from "logical_mod.f". Now can overwrite the anthro SOx emissions over the continental US if LNEI99=T. Now references IDTSO2 from "tracerid_mod.f. (rch, rjp, bmy, 11/16/04)

(7) Remove reference to "pressure_mod.f". Now reference GET_FRAC_OF_PBL and GET_PBL_TOP_L from "pbl_mix_mod.f". Removed reference to header file CMN. (bmy, 2/22/05)

(8) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)

```
(9 ) Now references GET_BRAVO_ANTHRO and GET_BRAVO_MASK from "bravo_mod.f"
     for BRAVO Mexican emissions. (rjp, kfb, bmy, 6/26/06)
(10) Bug fix: EPA emissions were overwritten by regular ones when both BRAVO
      and EPA were used. (phs, 10/4/07)
(11) Now use CAC Canadian emissions, if necessary (amv, 1/10/08)
(12) Bug fix: Always fill the diagnostic array AD13_SO2_sh because it
     is allocated anyway (phs, 2/27/09)
(13) Changed processing of volcanic SO2 emissions (jaf, bmy, 10/15/09)
(14) Read NEI now (amv, 10/07/2009)
(15) Now calls SULFATE_PBL_MIX to do the PBL mixing of
     emissions (phs, 10/27/09)
(16) Rewrite Aerocom SO2 emissions section to avoid errors on SunStudio
     compiler. Also avoid division by zero. (bmy, 12/3/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
14 Jun 2013 - R. Yantosca - Now determine weekday/weekend with respect to
                            the local time at each grid box.  (Formerly,
                            this had been done w/r/t the GMT time.
```

1.108.30 srcso4

Subroutine SRCSO4 (originally from Mian Chin) computes SO4 emissions from anthropogenic sources (rjp, bdf, bmy, 6/2/00, 5/27/09)

INTERFACE:

```
SUBROUTINE SRCSO4( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
USE BRAVO_MOD,          ONLY : GET_BRAVO_ANTHRO, GET_BRAVO_MASK
USE CAC_ANTHRO_MOD,     ONLY : GET_CANADA_MASK,  GET_CAC_ANTHRO
USE NEI2005_ANTHRO_MOD, ONLY : GET_NEI2005_ANTHRO
USE NEI2005_ANTHRO_MOD, ONLY : NEI05_MASK => USA_MASK
USE DIAG_MOD,           ONLY : AD13_SO4_an,     AD13_SO4_bf
USE EPA_NEI_MOD,        ONLY : GET_EPA_ANTHRO,  GET_EPA_BIOFUEL
USE EPA_NEI_MOD,        ONLY : GET_USA_MASK
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
USE TIME_MOD,           ONLY : GET_TS_EMIS
USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK_LT
USE TRACERID_MOD,       ONLY : IDTSO4, IDTSO2

USE CMN_SIZE_MOD             ! Size parameters
```

```
      USE CMN_DIAG_MOD             ! ND13 (for now)
      USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Emission of SO4 is read in SULFATE_READYR, in [kg/box/s].
     It is converted to [kg/box/timestep] here.
(2 ) Now use routine GET_TS_EMIS from the new "time_mod.f" (bmy, 3/27/03)
(3 ) For GEOS-4, convert PBL from [m] to [hPa] w/ the barometric law.
     Now references SCALE_HEIGHT from "CMN_GCTM".  Added BLTHIK variable
     to hold PBL thickness in [hPa]. (bmy, 1/15/04)
(4 ) Now references GET_EPA_ANTHRO, GET_EPA_BIOFUEL, and GET_USA_MASK from
     "epa_nei_mod.f".  Now references AD13_SO4_bf from "diag_mod.f".  Now
     references GET_AREA_CM2 from "grid_mod.f".  Now references
     GET_DAY_OF_WEEK from "time_mod.f".  Now references LNEI99 from
     "logical_mod.f".  Now can overwrite the anthro SOx emissions over
     the continental US if LNEI99=T.  Now references IDTSO4 from
     "tracerid_mod.f". (rch, rjp, bmy, 11/16/04)
(5 ) Remove reference to "pressure_mod.f".  Now reference GET_FRAC_OF_PBL
     and GET_PBL_TOP_L from "pbl_mix_mod.f".  Removed reference to header
     file CMN. (bmy, 2/22/05)
(6 ) Now references XNUMOL & XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
(7 ) Now overwrite CAC emissions over Canada, if necessary (amv,  1/10/08)
(8 ) Need to add CAC_AN to the PRIVATE statement (bmy, 5/27/09)
(9 ) Now account for BRAVO SO4. Fix typo for CAC (phs, 8/24/09)
(10) Now account for NEI 2005 inventory (amv, 10/07/2009)
(11) Now calls SULFATE_PBL_MIX to do the PBL mixing of
     emissions (phs, 10/27/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
14 Jun 2013 - R. Yantosca - Now determine weekday/weekend with respect to
                            the local time at each grid box.  (Formerly,
                            this had been done w/r/t the GMT time.
13 Dec 2013 - M. Sulprizio- Bug fix: Make sure we apply NEI05 emissions when
                            NEI05_MASK > 0, not NEI05_MASK < 0 (J. Fisher)
```

1.108.31 srcsf30

! Subroutine SRCSF30 handles 30bin sulfate SF1-SF30 and number NK1-NK30 emissions into the GEOS-CHEM tracer array.(win, 1/25/10)

INTERFACE:

```
SUBROUTINE SRCSF30( TC1, TC2, Input_Opt, State_Met )
```

USES:

```
USE CAC_ANTHRO_MOD,     ONLY : GET_CANADA_MASK
USE CAC_ANTHRO_MOD,     ONLY : GET_CAC_ANTHRO
USE DIAG_MOD,           ONLY : AD59_SULF,     AD59_NUMB
USE EPA_NEI_MOD,        ONLY : GET_EPA_ANTHRO,  GET_EPA_BIOFUEL
USE EPA_NEI_MOD,        ONLY : GET_USA_MASK
USE ERROR_MOD,          ONLY : ERROR_STOP,  IT_IS_NAN
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
USE PRESSURE_MOD,       ONLY : GET_PCENTER
USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK
USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK_LT
USE TIME_MOD,           ONLY : GET_TS_EMIS
USE TOMAS_MOD,          ONLY : IBINS, AVGMASS, ICOMP
USE TOMAS_MOD,          ONLY : Xk,  SUBGRIDCOAG, MNFIX
USE TOMAS_MOD,          ONLY : SRTSO4, SRTNH4,  DEBUGPRINT
USE TRACER_MOD,         ONLY : XNUMOL
USE TRACERID_MOD

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_DIAG_MOD             ! ND13 (for now)
USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
! TC1 (REAL*8 ) : Array for 30-bin NK1-NK30 tracer number [no.]
! TC2 (REAL*8)  : Array for 30-bin SF1-SF30 tracer mass [kg]
REAL*8,  INTENT(INOUT) :: TC1(IIPAR,JJPAR,LLPAR,IBINS)
REAL*8,  INTENT(INOUT) :: TC2(IIPAR,JJPAR,LLPAR,IBINS*ICOMP)
```

REMARKS:

```
NOTE: This subroutine is ignored unless you compile for TOMAS microphysics.
                                                                             .
Variable comments
```

```
=============================================================================
NdistInit(IBINS)    : Initial size dist of emission
NdistFinal(IBINS)   : Final size dist of emissions after subgrid coag
Ndist(IBINS)        : Number size dist of grid cell
Mdist(IBINS,ICOMP)  : Mass size dist of grid cell
MaddFinal(NBINS)    : madd added to bins due to coagulation
tscale              : mixing time (s) currently assumed 10 hr. (win, 10/4/07)
```

REVISION HISTORY:

```
(1 ) For now use the call subroutine SRCSO4 as the source of bulk mass
     emitted (win, 7/17/07) ---> did not work.  I need the SO4an and SO4bf
(2 ) Copy the subroutine SRCSO4 to use here. It may seem unwise to have the
     same code in two subroutine (if have to modify in the future, have to
     do at both places), but let's have it this way for now in case I can
     run the microphysics run without needing to have bulk SO4 tracer
     (win, 7/18/07)
(3 ) Overwrite SO4 emission of EPA/NEI99 inventory with a calculation using
     an assumption that EPA/NEI99 SO2 emission is 99% of total S emission
     (by mole) then calculate SO4 to be 1% of the total (win, 10/4/07)
(4 ) Add subgrid coagulation calculation (win, 10/4/07)
(5 ) Import SRCSF30 from geoschem v.7-04-11 to v.8-02-02 and update the code
     for CAC emissions and Lin's PBL scheme (win, 1/25/10)
16 Feb 2012 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
14 Jun 2013 - R. Yantosca - Now determine weekday/weekend with respect to
                            the local time at each grid box.  (Formerly,
                            this had been done w/r/t the GMT time.
```

1.108.32 srcnh3

Subroutine SRCNH3 handles NH3 emissions into the GEOS-CHEM tracer array. (rjp, bmy, 12/17/01, 5/27/09)

INTERFACE:

```
SUBROUTINE SRCNH3( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
USE CAC_ANTHRO_MOD,     ONLY : GET_CANADA_MASK
USE CAC_ANTHRO_MOD,     ONLY : GET_CAC_ANTHRO
USE NEI2005_ANTHRO_MOD, ONLY : GET_NEI2005_ANTHRO
USE NEI2005_ANTHRO_MOD, ONLY : NEI05_MASK => USA_MASK
USE DIAG_MOD,           ONLY : AD13_NH3_an, AD13_NH3_bb
USE DIAG_MOD,           ONLY : AD13_NH3_bf, AD13_NH3_na
```

```
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE EPA_NEI_MOD,        ONLY : GET_EPA_ANTHRO, GET_EPA_BIOFUEL
      USE EPA_NEI_MOD,        ONLY : GET_USA_MASK
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_OF_PBL, GET_PBL_TOP_L
      USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK_LT
      USE TIME_MOD,           ONLY : GET_TS_EMIS
      USE TRACERID_MOD,       ONLY : IDTNH3

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! ND13
      USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Now save NH3 emissions to ND13 diagnostic (bmy, 12/13/02)
(2 ) Now reference AD13_NH3_na from "diag_mod.f", and archive natural
     source NH3 diagnostics for ND13.  Also consider natural source NH3
     when partitioning by level into the STT array. (rjp, bmy, 3/23/03)
(3 ) Now use routine GET_TS_EMIS from the new "time_mod.f" (bmy, 3/27/03)
(4 ) For GEOS-4, convert PBL from [m] to [hPa] w/ the barometric law.
     Now references SCALE_HEIGHT from "CMN_GCTM".  Added BLTHIK variable
     to hold PBL thickness in [hPa]. (bmy, 1/15/04)
(5 ) Now references GET_EPA_ANTHRO, GET_EPA_BIOFUEL, and GET_USA_MASK from
     "epa_nei_mod.f".  Now references GET_DAY_OF_WEEK from "time_mod.f".
     Now references LNEI99 from "logical_mod.f".  Now references
     GET_AREA_CM2 from "grid_mod.f".  Now references IDTNH3 from
     "tracerid_mod.f".  Now references XNUMOL from CMN_O3.  Now can
     overwrite the anthro & biofuel NH3 emissions over the continental US
     if LNEI99=T.  Now references IDTNH3 from "tracerid_mod.f".
     (rjp, rch, bmy, 11/16/04)
(6 ) Remove reference to "pressure_mod.f".  Now reference GET_FRAC_OF_PBL
     and GET_PBL_TOP_L from "pbl_mix_mod.f".  Removed reference to header
     file CMN. (bmy, 2/22/05)
(7 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
```

```
(8 ) Need to add CAC_AN to the PRIVATE loop (bmy, 5/27/09)
(9 ) Added NIE 2005 (amv, 10/07/2009)
(10) Made NH3an 3D; Calls SULFATE_PBL_MIX to do the PBL mixing of
     emissions, and allows for emissions above the PBL (phs, 10/27/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
14 Jun 2013 - R. Yantosca - Now determine weekday/weekend with respect to
                            the local time at each grid box.  (Formerly,
                            this had been done w/r/t the GMT time.
22 Jul 2013 - M. Sulprizio- Now copy LRCP from Input_Opt
```

1.108.33 get_oh

Function GET_OH returns OH from SMVGEAR's CSPEC array (for coupled runs) or monthly mean OH (for offline runs). Imposes a diurnal variation on OH for offline simulations. (bmy, 12/16/02, 7/20/04)

INTERFACE:

```
  FUNCTION GET_OH( I, J, L, Input_Opt, State_Met )
 &         RESULT( OH_MOLEC_CM3 )
```

USES:

```
  USE CMN_SIZE_MOD
  USE COMODE_MOD,         ONLY : CSPEC, JLOP
  USE ERROR_MOD,          ONLY : ERROR_STOP
  USE GIGC_Input_Opt_Mod, ONLY : OptInput
  USE GIGC_State_Met_Mod, ONLY : MetState
  USE GLOBAL_OH_MOD,      ONLY : OH
  USE TIME_MOD,           ONLY : GET_TS_CHEM
  USE TRACERID_MOD,       ONLY : IDOH
```

INPUT PARAMETERS:

```
  INTEGER,        INTENT(IN) :: I, J, L     ! Lon, lat, level indices
  TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
  TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDOH (bmy, 11/1/02)
(2 ) Now use function GET_TS_CHEM from "time_mod.f" (bmy, 3/27/03)
(3 ) Now reference ITS_A_FULLCHEM_SIM, ITS_AN_AEROSOL_SIM from
     "tracer_mod.f".  Also replace IJSURF w/ an analytic function.
     (bmy, 7/20/04)
22 Dec 2011 - M. Payer    - Added ProTeX headers
28 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
```

```
28 Nov 2012 - R. Yantosca - Add State_Met to argument list
04 Mar 2013 - R. Yantosca - Now pass Input_Opt%ITS_A_FULLCHEM_SIM and
                            Input_Opt%ITS_AN_AEROSOL_SIM
```

1.108.34 set_oh

Subroutine SET_OH saves the modified OH value back to SMVGEAR's CSPEC array for coupled sulfate/aerosol simulations. (bmy, 12/16/02)

INTERFACE:

```
SUBROUTINE SET_OH( I, J, L, OH )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_MOD,   ONLY : CSPEC, JLOP
USE TRACERID_MOD, ONLY : IDOH
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L ! Indices for lon, lat, vertical level
REAL*8,  INTENT(IN) :: OH      ! OH at (I,J,L) to be saved into CSPEC
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDOH (bmy, 12/16/02)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.108.35 get_no3

Function GET_NO3 returns NO3 from SMVGEAR's CSPEC array (for coupled runs) or monthly mean OH (for offline runs). For offline runs, the concentration of NO3 is set to zero during the day. (rjp, bmy, 12/16/02)

INTERFACE:

```
FUNCTION GET_NO3( I, J, L, Input_Opt, State_Met )
&         RESULT( NO3_MOLEC_CM3 )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_MOD,         ONLY : CSPEC, JLOP
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE GLOBAL_NO3_MOD,     ONLY : NO3
USE TRACERID_MOD,       ONLY : IDNO3
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I, J, L     ! Lon, lat, vertical level
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
(1 ) Now references ERROR_STOP from "error_mod.f".  We also assume that
     SETTRACE has been called to define IDNO3.  Now also set NO3 to
     zero during the day. (rjp, bmy, 12/16/02)
(2 ) Now reference ITS_A_FULLCHEM_SIM and ITS_AN_AEROSOL_SIM from
     "tracer_mod.f".  Also remove reference to CMN.   Also replace
     IJSURF with an analytic function. (bmy, 7/20/04)
22 Dec 2011 - M. Payer    - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
28 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
04 Mar 2013 - R. Yantosca - Now pass Input_Opt%ITS_A_FULLCHEM_SIM and
                            Input_Opt%ITS_AN_AEROSOL_SIM
```

1.108.36 set_no3

Subroutine SET_NO3 saves the modified NO3 value back to SMVGEAR's CSPEC array for coupled lfate/aerosol simulations. (rjp, bmy, 12/16/02, 7/20/04)

INTERFACE:

```
SUBROUTINE SET_NO3( I, J, L, NO3 )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_MOD,   ONLY : CSPEC, JLOP
USE TRACERID_MOD, ONLY : IDNO3
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L ! Indices for lon, lat, vertical level
REAL*8,  INTENT(IN) :: NO3     ! NO3 at (I,J,L) to be saved into CSPEC
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDNO3. (bmy, 12/16/02)
(2 ) Remove references to "error_mod.f" and CMN (bmy, 7/20/04)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.108.37 get_o3

Function GET_O3 returns monthly mean O3 for offline sulfate aerosol simulations. (bmy, 12/16/02, 10/25/05)

INTERFACE:

```
FUNCTION GET_O3( I, J, L, Input_Opt, State_Met ) RESULT( O3_VV )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_MOD,         ONLY : CSPEC, JLOP, VOLUME
USE ERROR_MOD,          ONLY : ERROR_STOP
USE GIGC_Input_Opt_MOd, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE TRACER_MOD,         ONLY : XNUMOLAIR
USE TRACERID_MOD,       ONLY : IDO3
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)  :: I, J, L     ! Lon, lat, vertical level
TYPE(OptInput), INTENT(IN)  :: Input_Opt
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
(1 ) We assume SETTRACE has been called to define IDO3. (bmy, 12/16/02)
(2 ) Now reference inquiry functions from "tracer_mod.f" (bmy, 7/20/04)
(3 ) Now remove reference to CMN, it's obsolete.  (bmy, 8/22/05)
(4 ) Now references XNUMOLAIR from "tracer_mod.f" (bmy, 10/25/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
04 Mar 2013 - R. Yantosca - Now pass Input_Opt%ITS_A_FULLCHEM_SIM and
                            Input_Opt%ITS_AN_AEROSOL_SIM
```

1.108.38 read_nonerup_volc

Subroutine READ_NONERUP_VOLC reads SO2 emissions from non-eruptive volcanoes. (rjp, bdf, bmy, jaf, 9/19/02, 10/3/05, 10/15/09)

INTERFACE:

```
SUBROUTINE READ_NONERUP_VOLC( INDAY, INMONTH, INYEAR )
```

USES:

```
USE BPCH2_MOD,      ONLY : GET_TAU0, READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
USE TIME_MOD,       ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)     :: INDAY   ! Current 2-digit day
      INTEGER, INTENT(IN)     :: INMONTH ! Current month number (1-12)
      INTEGER, INTENT(IN)     :: INYEAR  ! Current 4-digit year
```

REVISION HISTORY:

```
   (1 ) Split off from old module routine "sulfate_readyr" (bmy, 9/19/02)
   (2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
   (3 ) Now read files from "sulfate_sim_200508/" (bmy, 7/28/05)
   (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (5 ) Complete re-write as volcanic emissions are now monthly and
  stored as BPCH files (jaf, bmy, 10/15/09)
   (6 ) Now use MNYEAR_VOLC and MXYEAR_VOLC as 1st and last year of emissions.
        (ccc, 9/30/10)
   (7 ) Volcanic data have been updated. Use a new directory. (ccc, 9/30/10)
   22 Dec 2011 - M. Payer    - Added ProTeX headers
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
   24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
   03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.108.39 read_erup_volc

Subroutine READ_ERUP_VOLC reads SO2 emissions from eruptive volcanoes. (rjp, bdf, bmy, jaf, 9/19/02, 10/3/05, 10/15/09)

INTERFACE:

```
      SUBROUTINE READ_ERUP_VOLC( INDAY, INMONTH, INYEAR )
```

USES:

```
      USE BPCH2_MOD,      ONLY : GET_TAU0, READ_BPCH2
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD,  ONLY : DATA_DIR_1x1
      USE REGRID_A2A_MOD, ONLY : DO_REGRID_A2A
      USE TIME_MOD,       ONLY : EXPAND_DATE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)     :: INDAY   ! Current 2-digit day
      INTEGER, INTENT(IN)     :: INMONTH ! Current month number (1-12)
      INTEGER, INTENT(IN)     :: INYEAR  ! Current 4-digit year
```

REVISION HISTORY:

```
   (1 ) Split off from old module routine "sulfate_readyr" (bmy, 9/19/02)
   (2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
```

```
   (3 ) Now read files from "sulfate_sim_200508/" (bmy, 7/28/05)
   (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
   (5 ) Complete re-write as volcanic emissions are now monthly and
  stored as BPCH files (jaf, bmy, 10/15/09)
   (6 ) Now use MNYEAR_VOLC and MXYEAR_VOLC as 1st and last year of emissions.
        (ccc, 9/30/10)
   (7 ) Volcanic data have been updated. Use a new directory. (ccc, 9/30/10)
   22 Dec 2011 - M. Payer    - Added ProTeX headers
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
   24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
   03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.108.40 read_anthro_sox

Suborutine READ_ANTHRO_SOx reads the anthropogenic SOx from disk, and partitions it into anthropogenic SO2 and SO4. (rjp, bdf, bmy, 9/20/02, 10/31/08)

INTERFACE:

```
      SUBROUTINE READ_ANTHRO_SOx( Input_Opt, THISMONTH, NSEASON )
```

USES:

```
      USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
      USE DIRECTORY_MOD,        ONLY : DATA_DIR
      USE EDGAR_MOD,            ONLY : GET_EDGAR_ANTH_SO2
      USE EMEP_MOD,             ONLY : GET_EMEP_ANTHRO
      USE EMEP_MOD,             ONLY : GET_EUROPE_MASK
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff
      USE GIGC_Input_Opt_Mod,   ONLY : OptInput
      USE GRID_MOD,             ONLY : GET_XMID,        GET_YMID
      USE GRID_MOD,             ONLY : GET_AREA_CM2
      USE RCP_MOD,              ONLY : GET_RCP_EMISSION
      USE STREETS_ANTHRO_MOD,   ONLY : GET_SE_ASIA_MASK
      USE STREETS_ANTHRO_MOD,   ONLY : GET_STREETS_ANTHRO
      USE TIME_MOD,             ONLY : GET_YEAR
      USE TRACER_MOD,           ONLY : XNUMOL
      USE TRACERID_MOD,         ONLY : IDTSO2, IDTSO4
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D
      USE SCALE_ANTHRO_MOD,     ONLY : GET_ANNUAL_SCALAR
 [eml
      USE LOGICAL_MOD,          ONLY : LHIST
 eml]
#if   defined( TOMAS )
      USE TRACERID_MOD,         ONLY : IDTNK1    ! For TOMAS microphysics
#endif
```

```
      USE CMN_SIZE_MOD              ! Size parameters
      USE CMN_O3_MOD                ! FSCALYR
```

INPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(IN)    :: Input_Opt ! Input Options object
      INTEGER,        INTENT(IN)    :: THISMONTH ! Current month number (1-12)
      INTEGER,        INTENT(IN)    :: NSEASON   ! Season #: 1=DJF; 2=MAM;
                                                 !           3=JJA; 4=SON
```

REVISION HISTORY:

```
(1 ) Now use functions GET_XMID and GET_YMID to compute lon and lat
     centers of grid box (I,J).  Now replace DXYP(JREF)*1d4 with routine
     GET_AREA_CM2 of "grid_mod.f".  Now use functions GET_MONTH and
     GET_YEAR of time_mod.f".  Now call READ_BPCH2 with QUIET=.TRUE.
     (bmy, 3/27/03)
(2 ) Now references DATA_DIR from "directory_mod.f".  Also removed
     reference to CMN, it's not needed. (bmy, 7/20/04)
(3 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(6 ) Now computes future SOx emissions (swu, bmy, 5/30/06)
(7 ) Now can read either EDGAR or GEIA emissions (avd, bmy, 7/14/06)
(8 ) Now overwrite David Streets' SO2, if necessary (yxw, bmy, 8/14/06)
(9 ) Now accounts for FSCLYR (phs, 3/17/08)
(9 ) Bug fix: Using tracer #30 in the call to GET_STREETS_ANTHRO can cause
     problems when adding or removing species.  Replace w/ IDTNH3.
     (dkh, 10/31/08)
(10) Account for multilevels emissions (amv, 10/07/2009)
(11 ) Use 1% SO4 fraction (out of total SOx) everywhere when running
      with TOMAS aerosols. (win, 1/25/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
30 May 2013 - S. Farina   - Merge in TOMAS updates
22 Jul 2013 - M. Sulprizio- Now copy LRCP from Input_Opt
```

1.108.41 read_ocean_dms

Subroutine READ_OCEAN_DMS reads seawater concentrations of DMS (nmol/L). (rjp, bdf, bmy, 9/20/02, 10/3/05)

INTERFACE:

```
SUBROUTINE READ_OCEAN_DMS( THISMONTH )
```

USES:

```
USE CMN_SIZE_MOD
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
(2 ) Now call READ_BPCH2 with QUIET=.TRUE. (bmy, 3/27/03)
(3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(4 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids (bmy, 8/16/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.108.42 read_sst

Subroutine READ_SST reads monthly mean sea surface temperatures. (rjp, bdf, bmy, 9/18/02, 7/13/09)

INTERFACE:

```
SUBROUTINE READ_SST( THISMONTH, THISYEAR, State_Met )
```

USES:

```
USE BPCH2_MOD,          ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,          ONLY : GET_TAU0,        READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : DATA_DIR,        DATA_DIR_1x1
USE GIGC_State_Met_Mod, ONLY : MetState
USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
USE TRANSFER_MOD,       ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN)    :: THISMONTH ! Current month number (1-12)
INTEGER,        INTENT(IN)    :: THISYEAR  ! Current 4-digit year
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met ! Meteorology State object
```

REVISION HISTORY:

```
(1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
(2 ) Now call READ_BPCH2 with QUIET=.TRUE. (bmy, 3/27/03)
(3 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(4 ) Now use interannual SST data from NOAA if present; otherwise use
     climatological SST data.  Now read data for both GCAP and GEOS
     grids (bmy, 8/16/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Now read int'annual SST data on the GEOS 1x1 grid (bmy, 11/17/05)
(7 ) Last year of data is now 2008 (bmy, 7/13/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.108.43 read_biofuel_so2

Subroutine READ_BIOFUEL_SO2 reads monthly mean biomass burning emissions for SO2. SOx is read in, and converted to SO2. (rjp, bdf, bmy, phs, 1/16/03, 12/23/08)

INTERFACE:

```
      SUBROUTINE READ_BIOFUEL_SO2( THISMONTH )
```

USES:

```
      USE BIOMASS_MOD,          ONLY : BIOMASS
      USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
      USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
      USE DIRECTORY_MOD,        ONLY : DATA_DIR,        DATA_DIR_1x1
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2bf
      USE LOGICAL_MOD,          ONLY : LBIOMASS,        LFUTURE
      USE TIME_MOD,             ONLY : ITS_A_LEAPYEAR
      USE TRACER_MOD,           ONLY : XNUMOL
      USE TRACERID_MOD,         ONLY : IDTSO2
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D
      USE REGRID_A2A_MOD,       ONLY : DO_REGRID_A2A
[eml
      USE LOGICAL_MOD,          ONLY : LHIST
      USE TIME_MOD,             ONLY : GET_HISTYR
eml]

      USE CMN_SIZE_MOD               ! Size parameters
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
(2 ) Modified molar ratio of biomass burning SO2 per CO.  Added SO2
     emission from biofuel burning. (rjp, bmy, 1/16/03)
(3 ) Now replace DXYP(J+J0)*1d4 with routine GET_AREA_CM2 of "grid_mod.f"
     Now replace MONTH with the argument THISMONTH.  Now call READ_BPCH2
     with QUIET=.TRUE. (bmy, 3/27/03)
(4 ) Now references DATA_DIR from "directory_mod.f".  Also removed
     references to CMN and CMN_SETUP. (bmy, 7/20/04)
(5 ) Now can read either seasonal or interannual biomass burning emissions.
     Now references routines from both "logical_mod.f" and "time_mod.f".
     Now reads SO2 biomass emissions directly rather than computing
     it by mole fraction from CO. (rjp, bmy, 1/11/05)
(6 ) Now read data for both GCAP and GEOS grids (bmy, 8/16/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Now computes future biomass emissions, if necessary (swu, bmy, 5/30/06)
(9 ) Now only read the biofuel, we have moved the biomass-reading code
     to "gc_biomass_mod.f" for compatibility with GFED2 biomass emissions
     (bmy, 9/27/06)
(10) Now prevent seg fault if BIOMASS emissions are turned off.
     (bmy, 10/3/06)
(11) Renamed READ_BIOFUEL_SO2, and move all biomass code to GET_BIOMASS_SO2
     to account for several GFED2 products (yc, phs, 12/23/08)
(12) IDBSO2 is not used anymore (ccc, 01/29/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Removed reference to GET_AREA_CM2
08 Mar 2012 - M. Payer    - Added modifications for historical emissions of
                            SO2 (E. Leibensperger)
06 Apr 2012 - M. Payer    - Changed regrid algorithm to map_a2a (M. Cooper)
24 May 2012 - R. Yantosca - Fixed minor bugs in map_a2a implementation
24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
03 Jan 2013 - M. Payer    - Bug fix for regridding of historical emissions.
                            Changed to PERAREA=1 since units are kg/yr.
03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
```

1.108.44 get_biomass_so2

Subroutine GET_BIOMASS_SO2 retrieve monthly/8-day/3hr biomass burning emissions for SO2. (yc, phs, 12/23/08)

INTERFACE:

```
SUBROUTINE GET_BIOMASS_SO2
```

USES:

```
USE BIOMASS_MOD,          ONLY : BIOMASS
```

```
      USE CMN_SIZE_MOD
      USE TRACERID_MOD,         ONLY : IDBSO2
      USE GRID_MOD,             ONLY : GET_AREA_CM2
      USE TRACER_MOD,           ONLY : XNUMOL
      USE TRACERID_MOD,         ONLY : IDTSO2
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D
```

REVISION HISTORY:

```
(1 ) Extracted from old module subroutine READ_BIOMASS_SO2
     (yc, phs, 12/23/08)
(2 ) IDBSO2 is now in tracerid_mod.f (fp, 6/2009)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.108.45 read_aircraft_so2

Subroutine READ_AIRCRAFT_SO2 reads monthly mean aircraft fuel emissions and converts them to SO2 emissions. (rjp, bdf, bmy, 9/18/02, 10/3/05)

INTERFACE:

```
      SUBROUTINE READ_AIRCRAFT_SO2( THISMONTH, State_Met )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_RES_EXT, GET_TAU0, READ_BPCH2
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD,      ONLY : DATA_DIR
      USE FILE_MOD,           ONLY : IOERROR
      USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN) :: THISMONTH   ! Current month number (1-12)
      TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
(1 ) Extracted from old module routine SULFATE_READMON (bmy, 9/18/02)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
02 Jul 2012 - R. Yantosca - Add simple kludge that prevents OOB error when
                            reading SO2 aircraft data for NA nested grid
01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.108.46 read_ship_so2

Subroutine READ_SHIP_SO2 reads in ship SO2 emissions, from either Corbett et al or EDGAR inventories. (bec, qli, 10/01/03, 7/14/06)

INTERFACE:

```
SUBROUTINE READ_SHIP_SO2( Input_Opt, THISMONTH )
```

USES:

```
USE ARCTAS_SHIP_EMISS_MOD,ONLY : GET_ARCTAS_SHIP
USE ICOADS_SHIP_MOD,      ONLY : GET_ICOADS_SHIP   !(cklee, 7/09/09)
USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
USE CMN_SIZE_MOD
USE EDGAR_MOD,            ONLY : GET_EDGAR_SHIP_SO2
USE EMEP_MOD,             ONLY : GET_EMEP_ANTHRO, GET_EUROPE_MASK
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_SO2ff
USE GIGC_Input_Opt_Mod,   ONLY : OptInput
USE GRID_MOD,             ONLY : GET_AREA_CM2
USE RCP_MOD,              ONLY : GET_RCP_EMISSION
USE TRACER_MOD,           ONLY : XNUMOL
USE TRACERID_MOD,         ONLY : IDTSO2
USE TRANSFER_MOD,         ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN) :: Input_Opt
INTEGER,        INTENT(IN) :: THISMONTH ! Current month (1-12)
```

REVISION HISTORY:

```
(1 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(2 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids. (bmy, 8/16/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(5 ) Now get EDGAR ship SO2 emissions if necessary.  Also apply future
     emissions scale factors to the default Corbett et al ship emissions.
     (avd, bmy, 7/14/06)
(6 ) Now references GET_ARCTAS_HIP from 'arctas_ship_emiss_mod.f" and
     GET_EMEP_ANTHRO to get ARCTAS and EMEP SO2 ship emissions (phs,12/5/08)
(7 ) Now get ICOADS ship SO2 if necessary (phs, cklee, 6/30/09)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
17 Jun 2013 - R. Yantosca - Now take values from Input_Opt
22 Jul 2013 - M. Sulprizio- Now copy LRCPSHIP from Input_Opt
```

1.108.47 read_anthro_nh3

Subroutine READ_ANTHRO_NH3 reads the monthly mean anthropogenic NH3 emissions from disk and converts to [kg NH3/box/s]. (rjp, bdf, bmy, 9/20/02, 3/5/10)

INTERFACE:

```
SUBROUTINE READ_ANTHRO_NH3( Input_Opt, THISMONTH )
```

USES:

```
USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,        ONLY : DATA_DIR
USE EMEP_MOD,             ONLY : GET_EMEP_ANTHRO
USE EMEP_MOD,             ONLY : GET_EUROPE_MASK
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NH3an
USE GIGC_Input_Opt_Mod,   ONLY : OptInput
USE GRID_MOD,             ONLY : GET_AREA_CM2
USE RCP_MOD,              ONLY : GET_RCP_EMISSION
USE STREETS_ANTHRO_MOD,   ONLY : GET_SE_ASIA_MASK
USE STREETS_ANTHRO_MOD,   ONLY : GET_STREETS_ANTHRO
USE TRACERID_MOD,         ONLY : IDTNH3
USE TRANSFER_MOD,         ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
TYPE(OptInput), INTENT(IN)    :: Input_Opt ! Input Options object
INTEGER, INTENT(IN)           :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Renamed from NH3_READ to READ_ANTHRO_NH3.  Also updated comments,
     made cosmetic changes. (bmy, 9/20/02)
(2 ) Changed filename to NH3_anthsrce.geos.*.  Also now reads data under
     category name "NH3-ANTH". (rjp, bmy, 3/23/03)
(3 ) Now reads from NH3emis.monthly.geos.* files.  Now call READ_BPCH2
     with QUIET=.TRUE. (bmy, 3/27/03)
(4 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(5 ) Now read files from "sulfate_sim_200508/". Now read data for both
     GCAP and GEOS grids. (bmy, 8/16/05)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(6 ) Now compute future emissions, if necessary (swu, bmy, 5/30/06)
(7 ) Now overwrite w/ David Streets' NH3, if necessary (yxw, bmy, 8/17/06)
(8 ) Bug fix: Using tracer #30 in the call to GET_STREETS_ANTHRO can cause
     problems when adding or removing species.  Replace w/ IDTNH3.
     (dkh, 10/31/08)
(9 ) Now check if NH3 Streets is available (phs, 12/10/08)
(10) Bug fix -- STREETS needs to be PRIVATE (dkh, bmy, 3/5/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
22 Jul 2013 - M. Sulprizio- Now copy LRCP from Input_Opt
```

1.108.48 read_natural_nh3

Subroutine READ_NATURAL_NH3 reads the monthly mean natural NH3 emissions from disk and converts to [kg NH3/box/s]. (rjp, bdf, bmy, 9/20/02, 10/3/05)

INTERFACE:

```
SUBROUTINE READ_NATURAL_NH3( THISMONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Updated FORMAT string.  Now also call READ_BPCH2 with QUIET=.TRUE.
     (bmy, 4/8/03)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids. (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.108.49 read_biofuel_nh3

Subroutine READ_BIOFUEL_NH3 reads the monthly mean biomass NH3 and biofuel emissions from disk and converts to [kg NH3/box/s]. (rjp, bdf, bmy, phs, 9/20/02, 12/23/08)

INTERFACE:

```
SUBROUTINE READ_BIOFUEL_NH3( THISMONTH )
```

USES:

```
USE BIOMASS_MOD,          ONLY : BIOMASS
USE BPCH2_MOD,            ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,            ONLY : GET_TAU0,        READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,        ONLY : DATA_DIR
USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NH3bf
USE LOGICAL_MOD,          ONLY : LBIOMASS,        LFUTURE
USE TIME_MOD,             ONLY : ITS_A_LEAPYEAR
USE TRACER_MOD,           ONLY : XNUMOL
```

```
      USE TRACERID_MOD,         ONLY : IDTNH3
      USE TRANSFER_MOD,         ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)           :: THISMONTH ! Current month number (1-12)
```

REVISION HISTORY:

```
(1 ) Renamed from NH3_READ to READ_BIOMASS_NH3.  Also updated comments,
     made cosmetic changes.  Now reads in both biomass and biofuel
     emissions. (rjp, bmy, 12/13/02)
(2 ) Now replace DXYP(J+J0) with routine GET_AREA_M2 of "grid_mod.f"
     Now use function GET_YEAR from "time_mod.f".  Replace MONTH with
     THISMONTH when referencing the NMDAY variable.  Now call READ_BPCH2
     with QUIET=.TRUE. (bmy, 3/27/03)
(3 ) If using interannual biomass emissions, substitute seasonal emissions
     for years where internannual emissions do not exist.  Now also
     reference GET_TAU from "time_mod.f" (bmy, 5/15/03)
(4 ) Now use ENCODE statement for PGI/F90 on Linux (bmy, 9/29/03)
(5 ) Changed cpp switch name from LINUX to LINUX_PGI (bmy, 12/2/03)
(6 ) Now references DATA_DIR from "directory_mod.f".  Now references LBBSEA
     from "logical_mod.f".  Removed references to CMN and CMN_SETUP.
     (bmy, 7/20/04)
(7 ) Now can read either seasonal or interannual biomass burning emissions.
     Now references routines from both and "time_mod.f".  Now reads SO2
     biomass emissions directly rather than computing it by mole fraction
     from CO. (rjp, bmy, 1/11/05)
(8 ) Now read files from "sulfate_sim_200508/".  Now read data for both
     GCAP and GEOS grids. (bmy, 8/16/05)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(10) Now only read the biofuel, we have moved the biomass-reading code to
     "gc_biomass_mod.f" for compatibility with GFED2 biomass emissions
     (bmy, 9/27/06)
(11) Prevent seg fault error when LBIOMASS=F (bmy, 11/3/06)
(12) Renamed READ_BIOFUEL_NH3, and move all biomass code to GET_BIOMASS_NH3
     to account for several GFED2 products (yc, phs, 12/23/08)
(13) IDBNH3 is not used anymore (ccc, 01/29/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Removed reference to GET_AREA_CM2
```

1.108.50 get_biomass_nh3

Subroutine GET_BIOMASS_NH3 retrieve the monthly/8days/3hr mean biomass NH3 (yc, phs, 12/23/08)

INTERFACE:

```
SUBROUTINE GET_BIOMASS_NH3
```

USES:

```
USE BIOMASS_MOD,          ONLY : BIOMASS
USE CMN_SIZE_MOD
USE GRID_MOD,             ONLY : GET_AREA_CM2
USE TRACER_MOD,           ONLY : XNUMOL
USE TRACERID_MOD,         ONLY : IDTNH3, IDBNH3
```

REVISION HISTORY:

```
(1 ) Extracted from old module subroutine READ_BIOMASS_NH3
     (yc, phs, 12/23/08)
(2 ) IDBNH3 is in tracerid_mod.f now (fp, 6/2009)
22 Dec 2011 - M. Payer    - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.108.51 read_oxidant

Subroutine READ_OXIDANT reads in monthly mean H2O2 and O3 fields for the offline sulfate + aerosol simulation. (rjp, bdf, bmy, 11/1/02, 10/3/05)

INTERFACE:

```
SUBROUTINE READ_OXIDANT( MONTH )
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE CMN_SIZE_MOD
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D_TROP
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)    :: MONTH ! Emission timestep in minutes
```

REVISION HISTORY:

```
(1 ) Now call READ_BPCH2 with QUIET=.TRUE. (bmy, 3/27/03)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now read files from "sulfate_sim_200508/offline/".  Now read data
     for both GEOS and GCAP grids (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.108.52 ohno3time

Subroutine OHNO3TIME computes the sum of cosine of the solar zenith angle over a 24 hour day, as well as the total length of daylight. This is needed to scale the offline OH and NO3 concentrations. (rjp, bmy, 12/16/02, 3/30/04)

INTERFACE:

```
SUBROUTINE OHNO3TIME
```

USES:

```
USE CMN_SIZE_MOD
USE CMN_GCTM_MOD
USE GRID_MOD, ONLY : GET_XMID,    GET_YMID_R
USE TIME_MOD, ONLY : GET_NHMSb,   GET_ELAPSED_SEC
USE TIME_MOD, ONLY : GET_TS_CHEM, GET_DAY_OF_YEAR, GET_GMT
```

REVISION HISTORY:

```
(1 ) Copy code from COSSZA directly for now, so that we don't get NaN
     values.  Figure this out later (rjp, bmy, 1/10/03)
(2 ) Now replace XMID(I) with routine GET_XMID from "grid_mod.f".
     Now replace RLAT(J) with routine GET_YMID_R from "grid_mod.f".
     Removed NTIME, NHMSb from the arg list.  Now use GET_NHMSb,
     GET_ELAPSED_SEC, GET_TS_CHEM, GET_DAY_OF_YEAR, GET_GMT from
     "time_mod.f". (bmy, 3/27/03)
(3 ) Now store the peak SUNCOS value for each surface grid box (I,J) in
     the COSZM array. (rjp, bmy, 3/30/04)
22 Dec 2011 - M. Payer    - Added ProTeX headers
```

1.108.53 init_sulfate

Subroutine INIT_SULFATE initializes and zeros all allocatable arrays declared in "sulfate_mod.f" (bmy, 6/2/00, 10/15/09)

INTERFACE:

```
SUBROUTINE INIT_SULFATE( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE DRYDEP_MOD,         ONLY : DEPNAME, NUMDEP
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
(1 ) Only allocate some arrays for the standalone simulation (NSRCX==10).
     Also reference NSRCX from "CMN".  Now eferences routine ALLOC_ERR
     from "error_mod.f" ((rjp, bdf, bmy, 10/15/02)
(2 ) Now also allocate the IJSURF array to keep the 1-D grid box indices
     for SUNCOS (for both coupled & offline runs).  Now allocate PH2O2m
     and O3m for offline runs.  Also allocate ESO2_bf (bmy, 1/16/03)
(3 ) Now allocate ENH3_na array (rjp, bmy, 3/23/03)
(4 ) Now allocate COSZM for offline runs (bmy, 3/30/04)
(5 ) Now allocate ESO2_sh array (bec, bmy, 5/20/04)
(6 ) Now allocates ITS_AN_AEROSOL_SIM from "tracer_mod.f".  Now remove
     IJSURF (bmy, 7/20/04)
(7 ) Now locate species in the DEPSAV array here instead of in CHEMSULFATE.
     Now reference LDRYD from "logical_mod.f".  Updated for AS, AHS, LET,
     SO4aq, NH4aq. (bmy, 1/6/06)
(8 ) Now allocates PSO4_ss, PNITs (bec, bmy, 4/13/05)
(9 ) Initialize drydep flags outside of IF block (bmy, 5/23/06)
(10) Now redimension EEV & NEV arrays for new SO2 volcanic emissions
     inventory.  Deleted obsolete arrays from older SO2 volcanic
     emissions inventory. (jaf, bmy, 10/15/09)
(11) Now alllocate PSO4_SO2AQ (win, 1/25/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
04 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC arguments
05 Mar 2013 - R. Yantosca - Now use Input_Opt%ITS_AN_AEROSOL_SIM
30 May 2013 - S. Farina   - Allocate PSO4_SO2AQ for TOMAS
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.108.54 cleanup_sulfate

Subroutine CLEANUP_SULFATE deallocates all previously allocated arrays for sulfate emissions – call at the end of the run (bmy, 6/1/00, 10/15/09)

INTERFACE:

```
SUBROUTINE CLEANUP_SULFATE
```

REVISION HISTORY:

```
(1 ) Now also deallocates IJSURF. (bmy, 11/12/02)
(2 ) Now also deallocates ENH3_na (rjp, bmy, 3/23/03)
(3 ) Now also deallocates COSZM (rjp, bmy, 3/30/04)
(4 ) Now also deallocates ESO4_sh (bec, bmy, 5/20/04)
(5 ) Now remove IJSURF (bmy, 7/20/04)
```

```
(6 ) Bug fix: now deallocate PSO4_ss, PNITs (bmy, 5/3/06)
(7 ) Deleted obsolete arrays from older SO2 volcanic emissions
      inventory (jaf, bmy, 10/15/09)
(8 ) Deallocate PSO4_SO2AQ (win, 1/25/10)
22 Dec 2011 - M. Payer    - Added ProTeX headers
30 May 2013 - S. Farina   - Deallocate PSO4_SO2AQ for TOMAS
```

1.109 Fortran: Module Interface tagged_co_mod

Module TAGGED_CO_MOD contains variables and routines used for the geographically tagged CO simulation.

INTERFACE:

```
MODULE TAGGED_CO_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: DEFINE_FF_CO_REGIONS
PRIVATE :: DEFINE_BB_CO_REGIONS
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: EMISS_TAGGED_CO
PUBLIC  :: CHEM_TAGGED_CO
PUBLIC  :: GET_ALPHA_ISOP
PUBLIC  :: READ_PCO_LCO_STRAT
PUBLIC  :: GET_PCO_LCO_STRAT
PUBLIC  :: READ_ACETONE
PUBLIC  :: INIT_TAGGED_CO
PUBLIC  :: CLEANUP_TAGGED_CO
```

PUBLIC DATA MEMBERS:

```
INTEGER, PUBLIC, ALLOCATABLE :: BB_REGION(:,:)   ! BB CO regions
INTEGER, PUBLIC, ALLOCATABLE :: FF_REGION(:,:)   ! FF CO regions
REAL*8,  PUBLIC, ALLOCATABLE :: EMACET(:,:)      ! Acetone emissions
```

REMARKS:

```
Tagged CO Tracers (you can modify these as needs be!)
=============================================================================
(1 ) Total CO
(2 ) CO from North American fossil fuel
(3 ) CO from European fossil fuel
(4 ) CO from Asian fossil fuel
```

```
(5 ) CO from fossil fuel from everywhere else
(6 ) CO from South American biomass burning
(7 ) CO from African biomass burning
(8 ) CO from Southeast Asian biomass burning
(9 ) CO from Oceania biomass burning
(10) CO from European biomass burning
(11) CO from North American biomass burning
(12) CO chemically produced from Methane
(13) CO from Biofuel burning (whole world)
(14) CO chemically produced from Isoprene
(15) CO chemically produced from Monoterpenes
(16) CO chemically produced from Methanol (CH3OH)
(17) CO chemically produced from Acetone
```

REVISION HISTORY:

```
28 Jul 2000- R. Yantosca - Initial version
(1 ) Removed obsolete code from CHEM_TAGGED_CO (bmy, 12/21/00)
(2 ) Added CO sources from oxidation of biofuel VOC's, biomass burning
     VOC's, fossil fuel VOC's, and natural VOC's (bnd, bmy, 1/2/01)
(3 ) Added chemical P(CO) from CH3OH and MONOTERPENES (bnd, bmy, 1/2/01)
(4 ) Now cap SCALEYEAR at 1997 in "emiss_tagged_co" (bnd, bmy, 4/6/01)
(5 ) Removed obsolete commented-out code (bmy, 4/23/01)
(6 ) Added new module variables SUMACETCO, EMACET, CO_PRODS, CO_LOSSS,
     ISOP96, MONO96, and MEOH96.  Also added new module routines
     GET_ALPHA_ISOP, READ_PCO_LCO_STRAT, GET_PCO_LCO_STRAT,
     READ_ACETONE, and READ_BIOG_FOR_GEOS3. (bnd, bmy, 6/14/01)
(7 ) Now read files from DATA_DIR/tagged_CO_200106/ (bmy, 6/19/01)
(8 ) Removed ISOP96, MONO96, and CH3OH96 since we now use the new GEOS-3
     fields and no longer have to correct for the surface temperature.
     (bmy, 8/21/01)
(9 ) Bug fix: don't call GLOBAL_NOX_MOD in routine CHEM_TAGGED_CO
     unless a logical switch is set (bmy, 8/28/01)
(10) Updated comments (bmy, 9/6/01)
(11) Deleted obsolete code for 1998 GEOS-3 fix.  Also now archive ND46
     diagnostic as [atoms C/cm2/s] (bmy, 9/13/01)
(12) Bug fix in CHEM_TAGGED_CO: now save CO sources/sinks into the
     Total CO tracer (N=1). (qli, bmy, 9/21/01)
(13) Resize arrays of (IIPAR,JJPAR) to (IIPAR,JJPAR) (bmy, 9/28/01)
(14) Removed obsolete code from 9/28/01 (bmy, 10/23/01)
(15) Updated comments (bmy, 2/15/02)
(16) Removed double definition of SUMCH3OHCO (bmy, 3/20/02)
(17) Now use P(I,J) + PTOP instead of PS(I,J) (bmy, 4/11/02)
(18) Now divide module header into MODULE PRIVATE, MODULE VARIABLES, and
     MODULE ROUTINES sections.  Updated comments (bmy, 5/28/02)
(19) Now references "pressure_mod.f" (dsa, bdf, bmy, 8/21/02)
(20) Now reference AD, BXHEIGHT, T and SUNCOS from "dao_mod.f".  Also
     removed obsolete code from various routines.  Now references
     ERROR_STOP from "error_mod.f". (bmy, 10/15/02)
```

```
(21) Now references "grid_mod.f" and the new "time_mod.f". (bmy, 2/3/03)
(22) Bug fix for NTAU in EMISS_TAGGED_CO.  Bug fix for FILENAME in routine
     READ_PCO_LCO_STRAT. (ave, bnd, bmy, 6/3/03)
(23) Updated arg list in call to EMISOP in EMISS_TAGGED_CO (bmy, 12/9/03)
(24) Now references "directory_mod.f", "logical_mod.f", "tracer_mod.f".
     Now remove IJLOOP_CO. (bmy, 7/20/04)
(25) Fixed bug in CHEM_TAGGED_CO (bmy, 3/7/05)
(26) Now reads data from both GEOS and GCAP grids.  Now also references
     "tropopause_mod.f". (bmy, 8/16/05)
(27) Now modified for new "biomass_mod.f" (bmy, 4/5/06)
(28) BIOMASS(:,:,IDBCO) from "biomass_mod.f" is now in units of
     [molec CO/cm2/s].  Adjust unit conversion accordingly. (bmy, 9/27/06)
(29) Routines GET_ALPHA_ISOP, GET_PCO_LCO_STRAT, READ_PCO_LCO_STRAT,
     READ_ACETONE and INIT_TAGGED_CO are public now. Variable
     EMACET is public now.  (phs, 9/18/07)
13 Aug 2010 - R. Yantosca - Add modifications for MERRA (treat like GEOS-5)
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.2 met
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
23 Oct 2012 - R. Yantosca - Update prod/loss for new GMI strat chem
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.109.1 define_ff_co_regions

Subroutine DEFINE_FF_CO_REGIONS defines the geographic regions for fossil fuel emissions for the Tagged CO simulation.

INTERFACE:

```
SUBROUTINE DEFINE_FF_CO_REGIONS( REGION )
```

USES:

```
USE CMN_SIZE_MOD
USE GRID_MOD,     ONLY : GET_XMID, GET_YMID
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: REGION(IIPAR,JJPAR)   ! Fossil fuel CO regions
```

REVISION HISTORY:

```
21 Jul 2000 - B. Duncan - Initial version
(1 ) This subroutine only has to be at the beginning of the run,
     since the regions don't change with time.
(2 ) Regions are hardwired for now -- change if necessary
(3 ) Now use regions from bnd simulation (bmy, 6/14/01)
(4 ) REGION is now of size (IIPAR,JJPAR) (bmy, 9/28/01)
(5 ) Removed obsolete code from 9/28/01 (bmy, 10/22/01)
(6 ) Now uses routines GET_XMID and GET_YMID from "grid_mod.f" to compute
```

```
      grid box lon & lat.  Remove XMID, YMID from arg list. (bmy, 2/3/03)
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
23 Oct 2012 - R. Yantosca - Added ProTeX headers
```

1.109.2 define_bb_co_regions

Subroutine DEFINE_BB_CO_REGIONS defines the geographic regions for biomass burning emissions for the Tagged CO simulation.

INTERFACE:

```
SUBROUTINE DEFINE_BB_CO_REGIONS( REGION )
```

USES:

```
USE CMN_SIZE_MOD
USE GRID_MOD,     ONLY : GET_XMID, GET_YMID
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: REGION(IIPAR,JJPAR)   ! Biomass CO regions
```

REVISION HISTORY:

```
21 Jul 2000 - B. Duncan - Initial version
(1 ) This subroutine only has to be at the beginning of the run,
      since the regions don't change with time.
(2 ) Regions are hardwired for now -- change if necessary
(3 ) Now use regions from bnd simulation (bmy, 6/14/01)
(4 ) REGION is now of size (IIPAR,JJPAR) (bmy, 9/28/01)
(5 ) Removed obsolete code from 9/28/01 (bmy, 10/22/01)
(6 ) Now uses routines GET_XMID and GET_YMID from "grid_mod.f" to compute
      grid box lon & lat.  Remove XMID, YMID from arg list. (bmy, 2/3/03)
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
23 Oct 2012 - R. Yantosca - Added ProTeX headers
```

1.109.3 emiss_tagged_co

Subroutine EMISS_TAGGED_CO reads in CO emissions for the Tagged CO run.

INTERFACE:

```
SUBROUTINE EMISS_TAGGED_CO( am_I_Root, Input_Opt,
&                           State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_O3_MOD               ! FSCALYR, SCNR89, TODH, EMISTCO, EMISRR
      USE CMN_DIAG_MOD             ! Diagnostic arrays & switches

      USE BIOFUEL_MOD,         ONLY : BIOFUEL
      USE BIOMASS_MOD,         ONLY : BIOMASS
      USE DIAG_MOD,            ONLY : AD29,          AD46
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod,  ONLY : OptInput
      USE GIGC_State_Chm_Mod,  ONLY : ChmState
      USE GIGC_State_Met_Mod,  ONLY : MetState
      USE GRID_MOD,            ONLY : GET_XOFFSET,   GET_YOFFSET
      USE GRID_MOD,            ONLY : GET_AREA_CM2
      USE MEGAN_MOD,           ONLY : GET_EMISOP_MEGAN
      USE MEGAN_MOD,           ONLY : GET_EMMONOT_MEGAN
      USE MEGANUT_MOD,         ONLY : XLTMMP
      USE PBL_MIX_MOD,         ONLY : GET_PBL_MAX_L, GET_FRAC_OF_PBL
      USE TIME_MOD,            ONLY : GET_MONTH,     GET_TAU
      USE TIME_MOD,            ONLY : GET_YEAR,      GET_TS_EMIS
      USE TRACERID_MOD,        ONLY : IDBFCO, IDECO, IDBCO

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    21 Jul 2000 - I. Bey, B. Field, B. Duncan - Initial version
    23 Oct 2012 - R. Yantosca - Added ProTeX headers
    (1 ) Adapted from "emiss_co.f" (bmy, 7/2100)
    (2 ) Add multiprocessor commands for DO-loops (bmy, 7/21/00)
    (3 ) Added references to F90 modules "biomass_mod.f" and "biofuel_mod.f".
         Also, TWOODIJ is now called BIOFUEL.  Finally, BURNEMIS is now
         referenced with IREF = I + I0 and JREF = J + J0. (bmy, 9/12/00)
    (4 ) Now reference FF_REGION with IREF & JREF.  Removed obsolete code
         from 7/00 and 9/00.  Also define NFAM in "ndxx_setup.f" (bmy, 10/6/00)
    (5 ) Added variables EMMO and references to functions EMMONOT, EMCH3OH --
         these are for CO production by VOC oxidation. (bnd, bmy, 1/2/01)
```

```
(6 ) Merged ISOP and MONOTERPENE sources into the same DO-loop, for
     computational efficiency (bmy, 1/3/01)
(7 ) Make sure that SCALEYEAR does not go higher than 1997.  1997 is
     the last year we have FF scale factor data. (bnd, bmy, 4/6/01)
(8 ) Now call READ_ACETONE to read acetone emissions into EMACET.
     Also call READ_BIOG_FOR_GEOS3 to read acetone emissions into
     ISOP96, MONO96, CH3OH96 for GEOS-3 simulations. (bnd, bmy, 6/14/01)
(9 ) Remove GEOS-3 fix for biogenic fields (ISOP96, MONO96, CH3OH96),
     since we now use updated met fields w/o the surface temperature
     problem (bmy, 8/21/01)
(10) Now archive ND46 as atoms C/cm2/s here.  Also deleted obsolete code
     for the 1998 GEOS-3 fix. (bmy, 9/13/01)
(11) BXHEIGHT is now dimensioned IIPAR,JJPAR,LLPAR.  BIOFUEL(:,IREF,JREF)
     is now BIOFUEL(:,I,J).  BB_REGION(IREF,JREF) is now BB_REGION(I,J).
     FF_REGION(IREF,JREF) is now FF_REGION(I,J). (bmy, 9/28/01)
(12) Removed obsolete code from 9/13/01 and 9/28/01 (bmy, 10/22/01)
(13) Now reference SUNCOS "dao_mod.f".  Remove SUNCOS and BXHEIGHT from
     the arg list -- BXHEIGHT isn't used!.  Now make FIRSTEMISS a local
     SAVEd variable.  Now do not let SCALEYEAR exceed 1998.  Now
     reference IDBCO, IDBFCO from "tracerid_mod.f". (bmy, 1/13/03)
(14) Remove XMID, YLMID from call to routines DEFINE_BB_CO_REGIONS and
     DEFINE_FF_CO_REGIONS.   Now replace DXYP(JREF)*1d4 with routine
     GET_AREA_CM2 of "grid_mod.f".  Removed IMONTH from call to BIOBURN.
     Now uses functions GET_MONTH, GET_YEAR, GET_ELAPSED_MIN, and
     GET_TS_EMIS from the new "time_mod.f".  Now only passes I in the
     call to GET_IHOUR. Now use functions GET_XOFFSET, GET_YOFFSET from
     "grid_mod.f".  I0 and J0 are now local variables. (bmy, 2/11/03)
(15) Bug fix: NTAU should be the integer value of TAU (bmy, 6/10/03)
(16) Now pass I, J to EMISOP (bmy, 12/9/03)
(17) Now reference LSPLIT, LANTHRO, LBIOMASS, & LBIOFUEL from
     "logical_mod.f".  Now reference STT from "tracer_mod.f".  Now replace
     IJLOOP_CO w/ an analytic function. (bmy, 7/20/04)
(18) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(19) Now modified for the new "biomass_mod.f" (bmy, 4/5/06)
(20) BIOMASS(:,:,IDBCO) from "biomass_mod.f" is now in units of
     [molec CO/cm2/s].  Adjust unit conversion accordingly. (bmy, 9/27/06)
(21) Now take CO emissions from the EMISRR array, which is archived by
     calling EMISSDR.  Remove duplicate scaling and other operations which
     are now done in EMISSDR. Remove references to BIOFUEL_BURN and
     all routines from GEIA_MOD. (jaf, mak, bmy, 2/14/08)
(22) Bug fix: Now use IDECO to be consistent (phs, bmy, 6/30/08)
(23) Now distribute CO biomass burning source through the PBL
     (yc, phs, 12/23/08)
(24) Now include switch to use MEGAN biogenics instead of default GEIA.
     (jaf, 3/10/09)
(25) Move XLTMMP to module MEGANUT_MOD (ccc, 11/20/09)
(26) IDBCO is now defined in tracerid_mod.f (fp, 6/09)
08 Dec 2011 - M. Payer    - Remove GEIA biogenic emission option
```

```
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
27 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOS
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.109.4 chem_tagged_co

Subroutine CHEM_TAGGED_CO performs CO chemistry on geographically "tagged" CO tracers. Loss is via reaction with OH.

INTERFACE:

```
SUBROUTINE CHEM_TAGGED_CO( am_I_Root, Input_Opt,
&                          State_Met, State_Chm, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE CMN_DIAG_MOD
USE DIAG_MOD,           ONLY : AD29
USE DIAG_PL_MOD,        ONLY : AD65
USE ERROR_MOD,          ONLY : CHECK_VALUE
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GLOBAL_OH_MOD,      ONLY : GET_GLOBAL_OH,   OH
USE GLOBAL_NOX_MOD,     ONLY : GET_GLOBAL_NOX,  BNOX
USE GRID_MOD,           ONLY : GET_YMID,        GET_AREA_CM2
USE PRESSURE_MOD,       ONLY : GET_PCENTER
USE TIME_MOD,           ONLY : GET_TS_CHEM,     GET_TS_EMIS
USE TIME_MOD,           ONLY : GET_MONTH,       GET_YEAR
USE TIME_MOD,           ONLY : ITS_A_NEW_MONTH, ITS_A_NEW_YEAR
USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
19 Oct 1999 - Q. Li, B. Duncan, B. Field - Initial version
(1 ) Now do chemistry all the way to the model top.
(2 ) Use monthly mean OH fields for oxidation.
(3 ) Now reference the monthly mean OH array and the routine which reads
     it from disk in "global_oh_mod.f" (bmy, 7/28/00)
(4 ) Removed obsolete code from 10/6/00 (bmy, 12/21/00)
(5 ) Added P(CO) from CH3OH and MONOTERPENES.  Also account for the
     variation of CH4 conc. w/ latitude and year (bnd, bmy, 1/2/01)
(6 ) Removed obsolete commented-out code (bmy, 4/23/01)
(7 ) Updated with new stuff from bnd.  Also references module routines
     & arrays from "global_nox_mod.f" and "error_mod.f".  Removed
     THISMONTH as an argument since we can use the MONTH value
     from the "CMN" include file. (bmy, 6/14/01)
(8 ) Remove GEOS-3 fix for biogenic fields (ISOP96, MONO96, CH3OH96),
     since we now use updated met fields w/o the surface temperature
     problem (bmy, 8/21/01)
(9 ) Now only call GLOBAL_NOX_MOD to define the BNOX array, if switch
     ALPHA_ISOP_FROM_NOX is set.  The NOx concentrations used to compute
     the CO yield from isoprene are currently only at 4x5 (bmy, 8/28/01)
(10) Bug fix: now make sure to add CO production and loss into the
     STT(:,:,:,1), which is the Total CO tracer. (qli, bmy, 9/21/01)
(11) Updated comments.  Bug fix: multiply CO_OH (after using it to update
     tagged tracers) by GCO (the initial value of STT in molec/cm3) to
     convert it to an amount of CO lost by OH [molec/cm3]. (bmy, 2/19/02)
(12) Removed PS as an argument; use P(I,J) + PTOP instead of PS, in order
     to ensure that we use P and AD computed from the same preesure
     by AIRQNT. (bmy, 4/11/02)
(13) Now use GET_PCENTER from "pressure_mod.f" to compute the pressure
     at the midpoint of box (I,J,L).  Also deleted obsolete, commented-out
     code. (dsa, bdf, bmy, 8/21/02)
(14) Now reference AD and T from "dao_mod.f".  Now make FIRSTCHEM a local
     SAVEd variable. (bmy, 11/15/02)
(15) Now replace YLMID(J) with routine GET_YMID of "grid_mod.f".  Now
     uses functions GET_TS_CHEM, GET_MONTH, GET_YEAR from the new
     "time_mod.f".  (bmy, 2/10/03)
(16) Now reference STT & N_TRACERS from "tracer_mod.f".  Now references
     LSPLIT from "logical_mod.f".  Now references AD65 from
     "diag_pl_mod.f".  Updated comments. (bmy, 7/20/04)
(17) Bug fix: re-insert ELSE between (1a-1) and (1a-2); it appears to have
     been mistakenly deleted. (bmy, 3/7/05)
(18) Now references ITS_IN_THE_STRAT from "tropopause_mod.f".  Now remove
     reference to "CMN", it's obsolete. (bmy, 8/22/05)
(19) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(20) Remove reference to "global_ch4_mod.f" (bmy, 5/31/06)
(21) Use newest JPL 2006 rate constant for CO+OH (jaf, jmao, 3/4/09)
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

```
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
22 Oct 2012 - R. Yantosca - Now pass am_I_Root=.TRUE. to GET_GLOBAL_CH4
23 Oct 2012 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
11 Apr 2013 - R. Yantosca - Now pass Input_Opt to GET_GLOBAL_NOX
10 Jun 2013 - R. Yantosca - Avoid array temporaries in CHECK_VALUE
23 Oct 2013 - R. Yantosca - Now pass objects to GET_GLOBAL_OH routine
```

1.109.5 get_alpha_isop

Function GET_ALPHA_ISOP returns the CO yield from Isoprene (ALPHA_ISOP) either as a function of NOx or as a constant.

INTERFACE:

```
FUNCTION GET_ALPHA_ISOP( FROM_NOX, NOX ) RESULT( ALPHA_ISOP )
```

USES:

```
USE ERROR_MOD, ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)           :: FROM_NOX    ! If =T, will take ALPHA_ISOP
                                             ! as f(NOx).  If =F, will set
                                             ! ALPHA_ISOP to a constant
REAL*8,  INTENT(IN), OPTIONAL :: NOX         ! NOx concentration [ppbv]
```

RETURN VALUE:

```
REAL*8                        :: ALPHA_ISOP  ! CO yield from ISOP
```

REVISION HISTORY:

```
13 Jun 2001 - B. Duncan - Initial version
01 Oct 1995 - R. Yantosca - Initial version
(1 ) Now make NOx an optional argument (bmy, 8/28/01)
(2 ) Now reference ERROR_STOP from "error_mod.f" (bmy, 10/15/02)
(3 ) Updated comments (bmy, 7/20/04)
23 Oct 2012 - R. Yantosca - Added ProTeX headers
```

1.109.6 read_pco_lco_strat

Subroutine READ_PCO_LCO_STRAT reads production and destruction rates for CO in the stratosphere. (bnd, bmy, 9/13/00, 8/13/10)

INTERFACE:

```
SUBROUTINE READ_PCO_LCO_STRAT( THISMONTH )
```

USES:

```
! GEOS-Chem modules
USE CMN_SIZE_MOD
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_3D

! netCDF modules
USE m_netcdf_io_open
USE m_netcdf_io_read
USE m_netcdf_io_close
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Month to read
```

REVISION HISTORY:

```
13 Sep 2000 - B. Duncan   - Initial version
(1 ) Now use IOS /= 0 to trap both I/O errors and EOF. (bmy, 9/13/00)
(2 ) Added to module "tagged_co_mod.f" (bmy, 6/13/01)
(3 ) ARRAY needs to be of size (IIPAR,JJPAR).  Use TRANSFER_ZONAL from
     "transfer_mod.f" to cast data from REAL*4 to REAL*8, and also to
     copy data to an array of size (JJPAR,LLPAR).  Use 3 arguments (M/D/Y)
     in call to GET_TAU0.  Use JJPAR,LGLOB in call to READ_BPCH2.
     (bmy, 9/28/01)
(4 ) Removed obsolete code from 9/28/01 (bmy, 10/22/01)
(5 ) Updated comments (bmy, 2/15/02)
(6 ) Update FILENAME so that it looks in the "pco_lco_200203" subdirectory
     of DATA_DIR. (bnd, bmy, 6/30/03)
(7 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(8 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.2 in the same way as MERRA
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.109.7 get_pco_lco_strat

Function GET_CO_STRAT_RATE uses production and loss rates for CO to calculate net production of CO in the stratosphere. The purpose of this SR is to prevent high CO concentrations from building up in the stratosphere; in these layers only transport is simulated (i.e., no chemistry). For a long simulation, a buildup of high concentrations could occur causing the stratosphere to become a significant source of CO.

INTERFACE:

```
FUNCTION GET_PCO_LCO_STRAT( IS_PROD, I, J, L ) RESULT( RATE )
```

USES:

```
USE CMN_SIZE_MOD                  ! Size parameters
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: IS_PROD   ! If = T, return CO production
                                  ! If = F, return CO loss
INTEGER, INTENT(IN)  :: I, J, L   ! GEOS-Chem grid box indices
```

RETURN VALUE:

```
REAL*8               :: RATE      ! CO prod [v/v/s] or loss [1/s]
```

REVISION HISTORY:

```
13 Jun 2001 - B. Duncan - Initial version
(1 ) Production (mixing ratio/sec) and loss (1/sec) rates provided by
      Dylan Jones.  Only production by CH4+OH and destruction by CO+OH
      are considered.
(2 ) The annual mean tropopause is stored in the LPAUSE array
     (from header file "CMN").  LPAUSE is defined such that:
     Levels            1 <= L <= LPAUSE(I,J) - 1 are tropospheric
             LPAUSE(I,J) <= L <= LLPAR           are stratospheric
(3 ) LPAUSE_MIN = minimun tropopause height.  Start L-loop from the
      lowest stratospheric level!
(4 ) Added to module "tagged_co_mod.f" (bmy, 6/18/01)
(5 ) Updated comments (bmy, 2/19/02)
(6 ) Removed reference to CMN, it's not needed (bmy, 7/20/04)
23 Oct 2012 - R. Yantosca - Added ProTeX headers
23 Oct 2012 - J. Fisher   - Now use (I,J,L) to reference CO_PRODS
                            and CO_LOSSS arrays for GMI strat chem
```

1.109.8 read_acetone

Subroutine READ_ACETONE reads in biogenic acetone emissions from a binary punch file.

INTERFACE:

```
SUBROUTINE READ_ACETONE( THISMONTH )
```

USES:

```
USE CMN_SIZE_MOD
USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,        READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE TRANSFER_MOD,  ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: THISMONTH   ! Month to read
```

REVISION HISTORY:

```
23 Oct 2012 - B. Field, B. Duncan - Initial version
(1 ) Eliminate variables that aren't used anymore.  Updated comments
     and made some cosmetic changes. (bnd, bmy, 6/14/01)
(2 ) Added to "tagged_co_mod.f" (bmy, 6/14/01)
(3 ) Now read acetone file from DATA_DIR/tagged_CO_200106 (bmy, 6/19/01)
(4 ) ARRAY needs to be of size (IIPAR,JJPAR).  Use TRANSFER_2D from
     "transfer_mod.f" to cast data from REAL*4 to REAL*8, and also to
     copy data to an array of size (IIPAR,JJPAR).  Use 3 arguments (M/D/Y)
     in call to GET_TAU0.  Use IIPAR,JJPAR in call to READ_BPCH2.
     Added array TEMP(IIPAR,JJPAR).  Updated comments. (bmy, 9/28/01)
(5 ) Removed obsolete code from 9/28/01 (bmy, 10/22/01)
(6 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(7 ) Now reads data from both GEOS and GCAP grids (bmy, 8/16/05)
(8 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
23 Oct 2012 - R. Yantosca - Added ProTeX headers
```

1.109.9 init_tagged_co

Subroutine INIT_TAGGED_CO allocates memory to module arrays.

INTERFACE:

```
SUBROUTINE INIT_TAGGED_CO
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,    ONLY : ALLOC_ERR
USE TRACER_MOD,   ONLY : ITS_A_H2HD_SIM
```

REVISION HISTORY:

```
19 Jul 2000 - R. Yantosca - Initial version
(1 ) Added ISOP96, MONO96, CH3OH96 for GEOS-3 (bnd, bmy, 6/14/01)
(2 ) Removed ISOP96, MONO96, CH3OH96 for GEOS-3, since the new GEOS-3
     fields make these no longer necessary (bmy, 8/21/09)
(3 ) Now allocate BB_REGION, FF_REGION as (IIPAR,JJPAR) (bmy, 9/28/01)
(4 ) Removed obsolete code from 9/28/01 (bmy, 10/22/01)
(5 ) Now references ALLOC_ERR from "error_mod.f" (bmy, 10/15/02)
(6 ) Now remove IJLOOP_CO (bmy, 7/20/04)
(7 ) Now public. Now references ITS_A_H2HD_SIM from "tracer_mod.f".
     Allocate needed variables if H2/HD simulation (phs, 9/18/07)
```

```
23 Oct 2012 - R. Yantosca - Added ProTeX headers
23 Oct 2012 - J. Fisher   - Dimension CO_PRODS and CO_LOSSS with
                            (IIPAR,JJPAR,LLPAR) for new GMI strat chem
```

1.109.10 cleanup_tagged_co

Subroutine CLEANUP_TAGGED_CO deallocates memory from previously allocated module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_TAGGED_CO
```

REVISION HISTORY:

```
19 Jul 2000 - R. Yantosca - Initial version
(1 ) Added ISOP96, MONO96, CH3OH96 for GEOS-3 (bnd, bmy, 6/14/01)
(2 ) Removed ISOP96, MONO96, CH3OH96 for GEOS-3, since the new GEOS-3
     fields make these no longer necessary (bmy, 8/21/09)
(3 ) Now remove IJLOOP_CO (bmy, 7/20/04)
23 Oct 2012 - R. Yantosca - Added ProTeX headers
```

1.110 Fortran: Module Interface tagged_ox_mod

Module TAGGED_OX_MOD contains variables and routines to perform a tagged Ox simulation. P(Ox) and L(Ox) rates need to be archived from a full chemistry simulation before you can run w/ Tagged Ox.

INTERFACE:

```
MODULE TAGGED_OX_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: ADD_STRAT_POX
PUBLIC  :: CHEM_TAGGED_OX
PUBLIC  :: CLEANUP_TAGGED_OX
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: GET_REGIONAL_POX
PRIVATE :: INIT_TAGGED_OX
PRIVATE :: READ_POX_LOX
```

REVISION HISTORY:

```
20 Aug 2003 - A. Fiore    - Initial version
(1 ) Now accounts for GEOS-4 PBL being in meters (bmy, 1/15/04)
(2 ) Bug fix: don't put function call in WRITE statement (bmy, 2/20/04)
(3 ) Now bracket AD44 with an !$OMP CRITICAL block (bmy, 3/24/04)
(4 ) Now define regions w/ levels in GET_REGIONAL_POX (amf,rch,bmy,5/27/04)
(5 ) Bug fix-avoid seg fault if PBLFRAC isn't allocated (bdf, bmy, 10/12/04)
(6 ) Now reference "pbl_mix_mod.f" (bmy, 2/17/05)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(9 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(10) Modified for variable tropopause (phs, bmy, 1/19/07)
(11) Now use LLTROP instead of LLTROP_FIX everywhere (bmy, 12/4/07)
(12) Now use LD65 instead of LLTROP everywhere (phs, 11/17/08)
(13) Updates for LINOZ (dbj, jliu, bmy, 10/26/09)
19 Nov 2010 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
14 Mar 2013 - M. Payer    - Replace Ox with O3 as part of removal of NOx-Ox
                            partitioning
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
23 Jan 2014 - M. Sulprizio- Now use LLTROP instead of LD65 or LLTROP_FIX
                            everywhere (hyl, bmy, 11/3/11)
```

1.110.1 add_strat_pox

Subroutine ADD_STRAT_POX adds the stratospheric influx of Ox to the stratospheric Ox tracer. This is called from routine Do_Synoz, which is applied when the tracer array has units of [v/v].

INTERFACE:

```
SUBROUTINE ADD_STRAT_POX( I, J, L, POx, State_Chm )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACERID_MOD,       ONLY : IDTO3Strt
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I     ! GEOS-Chem grid box lon index
INTEGER, INTENT(IN) :: J     ! GEOS-Chem grid box lat index
INTEGER, INTENT(IN) :: L     ! GEOS-Chem grid box level index
REAL*8,  INTENT(IN) :: POx   ! P(Ox) in the stratosphere [v/v]
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
19 Aug 2003 - R. Yantosca - Initial version
(1 ) Now references STT from "tracer_mod.f" (bmy, 7/20/04)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
10 Jun 2012 - L. Murray - Enable tagged Ox for Synoz.
05 Nov 2013 - R. Yantosca - Rename IDTOxStrt to IDTO3Strt
05 Nov 2013 - R. Yantosca - Remove STT pointer for simplicity
```

1.110.2 read_pox_lox

Subroutine READ_POX_LOX reads previously-archived Ox production and loss rates from binary punch file format.

INTERFACE:

```
      SUBROUTINE READ_POX_LOX
```

USES:

```
      USE BPCH2_MOD,     ONLY : READ_BPCH2
      USE BPCH2_MOD,     ONLY : GET_TAU0
      USE DIRECTORY_MOD, ONLY : O3PL_DIR
      USE TIME_MOD,      ONLY : EXPAND_DATE
      USE TIME_MOD,      ONLY : GET_NYMD
      USE TIME_MOD,      ONLY : GET_TAU
      USE TRANSFER_MOD,  ONLY : TRANSFER_3D_TROP
      ! JLIU,2008/10/01
      USE CHARPAK_MOD,   ONLY : STRREPL
      USE TIME_MOD,      ONLY : YMD_EXTRACT
      USE TIME_MOD,      ONLY : ITS_A_LEAPYEAR
      USE TIME_MOD,      ONLY : GET_DAY_OF_YEAR
      USE TIME_MOD,      ONLY : GET_YEAR
      USE TIME_MOD,      ONLY : GET_MONTH
      USE TIME_MOD,      ONLY : GET_DAY
      USE TIME_MOD,      ONLY : GET_HOUR
      USE DIAG_PL_MOD                                    !dbj
      USE JULDAY_MOD,    ONLY : JULDAY                   !dbj

      USE CMN_SIZE_MOD ! Size parameters
      USE CMN_DIAG_MOD ! LD65

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%% If you want to read archived O3 prod/loss data from a different year
%%% than the met field dates, then use this #ifdef.  Otherwise, just
```

```
 %%% comment this flag out. (bmy, 11/6/13)
#define USE_THIS_O3_YEAR 2004
 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

REVISION HISTORY:

```
20 Aug 2003 - R. Yantosca - Initial version
(1 ) Updated from the old routine "chemo3_split.f" (rch, bmy, 8/20/03)
(2 ) Now references O3PL_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Use LLTROP_FIX to limit array size to case of non-variable tropopause.
      Also zero ARRAY to avoid numerical problems (phs, 1/19/07)
(5 ) Now use LLTROP instead of LLTROP_FIX (phs, bmy, 12/4/07)
(6 ) Now use LD65, since this is the number of levels use to
      save diag20 (phs, 11/17/08)
(7 ) Updates for LINOZ (dbj, jliu, bmy, 10/16/09)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
06 Nov 2013 - R. Yantosca - Use an #ifdef to decide if we are reading O3
                            P/L data from a different year than the met
23 Jan 2014 - M. Sulprizio- Now use LLTROP instead of LD65 or LLTROP_FIX
                            (hyl,bmy/11/3/11)
```

1.110.3 get_regional_pox

Subroutine GET_REGIONAL_POX returns the P(Ox) for each of the tagged Ox tracers. Tagged Ox tracers are defined by both geographic location and altitude.

INTERFACE:

```
SUBROUTINE GET_REGIONAL_POX( I, J, L, PP, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,           ONLY : GET_XMID,  GET_YMID
USE TIME_MOD,           ONLY : GET_TS_CHEM
USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_TROP

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_DIAG_MOD             ! ND44, ND65, LD65
USE CMN_GCTM_MOD             ! SCALE_HEIGHT
```

INPUT PARAMETERS:

```
! GEOS-Chem grid box indices for lon, lat, alt
INTEGER,        INTENT(IN)  :: I, J, L

! Meteorology State object
TYPE(MetState), INTENT(IN)  :: State_Met
```

OUTPUT PARAMETERS:

```
! Array containing P(Ox) for each tagged tracer
REAL*8,  INTENT(OUT) :: PP(IIPAR,JJPAR,LLTROP,N_TAGGED)
```

REVISION HISTORY:

```
19 Aug 2003 - A. Fiore - Initial version
(1 ) Updated from the old routine "chemo3_split.f" (rch, bmy, 8/20/03)
(2 ) For GEOS-4, convert PBL from [m] to [hPa] w/ the hydrostatic law.
     Now references SCALE_HEIGHT from "CMN_GCTM". (bmy, 1/15/04)
(3 ) Now uses model levels instead of pressure in order to delineate
     between PBL, MT, and UT regions (amf, rch, bmy, 5/27/04)
(4 ) Now references ITS_IN_THE_TROP from "tropopause_mod.f".  Now remove
     reference to "CMN", it's obsolete. (bmy, 8/22/05)
(5 ) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(6 ) Resize the PP array from LLTROP to LLTROP_FIX (phs, 1/19/07)
(7 ) Now use LLTROP instead of LLTROP_FIX (bmy, 12/4/07)
(8 ) Now use LD65 instead of LLTROP (phs, 11/17/08)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
23 Jan 2014 - M. Sulprizio- Now use LLTROP instead of LD65 (hyl,bmy,11/3/11)
```

1.110.4 chem_tagged_ox

Subroutine CHEM_TAGGED_OX performs chemistry for several Ox tracers which are tagged by geographic and altitude regions.

INTERFACE:

```
SUBROUTINE CHEM_TAGGED_OX( am_I_Root, Input_Opt,
&                          State_Met, State_Chm, RC )
```

USES:

```
USE CMN_DIAG_MOD
USE CMN_SIZE_MOD
USE DIAG_MOD,           ONLY : AD44
USE DIAG_PL_MOD,        ONLY : AD65
USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
USE DRYDEP_MOD,         ONLY : DEPSAV
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
```

```
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE PBL_MIX_MOD,        ONLY : GET_FRAC_UNDER_PBLTOP
      USE PBL_MIX_MOD,        ONLY : GET_PBL_MAX_L
      USE TIME_MOD,           ONLY : GET_TS_CHEM
      USE TIME_MOD,           ONLY : ITS_A_NEW_DAY
      USE TIME_MOD,           ONLY : TIMESTAMP_STRING
      USE TRACERID_MOD,       ONLY : IDTO3
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_TROP

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    20 Aug 2003 - R. Hudman   - Initial version
    (1 ) Updated from the old routine "chemo3_split.f" (rch, bmy, 8/20/03)
    (2 ) Bug fix: don't put function call in WRITE statement (bmy, 2/20/04)
    (3 ) Now use ND44_TMP array to store vertical levels of drydep flux, then
         sum into AD44 array.  This prevents numerical differences when using
         multiple processors. (bmy, 3/24/04)
    (4 ) Now references LDRYD from "logical_mod.f".  Now references STT
         and N_TRACERS from "tracer_mod.f".  Now references AD65 from
         "diag_pl_mod.f".  Now uses ITS_A_NEW_DAY from "time_mod.f".
         (bmy, 7/20/04)
    (5 ) Bug fix: Now avoid a SEG FAULT error if PBLFRAC isn't allocated.
         (bdf, bmy, 10/12/04)
    (6 ) Replace PBLFRAC from "drydep_mod.f" with GET_FRAC_UNDER_PBLTOP
         from "pbl_mix_mod.f".  Now only sum ND44 diagnostic up to the
         maximum tropopsheric level. (bmy, 2/17/05)
    (7 ) Resize PP, N D44_TMP arrays from LLTROP to LLTROP_FIX.  Now only loop
         up to LLTROP_FIX (phs, 1/19/07)
    (8 ) Now use LLTROP instead of LLTROP_FIX (bmy, 12/4/07)
    (9 ) Now use LD65 instead of LLTROP (phs, 11/17/08)
    (10) Now only compute loss rate in troposphere (dbj, bmy, 10/26/09)
    08 Dec 2009 - R. Yantosca - Added ProTeX headers
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    14 Mar 2013 - M. Payer    - Replace Ox with O3 as part of removal of NOx-Ox
```

```
                              partitioning
    25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
    23 Jan 2014 - M. Sulprizio- Now use LLTROP instead of LD65 (hyl,bmy,11/3/11)
```

1.110.5 init_tagged_ox

Subroutine INIT_TAGGED_OX allocates and zeroes all module arrays.

INTERFACE:

```
      SUBROUTINE INIT_TAGGED_OX( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE ERROR_MOD,          ONLY : ALLOC_ERR
      USE ERROR_MOD,          ONLY : ERROR_STOP
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

LOCAL VARIABLES:

REVISION HISTORY:

```
    20 Aug 2003 - R. Yantosca - Initial version
    (1 ) Now reference N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
    (2 ) Now use LD65 instead of LLTROP to dimension P24H, L24H (phs, 11/18/08)
    08 Dec 2009 - R. Yantosca - Added ProTeX headers
    25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC args
    23 Jan 2014 - M. Sulprizio- Now use LLTROP instead of LD65 to dimension P24H,
                              L24H (hyl, bmy, 11/3/11)
```

1.110.6 cleanup_tagged_ox

CLEANUP_TAGGED_OX deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_TAGGED_OX
```

REVISION HISTORY:

```
20 Aug 2003 - R. Yantosca - Initial version
08 Dec 2009 - R. Yantosca - Added ProTeX headers
```

1.111 Fortran: Module Interface toms_mod

Module TOMS_MOD contains variables and routines for reading the TOMS/SBUV O3 column data from disk (for use w/ the FAST-J photolysis routines).

INTERFACE:

```
MODULE TOMS_MOD
```

USES:

```
USE CMN_SIZE_MOD                    ! Size parameters

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: INIT_TOMS
PUBLIC :: READ_TOMS
PUBLIC :: COMPUTE_OVERHEAD_O3
PUBLIC :: GET_OVERHEAD_O3
PUBLIC :: CLEANUP_TOMS
```

PUBLIC DATA MEMBERS:

```
! First & last years for which TOMS/SBUV data is is available
! (update these as new data is added to the archive)
INTEGER, PUBLIC, PARAMETER :: FIRST_TOMS_YEAR = 1979
INTEGER, PUBLIC, PARAMETER :: LAST_TOMS_YEAR  = 2010
```

REMARKS:

```
References:
============================================================================
Version 8 Merged Ozone Data Sets
Total Ozone Revision 05
DATA THROUGH: MAR 2009
```

```
LAST MODIFIED: 01 MAY 2009
                                                                             .
http://acdb-ext.gsfc.nasa.gov/Data_services/merged/index.html
                                                                             .
TOMS/SBUV MERGED TOTAL OZONE DATA, Version 8, Revision 5.
Resolution:  5 x 10 deg.
                                                                             .
* Includes reprocessed N16 and N17 SBUV/2 data using latest calibration.
* OMI data updated from Collection 2 to Collection 3.
* New offsets derived based on revised data sets.
* 1970-1972 N4 BUV data added with no adjustments. User may wish to apply
  offset based on Comparisons between BUV and Dobson Measurements.
                                                                             .
Responsible NASA official:
Dr. Richard Stolarski (Richard.S.Stolarski@nasa.gov)
Stacey Frith          (Stacey.M.Frith@nasa.gov     )
```

REVISION HISTORY:

```
14 Jul 2003 - R. Yantosca - Initial version
(1 ) Now references "directory_mod.f" (bmy, 7/20/04)
(2 ) Now can read files for GEOS or GCAP grids (bmy, 8/16/05)
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Now always use 2002 TOMS O3 data for GCAP (swu, bmy, 10/3/06)
(5 ) Now reads from TOMS_200701 directory, w/ updated data (bmy, 2/1/07)
(6 ) Now don't replace any tokens in the DATA_DIR variable (bmy, 12/5/07)
(7 ) Latest year of TOMS data is now 2007 (bmy, 1/14/09)
01 Dec 2010 - R. Yantosca - Added ProTeX headers
06 Mar 2012 - R. Yantosca - Added function GET_TOTAL_O3
06 Mar 2012 - R. Yantosca - Added parameters FIRST_TOMS_YEAR, LAST_TOMS_YEAR
06 Mar 2012 - R. Yantosca - Updated comments
06 Mar 2012 - R. Yantosca - Now make TOMS, DTOMS1, DTOMS2 arrays PRIVATE
06 Mar 2012 - R. Yantosca - Add TO3_DAILY as a PRIVATE module array
25 Jun 2012 - S. Kim      - Now reads from TOMS_201203 directory, w/
                            updated data
03 Jul 2012 - R. Yantosca - Restrict reading from TOMS_201203 directory
                            to GEOS-5.7.2 met data for the time being.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.111.1 read_toms

Subroutine READ_TOMS reads in TOMS O3 column data from a binary punch file for the given grid, month and year.

INTERFACE:

```
SUBROUTINE READ_TOMS( THISMONTH, THISYEAR, USE_O3_FROM_MET )
```

USES:

```
      USE BPCH2_MOD,     ONLY : GET_NAME_EXT_2D
      USE BPCH2_MOD,     ONLY : GET_RES_EXT
      USE BPCH2_MOD,     ONLY : GET_TAU0
      USE BPCH2_MOD,     ONLY : READ_BPCH2
      USE DIRECTORY_MOD, ONLY : DATA_DIR
      USE TIME_MOD,      ONLY : EXPAND_DATE
      USE TRANSFER_MOD,  ONLY : TRANSFER_2D
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: THISMONTH       ! Current month
      INTEGER, INTENT(IN)    :: THISYEAR        ! Current year
      LOGICAL, INTENT(IN)    :: USE_O3_FROM_MET ! Use TO3 from met fields?
```

REMARKS:

```
    TOMS/SBUV MERGED TOTAL OZONE DATA, Version 8, Revision 5.
    Resolution:  5 x 10 deg.

                                                                             .
    Methodology
    ---------------------------------------------------------------------------
    FAST-J comes with its own default O3 column climatology (from McPeters
    1992 & Nagatani 1991), which is stored in the input file "jv_atms.dat".
    These "FAST-J default" O3 columns are used in the computation of the
    actinic flux and other optical quantities for the FAST-J photolysis.

                                                                             .
    The TOMS/SBUV O3 columns and 1/2-monthly O3 trends (contained in the
    TOMS_200906 directory) are read into GEOS-Chem by routine READ_TOMS in
    "toms_mod.f".  Missing values (i.e. locations where there are no data)
    in the TOMS/SBUV O3 columns are defined by the flag -999.

                                                                             .
    After being read from disk in routine READ_TOMS, the TOMS/SBUV O3 data
    are then passed to the FAST-J routine "set_prof.F".  In "set_prof.F", a
    test is done to make sure that the TOMS/SBUV O3 columns and 1/2-monthly
    trends do not have any missing values for (lat,lon) location for the given
    month.  If so, then the TOMS/SBUV O3 column data is interpolated to the
    current day and is used to weight the "FAST-J default" O3 column.  This
    essentially "forces" the "FAST-J default" O3 column values to better match
    the observations, as defined by TOMS/SBUV.

                                                                             .
    If there are no TOMS/SBUV O3 columns (and 1/2-monthly trends) at a (lat,
    lon) location for given month, then FAST-J will revert to its own "default"
    climatology for that location and month.  Therefore, the TOMS O3 can be
    thought of as an  "overlay" data -- it is only used if it exists.

                                                                             .
    Note that there are no TOMS/SBUV O3 columns at the higher latitudes.
    At these latitudes, the code will revert to using the "FAST-J default"
    O3 columns.

                                                                             .
```

```
As of March 2012, we have TOMS/SBUV data for 1979 thru 2008.  We will
update to the latest TOMS/SBUV data set shortly.

This methodology was originally adopted by Mat Evans.
```

REVISION HISTORY:

```
10 Dec 2002 - M. Evans - Initial version
(1 ) Bundled into "toms_mod.f" (bmy, 7/14/03)
(2 ) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(3 ) Now can read files for GEOS or GCAP grids (bmy, 8/16/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now always use 2002 TOMS O3 data for GCAP (swu, bmy, 10/3/06)
(6 ) Now reads from TOMS_200701 directory, w/ updated data.  Also always
      use 1979 data prior to 1979 or 2005 data after 2005. (bmy, 2/12/07)
(7 ) Bug fix: don't include DATA_DIR in filename, just in case someone's
      file path has replaceable tokens (e.g. hh, mm, MM etc.) (bmy, 12/5/07)
(8 ) Latest year of TOMS data is now 2007 (bmy, 1/14/09)
(9 ) Updated TOMS data in TOMS_200906. Latest year is 2008. (ccc, 6/15/09)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
03 Jul 2012 - R. Yantosca - Restrict reading from TOMS_201203 directory
                            to GEOS-5.7.2 met data for the time being.
13 Dec 2013 - M. Sulprizio- Now pass USE_O3_FROM_MET logical flag so that
                            we bypass reading TOMS O3 data when using TO3
                            from the met fields.
```

1.111.2 compute_overhead_o3

Subroutine COMPUTE_OVERHEAD_O3 returns the resultant total overhead O3 column for the FAST-J photolysis. This will be one of two options:

1. Default: TOMS/SBUV overhead O3 columns. These will be used be the FAST-J routine set_prof.F to overwrite the existing FAST-J climatology (cf McPeters & Nagatani 1992). Missing data (i.e. for months & locations where TOMS/SBUV data does not exist) is denoted by the value -999; FAST-J will skip over these points.
2. Overhead O3 columns taken directly from the met fields. These will be returned if the flag USE_O3_FROM_MET is set to TRUE.

INTERFACE:

```
SUBROUTINE COMPUTE_OVERHEAD_O3( DAY, USE_O3_FROM_MET, TO3 )
```

INPUT PARAMETERS:

```
! Day of month
INTEGER, INTENT(IN)  :: DAY
```

```
      ! Switch to denote if we should use the default TO3
      ! directly from the met fields
      LOGICAL, INTENT(IN)  :: USE_O3_FROM_MET

      ! TO3 from the met fields [Dobsons]
      REAL*8,  INTENT(IN)  :: TO3(IIPAR,JJPAR)
```

REMARKS:

```
   Reference for the TOMS/SBUV merged O3 columns:
                                                                             .
   1985 - 2005 are taken from:
                                                                             .
    http://code916.gsfc.nasa.gov/Data_services/merged/index.html
                                                                             .
    TOMS/SBUV MERGED TOTAL OZONE DATA, Version 8, Revision 3.
    Resolution:  5 x 10 deg.
                                                                             .
    Contact person for the merged data product:
    Stacey Hollandsworth Frith (smh@hyperion.gsfc.nasa.gov)
                                                                             .
   2006 and 2007 are taken from:
                                                                             .
     http://code916.gsfc.nasa.gov/Data_services/merged/index.html
                                                                             .
     Version 8 Merged Ozone Data Sets
     Revision 04
     DATA THROUGH: SEP 2008
     LAST MODIFIED: 20 OCT 2008
                                                                             .
    Methodology (bmy, 2/12/07)
    ---------------------------------------------------------------
    FAST-J comes with its own default O3 column climatology (from
    McPeters 1992 & Nagatani 1991), which is stored in the input
    file "jv_atms.dat".  These "FAST-J default" O3 columns are used
    in the computation of the actinic flux and other optical
    quantities for the FAST-J photolysis.
                                                                             .
    The TOMS/SBUV O3 columns and 1/2-monthly O3 trends (contained
    in the TOMS_200701 directory) are read into GEOS-Chem by routine
    READ_TOMS in "toms_mod.f".  Missing values (i.e. locations where
    there are no data) in the TOMS/SBUV O3 columns are defined by
    the flag -999.
                                                                             .
    After being read from disk in routine READ_TOMS, the TOMS/SBUV
    O3 data are then passed to the FAST-J routine "set_prof.f".  In
    "set_prof.f", a test is done to make sure that the TOMS/SBUV O3
    columns and 1/2-monthly trends do not have any missing values
    for (lat,lon) location for the given month.  If so, then the
```

```
TOMS/SBUV O3 column data is interpolated to the current day and
is used to weight the "FAST-J default" O3 column.  This
essentially "forces" the "FAST-J default" O3 column values to
better match the observations, as defined by TOMS/SBUV.

If there are no TOMS/SBUV O3 columns (and 1/2-monthly trends)
at a (lat,lon) location for given month, then FAST-J will revert
to its own "default" climatology for that location and month.
Therefore, the TOMS O3 can be thought of as an  "overlay" data
-- it is only used if it exists.

Note that there are no TOMS/SBUV O3 columns at the higher
latitudes.  At these latitudes, the code will revert to using
the "FAST-J default" O3 columns.

As of February 2007, we have TOMS/SBUV data for 1979 thru 2005.
2006 TOMS/SBUV data is incomplete as of this writing.  For years
2006 and onward, we use 2005 TOMS O3 columns.

This methodology was originally adopted by Mat Evans.  Symeon
Koumoutsaris was responsible for creating the downloading and
processing the TOMS O3 data files from 1979 thru 2005 in the
TOMS_200701 directory.
```

REVISION HISTORY:

```
06 Mar 2012 - R. Yantosca - Initial version, pulled code out from
                            the FAST-J routine SET_PROF; based on the
                            GEOS-Chem column code routine
```

1.111.3 get_overhead_O3

Function GET_OVERHEAD_O3 returns the total overhead O3 column [DU] (which is taken either from TOMS/SBUV or directly from the met fields) at a given surface grid box location (I,J).

INTERFACE:

```
FUNCTION GET_OVERHEAD_O3( I, J ) RESULT( OVERHEAD_O3 )
```

INPUT PARAMETERS:

```
INTEGER :: I             ! Grid box longitude index
INTEGER :: J             ! Grid box latitude index
```

RETURN VALUE:

```
REAL*8  :: OVERHEAD_O3   ! Total overhead O3 column [DU]
```

REVISION HISTORY:

```
06 Mar 2012 - R. Yantosca - Initial version
```

1.111.4 init_toms

Subroutine INIT_TOMS allocates and zeroes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_TOMS
```

USES:

```
USE ERROR_MOD, ONLY : ALLOC_ERR

USE CMN_SIZE_MOD  ! Size parameters
```

REVISION HISTORY:

```
14 Jul 2003 - R. Yantosca - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
06 Mar 2012 - R. Yantosca - Now allocate TO3_DAILY
```

1.111.5 cleanup_toms

Subroutine CLEANUP_TOMS deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_TOMS
```

REVISION HISTORY:

```
14 Jul 2003 - R. Yantosca - Initial version
01 Dec 2010 - R. Yantosca - Added ProTeX headers
06 Mar 2012 - R. Yantosca - Now deallocate TO3_DAILY
```

1.112 Fortran: Module Interface tpcore_bc_mod

Module TPCORE_BC_MOD contains modules and variables which are needed to save and read TPCORE nested-grid boundary conditions to/from disk.

INTERFACE:

```
MODULE TPCORE_BC_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC DATA MEMBERS:

```
!-------------------------------------------------------------
! I0_W : Lon offset of TPCORE REGION [# boxes]
! J0_W : Lat offset of TPCORE REGION [# boxes]
! IM_W : Lon extent of TPCORE REGION [# boxes]
! JM_W : Lat extent of TPCORE REGION [# boxes]
! I1_W : Lower left-hand  (LL) lon index of NESTED WINDOW
! J1_W : Lower left-hand  (LL) lat index of NESTED WINDOW
! I2_W : Upper right-hand (UR) lon index of NESTED WINDOW
! J2_W : Upper right-hand (UR) lat index of NESTED WINDOW
! IGZD : ???
! Please also see the diagram in the REMARKS section.
!-------------------------------------------------------------
INTEGER, PUBLIC :: I0_W, J0_W
INTEGER, PUBLIC :: I1_W, J1_W
INTEGER, PUBLIC :: I2_W, J2_W
INTEGER, PUBLIC :: IM_W, JM_W
INTEGER, PUBLIC :: IGZD
```

PUBLIC MEMBER FUNCTIONS:

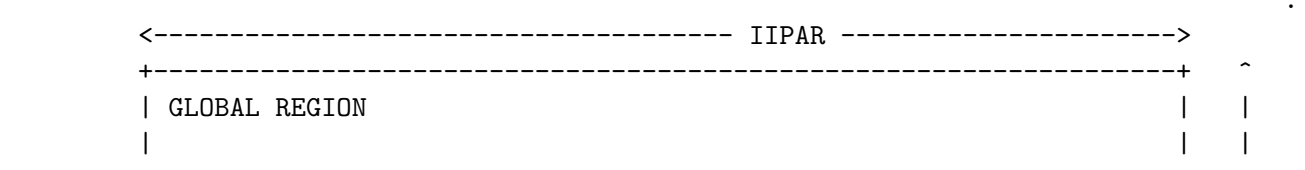
```
PUBLIC :: INIT_TPCORE_BC
PUBLIC :: DO_WINDOW_TPCORE_BC
PUBLIC :: SET_CLEAN_BC
PUBLIC :: SAVE_GLOBAL_TPCORE_BC
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: OPEN_BC_FILE
PRIVATE :: CLEAN_WINDOW_TPCORE_BC
PRIVATE :: READ_WINDOW_TPCORE_BC
PRIVATE :: GET_4x5_BC
PRIVATE :: GET_2x25_BC
PRIVATE :: ITS_TIME_FOR_BC
PRIVATE :: CLEANUP_TPCORE_BC
```

REMARKS:

Reference Diagram:



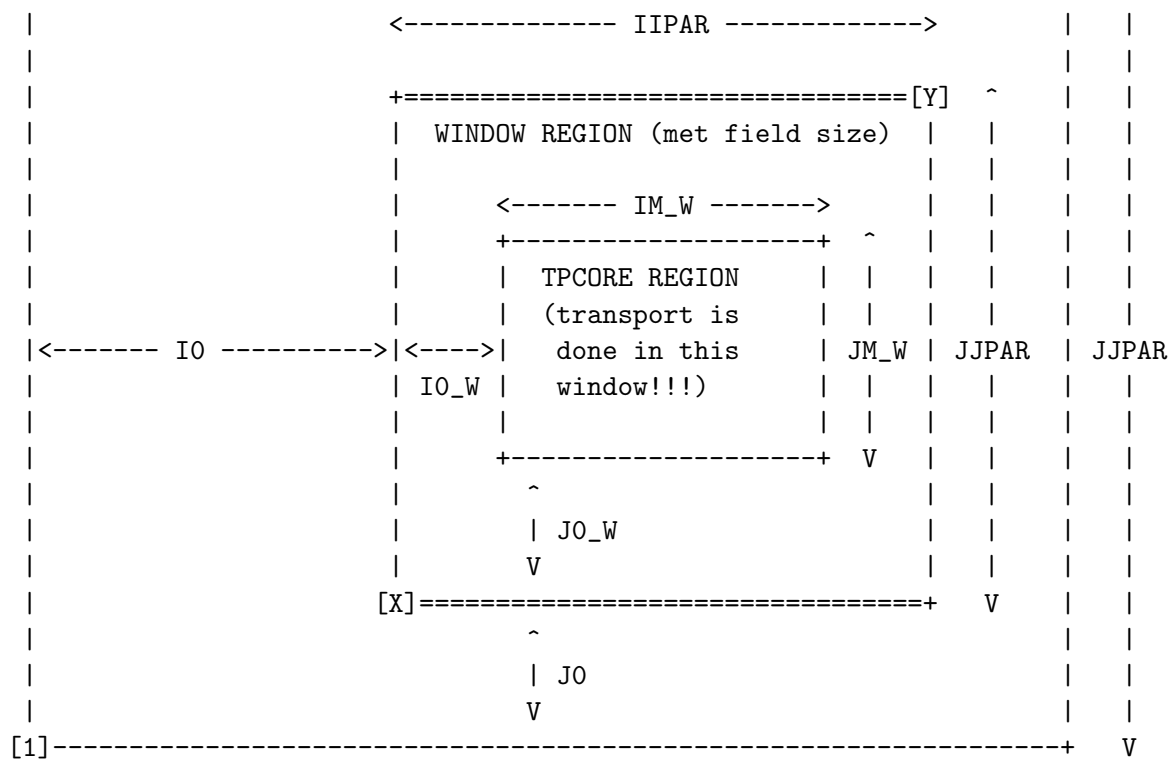


DIAGRAM NOTES:

(a) The outermost box ("Global Region") is the global grid size. This region has IIPAR boxes in longitude and JJPAR boxes in latitude. The origin of the "Global Region" is at the south pole, at the lower left-hand corner (point [1]).

(b) The next innermost box ("Window Region") is the nested-grid window. This region has IIPAR boxes in longitude and JJPAR boxes in latitude. This is the size of the trimmed met fields that will be used for a 1 x 1 "nested-grid" simulation.

(c) The innermost region ("TPCORE Region") is the actual area in which TPCORE transport will be performed. Note that this region is smaller than the "Window Region". It is set up this way since a cushion of grid boxes is needed TPCORE Region for boundary conditions.

(d) I0 is the longitude offset (# of boxes) and J0 is the latitude offset (# of boxes) which translate between the "Global Region" and the "Window Region".

(e) I0_W is the longitude offset (# of boxes), and J0_W is the latitude offset (# of boxes) which translate between the "Window Region" and the "TPCORE Region".

(f) The lower left-hand corner of the "Window Region" (point [X]) has longitude and latitude indices (I1_W, J1_W). Similarly, the upper

```
      right-hand corner (point [Y]) has longitude and latitude indices
      (I2_W, J2_W).

  (g) Note that if I0=0, J0=0, I0_W=0, J0_W=0, IIPAR=IIPAR, JJPAR=JJPAR
      specifies a global simulation.  In this case the "Window Region"
      totally coincides with the "Global Region".

  (h) In order for the nested-grid to work we must save out concentrations
      over the WINDOW REGION from a coarse model (e.g. 4x5) corresponding to
      the same WINDOW REGION at 1x1.  These concentrations are copied along
      the edges of the 1x1 WINDOW REGION and are thus used as boundary
      conditions for TPCORE.
```

REVISION HISTORY:

```
  04 Mar 2003 - R. Yantosca - Initial version
  (1 ) Bug fix for LINUX w/ TIMESTAMP_STRING (bmy, 9/29/03)
  (2 ) Now references "tracer_mod.f", "directory_mod.f", and
       "logical_mod.f" (bmy, 7/20/04)
  (3 ) Now get HALFPOLAR for GEOS or GCAP grids (bmy, 6/28/05)
  (4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
  (5 ) Rename arguments in GET_4x5_BC to avoid name conflict (bmy, 10/24/05)
  (6 ) Now use EXPAND_DATE instead of obsolete DATE_STRING (bmy, 3/15/06)
  (7 ) Added 2x2.5 boundary condition output (created GET_2x25_BC).
       Added multi-boundary condition output (NA, EU, CH and Custom region).
       Unternally defined boundary condition regions for NA, EU and CH.
       (amv, bmy, 12/18/09)
  16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
  01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
  15 May 2012 - R. Yantosca - Added ProTeX headers
  06 Aug 2012 - R. Yantosca - Now make IU_BC, IU_BC_NA, IU_BC_EU, IU_BC_CH,
                              and IU_BC_SE local variables for findFreeLUN
  07 Sep 2012 - R. Yantosca - Minor fixes for numerical stability
  20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.112.1

Subroutine SET_CLEAN_BC initializes the CLEAN_BC logical flag. CLEAN_BC decides whether or not we will zero the nested-grid tpcore boundary conditions.

INTERFACE:

```
  SUBROUTINE SET_CLEAN_BC( THIS_CLEAN_BC )
```

INPUT PARAMETERS:

```
  LOGICAL, INTENT(IN) :: THIS_CLEAN_BC
```

REVISION HISTORY:

```
04 Mar 2003 - R. Yantosca - Initial versioni
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.112.2 open_bc_file

Subroutine OPEN_BC_FILE opens the file which contains boundary conditions saved from the coarse-grid WINDOW REGION for either reading or writing.

INTERFACE:

```
SUBROUTINE OPEN_BC_FILE( FOR_READ, FOR_WRITE, WINDOW )
```

USES:

```
USE BPCH2_MOD,     ONLY : OPEN_BPCH2_FOR_WRITE
USE BPCH2_MOD,     ONLY : OPEN_BPCH2_FOR_READ
USE DIRECTORY_MOD, ONLY : TPBC_DIR,     TPBC_DIR_NA
USE DIRECTORY_MOD, ONLY : TPBC_DIR_CH,  TPBC_DIR_EU
USE DIRECTORY_MOD, ONLY : TPBC_DIR_SE
USE inquireMod,    ONLY : findFreeLUN
USE TIME_MOD,      ONLY : EXPAND_DATE,  GET_NYMD
USE TIME_MOD,      ONLY : ITS_A_NEW_DAY
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN), OPTIONAL :: FOR_READ   ! Open file for read?
LOGICAL, INTENT(IN), OPTIONAL :: FOR_WRITE  ! Open file for write?
INTEGER, INTENT(IN)           :: WINDOW     ! Specifies nested region
```

REMARKS:

```
Pass these values via the WINDOW argument to do the following actions;
  WINDOW = 1 : Save BC's to file (Custom window,        aka "CU")
  WINDOW = 2 : Save BC's to file (North America window, aka "NA")
  WINDOW = 3 : Save BC's to file (Europe window,        aka "EU")
  WINDOW = 4 : Save BC's to file (China/SE Asia window, aka "CH")
  WINDOW = 5 : Read BC's from file
```

REVISION HISTORY:

```
07 Mar 2003 - R. Yantosca - Initial version
(1 ) Now use ITS_A_NEW_DAY from "time_mod.f".  Now references TPBC_DIR
     from "directory_mod.f" (bmy, 7/20/04)
(2 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(3 ) DATE_STRING is now obsolete; use EXPAND_DATE instead (bmy, 3/15/06)
(4 ) Can now read files from different directories (amv, bmy, 12/18/09)
15 May 2012 - R. Yantosca - Added ProTeX headers
```

```
06 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
06 Aug 2012 - R. Yantosca - Cleaned up IF statement, added comments
06 Aug 2012 - R. Yantosca - Close existing files before opening new files
07 Aug 2012 - R. Yantosca - Now print LUN used to open file
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Removed SEAC4RS C-preprocessor switch
```

1.112.3 save_global_tpcore_bc

Subroutine SAVE_GLOBAL_TPCORE_BC saves concentrations from the WINDOW REGION of a coarse-resolution model run to a bpch file. A new boundary conditions file is created for each day.

INTERFACE:

```
      SUBROUTINE SAVE_GLOBAL_TPCORE_BC( am_I_Root, Input_Opt,
     &                                  State_Chm, RC         )
```

USES:

```
      USE BPCH2_MOD
      USE CMN_SIZE_MOD
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TIME_MOD,           ONLY : GET_NYMD,  GET_NHMS
      USE TIME_MOD,           ONLY : GET_TAU,   TIMESTAMP_STRING
#if   defined( APM )
      USE TRACER_MOD,         ONLY : N_APMTRA
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
04 Mar 2003 - Y. Wang     - Initial version
(1 ) Now references N_TRACERS and STT from "tracer_mod.f".  Also now
     references TIMESTAMP_STRING from "time_mod.f".  (bmy, 7/20/04)
(2 ) Now call GET_HALFPOLAR from "bpch2_mod.f" to get the HALFPOLAR flag
     value for GEOS or GCAP grids (bmy, 6/28/05)
```

```
(3 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(4 ) Can now save files to different directories (amv, bmy, 12/18/09)
16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
15 May 2012 - R. Yantosca - Added ProTeX headers
06 Aug 2012 - R. Yantosca - Added comments & cosmetic changes
06 Aug 2012 - R. Yantosca - Now use file unit variables from this module
                            instead of from GeosUtil/file_mod.F
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.112.4 do_window_tpcore_bc

Subroutine DO_WINDOW_TPCORE_BC is a driver routine for assigning TPCORE boundary conditions to the tracer array STT.

INTERFACE:

```
      SUBROUTINE DO_WINDOW_TPCORE_BC( am_I_Root, Input_Opt,
     &                                State_Chm, RC         )
```

USES:

```
      USE CMN_SIZE_MOD
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
#if   defined( APM )
      USE TRACER_MOD,         ONLY : N_APMTRA
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
07 Mar 2003 - R. Yantosca - Initial version
(1 ) Now references N_TRACERS and STT from "tracer_mod.f" (bmy, 7/20/04)
(2 ) Now can use 2 x 2.5 BC's (amv, bmy, 12/18/09)
16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.112.5 clean_window_tpcore_bc

Subroutine CLEAN_WINDOW_TPCORE_BC zeroes the boundary conditions array BC at each timestep. (bmy, 3/7/03, 12/18/09)

INTERFACE:

```
SUBROUTINE CLEAN_WINDOW_TPCORE_BC( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
07 Mar 2003 - M. Prather  - Initial version
(1 ) Now references N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
(2 ) Now zeroes the arrays for the different regions (amv, bmy, 12/18/09)
16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
15 May 2012 - R. Yantosca - Added ProTeX headers
07 Sep 2012 - R. Yantosca - Simplify coding, remove parallel loops
07 Sep 2012 - R. Yantosca - Now use 0d0 instead of 0e0 to zero BC arrays
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Removed SEAC4RS C-preprocessor switch
```

1.112.6 read_window_tpcore_bc

Subroutine READ_WINDOW_TPCORE_BC reads tracer concentrations saved on the WINDOW REGION of a coarse-grid simulation (e.g. 4x5, 2x2.5). These concentrations will be used as boundary conditions for TPCORE transport.

INTERFACE:

```
SUBROUTINE READ_WINDOW_TPCORE_BC( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE FILE_MOD,           ONLY : IOERROR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE TIME_MOD,           ONLY : GET_TAU, TIMESTAMP_STRING
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
07 Mar 2003 - R. Yantosca - Initial version
(1 ) LINUX has a problem putting a function call w/in a WRITE statement.
     Now save output from TIMESTAMP_STRING to STAMP and print that.
     (bmy, 9/29/03)
(2 ) Now references N_TRACERS from "tracer_mod.f" (bmy, 7/20/04)
(3 ) Rewritten to be more generic (amv, bmy, 12/18/09)
15 May 2012 - R. Yantosca - Added ProTeX headers
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.112.7 get_4x5_bc

Function GET_4x5_BC returns a value from the 4x5 BC boundary conditions array at the location of a nested grid box.

INTERFACE:

```
FUNCTION GET_4x5_BC( I_1x1, J_1x1, L_1x1, N_1x1 ) RESULT( VALUE )
```

USES:

```
USE CMN_SIZE_MOD
USE GRID_MOD,      ONLY : GET_XMID, GET_YMID
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I_1x1   ! Nested-grid lon    index
INTEGER, INTENT(IN) :: J_1x1   ! Nested-grid lat    index
INTEGER, INTENT(IN) :: L_1x1   ! Nested-grid level  index
INTEGER, INTENT(IN) :: N_1x1   ! Nested-grid tracer index
```

RETURN VALUE:

```
REAL*8              :: VALUE   ! 4 x 5 BC @ location of nested grid box
```

REMARKS:

```
NOTE: This routine was originally written for the 1 x 1 nested grid,
but this now works for the GEOS-5 0.5 x 0.666 nested grid data.  Keep
variable names I_1x1, J_1x1, etc. unchanged for the present.
```

```
For now we will assume that we have saved tracer concentrations from
a  4x5 window which overlays the corresponding 1x1 WINDOW REGION.
These 4x5 tracer concentrations are used as boundary conditions for
TPCORE.
```

REVISION HISTORY:

```
07 Mar 2003 - Y. Wang, R. Yantosca - Initial version
(1 ) Rename arguments to avoid conflict w/ I1x1, J1x1 parameters in
      CMN_SIZE. (bmy, 10/24/05)
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.112.8 get_2x25_bc

Function GET_2x25_BC returns a value from the 2 x 2.5 BC boundary conditions array at the location of a nested grid box.

INTERFACE:

```
FUNCTION GET_2x25_BC( I_1x1, J_1x1, L_1x1, N_1x1 ) RESULT( VALUE )
```

USES:

```
USE CMN_SIZE_MOD
USE GRID_MOD,     ONLY : GET_XMID, GET_YMID
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I_1x1   ! Nested-grid lon    index
INTEGER, INTENT(IN) :: J_1x1   ! Nested-grid lat    index
INTEGER, INTENT(IN) :: L_1x1   ! Nested-grid level  index
INTEGER, INTENT(IN) :: N_1x1   ! Nested-grid tracer index
```

RETURN VALUE:

```
REAL*8              :: VALUE   ! 2 x 2.5 BC @ location of nested grid box
```

REMARKS:

```
NOTE: This routine was originally written for the 1 x 1 nested grid,
but this now works for the GEOS-5 0.5 x 0.666 nested grid data.  Keep
variable names I_1x1, J_1x1, etc. unchanged for the present.

For now we will assume that we have saved tracer concentrations from
a 2 x 2.5 window which overlays the corresponding NESTED WINDOW REGION.
These 2 x 2.5 tracer concentrations are used as boundary conditions
for TPCORE.
```

REVISION HISTORY:

```
18 Dec 2009 - A. van Donkeelar - Initial version
01 Mar 2012 - R. Yantosca - Now use GET_XMID(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.112.9 its_time_for_bc

Subroutine ITS_TIME_FOR_BC returns TRUE if it is time to read in the next set of boundary conditions for TPCORE, or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_TIME_FOR_BC() RESULT( FLAG )
```

USES:

```
USE TIME_MOD, ONLY : GET_ELAPSED_MIN
```

RETURN VALUE:

```
LOGICAL :: FLAG   ! =T if it's time to read BC's from disk
```

REVISION HISTORY:

```
05 Mar 2003 - R. Yantosca - Initial version
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.112.10 init_tpcore_bc

Subroutine INIT_TPCORE_BC initializes module variables and arrays.

INTERFACE:

```
SUBROUTINE INIT_TPCORE_BC( TS, IOW, JOW, I1,
&                          J1, I2,  J2,  Input_Opt )
```

USES:

```
USE CMN_SIZE_MOD
USE DIRECTORY_MOD,      ONLY : TPBC_DIR
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_XOFFSET, GET_YOFFSET
USE GRID_MOD,           ONLY : ITS_A_NESTED_GRID
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN) :: TS          ! Timestep for BC data
INTEGER,        INTENT(IN) :: I0W, J0W    ! Transport region offsets
INTEGER,        INTENT(IN) :: I1,  J1     ! Lon, lat indices @ LL corner
INTEGER,        INTENT(IN) :: I2,  J2     ! Lon, lat indices @ UR corner
TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
10 Feb 2003 - R. Yantosca - Initial version
(1 ) Now references N_TRACERS from "tracer_mod.f".  Now references LWINDO
     from "logical_mod.f".  Now references TPBC_DIR from "directory_mod.f".
     Now references ITS_A_NESTED_GRID from "grid_mod.f".  Also added
     arguments to take values from "input_mod.f". (bmy, 7/20/04)
15 May 2012 - R. Yantosca - Added ProTeX headers
07 Sep 2012 - R. Yantosca - Now use 0d0 instead of 0e0 to zero BC arrays
17 Oct 2012 - M. Payer    - Bug fix: Define extent of coarse grid BC region
                            even if LWINDO_CH or LWINDO_SE = False to
                            avoid out-of-bounds errors in array BC
05 Jun 2013 - K. Yu       - Define BC boundaries for GEOS_57 0.25 NA grid
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Removed SEAC4RS C-preprocessor switch
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.112.11 cleanup_tpcore_bc

Subroutine CLEANUP_TPCORE_BC deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_TPCORE_BC
```

REVISION HISTORY:

```
04 Mar 2003 - R. Yantosca - Initial version
15 May 2012 - R. Yantosca - Added ProTeX headers
```

1.113 Fortran: Module Interface tracer_mod

Module TRACER_MOD contains GEOS-CHEM tracer array STT plus various other related quantities. TRACER_MOD also contains inquiry functions that can be used to determine the type of GEOS-CHEM simulation.

INTERFACE:

```
MODULE TRACER_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: ITS_A_RnPbBe_SIM
PUBLIC :: ITS_A_CH3I_SIM
PUBLIC :: ITS_A_FULLCHEM_SIM
PUBLIC :: ITS_A_HCN_SIM
PUBLIC :: ITS_A_TAGOX_SIM
PUBLIC :: ITS_A_TAGCO_SIM
PUBLIC :: ITS_A_C2H6_SIM
PUBLIC :: ITS_A_CH4_SIM
PUBLIC :: ITS_AN_AEROSOL_SIM
PUBLIC :: ITS_A_MERCURY_SIM
PUBLIC :: ITS_A_CO2_SIM
PUBLIC :: ITS_A_H2HD_SIM
PUBLIC :: ITS_A_POPS_SIM
PUBLIC :: ITS_NOT_COPARAM_OR_CH4
PUBLIC :: GET_SIM_NAME
PUBLIC :: CHECK_STT
PUBLIC :: CHECK_STT_05x0666
PUBLIC :: CHECK_STT_025x03125
PUBLIC :: INIT_TRACER
PUBLIC :: CLEANUP_TRACER
```

PUBLIC DATA MEMBERS:

```
!=========================================================================
! Module Variables:
! SIM_TYPE       : Number denoting simulation type
! N_TRACERS      : Number of GEOS-CHEM tracers
! N_MEMBERS      : Max # of constituents a tracer can have
! ID_TRACER      : Array of tracer numbers
! ID_EMITTED     : Index of which constituent has the emissions
! STT            : GEOS-CHEM Tracer array [kg]
! TCVV           : Molecular weight air / molecular weight tracer
! TRACER_COEFF   : Coefficient of each tracer constituent
! TRACER_MW_G    : Tracer molecular weight [g/mole]
! TRACER_MW_KG   : Tracer molecular weight [kg/mole]
! TRACER_N_CONST : Array of number of constituents per tracer
! TRACER_NAME    : Array of tracer names
! TRACER_CONST   : Array of names for tracer constituents
! SALA_REDGE_um  : Accum  mode seasalt radii bin edges [um]
! SALC_REDGE_um  : Coarse mode seasalt radii bin edges [um]
! XNUMOL         : Ratio of (molec/mole) / (kg/mole) = molec/kg
! XNUMOLAIR      : XNUMOL ratio for air
!=========================================================================
```

```
      ! Scalars
      INTEGER,           PUBLIC              :: SIM_TYPE
      INTEGER,           PUBLIC              :: N_TRACERS
#if   defined( APM )
      INTEGER,           PUBLIC              :: N_APMTRA
#endif
      ! N_MEMBERS increased from 10 to 15 (FP 8/2009)
      INTEGER,           PUBLIC, PARAMETER   :: N_MEMBERS = 15
      REAL*8,            PUBLIC, PARAMETER   :: XNUMOLAIR = 6.022d+23 /
     &                                                     28.9644d-3

      ! Arrays
      INTEGER,           PUBLIC, ALLOCATABLE :: ID_TRACER(:)
      INTEGER,           PUBLIC, ALLOCATABLE :: ID_EMITTED(:)
      INTEGER,           PUBLIC, ALLOCATABLE :: TRACER_N_CONST(:)
      REAL*8,            PUBLIC, ALLOCATABLE :: TCVV(:)
      REAL*8,            PUBLIC, ALLOCATABLE :: TRACER_COEFF(:,:)
      REAL*8,            PUBLIC, ALLOCATABLE :: TRACER_MW_G(:)
      REAL*8,            PUBLIC, ALLOCATABLE :: TRACER_MW_KG(:)
      REAL*8,            PUBLIC, ALLOCATABLE :: XNUMOL(:)
      CHARACTER(LEN=14), PUBLIC, ALLOCATABLE :: TRACER_NAME(:)
      CHARACTER(LEN=14), PUBLIC, ALLOCATABLE :: TRACER_CONST(:,:)

      ! Define seasalt radii bin edges [um] here since these
      ! need to be used both in "seasalt_mod.f" and "drydep_mod.f"
      REAL*8,            PUBLIC              :: SALA_REDGE_um(2)
      REAL*8,            PUBLIC              :: SALC_REDGE_um(2)
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca -  Initial version
(1 ) Added function GET_SIM_NAME (bmy, 5/3/05)
(2 ) Removed ITS_A_COPARAM_SIM; the CO-OH param is obsolete (bmy, 6/24/05)
(3 ) Added ITS_A_CO2_SIM (pns, bmy, 7/25/05)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Now added XNUMOL, XNUMOLAIR as module variables (bmy, 10/25/05)
(6 ) Added public routine ITS_A_H2HD_SIM (phs, 9/18/07)
(7 ) Added public routine ITS_A_POPS_SIM (eck, 9/20/10)
16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
05 Mar 2012 - M. Payer    - Added ProTeX headers
04 Apr 2013 - R. Yantosca - Removed STT (now in State_Chm)
```

1.113.1 its_a_rnpbbe_sim

Function ITS_A_RnPbBe_SIM returns TRUE if we are doing a GEOS-CHEM Rn-Pb-Be simulation.

INTERFACE:

```
FUNCTION ITS_A_RnPbBe_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.2 its_a_ch3i_sim

Function ITS_A_CH3I_SIM returns TRUE if we are doing a GEOS-CHEM CH3I (Methyl Iodide) simulation.

INTERFACE:

```
FUNCTION ITS_A_CH3I_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.3 its_a_fullchem_sim

Function ITS_A_FULLCHEM_SIM returns TRUE if we are doing a GEOS-CHEM full chemistry/aerosol simulation (i.e. via SMVGEAR).

INTERFACE:

```
FUNCTION ITS_A_FULLCHEM_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.4 its_a_hcn_sim

Function ITS_A_HCN_SIM returns TRUE if we are doing a GEOS-CHEM HCN (Hydrogen Cyanide) simulation.

INTERFACE:

```
FUNCTION ITS_A_HCN_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.5 its_a_tagox_sim

Function ITS_A_TAGOX_SIM returns TRUE if we are doing a GEOS-CHEM tagged Ox simulation.

INTERFACE:

```
FUNCTION ITS_A_TAGOX_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.6 its_a_tagco_sim

Function ITS_A_TAGCO_SIM returns TRUE if we are doing a GEOS-CHEM tagged CO simulation.

INTERFACE:

```
FUNCTION ITS_A_TAGCO_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.7 its_a_c2h6_sim

Function ITS_A_C2H6_SIM returns TRUE if we are doing a GEOS-CHEM C2H6 (Ethane) simulation.

INTERFACE:

```
FUNCTION ITS_A_C2H6_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.8 its_a_ch4_sim

Function ITS_A_CH4_SIM returns TRUE if we are doing a GEOS-CHEM CH4 (Methane) simulation.

INTERFACE:

```
FUNCTION ITS_A_CH4_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.9 its_an_aerosol_sim

Function ITS_AN_AEROSOL_SIM returns TRUE if we are doing a GEOS-CHEM offline Sulfate/Carbon/dust/seasalt aerosol simulation.

INTERFACE:

```
FUNCTION ITS_AN_AEROSOL_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.10 its_a_mercury_sim

Function ITS_A_MERCURY_SIM returns TRUE if we are doing a GEOS-CHEM Hg0/Hg2/HgP offline mercury simulation.

INTERFACE:

```
FUNCTION ITS_A_MERCURY_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.11 its_a_pops_sim

Function ITS_A_POPS_SIM returns TRUE if we are doing a GEOS-CHEM offline POPs simulation.

INTERFACE:

```
FUNCTION ITS_A_POPS_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
20 Sep 2010 - N.E. Selin  - Initial version
26 Nov 2012 - M. Payer    - Added ProTeX headers
```

1.113.12 its_a_co2_sim

Function ITS_A_CO2_SIM returns TRUE if we are doing a GEOS-CHEM CO2 offline simulation.

INTERFACE:

```
FUNCTION ITS_A_CO2_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
25 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.13 its_a_h2hd_sim

Function ITS_A_H2HD_SIM returns TRUE if we are doing a GEOS-CHEM H2-HD simulation.

INTERFACE:

```
FUNCTION ITS_A_H2HD_SIM() RESULT( VALUE )
```

REVISION HISTORY:

```
18 Sep 2007 - P. Le Sager - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.14 its_not_coparam_or_ch4

Function ITS_NOT_COPARAM_OR_CH4 returns TRUE if we are doing a GEOS-CHEM simulation other than CO with parameterized OH or CH4.

INTERFACE:

```
FUNCTION ITS_NOT_COPARAM_OR_CH4() RESULT( VALUE )
```

REMARKS:

```
The CO-OH param (SIM_TYPE=5) is now obsolete (bmy, 6/24/05)
```

REVISION HISTORY:

```
15 Jul 2004 - R. Yantosca - Initial version
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.15 get_sim_name

Function GET_SIM_NAME returns the name (e.g. "NOx-Ox-Hydrocarbon-Aerosol", "Tagged CO", etc.) of the GEOS-CHEM simulation.

INTERFACE:

```
FUNCTION GET_SIM_NAME() RESULT( NAME )
```

RETURN VALUE:

```
CHARACTER(LEN=40) :: NAME
```

REVISION HISTORY:

```
03 May 2005 - R. Yantosca - Initial version
(1 ) The CO-OH simulation has been removed (bmy, 6/24/05)
(2 ) Added CASE blocks for CO2 and H2/HD simulations (bmy, 9/18/07)
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.16 check_stt

Subroutine CHECK_STT checks the STT tracer array for negative values, NaN values, or Infinity values. If any of these are found, the code will stop with an error message.

INTERFACE:

```
SUBROUTINE CHECK_STT( State_Chm, LOCATION )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
USE ERROR_MOD,          ONLY : IT_IS_NAN
USE ERROR_MOD,          ONLY : IT_IS_FINITE
USE GIGC_State_Chm_Mod, ONLY : ChmState
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(IN) :: LOCATION
```

INPUT PARAMETERS:

```
TYPE(ChmState),   INTENT(IN) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
(1 ) CHECK_STT uses the interfaces defined above -- these will do the
     proper error checking for either SGI or DEC/Compaq platforms.
     (bmy, 3/8/01)
(2 ) Now call GEOS_CHEM_STOP to shutdown safely.  Now use logicals LNAN,
     LNEG, LINF to flag if we have error conditions, and then stop the
     run outside of the parallel DO-loop. (bmy, 11/27/02)
(3 ) Bug fix in FORMAT statement: replace missing commas (bmy, 3/23/03)
(4 ) Moved from "error_mod.f" to "tracer_mod.f" (bmy, 7/15/04)
(5 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
05 Mar 2012 - M. Payer    - Added ProTeX headers
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.113.17 check_stt_05x0666

Subroutine CHECK_STT_05x0666 checks the STT tracer array for negative values, NaN values, or Infinity values. If any of these are found, the STT array will be set to a specified value.

INTERFACE:

```
SUBROUTINE CHECK_STT_05x0666( State_Chm, LOCATION )
```

USES:

```
USE CMN_SIZE_MOD
USE ERROR_MOD,          ONLY : IT_IS_NAN
USE ERROR_MOD,          ONLY : IT_IS_FINITE
USE GIGC_State_Chm_Mod, ONLY : ChmState
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(IN)    :: LOCATION
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState),   INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
05 Mar 2012 - M. Payer    - Initial version based on CHECK_STT and updates
                            for nested grid by Yuxuan Wang.
05 Mar 2012 - M. Payer    - Added ProTeX headers
```

1.113.18 check_stt_025x03125

Subroutine CHECK_STT_025x03125 checks the STT tracer array for negative values, NaN values, or Infinity values. If any of these are found, the STT array will be set to a specified value.

INTERFACE:

```
SUBROUTINE CHECK_STT_025x03125( State_Chm, LOCATION )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE ERROR_MOD,          ONLY : IT_IS_NAN
USE ERROR_MOD,          ONLY : IT_IS_FINITE
```

INPUT PARAMETERS:

```
CHARACTER(LEN=*), INTENT(IN)    :: LOCATION
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState),   INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REVISION HISTORY:

```
05 Mar 2012 - M. Payer    - Initial version based on CHECK_STT and updates
                            for nested grid by Yuxuan Wang.
05 Mar 2012 - M. Payer    - Added ProTeX headers
07 Jun 2013 - R. Yantosca - Now pass State_Chm object via the arg list
```

1.113.19 init_tracer

Subroutine INIT_TRACER initializes all module arrays.

INTERFACE:

```
SUBROUTINE INIT_TRACER( am_I_Root, Input_Opt, RC )
```

USES:

```
#if   defined( APM )
      USE APM_INIT_MOD,       ONLY : APM_NTRACERS
      USE APM_INIT_MOD,       ONLY : LAPM
#endif
      USE CMN_SIZE_MOD
      USE ERROR_MOD,          ONLY : ALLOC_ERR
      USE ERROR_MOD,          ONLY : DEBUG_MSG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU
      TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT) :: RC          ! Success or failure
```

REVISION HISTORY:

```
   15 Jul 2004 - R. Yantosca - Initial version
   25 Oct 2005 - R. Yantosca - Now allocate XNUMOL
   16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
   05 Mar 2012 - M. Payer    - Added ProTeX headers
   26 Feb 2013 - R. Yantosca - Now pass am_I_Root, Input_Opt, RC as arguments
   07 Mar 2013 - R. Yantosca - Now assign RC=GIGC_SUCCESS outside of APM block
   04 Apr 2013 - R. Yantosca - Removed STT (now in State_Chm)
```

1.113.20 cleanup_tracer

Subroutine CLEANUP_TRACER deallocates all module arrays.

INTERFACE:

```
      SUBROUTINE CLEANUP_TRACER
```

REVISION HISTORY:

```
   15 Jul 2004 - R. Yantosca - Initial version
   25 Oct 2005 - R. Yantosca - Now deallocates XNUMOL
   05 Mar 2012 - M. Payer    - Added ProTeX headers
   04 Apr 2013 - R. Yantosca - Removed STT (now in State_Chm)
```

1.114 Fortran: Module Interface tropopause_mod

Module TROPOPAUSE_MOD contains routines and variables for reading and returning the value of the annual mean tropopause.

INTERFACE:

```
MODULE TROPOPAUSE_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CLEANUP_TROPOPAUSE
PUBLIC :: CHECK_VAR_TROP
PUBLIC :: COPY_FULL_TROP
PUBLIC :: DIAG_TROPOPAUSE
PUBLIC :: GET_MIN_TPAUSE_LEVEL
PUBLIC :: GET_MAX_TPAUSE_LEVEL
PUBLIC :: GET_TPAUSE_LEVEL
PUBLIC :: INIT_TROPOPAUSE
PUBLIC :: ITS_IN_THE_TROP
PUBLIC :: ITS_IN_THE_STRAT
PUBLIC :: READ_TROPOPAUSE
PUBLIC :: SAVE_FULL_TROP
```

PUBLIC DATA MEMBERS:

```
PUBLIC :: LMIN
PUBLIC :: LMAX
```

REVISION HISTORY:

```
22 Aug 2005 - R. Yantosca - Initial version
(1 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(2 ) Simplify counting of tropospheric boxes (bmy, 11/1/05)
(3 ) Added case of variable tropopause.
      The definition of the tropopause boxes is different in the two cases.
      They are part of the troposphere in the case of a variable
      troposphere. LMAX, LMIN are the min and max extent of the troposphere
      in that case.  (bdf, phs, 1/19/07)
(4 ) Bug fix: set NCS=NCSURBAN for safety's sake (bmy, 4/25/07)
(5 ) Updated comments (bmy, 9/18/07)
(6 ) Bug fix: make ITS_IN_THE_STRAT more robust. (phs, 11/14/08)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
29 Mar 2013 - R. Yantosca - Now make INIT_TROPOPAUSE a public function
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.114.1 copy_full_trop

Subroutine COPY_FULL_TROP takes the saved full troposphere and copies chemical species into the current troposphere that will be used in SMVGEAR for this timestep.

INTERFACE:

```
SUBROUTINE COPY_FULL_TROP( State_Chm )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_MOD,         ONLY : CSPEC
USE COMODE_MOD,         ONLY : IXSAVE, IYSAVE, IZSAVE
USE COMODE_LOOP_MOD
USE GIGC_State_Chm_Mod, ONLY : ChmState
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(IN) :: State_Chm   ! Chemistry State object
```

REMARKS:

```
ROUTINE NEEDED BECAUSE WITH VARIABLE TROPOPAUSE
JLOOP WILL NOT ALWAYS REFER TO THE SAME (I,J,L) BOX
```

REVISION HISTORY:

```
14 Sep 2006 - P. Le Sager - Initial version
(1 ) Very similar to a get_properties of an object. Should probably
      be in COMODE_MOD.F, and called GET_SPECIES_CONCENTRATION (phs)
(2 ) Bug fix: set NCS=NCSURBAN for safety's sake (bmy, 4/25/07)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.114.2 save_full_trop

Subroutine SAVE_FULL_TROP takes the current troposphere and copies chemical species into the full troposphere that will be used in SMVGEAR for this timestep.

INTERFACE:

```
SUBROUTINE SAVE_FULL_TROP( State_Chm )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_MOD,         ONLY : CSPEC
USE COMODE_MOD,         ONLY : IXSAVE, IYSAVE, IZSAVE
USE COMODE_LOOP_MOD
USE GIGC_State_Chm_Mod, ONLY : ChmState
```

OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

REMARKS:

```
ROUTINE NEEDED BECAUSE WITH VARIABLE TROPOPAUSE
JLOOP WILL NOT ALWAYS REFER TO THE SAME (I,J,L) BOX
```

REVISION HISTORY:

```
14 Sep 2006 - P. Le Sager - Initial version
(1 ) Very similar to a set_properties of an object. Should probably
      be in COMODE_MOD.F, and called SAVE_SPECIES_CONCENTRATION (phs)
(2 ) Bug fix: set NCS=NCSURBAN for safety's sake! (bmy, 4/25/07)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
```

1.114.3 check_var_trop

Subroutine CHECK_VAR_TROP checks that the entire variable troposphere is included in the 1..LLTROP range, and set the LMIN and LMAX to current min and max tropopause.

INTERFACE:

```
SUBROUTINE CHECK_VAR_TROP( State_Met )
```

USES:

```
USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
USE GIGC_State_Met_Mod, ONLY : MetState

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_MOD                  ! LPAUSE, for backwards compatibility
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
24 Aug 2006 - P. Le Sager - Initial version
(1 ) LLTROP is set at the first level entirely above 20 km (phs, 9/29/06)
(2 ) Fix LPAUSE for CH4 chemistry (phs, 1/19/07)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.114.4 read_tropopause

Subroutine READ_TROPOPAUSE reads in the annual mean tropopause.

INTERFACE:

```
SUBROUTINE READ_TROPOPAUSE
```

USES:

```
USE BPCH2_MOD,     ONLY : GET_NAME_EXT, GET_RES_EXT
USE BPCH2_MOD,     ONLY : GET_TAU0,     READ_BPCH2
USE DIRECTORY_MOD, ONLY : DATA_DIR
USE ERROR_MOD,     ONLY : GEOS_CHEM_STOP
USE TRANSFER_MOD,  ONLY : TRANSFER_2D

USE CMN_SIZE_MOD      ! Size parameters
USE CMN_MOD           ! LPAUSE, for backwards compatibility
```

REVISION HISTORY:

```
13 Dec 1999 - Q. Li, R. Yantosca - Initial version
(1 ) Call READ_BPCH2 to read in the annual mean tropopause data
     which is stored in binary punch file format. (bmy, 12/13/99)
(2 ) Now also read integer flags for ND27 diagnostic -- these determine
     how to sum fluxes from boxes adjacent to the annual mean tropoause.
     (qli, bmy, 1/7/00)
(3 ) Cosmetic changes (bmy, 3/17/00)
(4 ) Reference F90 module "bpch2_mod" which contains routine "read_bpch2"
     for reading data from binary punch files (bmy, 6/28/00)
(5 ) Call TRANSFER_2D from "transfer_mod.f" to cast data from REAL*4 to
     INTEGER and also to resize to (IIPAR,JJPAR).  ARRAY needs to be of
     size (IIPAR,JJPAR).  Also updated comments and made cosmetic changes.
     Removed obsolete variables.(bmy, 9/26/01)
(6 ) Removed obsolete code from 9/01 (bmy, 10/26/01)
(7 ) Now read annual mean tropopause files from the ann_mean_trop_200202/
     subdirectory of DATA_DIR (bmy, 1/24/02)
(8 ) Eliminated obsolete code from 1/02 (bmy, 2/27/02)
(9 ) Now write file name to stdout (bmy, 4/3/02)
(10) Now reference GEOS_CHEM_STOP from "error_mod.f", which frees all
     allocated memory before stopping the run. (bmy, 10/15/02)
(11) Now call READ_BPCH2 with QUIET=.TRUE. to suppress printing of extra
     info to stdout.  Also updated FORMAT strings. (bmy, 3/14/03)
(12) Now references DATA_DIR from "directory_mod.f" (bmy, 7/20/04)
(13) Now bundled into "tropopause_mod.f' (bmy, 2/10/05)
(14) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(15) Simplify counting of # of tropospheric boxes (bmy, 11/1/05)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
29 Mar 2013 - R. Yantosca - Remove call to INIT_TROPOPAUSE, this is now
                            done in the init stage
```

1.114.5 get_max_tpause_level

Function GET_MAX_TPAUSE_LEVEL returns GEOS-Chem level at the highest extent of the annual mean tropopause.

INTERFACE:

```
FUNCTION GET_MAX_TPAUSE_LEVEL() RESULT( L_MAX )
```

RETURN VALUE:

```
INTEGER :: L_MAX    ! Maximum tropopause level
```

REVISION HISTORY:

```
10 Feb 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.114.6 get_min_tpause_level

Function GET_MIN_TPAUSE_LEVEL returns GEOS-Chem level at the lowest extent of the annual mean tropopause.

INTERFACE:

```
FUNCTION GET_MIN_TPAUSE_LEVEL() RESULT( L_MIN )
```

RETURN VALUE:

```
INTEGER :: L_MIN   ! Minimum tropopause level
```

REVISION HISTORY:

```
10 Feb 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.114.7 get_tpause_level

Function GET_TPAUSE_LEVEL returns the tropopause level L_TP at surface location (I,J). Therefore, grid box (I,J,L_TP) is partially in the troposphere and partially in the stratosphere. The grid box below this, (I,J,L_TP-1), is the last totally tropospheric box in the column.

INTERFACE:

```
FUNCTION GET_TPAUSE_LEVEL( I, J, State_Met ) RESULT( L_TP )
```

USES:

```
USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
USE GIGC_State_Met_Mod, ONLY : MetState
USE LOGICAL_MOD,        ONLY : LVARTROP
USE PRESSURE_MOD,       ONLY : GET_PEDGE

USE CMN_SIZE_MOD             ! Size parameters
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN) :: I           ! Longitude index
INTEGER,        INTENT(IN) :: J           ! Latitude index
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
INTEGER                    :: L_TP   ! Tropopause level at (I,J)
```

REVISION HISTORY:

```
22 Aug 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
10 Sep 2010 - R. Yantosca - Update comments, remove obsolete documentation
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.114.8 its_in_the_trop

Function ITS_IN_THE_TROP returns TRUE if grid box (I,J,L) lies within the troposphere, or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_IN_THE_TROP( I, J, L, State_Met ) RESULT ( IS_TROP )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
USE LOGICAL_MOD,  ONLY : LVARTROP
USE PRESSURE_MOD, ONLY : GET_PEDGE
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN) :: I           ! Longitude index
INTEGER,        INTENT(IN) :: J           ! Latitude index
INTEGER,        INTENT(IN) :: L           ! Level index
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
LOGICAL                    :: IS_TROP   ! =T if we are in the troposphere
```

REMARKS:

REVISION HISTORY:

```
10 Feb 2005 - P. Le Sager - Initial version
(1 ) Modified for variable tropopause (phs, 9/14/06)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

1.114.9 its_in_the_strat

Function ITS_IN_THE_STRAT returns TRUE if grid box (I,J,L) lies within the stratosphere, or FALSE otherwise.

INTERFACE:

```
FUNCTION ITS_IN_THE_STRAT( I, J, L, State_Met ) RESULT( IS_STRAT )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN) :: I           ! Longitude index
INTEGER,        INTENT(IN) :: J           ! Latitude index
INTEGER,        INTENT(IN) :: L           ! Level index
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

RETURN VALUE:

```
LOGICAL                    :: IS_STRAT  ! =T if we are in the stratosphere
```

REVISION HISTORY:

```
10 Feb 2005 - P. Le Sager - Initial version
(1 ) Modified for variable tropopause (phs, 9/14/06)
(2 ) Now return the opposite value of ITS_IN_THE_TROP.  This should help
      to avoid numerical issues. (phs, 11/14/08)
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.114.10 diag_tropopause

Subroutine TROPOPAUSE archives the ND55 tropopause diagnostic.

INTERFACE:

```
SUBROUTINE DIAG_TROPOPAUSE( State_Met )
```

USES:

```
USE DIAG_MOD,           ONLY : AD55
USE GIGC_State_Met_Mod, ONLY : MetState
USE LOGICAL_MOD,        ONLY : LVARTROP
USE PRESSURE_MOD,       ONLY : GET_PCENTER
USE PRESSURE_MOD,       ONLY : GET_PEDGE

USE CMN_SIZE_MOD             ! Size parameters
USE CMN_DIAG_MOD             ! Diagnostic switches
```

INPUT PARAMETERS:

```
TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REMARKS:

For GEOS-4, GEOS-5, 'MERRA', we use the tropopause pressure from the met field archive to determine if we are in the tropopause or not. Therefore, the 3rd slot of AD55 should be archived with the tropopause pressure from the met fields.

For other met fields, we have to estimate the tropopause pressure from the tropopause level. Archive the pressure at the midpoint of the level in which the tropopause occurs. NOTE: this may result in lower minimum tropopause pressure than reality.

REVISION HISTORY:

30 Nov 1999 - H. Liu, R. Yantosca - Initial version
(1) Make sure the DO-loops go in the order L-J-I, wherever possible.
(2) Now archive ND55 diagnostic here rather than in DIAG1.F. Also, use an allocatable array (AD55) to archive tropopause heights.
(3) HTPAUSE is now a local variable, since it is only used here.
(4) Make LTPAUSE a local variable, since LPAUSE is used to store the annual mean tropopause. (bmy, 4/17/00)
(5) Replace PW(I,J) with P(I,J). Also updated comments. (bmy, 10/3/01)
(6) Removed obsolete code from 9/01 and 10/01 (bmy, 10/24/01)
(7) Added polar tropopause for GEOS-3 in #if defined(GEOS_3) block (bmy, 5/20/02)
(8) Replaced all instances of IM with IIPAR and JM with JJPAR, in order to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(9) Now use GET_PCENTER from "pressure_mod.f" to compute the pressure at the midpoint of box (I,J,L). Also deleted obsolete, commented-out code. (dsa, bdf, bmy, 8/21/02)
(10) Now reference BXHEIGHT and T from "dao_mod.f". Also reference routine ERROR_STOP from "error_mod.f" (bmy, 10/15/02)
(11) Now uses routine GET_YMID from "grid_mod.f" to compute grid box latitude. (bmy, 2/3/03)

```
(12) Add proper polar tropopause level for GEOS-4 (bmy, 6/18/03)
(13) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(14) Get tropopause level from TROPOPAUSE_MOD.F routines (phs, 10/17/06)
10 Sep 2010 - R. Yantosca - Added ProTeX headers
10 Sep 2010 - R. Yantosca - For GEOS-4, GEOS-5, MERRA met fields, take the
                            the tropopause pressure directly from the
                            met fields rather than computing it here.
10 Sep 2010 - R. Yantosca - Remove reference to LPAUSE, it's obsolete
10 Sep 2010 - R. Yantosca - Reorganize #if blocks for clarity
10 Sep 2010 - R. Yantosca - Renamed to DIAG_TROPOPAUSE and bundled into
                            tropopause_mod.f
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.114.11 init_tropopause

Subroutine INIT_TROPOPAUSE allocates and zeroes module arrays.

INTERFACE:

```
SUBROUTINE INIT_TROPOPAUSE( am_I_Root, Input_Opt, RC )
```

USES:

```
USE CMN_SIZE_MOD
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE ERROR_MOD,          ONLY : ALLOC_ERR
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
Now
```

REVISION HISTORY:

```
10 Feb 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
29 Mar 2013 - R. Yantosca - Now made public so we can shadow LVARTROP
```

1.114.12 cleanup_tropopause

Subroutine CLEANUP_TROPOPAUSE deallocates module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_TROPOPAUSE
```

REVISION HISTORY:

```
10 Feb 2005 - R. Yantosca - Initial version
09 Sep 2010 - R. Yantosca - Added ProTeX headers
```

1.115 Fortran: Module Interface Tpcore_FvDas_Mod

Overview

Module Tpcore_Fvdas_Mod contains routines for the TPCORE transport scheme, as implemented in the GMI model (cf. John Tannahill), based on Lin Rood 1995. The Harvard Atmospheric Chemistry Modeling Group has added modifications to implement the Philip-Cameron Smith pressure fixer for mass conservation. Mass flux diagnostics have also been added.

References

1. Lin, S.-J., and R. B. Rood, 1996: *Multidimensional flux form semi-Lagrangian transport schemes*, Mon. Wea. Rev., **124**, 2046-2070.

2. Lin, S.-J., W. C. Chao, Y. C. Sud, and G. K. Walker, 1994: *A class of the van Leer-type transport schemes and its applications to the moisture transport in a General Circulation Model*, Mon. Wea. Rev., **122**, 1575-1593.

Selecting E/W, N/S and vertical advection options

The flags IORD, JORD, KORD select which transport schemes are used in the E/W, N/S, and vertical directions, respectively. Here is a list of the possible values that IORD, JORD, KORD may be set to (original notes from S-J Lin):

1. 1st order upstream scheme (too diffusive, not a real option; it can be used for debugging purposes; this is THE only known "linear" monotonic advection scheme.).
2. 2nd order van Leer (full monotonicity constraint; see Lin et al 1994, MWR)
3. monotonic PPM* (Collela & Woodward 1984)
4. semi-monotonic PPM (same as 3, but overshoots are allowed)
5. positive-definite PPM (constraint on the subgrid distribution is only strong enough to prevent generation of negative values; both overshoots & undershoots are possible).

6. un-constrained PPM (nearly diffusion free; faster but positivity of the subgrid distribution is not quaranteed. Use this option only when the fields and winds are very smooth.

7. Huynh/Van Leer/Lin full monotonicity constraint. Only KORD can be set to 7 to enable the use of Huynh's 2nd monotonicity constraint for piece-wise parabolic distribution.

Recommended values:

- IORD=JORD=3 for high horizontal resolution.
- KORD=3 or 7

The implicit numerical diffusion decreases as _ORD increases. DO NOT use option 4 or 5 for non-positive definite scalars (such as Ertel Potential Vorticity).

In GEOS-Chem we have been using IORD=3, JORD=3, KORD=7. We have tested the OpenMP parallelization with these options. GEOS-Chem users who wish to use different (I,J,K)ORD options should consider doing single-procsessor vs. multi-processor tests to test the implementation of the parallelization.

GEOS-4 and GEOS-5 Hybrid Grid Definition

For GEOS-4 and GEOS-5 met fields, the pressure at the bottom edge of grid box (I,J,L) is defined as follows:

$$P_{edge}(I,J,L) = A_k(L) + [B_k(L) * P_{surface}(I,J)]$$

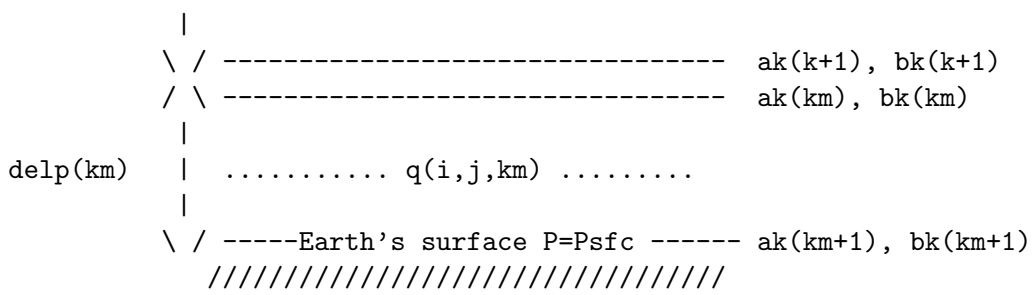
where

- $P_{surface}$(I,J) is the "true" surface pressure at lon,lat (I,J)
- A_k(L) has the same units as surface pressure [hPa]
- B_k(L) is a unitless constant given at level edges

$A_k(L)$ and $B_k(L)$ are supplied to us by GMAO.

REMARKS:

```
Ak(L) and Bk(L) are defined at layer edges.
                ////////////////////////////////
             / \ ------ Model top P=ak(1) --------- ak(1), bk(1)
              |
  delp(1)     |  ........... q(i,j,1) ............
              |
             \ / ---------------------------------  ak(2), bk(2)
             / \ ---------------------------------  ak(k), bk(k)
              |
  delp(k)     |  ........... q(i,j,k) ............
```



Note: surface pressure can be of any unit (e.g., pascal or mb) as long as it is consistent with the definition of (ak, bk) defined above. Winds (u,v), ps, and q are assumed to be defined at the same points.

The latitudes are given to the initialization routine: init_tpcore.

INTERFACE:

```
MODULE Tpcore_FvDas_Mod
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  ::  Init_Tpcore
PUBLIC  ::  Exit_Tpcore
PUBLIC  ::  Tpcore_FvDas
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE ::  Average_Const_Poles
PRIVATE ::  Set_Cross_Terms
PRIVATE ::  Calc_Vert_Mass_Flux
PRIVATE ::  Set_Jn_Js
PRIVATE ::  Calc_Advec_Cross_Terms
PRIVATE ::  Qckxyz
PRIVATE ::  Set_Lmts
PRIVATE ::  Set_Press_Terms
PRIVATE ::  Calc_Courant
PRIVATE ::  Calc_Divergence
PRIVATE ::  Do_Divergence_Pole_Sum
PRIVATE ::  Do_Cross_Terms_Pole_I2d2
PRIVATE ::  Xadv_Dao2
PRIVATE ::  Yadv_Dao2
PRIVATE ::  Do_Yadv_Pole_I2d2
PRIVATE ::  Do_Yadv_Pole_Sum
PRIVATE ::  Xtp
PRIVATE ::  Xmist
PRIVATE ::  Fxppm
PRIVATE ::  Lmtppm
```

```
PRIVATE ::  Ytp
PRIVATE ::  Ymist
PRIVATE ::  Do_Ymist_Pole1_I2d2
PRIVATE ::  Do_Ymist_Pole2_I2d2
PRIVATE ::  Fyppm
PRIVATE ::  Do_Fyppm_Pole_I2d2
PRIVATE ::  Do_Ytp_Pole_Sum
PRIVATE ::  Fzppm
PRIVATE ::  Average_Press_Poles
!PRIVATE DATA MEMBERS:

REAL*8, ALLOCATABLE, SAVE :: dtdx5(:)
REAL*8, ALLOCATABLE, SAVE :: dtdy5(:)
REAL*8, ALLOCATABLE, SAVE :: cosp(:)
REAL*8, ALLOCATABLE, SAVE :: cose(:)
REAL*8, ALLOCATABLE, SAVE :: gw(:)
REAL*8, ALLOCATABLE, SAVE :: DLAT(:)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, GMAO
Modified for GMI model by John Tannahill, LLNL (jrt@llnl.gov)
Implemented into GEOS-Chem by Claire Carouge (ccarouge@seas.harvard.edu)
ProTeX documentation added by Bob Yantosca (yantosca@seas.harvard.edu)
OpenMP parallelization added by Bob Yantosca (yantosca@seas.harvard.edu)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from the GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Added
                            OpenMP parallel loops in various routines (and
                            made some modifications to facilitate OpenMP).
01 Apr 2009 - C. Carouge  - Modified OpenMp parallelization and move the
                            loops over vertical levels outside the
                            horizontal transport routines for reducing
                            processing time.
 20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.115.1 Init_Tpcore

Subroutine Init_Tpcore allocates and initializes all module variables,

INTERFACE:

```
SUBROUTINE Init_Tpcore( IM, JM, KM, JFIRST, JLAST, NG, MG, dt, ae, clat )
```

USES:

```
USE CMN_GCTM_MOD
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN)  :: IM        ! Global E-W dimension
INTEGER, INTENT(IN)  :: JM        ! Global N-S dimension
INTEGER, INTENT(IN)  :: KM        ! Vertical dimension
INTEGER, INTENT(IN)  :: NG        ! large ghost width
INTEGER, INTENT(IN)  :: MG        ! small ghost width
REAL*8,  INTENT(IN)  :: dt        ! Time step in seconds
REAL*8,  INTENT(IN)  :: ae        ! Earth's radius (m)
REAL*8,  INTENT(IN)  :: clat(JM)  ! latitude in radian
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: JFIRST    ! Local first index for N-S direction
INTEGER, INTENT(OUT) :: JLAST     ! Local last  index for N-S direction
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.115.2 Exit_Tpcore

Subroutine Exit_Tpcore deallocates all module variables.

INTERFACE:

```
SUBROUTINE Exit_Tpcore
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.115.3 Tpcore_FvDas

Subroutine Tpcore_FvDas takes horizontal winds on sigma (or hybrid sigma-p) surfaces and calculates mass fluxes, and then updates the 3D mixing ratio fields one time step (tdt). The basic scheme is a Multi-Dimensional Flux Form Semi-Lagrangian (FFSL) based on the van Leer or PPM (see Lin and Rood, 1995).

INTERFACE:

```
SUBROUTINE Tpcore_FvDas( dt,       ae,       IM,       JM,      KM,       &
                         JFIRST,   JLAST,    ng,       mg,      nq,       &
                         ak,       bk,       u,        v,       ps1,      &
                         ps2,      ps,       q,        iord,    jord,     &
                         kord,     n_adj,    XMASS,    YMASS,   FILL,     &
                         MASSFLEW, MASSFLNS, MASSFLUP, AREA_M2, TCVV,     &
                         ND24,     ND25,     ND26 )
```

USES:

```
! Include file w/ physical constants
USE CMN_GCTM_MOD
```

INPUT PARAMETERS:

```
! Transport time step [s]
REAL*8,  INTENT(IN)    :: dt

! Earth's radius [m]
REAL*8,  INTENT(IN)    :: ae

! Global E-W, N-S, and vertical dimensions
INTEGER, INTENT(IN)    :: IM
INTEGER, INTENT(IN)    :: JM
INTEGER, INTENT(IN)    :: KM

! Latitude indices for local first box and local last box
! (NOTE: for global grids these are 1 and JM, respectively)
INTEGER, INTENT(IN)    :: JFIRST
INTEGER, INTENT(IN)    :: JLAST

! Primary ghost region
! (NOTE: only required for MPI parallelization; use 0 otherwise)
INTEGER, INTENT(IN)    :: ng

! Secondary ghost region
! (NOTE: only required for MPI parallelization; use 0 otherwise)
INTEGER, INTENT(IN)    :: mg

! Ghosted latitudes (3 required by PPM)
! (NOTE: only required for MPI parallelization; use 0 otherwise)
```

```
INTEGER, INTENT(IN)    :: nq

! Flags to denote E-W, N-S, and vertical transport schemes
INTEGER, INTENT(IN)    :: iord
INTEGER, INTENT(IN)    :: jord
INTEGER, INTENT(IN)    :: kord

! Number of adjustments to air_mass_flux (0 = no adjustment)
INTEGER, INTENT(IN)    :: n_adj

! Ak and Bk coordinates to specify the hybrid grid
! (see the REMARKS section below)
REAL*8,  INTENT(IN)    :: ak(KM+1)
REAL*8,  INTENT(IN)    :: bk(KM+1)

! u-wind (m/s) at mid-time-level (t=t+dt/2)
REAL*8,  INTENT(IN)    :: u(:,:,:)

! E/W and N/S mass fluxes [kg/s]
! (These are computed by the pressure fixer, and passed into TPCORE)
REAL*8,  INTENT(IN)    :: XMASS(:,:,:)
REAL*8,  INTENT(IN)    :: YMASS(:,:,:)

! Grid box surface area for mass flux diag [m2]
REAL*8,  INTENT(IN)    :: AREA_M2(JM)

! Tracer masses for flux diag
REAL*8,  INTENT(IN)    :: TCVV(NQ)

! Diagnostic flags
INTEGER, INTENT(IN)    :: ND24    ! Turns on E/W     flux diagnostic
INTEGER, INTENT(IN)    :: ND25    ! Turns on N/S     flux diagnostic
INTEGER, INTENT(IN)    :: ND26    ! Turns on up/down flux diagnostic

LOGICAL, INTENT(IN)    :: FILL    ! Fill negatives ?
```

INPUT/OUTPUT PARAMETERS:

```
! V-wind (m/s) at mid-time-level (t=t+dt/2)
REAL*8,  INTENT(INOUT) :: v(:,:,:)

! surface pressure at current time
REAL*8,  INTENT(INOUT) :: ps1(IM, JFIRST:JLAST)

! surface pressure at future time=t+dt
REAL*8,  INTENT(INOUT) :: ps2(IM, JFIRST:JLAST)

! Tracer "mixing ratios" [v/v]
REAL*8,  INTENT(INOUT), TARGET :: q(:,:,:,:)
```

```
! E/W, N/S, and up/down diagnostic mass fluxes
REAL*8,  INTENT(INOUT) :: MASSFLEW(:,:,:,:)  ! for ND24 diagnostic
REAL*8,  INTENT(INOUT) :: MASSFLNS(:,:,:,:)  ! for ND25 diagnostic
REAL*8,  INTENT(INOUT) :: MASSFLUP(:,:,:,:)  ! for ND26 diagnostic
```

OUTPUT PARAMETERS:

```
! "Predicted" surface pressure [hPa]
REAL*8,  INTENT(OUT)   :: ps(IM,JFIRST:JLAST)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Modified OpenMp parallelization and move the
                            loops over vertical levels outside the
                            horizontal transport routines for reducing
                            processing time.
03 Dec 2009 - C. Carouge  - Modify declarations of MASSFLEW, MASSFLNS and
                            MASSFLUP to save memory space.
30 May 2013 - S. Farina   - For TOMAS, zero out UA and VA variables
04 Jun 2013 - R. Yantosca - Use assumed-shape declarations for XMASS, YMASS,
                            U, V, and Q arrays.  These arrays are used to
                            pass pointer references, so this may help to
                            reduce the creation of array temporaries,
                            which will reduce memory.
 5 Jun 2013 - R. Yantosca - Avoid array temporary in call to FZPPM
```

1.115.4 Average_Const_Poles

Subroutine Average_Const_Poles averages the species concentrations at the Poles when the Polar cap is enlarged. It makes the last two latitudes equal.

INTERFACE:

```
SUBROUTINE Average_Const_Poles( dap ,   dbk,   rel_area, pctm1, const1, &
                                JU1_GL, J2_GL, I2_GL,    I1,    I2,     &
                                JU1,    J2,    ILO,    &
                                IHI,    JULO,  JHI )
```

INPUT PARAMETERS:

```
! Global latitude indices of the South Pole and North Pole
INTEGER, INTENT(IN)   :: JU1_GL, J2_GL

! Global max longitude index
INTEGER, INTENT(IN)   :: I2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)   :: I1,  I2
INTEGER, INTENT(IN)   :: JU1, J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: ILO,  IHI
INTEGER, INTENT(IN)   :: JULO, JHI

! Pressure difference across layer from (ai * pt) term [hPa]
REAL*8,  INTENT(IN)   :: dap

! Difference in bi across layer - the dSigma term
REAL*8,  INTENT(IN)   :: dbk

! Relative surface area of grid box [fraction]
REAL*8,  INTENT(IN)   :: rel_area(JU1:J2)

! CTM surface pressure at t1 [hPa]
REAL*8,  INTENT(IN)   :: pctm1( ILO:IHI, JULO:JHI )
```

INPUT/OUTPUT PARAMETERS:

```
! Species concentration, known at zone center [mixing ratio]
REAL*8, INTENT(INOUT) :: const1( I1:I2, JU1:J2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
```

```
Declare all REAL variables as REAL*8.  Also
make sure all numerical constants are declared
with the "D" double-precision exponent.
```

1.115.5 Set_Cross_Terms

Subroutine Set_Cross_Terms sets the cross terms for E-W horizontal advection.

INTERFACE:

```
SUBROUTINE Set_Cross_Terms( crx,   cry,   ua, va, J1P,   J2P,   &
                           I1_GL, I2_GL, JU1_GL, J2_GL, ILO,   &
                           IHI,   JULO,  JHI,    I1,    I2,    &
                           JU1,   J2,    CROSS )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)   :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: I1_GL,  I2_GL
INTEGER, INTENT(IN)   :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)   :: I1,     I2
INTEGER, INTENT(IN)   :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: ILO,    IHI
INTEGER, INTENT(IN)   :: JULO,   JHI

! Courant number in E-W direction
REAL*8,  INTENT(IN) :: crx(ILO:IHI, JULO:JHI)

! Courant number in N-S direction
REAL*8,  INTENT(IN) :: cry(ILO:IHI, JULO:JHI)

! Logical switch.  If CROSS=T then cross-terms will be computed.
LOGICAL, INTENT(IN) :: CROSS
```

OUTPUT PARAMETERS:

```
! Average of Courant numbers from il and il+1
REAL*8, INTENT(OUT) :: ua(ILO:IHI, JULO:JHI)
```

```
! Average of Courant numbers from ij and ij+1
REAL*8, INTENT(OUT) :: va(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.6 Calc_Vert_Mass_Flux

Subroutine Calc_Vert_Mass_Flux calculates the vertical mass flux.

INTERFACE:

```
SUBROUTINE Calc_Vert_Mass_Flux( dbk, dps_ctm, dpi, wz, I1,  &
                                I2,  JU1,     J2,  K1, K2 )
```

INPUT PARAMETERS:

```
! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)   :: I1,  I2
INTEGER, INTENT(IN)   :: JU1, J2
INTEGER, INTENT(IN)   :: K1,  K2

! Difference in bi across layer - the dSigma term
REAL*8,  INTENT(IN)  :: dbk(K1:K2)

! CTM surface pressure tendency; sum over vertical of dpi
! calculated from original mass fluxes [hPa]
REAL*8,  INTENT(IN)  :: dps_ctm(I1:I2, JU1:J2)

! Divergence at a grid point; used to calculate vertical motion [mb]
REAL*8,  INTENT(IN)  :: dpi(I1:I2, JU1:J2, K1:K2)
```

OUTPUT PARAMETERS:

```
! Large scale mass flux (per time step tdt) in the vertical
! direction as diagnosed from the hydrostatic relationship [hPa]
REAL*8, INTENT(OUT) :: wz(I1:I2, JU1:J2, K1:K2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops
```

1.115.7 Set_Jn_Js

Subroutine Set_Jn_Js determines Jn and Js, by looking where Courant number is ¿ 1.

INTERFACE:

```
SUBROUTINE Set_Jn_Js( jn,  js,     crx,   ILO, IHI, JULO, &
                      JHI, JU1_GL, J2_GL, J1P, J2P, I1,   &
                      I2,  JU1,    J2,    K1,  K2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)   :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)   :: I1,     I2
INTEGER, INTENT(IN)   :: JU1,    J2
INTEGER, INTENT(IN)   :: K1,     K2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: ILO,    IHI
```

```
INTEGER, INTENT(IN)   :: JULO,   JHI

! Courant number in E-W direction
REAL*8,  INTENT(IN)  :: crx(ILO:IHI, JULO:JHI, K1:K2)
```

OUTPUT PARAMETERS:

```
! Northward of latitude index = jn; Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(OUT) :: jn(K1:K2)

! Southward of latitude index = js; Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(OUT) :: js(K1:K2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REMARKS:

```
We cannot parallelize this subroutine because there is a CYCLE statement
within the outer loop.
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.115.8 Calc_Advec_Cross_Terms

Subroutine Calc_Advec_Cross_Terms calculates the advective cross terms.

INTERFACE:

```
SUBROUTINE Calc_Advec_Cross_Terms( jn,     js,    qq1,  qqu,  qqv,   &
                                   ua,     va,    J1P,  J2P,  I2_GL, &
                                   JU1_GL, J2_GL, ILO,  IHI,  JULO,  &
                                   JHI,    I1,    I2,   JU1,  J2,    &
                                   CROSS )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  ::         I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Northward of latitude index = jn, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)  :: Jn

! Southward of latitude index = js, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)  :: Js

! Species concentration (mixing ratio)
REAL*8,  INTENT(IN)  :: qq1(ILO:IHI, JULO:JHI)

! Average of Courant numbers from il and il+1
REAL*8,  INTENT(IN)  :: ua (ILO:IHI, JULO:JHI)

! Average of Courant numbers from ij and ij+1
REAL*8,  INTENT(IN)  :: va (ILO:IHI, JULO:JHI)

! Logical switch: If CROSS=T then cross-terms are being computed
LOGICAL, INTENT(IN)  :: CROSS
```

OUTPUT PARAMETERS:

```
! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(OUT) :: qqu(ILO:IHI, JULO:JHI)

! concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(OUT) :: qqv(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel do loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.9 Qckxyz

Subroutine Qckxyz routine checks for "filling".

INTERFACE:

```
SUBROUTINE Qckxyz( dq1, J1P, J2P,  JU1_GL, J2_GL, &
                   ILO, IHI, JULO, JHI,    I1,    &
                   I2,  JU1, J2,   K1,     K2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max latitude (J) indices
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2
INTEGER, INTENT(IN)  :: K1,     K2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI, K1:K2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
```

1.115.10 Set_Lmts

Subroutine Set_Lmts sets ILMT, JLMT, KLMT.

INTERFACE:

```
SUBROUTINE Set_Lmts( ilmt, jlmt, klmt, I2_GL, J2_GL, iord, jord, kord )
```

INPUT PARAMETERS:

```
! Global maximum longitude (I) and longitude (J) indices
INTEGER, INTENT(IN)  :: I2_GL, J2_GL

! Flags to denote E-W, N-S, and vertical transport schemes
! (See REMARKS section of routine Tpcore_FvDas for more info)
INTEGER, INTENT(IN)  :: iord, jord, kord
```

OUTPUT PARAMETERS:

```
! Controls various options in E-W advection
INTEGER, INTENT(OUT) :: ilmt

! Controls various options in N-S advection
INTEGER, INTENT(OUT) :: jlmt

! Controls various options in vertical advection
INTEGER, INTENT(OUT) :: klmt
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.115.11 Set_Press_Terms

Subroutine Set_Press_Terms sets the pressure terms: DELP1, DELPM, PU.

INTERFACE:

```
SUBROUTINE Set_Press_Terms( dap,   dbk,  pres1,  pres2, delp1,   &
                           delpm, pu,   JU1_GL, J2_GL, ILO,     &
                           IHI,   JULO, JHI,    J1P,   J2P,     &
                           I1,    I2,   JU1,    J2)
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max latitude (J) indices
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Pressure difference across layer from (ai * pt) term [hPa]
REAL*8,  INTENT(IN)  :: dap

! Difference in bi across layer - the dSigma term
REAL*8,  INTENT(IN)  :: dbk

! Surface pressure at t1 [hPa]
REAL*8,  INTENT(IN)  :: pres1(ILO:IHI, JULO:JHI)

! Surface pressure at t1+tdt [hPa]
```

```
REAL*8,  INTENT(IN)  :: pres2(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Pressure thickness, the pseudo-density in a
! hydrostatic system at t1 [hPa]
REAL*8, INTENT(OUT) :: delp1(ILO:IHI, JULO:JHI)

! Pressure thickness, the pseudo-density in a
! hydrostatic system at t1+tdt/2 (approximate) [hPa]
REAL*8, INTENT(OUT) :: delpm(ILO:IHI, JULO:JHI)

! Pressure at edges in "u" [hPa]
REAL*8, INTENT(OUT) :: pu(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.12 Calc_Courant

Subroutine Calc_Courant calculates courant numbers from the horizontal mass fluxes.

INTERFACE:

```
SUBROUTINE Calc_Courant( cose, delpm, pu,     xmass, ymass, crx, cry,  &
                         J1P,  J2P,   JU1_GL, J2_GL, ILO,   IHI, JULO, &
                         JHI,  I1,    I2,     JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P
```

```
! Global min & max latitude (J) indices
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Cosine of grid box edges
REAL*8,  INTENT(IN)  :: cose (JU1_GL:J2_GL)

! Pressure thickness, the pseudo-density in a hydrostatic system
! at t1+tdt/2 (approximate) (mb)
REAL*8,  INTENT(IN)  :: delpm(ILO:IHI, JULO:JHI)

! pressure at edges in "u"  (mb)
REAL*8,  INTENT(IN)  :: pu   (iLO:IHI, JULO:JHI)

! horizontal mass flux in E-W and N-S directions [hPa]
REAL*8,  INTENT(IN)  :: xmass(ILO:IHI, JULO:JHI)
REAL*8,  INTENT(IN)  :: ymass(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Courant numbers in E-W and N-S directions
REAL*8,  INTENT(OUT) :: crx(ILO:IHI, JULO:JHI)
REAL*8,  INTENT(OUT) :: cry(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO)
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.13 Calc_Divergence

Subroutine Calc_Divergence calculates the divergence.

INTERFACE:

```
SUBROUTINE Calc_Divergence( do_reduction, geofac_pc, geofac, dpi,   &
                            xmass,        ymass,     J1P,    J2P,   &
                            I1_GL,        I2_GL,     JU1_GL, J2_GL, &
                            ILO,          IHI,       JULO,   JHI,   &
                            I1,           I2,        JU1,    J2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Set to F if called on Master or T if called by Slaves
! (NOTE: This is only for MPI parallelization, for OPENMP it should be F)
LOGICAL, INTENT(IN)  :: do_reduction

! Special geometrical factor (geofac) for Polar cap
REAL*8 , INTENT(IN)  :: geofac_pc

! Geometrical factor for meridional advection; geofac uses correct
! spherical geometry, and replaces acosp as the meridional geometrical
! factor in TPCORE
REAL*8 , INTENT(IN)  :: geofac(JU1_GL:J2_GL)

! Horizontal mass flux in E/W and N/S directions [hPa]
REAL*8 , INTENT(IN)  :: xmass(ILO:IHI, JULO:JHI)
REAL*8 , INTENT(IN)  :: ymass(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Divergence at a grid point; used to calculate vertical motion [hPa]
```

```
REAL*8,  INTENT(OUT) :: dpi(I1:I2, JU1:J2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.14 Do_Divergence_Pole_Sum

Subroutine Do_Divergence_Pole_Sum sets the divergence at the Poles.

INTERFACE:

```
SUBROUTINE Do_Divergence_Pole_Sum( do_reduction, geofac_pc, dpi, ymass, &
                                   I1_GL,        I2_GL,     J1P, J2P,   &
                                   JU1_GL,       J2_GL,     ILO, IHI,   &
                                   JULO,         JHI,       I1,  I2,    &
                                   JU1,          J2)
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2
```

```
! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Set to T if called on Master or F if called by slaves
! NOTE: This seems not to be used here....)
LOGICAL, INTENT(IN)   :: do_reduction

! Special geometrical factor (geofac) for Polar cap
REAL*8,  INTENT(in)   :: geofac_pc

! Horizontal mass flux in N-S direction [hPa]
REAL*8,  INTENT(IN)   :: ymass(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Divergence at a grid point; used to calculate vertical motion [hPa]
REAL*8,  INTENT(OUT)  :: dpi(I1:I2, JU1:J2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent. Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.15 Do_Cross_Terms_Pole_I2d2

Subroutine Do_Cross_Terms_Pole_I2d2 sets "va" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Cross_Terms_Pole_I2d2( cry,   va,  I1_GL, I2_GL, JU1_GL, &
                                     J2_GL, J1P, ILO,   IHI,   JULO,   &
                                     JHI,   I1,  I2,    JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edge of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Courant number in N-S direction
REAL*8,  INTENT(IN)  :: cry(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Average of Courant numbers from ij and ij+1
REAL*8,  INTENT(OUT) :: va(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.16 Xadv_Dao2

Subroutine Xadv_Dao2 is the advective form E-W operator for computing the adx (E-W) cross term.

INTERFACE:

```
SUBROUTINE Xadv_Dao2( iad,    jn,    js,  adx,  qqv, &
                      ua,     ILO,   IHI, JULO, JHI, &
                      JU1_GL, J2_GL, J1P, J2P,  I1,  &
                      I2,     JU1,   J2)
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max latitude (J) indices
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! if iad = 1, use 1st order accurate scheme;
! if iad = 2, use 2nd order accurate scheme
INTEGER, INTENT(IN)  :: iad

! Northward of latitude index = jn, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)  :: jn

! southward of latitude index = js, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)  :: js

! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqv(ILO:IHI, JULO:JHI)

! Average of Courant numbers from il and il+1
REAL*8,  INTENT(IN)  :: ua(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Cross term due to E-W advection [mixing ratio]
REAL*8,  INTENT(OUT) :: adx(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.17 Yadv_Dao2

Subroutine Yadv_Dao2 is the advective form N-S operator for computing the ady (N-S) cross term.

INTERFACE:

```
SUBROUTINE Yadv_Dao2( iad,   ady,    qqu,   va,  I1_GL, &
                      I2_GL, JU1_GL, J2_GL, J1P, J2P,   &
                      ILO,   IHI,    JULO,  JHI, I1,    &
                      I2,    JU1,    J2)
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! If iad = 1, use 1st order accurate scheme;
! If iad = 2, use 2nd order accurate scheme
INTEGER, INTENT(IN)  :: iad
```

```
! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO:JHI)

! Average of Courant numbers from ij and ij+1
REAL*8,  INTENT(IN)  :: va(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Cross term due to N-S advection (mixing ratio)
REAL*8,  INTENT(OUT) :: ady(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.18 Do_Yadv_Pole_I2d2

Subroutine Do_Yadv_Pole_I2d2 sets "qquwk" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Yadv_Pole_I2d2 ( qqu, qquwk, I1_GL, I2_GL, JU1_GL, J2_GL, &
                               J1P, ILO,   IHI,   JULO,  JHI,    I1,    &
                               I2,  JU1,   J2  )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL
```

```
! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! qqu working array [mixing ratio]
REAL*8,  INTENT(OUT) :: qquwk(ILO:IHI, JULO-2:JHI+2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.19 Do_Yadv_Pole_Sum

Subroutine Do_Yadv_Pole_Sum sets the cross term due to N-S advection at the Poles.

INTERFACE:

```
SUBROUTINE Do_Yadv_Pole_Sum( ady, I1_GL, I2_GL, JU1_GL, J2_GL, J1P, &
                             ILO, IHI,   JULO,  JHI,    I1,    I2,  &
                             JU1, J2)
```

INPUT PARAMETERS:

```
! Global latitude index at the edge of the South polar cap
! J1P=JU1_GL+1; for a polar cap of 1 latitude band
```

```
! J1P=JU1_GL+2; for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)    :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: I1_GL,  I2_GL
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI
```

OUTPUT PARAMETERS:

```
! Cross term due to N-S advection (mixing ratio)
REAL*8,  INTENT(INOUT) :: ady(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.  Also make a logical
                            to test if we are using an extended polar cap.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.20 Xtp

Subroutine Xtp does horizontal advection in the E-W direction.

INTERFACE:

```
SUBROUTINE Xtp( ilmt, jn,  js,    pu,     crx,   dq1, qqv, xmass, fx,  &
                J1P,  J2P, I2_GL, JU1_GL, J2_GL, ILO, IHI, JULO,  JHI, &
                I1,   I2,  JU1,   J2,  iord )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)    :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    ::         I2_GL
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI

! Controls various options in E-W advection
INTEGER, INTENT(IN)    :: ilmt

! Northward of latitude index = jn, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)    :: jn

! Southward of latitude index = js, Courant numbers could be > 1,
! so use the flux-form semi-Lagrangian scheme
INTEGER, INTENT(IN)    :: js

! Option for E-W transport scheme.  See module header for more info.
INTEGER, INTENT(IN)    :: iord

! pressure at edges in "u" [hPa]
REAL*8,  INTENT(IN)    :: pu(ILO:IHI, JULO:JHI)

! Courant number in E-W direction
REAL*8,  INTENT(IN)    :: crx(ILO:IHI, JULO:JHI)

! Horizontal mass flux in E-W direction [hPa]
REAL*8,  INTENT(IN)    :: xmass(ILO:IHI, JULO:JHI)
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI)

! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(INOUT) :: qqv(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! E-W flux [mixing ratio]
REAL*8,  INTENT(OUT)   :: fx(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.21 Xmist

Subroutine Xmist computes the linear tracer slope in the E-W direction. It uses the Lin et. al. 1994 algorithm.

INTERFACE:

```
SUBROUTINE Xmist( dcx,  qqv, J1P, J2P, I2_GL, JU1_GL, J2_GL, ILO, IHI, &
                  JULO, JHI, I1,  I2,  JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  ::         I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
```

```
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqv(-I2/3:I2+I2/3, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in E-W direction [mixing ratio]
REAL*8,  INTENT(OUT) :: dcx(-I2/3:I2+I2/3, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.22 Fxppm

Subroutine Fxppm is the 1D "outer" flux form operator based on the Piecewise Parabolic Method (PPM; see also Lin and Rood 1996) for computing the fluxes in the E-W direction.

INTERFACE:

```
SUBROUTINE Fxppm( ij,  ilmt, crx, dcx, fx, qqv,     &
                  ILO, IHI, JULO, JHI, I1,  I2 )
```

INPUT PARAMETERS:

```
! Local min & max longitude (I) and altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI

! Latitude (IJ) and altitude (IK) indices
```

```
INTEGER, INTENT(IN)    :: ij

! Controls various options in E-W advection
INTEGER, INTENT(IN)    :: ilmt

! Courant number in E-W direction
REAL*8,  INTENT(IN)    :: crx(I1:I2, JULO:JHI)
```

INPUT/OUTPUT PARAMETERS:

```
  ! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(INOUT) :: qqv(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in E-W direction (mixing ratio)
REAL*8,  INTENT(OUT)   :: dcx(ILO:IHI, JULO:JHI)

! E-W flux [mixing ratio]
REAL*8,  INTENT(OUT)   :: fx(I1:I2, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REMARKS:

```
This routine is called from w/in a OpenMP parallel loop fro
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
                            Also remove the allocatable arrays, which
                            interfere w/ OpenMP parallelization.
01 Apr 2009 - C. Carouge  - The input arrays are now 2D only.
```

1.115.23 Lmtppm

Subroutine Lmtppm enforces the full monotonic, semi-monotonic, or the positive-definite constraint to the sub-grid parabolic distribution of the Piecewise Parabolic Method (PPM).

INTERFACE:

```
SUBROUTINE Lmtppm( lenx, lmt, a6, al, ar, dc, qa )
```

INPUT PARAMETERS:

```
! If 0 => full monotonicity;
! If 1 => semi-monotonic constraint (no undershoots);
! If 2 => positive-definite constraint
INTEGER, INTENT(IN)    :: lmt

! Vector length
INTEGER, INTENT(IN)    :: lenx
```

INPUT/OUTPUT PARAMETERS:

```
! Curvature of the test parabola
REAL*8,  INTENT(INOUT) :: a6(lenx)

! Left edge value of the test parabola
REAL*8,  INTENT(INOUT) :: al(lenx)

! Right edge value of the test parabola
REAL*8,  INTENT(INOUT) :: ar(lenx)

! 0.5 * mismatch
REAL*8,  INTENT(INOUT) :: dc(lenx)

! Cell-averaged value
REAL*8,  INTENT(INOUT) :: qa(lenx)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.115.24 Ytp

Subroutine Ytp does horizontal advection in the N-S direction.

INTERFACE:

```
SUBROUTINE Ytp( jlmt,  geofac_pc, geofac, cry,  dq1,   qqu,    qqv,    &
                ymass, fy,        J1P,    J2P,  I1_GL, I2_GL,  JU1_GL, &
                J2_GL, ilong,     ILO,    IHI,  JULO,  JHI,    I1,     &
                I2,    JU1,       J2,    jord )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)    :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: I1_GL,  I2_GL
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI

! ???
INTEGER, INTENT(IN)    :: ilong

! Controls various options in N-S advection
INTEGER, INTENT(IN)    :: jlmt

! N-S transport scheme (see module header for more info)
INTEGER, INTENT(IN)    :: jord

! special geometrical factor (geofac) for Polar cap
REAL*8,  INTENT(IN)    :: geofac_pc

! geometrical factor for meridional advection; geofac uses correct
! spherical geometry, and replaces acosp as the  meridional geometrical
! factor in tpcore
REAL*8,  INTENT(IN)    :: geofac(JU1_GL:J2_GL)

! Courant number in N-S direction
REAL*8,  INTENT(IN)    :: cry(ILO:IHI, JULO:JHI)

! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)    :: qqu(ILO:IHI, JULO:JHI)

! Horizontal mass flux in N-S direction [hPa]
REAL*8,  INTENT(IN)    :: ymass(ILO:IHI, JULO:JHI)
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI)

! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(INOUT) :: qqv(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! N-S flux [mixing ratio]
REAL*8,  INTENT(OUT)   :: fy(ILO:IHI, JULO:JHI+1)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.25 Ymist

Subroutine Ymist computes the linear tracer slope in the N-S direction. It uses the Lin et. al. 1994 algorithm.

INTERFACE:

```
SUBROUTINE Ymist( id,    dcy, qqu, I1_GL, I2_GL, JU1_GL, &
                  J2_GL, J1P, ILO, IHI,   JULO,  JHI,    &
                  I1,    I2,  JU1, J2 )
```

INPUT PARAMETERS:

```
! Global latitude index at the edge of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P
```

```
! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! The "order" of the accuracy in the computed linear "slope"
! (or mismatch, Lin et al. 1994); it is either 2 or 4.
INTEGER, INTENT(IN)  :: id

! Concentration contribution from E-W advection (mixing ratio)
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in N-S direction [mixing ratio]
REAL*8,  INTENT(OUT) :: dcy(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.26 Do_Ymist_Pole1_I2d2

Subroutine Do_Ymist_Pole1_I2d2 sets "dcy" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Ymist_Pole1_I2d2( dcy,   qqu, I1_GL, I2_GL, JU1_GL,   &
                                J2_GL, ILO, IHI,   JULO,  JHI,      &
                                I1,    I2,  JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global min & max longitude (I) and latitude (J) indices
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO-2:JHI+2)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in N-S direction [mixing ratio]
REAL*8, INTENT(OUT)  :: dcy(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.27 Do_Ymist_Pole2_I2d2

Subroutine Do_Ymist_Pole2_I2d2 sets "dcy" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Ymist_Pole2_I2d2( dcy,   qqu, I1_GL, I2_GL, JU1_GL, &
                                J2_GL, J1P, ILO,   IHI,   JULO,   &
                                JHI,   I1,  I2,    JU1,   J2 )
```

INPUT PARAMETERS:

```
! Global latitude index at the edge of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO-2:JHI+2)
```

OUTPUT PARAMETERS:

```
! Slope of concentration distribution in N-S direction [mixing ratio]
REAL*8,  INTENT(OUT) :: dcy(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.28 Fyppm

Subroutine Fyppm is the 1D "outer" flux form operator based on the Piecewise Parabolic Method (PPM; see also Lin and Rood 1996) for computing the fluxes in the N-S direction.

INTERFACE:

```
SUBROUTINE Fyppm( jlmt,  cry,   dcy,    qqu,   qqv,   j1p, j2p,    &
                  i1_gl, i2_gl, ju1_gl, j2_gl, ilong, ilo, ihi,    &
                  julo,  jhi,   i1,     i2,    ju1,   j2 )
```

INPUT PARAMETERS:

```
! Global latitude indices at the edges of the S/N polar caps
! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)  :: J1P,    J2P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: I1_GL,  I2_GL
INTEGER, INTENT(IN)  :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)  :: I1,     I2
INTEGER, INTENT(IN)  :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)  :: ILO,    IHI
INTEGER, INTENT(IN)  :: JULO,   JHI

! ILONG ??
INTEGER, INTENT(IN)  :: ilong

! Controls various options in N-S advection
INTEGER, INTENT(IN)  :: jlmt

! Courant number in N-S direction
REAL*8,  INTENT(IN)  :: cry(ILO:IHI, JULO:JHI)

! Slope of concentration distribution in N-S direction [mixing ratio]
REAL*8,  INTENT(IN)  :: dcy(ILO:IHI, JULO:JHI)

! Concentration contribution from E-W advection [mixing ratio]
REAL*8,  INTENT(IN)  :: qqu(ILO:IHI, JULO:JHI)
```

OUTPUT PARAMETERS:

```
! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(OUT) :: qqv(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.29 Do_Fyppm_Pole_I2d2

Subroutine Do_Fyppm_Pole_I2d2 sets "al" & "ar" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Fyppm_Pole_I2d2( al,  ar,  I1_GL, I2_GL, JU1_GL, J2_GL, &
                               ILO, IHI, JULO,  JHI,   I1,     I2,    &
                               JU1, J2 )
```

INPUT PARAMETERS:

```
! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: I1_GL,  I2_GL
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI
```

OUTPUT PARAMETERS:

```
! Left (al) and right (ar) edge values of the test parabola
REAL*8,  INTENT(INOUT) :: al(ILO:IHI, JULO:JHI)
REAL*8,  INTENT(INOUT) :: ar(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.30 Do_Ytp_Pole_Sum

Subroutine Do_Ytp_Pole_Sum sets "dq1" at the Poles.

INTERFACE:

```
SUBROUTINE Do_Ytp_Pole_Sum( geofac_pc, dq1,    qqv,   fy,  I1_GL,  &
                            I2_GL,     JU1_GL, J2_GL, J1P, J2P,    &
                            ILO,       IHI,    JULO,  JHI, I1,     &
                            I2,        JU1,    J2 )
!input PARAMETERS:
  ! Global latitude indices at the edges of the S/N polar caps
  ! J1P=JU1_GL+1; J2P=J2_GL-1 for a polar cap of 1 latitude band
  ! J1P=JU1_GL+2; J2P=J2_GL-2 for a polar cap of 2 latitude bands
  INTEGER, INTENT(IN)    :: J1P,    J2P

  ! Global min & max longitude (I) and latitude (J) indices
  INTEGER, INTENT(IN)    :: I1_GL,  I2_GL
  INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

  ! Local min & max longitude (I), latitude (J), altitude (K) indices
  INTEGER, INTENT(IN)    :: I1,     I2
  INTEGER, INTENT(IN)    :: JU1,    J2

  ! Local min & max longitude (I) and latitude (J) indices
  INTEGER, INTENT(IN)    :: ILO,    IHI
  INTEGER, INTENT(IN)    :: JULO,   JHI

  ! Special geometrical factor (geofac) for Polar cap
  REAL*8,  INTENT(IN)    :: geofac_pc
```

```
! Concentration contribution from N-S advection [mixing ratio]
REAL*8,  INTENT(IN)    :: qqv(ILO:IHI, JULO:JHI)
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI)

! N-S mass flux [mixing ratio]
REAL*8,  INTENT(INOUT) :: fy (ILO:IHI, JULO:JHI+1)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.  Added
                            OpenMP parallel DO loops.
01 Apr 2009 - C. Carouge  - Moved the IK loop outside the subroutine.
```

1.115.31 Fzppm

Subroutine Fzppm is the 1D "outer" flux form operator based on the Piecewise Parabolic Method (PPM; see also Lin and Rood 1996) for computing the fluxes in the vertical direction.

Fzppm was modified by S.-J. Lin, 12/14/98, to allow the use of the KORD=7 (klmt=4) option. KORD=7 enforces the 2nd monotonicity constraint of Huynh (1996). Note that in Huynh's original scheme, two constraints are necessary for the preservation of monotonicity. To use Huynh's algorithm, it was modified as follows. The original PPM is still used to obtain the first guesses for the cell edges, and as such Huynh's 1st constraint is no longer needed. Huynh's median function is also replaced by a simpler yet functionally equivalent in-line algorithm.

INTERFACE:

```
SUBROUTINE Fzppm( klmt,  delp1,  wz,  dq1, qq1,  fz,      &
                  J1P,   JU1_GL, J2_GL, ILO, IHI, JULO, JHI,     &
                  ILONG, IVERT,  I1,    I2,  JU1, J2,   K1,  K2 )
```

INPUT PARAMETERS:

```
! Global latitude index at the edges of the South polar cap
! J1P=JU1_GL+1 for a polar cap of 1 latitude band
! J1P=JU1_GL+2 for a polar cap of 2 latitude bands
INTEGER, INTENT(IN)    :: J1P

! Global min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: JU1_GL, J2_GL

! Local min & max longitude (I), latitude (J), altitude (K) indices
INTEGER, INTENT(IN)    :: I1,     I2
INTEGER, INTENT(IN)    :: JU1,    J2
INTEGER, INTENT(IN)    :: K1,     K2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)    :: ILO,    IHI
INTEGER, INTENT(IN)    :: JULO,   JHI

! Dimensions in longitude & altitude ???
INTEGER, INTENT(IN)    :: ilong,  ivert

! Controls various options in vertical advection
INTEGER, INTENT(IN)    :: klmt

! Pressure thickness, the pseudo-density in a
! hydrostatic system at t1 [hPa]
REAL*8,  INTENT(IN)    :: delp1(ILO:IHI, JULO:JHI, K1:K2)

! Large scale mass flux (per time step tdt) in the vertical
! direction as diagnosed from the hydrostatic relationship [hPa]
REAL*8,  INTENT(IN)    :: wz(I1:I2, JU1:J2, K1:K2)

! Species concentration [mixing ratio]
REAL*8,  INTENT(IN)    :: qq1(ILO:IHI, JULO:JHI, K1:K2)
```

INPUT/OUTPUT PARAMETERS:

```
! Species density [hPa]
REAL*8,  INTENT(INOUT) :: dq1(ILO:IHI, JULO:JHI, K1:K2)
```

OUTPUT PARAMETERS:

```
! Vertical flux [mixing ratio]
REAL*8,  INTENT(OUT)   :: fz(ILO:IHI, JULO:JHI,  K1:K2)
```

AUTHOR:

```
Original code from Shian-Jiann Lin, DAO
John Tannahill, LLNL (jrt@llnl.gov)
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.115.32 Average_Press_Poles

Subroutine Average_Press_Poles averages pressure at the Poles when the Polar cap is enlarged. It makes the last two latitudes equal.

INTERFACE:

```
SUBROUTINE Average_Press_Poles( area_1D, press, I1,  I2,   JU1,  &
                                J2,      ILO,   IHI, JULO, JHI )
```

INPUT PARAMETERS:

```
! Local min & max longitude (I), latitude (J)
INTEGER, INTENT(IN)   :: I1,     I2
INTEGER, INTENT(IN)   :: JU1,    J2

! Local min & max longitude (I) and latitude (J) indices
INTEGER, INTENT(IN)   :: ILO,    IHI
INTEGER, INTENT(IN)   :: JULO,   JHI

! Surface area of grid box
REAL*8,  INTENT(IN)   :: AREA_1D(JU1:J2)
```

INPUT/OUTPUT PARAMETERS:

```
! Surface pressure [hPa]
REAL*8, INTENT(INOUT) :: press(ILO:IHI, JULO:JHI)
```

AUTHOR:

```
Philip Cameron-Smith and John Tannahill, GMI project @ LLNL (2003)
Implemented into GEOS-Chem by Claire Carouge (ccarouge@seas.harvard.edu)
```

REMARKS:

```
Subroutine from pjc_pfix.  Call this one once everything is working fine.
```

REVISION HISTORY:

```
05 Dec 2008 - C. Carouge  - Replaced TPCORE routines by S-J Lin and Kevin
                            Yeh with the TPCORE routines from GMI model.
                            This eliminates the polar overshoot in the
                            stratosphere.
05 Dec 2008 - R. Yantosca - Updated documentation and added ProTeX headers.
                            Declare all REAL variables as REAL*8.  Also
                            make sure all numerical constants are declared
                            with the "D" double-precision exponent.
```

1.116 Fortran: Module Interface transport_mod

Module TRANSPORT_MOD is used to call the proper version of the TPCORE advection scheme for GCAP, GEOS-4, GEOS-5, or GEOS-5.7 nested-grid or global simulations.

INTERFACE:

```
MODULE TRANSPORT_MOD
```

USES:

```
IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC  :: CLEANUP_TRANSPORT
PUBLIC  :: DO_TRANSPORT
PUBLIC  :: INIT_TRANSPORT
PUBLIC  :: INIT_GEOS5_WINDOW_TRANSPORT
PUBLIC  :: INIT_GEOSFP_WINDOW_TRANSPORT
PUBLIC  :: SET_TRANSPORT
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: GEOS4_GEOS5_GLOBAL_ADV
PRIVATE :: GCAP_GLOBAL_ADV
PRIVATE :: DO_GEOS5_WINDOW_TRANSPORT
PRIVATE :: DO_GEOSFP_WINDOW_TRANSPORT
PRIVATE :: GET_AIR_MASS
```

REVISION HISTORY:

```
10 Mar 2003 - Y. Wang, R. Yantosca - Initial version
(1 ) Now can select transport scheme for GEOS-3 winds.  Added code for PJC
     pressure fixer. (bdf, bmy, 5/8/03)
(2 ) Now delete DSIG array, it's obsolete.  Also added new PRIVATE function
     GET_AIR_MASS to compute air masses from the input/output pressures
     from the new GEOS-4/fvDAS TPCORE. (bmy, 6/24/03)
(3 ) Now references DEBUG_MSG from "error_mod.f". (bmy, 8/7/03)
```

```
(4 ) Bug fix in DO_GLOBAL_TRANSPORT (bmy, 10/21/03)
(5 ) IORD, JORD, KORD are now module variables.  Now references
     "logical_mod.f" and "tracer_mod.f" (bmy, 7/20/04)
(6 ) Add mass-flux diagnostics to TPCORE_FVDAS (bdf, bmy, 9/28/04)
(7 ) Now references "diag_mod.f" (bmy, 9/28/04)
(8 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(9 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(10) Now flip arrays in call to TPCORE_FVDAS (bmy, 6/16/06)
(11) Added modifications for SUN compiler (bmy, 7/12/06)
(12) Bug fixes in DO_GLOBAL_TRANSPORT (bmy, 11/29/06)
(13) Split off GCAP, GEOS-3, GEOS-4/GEOS-5 specific calling sequences
     into separate subroutines.  Also removed some obsolete module
     variables. (bmy, 10/30/07)
(14) Modifications for GEOS-5 nested grid (yxw, dan, bmy, 11/6/08)
(15) Bug fix in mass balance in GCAP_GLOBAL_ADV and GEOS4_GEOS5_GLOBAL_ADV.
     (ccc, 2/17/09)
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTex Headers
08 Mar 2010 - C. Carouge  - Modify call to tpcore_fvdas. We do not re-order
                            mass fluxes diagnostics anymore.
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now reference new grid_mod.F90
21 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in vertical
21 Jun 2012 - R. Yantosca - Comment out GEOS-3 window subroutine
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed "GEOS57" to "GEOSFP" in routine names
```

1.116.1 do_transport

Subroutine DO_TRANSPORT is the driver routine for the proper TPCORE program for GEOS-3, GEOS-4/GEOS-5, or window simulations.

INTERFACE:

```
  SUBROUTINE DO_TRANSPORT( am_I_Root, Input_Opt,
 &                         State_Met, State_Chm, RC )
```

USES:

```
  USE CMN_SIZE_MOD
  USE GRID_MOD,           ONLY : ITS_A_NESTED_GRID
  USE GIGC_ErrCode_Mod
  USE GIGC_Input_Opt_Mod, ONLY : OptInput
  USE GIGC_State_Chm_Mod, ONLY : ChmState
  USE GIGC_State_Met_Mod, ONLY : MetState
  USE TPCORE_BC_MOD,      ONLY : INIT_TPCORE_BC
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
10 Mar 2003 - R. Yantosca - Initial version
(1 ) Removed IORD, JORD, KORD from the arg list.  Also now removed
     reference to CMN, it's not needed. (bmy, 7/20/04)
(2 ) Now call separate routines for different met fields. (bmy, 10/30/07)
(3 ) Now references subroutine INIT_TPCORE_BC from tpcore_bc_mod.f and
     DO_GEOS5_FVDAS_WINDOW_TRANSPORT from
     "tpcore_geos5_fvdas_window_mod.f90". (yxw, dan, bmy, 11/6/08)
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTeX headers
06 Oct 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5.
28 Feb 2012 - R. Yantosca - Treat GEOS-5.7 in the same way as MERRA
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.116.2 geos4_geos5_global_adv

Subroutine GEOS4_GEOS5_GLOBAL_ADV is the driver routine for TPCORE with the GMAO GEOS-4 or GEOS-5 met fields.

INTERFACE:

```
SUBROUTINE GEOS4_GEOS5_GLOBAL_ADV( am_I_Root, Input_Opt,
&                                  State_Met, State_Chm, RC )
```

USES:

```
USE DIAG_MOD,           ONLY : MASSFLEW, MASSFLNS, MASSFLUP
USE ERROR_MOD,          ONLY : IT_IS_NAN, DEBUG_MSG, SAFE_DIV
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GIGC_State_Met_Mod, ONLY : MetState
USE GIGC_State_Met_Mod, ONLY : MetState
USE PJC_PFIX_MOD,       ONLY : DO_PJC_PFIX
USE PRESSURE_MOD,       ONLY : GET_PEDGE, SET_FLOATING_PRESSURE
```

```
      USE TIME_MOD,           ONLY : GET_TS_DYN
      USE TPCORE_BC_MOD,      ONLY : SAVE_GLOBAL_TPCORE_BC
      USE TPCORE_FVDAS_MOD,   ONLY : TPCORE_FVDAS
#if   defined( APM )
      USE TRACER_MOD,         ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! NDxx flags
      USE CMN_GCTM_MOD             ! Physical constants
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   30 Oct 2007 - R. Yantosca - Initial version
   (1 ) Split off the GEOS-4 & GEOS-5 relevant parts from the previous
        routine DO_GLOBAL_TRANSPORT (bmy, 10/30/07)
   (2 ) Activate the call to SAVE_GLOBAL_TPCORE_BC (yxw, dan, bmy, 11/6/08)
   (3 ) Bug fix in mass balance: only account for cells of STT with non-zero
        concentrations when doing the computation (ccc, bmy, 2/17/09)
   26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
   26 Feb 2010 - R. Yantosca - Added ProTeX headers
   16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
   21 Jun 2012 - R. Yantosca - Now use pointers to flip indices in vertical
   09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                               derived type object
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
   04 Jun 2013 - R. Yantosca - Replace pointer STT with State_Chm%Tracers
```

1.116.3 gcap_global_adv

Subroutine GCAP_GLOBAL_ADV is the driver routine for TPCORE with the GCAP/GISS met fields.

INTERFACE:

```
      SUBROUTINE GCAP_GLOBAL_ADV( am_I_Root, Input_Opt,
     &                            State_Met, State_Chm, RC )
```

USES:

```
      USE DIAG_MOD,           ONLY : MASSFLEW, MASSFLNS, MASSFLUP
      USE ERROR_MOD,          ONLY : IT_IS_NAN, DEBUG_MSG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PJC_PFIX_MOD,       ONLY : DO_PJC_PFIX
      USE PRESSURE_MOD,       ONLY : GET_PEDGE, SET_FLOATING_PRESSURE
      USE TIME_MOD,           ONLY : GET_TS_DYN
      USE TPCORE_FVDAS_MOD,   ONLY : TPCORE_FVDAS
#if   defined( APM )
      USE TRACER_MOD,         ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! NDxx flags
      USE CMN_GCTM_MOD             ! Physical constants
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   30 Oct 2007 - R. Yantosca - Initial version
   (1 ) Split off the GCAP relevant parts from the previous routine
        DO_GLOBAL_TRANSPORT (bmy, 10/30/07)
   (2 ) Bug fix in mass balance: only account for cells of STT with non-zero
        concentrations when doing the computation (ccc, bmy, 2/17/09)
   26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
   26 Feb 2010 - R. Yantosca - Added ProTeX headers
   16 Feb 2011 - R. Yantosca - Add modifications for APM microphysics (G. Luo)
   21 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in the vertical
   09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                               derived type object
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
   04 Jun 2013 - R. Yantosca - Replace pointer STT with State_Chm%Tracers
```

1.116.4 do_geos5_window_transport

Subroutine DO_GEOS5_WINDOW_TRANSPORT is the driver program for the proper TPCORE program for the GEOS-5 nested-grid simulations.

INTERFACE:

```
      SUBROUTINE DO_GEOS5_WINDOW_TRANSPORT( am_I_Root, Input_Opt,
     &                                      State_Met, State_Chm, RC )
```

USES:

```
      ! References to F90 modules
      USE DIAG_MOD,                  ONLY : MASSFLEW, MASSFLNS, MASSFLUP
      USE ERROR_MOD,                 ONLY : IT_IS_NAN,     DEBUG_MSG
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod,        ONLY : OptInput
      USE GIGC_State_Chm_Mod,        ONLY : ChmState
      USE GIGC_State_Met_Mod,        ONLY : MetState
      USE GRID_MOD,                  ONLY : GET_XOFFSET,   GET_YOFFSET
      USE PJC_PFIX_GEOS5_WINDOW_MOD, ONLY : DO_PJC_PFIX_GEOS5_WINDOW
      USE PRESSURE_MOD,              ONLY : GET_PEDGE
      USE PRESSURE_MOD,              ONLY : SET_FLOATING_PRESSURE
      USE TIME_MOD,                  ONLY : GET_TS_DYN
      USE TPCORE_BC_MOD,             ONLY : IO_W, JO_W, I1_W, J1_W
      USE TPCORE_BC_MOD,             ONLY : I2_W, J2_W, IM_W, JM_W, IGZD
      USE TPCORE_BC_MOD,             ONLY : DO_WINDOW_TPCORE_BC
      USE TPCORE_GEOS5_WINDOW_MOD,   ONLY : TPCORE_GEOS5_WINDOW
#if   defined( APM )
      USE TRACER_MOD,                ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD                    ! Size parameters
      USE CMN_DIAG_MOD                    ! NDxx flags
      USE CMN_GCTM_MOD                    ! Physical constants
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    10 Mar 2003 - R. Yantosca - Initial version

    26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
    26 Feb 2010 - R. Yantosca - Added ProTeX headers
    16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
    21 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in the vertical
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
    04 Jun 2013 - R. Yantosca - Replace pointer STT with State_Chm%Tracers
```

1.116.5 do_geosfp_window_transport

Subroutine DO_GEOSFP_WINDOW_TRANSPORT is the driver program for the proper TPCORE program for the GEOS-5 nested-grid simulations.

INTERFACE:

```
      SUBROUTINE DO_GEOSFP_WINDOW_TRANSPORT( am_I_Root, Input_Opt,
     &                                       State_Met, State_Chm, RC )
```

USES:

```
      ! References to F90 modules
      USE DIAG_MOD,                   ONLY : MASSFLEW, MASSFLNS, MASSFLUP
      USE ERROR_MOD,                  ONLY : IT_IS_NAN,     DEBUG_MSG
      USE GRID_MOD,                   ONLY : GET_XOFFSET,   GET_YOFFSET
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod,         ONLY : OptInput
      USE GIGC_State_Chm_Mod,         ONLY : ChmState
      USE GIGC_State_Met_Mod,         ONLY : MetState
      USE PJC_PFIX_GEOSFP_WINDOW_MOD,ONLY : DO_PJC_PFIX_GEOSFP_WINDOW
      USE PRESSURE_MOD,               ONLY : GET_PEDGE
      USE PRESSURE_MOD,               ONLY : SET_FLOATING_PRESSURE
      USE TIME_MOD,                   ONLY : GET_TS_DYN
      USE TPCORE_BC_MOD,              ONLY : IO_W, JO_W, I1_W, J1_W
      USE TPCORE_BC_MOD,              ONLY : I2_W, J2_W, IM_W, JM_W, IGZD
      USE TPCORE_BC_MOD,              ONLY : DO_WINDOW_TPCORE_BC
      USE TPCORE_GEOSFP_WINDOW_MOD,  ONLY : TPCORE_GEOSFP_WINDOW
#if   defined( APM )
      USE TRACER_MOD,                 ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD                     ! Size parameters
      USE CMN_DIAG_MOD                     ! NDxx flags
      USE CMN_GCTM_MOD                     ! Physical constants
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
10 Mar 2003 - R. Yantosca - Initial version

26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTeX headers
16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
21 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in the vertical
04 Jun 2013 - R. Yantosca - Replace pointer STT with State_Chm%Tracers
```

1.116.6 get_air_mass

Function GET_AIR_MASS returns the air mass based on the pressures returned before and after the call to the GEOS-4/fvDAS TPCORE code. (bmy, 6/24/03)

INTERFACE:

```
FUNCTION GET_AIR_MASS( I, J, L, P_SURF ) RESULT( AIR_MASS )
```

USES:

```
USE CMN_SIZE_MOD              ! Size parameters
USE CMN_GCTM_MOD              ! g0_100
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I, J, L   ! GEOS-Chem lon, lat, level indices
REAL*8,  INTENT(IN) :: P_SURF    ! Surface pressure [hPa] at (I,J,L=1)
```

REVISION HISTORY:

```
24 Jun 2003 - R. Yantosca - Initial version
26 Feb 2010 - R. Yantosca - Added ProTeX headers
```

1.116.7 set_transport

Subroutine SET_TRANSPORT passes IORD, JORD, KORD values from "input_mod.f".

INTERFACE:

```
SUBROUTINE SET_TRANSPORT( I_ORD, J_ORD, K_ORD )
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I_ORD  ! IORD option for E/W advection
INTEGER, INTENT(IN) :: J_ORD  ! JORD option for N/S advection
INTEGER, INTENT(IN) :: K_ORD  ! KORD option for vertical diffusion
```

REVISION HISTORY:

```
20 Jul 2004 - R. Yantosca - Initial version
26 Feb 2010 - R. Yantosca - Added ProTeX headers
```

1.116.8 init_transport

Subroutine INIT_TRANSPORT initializes all module variables and arrays.

INTERFACE:

```
SUBROUTINE INIT_TRANSPORT( am_I_Root, Input_Opt, RC )
```

USES:

```
USE ERROR_MOD,          ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GRID_MOD,           ONLY : GET_AREA_M2, GET_YMID_R
USE PRESSURE_MOD,       ONLY : GET_AP,      GET_BP
USE TIME_MOD,           ONLY : GET_TS_DYN
USE TPCORE_FVDAS_MOD,   ONLY : INIT_TPCORE

USE CMN_SIZE_MOD         ! Size parameters
USE CMN_GCTM_MOD         ! Re
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
10 Mar 2003 - R. Yantosca - Initial version
(1 ) Now references GET_TS_DYN from "time_mod.f", INIT_TPCORE_FVDAS from
     "tpcore_fvdas_mod.f90", and GET_YMID_R from "grid_mod.f".  Now also
     include "CMN_SETUP".  (bdf, bmy, 4/28/03)
(2 ) Remove reference to DSIG, it's obsolete. (bmy, 6/24/03)
(3 ) Now references LEMBED & LTPFV from "logical_mod.f".  Now references
     N_TRACERS from "tracer_mod.f". (bmy, 7/20/04)
(4 ) Now modified for GEOS-5 and GCAP met fields (swu, bmy, 5/25/05)
(5 ) Removed reference to USE_GEOS_4_TRANSPORT, STT_I1, STT_I2, STT_J1,
     STT_J2, variables (bmy, 10/30/07)
(6 ) Deleted reference to CMN, it's not needed anymore (bmy, 11/6/08)
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTeX headers
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R_W(I,J,L) from grid_mod.F90
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.116.9 init_geos5_window_transport

Subroutine INIT_GEOS5_WINDOW_TRANSPORT initializes all module variables and arrays for the GEOS-5 nested grid simulation. This routine is only called if we are using the GEOS-5 nested grid simulation.

INTERFACE:

```
SUBROUTINE INIT_GEOS5_WINDOW_TRANSPORT( am_I_Root, Input_Opt, RC )
```

USES:

```
USE ERROR_MOD,                ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod,       ONLY : OptInput
USE GRID_MOD,                 ONLY : GET_AREA_M2
USE GRID_MOD,                 ONLY : GET_YMID_R_W
USE PRESSURE_MOD,             ONLY : GET_AP, GET_BP
USE TIME_MOD,                 ONLY : GET_TS_DYN
USE TPCORE_FVDAS_MOD,         ONLY : INIT_TPCORE
USE TPCORE_BC_MOD,            ONLY : I0_W, J0_W, I1_W, J1_W
USE TPCORE_BC_MOD,            ONLY : I2_W, J2_W, IM_W, JM_W
USE TPCORE_BC_MOD,            ONLY : IGZD, INIT_TPCORE_BC
USE TPCORE_GEOS5_WINDOW_MOD, ONLY : INIT_GEOS5_WINDOW

USE CMN_SIZE_MOD                 ! Size parameters
USE CMN_GCTM_MOD                 ! Re
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
06 Jun 2008 - D. Chen & R. Yantosca - Initial version
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R_W(I,J,L) from grid_mod.F90
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.116.10 init_geosfp_window_transport

Subroutine INIT_GEOSFP_WINDOW_TRANSPORT initializes all module variables and arrays for the GEOS-57 nested grid simulation. This routine is only called if we are using the GEOS-57 nested grid simulation.

INTERFACE:

```
SUBROUTINE INIT_GEOSFP_WINDOW_TRANSPORT( am_I_Root,Input_Opt,RC )
```

USES:

```
USE ERROR_MOD,                ONLY : ALLOC_ERR
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod,       ONLY : OptInput
USE GRID_MOD,                 ONLY : GET_AREA_M2
USE GRID_MOD,                 ONLY : GET_YMID_R_W
USE PRESSURE_MOD,             ONLY : GET_AP, GET_BP
USE TIME_MOD,                 ONLY : GET_TS_DYN
USE TPCORE_FVDAS_MOD,         ONLY : INIT_TPCORE
USE TPCORE_BC_MOD,            ONLY : I0_W, J0_W, I1_W, J1_W
USE TPCORE_BC_MOD,            ONLY : I2_W, J2_W, IM_W, JM_W
USE TPCORE_BC_MOD,            ONLY : IGZD, INIT_TPCORE_BC
USE TPCORE_GEOSFP_WINDOW_MOD,ONLY : INIT_GEOSFP_WINDOW

USE CMN_SIZE_MOD                 ! Size parameters
USE CMN_GCTM_MOD                 ! Re
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?
```

REVISION HISTORY:

```
06 Jun 2008 - D. Chen & R. Yantosca - Initial version
26 Feb 2010 - R. Yantosca - Removed references to obsolete LEMBED switch
26 Feb 2010 - R. Yantosca - Added ProTeX headers
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now use GET_YMID_R_W(I,J,L) from grid_mod.F90
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
26 Sep 2013 - R. Yantosca - Renamed to INIT_GEOSFP_WINDOW_TRANSPORT
```

1.116.11 cleanup_transport

Subroutine CLEANUP_TRANSPORT deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_TRANSPORT
```

REVISION HISTORY:

```
10 Mar 2003 - R. Yantosca - Initial version
(1 ) Remove reference to DSIG, it's obsolete. (bmy, 6/24/03)
(2 ) Remove obsolete embedded chemistry arrays (bmy, 10/30/07)
26 Feb 2010 - R. Yantosca - Added ProTeX headers
```

1.117 Fortran: Module Interface vdiff_mod

Module VDIFF_MOD includes all routines for the non-local PBL mixing scheme.

INTERFACE:

```
MODULE VDIFF_MOD
```

USES:

```
  USE TRACER_MOD,    ONLY : pcnst => N_TRACERS
  USE LOGICAL_MOD,   ONLY : LPRT
  USE ERROR_MOD,     ONLY : DEBUG_MSG
  USE VDIFF_PRE_MOD, ONLY : plev  => LLPAR
  USE CMN_SIZE_MOD,  ONLY : IIPAR, JJPAR, LLPAR

  IMPLICIT NONE
  PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
  public :: DO_PBL_MIX_2
  !PRIVATE DATA MEMBERS:

  save


  integer :: plevp

  real*8, parameter ::          &
       rearth = 6.37122d6,      & ! radius earth (m)
       cpwv   = 1.81d3,         &
       cpair  = 1004.64d0,      &
       rair   = 287.04d0,       &
       rh2o   = 461.d0,         &
       zvir   = rh2o/rair - 1., &
       gravit = 9.80616d0,      &
       ra     = 1.d0/rearth,    &
       epsilo = 0.622d0,        &
       latvap = 2.5104d06,      &
       latice = 3.336d5,        &
       cappa  = rair/cpair,     &
       rhoh2o = 1.d3,           &
       r_g    = rair / gravit,  &
       tfh2o  = 273.16d0

-----------------------------------------------------------------------
  ... pbl constants
-----------------------------------------------------------------------

  ! These are constants, so use PARAMETER tag
  real*8, parameter ::   &
       betam  = 15.d0,   & ! constant in wind gradient expression
       betas  =  5.d0,   & ! constant in surface layer gradient expression
       betah  = 15.d0,   & ! constant in temperature gradient expression
       fak    =  8.5d0,  & ! constant in surface temperature excess
       fakn   =  7.2d0,  & ! constant in turbulent prandtl number
       ricr   =   .3d0,  & ! critical richardson number
       sffrac =   .1d0,  & ! surface layer fraction of boundary layer
       vk     =   .4d0     ! von karmans constant

  ! These are assigned later, so we can't use the PARAMETER tag
  real*8 ::              &
       g,                & ! gravitational acceleration
       onet,             & ! 1/3 power in wind gradient expression
       ccon,             & ! fak * sffrac * vk
       binm,             & ! betam * sffrac
       binh                ! betah * sffrac
```

```
!-----------------------------------------------------------------------
!  ... constants used in vertical diffusion and pbl
!-----------------------------------------------------------------------
 real*8 :: &
      zkmin            ! minimum kneutral*f(ri)
 real*8, allocatable :: ml2(:)   ! mixing lengths squaredB
 real*8, allocatable :: qmincg(:)   ! min. constituent concentration
                                    !  counter-gradient term

 integer :: &
      ntopfl, &        ! top level to which vertical diffusion is applied.
      npbl             ! maximum number of levels in pbl from surface

 logical, parameter :: divdiff = .true. , arvdiff = .false.

 logical, parameter :: pblh_ar = .true.

 logical, parameter :: pbl_mean_drydep = .false.  ! use mean concentration
                                                  !  within the  PBL for
                                                  ! calculating drydep fluxes
 logical, parameter :: drydep_back_cons = .false. ! backward consistency
                                                  !  with previous GEOS-Chem
                                                  !  drydep budgets
                                                  !-- useless when
                                                  !   pbl_mean_drydep=.false.
```

REMARKS:

```
The non-local PBL mixing routine VDIFF modifies the specific humidity,
(State_Met%SPHU) field.  Therefore, we must pass State_Met as an argument
to DO_PBL_MIX_2 and VDIFFDR with INTENT(INOUT).
```

REVISION HISTORY:

```
(1 ) This code is modified from mo_vdiff.F90 in MOZART-2.4. (lin, 5/14/09)
07 Oct 2009 - R. Yantosca - Added CVS Id Tag
24 Sep 2010 - J. Lin      - Modified ND15 to account for all mixing
                            processes but not dry deposition and emissions.
17 Dec 2010 - R. Yantosca - Declare constants w/ the PARAMETER attribute
20 Dec 2010 - R. Yantosca - Bug fixes for the parallelization
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
25 Mar 2011 - R. Yantosca - Corrected bug fixes noted by Jintai Lin
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.2 met
22 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in vertical
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.117.1 pbinti

Subroutine PBINTI initializes time independent variables of pbl package

INTERFACE:

```
subroutine pbinti( gravx )
```

USES:

```
implicit none
```

INPUT PARAMETERS:

```
real*8, intent(in) :: gravx     !  acceleration of gravity
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.117.2 vdiff

Subroutine vdiff is the driver routine to compute vertical diffusion of momentum, moisture, trace constituents and potential temperature.

INTERFACE:

```
subroutine vdiff( lat,        ip,        uwnd,       vwnd,        &
                  tadv,       pmid,      pint,       rpdel_arg,   &
                  rpdeli_arg, ztodt,     zm_arg,     shflx_arg,   &
                  sflx,       thp_arg,   as2,        pblh_arg,    &
                  kvh_arg,    kvm_arg,   tpert_arg,  qpert_arg,   &
                  cgs_arg,    shp,       wvflx_arg,  plonl,       &
                  State_Met,  taux_arg,   tauy_arg,  ustar_arg )
```

USES:

```
USE DIAG_MOD,           ONLY : TURBFLUP
USE GIGC_State_Met_Mod, ONLY : MetState
USE TRACER_MOD,         ONLY : TCVV
USE VDIFF_PRE_MOD,      ONLY : ND15

implicit none
```

INPUT PARAMETERS:

```
integer, intent(in) :: lat, ip ! latitude index, long tile index
integer, intent(in) :: plonl   ! number of local longitudes
real*8,  intent(in) ::   &
     ztodt                     ! 2 delta-t
```

```
real*8,  intent(in) ::   &
     uwnd(:,:,:),        &     ! u wind input
     vwnd(:,:,:),        &     ! v wind input
     tadv(:,:,:),        &     ! temperature input
     pmid(:,:,:),        &     ! midpoint pressures
     pint(:,:,:),        &     ! interface pressures
     rpdel_arg(:,:,:),   &     ! 1./pdel  (thickness bet interfaces)
     rpdeli_arg(:,:,:),  &     ! 1./pdeli (thickness bet midpoints)
     zm_arg(:,:,:),      &     ! midpoint geoptl height above sfc
     shflx_arg(:,:),     &     ! surface sensible heat flux (w/m2)
     sflx(:,:,:),        &     ! surface constituent flux (kg/m2/s)
     wvflx_arg(:,:)            ! water vapor flux (kg/m2/s)
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
real*8, intent(inout) :: &
     as2(:,:,:,:),       &     ! moist, tracers after vert. diff
     shp(:,:,:),         &     ! specific humidity (kg/kg)
     thp_arg(:,:,:)            ! pot temp after vert. diffusion
```

OUTPUT PARAMETERS:

```
real*8, intent(out) ::   &
     kvh_arg(:,:,:),     &     ! coefficient for heat and tracers
     kvm_arg(:,:,:),     &     ! coefficient for momentum
     tpert_arg(:,:),     &     ! convective temperature excess
     qpert_arg(:,:),     &     ! convective humidity excess
     cgs_arg(:,:,:)            ! counter-grad star (cg/flux)

real*8, optional, intent(inout) :: &
     taux_arg(:,:),      &     ! x surface stress (n)
     tauy_arg(:,:),      &     ! y surface stress (n)
     ustar_arg(:,:)            ! surface friction velocity

real*8, intent(inout) :: pblh_arg(:,:) ! boundary-layer height [m]
```

REMARKS:

```
Free atmosphere diffusivities are computed first; then modified by the
boundary layer scheme; then passed to individual parameterizations mvdiff,
qvdiff.
The free atmosphere diffusivities are based on standard mixing length forms
for the neutral diffusivity multiplied by functions of Richardson number.
k = l^2 * |dv/dz| * f(ri). The same functions are used for momentum,
potential temperature, and constitutents.
The stable Richardson num function (ri>0) is taken from Holtslag and
Beljaars (1989), ECMWF proceedings. f = 1 / (1 + 10*ri*(1 + 8*ri)).
The unstable richardson number function (ri<0) is taken from ccm1.
f = sqrt(1 - 18*ri)
```

REVISION HISTORY:

```
(1 ) All arguments are full arrays now. Latitude slices are copied in local
     variables. (ccc, 11/19/09)
 24 Sep 2010 - J. Lin      - Moved call to ND15 at the end of vdiff.
                             Modified to account for all mixing processes.
 02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                             involve explicitly using "D" exponents
 09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                             derived type object
```

1.117.3 pbldif

Subroutine PBLDIF computes the atmospheric boundary layer. The nonlocal scheme determines eddy diffusivities based on a diagnosed boundary layer height and a turbulent velocity scale. Also, countergradient effects for heat and moisture, and constituents are included, along with temperature and humidity perturbations which measure the strength of convective thermals in the lower part of the atmospheric boundary layer.

References:

1. Holtslag, A. A. M., and B. A. Boville, 1993: *Local versus nonlocal boundary-layer diffusion in a global climate model*, J. Clim., **6**, 1825-1842.

INTERFACE:

```
subroutine pbldif( th      ,q       ,z       ,u       ,v, &
                   t       ,pmid    ,kvf     ,cflx    ,shflx, &
                   kvm     ,kvh, &
                   cgh     ,cgq     ,cgs     ,pblh    ,tpert, &
                   qpert   ,wvflx   ,cgsh    ,plonl, &
                   taux    ,tauy    ,ustar)
```

USES:

```
  implicit none
```

INPUT PARAMETERS:

```
  integer, intent(in) :: &
plonl
  real*8, intent(in) :: &
       th(plonl,plev), &          ! potential temperature [k]
       q(plonl,plev), &           ! specific humidity [kg/kg]
       z(plonl,plev), &           ! height above surface [m]
       u(plonl,plev), &           ! windspeed x-direction [m/s]
       v(plonl,plev), &           ! windspeed y-direction [m/s]
       t(plonl,plev), &           ! temperature (used for density)
       pmid(plonl,plev), &        ! midpoint pressures
```

```
     kvf(plonl,plevp), &        ! free atmospheric eddy diffsvty [m2/s]
     cflx(plonl,pcnst), &       ! surface constituent flux (kg/m2/s)
     wvflx(plonl), &            ! water vapor flux (kg/m2/s)
     shflx(plonl)               ! surface heat flux (w/m2)
```

INPUT/OUTPUT PARAMETERS:

```
real*8, optional, intent(inout) :: &
     taux(plonl), &            ! x surface stress (n)
     tauy(plonl), &            ! y surface stress (n)
     ustar(plonl)              ! surface friction velocity

real*8, intent(inout) :: pblh(plonl)       ! boundary-layer height [m]
```

OUTPUT PARAMETERS:

```
real*8, intent(out) :: &
     kvm(plonl,plevp), &        ! eddy diffusivity for momentum [m2/s]
     kvh(plonl,plevp), &        ! eddy diffusivity for heat [m2/s]
     cgh(plonl,plevp), &        ! counter-gradient term for heat [k/m]
     cgq(plonl,plevp,pcnst), &  ! counter-gradient term for constituents
     cgsh(plonl,plevp), &       ! counter-gradient term for sh
     cgs(plonl,plevp), &        ! counter-gradient star (cg/flux)
     tpert(plonl), &            ! convective temperature excess
     qpert(plonl)               ! convective humidity excess
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.117.4 qvdiff

Subroutine QVDIFF solve vertical diffusion eqtn for constituent with explicit srfc flux.

INTERFACE:

```
subroutine qvdiff( ncnst, qm1, qflx, cc, ze, &
            term, qp1, plonl )
```

USES:

```
implicit none
```

INPUT PARAMETERS:

```
integer, intent(in) :: &
     plonl
integer, intent(in) :: &
     ncnst                     ! num of constituents being diffused
```

```
real*8, intent(in) :: &
     qm1(plonl,plev,ncnst), & ! initial constituent
     qflx(plonl,ncnst), &     ! sfc q flux into lowest model level
     cc(plonl,plev), &        ! -lower diag coeff.of tri-diag matrix
     term(plonl,plev)         ! 1./(1. + ca(k) + cc(k) - cc(k)*ze(k-1))
```

INPUT/OUTPUT PARAMETERS:

```
real*8, intent(inout) :: &
     ze(plonl,plev)           ! term in tri-diag. matrix system
```

OUTPUT PARAMETERS:

```
real*8, intent(out) :: &
     qp1(plonl,plev,ncnst)    ! final constituent
```

REMARKS:

```
Procedure for solution of the implicit equation follows :
Richtmyer and Morton (1967,pp 198-199)
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.117.5 vdiffar

Subroutine VDIFFAR is the driver routine to compute vertical diffusion of trace constituents using archived coefficients for cgs and kvh. This is a gutted version of vdiff.

INTERFACE:

```
SUBROUTINE VDIFFAR( lat   ,tadv , &
                    pmid  ,pint ,rpdel_arg ,rpdeli_arg  ,ztodt, &
                    sflx  ,as2  ,kvh_arg   ,cgs_arg     ,plonl )
```

USES:

```
implicit none
```

INPUT PARAMETERS:

```
integer, intent(in) :: lat     ! latitude index
integer, intent(in) :: plonl   ! lon tile dim
real*8, intent(in) :: &
     ztodt , &                 ! 2 delta-t
     tadv(:,:,:), &        ! temperature input
     pmid(:,:,:), &     ! midpoint pressures
     pint(:,:,:), &    ! interface pressures
     rpdel_arg(:,:,:), &      ! 1./pdel  (thickness bet interfaces)
     rpdeli_arg(:,:,:), &     ! 1./pdeli (thickness bet midpoints)
     sflx(:,:,:), &      ! surface constituent flux (kg/m2/s)
     kvh_arg(:,:,:), &       ! coefficient for heat and tracers
     cgs_arg(:,:,:)          ! counter-grad star (cg/flux)
```

INPUT/OUTPUT PARAMETERS:

```
real*8, intent(inout) :: &
     as2(:,:,:,:)     ! moist, tracers after vert. diff
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.117.6 pbldifar

Subroutine PBLDIFAR is a modified version of pbldif which only calculates cgq given cgs.

INTERFACE:

```
SUBROUTINE PBLDIFAR( t, pmid, cflx, cgs, cgq, plonl )
```

USES:

```
implicit none
```

INPUT PARAMETERS:

```
integer, intent(in) :: &
     plonl
real*8, intent(in) :: &
     t(plonl,plev), &        ! temperature (used for density)
     pmid(plonl,plev), &     ! midpoint pressures
     cflx(plonl,pcnst), &     ! surface constituent flux (kg/m2/s)
     cgs(plonl,plevp)        ! counter-gradient star (cg/flux)
```

OUTPUT PARAMETERS:

```
real*8, intent(out) :: &
     cgq(plonl,plevp,pcnst)  ! counter-gradient term for constituents
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.117.7 vdinti

Subroutine VDINTI initializes time independent fields for vertical diffusion. Calls initialization routine for boundary layer scheme.

INTERFACE:

```
SUBROUTINE VDINTI
```

USES:

```
USE PRESSURE_MOD, ONLY : GET_AP, GET_BP
USE ERROR_MOD,    ONLY : ALLOC_ERR

implicit none
```

REVISION HISTORY:

```
02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                            involve explicitly using "D" exponents
```

1.117.8 vdiffdr

Subroutine VDIFFDR calculates the vertical diffusion on a latitude slice of data.

1. The dummy argument as2 is in vv. (lin, 06/04/08)
2. TCVV and TRACER_MW_KG assume 12 g/mol for all HCs. Thus, when using them to convert units of HCs to be the inputs for vdiffdr, the converted units are NOT kg/kg for concentrations and kg/m2/s for surface flux. However, since the units for both inputs are consistent, there should not be any problem. (lin, 06/04/08)

INTERFACE:

```
SUBROUTINE VDIFFDR( as2, Input_Opt, State_Met )
```

USES:

```
USE COMODE_MOD,          ONLY : JLOP,      REMIS,   VOLUME
USE DAO_MOD,             ONLY : IS_ICE, IS_LAND
USE DEPO_MERCURY_MOD,    ONLY : ADD_Hg2_DD, ADD_HgP_DD
USE DEPO_MERCURY_MOD,    ONLY : ADD_Hg2_SNOWPACK
USE DIAG_MOD,            ONLY : AD44
USE DRYDEP_MOD,          ONLY : DEPNAME, NUMDEP, NTRAIND, DEPSAV, &
                                SHIPO3DEP
USE DRYDEP_MOD,          ONLY : DRYHg0, DRYHg2, DRYHgP !cdh
USE GET_NDEP_MOD,        ONLY : SOIL_DRYDEP
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,            ONLY : GET_AREA_M2
USE OCEAN_MERCURY_MOD,   ONLY : Fp, Fg !hma
USE OCEAN_MERCURY_MOD,   ONLY : LHg2HalfAerosol !cdh
USE PBL_MIX_MOD,         ONLY : GET_PBL_TOP_m, COMPUTE_PBL_HEIGHT, &
                                GET_PBL_MAX_L, GET_FRAC_UNDER_PBLTOP
USE PRESSURE_MOD,        ONLY : GET_PEDGE, GET_PCENTER
USE TIME_MOD,            ONLY : GET_TS_CONV, GET_TS_EMIS
USE TRACER_MOD,          ONLY : N_MEMBERS
```

```
      USE TRACERID_MOD,       ONLY : IS_Hg0, IS_Hg2, IS_HgP
      USE VDIFF_PRE_MOD,      ONLY : IIPAR, JJPAR, IDEMS, NEMIS, NCS, ND44, &
                                     NDRYDEP, emis_save

      implicit none
```

INPUT/OUTPUT PARAMETERS:

```
      ! Input options object
      TYPE(OptInput), INTENT(IN)            :: Input_Opt

      ! Meteorology State object
      TYPE(MetState), INTENT(INOUT)         :: State_Met

      ! Advected species
      REAL*8,         intent(inout), TARGET :: as2(IIPAR,JJPAR,LLPAR,&
                                                   Input_Opt%N_TRACERS)
```

REMARKS:

```
    Need to declare the Meteorology State object (State_MET) with
    INTENT(INOUT).  This is because VDIFF will modify the specific
    humidity field. (bmy, 11/21/12)

    VDIFF also archives drydep fluxes to the soil NOx emissions module
    (by calling routine SOIL_DRYDEP) and to the ND44 diagnostic.
```

REVISION HISTORY:

```
   (1 ) Calls to vdiff and vdiffar are now done with full arrays as arguments.
        (ccc, 11/19/09)
    04 Jun 2010 - C. Carouge  - Updates for mercury simulations with GTMM
    25 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
    24 Sep 2010 - J. Lin      - Move ND15 to vdiff.
    21 Dec 2010 - R. Yantosca - Add logical flags for different sim types
    21 Dec 2010 - R. Yantosca - Now call ITS_A_FULLCHEM_SIM instead of
                                relying on NCS == 0
    22 Dec 2010 - C. Carouge  - Combine array flipping w/ unit conversion
                                to save on operations
    02 Mar 2011 - R. Yantosca - Bug fixes for PGI compiler: these mostly
                                involve explicitly using "D" exponents
    26 Apr 2011 - J. Fisher   - Use MERRA land fraction information
    25 Oct 2011 - H. Amos     - bring Hg2 gas-particle partitioning code into
                                v9-01-02
    08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.2 in the same way as MERRA
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    22 Jun 2012 - R. Yantosca - Now use pointers to flip arrays in vertical
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    18 Jun 2013 - M. Payer    - Add emissions for offline aerosol simulation
```

```
01 Aug 2013 - R. Yantosca - Now pass Input_Opt via the arg list
01 Aug 2013 - J. Lin      - Modified for Rn-Pb-Be simulation
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.117.9 do_pbl_mix_2

Subroutine DO_PBL_MIX_2 is the driver routine for planetary boundary layer mixing. The PBL layer height and related quantities are always computed. Mixing of tracers underneath the PBL top is toggled by the DO_TURBDAY switch.

INTERFACE:

```
SUBROUTINE DO_PBL_MIX_2( am_I_Root, DO_TURBDAY, Input_Opt,  &
                         State_Met, State_Chm,  RC         )
```

USES:

```
USE ERROR_MOD,          ONLY : DEBUG_MSG
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE LOGICAL_MOD,        ONLY : LTURB, LPRT
USE PBL_MIX_MOD,        ONLY : INIT_PBL_MIX, COMPUTE_PBL_HEIGHT
USE TIME_MOD,           ONLY : ITS_TIME_FOR_EMIS
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACER_MOD,         ONLY : N_TRACERS, TCVV, ITS_A_FULLCHEM_SIM
USE VDIFF_PRE_MOD,      ONLY : EMISRR, EMISRRN

IMPLICIT NONE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root    ! Are we on the root CPU?
LOGICAL,        INTENT(IN)    :: DO_TURBDAY   ! Switch which turns on PBL
                                              !  mixing of tracers
TYPE(OptInput), INTENT(IN)    :: Input_Opt    ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(MetState), INTENT(INOUT) :: State_Met    ! Meteorology State object
TYPE(ChmState), INTENT(INOUT) :: State_Chm    ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC           ! Success or failure?
```

REVISION HISTORY:

```
11 Feb 2005 - R. Yantosca - Initial version
21 Dec 2010 - R. Yantosca - Now only call SETEMIS for fullchem simulations
22 Dec 2010 - R. Yantosca - Bug fix: print debug output only if LPRT=T
05 Mar 2013 - R. Yantosca - Add am_I_root, Input_Opt, RC arguments
05 Mar 2013 - R. Yantosca - Now call SETEMIS with am_I_Root, Input_Opt, RC
05 Mar 2013 - R. Yantosca - Now use Input_Opt%ITS_A_FULLCHEM_SIM
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
01 Aug 2013 - R. Yantosca - Now pass the Input_Opt object to VDIFFDR
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.118 Fortran: Module Interface vdiff_pre_mod

Module VDIFF_PRE_MOD contains variables used in VDIFF_MOD.

INTERFACE:

```
MODULE VDIFF_PRE_MOD
```

USES:

```
USE TRACER_MOD, ONLY : N_TRACERS
USE CMN_SIZE_MOD
USE COMODE_LOOP_MOD                  ! IDEMS, NEMIS, NCS
USE CMN_O3_MOD                       ! EMISRR, EMISRRN
USE CMN_DIAG_MOD                     ! ND15

IMPLICIT NONE

PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: Init_VDIFF_PRE
PUBLIC :: Cleanup_VDIFF_PRE
```

PUBLIC DATA MEMBERS:

```
PUBLIC :: IIPAR, JJPAR, LLPAR         ! from "CMN_SIZE_mod"
PUBLIC :: IDEMS, NEMIS, NCS, NDRYDEP  ! from "comode_loop_mod"
PUBLIC :: EMISRR, EMISRRN             ! from "CMN_O3_mod"
PUBLIC :: ND15, ND44                  ! from "CMN_DIAG_mod"
PUBLIC :: emis_save

! Make sure MAXTRACERS >= N_TRACERS
INTEGER, PARAMETER :: MAXTRACERS = 100

REAL*8, ALLOCATABLE :: emis_save(:,:,:)
```

REVISION HISTORY:

```
01 Jun 2009 - C. Carouge & J. Lin - Initial version
07 Oct 2009 - R. Yantosca         - Added CVS Id tag
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.118.1 init_vdiff_pre

Subroutine INIT_VDIFF_PRE allocates all module arrays.

INTERFACE:

```
SUBROUTINE Init_VDIFF_PRE( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

```
Need to add error-checking on the allocation statements, so that we
exit the code upon error.
```

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Added ProTeX headers
```

1.118.2 cleanup_vdiff_pree

Subroutine CLEANUP_VDIFF_PRE deallocates all module arrays.

INTERFACE:

```
SUBROUTINE Cleanup_VDIFF_PRE( am_I_Root, RC )
```

USES:

```
USE GIGC_ErrCode_Mod

IMPLICIT NONE
```

INPUT PARAMETERS:

```
LOGICAL, INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
```

OUTPUT PARAMETERS:

```
INTEGER, INTENT(OUT) :: RC          ! Success or failure?
```

REMARKS:

REVISION HISTORY:

```
19 Nov 2012 - R. Yantosca - Initial version
```

1.119 Fortran: Module Interface vistas_anthro_mod

Module VISTAS_ANTHRO_MOD contains variables and routines to read the VISTAS anthropogenic emissions.

INTERFACE:

```
MODULE VISTAS_ANTHRO_MOD
```

USES:

```
USE EPA_NEI_MOD, ONLY : GET_USA_MASK

IMPLICIT NONE
PRIVATE
```

PUBLIC MEMBER FUNCTIONS:

```
PUBLIC :: CLEANUP_VISTAS_ANTHRO
PUBLIC :: EMISS_VISTAS_ANTHRO
PUBLIC :: GET_VISTAS_ANTHRO
```

PRIVATE MEMBER FUNCTIONS:

```
PRIVATE :: INIT_VISTAS_ANTHRO
PRIVATE :: VISTAS_SCALE_FUTURE
PRIVATE :: TOTAL_ANTHRO_Tg
```

REVISION HISTORY:

```
24 Nov 2008 - A. v. Donkelaar - Initial version
28 Jan 2009 - P. Le Sager     - Initial Version in GEOS-Chem
01 Mar 2012 - R. Yantosca     - Now reference new grid_mod.F90
14 Mar 2013 - M. Payer        - Replace NOx emissions with NO emissions as
                                part of removal of NOx-Ox partitioning
```

1.119.1 get_vistas_anthro

Function GET_VISTAS_ANTHRO returns the VISTAS emission for GEOS-Chem grid box (I,J) and tracer N. Emissions can be returned in units of [kg/s] or [molec/cm2/s].

INTERFACE:

```
 FUNCTION GET_VISTAS_ANTHRO( I,        J,           N,
&                            WEEKDAY,  MOLEC_CM2_S, KG_S )
&  RESULT( VALUE )
```

USES:

```
 USE GRID_MOD,     ONLY : GET_AREA_CM2
 USE TRACER_MOD,   ONLY : XNUMOL
 USE TRACERID_MOD, ONLY : IDTNO
```

INPUT PARAMETERS:

```
 ! Longitude, latitude, and tracer indices
 INTEGER, INTENT(IN)           :: I, J, N

 ! Return weekday or weekend emissions
 LOGICAL, INTENT(IN)           :: WEEKDAY

 ! OPTIONAL -- return emissions in [molec/cm2/s]
 LOGICAL, INTENT(IN), OPTIONAL :: MOLEC_CM2_S

 ! OPTIONAL -- return emissions in [kg/s]
 LOGICAL, INTENT(IN), OPTIONAL :: KG_S
```

RETURN VALUE:

```
 ! Emissions output
 REAL*8                        :: VALUE
```

REVISION HISTORY:

```
28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
```

1.119.2 emiss_vistas_anthro

Subroutine EMISS_VISTAS_ANTHRO reads the VISTAS emission fields at 1x1 resolution and regrids them to the current model resolution.

INTERFACE:

```
 SUBROUTINE EMISS_VISTAS_ANTHRO( am_I_Root, Input_Opt,
&                                State_Chm, RC         )
```

USES:

```
      USE BPCH2_MOD,          ONLY : GET_TAU0,      READ_BPCH2
      USE CMN_O3_MOD
      USE CMN_SIZE_MOD
      USE DIRECTORY_MOD,      ONLY : DATA_DIR_1x1
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE REGRID_A2A_MOD,     ONLY : DO_REGRID_A2A
      USE TIME_MOD,           ONLY : GET_YEAR, GET_MONTH
      USE SCALE_ANTHRO_MOD,   ONLY : GET_ANNUAL_SCALAR_1x1
#if defined( DEVEL )
      USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK_LT
      USE TRACERID_MOD,       ONLY : IDTNO
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE ERROR_MOD,          ONLY : ALLOC_ERR
#endif
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
   28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial Version
   13 Mar 2012 - M. Cooper   - Changed regrid algorithm to map_a2a
   24 May 2012 - R. Yantosca - Fix minor bugs in map_a2a algorithm
   24 Aug 2012 - R. Yantosca - DO_REGRID_A2A now reads netCDF input file
   03 Jan 2013 - M. Payer    - Renamed PERAREA to IS_MASS in DO_REGRID_A2A
   14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                               of removal of NOx-Ox partitioning
   25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
```

1.119.3 vistas_scale_future

Subroutine VISTAS_SCALE_FUTURE applies the IPCC future scale factors to the VISTAS anthropogenic emissions.

INTERFACE:

```
      SUBROUTINE VISTAS_SCALE_FUTURE
```

USES:

```
      USE FUTURE_EMISSIONS_MOD, ONLY : GET_FUTURE_SCALE_NOxff

      USE CMN_SIZE_MOD             ! Size parameters
```

REVISION HISTORY:

```
    28 Jan 2009 - A. v. Donkelaar, P. Le Sager - Initial Version
```

1.119.4 total_anthro_Tg

Subroutine TOTAL_ANTHRO_TG prints the totals for the anthropogenic emissions of NOx.

INTERFACE:

```
      SUBROUTINE TOTAL_ANTHRO_TG( YEAR, THISMONTH, Input_Opt )
```

USES:

```
      USE CMN_SIZE_MOD
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GRID_MOD,           ONLY : GET_AREA_CM2
      USE TRACERID_MOD,       ONLY : IDTNO
```

INPUT PARAMETERS:

```
      INTEGER,         INTENT(IN) :: YEAR        ! Year to compute totals
      INTEGER,         INTENT(IN) :: THISMONTH   ! Month to compute totals
      TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

REVISION HISTORY:

```
    28 Jan 2009 - P. Le Sager - Initial Version
    01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
    14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                                of removal of NOx-Ox partitioning
    28 Mar 2013 - R. Yantosca - Now use fields from Input_Opt
```

1.119.5 init_vistas_anthro

Subroutine INIT_VISTAS_ANTHRO allocates and zeroes all module arrays. (phs, 1/28/09)

INTERFACE:

```
      SUBROUTINE INIT_VISTAS_ANTHRO( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE ERROR_MOD,          ONLY : ALLOC_ERR
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)  :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)  :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT) :: RC          ! Success or failure?!
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
01 Mar 2012 - R. Yantosca - Remove A_CM2 array, use GET_AREA_CM2 instead
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC
```

1.119.6 cleanup_vistas_anthro

Subroutine CLEANUP_VISTAS_ANTHRO deallocates all module arrays.

INTERFACE:

```
SUBROUTINE CLEANUP_VISTAS_ANTHRO
```

REVISION HISTORY:

```
28 Jan 2009 - P. Le Sager - Initial Version
02 Mar 2012 - R. Yantosca - Remove A_CM2 array
```

1.120 Fortran: Module Interface Individual GEOS-Chem subroutines

Here follows a list of GEOS-Chem subroutines which do not belong to any F90 module.

1.120.1 anthroems

Subroutine ANTHROEMS reads anthropogenic tracers for each season. NOx emissions at levels other than the surface are now accounted for.

INTERFACE:

```
SUBROUTINE ANTHROEMS( NSEASON, Input_Opt )
```

USES:

```
USE GIGC_Input_Opt_Mod,  ONLY : OptInput
USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_ALK4ff
USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_C2H6ff
USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_C3H8ff
USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_COff
USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_NOxff
```

```
      USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_PRPEff
      USE FUTURE_EMISSIONS_MOD,ONLY : GET_FUTURE_SCALE_TONEff
      USE GEIA_MOD,            ONLY : READ_GEIA,    READ_C3H8_C2H6_NGAS
      USE GEIA_MOD,            ONLY : READ_LIQCO2,  READ_TODX
      USE GEIA_MOD,            ONLY : READ_TOTCO2,  TOTAL_FOSSIL_TG
      USE GRID_MOD,            ONLY : GET_AREA_CM2, GET_XOFFSET
      USE GRID_MOD,            ONLY : GET_YOFFSET
      USE TIME_MOD,            ONLY : GET_TS_EMIS,  GET_YEAR
      USE TIME_MOD,            ONLY : GET_SEASON
      USE TRACERID_MOD,        ONLY : IDEACET,      IDEALK4
      USE TRACERID_MOD,        ONLY : IDEC2H6,      IDEC3H8
      USE TRACERID_MOD,        ONLY : IDECO,        IDEMEK
      USE TRACERID_MOD,        ONLY : IDENO,       IDEPRPE
      USE TRACERID_MOD,        ONLY : NEMANTHRO
      USE TRACERID_MOD,        ONLY : IDEBENZ,     IDETOLU,    IDEXYLE
      USE TRACERID_MOD,        ONLY : IDEC2H4,      IDEC2H2
      USE TRACERID_MOD,        ONLY : IDTBENZ,     IDTTOLU,    IDTXYLE
      USE TRACERID_MOD,        ONLY : IDTC2H4,      IDTC2H2,   IDTNO2
      USE SCALE_ANTHRO_MOD,    ONLY : GET_ANNUAL_SCALAR
      USE SCALE_ANTHRO_MOD,    ONLY : GET_ANNUAL_SCALAR_05x0666_NESTED
      USE EDGAR_MOD,           ONLY : READ_AROMATICS, READ_C2H4
      USE EDGAR_MOD,           ONLY : READ_C2H2
      USE EDGAR_MOD,           ONLY : READ_AROMATICS_05x0666
      USE EDGAR_MOD,           ONLY : READ_C2H4_05x0666
      USE EDGAR_MOD,           ONLY : READ_C2H2_05x0666
      ! SOAupdate: for gas phase NAP chemistry (hotp 6/24/09)
      ! get location of NAP emissions in array
      USE TRACERID_MOD,        ONLY : IDENAP

      USE CMN_SIZE_MOD              ! Size parameters
      USE COMODE_LOOP_MOD           ! IDEMS
      USE CMN_O3_MOD                ! EMIST, EMISR, EMISRR, etc.

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN) :: NSEASON     ! Current season (1-4)
      TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

REMARKS:

```
    NSEASON:  is the seasonal index for NOx emissions:
      NSEASON=1 --> winter (Dec, Jan, Feb)
      NSEASON=2 --> spring (Mar, Apr, May)
      NSEASON=3 --> summer (Jun, Jul, Aug)
      NSEASON=4 --> autumn (Sep, Oct, Nov)

    Passed Via CMN_O3_mod:
```

```
=============================================================================
Fossil Fuel arrays: EMISTNOX,  EMISTCO,   EMISTETHE, EMISTPRPE,
                    EMISTC2H6, EMISTC3H8, EMISTALK4, EMISTACET,
                    EMISTMEK,  EMISTSOX
                                                                            .
Emissions arrays:   EMIST, EMISTN, EMISR, EMISRN, EMISRR, EMISRRN
                                                                            .
REFERENCES:
=============================================================================
(1 ) Zhang, Y.X., and S. Tao, "Global atmospheric emission inventory of
      polycyclic aromatic hydrocarbons (PAHs) for 2004", Atmos. Environ.,
      Vol 43, 812-819, doi:10.1016/J.ATMOSENV.2008.10.050, 2009.
```

REVISION HISTORY:

```
04 Jun 1998 - R. Yantosca - Initial version
(1 ) We now read the new merge file, created for SASS. (bey, 2/99)
(2 ) ANTHROEMS should be called each time the season changes, since
      the GEIA NOx emissions are seasonal.
(3 ) NOx emissions are stored separately in EMISTN, EMISRN, EMISRRN.
      This is because the NOx emissions can be located across several
      sigma levels, whereas the other tracers are only emitted into
      the surface level.
(4 ) NO2 is no longer emitted as the emission species for Ox.
      (bey, bmy, 4/14/99)
(5 ) There are 3 different types of scale factors for anthro emissions:
      (a) Yearly since 1985: done in anthroems.f
      (b) Weekday/weekend:   done in emf_scale.f
      (c) Time of day:       done in emfossil.f
(6 ) At present NEMANTHRO = Total number of emitted tracers
      (set in tracerid.f).  We no longer use moments in emissions.
      ORDER = NOx, CO, PRPE, C3H8, ALK4, C2H6, ALD2.
(7 ) NOx is assumed to be the first tracer (N=1).  The first usable
      row for tracers other than NOx in EMIST(I,J,N), etc. is N=2.
(8 ) Need to offset EMISR, which has global dimensions.
      EMIST has window dimensions.
(9 ) Now trap I/O errors and stop gracefully if file open or read
      errors are encountered.  Print an error message to alert user
      which file triggered the I/O error. (bmy, 4/14/99)
(10) Eliminate GISS-specific code and PLUMES code (bmy, 4/14/99)
(11) Now use F90 syntax where expedient. (bmy, 4/14/99)
(12) Cosmetic changes, added comments (bmy, 3/17/00)
(13) Do not let SCALYEAR go higher than 1996, since right now we don't
      have FF scaling data beyond 1996.  Also cosmetic changes and
      updated comments. (bmy, 4/6/01)
(14) Now reference routines from GEIA_MOD for reading scale factor and
      other emissions data from disk. (bmy, 4/23/01)
(15) Now read fossil-fuel emissions from a binary punch file (bmy, 4/23/01)
```

```
(16) CO and hydrocarbons are read from disk once per year.  Fossil fuel
     scale factors are also applied once per
(17) Now comment out LNAPAPNOX.  Also total fossil fuel emissions
     and echo to std output. (bmy, 4/27/01)
(18) Bug fix: Now convert units for CO, Hydrocarbon tracers only once
     per year.  Convert units for NOx once per season. (bmy, 6/7/01)
(19) Bug fix: Now index CH26 correctly when totaling it (bmy, 8/30/01)
(20) Now take C3H8 and C2H6 emissions as scaled from natural gas.  Read
     these in subroutine READ_C3H8_C2H6_NGAS.  Also scale anthropogenic
     ACET by 0.82 in order to match the acetone paper (bdf, bmy, 9/10/01)
(21) Removed obsolete, commented-out code from 6/01 (bmy, 11/26/01)
(22) Eliminated obsolete code from 11/01 (bmy, 2/27/02)
(23) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE (bmy, 6/25/02)
(24) Now reference IDTNOX, IDENOX, etc. from "tracerid_mod.f".  Also
     do not let SCALEYEAR exceed 1998. (bmy, 1/13/03)
(25) Now replace DXYP(JREF)*1d4 with routine GET_AREA_CM2 from "grid_mod.f"
     Now use functions GET_XOFFSET and GET_YOFFSET from "grid_mod.f".
     Now I0 and J0 are local variables.  Now use functions GET_TS_EMIS,
     GET_YEAR, GET_SEASON from "time_mod.f". (bmy, 2/11/03)
(26) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(27) Now replace FMOL with TRACER_MW_KG (bmy, 10/25/05)
(28) Modified for IPCC future emissions scale factors (swu, bmy, 5/30/06)
(29) Extend max value for FSCALYR to 2002 (bmy, 7/18/06)
(30) Use updated int'annual scale factors for 1985-2003 (amv, 08/24/07)
(31) As default, use EDGARv2.0 emission (fossil fuel + industry)
     for year 1985, scale to target year with CO2 from liquid fuel,
     for aromatics, C2H4, and C2H2. (tmf, 6/13/07)
(32) GET_ANNUAL_SCALAR_05x0666_NESTED_CH renamed to
     GET_ANNUAL_SCALAR_05x0666_NESTED (amv, bmy, 12/18/09)
19 Nov 2010 - R. Yantosca - Added ProTeX headers
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
25 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
13 Aug 2013 - M. Sulprizio- Add NAP emissions for SOA + semivolatile POA
                            simulation (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Remove SEAC4RS C-preprocessor switch
```

1.120.2 biofit

Function BIOFIT computes the light correction used in the dry deposition and canopy NOx modules.

INTERFACE:

```
REAL*8 FUNCTION BIOFIT( COEFF1, XLAI1, SUNCOS1, CFRAC1 )
```

USES:

```
USE CMN_SIZE_MOD, ONLY : NPOLY        ! # of drydep coefficients

IMPLICIT NONE
```

INPUT PARAMETERS:

```
REAL*8, INTENT(IN) :: COEFF1(NPOLY)   ! Baldocchi drydep coefficients
REAL*8, INTENT(IN) :: XLAI1           ! Leaf area index [cm2/cm2]
REAL*8, INTENT(IN) :: SUNCOS1         ! Cosine( Solar Zenith Angle )
REAL*8, INTENT(IN) :: CFRAC1          ! Cloud fraction [unitless]
```

REMARKS:

```
This routine is ancient code from Yuhang Wang.  It was part of the old
Harvard-GISS CTM and was ported into GEOS-Chem.  See this reference for
more information:

  Wang, Y., D.J. Jacob, and J.A. Logan, "Global simulation of tropospheric
   O3-NOx-hydrocarbon chemistry, 1. Model formulation", J. Geophys. Res.,
   103/D9, 10,713-10,726, 1998.
```

REVISION HISTORY:

```
13 Dec 2012 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.3 boxvl

The new function BOXVL converts the DAO grid box volume values stored in AIRVOL from m3 to cm3. The conversion factor is (100)**3 = 1e6 cm3 per m3.

INTERFACE:

```
REAL*8 FUNCTION BOXVL( I, J, L, State_Met )
```

USES:

```
USE GIGC_State_Met_Mod, ONLY : MetState

IMPLICIT NONE
```

INPUT PARAMETERS:

```
INTEGER,        INTENT(IN) :: I           ! Longitude index
INTEGER,        INTENT(IN) :: J           ! Latitude index
INTEGER,        INTENT(IN) :: L           ! Level index
TYPE(MetState), INTENT(IN) :: State_Met   ! Meteorology State object
```

REVISION HISTORY:

```
30 Jan 1998 - R. Yantosca - Initial version
(1 ) CMN_VOL is used to pass AIRVOL.
(2 ) Use C-preprocessor #include statement to include CMN_SIZE, which
     has IIPAR, JJPAR, LLPAR, IIPAR, JJPAR, LGLOB.
(3 ) Now use F90 syntax for declarations (bmy, 10/5/99)
(4 ) Now reference AIRVOL from "dao_mod.f" instead of from common
     block header file "CMN_VOL". (bmy, 6/26/00)
(5 ) Removed obsolete code from 6/26/00 (bmy, 8/31/00)
(6 ) Updated comments (bmy, 8/5/02)
02 Dec 2010 - R. Yantosca - Initial version
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.4 cldice_hbrhobr_rxn

Subroutine CLDICE_HBrHOBr_RXN calculates the rate constants for HBr and HOBr pseudo-reactions with ice.

INTERFACE:

```
 SUBROUTINE CLDICE_HBrHOBr_RXN( I,      J,      L,    DENAIR,
&                               QI,     hbr,    hobr,
&                               k_hbr,  k_hobr, AREA, State_Met )
```

USES:

```
 USE ERROR_MOD,          ONLY : IS_SAFE_DIV, IT_IS_NAN
 USE ERROR_MOD,          ONLY : GEOS_CHEM_STOP
 USE GIGC_State_Met_Mod, ONLY : MetState

 IMPLICIT NONE
```

INPUT PARAMETERS:

```
 INTEGER,        INTENT(IN)  :: I         ! Longitude index
 INTEGER,        INTENT(IN)  :: J         ! Latitude  index
 INTEGER,        INTENT(IN)  :: L         ! Altitude  index
 REAL*8,         INTENT(IN)  :: DENAIR    ! Density of air         [#/cm3]
 REAL*8,         INTENT(IN)  :: QI        ! Cloud ice mixing ratio [kg/kg]
 REAL*8,         INTENT(IN)  :: hbr       ! Concentration of HBr   [#/cm3]
 REAL*8,         INTENT(IN)  :: hobr      ! Concentration of HOBr  [#/cm3]
 TYPE(MetState), INTENT(IN)  :: State_Met ! Meteorology State object
```

OUTPUT PARAMETERS:

```
 REAL*8,         INTENT(OUT) :: k_hbr     ! Rate constant for HBr  + ice
                                          !   pseudo-rxn [cm3/s]
```

```
      REAL*8,         INTENT(OUT) :: k_hobr    ! Rate constant for HOBr + ice
                                               !   pseudo-rxn [cm3/s]
      REAL*8,         INTENT(OUT) :: AREA      ! Surface area [cm2/cm3]
```

REMARKS:

```
    The rate constant is calculated assuming:
                                                                             .
      1. A sticking coefficient of 0.1 [JPL 2006], Abbatt [1994],
         Chai et al. [2000]
      2. An effective radius is assumed as a function of (i) temperature and
         ice water content (IWC). This relationship is taken from Wyser [1998].
                                                                             .
    ** Calculations of a 1st order rate constent are borrowed from the
       subroutine arsl1k.F. Below are comments from that code:
                                                                             .
         The 1st-order loss rate on wet aerosol (Dentener's Thesis, p. 14)
         is computed as:
                                                                             .
           ARSL1K [1/s] = area / [ radius/dfkg + 4./(stkcf * nu) ]
                                                                             .
         where nu   = Mean molecular speed [cm/s] = sqrt(8R*TK/pi/M) for Maxwell
               DFKG = Gas phase diffusion coeff [cm2/s] (order of 0.1)
```

REVISION HISTORY:

```
    16 Jun 2011 - J. Parrella - Initial version
    22 May 2012 - M. Payer    - Added ProTeX headers
    26 Sep 2012 - R. Yantosca - For now, comment out debug print statements
    23 Oct 2012 - R. Yantosca - Add better error checks to prevent div-by-zero
    09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                                derived type object
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
    05 Sep 2013 - R. Yantosca - Now exit if IWC <= 0, this will cause the
                                logarithm to choke
    26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.120.5 diag1

Subroutine DIAG1 accumulates diagnostic quantities on every dynamic timestep.

INTERFACE:

```
      SUBROUTINE DIAG1( am_I_Root, Input_Opt,
     &                  State_Met, State_Chm, RC )
```

USES:

```
      ! References to F90 modules
```

```
      USE DAO_MOD,            ONLY : IS_ICE, IS_WATER, IS_LAND
      USE DIAG_MOD,           ONLY : AD30, AD31, AD33, AD35, AD45, AD54
      USE DIAG_MOD,           ONLY : AD47, AD67, AD68, AD69, LTOTH
      USE DIAG_MOD,           ONLY : AD57
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_AREA_M2
      USE PRESSURE_MOD,       ONLY : GET_PCENTER
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE TIME_MOD,           ONLY : ITS_TIME_FOR_CHEM
      USE TRACER_MOD,         ONLY : XNUMOLAIR
      USE TRACERID_MOD,       ONLY : IDTO3
      USE TRACERID_MOD,       ONLY : ID_HG2, ID_HGP, ID_Hg_TOT
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_TROP
      USE DIAG03_MOD,         ONLY : AD03_RGM, AD03_PBM, ND03

#if   defined( APM )
      USE TRACER_MOD,         ONLY : N_APMTRA
#endif

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! Diagnostic arrays & parameters
      USE CMN_GCTM_MOD             ! Physical constants

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

(1) This subroutine was reconstructed from gmg's version of (10/10/97)
(2) GISS-specific code has been eliminated (bmy, 3/15/99)
(3) UWND, VWND, WW no longer needs to be passed (bmy, 4/7/99)
(4) Use F90 syntax for declarations, etc (bmy, 4/7/99)
(5) Remove counter KWACC...this is now redundant (bmy, 11/5/99)
(6) ND31, ND33, ND35, ND67, and ND69 now use dynamically
      allocatable arrays declared in "diag_mod.f". (bmy, 3/9/00)

```
(7 ) LTOTH is now an allocatable array in "diag_mod.f". (bmy, 3/17/00)
(8 ) Add parallel loops over tracer where expedient (bmy, 5/4/00)
(9 ) Updated comments and diagnostics list.  Also add more parallel
     loops for ND31 and ND68.  (bmy, 6/21/00)
(10) Use NTRACE to dimension STT_VV instead of NNPAR (bmy, 10/17/00)
(11) Removed obsolete code from 10/17/00 (bmy, 12/21/00)
(12) Updated diagnostic list & comments, cosmetic changes (bmy, 6/19/01)
(13) Updated diagnostic list & comments (bmy, 9/4/01)
(14) Now reference AVGW from "dao_mod.f", and make sure it is allocated
     before we reference it in the ND68 diagnostic.  Also reference PBL,
     PS, AIRDEN from "dao_mod.f". (bmy, 9/25/01)
(15) Removed obsolete code from 9/01 (bmy, 10/23/01)
(16) Renamed ND33 to "ATMOSPHERIC COLUMN SUM OF TRACER", since this is
     a sum over all levels and not just in the troposphere.  Also
     removed more obsolete code from 9/01.  Now use P(I,J)+PTOP instead
     of PS, since that is the way to ensure that we use will be used
     consistently.  Remove reference to PS from "dao_mod.f"(bmy, 4/11/02)
(17) Replaced all instances of IM with IIPAR and JM with JJPAR, in order
     to prevent namespace confusion for the new TPCORE.  Also removed
     obsolete, commented-out code.  Also now replaced reference to
     P(IREF,JREF) with P(I,J). (bmy, 6/25/02)
(18) Replaced references to P(I,J) with call to GET_PEDGE(I,J,1) from
     "pressure_mod.f"  Eliminated obsolete commented-out code from
     6/02. (dsa, bdf, bmy, 8/20/02)
(19) Now reference AD, and BXHEIGHT from "dao_mod.f".  Removed obsolete
     code.  Now refEerence IDTOX from "tracerid_mod.f". (bmy, 11/6/02)
(20) Now replace DXYP(J) with routine GET_AREA_M2 from "grid_mod.f"
     (bmy, 2/4/03)
(21) Now compute PBL top for ND67 for GEOS-4/fvDAS.  Also now include
     SCALE_HEIGHT from header file "CMN_GCTM". (bmy, 6/23/03)
(22) Now references N_TRACERS, STT, and ITS_A_FULLCHEM_SIM from
     "tracer_mod.f" (bmy, 7/20/04)
(23) Fixed ND67 PS-PBL for GCAP and GEOS-5 met fields (swu, bmy, 6/9/05)
(24) Now archive ND30 diagnostic for land/water/ice flags (bmy, 8/18/05)
(25) Now reference XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(26) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
(27) Added count for time in the troposphere - array AD54 (phs, 9/22/06)
(28) Now only archive O3 in ND45 and ND47 at chem timsteps (phs, 1/24/07)
(29) Bug fix: Update ND30 for both GEOS-3 and otherwise.  Also now save
     3-D pressure edges in ND31 instead of PS-PTOP.  Revert to the !
     pre-near-land ND30 diagnostic algorithm. (bmy, 1/28/04)
(30) Use LTO3 for O3 in ND45. (ccc, 7/20/09)
(31) Add potential temperature diagnostic in ND57 (fp, 2/3/10)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
15 Feb 2011 - R. Yantosca - Added modifications for APM from G. Luo
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
```

```
                          derived type object
14 Mar 2013 - M. Payer    - Replace Ox with O3 as part of removal of
                            NOx-Ox partitioning
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, State_Chm, RC
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
29 Aug 2013 - R. Yantosca - In ND57, we need to make ND57 !$OMP PRIVATE
```

REMARKS:

```
For a complete list of GEOS-Chem diagnostics, please see this web page:
   http://acmg.seas.harvard.edu/geos/doc/man/appendix_5.html
```

1.120.6 diag3

Subroutine DIAG3 prints out diagnostics to the BINARY PUNCH format file.

INTERFACE:

```
SUBROUTINE DIAG3( am_I_Root, Input_Opt, State_Chm, RC )
```

USES:

```
! Modules from Headers directory
USE CMN_SIZE_MOD                      ! Size parameters
USE CMN_MOD                           ! IFLX, LPAUSE
USE CMN_O3_MOD                        ! FMOL, XNUMOL
USE CMN_DIAG_MOD                      ! Diagnostic switches & arrays
USE COMODE_LOOP_MOD                   ! IDEMS
USE FILE_MOD
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE GRID_MOD, ONLY : GET_AREA_M2, GET_YOFFSET, GET_XOFFSET
USE TIME_MOD

! Modules from GeosCore directory
USE BPCH2_MOD                         ! For binary punch I/O routines
USE BIOMASS_MOD                       ! For biomass emissions
USE BIOFUEL_MOD                       ! For biofuel emissions
USE DIAG_MOD                          ! For diagnostic arrays
USE DIAG03_MOD                        ! For Hg diagnostic
USE DIAG04_MOD                        ! For CO2 diagnostics
USE DIAG41_MOD                        ! For afternoon PBL diag
USE DIAG42_MOD                        ! For SOA diag
USE DIAG53_MOD                        ! For POPs diag
USE DIAG56_MOD                        ! For time in tropopause diag
USE DIAG_PL_MOD                       ! For prod/loss diagnostic
USE DEPO_MERCURY_MOD                  ! For offline Hg simulation
```

```
      USE DRYDEP_MOD                          ! For dry deposition
      USE LOGICAL_MOD                         ! For logical switches
      USE TRACERID_MOD                        ! For tracer flags
      USE WETSCAV_MOD                         ! For wet deposition
#if   defined( TOMAS )
      USE TOMAS_MOD, ONLY : ICOMP, IDIAG, IBINS  !(win, 1/25/10)
#endif

#if   defined( APM )
      USE TRACER_MOD,   ONLY : N_APMTRA
      ! Modules from GeosApm directory
      USE APM_DRIV_MOD, ONLY : IFTEMPOUT
      USE APM_DRIV_MOD, ONLY : TEMPOUT
      USE APM_DRIV_MOD, ONLY : NTEMPOUT
      USE APM_DRIV_MOD, ONLY : NPOUTSTEPS
#endif

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
    (40) Bug fix: Save levels 1:LD13 for ND13 diagnostic for diagnostic
         categories "SO2-AC-$" and "SO2-EV-$".  Now reference F90 module
         "tracerid_mod.f".  Now reference NUMDEP from "drydep_mod.f".
         Now save anthro, biofuel, biomass NH3 in ND13; also fixed ND13
         tracer numbers.  For ND13, change scale factor from SCALESRCE to 1.
         Now references "wetscav_mod.f".  Now also save true tracer numbers
         for ND38 and ND39 diagnostic.  Now also write out biomass SO2.
         Now convert ND01, ND02, ND44 diagnostics for Rn/Pb/Be from kg to
         kg/s here. (bmy, 1/24/03)
    (41) Now save out natural NH3 in ND13 as "NH3-NATU" (rjp, bmy, 3/23/03)
    (42) Now replace DXYP(JREF) by routine GET_AREA_M2, GET_XOFFSET, and
         GET_YOFFSET of "grid_mod.f".  Now references "time_mod.f".
         DIAGb, DIAGe are now local variables.  Now remove obsolete statements
         IF ( LBPNCH > 0 ).  Removed SCALE1, replaced with SCALEDYN.
         (bmy, 2/24/03)
    (43) Added TSKIN, PARDF, PARDR, GWET to ND67 diagnostic.  For GEOS-4/fvDAS,
         UWND, VWND, TMPU, SPHU are A-6 fields.  Adjust the ND66 scale factors
```

```
      accordingly.  Delete KZZ from ND66.  Updated comments. (bmy, 6/23/03)
(44) Bug fix: use LD68 instead of ND68 in DO-loop to avoid out-of-bounds
      error. (bec, bmy, 7/15/03)
(45) Now print out NTRACE drydep fluxes for tagged Ox.  Also tagged Ox
      now saves drydep in molec/cm2/s.  Now print out Kr85 prod/loss in
      ND03. (bmy, 8/20/03)
(46) Now use actual tracer number for ND37 diagnostic. (bmy, 1/21/04)
(47) Now loop over the actual # of soluble tracers for ND17, ND18.
      (bmy, 3/19/04)
(48) Now use the actual tracer # for ND17 and ND18 diagnostics.
      Rearrange ND44 code for clarity. (bmy, 3/23/04)
(49) Added ND06 (dust aerosol) and ND07 (carbon aerosol) diagnostics.
      Now scale online dust optical depths by SCALECHEM in ND21 diagnostic.
      (rjp, tdf, bmy, 4/5/04)
(50) Added ND08 (seasalt aerosol) diagnostic (rjp, bec, bmy, 4/20/04)
(51) Now save out SO2 from ships (if LSHIPSO2=T) (bec, bmy, 5/20/04)
(52) Added NVOC source diagnostics for ND07 (rjp, bmy, 7/13/04)
(53) Now reference "logical_mod.f", "tracer_mod.f", and "diag_pl_mod.f".
      Bug fix in write to DMS_BIOG. (bmy, 7/20/04)
(54) Comment out ND27 for GEOS-4.  It isn't working 100% right.  If you
      examine the flux at 200 hPa, you get the same info. (bmy, 10/15/04)
(55) Added biofuel SO4 to the bpch file under ND13.  Bug fix: replace ND68
      with LD68 in call to BPCH2 (auvray, bmy, 11/17/04)
(56) Now save ND03 mercury diagnostic arrays to bpch file.  Also updated
      ND44 for tagged Hg tracers (eck, bmy, 12/14/04)
(57) Now print out extra ND21 diagnostics for crystalline sulfur tracers.
      Also now save total oceanic mass of Hg0 and Hg2.  Now call
      WRITE_DIAG03 from "diag03_mod.f" (bmy, 1/21/05)
(58) Now call WRITE_DIAG41 from "diag41_mod.f" (bmy, 2/17/05)
(59) Add P(SO4s) to row 8 of ND05 diagnostic.  Also remove special tracer
      numbers for the ND67 diagnostic.  Now do not save CLDMAS for ND67
      for GEOS-4, since GEOS-4 convection uses different met fields.
      (bec, bmy, 5/3/05)
(60) Bug fix in ND68 diagnostic: use LD68 instead of ND68 in call to BPCH2.
      Now modified for GEOS-5 and GCAP met fields.  Remove references to
      CO-OH param simulation.  Also remove references to TRCOFFSET since
      that is always zero now.  Now call GET_HALFPOLAR from "bpch2_mod.f"
      to get the HALFPOLAR value for GEOS or GCAP grids. (swu, bmy, 6/24/05)
(61) References ND04, WRITE_DIAG04 from "diag04_mod.f".  Also now updated
      ND30 diagnostic for land/water/ice flags.  Also remove reference
      to LWI array. (bmy, 8/18/05)
(62) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(63) Added MBO as tracer #5 in ND46 diagnostic (tmf, bmy, 10/20/05)
(64) Removed duplicate variable declarations.  Now remove restriction on
      printing out cloud mass flux in GEOS-4 for the ND66 diagnostic.
      (bmy, 3/14/06)
(65) References ND56, WRITE_DIAG56 from "diag56_mod.f" (ltm, bmy, 5/5/06)
(66) Now remove TRCOFFSET; it's obsolete.  References ND42, WRITE_DIAG42
```

```
      from "diag42_mod.f" (dkh, bmy, 5/22/06)
     (67) Updated ND36 diagnostic for CH3I (bmy, 7/25/06)
     (68) Remove support for GEOS-1 and GEOS-STRAT met fields (bmy, 8/4/06)
     (69) Replace TINY(1d0) with 1d-32 to avoid problems on SUN 4100 platform
      (bmy, 9/5/06)
     (70) Now write diag 54 (time in the troposphere) if asked for (phs, 9/22/06)
     (71) Now use new time counters for ND43 & ND45,  Also now average between
      0 and 24 UT for ND47.  Bug fix in ND36. (phs, bmy, 3/5/07)
     (72) Bug fix in ND65: use 3-D counter array (phs, bmy, 3/6/07)
     (73) Bug fix in ND07: now save out IDTSOA4 tracer.  Modifications for H2/HD
      diagnostics (ND10, ND27, ND44) (tmf, phs, bmy, 9/18/07)
     (74) Now save out true pressure at 3-D level edges for ND31.  Change ND31
      diagnostic category name to "PEDGE-$". Bug fix in ND28 diagnostic to
      allow you to print out individual biomass tracers w/o having to print
      all of them. (bmy, dkh, 1/24/08)
     (75) Bug fix: Now divide ALBEDO in ND67 by SCALE_I6 for GEOS-3 met, but
      by SCALE_A3 for all other met types (phs, bmy, 10/7/08)
     (76) Fix ND65, ND47, and ozone case in ND45. Now only ND45 depends
      on LD45 (phs, 11/17/08)
     (77) Bug fix: Select the right index of AD34 to write.  Pick the right
       tracer field from AD22 if only a subset of tracers are requested
       to be printed out. (ccc, 12/15/08)
     (78) Added ND52 for gamma(HO2) (jaegle, 02/26/09)
     (79) Updated test on ship emissions flag for AD13 (phs, 3/3/09)
     (80) Add AD07_SOAGM for dicarbonyl SOA formation (tmf, 3/6/09)
     (81) Add output in AD22 for dicarbonyl photolysis J values (tmf, 3/6/09)
     (82) Add output in AD46 for biogenic C2H4 emissions (tmf, 3/6/09)
     (83) Modify ND17, ND18, ND37, ND38, ND44 to output the tracers selected
      by the user. (ccc, 5/29/09)
     (84) Add EFLUX output information for ND67. (lin, ccc, 5/29/09)
     (85) Add test on ICOADS (cklee, 06/30/09)
     (86) Add SCALE_DIAG to scale diagnostics with the number of accumulation
      steps. (ccc, 7/20/09)
     (87) Add diagnostics 19, 58 and 60 for methane. (kjw, 8/18/09)
     (88) Account for 3D AD13_NH3_an now (phs, 10/22/09)
     (89) Added TOMAS diagnostics (win, bmy, 1/25/10)
     (90) NBIOMAX is now in CMN_SIZE (hotp 7/31/09)
     (91) Add SOA5 to ND07_HC, add AD57 for potential temperature. (fp, 2/3/10)
     (92) Modify ND44 for tracers with several deposition tracers. (ccc, 2/3/10)
     (93) Add aromatics to ND43. (dkh, 06/21/07)
     (94) Add ND57 for potential temperature. (fp, 2/3/10)
     (95) Re-order levels in mass fluxes diagnostics before writing them to file.
      (ND24, 25, 26). (ccc, 3/8/10)
     (96) Add call to update_dep for mercury simulation at the end.(ccc, 7/19/10)
    20 Aug 2010 - R. Yantosca - Added ProTeX headers
    20 Aug 2010 - R. Yantosca - Now pick proper scale for ND66 for MERRA
    20 Aug 2010 - R. Yantosca - Now pick proper scale for ND67 for MERRA
    20 Aug 2010 - R. Yantosca - Now added SCALE_A1 for hourly data
```

```
20 Aug 2010 - R. Yantosca - Now reference GET_A1_TIME from "time_mod.f"
26 May 2011 - R. Yantosca - For ND44, omit the special treatment of
                            isoprene tracers if we are not doing fullchem
27 May 2011 - R. Yantosca - Now use SCALEDIAG for ND54 (time-in-trop) diag
08 Feb 2012 - R. Yantosca - Add modifications for GEOS-5.7.x met
08 Feb 2012 - R. Yantosca - Restructure USE statements for clarity
08 Feb 2012 - R. Yantosca - Add counter for I3 (inst 3hr) met fields
28 Feb 2012 - R. Yantosca - Removed support for GEOS-3
01 Mar 2012 - R. Yantosca - Now use GET_AREA_M2(I,J,L) from grid_mod.F90
05 Apr 2012 - R. Yantosca - Bug fix: use hourly scale for SLP in the
                            ND67 diagnostic for GEOS-5.7.x met fields
14 Mar 2013 - M. Payer    - Replace NOx and Ox with NO, NO2, and O3 as part
                            of removal of NOx-Ox partitioning
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
04 Sep 2013 - R. Yantosca - Make ND44 output consistent w/ modifications in
                            GeosCore/gamap_mod.F.
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
03 Dec 2013 - R. Yantosca - Change unit of PBL height to meters, this used
                            to be hPa in GEOS-1, GEOS-STRAT, GEOS-3, which
                            are no longer supported.
28 Jan 2014 - R. Yantosca - Avoid array temporaries in ND60 TOMAS diagnostic
```

1.120.7 diag_2pm

Subroutine DIAG_2PM constructs the diagnostic flag arrays:

- LTJV: J-values (ND22)
- LTOH: OH concentrations (ND43)
- LTHO2: HO2 concentrations (ND43)
- LTOTH: used for tracers (ND45)

These arrays are either 1 (if it is within a certain time interval) or 0 (if it is not within a certain time interval). The limits of the time intervals for CTOTH and CTJV are now defined in input.geos The arrays CTOTH, CTOH, CTJV count the number of times the diagnostics are accumulated for each grid box (i.e LTOTH is 1)

INTERFACE:

```
SUBROUTINE DIAG_2PM( State_Met )
```

USES:

```
USE DIAG_MOD,           ONLY : LTJV,  CTJV
USE DIAG_MOD,           ONLY : LTOH,  CTOH,  LTOTH, CTOTH
```

```
      USE DIAG_MOD,           ONLY : LTHO2, CTHO2
      USE DIAG_MOD,           ONLY : CTO3_24h
      USE DIAG_MOD,           ONLY : LTLBRO2H, LTLBRO2N
      USE DIAG_MOD,           ONLY : LTLTRO2H, LTLTRO2N
      USE DIAG_MOD,           ONLY : LTLXRO2H, LTLXRO2N
      USE DIAG_MOD,           ONLY : CTLBRO2H, CTLBRO2N
      USE DIAG_MOD,           ONLY : CTLTRO2H, CTLTRO2N
      USE DIAG_MOD,           ONLY : CTLXRO2H, CTLXRO2N
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TIME_MOD,           ONLY : GET_LOCALTIME
      USE TIME_MOD,           ONLY : ITS_TIME_FOR_DIAG
      USE TIME_MOD,           ONLY : ITS_TIME_FOR_CHEM
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_TROP
      USE TIME_MOD,           ONLY : GET_ELAPSED_MIN
      USE TIME_MOD,           ONLY : GET_TS_DIAG

      USE CMN_SIZE_MOD             ! Size parameters
      USE CMN_DIAG_MOD             ! HR_OH1, HR_OH2, etc.

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REMARKS:

```
For now use GET_LOCALTIME( I, 1, 1 ) which will be independent of J and L
for a pure cartesian grid.  This may need to be revisited once G-C is
interfaced into a GCM.
```

REVISION HISTORY:

```
26 Mar 1999 - R. Yantosca - Initial version
(1 ) Now use F90 syntax (bmy, 3/26/99)
(2 ) Now reference LTNO2, CTNO2, LTHO2, CTHO2 arrays from "diag_mod.f".
      Updated comments, cosmetic changes.  (rvm, bmy, 2/27/02)
(3 ) Now removed NMIN from the arg list.  Now use functions GET_LOCALTIME,
      ITS_TIME_FOR_CHEM, ITS_TIME_FOR_DYN from "time_mod.f" (bmy, 2/11/03)
(4 ) Now rewritten using a parallel DO-loop (bmy, 7/20/04)
(5 ) Now account for the time spent in the troposphere for ND43 and ND45
      pure O3.  Now only accumulate counter for 3D pure O3 in ND45 if
      it's a chemistry timestep. (phs, 1/24/07)
(6 ) Added 3D counter for ND65 and O3 in ND47 (phs, 11/17/08)
(7 ) Change re-initialization of ND45: only at the timestep after the
     diagnostics are accumulated. Add ITS_AFTER_DIAG and PREV_TS variables.
     (ccc, 6/12/09)
(8 ) Add LTO3 to accumulate O3 in ND45 at the same place as the
      chemistry (ccc, 7/17/09)
01 Mar 2012 - R. Yantosca - Now use GET_LOCALTIME(I,J,L) from time_mod.F90
```

```
02 Apr 2013 - M. Payer    - Remove code for LTNO, LTNO2, and LTNO3. These
                            are no longer needed because NO, NO2, and NO3
                            are now tracers.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
08 Nov 2013 - M. Sulprizio- Removed CTO3 and LTO3. They are no longer used
                            because O3 is now a tracer.
```

1.120.8 diagoh

Subroutine DIAGOH saves chemical diagnostic quantities for the ND43 chemical diagnostics.

INTERFACE:

```
SUBROUTINE DIAGOH
```

USES:

```
USE DIAG_MOD, ONLY: AD43, LTOH, LTHO2

USE CMN_SIZE_MOD  ! Size parameters
USE CMN_O3_MOD    ! SAVEOH
USE CMN_DIAG_MOD  ! Diagnostic switches & arrays

IMPLICIT NONE
```

REVISION HISTORY:

```
01 May 1998 - R. Yantosca - Initial version
(1 ) Now use F90 syntax for declarations (bmy, 3/29/99)
(2 ) Cosmetic changes (bmy, 3/29/99)
(3 ) AD43 and DIAGCHLORO are now declared allocatable in "diag_mod.f".
     Also eliminate obsolete code. (bmy, 11/29/99)
(4 ) LTNO, LTOH are now allocatable arrays in "diag_mod.f" (bmy, 3/17/00)
(5 ) Don't save OH into STT(:,:,:NTRACER+2) anymore.  The SAVEOH
     array is now used to save OH concentrations for diagnostics.
     Also revised out-of-date comments. (bmy, 4/24/00)
(6 ) Also save out NO2 and HO2 for use w/ the ND43 diagnostic.
     Now also reference LTNO2, LTHO2 arrays from "diag_mod.f".
     Updated comments, cosmetic changes. (rvm, bmy, 2/27/02)
(7 ) Removed obsolete reference to DIAGCHLORO (bmy, 8/2/02)
(8 ) Now save NO3 [molec/cm3] as AD43(:,:,:,5) (bmy, 1/13/03)
(9 ) Corrected typo in comments (bmy, 8/10/09)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
29 Mar 2013 - M. Payer    - Removed NO, NO2, and NO3 from ND43. These are
                            now tracers.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.9 emfossil

Subroutine EMFOSSIL emits fossil fuels into the EMISRR and EMISRRN arrays, which are then passed to SMVGEAR.

INTERFACE:

```
SUBROUTINE EMFOSSIL( I, J, N, NN, IREF, JREF, JSCEN, Input_Opt )
```

USES:

```
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE BRAVO_MOD,          ONLY : GET_BRAVO_ANTHRO, GET_BRAVO_MASK
USE CAC_ANTHRO_MOD,     ONLY : GET_CANADA_MASK,  GET_CAC_ANTHRO
!USE DAO_MOD,           ONLY : IS_WATER
USE DIAG_MOD,           ONLY : AD29,   AD32_an,  AD36
USE EDGAR_MOD,          ONLY : GET_EDGAR_CO,     GET_EDGAR_NOx
USE EDGAR_MOD,          ONLY : GET_EDGAR_TODN
USE EMEP_MOD,           ONLY : GET_EMEP_ANTHRO,  GET_EUROPE_MASK
USE EPA_NEI_MOD,        ONLY : GET_EPA_ANTHRO,   GET_USA_MASK
USE GRID_MOD,           ONLY : GET_AREA_CM2
USE RETRO_MOD,          ONLY : GET_RETRO_ANTHRO
USE C2H6_MOD,           ONLY : GET_C2H6_ANTHRO
USE NEI2005_ANTHRO_MOD, ONLY : GET_NEI2005_ANTHRO
USE NEI2005_ANTHRO_MOD, ONLY : NEI05_MASK => USA_MASK
USE LOGICAL_MOD,        ONLY : LICOADSSHIP !(cklee, 6/30/09)
USE RCP_MOD,            ONLY : GET_RCP_EMISSION

USE STREETS_ANTHRO_MOD, ONLY : GET_SE_ASIA_MASK
USE STREETS_ANTHRO_MOD, ONLY : GET_STREETS_ANTHRO
USE TIME_MOD,           ONLY : GET_TS_EMIS
USE TIME_MOD,           ONLY : GET_DAY_OF_WEEK_LT
USE TIME_MOD,           ONLY : GET_HOUR
USE TRACERID_MOD,       ONLY : IDENO,    IDEO3,    IDEHNO3
USE TRACERID_MOD,       ONLY : IDTCO,    IDTHNO3
USE TRACERID_MOD,       ONLY : IDTC2H6,  IDTNO2
USE VISTAS_ANTHRO_MOD,  ONLY : GET_VISTAS_ANTHRO
USE ICOADS_SHIP_MOD,    ONLY : GET_ICOADS_SHIP !(cklee, 7/09/09)

USE CMN_SIZE_MOD             ! Size parameters
USE COMODE_LOOP_MOD          ! IHOUR
USE CMN_O3_MOD               ! EMISR, EMISRR, etc...
USE CMN_DIAG_MOD             ! Diagnostic switches & arrays

! 10/24/12, ckeller: NOX diurnal scale factors fix:
USE TIME_MOD,           ONLY : GET_LOCALTIME

IMPLICIT NONE
```

INPUT PARAMETERS:

```
   INTEGER, INTENT(IN)   :: I       ! GEOS-Chem longitude index
   INTEGER, INTENT(IN)   :: J       ! GEOS-Chem latitude index
   INTEGER, INTENT(IN)   :: N       ! GEOS-Chem emission species index
   INTEGER, INTENT(IN)   :: NN      ! GEOS-Chem advected tracer index
   INTEGER, INTENT(IN)   :: IREF    ! Offset index I+I0
   INTEGER, INTENT(IN)   :: JREF    ! Offset index J+J0
   INTEGER, INTENT(IN)   :: JSCEN   ! Day index (Sat=1, Sun=2, Weekday=3)
   TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

REMARKS:

In most cases, I0=J0=0, so IREF=I and JREF=J. The offsets I0 and J0 are mostly historical baggage.

NOTE: The source code for ship emissions has been commented out, but left in place. Although PARANOX computes ship emissions in CALCRATE, we may have to disable this for the Grid-Independent model (because we have to have a clean separation between emissions & chemistry).

REVISION HISTORY:

19 Apr 1999 - R. Yantosca - Initial version
(1) Uses the correct seasonal NOx and multi-level NOx (anthroems.f)
(2) Uses anthro scale factors for years since 1985 (from anthroems.f)
(3) Scales emissions based on weekday/weekend (emf_scale.f)
(4) Preserves old sensitivity study cases (emf_scale.f, emissdr.f)
(5) Scales emissions based on time of day (emfossil.f)
(6) Get rid of all GISS and PLUMES code (bmy, 4/19/99)
(7) Now use F90 syntax for declarations, etc. (bmy, 4/19/99)
(8) Now use allocatable arrays for ND29 and ND36 diagnostics.
Also made minor cosmetic changes & updated comments. (bmy, 3/16/00)
(9) Eliminate obsolete code and ND63 diagnostic (bmy, 4/12/00)
(10) Enhance anthropogenic CO emission by 8%, to account for CO production
from oxidation of anthropogenic VOC's (bnd, bmy, 1/2/01)
(11) Comment out scaling by 1.08 for anthro CO (bmy, 2/12/01)
(12) Eliminate obsolete commented-out code (bmy, 4/20/01)
(13) Now use 2% as the enhancment factor for CO instead of 1.08,
according to new jal numbers (bmy, 4/26/01)
(14) Now references "tracerid_mod.f" (bmy, 11/6/02)
(15) Now replaced DXYP(JREF)*1d4 with GET_AREA_CM2(J). Now use function
GET_TS_EMIS() from "time_mod.f" (bmy, 2/11/03)
(16) Now can overwrite existing emissions with EPA/NEI data over the
continental USA if LNEI99=T. Now reference LNEI99 from F90
module "logical_mod.f". Now reference GET_EPA_ANTHRO and
GET_USA_MASK from "epa_nei_mod.f". (rch, rjp, bmy, 11/5/04)
(17) Now references GET_DAY_OF_WEEK from "time_mod.f" to correctly figure
out if this is a weekday or weekend. (bmy, 7/6/05)
(18) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)

```
(19) Now references XNUMOL from "tracer_mod.f" (bmy, 10/25/05)
(20) Now apply EMEP European emissions if necessary.  Remove reference
     to CMN, it's now obsolete. (bdf, bmy, 11/1/05)
(21) Rewrite IF statements to avoid seg fault errors when LEMEP and LNEI99
     are turned off. (bmy, 2/1/06)
(22) Now apply BRAVO Mexican emissions if necessary (rjp, kfb, bmy, 6/26/06)
(23) Now apply EDGAR emissions if necessary.  Also now only do the the
     EDGAR, EPA, EMEP, and BRAVO function calls in the LL=1 block.
     (avd, bmy, 7/10/06)
(24) Now do BRAVO emissions before EPA/NEI99 emissions in order to avoid
     zero emissions in some boxes.  Now add David Streets emissions for
     NOx over SE Asia and CO over just China (yxw, bmy, 8/17/06)
(25) Bug fix: Now only execute EDGAR CO block if the tracer is CO.
     Also, David Streets' CO is now applied over SE ASIA. (bmy, 9/8/06)
(26) Now references ITS_A_TAGCO_SIM from "tracer_mod.f".  Enhance CO prod
     by 18.5% for tagged CO sim here instead of in "tagged_co_mod.f".
     (bmy, 2/14/08)
(27) Use more robust test to only screen out "missing" values in EMEP,
     BRAVO, and David Streets emissions. (avd, phs, bmy, 11/19/08)
(28) Ship NOx is emitted as HNO3+10*O3  (phs, 3/4/08)
(29) Apply spatially-varying diurnal scalars for NOx (amv, 08/24/07)
(30) Now apply CAC Canadian emissions if necessary (amv, 01/09/08)
(31) Moved down BRAVO parts and add BRAVO and EPA emissions where they
     overlap (phs, 5/7/08)
(32) Now overwrite USA NOx with VISTAS if necessary (amv, 12/02/08)
(33) Modified CO scaling (jaf, 2/25/09)
(34) Add a test on existing emissions for EPA/NEI. (hotp, ccc, 5/29/09)
(35) Updated ship treatment (phs, 7/0/09)
(36) Add NEI2005 (amv, phs, 10/20/09)
(37) Bug fix for tagged CO and 0.5 x 0.666 Nested Grid (yxw, bmy, 11/23/09)
(38) Bug fix for array EMISRR, if emissions are already present in this
     array (e.g. ship O3 or HNO3) they no longer get overwritten.
     (gvinken, 11/16/10)
19 Nov 2010 - R. Yantosca - Added ProTeX headers
24 Feb 2012 - M. Payer    - Commented out ship emissions, which has been
                            moved to calcrate.F for PARANOX.  Left original
                            code in place, but commented out.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
22 Mar 2012 - M. Payer    - Update for C2H6. RETRO ethane emissions are too
                            low so we will use Yaping Xiao's offline emiss.
24 Oct 2012 - C. Keller   - Use localtime instead of UTC to derive NOx
                            diurnal scale factors.
14 Mar 2013 - M. Payer    - Replace NOx and Ox emissions with NO and O3
                            emissions as part of removal of NOx-Ox
                            partitioning
18 Apr 2013 - M. Payer    - Convert NOx using XNUMOL for NO2 since original
                            NOx emissions are in mass units of NO2
25 Mar 2013 - R. Yantosca - Now use logical fields from Input_Opt
```

```
14 Jun 2013 - R. Yantosca - Now determine weekday/weekend with respect to
                            the local time at each grid box.  (Formerly,
                            this had been done w/r/t the GMT time.
22 Jul 2013 - M. Sulprizio- Now copy LRCP and LRCPSHIP from Input_Opt
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.10 emf_scale

Subroutine EMF_SCALE does the following:

- Saves original values of EMISR, EMISRN, EMISPN so that they can be restored later (after scaling)
- Scales emissions to weekend or weekday usage (using scale factors stored in the SCNR89 array)

INTERFACE:

```
      SUBROUTINE EMF_SCALE( I,    J,    N,     NN,
     &                      IREF, JREF, JSCEN, XEMISR, XEMISRN )
```

USES:

```
      USE TRACERID_MOD, ONLY : IDTALK4, IDTC3H8, IDTISOP, IDTCO
      USE TRACERID_MOD, ONLY : IDTNO,   IDTO3,   IDTPRPE
      USE TRACERID_MOD, ONLY : IDTMEK,  IDTC2H2, IDTC2H4, IDTACET
      USE TRACERID_MOD, ONLY : IDTBENZ, IDTTOLU, IDTXYLE, IDTC2H6

      USE CMN_SIZE_MOD
      USE COMODE_LOOP_MOD
      USE CMN_O3_MOD

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: I       ! GEOS-Chem longitude index
      INTEGER, INTENT(IN)    :: J       ! GEOS-Chem latitude index
      INTEGER, INTENT(IN)    :: N       ! GEOS-Chem emission species index
      INTEGER, INTENT(IN)    :: NN      ! GEOS-Chem advected tracer index
      INTEGER, INTENT(IN)    :: IREF    ! Offset index I+I0
      INTEGER, INTENT(IN)    :: JREF    ! Offset index J+J0
      INTEGER, INTENT(IN)    :: JSCEN   ! Day index (Sat=1, Sun=2, Weekday=3)
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: XEMISR               ! HC emissions, scaled
      REAL*8,  INTENT(INOUT) :: XEMISRN(NOXLEVELS)   ! NOx emissions, scaled
```

REMARKS:

```
This is historical baggage...we need to clean this up one of these days.
```

REVISION HISTORY:

```
02 Apr 1998 - R. Yantosca - Initial version
(1 ) Use F90 syntax for declarations, etc. (bmy, 4/14/99)
(2 ) Now test with N instead of NN.  N is the emission species, and can
     be equal to zero, which denotes that the species is not emitted.
     This is necessary now, since IDEOX always = 0, but IDTOX is always
     nonzero. (bmy, 4/19/99)
(3 ) Commented out special cases via ICASE.  Also made a few cosmetic
     changes and updated comments. (bmy, 1/2/01)
(4 ) Remove old obsolete commented-out code (bmy, 4/20/01)
(5 ) Now references "tracerid_mod.f" (bmy, 11/6/02)
(6 ) Now references LFFNOX from "logical_mod.f" (bmy, 7/20/04)
(7 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(8 ) Modified to add weekday/weekend scaling to aromatics,
     C2H4, C2H2 (tmf, 1/7/09)
19 Nov 2010 - R. Yantosca - Added ProTeX headers
14 Mar 2013 - M. Payer    - Replace NOx and Ox emissions with NO and O3
                            emissions as part of removal of NOx-Ox
                            partitioning
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.11 fast_j.f

Subroutine FAST_J loops over longitude and latitude, and calls PHOTOJ to compute J-Values for each column at every chemistry time-step.

References:

1. H. Liu, J.H. Crawford, R.B. Pierce, P. Norris, S.E. Platnick, G. Chen, J.A. Logan, R.M. Yantosca, M.J. Evans, C. Kittaka, Y. Feng, and X. Tie, *Radiative effect of clouds on tropospheric chemistry in a global three-dimensional chemical transport model*, J. Geophys. Res., **111**, D20303, doi:10.1029/2005JD006403, 2006. http://research.nianet.org/ hyl/publicatio

INTERFACE:

```
SUBROUTINE FAST_J( am_I_Root, State_Met, RC )
```

USES:

```
USE CMN_SIZE_MOD,       ONLY : IIPAR
USE CMN_SIZE_MOD,       ONLY : JJPAR
USE CMN_SIZE_MOD,       ONLY : LLPAR
USE CMN_SIZE_MOD,       ONLY : NDUST
USE CMN_SIZE_MOD,       ONLY : MAXIJ
USE CMN_SIZE_MOD,       ONLY : NAER
```

```
      USE CMN_SIZE_MOD,       ONLY : NRH
      USE CMN_FJ_MOD,         ONLY : JPMAX
      USE CMN_FJ_MOD,         ONLY : JPPJ
      USE JV_CMN_MOD,         ONLY : NB
      USE JV_CMN_MOD,         ONLY : ODAER
      USE JV_CMN_MOD,         ONLY : ODMDUST
      USE JV_CMN_MOD,         ONLY : PJ
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE ERROR_MOD,          ONLY : ALLOC_ERR
      USE GIGC_ErrCode_Mod
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE GRID_MOD,           ONLY : GET_YMID
      USE PRESSURE_MOD,       ONLY : GET_PEDGE
      USE TIME_MOD,           ONLY : GET_MONTH
      USE TIME_MOD,           ONLY : GET_DAY
      USE TIME_MOD,           ONLY : GET_DAY_OF_YEAR
      USE TIME_MOD,           ONLY : GET_TAU
      USE TIME_MOD,           ONLY : GET_YEAR
      USE TOMS_MOD,           ONLY : GET_OVERHEAD_O3

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      ! Is this the root CPU?
      LOGICAL,        INTENT(IN)  :: am_I_Root

      ! Meteorology State object
      TYPE(MetState), INTENT(IN)  :: State_Met
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT) :: RC
```

REMARKS:

```
    Parameter to choose cloud overlap algorithm:
    ============================================================================
    (1 ) OVERLAP (INTEGER) : 1 - Linear Approximation (used up to v7-04-12)
                             2 - Approximate Random Overlap (default)
                             3 - Maximum Random Overlap (computation intensive)
```

REVISION HISTORY:

```
    01 Apr 1998 - P. Murti, R. Martin, R. Yantosca - Initial version
    (1 ) Call this routine EACH chemistry time-step, before solver.
    (2 ) This routine must know IMAX, JMAX, LMAX.
    (3 ) Now use new !$OMP compiler directives for parallelization (bmy, 5/2/00)
    (4 ) Now reference "cmn_fj.h" and "jv_cmn.h" for the aerosol
         optical depths (bmy, 10/2/00)
    (5 ) Add OPTDUST as a local variable -- make OPTDUST private for
```

```
      the parallel DO-loop, since it stores 1 column of aerosol optical
      depth for each dust type (bmy, rvm, 10/2/00)
(6 ) For now, LPAR in "cmn_fj.h" = LGLOB in "CMN_SIZE".  Therefore we
      assume that we are always doing global runs. (bmy, 10/2/00)
(7 ) Removed obsolete code from 10/2/00 (bmy, 12/21/00)
(8 ) Replace {IJL}GLOB w/ IIPAR,JJPAR,LLPAR everywhere.  Also YLMID(NLAT)
      needs to be referenced by YLMID(NLAT+J0). (bmy, 9/26/01)
(9 ) Remove obsolete code from 9/01.  Updated comments. (bmy, 10/24/01)
(10) Add OPTAER as a local variable, make it private for the parallel
      DO loop, since it stores 1 column of aerosol optical depths for each
      aerosol type.  Pass OPTAER to PHOTOJ via the argument list.  Declare
      OPTAER as PRIVATE for the parallel DO-loop. (rvm, bmy, 2/27/02)
(11) Now reference GET_PEDGE from "pressure_mod.f", which returns the
      correct "floating" pressure. (dsa, bdf, bmy, 8/20/02)
(12) Now reference T from "dao_mod.f" (bmy, 9/23/02)
(13) Now uses routine GET_YMID from "grid_mod.f" to compute grid box
      latitude.  Now make IDAY, MONTH local variables.  Now use function
      GET_DAY_OF_YEAR from "time_mod.f".  Bug fix: now IDAY (as passed to
      photoj.f) is day of year rather than cumulative days since Jan 1,
      1985. (bmy, 2/11/03)
(14) Now reference routine GET_YEAR from "time_mod.f".  Added LASTMONTH
      as a SAVEd variable.  Now call READ_TOMSO3 from "toms_mod.f" at the
      beginning of a new month (or the first timestep) to read TOMS O3
      columns which will be used by "set_prof.f".  Now also reference
      routine GET_DAY from "time_mod.f".  Rename IDAY to DAY_OF_YR. Pass
      day of month to PHOTOJ.  Updated comments, cosmetic changes.
      (bmy, 7/17/03)
(15) Bug fix: PRES needs to be the true surface pressure for GEOS-4, but
      PS-PTOP for all prior GEOS models.  (bmy, 2/6/04)
(16) Now account for cloud overlap (Maximum-Random Overlap and Random
      Overlap) in each column (hyl, phs, bmy, 9/18/07)
(17) Now initialize the PJ array here, instead of two layers below in
      "set_prof.f".  Now no longer pass PRES to "photoj.f". (bmy, 11/29/07)
(18) Now switch to approx. random overlap option (hyl, phs, bmy, 10/7/08)
(19) Now can handle GEOS-5 reprocessed met data with OPTDEPTH being
      in-cloud optical depths. (bmy, hyl, 10/24/08)
(10) Remove references to IN_CLOUD_OD (bmy, 10/15/09)
13 Aug 2010 - R. Yantosca - Added ProTeX headers
13 Aug 2010 - R. Yantosca - Treat MERRA in the same way as GEOS-5
08 Feb 2012 - R. Yantosca - Treat GEOS-5.7.x in the same way as MERRA
01 Mar 2012 - R. Yantosca - Now use GET_YMID(I,J,L) from grid_mod.F90
06 Mar 2012 - R. Yantosca - Now call GET_OVERHEAD_O3 to get the total
                            overhead O3 column for FAST-J
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
10 Aug 2012 - R. Yantosca - Replace IPAR, JPAR, LPAR w/ IIPAR, JJPAR, LLPAR
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
```

```
27 Nov 2012 - R. Yantosca - Cosmetic changes
27 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOSmid field
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
26 Sep 2013 - R. Yantosca - Renamed GEOS_57 Cpp switch to GEOS_FP
```

1.120.12 gasconc

Subroutine GASCONC initializes gas concentrations for SMVGEAR II.

INTERFACE:

```
      SUBROUTINE GASCONC( am_I_Root, FIRSTCHEM, READ_CSPEC,
     &                    Input_Opt, State_Met, State_Chm,  RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE COMODE_LOOP_MOD
      USE COMODE_MOD,          ONLY : ABSHUM
      USE COMODE_MOD,          ONLY : AIRDENS
      USE COMODE_MOD,          ONLY : CSPEC
      USE COMODE_MOD,          ONLY : IXSAVE
      USE COMODE_MOD,          ONLY : IYSAVE
      USE COMODE_MOD,          ONLY : IZSAVE
      USE COMODE_MOD,          ONLY : JLOP
      USE COMODE_MOD,          ONLY : PRESS3
      USE COMODE_MOD,          ONLY : T3
      USE DRYDEP_MOD,          ONLY : NUMDEP
      USE ERROR_MOD,           ONLY : ERROR_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PRESSURE_MOD,        ONLY : GET_PCENTER
      USE TROPOPAUSE_MOD,      ONLY : COPY_FULL_TROP
      USE TROPOPAUSE_MOD,      ONLY : ITS_IN_THE_TROP
      USE TROPOPAUSE_MOD,      ONLY : SAVE_FULL_TROP

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root       ! Is this the root CPU?
      LOGICAL,        INTENT(IN)    :: FIRSTCHEM       ! First-time flag
      LOGICAL,        INTENT(IN)    :: READ_CSPEC      ! Is
      TYPE(OptInput), INTENT(IN)    :: Input_Opt       ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met       ! Met State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm       ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC              ! Success or failure?
```

REMARKS:

```
!------------------------------------------------------------------------
!------------       WRITTEN BY MARK JACOBSON (1991-4)     ------------
!---            (C) COPYRIGHT, 1991-4 BY MARK Z. JACOBSON          ---
!---                          (650) 723-6836                       ---
!------------------------------------------------------------------------
!   GGGGGG      A       SSSSSS   CCCCCC   OOOOO   N     N   CCCCCC
!  G           A A     S        C        O     O  N N   N  C
!  G  GGGG    A   A    SSSSSSS  C        O     O  N  N  N  C
!  G     G   AAAAAAA         S  C        O     O  N   N N  C
!   GGGGGG  A       A  SSSSSS    CCCCCC   OOOOO   N     N   CCCCCC
!------------------------------------------------------------------------
!------       INITIALIZE GAS CONCENTRATIONS IN THE MODEL        ------
!-----------       AND SET MISCELLANEOUS PARAMETERS         -----------
!------------------------------------------------------------------------

!------------------------------------------------------------------------
! SET THE CONCENTRATION  (# CM-3) OF ACTIVE AND INACTIVE GASES      !
!------------------------------------------------------------------------

NTLOOP    = NUMBER OF GRID-CELLS IN THE ENTIRE GRID-DOMAIN
NTSPECGAS = NUMBER OF ACTIVE PLUS INACTIVE GASES
NVERT     = NUMBER OF VERTICAL LAYERS.
QBKGAS    = INITIAL BACKGROUND CONCENTRATION (VOL MIXING RATIO)
RHO3      = G-AIR CM-3-AIR
C(GAS)    = GAS CONCENTRATION IN A GIVEN GRID-CELL (# CM-3)
```

REVISION HISTORY:

```
 03 Jan 1997 - M. Jacobson - Initial version
 (1 ) Now reference ABSHUM, AIRDENS, CSPEC, IXSAVE, IYSAVE, IZSAVE,
      PRESS3, T3 from "comode_mod.f".  Also now references tracer ID flags
      from "tracerid_mod.f".  Also removed code that is not needed for
      GEOS-CHEM.  Now also force double precision with "D" exponents.
      (bdf, bmy, 4/18/03)
 (2 ) Remove IRUN -- it's obsolete.  Remove obsolete variables from
      documentation. (bmy, 7/16/03)
 (3 ) Now dimension args XNUMOL, STT w/ NTRACER and not NNPAR (bmy, 7/20/04)
 (4 ) Now remove LPAUSE from the arg list.  Now references ITS_IN_THE_TROP
      from "tropopause_mod.f". (bmy, 8/22/05)
 (5 ) Now make sure all USE statements are USE, ONLY.  Also remove
      reference to TRACERID_MOD, it's not needed. (bmy, 10/3/05)
```

```
(6 ) Now zero out the isoprene oxidation counter species (dkh, bmy, 6/1/06)
(7 ) Now take care of variable tropopause case.  Also set NCS=NCSURBAN
     (=1) instead of hardwiring it. (bdf, phs, 10/16/06)
(8 ) Now use NUMDEP instead of NDRYDEP(NCS) for the loop limit over drydep
     species.  NDRYDEP is the # of rxns in "globchem.dat", and NUMDEP is
     the # of drydep species in GEOS-Chem.  The two values may not be the
     same. (dbm, phs, 11/19/08)
(9 ) Add READ_SPEC in argument list (hotp, 2/26/09)
(10) Now CSPEC_FULL IS copied to CSPEC depending on
    the READ_CSPEC value. (hotp, 2/26/09)
(11) For SOA add check for LxRO2y species in globchem.dat and initialise.
    (dkh, 03/12/10)
18 Oct 2011 - M. Payer    - Do not overwrite CSPEC with CSPEC_FULL prior
                            to partitioning (D. Henze)
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
30 Jul 2012 - R. Yantosca - Added ProTeX headers
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LSOA and Input_Opt%LVARTROP
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
25 Mar 2013 - R. Yantosca - Now get XNUMOL, N_TRACERS from Input_Opt
13 Aug 2013 - M. Sulprizio- Add modifications for updated SOA and SOA +
                            semivolatile POA simulations (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.13 jratet

Subroutine JRATET calculates and prints J-values. Note that the loop in this routine only covers the jpnl levels actually needed by the CTM.

INTERFACE:

```
SUBROUTINE JRATET( T, IDAY )
```

USES:

```
USE FJX_ACET_MOD

USE CMN_FJ_MOD,   ONLY : JPMAX, JPPJ, JPNL
USE CMN_SIZE_MOD, ONLY : LLPAR
USE JV_CMN_MOD

IMPLICIT NONE
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: T(LLPAR)   ! Temperature [K]
INTEGER, INTENT(IN) :: IDAY       ! Day of year (0-365 or 0-366)
```

REMARKS:

```
FFF    Actinic flux at each level for each wavelength bin
QQQ    Cross sections for species (read in in RD_TJPL)
SOLF   Solar distance factor, for scaling; normally given by:
                 1.0-(0.034*cos(real(iday-172)*2.0*pi/365.))
TQQ    Temperatures at which QQQ cross sections supplied
```

REVISION HISTORY:

```
       1997 - O. Wild     - Initial version
(1 ) Added a pressure-dependancy function selector 'pdepf'
     in 'jv_spec.dat'. (tmf, 1/7/09)
(2 ) Added pressure dependency for MGLY. (tmf, 1/7/09)
(3 ) Updated pressure dependency algorithm for ACET. (tmf, 1/7/09)
(4 ) Added pressure dependancy for MeCOVi, EtCOMe, MeCOCHO. Rewritten
     pressure dependancy for Acetone according to FAST-JX v6.4.
     See more detailed documentation for Acetone in fjx_acet_mod.f.
     (ccc, 4/20/09)
25 Aug 2011 - R. Yantosca - Rewrite IF statement to prevent PF from
                            never being initialized.
31 Jul 2012 - R. Yantosca - Added ProTeX headers
10 Aug 2012 - R. Yantosca - Replace LPAR with LLPAR
```

1.120.14 jvalue

subroutine JVALUE calculates the actinic flux at each level for the current solar zenith angle.

INTERFACE:

```
SUBROUTINE JVALUE( SA, am_I_Root )
```

USES:

```
USE CMN_FJ_MOD,   ONLY : JPMAX, JPPJ, JPNL
USE CMN_SIZE_MOD, ONLY : LLPAR
USE JV_CMN_MOD

IMPLICIT NONE
```

INPUT PARAMETERS:

```
REAL*8,  INTENT(IN) :: SA          ! Surface albedo [unitless]
LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REMARKS:

```
-----------------------------------------------------------------------
      quit when SZA > 98.0 deg ==> tangent height = 63 km
```

```
            or         99.                          80 km
 ------------------------------------------------------------------------
   AVGF   Attenuation of beam at each level for each wavelength
   FFF    Actinic flux at each desired level
   WAVE   Effective wavelength of each wavelength bin
   XQO2   Absorption cross-section of O2
   XQO3   Absorption cross-section of O3
```

REVISION HISTORY:

```
         1997 - O. Wild     - Initial version
   30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                               running with the traditional driver main.F
   31 Jul 2012 - R. Yantosca - Added ProTeX headers
   10 Aug 2012 - R. Yantosca - Replace LPAR with LLPAR
   20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.15 jv_index

Subroutine JV_INDEX computes the mapping between the CTM indices (from "globchem.dat") for J-values to the FAST-J indices (from "ratj.d") for J-values. (bmy, 10/5/98, 4/27/10)

INTERFACE:

```
      SUBROUTINE JV_INDEX( am_I_Root )
```

USES:

```
      USE CMN_SIZE_MOD
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ  ! F77_CMN_SIZE
      USE CMN_FJ_MOD, ONLY : RINDEX, RNAMES, BRANCH
      USE COMODE_LOOP_MOD  ! SMVGEAR II arrays

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REVISION HISTORY:

```
   05 Oct 1998 - R. Yantosca - Initial version
   (1 ) Assumes the ordering of a species with several branches in
        "ratj.d" is the same as in "chem.dat".
   (2 ) Updated comments, cosmetic changes (bmy, 11/15/01)
   (3 ) NAMESPEC is now NAMEGAS for SMVGEAR II.   We don't need to reference
        CMN anymore. Now loop from NCS = 1..NCSGAS (bdf, bmy, 4/8/03)
   (4 ) Now reset NCS to NCSURBAN after loop (dbm, bmy, 10/16/06)
```

```
(5 ) Increase species name length (fp, 6/09)
(6 ) Change "Harvard #" to "GEOS-Chem #" in output (bmy, 4/27/10)
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
30 Jul 2012 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.16 initialize

Subroutine INITIALIZE does the following:

1. Zeroes globally defined GEOS-CHEM variables.
2. Zeroes accumulating diagnostic arrays.
3. Resets certain year/month/day and counter variables used in GEOS-Chem diagnostic subroutines.

INTERFACE:

```
SUBROUTINE INITIALIZE( IFLAG, am_I_Root )
```

USES:

```
! Modules from Headers subdirectory
USE CMN_SIZE_MOD
USE CMN_DIAG_MOD
USE ERROR_MOD
USE TIME_MOD

! Modules from GeosCore subdirectory
USE DIAG_MOD
USE DIAG03_MOD
USE DIAG04_MOD
USE DIAG41_MOD
USE DIAG42_MOD
USE DIAG53_MOD
USE DIAG56_MOD
USE DIAG_PL_MOD
USE LOGICAL_MOD

IMPLICIT NONE
```

INPUT PARAMETERS:

```
! If IFLAG=1, zero global CTM arrays
! If IFLAG=2, zero accumulating diagnostic arrays
! If IFLAG=3, zero accumulating diagnostic counters
INTEGER, INTENT(IN)  :: IFLAG

! Is this the root CPU?
LOGICAL, INTENT(IN) :: am_I_Root
```

REMARKS:

```
Eventually we will fold this into "diag_mod.f" in a cleaner,
 more consistent fashion.  Think about this later (bmy, 11/14/02)
```

REVISION HISTORY:

```
15 Jun 1998 - M. Prather  - Initial version
(1 ) INITIALIZE is written in Fixed-Form Fortran 90.
(2 ) To ensure double precision accuracy, use 0d0 instead of 0.0.
(3 ) Also zero the mass flux arrays from TPCORE (bmy, 4/26/99)
(4 ) Only zero allocatable arrays that are turned on. (bmy, 11/29/99)
(5 ) Added arrays for ND13 diagnostic -- sulfur emissions.
      Also updated comments (bmy, 6/21/00)
(6 ) Remove SAVEJ and SAVEL -- we don't call DIAG0 anymore (bmy, 9/8/00)
(7 ) Add array AD32_bf for ND32 NOx biofuel diagnostic (bmy, 9/12/00)
(8 ) Also zero the FAMPL array for ND65 (bmy, 12/5/00)
(9 ) Now initialize AD34 array for biofuel emissions (bmy, 3/15/01)
(10) Now initialize AD12 array for boundary layer emissions in "setemis.f".
      Also made cosmetic changes & updated comments. (bdf, bmy, 6/15/01)
(11) Now initialize AD11 array for acetone diagnostic (bmy, 8/1/01)
(12) Remove reference to AVGF -- it is obsolete.  Also, AVGW is now
      included in "dao_mod.f", and is initialized there. (bmy, 9/25/01)
(13) Removed obsolete code from 9/01 (bmy, 10/24/01)
(14) Make sure FAMPL is allocated before we reference it (bmy, 1/15/02)
(15) Eliminated obsolete code from 1/02.  Now also zero CTNO2, CTHO2
      counter arrays. (bmy, 2/27/02)
(16) Bug fix: CTHO2 and CTNO2 should be zeroed if ND43 > 0, not if
      ND45 > 0.  Fix this typo. (bmy, 4/19/02)
(17) Now also zero AD01, AD02 arrays (bmy, 8/7/02)
(18) Remove reference to arrays P, SIG, SIGE from "CMN", since we now
      use floating pressure + the hybrid grid. (dsa, bdf, bmy, 8/21/02)
(19) Now zero the AD05 array for sulfate P-L (rjp, bdf, bmy, 9/20/02)
(20) Now we no longer have to zero the T array.  Also reference ERROR_STOP
      from "error_mod.f". Now also initialize AD13_NH3_an, AD13_NH3_bb,
      AD13_NH3_bf. (bmy, 12/13/02)
(21) Now also zero AD13_NH3_na array for ND13 (rjp, bmy, 3/23/03)
(22) Now references "time_mod.f" (bmy, 3/27/03)
(23) Now zeroes AD03 array for Kr85 prod/loss diag. (jsw, bmy, 8/20/03)
(24) Now also zeroes AD06 and AD07* arrays (rjp, tdf, bmy, 4/5/04)
(25) Now also zeroes AD08 array (rjp, bec, bmy, 4/20/04)
(26) Now also initialize AD13_SO2_sh array (bec, bmy, 5/20/04)
(27) Now also initialize AD07_HC array (rjp, bmy, 7/13/04)
(28) Now references AD65 & FAM_PL from "diag_pl_mod.f".  Now remove
      reference to DIAGCHLORO, it's obsolete. (bmy, 7/20/04)
(29) Now initialize extra arrays for ND03 mercury diag.  Also remove
      reference to obsolete TOFDY0 variable. (eck, bmy, 12/7/04)
(30) Now initialize AD21_cr array for ND21 diag.  Also references
```

```
      LCRYST from "logical_mod.f"  Now call ZERO_DIAG03 from "diag03_mod.f"
      to zero ND03 arrays (bmy, 1/21/05)
(31) Now call ZERO_DIAG41 from "diag41_mod.f".  Also removed references
      to AD41 and AFTTOT. (bmy, 2/17/05)
(32) Now zero AD09 and AD09_em for HCN simulation (xyp, bmy, 6/27/05)
(33) Now references ND04, ZERO_DIAG04 from "diag04_mod.f".  Also remove
      reference to "CMN" and XTRA2.  Now zeroes AD30 array (bmy, 8/18/05)
(34) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(35) Now resets SET_CT_XTRA at the beginning of the run. (tmf, 10/20/05)
(36) Now references ND56, ZERO_DIAG56 from "diag56_mod.f" (ltm, bmy, 5/5/06)
(37) Now references ND42, ZERO_DIAG42 from "diag42_mod.f" (dkh, bmy,5/22/06)
(38) take care of AD54 (time in the troposphere diagnostic) (phs, 10/17/06)
(39) Now also zero CTO3 array.  Bug fix: ZERO_DIAG42 is now called when
      ND42 is turned on. (phs, bmy, 1/30/07)
(40) Now zero AD10 and AD10em for H2HD simulation (phs, 9/18/07)
(41) Now zero CTO3_24h (phs, 11/17/08)
(42) Now zero AD52 for Gamma HO2 diag. (ccc, jaegle, 2/26/09)
(43) Updated to diagnose GLYX production of SOAG in ND07. (tmf, 1/7/09)
(44) Add initialization of counter for diag time steps. (ccc, 7/20/09)
(45) Define new diagnostics, ND19, ND58, ND60 for methane
     (kjw, 8/18/09)
(46) Add ND59 and ND60 for initialization (win, 7/28/09)
(47) Add potential temperature diagnostic. (fp, 06/09)
(48) Add TOMAS diags using ifdefs. (sfarina, 01/13)
25 Aug 2010 - R. Yantosca - Added ProTeX headers
25 Aug 2010 - R. Yantosca - Now also reset the counter for A1 timesteps
08 Feb 2012 - R. Yantosca - Rewrote USE statements, for clarity
08 Feb 2012 - R. Yantosca - Now also reset the counter for I3 timesteps
15 Oct 2012 - R. Yantosca - Bug fix, make sure Counter arrays CTLBRO2H etc.
                            are allocated before we use them
02 Apr 2013 - M. Payer    - Remove code for CTNO, CTNO2, and CTNO3. These
                            are no onger needed because NO, NO2, and NO3
                            are now tracers.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
08 Nov 2013 - M. Sulprizio- Removed CTO3. It is no longer used because O3
                            is now a tracer.
```

1.120.17 inphot

Subroutine INPHOT initializes quantities for FAST-J photolysis, including JPL spectral data (e.g. cross sections, quantum yields), standard O3 and T profiles, and the translation indices between GEOS-Chem and FAST-J species names.

INTERFACE:

```
SUBROUTINE INPHOT( NLAYER, NREACS, Input_Opt, am_I_Root )
```

USES:

```
      USE ERROR_MOD,          ONLY : ERROR_STOP
      USE CMN_FJ_MOD,         ONLY : JPMAX, JPPJ, JPNL
      USE CMN_SIZE_MOD,       ONLY : LLPAR
      USE JV_CMN_MOD
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE inquireMod,         ONLY : findFreeLUN

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER,        INTENT(IN) :: NLAYER    ! # of layers for FAST-J photolysis
      INTEGER,        INTENT(IN) :: NREACS    ! # of FAST-J photolysis reactions
      LOGICAL,        INTENT(IN) :: am_I_Root ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN) :: Input_Opt ! Input Options
```

REVISION HISTORY:

```
    01 Apr 1999 - O. Wild     - Initial version
    (1 ) Remove PTOP from the arg list, since it is now a
         parameter in "CMN_SIZE" (bmy, 2/10/00).
    (2 ) Remove SIGE from the argument list, since we are now using
         a hybrid pressure specification.  Now define ETAA and ETAB
         for use in "set_prof.f". (bmy, 8/23/02)
    (3 ) Now reference ERROR_STOP from "error_mod.f".  Updated comments and
         made cosmetic changes (bmy, 10/15/02)
    (4 ) Remove IPH -- now use IU_FASTJ directly (bmy, 4/8/03)
    (5 ) Removed ETAA and ETAB arrays.  We now compute PJ directly from the
         GET_PEDGE routine.  Also remove reference to "pressure_mod.f".
         Updated comments. (bmy, 10/30/07)
    (6 ) Read jv_spec_aod.dat file for AOD diagnostics. (clh, bmy, 5/10/10)
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
    30 Jul 2012 - R. Yantosca - Added ProTeX headers
    30 Jul 2012 - R. Yantosca - Now add LUN as a local variable
    01 Aug 2012 - R. Yantosca - Add reference to findFreeLUN from inqure_mod.F90
    03 Aug 2012 - R. Yantosca - Move calls to findFreeLUN out of DEVEL block
    07 Aug 2012 - R. Yantosca - Now print LUN used to open file
    26 Feb 2013 - M. Long     - Now accept Input_Opt as an argument
    19 Mar 2013 - R. Yantosca - When using ESMF interface to GEOS-5, append
                                ".rc" to filenames (instead of ___.rc)
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.18 lump

Subroutine LUMP takes individual chemistry species and "lumps" them back into tracers after each SMVGEAR chemistry timestep.

INTERFACE:

```
SUBROUTINE LUMP( am_I_Root, Input_Opt, State_Chm, RC  )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_MOD,         ONLY : CSPEC,  JLOP,    VOLUME
USE COMODE_LOOP_MOD
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Chm_Mod, ONLY : ChmState
USE TRACERID_MOD,       ONLY : IDTRMB, NMEMBER, CTRMB

IMPLICIT NONE
```

INPUT PARAMETERS:

```
LOGICAL,        INTENT(IN)    :: am_I_Root   ! Are we on the root CPU?
TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
```

INPUT/OUTPUT PARAMETERS:

```
TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REVISION HISTORY:

```
01 Apr 2003 - R. Yantosca - Initial version
(1 ) Updated comments, cosmetic changes (bmy, 4/1/03)
(2 ) Added OpenMP parallelization commands (bmy, 8/1/03)
(3 ) Now dimension args XNUMOL, STT w/ NTRACER and not NNPAR (bmy, 7/20/04)
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
30 Jul 2012 - R. Yantosca - Added ProTeX headers
25 Mar 2013 - M. Payer    - Now pass State_Chm object via the arg list
25 Mar 2013 - R. Yantosca - Now accept am_I_Root, Input_Opt, RC\
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.19 ndxx_setup

Subroutine NDXX_SETUP dynamically allocates memory for certain diagnostic arrays that are declared allocatable in "diag_mod.f".

This allows us to reduce the amount of memory that needs to be declared globally. We only allocate memory for arrays if the corresponding diagnostic is turned on.

INTERFACE:

```
      SUBROUTINE NDXX_SETUP( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE BIOFUEL_MOD,     ONLY : NBFTRACE
      USE CMN_DIAG_MOD
      USE CMN_SIZE_MOD
      USE DIAG_MOD,        ONLY : AD01,         AD02,         AD05
      USE DIAG_MOD,        ONLY : AD06,         AD07,         AD07_BC
      USE DIAG_MOD,        ONLY : AD07_OC,      AD07_HC,      AD08
      USE DIAG_MOD,        ONLY : AD07_SOAGM
      USE DIAG_MOD,        ONLY : AD09,         AD09_em,      AD11
      USE DIAG_MOD,        ONLY : AD12,         AD13_DMS,     AD13_SO2_ac
      USE DIAG_MOD,        ONLY : AD13_SO2_an,  AD13_SO2_bb,  AD13_SO2_bf
      USE DIAG_MOD,        ONLY : AD13_SO2_ev,  AD13_SO2_nv,  AD13_SO4_an
      USE DIAG_MOD,        ONLY : AD13_SO4_bf,  AD13_SO2_sh,  AD13_NH3_an
      USE DIAG_MOD,        ONLY : AD13_NH3_na,  AD13_NH3_bb,  AD13_NH3_bf
      USE DIAG_MOD,        ONLY : CONVFLUP,     TURBFLUP,     AD16
      USE DIAG_MOD,        ONLY : CT16,         AD17,         CT17
      USE DIAG_MOD,        ONLY : AD18,         CT18,         AD21
      USE DIAG_MOD,        ONLY : AD21_cr,      AD22,         LTJV
      USE DIAG_MOD,        ONLY : CTJV,         MASSFLEW,     MASSFLNS
      USE DIAG_MOD,        ONLY : MASSFLUP,     AD28,         AD29
      USE DIAG_MOD,        ONLY : AD30,         AD31
      USE DIAG_MOD,        ONLY : AD57
      USE DIAG_MOD,        ONLY : AD32_ac,      AD32_an,      AD32_bb
      USE DIAG_MOD,        ONLY : AD32_bf,      AD32_fe,      AD32_li
      USE DIAG_MOD,        ONLY : AD32_so,      AD32_ub,      AD33
      USE DIAG_MOD,        ONLY : AD32_SHIP,    AD32_SHIP_COUNT
      USE DIAG_MOD,        ONLY : AD34,         AD35,         AD36
      USE DIAG_MOD,        ONLY : AD36_SHIP,    AD36_SHIP_COUNT
      USE DIAG_MOD,        ONLY : AD37,         AD38,         AD39
      USE DIAG_MOD,        ONLY : AD43
      USE DIAG_MOD,        ONLY : LTOH,         CTOH
      USE DIAG_MOD,        ONLY : LTHO2,        CTHO2
      USE DIAG_MOD,        ONLY : CTLBRO2H,     CTLBRO2N
      USE DIAG_MOD,        ONLY : CTLTRO2H,     CTLTRO2N
      USE DIAG_MOD,        ONLY : CTLXRO2H,     CTLXRO2N
      USE DIAG_MOD,        ONLY : LTLBRO2H,     LTLBRO2N
      USE DIAG_MOD,        ONLY : LTLTRO2H,     LTLTRO2N
      USE DIAG_MOD,        ONLY : LTLXRO2H,     LTLXRO2N
      USE DIAG_MOD,        ONLY : AD44,         AD45,         LTOTH
      USE DIAG_MOD,        ONLY : CTOTH,        AD46,         AD47
      USE DIAG_MOD,        ONLY : AD52,         AD54,         AD63
      USE DIAG_MOD,        ONLY : AD63_COUNT
      USE DIAG_MOD,        ONLY : AD19,         AD58,         AD60

#if   defined( TOMAS )
      USE DIAG_MOD,        ONLY : AD59_NUMB,    AD59_SULF,    AD59_SALT  !(win, 7/9/09)
```

```
      USE DIAG_MOD,        ONLY : AD59_ECIL,   AD59_ECOB               !(win, 7/9/09)
      USE DIAG_MOD,        ONLY : AD59_OCIL,   AD59_OCOB,   AD59_DUST  !(win, 7/9/09)
      USE DIAG_MOD,        ONLY : AD60_COND,   AD60_COAG,   AD60_NUCL  !(win, 7/9/09)
      USE DIAG_MOD,        ONLY : AD60_AQOX,   AD60_ERROR,  AD60_SOA   !(win, 7/9/09)
      USE DIAG_MOD,        ONLY : AD61,        AD61_INST               !(win, 7/9/09)
#endif

      USE DIAG_MOD,        ONLY : AD55,        AD66,        AD67
      USE DIAG_MOD,        ONLY : AD68,        AD69
      USE DIAG_MOD,        ONLY : AD10,        AD10em,      CTO3_24h
      USE DIAG63_MOD,      ONLY : DO_SAVE_DIAG63
      USE DIAG_OH_MOD,     ONLY : INIT_DIAG_OH
      USE DRYDEP_MOD,      ONLY : NUMDEP
      USE ERROR_MOD,       ONLY : ALLOC_ERR,   ERROR_STOP
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PLANEFLIGHT_MOD, ONLY : SETUP_PLANEFLIGHT
      USE TRACERID_MOD,    ONLY : NEMANTHRO
      USE WETSCAV_MOD,     ONLY : GET_WETDEP_NMAX

#if   defined( TOMAS )
      USE TOMAS_MOD,       ONLY : IBINS, ICOMP, IDIAG   !(win, 7/9/09)
      USE TRACERID_MOD,    ONLY : IDTNK1    !(win, 7/14/09)
#endif

#if   defined( APM )
      USE DIAG_MOD,        ONLY : AD07_OM
      USE TRACER_MOD,      ONLY : N_APMTRA
#endif

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)     :: am_I_Root
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(OptInput), INTENT(INOUT)  :: Input_Opt
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)    :: RC
```

REVISION HISTORY:

```
    16 Jun 1998 - I. Bey, R. Yantosca - Initial version
    (1 ) This subroutine was split off from subroutine INPUT, for clarity
    (2 ) Added call to READ49 (bey, 2/99)
```

```
(3 ) Eliminate GISS-Specific code, and AIJ, AIL diagnostics (bmy, 3/15/99)
(4 ) Define tracer offset TRCOFFSET for "alternate chemistry" runs.
(5 ) Multi-level diagnostics ND21, ND22, ND43, ND45, ND66, and ND68 have
     now been split off from the AIJ arrays (bmy, 3/29/99)
(6 ) Added code for ND14 and ND15.  Also eliminated obsolete code
     and updated comments (bmy, 11/10/99)
(7 ) Added new ND41 and ND51 diagnostics (from amf).  Freed up obsolete
     diagnostics ND34. ND37, and ND42 and updated comments. (bmy, 11/15/99)
     Also note: ND41 uses allocatable array AD41. (bmy, 12/6/99)
(8 ) The following diagnostic arrays are now declared allocatable
     in "diag_mod.f": AD21, AD22, AD38, AD39, AD43, AD45, AD47,
     AD66, AD68, CONVFLUP, TURBFLUP, MASSFLEW, MASSFLNS, MASSFLUP, TCOBOX
     Allocate memory for these arrays only if their respective
     diagnostic is turned on.  This will save memory. (bmy, 11/29/99)
(9 ) Added ND55 diagnostic for tropopause heights (hyl, bmy, 12/1/99)
(10) ND50 and ND20 now have dynamically allocatable arrays. (bmy, 1/5/00)
(11) ND27 diagnostic now also turns on ND24, ND25, ND26 (bmy, 1/7/00)
(12) ND31, ND33, ND35, ND37, ND67, and ND69 now use dynamically
     allocatable arrays declared in "diag_mod.f". (bmy, 2/17/00)
(13) ND16, ND17, ND18 now use allocatable arrays.  Also now use internal
     subroutine "alloc_err" to print error messages. (bmy, 3/14/00)
(14) AIJ is now obsolete.  All diagnostic variables now use allocatable
     arrays (cf. "diag_mod.f").  This is necessary in order to keep the
     size of the 2 x 2.5 executable within machine limits. (bmy, 3/28/00)
(15) Removed obsolete code.  Added TRCOFFSET of 3 for CO run
     with parameterized OH.  Removed reference to KAIJPAR. (bmy, 4/19/00)
(16) Add TRCOFFSET of 50 for DMS/SO2/SO4/MSA.  Also added arrays for
     ND13 diagnostic for sulfur emissions (bmy, 6/6/00)
(17) Add reference to F90 module "biomass_mod.f".  Also added array
     AD32_bf for biofuel NOx. (bmy, 9/11/00)
(18) Use NTRACE + 2 prodloss families for Tagged CO for the
     ND65 diagnostic (bmy, 10/6/00)
(19) Adjust TRCOFFSET for 10-tracer Tagged CO run.  Redimensioned
     AD45 and AD47 to save memory.  Renamed STATUS to AS. (bmy, 10/18/00)
(20) Removed obsolete code from 10/00.  Save out ND65 only to LLTROP
     levels for full chemistry.  Save out ND43 only to LLTROP levels
     for full chemistry.  Dimension DIAGCHLORO up to LLTROP for
     full chemistry (or LLPAR for CO/OH chemistry).  ND24, ND25, ND26
     can now save out less than LLPAR levels.  Eliminate dependence
     on PD35, PD37, PD39 parameters (bmy, 12/5/00)
(21) Only save out a maximum of LCONVM layers for ND14 (bmy, 12/7/00)
(22) Removed obsolete code from 7/00, 9/00, and 12/00 (bmy, 12/21/00)
(23) Increase to NTRACE + 4 prodloss families for Tagged CO (bmy, 1/2/01)
(24) Add TRCOFFSET of 54 for CH4 chemistry (NSRCX == 9) (bmy, 1/16/01)
(25) Now allocate DIAGCHLORO (ND23 diagnostic) for CH4 runs (bmy, 1/18/01)
(26) For ND43, save up to LLTROP for full chemistry, but save up to
     LLPAR for Tagged CO or CO-OH chemistry (bmy, 2/12/01)
(27) Now allocate AD34 for biofuel burning emissions (bmy, 3/15/01)
```

```
(28) Add L(CH3I) to ND65 diagnostic (nad, bmy, 3/20/01)
(29) For full chemistry, we only need to save up to LLTROP levels
     for the ND22 J-value diagnostic (bmy, 4/2/01)
(30) Remove reference to NBIOMAX from "biomass_mod.f" (bmy, 4/17/01)
(31) Eliminate obsolete commented-out code (bmy, 4/20/01)
(32) Now also allocate the AD12 diagnostic array (bdf, bmy, 6/15/01)
(33) Now assign TRCOFFSET = 40 for multi-tracer Ox run (when NSRCX = 6
     and LSPLIT = T).  Reference CMN_SETUP for LSPLIT.  Allocate AD44
     with NTRACE instead of NUMDEP for single or multi-tracer Ox runs
     (NSRCX = 6).  Now define NFAM as NTRACE*2 for single or multi-tracer
     Ox runs.  Updated comments & made cosmetic changes. (bmy, 7/3/01)
(34) Added AD11 diagnostic for acetone source.  Also removed obsolete
     code from 7/01. (bmy, 9/4/01)
(35) Turn off ND23 unless NSRCX = 3, 5, or 9.  This prevents us from
     referencing an unallocated DIAGCHLORO array.  Add error check for
     ND65, make sure that NFAM > 0.  Also clean up the code that
     allocates AD65 and FAMPL arrays. (bmy, 1/14/02)
(36) Now set TRCOFFSET = 64 for tagged C2H6 chemistry (bmy, 1/25/02)
(37) Eliminate obsolete code from 1/02 and 2/02.  Also allocate LTNO2,
     CTNO2, LTHO2, CTHO2 for the ND43 diagnostic. (bmy, 2/27/02)
(38) Call SETUP_PLANEFLIGHT to initialize the ND40 plane flight diagnostic
     for non-SMVGEAR chemistry runs. (mje, bmy, 7/2/02)
(39) Now set up variables & arrays for ND01 and ND02 diagnostics (i.e.
     Rn-Pb-Be emissions and decay).  (bmy, 9/20/02)
(40) Now allocate AD05 array.   Now allocate routines ALLOC_ERR and
     ERROR_STOP from "error_mod.f".  Now reference NEMANTHRO from F90
     module "tracerid_mod.f" instead of "comtrid.h".  Also added array
     AD13_SO2_bf for biofuel SO2. (bmy, 1/16/03)
(41) Now also allocate AD13_NH3_na array for ND13 (rjp, bmy, 3/23/03)
(42) Added ND03 diagnostic for Kr85 prod/loss.  Also removed special case
     TRCOFFSET for single-tracer Ox. (jsw, bmy, 8/20/03)
(43) Now use GET_WETDEP_NMAX to get max # of soluble tracers for ND37,
     ND18, and ND19.  Also set NFAM=NTRACE+5 for Tagged CO simulation.
     (3/18/04)
(44) Now initialize AD06 and AD07* arrays (rjp, tdf, bmy, 4/5/04)
(45) Now initialize AD08 array.  Reset TRCOFFSET for tagged CO from
     84 to 80.  Also activate ND52 diagnostic for ICARTT.
     (rjp, bec, stu, cas, bmy, 4/20/04)
(46) Now allocate AD13_SO2_sh array for ND13 (bec, bmy, 5/20/04)
(47) Now allocate AD07_HC array for ND07 (rjp, bmy, 7/13/04)
(48) Now references "tracer_mod.f" and "logical_mod.f" instead of "CMN"
     and "CMN_SETUP".  Now references INIT_DIAG_OH from "diag_oh_mod.f"
     Adjust TRCOFFSET for various aerosol simulations. (bmy, 7/20/04)
(49) Make sure ND21 only goes from 1-LLTROP (bmy, 9/28/04)
(50) Now allocate AD13_SO4_bf array (bmy, 11/17/04)
(51) Now allocate extra arrays for ND03 mercury diag.  Also set up for
     mercury tracers in ND44 diagnostic. (bmy, 12/14/04)
(52) Added separate ND21 array for cryst sulfur tracers.  Now reinstated
```

```
      AD03 array for mercury simulation.  Now move ND03 diagnostics into
      a separate module.  Remove TCOBOX reference, it's obsolete.
      (cas, sas, bmy, 1/21/05)
(53) Now remove references to AD41 & AFTTOT.  Now call SETUP_PLANEFLIGHT
      for non-full-chemistry runs in main.f -- this will allow it to look
      for flight files for each day (bmy, 3/24/05)
(54) Now use PD05=10 to dimension AD05 array (bmy, 4/13/05)
(55) Now also allocates AD09 and AD09_em (bmy, 6/27/05)
(56) Now allocates AD30 (bmy, 8/18/05)
(57) Removed duplicate variable declarations (bmy, 2/6/06)
(58) Now remove NBIOTRCE; it's obsolete.  Replace w/ NBIOMAX (bmy, 4/5/06)
(59) Now remove TRCOFFSET; it's obsolete (bmy, 5/16/06)
(60) Added the ND54 for time spend in the troposphere (phs, 10/17/06)
(61) Now allocate ND43 and ND45 counter arrays as 3-D (phs, 1/19/07)
(62) For ND20 diagnostic, reset ND65 diagnostic with LLTROP_FIX instead of
      LLTROP.  Added ND10 diagnostic setup.  Added modifications for H2-HD
      simulation. (phs, bmy, 9/18/07)
(63) Now save true pressure edges for ND31 diagnostic (bmy, 11/16/07)
(64) Now stop the run if ND20 is defined but ND65 isn't (bmy, 12/4/07)
(65) Allocate CTO3_24h (phs, 11/18/08)
(66) We don't need to set LD65=1 here anymore, we now call NDXX_SETUP!
      after DIAG_PL_MOD. (phs, bmy, 12/18/08)
(67) Added ND52 for GAMMA HO2 diagnostic. (ccc, jaegle, 2/26/09)
(68) Add AD07_SOAGM (tmf, 1/7/09)
(67) Added ND52 for GAMMA HO2 diagnostic. (ccc, jaegle, 2/26/09)
(68) Add AD07_SOAGM (tmf, 1/7/09)
(69) Now always allocate Mass Flux arrays (phs, 4/15/09)
(70) Allocate LTO3. (ccc, 7/20/09)
(71) Add AD19, AD58, AD60 (kjw, 8/18/09)
(72) Now AD13_SO2_an and AD13_SO4_an have NOXLEVELS levels to accomodate
   NEI 2005 (amv, 10/9/09)
(73) AD13_NH3_an is 3D now (phs, 10/22/09)
(74) Add new diagnostic ND59, ND60, ND61 (win, 7/9/09)
(75) Increase size for AD44 for TOMAS aerosol mass (win, 7/14/09)
(76) Initialize values for LD59, LD60, and LD61 (win, 8/10/09)
(77) NBIOMAX is now in CMN_SIZE. (fp, 2/26/10)
26 Aug 2010 - R. Yantosca - Added ProTeX headers
16 Feb 2011 - R. Yantosca - Add modifications for APM from G. Luo
09 Nov 2012 - R. Yantosca - Added GIGC-specific modifications
29 Mar 2013 - R. Yantosca - Pass objects to GET_WETDEP_NMAX
02 Apr 2013 - M. Payer    - Remove allocation of *NO, *NO2, and *NO3 arrays
                            for ND43. These are no longer needed because NO,
                            NO2, and NO3 are now tracers.
13 Aug 2013 - M. Sulprizio- Modify AD07_HC for updated SOA (H. Pye)
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
08 Nov 2013 - M. Sulprizio- Removed CTO3 and LTO3. They are no longer used
                            because O3 is now a tracer.
```

1.120.20 ohsave

Subroutine OHSAVE stores the concentrations of OH and HO2 for the ND43 diagnostic.

INTERFACE:

```
SUBROUTINE OHSAVE( SAVEOH, SAVEHO2 )
```

USES:

```
USE CMN_SIZE_MOD
USE COMODE_MOD,      ONLY : AIRDENS, CSPEC, JLOP
USE COMODE_LOOP_MOD
USE TRACERID_MOD,    ONLY : IDOH, IDHO2

IMPLICIT NONE
```

OUTPUT PARAMETERS:

```
! Array of OH  concentrations [molec/cm3]
REAL*8, INTENT(OUT) :: SAVEOH(IIPAR,JJPAR,LLPAR)

! Array of HO2 concentrations [v/v]
REAL*8, INTENT(OUT) :: SAVEHO2(IIPAR,JJPAR,LLPAR)
```

REVISION HISTORY:

```
27 Feb 2002 - R. Yantosca - Initial version
(1 ) Original code from lwh, gmg, djj, jyl, etc, 1990's.  Modified for
     GEOS-CHEM by Bob Yantosca et al.
(2 ) Added comment header and F90 declaration syntax.  Also now specify
     the units of each variable for clarity.
(3 ) Deleted NTRACER, it is not used.  Also added FRACNO2 and SAVEHO2
     variables.  Updated comments, cosmetic changes (rvm, bmy, 2/27/02)
(4 ) Bug fix: swap the order of the lines where TMPNOX is computed.
     Also deleted obsolete code from 2/02. (bmy, 7/31/02)
(5 ) Now reference IDTOX, IDTNOX, etc from "tracerid_mod.f". (1/13/03)
(6 ) Added OpenMP parallelization commands (bmy, 8/1/03)
(7 ) Now compute quantities for mean OH in "diag_oh_mod.f".  Now also
     references STT from "tracer_mod.f".  Added N_TRACERS to the arg list.
     Now dimension args XNUMOL, STT w/ N_TRACERS and not NNPAR.
     (bmy, 7/20/04)
(8 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(9 ) Reset FRAC* and SAVE* arrays, so that we don't carry dubious data
     over from boxes that used to be in the tropopause but aren't anymore.
     (phs, 1/19/07)
15 Sep 2010 - R. Yantosca - Added ProTeX headers
14 Mar 2013 - M. Payer    - FRACO3, FRACNO, and FRACNO2 are no longer needed
```

```
                            because O3, NO, and NO2 are now tracers.
   29 Mar 2013 - M. Payer    - Removed SAVENO, SAVENO2, SAVENO3.
   31 May 2013 - R. Yantosca - Extra cleanup, remove N_TRACERS, XNUMOL, STT
   20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.21

NEW Mie code for J's, only uses 8-term expansion, 4-Gauss pts Currently allow up to NP aerosol phase functions (at all altitudes) to be associated with optical depth AER(1:NC) = aerosol opt.depth @ 1000 nm

INTERFACE:

```
      SUBROUTINE OPMIE( KW, WAVEL, XQO2, XQO3, FMEAN )
```

USES:

```
      USE CMN_FJ_MOD,   ONLY : JPMAX, JPPJ
      USE CMN_SIZE_MOD, ONLY : LLPAR
      USE JV_CMN_MOD
      USE JV_MIE_MOD

      IMPLICIT NONE
```

INPUT/OUTPUT PARAMETERS:

```
      INTEGER KW
      REAL*8  WAVEL
      REAL*8  XQO2(NB)
      REAL*8  XQO3(NB)
      REAL*8  FMEAN(LLPAR)
```

REMARKS:

```
   Pick Mie-wavelength with phase function and Qext:
   01 RAYLE = Rayleigh phase
   02 ISOTR = isotropic
   03 ABSRB = fully absorbing 'soot', wavelength indep.
   04 S_Bkg = backgrnd stratospheric sulfate (n=1.46,log-norm:r=.09um/sigma=.6)
   05 S_Vol = volcanic stratospheric sulfate (n=1.46,log-norm:r=.08um/sigma=.8)
   06 W_H01 = water haze (H1/Deirm.) (n=1.335, gamma:  r-mode=0.1um /alpha=2)
   07 W_H04 = water haze (H1/Deirm.) (n=1.335, gamma:  r-mode=0.4um /alpha=2)
   08 W_C02 = water cloud (C1/Deirm.) (n=1.335, gamma:  r-mode=2.0um /alpha=6)
   09 W_C04 = water cloud (C1/Deirm.) (n=1.335, gamma:  r-mode=4.0um /alpha=6)
   10 W_C08 = water cloud (C1/Deirm.) (n=1.335, gamma:  r-mode=8.0um /alpha=6)
   11 W_C13 = water cloud (C1/Deirm.) (n=1.335, gamma:  r-mode=13.3um /alpha=6)
   12 W_L06 = water cloud (Lacis) (n=1.335, r-mode=5.5um / alpha=11/3)
   13 Ice-H = hexagonal ice cloud (Mishchenko)
   14 Ice-I = irregular ice cloud (Mishchenko)
```

```
.
  Choice of aerosol index MIEDX is made in SET_AER; optical depths are
  apportioned to the AER array in SET_PROF
.
-----------------------------------------------------------------------
  FUNCTION RAYLAY(WAVE)---RAYLEIGH CROSS-SECTION for wave > 170 nm
       WSQI = 1.E6/(WAVE*WAVE)
       REFRM1 = 1.0E-6*(64.328+29498.1/(146.-WSQI)+255.4/(41.-WSQI))
       RAYLAY = 5.40E-21*(REFRM1*WSQI)**2
-----------------------------------------------------------------------
.
     DTAUX    Local optical depth of each CTM level
     PIRAY    Contribution of Rayleigh scattering to extinction
     PIAER    Contribution of Aerosol scattering to extinction
     TTAU     Optical depth of air vertically above each point (to top of atm)
     FTAU     Attenuation of solar beam
     POMEGA   Scattering phase function
     FMEAN    Mean actinic flux at desired levels!
```

REVISION HISTORY:

```
01 Oct 1995 - R. Yantosca - Initial version
31 Jul 2012 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.22 partition

Subroutine PARTITION separates each GEOS-Chem tracer into its individual constituent chemistry species before each SMVGEAR or KPP chemistry timestep.

INTERFACE:

```
      SUBROUTINE PARTITION( NTRACER, XNUMOL, am_I_Root, State_Chm )
```

USES:

```
      USE COMODE_MOD,         ONLY : CSPEC,     JLOP,       VOLUME
      USE COMODE_MOD,         ONLY : JLOP_PREVIOUS
      USE ERROR_MOD,          ONLY : ALLOC_ERR, ERROR_STOP, SAFE_DIV
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE TRACERID_MOD,       ONLY : IDTRMB
      USE TRACERID_MOD,       ONLY : IDO3,      IDNO,       IDHNO2
      USE TRACERID_MOD,       ONLY : CTRMB,     NMEMBER
      USE CMN_SIZE_MOD
      USE COMODE_LOOP_MOD

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
! # of tracers
INTEGER, INTENT(IN)    :: NTRACER

! Conversion factor: molecules tracer / kg tracer
REAL*8,  INTENT(IN)    :: XNUMOL(NTRACER)

! Is this the root CPU?
LOGICAL, INTENT(IN)    :: am_I_Root
```

INPUT/OUTPUT PARAMETERS:

```
! Chemistry State object
TYPE(ChmState), INTENT(INOUT) :: State_Chm
```

REMARKS:

```
Warning:
========
Partition was written assuming NOx tracer is before Ox tracer
in the tracer declaration in input.geos. If you want to change this
order, you need to adjust the code.
```

REVISION HISTORY:

```
01 Apr 2003 - B. Field, R. Yantosca - Initial version, based on older code
(1 ) Now make CSAVE a local dynamic array.  Updated comments, cosmetic
      changes (bmy, 4/24/03)
(2 ) Add OpenMP parallelization commands (bmy, 8/1/03)
(3 ) Now dimension args XNUMOL, STT w/ NTRACER and not NNPAR (bmy, 7/20/04)
(4 ) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
(5 ) Resize CSAVE to save local memory, for SUN compiler. (bmy, 7/14/06)
(6 ) Now do safe division to eliminate FP errors (phs, bmy, 2/26/08)
(7 ) Now change error stop 30000 into a warning (phs, ccc, bmy, 1/7/09)
27 Jun 2011 - D. Henze, J. Koo - Fix to variable tropopause by Daven Henze.
                                 When initializing CSAVE, search downward
                                 in the column until we find a grid box
                                 that was in the troposphere on the previous
                                 timestep.
27 Jun 2011 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
14 Mar 2013 - M. Payer    - Remove partitioning of NOx and Ox. Family tracers
                            NOx and Ox have now been replaced with tracers
                            NO, NO2, NO3, HNO3, and O3.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.23 photoj

Subroutine PHOTOJ is the driver routine for the FAST-J photolysis package.

INTERFACE:

```
 SUBROUTINE PHOTOJ( NLON,   NLAT,    YLAT,    DAY_OF_YR,
&                   MONTH,  DAY,     CSZA,    T,
&                   SA,     OD,      OPTDUST, OPTAER,
&                   O3COL,  am_I_Root                   )
```

USES:

```
 USE CMN_SIZE_MOD, ONLY : NDUST, NAER, NRH,  LLPAR
 USE CMN_FJ_MOD,   ONLY : JPMAX, JPPJ, JPNL, ZPJ
 USE JV_CMN_MOD,   ONLY : ZJ,    U0,   SZA,  SZAMAX

 IMPLICIT NONE
```

INPUT PARAMETERS:

```
 INTEGER, INTENT(IN)    :: NLON                  ! Grid box lon index
 INTEGER, INTENT(IN)    :: NLAT                  ! Grid box lat index
 REAL*8,  INTENT(IN)    :: YLAT                  ! Latitude [degrees]
 INTEGER, INTENT(IN)    :: DAY_OF_YR             ! Day of year
 INTEGER, INTENT(IN)    :: MONTH                 ! Current month
 INTEGER, INTENT(IN)    :: DAY                   ! Day of month
 REAL*8,  INTENT(IN)    :: CSZA                  ! Cosine(SZA) [unitless]
 REAL*8,  INTENT(IN)    :: T(LLPAR)              ! Temperature [K]
 REAL*8,  INTENT(IN)    :: SA                    ! UV albedo [unitless]
 REAL*8,  INTENT(IN)    :: OD(LLPAR)             ! Visible OD [unitless]
 REAL*8,  INTENT(IN)    :: O3COL                 ! Overhead O3 column [DU]
 LOGICAL, INTENT(IN)    :: am_I_Root             ! Is this the root CPU?
```

INPUT/OUTPUT PARAMETERS:

```
 REAL*8,  INTENT(INOUT) :: OPTDUST(LLPAR,NDUST)   ! Dust OD [unitless]
 REAL*8,  INTENT(INOUT) :: OPTAER(LLPAR,NAER*NRH) ! Aerosol OD [unitless]
```

AUTHOR:

```
Oliver Wild & Michael Prather
```

REMARKS:

```
New FAST J-Value code, troposphere only (mjprather 6/96); uses special
wavelength quadrature spectral data (jv_spec.dat) that includes only
289 nm - 800 nm  (later a single 205 nm add-on); uses special compact Mie
code based on Feautrier/Auer/Prather vers.

                                                                        .
Important variables from other modules:
(1) ZJ   : Column array for J-values
```

```
(2) ZPJ  : Global array for J-values (passed to SMVGEAR)
(3) JPNL : # of GEOS-CHEM layers in which to compute J-values
(4) JPPJ : # of photolysis rxns for FAST-J

NOTE: The value of PI listed here is slightly different than the value
in CMN_GCTM_mod.F.  The last digit is 4, whereas in CMN_GCTM_mod.F, the
last digit is 3.  Keep for now during testing of grid-independent code, but
this may be something to revisit at a later data. (bmy, 3/6/12)
```

REVISION HISTORY:

```
01 Jun 1996 - M. Prather & O. Wild - Initial version
(1 ) Renamed NSLON to NLON and NSLAT to NLAT.  Now add DAY_OF_YR
      (formerly IDAY) and DAY to the arg list.  Swap places in arg list
      of SA and OD.  Now pass NLON, NLAT, DAY_OF_YR and DAY to "set_prof.f".
      Added standard documentation header; cosmetic changes. (bmy, 7/15/03)
(2 ) We don't need to pass "P" via the arg list (bmy, 2/13/07)
06 Mar 2012 - R. Yantosca - Now pass O3COL via the arg list
06 Mar 2012 - R. Yantosca - Added ProTeX headers
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.24 physproc

Subroutine PHYSPROC is the driver for SMVGEAR II chemistry. It calls both CALCRATE to compute the rxn rates and the SMVGEAR solver routine.

INTERFACE:

```
      SUBROUTINE PHYSPROC( am_I_Root, Input_Opt,
     &                     State_Met, State_Chm, RC )
```

USES:

```
      USE CMN_SIZE_MOD
      USE COMODE_MOD,         ONLY : ABSHUM
      USE COMODE_MOD,         ONLY : AIRDENS
      USE COMODE_MOD,         ONLY : CSPEC
      USE COMODE_MOD,         ONLY : CSUMA
      USE COMODE_MOD,         ONLY : CSUMC
      USE COMODE_MOD,         ONLY : ERRMX2
      USE COMODE_MOD,         ONLY : IXSAVE
      USE COMODE_MOD,         ONLY : IYSAVE
      USE COMODE_MOD,         ONLY : T3
      USE COMODE_LOOP_MOD
      USE CHEMISTRY_MOD,      ONLY : GCKPP_DRIVER
      USE GCKPP_GLOBAL,       ONLY : NTT
```

```
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput
      USE GIGC_State_Chm_Mod, ONLY : ChmState
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE TIME_MOD,           ONLY : TIMESTAMP_STRING

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
      TYPE(OptInput), INTENT(IN)    :: Input_Opt   ! Input Options object
      TYPE(MetState), INTENT(IN)    :: State_Met   ! Meteorology State object
```

INPUT/OUTPUT PARAMETERS:

```
      TYPE(ChmState), INTENT(INOUT) :: State_Chm   ! Chemistry State object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(OUT)   :: RC          ! Success or failure?
```

REMARKS:

```
  ****************************************************************************
  ************        WRITTEN BY MARK JACOBSON (1993)      ************
  ***              (C) COPYRIGHT, 1993 BY MARK Z. JACOBSON           ***
  ***       U.S. COPYRIGHT OFFICE REGISTRATION NO. TXu 670-279      ***
  ***                          (650) 723-6836                       ***
  ****************************************************************************
  PPPPPPP  H     H  Y     Y  SSSSSSS  PPPPPPP RRRRRRR  OOOOOOO  CCCCCCC
  P     P  H     H   Y   Y   S        P     P R     R  O     O  C
  PPPPPPP  HHHHHHH     Y     SSSSSSS  PPPPPPP RRRRRRR  O     O  C
  P        H     H     Y           S  P       R  R     O     O  C
  P        H     H     Y     SSSSSSS  P       P    P   OOOOOOO  CCCCCCC
  ****************************************************************************
  * THIS SUBROUTINE CALLS CALCRATE.F AND SMVGEAR.F. TO SOLVE GAS-     *
  * PHASE CHEMICAL EQUATIONS. THE ROUTINE DIVIDES THE GRID DOMAIN     *
  * INTO GRID BLOCKS, AND THE CODE VECTORIZES AROUND THE NUMBER OF    *
  * GRID CELLS IN EACH BLOCK.                                         *
  *                                                                   *
  ****************************************************************************

  ****************************************************************************
  ***************         UPDATE 24-HOUR CLOCK        ****************
  ****************************************************************************
  CHEMINTV = TIME INTERVAL FOR CHEMISTRY
  IRCHEM   = COUNTS # CHEMINTV TIME-INTERVALS
```

REVISION HISTORY:

```
03 Jan 1993 - M. Jacobson - Initial version
(1 ) For GEOS-CHEM we had to remove ABSHUM, AIRDENS, CSPEC, IXSAVE, IYSAVE,
     and T3 from "comode.h" and to declare these allocatable in F90 module
     "comode_mod.f".  This allows us to only allocate these if we are
     doing a fullchem run.  Now references TIMESTAMP_STRING from
     "time_mod.f".  Now pass SUNCOSB via the arg list.  Now force double
     precision with the "D" exponent. (bmy, 4/18/03)
(2 ) Comment out section that computes photorates from original SMVGEAR II
     file "photrate.dat"...this is not needed.  Remove TFROMID, it's not
     used anywhere else.  Remove references to LASTCHEM, this is mpt
     initialized anywhere.  Now reference CSUMA, CSUMC, ERRMX2 from
     "comode_mod.f". (bmy, 7/30/03)
(3 ) LINUX has a problem putting a function call w/in a WRITE statement.
     Now save output from TIMESTAMP_STRING to STAMP and print that.
     (bmy, 9/29/03)
(4 ) Fixed case of small KULOOP (phs, 10/5/07)
(5 ) Now only get the rx rates if not using SMVGEAR (phs,ks,dhk, 09/15/09)
(6 ) Now calls KPP after calculating the reaction rates to save memory.
     (ccc, 12/9/09)
(7 ) Remove obsolete print statements & formats (bmy, 12/18/09)
(8 ) Now call GCKPP_DRIVER with NSPEC(1), which is the # of active species
     for urban chemistry. (ccc, 1/20/10)!
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
30 Jul 2012 - R. Yantosca - Added ProTeX headers
27 Nov 2012 - R. Yantosca - Replace SUNCOS with State_Met%SUNCOSmid
01 Mar 2013 - R. Yantosca - Now set RC to GIGC_SUCCESS for default
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.25 rd_aod

Subroutine RD_AOD reads aerosol phase functions that are used to scale diagnostic output to an arbitrary wavelengh. This facilitates comparing with satellite observations.

INTERFACE:

```
SUBROUTINE RD_AOD( NJ1, NAMFIL, am_I_Root )
```

USES:

```
USE ERROR_MOD,  ONLY : ERROR_STOP
USE FILE_MOD,   ONLY : IOERROR
USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
USE JV_CMN_MOD

IMPLICIT NONE
```

INPUT PARAMETERS:

```
INTEGER,          INTENT(IN) :: NJ1         ! Unit # of file to open
CHARACTER(LEN=*), INTENT(IN) :: NAMFIL      ! Name of file to open
LOGICAL,          INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REMARKS:

```
The jv_spec_aod.dat file contains the optical properties for aerosols
at a single wavelength to be used in the online calculation of the aerosol
optical depth diagnostics.  The default properties are provided at 550 nm.
These properties have been calculated using the same size and optical
properties as the jv_spec.dat file used for the FAST-J photolysis
calculations.  The user can exchange this set of properties with those at
another wavelength.  We recommend that the wavelength used be included
in the first line of the header for traceability (this line is output to
the GEOS-Chem log file during run time). A complete set of optical
properties from 250-2000 nm for aerosols is available at:
ftp://ftp.as.harvard.edu/geos-chem/data/aerosol_optics/hi_spectral_res
                                                                             .
   -- Colette L. Heald, 05/10/10)
Important variables:
                                                                             .
   NAMFIL       Name of spectral data file (jv_spec_aod.dat)
   NJ1          Channel number for reading data file
   NAA2         Number of categories for scattering phase functions
   QAA_AOD      Aerosol scattering phase functions
   WAA_AOD      Wavelengths for the NK supplied phase functions
   PAA_AOD      Phase function: first 8 terms of expansion
   RAA_AOD      Effective radius associated with aerosol type
   SSA_AOD      Single scattering albedo
```

REVISION HISTORY:

```
10 May 2010 - C. Heald    - Initial version
06 Aug 2010 - C. Carouge  - Add an error check when opening the file
01 Aug 2012 - R. Yantosca - Now restore NJ1 to INTENT(IN) status
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.26 rd_js

Rereads the "ratj.d" file to map photolysis rate to reaction Read in quantum yield 'jfacta' and fastj labels 'jlabel'

INTERFACE:

```
SUBROUTINE RD_JS( NJ1, NAMFIL, am_I_Root )
```

USES:

```
USE CMN_FJ_MOD, ONLY : JPMAX,  JPPJ
```

```
USE CMN_FJ_MOD, ONLY : RNAMES, BRANCH
USE JV_CMN_MOD

IMPLICIT NONE
```

INPUT PARAMETERS:

```
INTEGER,          INTENT(INOUT) :: nj1         ! Logical unit #
CHARACTER(LEN=*), INTENT(IN)    :: namfil      ! File name
LOGICAL,          INTENT(IN)    :: am_I_Root   ! Is this the root CPU?
```

INPUT PARAMETERS:

REMARKS:

```
jfacta    Quantum yield (or multiplication factor) for photolysis
jlabel    Reference label identifying appropriate J-value to use
ipr       Photolysis reaction counter - should total 'jppj'
```

REVISION HISTORY:

```
01 Jun 1998 - P. Murti    - Initial version
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
30 Jul 2012 - R. Yantosca - Add reference to findFreeLUN under DEVEL tag
03 Aug 2012 - R. Yantosca - Restore NJ1 to INTENT(IN) status
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.27

Read in wavelength bins, solar fluxes, Rayleigh parameters, temperature-dependent cross sections and Rayleigh/aerosol scattering phase functions with temperature dependences.

INTERFACE:

```
SUBROUTINE RD_TJPL( NJ1, NAMFIL, am_I_Root )
```

USES:

```
USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
USE JV_CMN_MOD

IMPLICIT NONE
```

INPUT PARAMETERS:

```
INTEGER,          INTENT(IN) :: NJ1         ! Logical unit #
CHARACTER(LEN=*), INTENT(IN) :: NAMFIL      ! File name
LOGICAL,          INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

INPUT PARAMETERS:

REMARKS:

NAMFIL	Name of spectral data file (jv_spec.dat)
NJ1	Channel number for reading data file
NJVAL	Number of species to calculate J-values for
NWWW	Number of wavelength bins, from NW1:NW2
WBIN	Boundaries of wavelength bins
WL	Centres of wavelength bins - 'effective wavelength'
FL	Solar flux incident on top of atmosphere (cm-2.s-1)
QRAYL	Rayleigh parameters (effective cross-section) (cm2)
QBC	Black Carbon absorption extinct. (specific cross-sect.) (m2/g)
QO2	O2 cross-sections
QO3	O3 cross-sections
Q1D	O3 => O(1D) quantum yield
TQQ	Temperature for supplied cross sections
QQQ	Supplied cross sections in each wavelength bin (cm2)
NAA	Number of categories for scattering phase functions
QAA	Aerosol scattering phase functions
NK	Number of wavelengths at which functions supplied (set as 4)
WAA	Wavelengths for the NK supplied phase functions
PAA	Phase function: first 8 terms of expansion
RAA	Effective radius associated with aerosol type
SSA	Single scattering albedo
npdep	Number of pressure dependencies
zpdep	Pressure dependencies by wavelength bin
jpdep	Index of cross sections requiring pressure dependence
lpdep	Label for pressure dependence

REVISION HISTORY:

```
01 Jun 1998 - P. Murti - Initial version
(1 ) Updated to include new pressure-dependancy function for GLYX and MGLY.
     (tmf, 1/7/09)
(2 ) Added a pressure-dependancy function selector 'pdepf'.
     (tmf, ccc, 1/7/09)
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
30 Jul 2012 - R. Yantosca - AddedoTeX headers
01 Aug 2012 - R. Yantosca - Now restore NJ1 to INTENT(IN) status
01 Mar 2013 - R. Yantosca - Block some extra print statements w/ am_I_Root
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.28 read_jv_atms_dat

Reads the default T and O3 profiles for FAST-J photolysis. This replaces the obsolete rd_prof.F routine, which read from the ASCII file "jv_atms.dat".

INTERFACE:

```
 SUBROUTINE READ_JV_ATMS_DAT( am_I_Root, Data_Dir_1x1 )
```

USES:

```
   ! Modules for netCDF read
   USE m_netcdf_io_open
   USE m_netcdf_io_read
   USE m_netcdf_io_readattr
   USE m_netcdf_io_close

   ! GEOS-Chem modules
    USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1    ! Data directory
   USE JV_CMN_MOD,    ONLY : TREF            ! Default T profile [K]
   USE JV_CMN_MOD,    ONLY : OREF            ! Default O3 profile [ppm]

   IMPLICIT NONE

 # include "netcdf.inc"
```

INPUT PARAMETERS:

```
   LOGICAL, INTENT(IN)            :: am_I_Root          ! Is this the root CPU?
   CHARACTER(LEN=255), INTENT(IN) :: Data_Dir_1x1
```

REMARKS:

```
    This file was automatically generated by the Perl scripts in the
    NcdfUtilities package (which ships w/ GEOS-Chem) and was subsequently
    hand-edited.
```

REVISION HISTORY:

```
    19 Apr 2012 - R. Yantosca - Initial version
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
```

1.120.29 set_aer

Routine SET_AER sets aerosol/cloud types and define black carbon profile for the FAST-J photolysis scheme.

INTERFACE:

```
       SUBROUTINE SET_AER( am_I_Root )
```

USES:

```
      USE CMN_FJ_MOD, ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL, INTENT(IN) :: am_I_Root   ! Is this the root CPU?
```

REMARKS:

```
    MX       Number of different types of aerosol to be considered
    MIEDX    Index of aerosol types in jv_spec.dat - hardwire in here
```

REVISION HISTORY:

```
    01 Jun 1999 - O. Wild     - Initial version
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
    30 Jul 2012 - R. Yantosca - Added ProTeX headers
    20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.30 setemdep

Subroutine SETEMDEP stores SMVGEAR reaction numbers (listed in "globchem.dat") corresponding to GEOS-CHEM tracers which emit and dry deposit into the NTEMIS and NTDEP index arrays.

INTERFACE:

```
      SUBROUTINE SETEMDEP( am_I_Root, Input_Opt, RC )
```

USES:

```
      USE TRACERID_MOD, ONLY : IDEMIS, IDTRMB, NEMANTHRO, NEMBIOG
      USE CMN_SIZE_MOD                  ! Size parameters
      USE COMODE_LOOP_MOD               ! SMVGEAR II arrays
      USE GIGC_ErrCode_Mod
      USE GIGC_Input_Opt_Mod, ONLY : OptInput

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      LOGICAL,        INTENT(IN) :: am_I_Root   ! Are we on the root CPU?
      TYPE(OptInput), INTENT(IN) :: Input_Opt   ! Input Options object
```

OUTPUT PARAMETERS:

```
      INTEGER,        INTENT(IN) :: RC          ! Success or failure
```

REVISION HISTORY:

```
03 Jan 1994 - L. Horowitz et al - - Initial version
(1 ) Now references "drydep_mod.f" and "tracerid_mod.f".  Updated comments
     and made cosmetic changes. (bmy, 12/5/02)
(2 ) Cosmetic changes (bmy, 3/14/03)
(3 ) Updated for SMVGEAR II (gcc, bdf, bmy, 4/21/03)
(4 ) Now flag to "smv2.log" the emitted & dry-deposited tracers instead
     of flagging the tracers which aren't. (bmy, 7/20/04)
(5 ) Increase DEPNAME length format for output (fp, 3/15/10)
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
30 Jul 2012 - R. Yantosca - Added ProTeX headers
13 Nov 2012 - R. Yantosca - Now pass Input_Opt and RC as arguments for GIGC
05 Mar 2013 - R. Yantosca - Now use Input_Opt%NUMDEP and Input_Opt%DEPNAME
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.31 set_prof

Subroutine SET_PROF sets up atmospheric profiles required by Fast-J using a doubled version of the level scheme used in the CTM. First pressure and z* altitude are defined, then O3 and T are taken from the supplied climatology and integrated to the CTM levels (may be overwritten with values directly from the CTM, if desired) and then black carbon and aerosol profiles are constructed.

INTERFACE:

```
      SUBROUTINE SET_PROF( NLON,    NLAT,   YLAT, MONTH,
     &                     DAY,     T,      SA,   ODCOL,
     &                     OPTDUST, OPTAER, O3COL )
```

USES:

```
      USE CMN_SIZE_MOD,  ONLY : LLPAR
      USE CMN_FJ_MOD,    ONLY : JPMAX, JPPJ
      USE JV_CMN_MOD

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      INTEGER, INTENT(IN)    :: NLON                 ! Grid box lon index
      INTEGER, INTENT(IN)    :: NLAT                 ! Grid box lat index
      REAL*8,  INTENT(IN)    :: YLAT                 ! Latitude [degrees]
      INTEGER, INTENT(IN)    :: MONTH                ! Current month
      INTEGER, INTENT(IN)    :: DAY                  ! Day of month
      REAL*8,  INTENT(IN)    :: T(LLPAR)             ! Temperature [K]
      REAL*8,  INTENT(IN)    :: SA                   ! UV albedo [unitless]
```

```
      REAL*8,  INTENT(IN)    :: OPTDUST(LLPAR,NDUST)   ! Dust OD [unitless]
      REAL*8,  INTENT(IN)    :: OPTAER(LLPAR,NAER*NRH) ! Aerosol OD [unitless]
      REAL*8,  INTENT(IN)    :: O3COL                  ! Overhd O3 column [DU]
```

INPUT/OUTPUT PARAMETERS:

```
      REAL*8,  INTENT(INOUT) :: ODCOL(LLPAR)           ! Visible OD [unitless]
```

AUTHOR:

Oliver Wild & Michael Prather

REMARKS:

```
References:
============================================================================
TOMS/SBUV MERGED TOTAL OZONE DATA, Version 8, Revision 3.
Resolution:  5 x 10 deg.
                                                                            .
Source: http://code916.gsfc.nasa.gov/Data_services/merged/index.html
                                                                            .
Contact person for the merged data product:
Stacey Hollandsworth Frith (smh@hyperion.gsfc.nasa.gov)
                                                                            .
Important module variables:
============================================================================
(1 ) PJ     :  Pressure at boundaries of model levels [hPa]
(2 ) Z      :  Altitude of boundaries of model levels [cm]
(4 ) MASFAC :  Conversion factor for pressure to column density
(5 ) TJ     :  Temperature profile on model grid
(6 ) DM     :  Air column for each model level [molecules/cm2])
(7 ) DO3    :  Ozone column for each model level [molecules/cm2]
(8 ) DBC    :  Mass of Black Carbon at each model level [g/cm3]
(9 ) PSTD   :  Approximate pressures of levels for supplied climatology
```

REVISION HISTORY:

```
01 Jun 1996 - M. Prather & O. Wild - Initial version
(1 ) Since we parallelize over columns, T, ODCOL, OPTDUST, and OPTAER
      are 1-D vectors. In the original code from Oliver Wild, these were
      3-D arrays.  Also P and SA are just scalars since we just pass one
      surface location at a time w/in the parallel loop. (bmy, 9/13/99)
(2 ) Mineral dust profiles are also constructed (rvm, 06/04/00)
(3 ) Other aerosol profiles are also constructed (rvm, bmy, 2/27/02)
(4 ) Added NLON, NLAT, DAY to the arg list.  Now weight the O3 column by
      the observed monthly mean EP-TOMS data.  Also updated comments and
      added standard GEOS-CHEM documentation header. (mje, bmy, 7/13/03)
(5 ) We don't need to initialize the PJ array with ETAA and ETAB anymore.
      PJ is now defined in "fast_j.f".  Updated comments. (bmy, 10/30/07)
(6 ) Modified to use GEOS-5 O3 columns when TOMS/SBUV data don't exist,
      i.e. after 2008. (ccc, 7/13/09)
```

```
08 Dec 2009 - R. Yantosca - Added ProTeX headers
02 Aug 2012 - R. Yantosca - Use online temperature when connecting to GCM
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.32 sphere

Subroutine SPHERE calculates spherical geometry; derives tangent heights, slant path lengths and air mass factor for each layer. Not called when SZA ¿ 98 degrees. Beyond 90 degrees, include treatment of emergent beam (where tangent height is below altitude J-value desired at).

INTERFACE:

```
SUBROUTINE SPHERE
```

USES:

```
USE CMN_FJ_MOD,   ONLY : JPMAX, JPPJ
USE CMN_SIZE_MOD, ONLY : LLPAR
USE JV_CMN_MOD

IMPLICIT NONE
```

REMARKS:

```
GMU     MU, cos(solar zenith angle)
RZ      Distance from centre of Earth to each point (cm)
RQ      Square of radius ratios
TANHT   Tangent height for the current SZA
XL      Slant path between points
AMF     Air mass factor for slab between level and level above
```

REVISION HISTORY:

```
       1997 - O. Wild     - Initial version
31 Jul 2012 - R. Yantosca - Added ProTeX headers
10 Aug 2012 - R. Yantosca - Replace LPAR with LLPAR
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.33 read_jv_atms_dat

Reads the default T and O3 profiles for FAST-J photolysis. This replaces the obsolete rd_prof.F routine, which read from the ASCII file "jv_atms.dat".

INTERFACE:

```
SUBROUTINE READ_JV_ATMS_DAT( am_I_Root, Data_Dir_1x1 )
```

USES:

```
   ! Modules for netCDF read
   USE m_netcdf_io_open
   USE m_netcdf_io_read
   USE m_netcdf_io_readattr
   USE m_netcdf_io_close

   ! GEOS-Chem modules
    USE DIRECTORY_MOD, ONLY : DATA_DIR_1x1    ! Data directory
   USE JV_CMN_MOD,    ONLY : TREF            ! Default T profile [K]
   USE JV_CMN_MOD,    ONLY : OREF            ! Default O3 profile [ppm]

   IMPLICIT NONE

 # include "netcdf.inc"
```

INPUT PARAMETERS:

```
   LOGICAL, INTENT(IN)            :: am_I_Root          ! Is this the root CPU?
   CHARACTER(LEN=255), INTENT(IN) :: Data_Dir_1x1
```

REMARKS:

```
    This file was automatically generated by the Perl scripts in the
    NcdfUtilities package (which ships w/ GEOS-Chem) and was subsequently
    hand-edited.
```

REVISION HISTORY:

```
    19 Apr 2012 - R. Yantosca - Initial version
    30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                                running with the traditional driver main.F
```

1.120.34 ruralbox

Subroutine RURALBOX computes which boxes are tropospheric and which are stratospheric. SMVGEAR arrays are initialized with quantities from tropospheric boxes.

INTERFACE:

```
       SUBROUTINE RURALBOX( State_Met )
```

USES:

```
       USE COMODE_MOD,         ONLY : ABSHUM, AIRDENS
       USE COMODE_MOD,         ONLY : IXSAVE, IYSAVE
       USE COMODE_MOD,         ONLY : IZSAVE, JLOP
       USE COMODE_MOD,         ONLY : PRESS3, T3,       VOLUME
```

```
      USE GIGC_State_Met_Mod, ONLY : MetState
      USE PRESSURE_MOD,       ONLY : GET_PCENTER,      GET_PEDGE
      USE TROPOPAUSE_MOD,     ONLY : ITS_IN_THE_STRAT, ITS_IN_THE_TROP
      USE CMN_SIZE_MOD             ! Size parameters
      USE COMODE_LOOP_MOD          ! NPVERT

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      TYPE(MetState), INTENT(IN)  :: State_Met   ! Meteorology State object
```

REMARKS:

```
    Developers: amf, bey, ljm, lwh, gmg, bdf, bmy, 7/16/01, 2/25/10)
```

REVISION HISTORY:

```
    01 Oct 1995 - M. Prather  - Initial version
    (1 ) Remove PTOP from the arg list.  PTOP is now a parameter
         in "CMN_SIZE". (bmy, 2/10/00)
    (2 ) Add C-preprocessor switch LSLOWJ to bracket code for
         SLOW-J photolysis (bmy, 2/25/00)
    (3 ) Now reference ABHSUM, AIRDENS, IXSAVE, IYSAVE, IZSAVE, JLOP, PRESS3,
         T3, and VOLUME from F90 module "comode_mod.f" (bmy, 10/19/00)
    (4 ) PTOP is already a parameter in "CMN_SIZE", don't declare it here
         (bmy, 7/16/01)
    (5 ) Replace IGCMPAR,JGCMPAR,LGCMPAR with IIPAR,JJPAR,LLPAR.  Also moved
         CLOUDREF to SLOW-J block.  Also remove IREF, JREF, IOFF, JOFF, these
         are now obsolete.  Updated comments. (bmy, 9/25/01)
    (6 ) Eliminate I00 and J00 as arguments, these are obsolete (bmy, 9/28/01)
    (7 ) Removed obsolete, commented out code from 9/01 (bmy, 10/24/01)
    (8 ) Updated comment header.  Also updated comments, and made cosmetic
         changes. (bmy, 4/15/02)
    (9 ) Bug fix: declare variables for SLOW-J photolysis.  Also eliminated
         obsolete code from 4/15/02. (bmy, 8/5/02)
    (10) Now reference GET_PCENTER and GET_PEDGE from "pressure_mod.f",
         which return the correct "floating" pressure.  Also deleted obsolete,
         commented-out code.  Also eliminate P, SIG, and NSKIPL from the arg
         list, since we don't need them anymore. (dsa, bdf, bmy, 8/20/02)
    (11) Added modifications for SMVGEAR II (gcc, bdf, bmy, 4/1/03)
    (12) SLOW-J is now obsolete; remove LSLOWJ #ifdef blocks (bmy, 6/23/05)
    (13) Now reference ITS_IN_THE_TROP and ITS_IN_THE_STRAT from
         "tropopause_mod.f" to diagnose trop & strat boxes.  Also remove
         LPAUSE from the arg list (bmy, 8/22/05)
    (14) Remove ALT and CLOUDS from arg list -- they are obsolete (bmy, 4/10/06)
    (15) Remove obsolete embedded chemistry stuff (bmy, 2/25/10)
    10 Sep 2010 - R. Yantosca - Added ProTeX headers
```

```
09 Nov 2012 - M. Payer    - Replaced all met field arrays with State_Met
                            derived type object
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.35 setemis

Subroutine SETEMIS places emissions computed from GEOS-Chem subroutines into arrays for SMVGEAR II chemistry.

SETEMIS converts from units of [molec tracer/box/s] to units of [molec chemical species/cm3/s], and stores in the REMIS array. For hydrocarbons that are carried through the GEOS-CHEM model as [molec C], these are converted back to [molec hydrocarbon], and then stored in REMIS.

INTERFACE:

```
 SUBROUTINE SETEMIS( EMISRR,    EMISRRN,   am_I_Root,
&                    Input_Opt, State_Met, RC         )
```

USES:

```
USE BIOFUEL_MOD,         ONLY : BIOFUEL,   BFTRACE, NBFTRACE
USE BIOMASS_MOD,         ONLY : BIOMASS,   BIOTRCE
USE BIOMASS_MOD,         ONLY : BIOBGAS
USE COMODE_MOD,          ONLY : JLOP,      REMIS,   VOLUME
USE COMODE_MOD,          ONLY : IXSAVE,    IYSAVE,  IZSAVE
USE DIAG_MOD,            ONLY : AD12
USE EMISSIONS_MOD,       ONLY : NOx_SCALING
USE GIGC_ErrCode_Mod
USE GIGC_Input_Opt_Mod, ONLY : OptInput
USE GIGC_State_Met_Mod, ONLY : MetState
USE GRID_MOD,            ONLY : GET_AREA_CM2
USE LIGHTNING_NOX_MOD,   ONLY : EMIS_LI_NOx
USE PBL_MIX_MOD,         ONLY : GET_PBL_TOP_L
USE PRESSURE_MOD,        ONLY : GET_PEDGE
USE TRACERID_MOD,        ONLY : CTRMB,     IDEMIS,  IDENO
USE TROPOPAUSE_MOD,      ONLY : ITS_IN_THE_STRAT

! Ship plume emissions moved from calcrate.F (cdh, 4/24/2013)
USE DRYDEP_MOD,          ONLY : SHIPO3DEP
USE ICOADS_SHIP_MOD,     ONLY : GET_ICOADS_SHIP
USE EDGAR_MOD,           ONLY : GET_EDGAR_NOx
USE EMEP_MOD,            ONLY : GET_EMEP_ANTHRO, GET_EUROPE_MASK
USE TIME_MOD,            ONLY : GET_TS_EMIS
USE GRID_MOD,            ONLY : GET_AREA_CM2
USE TRACERID_MOD,        ONLY : IDTNO,  IDTO3,  IDTHNO3
USE TRACERID_MOD,        ONLY : IDNO,   IDO3,   IDHNO3, IDNO2
USE TRACERID_MOD,        ONLY : IDENO,  IDEO3,  IDEHNO3
```

```
      USE DIAG_MOD,           ONLY : AD32_SHIP, AD32_SHIP_COUNT
      USE DIAG_MOD,           ONLY : AD36_SHIP, AD36_SHIP_COUNT
      USE DIAG_MOD,           only : AD63,      AD63_COUNT
      USE DIAG63_MOD,         ONLY : DO_SAVE_DIAG63
      USE PARANOX_MOD,        ONLY : INTERPOLATE_LUT2
      USE COMODE_MOD,         ONLY : CSPEC, AIRDENS
      USE RCP_MOD,            ONLY : GET_RCP_EMISSION, RCP_AC_NOx
      USE CMN_SIZE_MOD             ! Size parameters
      USE COMODE_LOOP_MOD          ! IDEMS, NEMIS
      USE CMN_DIAG_MOD             ! Diagnostic flags
      USE CMN_NOX_MOD              ! GEMISNOX2

      IMPLICIT NONE
```

INPUT PARAMETERS:

```
      ! CO, hydrocarbon emission   [molec tracer/box/s]
      REAL*8,         INTENT(IN)  :: EMISRR(IIPAR,JJPAR,NEMPARA+NEMPARB)

      ! Multi-level NOx emissions  [molec NOx/box/s]
      REAL*8,         INTENT(IN)  :: EMISRRN(IIPAR,JJPAR,NOXEXTENT)

      ! Is this the root CPU?
      LOGICAL,        INTENT(IN)  :: am_I_Root

      ! Input Options object
      TYPE(OptInput), INTENT(IN)  :: Input_Opt

      ! Meteorology State object
      TYPE(MetState), INTENT(IN)  :: State_Met
```

OUTPUT PARAMETERS:

```
      ! Success or failure?
      INTEGER,        INTENT(OUT) :: RC
```

REMARKS:

```
    Developers: lwh, jyl, gmg, djj, bdf, bmy, 6/8/98, 6/11/08
    (lwh, jyl, gmg, djj, bdf, bmy, 6/8/98, 6/11/08)

    REMIS(JLOOP,N) = emis. rate of species corr. to tracer N in box JLOOP
                     (reaction number NTEMIS(N))
```

REVISION HISTORY:

```
    (1 ) Original code from Harvard Tropospheric Chemistry Module for 3-D
         applications by Larry Horowitz, Jinyou Liang, Gerry Gardner,
         Prof. Daniel Jacob of Harvard University (Release V2.0)
    (2 ) New version 3.0 by Bob Yantosca to place NOx emissions into boxes
```

```
      above the surface. (bmy, 6/8/98)
(3 ) Also now do chemistry up to the location of the annual mean
      tropopause (bmy, 12/9/99)
(4 ) BURNEMIS is now dynamically allocatable and is contained in F90
      module "biomass_mod.f".  BIOTRCE and NBIOTRCE are also contained
      in "biomass_mod.f".  (bmy, 9/12/00)
(5 ) BIOFUEL is now dynamically allocatable and is contained in F90
      module "biofuel_mod.f".  BFTRACE and NBFTRACE are also contained
      in "biofuel_mod.f" (bmy, 9/12/00, 4/17/01)
(6 ) BURNEMIS and BIOFUEL are now treated as true global arrays,
      and need to be referenced by the global offset variables
      IREF = I + I0 and JREF = J + J0 (bmy, 9/12/00)
(7 ) Now reference JLOP, REMIS, VOLUME from F90 module "comode_mod.f",
      in order to save memory (bmy, 10/19/00)
(8 ) Now add in up to NBFTRACE biofuel species (bmy, 4/17/01)
(9 ) Add new subroutine header, updated comments, cosmetic changes.
      (bmy, 4/17/01)
(10) Updated comments -- GEMISNOX is [molec/cm3/s]. (bdf, bmy, 6/7/01)
(11) For GEOS-3, we now distributes surface emissions throughout the
      boundary layer.  This is necessary since the first couple of GEOS-3
      surface layers are very thin.  Piling up of emissions into a small
      layer will cause SMVGEAR to choke.  (bdf, bmy, 6/15/01)
(12) Also now reference BFTRACE and NBFTRACE from "biofuel_mod.f",
      and reference AD12 from "diag_mod.f". (bdf, bmy, 6/15/01)
(13) For GEOS-1, GEOS-STRAT, emit into the surface layer, as we did
      in prior versions. (bmy, 6/26/01)
(14) Bug fix: corrected a typo for the biofuel emissions (bmy, 7/10/01)
(15) Bug fix: make sure BIOMASS and BIOFUEL, and SOIL NOx emissions have
      units of [molec/box/s] before distributing thru the boundary layer.
      This involves multiplication by VOLUME(JLOOP1) and division by
      VOLUME(JLOOP). (bmy, 7/16/01)
(16) XTRA2(IREF,JREF,5) is now XTRA2(I,J).  BIOFUEL(:,IREF,JREF) is now
      BIOFUEL(:,I,J). BURNEMIS(:,IREF,JREF) is now BURNEMIS(:,I,J).
      Replace PW(I,J) with P(I,J). (bmy, 9/28/01)
(17) Removed obsolete code from 9/01 (bmy, 10/24/01)
(18) Now references GET_PEDGE from "pressure_mod.f", to compute P at
      the bottom edge of grid box (I,J,L).  (dsa, bdf, bmy, 8/21/02)
(19) Now reference IDTNOX, IDENOX, etc from "tracerid_mod.f" (bmy, 11/6/02)
(20) Remove references to IREF, JREF (bmy, 2/11/03)
(21) NEMIS is now NEMIS(NCS) for SMVGEAR II (gcc, bdf, bmy, 4/1/03)
(22) Added parallel loop over N.  Also directly substituted JLOP(I,J,1)
      for all instances of JLOOP1.  Updated comments. (hamid, bmy, 3/19/04)
(23) Bug fix for COMPAQ compiler...do not use EXIT from w/in parallel loop.
      (auvray, bmy, 11/29/04)
(24) Now replace XTRA2 with GET_PBL_TOP_L in "pbl_mix_mod.f".  Now remove
      reference to CMN, it's obsolete.  Now references GET_TPAUSE_LEVEL
      from "tropopause_mod.f" (bmy, 8/22/05)
(25) Now make sure all USE statements are USE, ONLY (bmy, 10/3/05)
```

```
(26) Now updated for new "biomass_mod.f" (bmy, 4/5/06)
(27) Now account for the different definition of tropopause in case
     of variable tropopause.   The BIOMASS array from "biomass_mod.f" is
     now in units of [molec CO/cm2/s].  Adjust unit conversion accordingly.
     Also replace NBIOMAX with NBIOMAX_GAS, since aerosol biomass is
     handled elsewhere.  (bdf, phs, bmy, 9/27/06)
(28) Now replace GEMISNOX array (from CMN_NOX) with module arrays
     EMIS_LI_NOx and EMIS_AC_NOx (ltm, bmy, 10/3/07)
(29) Bug fix: resize EMISRR to be consistent w/ CMN_O3 (bmy, jaf, 6/11/08)
(30) Limit emissions into the surface level only (lin, 5/29/09)
(31) Bug fix: cycle if IDEMIS(NN) <= 0 to avoid array-out-of-bounds
     errors (bmy, 8/6/09)
(32) Check for emissions above PBL -anthro NOx only for now- (phs, 10/27/09)
(33) Modify selection of biomass burning emissions (hotp, 8/3/09)
(34) Moved NOx scaling to improve parallelization. (ccc, 11/10/10)
16 Dec 2010 - R. Yantosca - Removed obsolete, commented-out code
16 Dec 2010 - R. Yantosca - Added ProTeX headers
21 Dec 2010 - R. Yantosca - Now set REMIS=0d0.  Also updated comments.
01 Mar 2012 - R. Yantosca - Now use GET_AREA_CM2(I,J,L) from grid_mod.F90
01 Mar 2012 - R. Yantosca - Now reference IXSAVE, IZSAVE from comode_mod.F
30 Jul 2012 - R. Yantosca - Now accept am_I_Root as an argument when
                            running with the traditional driver main.F
02 Aug 2012 - R. Yantosca - Add error trap for JLOOP=0 under DEVEL tag
05 Mar 2013 - R. Yantosca - Now use Input_Opt%LPRT and Input_Opt%LNLPBL
14 Mar 2013 - M. Payer    - Replace NOx emissions with NO emissions as part
                            of removal of NOx-Ox partitioning
17 Jun 2013 - R. Yantosca - Bug fix: declare FRACTION_NOX, INT_OPE with
                            REAL*4 explicitly to avoid numerical errors
                            when OMP=yes.
18 Jun 2013 - R. Yantosca - Bug fix: always add into REMIS to better ensure
                            that identical results will be obtained when
                            compiling with OMP=no vs. OMP=yes.
18 Jun 2013 - R. Yantosca - Remove COEF11 variable, that is always =1 for
                            O3, HNO3, and NO.
22 Jul 2013 - M. Sulprizio- Now copy LRCPSHIP from Input_Opt
31 Jul 2013 - M. Sulprizio- Now only add aircraft emissions to REMIS if using
                            RCP aircraft emissions. Emissions are added
                            directly to STT in aeic_mod.F when using AEIC
                            aircraft emissions.
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.36 sfcwindsqr

Function SFCWINDSQR computes the surface wind squared from the U and V winds at 10 m above the surface.

INTERFACE:

```
REAL*8 FUNCTION SFCWINDSQR( I, J, U10M, V10M )
```

USES:

```
USE CMN_SIZE_MOD     ! Size parameters

IMPLICIT NONE
```

INPUT PARAMETERS:

```
INTEGER, INTENT(IN) :: I   ! Longitude index
INTEGER, INTENT(IN) :: J   ! Latitude index
REAL*8,  INTENT(IN) :: U10M(IIPAR,JJPAR) ! E/W wind speed @ 10m [m/s]
REAL*8,  INTENT(IN) :: V10M(IIPAR,JJPAR) ! N/S wind speed @ 10m [m/s]
```

REVISION HISTORY:

```
21 Dec 1998 - R. Yantosca - Initial version
(1 ) The old SFCWINDSQR computed the surface wind squared (m/s)^2 from the
     the Harvard CTM winds (kg/s).  But since the DAO winds are already
     in units of (m/s) then the previous unit conversion is unnecessary
     and costly in terms of computer resources.
(2 ) Since GEOS-1 has U and V at 10 m, these are more representative
     of the surface than UWND(I,J,1) and VWND(I,J,1).
(3 ) Pass GEOS-1 U10M and V10M fields via CMN_UV10M so that the argument
     list does not have to be modified in several existing Harvard CTM
     subroutines.
(4 ) GEOS-STRAT does not store U10M and V10M, so compute 10 m wind speed
     from UWND(I,J,1) and VWND(I,J,1) in MAKE_WIND10M.
(5 ) Now check for NaN's (bmy, 4/27/00)
(6 ) Now reference U10M and V10M from "dao_mod.f" instead of from
     common block header files "CMN_UV10M".  Also extend code
     to GEOS-2 and GEOS-3 met fields. (bmy, 7/11/00)
(7 ) Now use interface IT_IS_NAN (from "error_mod.f") to trap NaN's.
     This will work on DEC/Compaq and SGI platforms. (bmy, 3/8/01)
(8 ) Now call CHECK_VALUE from "error_mod.f".  This will test SFCWINDSQR
     for NaN or Infinity conditions.  Also updated comments and made
     cosmetic changes. (bmy, 7/16/01)
(9 ) Removed obsolete, commented-out code from 7/01 (bmy, 11/26/01)
(10) Remove support for GEOS-1 and GEOS-STRAT met fields.  Also remove
     call to CHECK_VALUE. (bmy, 8/4/06)
08 Dec 2009 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete
```

1.120.37 sunparam

Subroutine SUNPARAM is called by BIOFIT to perform the light correction used in the dry deposition and canopy NOx modules.

INTERFACE:

```
SUBROUTINE SUNPARAM( X )
```

USES:

```
IMPLICIT NONE
```

DEFINED PARAMETERS:

```
INTEGER, PARAMETER    :: NN = 3  ! # of variables (LAI, SUNCOS, CLDFRC)
```

INPUT/OUTPUT PARAMETERS:

```
REAL*8, INTENT(INOUT) :: X(NN)   ! LAI, SUNCOS, or cloud fraction
```

REMARKS:

This routine is ancient code from Yuhang Wang. It was part of the old Harvard-GISS CTM and was ported into GEOS-Chem. See this reference for more information:

Wang, Y., D.J. Jacob, and J.A. Logan, "Global simulation of tropospheric O3-NOx-hydrocarbon chemistry, 1. Model formulation", J. Geophys. Res., 103/D9, 10,713-10,726, 1998.

REVISION HISTORY:

13 Dec 2012 - R. Yantosca - Added ProTeX headers
20 Aug 2013 - R. Yantosca - Removed "define.h", this is now obsolete