

WRF | GC

## Running WRF with the GEOS-Chem Chemical Module Updated for WRF-GC v2.0

Haipeng Lin, Xu Feng  
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# A quick recap of the WRF-GC structure

**WRF | GC = WRF + GEOS-Chem + Coupler**

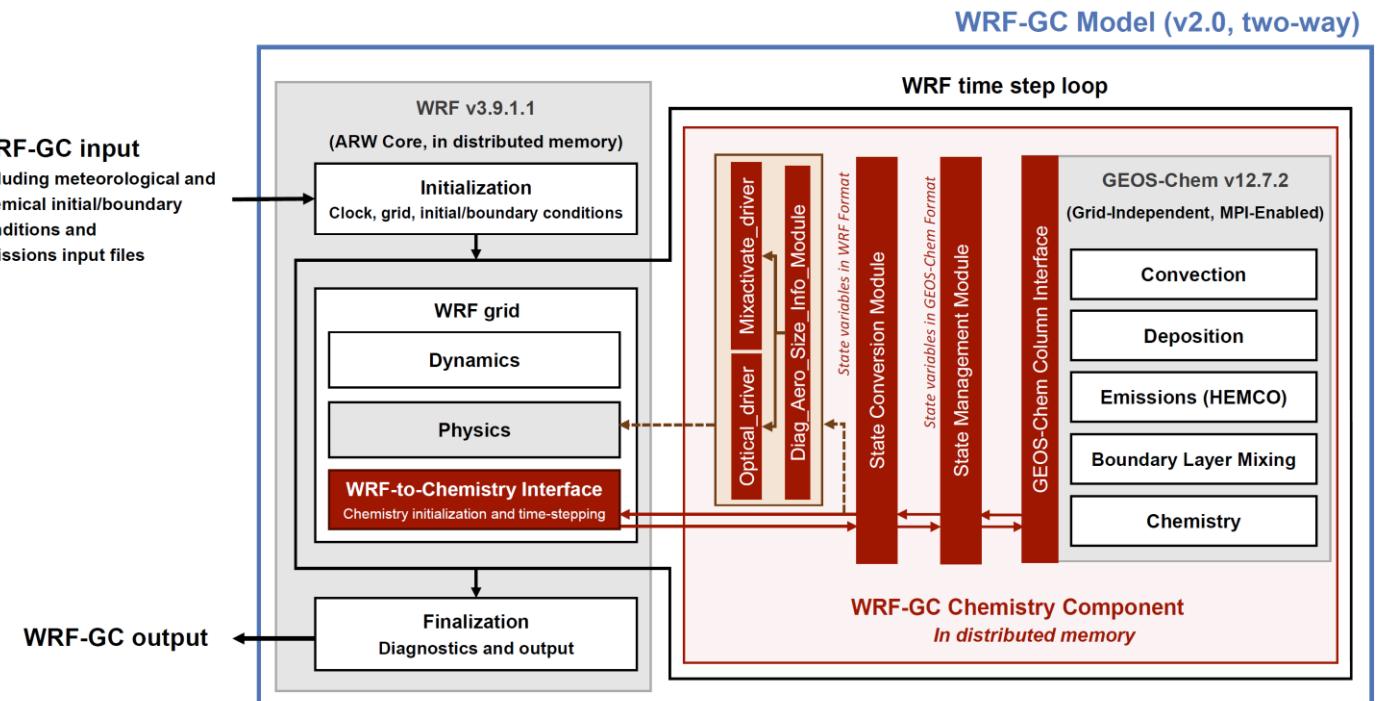
**WRF** drives the model

**Coupler** contains interfaces to two models

**GEOS-Chem** provides chemistry

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All models are off-the-shelf with no additional modifications needed!



# Getting ready · System requirements

**Compiler:** Intel (version 15 and above)

**MPI Library:** MVAPich2 (version 2.3+)

**Libraries:** zlib, hdf5 (1.8), netCDF C (4.6.1), netCDF Fortran (4.4.4), JasPer (1.900)

**Tools:** Git version management

- Above are recommended versions.
- If you are running on a cluster, contact your system administrator.
- We recommend reviewing the “Installing libraries for GEOS-Chem” wiki page:  
[http://wiki.seas.harvard.edu/geos-chem/index.php/Installing\\_libraries\\_for\\_GEOS-Chem](http://wiki.seas.harvard.edu/geos-chem/index.php/Installing_libraries_for_GEOS-Chem)

# Getting ready · Installing libraries

Installing on a shared system:



wrf-gc/

**1 Create a directory** for WRF-GC with sub-folders for libraries:

In our example, this will be /home/example/wrf-gc

- bin/
- lib/
- share/
- include/

**2 Install the compiler and libraries** in the following order:

MVAPich → zlib, jasper → hdf5 → netCDF-C → netCDF-Fortran

When configuring libraries, remember to specify the install location:

```
./configure --prefix=/home/example/wrf-gc
```

Usually the install process for each library is:

“make”(compile) → “make install”(install to folder) → “make check”(verify)

# Getting ready · Starter kit



wrf-gc/

Download our “WRF|GC Starter Kit”!



<https://fugroup.org/wrf-gc/starter-kit.zip>

It includes:

- ✓ Sample environmental configuration file (for the bash shell)
- ✓ Sample re-analysis met data\* for boundary conditions
- ✓ Sample initial and boundary chemical data
- ✓ Sample configuration namelist file for WRF-GC

Extract the files to your **WRF-GC working directory**

- bin/

- lib/

- share/

- include/

- samples/

- bashrc

\* NCAR/UCAR RDA FNL Dataset: <https://rda.ucar.edu/datasets/ds083.2/>

# Getting ready · Set up the environment



wrf-gc/

- 1 Modify the sample “bashrc” environment file with the correct directories like so:

```
export PATH="/home/example/wrf-gc /lib:$PATH"
export LD_LIBRARY_PATH="/home/example/wrf-gc /lib"
...
export NETCDF="/home/example/wrf-gc "
export HDF5="/home/example/wrf-gc "
...

```

- bin/
- lib/
- share/
- include/
- samples/
- bashrc

- 2 Load the configuration file using the “source” command:

```
source /home/example/wrf-gc /bashrc
```

# Obtaining WRF|GC

As WRF|GC is a coupled model, you need to obtain each model separately:

- Step 1: Obtaining the WRF Model
  - Step 2: Obtaining the WRF|GC Coupler & GEOS-Chem Code
  - Step 3: Obtaining auxiliary tools
- 
- Current supported versions of WRF and GEOS-Chem for **WRF-GC v2.0**:  
**WRF v3.9.1.1 & GEOS-Chem v12.8.2**
  - WRF **v3.9.1.1** is recommended. WRFv4 support will be available at a later date.

# Obtaining WRF|GC · Obtaining WRF



wrf-gc/

Download the WRF model and the WRF Pre-processing System.



<http://www2.mmm.ucar.edu/wrf/users/download/>

- We recommend version **3.9.1.1** for our **v2.0** release.
  - Only version 3.9+ is supported, due to the availability of sigma-eta hybrid grids by the WRF model required for GEOS-Chem.
- Extract the “WRFV3” and “WPS” folders into our **WRF-GC working directory**

- bin/
- lib/
- share/
- include/
- WRFV3/
- WPS/
- samples/
- bashrc

# Obtaining WRF|GC · Obtaining GC and the Coupler

Navigate to the WRFV3 folder.

Use Git to download WRF|GC into a folder named “chem”.

```
git clone https://github.com/jimmielin/wrf-gc-alpha.git chem
```



wrf-gc/



- WRFV3/

- main/

- frame/

- run/

- chem/

- gc/

- config/

...

- For our **v2.0** release, GEOS-Chem 12.8.2 is included.
- In future releases you will be able to download your own copy of GEOS-Chem.



We aim to support a “drop-in” replacement of GEOS-Chem latest releases.

# Obtaining WRF|GC · Obtaining tools

You will also need a set of utilities to aid running the model.

- “mozbc” uses output from MOZART4/GEOSS5 to generate initial and boundary conditions for WRF-GC chemistry:

👉 [https://github.com/fengx7/mozbc\\_for\\_WRFv3.9](https://github.com/fengx7/mozbc_for_WRFv3.9)

The original mozbc was developed by NCAR ACOM:

<https://www.acom.ucar.edu/wrf-chem/download.shtml>

- ... other tools available for WRF-Chem may also be used



wrf-gc/

- bin/
- lib/
- share/
- include/
- WRFV3/
- WPS/
- mozbc/
- samples/
- bashrc

# Building WRF|GC

- 1 Navigate to the WRFV3 folder, and configure WRF using the following command:

```
./configure -hyb
```

- When prompted, choose the “Intel compiler, icc, ifort, (dmpar)” option
  - Or choose the option relevant to your compiler.
  - (dmpar) means **distributed-memory parallel**, which is used in WRF & GCHP.

- 2 Navigate to the WRFV3/chem folder and install the GEOS-Chem species configuration file into WRF:

```
make install_registry
```



wrf-gc/

- bin/
- lib/
- share/
- include/
- WRFV3/
- chem/
- ...
- WPS/
- mozbc/
- samples/
- bashrc

# Building WRF|GC



wrf-gc/

Return to the WRFV3 folder, and build WRF-GC:

```
./compile em_real
```

- We recommend storing the output of this command in a log file, just in case.
- For errors in the compile process, please refer to our online guide for help.

- bin/

- lib/

- share/

- include/

- WRFV3/

- WPS/

- mozbc/

- samples/

- bashrc

# Building WRF|GC



wrf-gc/

When successful you should see the following output on your screen:

```
=====
build started: Sun Apr 15 12:00:00 CST 2018
build completed: Sun Apr 15 13:00:00 CST 2018
--->           Executables successfully built <---
-rwxrwxr-x 1 hplin hplin 63670720 Apr 15 05:34 main/ndown.exe
-rwxrwxr-x 1 hplin hplin 63753008 Apr 15 05:35 main/real.exe
-rwxrwxr-x 1 hplin hplin 62683008 Apr 15 05:34 main/tc.exe
-rwxrwxr-x 1 hplin hplin 71153896 Apr 15 05:34 main/wrf.exe
=====
```

**Your copy of WRF-GC will be available in the **run** directory.**

- bin/
- lib/
- share/
- include/
- WRFV3/
- chem/
- run/
- ...
- WPS/
- mozbc/
- samples/
- bashrc

# Building WRF|GC · Common Errors

Common troubleshooting steps:

- Ensure that:
  - The environmental variables are set correctly – the **source** command
  - Libraries are loaded from their correct location (and have been compiled correctly)
  - You have run the “`make install_registry`” command
- Try:
  - Compiling the GEOS-Chem part separately: go into the “chem” folder and use  
`make compile_chem`
  - Cleaning up and starting again: in the “WRFV3” folder, use “`./clean -all`”

# Building WRF|GC · Building WPS



wrf-gc/

Building the **WRF Preprocessor System (WPS)** is largely similar.

Navigate to the WPS folder and configure:

`./configure`

- When prompted, choose “Intel compiler, `icc`, `ifort`, (serial)” option

Build the WRF pre-processor system:

`./compile`

- `bin/`
- `lib/`
- `share/`
- `include/`
- `WRFV3/`
- `WPS/`
- `mozbc/`
- `samples/`
- `bashrc`

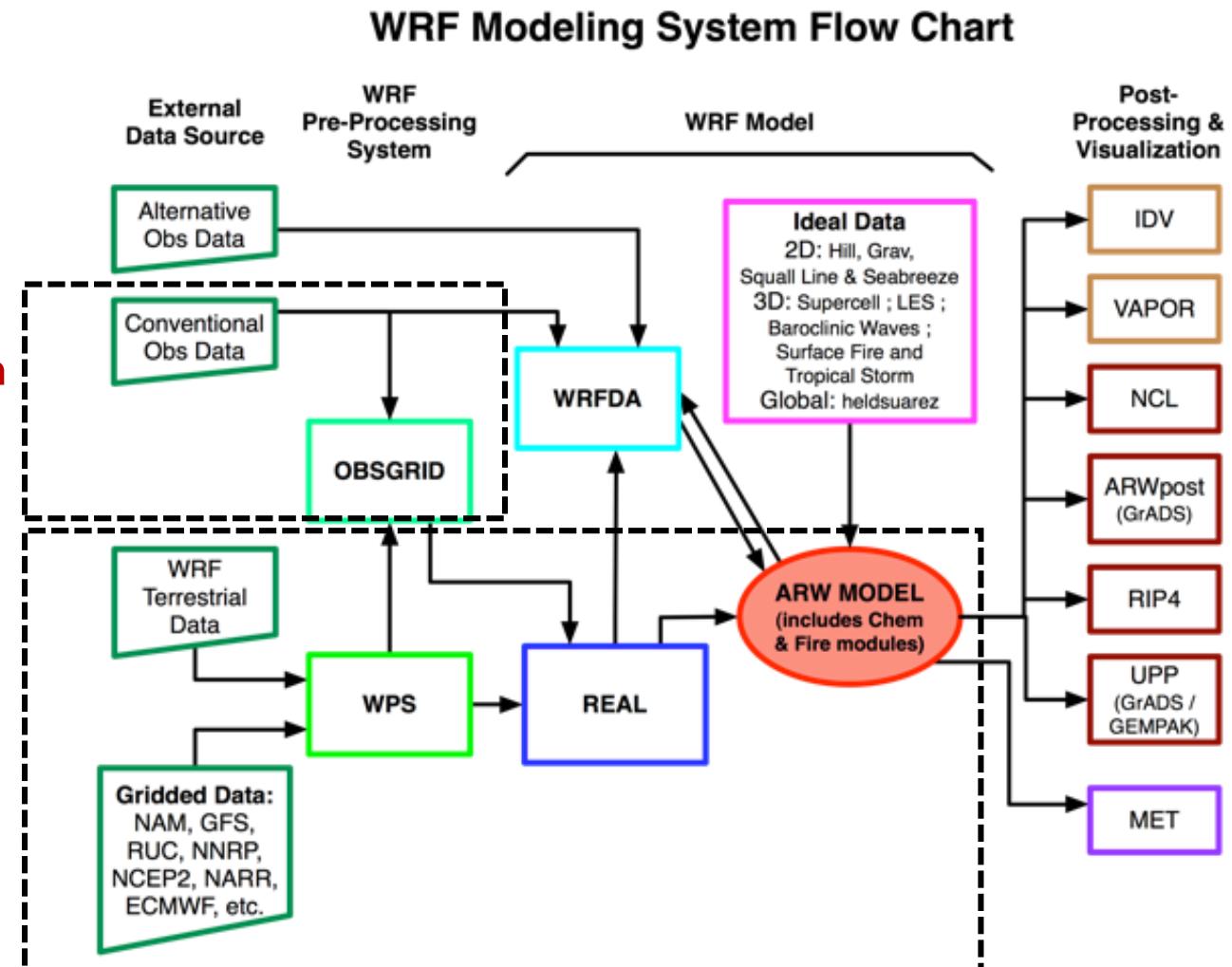


# Running WRF|GC

# Running WRF|GC is largely similar to running WRF-Chem

Optional: for nudging run

For real-data simulations

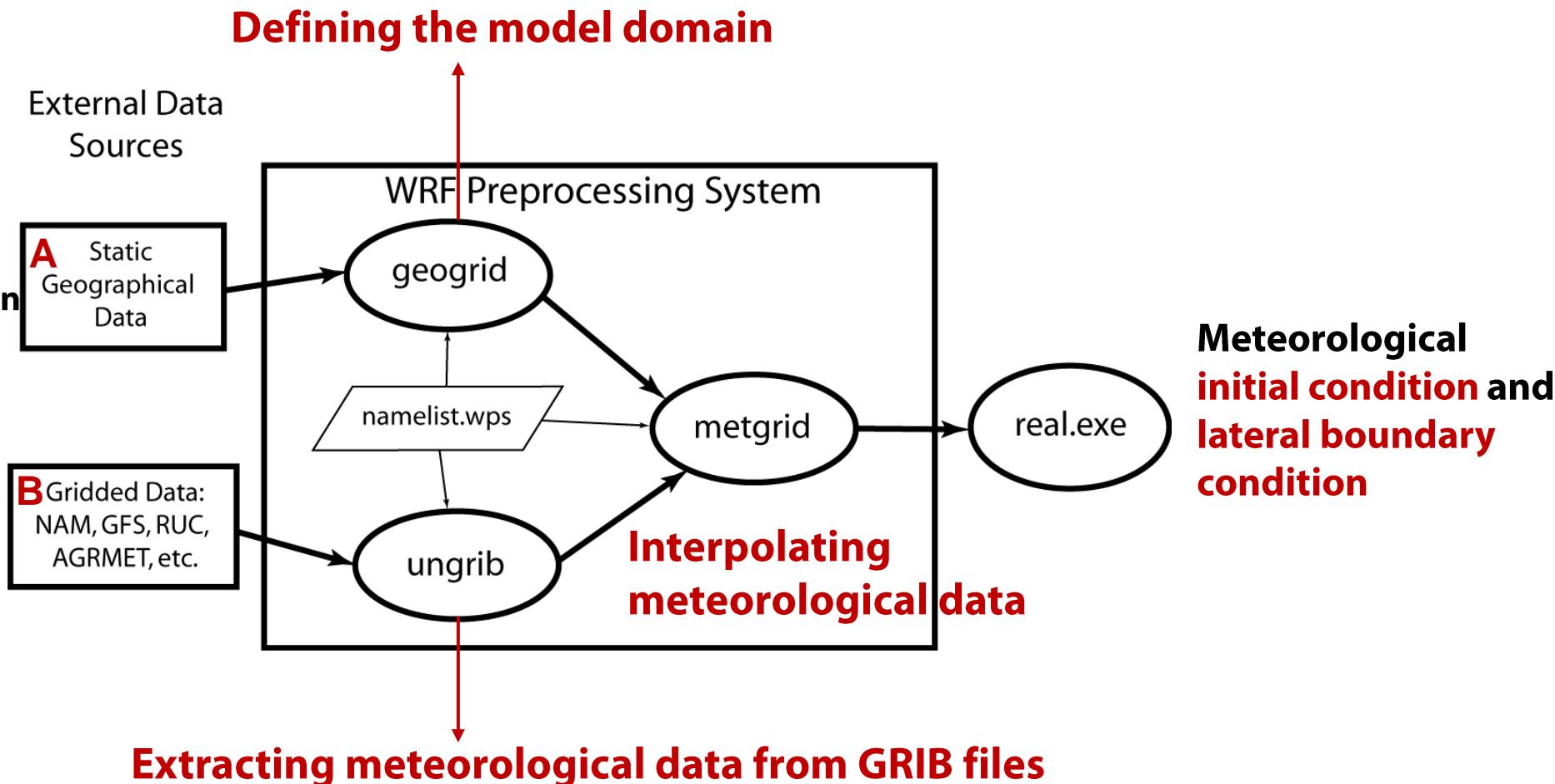


# WPS: WRF preprocessing System

arch compile configure.wps  
clean configure configure.wps.backup geogrid link\_grib.csh metgrid.exe namelist.wps.all\_options namelist.wps.global README ungrid.exe  
geogrid.exe metgrid namelist.wps namelist.wps.fire namelist.wps.nmm namelist.wps.nmm ungrid util

**MODIS IGBP land-cover classification (21 categories)**  
**USGS land-cover classification (24 categories)**

**Many available free meteorological datasets**  
**NCEP Final Analysis**  
1 degree; 6-hourly;  
1999-07-30 to current



A [http://www2.mmm.ucar.edu/wrf/users/download/get\\_sources\\_wps\\_geog\\_V3.html](http://www2.mmm.ucar.edu/wrf/users/download/get_sources_wps_geog_V3.html)

B [http://www2.mmm.ucar.edu/wrf/users/download/free\\_data.html](http://www2.mmm.ucar.edu/wrf/users/download/free_data.html)

# geogrid.exe: Defining the model domain

> ./geogrid.exe

An example of “geogrid” namelist records in “namelist.wps” file

Generating

geo\_em.d01.nc

```
&share
  wrf_core = 'ARW',
  max_dom = 1,
  start_date = '2015-01-18_00:00:00',
  end_date   = '2015-01-20_00:00:00',
  interval_seconds = 21600
  io_form_geogrid = 2,
/
```

```
&geogrid
  parent_id      = 1,
  parent_grid_ratio = 1,
  i_parent_start = 1,
  j_parent_start = 1,
  e_we           = 245,
  e_sn           = 181,
  geog_data_res = 'gtopo_2m+usgs_2m+nesdis_greenfrac+2m',
  dx = 27000,
  dy = 27000,
  map_proj = 'mercator',
  ref_lat   = 35,
  ref_lon   = 105,
  truelat1  = 30.0,
  stand_lon = 105,
  geog_data_path = '/glade/p/work/wrfhelp/WPS_GEOG/'
/
```

Only the single domain is supported currently

Simulation time

The interval of meteorological input files , unit: seconds

The format of the domain files created by the geogrid; 2 for NetCDF

These can be ignored for single domain

The size of the grid in the x/y direction

USGS categories are only supported

Grid distance in the x/y direction where the map scale factor is 1,  
unit: meters for ‘mercator’; degrees for ‘lat-lon’

Map projections and specified parameters

Only Mercator (‘mercator’)/ Unrotated regular latitude-longitude (‘lat-lon’) are supported

Path for geographical static data

# ungrib.exe: Extracting the meteorological data

An example of “ungrib” namelist records in “namelist.wps” file

```
&ungrib  
out_format = 'WPS',  
prefix = 'FILE',  
/
```

WPS intermediate-format files created by ungrib  
Prefix for intermediate-format files created by ungrib

```
> ln -s ungrib/Variable_Tables/Vtables.GFS Vtable  
> ./link_grib.csh /dir/met/data/fnl*  
> ./ungrib.exe
```

Generating

```
FILE:2015-01-18_00  
FILE:2015-01-18_06  
FILE:2015-01-18_12  
FILE:2015-01-18_18  
FILE:2015-01-19_00  
FILE:2015-01-19_06  
FILE:2015-01-19_12  
FILE:2015-01-19_18  
FILE:2015-01-20_00
```

# metgrid.exe: Interpolating the meteorological data

An example of “metgrid” namelist records in “namelist.wps” file

```
&metgrid  
  fg_name = 'FILE'  
  io_form_metgrid = 2,  
 /
```

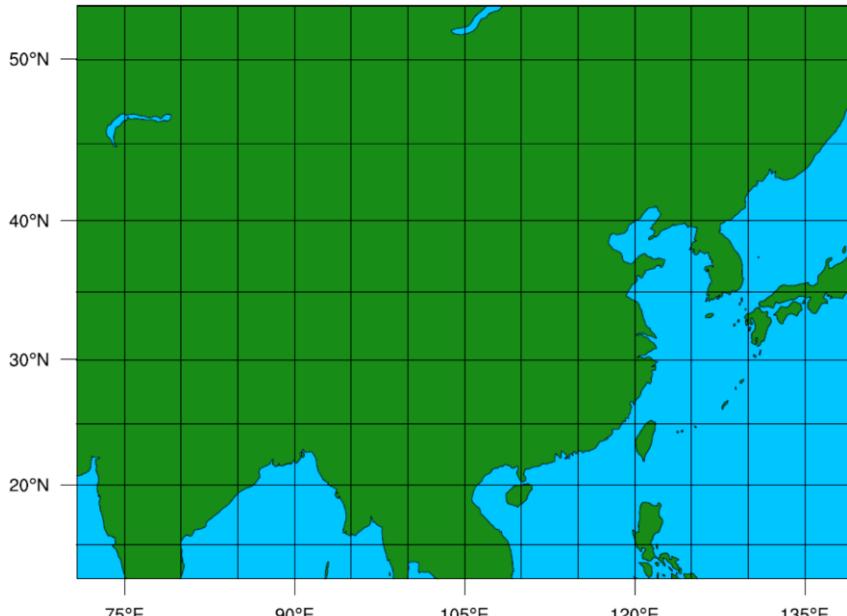
Prefix of intermediate-format files created by ungrb

The format of files created by metgrid; 2 for NetCDF

```
> ./metgrid.exe  
> ncl util/plotgrids_new.ncl
```

Check the domain

WPS Domain Configuration



Generating

```
met_em.d01.2015-01-18_00:00:00.nc  
met_em.d01.2015-01-18_06:00:00.nc  
met_em.d01.2015-01-18_12:00:00.nc  
met_em.d01.2015-01-18_18:00:00.nc  
met_em.d01.2015-01-19_00:00:00.nc  
met_em.d01.2015-01-19_06:00:00.nc  
met_em.d01.2015-01-19_12:00:00.nc  
met_em.d01.2015-01-19_18:00:00.nc  
met_em.d01.2015-01-20_00:00:00.nc
```

# Preparing GEOS-Chem shared data directories

Set up the top-level root directory for GEOS-Chem shared data (**ExtData**)

The ExtData directory structure contains two subdirectories (necessarily)

- **CHEM\_INPUTS**: Non-emission data for GEOS-Chem chemistry modules
- **HEMCO**: Emissions inventories for the HEMCO emissions component

# Preparing chemical initial/boundary condition data

- Chemical initial and boundary condition data can be used output from global simulation MOZART-4/GEOS-5 similar to WRF-Chem.
- Please download the data from <https://www.acom.ucar.edu/wrf-chem/mozart.shtml>

The screenshot shows two side-by-side web pages. The left page is the 'MOZART DOWNLOAD' section of the NCAR WRF-Chem website. It includes a sidebar with links to WRF-Chem Home, People, Development, Publications, and Presentations. The main content area contains text about MOZART-4 results, simulation details, and download instructions. The right page is a data request form titled 'Your information'. It asks for contact details like name, affiliation, usage, email, and phone. It also includes fields for specifying geographic bounds and a starting date. Labels on the right side of the right page point to specific features: 'Your information' points to the contact fields; 'Larger than your domain' points to the geographic bounding fields; and '3~5 days earlier than your start time' points to the starting date field.

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**Atmospheric Chemistry Observations & Modeling**

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**Presentations**

**MOZART DOWNLOAD**

MOZART-4 results for a subset of the globe and a range of dates can be downloaded from this page. Output is provided every 6 hours. Each request is provided as a single netcdf file. We **strongly** recommend that you **download a single day** for your region to check the file size and then request a range of dates that will result in a manageable file size. **Questions about MOZART-4 and requests for additional dates can be addressed to Louisa Emmons (emmons at ucar . edu).**

Simulation **MOZART-4/GEOS-5** is driven by meteorological fields from the NASA GMAO GEOS-5 model. SYNOZ and O3RAD are not used in this simulation, as there seems to be reasonable strat-trop exchange when using GEOS5 fields in MOZART-4. This simulation uses anthropogenic emissions based on David Streets' inventory for **ARCTAS** and fire emissions from FINN-v1 (Wiedinmyer et al., Geosci. Model Devel., 2011). These results are at 1.9x2.5 deg with 56 levels. Files for 1 day for the whole globe are 940 MB.

The 'date' and 'datesec' variables contain the date and time of the MOZART output. To verify the date of the downloaded files, please use 'ncdump -v date'. The program ncview does not properly interpret the 'time' variable and calculates an erroneous date. There is a change of variables between August 29 and 30, 2014; consequently, data requests across that boundary will deliver slightly fewer variables.

**MOZART-4/GEOS5 results are available for January 1, 2007 to January 21, 2018. For later dates, please use WACCM download instead.**

**Real-time MOZART-4 results that can be used for boundary conditions are available from the MOZART-4 forecast page.**

**Please enter your contact information in the space below:**

■ Your name:

■ Affiliation:

■ Intended usage (optional):

■ E-mail:

■ Phone:

**Your information**

**Enter the lat-lon and date bounds of the region to extract:**

To specify a box that crosses the Greenwich Meridian, enter longitude values like: 340 West and 20 East (from 20W to 20E).

North latitude (-90.0 to 90.0):

West longitude (0.0 to 360.0):  East longitude (0.0 to 360.0):

South latitude (-90.0 to 90.0):

Starting date:  January  1  Ending date:  January  1

**Larger than your domain**

**Submit your data request here:**   **3~5 days earlier than your start time**

# Preparing chemical IC/BC data using GEOS-Chem output

- We recommend you to use global GEOS-Chem output to prepare chemical IC/BC data.
- Please refer to [https://github.com/fengx7/WRF-GC-GCC\\_ICBC](https://github.com/fengx7/WRF-GC-GCC_ICBC)

## Step 1

Run the GEOS-Chem standard full-chemistry/tropchem simulation at a resolution of  $2 \times 2.5 / 4 \times 5$  degree (recommend  $2 \times 2.5$  degree). The running time must cover the WRF-GC simulation period: e.g. if the simulation period of WRF-GC is from 2015-06-10 00:00:00 to 2015-06-20 00:00:00 (UTC), the time ranges for GEOS-Chem can be from 2015-06-07 00:00:00 to 2015-06-21 00:00:00 (UTC). Output the netCDF diagnostic files every 6 hours (00, 06, 12, 18), including

- (a) GEOSChem.SpeciesConc.xxxxxxxxxxxxxxx.nc4 (contains instantaneous "SpeciesConc\_?ADV?")
- (b) GEOSChem.StateMet.xxxxxxxxxxxxxxx.nc4 (contains "Met\_PS1DRY").

## Step 2

Use the MATLAB script "convert\_gcoutput\_mozart\_structure\_selected\_domain.m" to merge the GEOS-Chem output files and reconstruct the data structure so that mozbc could read it.

## Step 3

Run mozbc using the generated file. We provide mozbc input files "GEOSCHEM\_v12\_2\_1.inp" and "GEOSCHEM\_v12\_8\_1.inp", which contain the default advected species ('SpeciesConc\_?ADV?) of GEOS-Chem v12.2.1 or GEOS-Chem v12.8.1. If you want to change the species, please modify the "spc\_map" in the input file, e.g.

```
'isoprene -> ISOP'
```

where "isoprene" is the name of WRF-GC chemical species and "ISOP" is the name of GEOS-Chem species.

If the chemical IC/BC have been successfully written into the wrfinput and wrfbdy file, "bc\_wrfchem completed successfully" will appear.

# Preprocessor tool MOZBC

- The chemical IC/BC data are processed by the WRF-Chem processor called mozbc. Please download the mozbc utility from [https://github.com/fengx7/mozbc\\_for\\_WRFv3.9](https://github.com/fengx7/mozbc_for_WRFv3.9) (**this modified version needs to be used for WRF-GC**).

## mozbc\_for\_WRFv3.9

Modify the WRF-Chem preprocessor tool (mozbc) to work with the hybrid sigma-pressure vertical coordinate introduced with WRF V3.9. The WRF-Chem preprocessor tool (mozbc) is used to creates chemical lateral boundary and initial conditions from global chemistry model output. WRF model introduced the hybrid sigma-pressure vertical coordinated in Version 3.9. Mozbc only works with the terrain-following vertical coordinate. The sourcecode of mozbc can be obtained from <https://www.acom.ucar.edu/wrf-chem/download.shtml>. We modified the definition of the dry air pressure with the hybrid sigma-pressure vertical coordinate in two files (main\_bc\_wrfchem.f90 and mo\_mozart\_lib.f90). Please download the modified verison of mozbc used for WRF-GC model.

To build mozbc:

```
mkdir /your/dir/mozbc  
cd /your/dir/mozbc  
tar -xvf mozbc_for_WRFv3.9.tar  
chmod 777 *  
.make_mozbc
```

CBMZ-MOSAIC_4bins.inp	GOCART.inp	make_mozbc	mo_utils.f90	mozbc	RACM.inp	RADM2SORG.inp
CBMZ-MOSAIC_8bins.inp	main_bc_wrfchem.f90	mo_calendar.f90	mo_wrfchem_lib.f90	mozbc.tar	RACMSORG.inp	README.mozbc
GEOSCHEM.inp	Makefile	mo_mozart_lib.f90	mozart_data	MOZCART.inp	RADM2.inp	T1 MOZCART.inp

Path for storing chemical IC/BC data

# Running WRF GC

aerosol.formatted	CCN_ACTIVATE.BIN	create_p3_lookupTable_1.f90	HISTORY.rc	README.namelist	tc.exe
aerosol_lat.formatted	clim_p_trop.nc	diaginfo.dat	input.geos	README.rasm_diag	termvels.asc
aerosol_lon.formatted	CLM_ALB_ICE_DFS_DATA	dust.dat	jv_spec_mie.dat	README.tslist	tr49t67
aerosol_plev.formatted	CLM_ALB_ICE_DRC_DATA	ETAMPNEW_DATA	kernels.asc_s_0_03_0_9	real.exe	tr49t85
brc.dat	CLM_ASM_ICE_DFS_DATA	ETAMPNEW_DATA_DBL	kernels_z.asc	RRTM_DATA	tr67t85
bulkdens.asc_s_0_03_0_9	CLM_ASM_ICE_DRC_DATA	ETAMPNEW_DATA.expanded_rain	LANDUSE.TBL	RRTM_DATA_DBL	tracerinfo.dat
bulkradii.asc_s_0_03_0_9	CLM_DRDSDT0_DATA	ETAMPNEW_DATA.expanded_rain_DBL	masses.asc	RRTMG_LW_DATA	URBPARM.TBL
CAM_ABS_DATA	CLM_EXT_ICE_DFS_DATA	FJX_j2j.dat	MPTABLE.TBL	RRTMG_LW_DATA_DBL	URBPARM_UZE.TBL
CAM_AEROPT_DATA	CLM_EXT_ICE_DRC_DATA	FJX_spec.dat	namelist.input	RRTMG_SW_DATA	VEGPARM.TBL
CAMtr_volume_mixing_ratio.A1B	CLM_KAPPA_DATA	GENPARM.TBL	ndown.exe	RRTMG_SW_DATA_DBL	wind-turbine-1.tbl
CAMtr_volume_mixing_ratio.A2	CLM_TAU_DATA	grib2map.tbl	org.dat	so4.dat	wrf.exe
CAMtr_volume_mixing_ratio.RCP4.5	co2_trans	gribmap.txt	ozone.formatted	SOILPARM.TBL	
CAMtr_volume_mixing_ratio.RCP6	coeff_p.asc	h2so4.dat	ozone_lat.formatted	soot.dat	
CAMtr_volume_mixing_ratio.RCP8.5	coeff_q.asc	HEMCO_Config.rc	ozone_plev.formatted	ssa.dat	
capacity.asc	constants.asc	HEMCO_Diagn.rc	p3_lookup_table_1.dat	ssc.dat	

To configure WRF-GC, you need to modify three files inside the WRF run directory.

- HEMCO\_Config.rc      Root : /dir/to/data/ExtData/HEMCO

- input.geos      Root data directory : /dir/to/data/ExtData

Safely ignored: SIMULATION MENU (except Root data directory); TIMESTEP MENU; RADIATION MENU; OUTPUT MENU; DIAGNOSTIC MENU; BENCHMARK MENU; NESTED GRID MENU.

- namelist.input      `&time_control &domains &physics &dynamics &bdy_control &chem &namelist_quilt`

# Running WRF|GC

## Modify namelist.input

```
&time_control
run_days = 2,
run_hours = 0,
run_minutes = 0,
run_seconds = 0,
start_year = 2015,
start_month = 01,
start_day = 18,
start_hour = 00,
start_minute = 00,
start_second = 00,
end_year = 2015,
end_month = 01,
end_day = 20,
end_hour = 00,
end_minute = 00,
end_second = 00,
interval_seconds = 21600,
input_from_file = .true.,
history_interval = 60,
frames_pre_outfile = 1,
restart = .false.,
restart_interval = 0,
in_form_history = ?
```

## Notes

- We suggest you do not change the default value of "&dynamics" and "&bdy\_control".

# Running WRF|GC

## Modify namelist.input

```
io_form_history      = 2,  
io_form_restart      = 2,  
io_form_input        = 2,  
io_form_boundary     = 2,  
debug_level          = 0,  
/  
&domains  
time_step            = 120,  
time_step_fract_num  = 0,  
time_step_fract_den  = 1,  
max_dom              = 1,  
e_we                 = 245,  
e_sn                 = 181,  
e_vert               = 50,  
p_top_requested      = 1000,  
num_metgrid_levels   = 27,  
num_metgrid_soil_levels = 4,  
dx                   = 27000,  
dy                   = 27000,  
grid_id              = 1,  
parent_id             = 1,  
i_parent_start        = 1,  
j_parent_start        = 1,  
nparent_grid_ratio    = 1
```

## Notes

- We suggest you do not change the default value of "&dynamics" and "&bdy\_control".
- Microphysics schemes (mp\_physics = 10) supported are New Thompson et al. scheme, and **Morrison Double-Moment scheme (recommended)**.

# Running WRF|GC

## Modify namelist.input

```
parent_grid_ratio          = 1,  
parent_time_step_ratio     = 1,  
feedback                   = 0,  
smooth_option              = 0  
  
/  
&physics  
mp_physics                 = 10,  
ra_lw_physics               = 4,  
ra_sw_physics               = 4,  
radt                        = 15,  
sf_sfclay_physics           = 1,  
sf_surface_physics           = 2,  
sf_urban_physics             = 0,  
bl_pbl_physics               = 5,  
bldt                        = 0,  
cu_physics                  = 16,  
cudt                        = 0,  
cu_diag                      = 1,  
isfflx                       = 1,  
ifsnow                       = 1,  
icloud                       = 1,  
surface_input_source          = 1,  
num_soil_layers               = 4,  
num_land_cat                 = 24
```

## Notes

- We suggest you do not change the default value of "&dynamics" and "&bdy\_control".
- Microphysics schemes (mp\_physics = 10) supported are New Thompson et al. scheme, and **Morrison Double-Moment scheme (recommended)**.
- Cumulus Parameterization schemes (cu\_physics = 16) supported are **New-Tiedtke scheme (recommended)** and Zhang-McFarlene scheme.

# Running WRF|GC

## Modify namelist.input

```
num_land_cat          = 24,  
progn                = 0,  
cu_rad_feedback       = .true.,  
/  
&dynamics  
w_damping             = 1,  
diff_opt              = 1,  
km_opt                = 4,  
diff_6th_opt          = 0,  
diff_6th_factor        = 0.12,  
base_temp              = 290.,  
damp_opt               = 0,  
zdamp                 = 5000.,  
dampcoef              = 0.01,  
khdif                 = 0,  
kvdif                 = 0,  
non_hydrostatic         = .true.,  
moist_adv_opt          = 2,  
scalar_adv_opt          = 2,  
hybrid_opt             = 2,  
/  
&bdy_control  
spec_bdy_width         = 5,  
spec_zone              = 1
```

## Notes

- We suggest you do not change the default value of "&dynamics" and "&bdy\_control".
- Microphysics schemes (mp\_physics = 10) supported are New Thompson et al. scheme, and **Morrison Double-Moment scheme (recommended)**.
- Cumulus Parameterization schemes (cu\_physics = 16) supported are **New-Tiedtke scheme (recommended)** and Zhang-McFarlene scheme.
- For WRF-GC chemistry, choose **chem\_opt = 233**.

# Running WRF|GC

## Modify namelist.input

```
/  
&bdy_control  
spec_bdy_width          = 5,  
spec_zone                = 1,  
relax_zone               = 4,  
specified                 = .true.,  
nested                   = .false.,  
  
&chem  
kemit                    = 1,  
chem_opt                 = 233,  
chemdt                   = 10,  
gc_do_convection         = 1,  
gc_do_pblmix              = 1,  
gc_do_hemco               = 1,  
gc_do_drydep              = 1,  
gc_do_wetdep              = 1,  
gc_do_chemistry            = 1,  
have_bcs_chem             = .true.,  
ne_area                   = 150,  
  
&namelist_quilt  
nio_tasks_per_group       = 0,  
nio_groups                = 1,  
/
```

## Notes

- We suggest you do not change the default value of "**&dynamics**" and "**&bdy\_control**".
- Microphysics schemes (`mp_physics = 10`) supported are New Thompson et al. scheme, and **Morrison Double-Moment scheme (recommended)**.
- Cumulus Parameterization schemes (`cu_physics = 16`) supported are **New-Tiedtke scheme (recommended)** and Zhang-McFarlene scheme.
- For WRF-GC chemistry, choose **chem\_opt = 233**.
- You can configure processes by GEOS-Chem using the following switches.
  - ✓ Convection: `gc_do_convection` (=1/0 for on/off)
  - ✓ Emissions: `gc_do_hemco`
  - ✓ Turbulence/PBL mixing: `gc_do_pblmix`
  - ✓ Chemistry: `gc_do_chemistry`
  - ✓ Dry deposition: `gc_do_drydep`
  - ✓ Wet deposition: `gc_do_wetdep`

# Running WRF|GC

## Initialization WRF-GC

```
> cd /your/dir/WRFV3/run  
> ln -s /your/dir/WPS/met_em* .  
> ./real.exe
```

After running the real.exe program, the initial condition file “*wrfinput\_d01*” and boundary condition file “*wrfbdy\_d01*” are generated.

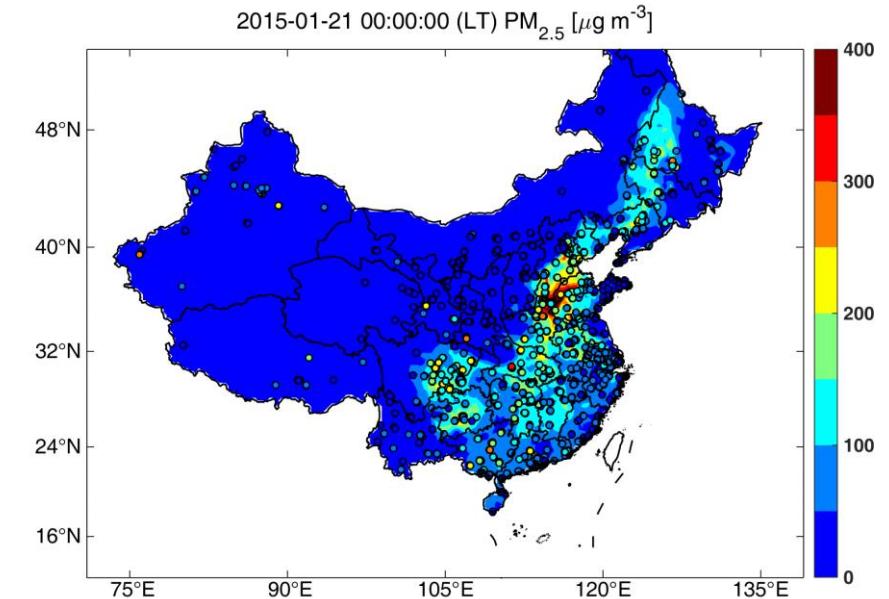
```
> cd /your/dir/mozbc  
> ./mozbc < GEOSCHEM.inp
```

After running the mozbc program, the **chemical species concentrations** from Mozart datasets are mapped to “*wrfinput\_d01*” and “*wrfbdy\_d01*” files.

```
> cd /your/dir/WRFV3/run  
> mpirun -n 6 ./wrf.exe
```

Output from WRF-GC are unified into the WRF output format (NetCDF Classic) files named “*wrfout\_d01\_2015-01-01\_00:00:00*”.

# Tools for analysing WRF|GC outputs



## NCL

The NCAR Command Language (NCL) can read in NetCDF data and create plots based on many example scripts for WRF. (Please refer to <http://www.ncl.ucar.edu/Applications/wrf.shtml> )

## NCVIEW

A visual browser for NetCDF format files (Please refer to <https://www.nersc.gov/users/data-analytics/data-management/i-o-libraries/netcdf-2/ncview/> )

## MATLAB

m\_map: A mapping package for MATLAB to create geographic plots. (Please refer to <https://www.eoas.ubc.ca/~rich/mapug.html> )

## PYTHON

wrf-python: A collection of diagnostic and interpolation routines to be used with WRF-ARW data.  
<https://pypi.org/project/wrf-python/1.0.1/>

# New features in WRF|GC v2.0

A two-way coupled version of WRF-GC model

# Running WRF|GC v2.0

**Running WRF-GC v2.0 is almost the same as running WRF-GC v1.0. To use the new features in WRF-GC v2.0, users just need to set the options in WRF-GC configuration file (namelist.input).**

- Step 1: Running WPS (geogrid.exe, ungrid.exe, and metgrid.exe) to define the model domain and interpolating the meteorological data.
- Step 2: Preparing chemical initial/boundary condition data (IC/BCs) .
- Step 3: Running real.exe to initialize WRF-GC (generating the initial condition file wrfinput\_d<domain> and boundary condition file wrfbdy\_d01).
- Step 4: Running mozbc to write the chemical IC/BCs into the wrfinput\_d<domain> and wrfbdy\_d01 files.
- Step 5: Running the main program wrf.exe.

# Aerosol-radiation interactions in WRF|GC v2.0

- To turn on the aerosol-radiation interactions in WRF-GC v2.0, you should use **RRTMG** shortwave scheme (**ra\_sw\_physics = 4**) and RRTMG longwave scheme (**ra\_lw\_physics = 4**).
- Please control the aerosol-radiation interactions using the option "**aer\_ra\_feedback**" in configuration file (namelist.input).

```
&chem
aer_ra_feedback = 0
(No feedback from the prognostic aerosols to the radiation schemes)
      = 1
(Turns on feedback from the prognostic aerosols to the radiation schemes)
/
```

# Diagnostic for aerosol-radiation interactions in WRF|GC v2.0

The diagnostic aerosol optical properties can be output from WRF-GC v2.0

- AOD at 300, 400, 600, 999nm wavelengths – **tauauer1, tauauer2, tauauer3, tauauer4**
- SSA at 300, 400, 600, 999nm wavelengths – **waer1, waer2, waer3, waer4**
- Asymmetry factor at 300, 400, 600, 999nm wavelengths – **gaer1, gaer2, gaer3, gaer4**
- Extinction coefficient at 300, 400, 600, 999nm wavelengths – **extaer1, extaer2, extaer3, extaer4**
- AOD at 16 specific longwave bands – **tauauerlw1, tauauerlw2, ..., tauauerlw16**
- Extinction coefficient at 16 specific longwave bands – **extaerlw1, extaerlw2, ..., extaerlw16**

\*16 specific longwave bands ( $\text{cm}^{-1}$ ): 10-350, 350-500, 500-630, 630-700, 700-820, 820-980, 980-1080, 1080-1180, 1180-1390, 1390-1480, 1480-1800, 1800-2080, 2080-2250, 2250-2390, 2390-2600, 2600-3250

# Aerosol-cloud interactions in WRF|GC v2.0

- To turn on the aerosol-cloud interactions in WRF-GC v2.0, you should use **Morrison double-moment** scheme (**mp\_physics = 10**).
- Please control the aerosol-cloud interactions using the option "**aer\_cu\_feedback**" and "**progn**" in configuration file (namelist.input). You should turn on both "**aer\_cu\_feedback**" and "**progn**" options.

```
&physics
progn = 0
(Turns off prognostic cloud droplet number in the microphysical scheme)
      = 1
(Prognostic cloud droplet number included in the microphysical scheme)
/

&chem
aer_cu_feedback = 0
(No feedback from the prognostic aerosols to the microphysical schemes)
      = 1
(Turns on feedback from the prognostic aerosols to the microphysical schemes)
/
```

# Diagnostic for aerosol-cloud interactions in WRF GC v2.0

**The diagnostic cloud droplet number can be output from WRF-GC v2.0**

- Cloud droplet number mixing ratio – **qndrop** ( $\# \text{ kg}^{-1}$ )
- CCN concentration at six specified supersaturation ratios (0.02%, 0.05%, 0.1%, 0.2%, 0.5% and 1%) –  
**CCN1, CCN2, ..., CCN6**

# Aerosol diagnostics added in registry.chem

- WRF-GC v2.0 supports **standard GEOS-Chem bulk aerosol scheme** including sulfate (**SO4**), nitrate (**NIT**), ammonium (**NH4**), hydrophobic/hydrophilic organic carbon (**OCPO/OCPI**), hydrophobic/hydrophilic black carbon (**BCPO/BCPI**), **dust**, sea salt (**SALA**, **SALC**) and simple secondary organic aerosols (**SOA**).
- We distribute dry mass of each aerosol constituent into 4 dry diameter bins and calculate the aerosol number concentration in each size bin with the assumption of internal-mixed aerosols.
- The diagnostic aerosol mass and number concentrations are treated as **interstitial phase** (unactivated) and **cloud-borne phase** (activated).
- Aerosol diagnostics are added in the registry file (registry.chem). Users can determine whether to output the variables in registry.chem. The aerosol diagnostics are named as follow.

```
diag_so4_a1    "interstitial SO4 mixing ratio in size bin 1, ug/kg-dry air"  
diag_so4_cw1   "cloud-borne SO4 mixing ratio in size bin 1, ug/kg-dry air"  
diag_num_a1    "interstitial aerosol number concentration in size bin 1, #/kg-dry air"  
diag_num_cw1   "cloud-borne aerosol number concentration in size bin 1, #/kg-dry air"
```

# Nested domain functionality supported in WRF|GC v2.0

- Nested domains are now supported in WRF-GC. The operation is similar to WRF-Chem.
- To define multiple domains, the WRF pre-processing system (WPS) input namelist.wps needs to be updated with information on nests. Refer to the WPS user's guide:

[https://www2.mmm.ucar.edu/wrf/users/docs/user\\_guide\\_V3.9/users\\_guide\\_chap3.html](https://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V3.9/users_guide_chap3.html)

- To run multiple domains, the “**max\_dom**” namelist.input option needs to be set to the desired number of domains. Output will be generated for each domain. **Most options in the namelist also need to be specified per-domain, e.g.:**

```
&chem
kemit
chem_opt
chemdt
          = 1,
          = 233, 233, 233,
          = 10, 10, 10,
gc_do_convection
gc_do_pblmix
gc_do_hemco
gc_do_drydep
gc_do_wetdep
gc_do_chemistry
          = 1, 1, 1,
          = 1, 1, 1,
          = 1, 1, 1,
          = 1, 1, 1,
          = 1, 1, 1,
          = 1, 1, 1,
gc_diagn_spc_n0
gc_diagn_spc_n1
gc_diagn_spc_n2
gc_diagn_spc_n3
          = 0, 0, 0,
          = 0, 0, 0,
          = 0, 0, 0,
          = 0, 0, 0,
have_bcs_chem
ne_area
          = .true., .true., .true.,
          = 150,
/
```

# Nested domain functionality supported in WRF|GC v2.0

- To use “mozbc” to prepare ic/bc for nested domains, the workflow is as follows:
  - Run “real.exe” to prepare WRF input ic/bc
  - Run “mozbc” for domain 1, do\_ic & do\_bc; then run for subsequent domains with do\_ic.
- **You should have wrfinput/wrfbdy\_d01, wrfinput\_d02, wrfinput\_d03, ... as WRF inputs** before starting the “wrf.exe” run.
- **Note that nested domains may be unstable.** Verify the outputs carefully. Performance may be slow.
- The following features are **not** supported in nested-domain mode:
  - HEMCO extensions: **ParaNOx** (for ship plumes).

# Lightning NOx emissions in WRF|GC v2.0

- To turn on the lightning NOx emissions in WRF-GC v2.0, you should turn on the **lightning scheme** in WRF-GC.
- Two lightning schemes are supported in WRF-GC
  - a. PR92 (Price and Rind, 1992) based on maximum w
  - b. PR92 based on 20 dBz top
- Please set the options in the configuration file (namelist.input) as follow.
- The lightning NOx emissions are highly dependent on the flash rate simulated by WRF model.

```
&physics
  lightning_option          = 2,
  lightning_dt              = 120,
  lightning_start_seconds   = 600,
  cellcount_method          = 0,
  iccg_method               = 2,
  do_radar_ref              = 1,
/
```

# Restart run supported in WRF|GC v2.0

- To do a restart run, users should first create a restart file by setting option "**restart\_interval**" (**default unit: minutes**) in namelist.input. The restart file will be generated every x minutes. The restart files should have the following naming convention

`wrfrst_d<domain>_<date>`

- When one starts the restart run, edit the namelist.input file, so that your "**start\_\***" time will be set to the restart time (which is the time the restart file is written). The other namelist variable one must set is "**restart**", this variable should be set to **.true.**.
- For more information, please refer to the WRF user's guide.

# Useful resources

- WRF-GC Homepage: <http://wrf.geos-chem.org>
- GEOS-Chem Homepage: <http://geos-chem.org>
- WRF & WPS Homepage: <https://www.mmm.ucar.edu/weather-research-and-forecasting-model>
- MOZBC and other NCAR tools originally developed by: <https://www2.acom.ucar.edu/wrf-chem/wrf-chem-tools-community>
- MOZART4 outputs for initial and boundary conditions: <https://www.acom.ucar.edu/wrf-chem/mozart.shtml>