MPTRAC

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1 Main Page

Massive-Parallel Trajectory Calculations (MPTRAC) is a Lagrangian particle dispersion model for the troposphere and stratosphere.

This reference manual provides information on the algorithms and data structures used in the code. Further information can be found at:

`https://github.com/slcs-jsc/mptrac`

2 Data Structure Index

2.1 Data Structures

Here are the data structures with brief descriptions:

3 File Index

3.1 File List

Here is a list of all files with brief descriptions:

4 Data Structure Documentation

4.1 atm_t Struct Reference

Atmospheric data.

```
#include <libtrac.h>
```

Data Fields

- int np
  Number of air parcels.
- double time [NP]
  Time [s].
- double p [NP]
  Pressure [hPa].
- double lon [NP]
  Longitude [deg].
- double lat [NP]
  Latitude [deg].
- double q [NQ][NP]
  Quantity data (for various, user-defined attributes).

4.1.1 Detailed Description

Atmospheric data.

Definition at line 898 of file libtrac.h.

4.1.2 Field Documentation

4.1.2.1 np `int atm_t::np`

Number of air parcels.

Definition at line 901 of file libtrac.h.

4.1.2.2 time `double atm_t::time[NP]`

Time [s].

Definition at line 904 of file libtrac.h.

4.1.2.3 p `double atm_t::p[NP]`

Pressure [hPa].

Definition at line 907 of file libtrac.h.

4.1.2.4 lon `double atm_t::lon[NP]`

Longitude [deg].

Definition at line 910 of file libtrac.h.

4.1.2.5 lat `double atm_t::lat[NP]`

Latitude [deg].

Definition at line 913 of file libtrac.h.

4.1.2.6 q `double atm_t::q[NQ][NP]`

Quantity data (for various, user-defined attributes).

Definition at line 916 of file libtrac.h.

The documentation for this struct was generated from the following file:

- libtrac.h

4.2 cache_t Struct Reference

Cache data.

```
#include <libtrac.h>
```

Data Fields

- float up [NP]

  Zonal wind perturbation [m/s].
- float vp [NP]

  Meridional wind perturbation [m/s].
- float wp [NP]

  Vertical velocity perturbation [hPa/s].
- double iso_var [NP]

  Isosurface variables.
- double iso_ps [NP]

  Isosurface balloon pressure [hPa].
- double iso_ts [NP]

  Isosurface balloon time [s].
- int iso_n

  Isosurface balloon number of data points.
- double tsig [EX][EY][EP]

  Cache for reference time of wind standard deviations.
- float usig [EX][EY][EP]

  Cache for zonal wind standard deviations.
- float vsig [EX][EY][EP]

  Cache for meridional wind standard deviations.
- float wsig [EX][EY][EP]

  Cache for vertical velocity standard deviations.

4.2.1 Detailed Description

Cache data.

Definition at line 921 of file libtrac.h.

4.2.2 Field Documentation

4.2.2.1 up `float cache_t::up[NP]`

Zonal wind perturbation [m/s].

Definition at line 924 of file libtrac.h.

4.2.2.2 vp `float cache_t::vp[NP]`

Meridional wind perturbation [m/s].

Definition at line 927 of file libtrac.h.

4.2.2.3 wp `float cache_t::wp[NP]`

Vertical velocity perturbation [hPa/s].

Definition at line 930 of file libtrac.h.

4.2.2.4 iso_var `double cache_t::iso_var[NP]`

Isosurface variables.

Definition at line 933 of file libtrac.h.

4.2.2.5 iso_ps `double cache_t::iso_ps[NP]`

Isosurface balloon pressure [hPa].

Definition at line 936 of file libtrac.h.

4.2.2.6 iso_ts `double cache_t::iso_ts[NP]`

Isosurface balloon time [s].

Definition at line 939 of file libtrac.h.

4.2.2.7 iso_n `int cache_t::iso_n`

Isosurface balloon number of data points.

Definition at line 942 of file libtrac.h.

4.2.2.8 tsig `double cache_t::tsig[EX][EY][EP]`

Cache for reference time of wind standard deviations.

Definition at line 945 of file libtrac.h.

4.2.2.9 usig `float cache_t::usig[EX][EY][EP]`

Cache for zonal wind standard deviations.

Definition at line 948 of file libtrac.h.

4.2.2.10 vsig `float cache_t::vsig[EX][EY][EP]`

Cache for meridional wind standard deviations.

Definition at line 951 of file libtrac.h.

4.2.2.11 wsig `float cache_t::wsig[EX][EY][EP]`

Cache for vertical velocity standard deviations.

Definition at line 954 of file libtrac.h.

The documentation for this struct was generated from the following file:

- libtrac.h

4.3 ctl_t Struct Reference

Control parameters.

```
#include <libtrac.h>
```

Data Fields

- int nq

  Number of quantities.
- char qnt_name [NQ][LEN]

  Quantity names.
- char qnt_unit [NQ][LEN]

  Quantity units.
- char qnt_format [NQ][LEN]

  Quantity output format.
- int qnt_ens

  Quantity array index for ensemble IDs.
- int qnt_m

  Quantity array index for mass.
- int qnt_rho

  Quantity array index for particle density.
- int qnt_r

  Quantity array index for particle radius.

- int qnt_ps

    Quantity array index for surface pressure.
- int qnt_ts

    Quantity array index for surface temperature.
- int qnt_zs

    Quantity array index for surface geopotential height.
- int qnt_us

    Quantity array index for surface zonal wind.
- int qnt_vs

    Quantity array index for surface meridional wind.
- int qnt_pt

    Quantity array index for tropopause pressure.
- int qnt_tt

    Quantity array index for tropopause temperature.
- int qnt_zt

    Quantity array index for tropopause geopotential height.
- int qnt_h2ot

    Quantity array index for tropopause water vapor vmr.
- int qnt_z

    Quantity array index for geopotential height.
- int qnt_p

    Quantity array index for pressure.
- int qnt_t

    Quantity array index for temperature.
- int qnt_u

    Quantity array index for zonal wind.
- int qnt_v

    Quantity array index for meridional wind.
- int qnt_w

    Quantity array index for vertical velocity.
- int qnt_h2o

    Quantity array index for water vapor vmr.
- int qnt_o3

    Quantity array index for ozone vmr.
- int qnt_lwc

    Quantity array index for cloud liquid water content.
- int qnt_iwc

    Quantity array index for cloud ice water content.
- int qnt_pc

    Quantity array index for cloud top pressure.
- int qnt_cl

    Quantity array index for total column cloud water.
- int qnt_plcl

    Quantity array index for pressure at lifted condensation level (LCL).
- int qnt_plfc

    Quantity array index for pressure at level of free convection (LCF).
- int qnt_pel

    Quantity array index for pressure at equilibrium level (EL).
- int qnt_cape

    Quantity array index for convective available potential energy (CAPE).
- int qnt_hno3

Quantity array index for nitric acid vmr.
- int qnt_oh
  Quantity array index for hydroxyl number concentrations.
- int qnt_psat
  Quantity array index for saturation pressure over water.
- int qnt_psice
  Quantity array index for saturation pressure over ice.
- int qnt_pw
  Quantity array index for partial water vapor pressure.
- int qnt_sh
  Quantity array index for specific humidity.
- int qnt_rh
  Quantity array index for relative humidity over water.
- int qnt_rhice
  Quantity array index for relative humidity over ice.
- int qnt_theta
  Quantity array index for potential temperature.
- int qnt_tvirt
  Quantity array index for virtual temperature.
- int qnt_lapse
  Quantity array index for lapse rate.
- int qnt_vh
  Quantity array index for horizontal wind.
- int qnt_vz
  Quantity array index for vertical velocity.
- int qnt_pv
  Quantity array index for potential vorticity.
- int qnt_tdew
  Quantity array index for dew point temperature.
- int qnt_tice
  Quantity array index for T_ice.
- int qnt_tsts
  Quantity array index for T_STS.
- int qnt_tnat
  Quantity array index for T_NAT.
- int qnt_stat
  Quantity array index for station flag.
- int direction
  Direction flag (1=forward calculation, -1=backward calculation).
- double t_start
  Start time of simulation [s].
- double t_stop
  Stop time of simulation [s].
- double dt_mod
  Time step of simulation [s].
- char metbase [LEN]
  Basename for meteorological data.
- double dt_met
  Time step of meteorological data [s].
- int met_dx
  Stride for longitudes.

- int met_dy

  Stride for latitudes.
- int met_dp

  Stride for pressure levels.
- int met_sx

  Smoothing for longitudes.
- int met_sy

  Smoothing for latitudes.
- int met_sp

  Smoothing for pressure levels.
- double met_detrend

  FWHM of horizontal Gaussian used for detrending [km].
- int met_np

  Number of target pressure levels.
- double met_p [EP]

  Target pressure levels [hPa].
- int met_geopot_sx

  Longitudinal smoothing of geopotential heights.
- int met_geopot_sy

  Latitudinal smoothing of geopotential heights.
- int met_tropo

  Tropopause definition (0=none, 1=clim, 2=cold point, 3=WMO_1st, 4=WMO_2nd).
- double met_dt_out

  Time step for sampling of meteo data along trajectories [s].
- int isosurf

  Isosurface parameter (0=none, 1=pressure, 2=density, 3=theta, 4=balloon).
- char balloon [LEN]

  Balloon position filename.
- double turb_dx_trop

  Horizontal turbulent diffusion coefficient (troposphere) [m^2/s].
- double turb_dx_strat

  Horizontal turbulent diffusion coefficient (stratosphere) [m^2/s].
- double turb_dz_trop

  Vertical turbulent diffusion coefficient (troposphere) [m^2/s].
- double turb_dz_strat

  Vertical turbulent diffusion coefficient (stratosphere) [m^2/s].
- double turb_mesox

  Horizontal scaling factor for mesoscale wind fluctuations.
- double turb_mesoz

  Vertical scaling factor for mesoscale wind fluctuations.
- double conv_cape

  CAPE threshold for convection module [J/kg].
- char species [LEN]

  Species.
- double molmass

  Molar mass [g/mol].
- double tdec_trop

  Life time of particles (troposphere) [s].
- double tdec_strat

  Life time of particles (stratosphere) [s].
- double oh_chem [4]

Coefficients for OH chemistry (k0, n, kinf, m).

- double dry_depo [1]

  Coefficients for dry deposition (v).
- double wet_depo [8]

  Coefficients for wet deposition (Ai, Bi, Hi, Ci, Ab, Bb, Hb, Cb).
- double psc_h2o

  H2O volume mixing ratio for PSC analysis.
- double psc_hno3

  HNO3 volume mixing ratio for PSC analysis.
- char atm_basename [LEN]

  Basename of atmospheric data files.
- char atm_gpfile [LEN]

  Gnuplot file for atmospheric data.
- double atm_dt_out

  Time step for atmospheric data output [s].
- int atm_filter

  Time filter for atmospheric data output (0=no, 1=yes).
- int atm_stride

  Particle index stride for atmospheric data files.
- int atm_type

  Type of atmospheric data files (0=ASCII, 1=binary, 2=netCDF).
- char csi_basename [LEN]

  Basename of CSI data files.
- double csi_dt_out

  Time step for CSI data output [s].
- char csi_obsfile [LEN]

  Observation data file for CSI analysis.
- double csi_obsmin

  Minimum observation index to trigger detection.
- double csi_modmin

  Minimum column density to trigger detection [kg/m^2].
- int csi_nz

  Number of altitudes of gridded CSI data.
- double csi_z0

  Lower altitude of gridded CSI data [km].
- double csi_z1

  Upper altitude of gridded CSI data [km].
- int csi_nx

  Number of longitudes of gridded CSI data.
- double csi_lon0

  Lower longitude of gridded CSI data [deg].
- double csi_lon1

  Upper longitude of gridded CSI data [deg].
- int csi_ny

  Number of latitudes of gridded CSI data.
- double csi_lat0

  Lower latitude of gridded CSI data [deg].
- double csi_lat1

  Upper latitude of gridded CSI data [deg].
- char grid_basename [LEN]

  Basename of grid data files.

- char grid_gpfile [LEN]

  Gnuplot file for gridded data.
- double grid_dt_out

  Time step for gridded data output [s].
- int grid_sparse

  Sparse output in grid data files (0=no, 1=yes).
- int grid_nz

  Number of altitudes of gridded data.
- double grid_z0

  Lower altitude of gridded data [km].
- double grid_z1

  Upper altitude of gridded data [km].
- int grid_nx

  Number of longitudes of gridded data.
- double grid_lon0

  Lower longitude of gridded data [deg].
- double grid_lon1

  Upper longitude of gridded data [deg].
- int grid_ny

  Number of latitudes of gridded data.
- double grid_lat0

  Lower latitude of gridded data [deg].
- double grid_lat1

  Upper latitude of gridded data [deg].
- char prof_basename [LEN]

  Basename for profile output file.
- char prof_obsfile [LEN]

  Observation data file for profile output.
- int prof_nz

  Number of altitudes of gridded profile data.
- double prof_z0

  Lower altitude of gridded profile data [km].
- double prof_z1

  Upper altitude of gridded profile data [km].
- int prof_nx

  Number of longitudes of gridded profile data.
- double prof_lon0

  Lower longitude of gridded profile data [deg].
- double prof_lon1

  Upper longitude of gridded profile data [deg].
- int prof_ny

  Number of latitudes of gridded profile data.
- double prof_lat0

  Lower latitude of gridded profile data [deg].
- double prof_lat1

  Upper latitude of gridded profile data [deg].
- char ens_basename [LEN]

  Basename of ensemble data file.
- char sample_basename [LEN]

  Basename of sample data file.
- char sample_obsfile [LEN]

Observation data file for sample output.
- double sample_dx

  Horizontal radius for sample output [km].
- double sample_dz

  Layer width for sample output [km].
- char stat_basename [LEN]

  Basename of station data file.
- double stat_lon

  Longitude of station [deg].
- double stat_lat

  Latitude of station [deg].
- double stat_r

  Search radius around station [km].

4.3.1 Detailed Description

Control parameters.

Definition at line 465 of file libtrac.h.

4.3.2 Field Documentation

4.3.2.1 nq `int ctl_t::nq`

Number of quantities.

Definition at line 468 of file libtrac.h.

4.3.2.2 qnt_name `char ctl_t::qnt_name[NQ][LEN]`

Quantity names.

Definition at line 471 of file libtrac.h.

4.3.2.3 qnt_unit `char ctl_t::qnt_unit[NQ][LEN]`

Quantity units.

Definition at line 474 of file libtrac.h.

4.3.2.4 qnt_format `char ctl_t::qnt_format[NQ][LEN]`

Quantity output format.

Definition at line 477 of file libtrac.h.

4.3.2.5 qnt_ens `int ctl_t::qnt_ens`

Quantity array index for ensemble IDs.

Definition at line 480 of file libtrac.h.

4.3.2.6 qnt_m `int ctl_t::qnt_m`

Quantity array index for mass.

Definition at line 483 of file libtrac.h.

4.3.2.7 qnt_rho `int ctl_t::qnt_rho`

Quantity array index for particle density.

Definition at line 486 of file libtrac.h.

4.3.2.8 qnt_r `int ctl_t::qnt_r`

Quantity array index for particle radius.

Definition at line 489 of file libtrac.h.

4.3.2.9 qnt_ps `int ctl_t::qnt_ps`

Quantity array index for surface pressure.

Definition at line 492 of file libtrac.h.

4.3.2.10 qnt_ts `int ctl_t::qnt_ts`

Quantity array index for surface temperature.

Definition at line 495 of file libtrac.h.

4.3.2.11 qnt_zs `int ctl_t::qnt_zs`

Quantity array index for surface geopotential height.

Definition at line 498 of file libtrac.h.

4.3.2.12 qnt_us `int ctl_t::qnt_us`

Quantity array index for surface zonal wind.

Definition at line 501 of file libtrac.h.

4.3.2.13 qnt_vs `int ctl_t::qnt_vs`

Quantity array index for surface meridional wind.

Definition at line 504 of file libtrac.h.

4.3.2.14 qnt_pt `int ctl_t::qnt_pt`

Quantity array index for tropopause pressure.

Definition at line 507 of file libtrac.h.

4.3.2.15 qnt_tt `int ctl_t::qnt_tt`

Quantity array index for tropopause temperature.

Definition at line 510 of file libtrac.h.

4.3.2.16 qnt_zt `int ctl_t::qnt_zt`

Quantity array index for tropopause geopotential height.

Definition at line 513 of file libtrac.h.

4.3.2.17 qnt_h2ot `int ctl_t::qnt_h2ot`

Quantity array index for tropopause water vapor vmr.

Definition at line 516 of file libtrac.h.

4.3.2.18 qnt_z `int ctl_t::qnt_z`

Quantity array index for geopotential height.

Definition at line 519 of file libtrac.h.

4.3.2.19 qnt_p `int ctl_t::qnt_p`

Quantity array index for pressure.

Definition at line 522 of file libtrac.h.

4.3.2.20 qnt_t `int ctl_t::qnt_t`

Quantity array index for temperature.

Definition at line 525 of file libtrac.h.

4.3.2.21 qnt_u `int ctl_t::qnt_u`

Quantity array index for zonal wind.

Definition at line 528 of file libtrac.h.

4.3.2.22 qnt_v `int ctl_t::qnt_v`

Quantity array index for meridional wind.

Definition at line 531 of file libtrac.h.

4.3.2.23 qnt_w `int ctl_t::qnt_w`

Quantity array index for vertical velocity.

Definition at line 534 of file libtrac.h.

4.3.2.24 qnt_h2o `int ctl_t::qnt_h2o`

Quantity array index for water vapor vmr.

Definition at line 537 of file libtrac.h.

4.3.2.25 qnt_o3 `int ctl_t::qnt_o3`

Quantity array index for ozone vmr.

Definition at line 540 of file libtrac.h.

4.3.2.26 qnt_lwc `int ctl_t::qnt_lwc`

Quantity array index for cloud liquid water content.

Definition at line 543 of file libtrac.h.

4.3.2.27 qnt_iwc `int ctl_t::qnt_iwc`

Quantity array index for cloud ice water content.

Definition at line 546 of file libtrac.h.

4.3.2.28 qnt_pc `int ctl_t::qnt_pc`

Quantity array index for cloud top pressure.

Definition at line 549 of file libtrac.h.

4.3.2.29 qnt_cl `int ctl_t::qnt_cl`

Quantity array index for total column cloud water.

Definition at line 552 of file libtrac.h.

4.3.2.30 qnt_plcl `int ctl_t::qnt_plcl`

Quantity array index for pressure at lifted condensation level (LCL).

Definition at line 555 of file libtrac.h.

4.3.2.31 qnt_plfc `int ctl_t::qnt_plfc`

Quantity array index for pressure at level of free convection (LCF).

Definition at line 558 of file libtrac.h.

4.3.2.32 qnt_pel `int ctl_t::qnt_pel`

Quantity array index for pressure at equilibrium level (EL).

Definition at line 561 of file libtrac.h.

4.3.2.33 qnt_cape `int ctl_t::qnt_cape`

Quantity array index for convective available potential energy (CAPE).

Definition at line 564 of file libtrac.h.

4.3.2.34 qnt_hno3 `int ctl_t::qnt_hno3`

Quantity array index for nitric acid vmr.

Definition at line 567 of file libtrac.h.

4.3.2.35 qnt_oh `int ctl_t::qnt_oh`

Quantity array index for hydroxyl number concentrations.

Definition at line 570 of file libtrac.h.

4.3.2.36 qnt_psat `int ctl_t::qnt_psat`

Quantity array index for saturation pressure over water.

Definition at line 573 of file libtrac.h.

4.3.2.37 qnt_psice `int ctl_t::qnt_psice`

Quantity array index for saturation pressure over ice.

Definition at line 576 of file libtrac.h.

4.3.2.38 qnt_pw `int ctl_t::qnt_pw`

Quantity array index for partial water vapor pressure.

Definition at line 579 of file libtrac.h.

4.3.2.39 qnt_sh `int ctl_t::qnt_sh`

Quantity array index for specific humidity.

Definition at line 582 of file libtrac.h.

4.3.2.40 qnt_rh `int ctl_t::qnt_rh`

Quantity array index for relative humidity over water.

Definition at line 585 of file libtrac.h.

4.3.2.41 qnt_rhice `int ctl_t::qnt_rhice`

Quantity array index for relative humidity over ice.

Definition at line 588 of file libtrac.h.

4.3.2.42 qnt_theta `int ctl_t::qnt_theta`

Quantity array index for potential temperature.

Definition at line 591 of file libtrac.h.

4.3.2.43 qnt_tvirt `int ctl_t::qnt_tvirt`

Quantity array index for virtual temperature.

Definition at line 594 of file libtrac.h.

4.3.2.44 qnt_lapse `int ctl_t::qnt_lapse`

Quantity array index for lapse rate.

Definition at line 597 of file libtrac.h.

4.3.2.45 qnt_vh `int ctl_t::qnt_vh`

Quantity array index for horizontal wind.

Definition at line 600 of file libtrac.h.

4.3.2.46 qnt_vz `int ctl_t::qnt_vz`

Quantity array index for vertical velocity.

Definition at line 603 of file libtrac.h.

4.3.2.47 qnt_pv `int ctl_t::qnt_pv`

Quantity array index for potential vorticity.

Definition at line 606 of file libtrac.h.

4.3.2.48 qnt_tdew `int ctl_t::qnt_tdew`

Quantity array index for dew point temperature.

Definition at line 609 of file libtrac.h.

4.3.2.49 qnt_tice `int ctl_t::qnt_tice`

Quantity array index for T_ice.

Definition at line 612 of file libtrac.h.

4.3.2.50 qnt_tsts `int ctl_t::qnt_tsts`

Quantity array index for T_STS.

Definition at line 615 of file libtrac.h.

4.3.2.51 qnt_tnat `int ctl_t::qnt_tnat`

Quantity array index for T_NAT.

Definition at line 618 of file libtrac.h.

4.3.2.52 qnt_stat `int ctl_t::qnt_stat`

Quantity array index for station flag.

Definition at line 621 of file libtrac.h.

4.3.2.53 direction `int ctl_t::direction`

Direction flag (1=forward calculation, -1=backward calculation).

Definition at line 624 of file libtrac.h.

4.3.2.54 t_start `double ctl_t::t_start`

Start time of simulation [s].

Definition at line 627 of file libtrac.h.

4.3.2.55 t_stop `double ctl_t::t_stop`

Stop time of simulation [s].

Definition at line 630 of file libtrac.h.

4.3.2.56 dt_mod `double ctl_t::dt_mod`

Time step of simulation [s].

Definition at line 633 of file libtrac.h.

4.3.2.57 metbase `char ctl_t::metbase[LEN]`

Basename for meteorological data.

Definition at line 636 of file libtrac.h.

4.3.2.58 dt_met `double ctl_t::dt_met`

Time step of meteorological data [s].

Definition at line 639 of file libtrac.h.

4.3.2.59 met_dx `int ctl_t::met_dx`

Stride for longitudes.

Definition at line 642 of file libtrac.h.

4.3.2.60 met_dy `int ctl_t::met_dy`

Stride for latitudes.

Definition at line 645 of file libtrac.h.

4.3.2.61 met_dp `int ctl_t::met_dp`

Stride for pressure levels.

Definition at line 648 of file libtrac.h.

4.3.2.62 met_sx `int ctl_t::met_sx`

Smoothing for longitudes.

Definition at line 651 of file libtrac.h.

4.3.2.63 met_sy `int ctl_t::met_sy`

Smoothing for latitudes.

Definition at line 654 of file libtrac.h.

4.3.2.64 met_sp `int ctl_t::met_sp`

Smoothing for pressure levels.

Definition at line 657 of file libtrac.h.

4.3.2.65 met_detrend `double ctl_t::met_detrend`

FWHM of horizontal Gaussian used for detrending [km].

Definition at line 660 of file libtrac.h.

4.3.2.66 met_np `int ctl_t::met_np`

Number of target pressure levels.

Definition at line 663 of file libtrac.h.

4.3.2.67 met_p `double ctl_t::met_p[EP]`

Target pressure levels [hPa].

Definition at line 666 of file libtrac.h.

4.3.2.68 met_geopot_sx `int ctl_t::met_geopot_sx`

Longitudinal smoothing of geopotential heights.

Definition at line 669 of file libtrac.h.

4.3.2.69 met_geopot_sy `int ctl_t::met_geopot_sy`

Latitudinal smoothing of geopotential heights.

Definition at line 672 of file libtrac.h.

4.3.2.70 met_tropo `int ctl_t::met_tropo`

Tropopause definition (0=none, 1=clim, 2=cold point, 3=WMO_1st, 4=WMO_2nd).

Definition at line 676 of file libtrac.h.

4.3.2.71 met_dt_out `double ctl_t::met_dt_out`

Time step for sampling of meteo data along trajectories [s].

Definition at line 679 of file libtrac.h.

4.3.2.72 isosurf `int ctl_t::isosurf`

Isosurface parameter (0=none, 1=pressure, 2=density, 3=theta, 4=balloon).

Definition at line 683 of file libtrac.h.

4.3.2.73 balloon `char ctl_t::balloon[LEN]`

Balloon position filename.

Definition at line 686 of file libtrac.h.

4.3.2.74 turb_dx_trop `double ctl_t::turb_dx_trop`

Horizontal turbulent diffusion coefficient (troposphere) [m^2/s].

Definition at line 689 of file libtrac.h.

4.3.2.75 turb_dx_strat `double ctl_t::turb_dx_strat`

Horizontal turbulent diffusion coefficient (stratosphere) [m^2/s].

Definition at line 692 of file libtrac.h.

4.3.2.76 turb_dz_trop `double ctl_t::turb_dz_trop`

Vertical turbulent diffusion coefficient (troposphere) [m^2/s].

Definition at line 695 of file libtrac.h.

4.3.2.77 turb_dz_strat `double ctl_t::turb_dz_strat`

Vertical turbulent diffusion coefficient (stratosphere) [m^2/s].

Definition at line 698 of file libtrac.h.

4.3.2.78 turb_mesox `double ctl_t::turb_mesox`

Horizontal scaling factor for mesoscale wind fluctuations.

Definition at line 701 of file libtrac.h.

4.3.2.79 turb_mesoz `double ctl_t::turb_mesoz`

Vertical scaling factor for mesoscale wind fluctuations.

Definition at line 704 of file libtrac.h.

4.3.2.80 conv_cape `double ctl_t::conv_cape`

CAPE threshold for convection module [J/kg].

Definition at line 707 of file libtrac.h.

4.3.2.81 species `char ctl_t::species[LEN]`

Species.

Definition at line 710 of file libtrac.h.

4.3.2.82 molmass `double ctl_t::molmass`

Molar mass [g/mol].

Definition at line 713 of file libtrac.h.

4.3.2.83 tdec_trop `double ctl_t::tdec_trop`

Life time of particles (troposphere) [s].

Definition at line 716 of file libtrac.h.

4.3.2.84 tdec_strat `double ctl_t::tdec_strat`

Life time of particles (stratosphere) [s].

Definition at line 719 of file libtrac.h.

4.3.2.85 oh_chem `double ctl_t::oh_chem[4]`

Coefficients for OH chemistry (k0, n, kinf, m).

Definition at line 722 of file libtrac.h.

4.3.2.86 dry_depo `double ctl_t::dry_depo[1]`

Coefficients for dry deposition (v).

Definition at line 725 of file libtrac.h.

4.3.2.87 wet_depo `double ctl_t::wet_depo[8]`

Coefficients for wet deposition (Ai, Bi, Hi, Ci, Ab, Bb, Hb, Cb).

Definition at line 728 of file libtrac.h.

4.3.2.88 psc_h2o `double ctl_t::psc_h2o`

H2O volume mixing ratio for PSC analysis.

Definition at line 731 of file libtrac.h.

4.3.2.89 psc_hno3 `double ctl_t::psc_hno3`

HNO3 volume mixing ratio for PSC analysis.

Definition at line 734 of file libtrac.h.

4.3.2.90 atm_basename `char ctl_t::atm_basename[LEN]`

Basename of atmospheric data files.

Definition at line 737 of file libtrac.h.

4.3.2.91 atm_gpfile `char ctl_t::atm_gpfile[LEN]`

Gnuplot file for atmospheric data.

Definition at line 740 of file libtrac.h.

4.3.2.92 atm_dt_out `double ctl_t::atm_dt_out`

Time step for atmospheric data output [s].

Definition at line 743 of file libtrac.h.

4.3.2.93 atm_filter `int ctl_t::atm_filter`

Time filter for atmospheric data output (0=no, 1=yes).

Definition at line 746 of file libtrac.h.

4.3.2.94 atm_stride `int ctl_t::atm_stride`

Particle index stride for atmospheric data files.

Definition at line 749 of file libtrac.h.

4.3.2.95 atm_type `int ctl_t::atm_type`

Type of atmospheric data files (0=ASCII, 1=binary, 2=netCDF).

Definition at line 752 of file libtrac.h.

4.3.2.96 csi_basename `char ctl_t::csi_basename[LEN]`

Basename of CSI data files.

Definition at line 755 of file libtrac.h.

4.3.2.97 csi_dt_out `double ctl_t::csi_dt_out`

Time step for CSI data output [s].

Definition at line 758 of file libtrac.h.

4.3.2.98 csi_obsfile `char ctl_t::csi_obsfile[LEN]`

Observation data file for CSI analysis.

Definition at line 761 of file libtrac.h.

4.3.2.99 csi_obsmin `double ctl_t::csi_obsmin`

Minimum observation index to trigger detection.

Definition at line 764 of file libtrac.h.

4.3.2.100 csi_modmin `double ctl_t::csi_modmin`

Minimum column density to trigger detection [kg/m^2].

Definition at line 767 of file libtrac.h.

4.3.2.101 csi_nz `int ctl_t::csi_nz`

Number of altitudes of gridded CSI data.

Definition at line 770 of file libtrac.h.

4.3.2.102 csi_z0 `double ctl_t::csi_z0`

Lower altitude of gridded CSI data [km].

Definition at line 773 of file libtrac.h.

4.3.2.103 csi_z1 `double ctl_t::csi_z1`

Upper altitude of gridded CSI data [km].

Definition at line 776 of file libtrac.h.

4.3.2.104 csi_nx `int ctl_t::csi_nx`

Number of longitudes of gridded CSI data.

Definition at line 779 of file libtrac.h.

4.3.2.105 csi_lon0 `double ctl_t::csi_lon0`

Lower longitude of gridded CSI data [deg].

Definition at line 782 of file libtrac.h.

4.3.2.106 csi_lon1 `double ctl_t::csi_lon1`

Upper longitude of gridded CSI data [deg].

Definition at line 785 of file libtrac.h.

4.3.2.107 csi_ny `int ctl_t::csi_ny`

Number of latitudes of gridded CSI data.

Definition at line 788 of file libtrac.h.

4.3.2.108 csi_lat0 `double ctl_t::csi_lat0`

Lower latitude of gridded CSI data [deg].

Definition at line 791 of file libtrac.h.

4.3.2.109 csi_lat1 `double ctl_t::csi_lat1`

Upper latitude of gridded CSI data [deg].

Definition at line 794 of file libtrac.h.

4.3.2.110 grid_basename `char ctl_t::grid_basename[LEN]`

Basename of grid data files.

Definition at line 797 of file libtrac.h.

4.3.2.111 grid_gpfile `char ctl_t::grid_gpfile[LEN]`

Gnuplot file for gridded data.

Definition at line 800 of file libtrac.h.

4.3.2.112 grid_dt_out `double ctl_t::grid_dt_out`

Time step for gridded data output [s].

Definition at line 803 of file libtrac.h.

4.3.2.113 grid_sparse `int ctl_t::grid_sparse`

Sparse output in grid data files (0=no, 1=yes).

Definition at line 806 of file libtrac.h.

4.3.2.114 grid_nz `int ctl_t::grid_nz`

Number of altitudes of gridded data.

Definition at line 809 of file libtrac.h.

4.3.2.115 grid_z0 `double ctl_t::grid_z0`

Lower altitude of gridded data [km].

Definition at line 812 of file libtrac.h.

4.3.2.116 grid_z1 `double ctl_t::grid_z1`

Upper altitude of gridded data [km].

Definition at line 815 of file libtrac.h.

4.3.2.117 grid_nx `int ctl_t::grid_nx`

Number of longitudes of gridded data.

Definition at line 818 of file libtrac.h.

4.3.2.118 grid_lon0 `double ctl_t::grid_lon0`

Lower longitude of gridded data [deg].

Definition at line 821 of file libtrac.h.

4.3.2.119 grid_lon1 `double ctl_t::grid_lon1`

Upper longitude of gridded data [deg].

Definition at line 824 of file libtrac.h.

4.3.2.120 grid_ny `int ctl_t::grid_ny`

Number of latitudes of gridded data.

Definition at line 827 of file libtrac.h.

4.3.2.121 grid_lat0 `double ctl_t::grid_lat0`

Lower latitude of gridded data [deg].

Definition at line 830 of file libtrac.h.

4.3.2.122 grid_lat1 `double ctl_t::grid_lat1`

Upper latitude of gridded data [deg].

Definition at line 833 of file libtrac.h.

4.3.2.123 prof_basename `char ctl_t::prof_basename[LEN]`

Basename for profile output file.

Definition at line 836 of file libtrac.h.

4.3.2.124 prof_obsfile `char ctl_t::prof_obsfile[LEN]`

Observation data file for profile output.

Definition at line 839 of file libtrac.h.

4.3.2.125 prof_nz `int ctl_t::prof_nz`

Number of altitudes of gridded profile data.

Definition at line 842 of file libtrac.h.

4.3.2.126 prof_z0 `double ctl_t::prof_z0`

Lower altitude of gridded profile data [km].

Definition at line 845 of file libtrac.h.

4.3.2.127 prof_z1 `double ctl_t::prof_z1`

Upper altitude of gridded profile data [km].

Definition at line 848 of file libtrac.h.

4.3.2.128 prof_nx `int ctl_t::prof_nx`

Number of longitudes of gridded profile data.

Definition at line 851 of file libtrac.h.

4.3.2.129 prof_lon0 `double ctl_t::prof_lon0`

Lower longitude of gridded profile data [deg].

Definition at line 854 of file libtrac.h.

4.3.2.130 prof_lon1 `double ctl_t::prof_lon1`

Upper longitude of gridded profile data [deg].

Definition at line 857 of file libtrac.h.

4.3.2.131 prof_ny `int ctl_t::prof_ny`

Number of latitudes of gridded profile data.

Definition at line 860 of file libtrac.h.

4.3.2.132 prof_lat0 `double ctl_t::prof_lat0`

Lower latitude of gridded profile data [deg].

Definition at line 863 of file libtrac.h.

4.3.2.133 prof_lat1 `double ctl_t::prof_lat1`

Upper latitude of gridded profile data [deg].

Definition at line 866 of file libtrac.h.

4.3.2.134 ens_basename `char ctl_t::ens_basename[LEN]`

Basename of ensemble data file.

Definition at line 869 of file libtrac.h.

4.3.2.135 sample_basename `char ctl_t::sample_basename[LEN]`

Basename of sample data file.

Definition at line 872 of file libtrac.h.

4.3.2.136 sample_obsfile `char ctl_t::sample_obsfile[LEN]`

Observation data file for sample output.

Definition at line 875 of file libtrac.h.

4.3.2.137 sample_dx `double ctl_t::sample_dx`

Horizontal radius for sample output [km].

Definition at line 878 of file libtrac.h.

4.3.2.138 sample_dz `double ctl_t::sample_dz`

Layer width for sample output [km].

Definition at line 881 of file libtrac.h.

4.3.2.139 stat_basename `char ctl_t::stat_basename[LEN]`

Basename of station data file.

Definition at line 884 of file libtrac.h.

4.3.2.140 stat_lon `double ctl_t::stat_lon`

Longitude of station [deg].

Definition at line 887 of file libtrac.h.

4.3.2.141 stat_lat `double ctl_t::stat_lat`

Latitude of station [deg].

Definition at line 890 of file libtrac.h.

4.3.2.142 stat_r `double ctl_t::stat_r`

Search radius around station [km].

Definition at line 893 of file libtrac.h.

The documentation for this struct was generated from the following file:

- libtrac.h

4.4 met_t Struct Reference

Meteorological data.

```
#include <libtrac.h>
```

Data Fields

- double time
  Time [s].
- int nx
  Number of longitudes.
- int ny
  Number of latitudes.
- int np
  Number of pressure levels.
- double lon [EX]
  Longitude [deg].
- double lat [EY]
  Latitude [deg].
- double p [EP]
  Pressure [hPa].
- float ps [EX][EY]
  Surface pressure [hPa].
- float ts [EX][EY]
  Surface temperature [K].
- float zs [EX][EY]
  Surface geopotential height [km].
- float us [EX][EY]
  Surface zonal wind [m/s].
- float vs [EX][EY]
  Surface meridional wind [m/s].
- float pt [EX][EY]
  Tropopause pressure [hPa].
- float tt [EX][EY]
  Tropopause temperature [K].
- float zt [EX][EY]
  Tropopause geopotential height [km].
- float h2ot [EX][EY]
  Tropopause water vapor vmr [ppv].

- float pc [EX][EY]

  Cloud top pressure [hPa].
- float cl [EX][EY]

  Total column cloud water [kg/m^2].
- float plcl [EX][EY]

  Pressure at lifted condensation level (LCL) [hPa].
- float plfc [EX][EY]

  Pressure at level of free convection (LFC) [hPa].
- float pel [EX][EY]

  Pressure at equilibrium level [hPa].
- float cape [EX][EY]

  Convective available potential energy [J/kg].
- float z [EX][EY][EP]

  Geopotential height at model levels [km].
- float t [EX][EY][EP]

  Temperature [K].
- float u [EX][EY][EP]

  Zonal wind [m/s].
- float v [EX][EY][EP]

  Meridional wind [m/s].
- float w [EX][EY][EP]

  Vertical velocity [hPa/s].
- float pv [EX][EY][EP]

  Potential vorticity [PVU].
- float h2o [EX][EY][EP]

  Water vapor volume mixing ratio [1].
- float o3 [EX][EY][EP]

  Ozone volume mixing ratio [1].
- float lwc [EX][EY][EP]

  Cloud liquid water content [kg/kg].
- float iwc [EX][EY][EP]

  Cloud ice water content [kg/kg].
- float pl [EX][EY][EP]

  Pressure on model levels [hPa].

4.4.1 Detailed Description

Meteorological data.

Definition at line 959 of file libtrac.h.

4.4.2 Field Documentation

4.4.2.1 time `double met_t::time`

Time [s].

Definition at line 962 of file libtrac.h.

4.4.2.2 nx `int met_t::nx`

Number of longitudes.

Definition at line 965 of file libtrac.h.

4.4.2.3 ny `int met_t::ny`

Number of latitudes.

Definition at line 968 of file libtrac.h.

4.4.2.4 np `int met_t::np`

Number of pressure levels.

Definition at line 971 of file libtrac.h.

4.4.2.5 lon `double met_t::lon[EX]`

Longitude [deg].

Definition at line 974 of file libtrac.h.

4.4.2.6 lat `double met_t::lat[EY]`

Latitude [deg].

Definition at line 977 of file libtrac.h.

4.4.2.7 p `double met_t::p[EP]`

Pressure [hPa].

Definition at line 980 of file libtrac.h.

4.4.2.8 ps `float met_t::ps[EX][EY]`

Surface pressure [hPa].

Definition at line 983 of file libtrac.h.

4.4.2.9 ts `float met_t::ts[EX][EY]`

Surface temperature [K].

Definition at line 986 of file libtrac.h.

4.4.2.10 zs `float met_t::zs[EX][EY]`

Surface geopotential height [km].

Definition at line 989 of file libtrac.h.

4.4.2.11 us `float met_t::us[EX][EY]`

Surface zonal wind [m/s].

Definition at line 992 of file libtrac.h.

4.4.2.12 vs `float met_t::vs[EX][EY]`

Surface meridional wind [m/s].

Definition at line 995 of file libtrac.h.

4.4.2.13 pt `float met_t::pt[EX][EY]`

Tropopause pressure [hPa].

Definition at line 998 of file libtrac.h.

4.4.2.14 tt `float met_t::tt[EX][EY]`

Tropopause temperature [K].

Definition at line 1001 of file libtrac.h.

4.4.2.15 zt `float met_t::zt[EX][EY]`

Tropopause geopotential height [km].

Definition at line 1004 of file libtrac.h.

4.4.2.16 h2ot `float met_t::h2ot[EX][EY]`

Tropopause water vapor vmr [ppv].

Definition at line 1007 of file libtrac.h.

4.4.2.17 pc `float met_t::pc[EX][EY]`

Cloud top pressure [hPa].

Definition at line 1010 of file libtrac.h.

4.4.2.18 cl `float met_t::cl[EX][EY]`

Total column cloud water [kg/m^2].

Definition at line 1013 of file libtrac.h.

4.4.2.19 plcl `float met_t::plcl[EX][EY]`

Pressure at lifted condensation level (LCL) [hPa].

Definition at line 1016 of file libtrac.h.

4.4.2.20 plfc `float met_t::plfc[EX][EY]`

Pressure at level of free convection (LFC) [hPa].

Definition at line 1019 of file libtrac.h.

4.4.2.21 pel `float met_t::pel[EX][EY]`

Pressure at equilibrium level [hPa].

Definition at line 1022 of file libtrac.h.

4.4.2.22 cape `float met_t::cape[EX][EY]`

Convective available potential energy [J/kg].

Definition at line 1025 of file libtrac.h.

4.4.2.23 z `float met_t::z[EX][EY][EP]`

Geopotential height at model levels [km].

Definition at line 1028 of file libtrac.h.

4.4.2.24 t `float met_t::t[EX][EY][EP]`

Temperature [K].

Definition at line 1031 of file libtrac.h.

4.4.2.25 u `float met_t::u[EX][EY][EP]`

Zonal wind [m/s].

Definition at line 1034 of file libtrac.h.

4.4.2.26 v `float met_t::v[EX][EY][EP]`

Meridional wind [m/s].

Definition at line 1037 of file libtrac.h.

4.4.2.27 w `float met_t::w[EX][EY][EP]`

Vertical velocity [hPa/s].

Definition at line 1040 of file libtrac.h.

4.4.2.28 pv `float met_t::pv[EX][EY][EP]`

Potential vorticity [PVU].

Definition at line 1043 of file libtrac.h.

4.4.2.29 h2o `float met_t::h2o[EX][EY][EP]`

Water vapor volume mixing ratio [1].

Definition at line 1046 of file libtrac.h.

4.4.2.30 o3 `float met_t::o3[EX][EY][EP]`

Ozone volume mixing ratio [1].

Definition at line 1049 of file libtrac.h.

4.4.2.31 lwc `float met_t::lwc[EX][EY][EP]`

Cloud liquid water content [kg/kg].

Definition at line 1052 of file libtrac.h.

4.4.2.32 iwc `float met_t::iwc[EX][EY][EP]`

Cloud ice water content [kg/kg].

Definition at line 1055 of file libtrac.h.

4.4.2.33 pl `float met_t::pl[EX][EY][EP]`

Pressure on model levels [hPa].

Definition at line 1058 of file libtrac.h.

The documentation for this struct was generated from the following file:

- libtrac.h

5 File Documentation

5.1 atm_conv.c File Reference

Functions

- int main (int argc, char ∗argv[ ])

5.1.1 Detailed Description

Convert file format of air parcel data files.

Definition in file atm_conv.c.

5.1.2 Function Documentation

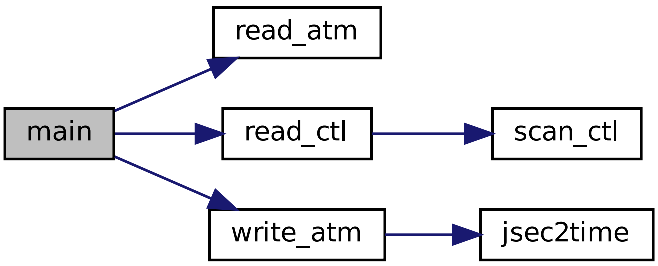
5.1.2.1 main()

```
int main (
        int argc,
        char * argv[] )
```

Definition at line 27 of file atm_conv.c.

```
                  {

  ctl_t ctl;

  atm_t *atm;

  /* Check arguments... */
  if (argc < 6)
    ERRMSG("Give parameters: <ctl> <atm_in> <atm_in_type>"
           " <atm_out> <atm_out_type>");

  /* Allocate... */
  ALLOC(atm, atm_t, 1);

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);

  /* Read atmospheric data... */
  ctl.atm_type = atoi(argv[3]);
  if (!read_atm(argv[2], &ctl, atm))
    ERRMSG("Cannot open file!");

  /* Write atmospheric data... */
  ctl.atm_type = atoi(argv[5]);
  write_atm(argv[4], &ctl, atm, 0);

  /* Free... */
  free(atm);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.2 atm_conv.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.
```

```

  Copyright (C) 2013-2019 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  atm_t *atm;

  /* Check arguments... */
  if (argc < 6)
    ERRMSG("Give parameters: <ctl> <atm_in> <atm_in_type>"
           " <atm_out> <atm_out_type>");

  /* Allocate... */
  ALLOC(atm, atm_t, 1);

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);

  /* Read atmospheric data... */
  ctl.atm_type = atoi(argv[3]);
  if (!read_atm(argv[2], &ctl, atm))
    ERRMSG("Cannot open file!");

  /* Write atmospheric data... */
  ctl.atm_type = atoi(argv[5]);
  write_atm(argv[4], &ctl, atm, 0);

  /* Free... */
  free(atm);

  return EXIT_SUCCESS;
}
```

5.3 atm_dist.c File Reference

Functions

- int main (int argc, char *argv[ ])

5.3.1 Detailed Description

Calculate transport deviations of trajectories.

Definition in file atm_dist.c.

5.3.2 Function Documentation

5.3.2.1 main()

```
int main (
    int argc,
    char * argv[] )
```

Definition at line 27 of file atm_dist.c.

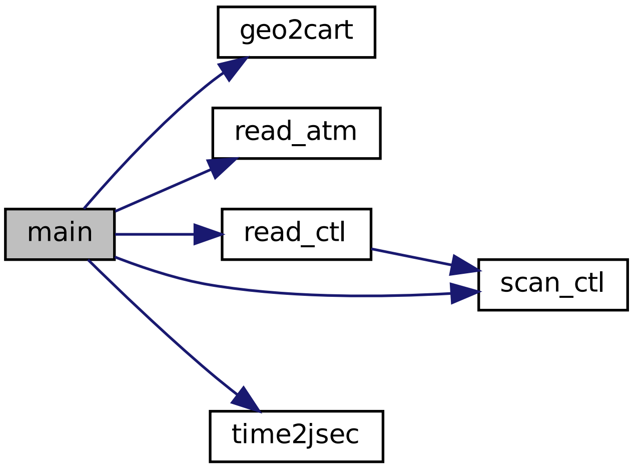
```
                      {

  ctl_t ctl;

  atm_t *atm1, *atm2;

  FILE *out;

  char tstr[LEN];

  double *ahtd, *aqtd, *avtd, ahtdm, aqtdm[NQ], avtdm, lat0, lat1,
    *lat1_old, *lat2_old, *lh1, *lh2, lon0, lon1, *lon1_old, *lon2_old,
    *lv1, *lv2, p0, p1, *rhtd, *rqtd, *rvtd, rhtdm, rqtdm[NQ], rvtdm,
    t, t0 = 0, x0[3], x1[3], x2[3], z1, *z1_old, z2, *z2_old, *work;

  int ens, f, init = 0, ip, iq, np, year, mon, day, hour, min;

  /* Allocate... */
  ALLOC(atm1, atm_t, 1);
  ALLOC(atm2, atm_t, 1);
  ALLOC(lon1_old, double,
        NP);
  ALLOC(lat1_old, double,
        NP);
  ALLOC(z1_old, double,
        NP);
  ALLOC(lh1, double,
        NP);
  ALLOC(lv1, double,
        NP);
  ALLOC(lon2_old, double,
        NP);
  ALLOC(lat2_old, double,
        NP);
  ALLOC(z2_old, double,
        NP);
  ALLOC(lh2, double,
        NP);
  ALLOC(lv2, double,
        NP);
  ALLOC(ahtd, double,
        NP);
  ALLOC(avtd, double,
        NP);
  ALLOC(aqtd, double,
        NP * NQ);
  ALLOC(rhtd, double,
        NP);
  ALLOC(rvtd, double,
        NP);
  ALLOC(rqtd, double,
        NP * NQ);
  ALLOC(work, double,
        NP);

  /* Check arguments... */
  if (argc < 6)
    ERRMSG("Give parameters: <ctl> <dist.tab> <param> <atm1a> <atm1b>"
           " [<atm2a> <atm2b> ...]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  ens = (int) scan_ctl(argv[1], argc, argv, "DIST_ENS", -1, "-999", NULL);
  p0 = P(scan_ctl(argv[1], argc, argv, "DIST_Z0", -1, "-1000", NULL));
  p1 = P(scan_ctl(argv[1], argc, argv, "DIST_Z1", -1, "1000", NULL));
  lat0 = scan_ctl(argv[1], argc, argv, "DIST_LAT0", -1, "-1000", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "DIST_LAT1", -1, "1000", NULL);
  lon0 = scan_ctl(argv[1], argc, argv, "DIST_LON0", -1, "-1000", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "DIST_LON1", -1, "1000", NULL);

  /* Write info... */
  printf("Write transport deviations: %s\n", argv[2]);

  /* Create output file... */
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
```

```
          "# $2 = time difference [s]\n"
          "# $3 = absolute horizontal distance (%s) [km]\n"
          "# $4 = relative horizontal distance (%s) [%%]\n"
          "# $5 = absolute vertical distance (%s) [km]\n"
          "# $6 = relative vertical distance (%s) [%%]\n",
          argv[3], argv[3], argv[3], argv[3]);
  for (iq = 0; iq < ctl.nq; iq++)
    fprintf(out,
            "# $%d = %s absolute difference (%s) [%s]\n"
            "# $%d = %s relative difference (%s) [%%]\n",
            7 + 2 * iq, ctl.qnt_name[iq], argv[3], ctl.qnt_unit[iq],
            8 + 2 * iq, ctl.qnt_name[iq], argv[3]);
  fprintf(out, "# $%d = number of particles\n\n", 7 + 2 * ctl.nq);

  /* Loop over file pairs... */
  for (f = 4; f < argc; f += 2) {

    /* Read atmopheric data... */
    if (!read_atm(argv[f], &ctl, atm1) || !read_atm(argv[f + 1], &ctl, atm2))
      continue;

    /* Check if structs match... */
    if (atm1->np != atm2->np)
      ERRMSG("Different numbers of particles!");

    /* Get time from filename... */
    sprintf(tstr, "%.4s", &argv[f][strlen(argv[f]) - 20]);
    year = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 15]);
    mon = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 12]);
    day = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 9]);
    hour = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 6]);
    min = atoi(tstr);
    time2jsec(year, mon, day, hour, min, 0, 0, &t);

    /* Save initial time... */
    if (!init) {
      init = 1;
      t0 = t;
    }

    /* Init... */
    np = 0;
    for (ip = 0; ip < atm1->np; ip++) {
      ahtd[ip] = avtd[ip] = rhtd[ip] = rvtd[ip] = 0;
      for (iq = 0; iq < ctl.nq; iq++)
        aqtd[iq * NP + ip] = rqtd[iq * NP + ip] = 0;
    }

    /* Loop over air parcels... */
    for (ip = 0; ip < atm1->np; ip++) {

      /* Check data... */
      if (!gsl_finite(atm1->time[ip]) || !gsl_finite(atm2->time[ip]))
        continue;

      /* Check ensemble index... */
      if (ctl.qnt_ens > 0
          && (atm1->q[ctl.qnt_ens][ip] != ens
              || atm2->q[ctl.qnt_ens][ip] != ens))
        continue;

      /* Check spatial range... */
      if (atm1->p[ip] > p0 || atm1->p[ip] < p1
          || atm1->lon[ip] < lon0 || atm1->lon[ip] > lon1
          || atm1->lat[ip] < lat0 || atm1->lat[ip] > lat1)
        continue;
      if (atm2->p[ip] > p0 || atm2->p[ip] < p1
          || atm2->lon[ip] < lon0 || atm2->lon[ip] > lon1
          || atm2->lat[ip] < lat0 || atm2->lat[ip] > lat1)
        continue;

      /* Convert coordinates... */
      geo2cart(0, atm1->lon[ip], atm1->lat[ip], x1);
      geo2cart(0, atm2->lon[ip], atm2->lat[ip], x2);
      z1 = Z(atm1->p[ip]);
      z2 = Z(atm2->p[ip]);

      /* Calculate absolute transport deviations... */
      ahtd[np] = DIST(x1, x2);
      avtd[np] = z1 - z2;
      for (iq = 0; iq < ctl.nq; iq++)
        aqtd[iq * NP + np] = atm1->q[iq][ip] - atm2->q[iq][ip];

```

```
      /* Calculate relative transport deviations... */
      if (f > 4) {

        /* Get trajectory lengths... */
        geo2cart(0, lon1_old[ip], lat1_old[ip], x0);
        lh1[ip] += DIST(x0, x1);
        lv1[ip] += fabs(z1_old[ip] - z1);

        geo2cart(0, lon2_old[ip], lat2_old[ip], x0);
        lh2[ip] += DIST(x0, x2);
        lv2[ip] += fabs(z2_old[ip] - z2);

        /* Get relative transport deviations... */
        if (lh1[ip] + lh2[ip] > 0)
          rhtd[np] = 200. * DIST(x1, x2) / (lh1[ip] + lh2[ip]);
        if (lv1[ip] + lv2[ip] > 0)
          rvtd[np] = 200. * (z1 - z2) / (lv1[ip] + lv2[ip]);
      }

      /* Get relative transport deviations... */
      for (iq = 0; iq < ctl.nq; iq++)
        rqtd[iq * NP + np] = 200. * (atm1->q[iq][ip] - atm2->q[iq][ip])
          / (fabs(atm1->q[iq][ip]) + fabs(atm2->q[iq][ip]));

      /* Save positions of air parcels... */
      lon1_old[ip] = atm1->lon[ip];
      lat1_old[ip] = atm1->lat[ip];
      z1_old[ip] = z1;

      lon2_old[ip] = atm2->lon[ip];
      lat2_old[ip] = atm2->lat[ip];
      z2_old[ip] = z2;

      /* Increment air parcel counter... */
      np++;
    }

    /* Get statistics... */
    if (strcasecmp(argv[3], "mean") == 0) {
      ahtdm = gsl_stats_mean(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_mean(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_mean(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_mean(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_mean(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_mean(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "stddev") == 0) {
      ahtdm = gsl_stats_sd(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_sd(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_sd(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_sd(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_sd(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_sd(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "min") == 0) {
      ahtdm = gsl_stats_min(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_min(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_min(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_min(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_min(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_min(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "max") == 0) {
      ahtdm = gsl_stats_max(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_max(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_max(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_max(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_max(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_max(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "skew") == 0) {
      ahtdm = gsl_stats_skew(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_skew(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_skew(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_skew(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_skew(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_skew(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "kurt") == 0) {
      ahtdm = gsl_stats_kurtosis(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_kurtosis(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_kurtosis(avtd, 1, (size_t) np);
```

```
      rvtdm = gsl_stats_kurtosis(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_kurtosis(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_kurtosis(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "median") == 0) {
      ahtdm = gsl_stats_median(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_median(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_median(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_median(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_median(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_median(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "absdev") == 0) {
      ahtdm = gsl_stats_absdev(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_absdev(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_absdev(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_absdev(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_absdev(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_absdev(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "mad") == 0) {
      ahtdm = gsl_stats_mad0(ahtd, 1, (size_t) np, work);
      rhtdm = gsl_stats_mad0(rhtd, 1, (size_t) np, work);
      avtdm = gsl_stats_mad0(avtd, 1, (size_t) np, work);
      rvtdm = gsl_stats_mad0(rvtd, 1, (size_t) np, work);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_mad0(&aqtd[iq * NP], 1, (size_t) np, work);
        rqtdm[iq] = gsl_stats_mad0(&rqtd[iq * NP], 1, (size_t) np, work);
      }
    } else
      ERRMSG("Unknown parameter!");

    /* Write output... */
    fprintf(out, "%.2f %.2f %g %g %g %g", t, t - t0,
            ahtdm, rhtdm, avtdm, rvtdm);
    for (iq = 0; iq < ctl.nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl.qnt_format[iq], aqtdm[iq]);
      fprintf(out, " ");
      fprintf(out, ctl.qnt_format[iq], rqtdm[iq]);
    }
    fprintf(out, " %d\n", np);
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(atm1);
  free(atm2);
  free(lon1_old);
  free(lat1_old);
  free(z1_old);
  free(lh1);
  free(lv1);
  free(lon2_old);
  free(lat2_old);
  free(z2_old);
  free(lh2);
  free(lv2);
  free(ahtd);
  free(avtd);
  free(aqtd);
  free(rhtd);
  free(rvtd);
  free(rqtd);
  free(work);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.4 atm_dist.c

```
/*
  This file is part of MPTRAC.

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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

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*/

#include "libtrac.h"

int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  atm_t *atm1, *atm2;

  FILE *out;

  char tstr[LEN];

  double *ahtd, *aqtd, *avtd, ahtdm, aqtdm[NQ], avtdm, lat0, lat1,
    *lat1_old, *lat2_old, *lh1, *lh2, lon0, lon1, *lon1_old, *lon2_old,
    *lv1, *lv2, p0, p1, *rhtd, *rqtd, *rvtd, rhtdm, rqtdm[NQ], rvtdm,
    t, t0 = 0, x0[3], x1[3], x2[3], z1, *z1_old, z2, *z2_old, *work;

  int ens, f, init = 0, ip, iq, np, year, mon, day, hour, min;

  /* Allocate... */
  ALLOC(atm1, atm_t, 1);
  ALLOC(atm2, atm_t, 1);
  ALLOC(lon1_old, double,
        NP);
  ALLOC(lat1_old, double,
```

```
        NP);
  ALLOC(z1_old, double,
        NP);
  ALLOC(lh1, double,
        NP);
  ALLOC(lv1, double,
        NP);
  ALLOC(lon2_old, double,
        NP);
  ALLOC(lat2_old, double,
        NP);
  ALLOC(z2_old, double,
        NP);
  ALLOC(lh2, double,
        NP);
  ALLOC(lv2, double,
        NP);
  ALLOC(ahtd, double,
        NP);
  ALLOC(avtd, double,
        NP);
  ALLOC(aqtd, double,
        NP * NQ);
  ALLOC(rhtd, double,
        NP);
  ALLOC(rvtd, double,
        NP);
  ALLOC(rqtd, double,
        NP * NQ);
  ALLOC(work, double,
        NP);

  /* Check arguments... */
  if (argc < 6)
    ERRMSG("Give parameters: <ctl> <dist.tab> <param> <atm1a> <atm1b>"
           " [<atm2a> <atm2b> ...]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  ens = (int) scan_ctl(argv[1], argc, argv, "DIST_ENS", -1, "-999", NULL);
  p0 = P(scan_ctl(argv[1], argc, argv, "DIST_Z0", -1, "-1000", NULL));
  p1 = P(scan_ctl(argv[1], argc, argv, "DIST_Z1", -1, "1000", NULL));
  lat0 = scan_ctl(argv[1], argc, argv, "DIST_LAT0", -1, "-1000", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "DIST_LAT1", -1, "1000", NULL);
  lon0 = scan_ctl(argv[1], argc, argv, "DIST_LON0", -1, "-1000", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "DIST_LON1", -1, "1000", NULL);

  /* Write info... */
  printf("Write transport deviations: %s\n", argv[2]);

  /* Create output file... */
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = time difference [s]\n"
          "# $3 = absolute horizontal distance (%s) [km]\n"
          "# $4 = relative horizontal distance (%s) [%%]\n"
          "# $5 = absolute vertical distance (%s) [km]\n"
          "# $6 = relative vertical distance (%s) [%%]\n",
          argv[3], argv[3], argv[3], argv[3]);
  for (iq = 0; iq < ctl.nq; iq++)
    fprintf(out,
            "# $%d = %s absolute difference (%s) [%s]\n"
            "# $%d = %s relative difference (%s) [%%]\n",
            7 + 2 * iq, ctl.qnt_name[iq], argv[3], ctl.qnt_unit[iq],
            8 + 2 * iq, ctl.qnt_name[iq], argv[3]);
  fprintf(out, "# $%d = number of particles\n\n", 7 + 2 * ctl.nq);

  /* Loop over file pairs... */
  for (f = 4; f < argc; f += 2) {

    /* Read atmopheric data... */
    if (!read_atm(argv[f], &ctl, atm1) || !read_atm(argv[f + 1], &ctl, atm2))
      continue;

    /* Check if structs match... */
    if (atm1->np != atm2->np)
      ERRMSG("Different numbers of particles!");

    /* Get time from filename... */
    sprintf(tstr, "%.4s", &argv[f][strlen(argv[f]) - 20]);
    year = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 15]);
    mon = atoi(tstr);
```

```
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 12]);
    day = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 9]);
    hour = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 6]);
    min = atoi(tstr);
    time2jsec(year, mon, day, hour, min, 0, 0, &t);

    /* Save initial time... */
    if (!init) {
      init = 1;
      t0 = t;
    }

    /* Init... */
    np = 0;
    for (ip = 0; ip < atm1->np; ip++) {
      ahtd[ip] = avtd[ip] = rhtd[ip] = rvtd[ip] = 0;
      for (iq = 0; iq < ctl.nq; iq++)
        aqtd[iq * NP + ip] = rqtd[iq * NP + ip] = 0;
    }

    /* Loop over air parcels... */
    for (ip = 0; ip < atm1->np; ip++) {

      /* Check data... */
      if (!gsl_finite(atm1->time[ip]) || !gsl_finite(atm2->time[ip]))
        continue;

      /* Check ensemble index... */
      if (ctl.qnt_ens > 0
          && (atm1->q[ctl.qnt_ens][ip] != ens
              || atm2->q[ctl.qnt_ens][ip] != ens))
        continue;

      /* Check spatial range... */
      if (atm1->p[ip] > p0 || atm1->p[ip] < p1
          || atm1->lon[ip] < lon0 || atm1->lon[ip] > lon1
          || atm1->lat[ip] < lat0 || atm1->lat[ip] > lat1)
        continue;
      if (atm2->p[ip] > p0 || atm2->p[ip] < p1
          || atm2->lon[ip] < lon0 || atm2->lon[ip] > lon1
          || atm2->lat[ip] < lat0 || atm2->lat[ip] > lat1)
        continue;

      /* Convert coordinates... */
      geo2cart(0, atm1->lon[ip], atm1->lat[ip], x1);
      geo2cart(0, atm2->lon[ip], atm2->lat[ip], x2);
      z1 = Z(atm1->p[ip]);
      z2 = Z(atm2->p[ip]);

      /* Calculate absolute transport deviations... */
      ahtd[np] = DIST(x1, x2);
      avtd[np] = z1 - z2;
      for (iq = 0; iq < ctl.nq; iq++)
        aqtd[iq * NP + np] = atm1->q[iq][ip] - atm2->q[iq][ip];

      /* Calculate relative transport deviations... */
      if (f > 4) {

        /* Get trajectory lengths... */
        geo2cart(0, lon1_old[ip], lat1_old[ip], x0);
        lh1[ip] += DIST(x0, x1);
        lv1[ip] += fabs(z1_old[ip] - z1);

        geo2cart(0, lon2_old[ip], lat2_old[ip], x0);
        lh2[ip] += DIST(x0, x2);
        lv2[ip] += fabs(z2_old[ip] - z2);

        /* Get relative transport deviations... */
        if (lh1[ip] + lh2[ip] > 0)
          rhtd[np] = 200. * DIST(x1, x2) / (lh1[ip] + lh2[ip]);
        if (lv1[ip] + lv2[ip] > 0)
          rvtd[np] = 200. * (z1 - z2) / (lv1[ip] + lv2[ip]);
      }

      /* Get relative transport deviations... */
      for (iq = 0; iq < ctl.nq; iq++)
        rqtd[iq * NP + np] = 200. * (atm1->q[iq][ip] - atm2->q[iq][ip])
          / (fabs(atm1->q[iq][ip]) + fabs(atm2->q[iq][ip]));

      /* Save positions of air parcels... */
      lon1_old[ip] = atm1->lon[ip];
      lat1_old[ip] = atm1->lat[ip];
      z1_old[ip] = z1;

      lon2_old[ip] = atm2->lon[ip];
```

```
      lat2_old[ip] = atm2->lat[ip];
      z2_old[ip] = z2;

      /* Increment air parcel counter... */
      np++;
    }

    /* Get statistics... */
    if (strcasecmp(argv[3], "mean") == 0) {
      ahtdm = gsl_stats_mean(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_mean(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_mean(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_mean(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_mean(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_mean(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "stddev") == 0) {
      ahtdm = gsl_stats_sd(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_sd(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_sd(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_sd(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_sd(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_sd(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "min") == 0) {
      ahtdm = gsl_stats_min(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_min(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_min(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_min(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_min(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_min(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "max") == 0) {
      ahtdm = gsl_stats_max(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_max(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_max(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_max(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_max(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_max(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "skew") == 0) {
      ahtdm = gsl_stats_skew(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_skew(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_skew(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_skew(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_skew(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_skew(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "kurt") == 0) {
      ahtdm = gsl_stats_kurtosis(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_kurtosis(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_kurtosis(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_kurtosis(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_kurtosis(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_kurtosis(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "median") == 0) {
      ahtdm = gsl_stats_median(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_median(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_median(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_median(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_median(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_median(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "absdev") == 0) {
      ahtdm = gsl_stats_absdev(ahtd, 1, (size_t) np);
      rhtdm = gsl_stats_absdev(rhtd, 1, (size_t) np);
      avtdm = gsl_stats_absdev(avtd, 1, (size_t) np);
      rvtdm = gsl_stats_absdev(rvtd, 1, (size_t) np);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_absdev(&aqtd[iq * NP], 1, (size_t) np);
        rqtdm[iq] = gsl_stats_absdev(&rqtd[iq * NP], 1, (size_t) np);
      }
    } else if (strcasecmp(argv[3], "mad") == 0) {
      ahtdm = gsl_stats_mad0(ahtd, 1, (size_t) np, work);
      rhtdm = gsl_stats_mad0(rhtd, 1, (size_t) np, work);
      avtdm = gsl_stats_mad0(avtd, 1, (size_t) np, work);
      rvtdm = gsl_stats_mad0(rvtd, 1, (size_t) np, work);
      for (iq = 0; iq < ctl.nq; iq++) {
        aqtdm[iq] = gsl_stats_mad0(&aqtd[iq * NP], 1, (size_t) np, work);
```

```
      rqtdm[iq] = gsl_stats_mad0(&rqtd[iq * NP], 1, (size_t) np, work);
    }
  } else
    ERRMSG("Unknown parameter!");

  /* Write output... */
  fprintf(out, "%.2f %.2f %g %g %g %g", t, t - t0,
          ahtdm, rhtdm, avtdm, rvtdm);
  for (iq = 0; iq < ctl.nq; iq++) {
    fprintf(out, " ");
    fprintf(out, ctl.qnt_format[iq], aqtdm[iq]);
    fprintf(out, " ");
    fprintf(out, ctl.qnt_format[iq], rqtdm[iq]);
  }
  fprintf(out, " %d\n", np);
}

/* Close file... */
fclose(out);

/* Free... */
free(atm1);
free(atm2);
free(lon1_old);
free(lat1_old);
free(z1_old);
free(lh1);
free(lv1);
free(lon2_old);
free(lat2_old);
free(z2_old);
free(lh2);
free(lv2);
free(ahtd);
free(avtd);
free(aqtd);
free(rhtd);
free(rvtd);
free(rqtd);
free(work);

return EXIT_SUCCESS;
}
```

5.5 atm_init.c File Reference

Functions

- int main (int argc, char *argv[ ])

5.5.1 Detailed Description

Create atmospheric data file with initial air parcel positions.

Definition in file atm_init.c.

5.5.2 Function Documentation

5.5.2.1 main()

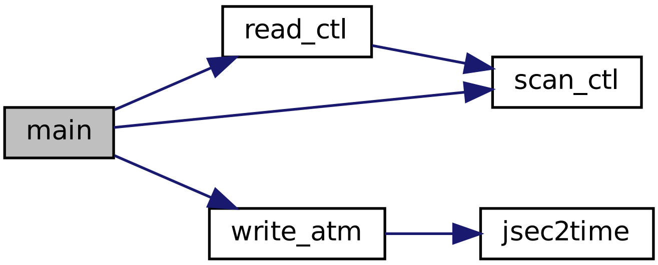
```
int main (
    int argc,
    char * argv[] )
```

Definition at line 27 of file atm_init.c.

```
                      {

  atm_t *atm;

  ctl_t ctl;

  gsl_rng *rng;

  double dt, dz, dlon, dlat, lat0, lat1, lon0, lon1, t0, t1, z0, z1,
    t, z, lon, lat, st, sz, slon, slat, sx, ut, uz, ulon, ulat, m;

  int even, ip, irep, rep;

  /* Allocate... */
  ALLOC(atm, atm_t, 1);

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <atm_out>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  t0 = scan_ctl(argv[1], argc, argv, "INIT_T0", -1, "0", NULL);
  t1 = scan_ctl(argv[1], argc, argv, "INIT_T1", -1, "0", NULL);
  dt = scan_ctl(argv[1], argc, argv, "INIT_DT", -1, "1", NULL);
  z0 = scan_ctl(argv[1], argc, argv, "INIT_Z0", -1, "0", NULL);
  z1 = scan_ctl(argv[1], argc, argv, "INIT_Z1", -1, "0", NULL);
  dz = scan_ctl(argv[1], argc, argv, "INIT_DZ", -1, "1", NULL);
  lon0 = scan_ctl(argv[1], argc, argv, "INIT_LON0", -1, "0", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "INIT_LON1", -1, "0", NULL);
  dlon = scan_ctl(argv[1], argc, argv, "INIT_DLON", -1, "1", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "INIT_LAT0", -1, "0", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "INIT_LAT1", -1, "0", NULL);
  dlat = scan_ctl(argv[1], argc, argv, "INIT_DLAT", -1, "1", NULL);
  st = scan_ctl(argv[1], argc, argv, "INIT_ST", -1, "0", NULL);
  sz = scan_ctl(argv[1], argc, argv, "INIT_SZ", -1, "0", NULL);
  slon = scan_ctl(argv[1], argc, argv, "INIT_SLON", -1, "0", NULL);
  slat = scan_ctl(argv[1], argc, argv, "INIT_SLAT", -1, "0", NULL);
  sx = scan_ctl(argv[1], argc, argv, "INIT_SX", -1, "0", NULL);
  ut = scan_ctl(argv[1], argc, argv, "INIT_UT", -1, "0", NULL);
  uz = scan_ctl(argv[1], argc, argv, "INIT_UZ", -1, "0", NULL);
  ulon = scan_ctl(argv[1], argc, argv, "INIT_ULON", -1, "0", NULL);
  ulat = scan_ctl(argv[1], argc, argv, "INIT_ULAT", -1, "0", NULL);
  even = (int) scan_ctl(argv[1], argc, argv, "INIT_EVENLY", -1, "0", NULL);
  rep = (int) scan_ctl(argv[1], argc, argv, "INIT_REP", -1, "1", NULL);
  m = scan_ctl(argv[1], argc, argv, "INIT_MASS", -1, "0", NULL);

  /* Initialize random number generator... */
  gsl_rng_env_setup();
  rng = gsl_rng_alloc(gsl_rng_default);

  /* Create grid... */
  for (t = t0; t <= t1; t += dt)
    for (z = z0; z <= z1; z += dz)
      for (lon = lon0; lon <= lon1; lon += dlon)
        for (lat = lat0; lat <= lat1; lat += dlat)
          for (irep = 0; irep < rep; irep++) {

            /* Set position... */
            atm->time[atm->np]
              = (t + gsl_ran_gaussian_ziggurat(rng, st / 2.3548)
                 + ut * (gsl_rng_uniform(rng) - 0.5));
            atm->p[atm->np]
              = P(z + gsl_ran_gaussian_ziggurat(rng, sz / 2.3548)
                  + uz * (gsl_rng_uniform(rng) - 0.5));
            atm->lon[atm->np]
              = (lon + gsl_ran_gaussian_ziggurat(rng, slon / 2.3548)
                 + gsl_ran_gaussian_ziggurat(rng, DX2DEG(sx, lat) / 2.3548)
                 + ulon * (gsl_rng_uniform(rng) - 0.5));
            do {
              atm->lat[atm->np]
                = (lat + gsl_ran_gaussian_ziggurat(rng, slat / 2.3548)
                   + gsl_ran_gaussian_ziggurat(rng, DY2DEG(sx) / 2.3548)
                   + ulat * (gsl_rng_uniform(rng) - 0.5));
            } while (even && gsl_rng_uniform(rng) >
                     fabs(cos(atm->lat[atm->np] * M_PI / 180.)));

            /* Set particle counter... */
            if ((++atm->np) > NP)
              ERRMSG("Too many particles!");
```

```
        }

  /* Check number of air parcels... */
  if (atm->np <= 0)
    ERRMSG("Did not create any air parcels!");

  /* Initialize mass... */
  if (ctl.qnt_m >= 0)
    for (ip = 0; ip < atm->np; ip++)
      atm->q[ctl.qnt_m][ip] = m / atm->np;

  /* Save data... */
  write_atm(argv[2], &ctl, atm, 0);

  /* Free... */
  gsl_rng_free(rng);
  free(atm);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.6 atm_init.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2019 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

int main(
  int argc,
  char *argv[]) {

  atm_t *atm;

  ctl_t ctl;

  gsl_rng *rng;

  double dt, dz, dlon, dlat, lat0, lat1, lon0, lon1, t0, t1, z0, z1,
    t, z, lon, lat, st, sz, slon, slat, sx, ut, uz, ulon, ulat, m;
```

```
int even, ip, irep, rep;

/* Allocate... */
ALLOC(atm, atm_t, 1);

/* Check arguments... */
if (argc < 3)
  ERRMSG("Give parameters: <ctl> <atm_out>");

/* Read control parameters... */
read_ctl(argv[1], argc, argv, &ctl);
t0 = scan_ctl(argv[1], argc, argv, "INIT_T0", -1, "0", NULL);
t1 = scan_ctl(argv[1], argc, argv, "INIT_T1", -1, "0", NULL);
dt = scan_ctl(argv[1], argc, argv, "INIT_DT", -1, "1", NULL);
z0 = scan_ctl(argv[1], argc, argv, "INIT_Z0", -1, "0", NULL);
z1 = scan_ctl(argv[1], argc, argv, "INIT_Z1", -1, "0", NULL);
dz = scan_ctl(argv[1], argc, argv, "INIT_DZ", -1, "1", NULL);
lon0 = scan_ctl(argv[1], argc, argv, "INIT_LON0", -1, "0", NULL);
lon1 = scan_ctl(argv[1], argc, argv, "INIT_LON1", -1, "0", NULL);
dlon = scan_ctl(argv[1], argc, argv, "INIT_DLON", -1, "1", NULL);
lat0 = scan_ctl(argv[1], argc, argv, "INIT_LAT0", -1, "0", NULL);
lat1 = scan_ctl(argv[1], argc, argv, "INIT_LAT1", -1, "0", NULL);
dlat = scan_ctl(argv[1], argc, argv, "INIT_DLAT", -1, "1", NULL);
st = scan_ctl(argv[1], argc, argv, "INIT_ST", -1, "0", NULL);
sz = scan_ctl(argv[1], argc, argv, "INIT_SZ", -1, "0", NULL);
slon = scan_ctl(argv[1], argc, argv, "INIT_SLON", -1, "0", NULL);
slat = scan_ctl(argv[1], argc, argv, "INIT_SLAT", -1, "0", NULL);
sx = scan_ctl(argv[1], argc, argv, "INIT_SX", -1, "0", NULL);
ut = scan_ctl(argv[1], argc, argv, "INIT_UT", -1, "0", NULL);
uz = scan_ctl(argv[1], argc, argv, "INIT_UZ", -1, "0", NULL);
ulon = scan_ctl(argv[1], argc, argv, "INIT_ULON", -1, "0", NULL);
ulat = scan_ctl(argv[1], argc, argv, "INIT_ULAT", -1, "0", NULL);
even = (int) scan_ctl(argv[1], argc, argv, "INIT_EVENLY", -1, "0", NULL);
rep = (int) scan_ctl(argv[1], argc, argv, "INIT_REP", -1, "1", NULL);
m = scan_ctl(argv[1], argc, argv, "INIT_MASS", -1, "0", NULL);

/* Initialize random number generator... */
gsl_rng_env_setup();
rng = gsl_rng_alloc(gsl_rng_default);

/* Create grid... */
for (t = t0; t <= t1; t += dt)
  for (z = z0; z <= z1; z += dz)
    for (lon = lon0; lon <= lon1; lon += dlon)
      for (lat = lat0; lat <= lat1; lat += dlat)
        for (irep = 0; irep < rep; irep++) {

          /* Set position... */
          atm->time[atm->np]
            = (t + gsl_ran_gaussian_ziggurat(rng, st / 2.3548)
               + ut * (gsl_rng_uniform(rng) - 0.5));
          atm->p[atm->np]
            = P(z + gsl_ran_gaussian_ziggurat(rng, sz / 2.3548)
                + uz * (gsl_rng_uniform(rng) - 0.5));
          atm->lon[atm->np]
            = (lon + gsl_ran_gaussian_ziggurat(rng, slon / 2.3548)
               + gsl_ran_gaussian_ziggurat(rng, DX2DEG(sx, lat) / 2.3548)
               + ulon * (gsl_rng_uniform(rng) - 0.5));
          do {
            atm->lat[atm->np]
              = (lat + gsl_ran_gaussian_ziggurat(rng, slat / 2.3548)
                 + gsl_ran_gaussian_ziggurat(rng, DY2DEG(sx) / 2.3548)
                 + ulat * (gsl_rng_uniform(rng) - 0.5));
          } while (even && gsl_rng_uniform(rng) >
                   fabs(cos(atm->lat[atm->np] * M_PI / 180.)));

          /* Set particle counter... */
          if ((++atm->np) > NP)
            ERRMSG("Too many particles!");
        }

/* Check number of air parcels... */
if (atm->np <= 0)
  ERRMSG("Did not create any air parcels!");

/* Initialize mass... */
if (ctl.qnt_m >= 0)
  for (ip = 0; ip < atm->np; ip++)
    atm->q[ctl.qnt_m][ip] = m / atm->np;

/* Save data... */
write_atm(argv[2], &ctl, atm, 0);

/* Free... */
gsl_rng_free(rng);
free(atm);
```

```
  return EXIT_SUCCESS;
}
```

5.7 atm_select.c File Reference

Functions

- int main (int argc, char *argv[ ])

5.7.1 Detailed Description

Extract subsets of air parcels from atmospheric data files.

Definition in file atm_select.c.

5.7.2 Function Documentation

5.7.2.1 main()

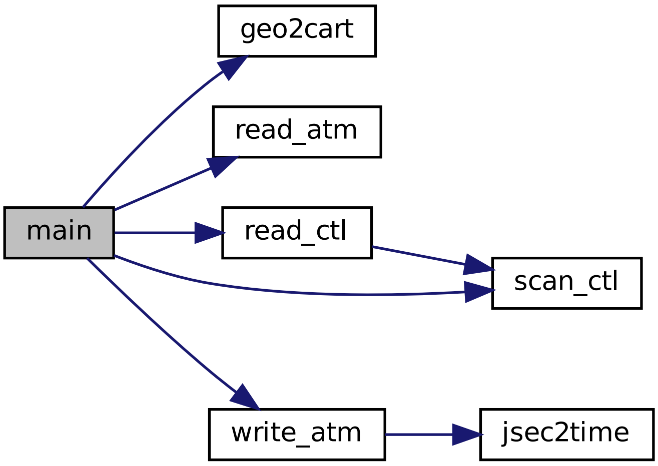
```
int main (
    int argc,
    char * argv[ ] )
```

Definition at line 27 of file atm_select.c.

```
                 {

  ctl_t ctl;

  atm_t *atm, *atm2;

  double lat0, lat1, lon0, lon1, p0, p1, r, r0, r1, rlon, rlat, t0, t1, x0[3],
    x1[3];

  int f, ip, ip0, ip1, iq, stride;

  /* Allocate... */
  ALLOC(atm, atm_t, 1);
  ALLOC(atm2, atm_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <atm_select> <atm1> [<atm2> ...]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  stride =
    (int) scan_ctl(argv[1], argc, argv, "SELECT_STRIDE", -1, "1", NULL);
  ip0 = (int) scan_ctl(argv[1], argc, argv, "SELECT_IP0", -1, "-999", NULL);
  ip1 = (int) scan_ctl(argv[1], argc, argv, "SELECT_IP1", -1, "-999", NULL);
  t0 = scan_ctl(argv[1], argc, argv, "SELECT_T0", -1, "0", NULL);
  t1 = scan_ctl(argv[1], argc, argv, "SELECT_T1", -1, "0", NULL);
  p0 = P(scan_ctl(argv[1], argc, argv, "SELECT_Z0", -1, "0", NULL));
  p1 = P(scan_ctl(argv[1], argc, argv, "SELECT_Z1", -1, "0", NULL));
  lon0 = scan_ctl(argv[1], argc, argv, "SELECT_LON0", -1, "0", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "SELECT_LON1", -1, "0", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "SELECT_LAT0", -1, "0", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "SELECT_LAT1", -1, "0", NULL);
  r0 = scan_ctl(argv[1], argc, argv, "SELECT_R0", -1, "0", NULL);
  r1 = scan_ctl(argv[1], argc, argv, "SELECT_R1", -1, "0", NULL);
  rlon = scan_ctl(argv[1], argc, argv, "SELECT_RLON", -1, "0", NULL);
  rlat = scan_ctl(argv[1], argc, argv, "SELECT_RLAT", -1, "0", NULL);

  /* Get Cartesian coordinates... */
  geo2cart(0, rlon, rlat, x0);

```

```
  /* Loop over files... */
  for (f = 3; f < argc; f++) {

    /* Read atmopheric data... */
    if (!read_atm(argv[f], &ctl, atm))
      continue;

    /* Adjust range of air parcels... */
    if (ip0 < 0)
      ip0 = 0;
    ip0 = GSL_MIN(ip0, atm->np - 1);
    if (ip1 < 0)
      ip1 = atm->np - 1;
    ip1 = GSL_MIN(ip1, atm->np - 1);
    if (ip1 < ip0)
      ip1 = ip0;

    /* Loop over air parcels... */
    for (ip = ip0; ip <= ip1; ip += stride) {

      /* Check time... */
      if (t0 != t1)
        if ((t1 > t0 && (atm->time[ip] < t0 || atm->time[ip] > t1))
            || (t1 < t0 && (atm->time[ip] < t0 && atm->time[ip] > t1)))
          continue;

      /* Check vertical distance... */
      if (p0 != p1)
        if ((p0 > p1 && (atm->p[ip] > p0 || atm->p[ip] < p1))
            || (p0 < p1 && (atm->p[ip] > p0 && atm->p[ip] < p1)))
          continue;

      /* Check longitude... */
      if (lon0 != lon1)
        if ((lon1 > lon0 && (atm->lon[ip] < lon0 || atm->lon[ip] > lon1))
            || (lon1 < lon0 && (atm->lon[ip] < lon0 && atm->lon[ip] > lon1)))
          continue;

      /* Check latitude... */
      if (lat0 != lat1)
        if ((lat1 > lat0 && (atm->lat[ip] < lat0 || atm->lat[ip] > lat1))
            || (lat1 < lat0 && (atm->lat[ip] < lat0 && atm->lat[ip] > lat1)))
          continue;

      /* Check horizontal distace... */
      if (r0 != r1) {
        geo2cart(0, atm->lon[ip], atm->lat[ip], x1);
        r = DIST(x0, x1);
        if ((r1 > r0 && (r < r0 || r > r1))
            || (r1 < r0 && (r < r0 && r > r1)))
          continue;
      }

      /* Copy data... */
      atm2->time[atm2->np] = atm->time[ip];
      atm2->p[atm2->np] = atm->p[ip];
      atm2->lon[atm2->np] = atm->lon[ip];
      atm2->lat[atm2->np] = atm->lat[ip];
      for (iq = 0; iq < ctl.nq; iq++)
        atm2->q[iq][atm2->np] = atm->q[iq][ip];
      if ((++atm2->np) > NP)
        ERRMSG("Too many air parcels!");
    }
  }

  /* Close file... */
  write_atm(argv[2], &ctl, atm2, 0);

  /* Free... */
  free(atm);
  free(atm2);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.8 atm_select.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
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  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

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*/

#include "libtrac.h"

int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  atm_t *atm, *atm2;

  double lat0, lat1, lon0, lon1, p0, p1, r, r0, r1, rlon, rlat, t0, t1, x0[3],
    x1[3];

  int f, ip, ip0, ip1, iq, stride;

  /* Allocate... */
  ALLOC(atm, atm_t, 1);
  ALLOC(atm2, atm_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <atm_select> <atm1> [<atm2> ...]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  stride =
    (int) scan_ctl(argv[1], argc, argv, "SELECT_STRIDE", -1, "1", NULL);
```

```
  ip0 = (int) scan_ctl(argv[1], argc, argv, "SELECT_IP0", -1, "-999", NULL);
  ip1 = (int) scan_ctl(argv[1], argc, argv, "SELECT_IP1", -1, "-999", NULL);
  t0 = scan_ctl(argv[1], argc, argv, "SELECT_T0", -1, "0", NULL);
  t1 = scan_ctl(argv[1], argc, argv, "SELECT_T1", -1, "0", NULL);
  p0 = P(scan_ctl(argv[1], argc, argv, "SELECT_Z0", -1, "0", NULL));
  p1 = P(scan_ctl(argv[1], argc, argv, "SELECT_Z1", -1, "0", NULL));
  lon0 = scan_ctl(argv[1], argc, argv, "SELECT_LON0", -1, "0", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "SELECT_LON1", -1, "0", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "SELECT_LAT0", -1, "0", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "SELECT_LAT1", -1, "0", NULL);
  r0 = scan_ctl(argv[1], argc, argv, "SELECT_R0", -1, "0", NULL);
  r1 = scan_ctl(argv[1], argc, argv, "SELECT_R1", -1, "0", NULL);
  rlon = scan_ctl(argv[1], argc, argv, "SELECT_RLON", -1, "0", NULL);
  rlat = scan_ctl(argv[1], argc, argv, "SELECT_RLAT", -1, "0", NULL);

  /* Get Cartesian coordinates... */
  geo2cart(0, rlon, rlat, x0);

  /* Loop over files... */
  for (f = 3; f < argc; f++) {

    /* Read atmopheric data... */
    if (!read_atm(argv[f], &ctl, atm))
      continue;

    /* Adjust range of air parcels... */
    if (ip0 < 0)
      ip0 = 0;
    ip0 = GSL_MIN(ip0, atm->np - 1);
    if (ip1 < 0)
      ip1 = atm->np - 1;
    ip1 = GSL_MIN(ip1, atm->np - 1);
    if (ip1 < ip0)
      ip1 = ip0;

    /* Loop over air parcels... */
    for (ip = ip0; ip <= ip1; ip += stride) {

      /* Check time... */
      if (t0 != t1)
        if ((t1 > t0 && (atm->time[ip] < t0 || atm->time[ip] > t1))
            || (t1 < t0 && (atm->time[ip] < t0 && atm->time[ip] > t1)))
          continue;

      /* Check vertical distance... */
      if (p0 != p1)
        if ((p0 > p1 && (atm->p[ip] > p0 || atm->p[ip] < p1))
            || (p0 < p1 && (atm->p[ip] > p0 && atm->p[ip] < p1)))
          continue;

      /* Check longitude... */
      if (lon0 != lon1)
        if ((lon1 > lon0 && (atm->lon[ip] < lon0 || atm->lon[ip] > lon1))
            || (lon1 < lon0 && (atm->lon[ip] < lon0 && atm->lon[ip] > lon1)))
          continue;

      /* Check latitude... */
      if (lat0 != lat1)
        if ((lat1 > lat0 && (atm->lat[ip] < lat0 || atm->lat[ip] > lat1))
            || (lat1 < lat0 && (atm->lat[ip] < lat0 && atm->lat[ip] > lat1)))
          continue;

      /* Check horizontal distace... */
      if (r0 != r1) {
        geo2cart(0, atm->lon[ip], atm->lat[ip], x1);
        r = DIST(x0, x1);
        if ((r1 > r0 && (r < r0 || r > r1))
            || (r1 < r0 && (r < r0 && r > r1)))
          continue;
      }

      /* Copy data... */
      atm2->time[atm2->np] = atm->time[ip];
      atm2->p[atm2->np] = atm->p[ip];
      atm2->lon[atm2->np] = atm->lon[ip];
      atm2->lat[atm2->np] = atm->lat[ip];
      for (iq = 0; iq < ctl.nq; iq++)
        atm2->q[iq][atm2->np] = atm->q[iq][ip];
      if ((++atm2->np) > NP)
        ERRMSG("Too many air parcels!");
    }
  }

  /* Close file... */
  write_atm(argv[2], &ctl, atm2, 0);

  /* Free... */
```

```
  free(atm);
  free(atm2);

  return EXIT_SUCCESS;
}
```

5.9 atm_split.c File Reference

Functions

- int main (int argc, char *argv[ ])

5.9.1 Detailed Description

Split air parcels into a larger number of parcels.

Definition in file atm_split.c.

5.9.2 Function Documentation

5.9.2.1 main()

```
int main (
    int argc,
    char * argv[ ] )
```

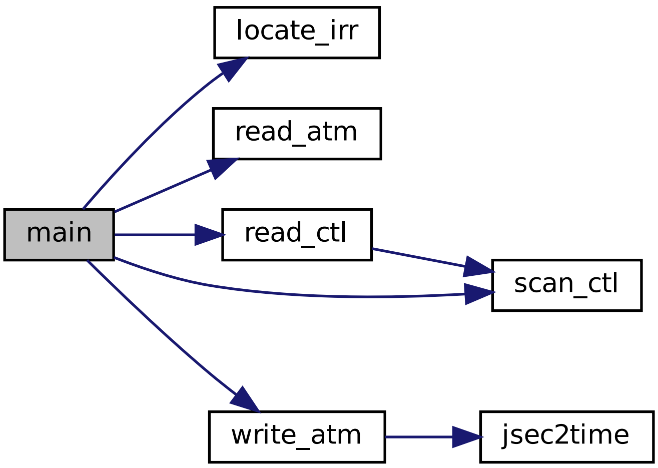
Definition at line 27 of file atm_split.c.

```
                      {

  atm_t *atm, *atm2;

  ctl_t ctl;

  gsl_rng *rng;

  FILE *in;

  char kernel[LEN], line[LEN];

  double dt, dx, dz, k, kk[GZ], kz[GZ], kmin, kmax, m, mmax = 0, mtot = 0,
    t0, t1, z, z0, z1, lon0, lon1, lat0, lat1, zmin, zmax;

  int i, ip, iq, iz, n, nz = 0;

  /* Allocate... */
  ALLOC(atm, atm_t, 1);
  ALLOC(atm2, atm_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <atm_in> <atm_out>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  n = (int) scan_ctl(argv[1], argc, argv, "SPLIT_N", -1, "", NULL);
  m = scan_ctl(argv[1], argc, argv, "SPLIT_M", -1, "-999", NULL);
  dt = scan_ctl(argv[1], argc, argv, "SPLIT_DT", -1, "0", NULL);
  t0 = scan_ctl(argv[1], argc, argv, "SPLIT_T0", -1, "0", NULL);
  t1 = scan_ctl(argv[1], argc, argv, "SPLIT_T1", -1, "0", NULL);
  dz = scan_ctl(argv[1], argc, argv, "SPLIT_DZ", -1, "0", NULL);
  z0 = scan_ctl(argv[1], argc, argv, "SPLIT_Z0", -1, "0", NULL);
  z1 = scan_ctl(argv[1], argc, argv, "SPLIT_Z1", -1, "0", NULL);
  dx = scan_ctl(argv[1], argc, argv, "SPLIT_DX", -1, "0", NULL);
  lon0 = scan_ctl(argv[1], argc, argv, "SPLIT_LON0", -1, "0", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "SPLIT_LON1", -1, "0", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "SPLIT_LAT0", -1, "0", NULL);
```

```
  lat1 = scan_ctl(argv[1], argc, argv, "SPLIT_LAT1", -1, "0", NULL);
  scan_ctl(argv[1], argc, argv, "SPLIT_KERNEL", -1, "-", kernel);

  /* Init random number generator... */
  gsl_rng_env_setup();
  rng = gsl_rng_alloc(gsl_rng_default);

  /* Read atmospheric data... */
  if (!read_atm(argv[2], &ctl, atm))
    ERRMSG("Cannot open file!");

  /* Read kernel function... */
  if (kernel[0] != '-') {

    /* Write info... */
    printf("Read kernel function: %s\n", kernel);

    /* Open file... */
    if (!(in = fopen(kernel, "r")))
      ERRMSG("Cannot open file!");

    /* Read data... */
    while (fgets(line, LEN, in))
      if (sscanf(line, "%lg %lg", &kz[nz], &kk[nz]) == 2)
        if ((++nz) >= GZ)
          ERRMSG("Too many height levels!");

    /* Close file... */
    fclose(in);

    /* Normalize kernel function... */
    zmax = gsl_stats_max(kz, 1, (size_t) nz);
    zmin = gsl_stats_min(kz, 1, (size_t) nz);
    kmax = gsl_stats_max(kk, 1, (size_t) nz);
    kmin = gsl_stats_min(kk, 1, (size_t) nz);
    for (iz = 0; iz < nz; iz++)
      kk[iz] = (kk[iz] - kmin) / (kmax - kmin);
  }

  /* Get total and maximum mass... */
  if (ctl.qnt_m >= 0)
    for (ip = 0; ip < atm->np; ip++) {
      mtot += atm->q[ctl.qnt_m][ip];
      mmax = GSL_MAX(mmax, atm->q[ctl.qnt_m][ip]);
    }
  if (m > 0)
    mtot = m;

  /* Loop over air parcels... */
  for (i = 0; i < n; i++) {

    /* Select air parcel... */
    if (ctl.qnt_m >= 0)
      do {
        ip = (int) gsl_rng_uniform_int(rng, (long unsigned int) atm->np);
      } while (gsl_rng_uniform(rng) > atm->q[ctl.qnt_m][ip] / mmax);
    else
      ip = (int) gsl_rng_uniform_int(rng, (long unsigned int) atm->np);

    /* Set time... */
    if (t1 > t0)
      atm2->time[atm2->np] = t0 + (t1 - t0) * gsl_rng_uniform_pos(rng);
    else
      atm2->time[atm2->np] = atm->time[ip]
        + gsl_ran_gaussian_ziggurat(rng, dt / 2.3548);

    /* Set vertical position... */
    do {
      if (nz > 0) {
        do {
          z = zmin + (zmax - zmin) * gsl_rng_uniform_pos(rng);
          iz = locate_irr(kz, nz, z);
          k = LIN(kz[iz], kk[iz], kz[iz + 1], kk[iz + 1], z);
        } while (gsl_rng_uniform(rng) > k);
        atm2->p[atm2->np] = P(z);
      } else if (z1 > z0)
        atm2->p[atm2->np] = P(z0 + (z1 - z0) * gsl_rng_uniform_pos(rng));
      else
        atm2->p[atm2->np] = atm->p[ip]
          + DZ2DP(gsl_ran_gaussian_ziggurat(rng, dz / 2.3548), atm->p[ip]);
    } while (atm2->p[atm2->np] < P(100.) || atm2->p[atm2->np] > P(-1.));

    /* Set horizontal position... */
    if (lon1 > lon0 && lat1 > lat0) {
      atm2->lon[atm2->np] = lon0 + (lon1 - lon0) * gsl_rng_uniform_pos(rng);
      atm2->lat[atm2->np] = lat0 + (lat1 - lat0) * gsl_rng_uniform_pos(rng);
    } else {
```

```
      atm2->lon[atm2->np] = atm->lon[ip]
        + gsl_ran_gaussian_ziggurat(rng, DX2DEG(dx, atm->lat[ip]) / 2.3548);
      atm2->lat[atm2->np] = atm->lat[ip]
        + gsl_ran_gaussian_ziggurat(rng, DY2DEG(dx) / 2.3548);
    }

    /* Copy quantities... */
    for (iq = 0; iq < ctl.nq; iq++)
      atm2->q[iq][atm2->np] = atm->q[iq][ip];

    /* Adjust mass... */
    if (ctl.qnt_m >= 0)
      atm2->q[ctl.qnt_m][atm2->np] = mtot / n;

    /* Increment particle counter... */
    if ((++atm2->np) > NP)
      ERRMSG("Too many air parcels!");
  }

  /* Save data and close file... */
  write_atm(argv[3], &ctl, atm2, 0);

  /* Free... */
  free(atm);
  free(atm2);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.10 atm_split.c

```
/*
  This file is part of MPTRAC.

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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

```

```
  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

int main(
  int argc,
  char *argv[]) {

  atm_t *atm, *atm2;

  ctl_t ctl;

  gsl_rng *rng;

  FILE *in;

  char kernel[LEN], line[LEN];

  double dt, dx, dz, k, kk[GZ], kz[GZ], kmin, kmax, m, mmax = 0, mtot = 0,
    t0, t1, z, z0, z1, lon0, lon1, lat0, lat1, zmin, zmax;

  int i, ip, iq, iz, n, nz = 0;

  /* Allocate... */
  ALLOC(atm, atm_t, 1);
  ALLOC(atm2, atm_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <atm_in> <atm_out>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  n = (int) scan_ctl(argv[1], argc, argv, "SPLIT_N", -1, "", NULL);
  m = scan_ctl(argv[1], argc, argv, "SPLIT_M", -1, "-999", NULL);
  dt = scan_ctl(argv[1], argc, argv, "SPLIT_DT", -1, "0", NULL);
  t0 = scan_ctl(argv[1], argc, argv, "SPLIT_T0", -1, "0", NULL);
  t1 = scan_ctl(argv[1], argc, argv, "SPLIT_T1", -1, "0", NULL);
  dz = scan_ctl(argv[1], argc, argv, "SPLIT_DZ", -1, "0", NULL);
  z0 = scan_ctl(argv[1], argc, argv, "SPLIT_Z0", -1, "0", NULL);
  z1 = scan_ctl(argv[1], argc, argv, "SPLIT_Z1", -1, "0", NULL);
  dx = scan_ctl(argv[1], argc, argv, "SPLIT_DX", -1, "0", NULL);
  lon0 = scan_ctl(argv[1], argc, argv, "SPLIT_LON0", -1, "0", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "SPLIT_LON1", -1, "0", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "SPLIT_LAT0", -1, "0", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "SPLIT_LAT1", -1, "0", NULL);
  scan_ctl(argv[1], argc, argv, "SPLIT_KERNEL", -1, "-", kernel);

  /* Init random number generator... */
  gsl_rng_env_setup();
  rng = gsl_rng_alloc(gsl_rng_default);

  /* Read atmospheric data... */
  if (!read_atm(argv[2], &ctl, atm))
    ERRMSG("Cannot open file!");

  /* Read kernel function... */
  if (kernel[0] != '-') {

    /* Write info... */
    printf("Read kernel function: %s\n", kernel);

    /* Open file... */
    if (!(in = fopen(kernel, "r")))
      ERRMSG("Cannot open file!");

    /* Read data... */
    while (fgets(line, LEN, in))
      if (sscanf(line, "%lg %lg", &kz[nz], &kk[nz]) == 2)
        if ((++nz) >= GZ)
          ERRMSG("Too many height levels!");

    /* Close file... */
    fclose(in);

    /* Normalize kernel function... */
    zmax = gsl_stats_max(kz, 1, (size_t) nz);
    zmin = gsl_stats_min(kz, 1, (size_t) nz);
    kmax = gsl_stats_max(kk, 1, (size_t) nz);
    kmin = gsl_stats_min(kk, 1, (size_t) nz);
    for (iz = 0; iz < nz; iz++)
      kk[iz] = (kk[iz] - kmin) / (kmax - kmin);
  }

  /* Get total and maximum mass... */
  if (ctl.qnt_m >= 0)
```

```
    for (ip = 0; ip < atm->np; ip++) {
      mtot += atm->q[ctl.qnt_m][ip];
      mmax = GSL_MAX(mmax, atm->q[ctl.qnt_m][ip]);
    }
  if (m > 0)
    mtot = m;

  /* Loop over air parcels... */
  for (i = 0; i < n; i++) {

    /* Select air parcel... */
    if (ctl.qnt_m >= 0)
      do {
        ip = (int) gsl_rng_uniform_int(rng, (long unsigned int) atm->np);
      } while (gsl_rng_uniform(rng) > atm->q[ctl.qnt_m][ip] / mmax);
    else
      ip = (int) gsl_rng_uniform_int(rng, (long unsigned int) atm->np);

    /* Set time... */
    if (t1 > t0)
      atm2->time[atm2->np] = t0 + (t1 - t0) * gsl_rng_uniform_pos(rng);
    else
      atm2->time[atm2->np] = atm->time[ip]
        + gsl_ran_gaussian_ziggurat(rng, dt / 2.3548);

    /* Set vertical position... */
    do {
      if (nz > 0) {
        do {
          z = zmin + (zmax - zmin) * gsl_rng_uniform_pos(rng);
          iz = locate_irr(kz, nz, z);
          k = LIN(kz[iz], kk[iz], kz[iz + 1], kk[iz + 1], z);
        } while (gsl_rng_uniform(rng) > k);
        atm2->p[atm2->np] = P(z);
      } else if (z1 > z0)
        atm2->p[atm2->np] = P(z0 + (z1 - z0) * gsl_rng_uniform_pos(rng));
      else
        atm2->p[atm2->np] = atm->p[ip]
          + DZ2DP(gsl_ran_gaussian_ziggurat(rng, dz / 2.3548), atm->p[ip]);
    } while (atm2->p[atm2->np] < P(100.) || atm2->p[atm2->np] > P(-1.));

    /* Set horizontal position... */
    if (lon1 > lon0 && lat1 > lat0) {
      atm2->lon[atm2->np] = lon0 + (lon1 - lon0) * gsl_rng_uniform_pos(rng);
      atm2->lat[atm2->np] = lat0 + (lat1 - lat0) * gsl_rng_uniform_pos(rng);
    } else {
      atm2->lon[atm2->np] = atm->lon[ip]
        + gsl_ran_gaussian_ziggurat(rng, DX2DEG(dx, atm->lat[ip]) / 2.3548);
      atm2->lat[atm2->np] = atm->lat[ip]
        + gsl_ran_gaussian_ziggurat(rng, DY2DEG(dx) / 2.3548);
    }

    /* Copy quantities... */
    for (iq = 0; iq < ctl.nq; iq++)
      atm2->q[iq][atm2->np] = atm->q[iq][ip];

    /* Adjust mass... */
    if (ctl.qnt_m >= 0)
      atm2->q[ctl.qnt_m][atm2->np] = mtot / n;

    /* Increment particle counter... */
    if ((++atm2->np) > NP)
      ERRMSG("Too many air parcels!");
  }

  /* Save data and close file... */
  write_atm(argv[3], &ctl, atm2, 0);

  /* Free... */
  free(atm);
  free(atm2);

  return EXIT_SUCCESS;
}
```

5.11 atm_stat.c File Reference

Functions

- int main (int argc, char *argv[ ])

5.11.1 Detailed Description

Calculate air parcel statistics.

Definition in file atm_stat.c.

5.11.2 Function Documentation

5.11.2.1 main()

```
int main (
    int argc,
    char * argv[] )
```

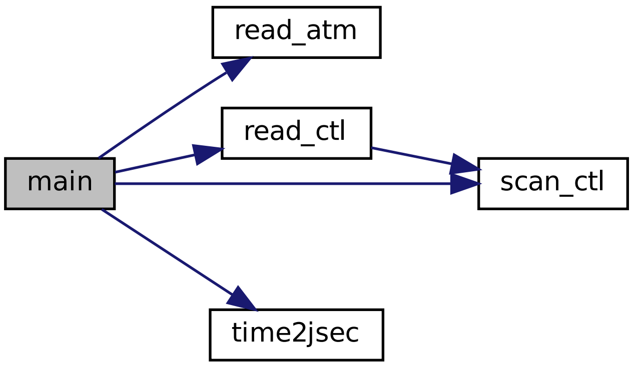
Definition at line 27 of file atm_stat.c.

```
                      {

  ctl_t ctl;

  atm_t *atm, *atm_filt;

  FILE *out;

  char tstr[LEN];

  double lat0, lat1, latm, lon0, lon1, lonm, p0, p1,
    t, t0, qm[NQ], *work, zm, *zs;

  int ens, f, init = 0, ip, iq, year, mon, day, hour, min;

  /* Allocate... */
  ALLOC(atm, atm_t, 1);
  ALLOC(atm_filt, atm_t, 1);
  ALLOC(work, double,
        NP);
  ALLOC(zs, double,
        NP);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <stat.tab> <param> <atm1> [<atm2> ...]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  ens = (int) scan_ctl(argv[1], argc, argv, "STAT_ENS", -1, "-999", NULL);
  p0 = P(scan_ctl(argv[1], argc, argv, "STAT_Z0", -1, "-1000", NULL));
  p1 = P(scan_ctl(argv[1], argc, argv, "STAT_Z1", -1, "1000", NULL));
  lat0 = scan_ctl(argv[1], argc, argv, "STAT_LAT0", -1, "-1000", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "STAT_LAT1", -1, "1000", NULL);
  lon0 = scan_ctl(argv[1], argc, argv, "STAT_LON0", -1, "-1000", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "STAT_LON1", -1, "1000", NULL);

  /* Write info... */
  printf("Write air parcel statistics: %s\n", argv[2]);

  /* Create output file... */
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = time difference [s]\n"
          "# $3 = altitude (%s) [km]\n"
          "# $4 = longitude (%s) [deg]\n"
          "# $5 = latitude (%s) [deg]\n", argv[3], argv[3], argv[3]);
  for (iq = 0; iq < ctl.nq; iq++)
    fprintf(out, "# $%d = %s (%s) [%s]\n", iq + 6,
            ctl.qnt_name[iq], argv[3], ctl.qnt_unit[iq]);
  fprintf(out, "# $%d = number of particles\n\n", ctl.nq + 6);

  /* Loop over files... */
  for (f = 4; f < argc; f++) {

    /* Read atmopheric data... */
```

```
    if (!read_atm(argv[f], &ctl, atm))
      continue;

    /* Get time from filename... */
    sprintf(tstr, "%.4s", &argv[f][strlen(argv[f]) - 20]);
    year = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 15]);
    mon = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 12]);
    day = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 9]);
    hour = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 6]);
    min = atoi(tstr);
    time2jsec(year, mon, day, hour, min, 0, 0, &t);

    /* Save intial time... */
    if (!init) {
      init = 1;
      t0 = t;
    }

    /* Filter data... */
    atm_filt->np = 0;
    for (ip = 0; ip < atm->np; ip++) {

      /* Check time... */
      if (!gsl_finite(atm->time[ip]))
        continue;

      /* Check ensemble index... */
      if (ctl.qnt_ens > 0 && atm->q[ctl.qnt_ens][ip] != ens)
        continue;

      /* Check spatial range... */
      if (atm->p[ip] > p0 || atm->p[ip] < p1
          || atm->lon[ip] < lon0 || atm->lon[ip] > lon1
          || atm->lat[ip] < lat0 || atm->lat[ip] > lat1)
        continue;

      /* Save data... */
      atm_filt->time[atm_filt->np] = atm->time[ip];
      atm_filt->p[atm_filt->np] = atm->p[ip];
      atm_filt->lon[atm_filt->np] = atm->lon[ip];
      atm_filt->lat[atm_filt->np] = atm->lat[ip];
      for (iq = 0; iq < ctl.nq; iq++)
        atm_filt->q[iq][atm_filt->np] = atm->q[iq][ip];
      atm_filt->np++;
    }

    /* Get heights... */
    for (ip = 0; ip < atm_filt->np; ip++)
      zs[ip] = Z(atm_filt->p[ip]);

    /* Get statistics... */
    if (strcasecmp(argv[3], "mean") == 0) {
      zm = gsl_stats_mean(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_mean(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_mean(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_mean(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "stddev") == 0) {
      zm = gsl_stats_sd(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_sd(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_sd(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_sd(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "min") == 0) {
      zm = gsl_stats_min(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_min(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_min(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_min(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "max") == 0) {
      zm = gsl_stats_max(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_max(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_max(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_max(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "skew") == 0) {
      zm = gsl_stats_skew(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_skew(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_skew(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_skew(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "kurt") == 0) {
      zm = gsl_stats_kurtosis(zs, 1, (size_t) atm_filt->np);
```

```
      lonm = gsl_stats_kurtosis(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_kurtosis(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] =
          gsl_stats_kurtosis(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "median") == 0) {
      zm = gsl_stats_median(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_median(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_median(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_median(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "absdev") == 0) {
      zm = gsl_stats_absdev(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_absdev(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_absdev(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_absdev(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "mad") == 0) {
      zm = gsl_stats_mad0(zs, 1, (size_t) atm_filt->np, work);
      lonm = gsl_stats_mad0(atm_filt->lon, 1, (size_t) atm_filt->np, work);
      latm = gsl_stats_mad0(atm_filt->lat, 1, (size_t) atm_filt->np, work);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] =
          gsl_stats_mad0(atm_filt->q[iq], 1, (size_t) atm_filt->np, work);
    } else
      ERRMSG("Unknown parameter!");

    /* Write data... */
    fprintf(out, "%.2f %.2f %g %g %g", t, t - t0, zm, lonm, latm);
    for (iq = 0; iq < ctl.nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl.qnt_format[iq], qm[iq]);
    }
    fprintf(out, " %d\n", atm_filt->np);
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(atm);
  free(atm_filt);
  free(work);
  free(zs);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.12 atm_stat.c

```
/*
```

```
  This file is part of MPTRAC.

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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2019 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  atm_t *atm, *atm_filt;

  FILE *out;

  char tstr[LEN];

  double lat0, lat1, latm, lon0, lon1, lonm, p0, p1,
    t, t0, qm[NQ], *work, zm, *zs;

  int ens, f, init = 0, ip, iq, year, mon, day, hour, min;

  /* Allocate... */
  ALLOC(atm, atm_t, 1);
  ALLOC(atm_filt, atm_t, 1);
  ALLOC(work, double,
        NP);
  ALLOC(zs, double,
        NP);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <stat.tab> <param> <atm1> [<atm2> ...]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  ens = (int) scan_ctl(argv[1], argc, argv, "STAT_ENS", -1, "-999", NULL);
  p0 = P(scan_ctl(argv[1], argc, argv, "STAT_Z0", -1, "-1000", NULL));
  p1 = P(scan_ctl(argv[1], argc, argv, "STAT_Z1", -1, "1000", NULL));
  lat0 = scan_ctl(argv[1], argc, argv, "STAT_LAT0", -1, "-1000", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "STAT_LAT1", -1, "1000", NULL);
  lon0 = scan_ctl(argv[1], argc, argv, "STAT_LON0", -1, "-1000", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "STAT_LON1", -1, "1000", NULL);

  /* Write info... */
  printf("Write air parcel statistics: %s\n", argv[2]);

  /* Create output file... */
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = time difference [s]\n"
          "# $3 = altitude (%s) [km]\n"
          "# $4 = longitude (%s) [deg]\n"
          "# $5 = latitude (%s) [deg]\n", argv[3], argv[3], argv[3]);
  for (iq = 0; iq < ctl.nq; iq++)
    fprintf(out, "# $%d = %s (%s) [%s]\n", iq + 6,
            ctl.qnt_name[iq], argv[3], ctl.qnt_unit[iq]);
  fprintf(out, "# $%d = number of particles\n\n", ctl.nq + 6);

  /* Loop over files... */
  for (f = 4; f < argc; f++) {

    /* Read atmopheric data... */
    if (!read_atm(argv[f], &ctl, atm))
      continue;

    /* Get time from filename... */
    sprintf(tstr, "%.4s", &argv[f][strlen(argv[f]) - 20]);
```

```
    year = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 15]);
    mon = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 12]);
    day = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 9]);
    hour = atoi(tstr);
    sprintf(tstr, "%.2s", &argv[f][strlen(argv[f]) - 6]);
    min = atoi(tstr);
    time2jsec(year, mon, day, hour, min, 0, 0, &t);

    /* Save intial time... */
    if (!init) {
      init = 1;
      t0 = t;
    }

    /* Filter data... */
    atm_filt->np = 0;
    for (ip = 0; ip < atm->np; ip++) {

      /* Check time... */
      if (!gsl_finite(atm->time[ip]))
        continue;

      /* Check ensemble index... */
      if (ctl.qnt_ens > 0 && atm->q[ctl.qnt_ens][ip] != ens)
        continue;

      /* Check spatial range... */
      if (atm->p[ip] > p0 || atm->p[ip] < p1
          || atm->lon[ip] < lon0 || atm->lon[ip] > lon1
          || atm->lat[ip] < lat0 || atm->lat[ip] > lat1)
        continue;

      /* Save data... */
      atm_filt->time[atm_filt->np] = atm->time[ip];
      atm_filt->p[atm_filt->np] = atm->p[ip];
      atm_filt->lon[atm_filt->np] = atm->lon[ip];
      atm_filt->lat[atm_filt->np] = atm->lat[ip];
      for (iq = 0; iq < ctl.nq; iq++)
        atm_filt->q[iq][atm_filt->np] = atm->q[iq][ip];
      atm_filt->np++;
    }

    /* Get heights... */
    for (ip = 0; ip < atm_filt->np; ip++)
      zs[ip] = Z(atm_filt->p[ip]);

    /* Get statistics... */
    if (strcasecmp(argv[3], "mean") == 0) {
      zm = gsl_stats_mean(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_mean(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_mean(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_mean(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "stddev") == 0) {
      zm = gsl_stats_sd(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_sd(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_sd(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_sd(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "min") == 0) {
      zm = gsl_stats_min(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_min(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_min(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_min(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "max") == 0) {
      zm = gsl_stats_max(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_max(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_max(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_max(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "skew") == 0) {
      zm = gsl_stats_skew(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_skew(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_skew(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_skew(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "kurt") == 0) {
      zm = gsl_stats_kurtosis(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_kurtosis(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_kurtosis(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] =
          gsl_stats_kurtosis(atm_filt->q[iq], 1, (size_t) atm_filt->np);
```

```
    } else if (strcasecmp(argv[3], "median") == 0) {
      zm = gsl_stats_median(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_median(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_median(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_median(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "absdev") == 0) {
      zm = gsl_stats_absdev(zs, 1, (size_t) atm_filt->np);
      lonm = gsl_stats_absdev(atm_filt->lon, 1, (size_t) atm_filt->np);
      latm = gsl_stats_absdev(atm_filt->lat, 1, (size_t) atm_filt->np);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] = gsl_stats_absdev(atm_filt->q[iq], 1, (size_t) atm_filt->np);
    } else if (strcasecmp(argv[3], "mad") == 0) {
      zm = gsl_stats_mad0(zs, 1, (size_t) atm_filt->np, work);
      lonm = gsl_stats_mad0(atm_filt->lon, 1, (size_t) atm_filt->np, work);
      latm = gsl_stats_mad0(atm_filt->lat, 1, (size_t) atm_filt->np, work);
      for (iq = 0; iq < ctl.nq; iq++)
        qm[iq] =
          gsl_stats_mad0(atm_filt->q[iq], 1, (size_t) atm_filt->np, work);
    } else
      ERRMSG("Unknown parameter!");

    /* Write data... */
    fprintf(out, "%.2f %.2f %g %g %g", t, t - t0, zm, lonm, latm);
    for (iq = 0; iq < ctl.nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl.qnt_format[iq], qm[iq]);
    }
    fprintf(out, " %d\n", atm_filt->np);
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(atm);
  free(atm_filt);
  free(work);
  free(zs);

  return EXIT_SUCCESS;
}
```

5.13 day2doy.c File Reference

Functions

- int main (int argc, char ∗argv[ ])

5.13.1 Detailed Description

Convert date to day of year.

Definition in file day2doy.c.

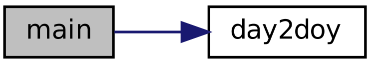
5.13.2 Function Documentation

5.13.2.1 main()
```
int main (
    int argc,
    char * argv[] )
```

Definition at line 27 of file day2doy.c.

```
00029                 {
00030
00031   int day, doy, mon, year;
00032
00033   /* Check arguments... */
00034   if (argc < 4)
00035     ERRMSG("Give parameters: <year> <mon> <day>");
00036
00037   /* Read arguments... */
00038   year = atoi(argv[1]);
00039   mon = atoi(argv[2]);
00040   day = atoi(argv[3]);
00041
00042   /* Convert... */
00043   day2doy(year, mon, day, &doy);
00044   printf("%d %d\n", year, doy);
00045
00046   return EXIT_SUCCESS;
00047 }
```

Here is the call graph for this function:



5.14 day2doy.c

```
00001 /*
00002   This file is part of MPTRAC.
00003
00004   MPTRAC is free software: you can redistribute it and/or modify
00005   it under the terms of the GNU General Public License as published by
00006   the Free Software Foundation, either version 3 of the License, or
00007   (at your option) any later version.
00008
00009   MPTRAC is distributed in the hope that it will be useful,
00010   but WITHOUT ANY WARRANTY; without even the implied warranty of
00011   MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
00012   GNU General Public License for more details.
00013
00014   You should have received a copy of the GNU General Public License
00015   along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.
00016
00017   Copyright (C) 2013-2019 Forschungszentrum Juelich GmbH
00018 */
00019
00025 #include "libtrac.h"
00026
00027 int main(
00028   int argc,
00029   char *argv[]) {
00030
00031   int day, doy, mon, year;
00032
00033   /* Check arguments... */
00034   if (argc < 4)
00035     ERRMSG("Give parameters: <year> <mon> <day>");
00036
00037   /* Read arguments... */
00038   year = atoi(argv[1]);
00039   mon = atoi(argv[2]);
00040   day = atoi(argv[3]);
00041
00042   /* Convert... */
```

```
  day2doy(year, mon, day, &doy);
  printf("%d %d\n", year, doy);

  return EXIT_SUCCESS;
}
```

5.15 doy2day.c File Reference

Functions

- int main (int argc, char ∗argv[ ])

5.15.1 Detailed Description

Convert day of year to date.

Definition in file doy2day.c.

5.15.2 Function Documentation

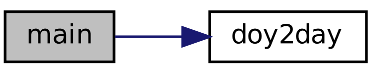
5.15.2.1 main()

```
int main (
    int argc,
    char * argv[ ] )
```

Definition at line 27 of file doy2day.c.

```
                   {

  int day, doy, mon, year;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <year> <doy>");

  /* Read arguments... */
  year = atoi(argv[1]);
  doy = atoi(argv[2]);

  /* Convert... */
  doy2day(year, doy, &mon, &day);
  printf("%d %d %d\n", year, mon, day);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.16 doy2day.c

```c
/*
  This file is part of MPTRAC.

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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2019 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

int main(
  int argc,
  char *argv[]) {

  int day, doy, mon, year;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <year> <doy>");

  /* Read arguments... */
  year = atoi(argv[1]);
  doy = atoi(argv[2]);

  /* Convert... */
  doy2day(year, doy, &mon, &day);
  printf("%d %d %d\n", year, mon, day);

  return EXIT_SUCCESS;
}
```

5.17 jsec2time.c File Reference

Functions

- int main (int argc, char ∗argv[ ])

5.17.1 Detailed Description

Convert Julian seconds to date.

Definition in file jsec2time.c.

5.17.2 Function Documentation

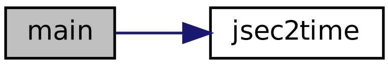
5.17.2.1 main()

```
int main (
        int argc,
        char * argv[ ] )
```

Definition at line 27 of file jsec2time.c.

```
00029                    {
00030
00031   double jsec, remain;
00032
00033   int day, hour, min, mon, sec, year;
00034
00035   /* Check arguments... */
00036   if (argc < 2)
00037     ERRMSG("Give parameters: <jsec>");
00038
00039   /* Read arguments... */
00040   jsec = atof(argv[1]);
00041
00042   /* Convert time... */
00043   jsec2time(jsec, &year, &mon, &day, &hour, &min, &sec, &remain);
00044   printf("%d %d %d %d %d %d %g\n", year, mon, day, hour, min, sec, remain);
00045
00046   return EXIT_SUCCESS;
00047 }
```

Here is the call graph for this function:



5.18 jsec2time.c

```
00001 /*
00002   This file is part of MPTRAC.
00003
00004   MPTRAC is free software: you can redistribute it and/or modify
00005   it under the terms of the GNU General Public License as published by
00006   the Free Software Foundation, either version 3 of the License, or
00007   (at your option) any later version.
00008
00009   MPTRAC is distributed in the hope that it will be useful,
00010   but WITHOUT ANY WARRANTY; without even the implied warranty of
00011   MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
00012   GNU General Public License for more details.
00013
00014   You should have received a copy of the GNU General Public License
00015   along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.
00016
00017   Copyright (C) 2013-2019 Forschungszentrum Juelich GmbH
00018 */
00019
00025 #include "libtrac.h"
00026
00027 int main(
00028   int argc,
00029   char *argv[]) {
00030
00031   double jsec, remain;
00032
00033   int day, hour, min, mon, sec, year;
00034
00035   /* Check arguments... */
00036   if (argc < 2)
00037     ERRMSG("Give parameters: <jsec>");
00038
00039   /* Read arguments... */
00040   jsec = atof(argv[1]);
00041
00042   /* Convert time... */
```

```
  jsec2time(jsec, &year, &mon, &day, &hour, &min, &sec, &remain);
  printf("%d %d %d %d %d %d %g\n", year, mon, day, hour, min, sec, remain);

  return EXIT_SUCCESS;
}
```

5.19 lapse.c File Reference

Functions

- int main (int argc, char ∗argv[ ])

5.19.1 Detailed Description

Calculate lapse rate statistics.

Definition in file lapse.c.

5.19.2 Function Documentation

5.19.2.1 main()

```
int main (
    int argc,
    char * argv[ ] )
```

Definition at line 44 of file lapse.c.

```
                  {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double p2[1000], t[1000], t2[1000], z[1000], z2[1000], lat_mean,
    z_mean;

  static int hist_max[1000], hist_min[1000], hist_mean[1000], hist_sig[1000],
    nhist_max, nhist_min, nhist_mean, nhist_sig, np;

  /* Allocate... */
  ALLOC(met, met_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <hist.tab> <met0> [ <met1> ... ]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  int dz = (int) scan_ctl(argv[1], argc, argv, "LAPSE_DZ", -1, "20", NULL);
  double lat0 =
    (int) scan_ctl(argv[1], argc, argv, "LAPSE_LAT0", -1, "-90", NULL);
  double lat1 =
    (int) scan_ctl(argv[1], argc, argv, "LAPSE_LAT1", -1, "90", NULL);
  double z0 = (int) scan_ctl(argv[1], argc, argv, "LAPSE_Z0", -1, "0", NULL);
  double z1 =
    (int) scan_ctl(argv[1], argc, argv, "LAPSE_Z1", -1, "100", NULL);

  /* Loop over files... */
  for (int i = 3; i < argc; i++) {

    /* Read meteorological data... */
    if (!read_met(&ctl, argv[i], met))
      continue;

```

```
  /* Get altitude and pressure profiles... */
  for (int iz = 0; iz < met->np; iz++)
    z[iz] = Z(met->p[iz]);
  for (int iz = 0; iz <= 250; iz++) {
    z2[iz] = 0.0 + 0.1 * iz;
    p2[iz] = P(z2[iz]);
  }

  /* Loop over grid points... */
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++) {

      /* Check latitude range... */
      if (met->lat[iy] < lat0 || met->lat[iy] > lat1)
        continue;

      /* Interpolate temperature profile... */
      for (int iz = 0; iz < met->np; iz++)
        t[iz] = met->t[ix][iy][iz];
      spline(z, t, met->np, z2, t2, 251);

      /* Loop over vertical levels... */
      for (int iz = 0; iz <= 250; iz++) {

        /* Check height range... */
        if (z2[iz] < z0 || z2[iz] > z1)
          continue;

        /* Check surface pressure... */
        if (p2[iz] > met->ps[ix][iy])
          continue;

        /* Get mean latitude and height... */
        lat_mean += met->lat[iy];
        z_mean += z2[iz];
        np++;

        /* Get lapse rates within a vertical layer... */
        int nlapse = 0;
        double lapse_max = -1e99, lapse_min = 1e99, lapse_mean =
          0, lapse_sig = 0;
        for (int iz2 = iz + 1; iz2 <= iz + dz; iz2++) {
          lapse_max =
            GSL_MAX(LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]), lapse_max);
          lapse_min =
            GSL_MIN(LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]), lapse_min);
          lapse_mean += LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]);
          lapse_sig += SQR(LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]));
          nlapse++;
        }
        lapse_mean /= nlapse;
        lapse_sig = sqrt(GSL_MAX(lapse_sig / nlapse - SQR(lapse_mean), 0));

        /* Get histograms... */
        int idx = (int) ((lapse_max - LAPSEMIN) / DLAPSE);
        if (idx >= 0 && idx < IDXMAX) {
          hist_max[idx]++;
          nhist_max++;
        }

        idx = (int) ((lapse_min - LAPSEMIN) / DLAPSE);
        if (idx >= 0 && idx < IDXMAX) {
          hist_min[idx]++;
          nhist_min++;
        }

        idx = (int) ((lapse_mean - LAPSEMIN) / DLAPSE);
        if (idx >= 0 && idx < IDXMAX) {
          hist_mean[idx]++;
          nhist_mean++;
        }

        idx = (int) ((lapse_sig - LAPSEMIN) / DLAPSE);
        if (idx >= 0 && idx < IDXMAX) {
          hist_sig[idx]++;
          nhist_sig++;
        }
      }
    }
}

/* Create output file... */
printf("Write lapse rate data: %s\n", argv[2]);
if (!(out = fopen(argv[2], "w")))
  ERRMSG("Cannot create file!");

/* Write header... */
```

```
  fprintf(out,
          "# $1 = mean altitude [km]\n"
          "# $2 = mean latitude [deg]\n"
          "# $3 = lapse rate [K/km]\n"
          "# $4 = counts of maxima per bin\n"
          "# $5 = total number of maxima\n"
          "# $6 = normalized frequency of maxima\n"
          "# $7 = counts of minima per bin\n"
          "# $8 = total number of minima\n"
          "# $9 = normalized frequency of minima\n"
          "# $10 = counts of means per bin\n"
          "# $11 = total number of means\n"
          "# $12 = normalized frequency of means\n"
          "# $13 = counts of sigmas per bin\n"
          "# $14 = total number of sigmas\n"
          "# $15 = normalized frequency of sigmas\n\n");

  /* Write data... */
  double nmax_max = 0, nmax_min = 0, nmax_mean = 0, nmax_sig = 0;
  for (int idx = 0; idx < IDXMAX; idx++) {
    nmax_max = GSL_MAX(hist_max[idx], nmax_max);
    nmax_min = GSL_MAX(hist_min[idx], nmax_min);
    nmax_mean = GSL_MAX(hist_mean[idx], nmax_mean);
    nmax_sig = GSL_MAX(hist_sig[idx], nmax_sig);

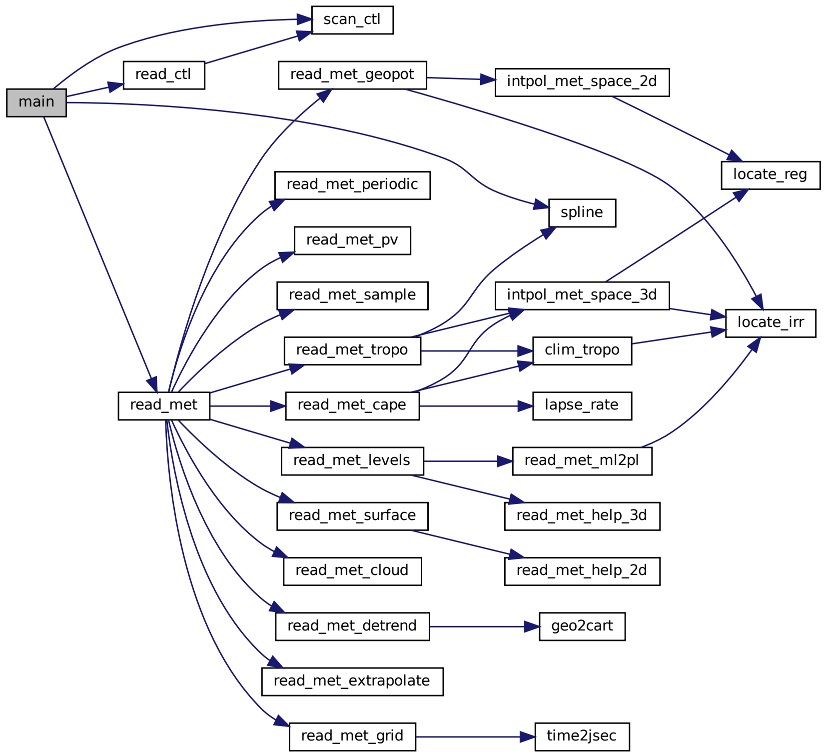
  }
  for (int idx = 0; idx < IDXMAX; idx++)
    fprintf(out,
            "%g %g %g %d %d %g %d %d %g %d %d %g %d %d %g\n",
            z_mean / np, lat_mean / np, (idx + .5) * DLAPSE + LAPSEMIN,
            hist_max[idx], nhist_max,
            (double) hist_max[idx] / (double) nmax_max, hist_min[idx],
            nhist_min, (double) hist_min[idx] / (double) nmax_min,
            hist_mean[idx], nhist_mean,
            (double) hist_mean[idx] / (double) nmax_mean, hist_sig[idx],
            nhist_sig, (double) hist_sig[idx] / (double) nmax_sig);

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.20 lapse.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

/* ------------------------------------------------------------
   Dimensions...
   ------------------------------------------------------------ */

#define LAPSEMIN -20.0

#define DLAPSE 0.1

#define IDXMAX 400

/* ------------------------------------------------------------
   Main...
   ------------------------------------------------------------ */

int main(
  int argc,
```

```
char *argv[]) {

ctl_t ctl;

met_t *met;

FILE *out;

static double p2[1000], t[1000], t2[1000], z[1000], z2[1000], lat_mean,
  z_mean;

static int hist_max[1000], hist_min[1000], hist_mean[1000], hist_sig[1000],
  nhist_max, nhist_min, nhist_mean, nhist_sig, np;

/* Allocate... */
ALLOC(met, met_t, 1);

/* Check arguments... */
if (argc < 4)
  ERRMSG("Give parameters: <ctl> <hist.tab> <met0> [ <met1> ... ]");

/* Read control parameters... */
read_ctl(argv[1], argc, argv, &ctl);
int dz = (int) scan_ctl(argv[1], argc, argv, "LAPSE_DZ", -1, "20", NULL);
double lat0 =
  (int) scan_ctl(argv[1], argc, argv, "LAPSE_LAT0", -1, "-90", NULL);
double lat1 =
  (int) scan_ctl(argv[1], argc, argv, "LAPSE_LAT1", -1, "90", NULL);
double z0 = (int) scan_ctl(argv[1], argc, argv, "LAPSE_Z0", -1, "0", NULL);
double z1 =
  (int) scan_ctl(argv[1], argc, argv, "LAPSE_Z1", -1, "100", NULL);

/* Loop over files... */
for (int i = 3; i < argc; i++) {

  /* Read meteorological data... */
  if (!read_met(&ctl, argv[i], met))
    continue;

  /* Get altitude and pressure profiles... */
  for (int iz = 0; iz < met->np; iz++)
    z[iz] = Z(met->p[iz]);
  for (int iz = 0; iz <= 250; iz++) {
    z2[iz] = 0.0 + 0.1 * iz;
    p2[iz] = P(z2[iz]);
  }

  /* Loop over grid points... */
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++) {

      /* Check latitude range... */
      if (met->lat[iy] < lat0 || met->lat[iy] > lat1)
        continue;

      /* Interpolate temperature profile... */
      for (int iz = 0; iz < met->np; iz++)
        t[iz] = met->t[ix][iy][iz];
      spline(z, t, met->np, z2, t2, 251);

      /* Loop over vertical levels... */
      for (int iz = 0; iz <= 250; iz++) {

        /* Check height range... */
        if (z2[iz] < z0 || z2[iz] > z1)
          continue;

        /* Check surface pressure... */
        if (p2[iz] > met->ps[ix][iy])
          continue;

        /* Get mean latitude and height... */
        lat_mean += met->lat[iy];
        z_mean += z2[iz];
        np++;

        /* Get lapse rates within a vertical layer... */
        int nlapse = 0;
        double lapse_max = -1e99, lapse_min = 1e99, lapse_mean =
          0, lapse_sig = 0;
        for (int iz2 = iz + 1; iz2 <= iz + dz; iz2++) {
          lapse_max =
            GSL_MAX(LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]), lapse_max);
          lapse_min =
            GSL_MIN(LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]), lapse_min);
          lapse_mean += LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]);
          lapse_sig += SQR(LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]));
```

```
          nlapse++;
        }
        lapse_mean /= nlapse;
        lapse_sig = sqrt(GSL_MAX(lapse_sig / nlapse - SQR(lapse_mean), 0));

        /* Get histograms... */
        int idx = (int) ((lapse_max - LAPSEMIN) / DLAPSE);
        if (idx >= 0 && idx < IDXMAX) {
          hist_max[idx]++;
          nhist_max++;
        }

        idx = (int) ((lapse_min - LAPSEMIN) / DLAPSE);
        if (idx >= 0 && idx < IDXMAX) {
          hist_min[idx]++;
          nhist_min++;
        }

        idx = (int) ((lapse_mean - LAPSEMIN) / DLAPSE);
        if (idx >= 0 && idx < IDXMAX) {
          hist_mean[idx]++;
          nhist_mean++;
        }

        idx = (int) ((lapse_sig - LAPSEMIN) / DLAPSE);
        if (idx >= 0 && idx < IDXMAX) {
          hist_sig[idx]++;
          nhist_sig++;
        }
      }
    }
  }

  /* Create output file... */
  printf("Write lapse rate data: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = mean altitude [km]\n"
          "# $2 = mean latitude [deg]\n"
          "# $3 = lapse rate [K/km]\n"
          "# $4 = counts of maxima per bin\n"
          "# $5 = total number of maxima\n"
          "# $6 = normalized frequency of maxima\n"
          "# $7 = counts of minima per bin\n"
          "# $8 = total number of minima\n"
          "# $9 = normalized frequency of minima\n"
          "# $10 = counts of means per bin\n"
          "# $11 = total number of means\n"
          "# $12 = normalized frequency of means\n"
          "# $13 = counts of sigmas per bin\n"
          "# $14 = total number of sigmas\n"
          "# $15 = normalized frequency of sigmas\n\n");

  /* Write data... */
  double nmax_max = 0, nmax_min = 0, nmax_mean = 0, nmax_sig = 0;
  for (int idx = 0; idx < IDXMAX; idx++) {
    nmax_max = GSL_MAX(hist_max[idx], nmax_max);
    nmax_min = GSL_MAX(hist_min[idx], nmax_min);
    nmax_mean = GSL_MAX(hist_mean[idx], nmax_mean);
    nmax_sig = GSL_MAX(hist_sig[idx], nmax_sig);

  }
  for (int idx = 0; idx < IDXMAX; idx++)
    fprintf(out,
            "%g %g %g %d %d %g %d %d %g %d %d %g %d %d %g\n",
            z_mean / np, lat_mean / np, (idx + .5) * DLAPSE + LAPSEMIN,
            hist_max[idx], nhist_max,
            (double) hist_max[idx] / (double) nmax_max, hist_min[idx],
            nhist_min, (double) hist_min[idx] / (double) nmax_min,
            hist_mean[idx], nhist_mean,
            (double) hist_mean[idx] / (double) nmax_mean, hist_sig[idx],
            nhist_sig, (double) hist_sig[idx] / (double) nmax_sig);

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}
```

5.21 libtrac.c File Reference

Functions

- void cart2geo (double ∗x, double ∗z, double ∗lon, double ∗lat)

  Convert Cartesian coordinates to geolocation.
- double clim_hno3 (double t, double lat, double p)

  Climatology of HNO3 volume mixing ratios.
- double clim_oh (double t, double lat, double p)

  Climatology of OH number concentrations.
- double clim_tropo (double t, double lat)

  Climatology of tropopause pressure.
- void day2doy (int year, int mon, int day, int ∗doy)

  Get day of year from date.
- void doy2day (int year, int doy, int ∗mon, int ∗day)

  Get date from day of year.
- void geo2cart (double z, double lon, double lat, double ∗x)

  Convert geolocation to Cartesian coordinates.
- void get_met (ctl_t ∗ctl, double t, met_t ∗∗met0, met_t ∗∗met1)

  Get meteorological data for given time step.
- void get_met_help (double t, int direct, char ∗metbase, double dt_met, char ∗filename)

  Get meteorological data for time step.
- void get_met_replace (char ∗orig, char ∗search, char ∗repl)

  Replace template strings in filename.
- void intpol_met_space_3d (met_t ∗met, float array[EX][EY][EP], double p, double lon, double lat, double ∗var, int ∗ci, double ∗cw, int init)

  Spatial interpolation of meteorological data.
- void intpol_met_space_2d (met_t ∗met, float array[EX][EY], double lon, double lat, double ∗var, int ∗ci, double ∗cw, int init)

  Spatial interpolation of meteorological data.
- void intpol_met_time_3d (met_t ∗met0, float array0[EX][EY][EP], met_t ∗met1, float array1[EX][EY][EP], double ts, double p, double lon, double lat, double ∗var, int ∗ci, double ∗cw, int init)

  Temporal interpolation of meteorological data.
- void intpol_met_time_2d (met_t ∗met0, float array0[EX][EY], met_t ∗met1, float array1[EX][EY], double ts, double lon, double lat, double ∗var, int ∗ci, double ∗cw, int init)

  Temporal interpolation of meteorological data.
- void jsec2time (double jsec, int ∗year, int ∗mon, int ∗day, int ∗hour, int ∗min, int ∗sec, double ∗remain)

  Convert seconds to date.
- double lapse_rate (double t, double h2o)

  Calculate moist adiabatic lapse rate.
- int locate_irr (double ∗xx, int n, double x)

  Find array index for irregular grid.
- int locate_reg (double ∗xx, int n, double x)

  Find array index for regular grid.
- double nat_temperature (double p, double h2o, double hno3)

  Calculate NAT existence temperature.
- int read_atm (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm)

  Read atmospheric data.
- void read_ctl (const char ∗filename, int argc, char ∗argv[ ], ctl_t ∗ctl)

  Read control parameters.
- int read_met (ctl_t ∗ctl, char ∗filename, met_t ∗met)

Read meteorological data file.
- void read_met_cape (met_t ∗met)

  Calculate convective available potential energy.
- void read_met_cloud (met_t ∗met)

  Calculate cloud properties.
- void read_met_detrend (ctl_t ∗ctl, met_t ∗met)

  Apply detrending method to temperature and winds.
- void read_met_extrapolate (met_t ∗met)

  Extrapolate meteorological data at lower boundary.
- void read_met_geopot (ctl_t ∗ctl, met_t ∗met)

  Calculate geopotential heights.
- void read_met_grid (char ∗filename, int ncid, ctl_t ∗ctl, met_t ∗met)

  Read coordinates of meteorological data.
- int read_met_help_3d (int ncid, char ∗varname, char ∗varname2, met_t ∗met, float dest[EX][EY][EP], float scl)

  Read and convert 3D variable from meteorological data file.
- int read_met_help_2d (int ncid, char ∗varname, char ∗varname2, met_t ∗met, float dest[EX][EY], float scl)

  Read and convert 2D variable from meteorological data file.
- void read_met_levels (int ncid, ctl_t ∗ctl, met_t ∗met)
- void read_met_ml2pl (ctl_t ∗ctl, met_t ∗met, float var[EX][EY][EP])

  Convert meteorological data from model levels to pressure levels.
- void read_met_periodic (met_t ∗met)

  Create meteorological data with periodic boundary conditions.
- void read_met_pv (met_t ∗met)

  Calculate potential vorticity.
- void read_met_sample (ctl_t ∗ctl, met_t ∗met)

  Downsampling of meteorological data.
- void read_met_surface (int ncid, met_t ∗met)

  Read surface data.
- void read_met_tropo (ctl_t ∗ctl, met_t ∗met)

  Calculate tropopause data.
- double scan_ctl (const char ∗filename, int argc, char ∗argv[ ], const char ∗varname, int arridx, const char ∗defvalue, char ∗value)

  Read a control parameter from file or command line.
- double sedi (double p, double T, double r_p, double rho_p)

  Calculate sedimentation velocity.
- void spline (double ∗x, double ∗y, int n, double ∗x2, double ∗y2, int n2)

  Spline interpolation.
- double stddev (double ∗data, int n)

  Calculate standard deviation.
- void time2jsec (int year, int mon, int day, int hour, int min, int sec, double remain, double ∗jsec)

  Convert date to seconds.
- void timer (const char ∗name, int output)

  Measure wall-clock time.
- void write_atm (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write atmospheric data.
- void write_csi (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write CSI data.
- void write_ens (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write ensemble data.
- void write_grid (const char ∗filename, ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double t)

Write gridded data.

- void write_prof (const char ∗filename, ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double t)

  Write profile data.

- void write_sample (const char ∗filename, ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double t)

  Write sample data.

- void write_station (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write station data.

5.21.1 Detailed Description

MPTRAC library definitions.

Definition in file libtrac.c.

5.21.2 Function Documentation

5.21.2.1 cart2geo()

```
void cart2geo (
        double * x,
        double * z,
        double * lon,
        double * lat )
```

Convert Cartesian coordinates to geolocation.

Definition at line 29 of file libtrac.c.

```
                  {

  double radius = NORM(x);
  *lat = asin(x[2] / radius) * 180. / M_PI;
  *lon = atan2(x[1], x[0]) * 180. / M_PI;
  *z = radius - RE;
}
```

5.21.2.2 clim_hno3()

```
double clim_hno3 (
        double t,
        double lat,
        double p )
```

Climatology of HNO3 volume mixing ratios.

Definition at line 295 of file libtrac.c.

```
              {

  /* Get seconds since begin of year... */
  double sec = FMOD(t, 365.25 * 86400.);
  while (sec < 0)
    sec += 365.25 * 86400.;

  /* Check pressure... */
  if (p < clim_hno3_ps[0])
    p = clim_hno3_ps[0];
  else if (p > clim_hno3_ps[9])
    p = clim_hno3_ps[9];

  /* Check latitude... */
```

```
  if (lat < clim_hno3_lats[0])
    lat = clim_hno3_lats[0];
  else if (lat > clim_hno3_lats[17])
    lat = clim_hno3_lats[17];

  /* Get indices... */
  int isec = locate_irr(clim_hno3_secs, 12, sec);
  int ilat = locate_reg(clim_hno3_lats, 18, lat);
  int ip = locate_irr(clim_hno3_ps, 10, p);

  /* Interpolate HNO3 climatology (Froidevaux et al., 2015)... */
  double aux00 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec][ilat][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec][ilat][ip + 1], p);
  double aux01 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec][ilat + 1][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec][ilat + 1][ip + 1], p);
  double aux10 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec + 1][ilat][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec + 1][ilat][ip + 1], p);
  double aux11 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec + 1][ilat + 1][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec + 1][ilat + 1][ip + 1], p);
  aux00 = LIN(clim_hno3_lats[ilat], aux00,
              clim_hno3_lats[ilat + 1], aux01, lat);
  aux11 = LIN(clim_hno3_lats[ilat], aux10,
              clim_hno3_lats[ilat + 1], aux11, lat);
  aux00 = LIN(clim_hno3_secs[isec], aux00,
              clim_hno3_secs[isec + 1], aux11, sec);
  return GSL_MAX(aux00, 0.0);
}
```

5.21.2.3 clim_oh()

```
double clim_oh (
    double t,
    double lat,
    double p )
```

Climatology of OH number concentrations.

Definition at line 1329 of file libtrac.c.

```
          {

  /* Get seconds since begin of year... */
  double sec = FMOD(t, 365.25 * 86400.);
  while (sec < 0)
    sec += 365.25 * 86400.;

  /* Check pressure... */
  if (p < clim_oh_ps[0])
    p = clim_oh_ps[0];
  else if (p > clim_oh_ps[33])
    p = clim_oh_ps[33];

  /* Check latitude... */
  if (lat < clim_oh_lats[0])
    lat = clim_oh_lats[0];
  else if (lat > clim_oh_lats[17])
    lat = clim_oh_lats[17];

  /* Get indices... */
  int isec = locate_irr(clim_oh_secs, 12, sec);
  int ilat = locate_reg(clim_oh_lats, 18, lat);
  int ip = locate_irr(clim_oh_ps, 34, p);

  /* Interpolate OH climatology (Pommrich et al., 2014)... */
  double aux00 = LIN(clim_oh_ps[ip],
                     clim_oh_var[isec][ilat][ip],
                     clim_oh_ps[ip + 1],
                     clim_oh_var[isec][ilat][ip + 1], p);
  double aux01 = LIN(clim_oh_ps[ip],
                     clim_oh_var[isec][ilat + 1][ip],
                     clim_oh_ps[ip + 1],
                     clim_oh_var[isec][ilat + 1][ip + 1], p);
  double aux10 = LIN(clim_oh_ps[ip],
```

```
                         clim_oh_var[isec + 1][ilat][ip],
                         clim_oh_ps[ip + 1],
                         clim_oh_var[isec + 1][ilat][ip + 1], p);
  double aux11 = LIN(clim_oh_ps[ip],
                         clim_oh_var[isec + 1][ilat + 1][ip],
                         clim_oh_ps[ip + 1],
                         clim_oh_var[isec + 1][ilat + 1][ip + 1], p);
  aux00 = LIN(clim_oh_lats[ilat], aux00, clim_oh_lats[ilat + 1], aux01, lat);
  aux11 = LIN(clim_oh_lats[ilat], aux10, clim_oh_lats[ilat + 1], aux11, lat);
  aux00 = LIN(clim_oh_secs[isec], aux00, clim_oh_secs[isec + 1], aux11, sec);
  return GSL_MAX(1e6 * aux00, 0.0);
}
```

5.21.2.4 clim_tropo()

```
double clim_tropo (
        double t,
        double lat )
```

Climatology of tropopause pressure.

Definition at line 1510 of file libtrac.c.

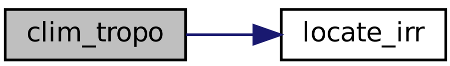
```
                    {

  /* Get seconds since begin of year... */
  double sec = FMOD(t, 365.25 * 86400.);
  while (sec < 0)
    sec += 365.25 * 86400.;

  /* Get indices... */
  int isec = locate_irr(clim_tropo_secs, 12, sec);
  int ilat = locate_reg(clim_tropo_lats, 73, lat);

  /* Interpolate tropopause data (NCEP/NCAR Reanalysis 1)... */
  double p0 = LIN(clim_tropo_lats[ilat],
                      clim_tropo_tps[isec][ilat],
                      clim_tropo_lats[ilat + 1],
                      clim_tropo_tps[isec][ilat + 1], lat);
  double p1 = LIN(clim_tropo_lats[ilat],
                      clim_tropo_tps[isec + 1][ilat],
                      clim_tropo_lats[ilat + 1],
                      clim_tropo_tps[isec + 1][ilat + 1], lat);
  return LIN(clim_tropo_secs[isec], p0, clim_tropo_secs[isec + 1], p1, sec);
}
```

Here is the call graph for this function:



5.21.2.5 day2doy()

```
void day2doy (
        int year,
        int mon,
        int day,
        int * doy )
```

Get day of year from date.

Definition at line 1537 of file libtrac.c.

```
                {

  int d0[12] = { 1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335 };
  int d01[12] = { 1, 32, 61, 92, 122, 153, 183, 214, 245, 275, 306, 336 };

  /* Get day of year... */
  if (year % 400 == 0 || (year % 100 != 0 && year % 4 == 0))
    *doy = d01[mon - 1] + day - 1;
  else
    *doy = d0[mon - 1] + day - 1;
}
```

5.21.2.6 doy2day()

```
void doy2day (
    int year,
    int doy,
    int * mon,
    int * day )
```

Get date from day of year.

Definition at line 1555 of file libtrac.c.

```
                {

  int d0[12] = { 1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335 };
  int d01[12] = { 1, 32, 61, 92, 122, 153, 183, 214, 245, 275, 306, 336 };
  int i;

  /* Get month and day... */
  if (year % 400 == 0 || (year % 100 != 0 && year % 4 == 0)) {
    for (i = 11; i >= 0; i--)
      if (d01[i] <= doy)
        break;
    *mon = i + 1;
    *day = doy - d01[i] + 1;
  } else {
    for (i = 11; i >= 0; i--)
      if (d0[i] <= doy)
        break;
    *mon = i + 1;
    *day = doy - d0[i] + 1;
  }
}
```

5.21.2.7 geo2cart()

```
void geo2cart (
    double z,
    double lon,
    double lat,
    double * x )
```

Convert geolocation to Cartesian coordinates.

Definition at line 1583 of file libtrac.c.

```
                 {

  double radius = z + RE;
  x[0] = radius * cos(lat / 180. * M_PI) * cos(lon / 180. * M_PI);
  x[1] = radius * cos(lat / 180. * M_PI) * sin(lon / 180. * M_PI);
  x[2] = radius * sin(lat / 180. * M_PI);
}
```

5.21.2.8 get_met()

```
void get_met (
    ctl_t * ctl,
    double t,
    met_t ** met0,
    met_t ** met1 )
```

Get meteorological data for given time step.

Definition at line 1597 of file libtrac.c.

```
                    {

  static int init, ip, ix, iy;

  met_t *mets;

  char filename[LEN];

  /* Set timer... */
  SELECT_TIMER("GET_MET", NVTX_READ);

  /* Init... */
  if (t == ctl->t_start || !init) {
    init = 1;

    get_met_help(t, -1, ctl->metbase, ctl->dt_met, filename);
    if (!read_met(ctl, filename, *met0))
      ERRMSG("Cannot open file!");

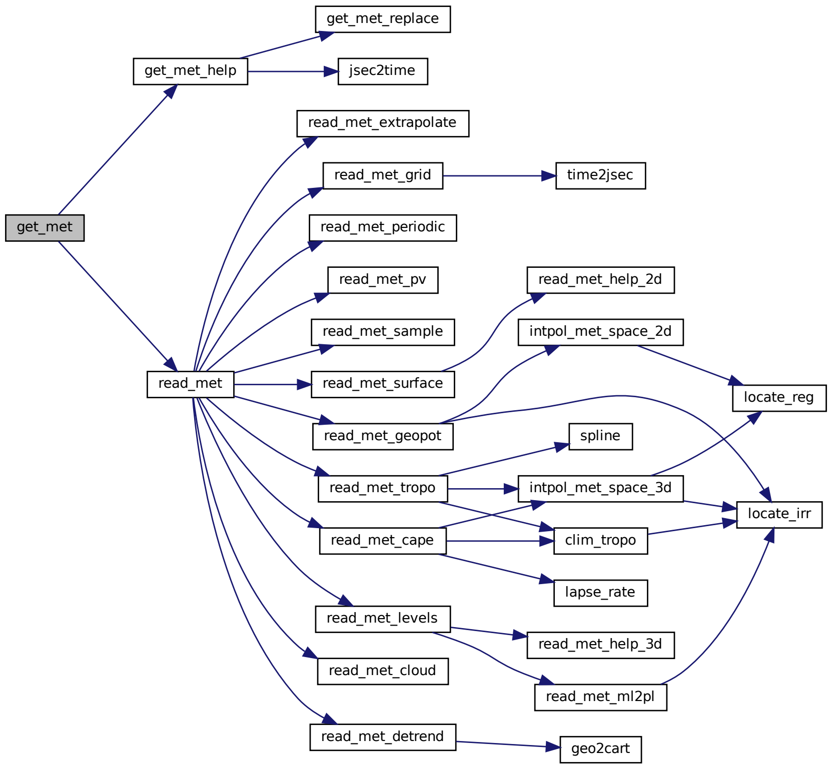
    get_met_help(t + 1.0 * ctl->direction, 1, ctl->metbase, ctl->dt_met,
                 filename);
    if (!read_met(ctl, filename, *met1))
      ERRMSG("Cannot open file!");
#ifdef _OPENACC
    met_t *met0up = *met0;
    met_t *met1up = *met1;
#pragma acc update device(met0up[:1],met1up[:1])
#endif
  }

  /* Read new data for forward trajectories... */
  if (t > (*met1)->time && ctl->direction == 1) {
    mets = *met1;
    *met1 = *met0;
    *met0 = mets;
    get_met_help(t, 1, ctl->metbase, ctl->dt_met, filename);
    if (!read_met(ctl, filename, *met1))
      ERRMSG("Cannot open file!");
#ifdef _OPENACC
    met_t *met1up = *met1;
#pragma acc update device(met1up[:1])
#endif
  }

  /* Read new data for backward trajectories... */
  if (t < (*met0)->time && ctl->direction == -1) {
    mets = *met1;
    *met1 = *met0;
    *met0 = mets;
    get_met_help(t, -1, ctl->metbase, ctl->dt_met, filename);
    if (!read_met(ctl, filename, *met0))
      ERRMSG("Cannot open file!");
#ifdef _OPENACC
    met_t *met0up = *met0;
#pragma acc update device(met0up[:1])
#endif
  }

  /* Check that grids are consistent... */
  if ((*met0)->nx != (*met1)->nx
      || (*met0)->ny != (*met1)->ny || (*met0)->np != (*met1)->np)
    ERRMSG("Meteo grid dimensions do not match!");
  for (ix = 0; ix < (*met0)->nx; ix++)
    if (fabs((*met0)->lon[ix] - (*met1)->lon[ix]) > 0.001)
      ERRMSG("Meteo grid longitudes do not match!");
  for (iy = 0; iy < (*met0)->ny; iy++)
    if (fabs((*met0)->lat[iy] - (*met1)->lat[iy]) > 0.001)
      ERRMSG("Meteo grid latitudes do not match!");
  for (ip = 0; ip < (*met0)->np; ip++)
    if (fabs((*met0)->p[ip] - (*met1)->p[ip]) > 0.001)
      ERRMSG("Meteo grid pressure levels do not match!");
}
```

Here is the call graph for this function:



5.21.2.9 get_met_help() `void get_met_help (`

```
double t,
int direct,
char * metbase,
double dt_met,
char * filename )
```

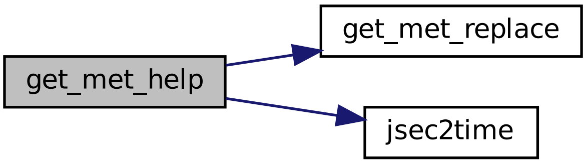
Get meteorological data for time step.

Definition at line 1676 of file libtrac.c.

```
01681                      {
01682
01683   char repl[LEN];
01684
01685   double t6, r;
01686
01687   int year, mon, day, hour, min, sec;
01688
01689   /* Round time to fixed intervals... */
01690   if (direct == -1)
01691     t6 = floor(t / dt_met) * dt_met;
01692   else
01693     t6 = ceil(t / dt_met) * dt_met;
01694
01695   /* Decode time... */
01696   jsec2time(t6, &year, &mon, &day, &hour, &min, &sec, &r);
01697
01698   /* Set filename... */
01699   sprintf(filename, "%s_YYYY_MM_DD_HH.nc", metbase);
01700   sprintf(repl, "%d", year);
```

```
  get_met_replace(filename, "YYYY", repl);
  sprintf(repl, "%02d", mon);
  get_met_replace(filename, "MM", repl);
  sprintf(repl, "%02d", day);
  get_met_replace(filename, "DD", repl);
  sprintf(repl, "%02d", hour);
  get_met_replace(filename, "HH", repl);
}
```

Here is the call graph for this function:



5.21.2.10 get_met_replace() `void get_met_replace ( char * orig, char * search, char * repl )`

Replace template strings in filename.

Definition at line 1712 of file libtrac.c.

```
                {

  char buffer[LEN], *ch;

  /* Iterate... */
  for (int i = 0; i < 3; i++) {

    /* Replace sub-string... */
    if (!(ch = strstr(orig, search)))
      return;
    strncpy(buffer, orig, (size_t) (ch - orig));
    buffer[ch - orig] = 0;
    sprintf(buffer + (ch - orig), "%s%s", repl, ch + strlen(search));
    orig[0] = 0;
    strcpy(orig, buffer);
  }
}
```

5.21.2.11 intpol_met_space_3d() `void intpol_met_space_3d ( met_t * met, float array[EX][EY][EP], double p, double lon, double lat, double * var, int * ci,`

```
double * cw,
int init )
```

Spatial interpolation of meteorological data.

Definition at line 1735 of file libtrac.c.

```
          {

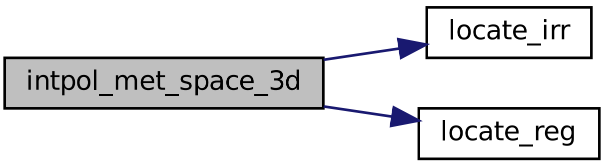
  /* Check longitude... */
  if (met->lon[met->nx - 1] > 180 && lon < 0)
    lon += 360;

  /* Get interpolation indices and weights... */
  if (init) {
    ci[0] = locate_irr(met->p, met->np, p);
    ci[1] = locate_reg(met->lon, met->nx, lon);
    ci[2] = locate_reg(met->lat, met->ny, lat);
    cw[0] = (met->p[ci[0] + 1] - p)
      / (met->p[ci[0] + 1] - met->p[ci[0]]);
    cw[1] = (met->lon[ci[1] + 1] - lon)
      / (met->lon[ci[1] + 1] - met->lon[ci[1]]);
    cw[2] = (met->lat[ci[2] + 1] - lat)
      / (met->lat[ci[2] + 1] - met->lat[ci[2]]);
  }

  /* Interpolate vertically... */
  double aux00 =
    cw[0] * (array[ci[1]][ci[2]][ci[0]] - array[ci[1]][ci[2]][ci[0] + 1])
    + array[ci[1]][ci[2]][ci[0] + 1];
  double aux01 =
    cw[0] * (array[ci[1]][ci[2] + 1][ci[0]] -
             array[ci[1]][ci[2] + 1][ci[0] + 1])
    + array[ci[1]][ci[2] + 1][ci[0] + 1];
  double aux10 =
    cw[0] * (array[ci[1] + 1][ci[2]][ci[0]] -
             array[ci[1] + 1][ci[2]][ci[0] + 1])
    + array[ci[1] + 1][ci[2]][ci[0] + 1];
  double aux11 =
    cw[0] * (array[ci[1] + 1][ci[2] + 1][ci[0]] -
             array[ci[1] + 1][ci[2] + 1][ci[0] + 1])
    + array[ci[1] + 1][ci[2] + 1][ci[0] + 1];

  /* Interpolate horizontally... */
  aux00 = cw[2] * (aux00 - aux01) + aux01;
  aux11 = cw[2] * (aux10 - aux11) + aux11;
  *var = cw[1] * (aux00 - aux11) + aux11;
}
```

Here is the call graph for this function:



5.21.2.12 intpol_met_space_2d()

```
void intpol_met_space_2d (
met_t * met,
float array[EX][EY],
double lon,
```

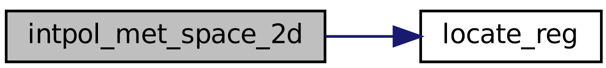
```
double lat,
double * var,
int * ci,
double * cw,
int init )
```

Spatial interpolation of meteorological data.

Definition at line 1789 of file libtrac.c.

```
01797               {
01798
01799   /* Check longitude... */
01800   if (met->lon[met->nx - 1] > 180 && lon < 0)
01801     lon += 360;
01802
01803   /* Get interpolation indices and weights... */
01804   if (init) {
01805     ci[1] = locate_reg(met->lon, met->nx, lon);
01806     ci[2] = locate_reg(met->lat, met->ny, lat);
01807     cw[1] = (met->lon[ci[1] + 1] - lon)
01808       / (met->lon[ci[1] + 1] - met->lon[ci[1]]);
01809     cw[2] = (met->lat[ci[2] + 1] - lat)
01810       / (met->lat[ci[2] + 1] - met->lat[ci[2]]);
01811   }
01812
01813   /* Set variables... */
01814   double aux00 = array[ci[1]][ci[2]];
01815   double aux01 = array[ci[1]][ci[2] + 1];
01816   double aux10 = array[ci[1] + 1][ci[2]];
01817   double aux11 = array[ci[1] + 1][ci[2] + 1];
01818
01819   /* Interpolate horizontally... */
01820   if (isfinite(aux00) && isfinite(aux01))
01821     aux00 = cw[2] * (aux00 - aux01) + aux01;
01822   else if (cw[2] < 0.5)
01823     aux00 = aux01;
01824   if (isfinite(aux10) && isfinite(aux11))
01825     aux11 = cw[2] * (aux10 - aux11) + aux11;
01826   else if (cw[2] > 0.5)
01827     aux11 = aux10;
01828   if (isfinite(aux00) && isfinite(aux11))
01829     *var = cw[1] * (aux00 - aux11) + aux11;
01830   else {
01831     if (cw[1] > 0.5)
01832       *var = aux00;
01833     else
01834       *var = aux11;
01835   }
01836 }
```

Here is the call graph for this function:



5.21.2.13 intpol_met_time_3d()

```
void intpol_met_time_3d (
met_t * met0,
float array0[EX][EY][EP],
met_t * met1,
float array1[EX][EY][EP],
```

```
double ts,
double p,
double lon,
double lat,
double * var,
int * ci,
double * cw,
int init )
```

Temporal interpolation of meteorological data.

Definition at line 1840 of file libtrac.c.

```
            {

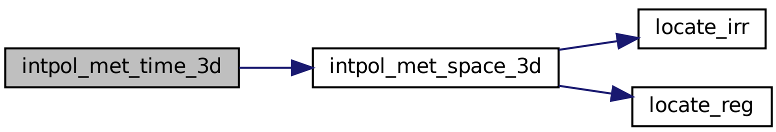
  double var0, var1, wt;

  /* Spatial interpolation... */
  intpol_met_space_3d(met0, array0, p, lon, lat, &var0, ci, cw, init);
  intpol_met_space_3d(met1, array1, p, lon, lat, &var1, ci, cw, init);

  /* Get weighting factor... */
  wt = (met1->time - ts) / (met1->time - met0->time);

  /* Interpolate... */
  *var = wt * (var0 - var1) + var1;
}
```

Here is the call graph for this function:



5.21.2.14 intpol_met_time_2d()

```
void intpol_met_time_2d (
met_t * met0,
float array0[EX][EY],
met_t * met1,
float array1[EX][EY],
double ts,
double lon,
double lat,
double * var,
int * ci,
double * cw,
int init )
```

Temporal interpolation of meteorological data.

Definition at line 1869 of file libtrac.c.

```
            {

  double var0, var1, wt;

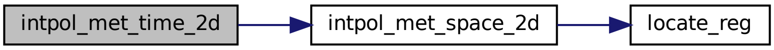
  /* Spatial interpolation... */
```

```
  intpol_met_space_2d(met0, array0, lon, lat, &var0, ci, cw, init);
  intpol_met_space_2d(met1, array1, lon, lat, &var1, ci, cw, init);

  /* Get weighting factor... */
  wt = (met1->time - ts) / (met1->time - met0->time);

  /* Interpolate... */
  *var = wt * (var0 - var1) + var1;
}
```

Here is the call graph for this function:



5.21.2.15 jsec2time()

```
void jsec2time (
    double jsec,
    int * year,
    int * mon,
    int * day,
    int * hour,
    int * min,
    int * sec,
    double * remain )
```

Convert seconds to date.

Definition at line 1897 of file libtrac.c.

```
                  {

  struct tm t0, *t1;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  time_t jsec0 = (time_t) jsec + timegm(&t0);
  t1 = gmtime(&jsec0);

  *year = t1->tm_year + 1900;
  *mon = t1->tm_mon + 1;
  *day = t1->tm_mday;
  *hour = t1->tm_hour;
  *min = t1->tm_min;
  *sec = t1->tm_sec;
  *remain = jsec - floor(jsec);
}
```

5.21.2.16 lapse_rate() double lapse_rate (
double *t*,
double *h2o*)

Calculate moist adiabatic lapse rate.

Definition at line 1930 of file libtrac.c.

```
                {

  /*
     Calculate moist adiabatic lapse rate [K/km] from temperature [K]
     and water vapor volume mixing ratio [1].

     Reference: https://en.wikipedia.org/wiki/Lapse_rate
   */

  const double a = RA * SQR(t), r = SH(h2o) / (1. - SH(h2o));

  return 1e3 * G0 * (a + LV * r * t) / (CPD * a + SQR(LV) * r * EPS);
}
```

5.21.2.17 locate_irr() int locate_irr (
double * *xx*,
int *n*,
double *x*)

Find array index for irregular grid.

Definition at line 1948 of file libtrac.c.

```
              {

  int ilo = 0;
  int ihi = n - 1;
  int i = (ihi + ilo) » 1;

  if (xx[i] < xx[i + 1])
    while (ihi > ilo + 1) {
      i = (ihi + ilo) » 1;
      if (xx[i] > x)
        ihi = i;
      else
        ilo = i;
  } else
    while (ihi > ilo + 1) {
      i = (ihi + ilo) » 1;
      if (xx[i] <= x)
        ihi = i;
      else
        ilo = i;
    }

  return ilo;
}
```

5.21.2.18 locate_reg() int locate_reg (
double * *xx*,
int *n*,
double *x*)

Find array index for regular grid.

Definition at line 1978 of file libtrac.c.

```
              {

  /* Calculate index... */
  int i = (int) ((x - xx[0]) / (xx[1] - xx[0]));
```

```
  /* Check range... */
  if (i < 0)
    i = 0;
  else if (i >= n - 2)
    i = n - 2;

  return i;
}
```

5.21.2.19 nat_temperature() `double nat_temperature ( double p, double h2o, double hno3 )`

Calculate NAT existence temperature.

Definition at line 1997 of file libtrac.c.

```
                 {

  double p_hno3 = hno3 * p / 1.333224;
  double p_h2o = h2o * p / 1.333224;
  double a = 0.009179 - 0.00088 * log10(p_h2o);
  double b = (38.9855 - log10(p_hno3) - 2.7836 * log10(p_h2o)) / a;
  double c = -11397.0 / a;
  double tnat = (-b + sqrt(b * b - 4. * c)) / 2.;
  double x2 = (-b - sqrt(b * b - 4. * c)) / 2.;
  if (x2 > 0)
    tnat = x2;

  return tnat;
}
```

5.21.2.20 read_atm() `int read_atm ( const char * filename, ctl_t * ctl, atm_t * atm )`

Read atmospheric data.

Definition at line 2017 of file libtrac.c.

```
                 {

  FILE *in;

  char line[LEN], *tok;

  double t0;

  int dimid, ip, iq, ncid, varid;

  size_t nparts;

  /* Set timer... */
  SELECT_TIMER("READ_ATM", NVTX_READ);

  /* Init... */
  atm->np = 0;

  /* Write info... */
  printf("Read atmospheric data: %s\n", filename);

  /* Read ASCII data... */
  if (ctl->atm_type == 0) {

    /* Open file... */
    if (!(in = fopen(filename, "r"))) {
      WARN("File not found!");
      return 0;
```

```
    }

    /* Read line... */
    while (fgets(line, LEN, in)) {

      /* Read data... */
      TOK(line, tok, "%lg", atm->time[atm->np]);
      TOK(NULL, tok, "%lg", atm->p[atm->np]);
      TOK(NULL, tok, "%lg", atm->lon[atm->np]);
      TOK(NULL, tok, "%lg", atm->lat[atm->np]);
      for (iq = 0; iq < ctl->nq; iq++)
        TOK(NULL, tok, "%lg", atm->q[iq][atm->np]);

      /* Convert altitude to pressure... */
      atm->p[atm->np] = P(atm->p[atm->np]);

      /* Increment data point counter... */
      if ((++atm->np) > NP)
        ERRMSG("Too many data points!");
    }

    /* Close file... */
    fclose(in);
  }

  /* Read binary data... */
  else if (ctl->atm_type == 1) {

    /* Open file... */
    if (!(in = fopen(filename, "r")))
      return 0;

    /* Read data... */
    FREAD(&atm->np, int,
          1,
          in);
    FREAD(atm->time, double,
            (size_t) atm->np,
          in);
    FREAD(atm->p, double,
            (size_t) atm->np,
          in);
    FREAD(atm->lon, double,
            (size_t) atm->np,
          in);
    FREAD(atm->lat, double,
            (size_t) atm->np,
          in);
    for (iq = 0; iq < ctl->nq; iq++)
      FREAD(atm->q[iq], double,
              (size_t) atm->np,
            in);

    /* Close file... */
    fclose(in);
  }

  /* Read netCDF data... */
  else if (ctl->atm_type == 2) {

    /* Open file... */
    if (nc_open(filename, NC_NOWRITE, &ncid) != NC_NOERR)
      return 0;

    /* Get dimensions... */
    NC(nc_inq_dimid(ncid, "NPARTS", &dimid));
    NC(nc_inq_dimlen(ncid, dimid, &nparts));
    atm->np = (int) nparts;
    if (atm->np > NP)
      ERRMSG("Too many particles!");

    /* Get time... */
    NC(nc_inq_varid(ncid, "time", &varid));
    NC(nc_get_var_double(ncid, varid, &t0));
    for (ip = 0; ip < atm->np; ip++)
      atm->time[ip] = t0;

    /* Read geolocations... */
    NC(nc_inq_varid(ncid, "PRESS", &varid));
    NC(nc_get_var_double(ncid, varid, atm->p));
    NC(nc_inq_varid(ncid, "LON", &varid));
    NC(nc_get_var_double(ncid, varid, atm->lon));
    NC(nc_inq_varid(ncid, "LAT", &varid));
    NC(nc_get_var_double(ncid, varid, atm->lat));

    /* Read variables... */
    if (ctl->qnt_p >= 0)
```

```
      if (nc_inq_varid(ncid, "PRESS", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_p]));
    if (ctl->qnt_t >= 0)
      if (nc_inq_varid(ncid, "TEMP", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_t]));
    if (ctl->qnt_u >= 0)
      if (nc_inq_varid(ncid, "U", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_u]));
    if (ctl->qnt_v >= 0)
      if (nc_inq_varid(ncid, "V", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_v]));
    if (ctl->qnt_w >= 0)
      if (nc_inq_varid(ncid, "W", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_w]));
    if (ctl->qnt_h2o >= 0)
      if (nc_inq_varid(ncid, "SH", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_h2o]));
    if (ctl->qnt_o3 >= 0)
      if (nc_inq_varid(ncid, "O3", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_o3]));
    if (ctl->qnt_theta >= 0)
      if (nc_inq_varid(ncid, "THETA", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_theta]));
    if (ctl->qnt_pv >= 0)
      if (nc_inq_varid(ncid, "PV", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_pv]));

    /* Check data... */
    for (ip = 0; ip < atm->np; ip++)
      if (fabs(atm->lon[ip]) > 360 || fabs(atm->lat[ip]) > 90
          || (ctl->qnt_t >= 0 && fabs(atm->q[ctl->qnt_t][ip]) > 350)
          || (ctl->qnt_h2o >= 0 && fabs(atm->q[ctl->qnt_h2o][ip]) > 1)
          || (ctl->qnt_theta >= 0 && fabs(atm->q[ctl->qnt_theta][ip]) > 1e10)
          || (ctl->qnt_pv >= 0 && fabs(atm->q[ctl->qnt_pv][ip]) > 1e10)) {
        atm->time[ip] = GSL_NAN;
        atm->p[ip] = GSL_NAN;
        atm->lon[ip] = GSL_NAN;
        atm->lat[ip] = GSL_NAN;
        for (iq = 0; iq < ctl->nq; iq++)
          atm->q[iq][ip] = GSL_NAN;
      } else {
        if (ctl->qnt_h2o >= 0)
          atm->q[ctl->qnt_h2o][ip] *= 1.608;
        if (ctl->qnt_pv >= 0)
          atm->q[ctl->qnt_pv][ip] *= 1e6;
        if (atm->lon[ip] > 180)
          atm->lon[ip] -= 360;
      }

    /* Close file... */
    NC(nc_close(ncid));
  }

  /* Error... */
  else
    ERRMSG("Atmospheric data type not supported!");

  /* Check number of points... */
  if (atm->np < 1)
    ERRMSG("Can not read any data!");

  /* Return success... */
  return 1;
}
```

5.21.2.21 read_ctl()

```
void read_ctl (
    const char * filename,
    int argc,
    char * argv[],
    ctl_t * ctl )
```

Read control parameters.

Definition at line 2202 of file libtrac.c.

```
               {

  /* Set timer... */
```

```
SELECT_TIMER("READ_CTL", NVTX_READ);

/* Write info... */
printf("\nMassive-Parallel Trajectory Calculations (MPTRAC)\n"
       "(executable: %s | compiled: %s, %s)\n\n",
       argv[0], __DATE__, __TIME__);

/* Initialize quantity indices... */
ctl->qnt_ens = -1;
ctl->qnt_m = -1;
ctl->qnt_r = -1;
ctl->qnt_rho = -1;
ctl->qnt_ps = -1;
ctl->qnt_ts = -1;
ctl->qnt_zs = -1;
ctl->qnt_us = -1;
ctl->qnt_vs = -1;
ctl->qnt_pt = -1;
ctl->qnt_tt = -1;
ctl->qnt_zt = -1;
ctl->qnt_h2ot = -1;
ctl->qnt_z = -1;
ctl->qnt_p = -1;
ctl->qnt_t = -1;
ctl->qnt_u = -1;
ctl->qnt_v = -1;
ctl->qnt_w = -1;
ctl->qnt_h2o = -1;
ctl->qnt_o3 = -1;
ctl->qnt_lwc = -1;
ctl->qnt_iwc = -1;
ctl->qnt_pc = -1;
ctl->qnt_cl = -1;
ctl->qnt_plcl = -1;
ctl->qnt_plfc = -1;
ctl->qnt_pel = -1;
ctl->qnt_cape = -1;
ctl->qnt_hno3 = -1;
ctl->qnt_oh = -1;
ctl->qnt_psat = -1;
ctl->qnt_psice = -1;
ctl->qnt_pw = -1;
ctl->qnt_sh = -1;
ctl->qnt_rh = -1;
ctl->qnt_rhice = -1;
ctl->qnt_theta = -1;
ctl->qnt_tvirt = -1;
ctl->qnt_lapse = -1;
ctl->qnt_vh = -1;
ctl->qnt_vz = -1;
ctl->qnt_pv = -1;
ctl->qnt_tdew = -1;
ctl->qnt_tice = -1;
ctl->qnt_tsts = -1;
ctl->qnt_tnat = -1;
ctl->qnt_stat = -1;

/* Read quantities... */
ctl->nq = (int) scan_ctl(filename, argc, argv, "NQ", -1, "0", NULL);
if (ctl->nq > NQ)
  ERRMSG("Too many quantities!");
for (int iq = 0; iq < ctl->nq; iq++) {

  /* Read quantity name and format... */
  scan_ctl(filename, argc, argv, "QNT_NAME", iq, "", ctl->qnt_name[iq]);
  scan_ctl(filename, argc, argv, "QNT_FORMAT", iq, "%g",
           ctl->qnt_format[iq]);

  /* Try to identify quantity... */
  if (strcasecmp(ctl->qnt_name[iq], "ens") == 0) {
    ctl->qnt_ens = iq;
    sprintf(ctl->qnt_unit[iq], "-");
  } else if (strcasecmp(ctl->qnt_name[iq], "m") == 0) {
    ctl->qnt_m = iq;
    sprintf(ctl->qnt_unit[iq], "kg");
  } else if (strcasecmp(ctl->qnt_name[iq], "r") == 0) {
    ctl->qnt_r = iq;
    sprintf(ctl->qnt_unit[iq], "m");
  } else if (strcasecmp(ctl->qnt_name[iq], "rho") == 0) {
    ctl->qnt_rho = iq;
    sprintf(ctl->qnt_unit[iq], "kg/m^3");
  } else if (strcasecmp(ctl->qnt_name[iq], "ps") == 0) {
    ctl->qnt_ps = iq;
    sprintf(ctl->qnt_unit[iq], "hPa");
  } else if (strcasecmp(ctl->qnt_name[iq], "pt") == 0) {
    ctl->qnt_pt = iq;
    sprintf(ctl->qnt_unit[iq], "hPa");
```

```
    } else if (strcasecmp(ctl->qnt_name[iq], "tt") == 0) {
      ctl->qnt_tt = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "zt") == 0) {
      ctl->qnt_zt = iq;
      sprintf(ctl->qnt_unit[iq], "km");
    } else if (strcasecmp(ctl->qnt_name[iq], "h2ot") == 0) {
      ctl->qnt_h2ot = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "z") == 0) {
      ctl->qnt_z = iq;
      sprintf(ctl->qnt_unit[iq], "km");
    } else if (strcasecmp(ctl->qnt_name[iq], "p") == 0) {
      ctl->qnt_p = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "t") == 0) {
      ctl->qnt_t = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "u") == 0) {
      ctl->qnt_u = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "v") == 0) {
      ctl->qnt_v = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "w") == 0) {
      ctl->qnt_w = iq;
      sprintf(ctl->qnt_unit[iq], "hPa/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "h2o") == 0) {
      ctl->qnt_h2o = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "o3") == 0) {
      ctl->qnt_o3 = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "lwc") == 0) {
      ctl->qnt_lwc = iq;
      sprintf(ctl->qnt_unit[iq], "kg/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "iwc") == 0) {
      ctl->qnt_iwc = iq;
      sprintf(ctl->qnt_unit[iq], "kg/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "pc") == 0) {
      ctl->qnt_pc = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "cl") == 0) {
      ctl->qnt_cl = iq;
      sprintf(ctl->qnt_unit[iq], "kg/m^2");
    } else if (strcasecmp(ctl->qnt_name[iq], "plcl") == 0) {
      ctl->qnt_plcl = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "plfc") == 0) {
      ctl->qnt_plfc = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "pel") == 0) {
      ctl->qnt_pel = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "cape") == 0) {
      ctl->qnt_cape = iq;
      sprintf(ctl->qnt_unit[iq], "J/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "hno3") == 0) {
      ctl->qnt_hno3 = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "oh") == 0) {
      ctl->qnt_oh = iq;
      sprintf(ctl->qnt_unit[iq], "molec/cm^3");
    } else if (strcasecmp(ctl->qnt_name[iq], "psat") == 0) {
      ctl->qnt_psat = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "psice") == 0) {
      ctl->qnt_psice = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "pw") == 0) {
      ctl->qnt_pw = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "sh") == 0) {
      ctl->qnt_sh = iq;
      sprintf(ctl->qnt_unit[iq], "kg/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "rh") == 0) {
      ctl->qnt_rh = iq;
      sprintf(ctl->qnt_unit[iq], "%%");
    } else if (strcasecmp(ctl->qnt_name[iq], "rhice") == 0) {
      ctl->qnt_rhice = iq;
      sprintf(ctl->qnt_unit[iq], "%%");
    } else if (strcasecmp(ctl->qnt_name[iq], "theta") == 0) {
      ctl->qnt_theta = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tvirt") == 0) {
      ctl->qnt_tvirt = iq;
      sprintf(ctl->qnt_unit[iq], "K");
```

```
    } else if (strcasecmp(ctl->qnt_name[iq], "lapse") == 0) {
      ctl->qnt_lapse = iq;
      sprintf(ctl->qnt_unit[iq], "K/km");
    } else if (strcasecmp(ctl->qnt_name[iq], "vh") == 0) {
      ctl->qnt_vh = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "vz") == 0) {
      ctl->qnt_vz = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "pv") == 0) {
      ctl->qnt_pv = iq;
      sprintf(ctl->qnt_unit[iq], "PVU");
    } else if (strcasecmp(ctl->qnt_name[iq], "tdew") == 0) {
      ctl->qnt_tdew = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tice") == 0) {
      ctl->qnt_tice = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tsts") == 0) {
      ctl->qnt_tsts = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tnat") == 0) {
      ctl->qnt_tnat = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "stat") == 0) {
      ctl->qnt_stat = iq;
      sprintf(ctl->qnt_unit[iq], "-");
    } else
      scan_ctl(filename, argc, argv, "QNT_UNIT", iq, "", ctl->qnt_unit[iq]);
  }

  /* Time steps of simulation... */
  ctl->direction =
    (int) scan_ctl(filename, argc, argv, "DIRECTION", -1, "1", NULL);
  if (ctl->direction != -1 && ctl->direction != 1)
    ERRMSG("Set DIRECTION to -1 or 1!");
  ctl->t_stop = scan_ctl(filename, argc, argv, "T_STOP", -1, "1e100", NULL);
  ctl->dt_mod = scan_ctl(filename, argc, argv, "DT_MOD", -1, "180", NULL);

  /* Meteorological data... */
  scan_ctl(filename, argc, argv, "METBASE", -1, "-", ctl->metbase);
  ctl->dt_met = scan_ctl(filename, argc, argv, "DT_MET", -1, "21600", NULL);
  ctl->met_dx = (int) scan_ctl(filename, argc, argv, "MET_DX", -1, "1", NULL);
  ctl->met_dy = (int) scan_ctl(filename, argc, argv, "MET_DY", -1, "1", NULL);
  ctl->met_dp = (int) scan_ctl(filename, argc, argv, "MET_DP", -1, "1", NULL);
  if (ctl->met_dx < 1 || ctl->met_dy < 1 || ctl->met_dp < 1)
    ERRMSG("MET_DX, MET_DY, and MET_DP need to be greater than zero!");
  ctl->met_sx = (int) scan_ctl(filename, argc, argv, "MET_SX", -1, "1", NULL);
  ctl->met_sy = (int) scan_ctl(filename, argc, argv, "MET_SY", -1, "1", NULL);
  ctl->met_sp = (int) scan_ctl(filename, argc, argv, "MET_SP", -1, "1", NULL);
  if (ctl->met_sx < 1 || ctl->met_sy < 1 || ctl->met_sp < 1)
    ERRMSG("MET_SX, MET_SY, and MET_SP need to be greater than zero!");
  ctl->met_detrend =
    scan_ctl(filename, argc, argv, "MET_DETREND", -1, "-999", NULL);
  ctl->met_np = (int) scan_ctl(filename, argc, argv, "MET_NP", -1, "0", NULL);
  if (ctl->met_np > EP)
    ERRMSG("Too many levels!");
  for (int ip = 0; ip < ctl->met_np; ip++)
    ctl->met_p[ip] = scan_ctl(filename, argc, argv, "MET_P", ip, "", NULL);
  ctl->met_geopot_sx
    = (int) scan_ctl(filename, argc, argv, "MET_GEOPOT_SX", -1, "6", NULL);
  ctl->met_geopot_sy
    = (int) scan_ctl(filename, argc, argv, "MET_GEOPOT_SY", -1, "4", NULL);
  if (ctl->met_geopot_sx < 1 || ctl->met_geopot_sy < 1)
    ERRMSG("MET_GEOPOT_SX and MET_GEOPOT_SY need to be greater than zero!");
  ctl->met_tropo =
    (int) scan_ctl(filename, argc, argv, "MET_TROPO", -1, "3", NULL);
  ctl->met_dt_out =
    scan_ctl(filename, argc, argv, "MET_DT_OUT", -1, "0.1", NULL);

  /* Isosurface parameters... */
  ctl->isosurf =
    (int) scan_ctl(filename, argc, argv, "ISOSURF", -1, "0", NULL);
  scan_ctl(filename, argc, argv, "BALLOON", -1, "-", ctl->balloon);

  /* Diffusion parameters... */
  ctl->turb_dx_trop =
    scan_ctl(filename, argc, argv, "TURB_DX_TROP", -1, "50", NULL);
  ctl->turb_dx_strat =
    scan_ctl(filename, argc, argv, "TURB_DX_STRAT", -1, "0", NULL);
  ctl->turb_dz_trop =
    scan_ctl(filename, argc, argv, "TURB_DZ_TROP", -1, "0", NULL);
  ctl->turb_dz_strat =
    scan_ctl(filename, argc, argv, "TURB_DZ_STRAT", -1, "0.1", NULL);
  ctl->turb_mesox =
    scan_ctl(filename, argc, argv, "TURB_MESOX", -1, "0.16", NULL);
  ctl->turb_mesoz =
```

```
    scan_ctl(filename, argc, argv, "TURB_MESOZ", -1, "0.16", NULL);

  /* Convection... */
  ctl->conv_cape =
    scan_ctl(filename, argc, argv, "CONV_CAPE", -1, "-999", NULL);

  /* Species parameters... */
  scan_ctl(filename, argc, argv, "SPECIES", -1, "-", ctl->species);
  if (strcasecmp(ctl->species, "SO2") == 0) {
    ctl->molmass = 64.066;
    ctl->oh_chem[0] = 3.3e-31;    /* (JPL Publication 15-10) */
    ctl->oh_chem[1] = 4.3;        /* (JPL Publication 15-10) */
    ctl->oh_chem[2] = 1.6e-12;    /* (JPL Publication 15-10) */
    ctl->oh_chem[3] = 0.0;        /* (JPL Publication 15-10) */
    ctl->wet_depo[2] = 1.3e-2;   /* (Sander, 2015) */
    ctl->wet_depo[3] = 2900.0;   /* (Sander, 2015) */
    ctl->wet_depo[6] = 1.3e-2;   /* (Sander, 2015) */
    ctl->wet_depo[7] = 2900.0;   /* (Sander, 2015) */
  } else {
    ctl->molmass =
      scan_ctl(filename, argc, argv, "MOLMASS", -1, "-999", NULL);
    ctl->tdec_trop =
      scan_ctl(filename, argc, argv, "TDEC_TROP", -1, "0", NULL);
    ctl->tdec_strat =
      scan_ctl(filename, argc, argv, "TDEC_STRAT", -1, "0", NULL);
    for (int ip = 0; ip < 4; ip++)
      ctl->oh_chem[ip] =
        scan_ctl(filename, argc, argv, "OH_CHEM", ip, "0", NULL);
    for (int ip = 0; ip < 1; ip++)
      ctl->dry_depo[ip] =
        scan_ctl(filename, argc, argv, "DRY_DEPO", ip, "0", NULL);
    for (int ip = 0; ip < 8; ip++)
      ctl->wet_depo[ip] =
        scan_ctl(filename, argc, argv, "WET_DEPO", ip, "0", NULL);
  }

  /* PSC analysis... */
  ctl->psc_h2o = scan_ctl(filename, argc, argv, "PSC_H2O", -1, "4e-6", NULL);
  ctl->psc_hno3 =
    scan_ctl(filename, argc, argv, "PSC_HNO3", -1, "9e-9", NULL);

  /* Output of atmospheric data... */
  scan_ctl(filename, argc, argv, "ATM_BASENAME", -1, "-", ctl->atm_basename);
  scan_ctl(filename, argc, argv, "ATM_GPFILE", -1, "-", ctl->atm_gpfile);
  ctl->atm_dt_out =
    scan_ctl(filename, argc, argv, "ATM_DT_OUT", -1, "86400", NULL);
  ctl->atm_filter =
    (int) scan_ctl(filename, argc, argv, "ATM_FILTER", -1, "0", NULL);
  ctl->atm_stride =
    (int) scan_ctl(filename, argc, argv, "ATM_STRIDE", -1, "1", NULL);
  ctl->atm_type =
    (int) scan_ctl(filename, argc, argv, "ATM_TYPE", -1, "0", NULL);

  /* Output of CSI data... */
  scan_ctl(filename, argc, argv, "CSI_BASENAME", -1, "-", ctl->csi_basename);
  ctl->csi_dt_out =
    scan_ctl(filename, argc, argv, "CSI_DT_OUT", -1, "86400", NULL);
  scan_ctl(filename, argc, argv, "CSI_OBSFILE", -1, "-", ctl->csi_obsfile);
  ctl->csi_obsmin =
    scan_ctl(filename, argc, argv, "CSI_OBSMIN", -1, "0", NULL);
  ctl->csi_modmin =
    scan_ctl(filename, argc, argv, "CSI_MODMIN", -1, "0", NULL);
  ctl->csi_z0 = scan_ctl(filename, argc, argv, "CSI_Z0", -1, "0", NULL);
  ctl->csi_z1 = scan_ctl(filename, argc, argv, "CSI_Z1", -1, "100", NULL);
  ctl->csi_nz = (int) scan_ctl(filename, argc, argv, "CSI_NZ", -1, "1", NULL);
  ctl->csi_lon0 =
    scan_ctl(filename, argc, argv, "CSI_LON0", -1, "-180", NULL);
  ctl->csi_lon1 = scan_ctl(filename, argc, argv, "CSI_LON1", -1, "180", NULL);
  ctl->csi_nx =
    (int) scan_ctl(filename, argc, argv, "CSI_NX", -1, "360", NULL);
  ctl->csi_lat0 = scan_ctl(filename, argc, argv, "CSI_LAT0", -1, "-90", NULL);
  ctl->csi_lat1 = scan_ctl(filename, argc, argv, "CSI_LAT1", -1, "90", NULL);
  ctl->csi_ny =
    (int) scan_ctl(filename, argc, argv, "CSI_NY", -1, "180", NULL);

  /* Output of ensemble data... */
  scan_ctl(filename, argc, argv, "ENS_BASENAME", -1, "-", ctl->ens_basename);

  /* Output of grid data... */
  scan_ctl(filename, argc, argv, "GRID_BASENAME", -1, "-",
           ctl->grid_basename);
  scan_ctl(filename, argc, argv, "GRID_GPFILE", -1, "-", ctl->grid_gpfile);
  ctl->grid_dt_out =
    scan_ctl(filename, argc, argv, "GRID_DT_OUT", -1, "86400", NULL);
  ctl->grid_sparse =
    (int) scan_ctl(filename, argc, argv, "GRID_SPARSE", -1, "0", NULL);
  ctl->grid_z0 = scan_ctl(filename, argc, argv, "GRID_Z0", -1, "0", NULL);
```

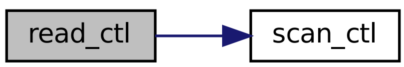
```
  ctl->grid_z1 = scan_ctl(filename, argc, argv, "GRID_Z1", -1, "100", NULL);
  ctl->grid_nz =
    (int) scan_ctl(filename, argc, argv, "GRID_NZ", -1, "1", NULL);
  ctl->grid_lon0 =
    scan_ctl(filename, argc, argv, "GRID_LON0", -1, "-180", NULL);
  ctl->grid_lon1 =
    scan_ctl(filename, argc, argv, "GRID_LON1", -1, "180", NULL);
  ctl->grid_nx =
    (int) scan_ctl(filename, argc, argv, "GRID_NX", -1, "360", NULL);
  ctl->grid_lat0 =
    scan_ctl(filename, argc, argv, "GRID_LAT0", -1, "-90", NULL);
  ctl->grid_lat1 =
    scan_ctl(filename, argc, argv, "GRID_LAT1", -1, "90", NULL);
  ctl->grid_ny =
    (int) scan_ctl(filename, argc, argv, "GRID_NY", -1, "180", NULL);

  /* Output of profile data... */
  scan_ctl(filename, argc, argv, "PROF_BASENAME", -1, "-",
           ctl->prof_basename);
  scan_ctl(filename, argc, argv, "PROF_OBSFILE", -1, "-", ctl->prof_obsfile);
  ctl->prof_z0 = scan_ctl(filename, argc, argv, "PROF_Z0", -1, "0", NULL);
  ctl->prof_z1 = scan_ctl(filename, argc, argv, "PROF_Z1", -1, "60", NULL);
  ctl->prof_nz =
    (int) scan_ctl(filename, argc, argv, "PROF_NZ", -1, "60", NULL);
  ctl->prof_lon0 =
    scan_ctl(filename, argc, argv, "PROF_LON0", -1, "-180", NULL);
  ctl->prof_lon1 =
    scan_ctl(filename, argc, argv, "PROF_LON1", -1, "180", NULL);
  ctl->prof_nx =
    (int) scan_ctl(filename, argc, argv, "PROF_NX", -1, "360", NULL);
  ctl->prof_lat0 =
    scan_ctl(filename, argc, argv, "PROF_LAT0", -1, "-90", NULL);
  ctl->prof_lat1 =
    scan_ctl(filename, argc, argv, "PROF_LAT1", -1, "90", NULL);
  ctl->prof_ny =
    (int) scan_ctl(filename, argc, argv, "PROF_NY", -1, "180", NULL);

  /* Output of sample data... */
  scan_ctl(filename, argc, argv, "SAMPLE_BASENAME", -1, "-",
           ctl->sample_basename);
  scan_ctl(filename, argc, argv, "SAMPLE_OBSFILE", -1, "-",
           ctl->sample_obsfile);
  ctl->sample_dx =
    scan_ctl(filename, argc, argv, "SAMPLE_DX", -1, "50", NULL);
  ctl->sample_dz =
    scan_ctl(filename, argc, argv, "SAMPLE_DZ", -1, "-999", NULL);

  /* Output of station data... */
  scan_ctl(filename, argc, argv, "STAT_BASENAME", -1, "-",
           ctl->stat_basename);
  ctl->stat_lon = scan_ctl(filename, argc, argv, "STAT_LON", -1, "0", NULL);
  ctl->stat_lat = scan_ctl(filename, argc, argv, "STAT_LAT", -1, "0", NULL);
  ctl->stat_r = scan_ctl(filename, argc, argv, "STAT_R", -1, "50", NULL);
}
```

Here is the call graph for this function:



5.21.2.22 read_met()

```
int read_met (
    ctl_t * ctl,
    char * filename,
    met_t * met )
```

Read meteorological data file.

Definition at line 2614 of file libtrac.c.

```
                  {

  int ncid;

  /* Write info... */
  printf("Read meteorological data: %s\n", filename);

  /* Open netCDF file... */
  if (nc_open(filename, NC_NOWRITE, &ncid) != NC_NOERR) {
    WARN("File not found!");
    return 0;
  }

  /* Read coordinates of meteorological data... */
  read_met_grid(filename, ncid, ctl, met);

  /* Read meteo data on vertical levels... */
  read_met_levels(ncid, ctl, met);

  /* Extrapolate data for lower boundary... */
  read_met_extrapolate(met);

  /* Read surface data... */
  read_met_surface(ncid, met);

  /* Create periodic boundary conditions... */
  read_met_periodic(met);

  /* Downsampling... */
  read_met_sample(ctl, met);

  /* Calculate geopotential heights... */
  read_met_geopot(ctl, met);

  /* Calculate potential vorticity... */
  read_met_pv(met);

  /* Calculate tropopause data... */
  read_met_tropo(ctl, met);

  /* Calculate cloud properties... */
  read_met_cloud(met);

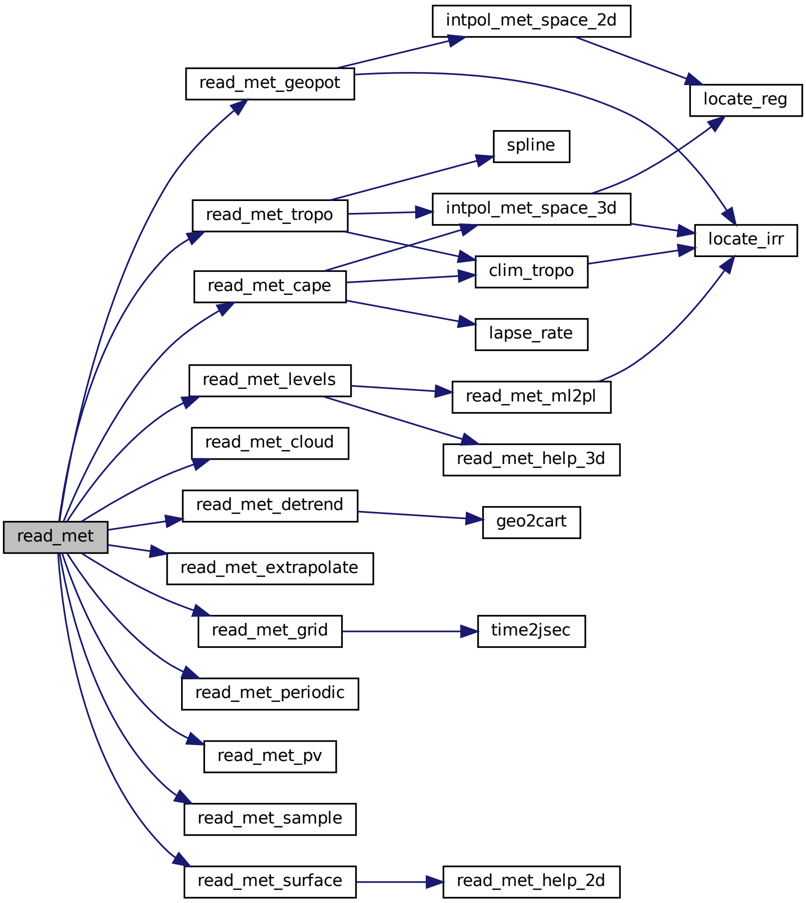
  /* Calculate convective available potential energy... */
  read_met_cape(met);

  /* Detrending... */
  read_met_detrend(ctl, met);

  /* Close file... */
  NC(nc_close(ncid));

  /* Return success... */
  return 1;
}
```

Here is the call graph for this function:



5.21.2.23 read_met_cape() void read_met_cape (met_t * *met*)

Calculate convective available potential energy.

Definition at line 2675 of file libtrac.c.

```
                          {

  /* Set timer... */
  SELECT_TIMER("READ_MET_CAPE", NVTX_READ);

  /* Vertical spacing (about 100 m)... */
  const double pfac = 1.01439, dz0 = RI / MA / G0 * log(pfac);

  /* Loop over columns... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++) {

      /* Get potential temperature and water vapor vmr at lowest 50 hPa... */
      int n = 0;
      double h2o = 0, t, theta = 0;
      double pbot = GSL_MIN(met->ps[ix][iy], met->p[0]);
      double ptop = pbot - 50.;
```

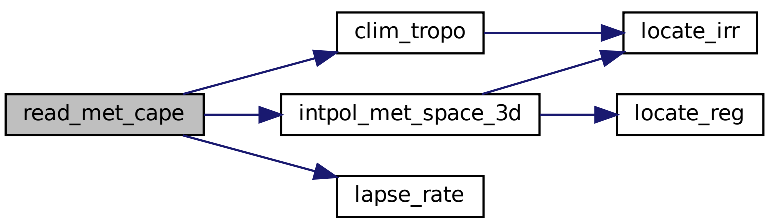
```
      for (int ip = 0; ip < met->np; ip++) {
        if (met->p[ip] <= pbot) {
          theta += THETA(met->p[ip], met->t[ix][iy][ip]);
          h2o += met->h2o[ix][iy][ip];
          n++;
        }
        if (met->p[ip] < ptop && n > 0)
          break;
      }
      theta /= n;
      h2o /= n;

      /* Cannot compute anything if water vapor is missing... */
      met->plcl[ix][iy] = GSL_NAN;
      met->plfc[ix][iy] = GSL_NAN;
      met->pel[ix][iy] = GSL_NAN;
      met->cape[ix][iy] = GSL_NAN;
      if (h2o <= 0)
        continue;

      /* Find lifted condensation level (LCL)... */
      ptop = P(20.);
      pbot = met->ps[ix][iy];
      do {
        met->plcl[ix][iy] = (float) (0.5 * (pbot + ptop));
        t = theta / pow(1000. / met->plcl[ix][iy], 0.286);
        if (RH(met->plcl[ix][iy], t, h2o) > 100.)
          ptop = met->plcl[ix][iy];
        else
          pbot = met->plcl[ix][iy];
      } while (pbot - ptop > 0.1);

      /* Calculate level of free convection (LFC), equilibrium level (EL),
         and convective available potential energy (CAPE)... */
      double dcape = 0, dcape_old, dz, h2o_env, p = met->plcl[ix][iy],
        psat, t_env;
      ptop = 0.75 * clim_tropo(met->time, met->lat[iy]);
      met->cape[ix][iy] = 0;
      do {
        dz = dz0 * TVIRT(t, h2o);
        p /= pfac;
        t -= lapse_rate(t, h2o) * dz;
        psat = PSAT(t);
        h2o = psat / (p - (1. - EPS) * psat);
        INTPOL_INIT;
        intpol_met_space_3d(met, met->t, p, met->lon[ix], met->lat[iy],
                            &t_env, ci, cw, 1);
        intpol_met_space_3d(met, met->h2o, p, met->lon[ix], met->lat[iy],
                            &h2o_env, ci, cw, 0);
        dcape_old = dcape;
        dcape = 1e3 * G0 * (TVIRT(t, h2o) - TVIRT(t_env, h2o_env)) /
          TVIRT(t_env, h2o_env) * dz;
        if (dcape > 0) {
          met->cape[ix][iy] += (float) dcape;
          if (!isfinite(met->plfc[ix][iy]))
            met->plfc[ix][iy] = (float) p;
        } else if (dcape_old > 0)
          met->pel[ix][iy] = (float) p;
      } while (p > ptop);
    }
}
```

Here is the call graph for this function:



5.21.2.24 read_met_cloud() void read_met_cloud (met_t * met)

Calculate cloud properties.

Definition at line 2758 of file libtrac.c.

```
                     {

  /* Set timer... */
  SELECT_TIMER("READ_MET_CLOUD", NVTX_READ);

  /* Loop over columns... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++) {

      /* Init... */
      met->pc[ix][iy] = GSL_NAN;
      met->cl[ix][iy] = 0;

      /* Loop over pressure levels... */
      for (int ip = 0; ip < met->np - 1; ip++) {

        /* Check pressure... */
        if (met->p[ip] > met->ps[ix][iy] || met->p[ip] < P(20.))
          continue;

        /* Get cloud top pressure ... */
        if (met->iwc[ix][iy][ip] > 0 || met->lwc[ix][iy][ip] > 0)
          met->pc[ix][iy] = (float) met->p[ip + 1];

        /* Get cloud water... */
        met->cl[ix][iy] += (float)
          (0.5 * (met->iwc[ix][iy][ip] + met->iwc[ix][iy][ip + 1]
                  + met->lwc[ix][iy][ip] + met->lwc[ix][iy][ip + 1])
           * 100. * (met->p[ip] - met->p[ip + 1]) / G0);
      }
    }
}
```

5.21.2.25 read_met_detrend() void read_met_detrend (ctl_t * ctl, met_t * met)

Apply detrending method to temperature and winds.

Definition at line 2795 of file libtrac.c.

```
                     {

  met_t *help;

  /* Check parameters... */
  if (ctl->met_detrend <= 0)
    return;

  /* Set timer... */
  SELECT_TIMER("READ_MET_DETREND", NVTX_READ);

  /* Allocate... */
  ALLOC(help, met_t, 1);

  /* Calculate standard deviation... */
  double sigma = ctl->met_detrend / 2.355;
  double tssq = 2. * SQR(sigma);

  /* Calculate box size in latitude... */
  int sy = (int) (3. * DY2DEG(sigma) / fabs(met->lat[1] - met->lat[0]));
  sy = GSL_MIN(GSL_MAX(1, sy), met->ny / 2);

  /* Calculate background... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++) {
    for (int iy = 0; iy < met->ny; iy++) {

      /* Calculate Cartesian coordinates... */
      double x0[3];
```

```
      geo2cart(0.0, met->lon[ix], met->lat[iy], x0);

      /* Calculate box size in longitude... */
      int sx =
        (int) (3. * DX2DEG(sigma, met->lat[iy]) /
               fabs(met->lon[1] - met->lon[0]));
      sx = GSL_MIN(GSL_MAX(1, sx), met->nx / 2);

      /* Init... */
      float wsum = 0;
      for (int ip = 0; ip < met->np; ip++) {
        help->t[ix][iy][ip] = 0;
        help->u[ix][iy][ip] = 0;
        help->v[ix][iy][ip] = 0;
        help->w[ix][iy][ip] = 0;
      }

      /* Loop over neighboring grid points... */
      for (int ix2 = ix - sx; ix2 <= ix + sx; ix2++) {
        int ix3 = ix2;
        if (ix3 < 0)
          ix3 += met->nx;
        else if (ix3 >= met->nx)
          ix3 -= met->nx;
        for (int iy2 = GSL_MAX(iy - sy, 0);
             iy2 <= GSL_MIN(iy + sy, met->ny - 1); iy2++) {

          /* Calculate Cartesian coordinates... */
          double x1[3];
          geo2cart(0.0, met->lon[ix3], met->lat[iy2], x1);

          /* Calculate weighting factor... */
          float w = (float) exp(-DIST2(x0, x1) / tssq);

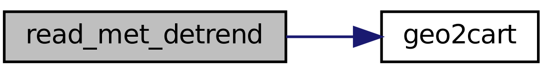
          /* Add data... */
          wsum += w;
          for (int ip = 0; ip < met->np; ip++) {
            help->t[ix][iy][ip] += w * met->t[ix3][iy2][ip];
            help->u[ix][iy][ip] += w * met->u[ix3][iy2][ip];
            help->v[ix][iy][ip] += w * met->v[ix3][iy2][ip];
            help->w[ix][iy][ip] += w * met->w[ix3][iy2][ip];
          }
        }
      }

      /* Normalize... */
      for (int ip = 0; ip < met->np; ip++) {
        help->t[ix][iy][ip] /= wsum;
        help->u[ix][iy][ip] /= wsum;
        help->v[ix][iy][ip] /= wsum;
        help->w[ix][iy][ip] /= wsum;
      }
    }
  }

  /* Subtract background... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++)
      for (int ip = 0; ip < met->np; ip++) {
        met->t[ix][iy][ip] -= help->t[ix][iy][ip];
        met->u[ix][iy][ip] -= help->u[ix][iy][ip];
        met->v[ix][iy][ip] -= help->v[ix][iy][ip];
        met->w[ix][iy][ip] -= help->w[ix][iy][ip];
      }

  /* Free... */
  free(help);
}
```

Here is the call graph for this function:



5.21.2.26 read_met_extrapolate()

```
void read_met_extrapolate (
    met_t * met )
```

Extrapolate meteorological data at lower boundary.

Definition at line 2898 of file libtrac.c.

```
                {

  int ip, ip0, ix, iy;

  /* Set timer... */
  SELECT_TIMER("READ_MET_EXTRAPOLATE", NVTX_READ);

  /* Loop over columns... */
#pragma omp parallel for default(shared) private(ix,iy,ip0,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {

      /* Find lowest valid data point... */
      for (ip0 = met->np - 1; ip0 >= 0; ip0--)
        if (!isfinite(met->t[ix][iy][ip0])
            || !isfinite(met->u[ix][iy][ip0])
            || !isfinite(met->v[ix][iy][ip0])
            || !isfinite(met->w[ix][iy][ip0]))
          break;

      /* Extrapolate... */
      for (ip = ip0; ip >= 0; ip--) {
        met->t[ix][iy][ip] = met->t[ix][iy][ip + 1];
        met->u[ix][iy][ip] = met->u[ix][iy][ip + 1];
        met->v[ix][iy][ip] = met->v[ix][iy][ip + 1];
        met->w[ix][iy][ip] = met->w[ix][iy][ip + 1];
        met->h2o[ix][iy][ip] = met->h2o[ix][iy][ip + 1];
        met->o3[ix][iy][ip] = met->o3[ix][iy][ip + 1];
        met->lwc[ix][iy][ip] = met->lwc[ix][iy][ip + 1];
        met->iwc[ix][iy][ip] = met->iwc[ix][iy][ip + 1];
      }
    }
}
```

5.21.2.27 read_met_geopot()

```
void read_met_geopot (
    ctl_t * ctl,
    met_t * met )
```

Calculate geopotential heights.

Definition at line 2935 of file libtrac.c.

```
                {

  const int dx = ctl->met_geopot_sx, dy = ctl->met_geopot_sy;

  static float help[EX][EY][EP], w, wsum;

  double h2os, logp[EP], ts, z0;

  int ip, ip0, ix, ix2, ix3, iy, iy2;

  /* Set timer... */
  SELECT_TIMER("READ_MET_GEOPOT", NVTX_READ);

  /* Calculate log pressure... */
  for (ip = 0; ip < met->np; ip++)
    logp[ip] = log(met->p[ip]);

  /* Initialize geopotential heights... */
#pragma omp parallel for default(shared) private(ix,iy,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++)
        met->z[ix][iy][ip] = GSL_NAN;

```

```
  /* Apply hydrostatic equation to calculate geopotential heights... */
#pragma omp parallel for default(shared) private(ix,iy,z0,ip0,ts,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {

      /* Get surface height... */
      INTPOL_INIT;
      intpol_met_space_2d(met, met->zs, met->lon[ix], met->lat[iy], &z0, ci,
                          cw, 1);

      /* Find surface pressure level index... */
      ip0 = locate_irr(met->p, met->np, met->ps[ix][iy]);

      /* Get temperature and water vapor vmr at the surface... */
      ts =
        LIN(met->p[ip0], met->t[ix][iy][ip0], met->p[ip0 + 1],
            met->t[ix][iy][ip0 + 1], met->ps[ix][iy]);
      h2os =
        LIN(met->p[ip0], met->h2o[ix][iy][ip0], met->p[ip0 + 1],
            met->h2o[ix][iy][ip0 + 1], met->ps[ix][iy]);

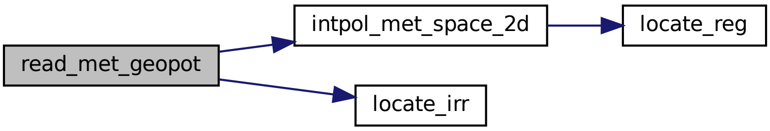
      /* Upper part of profile... */
      met->z[ix][iy][ip0 + 1]
        = (float) (z0 +
                   ZDIFF(log(met->ps[ix][iy]), ts, h2os, logp[ip0 + 1],
                         met->t[ix][iy][ip0 + 1], met->h2o[ix][iy][ip0 + 1]));
      for (ip = ip0 + 2; ip < met->np; ip++)
        met->z[ix][iy][ip]
          = (float) (met->z[ix][iy][ip - 1] +
                     ZDIFF(logp[ip - 1], met->t[ix][iy][ip - 1],
                           met->h2o[ix][iy][ip - 1], logp[ip],
                           met->t[ix][iy][ip], met->h2o[ix][iy][ip]));

      /* Lower part of profile... */
      met->z[ix][iy][ip0]
        = (float) (z0 +
                   ZDIFF(log(met->ps[ix][iy]), ts, h2os, logp[ip0],
                         met->t[ix][iy][ip0], met->h2o[ix][iy][ip0]));
      for (ip = ip0 - 1; ip >= 0; ip--)
        met->z[ix][iy][ip]
          = (float) (met->z[ix][iy][ip + 1] +
                     ZDIFF(logp[ip + 1], met->t[ix][iy][ip + 1],
                           met->h2o[ix][iy][ip + 1], logp[ip],
                           met->t[ix][iy][ip], met->h2o[ix][iy][ip]));
    }

  /* Horizontal smoothing... */
#pragma omp parallel for default(shared) private(ix,iy,ip,ix2,ix3,iy2,w,wsum)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++) {
        wsum = 0;
        help[ix][iy][ip] = 0;
        for (ix2 = ix - dx + 1; ix2 <= ix + dx - 1; ix2++) {
          ix3 = ix2;
          if (ix3 < 0)
            ix3 += met->nx;
          else if (ix3 >= met->nx)
            ix3 -= met->nx;
          for (iy2 = GSL_MAX(iy - dy + 1, 0);
               iy2 <= GSL_MIN(iy + dy - 1, met->ny - 1); iy2++)
            if (isfinite(met->z[ix3][iy2][ip])) {
              w = (1.0f - (float) abs(ix - ix2) / (float) dx)
                * (1.0f - (float) abs(iy - iy2) / (float) dy);
              help[ix][iy][ip] += w * met->z[ix3][iy2][ip];
              wsum += w;
            }
        }
        if (wsum > 0)
          help[ix][iy][ip] /= wsum;
        else
          help[ix][iy][ip] = GSL_NAN;
      }

  /* Copy data... */
#pragma omp parallel for default(shared) private(ix,iy,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++)
        met->z[ix][iy][ip] = help[ix][iy][ip];
}
```

Here is the call graph for this function:



5.21.2.28 read_met_grid()

```
void read_met_grid (
    char * filename,
    int ncid,
    ctl_t * ctl,
    met_t * met )
```

Read coordinates of meteorological data.

Definition at line 3045 of file libtrac.c.

```
                   {

  char levname[LEN], tstr[10];

  int dimid, ip, varid, year, mon, day, hour;

  size_t np, nx, ny;

  /* Set timer... */
  SELECT_TIMER("READ_MET_GRID", NVTX_READ);

  /* Get time from filename... */
  sprintf(tstr, "%.4s", &filename[strlen(filename) - 16]);
  year = atoi(tstr);
  sprintf(tstr, "%.2s", &filename[strlen(filename) - 11]);
  mon = atoi(tstr);
  sprintf(tstr, "%.2s", &filename[strlen(filename) - 8]);
  day = atoi(tstr);
  sprintf(tstr, "%.2s", &filename[strlen(filename) - 5]);
  hour = atoi(tstr);
  time2jsec(year, mon, day, hour, 0, 0, 0, &met->time);

  /* Get grid dimensions... */
  NC(nc_inq_dimid(ncid, "lon", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &nx));
  if (nx < 2 || nx > EX)
    ERRMSG("Number of longitudes out of range!");

  NC(nc_inq_dimid(ncid, "lat", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &ny));
  if (ny < 2 || ny > EY)
    ERRMSG("Number of latitudes out of range!");

  sprintf(levname, "lev");
  NC(nc_inq_dimid(ncid, levname, &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &np));
  if (np == 1) {
    sprintf(levname, "lev_2");
    if (nc_inq_dimid(ncid, levname, &dimid) != NC_NOERR) {
      sprintf(levname, "plev");
      nc_inq_dimid(ncid, levname, &dimid);
    }
    NC(nc_inq_dimlen(ncid, dimid, &np));
  }
  if (np < 2 || np > EP)
    ERRMSG("Number of levels out of range!");

  /* Store dimensions... */
```

```
  met->np = (int) np;
  met->nx = (int) nx;
  met->ny = (int) ny;

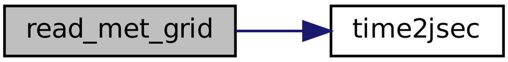
  /* Read longitudes and latitudes... */
  NC(nc_inq_varid(ncid, "lon", &varid));
  NC(nc_get_var_double(ncid, varid, met->lon));
  NC(nc_inq_varid(ncid, "lat", &varid));
  NC(nc_get_var_double(ncid, varid, met->lat));

  /* Read pressure levels... */
  if (ctl->met_np <= 0) {
    NC(nc_inq_varid(ncid, levname, &varid));
    NC(nc_get_var_double(ncid, varid, met->p));
    for (ip = 0; ip < met->np; ip++)
      met->p[ip] /= 100.;
  }

  /* Set pressure levels... */
  else {
    met->np = ctl->met_np;
    for (ip = 0; ip < met->np; ip++)
      met->p[ip] = ctl->met_p[ip];
  }

  /* Check ordering of pressure levels... */
  for (ip = 1; ip < met->np; ip++)
    if (met->p[ip - 1] < met->p[ip])
      ERRMSG("Pressure levels must be descending!");
}
```

Here is the call graph for this function:



5.21.2.29 read_met_help_3d()

```
int read_met_help_3d (
            int ncid,
            char * varname,
            char * varname2,
            met_t * met,
            float dest[EX][EY][EP],
            float scl )
```

Read and convert 3D variable from meteorological data file.

Definition at line 3130 of file libtrac.c.

```
                {

  float *help;

  int ip, ix, iy, varid;

  /* Check if variable exists... */
  if (nc_inq_varid(ncid, varname, &varid) != NC_NOERR)
    if (nc_inq_varid(ncid, varname2, &varid) != NC_NOERR)
      return 0;

  /* Allocate... */
  ALLOC(help, float,
        EX * EY * EP);

```

```
  /* Read data... */
  NC(nc_get_var_float(ncid, varid, help));

  /* Copy and check data... */
#pragma omp parallel for default(shared) private(ix,iy,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++) {
        dest[ix][iy][ip] = help[(ip * met->ny + iy) * met->nx + ix];
        if (fabsf(dest[ix][iy][ip]) < 1e14f)
          dest[ix][iy][ip] *= scl;
        else
          dest[ix][iy][ip] = GSL_NAN;
      }

  /* Free... */
  free(help);

  /* Return... */
  return 1;
}
```

5.21.2.30 read_met_help_2d()

```
int read_met_help_2d (
    int ncid,
    char * varname,
    char * varname2,
    met_t * met,
    float dest[EX][EY],
    float scl )
```

Read and convert 2D variable from meteorological data file.

Definition at line 3175 of file libtrac.c.

```
                {

  float *help;

  int ix, iy, varid;

  /* Check if variable exists... */
  if (nc_inq_varid(ncid, varname, &varid) != NC_NOERR)
    if (nc_inq_varid(ncid, varname2, &varid) != NC_NOERR)
      return 0;

  /* Allocate... */
  ALLOC(help, float,
        EX * EY);

  /* Read data... */
  NC(nc_get_var_float(ncid, varid, help));

  /* Copy and check data... */
#pragma omp parallel for default(shared) private(ix,iy)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {
      dest[ix][iy] = help[iy * met->nx + ix];
      if (fabsf(dest[ix][iy]) < 1e14f)
        dest[ix][iy] *= scl;
      else
        dest[ix][iy] = GSL_NAN;
    }

  /* Free... */
  free(help);

  /* Return... */
  return 1;
}
```

5.21.2.31 read_met_levels() void read_met_levels (

int *ncid*,
ctl_t * *ctl*,
met_t * *met*)

Definition at line 3219 of file libtrac.c.

```
                  {

  /* Set timer... */
  SELECT_TIMER("READ_MET_LEVELS", NVTX_READ);

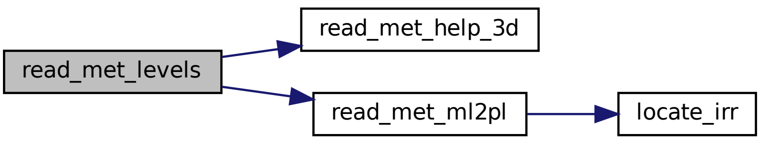
  /* Read meteorological data... */
  if (!read_met_help_3d(ncid, "t", "T", met, met->t, 1.0))
    ERRMSG("Cannot read temperature!");
  if (!read_met_help_3d(ncid, "u", "U", met, met->u, 1.0))
    ERRMSG("Cannot read zonal wind!");
  if (!read_met_help_3d(ncid, "v", "V", met, met->v, 1.0))
    ERRMSG("Cannot read meridional wind!");
  if (!read_met_help_3d(ncid, "w", "W", met, met->w, 0.01f))
    WARN("Cannot read vertical velocity");
  if (!read_met_help_3d(ncid, "q", "Q", met, met->h2o, (float) (MA / MH2O)))
    WARN("Cannot read specific humidity!");
  if (!read_met_help_3d(ncid, "o3", "O3", met, met->o3, (float) (MA / MO3)))
    WARN("Cannot read ozone data!");
  if (!read_met_help_3d(ncid, "clwc", "CLWC", met, met->lwc, 1.0))
    WARN("Cannot read cloud liquid water content!");
  if (!read_met_help_3d(ncid, "ciwc", "CIWC", met, met->iwc, 1.0))
    WARN("Cannot read cloud ice water content!");

  /* Transfer from model levels to pressure levels... */
  if (ctl->met_np > 0) {

    /* Read pressure on model levels... */
    if (!read_met_help_3d(ncid, "pl", "PL", met, met->pl, 0.01f))
      ERRMSG("Cannot read pressure on model levels!");

    /* Vertical interpolation from model to pressure levels... */
    read_met_ml2pl(ctl, met, met->t);
    read_met_ml2pl(ctl, met, met->u);
    read_met_ml2pl(ctl, met, met->v);
    read_met_ml2pl(ctl, met, met->w);
    read_met_ml2pl(ctl, met, met->h2o);
    read_met_ml2pl(ctl, met, met->o3);
    read_met_ml2pl(ctl, met, met->lwc);
    read_met_ml2pl(ctl, met, met->iwc);
  }
}
```

Here is the call graph for this function:



5.21.2.32 read_met_ml2pl() void read_met_ml2pl (

ctl_t * *ctl*,
met_t * *met*,
float *var[EX][EY][EP]*)

Convert meteorological data from model levels to pressure levels.

Definition at line 3266 of file libtrac.c.

```
                          {

  double aux[EP], p[EP], pt;

  int ip, ip2, ix, iy;

  /* Set timer... */
  SELECT_TIMER("READ_MET_ML2PL", NVTX_READ);

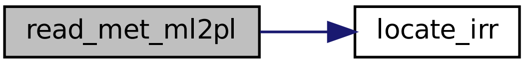
  /* Loop over columns... */
#pragma omp parallel for default(shared) private(ix,iy,ip,p,pt,ip2,aux)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {

      /* Copy pressure profile... */
      for (ip = 0; ip < met->np; ip++)
        p[ip] = met->pl[ix][iy][ip];

      /* Interpolate... */
      for (ip = 0; ip < ctl->met_np; ip++) {
        pt = ctl->met_p[ip];
        if ((pt > p[0] && p[0] > p[1]) || (pt < p[0] && p[0] < p[1]))
          pt = p[0];
        else if ((pt > p[met->np - 1] && p[1] > p[0])
                 || (pt < p[met->np - 1] && p[1] < p[0]))
          pt = p[met->np - 1];
        ip2 = locate_irr(p, met->np, pt);
        aux[ip] = LIN(p[ip2], var[ix][iy][ip2],
                      p[ip2 + 1], var[ix][iy][ip2 + 1], pt);
      }

      /* Copy data... */
      for (ip = 0; ip < ctl->met_np; ip++)
        var[ix][iy][ip] = (float) aux[ip];
    }
}
```

Here is the call graph for this function:



5.21.2.33 read_met_periodic()

```
void read_met_periodic (
        met_t * met )
```

Create meteorological data with periodic boundary conditions.

Definition at line 3308 of file libtrac.c.

```
              {

  /* Set timer... */
  SELECT_TIMER("READ_MET_PERIODIC", NVTX_READ);

  /* Check longitudes... */
  if (!(fabs(met->lon[met->nx - 1] - met->lon[0]
             + met->lon[1] - met->lon[0] - 360) < 0.01))
    return;

  /* Increase longitude counter... */
  if ((++met->nx) > EX)
    ERRMSG("Cannot create periodic boundary conditions!");

  /* Set longitude... */
```

```
  met->lon[met->nx - 1] = met->lon[met->nx - 2] + met->lon[1] - met->lon[0];

  /* Loop over latitudes and pressure levels... */
#pragma omp parallel for default(shared)
  for (int iy = 0; iy < met->ny; iy++) {
    met->ps[met->nx - 1][iy] = met->ps[0][iy];
    met->zs[met->nx - 1][iy] = met->zs[0][iy];
    for (int ip = 0; ip < met->np; ip++) {
      met->t[met->nx - 1][iy][ip] = met->t[0][iy][ip];
      met->u[met->nx - 1][iy][ip] = met->u[0][iy][ip];
      met->v[met->nx - 1][iy][ip] = met->v[0][iy][ip];
      met->w[met->nx - 1][iy][ip] = met->w[0][iy][ip];
      met->h2o[met->nx - 1][iy][ip] = met->h2o[0][iy][ip];
      met->o3[met->nx - 1][iy][ip] = met->o3[0][iy][ip];
      met->lwc[met->nx - 1][iy][ip] = met->lwc[0][iy][ip];
      met->iwc[met->nx - 1][iy][ip] = met->iwc[0][iy][ip];
    }
  }
}
```

5.21.2.34 read_met_pv() `void read_met_pv ( met_t * met )`

Calculate potential vorticity.

Definition at line 3346 of file libtrac.c.

```
                {

  double c0, c1, cr, dx, dy, dp0, dp1, denom, dtdx, dvdx, dtdy, dudy,
    dtdp, dudp, dvdp, latr, vort, pows[EP];

  int ip, ip0, ip1, ix, ix0, ix1, iy, iy0, iy1;

  /* Set timer... */
  SELECT_TIMER("READ_MET_PV", NVTX_READ);

  /* Set powers... */
  for (ip = 0; ip < met->np; ip++)
    pows[ip] = pow(1000. / met->p[ip], 0.286);

  /* Loop over grid points... */
#pragma omp parallel for default(shared)
 private(ix,ix0,ix1,iy,iy0,iy1,latr,dx,dy,c0,c1,cr,vort,ip,ip0,ip1,dp0,dp1,denom,dtdx,dvdx,dtdy,dudy,dtdp,dudp,dvdp)
  for (ix = 0; ix < met->nx; ix++) {

    /* Set indices... */
    ix0 = GSL_MAX(ix - 1, 0);
    ix1 = GSL_MIN(ix + 1, met->nx - 1);

    /* Loop over grid points... */
    for (iy = 0; iy < met->ny; iy++) {

      /* Set indices... */
      iy0 = GSL_MAX(iy - 1, 0);
      iy1 = GSL_MIN(iy + 1, met->ny - 1);

      /* Set auxiliary variables... */
      latr = 0.5 * (met->lat[iy1] + met->lat[iy0]);
      dx = 1000. * DEG2DX(met->lon[ix1] - met->lon[ix0], latr);
      dy = 1000. * DEG2DY(met->lat[iy1] - met->lat[iy0]);
      c0 = cos(met->lat[iy0] / 180. * M_PI);
      c1 = cos(met->lat[iy1] / 180. * M_PI);
      cr = cos(latr / 180. * M_PI);
      vort = 2 * 7.2921e-5 * sin(latr * M_PI / 180.);

      /* Loop over grid points... */
      for (ip = 0; ip < met->np; ip++) {

        /* Get gradients in longitude... */
        dtdx = (met->t[ix1][iy][ip] - met->t[ix0][iy][ip]) * pows[ip] / dx;
        dvdx = (met->v[ix1][iy][ip] - met->v[ix0][iy][ip]) / dx;

        /* Get gradients in latitude... */
        dtdy = (met->t[ix][iy1][ip] - met->t[ix][iy0][ip]) * pows[ip] / dy;
        dudy = (met->u[ix][iy1][ip] * c1 - met->u[ix][iy0][ip] * c0) / dy;

        /* Set indices... */
        ip0 = GSL_MAX(ip - 1, 0);
        ip1 = GSL_MIN(ip + 1, met->np - 1);
```

```
          /* Get gradients in pressure... */
          dp0 = 100. * (met->p[ip] - met->p[ip0]);
          dp1 = 100. * (met->p[ip1] - met->p[ip]);
          if (ip != ip0 && ip != ip1) {
            denom = dp0 * dp1 * (dp0 + dp1);
            dtdp = (dp0 * dp0 * met->t[ix][iy][ip1] * pows[ip1]
                    - dp1 * dp1 * met->t[ix][iy][ip0] * pows[ip0]
                    + (dp1 * dp1 - dp0 * dp0) * met->t[ix][iy][ip] * pows[ip])
              / denom;
            dudp = (dp0 * dp0 * met->u[ix][iy][ip1]
                    - dp1 * dp1 * met->u[ix][iy][ip0]
                    + (dp1 * dp1 - dp0 * dp0) * met->u[ix][iy][ip])
              / denom;
            dvdp = (dp0 * dp0 * met->v[ix][iy][ip1]
                    - dp1 * dp1 * met->v[ix][iy][ip0]
                    + (dp1 * dp1 - dp0 * dp0) * met->v[ix][iy][ip])
              / denom;
          } else {
            denom = dp0 + dp1;
            dtdp =
              (met->t[ix][iy][ip1] * pows[ip1] -
               met->t[ix][iy][ip0] * pows[ip0]) / denom;
            dudp = (met->u[ix][iy][ip1] - met->u[ix][iy][ip0]) / denom;
            dvdp = (met->v[ix][iy][ip1] - met->v[ix][iy][ip0]) / denom;
          }

          /* Calculate PV... */
          met->pv[ix][iy][ip] = (float)
            (1e6 * G0 *
             (-dtdp * (dvdx - dudy / cr + vort) + dvdp * dtdx - dudp * dtdy));
        }
      }
    }

    /* Fix for polar regions... */
#pragma omp parallel for default(shared) private(ix,ip)
    for (ix = 0; ix < met->nx; ix++)
      for (ip = 0; ip < met->np; ip++) {
        met->pv[ix][0][ip]
          = met->pv[ix][1][ip]
          = met->pv[ix][2][ip];
        met->pv[ix][met->ny - 1][ip]
          = met->pv[ix][met->ny - 2][ip]
          = met->pv[ix][met->ny - 3][ip];
      }
}
```

5.21.2.35 read_met_sample()

```
void read_met_sample (
        ctl_t * ctl,
        met_t * met )
```

Downsampling of meteorological data.

Definition at line 3449 of file libtrac.c.

```
                    {

  met_t *help;

  float w, wsum;

  int ip, ip2, ix, ix2, ix3, iy, iy2;

  /* Check parameters... */
  if (ctl->met_dp <= 1 && ctl->met_dx <= 1 && ctl->met_dy <= 1
      && ctl->met_sp <= 1 && ctl->met_sx <= 1 && ctl->met_sy <= 1)
    return;

  /* Set timer... */
  SELECT_TIMER("READ_MET_SAMPLE", NVTX_READ);

  /* Allocate... */
  ALLOC(help, met_t, 1);

  /* Copy data... */
  help->nx = met->nx;
  help->ny = met->ny;
  help->np = met->np;
```

```
memcpy(help->lon, met->lon, sizeof(met->lon));
memcpy(help->lat, met->lat, sizeof(met->lat));
memcpy(help->p, met->p, sizeof(met->p));

/* Smoothing... */
for (ix = 0; ix < met->nx; ix += ctl->met_dx) {
  for (iy = 0; iy < met->ny; iy += ctl->met_dy) {
    for (ip = 0; ip < met->np; ip += ctl->met_dp) {
      help->ps[ix][iy] = 0;
      help->zs[ix][iy] = 0;
      help->t[ix][iy][ip] = 0;
      help->u[ix][iy][ip] = 0;
      help->v[ix][iy][ip] = 0;
      help->w[ix][iy][ip] = 0;
      help->h2o[ix][iy][ip] = 0;
      help->o3[ix][iy][ip] = 0;
      help->lwc[ix][iy][ip] = 0;
      help->iwc[ix][iy][ip] = 0;
      wsum = 0;
      for (ix2 = ix - ctl->met_sx + 1; ix2 <= ix + ctl->met_sx - 1; ix2++) {
        ix3 = ix2;
        if (ix3 < 0)
          ix3 += met->nx;
        else if (ix3 >= met->nx)
          ix3 -= met->nx;

        for (iy2 = GSL_MAX(iy - ctl->met_sy + 1, 0);
             iy2 <= GSL_MIN(iy + ctl->met_sy - 1, met->ny - 1); iy2++)
          for (ip2 = GSL_MAX(ip - ctl->met_sp + 1, 0);
               ip2 <= GSL_MIN(ip + ctl->met_sp - 1, met->np - 1); ip2++) {
            w = (1.0f - (float) abs(ix - ix2) / (float) ctl->met_sx)
              * (1.0f - (float) abs(iy - iy2) / (float) ctl->met_sy)
              * (1.0f - (float) abs(ip - ip2) / (float) ctl->met_sp);
            help->ps[ix][iy] += w * met->ps[ix3][iy2];
            help->zs[ix][iy] += w * met->zs[ix3][iy2];
            help->t[ix][iy][ip] += w * met->t[ix3][iy2][ip2];
            help->u[ix][iy][ip] += w * met->u[ix3][iy2][ip2];
            help->v[ix][iy][ip] += w * met->v[ix3][iy2][ip2];
            help->w[ix][iy][ip] += w * met->w[ix3][iy2][ip2];
            help->h2o[ix][iy][ip] += w * met->h2o[ix3][iy2][ip2];
            help->o3[ix][iy][ip] += w * met->o3[ix3][iy2][ip2];
            help->lwc[ix][iy][ip] += w * met->lwc[ix3][iy2][ip2];
            help->iwc[ix][iy][ip] += w * met->iwc[ix3][iy2][ip2];
            wsum += w;
          }
      }
      help->ps[ix][iy] /= wsum;
      help->zs[ix][iy] /= wsum;
      help->t[ix][iy][ip] /= wsum;
      help->u[ix][iy][ip] /= wsum;
      help->v[ix][iy][ip] /= wsum;
      help->w[ix][iy][ip] /= wsum;
      help->h2o[ix][iy][ip] /= wsum;
      help->o3[ix][iy][ip] /= wsum;
      help->lwc[ix][iy][ip] /= wsum;
      help->iwc[ix][iy][ip] /= wsum;
    }
  }
}

/* Downsampling... */
met->nx = 0;
for (ix = 0; ix < help->nx; ix += ctl->met_dx) {
  met->lon[met->nx] = help->lon[ix];
  met->ny = 0;
  for (iy = 0; iy < help->ny; iy += ctl->met_dy) {
    met->lat[met->ny] = help->lat[iy];
    met->ps[met->nx][met->ny] = help->ps[ix][iy];
    met->zs[met->nx][met->ny] = help->zs[ix][iy];
    met->np = 0;
    for (ip = 0; ip < help->np; ip += ctl->met_dp) {
      met->p[met->np] = help->p[ip];
      met->t[met->nx][met->ny][met->np] = help->t[ix][iy][ip];
      met->u[met->nx][met->ny][met->np] = help->u[ix][iy][ip];
      met->v[met->nx][met->ny][met->np] = help->v[ix][iy][ip];
      met->w[met->nx][met->ny][met->np] = help->w[ix][iy][ip];
      met->h2o[met->nx][met->ny][met->np] = help->h2o[ix][iy][ip];
      met->o3[met->nx][met->ny][met->np] = help->o3[ix][iy][ip];
      met->lwc[met->nx][met->ny][met->np] = help->lwc[ix][iy][ip];
      met->iwc[met->nx][met->ny][met->np] = help->iwc[ix][iy][ip];
      met->np++;
    }
    met->ny++;
  }
  met->nx++;
}
```

```
  /* Free... */
  free(help);
}
```

5.21.2.36 read_met_surface() void read_met_surface (int ncid, met_t * met)

Read surface data.

Definition at line 3567 of file libtrac.c.

```
                {

  int ix, iy;

  /* Set timer... */
  SELECT_TIMER("READ_MET_SURFACE", NVTX_READ);

  /* Read surface pressure... */
  if (!read_met_help_2d(ncid, "ps", "PS", met, met->ps, 0.01f)) {
    if (!read_met_help_2d(ncid, "lnsp", "LNSP", met, met->ps, 1.0)) {
      ERRMSG("Cannot not read surface pressure data!");
      for (ix = 0; ix < met->nx; ix++)
        for (iy = 0; iy < met->ny; iy++)
          met->ps[ix][iy] = (float) met->p[0];
    } else {
      for (iy = 0; iy < met->ny; iy++)
        for (ix = 0; ix < met->nx; ix++)
          met->ps[ix][iy] = (float) (exp(met->ps[ix][iy]) / 100.);
    }
  }

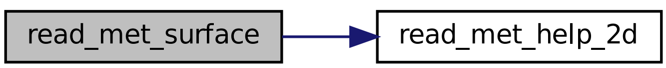
  /* Read geopotential height at the surface... */
  if (!read_met_help_2d
      (ncid, "z", "Z", met, met->zs, (float) (1. / (1000. * G0))))
    if (!read_met_help_2d
        (ncid, "zm", "ZM", met, met->zs, (float) (1. / 1000.)))
      ERRMSG("Cannot read surface geopotential height!");

  /* Read temperature at the surface... */
  if (!read_met_help_2d(ncid, "t2m", "T2M", met, met->ts, 1.0))
    WARN("Cannot read surface temperature!");

  /* Read zonal wind at the surface... */
  if (!read_met_help_2d(ncid, "u10m", "U10M", met, met->us, 1.0))
    WARN("Cannot read surface zonal wind!");

  /* Read meridional wind at the surface... */
  if (!read_met_help_2d(ncid, "v10m", "V10M", met, met->vs, 1.0))
    WARN("Cannot read surface meridional wind!");
}
```

Here is the call graph for this function:



5.21.2.37 read_met_tropo() void read_met_tropo (

ctl_t * ctl,

met_t * met)

Calculate tropopause data.

Definition at line 3612 of file libtrac.c.

```
                  {

  double h2ot, p2[200], pv[EP], pv2[200], t[EP], t2[200], th[EP],
    th2[200], tt, z[EP], z2[200], zt;

  int found, ix, iy, iz, iz2;

  /* Set timer... */
  SELECT_TIMER("READ_MET_TROPO", NVTX_READ);

  /* Get altitude and pressure profiles... */
  for (iz = 0; iz < met->np; iz++)
    z[iz] = Z(met->p[iz]);
  for (iz = 0; iz <= 190; iz++) {
    z2[iz] = 4.5 + 0.1 * iz;
    p2[iz] = P(z2[iz]);
  }

  /* Do not calculate tropopause... */
  if (ctl->met_tropo == 0)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        met->pt[ix][iy] = GSL_NAN;

  /* Use tropopause climatology... */
  else if (ctl->met_tropo == 1) {
#pragma omp parallel for default(shared) private(ix,iy)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        met->pt[ix][iy] = (float) clim_tropo(met->time, met->lat[iy]);
  }

  /* Use cold point... */
  else if (ctl->met_tropo == 2) {

    /* Loop over grid points... */
#pragma omp parallel for default(shared) private(ix,iy,iz,t,t2)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {

        /* Interpolate temperature profile... */
        for (iz = 0; iz < met->np; iz++)
          t[iz] = met->t[ix][iy][iz];
        spline(z, t, met->np, z2, t2, 171);

        /* Find minimum... */
        iz = (int) gsl_stats_min_index(t2, 1, 171);
        if (iz > 0 && iz < 170)
          met->pt[ix][iy] = (float) p2[iz];
        else
          met->pt[ix][iy] = GSL_NAN;
      }
  }

  /* Use WMO definition... */
  else if (ctl->met_tropo == 3 || ctl->met_tropo == 4) {

    /* Loop over grid points... */
#pragma omp parallel for default(shared) private(ix,iy,iz,iz2,t,t2,found)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {

        /* Interpolate temperature profile... */
        for (iz = 0; iz < met->np; iz++)
          t[iz] = met->t[ix][iy][iz];
        spline(z, t, met->np, z2, t2, 191);

        /* Find 1st tropopause... */
        met->pt[ix][iy] = GSL_NAN;
        for (iz = 0; iz <= 170; iz++) {
          found = 1;
          for (iz2 = iz + 1; iz2 <= iz + 20; iz2++)
            if (LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]) > 2.0) {
              found = 0;
              break;
            }
          if (found) {
```

```
            if (iz > 0 && iz < 170)
              met->pt[ix][iy] = (float) p2[iz];
            break;
          }
        }

        /* Find 2nd tropopause... */
        if (ctl->met_tropo == 4) {
          met->pt[ix][iy] = GSL_NAN;
          for (; iz <= 170; iz++) {
            found = 1;
            for (iz2 = iz + 1; iz2 <= iz + 10; iz2++)
              if (LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]) < 3.0) {
                found = 0;
                break;
              }
            if (found)
              break;
          }
          for (; iz <= 170; iz++) {
            found = 1;
            for (iz2 = iz + 1; iz2 <= iz + 20; iz2++)
              if (LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]) > 2.0) {
                found = 0;
                break;
              }
            if (found) {
              if (iz > 0 && iz < 170)
                met->pt[ix][iy] = (float) p2[iz];
              break;
            }
          }
        }
      }
  }

  /* Use dynamical tropopause... */
  else if (ctl->met_tropo == 5) {

    /* Loop over grid points... */
#pragma omp parallel for default(shared) private(ix,iy,iz,pv,pv2,th,th2)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {

        /* Interpolate potential vorticity profile... */
        for (iz = 0; iz < met->np; iz++)
          pv[iz] = met->pv[ix][iy][iz];
        spline(z, pv, met->np, z2, pv2, 171);

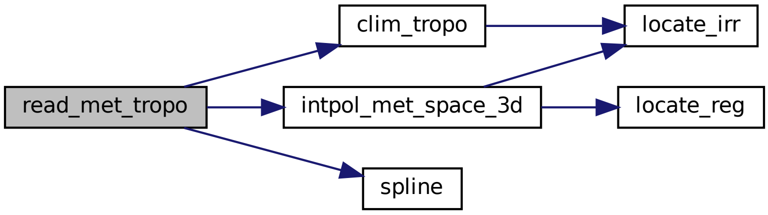
        /* Interpolate potential temperature profile... */
        for (iz = 0; iz < met->np; iz++)
          th[iz] = THETA(met->p[iz], met->t[ix][iy][iz]);
        spline(z, th, met->np, z2, th2, 171);

        /* Find dynamical tropopause 3.5 PVU + 380 K */
        met->pt[ix][iy] = GSL_NAN;
        for (iz = 0; iz <= 170; iz++)
          if (fabs(pv2[iz]) >= 3.5 || th2[iz] >= 380.) {
            if (iz > 0 && iz < 170)
              met->pt[ix][iy] = (float) p2[iz];
            break;
          }
      }
  }

  else
    ERRMSG("Cannot calculate tropopause!");

  /* Interpolate temperature, geopotential height, and water vapor vmr... */
#pragma omp parallel for default(shared) private(ix,iy,tt,zt,h2ot)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {
      INTPOL_INIT;
      intpol_met_space_3d(met, met->t, met->pt[ix][iy], met->lon[ix],
                          met->lat[iy], &tt, ci, cw, 1);
      intpol_met_space_3d(met, met->z, met->pt[ix][iy], met->lon[ix],
                          met->lat[iy], &zt, ci, cw, 0);
      intpol_met_space_3d(met, met->h2o, met->pt[ix][iy], met->lon[ix],
                          met->lat[iy], &h2ot, ci, cw, 0);
      met->tt[ix][iy] = (float) tt;
      met->zt[ix][iy] = (float) zt;
      met->h2ot[ix][iy] = (float) h2ot;
    }
}
```

Here is the call graph for this function:



5.21.2.38 scan_ctl()

```
double scan_ctl (
        const char * filename,
        int argc,
        char * argv[ ],
        const char * varname,
        int arridx,
        const char * defvalue,
        char * value )
```

Read a control parameter from file or command line.

Definition at line 3778 of file libtrac.c.

```
                  {

  FILE *in = NULL;

  char dummy[LEN], fullname1[LEN], fullname2[LEN], line[LEN],
    msg[2 * LEN], rvarname[LEN], rval[LEN];

  int contain = 0, i;

  /* Open file... */
  if (filename[strlen(filename) - 1] != '-')
    if (!(in = fopen(filename, "r")))
      ERRMSG("Cannot open file!");

  /* Set full variable name... */
  if (arridx >= 0) {
    sprintf(fullname1, "%s[%d]", varname, arridx);
    sprintf(fullname2, "%s[*]", varname);
  } else {
    sprintf(fullname1, "%s", varname);
    sprintf(fullname2, "%s", varname);
  }

  /* Read data... */
  if (in != NULL)
    while (fgets(line, LEN, in))
      if (sscanf(line, "%s %s %s", rvarname, dummy, rval) == 3)
        if (strcasecmp(rvarname, fullname1) == 0 ||
            strcasecmp(rvarname, fullname2) == 0) {
          contain = 1;
          break;
        }
  for (i = 1; i < argc - 1; i++)
    if (strcasecmp(argv[i], fullname1) == 0 ||
        strcasecmp(argv[i], fullname2) == 0) {
      sprintf(rval, "%s", argv[i + 1]);
      contain = 1;
      break;
    }

```

```
  /* Close file... */
  if (in != NULL)
    fclose(in);

  /* Check for missing variables... */
  if (!contain) {
    if (strlen(defvalue) > 0)
      sprintf(rval, "%s", defvalue);
    else {
      sprintf(msg, "Missing variable %s!\n", fullname1);
      ERRMSG(msg);
    }
  }

  /* Write info... */
  printf("%s = %s\n", fullname1, rval);

  /* Return values... */
  if (value != NULL)
    sprintf(value, "%s", rval);
  return atof(rval);
}
```

5.21.2.39 sedi()

```
double sedi (
    double p,
    double T,
    double r_p,
    double rho_p )
```

Calculate sedimentation velocity.

Definition at line 3850 of file libtrac.c.

```
                 {

  double eta, G, K, lambda, rho, v;

  /* Convert units... */
  p *= 100.;                        /* from hPa to Pa */
  r_p *= 1e-6;                      /* from microns to m */

  /* Density of dry air... */
  rho = p / (RA * T);

  /* Dynamic viscosity of air... */
  eta = 1.8325e-5 * (416.16 / (T + 120.)) * pow(T / 296.16, 1.5);

  /* Thermal velocity of an air molecule... */
  v = sqrt(8. * KB * T / (M_PI * 4.8096e-26));

  /* Mean free path of an air molecule... */
  lambda = 2. * eta / (rho * v);

  /* Knudsen number for air... */
  K = lambda / r_p;

  /* Cunningham slip-flow correction... */
  G = 1. + K * (1.249 + 0.42 * exp(-0.87 / K));

  /* Sedimentation velocity... */
  return 2. * SQR(r_p) * (rho_p - rho) * G0 / (9. * eta) * G;
}
```

5.21.2.40 spline()

```
void spline (
    double * x,
    double * y,
    int n,
    double * x2,
    double * y2,
    int n2 )
```

Spline interpolation.

Definition at line 3886 of file libtrac.c.

```
            {

  gsl_interp_accel *acc;

  gsl_spline *s;

  /* Allocate... */
  acc = gsl_interp_accel_alloc();
  s = gsl_spline_alloc(gsl_interp_cspline, (size_t) n);

  /* Interpolate profile... */
  gsl_spline_init(s, x, y, (size_t) n);
  for (int i = 0; i < n2; i++)
    if (x2[i] <= x[0])
      y2[i] = y[0];
    else if (x2[i] >= x[n - 1])
      y2[i] = y[n - 1];
    else
      y2[i] = gsl_spline_eval(s, x2[i], acc);

  /* Free... */
  gsl_spline_free(s);
  gsl_interp_accel_free(acc);
}
```

5.21.2.41 stddev() `double stddev ( double * data, int n )`

Calculate standard deviation.

Definition at line 3919 of file libtrac.c.

```
           {

  if (n <= 0)
    return 0;

  double avg = 0, rms = 0;

  for (int i = 0; i < n; ++i)
    avg += data[i];
  avg /= n;

  for (int i = 0; i < n; ++i)
    rms += SQR(data[i] - avg);

  return sqrt(rms / (n - 1));
}
```

5.21.2.42 time2jsec() `void time2jsec ( int year, int mon, int day, int hour, int min, int sec, double remain, double * jsec )`

Convert date to seconds.

Definition at line 3940 of file libtrac.c.

```
                  {
```

```
  struct tm t0, t1;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  t1.tm_year = year - 1900;
  t1.tm_mon = mon - 1;
  t1.tm_mday = day;
  t1.tm_hour = hour;
  t1.tm_min = min;
  t1.tm_sec = sec;

  *jsec = (double) timegm(&t1) - (double) timegm(&t0) + remain;
}
```

5.21.2.43 timer()

```
void timer (
    const char * name,
    int output )
```

Measure wall-clock time.

Definition at line 3971 of file libtrac.c.

```
                   {

  static char namelist[NTIMER][100];

  static double runtime[NTIMER], t0, t1;

  static int it = -1, nt;

  /* Get time... */
  t1 = omp_get_wtime();

  /* Add elapsed timer to old timer... */
  if (it >= 0)
    runtime[it] += t1 - t0;

  /* Identify ID of new timer... */
  for (it = 0; it < nt; it++)
    if (strcasecmp(name, namelist[it]) == 0)
      break;

  /* Check whether this is a new timer... */
  if (it >= nt) {
    sprintf(namelist[it], "%s", name);
    if ((++nt) > NTIMER)
      ERRMSG("Too many timers!");
  }

  /* Save starting time... */
  t0 = t1;

  /* Report timers... */
  if (output) {
    for (int it2 = 0; it2 < nt; it2++)
      printf("TIMER_%s = %.3f s\n", namelist[it2], runtime[it2]);
    double total = 0.0;
    for (int it2 = 0; it2 < nt; it2++)
      total += runtime[it2];
    printf("TIMER_TOTAL = %.3f s\n", total);
  }
}
```

5.21.2.44 write_atm() void write_atm (

const char * *filename*,
ctl_t * *ctl*,
atm_t * *atm*,
double *t*)

Write atmospheric data.

Definition at line 4016 of file libtrac.c.

```
                 {

  FILE *in, *out;

  char line[LEN];

  double r, t0, t1;

  int ip, iq, year, mon, day, hour, min, sec;

  /* Set timer... */
  SELECT_TIMER("WRITE_ATM", NVTX_WRITE);

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Write info... */
  printf("Write atmospheric data: %s\n", filename);

  /* Write ASCII data... */
  if (ctl->atm_type == 0) {

    /* Check if gnuplot output is requested... */
    if (ctl->atm_gpfile[0] != '-') {

      /* Create gnuplot pipe... */
      if (!(out = popen("gnuplot", "w")))
        ERRMSG("Cannot create pipe to gnuplot!");

      /* Set plot filename... */
      fprintf(out, "set out \"%s.png\"\n", filename);

      /* Set time string... */
      jsec2time(t, &year, &mon, &day, &hour, &min, &sec, &r);
      fprintf(out, "timestr=\"%d-%02d-%02d, %02d:%02d UTC\"\n",
              year, mon, day, hour, min);

      /* Dump gnuplot file to pipe... */
      if (!(in = fopen(ctl->atm_gpfile, "r")))
        ERRMSG("Cannot open file!");
      while (fgets(line, LEN, in))
        fprintf(out, "%s", line);
      fclose(in);
    }

    else {

      /* Create file... */
      if (!(out = fopen(filename, "w")))
        ERRMSG("Cannot create file!");
    }

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
    for (iq = 0; iq < ctl->nq; iq++)
      fprintf(out, "# $%i = %s [%s]\n", iq + 5, ctl->qnt_name[iq],
              ctl->qnt_unit[iq]);
    fprintf(out, "\n");

    /* Write data... */
    for (ip = 0; ip < atm->np; ip += ctl->atm_stride) {

      /* Check time... */
      if (ctl->atm_filter && (atm->time[ip] < t0 || atm->time[ip] > t1))
        continue;

      /* Write output... */
      fprintf(out, "%.2f %g %g %g", atm->time[ip], Z(atm->p[ip]),
              atm->lon[ip], atm->lat[ip]);
      for (iq = 0; iq < ctl->nq; iq++) {
```

```
        fprintf(out, " ");
        fprintf(out, ctl->qnt_format[iq], atm->q[iq][ip]);
      }
      fprintf(out, "\n");
    }

    /* Close file... */
    fclose(out);
  }

  /* Write binary data... */
  else if (ctl->atm_type == 1) {

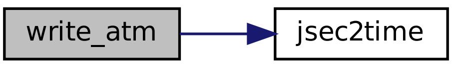
    /* Create file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write data... */
    FWRITE(&atm->np, int,
           1,
           out);
    FWRITE(atm->time, double,
             (size_t) atm->np,
           out);
    FWRITE(atm->p, double,
             (size_t) atm->np,
           out);
    FWRITE(atm->lon, double,
             (size_t) atm->np,
           out);
    FWRITE(atm->lat, double,
             (size_t) atm->np,
           out);
    for (iq = 0; iq < ctl->nq; iq++)
      FWRITE(atm->q[iq], double,
               (size_t) atm->np,
             out);

    /* Close file... */
    fclose(out);
  }

  /* Error... */
  else
    ERRMSG("Atmospheric data type not supported!");
}
```

Here is the call graph for this function:



5.21.2.45 write_csi()

```
void write_csi (
    const char * filename,
    ctl_t * ctl,
    atm_t * atm,
    double t )
```

Write CSI data.

Definition at line 4143 of file libtrac.c.

```
                {

```

```
  static FILE *in, *out;

  static char line[LEN];

  static double modmean[GX][GY][GZ], obsmean[GX][GY][GZ], rt, rt_old = -1e99,
    rz, rlon, rlat, robs, t0, t1, area[GY], dlon, dlat, dz, lat,
    x[1000000], y[1000000], work[2000000];

  static int obscount[GX][GY][GZ], ct, cx, cy, cz, ip, ix, iy, iz, n;

  /* Set timer... */
  SELECT_TIMER("WRITE_CSI", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Check quantity index for mass... */
    if (ctl->qnt_m < 0)
      ERRMSG("Need quantity mass!");

    /* Open observation data file... */
    printf("Read CSI observation data: %s\n", ctl->csi_obsfile);
    if (!(in = fopen(ctl->csi_obsfile, "r")))
      ERRMSG("Cannot open file!");

    /* Create new file... */
    printf("Write CSI data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = number of hits (cx)\n"
            "# $3 = number of misses (cy)\n"
            "# $4 = number of false alarms (cz)\n"
            "# $5 = number of observations (cx + cy)\n"
            "# $6 = number of forecasts (cx + cz)\n"
            "# $7 = bias (ratio of forecasts and observations) [%%]\n"
            "# $8 = probability of detection (POD) [%%]\n"
            "# $9 = false alarm rate (FAR) [%%]\n"
            "# $10 = critical success index (CSI) [%%]\n");
    fprintf(out,
            "# $11 = hits associated with random chance\n"
            "# $12 = equitable threat score (ETS) [%%]\n"
            "# $13 = Pearson linear correlation coefficient\n"
            "# $14 = Spearman rank-order correlation coefficient\n"
            "# $15 = column density mean error (F - O) [kg/m^2]\n"
            "# $16 = column density root mean square error (RMSE) [kg/m^2]\n"
            "# $17 = column density mean absolute error [kg/m^2]\n"
            "# $18 = number of data points\n\n");

    /* Set grid box size... */
    dz = (ctl->csi_z1 - ctl->csi_z0) / ctl->csi_nz;
    dlon = (ctl->csi_lon1 - ctl->csi_lon0) / ctl->csi_nx;
    dlat = (ctl->csi_lat1 - ctl->csi_lat0) / ctl->csi_ny;

    /* Set horizontal coordinates... */
    for (iy = 0; iy < ctl->csi_ny; iy++) {
      lat = ctl->csi_lat0 + dlat * (iy + 0.5);
      area[iy] = dlat * dlon * SQR(RE * M_PI / 180.) * cos(lat * M_PI / 180.);
    }
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize grid cells... */
#pragma omp parallel for default(shared) private(ix,iy,iz)
  for (ix = 0; ix < ctl->csi_nx; ix++)
    for (iy = 0; iy < ctl->csi_ny; iy++)
      for (iz = 0; iz < ctl->csi_nz; iz++)
        modmean[ix][iy][iz] = obsmean[ix][iy][iz] = obscount[ix][iy][iz] = 0;

  /* Read observation data... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg %lg", &rt, &rz, &rlon, &rlat, &robs) !=
        5)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt > t1)
```

```
      break;
    if (rt < rt_old)
      ERRMSG("Time must be ascending!");
    rt_old = rt;

    /* Check observation data... */
    if (!isfinite(robs))
      continue;

    /* Calculate indices... */
    ix = (int) ((rlon - ctl->csi_lon0) / dlon);
    iy = (int) ((rlat - ctl->csi_lat0) / dlat);
    iz = (int) ((rz - ctl->csi_z0) / dz);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->csi_nx ||
        iy < 0 || iy >= ctl->csi_ny || iz < 0 || iz >= ctl->csi_nz)
      continue;

    /* Get mean observation index... */
    obsmean[ix][iy][iz] += robs;
    obscount[ix][iy][iz]++;
  }

  /* Analyze model data... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Get indices... */
    ix = (int) ((atm->lon[ip] - ctl->csi_lon0) / dlon);
    iy = (int) ((atm->lat[ip] - ctl->csi_lat0) / dlat);
    iz = (int) ((Z(atm->p[ip]) - ctl->csi_z0) / dz);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->csi_nx ||
        iy < 0 || iy >= ctl->csi_ny || iz < 0 || iz >= ctl->csi_nz)
      continue;

    /* Get total mass in grid cell... */
    modmean[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
  }

  /* Analyze all grid cells... */
  for (ix = 0; ix < ctl->csi_nx; ix++)
    for (iy = 0; iy < ctl->csi_ny; iy++)
      for (iz = 0; iz < ctl->csi_nz; iz++) {

        /* Calculate mean observation index... */
        if (obscount[ix][iy][iz] > 0)
          obsmean[ix][iy][iz] /= obscount[ix][iy][iz];

        /* Calculate column density... */
        if (modmean[ix][iy][iz] > 0)
          modmean[ix][iy][iz] /= (1e6 * area[iy]);

        /* Calculate CSI... */
        if (obscount[ix][iy][iz] > 0) {
          ct++;
          if (obsmean[ix][iy][iz] >= ctl->csi_obsmin &&
              modmean[ix][iy][iz] >= ctl->csi_modmin)
            cx++;
          else if (obsmean[ix][iy][iz] >= ctl->csi_obsmin &&
                   modmean[ix][iy][iz] < ctl->csi_modmin)
            cy++;
          else if (obsmean[ix][iy][iz] < ctl->csi_obsmin &&
                   modmean[ix][iy][iz] >= ctl->csi_modmin)
            cz++;
        }

        /* Save data for other verification statistics... */
        if (obscount[ix][iy][iz] > 0
            && (obsmean[ix][iy][iz] >= ctl->csi_obsmin
                || modmean[ix][iy][iz] >= ctl->csi_modmin)) {
          x[n] = modmean[ix][iy][iz];
          y[n] = obsmean[ix][iy][iz];
          if ((++n) > 1000000)
            ERRMSG("Too many data points to calculate statistics!");
        }
      }

  /* Write output... */
  if (fmod(t, ctl->csi_dt_out) == 0) {

    /* Calculate verification statistics
```

```
      (https://www.cawcr.gov.au/projects/verification/) ... */
    int nobs = cx + cy;
    int nfor = cx + cz;
    double bias = (nobs > 0) ? 100. * nfor / nobs : GSL_NAN;
    double pod = (nobs > 0) ? (100. * cx) / nobs : GSL_NAN;
    double far = (nfor > 0) ? (100. * cz) / nfor : GSL_NAN;
    double csi = (cx + cy + cz > 0) ? (100. * cx) / (cx + cy + cz) : GSL_NAN;
    double cx_rd = (ct > 0) ? (1. * nobs * nfor) / ct : GSL_NAN;
    double ets = (cx + cy + cz - cx_rd > 0) ?
      (100. * (cx - cx_rd)) / (cx + cy + cz - cx_rd) : GSL_NAN;
    double rho_p =
      (n > 0) ? gsl_stats_correlation(x, 1, y, 1, (size_t) n) : GSL_NAN;
    double rho_s =
      (n > 0) ? gsl_stats_spearman(x, 1, y, 1, (size_t) n, work) : GSL_NAN;
    for (int i = 0; i < n; i++)
      work[i] = x[i] - y[i];
    double mean = (n > 0) ? gsl_stats_mean(work, 1, (size_t) n) : GSL_NAN;
    double rmse = (n > 0) ? gsl_stats_sd_with_fixed_mean(work, 1, (size_t) n,
                                                         0.0) : GSL_NAN;
    double absdev =
      (n > 0) ? gsl_stats_absdev_m(work, 1, (size_t) n, 0.0) : GSL_NAN;

    /* Write... */
    fprintf(out, "%.2f %d %d %d %d %d %g %g %g %g %g %g %g %g %g %g %g %d\n",
            t, cx, cy, cz, nobs, nfor, bias, pod, far, csi, cx_rd, ets,
            rho_p, rho_s, mean, rmse, absdev, n);

    /* Set counters to zero... */
    n = ct = cx = cy = cz = 0;
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

5.21.2.46 write_ens()

```
void write_ens (
          const char * filename,
          ctl_t * ctl,
          atm_t * atm,
          double t )
```

Write ensemble data.

Definition at line 4361 of file libtrac.c.

```
                {

  static FILE *out;

  static double dummy, ens, lat, lon, p[NENS], q[NQ][NENS],
    t0, t1, x[NENS][3], xm[3];

  static int ip, iq;

  static size_t i, n;

  /* Set timer... */
  SELECT_TIMER("WRITE_ENS", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Check quantities... */
    if (ctl->qnt_ens < 0)
      ERRMSG("Missing ensemble IDs!");

    /* Create new file... */
    printf("Write ensemble data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
    for (iq = 0; iq < ctl->nq; iq++)
```

```
      fprintf(out, "# $%d = %s (mean) [%s]\n", 5 + iq,
              ctl->qnt_name[iq], ctl->qnt_unit[iq]);
    for (iq = 0; iq < ctl->nq; iq++)
      fprintf(out, "# $%d = %s (sigma) [%s]\n", 5 + ctl->nq + iq,
              ctl->qnt_name[iq], ctl->qnt_unit[iq]);
    fprintf(out, "# $%d = number of members\n\n", 5 + 2 * ctl->nq);
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Init... */
  ens = GSL_NAN;
  n = 0;

  /* Loop over air parcels... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Check ensemble id... */
    if (atm->q[ctl->qnt_ens][ip] != ens) {

      /* Write results... */
      if (n > 0) {

        /* Get mean position... */
        xm[0] = xm[1] = xm[2] = 0;
        for (i = 0; i < n; i++) {
          xm[0] += x[i][0] / (double) n;
          xm[1] += x[i][1] / (double) n;
          xm[2] += x[i][2] / (double) n;
        }
        cart2geo(xm, &dummy, &lon, &lat);
        fprintf(out, "%.2f %g %g %g", t, Z(gsl_stats_mean(p, 1, n)), lon,
                lat);

        /* Get quantity statistics... */
        for (iq = 0; iq < ctl->nq; iq++) {
          fprintf(out, " ");
          fprintf(out, ctl->qnt_format[iq], gsl_stats_mean(q[iq], 1, n));
        }
        for (iq = 0; iq < ctl->nq; iq++) {
          fprintf(out, " ");
          fprintf(out, ctl->qnt_format[iq], gsl_stats_sd(q[iq], 1, n));
        }
        fprintf(out, " %lu\n", n);
      }

      /* Init new ensemble... */
      ens = atm->q[ctl->qnt_ens][ip];
      n = 0;
    }

    /* Save data... */
    p[n] = atm->p[ip];
    geo2cart(0, atm->lon[ip], atm->lat[ip], x[n]);
    for (iq = 0; iq < ctl->nq; iq++)
      q[iq][n] = atm->q[iq][ip];
    if ((++n) >= NENS)
      ERRMSG("Too many data points!");
  }

  /* Write results... */
  if (n > 0) {

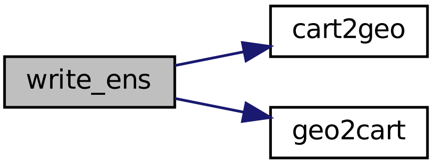
    /* Get mean position... */
    xm[0] = xm[1] = xm[2] = 0;
    for (i = 0; i < n; i++) {
      xm[0] += x[i][0] / (double) n;
      xm[1] += x[i][1] / (double) n;
      xm[2] += x[i][2] / (double) n;
    }
    cart2geo(xm, &dummy, &lon, &lat);
    fprintf(out, "%.2f %g %g %g", t, Z(gsl_stats_mean(p, 1, n)), lon, lat);

    /* Get quantity statistics... */
    for (iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], gsl_stats_mean(q[iq], 1, n));
    }
    for (iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], gsl_stats_sd(q[iq], 1, n));
```

```
    }
    fprintf(out, " %lu\n", n);
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

Here is the call graph for this function:



5.21.2.47 write_grid()

```
void write_grid (
        const char * filename,
        ctl_t * ctl,
        met_t * met0,
        met_t * met1,
        atm_t * atm,
        double t )
```

Write gridded data.

Definition at line 4495 of file libtrac.c.

```
                {

  FILE *in, *out;

  char line[LEN];

  static double mass[GX][GY][GZ], z[GZ], dz, lon[GX], dlon, lat[GY], dlat,
    area[GY], rho_air, press[GZ], temp, cd, vmr, t0, t1, r;

  static int ip, ix, iy, iz, np[GX][GY][GZ], year, mon, day, hour, min, sec;

  /* Set timer... */
  SELECT_TIMER("WRITE_GRID", NVTX_WRITE);

  /* Check dimensions... */
  if (ctl->grid_nx > GX || ctl->grid_ny > GY || ctl->grid_nz > GZ)
    ERRMSG("Grid dimensions too large!");

  /* Set grid box size... */
  dz = (ctl->grid_z1 - ctl->grid_z0) / ctl->grid_nz;
  dlon = (ctl->grid_lon1 - ctl->grid_lon0) / ctl->grid_nx;
  dlat = (ctl->grid_lat1 - ctl->grid_lat0) / ctl->grid_ny;

  /* Set vertical coordinates... */
  for (iz = 0; iz < ctl->grid_nz; iz++) {
    z[iz] = ctl->grid_z0 + dz * (iz + 0.5);
    press[iz] = P(z[iz]);
  }

  /* Set horizontal coordinates... */
  for (ix = 0; ix < ctl->grid_nx; ix++)
    lon[ix] = ctl->grid_lon0 + dlon * (ix + 0.5);
```

```
  for (iy = 0; iy < ctl->grid_ny; iy++) {
    lat[iy] = ctl->grid_lat0 + dlat * (iy + 0.5);
    area[iy] = dlat * dlon * SQR(RE * M_PI / 180.)
      * cos(lat[iy] * M_PI / 180.);
  }

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize grid... */
#pragma omp parallel for default(shared) private(ix,iy,iz)
  for (ix = 0; ix < ctl->grid_nx; ix++)
    for (iy = 0; iy < ctl->grid_ny; iy++)
      for (iz = 0; iz < ctl->grid_nz; iz++) {
        mass[ix][iy][iz] = 0;
        np[ix][iy][iz] = 0;
      }

  /* Average data... */
  for (ip = 0; ip < atm->np; ip++)
    if (atm->time[ip] >= t0 && atm->time[ip] <= t1) {

      /* Get index... */
      ix = (int) ((atm->lon[ip] - ctl->grid_lon0) / dlon);
      iy = (int) ((atm->lat[ip] - ctl->grid_lat0) / dlat);
      iz = (int) ((Z(atm->p[ip]) - ctl->grid_z0) / dz);

      /* Check indices... */
      if (ix < 0 || ix >= ctl->grid_nx ||
          iy < 0 || iy >= ctl->grid_ny || iz < 0 || iz >= ctl->grid_nz)
        continue;

      /* Add mass... */
      if (ctl->qnt_m >= 0)
        mass[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
      np[ix][iy][iz]++;
    }

  /* Check if gnuplot output is requested... */
  if (ctl->grid_gpfile[0] != '-') {

    /* Write info... */
    printf("Plot grid data: %s.png\n", filename);

    /* Create gnuplot pipe... */
    if (!(out = popen("gnuplot", "w")))
      ERRMSG("Cannot create pipe to gnuplot!");

    /* Set plot filename... */
    fprintf(out, "set out \"%s.png\"\n", filename);

    /* Set time string... */
    jsec2time(t, &year, &mon, &day, &hour, &min, &sec, &r);
    fprintf(out, "timestr=\"%d-%02d-%02d, %02d:%02d UTC\"\n",
            year, mon, day, hour, min);

    /* Dump gnuplot file to pipe... */
    if (!(in = fopen(ctl->grid_gpfile, "r")))
      ERRMSG("Cannot open file!");
    while (fgets(line, LEN, in))
      fprintf(out, "%s", line);
    fclose(in);
  }

  else {

    /* Write info... */
    printf("Write grid data: %s\n", filename);

    /* Create file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");
  }

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = surface area [km^2]\n"
          "# $6 = layer width [km]\n"
          "# $7 = number of particles [1]\n"
          "# $8 = column density [kg/m^2]\n"
          "# $9 = volume mixing ratio [ppv]\n\n");

```

```
  /* Write data... */
  for (ix = 0; ix < ctl->grid_nx; ix++) {
    if (ix > 0 && ctl->grid_ny > 1 && !ctl->grid_sparse)
      fprintf(out, "\n");
    for (iy = 0; iy < ctl->grid_ny; iy++) {
      if (iy > 0 && ctl->grid_nz > 1 && !ctl->grid_sparse)
        fprintf(out, "\n");
      for (iz = 0; iz < ctl->grid_nz; iz++)
        if (!ctl->grid_sparse || mass[ix][iy][iz] > 0) {

          /* Calculate column density... */
          cd = mass[ix][iy][iz] / (1e6 * area[iy]);

          /* Calculate volume mixing ratio... */
          vmr = 0;
          if (ctl->molmass > 0) {
            if (mass[ix][iy][iz] > 0) {

              /* Get temperature... */
              INTPOL_INIT;
              intpol_met_time_3d(met0, met0->t, met1, met1->t, t, press[iz],
                                 lon[ix], lat[iy], &temp, ci, cw, 1);

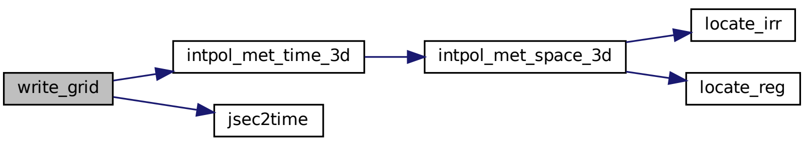
              /* Calculate density of air... */
              rho_air = 100. * press[iz] / (RA * temp);

              /* Calculate volume mixing ratio... */
              vmr = MA / ctl->molmass * mass[ix][iy][iz]
                / (rho_air * 1e6 * area[iy] * 1e3 * dz);
            }
          } else
            vmr = GSL_NAN;

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %d %g %g\n", t, z[iz],
                  lon[ix], lat[iy], area[iy], dz, np[ix][iy][iz], cd, vmr);
        }
    }
  }

  /* Close file... */
  fclose(out);
}
```

Here is the call graph for this function:



5.21.2.48 write_prof()

```
void write_prof (
        const char * filename,
        ctl_t * ctl,
        met_t * met0,
        met_t * met1,
        atm_t * atm,
        double t )
```

Write profile data.

Definition at line 4666 of file libtrac.c.

```
{

```

```
static FILE *in, *out;

static char line[LEN];

static double mass[GX][GY][GZ], obsmean[GX][GY], rt, rt_old = -1e99,
  rz, rlon, rlat, robs, t0, t1, area[GY], dz, dlon, dlat, lon[GX], lat[GY],
  z[GZ], press[GZ], temp, rho_air, vmr, h2o, o3;

static int obscount[GX][GY], ip, ix, iy, iz, okay;

/* Set timer... */
SELECT_TIMER("WRITE_PROF", NVTX_WRITE);

/* Init... */
if (t == ctl->t_start) {

  /* Check quantity index for mass... */
  if (ctl->qnt_m < 0)
    ERRMSG("Need quantity mass!");

  /* Check dimensions... */
  if (ctl->prof_nx > GX || ctl->prof_ny > GY || ctl->prof_nz > GZ)
    ERRMSG("Grid dimensions too large!");

  /* Check molar mass... */
  if (ctl->molmass <= 0)
    ERRMSG("Specify molar mass!");

  /* Open observation data file... */
  printf("Read profile observation data: %s\n", ctl->prof_obsfile);
  if (!(in = fopen(ctl->prof_obsfile, "r")))
    ERRMSG("Cannot open file!");

  /* Create new output file... */
  printf("Write profile data: %s\n", filename);
  if (!(out = fopen(filename, "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n"
          "# $6 = temperature [K]\n"
          "# $7 = volume mixing ratio [ppv]\n"
          "# $8 = H2O volume mixing ratio [ppv]\n"
          "# $9 = O3 volume mixing ratio [ppv]\n"
          "# $10 = observed BT index [K]\n");

  /* Set grid box size... */
  dz = (ctl->prof_z1 - ctl->prof_z0) / ctl->prof_nz;
  dlon = (ctl->prof_lon1 - ctl->prof_lon0) / ctl->prof_nx;
  dlat = (ctl->prof_lat1 - ctl->prof_lat0) / ctl->prof_ny;

  /* Set vertical coordinates... */
  for (iz = 0; iz < ctl->prof_nz; iz++) {
    z[iz] = ctl->prof_z0 + dz * (iz + 0.5);
    press[iz] = P(z[iz]);
  }

  /* Set horizontal coordinates... */
  for (ix = 0; ix < ctl->prof_nx; ix++)
    lon[ix] = ctl->prof_lon0 + dlon * (ix + 0.5);
  for (iy = 0; iy < ctl->prof_ny; iy++) {
    lat[iy] = ctl->prof_lat0 + dlat * (iy + 0.5);
    area[iy] = dlat * dlon * SQR(RE * M_PI / 180.)
      * cos(lat[iy] * M_PI / 180.);
  }
}

/* Set time interval... */
t0 = t - 0.5 * ctl->dt_mod;
t1 = t + 0.5 * ctl->dt_mod;

/* Initialize... */
#pragma omp parallel for default(shared) private(ix,iy,iz)
for (ix = 0; ix < ctl->prof_nx; ix++)
  for (iy = 0; iy < ctl->prof_ny; iy++) {
    obsmean[ix][iy] = 0;
    obscount[ix][iy] = 0;
    for (iz = 0; iz < ctl->prof_nz; iz++)
      mass[ix][iy][iz] = 0;
  }

/* Read observation data... */
```

```
  while (fgets(line, LEN, in)) {

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg %lg", &rt, &rz, &rlon, &rlat, &robs) !=
        5)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt > t1)
      break;
    if (rt < rt_old)
      ERRMSG("Time must be ascending!");
    rt_old = rt;

    /* Check observation data... */
    if (!isfinite(robs))
      continue;

    /* Calculate indices... */
    ix = (int) ((rlon - ctl->prof_lon0) / dlon);
    iy = (int) ((rlat - ctl->prof_lat0) / dlat);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->prof_nx || iy < 0 || iy >= ctl->prof_ny)
      continue;

    /* Get mean observation index... */
    obsmean[ix][iy] += robs;
    obscount[ix][iy]++;
  }

  /* Analyze model data... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Get indices... */
    ix = (int) ((atm->lon[ip] - ctl->prof_lon0) / dlon);
    iy = (int) ((atm->lat[ip] - ctl->prof_lat0) / dlat);
    iz = (int) ((Z(atm->p[ip]) - ctl->prof_z0) / dz);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->prof_nx ||
        iy < 0 || iy >= ctl->prof_ny || iz < 0 || iz >= ctl->prof_nz)
      continue;

    /* Get total mass in grid cell... */
    mass[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
  }

  /* Extract profiles... */
  for (ix = 0; ix < ctl->prof_nx; ix++)
    for (iy = 0; iy < ctl->prof_ny; iy++)
      if (obscount[ix][iy] > 0) {

        /* Check profile... */
        okay = 0;
        for (iz = 0; iz < ctl->prof_nz; iz++)
          if (mass[ix][iy][iz] > 0) {
            okay = 1;
            break;
          }
        if (!okay)
          continue;

        /* Write output... */
        fprintf(out, "\n");

        /* Loop over altitudes... */
        for (iz = 0; iz < ctl->prof_nz; iz++) {

          /* Get pressure and temperature... */
          INTPOL_INIT;
          intpol_met_time_3d(met0, met0->t, met1, met1->t, t, press[iz],
                             lon[ix], lat[iy], &temp, ci, cw, 1);
          intpol_met_time_3d(met0, met0->h2o, met1, met1->h2o, t, press[iz],
                             lon[ix], lat[iy], &h2o, ci, cw, 0);
          intpol_met_time_3d(met0, met0->o3, met1, met1->o3, t, press[iz],
                             lon[ix], lat[iy], &o3, ci, cw, 0);

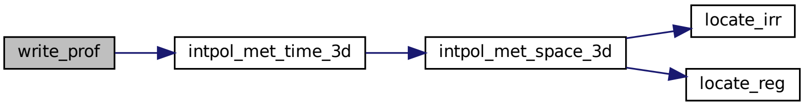
          /* Calculate volume mixing ratio... */
          rho_air = 100. * press[iz] / (RA * temp);
          vmr = MA / ctl->molmass * mass[ix][iy][iz]
```

```
              / (rho_air * area[iy] * dz * 1e9);

            /* Write output... */
            fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g\n",
                    t, z[iz], lon[ix], lat[iy], press[iz], temp, vmr, h2o, o3,
                    obsmean[ix][iy] / obscount[ix][iy]);
          }
        }

    /* Close files... */
    if (t == ctl->t_stop) {
      fclose(in);
      fclose(out);
    }
}
```

Here is the call graph for this function:



5.21.2.49 write_sample()

```
void write_sample (
    const char * filename,
    ctl_t * ctl,
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    double t )
```

Write sample data.

Definition at line 4866 of file libtrac.c.

```
              {

    static FILE *in, *out;

    static char line[LEN];

    static double area, dlat, rmax2, t0, t1, rt, rt_old, rz, rlon, rlat, robs;

    /* Set timer... */
    SELECT_TIMER("WRITE_SAMPLE", NVTX_WRITE);

    /* Init... */
    if (t == ctl->t_start) {

      /* Open observation data file... */
      printf("Read sample observation data: %s\n", ctl->sample_obsfile);
      if (!(in = fopen(ctl->sample_obsfile, "r")))
        ERRMSG("Cannot open file!");

      /* Create new file... */
      printf("Write sample data: %s\n", filename);
      if (!(out = fopen(filename, "w")))
        ERRMSG("Cannot create file!");

      /* Write header... */
      fprintf(out,
              "# $1 = time [s]\n"
              "# $2 = altitude [km]\n"
              "# $3 = longitude [deg]\n"
              "# $4 = latitude [deg]\n"
              "# $5 = surface area [km^2]\n"
```

```
            "# $6 = layer width [km]\n"
            "# $7 = number of particles [1]\n"
            "# $8 = column density [kg/m^2]\n"
            "# $9 = volume mixing ratio [ppv]\n"
            "# $10 = observed BT index [K]\n\n");

    /* Set latitude range, squared radius, and area... */
    dlat = DY2DEG(ctl->sample_dx);
    rmax2 = SQR(ctl->sample_dx);
    area = M_PI * rmax2;
  }

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Read observation data... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg %lg", &rt, &rz, &rlon, &rlat, &robs) !=
        5)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt < rt_old)
      ERRMSG("Time must be ascending!");
    rt_old = rt;

    /* Calculate Cartesian coordinates... */
    double x0[3];
    geo2cart(0, rlon, rlat, x0);

    /* Set pressure range... */
    double rp = P(rz);
    double ptop = P(rz + ctl->sample_dz);
    double pbot = P(rz - ctl->sample_dz);

    /* Init... */
    double mass = 0;
    int np = 0;

    /* Loop over air parcels... */
#pragma omp parallel for default(shared) reduction(+:mass,np)
    for (int ip = 0; ip < atm->np; ip++) {

      /* Check time... */
      if (atm->time[ip] < t0 || atm->time[ip] > t1)
        continue;

      /* Check latitude... */
      if (fabs(rlat - atm->lat[ip]) > dlat)
        continue;

      /* Check horizontal distance... */
      double x1[3];
      geo2cart(0, atm->lon[ip], atm->lat[ip], x1);
      if (DIST2(x0, x1) > rmax2)
        continue;

      /* Check pressure... */
      if (ctl->sample_dz > 0)
        if (atm->p[ip] > pbot || atm->p[ip] < ptop)
          continue;

      /* Add mass... */
      if (ctl->qnt_m >= 0)
        mass += atm->q[ctl->qnt_m][ip];
      np++;
    }

    /* Calculate column density... */
    double cd = mass / (1e6 * area);

    /* Calculate volume mixing ratio... */
    double vmr = 0;
    if (ctl->molmass > 0 && ctl->sample_dz > 0) {
      if (mass > 0) {

        /* Get temperature... */
        double temp;
        INTPOL_INIT;
        intpol_met_time_3d(met0, met0->t, met1, met1->t, rt, rp,
                           rlon, rlat, &temp, ci, cw, 1);

```

```
        /* Calculate density of air... */
        double rho_air = 100. * rp / (RA * temp);

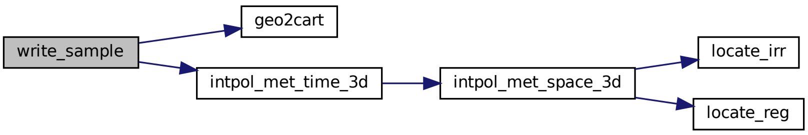
        /* Calculate volume mixing ratio... */
        vmr = MA / ctl->molmass * mass
          / (rho_air * 1e6 * area * 1e3 * ctl->sample_dz);
      }
    } else
      vmr = GSL_NAN;

    /* Write output... */
    fprintf(out, "%.2f %g %g %g %g %g %d %g %g %g\n", rt, rz, rlon, rlat,
            area, ctl->sample_dz, np, cd, vmr, robs);

    /* Check time... */
    if (rt >= t1)
      break;
  }

  /* Close files... */
  if (t == ctl->t_stop) {
    fclose(in);
    fclose(out);
  }
}
```

Here is the call graph for this function:



5.21.2.50 write_station() `void write_station ( const char * filename, ctl_t * ctl, atm_t * atm, double t )`

Write station data.

Definition at line 5018 of file libtrac.c.

```
               {

  static FILE *out;

  static double rmax2, t0, t1, x0[3], x1[3];

  /* Set timer... */
  SELECT_TIMER("WRITE_STATION", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Write info... */
    printf("Write station data: %s\n", filename);

    /* Create new file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
```

```
            "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
    for (int iq = 0; iq < ctl->nq; iq++)
      fprintf(out, "# $%i = %s [%s]\n", (iq + 5),
              ctl->qnt_name[iq], ctl->qnt_unit[iq]);
    fprintf(out, "\n");

    /* Set geolocation and search radius... */
    geo2cart(0, ctl->stat_lon, ctl->stat_lat, x0);
    rmax2 = SQR(ctl->stat_r);
  }

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Loop over air parcels... */
  for (int ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Check station flag... */
    if (ctl->qnt_stat >= 0)
      if (atm->q[ctl->qnt_stat][ip])
        continue;

    /* Get Cartesian coordinates... */
    geo2cart(0, atm->lon[ip], atm->lat[ip], x1);

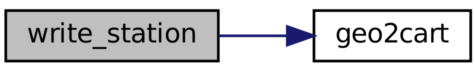
    /* Check horizontal distance... */
    if (DIST2(x0, x1) > rmax2)
      continue;

    /* Set station flag... */
    if (ctl->qnt_stat >= 0)
      atm->q[ctl->qnt_stat][ip] = 1;

    /* Write data... */
    fprintf(out, "%.2f %g %g %g",
            atm->time[ip], Z(atm->p[ip]), atm->lon[ip], atm->lat[ip]);
    for (int iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], atm->q[iq][ip]);
    }
    fprintf(out, "\n");
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

Here is the call graph for this function:



5.22 libtrac.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  but WITHOUT ANY WARRANTY; without even the implied warranty of
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```

```
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  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

/*****************************************************************************/

void cart2geo(
  double *x,
  double *z,
  double *lon,
  double *lat) {

  double radius = NORM(x);
  *lat = asin(x[2] / radius) * 180. / M_PI;
  *lon = atan2(x[1], x[0]) * 180. / M_PI;
  *z = radius - RE;
}

/*****************************************************************************/

static double clim_hno3_secs[12] = {
  1209600.00, 3888000.00, 6393600.00,
  9072000.00, 11664000.00, 14342400.00,
  16934400.00, 19612800.00, 22291200.00,
  24883200.00, 27561600.00, 30153600.00
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_hno3_secs)
#endif

static double clim_hno3_lats[18] = {
  -85, -75, -65, -55, -45, -35, -25, -15, -5,
  5, 15, 25, 35, 45, 55, 65, 75, 85
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_hno3_lats)
#endif

static double clim_hno3_ps[10] = {
  4.64159, 6.81292, 10, 14.678, 21.5443,
  31.6228, 46.4159, 68.1292, 100, 146.78
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_hno3_ps)
#endif

static double clim_hno3_var[12][18][10] = {
  {{0.782, 1.65, 2.9, 4.59, 6.71, 8.25, 7.16, 5.75, 2.9, 1.74},
   {0.529, 1.64, 2.76, 4.55, 6.58, 8, 6.99, 5.55, 2.68, 1.57},
   {0.723, 1.55, 2.73, 4.48, 6.32, 7.58, 7.05, 5.16, 2.49, 1.54},
   {0.801, 1.56, 2.74, 4.52, 6.23, 7.35, 6.68, 4.4, 1.97, 1.23},
   {0.818, 1.62, 2.77, 4.38, 5.98, 6.84, 5.83, 3.05, 1.15, 0.709},
   {0.901, 1.73, 2.78, 4.21, 5.63, 6.16, 4.68, 1.87, 0.617, 0.37},
   {0.997, 1.8, 2.79, 4.09, 4.88, 4.96, 3.12, 1.22, 0.311, 0.244},
   {1, 1.71, 2.51, 3.4, 3.74, 3.39, 2.25, 0.845, 0.204, 0.222},
   {0.997, 1.7, 2.36, 2.88, 3.01, 2.25, 1.77, 0.608, 0.163, 0.181},
   {0.991, 1.79, 2.57, 3.06, 3.08, 2.15, 1.81, 0.59, 0.168, 0.104},
   {0.974, 1.86, 2.84, 3.8, 3.93, 3.79, 2.91, 1.02, 0.152, 0.0985},
   {0.85, 1.86, 3.3, 5.24, 6.55, 6.86, 5.12, 1.93, 0.378, 0.185},
   {0.783, 1.89, 3.85, 6.6, 8.56, 8.66, 6.95, 3.95, 1.47, 0.745},
   {0.883, 2.05, 4.34, 7.54, 9.68, 9.77, 8.19, 5.72, 3.15, 1.77},
   {1.4, 2.44, 4.72, 8.07, 10.5, 10.9, 9.28, 6.95, 4.47, 2.49},
   {1.7, 2.43, 4.24, 7.43, 10.4, 11.2, 9.72, 8.15, 5.7, 2.97},
   {2.06, 2.27, 3.68, 6.77, 10.3, 10.3, 9.05, 9.1, 6.73, 3.14},
   {2.33, 2.39, 3.51, 6.45, 10.3, 9.88, 8.57, 9.42, 7.22, 3.19}},
  {{0.947, 2.21, 3.81, 5.69, 7.55, 8.63, 7.53, 5.98, 3.03, 1.64},
   {0.642, 2, 3.4, 5.49, 7.5, 8.52, 7.53, 5.83, 2.74, 1.42},
   {0.756, 1.83, 3.18, 5.11, 7.24, 8.63, 7.66, 5.5, 2.45, 1.33},
   {0.837, 1.75, 3.06, 5, 6.79, 8.08, 7.05, 4.42, 1.81, 1.05},
   {0.86, 1.73, 2.96, 4.68, 6.38, 7.38, 6.09, 2.92, 1.06, 0.661},
   {0.926, 1.78, 2.89, 4.37, 5.74, 6.14, 4.59, 1.78, 0.561, 0.332},
   {0.988, 1.78, 2.75, 3.95, 4.64, 4.49, 2.85, 1.13, 0.271, 0.184},
   {0.999, 1.7, 2.44, 3.27, 3.57, 3.03, 2.06, 0.736, 0.181, 0.189},
   {0.971, 1.67, 2.23, 2.63, 2.83, 2.15, 1.74, 0.554, 0.157, 0.167},
   {0.985, 1.72, 2.34, 2.69, 2.81, 2.11, 1.78, 0.592, 0.152, 0.101},
   {0.95, 1.72, 2.57, 3.44, 3.84, 3.89, 2.91, 0.976, 0.135, 0.114},
   {0.819, 1.64, 2.93, 4.75, 6.02, 6.93, 5.2, 1.83, 0.347, 0.191},
   {0.731, 1.58, 3.3, 5.95, 7.81, 8.32, 6.93, 3.83, 1.47, 0.875},
```

```
     {0.77, 1.75, 3.74, 6.67, 8.76, 9.41, 8.19, 5.78, 3.32, 2.11},
     {1.08, 2.17, 4.24, 7.13, 9.2, 10.3, 9.03, 6.87, 4.65, 3.01},
     {1.43, 2.49, 4.31, 7, 9.14, 10.6, 9.34, 7.6, 5.86, 3.64},
     {1.5, 2.68, 4.32, 6.75, 8.78, 10.6, 9.05, 7.65, 6.27, 4.07},
     {1.73, 2.91, 4.33, 6.67, 8.73, 10.6, 8.5, 7.54, 6.63, 4.17}},
    {{1.43, 3.07, 5.22, 7.54, 9.78, 10.4, 10.1, 7.26, 3.61, 1.69},
     {0.989, 2.69, 4.76, 7.19, 9.44, 9.94, 9.5, 6.74, 3.24, 1.52},
     {0.908, 2.23, 4.11, 6.48, 8.74, 9.41, 8.58, 5.8, 2.66, 1.3},
     {0.923, 1.99, 3.61, 5.83, 7.84, 8.6, 7.55, 4.57, 1.87, 0.98},
     {0.933, 1.9, 3.31, 5.28, 7.1, 7.84, 6.44, 3.18, 1.1, 0.642},
     {0.982, 1.88, 3.1, 4.76, 6.16, 6.57, 5.16, 2.04, 0.598, 0.33},
     {1.02, 1.82, 2.88, 4.12, 4.71, 4.54, 3.03, 1.22, 0.268, 0.174},
     {0.992, 1.7, 2.51, 3.33, 3.62, 2.87, 2.05, 0.705, 0.161, 0.169},
     {0.969, 1.69, 2.2, 2.62, 2.84, 2.13, 1.78, 0.529, 0.146, 0.186},
     {0.945, 1.69, 2.27, 2.64, 2.83, 2.2, 1.83, 0.561, 0.139, 0.121},
     {0.922, 1.65, 2.48, 3.33, 3.83, 4.09, 2.92, 0.973, 0.117, 0.135},
     {0.886, 1.59, 2.66, 4.26, 5.51, 6.57, 5.09, 1.79, 0.342, 0.194},
     {0.786, 1.5, 2.78, 5.01, 6.8, 7.83, 6.65, 3.62, 1.45, 1},
     {0.745, 1.55, 3.05, 5.49, 7.44, 8.6, 7.8, 5.28, 2.95, 2.12},
     {0.938, 1.76, 3.4, 5.82, 7.8, 9.04, 8.43, 6.15, 3.85, 2.82},
     {0.999, 2, 3.66, 5.95, 7.94, 9.27, 8.8, 6.93, 4.87, 3.54},
     {1.13, 2.23, 3.86, 5.82, 7.65, 9, 8.82, 7.17, 5.72, 4.08},
     {1.23, 2.33, 3.94, 5.74, 7.48, 8.9, 8.84, 7.35, 6.3, 4.42}},
    {{1.55, 3.2, 6.25, 10, 12.9, 12.9, 11.9, 7.96, 3.96, 1.75},
     {1.32, 3.27, 6.32, 9.99, 12.7, 12.4, 11.3, 7.51, 3.66, 1.58},
     {1.25, 3.08, 5.77, 8.71, 11.2, 11.2, 9.84, 6.52, 3.23, 1.5},
     {1.18, 2.59, 4.76, 7.46, 9.61, 9.66, 8.42, 5.06, 2.25, 1.09},
     {1.09, 2.24, 3.99, 6.4, 8.33, 8.54, 7.08, 3.69, 1.36, 0.727},
     {1.06, 2.07, 3.52, 5.52, 7.06, 7.26, 5.83, 2.46, 0.732, 0.409},
     {1.07, 1.91, 3.09, 4.63, 5.21, 4.9, 3.68, 1.43, 0.326, 0.198},
     {1.03, 1.74, 2.63, 3.54, 3.78, 2.89, 2.09, 0.743, 0.175, 0.12},
     {0.959, 1.71, 2.32, 2.77, 2.99, 2.24, 1.76, 0.519, 0.149, 0.172},
     {0.931, 1.68, 2.32, 2.74, 2.99, 2.46, 1.88, 0.578, 0.156, 0.157},
     {0.933, 1.66, 2.49, 3.42, 3.99, 4.12, 2.93, 1.02, 0.181, 0.138},
     {0.952, 1.64, 2.6, 4, 5.15, 6.07, 4.84, 1.78, 0.407, 0.286},
     {0.84, 1.54, 2.68, 4.47, 5.97, 7.13, 6.23, 3.25, 1.38, 1.02},
     {0.714, 1.44, 2.73, 4.68, 6.28, 7.68, 7.21, 4.82, 2.55, 1.96},
     {0.838, 1.57, 2.96, 4.93, 6.55, 8.08, 7.74, 5.77, 3.32, 2.52},
     {0.823, 1.65, 3.11, 5.09, 6.89, 8.36, 8.31, 6.59, 4.1, 3.04},
     {0.886, 1.83, 3.42, 5.33, 6.92, 8.36, 8.63, 7.21, 4.82, 3.46},
     {1.07, 2.12, 3.74, 5.54, 6.98, 8.41, 8.75, 7.41, 5.16, 3.62}},
    {{1.13, 2.59, 7.49, 13.5, 15.4, 12.9, 11.3, 8.62, 4.18, 1.63},
     {0.973, 2.79, 7.23, 12.8, 15.2, 13.3, 11.6, 8.42, 4.06, 1.57},
     {1.46, 3.44, 6.78, 10.4, 12.7, 12.1, 10.5, 7.04, 3.59, 1.63},
     {1.52, 3.38, 6.04, 9.08, 11, 10.3, 8.9, 5.7, 2.77, 1.37},
     {1.32, 2.65, 4.75, 7.49, 9.32, 8.89, 7.42, 4.27, 1.7, 0.88},
     {1.19, 2.2, 3.88, 6.36, 8.03, 7.81, 6.19, 2.94, 0.948, 0.527},
     {1.14, 1.96, 3.28, 5.26, 6.12, 5.8, 4.47, 1.66, 0.388, 0.229},
     {1.07, 1.82, 2.82, 3.92, 4.03, 3.15, 2.31, 0.871, 0.183, 0.0972},
     {0.978, 1.77, 2.53, 3.04, 3.1, 2.36, 1.76, 0.575, 0.16, 0.126},
     {0.962, 1.72, 2.49, 3.01, 3.22, 2.72, 2, 0.716, 0.162, 0.183},
     {0.968, 1.7, 2.6, 3.57, 4.28, 4.35, 3.09, 1.2, 0.262, 0.18},
     {0.977, 1.68, 2.71, 4.03, 5.17, 6.01, 4.81, 1.81, 0.473, 0.343},
     {0.819, 1.58, 2.75, 4.37, 5.8, 6.9, 5.96, 2.95, 1.19, 0.964},
     {0.672, 1.44, 2.69, 4.42, 5.92, 7.26, 6.79, 4.32, 2.22, 1.83},
     {0.783, 1.42, 2.65, 4.45, 6.04, 7.57, 7.39, 5.4, 2.94, 2.25},
     {0.757, 1.43, 2.7, 4.54, 6.14, 7.65, 7.51, 5.95, 3.42, 2.39},
     {0.758, 1.57, 3.04, 4.88, 6.24, 7.85, 7.58, 6.35, 3.81, 2.52},
     {0.835, 1.72, 3.35, 5.24, 6.5, 8.1, 7.67, 6.51, 4, 2.6}},
    {{1.5, 2.12, 7.64, 10.5, 5.59, 2.14, 2.2, 3.5, 4.71, 3.26},
     {1.32, 2.14, 7.23, 12, 9.3, 5.3, 5.11, 5.37, 5.12, 3.05},
     {1.53, 2.92, 6.9, 11.9, 13.5, 11.3, 9.91, 7.18, 4.75, 2.65},
     {1.66, 3.48, 6.25, 9.53, 11.3, 10.3, 9.01, 5.76, 2.99, 1.67},
     {1.54, 3.03, 5.21, 8.03, 9.66, 8.98, 7.5, 4.64, 2.11, 1.13},
     {1.32, 2.39, 4.03, 6.74, 8.52, 8.05, 6.4, 3.48, 1.2, 0.639},
     {1.17, 2.08, 3.35, 5.52, 6.86, 6.54, 5.08, 1.97, 0.462, 0.217},
     {1.07, 1.92, 3.01, 4.24, 4.47, 3.77, 2.77, 1.07, 0.213, 0.0694},
     {0.992, 1.88, 2.76, 3.39, 3.32, 2.52, 1.8, 0.713, 0.192, 0.136},
     {0.992, 1.8, 2.63, 3.34, 3.46, 2.95, 2.09, 0.9, 0.242, 0.194},
     {0.987, 1.77, 2.67, 3.64, 4.37, 4.36, 3, 1.27, 0.354, 0.229},
     {0.979, 1.74, 2.77, 3.99, 5.12, 5.75, 4.53, 1.75, 0.555, 0.302},
     {0.832, 1.6, 2.78, 4.32, 5.53, 6.67, 5.69, 2.59, 0.982, 0.66},
     {0.696, 1.41, 2.64, 4.31, 5.65, 7.14, 6.56, 3.8, 1.75, 1.41},
     {0.788, 1.36, 2.59, 4.3, 5.73, 7.35, 7.04, 4.82, 2.41, 1.8},
     {0.761, 1.43, 2.61, 4.28, 5.64, 7.37, 7.11, 5.37, 2.68, 1.9},
     {0.701, 1.44, 2.82, 4.64, 5.76, 7.63, 7.07, 5.74, 2.98, 1.88},
     {0.763, 1.5, 2.95, 4.97, 6.08, 7.88, 7.12, 5.98, 3.21, 1.91}},
    {{3.58, 2.59, 6.49, 5.84, 1.63, 0.282, 0.647, 0.371, 1.36, 2.33},
     {3.09, 2.38, 6.37, 7.66, 4.06, 1.23, 1.8, 1.65, 2.32, 2.78},
     {2.31, 2.84, 5.58, 9.63, 11, 9.02, 8.2, 6.23, 4.17, 3.08},
     {1.61, 3.16, 5.72, 9.13, 11.4, 10.4, 9.15, 6.18, 3.52, 2.3},
     {1.32, 2.8, 4.79, 7.44, 9.43, 8.83, 7.41, 4.9, 2.38, 1.38},
     {1.14, 2.36, 3.94, 6.41, 8.38, 8.17, 6.53, 3.76, 1.31, 0.656},
     {1.05, 2.1, 3.36, 5.45, 7.07, 6.98, 5.44, 2.22, 0.52, 0.176},
     {1.02, 2, 3.05, 4.33, 4.74, 4.21, 3.2, 1.26, 0.277, 0.0705},
     {1.01, 1.96, 2.9, 3.53, 3.46, 2.69, 1.89, 0.859, 0.254, 0.12},
     {1.01, 1.86, 2.7, 3.46, 3.59, 3.03, 2.14, 1, 0.34, 0.199},
```

```
    {1.02, 1.81, 2.67, 3.68, 4.39, 4.3, 2.93, 1.35, 0.477, 0.25},
    {0.991, 1.79, 2.82, 4.05, 5.08, 5.5, 4.21, 1.74, 0.605, 0.259},
    {0.844, 1.73, 2.87, 4.38, 5.49, 6.47, 5.5, 2.44, 0.85, 0.422},
    {0.729, 1.57, 2.76, 4.43, 5.73, 7.13, 6.43, 3.52, 1.38, 0.913},
    {0.819, 1.46, 2.69, 4.45, 5.92, 7.47, 7.05, 4.52, 2, 1.4},
    {0.783, 1.47, 2.71, 4.48, 5.92, 7.46, 7.16, 5.08, 2.35, 1.56},
    {0.735, 1.51, 2.96, 4.84, 5.92, 7.77, 7.2, 5.54, 2.56, 1.61},
    {0.8, 1.61, 3.14, 5.2, 6.26, 8.08, 7.27, 5.72, 2.75, 1.62}},
   {{5, 4.43, 5.53, 5.35, 2.33, 0.384, 0.663, 0.164, 0.692, 1.4},
    {3.62, 3.79, 4.77, 5.94, 4.12, 1.36, 1.3, 0.973, 1.37, 1.73},
    {2.11, 2.7, 4.12, 7.14, 9.03, 7.74, 7.12, 5.44, 3.73, 2.6},
    {1.13, 2.32, 4.12, 6.97, 9.86, 9.69, 8.85, 6.22, 3.59, 2.14},
    {0.957, 2.28, 4.11, 6.47, 8.66, 8.78, 7.33, 4.94, 2.44, 1.38},
    {0.881, 2.1, 3.65, 5.94, 7.98, 8.29, 6.69, 3.95, 1.36, 0.672},
    {0.867, 1.96, 3.26, 5.23, 6.94, 7.2, 5.63, 2.41, 0.578, 0.19},
    {0.953, 1.94, 2.98, 4.23, 4.83, 4.52, 3.38, 1.34, 0.293, 0.181},
    {1.01, 1.91, 2.77, 3.35, 3.3, 2.62, 1.99, 0.905, 0.245, 0.107},
    {1.03, 1.81, 2.57, 3.29, 3.43, 2.87, 2.13, 0.988, 0.306, 0.185},
    {1.02, 1.78, 2.58, 3.59, 4.19, 4, 2.72, 1.29, 0.389, 0.224},
    {1.01, 1.84, 2.84, 4.06, 4.9, 5.08, 3.71, 1.64, 0.529, 0.232},
    {0.902, 1.84, 2.98, 4.43, 5.5, 6.28, 5.18, 2.35, 0.734, 0.341},
    {0.785, 1.68, 2.93, 4.67, 5.95, 7.3, 6.52, 3.48, 1.24, 0.754},
    {0.847, 1.62, 2.94, 4.86, 6.38, 7.99, 7.5, 4.64, 1.93, 1.23},
    {0.8, 1.6, 2.94, 4.95, 6.62, 8.16, 7.91, 5.43, 2.43, 1.45},
    {0.82, 1.76, 3.37, 5.47, 6.82, 8.24, 7.73, 5.79, 2.69, 1.5},
    {0.988, 2.05, 3.87, 6.01, 7.18, 8.41, 7.7, 5.93, 2.89, 1.55}},
   {{1.52, 2.7, 3.79, 4.95, 3.8, 1.51, 1.11, 0.784, 1.1, 1.56},
    {1.19, 2.16, 3.34, 4.76, 4.61, 2.93, 2.07, 1.65, 1.63, 1.74},
    {0.804, 1.65, 2.79, 4.63, 6.64, 6.95, 6.68, 5.11, 3.3, 2.09},
    {0.86, 1.8, 3.25, 5.3, 7.91, 8.76, 8.28, 6.01, 3.39, 1.83},
    {0.859, 1.95, 3.54, 5.64, 7.88, 8.55, 7.3, 4.88, 2.3, 1.22},
    {0.809, 1.88, 3.38, 5.45, 7.47, 8.02, 6.69, 3.98, 1.35, 0.646},
    {0.822, 1.81, 3.11, 4.9, 6.62, 6.96, 5.63, 2.47, 0.614, 0.169},
    {0.92, 1.83, 2.8, 3.93, 4.56, 4.4, 3.25, 1.31, 0.295, 0.0587},
    {0.986, 1.83, 2.6, 3.13, 3.08, 2.53, 1.94, 0.886, 0.244, 0.0815},
    {0.997, 1.74, 2.5, 3.16, 3.24, 2.67, 2.05, 0.939, 0.281, 0.147},
    {1.01, 1.75, 2.57, 3.55, 4.1, 3.81, 2.53, 1.21, 0.354, 0.197},
    {1.04, 1.88, 2.9, 4.16, 4.95, 4.96, 3.48, 1.63, 0.502, 0.163},
    {0.967, 1.95, 3.17, 4.72, 5.85, 6.5, 5.34, 2.53, 0.748, 0.303},
    {0.846, 1.83, 3.23, 5.15, 6.62, 7.82, 6.85, 3.79, 1.36, 0.714},
    {0.91, 1.81, 3.35, 5.55, 7.32, 8.55, 7.88, 5.03, 2.13, 1.1},
    {0.87, 1.94, 3.6, 5.97, 7.98, 9.14, 8.71, 6.04, 2.73, 1.41},
    {1.04, 2.36, 4.22, 6.57, 8.5, 9.53, 9.22, 6.71, 3.2, 1.56},
    {1.36, 2.84, 4.72, 6.94, 8.81, 9.87, 9.59, 7.1, 3.43, 1.65}},
   {{0.704, 1.4, 2.03, 3.08, 4.64, 4.24, 2.55, 1.57, 1.99, 1.91},
    {0.484, 1.38, 2.08, 3.54, 5.11, 4.98, 3.73, 2.57, 2.29, 1.84},
    {0.749, 1.57, 2.63, 4.17, 6.15, 6.97, 6.64, 5.11, 3.35, 1.97},
    {0.864, 1.69, 3.16, 4.87, 7.13, 8.33, 7.87, 5.9, 3.17, 1.56},
    {0.861, 1.79, 3.28, 5.2, 7.29, 8.32, 7.38, 4.9, 2.23, 1.11},
    {0.835, 1.79, 3.19, 4.99, 6.72, 7.58, 6.45, 3.68, 1.25, 0.616},
    {0.847, 1.8, 3.07, 4.66, 6.12, 6.6, 5.21, 2.18, 0.554, 0.21},
    {0.941, 1.78, 2.68, 3.68, 4.28, 4.18, 2.97, 1.15, 0.238, 0.0968},
    {0.98, 1.78, 2.48, 2.99, 2.96, 2.35, 1.88, 0.747, 0.207, 0.105},
    {0.978, 1.74, 2.51, 3.07, 3.12, 2.36, 1.95, 0.777, 0.216, 0.146},
    {1.01, 1.79, 2.63, 3.53, 3.95, 3.47, 2.38, 1.08, 0.265, 0.178},
    {1.06, 1.94, 3.02, 4.43, 5.19, 5.01, 3.68, 1.71, 0.429, 0.14},
    {0.99, 2.02, 3.38, 5.22, 6.56, 6.91, 5.56, 2.75, 0.816, 0.353},
    {0.923, 2.05, 3.66, 5.98, 7.78, 8.5, 7.23, 4.26, 1.67, 0.802},
    {1.08, 2.27, 4.17, 6.8, 8.89, 9.55, 8.59, 5.64, 2.58, 1.2},
    {1.12, 2.5, 4.52, 7.22, 9.76, 10.3, 9.72, 6.79, 3.32, 1.52},
    {1.2, 2.64, 4.81, 7.64, 10.5, 11.4, 10.6, 7.65, 3.87, 1.73},
    {1.4, 2.91, 5.01, 7.75, 10.7, 11.6, 11.1, 8.02, 4.04, 1.8}},
   {{0.75, 1.49, 2.39, 3.39, 4.93, 5.94, 5.03, 2.75, 2.27, 1.78},
    {0.508, 1.52, 2.38, 3.82, 5.34, 6.13, 5.6, 3.31, 2.42, 1.73},
    {0.715, 1.56, 2.7, 4.39, 6.18, 6.96, 7.1, 5.04, 3.01, 1.75},
    {0.813, 1.62, 2.94, 4.65, 6.53, 7.65, 7.52, 5.49, 2.75, 1.41},
    {0.802, 1.68, 2.97, 4.64, 6.37, 7.53, 7.01, 4.56, 1.9, 0.955},
    {0.816, 1.75, 3.01, 4.59, 6.15, 7.06, 6.15, 3.38, 1.11, 0.61},
    {0.867, 1.78, 2.92, 4.35, 5.69, 6.05, 4.73, 1.91, 0.519, 0.269},
    {0.932, 1.7, 2.55, 3.44, 4.03, 3.98, 2.74, 1.08, 0.247, 0.132},
    {0.937, 1.74, 2.51, 3.09, 3.11, 2.34, 1.84, 0.67, 0.189, 0.121},
    {0.942, 1.75, 2.63, 3.3, 3.27, 2.21, 1.87, 0.663, 0.171, 0.147},
    {0.959, 1.8, 2.82, 3.78, 4.03, 3.37, 2.53, 1.04, 0.199, 0.146},
    {1.01, 1.9, 3.13, 4.76, 5.63, 5.6, 4.31, 1.83, 0.367, 0.172},
    {0.989, 2.04, 3.64, 6, 7.62, 7.6, 6, 3.35, 1.05, 0.448},
    {1.02, 2.28, 4.32, 7.19, 9.21, 9.16, 7.64, 4.97, 2.2, 0.948},
    {1.26, 2.77, 5.2, 8.31, 10.5, 10.4, 9.01, 6.37, 3.46, 1.56},
    {1.31, 2.76, 5.23, 8.49, 11.2, 11.3, 10.1, 7.27, 3.98, 1.76},
    {1.26, 2.5, 5.14, 8.85, 12.3, 12.3, 11.2, 8.13, 4.45, 1.97},
    {1.35, 2.49, 5.26, 9.16, 13, 12.8, 11.8, 8.57, 4.72, 2.05}},
   {{0.759, 1.54, 2.54, 4.22, 6.26, 7.44, 7.14, 4.99, 2.84, 1.89},
    {0.508, 1.55, 2.5, 4.29, 6.29, 7.29, 7.07, 5.03, 2.77, 1.74},
    {0.699, 1.56, 2.62, 4.17, 6.08, 7.38, 7.04, 5.17, 2.81, 1.65},
    {0.778, 1.5, 2.65, 4.35, 6.07, 7.28, 6.84, 4.8, 2.28, 1.28},
    {0.772, 1.55, 2.71, 4.3, 5.76, 6.91, 6.2, 3.69, 1.45, 0.837},
    {0.836, 1.67, 2.78, 4.21, 5.56, 6.41, 5.33, 2.47, 0.807, 0.488},
    {0.937, 1.79, 2.78, 4.12, 5.17, 5.38, 3.89, 1.47, 0.392, 0.256},
```

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  {0.97, 1.75, 2.52, 3.39, 3.83, 3.63, 2.48, 0.968, 0.212, 0.198},
  {0.968, 1.74, 2.5, 3.11, 3.2, 2.34, 1.79, 0.629, 0.169, 0.173},
  {0.98, 1.8, 2.69, 3.42, 3.4, 2.18, 1.81, 0.606, 0.164, 0.138},
  {0.975, 1.84, 2.96, 4.08, 4.12, 3.5, 2.79, 1.02, 0.145, 0.133},
  {0.96, 1.94, 3.27, 5.17, 6.26, 6.35, 4.88, 1.91, 0.329, 0.189},
  {0.954, 2.06, 3.8, 6.53, 8.46, 8.32, 6.53, 3.83, 1.32, 0.6},
  {1, 2.34, 4.58, 7.71, 9.68, 9.75, 7.96, 5.45, 2.84, 1.39},
  {1.24, 2.65, 5.14, 8.51, 10.7, 10.6, 8.96, 6.51, 3.83, 1.85},
  {1.34, 2.44, 4.99, 8.63, 11.6, 11.4, 10.1, 7.84, 4.77, 2.24},
  {1.33, 2.1, 4.76, 8.78, 12.2, 11.7, 10.8, 8.68, 5.15, 2.35},
  {1.42, 2.04, 4.68, 8.92, 12.7, 12, 11.2, 8.99, 5.32, 2.33}}
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_hno3_var)
#endif

double clim_hno3(
  double t,
  double lat,
  double p) {

  /* Get seconds since begin of year... */
  double sec = FMOD(t, 365.25 * 86400.);
  while (sec < 0)
    sec += 365.25 * 86400.;

  /* Check pressure... */
  if (p < clim_hno3_ps[0])
    p = clim_hno3_ps[0];
  else if (p > clim_hno3_ps[9])
    p = clim_hno3_ps[9];

  /* Check latitude... */
  if (lat < clim_hno3_lats[0])
    lat = clim_hno3_lats[0];
  else if (lat > clim_hno3_lats[17])
    lat = clim_hno3_lats[17];

  /* Get indices... */
  int isec = locate_irr(clim_hno3_secs, 12, sec);
  int ilat = locate_reg(clim_hno3_lats, 18, lat);
  int ip = locate_irr(clim_hno3_ps, 10, p);

  /* Interpolate HNO3 climatology (Froidevaux et al., 2015)... */
  double aux00 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec][ilat][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec][ilat][ip + 1], p);
  double aux01 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec][ilat + 1][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec][ilat + 1][ip + 1], p);
  double aux10 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec + 1][ilat][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec + 1][ilat][ip + 1], p);
  double aux11 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec + 1][ilat + 1][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec + 1][ilat + 1][ip + 1], p);
  aux00 = LIN(clim_hno3_lats[ilat], aux00,
              clim_hno3_lats[ilat + 1], aux01, lat);
  aux11 = LIN(clim_hno3_lats[ilat], aux10,
              clim_hno3_lats[ilat + 1], aux11, lat);
  aux00 = LIN(clim_hno3_secs[isec], aux00,
              clim_hno3_secs[isec + 1], aux11, sec);
  return GSL_MAX(aux00, 0.0);
}

/*****************************************************************************/

static double clim_oh_secs[12] = {
  1209600.00, 3888000.00, 6393600.00,
  9072000.00, 11664000.00, 14342400.00,
  16934400.00, 19612800.00, 22291200.00,
  24883200.00, 27561600.00, 30153600.00
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_oh_secs)
#endif

static double clim_oh_lats[18] = {
  -85, -75, -65, -55, -45, -35, -25, -15, -5,
  5, 15, 25, 35, 45, 55, 65, 75, 85
};
```

```

#ifdef _OPENACC
#pragma acc declare copyin(clim_oh_lats)
#endif

static double clim_oh_ps[34] = {
  0.17501, 0.233347, 0.31113, 0.41484, 0.553119, 0.737493, 0.983323,
  1.3111, 1.74813, 2.33084, 3.10779, 4.14372, 5.52496, 7.36661, 9.82214,
  13.0962, 17.4616, 23.2821, 31.0428, 41.3904, 55.1872, 73.583, 98.1107,
  130.814, 174.419, 232.559, 310.078, 413.438, 551.25, 735, 789.809,
  848.705, 911.993, 980
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_oh_ps)
#endif

static double clim_oh_var[12][18][34] = {
  {{6.422, 6.418, 7.221, 8.409, 9.768, 11.22, 12.65, 13.68, 14.03,
    13.06, 11.01, 8.791, 7.096, 6.025, 5.135, 4.057, 2.791, 1.902,
    1.318, 0.9553, 0.7083, 0.5542, 0.5145, 0.5485, 0.6292, 0.5982, 1.716,
    1.111, 0.9802, 0.6707, 0.5235, 0.4476, 0.3783, 0.3091},
   {6.311, 6.394, 7.2, 8.349, 9.664, 11.02, 12.21, 13.06, 13.28,
    12.42, 10.59, 8.552, 6.944, 5.862, 4.948, 3.826, 2.689, 1.873,
    1.302, 0.9316, 0.7053, 0.5634, 0.508, 0.5207, 0.6166, 0.6789, 1.682,
    1.218, 1.079, 0.7621, 0.6662, 0.5778, 0.4875, 0.3997},
   {5.851, 5.827, 6.393, 7.294, 8.322, 9.415, 10.46, 11.24, 11.59,
    11.13, 9.754, 7.97, 6.417, 5.331, 4.468, 3.512, 2.581, 1.855,
    1.336, 0.9811, 0.756, 0.6328, 0.6011, 0.6202, 0.7603, 0.8883, 1.303,
    1.124, 1.118, 0.9428, 0.8655, 0.8156, 0.7602, 0.6805},
   {5.276, 5.158, 5.66, 6.463, 7.419, 8.488, 9.563, 10.45, 10.94,
    10.65, 9.465, 7.762, 6.204, 5.074, 4.209, 3.324, 2.511, 1.865,
    1.386, 1.066, 0.8521, 0.723, 0.6997, 0.7492, 0.8705, 0.8088, 1.22,
    1.192, 1.298, 1.096, 1.037, 0.9589, 0.8856, 0.7726},
   {5.06, 4.919, 5.379, 6.142, 7.095, 8.156, 9.18, 10.09, 10.62,
    10.33, 9.123, 7.479, 5.967, 4.858, 3.987, 3.097, 2.342, 1.743,
    1.323, 1.044, 0.8598, 0.7596, 0.7701, 0.7858, 0.8741, 1.256, 1.266,
    1.418, 1.594, 1.247, 1.169, 1.111, 1.054, 0.9141},
   {4.921, 4.759, 5.188, 5.936, 6.847, 7.871, 8.903, 9.805, 10.31,
    10, 8.818, 7.223, 5.757, 4.66, 3.75, 2.831, 2.1, 1.579,
    1.243, 1.017, 0.8801, 0.8193, 0.9409, 1.131, 0.7313, 1.201, 1.383,
    1.643, 1.751, 1.494, 1.499, 1.647, 1.934, 2.147},
   {4.665, 4.507, 4.947, 5.652, 6.549, 7.573, 8.609, 9.499, 9.985,
    9.664, 8.478, 6.944, 5.519, 4.407, 3.511, 2.595, 1.917, 1.46,
    1.172, 1.009, 0.9372, 0.9439, 1.047, 1.219, 0.5712, 1.032, 1.342,
    1.716, 1.846, 1.551, 1.55, 1.686, 2.006, 2.235},
   {4.424, 4.288, 4.678, 5.38, 6.271, 7.291, 8.324, 9.231, 9.678,
    9.264, 8.037, 6.532, 5.141, 4.037, 3.148, 2.319, 1.715, 1.318,
    1.078, 0.9647, 0.9327, 0.9604, 1.023, 0.4157, 0.4762, 1.04, 1.589,
    2.093, 1.957, 1.557, 1.52, 1.565, 1.776, 1.904},
   {4.154, 3.996, 4.347, 5.004, 5.854, 6.869, 7.929, 8.837, 9.23,
    8.708, 7.447, 6.024, 4.761, 3.742, 2.898, 2.096, 1.55, 1.191,
    0.9749, 0.8889, 0.8745, 0.9004, 0.9648, 0.36, 0.4423, 0.973, 1.571,
    2.086, 1.971, 1.569, 1.537, 1.567, 1.74, 1.811},
   {3.862, 3.738, 4.093, 4.693, 5.499, 6.481, 7.489, 8.328, 8.637,
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   1.303, 1.515, 1.253, 1.185, 1.131, 1.076, 0.9437},
  {4.936, 4.795, 5.272, 5.985, 6.878, 7.91, 8.989, 9.922, 10.53,
   10.37, 9.278, 7.698, 6.176, 5.044, 4.178, 3.263, 2.472, 1.849,
   1.402, 1.087, 0.8859, 0.7846, 0.8226, 0.8854, 0.9635, 1.037, 1.251,
   1.527, 1.706, 1.5, 1.503, 1.644, 1.914, 2.113},
  {4.796, 4.617, 5.024, 5.703, 6.591, 7.617, 8.632, 9.544, 10.07,
   9.749, 8.552, 6.983, 5.55, 4.462, 3.573, 2.707, 2.021, 1.537,
   1.216, 1.017, 0.9039, 0.8702, 0.9836, 1.21, 0.6125, 1.009, 1.311,
   1.688, 1.862, 1.575, 1.568, 1.696, 2.001, 2.214},
  {4.522, 4.356, 4.742, 5.465, 6.36, 7.357, 8.359, 9.269, 9.706,
   9.237, 7.95, 6.476, 5.137, 4.086, 3.214, 2.373, 1.75, 1.33,
   1.071, 0.9379, 0.8929, 0.9071, 0.9736, 1.305, 0.5218, 1.054, 1.605,
   2.105, 1.976, 1.563, 1.521, 1.56, 1.765, 1.875},
  {4.201, 4.084, 4.453, 5.134, 5.998, 7.007, 8.042, 8.894, 9.218,
   8.665, 7.393, 5.966, 4.728, 3.77, 2.956, 2.16, 1.585, 1.199,
   0.9637, 0.8579, 0.8414, 0.8686, 0.8189, 1.154, 0.4693, 0.9934, 1.568,
   2.075, 1.962, 1.563, 1.524, 1.545, 1.704, 1.786},
  {3.87, 3.761, 4.135, 4.74, 5.547, 6.523, 7.533, 8.287, 8.542,
   7.978, 6.743, 5.463, 4.36, 3.491, 2.739, 1.993, 1.453, 1.095,
   0.8767, 0.7822, 0.7664, 0.777, 0.8145, 1.109, 0.4094, 0.8854, 1.413,
   1.91, 1.872, 1.47, 1.421, 1.428, 1.538, 1.583},
  {3.565, 3.517, 3.908, 4.525, 5.299, 6.159, 6.982, 7.581, 7.734,
   7.15, 6.028, 4.918, 3.993, 3.242, 2.541, 1.833, 1.321, 0.9862,
   0.7851, 0.6877, 0.6504, 0.6409, 0.6657, 0.7916, 0.3852, 0.627, 0.8774,
   1.306, 1.713, 1.397, 1.317, 1.308, 1.379, 1.377},
  {3.27, 3.307, 3.718, 4.324, 5.008, 5.72, 6.391, 6.82, 6.844,
   6.25, 5.256, 4.321, 3.562, 2.929, 2.309, 1.67, 1.183, 0.8581,
   0.6613, 0.5437, 0.4817, 0.4549, 0.4828, 0.4971, 0.343, 0.4517, 0.5928,
   0.7482, 1.114, 1.156, 1.127, 1.142, 1.266, 1.325},
  {2.881, 2.972, 3.365, 3.885, 4.479, 5.095, 5.612, 5.869, 5.739,
   5.109, 4.233, 3.497, 2.928, 2.45, 1.923, 1.37, 0.937, 0.6588,
   0.4974, 0.3913, 0.3216, 0.2799, 0.263, 0.2476, 0.2702, 0.3664, 0.3897,
   0.4754, 0.6181, 0.6968, 0.7144, 0.7507, 0.8199, 0.8256},
  {2.352, 2.522, 2.914, 3.377, 3.888, 4.391, 4.73, 4.773, 4.456,
   3.814, 3.103, 2.576, 2.19, 1.824, 1.372, 0.9129, 0.606, 0.4281,
   0.3241, 0.25, 0.1992, 0.1685, 0.1489, 0.1316, 0.116, 0.1598, 0.1448,
   0.1805, 0.2224, 0.2379, 0.2369, 0.2454, 0.2679, 0.2718},
  {1.666, 1.833, 2.135, 2.486, 2.847, 3.14, 3.202, 3.006, 2.612,
   2.127, 1.726, 1.486, 1.277, 0.9733, 0.6654, 0.4233, 0.2852, 0.2051,
   0.1537, 0.1174, 0.09422, 0.08017, 0.06975, 0.06009, 0.04775, 0.03319,
   0.03371,
   0.03896, 0.04544, 0.04203, 0.03927, 0.03814, 0.03917, 0.04012},
  {0.8975, 0.9719, 1.03, 1.066, 1.034, 0.9374, 0.7957, 0.662, 0.5656,
   0.4856, 0.4141, 0.3239, 0.2283, 0.1478, 0.09439, 0.06056, 0.04188,
   0.03179,
   0.02625, 0.02293, 0.02134, 0.01999, 0.01796, 0.01508, 0.01136, 0.006243,
   0.005399,
   0.002554, 0.002671, 0.002877, 0.002693, 0.002456, 0.002169, 0.001592},
  {0.005568, 0.003081, 0.001936, 0.001388, 0.001138, 0.0009141, 0.0003913,
   7.042e-05, 1.305e-05,
   9.014e-06, 5.819e-06, 3.047e-06, 1.303e-06, 5.602e-07, 2.183e-07,
   1.757e-07, 3.825e-07, 2.566e-06,
   1.334e-05, 1.436e-05, 1.976e-05, 7.261e-05, 0.0002657, 0.0005962,
   0.001653, 0.0002773, 0.0008521,
   1.309e-06, 3.72e-14, 2.315e-16, 2.404e-15, 7.283e-17, 5.816e-17,
   1.165e-16},
  {5.606e-05, 7.174e-05, 7.065e-05, 8.779e-05, 0.0001175, 0.0001418,
   6.181e-05, 7.462e-06, 8.135e-06,
   6.922e-06, 3.21e-06, 1.063e-06, 3.185e-07, 7.307e-08, 1.298e-08,
   1.751e-08, 6.792e-08, 5.277e-07,
   7.612e-06, 1.832e-05, 4.78e-05, 0.0001019, 0.0001703, 0.0003801, 0.001213,
   0.0002105, 0.0006011,
   2.875e-06, 7.798e-13, 1.214e-13, 8.329e-14, 7.553e-14, 1.014e-13,
```

```
    1.901e-13}}
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_oh_var)
#endif

double clim_oh(
  double t,
  double lat,
  double p) {

  /* Get seconds since begin of year... */
  double sec = FMOD(t, 365.25 * 86400.);
  while (sec < 0)
    sec += 365.25 * 86400.;

  /* Check pressure... */
  if (p < clim_oh_ps[0])
    p = clim_oh_ps[0];
  else if (p > clim_oh_ps[33])
    p = clim_oh_ps[33];

  /* Check latitude... */
  if (lat < clim_oh_lats[0])
    lat = clim_oh_lats[0];
  else if (lat > clim_oh_lats[17])
    lat = clim_oh_lats[17];

  /* Get indices... */
  int isec = locate_irr(clim_oh_secs, 12, sec);
  int ilat = locate_reg(clim_oh_lats, 18, lat);
  int ip = locate_irr(clim_oh_ps, 34, p);

  /* Interpolate OH climatology (Pommrich et al., 2014)... */
  double aux00 = LIN(clim_oh_ps[ip],
                     clim_oh_var[isec][ilat][ip],
                     clim_oh_ps[ip + 1],
                     clim_oh_var[isec][ilat][ip + 1], p);
  double aux01 = LIN(clim_oh_ps[ip],
                     clim_oh_var[isec][ilat + 1][ip],
                     clim_oh_ps[ip + 1],
                     clim_oh_var[isec][ilat + 1][ip + 1], p);
  double aux10 = LIN(clim_oh_ps[ip],
                     clim_oh_var[isec + 1][ilat][ip],
                     clim_oh_ps[ip + 1],
                     clim_oh_var[isec + 1][ilat][ip + 1], p);
  double aux11 = LIN(clim_oh_ps[ip],
                     clim_oh_var[isec + 1][ilat + 1][ip],
                     clim_oh_ps[ip + 1],
                     clim_oh_var[isec + 1][ilat + 1][ip + 1], p);
  aux00 = LIN(clim_oh_lats[ilat], aux00, clim_oh_lats[ilat + 1], aux01, lat);
  aux11 = LIN(clim_oh_lats[ilat], aux10, clim_oh_lats[ilat + 1], aux11, lat);
  aux00 = LIN(clim_oh_secs[isec], aux00, clim_oh_secs[isec + 1], aux11, sec);
  return GSL_MAX(1e6 * aux00, 0.0);
}

/*****************************************************************************/

static double clim_tropo_secs[12] = {
  1209600.00, 3888000.00, 6393600.00,
  9072000.00, 11664000.00, 14342400.00,
  16934400.00, 19612800.00, 22291200.00,
  24883200.00, 27561600.00, 30153600.00
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_tropo_secs)
#endif

static double clim_tropo_lats[73]
  = { -90, -87.5, -85, -82.5, -80, -77.5, -75, -72.5, -70, -67.5,
  -65, -62.5, -60, -57.5, -55, -52.5, -50, -47.5, -45, -42.5,
  -40, -37.5, -35, -32.5, -30, -27.5, -25, -22.5, -20, -17.5,
  -15, -12.5, -10, -7.5, -5, -2.5, 0, 2.5, 5, 7.5, 10, 12.5,
  15, 17.5, 20, 22.5, 25, 27.5, 30, 32.5, 35, 37.5, 40, 42.5,
  45, 47.5, 50, 52.5, 55, 57.5, 60, 62.5, 65, 67.5, 70, 72.5,
  75, 77.5, 80, 82.5, 85, 87.5, 90
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_tropo_lats)
#endif

static double clim_tropo_tps[12][73]
  = { {324.1, 325.6, 325, 324.3, 322.5, 319.7, 314, 307.2, 301.8, 299.6,
       297.1, 292.2, 285.6, 276.1, 264, 248.9, 231.9, 213.5, 194.4,
```

```
        175.3, 157, 140.4, 126.7, 116.3, 109.5, 105.4, 103, 101.4, 100.4,
        99.69, 99.19, 98.84, 98.56, 98.39, 98.39, 98.42, 98.44, 98.54,
        98.68, 98.81, 98.89, 98.96, 99.12, 99.65, 101.4, 105.4, 113.5, 128,
        152.1, 184.7, 214, 234.1, 247.3, 255.8, 262.6, 267.7, 271.7, 275,
        277.2, 279, 280.1, 280.4, 280.6, 280.1, 279.3, 278.3, 276.8, 275.8,
        275.3, 275.6, 275.4, 274.1, 273.5},
{337.3, 338.7, 337.8, 336.4, 333, 328.8, 321.1, 312.6, 306.6, 303.7,
 300.2, 293.8, 285.4, 273.8, 259.6, 242.7, 224.4, 205.2, 186, 167.5,
 150.3, 135, 122.8, 113.9, 108.2, 104.7, 102.5, 101.1, 100.2, 99.42,
 98.88, 98.52, 98.25, 98.09, 98.07, 98.1, 98.12, 98.2, 98.25, 98.27,
 98.26, 98.27, 98.36, 98.79, 100.2, 104.2, 113.7, 131.2, 159.5, 193,
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 287.5, 286.2, 285.8},
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 297.6, 290, 280.4, 268.3, 254.6, 239.6, 223.9, 207.9, 192.2, 176.9,
 161.7, 146.4, 132.2, 120.6, 112.3, 107.2, 104.3, 102.4, 101.3,
 100.4, 99.86, 99.47, 99.16, 98.97, 98.94, 98.97, 99, 99.09, 99.2,
 99.31, 99.35, 99.41, 99.51, 99.86, 101.1, 104.9, 114.3, 131, 156.8,
 186.3, 209.3, 224.6, 236.8, 246.3, 254.9, 262.3, 268.8, 274.8,
 279.9, 284.6, 288.6, 291.6, 294.9, 297.5, 299.8, 301.8, 303.1,
 304.3, 304.9, 306, 306.6, 306.2, 306},
{306.2, 306.7, 305.7, 307.1, 307.3, 306.4, 301.8, 296.2, 292.4,
 290.3, 287.1, 280.9, 273.4, 264.3, 254.1, 242.8, 231, 219, 207.2,
 195.5, 183.3, 169.7, 154.7, 138.7, 124.1, 113.6, 107.8, 104.7,
 102.8, 101.7, 100.9, 100.4, 100, 99.79, 99.7, 99.66, 99.68, 99.79,
 99.94, 100.2, 100.5, 100.9, 101.4, 102.1, 103.4, 107, 115.2, 129.1,
 148.7, 171, 190.8, 205.6, 218.4, 229.4, 239.6, 248.6, 256.5,
 263.7, 270.3, 276.6, 282.6, 288.1, 294.5, 300.4, 306.3, 311.4,
 315.1, 318.3, 320.3, 322.2, 322.8, 321.5, 321.1},
{266.5, 264.9, 260.8, 261, 262, 263, 261.3, 259.7, 259.2, 259.8,
 260.1, 258.6, 256.7, 253.6, 249.5, 243.9, 237.4, 230, 222.1, 213.9,
 205, 194.4, 180.4, 161.8, 140.7, 122.9, 112.1, 106.7, 104.1, 102.7,
 101.8, 101.4, 101.1, 101, 101, 101, 101.1, 101.2, 101.5, 101.9,
 102.4, 103, 103.8, 104.9, 106.8, 110.1, 115.6, 124, 135.2, 148.9,
 165.2, 181.3, 198, 211.8, 223.5, 233.8, 242.9, 251.5, 259, 266.2,
 273.1, 279.2, 286.2, 292.8, 299.6, 306, 311.1, 315.5, 318.8, 322.6,
 325.3, 325.8, 325.8},
{220.1, 218.1, 210.8, 207.2, 207.6, 210.5, 211.4, 213.5, 217.3,
 222.4, 227.9, 232.8, 237.4, 240.8, 242.8, 243, 241.5, 238.6, 234.2,
 228.5, 221, 210.7, 195.1, 172.9, 147.8, 127.6, 115.6, 109.9, 107.1,
 105.7, 105, 104.8, 104.8, 104.9, 105, 105.1, 105.3, 105.5, 105.8,
 106.4, 107, 107.6, 108.1, 108.8, 110, 111.8, 114.2, 117.4, 121.6,
 127.9, 137.3, 151.2, 169.5, 189, 205.8, 218.9, 229.1, 237.8, 245,
 251.5, 257.1, 262.3, 268.2, 274, 280.4, 286.7, 292.4, 297.9, 302.9,
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{187.4, 184.5, 173.3, 166.1, 165.4, 167.8, 169.6, 173.6, 179.6,
 187.9, 198.9, 210, 220.5, 229.2, 235.7, 239.9, 241.8, 241.6, 239.6,
 235.8, 229.4, 218.6, 200.9, 175.9, 149.4, 129.4, 118.3, 113.1,
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 111, 111.4, 111.8, 112.1, 112.3, 112.7, 113.2, 113.9, 115, 116.4,
 117.9, 120.4, 124.1, 130.9, 142.2, 159.6, 179.6, 198.5, 212.9,
 224.2, 232.7, 239.1, 243.8, 247.7, 252.4, 257.3, 263.2, 269.5,
 275.4, 281.1, 286.3, 292, 296.3, 298.2, 298.8},
{166, 166.4, 155.7, 148.3, 147.1, 149, 152.1, 157, 163.6, 172.4,
 185.3, 199.2, 212.6, 224, 233.2, 239.6, 243.3, 244.6, 243.6, 240.3,
 233.9, 222.6, 203.7, 177, 149.5, 129.7, 119, 114, 111.7, 110.7,
 110.3, 110.3, 110.6, 110.9, 111.1, 111.3, 111.5, 111.6, 111.9,
 112.2, 112.5, 112.6, 112.8, 113, 113.4, 114, 115.1, 116.5, 118.3,
 120.9, 124.4, 130.2, 139.4, 154.6, 173.8, 193.1, 208.1, 220.4,
 230.1, 238.2, 244.7, 249.5, 254.5, 259.3, 264.5, 269.4, 273.7,
 278.2, 282.6, 287.4, 290.9, 292.5, 293},
{171.9, 172.8, 166.2, 162.3, 161.4, 162.5, 165.2, 169.6, 175.3,
 183.1, 193.8, 205.9, 218.3, 229.6, 238.5, 244.3, 246.9, 246.7,
 243.8, 238.4, 230.2, 217.9, 199.6, 174.9, 148.9, 129.8, 119.5,
 114.8, 112.3, 110.9, 110.3, 110.1, 110.2, 110.3, 110.4, 110.5,
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 203.3, 217, 229.1, 238.7, 247, 254, 259.3, 264.3, 268.3, 272.5,
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 223.9, 211.7, 198.3, 183.1, 165.6, 147.1, 130.5, 118.7, 111.9,
 108.1, 105.8, 104.3, 103.4, 102.8, 102.5, 102.4, 102.5, 102.5,
 102.5, 102.7, 103.1, 103.8, 104.6, 105.4, 106.1, 107, 108.2,
 109.9, 112.8, 117.5, 126, 140.4, 161, 181.9, 201.2, 216.8, 230.4,
 241.8, 251.4, 259.9, 266.9, 272.8, 277.4, 280.4, 282.9, 284.6,
 286.1, 287.4, 288.3, 289.5, 290.9, 294.2, 296.9, 297.5, 297.6},
```

```
{301.2, 300.3, 296.6, 295.4, 295, 294.3, 291.2, 287.4, 284.9, 284.7,
 284.1, 281.5, 277.1, 270.4, 261.7, 250.6, 237.6, 223.1, 207.9, 192,
 175.8, 158.8, 142.1, 127.6, 116.8, 109.9, 106, 103.6, 102.1, 101.1,
 100.4, 99.96, 99.6, 99.37, 99.32, 99.32, 99.31, 99.46, 99.77, 100.2,
 100.7, 101.3, 101.8, 102.7, 104.1, 106.8, 111.9, 121, 136.7, 160,
 186.9, 209.9, 228.1, 241.2, 251.5, 259.5, 265.7, 270.9, 274.8, 278,
 280.3, 281.8, 283, 283.3, 283.7, 283.8, 283, 282.2, 281.2, 281.4,
 281.7, 281.1, 281.2}
};

#ifdef _OPENACC
#pragma acc declare copyin(clim_tropo_tps)
#endif

double clim_tropo(
  double t,
  double lat) {

  /* Get seconds since begin of year... */
  double sec = FMOD(t, 365.25 * 86400.);
  while (sec < 0)
    sec += 365.25 * 86400.;

  /* Get indices... */
  int isec = locate_irr(clim_tropo_secs, 12, sec);
  int ilat = locate_reg(clim_tropo_lats, 73, lat);

  /* Interpolate tropopause data (NCEP/NCAR Reanalysis 1)... */
  double p0 = LIN(clim_tropo_lats[ilat],
                  clim_tropo_tps[isec][ilat],
                  clim_tropo_lats[ilat + 1],
                  clim_tropo_tps[isec][ilat + 1], lat);
  double p1 = LIN(clim_tropo_lats[ilat],
                  clim_tropo_tps[isec + 1][ilat],
                  clim_tropo_lats[ilat + 1],
                  clim_tropo_tps[isec + 1][ilat + 1], lat);
  return LIN(clim_tropo_secs[isec], p0, clim_tropo_secs[isec + 1], p1, sec);
}

/*****************************************************************************/

void day2doy(
  int year,
  int mon,
  int day,
  int *doy) {

  int d0[12] = { 1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335 };
  int d0l[12] = { 1, 32, 61, 92, 122, 153, 183, 214, 245, 275, 306, 336 };

  /* Get day of year... */
  if (year % 400 == 0 || (year % 100 != 0 && year % 4 == 0))
    *doy = d0l[mon - 1] + day - 1;
  else
    *doy = d0[mon - 1] + day - 1;
}

/*****************************************************************************/

void doy2day(
  int year,
  int doy,
  int *mon,
  int *day) {

  int d0[12] = { 1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335 };
  int d0l[12] = { 1, 32, 61, 92, 122, 153, 183, 214, 245, 275, 306, 336 };
  int i;

  /* Get month and day... */
  if (year % 400 == 0 || (year % 100 != 0 && year % 4 == 0)) {
    for (i = 11; i >= 0; i--)
      if (d0l[i] <= doy)
        break;
    *mon = i + 1;
    *day = doy - d0l[i] + 1;
  } else {
    for (i = 11; i >= 0; i--)
      if (d0[i] <= doy)
        break;
    *mon = i + 1;
    *day = doy - d0[i] + 1;
  }
}

/*****************************************************************************/

```

```
void geo2cart(
  double z,
  double lon,
  double lat,
  double *x) {

  double radius = z + RE;
  x[0] = radius * cos(lat / 180. * M_PI) * cos(lon / 180. * M_PI);
  x[1] = radius * cos(lat / 180. * M_PI) * sin(lon / 180. * M_PI);
  x[2] = radius * sin(lat / 180. * M_PI);
}

/*****************************************************************************/

void get_met(
  ctl_t * ctl,
  double t,
  met_t ** met0,
  met_t ** met1) {

  static int init, ip, ix, iy;

  met_t *mets;

  char filename[LEN];

  /* Set timer... */
  SELECT_TIMER("GET_MET", NVTX_READ);

  /* Init... */
  if (t == ctl->t_start || !init) {
    init = 1;

    get_met_help(t, -1, ctl->metbase, ctl->dt_met, filename);
    if (!read_met(ctl, filename, *met0))
      ERRMSG("Cannot open file!");

    get_met_help(t + 1.0 * ctl->direction, 1, ctl->metbase, ctl->dt_met,
                 filename);
    if (!read_met(ctl, filename, *met1))
      ERRMSG("Cannot open file!");
#ifdef _OPENACC
    met_t *met0up = *met0;
    met_t *met1up = *met1;
#pragma acc update device(met0up[:1],met1up[:1])
#endif
  }

  /* Read new data for forward trajectories... */
  if (t > (*met1)->time && ctl->direction == 1) {
    mets = *met1;
    *met1 = *met0;
    *met0 = mets;
    get_met_help(t, 1, ctl->metbase, ctl->dt_met, filename);
    if (!read_met(ctl, filename, *met1))
      ERRMSG("Cannot open file!");
#ifdef _OPENACC
    met_t *met1up = *met1;
#pragma acc update device(met1up[:1])
#endif
  }

  /* Read new data for backward trajectories... */
  if (t < (*met0)->time && ctl->direction == -1) {
    mets = *met1;
    *met1 = *met0;
    *met0 = mets;
    get_met_help(t, -1, ctl->metbase, ctl->dt_met, filename);
    if (!read_met(ctl, filename, *met0))
      ERRMSG("Cannot open file!");
#ifdef _OPENACC
    met_t *met0up = *met0;
#pragma acc update device(met0up[:1])
#endif
  }

  /* Check that grids are consistent... */
  if ((*met0)->nx != (*met1)->nx
      || (*met0)->ny != (*met1)->ny || (*met0)->np != (*met1)->np)
    ERRMSG("Meteo grid dimensions do not match!");
  for (ix = 0; ix < (*met0)->nx; ix++)
    if (fabs((*met0)->lon[ix] - (*met1)->lon[ix]) > 0.001)
      ERRMSG("Meteo grid longitudes do not match!");
  for (iy = 0; iy < (*met0)->ny; iy++)
    if (fabs((*met0)->lat[iy] - (*met1)->lat[iy]) > 0.001)
      ERRMSG("Meteo grid latitudes do not match!");
  for (ip = 0; ip < (*met0)->np; ip++)
```

```
    if (fabs((*met0)->p[ip] - (*met1)->p[ip]) > 0.001)
      ERRMSG("Meteo grid pressure levels do not match!");
}

/*****************************************************************************/

void get_met_help(
  double t,
  int direct,
  char *metbase,
  double dt_met,
  char *filename) {

  char repl[LEN];

  double t6, r;

  int year, mon, day, hour, min, sec;

  /* Round time to fixed intervals... */
  if (direct == -1)
    t6 = floor(t / dt_met) * dt_met;
  else
    t6 = ceil(t / dt_met) * dt_met;

  /* Decode time... */
  jsec2time(t6, &year, &mon, &day, &hour, &min, &sec, &r);

  /* Set filename... */
  sprintf(filename, "%s_YYYY_MM_DD_HH.nc", metbase);
  sprintf(repl, "%d", year);
  get_met_replace(filename, "YYYY", repl);
  sprintf(repl, "%02d", mon);
  get_met_replace(filename, "MM", repl);
  sprintf(repl, "%02d", day);
  get_met_replace(filename, "DD", repl);
  sprintf(repl, "%02d", hour);
  get_met_replace(filename, "HH", repl);
}

/*****************************************************************************/

void get_met_replace(
  char *orig,
  char *search,
  char *repl) {

  char buffer[LEN], *ch;

  /* Iterate... */
  for (int i = 0; i < 3; i++) {

    /* Replace sub-string... */
    if (!(ch = strstr(orig, search)))
      return;
    strncpy(buffer, orig, (size_t) (ch - orig));
    buffer[ch - orig] = 0;
    sprintf(buffer + (ch - orig), "%s%s", repl, ch + strlen(search));
    orig[0] = 0;
    strcpy(orig, buffer);
  }
}

/*****************************************************************************/

void intpol_met_space_3d(
  met_t * met,
  float array[EX][EY][EP],
  double p,
  double lon,
  double lat,
  double *var,
  int *ci,
  double *cw,
  int init) {

  /* Check longitude... */
  if (met->lon[met->nx - 1] > 180 && lon < 0)
    lon += 360;

  /* Get interpolation indices and weights... */
  if (init) {
    ci[0] = locate_irr(met->p, met->np, p);
    ci[1] = locate_reg(met->lon, met->nx, lon);
    ci[2] = locate_reg(met->lat, met->ny, lat);
    cw[0] = (met->p[ci[0] + 1] - p)
      / (met->p[ci[0] + 1] - met->p[ci[0]]);
```

```
    cw[1] = (met->lon[ci[1] + 1] - lon)
      / (met->lon[ci[1] + 1] - met->lon[ci[1]]);
    cw[2] = (met->lat[ci[2] + 1] - lat)
      / (met->lat[ci[2] + 1] - met->lat[ci[2]]);
  }

  /* Interpolate vertically... */
  double aux00 =
    cw[0] * (array[ci[1]][ci[2]][ci[0]] - array[ci[1]][ci[2]][ci[0] + 1])
    + array[ci[1]][ci[2]][ci[0] + 1];
  double aux01 =
    cw[0] * (array[ci[1]][ci[2] + 1][ci[0]] -
             array[ci[1]][ci[2] + 1][ci[0] + 1])
    + array[ci[1]][ci[2] + 1][ci[0] + 1];
  double aux10 =
    cw[0] * (array[ci[1] + 1][ci[2]][ci[0]] -
             array[ci[1] + 1][ci[2]][ci[0] + 1])
    + array[ci[1] + 1][ci[2]][ci[0] + 1];
  double aux11 =
    cw[0] * (array[ci[1] + 1][ci[2] + 1][ci[0]] -
             array[ci[1] + 1][ci[2] + 1][ci[0] + 1])
    + array[ci[1] + 1][ci[2] + 1][ci[0] + 1];

  /* Interpolate horizontally... */
  aux00 = cw[2] * (aux00 - aux01) + aux01;
  aux11 = cw[2] * (aux10 - aux11) + aux11;
  *var = cw[1] * (aux00 - aux11) + aux11;
}


/*****************************************************************************/

void intpol_met_space_2d(
  met_t * met,
  float array[EX][EY],
  double lon,
  double lat,
  double *var,
  int *ci,
  double *cw,
  int init) {

  /* Check longitude... */
  if (met->lon[met->nx - 1] > 180 && lon < 0)
    lon += 360;

  /* Get interpolation indices and weights... */
  if (init) {
    ci[1] = locate_reg(met->lon, met->nx, lon);
    ci[2] = locate_reg(met->lat, met->ny, lat);
    cw[1] = (met->lon[ci[1] + 1] - lon)
      / (met->lon[ci[1] + 1] - met->lon[ci[1]]);
    cw[2] = (met->lat[ci[2] + 1] - lat)
      / (met->lat[ci[2] + 1] - met->lat[ci[2]]);
  }

  /* Set variables... */
  double aux00 = array[ci[1]][ci[2]];
  double aux01 = array[ci[1]][ci[2] + 1];
  double aux10 = array[ci[1] + 1][ci[2]];
  double aux11 = array[ci[1] + 1][ci[2] + 1];

  /* Interpolate horizontally... */
  if (isfinite(aux00) && isfinite(aux01))
    aux00 = cw[2] * (aux00 - aux01) + aux01;
  else if (cw[2] < 0.5)
    aux00 = aux01;
  if (isfinite(aux10) && isfinite(aux11))
    aux11 = cw[2] * (aux10 - aux11) + aux11;
  else if (cw[2] > 0.5)
    aux11 = aux10;
  if (isfinite(aux00) && isfinite(aux11))
    *var = cw[1] * (aux00 - aux11) + aux11;
  else {
    if (cw[1] > 0.5)
      *var = aux00;
    else
      *var = aux11;
  }
}

/*****************************************************************************/

void intpol_met_time_3d(
  met_t * met0,
  float array0[EX][EY][EP],
  met_t * met1,
```

```
  float array1[EX][EY][EP],
  double ts,
  double p,
  double lon,
  double lat,
  double *var,
  int *ci,
  double *cw,
  int init) {

  double var0, var1, wt;

  /* Spatial interpolation... */
  intpol_met_space_3d(met0, array0, p, lon, lat, &var0, ci, cw, init);
  intpol_met_space_3d(met1, array1, p, lon, lat, &var1, ci, cw, init);

  /* Get weighting factor... */
  wt = (met1->time - ts) / (met1->time - met0->time);

  /* Interpolate... */
  *var = wt * (var0 - var1) + var1;
}

/*****************************************************************************/

void intpol_met_time_2d(
  met_t * met0,
  float array0[EX][EY],
  met_t * met1,
  float array1[EX][EY],
  double ts,
  double lon,
  double lat,
  double *var,
  int *ci,
  double *cw,
  int init) {

  double var0, var1, wt;

  /* Spatial interpolation... */
  intpol_met_space_2d(met0, array0, lon, lat, &var0, ci, cw, init);
  intpol_met_space_2d(met1, array1, lon, lat, &var1, ci, cw, init);

  /* Get weighting factor... */
  wt = (met1->time - ts) / (met1->time - met0->time);

  /* Interpolate... */
  *var = wt * (var0 - var1) + var1;
}

/*****************************************************************************/

void jsec2time(
  double jsec,
  int *year,
  int *mon,
  int *day,
  int *hour,
  int *min,
  int *sec,
  double *remain) {

  struct tm t0, *t1;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  time_t jsec0 = (time_t) jsec + timegm(&t0);
  t1 = gmtime(&jsec0);

  *year = t1->tm_year + 1900;
  *mon = t1->tm_mon + 1;
  *day = t1->tm_mday;
  *hour = t1->tm_hour;
  *min = t1->tm_min;
  *sec = t1->tm_sec;
  *remain = jsec - floor(jsec);
}

/*****************************************************************************/

double lapse_rate(
```

```
  double t,
  double h2o) {

  /*
     Calculate moist adiabatic lapse rate [K/km] from temperature [K]
     and water vapor volume mixing ratio [1].

     Reference: https://en.wikipedia.org/wiki/Lapse_rate
   */

  const double a = RA * SQR(t), r = SH(h2o) / (1. - SH(h2o));

  return 1e3 * G0 * (a + LV * r * t) / (CPD * a + SQR(LV) * r * EPS);
}

/*****************************************************************************/

int locate_irr(
  double *xx,
  int n,
  double x) {

  int ilo = 0;
  int ihi = n - 1;
  int i = (ihi + ilo) » 1;

  if (xx[i] < xx[i + 1])
    while (ihi > ilo + 1) {
      i = (ihi + ilo) » 1;
      if (xx[i] > x)
        ihi = i;
      else
        ilo = i;
  } else
    while (ihi > ilo + 1) {
      i = (ihi + ilo) » 1;
      if (xx[i] <= x)
        ihi = i;
      else
        ilo = i;
    }

  return ilo;
}

/*****************************************************************************/

int locate_reg(
  double *xx,
  int n,
  double x) {

  /* Calculate index... */
  int i = (int) ((x - xx[0]) / (xx[1] - xx[0]));

  /* Check range... */
  if (i < 0)
    i = 0;
  else if (i >= n - 2)
    i = n - 2;

  return i;
}

/*****************************************************************************/

double nat_temperature(
  double p,
  double h2o,
  double hno3) {

  double p_hno3 = hno3 * p / 1.333224;
  double p_h2o = h2o * p / 1.333224;
  double a = 0.009179 - 0.00088 * log10(p_h2o);
  double b = (38.9855 - log10(p_hno3) - 2.7836 * log10(p_h2o)) / a;
  double c = -11397.0 / a;
  double tnat = (-b + sqrt(b * b - 4. * c)) / 2.;
  double x2 = (-b - sqrt(b * b - 4. * c)) / 2.;
  if (x2 > 0)
    tnat = x2;

  return tnat;
}

/*****************************************************************************/

int read_atm(
```

```
const char *filename,
ctl_t * ctl,
atm_t * atm) {

FILE *in;

char line[LEN], *tok;

double t0;

int dimid, ip, iq, ncid, varid;

size_t nparts;

/* Set timer... */
SELECT_TIMER("READ_ATM", NVTX_READ);

/* Init... */
atm->np = 0;

/* Write info... */
printf("Read atmospheric data: %s\n", filename);

/* Read ASCII data... */
if (ctl->atm_type == 0) {

  /* Open file... */
  if (!(in = fopen(filename, "r"))) {
    WARN("File not found!");
    return 0;
  }

  /* Read line... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    TOK(line, tok, "%lg", atm->time[atm->np]);
    TOK(NULL, tok, "%lg", atm->p[atm->np]);
    TOK(NULL, tok, "%lg", atm->lon[atm->np]);
    TOK(NULL, tok, "%lg", atm->lat[atm->np]);
    for (iq = 0; iq < ctl->nq; iq++)
      TOK(NULL, tok, "%lg", atm->q[iq][atm->np]);

    /* Convert altitude to pressure... */
    atm->p[atm->np] = P(atm->p[atm->np]);

    /* Increment data point counter... */
    if ((++atm->np) > NP)
      ERRMSG("Too many data points!");
  }

  /* Close file... */
  fclose(in);
}

/* Read binary data... */
else if (ctl->atm_type == 1) {

  /* Open file... */
  if (!(in = fopen(filename, "r")))
    return 0;

  /* Read data... */
  FREAD(&atm->np, int,
        1,
        in);
  FREAD(atm->time, double,
          (size_t) atm->np,
        in);
  FREAD(atm->p, double,
          (size_t) atm->np,
        in);
  FREAD(atm->lon, double,
          (size_t) atm->np,
        in);
  FREAD(atm->lat, double,
          (size_t) atm->np,
        in);
  for (iq = 0; iq < ctl->nq; iq++)
    FREAD(atm->q[iq], double,
            (size_t) atm->np,
          in);

  /* Close file... */
  fclose(in);
}

```

```
  /* Read netCDF data... */
  else if (ctl->atm_type == 2) {

    /* Open file... */
    if (nc_open(filename, NC_NOWRITE, &ncid) != NC_NOERR)
      return 0;

    /* Get dimensions... */
    NC(nc_inq_dimid(ncid, "NPARTS", &dimid));
    NC(nc_inq_dimlen(ncid, dimid, &nparts));
    atm->np = (int) nparts;
    if (atm->np > NP)
      ERRMSG("Too many particles!");

    /* Get time... */
    NC(nc_inq_varid(ncid, "time", &varid));
    NC(nc_get_var_double(ncid, varid, &t0));
    for (ip = 0; ip < atm->np; ip++)
      atm->time[ip] = t0;

    /* Read geolocations... */
    NC(nc_inq_varid(ncid, "PRESS", &varid));
    NC(nc_get_var_double(ncid, varid, atm->p));
    NC(nc_inq_varid(ncid, "LON", &varid));
    NC(nc_get_var_double(ncid, varid, atm->lon));
    NC(nc_inq_varid(ncid, "LAT", &varid));
    NC(nc_get_var_double(ncid, varid, atm->lat));

    /* Read variables... */
    if (ctl->qnt_p >= 0)
      if (nc_inq_varid(ncid, "PRESS", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_p]));
    if (ctl->qnt_t >= 0)
      if (nc_inq_varid(ncid, "TEMP", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_t]));
    if (ctl->qnt_u >= 0)
      if (nc_inq_varid(ncid, "U", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_u]));
    if (ctl->qnt_v >= 0)
      if (nc_inq_varid(ncid, "V", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_v]));
    if (ctl->qnt_w >= 0)
      if (nc_inq_varid(ncid, "W", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_w]));
    if (ctl->qnt_h2o >= 0)
      if (nc_inq_varid(ncid, "SH", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_h2o]));
    if (ctl->qnt_o3 >= 0)
      if (nc_inq_varid(ncid, "O3", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_o3]));
    if (ctl->qnt_theta >= 0)
      if (nc_inq_varid(ncid, "THETA", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_theta]));
    if (ctl->qnt_pv >= 0)
      if (nc_inq_varid(ncid, "PV", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_pv]));

    /* Check data... */
    for (ip = 0; ip < atm->np; ip++)
      if (fabs(atm->lon[ip]) > 360 || fabs(atm->lat[ip]) > 90
          || (ctl->qnt_t >= 0 && fabs(atm->q[ctl->qnt_t][ip]) > 350)
          || (ctl->qnt_h2o >= 0 && fabs(atm->q[ctl->qnt_h2o][ip]) > 1)
          || (ctl->qnt_theta >= 0 && fabs(atm->q[ctl->qnt_theta][ip]) > 1e10)
          || (ctl->qnt_pv >= 0 && fabs(atm->q[ctl->qnt_pv][ip]) > 1e10)) {
        atm->time[ip] = GSL_NAN;
        atm->p[ip] = GSL_NAN;
        atm->lon[ip] = GSL_NAN;
        atm->lat[ip] = GSL_NAN;
        for (iq = 0; iq < ctl->nq; iq++)
          atm->q[iq][ip] = GSL_NAN;
      } else {
        if (ctl->qnt_h2o >= 0)
          atm->q[ctl->qnt_h2o][ip] *= 1.608;
        if (ctl->qnt_pv >= 0)
          atm->q[ctl->qnt_pv][ip] *= 1e6;
        if (atm->lon[ip] > 180)
          atm->lon[ip] -= 360;
      }

    /* Close file... */
    NC(nc_close(ncid));
  }

  /* Error... */
  else
    ERRMSG("Atmospheric data type not supported!");

```

```c
  /* Check number of points... */
  if (atm->np < 1)
    ERRMSG("Can not read any data!");

  /* Return success... */
  return 1;
}

/*****************************************************************************/

void read_ctl(
  const char *filename,
  int argc,
  char *argv[],
  ctl_t * ctl) {

  /* Set timer... */
  SELECT_TIMER("READ_CTL", NVTX_READ);

  /* Write info... */
  printf("\nMassive-Parallel Trajectory Calculations (MPTRAC)\n"
         "(executable: %s | compiled: %s, %s)\n\n",
         argv[0], __DATE__, __TIME__);

  /* Initialize quantity indices... */
  ctl->qnt_ens = -1;
  ctl->qnt_m = -1;
  ctl->qnt_r = -1;
  ctl->qnt_rho = -1;
  ctl->qnt_ps = -1;
  ctl->qnt_ts = -1;
  ctl->qnt_zs = -1;
  ctl->qnt_us = -1;
  ctl->qnt_vs = -1;
  ctl->qnt_pt = -1;
  ctl->qnt_tt = -1;
  ctl->qnt_zt = -1;
  ctl->qnt_h2ot = -1;
  ctl->qnt_z = -1;
  ctl->qnt_p = -1;
  ctl->qnt_t = -1;
  ctl->qnt_u = -1;
  ctl->qnt_v = -1;
  ctl->qnt_w = -1;
  ctl->qnt_h2o = -1;
  ctl->qnt_o3 = -1;
  ctl->qnt_lwc = -1;
  ctl->qnt_iwc = -1;
  ctl->qnt_pc = -1;
  ctl->qnt_cl = -1;
  ctl->qnt_plcl = -1;
  ctl->qnt_plfc = -1;
  ctl->qnt_pel = -1;
  ctl->qnt_cape = -1;
  ctl->qnt_hno3 = -1;
  ctl->qnt_oh = -1;
  ctl->qnt_psat = -1;
  ctl->qnt_psice = -1;
  ctl->qnt_pw = -1;
  ctl->qnt_sh = -1;
  ctl->qnt_rh = -1;
  ctl->qnt_rhice = -1;
  ctl->qnt_theta = -1;
  ctl->qnt_tvirt = -1;
  ctl->qnt_lapse = -1;
  ctl->qnt_vh = -1;
  ctl->qnt_vz = -1;
  ctl->qnt_pv = -1;
  ctl->qnt_tdew = -1;
  ctl->qnt_tice = -1;
  ctl->qnt_tsts = -1;
  ctl->qnt_tnat = -1;
  ctl->qnt_stat = -1;

  /* Read quantities... */
  ctl->nq = (int) scan_ctl(filename, argc, argv, "NQ", -1, "0", NULL);
  if (ctl->nq > NQ)
    ERRMSG("Too many quantities!");
  for (int iq = 0; iq < ctl->nq; iq++) {

    /* Read quantity name and format... */
    scan_ctl(filename, argc, argv, "QNT_NAME", iq, "", ctl->qnt_name[iq]);
    scan_ctl(filename, argc, argv, "QNT_FORMAT", iq, "%g",
             ctl->qnt_format[iq]);

    /* Try to identify quantity... */
    if (strcasecmp(ctl->qnt_name[iq], "ens") == 0) {
```

```
      ctl->qnt_ens = iq;
      sprintf(ctl->qnt_unit[iq], "-");
    } else if (strcasecmp(ctl->qnt_name[iq], "m") == 0) {
      ctl->qnt_m = iq;
      sprintf(ctl->qnt_unit[iq], "kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "r") == 0) {
      ctl->qnt_r = iq;
      sprintf(ctl->qnt_unit[iq], "m");
    } else if (strcasecmp(ctl->qnt_name[iq], "rho") == 0) {
      ctl->qnt_rho = iq;
      sprintf(ctl->qnt_unit[iq], "kg/m^3");
    } else if (strcasecmp(ctl->qnt_name[iq], "ps") == 0) {
      ctl->qnt_ps = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "pt") == 0) {
      ctl->qnt_pt = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "tt") == 0) {
      ctl->qnt_tt = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "zt") == 0) {
      ctl->qnt_zt = iq;
      sprintf(ctl->qnt_unit[iq], "km");
    } else if (strcasecmp(ctl->qnt_name[iq], "h2ot") == 0) {
      ctl->qnt_h2ot = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "z") == 0) {
      ctl->qnt_z = iq;
      sprintf(ctl->qnt_unit[iq], "km");
    } else if (strcasecmp(ctl->qnt_name[iq], "p") == 0) {
      ctl->qnt_p = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "t") == 0) {
      ctl->qnt_t = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "u") == 0) {
      ctl->qnt_u = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "v") == 0) {
      ctl->qnt_v = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "w") == 0) {
      ctl->qnt_w = iq;
      sprintf(ctl->qnt_unit[iq], "hPa/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "h2o") == 0) {
      ctl->qnt_h2o = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "o3") == 0) {
      ctl->qnt_o3 = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "lwc") == 0) {
      ctl->qnt_lwc = iq;
      sprintf(ctl->qnt_unit[iq], "kg/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "iwc") == 0) {
      ctl->qnt_iwc = iq;
      sprintf(ctl->qnt_unit[iq], "kg/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "pc") == 0) {
      ctl->qnt_pc = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "cl") == 0) {
      ctl->qnt_cl = iq;
      sprintf(ctl->qnt_unit[iq], "kg/m^2");
    } else if (strcasecmp(ctl->qnt_name[iq], "plcl") == 0) {
      ctl->qnt_plcl = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "plfc") == 0) {
      ctl->qnt_plfc = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "pel") == 0) {
      ctl->qnt_pel = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "cape") == 0) {
      ctl->qnt_cape = iq;
      sprintf(ctl->qnt_unit[iq], "J/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "hno3") == 0) {
      ctl->qnt_hno3 = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "oh") == 0) {
      ctl->qnt_oh = iq;
      sprintf(ctl->qnt_unit[iq], "molec/cm^3");
    } else if (strcasecmp(ctl->qnt_name[iq], "psat") == 0) {
      ctl->qnt_psat = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "psice") == 0) {
      ctl->qnt_psice = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "pw") == 0) {
```

```
      ctl->qnt_pw = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "sh") == 0) {
      ctl->qnt_sh = iq;
      sprintf(ctl->qnt_unit[iq], "kg/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "rh") == 0) {
      ctl->qnt_rh = iq;
      sprintf(ctl->qnt_unit[iq], "%%");
    } else if (strcasecmp(ctl->qnt_name[iq], "rhice") == 0) {
      ctl->qnt_rhice = iq;
      sprintf(ctl->qnt_unit[iq], "%%");
    } else if (strcasecmp(ctl->qnt_name[iq], "theta") == 0) {
      ctl->qnt_theta = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tvirt") == 0) {
      ctl->qnt_tvirt = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "lapse") == 0) {
      ctl->qnt_lapse = iq;
      sprintf(ctl->qnt_unit[iq], "K/km");
    } else if (strcasecmp(ctl->qnt_name[iq], "vh") == 0) {
      ctl->qnt_vh = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "vz") == 0) {
      ctl->qnt_vz = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "pv") == 0) {
      ctl->qnt_pv = iq;
      sprintf(ctl->qnt_unit[iq], "PVU");
    } else if (strcasecmp(ctl->qnt_name[iq], "tdew") == 0) {
      ctl->qnt_tdew = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tice") == 0) {
      ctl->qnt_tice = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tsts") == 0) {
      ctl->qnt_tsts = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tnat") == 0) {
      ctl->qnt_tnat = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "stat") == 0) {
      ctl->qnt_stat = iq;
      sprintf(ctl->qnt_unit[iq], "-");
    } else
      scan_ctl(filename, argc, argv, "QNT_UNIT", iq, "", ctl->qnt_unit[iq]);
  }

  /* Time steps of simulation... */
  ctl->direction =
    (int) scan_ctl(filename, argc, argv, "DIRECTION", -1, "1", NULL);
  if (ctl->direction != -1 && ctl->direction != 1)
    ERRMSG("Set DIRECTION to -1 or 1!");
  ctl->t_stop = scan_ctl(filename, argc, argv, "T_STOP", -1, "1e100", NULL);
  ctl->dt_mod = scan_ctl(filename, argc, argv, "DT_MOD", -1, "180", NULL);

  /* Meteorological data... */
  scan_ctl(filename, argc, argv, "METBASE", -1, "-", ctl->metbase);
  ctl->dt_met = scan_ctl(filename, argc, argv, "DT_MET", -1, "21600", NULL);
  ctl->met_dx = (int) scan_ctl(filename, argc, argv, "MET_DX", -1, "1", NULL);
  ctl->met_dy = (int) scan_ctl(filename, argc, argv, "MET_DY", -1, "1", NULL);
  ctl->met_dp = (int) scan_ctl(filename, argc, argv, "MET_DP", -1, "1", NULL);
  if (ctl->met_dx < 1 || ctl->met_dy < 1 || ctl->met_dp < 1)
    ERRMSG("MET_DX, MET_DY, and MET_DP need to be greater than zero!");
  ctl->met_sx = (int) scan_ctl(filename, argc, argv, "MET_SX", -1, "1", NULL);
  ctl->met_sy = (int) scan_ctl(filename, argc, argv, "MET_SY", -1, "1", NULL);
  ctl->met_sp = (int) scan_ctl(filename, argc, argv, "MET_SP", -1, "1", NULL);
  if (ctl->met_sx < 1 || ctl->met_sy < 1 || ctl->met_sp < 1)
    ERRMSG("MET_SX, MET_SY, and MET_SP need to be greater than zero!");
  ctl->met_detrend =
    scan_ctl(filename, argc, argv, "MET_DETREND", -1, "-999", NULL);
  ctl->met_np = (int) scan_ctl(filename, argc, argv, "MET_NP", -1, "0", NULL);
  if (ctl->met_np > EP)
    ERRMSG("Too many levels!");
  for (int ip = 0; ip < ctl->met_np; ip++)
    ctl->met_p[ip] = scan_ctl(filename, argc, argv, "MET_P", ip, "", NULL);
  ctl->met_geopot_sx
    = (int) scan_ctl(filename, argc, argv, "MET_GEOPOT_SX", -1, "6", NULL);
  ctl->met_geopot_sy
    = (int) scan_ctl(filename, argc, argv, "MET_GEOPOT_SY", -1, "4", NULL);
  if (ctl->met_geopot_sx < 1 || ctl->met_geopot_sy < 1)
    ERRMSG("MET_GEOPOT_SX and MET_GEOPOT_SY need to be greater than zero!");
  ctl->met_tropo =
    (int) scan_ctl(filename, argc, argv, "MET_TROPO", -1, "3", NULL);
  ctl->met_dt_out =
    scan_ctl(filename, argc, argv, "MET_DT_OUT", -1, "0.1", NULL);

```

```
/* Isosurface parameters... */
ctl->isosurf =
  (int) scan_ctl(filename, argc, argv, "ISOSURF", -1, "0", NULL);
scan_ctl(filename, argc, argv, "BALLOON", -1, "-", ctl->balloon);

/* Diffusion parameters... */
ctl->turb_dx_trop =
  scan_ctl(filename, argc, argv, "TURB_DX_TROP", -1, "50", NULL);
ctl->turb_dx_strat =
  scan_ctl(filename, argc, argv, "TURB_DX_STRAT", -1, "0", NULL);
ctl->turb_dz_trop =
  scan_ctl(filename, argc, argv, "TURB_DZ_TROP", -1, "0", NULL);
ctl->turb_dz_strat =
  scan_ctl(filename, argc, argv, "TURB_DZ_STRAT", -1, "0.1", NULL);
ctl->turb_mesox =
  scan_ctl(filename, argc, argv, "TURB_MESOX", -1, "0.16", NULL);
ctl->turb_mesoz =
  scan_ctl(filename, argc, argv, "TURB_MESOZ", -1, "0.16", NULL);

/* Convection... */
ctl->conv_cape =
  scan_ctl(filename, argc, argv, "CONV_CAPE", -1, "-999", NULL);

/* Species parameters... */
scan_ctl(filename, argc, argv, "SPECIES", -1, "-", ctl->species);
if (strcasecmp(ctl->species, "SO2") == 0) {
  ctl->molmass = 64.066;
  ctl->oh_chem[0] = 3.3e-31;   /* (JPL Publication 15-10) */
  ctl->oh_chem[1] = 4.3;       /* (JPL Publication 15-10) */
  ctl->oh_chem[2] = 1.6e-12;   /* (JPL Publication 15-10) */
  ctl->oh_chem[3] = 0.0;       /* (JPL Publication 15-10) */
  ctl->wet_depo[2] = 1.3e-2;  /* (Sander, 2015) */
  ctl->wet_depo[3] = 2900.0;  /* (Sander, 2015) */
  ctl->wet_depo[6] = 1.3e-2;  /* (Sander, 2015) */
  ctl->wet_depo[7] = 2900.0;  /* (Sander, 2015) */
} else {
  ctl->molmass =
    scan_ctl(filename, argc, argv, "MOLMASS", -1, "-999", NULL);
  ctl->tdec_trop =
    scan_ctl(filename, argc, argv, "TDEC_TROP", -1, "0", NULL);
  ctl->tdec_strat =
    scan_ctl(filename, argc, argv, "TDEC_STRAT", -1, "0", NULL);
  for (int ip = 0; ip < 4; ip++)
    ctl->oh_chem[ip] =
      scan_ctl(filename, argc, argv, "OH_CHEM", ip, "0", NULL);
  for (int ip = 0; ip < 1; ip++)
    ctl->dry_depo[ip] =
      scan_ctl(filename, argc, argv, "DRY_DEPO", ip, "0", NULL);
  for (int ip = 0; ip < 8; ip++)
    ctl->wet_depo[ip] =
      scan_ctl(filename, argc, argv, "WET_DEPO", ip, "0", NULL);
}

/* PSC analysis... */
ctl->psc_h2o = scan_ctl(filename, argc, argv, "PSC_H2O", -1, "4e-6", NULL);
ctl->psc_hno3 =
  scan_ctl(filename, argc, argv, "PSC_HNO3", -1, "9e-9", NULL);

/* Output of atmospheric data... */
scan_ctl(filename, argc, argv, "ATM_BASENAME", -1, "-", ctl->atm_basename);
scan_ctl(filename, argc, argv, "ATM_GPFILE", -1, "-", ctl->atm_gpfile);
ctl->atm_dt_out =
  scan_ctl(filename, argc, argv, "ATM_DT_OUT", -1, "86400", NULL);
ctl->atm_filter =
  (int) scan_ctl(filename, argc, argv, "ATM_FILTER", -1, "0", NULL);
ctl->atm_stride =
  (int) scan_ctl(filename, argc, argv, "ATM_STRIDE", -1, "1", NULL);
ctl->atm_type =
  (int) scan_ctl(filename, argc, argv, "ATM_TYPE", -1, "0", NULL);

/* Output of CSI data... */
scan_ctl(filename, argc, argv, "CSI_BASENAME", -1, "-", ctl->csi_basename);
ctl->csi_dt_out =
  scan_ctl(filename, argc, argv, "CSI_DT_OUT", -1, "86400", NULL);
scan_ctl(filename, argc, argv, "CSI_OBSFILE", -1, "-", ctl->csi_obsfile);
ctl->csi_obsmin =
  scan_ctl(filename, argc, argv, "CSI_OBSMIN", -1, "0", NULL);
ctl->csi_modmin =
  scan_ctl(filename, argc, argv, "CSI_MODMIN", -1, "0", NULL);
ctl->csi_z0 = scan_ctl(filename, argc, argv, "CSI_Z0", -1, "0", NULL);
ctl->csi_z1 = scan_ctl(filename, argc, argv, "CSI_Z1", -1, "100", NULL);
ctl->csi_nz = (int) scan_ctl(filename, argc, argv, "CSI_NZ", -1, "1", NULL);
ctl->csi_lon0 =
  scan_ctl(filename, argc, argv, "CSI_LON0", -1, "-180", NULL);
ctl->csi_lon1 = scan_ctl(filename, argc, argv, "CSI_LON1", -1, "180", NULL);
ctl->csi_nx =
  (int) scan_ctl(filename, argc, argv, "CSI_NX", -1, "360", NULL);
```

```
  ctl->csi_lat0 = scan_ctl(filename, argc, argv, "CSI_LAT0", -1, "-90", NULL);
  ctl->csi_lat1 = scan_ctl(filename, argc, argv, "CSI_LAT1", -1, "90", NULL);
  ctl->csi_ny =
    (int) scan_ctl(filename, argc, argv, "CSI_NY", -1, "180", NULL);

  /* Output of ensemble data... */
  scan_ctl(filename, argc, argv, "ENS_BASENAME", -1, "-", ctl->ens_basename);

  /* Output of grid data... */
  scan_ctl(filename, argc, argv, "GRID_BASENAME", -1, "-",
           ctl->grid_basename);
  scan_ctl(filename, argc, argv, "GRID_GPFILE", -1, "-", ctl->grid_gpfile);
  ctl->grid_dt_out =
    scan_ctl(filename, argc, argv, "GRID_DT_OUT", -1, "86400", NULL);
  ctl->grid_sparse =
    (int) scan_ctl(filename, argc, argv, "GRID_SPARSE", -1, "0", NULL);
  ctl->grid_z0 = scan_ctl(filename, argc, argv, "GRID_Z0", -1, "0", NULL);
  ctl->grid_z1 = scan_ctl(filename, argc, argv, "GRID_Z1", -1, "100", NULL);
  ctl->grid_nz =
    (int) scan_ctl(filename, argc, argv, "GRID_NZ", -1, "1", NULL);
  ctl->grid_lon0 =
    scan_ctl(filename, argc, argv, "GRID_LON0", -1, "-180", NULL);
  ctl->grid_lon1 =
    scan_ctl(filename, argc, argv, "GRID_LON1", -1, "180", NULL);
  ctl->grid_nx =
    (int) scan_ctl(filename, argc, argv, "GRID_NX", -1, "360", NULL);
  ctl->grid_lat0 =
    scan_ctl(filename, argc, argv, "GRID_LAT0", -1, "-90", NULL);
  ctl->grid_lat1 =
    scan_ctl(filename, argc, argv, "GRID_LAT1", -1, "90", NULL);
  ctl->grid_ny =
    (int) scan_ctl(filename, argc, argv, "GRID_NY", -1, "180", NULL);

  /* Output of profile data... */
  scan_ctl(filename, argc, argv, "PROF_BASENAME", -1, "-",
           ctl->prof_basename);
  scan_ctl(filename, argc, argv, "PROF_OBSFILE", -1, "-", ctl->prof_obsfile);
  ctl->prof_z0 = scan_ctl(filename, argc, argv, "PROF_Z0", -1, "0", NULL);
  ctl->prof_z1 = scan_ctl(filename, argc, argv, "PROF_Z1", -1, "60", NULL);
  ctl->prof_nz =
    (int) scan_ctl(filename, argc, argv, "PROF_NZ", -1, "60", NULL);
  ctl->prof_lon0 =
    scan_ctl(filename, argc, argv, "PROF_LON0", -1, "-180", NULL);
  ctl->prof_lon1 =
    scan_ctl(filename, argc, argv, "PROF_LON1", -1, "180", NULL);
  ctl->prof_nx =
    (int) scan_ctl(filename, argc, argv, "PROF_NX", -1, "360", NULL);
  ctl->prof_lat0 =
    scan_ctl(filename, argc, argv, "PROF_LAT0", -1, "-90", NULL);
  ctl->prof_lat1 =
    scan_ctl(filename, argc, argv, "PROF_LAT1", -1, "90", NULL);
  ctl->prof_ny =
    (int) scan_ctl(filename, argc, argv, "PROF_NY", -1, "180", NULL);

  /* Output of sample data... */
  scan_ctl(filename, argc, argv, "SAMPLE_BASENAME", -1, "-",
           ctl->sample_basename);
  scan_ctl(filename, argc, argv, "SAMPLE_OBSFILE", -1, "-",
           ctl->sample_obsfile);
  ctl->sample_dx =
    scan_ctl(filename, argc, argv, "SAMPLE_DX", -1, "50", NULL);
  ctl->sample_dz =
    scan_ctl(filename, argc, argv, "SAMPLE_DZ", -1, "-999", NULL);

  /* Output of station data... */
  scan_ctl(filename, argc, argv, "STAT_BASENAME", -1, "-",
           ctl->stat_basename);
  ctl->stat_lon = scan_ctl(filename, argc, argv, "STAT_LON", -1, "0", NULL);
  ctl->stat_lat = scan_ctl(filename, argc, argv, "STAT_LAT", -1, "0", NULL);
  ctl->stat_r = scan_ctl(filename, argc, argv, "STAT_R", -1, "50", NULL);
}

/*****************************************************************************/

int read_met(
  ctl_t * ctl,
  char *filename,
  met_t * met) {

  int ncid;

  /* Write info... */
  printf("Read meteorological data: %s\n", filename);

  /* Open netCDF file... */
  if (nc_open(filename, NC_NOWRITE, &ncid) != NC_NOERR) {
    WARN("File not found!");
```

```
    return 0;
  }

  /* Read coordinates of meteorological data... */
  read_met_grid(filename, ncid, ctl, met);

  /* Read meteo data on vertical levels... */
  read_met_levels(ncid, ctl, met);

  /* Extrapolate data for lower boundary... */
  read_met_extrapolate(met);

  /* Read surface data... */
  read_met_surface(ncid, met);

  /* Create periodic boundary conditions... */
  read_met_periodic(met);

  /* Downsampling... */
  read_met_sample(ctl, met);

  /* Calculate geopotential heights... */
  read_met_geopot(ctl, met);

  /* Calculate potential vorticity... */
  read_met_pv(met);

  /* Calculate tropopause data... */
  read_met_tropo(ctl, met);

  /* Calculate cloud properties... */
  read_met_cloud(met);

  /* Calculate convective available potential energy... */
  read_met_cape(met);

  /* Detrending... */
  read_met_detrend(ctl, met);

  /* Close file... */
  NC(nc_close(ncid));

  /* Return success... */
  return 1;
}

/*****************************************************************************/

void read_met_cape(
  met_t * met) {

  /* Set timer... */
  SELECT_TIMER("READ_MET_CAPE", NVTX_READ);

  /* Vertical spacing (about 100 m)... */
  const double pfac = 1.01439, dz0 = RI / MA / G0 * log(pfac);

  /* Loop over columns... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++) {

      /* Get potential temperature and water vapor vmr at lowest 50 hPa... */
      int n = 0;
      double h2o = 0, t, theta = 0;
      double pbot = GSL_MIN(met->ps[ix][iy], met->p[0]);
      double ptop = pbot - 50.;
      for (int ip = 0; ip < met->np; ip++) {
        if (met->p[ip] <= pbot) {
          theta += THETA(met->p[ip], met->t[ix][iy][ip]);
          h2o += met->h2o[ix][iy][ip];
          n++;
        }
        if (met->p[ip] < ptop && n > 0)
          break;
      }
      theta /= n;
      h2o /= n;

      /* Cannot compute anything if water vapor is missing... */
      met->plcl[ix][iy] = GSL_NAN;
      met->plfc[ix][iy] = GSL_NAN;
      met->pel[ix][iy] = GSL_NAN;
      met->cape[ix][iy] = GSL_NAN;
      if (h2o <= 0)
        continue;

```

```
      /* Find lifted condensation level (LCL)... */
      ptop = P(20.);
      pbot = met->ps[ix][iy];
      do {
        met->plcl[ix][iy] = (float) (0.5 * (pbot + ptop));
        t = theta / pow(1000. / met->plcl[ix][iy], 0.286);
        if (RH(met->plcl[ix][iy], t, h2o) > 100.)
          ptop = met->plcl[ix][iy];
        else
          pbot = met->plcl[ix][iy];
      } while (pbot - ptop > 0.1);

      /* Calculate level of free convection (LFC), equilibrium level (EL),
         and convective available potential energy (CAPE)... */
      double dcape = 0, dcape_old, dz, h2o_env, p = met->plcl[ix][iy],
        psat, t_env;
      ptop = 0.75 * clim_tropo(met->time, met->lat[iy]);
      met->cape[ix][iy] = 0;
      do {
        dz = dz0 * TVIRT(t, h2o);
        p /= pfac;
        t -= lapse_rate(t, h2o) * dz;
        psat = PSAT(t);
        h2o = psat / (p - (1. - EPS) * psat);
        INTPOL_INIT;
        intpol_met_space_3d(met, met->t, p, met->lon[ix], met->lat[iy],
                            &t_env, ci, cw, 1);
        intpol_met_space_3d(met, met->h2o, p, met->lon[ix], met->lat[iy],
                            &h2o_env, ci, cw, 0);
        dcape_old = dcape;
        dcape = 1e3 * G0 * (TVIRT(t, h2o) - TVIRT(t_env, h2o_env)) /
          TVIRT(t_env, h2o_env) * dz;
        if (dcape > 0) {
          met->cape[ix][iy] += (float) dcape;
          if (!isfinite(met->plfc[ix][iy]))
            met->plfc[ix][iy] = (float) p;
        } else if (dcape_old > 0)
          met->pel[ix][iy] = (float) p;
      } while (p > ptop);
    }
}

/*****************************************************************************/

void read_met_cloud(
  met_t * met) {

  /* Set timer... */
  SELECT_TIMER("READ_MET_CLOUD", NVTX_READ);

  /* Loop over columns... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++) {

      /* Init... */
      met->pc[ix][iy] = GSL_NAN;
      met->cl[ix][iy] = 0;

      /* Loop over pressure levels... */
      for (int ip = 0; ip < met->np - 1; ip++) {

        /* Check pressure... */
        if (met->p[ip] > met->ps[ix][iy] || met->p[ip] < P(20.))
          continue;

        /* Get cloud top pressure ... */
        if (met->iwc[ix][iy][ip] > 0 || met->lwc[ix][iy][ip] > 0)
          met->pc[ix][iy] = (float) met->p[ip + 1];

        /* Get cloud water... */
        met->cl[ix][iy] += (float)
          (0.5 * (met->iwc[ix][iy][ip] + met->iwc[ix][iy][ip + 1]
                  + met->lwc[ix][iy][ip] + met->lwc[ix][iy][ip + 1])
           * 100. * (met->p[ip] - met->p[ip + 1]) / G0);
      }
    }
}

/*****************************************************************************/

void read_met_detrend(
  ctl_t * ctl,
  met_t * met) {

  met_t *help;

```

```
  /* Check parameters... */
  if (ctl->met_detrend <= 0)
    return;

  /* Set timer... */
  SELECT_TIMER("READ_MET_DETREND", NVTX_READ);

  /* Allocate... */
  ALLOC(help, met_t, 1);

  /* Calculate standard deviation... */
  double sigma = ctl->met_detrend / 2.355;
  double tssq = 2. * SQR(sigma);

  /* Calculate box size in latitude... */
  int sy = (int) (3. * DY2DEG(sigma) / fabs(met->lat[1] - met->lat[0]));
  sy = GSL_MIN(GSL_MAX(1, sy), met->ny / 2);

  /* Calculate background... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++) {
    for (int iy = 0; iy < met->ny; iy++) {

      /* Calculate Cartesian coordinates... */
      double x0[3];
      geo2cart(0.0, met->lon[ix], met->lat[iy], x0);

      /* Calculate box size in longitude... */
      int sx =
        (int) (3. * DX2DEG(sigma, met->lat[iy]) /
               fabs(met->lon[1] - met->lon[0]));
      sx = GSL_MIN(GSL_MAX(1, sx), met->nx / 2);

      /* Init... */
      float wsum = 0;
      for (int ip = 0; ip < met->np; ip++) {
        help->t[ix][iy][ip] = 0;
        help->u[ix][iy][ip] = 0;
        help->v[ix][iy][ip] = 0;
        help->w[ix][iy][ip] = 0;
      }

      /* Loop over neighboring grid points... */
      for (int ix2 = ix - sx; ix2 <= ix + sx; ix2++) {
        int ix3 = ix2;
        if (ix3 < 0)
          ix3 += met->nx;
        else if (ix3 >= met->nx)
          ix3 -= met->nx;
        for (int iy2 = GSL_MAX(iy - sy, 0);
             iy2 <= GSL_MIN(iy + sy, met->ny - 1); iy2++) {

          /* Calculate Cartesian coordinates... */
          double x1[3];
          geo2cart(0.0, met->lon[ix3], met->lat[iy2], x1);

          /* Calculate weighting factor... */
          float w = (float) exp(-DIST2(x0, x1) / tssq);

          /* Add data... */
          wsum += w;
          for (int ip = 0; ip < met->np; ip++) {
            help->t[ix][iy][ip] += w * met->t[ix3][iy2][ip];
            help->u[ix][iy][ip] += w * met->u[ix3][iy2][ip];
            help->v[ix][iy][ip] += w * met->v[ix3][iy2][ip];
            help->w[ix][iy][ip] += w * met->w[ix3][iy2][ip];
          }
        }
      }

      /* Normalize... */
      for (int ip = 0; ip < met->np; ip++) {
        help->t[ix][iy][ip] /= wsum;
        help->u[ix][iy][ip] /= wsum;
        help->v[ix][iy][ip] /= wsum;
        help->w[ix][iy][ip] /= wsum;
      }
    }
  }

  /* Subtract background... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++)
      for (int ip = 0; ip < met->np; ip++) {
        met->t[ix][iy][ip] -= help->t[ix][iy][ip];
        met->u[ix][iy][ip] -= help->u[ix][iy][ip];
```

```
        met->v[ix][iy][ip] -= help->v[ix][iy][ip];
        met->w[ix][iy][ip] -= help->w[ix][iy][ip];
      }

  /* Free... */
  free(help);
}

/*****************************************************************************/

void read_met_extrapolate(
  met_t * met) {

  int ip, ip0, ix, iy;

  /* Set timer... */
  SELECT_TIMER("READ_MET_EXTRAPOLATE", NVTX_READ);

  /* Loop over columns... */
#pragma omp parallel for default(shared) private(ix,iy,ip0,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {

      /* Find lowest valid data point... */
      for (ip0 = met->np - 1; ip0 >= 0; ip0--)
        if (!isfinite(met->t[ix][iy][ip0])
            || !isfinite(met->u[ix][iy][ip0])
            || !isfinite(met->v[ix][iy][ip0])
            || !isfinite(met->w[ix][iy][ip0]))
          break;

      /* Extrapolate... */
      for (ip = ip0; ip >= 0; ip--) {
        met->t[ix][iy][ip] = met->t[ix][iy][ip + 1];
        met->u[ix][iy][ip] = met->u[ix][iy][ip + 1];
        met->v[ix][iy][ip] = met->v[ix][iy][ip + 1];
        met->w[ix][iy][ip] = met->w[ix][iy][ip + 1];
        met->h2o[ix][iy][ip] = met->h2o[ix][iy][ip + 1];
        met->o3[ix][iy][ip] = met->o3[ix][iy][ip + 1];
        met->lwc[ix][iy][ip] = met->lwc[ix][iy][ip + 1];
        met->iwc[ix][iy][ip] = met->iwc[ix][iy][ip + 1];
      }
    }
}

/*****************************************************************************/

void read_met_geopot(
  ctl_t * ctl,
  met_t * met) {

  const int dx = ctl->met_geopot_sx, dy = ctl->met_geopot_sy;

  static float help[EX][EY][EP], w, wsum;

  double h2os, logp[EP], ts, z0;

  int ip, ip0, ix, ix2, ix3, iy, iy2;

  /* Set timer... */
  SELECT_TIMER("READ_MET_GEOPOT", NVTX_READ);

  /* Calculate log pressure... */
  for (ip = 0; ip < met->np; ip++)
    logp[ip] = log(met->p[ip]);

  /* Initialize geopotential heights... */
#pragma omp parallel for default(shared) private(ix,iy,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++)
        met->z[ix][iy][ip] = GSL_NAN;

  /* Apply hydrostatic equation to calculate geopotential heights... */
#pragma omp parallel for default(shared) private(ix,iy,z0,ip0,ts,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {

      /* Get surface height... */
      INTPOL_INIT;
      intpol_met_space_2d(met, met->zs, met->lon[ix], met->lat[iy], &z0, ci,
                          cw, 1);

      /* Find surface pressure level index... */
      ip0 = locate_irr(met->p, met->np, met->ps[ix][iy]);

      /* Get temperature and water vapor vmr at the surface... */
```

```
      ts =
        LIN(met->p[ip0], met->t[ix][iy][ip0], met->p[ip0 + 1],
            met->t[ix][iy][ip0 + 1], met->ps[ix][iy]);
      h2os =
        LIN(met->p[ip0], met->h2o[ix][iy][ip0], met->p[ip0 + 1],
            met->h2o[ix][iy][ip0 + 1], met->ps[ix][iy]);

      /* Upper part of profile... */
      met->z[ix][iy][ip0 + 1]
        = (float) (z0 +
                   ZDIFF(log(met->ps[ix][iy]), ts, h2os, logp[ip0 + 1],
                         met->t[ix][iy][ip0 + 1], met->h2o[ix][iy][ip0 + 1]));
      for (ip = ip0 + 2; ip < met->np; ip++)
        met->z[ix][iy][ip]
          = (float) (met->z[ix][iy][ip - 1] +
                     ZDIFF(logp[ip - 1], met->t[ix][iy][ip - 1],
                           met->h2o[ix][iy][ip - 1], logp[ip],
                           met->t[ix][iy][ip], met->h2o[ix][iy][ip]));

      /* Lower part of profile... */
      met->z[ix][iy][ip0]
        = (float) (z0 +
                   ZDIFF(log(met->ps[ix][iy]), ts, h2os, logp[ip0],
                         met->t[ix][iy][ip0], met->h2o[ix][iy][ip0]));
      for (ip = ip0 - 1; ip >= 0; ip--)
        met->z[ix][iy][ip]
          = (float) (met->z[ix][iy][ip + 1] +
                     ZDIFF(logp[ip + 1], met->t[ix][iy][ip + 1],
                           met->h2o[ix][iy][ip + 1], logp[ip],
                           met->t[ix][iy][ip], met->h2o[ix][iy][ip]));
    }

  /* Horizontal smoothing... */
#pragma omp parallel for default(shared) private(ix,iy,ip,ix2,ix3,iy2,w,wsum)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++) {
        wsum = 0;
        help[ix][iy][ip] = 0;
        for (ix2 = ix - dx + 1; ix2 <= ix + dx - 1; ix2++) {
          ix3 = ix2;
          if (ix3 < 0)
            ix3 += met->nx;
          else if (ix3 >= met->nx)
            ix3 -= met->nx;
          for (iy2 = GSL_MAX(iy - dy + 1, 0);
               iy2 <= GSL_MIN(iy + dy - 1, met->ny - 1); iy2++)
            if (isfinite(met->z[ix3][iy2][ip])) {
              w = (1.0f - (float) abs(ix - ix2) / (float) dx)
                * (1.0f - (float) abs(iy - iy2) / (float) dy);
              help[ix][iy][ip] += w * met->z[ix3][iy2][ip];
              wsum += w;
            }
        }
        if (wsum > 0)
          help[ix][iy][ip] /= wsum;
        else
          help[ix][iy][ip] = GSL_NAN;
      }

  /* Copy data... */
#pragma omp parallel for default(shared) private(ix,iy,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++)
        met->z[ix][iy][ip] = help[ix][iy][ip];
}

/*****************************************************************************/

void read_met_grid(
  char *filename,
  int ncid,
  ctl_t * ctl,
  met_t * met) {

  char levname[LEN], tstr[10];

  int dimid, ip, varid, year, mon, day, hour;

  size_t np, nx, ny;

  /* Set timer... */
  SELECT_TIMER("READ_MET_GRID", NVTX_READ);

  /* Get time from filename... */
  sprintf(tstr, "%.4s", &filename[strlen(filename) - 16]);
```

```
  year = atoi(tstr);
  sprintf(tstr, "%.2s", &filename[strlen(filename) - 11]);
  mon = atoi(tstr);
  sprintf(tstr, "%.2s", &filename[strlen(filename) - 8]);
  day = atoi(tstr);
  sprintf(tstr, "%.2s", &filename[strlen(filename) - 5]);
  hour = atoi(tstr);
  time2jsec(year, mon, day, hour, 0, 0, 0, &met->time);

  /* Get grid dimensions... */
  NC(nc_inq_dimid(ncid, "lon", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &nx));
  if (nx < 2 || nx > EX)
    ERRMSG("Number of longitudes out of range!");

  NC(nc_inq_dimid(ncid, "lat", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &ny));
  if (ny < 2 || ny > EY)
    ERRMSG("Number of latitudes out of range!");

  sprintf(levname, "lev");
  NC(nc_inq_dimid(ncid, levname, &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &np));
  if (np == 1) {
    sprintf(levname, "lev_2");
    if (nc_inq_dimid(ncid, levname, &dimid) != NC_NOERR) {
      sprintf(levname, "plev");
      nc_inq_dimid(ncid, levname, &dimid);
    }
    NC(nc_inq_dimlen(ncid, dimid, &np));
  }
  if (np < 2 || np > EP)
    ERRMSG("Number of levels out of range!");

  /* Store dimensions... */
  met->np = (int) np;
  met->nx = (int) nx;
  met->ny = (int) ny;

  /* Read longitudes and latitudes... */
  NC(nc_inq_varid(ncid, "lon", &varid));
  NC(nc_get_var_double(ncid, varid, met->lon));
  NC(nc_inq_varid(ncid, "lat", &varid));
  NC(nc_get_var_double(ncid, varid, met->lat));

  /* Read pressure levels... */
  if (ctl->met_np <= 0) {
    NC(nc_inq_varid(ncid, levname, &varid));
    NC(nc_get_var_double(ncid, varid, met->p));
    for (ip = 0; ip < met->np; ip++)
      met->p[ip] /= 100.;
  }

  /* Set pressure levels... */
  else {
    met->np = ctl->met_np;
    for (ip = 0; ip < met->np; ip++)
      met->p[ip] = ctl->met_p[ip];
  }

  /* Check ordering of pressure levels... */
  for (ip = 1; ip < met->np; ip++)
    if (met->p[ip - 1] < met->p[ip])
      ERRMSG("Pressure levels must be descending!");
}

/*****************************************************************************/

int read_met_help_3d(
  int ncid,
  char *varname,
  char *varname2,
  met_t * met,
  float dest[EX][EY][EP],
  float scl) {

  float *help;

  int ip, ix, iy, varid;

  /* Check if variable exists... */
  if (nc_inq_varid(ncid, varname, &varid) != NC_NOERR)
    if (nc_inq_varid(ncid, varname2, &varid) != NC_NOERR)
      return 0;

  /* Allocate... */
  ALLOC(help, float,
```

```
        EX * EY * EP);

  /* Read data... */
  NC(nc_get_var_float(ncid, varid, help));

  /* Copy and check data... */
#pragma omp parallel for default(shared) private(ix,iy,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++) {
        dest[ix][iy][ip] = help[(ip * met->ny + iy) * met->nx + ix];
        if (fabsf(dest[ix][iy][ip]) < 1e14f)
          dest[ix][iy][ip] *= scl;
        else
          dest[ix][iy][ip] = GSL_NAN;
      }

  /* Free... */
  free(help);

  /* Return... */
  return 1;
}

/*****************************************************************************/

int read_met_help_2d(
  int ncid,
  char *varname,
  char *varname2,
  met_t * met,
  float dest[EX][EY],
  float scl) {

  float *help;

  int ix, iy, varid;

  /* Check if variable exists... */
  if (nc_inq_varid(ncid, varname, &varid) != NC_NOERR)
    if (nc_inq_varid(ncid, varname2, &varid) != NC_NOERR)
      return 0;

  /* Allocate... */
  ALLOC(help, float,
        EX * EY);

  /* Read data... */
  NC(nc_get_var_float(ncid, varid, help));

  /* Copy and check data... */
#pragma omp parallel for default(shared) private(ix,iy)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {
      dest[ix][iy] = help[iy * met->nx + ix];
      if (fabsf(dest[ix][iy]) < 1e14f)
        dest[ix][iy] *= scl;
      else
        dest[ix][iy] = GSL_NAN;
    }

  /* Free... */
  free(help);

  /* Return... */
  return 1;
}

/*****************************************************************************/

void read_met_levels(
  int ncid,
  ctl_t * ctl,
  met_t * met) {

  /* Set timer... */
  SELECT_TIMER("READ_MET_LEVELS", NVTX_READ);

  /* Read meteorological data... */
  if (!read_met_help_3d(ncid, "t", "T", met, met->t, 1.0))
    ERRMSG("Cannot read temperature!");
  if (!read_met_help_3d(ncid, "u", "U", met, met->u, 1.0))
    ERRMSG("Cannot read zonal wind!");
  if (!read_met_help_3d(ncid, "v", "V", met, met->v, 1.0))
    ERRMSG("Cannot read meridional wind!");
  if (!read_met_help_3d(ncid, "w", "W", met, met->w, 0.01f))
    WARN("Cannot read vertical velocity");
```

```
  if (!read_met_help_3d(ncid, "q", "Q", met, met->h2o, (float) (MA / MH2O)))
    WARN("Cannot read specific humidity!");
  if (!read_met_help_3d(ncid, "o3", "O3", met, met->o3, (float) (MA / MO3)))
    WARN("Cannot read ozone data!");
  if (!read_met_help_3d(ncid, "clwc", "CLWC", met, met->lwc, 1.0))
    WARN("Cannot read cloud liquid water content!");
  if (!read_met_help_3d(ncid, "ciwc", "CIWC", met, met->iwc, 1.0))
    WARN("Cannot read cloud ice water content!");

  /* Transfer from model levels to pressure levels... */
  if (ctl->met_np > 0) {

    /* Read pressure on model levels... */
    if (!read_met_help_3d(ncid, "pl", "PL", met, met->pl, 0.01f))
      ERRMSG("Cannot read pressure on model levels!");

    /* Vertical interpolation from model to pressure levels... */
    read_met_ml2pl(ctl, met, met->t);
    read_met_ml2pl(ctl, met, met->u);
    read_met_ml2pl(ctl, met, met->v);
    read_met_ml2pl(ctl, met, met->w);
    read_met_ml2pl(ctl, met, met->h2o);
    read_met_ml2pl(ctl, met, met->o3);
    read_met_ml2pl(ctl, met, met->lwc);
    read_met_ml2pl(ctl, met, met->iwc);
  }
}

/*****************************************************************************/

void read_met_ml2pl(
  ctl_t * ctl,
  met_t * met,
  float var[EX][EY][EP]) {

  double aux[EP], p[EP], pt;

  int ip, ip2, ix, iy;

  /* Set timer... */
  SELECT_TIMER("READ_MET_ML2PL", NVTX_READ);

  /* Loop over columns... */
#pragma omp parallel for default(shared) private(ix,iy,ip,p,pt,ip2,aux)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {

      /* Copy pressure profile... */
      for (ip = 0; ip < met->np; ip++)
        p[ip] = met->pl[ix][iy][ip];

      /* Interpolate... */
      for (ip = 0; ip < ctl->met_np; ip++) {
        pt = ctl->met_p[ip];
        if ((pt > p[0] && p[0] > p[1]) || (pt < p[0] && p[0] < p[1]))
          pt = p[0];
        else if ((pt > p[met->np - 1] && p[1] > p[0])
                 || (pt < p[met->np - 1] && p[1] < p[0]))
          pt = p[met->np - 1];
        ip2 = locate_irr(p, met->np, pt);
        aux[ip] = LIN(p[ip2], var[ix][iy][ip2],
                      p[ip2 + 1], var[ix][iy][ip2 + 1], pt);
      }

      /* Copy data... */
      for (ip = 0; ip < ctl->met_np; ip++)
        var[ix][iy][ip] = (float) aux[ip];
    }
}

/*****************************************************************************/

void read_met_periodic(
  met_t * met) {

  /* Set timer... */
  SELECT_TIMER("READ_MET_PERIODIC", NVTX_READ);

  /* Check longitudes... */
  if (!(fabs(met->lon[met->nx - 1] - met->lon[0]
             + met->lon[1] - met->lon[0] - 360) < 0.01))
    return;

  /* Increase longitude counter... */
  if ((++met->nx) > EX)
    ERRMSG("Cannot create periodic boundary conditions!");

```

```
  /* Set longitude... */
  met->lon[met->nx - 1] = met->lon[met->nx - 2] + met->lon[1] - met->lon[0];

  /* Loop over latitudes and pressure levels... */
#pragma omp parallel for default(shared)
  for (int iy = 0; iy < met->ny; iy++) {
    met->ps[met->nx - 1][iy] = met->ps[0][iy];
    met->zs[met->nx - 1][iy] = met->zs[0][iy];
    for (int ip = 0; ip < met->np; ip++) {
      met->t[met->nx - 1][iy][ip] = met->t[0][iy][ip];
      met->u[met->nx - 1][iy][ip] = met->u[0][iy][ip];
      met->v[met->nx - 1][iy][ip] = met->v[0][iy][ip];
      met->w[met->nx - 1][iy][ip] = met->w[0][iy][ip];
      met->h2o[met->nx - 1][iy][ip] = met->h2o[0][iy][ip];
      met->o3[met->nx - 1][iy][ip] = met->o3[0][iy][ip];
      met->lwc[met->nx - 1][iy][ip] = met->lwc[0][iy][ip];
      met->iwc[met->nx - 1][iy][ip] = met->iwc[0][iy][ip];
    }
  }
}

/*****************************************************************************/

void read_met_pv(
  met_t * met) {

  double c0, c1, cr, dx, dy, dp0, dp1, denom, dtdx, dvdx, dtdy, dudy,
    dtdp, dudp, dvdp, latr, vort, pows[EP];

  int ip, ip0, ip1, ix, ix0, ix1, iy, iy0, iy1;

  /* Set timer... */
  SELECT_TIMER("READ_MET_PV", NVTX_READ);

  /* Set powers... */
  for (ip = 0; ip < met->np; ip++)
    pows[ip] = pow(1000. / met->p[ip], 0.286);

  /* Loop over grid points... */
#pragma omp parallel for default(shared)
 private(ix,ix0,ix1,iy,iy0,iy1,latr,dx,dy,c0,c1,cr,vort,ip,ip0,ip1,dp0,dp1,denom,dtdx,dvdx,dtdy,dudy,dtdp,dudp,dvdp)
  for (ix = 0; ix < met->nx; ix++) {

    /* Set indices... */
    ix0 = GSL_MAX(ix - 1, 0);
    ix1 = GSL_MIN(ix + 1, met->nx - 1);

    /* Loop over grid points... */
    for (iy = 0; iy < met->ny; iy++) {

      /* Set indices... */
      iy0 = GSL_MAX(iy - 1, 0);
      iy1 = GSL_MIN(iy + 1, met->ny - 1);

      /* Set auxiliary variables... */
      latr = 0.5 * (met->lat[iy1] + met->lat[iy0]);
      dx = 1000. * DEG2DX(met->lon[ix1] - met->lon[ix0], latr);
      dy = 1000. * DEG2DY(met->lat[iy1] - met->lat[iy0]);
      c0 = cos(met->lat[iy0] / 180. * M_PI);
      c1 = cos(met->lat[iy1] / 180. * M_PI);
      cr = cos(latr / 180. * M_PI);
      vort = 2 * 7.2921e-5 * sin(latr * M_PI / 180.);

      /* Loop over grid points... */
      for (ip = 0; ip < met->np; ip++) {

        /* Get gradients in longitude... */
        dtdx = (met->t[ix1][iy][ip] - met->t[ix0][iy][ip]) * pows[ip] / dx;
        dvdx = (met->v[ix1][iy][ip] - met->v[ix0][iy][ip]) / dx;

        /* Get gradients in latitude... */
        dtdy = (met->t[ix][iy1][ip] - met->t[ix][iy0][ip]) * pows[ip] / dy;
        dudy = (met->u[ix][iy1][ip] * c1 - met->u[ix][iy0][ip] * c0) / dy;

        /* Set indices... */
        ip0 = GSL_MAX(ip - 1, 0);
        ip1 = GSL_MIN(ip + 1, met->np - 1);

        /* Get gradients in pressure... */
        dp0 = 100. * (met->p[ip] - met->p[ip0]);
        dp1 = 100. * (met->p[ip1] - met->p[ip]);
        if (ip != ip0 && ip != ip1) {
          denom = dp0 * dp1 * (dp0 + dp1);
          dtdp = (dp0 * dp0 * met->t[ix][iy][ip1] * pows[ip1]
                  - dp1 * dp1 * met->t[ix][iy][ip0] * pows[ip0]
                  + (dp1 * dp1 - dp0 * dp0) * met->t[ix][iy][ip] * pows[ip])
            / denom;
```

```
          dudp = (dp0 * dp0 * met->u[ix][iy][ip1]
                  - dp1 * dp1 * met->u[ix][iy][ip0]
                  + (dp1 * dp1 - dp0 * dp0) * met->u[ix][iy][ip])
            / denom;
          dvdp = (dp0 * dp0 * met->v[ix][iy][ip1]
                  - dp1 * dp1 * met->v[ix][iy][ip0]
                  + (dp1 * dp1 - dp0 * dp0) * met->v[ix][iy][ip])
            / denom;
        } else {
          denom = dp0 + dp1;
          dtdp =
            (met->t[ix][iy][ip1] * pows[ip1] -
             met->t[ix][iy][ip0] * pows[ip0]) / denom;
          dudp = (met->u[ix][iy][ip1] - met->u[ix][iy][ip0]) / denom;
          dvdp = (met->v[ix][iy][ip1] - met->v[ix][iy][ip0]) / denom;
        }

        /* Calculate PV... */
        met->pv[ix][iy][ip] = (float)
          (1e6 * G0 *
           (-dtdp * (dvdx - dudy / cr + vort) + dvdp * dtdx - dudp * dtdy));
      }
    }
  }

  /* Fix for polar regions... */
#pragma omp parallel for default(shared) private(ix,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (ip = 0; ip < met->np; ip++) {
      met->pv[ix][0][ip]
        = met->pv[ix][1][ip]
        = met->pv[ix][2][ip];
      met->pv[ix][met->ny - 1][ip]
        = met->pv[ix][met->ny - 2][ip]
        = met->pv[ix][met->ny - 3][ip];
    }
}

/*****************************************************************************/

void read_met_sample(
  ctl_t * ctl,
  met_t * met) {

  met_t *help;

  float w, wsum;

  int ip, ip2, ix, ix2, ix3, iy, iy2;

  /* Check parameters... */
  if (ctl->met_dp <= 1 && ctl->met_dx <= 1 && ctl->met_dy <= 1
      && ctl->met_sp <= 1 && ctl->met_sx <= 1 && ctl->met_sy <= 1)
    return;

  /* Set timer... */
  SELECT_TIMER("READ_MET_SAMPLE", NVTX_READ);

  /* Allocate... */
  ALLOC(help, met_t, 1);

  /* Copy data... */
  help->nx = met->nx;
  help->ny = met->ny;
  help->np = met->np;
  memcpy(help->lon, met->lon, sizeof(met->lon));
  memcpy(help->lat, met->lat, sizeof(met->lat));
  memcpy(help->p, met->p, sizeof(met->p));

  /* Smoothing... */
  for (ix = 0; ix < met->nx; ix += ctl->met_dx) {
    for (iy = 0; iy < met->ny; iy += ctl->met_dy) {
      for (ip = 0; ip < met->np; ip += ctl->met_dp) {
        help->ps[ix][iy] = 0;
        help->zs[ix][iy] = 0;
        help->t[ix][iy][ip] = 0;
        help->u[ix][iy][ip] = 0;
        help->v[ix][iy][ip] = 0;
        help->w[ix][iy][ip] = 0;
        help->h2o[ix][iy][ip] = 0;
        help->o3[ix][iy][ip] = 0;
        help->lwc[ix][iy][ip] = 0;
        help->iwc[ix][iy][ip] = 0;
        wsum = 0;
        for (ix2 = ix - ctl->met_sx + 1; ix2 <= ix + ctl->met_sx - 1; ix2++) {
          ix3 = ix2;
          if (ix3 < 0)
```

```
            ix3 += met->nx;
          else if (ix3 >= met->nx)
            ix3 -= met->nx;

          for (iy2 = GSL_MAX(iy - ctl->met_sy + 1, 0);
               iy2 <= GSL_MIN(iy + ctl->met_sy - 1, met->ny - 1); iy2++)
            for (ip2 = GSL_MAX(ip - ctl->met_sp + 1, 0);
                 ip2 <= GSL_MIN(ip + ctl->met_sp - 1, met->np - 1); ip2++) {
              w = (1.0f - (float) abs(ix - ix2) / (float) ctl->met_sx)
                * (1.0f - (float) abs(iy - iy2) / (float) ctl->met_sy)
                * (1.0f - (float) abs(ip - ip2) / (float) ctl->met_sp);
              help->ps[ix][iy] += w * met->ps[ix3][iy2];
              help->zs[ix][iy] += w * met->zs[ix3][iy2];
              help->t[ix][iy][ip] += w * met->t[ix3][iy2][ip2];
              help->u[ix][iy][ip] += w * met->u[ix3][iy2][ip2];
              help->v[ix][iy][ip] += w * met->v[ix3][iy2][ip2];
              help->w[ix][iy][ip] += w * met->w[ix3][iy2][ip2];
              help->h2o[ix][iy][ip] += w * met->h2o[ix3][iy2][ip2];
              help->o3[ix][iy][ip] += w * met->o3[ix3][iy2][ip2];
              help->lwc[ix][iy][ip] += w * met->lwc[ix3][iy2][ip2];
              help->iwc[ix][iy][ip] += w * met->iwc[ix3][iy2][ip2];
              wsum += w;
            }
        }
        help->ps[ix][iy] /= wsum;
        help->zs[ix][iy] /= wsum;
        help->t[ix][iy][ip] /= wsum;
        help->u[ix][iy][ip] /= wsum;
        help->v[ix][iy][ip] /= wsum;
        help->w[ix][iy][ip] /= wsum;
        help->h2o[ix][iy][ip] /= wsum;
        help->o3[ix][iy][ip] /= wsum;
        help->lwc[ix][iy][ip] /= wsum;
        help->iwc[ix][iy][ip] /= wsum;
      }
    }
  }

  /* Downsampling... */
  met->nx = 0;
  for (ix = 0; ix < help->nx; ix += ctl->met_dx) {
    met->lon[met->nx] = help->lon[ix];
    met->ny = 0;
    for (iy = 0; iy < help->ny; iy += ctl->met_dy) {
      met->lat[met->ny] = help->lat[iy];
      met->ps[met->nx][met->ny] = help->ps[ix][iy];
      met->zs[met->nx][met->ny] = help->zs[ix][iy];
      met->np = 0;
      for (ip = 0; ip < help->np; ip += ctl->met_dp) {
        met->p[met->np] = help->p[ip];
        met->t[met->nx][met->ny][met->np] = help->t[ix][iy][ip];
        met->u[met->nx][met->ny][met->np] = help->u[ix][iy][ip];
        met->v[met->nx][met->ny][met->np] = help->v[ix][iy][ip];
        met->w[met->nx][met->ny][met->np] = help->w[ix][iy][ip];
        met->h2o[met->nx][met->ny][met->np] = help->h2o[ix][iy][ip];
        met->o3[met->nx][met->ny][met->np] = help->o3[ix][iy][ip];
        met->lwc[met->nx][met->ny][met->np] = help->lwc[ix][iy][ip];
        met->iwc[met->nx][met->ny][met->np] = help->iwc[ix][iy][ip];
        met->np++;
      }
      met->ny++;
    }
    met->nx++;
  }

  /* Free... */
  free(help);
}

/*****************************************************************************/

void read_met_surface(
  int ncid,
  met_t * met) {

  int ix, iy;

  /* Set timer... */
  SELECT_TIMER("READ_MET_SURFACE", NVTX_READ);

  /* Read surface pressure... */
  if (!read_met_help_2d(ncid, "ps", "PS", met, met->ps, 0.01f)) {
    if (!read_met_help_2d(ncid, "lnsp", "LNSP", met, met->ps, 1.0)) {
      ERRMSG("Cannot not read surface pressure data!");
      for (ix = 0; ix < met->nx; ix++)
        for (iy = 0; iy < met->ny; iy++)
          met->ps[ix][iy] = (float) met->p[0];
```

```
    } else {
      for (iy = 0; iy < met->ny; iy++)
        for (ix = 0; ix < met->nx; ix++)
          met->ps[ix][iy] = (float) (exp(met->ps[ix][iy]) / 100.);
    }
  }

  /* Read geopotential height at the surface... */
  if (!read_met_help_2d
      (ncid, "z", "Z", met, met->zs, (float) (1. / (1000. * G0))))
    if (!read_met_help_2d
        (ncid, "zm", "ZM", met, met->zs, (float) (1. / 1000.)))
      ERRMSG("Cannot read surface geopotential height!");

  /* Read temperature at the surface... */
  if (!read_met_help_2d(ncid, "t2m", "T2M", met, met->ts, 1.0))
    WARN("Cannot read surface temperature!");

  /* Read zonal wind at the surface... */
  if (!read_met_help_2d(ncid, "u10m", "U10M", met, met->us, 1.0))
    WARN("Cannot read surface zonal wind!");

  /* Read meridional wind at the surface... */
  if (!read_met_help_2d(ncid, "v10m", "V10M", met, met->vs, 1.0))
    WARN("Cannot read surface meridional wind!");
}

/*****************************************************************************/

void read_met_tropo(
  ctl_t * ctl,
  met_t * met) {

  double h2ot, p2[200], pv[EP], pv2[200], t[EP], t2[200], th[EP],
    th2[200], tt, z[EP], z2[200], zt;

  int found, ix, iy, iz, iz2;

  /* Set timer... */
  SELECT_TIMER("READ_MET_TROPO", NVTX_READ);

  /* Get altitude and pressure profiles... */
  for (iz = 0; iz < met->np; iz++)
    z[iz] = Z(met->p[iz]);
  for (iz = 0; iz <= 190; iz++) {
    z2[iz] = 4.5 + 0.1 * iz;
    p2[iz] = P(z2[iz]);
  }

  /* Do not calculate tropopause... */
  if (ctl->met_tropo == 0)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        met->pt[ix][iy] = GSL_NAN;

  /* Use tropopause climatology... */
  else if (ctl->met_tropo == 1) {
#pragma omp parallel for default(shared) private(ix,iy)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        met->pt[ix][iy] = (float) clim_tropo(met->time, met->lat[iy]);
  }

  /* Use cold point... */
  else if (ctl->met_tropo == 2) {

    /* Loop over grid points... */
#pragma omp parallel for default(shared) private(ix,iy,iz,t,t2)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {

        /* Interpolate temperature profile... */
        for (iz = 0; iz < met->np; iz++)
          t[iz] = met->t[ix][iy][iz];
        spline(z, t, met->np, z2, t2, 171);

        /* Find minimum... */
        iz = (int) gsl_stats_min_index(t2, 1, 171);
        if (iz > 0 && iz < 170)
          met->pt[ix][iy] = (float) p2[iz];
        else
          met->pt[ix][iy] = GSL_NAN;
      }
  }

  /* Use WMO definition... */
  else if (ctl->met_tropo == 3 || ctl->met_tropo == 4) {
```

```

    /* Loop over grid points... */
#pragma omp parallel for default(shared) private(ix,iy,iz,iz2,t,t2,found)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {

        /* Interpolate temperature profile... */
        for (iz = 0; iz < met->np; iz++)
          t[iz] = met->t[ix][iy][iz];
        spline(z, t, met->np, z2, t2, 191);

        /* Find 1st tropopause... */
        met->pt[ix][iy] = GSL_NAN;
        for (iz = 0; iz <= 170; iz++) {
          found = 1;
          for (iz2 = iz + 1; iz2 <= iz + 20; iz2++)
            if (LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]) > 2.0) {
              found = 0;
              break;
            }
          if (found) {
            if (iz > 0 && iz < 170)
              met->pt[ix][iy] = (float) p2[iz];
            break;
          }
        }

        /* Find 2nd tropopause... */
        if (ctl->met_tropo == 4) {
          met->pt[ix][iy] = GSL_NAN;
          for (; iz <= 170; iz++) {
            found = 1;
            for (iz2 = iz + 1; iz2 <= iz + 10; iz2++)
              if (LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]) < 3.0) {
                found = 0;
                break;
              }
            if (found)
              break;
          }
          for (; iz <= 170; iz++) {
            found = 1;
            for (iz2 = iz + 1; iz2 <= iz + 20; iz2++)
              if (LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]) > 2.0) {
                found = 0;
                break;
              }
            if (found) {
              if (iz > 0 && iz < 170)
                met->pt[ix][iy] = (float) p2[iz];
              break;
            }
          }
        }
      }
  }

  /* Use dynamical tropopause... */
  else if (ctl->met_tropo == 5) {

    /* Loop over grid points... */
#pragma omp parallel for default(shared) private(ix,iy,iz,pv,pv2,th,th2)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {

        /* Interpolate potential vorticity profile... */
        for (iz = 0; iz < met->np; iz++)
          pv[iz] = met->pv[ix][iy][iz];
        spline(z, pv, met->np, z2, pv2, 171);

        /* Interpolate potential temperature profile... */
        for (iz = 0; iz < met->np; iz++)
          th[iz] = THETA(met->p[iz], met->t[ix][iy][iz]);
        spline(z, th, met->np, z2, th2, 171);

        /* Find dynamical tropopause 3.5 PVU + 380 K */
        met->pt[ix][iy] = GSL_NAN;
        for (iz = 0; iz <= 170; iz++)
          if (fabs(pv2[iz]) >= 3.5 || th2[iz] >= 380.) {
            if (iz > 0 && iz < 170)
              met->pt[ix][iy] = (float) p2[iz];
            break;
          }
      }
  }

  else
```

```
    ERRMSG("Cannot calculate tropopause!");

  /* Interpolate temperature, geopotential height, and water vapor vmr... */
#pragma omp parallel for default(shared) private(ix,iy,tt,zt,h2ot)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {
      INTPOL_INIT;
      intpol_met_space_3d(met, met->t, met->pt[ix][iy], met->lon[ix],
                          met->lat[iy], &tt, ci, cw, 1);
      intpol_met_space_3d(met, met->z, met->pt[ix][iy], met->lon[ix],
                          met->lat[iy], &zt, ci, cw, 0);
      intpol_met_space_3d(met, met->h2o, met->pt[ix][iy], met->lon[ix],
                          met->lat[iy], &h2ot, ci, cw, 0);
      met->tt[ix][iy] = (float) tt;
      met->zt[ix][iy] = (float) zt;
      met->h2ot[ix][iy] = (float) h2ot;
    }
}

/*****************************************************************************/

double scan_ctl(
  const char *filename,
  int argc,
  char *argv[],
  const char *varname,
  int arridx,
  const char *defvalue,
  char *value) {

  FILE *in = NULL;

  char dummy[LEN], fullname1[LEN], fullname2[LEN], line[LEN],
    msg[2 * LEN], rvarname[LEN], rval[LEN];

  int contain = 0, i;

  /* Open file... */
  if (filename[strlen(filename) - 1] != '-')
    if (!(in = fopen(filename, "r")))
      ERRMSG("Cannot open file!");

  /* Set full variable name... */
  if (arridx >= 0) {
    sprintf(fullname1, "%s[%d]", varname, arridx);
    sprintf(fullname2, "%s[*]", varname);
  } else {
    sprintf(fullname1, "%s", varname);
    sprintf(fullname2, "%s", varname);
  }

  /* Read data... */
  if (in != NULL)
    while (fgets(line, LEN, in))
      if (sscanf(line, "%s %s %s", rvarname, dummy, rval) == 3)
        if (strcasecmp(rvarname, fullname1) == 0 ||
            strcasecmp(rvarname, fullname2) == 0) {
          contain = 1;
          break;
        }
  for (i = 1; i < argc - 1; i++)
    if (strcasecmp(argv[i], fullname1) == 0 ||
        strcasecmp(argv[i], fullname2) == 0) {
      sprintf(rval, "%s", argv[i + 1]);
      contain = 1;
      break;
    }

  /* Close file... */
  if (in != NULL)
    fclose(in);

  /* Check for missing variables... */
  if (!contain) {
    if (strlen(defvalue) > 0)
      sprintf(rval, "%s", defvalue);
    else {
      sprintf(msg, "Missing variable %s!\n", fullname1);
      ERRMSG(msg);
    }
  }

  /* Write info... */
  printf("%s = %s\n", fullname1, rval);

  /* Return values... */
  if (value != NULL)
```

```
    sprintf(value, "%s", rval);
  return atof(rval);
}

/*****************************************************************************/

double sedi(
  double p,
  double T,
  double r_p,
  double rho_p) {

  double eta, G, K, lambda, rho, v;

  /* Convert units... */
  p *= 100.;                      /* from hPa to Pa */
  r_p *= 1e-6;                    /* from microns to m */

  /* Density of dry air... */
  rho = p / (RA * T);

  /* Dynamic viscosity of air... */
  eta = 1.8325e-5 * (416.16 / (T + 120.)) * pow(T / 296.16, 1.5);

  /* Thermal velocity of an air molecule... */
  v = sqrt(8. * KB * T / (M_PI * 4.8096e-26));

  /* Mean free path of an air molecule... */
  lambda = 2. * eta / (rho * v);

  /* Knudsen number for air... */
  K = lambda / r_p;

  /* Cunningham slip-flow correction... */
  G = 1. + K * (1.249 + 0.42 * exp(-0.87 / K));

  /* Sedimentation velocity... */
  return 2. * SQR(r_p) * (rho_p - rho) * G0 / (9. * eta) * G;
}

/*****************************************************************************/

void spline(
  double *x,
  double *y,
  int n,
  double *x2,
  double *y2,
  int n2) {

  gsl_interp_accel *acc;

  gsl_spline *s;

  /* Allocate... */
  acc = gsl_interp_accel_alloc();
  s = gsl_spline_alloc(gsl_interp_cspline, (size_t) n);

  /* Interpolate profile... */
  gsl_spline_init(s, x, y, (size_t) n);
  for (int i = 0; i < n2; i++)
    if (x2[i] <= x[0])
      y2[i] = y[0];
    else if (x2[i] >= x[n - 1])
      y2[i] = y[n - 1];
    else
      y2[i] = gsl_spline_eval(s, x2[i], acc);

  /* Free... */
  gsl_spline_free(s);
  gsl_interp_accel_free(acc);
}

/*****************************************************************************/

double stddev(
  double *data,
  int n) {

  if (n <= 0)
    return 0;

  double avg = 0, rms = 0;

  for (int i = 0; i < n; ++i)
    avg += data[i];
  avg /= n;
```

```

  for (int i = 0; i < n; ++i)
    rms += SQR(data[i] - avg);

  return sqrt(rms / (n - 1));
}

/*****************************************************************************/

void time2jsec(
  int year,
  int mon,
  int day,
  int hour,
  int min,
  int sec,
  double remain,
  double *jsec) {

  struct tm t0, t1;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  t1.tm_year = year - 1900;
  t1.tm_mon = mon - 1;
  t1.tm_mday = day;
  t1.tm_hour = hour;
  t1.tm_min = min;
  t1.tm_sec = sec;

  *jsec = (double) timegm(&t1) - (double) timegm(&t0) + remain;
}

/*****************************************************************************/

void timer(
  const char *name,
  int output) {

  static char namelist[NTIMER][100];

  static double runtime[NTIMER], t0, t1;

  static int it = -1, nt;

  /* Get time... */
  t1 = omp_get_wtime();

  /* Add elapsed timer to old timer... */
  if (it >= 0)
    runtime[it] += t1 - t0;

  /* Identify ID of new timer... */
  for (it = 0; it < nt; it++)
    if (strcasecmp(name, namelist[it]) == 0)
      break;

  /* Check whether this is a new timer... */
  if (it >= nt) {
    sprintf(namelist[it], "%s", name);
    if ((++nt) > NTIMER)
      ERRMSG("Too many timers!");
  }

  /* Save starting time... */
  t0 = t1;

  /* Report timers... */
  if (output) {
    for (int it2 = 0; it2 < nt; it2++)
      printf("TIMER_%s = %.3f s\n", namelist[it2], runtime[it2]);
    double total = 0.0;
    for (int it2 = 0; it2 < nt; it2++)
      total += runtime[it2];
    printf("TIMER_TOTAL = %.3f s\n", total);
  }
}

/*****************************************************************************/

void write_atm(
  const char *filename,
```

```
ctl_t * ctl,
atm_t * atm,
double t) {

FILE *in, *out;

char line[LEN];

double r, t0, t1;

int ip, iq, year, mon, day, hour, min, sec;

/* Set timer... */
SELECT_TIMER("WRITE_ATM", NVTX_WRITE);

/* Set time interval for output... */
t0 = t - 0.5 * ctl->dt_mod;
t1 = t + 0.5 * ctl->dt_mod;

/* Write info... */
printf("Write atmospheric data: %s\n", filename);

/* Write ASCII data... */
if (ctl->atm_type == 0) {

  /* Check if gnuplot output is requested... */
  if (ctl->atm_gpfile[0] != '-') {

    /* Create gnuplot pipe... */
    if (!(out = popen("gnuplot", "w")))
      ERRMSG("Cannot create pipe to gnuplot!");

    /* Set plot filename... */
    fprintf(out, "set out \"%s.png\"\n", filename);

    /* Set time string... */
    jsec2time(t, &year, &mon, &day, &hour, &min, &sec, &r);
    fprintf(out, "timestr=\"%d-%02d-%02d, %02d:%02d UTC\"\n",
            year, mon, day, hour, min);

    /* Dump gnuplot file to pipe... */
    if (!(in = fopen(ctl->atm_gpfile, "r")))
      ERRMSG("Cannot open file!");
    while (fgets(line, LEN, in))
      fprintf(out, "%s", line);
    fclose(in);
  }

  else {

    /* Create file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");
  }

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
  for (iq = 0; iq < ctl->nq; iq++)
    fprintf(out, "# $%i = %s [%s]\n", iq + 5, ctl->qnt_name[iq],
            ctl->qnt_unit[iq]);
  fprintf(out, "\n");

  /* Write data... */
  for (ip = 0; ip < atm->np; ip += ctl->atm_stride) {

    /* Check time... */
    if (ctl->atm_filter && (atm->time[ip] < t0 || atm->time[ip] > t1))
      continue;

    /* Write output... */
    fprintf(out, "%.2f %g %g %g", atm->time[ip], Z(atm->p[ip]),
            atm->lon[ip], atm->lat[ip]);
    for (iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], atm->q[iq][ip]);
    }
    fprintf(out, "\n");
  }

  /* Close file... */
  fclose(out);
}

/* Write binary data... */
```

```
  else if (ctl->atm_type == 1) {

    /* Create file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write data... */
    FWRITE(&atm->np, int,
           1,
           out);
    FWRITE(atm->time, double,
             (size_t) atm->np,
           out);
    FWRITE(atm->p, double,
             (size_t) atm->np,
           out);
    FWRITE(atm->lon, double,
             (size_t) atm->np,
           out);
    FWRITE(atm->lat, double,
             (size_t) atm->np,
           out);
    for (iq = 0; iq < ctl->nq; iq++)
      FWRITE(atm->q[iq], double,
               (size_t) atm->np,
             out);

    /* Close file... */
    fclose(out);
  }

  /* Error... */
  else
    ERRMSG("Atmospheric data type not supported!");
}

/*****************************************************************************/

void write_csi(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm,
  double t) {

  static FILE *in, *out;

  static char line[LEN];

  static double modmean[GX][GY][GZ], obsmean[GX][GY][GZ], rt, rt_old = -1e99,
    rz, rlon, rlat, robs, t0, t1, area[GY], dlon, dlat, dz, lat,
    x[1000000], y[1000000], work[2000000];

  static int obscount[GX][GY][GZ], ct, cx, cy, cz, ip, ix, iy, iz, n;

  /* Set timer... */
  SELECT_TIMER("WRITE_CSI", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Check quantity index for mass... */
    if (ctl->qnt_m < 0)
      ERRMSG("Need quantity mass!");

    /* Open observation data file... */
    printf("Read CSI observation data: %s\n", ctl->csi_obsfile);
    if (!(in = fopen(ctl->csi_obsfile, "r")))
      ERRMSG("Cannot open file!");

    /* Create new file... */
    printf("Write CSI data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = number of hits (cx)\n"
            "# $3 = number of misses (cy)\n"
            "# $4 = number of false alarms (cz)\n"
            "# $5 = number of observations (cx + cy)\n"
            "# $6 = number of forecasts (cx + cz)\n"
            "# $7 = bias (ratio of forecasts and observations) [%%]\n"
            "# $8 = probability of detection (POD) [%%]\n"
            "# $9 = false alarm rate (FAR) [%%]\n"
            "# $10 = critical success index (CSI) [%%]\n");
    fprintf(out,
```

```
            "# $11 = hits associated with random chance\n"
            "# $12 = equitable threat score (ETS) [%%]\n"
            "# $13 = Pearson linear correlation coefficient\n"
            "# $14 = Spearman rank-order correlation coefficient\n"
            "# $15 = column density mean error (F - O) [kg/m^2]\n"
            "# $16 = column density root mean square error (RMSE) [kg/m^2]\n"
            "# $17 = column density mean absolute error [kg/m^2]\n"
            "# $18 = number of data points\n\n");

    /* Set grid box size... */
    dz = (ctl->csi_z1 - ctl->csi_z0) / ctl->csi_nz;
    dlon = (ctl->csi_lon1 - ctl->csi_lon0) / ctl->csi_nx;
    dlat = (ctl->csi_lat1 - ctl->csi_lat0) / ctl->csi_ny;

    /* Set horizontal coordinates... */
    for (iy = 0; iy < ctl->csi_ny; iy++) {
      lat = ctl->csi_lat0 + dlat * (iy + 0.5);
      area[iy] = dlat * dlon * SQR(RE * M_PI / 180.) * cos(lat * M_PI / 180.);
    }
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize grid cells... */
#pragma omp parallel for default(shared) private(ix,iy,iz)
  for (ix = 0; ix < ctl->csi_nx; ix++)
    for (iy = 0; iy < ctl->csi_ny; iy++)
      for (iz = 0; iz < ctl->csi_nz; iz++)
        modmean[ix][iy][iz] = obsmean[ix][iy][iz] = obscount[ix][iy][iz] = 0;

  /* Read observation data... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg %lg", &rt, &rz, &rlon, &rlat, &robs) !=
        5)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt > t1)
      break;
    if (rt < rt_old)
      ERRMSG("Time must be ascending!");
    rt_old = rt;

    /* Check observation data... */
    if (!isfinite(robs))
      continue;

    /* Calculate indices... */
    ix = (int) ((rlon - ctl->csi_lon0) / dlon);
    iy = (int) ((rlat - ctl->csi_lat0) / dlat);
    iz = (int) ((rz - ctl->csi_z0) / dz);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->csi_nx ||
        iy < 0 || iy >= ctl->csi_ny || iz < 0 || iz >= ctl->csi_nz)
      continue;

    /* Get mean observation index... */
    obsmean[ix][iy][iz] += robs;
    obscount[ix][iy][iz]++;
  }

  /* Analyze model data... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Get indices... */
    ix = (int) ((atm->lon[ip] - ctl->csi_lon0) / dlon);
    iy = (int) ((atm->lat[ip] - ctl->csi_lat0) / dlat);
    iz = (int) ((Z(atm->p[ip]) - ctl->csi_z0) / dz);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->csi_nx ||
        iy < 0 || iy >= ctl->csi_ny || iz < 0 || iz >= ctl->csi_nz)
      continue;

    /* Get total mass in grid cell... */
    modmean[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
```

```
  }

  /* Analyze all grid cells... */
  for (ix = 0; ix < ctl->csi_nx; ix++)
    for (iy = 0; iy < ctl->csi_ny; iy++)
      for (iz = 0; iz < ctl->csi_nz; iz++) {

        /* Calculate mean observation index... */
        if (obscount[ix][iy][iz] > 0)
          obsmean[ix][iy][iz] /= obscount[ix][iy][iz];

        /* Calculate column density... */
        if (modmean[ix][iy][iz] > 0)
          modmean[ix][iy][iz] /= (1e6 * area[iy]);

        /* Calculate CSI... */
        if (obscount[ix][iy][iz] > 0) {
          ct++;
          if (obsmean[ix][iy][iz] >= ctl->csi_obsmin &&
              modmean[ix][iy][iz] >= ctl->csi_modmin)
            cx++;
          else if (obsmean[ix][iy][iz] >= ctl->csi_obsmin &&
                   modmean[ix][iy][iz] < ctl->csi_modmin)
            cy++;
          else if (obsmean[ix][iy][iz] < ctl->csi_obsmin &&
                   modmean[ix][iy][iz] >= ctl->csi_modmin)
            cz++;
        }

        /* Save data for other verification statistics... */
        if (obscount[ix][iy][iz] > 0
            && (obsmean[ix][iy][iz] >= ctl->csi_obsmin
                || modmean[ix][iy][iz] >= ctl->csi_modmin)) {
          x[n] = modmean[ix][iy][iz];
          y[n] = obsmean[ix][iy][iz];
          if ((++n) > 1000000)
            ERRMSG("Too many data points to calculate statistics!");
        }
      }

  /* Write output... */
  if (fmod(t, ctl->csi_dt_out) == 0) {

    /* Calculate verification statistics
       (https://www.cawcr.gov.au/projects/verification/) ... */
    int nobs = cx + cy;
    int nfor = cx + cz;
    double bias = (nobs > 0) ? 100. * nfor / nobs : GSL_NAN;
    double pod = (nobs > 0) ? (100. * cx) / nobs : GSL_NAN;
    double far = (nfor > 0) ? (100. * cz) / nfor : GSL_NAN;
    double csi = (cx + cy + cz > 0) ? (100. * cx) / (cx + cy + cz) : GSL_NAN;
    double cx_rd = (ct > 0) ? (1. * nobs * nfor) / ct : GSL_NAN;
    double ets = (cx + cy + cz - cx_rd > 0) ?
      (100. * (cx - cx_rd)) / (cx + cy + cz - cx_rd) : GSL_NAN;
    double rho_p =
      (n > 0) ? gsl_stats_correlation(x, 1, y, 1, (size_t) n) : GSL_NAN;
    double rho_s =
      (n > 0) ? gsl_stats_spearman(x, 1, y, 1, (size_t) n, work) : GSL_NAN;
    for (int i = 0; i < n; i++)
      work[i] = x[i] - y[i];
    double mean = (n > 0) ? gsl_stats_mean(work, 1, (size_t) n) : GSL_NAN;
    double rmse = (n > 0) ? gsl_stats_sd_with_fixed_mean(work, 1, (size_t) n,
                                                         0.0) : GSL_NAN;
    double absdev =
      (n > 0) ? gsl_stats_absdev_m(work, 1, (size_t) n, 0.0) : GSL_NAN;

    /* Write... */
    fprintf(out, "%.2f %d %d %d %d %d %g %g %g %g %g %g %g %g %g %g %g %d\n",
            t, cx, cy, cz, nobs, nfor, bias, pod, far, csi, cx_rd, ets,
            rho_p, rho_s, mean, rmse, absdev, n);

    /* Set counters to zero... */
    n = ct = cx = cy = cz = 0;
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}

/*****************************************************************************/

void write_ens(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm,
  double t) {
```

```

  static FILE *out;

  static double dummy, ens, lat, lon, p[NENS], q[NQ][NENS],
    t0, t1, x[NENS][3], xm[3];

  static int ip, iq;

  static size_t i, n;

  /* Set timer... */
  SELECT_TIMER("WRITE_ENS", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Check quantities... */
    if (ctl->qnt_ens < 0)
      ERRMSG("Missing ensemble IDs!");

    /* Create new file... */
    printf("Write ensemble data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
    for (iq = 0; iq < ctl->nq; iq++)
      fprintf(out, "# $%d = %s (mean) [%s]\n", 5 + iq,
              ctl->qnt_name[iq], ctl->qnt_unit[iq]);
    for (iq = 0; iq < ctl->nq; iq++)
      fprintf(out, "# $%d = %s (sigma) [%s]\n", 5 + ctl->nq + iq,
              ctl->qnt_name[iq], ctl->qnt_unit[iq]);
    fprintf(out, "# $%d = number of members\n\n", 5 + 2 * ctl->nq);
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Init... */
  ens = GSL_NAN;
  n = 0;

  /* Loop over air parcels... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Check ensemble id... */
    if (atm->q[ctl->qnt_ens][ip] != ens) {

      /* Write results... */
      if (n > 0) {

        /* Get mean position... */
        xm[0] = xm[1] = xm[2] = 0;
        for (i = 0; i < n; i++) {
          xm[0] += x[i][0] / (double) n;
          xm[1] += x[i][1] / (double) n;
          xm[2] += x[i][2] / (double) n;
        }
        cart2geo(xm, &dummy, &lon, &lat);
        fprintf(out, "%.2f %g %g %g", t, Z(gsl_stats_mean(p, 1, n)), lon,
                lat);

        /* Get quantity statistics... */
        for (iq = 0; iq < ctl->nq; iq++) {
          fprintf(out, " ");
          fprintf(out, ctl->qnt_format[iq], gsl_stats_mean(q[iq], 1, n));
        }
        for (iq = 0; iq < ctl->nq; iq++) {
          fprintf(out, " ");
          fprintf(out, ctl->qnt_format[iq], gsl_stats_sd(q[iq], 1, n));
        }
        fprintf(out, " %lu\n", n);
      }

      /* Init new ensemble... */
      ens = atm->q[ctl->qnt_ens][ip];
      n = 0;
    }
```

```

    /* Save data... */
    p[n] = atm->p[ip];
    geo2cart(0, atm->lon[ip], atm->lat[ip], x[n]);
    for (iq = 0; iq < ctl->nq; iq++)
      q[iq][n] = atm->q[iq][ip];
    if ((++n) >= NENS)
      ERRMSG("Too many data points!");
  }

  /* Write results... */
  if (n > 0) {

    /* Get mean position... */
    xm[0] = xm[1] = xm[2] = 0;
    for (i = 0; i < n; i++) {
      xm[0] += x[i][0] / (double) n;
      xm[1] += x[i][1] / (double) n;
      xm[2] += x[i][2] / (double) n;
    }
    cart2geo(xm, &dummy, &lon, &lat);
    fprintf(out, "%.2f %g %g %g", t, Z(gsl_stats_mean(p, 1, n)), lon, lat);

    /* Get quantity statistics... */
    for (iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], gsl_stats_mean(q[iq], 1, n));
    }
    for (iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], gsl_stats_sd(q[iq], 1, n));
    }
    fprintf(out, " %lu\n", n);
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}

/*****************************************************************************/

void write_grid(
  const char *filename,
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double t) {

  FILE *in, *out;

  char line[LEN];

  static double mass[GX][GY][GZ], z[GZ], dz, lon[GX], dlon, lat[GY], dlat,
    area[GY], rho_air, press[GZ], temp, cd, vmr, t0, t1, r;

  static int ip, ix, iy, iz, np[GX][GY][GZ], year, mon, day, hour, min, sec;

  /* Set timer... */
  SELECT_TIMER("WRITE_GRID", NVTX_WRITE);

  /* Check dimensions... */
  if (ctl->grid_nx > GX || ctl->grid_ny > GY || ctl->grid_nz > GZ)
    ERRMSG("Grid dimensions too large!");

  /* Set grid box size... */
  dz = (ctl->grid_z1 - ctl->grid_z0) / ctl->grid_nz;
  dlon = (ctl->grid_lon1 - ctl->grid_lon0) / ctl->grid_nx;
  dlat = (ctl->grid_lat1 - ctl->grid_lat0) / ctl->grid_ny;

  /* Set vertical coordinates... */
  for (iz = 0; iz < ctl->grid_nz; iz++) {
    z[iz] = ctl->grid_z0 + dz * (iz + 0.5);
    press[iz] = P(z[iz]);
  }

  /* Set horizontal coordinates... */
  for (ix = 0; ix < ctl->grid_nx; ix++)
    lon[ix] = ctl->grid_lon0 + dlon * (ix + 0.5);
  for (iy = 0; iy < ctl->grid_ny; iy++) {
    lat[iy] = ctl->grid_lat0 + dlat * (iy + 0.5);
    area[iy] = dlat * dlon * SQR(RE * M_PI / 180.)
      * cos(lat[iy] * M_PI / 180.);
  }

  /* Set time interval for output... */
```

```
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize grid... */
#pragma omp parallel for default(shared) private(ix,iy,iz)
  for (ix = 0; ix < ctl->grid_nx; ix++)
    for (iy = 0; iy < ctl->grid_ny; iy++)
      for (iz = 0; iz < ctl->grid_nz; iz++) {
        mass[ix][iy][iz] = 0;
        np[ix][iy][iz] = 0;
      }

  /* Average data... */
  for (ip = 0; ip < atm->np; ip++)
    if (atm->time[ip] >= t0 && atm->time[ip] <= t1) {

      /* Get index... */
      ix = (int) ((atm->lon[ip] - ctl->grid_lon0) / dlon);
      iy = (int) ((atm->lat[ip] - ctl->grid_lat0) / dlat);
      iz = (int) ((Z(atm->p[ip]) - ctl->grid_z0) / dz);

      /* Check indices... */
      if (ix < 0 || ix >= ctl->grid_nx ||
          iy < 0 || iy >= ctl->grid_ny || iz < 0 || iz >= ctl->grid_nz)
        continue;

      /* Add mass... */
      if (ctl->qnt_m >= 0)
        mass[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
      np[ix][iy][iz]++;
    }

  /* Check if gnuplot output is requested... */
  if (ctl->grid_gpfile[0] != '-') {

    /* Write info... */
    printf("Plot grid data: %s.png\n", filename);

    /* Create gnuplot pipe... */
    if (!(out = popen("gnuplot", "w")))
      ERRMSG("Cannot create pipe to gnuplot!");

    /* Set plot filename... */
    fprintf(out, "set out \"%s.png\"\n", filename);

    /* Set time string... */
    jsec2time(t, &year, &mon, &day, &hour, &min, &sec, &r);
    fprintf(out, "timestr=\"%d-%02d-%02d, %02d:%02d UTC\"\n",
            year, mon, day, hour, min);

    /* Dump gnuplot file to pipe... */
    if (!(in = fopen(ctl->grid_gpfile, "r")))
      ERRMSG("Cannot open file!");
    while (fgets(line, LEN, in))
      fprintf(out, "%s", line);
    fclose(in);
  }

  else {

    /* Write info... */
    printf("Write grid data: %s\n", filename);

    /* Create file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");
  }

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = surface area [km^2]\n"
          "# $6 = layer width [km]\n"
          "# $7 = number of particles [1]\n"
          "# $8 = column density [kg/m^2]\n"
          "# $9 = volume mixing ratio [ppv]\n\n");

  /* Write data... */
  for (ix = 0; ix < ctl->grid_nx; ix++) {
    if (ix > 0 && ctl->grid_ny > 1 && !ctl->grid_sparse)
      fprintf(out, "\n");
    for (iy = 0; iy < ctl->grid_ny; iy++) {
      if (iy > 0 && ctl->grid_nz > 1 && !ctl->grid_sparse)
        fprintf(out, "\n");
```

```
      for (iz = 0; iz < ctl->grid_nz; iz++)
        if (!ctl->grid_sparse || mass[ix][iy][iz] > 0) {

          /* Calculate column density... */
          cd = mass[ix][iy][iz] / (1e6 * area[iy]);

          /* Calculate volume mixing ratio... */
          vmr = 0;
          if (ctl->molmass > 0) {
            if (mass[ix][iy][iz] > 0) {

              /* Get temperature... */
              INTPOL_INIT;
              intpol_met_time_3d(met0, met0->t, met1, met1->t, t, press[iz],
                                 lon[ix], lat[iy], &temp, ci, cw, 1);

              /* Calculate density of air... */
              rho_air = 100. * press[iz] / (RA * temp);

              /* Calculate volume mixing ratio... */
              vmr = MA / ctl->molmass * mass[ix][iy][iz]
                / (rho_air * 1e6 * area[iy] * 1e3 * dz);
            }
          } else
            vmr = GSL_NAN;

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %d %g %g\n", t, z[iz],
                  lon[ix], lat[iy], area[iy], dz, np[ix][iy][iz], cd, vmr);
        }
    }
  }

  /* Close file... */
  fclose(out);
}

/*****************************************************************************/

void write_prof(
  const char *filename,
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double t) {

  static FILE *in, *out;

  static char line[LEN];

  static double mass[GX][GY][GZ], obsmean[GX][GY], rt, rt_old = -1e99,
    rz, rlon, rlat, robs, t0, t1, area[GY], dz, dlon, dlat, lon[GX], lat[GY],
    z[GZ], press[GZ], temp, rho_air, vmr, h2o, o3;

  static int obscount[GX][GY], ip, ix, iy, iz, okay;

  /* Set timer... */
  SELECT_TIMER("WRITE_PROF", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Check quantity index for mass... */
    if (ctl->qnt_m < 0)
      ERRMSG("Need quantity mass!");

    /* Check dimensions... */
    if (ctl->prof_nx > GX || ctl->prof_ny > GY || ctl->prof_nz > GZ)
      ERRMSG("Grid dimensions too large!");

    /* Check molar mass... */
    if (ctl->molmass <= 0)
      ERRMSG("Specify molar mass!");

    /* Open observation data file... */
    printf("Read profile observation data: %s\n", ctl->prof_obsfile);
    if (!(in = fopen(ctl->prof_obsfile, "r")))
      ERRMSG("Cannot open file!");

    /* Create new output file... */
    printf("Write profile data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
```

```
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n"
            "# $4 = latitude [deg]\n"
            "# $5 = pressure [hPa]\n"
            "# $6 = temperature [K]\n"
            "# $7 = volume mixing ratio [ppv]\n"
            "# $8 = H2O volume mixing ratio [ppv]\n"
            "# $9 = O3 volume mixing ratio [ppv]\n"
            "# $10 = observed BT index [K]\n");

    /* Set grid box size... */
    dz = (ctl->prof_z1 - ctl->prof_z0) / ctl->prof_nz;
    dlon = (ctl->prof_lon1 - ctl->prof_lon0) / ctl->prof_nx;
    dlat = (ctl->prof_lat1 - ctl->prof_lat0) / ctl->prof_ny;

    /* Set vertical coordinates... */
    for (iz = 0; iz < ctl->prof_nz; iz++) {
      z[iz] = ctl->prof_z0 + dz * (iz + 0.5);
      press[iz] = P(z[iz]);
    }

    /* Set horizontal coordinates... */
    for (ix = 0; ix < ctl->prof_nx; ix++)
      lon[ix] = ctl->prof_lon0 + dlon * (ix + 0.5);
    for (iy = 0; iy < ctl->prof_ny; iy++) {
      lat[iy] = ctl->prof_lat0 + dlat * (iy + 0.5);
      area[iy] = dlat * dlon * SQR(RE * M_PI / 180.)
        * cos(lat[iy] * M_PI / 180.);
    }
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize... */
#pragma omp parallel for default(shared) private(ix,iy,iz)
  for (ix = 0; ix < ctl->prof_nx; ix++)
    for (iy = 0; iy < ctl->prof_ny; iy++) {
      obsmean[ix][iy] = 0;
      obscount[ix][iy] = 0;
      for (iz = 0; iz < ctl->prof_nz; iz++)
        mass[ix][iy][iz] = 0;
    }

  /* Read observation data... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg %lg", &rt, &rz, &rlon, &rlat, &robs) !=
        5)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt > t1)
      break;
    if (rt < rt_old)
      ERRMSG("Time must be ascending!");
    rt_old = rt;

    /* Check observation data... */
    if (!isfinite(robs))
      continue;

    /* Calculate indices... */
    ix = (int) ((rlon - ctl->prof_lon0) / dlon);
    iy = (int) ((rlat - ctl->prof_lat0) / dlat);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->prof_nx || iy < 0 || iy >= ctl->prof_ny)
      continue;

    /* Get mean observation index... */
    obsmean[ix][iy] += robs;
    obscount[ix][iy]++;
  }

  /* Analyze model data... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

```

```
    /* Get indices... */
    ix = (int) ((atm->lon[ip] - ctl->prof_lon0) / dlon);
    iy = (int) ((atm->lat[ip] - ctl->prof_lat0) / dlat);
    iz = (int) ((Z(atm->p[ip]) - ctl->prof_z0) / dz);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->prof_nx ||
        iy < 0 || iy >= ctl->prof_ny || iz < 0 || iz >= ctl->prof_nz)
      continue;

    /* Get total mass in grid cell... */
    mass[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
  }

  /* Extract profiles... */
  for (ix = 0; ix < ctl->prof_nx; ix++)
    for (iy = 0; iy < ctl->prof_ny; iy++)
      if (obscount[ix][iy] > 0) {

        /* Check profile... */
        okay = 0;
        for (iz = 0; iz < ctl->prof_nz; iz++)
          if (mass[ix][iy][iz] > 0) {
            okay = 1;
            break;
          }
        if (!okay)
          continue;

        /* Write output... */
        fprintf(out, "\n");

        /* Loop over altitudes... */
        for (iz = 0; iz < ctl->prof_nz; iz++) {

          /* Get pressure and temperature... */
          INTPOL_INIT;
          intpol_met_time_3d(met0, met0->t, met1, met1->t, t, press[iz],
                             lon[ix], lat[iy], &temp, ci, cw, 1);
          intpol_met_time_3d(met0, met0->h2o, met1, met1->h2o, t, press[iz],
                             lon[ix], lat[iy], &h2o, ci, cw, 0);
          intpol_met_time_3d(met0, met0->o3, met1, met1->o3, t, press[iz],
                             lon[ix], lat[iy], &o3, ci, cw, 0);

          /* Calculate volume mixing ratio... */
          rho_air = 100. * press[iz] / (RA * temp);
          vmr = MA / ctl->molmass * mass[ix][iy][iz]
            / (rho_air * area[iy] * dz * 1e9);

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g\n",
                  t, z[iz], lon[ix], lat[iy], press[iz], temp, vmr, h2o, o3,
                  obsmean[ix][iy] / obscount[ix][iy]);
        }
      }

  /* Close files... */
  if (t == ctl->t_stop) {
    fclose(in);
    fclose(out);
  }
}

/*****************************************************************************/

void write_sample(
  const char *filename,
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double t) {

  static FILE *in, *out;

  static char line[LEN];

  static double area, dlat, rmax2, t0, t1, rt, rt_old, rz, rlon, rlat, robs;

  /* Set timer... */
  SELECT_TIMER("WRITE_SAMPLE", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Open observation data file... */
    printf("Read sample observation data: %s\n", ctl->sample_obsfile);
```

```
    if (!(in = fopen(ctl->sample_obsfile, "r")))
      ERRMSG("Cannot open file!");

    /* Create new file... */
    printf("Write sample data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n"
            "# $4 = latitude [deg]\n"
            "# $5 = surface area [km^2]\n"
            "# $6 = layer width [km]\n"
            "# $7 = number of particles [1]\n"
            "# $8 = column density [kg/m^2]\n"
            "# $9 = volume mixing ratio [ppv]\n"
            "# $10 = observed BT index [K]\n\n");

    /* Set latitude range, squared radius, and area... */
    dlat = DY2DEG(ctl->sample_dx);
    rmax2 = SQR(ctl->sample_dx);
    area = M_PI * rmax2;
  }

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Read observation data... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg %lg", &rt, &rz, &rlon, &rlat, &robs) !=
        5)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt < rt_old)
      ERRMSG("Time must be ascending!");
    rt_old = rt;

    /* Calculate Cartesian coordinates... */
    double x0[3];
    geo2cart(0, rlon, rlat, x0);

    /* Set pressure range... */
    double rp = P(rz);
    double ptop = P(rz + ctl->sample_dz);
    double pbot = P(rz - ctl->sample_dz);

    /* Init... */
    double mass = 0;
    int np = 0;

    /* Loop over air parcels... */
#pragma omp parallel for default(shared) reduction(+:mass,np)
    for (int ip = 0; ip < atm->np; ip++) {

      /* Check time... */
      if (atm->time[ip] < t0 || atm->time[ip] > t1)
        continue;

      /* Check latitude... */
      if (fabs(rlat - atm->lat[ip]) > dlat)
        continue;

      /* Check horizontal distance... */
      double x1[3];
      geo2cart(0, atm->lon[ip], atm->lat[ip], x1);
      if (DIST2(x0, x1) > rmax2)
        continue;

      /* Check pressure... */
      if (ctl->sample_dz > 0)
        if (atm->p[ip] > pbot || atm->p[ip] < ptop)
          continue;

      /* Add mass... */
      if (ctl->qnt_m >= 0)
        mass += atm->q[ctl->qnt_m][ip];
      np++;
    }
```

```

    /* Calculate column density... */
    double cd = mass / (1e6 * area);

    /* Calculate volume mixing ratio... */
    double vmr = 0;
    if (ctl->molmass > 0 && ctl->sample_dz > 0) {
      if (mass > 0) {

        /* Get temperature... */
        double temp;
        INTPOL_INIT;
        intpol_met_time_3d(met0, met0->t, met1, met1->t, rt, rp,
                           rlon, rlat, &temp, ci, cw, 1);

        /* Calculate density of air... */
        double rho_air = 100. * rp / (RA * temp);

        /* Calculate volume mixing ratio... */
        vmr = MA / ctl->molmass * mass
          / (rho_air * 1e6 * area * 1e3 * ctl->sample_dz);
      }
    } else
      vmr = GSL_NAN;

    /* Write output... */
    fprintf(out, "%.2f %g %g %g %g %g %d %g %g %g\n", rt, rz, rlon, rlat,
            area, ctl->sample_dz, np, cd, vmr, robs);

    /* Check time... */
    if (rt >= t1)
      break;
  }

  /* Close files... */
  if (t == ctl->t_stop) {
    fclose(in);
    fclose(out);
  }
}

/*****************************************************************************/

void write_station(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm,
  double t) {

  static FILE *out;

  static double rmax2, t0, t1, x0[3], x1[3];

  /* Set timer... */
  SELECT_TIMER("WRITE_STATION", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Write info... */
    printf("Write station data: %s\n", filename);

    /* Create new file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
    for (int iq = 0; iq < ctl->nq; iq++)
      fprintf(out, "# $%i = %s [%s]\n", (iq + 5),
              ctl->qnt_name[iq], ctl->qnt_unit[iq]);
    fprintf(out, "\n");

    /* Set geolocation and search radius... */
    geo2cart(0, ctl->stat_lon, ctl->stat_lat, x0);
    rmax2 = SQR(ctl->stat_r);
  }

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Loop over air parcels... */
  for (int ip = 0; ip < atm->np; ip++) {
```

```
    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Check station flag... */
    if (ctl->qnt_stat >= 0)
      if (atm->q[ctl->qnt_stat][ip])
        continue;

    /* Get Cartesian coordinates... */
    geo2cart(0, atm->lon[ip], atm->lat[ip], x1);

    /* Check horizontal distance... */
    if (DIST2(x0, x1) > rmax2)
      continue;

    /* Set station flag... */
    if (ctl->qnt_stat >= 0)
      atm->q[ctl->qnt_stat][ip] = 1;

    /* Write data... */
    fprintf(out, "%.2f %g %g %g",
            atm->time[ip], Z(atm->p[ip]), atm->lon[ip], atm->lat[ip]);
    for (int iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], atm->q[iq][ip]);
    }
    fprintf(out, "\n");
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

5.23 libtrac.h File Reference

Data Structures

- struct ctl_t

  Control parameters.
- struct atm_t

  Atmospheric data.
- struct cache_t

  Cache data.
- struct met_t

  Meteorological data.

Functions

- void cart2geo (double ∗x, double ∗z, double ∗lon, double ∗lat)

  Convert Cartesian coordinates to geolocation.
- int check_finite (const double x)

  Check if x is finite.
- double clim_hno3 (double t, double lat, double p)

  Climatology of HNO3 volume mixing ratios.
- double clim_oh (double t, double lat, double p)

  Climatology of OH number concentrations.
- double clim_tropo (double t, double lat)

  Climatology of tropopause pressure.
- void day2doy (int year, int mon, int day, int ∗doy)

  Get day of year from date.
- void doy2day (int year, int doy, int ∗mon, int ∗day)

Get date from day of year.
- void geo2cart (double z, double lon, double lat, double ∗x)

  Convert geolocation to Cartesian coordinates.
- void get_met (ctl_t ∗ctl, double t, met_t ∗∗met0, met_t ∗∗met1)

  Get meteorological data for given time step.
- void get_met_help (double t, int direct, char ∗metbase, double dt_met, char ∗filename)

  Get meteorological data for time step.
- void get_met_replace (char ∗orig, char ∗search, char ∗repl)

  Replace template strings in filename.
- void intpol_met_space_3d (met_t ∗met, float array[EX][EY][EP], double p, double lon, double lat, double ∗var, int ∗ci, double ∗cw, int init)

  Spatial interpolation of meteorological data.
- void intpol_met_space_2d (met_t ∗met, float array[EX][EY], double lon, double lat, double ∗var, int ∗ci, double ∗cw, int init)

  Spatial interpolation of meteorological data.
- void intpol_met_time_3d (met_t ∗met0, float array0[EX][EY][EP], met_t ∗met1, float array1[EX][EY][EP], double ts, double p, double lon, double lat, double ∗var, int ∗ci, double ∗cw, int init)

  Temporal interpolation of meteorological data.
- void intpol_met_time_2d (met_t ∗met0, float array0[EX][EY], met_t ∗met1, float array1[EX][EY], double ts, double lon, double lat, double ∗var, int ∗ci, double ∗cw, int init)

  Temporal interpolation of meteorological data.
- void jsec2time (double jsec, int ∗year, int ∗mon, int ∗day, int ∗hour, int ∗min, int ∗sec, double ∗remain)

  Convert seconds to date.
- double lapse_rate (double t, double h2o)

  Calculate moist adiabatic lapse rate.
- int locate_irr (double ∗xx, int n, double x)

  Find array index for irregular grid.
- int locate_reg (double ∗xx, int n, double x)

  Find array index for regular grid.
- double nat_temperature (double p, double h2o, double hno3)

  Calculate NAT existence temperature.
- int read_atm (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm)

  Read atmospheric data.
- void read_ctl (const char ∗filename, int argc, char ∗argv[ ], ctl_t ∗ctl)

  Read control parameters.
- int read_met (ctl_t ∗ctl, char ∗filename, met_t ∗met)

  Read meteorological data file.
- void read_met_cape (met_t ∗met)

  Calculate convective available potential energy.
- void read_met_cloud (met_t ∗met)

  Calculate cloud properties.
- void read_met_detrend (ctl_t ∗ctl, met_t ∗met)

  Apply detrending method to temperature and winds.
- void read_met_extrapolate (met_t ∗met)

  Extrapolate meteorological data at lower boundary.
- void read_met_geopot (ctl_t ∗ctl, met_t ∗met)

  Calculate geopotential heights.
- void read_met_grid (char ∗filename, int ncid, ctl_t ∗ctl, met_t ∗met)

  Read coordinates of meteorological data.
- int read_met_help_3d (int ncid, char ∗varname, char ∗varname2, met_t ∗met, float dest[EX][EY][EP], float scl)

Read and convert 3D variable from meteorological data file.
- int read_met_help_2d (int ncid, char ∗varname, char ∗varname2, met_t ∗met, float dest[EX][EY], float scl)

  Read and convert 2D variable from meteorological data file.
- void read_met_levels (int ncid, ctl_t ∗ctl, met_t ∗met)
- void read_met_ml2pl (ctl_t ∗ctl, met_t ∗met, float var[EX][EY][EP])

  Convert meteorological data from model levels to pressure levels.
- void read_met_periodic (met_t ∗met)

  Create meteorological data with periodic boundary conditions.
- void read_met_pv (met_t ∗met)

  Calculate potential vorticity.
- void read_met_sample (ctl_t ∗ctl, met_t ∗met)

  Downsampling of meteorological data.
- void read_met_surface (int ncid, met_t ∗met)

  Read surface data.
- void read_met_tropo (ctl_t ∗ctl, met_t ∗met)

  Calculate tropopause data.
- double scan_ctl (const char ∗filename, int argc, char ∗argv[ ], const char ∗varname, int arridx, const char ∗defvalue, char ∗value)

  Read a control parameter from file or command line.
- double sedi (double p, double T, double r_p, double rho_p)

  Calculate sedimentation velocity.
- void spline (double ∗x, double ∗y, int n, double ∗x2, double ∗y2, int n2)

  Spline interpolation.
- double stddev (double ∗data, int n)

  Calculate standard deviation.
- void time2jsec (int year, int mon, int day, int hour, int min, int sec, double remain, double ∗jsec)

  Convert date to seconds.
- void timer (const char ∗name, int output)

  Measure wall-clock time.
- void write_atm (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write atmospheric data.
- void write_csi (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write CSI data.
- void write_ens (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write ensemble data.
- void write_grid (const char ∗filename, ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double t)

  Write gridded data.
- void write_prof (const char ∗filename, ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double t)

  Write profile data.
- void write_sample (const char ∗filename, ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double t)

  Write sample data.
- void write_station (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write station data.

5.23.1 Function Documentation

5.23.1.1 cart2geo()

```
void cart2geo (
        double * x,
        double * z,
        double * lon,
        double * lat )
```

Convert Cartesian coordinates to geolocation.

Definition at line 29 of file libtrac.c.

```
                  {

  double radius = NORM(x);
  *lat = asin(x[2] / radius) * 180. / M_PI;
  *lon = atan2(x[1], x[0]) * 180. / M_PI;
  *z = radius - RE;
}
```

5.23.1.2 check_finite()

```
int check_finite (
        const double x )
```

Check if x is finite.

5.23.1.3 clim_hno3()

```
double clim_hno3 (
        double t,
        double lat,
        double p )
```

Climatology of HNO3 volume mixing ratios.

Definition at line 295 of file libtrac.c.

```
              {

  /* Get seconds since begin of year... */
  double sec = FMOD(t, 365.25 * 86400.);
  while (sec < 0)
    sec += 365.25 * 86400.;

  /* Check pressure... */
  if (p < clim_hno3_ps[0])
    p = clim_hno3_ps[0];
  else if (p > clim_hno3_ps[9])
    p = clim_hno3_ps[9];

  /* Check latitude... */
  if (lat < clim_hno3_lats[0])
    lat = clim_hno3_lats[0];
  else if (lat > clim_hno3_lats[17])
    lat = clim_hno3_lats[17];

  /* Get indices... */
  int isec = locate_irr(clim_hno3_secs, 12, sec);
  int ilat = locate_reg(clim_hno3_lats, 18, lat);
  int ip = locate_irr(clim_hno3_ps, 10, p);

  /* Interpolate HNO3 climatology (Froidevaux et al., 2015)... */
  double aux00 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec][ilat][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec][ilat][ip + 1], p);
  double aux01 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec][ilat + 1][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec][ilat + 1][ip + 1], p);
  double aux10 = LIN(clim_hno3_ps[ip],
                     clim_hno3_var[isec + 1][ilat][ip],
                     clim_hno3_ps[ip + 1],
                     clim_hno3_var[isec + 1][ilat][ip + 1], p);
```

```
double aux11 = LIN(clim_hno3_ps[ip],
                   clim_hno3_var[isec + 1][ilat + 1][ip],
                   clim_hno3_ps[ip + 1],
                   clim_hno3_var[isec + 1][ilat + 1][ip + 1], p);
aux00 = LIN(clim_hno3_lats[ilat], aux00,
            clim_hno3_lats[ilat + 1], aux01, lat);
aux11 = LIN(clim_hno3_lats[ilat], aux10,
            clim_hno3_lats[ilat + 1], aux11, lat);
aux00 = LIN(clim_hno3_secs[isec], aux00,
            clim_hno3_secs[isec + 1], aux11, sec);
return GSL_MAX(aux00, 0.0);
}
```

5.23.1.4 clim_oh()

```
double clim_oh (
    double t,
    double lat,
    double p )
```

Climatology of OH number concentrations.

Definition at line 1329 of file libtrac.c.

```
               {

/* Get seconds since begin of year... */
double sec = FMOD(t, 365.25 * 86400.);
while (sec < 0)
  sec += 365.25 * 86400.;

/* Check pressure... */
if (p < clim_oh_ps[0])
  p = clim_oh_ps[0];
else if (p > clim_oh_ps[33])
  p = clim_oh_ps[33];

/* Check latitude... */
if (lat < clim_oh_lats[0])
  lat = clim_oh_lats[0];
else if (lat > clim_oh_lats[17])
  lat = clim_oh_lats[17];

/* Get indices... */
int isec = locate_irr(clim_oh_secs, 12, sec);
int ilat = locate_reg(clim_oh_lats, 18, lat);
int ip = locate_irr(clim_oh_ps, 34, p);

/* Interpolate OH climatology (Pommrich et al., 2014)... */
double aux00 = LIN(clim_oh_ps[ip],
                   clim_oh_var[isec][ilat][ip],
                   clim_oh_ps[ip + 1],
                   clim_oh_var[isec][ilat][ip + 1], p);
double aux01 = LIN(clim_oh_ps[ip],
                   clim_oh_var[isec][ilat + 1][ip],
                   clim_oh_ps[ip + 1],
                   clim_oh_var[isec][ilat + 1][ip + 1], p);
double aux10 = LIN(clim_oh_ps[ip],
                   clim_oh_var[isec + 1][ilat][ip],
                   clim_oh_ps[ip + 1],
                   clim_oh_var[isec + 1][ilat][ip + 1], p);
double aux11 = LIN(clim_oh_ps[ip],
                   clim_oh_var[isec + 1][ilat + 1][ip],
                   clim_oh_ps[ip + 1],
                   clim_oh_var[isec + 1][ilat + 1][ip + 1], p);
aux00 = LIN(clim_oh_lats[ilat], aux00, clim_oh_lats[ilat + 1], aux01, lat);
aux11 = LIN(clim_oh_lats[ilat], aux10, clim_oh_lats[ilat + 1], aux11, lat);
aux00 = LIN(clim_oh_secs[isec], aux00, clim_oh_secs[isec + 1], aux11, sec);
return GSL_MAX(1e6 * aux00, 0.0);
}
```

5.23.1.5 clim_tropo()

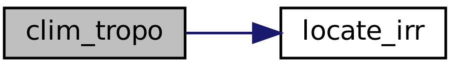
```
double clim_tropo (
    double t,
    double lat )
```

Climatology of tropopause pressure.

Definition at line 1510 of file libtrac.c.

```
                {

  /* Get seconds since begin of year... */
  double sec = FMOD(t, 365.25 * 86400.);
  while (sec < 0)
    sec += 365.25 * 86400.;

  /* Get indices... */
  int isec = locate_irr(clim_tropo_secs, 12, sec);
  int ilat = locate_reg(clim_tropo_lats, 73, lat);

  /* Interpolate tropopause data (NCEP/NCAR Reanalysis 1)... */
  double p0 = LIN(clim_tropo_lats[ilat],
                  clim_tropo_tps[isec][ilat],
                  clim_tropo_lats[ilat + 1],
                  clim_tropo_tps[isec][ilat + 1], lat);
  double p1 = LIN(clim_tropo_lats[ilat],
                  clim_tropo_tps[isec + 1][ilat],
                  clim_tropo_lats[ilat + 1],
                  clim_tropo_tps[isec + 1][ilat + 1], lat);
  return LIN(clim_tropo_secs[isec], p0, clim_tropo_secs[isec + 1], p1, sec);
}
```

Here is the call graph for this function:



5.23.1.6 day2doy()

```
void day2doy (
    int year,
    int mon,
    int day,
    int * doy )
```

Get day of year from date.

Definition at line 1537 of file libtrac.c.

```
              {

  int d0[12] = { 1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335 };
  int d0l[12] = { 1, 32, 61, 92, 122, 153, 183, 214, 245, 275, 306, 336 };

  /* Get day of year... */
  if (year % 400 == 0 || (year % 100 != 0 && year % 4 == 0))
    *doy = d0l[mon - 1] + day - 1;
  else
    *doy = d0[mon - 1] + day - 1;
}
```

5.23.1.7 doy2day()

```
void doy2day (
    int year,
    int doy,
    int * mon,
    int * day )
```

Get date from day of year.

Definition at line 1555 of file libtrac.c.

```
                  {

  int d0[12] = { 1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335 };
  int d01[12] = { 1, 32, 61, 92, 122, 153, 183, 214, 245, 275, 306, 336 };
  int i;

  /* Get month and day... */
  if (year % 400 == 0 || (year % 100 != 0 && year % 4 == 0)) {
    for (i = 11; i >= 0; i--)
      if (d01[i] <= doy)
        break;
    *mon = i + 1;
    *day = doy - d01[i] + 1;
  } else {
    for (i = 11; i >= 0; i--)
      if (d0[i] <= doy)
        break;
    *mon = i + 1;
    *day = doy - d0[i] + 1;
  }
}
```

5.23.1.8 geo2cart()

```
void geo2cart (
    double z,
    double lon,
    double lat,
    double * x )
```

Convert geolocation to Cartesian coordinates.

Definition at line 1583 of file libtrac.c.

```
                   {

  double radius = z + RE;
  x[0] = radius * cos(lat / 180. * M_PI) * cos(lon / 180. * M_PI);
  x[1] = radius * cos(lat / 180. * M_PI) * sin(lon / 180. * M_PI);
  x[2] = radius * sin(lat / 180. * M_PI);
}
```

5.23.1.9 get_met()

```
void get_met (
    ctl_t * ctl,
    double t,
    met_t ** met0,
    met_t ** met1 )
```

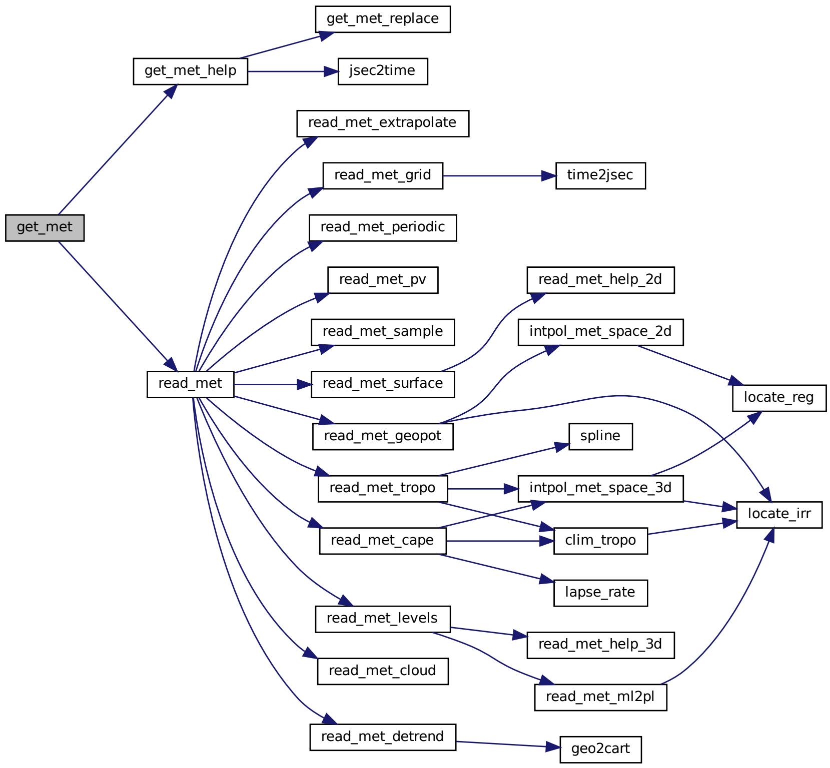
Get meteorological data for given time step.

Definition at line 1597 of file libtrac.c.

```
                       {

  static int init, ip, ix, iy;

  met_t *mets;

  char filename[LEN];
```

```

  /* Set timer... */
  SELECT_TIMER("GET_MET", NVTX_READ);

  /* Init... */
  if (t == ctl->t_start || !init) {
    init = 1;

    get_met_help(t, -1, ctl->metbase, ctl->dt_met, filename);
    if (!read_met(ctl, filename, *met0))
      ERRMSG("Cannot open file!");

    get_met_help(t + 1.0 * ctl->direction, 1, ctl->metbase, ctl->dt_met,
                 filename);
    if (!read_met(ctl, filename, *met1))
      ERRMSG("Cannot open file!");
#ifdef _OPENACC
    met_t *met0up = *met0;
    met_t *met1up = *met1;
#pragma acc update device(met0up[:1],met1up[:1])
#endif
  }

  /* Read new data for forward trajectories... */
  if (t > (*met1)->time && ctl->direction == 1) {
    mets = *met1;
    *met1 = *met0;
    *met0 = mets;
    get_met_help(t, 1, ctl->metbase, ctl->dt_met, filename);
    if (!read_met(ctl, filename, *met1))
      ERRMSG("Cannot open file!");
#ifdef _OPENACC
    met_t *met1up = *met1;
#pragma acc update device(met1up[:1])
#endif
  }

  /* Read new data for backward trajectories... */
  if (t < (*met0)->time && ctl->direction == -1) {
    mets = *met1;
    *met1 = *met0;
    *met0 = mets;
    get_met_help(t, -1, ctl->metbase, ctl->dt_met, filename);
    if (!read_met(ctl, filename, *met0))
      ERRMSG("Cannot open file!");
#ifdef _OPENACC
    met_t *met0up = *met0;
#pragma acc update device(met0up[:1])
#endif
  }

  /* Check that grids are consistent... */
  if ((*met0)->nx != (*met1)->nx
      || (*met0)->ny != (*met1)->ny || (*met0)->np != (*met1)->np)
    ERRMSG("Meteo grid dimensions do not match!");
  for (ix = 0; ix < (*met0)->nx; ix++)
    if (fabs((*met0)->lon[ix] - (*met1)->lon[ix]) > 0.001)
      ERRMSG("Meteo grid longitudes do not match!");
  for (iy = 0; iy < (*met0)->ny; iy++)
    if (fabs((*met0)->lat[iy] - (*met1)->lat[iy]) > 0.001)
      ERRMSG("Meteo grid latitudes do not match!");
  for (ip = 0; ip < (*met0)->np; ip++)
    if (fabs((*met0)->p[ip] - (*met1)->p[ip]) > 0.001)
      ERRMSG("Meteo grid pressure levels do not match!");
}
```

Here is the call graph for this function:



5.23.1.10 get_met_help() void get_met_help (

```
double t,
int direct,
char * metbase,
double dt_met,
char * filename )
```

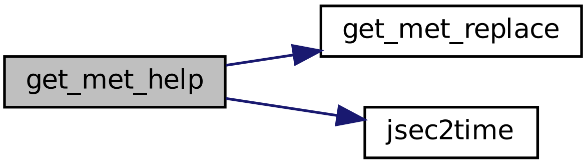
Get meteorological data for time step.

Definition at line 1676 of file libtrac.c.

```
                       {

  char repl[LEN];

  double t6, r;

  int year, mon, day, hour, min, sec;

  /* Round time to fixed intervals... */
  if (direct == -1)
    t6 = floor(t / dt_met) * dt_met;
  else
    t6 = ceil(t / dt_met) * dt_met;

  /* Decode time... */
  jsec2time(t6, &year, &mon, &day, &hour, &min, &sec, &r);

  /* Set filename... */
  sprintf(filename, "%s_YYYY_MM_DD_HH.nc", metbase);
  sprintf(repl, "%d", year);
```

```
  get_met_replace(filename, "YYYY", repl);
  sprintf(repl, "%02d", mon);
  get_met_replace(filename, "MM", repl);
  sprintf(repl, "%02d", day);
  get_met_replace(filename, "DD", repl);
  sprintf(repl, "%02d", hour);
  get_met_replace(filename, "HH", repl);
}
```

Here is the call graph for this function:



5.23.1.11 get_met_replace()

```
void get_met_replace (
    char * orig,
    char * search,
    char * repl )
```

Replace template strings in filename.

Definition at line 1712 of file libtrac.c.

```
                {

  char buffer[LEN], *ch;

  /* Iterate... */
  for (int i = 0; i < 3; i++) {

    /* Replace sub-string... */
    if (!(ch = strstr(orig, search)))
      return;
    strncpy(buffer, orig, (size_t) (ch - orig));
    buffer[ch - orig] = 0;
    sprintf(buffer + (ch - orig), "%s%s", repl, ch + strlen(search));
    orig[0] = 0;
    strcpy(orig, buffer);
  }
}
```

5.23.1.12 intpol_met_space_3d()

```
void intpol_met_space_3d (
    met_t * met,
    float array[EX][EY][EP],
    double p,
    double lon,
    double lat,
    double * var,
    int * ci,
```

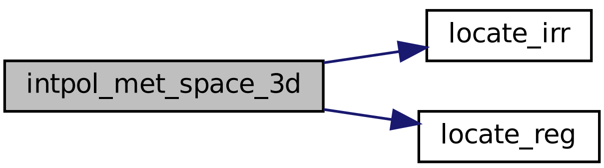
```
double * cw,
int init )
```

Spatial interpolation of meteorological data.

Definition at line 1735 of file libtrac.c.

```
                 {

  /* Check longitude... */
  if (met->lon[met->nx - 1] > 180 && lon < 0)
    lon += 360;

  /* Get interpolation indices and weights... */
  if (init) {
    ci[0] = locate_irr(met->p, met->np, p);
    ci[1] = locate_reg(met->lon, met->nx, lon);
    ci[2] = locate_reg(met->lat, met->ny, lat);
    cw[0] = (met->p[ci[0] + 1] - p)
      / (met->p[ci[0] + 1] - met->p[ci[0]]);
    cw[1] = (met->lon[ci[1] + 1] - lon)
      / (met->lon[ci[1] + 1] - met->lon[ci[1]]);
    cw[2] = (met->lat[ci[2] + 1] - lat)
      / (met->lat[ci[2] + 1] - met->lat[ci[2]]);
  }

  /* Interpolate vertically... */
  double aux00 =
    cw[0] * (array[ci[1]][ci[2]][ci[0]] - array[ci[1]][ci[2]][ci[0] + 1])
    + array[ci[1]][ci[2]][ci[0] + 1];
  double aux01 =
    cw[0] * (array[ci[1]][ci[2] + 1][ci[0]] -
             array[ci[1]][ci[2] + 1][ci[0] + 1])
    + array[ci[1]][ci[2] + 1][ci[0] + 1];
  double aux10 =
    cw[0] * (array[ci[1] + 1][ci[2]][ci[0]] -
             array[ci[1] + 1][ci[2]][ci[0] + 1])
    + array[ci[1] + 1][ci[2]][ci[0] + 1];
  double aux11 =
    cw[0] * (array[ci[1] + 1][ci[2] + 1][ci[0]] -
             array[ci[1] + 1][ci[2] + 1][ci[0] + 1])
    + array[ci[1] + 1][ci[2] + 1][ci[0] + 1];

  /* Interpolate horizontally... */
  aux00 = cw[2] * (aux00 - aux01) + aux01;
  aux11 = cw[2] * (aux10 - aux11) + aux11;
  *var = cw[1] * (aux00 - aux11) + aux11;
}
```

Here is the call graph for this function:



5.23.1.13 intpol_met_space_2d()

```
void intpol_met_space_2d (
met_t * met,
float array[EX][EY],
double lon,
```

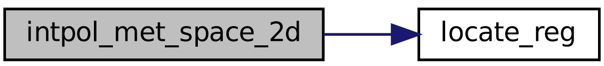
double *lat*,
double * *var*,
int * *ci*,
double * *cw*,
int *init*)

Spatial interpolation of meteorological data.

Definition at line 1789 of file libtrac.c.

```
           {

  /* Check longitude... */
  if (met->lon[met->nx - 1] > 180 && lon < 0)
    lon += 360;

  /* Get interpolation indices and weights... */
  if (init) {
    ci[1] = locate_reg(met->lon, met->nx, lon);
    ci[2] = locate_reg(met->lat, met->ny, lat);
    cw[1] = (met->lon[ci[1] + 1] - lon)
      / (met->lon[ci[1] + 1] - met->lon[ci[1]]);
    cw[2] = (met->lat[ci[2] + 1] - lat)
      / (met->lat[ci[2] + 1] - met->lat[ci[2]]);
  }

  /* Set variables... */
  double aux00 = array[ci[1]][ci[2]];
  double aux01 = array[ci[1]][ci[2] + 1];
  double aux10 = array[ci[1] + 1][ci[2]];
  double aux11 = array[ci[1] + 1][ci[2] + 1];

  /* Interpolate horizontally... */
  if (isfinite(aux00) && isfinite(aux01))
    aux00 = cw[2] * (aux00 - aux01) + aux01;
  else if (cw[2] < 0.5)
    aux00 = aux01;
  if (isfinite(aux10) && isfinite(aux11))
    aux11 = cw[2] * (aux10 - aux11) + aux11;
  else if (cw[2] > 0.5)
    aux11 = aux10;
  if (isfinite(aux00) && isfinite(aux11))
    *var = cw[1] * (aux00 - aux11) + aux11;
  else {
    if (cw[1] > 0.5)
      *var = aux00;
    else
      *var = aux11;
  }
}
```

Here is the call graph for this function:



5.23.1.14 intpol_met_time_3d()

void intpol_met_time_3d (
met_t * *met0*,
float *array0[EX][EY][EP]*,
met_t * *met1*,
float *array1[EX][EY][EP]*,

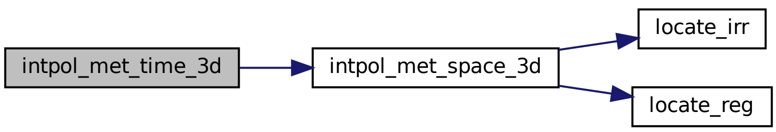
```
double ts,
double p,
double lon,
double lat,
double * var,
int * ci,
double * cw,
int init )
```

Temporal interpolation of meteorological data.

Definition at line 1840 of file libtrac.c.

```
                {

  double var0, var1, wt;

  /* Spatial interpolation... */
  intpol_met_space_3d(met0, array0, p, lon, lat, &var0, ci, cw, init);
  intpol_met_space_3d(met1, array1, p, lon, lat, &var1, ci, cw, init);

  /* Get weighting factor... */
  wt = (met1->time - ts) / (met1->time - met0->time);

  /* Interpolate... */
  *var = wt * (var0 - var1) + var1;
}
```

Here is the call graph for this function:



5.23.1.15 intpol_met_time_2d()

```
void intpol_met_time_2d (
met_t * met0,
float array0[EX][EY],
met_t * met1,
float array1[EX][EY],
double ts,
double lon,
double lat,
double * var,
int * ci,
double * cw,
int init )
```

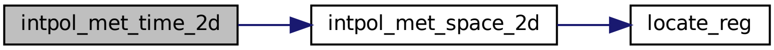
Temporal interpolation of meteorological data.

Definition at line 1869 of file libtrac.c.

```
                {

  double var0, var1, wt;

  /* Spatial interpolation... */
```

```
  intpol_met_space_2d(met0, array0, lon, lat, &var0, ci, cw, init);
  intpol_met_space_2d(met1, array1, lon, lat, &var1, ci, cw, init);

  /* Get weighting factor... */
  wt = (met1->time - ts) / (met1->time - met0->time);

  /* Interpolate... */
  *var = wt * (var0 - var1) + var1;
}
```

Here is the call graph for this function:



5.23.1.16 jsec2time()

`void jsec2time ( double jsec, int * year, int * mon, int * day, int * hour, int * min, int * sec, double * remain )`

Convert seconds to date.

Definition at line 1897 of file libtrac.c.

```
                    {

  struct tm t0, *t1;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  time_t jsec0 = (time_t) jsec + timegm(&t0);
  t1 = gmtime(&jsec0);

  *year = t1->tm_year + 1900;
  *mon = t1->tm_mon + 1;
  *day = t1->tm_mday;
  *hour = t1->tm_hour;
  *min = t1->tm_min;
  *sec = t1->tm_sec;
  *remain = jsec - floor(jsec);
}
```

5.23.1.17 lapse_rate()

```
double lapse_rate (
    double t,
    double h2o )
```

Calculate moist adiabatic lapse rate.

Definition at line 1930 of file libtrac.c.

```
                {

  /*
     Calculate moist adiabatic lapse rate [K/km] from temperature [K]
     and water vapor volume mixing ratio [1].

     Reference: https://en.wikipedia.org/wiki/Lapse_rate
   */

  const double a = RA * SQR(t), r = SH(h2o) / (1. - SH(h2o));

  return 1e3 * G0 * (a + LV * r * t) / (CPD * a + SQR(LV) * r * EPS);
}
```

5.23.1.18 locate_irr()

```
int locate_irr (
    double * xx,
    int n,
    double x )
```

Find array index for irregular grid.

Definition at line 1948 of file libtrac.c.

```
              {

  int ilo = 0;
  int ihi = n - 1;
  int i = (ihi + ilo) >> 1;

  if (xx[i] < xx[i + 1])
    while (ihi > ilo + 1) {
      i = (ihi + ilo) >> 1;
      if (xx[i] > x)
        ihi = i;
      else
        ilo = i;
  } else
    while (ihi > ilo + 1) {
      i = (ihi + ilo) >> 1;
      if (xx[i] <= x)
        ihi = i;
      else
        ilo = i;
    }

  return ilo;
}
```

5.23.1.19 locate_reg()

```
int locate_reg (
    double * xx,
    int n,
    double x )
```

Find array index for regular grid.

Definition at line 1978 of file libtrac.c.

```
              {

  /* Calculate index... */
  int i = (int) ((x - xx[0]) / (xx[1] - xx[0]));
```

```

  /* Check range... */
  if (i < 0)
    i = 0;
  else if (i >= n - 2)
    i = n - 2;

  return i;
}
```

5.23.1.20 nat_temperature()

```
double nat_temperature (
    double p,
    double h2o,
    double hno3 )
```

Calculate NAT existence temperature.

Definition at line 1997 of file libtrac.c.

```
                {

  double p_hno3 = hno3 * p / 1.333224;
  double p_h2o = h2o * p / 1.333224;
  double a = 0.009179 - 0.00088 * log10(p_h2o);
  double b = (38.9855 - log10(p_hno3) - 2.7836 * log10(p_h2o)) / a;
  double c = -11397.0 / a;
  double tnat = (-b + sqrt(b * b - 4. * c)) / 2.;
  double x2 = (-b - sqrt(b * b - 4. * c)) / 2.;
  if (x2 > 0)
    tnat = x2;

  return tnat;
}
```

5.23.1.21 read_atm()

```
int read_atm (
    const char * filename,
    ctl_t * ctl,
    atm_t * atm )
```

Read atmospheric data.

Definition at line 2017 of file libtrac.c.

```
                {

  FILE *in;

  char line[LEN], *tok;

  double t0;

  int dimid, ip, iq, ncid, varid;

  size_t nparts;

  /* Set timer... */
  SELECT_TIMER("READ_ATM", NVTX_READ);

  /* Init... */
  atm->np = 0;

  /* Write info... */
  printf("Read atmospheric data: %s\n", filename);

  /* Read ASCII data... */
  if (ctl->atm_type == 0) {

    /* Open file... */
    if (!(in = fopen(filename, "r"))) {
      WARN("File not found!");
      return 0;
```

```
    }

    /* Read line... */
    while (fgets(line, LEN, in)) {

      /* Read data... */
      TOK(line, tok, "%lg", atm->time[atm->np]);
      TOK(NULL, tok, "%lg", atm->p[atm->np]);
      TOK(NULL, tok, "%lg", atm->lon[atm->np]);
      TOK(NULL, tok, "%lg", atm->lat[atm->np]);
      for (iq = 0; iq < ctl->nq; iq++)
        TOK(NULL, tok, "%lg", atm->q[iq][atm->np]);

      /* Convert altitude to pressure... */
      atm->p[atm->np] = P(atm->p[atm->np]);

      /* Increment data point counter... */
      if ((++atm->np) > NP)
        ERRMSG("Too many data points!");
    }

    /* Close file... */
    fclose(in);
  }

  /* Read binary data... */
  else if (ctl->atm_type == 1) {

    /* Open file... */
    if (!(in = fopen(filename, "r")))
      return 0;

    /* Read data... */
    FREAD(&atm->np, int,
          1,
          in);
    FREAD(atm->time, double,
            (size_t) atm->np,
          in);
    FREAD(atm->p, double,
            (size_t) atm->np,
          in);
    FREAD(atm->lon, double,
            (size_t) atm->np,
          in);
    FREAD(atm->lat, double,
            (size_t) atm->np,
          in);
    for (iq = 0; iq < ctl->nq; iq++)
      FREAD(atm->q[iq], double,
              (size_t) atm->np,
            in);

    /* Close file... */
    fclose(in);
  }

  /* Read netCDF data... */
  else if (ctl->atm_type == 2) {

    /* Open file... */
    if (nc_open(filename, NC_NOWRITE, &ncid) != NC_NOERR)
      return 0;

    /* Get dimensions... */
    NC(nc_inq_dimid(ncid, "NPARTS", &dimid));
    NC(nc_inq_dimlen(ncid, dimid, &nparts));
    atm->np = (int) nparts;
    if (atm->np > NP)
      ERRMSG("Too many particles!");

    /* Get time... */
    NC(nc_inq_varid(ncid, "time", &varid));
    NC(nc_get_var_double(ncid, varid, &t0));
    for (ip = 0; ip < atm->np; ip++)
      atm->time[ip] = t0;

    /* Read geolocations... */
    NC(nc_inq_varid(ncid, "PRESS", &varid));
    NC(nc_get_var_double(ncid, varid, atm->p));
    NC(nc_inq_varid(ncid, "LON", &varid));
    NC(nc_get_var_double(ncid, varid, atm->lon));
    NC(nc_inq_varid(ncid, "LAT", &varid));
    NC(nc_get_var_double(ncid, varid, atm->lat));

    /* Read variables... */
    if (ctl->qnt_p >= 0)
```

```
      if (nc_inq_varid(ncid, "PRESS", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_p]));
    if (ctl->qnt_t >= 0)
      if (nc_inq_varid(ncid, "TEMP", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_t]));
    if (ctl->qnt_u >= 0)
      if (nc_inq_varid(ncid, "U", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_u]));
    if (ctl->qnt_v >= 0)
      if (nc_inq_varid(ncid, "V", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_v]));
    if (ctl->qnt_w >= 0)
      if (nc_inq_varid(ncid, "W", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_w]));
    if (ctl->qnt_h2o >= 0)
      if (nc_inq_varid(ncid, "SH", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_h2o]));
    if (ctl->qnt_o3 >= 0)
      if (nc_inq_varid(ncid, "O3", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_o3]));
    if (ctl->qnt_theta >= 0)
      if (nc_inq_varid(ncid, "THETA", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_theta]));
    if (ctl->qnt_pv >= 0)
      if (nc_inq_varid(ncid, "PV", &varid) == NC_NOERR)
        NC(nc_get_var_double(ncid, varid, atm->q[ctl->qnt_pv]));

    /* Check data... */
    for (ip = 0; ip < atm->np; ip++)
      if (fabs(atm->lon[ip]) > 360 || fabs(atm->lat[ip]) > 90
          || (ctl->qnt_t >= 0 && fabs(atm->q[ctl->qnt_t][ip]) > 350)
          || (ctl->qnt_h2o >= 0 && fabs(atm->q[ctl->qnt_h2o][ip]) > 1)
          || (ctl->qnt_theta >= 0 && fabs(atm->q[ctl->qnt_theta][ip]) > 1e10)
          || (ctl->qnt_pv >= 0 && fabs(atm->q[ctl->qnt_pv][ip]) > 1e10)) {
        atm->time[ip] = GSL_NAN;
        atm->p[ip] = GSL_NAN;
        atm->lon[ip] = GSL_NAN;
        atm->lat[ip] = GSL_NAN;
        for (iq = 0; iq < ctl->nq; iq++)
          atm->q[iq][ip] = GSL_NAN;
      } else {
        if (ctl->qnt_h2o >= 0)
          atm->q[ctl->qnt_h2o][ip] *= 1.608;
        if (ctl->qnt_pv >= 0)
          atm->q[ctl->qnt_pv][ip] *= 1e6;
        if (atm->lon[ip] > 180)
          atm->lon[ip] -= 360;
      }

    /* Close file... */
    NC(nc_close(ncid));
  }

  /* Error... */
  else
    ERRMSG("Atmospheric data type not supported!");

  /* Check number of points... */
  if (atm->np < 1)
    ERRMSG("Can not read any data!");

  /* Return success... */
  return 1;
}
```

5.23.1.22 read_ctl()

```
void read_ctl (
    const char * filename,
    int argc,
    char * argv[],
    ctl_t * ctl )
```

Read control parameters.

Definition at line 2202 of file libtrac.c.

```
                  {

  /* Set timer... */
```

```
  SELECT_TIMER("READ_CTL", NVTX_READ);

  /* Write info... */
  printf("\nMassive-Parallel Trajectory Calculations (MPTRAC)\n"
         "(executable: %s | compiled: %s, %s)\n\n",
         argv[0], __DATE__, __TIME__);

  /* Initialize quantity indices... */
  ctl->qnt_ens = -1;
  ctl->qnt_m = -1;
  ctl->qnt_r = -1;
  ctl->qnt_rho = -1;
  ctl->qnt_ps = -1;
  ctl->qnt_ts = -1;
  ctl->qnt_zs = -1;
  ctl->qnt_us = -1;
  ctl->qnt_vs = -1;
  ctl->qnt_pt = -1;
  ctl->qnt_tt = -1;
  ctl->qnt_zt = -1;
  ctl->qnt_h2ot = -1;
  ctl->qnt_z = -1;
  ctl->qnt_p = -1;
  ctl->qnt_t = -1;
  ctl->qnt_u = -1;
  ctl->qnt_v = -1;
  ctl->qnt_w = -1;
  ctl->qnt_h2o = -1;
  ctl->qnt_o3 = -1;
  ctl->qnt_lwc = -1;
  ctl->qnt_iwc = -1;
  ctl->qnt_pc = -1;
  ctl->qnt_cl = -1;
  ctl->qnt_plcl = -1;
  ctl->qnt_plfc = -1;
  ctl->qnt_pel = -1;
  ctl->qnt_cape = -1;
  ctl->qnt_hno3 = -1;
  ctl->qnt_oh = -1;
  ctl->qnt_psat = -1;
  ctl->qnt_psice = -1;
  ctl->qnt_pw = -1;
  ctl->qnt_sh = -1;
  ctl->qnt_rh = -1;
  ctl->qnt_rhice = -1;
  ctl->qnt_theta = -1;
  ctl->qnt_tvirt = -1;
  ctl->qnt_lapse = -1;
  ctl->qnt_vh = -1;
  ctl->qnt_vz = -1;
  ctl->qnt_pv = -1;
  ctl->qnt_tdew = -1;
  ctl->qnt_tice = -1;
  ctl->qnt_tsts = -1;
  ctl->qnt_tnat = -1;
  ctl->qnt_stat = -1;

  /* Read quantities... */
  ctl->nq = (int) scan_ctl(filename, argc, argv, "NQ", -1, "0", NULL);
  if (ctl->nq > NQ)
    ERRMSG("Too many quantities!");
  for (int iq = 0; iq < ctl->nq; iq++) {

    /* Read quantity name and format... */
    scan_ctl(filename, argc, argv, "QNT_NAME", iq, "", ctl->qnt_name[iq]);
    scan_ctl(filename, argc, argv, "QNT_FORMAT", iq, "%g",
             ctl->qnt_format[iq]);

    /* Try to identify quantity... */
    if (strcasecmp(ctl->qnt_name[iq], "ens") == 0) {
      ctl->qnt_ens = iq;
      sprintf(ctl->qnt_unit[iq], "-");
    } else if (strcasecmp(ctl->qnt_name[iq], "m") == 0) {
      ctl->qnt_m = iq;
      sprintf(ctl->qnt_unit[iq], "kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "r") == 0) {
      ctl->qnt_r = iq;
      sprintf(ctl->qnt_unit[iq], "m");
    } else if (strcasecmp(ctl->qnt_name[iq], "rho") == 0) {
      ctl->qnt_rho = iq;
      sprintf(ctl->qnt_unit[iq], "kg/m^3");
    } else if (strcasecmp(ctl->qnt_name[iq], "ps") == 0) {
      ctl->qnt_ps = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "pt") == 0) {
      ctl->qnt_pt = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
```

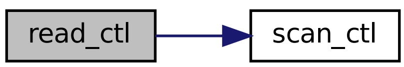
```
    } else if (strcasecmp(ctl->qnt_name[iq], "tt") == 0) {
      ctl->qnt_tt = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "zt") == 0) {
      ctl->qnt_zt = iq;
      sprintf(ctl->qnt_unit[iq], "km");
    } else if (strcasecmp(ctl->qnt_name[iq], "h2ot") == 0) {
      ctl->qnt_h2ot = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "z") == 0) {
      ctl->qnt_z = iq;
      sprintf(ctl->qnt_unit[iq], "km");
    } else if (strcasecmp(ctl->qnt_name[iq], "p") == 0) {
      ctl->qnt_p = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "t") == 0) {
      ctl->qnt_t = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "u") == 0) {
      ctl->qnt_u = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "v") == 0) {
      ctl->qnt_v = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "w") == 0) {
      ctl->qnt_w = iq;
      sprintf(ctl->qnt_unit[iq], "hPa/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "h2o") == 0) {
      ctl->qnt_h2o = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "o3") == 0) {
      ctl->qnt_o3 = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "lwc") == 0) {
      ctl->qnt_lwc = iq;
      sprintf(ctl->qnt_unit[iq], "kg/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "iwc") == 0) {
      ctl->qnt_iwc = iq;
      sprintf(ctl->qnt_unit[iq], "kg/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "pc") == 0) {
      ctl->qnt_pc = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "cl") == 0) {
      ctl->qnt_cl = iq;
      sprintf(ctl->qnt_unit[iq], "kg/m^2");
    } else if (strcasecmp(ctl->qnt_name[iq], "plcl") == 0) {
      ctl->qnt_plcl = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "plfc") == 0) {
      ctl->qnt_plfc = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "pel") == 0) {
      ctl->qnt_pel = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "cape") == 0) {
      ctl->qnt_cape = iq;
      sprintf(ctl->qnt_unit[iq], "J/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "hno3") == 0) {
      ctl->qnt_hno3 = iq;
      sprintf(ctl->qnt_unit[iq], "ppv");
    } else if (strcasecmp(ctl->qnt_name[iq], "oh") == 0) {
      ctl->qnt_oh = iq;
      sprintf(ctl->qnt_unit[iq], "molec/cm^3");
    } else if (strcasecmp(ctl->qnt_name[iq], "psat") == 0) {
      ctl->qnt_psat = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "psice") == 0) {
      ctl->qnt_psice = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "pw") == 0) {
      ctl->qnt_pw = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcasecmp(ctl->qnt_name[iq], "sh") == 0) {
      ctl->qnt_sh = iq;
      sprintf(ctl->qnt_unit[iq], "kg/kg");
    } else if (strcasecmp(ctl->qnt_name[iq], "rh") == 0) {
      ctl->qnt_rh = iq;
      sprintf(ctl->qnt_unit[iq], "%%");
    } else if (strcasecmp(ctl->qnt_name[iq], "rhice") == 0) {
      ctl->qnt_rhice = iq;
      sprintf(ctl->qnt_unit[iq], "%%");
    } else if (strcasecmp(ctl->qnt_name[iq], "theta") == 0) {
      ctl->qnt_theta = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tvirt") == 0) {
      ctl->qnt_tvirt = iq;
      sprintf(ctl->qnt_unit[iq], "K");
```

```
    } else if (strcasecmp(ctl->qnt_name[iq], "lapse") == 0) {
      ctl->qnt_lapse = iq;
      sprintf(ctl->qnt_unit[iq], "K/km");
    } else if (strcasecmp(ctl->qnt_name[iq], "vh") == 0) {
      ctl->qnt_vh = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "vz") == 0) {
      ctl->qnt_vz = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcasecmp(ctl->qnt_name[iq], "pv") == 0) {
      ctl->qnt_pv = iq;
      sprintf(ctl->qnt_unit[iq], "PVU");
    } else if (strcasecmp(ctl->qnt_name[iq], "tdew") == 0) {
      ctl->qnt_tdew = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tice") == 0) {
      ctl->qnt_tice = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tsts") == 0) {
      ctl->qnt_tsts = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "tnat") == 0) {
      ctl->qnt_tnat = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcasecmp(ctl->qnt_name[iq], "stat") == 0) {
      ctl->qnt_stat = iq;
      sprintf(ctl->qnt_unit[iq], "-");
    } else
      scan_ctl(filename, argc, argv, "QNT_UNIT", iq, "", ctl->qnt_unit[iq]);
  }

  /* Time steps of simulation... */
  ctl->direction =
    (int) scan_ctl(filename, argc, argv, "DIRECTION", -1, "1", NULL);
  if (ctl->direction != -1 && ctl->direction != 1)
    ERRMSG("Set DIRECTION to -1 or 1!");
  ctl->t_stop = scan_ctl(filename, argc, argv, "T_STOP", -1, "1e100", NULL);
  ctl->dt_mod = scan_ctl(filename, argc, argv, "DT_MOD", -1, "180", NULL);

  /* Meteorological data... */
  scan_ctl(filename, argc, argv, "METBASE", -1, "-", ctl->metbase);
  ctl->dt_met = scan_ctl(filename, argc, argv, "DT_MET", -1, "21600", NULL);
  ctl->met_dx = (int) scan_ctl(filename, argc, argv, "MET_DX", -1, "1", NULL);
  ctl->met_dy = (int) scan_ctl(filename, argc, argv, "MET_DY", -1, "1", NULL);
  ctl->met_dp = (int) scan_ctl(filename, argc, argv, "MET_DP", -1, "1", NULL);
  if (ctl->met_dx < 1 || ctl->met_dy < 1 || ctl->met_dp < 1)
    ERRMSG("MET_DX, MET_DY, and MET_DP need to be greater than zero!");
  ctl->met_sx = (int) scan_ctl(filename, argc, argv, "MET_SX", -1, "1", NULL);
  ctl->met_sy = (int) scan_ctl(filename, argc, argv, "MET_SY", -1, "1", NULL);
  ctl->met_sp = (int) scan_ctl(filename, argc, argv, "MET_SP", -1, "1", NULL);
  if (ctl->met_sx < 1 || ctl->met_sy < 1 || ctl->met_sp < 1)
    ERRMSG("MET_SX, MET_SY, and MET_SP need to be greater than zero!");
  ctl->met_detrend =
    scan_ctl(filename, argc, argv, "MET_DETREND", -1, "-999", NULL);
  ctl->met_np = (int) scan_ctl(filename, argc, argv, "MET_NP", -1, "0", NULL);
  if (ctl->met_np > EP)
    ERRMSG("Too many levels!");
  for (int ip = 0; ip < ctl->met_np; ip++)
    ctl->met_p[ip] = scan_ctl(filename, argc, argv, "MET_P", ip, "", NULL);
  ctl->met_geopot_sx
    = (int) scan_ctl(filename, argc, argv, "MET_GEOPOT_SX", -1, "6", NULL);
  ctl->met_geopot_sy
    = (int) scan_ctl(filename, argc, argv, "MET_GEOPOT_SY", -1, "4", NULL);
  if (ctl->met_geopot_sx < 1 || ctl->met_geopot_sy < 1)
    ERRMSG("MET_GEOPOT_SX and MET_GEOPOT_SY need to be greater than zero!");
  ctl->met_tropo =
    (int) scan_ctl(filename, argc, argv, "MET_TROPO", -1, "3", NULL);
  ctl->met_dt_out =
    scan_ctl(filename, argc, argv, "MET_DT_OUT", -1, "0.1", NULL);

  /* Isosurface parameters... */
  ctl->isosurf =
    (int) scan_ctl(filename, argc, argv, "ISOSURF", -1, "0", NULL);
  scan_ctl(filename, argc, argv, "BALLOON", -1, "-", ctl->balloon);

  /* Diffusion parameters... */
  ctl->turb_dx_trop =
    scan_ctl(filename, argc, argv, "TURB_DX_TROP", -1, "50", NULL);
  ctl->turb_dx_strat =
    scan_ctl(filename, argc, argv, "TURB_DX_STRAT", -1, "0", NULL);
  ctl->turb_dz_trop =
    scan_ctl(filename, argc, argv, "TURB_DZ_TROP", -1, "0", NULL);
  ctl->turb_dz_strat =
    scan_ctl(filename, argc, argv, "TURB_DZ_STRAT", -1, "0.1", NULL);
  ctl->turb_mesox =
    scan_ctl(filename, argc, argv, "TURB_MESOX", -1, "0.16", NULL);
  ctl->turb_mesoz =
```

```
    scan_ctl(filename, argc, argv, "TURB_MESOZ", -1, "0.16", NULL);

  /* Convection... */
  ctl->conv_cape =
    scan_ctl(filename, argc, argv, "CONV_CAPE", -1, "-999", NULL);

  /* Species parameters... */
  scan_ctl(filename, argc, argv, "SPECIES", -1, "-", ctl->species);
  if (strcasecmp(ctl->species, "SO2") == 0) {
    ctl->molmass = 64.066;
    ctl->oh_chem[0] = 3.3e-31;   /* (JPL Publication 15-10) */
    ctl->oh_chem[1] = 4.3;       /* (JPL Publication 15-10) */
    ctl->oh_chem[2] = 1.6e-12;   /* (JPL Publication 15-10) */
    ctl->oh_chem[3] = 0.0;       /* (JPL Publication 15-10) */
    ctl->wet_depo[2] = 1.3e-2;  /* (Sander, 2015) */
    ctl->wet_depo[3] = 2900.0;  /* (Sander, 2015) */
    ctl->wet_depo[6] = 1.3e-2;  /* (Sander, 2015) */
    ctl->wet_depo[7] = 2900.0;  /* (Sander, 2015) */
  } else {
    ctl->molmass =
      scan_ctl(filename, argc, argv, "MOLMASS", -1, "-999", NULL);
    ctl->tdec_trop =
      scan_ctl(filename, argc, argv, "TDEC_TROP", -1, "0", NULL);
    ctl->tdec_strat =
      scan_ctl(filename, argc, argv, "TDEC_STRAT", -1, "0", NULL);
    for (int ip = 0; ip < 4; ip++)
      ctl->oh_chem[ip] =
        scan_ctl(filename, argc, argv, "OH_CHEM", ip, "0", NULL);
    for (int ip = 0; ip < 1; ip++)
      ctl->dry_depo[ip] =
        scan_ctl(filename, argc, argv, "DRY_DEPO", ip, "0", NULL);
    for (int ip = 0; ip < 8; ip++)
      ctl->wet_depo[ip] =
        scan_ctl(filename, argc, argv, "WET_DEPO", ip, "0", NULL);
  }

  /* PSC analysis... */
  ctl->psc_h2o = scan_ctl(filename, argc, argv, "PSC_H2O", -1, "4e-6", NULL);
  ctl->psc_hno3 =
    scan_ctl(filename, argc, argv, "PSC_HNO3", -1, "9e-9", NULL);

  /* Output of atmospheric data... */
  scan_ctl(filename, argc, argv, "ATM_BASENAME", -1, "-", ctl->atm_basename);
  scan_ctl(filename, argc, argv, "ATM_GPFILE", -1, "-", ctl->atm_gpfile);
  ctl->atm_dt_out =
    scan_ctl(filename, argc, argv, "ATM_DT_OUT", -1, "86400", NULL);
  ctl->atm_filter =
    (int) scan_ctl(filename, argc, argv, "ATM_FILTER", -1, "0", NULL);
  ctl->atm_stride =
    (int) scan_ctl(filename, argc, argv, "ATM_STRIDE", -1, "1", NULL);
  ctl->atm_type =
    (int) scan_ctl(filename, argc, argv, "ATM_TYPE", -1, "0", NULL);

  /* Output of CSI data... */
  scan_ctl(filename, argc, argv, "CSI_BASENAME", -1, "-", ctl->csi_basename);
  ctl->csi_dt_out =
    scan_ctl(filename, argc, argv, "CSI_DT_OUT", -1, "86400", NULL);
  scan_ctl(filename, argc, argv, "CSI_OBSFILE", -1, "-", ctl->csi_obsfile);
  ctl->csi_obsmin =
    scan_ctl(filename, argc, argv, "CSI_OBSMIN", -1, "0", NULL);
  ctl->csi_modmin =
    scan_ctl(filename, argc, argv, "CSI_MODMIN", -1, "0", NULL);
  ctl->csi_z0 = scan_ctl(filename, argc, argv, "CSI_Z0", -1, "0", NULL);
  ctl->csi_z1 = scan_ctl(filename, argc, argv, "CSI_Z1", -1, "100", NULL);
  ctl->csi_nz = (int) scan_ctl(filename, argc, argv, "CSI_NZ", -1, "1", NULL);
  ctl->csi_lon0 =
    scan_ctl(filename, argc, argv, "CSI_LON0", -1, "-180", NULL);
  ctl->csi_lon1 = scan_ctl(filename, argc, argv, "CSI_LON1", -1, "180", NULL);
  ctl->csi_nx =
    (int) scan_ctl(filename, argc, argv, "CSI_NX", -1, "360", NULL);
  ctl->csi_lat0 = scan_ctl(filename, argc, argv, "CSI_LAT0", -1, "-90", NULL);
  ctl->csi_lat1 = scan_ctl(filename, argc, argv, "CSI_LAT1", -1, "90", NULL);
  ctl->csi_ny =
    (int) scan_ctl(filename, argc, argv, "CSI_NY", -1, "180", NULL);

  /* Output of ensemble data... */
  scan_ctl(filename, argc, argv, "ENS_BASENAME", -1, "-", ctl->ens_basename);

  /* Output of grid data... */
  scan_ctl(filename, argc, argv, "GRID_BASENAME", -1, "-",
           ctl->grid_basename);
  scan_ctl(filename, argc, argv, "GRID_GPFILE", -1, "-", ctl->grid_gpfile);
  ctl->grid_dt_out =
    scan_ctl(filename, argc, argv, "GRID_DT_OUT", -1, "86400", NULL);
  ctl->grid_sparse =
    (int) scan_ctl(filename, argc, argv, "GRID_SPARSE", -1, "0", NULL);
  ctl->grid_z0 = scan_ctl(filename, argc, argv, "GRID_Z0", -1, "0", NULL);
```

```
  ctl->grid_z1 = scan_ctl(filename, argc, argv, "GRID_Z1", -1, "100", NULL);
  ctl->grid_nz =
    (int) scan_ctl(filename, argc, argv, "GRID_NZ", -1, "1", NULL);
  ctl->grid_lon0 =
    scan_ctl(filename, argc, argv, "GRID_LON0", -1, "-180", NULL);
  ctl->grid_lon1 =
    scan_ctl(filename, argc, argv, "GRID_LON1", -1, "180", NULL);
  ctl->grid_nx =
    (int) scan_ctl(filename, argc, argv, "GRID_NX", -1, "360", NULL);
  ctl->grid_lat0 =
    scan_ctl(filename, argc, argv, "GRID_LAT0", -1, "-90", NULL);
  ctl->grid_lat1 =
    scan_ctl(filename, argc, argv, "GRID_LAT1", -1, "90", NULL);
  ctl->grid_ny =
    (int) scan_ctl(filename, argc, argv, "GRID_NY", -1, "180", NULL);

  /* Output of profile data... */
  scan_ctl(filename, argc, argv, "PROF_BASENAME", -1, "-",
           ctl->prof_basename);
  scan_ctl(filename, argc, argv, "PROF_OBSFILE", -1, "-", ctl->prof_obsfile);
  ctl->prof_z0 = scan_ctl(filename, argc, argv, "PROF_Z0", -1, "0", NULL);
  ctl->prof_z1 = scan_ctl(filename, argc, argv, "PROF_Z1", -1, "60", NULL);
  ctl->prof_nz =
    (int) scan_ctl(filename, argc, argv, "PROF_NZ", -1, "60", NULL);
  ctl->prof_lon0 =
    scan_ctl(filename, argc, argv, "PROF_LON0", -1, "-180", NULL);
  ctl->prof_lon1 =
    scan_ctl(filename, argc, argv, "PROF_LON1", -1, "180", NULL);
  ctl->prof_nx =
    (int) scan_ctl(filename, argc, argv, "PROF_NX", -1, "360", NULL);
  ctl->prof_lat0 =
    scan_ctl(filename, argc, argv, "PROF_LAT0", -1, "-90", NULL);
  ctl->prof_lat1 =
    scan_ctl(filename, argc, argv, "PROF_LAT1", -1, "90", NULL);
  ctl->prof_ny =
    (int) scan_ctl(filename, argc, argv, "PROF_NY", -1, "180", NULL);

  /* Output of sample data... */
  scan_ctl(filename, argc, argv, "SAMPLE_BASENAME", -1, "-",
           ctl->sample_basename);
  scan_ctl(filename, argc, argv, "SAMPLE_OBSFILE", -1, "-",
           ctl->sample_obsfile);
  ctl->sample_dx =
    scan_ctl(filename, argc, argv, "SAMPLE_DX", -1, "50", NULL);
  ctl->sample_dz =
    scan_ctl(filename, argc, argv, "SAMPLE_DZ", -1, "-999", NULL);

  /* Output of station data... */
  scan_ctl(filename, argc, argv, "STAT_BASENAME", -1, "-",
           ctl->stat_basename);
  ctl->stat_lon = scan_ctl(filename, argc, argv, "STAT_LON", -1, "0", NULL);
  ctl->stat_lat = scan_ctl(filename, argc, argv, "STAT_LAT", -1, "0", NULL);
  ctl->stat_r = scan_ctl(filename, argc, argv, "STAT_R", -1, "50", NULL);
}
```

Here is the call graph for this function:



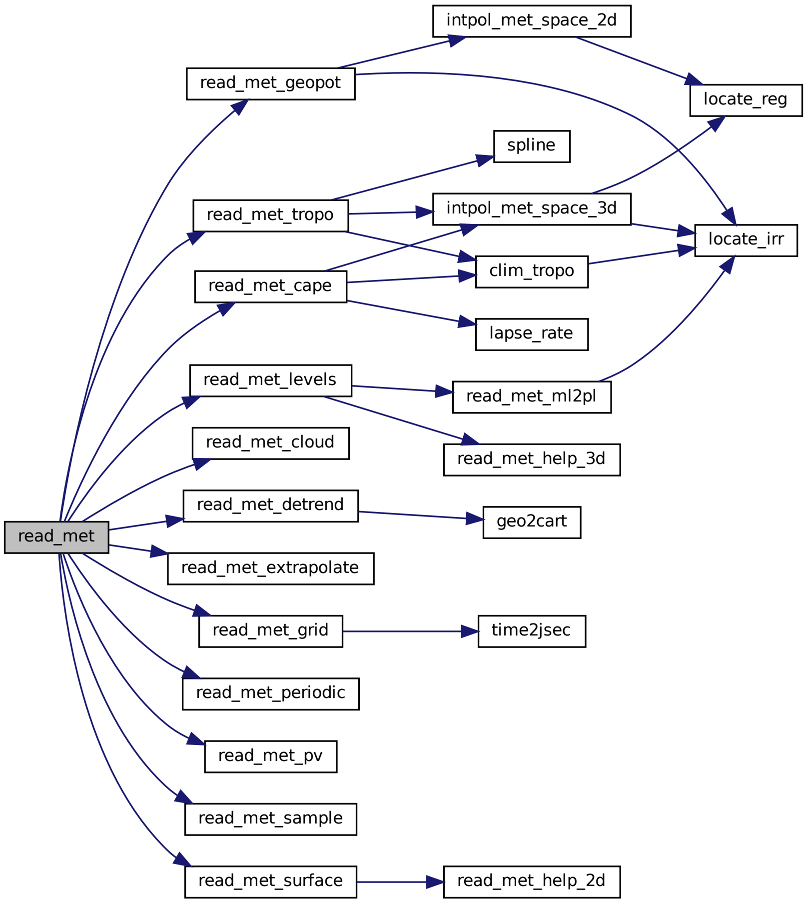
5.23.1.23 read_met() `int read_met ( ctl_t * ctl, char * filename, met_t * met )`

Read meteorological data file.

Definition at line 2614 of file libtrac.c.

```
                  {

  int ncid;

  /* Write info... */
  printf("Read meteorological data: %s\n", filename);

  /* Open netCDF file... */
  if (nc_open(filename, NC_NOWRITE, &ncid) != NC_NOERR) {
    WARN("File not found!");
    return 0;
  }

  /* Read coordinates of meteorological data... */
  read_met_grid(filename, ncid, ctl, met);

  /* Read meteo data on vertical levels... */
  read_met_levels(ncid, ctl, met);

  /* Extrapolate data for lower boundary... */
  read_met_extrapolate(met);

  /* Read surface data... */
  read_met_surface(ncid, met);

  /* Create periodic boundary conditions... */
  read_met_periodic(met);

  /* Downsampling... */
  read_met_sample(ctl, met);

  /* Calculate geopotential heights... */
  read_met_geopot(ctl, met);

  /* Calculate potential vorticity... */
  read_met_pv(met);

  /* Calculate tropopause data... */
  read_met_tropo(ctl, met);

  /* Calculate cloud properties... */
  read_met_cloud(met);

  /* Calculate convective available potential energy... */
  read_met_cape(met);

  /* Detrending... */
  read_met_detrend(ctl, met);

  /* Close file... */
  NC(nc_close(ncid));

  /* Return success... */
  return 1;
}
```

Here is the call graph for this function:



5.23.1.24 read_met_cape() void read_met_cape (met_t * met)

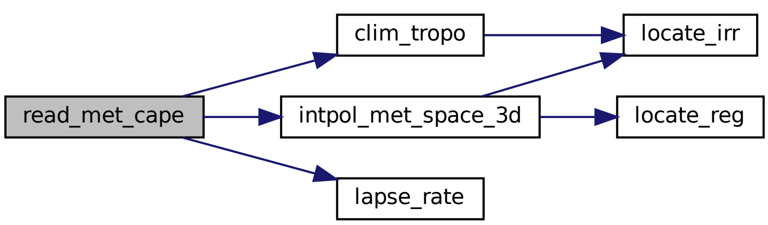
Calculate convective available potential energy.

Definition at line 2675 of file libtrac.c.

```
                    {

  /* Set timer... */
  SELECT_TIMER("READ_MET_CAPE", NVTX_READ);

  /* Vertical spacing (about 100 m)... */
  const double pfac = 1.01439, dz0 = RI / MA / G0 * log(pfac);

  /* Loop over columns... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++) {

      /* Get potential temperature and water vapor vmr at lowest 50 hPa... */
      int n = 0;
      double h2o = 0, t, theta = 0;
      double pbot = GSL_MIN(met->ps[ix][iy], met->p[0]);
      double ptop = pbot - 50.;
```

```
      for (int ip = 0; ip < met->np; ip++) {
        if (met->p[ip] <= pbot) {
          theta += THETA(met->p[ip], met->t[ix][iy][ip]);
          h2o += met->h2o[ix][iy][ip];
          n++;
        }
        if (met->p[ip] < ptop && n > 0)
          break;
      }
      theta /= n;
      h2o /= n;

      /* Cannot compute anything if water vapor is missing... */
      met->plcl[ix][iy] = GSL_NAN;
      met->plfc[ix][iy] = GSL_NAN;
      met->pel[ix][iy] = GSL_NAN;
      met->cape[ix][iy] = GSL_NAN;
      if (h2o <= 0)
        continue;

      /* Find lifted condensation level (LCL)... */
      ptop = P(20.);
      pbot = met->ps[ix][iy];
      do {
        met->plcl[ix][iy] = (float) (0.5 * (pbot + ptop));
        t = theta / pow(1000. / met->plcl[ix][iy], 0.286);
        if (RH(met->plcl[ix][iy], t, h2o) > 100.)
          ptop = met->plcl[ix][iy];
        else
          pbot = met->plcl[ix][iy];
      } while (pbot - ptop > 0.1);

      /* Calculate level of free convection (LFC), equilibrium level (EL),
         and convective available potential energy (CAPE)... */
      double dcape = 0, dcape_old, dz, h2o_env, p = met->plcl[ix][iy],
        psat, t_env;
      ptop = 0.75 * clim_tropo(met->time, met->lat[iy]);
      met->cape[ix][iy] = 0;
      do {
        dz = dz0 * TVIRT(t, h2o);
        p /= pfac;
        t -= lapse_rate(t, h2o) * dz;
        psat = PSAT(t);
        h2o = psat / (p - (1. - EPS) * psat);
        INTPOL_INIT;
        intpol_met_space_3d(met, met->t, p, met->lon[ix], met->lat[iy],
                            &t_env, ci, cw, 1);
        intpol_met_space_3d(met, met->h2o, p, met->lon[ix], met->lat[iy],
                            &h2o_env, ci, cw, 0);
        dcape_old = dcape;
        dcape = 1e3 * G0 * (TVIRT(t, h2o) - TVIRT(t_env, h2o_env)) /
          TVIRT(t_env, h2o_env) * dz;
        if (dcape > 0) {
          met->cape[ix][iy] += (float) dcape;
          if (!isfinite(met->plfc[ix][iy]))
            met->plfc[ix][iy] = (float) p;
        } else if (dcape_old > 0)
          met->pel[ix][iy] = (float) p;
      } while (p > ptop);
    }
}
```

Here is the call graph for this function:



5.23.1.25 read_met_cloud() void read_met_cloud (
met_t * met)

Calculate cloud properties.

Definition at line 2758 of file libtrac.c.

```
                    {

  /* Set timer... */
  SELECT_TIMER("READ_MET_CLOUD", NVTX_READ);

  /* Loop over columns... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++) {

      /* Init... */
      met->pc[ix][iy] = GSL_NAN;
      met->cl[ix][iy] = 0;

      /* Loop over pressure levels... */
      for (int ip = 0; ip < met->np - 1; ip++) {

        /* Check pressure... */
        if (met->p[ip] > met->ps[ix][iy] || met->p[ip] < P(20.))
          continue;

        /* Get cloud top pressure ... */
        if (met->iwc[ix][iy][ip] > 0 || met->lwc[ix][iy][ip] > 0)
          met->pc[ix][iy] = (float) met->p[ip + 1];

        /* Get cloud water... */
        met->cl[ix][iy] += (float)
          (0.5 * (met->iwc[ix][iy][ip] + met->iwc[ix][iy][ip + 1]
                  + met->lwc[ix][iy][ip] + met->lwc[ix][iy][ip + 1])
           * 100. * (met->p[ip] - met->p[ip + 1]) / G0);
      }
    }
}
```

5.23.1.26 read_met_detrend() void read_met_detrend (
ctl_t * ctl,
met_t * met)

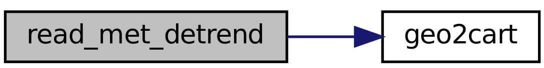
Apply detrending method to temperature and winds.

Definition at line 2795 of file libtrac.c.

```
                    {

  met_t *help;

  /* Check parameters... */
  if (ctl->met_detrend <= 0)
    return;

  /* Set timer... */
  SELECT_TIMER("READ_MET_DETREND", NVTX_READ);

  /* Allocate... */
  ALLOC(help, met_t, 1);

  /* Calculate standard deviation... */
  double sigma = ctl->met_detrend / 2.355;
  double tssq = 2. * SQR(sigma);

  /* Calculate box size in latitude... */
  int sy = (int) (3. * DY2DEG(sigma) / fabs(met->lat[1] - met->lat[0]));
  sy = GSL_MIN(GSL_MAX(1, sy), met->ny / 2);

  /* Calculate background... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++) {
    for (int iy = 0; iy < met->ny; iy++) {

      /* Calculate Cartesian coordinates... */
      double x0[3];
```

```
      geo2cart(0.0, met->lon[ix], met->lat[iy], x0);

      /* Calculate box size in longitude... */
      int sx =
        (int) (3. * DX2DEG(sigma, met->lat[iy]) /
               fabs(met->lon[1] - met->lon[0]));
      sx = GSL_MIN(GSL_MAX(1, sx), met->nx / 2);

      /* Init... */
      float wsum = 0;
      for (int ip = 0; ip < met->np; ip++) {
        help->t[ix][iy][ip] = 0;
        help->u[ix][iy][ip] = 0;
        help->v[ix][iy][ip] = 0;
        help->w[ix][iy][ip] = 0;
      }

      /* Loop over neighboring grid points... */
      for (int ix2 = ix - sx; ix2 <= ix + sx; ix2++) {
        int ix3 = ix2;
        if (ix3 < 0)
          ix3 += met->nx;
        else if (ix3 >= met->nx)
          ix3 -= met->nx;
        for (int iy2 = GSL_MAX(iy - sy, 0);
             iy2 <= GSL_MIN(iy + sy, met->ny - 1); iy2++) {

          /* Calculate Cartesian coordinates... */
          double x1[3];
          geo2cart(0.0, met->lon[ix3], met->lat[iy2], x1);

          /* Calculate weighting factor... */
          float w = (float) exp(-DIST2(x0, x1) / tssq);

          /* Add data... */
          wsum += w;
          for (int ip = 0; ip < met->np; ip++) {
            help->t[ix][iy][ip] += w * met->t[ix3][iy2][ip];
            help->u[ix][iy][ip] += w * met->u[ix3][iy2][ip];
            help->v[ix][iy][ip] += w * met->v[ix3][iy2][ip];
            help->w[ix][iy][ip] += w * met->w[ix3][iy2][ip];
          }
        }
      }

      /* Normalize... */
      for (int ip = 0; ip < met->np; ip++) {
        help->t[ix][iy][ip] /= wsum;
        help->u[ix][iy][ip] /= wsum;
        help->v[ix][iy][ip] /= wsum;
        help->w[ix][iy][ip] /= wsum;
      }
    }
  }

  /* Subtract background... */
#pragma omp parallel for default(shared)
  for (int ix = 0; ix < met->nx; ix++)
    for (int iy = 0; iy < met->ny; iy++)
      for (int ip = 0; ip < met->np; ip++) {
        met->t[ix][iy][ip] -= help->t[ix][iy][ip];
        met->u[ix][iy][ip] -= help->u[ix][iy][ip];
        met->v[ix][iy][ip] -= help->v[ix][iy][ip];
        met->w[ix][iy][ip] -= help->w[ix][iy][ip];
      }

  /* Free... */
  free(help);
}
```

Here is the call graph for this function:



5.23.1.27 read_met_extrapolate()

void read_met_extrapolate (
met_t * met)

Extrapolate meteorological data at lower boundary.

Definition at line 2898 of file libtrac.c.

```
                {

  int ip, ip0, ix, iy;

  /* Set timer... */
  SELECT_TIMER("READ_MET_EXTRAPOLATE", NVTX_READ);

  /* Loop over columns... */
#pragma omp parallel for default(shared) private(ix,iy,ip0,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {

      /* Find lowest valid data point... */
      for (ip0 = met->np - 1; ip0 >= 0; ip0--)
        if (!isfinite(met->t[ix][iy][ip0])
            || !isfinite(met->u[ix][iy][ip0])
            || !isfinite(met->v[ix][iy][ip0])
            || !isfinite(met->w[ix][iy][ip0]))
          break;

      /* Extrapolate... */
      for (ip = ip0; ip >= 0; ip--) {
        met->t[ix][iy][ip] = met->t[ix][iy][ip + 1];
        met->u[ix][iy][ip] = met->u[ix][iy][ip + 1];
        met->v[ix][iy][ip] = met->v[ix][iy][ip + 1];
        met->w[ix][iy][ip] = met->w[ix][iy][ip + 1];
        met->h2o[ix][iy][ip] = met->h2o[ix][iy][ip + 1];
        met->o3[ix][iy][ip] = met->o3[ix][iy][ip + 1];
        met->lwc[ix][iy][ip] = met->lwc[ix][iy][ip + 1];
        met->iwc[ix][iy][ip] = met->iwc[ix][iy][ip + 1];
      }
    }
}
```

5.23.1.28 read_met_geopot()

void read_met_geopot (
ctl_t * ctl,
met_t * met)

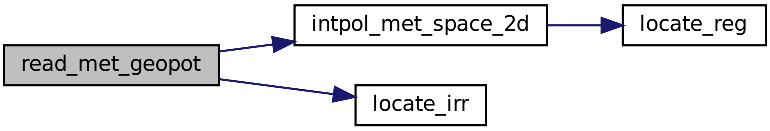
Calculate geopotential heights.

Definition at line 2935 of file libtrac.c.

```
                {

  const int dx = ctl->met_geopot_sx, dy = ctl->met_geopot_sy;

  static float help[EX][EY][EP], w, wsum;

  double h2os, logp[EP], ts, z0;

  int ip, ip0, ix, ix2, ix3, iy, iy2;

  /* Set timer... */
  SELECT_TIMER("READ_MET_GEOPOT", NVTX_READ);

  /* Calculate log pressure... */
  for (ip = 0; ip < met->np; ip++)
    logp[ip] = log(met->p[ip]);

  /* Initialize geopotential heights... */
#pragma omp parallel for default(shared) private(ix,iy,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++)
        met->z[ix][iy][ip] = GSL_NAN;

```

```
  /* Apply hydrostatic equation to calculate geopotential heights... */
#pragma omp parallel for default(shared) private(ix,iy,z0,ip0,ts,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {

      /* Get surface height... */
      INTPOL_INIT;
      intpol_met_space_2d(met, met->zs, met->lon[ix], met->lat[iy], &z0, ci,
                          cw, 1);

      /* Find surface pressure level index... */
      ip0 = locate_irr(met->p, met->np, met->ps[ix][iy]);

      /* Get temperature and water vapor vmr at the surface... */
      ts =
        LIN(met->p[ip0], met->t[ix][iy][ip0], met->p[ip0 + 1],
            met->t[ix][iy][ip0 + 1], met->ps[ix][iy]);
      h2os =
        LIN(met->p[ip0], met->h2o[ix][iy][ip0], met->p[ip0 + 1],
            met->h2o[ix][iy][ip0 + 1], met->ps[ix][iy]);

      /* Upper part of profile... */
      met->z[ix][iy][ip0 + 1]
        = (float) (z0 +
                   ZDIFF(log(met->ps[ix][iy]), ts, h2os, logp[ip0 + 1],
                         met->t[ix][iy][ip0 + 1], met->h2o[ix][iy][ip0 + 1]));
      for (ip = ip0 + 2; ip < met->np; ip++)
        met->z[ix][iy][ip]
          = (float) (met->z[ix][iy][ip - 1] +
                     ZDIFF(logp[ip - 1], met->t[ix][iy][ip - 1],
                           met->h2o[ix][iy][ip - 1], logp[ip],
                           met->t[ix][iy][ip], met->h2o[ix][iy][ip]));

      /* Lower part of profile... */
      met->z[ix][iy][ip0]
        = (float) (z0 +
                   ZDIFF(log(met->ps[ix][iy]), ts, h2os, logp[ip0],
                         met->t[ix][iy][ip0], met->h2o[ix][iy][ip0]));
      for (ip = ip0 - 1; ip >= 0; ip--)
        met->z[ix][iy][ip]
          = (float) (met->z[ix][iy][ip + 1] +
                     ZDIFF(logp[ip + 1], met->t[ix][iy][ip + 1],
                           met->h2o[ix][iy][ip + 1], logp[ip],
                           met->t[ix][iy][ip], met->h2o[ix][iy][ip]));
    }

  /* Horizontal smoothing... */
#pragma omp parallel for default(shared) private(ix,iy,ip,ix2,ix3,iy2,w,wsum)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++) {
        wsum = 0;
        help[ix][iy][ip] = 0;
        for (ix2 = ix - dx + 1; ix2 <= ix + dx - 1; ix2++) {
          ix3 = ix2;
          if (ix3 < 0)
            ix3 += met->nx;
          else if (ix3 >= met->nx)
            ix3 -= met->nx;
          for (iy2 = GSL_MAX(iy - dy + 1, 0);
               iy2 <= GSL_MIN(iy + dy - 1, met->ny - 1); iy2++)
            if (isfinite(met->z[ix3][iy2][ip])) {
              w = (1.0f - (float) abs(ix - ix2) / (float) dx)
                * (1.0f - (float) abs(iy - iy2) / (float) dy);
              help[ix][iy][ip] += w * met->z[ix3][iy2][ip];
              wsum += w;
            }
        }
        if (wsum > 0)
          help[ix][iy][ip] /= wsum;
        else
          help[ix][iy][ip] = GSL_NAN;
      }

  /* Copy data... */
#pragma omp parallel for default(shared) private(ix,iy,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++)
        met->z[ix][iy][ip] = help[ix][iy][ip];
}
```

Here is the call graph for this function:



5.23.1.29 read_met_grid()

```
void read_met_grid (
    char * filename,
    int ncid,
    ctl_t * ctl,
    met_t * met )
```

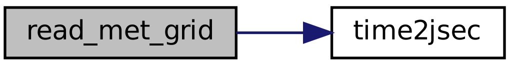
Read coordinates of meteorological data.

Definition at line 3045 of file libtrac.c.

```
                  {

  char levname[LEN], tstr[10];

  int dimid, ip, varid, year, mon, day, hour;

  size_t np, nx, ny;

  /* Set timer... */
  SELECT_TIMER("READ_MET_GRID", NVTX_READ);

  /* Get time from filename... */
  sprintf(tstr, "%.4s", &filename[strlen(filename) - 16]);
  year = atoi(tstr);
  sprintf(tstr, "%.2s", &filename[strlen(filename) - 11]);
  mon = atoi(tstr);
  sprintf(tstr, "%.2s", &filename[strlen(filename) - 8]);
  day = atoi(tstr);
  sprintf(tstr, "%.2s", &filename[strlen(filename) - 5]);
  hour = atoi(tstr);
  time2jsec(year, mon, day, hour, 0, 0, 0, &met->time);

  /* Get grid dimensions... */
  NC(nc_inq_dimid(ncid, "lon", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &nx));
  if (nx < 2 || nx > EX)
    ERRMSG("Number of longitudes out of range!");

  NC(nc_inq_dimid(ncid, "lat", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &ny));
  if (ny < 2 || ny > EY)
    ERRMSG("Number of latitudes out of range!");

  sprintf(levname, "lev");
  NC(nc_inq_dimid(ncid, levname, &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &np));
  if (np == 1) {
    sprintf(levname, "lev_2");
    if (nc_inq_dimid(ncid, levname, &dimid) != NC_NOERR) {
      sprintf(levname, "plev");
      nc_inq_dimid(ncid, levname, &dimid);
    }
    NC(nc_inq_dimlen(ncid, dimid, &np));
  }
  if (np < 2 || np > EP)
    ERRMSG("Number of levels out of range!");

  /* Store dimensions... */
```

```
  met->np = (int) np;
  met->nx = (int) nx;
  met->ny = (int) ny;

  /* Read longitudes and latitudes... */
  NC(nc_inq_varid(ncid, "lon", &varid));
  NC(nc_get_var_double(ncid, varid, met->lon));
  NC(nc_inq_varid(ncid, "lat", &varid));
  NC(nc_get_var_double(ncid, varid, met->lat));

  /* Read pressure levels... */
  if (ctl->met_np <= 0) {
    NC(nc_inq_varid(ncid, levname, &varid));
    NC(nc_get_var_double(ncid, varid, met->p));
    for (ip = 0; ip < met->np; ip++)
      met->p[ip] /= 100.;
  }

  /* Set pressure levels... */
  else {
    met->np = ctl->met_np;
    for (ip = 0; ip < met->np; ip++)
      met->p[ip] = ctl->met_p[ip];
  }

  /* Check ordering of pressure levels... */
  for (ip = 1; ip < met->np; ip++)
    if (met->p[ip - 1] < met->p[ip])
      ERRMSG("Pressure levels must be descending!");
}
```

Here is the call graph for this function:



5.23.1.30 read_met_help_3d()

```
int read_met_help_3d (
        int ncid,
        char * varname,
        char * varname2,
        met_t * met,
        float dest[EX][EY][EP],
        float scl )
```

Read and convert 3D variable from meteorological data file.

Definition at line 3130 of file libtrac.c.

```
                  {

  float *help;

  int ip, ix, iy, varid;

  /* Check if variable exists... */
  if (nc_inq_varid(ncid, varname, &varid) != NC_NOERR)
    if (nc_inq_varid(ncid, varname2, &varid) != NC_NOERR)
      return 0;

  /* Allocate... */
  ALLOC(help, float,
        EX * EY * EP);

```

```
  /* Read data... */
  NC(nc_get_var_float(ncid, varid, help));

  /* Copy and check data... */
#pragma omp parallel for default(shared) private(ix,iy,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++)
      for (ip = 0; ip < met->np; ip++) {
        dest[ix][iy][ip] = help[(ip * met->ny + iy) * met->nx + ix];
        if (fabsf(dest[ix][iy][ip]) < 1e14f)
          dest[ix][iy][ip] *= scl;
        else
          dest[ix][iy][ip] = GSL_NAN;
      }

  /* Free... */
  free(help);

  /* Return... */
  return 1;
}
```

5.23.1.31 read_met_help_2d()

```
int read_met_help_2d (
    int ncid,
    char * varname,
    char * varname2,
    met_t * met,
    float dest[EX][EY],
    float scl )
```

Read and convert 2D variable from meteorological data file.

Definition at line 3175 of file libtrac.c.

```
                {

  float *help;

  int ix, iy, varid;

  /* Check if variable exists... */
  if (nc_inq_varid(ncid, varname, &varid) != NC_NOERR)
    if (nc_inq_varid(ncid, varname2, &varid) != NC_NOERR)
      return 0;

  /* Allocate... */
  ALLOC(help, float,
        EX * EY);

  /* Read data... */
  NC(nc_get_var_float(ncid, varid, help));

  /* Copy and check data... */
#pragma omp parallel for default(shared) private(ix,iy)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {
      dest[ix][iy] = help[iy * met->nx + ix];
      if (fabsf(dest[ix][iy]) < 1e14f)
        dest[ix][iy] *= scl;
      else
        dest[ix][iy] = GSL_NAN;
    }

  /* Free... */
  free(help);

  /* Return... */
  return 1;
}
```

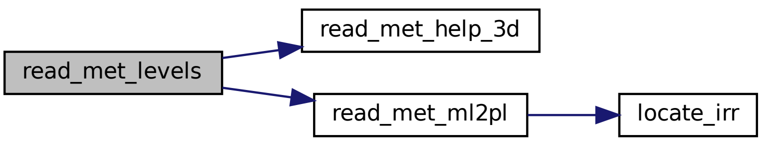
5.23.1.32 read_met_levels()

```
void read_met_levels (
    int ncid,
    ctl_t * ctl,
    met_t * met )
```

Definition at line 3219 of file libtrac.c.

```
                          {

  /* Set timer... */
  SELECT_TIMER("READ_MET_LEVELS", NVTX_READ);

  /* Read meteorological data... */
  if (!read_met_help_3d(ncid, "t", "T", met, met->t, 1.0))
    ERRMSG("Cannot read temperature!");
  if (!read_met_help_3d(ncid, "u", "U", met, met->u, 1.0))
    ERRMSG("Cannot read zonal wind!");
  if (!read_met_help_3d(ncid, "v", "V", met, met->v, 1.0))
    ERRMSG("Cannot read meridional wind!");
  if (!read_met_help_3d(ncid, "w", "W", met, met->w, 0.01f))
    WARN("Cannot read vertical velocity");
  if (!read_met_help_3d(ncid, "q", "Q", met, met->h2o, (float) (MA / MH2O)))
    WARN("Cannot read specific humidity!");
  if (!read_met_help_3d(ncid, "o3", "O3", met, met->o3, (float) (MA / MO3)))
    WARN("Cannot read ozone data!");
  if (!read_met_help_3d(ncid, "clwc", "CLWC", met, met->lwc, 1.0))
    WARN("Cannot read cloud liquid water content!");
  if (!read_met_help_3d(ncid, "ciwc", "CIWC", met, met->iwc, 1.0))
    WARN("Cannot read cloud ice water content!");

  /* Transfer from model levels to pressure levels... */
  if (ctl->met_np > 0) {

    /* Read pressure on model levels... */
    if (!read_met_help_3d(ncid, "pl", "PL", met, met->pl, 0.01f))
      ERRMSG("Cannot read pressure on model levels!");

    /* Vertical interpolation from model to pressure levels... */
    read_met_ml2pl(ctl, met, met->t);
    read_met_ml2pl(ctl, met, met->u);
    read_met_ml2pl(ctl, met, met->v);
    read_met_ml2pl(ctl, met, met->w);
    read_met_ml2pl(ctl, met, met->h2o);
    read_met_ml2pl(ctl, met, met->o3);
    read_met_ml2pl(ctl, met, met->lwc);
    read_met_ml2pl(ctl, met, met->iwc);
  }
}
```

Here is the call graph for this function:



5.23.1.33 read_met_ml2pl()

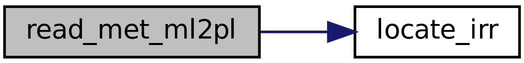
```
void read_met_ml2pl (
    ctl_t * ctl,
    met_t * met,
    float var[EX][EY][EP] )
```

Convert meteorological data from model levels to pressure levels.

Definition at line 3266 of file libtrac.c.

```
                              {

  double aux[EP], p[EP], pt;

  int ip, ip2, ix, iy;

  /* Set timer... */
  SELECT_TIMER("READ_MET_ML2PL", NVTX_READ);

  /* Loop over columns... */
#pragma omp parallel for default(shared) private(ix,iy,ip,p,pt,ip2,aux)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {

      /* Copy pressure profile... */
      for (ip = 0; ip < met->np; ip++)
        p[ip] = met->pl[ix][iy][ip];

      /* Interpolate... */
      for (ip = 0; ip < ctl->met_np; ip++) {
        pt = ctl->met_p[ip];
        if ((pt > p[0] && p[0] > p[1]) || (pt < p[0] && p[0] < p[1]))
          pt = p[0];
        else if ((pt > p[met->np - 1] && p[1] > p[0])
                 || (pt < p[met->np - 1] && p[1] < p[0]))
          pt = p[met->np - 1];
        ip2 = locate_irr(p, met->np, pt);
        aux[ip] = LIN(p[ip2], var[ix][iy][ip2],
                      p[ip2 + 1], var[ix][iy][ip2 + 1], pt);
      }

      /* Copy data... */
      for (ip = 0; ip < ctl->met_np; ip++)
        var[ix][iy][ip] = (float) aux[ip];
    }
}
```

Here is the call graph for this function:



5.23.1.34 read_met_periodic() void read_met_periodic (met_t * *met*)

Create meteorological data with periodic boundary conditions.

Definition at line 3308 of file libtrac.c.

```
                    {

  /* Set timer... */
  SELECT_TIMER("READ_MET_PERIODIC", NVTX_READ);

  /* Check longitudes... */
  if (!(fabs(met->lon[met->nx - 1] - met->lon[0]
             + met->lon[1] - met->lon[0] - 360) < 0.01))
    return;

  /* Increase longitude counter... */
  if ((++met->nx) > EX)
    ERRMSG("Cannot create periodic boundary conditions!");

  /* Set longitude... */
```

```
  met->lon[met->nx - 1] = met->lon[met->nx - 2] + met->lon[1] - met->lon[0];

  /* Loop over latitudes and pressure levels... */
#pragma omp parallel for default(shared)
  for (int iy = 0; iy < met->ny; iy++) {
    met->ps[met->nx - 1][iy] = met->ps[0][iy];
    met->zs[met->nx - 1][iy] = met->zs[0][iy];
    for (int ip = 0; ip < met->np; ip++) {
      met->t[met->nx - 1][iy][ip] = met->t[0][iy][ip];
      met->u[met->nx - 1][iy][ip] = met->u[0][iy][ip];
      met->v[met->nx - 1][iy][ip] = met->v[0][iy][ip];
      met->w[met->nx - 1][iy][ip] = met->w[0][iy][ip];
      met->h2o[met->nx - 1][iy][ip] = met->h2o[0][iy][ip];
      met->o3[met->nx - 1][iy][ip] = met->o3[0][iy][ip];
      met->lwc[met->nx - 1][iy][ip] = met->lwc[0][iy][ip];
      met->iwc[met->nx - 1][iy][ip] = met->iwc[0][iy][ip];
    }
  }
}
```

5.23.1.35 read_met_pv() void read_met_pv (met_t * met)

Calculate potential vorticity.

Definition at line 3346 of file libtrac.c.

```
                {

  double c0, c1, cr, dx, dy, dp0, dp1, denom, dtdx, dvdx, dtdy, dudy,
    dtdp, dudp, dvdp, latr, vort, pows[EP];

  int ip, ip0, ip1, ix, ix0, ix1, iy, iy0, iy1;

  /* Set timer... */
  SELECT_TIMER("READ_MET_PV", NVTX_READ);

  /* Set powers... */
  for (ip = 0; ip < met->np; ip++)
    pows[ip] = pow(1000. / met->p[ip], 0.286);

  /* Loop over grid points... */
#pragma omp parallel for default(shared)
 private(ix,ix0,ix1,iy,iy0,iy1,latr,dx,dy,c0,c1,cr,vort,ip,ip0,ip1,dp0,dp1,denom,dtdx,dvdx,dtdy,dudy,dtdp,dudp,dvdp)
  for (ix = 0; ix < met->nx; ix++) {

    /* Set indices... */
    ix0 = GSL_MAX(ix - 1, 0);
    ix1 = GSL_MIN(ix + 1, met->nx - 1);

    /* Loop over grid points... */
    for (iy = 0; iy < met->ny; iy++) {

      /* Set indices... */
      iy0 = GSL_MAX(iy - 1, 0);
      iy1 = GSL_MIN(iy + 1, met->ny - 1);

      /* Set auxiliary variables... */
      latr = 0.5 * (met->lat[iy1] + met->lat[iy0]);
      dx = 1000. * DEG2DX(met->lon[ix1] - met->lon[ix0], latr);
      dy = 1000. * DEG2DY(met->lat[iy1] - met->lat[iy0]);
      c0 = cos(met->lat[iy0] / 180. * M_PI);
      c1 = cos(met->lat[iy1] / 180. * M_PI);
      cr = cos(latr / 180. * M_PI);
      vort = 2 * 7.2921e-5 * sin(latr * M_PI / 180.);

      /* Loop over grid points... */
      for (ip = 0; ip < met->np; ip++) {

        /* Get gradients in longitude... */
        dtdx = (met->t[ix1][iy][ip] - met->t[ix0][iy][ip]) * pows[ip] / dx;
        dvdx = (met->v[ix1][iy][ip] - met->v[ix0][iy][ip]) / dx;

        /* Get gradients in latitude... */
        dtdy = (met->t[ix][iy1][ip] - met->t[ix][iy0][ip]) * pows[ip] / dy;
        dudy = (met->u[ix][iy1][ip] * c1 - met->u[ix][iy0][ip] * c0) / dy;

        /* Set indices... */
        ip0 = GSL_MAX(ip - 1, 0);
        ip1 = GSL_MIN(ip + 1, met->np - 1);
```

```

        /* Get gradients in pressure... */
        dp0 = 100. * (met->p[ip] - met->p[ip0]);
        dp1 = 100. * (met->p[ip1] - met->p[ip]);
        if (ip != ip0 && ip != ip1) {
          denom = dp0 * dp1 * (dp0 + dp1);
          dtdp = (dp0 * dp0 * met->t[ix][iy][ip1] * pows[ip1]
                  - dp1 * dp1 * met->t[ix][iy][ip0] * pows[ip0]
                  + (dp1 * dp1 - dp0 * dp0) * met->t[ix][iy][ip] * pows[ip])
            / denom;
          dudp = (dp0 * dp0 * met->u[ix][iy][ip1]
                  - dp1 * dp1 * met->u[ix][iy][ip0]
                  + (dp1 * dp1 - dp0 * dp0) * met->u[ix][iy][ip])
            / denom;
          dvdp = (dp0 * dp0 * met->v[ix][iy][ip1]
                  - dp1 * dp1 * met->v[ix][iy][ip0]
                  + (dp1 * dp1 - dp0 * dp0) * met->v[ix][iy][ip])
            / denom;
        } else {
          denom = dp0 + dp1;
          dtdp =
            (met->t[ix][iy][ip1] * pows[ip1] -
             met->t[ix][iy][ip0] * pows[ip0]) / denom;
          dudp = (met->u[ix][iy][ip1] - met->u[ix][iy][ip0]) / denom;
          dvdp = (met->v[ix][iy][ip1] - met->v[ix][iy][ip0]) / denom;
        }

        /* Calculate PV... */
        met->pv[ix][iy][ip] = (float)
          (1e6 * G0 *
           (-dtdp * (dvdx - dudy / cr + vort) + dvdp * dtdx - dudp * dtdy));
      }
    }
  }

  /* Fix for polar regions... */
#pragma omp parallel for default(shared) private(ix,ip)
  for (ix = 0; ix < met->nx; ix++)
    for (ip = 0; ip < met->np; ip++) {
      met->pv[ix][0][ip]
        = met->pv[ix][1][ip]
        = met->pv[ix][2][ip];
      met->pv[ix][met->ny - 1][ip]
        = met->pv[ix][met->ny - 2][ip]
        = met->pv[ix][met->ny - 3][ip];
    }
}
```

5.23.1.36 read_met_sample()

```
void read_met_sample (
    ctl_t * ctl,
    met_t * met )
```

Downsampling of meteorological data.

Definition at line 3449 of file libtrac.c.

```
               {

  met_t *help;

  float w, wsum;

  int ip, ip2, ix, ix2, ix3, iy, iy2;

  /* Check parameters... */
  if (ctl->met_dp <= 1 && ctl->met_dx <= 1 && ctl->met_dy <= 1
      && ctl->met_sp <= 1 && ctl->met_sx <= 1 && ctl->met_sy <= 1)
    return;

  /* Set timer... */
  SELECT_TIMER("READ_MET_SAMPLE", NVTX_READ);

  /* Allocate... */
  ALLOC(help, met_t, 1);

  /* Copy data... */
  help->nx = met->nx;
  help->ny = met->ny;
  help->np = met->np;
```

```
memcpy(help->lon, met->lon, sizeof(met->lon));
memcpy(help->lat, met->lat, sizeof(met->lat));
memcpy(help->p, met->p, sizeof(met->p));

/* Smoothing... */
for (ix = 0; ix < met->nx; ix += ctl->met_dx) {
  for (iy = 0; iy < met->ny; iy += ctl->met_dy) {
    for (ip = 0; ip < met->np; ip += ctl->met_dp) {
      help->ps[ix][iy] = 0;
      help->zs[ix][iy] = 0;
      help->t[ix][iy][ip] = 0;
      help->u[ix][iy][ip] = 0;
      help->v[ix][iy][ip] = 0;
      help->w[ix][iy][ip] = 0;
      help->h2o[ix][iy][ip] = 0;
      help->o3[ix][iy][ip] = 0;
      help->lwc[ix][iy][ip] = 0;
      help->iwc[ix][iy][ip] = 0;
      wsum = 0;
      for (ix2 = ix - ctl->met_sx + 1; ix2 <= ix + ctl->met_sx - 1; ix2++) {
        ix3 = ix2;
        if (ix3 < 0)
          ix3 += met->nx;
        else if (ix3 >= met->nx)
          ix3 -= met->nx;

        for (iy2 = GSL_MAX(iy - ctl->met_sy + 1, 0);
             iy2 <= GSL_MIN(iy + ctl->met_sy - 1, met->ny - 1); iy2++)
          for (ip2 = GSL_MAX(ip - ctl->met_sp + 1, 0);
               ip2 <= GSL_MIN(ip + ctl->met_sp - 1, met->np - 1); ip2++) {
            w = (1.0f - (float) abs(ix - ix2) / (float) ctl->met_sx)
              * (1.0f - (float) abs(iy - iy2) / (float) ctl->met_sy)
              * (1.0f - (float) abs(ip - ip2) / (float) ctl->met_sp);
            help->ps[ix][iy] += w * met->ps[ix3][iy2];
            help->zs[ix][iy] += w * met->zs[ix3][iy2];
            help->t[ix][iy][ip] += w * met->t[ix3][iy2][ip2];
            help->u[ix][iy][ip] += w * met->u[ix3][iy2][ip2];
            help->v[ix][iy][ip] += w * met->v[ix3][iy2][ip2];
            help->w[ix][iy][ip] += w * met->w[ix3][iy2][ip2];
            help->h2o[ix][iy][ip] += w * met->h2o[ix3][iy2][ip2];
            help->o3[ix][iy][ip] += w * met->o3[ix3][iy2][ip2];
            help->lwc[ix][iy][ip] += w * met->lwc[ix3][iy2][ip2];
            help->iwc[ix][iy][ip] += w * met->iwc[ix3][iy2][ip2];
            wsum += w;
          }
      }
      help->ps[ix][iy] /= wsum;
      help->zs[ix][iy] /= wsum;
      help->t[ix][iy][ip] /= wsum;
      help->u[ix][iy][ip] /= wsum;
      help->v[ix][iy][ip] /= wsum;
      help->w[ix][iy][ip] /= wsum;
      help->h2o[ix][iy][ip] /= wsum;
      help->o3[ix][iy][ip] /= wsum;
      help->lwc[ix][iy][ip] /= wsum;
      help->iwc[ix][iy][ip] /= wsum;
    }
  }
}

/* Downsampling... */
met->nx = 0;
for (ix = 0; ix < help->nx; ix += ctl->met_dx) {
  met->lon[met->nx] = help->lon[ix];
  met->ny = 0;
  for (iy = 0; iy < help->ny; iy += ctl->met_dy) {
    met->lat[met->ny] = help->lat[iy];
    met->ps[met->nx][met->ny] = help->ps[ix][iy];
    met->zs[met->nx][met->ny] = help->zs[ix][iy];
    met->np = 0;
    for (ip = 0; ip < help->np; ip += ctl->met_dp) {
      met->p[met->np] = help->p[ip];
      met->t[met->nx][met->ny][met->np] = help->t[ix][iy][ip];
      met->u[met->nx][met->ny][met->np] = help->u[ix][iy][ip];
      met->v[met->nx][met->ny][met->np] = help->v[ix][iy][ip];
      met->w[met->nx][met->ny][met->np] = help->w[ix][iy][ip];
      met->h2o[met->nx][met->ny][met->np] = help->h2o[ix][iy][ip];
      met->o3[met->nx][met->ny][met->np] = help->o3[ix][iy][ip];
      met->lwc[met->nx][met->ny][met->np] = help->lwc[ix][iy][ip];
      met->iwc[met->nx][met->ny][met->np] = help->iwc[ix][iy][ip];
      met->np++;
    }
    met->ny++;
  }
  met->nx++;
}

```

```
  /* Free... */
  free(help);
}
```

5.23.1.37 read_met_surface()

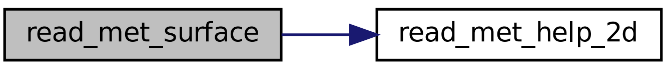
```
void read_met_surface (
    int ncid,
    met_t * met )
```

Read surface data.

Definition at line 3567 of file libtrac.c.

```
                {

  int ix, iy;

  /* Set timer... */
  SELECT_TIMER("READ_MET_SURFACE", NVTX_READ);

  /* Read surface pressure... */
  if (!read_met_help_2d(ncid, "ps", "PS", met, met->ps, 0.01f)) {
    if (!read_met_help_2d(ncid, "lnsp", "LNSP", met, met->ps, 1.0)) {
      ERRMSG("Cannot not read surface pressure data!");
      for (ix = 0; ix < met->nx; ix++)
        for (iy = 0; iy < met->ny; iy++)
          met->ps[ix][iy] = (float) met->p[0];
    } else {
      for (iy = 0; iy < met->ny; iy++)
        for (ix = 0; ix < met->nx; ix++)
          met->ps[ix][iy] = (float) (exp(met->ps[ix][iy]) / 100.);
    }
  }

  /* Read geopotential height at the surface... */
  if (!read_met_help_2d
      (ncid, "z", "Z", met, met->zs, (float) (1. / (1000. * G0))))
    if (!read_met_help_2d
        (ncid, "zm", "ZM", met, met->zs, (float) (1. / 1000.)))
      ERRMSG("Cannot read surface geopotential height!");

  /* Read temperature at the surface... */
  if (!read_met_help_2d(ncid, "t2m", "T2M", met, met->ts, 1.0))
    WARN("Cannot read surface temperature!");

  /* Read zonal wind at the surface... */
  if (!read_met_help_2d(ncid, "u10m", "U10M", met, met->us, 1.0))
    WARN("Cannot read surface zonal wind!");

  /* Read meridional wind at the surface... */
  if (!read_met_help_2d(ncid, "v10m", "V10M", met, met->vs, 1.0))
    WARN("Cannot read surface meridional wind!");
}
```

Here is the call graph for this function:



5.23.1.38 read_met_tropo()

```
void read_met_tropo (
    ctl_t * ctl,
    met_t * met )
```

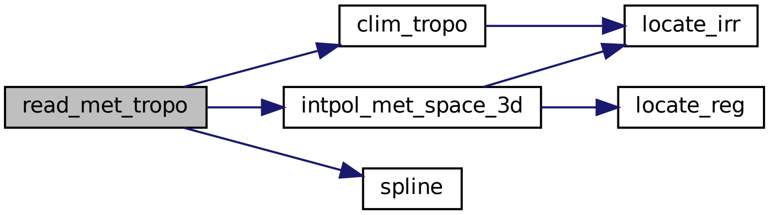
Calculate tropopause data.

Definition at line 3612 of file libtrac.c.

```
             {

  double h2ot, p2[200], pv[EP], pv2[200], t[EP], t2[200], th[EP],
    th2[200], tt, z[EP], z2[200], zt;

  int found, ix, iy, iz, iz2;

  /* Set timer... */
  SELECT_TIMER("READ_MET_TROPO", NVTX_READ);

  /* Get altitude and pressure profiles... */
  for (iz = 0; iz < met->np; iz++)
    z[iz] = Z(met->p[iz]);
  for (iz = 0; iz <= 190; iz++) {
    z2[iz] = 4.5 + 0.1 * iz;
    p2[iz] = P(z2[iz]);
  }

  /* Do not calculate tropopause... */
  if (ctl->met_tropo == 0)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        met->pt[ix][iy] = GSL_NAN;

  /* Use tropopause climatology... */
  else if (ctl->met_tropo == 1) {
#pragma omp parallel for default(shared) private(ix,iy)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        met->pt[ix][iy] = (float) clim_tropo(met->time, met->lat[iy]);
  }

  /* Use cold point... */
  else if (ctl->met_tropo == 2) {

    /* Loop over grid points... */
#pragma omp parallel for default(shared) private(ix,iy,iz,t,t2)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {

        /* Interpolate temperature profile... */
        for (iz = 0; iz < met->np; iz++)
          t[iz] = met->t[ix][iy][iz];
        spline(z, t, met->np, z2, t2, 171);

        /* Find minimum... */
        iz = (int) gsl_stats_min_index(t2, 1, 171);
        if (iz > 0 && iz < 170)
          met->pt[ix][iy] = (float) p2[iz];
        else
          met->pt[ix][iy] = GSL_NAN;
      }
  }

  /* Use WMO definition... */
  else if (ctl->met_tropo == 3 || ctl->met_tropo == 4) {

    /* Loop over grid points... */
#pragma omp parallel for default(shared) private(ix,iy,iz,iz2,t,t2,found)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {

        /* Interpolate temperature profile... */
        for (iz = 0; iz < met->np; iz++)
          t[iz] = met->t[ix][iy][iz];
        spline(z, t, met->np, z2, t2, 191);

        /* Find 1st tropopause... */
        met->pt[ix][iy] = GSL_NAN;
        for (iz = 0; iz <= 170; iz++) {
          found = 1;
          for (iz2 = iz + 1; iz2 <= iz + 20; iz2++)
            if (LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]) > 2.0) {
              found = 0;
              break;
            }
          if (found) {
```

```
            if (iz > 0 && iz < 170)
              met->pt[ix][iy] = (float) p2[iz];
            break;
          }
        }

        /* Find 2nd tropopause... */
        if (ctl->met_tropo == 4) {
          met->pt[ix][iy] = GSL_NAN;
          for (; iz <= 170; iz++) {
            found = 1;
            for (iz2 = iz + 1; iz2 <= iz + 10; iz2++)
              if (LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]) < 3.0) {
                found = 0;
                break;
              }
            if (found)
              break;
          }
          for (; iz <= 170; iz++) {
            found = 1;
            for (iz2 = iz + 1; iz2 <= iz + 20; iz2++)
              if (LAPSE(p2[iz], t2[iz], p2[iz2], t2[iz2]) > 2.0) {
                found = 0;
                break;
              }
            if (found) {
              if (iz > 0 && iz < 170)
                met->pt[ix][iy] = (float) p2[iz];
              break;
            }
          }
        }
      }
  }

  /* Use dynamical tropopause... */
  else if (ctl->met_tropo == 5) {

    /* Loop over grid points... */
#pragma omp parallel for default(shared) private(ix,iy,iz,pv,pv2,th,th2)
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {

        /* Interpolate potential vorticity profile... */
        for (iz = 0; iz < met->np; iz++)
          pv[iz] = met->pv[ix][iy][iz];
        spline(z, pv, met->np, z2, pv2, 171);

        /* Interpolate potential temperature profile... */
        for (iz = 0; iz < met->np; iz++)
          th[iz] = THETA(met->p[iz], met->t[ix][iy][iz]);
        spline(z, th, met->np, z2, th2, 171);

        /* Find dynamical tropopause 3.5 PVU + 380 K */
        met->pt[ix][iy] = GSL_NAN;
        for (iz = 0; iz <= 170; iz++)
          if (fabs(pv2[iz]) >= 3.5 || th2[iz] >= 380.) {
            if (iz > 0 && iz < 170)
              met->pt[ix][iy] = (float) p2[iz];
            break;
          }
      }
  }

  else
    ERRMSG("Cannot calculate tropopause!");

  /* Interpolate temperature, geopotential height, and water vapor vmr... */
#pragma omp parallel for default(shared) private(ix,iy,tt,zt,h2ot)
  for (ix = 0; ix < met->nx; ix++)
    for (iy = 0; iy < met->ny; iy++) {
      INTPOL_INIT;
      intpol_met_space_3d(met, met->t, met->pt[ix][iy], met->lon[ix],
                          met->lat[iy], &tt, ci, cw, 1);
      intpol_met_space_3d(met, met->z, met->pt[ix][iy], met->lon[ix],
                          met->lat[iy], &zt, ci, cw, 0);
      intpol_met_space_3d(met, met->h2o, met->pt[ix][iy], met->lon[ix],
                          met->lat[iy], &h2ot, ci, cw, 0);
      met->tt[ix][iy] = (float) tt;
      met->zt[ix][iy] = (float) zt;
      met->h2ot[ix][iy] = (float) h2ot;
    }
}
```

Here is the call graph for this function:



5.23.1.39 scan_ctl()

```
double scan_ctl (
    const char * filename,
    int argc,
    char * argv[ ],
    const char * varname,
    int arridx,
    const char * defvalue,
    char * value )
```

Read a control parameter from file or command line.

Definition at line 3778 of file libtrac.c.

```
                  {

  FILE *in = NULL;

  char dummy[LEN], fullname1[LEN], fullname2[LEN], line[LEN],
    msg[2 * LEN], rvarname[LEN], rval[LEN];

  int contain = 0, i;

  /* Open file... */
  if (filename[strlen(filename) - 1] != '-')
    if (!(in = fopen(filename, "r")))
      ERRMSG("Cannot open file!");

  /* Set full variable name... */
  if (arridx >= 0) {
    sprintf(fullname1, "%s[%d]", varname, arridx);
    sprintf(fullname2, "%s[*]", varname);
  } else {
    sprintf(fullname1, "%s", varname);
    sprintf(fullname2, "%s", varname);
  }

  /* Read data... */
  if (in != NULL)
    while (fgets(line, LEN, in))
      if (sscanf(line, "%s %s %s", rvarname, dummy, rval) == 3)
        if (strcasecmp(rvarname, fullname1) == 0 ||
            strcasecmp(rvarname, fullname2) == 0) {
          contain = 1;
          break;
        }
  for (i = 1; i < argc - 1; i++)
    if (strcasecmp(argv[i], fullname1) == 0 ||
        strcasecmp(argv[i], fullname2) == 0) {
      sprintf(rval, "%s", argv[i + 1]);
      contain = 1;
      break;
    }

```

```
  /* Close file... */
  if (in != NULL)
    fclose(in);

  /* Check for missing variables... */
  if (!contain) {
    if (strlen(defvalue) > 0)
      sprintf(rval, "%s", defvalue);
    else {
      sprintf(msg, "Missing variable %s!\n", fullname1);
      ERRMSG(msg);
    }
  }

  /* Write info... */
  printf("%s = %s\n", fullname1, rval);

  /* Return values... */
  if (value != NULL)
    sprintf(value, "%s", rval);
  return atof(rval);
}
```

5.23.1.40 sedi()

```
double sedi (
        double p,
        double T,
        double r_p,
        double rho_p )
```

Calculate sedimentation velocity.

Definition at line 3850 of file libtrac.c.

```
                {

  double eta, G, K, lambda, rho, v;

  /* Convert units... */
  p *= 100.;                       /* from hPa to Pa */
  r_p *= 1e-6;                     /* from microns to m */

  /* Density of dry air... */
  rho = p / (RA * T);

  /* Dynamic viscosity of air... */
  eta = 1.8325e-5 * (416.16 / (T + 120.)) * pow(T / 296.16, 1.5);

  /* Thermal velocity of an air molecule... */
  v = sqrt(8. * KB * T / (M_PI * 4.8096e-26));

  /* Mean free path of an air molecule... */
  lambda = 2. * eta / (rho * v);

  /* Knudsen number for air... */
  K = lambda / r_p;

  /* Cunningham slip-flow correction... */
  G = 1. + K * (1.249 + 0.42 * exp(-0.87 / K));

  /* Sedimentation velocity... */
  return 2. * SQR(r_p) * (rho_p - rho) * G0 / (9. * eta) * G;
}
```

5.23.1.41 spline()

```
void spline (
        double * x,
        double * y,
        int n,
        double * x2,
        double * y2,
        int n2 )
```

Spline interpolation.

Definition at line 3886 of file libtrac.c.

```
        {

  gsl_interp_accel *acc;

  gsl_spline *s;

  /* Allocate... */
  acc = gsl_interp_accel_alloc();
  s = gsl_spline_alloc(gsl_interp_cspline, (size_t) n);

  /* Interpolate profile... */
  gsl_spline_init(s, x, y, (size_t) n);
  for (int i = 0; i < n2; i++)
    if (x2[i] <= x[0])
      y2[i] = y[0];
    else if (x2[i] >= x[n - 1])
      y2[i] = y[n - 1];
    else
      y2[i] = gsl_spline_eval(s, x2[i], acc);

  /* Free... */
  gsl_spline_free(s);
  gsl_interp_accel_free(acc);
}
```

5.23.1.42 stddev() `double stddev ( double * data, int n )`

Calculate standard deviation.

Definition at line 3919 of file libtrac.c.

```
       {

  if (n <= 0)
    return 0;

  double avg = 0, rms = 0;

  for (int i = 0; i < n; ++i)
    avg += data[i];
  avg /= n;

  for (int i = 0; i < n; ++i)
    rms += SQR(data[i] - avg);

  return sqrt(rms / (n - 1));
}
```

5.23.1.43 time2jsec() `void time2jsec ( int year, int mon, int day, int hour, int min, int sec, double remain, double * jsec )`

Convert date to seconds.

Definition at line 3940 of file libtrac.c.

```
              {
```

```

  struct tm t0, t1;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  t1.tm_year = year - 1900;
  t1.tm_mon = mon - 1;
  t1.tm_mday = day;
  t1.tm_hour = hour;
  t1.tm_min = min;
  t1.tm_sec = sec;

  *jsec = (double) timegm(&t1) - (double) timegm(&t0) + remain;
}
```

5.23.1.44 timer()

```
void timer (
    const char * name,
    int output )
```

Measure wall-clock time.

Definition at line 3971 of file libtrac.c.

```
                  {

  static char namelist[NTIMER][100];

  static double runtime[NTIMER], t0, t1;

  static int it = -1, nt;

  /* Get time... */
  t1 = omp_get_wtime();

  /* Add elapsed timer to old timer... */
  if (it >= 0)
    runtime[it] += t1 - t0;

  /* Identify ID of new timer... */
  for (it = 0; it < nt; it++)
    if (strcasecmp(name, namelist[it]) == 0)
      break;

  /* Check whether this is a new timer... */
  if (it >= nt) {
    sprintf(namelist[it], "%s", name);
    if ((++nt) > NTIMER)
      ERRMSG("Too many timers!");
  }

  /* Save starting time... */
  t0 = t1;

  /* Report timers... */
  if (output) {
    for (int it2 = 0; it2 < nt; it2++)
      printf("TIMER_%s = %.3f s\n", namelist[it2], runtime[it2]);
    double total = 0.0;
    for (int it2 = 0; it2 < nt; it2++)
      total += runtime[it2];
    printf("TIMER_TOTAL = %.3f s\n", total);
  }
}
```

5.23.1.45 write_atm()

```
void write_atm (
    const char * filename,
    ctl_t * ctl,
    atm_t * atm,
    double t )
```

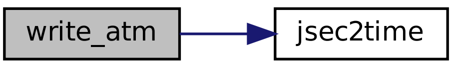
Write atmospheric data.

Definition at line 4016 of file libtrac.c.

```
               {

  FILE *in, *out;

  char line[LEN];

  double r, t0, t1;

  int ip, iq, year, mon, day, hour, min, sec;

  /* Set timer... */
  SELECT_TIMER("WRITE_ATM", NVTX_WRITE);

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Write info... */
  printf("Write atmospheric data: %s\n", filename);

  /* Write ASCII data... */
  if (ctl->atm_type == 0) {

    /* Check if gnuplot output is requested... */
    if (ctl->atm_gpfile[0] != '-') {

      /* Create gnuplot pipe... */
      if (!(out = popen("gnuplot", "w")))
        ERRMSG("Cannot create pipe to gnuplot!");

      /* Set plot filename... */
      fprintf(out, "set out \"%s.png\"\n", filename);

      /* Set time string... */
      jsec2time(t, &year, &mon, &day, &hour, &min, &sec, &r);
      fprintf(out, "timestr=\"%d-%02d-%02d, %02d:%02d UTC\"\n",
              year, mon, day, hour, min);

      /* Dump gnuplot file to pipe... */
      if (!(in = fopen(ctl->atm_gpfile, "r")))
        ERRMSG("Cannot open file!");
      while (fgets(line, LEN, in))
        fprintf(out, "%s", line);
      fclose(in);
    }

    else {

      /* Create file... */
      if (!(out = fopen(filename, "w")))
        ERRMSG("Cannot create file!");
    }

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
    for (iq = 0; iq < ctl->nq; iq++)
      fprintf(out, "# $%i = %s [%s]\n", iq + 5, ctl->qnt_name[iq],
              ctl->qnt_unit[iq]);
    fprintf(out, "\n");

    /* Write data... */
    for (ip = 0; ip < atm->np; ip += ctl->atm_stride) {

      /* Check time... */
      if (ctl->atm_filter && (atm->time[ip] < t0 || atm->time[ip] > t1))
        continue;

      /* Write output... */
      fprintf(out, "%.2f %g %g %g", atm->time[ip], Z(atm->p[ip]),
              atm->lon[ip], atm->lat[ip]);
      for (iq = 0; iq < ctl->nq; iq++) {
```

```
        fprintf(out, " ");
        fprintf(out, ctl->qnt_format[iq], atm->q[iq][ip]);
      }
      fprintf(out, "\n");
    }

    /* Close file... */
    fclose(out);
  }

  /* Write binary data... */
  else if (ctl->atm_type == 1) {

    /* Create file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write data... */
    FWRITE(&atm->np, int,
           1,
           out);
    FWRITE(atm->time, double,
             (size_t) atm->np,
           out);
    FWRITE(atm->p, double,
             (size_t) atm->np,
           out);
    FWRITE(atm->lon, double,
             (size_t) atm->np,
           out);
    FWRITE(atm->lat, double,
             (size_t) atm->np,
           out);
    for (iq = 0; iq < ctl->nq; iq++)
      FWRITE(atm->q[iq], double,
               (size_t) atm->np,
             out);

    /* Close file... */
    fclose(out);
  }

  /* Error... */
  else
    ERRMSG("Atmospheric data type not supported!");
}
```

Here is the call graph for this function:



5.23.1.46 write_csi() `void write_csi ( const char * filename, ctl_t * ctl, atm_t * atm, double t )`

Write CSI data.

Definition at line 4143 of file libtrac.c.

```
            {

```

```
  static FILE *in, *out;

  static char line[LEN];

  static double modmean[GX][GY][GZ], obsmean[GX][GY][GZ], rt, rt_old = -1e99,
    rz, rlon, rlat, robs, t0, t1, area[GY], dlon, dlat, dz, lat,
    x[1000000], y[1000000], work[2000000];

  static int obscount[GX][GY][GZ], ct, cx, cy, cz, ip, ix, iy, iz, n;

  /* Set timer... */
  SELECT_TIMER("WRITE_CSI", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Check quantity index for mass... */
    if (ctl->qnt_m < 0)
      ERRMSG("Need quantity mass!");

    /* Open observation data file... */
    printf("Read CSI observation data: %s\n", ctl->csi_obsfile);
    if (!(in = fopen(ctl->csi_obsfile, "r")))
      ERRMSG("Cannot open file!");

    /* Create new file... */
    printf("Write CSI data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = number of hits (cx)\n"
            "# $3 = number of misses (cy)\n"
            "# $4 = number of false alarms (cz)\n"
            "# $5 = number of observations (cx + cy)\n"
            "# $6 = number of forecasts (cx + cz)\n"
            "# $7 = bias (ratio of forecasts and observations) [%%]\n"
            "# $8 = probability of detection (POD) [%%]\n"
            "# $9 = false alarm rate (FAR) [%%]\n"
            "# $10 = critical success index (CSI) [%%]\n");
    fprintf(out,
            "# $11 = hits associated with random chance\n"
            "# $12 = equitable threat score (ETS) [%%]\n"
            "# $13 = Pearson linear correlation coefficient\n"
            "# $14 = Spearman rank-order correlation coefficient\n"
            "# $15 = column density mean error (F - O) [kg/m^2]\n"
            "# $16 = column density root mean square error (RMSE) [kg/m^2]\n"
            "# $17 = column density mean absolute error [kg/m^2]\n"
            "# $18 = number of data points\n\n");

    /* Set grid box size... */
    dz = (ctl->csi_z1 - ctl->csi_z0) / ctl->csi_nz;
    dlon = (ctl->csi_lon1 - ctl->csi_lon0) / ctl->csi_nx;
    dlat = (ctl->csi_lat1 - ctl->csi_lat0) / ctl->csi_ny;

    /* Set horizontal coordinates... */
    for (iy = 0; iy < ctl->csi_ny; iy++) {
      lat = ctl->csi_lat0 + dlat * (iy + 0.5);
      area[iy] = dlat * dlon * SQR(RE * M_PI / 180.) * cos(lat * M_PI / 180.);
    }
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize grid cells... */
#pragma omp parallel for default(shared) private(ix,iy,iz)
  for (ix = 0; ix < ctl->csi_nx; ix++)
    for (iy = 0; iy < ctl->csi_ny; iy++)
      for (iz = 0; iz < ctl->csi_nz; iz++)
        modmean[ix][iy][iz] = obsmean[ix][iy][iz] = obscount[ix][iy][iz] = 0;

  /* Read observation data... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg %lg", &rt, &rz, &rlon, &rlat, &robs) !=
        5)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt > t1)
```

```
      break;
    if (rt < rt_old)
      ERRMSG("Time must be ascending!");
    rt_old = rt;

    /* Check observation data... */
    if (!isfinite(robs))
      continue;

    /* Calculate indices... */
    ix = (int) ((rlon - ctl->csi_lon0) / dlon);
    iy = (int) ((rlat - ctl->csi_lat0) / dlat);
    iz = (int) ((rz - ctl->csi_z0) / dz);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->csi_nx ||
        iy < 0 || iy >= ctl->csi_ny || iz < 0 || iz >= ctl->csi_nz)
      continue;

    /* Get mean observation index... */
    obsmean[ix][iy][iz] += robs;
    obscount[ix][iy][iz]++;
  }

  /* Analyze model data... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Get indices... */
    ix = (int) ((atm->lon[ip] - ctl->csi_lon0) / dlon);
    iy = (int) ((atm->lat[ip] - ctl->csi_lat0) / dlat);
    iz = (int) ((Z(atm->p[ip]) - ctl->csi_z0) / dz);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->csi_nx ||
        iy < 0 || iy >= ctl->csi_ny || iz < 0 || iz >= ctl->csi_nz)
      continue;

    /* Get total mass in grid cell... */
    modmean[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
  }

  /* Analyze all grid cells... */
  for (ix = 0; ix < ctl->csi_nx; ix++)
    for (iy = 0; iy < ctl->csi_ny; iy++)
      for (iz = 0; iz < ctl->csi_nz; iz++) {

        /* Calculate mean observation index... */
        if (obscount[ix][iy][iz] > 0)
          obsmean[ix][iy][iz] /= obscount[ix][iy][iz];

        /* Calculate column density... */
        if (modmean[ix][iy][iz] > 0)
          modmean[ix][iy][iz] /= (1e6 * area[iy]);

        /* Calculate CSI... */
        if (obscount[ix][iy][iz] > 0) {
          ct++;
          if (obsmean[ix][iy][iz] >= ctl->csi_obsmin &&
              modmean[ix][iy][iz] >= ctl->csi_modmin)
            cx++;
          else if (obsmean[ix][iy][iz] >= ctl->csi_obsmin &&
                   modmean[ix][iy][iz] < ctl->csi_modmin)
            cy++;
          else if (obsmean[ix][iy][iz] < ctl->csi_obsmin &&
                   modmean[ix][iy][iz] >= ctl->csi_modmin)
            cz++;
        }

        /* Save data for other verification statistics... */
        if (obscount[ix][iy][iz] > 0
            && (obsmean[ix][iy][iz] >= ctl->csi_obsmin
                || modmean[ix][iy][iz] >= ctl->csi_modmin)) {
          x[n] = modmean[ix][iy][iz];
          y[n] = obsmean[ix][iy][iz];
          if ((++n) > 1000000)
            ERRMSG("Too many data points to calculate statistics!");
        }
      }

  /* Write output... */
  if (fmod(t, ctl->csi_dt_out) == 0) {

    /* Calculate verification statistics
```

```
      (https://www.cawcr.gov.au/projects/verification/) ... */
    int nobs = cx + cy;
    int nfor = cx + cz;
    double bias = (nobs > 0) ? 100. * nfor / nobs : GSL_NAN;
    double pod = (nobs > 0) ? (100. * cx) / nobs : GSL_NAN;
    double far = (nfor > 0) ? (100. * cz) / nfor : GSL_NAN;
    double csi = (cx + cy + cz > 0) ? (100. * cx) / (cx + cy + cz) : GSL_NAN;
    double cx_rd = (ct > 0) ? (1. * nobs * nfor) / ct : GSL_NAN;
    double ets = (cx + cy + cz - cx_rd > 0) ?
      (100. * (cx - cx_rd)) / (cx + cy + cz - cx_rd) : GSL_NAN;
    double rho_p =
      (n > 0) ? gsl_stats_correlation(x, 1, y, 1, (size_t) n) : GSL_NAN;
    double rho_s =
      (n > 0) ? gsl_stats_spearman(x, 1, y, 1, (size_t) n, work) : GSL_NAN;
    for (int i = 0; i < n; i++)
      work[i] = x[i] - y[i];
    double mean = (n > 0) ? gsl_stats_mean(work, 1, (size_t) n) : GSL_NAN;
    double rmse = (n > 0) ? gsl_stats_sd_with_fixed_mean(work, 1, (size_t) n,
                                                          0.0) : GSL_NAN;
    double absdev =
      (n > 0) ? gsl_stats_absdev_m(work, 1, (size_t) n, 0.0) : GSL_NAN;

    /* Write... */
    fprintf(out, "%.2f %d %d %d %d %d %g %g %g %g %g %g %g %g %g %g %g %d\n",
            t, cx, cy, cz, nobs, nfor, bias, pod, far, csi, cx_rd, ets,
            rho_p, rho_s, mean, rmse, absdev, n);

    /* Set counters to zero... */
    n = ct = cx = cy = cz = 0;
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

5.23.1.47 write_ens()

```
void write_ens (
        const char * filename,
        ctl_t * ctl,
        atm_t * atm,
        double t )
```

Write ensemble data.

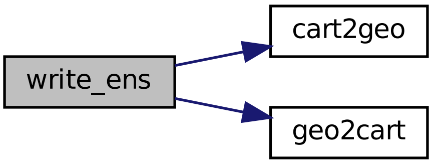
Definition at line 4361 of file libtrac.c.

```
            {

  static FILE *out;

  static double dummy, ens, lat, lon, p[NENS], q[NQ][NENS],
    t0, t1, x[NENS][3], xm[3];

  static int ip, iq;

  static size_t i, n;

  /* Set timer... */
  SELECT_TIMER("WRITE_ENS", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Check quantities... */
    if (ctl->qnt_ens < 0)
      ERRMSG("Missing ensemble IDs!");

    /* Create new file... */
    printf("Write ensemble data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
    for (iq = 0; iq < ctl->nq; iq++)
```

```
      fprintf(out, "# $%d = %s (mean) [%s]\n", 5 + iq,
              ctl->qnt_name[iq], ctl->qnt_unit[iq]);
    for (iq = 0; iq < ctl->nq; iq++)
      fprintf(out, "# $%d = %s (sigma) [%s]\n", 5 + ctl->nq + iq,
              ctl->qnt_name[iq], ctl->qnt_unit[iq]);
    fprintf(out, "# $%d = number of members\n\n", 5 + 2 * ctl->nq);
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Init... */
  ens = GSL_NAN;
  n = 0;

  /* Loop over air parcels... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Check ensemble id... */
    if (atm->q[ctl->qnt_ens][ip] != ens) {

      /* Write results... */
      if (n > 0) {

        /* Get mean position... */
        xm[0] = xm[1] = xm[2] = 0;
        for (i = 0; i < n; i++) {
          xm[0] += x[i][0] / (double) n;
          xm[1] += x[i][1] / (double) n;
          xm[2] += x[i][2] / (double) n;
        }
        cart2geo(xm, &dummy, &lon, &lat);
        fprintf(out, "%.2f %g %g %g", t, Z(gsl_stats_mean(p, 1, n)), lon,
                lat);

        /* Get quantity statistics... */
        for (iq = 0; iq < ctl->nq; iq++) {
          fprintf(out, " ");
          fprintf(out, ctl->qnt_format[iq], gsl_stats_mean(q[iq], 1, n));
        }
        for (iq = 0; iq < ctl->nq; iq++) {
          fprintf(out, " ");
          fprintf(out, ctl->qnt_format[iq], gsl_stats_sd(q[iq], 1, n));
        }
        fprintf(out, " %lu\n", n);
      }

      /* Init new ensemble... */
      ens = atm->q[ctl->qnt_ens][ip];
      n = 0;
    }

    /* Save data... */
    p[n] = atm->p[ip];
    geo2cart(0, atm->lon[ip], atm->lat[ip], x[n]);
    for (iq = 0; iq < ctl->nq; iq++)
      q[iq][n] = atm->q[iq][ip];
    if ((++n) >= NENS)
      ERRMSG("Too many data points!");
  }

  /* Write results... */
  if (n > 0) {

    /* Get mean position... */
    xm[0] = xm[1] = xm[2] = 0;
    for (i = 0; i < n; i++) {
      xm[0] += x[i][0] / (double) n;
      xm[1] += x[i][1] / (double) n;
      xm[2] += x[i][2] / (double) n;
    }
    cart2geo(xm, &dummy, &lon, &lat);
    fprintf(out, "%.2f %g %g %g", t, Z(gsl_stats_mean(p, 1, n)), lon, lat);

    /* Get quantity statistics... */
    for (iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], gsl_stats_mean(q[iq], 1, n));
    }
    for (iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], gsl_stats_sd(q[iq], 1, n));
```

```
  }
  fprintf(out, " %lu\n", n);
 }

 /* Close file... */
 if (t == ctl->t_stop)
  fclose(out);
}
```

Here is the call graph for this function:



5.23.1.48 write_grid() `void write_grid ( const char * filename, ctl_t * ctl, met_t * met0, met_t * met1, atm_t * atm, double t )`

Write gridded data.

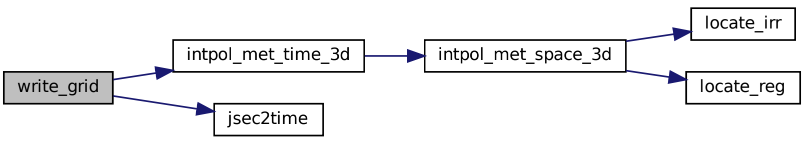
Definition at line 4495 of file libtrac.c.

```
              {

 FILE *in, *out;

 char line[LEN];

 static double mass[GX][GY][GZ], z[GZ], dz, lon[GX], dlon, lat[GY], dlat,
   area[GY], rho_air, press[GZ], temp, cd, vmr, t0, t1, r;

 static int ip, ix, iy, iz, np[GX][GY][GZ], year, mon, day, hour, min, sec;

 /* Set timer... */
 SELECT_TIMER("WRITE_GRID", NVTX_WRITE);

 /* Check dimensions... */
 if (ctl->grid_nx > GX || ctl->grid_ny > GY || ctl->grid_nz > GZ)
   ERRMSG("Grid dimensions too large!");

 /* Set grid box size... */
 dz = (ctl->grid_z1 - ctl->grid_z0) / ctl->grid_nz;
 dlon = (ctl->grid_lon1 - ctl->grid_lon0) / ctl->grid_nx;
 dlat = (ctl->grid_lat1 - ctl->grid_lat0) / ctl->grid_ny;

 /* Set vertical coordinates... */
 for (iz = 0; iz < ctl->grid_nz; iz++) {
   z[iz] = ctl->grid_z0 + dz * (iz + 0.5);
   press[iz] = P(z[iz]);
 }

 /* Set horizontal coordinates... */
 for (ix = 0; ix < ctl->grid_nx; ix++)
   lon[ix] = ctl->grid_lon0 + dlon * (ix + 0.5);
```

```
  for (iy = 0; iy < ctl->grid_ny; iy++) {
    lat[iy] = ctl->grid_lat0 + dlat * (iy + 0.5);
    area[iy] = dlat * dlon * SQR(RE * M_PI / 180.)
      * cos(lat[iy] * M_PI / 180.);
  }

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize grid... */
#pragma omp parallel for default(shared) private(ix,iy,iz)
  for (ix = 0; ix < ctl->grid_nx; ix++)
    for (iy = 0; iy < ctl->grid_ny; iy++)
      for (iz = 0; iz < ctl->grid_nz; iz++) {
        mass[ix][iy][iz] = 0;
        np[ix][iy][iz] = 0;
      }

  /* Average data... */
  for (ip = 0; ip < atm->np; ip++)
    if (atm->time[ip] >= t0 && atm->time[ip] <= t1) {

      /* Get index... */
      ix = (int) ((atm->lon[ip] - ctl->grid_lon0) / dlon);
      iy = (int) ((atm->lat[ip] - ctl->grid_lat0) / dlat);
      iz = (int) ((Z(atm->p[ip]) - ctl->grid_z0) / dz);

      /* Check indices... */
      if (ix < 0 || ix >= ctl->grid_nx ||
          iy < 0 || iy >= ctl->grid_ny || iz < 0 || iz >= ctl->grid_nz)
        continue;

      /* Add mass... */
      if (ctl->qnt_m >= 0)
        mass[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
      np[ix][iy][iz]++;
    }

  /* Check if gnuplot output is requested... */
  if (ctl->grid_gpfile[0] != '-') {

    /* Write info... */
    printf("Plot grid data: %s.png\n", filename);

    /* Create gnuplot pipe... */
    if (!(out = popen("gnuplot", "w")))
      ERRMSG("Cannot create pipe to gnuplot!");

    /* Set plot filename... */
    fprintf(out, "set out \"%s.png\"\n", filename);

    /* Set time string... */
    jsec2time(t, &year, &mon, &day, &hour, &min, &sec, &r);
    fprintf(out, "timestr=\"%d-%02d-%02d, %02d:%02d UTC\"\n",
            year, mon, day, hour, min);

    /* Dump gnuplot file to pipe... */
    if (!(in = fopen(ctl->grid_gpfile, "r")))
      ERRMSG("Cannot open file!");
    while (fgets(line, LEN, in))
      fprintf(out, "%s", line);
    fclose(in);
  }

  else {

    /* Write info... */
    printf("Write grid data: %s\n", filename);

    /* Create file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");
  }

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = surface area [km^2]\n"
          "# $6 = layer width [km]\n"
          "# $7 = number of particles [1]\n"
          "# $8 = column density [kg/m^2]\n"
          "# $9 = volume mixing ratio [ppv]\n\n");

```

```
  /* Write data... */
  for (ix = 0; ix < ctl->grid_nx; ix++) {
    if (ix > 0 && ctl->grid_ny > 1 && !ctl->grid_sparse)
      fprintf(out, "\n");
    for (iy = 0; iy < ctl->grid_ny; iy++) {
      if (iy > 0 && ctl->grid_nz > 1 && !ctl->grid_sparse)
        fprintf(out, "\n");
      for (iz = 0; iz < ctl->grid_nz; iz++)
        if (!ctl->grid_sparse || mass[ix][iy][iz] > 0) {

          /* Calculate column density... */
          cd = mass[ix][iy][iz] / (1e6 * area[iy]);

          /* Calculate volume mixing ratio... */
          vmr = 0;
          if (ctl->molmass > 0) {
            if (mass[ix][iy][iz] > 0) {

              /* Get temperature... */
              INTPOL_INIT;
              intpol_met_time_3d(met0, met0->t, met1, met1->t, t, press[iz],
                                 lon[ix], lat[iy], &temp, ci, cw, 1);

              /* Calculate density of air... */
              rho_air = 100. * press[iz] / (RA * temp);

              /* Calculate volume mixing ratio... */
              vmr = MA / ctl->molmass * mass[ix][iy][iz]
                / (rho_air * 1e6 * area[iy] * 1e3 * dz);
            }
          } else
            vmr = GSL_NAN;

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %d %g %g\n", t, z[iz],
                  lon[ix], lat[iy], area[iy], dz, np[ix][iy][iz], cd, vmr);
        }
    }
  }

  /* Close file... */
  fclose(out);
}
```

Here is the call graph for this function:



5.23.1.49 write_prof()

```
void write_prof (
    const char * filename,
    ctl_t * ctl,
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    double t )
```

Write profile data.

Definition at line 4666 of file libtrac.c.

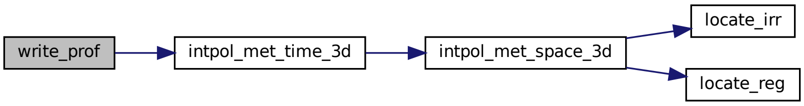
```
                {

```

```
  static FILE *in, *out;

  static char line[LEN];

  static double mass[GX][GY][GZ], obsmean[GX][GY], rt, rt_old = -1e99,
    rz, rlon, rlat, robs, t0, t1, area[GY], dz, dlon, dlat, lon[GX], lat[GY],
    z[GZ], press[GZ], temp, rho_air, vmr, h2o, o3;

  static int obscount[GX][GY], ip, ix, iy, iz, okay;

  /* Set timer... */
  SELECT_TIMER("WRITE_PROF", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Check quantity index for mass... */
    if (ctl->qnt_m < 0)
      ERRMSG("Need quantity mass!");

    /* Check dimensions... */
    if (ctl->prof_nx > GX || ctl->prof_ny > GY || ctl->prof_nz > GZ)
      ERRMSG("Grid dimensions too large!");

    /* Check molar mass... */
    if (ctl->molmass <= 0)
      ERRMSG("Specify molar mass!");

    /* Open observation data file... */
    printf("Read profile observation data: %s\n", ctl->prof_obsfile);
    if (!(in = fopen(ctl->prof_obsfile, "r")))
      ERRMSG("Cannot open file!");

    /* Create new output file... */
    printf("Write profile data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n"
            "# $4 = latitude [deg]\n"
            "# $5 = pressure [hPa]\n"
            "# $6 = temperature [K]\n"
            "# $7 = volume mixing ratio [ppv]\n"
            "# $8 = H2O volume mixing ratio [ppv]\n"
            "# $9 = O3 volume mixing ratio [ppv]\n"
            "# $10 = observed BT index [K]\n");

    /* Set grid box size... */
    dz = (ctl->prof_z1 - ctl->prof_z0) / ctl->prof_nz;
    dlon = (ctl->prof_lon1 - ctl->prof_lon0) / ctl->prof_nx;
    dlat = (ctl->prof_lat1 - ctl->prof_lat0) / ctl->prof_ny;

    /* Set vertical coordinates... */
    for (iz = 0; iz < ctl->prof_nz; iz++) {
      z[iz] = ctl->prof_z0 + dz * (iz + 0.5);
      press[iz] = P(z[iz]);
    }

    /* Set horizontal coordinates... */
    for (ix = 0; ix < ctl->prof_nx; ix++)
      lon[ix] = ctl->prof_lon0 + dlon * (ix + 0.5);
    for (iy = 0; iy < ctl->prof_ny; iy++) {
      lat[iy] = ctl->prof_lat0 + dlat * (iy + 0.5);
      area[iy] = dlat * dlon * SQR(RE * M_PI / 180.)
        * cos(lat[iy] * M_PI / 180.);
    }
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize... */
#pragma omp parallel for default(shared) private(ix,iy,iz)
  for (ix = 0; ix < ctl->prof_nx; ix++)
    for (iy = 0; iy < ctl->prof_ny; iy++) {
      obsmean[ix][iy] = 0;
      obscount[ix][iy] = 0;
      for (iz = 0; iz < ctl->prof_nz; iz++)
        mass[ix][iy][iz] = 0;
    }

  /* Read observation data... */
```

```
  while (fgets(line, LEN, in)) {

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg %lg", &rt, &rz, &rlon, &rlat, &robs) !=
        5)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt > t1)
      break;
    if (rt < rt_old)
      ERRMSG("Time must be ascending!");
    rt_old = rt;

    /* Check observation data... */
    if (!isfinite(robs))
      continue;

    /* Calculate indices... */
    ix = (int) ((rlon - ctl->prof_lon0) / dlon);
    iy = (int) ((rlat - ctl->prof_lat0) / dlat);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->prof_nx || iy < 0 || iy >= ctl->prof_ny)
      continue;

    /* Get mean observation index... */
    obsmean[ix][iy] += robs;
    obscount[ix][iy]++;
  }

  /* Analyze model data... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Get indices... */
    ix = (int) ((atm->lon[ip] - ctl->prof_lon0) / dlon);
    iy = (int) ((atm->lat[ip] - ctl->prof_lat0) / dlat);
    iz = (int) ((Z(atm->p[ip]) - ctl->prof_z0) / dz);

    /* Check indices... */
    if (ix < 0 || ix >= ctl->prof_nx ||
        iy < 0 || iy >= ctl->prof_ny || iz < 0 || iz >= ctl->prof_nz)
      continue;

    /* Get total mass in grid cell... */
    mass[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
  }

  /* Extract profiles... */
  for (ix = 0; ix < ctl->prof_nx; ix++)
    for (iy = 0; iy < ctl->prof_ny; iy++)
      if (obscount[ix][iy] > 0) {

        /* Check profile... */
        okay = 0;
        for (iz = 0; iz < ctl->prof_nz; iz++)
          if (mass[ix][iy][iz] > 0) {
            okay = 1;
            break;
          }
        if (!okay)
          continue;

        /* Write output... */
        fprintf(out, "\n");

        /* Loop over altitudes... */
        for (iz = 0; iz < ctl->prof_nz; iz++) {

          /* Get pressure and temperature... */
          INTPOL_INIT;
          intpol_met_time_3d(met0, met0->t, met1, met1->t, t, press[iz],
                             lon[ix], lat[iy], &temp, ci, cw, 1);
          intpol_met_time_3d(met0, met0->h2o, met1, met1->h2o, t, press[iz],
                             lon[ix], lat[iy], &h2o, ci, cw, 0);
          intpol_met_time_3d(met0, met0->o3, met1, met1->o3, t, press[iz],
                             lon[ix], lat[iy], &o3, ci, cw, 0);

          /* Calculate volume mixing ratio... */
          rho_air = 100. * press[iz] / (RA * temp);
          vmr = MA / ctl->molmass * mass[ix][iy][iz]
```

```
            / (rho_air * area[iy] * dz * 1e9);

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g\n",
                  t, z[iz], lon[ix], lat[iy], press[iz], temp, vmr, h2o, o3,
                  obsmean[ix][iy] / obscount[ix][iy]);
        }
      }

  /* Close files... */
  if (t == ctl->t_stop) {
    fclose(in);
    fclose(out);
  }
}
```

Here is the call graph for this function:



5.23.1.50 write_sample()

```
void write_sample (
        const char * filename,
        ctl_t * ctl,
        met_t * met0,
        met_t * met1,
        atm_t * atm,
        double t )
```

Write sample data.

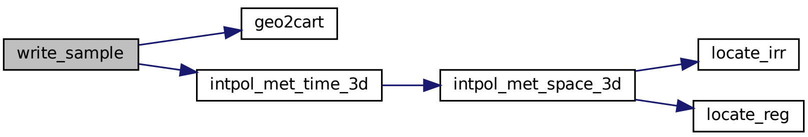
Definition at line 4866 of file libtrac.c.

```
            {

  static FILE *in, *out;

  static char line[LEN];

  static double area, dlat, rmax2, t0, t1, rt, rt_old, rz, rlon, rlat, robs;

  /* Set timer... */
  SELECT_TIMER("WRITE_SAMPLE", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Open observation data file... */
    printf("Read sample observation data: %s\n", ctl->sample_obsfile);
    if (!(in = fopen(ctl->sample_obsfile, "r")))
      ERRMSG("Cannot open file!");

    /* Create new file... */
    printf("Write sample data: %s\n", filename);
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
            "# $3 = longitude [deg]\n"
            "# $4 = latitude [deg]\n"
            "# $5 = surface area [km^2]\n"
```

```
            "# $6 = layer width [km]\n"
            "# $7 = number of particles [1]\n"
            "# $8 = column density [kg/m^2]\n"
            "# $9 = volume mixing ratio [ppv]\n"
            "# $10 = observed BT index [K]\n\n");

    /* Set latitude range, squared radius, and area... */
    dlat = DY2DEG(ctl->sample_dx);
    rmax2 = SQR(ctl->sample_dx);
    area = M_PI * rmax2;
  }

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Read observation data... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg %lg", &rt, &rz, &rlon, &rlat, &robs) !=
        5)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt < rt_old)
      ERRMSG("Time must be ascending!");
    rt_old = rt;

    /* Calculate Cartesian coordinates... */
    double x0[3];
    geo2cart(0, rlon, rlat, x0);

    /* Set pressure range... */
    double rp = P(rz);
    double ptop = P(rz + ctl->sample_dz);
    double pbot = P(rz - ctl->sample_dz);

    /* Init... */
    double mass = 0;
    int np = 0;

    /* Loop over air parcels... */
#pragma omp parallel for default(shared) reduction(+:mass,np)
    for (int ip = 0; ip < atm->np; ip++) {

      /* Check time... */
      if (atm->time[ip] < t0 || atm->time[ip] > t1)
        continue;

      /* Check latitude... */
      if (fabs(rlat - atm->lat[ip]) > dlat)
        continue;

      /* Check horizontal distance... */
      double x1[3];
      geo2cart(0, atm->lon[ip], atm->lat[ip], x1);
      if (DIST2(x0, x1) > rmax2)
        continue;

      /* Check pressure... */
      if (ctl->sample_dz > 0)
        if (atm->p[ip] > pbot || atm->p[ip] < ptop)
          continue;

      /* Add mass... */
      if (ctl->qnt_m >= 0)
        mass += atm->q[ctl->qnt_m][ip];
      np++;
    }

    /* Calculate column density... */
    double cd = mass / (1e6 * area);

    /* Calculate volume mixing ratio... */
    double vmr = 0;
    if (ctl->molmass > 0 && ctl->sample_dz > 0) {
      if (mass > 0) {

        /* Get temperature... */
        double temp;
        INTPOL_INIT;
        intpol_met_time_3d(met0, met0->t, met1, met1->t, rt, rp,
                           rlon, rlat, &temp, ci, cw, 1);

```

```
        /* Calculate density of air... */
        double rho_air = 100. * rp / (RA * temp);

        /* Calculate volume mixing ratio... */
        vmr = MA / ctl->molmass * mass
          / (rho_air * 1e6 * area * 1e3 * ctl->sample_dz);
      }
    } else
      vmr = GSL_NAN;

    /* Write output... */
    fprintf(out, "%.2f %g %g %g %g %g %d %g %g %g\n", rt, rz, rlon, rlat,
            area, ctl->sample_dz, np, cd, vmr, robs);

    /* Check time... */
    if (rt >= t1)
      break;
  }

  /* Close files... */
  if (t == ctl->t_stop) {
    fclose(in);
    fclose(out);
  }
}
```

Here is the call graph for this function:



5.23.1.51 write_station()

```
void write_station (
    const char * filename,
    ctl_t * ctl,
    atm_t * atm,
    double t )
```

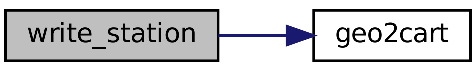
Write station data.

Definition at line 5018 of file libtrac.c.

```
            {

  static FILE *out;

  static double rmax2, t0, t1, x0[3], x1[3];

  /* Set timer... */
  SELECT_TIMER("WRITE_STATION", NVTX_WRITE);

  /* Init... */
  if (t == ctl->t_start) {

    /* Write info... */
    printf("Write station data: %s\n", filename);

    /* Create new file... */
    if (!(out = fopen(filename, "w")))
      ERRMSG("Cannot create file!");

    /* Write header... */
    fprintf(out,
            "# $1 = time [s]\n"
            "# $2 = altitude [km]\n"
```

```
            "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
    for (int iq = 0; iq < ctl->nq; iq++)
      fprintf(out, "# $%i = %s [%s]\n", (iq + 5),
              ctl->qnt_name[iq], ctl->qnt_unit[iq]);
    fprintf(out, "\n");

    /* Set geolocation and search radius... */
    geo2cart(0, ctl->stat_lon, ctl->stat_lat, x0);
    rmax2 = SQR(ctl->stat_r);
  }

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Loop over air parcels... */
  for (int ip = 0; ip < atm->np; ip++) {

    /* Check time... */
    if (atm->time[ip] < t0 || atm->time[ip] > t1)
      continue;

    /* Check station flag... */
    if (ctl->qnt_stat >= 0)
      if (atm->q[ctl->qnt_stat][ip])
        continue;

    /* Get Cartesian coordinates... */
    geo2cart(0, atm->lon[ip], atm->lat[ip], x1);

    /* Check horizontal distance... */
    if (DIST2(x0, x1) > rmax2)
      continue;

    /* Set station flag... */
    if (ctl->qnt_stat >= 0)
      atm->q[ctl->qnt_stat][ip] = 1;

    /* Write data... */
    fprintf(out, "%.2f %g %g %g",
            atm->time[ip], Z(atm->p[ip]), atm->lon[ip], atm->lat[ip]);
    for (int iq = 0; iq < ctl->nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl->qnt_format[iq], atm->q[iq][ip]);
    }
    fprintf(out, "\n");
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

Here is the call graph for this function:



5.24 libtrac.h

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
```

```
  GNU General Public License for more details.
  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.
  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/
/* ------------------------------------------------------------
   Includes...
   ------------------------------------------------------------ */
#include <ctype.h>
#include <gsl/gsl_fft_complex.h>
#include <gsl/gsl_math.h>
#include <gsl/gsl_randist.h>
#include <gsl/gsl_rng.h>
#include <gsl/gsl_sort.h>
#include <gsl/gsl_spline.h>
#include <gsl/gsl_statistics.h>
#include <math.h>
#include <netcdf.h>
#include <omp.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>
#include <sys/time.h>
#ifdef MPI
#include "mpi.h"
#endif
#ifdef _OPENACC
#include "openacc.h"
#include "curand.h"
#endif
/* ------------------------------------------------------------
   Constants...
   ------------------------------------------------------------ */
#define CPD 1003.5
#define EPS (MH2O / MA)
#define G0 9.80665
#define H0 7.0
#define LV 2501000.
#define KB 1.3806504e-23
#define MA 28.9644
#define MH2O 18.01528
#define MO3 48.00
#define P0 1013.25
#define RA (1e3 * RI / MA)
#define RE 6367.421
#define RI 8.3144598
#define T0 273.15
/* ------------------------------------------------------------
   Dimensions...
   ------------------------------------------------------------ */
#define LEN 5000
#define NP 10000000
#define NQ 15
#define EP 140
#define EX 1201
#define EY 601
#define GX 720
```

```
#define GY 360

#define GZ 100

#define NENS 2000

#define NTHREADS 512

/* ------------------------------------------------------------
   Macros...
   ------------------------------------------------------------ */

#define ALLOC(ptr, type, n)                                  \
  if((ptr=calloc((size_t)(n), sizeof(type)))==NULL)      \
    ERRMSG("Out of memory!");

#define ATM_SET(qnt, val)                           \
  if (ctl->qnt >= 0)                               \
    atm->q[ctl->qnt][ip] = val;

#define DEG2DX(dlon, lat)                                         \
  ((dlon) * M_PI * RE / 180. * cos((lat) / 180. * M_PI))

#define DEG2DY(dlat)                                \
  ((dlat) * M_PI * RE / 180.)

#define DP2DZ(dp, p)                                \
  (- (dp) * H0 / (p))

#define DX2DEG(dx, lat)                                           \
  (((lat) < -89.999 || (lat) > 89.999) ? 0                        \
   : (dx) * 180. / (M_PI * RE * cos((lat) / 180. * M_PI)))

#define DY2DEG(dy)                                  \
  ((dy) * 180. / (M_PI * RE))

#define DZ2DP(dz, p)                                \
  (-(dz) * (p) / H0)

#define DIST(a, b) sqrt(DIST2(a, b))

#define DIST2(a, b)                                                        \
  ((a[0]-b[0])*(a[0]-b[0])+(a[1]-b[1])*(a[1]-b[1])+(a[2]-b[2])*(a[2]-b[2]))

#define DOTP(a, b) (a[0]*b[0]+a[1]*b[1]+a[2]*b[2])

#define ERRMSG(msg) {                                                      \
    printf("\nError (%s, %s, l%d): %s\n\n",                                \
           __FILE__, __func__, __LINE__, msg);                             \
    exit(EXIT_FAILURE);                                                    \
  }

#define FMOD(x, y)                                  \
  ((x) - (int) ((x) / (y)) * (y))

#define FREAD(ptr, type, size, out) {                                      \
    if(fread(ptr, sizeof(type), size, out)!=size)                          \
      ERRMSG("Error while reading!");                                      \
  }

#define FWRITE(ptr, type, size, out) {                                     \
    if(fwrite(ptr, sizeof(type), size, out)!=size)                         \
      ERRMSG("Error while writing!");                                      \
  }

#define INTPOL_INIT                                 \
  double cw[3] = {0.0, 0.0, 0.0}; int ci[3] = {0, 0, 0};

#define INTPOL_2D(var, init)                                               \
  intpol_met_time_2d(met0, met0->var, met1, met1->var,                     \
                     atm->time[ip], atm->lon[ip], atm->lat[ip],            \
                     &var, ci, cw, init);

#define INTPOL_3D(var, init)                                               \
  intpol_met_time_3d(met0, met0->var, met1, met1->var,                     \
                     atm->time[ip], atm->p[ip],                            \
                     atm->lon[ip], atm->lat[ip],                           \
                     &var, ci, cw, init);

#define INTPOL_SPACE_ALL(p, lon, lat) {                                    \
  intpol_met_space_3d(met, met->z, p, lon, lat, &z, ci, cw, 1);           \
  intpol_met_space_3d(met, met->t, p, lon, lat, &t, ci, cw, 0);           \
  intpol_met_space_3d(met, met->u, p, lon, lat, &u, ci, cw, 0);           \
  intpol_met_space_3d(met, met->v, p, lon, lat, &v, ci, cw, 0);           \
  intpol_met_space_3d(met, met->w, p, lon, lat, &w, ci, cw, 0);           \
  intpol_met_space_3d(met, met->pv, p, lon, lat, &pv, ci, cw, 0);         \
```

```
  intpol_met_space_3d(met, met->h2o, p, lon, lat, &h2o, ci, cw, 0);     \
  intpol_met_space_3d(met, met->o3, p, lon, lat, &o3, ci, cw, 0);       \
  intpol_met_space_3d(met, met->lwc, p, lon, lat, &lwc, ci, cw, 0);     \
  intpol_met_space_3d(met, met->iwc, p, lon, lat, &iwc, ci, cw, 0);     \
  intpol_met_space_2d(met, met->ps, lon, lat, &ps, ci, cw, 0);          \
  intpol_met_space_2d(met, met->ts, lon, lat, &ts, ci, cw, 0);          \
  intpol_met_space_2d(met, met->zs, lon, lat, &zs, ci, cw, 0);          \
  intpol_met_space_2d(met, met->us, lon, lat, &us, ci, cw, 0);          \
  intpol_met_space_2d(met, met->vs, lon, lat, &vs, ci, cw, 0);          \
  intpol_met_space_2d(met, met->pt, lon, lat, &pt, ci, cw, 0);          \
  intpol_met_space_2d(met, met->tt, lon, lat, &tt, ci, cw, 0);          \
  intpol_met_space_2d(met, met->zt, lon, lat, &zt, ci, cw, 0);          \
  intpol_met_space_2d(met, met->h2ot, lon, lat, &h2ot, ci, cw, 0);      \
  intpol_met_space_2d(met, met->pc, lon, lat, &pc, ci, cw, 0);          \
  intpol_met_space_2d(met, met->cl, lon, lat, &cl, ci, cw, 0);          \
  intpol_met_space_2d(met, met->plcl, lon, lat, &plcl, ci, cw, 0);      \
  intpol_met_space_2d(met, met->plfc, lon, lat, &plfc, ci, cw, 0);      \
  intpol_met_space_2d(met, met->pel, lon, lat, &pel, ci, cw, 0);        \
  intpol_met_space_2d(met, met->cape, lon, lat, &cape, ci, cw, 0);      \
  }

#define INTPOL_TIME_ALL(time, p, lon, lat) {                            \
  intpol_met_time_3d(met0, met0->z, met1, met1->z, time, p, lon, lat, &z, ci, cw, 1); \
  intpol_met_time_3d(met0, met0->t, met1, met1->t, time, p, lon, lat, &t, ci, cw, 0); \
  intpol_met_time_3d(met0, met0->u, met1, met1->u, time, p, lon, lat, &u, ci, cw, 0); \
  intpol_met_time_3d(met0, met0->v, met1, met1->v, time, p, lon, lat, &v, ci, cw, 0); \
  intpol_met_time_3d(met0, met0->w, met1, met1->w, time, p, lon, lat, &w, ci, cw, 0); \
  intpol_met_time_3d(met0, met0->pv, met1, met1->pv, time, p, lon, lat, &pv, ci, cw, 0); \
  intpol_met_time_3d(met0, met0->h2o, met1, met1->h2o, time, p, lon, lat, &h2o, ci, cw, 0); \
  intpol_met_time_3d(met0, met0->o3, met1, met1->o3, time, p, lon, lat, &o3, ci, cw, 0); \
  intpol_met_time_3d(met0, met0->lwc, met1, met1->lwc, time, p, lon, lat, &lwc, ci, cw, 0); \
  intpol_met_time_3d(met0, met0->iwc, met1, met1->iwc, time, p, lon, lat, &iwc, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->ps, met1, met1->ps, time, lon, lat, &ps, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->ts, met1, met1->ts, time, lon, lat, &ts, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->zs, met1, met1->zs, time, lon, lat, &zs, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->us, met1, met1->us, time, lon, lat, &us, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->vs, met1, met1->vs, time, lon, lat, &vs, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->pt, met1, met1->pt, time, lon, lat, &pt, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->tt, met1, met1->tt, time, lon, lat, &tt, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->zt, met1, met1->zt, time, lon, lat, &zt, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->h2ot, met1, met1->h2ot, time, lon, lat, &h2ot, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->pc, met1, met1->pc, time, lon, lat, &pc, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->cl, met1, met1->cl, time, lon, lat, &cl, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->plcl, met1, met1->plcl, time, lon, lat, &plcl, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->plfc, met1, met1->plfc, time, lon, lat, &plfc, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->pel, met1, met1->pel, time, lon, lat, &pel, ci, cw, 0); \
  intpol_met_time_2d(met0, met0->cape, met1, met1->cape, time, lon, lat, &cape, ci, cw, 0); \
  }

#define LAPSE(p1, t1, p2, t2)                                           \
  (1e3 * G0 / RA * ((t2) - (t1)) / ((t2) + (t1)) * ((p2) + (p1)) / ((p2) - (p1)))

#define LIN(x0, y0, x1, y1, x)                          \
  ((y0)+((y1)-(y0))/((x1)-(x0))*((x)-(x0)))

#define NC(cmd) {                                       \
    if((cmd)!=NC_NOERR)                                 \
      ERRMSG(nc_strerror(cmd));                         \
  }

#define NN(x0, y0, x1, y1, x)                                   \
  (fabs((x) - (x0)) <= fabs((x) - (x1)) ? (y0) : (y1))

#define NORM(a) sqrt(DOTP(a, a))

#define PRINT(format, var)                                              \
  printf("Print (%s, %s, l%d): %s= "format"\n",                         \
         __FILE__, __func__, __LINE__, #var, var);

#define P(z) (P0 * exp(-(z) / H0))

#define PSAT(t)                                                 \
  (6.112 * exp(17.62 * ((t) - T0) / (243.12 + (t) - T0)))

#define PSICE(t)                                        \
  (0.01 * pow(10., -2663.5 / (t) + 12.537))

#define PW(p, h2o)                                      \
  ((p) * (h2o) / (1. + (1. - EPS) * (h2o)))

#define RH(p, t, h2o)                                   \
  (PW(p, h2o) / PSAT(t) * 100.)

#define RHICE(p, t, h2o)                                \
  (PW(p, h2o) / PSICE(t) * 100.)

#define SH(h2o) (EPS * (h2o))
```

```
#define SQR(x) ((x)*(x))

#define TDEW(p, h2o)                                    \
  (T0 + 243.12 * log(PW((p), (h2o)) / 6.112)            \
   / (17.62 - log(PW((p), (h2o)) / 6.112)))

#define TICE(p, h2o)                                            \
  (-2663.5 / (log10(100. * PW((p), (h2o))) - 12.537))

#define THETA(p, t) ((t) * pow(1000. / (p), 0.286))

#define TOK(line, tok, format, var) {                                   \
    if(((tok)=strtok((line), " \t"))) {                                 \
      if(sscanf(tok, format, &(var))!=1) continue;                      \
    } else ERRMSG("Error while reading!");                              \
  }

#define TVIRT(t, h2o)                                   \
  ((t) * (1. + (1. - EPS) * (h2o)))

#define WARN(msg) {                                                     \
    printf("\nWarning (%s, %s, l%d): %s\n\n",                           \
           __FILE__, __func__, __LINE__, msg);                          \
  }

#define Z(p) (H0 * log(P0 / (p)))

#define ZDIFF(lnp0, t0, h2o0, lnp1, t1, h2o1)                           \
  (RI / MA / G0 * 0.5 * (TVIRT((t0), (h2o0)) + TVIRT((t1), (h2o1))) * ((lnp0) - (lnp1)))

/* ------------------------------------------------------------
   Timers...
   ------------------------------------------------------------ */

#define NTIMER 100

#define PRINT_TIMERS                                    \
  timer("END", 1);

#define SELECT_TIMER(id, color)                                 \
  {NVTX_POP; NVTX_PUSH(id, color); timer(id, 0);}

#define START_TIMERS                                    \
  NVTX_PUSH("START", NVTX_CPU);

#define STOP_TIMERS                                     \
  NVTX_POP;

/* ------------------------------------------------------------
   NVIDIA Tools Extension (NVTX)...
   ------------------------------------------------------------ */

#ifdef NVTX
#include "nvToolsExt.h"

#define NVTX_CPU 0xFFADD8E6

#define NVTX_GPU 0xFF00008B

#define NVTX_H2D 0xFFFFFF00

#define NVTX_D2H 0xFFFF8800

#define NVTX_READ 0xFFFFCCCB

#define NVTX_WRITE 0xFF8B0000

#define NVTX_MISC 0xFF808080

#define NVTX_PUSH(range_title, range_color) {                   \
    nvtxEventAttributes_t eventAttrib = {0};                    \
    eventAttrib.version = NVTX_VERSION;                         \
    eventAttrib.size = NVTX_EVENT_ATTRIB_STRUCT_SIZE;           \
    eventAttrib.messageType = NVTX_MESSAGE_TYPE_ASCII;          \
    eventAttrib.colorType = NVTX_COLOR_ARGB;                    \
    eventAttrib.color = range_color;                            \
    eventAttrib.message.ascii = range_title;                    \
    nvtxRangePushEx(&eventAttrib);                              \
  }

#define NVTX_POP {                                      \
    nvtxRangePop();                                     \
  }
#else

/* Empty definitions of NVTX_PUSH and NVTX_POP... */
```

```
#define NVTX_PUSH(range_title, range_color) {}
#define NVTX_POP {}
#endif
/* ------------------------------------------------------------
   Structs...
   ------------------------------------------------------------ */
typedef struct {
  int nq;
  char qnt_name[NQ][LEN];
  char qnt_unit[NQ][LEN];
  char qnt_format[NQ][LEN];
  int qnt_ens;
  int qnt_m;
  int qnt_rho;
  int qnt_r;
  int qnt_ps;
  int qnt_ts;
  int qnt_zs;
  int qnt_us;
  int qnt_vs;
  int qnt_pt;
  int qnt_tt;
  int qnt_zt;
  int qnt_h2ot;
  int qnt_z;
  int qnt_p;
  int qnt_t;
  int qnt_u;
  int qnt_v;
  int qnt_w;
  int qnt_h2o;
  int qnt_o3;
  int qnt_lwc;
  int qnt_iwc;
  int qnt_pc;
  int qnt_cl;
  int qnt_plcl;
  int qnt_plfc;
  int qnt_pel;
  int qnt_cape;
  int qnt_hno3;
  int qnt_oh;
  int qnt_psat;
  int qnt_psice;
  int qnt_pw;
  int qnt_sh;
```

```
    int qnt_rh;
    int qnt_rhice;
    int qnt_theta;
    int qnt_tvirt;
    int qnt_lapse;
    int qnt_vh;
    int qnt_vz;
    int qnt_pv;
    int qnt_tdew;
    int qnt_tice;
    int qnt_tsts;
    int qnt_tnat;
    int qnt_stat;
    int direction;
    double t_start;
    double t_stop;
    double dt_mod;
    char metbase[LEN];
    double dt_met;
    int met_dx;
    int met_dy;
    int met_dp;
    int met_sx;
    int met_sy;
    int met_sp;
    double met_detrend;
    int met_np;
    double met_p[EP];
    int met_geopot_sx;
    int met_geopot_sy;
    int met_tropo;
    double met_dt_out;
    int isosurf;
    char balloon[LEN];
    double turb_dx_trop;
    double turb_dx_strat;
    double turb_dz_trop;
    double turb_dz_strat;
    double turb_mesox;
    double turb_mesoz;
    double conv_cape;
    char species[LEN];
    double molmass;
```

```
double tdec_trop;
double tdec_strat;
double oh_chem[4];
double dry_depo[1];
double wet_depo[8];
double psc_h2o;
double psc_hno3;
char atm_basename[LEN];
char atm_gpfile[LEN];
double atm_dt_out;
int atm_filter;
int atm_stride;
int atm_type;
char csi_basename[LEN];
double csi_dt_out;
char csi_obsfile[LEN];
double csi_obsmin;
double csi_modmin;
int csi_nz;
double csi_z0;
double csi_z1;
int csi_nx;
double csi_lon0;
double csi_lon1;
int csi_ny;
double csi_lat0;
double csi_lat1;
char grid_basename[LEN];
char grid_gpfile[LEN];
double grid_dt_out;
int grid_sparse;
int grid_nz;
double grid_z0;
double grid_z1;
int grid_nx;
double grid_lon0;
double grid_lon1;
int grid_ny;
double grid_lat0;
double grid_lat1;
char prof_basename[LEN];
char prof_obsfile[LEN];
int prof_nz;
double prof_z0;
```

```
  double prof_z1;
  int prof_nx;
  double prof_lon0;
  double prof_lon1;
  int prof_ny;
  double prof_lat0;
  double prof_lat1;
  char ens_basename[LEN];
  char sample_basename[LEN];
  char sample_obsfile[LEN];
  double sample_dx;
  double sample_dz;
  char stat_basename[LEN];
  double stat_lon;
  double stat_lat;
  double stat_r;
} ctl_t;
typedef struct {
  int np;
  double time[NP];
  double p[NP];
  double lon[NP];
  double lat[NP];
  double q[NQ][NP];
} atm_t;
typedef struct {
  float up[NP];
  float vp[NP];
  float wp[NP];
  double iso_var[NP];
  double iso_ps[NP];
  double iso_ts[NP];
  int iso_n;
  double tsig[EX][EY][EP];
  float usig[EX][EY][EP];
  float vsig[EX][EY][EP];
  float wsig[EX][EY][EP];
} cache_t;
typedef struct {
  double time;
  int nx;
  int ny;
  int np;
```

```
  double lon[EX];

  double lat[EY];

  double p[EP];

  float ps[EX][EY];

  float ts[EX][EY];

  float zs[EX][EY];

  float us[EX][EY];

  float vs[EX][EY];

  float pt[EX][EY];

  float tt[EX][EY];

  float zt[EX][EY];

  float h2ot[EX][EY];

  float pc[EX][EY];

  float cl[EX][EY];

  float plcl[EX][EY];

  float plfc[EX][EY];

  float pel[EX][EY];

  float cape[EX][EY];

  float z[EX][EY][EP];

  float t[EX][EY][EP];

  float u[EX][EY][EP];

  float v[EX][EY][EP];

  float w[EX][EY][EP];

  float pv[EX][EY][EP];

  float h2o[EX][EY][EP];

  float o3[EX][EY][EP];

  float lwc[EX][EY][EP];

  float iwc[EX][EY][EP];

  float pl[EX][EY][EP];

} met_t;

/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

void cart2geo(
  double *x,
  double *z,
  double *lon,
  double *lat);

#ifdef _OPENACC
#pragma acc routine (check_finite)
#endif
int check_finite(
  const double x);

#ifdef _OPENACC
#pragma acc routine (clim_hno3)
#endif
double clim_hno3(
  double t,
  double lat,
  double p);

#ifdef _OPENACC
#pragma acc routine (clim_oh)
#endif
```

```
double clim_oh(
  double t,
  double lat,
  double p);

#ifdef _OPENACC
#pragma acc routine (clim_tropo)
#endif
double clim_tropo(
  double t,
  double lat);

void day2doy(
  int year,
  int mon,
  int day,
  int *doy);

void doy2day(
  int year,
  int doy,
  int *mon,
  int *day);

void geo2cart(
  double z,
  double lon,
  double lat,
  double *x);

void get_met(
  ctl_t * ctl,
  double t,
  met_t ** met0,
  met_t ** met1);

void get_met_help(
  double t,
  int direct,
  char *metbase,
  double dt_met,
  char *filename);

void get_met_replace(
  char *orig,
  char *search,
  char *repl);

#ifdef _OPENACC
#pragma acc routine (intpol_met_space_3d)
#endif
void intpol_met_space_3d(
  met_t * met,
  float array[EX][EY][EP],
  double p,
  double lon,
  double lat,
  double *var,
  int *ci,
  double *cw,
  int init);

#ifdef _OPENACC
#pragma acc routine (intpol_met_space_2d)
#endif
void intpol_met_space_2d(
  met_t * met,
  float array[EX][EY],
  double lon,
  double lat,
  double *var,
  int *ci,
  double *cw,
  int init);

#ifdef _OPENACC
#pragma acc routine (intpol_met_time_3d)
#endif
void intpol_met_time_3d(
  met_t * met0,
  float array0[EX][EY][EP],
  met_t * met1,
  float array1[EX][EY][EP],
  double ts,
  double p,
  double lon,
  double lat,
```

```
  double *var,
  int *ci,
  double *cw,
  int init);

#ifdef _OPENACC
#pragma acc routine (intpol_met_time_2d)
#endif
void intpol_met_time_2d(
  met_t * met0,
  float array0[EX][EY],
  met_t * met1,
  float array1[EX][EY],
  double ts,
  double lon,
  double lat,
  double *var,
  int *ci,
  double *cw,
  int init);

void jsec2time(
  double jsec,
  int *year,
  int *mon,
  int *day,
  int *hour,
  int *min,
  int *sec,
  double *remain);

#ifdef _OPENACC
#pragma acc routine (lapse_rate)
#endif
double lapse_rate(
  double t,
  double h2o);

#ifdef _OPENACC
#pragma acc routine (locate_irr)
#endif
int locate_irr(
  double *xx,
  int n,
  double x);

#ifdef _OPENACC
#pragma acc routine (locate_reg)
#endif
int locate_reg(
  double *xx,
  int n,
  double x);

#ifdef _OPENACC
#pragma acc routine (nat_temperature)
#endif
double nat_temperature(
  double p,
  double h2o,
  double hno3);

int read_atm(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm);

void read_ctl(
  const char *filename,
  int argc,
  char *argv[],
  ctl_t * ctl);

int read_met(
  ctl_t * ctl,
  char *filename,
  met_t * met);

void read_met_cape(
  met_t * met);

void read_met_cloud(
  met_t * met);

void read_met_detrend(
  ctl_t * ctl,
  met_t * met);
```

```
void read_met_extrapolate(
  met_t * met);

void read_met_geopot(
  ctl_t * ctl,
  met_t * met);

void read_met_grid(
  char *filename,
  int ncid,
  ctl_t * ctl,
  met_t * met);

int read_met_help_3d(
  int ncid,
  char *varname,
  char *varname2,
  met_t * met,
  float dest[EX][EY][EP],
  float scl);

int read_met_help_2d(
  int ncid,
  char *varname,
  char *varname2,
  met_t * met,
  float dest[EX][EY],
  float scl);

/* Read meteorological data on vertical levels. */
void read_met_levels(
  int ncid,
  ctl_t * ctl,
  met_t * met);

void read_met_ml2pl(
  ctl_t * ctl,
  met_t * met,
  float var[EX][EY][EP]);

void read_met_periodic(
  met_t * met);

void read_met_pv(
  met_t * met);

void read_met_sample(
  ctl_t * ctl,
  met_t * met);

void read_met_surface(
  int ncid,
  met_t * met);

void read_met_tropo(
  ctl_t * ctl,
  met_t * met);

double scan_ctl(
  const char *filename,
  int argc,
  char *argv[],
  const char *varname,
  int arridx,
  const char *defvalue,
  char *value);

#ifdef _OPENACC
#pragma acc routine (sedi)
#endif
double sedi(
  double p,
  double T,
  double r_p,
  double rho_p);

void spline(
  double *x,
  double *y,
  int n,
  double *x2,
  double *y2,
  int n2);

#ifdef _OPENACC
#pragma acc routine (stddev)
```

```
#endif
double stddev(
  double *data,
  int n);

void time2jsec(
  int year,
  int mon,
  int day,
  int hour,
  int min,
  int sec,
  double remain,
  double *jsec);

void timer(
  const char *name,
  int output);

void write_atm(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm,
  double t);

void write_csi(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm,
  double t);

void write_ens(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm,
  double t);

void write_grid(
  const char *filename,
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double t);

void write_prof(
  const char *filename,
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double t);

void write_sample(
  const char *filename,
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double t);

void write_station(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm,
  double t);
```

5.25 met_map.c File Reference

Functions

- int main (int argc, char *argv[ ])

5.25.1 Detailed Description

Extract map from meteorological data.

Definition in file met_map.c.

5.25.2 Function Documentation

5.25.2.1 main()

```
int main (
    int argc,
    char * argv[] )
```

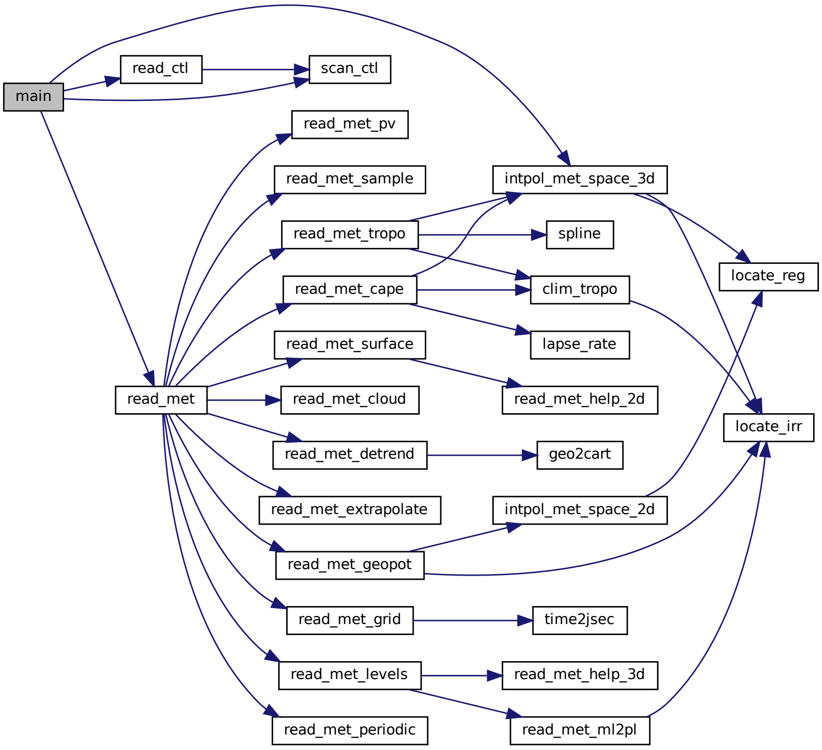
Definition at line 41 of file met_map.c.

```
                    {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double timem[NX][NY], p0, ps, psm[NX][NY], ts, tsm[NX][NY],
    zs, zsm[NX][NY], us, usm[NX][NY], vs, vsm[NX][NY], pt, ptm[NX][NY], t,
    pm[NX][NY], tm[NX][NY], u, um[NX][NY], v, vm[NX][NY], w, wm[NX][NY], h2o,
    h2om[NX][NY], h2ot, h2otm[NX][NY], o3, o3m[NX][NY], lwc, lwcm[NX][NY],
    iwc, iwcm[NX][NY], z, zm[NX][NY], pv, pvm[NX][NY], zt, ztm[NX][NY],
    tt, ttm[NX][NY], pc, pcm[NX][NY], cl, clm[NX][NY], plcl, plclm[NX][NY],
    plfc, plfcm[NX][NY], pel, pelm[NX][NY], cape, capem[NX][NY], theta,
    ptop, pbot, t0, lon, lon0, lon1, lons[NX], dlon,
    lat, lat0, lat1, lats[NY], dlat, cw[3];

  static int i, ix, iy, np[NX][NY], nx, ny, ci[3];

  /* Allocate... */
  ALLOC(met, met_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <map.tab> <met0> [ <met1> ... ]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  p0 = P(scan_ctl(argv[1], argc, argv, "MAP_Z0", -1, "10", NULL));
  lon0 = scan_ctl(argv[1], argc, argv, "MAP_LON0", -1, "-180", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "MAP_LON1", -1, "180", NULL);
  dlon = scan_ctl(argv[1], argc, argv, "MAP_DLON", -1, "-999", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "MAP_LAT0", -1, "-90", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "MAP_LAT1", -1, "90", NULL);
  dlat = scan_ctl(argv[1], argc, argv, "MAP_DLAT", -1, "-999", NULL);
  theta = scan_ctl(argv[1], argc, argv, "MAP_THETA", -1, "-999", NULL);

  /* Loop over files... */
  for (i = 3; i < argc; i++) {

    /* Read meteorological data... */
    if (!read_met(&ctl, argv[i], met))
      continue;

    /* Set horizontal grid... */
    if (dlon <= 0)
      dlon = fabs(met->lon[1] - met->lon[0]);
    if (dlat <= 0)
      dlat = fabs(met->lat[1] - met->lat[0]);
    if (lon0 < -360 && lon1 > 360) {
      lon0 = gsl_stats_min(met->lon, 1, (size_t) met->nx);
      lon1 = gsl_stats_max(met->lon, 1, (size_t) met->nx);
    }
    nx = ny = 0;
    for (lon = lon0; lon <= lon1; lon += dlon) {
      lons[nx] = lon;
      if ((++nx) > NX)
        ERRMSG("Too many longitudes!");
    }
    if (lat0 < -90 && lat1 > 90) {
      lat0 = gsl_stats_min(met->lat, 1, (size_t) met->ny);
      lat1 = gsl_stats_max(met->lat, 1, (size_t) met->ny);
    }
    for (lat = lat0; lat <= lat1; lat += dlat) {
      lats[ny] = lat;
      if ((++ny) > NY)
        ERRMSG("Too many latitudes!");
    }

    /* Average... */
    for (ix = 0; ix < nx; ix++)
```

```
      for (iy = 0; iy < ny; iy++) {

        /* Find pressure level for given theta level... */
        if (theta > 0) {
          ptop = met->p[met->np - 1];
          pbot = met->p[0];
          do {
            p0 = 0.5 * (ptop + pbot);
            intpol_met_space_3d(met, met->t, p0, lons[ix], lats[iy],
                                &t0, ci, cw, 1);
            if (THETA(p0, t0) > theta)
              ptop = p0;
            else
              pbot = p0;
          } while (fabs(ptop - pbot) > 1e-5);
        }

        /* Interpolate meteo data... */
        INTPOL_SPACE_ALL(p0, lons[ix], lats[iy]);

        /* Averaging... */
        timem[ix][iy] += met->time;
        zm[ix][iy] += z;
        pm[ix][iy] += p0;
        tm[ix][iy] += t;
        um[ix][iy] += u;
        vm[ix][iy] += v;
        wm[ix][iy] += w;
        pvm[ix][iy] += pv;
        h2om[ix][iy] += h2o;
        o3m[ix][iy] += o3;
        lwcm[ix][iy] += lwc;
        iwcm[ix][iy] += iwc;
        psm[ix][iy] += ps;
        tsm[ix][iy] += ts;
        zsm[ix][iy] += zs;
        usm[ix][iy] += us;
        vsm[ix][iy] += vs;
        ptm[ix][iy] += pt;
        pcm[ix][iy] += pc;
        clm[ix][iy] += cl;
        plclm[ix][iy] += plcl;
        plfcm[ix][iy] += plfc;
        pelm[ix][iy] += pel;
        capem[ix][iy] += cape;
        ztm[ix][iy] += zt;
        ttm[ix][iy] += tt;
        h2otm[ix][iy] += h2ot;
        np[ix][iy]++;
      }
  }

  /* Create output file... */
  printf("Write meteorological data file: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n"
          "# $6 = temperature [K]\n"
          "# $7 = zonal wind [m/s]\n"
          "# $8 = meridional wind [m/s]\n"
          "# $9 = vertical velocity [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [ppv]\n");
  fprintf(out,
          "# $11 = O3 volume mixing ratio [ppv]\n"
          "# $12 = geopotential height [km]\n"
          "# $13 = potential vorticity [PVU]\n"
          "# $14 = surface pressure [hPa]\n"
          "# $15 = surface temperature [K]\n"
          "# $16 = surface geopotential height [km]\n"
          "# $17 = surface zonal wind [m/s]\n"
          "# $18 = surface meridional wind [m/s]\n"
          "# $19 = tropopause pressure [hPa]\n"
          "# $20 = tropopause geopotential height [km]\n");
  fprintf(out,
          "# $21 = tropopause temperature [K]\n"
          "# $22 = tropopause water vapor [ppv]\n"
          "# $23 = cloud liquid water content [kg/kg]\n"
          "# $24 = cloud ice water content [kg/kg]\n"
          "# $25 = total column cloud water [kg/m^2]\n"
          "# $26 = cloud top pressure [hPa]\n"
```

```
          "# $27 = pressure at lifted condensation level (LCL) [hPa]\n"
          "# $28 = pressure at level of free convection (LFC) [hPa]\n"
          "# $29 = pressure at equilibrium level (EL) [hPa]\n"
          "# $30 = convective available potential energy (CAPE) [J/kg]\n");
  fprintf(out,
          "# $31 = relative humidity over water [%%]\n"
          "# $32 = relative humidity over ice [%%]\n"
          "# $33 = dew point temperature [K]\n"
          "# $34 = frost point temperature [K]\n");

  /* Write data... */
  for (iy = 0; iy < ny; iy++) {
    fprintf(out, "\n");
    for (ix = 0; ix < nx; ix++)
      fprintf(out,
              "%.2f %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g"
              " %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g\n",
              timem[ix][iy] / np[ix][iy], Z(pm[ix][iy] / np[ix][iy]),
              lons[ix], lats[iy], pm[ix][iy] / np[ix][iy],
              tm[ix][iy] / np[ix][iy], um[ix][iy] / np[ix][iy],
              vm[ix][iy] / np[ix][iy], wm[ix][iy] / np[ix][iy],
              h2om[ix][iy] / np[ix][iy], o3m[ix][iy] / np[ix][iy],
              zm[ix][iy] / np[ix][iy], pvm[ix][iy] / np[ix][iy],
              psm[ix][iy] / np[ix][iy], tsm[ix][iy] / np[ix][iy],
              zsm[ix][iy] / np[ix][iy], usm[ix][iy] / np[ix][iy],
              vsm[ix][iy] / np[ix][iy], ptm[ix][iy] / np[ix][iy],
              ztm[ix][iy] / np[ix][iy], ttm[ix][iy] / np[ix][iy],
              h2otm[ix][iy] / np[ix][iy], lwcm[ix][iy] / np[ix][iy],
              iwcm[ix][iy] / np[ix][iy], clm[ix][iy] / np[ix][iy],
              pcm[ix][iy] / np[ix][iy], plclm[ix][iy] / np[ix][iy],
              plfcm[ix][iy] / np[ix][iy], pelm[ix][iy] / np[ix][iy],
              capem[ix][iy] / np[ix][iy],
              RH(pm[ix][iy] / np[ix][iy], tm[ix][iy] / np[ix][iy],
                 h2om[ix][iy] / np[ix][iy]),
              RHICE(pm[ix][iy] / np[ix][iy], tm[ix][iy] / np[ix][iy],
                    h2om[ix][iy] / np[ix][iy]),
              TDEW(pm[ix][iy] / np[ix][iy], h2om[ix][iy] / np[ix][iy]),
              TICE(pm[ix][iy] / np[ix][iy], h2om[ix][iy] / np[ix][iy]));
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.26 met_map.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

/* ------------------------------------------------------------
   Dimensions...
   ------------------------------------------------------------ */

#define NX 1441

#define NY 721

/* ------------------------------------------------------------
   Main...
   ------------------------------------------------------------ */

int main(
  int argc,
  char *argv[]) {

```

```
  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double timem[NX][NY], p0, ps, psm[NX][NY], ts, tsm[NX][NY],
    zs, zsm[NX][NY], us, usm[NX][NY], vs, vsm[NX][NY], pt, ptm[NX][NY], t,
    pm[NX][NY], tm[NX][NY], u, um[NX][NY], v, vm[NX][NY], w, wm[NX][NY], h2o,
    h2om[NX][NY], h2ot, h2otm[NX][NY], o3, o3m[NX][NY], lwc, lwcm[NX][NY],
    iwc, iwcm[NX][NY], z, zm[NX][NY], pv, pvm[NX][NY], zt, ztm[NX][NY],
    tt, ttm[NX][NY], pc, pcm[NX][NY], cl, clm[NX][NY], plcl, plclm[NX][NY],
    plfc, plfcm[NX][NY], pel, pelm[NX][NY], cape, capem[NX][NY], theta,
    ptop, pbot, t0, lon, lon0, lon1, lons[NX], dlon,
    lat, lat0, lat1, lats[NY], dlat, cw[3];

  static int i, ix, iy, np[NX][NY], nx, ny, ci[3];

  /* Allocate... */
  ALLOC(met, met_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <map.tab> <met0> [ <met1> ... ]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  p0 = P(scan_ctl(argv[1], argc, argv, "MAP_Z0", -1, "10", NULL));
  lon0 = scan_ctl(argv[1], argc, argv, "MAP_LON0", -1, "-180", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "MAP_LON1", -1, "180", NULL);
  dlon = scan_ctl(argv[1], argc, argv, "MAP_DLON", -1, "-999", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "MAP_LAT0", -1, "-90", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "MAP_LAT1", -1, "90", NULL);
  dlat = scan_ctl(argv[1], argc, argv, "MAP_DLAT", -1, "-999", NULL);
  theta = scan_ctl(argv[1], argc, argv, "MAP_THETA", -1, "-999", NULL);

  /* Loop over files... */
  for (i = 3; i < argc; i++) {

    /* Read meteorological data... */
    if (!read_met(&ctl, argv[i], met))
      continue;

    /* Set horizontal grid... */
    if (dlon <= 0)
      dlon = fabs(met->lon[1] - met->lon[0]);
    if (dlat <= 0)
      dlat = fabs(met->lat[1] - met->lat[0]);
    if (lon0 < -360 && lon1 > 360) {
      lon0 = gsl_stats_min(met->lon, 1, (size_t) met->nx);
      lon1 = gsl_stats_max(met->lon, 1, (size_t) met->nx);
    }
    nx = ny = 0;
    for (lon = lon0; lon <= lon1; lon += dlon) {
      lons[nx] = lon;
      if ((++nx) > NX)
        ERRMSG("Too many longitudes!");
    }
    if (lat0 < -90 && lat1 > 90) {
      lat0 = gsl_stats_min(met->lat, 1, (size_t) met->ny);
      lat1 = gsl_stats_max(met->lat, 1, (size_t) met->ny);
    }
    for (lat = lat0; lat <= lat1; lat += dlat) {
      lats[ny] = lat;
      if ((++ny) > NY)
        ERRMSG("Too many latitudes!");
    }

    /* Average... */
    for (ix = 0; ix < nx; ix++)
      for (iy = 0; iy < ny; iy++) {

        /* Find pressure level for given theta level... */
        if (theta > 0) {
          ptop = met->p[met->np - 1];
          pbot = met->p[0];
          do {
            p0 = 0.5 * (ptop + pbot);
            intpol_met_space_3d(met, met->t, p0, lons[ix], lats[iy],
                                &t0, ci, cw, 1);
            if (THETA(p0, t0) > theta)
              ptop = p0;
            else
              pbot = p0;
          } while (fabs(ptop - pbot) > 1e-5);
        }

```

```
      /* Interpolate meteo data... */
      INTPOL_SPACE_ALL(p0, lons[ix], lats[iy]);

      /* Averaging... */
      timem[ix][iy] += met->time;
      zm[ix][iy] += z;
      pm[ix][iy] += p0;
      tm[ix][iy] += t;
      um[ix][iy] += u;
      vm[ix][iy] += v;
      wm[ix][iy] += w;
      pvm[ix][iy] += pv;
      h2om[ix][iy] += h2o;
      o3m[ix][iy] += o3;
      lwcm[ix][iy] += lwc;
      iwcm[ix][iy] += iwc;
      psm[ix][iy] += ps;
      tsm[ix][iy] += ts;
      zsm[ix][iy] += zs;
      usm[ix][iy] += us;
      vsm[ix][iy] += vs;
      ptm[ix][iy] += pt;
      pcm[ix][iy] += pc;
      clm[ix][iy] += cl;
      plclm[ix][iy] += plcl;
      plfcm[ix][iy] += plfc;
      pelm[ix][iy] += pel;
      capem[ix][iy] += cape;
      ztm[ix][iy] += zt;
      ttm[ix][iy] += tt;
      h2otm[ix][iy] += h2ot;
      np[ix][iy]++;
    }
  }

  /* Create output file... */
  printf("Write meteorological data file: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n"
          "# $6 = temperature [K]\n"
          "# $7 = zonal wind [m/s]\n"
          "# $8 = meridional wind [m/s]\n"
          "# $9 = vertical velocity [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [ppv]\n");
  fprintf(out,
          "# $11 = O3 volume mixing ratio [ppv]\n"
          "# $12 = geopotential height [km]\n"
          "# $13 = potential vorticity [PVU]\n"
          "# $14 = surface pressure [hPa]\n"
          "# $15 = surface temperature [K]\n"
          "# $16 = surface geopotential height [km]\n"
          "# $17 = surface zonal wind [m/s]\n"
          "# $18 = surface meridional wind [m/s]\n"
          "# $19 = tropopause pressure [hPa]\n"
          "# $20 = tropopause geopotential height [km]\n");
  fprintf(out,
          "# $21 = tropopause temperature [K]\n"
          "# $22 = tropopause water vapor [ppv]\n"
          "# $23 = cloud liquid water content [kg/kg]\n"
          "# $24 = cloud ice water content [kg/kg]\n"
          "# $25 = total column cloud water [kg/m^2]\n"
          "# $26 = cloud top pressure [hPa]\n"
          "# $27 = pressure at lifted condensation level (LCL) [hPa]\n"
          "# $28 = pressure at level of free convection (LFC) [hPa]\n"
          "# $29 = pressure at equilibrium level (EL) [hPa]\n"
          "# $30 = convective available potential energy (CAPE) [J/kg]\n");
  fprintf(out,
          "# $31 = relative humidity over water [%%]\n"
          "# $32 = relative humidity over ice [%%]\n"
          "# $33 = dew point temperature [K]\n"
          "# $34 = frost point temperature [K]\n");

  /* Write data... */
  for (iy = 0; iy < ny; iy++) {
    fprintf(out, "\n");
    for (ix = 0; ix < nx; ix++)
      fprintf(out,
              "%.2f %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g"
              " %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g\n",
```

```
            timem[ix][iy] / np[ix][iy], Z(pm[ix][iy] / np[ix][iy]),
            lons[ix], lats[iy], pm[ix][iy] / np[ix][iy],
            tm[ix][iy] / np[ix][iy], um[ix][iy] / np[ix][iy],
            vm[ix][iy] / np[ix][iy], wm[ix][iy] / np[ix][iy],
            h2om[ix][iy] / np[ix][iy], o3m[ix][iy] / np[ix][iy],
            zm[ix][iy] / np[ix][iy], pvm[ix][iy] / np[ix][iy],
            psm[ix][iy] / np[ix][iy], tsm[ix][iy] / np[ix][iy],
            zsm[ix][iy] / np[ix][iy], usm[ix][iy] / np[ix][iy],
            vsm[ix][iy] / np[ix][iy], ptm[ix][iy] / np[ix][iy],
            ztm[ix][iy] / np[ix][iy], ttm[ix][iy] / np[ix][iy],
            h2otm[ix][iy] / np[ix][iy], lwcm[ix][iy] / np[ix][iy],
            iwcm[ix][iy] / np[ix][iy], clm[ix][iy] / np[ix][iy],
            pcm[ix][iy] / np[ix][iy], plclm[ix][iy] / np[ix][iy],
            plfcm[ix][iy] / np[ix][iy], pelm[ix][iy] / np[ix][iy],
            capem[ix][iy] / np[ix][iy],
            RH(pm[ix][iy] / np[ix][iy], tm[ix][iy] / np[ix][iy],
               h2om[ix][iy] / np[ix][iy]),
            RHICE(pm[ix][iy] / np[ix][iy], tm[ix][iy] / np[ix][iy],
                  h2om[ix][iy] / np[ix][iy]),
            TDEW(pm[ix][iy] / np[ix][iy], h2om[ix][iy] / np[ix][iy]),
            TICE(pm[ix][iy] / np[ix][iy], h2om[ix][iy] / np[ix][iy]));
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}
```

5.27 met_prof.c File Reference

Functions

- int main (int argc, char ∗argv[ ])

5.27.1 Detailed Description

Extract vertical profile from meteorological data.

Definition in file met_prof.c.

5.27.2 Function Documentation

5.27.2.1 main() int main (int argc, char ∗ argv[ ])

Definition at line 38 of file met_prof.c.

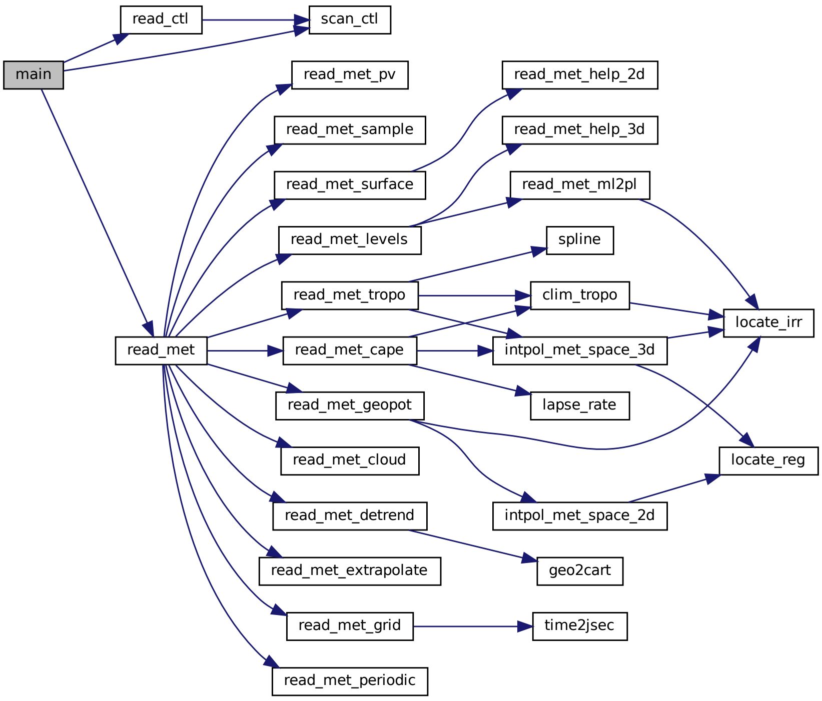
```
                {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double timem[NZ], z, z0, z1, dz, lon, lon0, lon1, dlon, lonm[NZ],
    lat, lat0, lat1, dlat, latm[NZ], t, tm[NZ], u, um[NZ], v, vm[NZ], w,
    wm[NZ], h2o, h2om[NZ], h2ot, h2otm[NZ], o3, o3m[NZ], lwc, lwcm[NZ],
    iwc, iwcm[NZ], ps, psm[NZ], ts, tsm[NZ], zs, zsm[NZ], us, usm[NZ],
    vs, vsm[NZ], pt, ptm[NZ], pc, pcm[NZ], cl, clm[NZ],
```

```
  plcl, plclm[NZ], plfc, plfcm[NZ], pel, pelm[NZ], cape, capem[NZ],
  tt, ttm[NZ], zm[NZ], zt, ztm[NZ], pv, pvm[NZ], plev[NZ], cw[3];

static int i, iz, np[NZ], npt[NZ], nz, ci[3];

/* Allocate... */
ALLOC(met, met_t, 1);

/* Check arguments... */
if (argc < 4)
  ERRMSG("Give parameters: <ctl> <prof.tab> <met0> [ <met1> ... ]");

/* Read control parameters... */
read_ctl(argv[1], argc, argv, &ctl);
z0 = scan_ctl(argv[1], argc, argv, "PROF_Z0", -1, "-999", NULL);
z1 = scan_ctl(argv[1], argc, argv, "PROF_Z1", -1, "-999", NULL);
dz = scan_ctl(argv[1], argc, argv, "PROF_DZ", -1, "-999", NULL);
lon0 = scan_ctl(argv[1], argc, argv, "PROF_LON0", -1, "0", NULL);
lon1 = scan_ctl(argv[1], argc, argv, "PROF_LON1", -1, "0", NULL);
dlon = scan_ctl(argv[1], argc, argv, "PROF_DLON", -1, "-999", NULL);
lat0 = scan_ctl(argv[1], argc, argv, "PROF_LAT0", -1, "0", NULL);
lat1 = scan_ctl(argv[1], argc, argv, "PROF_LAT1", -1, "0", NULL);
dlat = scan_ctl(argv[1], argc, argv, "PROF_DLAT", -1, "-999", NULL);

/* Loop over input files... */
for (i = 3; i < argc; i++) {

  /* Read meteorological data... */
  if (!read_met(&ctl, argv[i], met))
    continue;

  /* Set vertical grid... */
  if (z0 < 0)
    z0 = Z(met->p[0]);
  if (z1 < 0)
    z1 = Z(met->p[met->np - 1]);
  nz = 0;
  if (dz < 0) {
    for (iz = 0; iz < met->np; iz++)
      if (Z(met->p[iz]) >= z0 && Z(met->p[iz]) <= z1) {
        plev[nz] = met->p[iz];
        if ((++nz) > NZ)
          ERRMSG("Too many pressure levels!");
      }
  } else
    for (z = z0; z <= z1; z += dz) {
      plev[nz] = P(z);
      if ((++nz) > NZ)
        ERRMSG("Too many pressure levels!");
    }

  /* Set horizontal grid... */
  if (dlon <= 0)
    dlon = fabs(met->lon[1] - met->lon[0]);
  if (dlat <= 0)
    dlat = fabs(met->lat[1] - met->lat[0]);

  /* Average... */
  for (iz = 0; iz < nz; iz++)
    for (lon = lon0; lon <= lon1; lon += dlon)
      for (lat = lat0; lat <= lat1; lat += dlat) {

        /* Interpolate meteo data... */
        INTPOL_SPACE_ALL(plev[iz], lon, lat);

        /* Averaging... */
        if (gsl_finite(t) && gsl_finite(u)
            && gsl_finite(v) && gsl_finite(w)) {
          timem[iz] += met->time;
          lonm[iz] += lon;
          latm[iz] += lat;
          zm[iz] += z;
          tm[iz] += t;
          um[iz] += u;
          vm[iz] += v;
          wm[iz] += w;
          pvm[iz] += pv;
          h2om[iz] += h2o;
          o3m[iz] += o3;
          psm[iz] += ps;
          tsm[iz] += ts;
          zsm[iz] += zs;
          usm[iz] += us;
          vsm[iz] += vs;
          pcm[iz] += pc;
          clm[iz] += cl;
          plclm[iz] += plcl;
```

```
          plfcm[iz] += plfc;
          pelm[iz] += pel;
          capem[iz] += cape;
          lwcm[iz] += lwc;
          iwcm[iz] += iwc;
          if (gsl_finite(pt)) {
            ptm[iz] += pt;
            ztm[iz] += zt;
            ttm[iz] += tt;
            h2otm[iz] += h2ot;
            npt[iz]++;
          }
          np[iz]++;
        }
      }
  }

  /* Create output file... */
  printf("Write meteorological data file: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n"
          "# $6 = temperature [K]\n"
          "# $7 = zonal wind [m/s]\n"
          "# $8 = meridional wind [m/s]\n"
          "# $9 = vertical velocity [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [ppv]\n");
  fprintf(out,
          "# $11 = O3 volume mixing ratio [ppv]\n"
          "# $12 = geopotential height [km]\n"
          "# $13 = potential vorticity [PVU]\n"
          "# $14 = surface pressure [hPa]\n"
          "# $15 = surface temperature [K]\n"
          "# $16 = surface geopotential height [km]\n"
          "# $17 = surface zonal wind [m/s]\n"
          "# $18 = surface meridional wind [m/s]\n"
          "# $19 = tropopause pressure [hPa]\n"
          "# $20 = tropopause geopotential height [km]\n");
  fprintf(out,
          "# $21 = tropopause temperature [K]\n"
          "# $22 = tropopause water vapor [ppv]\n"
          "# $23 = cloud liquid water content [kg/kg]\n"
          "# $24 = cloud ice water content [kg/kg]\n"
          "# $25 = total column cloud water [kg/m^2]\n"
          "# $26 = cloud top pressure [hPa]\n"
          "# $27 = pressure at lifted condensation level (LCL) [hPa]\n"
          "# $28 = pressure at level of free convection (LFC) [hPa]\n"
          "# $29 = pressure at equilibrium level (EL) [hPa]\n"
          "# $30 = convective available potential energy (CAPE) [J/kg]\n");
  fprintf(out,
          "# $31 = relative humidity over water [%%]\n"
          "# $32 = relative humidity over ice [%%]\n"
          "# $33 = dew point temperature [K]\n"
          "# $34 = frost point temperature [K]\n\n");

  /* Write data... */
  for (iz = 0; iz < nz; iz++)
    fprintf(out,
            "%.2f %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g"
            " %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g\n",
            timem[iz] / np[iz], Z(plev[iz]), lonm[iz] / np[iz],
            latm[iz] / np[iz], plev[iz], tm[iz] / np[iz], um[iz] / np[iz],
            vm[iz] / np[iz], wm[iz] / np[iz], h2om[iz] / np[iz],
            o3m[iz] / np[iz], zm[iz] / np[iz], pvm[iz] / np[iz],
            psm[iz] / np[iz], tsm[iz] / np[iz], zsm[iz] / np[iz],
            usm[iz] / np[iz], vsm[iz] / np[iz], ptm[iz] / npt[iz],
            ztm[iz] / npt[iz], ttm[iz] / npt[iz], h2otm[iz] / npt[iz],
            lwcm[iz] / np[iz], iwcm[iz] / np[iz], clm[iz] / np[iz],
            pcm[iz] / np[iz], plclm[iz] / np[iz], plfcm[iz] / np[iz],
            pelm[iz] / np[iz], capem[iz] / np[iz],
            RH(plev[iz], tm[iz] / np[iz], h2om[iz] / np[iz]),
            RHICE(plev[iz], tm[iz] / np[iz], h2om[iz] / np[iz]),
            TDEW(plev[iz], h2om[iz] / np[iz]),
            TICE(plev[iz], h2om[iz] / np[iz]));

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);
```

```
  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.28 met_prof.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

/* ------------------------------------------------------------
   Dimensions...
   ------------------------------------------------------------ */

#define NZ 1000

/* ------------------------------------------------------------
   Main...
   ------------------------------------------------------------ */

int main(
  int argc,
  char *argv[]) {
```

```
ctl_t ctl;

met_t *met;

FILE *out;

static double timem[NZ], z, z0, z1, dz, lon, lon0, lon1, dlon, lonm[NZ],
  lat, lat0, lat1, dlat, latm[NZ], t, tm[NZ], u, um[NZ], v, vm[NZ], w,
  wm[NZ], h2o, h2om[NZ], h2ot, h2otm[NZ], o3, o3m[NZ], lwc, lwcm[NZ],
  iwc, iwcm[NZ], ps, psm[NZ], ts, tsm[NZ], zs, zsm[NZ], us, usm[NZ],
  vs, vsm[NZ], pt, ptm[NZ], pc, pcm[NZ], cl, clm[NZ],
  plcl, plclm[NZ], plfc, plfcm[NZ], pel, pelm[NZ], cape, capem[NZ],
  tt, ttm[NZ], zm[NZ], zt, ztm[NZ], pv, pvm[NZ], plev[NZ], cw[3];

static int i, iz, np[NZ], npt[NZ], nz, ci[3];

/* Allocate... */
ALLOC(met, met_t, 1);

/* Check arguments... */
if (argc < 4)
  ERRMSG("Give parameters: <ctl> <prof.tab> <met0> [ <met1> ... ]");

/* Read control parameters... */
read_ctl(argv[1], argc, argv, &ctl);
z0 = scan_ctl(argv[1], argc, argv, "PROF_Z0", -1, "-999", NULL);
z1 = scan_ctl(argv[1], argc, argv, "PROF_Z1", -1, "-999", NULL);
dz = scan_ctl(argv[1], argc, argv, "PROF_DZ", -1, "-999", NULL);
lon0 = scan_ctl(argv[1], argc, argv, "PROF_LON0", -1, "0", NULL);
lon1 = scan_ctl(argv[1], argc, argv, "PROF_LON1", -1, "0", NULL);
dlon = scan_ctl(argv[1], argc, argv, "PROF_DLON", -1, "-999", NULL);
lat0 = scan_ctl(argv[1], argc, argv, "PROF_LAT0", -1, "0", NULL);
lat1 = scan_ctl(argv[1], argc, argv, "PROF_LAT1", -1, "0", NULL);
dlat = scan_ctl(argv[1], argc, argv, "PROF_DLAT", -1, "-999", NULL);

/* Loop over input files... */
for (i = 3; i < argc; i++) {

  /* Read meteorological data... */
  if (!read_met(&ctl, argv[i], met))
    continue;

  /* Set vertical grid... */
  if (z0 < 0)
    z0 = Z(met->p[0]);
  if (z1 < 0)
    z1 = Z(met->p[met->np - 1]);
  nz = 0;
  if (dz < 0) {
    for (iz = 0; iz < met->np; iz++)
      if (Z(met->p[iz]) >= z0 && Z(met->p[iz]) <= z1) {
        plev[nz] = met->p[iz];
        if ((++nz) > NZ)
          ERRMSG("Too many pressure levels!");
      }
  } else
    for (z = z0; z <= z1; z += dz) {
      plev[nz] = P(z);
      if ((++nz) > NZ)
        ERRMSG("Too many pressure levels!");
    }

  /* Set horizontal grid... */
  if (dlon <= 0)
    dlon = fabs(met->lon[1] - met->lon[0]);
  if (dlat <= 0)
    dlat = fabs(met->lat[1] - met->lat[0]);

  /* Average... */
  for (iz = 0; iz < nz; iz++)
    for (lon = lon0; lon <= lon1; lon += dlon)
      for (lat = lat0; lat <= lat1; lat += dlat) {

        /* Interpolate meteo data... */
        INTPOL_SPACE_ALL(plev[iz], lon, lat);

        /* Averaging... */
        if (gsl_finite(t) && gsl_finite(u)
            && gsl_finite(v) && gsl_finite(w)) {
          timem[iz] += met->time;
          lonm[iz] += lon;
          latm[iz] += lat;
          zm[iz] += z;
          tm[iz] += t;
          um[iz] += u;
          vm[iz] += v;
```

```
          wm[iz] += w;
          pvm[iz] += pv;
          h2om[iz] += h2o;
          o3m[iz] += o3;
          psm[iz] += ps;
          tsm[iz] += ts;
          zsm[iz] += zs;
          usm[iz] += us;
          vsm[iz] += vs;
          pcm[iz] += pc;
          clm[iz] += cl;
          plclm[iz] += plcl;
          plfcm[iz] += plfc;
          pelm[iz] += pel;
          capem[iz] += cape;
          lwcm[iz] += lwc;
          iwcm[iz] += iwc;
          if (gsl_finite(pt)) {
            ptm[iz] += pt;
            ztm[iz] += zt;
            ttm[iz] += tt;
            h2otm[iz] += h2ot;
            npt[iz]++;
          }
          np[iz]++;
        }
      }
  }

  /* Create output file... */
  printf("Write meteorological data file: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n"
          "# $6 = temperature [K]\n"
          "# $7 = zonal wind [m/s]\n"
          "# $8 = meridional wind [m/s]\n"
          "# $9 = vertical velocity [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [ppv]\n");
  fprintf(out,
          "# $11 = O3 volume mixing ratio [ppv]\n"
          "# $12 = geopotential height [km]\n"
          "# $13 = potential vorticity [PVU]\n"
          "# $14 = surface pressure [hPa]\n"
          "# $15 = surface temperature [K]\n"
          "# $16 = surface geopotential height [km]\n"
          "# $17 = surface zonal wind [m/s]\n"
          "# $18 = surface meridional wind [m/s]\n"
          "# $19 = tropopause pressure [hPa]\n"
          "# $20 = tropopause geopotential height [km]\n");
  fprintf(out,
          "# $21 = tropopause temperature [K]\n"
          "# $22 = tropopause water vapor [ppv]\n"
          "# $23 = cloud liquid water content [kg/kg]\n"
          "# $24 = cloud ice water content [kg/kg]\n"
          "# $25 = total column cloud water [kg/m^2]\n"
          "# $26 = cloud top pressure [hPa]\n"
          "# $27 = pressure at lifted condensation level (LCL) [hPa]\n"
          "# $28 = pressure at level of free convection (LFC) [hPa]\n"
          "# $29 = pressure at equilibrium level (EL) [hPa]\n"
          "# $30 = convective available potential energy (CAPE) [J/kg]\n");
  fprintf(out,
          "# $31 = relative humidity over water [%%]\n"
          "# $32 = relative humidity over ice [%%]\n"
          "# $33 = dew point temperature [K]\n"
          "# $34 = frost point temperature [K]\n\n");

  /* Write data... */
  for (iz = 0; iz < nz; iz++)
    fprintf(out,
            "%.2f %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g"
            " %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g\n",
            timem[iz] / np[iz], Z(plev[iz]), lonm[iz] / np[iz],
            latm[iz] / np[iz], plev[iz], tm[iz] / np[iz], um[iz] / np[iz],
            vm[iz] / np[iz], wm[iz] / np[iz], h2om[iz] / np[iz],
            o3m[iz] / np[iz], zm[iz] / np[iz], pvm[iz] / np[iz],
            psm[iz] / np[iz], tsm[iz] / np[iz], zsm[iz] / np[iz],
            usm[iz] / np[iz], vsm[iz] / np[iz], ptm[iz] / npt[iz],
            ztm[iz] / npt[iz], ttm[iz] / npt[iz], h2otm[iz] / npt[iz],
            lwcm[iz] / np[iz], iwcm[iz] / np[iz], clm[iz] / np[iz],
```

```
            pcm[iz] / np[iz], plclm[iz] / np[iz], plfcm[iz] / np[iz],
            pelm[iz] / np[iz], capem[iz] / np[iz],
            RH(plev[iz], tm[iz] / np[iz], h2om[iz] / np[iz]),
            RHICE(plev[iz], tm[iz] / np[iz], h2om[iz] / np[iz]),
            TDEW(plev[iz], h2om[iz] / np[iz]),
            TICE(plev[iz], h2om[iz] / np[iz]));

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}
```

5.29 met_sample.c File Reference

Functions

- int main (int argc, char ∗argv[ ])

5.29.1 Detailed Description

Sample meteorological data at given geolocations.

Definition in file met_sample.c.

5.29.2 Function Documentation

5.29.2.1 main()

```
int main (
    int argc,
    char * argv[ ] )
```

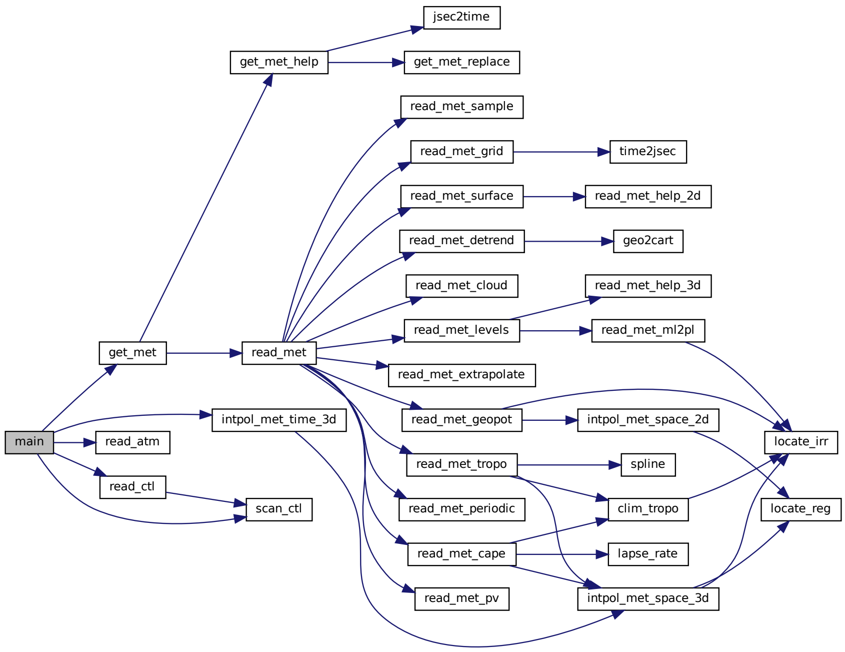
Definition at line 31 of file met_sample.c.

```
                  {

  ctl_t ctl;

  atm_t *atm;

  met_t *met0, *met1;

  FILE *out;

  double h2o, h2ot, o3, lwc, iwc, p0, p1, pref, ps, ts, zs, us, vs, pt, pc,
    cl, plcl, plfc, pel, cape, pv, t, tt, u, v, w, z, zm, zref, zt, cw[3],
    time_old = -999, p_old = -999, lon_old = -999, lat_old = -999;

  int geopot, grid_time, grid_z, grid_lon, grid_lat, ip, it, ci[3];

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <sample.tab> <atm_in>");

  /* Allocate... */
  ALLOC(atm, atm_t, 1);
  ALLOC(met0, met_t, 1);
  ALLOC(met1, met_t, 1);

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  geopot =
    (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GEOPOT", -1, "0", NULL);
```

```
grid_time =
  (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GRID_TIME", -1, "0", NULL);
grid_z =
  (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GRID_Z", -1, "0", NULL);
grid_lon =
  (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GRID_LON", -1, "0", NULL);
grid_lat =
  (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GRID_LAT", -1, "0", NULL);

/* Read atmospheric data... */
if (!read_atm(argv[3], &ctl, atm))
  ERRMSG("Cannot open file!");

/* Create output file... */
printf("Write meteorological data file: %s\n", argv[2]);
if (!(out = fopen(argv[2], "w")))
  ERRMSG("Cannot create file!");

/* Write header... */
fprintf(out,
        "# $1 = time [s]\n"
        "# $2 = altitude [km]\n"
        "# $3 = longitude [deg]\n"
        "# $4 = latitude [deg]\n"
        "# $5 = pressure [hPa]\n"
        "# $6 = temperature [K]\n"
        "# $7 = zonal wind [m/s]\n"
        "# $8 = meridional wind [m/s]\n"
        "# $9 = vertical velocity [hPa/s]\n"
        "# $10 = H2O volume mixing ratio [ppv]\n");
fprintf(out,
        "# $11 = O3 volume mixing ratio [ppv]\n"
        "# $12 = geopotential height [km]\n"
        "# $13 = potential vorticity [PVU]\n"
        "# $14 = surface pressure [hPa]\n"
        "# $15 = surface temperature [K]\n"
        "# $16 = surface geopotential height [km]\n"
        "# $17 = surface zonal wind [m/s]\n"
        "# $18 = surface meridional wind [m/s]\n"
        "# $19 = tropopause pressure [hPa]\n"
        "# $20 = tropopause geopotential height [km]\n");
fprintf(out,
        "# $21 = tropopause temperature [K]\n"
        "# $22 = tropopause water vapor [ppv]\n"
        "# $23 = cloud liquid water content [kg/kg]\n"
        "# $24 = cloud ice water content [kg/kg]\n"
        "# $25 = total column cloud water [kg/m^2]\n"
        "# $26 = cloud top pressure [hPa]\n"
        "# $27 = pressure at lifted condensation level (LCL) [hPa]\n"
        "# $28 = pressure at level of free convection (LFC) [hPa]\n"
        "# $29 = pressure at equilibrium level (EL) [hPa]\n"
        "# $30 = convective available potential energy (CAPE) [J/kg]\n");
fprintf(out,
        "# $31 = relative humidity over water [%%]\n"
        "# $32 = relative humidity over ice [%%]\n"
        "# $33 = dew point temperature [K]\n"
        "# $34 = frost point temperature [K]\n");

/* Loop over air parcels... */
for (ip = 0; ip < atm->np; ip++) {

  /* Get meteorological data... */
  get_met(&ctl, atm->time[ip], &met0, &met1);

  /* Set reference pressure for interpolation... */
  pref = atm->p[ip];
  if (geopot) {
    zref = Z(pref);
    p0 = met0->p[0];
    p1 = met0->p[met0->np - 1];
    for (it = 0; it < 24; it++) {
      pref = 0.5 * (p0 + p1);
      intpol_met_time_3d(met0, met0->z, met1, met1->z, atm->time[ip], pref,
                         atm->lon[ip], atm->lat[ip], &zm, ci, cw, 1);
      if (zref > zm || !gsl_finite(zm))
        p0 = pref;
      else
        p1 = pref;
    }
    pref = 0.5 * (p0 + p1);
  }

  /* Interpolate meteo data... */
  INTPOL_TIME_ALL(atm->time[ip], pref, atm->lon[ip], atm->lat[ip]);

  /* Make blank lines... */
  if (ip == 0 || (grid_time && atm->time[ip] != time_old)
```

```
        || (grid_z && atm->p[ip] != p_old)
        || (grid_lon && atm->lon[ip] != lon_old)
        || (grid_lat && atm->lat[ip] != lat_old))
      fprintf(out, "\n");
    time_old = atm->time[ip];
    p_old = atm->p[ip];
    lon_old = atm->lon[ip];
    lat_old = atm->lat[ip];

    /* Write data... */
    fprintf(out,
            "%.2f %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g"
            " %g %g %g %g %g %g %g %g %g %g %g %g %g %g\n",
            atm->time[ip], Z(atm->p[ip]), atm->lon[ip], atm->lat[ip],
            atm->p[ip], t, u, v, w, h2o, o3, z, pv, ps, ts, zs, us, vs,
            pt, zt, tt, h2ot, lwc, iwc, cl, pc, plcl, plfc, pel, cape,
            RH(atm->p[ip], t, h2o), RHICE(atm->p[ip], t, h2o),
            TDEW(atm->p[ip], h2o), TICE(atm->p[ip], h2o));
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(atm);
  free(met0);
  free(met1);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.30 met_sample.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
```

```
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

/* ------------------------------------------------------------
   Main...
   ------------------------------------------------------------ */

int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  atm_t *atm;

  met_t *met0, *met1;

  FILE *out;

  double h2o, h2ot, o3, lwc, iwc, p0, p1, pref, ps, ts, zs, us, vs, pt, pc,
    cl, plcl, plfc, pel, cape, pv, t, tt, u, v, w, z, zm, zref, zt, cw[3],
    time_old = -999, p_old = -999, lon_old = -999, lat_old = -999;

  int geopot, grid_time, grid_z, grid_lon, grid_lat, ip, it, ci[3];

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <sample.tab> <atm_in>");

  /* Allocate... */
  ALLOC(atm, atm_t, 1);
  ALLOC(met0, met_t, 1);
  ALLOC(met1, met_t, 1);

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  geopot =
    (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GEOPOT", -1, "0", NULL);
  grid_time =
    (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GRID_TIME", -1, "0", NULL);
  grid_z =
    (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GRID_Z", -1, "0", NULL);
  grid_lon =
    (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GRID_LON", -1, "0", NULL);
  grid_lat =
    (int) scan_ctl(argv[1], argc, argv, "SAMPLE_GRID_LAT", -1, "0", NULL);

  /* Read atmospheric data... */
  if (!read_atm(argv[3], &ctl, atm))
    ERRMSG("Cannot open file!");

  /* Create output file... */
  printf("Write meteorological data file: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n"
          "# $6 = temperature [K]\n"
          "# $7 = zonal wind [m/s]\n"
          "# $8 = meridional wind [m/s]\n"
          "# $9 = vertical velocity [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [ppv]\n");
  fprintf(out,
          "# $11 = O3 volume mixing ratio [ppv]\n"
          "# $12 = geopotential height [km]\n"
          "# $13 = potential vorticity [PVU]\n"
          "# $14 = surface pressure [hPa]\n"
          "# $15 = surface temperature [K]\n"
          "# $16 = surface geopotential height [km]\n"
          "# $17 = surface zonal wind [m/s]\n"
          "# $18 = surface meridional wind [m/s]\n"
          "# $19 = tropopause pressure [hPa]\n"
          "# $20 = tropopause geopotential height [km]\n");
  fprintf(out,
```

```
          "# $21 = tropopause temperature [K]\n"
          "# $22 = tropopause water vapor [ppv]\n"
          "# $23 = cloud liquid water content [kg/kg]\n"
          "# $24 = cloud ice water content [kg/kg]\n"
          "# $25 = total column cloud water [kg/m^2]\n"
          "# $26 = cloud top pressure [hPa]\n"
          "# $27 = pressure at lifted condensation level (LCL) [hPa]\n"
          "# $28 = pressure at level of free convection (LFC) [hPa]\n"
          "# $29 = pressure at equilibrium level (EL) [hPa]\n"
          "# $30 = convective available potential energy (CAPE) [J/kg]\n");
  fprintf(out,
          "# $31 = relative humidity over water [%%]\n"
          "# $32 = relative humidity over ice [%%]\n"
          "# $33 = dew point temperature [K]\n"
          "# $34 = frost point temperature [K]\n");

  /* Loop over air parcels... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Get meteorological data... */
    get_met(&ctl, atm->time[ip], &met0, &met1);

    /* Set reference pressure for interpolation... */
    pref = atm->p[ip];
    if (geopot) {
      zref = Z(pref);
      p0 = met0->p[0];
      p1 = met0->p[met0->np - 1];
      for (it = 0; it < 24; it++) {
        pref = 0.5 * (p0 + p1);
        intpol_met_time_3d(met0, met0->z, met1, met1->z, atm->time[ip], pref,
                           atm->lon[ip], atm->lat[ip], &zm, ci, cw, 1);
        if (zref > zm || !gsl_finite(zm))
          p0 = pref;
        else
          p1 = pref;
      }
      pref = 0.5 * (p0 + p1);
    }

    /* Interpolate meteo data... */
    INTPOL_TIME_ALL(atm->time[ip], pref, atm->lon[ip], atm->lat[ip]);

    /* Make blank lines... */
    if (ip == 0 || (grid_time && atm->time[ip] != time_old)
        || (grid_z && atm->p[ip] != p_old)
        || (grid_lon && atm->lon[ip] != lon_old)
        || (grid_lat && atm->lat[ip] != lat_old))
      fprintf(out, "\n");
    time_old = atm->time[ip];
    p_old = atm->p[ip];
    lon_old = atm->lon[ip];
    lat_old = atm->lat[ip];

    /* Write data... */
    fprintf(out,
            "%.2f %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g"
            " %g %g %g %g %g %g %g %g %g %g %g %g %g %g\n",
            atm->time[ip], Z(atm->p[ip]), atm->lon[ip], atm->lat[ip],
            atm->p[ip], t, u, v, w, h2o, o3, z, pv, ps, ts, zs, us, vs,
            pt, zt, tt, h2ot, lwc, iwc, cl, pc, plcl, plfc, pel, cape,
            RH(atm->p[ip], t, h2o), RHICE(atm->p[ip], t, h2o),
            TDEW(atm->p[ip], h2o), TICE(atm->p[ip], h2o));
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(atm);
  free(met0);
  free(met1);

  return EXIT_SUCCESS;
}
```

5.31 met_spec.c File Reference

Functions

- void fft_help (double *fcReal, double *fcImag, int n)
- int main (int argc, char *argv[ ])

5.31.1 Detailed Description

Extract zonal mean from meteorological data.

Definition in file met_spec.c.

5.31.2 Function Documentation

5.31.2.1 fft_help()

```
void fft_help (
        double * fcReal,
        double * fcImag,
        int n )
```

Definition at line 143 of file met_spec.c.

```
                {

  gsl_fft_complex_wavetable *wavetable;
  gsl_fft_complex_workspace *workspace;

  double data[2 * PMAX];

  int i;

  /* Check size... */
  if (n > PMAX)
    ERRMSG("Too many data points!");

  /* Allocate... */
  wavetable = gsl_fft_complex_wavetable_alloc((size_t) n);
  workspace = gsl_fft_complex_workspace_alloc((size_t) n);

  /* Set data (real, complex)... */
  for (i = 0; i < n; i++) {
    data[2 * i] = fcReal[i];
    data[2 * i + 1] = fcImag[i];
  }

  /* Calculate FFT... */
  gsl_fft_complex_forward(data, 1, (size_t) n, wavetable, workspace);

  /* Copy data... */
  for (i = 0; i < n; i++) {
    fcReal[i] = data[2 * i];
    fcImag[i] = data[2 * i + 1];
  }

  /* Free... */
  gsl_fft_complex_wavetable_free(wavetable);
  gsl_fft_complex_workspace_free(workspace);
}
```

5.31.2.2 main()

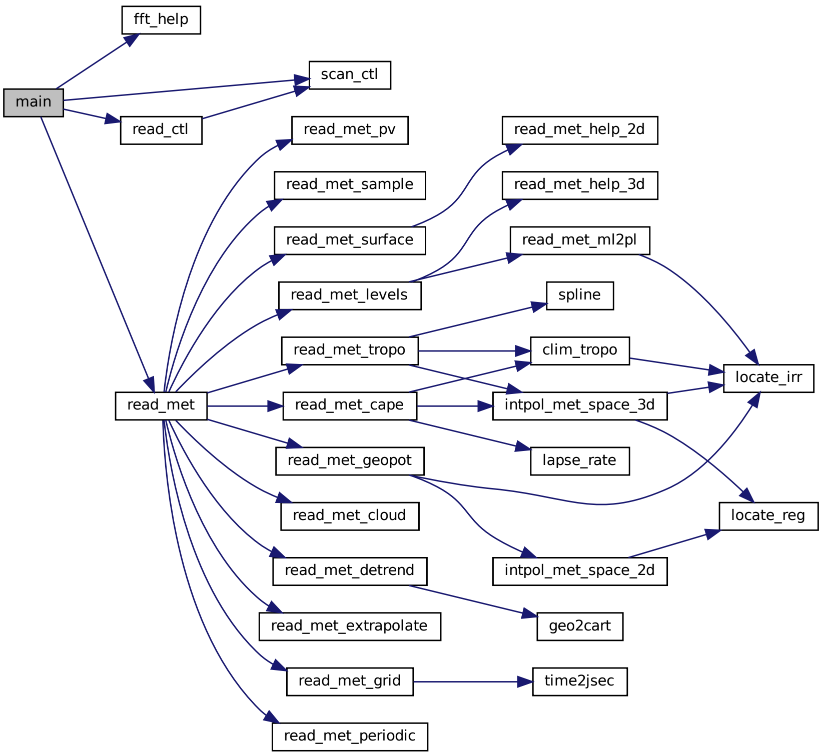
```
int main (
        int argc,
        char * argv[] )
```

Definition at line 47 of file met_spec.c.

```
                      {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double cutImag[PMAX], cutReal[PMAX], lx[PMAX], A[PMAX], phi[PMAX],
```

```
    wavemax;

  /* Allocate... */
  ALLOC(met, met_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <spec.tab> <met0>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  wavemax =
    (int) scan_ctl(argv[1], argc, argv, "SPEC_WAVEMAX", -1, "7", NULL);

  /* Read meteorological data... */
  if (!read_met(&ctl, argv[3], met))
    ERRMSG("Cannot read meteo data!");

  /* Create output file... */
  printf("Write spectral data file: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
  for (int ix = 0; ix <= wavemax; ix++) {
    fprintf(out, "# $%d = wavelength (PW%d) [km]\n", 5 + 3 * ix, ix);
    fprintf(out, "# $%d = amplitude (PW%d) [K]\n", 6 + 3 * ix, ix);
    fprintf(out, "# $%d = phase (PW%d) [deg]\n", 7 + 3 * ix, ix);
  }

  /* Loop over pressure levels... */
  for (int ip = 0; ip < met->np; ip++) {

    /* Write output... */
    fprintf(out, "\n");

    /* Loop over latitudes... */
    for (int iy = 0; iy < met->ny; iy++) {

      /* Copy data... */
      for (int ix = 0; ix < met->nx; ix++) {
        cutReal[ix] = met->t[ix][iy][ip];
        cutImag[ix] = 0.0;
      }

      /* FFT... */
      fft_help(cutReal, cutImag, met->nx);

      /*
         Get wavelength, amplitude, and phase:
         A(x) = A[0] + A[1] * cos(2 pi x / lx[1] + phi[1]) + A[2] * cos...
       */
      for (int ix = 0; ix < met->nx; ix++) {
        lx[ix] = DEG2DX(met->lon[met->nx - 1] - met->lon[0], met->lat[iy])
          / ((ix < met->nx / 2) ? (double) ix : -(double) (met->nx - ix));
        A[ix] = (ix == 0 ? 1.0 : 2.0) / (met->nx)
          * sqrt(gsl_pow_2(cutReal[ix]) + gsl_pow_2(cutImag[ix]));
        phi[ix]
          = 180. / M_PI * atan2(cutImag[ix], cutReal[ix]);
      }

      /* Write data... */
      fprintf(out, "%.2f %g %g %g", met->time, Z(met->p[ip]), 0.0,
              met->lat[iy]);
      for (int ix = 0; ix <= wavemax; ix++)
        fprintf(out, " %g %g %g", lx[ix], A[ix], phi[ix]);
      fprintf(out, "\n");
    }
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.32 met_spec.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

/* ------------------------------------------------------------
   Dimensions...
   ------------------------------------------------------------ */

#define PMAX EX

/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

void fft_help(
  double *fcReal,
  double *fcImag,
  int n);

/* ------------------------------------------------------------
```

```
   Main...
   -------------------------------------------------------------- */

int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double cutImag[PMAX], cutReal[PMAX], lx[PMAX], A[PMAX], phi[PMAX],
    wavemax;

  /* Allocate... */
  ALLOC(met, met_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <spec.tab> <met0>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  wavemax =
    (int) scan_ctl(argv[1], argc, argv, "SPEC_WAVEMAX", -1, "7", NULL);

  /* Read meteorological data... */
  if (!read_met(&ctl, argv[3], met))
    ERRMSG("Cannot read meteo data!");

  /* Create output file... */
  printf("Write spectral data file: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
  for (int ix = 0; ix <= wavemax; ix++) {
    fprintf(out, "# $%d = wavelength (PW%d) [km]\n", 5 + 3 * ix, ix);
    fprintf(out, "# $%d = amplitude (PW%d) [K]\n", 6 + 3 * ix, ix);
    fprintf(out, "# $%d = phase (PW%d) [deg]\n", 7 + 3 * ix, ix);
  }

  /* Loop over pressure levels... */
  for (int ip = 0; ip < met->np; ip++) {

    /* Write output... */
    fprintf(out, "\n");

    /* Loop over latitudes... */
    for (int iy = 0; iy < met->ny; iy++) {

      /* Copy data... */
      for (int ix = 0; ix < met->nx; ix++) {
        cutReal[ix] = met->t[ix][iy][ip];
        cutImag[ix] = 0.0;
      }

      /* FFT... */
      fft_help(cutReal, cutImag, met->nx);

      /*
         Get wavelength, amplitude, and phase:
         A(x) = A[0] + A[1] * cos(2 pi x / lx[1] + phi[1]) + A[2] * cos...
       */
      for (int ix = 0; ix < met->nx; ix++) {
        lx[ix] = DEG2DX(met->lon[met->nx - 1] - met->lon[0], met->lat[iy])
          / ((ix < met->nx / 2) ? (double) ix : -(double) (met->nx - ix));
        A[ix] = (ix == 0 ? 1.0 : 2.0) / (met->nx)
          * sqrt(gsl_pow_2(cutReal[ix]) + gsl_pow_2(cutImag[ix]));
        phi[ix]
          = 180. / M_PI * atan2(cutImag[ix], cutReal[ix]);
      }

      /* Write data... */
      fprintf(out, "%.2f %g %g %g", met->time, Z(met->p[ip]), 0.0,
              met->lat[iy]);
      for (int ix = 0; ix <= wavemax; ix++)
        fprintf(out, " %g %g %g", lx[ix], A[ix], phi[ix]);
      fprintf(out, "\n");
    }
  }
```

```

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}

/*****************************************************************************/

void fft_help(
  double *fcReal,
  double *fcImag,
  int n) {

  gsl_fft_complex_wavetable *wavetable;
  gsl_fft_complex_workspace *workspace;

  double data[2 * PMAX];

  int i;

  /* Check size... */
  if (n > PMAX)
    ERRMSG("Too many data points!");

  /* Allocate... */
  wavetable = gsl_fft_complex_wavetable_alloc((size_t) n);
  workspace = gsl_fft_complex_workspace_alloc((size_t) n);

  /* Set data (real, complex)... */
  for (i = 0; i < n; i++) {
    data[2 * i] = fcReal[i];
    data[2 * i + 1] = fcImag[i];
  }

  /* Calculate FFT... */
  gsl_fft_complex_forward(data, 1, (size_t) n, wavetable, workspace);

  /* Copy data... */
  for (i = 0; i < n; i++) {
    fcReal[i] = data[2 * i];
    fcImag[i] = data[2 * i + 1];
  }

  /* Free... */
  gsl_fft_complex_wavetable_free(wavetable);
  gsl_fft_complex_workspace_free(workspace);
}
```

5.33 met_zm.c File Reference

Functions

- int main (int argc, char *argv[ ])

5.33.1 Detailed Description

Extract zonal mean from meteorological data.

Definition in file met_zm.c.

5.33.2 Function Documentation

5.33.2.1 main()

```
int main (
    int argc,
    char * argv[] )
```

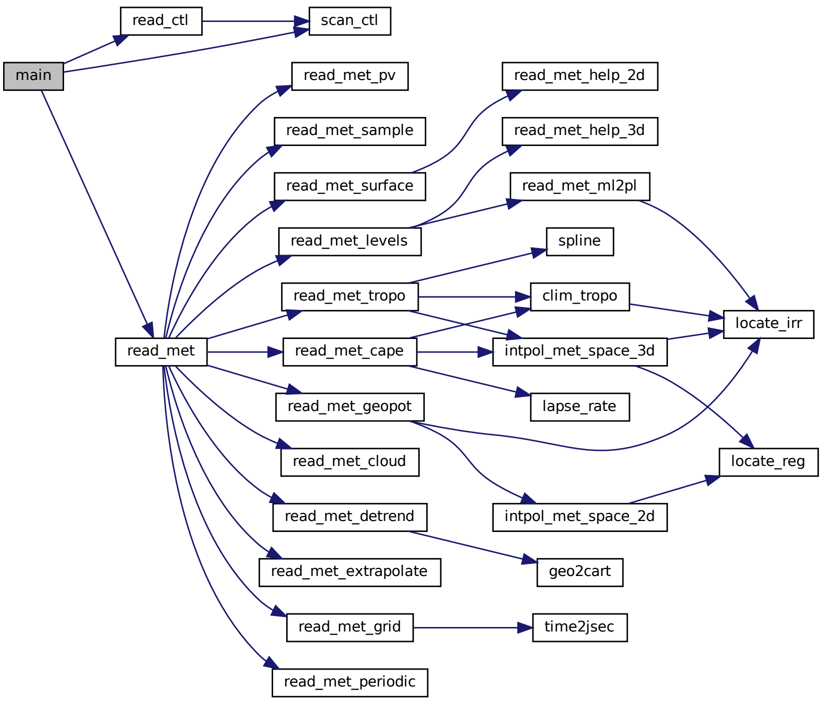
Definition at line 41 of file met_zm.c.

```
                {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double timem[NZ][NY], psm[NZ][NY], tsm[NZ][NY], zsm[NZ][NY],
    usm[NZ][NY], vsm[NZ][NY], ptm[NZ][NY], pcm[NZ][NY],
    clm[NZ][NY], plclm[NZ][NY], plfcm[NZ][NY], pelm[NZ][NY], capem[NZ][NY],
    ttm[NZ][NY], ztm[NZ][NY], tm[NZ][NY], um[NZ][NY], vm[NZ][NY],
    wm[NZ][NY], h2om[NZ][NY], h2otm[NZ][NY], pvm[NZ][NY], o3m[NZ][NY],
    lwcm[NZ][NY], iwcm[NZ][NY], zm[NZ][NY], z, z0, z1, dz, zt, tt, plev[NZ],
    ps, ts, zs, us, vs, pt, pc, plcl, plfc, pel, cape, cl, t, u, v, w, pv,
    h2o, h2ot, o3, lwc, iwc, lat, lat0, lat1, dlat, lats[NY], cw[3];

  static int i, ix, iy, iz, np[NZ][NY], npt[NZ][NY], ny, nz, ci[3];

  /* Allocate... */
  ALLOC(met, met_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <zm.tab> <met0> [ <met1> ... ]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  z0 = scan_ctl(argv[1], argc, argv, "ZM_Z0", -1, "-999", NULL);
  z1 = scan_ctl(argv[1], argc, argv, "ZM_Z1", -1, "-999", NULL);
  dz = scan_ctl(argv[1], argc, argv, "ZM_DZ", -1, "-999", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "ZM_LAT0", -1, "-90", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "ZM_LAT1", -1, "90", NULL);
  dlat = scan_ctl(argv[1], argc, argv, "ZM_DLAT", -1, "-999", NULL);

  /* Loop over files... */
  for (i = 3; i < argc; i++) {

    /* Read meteorological data... */
    if (!read_met(&ctl, argv[i], met))
      continue;

    /* Set vertical grid... */
    if (z0 < 0)
      z0 = Z(met->p[0]);
    if (z1 < 0)
      z1 = Z(met->p[met->np - 1]);
    nz = 0;
    if (dz < 0) {
      for (iz = 0; iz < met->np; iz++)
        if (Z(met->p[iz]) >= z0 && Z(met->p[iz]) <= z1) {
          plev[nz] = met->p[iz];
          if ((++nz) > NZ)
            ERRMSG("Too many pressure levels!");
        }
    } else
      for (z = z0; z <= z1; z += dz) {
        plev[nz] = P(z);
        if ((++nz) > NZ)
          ERRMSG("Too many pressure levels!");
      }

    /* Set horizontal grid... */
    if (dlat <= 0)
      dlat = fabs(met->lat[1] - met->lat[0]);
    ny = 0;
    if (lat0 < -90 && lat1 > 90) {
      lat0 = gsl_stats_min(met->lat, 1, (size_t) met->ny);
      lat1 = gsl_stats_max(met->lat, 1, (size_t) met->ny);
    }
    for (lat = lat0; lat <= lat1; lat += dlat) {
      lats[ny] = lat;
      if ((++ny) > NY)
        ERRMSG("Too many latitudes!");
    }

    /* Average... */
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < ny; iy++)
        for (iz = 0; iz < nz; iz++) {
```

```
        /* Interpolate meteo data... */
        INTPOL_SPACE_ALL(plev[iz], met->lon[ix], met->lat[iy]);

        /* Averaging... */
        timem[iz][iy] += met->time;
        zm[iz][iy] += z;
        tm[iz][iy] += t;
        um[iz][iy] += u;
        vm[iz][iy] += v;
        wm[iz][iy] += w;
        pvm[iz][iy] += pv;
        h2om[iz][iy] += h2o;
        o3m[iz][iy] += o3;
        lwcm[iz][iy] += lwc;
        iwcm[iz][iy] += iwc;
        psm[iz][iy] += ps;
        tsm[iz][iy] += ts;
        zsm[iz][iy] += zs;
        usm[iz][iy] += us;
        vsm[iz][iy] += vs;
        pcm[iz][iy] += pc;
        clm[iz][iy] += cl;
        plclm[iz][iy] += plcl;
        plfcm[iz][iy] += plfc;
        pelm[iz][iy] += pel;
        capem[iz][iy] += cape;
        if (gsl_finite(pt)) {
          ptm[iz][iy] += pt;
          ztm[iz][iy] += zt;
          ttm[iz][iy] += tt;
          h2otm[iz][iy] += h2ot;
          npt[iz][iy]++;
        }
        np[iz][iy]++;
      }
  }

  /* Create output file... */
  printf("Write meteorological data file: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n"
          "# $6 = temperature [K]\n"
          "# $7 = zonal wind [m/s]\n"
          "# $8 = meridional wind [m/s]\n"
          "# $9 = vertical velocity [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [ppv]\n");
  fprintf(out,
          "# $11 = O3 volume mixing ratio [ppv]\n"
          "# $12 = geopotential height [km]\n"
          "# $13 = potential vorticity [PVU]\n"
          "# $14 = surface pressure [hPa]\n"
          "# $15 = surface temperature [K]\n"
          "# $16 = surface geopotential height [km]\n"
          "# $17 = surface zonal wind [m/s]\n"
          "# $18 = surface meridional wind [m/s]\n"
          "# $19 = tropopause pressure [hPa]\n"
          "# $20 = tropopause geopotential height [km]\n");
  fprintf(out,
          "# $21 = tropopause temperature [K]\n"
          "# $22 = tropopause water vapor [ppv]\n"
          "# $23 = cloud liquid water content [kg/kg]\n"
          "# $24 = cloud ice water content [kg/kg]\n"
          "# $25 = total column cloud water [kg/m^2]\n"
          "# $26 = cloud top pressure [hPa]\n"
          "# $27 = pressure at lifted condensation level (LCL) [hPa]\n"
          "# $28 = pressure at level of free convection (LFC) [hPa]\n"
          "# $29 = pressure at equilibrium level (EL) [hPa]\n"
          "# $30 = convective available potential energy (CAPE) [J/kg]\n");
  fprintf(out,
          "# $31 = relative humidity over water [%%]\n"
          "# $32 = relative humidity over ice [%%]\n"
          "# $33 = dew point temperature [K]\n"
          "# $34 = frost point temperature [K]\n");

  /* Write data... */
  for (iz = 0; iz < nz; iz++) {
    fprintf(out, "\n");
    for (iy = 0; iy < ny; iy++)
```

```
      fprintf(out,
              "%.2f %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g"
              " %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g\n",
              timem[iz][iy] / np[iz][iy], Z(plev[iz]), 0.0, lats[iy],
              plev[iz], tm[iz][iy] / np[iz][iy], um[iz][iy] / np[iz][iy],
              vm[iz][iy] / np[iz][iy], wm[iz][iy] / np[iz][iy],
              h2om[iz][iy] / np[iz][iy], o3m[iz][iy] / np[iz][iy],
              zm[iz][iy] / np[iz][iy], pvm[iz][iy] / np[iz][iy],
              psm[iz][iy] / np[iz][iy], tsm[iz][iy] / np[iz][iy],
              zsm[iz][iy] / np[iz][iy], usm[iz][iy] / np[iz][iy],
              vsm[iz][iy] / np[iz][iy], ptm[iz][iy] / npt[iz][iy],
              ztm[iz][iy] / npt[iz][iy], ttm[iz][iy] / npt[iz][iy],
              h2otm[iz][iy] / npt[iz][iy], lwcm[iz][iy] / np[iz][iy],
              iwcm[iz][iy] / np[iz][iy], clm[iz][iy] / np[iz][iy],
              pcm[iz][iy] / np[iz][iy], plclm[iz][iy] / np[iz][iy],
              plfcm[iz][iy] / np[iz][iy], pelm[iz][iy] / np[iz][iy],
              capem[iz][iy] / np[iz][iy],
              RH(plev[iz], tm[iz][iy] / np[iz][iy],
                 h2om[iz][iy] / np[iz][iy]),
              RHICE(plev[iz], tm[iz][iy] / np[iz][iy],
                    h2om[iz][iy] / np[iz][iy]),
              TDEW(plev[iz], h2om[iz][iy] / np[iz][iy]),
              TICE(plev[iz], h2om[iz][iy] / np[iz][iy]));
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.34 met_zm.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
```

```
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

/* ------------------------------------------------------------
   Dimensions...
   ------------------------------------------------------------ */

#define NZ 1000

#define NY 721

/* ------------------------------------------------------------
   Main...
   ------------------------------------------------------------ */

int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double timem[NZ][NY], psm[NZ][NY], tsm[NZ][NY], zsm[NZ][NY],
    usm[NZ][NY], vsm[NZ][NY], ptm[NZ][NY], pcm[NZ][NY],
    clm[NZ][NY], plclm[NZ][NY], plfcm[NZ][NY], pelm[NZ][NY], capem[NZ][NY],
    ttm[NZ][NY], ztm[NZ][NY], tm[NZ][NY], um[NZ][NY], vm[NZ][NY],
    wm[NZ][NY], h2om[NZ][NY], h2otm[NZ][NY], pvm[NZ][NY], o3m[NZ][NY],
    lwcm[NZ][NY], iwcm[NZ][NY], zm[NZ][NY], z, z0, z1, dz, zt, tt, plev[NZ],
    ps, ts, zs, us, vs, pt, pc, plcl, plfc, pel, cape, cl, t, u, v, w, pv,
    h2o, h2ot, o3, lwc, iwc, lat, lat0, lat1, dlat, lats[NY], cw[3];

  static int i, ix, iy, iz, np[NZ][NY], npt[NZ][NY], ny, nz, ci[3];

  /* Allocate... */
  ALLOC(met, met_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <zm.tab> <met0> [ <met1> ... ]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  z0 = scan_ctl(argv[1], argc, argv, "ZM_Z0", -1, "-999", NULL);
  z1 = scan_ctl(argv[1], argc, argv, "ZM_Z1", -1, "-999", NULL);
  dz = scan_ctl(argv[1], argc, argv, "ZM_DZ", -1, "-999", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "ZM_LAT0", -1, "-90", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "ZM_LAT1", -1, "90", NULL);
  dlat = scan_ctl(argv[1], argc, argv, "ZM_DLAT", -1, "-999", NULL);

  /* Loop over files... */
  for (i = 3; i < argc; i++) {

    /* Read meteorological data... */
    if (!read_met(&ctl, argv[i], met))
      continue;

    /* Set vertical grid... */
    if (z0 < 0)
      z0 = Z(met->p[0]);
    if (z1 < 0)
      z1 = Z(met->p[met->np - 1]);
    nz = 0;
    if (dz < 0) {
      for (iz = 0; iz < met->np; iz++)
        if (Z(met->p[iz]) >= z0 && Z(met->p[iz]) <= z1) {
          plev[nz] = met->p[iz];
          if ((++nz) > NZ)
            ERRMSG("Too many pressure levels!");
        }
    } else
```

```
      for (z = z0; z <= z1; z += dz) {
        plev[nz] = P(z);
        if ((++nz) > NZ)
          ERRMSG("Too many pressure levels!");
      }

    /* Set horizontal grid... */
    if (dlat <= 0)
      dlat = fabs(met->lat[1] - met->lat[0]);
    ny = 0;
    if (lat0 < -90 && lat1 > 90) {
      lat0 = gsl_stats_min(met->lat, 1, (size_t) met->ny);
      lat1 = gsl_stats_max(met->lat, 1, (size_t) met->ny);
    }
    for (lat = lat0; lat <= lat1; lat += dlat) {
      lats[ny] = lat;
      if ((++ny) > NY)
        ERRMSG("Too many latitudes!");
    }

    /* Average... */
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < ny; iy++)
        for (iz = 0; iz < nz; iz++) {

          /* Interpolate meteo data... */
          INTPOL_SPACE_ALL(plev[iz], met->lon[ix], met->lat[iy]);

          /* Averaging... */
          timem[iz][iy] += met->time;
          zm[iz][iy] += z;
          tm[iz][iy] += t;
          um[iz][iy] += u;
          vm[iz][iy] += v;
          wm[iz][iy] += w;
          pvm[iz][iy] += pv;
          h2om[iz][iy] += h2o;
          o3m[iz][iy] += o3;
          lwcm[iz][iy] += lwc;
          iwcm[iz][iy] += iwc;
          psm[iz][iy] += ps;
          tsm[iz][iy] += ts;
          zsm[iz][iy] += zs;
          usm[iz][iy] += us;
          vsm[iz][iy] += vs;
          pcm[iz][iy] += pc;
          clm[iz][iy] += cl;
          plclm[iz][iy] += plcl;
          plfcm[iz][iy] += plfc;
          pelm[iz][iy] += pel;
          capem[iz][iy] += cape;
          if (gsl_finite(pt)) {
            ptm[iz][iy] += pt;
            ztm[iz][iy] += zt;
            ttm[iz][iy] += tt;
            h2otm[iz][iy] += h2ot;
            npt[iz][iy]++;
          }
          np[iz][iy]++;
        }
  }

  /* Create output file... */
  printf("Write meteorological data file: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n"
          "# $6 = temperature [K]\n"
          "# $7 = zonal wind [m/s]\n"
          "# $8 = meridional wind [m/s]\n"
          "# $9 = vertical velocity [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [ppv]\n");
  fprintf(out,
          "# $11 = O3 volume mixing ratio [ppv]\n"
          "# $12 = geopotential height [km]\n"
          "# $13 = potential vorticity [PVU]\n"
          "# $14 = surface pressure [hPa]\n"
          "# $15 = surface temperature [K]\n"
          "# $16 = surface geopotential height [km]\n"
          "# $17 = surface zonal wind [m/s]\n"
```

```
          "# $18 = surface meridional wind [m/s]\n"
          "# $19 = tropopause pressure [hPa]\n"
          "# $20 = tropopause geopotential height [km]\n");
  fprintf(out,
          "# $21 = tropopause temperature [K]\n"
          "# $22 = tropopause water vapor [ppv]\n"
          "# $23 = cloud liquid water content [kg/kg]\n"
          "# $24 = cloud ice water content [kg/kg]\n"
          "# $25 = total column cloud water [kg/m^2]\n"
          "# $26 = cloud top pressure [hPa]\n"
          "# $27 = pressure at lifted condensation level (LCL) [hPa]\n"
          "# $28 = pressure at level of free convection (LFC) [hPa]\n"
          "# $29 = pressure at equilibrium level (EL) [hPa]\n"
          "# $30 = convective available potential energy (CAPE) [J/kg]\n");
  fprintf(out,
          "# $31 = relative humidity over water [%%]\n"
          "# $32 = relative humidity over ice [%%]\n"
          "# $33 = dew point temperature [K]\n"
          "# $34 = frost point temperature [K]\n");

  /* Write data... */
  for (iz = 0; iz < nz; iz++) {
    fprintf(out, "\n");
    for (iy = 0; iy < ny; iy++)
      fprintf(out,
              "%.2f %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g"
              " %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g %g\n",
              timem[iz][iy] / np[iz][iy], Z(plev[iz]), 0.0, lats[iy],
              plev[iz], tm[iz][iy] / np[iz][iy], um[iz][iy] / np[iz][iy],
              vm[iz][iy] / np[iz][iy], wm[iz][iy] / np[iz][iy],
              h2om[iz][iy] / np[iz][iy], o3m[iz][iy] / np[iz][iy],
              zm[iz][iy] / np[iz][iy], pvm[iz][iy] / np[iz][iy],
              psm[iz][iy] / np[iz][iy], tsm[iz][iy] / np[iz][iy],
              zsm[iz][iy] / np[iz][iy], usm[iz][iy] / np[iz][iy],
              vsm[iz][iy] / np[iz][iy], ptm[iz][iy] / npt[iz][iy],
              ztm[iz][iy] / npt[iz][iy], ttm[iz][iy] / npt[iz][iy],
              h2otm[iz][iy] / npt[iz][iy], lwcm[iz][iy] / np[iz][iy],
              iwcm[iz][iy] / np[iz][iy], clm[iz][iy] / np[iz][iy],
              pcm[iz][iy] / np[iz][iy], plclm[iz][iy] / np[iz][iy],
              plfcm[iz][iy] / np[iz][iy], pelm[iz][iy] / np[iz][iy],
              capem[iz][iy] / np[iz][iy],
              RH(plev[iz], tm[iz][iy] / np[iz][iy],
                 h2om[iz][iy] / np[iz][iy]),
              RHICE(plev[iz], tm[iz][iy] / np[iz][iy],
                    h2om[iz][iy] / np[iz][iy]),
              TDEW(plev[iz], h2om[iz][iy] / np[iz][iy]),
              TICE(plev[iz], h2om[iz][iy] / np[iz][iy]));
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}
```

5.35 time2jsec.c File Reference

Functions

- int main (int argc, char *argv[ ])

5.35.1 Detailed Description

Convert date to Julian seconds.

Definition in file time2jsec.c.

5.35.2 Function Documentation

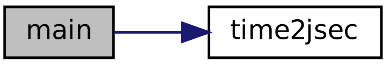
5.35.2.1 main()

```
int main (
    int argc,
    char * argv[] )
```

Definition at line 27 of file time2jsec.c.

```
00029                  {
00030
00031   double jsec, remain;
00032
00033   int day, hour, min, mon, sec, year;
00034
00035   /* Check arguments... */
00036   if (argc < 8)
00037     ERRMSG("Give parameters: <year> <mon> <day> <hour> <min> <sec> <remain>");
00038
00039   /* Read arguments... */
00040   year = atoi(argv[1]);
00041   mon = atoi(argv[2]);
00042   day = atoi(argv[3]);
00043   hour = atoi(argv[4]);
00044   min = atoi(argv[5]);
00045   sec = atoi(argv[6]);
00046   remain = atof(argv[7]);
00047
00048   /* Convert... */
00049   time2jsec(year, mon, day, hour, min, sec, remain, &jsec);
00050   printf("%.2f\n", jsec);
00051
00052   return EXIT_SUCCESS;
00053 }
```

Here is the call graph for this function:



5.36 time2jsec.c

```
00001 /*
00002   This file is part of MPTRAC.
00003
00004   MPTRAC is free software: you can redistribute it and/or modify
00005   it under the terms of the GNU General Public License as published by
00006   the Free Software Foundation, either version 3 of the License, or
00007   (at your option) any later version.
00008
00009   MPTRAC is distributed in the hope that it will be useful,
00010   but WITHOUT ANY WARRANTY; without even the implied warranty of
00011   MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
00012   GNU General Public License for more details.
00013
00014   You should have received a copy of the GNU General Public License
00015   along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.
00016
00017   Copyright (C) 2013-2019 Forschungszentrum Juelich GmbH
00018 */
00019
00025 #include "libtrac.h"
00026
00027 int main(
00028   int argc,
00029   char *argv[]) {
00030
00031   double jsec, remain;
00032
00033   int day, hour, min, mon, sec, year;
00034
00035   /* Check arguments... */
00036   if (argc < 8)
```

```
    ERRMSG("Give parameters: <year> <mon> <day> <hour> <min> <sec> <remain>");

  /* Read arguments... */
  year = atoi(argv[1]);
  mon = atoi(argv[2]);
  day = atoi(argv[3]);
  hour = atoi(argv[4]);
  min = atoi(argv[5]);
  sec = atoi(argv[6]);
  remain = atof(argv[7]);

  /* Convert... */
  time2jsec(year, mon, day, hour, min, sec, remain, &jsec);
  printf("%.2f\n", jsec);

  return EXIT_SUCCESS;
}
```

5.37 trac.c File Reference

Functions

- void module_advection (met_t ∗met0, met_t ∗met1, atm_t ∗atm, double ∗dt)

  Calculate advection of air parcels.
- void module_convection (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double ∗dt, double ∗rs)

  Calculate convection of air parcels.
- void module_decay (ctl_t ∗ctl, atm_t ∗atm, double ∗dt)

  Calculate exponential decay of particle mass.
- void module_diffusion_meso (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, cache_t ∗cache, double ∗dt, double ∗rs)

  Calculate mesoscale diffusion.
- void module_diffusion_turb (ctl_t ∗ctl, atm_t ∗atm, double ∗dt, double ∗rs)

  Calculate turbulent diffusion.
- void module_dry_deposition (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double ∗dt)

  Calculate dry deposition.
- void module_isosurf_init (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, cache_t ∗cache)

  Initialize isosurface module.
- void module_isosurf (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, cache_t ∗cache)

  Force air parcels to stay on isosurface.
- void module_meteo (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm)

  Interpolate meteorological data for air parcel positions.
- void module_position (met_t ∗met0, met_t ∗met1, atm_t ∗atm, double ∗dt)

  Check position of air parcels.
- void module_rng_init (void)

  Initialize random number generator...
- void module_rng (double ∗rs, size_t n, int method)

  Generate random numbers.
- void module_sedi (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double ∗dt)

  Calculate sedimentation of air parcels.
- void module_oh_chem (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double ∗dt)

  Calculate OH chemistry.
- void module_wet_deposition (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double ∗dt)

  Calculate wet deposition.
- void write_output (const char ∗dirname, ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, double t)

  Write simulation output.
- int main (int argc, char ∗argv[ ])

Variables

- curandGenerator_t rng

5.37.1 Detailed Description

Lagrangian particle dispersion model.

Definition in file trac.c.

5.37.2 Function Documentation

5.37.2.1 module_advection()

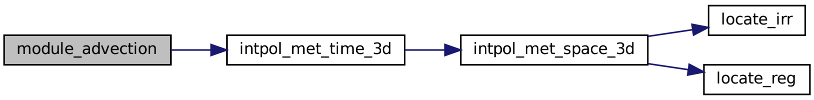
```
void module_advection (
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    double * dt )
```

Calculate advection of air parcels.

Definition at line 450 of file trac.c.

```
                  {

  /* Set timer... */
  SELECT_TIMER("MODULE_ADVECTION", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double u, v, w;

      /* Interpolate meteorological data... */
      INTPOL_INIT;
      INTPOL_3D(u, 1);
      INTPOL_3D(v, 0);
      INTPOL_3D(w, 0);

      /* Get position of the mid point... */
      double dtm = atm->time[ip] + 0.5 * dt[ip];
      double xm0 =
        atm->lon[ip] + DX2DEG(0.5 * dt[ip] * u / 1000., atm->lat[ip]);
      double xm1 = atm->lat[ip] + DY2DEG(0.5 * dt[ip] * v / 1000.);
      double xm2 = atm->p[ip] + 0.5 * dt[ip] * w;

      /* Interpolate meteorological data for mid point... */
      intpol_met_time_3d(met0, met0->u, met1, met1->u,
                         dtm, xm2, xm0, xm1, &u, ci, cw, 1);
      intpol_met_time_3d(met0, met0->v, met1, met1->v,
                         dtm, xm2, xm0, xm1, &v, ci, cw, 0);
      intpol_met_time_3d(met0, met0->w, met1, met1->w,
                         dtm, xm2, xm0, xm1, &w, ci, cw, 0);

      /* Save new position... */
      atm->time[ip] += dt[ip];
      atm->lon[ip] += DX2DEG(dt[ip] * u / 1000., xm1);
      atm->lat[ip] += DY2DEG(dt[ip] * v / 1000.);
      atm->p[ip] += dt[ip] * w;
    }
}
```

Here is the call graph for this function:



5.37.2.2 module_convection()

```
void module_convection (
    ctl_t * ctl,
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    double * dt,
    double * rs )
```

Calculate convection of air parcels.

Definition at line 501 of file trac.c.

```
                  {

  /* Set timer... */
  SELECT_TIMER("MODULE_CONVECTION", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt,rs)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double cape, pel, ps;

      /* Interpolate CAPE... */
      INTPOL_INIT;
      INTPOL_2D(cape, 1);

      /* Check threshold... */
      if (isfinite(cape) && cape >= ctl->conv_cape) {

        /* Interpolate equilibrium level... */
        INTPOL_2D(pel, 0);

        /* Check whether particle is above cloud top... */
        if (!isfinite(pel) || atm->p[ip] < pel)
          continue;

        /* Interpolate surface pressure... */
        INTPOL_2D(ps, 0);

        /* Redistribute particle in cloud column... */
        atm->p[ip] = ps + (pel - ps) * rs[ip];
      }
    }
}
```

5.37.2.3 module_decay()

```
void module_decay (
    ctl_t * ctl,
    atm_t * atm,
    double * dt )
```

Calculate exponential decay of particle mass.

Definition at line 548 of file trac.c.

```
                  {

  /* Set timer... */
  SELECT_TIMER("MODULE_DECAY", NVTX_GPU);

  /* Check quantity flags... */
  if (ctl->qnt_m < 0)
    ERRMSG("Module needs quantity mass!");

#ifdef _OPENACC
#pragma acc data present(ctl,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Get tropopause pressure... */
      double pt = clim_tropo(atm->time[ip], atm->lat[ip]);

      /* Get weighting factor... */
      double w;
      double p1 = pt * 0.866877899;
      double p0 = pt / 0.866877899;
      if (atm->p[ip] > p0)
        w = 1;
      else if (atm->p[ip] < p1)
        w = 0;
      else
        w = LIN(p0, 1.0, p1, 0.0, atm->p[ip]);

      /* Set lifetime... */
      double tdec = w * ctl->tdec_trop + (1 - w) * ctl->tdec_strat;

      /* Calculate exponential decay... */
      atm->q[ctl->qnt_m][ip] *= exp(-dt[ip] / tdec);
    }
}
```

Here is the call graph for this function:

5.37.2.4 module_diffusion_meso()

```
void module_diffusion_meso (
    ctl_t * ctl,
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    cache_t * cache,
    double * dt,
    double * rs )
```

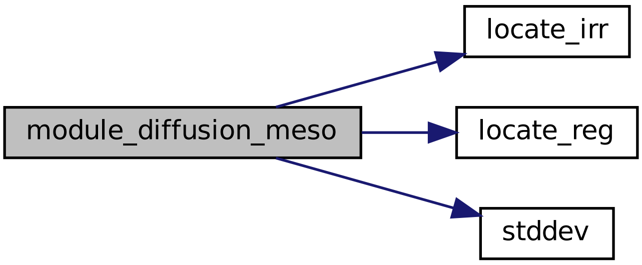
Calculate mesoscale diffusion.

Definition at line 593 of file trac.c.

```
                    {

  /* Set timer... */
  SELECT_TIMER("MODULE_TURBMESO", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,cache,dt,rs)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double u[16], v[16], w[16];

      /* Get indices... */
      int ix = locate_reg(met0->lon, met0->nx, atm->lon[ip]);
      int iy = locate_reg(met0->lat, met0->ny, atm->lat[ip]);
      int iz = locate_irr(met0->p, met0->np, atm->p[ip]);

      /* Caching of wind standard deviations... */
      if (cache->tsig[ix][iy][iz] != met0->time) {

        /* Collect local wind data... */
        u[0] = met0->u[ix][iy][iz];
        u[1] = met0->u[ix + 1][iy][iz];
        u[2] = met0->u[ix][iy + 1][iz];
        u[3] = met0->u[ix + 1][iy + 1][iz];
        u[4] = met0->u[ix][iy][iz + 1];
        u[5] = met0->u[ix + 1][iy][iz + 1];
        u[6] = met0->u[ix][iy + 1][iz + 1];
        u[7] = met0->u[ix + 1][iy + 1][iz + 1];

        v[0] = met0->v[ix][iy][iz];
        v[1] = met0->v[ix + 1][iy][iz];
        v[2] = met0->v[ix][iy + 1][iz];
        v[3] = met0->v[ix + 1][iy + 1][iz];
        v[4] = met0->v[ix][iy][iz + 1];
        v[5] = met0->v[ix + 1][iy][iz + 1];
        v[6] = met0->v[ix][iy + 1][iz + 1];
        v[7] = met0->v[ix + 1][iy + 1][iz + 1];

        w[0] = met0->w[ix][iy][iz];
        w[1] = met0->w[ix + 1][iy][iz];
        w[2] = met0->w[ix][iy + 1][iz];
        w[3] = met0->w[ix + 1][iy + 1][iz];
        w[4] = met0->w[ix][iy][iz + 1];
        w[5] = met0->w[ix + 1][iy][iz + 1];
        w[6] = met0->w[ix][iy + 1][iz + 1];
        w[7] = met0->w[ix + 1][iy + 1][iz + 1];

        /* Collect local wind data... */
        u[8] = met1->u[ix][iy][iz];
        u[9] = met1->u[ix + 1][iy][iz];
        u[10] = met1->u[ix][iy + 1][iz];
        u[11] = met1->u[ix + 1][iy + 1][iz];
        u[12] = met1->u[ix][iy][iz + 1];
        u[13] = met1->u[ix + 1][iy][iz + 1];
        u[14] = met1->u[ix][iy + 1][iz + 1];
        u[15] = met1->u[ix + 1][iy + 1][iz + 1];

        v[8] = met1->v[ix][iy][iz];
        v[9] = met1->v[ix + 1][iy][iz];
        v[10] = met1->v[ix][iy + 1][iz];
        v[11] = met1->v[ix + 1][iy + 1][iz];
        v[12] = met1->v[ix][iy][iz + 1];
        v[13] = met1->v[ix + 1][iy][iz + 1];
        v[14] = met1->v[ix][iy + 1][iz + 1];
        v[15] = met1->v[ix + 1][iy + 1][iz + 1];

        w[8] = met1->w[ix][iy][iz];
        w[9] = met1->w[ix + 1][iy][iz];
        w[10] = met1->w[ix][iy + 1][iz];
        w[11] = met1->w[ix + 1][iy + 1][iz];
        w[12] = met1->w[ix][iy][iz + 1];
        w[13] = met1->w[ix + 1][iy][iz + 1];
        w[14] = met1->w[ix][iy + 1][iz + 1];
        w[15] = met1->w[ix + 1][iy + 1][iz + 1];

        /* Get standard deviations of local wind data... */
        cache->usig[ix][iy][iz] = (float) stddev(u, 16);
        cache->vsig[ix][iy][iz] = (float) stddev(v, 16);
```

```
        cache->wsig[ix][iy][iz] = (float) stddev(w, 16);
        cache->tsig[ix][iy][iz] = met0->time;
      }

      /* Set temporal correlations for mesoscale fluctuations... */
      double r = 1 - 2 * fabs(dt[ip]) / ctl->dt_met;
      double r2 = sqrt(1 - r * r);

      /* Calculate horizontal mesoscale wind fluctuations... */
      if (ctl->turb_mesox > 0) {
        cache->up[ip] = (float)
          (r * cache->up[ip]
           + r2 * rs[3 * ip] * ctl->turb_mesox * cache->usig[ix][iy][iz]);
        atm->lon[ip] += DX2DEG(cache->up[ip] * dt[ip] / 1000., atm->lat[ip]);

        cache->vp[ip] = (float)
          (r * cache->vp[ip]
           + r2 * rs[3 * ip + 1] * ctl->turb_mesox * cache->vsig[ix][iy][iz]);
        atm->lat[ip] += DY2DEG(cache->vp[ip] * dt[ip] / 1000.);
      }

      /* Calculate vertical mesoscale wind fluctuations... */
      if (ctl->turb_mesoz > 0) {
        cache->wp[ip] = (float)
          (r * cache->wp[ip]
           + r2 * rs[3 * ip + 2] * ctl->turb_mesoz * cache->wsig[ix][iy][iz]);
        atm->p[ip] += cache->wp[ip] * dt[ip];
      }
    }
}
```

Here is the call graph for this function:



5.37.2.5 module_diffusion_turb() `void module_diffusion_turb ( ctl_t * ctl, atm_t * atm, double * dt, double * rs )`

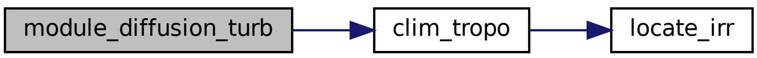
Calculate turbulent diffusion.

Definition at line 716 of file trac.c.

```
                  {

  /* Set timer... */
  SELECT_TIMER("MODULE_TURBDIFF", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,atm,dt,rs)
#pragma acc parallel loop independent gang vector
```

```
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Get tropopause pressure... */
      double pt = clim_tropo(atm->time[ip], atm->lat[ip]);

      /* Get weighting factor... */
      double w;
      double p1 = pt * 0.866877899;
      double p0 = pt / 0.866877899;
      if (atm->p[ip] > p0)
        w = 1;
      else if (atm->p[ip] < p1)
        w = 0;
      else
        w = LIN(p0, 1.0, p1, 0.0, atm->p[ip]);

      /* Set diffusivity... */
      double dx = w * ctl->turb_dx_trop + (1 - w) * ctl->turb_dx_strat;
      double dz = w * ctl->turb_dz_trop + (1 - w) * ctl->turb_dz_strat;

      /* Horizontal turbulent diffusion... */
      if (dx > 0) {
        double sigma = sqrt(2.0 * dx * fabs(dt[ip]));
        atm->lon[ip] += DX2DEG(rs[3 * ip] * sigma / 1000., atm->lat[ip]);
        atm->lat[ip] += DY2DEG(rs[3 * ip + 1] * sigma / 1000.);
      }

      /* Vertical turbulent diffusion... */
      if (dz > 0) {
        double sigma = sqrt(2.0 * dz * fabs(dt[ip]));
        atm->p[ip]
          += DZ2DP(rs[3 * ip + 2] * sigma / 1000., atm->p[ip]);
      }
    }
}
```

Here is the call graph for this function:



5.37.2.6 module_dry_deposition()

```
void module_dry_deposition (
        ctl_t * ctl,
        met_t * met0,
        met_t * met1,
        atm_t * atm,
        double * dt )
```

Calculate dry deposition.

Definition at line 770 of file trac.c.

```
                 {

  /* Set timer... */
  SELECT_TIMER("MODULE_DRYDEPO", NVTX_GPU);

  /* Width of the surface layer [hPa]. */
  const double dp = 30.;

  /* Check quantity flags... */
```

```
  if (ctl->qnt_m < 0)
    ERRMSG("Module needs quantity mass!");

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double ps, t, v_dep;

      /* Get surface pressure... */
      INTPOL_INIT;
      INTPOL_2D(ps, 1);

      /* Check whether particle is above the surface layer... */
      if (atm->p[ip] < ps - dp)
        continue;

      /* Set width of surface layer... */
      double dz = 1000. * (Z(ps - dp) - Z(ps));

      /* Calculate sedimentation velocity for particles... */
      if (ctl->qnt_r >= 0 && ctl->qnt_rho >= 0) {

        /* Get temperature... */
        INTPOL_3D(t, 1);

        /* Set deposition velocity... */
        v_dep = sedi(atm->p[ip], t, atm->q[ctl->qnt_r][ip],
                     atm->q[ctl->qnt_rho][ip]);
      }

      /* Use explicit sedimentation velocity for gases... */
      else
        v_dep = ctl->dry_depo[0];

      /* Calculate loss of mass based on deposition velocity... */
      atm->q[ctl->qnt_m][ip] *= exp(-dt[ip] * v_dep / dz);
    }
}
```

Here is the call graph for this function:

5.37.2.7 module_isosurf_init()

```
void module_isosurf_init (
    ctl_t * ctl,
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    cache_t * cache )
```

Initialize isosurface module.

Definition at line 831 of file trac.c.

```
                         {

```

```
  FILE *in;

  char line[LEN];

  double t;

  /* Set timer... */
  SELECT_TIMER("MODULE_ISOSURF", NVTX_GPU);

  /* Init... */
  INTPOL_INIT;

  /* Save pressure... */
  if (ctl->isosurf == 1)
    for (int ip = 0; ip < atm->np; ip++)
      cache->iso_var[ip] = atm->p[ip];

  /* Save density... */
  else if (ctl->isosurf == 2)
    for (int ip = 0; ip < atm->np; ip++) {
      INTPOL_3D(t, 1);
      cache->iso_var[ip] = atm->p[ip] / t;
    }

  /* Save potential temperature... */
  else if (ctl->isosurf == 3)
    for (int ip = 0; ip < atm->np; ip++) {
      INTPOL_3D(t, 1);
      cache->iso_var[ip] = THETA(atm->p[ip], t);
    }

  /* Read balloon pressure data... */
  else if (ctl->isosurf == 4) {

    /* Write info... */
    printf("Read balloon pressure data: %s\n", ctl->balloon);

    /* Open file... */
    if (!(in = fopen(ctl->balloon, "r")))
      ERRMSG("Cannot open file!");

    /* Read pressure time series... */
    while (fgets(line, LEN, in))
      if (sscanf(line, "%lg %lg", &(cache->iso_ts[cache->iso_n]),
                 &(cache->iso_ps[cache->iso_n])) == 2)
        if ((++cache->iso_n) > NP)
          ERRMSG("Too many data points!");

    /* Check number of points... */
    if (cache->iso_n < 1)
      ERRMSG("Could not read any data!");

    /* Close file... */
    fclose(in);
  }
}
```

5.37.2.8 module_isosurf()

```
void module_isosurf (
    ctl_t * ctl,
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    cache_t * cache )
```

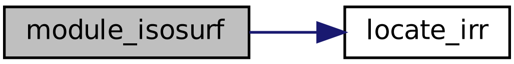
Force air parcels to stay on isosurface.

Definition at line 897 of file trac.c.

```
                         {

  /* Set timer... */
  SELECT_TIMER("MODULE_ISOSURF", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,cache)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
```

```
#endif
  for (int ip = 0; ip < atm->np; ip++) {

    double t;

    /* Init... */
    INTPOL_INIT;

    /* Restore pressure... */
    if (ctl->isosurf == 1)
      atm->p[ip] = cache->iso_var[ip];

    /* Restore density... */
    else if (ctl->isosurf == 2) {
      INTPOL_3D(t, 1);
      atm->p[ip] = cache->iso_var[ip] * t;
    }

    /* Restore potential temperature... */
    else if (ctl->isosurf == 3) {
      INTPOL_3D(t, 1);
      atm->p[ip] = 1000. * pow(cache->iso_var[ip] / t, -1. / 0.286);
    }

    /* Interpolate pressure... */
    else if (ctl->isosurf == 4) {
      if (atm->time[ip] <= cache->iso_ts[0])
        atm->p[ip] = cache->iso_ps[0];
      else if (atm->time[ip] >= cache->iso_ts[cache->iso_n - 1])
        atm->p[ip] = cache->iso_ps[cache->iso_n - 1];
      else {
        int idx = locate_irr(cache->iso_ts, cache->iso_n, atm->time[ip]);
        atm->p[ip] = LIN(cache->iso_ts[idx], cache->iso_ps[idx],
                         cache->iso_ts[idx + 1], cache->iso_ps[idx + 1],
                         atm->time[ip]);
      }
    }
  }
}
```

Here is the call graph for this function:



5.37.2.9 module_meteo() `void module_meteo ( ctl_t * ctl, met_t * met0, met_t * met1, atm_t * atm )`

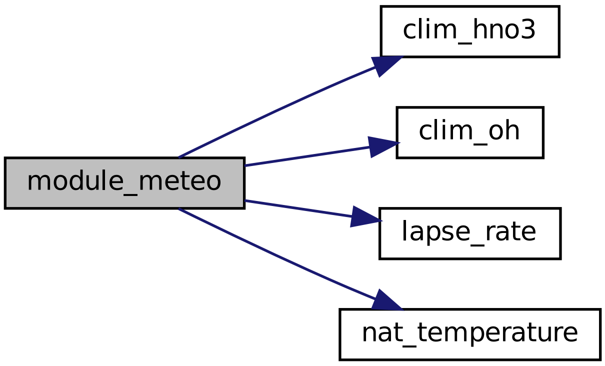
Interpolate meteorological data for air parcel positions.

Definition at line 954 of file trac.c.

```
               {

  /* Set timer... */
  SELECT_TIMER("MODULE_METEO", NVTX_GPU);

  /* Check quantity flags... */
  if (ctl->qnt_tsts >= 0)
    if (ctl->qnt_tice < 0 || ctl->qnt_tnat < 0)
      ERRMSG("Need T_ice and T_NAT to calculate T_STS!");
```

```

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++) {

    double ps, ts, zs, us, vs, pt, pc, cl, plcl, plfc, pel, cape, pv, t, tt,
      u, v, w, h2o, h2ot, o3, lwc, iwc, z, zt;

    /* Interpolate meteorological data... */
    INTPOL_INIT;
    INTPOL_TIME_ALL(atm->time[ip], atm->p[ip], atm->lon[ip], atm->lat[ip]);

    /* Set quantities... */
    ATM_SET(qnt_ps, ps);
    ATM_SET(qnt_ts, ts);
    ATM_SET(qnt_zs, zs);
    ATM_SET(qnt_us, us);
    ATM_SET(qnt_vs, vs);
    ATM_SET(qnt_pt, pt);
    ATM_SET(qnt_tt, tt);
    ATM_SET(qnt_zt, zt);
    ATM_SET(qnt_h2ot, h2ot);
    ATM_SET(qnt_p, atm->p[ip]);
    ATM_SET(qnt_z, z);
    ATM_SET(qnt_t, t);
    ATM_SET(qnt_u, u);
    ATM_SET(qnt_v, v);
    ATM_SET(qnt_w, w);
    ATM_SET(qnt_h2o, h2o);
    ATM_SET(qnt_o3, o3);
    ATM_SET(qnt_lwc, lwc);
    ATM_SET(qnt_iwc, iwc);
    ATM_SET(qnt_pc, pc);
    ATM_SET(qnt_cl, cl);
    ATM_SET(qnt_plcl, plcl);
    ATM_SET(qnt_plfc, plfc);
    ATM_SET(qnt_pel, pel);
    ATM_SET(qnt_cape, cape);
    ATM_SET(qnt_hno3, clim_hno3(atm->time[ip], atm->lat[ip], atm->p[ip]));
    ATM_SET(qnt_oh, clim_oh(atm->time[ip], atm->lat[ip], atm->p[ip]));
    ATM_SET(qnt_vh, sqrt(u * u + v * v));
    ATM_SET(qnt_vz, -1e3 * H0 / atm->p[ip] * w);
    ATM_SET(qnt_psat, PSAT(t));
    ATM_SET(qnt_psice, PSICE(t));
    ATM_SET(qnt_pw, PW(atm->p[ip], h2o));
    ATM_SET(qnt_sh, SH(h2o));
    ATM_SET(qnt_rh, RH(atm->p[ip], t, h2o));
    ATM_SET(qnt_rhice, RHICE(atm->p[ip], t, h2o));
    ATM_SET(qnt_theta, THETA(atm->p[ip], t));
    ATM_SET(qnt_tvirt, TVIRT(t, h2o));
    ATM_SET(qnt_lapse, lapse_rate(t, h2o));
    ATM_SET(qnt_pv, pv);
    ATM_SET(qnt_tdew, TDEW(atm->p[ip], h2o));
    ATM_SET(qnt_tice, TICE(atm->p[ip], h2o));
    ATM_SET(qnt_tnat,
            nat_temperature(atm->p[ip], h2o,
                            clim_hno3(atm->time[ip], atm->lat[ip],
                                      atm->p[ip]) * 1e-9));
    ATM_SET(qnt_tsts,
            0.5 * (atm->q[ctl->qnt_tice][ip] + atm->q[ctl->qnt_tnat][ip]));
  }
}
```

Here is the call graph for this function:



5.37.2.10 module_position()

```
void module_position (
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    double * dt )
```

Check position of air parcels.

Definition at line 1036 of file trac.c.

```
              {

  /* Set timer... */
  SELECT_TIMER("MODULE_POSITION", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Calculate modulo... */
      atm->lon[ip] = FMOD(atm->lon[ip], 360.);
      atm->lat[ip] = FMOD(atm->lat[ip], 360.);

      /* Check latitude... */
      while (atm->lat[ip] < -90 || atm->lat[ip] > 90) {
        if (atm->lat[ip] > 90) {
          atm->lat[ip] = 180 - atm->lat[ip];
          atm->lon[ip] += 180;
        }
        if (atm->lat[ip] < -90) {
          atm->lat[ip] = -180 - atm->lat[ip];
          atm->lon[ip] += 180;
        }
      }

      /* Check longitude... */
      while (atm->lon[ip] < -180)
        atm->lon[ip] += 360;
      while (atm->lon[ip] >= 180)
        atm->lon[ip] -= 360;
```

```

      /* Check pressure... */
      if (atm->p[ip] < met0->p[met0->np - 1])
        atm->p[ip] = met0->p[met0->np - 1];
      else if (atm->p[ip] > 300.) {
        double ps;
        INTPOL_INIT;
        INTPOL_2D(ps, 1);
        if (atm->p[ip] > ps)
          atm->p[ip] = ps;
      }
    }
}
```

5.37.2.11 module_rng_init()

```
void module_rng_init (
    void )
```

Initialize random number generator...

Definition at line 1091 of file trac.c.

```
        {

  /* Set timer... */
  SELECT_TIMER("MODULE_RNG", NVTX_GPU);

  /* Initialize random number generator... */
#ifdef _OPENACC

  if (curandCreateGenerator(&rng, CURAND_RNG_PSEUDO_DEFAULT)
      != CURAND_STATUS_SUCCESS)
    ERRMSG("Cannot create random number generator!");
  if (curandSetStream(rng, (cudaStream_t) acc_get_cuda_stream(acc_async_sync))
      != CURAND_STATUS_SUCCESS)
    ERRMSG("Cannot set stream for random number generator!");

#else

  gsl_rng_env_setup();
  if (omp_get_max_threads() > NTHREADS)
    ERRMSG("Too many threads!");
  for (int i = 0; i < NTHREADS; i++) {
    rng[i] = gsl_rng_alloc(gsl_rng_default);
    gsl_rng_set(rng[i], gsl_rng_default_seed + (long unsigned) i);
  }

#endif
}
```

5.37.2.12 module_rng()

```
void module_rng (
    double * rs,
    size_t n,
    int method )
```

Generate random numbers.

Definition at line 1122 of file trac.c.

```
              {

  /* Set timer... */
  SELECT_TIMER("MODULE_RNG", NVTX_GPU);

#ifdef _OPENACC

#pragma acc host_data use_device(rs)
  {
    /* Uniform distribution... */
    if (method == 0) {
      if (curandGenerateUniform(rng, rs, n)
          != CURAND_STATUS_SUCCESS)
        ERRMSG("Cannot create random numbers!");
```

```
    }

    /* Normal distribution... */
    else if (method == 1) {
      if (curandGenerateNormalDouble(rng, rs, n, 0.0, 1.0)
          != CURAND_STATUS_SUCCESS)
        ERRMSG("Cannot create random numbers!");
    }
  }

#else

  /* Uniform distribution... */
  if (method == 0) {
#pragma omp parallel for default(shared)
    for (size_t i = 0; i < n; ++i)
      rs[i] = gsl_rng_uniform(rng[omp_get_thread_num()]);
  }

  /* Normal distribution... */
  else if (method == 1) {
#pragma omp parallel for default(shared)
    for (size_t i = 0; i < n; ++i)
      rs[i] = gsl_ran_gaussian_ziggurat(rng[omp_get_thread_num()], 1.0);
  }
#endif

}
```

5.37.2.13 module_sedi()

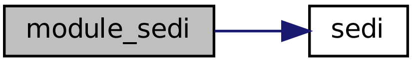
```
void module_sedi (
    ctl_t * ctl,
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    double * dt )
```

Calculate sedimentation of air parcels.

Definition at line 1170 of file trac.c.

```
                 {

  /* Set timer... */
  SELECT_TIMER("MODULE_SEDI", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Get temperature... */
      double t;
      INTPOL_INIT;
      INTPOL_3D(t, 1);

      /* Sedimentation velocity... */
      double v_s = sedi(atm->p[ip], t, atm->q[ctl->qnt_r][ip],
                        atm->q[ctl->qnt_rho][ip]);

      /* Calculate pressure change... */
      atm->p[ip] += DZ2DP(v_s * dt[ip] / 1000., atm->p[ip]);
    }
}
```

Here is the call graph for this function:



5.37.2.14 module_oh_chem()

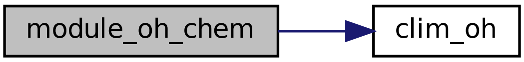
```
void module_oh_chem (
    ctl_t * ctl,
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    double * dt )
```

Calculate OH chemistry.

Definition at line 1205 of file trac.c.

```
                {

  /* Set timer... */
  SELECT_TIMER("MODULE_OHCHEM", NVTX_GPU);

  /* Check quantity flags... */
  if (ctl->qnt_m < 0)
    ERRMSG("Module needs quantity mass!");

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Get temperature... */
      double t;
      INTPOL_INIT;
      INTPOL_3D(t, 1);

      /* Calculate molecular density... */
      double M = 7.243e21 * (atm->p[ip] / P0) / t;

      /* Calculate rate coefficient for X + OH + M -> XOH + M
         (JPL Publication 15-10) ... */
      double k0 = ctl->oh_chem[0] *
        (ctl->oh_chem[1] > 0 ? pow(t / 300., -ctl->oh_chem[1]) : 1.);
      double ki = ctl->oh_chem[2] *
        (ctl->oh_chem[3] > 0 ? pow(t / 300., -ctl->oh_chem[3]) : 1.);
      double c = log10(k0 * M / ki);
      double k = k0 * M / (1. + k0 * M / ki) * pow(0.6, 1. / (1. + c * c));

      /* Calculate exponential decay... */
      atm->q[ctl->qnt_m][ip] *=
        exp(-dt[ip] * k * clim_oh(atm->time[ip], atm->lat[ip], atm->p[ip]));
    }
}
```

Here is the call graph for this function:



5.37.2.15 module_wet_deposition()

```
void module_wet_deposition (
        ctl_t * ctl,
        met_t * met0,
        met_t * met1,
        atm_t * atm,
        double * dt )
```

Calculate wet deposition.

Definition at line 1253 of file trac.c.

```
                  {

  /* Set timer... */
  SELECT_TIMER("MODULE_WETDEPO", NVTX_GPU);

  /* Check quantity flags... */
  if (ctl->qnt_m < 0)
    ERRMSG("Module needs quantity mass!");

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double cl, dz, h, lambda = 0, t, iwc, lwc, pc;

      int inside;

      /* Check whether particle is below cloud top... */
      INTPOL_INIT;
      INTPOL_2D(pc, 1);
      if (!isfinite(pc) || atm->p[ip] <= pc)
        continue;

      /* Estimate precipitation rate (Pisso et al., 2019)... */
      INTPOL_2D(cl, 0);
      double Is = pow(2. * cl, 1. / 0.36);
      if (Is < 0.01)
        continue;

      /* Check whether particle is inside or below cloud... */
      INTPOL_3D(lwc, 1);
      INTPOL_3D(iwc, 0);
      inside = (iwc > 0 || lwc > 0);

      /* Calculate in-cloud scavenging coefficient... */
      if (inside) {

        /* Use exponential dependency for particles... */
        if (ctl->wet_depo[0] > 0)
          lambda = ctl->wet_depo[0] * pow(Is, ctl->wet_depo[1]);

        /* Use Henry's law for gases... */
        else if (ctl->wet_depo[2] > 0) {
```

```

          /* Get temperature... */
          INTPOL_3D(t, 0);

          /* Get Henry's constant (Sander, 2015)... */
          h = ctl->wet_depo[2]
            * exp(ctl->wet_depo[3] * (1. / t - 1. / 298.15));

          /* Estimate depth of cloud layer... */
          dz = 1e3 * Z(pc);

          /* Calculate scavenging coefficient (Draxler and Hess, 1997)... */
          lambda = h * RI * t * Is / 3.6e6 * dz;
        }
      }

      /* Calculate below-cloud scavenging coefficient... */
      else {

        /* Use exponential dependency for particles... */
        if (ctl->wet_depo[4] > 0)
          lambda = ctl->wet_depo[4] * pow(Is, ctl->wet_depo[5]);

        /* Use Henry's law for gases... */
        else if (ctl->wet_depo[6] > 0) {

          /* Get temperature... */
          INTPOL_3D(t, 0);

          /* Get Henry's constant (Sander, 2015)... */
          h = ctl->wet_depo[6]
            * exp(ctl->wet_depo[7] * (1. / t - 1. / 298.15));

          /* Estimate depth of cloud layer... */
          dz = 1e3 * Z(pc);

          /* Calculate scavenging coefficient (Draxler and Hess, 1997)... */
          lambda = h * RI * t * Is / 3.6e6 * dz;
        }
      }

      /* Calculate exponential decay of mass... */
      atm->q[ctl->qnt_m][ip] *= exp(-dt[ip] * lambda);
    }
}
```

5.37.2.16 write_output()

```
void write_output (
    const char * dirname,
    ctl_t * ctl,
    met_t * met0,
    met_t * met1,
    atm_t * atm,
    double t )
```

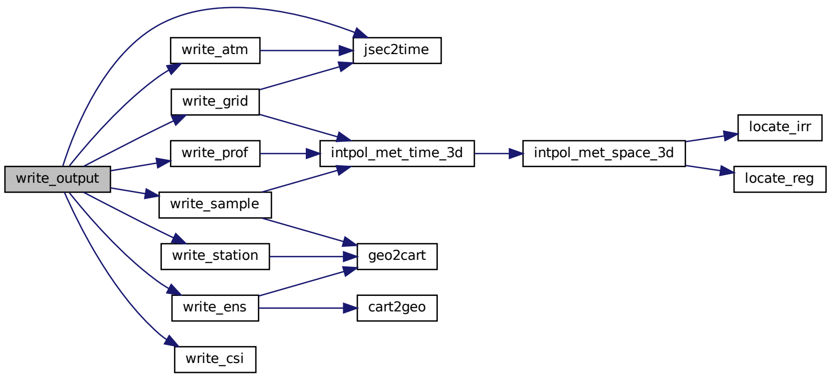
Write simulation output.

Definition at line 1354 of file trac.c.

```
                {

  char filename[2 * LEN];

  double r;

  int year, mon, day, hour, min, sec, updated = 0;

  /* Get time... */
  jsec2time(t, &year, &mon, &day, &hour, &min, &sec, &r);

  /* Write atmospheric data... */
  if (ctl->atm_basename[0] != '-' && fmod(t, ctl->atm_dt_out) == 0) {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
```

```
    }
    sprintf(filename, "%s/%s_%04d_%02d_%02d_%02d_%02d.tab",
            dirname, ctl->atm_basename, year, mon, day, hour, min);
    write_atm(filename, ctl, atm, t);
  }

  /* Write gridded data... */
  if (ctl->grid_basename[0] != '-' && fmod(t, ctl->grid_dt_out) == 0) {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s_%04d_%02d_%02d_%02d_%02d.tab",
            dirname, ctl->grid_basename, year, mon, day, hour, min);
    write_grid(filename, ctl, met0, met1, atm, t);
  }

  /* Write CSI data... */
  if (ctl->csi_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->csi_basename);
    write_csi(filename, ctl, atm, t);
  }

  /* Write ensemble data... */
  if (ctl->ens_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->ens_basename);
    write_ens(filename, ctl, atm, t);
  }

  /* Write profile data... */
  if (ctl->prof_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->prof_basename);
    write_prof(filename, ctl, met0, met1, atm, t);
  }

  /* Write sample data... */
  if (ctl->sample_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->sample_basename);
    write_sample(filename, ctl, met0, met1, atm, t);
  }

  /* Write station data... */
  if (ctl->stat_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->stat_basename);
    write_station(filename, ctl, atm, t);
  }
}
```

Here is the call graph for this function:



5.37.2.17 main() int main (int *argc*, char ∗ *argv[ ]*)

Definition at line 165 of file trac.c.

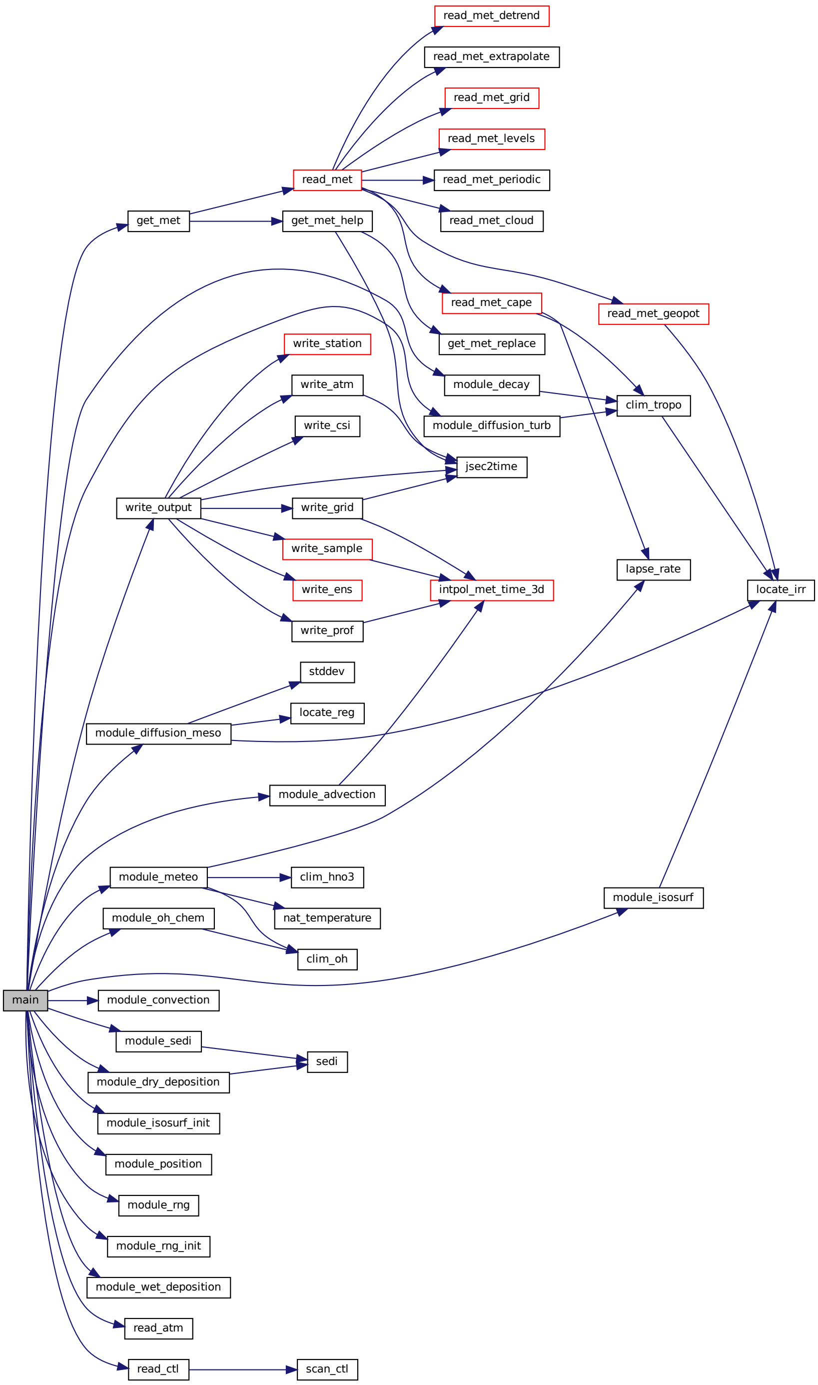
```
                      {

  ctl_t ctl;

  atm_t *atm;

  cache_t *cache;

  met_t *met0, *met1;

  FILE *dirlist;

  char dirname[LEN], filename[2 * LEN];

  double *dt, *rs, t;

  int num_devices = 0, ntask = -1, rank = 0, size = 1;

  /* Start timers... */
  START_TIMERS;

  /* Initialize MPI... */
#ifdef MPI
  SELECT_TIMER("MPI_INIT", NVTX_CPU);
  MPI_Init(&argc, &argv);
  MPI_Comm_rank(MPI_COMM_WORLD, &rank);
  MPI_Comm_size(MPI_COMM_WORLD, &size);
#endif

  /* Initialize GPUs... */
#ifdef _OPENACC
  SELECT_TIMER("ACC_INIT", NVTX_GPU);
  acc_device_t device_type = acc_get_device_type();
  num_devices = acc_get_num_devices(acc_device_nvidia);
  int device_num = rank % num_devices;
  acc_set_device_num(device_num, acc_device_nvidia);
  acc_init(device_type);
#endif

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <dirlist> <ctl> <atm_in>");

  /* Open directory list... */
  if (!(dirlist = fopen(argv[1], "r")))
    ERRMSG("Cannot open directory list!");
```

```

  /* Loop over directories... */
  while (fscanf(dirlist, "%s", dirname) != EOF) {

    /* MPI parallelization... */
    if ((++ntask) % size != rank)
      continue;

    /* ------------------------------------------------------------
       Initialize model run...
       ------------------------------------------------------------ */

    /* Allocate... */
    SELECT_TIMER("ALLOC", NVTX_CPU);
    ALLOC(atm, atm_t, 1);
    ALLOC(cache, cache_t, 1);
    ALLOC(met0, met_t, 1);
    ALLOC(met1, met_t, 1);
    ALLOC(dt, double,
          NP);
    ALLOC(rs, double,
          3 * NP);

    /* Create data region on GPUs... */
#ifdef _OPENACC
    SELECT_TIMER("CREATE_DATA_REGION", NVTX_GPU);
#pragma acc enter data create(atm[:1],cache[:1],ctl,met0[:1],met1[:1],dt[:NP],rs[:3*NP])
#endif

    /* Read control parameters... */
    sprintf(filename, "%s/%s", dirname, argv[2]);
    read_ctl(filename, argc, argv, &ctl);

    /* Read atmospheric data... */
    sprintf(filename, "%s/%s", dirname, argv[3]);
    if (!read_atm(filename, &ctl, atm))
      ERRMSG("Cannot open file!");

    /* Set start time... */
    SELECT_TIMER("TIMESTEPS", NVTX_CPU);
    if (ctl.direction == 1) {
      ctl.t_start = gsl_stats_min(atm->time, 1, (size_t) atm->np);
      if (ctl.t_stop > 1e99)
        ctl.t_stop = gsl_stats_max(atm->time, 1, (size_t) atm->np);
    } else {
      ctl.t_start = gsl_stats_max(atm->time, 1, (size_t) atm->np);
      if (ctl.t_stop > 1e99)
        ctl.t_stop = gsl_stats_min(atm->time, 1, (size_t) atm->np);
    }

    /* Check time interval... */
    if (ctl.direction * (ctl.t_stop - ctl.t_start) <= 0)
      ERRMSG("Nothing to do! Check T_STOP and DIRECTION!");

    /* Round start time... */
    if (ctl.direction == 1)
      ctl.t_start = floor(ctl.t_start / ctl.dt_mod) * ctl.dt_mod;
    else
      ctl.t_start = ceil(ctl.t_start / ctl.dt_mod) * ctl.dt_mod;

    /* Update GPU... */
#ifdef _OPENACC
    SELECT_TIMER("UPDATE_DEVICE", NVTX_H2D);
#pragma acc update device(atm[:1],ctl)
#endif

    /* Initialize random number generator... */
    module_rng_init();

    /* Initialize meteorological data... */
    get_met(&ctl, ctl.t_start, &met0, &met1);
    if (ctl.dt_mod > fabs(met0->lon[1] - met0->lon[0]) * 111132. / 150.)
      WARN("Violation of CFL criterion! Check DT_MOD!");

    /* Initialize isosurface... */
    if (ctl.isosurf >= 1 && ctl.isosurf <= 4)
      module_isosurf_init(&ctl, met0, met1, atm, cache);

    /* Update GPU... */
#ifdef _OPENACC
    SELECT_TIMER("UPDATE_DEVICE", NVTX_H2D);
#pragma acc update device(cache[:1])
#endif

    /* ------------------------------------------------------------
       Loop over timesteps...
       ------------------------------------------------------------ */
```

```

  /* Loop over timesteps... */
  for (t = ctl.t_start; ctl.direction * (t - ctl.t_stop) < ctl.dt_mod;
       t += ctl.direction * ctl.dt_mod) {

    /* Adjust length of final time step... */
    if (ctl.direction * (t - ctl.t_stop) > 0)
      t = ctl.t_stop;

    /* Set time steps for air parcels... */
    SELECT_TIMER("TIMESTEPS", NVTX_GPU);
#ifdef _OPENACC
#pragma acc parallel loop independent gang vector present(ctl,atm,atm->time,dt)
#endif
    for (int ip = 0; ip < atm->np; ip++) {
      double atmtime = atm->time[ip];
      double tstart = ctl.t_start;
      double tstop = ctl.t_stop;
      int dir = ctl.direction;
      if ((dir * (atmtime - tstart) >= 0 && dir * (atmtime - tstop) <= 0
           && dir * (atmtime - t) < 0))
        dt[ip] = t - atmtime;
      else
        dt[ip] = 0;
    }

    /* Get meteorological data... */
    if (t != ctl.t_start)
      get_met(&ctl, t, &met0, &met1);

    /* Check initial positions... */
    module_position(met0, met1, atm, dt);

    /* Advection... */
    module_advection(met0, met1, atm, dt);

    /* Turbulent diffusion... */
    if (ctl.turb_dx_trop > 0 || ctl.turb_dz_trop > 0
        || ctl.turb_dx_strat > 0 || ctl.turb_dz_strat > 0) {
      module_rng(rs, 3 * (size_t) atm->np, 1);
      module_diffusion_turb(&ctl, atm, dt, rs);
    }

    /* Mesoscale diffusion... */
    if (ctl.turb_mesox > 0 || ctl.turb_mesoz > 0) {
      module_rng(rs, 3 * (size_t) atm->np, 1);
      module_diffusion_meso(&ctl, met0, met1, atm, cache, dt, rs);
    }

    /* Convection... */
    if (ctl.conv_cape >= 0) {
      module_rng(rs, (size_t) atm->np, 0);
      module_convection(&ctl, met0, met1, atm, dt, rs);
    }

    /* Sedimentation... */
    if (ctl.qnt_r >= 0 && ctl.qnt_rho >= 0)
      module_sedi(&ctl, met0, met1, atm, dt);

    /* Isosurface... */
    if (ctl.isosurf >= 1 && ctl.isosurf <= 4)
      module_isosurf(&ctl, met0, met1, atm, cache);

    /* Check final positions... */
    module_position(met0, met1, atm, dt);

    /* Interpolate meteorological data... */
    if (ctl.met_dt_out > 0
        && (ctl.met_dt_out < ctl.dt_mod || fmod(t, ctl.met_dt_out) == 0))
      module_meteo(&ctl, met0, met1, atm);

    /* Decay of particle mass... */
    if (ctl.tdec_trop > 0 && ctl.tdec_strat > 0)
      module_decay(&ctl, atm, dt);

    /* OH chemistry... */
    if (ctl.oh_chem[0] > 0 && ctl.oh_chem[2] > 0)
      module_oh_chem(&ctl, met0, met1, atm, dt);

    /* Dry deposition... */
    if (ctl.dry_depo[0] > 0)
      module_dry_deposition(&ctl, met0, met1, atm, dt);

    /* Wet deposition... */
    if ((ctl.wet_depo[0] > 0 || ctl.wet_depo[2] > 0)
        && (ctl.wet_depo[4] > 0 || ctl.wet_depo[6] > 0))
      module_wet_deposition(&ctl, met0, met1, atm, dt);
```

```
      /* Write output... */
      write_output(dirname, &ctl, met0, met1, atm, t);
    }

    /* ------------------------------------------------------------
       Finalize model run...
       ------------------------------------------------------------ */

    /* Report problem size... */
    printf("SIZE_NP = %d\n", atm->np);
    printf("SIZE_MPI_TASKS = %d\n", size);
    printf("SIZE_OMP_THREADS = %d\n", omp_get_max_threads());
    printf("SIZE_ACC_DEVICES = %d\n", num_devices);

    /* Report memory usage... */
    printf("MEMORY_ATM = %g MByte\n", sizeof(atm_t) / 1024. / 1024.);
    printf("MEMORY_CACHE = %g MByte\n", sizeof(cache_t) / 1024. / 1024.);
    printf("MEMORY_METEO = %g MByte\n", 2 * sizeof(met_t) / 1024. / 1024.);
    printf("MEMORY_DYNAMIC = %g MByte\n", (sizeof(met_t)
                                          + 4 * NP * sizeof(double)
                                          + EX * EY * EP * sizeof(float)) /
           1024. / 1024.);
    printf("MEMORY_STATIC = %g MByte\n", (EX * EY * sizeof(double)
                                         + EX * EY * EP * sizeof(float)
                                         + 4 * GX * GY * GZ * sizeof(double)
                                         + 2 * GX * GY * GZ * sizeof(int)
                                         + 2 * GX * GY * sizeof(double)
                                         + GX * GY * sizeof(int)) / 1024. /
           1024.);

    /* Delete data region on GPUs... */
#ifdef _OPENACC
    SELECT_TIMER("DELETE_DATA_REGION", NVTX_GPU);
#pragma acc exit data delete(ctl,atm,cache,met0,met1,dt,rs)
#endif

    /* Free... */
    SELECT_TIMER("FREE", NVTX_CPU);
    free(atm);
    free(cache);
    free(met0);
    free(met1);
    free(dt);
    free(rs);

    /* Report timers... */
    PRINT_TIMERS;
  }

  /* Finalize MPI... */
#ifdef MPI
  MPI_Finalize();
#endif

  /* Stop timers... */
  STOP_TIMERS;

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.37.3 Variable Documentation

5.37.3.1 rng `static gsl_rng * rng`

Definition at line 32 of file trac.c.

5.38 trac.c

```
/*
  This file is part of MPTRAC.

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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

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*/

#include "libtrac.h"

/* ------------------------------------------------------------
   Global variables...
   ------------------------------------------------------------ */

#ifdef _OPENACC
curandGenerator_t rng;
#else
static gsl_rng *rng[NTHREADS];
#endif

/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

void module_advection(
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt);

void module_convection(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt,
  double *rs);

void module_decay(
  ctl_t * ctl,
  atm_t * atm,
  double *dt);

void module_diffusion_meso(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  cache_t * cache,
  double *dt,
  double *rs);

void module_diffusion_turb(
  ctl_t * ctl,
  atm_t * atm,
  double *dt,
  double *rs);

void module_dry_deposition(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt);

void module_isosurf_init(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  cache_t * cache);

void module_isosurf(
  ctl_t * ctl,
```

```
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  cache_t * cache);

void module_meteo(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm);

void module_position(
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt);

void module_rng_init(
  void);

void module_rng(
  double *rs,
  size_t n,
  int method);

void module_sedi(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt);

void module_oh_chem(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt);

void module_wet_deposition(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt);

void write_output(
  const char *dirname,
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double t);

/* ------------------------------------------------------------
   Main...
   ------------------------------------------------------------ */

int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  atm_t *atm;

  cache_t *cache;

  met_t *met0, *met1;

  FILE *dirlist;

  char dirname[LEN], filename[2 * LEN];

  double *dt, *rs, t;

  int num_devices = 0, ntask = -1, rank = 0, size = 1;

  /* Start timers... */
  START_TIMERS;

  /* Initialize MPI... */
#ifdef MPI
  SELECT_TIMER("MPI_INIT", NVTX_CPU);
  MPI_Init(&argc, &argv);
  MPI_Comm_rank(MPI_COMM_WORLD, &rank);
  MPI_Comm_size(MPI_COMM_WORLD, &size);
```

```
#endif

  /* Initialize GPUs... */
#ifdef _OPENACC
  SELECT_TIMER("ACC_INIT", NVTX_GPU);
  acc_device_t device_type = acc_get_device_type();
  num_devices = acc_get_num_devices(acc_device_nvidia);
  int device_num = rank % num_devices;
  acc_set_device_num(device_num, acc_device_nvidia);
  acc_init(device_type);
#endif

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <dirlist> <ctl> <atm_in>");

  /* Open directory list... */
  if (!(dirlist = fopen(argv[1], "r")))
    ERRMSG("Cannot open directory list!");

  /* Loop over directories... */
  while (fscanf(dirlist, "%s", dirname) != EOF) {

    /* MPI parallelization... */
    if ((++ntask) % size != rank)
      continue;

    /* ------------------------------------------------------------
       Initialize model run...
       ------------------------------------------------------------ */

    /* Allocate... */
    SELECT_TIMER("ALLOC", NVTX_CPU);
    ALLOC(atm, atm_t, 1);
    ALLOC(cache, cache_t, 1);
    ALLOC(met0, met_t, 1);
    ALLOC(met1, met_t, 1);
    ALLOC(dt, double,
          NP);
    ALLOC(rs, double,
          3 * NP);

    /* Create data region on GPUs... */
#ifdef _OPENACC
    SELECT_TIMER("CREATE_DATA_REGION", NVTX_GPU);
#pragma acc enter data create(atm[:1],cache[:1],ctl,met0[:1],met1[:1],dt[:NP],rs[:3*NP])
#endif

    /* Read control parameters... */
    sprintf(filename, "%s/%s", dirname, argv[2]);
    read_ctl(filename, argc, argv, &ctl);

    /* Read atmospheric data... */
    sprintf(filename, "%s/%s", dirname, argv[3]);
    if (!read_atm(filename, &ctl, atm))
      ERRMSG("Cannot open file!");

    /* Set start time... */
    SELECT_TIMER("TIMESTEPS", NVTX_CPU);
    if (ctl.direction == 1) {
      ctl.t_start = gsl_stats_min(atm->time, 1, (size_t) atm->np);
      if (ctl.t_stop > 1e99)
        ctl.t_stop = gsl_stats_max(atm->time, 1, (size_t) atm->np);
    } else {
      ctl.t_start = gsl_stats_max(atm->time, 1, (size_t) atm->np);
      if (ctl.t_stop > 1e99)
        ctl.t_stop = gsl_stats_min(atm->time, 1, (size_t) atm->np);
    }

    /* Check time interval... */
    if (ctl.direction * (ctl.t_stop - ctl.t_start) <= 0)
      ERRMSG("Nothing to do! Check T_STOP and DIRECTION!");

    /* Round start time... */
    if (ctl.direction == 1)
      ctl.t_start = floor(ctl.t_start / ctl.dt_mod) * ctl.dt_mod;
    else
      ctl.t_start = ceil(ctl.t_start / ctl.dt_mod) * ctl.dt_mod;

    /* Update GPU... */
#ifdef _OPENACC
    SELECT_TIMER("UPDATE_DEVICE", NVTX_H2D);
#pragma acc update device(atm[:1],ctl)
#endif

    /* Initialize random number generator... */
    module_rng_init();
```

```

    /* Initialize meteorological data... */
    get_met(&ctl, ctl.t_start, &met0, &met1);
    if (ctl.dt_mod > fabs(met0->lon[1] - met0->lon[0]) * 111132. / 150.)
      WARN("Violation of CFL criterion! Check DT_MOD!");

    /* Initialize isosurface... */
    if (ctl.isosurf >= 1 && ctl.isosurf <= 4)
      module_isosurf_init(&ctl, met0, met1, atm, cache);

    /* Update GPU... */
#ifdef _OPENACC
    SELECT_TIMER("UPDATE_DEVICE", NVTX_H2D);
#pragma acc update device(cache[:1])
#endif

    /* ------------------------------------------------------------
       Loop over timesteps...
       ------------------------------------------------------------ */

    /* Loop over timesteps... */
    for (t = ctl.t_start; ctl.direction * (t - ctl.t_stop) < ctl.dt_mod;
         t += ctl.direction * ctl.dt_mod) {

      /* Adjust length of final time step... */
      if (ctl.direction * (t - ctl.t_stop) > 0)
        t = ctl.t_stop;

      /* Set time steps for air parcels... */
      SELECT_TIMER("TIMESTEPS", NVTX_GPU);
#ifdef _OPENACC
#pragma acc parallel loop independent gang vector present(ctl,atm,atm->time,dt)
#endif
      for (int ip = 0; ip < atm->np; ip++) {
        double atmtime = atm->time[ip];
        double tstart = ctl.t_start;
        double tstop = ctl.t_stop;
        int dir = ctl.direction;
        if ((dir * (atmtime - tstart) >= 0 && dir * (atmtime - tstop) <= 0
             && dir * (atmtime - t) < 0))
          dt[ip] = t - atmtime;
        else
          dt[ip] = 0;
      }

      /* Get meteorological data... */
      if (t != ctl.t_start)
        get_met(&ctl, t, &met0, &met1);

      /* Check initial positions... */
      module_position(met0, met1, atm, dt);

      /* Advection... */
      module_advection(met0, met1, atm, dt);

      /* Turbulent diffusion... */
      if (ctl.turb_dx_trop > 0 || ctl.turb_dz_trop > 0
          || ctl.turb_dx_strat > 0 || ctl.turb_dz_strat > 0) {
        module_rng(rs, 3 * (size_t) atm->np, 1);
        module_diffusion_turb(&ctl, atm, dt, rs);
      }

      /* Mesoscale diffusion... */
      if (ctl.turb_mesox > 0 || ctl.turb_mesoz > 0) {
        module_rng(rs, 3 * (size_t) atm->np, 1);
        module_diffusion_meso(&ctl, met0, met1, atm, cache, dt, rs);
      }

      /* Convection... */
      if (ctl.conv_cape >= 0) {
        module_rng(rs, (size_t) atm->np, 0);
        module_convection(&ctl, met0, met1, atm, dt, rs);
      }

      /* Sedimentation... */
      if (ctl.qnt_r >= 0 && ctl.qnt_rho >= 0)
        module_sedi(&ctl, met0, met1, atm, dt);

      /* Isosurface... */
      if (ctl.isosurf >= 1 && ctl.isosurf <= 4)
        module_isosurf(&ctl, met0, met1, atm, cache);

      /* Check final positions... */
      module_position(met0, met1, atm, dt);

      /* Interpolate meteorological data... */
      if (ctl.met_dt_out > 0
```

```
          && (ctl.met_dt_out < ctl.dt_mod || fmod(t, ctl.met_dt_out) == 0))
        module_meteo(&ctl, met0, met1, atm);

      /* Decay of particle mass... */
      if (ctl.tdec_trop > 0 && ctl.tdec_strat > 0)
        module_decay(&ctl, atm, dt);

      /* OH chemistry... */
      if (ctl.oh_chem[0] > 0 && ctl.oh_chem[2] > 0)
        module_oh_chem(&ctl, met0, met1, atm, dt);

      /* Dry deposition... */
      if (ctl.dry_depo[0] > 0)
        module_dry_deposition(&ctl, met0, met1, atm, dt);

      /* Wet deposition... */
      if ((ctl.wet_depo[0] > 0 || ctl.wet_depo[2] > 0)
          && (ctl.wet_depo[4] > 0 || ctl.wet_depo[6] > 0))
        module_wet_deposition(&ctl, met0, met1, atm, dt);

      /* Write output... */
      write_output(dirname, &ctl, met0, met1, atm, t);
    }

    /* ------------------------------------------------------------
       Finalize model run...
       ------------------------------------------------------------ */

    /* Report problem size... */
    printf("SIZE_NP = %d\n", atm->np);
    printf("SIZE_MPI_TASKS = %d\n", size);
    printf("SIZE_OMP_THREADS = %d\n", omp_get_max_threads());
    printf("SIZE_ACC_DEVICES = %d\n", num_devices);

    /* Report memory usage... */
    printf("MEMORY_ATM = %g MByte\n", sizeof(atm_t) / 1024. / 1024.);
    printf("MEMORY_CACHE = %g MByte\n", sizeof(cache_t) / 1024. / 1024.);
    printf("MEMORY_METEO = %g MByte\n", 2 * sizeof(met_t) / 1024. / 1024.);
    printf("MEMORY_DYNAMIC = %g MByte\n", (sizeof(met_t)
                                           + 4 * NP * sizeof(double)
                                           + EX * EY * EP * sizeof(float)) /
           1024. / 1024.);
    printf("MEMORY_STATIC = %g MByte\n", (EX * EY * sizeof(double)
                                          + EX * EY * EP * sizeof(float)
                                          + 4 * GX * GY * GZ * sizeof(double)
                                          + 2 * GX * GY * GZ * sizeof(int)
                                          + 2 * GX * GY * sizeof(double)
                                          + GX * GY * sizeof(int)) / 1024. /
           1024.);

    /* Delete data region on GPUs... */
#ifdef _OPENACC
    SELECT_TIMER("DELETE_DATA_REGION", NVTX_GPU);
#pragma acc exit data delete(ctl,atm,cache,met0,met1,dt,rs)
#endif

    /* Free... */
    SELECT_TIMER("FREE", NVTX_CPU);
    free(atm);
    free(cache);
    free(met0);
    free(met1);
    free(dt);
    free(rs);

    /* Report timers... */
    PRINT_TIMERS;
  }

  /* Finalize MPI... */
#ifdef MPI
  MPI_Finalize();
#endif

  /* Stop timers... */
  STOP_TIMERS;

  return EXIT_SUCCESS;
}

/*****************************************************************************/

void module_advection(
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt) {
```

```
  /* Set timer... */
  SELECT_TIMER("MODULE_ADVECTION", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double u, v, w;

      /* Interpolate meteorological data... */
      INTPOL_INIT;
      INTPOL_3D(u, 1);
      INTPOL_3D(v, 0);
      INTPOL_3D(w, 0);

      /* Get position of the mid point... */
      double dtm = atm->time[ip] + 0.5 * dt[ip];
      double xm0 =
        atm->lon[ip] + DX2DEG(0.5 * dt[ip] * u / 1000., atm->lat[ip]);
      double xm1 = atm->lat[ip] + DY2DEG(0.5 * dt[ip] * v / 1000.);
      double xm2 = atm->p[ip] + 0.5 * dt[ip] * w;

      /* Interpolate meteorological data for mid point... */
      intpol_met_time_3d(met0, met0->u, met1, met1->u,
                         dtm, xm2, xm0, xm1, &u, ci, cw, 1);
      intpol_met_time_3d(met0, met0->v, met1, met1->v,
                         dtm, xm2, xm0, xm1, &v, ci, cw, 0);
      intpol_met_time_3d(met0, met0->w, met1, met1->w,
                         dtm, xm2, xm0, xm1, &w, ci, cw, 0);

      /* Save new position... */
      atm->time[ip] += dt[ip];
      atm->lon[ip] += DX2DEG(dt[ip] * u / 1000., xm1);
      atm->lat[ip] += DY2DEG(dt[ip] * v / 1000.);
      atm->p[ip] += dt[ip] * w;
    }
}

/*****************************************************************************/

void module_convection(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt,
  double *rs) {

  /* Set timer... */
  SELECT_TIMER("MODULE_CONVECTION", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt,rs)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double cape, pel, ps;

      /* Interpolate CAPE... */
      INTPOL_INIT;
      INTPOL_2D(cape, 1);

      /* Check threshold... */
      if (isfinite(cape) && cape >= ctl->conv_cape) {

        /* Interpolate equilibrium level... */
        INTPOL_2D(pel, 0);

        /* Check whether particle is above cloud top... */
        if (!isfinite(pel) || atm->p[ip] < pel)
          continue;

        /* Interpolate surface pressure... */
        INTPOL_2D(ps, 0);

        /* Redistribute particle in cloud column... */
        atm->p[ip] = ps + (pel - ps) * rs[ip];
```

```
    }
  }
}

/*****************************************************************************/

void module_decay(
  ctl_t * ctl,
  atm_t * atm,
  double *dt) {

  /* Set timer... */
  SELECT_TIMER("MODULE_DECAY", NVTX_GPU);

  /* Check quantity flags... */
  if (ctl->qnt_m < 0)
    ERRMSG("Module needs quantity mass!");

#ifdef _OPENACC
#pragma acc data present(ctl,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Get tropopause pressure... */
      double pt = clim_tropo(atm->time[ip], atm->lat[ip]);

      /* Get weighting factor... */
      double w;
      double p1 = pt * 0.866877899;
      double p0 = pt / 0.866877899;
      if (atm->p[ip] > p0)
        w = 1;
      else if (atm->p[ip] < p1)
        w = 0;
      else
        w = LIN(p0, 1.0, p1, 0.0, atm->p[ip]);

      /* Set lifetime... */
      double tdec = w * ctl->tdec_trop + (1 - w) * ctl->tdec_strat;

      /* Calculate exponential decay... */
      atm->q[ctl->qnt_m][ip] *= exp(-dt[ip] / tdec);
    }
}

/*****************************************************************************/

void module_diffusion_meso(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  cache_t * cache,
  double *dt,
  double *rs) {

  /* Set timer... */
  SELECT_TIMER("MODULE_TURBMESO", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,cache,dt,rs)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double u[16], v[16], w[16];

      /* Get indices... */
      int ix = locate_reg(met0->lon, met0->nx, atm->lon[ip]);
      int iy = locate_reg(met0->lat, met0->ny, atm->lat[ip]);
      int iz = locate_irr(met0->p, met0->np, atm->p[ip]);

      /* Caching of wind standard deviations... */
      if (cache->tsig[ix][iy][iz] != met0->time) {

        /* Collect local wind data... */
        u[0] = met0->u[ix][iy][iz];
        u[1] = met0->u[ix + 1][iy][iz];
        u[2] = met0->u[ix][iy + 1][iz];
        u[3] = met0->u[ix + 1][iy + 1][iz];
```

```
      u[4] = met0->u[ix][iy][iz + 1];
      u[5] = met0->u[ix + 1][iy][iz + 1];
      u[6] = met0->u[ix][iy + 1][iz + 1];
      u[7] = met0->u[ix + 1][iy + 1][iz + 1];

      v[0] = met0->v[ix][iy][iz];
      v[1] = met0->v[ix + 1][iy][iz];
      v[2] = met0->v[ix][iy + 1][iz];
      v[3] = met0->v[ix + 1][iy + 1][iz];
      v[4] = met0->v[ix][iy][iz + 1];
      v[5] = met0->v[ix + 1][iy][iz + 1];
      v[6] = met0->v[ix][iy + 1][iz + 1];
      v[7] = met0->v[ix + 1][iy + 1][iz + 1];

      w[0] = met0->w[ix][iy][iz];
      w[1] = met0->w[ix + 1][iy][iz];
      w[2] = met0->w[ix][iy + 1][iz];
      w[3] = met0->w[ix + 1][iy + 1][iz];
      w[4] = met0->w[ix][iy][iz + 1];
      w[5] = met0->w[ix + 1][iy][iz + 1];
      w[6] = met0->w[ix][iy + 1][iz + 1];
      w[7] = met0->w[ix + 1][iy + 1][iz + 1];

      /* Collect local wind data... */
      u[8] = met1->u[ix][iy][iz];
      u[9] = met1->u[ix + 1][iy][iz];
      u[10] = met1->u[ix][iy + 1][iz];
      u[11] = met1->u[ix + 1][iy + 1][iz];
      u[12] = met1->u[ix][iy][iz + 1];
      u[13] = met1->u[ix + 1][iy][iz + 1];
      u[14] = met1->u[ix][iy + 1][iz + 1];
      u[15] = met1->u[ix + 1][iy + 1][iz + 1];

      v[8] = met1->v[ix][iy][iz];
      v[9] = met1->v[ix + 1][iy][iz];
      v[10] = met1->v[ix][iy + 1][iz];
      v[11] = met1->v[ix + 1][iy + 1][iz];
      v[12] = met1->v[ix][iy][iz + 1];
      v[13] = met1->v[ix + 1][iy][iz + 1];
      v[14] = met1->v[ix][iy + 1][iz + 1];
      v[15] = met1->v[ix + 1][iy + 1][iz + 1];

      w[8] = met1->w[ix][iy][iz];
      w[9] = met1->w[ix + 1][iy][iz];
      w[10] = met1->w[ix][iy + 1][iz];
      w[11] = met1->w[ix + 1][iy + 1][iz];
      w[12] = met1->w[ix][iy][iz + 1];
      w[13] = met1->w[ix + 1][iy][iz + 1];
      w[14] = met1->w[ix][iy + 1][iz + 1];
      w[15] = met1->w[ix + 1][iy + 1][iz + 1];

      /* Get standard deviations of local wind data... */
      cache->usig[ix][iy][iz] = (float) stddev(u, 16);
      cache->vsig[ix][iy][iz] = (float) stddev(v, 16);
      cache->wsig[ix][iy][iz] = (float) stddev(w, 16);
      cache->tsig[ix][iy][iz] = met0->time;
    }

    /* Set temporal correlations for mesoscale fluctuations... */
    double r = 1 - 2 * fabs(dt[ip]) / ctl->dt_met;
    double r2 = sqrt(1 - r * r);

    /* Calculate horizontal mesoscale wind fluctuations... */
    if (ctl->turb_mesox > 0) {
      cache->up[ip] = (float)
        (r * cache->up[ip]
         + r2 * rs[3 * ip] * ctl->turb_mesox * cache->usig[ix][iy][iz]);
      atm->lon[ip] += DX2DEG(cache->up[ip] * dt[ip] / 1000., atm->lat[ip]);

      cache->vp[ip] = (float)
        (r * cache->vp[ip]
         + r2 * rs[3 * ip + 1] * ctl->turb_mesox * cache->vsig[ix][iy][iz]);
      atm->lat[ip] += DY2DEG(cache->vp[ip] * dt[ip] / 1000.);
    }

    /* Calculate vertical mesoscale wind fluctuations... */
    if (ctl->turb_mesoz > 0) {
      cache->wp[ip] = (float)
        (r * cache->wp[ip]
         + r2 * rs[3 * ip + 2] * ctl->turb_mesoz * cache->wsig[ix][iy][iz]);
      atm->p[ip] += cache->wp[ip] * dt[ip];
    }
  }
}

/*****************************************************************************/

```

```
void module_diffusion_turb(
  ctl_t * ctl,
  atm_t * atm,
  double *dt,
  double *rs) {

  /* Set timer... */
  SELECT_TIMER("MODULE_TURBDIFF", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,atm,dt,rs)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Get tropopause pressure... */
      double pt = clim_tropo(atm->time[ip], atm->lat[ip]);

      /* Get weighting factor... */
      double w;
      double p1 = pt * 0.866877899;
      double p0 = pt / 0.866877899;
      if (atm->p[ip] > p0)
        w = 1;
      else if (atm->p[ip] < p1)
        w = 0;
      else
        w = LIN(p0, 1.0, p1, 0.0, atm->p[ip]);

      /* Set diffusivity... */
      double dx = w * ctl->turb_dx_trop + (1 - w) * ctl->turb_dx_strat;
      double dz = w * ctl->turb_dz_trop + (1 - w) * ctl->turb_dz_strat;

      /* Horizontal turbulent diffusion... */
      if (dx > 0) {
        double sigma = sqrt(2.0 * dx * fabs(dt[ip]));
        atm->lon[ip] += DX2DEG(rs[3 * ip] * sigma / 1000., atm->lat[ip]);
        atm->lat[ip] += DY2DEG(rs[3 * ip + 1] * sigma / 1000.);
      }

      /* Vertical turbulent diffusion... */
      if (dz > 0) {
        double sigma = sqrt(2.0 * dz * fabs(dt[ip]));
        atm->p[ip]
          += DZ2DP(rs[3 * ip + 2] * sigma / 1000., atm->p[ip]);
      }
    }
}

/*****************************************************************************/

void module_dry_deposition(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt) {

  /* Set timer... */
  SELECT_TIMER("MODULE_DRYDEPO", NVTX_GPU);

  /* Width of the surface layer [hPa]. */
  const double dp = 30.;

  /* Check quantity flags... */
  if (ctl->qnt_m < 0)
    ERRMSG("Module needs quantity mass!");

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double ps, t, v_dep;

      /* Get surface pressure... */
      INTPOL_INIT;
      INTPOL_2D(ps, 1);

      /* Check whether particle is above the surface layer... */
```

```
      if (atm->p[ip] < ps - dp)
        continue;

      /* Set width of surface layer... */
      double dz = 1000. * (Z(ps - dp) - Z(ps));

      /* Calculate sedimentation velocity for particles... */
      if (ctl->qnt_r >= 0 && ctl->qnt_rho >= 0) {

        /* Get temperature... */
        INTPOL_3D(t, 1);

        /* Set deposition velocity... */
        v_dep = sedi(atm->p[ip], t, atm->q[ctl->qnt_r][ip],
                     atm->q[ctl->qnt_rho][ip]);
      }

      /* Use explicit sedimentation velocity for gases... */
      else
        v_dep = ctl->dry_depo[0];

      /* Calculate loss of mass based on deposition velocity... */
      atm->q[ctl->qnt_m][ip] *= exp(-dt[ip] * v_dep / dz);
    }
}

/*****************************************************************************/

void module_isosurf_init(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  cache_t * cache) {

  FILE *in;

  char line[LEN];

  double t;

  /* Set timer... */
  SELECT_TIMER("MODULE_ISOSURF", NVTX_GPU);

  /* Init... */
  INTPOL_INIT;

  /* Save pressure... */
  if (ctl->isosurf == 1)
    for (int ip = 0; ip < atm->np; ip++)
      cache->iso_var[ip] = atm->p[ip];

  /* Save density... */
  else if (ctl->isosurf == 2)
    for (int ip = 0; ip < atm->np; ip++) {
      INTPOL_3D(t, 1);
      cache->iso_var[ip] = atm->p[ip] / t;
    }

  /* Save potential temperature... */
  else if (ctl->isosurf == 3)
    for (int ip = 0; ip < atm->np; ip++) {
      INTPOL_3D(t, 1);
      cache->iso_var[ip] = THETA(atm->p[ip], t);
    }

  /* Read balloon pressure data... */
  else if (ctl->isosurf == 4) {

    /* Write info... */
    printf("Read balloon pressure data: %s\n", ctl->balloon);

    /* Open file... */
    if (!(in = fopen(ctl->balloon, "r")))
      ERRMSG("Cannot open file!");

    /* Read pressure time series... */
    while (fgets(line, LEN, in))
      if (sscanf(line, "%lg %lg", &(cache->iso_ts[cache->iso_n]),
                 &(cache->iso_ps[cache->iso_n])) == 2)
        if ((++cache->iso_n) > NP)
          ERRMSG("Too many data points!");

    /* Check number of points... */
    if (cache->iso_n < 1)
      ERRMSG("Could not read any data!");

```

```
    /* Close file... */
    fclose(in);
  }
}

/*****************************************************************************/

void module_isosurf(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  cache_t * cache) {

  /* Set timer... */
  SELECT_TIMER("MODULE_ISOSURF", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,cache)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++) {

    double t;

    /* Init... */
    INTPOL_INIT;

    /* Restore pressure... */
    if (ctl->isosurf == 1)
      atm->p[ip] = cache->iso_var[ip];

    /* Restore density... */
    else if (ctl->isosurf == 2) {
      INTPOL_3D(t, 1);
      atm->p[ip] = cache->iso_var[ip] * t;
    }

    /* Restore potential temperature... */
    else if (ctl->isosurf == 3) {
      INTPOL_3D(t, 1);
      atm->p[ip] = 1000. * pow(cache->iso_var[ip] / t, -1. / 0.286);
    }

    /* Interpolate pressure... */
    else if (ctl->isosurf == 4) {
      if (atm->time[ip] <= cache->iso_ts[0])
        atm->p[ip] = cache->iso_ps[0];
      else if (atm->time[ip] >= cache->iso_ts[cache->iso_n - 1])
        atm->p[ip] = cache->iso_ps[cache->iso_n - 1];
      else {
        int idx = locate_irr(cache->iso_ts, cache->iso_n, atm->time[ip]);
        atm->p[ip] = LIN(cache->iso_ts[idx], cache->iso_ps[idx],
                         cache->iso_ts[idx + 1], cache->iso_ps[idx + 1],
                         atm->time[ip]);
      }
    }
  }
}

/*****************************************************************************/

void module_meteo(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm) {

  /* Set timer... */
  SELECT_TIMER("MODULE_METEO", NVTX_GPU);

  /* Check quantity flags... */
  if (ctl->qnt_tsts >= 0)
    if (ctl->qnt_tice < 0 || ctl->qnt_tnat < 0)
      ERRMSG("Need T_ice and T_NAT to calculate T_STS!");

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++) {

    double ps, ts, zs, us, vs, pt, pc, cl, plcl, plfc, pel, cape, pv, t, tt,
```

```
      u, v, w, h2o, h2ot, o3, lwc, iwc, z, zt;

    /* Interpolate meteorological data... */
    INTPOL_INIT;
    INTPOL_TIME_ALL(atm->time[ip], atm->p[ip], atm->lon[ip], atm->lat[ip]);

    /* Set quantities... */
    ATM_SET(qnt_ps, ps);
    ATM_SET(qnt_ts, ts);
    ATM_SET(qnt_zs, zs);
    ATM_SET(qnt_us, us);
    ATM_SET(qnt_vs, vs);
    ATM_SET(qnt_pt, pt);
    ATM_SET(qnt_tt, tt);
    ATM_SET(qnt_zt, zt);
    ATM_SET(qnt_h2ot, h2ot);
    ATM_SET(qnt_p, atm->p[ip]);
    ATM_SET(qnt_z, z);
    ATM_SET(qnt_t, t);
    ATM_SET(qnt_u, u);
    ATM_SET(qnt_v, v);
    ATM_SET(qnt_w, w);
    ATM_SET(qnt_h2o, h2o);
    ATM_SET(qnt_o3, o3);
    ATM_SET(qnt_lwc, lwc);
    ATM_SET(qnt_iwc, iwc);
    ATM_SET(qnt_pc, pc);
    ATM_SET(qnt_cl, cl);
    ATM_SET(qnt_plcl, plcl);
    ATM_SET(qnt_plfc, plfc);
    ATM_SET(qnt_pel, pel);
    ATM_SET(qnt_cape, cape);
    ATM_SET(qnt_hno3, clim_hno3(atm->time[ip], atm->lat[ip], atm->p[ip]));
    ATM_SET(qnt_oh, clim_oh(atm->time[ip], atm->lat[ip], atm->p[ip]));
    ATM_SET(qnt_vh, sqrt(u * u + v * v));
    ATM_SET(qnt_vz, -1e3 * H0 / atm->p[ip] * w);
    ATM_SET(qnt_psat, PSAT(t));
    ATM_SET(qnt_psice, PSICE(t));
    ATM_SET(qnt_pw, PW(atm->p[ip], h2o));
    ATM_SET(qnt_sh, SH(h2o));
    ATM_SET(qnt_rh, RH(atm->p[ip], t, h2o));
    ATM_SET(qnt_rhice, RHICE(atm->p[ip], t, h2o));
    ATM_SET(qnt_theta, THETA(atm->p[ip], t));
    ATM_SET(qnt_tvirt, TVIRT(t, h2o));
    ATM_SET(qnt_lapse, lapse_rate(t, h2o));
    ATM_SET(qnt_pv, pv);
    ATM_SET(qnt_tdew, TDEW(atm->p[ip], h2o));
    ATM_SET(qnt_tice, TICE(atm->p[ip], h2o));
    ATM_SET(qnt_tnat,
            nat_temperature(atm->p[ip], h2o,
                            clim_hno3(atm->time[ip], atm->lat[ip],
                                      atm->p[ip]) * 1e-9));
    ATM_SET(qnt_tsts,
            0.5 * (atm->q[ctl->qnt_tice][ip] + atm->q[ctl->qnt_tnat][ip]));
  }
}

/*****************************************************************************/

void module_position(
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt) {

  /* Set timer... */
  SELECT_TIMER("MODULE_POSITION", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Calculate modulo... */
      atm->lon[ip] = FMOD(atm->lon[ip], 360.);
      atm->lat[ip] = FMOD(atm->lat[ip], 360.);

      /* Check latitude... */
      while (atm->lat[ip] < -90 || atm->lat[ip] > 90) {
        if (atm->lat[ip] > 90) {
          atm->lat[ip] = 180 - atm->lat[ip];
          atm->lon[ip] += 180;
        }
```

```
        if (atm->lat[ip] < -90) {
          atm->lat[ip] = -180 - atm->lat[ip];
          atm->lon[ip] += 180;
        }
      }

      /* Check longitude... */
      while (atm->lon[ip] < -180)
        atm->lon[ip] += 360;
      while (atm->lon[ip] >= 180)
        atm->lon[ip] -= 360;

      /* Check pressure... */
      if (atm->p[ip] < met0->p[met0->np - 1])
        atm->p[ip] = met0->p[met0->np - 1];
      else if (atm->p[ip] > 300.) {
        double ps;
        INTPOL_INIT;
        INTPOL_2D(ps, 1);
        if (atm->p[ip] > ps)
          atm->p[ip] = ps;
      }
    }
}

/*****************************************************************************/

void module_rng_init(
  void) {

  /* Set timer... */
  SELECT_TIMER("MODULE_RNG", NVTX_GPU);

  /* Initialize random number generator... */
#ifdef _OPENACC

  if (curandCreateGenerator(&rng, CURAND_RNG_PSEUDO_DEFAULT)
      != CURAND_STATUS_SUCCESS)
    ERRMSG("Cannot create random number generator!");
  if (curandSetStream(rng, (cudaStream_t) acc_get_cuda_stream(acc_async_sync))
      != CURAND_STATUS_SUCCESS)
    ERRMSG("Cannot set stream for random number generator!");

#else

  gsl_rng_env_setup();
  if (omp_get_max_threads() > NTHREADS)
    ERRMSG("Too many threads!");
  for (int i = 0; i < NTHREADS; i++) {
    rng[i] = gsl_rng_alloc(gsl_rng_default);
    gsl_rng_set(rng[i], gsl_rng_default_seed + (long unsigned) i);
  }

#endif
}

/*****************************************************************************/

void module_rng(
  double *rs,
  size_t n,
  int method) {

  /* Set timer... */
  SELECT_TIMER("MODULE_RNG", NVTX_GPU);

#ifdef _OPENACC

#pragma acc host_data use_device(rs)
  {
    /* Uniform distribution... */
    if (method == 0) {
      if (curandGenerateUniform(rng, rs, n)
          != CURAND_STATUS_SUCCESS)
        ERRMSG("Cannot create random numbers!");
    }

    /* Normal distribution... */
    else if (method == 1) {
      if (curandGenerateNormalDouble(rng, rs, n, 0.0, 1.0)
          != CURAND_STATUS_SUCCESS)
        ERRMSG("Cannot create random numbers!");
    }
  }

#else

```

```
  /* Uniform distribution... */
  if (method == 0) {
#pragma omp parallel for default(shared)
    for (size_t i = 0; i < n; ++i)
      rs[i] = gsl_rng_uniform(rng[omp_get_thread_num()]);
  }

  /* Normal distribution... */
  else if (method == 1) {
#pragma omp parallel for default(shared)
    for (size_t i = 0; i < n; ++i)
      rs[i] = gsl_ran_gaussian_ziggurat(rng[omp_get_thread_num()], 1.0);
  }
#endif

}

/*****************************************************************************/

void module_sedi(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt) {

  /* Set timer... */
  SELECT_TIMER("MODULE_SEDI", NVTX_GPU);

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Get temperature... */
      double t;
      INTPOL_INIT;
      INTPOL_3D(t, 1);

      /* Sedimentation velocity... */
      double v_s = sedi(atm->p[ip], t, atm->q[ctl->qnt_r][ip],
                        atm->q[ctl->qnt_rho][ip]);

      /* Calculate pressure change... */
      atm->p[ip] += DZ2DP(v_s * dt[ip] / 1000., atm->p[ip]);
    }
}

/*****************************************************************************/

void module_oh_chem(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt) {

  /* Set timer... */
  SELECT_TIMER("MODULE_OHCHEM", NVTX_GPU);

  /* Check quantity flags... */
  if (ctl->qnt_m < 0)
    ERRMSG("Module needs quantity mass!");

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      /* Get temperature... */
      double t;
      INTPOL_INIT;
      INTPOL_3D(t, 1);

      /* Calculate molecular density... */
      double M = 7.243e21 * (atm->p[ip] / P0) / t;

      /* Calculate rate coefficient for X + OH + M -> XOH + M
         (JPL Publication 15-10) ... */
```

```
      double k0 = ctl->oh_chem[0] *
        (ctl->oh_chem[1] > 0 ? pow(t / 300., -ctl->oh_chem[1]) : 1.);
      double ki = ctl->oh_chem[2] *
        (ctl->oh_chem[3] > 0 ? pow(t / 300., -ctl->oh_chem[3]) : 1.);
      double c = log10(k0 * M / ki);
      double k = k0 * M / (1. + k0 * M / ki) * pow(0.6, 1. / (1. + c * c));

      /* Calculate exponential decay... */
      atm->q[ctl->qnt_m][ip] *=
        exp(-dt[ip] * k * clim_oh(atm->time[ip], atm->lat[ip], atm->p[ip]));
    }
}

/*****************************************************************************/

void module_wet_deposition(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double *dt) {

  /* Set timer... */
  SELECT_TIMER("MODULE_WETDEPO", NVTX_GPU);

  /* Check quantity flags... */
  if (ctl->qnt_m < 0)
    ERRMSG("Module needs quantity mass!");

#ifdef _OPENACC
#pragma acc data present(ctl,met0,met1,atm,dt)
#pragma acc parallel loop independent gang vector
#else
#pragma omp parallel for default(shared)
#endif
  for (int ip = 0; ip < atm->np; ip++)
    if (dt[ip] != 0) {

      double cl, dz, h, lambda = 0, t, iwc, lwc, pc;

      int inside;

      /* Check whether particle is below cloud top... */
      INTPOL_INIT;
      INTPOL_2D(pc, 1);
      if (!isfinite(pc) || atm->p[ip] <= pc)
        continue;

      /* Estimate precipitation rate (Pisso et al., 2019)... */
      INTPOL_2D(cl, 0);
      double Is = pow(2. * cl, 1. / 0.36);
      if (Is < 0.01)
        continue;

      /* Check whether particle is inside or below cloud... */
      INTPOL_3D(lwc, 1);
      INTPOL_3D(iwc, 0);
      inside = (iwc > 0 || lwc > 0);

      /* Calculate in-cloud scavenging coefficient... */
      if (inside) {

        /* Use exponential dependency for particles... */
        if (ctl->wet_depo[0] > 0)
          lambda = ctl->wet_depo[0] * pow(Is, ctl->wet_depo[1]);

        /* Use Henry's law for gases... */
        else if (ctl->wet_depo[2] > 0) {

          /* Get temperature... */
          INTPOL_3D(t, 0);

          /* Get Henry's constant (Sander, 2015)... */
          h = ctl->wet_depo[2]
            * exp(ctl->wet_depo[3] * (1. / t - 1. / 298.15));

          /* Estimate depth of cloud layer... */
          dz = 1e3 * Z(pc);

          /* Calculate scavenging coefficient (Draxler and Hess, 1997)... */
          lambda = h * RI * t * Is / 3.6e6 * dz;
        }
      }

      /* Calculate below-cloud scavenging coefficient... */
      else {

```

```
        /* Use exponential dependency for particles... */
        if (ctl->wet_depo[4] > 0)
          lambda = ctl->wet_depo[4] * pow(Is, ctl->wet_depo[5]);

        /* Use Henry's law for gases... */
        else if (ctl->wet_depo[6] > 0) {

          /* Get temperature... */
          INTPOL_3D(t, 0);

          /* Get Henry's constant (Sander, 2015)... */
          h = ctl->wet_depo[6]
            * exp(ctl->wet_depo[7] * (1. / t - 1. / 298.15));

          /* Estimate depth of cloud layer... */
          dz = 1e3 * Z(pc);

          /* Calculate scavenging coefficient (Draxler and Hess, 1997)... */
          lambda = h * RI * t * Is / 3.6e6 * dz;
        }
      }

      /* Calculate exponential decay of mass... */
      atm->q[ctl->qnt_m][ip] *= exp(-dt[ip] * lambda);
    }
}

/*****************************************************************************/

void write_output(
  const char *dirname,
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double t) {

  char filename[2 * LEN];

  double r;

  int year, mon, day, hour, min, sec, updated = 0;

  /* Get time... */
  jsec2time(t, &year, &mon, &day, &hour, &min, &sec, &r);

  /* Write atmospheric data... */
  if (ctl->atm_basename[0] != '-' && fmod(t, ctl->atm_dt_out) == 0) {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s_%04d_%02d_%02d_%02d_%02d.tab",
            dirname, ctl->atm_basename, year, mon, day, hour, min);
    write_atm(filename, ctl, atm, t);
  }

  /* Write gridded data... */
  if (ctl->grid_basename[0] != '-' && fmod(t, ctl->grid_dt_out) == 0) {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s_%04d_%02d_%02d_%02d_%02d.tab",
            dirname, ctl->grid_basename, year, mon, day, hour, min);
    write_grid(filename, ctl, met0, met1, atm, t);
  }

  /* Write CSI data... */
  if (ctl->csi_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->csi_basename);
    write_csi(filename, ctl, atm, t);
  }

```

```
  /* Write ensemble data... */
  if (ctl->ens_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->ens_basename);
    write_ens(filename, ctl, atm, t);
  }

  /* Write profile data... */
  if (ctl->prof_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->prof_basename);
    write_prof(filename, ctl, met0, met1, atm, t);
  }

  /* Write sample data... */
  if (ctl->sample_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->sample_basename);
    write_sample(filename, ctl, met0, met1, atm, t);
  }

  /* Write station data... */
  if (ctl->stat_basename[0] != '-') {
    if (!updated) {
#ifdef _OPENACC
      SELECT_TIMER("UPDATE_HOST", NVTX_D2H);
#pragma acc update host(atm[:1])
#endif
      updated = 1;
    }
    sprintf(filename, "%s/%s.tab", dirname, ctl->stat_basename);
    write_station(filename, ctl, atm, t);
  }
}
```

5.39 tropo.c File Reference

Functions

- void add_text_attribute (int ncid, char ∗varname, char ∗attrname, char ∗text)
- int main (int argc, char ∗argv[ ])

5.39.1 Detailed Description

Create tropopause data set from meteorological data.

Definition in file tropo.c.

5.39.2 Function Documentation

5.39.2.1 add_text_attribute()

```
void add_text_attribute (
    int ncid,
    char * varname,
    char * attrname,
    char * text )
```

Definition at line 337 of file tropo.c.

```
                  {

  int varid;

  NC(nc_inq_varid(ncid, varname, &varid));
  NC(nc_put_att_text(ncid, varid, attrname, strlen(text), text));
}
```

5.39.2.2 main()

```
int main (
    int argc,
    char * argv[] )
```

Definition at line 41 of file tropo.c.

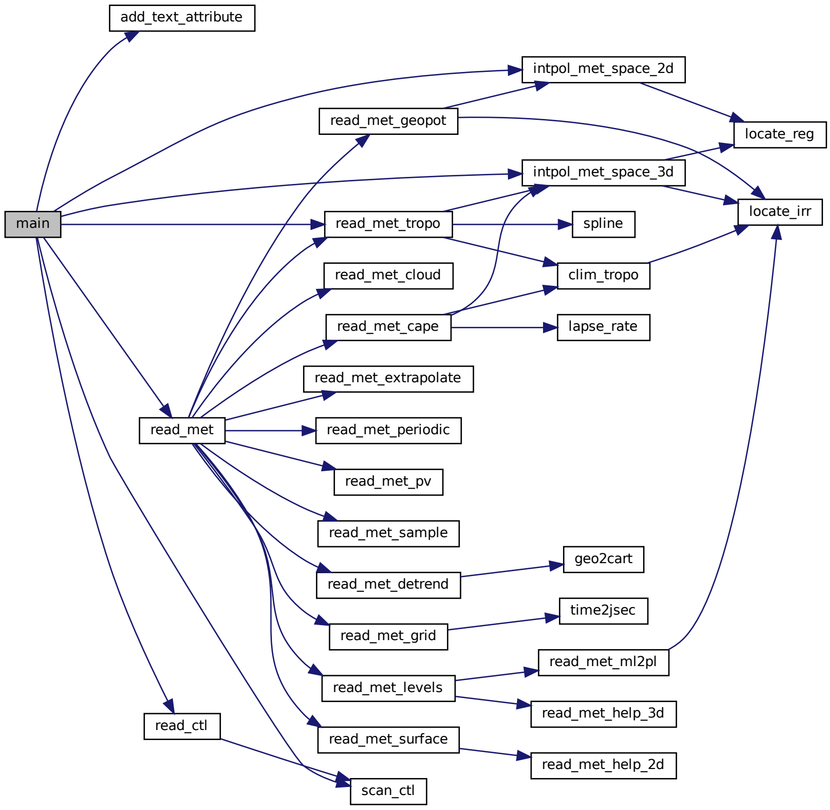
```
                    {

  ctl_t ctl;

  met_t *met;

  static double pt[EX * EY], qt[EX * EY], zt[EX * EY], tt[EX * EY], lon, lon0,
    lon1, lons[EX], dlon, lat, lat0, lat1, lats[EY], dlat, cw[3];

  static int init, i, ix, iy, nx, ny, nt, ncid, dims[3], timid, lonid, latid,
    clppid, clpqid, clptid, clpzid, dynpid, dynqid, dyntid, dynzid, wmo1pid,
    wmo1qid, wmo1tid, wmo1zid, wmo2pid, wmo2qid, wmo2tid, wmo2zid, h2o, ci[3];

  static size_t count[10], start[10];

  /* Allocate... */
  ALLOC(met, met_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <tropo.nc> <met0> [ <met1> ... ]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  lon0 = scan_ctl(argv[1], argc, argv, "TROPO_LON0", -1, "-180", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "TROPO_LON1", -1, "180", NULL);
  dlon = scan_ctl(argv[1], argc, argv, "TROPO_DLON", -1, "-999", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "TROPO_LAT0", -1, "-90", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "TROPO_LAT1", -1, "90", NULL);
  dlat = scan_ctl(argv[1], argc, argv, "TROPO_DLAT", -1, "-999", NULL);
  h2o = (int) scan_ctl(argv[1], argc, argv, "TROPO_H2O", -1, "1", NULL);

  /* Loop over files... */
  for (i = 3; i < argc; i++) {

    /* Read meteorological data... */
    ctl.met_tropo = 0;
    if (!read_met(&ctl, argv[i], met))
      continue;

    /* Set horizontal grid... */
    if (!init) {
      init = 1;

      /* Get grid... */
      if (dlon <= 0)
        dlon = fabs(met->lon[1] - met->lon[0]);
      if (dlat <= 0)
        dlat = fabs(met->lat[1] - met->lat[0]);
      if (lon0 < -360 && lon1 > 360) {
        lon0 = gsl_stats_min(met->lon, 1, (size_t) met->nx);
        lon1 = gsl_stats_max(met->lon, 1, (size_t) met->nx);
      }
      nx = ny = 0;
      for (lon = lon0; lon <= lon1; lon += dlon) {
        lons[nx] = lon;
```

```
    if ((++nx) > EX)
      ERRMSG("Too many longitudes!");
  }
  if (lat0 < -90 && lat1 > 90) {
    lat0 = gsl_stats_min(met->lat, 1, (size_t) met->ny);
    lat1 = gsl_stats_max(met->lat, 1, (size_t) met->ny);
  }
  for (lat = lat0; lat <= lat1; lat += dlat) {
    lats[ny] = lat;
    if ((++ny) > EY)
      ERRMSG("Too many latitudes!");
  }

  /* Create netCDF file... */
  printf("Write tropopause data file: %s\n", argv[2]);
  NC(nc_create(argv[2], NC_CLOBBER, &ncid));

  /* Create dimensions... */
  NC(nc_def_dim(ncid, "time", (size_t) NC_UNLIMITED, &dims[0]));
  NC(nc_def_dim(ncid, "lat", (size_t) ny, &dims[1]));
  NC(nc_def_dim(ncid, "lon", (size_t) nx, &dims[2]));

  /* Create variables... */
  NC(nc_def_var(ncid, "time", NC_DOUBLE, 1, &dims[0], &timid));
  NC(nc_def_var(ncid, "lat", NC_DOUBLE, 1, &dims[1], &latid));
  NC(nc_def_var(ncid, "lon", NC_DOUBLE, 1, &dims[2], &lonid));
  NC(nc_def_var(ncid, "clp_z", NC_FLOAT, 3, &dims[0], &clpzid));
  NC(nc_def_var(ncid, "clp_p", NC_FLOAT, 3, &dims[0], &clppid));
  NC(nc_def_var(ncid, "clp_t", NC_FLOAT, 3, &dims[0], &clptid));
  if (h2o)
    NC(nc_def_var(ncid, "clp_q", NC_FLOAT, 3, &dims[0], &clpqid));
  NC(nc_def_var(ncid, "dyn_z", NC_FLOAT, 3, &dims[0], &dynzid));
  NC(nc_def_var(ncid, "dyn_p", NC_FLOAT, 3, &dims[0], &dynpid));
  NC(nc_def_var(ncid, "dyn_t", NC_FLOAT, 3, &dims[0], &dyntid));
  if (h2o)
    NC(nc_def_var(ncid, "dyn_q", NC_FLOAT, 3, &dims[0], &dynqid));
  NC(nc_def_var(ncid, "wmo_1st_z", NC_FLOAT, 3, &dims[0], &wmo1zid));
  NC(nc_def_var(ncid, "wmo_1st_p", NC_FLOAT, 3, &dims[0], &wmo1pid));
  NC(nc_def_var(ncid, "wmo_1st_t", NC_FLOAT, 3, &dims[0], &wmo1tid));
  if (h2o)
    NC(nc_def_var(ncid, "wmo_1st_q", NC_FLOAT, 3, &dims[0], &wmo1qid));
  NC(nc_def_var(ncid, "wmo_2nd_z", NC_FLOAT, 3, &dims[0], &wmo2zid));
  NC(nc_def_var(ncid, "wmo_2nd_p", NC_FLOAT, 3, &dims[0], &wmo2pid));
  NC(nc_def_var(ncid, "wmo_2nd_t", NC_FLOAT, 3, &dims[0], &wmo2tid));
  if (h2o)
    NC(nc_def_var(ncid, "wmo_2nd_q", NC_FLOAT, 3, &dims[0], &wmo2qid));

  /* Set attributes... */
  add_text_attribute(ncid, "time", "units",
                     "seconds since 2000-01-01 00:00:00 UTC");
  add_text_attribute(ncid, "time", "long_name", "time");
  add_text_attribute(ncid, "lon", "units", "degrees_east");
  add_text_attribute(ncid, "lon", "long_name", "longitude");
  add_text_attribute(ncid, "lat", "units", "degrees_north");
  add_text_attribute(ncid, "lat", "long_name", "latitude");

  add_text_attribute(ncid, "clp_z", "units", "km");
  add_text_attribute(ncid, "clp_z", "long_name", "cold point height");
  add_text_attribute(ncid, "clp_p", "units", "hPa");
  add_text_attribute(ncid, "clp_p", "long_name", "cold point pressure");
  add_text_attribute(ncid, "clp_t", "units", "K");
  add_text_attribute(ncid, "clp_t", "long_name",
                     "cold point temperature");
  if (h2o) {
    add_text_attribute(ncid, "clp_q", "units", "ppv");
    add_text_attribute(ncid, "clp_q", "long_name",
                       "cold point water vapor");
  }

  add_text_attribute(ncid, "dyn_z", "units", "km");
  add_text_attribute(ncid, "dyn_z", "long_name",
                     "dynamical tropopause height");
  add_text_attribute(ncid, "dyn_p", "units", "hPa");
  add_text_attribute(ncid, "dyn_p", "long_name",
                     "dynamical tropopause pressure");
  add_text_attribute(ncid, "dyn_t", "units", "K");
  add_text_attribute(ncid, "dyn_t", "long_name",
                     "dynamical tropopause temperature");
  if (h2o) {
    add_text_attribute(ncid, "dyn_q", "units", "ppv");
    add_text_attribute(ncid, "dyn_q", "long_name",
                       "dynamical tropopause water vapor");
  }

  add_text_attribute(ncid, "wmo_1st_z", "units", "km");
  add_text_attribute(ncid, "wmo_1st_z", "long_name",
                     "WMO 1st tropopause height");
```

```
      add_text_attribute(ncid, "wmo_1st_p", "units", "hPa");
      add_text_attribute(ncid, "wmo_1st_p", "long_name",
                         "WMO 1st tropopause pressure");
      add_text_attribute(ncid, "wmo_1st_t", "units", "K");
      add_text_attribute(ncid, "wmo_1st_t", "long_name",
                         "WMO 1st tropopause temperature");
      if (h2o) {
        add_text_attribute(ncid, "wmo_1st_q", "units", "ppv");
        add_text_attribute(ncid, "wmo_1st_q", "long_name",
                           "WMO 1st tropopause water vapor");
      }

      add_text_attribute(ncid, "wmo_2nd_z", "units", "km");
      add_text_attribute(ncid, "wmo_2nd_z", "long_name",
                         "WMO 2nd tropopause height");
      add_text_attribute(ncid, "wmo_2nd_p", "units", "hPa");
      add_text_attribute(ncid, "wmo_2nd_p", "long_name",
                         "WMO 2nd tropopause pressure");
      add_text_attribute(ncid, "wmo_2nd_t", "units", "K");
      add_text_attribute(ncid, "wmo_2nd_t", "long_name",
                         "WMO 2nd tropopause temperature");
      if (h2o) {
        add_text_attribute(ncid, "wmo_2nd_q", "units", "ppv");
        add_text_attribute(ncid, "wmo_2nd_q", "long_name",
                           "WMO 2nd tropopause water vapor");
      }

      /* End definition... */
      NC(nc_enddef(ncid));

      /* Write longitude and latitude... */
      NC(nc_put_var_double(ncid, latid, lats));
      NC(nc_put_var_double(ncid, lonid, lons));
    }

    /* Write time... */
    start[0] = (size_t) nt;
    count[0] = 1;
    start[1] = 0;
    count[1] = (size_t) ny;
    start[2] = 0;
    count[2] = (size_t) nx;
    NC(nc_put_vara_double(ncid, timid, start, count, &met->time));

    /* Get cold point... */
    ctl.met_tropo = 2;
    read_met_tropo(&ctl, met);
#pragma omp parallel for default(shared) private(ix,iy,ci,cw)
    for (ix = 0; ix < nx; ix++)
      for (iy = 0; iy < ny; iy++) {
        intpol_met_space_2d(met, met->pt, lons[ix], lats[iy],
                            &pt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->z, pt[iy * nx + ix], lons[ix],
                            lats[iy], &zt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->t, pt[iy * nx + ix], lons[ix],
                            lats[iy], &tt[iy * nx + ix], ci, cw, 0);
        intpol_met_space_3d(met, met->h2o, pt[iy * nx + ix], lons[ix],
                            lats[iy], &qt[iy * nx + ix], ci, cw, 0);
      }

    /* Write data... */
    NC(nc_put_vara_double(ncid, clpzid, start, count, zt));
    NC(nc_put_vara_double(ncid, clppid, start, count, pt));
    NC(nc_put_vara_double(ncid, clptid, start, count, tt));
    if (h2o)
      NC(nc_put_vara_double(ncid, clpqid, start, count, qt));

    /* Get dynamical tropopause... */
    ctl.met_tropo = 5;
    read_met_tropo(&ctl, met);
#pragma omp parallel for default(shared) private(ix,iy,ci,cw)
    for (ix = 0; ix < nx; ix++)
      for (iy = 0; iy < ny; iy++) {
        intpol_met_space_2d(met, met->pt, lons[ix], lats[iy],
                            &pt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->z, pt[iy * nx + ix], lons[ix],
                            lats[iy], &zt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->t, pt[iy * nx + ix], lons[ix],
                            lats[iy], &tt[iy * nx + ix], ci, cw, 0);
        intpol_met_space_3d(met, met->h2o, pt[iy * nx + ix], lons[ix],
                            lats[iy], &qt[iy * nx + ix], ci, cw, 0);
      }

    /* Write data... */
    NC(nc_put_vara_double(ncid, dynzid, start, count, zt));
    NC(nc_put_vara_double(ncid, dynpid, start, count, pt));
    NC(nc_put_vara_double(ncid, dyntid, start, count, tt));
```

```
    if (h2o)
      NC(nc_put_vara_double(ncid, dynqid, start, count, qt));

    /* Get WMO 1st tropopause... */
    ctl.met_tropo = 3;
    read_met_tropo(&ctl, met);
#pragma omp parallel for default(shared) private(ix,iy,ci,cw)
    for (ix = 0; ix < nx; ix++)
      for (iy = 0; iy < ny; iy++) {
        intpol_met_space_2d(met, met->pt, lons[ix], lats[iy],
                            &pt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->z, pt[iy * nx + ix], lons[ix],
                            lats[iy], &zt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->t, pt[iy * nx + ix], lons[ix],
                            lats[iy], &tt[iy * nx + ix], ci, cw, 0);
        intpol_met_space_3d(met, met->h2o, pt[iy * nx + ix], lons[ix],
                            lats[iy], &qt[iy * nx + ix], ci, cw, 0);
      }

    /* Write data... */
    NC(nc_put_vara_double(ncid, wmo1zid, start, count, zt));
    NC(nc_put_vara_double(ncid, wmo1pid, start, count, pt));
    NC(nc_put_vara_double(ncid, wmo1tid, start, count, tt));
    if (h2o)
      NC(nc_put_vara_double(ncid, wmo1qid, start, count, qt));

    /* Get WMO 2nd tropopause... */
    ctl.met_tropo = 4;
    read_met_tropo(&ctl, met);
#pragma omp parallel for default(shared) private(ix,iy,ci,cw)
    for (ix = 0; ix < nx; ix++)
      for (iy = 0; iy < ny; iy++) {
        intpol_met_space_2d(met, met->pt, lons[ix], lats[iy],
                            &pt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->z, pt[iy * nx + ix], lons[ix],
                            lats[iy], &zt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->t, pt[iy * nx + ix], lons[ix],
                            lats[iy], &tt[iy * nx + ix], ci, cw, 0);
        intpol_met_space_3d(met, met->h2o, pt[iy * nx + ix], lons[ix],
                            lats[iy], &qt[iy * nx + ix], ci, cw, 0);
      }

    /* Write data... */
    NC(nc_put_vara_double(ncid, wmo2zid, start, count, zt));
    NC(nc_put_vara_double(ncid, wmo2pid, start, count, pt));
    NC(nc_put_vara_double(ncid, wmo2tid, start, count, tt));
    if (h2o)
      NC(nc_put_vara_double(ncid, wmo2qid, start, count, qt));

    /* Increment time step counter... */
    nt++;
  }

  /* Close file... */
  NC(nc_close(ncid));

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.40 tropo.c

```
/*
  This file is part of MPTRAC.

  MPTRAC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  MPTRAC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with MPTRAC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2013-2021 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

void add_text_attribute(
  int ncid,
  char *varname,
  char *attrname,
  char *text);

/* ------------------------------------------------------------
   Main...
   ------------------------------------------------------------ */
```

```
int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  met_t *met;

  static double pt[EX * EY], qt[EX * EY], zt[EX * EY], tt[EX * EY], lon, lon0,
    lon1, lons[EX], dlon, lat, lat0, lat1, lats[EY], dlat, cw[3];

  static int init, i, ix, iy, nx, ny, nt, ncid, dims[3], timid, lonid, latid,
    clppid, clpqid, clptid, clpzid, dynpid, dynqid, dyntid, dynzid, wmo1pid,
    wmo1qid, wmo1tid, wmo1zid, wmo2pid, wmo2qid, wmo2tid, wmo2zid, h2o, ci[3];

  static size_t count[10], start[10];

  /* Allocate... */
  ALLOC(met, met_t, 1);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <tropo.nc> <met0> [ <met1> ... ]");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  lon0 = scan_ctl(argv[1], argc, argv, "TROPO_LON0", -1, "-180", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "TROPO_LON1", -1, "180", NULL);
  dlon = scan_ctl(argv[1], argc, argv, "TROPO_DLON", -1, "-999", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "TROPO_LAT0", -1, "-90", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "TROPO_LAT1", -1, "90", NULL);
  dlat = scan_ctl(argv[1], argc, argv, "TROPO_DLAT", -1, "-999", NULL);
  h2o = (int) scan_ctl(argv[1], argc, argv, "TROPO_H2O", -1, "1", NULL);

  /* Loop over files... */
  for (i = 3; i < argc; i++) {

    /* Read meteorological data... */
    ctl.met_tropo = 0;
    if (!read_met(&ctl, argv[i], met))
      continue;

    /* Set horizontal grid... */
    if (!init) {
      init = 1;

      /* Get grid... */
      if (dlon <= 0)
        dlon = fabs(met->lon[1] - met->lon[0]);
      if (dlat <= 0)
        dlat = fabs(met->lat[1] - met->lat[0]);
      if (lon0 < -360 && lon1 > 360) {
        lon0 = gsl_stats_min(met->lon, 1, (size_t) met->nx);
        lon1 = gsl_stats_max(met->lon, 1, (size_t) met->nx);
      }
      nx = ny = 0;
      for (lon = lon0; lon <= lon1; lon += dlon) {
        lons[nx] = lon;
        if ((++nx) > EX)
          ERRMSG("Too many longitudes!");
      }
      if (lat0 < -90 && lat1 > 90) {
        lat0 = gsl_stats_min(met->lat, 1, (size_t) met->ny);
        lat1 = gsl_stats_max(met->lat, 1, (size_t) met->ny);
      }
      for (lat = lat0; lat <= lat1; lat += dlat) {
        lats[ny] = lat;
        if ((++ny) > EY)
          ERRMSG("Too many latitudes!");
      }

      /* Create netCDF file... */
      printf("Write tropopause data file: %s\n", argv[2]);
      NC(nc_create(argv[2], NC_CLOBBER, &ncid));

      /* Create dimensions... */
      NC(nc_def_dim(ncid, "time", (size_t) NC_UNLIMITED, &dims[0]));
      NC(nc_def_dim(ncid, "lat", (size_t) ny, &dims[1]));
      NC(nc_def_dim(ncid, "lon", (size_t) nx, &dims[2]));

      /* Create variables... */
      NC(nc_def_var(ncid, "time", NC_DOUBLE, 1, &dims[0], &timid));
      NC(nc_def_var(ncid, "lat", NC_DOUBLE, 1, &dims[1], &latid));
      NC(nc_def_var(ncid, "lon", NC_DOUBLE, 1, &dims[2], &lonid));
      NC(nc_def_var(ncid, "clp_z", NC_FLOAT, 3, &dims[0], &clpzid));
      NC(nc_def_var(ncid, "clp_p", NC_FLOAT, 3, &dims[0], &clppid));
```

```
    NC(nc_def_var(ncid, "clp_t", NC_FLOAT, 3, &dims[0], &clptid));
    if (h2o)
      NC(nc_def_var(ncid, "clp_q", NC_FLOAT, 3, &dims[0], &clpqid));
    NC(nc_def_var(ncid, "dyn_z", NC_FLOAT, 3, &dims[0], &dynzid));
    NC(nc_def_var(ncid, "dyn_p", NC_FLOAT, 3, &dims[0], &dynpid));
    NC(nc_def_var(ncid, "dyn_t", NC_FLOAT, 3, &dims[0], &dyntid));
    if (h2o)
      NC(nc_def_var(ncid, "dyn_q", NC_FLOAT, 3, &dims[0], &dynqid));
    NC(nc_def_var(ncid, "wmo_1st_z", NC_FLOAT, 3, &dims[0], &wmo1zid));
    NC(nc_def_var(ncid, "wmo_1st_p", NC_FLOAT, 3, &dims[0], &wmo1pid));
    NC(nc_def_var(ncid, "wmo_1st_t", NC_FLOAT, 3, &dims[0], &wmo1tid));
    if (h2o)
      NC(nc_def_var(ncid, "wmo_1st_q", NC_FLOAT, 3, &dims[0], &wmo1qid));
    NC(nc_def_var(ncid, "wmo_2nd_z", NC_FLOAT, 3, &dims[0], &wmo2zid));
    NC(nc_def_var(ncid, "wmo_2nd_p", NC_FLOAT, 3, &dims[0], &wmo2pid));
    NC(nc_def_var(ncid, "wmo_2nd_t", NC_FLOAT, 3, &dims[0], &wmo2tid));
    if (h2o)
      NC(nc_def_var(ncid, "wmo_2nd_q", NC_FLOAT, 3, &dims[0], &wmo2qid));

    /* Set attributes... */
    add_text_attribute(ncid, "time", "units",
                       "seconds since 2000-01-01 00:00:00 UTC");
    add_text_attribute(ncid, "time", "long_name", "time");
    add_text_attribute(ncid, "lon", "units", "degrees_east");
    add_text_attribute(ncid, "lon", "long_name", "longitude");
    add_text_attribute(ncid, "lat", "units", "degrees_north");
    add_text_attribute(ncid, "lat", "long_name", "latitude");

    add_text_attribute(ncid, "clp_z", "units", "km");
    add_text_attribute(ncid, "clp_z", "long_name", "cold point height");
    add_text_attribute(ncid, "clp_p", "units", "hPa");
    add_text_attribute(ncid, "clp_p", "long_name", "cold point pressure");
    add_text_attribute(ncid, "clp_t", "units", "K");
    add_text_attribute(ncid, "clp_t", "long_name",
                       "cold point temperature");
    if (h2o) {
      add_text_attribute(ncid, "clp_q", "units", "ppv");
      add_text_attribute(ncid, "clp_q", "long_name",
                         "cold point water vapor");
    }

    add_text_attribute(ncid, "dyn_z", "units", "km");
    add_text_attribute(ncid, "dyn_z", "long_name",
                       "dynamical tropopause height");
    add_text_attribute(ncid, "dyn_p", "units", "hPa");
    add_text_attribute(ncid, "dyn_p", "long_name",
                       "dynamical tropopause pressure");
    add_text_attribute(ncid, "dyn_t", "units", "K");
    add_text_attribute(ncid, "dyn_t", "long_name",
                       "dynamical tropopause temperature");
    if (h2o) {
      add_text_attribute(ncid, "dyn_q", "units", "ppv");
      add_text_attribute(ncid, "dyn_q", "long_name",
                         "dynamical tropopause water vapor");
    }

    add_text_attribute(ncid, "wmo_1st_z", "units", "km");
    add_text_attribute(ncid, "wmo_1st_z", "long_name",
                       "WMO 1st tropopause height");
    add_text_attribute(ncid, "wmo_1st_p", "units", "hPa");
    add_text_attribute(ncid, "wmo_1st_p", "long_name",
                       "WMO 1st tropopause pressure");
    add_text_attribute(ncid, "wmo_1st_t", "units", "K");
    add_text_attribute(ncid, "wmo_1st_t", "long_name",
                       "WMO 1st tropopause temperature");
    if (h2o) {
      add_text_attribute(ncid, "wmo_1st_q", "units", "ppv");
      add_text_attribute(ncid, "wmo_1st_q", "long_name",
                         "WMO 1st tropopause water vapor");
    }

    add_text_attribute(ncid, "wmo_2nd_z", "units", "km");
    add_text_attribute(ncid, "wmo_2nd_z", "long_name",
                       "WMO 2nd tropopause height");
    add_text_attribute(ncid, "wmo_2nd_p", "units", "hPa");
    add_text_attribute(ncid, "wmo_2nd_p", "long_name",
                       "WMO 2nd tropopause pressure");
    add_text_attribute(ncid, "wmo_2nd_t", "units", "K");
    add_text_attribute(ncid, "wmo_2nd_t", "long_name",
                       "WMO 2nd tropopause temperature");
    if (h2o) {
      add_text_attribute(ncid, "wmo_2nd_q", "units", "ppv");
      add_text_attribute(ncid, "wmo_2nd_q", "long_name",
                         "WMO 2nd tropopause water vapor");
    }

    /* End definition... */
```

```
      NC(nc_enddef(ncid));

      /* Write longitude and latitude... */
      NC(nc_put_var_double(ncid, latid, lats));
      NC(nc_put_var_double(ncid, lonid, lons));
    }

    /* Write time... */
    start[0] = (size_t) nt;
    count[0] = 1;
    start[1] = 0;
    count[1] = (size_t) ny;
    start[2] = 0;
    count[2] = (size_t) nx;
    NC(nc_put_vara_double(ncid, timid, start, count, &met->time));

    /* Get cold point... */
    ctl.met_tropo = 2;
    read_met_tropo(&ctl, met);
#pragma omp parallel for default(shared) private(ix,iy,ci,cw)
    for (ix = 0; ix < nx; ix++)
      for (iy = 0; iy < ny; iy++) {
        intpol_met_space_2d(met, met->pt, lons[ix], lats[iy],
                            &pt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->z, pt[iy * nx + ix], lons[ix],
                            lats[iy], &zt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->t, pt[iy * nx + ix], lons[ix],
                            lats[iy], &tt[iy * nx + ix], ci, cw, 0);
        intpol_met_space_3d(met, met->h2o, pt[iy * nx + ix], lons[ix],
                            lats[iy], &qt[iy * nx + ix], ci, cw, 0);
      }

    /* Write data... */
    NC(nc_put_vara_double(ncid, clpzid, start, count, zt));
    NC(nc_put_vara_double(ncid, clppid, start, count, pt));
    NC(nc_put_vara_double(ncid, clptid, start, count, tt));
    if (h2o)
      NC(nc_put_vara_double(ncid, clpqid, start, count, qt));

    /* Get dynamical tropopause... */
    ctl.met_tropo = 5;
    read_met_tropo(&ctl, met);
#pragma omp parallel for default(shared) private(ix,iy,ci,cw)
    for (ix = 0; ix < nx; ix++)
      for (iy = 0; iy < ny; iy++) {
        intpol_met_space_2d(met, met->pt, lons[ix], lats[iy],
                            &pt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->z, pt[iy * nx + ix], lons[ix],
                            lats[iy], &zt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->t, pt[iy * nx + ix], lons[ix],
                            lats[iy], &tt[iy * nx + ix], ci, cw, 0);
        intpol_met_space_3d(met, met->h2o, pt[iy * nx + ix], lons[ix],
                            lats[iy], &qt[iy * nx + ix], ci, cw, 0);
      }

    /* Write data... */
    NC(nc_put_vara_double(ncid, dynzid, start, count, zt));
    NC(nc_put_vara_double(ncid, dynpid, start, count, pt));
    NC(nc_put_vara_double(ncid, dyntid, start, count, tt));
    if (h2o)
      NC(nc_put_vara_double(ncid, dynqid, start, count, qt));

    /* Get WMO 1st tropopause... */
    ctl.met_tropo = 3;
    read_met_tropo(&ctl, met);
#pragma omp parallel for default(shared) private(ix,iy,ci,cw)
    for (ix = 0; ix < nx; ix++)
      for (iy = 0; iy < ny; iy++) {
        intpol_met_space_2d(met, met->pt, lons[ix], lats[iy],
                            &pt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->z, pt[iy * nx + ix], lons[ix],
                            lats[iy], &zt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->t, pt[iy * nx + ix], lons[ix],
                            lats[iy], &tt[iy * nx + ix], ci, cw, 0);
        intpol_met_space_3d(met, met->h2o, pt[iy * nx + ix], lons[ix],
                            lats[iy], &qt[iy * nx + ix], ci, cw, 0);
      }

    /* Write data... */
    NC(nc_put_vara_double(ncid, wmo1zid, start, count, zt));
    NC(nc_put_vara_double(ncid, wmo1pid, start, count, pt));
    NC(nc_put_vara_double(ncid, wmo1tid, start, count, tt));
    if (h2o)
      NC(nc_put_vara_double(ncid, wmo1qid, start, count, qt));

    /* Get WMO 2nd tropopause... */
    ctl.met_tropo = 4;
```

```
    read_met_tropo(&ctl, met);
#pragma omp parallel for default(shared) private(ix,iy,ci,cw)
    for (ix = 0; ix < nx; ix++)
      for (iy = 0; iy < ny; iy++) {
        intpol_met_space_2d(met, met->pt, lons[ix], lats[iy],
                            &pt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->z, pt[iy * nx + ix], lons[ix],
                            lats[iy], &zt[iy * nx + ix], ci, cw, 1);
        intpol_met_space_3d(met, met->t, pt[iy * nx + ix], lons[ix],
                            lats[iy], &tt[iy * nx + ix], ci, cw, 0);
        intpol_met_space_3d(met, met->h2o, pt[iy * nx + ix], lons[ix],
                            lats[iy], &qt[iy * nx + ix], ci, cw, 0);
      }

    /* Write data... */
    NC(nc_put_vara_double(ncid, wmo2zid, start, count, zt));
    NC(nc_put_vara_double(ncid, wmo2pid, start, count, pt));
    NC(nc_put_vara_double(ncid, wmo2tid, start, count, tt));
    if (h2o)
      NC(nc_put_vara_double(ncid, wmo2qid, start, count, qt));

    /* Increment time step counter... */
    nt++;
  }

  /* Close file... */
  NC(nc_close(ncid));

  /* Free... */
  free(met);

  return EXIT_SUCCESS;
}

/*****************************************************************************/

void add_text_attribute(
  int ncid,
  char *varname,
  char *attrname,
  char *text) {

  int varid;

  NC(nc_inq_varid(ncid, varname, &varid));
  NC(nc_put_att_text(ncid, varid, attrname, strlen(text), text));
}
```

5.41 tropo_sample.c File Reference

Functions

- void intpol_tropo_3d (double time0, float array0[EX][EY], double time1, float array1[EX][EY], double lons[EX], double lats[EY], size_t nlon, size_t nlat, double time, double lon, double lat, int method, double ∗var, double ∗sigma)

  3-D linear interpolation of tropopause data.
- int main (int argc, char ∗argv[ ])

5.41.1 Detailed Description

Sample tropopause data set.

Definition in file tropo_sample.c.

5.41.2 Function Documentation

5.41.2.1 intpol_tropo_3d()

```
void intpol_tropo_3d (
    double time0,
    float array0[EX][EY],
    double time1,
    float array1[EX][EY],
    double lons[EX],
    double lats[EY],
    size_t nlon,
    size_t nlat,
    double time,
    double lon,
    double lat,
    int method,
    double * var,
    double * sigma )
```

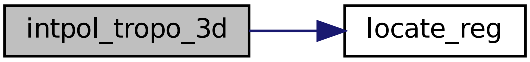
3-D linear interpolation of tropopause data.

Definition at line 266 of file tropo_sample.c.

```
        {

double aux0, aux1, aux00, aux01, aux10, aux11, mean = 0;

int n = 0;

/* Adjust longitude... */
if (lon < lons[0])
 lon += 360;
else if (lon > lons[nlon - 1])
 lon -= 360;

/* Get indices... */
int ix = locate_reg(lons, (int) nlon, lon);
int iy = locate_reg(lats, (int) nlat, lat);

/* Calculate standard deviation... */
*sigma = 0;
for (int dx = 0; dx < 2; dx++)
 for (int dy = 0; dy < 2; dy++) {
  if (isfinite(array0[ix + dx][iy + dy])) {
   mean += array0[ix + dx][iy + dy];
   *sigma += SQR(array0[ix + dx][iy + dy]);
   n++;
  }
  if (isfinite(array1[ix + dx][iy + dy])) {
   mean += array1[ix + dx][iy + dy];
   *sigma += SQR(array1[ix + dx][iy + dy]);
   n++;
  }
 }
if (n > 0)
 *sigma = sqrt(GSL_MAX(*sigma / n - SQR(mean / n), 0.0));

/* Linear interpolation... */
if (method == 1 && isfinite(array0[ix][iy])
  && isfinite(array0[ix][iy + 1])
  && isfinite(array0[ix + 1][iy])
  && isfinite(array0[ix + 1][iy + 1])
  && isfinite(array1[ix][iy])
  && isfinite(array1[ix][iy + 1])
  && isfinite(array1[ix + 1][iy])
  && isfinite(array1[ix + 1][iy + 1])) {

 aux00 = LIN(lons[ix], array0[ix][iy],
       lons[ix + 1], array0[ix + 1][iy], lon);
 aux01 = LIN(lons[ix], array0[ix][iy + 1],
       lons[ix + 1], array0[ix + 1][iy + 1], lon);
 aux0 = LIN(lats[iy], aux00, lats[iy + 1], aux01, lat);

 aux10 = LIN(lons[ix], array1[ix][iy],
       lons[ix + 1], array1[ix + 1][iy], lon);
 aux11 = LIN(lons[ix], array1[ix][iy + 1],
       lons[ix + 1], array1[ix + 1][iy + 1], lon);
 aux1 = LIN(lats[iy], aux10, lats[iy + 1], aux11, lat);

 *var = LIN(time0, aux0, time1, aux1, time);
}

```

```
  /* Nearest neighbor interpolation... */
  else {
    aux00 = NN(lons[ix], array0[ix][iy],
               lons[ix + 1], array0[ix + 1][iy], lon);
    aux01 = NN(lons[ix], array0[ix][iy + 1],
               lons[ix + 1], array0[ix + 1][iy + 1], lon);
    aux0 = NN(lats[iy], aux00, lats[iy + 1], aux01, lat);

    aux10 = NN(lons[ix], array1[ix][iy],
               lons[ix + 1], array1[ix + 1][iy], lon);
    aux11 = NN(lons[ix], array1[ix][iy + 1],
               lons[ix + 1], array1[ix + 1][iy + 1], lon);
    aux1 = NN(lats[iy], aux10, lats[iy + 1], aux11, lat);

    *var = NN(time0, aux0, time1, aux1, time);
  }
}
```

Here is the call graph for this function:



5.41.2.2 main() int main (int argc, char * argv[])

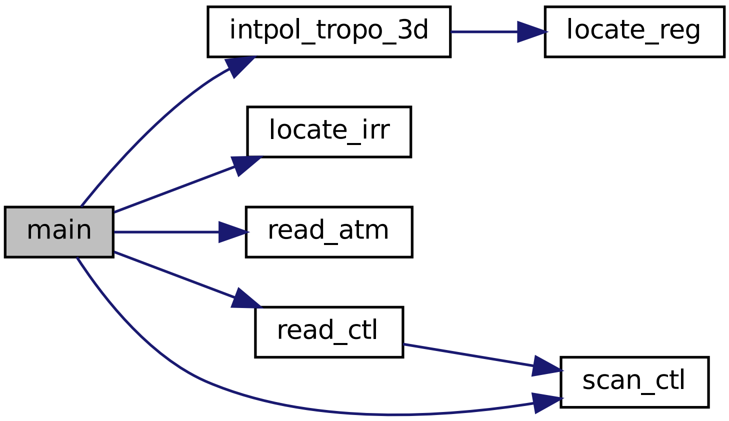
Definition at line 59 of file tropo_sample.c.

```
                      {

  ctl_t ctl;

  atm_t *atm;

  static FILE *out;

  static char varname[LEN];

  static double times[NT], lons[EX], lats[EY], time0, time1, z0, z0sig,
    p0, p0sig, t0, t0sig, q0, q0sig;

  static float help[EX * EY], tropo_z0[EX][EY], tropo_z1[EX][EY],
    tropo_p0[EX][EY], tropo_p1[EX][EY], tropo_t0[EX][EY],
    tropo_t1[EX][EY], tropo_q0[EX][EY], tropo_q1[EX][EY];

  static int ip, iq, it, it_old = -999, method, dimid[10], ncid,
    varid, varid_z, varid_p, varid_t, varid_q, h2o;

  static size_t count[10], start[10], ntime, nlon, nlat, ilon, ilat;

  /* Allocate... */
  ALLOC(atm, atm_t, 1);

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <sample.tab> <tropo.nc> <var> <atm_in>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  method =
    (int) scan_ctl(argv[1], argc, argv, "TROPO_SAMPLE_METHOD", -1, "1", NULL);

  /* Read atmospheric data... */
  if (!read_atm(argv[5], &ctl, atm))
```

```
    ERRMSG("Cannot open file!");

  /* Open tropopause file... */
  printf("Read tropopause data: %s\n", argv[3]);
  if (nc_open(argv[3], NC_NOWRITE, &ncid) != NC_NOERR)
    ERRMSG("Cannot open file!");

  /* Get dimensions... */
  NC(nc_inq_dimid(ncid, "time", &dimid[0]));
  NC(nc_inq_dimlen(ncid, dimid[0], &ntime));
  if (ntime > NT)
    ERRMSG("Too many times!");
  NC(nc_inq_dimid(ncid, "lat", &dimid[1]));
  NC(nc_inq_dimlen(ncid, dimid[1], &nlat));
  if (nlat > EY)
    ERRMSG("Too many latitudes!");
  NC(nc_inq_dimid(ncid, "lon", &dimid[2]));
  NC(nc_inq_dimlen(ncid, dimid[2], &nlon));
  if (nlon > EX)
    ERRMSG("Too many longitudes!");

  /* Read coordinates... */
  NC(nc_inq_varid(ncid, "time", &varid));
  NC(nc_get_var_double(ncid, varid, times));
  NC(nc_inq_varid(ncid, "lat", &varid));
  NC(nc_get_var_double(ncid, varid, lats));
  NC(nc_inq_varid(ncid, "lon", &varid));
  NC(nc_get_var_double(ncid, varid, lons));

  /* Get variable indices... */
  sprintf(varname, "%s_z", argv[4]);
  NC(nc_inq_varid(ncid, varname, &varid_z));
  sprintf(varname, "%s_p", argv[4]);
  NC(nc_inq_varid(ncid, varname, &varid_p));
  sprintf(varname, "%s_t", argv[4]);
  NC(nc_inq_varid(ncid, varname, &varid_t));
  sprintf(varname, "%s_q", argv[4]);
  h2o = (nc_inq_varid(ncid, varname, &varid_q) == NC_NOERR);

  /* Set dimensions... */
  count[0] = 1;
  count[1] = nlat;
  count[2] = nlon;

  /* Create file... */
  printf("Write tropopause sample data: %s\n", argv[2]);
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
  for (iq = 0; iq < ctl.nq; iq++)
    fprintf(out, "# $%i = %s [%s]\n", iq + 5, ctl.qnt_name[iq],
            ctl.qnt_unit[iq]);
  fprintf(out, "# $%d = tropopause height [km]\n", 5 + ctl.nq);
  fprintf(out, "# $%d = tropopause pressure [hPa]\n", 6 + ctl.nq);
  fprintf(out, "# $%d = tropopause temperature [K]\n", 7 + ctl.nq);
  fprintf(out, "# $%d = tropopause water vapor [ppv]\n", 8 + ctl.nq);
  fprintf(out, "# $%d = tropopause height (sigma) [km]\n", 9 + ctl.nq);
  fprintf(out, "# $%d = tropopause pressure (sigma) [hPa]\n", 10 + ctl.nq);
  fprintf(out, "# $%d = tropopause temperature (sigma) [K]\n", 11 + ctl.nq);
  fprintf(out, "# $%d = tropopause water vapor (sigma) [ppv]\n\n",
          12 + ctl.nq);

  /* Loop over particles... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check temporal ordering... */
    if (ip > 0 && atm->time[ip] < atm->time[ip - 1])
      ERRMSG("Time must be ascending!");

    /* Check range... */
    if (atm->time[ip] < times[0] || atm->time[ip] > times[ntime - 1])
      continue;

    /* Read data... */
    it = locate_irr(times, (int) ntime, atm->time[ip]);
    if (it != it_old) {

      time0 = times[it];
      start[0] = (size_t) it;
      NC(nc_get_vara_float(ncid, varid_z, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
```

```
          tropo_z0[ilon][ilat] = help[ilat * nlon + ilon];
      NC(nc_get_vara_float(ncid, varid_p, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_p0[ilon][ilat] = help[ilat * nlon + ilon];
      NC(nc_get_vara_float(ncid, varid_t, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_t0[ilon][ilat] = help[ilat * nlon + ilon];
      if (h2o) {
        NC(nc_get_vara_float(ncid, varid_q, start, count, help));
        for (ilon = 0; ilon < nlon; ilon++)
          for (ilat = 0; ilat < nlat; ilat++)
            tropo_q0[ilon][ilat] = help[ilat * nlon + ilon];
      } else
        for (ilon = 0; ilon < nlon; ilon++)
          for (ilat = 0; ilat < nlat; ilat++)
            tropo_q0[ilon][ilat] = GSL_NAN;

      time1 = times[it + 1];
      start[0] = (size_t) it + 1;
      NC(nc_get_vara_float(ncid, varid_z, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_z1[ilon][ilat] = help[ilat * nlon + ilon];
      NC(nc_get_vara_float(ncid, varid_p, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_p1[ilon][ilat] = help[ilat * nlon + ilon];
      NC(nc_get_vara_float(ncid, varid_t, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_t1[ilon][ilat] = help[ilat * nlon + ilon];
      if (h2o) {
        NC(nc_get_vara_float(ncid, varid_q, start, count, help));
        for (ilon = 0; ilon < nlon; ilon++)
          for (ilat = 0; ilat < nlat; ilat++)
            tropo_q1[ilon][ilat] = help[ilat * nlon + ilon];
      } else
        for (ilon = 0; ilon < nlon; ilon++)
          for (ilat = 0; ilat < nlat; ilat++)
            tropo_q1[ilon][ilat] = GSL_NAN;;
    }
    it_old = it;

    /* Interpolate... */
    intpol_tropo_3d(time0, tropo_z0, time1, tropo_z1,
                    lons, lats, nlon, nlat, atm->time[ip], atm->lon[ip],
                    atm->lat[ip], method, &z0, &z0sig);
    intpol_tropo_3d(time0, tropo_p0, time1, tropo_p1,
                    lons, lats, nlon, nlat, atm->time[ip], atm->lon[ip],
                    atm->lat[ip], method, &p0, &p0sig);
    intpol_tropo_3d(time0, tropo_t0, time1, tropo_t1,
                    lons, lats, nlon, nlat, atm->time[ip], atm->lon[ip],
                    atm->lat[ip], method, &t0, &t0sig);
    intpol_tropo_3d(time0, tropo_q0, time1, tropo_q1,
                    lons, lats, nlon, nlat, atm->time[ip], atm->lon[ip],
                    atm->lat[ip], method, &q0, &q0sig);

    /* Write output... */
    fprintf(out, "%.2f %g %g %g", atm->time[ip], Z(atm->p[ip]),
            atm->lon[ip], atm->lat[ip]);
    for (iq = 0; iq < ctl.nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl.qnt_format[iq], atm->q[iq][ip]);
    }
    fprintf(out, " %g %g %g %g %g %g %g %g\n",
            z0, p0, t0, q0, z0sig, p0sig, t0sig, q0sig);
  }

  /* Close files... */
  fclose(out);
  NC(nc_close(ncid));

  /* Free... */
  free(atm);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.42 tropo_sample.c

```
/*
  This file is part of MPTRAC.

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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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*/

#include "libtrac.h"

/* ------------------------------------------------------------
   Dimensions...
   ------------------------------------------------------------ */

#define NT 744

/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

void intpol_tropo_3d(
  double time0,
  float array0[EX][EY],
  double time1,
  float array1[EX][EY],
  double lons[EX],
  double lats[EY],
  size_t nlon,
  size_t nlat,
  double time,
  double lon,
  double lat,
  int method,
  double *var,
  double *sigma);

/* ------------------------------------------------------------
```

```
 Main...
 ------------------------------------------------------------ */

int main(
  int argc,
  char *argv[]) {

  ctl_t ctl;

  atm_t *atm;

  static FILE *out;

  static char varname[LEN];

  static double times[NT], lons[EX], lats[EY], time0, time1, z0, z0sig,
    p0, p0sig, t0, t0sig, q0, q0sig;

  static float help[EX * EY], tropo_z0[EX][EY], tropo_z1[EX][EY],
    tropo_p0[EX][EY], tropo_p1[EX][EY], tropo_t0[EX][EY],
    tropo_t1[EX][EY], tropo_q0[EX][EY], tropo_q1[EX][EY];

  static int ip, iq, it, it_old = -999, method, dimid[10], ncid,
    varid, varid_z, varid_p, varid_t, varid_q, h2o;

  static size_t count[10], start[10], ntime, nlon, nlat, ilon, ilat;

  /* Allocate... */
  ALLOC(atm, atm_t, 1);

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <sample.tab> <tropo.nc> <var> <atm_in>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  method =
    (int) scan_ctl(argv[1], argc, argv, "TROPO_SAMPLE_METHOD", -1, "1", NULL);

  /* Read atmospheric data... */
  if (!read_atm(argv[5], &ctl, atm))
    ERRMSG("Cannot open file!");

  /* Open tropopause file... */
  printf("Read tropopause data: %s\n", argv[3]);
  if (nc_open(argv[3], NC_NOWRITE, &ncid) != NC_NOERR)
    ERRMSG("Cannot open file!");

  /* Get dimensions... */
  NC(nc_inq_dimid(ncid, "time", &dimid[0]));
  NC(nc_inq_dimlen(ncid, dimid[0], &ntime));
  if (ntime > NT)
    ERRMSG("Too many times!");
  NC(nc_inq_dimid(ncid, "lat", &dimid[1]));
  NC(nc_inq_dimlen(ncid, dimid[1], &nlat));
  if (nlat > EY)
    ERRMSG("Too many latitudes!");
  NC(nc_inq_dimid(ncid, "lon", &dimid[2]));
  NC(nc_inq_dimlen(ncid, dimid[2], &nlon));
  if (nlon > EX)
    ERRMSG("Too many longitudes!");

  /* Read coordinates... */
  NC(nc_inq_varid(ncid, "time", &varid));
  NC(nc_get_var_double(ncid, varid, times));
  NC(nc_inq_varid(ncid, "lat", &varid));
  NC(nc_get_var_double(ncid, varid, lats));
  NC(nc_inq_varid(ncid, "lon", &varid));
  NC(nc_get_var_double(ncid, varid, lons));

  /* Get variable indices... */
  sprintf(varname, "%s_z", argv[4]);
  NC(nc_inq_varid(ncid, varname, &varid_z));
  sprintf(varname, "%s_p", argv[4]);
  NC(nc_inq_varid(ncid, varname, &varid_p));
  sprintf(varname, "%s_t", argv[4]);
  NC(nc_inq_varid(ncid, varname, &varid_t));
  sprintf(varname, "%s_q", argv[4]);
  h2o = (nc_inq_varid(ncid, varname, &varid_q) == NC_NOERR);

  /* Set dimensions... */
  count[0] = 1;
  count[1] = nlat;
  count[2] = nlon;

  /* Create file... */
  printf("Write tropopause sample data: %s\n", argv[2]);
```

```
  if (!(out = fopen(argv[2], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time [s]\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n" "# $4 = latitude [deg]\n");
  for (iq = 0; iq < ctl.nq; iq++)
    fprintf(out, "# $%i = %s [%s]\n", iq + 5, ctl.qnt_name[iq],
            ctl.qnt_unit[iq]);
  fprintf(out, "# $%d = tropopause height [km]\n", 5 + ctl.nq);
  fprintf(out, "# $%d = tropopause pressure [hPa]\n", 6 + ctl.nq);
  fprintf(out, "# $%d = tropopause temperature [K]\n", 7 + ctl.nq);
  fprintf(out, "# $%d = tropopause water vapor [ppv]\n", 8 + ctl.nq);
  fprintf(out, "# $%d = tropopause height (sigma) [km]\n", 9 + ctl.nq);
  fprintf(out, "# $%d = tropopause pressure (sigma) [hPa]\n", 10 + ctl.nq);
  fprintf(out, "# $%d = tropopause temperature (sigma) [K]\n", 11 + ctl.nq);
  fprintf(out, "# $%d = tropopause water vapor (sigma) [ppv]\n\n",
          12 + ctl.nq);

  /* Loop over particles... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Check temporal ordering... */
    if (ip > 0 && atm->time[ip] < atm->time[ip - 1])
      ERRMSG("Time must be ascending!");

    /* Check range... */
    if (atm->time[ip] < times[0] || atm->time[ip] > times[ntime - 1])
      continue;

    /* Read data... */
    it = locate_irr(times, (int) ntime, atm->time[ip]);
    if (it != it_old) {

      time0 = times[it];
      start[0] = (size_t) it;
      NC(nc_get_vara_float(ncid, varid_z, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_z0[ilon][ilat] = help[ilat * nlon + ilon];
      NC(nc_get_vara_float(ncid, varid_p, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_p0[ilon][ilat] = help[ilat * nlon + ilon];
      NC(nc_get_vara_float(ncid, varid_t, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_t0[ilon][ilat] = help[ilat * nlon + ilon];
      if (h2o) {
        NC(nc_get_vara_float(ncid, varid_q, start, count, help));
        for (ilon = 0; ilon < nlon; ilon++)
          for (ilat = 0; ilat < nlat; ilat++)
            tropo_q0[ilon][ilat] = help[ilat * nlon + ilon];
      } else
        for (ilon = 0; ilon < nlon; ilon++)
          for (ilat = 0; ilat < nlat; ilat++)
            tropo_q0[ilon][ilat] = GSL_NAN;

      time1 = times[it + 1];
      start[0] = (size_t) it + 1;
      NC(nc_get_vara_float(ncid, varid_z, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_z1[ilon][ilat] = help[ilat * nlon + ilon];
      NC(nc_get_vara_float(ncid, varid_p, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_p1[ilon][ilat] = help[ilat * nlon + ilon];
      NC(nc_get_vara_float(ncid, varid_t, start, count, help));
      for (ilon = 0; ilon < nlon; ilon++)
        for (ilat = 0; ilat < nlat; ilat++)
          tropo_t1[ilon][ilat] = help[ilat * nlon + ilon];
      if (h2o) {
        NC(nc_get_vara_float(ncid, varid_q, start, count, help));
        for (ilon = 0; ilon < nlon; ilon++)
          for (ilat = 0; ilat < nlat; ilat++)
            tropo_q1[ilon][ilat] = help[ilat * nlon + ilon];
      } else
        for (ilon = 0; ilon < nlon; ilon++)
          for (ilat = 0; ilat < nlat; ilat++)
            tropo_q1[ilon][ilat] = GSL_NAN;;
    }
    it_old = it;

    /* Interpolate... */
```

```
    intpol_tropo_3d(time0, tropo_z0, time1, tropo_z1,
                    lons, lats, nlon, nlat, atm->time[ip], atm->lon[ip],
                    atm->lat[ip], method, &z0, &z0sig);
    intpol_tropo_3d(time0, tropo_p0, time1, tropo_p1,
                    lons, lats, nlon, nlat, atm->time[ip], atm->lon[ip],
                    atm->lat[ip], method, &p0, &p0sig);
    intpol_tropo_3d(time0, tropo_t0, time1, tropo_t1,
                    lons, lats, nlon, nlat, atm->time[ip], atm->lon[ip],
                    atm->lat[ip], method, &t0, &t0sig);
    intpol_tropo_3d(time0, tropo_q0, time1, tropo_q1,
                    lons, lats, nlon, nlat, atm->time[ip], atm->lon[ip],
                    atm->lat[ip], method, &q0, &q0sig);

    /* Write output... */
    fprintf(out, "%.2f %g %g %g", atm->time[ip], Z(atm->p[ip]),
            atm->lon[ip], atm->lat[ip]);
    for (iq = 0; iq < ctl.nq; iq++) {
      fprintf(out, " ");
      fprintf(out, ctl.qnt_format[iq], atm->q[iq][ip]);
    }
    fprintf(out, " %g %g %g %g %g %g %g %g\n",
            z0, p0, t0, q0, z0sig, p0sig, t0sig, q0sig);
  }

  /* Close files... */
  fclose(out);
  NC(nc_close(ncid));

  /* Free... */
  free(atm);

  return EXIT_SUCCESS;
}

/*****************************************************************************/

void intpol_tropo_3d(
  double time0,
  float array0[EX][EY],
  double time1,
  float array1[EX][EY],
  double lons[EX],
  double lats[EY],
  size_t nlon,
  size_t nlat,
  double time,
  double lon,
  double lat,
  int method,
  double *var,
  double *sigma) {

  double aux0, aux1, aux00, aux01, aux10, aux11, mean = 0;

  int n = 0;

  /* Adjust longitude... */
  if (lon < lons[0])
    lon += 360;
  else if (lon > lons[nlon - 1])
    lon -= 360;

  /* Get indices... */
  int ix = locate_reg(lons, (int) nlon, lon);
  int iy = locate_reg(lats, (int) nlat, lat);

  /* Calculate standard deviation... */
  *sigma = 0;
  for (int dx = 0; dx < 2; dx++)
    for (int dy = 0; dy < 2; dy++) {
      if (isfinite(array0[ix + dx][iy + dy])) {
        mean += array0[ix + dx][iy + dy];
        *sigma += SQR(array0[ix + dx][iy + dy]);
        n++;
      }
      if (isfinite(array1[ix + dx][iy + dy])) {
        mean += array1[ix + dx][iy + dy];
        *sigma += SQR(array1[ix + dx][iy + dy]);
        n++;
      }
    }
  if (n > 0)
    *sigma = sqrt(GSL_MAX(*sigma / n - SQR(mean / n), 0.0));

  /* Linear interpolation... */
  if (method == 1 && isfinite(array0[ix][iy])
      && isfinite(array0[ix][iy + 1])
```

```
      && isfinite(array0[ix + 1][iy])
      && isfinite(array0[ix + 1][iy + 1])
      && isfinite(array1[ix][iy])
      && isfinite(array1[ix][iy + 1])
      && isfinite(array1[ix + 1][iy])
      && isfinite(array1[ix + 1][iy + 1])) {

    aux00 = LIN(lons[ix], array0[ix][iy],
                lons[ix + 1], array0[ix + 1][iy], lon);
    aux01 = LIN(lons[ix], array0[ix][iy + 1],
                lons[ix + 1], array0[ix + 1][iy + 1], lon);
    aux0 = LIN(lats[iy], aux00, lats[iy + 1], aux01, lat);

    aux10 = LIN(lons[ix], array1[ix][iy],
                lons[ix + 1], array1[ix + 1][iy], lon);
    aux11 = LIN(lons[ix], array1[ix][iy + 1],
                lons[ix + 1], array1[ix + 1][iy + 1], lon);
    aux1 = LIN(lats[iy], aux10, lats[iy + 1], aux11, lat);

    *var = LIN(time0, aux0, time1, aux1, time);
  }

  /* Nearest neighbor interpolation... */
  else {
    aux00 = NN(lons[ix], array0[ix][iy],
               lons[ix + 1], array0[ix + 1][iy], lon);
    aux01 = NN(lons[ix], array0[ix][iy + 1],
               lons[ix + 1], array0[ix + 1][iy + 1], lon);
    aux0 = NN(lats[iy], aux00, lats[iy + 1], aux01, lat);

    aux10 = NN(lons[ix], array1[ix][iy],
               lons[ix + 1], array1[ix + 1][iy], lon);
    aux11 = NN(lons[ix], array1[ix][iy + 1],
               lons[ix + 1], array1[ix + 1][iy + 1], lon);
    aux1 = NN(lats[iy], aux10, lats[iy + 1], aux11, lat);

    *var = NN(time0, aux0, time1, aux1, time);
  }
}
```

Index