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: http://www.fz-juelich.de/ias/jsc/mptrac

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2.1 Data Structures

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4 Data Structure Documentation

4.1 atm_t Struct Reference

Atmospheric data.

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

Data Fields

- int np

  Number of air pacels.
- double time [NP]

  Time [s].
- double p [NP]

  Pressure [hPa].
- double lon [NP]

  Longitude [deg].
- double lat [NP]

  Latitude [deg].
- double q [NQ][NP]

  Quantitiy data (for various, user-defined attributes).
- double up [NP]

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

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

  Vertical velocity perturbation [hPa/s].

4.1.1 Detailed Description

Atmospheric data.

Definition at line 505 of file libtrac.h.

4.1.2 Field Documentation

4.1.2.1 int atm_t::np

Number of air pacels.

Definition at line 508 of file libtrac.h.

4.1.2.2 double atm_t::time[NP]

Time [s].

Definition at line 511 of file libtrac.h.

4.1.2.3 double atm_t::p[NP]

Pressure [hPa].

Definition at line 514 of file libtrac.h.

4.1.2.4 double atm_t::lon[NP]

Longitude [deg].

Definition at line 517 of file libtrac.h.

4.1.2.5 double atm_t::lat[NP]

Latitude [deg].

Definition at line 520 of file libtrac.h.

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

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

Definition at line 523 of file libtrac.h.

4.1.2.7 double atm_t::up[NP]

Zonal wind perturbation [m/s].

Definition at line 526 of file libtrac.h.

4.1.2.8 double atm_t::vp[NP]

Meridional wind perturbation [m/s].

Definition at line 529 of file libtrac.h.

4.1.2.9 double atm_t::wp[NP]

Vertical velocity perturbation [hPa/s].

Definition at line 532 of file libtrac.h.

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

- libtrac.h

4.2 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_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_theta

  Quantity array index for potential temperature.
- int qnt_pv

  Quantity array index for potential vorticity.
- 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 qnt_gw_u750

  Quantity array index for low-level zonal wind.
- int qnt_gw_v750

  Quantity array index for low-level meridional wind.
- int qnt_gw_sso

  Quantity array index for subgrid-scale orography.
- int qnt_gw_var

  Quantity array index for gravity wave variances.
- 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].
- double dt_met

  Time step of meteorological data [s].
- int met_np

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

  Target pressure levels [hPa].
- char met_stage [LEN]

  Command to stage meteo data.
- 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_meso

  Scaling factor for mesoscale wind fluctuations.
- double tdec_trop

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

  Life time of particles (stratosphere) [s].
- double psc_h2o

  H2O volume mixing ratio for PSC analysis.
- double psc_hno3

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

  Basename for gravity wave variance data.
- 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).
- 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 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].

4.2.1 Detailed Description

Control parameters.

Definition at line 220 of file libtrac.h.

4.2.2 Field Documentation

4.2.2.1 int ctl_t::nq

Number of quantities.

Definition at line 223 of file libtrac.h.

4.2.2.2 char ctl_t::qnt_name[NQ][LEN]

Quantity names.

Definition at line 226 of file libtrac.h.

4.2.2.3 char ctl_t::qnt_unit[NQ][LEN]

Quantity units.

Definition at line 229 of file libtrac.h.

4.2.2.4 char ctl_t::qnt_format[NQ][LEN]

Quantity output format.

Definition at line 232 of file libtrac.h.

4.2.2.5 int ctl_t::qnt_ens

Quantity array index for ensemble IDs.

Definition at line 235 of file libtrac.h.

4.2.2.6 int ctl_t::qnt_m

Quantity array index for mass.

Definition at line 238 of file libtrac.h.

4.2.2.7 int ctl_t::qnt_rho

Quantity array index for particle density.

Definition at line 241 of file libtrac.h.

4.2.2.8 int ctl_t::qnt_r

Quantity array index for particle radius.

Definition at line 244 of file libtrac.h.

4.2.2.9 int ctl_t::qnt_ps

Quantity array index for surface pressure.

Definition at line 247 of file libtrac.h.

4.2.2.10 int ctl_t::qnt_p

Quantity array index for pressure.

Definition at line 250 of file libtrac.h.

4.2.2.11 int ctl_t::qnt_t

Quantity array index for temperature.

Definition at line 253 of file libtrac.h.

4.2.2.12 int ctl_t::qnt_u

Quantity array index for zonal wind.

Definition at line 256 of file libtrac.h.

4.2.2.13 int ctl_t::qnt_v

Quantity array index for meridional wind.

Definition at line 259 of file libtrac.h.

4.2.2.14 int ctl_t::qnt_w

Quantity array index for vertical velocity.

Definition at line 262 of file libtrac.h.

4.2.2.15 int ctl_t::qnt_h2o

Quantity array index for water vapor vmr.

Definition at line 265 of file libtrac.h.

4.2.2.16 int ctl_t::qnt_o3

Quantity array index for ozone vmr.

Definition at line 268 of file libtrac.h.

4.2.2.17 int ctl_t::qnt_theta

Quantity array index for potential temperature.

Definition at line 271 of file libtrac.h.

4.2.2.18 int ctl_t::qnt_pv

Quantity array index for potential vorticity.

Definition at line 274 of file libtrac.h.

4.2.2.19 int ctl_t::qnt_tice

Quantity array index for T_ice.

Definition at line 277 of file libtrac.h.

4.2.2.20 int ctl_t::qnt_tsts

Quantity array index for T_STS.

Definition at line 280 of file libtrac.h.

4.2.2.21 int ctl_t::qnt_tnat

Quantity array index for T_NAT.

Definition at line 283 of file libtrac.h.

4.2.2.22 int ctl_t::qnt_stat

Quantity array index for station flag.

Definition at line 286 of file libtrac.h.

4.2.2.23 int ctl_t::qnt_gw_u750

Quantity array index for low-level zonal wind.

Definition at line 289 of file libtrac.h.

4.2.2.24 int ctl_t::qnt_gw_v750

Quantity array index for low-level meridional wind.

Definition at line 292 of file libtrac.h.

4.2.2.25 int ctl_t::qnt_gw_sso

Quantity array index for subgrid-scale orography.

Definition at line 295 of file libtrac.h.

4.2.2.26 int ctl_t::qnt_gw_var

Quantity array index for gravity wave variances.

Definition at line 298 of file libtrac.h.

4.2.2.27 int ctl_t::direction

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

Definition at line 301 of file libtrac.h.

4.2.2.28 double ctl_t::t_start

Start time of simulation [s].

Definition at line 304 of file libtrac.h.

4.2.2.29 double ctl_t::t_stop

Stop time of simulation [s].

Definition at line 307 of file libtrac.h.

4.2.2.30 double ctl_t::dt_mod

Time step of simulation [s].

Definition at line 310 of file libtrac.h.

4.2.2.31 double ctl_t::dt_met

Time step of meteorological data [s].

Definition at line 313 of file libtrac.h.

4.2.2.32 int ctl_t::met_np

Number of target pressure levels.

Definition at line 316 of file libtrac.h.

4.2.2.33 double ctl_t::met_p[EP]

Target pressure levels [hPa].

Definition at line 319 of file libtrac.h.

4.2.2.34 char ctl_t::met_stage[LEN]

Command to stage meteo data.

Definition at line 322 of file libtrac.h.

4.2.2.35 int ctl_t::isosurf

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

Definition at line 326 of file libtrac.h.

4.2.2.36 char ctl_t::balloon[LEN]

Balloon position filename.

Definition at line 329 of file libtrac.h.

4.2.2.37 double ctl_t::turb_dx_trop

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

Definition at line 332 of file libtrac.h.

4.2.2.38 double ctl_t::turb_dx_strat

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

Definition at line 335 of file libtrac.h.

4.2.2.39 double ctl_t::turb_dz_trop

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

Definition at line 338 of file libtrac.h.

4.2.2.40 double ctl_t::turb_dz_strat

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

Definition at line 341 of file libtrac.h.

4.2.2.41 double ctl_t::turb_meso

Scaling factor for mesoscale wind fluctuations.

Definition at line 344 of file libtrac.h.

4.2.2.42 double ctl_t::tdec_trop

Life time of particles (troposphere) [s].

Definition at line 347 of file libtrac.h.

4.2.2.43 double ctl_t::tdec_strat

Life time of particles (stratosphere) [s].

Definition at line 350 of file libtrac.h.

4.2.2.44 double ctl_t::psc_h2o

H2O volume mixing ratio for PSC analysis.

Definition at line 353 of file libtrac.h.

4.2.2.45 double ctl_t::psc_hno3

HNO3 volume mixing ratio for PSC analysis.

Definition at line 356 of file libtrac.h.

4.2.2.46 char ctl_t::gw_basename[LEN]

Basename for gravity wave variance data.

Definition at line 359 of file libtrac.h.

4.2.2.47 char ctl_t::atm_basename[LEN]

Basename of atmospheric data files.

Definition at line 362 of file libtrac.h.

4.2.2.48 char ctl_t::atm_gpfile[LEN]

Gnuplot file for atmospheric data.

Definition at line 365 of file libtrac.h.

4.2.2.49 double ctl_t::atm_dt_out

Time step for atmospheric data output [s].

Definition at line 368 of file libtrac.h.

4.2.2.50 int ctl_t::atm_filter

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

Definition at line 371 of file libtrac.h.

4.2.2.51 char ctl_t::csi_basename[LEN]

Basename of CSI data files.

Definition at line 374 of file libtrac.h.

4.2.2.52 double ctl_t::csi_dt_out

Time step for CSI data output [s].

Definition at line 377 of file libtrac.h.

4.2.2.53 char ctl_t::csi_obsfile[LEN]

Observation data file for CSI analysis.

Definition at line 380 of file libtrac.h.

4.2.2.54 double ctl_t::csi_obsmin

Minimum observation index to trigger detection.

Definition at line 383 of file libtrac.h.

4.2.2.55 double ctl_t::csi_modmin

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

Definition at line 386 of file libtrac.h.

4.2.2.56 int ctl_t::csi_nz

Number of altitudes of gridded CSI data.

Definition at line 389 of file libtrac.h.

4.2.2.57 double ctl_t::csi_z0

Lower altitude of gridded CSI data [km].

Definition at line 392 of file libtrac.h.

4.2.2.58 double ctl_t::csi_z1

Upper altitude of gridded CSI data [km].

Definition at line 395 of file libtrac.h.

4.2.2.59 int ctl_t::csi_nx

Number of longitudes of gridded CSI data.

Definition at line 398 of file libtrac.h.

4.2.2.60 double ctl_t::csi_lon0

Lower longitude of gridded CSI data [deg].

Definition at line 401 of file libtrac.h.

4.2.2.61 double ctl_t::csi_lon1

Upper longitude of gridded CSI data [deg].

Definition at line 404 of file libtrac.h.

4.2.2.62 int ctl_t::csi_ny

Number of latitudes of gridded CSI data.

Definition at line 407 of file libtrac.h.

4.2.2.63 double ctl_t::csi_lat0

Lower latitude of gridded CSI data [deg].

Definition at line 410 of file libtrac.h.

4.2.2.64 double ctl_t::csi_lat1

Upper latitude of gridded CSI data [deg].

Definition at line 413 of file libtrac.h.

4.2.2.65 char ctl_t::grid_basename[LEN]

Basename of grid data files.

Definition at line 416 of file libtrac.h.

4.2.2.66 char ctl_t::grid_gpfile[LEN]

Gnuplot file for gridded data.

Definition at line 419 of file libtrac.h.

4.2.2.67 double ctl_t::grid_dt_out

Time step for gridded data output [s].

Definition at line 422 of file libtrac.h.

4.2.2.68 int ctl_t::grid_sparse

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

Definition at line 425 of file libtrac.h.

4.2.2.69 int ctl_t::grid_nz

Number of altitudes of gridded data.

Definition at line 428 of file libtrac.h.

4.2.2.70 double ctl_t::grid_z0

Lower altitude of gridded data [km].

Definition at line 431 of file libtrac.h.

4.2.2.71 double ctl_t::grid_z1

Upper altitude of gridded data [km].

Definition at line 434 of file libtrac.h.

4.2.2.72 int ctl_t::grid_nx

Number of longitudes of gridded data.

Definition at line 437 of file libtrac.h.

4.2.2.73 double ctl_t::grid_lon0

Lower longitude of gridded data [deg].

Definition at line 440 of file libtrac.h.

4.2.2.74 double ctl_t::grid_lon1

Upper longitude of gridded data [deg].

Definition at line 443 of file libtrac.h.

4.2.2.75 int ctl_t::grid_ny

Number of latitudes of gridded data.

Definition at line 446 of file libtrac.h.

4.2.2.76 double ctl_t::grid_lat0

Lower latitude of gridded data [deg].

Definition at line 449 of file libtrac.h.

4.2.2.77 double ctl_t::grid_lat1

Upper latitude of gridded data [deg].

Definition at line 452 of file libtrac.h.

4.2.2.78 char ctl_t::prof_basename[LEN]

Basename for profile output file.

Definition at line 455 of file libtrac.h.

4.2.2.79 char ctl_t::prof_obsfile[LEN]

Observation data file for profile output.

Definition at line 458 of file libtrac.h.

4.2.2.80 int ctl_t::prof_nz

Number of altitudes of gridded profile data.

Definition at line 461 of file libtrac.h.

4.2.2.81 double ctl_t::prof_z0

Lower altitude of gridded profile data [km].

Definition at line 464 of file libtrac.h.

4.2.2.82 double ctl_t::prof_z1

Upper altitude of gridded profile data [km].

Definition at line 467 of file libtrac.h.

4.2.2.83 int ctl_t::prof_nx

Number of longitudes of gridded profile data.

Definition at line 470 of file libtrac.h.

4.2.2.84 double ctl_t::prof_lon0

Lower longitude of gridded profile data [deg].

Definition at line 473 of file libtrac.h.

4.2.2.85 double ctl_t::prof_lon1

Upper longitude of gridded profile data [deg].

Definition at line 476 of file libtrac.h.

4.2.2.86 int ctl_t::prof_ny

Number of latitudes of gridded profile data.

Definition at line 479 of file libtrac.h.

4.2.2.87 double ctl_t::prof_lat0

Lower latitude of gridded profile data [deg].

Definition at line 482 of file libtrac.h.

4.2.2.88 double ctl_t::prof_lat1

Upper latitude of gridded profile data [deg].

Definition at line 485 of file libtrac.h.

4.2.2.89 char ctl_t::ens_basename[LEN]

Basename of ensemble data file.

Definition at line 488 of file libtrac.h.

4.2.2.90 char ctl_t::stat_basename[LEN]

Basename of station data file.

Definition at line 491 of file libtrac.h.

4.2.2.91 double ctl_t::stat_lon

Longitude of station [deg].

Definition at line 494 of file libtrac.h.

4.2.2.92 double ctl_t::stat_lat

Latitude of station [deg].

Definition at line 497 of file libtrac.h.

4.2.2.93 double ctl_t::stat_r

Search radius around station [km].

Definition at line 500 of file libtrac.h.

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

- libtrac.h

4.3 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].
- double ps [EX][EY]

  Surface pressure [hPa].
- float pl [EX][EY][EP]

  Pressure on model levels [hPa].
- 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 wind [hPa/s].
- float h2o [EX][EY][EP]

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

  Ozone volume mixing ratio [1].

4.3.1 Detailed Description

Meteorological data.

Definition at line 537 of file libtrac.h.

4.3.2 Field Documentation

4.3.2.1 double met_t::time

Time [s].

Definition at line 540 of file libtrac.h.

4.3.2.2 int met_t::nx

Number of longitudes.

Definition at line 543 of file libtrac.h.

4.3.2.3 int met_t::ny

Number of latitudes.

Definition at line 546 of file libtrac.h.

4.3.2.4 int met_t::np

Number of pressure levels.

Definition at line 549 of file libtrac.h.

4.3.2.5 double met_t::lon[EX]

Longitude [deg].

Definition at line 552 of file libtrac.h.

4.3.2.6 double met_t::lat[EY]

Latitude [deg].

Definition at line 555 of file libtrac.h.

4.3.2.7 double met_t::p[EP]

Pressure [hPa].

Definition at line 558 of file libtrac.h.

4.3.2.8 double met_t::ps[EX][EY]

Surface pressure [hPa].

Definition at line 561 of file libtrac.h.

4.3.2.9 float met_t::pl[EX][EY][EP]

Pressure on model levels [hPa].

Definition at line 564 of file libtrac.h.

4.3.2.10 float met_t::t[EX][EY][EP]

Temperature [K].

Definition at line 567 of file libtrac.h.

4.3.2.11 float met_t::u[EX][EY][EP]

Zonal wind [m/s].

Definition at line 570 of file libtrac.h.

4.3.2.12 float met_t::v[EX][EY][EP]

Meridional wind [m/s].

Definition at line 573 of file libtrac.h.

4.3.2.13 float met_t::w[EX][EY][EP]

Vertical wind [hPa/s].

Definition at line 576 of file libtrac.h.

4.3.2.14 float met_t::h2o[EX][EY][EP]

Water vapor volume mixing ratio [1].

Definition at line 579 of file libtrac.h.

4.3.2.15 float met_t::o3[EX][EY][EP]

Ozone volume mixing ratio [1].

Definition at line 582 of file libtrac.h.

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

- libtrac.h

5 File Documentation

5.1 center.c File Reference

Calculate center of mass of air parcels.

Functions

- int main (int argc, char ∗argv[ ])

5.1.1 Detailed Description

Calculate center of mass of air parcels.

Definition in file center.c.

5.1.2 Function Documentation

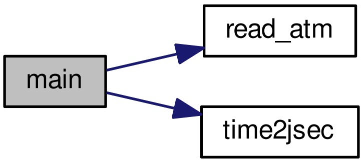
5.1.2.1 int main (int *argc*, char ∗ *argv[]*)

Definition at line 28 of file center.c.

```
              {

ctl_t ctl;

atm_t *atm;

FILE *out;

char tstr[LEN];

double latm, lats, lonm, lons, t, zm, zs;

int f, ip, year, mon, day, hour, min;

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

/* Check arguments... */
if (argc < 3)
  ERRMSG("Give parameters: <outfile> <atm1> [<atm2> ...]");

/* Write info... */
printf("Write center of mass data: %s\n", argv[1]);

/* Create output file... */
if (!(out = fopen(argv[1], "w")))
  ERRMSG("Cannot create file!");

/* Write header... */
fprintf(out,
        "# $1  = time [s]\n"
        "# $2  = altitude (mean) [km]\n"
        "# $3  = altitude (sigma) [km]\n"
        "# $4  = altitude (minimum) [km]\n"
        "# $5  = altitude (10%% percentile) [km]\n"
        "# $6  = altitude (1st quarter) [km]\n"
        "# $7  = altitude (median) [km]\n"
        "# $8  = altitude (3rd quarter) [km]\n"
        "# $9  = altitude (90%% percentile) [km]\n"
        "# $10 = altitude (maximum) [km]\n");
fprintf(out,
        "# $11 = longitude (mean) [deg]\n"
        "# $12 = longitude (sigma) [deg]\n"
        "# $13 = longitude (minimum) [deg]\n"
        "# $14 = longitude (10%% percentile) [deg]\n"
        "# $15 = longitude (1st quarter) [deg]\n"
        "# $16 = longitude (median) [deg]\n"
        "# $17 = longitude (3rd quarter) [deg]\n"
        "# $18 = longitude (90%% percentile) [deg]\n"
        "# $19 = longitude (maximum) [deg]\n");
fprintf(out,
        "# $20 = latitude (mean) [deg]\n"
        "# $21 = latitude (sigma) [deg]\n"
        "# $22 = latitude (minimum) [deg]\n"
        "# $23 = latitude (10%% percentile) [deg]\n"
        "# $24 = latitude (1st quarter) [deg]\n"
        "# $25 = latitude (median) [deg]\n"
        "# $26 = latitude (3rd quarter) [deg]\n"
        "# $27 = latitude (90%% percentile) [deg]\n"
        "# $28 = latitude (maximum) [deg]\n\n");

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

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

  /* Initialize... */
  zm = zs = 0;
  lonm = lons = 0;
  latm = lats = 0;

  /* Calculate mean and standard deviation... */
  for (ip = 0; ip < atm->np; ip++) {
    zm += Z(atm->p[ip]) / atm->np;
    lonm += atm->lon[ip] / atm->np;
```

```
      latm += atm->lat[ip] / atm->np;
      zs += gsl_pow_2(Z(atm->p[ip])) / atm->np;
      lons += gsl_pow_2(atm->lon[ip]) / atm->np;
      lats += gsl_pow_2(atm->lat[ip]) / atm->np;
    }

    /* Normalize... */
    zs = sqrt(zs - gsl_pow_2(zm));
    lons = sqrt(lons - gsl_pow_2(lonm));
    lats = sqrt(lats - gsl_pow_2(latm));

    /* Sort arrays... */
    gsl_sort(atm->p, 1, (size_t) atm->np);
    gsl_sort(atm->lon, 1, (size_t) atm->np);
    gsl_sort(atm->lat, 1, (size_t) atm->np);

    /* 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);

    /* 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\n",
            t, zm, zs, Z(atm->p[atm->np - 1]),
            Z(atm->p[atm->np - atm->np / 10]),
            Z(atm->p[atm->np - atm->np / 4]),
            Z(atm->p[atm->np / 2]), Z(atm->p[atm->np / 4]),
            Z(atm->p[atm->np / 10]), Z(atm->p[0]),
            lonm, lons, atm->lon[0], atm->lon[atm->np / 10],
            atm->lon[atm->np / 4], atm->lon[atm->np / 2],
            atm->lon[atm->np - atm->np / 4],
            atm->lon[atm->np - atm->np / 10],
            atm->lon[atm->np - 1],
            latm, lats, atm->lat[0], atm->lat[atm->np / 10],
            atm->lat[atm->np / 4], atm->lat[atm->np / 2],
            atm->lat[atm->np - atm->np / 4],
            atm->lat[atm->np - atm->np / 10], atm->lat[atm->np - 1]);
  }

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

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

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



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

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"
#include <gsl/gsl_sort.h>

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

  ctl_t ctl;

  atm_t *atm;

  FILE *out;

  char tstr[LEN];

  double latm, lats, lonm, lons, t, zm, zs;

  int f, ip, year, mon, day, hour, min;

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

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <outfile> <atm1> [<atm2> ...]");

  /* Write info... */
  printf("Write center of mass data: %s\n", argv[1]);

  /* Create output file... */
  if (!(out = fopen(argv[1], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1  = time [s]\n"
          "# $2  = altitude (mean) [km]\n"
          "# $3  = altitude (sigma) [km]\n"
          "# $4  = altitude (minimum) [km]\n"
          "# $5  = altitude (10%% percentile) [km]\n"
          "# $6  = altitude (1st quarter) [km]\n"
          "# $7  = altitude (median) [km]\n"
          "# $8  = altitude (3rd quarter) [km]\n"
          "# $9  = altitude (90%% percentile) [km]\n"
          "# $10 = altitude (maximum) [km]\n");
  fprintf(out,
          "# $11 = longitude (mean) [deg]\n"
          "# $12 = longitude (sigma) [deg]\n"
          "# $13 = longitude (minimum) [deg]\n"
          "# $14 = longitude (10%% percentile) [deg]\n"
          "# $15 = longitude (1st quarter) [deg]\n"
          "# $16 = longitude (median) [deg]\n"
          "# $17 = longitude (3rd quarter) [deg]\n"
          "# $18 = longitude (90%% percentile) [deg]\n"
          "# $19 = longitude (maximum) [deg]\n");
  fprintf(out,
          "# $20 = latitude (mean) [deg]\n"
          "# $21 = latitude (sigma) [deg]\n"
          "# $22 = latitude (minimum) [deg]\n"
          "# $23 = latitude (10%% percentile) [deg]\n"
          "# $24 = latitude (1st quarter) [deg]\n"
          "# $25 = latitude (median) [deg]\n"
          "# $26 = latitude (3rd quarter) [deg]\n"
          "# $27 = latitude (90%% percentile) [deg]\n"
          "# $28 = latitude (maximum) [deg]\n\n");

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

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

    /* Initialize... */
    zm = zs = 0;
    lonm = lons = 0;
    latm = lats = 0;

    /* Calculate mean and standard deviation... */
    for (ip = 0; ip < atm->np; ip++) {
      zm += Z(atm->p[ip]) / atm->np;
      lonm += atm->lon[ip] / atm->np;
      latm += atm->lat[ip] / atm->np;
      zs += gsl_pow_2(Z(atm->p[ip])) / atm->np;
      lons += gsl_pow_2(atm->lon[ip]) / atm->np;
      lats += gsl_pow_2(atm->lat[ip]) / atm->np;
    }

    /* Normalize... */
    zs = sqrt(zs - gsl_pow_2(zm));
    lons = sqrt(lons - gsl_pow_2(lonm));
    lats = sqrt(lats - gsl_pow_2(latm));

    /* Sort arrays... */
    gsl_sort(atm->p, 1, (size_t) atm->np);
    gsl_sort(atm->lon, 1, (size_t) atm->np);
    gsl_sort(atm->lat, 1, (size_t) atm->np);

    /* 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);

    /* 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\n",
            t, zm, zs, Z(atm->p[atm->np - 1]),
            Z(atm->p[atm->np - atm->np / 10]),
            Z(atm->p[atm->np - atm->np / 4]),
            Z(atm->p[atm->np / 2]), Z(atm->p[atm->np / 4]),
            Z(atm->p[atm->np / 10]), Z(atm->p[0]),
            lonm, lons, atm->lon[0], atm->lon[atm->np / 10],
            atm->lon[atm->np / 4], atm->lon[atm->np / 2],
            atm->lon[atm->np - atm->np / 4],
            atm->lon[atm->np - atm->np / 10],
            atm->lon[atm->np - 1],
            latm, lats, atm->lat[0], atm->lat[atm->np / 10],
            atm->lat[atm->np / 4], atm->lat[atm->np / 2],
            atm->lat[atm->np - atm->np / 4],
            atm->lat[atm->np - atm->np / 10], atm->lat[atm->np - 1]);
  }

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

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

  return EXIT_SUCCESS;
}
```

5.3 dist.c File Reference

Calculate transport deviations of trajectories.

Functions

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

5.3.1 Detailed Description

Calculate transport deviations of trajectories.

Definition in file dist.c.

5.3.2 Function Documentation

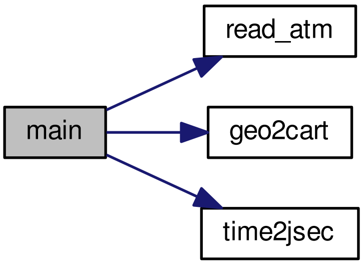
5.3.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 28 of file dist.c.

```
00030                 {
00031
00032   ctl_t ctl;
00033
00034   atm_t *atm1, *atm2;
00035
00036   FILE *out;
00037
00038   char tstr[LEN];
00039
00040   double aux, x0[3], x1[3], x2[3], *lon1, *lat1, *p1, *lh1, *lv1,
00041     *lon2, *lat2, *p2, *lh2, *lv2, ahtd, avtd, ahtd2, avtd2,
00042     rhtd, rvtd, rhtd2, rvtd2, t, *dh, *dv;
00043
00044   int f, ip, iph, ipv, year, mon, day, hour, min;
00045
00046   /* Allocate... */
00047   ALLOC(atm1, atm_t, 1);
00048   ALLOC(atm2, atm_t, 1);
00049   ALLOC(lon1, double,
00050         NP);
00051   ALLOC(lat1, double,
00052         NP);
00053   ALLOC(p1, double,
00054         NP);
00055   ALLOC(lh1, double,
00056         NP);
00057   ALLOC(lv1, double,
00058         NP);
00059   ALLOC(lon2, double,
00060         NP);
00061   ALLOC(lat2, double,
00062         NP);
00063   ALLOC(p2, double,
00064         NP);
00065   ALLOC(lh2, double,
00066         NP);
00067   ALLOC(lv2, double,
00068         NP);
00069   ALLOC(dh, double,
00070         NP);
00071   ALLOC(dv, double,
00072         NP);
00073
00074   /* Check arguments... */
00075   if (argc < 4)
00076     ERRMSG
00077       ("Give parameters: <outfile> <atm1a> <atm1b> [<atm2a> <atm2b> ...]");
00078
00079   /* Write info... */
00080   printf("Write transport deviations: %s\n", argv[1]);
00081
00082   /* Create output file... */
00083   if (!(out = fopen(argv[1], "w")))
00084     ERRMSG("Cannot create file!");
00085
00086   /* Write header... */
00087   fprintf(out,
00088           "# $1  = time [s]\n"
00089           "# $2  = AHTD (mean) [km]\n"
00090           "# $3  = AHTD (sigma) [km]\n"
00091           "# $4  = AHTD (minimum) [km]\n"
00092           "# $5  = AHTD (10%% percentile) [km]\n"
00093           "# $6  = AHTD (1st quartile) [km]\n"
00094           "# $7  = AHTD (median) [km]\n"
```

```
          "# $8  = AHTD (3rd quartile) [km]\n"
          "# $9  = AHTD (90%% percentile) [km]\n"
          "# $10 = AHTD (maximum) [km]\n"
          "# $11 = AHTD (maximum trajectory index)\n"
          "# $12 = RHTD (mean) [%%]\n" "# $13 = RHTD (sigma) [%%]\n");
  fprintf(out,
          "# $14 = AVTD (mean) [km]\n"
          "# $15 = AVTD (sigma) [km]\n"
          "# $16 = AVTD (minimum) [km]\n"
          "# $17 = AVTD (10%% percentile) [km]\n"
          "# $18 = AVTD (1st quartile) [km]\n"
          "# $19 = AVTD (median) [km]\n"
          "# $20 = AVTD (3rd quartile) [km]\n"
          "# $21 = AVTD (90%% percentile) [km]\n"
          "# $22 = AVTD (maximum) [km]\n"
          "# $23 = AVTD (maximum trajectory index)\n"
          "# $24 = RVTD (mean) [%%]\n" "# $25 = RVTD (sigma) [%%]\n\n");

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

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

    /* Check if structs match... */
    if (atm1->np != atm2->np)
      ERRMSG("Different numbers of parcels!");
    for (ip = 0; ip < atm1->np; ip++)
      if (atm1->time[ip] != atm2->time[ip])
        ERRMSG("Times do not match!");

    /* Init... */
    ahtd = ahtd2 = 0;
    avtd = avtd2 = 0;
    rhtd = rhtd2 = 0;
    rvtd = rvtd2 = 0;

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

      /* Get Cartesian coordinates... */
      geo2cart(0, atm1->lon[ip], atm1->lat[ip], x1);
      geo2cart(0, atm2->lon[ip], atm2->lat[ip], x2);

      /* Calculate absolute transport deviations... */
      dh[ip] = DIST(x1, x2);
      ahtd += dh[ip];
      ahtd2 += gsl_pow_2(dh[ip]);

      dv[ip] = fabs(Z(atm1->p[ip]) - Z(atm2->p[ip]));
      avtd += dv[ip];
      avtd2 += gsl_pow_2(dv[ip]);

      /* Calculate relative transport deviations... */
      if (f > 2) {

        /* Get trajectory lengths... */
        geo2cart(0, lon1[ip], lat1[ip], x0);
        lh1[ip] += DIST(x0, x1);
        lv1[ip] += fabs(Z(p1[ip]) - Z(atm1->p[ip]));

        geo2cart(0, lon2[ip], lat2[ip], x0);
        lh2[ip] += DIST(x0, x2);
        lv2[ip] += fabs(Z(p2[ip]) - Z(atm2->p[ip]));

        /* Get relative transport devations... */
        if (lh1[ip] + lh2[ip] > 0) {
          aux = 200. * DIST(x1, x2) / (lh1[ip] + lh2[ip]);
          rhtd += aux;
          rhtd2 += gsl_pow_2(aux);
        }
        if (lv1[ip] + lv2[ip] > 0) {
          aux =
            200. * fabs(Z(atm1->p[ip]) - Z(atm2->p[ip])) / (lv1[ip] +
                                                              lv2[ip]);
          rvtd += aux;
          rvtd2 += gsl_pow_2(aux);
        }
      }

      /* Save positions of air parcels... */
      lon1[ip] = atm1->lon[ip];
      lat1[ip] = atm1->lat[ip];
      p1[ip] = atm1->p[ip];

      lon2[ip] = atm2->lon[ip];
      lat2[ip] = atm2->lat[ip];
      p2[ip] = atm2->p[ip];
    }

    /* Get indices of trajectories with maximum errors... */
    iph = (int) gsl_stats_max_index(dh, 1, (size_t) atm1->np);
    ipv = (int) gsl_stats_max_index(dv, 1, (size_t) atm1->np);

    /* Sort distances to calculate percentiles... */
    gsl_sort(dh, 1, (size_t) atm1->np);
    gsl_sort(dv, 1, (size_t) atm1->np);

    /* 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);

    /* Write output... */
    fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %d %g %g"
            " %g %g %g %g %g %g %g %g %g %d %g %g\n", t,
            ahtd / atm1->np,
            sqrt(ahtd2 / atm1->np - gsl_pow_2(ahtd / atm1->np)),
            dh[0], dh[atm1->np / 10], dh[atm1->np / 4], dh[atm1->np / 2],
            dh[atm1->np - atm1->np / 4], dh[atm1->np - atm1->np / 10],
            dh[atm1->np - 1], iph, rhtd / atm1->np,
            sqrt(rhtd2 / atm1->np - gsl_pow_2(rhtd / atm1->np)),
            avtd / atm1->np,
            sqrt(avtd2 / atm1->np - gsl_pow_2(avtd / atm1->np)),
            dv[0], dv[atm1->np / 10], dv[atm1->np / 4], dv[atm1->np / 2],
            dv[atm1->np - atm1->np / 4], dv[atm1->np - atm1->np / 10],
            dv[atm1->np - 1], ipv, rvtd / atm1->np,
            sqrt(rvtd2 / atm1->np - gsl_pow_2(rvtd / atm1->np)));
  }

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

  /* Free... */
  free(atm1);
  free(atm2);
  free(lon1);
  free(lat1);
  free(p1);
  free(lh1);
  free(lv1);
  free(lon2);
  free(lat2);
  free(p2);
  free(lh2);
  free(lv2);
  free(dh);
  free(dv);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.4 dist.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.

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

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*/

#include "libtrac.h"
#include <gsl/gsl_sort.h>

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

  ctl_t ctl;

  atm_t *atm1, *atm2;

  FILE *out;

  char tstr[LEN];

  double aux, x0[3], x1[3], x2[3], *lon1, *lat1, *p1, *lh1, *lv1,
    *lon2, *lat2, *p2, *lh2, *lv2, ahtd, avtd, ahtd2, avtd2,
    rhtd, rvtd, rhtd2, rvtd2, t, *dh, *dv;

  int f, ip, iph, ipv, year, mon, day, hour, min;

  /* Allocate... */
  ALLOC(atm1, atm_t, 1);
  ALLOC(atm2, atm_t, 1);
  ALLOC(lon1, double,
        NP);
  ALLOC(lat1, double,
        NP);
  ALLOC(p1, double,
        NP);
  ALLOC(lh1, double,
        NP);
  ALLOC(lv1, double,
        NP);
  ALLOC(lon2, double,
        NP);
  ALLOC(lat2, double,
        NP);
  ALLOC(p2, double,
        NP);
  ALLOC(lh2, double,
        NP);
  ALLOC(lv2, double,
        NP);
  ALLOC(dh, double,
        NP);
  ALLOC(dv, double,
        NP);

  /* Check arguments... */
  if (argc < 4)
    ERRMSG
      ("Give parameters: <outfile> <atm1a> <atm1b> [<atm2a> <atm2b> ...]");

  /* Write info... */
  printf("Write transport deviations: %s\n", argv[1]);

  /* Create output file... */
  if (!(out = fopen(argv[1], "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1  = time [s]\n"
          "# $2  = AHTD (mean) [km]\n"
          "# $3  = AHTD (sigma) [km]\n"
          "# $4  = AHTD (minimum) [km]\n"
          "# $5  = AHTD (10%% percentile) [km]\n"
          "# $6  = AHTD (1st quartile) [km]\n"
          "# $7  = AHTD (median) [km]\n"
          "# $8  = AHTD (3rd quartile) [km]\n"
          "# $9  = AHTD (90%% percentile) [km]\n"
          "# $10 = AHTD (maximum) [km]\n"
          "# $11 = AHTD (maximum trajectory index)\n"
          "# $12 = RHTD (mean) [%%]\n" "# $13 = RHTD (sigma) [%%]\n");
  fprintf(out,
          "# $14 = AVTD (mean) [km]\n"
          "# $15 = AVTD (sigma) [km]\n"
          "# $16 = AVTD (minimum) [km]\n"
          "# $17 = AVTD (10%% percentile) [km]\n"
          "# $18 = AVTD (1st quartile) [km]\n"
          "# $19 = AVTD (median) [km]\n"
          "# $20 = AVTD (3rd quartile) [km]\n"
          "# $21 = AVTD (90%% percentile) [km]\n"
          "# $22 = AVTD (maximum) [km]\n"
          "# $23 = AVTD (maximum trajectory index)\n"
          "# $24 = RVTD (mean) [%%]\n" "# $25 = RVTD (sigma) [%%]\n\n");

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

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

    /* Check if structs match... */
    if (atm1->np != atm2->np)
      ERRMSG("Different numbers of parcels!");
    for (ip = 0; ip < atm1->np; ip++)
      if (atm1->time[ip] != atm2->time[ip])
        ERRMSG("Times do not match!");

    /* Init... */
    ahtd = ahtd2 = 0;
    avtd = avtd2 = 0;
    rhtd = rhtd2 = 0;
    rvtd = rvtd2 = 0;

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

      /* Get Cartesian coordinates... */
      geo2cart(0, atm1->lon[ip], atm1->lat[ip], x1);
      geo2cart(0, atm2->lon[ip], atm2->lat[ip], x2);

      /* Calculate absolute transport deviations... */
      dh[ip] = DIST(x1, x2);
      ahtd += dh[ip];
      ahtd2 += gsl_pow_2(dh[ip]);

      dv[ip] = fabs(Z(atm1->p[ip]) - Z(atm2->p[ip]));
      avtd += dv[ip];
      avtd2 += gsl_pow_2(dv[ip]);

      /* Calculate relative transport deviations... */
      if (f > 2) {

        /* Get trajectory lengths... */
        geo2cart(0, lon1[ip], lat1[ip], x0);
        lh1[ip] += DIST(x0, x1);
        lv1[ip] += fabs(Z(p1[ip]) - Z(atm1->p[ip]));

        geo2cart(0, lon2[ip], lat2[ip], x0);
        lh2[ip] += DIST(x0, x2);
        lv2[ip] += fabs(Z(p2[ip]) - Z(atm2->p[ip]));

        /* Get relative transport devations... */
        if (lh1[ip] + lh2[ip] > 0) {
          aux = 200. * DIST(x1, x2) / (lh1[ip] + lh2[ip]);
          rhtd += aux;
          rhtd2 += gsl_pow_2(aux);
        }
        if (lv1[ip] + lv2[ip] > 0) {
          aux =
            200. * fabs(Z(atm1->p[ip]) - Z(atm2->p[ip])) / (lv1[ip] +
                                                            lv2[ip]);
          rvtd += aux;
          rvtd2 += gsl_pow_2(aux);
        }
      }

      /* Save positions of air parcels... */
      lon1[ip] = atm1->lon[ip];
      lat1[ip] = atm1->lat[ip];
      p1[ip] = atm1->p[ip];

      lon2[ip] = atm2->lon[ip];
      lat2[ip] = atm2->lat[ip];
      p2[ip] = atm2->p[ip];
    }

    /* Get indices of trajectories with maximum errors... */
    iph = (int) gsl_stats_max_index(dh, 1, (size_t) atm1->np);
    ipv = (int) gsl_stats_max_index(dv, 1, (size_t) atm1->np);

    /* Sort distances to calculate percentiles... */
    gsl_sort(dh, 1, (size_t) atm1->np);
    gsl_sort(dv, 1, (size_t) atm1->np);

    /* 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);

    /* Write output... */
    fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %d %g %g"
            " %g %g %g %g %g %g %g %g %g %d %g %g\n", t,
            ahtd / atm1->np,
            sqrt(ahtd2 / atm1->np - gsl_pow_2(ahtd / atm1->np)),
            dh[0], dh[atm1->np / 10], dh[atm1->np / 4], dh[atm1->np / 2],
            dh[atm1->np - atm1->np / 4], dh[atm1->np - atm1->np / 10],
            dh[atm1->np - 1], iph, rhtd / atm1->np,
            sqrt(rhtd2 / atm1->np - gsl_pow_2(rhtd / atm1->np)),
            avtd / atm1->np,
            sqrt(avtd2 / atm1->np - gsl_pow_2(avtd / atm1->np)),
            dv[0], dv[atm1->np / 10], dv[atm1->np / 4], dv[atm1->np / 2],
            dv[atm1->np - atm1->np / 4], dv[atm1->np - atm1->np / 10],
            dv[atm1->np - 1], ipv, rvtd / atm1->np,
            sqrt(rvtd2 / atm1->np - gsl_pow_2(rvtd / atm1->np)));
  }

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

  /* Free... */
  free(atm1);
  free(atm2);
  free(lon1);
  free(lat1);
  free(p1);
  free(lh1);
  free(lv1);
  free(lon2);
  free(lat2);
  free(p2);
  free(lh2);
  free(lv2);
  free(dh);
  free(dv);

  return EXIT_SUCCESS;
}
```

5.5 extract.c File Reference

Extract single trajectory from atmospheric data files.

Functions

- int main (int argc, char ∗argv[ ])

5.5.1 Detailed Description

Extract single trajectory from atmospheric data files.

Definition in file extract.c.

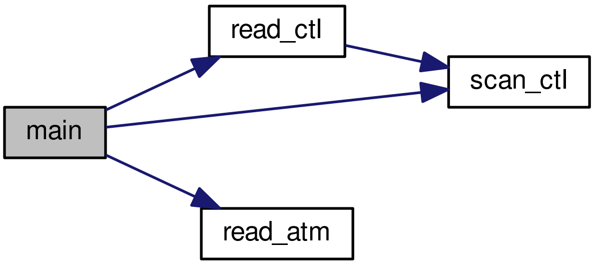
5.5.2 Function Documentation

5.5.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 28 of file extract.c.

```
                {

  ctl_t ctl;

  atm_t *atm;

  FILE *in, *out;

  int f, ip, iq;

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

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

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  ip = (int) scan_ctl(argv[1], argc, argv, "EXTRACT_IP", -1, "0", NULL);

  /* Write info... */
  printf("Write trajectory data: %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 = 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");

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

    /* Read atmopheric data... */
    if (!(in = fopen(argv[f], "r")))
      continue;
    else
      fclose(in);
    read_atm(argv[f], &ctl, atm);

    /* Write data... */
    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);

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

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.6 extract.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/>.

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/
```

```

#include "libtrac.h"
#include <gsl/gsl_sort.h>

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

  ctl_t ctl;

  atm_t *atm;

  FILE *in, *out;

  int f, ip, iq;

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

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

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  ip = (int) scan_ctl(argv[1], argc, argv, "EXTRACT_IP", -1, "0", NULL);

  /* Write info... */
  printf("Write trajectory data: %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 = 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");

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

    /* Read atmopheric data... */
    if (!(in = fopen(argv[f], "r")))
      continue;
    else
      fclose(in);
    read_atm(argv[f], &ctl, atm);

    /* Write data... */
    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);

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

  return EXIT_SUCCESS;
}
```

5.7 init.c File Reference

Create atmospheric data file with initial air parcel positions.

Functions

- int main (int argc, char ∗argv[ ])

5.7.1 Detailed Description

Create atmospheric data file with initial air parcel positions.

Definition in file init.c.

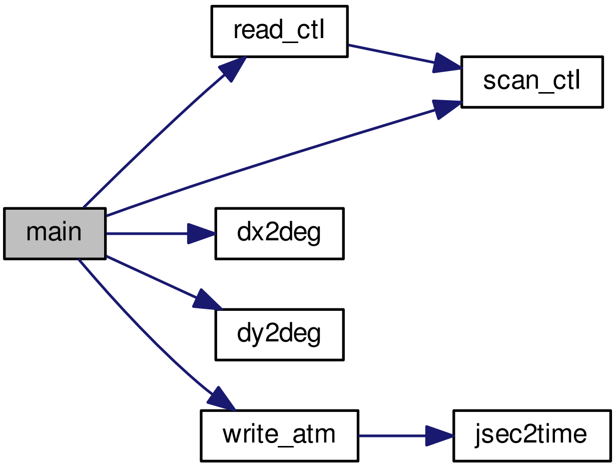
5.7.2 Function Documentation

5.7.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file 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, "1", 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));
            do {
              atm->p[atm->np]
                = P(z + gsl_ran_gaussian_ziggurat(rng, sz / 2.3548)
                    + uz * (gsl_rng_uniform(rng) - 0.5));
            } while (atm->p[atm->np] < 0);
            do {
              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));
            } while (atm->lon[atm->np] < -180 || atm->lon[atm->np] >= 180);
            do {
              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 (atm->lat[atm->np] < -90 || atm->lat[atm->np] >= 90);
            } 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, t0);

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

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.8 init.c

```
/*
```

```
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  the Free Software Foundation, either version 3 of the License, or
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  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/>.

  Copright (C) 2013-2015 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, "1", 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));
            do {
              atm->p[atm->np]
                = P(z + gsl_ran_gaussian_ziggurat(rng, sz / 2.3548)
                    + uz * (gsl_rng_uniform(rng) - 0.5));
            } while (atm->p[atm->np] < 0);
            do {
              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));
            } while (atm->lon[atm->np] < -180 || atm->lon[atm->np] >= 180);
            do {
              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 (atm->lat[atm->np] < -90 || atm->lat[atm->np] >= 90);
            } 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, t0);

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

  return EXIT_SUCCESS;
}
```

5.9 jsec2time.c File Reference

Convert Julian seconds to date.

Functions

- int main (int argc, char ∗argv[ ])

5.9.1 Detailed Description

Convert Julian seconds to date.

Definition in file jsec2time.c.

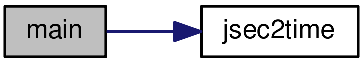
5.9.2 Function Documentation

5.9.2.1 int main (int *argc*, char ∗ *argv[ ]*)

Definition at line 27 of file jsec2time.c.

```
                {

  double jsec, remain;

  int day, hour, min, mon, sec, year;

  /* Check arguments... */
  if (argc < 2)
    ERRMSG("Give parameters: <jsec>");

  /* Read arguments... */
  jsec = atof(argv[1]);

  /* 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;
}
```

Here is the call graph for this function:



5.10 jsec2time.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/>.

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

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

  double jsec, remain;

  int day, hour, min, mon, sec, year;

  /* Check arguments... */
  if (argc < 2)
    ERRMSG("Give parameters: <jsec>");

  /* Read arguments... */
  jsec = atof(argv[1]);

  /* 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;
}
```

5.11 libtrac.c File Reference

MPTRAC library definitions.

Functions

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

  Convert Cartesian coordinates to geolocation.
- double deg2dx (double dlon, double lat)

  Convert degrees to horizontal distance.
- double deg2dy (double dlat)

  Convert degrees to horizontal distance.
- double dp2dz (double dp, double p)

  Convert pressure to vertical distance.
- double dx2deg (double dx, double lat)

  Convert horizontal distance to degrees.
- double dy2deg (double dy)

  Convert horizontal distance to degrees.
- double dz2dp (double dz, double p)

  Convert vertical distance to pressure.
- void geo2cart (double z, double lon, double lat, double ∗x)

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

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

  Get meteorological data for timestep.
- void intpol_met_2d (double array[EX][EY], int ix, int iy, double wx, double wy, double ∗var)

  Linear interpolation of 2-D meteorological data.
- void intpol_met_3d (float array[EX][EY][EP], int ip, int ix, int iy, double wp, double wx, double wy, double ∗var)

  Linear interpolation of 3-D meteorological data.
- void intpol_met_space (met_t ∗met, double p, double lon, double lat, double ∗ps, double ∗t, double ∗u, double ∗v, double ∗w, double ∗h2o, double ∗o3)

  Spatial interpolation of meteorological data.
- void intpol_met_time (met_t ∗met0, met_t ∗met1, double ts, double p, double lon, double lat, double ∗ps, double ∗t, double ∗u, double ∗v, double ∗w, double ∗h2o, double ∗o3)

  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.
- int locate (double ∗xx, int n, double x)

  Find array index.
- void 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.
- void read_met (ctl_t ∗ctl, char ∗filename, met_t ∗met)

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

  Extrapolate meteorological data at lower boundary.
- void read_met_help (int ncid, char ∗varname, char ∗varname2, met_t ∗met, float dest[EX][EY][EP], float scl)

  Read and convert variable from meteorological data file.

- 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.
- 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.
- 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 id, int mode)

  Measure wall-clock time.
- double tropopause (double t, double lat)
- 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_station (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write station data.

5.11.1 Detailed Description

MPTRAC library definitions.

Definition in file libtrac.c.

5.11.2 Function Documentation

5.11.2.1 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;

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

5.11.2.2 double deg2dx (double *dlon,* double *lat*)

Convert degrees to horizontal distance.

Definition at line 45 of file libtrac.c.

```
                  {

  return dlon * M_PI * RE / 180. * cos(lat / 180. * M_PI);
}
```

5.11.2.3 double deg2dy (double *dlat*)

Convert degrees to horizontal distance.

Definition at line 54 of file libtrac.c.

```
                   {

  return dlat * M_PI * RE / 180.;
}
```

5.11.2.4 double dp2dz (double *dp,* double *p*)

Convert pressure to vertical distance.

Definition at line 62 of file libtrac.c.

```
               {

  return -dp * H0 / p;
}
```

5.11.2.5 double dx2deg (double *dx,* double *lat*)

Convert horizontal distance to degrees.

Definition at line 71 of file libtrac.c.

```
                  {

  /* Avoid singularity at poles... */
  if (lat < -89.999 || lat > 89.999)
    return 0;
  else
    return dx * 180. / (M_PI * RE * cos(lat / 180. * M_PI));
}
```

5.11.2.6 double dy2deg (double *dy*)

Convert horizontal distance to degrees.

Definition at line 84 of file libtrac.c.

```
                 {

  return dy * 180. / (M_PI * RE);
}
```

5.11.2.7 double dz2dp (double *dz,* double *p*)

Convert vertical distance to pressure.

Definition at line 92 of file libtrac.c.

```
              {

  return -dz * p / H0;
}
```

5.11.2.8 void geo2cart (double *z,* double *lon,* double *lat,* double ∗ *x*)

Convert geolocation to Cartesian coordinates.

Definition at line 101 of file libtrac.c.

```
               {

  double radius;

  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);
}
```

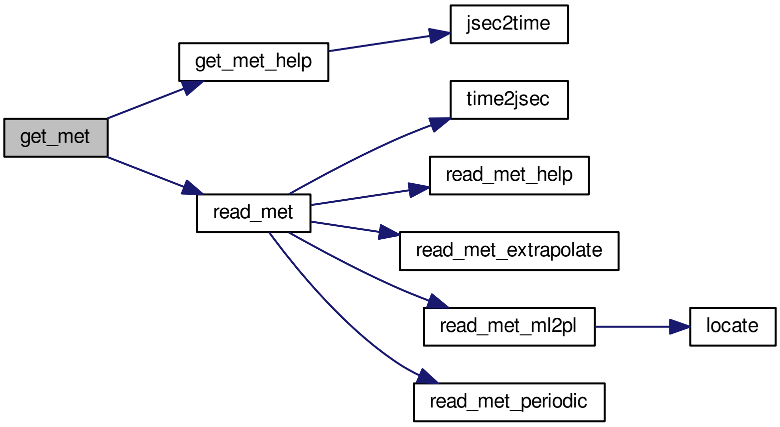
5.11.2.9 void get_met (ctl_t ∗ *ctl,* char ∗ *metbase,* double *t,* met_t ∗ *met0,* met_t ∗ *met1*)

Get meteorological data for given timestep.

Definition at line 117 of file libtrac.c.

```
                  {

  char filename[LEN];

  static int init;

  /* Init... */
  if (!init) {
    init = 1;

    get_met_help(t, -1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met0);

    get_met_help(t + 1.0 * ctl->direction, 1, metbase, ctl->
dt_met, filename);
    read_met(ctl, filename, met1);
  }

  /* Read new data for forward trajectories... */
  if (t > met1->time && ctl->direction == 1) {
    memcpy(met0, met1, sizeof(met_t));
    get_met_help(t, 1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met1);
  }

  /* Read new data for backward trajectories... */
  if (t < met0->time && ctl->direction == -1) {
    memcpy(met1, met0, sizeof(met_t));
    get_met_help(t, -1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met0);
  }
}
```

Here is the call graph for this function:



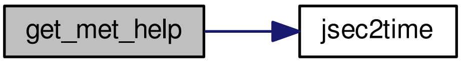
5.11.2.10 void get_met_help (double *t*, int *direct*, char ∗ *metbase*, double *dt_met*, char ∗ *filename*)

Get meteorological data for timestep.

Definition at line 156 of file libtrac.c.

```
                  {

  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_%d_%02d_%02d_%02d.nc", metbase, year, mon, day, hour);
}
```

Here is the call graph for this function:



5.11.2.11 void intpol_met_2d (double *array[EX][EY]*, int *ix*, int *iy*, double *wx*, double *wy*, double ∗ *var*)

Linear interpolation of 2-D meteorological data.

Definition at line 182 of file libtrac.c.

```
                 {

  double aux00, aux01, aux10, aux11;

  /* Set variables... */
  aux00 = array[ix][iy];
  aux01 = array[ix][iy + 1];
  aux10 = array[ix + 1][iy];
  aux11 = array[ix + 1][iy + 1];

  /* Interpolate horizontally... */
  aux00 = wy * (aux00 - aux01) + aux01;
  aux11 = wy * (aux10 - aux11) + aux11;
  *var = wx * (aux00 - aux11) + aux11;
}
```

5.11.2.12 void intpol_met_3d (float *array[EX][EY][EP]*, int *ip*, int *ix*, int *iy*, double *wp*, double *wx*, double *wy*, double ∗ *var*)

Linear interpolation of 3-D meteorological data.

Definition at line 206 of file libtrac.c.

```
                 {

  double aux00, aux01, aux10, aux11;

  /* Interpolate vertically... */
  aux00 = wp * (array[ix][iy][ip] - array[ix][iy][ip + 1])
    + array[ix][iy][ip + 1];
  aux01 = wp * (array[ix][iy + 1][ip] - array[ix][iy + 1][ip + 1])
    + array[ix][iy + 1][ip + 1];
  aux10 = wp * (array[ix + 1][iy][ip] - array[ix + 1][iy][ip + 1])
    + array[ix + 1][iy][ip + 1];
  aux11 = wp * (array[ix + 1][iy + 1][ip] - array[ix + 1][iy + 1][ip + 1])
    + array[ix + 1][iy + 1][ip + 1];

  /* Interpolate horizontally... */
  aux00 = wy * (aux00 - aux01) + aux01;
  aux11 = wy * (aux10 - aux11) + aux11;
  *var = wx * (aux00 - aux11) + aux11;
}
```

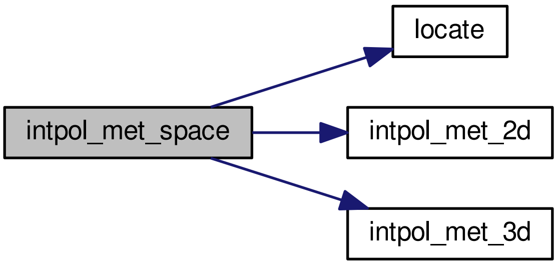
5.11.2.13 void intpol_met_space (met_t ∗ *met*, double *p*, double *lon*, double *lat*, double ∗ *ps*, double ∗ *t*, double ∗ *u*, double ∗ *v*, double ∗ *w*, double ∗ *h2o*, double ∗ *o3*)

Spatial interpolation of meteorological data.

Definition at line 236 of file libtrac.c.

```
                {

  double wp, wx, wy;

  int ip, ix, iy;

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

  /* Get indices... */
  ip = locate(met->p, met->np, p);
  ix = locate(met->lon, met->nx, lon);
  iy = locate(met->lat, met->ny, lat);
  /* Get weights... */
  wp = (met->p[ip + 1] - p) / (met->p[ip + 1] - met->p[ip]);
  wx = (met->lon[ix + 1] - lon) / (met->lon[ix + 1] - met->lon[ix]);
  wy = (met->lat[iy + 1] - lat) / (met->lat[iy + 1] - met->lat[iy]);

  /* Interpolate... */
  if (ps != NULL)
    intpol_met_2d(met->ps, ix, iy, wx, wy, ps);
  if (t != NULL)
    intpol_met_3d(met->t, ip, ix, iy, wp, wx, wy, t);
  if (u != NULL)
    intpol_met_3d(met->u, ip, ix, iy, wp, wx, wy, u);
  if (v != NULL)
    intpol_met_3d(met->v, ip, ix, iy, wp, wx, wy, v);
  if (w != NULL)
    intpol_met_3d(met->w, ip, ix, iy, wp, wx, wy, w);
  if (h2o != NULL)
    intpol_met_3d(met->h2o, ip, ix, iy, wp, wx, wy, h2o);
  if (o3 != NULL)
    intpol_met_3d(met->o3, ip, ix, iy, wp, wx, wy, o3);
}
```

Here is the call graph for this function:



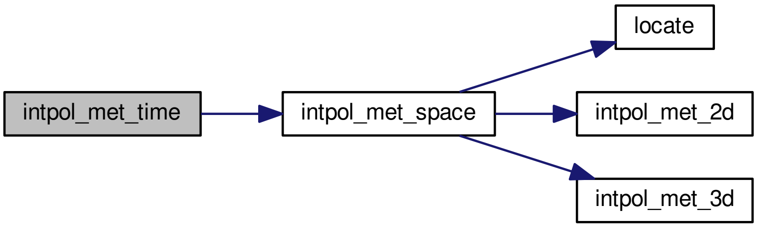
5.11.2.14 void intpol_met_time (met_t ∗ *met0,* met_t ∗ *met1,* double *ts,* double *p,* double *lon,* double *lat,* double ∗ *ps,* double ∗ *t,* double ∗ *u,* double ∗ *v,* double ∗ *w,* double ∗ *h2o,* double ∗ *o3*)

Temporal interpolation of meteorological data.

Definition at line 286 of file libtrac.c.

```
              {

  double h2o0, h2o1, o30, o31, ps0, ps1, t0, t1, u0, u1, v0, v1, w0, w1, wt;

  /* Spatial interpolation... */
  intpol_met_space(met0, p, lon, lat,
                   ps == NULL ? NULL : &ps0,
                   t == NULL ? NULL : &t0,
                   u == NULL ? NULL : &u0,
                   v == NULL ? NULL : &v0,
                   w == NULL ? NULL : &w0,
                   h2o == NULL ? NULL : &h2o0, o3 == NULL ? NULL : &o30);
  intpol_met_space(met1, p, lon, lat,
                   ps == NULL ? NULL : &ps1,
                   t == NULL ? NULL : &t1,
                   u == NULL ? NULL : &u1,
                   v == NULL ? NULL : &v1,
                   w == NULL ? NULL : &w1,
                   h2o == NULL ? NULL : &h2o1, o3 == NULL ? NULL : &o31);

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

  /* Interpolate... */
  if (ps != NULL)
    *ps = wt * (ps0 - ps1) + ps1;
  if (t != NULL)
    *t = wt * (t0 - t1) + t1;
  if (u != NULL)
    *u = wt * (u0 - u1) + u1;
  if (v != NULL)
    *v = wt * (v0 - v1) + v1;
  if (w != NULL)
    *w = wt * (w0 - w1) + w1;
  if (h2o != NULL)
    *h2o = wt * (h2o0 - h2o1) + h2o1;
  if (o3 != NULL)
    *o3 = wt * (o30 - o31) + o31;
}
```

Here is the call graph for this function:



5.11.2.15 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 341 of file libtrac.c.

```
                    {

  struct tm t0, *t1;

  time_t jsec0;

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

  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);
}
```

5.11.2.16 int locate (double ∗ *xx,* int *n,* double *x*)

Find array index.

Definition at line 376 of file libtrac.c.

```
            {

  int i, ilo, ihi;

  ilo = 0;
  ihi = n - 1;
  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;
}
```

5.11.2.17 void read_atm (const char ∗ *filename,* ctl_t ∗ *ctl,* atm_t ∗ *atm*)

Read atmospheric data.

Definition at line 408 of file libtrac.c.

```
               {

  FILE *in;

  char line[LEN], *tok;

  int iq;

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

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

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

  /* 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);

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

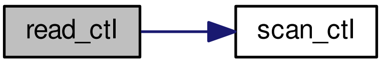
5.11.2.18 void read_ctl (const char * *filename,* int *argc,* char * *argv[ ],* ctl_t * *ctl*)

Read control parameters.

Definition at line 458 of file libtrac.c.

```
               {

  int ip, iq;

  /* 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_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_theta = -1;
  ctl->qnt_pv = -1;
  ctl->qnt_tice = -1;
  ctl->qnt_tsts = -1;
  ctl->qnt_tnat = -1;
  ctl->qnt_gw_var = -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 (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 (strcmp(ctl->qnt_name[iq], "ens") == 0) {
      ctl->qnt_ens = iq;
      sprintf(ctl->qnt_unit[iq], "-");
    } else if (strcmp(ctl->qnt_name[iq], "m") == 0) {
      ctl->qnt_m = iq;
      sprintf(ctl->qnt_unit[iq], "kg");
    } else if (strcmp(ctl->qnt_name[iq], "r") == 0) {
      ctl->qnt_r = iq;
      sprintf(ctl->qnt_unit[iq], "m");
    } else if (strcmp(ctl->qnt_name[iq], "rho") == 0) {
      ctl->qnt_rho = iq;
      sprintf(ctl->qnt_unit[iq], "kg/m^3");
    } else if (strcmp(ctl->qnt_name[iq], "ps") == 0) {
      ctl->qnt_ps = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcmp(ctl->qnt_name[iq], "p") == 0) {
      ctl->qnt_p = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcmp(ctl->qnt_name[iq], "t") == 0) {
      ctl->qnt_t = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "u") == 0) {
      ctl->qnt_u = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcmp(ctl->qnt_name[iq], "v") == 0) {
      ctl->qnt_v = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcmp(ctl->qnt_name[iq], "w") == 0) {
      ctl->qnt_w = iq;
      sprintf(ctl->qnt_unit[iq], "hPa/s");
    } else if (strcmp(ctl->qnt_name[iq], "h2o") == 0) {
      ctl->qnt_h2o = iq;
      sprintf(ctl->qnt_unit[iq], "1");
    } else if (strcmp(ctl->qnt_name[iq], "o3") == 0) {
      ctl->qnt_o3 = iq;
      sprintf(ctl->qnt_unit[iq], "1");
    } else if (strcmp(ctl->qnt_name[iq], "theta") == 0) {
      ctl->qnt_theta = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "pv") == 0) {
      ctl->qnt_pv = iq;
      sprintf(ctl->qnt_unit[iq], "PVU");
    } else if (strcmp(ctl->qnt_name[iq], "tice") == 0) {
      ctl->qnt_tice = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "tsts") == 0) {
      ctl->qnt_tsts = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "tnat") == 0) {
      ctl->qnt_tnat = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "gw_var") == 0) {
      ctl->qnt_gw_var = iq;
      sprintf(ctl->qnt_unit[iq], "K^2");
    } else if (strcmp(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_start =
    scan_ctl(filename, argc, argv, "T_START", -1, "-1e100", NULL);
  ctl->t_stop = scan_ctl(filename, argc, argv, "T_STOP", -1, "-1e100", NULL);
  ctl->dt_mod = scan_ctl(filename, argc, argv, "DT_MOD", -1, "600", NULL);

  /* Meteorological data... */
  ctl->dt_met = scan_ctl(filename, argc, argv, "DT_MET", -1, "21600", 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 (ip = 0; ip < ctl->met_np; ip++)
    ctl->met_p[ip] = scan_ctl(filename, argc, argv, "MET_P", ip, "", NULL);
  scan_ctl(filename, argc, argv, "MET_STAGE", -1, "-", ctl->met_stage);

  /* 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, "50.0", NULL);
  ctl->turb_dx_strat
    = scan_ctl(filename, argc, argv, "TURB_DX_STRAT", -1, "0.0", NULL);
  ctl->turb_dz_trop
    = scan_ctl(filename, argc, argv, "TURB_DZ_TROP", -1, "0.0", NULL);
  ctl->turb_dz_strat
    = scan_ctl(filename, argc, argv, "TURB_DZ_STRAT", -1, "0.1", NULL);
  ctl->turb_meso =
    scan_ctl(filename, argc, argv, "TURB_MESO", -1, "0.16", NULL);

  /* Life time of particles... */
  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);

  /* 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);

  /* Gravity wave analysis... */
  scan_ctl(filename, argc, argv, "GW_BASENAME", -1, "-", ctl->
gw_basename);

  /* 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);

  /* 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, "obs.tab",
           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 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:



5.11.2.19 void read_met (ctl_t ∗ *ctl*, char ∗ *filename*, met_t ∗ *met*)

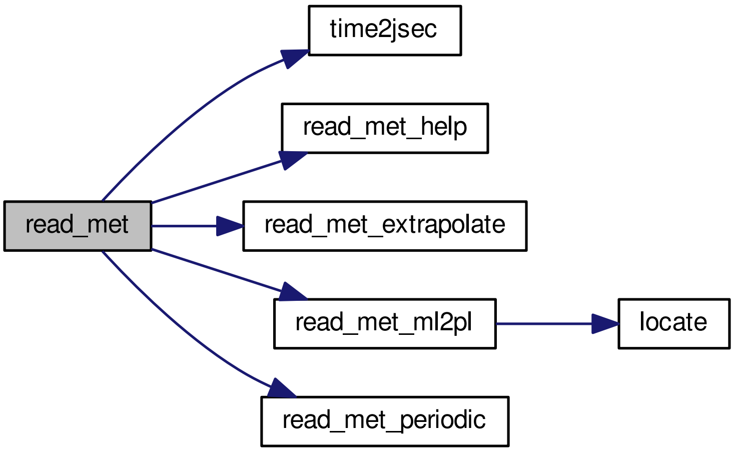
Read meteorological data file.

Definition at line 704 of file libtrac.c.

```
             {

char cmd[LEN], levname[LEN], tstr[10];

static float help[EX * EY];

int ix, iy, ip, dimid, ncid, varid, year, mon, day, hour;

size_t np, nx, ny;

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

/* 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);

/* Open netCDF file... */
if (nc_open(filename, NC_NOWRITE, &ncid) != NC_NOERR) {

  /* Try to stage meteo file... */
  START_TIMER(TIMER_STAGE);
  if (ctl->met_stage[0] != '-') {
    sprintf(cmd, "%s %d %02d %02d %02d %s", ctl->met_stage,
            year, mon, day, hour, filename);
    if (system(cmd) != 0)
      ERRMSG("Error while staging meteo data!");
  }
  STOP_TIMER(TIMER_STAGE);

  /* Try to open again... */
  NC(nc_open(filename, NC_NOWRITE, &ncid));
}

/* Get 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");
```

```
    NC(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;

  /* Get horizontal grid... */
  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 meteorological data... */
  read_met_help(ncid, "t", "T", met, met->t, 1.0);
  read_met_help(ncid, "u", "U", met, met->u, 1.0);
  read_met_help(ncid, "v", "V", met, met->v, 1.0);
  read_met_help(ncid, "w", "W", met, met->w, 0.01f);
  read_met_help(ncid, "q", "Q", met, met->h2o, 1.608f);
  read_met_help(ncid, "o3", "O3", met, met->o3, 0.602f);

  /* Meteo data on pressure levels... */
  if (ctl->met_np <= 0) {

    /* Read pressure levels from file... */
    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.;

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

  /* Meteo data on model levels... */
  else {

    /* Read pressure data from file... */
    read_met_help(ncid, "pl", "PL", met, met->pl, 0.01f);

    /* Interpolate from model levels 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);

    /* Set pressure levels... */
    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!");

  /* Read surface pressure... */
  if (nc_inq_varid(ncid, "ps", &varid) == NC_NOERR
      || nc_inq_varid(ncid, "PS", &varid) == NC_NOERR) {
    NC(nc_get_var_float(ncid, varid, help));
    for (iy = 0; iy < met->ny; iy++)
      for (ix = 0; ix < met->nx; ix++)
        met->ps[ix][iy] = help[iy * met->nx + ix] / 100.;
  } else if (nc_inq_varid(ncid, "lnsp", &varid) == NC_NOERR
             || nc_inq_varid(ncid, "LNSP", &varid) == NC_NOERR) {
    NC(nc_get_var_float(ncid, varid, help));
    for (iy = 0; iy < met->ny; iy++)
      for (ix = 0; ix < met->nx; ix++)
        met->ps[ix][iy] = exp(help[iy * met->nx + ix]) / 100.;
  } else
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        met->ps[ix][iy] = met->p[0];

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

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

Here is the call graph for this function:



5.11.2.20 void read_met_extrapolate (met_t * *met*)

Extrapolate meteorological data at lower boundary.

Definition at line 854 of file libtrac.c.

```
                 {

  int ip, ip0, ix, iy;

  /* Loop over columns... */
  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 (!gsl_finite(met->t[ix][iy][ip0])
            || !gsl_finite(met->u[ix][iy][ip0])
            || !gsl_finite(met->v[ix][iy][ip0])
            || !gsl_finite(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];
      }
    }
}
```

5.11.2.21 void read_met_help (int *ncid,* char * *varname,* char * *varname2,* met_t * *met,* float *dest[EX][EY][EP],* float *scl*)

Read and convert variable from meteorological data file.

Definition at line 885 of file libtrac.c.

```
             {

  static float help[EX * EY * EP];

  int ip, ix, iy, n = 0, varid;

  /* Check if variable exists... */
  if (nc_inq_varid(ncid, varname, &varid) != NC_NOERR)
    if (nc_inq_varid(ncid, varname2, &varid) != NC_NOERR)
      return;

  /* Read data... */
  NC(nc_get_var_float(ncid, varid, help));

  /* Copy and check data... */
  for (ip = 0; ip < met->np; ip++)
    for (iy = 0; iy < met->ny; iy++)
      for (ix = 0; ix < met->nx; ix++) {
        dest[ix][iy][ip] = scl * help[n++];
        if (fabs(dest[ix][iy][ip] / scl) > 1e14)
          dest[ix][iy][ip] = GSL_NAN;
      }
}
```

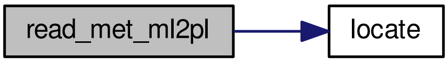
5.11.2.22 void read_met_ml2pl (ctl_t ∗ *ctl,* met_t ∗ *met,* float *var[EX][EY][EP]*)

Convert meteorological data from model levels to pressure levels.

Definition at line 917 of file libtrac.c.

```
                         {

  double aux[EP], p[EP], pt;

  int ip, ip2, ix, iy;

  /* Loop over columns... */
  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(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:



5.11.2.23 void read_met_periodic (met_t * *met*)

Create meteorological data with periodic boundary conditions.

Definition at line 955 of file libtrac.c.

```
               {

  int ip, iy;

  /* 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... */
  for (iy = 0; iy < met->ny; iy++)
    for (ip = 0; ip < met->np; ip++) {
      met->ps[met->nx - 1][iy] = met->ps[0][iy];
      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->t[met->nx - 1][iy][ip] = met->t[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];
    }
}
```

5.11.2.24 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 987 of file libtrac.c.

```
               {

  FILE *in = NULL;

  char dummy[LEN], fullname1[LEN], fullname2[LEN], line[LEN],
    msg[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);
}
```

5.11.2.25 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 1059 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;
}
```

5.11.2.26 void timer (const char ∗ *name,* int *id,* int *mode*)

Measure wall-clock time.

Definition at line 1090 of file libtrac.c.

```
            {

  static double starttime[NTIMER], runtime[NTIMER];

  /* Check id... */
  if (id < 0 || id >= NTIMER)
    ERRMSG("Too many timers!");

  /* Start timer... */
  if (mode == 1) {
    if (starttime[id] <= 0)
```

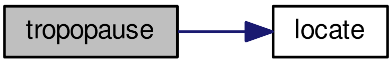
```
      starttime[id] = omp_get_wtime();
    else
      ERRMSG("Timer already started!");
  }

  /* Stop timer... */
  else if (mode == 2) {
    if (starttime[id] > 0) {
      runtime[id] = runtime[id] + omp_get_wtime() - starttime[id];
      starttime[id] = -1;
    } else
      ERRMSG("Timer not started!");
  }

  /* Print timer... */
  else if (mode == 3)
    printf("%s = %g s\n", name, runtime[id]);
}
```

5.11.2.27 double tropopause (double *t*, double *lat*)

Definition at line 1125 of file libtrac.c.

```
              {

  static double doys[12]
  = { 1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335 };

  static double 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
  };

  static double 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,
   220.4, 238.1, 250.2, 258.1, 264.7, 269.7, 273.7, 277.3, 280.2, 282.8,
   284.9, 286.5, 288.1, 288.8, 289, 288.5, 287.2, 286.3, 286.1, 287.2,
   287.5, 286.2, 285.8},
  {335, 336, 335.7, 335.1, 332.3, 328.1, 320.6, 311.8, 305.1, 301.9,
   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,
   308.5, 312.2, 313.1, 313.3},
  {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,
   110.8, 109.7, 109.3, 109.4, 109.7, 110, 110.2, 110.4, 110.5, 110.7,
   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,
   110.6, 110.8, 111, 111.4, 111.8, 112, 112.2, 112.4, 112.9, 113.6,
   114.7, 116.3, 118.4, 121.9, 127.1, 136.1, 149.8, 168.4, 186.9,
   203.3, 217, 229.1, 238.7, 247, 254, 259.3, 264.3, 268.3, 272.5,
   276.6, 280.4, 284.4, 288.4, 293.3, 297.2, 298.7, 299.1},
  {191.6, 192.2, 189, 188.1, 190.2, 193.7, 197.8, 202.9, 208.5,
   215.6, 224.2, 233.1, 241.2, 247.3, 250.8, 251.3, 248.9, 244.2,
   237.3, 228.4, 217.2, 202.9, 184.5, 162.5, 140.7, 124.8, 116.2,
   111.8, 109.4, 107.9, 107, 106.7, 106.6, 106.6, 106.7, 106.7,
   106.8, 107, 107.4, 108, 108.7, 109.3, 109.8, 110.4, 111.2,
   112.4, 114.2, 116.9, 121.1, 127.9, 139.3, 155.2, 173.6, 190.7,
   206.1, 220.1, 232.3, 243, 251.8, 259.2, 265.7, 270.6, 275.3,
   279.3, 283.3, 286.9, 289.7, 292.8, 296.1, 300.5, 303.9, 304.8,
   305.1},
  {241.5, 239.6, 236.8, 237.4, 239.4, 242.3, 244.2, 246.4, 249.2,
   253.6, 258.6, 262.7, 264.8, 264.2, 260.6, 254.1, 245.5, 235.3,
   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}
  };

  double doy, p0, p1, pt;

  int imon, ilat;

  /* Get day of year... */
  doy = fmod(t / 86400., 365.25);
  while (doy < 0)
    doy += 365.25;

  /* Get indices... */
  imon = locate(doys, 12, doy);
  ilat = locate(lats, 73, lat);

  /* Get tropopause pressure... */
  p0 = LIN(lats[ilat], tps[imon][ilat],
           lats[ilat + 1], tps[imon][ilat + 1], lat);
  p1 = LIN(lats[ilat], tps[imon + 1][ilat],
           lats[ilat + 1], tps[imon + 1][ilat + 1], lat);
  pt = LIN(doys[imon], p0, doys[imon + 1], p1, doy);

  /* Return tropopause pressure... */
  return pt;
}
```

Here is the call graph for this function:



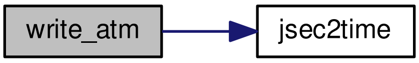
5.11.2.28 void write_atm (const char ∗ *filename,* ctl_t ∗ *ctl,* atm_t ∗ *atm,* double *t*)

Write atmospheric data.

Definition at line 1268 of file libtrac.c.

```
            {

  FILE *in, *out;

  char line[LEN];

  double r, t0, t1;

  int ip, iq, year, mon, day, hour, min, sec;

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Check if gnuplot output is requested... */
  if (ctl->atm_gpfile[0] != '-') {

    /* Write info... */
    printf("Plot atmospheric 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->atm_gpfile, "r")))
      ERRMSG("Cannot open file!");
    while (fgets(line, LEN, in))
      fprintf(out, "%s", line);
    fclose(in);
  }

  else {

    /* Write info... */
    printf("Write atmospheric 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");
  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++) {

    /* 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);
}
```

Here is the call graph for this function:



5.11.2.29 void write_csi (const char ∗ *filename,* ctl_t ∗ *ctl,* atm_t ∗ *atm,* double *t*)

Write CSI data.

Definition at line 1355 of file libtrac.c.

```
            {

  static FILE *in, *out;

  static char line[LEN];

  static double modmean[GX][GY][GZ], obsmean[GX][GY][GZ],
    rt, rz, rlon, rlat, robs, t0, t1, area, dlon, dlat, lat;

  static int init, obscount[GX][GY][GZ], cx, cy, cz, ip, ix, iy, iz;

  /* Init... */
  if (!init) {
    init = 1;

    /* Check quantity index for mass... */
    if (ctl->qnt_m < 0)
      ERRMSG("Need quantity mass to analyze CSI!");

    /* 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 (forecasts/observations) [%%]\n"
            "# $8 = probability of detection (POD) [%%]\n"
            "# $9 = false alarm rate (FAR) [%%]\n"
            "# $10 = critical success index (CSI) [%%]\n\n");
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize 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++)
        modmean[ix][iy][iz] = obsmean[ix][iy][iz] = obscount[ix][iy][iz] = 0;

  /* Read 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;

    /* Calculate indices... */
    ix = (int) ((rlon - ctl->csi_lon0)
                / (ctl->csi_lon1 - ctl->csi_lon0) * ctl->csi_nx);
    iy = (int) ((rlat - ctl->csi_lat0)
                / (ctl->csi_lat1 - ctl->csi_lat0) * ctl->csi_ny);
    iz = (int) ((rz - ctl->csi_z0)
                / (ctl->csi_z1 - ctl->csi_z0) * ctl->csi_nz);

    /* 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)
                / (ctl->csi_lon1 - ctl->csi_lon0) * ctl->csi_nx);
    iy = (int) ((atm->lat[ip] - ctl->csi_lat0)
                / (ctl->csi_lat1 - ctl->csi_lat0) * ctl->csi_ny);
    iz = (int) ((Z(atm->p[ip]) - ctl->csi_z0)
                / (ctl->csi_z1 - ctl->csi_z0) * ctl->csi_nz);

    /* 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) {
          dlon = (ctl->csi_lon1 - ctl->csi_lon0) / ctl->csi_nx;
          dlat = (ctl->csi_lat1 - ctl->csi_lat0) / ctl->csi_ny;
          lat = ctl->csi_lat0 + dlat * (iy + 0.5);
          area = dlat * M_PI * RE / 180. * dlon * M_PI * RE / 180.
            * cos(lat * M_PI / 180.);
          modmean[ix][iy][iz] /= (1e6 * area);
        }

        /* Calculate CSI... */
        if (obscount[ix][iy][iz] > 0) {
          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++;
        }
      }

  /* Write output... */
  if (fmod(t, ctl->csi_dt_out) == 0) {

    /* Write... */
    fprintf(out, "%.2f %d %d %d %d %d %g %g %g %g\n",
            t, cx, cy, cz, cx + cy, cx + cz,
            (cx + cy > 0) ? 100. * (cx + cz) / (cx + cy) : GSL_NAN,
            (cx + cy > 0) ? (100. * cx) / (cx + cy) : GSL_NAN,
            (cx + cz > 0) ? (100. * cz) / (cx + cz) : GSL_NAN,
            (cx + cy + cz > 0) ? (100. * cx) / (cx + cy + cz) : GSL_NAN);

    /* Set counters to zero... */
    cx = cy = cz = 0;
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

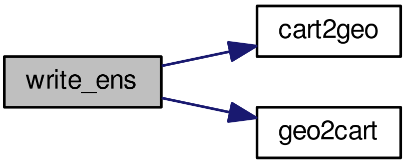
5.11.2.30 void write_ens (const char * *filename*, ctl_t * *ctl*, atm_t * *atm*, double *t*)

Write ensemble data.

Definition at line 1523 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 init, ip, iq;

  static size_t i, n;

  /* Init... */
  if (!init) {
    init = 1;

    /* 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:



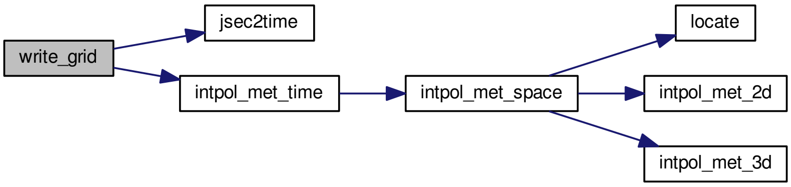
5.11.2.31 void write_grid (const char * *filename,* ctl_t * *ctl,* met_t * *met0,* met_t * *met1,* atm_t * *atm,* double *t*)

Write gridded data.

Definition at line 1655 of file libtrac.c.

```
            {

  FILE *in, *out;

  char line[LEN];

  static double grid_m[GX][GY][GZ], z, dz, lon, dlon, lat, dlat,
    area, rho_air, press, temp, cd, mmr, t0, t1, r;

  static int ip, ix, iy, iz, year, mon, day, hour, min, sec;

  /* Check dimensions... */
  if (ctl->grid_nx > GX || ctl->grid_ny > GY || ctl->grid_nz > GZ)
    ERRMSG("Grid dimensions too large!");

  /* Check quantity index for mass... */
  if (ctl->qnt_m < 0)
    ERRMSG("Need quantity mass to write grid data!");

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* 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;

  /* Initialize grid... */
  for (ix = 0; ix < ctl->grid_nx; ix++)
    for (iy = 0; iy < ctl->grid_ny; iy++)
      for (iz = 0; iz < ctl->grid_nz; iz++)
        grid_m[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... */
      grid_m[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
    }

  /* 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 = temperature [K]\n"
          "# $8 = column density [kg/m^2]\n"
          "# $9 = mass mixing ratio [1]\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
            || ix == 0 || iy == 0 || iz == 0 || grid_m[ix][iy][iz] > 0) {

          /* Set coordinates... */
          z = ctl->grid_z0 + dz * (iz + 0.5);
          lon = ctl->grid_lon0 + dlon * (ix + 0.5);
          lat = ctl->grid_lat0 + dlat * (iy + 0.5);

          /* Get pressure and temperature... */
          press = P(z);
          intpol_met_time(met0, met1, t, press, lon, lat,
                          NULL, &temp, NULL, NULL, NULL, NULL, NULL);

          /* Calculate surface area... */
          area = dlat * dlon * gsl_pow_2(RE * M_PI / 180.)
            * cos(lat * M_PI / 180.);

          /* Calculate column density... */
          cd = grid_m[ix][iy][iz] / (1e6 * area);

          /* Calculate mass mixing ratio... */
          rho_air = 100. * press / (287.058 * temp);
          mmr = grid_m[ix][iy][iz] / (rho_air * 1e6 * area * 1e3 * dz);

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %g %g %g\n",
                  t, z, lon, lat, area, dz, temp, cd, mmr);
        }
    }
  }

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

Here is the call graph for this function:



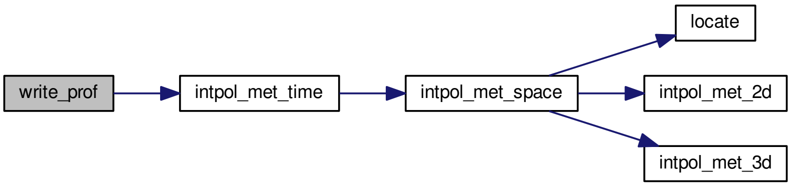
5.11.2.32 void write_prof (const char ∗ *filename,* ctl_t ∗ *ctl,* met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* double *t*)

Write profile data.

Definition at line 1806 of file libtrac.c.

```
            {

  static FILE *in, *out;

  static char line[LEN];

  static double mass[GX][GY][GZ], obsmean[GX][GY], tmean[GX][GY],
    rt, rlon, rlat, robs, t0, t1, area, dz, dlon, dlat, lon, lat, z,
    press, temp, rho_air, mmr, h2o, o3;

  static int init, obscount[GX][GY], ip, ix, iy, iz;

  /* Init... */
  if (!init) {
    init = 1;

    /* 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!");

    /* 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 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  = mass mixing ratio [1]\n"
            "# $8  = H2O volume mixing ratio [1]\n"
            "# $9  = O3 volume mixing ratio [1]\n"
            "# $10 = mean 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 time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize... */
  for (ix = 0; ix < ctl->prof_nx; ix++)
    for (iy = 0; iy < ctl->prof_ny; iy++) {
      obsmean[ix][iy] = 0;
      obscount[ix][iy] = 0;
      tmean[ix][iy] = 0;
      for (iz = 0; iz < ctl->prof_nz; iz++)
        mass[ix][iy][iz] = 0;
    }

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

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg", &rt, &rlon, &rlat, &robs) != 4)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt > t1)
      break;

    /* 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;
    tmean[ix][iy] += rt;
    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) {

        /* Write output... */
        fprintf(out, "\n");

        /* Loop over altitudes... */
        for (iz = 0; iz < ctl->prof_nz; iz++) {

          /* Set coordinates... */
          z = ctl->prof_z0 + dz * (iz + 0.5);
          lon = ctl->prof_lon0 + dlon * (ix + 0.5);
          lat = ctl->prof_lat0 + dlat * (iy + 0.5);

          /* Get meteorological data... */
          press = P(z);
          intpol_met_time(met0, met1, t, press, lon, lat,
                          NULL, &temp, NULL, NULL, NULL, &h2o, &o3);

          /* Calculate mass mixing ratio... */
          rho_air = 100. * press / (287.058 * temp);
          area = dlat * dlon * gsl_pow_2(M_PI * RE / 180.)
            * cos(lat * M_PI / 180.);
          mmr = mass[ix][iy][iz] / (rho_air * area * dz * 1e9);

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g\n",
                  tmean[ix][iy] / obscount[ix][iy],
                  z, lon, lat, press, temp, mmr, h2o, o3,
                  obsmean[ix][iy] / obscount[ix][iy]);
        }
      }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

Here is the call graph for this function:



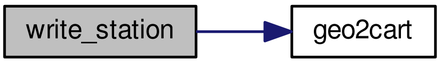
5.11.2.33 void write_station (const char * *filename,* ctl_t * *ctl,* atm_t * *atm,* double *t*)

Write station data.

Definition at line 1969 of file libtrac.c.

```
                  {

  static FILE *out;

  static double rmax2, t0, t1, x0[3], x1[3];

  static int init, ip, iq;

  /* Init... */
  if (!init) {
    init = 1;

    /* 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 (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 = gsl_pow_2(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 (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 (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:



5.12 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
```

```c
  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/>.

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

/*****************************************************************************/

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

  double radius;

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

/*****************************************************************************/

double deg2dx(
  double dlon,
  double lat) {

  return dlon * M_PI * RE / 180. * cos(lat / 180. * M_PI);
}

/*****************************************************************************/

double deg2dy(
  double dlat) {

  return dlat * M_PI * RE / 180.;
}

/*****************************************************************************/

double dp2dz(
  double dp,
  double p) {

  return -dp * H0 / p;
}

/*****************************************************************************/

double dx2deg(
  double dx,
  double lat) {

  /* Avoid singularity at poles... */
  if (lat < -89.999 || lat > 89.999)
    return 0;
  else
    return dx * 180. / (M_PI * RE * cos(lat / 180. * M_PI));
}

/*****************************************************************************/

double dy2deg(
  double dy) {

  return dy * 180. / (M_PI * RE);
}

/*****************************************************************************/

double dz2dp(
  double dz,
  double p) {

  return -dz * p / H0;
}
```

```

/*****************************************************************************/

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

  double radius;

  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,
  char *metbase,
  double t,
  met_t * met0,
  met_t * met1) {

  char filename[LEN];

  static int init;

  /* Init... */
  if (!init) {
    init = 1;

    get_met_help(t, -1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met0);

    get_met_help(t + 1.0 * ctl->direction, 1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met1);
  }

  /* Read new data for forward trajectories... */
  if (t > met1->time && ctl->direction == 1) {
    memcpy(met0, met1, sizeof(met_t));
    get_met_help(t, 1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met1);
  }

  /* Read new data for backward trajectories... */
  if (t < met0->time && ctl->direction == -1) {
    memcpy(met1, met0, sizeof(met_t));
    get_met_help(t, -1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met0);
  }
}

/*****************************************************************************/

void get_met_help(
  double t,
  int direct,
  char *metbase,
  double dt_met,
  char *filename) {

  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_%d_%02d_%02d_%02d.nc", metbase, year, mon, day, hour);
}

/*****************************************************************************/

void intpol_met_2d(
  double array[EX][EY],
  int ix,
  int iy,
  double wx,
  double wy,
  double *var) {

  double aux00, aux01, aux10, aux11;

  /* Set variables... */
  aux00 = array[ix][iy];
  aux01 = array[ix][iy + 1];
  aux10 = array[ix + 1][iy];
  aux11 = array[ix + 1][iy + 1];

  /* Interpolate horizontally... */
  aux00 = wy * (aux00 - aux01) + aux01;
  aux11 = wy * (aux10 - aux11) + aux11;
  *var = wx * (aux00 - aux11) + aux11;
}

/*****************************************************************************/

void intpol_met_3d(
  float array[EX][EY][EP],
  int ip,
  int ix,
  int iy,
  double wp,
  double wx,
  double wy,
  double *var) {

  double aux00, aux01, aux10, aux11;

  /* Interpolate vertically... */
  aux00 = wp * (array[ix][iy][ip] - array[ix][iy][ip + 1])
    + array[ix][iy][ip + 1];
  aux01 = wp * (array[ix][iy + 1][ip] - array[ix][iy + 1][ip + 1])
    + array[ix][iy + 1][ip + 1];
  aux10 = wp * (array[ix + 1][iy][ip] - array[ix + 1][iy][ip + 1])
    + array[ix + 1][iy][ip + 1];
  aux11 = wp * (array[ix + 1][iy + 1][ip] - array[ix + 1][iy + 1][ip + 1])
    + array[ix + 1][iy + 1][ip + 1];

  /* Interpolate horizontally... */
  aux00 = wy * (aux00 - aux01) + aux01;
  aux11 = wy * (aux10 - aux11) + aux11;
  *var = wx * (aux00 - aux11) + aux11;
}

/*****************************************************************************/

void intpol_met_space(
  met_t * met,
  double p,
  double lon,
  double lat,
  double *ps,
  double *t,
  double *u,
  double *v,
  double *w,
  double *h2o,
  double *o3) {

  double wp, wx, wy;

  int ip, ix, iy;

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

  /* Get indices... */
  ip = locate(met->p, met->np, p);
  ix = locate(met->lon, met->nx, lon);
  iy = locate(met->lat, met->ny, lat);

  /* Get weights... */
  wp = (met->p[ip + 1] - p) / (met->p[ip + 1] - met->p[ip]);
  wx = (met->lon[ix + 1] - lon) / (met->lon[ix + 1] - met->lon[ix]);
  wy = (met->lat[iy + 1] - lat) / (met->lat[iy + 1] - met->lat[iy]);

  /* Interpolate... */
  if (ps != NULL)
    intpol_met_2d(met->ps, ix, iy, wx, wy, ps);
  if (t != NULL)
```

```
    intpol_met_3d(met->t, ip, ix, iy, wp, wx, wy, t);
  if (u != NULL)
    intpol_met_3d(met->u, ip, ix, iy, wp, wx, wy, u);
  if (v != NULL)
    intpol_met_3d(met->v, ip, ix, iy, wp, wx, wy, v);
  if (w != NULL)
    intpol_met_3d(met->w, ip, ix, iy, wp, wx, wy, w);
  if (h2o != NULL)
    intpol_met_3d(met->h2o, ip, ix, iy, wp, wx, wy, h2o);
  if (o3 != NULL)
    intpol_met_3d(met->o3, ip, ix, iy, wp, wx, wy, o3);
}

/*****************************************************************************/

void intpol_met_time(
  met_t * met0,
  met_t * met1,
  double ts,
  double p,
  double lon,
  double lat,
  double *ps,
  double *t,
  double *u,
  double *v,
  double *w,
  double *h2o,
  double *o3) {

  double h2o0, h2o1, o30, o31, ps0, ps1, t0, t1, u0, u1, v0, v1, w0, w1, wt;

  /* Spatial interpolation... */
  intpol_met_space(met0, p, lon, lat,
                   ps == NULL ? NULL : &ps0,
                   t == NULL ? NULL : &t0,
                   u == NULL ? NULL : &u0,
                   v == NULL ? NULL : &v0,
                   w == NULL ? NULL : &w0,
                   h2o == NULL ? NULL : &h2o0, o3 == NULL ? NULL : &o30);
  intpol_met_space(met1, p, lon, lat,
                   ps == NULL ? NULL : &ps1,
                   t == NULL ? NULL : &t1,
                   u == NULL ? NULL : &u1,
                   v == NULL ? NULL : &v1,
                   w == NULL ? NULL : &w1,
                   h2o == NULL ? NULL : &h2o1, o3 == NULL ? NULL : &o31);

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

  /* Interpolate... */
  if (ps != NULL)
    *ps = wt * (ps0 - ps1) + ps1;
  if (t != NULL)
    *t = wt * (t0 - t1) + t1;
  if (u != NULL)
    *u = wt * (u0 - u1) + u1;
  if (v != NULL)
    *v = wt * (v0 - v1) + v1;
  if (w != NULL)
    *w = wt * (w0 - w1) + w1;
  if (h2o != NULL)
    *h2o = wt * (h2o0 - h2o1) + h2o1;
  if (o3 != NULL)
    *o3 = wt * (o30 - o31) + o31;
}

/*****************************************************************************/

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

  struct tm t0, *t1;

  time_t jsec0;

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

  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);
}

/*****************************************************************************/

int locate(
  double *xx,
  int n,
  double x) {

  int i, ilo, ihi;

  ilo = 0;
  ihi = n - 1;
  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;
}

/*****************************************************************************/

void read_atm(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm) {

  FILE *in;

  char line[LEN], *tok;

  int iq;

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

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

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

  /* 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);

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

/*****************************************************************************/

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

  int ip, iq;

  /* 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_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_theta = -1;
  ctl->qnt_pv = -1;
  ctl->qnt_tice = -1;
  ctl->qnt_tsts = -1;
  ctl->qnt_tnat = -1;
  ctl->qnt_gw_var = -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 (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 (strcmp(ctl->qnt_name[iq], "ens") == 0) {
      ctl->qnt_ens = iq;
      sprintf(ctl->qnt_unit[iq], "-");
    } else if (strcmp(ctl->qnt_name[iq], "m") == 0) {
      ctl->qnt_m = iq;
      sprintf(ctl->qnt_unit[iq], "kg");
    } else if (strcmp(ctl->qnt_name[iq], "r") == 0) {
      ctl->qnt_r = iq;
      sprintf(ctl->qnt_unit[iq], "m");
    } else if (strcmp(ctl->qnt_name[iq], "rho") == 0) {
      ctl->qnt_rho = iq;
      sprintf(ctl->qnt_unit[iq], "kg/m^3");
    } else if (strcmp(ctl->qnt_name[iq], "ps") == 0) {
      ctl->qnt_ps = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcmp(ctl->qnt_name[iq], "p") == 0) {
      ctl->qnt_p = iq;
      sprintf(ctl->qnt_unit[iq], "hPa");
    } else if (strcmp(ctl->qnt_name[iq], "t") == 0) {
      ctl->qnt_t = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "u") == 0) {
      ctl->qnt_u = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcmp(ctl->qnt_name[iq], "v") == 0) {
      ctl->qnt_v = iq;
      sprintf(ctl->qnt_unit[iq], "m/s");
    } else if (strcmp(ctl->qnt_name[iq], "w") == 0) {
      ctl->qnt_w = iq;
      sprintf(ctl->qnt_unit[iq], "hPa/s");
    } else if (strcmp(ctl->qnt_name[iq], "h2o") == 0) {
      ctl->qnt_h2o = iq;
      sprintf(ctl->qnt_unit[iq], "1");
    } else if (strcmp(ctl->qnt_name[iq], "o3") == 0) {
      ctl->qnt_o3 = iq;
      sprintf(ctl->qnt_unit[iq], "1");
    } else if (strcmp(ctl->qnt_name[iq], "theta") == 0) {
      ctl->qnt_theta = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "pv") == 0) {
      ctl->qnt_pv = iq;
      sprintf(ctl->qnt_unit[iq], "PVU");
    } else if (strcmp(ctl->qnt_name[iq], "tice") == 0) {
      ctl->qnt_tice = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "tsts") == 0) {
      ctl->qnt_tsts = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "tnat") == 0) {
      ctl->qnt_tnat = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } else if (strcmp(ctl->qnt_name[iq], "gw_var") == 0) {
      ctl->qnt_gw_var = iq;
      sprintf(ctl->qnt_unit[iq], "K^2");
    } else if (strcmp(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_start =
    scan_ctl(filename, argc, argv, "T_START", -1, "-1e100", NULL);
  ctl->t_stop = scan_ctl(filename, argc, argv, "T_STOP", -1, "-1e100", NULL);
  ctl->dt_mod = scan_ctl(filename, argc, argv, "DT_MOD", -1, "600", NULL);

  /* Meteorological data... */
  ctl->dt_met = scan_ctl(filename, argc, argv, "DT_MET", -1, "21600", 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 (ip = 0; ip < ctl->met_np; ip++)
    ctl->met_p[ip] = scan_ctl(filename, argc, argv, "MET_P", ip, "", NULL);
  scan_ctl(filename, argc, argv, "MET_STAGE", -1, "-", ctl->met_stage);

  /* 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, "50.0", NULL);
  ctl->turb_dx_strat
    = scan_ctl(filename, argc, argv, "TURB_DX_STRAT", -1, "0.0", NULL);
  ctl->turb_dz_trop
    = scan_ctl(filename, argc, argv, "TURB_DZ_TROP", -1, "0.0", NULL);
  ctl->turb_dz_strat
    = scan_ctl(filename, argc, argv, "TURB_DZ_STRAT", -1, "0.1", NULL);
  ctl->turb_meso =
    scan_ctl(filename, argc, argv, "TURB_MESO", -1, "0.16", NULL);

  /* Life time of particles... */
  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);

  /* 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);

  /* Gravity wave analysis... */
  scan_ctl(filename, argc, argv, "GW_BASENAME", -1, "-", ctl->gw_basename);

  /* 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);

  /* 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, "obs.tab",
           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 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);
```

```
}

/*****************************************************************************/

void read_met(
  ctl_t * ctl,
  char *filename,
  met_t * met) {

  char cmd[LEN], levname[LEN], tstr[10];

  static float help[EX * EY];

  int ix, iy, ip, dimid, ncid, varid, year, mon, day, hour;

  size_t np, nx, ny;

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

  /* 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);

  /* Open netCDF file... */
  if (nc_open(filename, NC_NOWRITE, &ncid) != NC_NOERR) {

    /* Try to stage meteo file... */
    START_TIMER(TIMER_STAGE);
    if (ctl->met_stage[0] != '-') {
      sprintf(cmd, "%s %d %02d %02d %02d %s", ctl->met_stage,
              year, mon, day, hour, filename);
      if (system(cmd) != 0)
        ERRMSG("Error while staging meteo data!");
    }
    STOP_TIMER(TIMER_STAGE);

    /* Try to open again... */
    NC(nc_open(filename, NC_NOWRITE, &ncid));
  }

  /* Get 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");
    NC(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;

  /* Get horizontal grid... */
  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 meteorological data... */
  read_met_help(ncid, "t", "T", met, met->t, 1.0);
  read_met_help(ncid, "u", "U", met, met->u, 1.0);
  read_met_help(ncid, "v", "V", met, met->v, 1.0);
  read_met_help(ncid, "w", "W", met, met->w, 0.01f);
  read_met_help(ncid, "q", "Q", met, met->h2o, 1.608f);
  read_met_help(ncid, "o3", "O3", met, met->o3, 0.602f);

  /* Meteo data on pressure levels... */
  if (ctl->met_np <= 0) {

    /* Read pressure levels from file... */
    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.;

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

  /* Meteo data on model levels... */
  else {

    /* Read pressure data from file... */
    read_met_help(ncid, "pl", "PL", met, met->pl, 0.01f);

    /* Interpolate from model levels 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);

    /* Set pressure levels... */
    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!");

  /* Read surface pressure... */
  if (nc_inq_varid(ncid, "ps", &varid) == NC_NOERR
      || nc_inq_varid(ncid, "PS", &varid) == NC_NOERR) {
    NC(nc_get_var_float(ncid, varid, help));
    for (iy = 0; iy < met->ny; iy++)
      for (ix = 0; ix < met->nx; ix++)
        met->ps[ix][iy] = help[iy * met->nx + ix] / 100.;
  } else if (nc_inq_varid(ncid, "lnsp", &varid) == NC_NOERR
             || nc_inq_varid(ncid, "LNSP", &varid) == NC_NOERR) {
    NC(nc_get_var_float(ncid, varid, help));
    for (iy = 0; iy < met->ny; iy++)
      for (ix = 0; ix < met->nx; ix++)
        met->ps[ix][iy] = exp(help[iy * met->nx + ix]) / 100.;
  } else
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        met->ps[ix][iy] = met->p[0];

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

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

/*****************************************************************************/

void read_met_extrapolate(
  met_t * met) {

  int ip, ip0, ix, iy;

  /* Loop over columns... */
  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 (!gsl_finite(met->t[ix][iy][ip0])
            || !gsl_finite(met->u[ix][iy][ip0])
            || !gsl_finite(met->v[ix][iy][ip0])
            || !gsl_finite(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];
      }
    }
}

/*****************************************************************************/

void read_met_help(
  int ncid,
  char *varname,
  char *varname2,
  met_t * met,
  float dest[EX][EY][EP],
  float scl) {

  static float help[EX * EY * EP];

  int ip, ix, iy, n = 0, varid;

  /* Check if variable exists... */
  if (nc_inq_varid(ncid, varname, &varid) != NC_NOERR)
    if (nc_inq_varid(ncid, varname2, &varid) != NC_NOERR)
      return;

  /* Read data... */
  NC(nc_get_var_float(ncid, varid, help));

  /* Copy and check data... */
  for (ip = 0; ip < met->np; ip++)
    for (iy = 0; iy < met->ny; iy++)
      for (ix = 0; ix < met->nx; ix++) {
        dest[ix][iy][ip] = scl * help[n++];
        if (fabs(dest[ix][iy][ip] / scl) > 1e14)
          dest[ix][iy][ip] = GSL_NAN;
      }
}

/*****************************************************************************/

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;

  /* Loop over columns... */
  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(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) {

  int ip, iy;

  /* 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... */
  for (iy = 0; iy < met->ny; iy++)
    for (ip = 0; ip < met->np; ip++) {
      met->ps[met->nx - 1][iy] = met->ps[0][iy];
      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->t[met->nx - 1][iy][ip] = met->t[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];
    }
}

/*****************************************************************************/

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[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);
}

/*****************************************************************************/

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 id,
  int mode) {

  static double starttime[NTIMER], runtime[NTIMER];

  /* Check id... */
  if (id < 0 || id >= NTIMER)
    ERRMSG("Too many timers!");

  /* Start timer... */
  if (mode == 1) {
    if (starttime[id] <= 0)
      starttime[id] = omp_get_wtime();
    else
      ERRMSG("Timer already started!");
  }

  /* Stop timer... */
  else if (mode == 2) {
    if (starttime[id] > 0) {
      runtime[id] = runtime[id] + omp_get_wtime() - starttime[id];
      starttime[id] = -1;
    } else
      ERRMSG("Timer not started!");
  }

  /* Print timer... */
  else if (mode == 3)
    printf("%s = %g s\n", name, runtime[id]);
}

/*****************************************************************************/

double tropopause(
  double t,
  double lat) {

  static double doys[12]
  = { 1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335 };

  static double 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
};

static double 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,
 220.4, 238.1, 250.2, 258.1, 264.7, 269.7, 273.7, 277.3, 280.2, 282.8,
 284.9, 286.5, 288.1, 288.8, 289, 288.5, 287.2, 286.3, 286.1, 287.2,
 287.5, 286.2, 285.8},
{335, 336, 335.7, 335.1, 332.3, 328.1, 320.6, 311.8, 305.1, 301.9,
 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,
 308.5, 312.2, 313.1, 313.3},
{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,
 110.8, 109.7, 109.3, 109.4, 109.7, 110, 110.2, 110.4, 110.5, 110.7,
 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,
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{166, 166.4, 155.7, 148.3, 147.1, 149, 152.1, 157, 163.6, 172.4,
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 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,
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 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,
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 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,
 110.6, 110.8, 111, 111.4, 111.8, 112, 112.2, 112.4, 112.9, 113.6,
 114.7, 116.3, 118.4, 121.9, 127.1, 136.1, 149.8, 168.4, 186.9,
 203.3, 217, 229.1, 238.7, 247, 254, 259.3, 264.3, 268.3, 272.5,
 276.6, 280.4, 284.4, 288.4, 293.3, 297.2, 298.7, 299.1},
{191.6, 192.2, 189, 188.1, 190.2, 193.7, 197.8, 202.9, 208.5,
 215.6, 224.2, 233.1, 241.2, 247.3, 250.8, 251.3, 248.9, 244.2,
 237.3, 228.4, 217.2, 202.9, 184.5, 162.5, 140.7, 124.8, 116.2,
 111.8, 109.4, 107.9, 107, 106.7, 106.6, 106.6, 106.7, 106.7,
 106.8, 107, 107.4, 108, 108.7, 109.3, 109.8, 110.4, 111.2,
 112.4, 114.2, 116.9, 121.1, 127.9, 139.3, 155.2, 173.6, 190.7,
   206.1, 220.1, 232.3, 243, 251.8, 259.2, 265.7, 270.6, 275.3,
   279.3, 283.3, 286.9, 289.7, 292.8, 296.1, 300.5, 303.9, 304.8,
   305.1},
  {241.5, 239.6, 236.8, 237.4, 239.4, 242.3, 244.2, 246.4, 249.2,
   253.6, 258.6, 262.7, 264.8, 264.2, 260.6, 254.1, 245.5, 235.3,
   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}
  };

  double doy, p0, p1, pt;

  int imon, ilat;

  /* Get day of year... */
  doy = fmod(t / 86400., 365.25);
  while (doy < 0)
    doy += 365.25;

  /* Get indices... */
  imon = locate(doys, 12, doy);
  ilat = locate(lats, 73, lat);

  /* Get tropopause pressure... */
  p0 = LIN(lats[ilat], tps[imon][ilat],
           lats[ilat + 1], tps[imon][ilat + 1], lat);
  p1 = LIN(lats[ilat], tps[imon + 1][ilat],
           lats[ilat + 1], tps[imon + 1][ilat + 1], lat);
  pt = LIN(doys[imon], p0, doys[imon + 1], p1, doy);

  /* Return tropopause pressure... */
  return pt;
}

/*****************************************************************************/

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 time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Check if gnuplot output is requested... */
  if (ctl->atm_gpfile[0] != '-') {

    /* Write info... */
    printf("Plot atmospheric 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->atm_gpfile, "r")))
      ERRMSG("Cannot open file!");
    while (fgets(line, LEN, in))
```

```
      fprintf(out, "%s", line);
    fclose(in);
  }

  else {

    /* Write info... */
    printf("Write atmospheric 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");
  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++) {

    /* 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);
}

/*****************************************************************************/

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, rz, rlon, rlat, robs, t0, t1, area, dlon, dlat, lat;

  static int init, obscount[GX][GY][GZ], cx, cy, cz, ip, ix, iy, iz;

  /* Init... */
  if (!init) {
    init = 1;

    /* Check quantity index for mass... */
    if (ctl->qnt_m < 0)
      ERRMSG("Need quantity mass to analyze CSI!");

    /* 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 (forecasts/observations) [%%]\n"
            "# $8 = probability of detection (POD) [%%]\n"
            "# $9 = false alarm rate (FAR) [%%]\n"
            "# $10 = critical success index (CSI) [%%]\n\n");
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize 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++)
        modmean[ix][iy][iz] = obsmean[ix][iy][iz] = obscount[ix][iy][iz] = 0;

  /* Read 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;

    /* Calculate indices... */
    ix = (int) ((rlon - ctl->csi_lon0)
                / (ctl->csi_lon1 - ctl->csi_lon0) * ctl->csi_nx);
    iy = (int) ((rlat - ctl->csi_lat0)
                / (ctl->csi_lat1 - ctl->csi_lat0) * ctl->csi_ny);
    iz = (int) ((rz - ctl->csi_z0)
                / (ctl->csi_z1 - ctl->csi_z0) * ctl->csi_nz);

    /* 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)
                / (ctl->csi_lon1 - ctl->csi_lon0) * ctl->csi_nx);
    iy = (int) ((atm->lat[ip] - ctl->csi_lat0)
                / (ctl->csi_lat1 - ctl->csi_lat0) * ctl->csi_ny);
    iz = (int) ((Z(atm->p[ip]) - ctl->csi_z0)
                / (ctl->csi_z1 - ctl->csi_z0) * ctl->csi_nz);

    /* 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) {
          dlon = (ctl->csi_lon1 - ctl->csi_lon0) / ctl->csi_nx;
          dlat = (ctl->csi_lat1 - ctl->csi_lat0) / ctl->csi_ny;
          lat = ctl->csi_lat0 + dlat * (iy + 0.5);
          area = dlat * M_PI * RE / 180. * dlon * M_PI * RE / 180.
            * cos(lat * M_PI / 180.);
          modmean[ix][iy][iz] /= (1e6 * area);
        }

        /* Calculate CSI... */
        if (obscount[ix][iy][iz] > 0) {
          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++;
        }
      }

  /* Write output... */
  if (fmod(t, ctl->csi_dt_out) == 0) {

    /* Write... */
    fprintf(out, "%.2f %d %d %d %d %d %g %g %g %g\n",
            t, cx, cy, cz, cx + cy, cx + cz,
            (cx + cy > 0) ? 100. * (cx + cz) / (cx + cy) : GSL_NAN,
            (cx + cy > 0) ? (100. * cx) / (cx + cy) : GSL_NAN,
            (cx + cz > 0) ? (100. * cz) / (cx + cz) : GSL_NAN,
            (cx + cy + cz > 0) ? (100. * cx) / (cx + cy + cz) : GSL_NAN);

    /* Set counters to zero... */
    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 init, ip, iq;

  static size_t i, n;

  /* Init... */
  if (!init) {
    init = 1;

    /* 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 grid_m[GX][GY][GZ], z, dz, lon, dlon, lat, dlat,
    area, rho_air, press, temp, cd, mmr, t0, t1, r;

  static int ip, ix, iy, iz, year, mon, day, hour, min, sec;

  /* Check dimensions... */
  if (ctl->grid_nx > GX || ctl->grid_ny > GY || ctl->grid_nz > GZ)
    ERRMSG("Grid dimensions too large!");

  /* Check quantity index for mass... */
  if (ctl->qnt_m < 0)
    ERRMSG("Need quantity mass to write grid data!");

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* 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;

  /* Initialize grid... */
  for (ix = 0; ix < ctl->grid_nx; ix++)
    for (iy = 0; iy < ctl->grid_ny; iy++)
      for (iz = 0; iz < ctl->grid_nz; iz++)
        grid_m[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... */
      grid_m[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
    }

  /* 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 = temperature [K]\n"
          "# $8 = column density [kg/m^2]\n"
          "# $9 = mass mixing ratio [1]\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
            || ix == 0 || iy == 0 || iz == 0 || grid_m[ix][iy][iz] > 0) {

          /* Set coordinates... */
          z = ctl->grid_z0 + dz * (iz + 0.5);
          lon = ctl->grid_lon0 + dlon * (ix + 0.5);
          lat = ctl->grid_lat0 + dlat * (iy + 0.5);

          /* Get pressure and temperature... */
          press = P(z);
          intpol_met_time(met0, met1, t, press, lon, lat,
                          NULL, &temp, NULL, NULL, NULL, NULL, NULL);

          /* Calculate surface area... */
          area = dlat * dlon * gsl_pow_2(RE * M_PI / 180.)
            * cos(lat * M_PI / 180.);

          /* Calculate column density... */
          cd = grid_m[ix][iy][iz] / (1e6 * area);

          /* Calculate mass mixing ratio... */
          rho_air = 100. * press / (287.058 * temp);
          mmr = grid_m[ix][iy][iz] / (rho_air * 1e6 * area * 1e3 * dz);

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %g %g %g\n",
                  t, z, lon, lat, area, dz, temp, cd, mmr);
        }
    }
  }

  /* 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], tmean[GX][GY],
    rt, rlon, rlat, robs, t0, t1, area, dz, dlon, dlat, lon, lat, z,
    press, temp, rho_air, mmr, h2o, o3;

  static int init, obscount[GX][GY], ip, ix, iy, iz;

  /* Init... */
  if (!init) {
    init = 1;

    /* 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!");

    /* 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 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  = mass mixing ratio [1]\n"
            "# $8  = H2O volume mixing ratio [1]\n"
            "# $9  = O3 volume mixing ratio [1]\n"
            "# $10 = mean 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 time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize... */
  for (ix = 0; ix < ctl->prof_nx; ix++)
    for (iy = 0; iy < ctl->prof_ny; iy++) {
      obsmean[ix][iy] = 0;
      obscount[ix][iy] = 0;
      tmean[ix][iy] = 0;
      for (iz = 0; iz < ctl->prof_nz; iz++)
        mass[ix][iy][iz] = 0;
    }

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

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg", &rt, &rlon, &rlat, &robs) != 4)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt > t1)
      break;

    /* 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;
    tmean[ix][iy] += rt;
    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) {

        /* Write output... */
        fprintf(out, "\n");

        /* Loop over altitudes... */
        for (iz = 0; iz < ctl->prof_nz; iz++) {

          /* Set coordinates... */
          z = ctl->prof_z0 + dz * (iz + 0.5);
          lon = ctl->prof_lon0 + dlon * (ix + 0.5);
          lat = ctl->prof_lat0 + dlat * (iy + 0.5);

          /* Get meteorological data... */
          press = P(z);
          intpol_met_time(met0, met1, t, press, lon, lat,
                          NULL, &temp, NULL, NULL, NULL, &h2o, &o3);

          /* Calculate mass mixing ratio... */
          rho_air = 100. * press / (287.058 * temp);
          area = dlat * dlon * gsl_pow_2(M_PI * RE / 180.)
            * cos(lat * M_PI / 180.);
          mmr = mass[ix][iy][iz] / (rho_air * area * dz * 1e9);

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g\n",
                  tmean[ix][iy] / obscount[ix][iy],
                  z, lon, lat, press, temp, mmr, h2o, o3,
                  obsmean[ix][iy] / obscount[ix][iy]);
        }
      }

  /* Close file... */
  if (t == ctl->t_stop)
    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];

  static int init, ip, iq;

  /* Init... */
  if (!init) {
    init = 1;

    /* 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 (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 = gsl_pow_2(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 (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 (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);
}
```

5.13 libtrac.h File Reference

MPTRAC library declarations.

Data Structures

- struct ctl_t

  Control parameters.
- struct atm_t

  Atmospheric data.
- struct met_t

  Meteorological data.

Functions

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

  Convert Cartesian coordinates to geolocation.
- double deg2dx (double dlon, double lat)

  Convert degrees to horizontal distance.
- double deg2dy (double dlat)

  Convert degrees to horizontal distance.
- double dp2dz (double dp, double p)

Convert pressure to vertical distance.

- double dx2deg (double dx, double lat)

  Convert horizontal distance to degrees.
- double dy2deg (double dy)

  Convert horizontal distance to degrees.
- double dz2dp (double dz, double p)

  Convert vertical distance to pressure.
- void geo2cart (double z, double lon, double lat, double ∗x)

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

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

  Get meteorological data for timestep.
- void intpol_met_2d (double array[EX][EY], int ix, int iy, double wx, double wy, double ∗var)

  Linear interpolation of 2-D meteorological data.
- void intpol_met_3d (float array[EX][EY][EP], int ip, int ix, int iy, double wp, double wx, double wy, double ∗var)

  Linear interpolation of 3-D meteorological data.
- void intpol_met_space (met_t ∗met, double p, double lon, double lat, double ∗ps, double ∗t, double ∗u, double ∗v, double ∗w, double ∗h2o, double ∗o3)

  Spatial interpolation of meteorological data.
- void intpol_met_time (met_t ∗met0, met_t ∗met1, double ts, double p, double lon, double lat, double ∗ps, double ∗t, double ∗u, double ∗v, double ∗w, double ∗h2o, double ∗o3)

  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.
- int locate (double ∗xx, int n, double x)

  Find array index.
- void 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.
- void read_met (ctl_t ∗ctl, char ∗filename, met_t ∗met)

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

  Extrapolate meteorological data at lower boundary.
- void read_met_help (int ncid, char ∗varname, char ∗varname2, met_t ∗met, float dest[EX][EY][EP], float scl)

  Read and convert variable from meteorological data file.
- 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.
- 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.
- 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 id, int mode)

  Measure wall-clock time.
- double tropopause (double t, double lat)
- 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_station (const char ∗filename, ctl_t ∗ctl, atm_t ∗atm, double t)

  Write station data.

5.13.1 Detailed Description

MPTRAC library declarations.

Definition in file libtrac.h.

5.13.2 Function Documentation

5.13.2.1 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;

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

5.13.2.2 double deg2dx (double *dlon,* double *lat*)

Convert degrees to horizontal distance.

Definition at line 45 of file libtrac.c.

```
               {

  return dlon * M_PI * RE / 180. * cos(lat / 180. * M_PI);
}
```

5.13.2.3 double deg2dy (double *dlat*)

Convert degrees to horizontal distance.

Definition at line 54 of file libtrac.c.

```
                {

  return dlat * M_PI * RE / 180.;
}
```

5.13.2.4 double dp2dz (double *dp,* double *p*)

Convert pressure to vertical distance.

Definition at line 62 of file libtrac.c.

```
              {

  return -dp * H0 / p;
}
```

5.13.2.5 double dx2deg (double *dx,* double *lat*)

Convert horizontal distance to degrees.

Definition at line 71 of file libtrac.c.

```
                {

  /* Avoid singularity at poles... */
  if (lat < -89.999 || lat > 89.999)
    return 0;
  else
    return dx * 180. / (M_PI * RE * cos(lat / 180. * M_PI));
}
```

5.13.2.6 double dy2deg (double *dy*)

Convert horizontal distance to degrees.

Definition at line 84 of file libtrac.c.

```
               {

  return dy * 180. / (M_PI * RE);
}
```

5.13.2.7 double dz2dp (double *dz,* double *p*)

Convert vertical distance to pressure.

Definition at line 92 of file libtrac.c.

```
              {

  return -dz * p / H0;
}
```

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

Convert geolocation to Cartesian coordinates.

Definition at line 101 of file libtrac.c.

```
               {

  double radius;

  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);
}
```

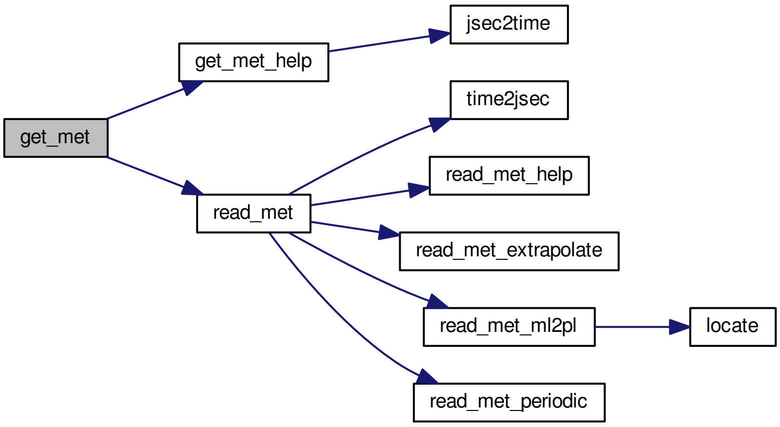
5.13.2.9 void get_met (ctl_t ∗ *ctl*, char ∗ *metbase*, double *t*, met_t ∗ *met0*, met_t ∗ *met1*)

Get meteorological data for given timestep.

Definition at line 117 of file libtrac.c.

```
                  {

  char filename[LEN];

  static int init;

  /* Init... */
  if (!init) {
    init = 1;

    get_met_help(t, -1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met0);

    get_met_help(t + 1.0 * ctl->direction, 1, metbase, ctl->
dt_met, filename);
    read_met(ctl, filename, met1);
  }

  /* Read new data for forward trajectories... */
  if (t > met1->time && ctl->direction == 1) {
    memcpy(met0, met1, sizeof(met_t));
    get_met_help(t, 1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met1);
  }

  /* Read new data for backward trajectories... */
  if (t < met0->time && ctl->direction == -1) {
    memcpy(met1, met0, sizeof(met_t));
    get_met_help(t, -1, metbase, ctl->dt_met, filename);
    read_met(ctl, filename, met0);
  }
}
```

Here is the call graph for this function:



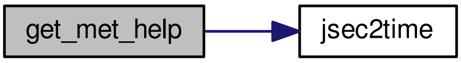
5.13.2.10 void get_met_help (double *t*, int *direct*, char ∗ *metbase*, double *dt_met*, char ∗ *filename*)

Get meteorological data for timestep.

Definition at line 156 of file libtrac.c.

```
                   {

  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_%d_%02d_%02d_%02d.nc", metbase, year, mon, day, hour);
}
```

Here is the call graph for this function:



5.13.2.11 void intpol_met_2d (double *array[EX][EY]*, int *ix*, int *iy*, double *wx*, double *wy*, double * *var*)

Linear interpolation of 2-D meteorological data.

Definition at line 182 of file libtrac.c.

```
                {

  double aux00, aux01, aux10, aux11;

  /* Set variables... */
  aux00 = array[ix][iy];
  aux01 = array[ix][iy + 1];
  aux10 = array[ix + 1][iy];
  aux11 = array[ix + 1][iy + 1];

  /* Interpolate horizontally... */
  aux00 = wy * (aux00 - aux01) + aux01;
  aux11 = wy * (aux10 - aux11) + aux11;
  *var = wx * (aux00 - aux11) + aux11;
}
```

5.13.2.12 void intpol_met_3d (float *array[EX][EY][EP]*, int *ip*, int *ix*, int *iy*, double *wp*, double *wx*, double *wy*, double * *var*)

Linear interpolation of 3-D meteorological data.

Definition at line 206 of file libtrac.c.

```
                {

  double aux00, aux01, aux10, aux11;

  /* Interpolate vertically... */
  aux00 = wp * (array[ix][iy][ip] - array[ix][iy][ip + 1])
    + array[ix][iy][ip + 1];
  aux01 = wp * (array[ix][iy + 1][ip] - array[ix][iy + 1][ip + 1])
    + array[ix][iy + 1][ip + 1];
  aux10 = wp * (array[ix + 1][iy][ip] - array[ix + 1][iy][ip + 1])
    + array[ix + 1][iy][ip + 1];
  aux11 = wp * (array[ix + 1][iy + 1][ip] - array[ix + 1][iy + 1][ip + 1])
    + array[ix + 1][iy + 1][ip + 1];

  /* Interpolate horizontally... */
  aux00 = wy * (aux00 - aux01) + aux01;
  aux11 = wy * (aux10 - aux11) + aux11;
  *var = wx * (aux00 - aux11) + aux11;
}
```

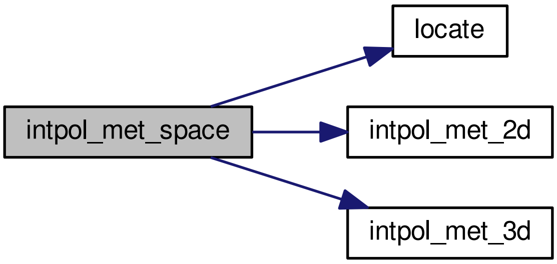
5.13.2.13 void intpol_met_space (met_t ∗ *met,* double *p,* double *lon,* double *lat,* double ∗ *ps,* double ∗ *t,* double ∗ *u,* double ∗ *v,* double ∗ *w,* double ∗ *h2o,* double ∗ *o3*)

Spatial interpolation of meteorological data.

Definition at line 236 of file libtrac.c.

```
               {

  double wp, wx, wy;

  int ip, ix, iy;

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

  /* Get indices... */
  ip = locate(met->p, met->np, p);
  ix = locate(met->lon, met->nx, lon);
  iy = locate(met->lat, met->ny, lat);

  /* Get weights... */
  wp = (met->p[ip + 1] - p) / (met->p[ip + 1] - met->p[ip]);
  wx = (met->lon[ix + 1] - lon) / (met->lon[ix + 1] - met->lon[ix]);
  wy = (met->lat[iy + 1] - lat) / (met->lat[iy + 1] - met->lat[iy]);

  /* Interpolate... */
  if (ps != NULL)
    intpol_met_2d(met->ps, ix, iy, wx, wy, ps);
  if (t != NULL)
    intpol_met_3d(met->t, ip, ix, iy, wp, wx, wy, t);
  if (u != NULL)
    intpol_met_3d(met->u, ip, ix, iy, wp, wx, wy, u);
  if (v != NULL)
    intpol_met_3d(met->v, ip, ix, iy, wp, wx, wy, v);
  if (w != NULL)
    intpol_met_3d(met->w, ip, ix, iy, wp, wx, wy, w);
  if (h2o != NULL)
    intpol_met_3d(met->h2o, ip, ix, iy, wp, wx, wy, h2o);
  if (o3 != NULL)
    intpol_met_3d(met->o3, ip, ix, iy, wp, wx, wy, o3);
}
```

Here is the call graph for this function:



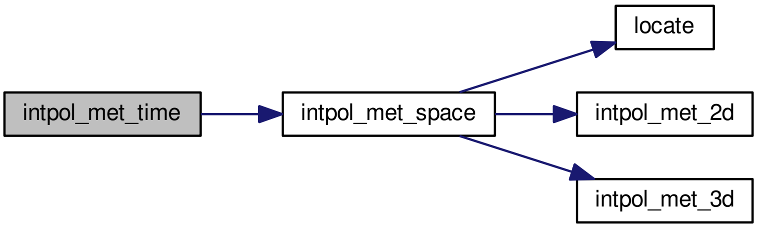
5.13.2.14 void intpol_met_time (met_t ∗ *met0,* met_t ∗ *met1,* double *ts,* double *p,* double *lon,* double *lat,* double ∗ *ps,* double ∗ *t,* double ∗ *u,* double ∗ *v,* double ∗ *w,* double ∗ *h2o,* double ∗ *o3*)

Temporal interpolation of meteorological data.

Definition at line 286 of file libtrac.c.

```
              {

  double h2o0, h2o1, o30, o31, ps0, ps1, t0, t1, u0, u1, v0, v1, w0, w1, wt;

  /* Spatial interpolation... */
  intpol_met_space(met0, p, lon, lat,
                   ps == NULL ? NULL : &ps0,
                   t == NULL ? NULL : &t0,
                   u == NULL ? NULL : &u0,
                   v == NULL ? NULL : &v0,
                   w == NULL ? NULL : &w0,
                   h2o == NULL ? NULL : &h2o0, o3 == NULL ? NULL : &o30);
  intpol_met_space(met1, p, lon, lat,
                   ps == NULL ? NULL : &ps1,
                   t == NULL ? NULL : &t1,
                   u == NULL ? NULL : &u1,
                   v == NULL ? NULL : &v1,
                   w == NULL ? NULL : &w1,
                   h2o == NULL ? NULL : &h2o1, o3 == NULL ? NULL : &o31);

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

  /* Interpolate... */
  if (ps != NULL)
    *ps = wt * (ps0 - ps1) + ps1;
  if (t != NULL)
    *t = wt * (t0 - t1) + t1;
  if (u != NULL)
    *u = wt * (u0 - u1) + u1;
  if (v != NULL)
    *v = wt * (v0 - v1) + v1;
  if (w != NULL)
    *w = wt * (w0 - w1) + w1;
  if (h2o != NULL)
    *h2o = wt * (h2o0 - h2o1) + h2o1;
  if (o3 != NULL)
    *o3 = wt * (o30 - o31) + o31;
}
```

Here is the call graph for this function:



5.13.2.15 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 341 of file libtrac.c.

```
                  {

  struct tm t0, *t1;

  time_t jsec0;

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

  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);
}
```

5.13.2.16 int locate (double ∗ *xx,* int *n,* double *x*)

Find array index.

Definition at line 376 of file libtrac.c.

```
            {

  int i, ilo, ihi;

  ilo = 0;
  ihi = n - 1;
  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;
}
```

5.13.2.17 void read_atm (const char ∗ *filename,* ctl_t ∗ *ctl,* atm_t ∗ *atm*)

Read atmospheric data.

Definition at line 408 of file libtrac.c.

```
               {

  FILE *in;

  char line[LEN], *tok;

  int iq;

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

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

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

  /* 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);

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

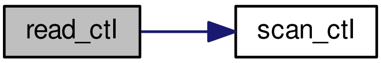
5.13.2.18 void read_ctl (const char ∗ *filename,* int *argc,* char ∗ *argv[ ],* ctl_t ∗ *ctl*)

Read control parameters.

Definition at line 458 of file libtrac.c.

```
             {

int ip, iq;

/* 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_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_theta = -1;
ctl->qnt_pv = -1;
ctl->qnt_tice = -1;
ctl->qnt_tsts = -1;
ctl->qnt_tnat = -1;
ctl->qnt_gw_var = -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 (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 (strcmp(ctl->qnt_name[iq], "ens") == 0) {
    ctl->qnt_ens = iq;
    sprintf(ctl->qnt_unit[iq], "-");
  } else if (strcmp(ctl->qnt_name[iq], "m") == 0) {
    ctl->qnt_m = iq;
    sprintf(ctl->qnt_unit[iq], "kg");
  } else if (strcmp(ctl->qnt_name[iq], "r") == 0) {
    ctl->qnt_r = iq;
    sprintf(ctl->qnt_unit[iq], "m");
  } else if (strcmp(ctl->qnt_name[iq], "rho") == 0) {
    ctl->qnt_rho = iq;
    sprintf(ctl->qnt_unit[iq], "kg/m^3");
  } else if (strcmp(ctl->qnt_name[iq], "ps") == 0) {
    ctl->qnt_ps = iq;
    sprintf(ctl->qnt_unit[iq], "hPa");
  } else if (strcmp(ctl->qnt_name[iq], "p") == 0) {
    ctl->qnt_p = iq;
    sprintf(ctl->qnt_unit[iq], "hPa");
  } else if (strcmp(ctl->qnt_name[iq], "t") == 0) {
    ctl->qnt_t = iq;
    sprintf(ctl->qnt_unit[iq], "K");
  } else if (strcmp(ctl->qnt_name[iq], "u") == 0) {
    ctl->qnt_u = iq;
    sprintf(ctl->qnt_unit[iq], "m/s");
  } else if (strcmp(ctl->qnt_name[iq], "v") == 0) {
    ctl->qnt_v = iq;
    sprintf(ctl->qnt_unit[iq], "m/s");
  } else if (strcmp(ctl->qnt_name[iq], "w") == 0) {
    ctl->qnt_w = iq;
    sprintf(ctl->qnt_unit[iq], "hPa/s");
  } else if (strcmp(ctl->qnt_name[iq], "h2o") == 0) {
    ctl->qnt_h2o = iq;
    sprintf(ctl->qnt_unit[iq], "1");
  } else if (strcmp(ctl->qnt_name[iq], "o3") == 0) {
    ctl->qnt_o3 = iq;
    sprintf(ctl->qnt_unit[iq], "1");
  } else if (strcmp(ctl->qnt_name[iq], "theta") == 0) {
    ctl->qnt_theta = iq;
    sprintf(ctl->qnt_unit[iq], "K");
  } else if (strcmp(ctl->qnt_name[iq], "pv") == 0) {
    ctl->qnt_pv = iq;
    sprintf(ctl->qnt_unit[iq], "PVU");
  } else if (strcmp(ctl->qnt_name[iq], "tice") == 0) {
    ctl->qnt_tice = iq;
    sprintf(ctl->qnt_unit[iq], "K");
  } else if (strcmp(ctl->qnt_name[iq], "tsts") == 0) {
    ctl->qnt_tsts = iq;
    sprintf(ctl->qnt_unit[iq], "K");
  } else if (strcmp(ctl->qnt_name[iq], "tnat") == 0) {
    ctl->qnt_tnat = iq;
    sprintf(ctl->qnt_unit[iq], "K");
  } else if (strcmp(ctl->qnt_name[iq], "gw_var") == 0) {
    ctl->qnt_gw_var = iq;
    sprintf(ctl->qnt_unit[iq], "K^2");
  } else if (strcmp(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_start =
  scan_ctl(filename, argc, argv, "T_START", -1, "-1e100", NULL);
ctl->t_stop = scan_ctl(filename, argc, argv, "T_STOP", -1, "-1e100", NULL);
ctl->dt_mod = scan_ctl(filename, argc, argv, "DT_MOD", -1, "600", NULL);

/* Meteorological data... */
ctl->dt_met = scan_ctl(filename, argc, argv, "DT_MET", -1, "21600", 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 (ip = 0; ip < ctl->met_np; ip++)
  ctl->met_p[ip] = scan_ctl(filename, argc, argv, "MET_P", ip, "", NULL);
scan_ctl(filename, argc, argv, "MET_STAGE", -1, "-", ctl->met_stage);

/* 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, "50.0", NULL);
ctl->turb_dx_strat
  = scan_ctl(filename, argc, argv, "TURB_DX_STRAT", -1, "0.0", NULL);
ctl->turb_dz_trop
  = scan_ctl(filename, argc, argv, "TURB_DZ_TROP", -1, "0.0", NULL);
ctl->turb_dz_strat
  = scan_ctl(filename, argc, argv, "TURB_DZ_STRAT", -1, "0.1", NULL);
ctl->turb_meso =
  scan_ctl(filename, argc, argv, "TURB_MESO", -1, "0.16", NULL);

/* Life time of particles... */
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);

/* 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);

/* Gravity wave analysis... */
scan_ctl(filename, argc, argv, "GW_BASENAME", -1, "-", ctl->gw_basename);

/* 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);

/* 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, "obs.tab",
         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 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:



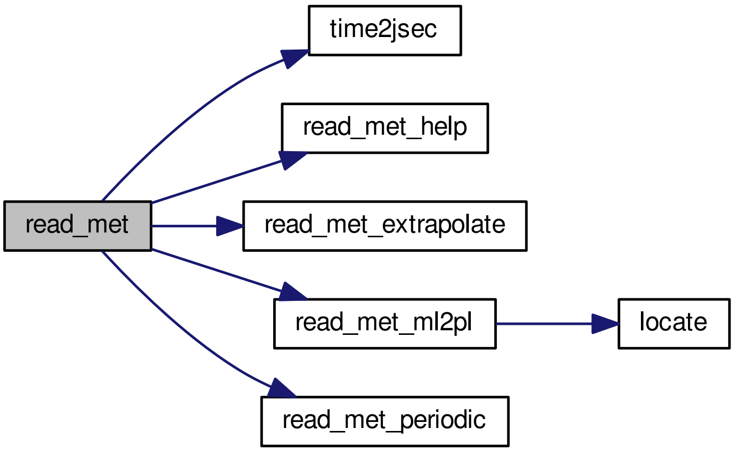
5.13.2.19 void read_met (ctl_t ∗ *ctl,* char ∗ *filename,* met_t ∗ *met*)

Read meteorological data file.

Definition at line 704 of file libtrac.c.

```
               {

  char cmd[LEN], levname[LEN], tstr[10];

  static float help[EX * EY];

  int ix, iy, ip, dimid, ncid, varid, year, mon, day, hour;

  size_t np, nx, ny;

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

  /* 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);

  /* Open netCDF file... */
  if (nc_open(filename, NC_NOWRITE, &ncid) != NC_NOERR) {

    /* Try to stage meteo file... */
    START_TIMER(TIMER_STAGE);
    if (ctl->met_stage[0] != '-') {
      sprintf(cmd, "%s %d %02d %02d %02d %s", ctl->met_stage,
              year, mon, day, hour, filename);
      if (system(cmd) != 0)
        ERRMSG("Error while staging meteo data!");
    }
    STOP_TIMER(TIMER_STAGE);

    /* Try to open again... */
    NC(nc_open(filename, NC_NOWRITE, &ncid));
  }

  /* Get 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");
    NC(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;

  /* Get horizontal grid... */
  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 meteorological data... */
  read_met_help(ncid, "t", "T", met, met->t, 1.0);
  read_met_help(ncid, "u", "U", met, met->u, 1.0);
  read_met_help(ncid, "v", "V", met, met->v, 1.0);
  read_met_help(ncid, "w", "W", met, met->w, 0.01f);
  read_met_help(ncid, "q", "Q", met, met->h2o, 1.608f);
  read_met_help(ncid, "o3", "O3", met, met->o3, 0.602f);

  /* Meteo data on pressure levels... */
  if (ctl->met_np <= 0) {

    /* Read pressure levels from file... */
    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.;

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

  /* Meteo data on model levels... */
  else {

    /* Read pressure data from file... */
    read_met_help(ncid, "pl", "PL", met, met->pl, 0.01f);

    /* Interpolate from model levels 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);

    /* Set pressure levels... */
    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!");

  /* Read surface pressure... */
  if (nc_inq_varid(ncid, "ps", &varid) == NC_NOERR
      || nc_inq_varid(ncid, "PS", &varid) == NC_NOERR) {
    NC(nc_get_var_float(ncid, varid, help));
    for (iy = 0; iy < met->ny; iy++)
      for (ix = 0; ix < met->nx; ix++)
        met->ps[ix][iy] = help[iy * met->nx + ix] / 100.;
  } else if (nc_inq_varid(ncid, "lnsp", &varid) == NC_NOERR
             || nc_inq_varid(ncid, "LNSP", &varid) == NC_NOERR) {
    NC(nc_get_var_float(ncid, varid, help));
    for (iy = 0; iy < met->ny; iy++)
      for (ix = 0; ix < met->nx; ix++)
        met->ps[ix][iy] = exp(help[iy * met->nx + ix]) / 100.;
  } else
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        met->ps[ix][iy] = met->p[0];

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

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

Here is the call graph for this function:



5.13.2.20 void read_met_extrapolate (met_t ∗ *met*)

Extrapolate meteorological data at lower boundary.

Definition at line 854 of file libtrac.c.

```
               {

  int ip, ip0, ix, iy;

  /* Loop over columns... */
  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 (!gsl_finite(met->t[ix][iy][ip0])
            || !gsl_finite(met->u[ix][iy][ip0])
            || !gsl_finite(met->v[ix][iy][ip0])
            || !gsl_finite(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];
      }
    }
}
```

5.13.2.21 void read_met_help (int *ncid,* char ∗ *varname,* char ∗ *varname2,* met_t ∗ *met,* float *dest[EX][EY][EP],* float *scl*)

Read and convert variable from meteorological data file.

Definition at line 885 of file libtrac.c.

```
                   {

  static float help[EX * EY * EP];

  int ip, ix, iy, n = 0, varid;

  /* Check if variable exists... */
  if (nc_inq_varid(ncid, varname, &varid) != NC_NOERR)
    if (nc_inq_varid(ncid, varname2, &varid) != NC_NOERR)
      return;

  /* Read data... */
  NC(nc_get_var_float(ncid, varid, help));

  /* Copy and check data... */
  for (ip = 0; ip < met->np; ip++)
    for (iy = 0; iy < met->ny; iy++)
      for (ix = 0; ix < met->nx; ix++) {
        dest[ix][iy][ip] = scl * help[n++];
        if (fabs(dest[ix][iy][ip] / scl) > 1e14)
          dest[ix][iy][ip] = GSL_NAN;
      }
}
```

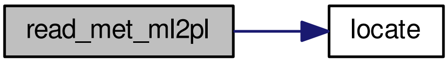
5.13.2.22 void read_met_ml2pl (ctl_t ∗ *ctl,* met_t ∗ *met,* float *var[EX][EY][EP]*)

Convert meteorological data from model levels to pressure levels.

Definition at line 917 of file libtrac.c.

```
                                 {

  double aux[EP], p[EP], pt;

  int ip, ip2, ix, iy;

  /* Loop over columns... */
  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(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:



5.13.2.23 void read_met_periodic (met_t * *met*)

Create meteorological data with periodic boundary conditions.

Definition at line 955 of file libtrac.c.

```
00956                 {
00957 
00958   int ip, iy;
00959 
00960   /* Check longitudes... */
00961   if (!(fabs(met->lon[met->nx - 1] - met->lon[0]
00962              + met->lon[1] - met->lon[0] - 360) < 0.01))
00963     return;
00964 
00965   /* Increase longitude counter... */
00966   if ((++met->nx) > EX)
00967     ERRMSG("Cannot create periodic boundary conditions!");
00968 
00969   /* Set longitude... */
00970   met->lon[met->nx - 1] = met->lon[met->nx - 2] + met->lon[1] - met->
      lon[0];
00971 
00972   /* Loop over latitudes and pressure levels... */
00973   for (iy = 0; iy < met->ny; iy++)
00974     for (ip = 0; ip < met->np; ip++) {
00975       met->ps[met->nx - 1][iy] = met->ps[0][iy];
00976       met->u[met->nx - 1][iy][ip] = met->u[0][iy][ip];
00977       met->v[met->nx - 1][iy][ip] = met->v[0][iy][ip];
00978       met->w[met->nx - 1][iy][ip] = met->w[0][iy][ip];
00979       met->t[met->nx - 1][iy][ip] = met->t[0][iy][ip];
00980       met->h2o[met->nx - 1][iy][ip] = met->h2o[0][iy][ip];
00981       met->o3[met->nx - 1][iy][ip] = met->o3[0][iy][ip];
00982     }
00983 }
```

5.13.2.24 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 987 of file libtrac.c.

```
00994                 {
00995 
00996   FILE *in = NULL;
00997 
00998   char dummy[LEN], fullname1[LEN], fullname2[LEN], line[LEN],
00999     msg[LEN], rvarname[LEN], rval[LEN];
01000 
01001   int contain = 0, i;
01002 
01003   /* Open file... */
01004   if (filename[strlen(filename) - 1] != '-')
01005     if (!(in = fopen(filename, "r")))
01006       ERRMSG("Cannot open file!");
01007 
01008   /* Set full variable name... */
01009   if (arridx >= 0) {
01010     sprintf(fullname1, "%s[%d]", varname, arridx);
01011     sprintf(fullname2, "%s[*]", varname);
01012   } else {
01013     sprintf(fullname1, "%s", varname);
01014     sprintf(fullname2, "%s", varname);
01015   }
01016 
01017   /* Read data... */
01018   if (in != NULL)
01019     while (fgets(line, LEN, in))
01020       if (sscanf(line, "%s %s %s", rvarname, dummy, rval) == 3)
01021         if (strcasecmp(rvarname, fullname1) == 0 ||
01022             strcasecmp(rvarname, fullname2) == 0) {
01023           contain = 1;
01024           break;
01025         }
01026   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);
}
```

5.13.2.25 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 1059 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;
}
```

5.13.2.26 void timer (const char ∗ *name,* int *id,* int *mode*)

Measure wall-clock time.

Definition at line 1090 of file libtrac.c.

```
            {

  static double starttime[NTIMER], runtime[NTIMER];

  /* Check id... */
  if (id < 0 || id >= NTIMER)
    ERRMSG("Too many timers!");

  /* Start timer... */
  if (mode == 1) {
    if (starttime[id] <= 0)
```

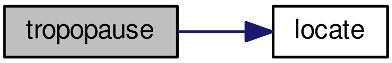
```
01104       starttime[id] = omp_get_wtime();
01105     else
01106       ERRMSG("Timer already started!");
01107   }
01108 
01109   /* Stop timer... */
01110   else if (mode == 2) {
01111     if (starttime[id] > 0) {
01112       runtime[id] = runtime[id] + omp_get_wtime() - starttime[id];
01113       starttime[id] = -1;
01114     } else
01115       ERRMSG("Timer not started!");
01116   }
01117 
01118   /* Print timer... */
01119   else if (mode == 3)
01120     printf("%s = %g s\n", name, runtime[id]);
01121 }
```

5.13.2.27 double tropopause (double *t*, double *lat*)

Definition at line 1125 of file libtrac.c.

```
01127               {
01128 
01129   static double doys[12]
01130   = { 1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335 };
01131 
01132   static double lats[73]
01133     = { -90, -87.5, -85, -82.5, -80, -77.5, -75, -72.5, -70, -67.5,
01134     -65, -62.5, -60, -57.5, -55, -52.5, -50, -47.5, -45, -42.5,
01135     -40, -37.5, -35, -32.5, -30, -27.5, -25, -22.5, -20, -17.5,
01136     -15, -12.5, -10, -7.5, -5, -2.5, 0, 2.5, 5, 7.5, 10, 12.5,
01137     15, 17.5, 20, 22.5, 25, 27.5, 30, 32.5, 35, 37.5, 40, 42.5,
01138     45, 47.5, 50, 52.5, 55, 57.5, 60, 62.5, 65, 67.5, 70, 72.5,
01139     75, 77.5, 80, 82.5, 85, 87.5, 90
01140   };
01141 
01142   static double tps[12][73]
01143     = { {324.1, 325.6, 325, 324.3, 322.5, 319.7, 314, 307.2, 301.8, 299.6,
01144          297.1, 292.2, 285.6, 276.1, 264, 248.9, 231.9, 213.5, 194.4,
01145          175.3, 157, 140.4, 126.7, 116.3, 109.5, 105.4, 103, 101.4, 100.4,
01146          99.69, 99.19, 98.84, 98.56, 98.39, 98.39, 98.42, 98.44, 98.54,
01147          98.68, 98.81, 98.89, 98.96, 99.12, 99.65, 101.4, 105.4, 113.5, 128,
01148          152.1, 184.7, 214, 234.1, 247.3, 255.8, 262.6, 267.7, 271.7, 275,
01149          277.2, 279, 280.1, 280.4, 280.6, 280.1, 279.3, 278.3, 276.8, 275.8,
01150          275.3, 275.6, 275.4, 274.1, 273.5},
01151   {337.3, 338.7, 337.8, 336.4, 333, 328.8, 321.1, 312.6, 306.6, 303.7,
01152    300.2, 293.8, 285.4, 273.8, 259.6, 242.7, 224.4, 205.2, 186, 167.5,
01153    150.3, 135, 122.8, 113.9, 108.2, 104.7, 102.5, 101.1, 100.2, 99.42,
01154    98.88, 98.52, 98.25, 98.09, 98.07, 98.1, 98.12, 98.2, 98.25, 98.27,
01155    98.26, 98.27, 98.36, 98.79, 100.2, 104.2, 113.7, 131.2, 159.5, 193,
01156    220.4, 238.1, 250.2, 258.1, 264.7, 269.7, 273.7, 277.3, 280.2, 282.8,
01157    284.9, 286.5, 288.1, 288.8, 289, 288.5, 287.2, 286.3, 286.1, 287.2,
01158    287.5, 286.2, 285.8},
01159   {335, 336, 335.7, 335.1, 332.3, 328.1, 320.6, 311.8, 305.1, 301.9,
01160    297.6, 290, 280.4, 268.3, 254.6, 239.6, 223.9, 207.9, 192.2, 176.9,
01161    161.7, 146.4, 132.2, 120.6, 112.3, 107.2, 104.3, 102.4, 101.3,
01162    100.4, 99.86, 99.47, 99.16, 98.97, 98.94, 98.97, 99, 99.09, 99.2,
01163    99.31, 99.35, 99.41, 99.51, 99.86, 101.1, 104.9, 114.3, 131, 156.8,
01164    186.3, 209.3, 224.6, 236.8, 246.3, 254.9, 262.3, 268.8, 274.8,
01165    279.9, 284.6, 288.6, 291.6, 294.9, 297.5, 299.8, 301.8, 303.1,
01166    304.3, 304.9, 306, 306.6, 306.2, 306},
01167   {306.2, 306.7, 305.7, 307.1, 307.3, 306.4, 301.8, 296.2, 292.4,
01168    290.3, 287.1, 280.9, 273.4, 264.3, 254.1, 242.8, 231, 219, 207.2,
01169    195.5, 183.3, 169.7, 154.7, 138.7, 124.1, 113.6, 107.8, 104.7,
01170    102.8, 101.7, 100.9, 100.4, 100, 99.79, 99.7, 99.66, 99.68, 99.79,
01171    99.94, 100.2, 100.5, 100.9, 101.4, 102.1, 103.4, 107, 115.2, 129.1,
01172    148.7, 171, 190.8, 205.6, 218.4, 229.4, 239.6, 248.6, 256.5,
01173    263.7, 270.3, 276.6, 282.6, 288.1, 294.5, 300.4, 306.3, 311.4,
01174    315.1, 318.3, 320.3, 322.2, 322.8, 321.5, 321.1},
01175   {266.5, 264.9, 260.8, 261, 262, 263, 261.3, 259.7, 259.2, 259.8,
01176    260.1, 258.6, 256.7, 253.6, 249.5, 243.9, 237.4, 230, 222.1, 213.9,
01177    205, 194.4, 180.4, 161.8, 140.7, 122.9, 112.1, 106.7, 104.1, 102.7,
01178    101.8, 101.4, 101.1, 101, 101, 101, 101.1, 101.2, 101.5, 101.9,
01179    102.4, 103, 103.8, 104.9, 106.8, 110.1, 115.6, 124, 135.2, 148.9,
01180    165.2, 181.3, 198, 211.8, 223.5, 233.8, 242.9, 251.5, 259, 266.2,
01181    273.1, 279.2, 286.2, 292.8, 299.6, 306, 311.1, 315.5, 318.8, 322.6,
01182    325.3, 325.8, 325.8},
01183   {220.1, 218.1, 210.8, 207.2, 207.6, 210.5, 211.4, 213.5, 217.3,
01184    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,
   308.5, 312.2, 313.1, 313.3},
  {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,
   110.8, 109.7, 109.3, 109.4, 109.7, 110, 110.2, 110.4, 110.5, 110.7,
   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,
   110.6, 110.8, 111, 111.4, 111.8, 112, 112.2, 112.4, 112.9, 113.6,
   114.7, 116.3, 118.4, 121.9, 127.1, 136.1, 149.8, 168.4, 186.9,
   203.3, 217, 229.1, 238.7, 247, 254, 259.3, 264.3, 268.3, 272.5,
   276.6, 280.4, 284.4, 288.4, 293.3, 297.2, 298.7, 299.1},
  {191.6, 192.2, 189, 188.1, 190.2, 193.7, 197.8, 202.9, 208.5,
   215.6, 224.2, 233.1, 241.2, 247.3, 250.8, 251.3, 248.9, 244.2,
   237.3, 228.4, 217.2, 202.9, 184.5, 162.5, 140.7, 124.8, 116.2,
   111.8, 109.4, 107.9, 107, 106.7, 106.6, 106.6, 106.7, 106.7,
   106.8, 107, 107.4, 108, 108.7, 109.3, 109.8, 110.4, 111.2,
   112.4, 114.2, 116.9, 121.1, 127.9, 139.3, 155.2, 173.6, 190.7,
   206.1, 220.1, 232.3, 243, 251.8, 259.2, 265.7, 270.6, 275.3,
   279.3, 283.3, 286.9, 289.7, 292.8, 296.1, 300.5, 303.9, 304.8,
   305.1},
  {241.5, 239.6, 236.8, 237.4, 239.4, 242.3, 244.2, 246.4, 249.2,
   253.6, 258.6, 262.7, 264.8, 264.2, 260.6, 254.1, 245.5, 235.3,
   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}
  };

  double doy, p0, p1, pt;

  int imon, ilat;

  /* Get day of year... */
  doy = fmod(t / 86400., 365.25);
  while (doy < 0)
    doy += 365.25;

  /* Get indices... */
  imon = locate(doys, 12, doy);
  ilat = locate(lats, 73, lat);

  /* Get tropopause pressure... */
  p0 = LIN(lats[ilat], tps[imon][ilat],
           lats[ilat + 1], tps[imon][ilat + 1], lat);
  p1 = LIN(lats[ilat], tps[imon + 1][ilat],
           lats[ilat + 1], tps[imon + 1][ilat + 1], lat);
  pt = LIN(doys[imon], p0, doys[imon + 1], p1, doy);

  /* Return tropopause pressure... */
  return pt;
}
```

Here is the call graph for this function:



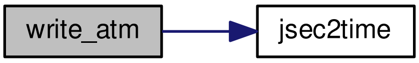
5.13.2.28 void write_atm (const char ∗ *filename,* ctl_t ∗ *ctl,* atm_t ∗ *atm,* double *t*)

Write atmospheric data.

Definition at line 1268 of file libtrac.c.

```
            {

  FILE *in, *out;

  char line[LEN];

  double r, t0, t1;

  int ip, iq, year, mon, day, hour, min, sec;

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Check if gnuplot output is requested... */
  if (ctl->atm_gpfile[0] != '-') {

    /* Write info... */
    printf("Plot atmospheric 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->atm_gpfile, "r")))
      ERRMSG("Cannot open file!");
    while (fgets(line, LEN, in))
      fprintf(out, "%s", line);
    fclose(in);
  }

  else {

    /* Write info... */
    printf("Write atmospheric 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");
  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++) {

    /* 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);
}
```

Here is the call graph for this function:



5.13.2.29 void write_csi (const char ∗ *filename,* ctl_t ∗ *ctl,* atm_t ∗ *atm,* double *t*)

Write CSI data.

Definition at line 1355 of file libtrac.c.

```
            {

  static FILE *in, *out;

  static char line[LEN];

  static double modmean[GX][GY][GZ], obsmean[GX][GY][GZ],
    rt, rz, rlon, rlat, robs, t0, t1, area, dlon, dlat, lat;

  static int init, obscount[GX][GY][GZ], cx, cy, cz, ip, ix, iy, iz;

  /* Init... */
  if (!init) {
    init = 1;

    /* Check quantity index for mass... */
    if (ctl->qnt_m < 0)
      ERRMSG("Need quantity mass to analyze CSI!");

    /* 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 (forecasts/observations) [%%]\n"
            "# $8 = probability of detection (POD) [%%]\n"
            "# $9 = false alarm rate (FAR) [%%]\n"
            "# $10 = critical success index (CSI) [%%]\n\n");
  }

  /* Set time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize 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++)
        modmean[ix][iy][iz] = obsmean[ix][iy][iz] = obscount[ix][iy][iz] = 0;

  /* Read 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;

    /* Calculate indices... */
    ix = (int) ((rlon - ctl->csi_lon0)
                / (ctl->csi_lon1 - ctl->csi_lon0) * ctl->csi_nx);
    iy = (int) ((rlat - ctl->csi_lat0)
                / (ctl->csi_lat1 - ctl->csi_lat0) * ctl->csi_ny);
    iz = (int) ((rz - ctl->csi_z0)
                / (ctl->csi_z1 - ctl->csi_z0) * ctl->csi_nz);

    /* 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)
                / (ctl->csi_lon1 - ctl->csi_lon0) * ctl->csi_nx);
    iy = (int) ((atm->lat[ip] - ctl->csi_lat0)
                / (ctl->csi_lat1 - ctl->csi_lat0) * ctl->csi_ny);
    iz = (int) ((Z(atm->p[ip]) - ctl->csi_z0)
                / (ctl->csi_z1 - ctl->csi_z0) * ctl->csi_nz);

    /* 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) {
          dlon = (ctl->csi_lon1 - ctl->csi_lon0) / ctl->csi_nx;
          dlat = (ctl->csi_lat1 - ctl->csi_lat0) / ctl->csi_ny;
          lat = ctl->csi_lat0 + dlat * (iy + 0.5);
          area = dlat * M_PI * RE / 180. * dlon * M_PI * RE / 180.
            * cos(lat * M_PI / 180.);
          modmean[ix][iy][iz] /= (1e6 * area);
        }

        /* Calculate CSI... */
        if (obscount[ix][iy][iz] > 0) {
          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++;
        }
      }

  /* Write output... */
  if (fmod(t, ctl->csi_dt_out) == 0) {

    /* Write... */
    fprintf(out, "%.2f %d %d %d %d %d %g %g %g %g\n",
            t, cx, cy, cz, cx + cy, cx + cz,
            (cx + cy > 0) ? 100. * (cx + cz) / (cx + cy) : GSL_NAN,
            (cx + cy > 0) ? (100. * cx) / (cx + cy) : GSL_NAN,
            (cx + cz > 0) ? (100. * cz) / (cx + cz) : GSL_NAN,
            (cx + cy + cz > 0) ? (100. * cx) / (cx + cy + cz) : GSL_NAN);

    /* Set counters to zero... */
    cx = cy = cz = 0;
  }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

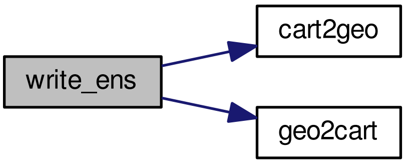
5.13.2.30 void write_ens (const char ∗ *filename*, ctl_t ∗ *ctl*, atm_t ∗ *atm*, double *t*)

Write ensemble data.

Definition at line 1523 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 init, ip, iq;

  static size_t i, n;

  /* Init... */
  if (!init) {
    init = 1;

    /* 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:



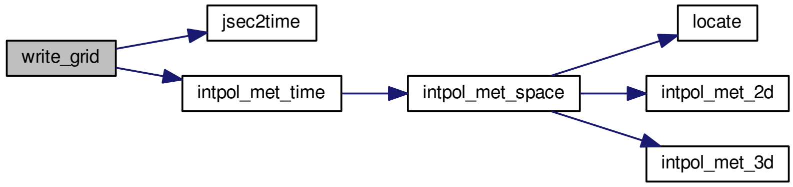
5.13.2.31 void write_grid (const char ∗ *filename,* ctl_t ∗ *ctl,* met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* double *t*)

Write gridded data.

Definition at line 1655 of file libtrac.c.

```
            {

  FILE *in, *out;

  char line[LEN];

  static double grid_m[GX][GY][GZ], z, dz, lon, dlon, lat, dlat,
    area, rho_air, press, temp, cd, mmr, t0, t1, r;

  static int ip, ix, iy, iz, year, mon, day, hour, min, sec;

  /* Check dimensions... */
  if (ctl->grid_nx > GX || ctl->grid_ny > GY || ctl->grid_nz > GZ)
    ERRMSG("Grid dimensions too large!");

  /* Check quantity index for mass... */
  if (ctl->qnt_m < 0)
    ERRMSG("Need quantity mass to write grid data!");

  /* Set time interval for output... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* 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;

  /* Initialize grid... */
  for (ix = 0; ix < ctl->grid_nx; ix++)
    for (iy = 0; iy < ctl->grid_ny; iy++)
      for (iz = 0; iz < ctl->grid_nz; iz++)
        grid_m[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... */
      grid_m[ix][iy][iz] += atm->q[ctl->qnt_m][ip];
    }

  /* 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 = temperature [K]\n"
          "# $8 = column density [kg/m^2]\n"
          "# $9 = mass mixing ratio [1]\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
            || ix == 0 || iy == 0 || iz == 0 || grid_m[ix][iy][iz] > 0) {

          /* Set coordinates... */
          z = ctl->grid_z0 + dz * (iz + 0.5);
          lon = ctl->grid_lon0 + dlon * (ix + 0.5);
          lat = ctl->grid_lat0 + dlat * (iy + 0.5);

          /* Get pressure and temperature... */
          press = P(z);
          intpol_met_time(met0, met1, t, press, lon, lat,
                          NULL, &temp, NULL, NULL, NULL, NULL, NULL);

          /* Calculate surface area... */
          area = dlat * dlon * gsl_pow_2(RE * M_PI / 180.)
            * cos(lat * M_PI / 180.);

          /* Calculate column density... */
          cd = grid_m[ix][iy][iz] / (1e6 * area);

          /* Calculate mass mixing ratio... */
          rho_air = 100. * press / (287.058 * temp);
          mmr = grid_m[ix][iy][iz] / (rho_air * 1e6 * area * 1e3 * dz);

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %g %g %g\n",
                  t, z, lon, lat, area, dz, temp, cd, mmr);
        }
    }
  }

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

Here is the call graph for this function:



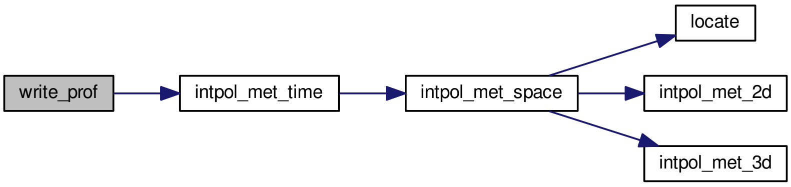
5.13.2.32 void write_prof (const char * *filename,* ctl_t * *ctl,* met_t * *met0,* met_t * *met1,* atm_t * *atm,* double *t*)

Write profile data.

Definition at line 1806 of file libtrac.c.

```
            {

  static FILE *in, *out;

  static char line[LEN];

  static double mass[GX][GY][GZ], obsmean[GX][GY], tmean[GX][GY],
    rt, rlon, rlat, robs, t0, t1, area, dz, dlon, dlat, lon, lat, z,
    press, temp, rho_air, mmr, h2o, o3;

  static int init, obscount[GX][GY], ip, ix, iy, iz;

  /* Init... */
  if (!init) {
    init = 1;

    /* 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!");

    /* 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 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  = mass mixing ratio [1]\n"
            "# $8  = H2O volume mixing ratio [1]\n"
            "# $9  = O3 volume mixing ratio [1]\n"
            "# $10 = mean 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 time interval... */
  t0 = t - 0.5 * ctl->dt_mod;
  t1 = t + 0.5 * ctl->dt_mod;

  /* Initialize... */
  for (ix = 0; ix < ctl->prof_nx; ix++)
    for (iy = 0; iy < ctl->prof_ny; iy++) {
      obsmean[ix][iy] = 0;
      obscount[ix][iy] = 0;
      tmean[ix][iy] = 0;
      for (iz = 0; iz < ctl->prof_nz; iz++)
        mass[ix][iy][iz] = 0;
    }

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

    /* Read data... */
    if (sscanf(line, "%lg %lg %lg %lg", &rt, &rlon, &rlat, &robs) != 4)
      continue;

    /* Check time... */
    if (rt < t0)
      continue;
    if (rt > t1)
      break;

    /* 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;
    tmean[ix][iy] += rt;
    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) {

        /* Write output... */
        fprintf(out, "\n");

        /* Loop over altitudes... */
        for (iz = 0; iz < ctl->prof_nz; iz++) {

          /* Set coordinates... */
          z = ctl->prof_z0 + dz * (iz + 0.5);
          lon = ctl->prof_lon0 + dlon * (ix + 0.5);
          lat = ctl->prof_lat0 + dlat * (iy + 0.5);

          /* Get meteorological data... */
          press = P(z);
          intpol_met_time(met0, met1, t, press, lon, lat,
                          NULL, &temp, NULL, NULL, NULL, &h2o, &o3);

          /* Calculate mass mixing ratio... */
          rho_air = 100. * press / (287.058 * temp);
          area = dlat * dlon * gsl_pow_2(M_PI * RE / 180.)
            * cos(lat * M_PI / 180.);
          mmr = mass[ix][iy][iz] / (rho_air * area * dz * 1e9);

          /* Write output... */
          fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g\n",
                  tmean[ix][iy] / obscount[ix][iy],
                  z, lon, lat, press, temp, mmr, h2o, o3,
                  obsmean[ix][iy] / obscount[ix][iy]);
        }
      }

  /* Close file... */
  if (t == ctl->t_stop)
    fclose(out);
}
```

Here is the call graph for this function:



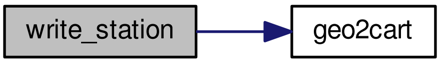
5.13.2.33 void write_station (const char * *filename,* ctl_t * *ctl,* atm_t * *atm,* double *t*)

Write station data.

Definition at line 1969 of file libtrac.c.

```
                 {

  static FILE *out;

  static double rmax2, t0, t1, x0[3], x1[3];

  static int init, ip, iq;

  /* Init... */
  if (!init) {
    init = 1;

    /* 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 (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 = gsl_pow_2(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 (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 (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:



5.14 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) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include <ctype.h>
#include <gsl/gsl_const_mksa.h>
#include <gsl/gsl_math.h>
#include <gsl/gsl_randist.h>
#include <gsl/gsl_rng.h>
#include <gsl/gsl_sort.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>

/* ------------------------------------------------------------
   Constants...
   ------------------------------------------------------------ */

#define G0 9.80665

#define H0 7.0

#define P0 1013.25

#define RE 6367.421

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

#define LEN 5000

#define NP 10000000

#define NQ 12

#define EP 137

#define EX 1201

#define EY 601

#define GX 720

#define GY 360

#define GZ 100

#define NENS 2000

#define NTHREADS 128

/* ------------------------------------------------------------
   Macros...
   ------------------------------------------------------------ */

#define ALLOC(ptr, type, n)                                      \
  if((ptr=calloc((size_t)(n), sizeof(type)))==NULL)      \
    ERRMSG("Out of memory!");

#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 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 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 TOK(line, tok, format, var) {                                    \
    if(((tok)=strtok((line), " \t"))) {                                  \
      if(sscanf(tok, format, &(var))!=1) continue;                       \
    } else ERRMSG("Error while reading!");                               \
  }

#define Z(p) (H0*log(P0/(p)))

/* ------------------------------------------------------------
   Timers...
   ------------------------------------------------------------ */

#define START_TIMER(id) timer(#id, id, 1)

#define STOP_TIMER(id) timer(#id, id, 2)

#define PRINT_TIMER(id) timer(#id, id, 3)

#define NTIMER 13

#define TIMER_TOTAL 0

#define TIMER_INIT 1

#define TIMER_STAGE 2

#define TIMER_INPUT 3

#define TIMER_OUTPUT 4

#define TIMER_ADVECT 5

#define TIMER_DECAY 6

#define TIMER_DIFFMESO 7

#define TIMER_DIFFTURB 8

#define TIMER_ISOSURF 9

#define TIMER_METEO 10

#define TIMER_POSITION 11

#define TIMER_SEDI 12

/* ------------------------------------------------------------
   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_p;

  int qnt_t;

  int qnt_u;

  int qnt_v;

  int qnt_w;

  int qnt_h2o;

  int qnt_o3;

  int qnt_theta;

  int qnt_pv;

  int qnt_tice;

  int qnt_tsts;

  int qnt_tnat;

  int qnt_stat;

  int qnt_gw_u750;

  int qnt_gw_v750;

  int qnt_gw_sso;

  int qnt_gw_var;

  int direction;

  double t_start;

  double t_stop;

  double dt_mod;

  double dt_met;

  int met_np;

  double met_p[EP];

  char met_stage[LEN];

  int isosurf;

  char balloon[LEN];

  double turb_dx_trop;

  double turb_dx_strat;

  double turb_dz_trop;

  double turb_dz_strat;

  double turb_meso;

  double tdec_trop;

  double tdec_strat;

  double psc_h2o;

  double psc_hno3;

  char gw_basename[LEN];

  char atm_basename[LEN];

  char atm_gpfile[LEN];

  double atm_dt_out;

  int atm_filter;

  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 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];

  double up[NP];

  double vp[NP];

  double wp[NP];

} atm_t;

typedef struct {

  double time;

  int nx;

  int ny;

  int np;

  double lon[EX];

  double lat[EY];

  double p[EP];

  double ps[EX][EY];

  float pl[EX][EY][EP];

  float t[EX][EY][EP];

  float u[EX][EY][EP];

  float v[EX][EY][EP];

  float w[EX][EY][EP];

  float h2o[EX][EY][EP];

  float o3[EX][EY][EP];

} met_t;

/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

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

double deg2dx(
  double dlon,
  double lat);

double deg2dy(
  double dlat);

double dp2dz(
  double dp,
  double p);

double dx2deg(
  double dx,
  double lat);

double dy2deg(
  double dy);

double dz2dp(
  double dz,
  double p);

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

void get_met(
  ctl_t * ctl,
  char *metbase,
  double t,
  met_t * met0,
  met_t * met1);

void get_met_help(
  double t,
  int direct,
  char *metbase,
  double dt_met,
  char *filename);

void intpol_met_2d(
  double array[EX][EY],
  int ix,
  int iy,
  double wx,
  double wy,
  double *var);

void intpol_met_3d(
  float array[EX][EY][EP],
  int ip,
  int ix,
  int iy,
  double wp,
  double wx,
  double wy,
  double *var);

void intpol_met_space(
  met_t * met,
  double p,
  double lon,
  double lat,
  double *ps,
  double *t,
  double *u,
  double *v,
  double *w,
  double *h2o,
  double *o3);

void intpol_met_time(
  met_t * met0,
  met_t * met1,
  double ts,
  double p,
  double lon,
  double lat,
  double *ps,
  double *t,
  double *u,
  double *v,
  double *w,
  double *h2o,
  double *o3);

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

int locate(
  double *xx,
  int n,
  double x);

void read_atm(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm);

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

void read_met(
  ctl_t * ctl,
  char *filename,
  met_t * met);

void read_met_extrapolate(
  met_t * met);

void read_met_help(
  int ncid,
  char *varname,
  char *varname2,
  met_t * met,
  float dest[EX][EY][EP],
  float scl);

void read_met_ml2pl(
  ctl_t * ctl,
  met_t * met,
  float var[EX][EY][EP]);

void read_met_periodic(
  met_t * met);

double scan_ctl(
  const char *filename,
  int argc,
  char *argv[],
  const char *varname,
  int arridx,
  const char *defvalue,
  char *value);

void time2jsec(
  int year,
  int mon,
  int day,
  int hour,
  int min,
  int sec,
  double remain,
  double *jsec);

void timer(
  const char *name,
  int id,
  int mode);

/* Get tropopause pressure... */
double tropopause(
  double t,
  double lat);

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_station(
  const char *filename,
  ctl_t * ctl,
  atm_t * atm,
  double t);
```

5.15 match.c File Reference

Calculate deviations between two trajectories.

Functions

- int main (int argc, char ∗argv[ ])

5.15.1 Detailed Description

Calculate deviations between two trajectories.

Definition in file match.c.

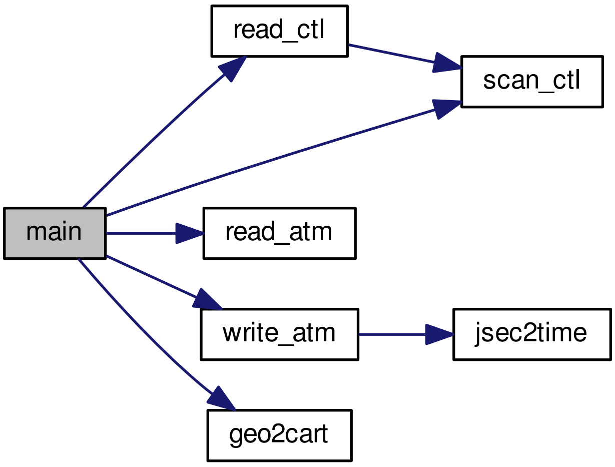
5.15.2 Function Documentation

5.15.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 28 of file match.c.

```
                {

  ctl_t ctl;

  atm_t *atm1, *atm2, *atm3;

  FILE *out;

  char filename[LEN];

  double filter_dt, x1[3], x2[3], dh, dq[NQ], dv, lh = 0, lt = 0, lv = 0;

  int filter, ip1, ip2, iq, n;

  /* Allocate... */
  ALLOC(atm1, atm_t, 1);
  ALLOC(atm2, atm_t, 1);
  ALLOC(atm3, atm_t, 1);

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <atm_test> <atm_ref> <outfile>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  filter = (int) scan_ctl(argv[1], argc, argv, "FILTER", -1, "0", NULL);
  filter_dt = scan_ctl(argv[1], argc, argv, "FILTER_DT", -1, "0", NULL);

  /* Read atmospheric data... */
  read_atm(argv[2], &ctl, atm1);
  read_atm(argv[3], &ctl, atm2);

  /* Write info... */
  printf("Write transport deviations: %s\n", argv[4]);

  /* Create output file... */
  if (!(out = fopen(argv[4], "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 = trajectory time [s]\n"
          "# $%d = vertical length of trajectory [km]\n"
          "# $%d = horizontal length of trajectory [km]\n"
          "# $%d = vertical deviation [km]\n"
          "# $%d = horizontal deviation [km]\n",
          5 + ctl.nq, 6 + ctl.nq, 7 + ctl.nq, 8 + ctl.nq, 9 + ctl.nq);
  for (iq = 0; iq < ctl.nq; iq++)
    fprintf(out, "# $%d = %s deviation [%s]\n", ctl.nq + iq + 10,
            ctl.qnt_name[iq], ctl.qnt_unit[iq]);
  fprintf(out, "\n");

  /* Filtering of reference time series... */
  if (filter) {

    /* Copy data... */
    memcpy(atm3, atm2, sizeof(atm_t));

    /* Loop over data points... */
    for (ip1 = 0; ip1 < atm2->np; ip1++) {
      n = 0;
      atm2->p[ip1] = 0;
      for (iq = 0; iq < ctl.nq; iq++)
        atm2->q[iq][ip1] = 0;
      for (ip2 = 0; ip2 < atm2->np; ip2++)
        if (fabs(atm2->time[ip1] - atm2->time[ip2]) < filter_dt) {
          atm2->p[ip1] += atm3->p[ip2];
          for (iq = 0; iq < ctl.nq; iq++)
            atm2->q[iq][ip1] += atm3->q[iq][ip2];
          n++;
        }
      atm2->p[ip1] /= n;
      for (iq = 0; iq < ctl.nq; iq++)
        atm2->q[iq][ip1] /= n;
    }

    /* Write filtered data... */
    sprintf(filename, "%s.filt", argv[3]);
    write_atm(filename, &ctl, atm2, 0);
  }

  /* Loop over air parcels (reference data)... */
  for (ip2 = 0; ip2 < atm2->np; ip2++) {

    /* Get trajectory length... */
    if (ip2 > 0) {
      geo2cart(0, atm2->lon[ip2 - 1], atm2->lat[ip2 - 1], x1);
      geo2cart(0, atm2->lon[ip2], atm2->lat[ip2], x2);
      lh += DIST(x1, x2);
      lv += fabs(Z(atm2->p[ip2 - 1]) - Z(atm2->p[ip2]));
      lt = fabs(atm2->time[ip2] - atm2->time[0]);
    }

    /* Init... */
    n = 0;
    dh = 0;
    dv = 0;
    for (iq = 0; iq < ctl.nq; iq++)
      dq[iq] = 0;
    geo2cart(0, atm2->lon[ip2], atm2->lat[ip2], x2);

    /* Find corresponding time step (test data)... */
    for (ip1 = 0; ip1 < atm1->np; ip1++)
      if (fabs(atm1->time[ip1] - atm2->time[ip2])
          < (filter ? filter_dt : 0.1)) {

        /* Calculate deviations... */
        geo2cart(0, atm1->lon[ip1], atm1->lat[ip1], x1);
        dh += DIST(x1, x2);
        dv += Z(atm1->p[ip1]) - Z(atm2->p[ip2]);
        for (iq = 0; iq < ctl.nq; iq++)
          dq[iq] += atm1->q[iq][ip1] - atm2->q[iq][ip2];
        n++;
      }

    /* Write output... */
    if (n > 0) {
      fprintf(out, "%.2f %.4f %.4f %.4f",
              atm2->time[ip2], Z(atm2->p[ip2]),
              atm2->lon[ip2], atm2->lat[ip2]);
      for (iq = 0; iq < ctl.nq; iq++) {
        fprintf(out, " ");
        fprintf(out, ctl.qnt_format[iq], atm2->q[iq][ip2]);
      }
      fprintf(out, " %.2f %g %g %g %g", lt, lv, lh, dv / n, dh / n);
      for (iq = 0; iq < ctl.nq; iq++) {
        fprintf(out, " ");
        fprintf(out, ctl.qnt_format[iq], dq[iq] / n);
      }
      fprintf(out, "\n");
    }
  }

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

  /* Free... */
  free(atm1);
  free(atm2);
  free(atm3);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.16 match.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/>.

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"
#include <gsl/gsl_sort.h>

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

  ctl_t ctl;

  atm_t *atm1, *atm2, *atm3;

  FILE *out;

  char filename[LEN];

  double filter_dt, x1[3], x2[3], dh, dq[NQ], dv, lh = 0, lt = 0, lv = 0;

  int filter, ip1, ip2, iq, n;

  /* Allocate... */
  ALLOC(atm1, atm_t, 1);
  ALLOC(atm2, atm_t, 1);
  ALLOC(atm3, atm_t, 1);

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <atm_test> <atm_ref> <outfile>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  filter = (int) scan_ctl(argv[1], argc, argv, "FILTER", -1, "0", NULL);
  filter_dt = scan_ctl(argv[1], argc, argv, "FILTER_DT", -1, "0", NULL);

  /* Read atmospheric data... */
  read_atm(argv[2], &ctl, atm1);
  read_atm(argv[3], &ctl, atm2);

  /* Write info... */
  printf("Write transport deviations: %s\n", argv[4]);

  /* Create output file... */
  if (!(out = fopen(argv[4], "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 = trajectory time [s]\n"
          "# $%d = vertical length of trajectory [km]\n"
          "# $%d = horizontal length of trajectory [km]\n"
          "# $%d = vertical deviation [km]\n"
          "# $%d = horizontal deviation [km]\n",
          5 + ctl.nq, 6 + ctl.nq, 7 + ctl.nq, 8 + ctl.nq, 9 + ctl.nq);
  for (iq = 0; iq < ctl.nq; iq++)
    fprintf(out, "# $%d = %s deviation [%s]\n", ctl.nq + iq + 10,
            ctl.qnt_name[iq], ctl.qnt_unit[iq]);
  fprintf(out, "\n");

  /* Filtering of reference time series... */
  if (filter) {

    /* Copy data... */
    memcpy(atm3, atm2, sizeof(atm_t));

    /* Loop over data points... */
    for (ip1 = 0; ip1 < atm2->np; ip1++) {
      n = 0;
      atm2->p[ip1] = 0;
      for (iq = 0; iq < ctl.nq; iq++)
        atm2->q[iq][ip1] = 0;
      for (ip2 = 0; ip2 < atm2->np; ip2++)
        if (fabs(atm2->time[ip1] - atm2->time[ip2]) < filter_dt) {
          atm2->p[ip1] += atm3->p[ip2];
          for (iq = 0; iq < ctl.nq; iq++)
            atm2->q[iq][ip1] += atm3->q[iq][ip2];
          n++;
        }
      atm2->p[ip1] /= n;
      for (iq = 0; iq < ctl.nq; iq++)
        atm2->q[iq][ip1] /= n;
    }

    /* Write filtered data... */
    sprintf(filename, "%s.filt", argv[3]);
    write_atm(filename, &ctl, atm2, 0);
  }

  /* Loop over air parcels (reference data)... */
  for (ip2 = 0; ip2 < atm2->np; ip2++) {

    /* Get trajectory length... */
    if (ip2 > 0) {
      geo2cart(0, atm2->lon[ip2 - 1], atm2->lat[ip2 - 1], x1);
      geo2cart(0, atm2->lon[ip2], atm2->lat[ip2], x2);
      lh += DIST(x1, x2);
      lv += fabs(Z(atm2->p[ip2 - 1]) - Z(atm2->p[ip2]));
      lt = fabs(atm2->time[ip2] - atm2->time[0]);
    }

    /* Init... */
    n = 0;
    dh = 0;
    dv = 0;
    for (iq = 0; iq < ctl.nq; iq++)
      dq[iq] = 0;
    geo2cart(0, atm2->lon[ip2], atm2->lat[ip2], x2);

    /* Find corresponding time step (test data)... */
    for (ip1 = 0; ip1 < atm1->np; ip1++)
      if (fabs(atm1->time[ip1] - atm2->time[ip2])
          < (filter ? filter_dt : 0.1)) {

        /* Calculate deviations... */
        geo2cart(0, atm1->lon[ip1], atm1->lat[ip1], x1);
        dh += DIST(x1, x2);
        dv += Z(atm1->p[ip1]) - Z(atm2->p[ip2]);
        for (iq = 0; iq < ctl.nq; iq++)
          dq[iq] += atm1->q[iq][ip1] - atm2->q[iq][ip2];
        n++;
      }

    /* Write output... */
    if (n > 0) {
      fprintf(out, "%.2f %.4f %.4f %.4f",
              atm2->time[ip2], Z(atm2->p[ip2]),
              atm2->lon[ip2], atm2->lat[ip2]);
      for (iq = 0; iq < ctl.nq; iq++) {
        fprintf(out, " ");
        fprintf(out, ctl.qnt_format[iq], atm2->q[iq][ip2]);
      }
      fprintf(out, " %.2f %g %g %g %g", lt, lv, lh, dv / n, dh / n);
      for (iq = 0; iq < ctl.nq; iq++) {
        fprintf(out, " ");
        fprintf(out, ctl.qnt_format[iq], dq[iq] / n);
      }
      fprintf(out, "\n");
    }
  }

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

  /* Free... */
  free(atm1);
  free(atm2);
  free(atm3);

  return EXIT_SUCCESS;
}
```

5.17 met_map.c File Reference

Extract global map from meteorological data.

Functions

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

5.17.1 Detailed Description

Extract global map from meteorological data.

Definition in file met_map.c.

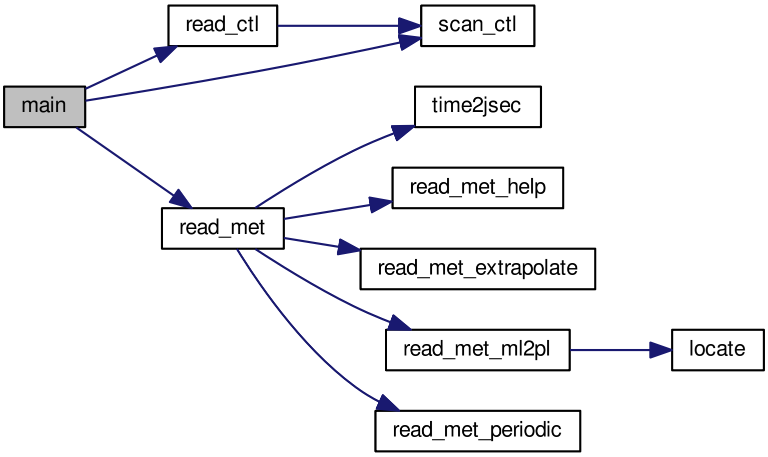
5.17.2 Function Documentation

5.17.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file met_map.c.

```
                {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double dz, dzmin = 1e10, z, timem[EX][EY], psm[EX][EY], tm[EX][EY],
    um[EX][EY], vm[EX][EY], wm[EX][EY], h2om[EX][EY], o3m[EX][EY];

  static int i, ip, ip2, ix, iy, np[EX][EY];

  /* 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);
  z = scan_ctl(argv[1], argc, argv, "Z", -1, "", NULL);

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

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

    /* Find nearest pressure level... */
    for (ip2 = 0; ip2 < met->np; ip2++) {
      dz = fabs(Z(met->p[ip2]) - z);
      if (dz < dzmin) {
        dzmin = dz;
        ip = ip2;
      }
    }

    /* Average data... */
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {
        timem[ix][iy] += met->time;
        tm[ix][iy] += met->t[ix][iy][ip];
        um[ix][iy] += met->u[ix][iy][ip];
        vm[ix][iy] += met->v[ix][iy][ip];
        wm[ix][iy] += met->w[ix][iy][ip];
        h2om[ix][iy] += met->h2o[ix][iy][ip];
        o3m[ix][iy] += met->o3[ix][iy][ip];
        psm[ix][iy] += met->ps[ix][iy];
        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 wind [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [1]\n"
          "# $11 = O3 volume mixing ratio [1]\n"
          "# $12 = surface pressure [hPa]\n");

  /* Write data... */
  for (iy = 0; iy < met->ny; iy++) {
    fprintf(out, "\n");
    for (ix = 0; ix < met->nx; ix++)
      if (met->lon[ix] >= 180)
        fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %g %g\n",
                timem[ix][iy] / np[ix][iy], Z(met->p[ip]),
                met->lon[ix] - 360.0, met->lat[iy], met->p[ip],
                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],
                psm[ix][iy] / np[ix][iy]);
    for (ix = 0; ix < met->nx; ix++)
      if (met->lon[ix] <= 180)
        fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %g %g\n",
                timem[ix][iy] / np[ix][iy], Z(met->p[ip]),
                met->lon[ix], met->lat[iy], met->p[ip],
                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],
                psm[ix][iy] / np[ix][iy]);
  }

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

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

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.18 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/>.

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

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

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double dz, dzmin = 1e10, z, timem[EX][EY], psm[EX][EY], tm[EX][EY],
    um[EX][EY], vm[EX][EY], wm[EX][EY], h2om[EX][EY], o3m[EX][EY];

  static int i, ip, ip2, ix, iy, np[EX][EY];

  /* 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);
  z = scan_ctl(argv[1], argc, argv, "Z", -1, "", NULL);

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

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

    /* Find nearest pressure level... */
    for (ip2 = 0; ip2 < met->np; ip2++) {
      dz = fabs(Z(met->p[ip2]) - z);
      if (dz < dzmin) {
        dzmin = dz;
        ip = ip2;
      }
    }

    /* Average data... */
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++) {
        timem[ix][iy] += met->time;
        tm[ix][iy] += met->t[ix][iy][ip];
        um[ix][iy] += met->u[ix][iy][ip];
        vm[ix][iy] += met->v[ix][iy][ip];
        wm[ix][iy] += met->w[ix][iy][ip];
        h2om[ix][iy] += met->h2o[ix][iy][ip];
        o3m[ix][iy] += met->o3[ix][iy][ip];
        psm[ix][iy] += met->ps[ix][iy];
        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 wind [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [1]\n"
          "# $11 = O3 volume mixing ratio [1]\n"
          "# $12 = surface pressure [hPa]\n");

  /* Write data... */
  for (iy = 0; iy < met->ny; iy++) {
    fprintf(out, "\n");
    for (ix = 0; ix < met->nx; ix++)
      if (met->lon[ix] >= 180)
        fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %g %g\n",
                timem[ix][iy] / np[ix][iy], Z(met->p[ip]),
                met->lon[ix] - 360.0, met->lat[iy], met->p[ip],
                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],
                psm[ix][iy] / np[ix][iy]);
    for (ix = 0; ix < met->nx; ix++)
      if (met->lon[ix] <= 180)
        fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %g %g\n",
                timem[ix][iy] / np[ix][iy], Z(met->p[ip]),
                met->lon[ix], met->lat[iy], met->p[ip],
                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],
                psm[ix][iy] / np[ix][iy]);
  }

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

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

  return EXIT_SUCCESS;
}
```

5.19 met_prof.c File Reference

Extract vertical profile from meteorological data.

Functions

- int main (int argc, char ∗argv[ ])

5.19.1 Detailed Description

Extract vertical profile from meteorological data.

Definition in file met_prof.c.

5.19.2 Function Documentation

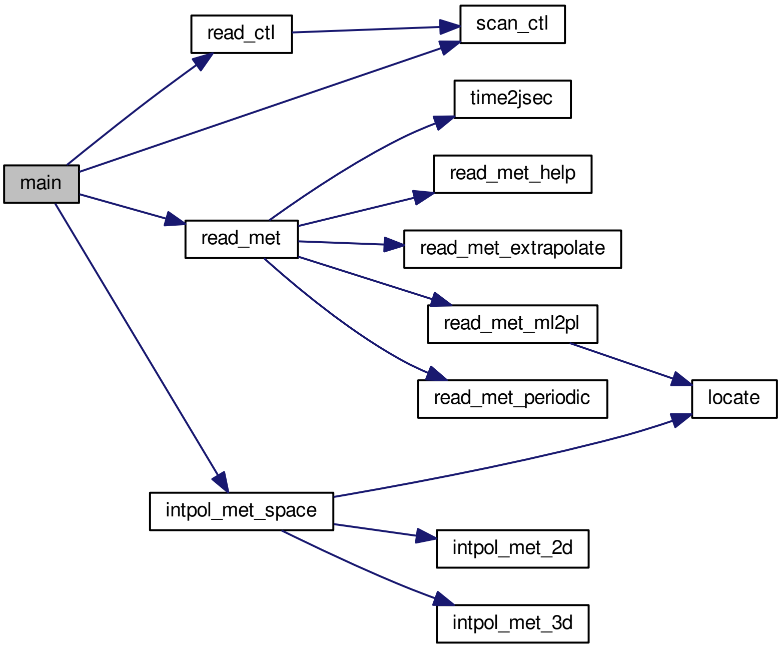
5.19.2.1 int main (int *argc,* char ∗ *argv[ ]*)

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], o3, o3m[NZ], ps, psm[NZ];

static int i, iz, np[NZ];

/* 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, "Z0", -1, "0", NULL);
z1 = scan_ctl(argv[1], argc, argv, "Z1", -1, "60", NULL);
dz = scan_ctl(argv[1], argc, argv, "DZ", -1, "1", NULL);
lon0 = scan_ctl(argv[1], argc, argv, "LON0", -1, "0", NULL);
lon1 = scan_ctl(argv[1], argc, argv, "LON1", -1, "0", NULL);
dlon = scan_ctl(argv[1], argc, argv, "DLON", -1, "1", NULL);
lat0 = scan_ctl(argv[1], argc, argv, "LAT0", -1, "0", NULL);
lat1 = scan_ctl(argv[1], argc, argv, "LAT1", -1, "0", NULL);
dlat = scan_ctl(argv[1], argc, argv, "DLAT", -1, "1", NULL);

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

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

  /* Average... */
  for (z = z0; z <= z1; z += dz) {
    iz = (int) ((z - z0) / dz);
    if (iz < 0 || iz > NZ)
      ERRMSG("Too many altitudes!");
    for (lon = lon0; lon <= lon1; lon += dlon)
      for (lat = lat0; lat <= lat1; lat += dlat) {
        intpol_met_space(met, P(z), lon, lat, &ps,
                         &t, &u, &v, &w, &h2o, &o3);
        if (gsl_finite(t) && gsl_finite(u)
            && gsl_finite(v) && gsl_finite(w)) {
          timem[iz] += met->time;
          lonm[iz] += lon;
          latm[iz] += lat;
          tm[iz] += t;
          um[iz] += u;
          vm[iz] += v;
          wm[iz] += w;
          h2om[iz] += h2o;
          o3m[iz] += o3;
          psm[iz] += ps;
          np[iz]++;
        }
      }
  }
}

/* Normalize... */
for (z = z0; z <= z1; z += dz) {
  iz = (int) ((z - z0) / dz);
  if (np[iz] > 0) {
    timem[iz] /= np[iz];
    lonm[iz] /= np[iz];
    latm[iz] /= np[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];
    psm[iz] /= np[iz];
  } else {
    timem[iz] = GSL_NAN;
    lonm[iz] = GSL_NAN;
    latm[iz] = GSL_NAN;
    tm[iz] = GSL_NAN;
    um[iz] = GSL_NAN;
    vm[iz] = GSL_NAN;
```

```
      wm[iz] = GSL_NAN;
      h2om[iz] = GSL_NAN;
      o3m[iz] = GSL_NAN;
      psm[iz] = GSL_NAN;
    }
  }

  /* 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 wind [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [1]\n"
          "# $11 = O3 volume mixing ratio [1]\n"
          "# $12 = surface pressure [hPa]\n\n");

  /* Write data... */
  for (z = z0; z <= z1; z += dz) {
    iz = (int) ((z - z0) / dz);
    fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %g %g\n",
            timem[iz], z, lonm[iz], latm[iz], P(z), tm[iz],
            um[iz], vm[iz], wm[iz], h2om[iz], o3m[iz], psm[iz]);
  }

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

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

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.20 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/>.

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

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

/* Maximum number of altitudes. */
#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], o3, o3m[NZ], ps, psm[NZ];

  static int i, iz, np[NZ];

  /* 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, "Z0", -1, "0", NULL);
  z1 = scan_ctl(argv[1], argc, argv, "Z1", -1, "60", NULL);
  dz = scan_ctl(argv[1], argc, argv, "DZ", -1, "1", NULL);
  lon0 = scan_ctl(argv[1], argc, argv, "LON0", -1, "0", NULL);
  lon1 = scan_ctl(argv[1], argc, argv, "LON1", -1, "0", NULL);
  dlon = scan_ctl(argv[1], argc, argv, "DLON", -1, "1", NULL);
  lat0 = scan_ctl(argv[1], argc, argv, "LAT0", -1, "0", NULL);
  lat1 = scan_ctl(argv[1], argc, argv, "LAT1", -1, "0", NULL);
  dlat = scan_ctl(argv[1], argc, argv, "DLAT", -1, "1", NULL);

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

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

    /* Average... */
    for (z = z0; z <= z1; z += dz) {
      iz = (int) ((z - z0) / dz);
      if (iz < 0 || iz > NZ)
        ERRMSG("Too many altitudes!");
      for (lon = lon0; lon <= lon1; lon += dlon)
        for (lat = lat0; lat <= lat1; lat += dlat) {
          intpol_met_space(met, P(z), lon, lat, &ps,
                           &t, &u, &v, &w, &h2o, &o3);
          if (gsl_finite(t) && gsl_finite(u)
              && gsl_finite(v) && gsl_finite(w)) {
```

```
            timem[iz] += met->time;
            lonm[iz] += lon;
            latm[iz] += lat;
            tm[iz] += t;
            um[iz] += u;
            vm[iz] += v;
            wm[iz] += w;
            h2om[iz] += h2o;
            o3m[iz] += o3;
            psm[iz] += ps;
            np[iz]++;
          }
        }
    }
  }

  /* Normalize... */
  for (z = z0; z <= z1; z += dz) {
    iz = (int) ((z - z0) / dz);
    if (np[iz] > 0) {
      timem[iz] /= np[iz];
      lonm[iz] /= np[iz];
      latm[iz] /= np[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];
      psm[iz] /= np[iz];
    } else {
      timem[iz] = GSL_NAN;
      lonm[iz] = GSL_NAN;
      latm[iz] = GSL_NAN;
      tm[iz] = GSL_NAN;
      um[iz] = GSL_NAN;
      vm[iz] = GSL_NAN;
      wm[iz] = GSL_NAN;
      h2om[iz] = GSL_NAN;
      o3m[iz] = GSL_NAN;
      psm[iz] = GSL_NAN;
    }
  }

  /* 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 wind [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [1]\n"
          "# $11 = O3 volume mixing ratio [1]\n"
          "# $12 = surface pressure [hPa]\n\n");

  /* Write data... */
  for (z = z0; z <= z1; z += dz) {
    iz = (int) ((z - z0) / dz);
    fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %g %g\n",
            timem[iz], z, lonm[iz], latm[iz], P(z), tm[iz],
            um[iz], vm[iz], wm[iz], h2om[iz], o3m[iz], psm[iz]);
  }

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

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

  return EXIT_SUCCESS;
}
```

5.21 met_sample.c File Reference

Sample meteorological data at given geolocations.

Functions

- int main (int argc, char ∗argv[ ])

5.21.1 Detailed Description

Sample meteorological data at given geolocations.

Definition in file met_sample.c.

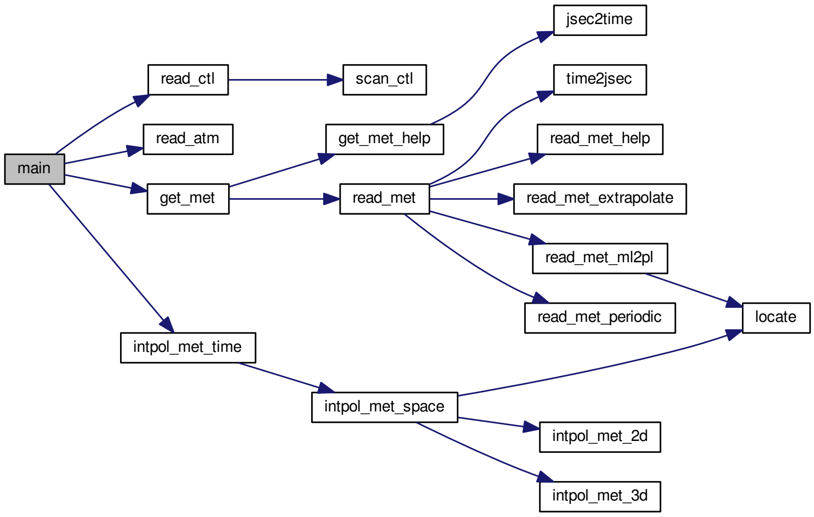
5.21.2 Function Documentation

5.21.2.1 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 t, u, v, w, h2o, o3;

  int ip;

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

  /* 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);

  /* Read atmospheric data... */
  read_atm(argv[3], &ctl, atm);

  /* Create output file... */
  printf("Write meteorological data file: %s\n", argv[4]);
  if (!(out = fopen(argv[4], "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 wind [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [1]\n"
          "# $11 = O3 volume mixing ratio [1]\n\n");

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

    /* Get meteorological data... */
    get_met(&ctl, argv[2], atm->time[ip], met0, met1);

    /* Interpolate meteorological data... */
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->
lon[ip],
                    atm->lat[ip], NULL, &t, &u, &v, &w, &h2o, &o3);

    /* Write data... */
    fprintf(out, "%.2f %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);
  }

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

  /* Free... */
  free(atm);
  free(met0);
  free(met1);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.22 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/>.

  Copright (C) 2013-2015 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 t, u, v, w, h2o, o3;

  int ip;

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

  /* 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);

  /* Read atmospheric data... */
  read_atm(argv[3], &ctl, atm);

  /* Create output file... */
  printf("Write meteorological data file: %s\n", argv[4]);
  if (!(out = fopen(argv[4], "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 wind [hPa/s]\n"
          "# $10 = H2O volume mixing ratio [1]\n"
          "# $11 = O3 volume mixing ratio [1]\n\n");

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

    /* Get meteorological data... */
    get_met(&ctl, argv[2], atm->time[ip], met0, met1);

    /* Interpolate meteorological data... */
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->
lon[ip],
                    atm->lat[ip], NULL, &t, &u, &v, &w, &h2o, &o3);

    /* Write data... */
    fprintf(out, "%.2f %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);
  }

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

  /* Free... */
  free(atm);
  free(met0);
  free(met1);

  return EXIT_SUCCESS;
}
```

5.23 met_zm.c File Reference

Extract zonal mean from meteorological data.

Functions

- int main (int argc, char ∗argv[ ])

5.23.1 Detailed Description

Extract zonal mean from meteorological data.

Definition in file met_zm.c.

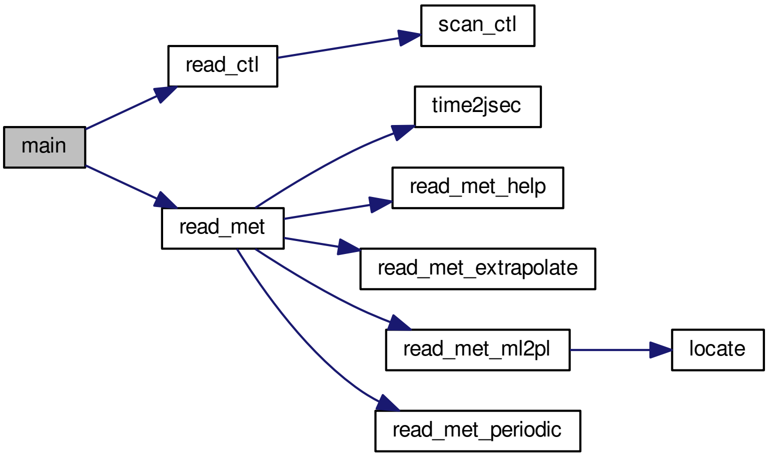
5.23.2 Function Documentation

5.23.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file met_zm.c.

```
                {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double timem[EP][EY], psm[EP][EY], tm[EP][EY], um[EP][EY],
    vm[EP][EY], vhm[EP][EY], wm[EP][EY], h2om[EP][EY], o3m[EP][EY],
    psm2[EP][EY], tm2[EP][EY], um2[EP][EY], vm2[EP][EY], vhm2[EP][EY],
    wm2[EP][EY], h2om2[EP][EY], o3m2[EP][EY];

  static int i, ip, ix, iy, np[EP][EY];

  /* 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);

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

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

    /* Average data... */
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        for (ip = 0; ip < met->np; ip++) {
          timem[ip][iy] += met->time;
          tm[ip][iy] += met->t[ix][iy][ip];
          um[ip][iy] += met->u[ix][iy][ip];
          vm[ip][iy] += met->v[ix][iy][ip];
          vhm[ip][iy] += sqrt(gsl_pow_2(met->u[ix][iy][ip])
                              + gsl_pow_2(met->v[ix][iy][ip]));
          wm[ip][iy] += met->w[ix][iy][ip];
          h2om[ip][iy] += met->h2o[ix][iy][ip];
          o3m[ip][iy] += met->o3[ix][iy][ip];
          psm[ip][iy] += met->ps[ix][iy];
          tm2[ip][iy] += gsl_pow_2(met->t[ix][iy][ip]);
          um2[ip][iy] += gsl_pow_2(met->u[ix][iy][ip]);
          vm2[ip][iy] += gsl_pow_2(met->v[ix][iy][ip]);
          vhm2[ip][iy] += gsl_pow_2(met->u[ix][iy][ip])
            + gsl_pow_2(met->v[ix][iy][ip]);
          wm2[ip][iy] += gsl_pow_2(met->w[ix][iy][ip]);
          h2om2[ip][iy] += gsl_pow_2(met->h2o[ix][iy][ip]);
          o3m2[ip][iy] += gsl_pow_2(met->o3[ix][iy][ip]);
          psm2[ip][iy] += gsl_pow_2(met->ps[ix][iy]);
          np[ip][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  = latitude [deg]\n"
          "# $4  = temperature mean [K]\n"
          "# $5  = temperature standard deviation [K]\n"
          "# $6  = zonal wind mean [m/s]\n"
          "# $7  = zonal wind standard deviation [m/s]\n"
          "# $8  = meridional wind mean [m/s]\n"
          "# $9  = meridional wind standard deviation [m/s]\n"
          "# $10 = horizontal wind mean [m/s]\n"
          "# $11 = horizontal wind standard deviation [m/s]\n"
          "# $12 = vertical wind mean [hPa/s]\n"
          "# $13 = vertical wind standard deviation [hPa/s]\n"
          "# $14 = H2O vmr mean [1]\n"
          "# $15 = H2O vmr standard deviation [1]\n"
          "# $16 = O3 vmr mean [1]\n"
          "# $17 = O3 vmr standard deviation [1]\n"
          "# $18 = surface pressure mean [hPa]\n"
          "# $19 = surface pressure standard deviation [hPa]\n");

  /* Write data... */
  for (iy = 0; iy < met->ny; iy++) {
    fprintf(out, "\n");
    for (ip = 0; ip < met->np; ip++)
      fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %g"
              " %g %g %g %g %g %g %g %g\n",
              timem[ip][iy] / np[ip][iy], Z(met->p[ip]), met->lat[iy],
              tm[ip][iy] / np[ip][iy],
              sqrt(tm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(tm[ip][iy] / np[ip][iy])),
              um[ip][iy] / np[ip][iy],
              sqrt(um2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(um[ip][iy] / np[ip][iy])),
              vm[ip][iy] / np[ip][iy],
              sqrt(vm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(vm[ip][iy] / np[ip][iy])),
              vhm[ip][iy] / np[ip][iy],
              sqrt(vhm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(vhm[ip][iy] / np[ip][iy])),
              wm[ip][iy] / np[ip][iy],
              sqrt(wm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(wm[ip][iy] / np[ip][iy])),
              h2om[ip][iy] / np[ip][iy],
              sqrt(h2om2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(h2om[ip][iy] / np[ip][iy])),
              o3m[ip][iy] / np[ip][iy],
              sqrt(o3m2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(o3m[ip][iy] / np[ip][iy])),
              psm[ip][iy] / np[ip][iy],
              sqrt(psm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(psm[ip][iy] / np[ip][iy])));
  }

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

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

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.24 met_zm.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/>.

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

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

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double timem[EP][EY], psm[EP][EY], tm[EP][EY], um[EP][EY],
    vm[EP][EY], vhm[EP][EY], wm[EP][EY], h2om[EP][EY], o3m[EP][EY],
    psm2[EP][EY], tm2[EP][EY], um2[EP][EY], vm2[EP][EY], vhm2[EP][EY],
    wm2[EP][EY], h2om2[EP][EY], o3m2[EP][EY];

  static int i, ip, ix, iy, np[EP][EY];

  /* 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);

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

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

    /* Average data... */
    for (ix = 0; ix < met->nx; ix++)
      for (iy = 0; iy < met->ny; iy++)
        for (ip = 0; ip < met->np; ip++) {
          timem[ip][iy] += met->time;
          tm[ip][iy] += met->t[ix][iy][ip];
          um[ip][iy] += met->u[ix][iy][ip];
          vm[ip][iy] += met->v[ix][iy][ip];
          vhm[ip][iy] += sqrt(gsl_pow_2(met->u[ix][iy][ip])
                              + gsl_pow_2(met->v[ix][iy][ip]));
          wm[ip][iy] += met->w[ix][iy][ip];
          h2om[ip][iy] += met->h2o[ix][iy][ip];
          o3m[ip][iy] += met->o3[ix][iy][ip];
          psm[ip][iy] += met->ps[ix][iy];
          tm2[ip][iy] += gsl_pow_2(met->t[ix][iy][ip]);
          um2[ip][iy] += gsl_pow_2(met->u[ix][iy][ip]);
          vm2[ip][iy] += gsl_pow_2(met->v[ix][iy][ip]);
          vhm2[ip][iy] += gsl_pow_2(met->u[ix][iy][ip])
            + gsl_pow_2(met->v[ix][iy][ip]);
          wm2[ip][iy] += gsl_pow_2(met->w[ix][iy][ip]);
          h2om2[ip][iy] += gsl_pow_2(met->h2o[ix][iy][ip]);
          o3m2[ip][iy] += gsl_pow_2(met->o3[ix][iy][ip]);
          psm2[ip][iy] += gsl_pow_2(met->ps[ix][iy]);
          np[ip][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  = latitude [deg]\n"
          "# $4  = temperature mean [K]\n"
          "# $5  = temperature standard deviation [K]\n"
          "# $6  = zonal wind mean [m/s]\n"
          "# $7  = zonal wind standard deviation [m/s]\n"
          "# $8  = meridional wind mean [m/s]\n"
          "# $9  = meridional wind standard deviation [m/s]\n"
          "# $10 = horizontal wind mean [m/s]\n"
          "# $11 = horizontal wind standard deviation [m/s]\n"
          "# $12 = vertical wind mean [hPa/s]\n"
          "# $13 = vertical wind standard deviation [hPa/s]\n"
          "# $14 = H2O vmr mean [1]\n"
          "# $15 = H2O vmr standard deviation [1]\n"
          "# $16 = O3 vmr mean [1]\n"
          "# $17 = O3 vmr standard deviation [1]\n"
          "# $18 = surface pressure mean [hPa]\n"
          "# $19 = surface pressure standard deviation [hPa]\n");

  /* Write data... */
  for (iy = 0; iy < met->ny; iy++) {
    fprintf(out, "\n");
    for (ip = 0; ip < met->np; ip++)
      fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g %g"
              " %g %g %g %g %g %g %g %g\n",
              timem[ip][iy] / np[ip][iy], Z(met->p[ip]), met->lat[iy],
              tm[ip][iy] / np[ip][iy],
              sqrt(tm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(tm[ip][iy] / np[ip][iy])),
              um[ip][iy] / np[ip][iy],
              sqrt(um2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(um[ip][iy] / np[ip][iy])),
              vm[ip][iy] / np[ip][iy],
              sqrt(vm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(vm[ip][iy] / np[ip][iy])),
              vhm[ip][iy] / np[ip][iy],
              sqrt(vhm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(vhm[ip][iy] / np[ip][iy])),
              wm[ip][iy] / np[ip][iy],
              sqrt(wm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(wm[ip][iy] / np[ip][iy])),
              h2om[ip][iy] / np[ip][iy],
              sqrt(h2om2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(h2om[ip][iy] / np[ip][iy])),
              o3m[ip][iy] / np[ip][iy],
              sqrt(o3m2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(o3m[ip][iy] / np[ip][iy])),
              psm[ip][iy] / np[ip][iy],
              sqrt(psm2[ip][iy] / np[ip][iy] -
                   gsl_pow_2(psm[ip][iy] / np[ip][iy])));
  }

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

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

  return EXIT_SUCCESS;
}
```

5.25 smago.c File Reference

Estimate horizontal diffusivity based on Smagorinsky theory.

Functions

- int main (int argc, char ∗argv[ ])

5.25.1 Detailed Description

Estimate horizontal diffusivity based on Smagorinsky theory.

Definition in file smago.c.

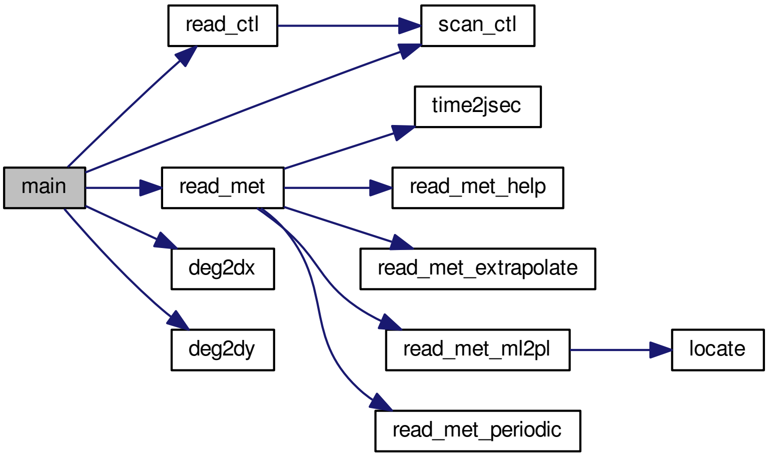
5.25.2 Function Documentation

5.25.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 8 of file smago.c.

```
                {

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double dz, dzmin = 1e10, z, t, s, ls2, k[EX][EY], c = 0.15;

  static int ip, ip2, ix, iy;

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

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <map.tab> <met>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  z = scan_ctl(argv[1], argc, argv, "Z", -1, "", NULL);

  /* Read meteorological data... */
  read_met(&ctl, argv[3], met);

  /* Find nearest pressure level... */
  for (ip2 = 0; ip2 < met->np; ip2++) {
    dz = fabs(Z(met->p[ip2]) - z);
    if (dz < dzmin) {
      dzmin = dz;
      ip = ip2;
    }
  }

  /* Write info... */
  printf("Analyze %g hPa...\n", met->p[ip]);

  /* Calculate horizontal diffusion coefficients... */
  for (ix = 1; ix < met->nx - 1; ix++)
    for (iy = 1; iy < met->ny - 1; iy++) {
      t = 0.5 * ((met->u[ix + 1][iy][ip] - met->u[ix - 1][iy][ip])
                 / (1000. *
                    deg2dx(met->lon[ix + 1] - met->lon[ix - 1], met->lat[iy]))
                 - (met->v[ix][iy + 1][ip] - met->v[ix][iy - 1][ip])
                 / (1000. * deg2dy(met->lat[iy + 1] - met->lat[iy - 1])));
      s = 0.5 * ((met->u[ix][iy + 1][ip] - met->u[ix][iy - 1][ip])
                 / (1000. * deg2dy(met->lat[iy + 1] - met->lat[iy - 1]))
                 + (met->v[ix + 1][iy][ip] - met->v[ix - 1][iy][ip])
                 / (1000. *
                    deg2dx(met->lon[ix + 1] - met->lon[ix - 1],
                           met->lat[iy])));
      ls2 = gsl_pow_2(c * 500. * deg2dy(met->lat[iy + 1] - met->lat[iy - 1]));
      if (fabs(met->lat[iy]) > 80)
        ls2 *= (90. - fabs(met->lat[iy])) / 10.;
      k[ix][iy] = ls2 * sqrt(2.0 * (gsl_pow_2(t) + gsl_pow_2(s)));
    }

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

  /* Write header... */
  fprintf(out,
          "# $1 = longitude [deg]\n"
          "# $2 = latitude [deg]\n"
          "# $3 = zonal wind [m/s]\n"
          "# $4 = meridional wind [m/s]\n"
          "# $5 = horizontal diffusivity [m^2/s]\n");

  /* Write data... */
  for (iy = 0; iy < met->ny; iy++) {
    fprintf(out, "\n");
    for (ix = 0; ix < met->nx; ix++)
      if (met->lon[ix] >= 180)
        fprintf(out, "%g %g %g %g %g\n",
                met->lon[ix] - 360.0, met->lat[iy],
                met->u[ix][iy][ip], met->v[ix][iy][ip], k[ix][iy]);
    for (ix = 0; ix < met->nx; ix++)
      if (met->lon[ix] <= 180)
        fprintf(out, "%g %g %g %g %g\n",
                met->lon[ix], met->lat[iy],
                met->u[ix][iy][ip], met->v[ix][iy][ip], k[ix][iy]);
  }

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

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

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.26 smago.c

```

#include "libtrac.h"

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

  ctl_t ctl;

  met_t *met;

  FILE *out;

  static double dz, dzmin = 1e10, z, t, s, ls2, k[EX][EY], c = 0.15;

  static int ip, ip2, ix, iy;

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

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <map.tab> <met>");

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  z = scan_ctl(argv[1], argc, argv, "Z", -1, "", NULL);

  /* Read meteorological data... */
  read_met(&ctl, argv[3], met);

  /* Find nearest pressure level... */
  for (ip2 = 0; ip2 < met->np; ip2++) {
    dz = fabs(Z(met->p[ip2]) - z);
    if (dz < dzmin) {
      dzmin = dz;
      ip = ip2;
    }
  }

  /* Write info... */
  printf("Analyze %g hPa...\n", met->p[ip]);

  /* Calculate horizontal diffusion coefficients... */
  for (ix = 1; ix < met->nx - 1; ix++)
    for (iy = 1; iy < met->ny - 1; iy++) {
      t = 0.5 * ((met->u[ix + 1][iy][ip] - met->u[ix - 1][iy][ip])
                 / (1000. *
                    deg2dx(met->lon[ix + 1] - met->lon[ix - 1], met->lat[iy]))
                 - (met->v[ix][iy + 1][ip] - met->v[ix][iy - 1][ip])
                 / (1000. * deg2dy(met->lat[iy + 1] - met->lat[iy - 1])));
      s = 0.5 * ((met->u[ix][iy + 1][ip] - met->u[ix][iy - 1][ip])
                 / (1000. * deg2dy(met->lat[iy + 1] - met->lat[iy - 1]))
                 + (met->v[ix + 1][iy][ip] - met->v[ix - 1][iy][ip])
                 / (1000. *
                    deg2dx(met->lon[ix + 1] - met->lon[ix - 1],
                           met->lat[iy])));
      ls2 = gsl_pow_2(c * 500. * deg2dy(met->lat[iy + 1] - met->lat[iy - 1]));
      if (fabs(met->lat[iy]) > 80)
        ls2 *= (90. - fabs(met->lat[iy])) / 10.;
      k[ix][iy] = ls2 * sqrt(2.0 * (gsl_pow_2(t) + gsl_pow_2(s)));
    }

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

  /* Write header... */
  fprintf(out,
          "# $1 = longitude [deg]\n"
          "# $2 = latitude [deg]\n"
          "# $3 = zonal wind [m/s]\n"
          "# $4 = meridional wind [m/s]\n"
          "# $5 = horizontal diffusivity [m^2/s]\n");

  /* Write data... */
  for (iy = 0; iy < met->ny; iy++) {
    fprintf(out, "\n");
    for (ix = 0; ix < met->nx; ix++)
      if (met->lon[ix] >= 180)
        fprintf(out, "%g %g %g %g %g\n",
                met->lon[ix] - 360.0, met->lat[iy],
                met->u[ix][iy][ip], met->v[ix][iy][ip], k[ix][iy]);
    for (ix = 0; ix < met->nx; ix++)
      if (met->lon[ix] <= 180)
        fprintf(out, "%g %g %g %g %g\n",
                met->lon[ix], met->lat[iy],
                met->u[ix][iy][ip], met->v[ix][iy][ip], k[ix][iy]);
  }

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

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

  return EXIT_SUCCESS;
}
```

5.27 split.c File Reference

Split air parcels into a larger number of parcels.

Functions

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

5.27.1 Detailed Description

Split air parcels into a larger number of parcels.

Definition in file split.c.

5.27.2 Function Documentation

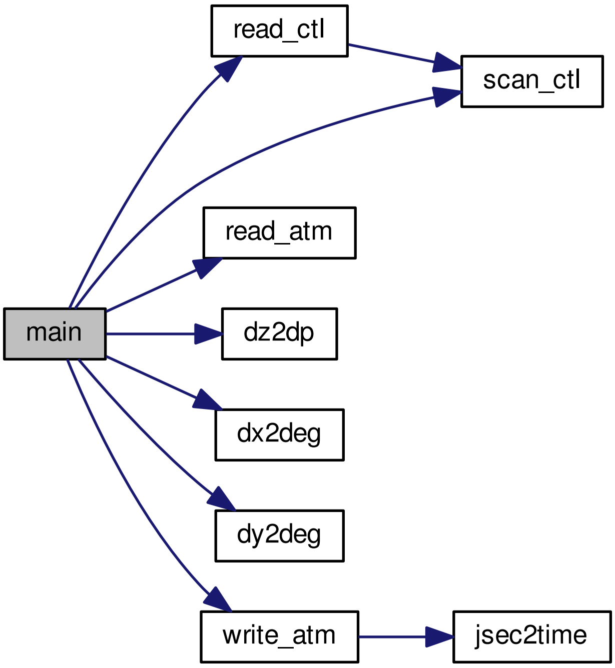
5.27.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file split.c.

```
               {

  atm_t *atm, *atm2;

  ctl_t ctl;

  gsl_rng *rng;

  double m, mtot = 0, dt, dx, dz, mmax = 0,
    t0, t1, z0, z1, lon0, lon1, lat0, lat1;

  int i, ip, iq, n;

  /* 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);

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

  /* Read atmospheric data... */
  read_atm(argv[2], &ctl, atm);

  /* 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... */
    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]);

    /* 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, atm->time[0]);

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

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.28 split.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/>.

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

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

  atm_t *atm, *atm2;

  ctl_t ctl;

  gsl_rng *rng;

  double m, mtot = 0, dt, dx, dz, mmax = 0,
    t0, t1, z0, z1, lon0, lon1, lat0, lat1;

  int i, ip, iq, n;

  /* 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);

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

  /* Read atmospheric data... */
  read_atm(argv[2], &ctl, atm);

  /* 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... */
    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]);

    /* 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, atm->time[0]);

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

  return EXIT_SUCCESS;
}
```

5.29 time2jsec.c File Reference

Convert date to Julian seconds.

Functions

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

5.29.1 Detailed Description

Convert date to Julian seconds.

Definition in file time2jsec.c.

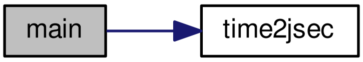
5.29.2 Function Documentation

5.29.2.1 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:



5.30 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   Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
00018 */
00019 
00025 #include "libtrac.h"
00026 
00027 int main(
00028   int argc,
00029   char *argv[]) {

  double jsec, remain;

  int day, hour, min, mon, sec, year;

  /* Check arguments... */
  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;
}
```

5.31 trac.c File Reference

Lagrangian particle dispersion model.

Functions

- void init_simtime (ctl_t ∗ctl, atm_t ∗atm)

  Set simulation time interval.
- void module_advection (met_t ∗met0, met_t ∗met1, atm_t ∗atm, int ip, double dt)

  Calculate advection of air parcels.
- void module_decay (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, int ip, double dt)

  Calculate exponential decay of particle mass.
- void module_diffusion_meso (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, int ip, double dt, gsl_rng ∗rng)

  Calculate mesoscale diffusion.
- void module_diffusion_turb (ctl_t ∗ctl, atm_t ∗atm, int ip, double dt, gsl_rng ∗rng)

  Calculate turbulent diffusion.
- void module_isosurf (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, int ip)

  Force air parcels to stay on isosurface.
- void module_meteo (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, int ip)

  Interpolate meteorological data for air parcel positions.
- double module_meteo_hno3 (double t, double lat, double p)

  Auxiliary function for meteo module.
- void module_position (met_t ∗met0, met_t ∗met1, atm_t ∗atm, int ip)

  Check position of air parcels.
- void module_sedi (ctl_t ∗ctl, met_t ∗met0, met_t ∗met1, atm_t ∗atm, int ip, double dt)

  Calculate sedimentation of air parcels.
- 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[ ])

5.31.1 Detailed Description

Lagrangian particle dispersion model.

Definition in file trac.c.

5.31.2 Function Documentation

5.31.2.1 void init_simtime (ctl_t * *ctl,* atm_t * *atm*)

Set simulation time interval.

Definition at line 371 of file trac.c.

```
                {

  /* Set inital and final time... */
  if (ctl->direction == 1) {
    if (ctl->t_start < -1e99)
      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 if (ctl->direction == -1) {
    if (ctl->t_stop < -1e99)
      ctl->t_stop = gsl_stats_min(atm->time, 1, (size_t) atm->np);
    if (ctl->t_start < -1e99)
      ctl->t_start = gsl_stats_max(atm->time, 1, (size_t) atm->np);
  }

  /* Check time... */
  if (ctl->direction * (ctl->t_stop - ctl->t_start) <= 0)
    ERRMSG("Nothing to do!");
}
```

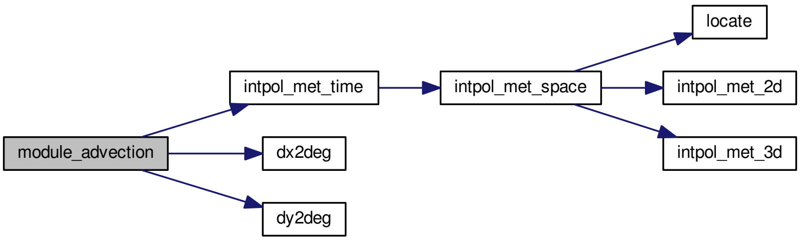
5.31.2.2 void module_advection (met_t * *met0,* met_t * *met1,* atm_t * *atm,* int *ip,* double *dt*)

Calculate advection of air parcels.

Definition at line 395 of file trac.c.

```
              {

  double v[3], xm[3];

  /* Interpolate meteorological data... */
  intpol_met_time(met0, met1, atm->time[ip], atm->p[ip],
                  atm->lon[ip], atm->lat[ip], NULL, NULL,
                  &v[0], &v[1], &v[2], NULL, NULL);

  /* Get position of the mid point... */
  xm[0] = atm->lon[ip] + dx2deg(0.5 * dt * v[0] / 1000., atm->lat[ip]);
  xm[1] = atm->lat[ip] + dy2deg(0.5 * dt * v[1] / 1000.);
  xm[2] = atm->p[ip] + 0.5 * dt * v[2];

  /* Interpolate meteorological data for mid point... */
  intpol_met_time(met0, met1, atm->time[ip] + 0.5 * dt,
                  xm[2], xm[0], xm[1], NULL, NULL,
                  &v[0], &v[1], &v[2], NULL, NULL);

  /* Save new position... */
  atm->time[ip] += dt;
  atm->lon[ip] += dx2deg(dt * v[0] / 1000., xm[1]);
  atm->lat[ip] += dy2deg(dt * v[1] / 1000.);
  atm->p[ip] += dt * v[2];
}
```

Here is the call graph for this function:



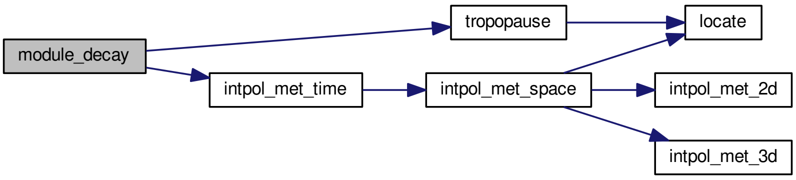
5.31.2.3 void module_decay (ctl_t ∗ *ctl,* met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* int *ip,* double *dt*)

Calculate exponential decay of particle mass.

Definition at line 428 of file trac.c.

```
             {

  double ps, pt, tdec;

  /* Check lifetime values... */
  if ((ctl->tdec_trop <= 0 && ctl->tdec_strat <= 0) || ctl->qnt_m < 0)
    return;

  /* Set constant lifetime... */
  if (ctl->tdec_trop == ctl->tdec_strat)
    tdec = ctl->tdec_trop;

  /* Set altitude-dependent lifetime... */
  else {

    /* Get surface pressure... */
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip],
                    atm->lon[ip], atm->lat[ip], &ps, NULL,
                    NULL, NULL, NULL, NULL, NULL);

    /* Get tropopause pressure... */
    pt = tropopause(atm->time[ip], atm->lat[ip]);

    /* Set lifetime... */
    if (atm->p[ip] <= pt)
      tdec = ctl->tdec_strat;
    else
      tdec = LIN(ps, ctl->tdec_trop, pt, ctl->tdec_strat, atm->p[ip]);
  }

  /* Calculate exponential decay... */
  atm->q[ctl->qnt_m][ip] *= exp(-dt / tdec);
}
```

Here is the call graph for this function:



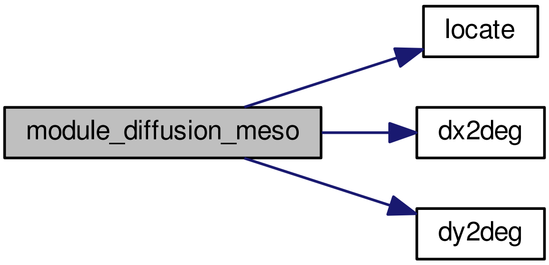
5.31.2.4 void module_diffusion_meso (ctl_t ∗ *ctl,* met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* int *ip,* double *dt,* gsl_rng ∗ *rng*)

Calculate mesoscale diffusion.

Definition at line 470 of file trac.c.

```
               {

double r, rs, u[16], v[16], w[16], usig, vsig, wsig;

int ix, iy, iz;

/* Calculate mesoscale velocity fluctuations... */
if (ctl->turb_meso > 0) {

  /* Get indices... */
  ix = locate(met0->lon, met0->nx, atm->lon[ip]);
  iy = locate(met0->lat, met0->ny, atm->lat[ip]);
  iz = locate(met0->p, met0->np, atm->p[ip]);

  /* 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];

  /* Get indices... */
  ix = locate(met1->lon, met1->nx, atm->lon[ip]);
  iy = locate(met1->lat, met1->ny, atm->lat[ip]);
  iz = locate(met1->p, met1->np, atm->p[ip]);

  /* 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... */
  usig = gsl_stats_sd(u, 1, 16);
  vsig = gsl_stats_sd(v, 1, 16);
  wsig = gsl_stats_sd(w, 1, 16);

  /* Set temporal correlations for mesoscale fluctuations... */
  r = 1 - 2 * fabs(dt) / ctl->dt_met;
  rs = sqrt(1 - r * r);

  /* Calculate mesoscale wind fluctuations... */
  atm->up[ip] =
    r * atm->up[ip] + rs * gsl_ran_gaussian_ziggurat(rng,
                                                       ctl->turb_meso * usig);
    atm->vp[ip] =
      r * atm->vp[ip] + rs * gsl_ran_gaussian_ziggurat(rng,
                                                       ctl->turb_meso * vsig);
    atm->wp[ip] =
      r * atm->wp[ip] + rs * gsl_ran_gaussian_ziggurat(rng,
                                                       ctl->turb_meso * wsig);

    /* Calculate air parcel displacement... */
    atm->lon[ip] += dx2deg(atm->up[ip] * dt / 1000., atm->lat[ip]);
    atm->lat[ip] += dy2deg(atm->vp[ip] * dt / 1000.);
    atm->p[ip] += atm->wp[ip] * dt;
  }
}
```

Here is the call graph for this function:



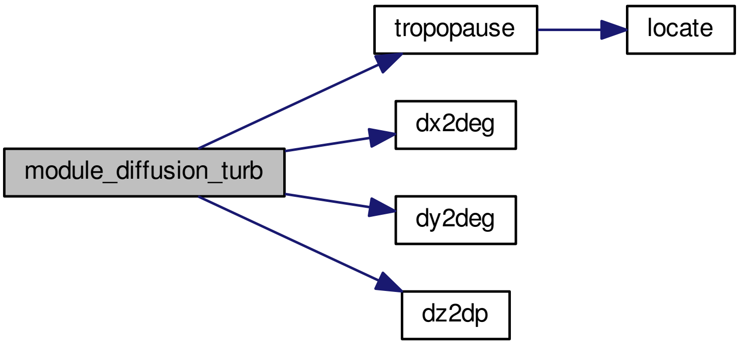
5.31.2.5 void module_diffusion_turb (ctl_t * *ctl,* atm_t * *atm,* int *ip,* double *dt,* gsl_rng * *rng*)

Calculate turbulent diffusion.

Definition at line 581 of file trac.c.

```
                 {

  double dx, dz, pt, p0, p1, w;

  /* Get tropopause pressure... */
  pt = tropopause(atm->time[ip], atm->lat[ip]);

  /* Get weighting factor... */
  p1 = pt * 0.866877899;
  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 diffusivitiy... */
  dx = w * ctl->turb_dx_trop + (1 - w) * ctl->turb_dx_strat;
  dz = w * ctl->turb_dz_trop + (1 - w) * ctl->turb_dz_strat;

  /* Horizontal turbulent diffusion... */
  if (dx > 0) {
    atm->lon[ip]
      += dx2deg(gsl_ran_gaussian_ziggurat(rng, sqrt(2.0 * dx * fabs(dt)))
                / 1000., atm->lat[ip]);
    atm->lat[ip]
      += dy2deg(gsl_ran_gaussian_ziggurat(rng, sqrt(2.0 * dx * fabs(dt)))
                / 1000.);
  }
  /* Vertical turbulent diffusion... */
  if (dz > 0)
    atm->p[ip]
      += dz2dp(gsl_ran_gaussian_ziggurat(rng, sqrt(2.0 * dz * fabs(dt)))
               / 1000., atm->p[ip]);
}
```

Here is the call graph for this function:



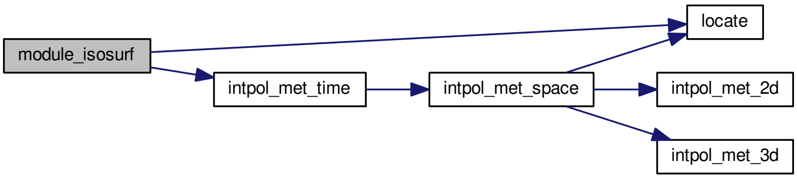
5.31.2.6 void module_isosurf (ctl_t * *ctl,* met_t * *met0,* met_t * *met1,* atm_t * *atm,* int *ip*)

Force air parcels to stay on isosurface.

Definition at line 626 of file trac.c.

```
         {

  static double *iso, *ps, t, *ts;

  static int idx, ip2, n, nb = 100000;

  FILE *in;

  char line[LEN];

  /* Check control parameter... */
  if (ctl->isosurf < 1 || ctl->isosurf > 4)
    return;

  /* Initialize... */
  if (ip < 0) {

    /* Allocate... */
    ALLOC(iso, double,
          NP);
    ALLOC(ps, double,
          nb);
    ALLOC(ts, double,
          nb);

    /* Save pressure... */
    if (ctl->isosurf == 1)
      for (ip2 = 0; ip2 < atm->np; ip2++)
        iso[ip2] = atm->p[ip2];

    /* Save density... */
    else if (ctl->isosurf == 2)
      for (ip2 = 0; ip2 < atm->np; ip2++) {
        intpol_met_time(met0, met1, atm->time[ip2], atm->p[ip2],
                        atm->lon[ip2], atm->lat[ip2], NULL, &t, NULL, NULL,
                        NULL, NULL, NULL);
        iso[ip2] = atm->p[ip2] / t;
      }

    /* Save potential temperature... */
    else if (ctl->isosurf == 3)
      for (ip2 = 0; ip2 < atm->np; ip2++) {
        intpol_met_time(met0, met1, atm->time[ip2], atm->p[ip2],
                        atm->lon[ip2], atm->lat[ip2], NULL, &t, NULL, NULL,
                        NULL, NULL, NULL);
        iso[ip2] = t * pow(P0 / atm->p[ip2], 0.286);
      }

    /* 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", &ts[n], &ps[n]) == 2)
          if ((++n) > 100000)
            ERRMSG("Too many data points!");

      /* Check number of points... */
      if (n < 1)
        ERRMSG("Could not read any data!");

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

    /* Leave initialization... */
    return;
  }

  /* Restore pressure... */
  if (ctl->isosurf == 1)
    atm->p[ip] = iso[ip];

  /* Restore density... */
  else if (ctl->isosurf == 2) {
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->lon[ip],
                    atm->lat[ip], NULL, &t, NULL, NULL, NULL, NULL, NULL);
    atm->p[ip] = iso[ip] * t;
  }

  /* Restore potential temperature... */
  else if (ctl->isosurf == 3) {
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->lon[ip],
                    atm->lat[ip], NULL, &t, NULL, NULL, NULL, NULL, NULL);
    atm->p[ip] = P0 * pow(iso[ip] / t, -1. / 0.286);
  }

  /* Interpolate pressure... */
  else if (ctl->isosurf == 4) {
    if (atm->time[ip] <= ts[0])
      atm->p[ip] = ps[0];
    else if (atm->time[ip] >= ts[n - 1])
      atm->p[ip] = ps[n - 1];
    else {
      idx = locate(ts, n, atm->time[ip]);
      atm->p[ip] = LIN(ts[idx], ps[idx],
                       ts[idx + 1], ps[idx + 1], atm->time[ip]);
    }
  }
}
```

Here is the call graph for this function:



5.31.2.7 void module_meteo (ctl_t ∗ *ctl,* met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* int *ip*)

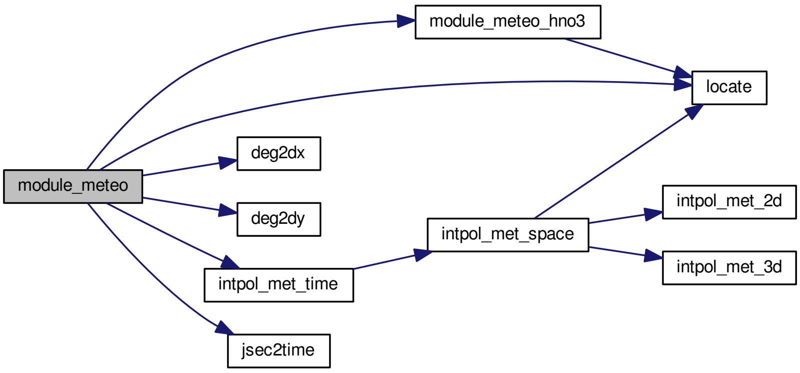
Interpolate meteorological data for air parcel positions.

Definition at line 741 of file trac.c.

```
          {

  static FILE *in;

  static char filename[LEN], line[LEN];

  static double lon[GX], lat[GY], var[GX][GY],
    rdum, rlat, rlat_old = -999, rlon, rvar;

  static int year_old, mon_old, day_old, nlon, nlat;

  double a, b, c, ps, p1, p_hno3, p_h2o, t, t1, u, u1, v, v1, w,
    x1, x2, h2o, o3, grad, vort, var0, var1;

  int day, mon, year, idum, ilat, ilon;

  /* Interpolate meteorological data... */
  intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->lon[ip],
                  atm->lat[ip], &ps, &t, &u, &v, &w, &h2o, &o3);

  /* Set surface pressure... */
  if (ctl->qnt_ps >= 0)
    atm->q[ctl->qnt_ps][ip] = ps;

  /* Set pressure... */
  if (ctl->qnt_p >= 0)
    atm->q[ctl->qnt_p][ip] = atm->p[ip];

  /* Set temperature... */
  if (ctl->qnt_t >= 0)
    atm->q[ctl->qnt_t][ip] = t;

  /* Set zonal wind... */
  if (ctl->qnt_u >= 0)
    atm->q[ctl->qnt_u][ip] = u;

  /* Set meridional wind... */
  if (ctl->qnt_v >= 0)
    atm->q[ctl->qnt_v][ip] = v;

  /* Set vertical velocity... */
  if (ctl->qnt_w >= 0)
    atm->q[ctl->qnt_w][ip] = w;

  /* Set water vapor vmr... */
  if (ctl->qnt_h2o >= 0)
    atm->q[ctl->qnt_h2o][ip] = h2o;

  /* Set ozone vmr... */
  if (ctl->qnt_o3 >= 0)
    atm->q[ctl->qnt_o3][ip] = o3;

  /* Calculate potential temperature... */
  if (ctl->qnt_theta >= 0)
    atm->q[ctl->qnt_theta][ip] = t * pow(P0 / atm->p[ip], 0.286);

  /* Calculate potential vorticity... */
  if (ctl->qnt_pv >= 0) {

    /* Absolute vorticity... */
    vort = 2 * 7.2921e-5 * sin(atm->lat[ip] * M_PI / 180.);
    if (fabs(atm->lat[ip]) < 89.) {
      intpol_met_time(met0, met1, atm->time[ip], atm->p[ip],
                      (atm->lon[ip] >=
                       0 ? atm->lon[ip] - 1. : atm->lon[ip] + 1.),
                      atm->lat[ip], NULL, NULL, NULL, &v1, NULL, NULL, NULL);
      vort += (v1 - v) / 1000.
        / ((atm->lon[ip] >= 0 ? -1 : 1) * deg2dx(1., atm->lat[ip]));
    }
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->lon[ip],
                    (atm->lat[ip] >=
                     0 ? atm->lat[ip] - 1. : atm->lat[ip] + 1.), NULL, NULL,
                    &u1, NULL, NULL, NULL, NULL);
    vort += (u1 - u) / 1000. / ((atm->lat[ip] >= 0 ? -1 : 1) * deg2dy(1.));

    /* Potential temperature gradient... */
    p1 = 0.85 * atm->p[ip];
    intpol_met_time(met0, met1, atm->time[ip], p1, atm->lon[ip],
                    atm->lat[ip], NULL, &t1, NULL, NULL, NULL, NULL, NULL);
    grad = (t1 * pow(P0 / p1, 0.286) - t * pow(P0 / atm->p[ip], 0.286))
      / (100. * (p1 - atm->p[ip]));

    /* Calculate PV... */
    atm->q[ctl->qnt_pv][ip] = -1e6 * G0 * vort * grad;
  }

  /* Calculate T_ice (Marti and Mauersberger, 1993)... */
  if (ctl->qnt_tice >= 0 || ctl->qnt_tsts >= 0)
    atm->q[ctl->qnt_tice][ip] =
      -2663.5 /
      (log10((ctl->psc_h2o > 0 ? ctl->psc_h2o : h2o) * atm->p[ip] * 100.) -
       12.537);

  /* Calculate T_NAT (Hanson and Mauersberger, 1988)... */
  if (ctl->qnt_tnat >= 0 || ctl->qnt_tsts >= 0) {
    if (ctl->psc_hno3 > 0)
      p_hno3 = ctl->psc_hno3 * atm->p[ip] / 1.333224;
    else
      p_hno3 = module_meteo_hno3(atm->time[ip], atm->lat[ip], atm->p[ip])
        * 1e-9 * atm->p[ip] / 1.333224;
    p_h2o = (ctl->psc_h2o > 0 ? ctl->psc_h2o : h2o) * atm->p[ip] / 1.333224;
    a = 0.009179 - 0.00088 * log10(p_h2o);
    b = (38.9855 - log10(p_hno3) - 2.7836 * log10(p_h2o)) / a;
    c = -11397.0 / a;
    x1 = (-b + sqrt(b * b - 4. * c)) / 2.;
    x2 = (-b - sqrt(b * b - 4. * c)) / 2.;
    if (x1 > 0)
      atm->q[ctl->qnt_tnat][ip] = x1;
    if (x2 > 0)
      atm->q[ctl->qnt_tnat][ip] = x2;
  }

  /* Calculate T_STS (mean of T_ice and T_NAT)... */
  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!");
    atm->q[ctl->qnt_tsts][ip] = 0.5 * (atm->q[ctl->qnt_tice][ip]
                                       + atm->q[ctl->qnt_tnat][ip]);
  }

  /* Read variance data for current day... */
  if (ip == 0 && ctl->qnt_gw_var >= 0) {
    jsec2time(atm->time[ip], &year, &mon, &day, &idum, &idum, &idum, &rdum);
    if (year != year_old || mon != mon_old || day != day_old) {
      year_old = year;
      mon_old = mon;
      day_old = day;
      nlon = nlat = -1;
      sprintf(filename, "%s_%d_%02d_%02d.tab",
              ctl->gw_basename, year, mon, day);
      if ((in = fopen(filename, "r"))) {
        printf("Read gravity wave data: %s\n", filename);
        while (fgets(line, LEN, in)) {
          if (sscanf(line, "%lg %lg %lg", &rlon, &rlat, &rvar) != 3)
            continue;
          if (rlat != rlat_old) {
            rlat_old = rlat;
            if ((++nlat) > GY)
```

```
              ERRMSG("Too many latitudes!");
            nlon = -1;
          }
          if ((++nlon) > GX)
            ERRMSG("Too many longitudes!");
          lon[nlon] = rlon;
          lat[nlat] = rlat;
          var[nlon][nlat] = GSL_MAX(0, rvar);
        }
        fclose(in);
        nlat++;
        nlon++;
      } else
        printf("Missing gravity wave data: %s\n", filename);
    }
  }

  /* Interpolate variance data... */
  if (ctl->qnt_gw_var >= 0) {
    if (nlat >= 2 && nlon >= 2) {
      ilat = locate(lat, nlat, atm->lat[ip]);
      ilon = locate(lon, nlon, atm->lon[ip]);
      var0 = LIN(lat[ilat], var[ilon][ilat],
                 lat[ilat + 1], var[ilon][ilat + 1], atm->lat[ip]);
      var1 = LIN(lat[ilat], var[ilon + 1][ilat],
                 lat[ilat + 1], var[ilon + 1][ilat + 1], atm->lat[ip]);
      atm->q[ctl->qnt_gw_var][ip]
        = LIN(lon[ilon], var0, lon[ilon + 1], var1, atm->lon[ip]);
    } else
      atm->q[ctl->qnt_gw_var][ip] = GSL_NAN;
  }
}
```

Here is the call graph for this function:



5.31.2.8 double module_meteo_hno3 (double *t*, double *lat*, double *p*)

Auxiliary function for meteo module.

Definition at line 919 of file trac.c.

```
             {

  static double 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
  };

  static double lats[18] = { -85, -75, -65, -55, -45, -35, -25, -15, -5,
    5, 15, 25, 35, 45, 55, 65, 75, 85
```

```
};

static double ps[10] = { 4.64159, 6.81292, 10, 14.678, 21.5443,
  31.6228, 46.4159, 68.1292, 100, 146.78
};

static double hno3[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},
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   {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},
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   {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},
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   {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},
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   {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},
   {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}}
};

double aux00, aux01, aux10, aux11, sec;

int ilat, ip, isec;

/* Get seconds since begin of year... */
sec = fmod(t, 365.25 * 86400.);

/* Get indices... */
ilat = locate(lats, 18, lat);
ip = locate(ps, 10, p);
isec = locate(secs, 12, sec);

/* Interpolate... */
aux00 = LIN(ps[ip], hno3[isec][ilat][ip],
            ps[ip + 1], hno3[isec][ilat][ip + 1], p);
aux01 = LIN(ps[ip], hno3[isec][ilat + 1][ip],
            ps[ip + 1], hno3[isec][ilat + 1][ip + 1], p);
aux10 = LIN(ps[ip], hno3[isec + 1][ilat][ip],
            ps[ip + 1], hno3[isec + 1][ilat][ip + 1], p);
aux11 = LIN(ps[ip], hno3[isec + 1][ilat + 1][ip],
            ps[ip + 1], hno3[isec + 1][ilat + 1][ip + 1], p);
aux00 = LIN(lats[ilat], aux00, lats[ilat + 1], aux01, lat);
aux11 = LIN(lats[ilat], aux10, lats[ilat + 1], aux11, lat);
return LIN(secs[isec], aux00, secs[isec + 1], aux11, sec);
}
```
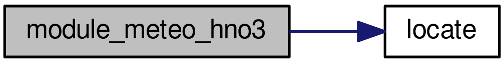

Here is the call graph for this function:



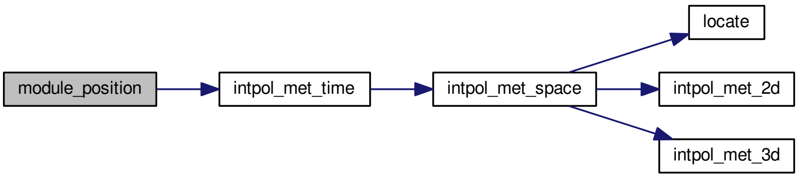
5.31.2.9 void module_position (met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* int *ip*)

Check position of air parcels.

Definition at line 1185 of file trac.c.

```
         {

  double ps;

  /* 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;

  /* Get surface pressure... */
  intpol_met_time(met0, met1, atm->time[ip], atm->p[ip],
                  atm->lon[ip], atm->lat[ip], &ps, NULL,
                  NULL, NULL, NULL, NULL, NULL);

  /* Check pressure... */
  if (atm->p[ip] > ps)
    atm->p[ip] = ps;
  else if (atm->p[ip] < met0->p[met0->np - 1])
    atm->p[ip] = met0->p[met0->np - 1];
}
```

Here is the call graph for this function:



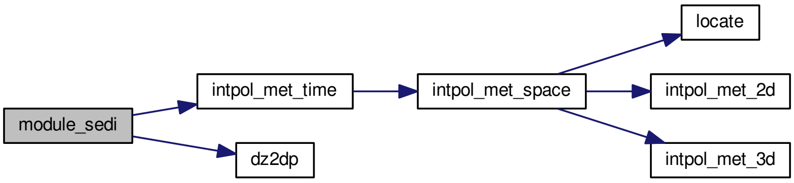
5.31.2.10 void module_sedi (ctl_t * *ctl,* met_t * *met0,* met_t * *met1,* atm_t * *atm,* int *ip,* double *dt*)

Calculate sedimentation of air parcels.

Definition at line 1229 of file trac.c.

```
             {

  /* Coefficients for Cunningham slip-flow correction (Kasten, 1968): */
  const double A = 1.249, B = 0.42, C = 0.87;

  /* Specific gas constant for dry air [J/(kg K)]: */
  const double R = 287.058;

  /* Average mass of an air molecule [kg/molec]: */
  const double m = 4.8096e-26;

  double G, K, eta, lambda, p, r_p, rho, rho_p, T, v, v_p;

  /* Check if parameters are available... */
  if (ctl->qnt_r < 0 || ctl->qnt_rho < 0)
    return;

  /* Convert units... */
  p = 100 * atm->p[ip];
  r_p = 1e-6 * atm->q[ctl->qnt_r][ip];
  rho_p = atm->q[ctl->qnt_rho][ip];

  /* Get temperature... */
  intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->
lon[ip],
                  atm->lat[ip], NULL, &T, NULL, NULL, NULL, NULL, NULL);

  /* Density of dry air... */
  rho = p / (R * 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 * GSL_CONST_MKSA_BOLTZMANN * T / (M_PI * m));

  /* 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 * (A + B * exp(-C / K));

  /* Sedimentation (fall) velocity... */
  v_p =
    2. * gsl_pow_2(r_p) * (rho_p -
                           rho) * GSL_CONST_MKSA_GRAV_ACCEL / (9. * eta) * G;

  /* Calculate pressure change... */
  atm->p[ip] += dz2dp(v_p * dt / 1000., atm->p[ip]);
}
```

Here is the call graph for this function:



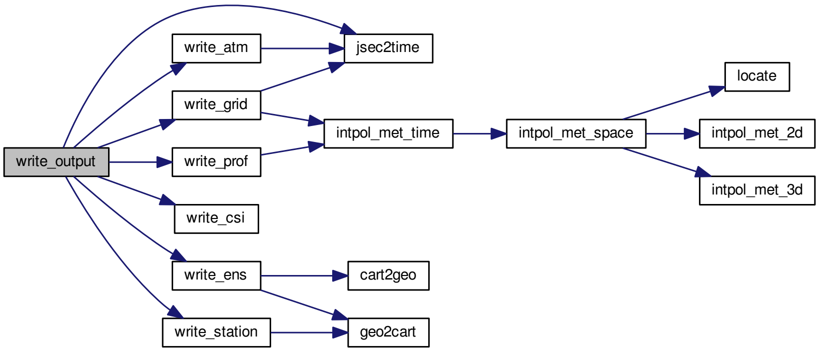
5.31.2.11 void write_output (const char ∗ *dirname,* ctl_t ∗ *ctl,* met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* double *t*)

Write simulation output.

Definition at line 1290 of file trac.c.

```
            {

  char filename[LEN];

  double r;

  int year, mon, day, hour, min, sec;

  /* 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) {
    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 CSI data... */
  if (ctl->csi_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->csi_basename);
    write_csi(filename, ctl, atm, t);
  }

  /* Write ensemble data... */
  if (ctl->ens_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->ens_basename);
    write_ens(filename, ctl, atm, t);
  }

  /* Write gridded data... */
  if (ctl->grid_basename[0] != '-' && fmod(t, ctl->grid_dt_out) == 0) {
    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 profile data... */
  if (ctl->prof_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->prof_basename);
    write_prof(filename, ctl, met0, met1, atm, t);
  }

  /* Write station data... */
  if (ctl->stat_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->stat_basename);
    write_station(filename, ctl, atm, t);
  }
}
```

Here is the call graph for this function:

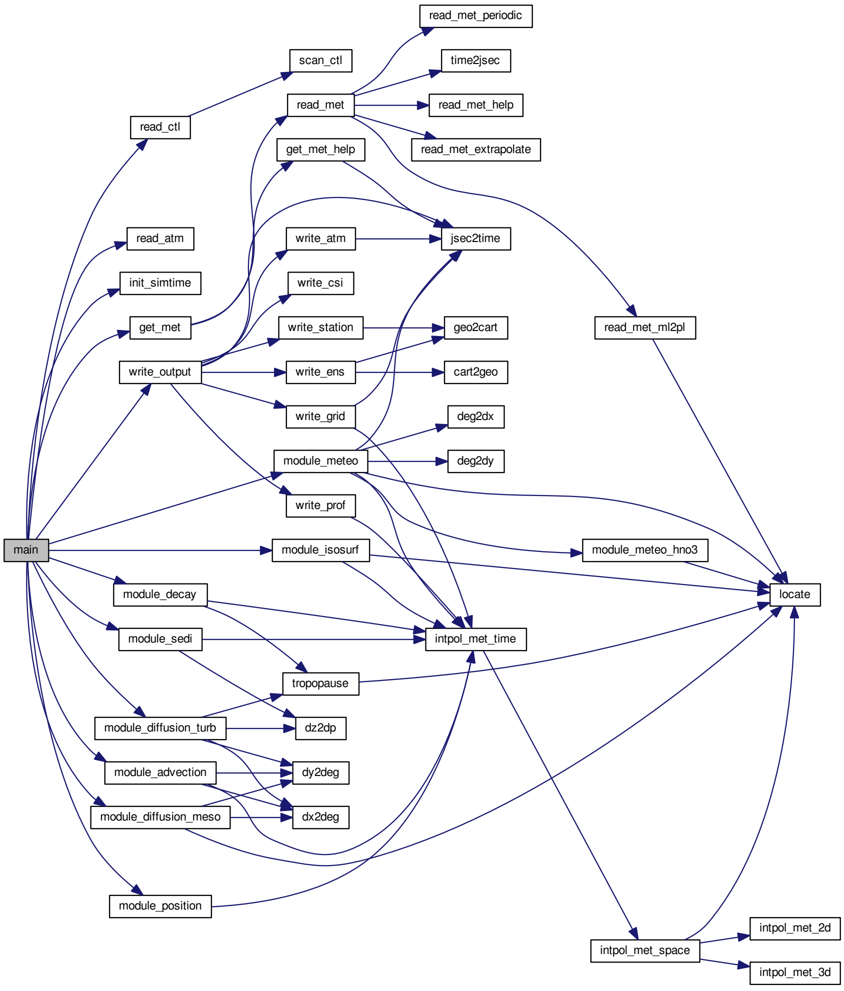


5.31.2.12 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 126 of file trac.c.

```
                {

  ctl_t ctl;

  atm_t *atm;

  met_t *met0, *met1;

  gsl_rng *rng[NTHREADS];

  FILE *dirlist;

  char dirname[LEN], filename[LEN];

  double *dt, t, t0;

  int i, ip, ntask = 0, rank = 0, size = 1;

#ifdef MPI
  /* Initialize MPI... */
  MPI_Init(&argc, &argv);
  MPI_Comm_rank(MPI_COMM_WORLD, &rank);
  MPI_Comm_size(MPI_COMM_WORLD, &size);
#endif

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <dirlist> <ctl> <atm_in> <metbase>");

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

    /* Set timers... */
    START_TIMER(TIMER_TOTAL);
    START_TIMER(TIMER_INIT);

    /* Allocate... */
    ALLOC(atm, atm_t, 1);
    ALLOC(met0, met_t, 1);
    ALLOC(met1, met_t, 1);
    ALLOC(dt, double,
          NP);

    /* Read control parameters... */
    sprintf(filename, "%s/%s", dirname, argv[2]);
    read_ctl(filename, argc, argv, &ctl);

    /* Initialize random number generators... */
    gsl_rng_env_setup();
    if (omp_get_max_threads() > NTHREADS)
      ERRMSG("Too many threads!");
    for (i = 0; i < NTHREADS; i++)
      rng[i] = gsl_rng_alloc(gsl_rng_default);

    /* Read atmospheric data... */
    sprintf(filename, "%s/%s", dirname, argv[3]);
    read_atm(filename, &ctl, atm);

    /* Get simulation time interval... */
    init_simtime(&ctl, atm);

    /* Get rounded start time... */
    if (ctl.direction == 1)
      t0 = floor(ctl.t_start / ctl.dt_mod) * ctl.dt_mod;
    else
      t0 = ceil(ctl.t_start / ctl.dt_mod) * ctl.dt_mod;

    /* Set timers... */
    STOP_TIMER(TIMER_INIT);

    /* ------------------------------------------------------------
       Loop over timesteps...
       ------------------------------------------------------------ */

    /* Loop over timesteps... */
    for (t = t0; 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... */
      for (ip = 0; ip < atm->np; ip++)
        if ((ctl.direction * (atm->time[ip] - ctl.t_start) >= 0
             && ctl.direction * (atm->time[ip] - ctl.t_stop) <= 0
             && ctl.direction * (atm->time[ip] - t) < 0))
          dt[ip] = t - atm->time[ip];
        else
          dt[ip] = GSL_NAN;

      /* Get meteorological data... */
      START_TIMER(TIMER_INPUT);
      get_met(&ctl, argv[4], t, met0, met1);
      if (ctl.dt_mod > fabs(met0->lon[1] - met0->lon[1]) * 111132. / 150.
          || ctl.dt_mod > fabs(met1->lon[1] - met1->lon[1]) * 111132. / 150.)
        printf("Warning: Time step DT_MOD violates the CFL criterion!\n");
      STOP_TIMER(TIMER_INPUT);

      /* Initialize isosurface... */
      START_TIMER(TIMER_ISOSURF);
      if (t == t0)
        module_isosurf(&ctl, met0, met1, atm, -1);
      STOP_TIMER(TIMER_ISOSURF);

      /* Advection... */
      START_TIMER(TIMER_ADVECT);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_advection(met0, met1, atm, ip, dt[ip]);
      STOP_TIMER(TIMER_ADVECT);

      /* Turbulent diffusion... */
      START_TIMER(TIMER_DIFFTURB);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_diffusion_turb(&ctl, atm, ip, dt[ip],
                                rng[omp_get_thread_num()]);
      STOP_TIMER(TIMER_DIFFTURB);

      /* Mesoscale diffusion... */
      START_TIMER(TIMER_DIFFMESO);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_diffusion_meso(&ctl, met0, met1, atm, ip, dt[ip],
                                rng[omp_get_thread_num()]);
      STOP_TIMER(TIMER_DIFFMESO);

      /* Sedimentation... */
      START_TIMER(TIMER_SEDI);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_sedi(&ctl, met0, met1, atm, ip, dt[ip]);
      STOP_TIMER(TIMER_SEDI);

      /* Isosurface... */
      START_TIMER(TIMER_ISOSURF);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        module_isosurf(&ctl, met0, met1, atm, ip);
      STOP_TIMER(TIMER_ISOSURF);

      /* Position... */
      START_TIMER(TIMER_POSITION);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        module_position(met0, met1, atm, ip);
      STOP_TIMER(TIMER_POSITION);

      /* Meteorological data... */
      START_TIMER(TIMER_METEO);
      module_meteo(&ctl, met0, met1, atm, 0);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 1; ip < atm->np; ip++)
        module_meteo(&ctl, met0, met1, atm, ip);
      STOP_TIMER(TIMER_METEO);

      /* Decay... */
      START_TIMER(TIMER_DECAY);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_decay(&ctl, met0, met1, atm, ip, dt[ip]);
      STOP_TIMER(TIMER_DECAY);

      /* Write output... */
      START_TIMER(TIMER_OUTPUT);
      write_output(dirname, &ctl, met0, met1, atm, t);
      STOP_TIMER(TIMER_OUTPUT);
    }

    /* ------------------------------------------------------------
       Finalize model run...
       ------------------------------------------------------------ */

    /* Report timers... */
    STOP_TIMER(TIMER_TOTAL);
    PRINT_TIMER(TIMER_TOTAL);
    PRINT_TIMER(TIMER_INIT);
    PRINT_TIMER(TIMER_STAGE);
    PRINT_TIMER(TIMER_INPUT);
    PRINT_TIMER(TIMER_OUTPUT);
    PRINT_TIMER(TIMER_ADVECT);
    PRINT_TIMER(TIMER_DECAY);
    PRINT_TIMER(TIMER_DIFFMESO);
    PRINT_TIMER(TIMER_DIFFTURB);
    PRINT_TIMER(TIMER_ISOSURF);
    PRINT_TIMER(TIMER_METEO);
    PRINT_TIMER(TIMER_POSITION);
    PRINT_TIMER(TIMER_SEDI);

    /* Report memory usage... */
    printf("MEMORY_ATM = %g MByte\n", 2. * sizeof(atm_t) / 1024. / 1024.);
    printf("MEMORY_METEO = %g MByte\n", 2. * sizeof(met_t) / 1024. / 1024.);
    printf("MEMORY_DYNAMIC = %g MByte\n",
           NP * sizeof(double) / 1024. / 1024.);
    printf("MEMORY_STATIC = %g MByte\n",
           (((EX + EY) + (2 + NQ) * GX * GY * GZ) * sizeof(double)
            + (EX * EY + EX * EY * EP) * sizeof(float)
            + (2 * GX * GY * GZ) * sizeof(int)) / 1024. / 1024.);

    /* Report problem size... */
    printf("SIZE_NP = %d\n", atm->np);
    printf("SIZE_TASKS = %d\n", size);
    printf("SIZE_THREADS = %d\n", omp_get_max_threads());

    /* Free random number generators... */
    for (i = 0; i < NTHREADS; i++)
      gsl_rng_free(rng[i]);

    /* Free... */
    free(atm);
    free(met0);
    free(met1);
    free(dt);
  }

#ifdef MPI
  /* Finalize MPI... */
  MPI_Finalize();
#endif

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.32 trac.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/>.

  Copright (C) 2013-2015 Forschungszentrum Juelich GmbH
*/

#include "libtrac.h"

#ifdef MPI
#include "mpi.h"
#endif

```

```
/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

void init_simtime(
  ctl_t * ctl,
  atm_t * atm);

void module_advection(
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip,
  double dt);

void module_decay(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip,
  double dt);

void module_diffusion_meso(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip,
  double dt,
  gsl_rng * rng);

void module_diffusion_turb(
  ctl_t * ctl,
  atm_t * atm,
  int ip,
  double dt,
  gsl_rng * rng);

void module_isosurf(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip);

void module_meteo(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip);

double module_meteo_hno3(
  double t,
  double lat,
  double p);

void module_position(
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip);

void module_sedi(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip,
  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;

  met_t *met0, *met1;

  gsl_rng *rng[NTHREADS];

  FILE *dirlist;

  char dirname[LEN], filename[LEN];

  double *dt, t, t0;

  int i, ip, ntask = 0, rank = 0, size = 1;

#ifdef MPI
  /* Initialize MPI... */
  MPI_Init(&argc, &argv);
  MPI_Comm_rank(MPI_COMM_WORLD, &rank);
  MPI_Comm_size(MPI_COMM_WORLD, &size);
#endif

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <dirlist> <ctl> <atm_in> <metbase>");

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

    /* Set timers... */
    START_TIMER(TIMER_TOTAL);
    START_TIMER(TIMER_INIT);

    /* Allocate... */
    ALLOC(atm, atm_t, 1);
    ALLOC(met0, met_t, 1);
    ALLOC(met1, met_t, 1);
    ALLOC(dt, double,
          NP);

    /* Read control parameters... */
    sprintf(filename, "%s/%s", dirname, argv[2]);
    read_ctl(filename, argc, argv, &ctl);

    /* Initialize random number generators... */
    gsl_rng_env_setup();
    if (omp_get_max_threads() > NTHREADS)
      ERRMSG("Too many threads!");
    for (i = 0; i < NTHREADS; i++)
      rng[i] = gsl_rng_alloc(gsl_rng_default);

    /* Read atmospheric data... */
    sprintf(filename, "%s/%s", dirname, argv[3]);
    read_atm(filename, &ctl, atm);

    /* Get simulation time interval... */
    init_simtime(&ctl, atm);

    /* Get rounded start time... */
    if (ctl.direction == 1)
      t0 = floor(ctl.t_start / ctl.dt_mod) * ctl.dt_mod;
    else
      t0 = ceil(ctl.t_start / ctl.dt_mod) * ctl.dt_mod;

    /* Set timers... */
    STOP_TIMER(TIMER_INIT);

    /* ------------------------------------------------------------
       Loop over timesteps...
       ------------------------------------------------------------ */

    /* Loop over timesteps... */
    for (t = t0; 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... */
      for (ip = 0; ip < atm->np; ip++)
        if ((ctl.direction * (atm->time[ip] - ctl.t_start) >= 0
             && ctl.direction * (atm->time[ip] - ctl.t_stop) <= 0
             && ctl.direction * (atm->time[ip] - t) < 0))
          dt[ip] = t - atm->time[ip];
        else
          dt[ip] = GSL_NAN;

      /* Get meteorological data... */
      START_TIMER(TIMER_INPUT);
      get_met(&ctl, argv[4], t, met0, met1);
      if (ctl.dt_mod > fabs(met0->lon[1] - met0->lon[1]) * 111132. / 150.
          || ctl.dt_mod > fabs(met1->lon[1] - met1->lon[1]) * 111132. / 150.)
        printf("Warning: Time step DT_MOD violates the CFL criterion!\n");
      STOP_TIMER(TIMER_INPUT);

      /* Initialize isosurface... */
      START_TIMER(TIMER_ISOSURF);
      if (t == t0)
        module_isosurf(&ctl, met0, met1, atm, -1);
      STOP_TIMER(TIMER_ISOSURF);

      /* Advection... */
      START_TIMER(TIMER_ADVECT);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_advection(met0, met1, atm, ip, dt[ip]);
      STOP_TIMER(TIMER_ADVECT);

      /* Turbulent diffusion... */
      START_TIMER(TIMER_DIFFTURB);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_diffusion_turb(&ctl, atm, ip, dt[ip],
                                rng[omp_get_thread_num()]);
      STOP_TIMER(TIMER_DIFFTURB);

      /* Mesoscale diffusion... */
      START_TIMER(TIMER_DIFFMESO);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_diffusion_meso(&ctl, met0, met1, atm, ip, dt[ip],
                                rng[omp_get_thread_num()]);
      STOP_TIMER(TIMER_DIFFMESO);

      /* Sedimentation... */
      START_TIMER(TIMER_SEDI);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_sedi(&ctl, met0, met1, atm, ip, dt[ip]);
      STOP_TIMER(TIMER_SEDI);

      /* Isosurface... */
      START_TIMER(TIMER_ISOSURF);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        module_isosurf(&ctl, met0, met1, atm, ip);
      STOP_TIMER(TIMER_ISOSURF);

      /* Position... */
      START_TIMER(TIMER_POSITION);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        module_position(met0, met1, atm, ip);
      STOP_TIMER(TIMER_POSITION);

      /* Meteorological data... */
      START_TIMER(TIMER_METEO);
      module_meteo(&ctl, met0, met1, atm, 0);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 1; ip < atm->np; ip++)
        module_meteo(&ctl, met0, met1, atm, ip);
      STOP_TIMER(TIMER_METEO);

      /* Decay... */
      START_TIMER(TIMER_DECAY);
```

```
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; ip < atm->np; ip++)
        if (gsl_finite(dt[ip]))
          module_decay(&ctl, met0, met1, atm, ip, dt[ip]);
      STOP_TIMER(TIMER_DECAY);

      /* Write output... */
      START_TIMER(TIMER_OUTPUT);
      write_output(dirname, &ctl, met0, met1, atm, t);
      STOP_TIMER(TIMER_OUTPUT);
    }

    /* ------------------------------------------------------------
       Finalize model run...
       ------------------------------------------------------------ */

    /* Report timers... */
    STOP_TIMER(TIMER_TOTAL);
    PRINT_TIMER(TIMER_TOTAL);
    PRINT_TIMER(TIMER_INIT);
    PRINT_TIMER(TIMER_STAGE);
    PRINT_TIMER(TIMER_INPUT);
    PRINT_TIMER(TIMER_OUTPUT);
    PRINT_TIMER(TIMER_ADVECT);
    PRINT_TIMER(TIMER_DECAY);
    PRINT_TIMER(TIMER_DIFFMESO);
    PRINT_TIMER(TIMER_DIFFTURB);
    PRINT_TIMER(TIMER_ISOSURF);
    PRINT_TIMER(TIMER_METEO);
    PRINT_TIMER(TIMER_POSITION);
    PRINT_TIMER(TIMER_SEDI);

    /* Report memory usage... */
    printf("MEMORY_ATM = %g MByte\n", 2. * sizeof(atm_t) / 1024. / 1024.);
    printf("MEMORY_METEO = %g MByte\n", 2. * sizeof(met_t) / 1024. / 1024.);
    printf("MEMORY_DYNAMIC = %g MByte\n",
           NP * sizeof(double) / 1024. / 1024.);
    printf("MEMORY_STATIC = %g MByte\n",
           (((EX + EY) + (2 + NQ) * GX * GY * GZ) * sizeof(double)
            + (EX * EY + EX * EY * EP) * sizeof(float)
            + (2 * GX * GY * GZ) * sizeof(int)) / 1024. / 1024.);

    /* Report problem size... */
    printf("SIZE_NP = %d\n", atm->np);
    printf("SIZE_TASKS = %d\n", size);
    printf("SIZE_THREADS = %d\n", omp_get_max_threads());

    /* Free random number generators... */
    for (i = 0; i < NTHREADS; i++)
      gsl_rng_free(rng[i]);

    /* Free... */
    free(atm);
    free(met0);
    free(met1);
    free(dt);
  }

#ifdef MPI
  /* Finalize MPI... */
  MPI_Finalize();
#endif

  return EXIT_SUCCESS;
}

/*****************************************************************************/

void init_simtime(
  ctl_t * ctl,
  atm_t * atm) {

  /* Set inital and final time... */
  if (ctl->direction == 1) {
    if (ctl->t_start < -1e99)
      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 if (ctl->direction == -1) {
    if (ctl->t_stop < -1e99)
      ctl->t_stop = gsl_stats_min(atm->time, 1, (size_t) atm->np);
    if (ctl->t_start < -1e99)
      ctl->t_start = gsl_stats_max(atm->time, 1, (size_t) atm->np);
  }

  /* Check time... */
  if (ctl->direction * (ctl->t_stop - ctl->t_start) <= 0)
```

```
    ERRMSG("Nothing to do!");
}

/*****************************************************************************/

void module_advection(
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip,
  double dt) {

  double v[3], xm[3];

  /* Interpolate meteorological data... */
  intpol_met_time(met0, met1, atm->time[ip], atm->p[ip],
                  atm->lon[ip], atm->lat[ip], NULL, NULL,
                  &v[0], &v[1], &v[2], NULL, NULL);

  /* Get position of the mid point... */
  xm[0] = atm->lon[ip] + dx2deg(0.5 * dt * v[0] / 1000., atm->lat[ip]);
  xm[1] = atm->lat[ip] + dy2deg(0.5 * dt * v[1] / 1000.);
  xm[2] = atm->p[ip] + 0.5 * dt * v[2];

  /* Interpolate meteorological data for mid point... */
  intpol_met_time(met0, met1, atm->time[ip] + 0.5 * dt,
                  xm[2], xm[0], xm[1], NULL, NULL,
                  &v[0], &v[1], &v[2], NULL, NULL);

  /* Save new position... */
  atm->time[ip] += dt;
  atm->lon[ip] += dx2deg(dt * v[0] / 1000., xm[1]);
  atm->lat[ip] += dy2deg(dt * v[1] / 1000.);
  atm->p[ip] += dt * v[2];
}

/*****************************************************************************/

void module_decay(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip,
  double dt) {

  double ps, pt, tdec;

  /* Check lifetime values... */
  if ((ctl->tdec_trop <= 0 && ctl->tdec_strat <= 0) || ctl->qnt_m < 0)
    return;

  /* Set constant lifetime... */
  if (ctl->tdec_trop == ctl->tdec_strat)
    tdec = ctl->tdec_trop;

  /* Set altitude-dependent lifetime... */
  else {

    /* Get surface pressure... */
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip],
                    atm->lon[ip], atm->lat[ip], &ps, NULL,
                    NULL, NULL, NULL, NULL, NULL);

    /* Get tropopause pressure... */
    pt = tropopause(atm->time[ip], atm->lat[ip]);

    /* Set lifetime... */
    if (atm->p[ip] <= pt)
      tdec = ctl->tdec_strat;
    else
      tdec = LIN(ps, ctl->tdec_trop, pt, ctl->tdec_strat, atm->p[ip]);
  }

  /* Calculate exponential decay... */
  atm->q[ctl->qnt_m][ip] *= exp(-dt / tdec);
}

/*****************************************************************************/

void module_diffusion_meso(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip,
  double dt,
  gsl_rng * rng) {

  double r, rs, u[16], v[16], w[16], usig, vsig, wsig;

  int ix, iy, iz;

  /* Calculate mesoscale velocity fluctuations... */
  if (ctl->turb_meso > 0) {

    /* Get indices... */
    ix = locate(met0->lon, met0->nx, atm->lon[ip]);
    iy = locate(met0->lat, met0->ny, atm->lat[ip]);
    iz = locate(met0->p, met0->np, atm->p[ip]);

    /* 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];

    /* Get indices... */
    ix = locate(met1->lon, met1->nx, atm->lon[ip]);
    iy = locate(met1->lat, met1->ny, atm->lat[ip]);
    iz = locate(met1->p, met1->np, atm->p[ip]);

    /* 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... */
    usig = gsl_stats_sd(u, 1, 16);
    vsig = gsl_stats_sd(v, 1, 16);
    wsig = gsl_stats_sd(w, 1, 16);

    /* Set temporal correlations for mesoscale fluctuations... */
    r = 1 - 2 * fabs(dt) / ctl->dt_met;
    rs = sqrt(1 - r * r);

    /* Calculate mesoscale wind fluctuations... */
```

```
    atm->up[ip] =
      r * atm->up[ip] + rs * gsl_ran_gaussian_ziggurat(rng,
                                                       ctl->turb_meso * usig);
    atm->vp[ip] =
      r * atm->vp[ip] + rs * gsl_ran_gaussian_ziggurat(rng,
                                                       ctl->turb_meso * vsig);
    atm->wp[ip] =
      r * atm->wp[ip] + rs * gsl_ran_gaussian_ziggurat(rng,
                                                       ctl->turb_meso * wsig);

    /* Calculate air parcel displacement... */
    atm->lon[ip] += dx2deg(atm->up[ip] * dt / 1000., atm->lat[ip]);
    atm->lat[ip] += dy2deg(atm->vp[ip] * dt / 1000.);
    atm->p[ip] += atm->wp[ip] * dt;
  }
}

/*****************************************************************************/

void module_diffusion_turb(
  ctl_t * ctl,
  atm_t * atm,
  int ip,
  double dt,
  gsl_rng * rng) {

  double dx, dz, pt, p0, p1, w;

  /* Get tropopause pressure... */
  pt = tropopause(atm->time[ip], atm->lat[ip]);

  /* Get weighting factor... */
  p1 = pt * 0.866877899;
  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 diffusivitiy... */
  dx = w * ctl->turb_dx_trop + (1 - w) * ctl->turb_dx_strat;
  dz = w * ctl->turb_dz_trop + (1 - w) * ctl->turb_dz_strat;

  /* Horizontal turbulent diffusion... */
  if (dx > 0) {
    atm->lon[ip]
      += dx2deg(gsl_ran_gaussian_ziggurat(rng, sqrt(2.0 * dx * fabs(dt)))
                / 1000., atm->lat[ip]);
    atm->lat[ip]
      += dy2deg(gsl_ran_gaussian_ziggurat(rng, sqrt(2.0 * dx * fabs(dt)))
                / 1000.);
  }

  /* Vertical turbulent diffusion... */
  if (dz > 0)
    atm->p[ip]
      += dz2dp(gsl_ran_gaussian_ziggurat(rng, sqrt(2.0 * dz * fabs(dt)))
               / 1000., atm->p[ip]);
}

/*****************************************************************************/

void module_isosurf(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip) {

  static double *iso, *ps, t, *ts;

  static int idx, ip2, n, nb = 100000;

  FILE *in;

  char line[LEN];

  /* Check control parameter... */
  if (ctl->isosurf < 1 || ctl->isosurf > 4)
    return;

  /* Initialize... */
  if (ip < 0) {

    /* Allocate... */
    ALLOC(iso, double,
          NP);
    ALLOC(ps, double,
          nb);
    ALLOC(ts, double,
          nb);

    /* Save pressure... */
    if (ctl->isosurf == 1)
      for (ip2 = 0; ip2 < atm->np; ip2++)
        iso[ip2] = atm->p[ip2];

    /* Save density... */
    else if (ctl->isosurf == 2)
      for (ip2 = 0; ip2 < atm->np; ip2++) {
        intpol_met_time(met0, met1, atm->time[ip2], atm->p[ip2],
                        atm->lon[ip2], atm->lat[ip2], NULL, &t, NULL, NULL,
                        NULL, NULL, NULL);
        iso[ip2] = atm->p[ip2] / t;
      }

    /* Save potential temperature... */
    else if (ctl->isosurf == 3)
      for (ip2 = 0; ip2 < atm->np; ip2++) {
        intpol_met_time(met0, met1, atm->time[ip2], atm->p[ip2],
                        atm->lon[ip2], atm->lat[ip2], NULL, &t, NULL, NULL,
                        NULL, NULL, NULL);
        iso[ip2] = t * pow(P0 / atm->p[ip2], 0.286);
      }

    /* 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", &ts[n], &ps[n]) == 2)
          if ((++n) > 100000)
            ERRMSG("Too many data points!");

      /* Check number of points... */
      if (n < 1)
        ERRMSG("Could not read any data!");

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

    /* Leave initialization... */
    return;
  }

  /* Restore pressure... */
  if (ctl->isosurf == 1)
    atm->p[ip] = iso[ip];

  /* Restore density... */
  else if (ctl->isosurf == 2) {
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->
lon[ip],
                    atm->lat[ip], NULL, &t, NULL, NULL, NULL, NULL, NULL);
    atm->p[ip] = iso[ip] * t;
  }

  /* Restore potential temperature... */
  else if (ctl->isosurf == 3) {
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->
lon[ip],
                    atm->lat[ip], NULL, &t, NULL, NULL, NULL, NULL, NULL);
    atm->p[ip] = P0 * pow(iso[ip] / t, -1. / 0.286);
  }

  /* Interpolate pressure... */
  else if (ctl->isosurf == 4) {
    if (atm->time[ip] <= ts[0])
      atm->p[ip] = ps[0];
    else if (atm->time[ip] >= ts[n - 1])
      atm->p[ip] = ps[n - 1];
    else {
      idx = locate(ts, n, atm->time[ip]);
      atm->p[ip] = LIN(ts[idx], ps[idx],
                       ts[idx + 1], ps[idx + 1], atm->time[ip]);
    }
  }
}

/*****************************************************************************/

void module_meteo(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip) {

  static FILE *in;

  static char filename[LEN], line[LEN];

  static double lon[GX], lat[GY], var[GX][GY],
    rdum, rlat, rlat_old = -999, rlon, rvar;

  static int year_old, mon_old, day_old, nlon, nlat;

  double a, b, c, ps, p1, p_hno3, p_h2o, t, t1, u, u1, v, v1, w,
    x1, x2, h2o, o3, grad, vort, var0, var1;

  int day, mon, year, idum, ilat, ilon;

  /* Interpolate meteorological data... */
  intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->
lon[ip],
                  atm->lat[ip], &ps, &t, &u, &v, &w, &h2o, &o3);

  /* Set surface pressure... */
  if (ctl->qnt_ps >= 0)
    atm->q[ctl->qnt_ps][ip] = ps;

  /* Set pressure... */
  if (ctl->qnt_p >= 0)
    atm->q[ctl->qnt_p][ip] = atm->p[ip];

  /* Set temperature... */
  if (ctl->qnt_t >= 0)
    atm->q[ctl->qnt_t][ip] = t;

  /* Set zonal wind... */
  if (ctl->qnt_u >= 0)
    atm->q[ctl->qnt_u][ip] = u;

  /* Set meridional wind... */
  if (ctl->qnt_v >= 0)
    atm->q[ctl->qnt_v][ip] = v;

  /* Set vertical velocity... */
  if (ctl->qnt_w >= 0)
    atm->q[ctl->qnt_w][ip] = w;

  /* Set water vapor vmr... */
  if (ctl->qnt_h2o >= 0)
    atm->q[ctl->qnt_h2o][ip] = h2o;

  /* Set ozone vmr... */
  if (ctl->qnt_o3 >= 0)
    atm->q[ctl->qnt_o3][ip] = o3;

  /* Calculate potential temperature... */
  if (ctl->qnt_theta >= 0)
    atm->q[ctl->qnt_theta][ip] = t * pow(P0 / atm->p[ip], 0.286);

  /* Calculate potential vorticity... */
  if (ctl->qnt_pv >= 0) {

    /* Absolute vorticity... */
    vort = 2 * 7.2921e-5 * sin(atm->lat[ip] * M_PI / 180.);
    if (fabs(atm->lat[ip]) < 89.) {
      intpol_met_time(met0, met1, atm->time[ip], atm->p[ip],
                      (atm->lon[ip] >=
                       0 ? atm->lon[ip] - 1. : atm->lon[ip] + 1.),
                      atm->lat[ip], NULL, NULL, NULL, &v1, NULL, NULL, NULL);
      vort += (v1 - v) / 1000.
        / ((atm->lon[ip] >= 0 ? -1 : 1) * deg2dx(1., atm->lat[ip]));
    }
    intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->
lon[ip],
                    (atm->lat[ip] >=
                     0 ? atm->lat[ip] - 1. : atm->lat[ip] + 1.), NULL, NULL,
                    &u1, NULL, NULL, NULL, NULL);
    vort += (u1 - u) / 1000. / ((atm->lat[ip] >= 0 ? -1 : 1) * deg2dy(1.));

    /* Potential temperature gradient... */
    p1 = 0.85 * atm->p[ip];
    intpol_met_time(met0, met1, atm->time[ip], p1, atm->lon[ip],
                    atm->lat[ip], NULL, &t1, NULL, NULL, NULL, NULL, NULL);
    grad = (t1 * pow(P0 / p1, 0.286) - t * pow(P0 / atm->p[ip], 0.286))
      / (100. * (p1 - atm->p[ip]));

    /* Calculate PV... */
    atm->q[ctl->qnt_pv][ip] = -1e6 * G0 * vort * grad;
  }

  /* Calculate T_ice (Marti and Mauersberger, 1993)... */
  if (ctl->qnt_tice >= 0 || ctl->qnt_tsts >= 0)
    atm->q[ctl->qnt_tice][ip] =
      -2663.5 /
      (log10((ctl->psc_h2o > 0 ? ctl->psc_h2o : h2o) * atm->p[ip] * 100.) -
       12.537);

  /* Calculate T_NAT (Hanson and Mauersberger, 1988)... */
  if (ctl->qnt_tnat >= 0 || ctl->qnt_tsts >= 0) {
    if (ctl->psc_hno3 > 0)
      p_hno3 = ctl->psc_hno3 * atm->p[ip] / 1.333224;
    else
      p_hno3 = module_meteo_hno3(atm->time[ip], atm->lat[ip], atm->p[ip])
        * 1e-9 * atm->p[ip] / 1.333224;
    p_h2o = (ctl->psc_h2o > 0 ? ctl->psc_h2o : h2o) * atm->p[ip] / 1.333224;
    a = 0.009179 - 0.00088 * log10(p_h2o);
    b = (38.9855 - log10(p_hno3) - 2.7836 * log10(p_h2o)) / a;
    c = -11397.0 / a;
    x1 = (-b + sqrt(b * b - 4. * c)) / 2.;
    x2 = (-b - sqrt(b * b - 4. * c)) / 2.;
    if (x1 > 0)
      atm->q[ctl->qnt_tnat][ip] = x1;
    if (x2 > 0)
      atm->q[ctl->qnt_tnat][ip] = x2;
  }

  /* Calculate T_STS (mean of T_ice and T_NAT)... */
  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!");
    atm->q[ctl->qnt_tsts][ip] = 0.5 * (atm->q[ctl->qnt_tice][ip]
                                       + atm->q[ctl->qnt_tnat][ip]);
  }

  /* Read variance data for current day... */
  if (ip == 0 && ctl->qnt_gw_var >= 0) {
    jsec2time(atm->time[ip], &year, &mon, &day, &idum, &idum, &idum, &rdum);
    if (year != year_old || mon != mon_old || day != day_old) {
      year_old = year;
      mon_old = mon;
      day_old = day;
      nlon = nlat = -1;
      sprintf(filename, "%s_%d_%02d_%02d.tab",
              ctl->gw_basename, year, mon, day);
      if ((in = fopen(filename, "r"))) {
        printf("Read gravity wave data: %s\n", filename);
        while (fgets(line, LEN, in)) {
          if (sscanf(line, "%lg %lg %lg", &rlon, &rlat, &rvar) != 3)
            continue;
          if (rlat != rlat_old) {
            rlat_old = rlat;
            if ((++nlat) > GY)
              ERRMSG("Too many latitudes!");
            nlon = -1;
          }
          if ((++nlon) > GX)
            ERRMSG("Too many longitudes!");
          lon[nlon] = rlon;
          lat[nlat] = rlat;
          var[nlon][nlat] = GSL_MAX(0, rvar);
        }
        fclose(in);
        nlat++;
        nlon++;
      } else
        printf("Missing gravity wave data: %s\n", filename);
    }
  }

  /* Interpolate variance data... */
  if (ctl->qnt_gw_var >= 0) {
    if (nlat >= 2 && nlon >= 2) {
      ilat = locate(lat, nlat, atm->lat[ip]);
      ilon = locate(lon, nlon, atm->lon[ip]);
      var0 = LIN(lat[ilat], var[ilon][ilat],
                 lat[ilat + 1], var[ilon][ilat + 1], atm->lat[ip]);
      var1 = LIN(lat[ilat], var[ilon + 1][ilat],
                 lat[ilat + 1], var[ilon + 1][ilat + 1], atm->lat[ip]);
      atm->q[ctl->qnt_gw_var][ip]
        = LIN(lon[ilon], var0, lon[ilon + 1], var1, atm->lon[ip]);
    } else
      atm->q[ctl->qnt_gw_var][ip] = GSL_NAN;
  }
}

/*****************************************************************************/

double module_meteo_hno3(
  double t,
  double lat,
  double p) {

  static double 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
  };

  static double lats[18] = { -85, -75, -65, -55, -45, -35, -25, -15, -5,
    5, 15, 25, 35, 45, 55, 65, 75, 85
  };

  static double ps[10] = { 4.64159, 6.81292, 10, 14.678, 21.5443,
    31.6228, 46.4159, 68.1292, 100, 146.78
  };

  static double hno3[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},
     {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}}
  };

  double aux00, aux01, aux10, aux11, sec;

  int ilat, ip, isec;

  /* Get seconds since begin of year... */
  sec = fmod(t, 365.25 * 86400.);

  /* Get indices... */
  ilat = locate(lats, 18, lat);
  ip = locate(ps, 10, p);
  isec = locate(secs, 12, sec);

  /* Interpolate... */
  aux00 = LIN(ps[ip], hno3[isec][ilat][ip],
              ps[ip + 1], hno3[isec][ilat][ip + 1], p);
  aux01 = LIN(ps[ip], hno3[isec][ilat + 1][ip],
              ps[ip + 1], hno3[isec][ilat + 1][ip + 1], p);
  aux10 = LIN(ps[ip], hno3[isec + 1][ilat][ip],
              ps[ip + 1], hno3[isec + 1][ilat][ip + 1], p);
  aux11 = LIN(ps[ip], hno3[isec + 1][ilat + 1][ip],
              ps[ip + 1], hno3[isec + 1][ilat + 1][ip + 1], p);
  aux00 = LIN(lats[ilat], aux00, lats[ilat + 1], aux01, lat);
  aux11 = LIN(lats[ilat], aux10, lats[ilat + 1], aux11, lat);
  return LIN(secs[isec], aux00, secs[isec + 1], aux11, sec);
}

/*****************************************************************************/

void module_position(
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip) {

  double ps;

  /* 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;

  /* Get surface pressure... */
  intpol_met_time(met0, met1, atm->time[ip], atm->p[ip],
                  atm->lon[ip], atm->lat[ip], &ps, NULL,
                  NULL, NULL, NULL, NULL, NULL);

  /* Check pressure... */
  if (atm->p[ip] > ps)
    atm->p[ip] = ps;
  else if (atm->p[ip] < met0->p[met0->np - 1])
    atm->p[ip] = met0->p[met0->np - 1];
}

/*****************************************************************************/

void module_sedi(
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  int ip,
  double dt) {

  /* Coefficients for Cunningham slip-flow correction (Kasten, 1968): */
  const double A = 1.249, B = 0.42, C = 0.87;

  /* Specific gas constant for dry air [J/(kg K)]: */
  const double R = 287.058;

  /* Average mass of an air molecule [kg/molec]: */
  const double m = 4.8096e-26;

  double G, K, eta, lambda, p, r_p, rho, rho_p, T, v, v_p;

  /* Check if parameters are available... */
  if (ctl->qnt_r < 0 || ctl->qnt_rho < 0)
    return;

  /* Convert units... */
  p = 100 * atm->p[ip];
  r_p = 1e-6 * atm->q[ctl->qnt_r][ip];
  rho_p = atm->q[ctl->qnt_rho][ip];

  /* Get temperature... */
  intpol_met_time(met0, met1, atm->time[ip], atm->p[ip], atm->
lon[ip],
                  atm->lat[ip], NULL, &T, NULL, NULL, NULL, NULL, NULL);

  /* Density of dry air... */
  rho = p / (R * 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 * GSL_CONST_MKSA_BOLTZMANN * T / (M_PI * m));

  /* 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 * (A + B * exp(-C / K));

  /* Sedimentation (fall) velocity... */
  v_p =
    2. * gsl_pow_2(r_p) * (rho_p -
                           rho) * GSL_CONST_MKSA_GRAV_ACCEL / (9. * eta) * G;

  /* Calculate pressure change... */
  atm->p[ip] += dz2dp(v_p * dt / 1000., atm->p[ip]);
}

/*****************************************************************************/

void write_output(
  const char *dirname,
  ctl_t * ctl,
  met_t * met0,
  met_t * met1,
  atm_t * atm,
  double t) {

  char filename[LEN];

  double r;

  int year, mon, day, hour, min, sec;

  /* 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) {
    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 CSI data... */
  if (ctl->csi_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->csi_basename);
    write_csi(filename, ctl, atm, t);
  }

  /* Write ensemble data... */
  if (ctl->ens_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->ens_basename);
    write_ens(filename, ctl, atm, t);
  }

  /* Write gridded data... */
  if (ctl->grid_basename[0] != '-' && fmod(t, ctl->grid_dt_out) == 0) {
    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 profile data... */
  if (ctl->prof_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->prof_basename);
    write_prof(filename, ctl, met0, met1, atm, t);
  }

  /* Write station data... */
  if (ctl->stat_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->stat_basename);
    write_station(filename, ctl, atm, t);
  }
}
```

5.33 wind.c File Reference

Create meteorological data files with synthetic wind fields.

Functions

- void add_text_attribute (int ncid, char ∗varname, char ∗attrname, char ∗text)
- int main (int argc, char ∗argv[ ])

5.33.1 Detailed Description

Create meteorological data files with synthetic wind fields.

Definition in file wind.c.

5.33.2 Function Documentation

5.33.2.1 void add_text_attribute (int *ncid,* char ∗ *varname,* char ∗ *attrname,* char ∗ *text*)

Definition at line 188 of file wind.c.

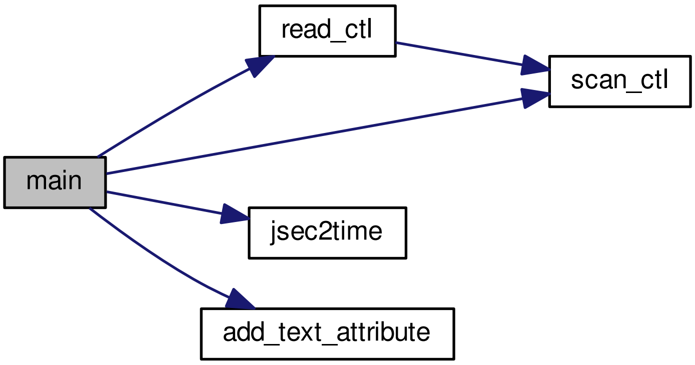
```
              {

  int varid;

  NC(nc_inq_varid(ncid, varname, &varid));
  NC(nc_put_att_text(ncid, varid, attrname, strlen(text), text));
}
```

5.33.2.2 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 41 of file wind.c.

```
                {

  ctl_t ctl;

  static char filename[LEN];

  static double r, t0, z0, z1, dataLon[EX], dataLat[EY], dataZ[EP],
    u0, u1, alpha;

  static float *dataT, *dataU, *dataV, *dataW;

  static int ncid, dims[4], timid, levid, latid, lonid, tid, uid, vid, wid,
    idx, ix, iy, iz, nx, ny, nz, year, mon, day, hour, min, sec;

  /* Allocate... */
  ALLOC(dataT, float,
        EP * EY * EX);
  ALLOC(dataU, float,
        EP * EY * EX);
  ALLOC(dataV, float,
        EP * EY * EX);
  ALLOC(dataW, float,
        EP * EY * EX);

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

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  t0 = scan_ctl(argv[1], argc, argv, "WIND_T0", -1, "0", NULL);
  nx = (int) scan_ctl(argv[1], argc, argv, "WIND_NX", -1, "360", NULL);
  ny = (int) scan_ctl(argv[1], argc, argv, "WIND_NY", -1, "181", NULL);
  nz = (int) scan_ctl(argv[1], argc, argv, "WIND_NZ", -1, "61", NULL);
  z0 = scan_ctl(argv[1], argc, argv, "WIND_Z0", -1, "0", NULL);
  z1 = scan_ctl(argv[1], argc, argv, "WIND_Z1", -1, "60", NULL);
  u0 = scan_ctl(argv[1], argc, argv, "WIND_U0", -1, "38.587660177302", NULL);
  u1 = scan_ctl(argv[1], argc, argv, "WIND_U1", -1, "38.587660177302", NULL);
  alpha = scan_ctl(argv[1], argc, argv, "WIND_ALPHA", -1, "0.0", NULL);

  /* Check dimensions... */
  if (nx < 1 || nx > EX)
    ERRMSG("Set 1 <= NX <= MAX!");
  if (ny < 1 || ny > EY)
    ERRMSG("Set 1 <= NY <= MAX!");
  if (nz < 1 || nz > EP)
    ERRMSG("Set 1 <= NZ <= MAX!");

  /* Get time... */
  jsec2time(t0, &year, &mon, &day, &hour, &min, &sec, &r);
  t0 = year * 10000. + mon * 100. + day + hour / 24.;

  /* Set filename... */
  sprintf(filename, "%s_%d_%02d_%02d_%02d.nc", argv[2], year, mon, day, hour);

  /* Create netCDF file... */
  NC(nc_create(filename, NC_CLOBBER, &ncid));

  /* Create dimensions... */
  NC(nc_def_dim(ncid, "time", 1, &dims[0]));
  NC(nc_def_dim(ncid, "lev", (size_t) nz, &dims[1]));
  NC(nc_def_dim(ncid, "lat", (size_t) ny, &dims[2]));
  NC(nc_def_dim(ncid, "lon", (size_t) nx, &dims[3]));

  /* Create variables... */
  NC(nc_def_var(ncid, "time", NC_DOUBLE, 1, &dims[0], &timid));
  NC(nc_def_var(ncid, "lev", NC_DOUBLE, 1, &dims[1], &levid));
  NC(nc_def_var(ncid, "lat", NC_DOUBLE, 1, &dims[2], &latid));
  NC(nc_def_var(ncid, "lon", NC_DOUBLE, 1, &dims[3], &lonid));
  NC(nc_def_var(ncid, "T", NC_FLOAT, 4, &dims[0], &tid));
  NC(nc_def_var(ncid, "U", NC_FLOAT, 4, &dims[0], &uid));
  NC(nc_def_var(ncid, "V", NC_FLOAT, 4, &dims[0], &vid));
  NC(nc_def_var(ncid, "W", NC_FLOAT, 4, &dims[0], &wid));

  /* Set attributes... */
  add_text_attribute(ncid, "time", "long_name", "time");
  add_text_attribute(ncid, "time", "units", "day as %Y%m%d.%f");
  add_text_attribute(ncid, "lon", "long_name", "longitude");
  add_text_attribute(ncid, "lon", "units", "degrees_east");
  add_text_attribute(ncid, "lat", "long_name", "latitude");
  add_text_attribute(ncid, "lat", "units", "degrees_north");
  add_text_attribute(ncid, "lev", "long_name", "air_pressure");
  add_text_attribute(ncid, "lev", "units", "Pa");
  add_text_attribute(ncid, "T", "long_name", "Temperature");
  add_text_attribute(ncid, "T", "units", "K");
  add_text_attribute(ncid, "U", "long_name", "U velocity");
  add_text_attribute(ncid, "U", "units", "m s**-1");
  add_text_attribute(ncid, "V", "long_name", "V velocity");
  add_text_attribute(ncid, "V", "units", "m s**-1");
  add_text_attribute(ncid, "W", "long_name", "Vertical velocity");
  add_text_attribute(ncid, "W", "units", "Pa s**-1");

  /* End definition... */
  NC(nc_enddef(ncid));

  /* Set coordinates... */
  for (ix = 0; ix < nx; ix++)
    dataLon[ix] = 360.0 / nx * (double) ix;
  for (iy = 0; iy < ny; iy++)
    dataLat[iy] = 180.0 / (ny - 1) * (double) iy - 90;
  for (iz = 0; iz < nz; iz++)
    dataZ[iz] = 100. * P(LIN(0.0, z0, nz - 1.0, z1, iz));

  /* Write coordinates... */
  NC(nc_put_var_double(ncid, timid, &t0));
  NC(nc_put_var_double(ncid, levid, dataZ));
  NC(nc_put_var_double(ncid, lonid, dataLon));
  NC(nc_put_var_double(ncid, latid, dataLat));

  /* Create wind fields (Williamson et al., 1992)... */
  for (ix = 0; ix < nx; ix++)
    for (iy = 0; iy < ny; iy++)
      for (iz = 0; iz < nz; iz++) {
        idx = (iz * ny + iy) * nx + ix;
        dataU[idx] = (float) (LIN(0.0, u0, nz - 1.0, u1, iz)
                              * (cos(dataLat[iy] * M_PI / 180.0)
                                 * cos(alpha * M_PI / 180.0)
                                 + sin(dataLat[iy] * M_PI / 180.0)
                                 * cos(dataLon[ix] * M_PI / 180.0)
                                 * sin(alpha * M_PI / 180.0)));
        dataV[idx] = (float) (-LIN(0.0, u0, nz - 1.0, u1, iz)
                              * sin(dataLon[ix] * M_PI / 180.0)
                              * sin(alpha * M_PI / 180.0));
      }

  /* Write wind data... */
  NC(nc_put_var_float(ncid, tid, dataT));
  NC(nc_put_var_float(ncid, uid, dataU));
  NC(nc_put_var_float(ncid, vid, dataV));
  NC(nc_put_var_float(ncid, wid, dataW));

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

  /* Free... */
  free(dataT);
  free(dataU);
  free(dataV);
  free(dataW);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.34 wind.c

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

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

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*/

#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;

  static char filename[LEN];

  static double r, t0, z0, z1, dataLon[EX], dataLat[EY], dataZ[EP],
    u0, u1, alpha;

  static float *dataT, *dataU, *dataV, *dataW;

  static int ncid, dims[4], timid, levid, latid, lonid, tid, uid, vid, wid,
    idx, ix, iy, iz, nx, ny, nz, year, mon, day, hour, min, sec;

  /* Allocate... */
  ALLOC(dataT, float,
        EP * EY * EX);
  ALLOC(dataU, float,
        EP * EY * EX);
  ALLOC(dataV, float,
        EP * EY * EX);
  ALLOC(dataW, float,
        EP * EY * EX);

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

  /* Read control parameters... */
  read_ctl(argv[1], argc, argv, &ctl);
  t0 = scan_ctl(argv[1], argc, argv, "WIND_T0", -1, "0", NULL);
  nx = (int) scan_ctl(argv[1], argc, argv, "WIND_NX", -1, "360", NULL);
  ny = (int) scan_ctl(argv[1], argc, argv, "WIND_NY", -1, "181", NULL);
  nz = (int) scan_ctl(argv[1], argc, argv, "WIND_NZ", -1, "61", NULL);
  z0 = scan_ctl(argv[1], argc, argv, "WIND_Z0", -1, "0", NULL);
  z1 = scan_ctl(argv[1], argc, argv, "WIND_Z1", -1, "60", NULL);
  u0 = scan_ctl(argv[1], argc, argv, "WIND_U0", -1, "38.587660177302", NULL);
  u1 = scan_ctl(argv[1], argc, argv, "WIND_U1", -1, "38.587660177302", NULL);
  alpha = scan_ctl(argv[1], argc, argv, "WIND_ALPHA", -1, "0.0", NULL);

  /* Check dimensions... */
  if (nx < 1 || nx > EX)
    ERRMSG("Set 1 <= NX <= MAX!");
  if (ny < 1 || ny > EY)
    ERRMSG("Set 1 <= NY <= MAX!");
  if (nz < 1 || nz > EP)
    ERRMSG("Set 1 <= NZ <= MAX!");

  /* Get time... */
  jsec2time(t0, &year, &mon, &day, &hour, &min, &sec, &r);
  t0 = year * 10000. + mon * 100. + day + hour / 24.;

  /* Set filename... */
  sprintf(filename, "%s_%d_%02d_%02d_%02d.nc", argv[2], year, mon, day, hour);

  /* Create netCDF file... */
  NC(nc_create(filename, NC_CLOBBER, &ncid));

  /* Create dimensions... */
  NC(nc_def_dim(ncid, "time", 1, &dims[0]));
  NC(nc_def_dim(ncid, "lev", (size_t) nz, &dims[1]));
  NC(nc_def_dim(ncid, "lat", (size_t) ny, &dims[2]));
  NC(nc_def_dim(ncid, "lon", (size_t) nx, &dims[3]));

  /* Create variables... */
  NC(nc_def_var(ncid, "time", NC_DOUBLE, 1, &dims[0], &timid));
  NC(nc_def_var(ncid, "lev", NC_DOUBLE, 1, &dims[1], &levid));
  NC(nc_def_var(ncid, "lat", NC_DOUBLE, 1, &dims[2], &latid));
  NC(nc_def_var(ncid, "lon", NC_DOUBLE, 1, &dims[3], &lonid));
  NC(nc_def_var(ncid, "T", NC_FLOAT, 4, &dims[0], &tid));
  NC(nc_def_var(ncid, "U", NC_FLOAT, 4, &dims[0], &uid));
  NC(nc_def_var(ncid, "V", NC_FLOAT, 4, &dims[0], &vid));
  NC(nc_def_var(ncid, "W", NC_FLOAT, 4, &dims[0], &wid));

  /* Set attributes... */
  add_text_attribute(ncid, "time", "long_name", "time");
  add_text_attribute(ncid, "time", "units", "day as %Y%m%d.%f");
  add_text_attribute(ncid, "lon", "long_name", "longitude");
  add_text_attribute(ncid, "lon", "units", "degrees_east");
  add_text_attribute(ncid, "lat", "long_name", "latitude");
  add_text_attribute(ncid, "lat", "units", "degrees_north");
  add_text_attribute(ncid, "lev", "long_name", "air_pressure");
  add_text_attribute(ncid, "lev", "units", "Pa");
  add_text_attribute(ncid, "T", "long_name", "Temperature");
  add_text_attribute(ncid, "T", "units", "K");
  add_text_attribute(ncid, "U", "long_name", "U velocity");
  add_text_attribute(ncid, "U", "units", "m s**-1");
  add_text_attribute(ncid, "V", "long_name", "V velocity");
  add_text_attribute(ncid, "V", "units", "m s**-1");
  add_text_attribute(ncid, "W", "long_name", "Vertical velocity");
  add_text_attribute(ncid, "W", "units", "Pa s**-1");

  /* End definition... */
  NC(nc_enddef(ncid));

  /* Set coordinates... */
  for (ix = 0; ix < nx; ix++)
    dataLon[ix] = 360.0 / nx * (double) ix;
  for (iy = 0; iy < ny; iy++)
    dataLat[iy] = 180.0 / (ny - 1) * (double) iy - 90;
  for (iz = 0; iz < nz; iz++)
    dataZ[iz] = 100. * P(LIN(0.0, z0, nz - 1.0, z1, iz));

  /* Write coordinates... */
  NC(nc_put_var_double(ncid, timid, &t0));
  NC(nc_put_var_double(ncid, levid, dataZ));
  NC(nc_put_var_double(ncid, lonid, dataLon));
  NC(nc_put_var_double(ncid, latid, dataLat));

  /* Create wind fields (Williamson et al., 1992)... */
  for (ix = 0; ix < nx; ix++)
    for (iy = 0; iy < ny; iy++)
      for (iz = 0; iz < nz; iz++) {
        idx = (iz * ny + iy) * nx + ix;
        dataU[idx] = (float) (LIN(0.0, u0, nz - 1.0, u1, iz)
                              * (cos(dataLat[iy] * M_PI / 180.0)
                                 * cos(alpha * M_PI / 180.0)
                                 + sin(dataLat[iy] * M_PI / 180.0)
                                 * cos(dataLon[ix] * M_PI / 180.0)
                                 * sin(alpha * M_PI / 180.0)));
        dataV[idx] = (float) (-LIN(0.0, u0, nz - 1.0, u1, iz)
                              * sin(dataLon[ix] * M_PI / 180.0)
                              * sin(alpha * M_PI / 180.0));
      }

  /* Write wind data... */
  NC(nc_put_var_float(ncid, tid, dataT));
  NC(nc_put_var_float(ncid, uid, dataU));
  NC(nc_put_var_float(ncid, vid, dataV));
  NC(nc_put_var_float(ncid, wid, dataW));

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

  /* Free... */
  free(dataT);
  free(dataU);
  free(dataV);
  free(dataW);

  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));
}
```

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