# MPTRAC

Generated by Doxygen 1.8.11

# Contents

# 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`

# 2 Data Structure Index

## 2.1 Data Structures

Here are the data structures with brief descriptions:

# 3 File Index

## 3.1 File List

Here is a list of all files with brief descriptions:

# 4 Data Structure Documentation

## 4.1 atm_t Struct Reference

Atmospheric data.

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

### Data Fields

- int np

  *Number of air 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 422 of file libtrac.h.

### 4.1.2 Field Documentation

#### 4.1.2.1 int atm_t::np

Number of air pacels.

Definition at line 425 of file libtrac.h.

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

Time [s].

Definition at line 428 of file libtrac.h.

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

Pressure [hPa].

Definition at line 431 of file libtrac.h.

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

Longitude [deg].

Definition at line 434 of file libtrac.h.

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

Latitude [deg].

Definition at line 437 of file libtrac.h.

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

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

Definition at line 440 of file libtrac.h.

#### 4.1.2.7 double atm_t::up[NP]

Zonal wind perturbation [m/s].

Definition at line 443 of file libtrac.h.

#### 4.1.2.8 double atm_t::vp[NP]

Meridional wind perturbation [m/s].

Definition at line 446 of file libtrac.h.

#### 4.1.2.9 double atm_t::wp[NP]

Vertical velocity perturbation [hPa/s].

Definition at line 449 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_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_tnat

  *Quantity array index for T_NAT.*
- int qnt_stat

  *Quantity array index for station flag.*
- int direction

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

  *Start time of simulation [s].*
- double t_stop

  *Stop time of simulation [s].*
- double dt_mod

  *Time step of simulation [s].*
- 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].*
- 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].*
- 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].*

- 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 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 173 of file libtrac.h.

### 4.2.2 Field Documentation

#### 4.2.2.1 int ctl_t::nq

Number of quantities.

Definition at line 176 of file libtrac.h.

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

Quantity names.

Definition at line 179 of file libtrac.h.

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

Quantity units.

Definition at line 182 of file libtrac.h.

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

Quantity output format.

Definition at line 185 of file libtrac.h.

#### 4.2.2.5 int ctl_t::qnt_m

Quantity array index for mass.

Definition at line 188 of file libtrac.h.

#### 4.2.2.6 int ctl_t::qnt_rho

Quantity array index for particle density.

Definition at line 191 of file libtrac.h.

#### 4.2.2.7 int ctl_t::qnt_r

Quantity array index for particle radius.

Definition at line 194 of file libtrac.h.

#### 4.2.2.8 int ctl_t::qnt_ps

Quantity array index for surface pressure.

Definition at line 197 of file libtrac.h.

#### 4.2.2.9 int ctl_t::qnt_p

Quantity array index for pressure.

Definition at line 200 of file libtrac.h.

#### 4.2.2.10 int ctl_t::qnt_t

Quantity array index for temperature.

Definition at line 203 of file libtrac.h.

#### 4.2.2.11 int ctl_t::qnt_u

Quantity array index for zonal wind.

Definition at line 206 of file libtrac.h.

#### 4.2.2.12 int ctl_t::qnt_v

Quantity array index for meridional wind.

Definition at line 209 of file libtrac.h.

#### 4.2.2.13 int ctl_t::qnt_w

Quantity array index for vertical velocity.

Definition at line 212 of file libtrac.h.

#### 4.2.2.14 int ctl_t::qnt_h2o

Quantity array index for water vapor vmr.

Definition at line 215 of file libtrac.h.

#### 4.2.2.15 int ctl_t::qnt_o3

Quantity array index for ozone vmr.

Definition at line 218 of file libtrac.h.

#### 4.2.2.16 int ctl_t::qnt_theta

Quantity array index for potential temperature.

Definition at line 221 of file libtrac.h.

#### 4.2.2.17 int ctl_t::qnt_pv

Quantity array index for potential vorticity.

Definition at line 224 of file libtrac.h.

#### 4.2.2.18 int ctl_t::qnt_tice

Quantity array index for T_ice.

Definition at line 227 of file libtrac.h.

#### 4.2.2.19 int ctl_t::qnt_tnat

Quantity array index for T_NAT.

Definition at line 230 of file libtrac.h.

#### 4.2.2.20 int ctl_t::qnt_stat

Quantity array index for station flag.

Definition at line 233 of file libtrac.h.

#### 4.2.2.21 int ctl_t::direction

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

Definition at line 236 of file libtrac.h.

#### 4.2.2.22 double ctl_t::t_start

Start time of simulation [s].

Definition at line 239 of file libtrac.h.

#### 4.2.2.23 double ctl_t::t_stop

Stop time of simulation [s].

Definition at line 242 of file libtrac.h.

#### 4.2.2.24 double ctl_t::dt_mod

Time step of simulation [s].

Definition at line 245 of file libtrac.h.

#### 4.2.2.25 double ctl_t::dt_met

Time step of meteorological data [s].

Definition at line 248 of file libtrac.h.

#### 4.2.2.26 int ctl_t::met_np

Number of target pressure levels.

Definition at line 251 of file libtrac.h.

#### 4.2.2.27 double ctl_t::met_p[EP]

Target pressure levels [hPa].

Definition at line 254 of file libtrac.h.

#### 4.2.2.28 int ctl_t::isosurf

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

Definition at line 258 of file libtrac.h.

#### 4.2.2.29 char ctl_t::balloon[LEN]

Balloon position filename.

Definition at line 261 of file libtrac.h.

#### 4.2.2.30 double ctl_t::turb_dx_trop

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

Definition at line 264 of file libtrac.h.

#### 4.2.2.31 double ctl_t::turb_dx_strat

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

Definition at line 267 of file libtrac.h.

#### 4.2.2.32 double ctl_t::turb_dz_trop

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

Definition at line 270 of file libtrac.h.

#### 4.2.2.33 double ctl_t::turb_dz_strat

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

Definition at line 273 of file libtrac.h.

#### 4.2.2.34 double ctl_t::turb_meso

Scaling factor for mesoscale wind fluctuations.

Definition at line 276 of file libtrac.h.

#### 4.2.2.35 double ctl_t::tdec_trop

Life time of particles (troposphere) [s].

Definition at line 279 of file libtrac.h.

#### 4.2.2.36 double ctl_t::tdec_strat

Life time of particles (stratosphere) [s].

Definition at line 282 of file libtrac.h.

#### 4.2.2.37 char ctl_t::atm_basename[LEN]

Basename of atmospheric data files.

Definition at line 285 of file libtrac.h.

#### 4.2.2.38 char ctl_t::atm_gpfile[LEN]

Gnuplot file for atmospheric data.

Definition at line 288 of file libtrac.h.

#### 4.2.2.39 double ctl_t::atm_dt_out

Time step for atmospheric data output [s].

Definition at line 291 of file libtrac.h.

#### 4.2.2.40 char ctl_t::csi_basename[LEN]

Basename of CSI data files.

Definition at line 294 of file libtrac.h.

#### 4.2.2.41 double ctl_t::csi_dt_out

Time step for CSI data output [s].

Definition at line 297 of file libtrac.h.

#### 4.2.2.42 char ctl_t::csi_obsfile[LEN]

Observation data file for CSI analysis.

Definition at line 300 of file libtrac.h.

#### 4.2.2.43 double ctl_t::csi_obsmin

Minimum observation index to trigger detection.

Definition at line 303 of file libtrac.h.

#### 4.2.2.44 double ctl_t::csi_modmin

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

Definition at line 306 of file libtrac.h.

#### 4.2.2.45 int ctl_t::csi_nz

Number of altitudes of gridded CSI data.

Definition at line 309 of file libtrac.h.

#### 4.2.2.46 double ctl_t::csi_z0

Lower altitude of gridded CSI data [km].

Definition at line 312 of file libtrac.h.

#### 4.2.2.47 double ctl_t::csi_z1

Upper altitude of gridded CSI data [km].

Definition at line 315 of file libtrac.h.

#### 4.2.2.48 int ctl_t::csi_nx

Number of longitudes of gridded CSI data.

Definition at line 318 of file libtrac.h.

#### 4.2.2.49 double ctl_t::csi_lon0

Lower longitude of gridded CSI data [deg].

Definition at line 321 of file libtrac.h.

#### 4.2.2.50 double ctl_t::csi_lon1

Upper longitude of gridded CSI data [deg].

Definition at line 324 of file libtrac.h.

#### 4.2.2.51 int ctl_t::csi_ny

Number of latitudes of gridded CSI data.

Definition at line 327 of file libtrac.h.

#### 4.2.2.52 double ctl_t::csi_lat0

Lower latitude of gridded CSI data [deg].

Definition at line 330 of file libtrac.h.

#### 4.2.2.53 double ctl_t::csi_lat1

Upper latitude of gridded CSI data [deg].

Definition at line 333 of file libtrac.h.

#### 4.2.2.54 char ctl_t::grid_basename[LEN]

Basename of grid data files.

Definition at line 336 of file libtrac.h.

#### 4.2.2.55 char ctl_t::grid_gpfile[LEN]

Gnuplot file for gridded data.

Definition at line 339 of file libtrac.h.

#### 4.2.2.56 double ctl_t::grid_dt_out

Time step for gridded data output [s].

Definition at line 342 of file libtrac.h.

#### 4.2.2.57 int ctl_t::grid_sparse

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

Definition at line 345 of file libtrac.h.

#### 4.2.2.58 int ctl_t::grid_nz

Number of altitudes of gridded data.

Definition at line 348 of file libtrac.h.

#### 4.2.2.59 double ctl_t::grid_z0

Lower altitude of gridded data [km].

Definition at line 351 of file libtrac.h.

#### 4.2.2.60 double ctl_t::grid_z1

Upper altitude of gridded data [km].

Definition at line 354 of file libtrac.h.

#### 4.2.2.61 int ctl_t::grid_nx

Number of longitudes of gridded data.

Definition at line 357 of file libtrac.h.

#### 4.2.2.62 double ctl_t::grid_lon0

Lower longitude of gridded data [deg].

Definition at line 360 of file libtrac.h.

#### 4.2.2.63 double ctl_t::grid_lon1

Upper longitude of gridded data [deg].

Definition at line 363 of file libtrac.h.

#### 4.2.2.64 int ctl_t::grid_ny

Number of latitudes of gridded data.

Definition at line 366 of file libtrac.h.

#### 4.2.2.65 double ctl_t::grid_lat0

Lower latitude of gridded data [deg].

Definition at line 369 of file libtrac.h.

#### 4.2.2.66 double ctl_t::grid_lat1

Upper latitude of gridded data [deg].

Definition at line 372 of file libtrac.h.

#### 4.2.2.67 char ctl_t::prof_basename[LEN]

Basename for profile output file.

Definition at line 375 of file libtrac.h.

#### 4.2.2.68 char ctl_t::prof_obsfile[LEN]

Observation data file for profile output.

Definition at line 378 of file libtrac.h.

#### 4.2.2.69 int ctl_t::prof_nz

Number of altitudes of gridded profile data.

Definition at line 381 of file libtrac.h.

#### 4.2.2.70 double ctl_t::prof_z0

Lower altitude of gridded profile data [km].

Definition at line 384 of file libtrac.h.

#### 4.2.2.71 double ctl_t::prof_z1

Upper altitude of gridded profile data [km].

Definition at line 387 of file libtrac.h.

#### 4.2.2.72 int ctl_t::prof_nx

Number of longitudes of gridded profile data.

Definition at line 390 of file libtrac.h.

#### 4.2.2.73 double ctl_t::prof_lon0

Lower longitude of gridded profile data [deg].

Definition at line 393 of file libtrac.h.

#### 4.2.2.74 double ctl_t::prof_lon1

Upper longitude of gridded profile data [deg].

Definition at line 396 of file libtrac.h.

#### 4.2.2.75 int ctl_t::prof_ny

Number of latitudes of gridded profile data.

Definition at line 399 of file libtrac.h.

#### 4.2.2.76 double ctl_t::prof_lat0

Lower latitude of gridded profile data [deg].

Definition at line 402 of file libtrac.h.

#### 4.2.2.77 double ctl_t::prof_lat1

Upper latitude of gridded profile data [deg].

Definition at line 405 of file libtrac.h.

#### 4.2.2.78 char ctl_t::stat_basename[LEN]

Basename of station data file.

Definition at line 408 of file libtrac.h.

#### 4.2.2.79 double ctl_t::stat_lon

Longitude of station [deg].

Definition at line 411 of file libtrac.h.

#### 4.2.2.80 double ctl_t::stat_lat

Latitude of station [deg].

Definition at line 414 of file libtrac.h.

#### 4.2.2.81 double ctl_t::stat_r

Search radius around station [km].

Definition at line 417 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 454 of file libtrac.h.

### 4.3.2 Field Documentation

#### 4.3.2.1 double met_t::time

Time [s].

Definition at line 457 of file libtrac.h.

#### 4.3.2.2 int met_t::nx

Number of longitudes.

Definition at line 460 of file libtrac.h.

#### 4.3.2.3 int met_t::ny

Number of latitudes.

Definition at line 463 of file libtrac.h.

#### 4.3.2.4 int met_t::np

Number of pressure levels.

Definition at line 466 of file libtrac.h.

#### 4.3.2.5 double met_t::lon[EX]

Longitude [deg].

Definition at line 469 of file libtrac.h.

#### 4.3.2.6 double met_t::lat[EY]

Latitude [deg].

Definition at line 472 of file libtrac.h.

#### 4.3.2.7 double met_t::p[EP]

Pressure [hPa].

Definition at line 475 of file libtrac.h.

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

Surface pressure [hPa].

Definition at line 478 of file libtrac.h.

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

Pressure on model levels [hPa].

Definition at line 481 of file libtrac.h.

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

Temperature [K].

Definition at line 484 of file libtrac.h.

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

Zonal wind [m/s].

Definition at line 487 of file libtrac.h.

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

Meridional wind [m/s].

Definition at line 490 of file libtrac.h.

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

Vertical wind [hPa/s].

Definition at line 493 of file libtrac.h.

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

Water vapor volume mixing ratio [1].

Definition at line 496 of file libtrac.h.

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

Ozone volume mixing ratio [1].

Definition at line 499 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.

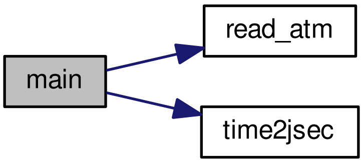
### 5.1.2 Function Documentation

#### 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 *name, *year, *mon, *day, *hour, *min;

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

  int i, f, ip;

  /* 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 date from filename... */
    for (i = (int) strlen(argv[f]) - 1; argv[f][i] != '/' || i == 0; i--);
    name = strtok(&(argv[f][i]), "_");
    year = strtok(NULL, "_");
    mon = strtok(NULL, "_");
    day = strtok(NULL, "_");
    hour = strtok(NULL, "_");
    name = strtok(NULL, "_");   /* TODO: Why another "name" here? */
    min = strtok(name, ".");
    time2jsec(atoi(year), atoi(mon), atoi(day), atoi(hour), atoi(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,
  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 "libtrac.h"
#include <gsl/gsl_sort.h>

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

  ctl_t ctl;

  atm_t *atm;

  FILE *out;

  char *name, *year, *mon, *day, *hour, *min;

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

  int i, f, ip;

  /* 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 date from filename... */
    for (i = (int) strlen(argv[f]) - 1; argv[f][i] != '/' || i == 0; i--);
    name = strtok(&(argv[f][i]), "_");
    year = strtok(NULL, "_");
    mon = strtok(NULL, "_");
    day = strtok(NULL, "_");
    hour = strtok(NULL, "_");
    name = strtok(NULL, "_");   /* TODO: Why another "name" here? */
    min = strtok(name, ".");
    time2jsec(atoi(year), atoi(mon), atoi(day), atoi(hour), atoi(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[ ]* )

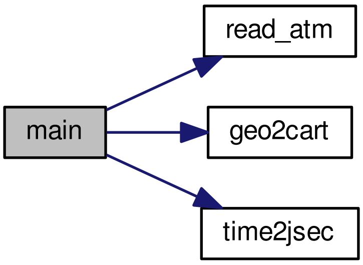
Definition at line 28 of file dist.c.

```
              {

ctl_t ctl;

atm_t *atm1, *atm2;

FILE *out;

char *name, *year, *mon, *day, *hour, *min;

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, i, ip, iph, ipv;

/* 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];
```

```c
      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 date from filename... */
    for (i = (int) strlen(argv[f]) - 1; argv[f][i] != '/' || i == 0; i--);
    name = strtok(&(argv[f][i]), "_");
    year = strtok(NULL, "_");
    mon = strtok(NULL, "_");
    day = strtok(NULL, "_");
    hour = strtok(NULL, "_");
    name = strtok(NULL, "_");   /* TODO: Why another "name" here? */
    min = strtok(name, ".");
    time2jsec(atoi(year), atoi(mon), atoi(day), atoi(hour), atoi(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.

  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;

  FILE *out;

  char *name, *year, *mon, *day, *hour, *min;

  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, i, ip, iph, ipv;

  /* 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 date from filename... */
    for (i = (int) strlen(argv[f]) - 1; argv[f][i] != '/' || i == 0; i--);
    name = strtok(&(argv[f][i]), "_");
    year = strtok(NULL, "_");
    mon = strtok(NULL, "_");
    day = strtok(NULL, "_");
    hour = strtok(NULL, "_");
    name = strtok(NULL, "_");   /* TODO: Why another "name" here? */
    min = strtok(name, ".");
    time2jsec(atoi(year), atoi(mon), atoi(day), atoi(hour), atoi(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

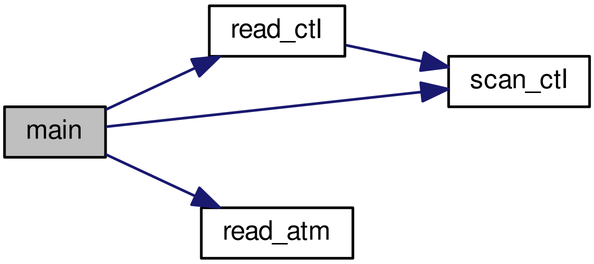
#### 5.5.2.1 int main ( int *argc,* char ∗ *argv[ ]* )

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.

  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 *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

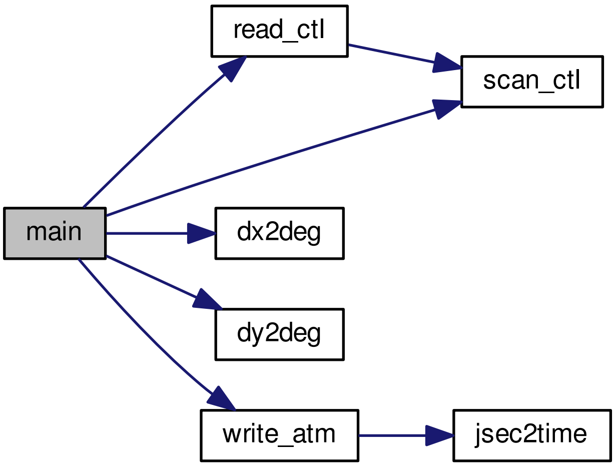
#### 5.7.2.1 int main ( int *argc*, char ∗ *argv[ ]* )

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 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);
  rep = (int) scan_ctl(argv[1], argc, argv, "INIT_REP", -1, "1", NULL);
  m = scan_ctl(argv[1], argc, argv, "INIT_MASS", -1, "0", NULL);

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

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

            /* Set position... */
            atm->time[atm->np]
              = (t + gsl_ran_gaussian_ziggurat(rng, st / 2.3548)
                 + ut * (gsl_rng_uniform(rng) - 0.5));
            atm->p[atm->np]
              = P(z + gsl_ran_gaussian_ziggurat(rng, sz / 2.3548)
                  + uz * (gsl_rng_uniform(rng) - 0.5));
            atm->lon[atm->np]
```

```
              = (lon + gsl_ran_gaussian_ziggurat(rng, slon / 2.3548)
                 + gsl_ran_gaussian_ziggurat(rng, dx2deg(sx, lat) / 2.3548)
                 + ulon * (gsl_rng_uniform(rng) - 0.5));
            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));

            /* 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

```
/*
  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;

  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 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);
  rep = (int) scan_ctl(argv[1], argc, argv, "INIT_REP", -1, "1", NULL);
  m = scan_ctl(argv[1], argc, argv, "INIT_MASS", -1, "0", NULL);

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

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

            /* Set position... */
            atm->time[atm->np]
              = (t + gsl_ran_gaussian_ziggurat(rng, st / 2.3548)
                 + ut * (gsl_rng_uniform(rng) - 0.5));
            atm->p[atm->np]
              = P(z + gsl_ran_gaussian_ziggurat(rng, sz / 2.3548)
                  + uz * (gsl_rng_uniform(rng) - 0.5));
            atm->lon[atm->np]
              = (lon + gsl_ran_gaussian_ziggurat(rng, slon / 2.3548)
                 + gsl_ran_gaussian_ziggurat(rng, dx2deg(sx, lat) / 2.3548)
                 + ulon * (gsl_rng_uniform(rng) - 0.5));
            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));

            /* 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.

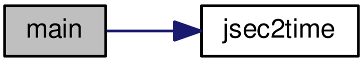
### 5.9.2 Function Documentation

#### 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_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.

```
00055                 {
00056
00057   return dlat * M_PI * RE / 180.;
00058 }
```

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

Convert pressure to vertical distance.

Definition at line 62 of file libtrac.c.

```
00064              {
00065
00066   return -dp * H0 / p;
00067 }
```

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

Convert horizontal distance to degrees.

Definition at line 71 of file libtrac.c.

```
00073               {
00074
00075   /* Avoid singularity at poles... */
00076   if (lat < -89.999 || lat > 89.999)
00077     return 0;
00078   else
00079     return dx * 180. / (M_PI * RE * cos(lat / 180. * M_PI));
00080 }
```

#### 5.11.2.6 double dy2deg ( double *dy* )

Convert horizontal distance to degrees.

Definition at line 84 of file libtrac.c.

```
00085               {
00086
00087   return dy * 180. / (M_PI * RE);
00088 }
```

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

Convert vertical distance to pressure.

Definition at line 92 of file libtrac.c.

```
00094              {
00095
00096   return -dz * p / H0;
00097 }
```

#### 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);
}
```

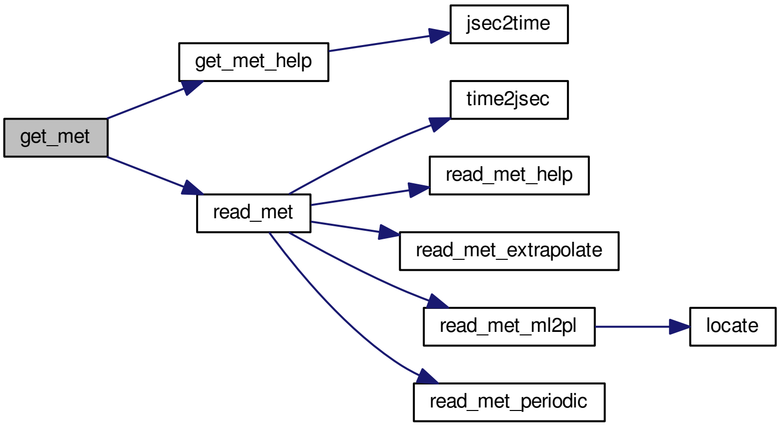
#### 5.11.2.9 void get_met ( ctl_t ∗ *ctl*, char ∗ *metbase*, double *t*, met_t ∗ *met0*, met_t ∗ *met1* )

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:



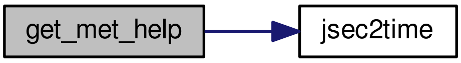
#### 5.11.2.10 void get_met_help ( double *t*, int *direct*, char ∗ *metbase*, double *dt_met*, char ∗ *filename* )

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;
}
```

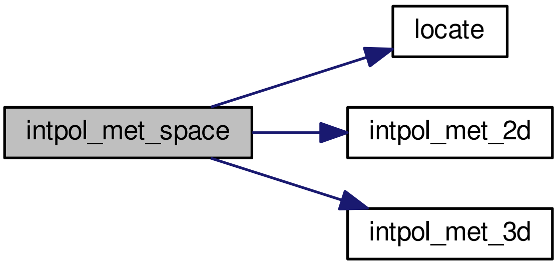
### 5.11.2.13 void intpol_met_space ( met_t ∗ *met*, double *p*, double *lon*, double *lat*, double ∗ *ps*, double ∗ *t*, double ∗ *u*, double ∗ *v*, double ∗ *w*, double ∗ *h2o*, double ∗ *o3* )

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:



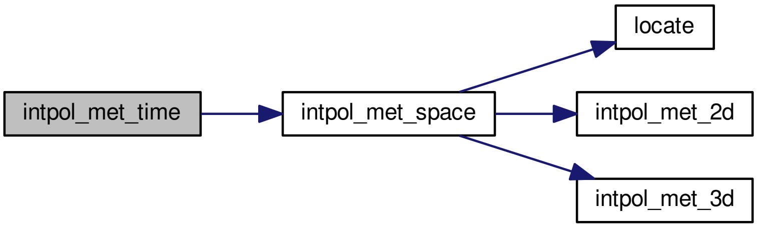
### 5.11.2.14 void intpol_met_time ( met_t ∗ *met0,* met_t ∗ *met1,* double *ts,* double *p,* double *lon,* double *lat,* double ∗ *ps,* double ∗ *t,* double ∗ *u,* double ∗ *v,* double ∗ *w,* double ∗ *h2o,* double ∗ *o3* )

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!");
}
```

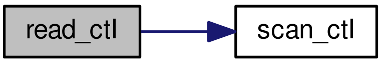
#### 5.11.2.18 void read_ctl ( const char * *filename,* int *argc,* char * *argv[ ],* ctl_t * *ctl* )

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_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_tnat = -1;
  ctl->qnt_stat = -1;

  /* Read quantities... */
  ctl->nq = (int) scan_ctl(filename, argc, argv, "NQ", -1, "0", NULL);
  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], "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], "tnat") == 0) {
      ctl->qnt_tnat = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } 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);

  /* 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);

  /* 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);

  /* 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 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* )

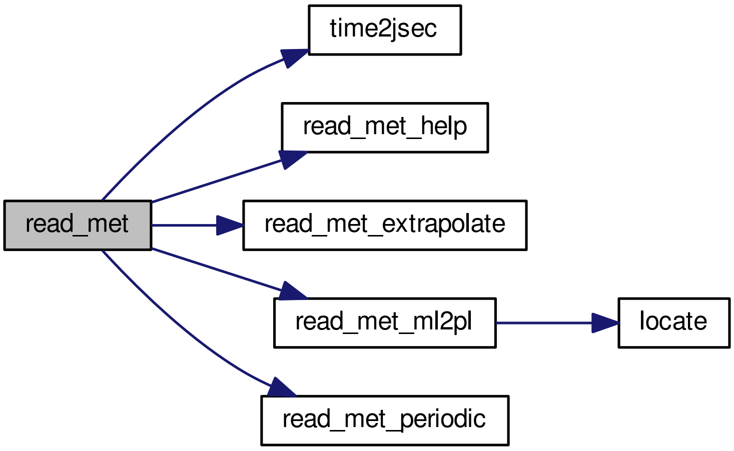
Read meteorological data file.

Definition at line 676 of file libtrac.c.

```
               {

```

```
  char 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... */
  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 > EX)
    ERRMSG("Too many longitudes!");

  NC(nc_inq_dimid(ncid, "lat", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &ny));
  if (ny > EY)
    ERRMSG("Too many latitudes!");

  NC(nc_inq_dimid(ncid, "lev", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &np));
  if (np > EP)
    ERRMSG("Too many levels!");

  /* 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, "lev", &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(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(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 804 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 835 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]* )

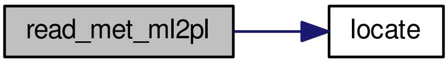
Convert meteorological data from model levels to pressure levels.

Definition at line 867 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 905 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 937 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 1009 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 1040 of file libtrac.c.

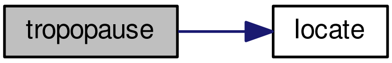
```
            {
  
  static double starttime[NTIMER], runtime[NTIMER];
  
  /* Check id... */
  if (id < 0 || id >= NTIMER)
    ERRMSG("Too many timers!");
  
  /* Start timer... */
  if (mode == 1) {
    if (starttime[id] <= 0)
      starttime[id] = omp_get_wtime();
    else
      ERRMSG("Timer already 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 1075 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:



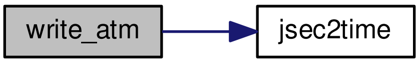
### 5.11.2.28 void write_atm ( const char * *filename*, ctl_t * *ctl*, atm_t * *atm*, double *t* )

Write atmospheric data.

Definition at line 1218 of file libtrac.c.

```
            {

  FILE *in, *out;

  char line[LEN];

  double r;

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

  /* 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++) {
    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 1295 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_grid ( const char * *filename*, ctl_t * *ctl*, met_t * *met0*, met_t * *met1*, atm_t * *atm*, double *t* )

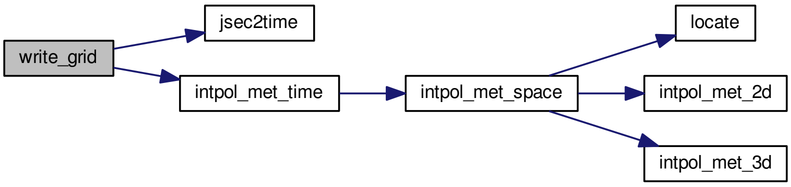
Write gridded data.

Definition at line 1463 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:



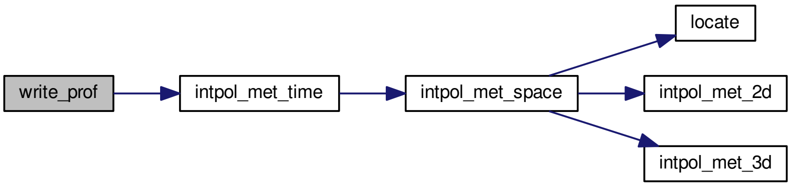
#### 5.11.2.31 void write_prof ( const char * *filename,* ctl_t * *ctl,* met_t * *met0,* met_t * *met1,* atm_t * *atm,* double *t* )

Write profile data.

Definition at line 1614 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:



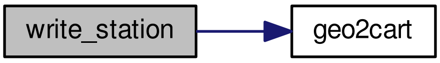
#### 5.11.2.32 void write_station ( const char * *filename,* ctl_t * *ctl,* atm_t * *atm,* double *t* )

Write station data.

Definition at line 1777 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
  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"

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

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_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_tnat = -1;
  ctl->qnt_stat = -1;

  /* Read quantities... */
  ctl->nq = (int) scan_ctl(filename, argc, argv, "NQ", -1, "0", NULL);
  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], "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], "tnat") == 0) {
      ctl->qnt_tnat = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } 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);

  /* 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);

  /* 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);

  /* 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 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 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... */
  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 > EX)
    ERRMSG("Too many longitudes!");

  NC(nc_inq_dimid(ncid, "lat", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &ny));
  if (ny > EY)
    ERRMSG("Too many latitudes!");

  NC(nc_inq_dimid(ncid, "lev", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &np));
  if (np > EP)
    ERRMSG("Too many levels!");

  /* 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, "lev", &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(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(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,
   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;
}

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

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

  FILE *in, *out;

  char line[LEN];

  double r;

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

  /* 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++) {
    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_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_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);
}
```

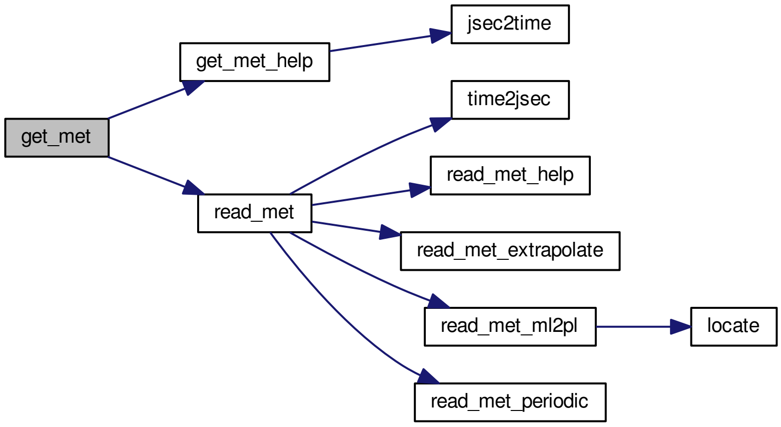
#### 5.13.2.9 void get_met ( ctl_t * *ctl,* char * *metbase,* double *t,* met_t * *met0,* met_t * *met1* )

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:



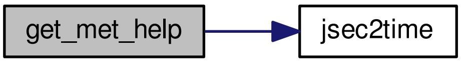
#### 5.13.2.10 void get_met_help ( double *t*, int *direct*, char ∗ *metbase*, double *dt_met*, char ∗ *filename* )

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;
}
```

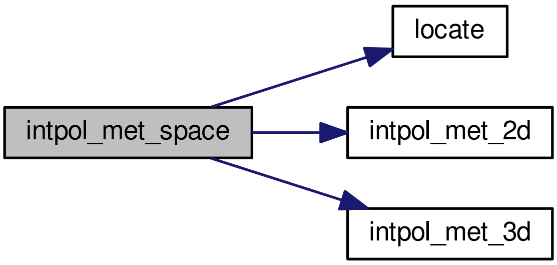
### 5.13.2.13 void intpol_met_space ( met_t ∗ *met*, double *p*, double *lon*, double *lat*, double ∗ *ps*, double ∗ *t*, double ∗ *u*, double ∗ *v*, double ∗ *w*, double ∗ *h2o*, double ∗ *o3* )

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:



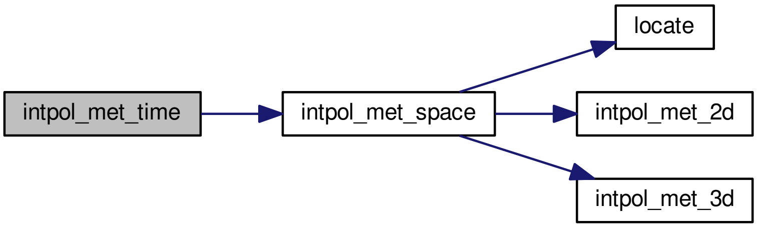
#### 5.13.2.14 void intpol_met_time ( met_t ∗ *met0,* met_t ∗ *met1,* double *ts,* double *p,* double *lon,* double *lat,* double ∗ *ps,* double ∗ *t,* double ∗ *u,* double ∗ *v,* double ∗ *w,* double ∗ *h2o,* double ∗ *o3* )

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!");
}
```

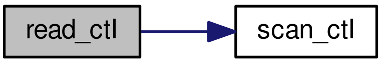
### 5.13.2.18 void read_ctl ( const char * *filename*, int *argc*, char * *argv[ ]*, ctl_t * *ctl* )

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_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_tnat = -1;
  ctl->qnt_stat = -1;

  /* Read quantities... */
  ctl->nq = (int) scan_ctl(filename, argc, argv, "NQ", -1, "0", NULL);
  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], "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], "tnat") == 0) {
      ctl->qnt_tnat = iq;
      sprintf(ctl->qnt_unit[iq], "K");
    } 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);

  /* 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);

  /* 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);

  /* 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 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* )

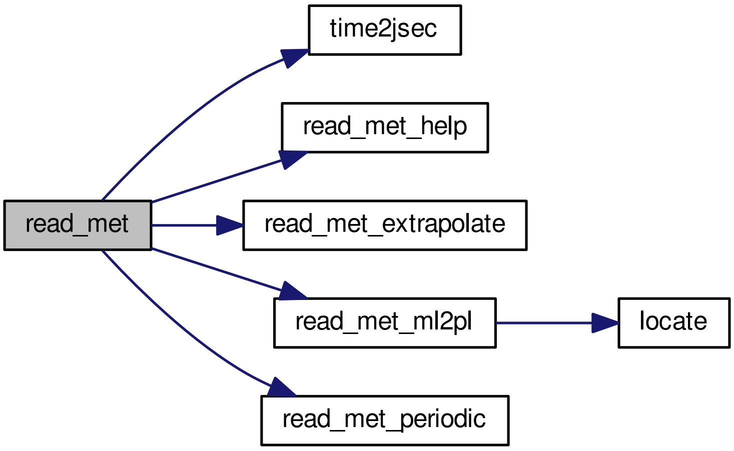
Read meteorological data file.

Definition at line 676 of file libtrac.c.

```
               {

```

```
  char 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... */
  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 > EX)
    ERRMSG("Too many longitudes!");

  NC(nc_inq_dimid(ncid, "lat", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &ny));
  if (ny > EY)
    ERRMSG("Too many latitudes!");

  NC(nc_inq_dimid(ncid, "lev", &dimid));
  NC(nc_inq_dimlen(ncid, dimid, &np));
  if (np > EP)
    ERRMSG("Too many levels!");

  /* 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, "lev", &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(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(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 804 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 835 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]* )

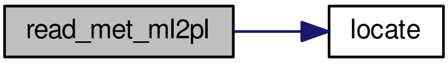
Convert meteorological data from model levels to pressure levels.

Definition at line 867 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 905 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];
    }
}
```

#### 5.13.2.24 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 937 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);
}
```

#### 5.13.2.25 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 1009 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 1040 of file libtrac.c.

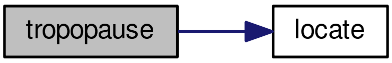
```
            {

  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]);
}
```

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

Definition at line 1075 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:



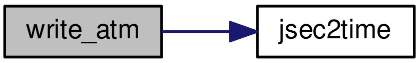
### 5.13.2.28 void write_atm ( const char * *filename*, ctl_t * *ctl*, atm_t * *atm*, double *t* )

Write atmospheric data.

Definition at line 1218 of file libtrac.c.

```
            {

  FILE *in, *out;

  char line[LEN];

  double r;

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

  /* 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++) {
    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 1295 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_grid ( const char * *filename*, ctl_t * *ctl*, met_t * *met0*, met_t * *met1*, atm_t * *atm*, double *t* )

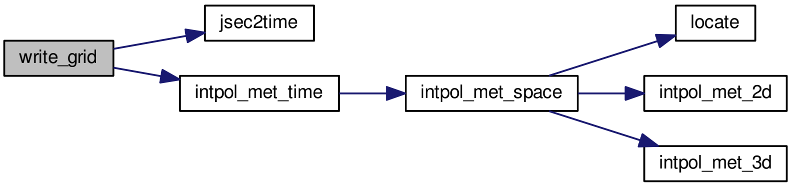
Write gridded data.

Definition at line 1463 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:



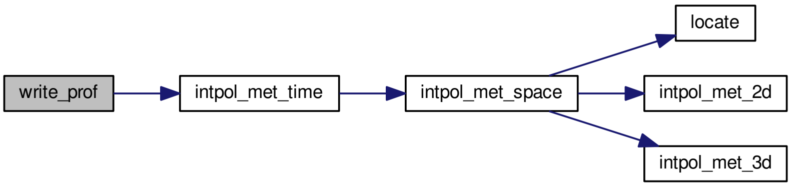
#### 5.13.2.31 void write_prof ( const char ∗ *filename,* ctl_t ∗ *ctl,* met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* double *t* )

Write profile data.

Definition at line 1614 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:



### 5.13.2.32 void write_station ( const char ∗ *filename,* ctl_t ∗ *ctl,* atm_t ∗ *atm,* double *t* )

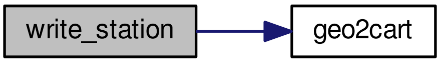
Write station data.

Definition at line 1777 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/>.

  Copright (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_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>

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

#define ALLOC(ptr, type, n)                             \
```

```c
  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)))

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

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

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

/* ------------------------------------------------------------
   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 10

#define EP 73

#define EX 721

#define EY 361

#define GX 720

#define GY 360

#define GZ 100

#define NTHREADS 128

#define NTIMER 20

/* ------------------------------------------------------------
   Structs...
   ------------------------------------------------------------ */
```

```

typedef struct {

  int nq;

  char qnt_name[NQ][LEN];

  char qnt_unit[NQ][LEN];

  char qnt_format[NQ][LEN];

  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_tnat;

  int qnt_stat;

  int direction;

  double t_start;

  double t_stop;

  double dt_mod;

  double dt_met;

  int met_np;

  double met_p[EP];

  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;

  char atm_basename[LEN];

  char atm_gpfile[LEN];

  double atm_dt_out;

  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 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_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.

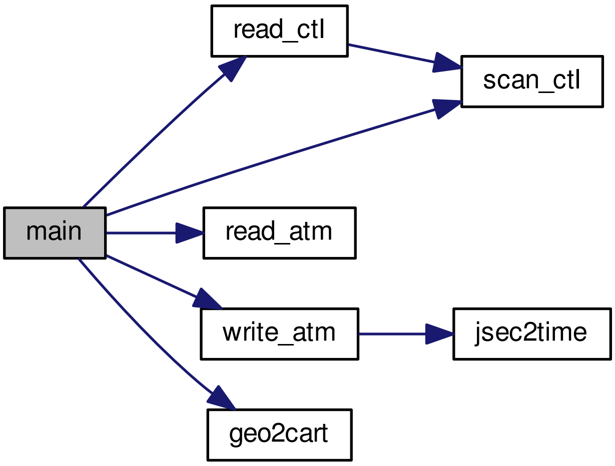
### 5.15.2 Function Documentation

#### 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.

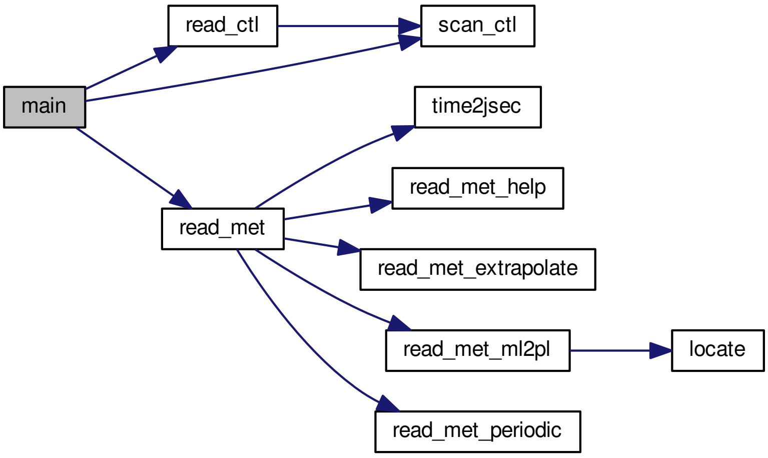
### 5.17.2 Function Documentation

#### 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 *in, *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... */
    if (!(in = fopen(argv[i], "r")))
      continue;
    else
      fclose(in);
    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
```

```c
  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 "libtrac.h"

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

  ctl_t ctl;

  met_t *met;

  FILE *in, *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... */
    if (!(in = fopen(argv[i], "r")))
      continue;
    else
      fclose(in);
    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.

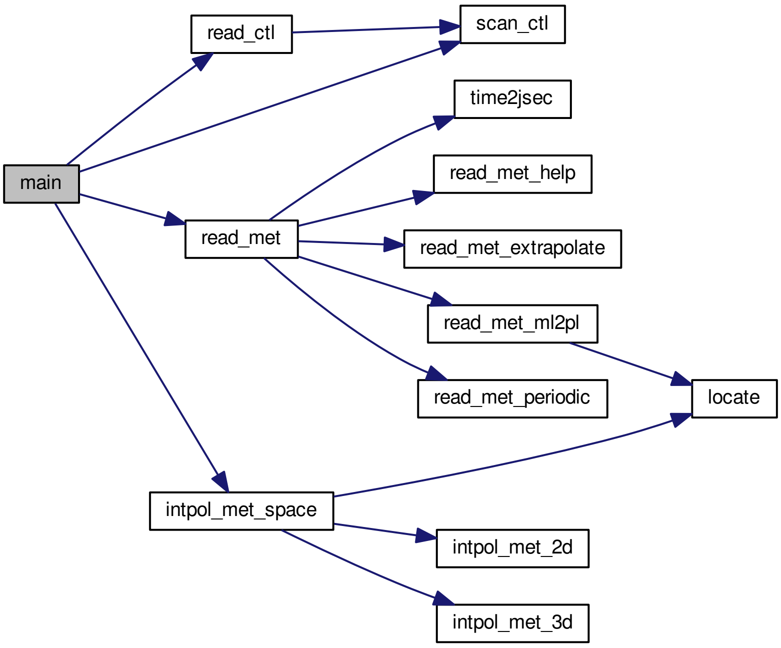
### 5.19.2 Function Documentation

#### 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 *in, *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... */
    if (!(in = fopen(argv[i], "r")))
      continue;
    else
      fclose(in);
    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 *in, *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... */
    if (!(in = fopen(argv[i], "r")))
      continue;
    else
      fclose(in);
    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.

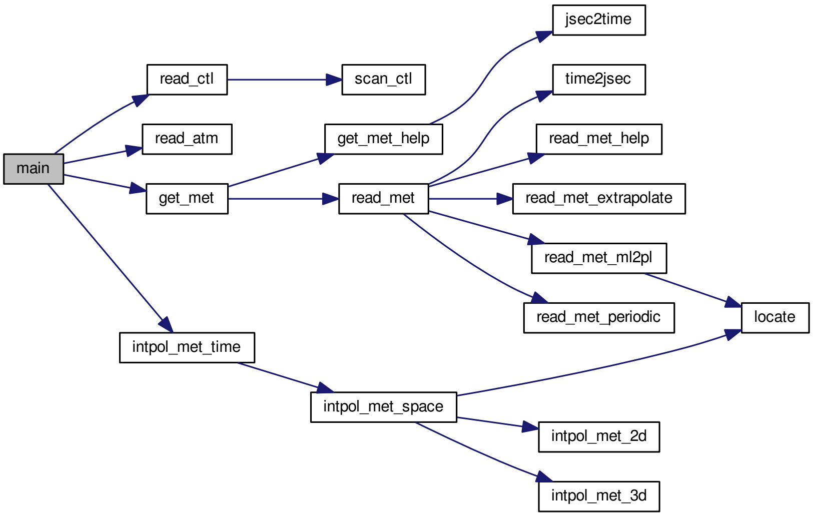
### 5.21.2 Function Documentation

#### 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.

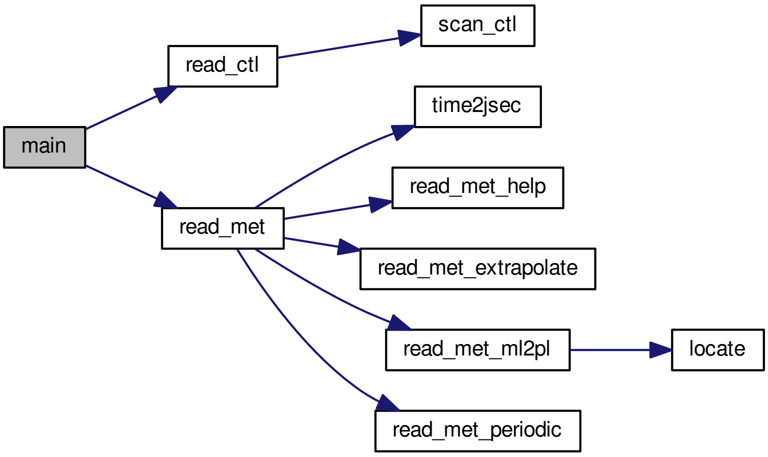
### 5.23.2 Function Documentation

#### 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 *in, *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... */
    if (!(in = fopen(argv[i], "r")))
      continue;
    else
      fclose(in);
    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.

  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 *in, *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... */
    if (!(in = fopen(argv[i], "r")))
      continue;
    else
      fclose(in);
    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.

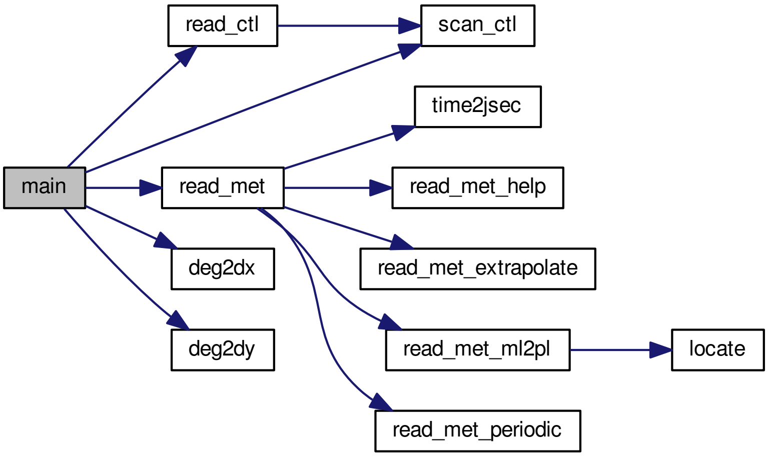
### 5.25.2 Function Documentation

#### 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

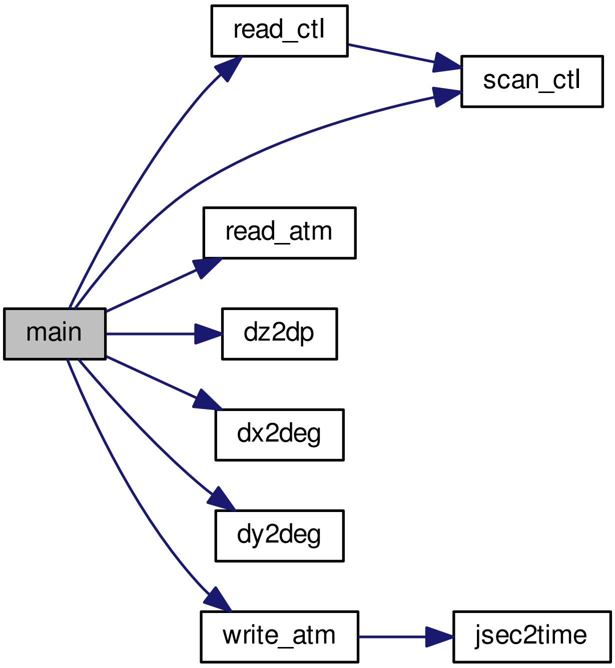
#### 5.27.2.1 int main ( int *argc,* char ∗ *argv[ ]* )

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.

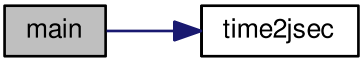
### 5.29.2 Function Documentation

#### 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.*
- 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 398 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!");
}
```

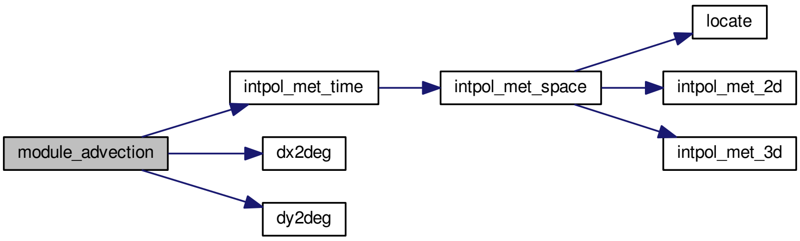
#### 5.31.2.2 void module_advection ( met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* int *ip,* double *dt* )

Calculate advection of air parcels.

Definition at line 422 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:



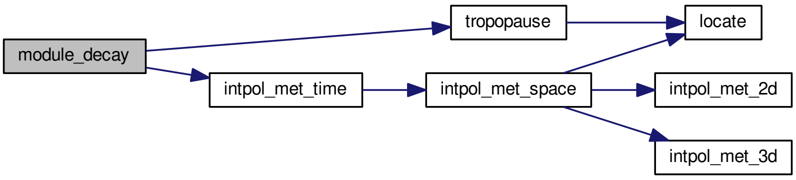
### 5.31.2.3 void module_decay ( ctl_t * *ctl,* met_t * *met0,* met_t * *met1,* atm_t * *atm,* int *ip,* double *dt* )

Calculate exponential decay of particle mass.

Definition at line 455 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:



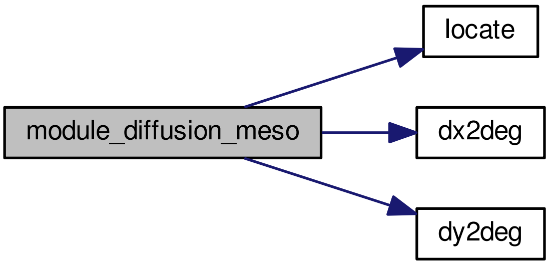
### 5.31.2.4 void module_diffusion_meso ( ctl_t * *ctl,* met_t * *met0,* met_t * *met1,* atm_t * *atm,* int *ip,* double *dt,* gsl_rng * *rng* )

Calculate mesoscale diffusion.

Definition at line 497 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:



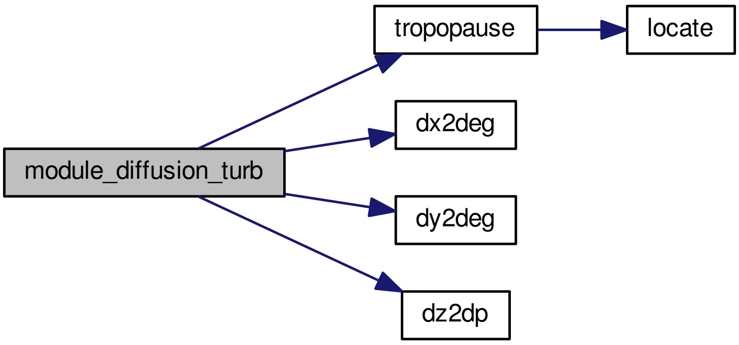
### 5.31.2.5 void module_diffusion_turb ( ctl_t * *ctl,* atm_t * *atm,* int *ip,* double *dt,* gsl_rng * *rng* )

Calculate turbulent diffusion.

Definition at line 608 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:



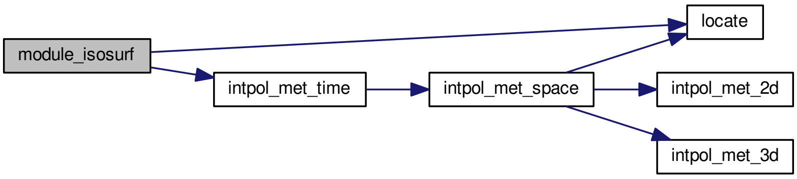
#### 5.31.2.6 void module_isosurf ( ctl_t * *ctl,* met_t * *met0,* met_t * *met1,* atm_t * *atm,* int *ip* )

Force air parcels to stay on isosurface.

Definition at line 653 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:



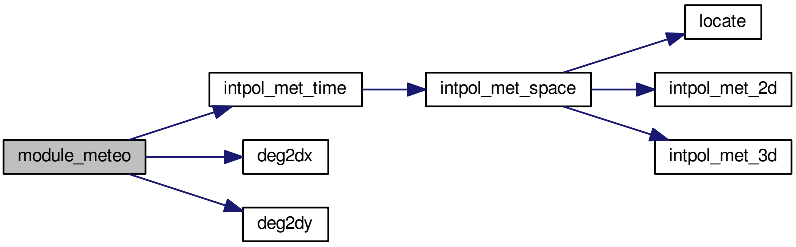
#### 5.31.2.7 void module_meteo ( ctl_t ∗ *ctl,* met_t ∗ *met0,* met_t ∗ *met1,* atm_t ∗ *atm,* int *ip* )

Interpolate meteorological data for air parcel positions.

Definition at line 768 of file trac.c.

```
          {

  double b, c, ps, p1, p_hno3, p_h2o, t, t1, term1, term2,
    u, u1, v, v1, w, x1, x2, h2o, o3, grad, vort;

  /* 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)
    atm->q[ctl->qnt_tice][ip] = -2663.5
      / (log10(4e-6 * atm->p[ip] * 100.) - 12.537);

  /* Calculate T_NAT (Hanson and Mauersberger, 1988)... */
  if (ctl->qnt_tnat >= 0) {
    p_hno3 = 9e-9 * atm->p[ip] / 1.333224;
    p_h2o = 4e-6 * atm->p[ip] / 1.333224;
    term1 = 38.9855 - log10(p_hno3) - 2.7836 * log10(p_h2o);
    term2 = 0.009179 - 0.00088 * log10(p_h2o);
    b = term1 / term2;
    c = -11397.0 / term2;
    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;
  }
}
```

Here is the call graph for this function:



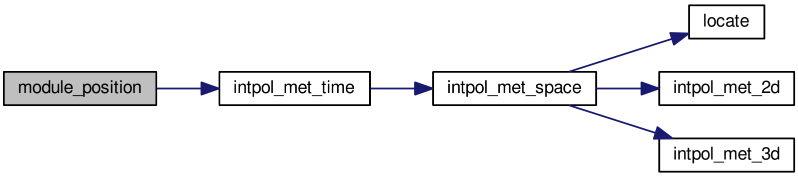
#### 5.31.2.8 void module_position ( met_t * *met0*, met_t * *met1*, atm_t * *atm*, int *ip* )

Check position of air parcels.

Definition at line 872 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:



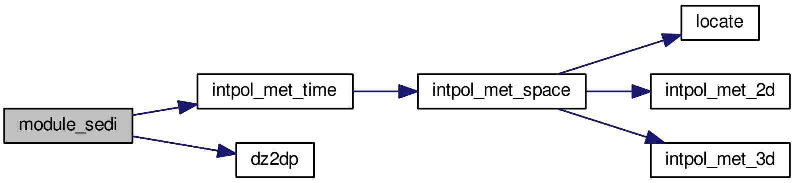
### 5.31.2.9 void module_sedi ( ctl_t * *ctl*, met_t * *met0*, met_t * *met1*, atm_t * *atm*, int *ip*, double *dt* )

Calculate sedimentation of air parcels.

Definition at line 916 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:



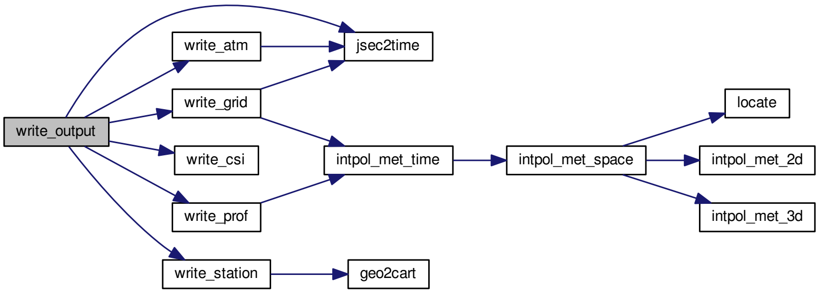
#### 5.31.2.10 void write_output ( const char * *dirname,* ctl_t * *ctl,* met_t * *met0,* met_t * *met1,* atm_t * *atm,* double *t* )

Write simulation output.

Definition at line 977 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 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 CSI data... */
  if (ctl->csi_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->csi_basename);
    write_csi(filename, ctl, 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:



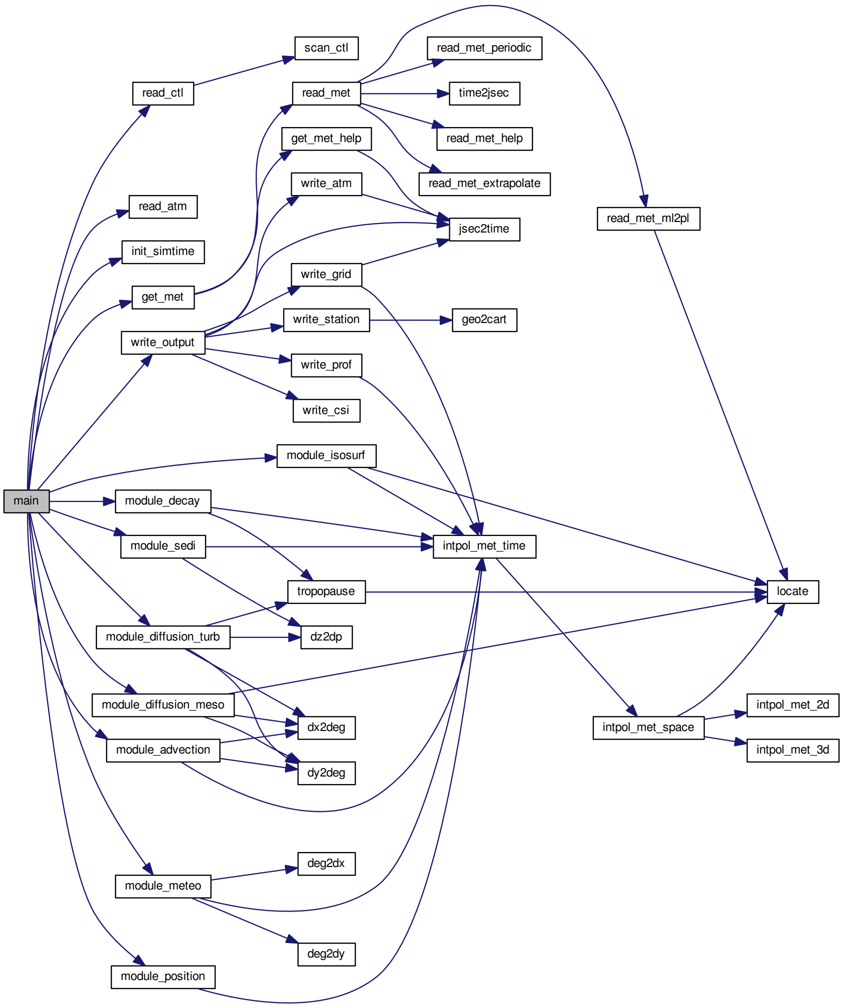
### 5.31.2.11 int main ( int *argc,* char ∗ *argv[ ]* )

Definition at line 160 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();
    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);
      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);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; 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_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
```

```

/* ------------------------------------------------------------
   Defines...
   ------------------------------------------------------------ */

#define TIMER_TOTAL 0

#define TIMER_INIT 1

#define TIMER_INPUT 2

#define TIMER_OUTPUT 3

#define TIMER_ADVECT 4

#define TIMER_DECAY 5

#define TIMER_DIFFMESO 6

#define TIMER_DIFFTURB 7

#define TIMER_ISOSURF 8

#define TIMER_METEO 9

#define TIMER_POSITION 10

#define TIMER_SEDI 11

/* ------------------------------------------------------------
   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);

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();
    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);
      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);
#pragma omp parallel for default(shared) private(ip)
      for (ip = 0; 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_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) {

  double b, c, ps, p1, p_hno3, p_h2o, t, t1, term1, term2,
    u, u1, v, v1, w, x1, x2, h2o, o3, grad, vort;

  /* 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);
    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)
    atm->q[ctl->qnt_tice][ip] = -2663.5
      / (log10(4e-6 * atm->p[ip] * 100.) - 12.537);

  /* Calculate T_NAT (Hanson and Mauersberger, 1988)... */
  if (ctl->qnt_tnat >= 0) {
    p_hno3 = 9e-9 * atm->p[ip] / 1.333224;
    p_h2o = 4e-6 * atm->p[ip] / 1.333224;
    term1 = 38.9855 - log10(p_hno3) - 2.7836 * log10(p_h2o);
    term2 = 0.009179 - 0.00088 * log10(p_h2o);
    b = term1 / term2;
    c = -11397.0 / term2;
    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;
  }
}

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

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 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 CSI data... */
  if (ctl->csi_basename[0] != '-') {
    sprintf(filename, "%s/%s.tab", dirname, ctl->csi_basename);
    write_csi(filename, ctl, 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 173 of file wind.c.

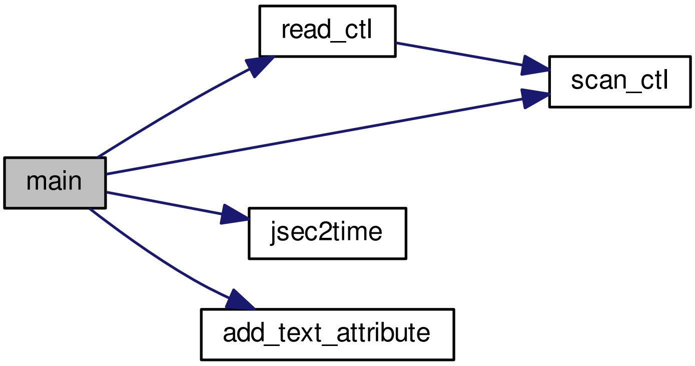
```
              {

  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[EP * EY * EX], dataU[EP * EY * EX], dataV[EP * EY * EX],
    dataW[EP * EY * EX];

  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;

  /* 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));

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



## 5.34 wind.c

```
/*
```

```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"

/* ------------------------------------------------------------
   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[EP * EY * EX], dataU[EP * EY * EX], dataV[EP * EY * EX],
    dataW[EP * EY * EX];

  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;

  /* 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));

  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));
}
```

# Index