

**MARS CLIMATE DATABASE 3.0**

**"*ATMEMCD*" SUBROUTINE**

**PROGRAMMER'S GUIDE**

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## ACRONYMS

DRS	Data Retrieval and Storage System
EOF	Empirical Orthogonal Functions
GCM	General Circulation Model
GrADS	Grid Analysis and Display System
LMD	Laboratoire de Meteorologie Dynamique
Mars-GRAM	Mars Global Reference Atmospheric Model
MCD	Mars Climate Database
PC	Principal Component

## REFERENCE DOCUMENT

- [RD1] MARS CLIMATE DATABASE v3.0 – Detailed Design Document , S.R. Lewis, M. Collins and F.Forget
- [RD2] MARS CLIMATE DATABASE v3.0 – User Manual , S.R. Lewis, M. Collins, F. Forget,.
- [RD3] ATMEMCD subroutine programmer's guide,. F. Forget, C. Hourtolle, S.Lewis
- [RD4] "A climate Database for Mars", Lewis et al., Journal of Geophysical Research 104, 24,1777-24,188, 1999
- [RD5] "Improved General circulation models of the Martian atmosphere from the surface to above 80 km", Forget et al., Journal of Geophysical Research 104, 24,1755-24,176, 1999

## SCOPE

This document is the programmer's guide for the subroutine mode of the Mars Climate Database V3.0 (Subroutine ATMEMCD) which computes meteorological variables from Mars Climate Database (MCD) developed by LMD (Paris) and AOPP (Oxford) with the support of the European Space Agency. The subroutine mode was especially developed by CNES (Toulouse) for Atmospheric Trajectories Computation purpose, but it can be used for various technical or scientific application.

## 1 INTRODUCTION

The MCD is a database of atmospheric statistics compiled from General Circulation Model (GCM) simulations of the Martian atmosphere. These data have been validated through several Mars missions observations. The database can be consulted on web site :

[www.lmd.jussieu.fr/mars.html](http://www.lmd.jussieu.fr/mars.html)

The data in the MCD have been written using the Data Retrieval and Storage System (DRS) and a package of FORTRAN77 and C subroutines have been developed to access the data.

A subroutine mode of the software supplied with the Mars Climate Database (MCD) has been developed by CNES for trajectory simulation programs. [RD1-2-4-5] should be consulted for more information on the original source code and description of the method.

When referred to in an article or a document, the references "Forget et al. (1999)" and "Lewis et al. (1999)" ([RD4] and [RD5]) should be cited.

The subroutine computes a set of meteorological variables at a given location and time. Several dust scenarios are available. The subroutine provides mean values of the variables and allows to account for realistic types of perturbations.

This version of the database extend up to about 120 km height. Above the top model level, the subroutine provides relatively realistic values of the meteorological variables (e.g. density) by integration of hydrostatic equation assuming a constant thermospheric temperature of 200 K above ~140km, with a linear transition between the upper database layer (~120km) and the 140 km level.

## 2 DIFFERENCES BETWEEN THE DELIVERED VERSIONS

### Difference between Version 3.0 and Version 2.3 of ATMEMCD

This corresponds to version 3.0 of the Mars Climate Database. See main user manual for further informations about the evolution since the previous version of the database. Compared to the previous version of **atmemcd** (V2.3), the main differences are :

- Dimensions in `constants_atmemcd.h` were changed for new database resolution, for new horizontal grid (now  $5^\circ \times 5^\circ$ ) and for increased range in vertical coordinates ( $\sigma=p/ps$ ). EOFs are now stored on a slightly different latitude grid.
- New table variables (`tabfslw`, `tabfslw`, `tabftlw`, `tabftsw`) were introduced to hold fluxes at surface and top of atmosphere. Code added to read these into `atmemcd` with other mean variables.
- Changes to arguments to `atmemcd`:
  - Time and date can be provided in Mars time (Solar Longitude and local time) in addition to Earth date (i.e. Julian dates computed from time, day, month, year)

- *dset* special options of 's' and 'b' have been removed since only one set of dust properties is now supplied. *dset* still used to choose default link or specify a full path to the data.
- *scena*, and internal variable, *dust*, can now take values from 1 to 5 to allow for new default MGS scenario (note values of other scenarios have increased by 1). 1 = MGS dust, 2 = Viking dust, 3 = low dust, 4 = dust storm tau=2, 5 = dust storm tau=5. The Variable *intens* has been removed.
- *extvar* now increased to dimension 25 to allow for extra variables to be returned at positions 15 onwards (all variables from v2.3 keep the same index in the *extvar* vector, 1-14). The new *Extvar* variables are :
  - extvar(15)= mean surface pressure (Pa)
  - extvar(16)= daily maximum mean surface pressure (Pa)
  - extvar(17)= daily minimum mean surface pressure (Pa)
  - extvar(18)= seasonal std. dev. surface pressure (Pa)
  - extvar(19)= mean LW flux to surface (W/m2)
  - extvar(20)= mean SW flux to surface (W/m2)
  - extvar(21)= mean LW flux to space (W/m2)
  - extvar(22)= mean SW flux to space (W/m2)
  - extvar(23)= areocentric longitude of Mars, Ls (deg)
  - extvar(24)= local solar time (hrs)
  - extvar(25)= prime meridian time (hrs)
- Internal changes:
  - The meteorological data retrieved by *atmemcd* are now interpolated in time of day (but not season) between database timestep. Thus, universal time (= local tile at longitude 0) is now transferred between most subroutines.
  - *atime* routine replaced by *mars\_ptime* which returns a prime meridian time as a real hour number and *mcd\_time*
  - Above the top model level, the subroutine provides relatively realistic values of the meteorological variables (e.g. density) by assuming a constant thermospheric temperature of 200 K above ~140km, with a linear transition between the upper database layer (~120km) and the 140 km level, rather than keeping the top model level temperature as before.
  - New internal parameters used in **grwpb** (small-scale variance) routine:
    - *hmax* is now set to 100km since model data is reliable to greater heights than was the case before (*hmax* is the level above which perturbations amplitude is kept constant)
    - *usat* is set to 0.5 m/s (for windspeeds below *usat*, wave amplitude saturates). Wave amplitudes at very low speeds are likely to be limited by algorithm which now checks stability anyway).

### 3 SOFTWARE PACKAGE

The delivery contains the FORTRAN77 subroutines and data files required to use the Martian Climate Database in subroutine mode for trajectory simulation programs.

The delivery is composed of 4 directories :

#### ■ **emcd** contains :

- the file “*atmemcd.F*”, which contains the ATMEMCD main subroutine and all the subroutines or functions it calls
- the *include* file “*constantes\_atmemcd.h*”,

- the “*julian.F*” file, which contains the subroutine which computes Julian date from calendar date.
- The “*height.F*” file which contains a subroutine used to make the conversion between height above the local surface, height above the zero datum “areoid” and the distance (radius) from the centre of the planet.
- The file “*test\_emcd.F*” which contains a simple sample program using *atmemcd*, *julian* and *height*.
- A *makefile* used to compile these softwares (see user manual)
- A subdirectory *testcase* containing test cases used to test the accuracy of your installation of the database (See user manual).

As well as the Mars Gram like interface and other tools (see main user manual)

- **data** contains the full MCD dataset derived from the model GCM run.
- **docs** contains :
  - the documentation associated to the MCD V3.0 software : [RD1] et [RD2] in postscript and pdf format

The complete description of each directory is provided in Annexe A.

- **drs** contains the DRS library (with some documentation) used to read the database files.

## 4 INSTALLING THE MCD

See User Manual [RD2], section “Installation”.

## 5 RUNNING THE MCD SUBROUTINE MODE

### 5.1 ROLE OF ATMEMCD

- The subroutine ATMEMCD allows to compute the following basic meteorological variables for atmospheric trajectory computation:

- pressure
- temperature
- density
- wind speed defined by two components
  - the meridional wind (positive when oriented from south to north)
  - the zonal wind (positive when oriented from west to east)

The radiative fluxes (Solar and thermal IR) on the ground and at the top of the atmosphere are also available.

- The values are dependant of the point of the space defined by its altitude, latitude and longitude and of the date. Meteorological variables are calculated by interpolation in space and day time (no interpolation on season) from data stored in the MCD.
- Above the top level of the database (currently at sigma level  $2.209 \cdot 10^{-7}$ , about 120 km), the density and pressure are computed by integration of hydrostatic equation assuming that mean temperature follow a linear transition from the top level to an additional “thermosphere level” (located at sigma level  $1.269 \cdot 10^{-8}$ , around 140 – 150 km) above which the temperature is set to 200K. The wind components are kept equal to the value in the upper layer of the database.
- For the variables, the subroutine delivers mean values as stored in the database. On request, supplementary variables are computed (see output description). Also, if requested different kind of perturbation can be added to the mean values:.

The available perturbations are :

- ◆ small scale perturbations due to the upward propagation of gravity waves for any altitudes (no small scale perturbation for pressure)
- ◆ large scale perturbations due to the motion of baroclinic weather systems. These perturbations are correlated in longitude and altitude,
- ◆ perturbation equal to n times the standard deviations for all the variables.

The two first types of perturbations have a random component. The perturbations are described in details in the *Detailed Design Document*. In summary :

1. The **gravity wave perturbation** to a meteorological variable is calculated by considering vertical displacements of the form :

$$\delta z = \delta h(z) \cdot \sin\left(\frac{2\pi z}{\lambda} + \phi_0\right)$$

where :

$\lambda$  is a characteristic vertical wavelenght for the gravity wave (input of **atmemcd**. Default value : 16 km)

$\phi_0$  is a randomly generated surface angle.

$\delta h$  is the amplitude of the wave depending of the height  $z$

If  $z$  is higher than 100 km, the amplitude of the wave is taken equal to the amplitude at 100 km. The amplitude of the wave is limited to  $\lambda / 2\pi$  to saturate the amplitude of the perturbation when it becomes statically unstable. The perturbation is deduced from the difference between the variable value at the altitude  $z + \delta z$  and the variable value at the altitude  $z$ , assuming adiabatic motion between those altitudes.

2. The **large scale perturbation** in the Mars Climate Database is represented using a technique that is widely used in meteorological data analysis, namely, Empirical Orthogonal Function (EOF) analysis. A two-dimensional, multivariate EOF of the main atmospheric variables (surface pressure, temperature, wind components and density) is used which describes correlations in the model variability as a function of both height and longitude. 72 EOFs have been retained in the series. It allows to capture approximately 95% or greater of the variance. Above the top level of the database, the perturbation represents a constant percentage of the mean value ; this percentage is equal to those at the top of the database.
3. For the last type of perturbation (i.e. n times the standard deviation), the standard deviation is interpolated from the standard deviation values stored in the database. Above the top level of the database, the standard deviation represents a constant percentage of the mean value ; this percentage is equal to those at the top of the database.

## 5.2 COMPILING AND RUNNING ATMEMCD

A simple program using the *atmemcd* subroutine (as well as the complementary subroutines *julian* and *height*) named *test\_emcd* is provided in the *emcd* directory. You can easily modify it or use part of this code for your own purpose.

To compile the program, the Unix command *make* can be used. For that purpose, a sample *makefile* file (containing information required by make) is provided. The *makefile* file is adapted to *test\_emcd* (and *mcdgm*), but it is straightforward to adapt it to your own program by mimicking what is done for *test\_emcd*.

For instance, to compile and run *test\_emcd*, type:

- *make test\_emcd*
- *test\_emcd*

Then, just answer the questions...

In the *emcd/testcase* sub-directory, a tool to test the accurate performance of *atmemcd* on your computer is provided. Please read the README file for further information.

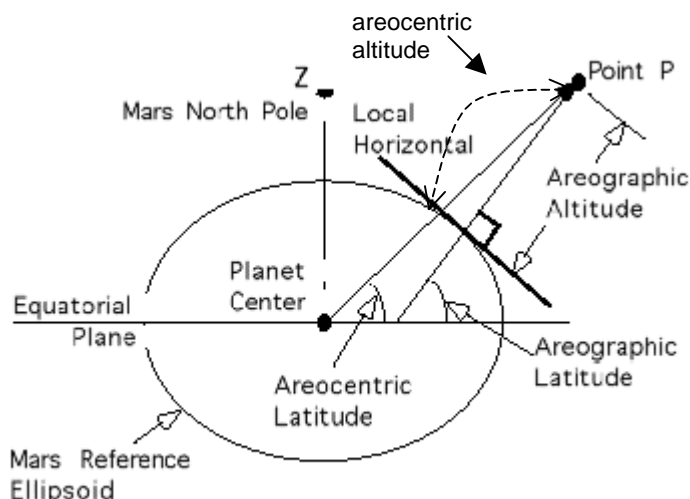


## ATMEMCD SUBROUTINE INPUTS

Name	Type	description
Xz	double precision	Height in meters above zero datum Mars geoid or "areoid". (see note below)
xlat	double precision	Latitude in radians
Xlon	double precision	EAST Longitude in radians
Xdate	double precision	Date : <i>IF Xdate &gt; 0</i> : Earth Julian date (see note below) <i>IF Xdate &lt; 0</i> : "Mars xdate" = -INT(Ls) + localtime/100 (i.e.xdate=-91.18 means Ls=91,LT=18 :00)
Dset	Character chain	Data set name (can be any length to specify a full path to any data set). It can usually be a blank to get the default data set (see note below)..
Scena	Integer	Dust scenario : 1 = MGS dust Scenario 2 = Viking dust 3 = low dust 4 = moderate global dust storm ( $\tau = 2$ ) 5 = heavy global dust storm ( $\tau = 5$ )
Typper	double precision (dim 2)	Perturbation type to add to the mean values (1., 0.) = none (2., seed number) = add large scale (3., seed number) = add small scale (4., seed number) = add small and large scale (5., number of standard deviation) = add n times the standard deviation
Invar	double precision	An argument used to allow control of the variability model features. In the current versions, invar is the vertical gravity wave wavelength (see note below).
init_atm	logical	true: re-initialize atmospheric model perturbations (see note below)
Ikey	Integer	Flag to request extra variable computation 0 = extra variables not computed 1 = extra variables computed

## Altitude

- A subroutine, namely *height* in *height.F* is provided to make the conversion between height above the local surface, height above the zero datum “areoid” and the distance (radius) from the centre of the planet (meters). Given any of the above this routine finds the other two, according to the value of input index *iconv*.
- The model of surface topography used by MCD is the topography retrieved by the Mars Orbiter laser Altimeter (MOLA) aboard Mars Global Surveyor. Note that the MOLA areoid is not the same as the DTM zero datum previously used (it is slightly higher). The zero elevation is now defined as the gravitational equipotential surface whose average value at the equator is equal to the mean radius as determined by MOLA. This areoid is not defined by an ellipsoid, but by a map of radius from the center of the planet provided in files *mountain.dat* , *.dic*, *.ctl* which is read by subroutine *height*, for instance.
- The "altitude" used by the database is thus an "areocentric altitude". This means that the altitude above the reference areoid is computed as the difference between the areocentric spacecraft radius and the radius to the surface of the reference ellipsoid. The radius of the reference ellipsoid is, of course, computed at the same areocentric latitude of



the spacecraft.

## Julian date

A subroutine, namely ‘*julian*’, in “*julian.F*” is provided to compute the Julian date given a calendar date (day, month, year, hour, minute, second) on Earth.

## Dataset

If the dataset is not specified (i.e. *dset* is equal to blank), the default path for the data file directory is « EMCD\_DATA »

## Scenario type :

The different scenarios differ by dust amount and distribution used to create the data files. Dust is highly variable on Mars. The MGS scenario (*Scena=1*) is thought to represent a moderate, realistic Mars Atmosphere without big dust storms. The other scenarios are provided to account for the variability on Mars, including the possibility of global dust storms. Please see the *Detailed design document* for further

information. Note that for the dust storm scenarios, the data were only stored in the database when dust storm are most likely to occur, that is for seasons 8-10 corresponding to  $Ls = 210^\circ - 300^\circ$ .

### **Perturbations**

For the small scale or large scale perturbations, a seed number input has to be specified as a real double precision. The subroutine convert this input in a negative integer for the random number generator.

When large scale perturbation is requested, as long as the seed number remains the same, no new random vector is generated and you work with the same correlated perturbed atmosphere.

When small scale perturbation is requested, a new random phase is computed if the seed number input changes or if the displacement in latitude or in longitude is greater than 1 degree, because gravity waves are not correlated on large scale, low resolution map.

### **init\_atm :**

This logical argument is used to indicate whether a new set of random atmospheric perturbations are required this time. It is set to .true. on first call if using perturbation models. It is reset by the subroutine atmemcd to false on output to maintain the same set of perturbations (EOF amplitude, Gravity Wave phase) for next call. If uncorrelated perturbations are required then set it to .true. for each call of the subroutine atmemcd.

### **Invar :**

*Invar* is used (in the current version) to control the vertical gravity wave wavelength (km). It should be between 2 and 30 km. If set to 0 , the default value (16 km) is used.

## **5.3 ATMEMCD SUBROUTINE OUTPUTS**

<b>Name</b>	<b>Type</b>	<b>description</b>
Seedout	double precision	seed number to generate the next perturbed atmosphere
Pres	double precision	pressure (Pa)
Ro	double precision	density ( $\text{kg/m}^3$ )
Temp	double precision	temperature (K)
Ventu	double precision	zonal wind component (Eastward) in m/s
Ventv	double precision	meridional wind component (Northward) in m/s

Meanvar	double precision (dim 5)	<p>mean values array</p> <p>meanvar(1) = mean pressure</p> <p>meanvar(2) = mean density</p> <p>meanvar(3) = mean temperature</p> <p>meanvar(4) = mean zonal wind component</p> <p>meanvar(5) = mean meridional wind component</p>
Extvar	double precision (dim 25)	<p>supplementary variables array</p> <p>extvar(1) = upper density value (<math>\text{kg/m}^3</math>)</p> <p>extvar(2) = lower density value (<math>\text{kg/m}^3</math>)</p> <p>extvar(3) = density standard deviation (<math>\text{kg/m}^3</math>)</p> <p>extvar(4) = random density perturbation (<math>\text{kg/m}^3</math>)</p> <p>extvar(5) = scale height H(p)</p> <p>extvar(6) = density scale height H(rho) (km)</p> <p>extvar(7) = Reserved for future use</p> <p>extvar(8) = Reserved for future use</p> <p>extvar(9) = Reserved for future use</p> <p>extvar(10) = mean ground temperature (K)</p> <p>extvar(11) = maximum ground temperature (K)</p> <p>extvar(12) = minimum ground temperature (K)</p> <p>extvar(13) = density small scale perturbation (gravity wave) (<math>\text{kg/m}^3</math>)</p> <p>extvar(14)= orographic height (m)</p> <p>extvar(15)= mean surface pressure (Pa)</p> <p>extvar(16)= daily maximum mean surface pressure (Pa)</p> <p>extvar(17)= daily minimum mean surface pressure (Pa)</p> <p>extvar(18)= seasonal std. dev. surface pressure (Pa)</p> <p>extvar(19)= mean LW flux to surface (<math>\text{W/m}^2</math>)</p> <p>extvar(20)= mean SW flux to surface (<math>\text{W/m}^2</math>)</p>

		extvar(21)= mean LW flux to space (W/m2) extvar(22)= mean SW flux to space (W/m2) extvar(23)= areocentric longitude of Mars, Ls (deg) extvar(24)= local solar time (hrs) extvar(25)= universal (prime meridian) time (hrs)
Ier	integer	Error code  0 = OK 1 = unknown database 2 = unknown scenario 3 = unknown perturbation type 4 = underground object 5 = no dust storm for the season 6 = impossible to open database file 7 = impossible to load data from database 8 = undetermined sigma levels

### Supplementary variables

‘extvar’ is computed if and only if ‘ikey’ = 1. Otherwise it remains equal to 0.0. Usually, these supplementary variables are not used for atmospheric trajectories computation but useful for environmental studies.

◆ extvar(1) & extvar(2) : upper and lower density

- Upper and lower densities are equal to :

$$\rho_{\text{mean}} \pm (\sigma_p + \text{pert}_{\text{gw}})$$

- where  $\rho_{\text{mean}}$  is the mean value of density interpolated from MCD data,  $\sigma_p$  the density standard deviation interpolated from MCD data and  $\text{pert}_{\text{gw}}$  the density perturbation due to gravity wave (i.e small scale perturbation)

◆ extvar(3) : density standard deviation:

the density standard deviation is computed by interpolation of MCD density standard deviations,

◆ extvar(4) : random density perturbation value:

- This variable is equal to the random component computed for the density large scale perturbation from EOF data stored in MCD,

- ◆ extvar(5) & extvar(6) : scale height H(pressure) and H(density) :

-these values are evaluated with the formula ' $R*Temp/g$ ' with 'R' equal to 191.2 and 'g' equal to 3.72

- ◆ extvar(7) & extvar(8) & extvar(9) : Set to -999. for the moment.
- ◆ extvar(10) & extvar(11) & extvar(12) : respectively the mean surface temperature for the given latitude, longitude and day time, the daily maximum mean surface temperature and daily minimum mean surface temperature for the season are computed using the MCD data.
- ◆ extvar(14) : the orographic height is the surface elevation relative to zero datum (areoid)
- ◆ extvar(19 - 20) Radiative fluxes ( W/m<sup>2</sup>) at Shortwave (SW = solar wavelength below 5 microns) and at Longwave (LW = thermal infrared beyond 5 microns) incident to the surface.
- ◆ extvar(21 - 22) Radiative fluxes ( W/m<sup>2</sup>) at Shortwave (SW = solar wavelength below 5 microns) and at Longwave (LW = thermal infrared beyond 5 microns) emitted to space at the top of the atmosphere.

## Error detection

When an error is raised by the subroutine, a message is delivered on the standard output and all the outputs are set to -999.

## 5.4 THE RIGHT USE OF THE ATMEMCD SUBROUTINE

### 5.4.1 PERTURBED ATMOSPHERE

The **perturbation consisting to add  $n$  times the standard deviation to the mean value** (type 5) must not be used to create randomly perturbed atmospheres, but only as a mean to globally overestimate or underestimate the profiles of the meteorological variables. To generate randomly perturbed atmospheres you must use small or large scale perturbations which take into account some correlation of perturbations in the space and between variables. Then when you use the type 5 perturbation, you have to keep the same  $n$  factor along the whole trajectory to avoid to introduce unrealistic gradients between consecutive values.

When you generate a randomly perturbed atmosphere **using the large scale perturbations** to simulate a trajectory, you will have to give the same seed number input for all the points of your trajectory to retain the correlation between these points.

When **using the perturbation due to gravity wave propagation (small scale perturbation)**, if you generate a vertical profile, the same phase, then the seed number, must be used for the whole profile. If you simulate a trajectory with a high resolution, that is with small distance between two consecutive points, it doesn't make much sense to reset randomly the phase because it can give huge, unrealistic horizontal gradients. Then the better is to hold the phase constant, that is hold the same seed number for all the trajectory.

Of course, if you use the large **and** small scale perturbations, the same seed number must be used for all the points of the trajectory or vertical profile.

### 5.4.2 RUNNING TIME

To make the computation time faster, the data corresponding to the season determined by the input 'xdate' are read and loaded from the database at the first call of the 'atmemcd'. This loading is time consuming, but these data are loaded once and then used for the further calls, as long as the season does not change.

In the same way, only the strictly required data are loaded : for example, if no perturbation are requested, only the mean values are loaded.

If you have to simulate several trajectories, in the same season, the best way to save time is to loop on the simulations at the main program level. This way the data are not reloaded from the database. If you want to simulate trajectories thought different perturbed atmospheres, you can use *seedout* value as new seed number for the next atmosphere.

If the supplementary variables are requested, this implies an extra running time to compute them and to load data used for small and large scale perturbation computation if large and small scale perturbations are not already requested.

## 6 ANNEXE : MCD CONTENTS

### 6.1 DATABASE FILE NAMING CONVENTIONS

The data in the MCD have been written using the Data Retrieval and Storage (DRS) library. These binary data can be accessed using the DRS library subroutines provided in / mcd / drs\_lib /.

You need files ending with filename extension **.dic** and **.dat**. Files ending with **.ctl** are provided but not used by the subroutine ATMEMCD.

Files ending with **.dat** correspond to the MCD data in binary format.

Files ending with **.dic** are DRS dictionary files.

Files ending with **.ctl** are provided for accessing the database using a graphical software package GrADS (not provided).. See <http://grads.iges.org/grads> and the User Manual [RD2] for more details on GrADS.

#### 6.1.1 ATMOSPHERIC DATABASE FILE NAMING CONVENTION

The file naming convention for each file with filename extension '**.dic**', '**.dat**' and '**.ctl**' is as follows :

Data Filename = 'scen''seas''type'.'filename extension'

where 'scen' denotes the dust scenario type :

'scen' = 'mgs' indicates Mars Global Surveyor scenario,

'scen' = 'low' indicates low dust scenario,

'scen' = 'vik' indicates Viking Lander scenario data,

'scen' = 'ds2' indicates dust storm with optical depth 2 (moderate storm),

'scen' = 'ds5' indicates dust storm with optical depth 5 (heavy storm),

where 'seas' denotes the season number :

'seas' = 's01' is season 1,  $L_s = 0^\circ - 30^\circ$ ,

'seas' = 's02' is season 2,  $L_s = 30^\circ - 60^\circ$ ,

'seas' = 's03' is season 3,  $L_s = 60^\circ - 90^\circ$ ,

'seas' = 's04' is season 4,  $L_s = 90^\circ - 120^\circ$ ,

'seas' = 's05' is season 5,  $L_s = 120^\circ - 150^\circ$ ,

'seas' = 's06' is season 6,  $L_s = 150^\circ - 180^\circ$ ,

'seas' = 's07' is season 7,  $L_s = 180^\circ - 210^\circ$ ,

'seas' = 's08' is season 8,  $L_s = 210^\circ - 240^\circ$ ,

'seas' = 's09' is season 9,  $L_s = 240^\circ - 270^\circ$ ,

'seas' = 's10' is season 10,  $L_s = 270^\circ - 300^\circ$ ,



‘seas’ = ‘s11’ is season 11,  $L_s = 300^\circ - 330^\circ$ ,

‘seas’ = ‘s12’ is season 12,  $L_s = 330^\circ - 360^\circ$ ,

‘seas’ = ‘all’ is the whole year for the Empirical Orthogonal Functions (EOF) data for the large-scale variability model,

and where ‘type’ indicates the type of data in the file :

‘type’ = ‘me’ means “mean data”,

‘type’ = ‘sd’ means “standard deviation data”,

‘type’ = ‘eo’ means EOF data for large scale perturbations.

### 6.1.2 OROGRAPHIC DATABASE FILE NAMING CONVENTION

Three files, ‘**moutain.dat**’, ‘**moutain.dic**’ and ‘**mountain.ctl**’, are provided, which contain maps of the topographic height on Mars, map of the zero datum areoid (radius from the center of Mars) and sub-grid standard deviation of the topographic height.

The model of surface topography used by MCD is the topography retrieved by the Mars Orbiter laser Altimeter (MOLA) aboard Mars Global Surveyor. Note that the MOLA areoid is not the same as the DTM zero datum previously used (it is usually higher)

## 6.2 DIMENSIONAL REPRESENTATION

Each file with the mentioned file naming convention contains a set of variables stored with a specific structural representation which depends on the variable type.

A summary of the variables type, name and dimensional representation is given in section 4.3 for the variables accessed by the ‘atmemcd’ subroutine. For the other variables, see [RD2]

### 6.2.1 DEFINITIONS

- **dust scenario representation** : see file naming convention.
- **seasonal representation** : see file naming convention.
- **horizontal structure** : grid of  $5^\circ \times 5^\circ$  longitude and latitude points ; 72 longitude points numbered from  $0^\circ$  to  $355^\circ$  and 36 latitude points numbered from  $-87.5^\circ$  to  $87.5^\circ$ .
- **vertical structure** : the database vertical coordinate is defined by the sigma levels

$$\sigma = \frac{p}{p_s}$$

where  $p_s$  is the surface pressure and  $p$  is the pressure at the altitude of the point. Hence,  $\sigma$  is 1 at the surface and 0 at infinite height.

- **temporal representation** : mean data are stored 12 times per seasonal mean Martian day, using prime meridian time, not local time. Day to day standart deviation data are only stored once per season. (669 days in a Martian year splitted in 12 seasons).

- **longitudinal structure of the EOF large scale variability model** : first element in longitude is  $-180^\circ$  and last element is  $160^\circ$ . Step size is  $20^\circ$ .
- **latitudinal structure of the EOF large scale variability model** : first element in latitude is  $-77.5^\circ$  and last element is  $82.5^\circ$ .
- **statistical structure** : series including 72 coefficients calculated over the entire year.

### 6.3 DATA STRUCTURAL REPRESENTATION SUMMARY

#### 6.3.1 MEAN PARAMETERS

- ‘t’ : mean temperatures.  
 ‘u’ : mean eastward winds.  
 ‘v’ : mean northward winds.  
*Other 3D variables* : q2 (Turbulent kinetic energy)  
 ‘rho’ : mean densities.  
 ‘ps’ : mean surface pressures.  
 ‘tsurf’ : mean surface temperatures.  
*Other 2D variables* : co2ice, emis, radiative fluxes.

Data Name	Horizontal Structure $5^\circ \times 5^\circ$	Vertical Structure $\sigma$ levels	Temporal Structure 12 times a day	Seasonal Structure 12 times a year	Dust Scenario
t	√	√	√	√	√
u	√	√	√	√	√
v	√	√	√	√	√
rho	√	√	√	√	√
ps	√		√	√	√
tsurf	√		√	√	√

#### 6.3.2 STANDARD DEVIATION PARAMETERS

- ‘sdt’ : standard deviation temperatures.  
 ‘sdu’ : standard deviation eastward winds.  
 ‘sdv’ : standard deviation northward winds.  
 ‘sdrho’ : standard deviation densities.  
 ‘sdps’ : standard deviation surface pressures.  
 ‘sdtsurf’ : standard deviation surface temperatures.  
*Other 2D variable* : sdco2ice, sdemis

Data Name	Horizontal Structure $3.75^\circ \times 3.75^\circ$	Vertical Structure $\sigma$ levels	Temporal Structure 1 time a day	Seasonal Structure 12 times a year	Dust Scenario
sdt	√	√	√	√	√
sdu	√	√	√	√	√
sdv	√	√	√	√	√
sdrho	√	√	√	√	√
sdps	√		√	√	√
sdtsurf	√		√	√	√

### 6.3.3 EOF PARAMETERS

- 'normt' : normalization factors for temperature.  
 'normu' : normalization factors for eastward wind.  
 'normv' : normalization factors for northward wind.  
 'normp' : normalization factors for pressure.  
 'normr' : normalization factors for density.  
 't' : EOFs for temperature. 'u' : EOFs for eastward wind.  
 'v' : EOFs for northward wind.  
 'rho' : EOFs for density.  
 'ps' : EOFs for pressure.  
 'pcsmth' : smooth principal components (PC).  
 'pcvar' : PCs with variance.

Data Name	Longitudinal Structure	Latitudinal Structure	Vertical Structure $\sigma$ levels	Statistical Structure	Temporal Structure 669 times a year	Dust Scenario
normt		√				√
normu		√				√
normv		√				√
normp		√				√
normr		√				√
t	√	√	√	√		√
u	√	√	√	√		√
v	√	√	√	√		√
rho	√	√	√	√		√
ps	√	√		√		√
pcsmth		√		√	√	√
pcvar		√		√	√	√

### 6.3.4 OROGRAPHIC PARAMETERS

- 'topogy' : maps the topographic height on Mars.  
 'substd' : standard deviation of the topographic height (for computing gravity wave perturbations).  
 'areoid' : areoid radius (m)

Data Name	Horizontal Structure $5^\circ \times 5^\circ$
topogy	√
Substd	√
areoid	√