# MARS CLIMATE DATABASE v1.0
# USER MANUAL
# (ESTEC Contract 11369/95/NL/JG)

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# Contents

# 1 Introduction

The Mars Climate Database (MCD) is a database of atmospheric statistics compiled from state-of-the art Global Circulation Model simulations of the Martian atmosphere. The models used to compile the statistics have been extensively validated using available observational data and represent the current best knowledge of the state of the Martian atmosphere given the observations and the physical laws that govern the atmospheric circulation and surface conditions on the planet.

The MCD contains simulated data on $3.75° x 3.75°$ longitude latitude grid from the surface up to an approximate altitude of $90 km$. If data is required above this altitude range it is recommended that the user run the latest version of MarsGRAM which provides a parametrisation of the upper atmosphere and thermosphere. Four dust scenarios have been used representing Viking type conditions (without dust storms), clear atmosphere conditions (similar to those observed recently by Phobos), a moderate global dust storm and an intense global dust storm. Fields are stored 12 times a day for 12 Martian "seasons" to give a comprehensive representation of the annual and diurnal cycles. The user is referred to the Detailed Design Document for further information.

This document provides the user of the MCD with a detailed description of how to access the data in the database. Detailed descriptions of the models and of the validation procedure are available in other documents relating to the project.

**Note:** This document refers to the first release of the Mars Climate Database (MCDv1.0). Future releases will contain updates to the database, to the access software and to the documentation. If you have any queries, or if you want to find out if this is the latest version of the MCD please email `euromars@lmd.ens.fr`.

# 2 Installation

## 2.1 Minimum Software Requirements

The MCD is designed to operate in the UNIX environment on a modern workstation. Access software is written in FORTRAN 77 for which a compiler is needed. Most UNIX workstations will possess such a complier e.g. `f77`.

The data in the MCD is written using the Data Retrieval and Storage (DRS) library developed for the Program for (Terrestrial) Climate Model Diagnosis and Inter comparison (PCMDI). The library is available (pre-compiled for common platforms or as source code) from the Lawrence Livermore National Laboratory World Wide Web server at

`http://www-pcmdi.llnl.gov/drach/DRS.html`

Please follow the instructions on how to down load the library.

We also recommend that you install the Grid Analysis and Display System (GrADS) which is an excellent system for displaying graphical output from geophysical datasets. GrADS can read DRS files and display their contents using a few easy instructions. GrADS can be down loaded from the Institute for Global Environment and Society World Wide Web server at

`http://grads.iges.org/grads`

## 2.2 Installing the MCD

To install the MCD you must have 0.9 Gb of disk space free for the full distribution and a DAT drive; DDS1 or DDS2 format tapes can be supplied on request. If absolutely necessary the amount of disk space needed could be reduced by only retaining a limited range of dust scenarios or seasons of interest within the `mcd/data` subdirectory. Set your working directory to the one which will contain the database, place the cassette in the DAT drive and type,

```
tar -xvf /dev/rmt0h
```

where `/dev/rmt0h` is the name of the DAT device on your machine and may vary. This will create a directory `mcd` in which all the MCD data and software is stored.

# 3 Data Structure

## 3.1 Filename Conventions

The MCD data is stored in various files in the directory

```
mcd/data
```

e.g.

```
mcd/data/viks04me.dat
```

The file naming convention is as follows:

- The first 3 characters denote the dust scenario. The various scenarios are explained in an appendix to the Detailed Design Document.
  - `ds2` indicates a dust storm with optical depth 2.
  - `ds5` indicates a dust storm with optical depth 5.
  - `low` indicates low dust data.
  - `vik` indicates Viking scenario data.
- The next 3 characters indicate the season number. The northern hemisphere spring equinox is at $L_S = 0°$, with northern summer solstice at $L_S = 90°$, autumn equinox at $L_S = 180°$ and winter solstice at $L_S = 270°$.
  - `s01` is season 1, $L_S = 0° - 30°$.
  - `s02` is season 2, $L_S = 30° - 60°$.
  - `s03` is season 3, $L_S = 60° - 90°$.
  - `s04` is season 4, $L_S = 90° - 120°$.
  - `s05` is season 5, $L_S = 120° - 150°$.
  - `s06` is season 6, $L_S = 150° - 180°$.
  - `s07` is season 7, $L_S = 180° - 210°$.
  - `s08` is season 8, $L_S = 210° - 240°$.
  - `s09` is season 9, $L_S = 240° - 270°$.
  - `s10` is season 10, $L_S = 270° - 300°$.
  - `s11` is season 11, $L_S = 300° - 330°$.
  - `s12` is season 12, $L_S = 330° - 360°$.
- The next 2 characters indicate the type of data in the file.
  - `me` indicates mean data.
  - `sd` indicates standard deviation data.

– `eo` indicates Empirical Orthogonal Function (EOF) data (for the large scale variability model).

- The last 4 characters (the filename extension) indicate the type of file.
  – `.dat` is a DRS data file.
  – `.dic` is a DRS dictionary file.
  – `.ctl` is a GrADS descriptor file.

Hence the file `mcd/data/viks04me.dat` contains mean data for the Viking dust scenario for season 4.

## 3.2 File Data Structures

Mean data files (`me`) contain 12 seasonal mean values (corresponding to 12 universal times of day) for the following variables,

| Mean variable | symbol | units | 2-D or 3-D |
|---|---|---|---|
| $CO_2$ ice cover | co2ice | $kg\, m^{-2}$ | 2-D |
| Surface emissivity | emis | none | 2-D |
| Surface temperature | tsurf | $K$ | 2-D |
| Surface pressure | ps | $Pa$ | 2-D |
| Atmospheric temperature | t | $K$ | 3-D |
| Zonal (east-west) wind | u | $m\, s^{-2}$ | 3-D |
| Meridional (north-south) wind | v | $m\, s^{-2}$ | 3-D |
| Atmospheric density | rho | $kg\, m^{-3}$ | 3-D |
| Boundary layer eddy kinetic energy | q2 | $m^2\, s^{-2}$ | 3-D |

Standard deviation data files (`sd`) contain seasonal standard deviation values of the following variables,

| Standard deviation | symbol | units | 2-D or 3-D |
|---|---|---|---|
| $CO_2$ ice cover | sdco2ice | $kg\, m^{-2}$ | 2-D |
| Surface emissivity | sdemis | none | 2-D |
| Surface temperature | sdtsurf | $K$ | 2-D |
| Surface pressure | sdps | $Pa$ | 2-D |
| Atmospheric temperature | sdt | $K$ | 3-D |
| Zonal (east-west) wind | sdu | $m\, s^{-2}$ | 3-D |
| Meridional (north-south) wind | sdv | $m\, s^{-2}$ | 3-D |
| Atmospheric density | sdrho | $kg\, m^{-3}$ | 3-D |
| Boundary layer eddy kinetic energy | sdq2 | $m^2\, s^{-2}$ | 3-D |

EOF data files (`eo`) contain normalised multi-dimensional EOFS of density, zonal wind, meridional wind, temperature and surface pressure as well as some normalisation factors, eigenvalues and principal component model coefficients. It is recommended that you use the software supplied to access and exploit the data in these files.

In addition there are three files, `mountain.ctl`, `mountain.dat` and `mountain.dic` which contain maps of the topographic height on Mars and sub-grid scale standard deviation of the topographic height (useful for computing gravity wave perturbations).

# 4 Accessing Data

## 4.1 Choosing a Method of Database Access

There are three main ways of accessing data from the MCD which have currently been implemented.

Firstly, a complete interface, MCDGM, is supplied with the Mars Climate Database as a set of FORTRAN source code in the `mcd/mcdgm` subdirectory. The MCDGM interface performs in a very similar way to MarsGRAM version 3.5. It is intended to make the database as easy to use as possible for those with prior experience of MarsGRAM as well as providing straightforward access for all users to the complete database, including the variability model and orographic wave model. It can be run in interactive or batch mode.

Secondly, it is possible to access the database directly from within any program, written in FORTRAN or C, by using the DRS library. This gives the most flexibility for particular applications, although it does demand a greater understanding of how the database and variability models, if they are required, should be used. Some examples of programs which open and read the database files are given, along with some useful general purpose routines, and the MCDGM interface itself also provides an example of source code which accesses the data files using the DRS library.

Thirdly, control files, instructions and example scripts (in the `mcd/grads subdirectory`, are provided for accessing the database using GrADS. GrADS is a freely available package for access, manipulation and display of earth science data which runs on many computing platforms. This provides a very easy method of examining and plotting mean and standard deviation data from the MCD in a variety of formats. It is not straightforward at present to use the variability model or orographic wave model from within a GrADS script; though GrADS or any other visualization package could, of course, be applied to the output from either of the first two access methods when these features are required. A second disadvantage is that GrADS requires a uniform vertical grid. Since the database has been stored in terrain-following $\sigma$ levels ($\sigma = p/p_s$, where $p$ is the pressure and $p_s$ is the surface pressure which varies as a function of position and time), to retain the model's high resolution near the surface, this means that it is not possible for GrADS to display data on a true height coordinate without writing FORTRAN routines to read the entire database, convert to height coordinates by integrating the hydrostatic equation for each profile, add the height of the local surface above the geoid, interpolate onto a uniform height coordinate grid and then re-write the database and control files in this new form. This process is perfectly feasible using the FORTRAN routines supplied with the MCD, but requires as much disk space again to store the new data and results in losing nearly all the high-vertical resolution, near-surface information. This is not worthwhile for simple data visualization and so the GrADS routines supplied access the standard $\sigma$ level database; $\ln(\sigma)$ is approximately proportional to height above the local surface for an isothermal atmosphere (very roughly for Mars, $z \approx 10\ln(\sigma)\ km$) and so a $\ln(\sigma)$ axis is adequate for most plots. For individual profiles, the surface pressure at that location and time can be read and multiplied by $\sigma$ to give a pressure-coordinate axis. If accurate height is a priority then access to the database should be made through either of the first two methods. Nevertheless, GrADS is recommended as a way of producing reasonable quality colour or black and white graphical output quickly and is ideal for examining one, two or three dimensional "slices" through the data.

## 4.2 MCDGM – the MarsGRAM-style interface

### 4.2.1 In interactive mode

Given the widespread use of MarsGRAM in the community a MarsGRAM-style interface is supplied with the MCD. The software for this is contained in the `mcd/mcdgm` directory and the main program is called `mcdgm`. To compile this software simply issue the command `make`. A comprehensive explanation of the interface is included in the Detailed Design Document.

The MCDGM interface performs in a very similar way to MarsGRAM version 3.5 with regards to input and output and is self-explanatory in its usage. A sample interactive session is shown below.

```
> mcdgm
Mars Climate Database Version 1.0 - MarsGRAM style interface
Enter file name for full output listing (CON for screen listing):
con
Enter file name for tabulated output:
list
Enter month, day of month, 4-digit year,
and maximum number of positions (all integers) - Enter zero
number of positions to read positions from TRAJDATA file
7,20,1976,10
Enter initial GMT Time in Hours, Minutes, Seconds (all integers)
12,50,0
Date = 7/20/1976 Julian Date = 2442980.0 GMT Time = 12:50:  0.0
Ls = 99.1 degrees for this date.
Select dust scenario (1) Viking dust scenario (2) Low dust scenario
(3) Dust storm, tau=2 (4) Dust storm, tau=5
1
Enter perturbation model:  1=none, 2=large scale
3=small scale, 4=large scale and small scale
1
Enter seed for random number generator (any positive integer < 30,000)
1

Select x-code and y-code for plotable output versus desired parameter(s):

Code Parameter
---- ------------------------------------------------
1 Height (above reference ellipsoid, km)
2 Height (above local terrain, km)
3 Latitude (deg.)
4 Longitude (deg.)
5 Time from start (Earth seconds)
6 Time from start (Martian Sols)
7 Areocentric Longitude of Sun, Ls (deg.)
8 Hour Angle for Local Time (Mars hours * 15)

Use y-code = 0 for plotable output vs x-code variable only
2,0
Enter 0 for normal (MKS) units for density,
1 for log-base-10 or 2 for % difference from COSPAR
0
Enter initial latitude and west longitude in degrees
22.,48.
Surface elevation = -1.217483 km at this location
Enter Initial Height relative to zero datum (km)
-1.217483
Enter Increments in Height (km), Latitude (deg.),
West Longitude (deg.), and Time (sec.)
10.,0.,0.,0.
```

#### 4.2.2 Output produced

The above example produces the following output at the console (Viking Lander 1 entry profile). We suggest that the user first try this example to insure that the MCDGM interface has been installed correctly.

```
 Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
 Height =  -1.22 km (   0.00 km)   Scale Hgt H(p) = 12.26 H(rho) = 12.26 km
 Latitude =   22.000 degrees       West Longitude =   48.000 degrees
 Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
 Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
 Temperature =   238.4 K           Pressure =    7.262E+02 N/m**2
 Density (Low, Avg., High) =      1.569E-02   1.593E-02   1.618E-02 kg/m**3
 Departure, COSPAR NH Mean =        -9.6 %      -8.2 %      -6.8 %
 Density perturbation =           2.28 % of mean value
 Eastward Wind =    -2.8 m/s       Northward Wind =    -1.2 m/s
 ---------------------------------------------------------------------------
 Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
 Height =   8.78 km (  10.00 km)   Scale Hgt H(p) = 11.20 H(rho) = 11.20 km
 Latitude =   22.000 degrees       West Longitude =   48.000 degrees
 Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
 Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
 Temperature =   217.9 K           Pressure =    4.365E+02 N/m**2
 Density (Low, Avg., High) =      8.238E-03   8.564E-03   8.891E-03 kg/m**3
 Departure, COSPAR NH Mean =        14.9 %      19.5 %      24.0 %
 Density perturbation =           1.27 % of mean value
 Eastward Wind =    -5.8 m/s       Northward Wind =    -0.8 m/s
 ---------------------------------------------------------------------------
 Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
 Height =  18.78 km (  20.00 km)   Scale Hgt H(p) = 10.52 H(rho) = 10.52 km
 Latitude =   22.000 degrees       West Longitude =   48.000 degrees
 Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
 Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
 Temperature =   204.6 K           Pressure =    2.300E+02 N/m**2
 Density (Low, Avg., High) =      3.696E-03   3.847E-03   3.997E-03 kg/m**3
 Departure, COSPAR NH Mean =        25.3 %      30.4 %      35.6 %
 Density perturbation =           0.57 % of mean value
 Eastward Wind =   -22.9 m/s       Northward Wind =     2.2 m/s
 ---------------------------------------------------------------------------
 Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
 Height =  28.78 km (  30.00 km)   Scale Hgt H(p) =  9.46 H(rho) =  9.46 km
 Latitude =   22.000 degrees       West Longitude =   48.000 degrees
 Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
 Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
 Temperature =   184.0 K           Pressure =    8.974E+01 N/m**2
 Density (Low, Avg., High) =      1.577E-03   1.649E-03   1.722E-03 kg/m**3
 Departure, COSPAR NH Mean =        41.7 %      48.2 %      54.7 %
 Density perturbation =           0.25 % of mean value
 Eastward Wind =   -35.6 m/s       Northward Wind =    11.2 m/s
 ---------------------------------------------------------------------------
 Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
 Height =  38.78 km (  40.00 km)   Scale Hgt H(p) =  8.13 H(rho) =  8.13 km
 Latitude =   22.000 degrees       West Longitude =   48.000 degrees
 Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
 Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
 Temperature =   158.2 K           Pressure =    2.928E+01 N/m**2
 Density (Low, Avg., High) =      5.874E-04   6.399E-04   6.924E-04 kg/m**3
 Departure, COSPAR NH Mean =        51.3 %      64.8 %      78.4 %
 Density perturbation =           0.13 % of mean value
 Eastward Wind =   -45.6 m/s       Northward Wind =    12.0 m/s
 ---------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
 Height =  48.78 km (  50.00 km)   Scale Hgt H(p) =  6.99 H(rho) =  6.99 km
 Latitude =   22.000 degrees       West Longitude =   48.000 degrees
 Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
 Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
 Temperature =   136.1 K           Pressure =    8.681E+00 N/m**2
 Density (Low, Avg., High) =      1.793E-04   2.057E-04   2.320E-04 kg/m**3
 Departure, COSPAR NH Mean =        43.3 %      64.4 %      85.5 %
 Density perturbation =          -0.02 % of mean value
 Eastward Wind =   -67.3 m/s       Northward Wind =     7.3 m/s
```

```
--------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
Height =  58.78 km (  60.00 km)   Scale Hgt H(p) =  7.42 H(rho) =  7.42 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Temperature =   144.4 K           Pressure =    2.323E+00 N/m**2
Density (Low, Avg., High) =      4.463E-05   5.857E-05   7.251E-05 kg/m**3
Departure, COSPAR NH Mean =        20.3 %      57.9 %      95.5 %
Density perturbation =           0.01 % of mean value
Eastward Wind =   -96.8 m/s       Northward Wind =   -15.0 m/s
--------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
Height =  68.78 km (  70.00 km)   Scale Hgt H(p) =  8.09 H(rho) =  8.09 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Temperature =   157.4 K           Pressure =    1.119E+00 N/m**2
Density (Low, Avg., High) =      1.066E-05   1.692E-05   2.318E-05 kg/m**3
Departure, COSPAR NH Mean =         3.9 %      64.9 %     125.9 %
Density perturbation =           0.00 % of mean value
Eastward Wind =   -90.5 m/s       Northward Wind =     8.8 m/s
--------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
Height =  78.78 km (  80.00 km)   Scale Hgt H(p) =  8.64 H(rho) =  8.49 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Exospheric Temp. =  336.0 K       Tbase =  159.6 K    Zbase =  129.3 km
Temperature =   160.8 K           Pressure =    3.899E-01 N/m**2
Density (Low, Avg., High) =      3.245E-06   6.705E-06   1.016E-05 kg/m**3
Departure, COSPAR NH Mean =        20.3 %     148.7 %     277.0 %
Density perturbation =          -3.70 % of mean value
Eastward Wind =   -42.4 m/s       Northward Wind =    39.2 m/s
--------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   99.1 deg.
Height =  88.78 km (  90.00 km)   Scale Hgt H(p) =  8.89 H(rho) =  8.73 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    24.98 deg.      Mars Orbital Radius = 1.639 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Exospheric Temp. =  336.0 K       Tbase =  159.6 K    Zbase =  129.3 km
Temperature =   163.9 K           Pressure =    4.785E-02 N/m**2
Density (Low, Avg., High) =      1.367E-06   1.519E-06   1.671E-06 kg/m**3
Departure, COSPAR NH Mean =        93.3 %     114.8 %     136.3 %
Density perturbation =          -8.28 % of mean value
Eastward Wind =   -14.5 m/s       Northward Wind =    76.8 m/s
--------------------------------------------------------------------------
```

Also the following data files are produced, holding the data indicated tabulated against a user specified coordinate. Data is presented in SI units unless otherwise stated.

| Filename | Contents |
|---|---|
| DENSAV | Mean density |
| DENSHI | High value of density |
| DENSLO | Low value of density |
| DENSRM | Percentage density standard deviation |
| DENSRP | Large scale density perturbation |
| DENSWA | Small scale (garvity wave) density perturbation |
| EWWIND | East-West (zonal) wind |
| HGTrho | Density scale height |
| NSWIND | North-South (meridional) wind |
| PRES | Pressure |
| TAVG | Mean ground temperature |
| TEMP | Mean atmospheric temperature |
| TMAX | Maximum ground temperature |
| TMIN | Minimum ground temperature |
| list (user specified filename) | Tabulated output (see below) |

The user specified `list` file contains tabulated output in a column wise basis of the following variables: time, height, latitude, longitude, density, temperature, zonal wind, meridional wind, percentage density standard deviation, small scale (gravity wave) density perturbation and $L_s$.

#### 4.2.3 Running the MCDGM in batch mode

Alternatively the user can run the MCDGM interface in batch mode using a simple unix script. e.g. (can be found in the file mcdbj).

```
#
# Script to run the Mars Climate Database MarsGRAM style interface (mcdgm)
#
set workdir = "/YOUR/WORK/DIRECTORY/PATH/HERE"
set mcddir = "/YOUR/MCD/PATH/HERE"
#
cd $workdir
#
rm -f mcdgm.in
#
cat > mcdgm.in << eof_mcdgm.in
vl1_ent.list
vl1_ent.out
7
20
1976
10
12
50
0
1
1
1
2
0
0
22.
48.
-1.217483
10
0
```

```
0
0
eof_mcdgm.in
#
$mcddir/mcdgm < mcdgm.in > mcdgm.out
#
```

This script can be executed as a background job e.g.

```
> nice -19 mcdbj &
```

or at a later time using `at` or some batch queueing software, e.g.

```
> at 10pm Wednesday mcdbj
```

## 4.3 Using the DRS Library

Data in the MCD is written in DRS format. If you are not using a package (such as GrADS) which can read DRS format you can write a FORTRAN (or C) program to access the data using the DRS library. We supply several FORTRAN subroutines which are also used in the MarsGRAM-style interface to the MCD (see previous section) to aid you in this process. Please ensure that the DRS library has been installed on your system.

### 4.3.1 Opening and Closing Files

To access the data you must first open the file. An example of opening a MCD file is shown below.

```
     program mcd_read
.
.
.
#include "drsdef.h"
.
.
.
     integer udrs !DRS file channel number
     integer ierr
     character*255 datfile !DRS data file
     character*255 dicfile !DRS dictionary file
.
.
.
     udrs=60
     datfile='/YOUR/PATH/NAME/HERE/mcd/data/viks04me.dat'
     dicfile='/YOUR/PATH/NAME/HERE/mcd/data/viks04me.dic'
     ierr=aslun(udrs,dicfile,udrs+1,datfile,IDRS_READ)
.
.
.
     ierr=cllun(udrs)
.
.
.
     end
```

### 4.3.2 Reading Data

Once the file has been opened you can read data from the MCD using one of two subroutines. Both routines use bilinear interpolation to translate the database fields to the user specified longitude and latitude. The hydrostatic equation is solved to find the value of $\sigma$ (the MCD vertical coordinate) corresponding to the user specified height above the surface and linear interpolation is $\sigma$ is performed.

`var2d.f` Reads one value of a 2-D field from the MCD. An example might be

```
      integer udrs !DRS file channel number
      real lon !Longitude of point
      real lat !Latitude of point
      real time !MCD universal time
      character*16 name !Name of variable
      real a !Value of variable at point
.
.
.
c
c Open DRS file somewhere
c
.
.
.
      udrs=60
      lon=90.
      lat=45.
      time=1.
      name='tsurf'
      call var2d(udrs,a,lon,lat,time,name)
```

`var3d.f` Reads one value of a 3-D field from the MCD. The subroutine `getsi.f` must be called first to translate height into the $\sigma$ levels used in the MCD. An example might be

```
#include "drsdef.h"
      integer udrs !DRS file channel number
      real lon !Longitude of point
      real lat !Latitude of point
      real height !Height (km) of varaible above surface
      real time !MCD universal time
      character*16 name !Name of variable
      real a !Value of variable at point
      real sigma(25) !Model sigma levels
      integer levl
      integer levh
      real levw
.
.
.
c
c Open DRS file somewhere
c
.
.
.
c
c Get sigma levels from DRS file
```

```
c
     ierr = cluvdb()
     ierr = setname(' ','sigma',' ',' ',' ')
     ierr = getdat(udrsm,sigma,IDRS_BYTES_PER_WORD*nl)
.
.
.
     udrs=60
     lon=90.
     lat=45.
     height=60.
     time=1.
     name='rho'
     call getsi(udrs,sigma,lon,lat,height,time,levh,levl,levw)
     call var3d(udrs,a,lon,lat,levh,levl,levw,time,name)
```

### 4.3.3 Other useful routines

In addition to these basic subroutines some further routines can be used to aid in the accessing of data.

`atime.f` This routine takes the local time at a particular longitude and turns it into database universal time. Usage is

```
     real localtime !Local time
     real univtime !Universal time
     real lon !Longitude
.
.
.
     call atime(localtime,univtime,lon)
```

`grwpb.f` This routine computes a small scale gravity wave perturbation to a variable (only density, temperature, zonal wind and meridional wind).

```
     integer udrs !DRS file channel number
     real lon !Longitude of point
     real lat !Latitude of point
     real height !Height (km) of varaible above surface
     real time !MCD universal time
     character*16 name !Name of variable
     real sigma(25) !Model sigma levels
     integer levl
     integer levh
     real levw
     real dvardz
     real rho
     real u
     real v
     real pert
.
.
.
c
c Open DRS file somewhere
c
```

```
.
.
.
c
c Get sigma levels from DRS file
c
     ierr = cluvdb()
     ierr = setname(' ','sigma',' ',' ',' ')
     ierr = getdat(udrsm,sigma,IDRS_BYTES_PER_WORD*nl)
.
.
.
     udrs=60
     lon=90.
     lat=45.
     height=60.
     time=1.
     call getsi(udrs,sigma,lon,lat,height,time,levh,levl,levw)
     name='u'
     call var3d(udrs,u,lon,lat,levh,levl,levw,time,name)
     name='v'
     call var3d(udrs,v,lon,lat,levh,levl,levw,time,name)
     name='rho'
     call var3d(udrs,rho,lon,lat,levh,levl,levw,time,name)
c
c Compute the vertical derivative of a variable
c
     call vgrad(udrs,lon,lat,height,time,sigma,dvardz,name)
c
c Small scale perturbation is in pert
c
     call grwpb(udrs,lon,lat,height,rho,u,v,time,dvardz,sigma,pert)
```

`eofpb.f` This routine computes a large scale EOF perturbation to a variable (only density surface pressure, temperature, zonal wind and meridional wind). Usage is

```
     integer ueof !DRS file channel number for EOF files
     integer usd !DRS file channel number for standard dev.
     real lon !Longitude of point
     real lat !Latitude of point
     real height !Height (km) of varaible above surface
     real time !MCD universal time
     real ls !Ls      character*16 name !Name of variable
     real sigma(25) !Model sigma levels
     integer levl
     integer levh
     real levw
     real s1
     real sd
     real gasd(6)
     real pertm
     real pertr
.
.
.
c
c Open DRS files somewhere
c
```

```
.
.
.
c
c Get sigma levels from DRS file
c
      ierr = cluvdb()
      ierr = setname(' ','sigma',' ',' ',' ')
      ierr = getdat(udrsm,sigma,IDRS_BYTES_PER_WORD*nl)
.
.
.
      udrs=60
      lon=90.
      lat=45.
      height=60.
      time=1.
      ls=250.
      call getsi(udrs,sigma,lon,lat,height,time,levh,levl,levw)
      if (levw.lt..5) then
        s1=sigma(levlow) !nearest sigma level
      else
        s1=sigma(levhi) !nearest sigma level
      endif
c
c Get standard deviation of variable from DRS file
c
      name='sdrho'
      call var3d(usd,sd,lon,lat,levh,levl,levw,time,name)
c
c Compute 6 Gaussian deviates with zero mean and unit standard deviation
c Note:  The same deviates must be used when computing a profile at
c a particular location.
c
      do i=1,6
        gasd(i)=gasdev()
      enddo
c
c Get EOF perturbation of variable from DRS file
c
      name='sdrho'
      call eofpb(ueof,pertm,pertr,gasd,lon,lat,s1,ls,sd,name)
c
c The perturbation is in pertm (trend) and pertr (random component)
c
```

`mount.f` Returns the orographic height in metres at a particular longitude and latitude. Usage is

```
      real lon !Longitude of point
      real lat !Latitude of point
      real oroheight !Height (m) of orography
      character*16 name /'orography'/ .
.
.
      lon=90.
      lat=45.
      call mount(lon,lat,oroheight,name)
```

## 4.4 Using GrADS

GrADS can be used for simple manipulation and display of mean and standard deviation data from the MCD and for more complicated calculations of derived quantities, e.g. vorticity. *N.B.* Some GrADS routines, in particular `hdivg` and `hcurl` which compute horizontal derivatives, assume that the data relates to the Earth; if they are used for calculating derived quantities from the database, results from them should always be multiplied by a factor of approximately 1.88 to account for the relative radii of Mars and the Earth. The dates used for the GrADS scripts are in Earth format, and are arbitrary, but the universal time of day is correct with one "hour" corresponding to 1/24 of a martian solar day (a martian solar day is 88775.2 seconds, so here 1 "hour" is actually about 3699 seconds). In the database 00:00 is midnight and 12:00 is noon at 0° longitude.

A simple GrADS session to plot the seasonal average surface temperature for season 4 from the Viking scenario simulation may go something like this:

```
> grads
Grid Analysis and Display System (GrADS) Version 1.5.1.15
Copyright (c) 1988-1995 by Brian Doty
Center for Ocean-Land-Atmosphere Studies
Institute for Global Environment and Society
mf 1 = add " " to parser
mf 2 = bug in gscrpt script search
mf 3 = NMC unstaggered eta grid xfrms
mf 4 = default to draw vector label in gxout vector
mf 5 = 32-bit IEEE floats on cray
mf 6 = bug in the mean function for 1-D grids
mf 7 = bug in malloc for script name using GASCRP environment variable
mf 8 = size of record script read increased to RSIZ-4 (gs.h)
mf 9 = wind rotation in NMC unstaggered eta grid xfrms and more accurate polar s ter pre proj
mf 10 = 2nd attempt at mean function bug fix 950728
mf 11 = Oblique Polar Stereo projection for CSU RAMS model 950808
mf 12 = FNMOC template support (h3 ih3 and f3)
mf 13 = enable cmark in gxout scatter
mf 14 = bug in hi and mres map data set for cray verion
mf 15 = bug in amean function
All Rights Reserved

Landscape mode?  (no for portrait):  yes
GX Package Initialization:  Size = 11 8.5

!!!!  32-BIT little endian MACHINE VERSION

ga> open viks05me
Scanning description file:  viks05me
Data file viks05me.dat is open as file 1
LON set to 0 360
LAT set to -88.125 88.125
LEV set to 0.9995 0.9995
Time values set:  2001:1:1:0 2001:1:1:0
ga> set mpdraw off
ga> display ave(tsurf,t=1,t=12)
Averaging.  dim = 3, start = 1, end = 12
Contouring:  150 to 230 interval 10
ga>
```

To produce hard copy, type `enable print filename.gx`, then display the data which you require and type `print` when you have what you want. A `clear` command will start a new page and `disable print` or `quit` at the end of the session closes the `filename.gx` file. The `.gx` file can be viewed again on the screen with the `gxtran` utility or converted to PostScript for printing with `gxps` or `gxeps`. These utilities, and instructions for using them, are provided with the GrADS distribution (whether you get `gxps`, `gxeps` or other programs with similar names depends on exactly which version of GrADS you obtain).

For more complicated output, or for repeated applications which can be run in batch mode, it is more convenient to write a GrADS script. Some are provided in the `mcd/grads` subdirectory; it might be necessary to change the path to the data files in front of the `.../mcd/data/viks04me` part to where the `mcd` directory has been installed on your machine if this has not been done already. The final part of the filename determines the dust scenario and season according to the code described previously in this document. These can be changed, and the titles modified accordingly, by editing the scripts. If different quantities are required from those which they plot, it should be straightforward to write new scripts using the ones supplied as templates. Most of the scripts are intended to produce output in portrait orientation, so either run GrADS and answer `no` to the initial landscape mode question, or specify portrait mode from the command line, `grads -p`. It is also convenient to always run the GrADS command `set mpdraw off`, which prevents GrADS from drawing outlines of countries on the Earth, although the scripts here will all do this explicitly when necessary; this could be achieved with a command aliased to `grads -pc "set mpdraw off"` which would run GrADS in portrait mode with no maps outlines.

The example script given below plots diurnal and zonal mean contour plots of temperature, zonal and meridional wind in a $\ln(\sigma)$–latitude coordinate system and shows how a relatively simple script can be used to extract mean data form the MCD files.

```
*
* zonal_tuv.gs
*
* Plots the zonal mean and diurnal time mean temperature, zonal and
* meridional velocity for one season.  GrADS should be run in portrait mode
* for this script.
*
'open /home/ares/md1/esa/mcd/data/viks04me'
'set t 1'
'set lat -90 90'
'set z 1 25'
'set x 1'
'set zlog on'
'set vpage 0 8.5 7 11'
'set parea 1 7  1 3.5'
'set grads off'
'set ylevs 1 0.5 0.2 0.1 0.05 0.02 0.01 0.005 0.002 0.001 0.0005 0.0002 0.0001'
'define Tave = ave(ave(T, lon=-180, lon=180, -b), t=1, t=12)'
'set gxout shaded'
'set rbrange 130 250 '
'set cint 10'
'display Tave'
'set gxout contour'
'set ccolor 0'
'set cint 10'
'display Tave'
'draw xlab Zonal/Diurnal Mean Temperature (K)'
'draw ylab Sigma'
'draw title MCD Viking dust, Ls = 90-120.'
'set vpage 0 8.5 3.5 7.5'
'set grads off'
'set ylevs 1 0.5 0.2 0.1 0.05 0.02 0.01 0.005 0.002 0.001 0.0005 0.0002 0.0001'
'define Uave = ave(ave(U, lon=-180, lon=180, -b), t=1, t=12) '
'set gxout shaded'
'set rbrange -140 140'
'set cint 20'
```

```
'display Uave'
'set gxout contour'
'set ccolor 0'
'set cint 20'
'display Uave'
'draw xlab Zonal/Diurnal Mean Zonal Wind (m/s)'
'draw ylab Sigma'
'set vpage 0 8.5  0. 4'
'set grads off'
'set ylevs 1 0.5 0.2 0.1 0.05 0.02 0.01 0.005 0.002 0.001 0.0005 0.0002 0.0001'
'define Vave = ave(ave(V, lon=-180, lon=180, -b), t=1, t=12)'
'set gxout shaded'
'set rbrange -30 30'
'set cint 5'
'display Vave'
'set gxout contour'
'set ccolor 0'
'set cint 5'
'display Vave'
'draw xlab Zonal/Diurnal Mean Meridinal Wind (m/s)'
'draw ylab Sigma'
```

Sample output from this script is given in figure 1.

The scripts which are provided in the `mcd/grads` subdirectory are briefly described below. Where necessary the scripts have been commented and they should provide a useful starting point.

- `anim_tsurf.gs` A simple animation of the diurnal cycle of surface temperature means during one season. Useful for a quick check that the data has been read correctly; a warm region (local afternoon) should be seen to propagate from east to west across the map.
- `map_ps.gs` Plots maps of the diurnal mean surface pressure and its (non-diurnal) standard deviation. GrADS should be run in portrait mode for this script.
- `map_windt.gs` Plots maps of the diurnal mean near-surface wind and surface temperature. GrADS should be run in portrait mode for this script.
- `profile.gs` This script gives the mean, and confidence limits at a chosen number of standard deviations, for surface variables and also plots the vertical profile of three dimensional variables from the Mars Climate Database. It is important to note that the standard deviation merely represents the variability between profiles at that location and the same local solar time of day during that season. It does not include any diurnal variability (this is respresented in the twelve means contained in the mean data file for different times of day) nor any small-scale variability nor any information about correlation and scales of variability within or between individual profiles (the last two points are addressed by the main database software).

  The longitude, latitude and local solar time are supplied as arguments. The longitude should be given in degrees east and the time in hours (00..24). This script must be edited to select a dust scenario and season and to change the title accordingly.

  A metafile, named using the plot parameters is written, e.g. profile_000_00_00.gx, which can then be viewed with `gxtran` or converted to postscript for printing with `gxps` or `gxeps`.

  GrADS should be run in portrait mode.
- `section_lat.gs` This script is similar to profile.gs, except that a range of latitudes can be given to produce a sigma-latitude section through the database.

  The longitude, first and last latitude and local solar time are supplied as arguments. If the latitude range given is too small, it is expanded to include several database gridpoints; otherwise profile.gs could be used. The longitude should be given in degrees east and the time in hours (00..24). This script must be edited to select a dust scenario and season and to change the title accordingly.

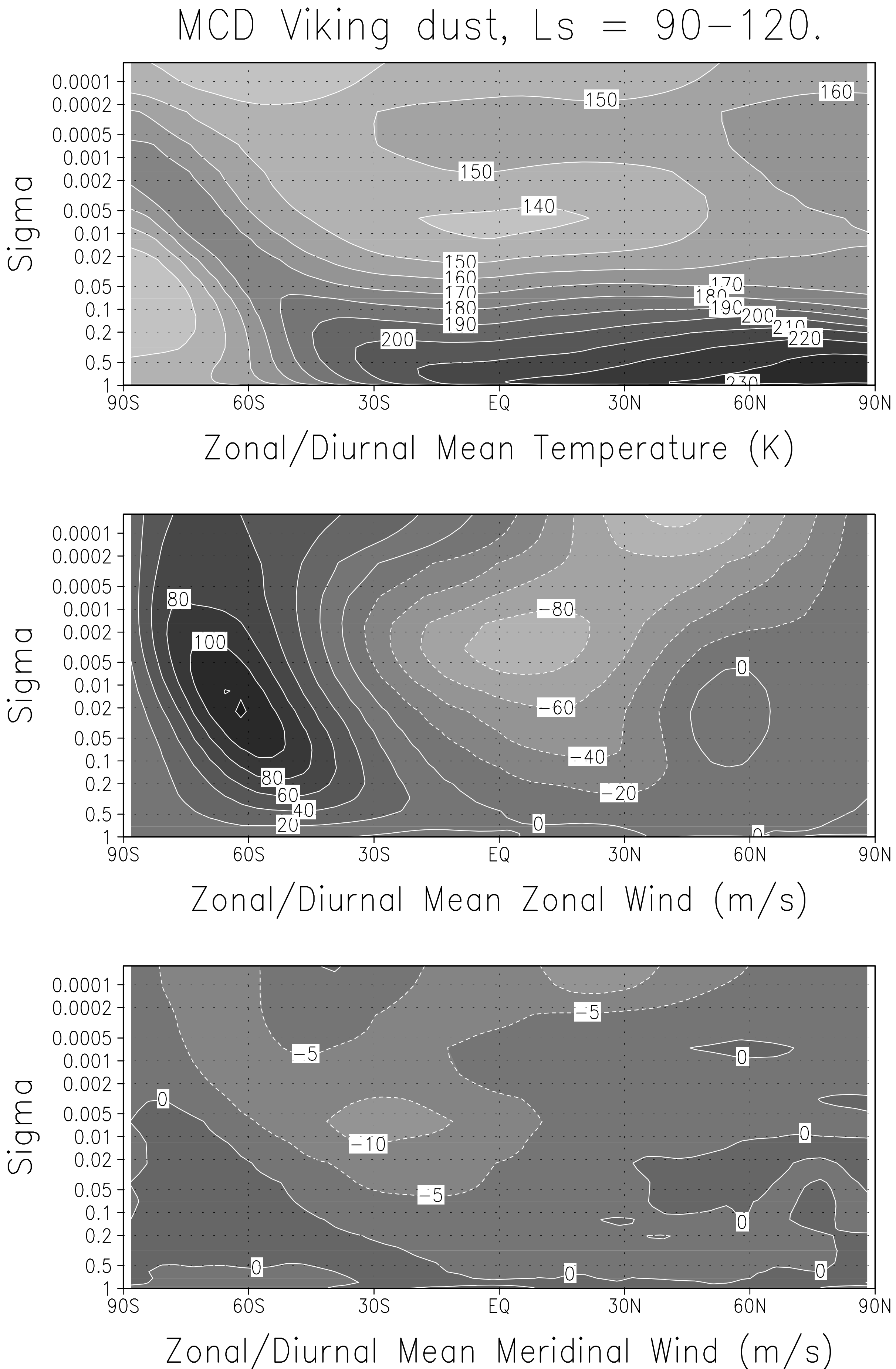

Figure 1: Sample output from `zonal_tuv.gs`.

GrADS should be run in portrait mode.

- `zonal_sdtuv.gs` Plots the zonal mean standard deviation of temperature, zonal and meridional velocity for one season. GrADS should be run in portrait mode for this script.
- `zonal_tuv.gs` Plots the zonal mean and diurnal time mean temperature, zonal and meridional velocity for one season. GrADS should be run in portrait mode for this script.

Sample output from the `profile.gs` script is shown in figure 2 for summer afternoon profiles near the Viking Lander 1 site and for contrast figure 3 shows nighttime profiles in a winter polar region at the same time of year.

GrADS is a very popular and powerful software package for displaying meteorological variables. You are referred to the manual for a description of all the features available. Also note that as GrADS is widely used there may be scripts already written to perform the particular task you are undertaking. It may be worth a search of the internet and related newsgroups for GrADS scripts. The World Wide Web page at `http://grads.iges.org/grads` is a good starting place.

# 5 References

Collins, M., Lewis, S.R. and Read, P.L., "Mars Climate Database v1.0: Detailed Design Document", 1997.

Justus, C. G., "A Mars Global Reference Atmosphere Model (Mars-GRAM) for mission planning and analysis", *AIAA Paper No. 90-0004,* 28th Aerospace Sciences Meeting, 1990.

Justus, C. G., Alyea, F. N., Cunnold, D. M., Jeffries, W. R. III, and Johnson, D. L., "The NASA/MSFC Global Reference Atmosphere Model - 1995 Version (GRAM-95)", *NASA Technical Memorandum*, 1995.

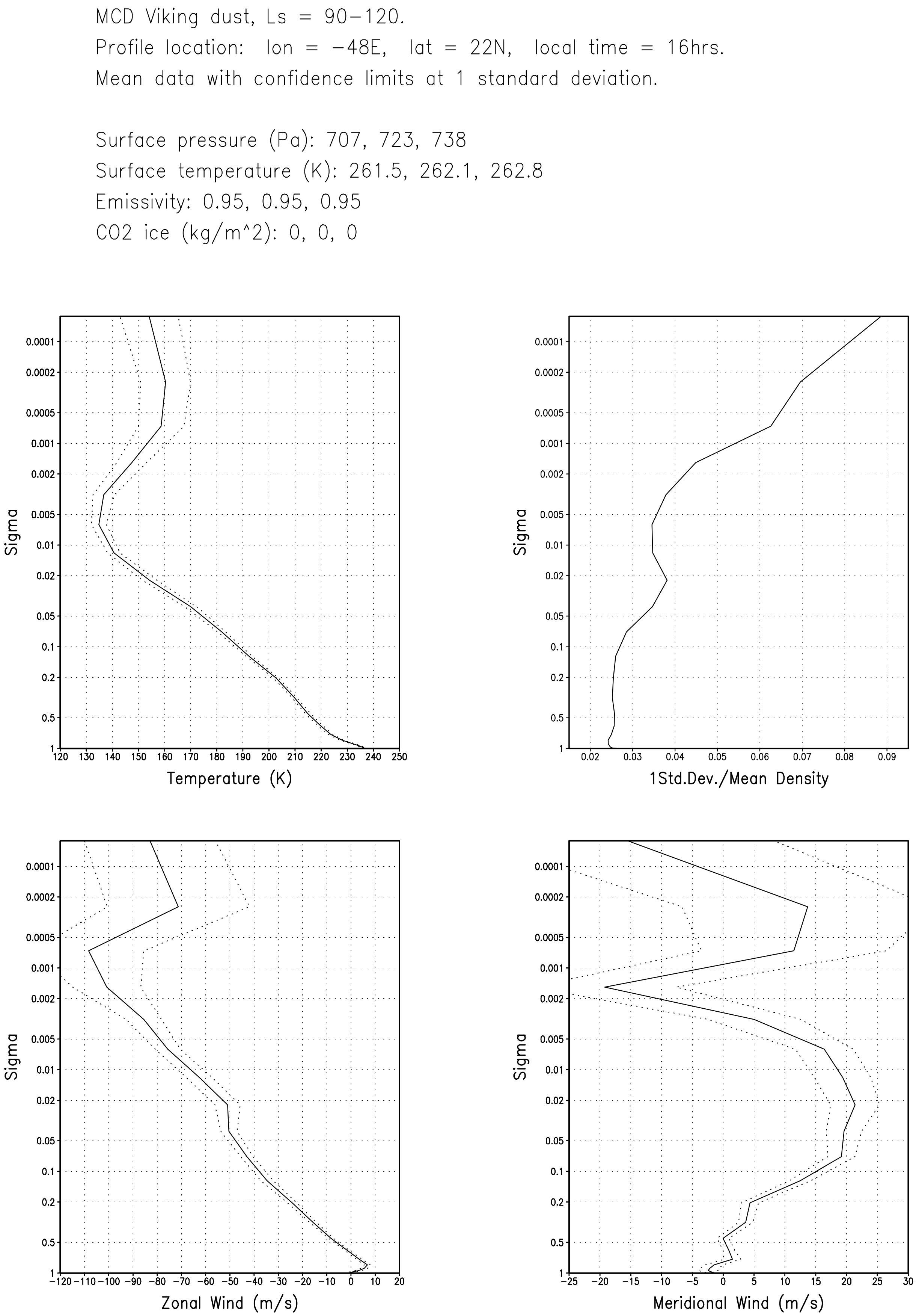


Figure 2: Sample output from `profile.gs`: an afternoon profile at the Viking Lander 1 site.

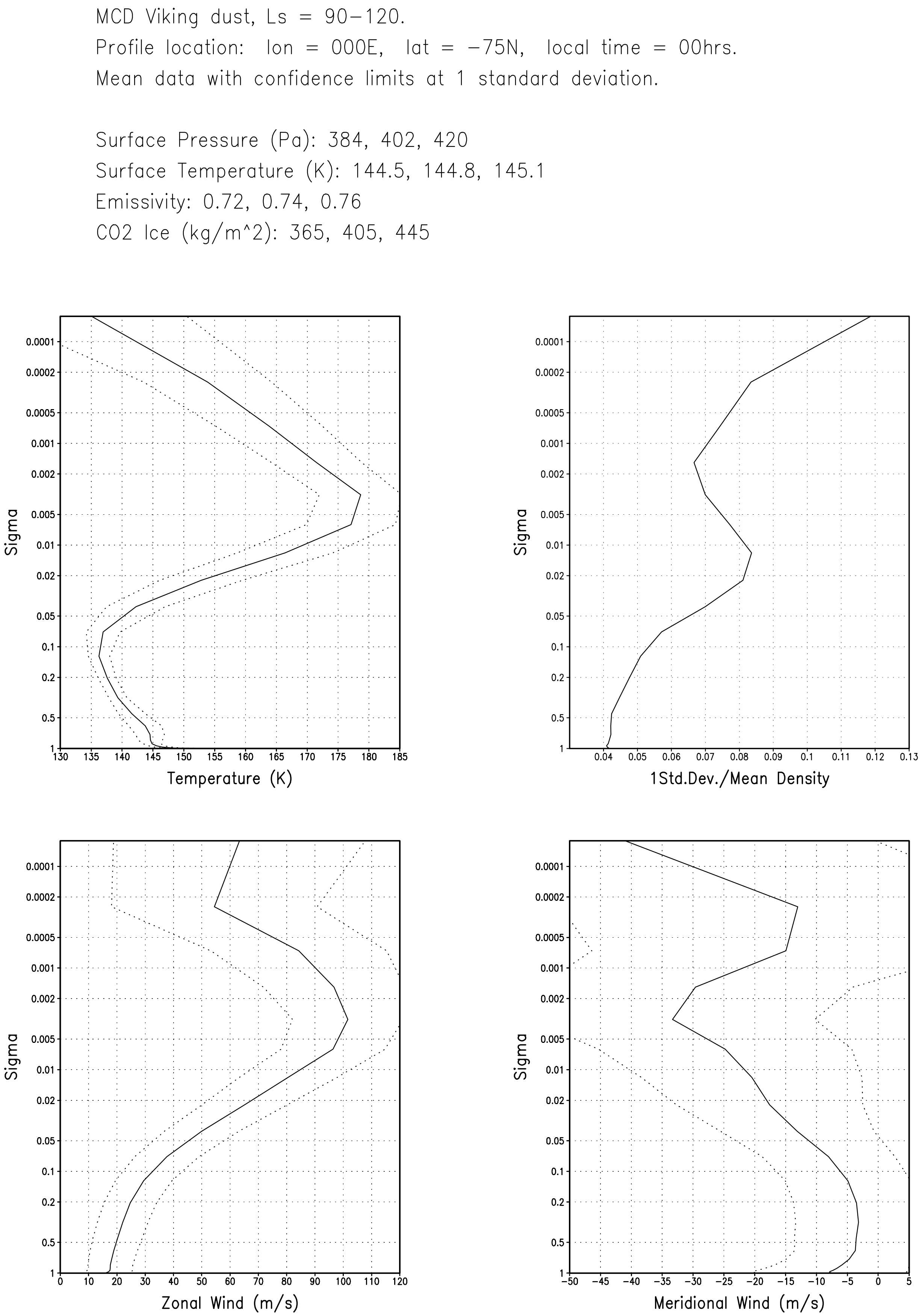


Figure 3: Sample output from `profile.gs`: a profile in the southern polar night.