MARS CLIMATE DATABASE v2.0
USER MANUAL
(ESTEC Contract 11369/95/NL/JG)

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Abstract

This document is the User Manual for version 2.0 of the Mars Climate Database (MCD) and replaces Collins and Lewis (1997a) which described version 1.0. Version 2.0 of the MCD incorporates several improvements, outlined in this document, but should appear almost identical to the user in terms of operating procedure, unless low-level use is being made of the large-scale variability model. This document reproduces and updates material from Collins and Lewis (1997a), where it is still relevant, as well as adding sections on the new features. For descriptions of the contents and structure of files, details of the dust distribution scenarios and descriptions of the variability models, see the Detailed Design Document (Lewis and Collins, 1999b).

The diagrams and data examples given have been prepared using the version 2.0 database and the "bright dust" dataset, unless stated otherwise.

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1 Introduction

The Mars Climate Database (MCD) is a database of atmospheric statistics compiled from state-of-the art General Circulation Model (GCM) 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 which govern the atmospheric circulation and surface conditions on the planet.

The MCD contains simulated data on a $3.75^\circ \times 3.75^\circ$ longitude–latitude grid from the surface up to an approximate altitude of 90km. Four dust scenarios have been used representing moderate, Viking-type conditions (without dust storms), clear atmosphere conditions (perhaps similar to those observed 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 description of how to access the data in the database. Descriptions of the models and of the validation procedure are available in other documents relating to the project.

The MCD can also be accessed in a variety of data formats using the World Wide Web at `http://www.lmd.jussieu.fr/mars.html`.

2 Differences Between Version 2.0 and Version 1.0 of the MCD

The principal difference between version 2.0 and 1.0 of the MCD is that the large-scale variability model now makes use of two-dimensional, multivariate Empirical Orthogonal Functions (EOFs), which describe correlations in the model variability as a function of both height and longitude (rather than solely of height as in version 1.0). These are described in the Detailed Design Document which accompanies this report. The 2-D EOFs allow realistic variability to be modelled for trajectories which span a range of longitudes. As in version 1.0, EOFs are stored for a range of latitude bands, but instead of retaining 6 1-D EOFs at each horizontal location for each of 12 seasons, now 72 2-D EOFs are stored for each latitude band and their amplitude is modelled by a set of principal components tabulated once per day (669 times) throughout the model Mars year. This procedure is no more costly to the end-user in terms of either disk storage or CPU time, but gives a much improved description of the variability as a function of both space and time and a larger variance capture.

A second difference is that two parallel datasets are now included in the climate database distribution. The first has been compiled with the same set of model properties as the version 1.0 database, although the GCMs which were used to compile the database have been extensively validated as a result of the first study and improved in several respects (Forget *et al.*, 1999). This dataset is referred to as the "standard dust" dataset. A second complete database has also been prepared with an increased dust single scattering albedo in the models (see Forget *et al.*, 1999, for details) and is referred to as the "bright dust" dataset. The main systematic difference between these datasets is that the "bright dust" data tend to have temperatures which are cooler

by up to 10K in the lower atmosphere (between about 5km and 30km altitude). Differences elsewhere are less marked and are often smaller than the intrinsic model variability. An example of the differences can be seen in Figures 3 and 4. The "bright dust" properties tend to give a better fit to a few previous observations of Martian atmospheric temperatures (Lewis *et al.*, 1999) and could be used if only a single dataset is required. The "standard dust" dataset gives a better correspondance with the previous version of the database. Both may be used to check warmer and cooler extremes.

There have also been numerous small improvements and error corrections to the climate database access software since version 1.0 was released, which are now all incorporated into version 2.0. These are listed in a `Changes` file supplied with the software.

3 Installation

3.1 Minimum Software Requirements

The MCD is primarily designed to operate in the UNIX environment on a workstation. Access software is written in FORTRAN77, for which a compiler is needed.

The data in the MCD are written using the Data Retrieval and Storage (DRS) library developed for the Program for (Terrestrial) Climate Model Diagnosis and Intercomparison (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 install 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`

3.2 Installing the MCD

A full installation of the MCD can now take up to 1.9Gb of disk space. This can be reduced to less than 0.9Gb if a fully functional database, with all dust scenarios, is required, but only data from either the "standard dust" or "bright dust" experiments are needed on disk (equivalent to a full installation of the version 1.0 MCD). If absolutely necessary the amount of disk space needed could be reduced further by only retaining a limited range of dust scenarios or seasons of interest within the `data` subdirectory.

To extract everything at once, set the working directory to the one which will contain the database subdirectory, check that about 1.9Gb of disk space is available, 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 (which may vary). This will create a directory `mcd` in which all the MCD data and software is stored.

To chose which set of dust properties is used, create a symbolic link `data` within the `mcd` directory to point to either `data_s` for "standard dust" or `data_b` for "bright dust," e.g.

```
cd mcd
rm data            # if a symbolic link already exists, remove it
ln -s data_s data  # to select the ``standard dust'' dataset for use
                   # or
ln -s data_b data  # to select the ``bright dust'' dataset for use
```

or, alternatively, just rename either `data_s` or `data_b` to `data` as required, having first removed any symbolic link called `data`.

If there is not room to extract everything at once then first extract the smaller directories which contain the documentation, GrADS scripts and MCDGM interface routines

```
tar -xvf /dev/rmt0h mcd/docs
tar -xvf /dev/rmt0h mcd/grads
tar -xvf /dev/rmt0h mcd/mcdgm
```

and then extract either of the larger data directories as required

```
tar -xvf /dev/rmt0h mcd/data_s
```
or
```
tar -xvf /dev/rmt0h mcd/data_b
```

again renaming to `data` once extracted.

3.3 MCD Contents

The contents of each subdirectory of the MCD are summarized here.

- `mcd/docs` This directory contains PostScript files which can be used to print further copies of the User Manual (`um.ps`) and the Detailed Design Document (`ddd.ps`). It also contains subdirectories (`um` and `ddd`) which have hypertext versions of these documents, suitable for viewing in a WWW browser. Open the file `mcd/docs/index.html` in your browser to view these.
- `mcd/mcdgm` This contains FORTRAN source code for the MCDGM interface, see Section 4.2.

  Once the MCD has been installed on disk it is necessary to compile the `mcdgm` program if the MCDGM interface is required. The Unix command `make` can be used. Sample files are

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^{-1}	3-D
Meridional (North-South) wind	v	m s^{-1}	3-D
Atmospheric density	rho	kg m^{-3}	3-D
Boundary layer eddy kinetic energy	q2	m^2 s^{-2}	3-D

Table 1: Variables stored in database mean data files.

provided for two systems (`Makefile.DEC and Makefile.SGI`); rename one to `Makefile` before issuing the command `make`. It should only be necessary to edit the `Makefile` to alter the variable `LIB_DIR` to point to the directory which contains the DRS header files on your system.

As the `mcdgm` program stands it will only run in its own directory once the `mcd/data` directory or symbolic link has been set up. It may be more convenient to be able to run it from elsewhere on your system. To do this either create a symbolic link to point to the data directory which you require in the directory above that where the `mcdgm` executable is run from, e.g.

```
ln -s /FULL/PATH/NAME/mcd/data ../data
```

Another solution is to edit the subroutines `cospa.f`, `mount.f` and `opend.f`, replacing `../data/` in all strings with `/FULL/PATH/NAME/mcd/data/`, where `/FULL/PATH/NAME` should be replaced with whatever the location of the `mcd` directory is on your system. Then issue the command `make` and the executable will operate from anywhere on the system.

- `mcd/grads` Some sample GrADS scripts which plot MCD data, see Section 4.4.
- `mcd/data_s` The full MCD dataset derived from model runs with "standard dust" parameters.
- `mcd/data_b` The full MCD dataset derived from model runs with "bright dust" parameters.

The file structure of the two data directories is discussed in the Detailed Design Document for the MCD (Lewis and Collins, 1999b). Tables which show the variables available are reproduced here for convenience: mean data files (`me`) contain 12 seasonal mean values (corresponding to 12 Solar times of day) for the variables shown in Table 1 and standard deviation data files (`sd`) contain seasonal standard deviation values of the variables in Table 2.

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^{-1}	3-D
Meridional (North-South) wind	sdv	m s^{-1}	3-D
Atmospheric density	sdrho	kg m^{-3}	3-D
Boundary layer eddy kinetic energy	sdq2	m^2 s^{-2}	3-D

Table 2: Variables stored in database standard deviation data files.

4 Accessing Data

4.1 Choosing a Method of Database Access

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

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 σ 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) in order 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 external 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 disk space 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 σ 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 σ 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 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 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`. The program first has to be compiled, see Section 3.3. 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 here.

```
> mcdgm
Mars Climate Database Version 2.0 - 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)
12,50,00
Date = 7/20/1976 Julian Date = 2442980.0 GMT Time = 12:50:  0.0
Ls = 98.9 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). The user can first try this example to check that the MCDGM interface has been installed correctly; the run documented here was made using the "bright dust" dataset and there will of course be differences in the data values output if the other dataset, or any of the variability models are used.

```
 Mars Climate Database Version 2.0 - MarsGRAM style interface
 Date =  7/20/1976  Julian Date = 2442980.0  GMT Time = 12:50: 0.0
 Random seed =     1
 Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
 Height =  -1.22 km (   0.00 km)   Scale Hgt H(p) = 11.98 H(rho) = 11.98 km
 Latitude =   22.000 degrees       West Longitude =   48.000 degrees
 Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
 Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
 Temperature =   233.2 K           Pressure =    6.833E+02 N/m**2
 Density (Low, Avg., High) =      1.466E-02   1.533E-02   1.601E-02 kg/m**3
 Departure, COSPAR NH Mean =       -15.5 %     -11.7 %      -7.8 %
```

```
Density perturbation =           0.13 % of mean value
Eastward Wind =    -4.0 m/s       Northward Wind =     0.4 m/s
--------------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
Height =   8.78 km (  10.00 km)   Scale Hgt H(p) = 10.55 H(rho) = 10.55 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Temperature =   205.4 K           Pressure =    2.805E+02 N/m**2
Density (Low, Avg., High) =      6.834E-03   7.130E-03   7.426E-03 kg/m**3
Departure, COSPAR NH Mean =        -4.7 %      -0.5 %       3.6 %
Density perturbation =          -0.77 % of mean value
Eastward Wind =    -8.9 m/s       Northward Wind =    -0.2 m/s
--------------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
Height =  18.78 km (  20.00 km)   Scale Hgt H(p) =  9.65 H(rho) =  9.65 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Temperature =   187.8 K           Pressure =    1.043E+02 N/m**2
Density (Low, Avg., High) =      2.776E-03   2.888E-03   2.999E-03 kg/m**3
Departure, COSPAR NH Mean =        -5.9 %      -2.1 %       1.7 %
Density perturbation =          -0.52 % of mean value
Eastward Wind =   -24.7 m/s       Northward Wind =     3.6 m/s
--------------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
Height =  28.78 km (  30.00 km)   Scale Hgt H(p) =  8.45 H(rho) =  8.45 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Temperature =   164.5 K           Pressure =    3.382E+01 N/m**2
Density (Low, Avg., High) =      1.023E-03   1.067E-03   1.110E-03 kg/m**3
Departure, COSPAR NH Mean =        -8.1 %      -4.2 %      -0.3 %
Density perturbation =          -0.77 % of mean value
Eastward Wind =   -39.8 m/s       Northward Wind =    10.8 m/s
--------------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
Height =  38.78 km (  40.00 km)   Scale Hgt H(p) =  7.09 H(rho) =  7.09 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Temperature =   137.9 K           Pressure =    8.738E+00 N/m**2
Density (Low, Avg., High) =      3.134E-04   3.304E-04   3.473E-04 kg/m**3
Departure, COSPAR NH Mean =       -19.3 %     -14.9 %     -10.5 %
Density perturbation =           0.17 % of mean value
Eastward Wind =   -61.0 m/s       Northward Wind =     8.8 m/s
--------------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
Height =  48.78 km (  50.00 km)   Scale Hgt H(p) =  7.61 H(rho) =  7.61 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Temperature =   148.1 K           Pressure =    2.089E+00 N/m**2
Density (Low, Avg., High) =      6.675E-05   7.402E-05   8.129E-05 kg/m**3
Departure, COSPAR NH Mean =       -46.7 %     -40.8 %     -35.0 %
Density perturbation =          -0.51 % of mean value
Eastward Wind =   -79.9 m/s       Northward Wind =   -14.1 m/s
```

```
------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
Height =  58.78 km (  60.00 km)   Scale Hgt H(p) =  8.19 H(rho) =  8.19 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Temperature =   159.4 K           Pressure =    5.805E-01 N/m**2
Density (Low, Avg., High) =      1.630E-05   1.921E-05   2.213E-05 kg/m**3
Departure, COSPAR NH Mean =       -56.1 %     -48.2 %     -40.4 %
Density perturbation =          -6.63 % of mean value
Eastward Wind =   -58.4 m/s       Northward Wind =    -7.7 m/s
------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
Height =  68.78 km (  70.00 km)   Scale Hgt H(p) =  8.18 H(rho) =  8.18 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Temperature =   159.2 K           Pressure =    1.558E-01 N/m**2
Density (Low, Avg., High) =      4.740E-06   5.122E-06   5.503E-06 kg/m**3
Departure, COSPAR NH Mean =       -53.8 %     -50.1 %     -46.4 %
Density perturbation =          -4.74 % of mean value
Eastward Wind =   -46.0 m/s       Northward Wind =   -10.8 m/s
------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
Height =  78.78 km (  80.00 km)   Scale Hgt H(p) =  8.51 H(rho) =  8.44 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Exospheric Temp. =  336.0 K       Tbase =  159.6 K    Zbase =  128.5 km
Temperature =   157.6 K           Pressure =    3.940E-02 N/m**2
Density (Low, Avg., High) =      1.080E-06   1.310E-06   1.540E-06 kg/m**3
Departure, COSPAR NH Mean =       -60.0 %     -51.4 %     -42.9 %
Density perturbation =          25.96 % of mean value
Eastward Wind =   -30.5 m/s       Northward Wind =    46.7 m/s
------------------------------------------------------------------------
Time (rel. to T0) =       0.0 sec. (   0.000 sols)    Ls =   98.9 deg.
Height =  88.78 km (  90.00 km)   Scale Hgt H(p) =  8.66 H(rho) =  8.59 km
Latitude =   22.000 degrees       West Longitude =   48.000 degrees
Sun Latitude =    25.00 deg.      Mars Orbital Radius = 1.640 AU
Sun Longitude =  111.31 deg.      Local Time =  16.22 Mars hours
Exospheric Temp. =  336.0 K       Tbase =  159.6 K    Zbase =  128.5 km
Temperature =   159.5 K           Pressure =    1.395E-02 N/m**2
Density (Low, Avg., High) =      4.117E-07   4.574E-07   5.032E-07 kg/m**3
Departure, COSPAR NH Mean =       -41.8 %     -35.3 %     -28.9 %
Density perturbation =          13.75 % of mean value
Eastward Wind =   -19.3 m/s       Northward Wind =    84.6 m/s
------------------------------------------------------------------------
```

In addition to the output shown above, which may be directed to the console or a file, the data files shown in Table 3 are produced, holding the data indicated tabulated against a user specified coordinate. Data are presented in SI units unless otherwise stated.

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.

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 (gravity 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)

Table 3: Output files produced by the MCDGM interface software.

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. This script could be executed as a background job or at a later time using some batch queueing software.

```
#
# Script to run the Mars Climate Database MarsGRAM style interface (mcdgm)
#
set workdir = "/YOUR/WORK/DIRECTORY"
set mcddir = "/FULL/PATH/NAME/mcd"
#
cd $workdir
#
cat >! mcdgm.in << eof_mcdgm.in
vl1_ent.list
vl1_ent.out
7
20
1976
10
12
50
00
1
1
1
2
0
0
```

```
22.
48.
-1.217483
10.
0.
0.
0.
eof_mcdgm.in
#
$mcddir/mcdgm < mcdgm.in > mcdgm.out
#
```

4.3 Using the DRS Library

Data in the MCD are written in DRS format. If you are not using a package (such as GrADS) which can read DRS format you can write a program in FORTRAN (or some other language, such as C or IDL) 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 Section 4.2) to help in this process. The advantage of this method of access over GrADS, for example, is that the large- and small-scale variability models may be used if the appropriate subroutines are called.

4.3.1 Opening and Closing Files

To access the data you must first open the file. An example of opening an MCD file within a FORTRAN program is shown here.

```
.
.
#include "drsdef.h"
.
.
     integer udrs !  DRS file unit number
     integer ierr
     character*256 datfile !  DRS data file
     character*256 dicfile !  DRS dictionary file
.
.
     udrs=60
     datfile='/FULL/PATH/NAME/mcd/data/viks04me.dat'
     dicfile='/FULL/PATH/NAME/mcd/data/viks04me.dic'
     ierr=aslun(udrs,dicfile,udrs+1,datfile,IDRS_READ)
.
.
     !  read some DRS data
.
.
```

```
      ierr=cllun(udrs) !  close the file again
.
.
```

4.3.2 Reading and Manipulating Data

Once the file has been opened you can read data from the MCD either by using the DRS routines directly or by using subroutines from the `mcdgm` directory. The following routines may prove particularly useful. Each is commented within the code to indicate the type and size of arguments which it expects; note that in some cases the number of arguments has changed since earlier versions of the MCD. The MCDGM program provides one example of how to call these routines (examine the `dstep.f` routine in particular).

- `var2d.f` Reads one value of a 2-D field from the MCD. Uses bilinear interpolation to translate the database fields to the user specified longitude and latitude.
- `var3d.f` Reads one value of a 3-D field from the MCD. Uses trilinear interpolation to translate the database fields to the user specified longitude, latitude and σ level. The subroutine `getsi.f` can be called first to translate geometric height into the σ levels used in the MCD.
- `profi.f` Reads a vertical profile from a 3-D field on model σ levels. Uses bilinear interpolation to translate the database fields to the user specified longitude and latitude.
- `getsi.f` Solves the hydrostatic equation to find the value of σ (the MCD vertical coordinate) corresponding to the user specified height above the surface.
- `mount.f` Returns the model orographic height in metres at a particular longitude and latitude.
- `atime.f` This routine takes the local time at a particular longitude and turns it into database prime meridian time. Database times always correspond to True Solar Times, as opposed to a Mean Solar Time.
- `eofpb.f` This routine computes a large-scale EOF perturbation to a variable (density surface pressure, temperature, zonal wind and meridional wind). Note that this routine has changed substantially since version 1.0.
- `grwpb.f` This routine computes a small-scale gravity wave perturbation to a variable (density, temperature, zonal wind and meridional wind). Note that this routine has changed since version 1.0.

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. GrADS can also be useful for quickly translating portions of the DRS format files into other formats.

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 the Earth and Mars. 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 in True Solar Time.

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

```
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 to where the `mcd` directory has been installed on your machine if these scripts are to be run from another directory. 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 useful to 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 map outlines.

The scripts which are provided in the `mcd/grads` subdirectory are briefly described below. 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 have 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 True Solar Time of day during that season. It does not include any diurnal variability (this is represented 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 True 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, `profile_lon_lat_hr.gx` (where `lon` is the longitude, `lat` the latitude and `hr` the local time selected), which can then be viewed with `gxtran` or converted to postscript for printing with `gxps` or `gxeps`.

  GrADS should be run in portrait mode.

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

- `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 True 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.

  GrADS should be run in portrait mode.

- `zonal_tuv.gs` Plots the zonal mean and diurnal time mean temperature, zonal and meridional velocity for one season in a $\ln(\sigma)$–latitude coordinate system. GrADS should be run in portrait mode for this script.

  Sample output from this script is given in Figures 3 and 4, which also allow a comparison of data from the "standard" and "bright" dust properties datasets.

- `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.

GrADS is a popular and powerful public domain software package for displaying meteorological variables. You are referred to the manual for a description of all the features available.

MCD Viking dust, Ls = 90–120.
Profile location: lon = –48E, lat = 22N, local time = 16hrs.
Mean data with confidence limits at 1 standard deviation.

Surface Pressure (Pa): 658, 679, 700
Surface Temperature (K): 260.9, 261.6, 262.2
Emissivity: 0.95, 0.95, 0.95
CO2 Ice (kg/m^2): 0, 0, 0

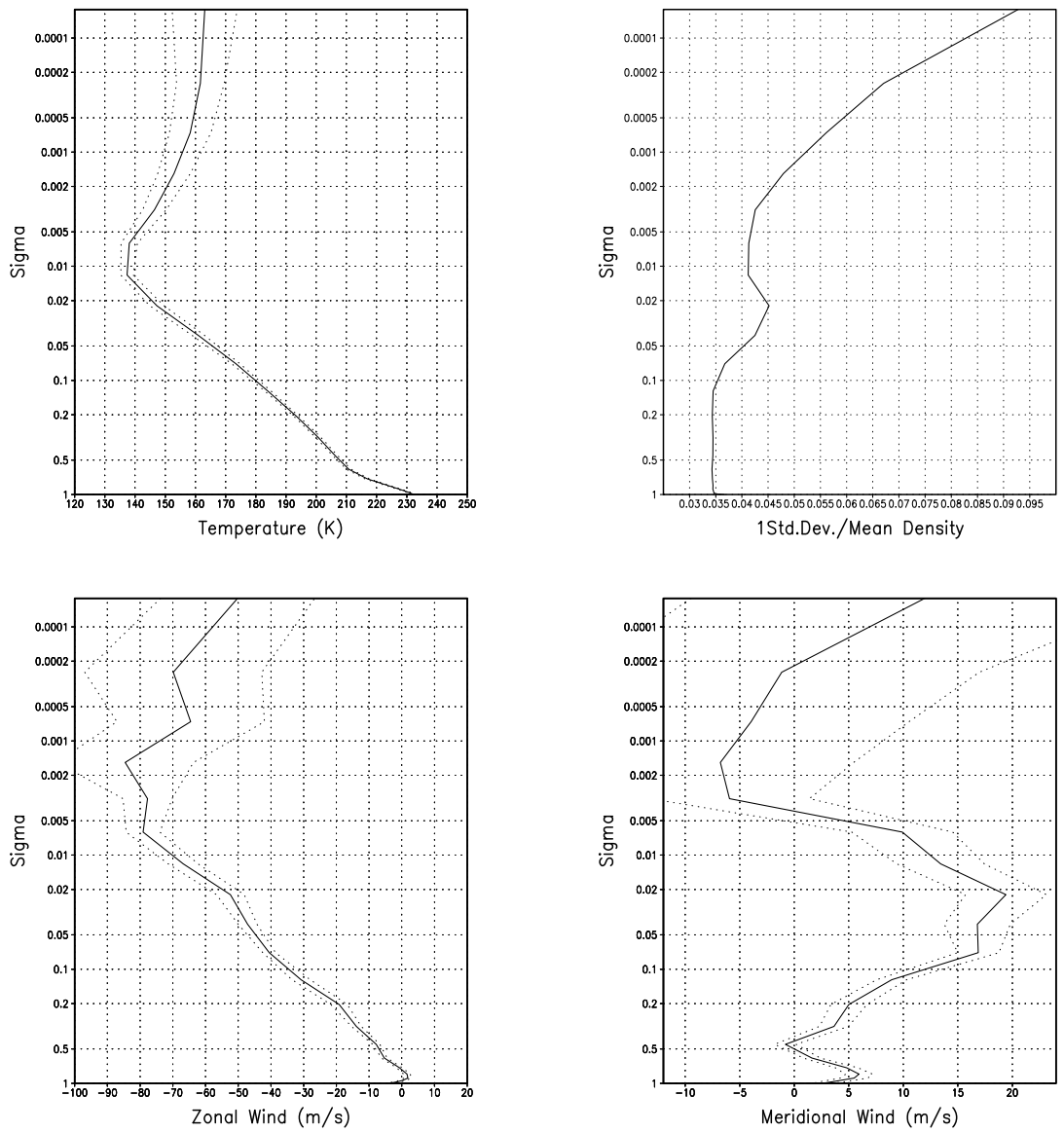

Figure 1: Sample output from `profile.gs`: an afternoon profile at the Viking Lander 1 site.

MCD Viking dust, Ls = 90−120.
Profile location: lon = 000E, lat = −75N, local time = 00hrs.
Mean data with confidence limits at 1 standard deviation.

Surface Pressure (Pa): 363, 379, 395
Surface Temperature (K): 144.2, 144.4, 144.7
Emissivity: 0.91, 0.93, 0.96
CO2 Ice (kg/m^2): 454, 501, 548

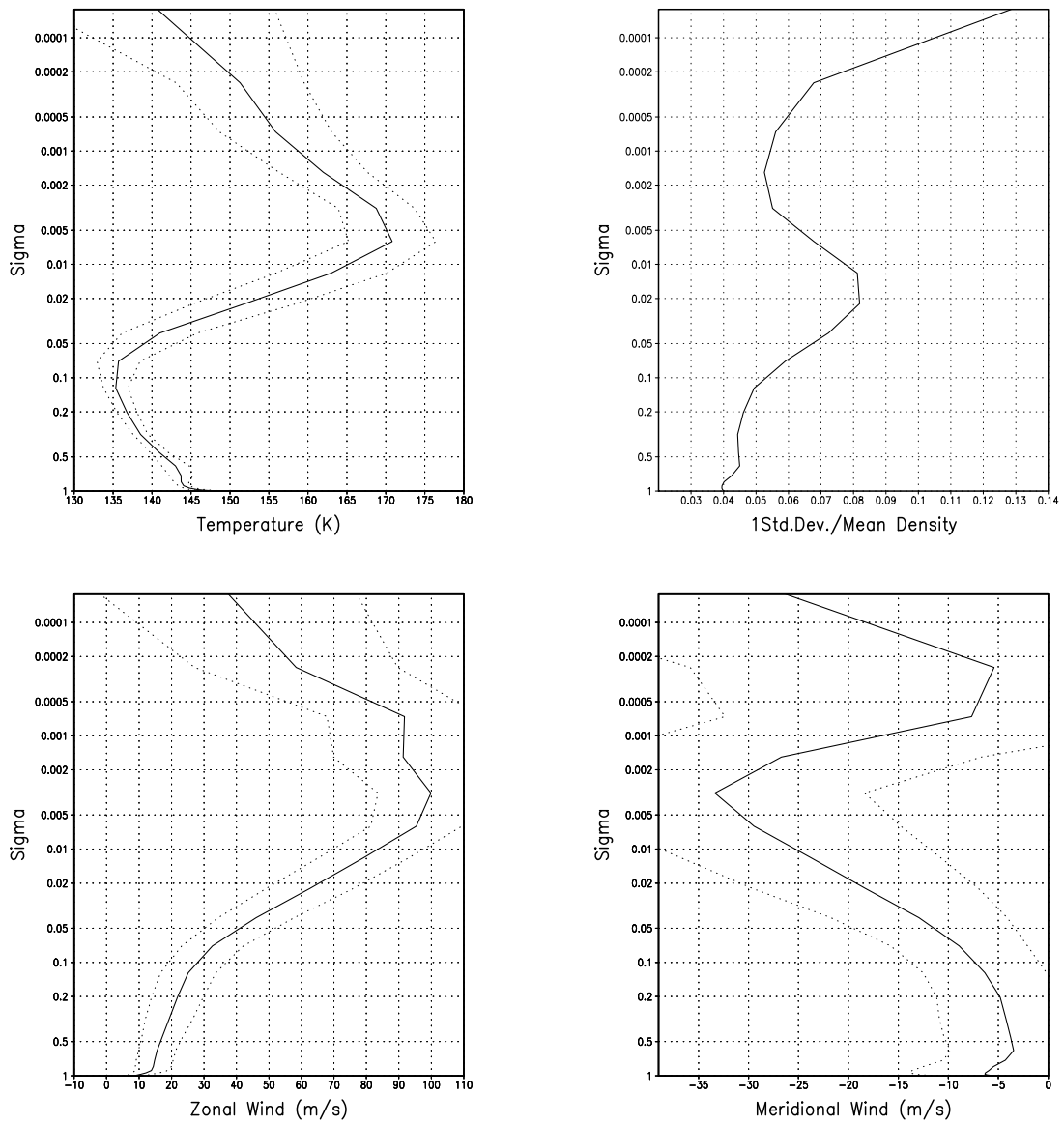

Figure 2: Sample output from `profile.gs`: a profile in the Southern polar night.

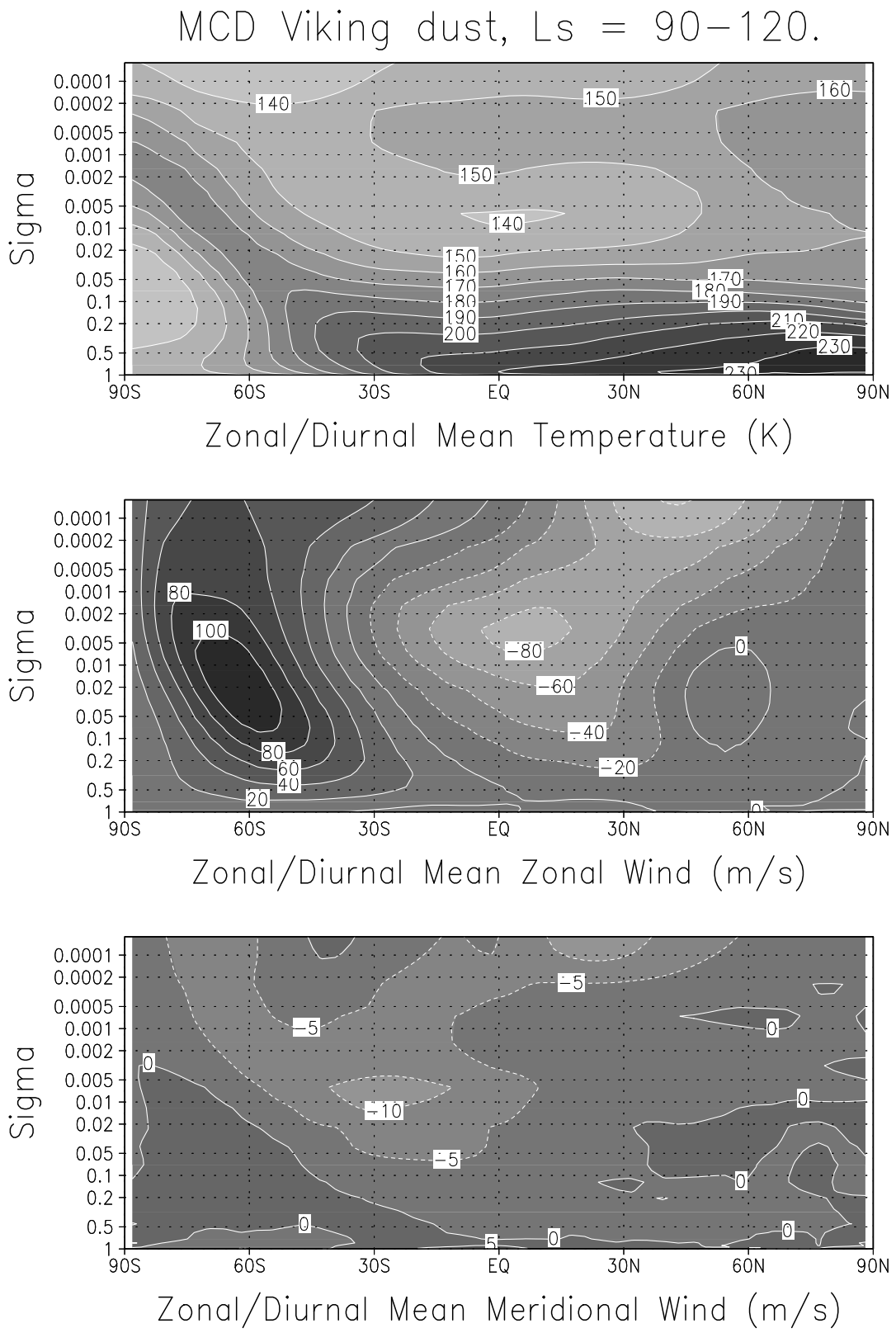

Figure 3: Sample output from `zonal_tuv.gs`, using data from the "standard dust" dataset, `data_s`.

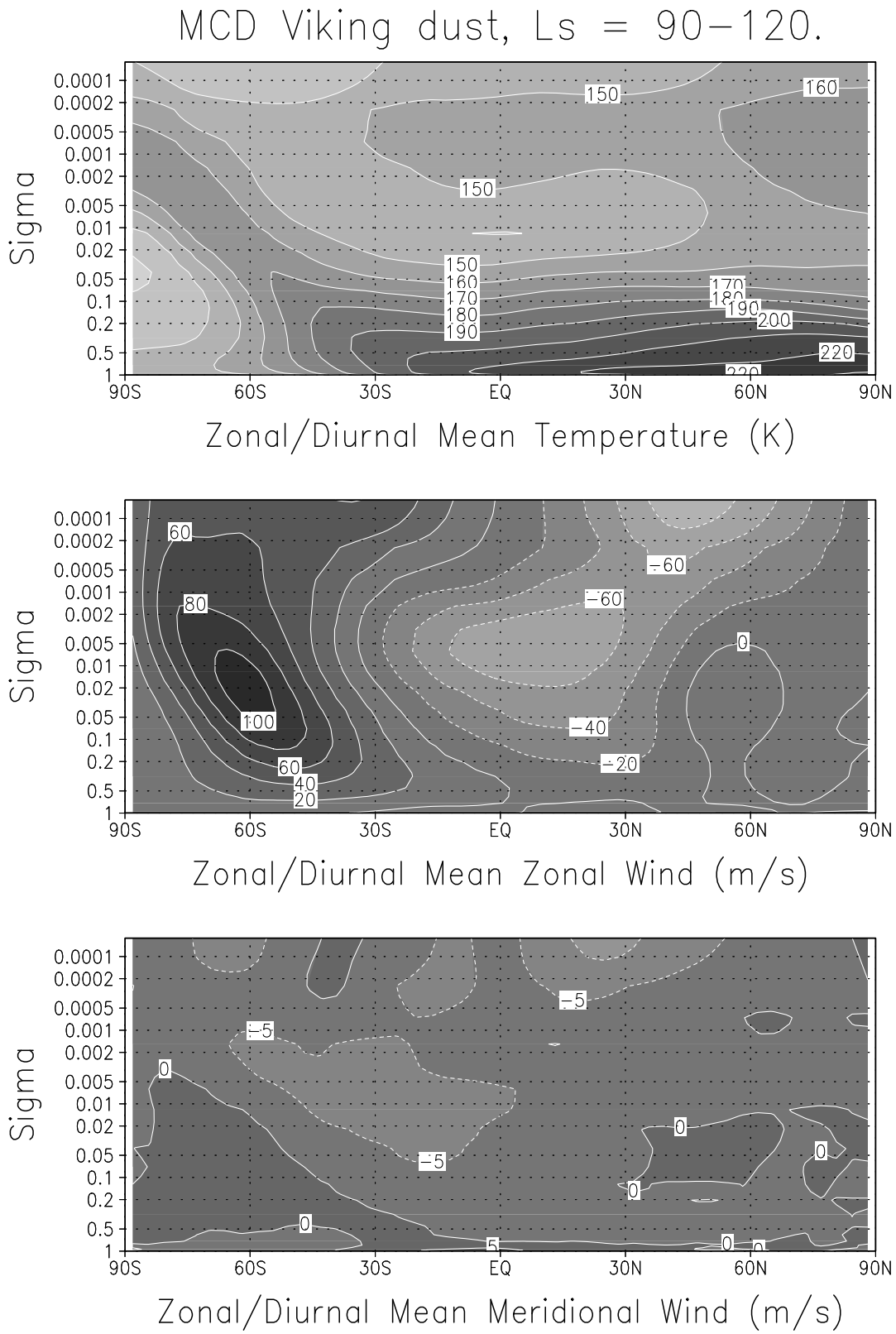

Figure 4: Sample output from **zonal_tuv.gs**, using data from the "bright dust" dataset, **data_b**.

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

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