MOLAutils
*v*1.4
User's guide

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COVER ILLUSTRATION: credits to Garry McCarthy.

Contents

1 What is MOLAutils ?

MOLAutils is a program that wants to help users of MOLA data. It provides:

- translation of PEDRs files in different easily manageable formats;
- computation of the areoid surface (and the corresponding topography) with the spherical harmonic model of choice;
- computation of the IAU standard ellipsoid surface (and the corresponding topography).

2 Installing the software

2.1 Software and hardware requirements

MOLAutils is written in C. It has been developed on Linux PCs. The software is run in (ANSI) text-mode from a shell. A window system is therefore unnecessary with the present version.

2.2 Obtaining MOLAutils

The easiest way to obtain MOLAutils is to download it from the current official http site[1]. The latest version of the program is provided there as standard .tar.gz Unix source archives. RPM packages for x86 or x86-64 architectures are also available. Windows executable has been cross-compiled (using MinGW[2]) and is distributed in .zip archive, containing the source.

2.3 Installation

2.3.1 Linux or Unix-like systems

To install MOLAutils , you must first uncompress and unarchive the archive:

```
tar zxvf molautils-x.x.tar.gz
```

A new directory called molautils-x.x should now appear at the current position on your disk. You should then just enter the directory and follow the instructions in the file called "INSTALL".

The simplest way to install an RPM package is to log in as root and use the following command

```
rpm -i molautils-x.x-dist.arch.rpm
```

2.3.2 Windows

To install MOLAutils , you just extract the .zip archive. A new directory called molautils should appear: the executable is in the subdirectory src, you could link it where you prefer.

[1] http://planeto.geol.u-psud.fr/MOLAutils.html
[2] Minimalist GNU for Windows (http://www.mingw.org/)

3 Overview of the software

4 Using MOLAutils

MOLAutils is run from the shell (you need a DOS shell emulator if you work on Windows) with the following syntax[3]:

% molautils *pedrs-file(s)* -c *configuration-file* [--*Parameter1 Value1*] [--*Parameter2 Value2*] ...

The part enclosed within brackets is optional. Any "--*Parameter Value*" statement in the command-line overrides the corresponding definition in the configuration-file or any default value (see below).

4.1 The Configuration file

Each time MOLAutils runs, if no configuration file is found, MOLAutils will use its own internal default configuration.

4.1.1 Creating a configuration file

MOLAutils can generate an ASCII dump of its internal default configuration, using the "-d" option. By redirecting the standard output of MOLAutils to a file, one creates a configuration file that can easily be modified afterwards:

% molautils -d > default.molautils

4.1.2 Format of the configuration file

The format is ASCII. There must be only one parameter per line, following the form:

Config-parameter *Value(s)*

Extra spaces or linefeeds are ignored. Comments must begin with a "#" and end with a linefeed. Values can be of different types: strings (can be enclosed between double quotes), floats, integers, keywords or boolean (Y/y or N/n). Some parameters accept zero or several values, which must then be separated by commas.

4.1.3 Parameter list

Here is a list of all the parameters known to MOLAutils . Please refer to §4.2 for a detailed description of their meaning.

Parameter	default	type	Description
ORBIT_NUMBER	0	*integer*	selection on orbit number.
LAT_RANGE	-90.00,90.00	*floats*	ground areocentric latitude range.
LONG_RANGE	0.00,360.00	*floats*	ground areocentric east longitude range.
SHOT_CODE	-1	*integer*	ground trigger selection 1=good 0=bad.
QUALITY_FLAG	-1	*integer*	quality selection 0=good 1=bad.
REF_ELLIPSOID	IAU2000	*keyword*	ellipsoid model

[3]Remember that on Windows system the executable name is molautils.exe

OUTPUT_FORMAT	ASCII	*keyword(s)*	output file format (ASCII, XML are only available at the moment)
OUTPUT_FILENAME	pedrs.ascii	*string(s)*	output file name.
OUTPUT_FIELDS	AREOCENTRIC_COORDINATES	*keyword(s)*	output fields (see section 5 for a detailed description).
AREOID_SELECT	N	*boolean*	compute areoid model? (Yes or No) (see section 4.2.4) for a detailed description).
SPHEHARM_FILE	ggm1025a.sha	*string*	name of the spherical harmonics file.
SPHEHARM_ORDEG	50	*int*	order and degree of last spherical harmonics coeefficient.
REF_RADIUS	3.396e+03	*float*	radius of reference surface in *Km*.
XSL_FILT	pedrs.xsl	*string*	Filename for XSL style-sheet.

Table 1: Configuration parameters.

4.2 Detailed description of the configuration parameters

4.2.1 Selection criteria

ORBIT_NUMBER - The MOLA orbit number can be specified: only measures belonging to that orbit are then extracted.

LAT_RANGE - The planetocentric latitude (IAU 2000 [6]) range can be selected: only measures in that range are then extracted. Latitude range had to be included between -90 and 90 degrees.

LONG_RANGE - The planetocentric longitude (IAU 2000 [6]) range can be selected: only measures in that range are then extracted. Longitude values go from 0 to 360 degrees.

SHOT_CODE - The shot classification code identifies true ground hits (i.e. classified as in the catalog). The 0 value corresponds to cloud detections.

QUALITY_FLAG - The quality flag indicates whether the packet or individual shots passed or failed the various shot quality tests. The 0 value corresponds to good shots.

4.2.2 Physical parameters

REF_ELLIPSOID - The geometry of the reference ellipsoid. The default (the only one at the moment) value is IAU2000 ([6]). Equatorial (R_e) and Polar (R_p) radius are defined, the flattening ($f = 1 - R_p/R_e$) is derived. They are used in computing:

- planetographic latitude from the planetocentric one;
- the ellipsoidal reference surface for topography.

The relationship between planetographic and planetocentric latitudes is approximated as:

$$\tan(lc) = (1 - f) \times (1 - f) \times \tan(lg) \quad (1)$$

where f is the flattening, *lg* is the planetographic latitude and *lc* is the planetocentric latitude.

4.2.3 Output properties

`OUTPUT_FORMAT` - ASCII and XML formats are available at the moment. Both are available at the same time.

`OUTPUT_FILENAME` - The name of each output file separated by a comma.

`OUTPUT_FIELDS` - The columns of PEDRs catalogs to be written in the output, separated by commas. If this parameter is set to `ALL`, all available columns are outputted. A detailed description of columns can be found in section 5.

4.2.4 Spherical Harmonics parameters

`AREOID_SELECT` - The MOLA topography is not directly available from the catalogs: by default `MOLAutils` computes the `TOPOGRAPHY` column as the difference between the two quantities `PLANETARY_RADIUS` and `AREOID_RADIUS`.

For that reason setting this option to Y, `MOLAutils` can be asked to recompute the areoid radius from a model of the Mars gravitational potential described by spherical harmonic coefficients. The rotational potential is computed using the value of 0.70882187^{-4} *rad* sec^{-1} (from [6]) for ω, the Mars inertial rotation rate. In that case the output topography will be the difference between `PLANETARY_RADIUS` and computed areoid. `AREOID_RADIUS` (for shot and/or frame) need to be selected as `OUTPUT_FIELDS`, then a new column, `SPHEARM_AREOID` (for shot and/or frame) will be added in the output file.

`SPHEHARM_FILE` - The file containing the spherical harmonics coefficients. By default the ggm1025a model ([1]) is used by `MOLAutils` . The `MOLAutils` distribution contains the files `ggm1025a.sha`[4] and `jgm95j01.sha`[5] ([4]) together with the associated label files. Any other model can be used: the file containing the spherical harmonics coefficients has to be formatted as described by the label file `ggm1025a.lbl`.

`SPHEHARM_ORDEG` - The spherical harmonics order and degree at what the potential calculation is stopped (50, by default).

`REF_RADIUS` - The mean equatorial radius at the reference surface. By default `MOLAutils` use the value 3396.0 *Km* from [1].

4.2.5 Miscellanea

`XSL_FILT` - The XSLT filter used to display XML output file, by default the `pedrs.xsl` available in the distribution (in the `xsl/` directory).

[4] http://starbrite.jpl.nasa.gov/pds-explorer/dsidnode.jsp?nodename=GEOSCIENCE&datasetid=MGS-M-RSS-5-SDP-V1.0&volume=mors_1015&dir=sha

[5] http://pds-geosciences.wustl.edu/geo/mgs-m-rss-5-sdp-v1/mors_1033/sha/

4.3 Examples of configuration

```
# Default configuration file for MOLAutils
# CM 2008-09-03
#
#----------------------------- selection ------------------------------
ORBIT_NUMBER            0     # selected orbit number (short option -o)
LAT_RANGE       -90.00,90.00  # ground areocentric latitude range
LONG_RANGE        0.00,360.00 # ground areocentric east longitude range
SHOT_CODE             -1      # ground trigger selection 1=good 0=bad
QUALITY_FLAG          -1      # quality selection 0=good 1=bad
#
#----------------------------- parameters -----------------------------
REF_ELLIPSOID      IAU2000    # ellipsoid model for topography
#
#------------------------------ output --------------------------------
OUTPUT_FORMAT          ASCII  # output file format (ASCII,XML,PNG)
OUTPUT_FILENAME pedrs.ascii   # output file name
OUTPUT_FIELDS   AREOCENTRIC_COORDINATES
                              # output fields: ALL or
                              # AREOCENTRIC_COORDINATES,
                              # AREOGRAPHIC_COORDINATES,
                              # FRAME_COORDINATES, MGS_TWIST,
                              # CROSSOVER_COORDINATES_CORR,
                              # CROSSOVER_CORRECTION,
                              # REC_PULSE_WIDTH, SURFACE_REFLECT,
                              # ATMOSPHERIC_OPAC, ATTITUDE_FLAG,
                              # EMISSION_ANGLE, MOLA_RANGE,
                              # ORBIT_NUMBER, ORBIT_FLAG,
                              # SHOT_CODE, QUALITY_FLAG,
                              # PLANETARY_RADIUS, AREOID_RADIUS,
                              # FRAME_PLANETARY_RADIUS,
                              # FRAME_AREOID_RADIUS, DP_FRAME_TIME,
                              # TOPOGRAPHY, FRAME_TOPOGRAPHY
                              # RADIAL_DISTANCE, CORR_RECV_PULSE_ENERGY
                              # OFF_NADIR_ANGLE, ELLIPSOID
                              # FRAME_ELLIPSOID
#
#----------------------- spherical harmonics -------------------------
AREOID_SELECT   N             # compute areoid model? (Y/N)
SPHEHARM_FILE   /usr/local/share/molautils/ggm1025a.sha
                              # spherical harmonics file
SPHEHARM_ORDEG   50           # spherical harmonics order and degree
REF_RADIUS       3.396e+03    # radius of reference surface (Km)
                              # (short option -r)
#
#---------------------------- miscellaneous ---------------------------
XSL_FILT      file:///usr/local/share/molautils/pedrs.xsl
                              # Filename for XSL style-sheet
```

5 Available `MOLAutils` output columns description

A Precision Experiment Data Record (PEDR) contains MOLA telemetry data that has been converted to engineering and physical units. Each PEDR entry contains a 2 second span of data, called a frame, that is retrieved from the 14 second MOLA science mode telemetry packets. There are 20 possible shots in a 2 second frame, numbered from 1 to 20. Some quantities are recorded in PEDRs for every shot. Other ones have just the frame value, referred to the spatial central point of the frame: this reference point is called 'frame mid-point'. The way to obtain shot values is detailed in [8] (the file `pedrs.cat` is available also in the `MOLAutils` distribution, in the `doc/` directory).

Table 2 will be useful to determine errors on output values.

Table 2: MOLA instrument resolution, (from [7]), see also [9])

Range resolution	37.5cm
Vertical accuracy[a]	1 m
Surface spot size[b]	168 m
Along-track shot spacing	300 m
Across-track shot spacing[c]	4 km
Pulse FWHM	8 ns
Time resolution	2.5 ns

[a] Includes radial orbit error.

[b] In 400-km-elevation mapping orbit.

[c] Average at equator; varies with cos (*latitude*)

5.1 Position columns

`AREOCENTRIC_COORDINATES` - The planetocentric latitude and East longitude of each shot (in degrees). The location of individual shots are obtained by interpolation via the generic formula:

$$coordinate_{shot} = coordinate_{frame} + \frac{(n_{shot} - 10.5)}{20} \times \delta_{coordinate} + \delta_{parallax}, \quad (2)$$

where n_{shot} goes from 1 to 20, $\delta_{coordinate}$ is the interpolation step (read from PEDR), $\delta_{parallax}$ (obtained from PEDR data) is an added first-order correction for deviations in radius from the frame mid-point radius due to the parallax introduced by off-nadir observations.

The cartographic reference frame and rotational model describing ground locations used in the last PEDR release (2003) is the IAU2000 model [6] based on Viking, Pathfinder, and MGS data.

`AREOGRAPHIC_COORDINATES` - The planetographic latitude and West longitude of each shot (in degrees). The planetographic latitude is approximated as in section 4.2.2, at the reference ellipsoid parameter description.

`FRAME_COORDINATES` - The planetocentric latitude and East longitude of the frame mid-point (in degrees).

CROSSOVER_COORDINATES_CORR - The correction values that were added to the FRAME_COORDINATES to account for systematic crossover mismatch. For a detailed description of the crossover correction calculation see [2].

DP_FRAME_TIME - The IEEE standard 754-1985[6] double precision frame mid-point time in elapsed time from J2000[7] (in seconds).

5.2 Topography columns

MOLA_RANGE - The raw MOLA time-of-flight range for each shot corrected to the detector response and range walk (in meters). The limiting nominal resolution of 37.5 *cm* is approached on smooth flat surfaces. It can increase until ~ 10 *m* on $\sim 30^o$ slopes ([7]).

RADIAL_DISTANCE - The distance from the Mars center of mass to the Mars Global Surveyor center of mass (in meters). The value is associated with the MOLA frame mid-point. The reference coordinate system is centered in the Mars center of mass.

PLANETARY_RADIUS - The planetary radius for each shot (in meters). It is defined as the distance from Mars center of mass to the point on the surface of Mars intersected by the MOLA range. Crossover correction (see [2]) is already applied. Its vertical accuracy, including radial orbit error is 1 *m* (see Table 2).

FRAME_PLANETARY_RADIUS - The planetary radius associated with MOLA data frame mid-point (in meters). A weighted fit to the valid observations of planetary radius in the data frame is performed and the value at the frame mid-point is kept. No crossover correction has been added.

FRAME_AREOID_RADIUS - The radius of the reference areoid at the frame mid-point (in meters), with a 3396 kilometer mean radius at the equator. The Goddard Mars Model 3 (mgm1025) [1], with the coordinate system of IAU2000, is used. The global areoid error through degree 60×60 for the mgm1025 model is 1.8 *m*.

AREOID_RADIUS - The radius of the reference areoid for each shot (in meters), computed via the following equation

$$areoid_{shot} = areoid_{frame} + \frac{(n_{shot} - 10.5)}{20} \times \delta_{areoid}, \tag{3}$$

where n_{shot} goes from 1 to 20, δ_{areoid} is the average change in the reference areoid associated with each 20-shot MOLA frame (read from PEDR).

[6]The IEEE Standard for Binary Floating-Point Arithmetic (IEEE 754) is the most widely-used standard for floating-point computation, and is followed by many CPU and FPU implementations (http://en.wikipedia.org/wiki/IEEE_754-1985).

[7]This is equivalent to January 1, 2000, 11:59:27.816 TAI (International Atomic Time) or January 1, 2000, 11:58:55.816 UTC (Coordinated Universal Time).

FRAME_SPHEARM_AREOID - This column is outputted if the option AREOID_SELECT and the output column FRAME_AREOID_RADIUS are set. It is defined as the radius of the reference areoid at the frame mid-point coordinates (in meters), with a mean radius at the equator as in the REF_RADIUS input option, degree and order as in the SPHEHARM_ORDEG input option, potential model described in the SPHEHARM_FILE input option. The coordinate system of IAU2000 is used.

SPHEARM_AREOID - This column is outputted if the option AREOID_SELECT and the output column AREOID_RADIUS are set. It is defined as the radius of the reference areoid at the shot coordinates (in meters), with a mean radius at the equator as in the REF_RADIUS input option, degree and order as in the SPHEHARM_ORDEG input option, potential model described in the SPHEHARM_FILE input option. The coordinate system of IAU2000 is used.

TOPOGRAPHY - The difference between the PLANETARY_RADIUS and the AREOID_RADIUS (in meters). If the option AREOID_SELECT is set, the SPHEARM_AREOID is used in place of the AREOID_RADIUS.

FRAME_TOPOGRAPHY - The difference between the FRAME_PLANETARY_RADIUS and the FRAME_AREOID_RADIUS (in meters). If the option AREOID_SELECT is set, the SPHEARM_FRAME_AREOID is used in place of the FRAME_AREOID_RADIUS.

ELLIPSOID - The value of the standard IAU ellipsoid radius at the shot position (in meters). If the TOPOGRAPHY output column is selected, an additional quantity SHOT TOPOGRAPHY ON ELLIPSOID is calculated as the difference between the PLANETARY_RADIUS and the ELLIPSOID_RADIUS.

FRAME_ELLIPSOID - The value of the standard IAU ellipsoid radius at the frame mid-point position (in meters). If the FRAME_TOPOGRAPHY output column is selected, an additional quantity FRAME TOPOGRAPHY ON ELLIPSOID is calculated as the difference between the FRAME_PLANETARY_RADIUS and the FRAME_ELLIPSOID_RADIUS.

CROSSOVER_CORRECTION - Crossover correction of planetary radius (in meters) with respect to the value at frame mid-point (see [2] for details). It may be used to perform preliminary selection on records that have excessive range corrections ($\sim$ 100 meters of vertical correction). In the output file the crossover correction is already applied, i.e. subtracted from the raw shot planetary radius read in the catalog.

5.3 Instrumental properties columns

MGS_TWIST - The twist angle of the MOLA instruments at data frame mid-point (in degrees).

REC_PULSE_WIDTH - The received optical pulse width (in nanoseconds), corrected for filter characteristics and threshold settings, as determined by the receiver model. One value for each shot. The pulse width provides an estimate of the target slope and/or roughness[3], assuming linear detector response and nadir-looking geometry.

CORR_RECV_PULSE_ENERGY - The surface-scattered return energy as measured by the pulse width and area counters, corrected for threshold setting (in attojoules).

ATTITUDE_FLAG - A flag to indicate if spacecraft attitude information was missing for a frame. It is set to 2, if attitude information was missing for part of the frame; to 3, if missing for entire frame; otherwise to 0.

EMISSION_ANGLE - The angle between the Mars surface normal vector and the Mars Global Surveyor vector at the frame mid-point location (in degrees).

OFF_NADIR_ANGLE - The angle between the transmitted laser shot direction and the areocentric direction, at spacecraft frame mid-point (in degrees).

ORBIT_NUMBER - The mapping mission orbit number determined by Mars Global Surveyor flight operations system.

ORBIT_FLAG - A flag indicating the orbit origin. 0 indicates that JPL NAV team was producer; 1 or higher indicates the MOLA Science Team reference gravity model number.

SHOT_CODE - A shot classification: 0=false trigger or no trigger; 1=probable ground trigger; other values unassigned.

QUALITY_FLAG - A flag indicating whether the packet or individual shots passed or failed the various shot quality tests. A 1 indicates the test was failed, 0 indicates the test was passed.

5.4 Mars physical properties columns

ATMOSPHERIC_OPAC - The Mars atmospheric opacity τ; may be retrieved from TES data. A pure number, nominally 0.5.

SURFACE_REFLECT - Relative Martian surface reflectivity (a pure number), calculated dividing the reflectivity-transmission product (read in PEDRs) by $exp(2\tau)$.

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