A new Mars Climate Database v5.1

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A NEW MARS CLIMATE DATABASE, VERSION 5.1

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Introduction: What is the Mars Climate Database?

The Mars Climate Database (MCD) is a database of meteorological fields derived from General Circulation Model (GCM) numerical simulations of the Martian atmosphere and validated using available observational data. The MCD includes complementary post-processing schemes such as high spatial resolution interpolation of environmental data and means of reconstructing the variability thereof.

The GCM is developed at Laboratoire de Météorologie Dynamique du CNRS (Paris, France) [1-3] in collaboration with the Open University (UK), the Oxford University (UK) and the Instituto de Astrofisica de Andalucia (Spain) with support from the European Space Agency (ESA) and the Centre National d'Etudes Spatiales (CNES).

The MCD is freely distributed and intended to be useful and used in the framework of engineering applications as well as in the context of scientific studies which require accurate knowledge of the state of the Martian atmosphere.

The MCD may be accessed either online (in a somewhat simplified form) via an interactive server available at http://www-mars.lmd.jussieu.fr (useful for moderate needs), or from the complete version which includes advanced access and post-processing software (contact millour@lmd.jussieu.fr and/or forget@lmd.jussieu.fr to obtain a free copy).

Overview of MCDv5 contents:

The MCD provides mean values and statistics of the main meteorological variables (atmospheric temperature, density, pressure and winds) as well as atmospheric composition (including dust and water vapor and ice content), as the GCM from which the datasets are obtained includes water cycle [4-6], chemistry [7,8], and ionosphere [9,10] models.

The database extends up to and including the thermosphere[11-13] (~350km). Since the influence of Extreme Ultra Violet (EUV) input from the sun is significant in the latter, 3 EUV scenarios (solar minimum, average and maximum inputs) account for the impact of the various states of the solar cycle.

To be more specific, the MCD provides users with:

- Climatologies over a series of dust scenarios: **standard year**, **cold** (ie: low dust), **warm** (ie: dusty atmosphere) and **dust storm**, all topped by various cases of Extreme UV solar inputs (low, mean or maximum). These scenarios differ from those of previous versions of the MCD as they have been derived from home-made, instrument-derived (TES, THEMIS, MCS, MERs), dust climatology of the last 7 Martian years [14]. We are also considering making specific simulations (i.e. with specific dust loading of each Mars Year and corresponding realistic EUV input) available to interested users as additional “add-on” scenarios.
- Mean values and statistics of main meteorological variables (atmospheric temperature, density, pressure and winds), as well as surface pressure and temperature, CO2 ice cover, thermal and solar radiative fluxes, dust column opacity and mixing ratio, [H20] vapour and ice concentrations, along with concentrations of many species: [CO], [O2], [O], [N2], [Ar], [H2], [O3], [H] ..., as well as electrons mixing ratios.
- Dust mass mixing ratio, along with estimated dust effective radius and dust deposition rate on the surface are also provided.
- Following the recent improvements on the parametrization of physical processes in the Planetary Boundary Layer (PBL) [15], many related fundamental quantities such as PBL height, minimum and maximum vertical convective winds in the PBL, surface wind stress and sensible heat flux,...are part of available MCD outputs.
- A high resolution mode which combines high resolution (32 pixel/degree) MOLA topography records and Viking Lander 1 pressure records with raw lower resolution GCM results to yield, within the restriction of the procedure, high resolution values of atmospheric variables.
- The possibility to reconstruct realistic conditions by combining the provided climatology with additional large scale and small scale perturbations schemes.

Validation of the MCD climatology

The MCD has been validated using the many available datasets obtained by various instruments. The assessment of the correctness of the surface pressure predictions was obtained using Viking Lander 1 measurements (see Figure 1).

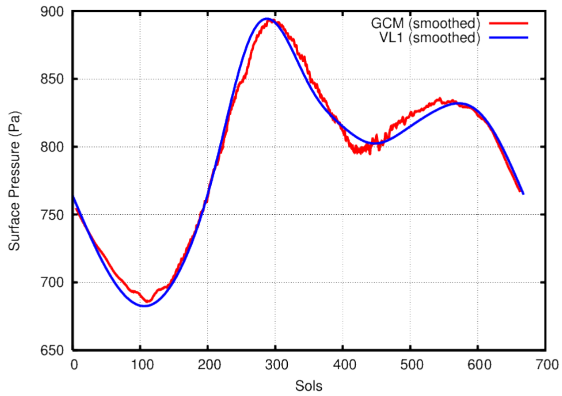

Figure 1: Illustration of the surface pressure at Viking Lander 1 over a Mars year, as obtained from one of the LMD GCM runs used to create the MCD, compared to VL1 measurements. In both cases values were smoothed over tens of sols in order to exclude diurnal variations and depict the seasonal evolution of the Martian CO2 cycle.

Evaluation of correctness of surface and atmospheric temperature was obtained by comparing with TES (onboard MGS) (see Figures 2 and 3), and MCS (onboard MRO) (not shown here), but also from atmospheric temperature retrieved from radio occultation from MGS and Mars Express (Figure 4).

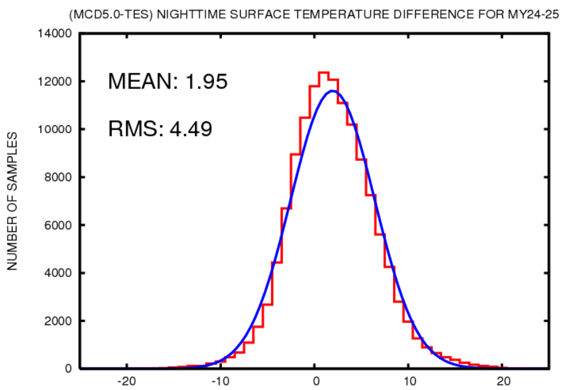

Figure 2: Example of comparisons between MCD predictions of surface temperatures and nighttime measurements by the Thermal Emission Spectrometer (TES) onboard Mars Global Surveyor (data kindly provided by M.D. Smith). Distributions of binned temperature differences (using bins of 1K) between MCD5 Climatology scenario predictions and TES measurements (at 2am) over Mars Years 24 and 25 (up to Ls=180°, i.e. before the global dust storm) for latitudes ranging from 50°S to 50°N. Displayed MEAN and RMS values are computed from the obtained histograms and the blue curve correspond to normal distributions of same MEAN and RMS.

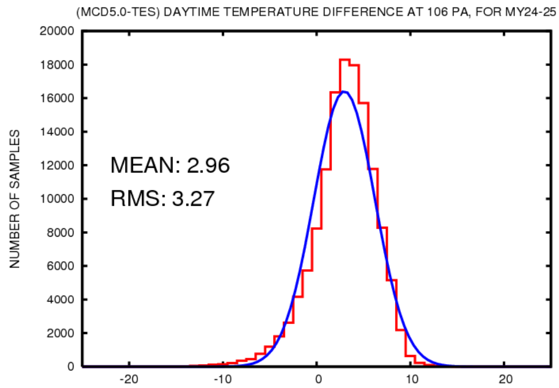

Figure 3: As in figure 2, but displaying the comparison between daytime (2pm) atmospheric temperatures at 106Pa.

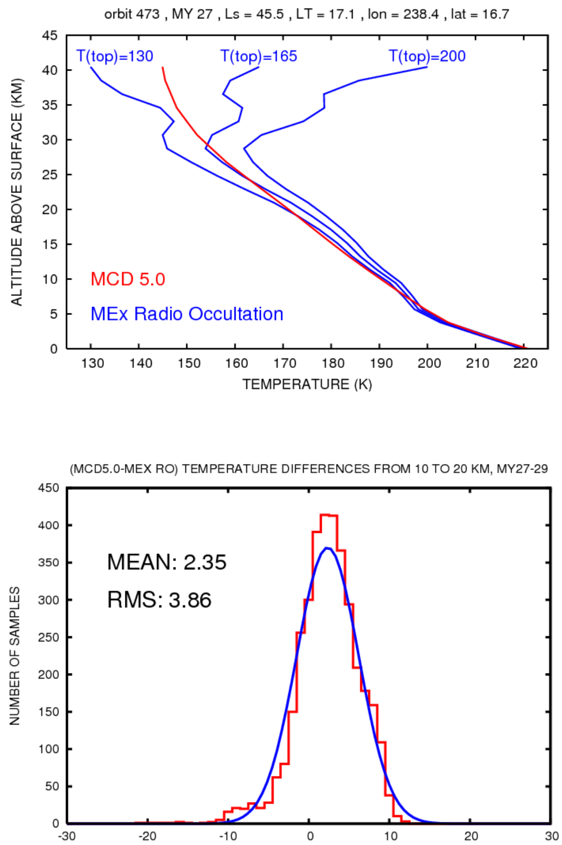

Figure 4: Top: Illustration of a MeX radio occultation (MaRS data kindly provided by S. Tellman), different shown profiles display the influence of the arbitrary choice of upper atmosphere (40km) temperature on the derived profile, along with the MCDv5.0 Climatology scenario prediction.
Bottom: Statistics on the temperature differences (for altitudes between 10 and 20 km) between MCD predictions and Mars Express radio occulation profiles (209 profiles overall, gathered over Earth years 2004-2008, i.e. MY27-MY29).

Applications of the MCD:

Since the release of MCDv5.0 in October 2012, it has been distributed to over 40 teams in various countries, in many cases users already using previous versions of the MCD. Overall, various versions of the MCD have been delivered to around 150 teams around the world . Current applications include entry descent and landing (EDL) studies for future missions (ExoMars, MSL), investigations of some specific Martian issues (via coupling of the MCD with homemade codes), analysis of observations (Earth-based as well as with various instruments onboard Mars Express and Mars Reconnaissance Orbiter),...

More specifically, recent applications of the MCD include :

- Analysis of SPICAM data at LATMOS, France,
- Analysis of PFS data at IAPS, Italy and Tohoku University, Japan,
- Analysis of TES and MCS retrievals at JPL, USA
- Analysis of gravity waves and tides observed by spacecrafts at Boston University, USA.
- Analysis of MaRS Mars Express radio science observations of the neutral atmosphere and ionosphere at RIU-Planetenforschung Koeln, Germany.
- Modeling interaction between atmospheric gases and surface minerals on Mars at the Arkansas Space Center, USA,
- Entry Descent and Landing (EDL) studies for MSL at JPL, USA,
- EDL studies at the Vikram Sarabhai Space Center, India,
- EDL studies for ExoMars by companies contracted by ESA ESTEC, and by CNES.
- Mission analysis of the Chinese Planetary Science Program on Martian Atmosphere at the Chinese Space Science Application Center, Beijing,
- Simulation of radiance spectra to study observational requirements for trace gas observations at the University of Leicester, UK,
- Studies of the effects of the atmosphere on observed surface temperatures at the Space Science Institute, USA,
- Testing an initializing an implementation of the EPIC (Explicit Planetary Isentropic Coordinate) atmospheric model at the University of Louisville, USA,
- Used as an input for a model of the ionosphere of Mars at the University of California, USA,
- … and many more…

Towards MCD version 5.1

At the time of writing, the currently distributed Mars Climate Database is MCDv5.0. We are however currently running GCM simulations which include some updates and improvements which will be beneficial and thus plan to issue an MCDv5.1 in the beginning of 2014.

Obtaining the Mars Climate Database

The MCD may be accessed either online (in a somewhat simplified form) via an interactive server available at http://www-mars.lmd.jussieu.fr (useful for moderate needs; see Figure 5), or from the full version which includes advanced access and post-processing software (written in Fortran, but examples of Matlab, IDL, C/C++ and python interfaces are provided), just contact millour@lmd.jussieu.fr and/or forget@lmd.jussieu.fr to obtain a free copy.

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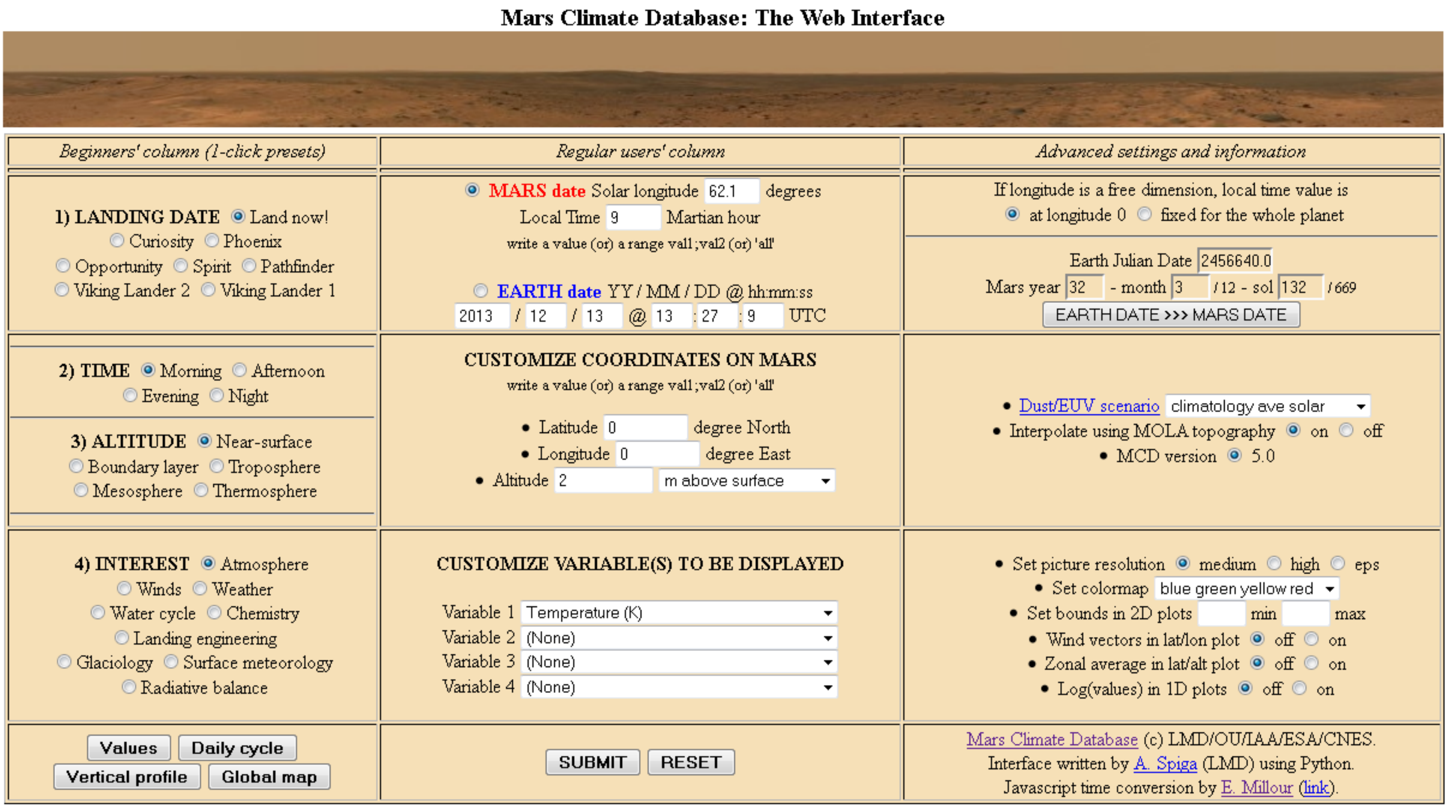

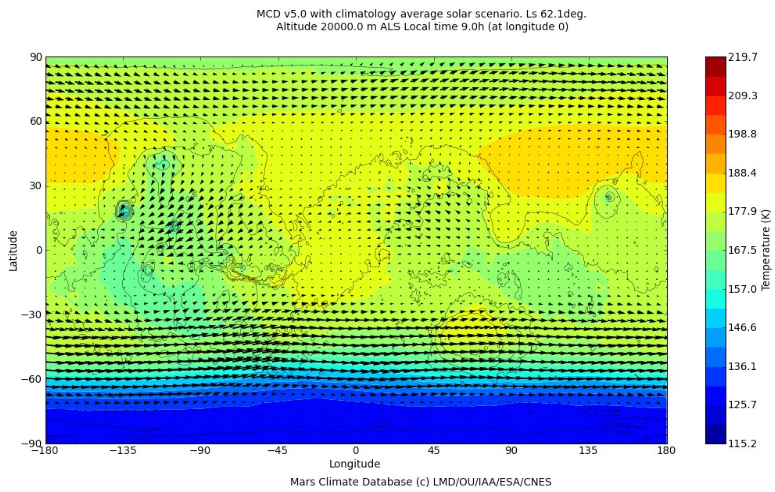

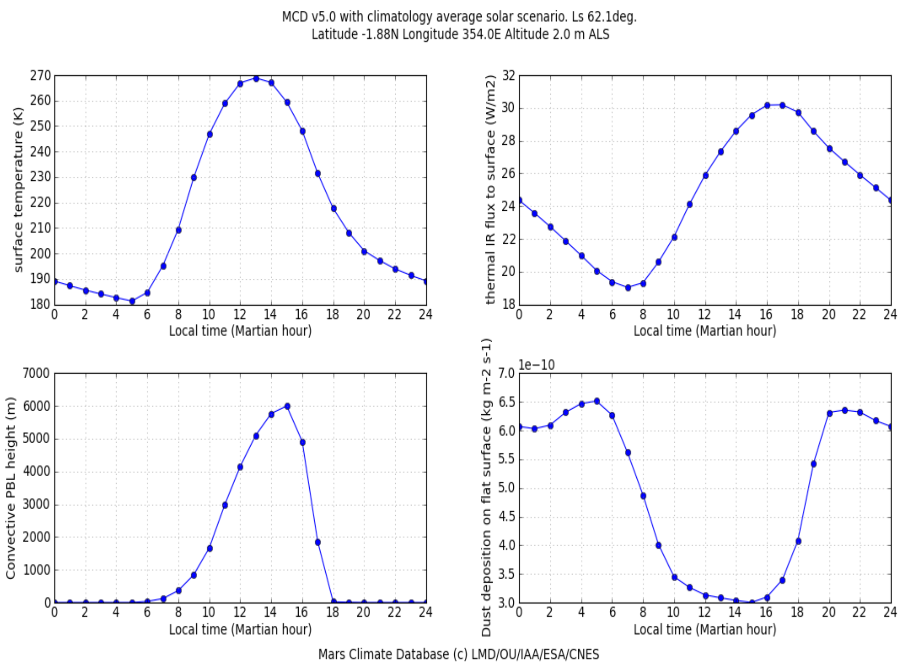

Figure 5: The new Mars Climate Database v5 web interface (http://www-mars.lmd.jussieu.fr) and some illustrative sample outputs: a winds and temperature map at 20km for Ls=62.1, and a series of diurnal evolution of surface pressure, thermal infrared flux to the surface, convective PBL height and dust deposition at the surface predicted at longitude 354E, latitude -1.88N (Meridiani Planum, target landing site for the ExoMars 2016 EDL demonstrator).