What is the Mars Climate Database?

- The Mars Climate Database (MCD) is a collection of meteorological fields derived from General Circulation Model (GCM) numerical simulations of the Martian atmosphere and validated using available observational data.
- The MCD is also a data output of the GCM but also provides: complementary post-processing schemes such as high spatial resolution interpolation of environmental data and means of reconstructing the Martian climate. The GCM is developed at LMD (Paris, France) in collaboration with LATMOS (Paris, France), the Open University (UK) and the Instituto de Astrofisica de Andalucia (Granada, Spain), with support from the European Space Agency (ESA) and the Centre National d'Études Spatiales (CNES, France).

Using the Mars Climate Database

- For introductory and precise work: You need to use the full MCD, which contains the data flex (in HICDAP format) and various other parameters. To access and download the MCD, you can search for its name and access the full version which includes all the datafiles and the advanced access tool, using: https://cmh.jussieu.fr/mcd/Mars/.webkiosk_login.html.
- MCD version 6.0 was released in July, 2017. We are implementing MCD version 6.0 which should be available in autumn 2019.

Overview of MCD contents

- The MCD contains 4 synthetic dust scenarios in order to better represent the range of variability of the Martian atmosphere due to the dust and transitions between dust. A dust scenario is defined as a set of output MCD runs that, when observed, a warm (winter) or dry (summer) season, and a global dust storm (at least 85%) and/or each of these using "binned" dust optical properties from Brinck-Baftig et al. 1997, rather than the more recent Wolff et al. 2003 ones.
- The MCD outputs the thermodynamic, up to T = 500 K and beyond, and the Mariner-9 pressure (at P = 100 Pa). The MCD includes a thermosphere model above ~100 km. Three Extreme Ultra Violet (EUV) scenarios, which account for various states of the solar cycle (minimum, average, and maximum), are thus explored.
- The MCD provides wind data (velocity components, latitude, temperature and horizontal and vertical temperature and pressure), CO₂ ice cover, Seasonal H₂O ice cover, thermal and solar radiative fluxes, dust column density and dust mixing ratio, estimation of dust effective radius and deposition rate, [O₃] vapor and [O₂] column and mixing ratio, solar effective radius, [CO₂] CO, [HO₂], [H₂O], [H₂], [O], [O3], [OH], and [CI] mixing ratios and columns, AIR specific heat capacity, viscosity and reduced molecular gas constant R, Planetary boundary layer (PBL) height, vertical convective winds in PBL, Surface wind stress and sensible heat flux.
- Additional scenarios, representative of the last 16 Mars Years (MY) (MY 2012 to MY 332) both in terms of observed atmospheric dust conditions (dust deposition) and in terms of possible variations of the MCDs (e.g., warmer winters) and EUV input (e.g., increased solar activity), are also considered in order to provide our best estimate of these years. The EUV for these scenarios is that of the observed solar cycle.

Illustrative examples:

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<th>20</th>
<th>30</th>
<th>40</th>
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<th>60</th>
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<tbody>
<tr>
<td>Pressure (Pa)</td>
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</tbody>
</table>

Comparability Between Observations (Mars Year 26, solar longitude Ls 130°, 80 km altitude, seasonal phase f/4, Paul Whitten and mean MCD profiles obtained for various dust scenarios).

Atmospheric variability in the MCD

To represent the wide range of variations over which meteorological variables vary, the MCD includes:

- 2 Year to year variability and dust content variations: Simulation of years with three different Solar Cycle conditions (minimum, average, maximum).
- Diurnal cycle: In the MCD are stored 12 "typical" days (average of 30° of Ls) around the year. The weather varies from day to day with slight variations (from minimum to maximum).
- Diurnal cycle: Environmental data within 12 times per day: interpolation is used to evaluate values of variates at a given time increments (e.g., every 2 hours).
- Day to day variability (i.e., representation of transient waves). Various tools are provided to reconstruct the variability of meteorological parameters.

Perturbations may be added:

- Large scale perturbations, using Empirical Oxidant Functions (EOFs) derived from the GCM runs.
- Small scale perturbations, by adding a proxy of events of defined wavelength.

Standard deviations of mean climatological fields are given for:

- Atmospheric density, pressure, temperature and winds.
- Solar radiative fluxes, dust column density and dust mixing ratio, estimation of dust effective radius and deposition rate, [O₃] vapor and [O₂] column and mixing ratio, solar effective radius, [CO₂] CO, [HO₂], [H₂O], [H₂], [O], [O3], [OH], and [CI] mixing ratios and columns, AIR specific heat capacity, viscosity and reduced molecular gas constant R, Planetary boundary layer (PBL) height, vertical convective winds in PBL.

The high resolution mode

- The GCM horizontal resolution (latitude-longitude) computerized is 5.075° x 5.075°.
- By combining high resolution (32 pixels/degree) MOLA topography and Viking Lander 1 pressure records (used for the GCM horizontal resolution) and climatic scenarios (for Opportunity entry), temperature profiles can be obtained to 

The Mars Climate Database validation

- The MCD has been validated using observational data from many available sources: Mars Global Surveyor (TES, Pathfinder, MGS; ASPERA-3, OMEGA, MARS), Mars Exploration Rovers (MRO; MER), Venus Express (VE), Mars Express (VCCS), Mars Odyssey (MRO), Mars Reconnaissance Orbiter (MRO), Venus Express (VEX), Pathfinder, MROs, Spirit and Opportunity. Curiosity, as a new measurement are made available, these are added to the MCD predictions. We are working on a validation document which will report on all these comparisons.

Example n°1: Surface pressure at Viking Lander 2 site

The Viking lander reached Mars in Mars Year 12 and collected data for a few Mars years (3 for VL1 and 1 for VL2).

- Switching from the baseline climatology scenario to the Dust Storm scenario enables to simulate in behavior observed by Viking Lander 2 during the 1977 global dust storm.
- Surface pressure cycle over a Martian year, as predicted by the MCD climatology scenario at Viking Lander 2 site, with an envelope of ±0.2 bars times its standard deviation, compared to the measured values.

Example n°2: MSL Curiosity surface pressure

The REMS station located Curiosity (17°14‘7" E and 4°51”) measures surface pressure since the rover’s arrival on Mars (Mars Year 31, solar longitude Ls189°) and is currently still collecting data.

Example n°3: TES atmospheric temperatures

The Thermal Emissivity Spectrometer (TES) onboard Mars Global Surveyor has nearly continuously monitored the Martian atmosphere for almost 3 Martian years (from early in Mars Year 24 to the beginning of Mars Year 27), yielding information on the local and seasonal evolution of atmospheric conditions on Mars.

Example n°4: MGS atmospheric temperatures

The Mars Climate Sounder (MCS) onboard Mars Reconnaissance Orbiter has been monitoring the Martian Atmosphere since Mars Year 28 and is still collecting data, more than 7 Martian years later.

Towards MCD version 6.0

- Many developments have been made in our GCM physics package over the last years:
  - The water cycle has been improved by introducing a representation of sub-grid scale clouds (when only a fraction of the mesh is covered by clouds). Potter et al. 2017, et al. and the new version of the MCD (Version 6.0) has been implemented.
  - A parameterization of the impact of non-radiative gravity waves, which seem to be crucial components of the atmospheric circulation, has been developed and is fixed to significantly improve the simulations in some high gravity models (SOI et al. submitted).
- A parameterization of a new type of dust storms (SOGs) (Spiga et al. 2013) generating detached dust layers observed between 20 and 30 km altitude has been implemented (Wang et al. 2018). But these only occur during the day season and requires a parameterization of dust injection by winds along mountains.