Towards a (GCM based) Venus Climate Database

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The IPSL Venus GCM

- A well validated model of the Venusian atmosphere (S. Lebonnois' talk) Its main features may be summarized as:

➢ **Dynamical core**:

- Heritage from LMDZ Earth GCM
- Finite differences lon-lat grid:
  Typical horizontal resolution: 96x96
- Hybrid Sigma-P vertical coordinate:
  Typically 50 level (up to ~95km)

➢ **Physics packages**:

- Mellor and Yamada boundary layer scheme
- Topography is implemented
- Full radiative transfer scheme

➢ **Optional physics packages**:

- Extention to the thermosphere (~150km), including non-LTE effects and EUV (Extreme UV) heating, and the effect of non-orographic gravity waves
- Photochemistry and cloud microphysics modules.

The Mars Climate Database

- The Mars Climate Database (MCD) is a database **derived from Global Climate Model** (GCM) **simulations**, using the LMD-GCM.
- The MCD is intended to be useful for engineering applications (e.g. Entry Descent & Landing studies) and scientific work which require accurate knowledge of the Martian atmosphere (e.g. Analysis of observations).
- The MCD is freely available, either via light online access (http://www-mars.lmd.jussieu.fr) for moderate needs, or a full version which includes advanced post-processing software (Fortran subroutine call_mcd; examples of C, C++, IDL, MATLAB, SCILAB, Python interfaces are provided).
- MCD v4.x and v5.x have been distributed to more than 400 teams around the world. v5.3 was released in July 2017

MCD contents & main features

- The MCD provides mean values and statistics of main meteorological variables: **pressure**, **atmospheric density**, **temperature**, **winds**.
- Other variables included in the MCD:
  - Surface temperature and pressure
  - Thermal and solar radiative fluxes
  - CO_2 ice cover
  - Dust column opacity and mass mixing ratio
  - Dust effective radius and dust deposition rate
  - [H_2O] vapour and [H_2O] ice columns and mixing ratio
  - Water ice effective radius
  - [CO_2], [CO], [O], [O_2], [O_3] [N_2], [Ar], [H], [H_2], [He], [electrons] mixing ratios
  - Air specific heat capacity, viscosity and reduced gas constant r
  - Convective PBL height, typical updraft and downdraft velocities in PBL
  - Surface heat stress and surface sensible heat flux
  - …

Water cycle model

Chemistry model

Thermosphere model

Ionosphere model

MCD contents & main features

- The MCD enables to reconstruct realistic conditions using:

  - day-to-day variability of main variables

  - adding random small scale perturbations as gravity waves (of user specified wavelength)

  - adding random large scale perturbations (extracted from EOFs of individual GCM runs)

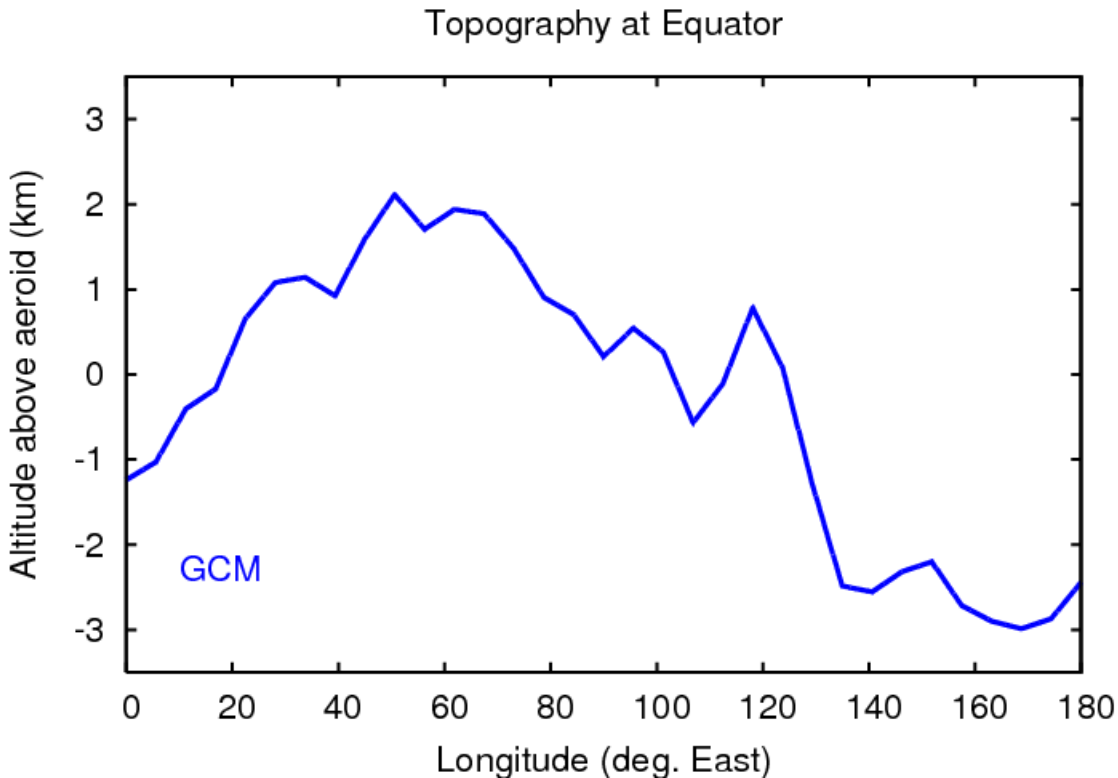
- The MCD provides a high resolution mode based on 32 pix./deg. MOLA topography (where GCM resolution is 5.625° x 3.75°) combined to Viking Lander 1 pressure records, which yields:

  - high resolution surface pressure

  - reconstructed high resolution atmospheric temperature, using an empirical scheme validated using high resolution GCM runs.

MCD high resolution outputs

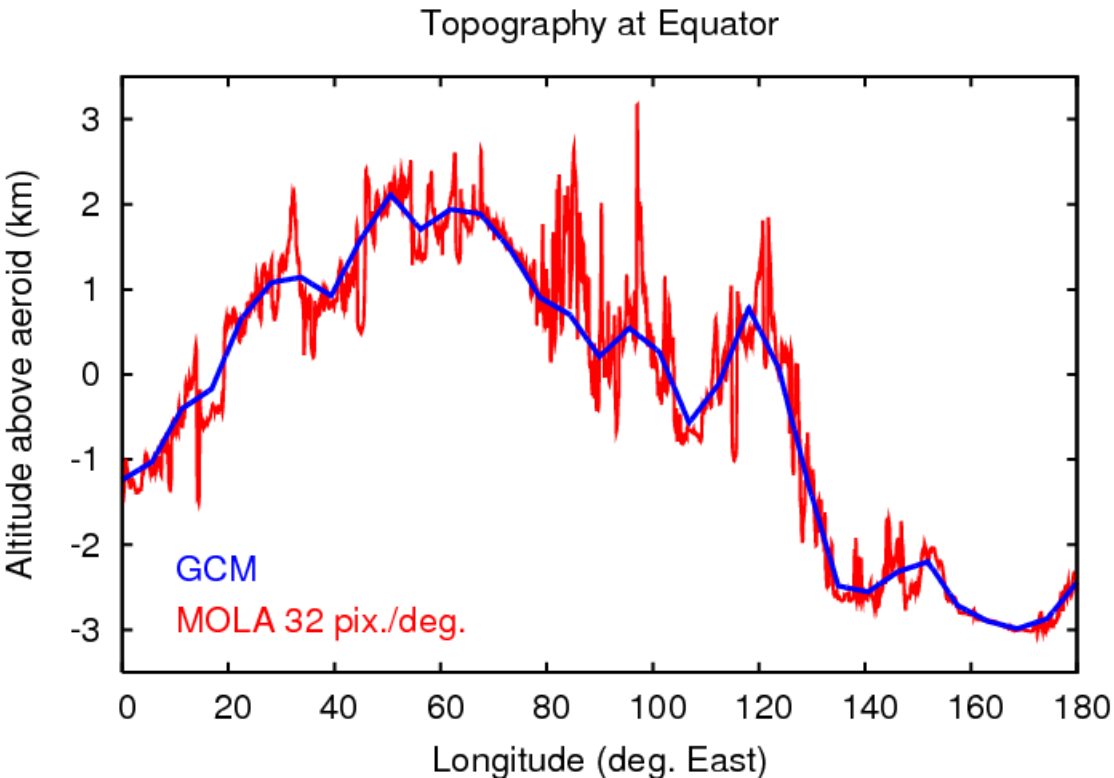
The GCM from which the MCD is derived is run at 5.625° x 3.75° resolution in longitude x latitude.



MCD high resolution outputs

- The GCM from which the MCD is derived is run at 5.625° x 3.75° resolution in longitude x latitude.
- The MCD post-processing software includes a high resolution mode based on 32 pix./deg. MOLA topography

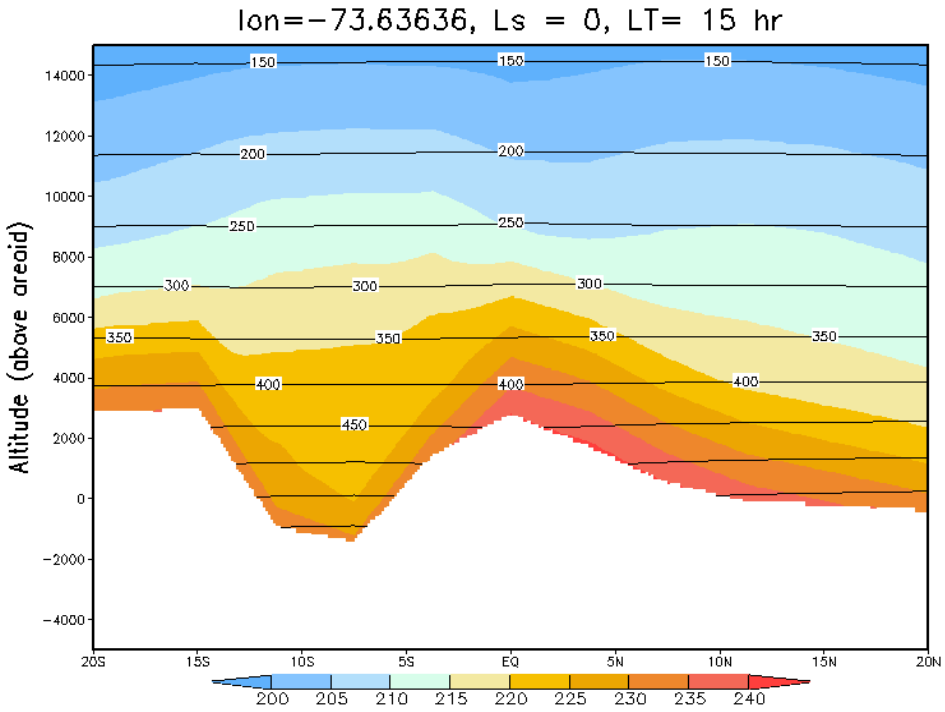
High resolution surface pressure is obtained by combining GCM surface pressure, MOLA topography and VL1 pressure records (procedure validated by Spiga et al. 2007)

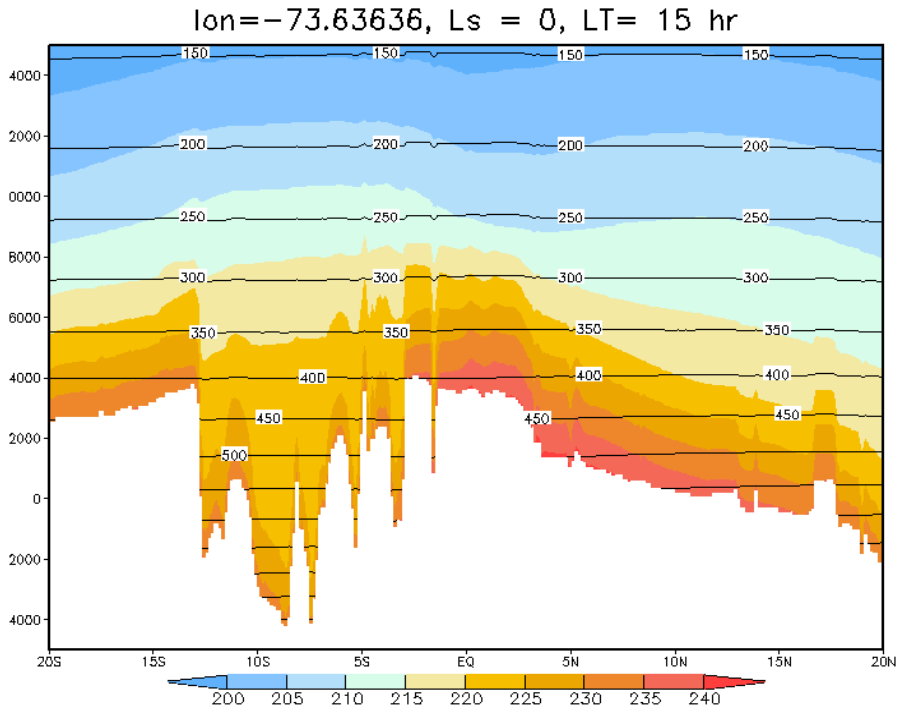


MCD high resolution outputs

The high resolution scheme extends to the reconstruction of atmospheric temperature and density (empirical scheme validated using high resolution GCM runs).

Example: temperatures above Valles Marineris





Planned Venus Climate Database

- Main access software:
  - Primarily composed of a Fortran subroutine (to benefit from MCD heritage) designed to provide access, with adequate interpolations, to fields and variables as a result of a point-wise (in location and time) query.
  - Enabling the user to query along the time dimension either by specifying an Earth date or a Venus Local Time.

Planned VCD contents

- Main access software:
  - Enabling the user to choose between different possible vertical coordinates (pressure, altitude above surface or altitude above reference geoid).
  - Provide not only climatological values of the fields but also some information on the variability (e.g. day-to-day RMS) thereof.
  - The VCD dataset will include one full Venus day of computations, sampled at 1/24th of a Venusian day to accurately represent the diurnal cycle

Planned VCD contents

- Foreseen baseline fields available in the VCD:
  - Atmospheric temperature, winds, density and pressure.
  - Surface temperature and surface pressure.
  - Solar radiation received at the top of the atmosphere.
  - Net short wave and long wave fluxes at the surface.
  - Topography.

Planned VCD contents

- Beyond baseline fields:
  - Results from the latest validated versions of chemistry and microphysics packages (Poster P23, F. Lefèvre et al.), will also naturally be made available
  - **Extra post-processing capabilities** such as high resolution (wrt GCM resolution) prediction of surface pressure when taking into account a higher resolution topography (Magellan map).

High resolution prediction of surface pressure on Venus

- Can be derived at a given altitude by combining hydrostatic equilibrium and the adiabatic lapse rate:

$$p = p_0 \, e^{-(g/R)/[\Gamma/2 + T_0/(z-z_0)]}$$

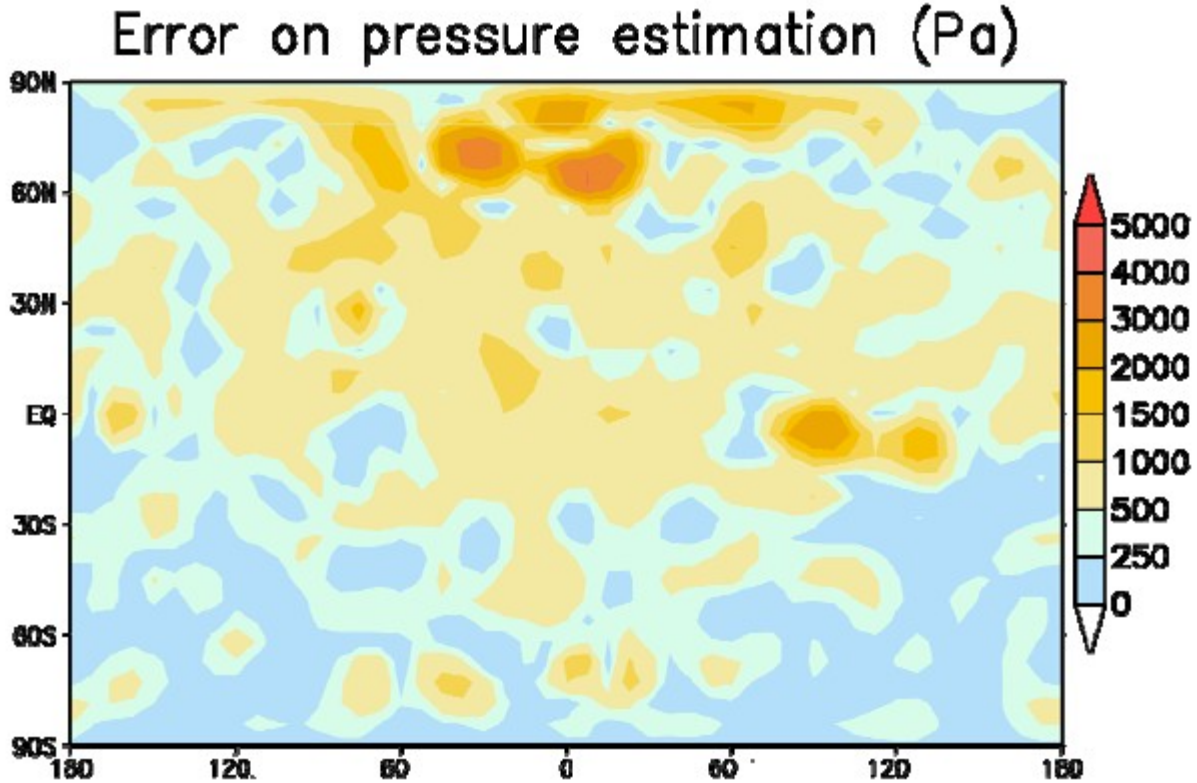
with :

- p_0 a reference surface pressure at a reference landing site (e.g. Vega 2 or more combination)
- T_0 the reference near-surface atmospheric temperature at the reference site (K)
- z_0 the altitude of the reference site
- g the acceleration of gravity
- R the gas constant on Venus (we use $R = 191.39$ m^2 s^{-2} K^{-1} , corresponding to a mean molecular mass of 43.44 g mol^{-1}).
- Γ the adiabatic lapse rate ($dT/dz = -g/Cp$) in K/m

Study by F. Forget

High resolution prediction of surface pressure on Venus

- Has been tested with the GCM and yields in most locations a total error below 2000Pa, i.e. less than 0.02% relative error. This technique could be extended to finer topography.



Study by F. Forget

Additional means to access the VCD

- Based on our experience with the MCD
  - Interfaces with other programming languages (e.g. C, C++, IDL, Matlab, Python, …) must also be provided.
  - A web interface for quick-looks and plots is always very welcome.
  - We are also very much interested in the possibility of distributing the VCD as a virtual observatory in the frame of the Virtual European Solar and Planetary Access (VESPA) Europlanet 2020 Research Infrastructure program http://www.europlanet-vespa.eu

Take home messages

- Based on our experience with the Mars Climate Database (MCD), we plan to make a Venus Climate Database (VCD).

- This VCD will be freely distributed to the community as software to interface with home-made codes and via a web interface for quick looks.

- Suggestions and comments from potential future users are very welcome!