



## 3D Simulations of the Early Mars Climate with a General Circulation Model

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**3D SIMULATIONS OF THE EARLY MARS CLIMATE WITH A GENERAL CIRCULATION MODEL.** F. Forget<sup>1</sup>, R. M. Haberle<sup>2</sup>, F. Montmessin<sup>2</sup>, S. Cha<sup>2</sup>, E. Marcq<sup>1,2</sup>, J. Schaeffer<sup>2</sup>, Y. Wanherdrick<sup>1</sup>, <sup>1</sup> *Laboratoire de Météorologie Dynamique, IPSL, UPMC BP99, place Jussieu, 75252 Paris cedex 05 (forget@lmd.jussieu.fr),* <sup>2</sup> *NASA Ames Research Center, Space Science Division, Moffett Field, California, ..*

## Introduction

The environmental conditions that existed on Mars during the Noachian period are subject to debate in the community. In any case, there are compelling evidence that these conditions were different than what they became later in the Amazonian and possibly the Hesperian periods. Indeed, most of the old cratered terrains are dissected by valley networks (thought to have been carved by flowing liquid water), whereas younger surface are almost devoid of such valleys. In addition, there are evidence that the erosion rate was much higher during the early Noachian than later [1]. Flowing water is surprising on early Mars because the solar luminosity was significantly lower than today. Even with the thick atmosphere (up to several bars) that is expected to have existed on Mars at the time, simple 1D models based on a purely gaseous atmosphere predicted climate conditions too cold to allow liquid water to flow [2]. On this basis, some authors have suggested that the difference resulted from a stronger geothermism during that period, and that a warm climate was not necessary to explain the valley network [3]. However, other authors claim that a warm, wet early climate capable of supporting rainfall and surface runoff is the most plausible scenario for explaining the entire suite of geologic features in the Martian cratered highlands [1].

To help understand this key issue in Mars science, it is important to extend the initial climate simulations that concluded that early Mars must have been cold [2,3], since these calculations were performed with very simple 1D models [4]. Such improvements have been performed by several authors, and in particular it has been suggested that the CO<sub>2</sub> ice clouds that must have formed in such an atmosphere could have produced a strong "scattering" greenhouse effect sufficient to warm the planet above the freezing point of water [5]. However, there again, these simulations were performed with simple 1D models, from which it is difficult to predict the environmental conditions.

## A Global Climate model for early Mars

To improve our understanding of the early Mars Climate, we have developed a 3D general circulation model similar to the one used on current Earth or Mars to study the details of the climate today. Our first objective is to answer the following questions: how is the Martian climate modified if 1) the surface pressure is increased up to several bars (our baseline: 2 bars) and 2) if the sun luminosity is decreased by 25% account the heat possibly released by impacts during short periods, although it may have played a role [6]

For this purpose, we have coupled the Martian General Circulation model developed at LMD [7] with a sophisticated

correlated k distribution model developed at NASA Ames Research Center. It is a narrow band model which computes the radiative transfer at both solar and thermal wavelengths (from 0.3 to 250 microns). The correlated-k's for each bands are generated from a line-by-line code using the HITEMP data base from HITRAN. In addition, pressure induced absorption by CO<sub>2</sub> is included using a simple parameterisation from an analytical formula produced by Moore et al. (1971). This is a major source of uncertainty.

In addition to the radiative transfer and to the parameterisation that are usually included in such a climate models (dynamical core to solve the 3D fluid dynamic equations, sub-grid scale turbulent and convective mixing, surface heat balance and subsurface heat conduction, etc...), we have included parameterisations to account for the condensation, transport, gravitational sedimentation and radiative effects of the CO<sub>2</sub> ice clouds that readily form in a thick CO<sub>2</sub> atmosphere. model. Using the correlated k distribution model allowed us to compute the complex radiative transfer processes (scattering in the thermal infrared) that cannot usually be accounted for with the usual GCM's wide band model.

## Results

Preliminary results obtained assuming a 2 bars atmosphere suggest that, even without taking into account the radiative effect of CO<sub>2</sub> clouds, temperature near or above the freezing point of water may be obtained seasonally in the summer hemisphere. The diurnal amplitude of surface temperature is small, and therefore warm temperatures may last for long periods. CO<sub>2</sub> ice clouds are found to form almost everywhere on the planet in the upper atmosphere above 40 km. Their radiative effect on the climate is very model dependent but, in most cases, should correspond to a warming of the surface.

Ultimately, such a model may enable us to simulate the water cycle by applying parameterisations currently used in Earth models. It will be interesting to investigate whether snow or rain could have occurred on such a planet.

## Reference

- [1] Craddock and Howard, *J.G.R* 107 [2002]
- [2] Kasting, *Icarus* **94**,1 (1991)
- [3] Squires and Kasting, *Science* **265**, 744 (1994).
- [4] Haberle, *J.G.R* 103, 28467, (1999)
- [5] Forget and Pierrehumbert, *Science* 278, 1273 (1997)
- [6] Segura et al. *Science* 298, 1977 (2002)
- [7] Forget et al. *J.G.R* 104, 24,155 (1999)