

AMAZONIAN GLACIAL CYCLES ON MARS: RESPONSE OF THE NEW LMD GLOBAL CLIMATE MODEL TO ORBITAL VARIATIONS. J.-B. Madeleine¹, F. Forget², J. W. Head¹, T. Navarro², E. Millour², A. Spiga², A. Colaitis², F. Montmessin³ and A. Määttänen³, ¹Dept. of Geological Sciences, Brown University, Providence, USA (jean-baptiste_madeleine@brown.edu), ²Laboratoire de Météorologie Dynamique (LMD), Paris, France, ³Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), Paris, France.

Under various latitudes, the martian surface shows evidence for non-polar ice-related deposits in the last hundreds of millions of years of the planet's history. These deposits are diverse (tropical mountain glaciers, lobate debris aprons, lineated valley fill, concentric crater fill, see Fig. 1) and provide some specific constraints on the paleoenvironment in which they formed.

The goal of our study is to analyze the response of the Mars climate system to changes in the orbital conditions and climate parameters, in order to better understand glacial cycles as represented in the geological record [1]. To do so, we model the past climate of Mars using the LMD Global Climate Model, and include the various processes which are necessary to simulate the Mars past climate.

The new version of the LMD/GCM: We have been working on developing a new version of the LMD (Laboratoire de Météorologie Dynamique) Mars GCM (Global Climate Model) [2] which includes current and paleoclimatic processes and allows us to assess their impact on the Mars climate system under past conditions. These processes include:

Interactive aerosols: The scavenging of dust particles is made possible by a semi-interactive dust transport scheme [3] which is coupled to the water cycle

scheme. The dust particles serve as condensation nuclei for water-ice cloud formation and can be scavenged. Both dust particles and water-ice crystals can scatter radiation depending on their size.

Near-surface convection: A new parameterization of the convection in the boundary layer has been developed [4] and accounts for the turbulent mixing produced by local thermals. This new parameterization may have an impact on ice stability under paleoclimate conditions.

Ice deposition and surface properties: A new soil conduction model allows us to account for the changes in surface thermal inertia due to ice deposition, meaning that the thermal-inertia feedback is active. Also, the coupling between the dust cycle and the water cycle gives access to the amount of dust which is included in the ice deposits, and thereby provides an assessment of the stratigraphy.

Coalescence of ice crystals: We are also currently implementing the coalescence of ice crystals, which may not be negligible under past conditions.

Results: We are studying the response of the new model to orbital variations typical of the Late Amazonian period, starting with the impact of radiatively active water-ice clouds on ice accumulation.

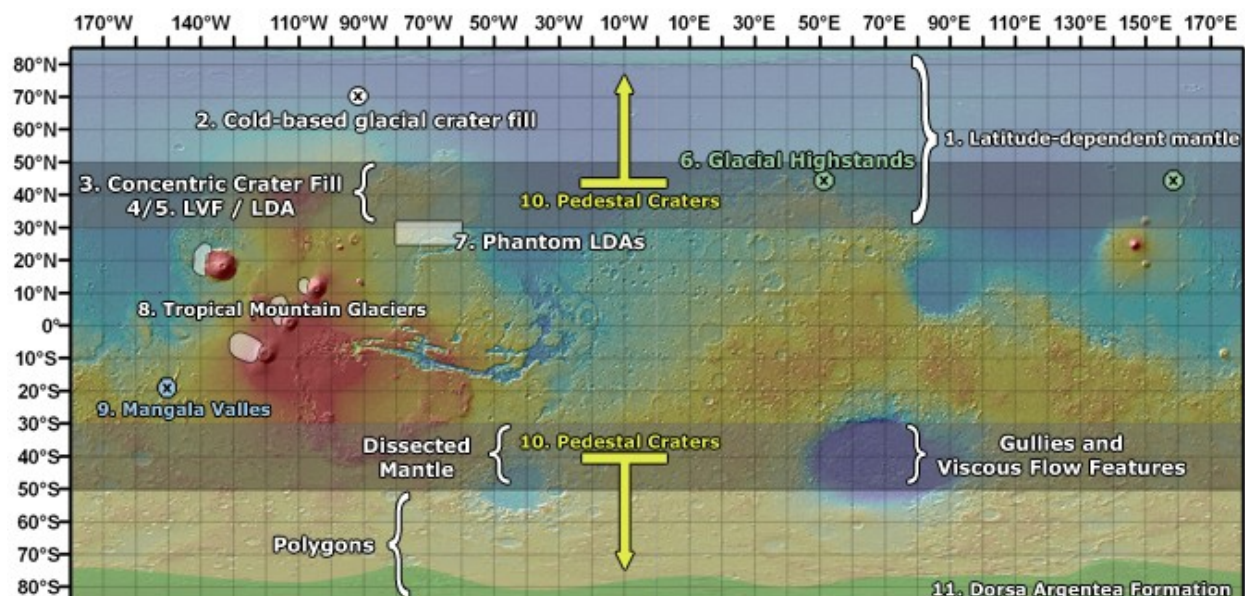


Figure 1: Map of the different ice-related deposits formed during the Late Amazonian, and further described in [1].

Water-ice clouds have a complex effect on surface temperature. Indeed, they are strong infrared emitters as well as efficient reflectors of sunlight. Consequently, when clouds are present, daytime atmospheric temperatures tend to be warmer due to the absorption of the infrared radiation coming from the surface, and surface temperature tends to be lowered by the reflection of sunlight. During the night, the opposite phenomenon occurs: atmospheric temperatures are lowered by infrared emission to space, and surface temperature is increased due to the emission by the clouds of infrared radiation toward the surface. Therefore, the surface radiation budget is very sensitive to the cloud properties.

Outside the polar regions, our simulations show that the net effect of water-ice clouds is to warm the surface, making the ice deposits less stable. Figure 2 shows the increase in surface temperature due to the nighttime emission of longwave radiation by water-ice clouds in a paleoclimate simulation performed at high obliquity (45°). This warming tends to sublimate the ice deposits, which are therefore less stable, for example east of Alba Patera (15K warming, see Fig. 2 and areas 3, 4 and 5 in Fig. 1), Utopia Planitia (20K warming) or on the Tharsis plateau (15K warming, area 8 in Fig. 1). Detailed analysis of this simulation reveals a

sensitive equilibrium between ice accumulation by precipitation and ice sublimation by infrared emission toward the surface. The radiative effect of water-ice clouds therefore appears to play a large role in the mass balance of ice-related deposits.

Perspectives: We are analyzing the impact of the other implemented physical processes (scavenging of dust particles, coalescence of water-ice crystals...) on the formation of the ice-related deposits and revisiting our previous paleoclimate simulations [5,6]. The new version of the LMD/GCM will help us better understand the Mars climate system as well as the glacial features which remain poorly understood in terms of global climate conditions, pathways of volatile transport, specific spin-axis/orbital parameters, age and duration.

References: [1] J. W. Head et al. (2008) 39th LPSC Conference Abstract 1295. [2] F. Forget et al. (2011) EPSC-DPS Joint Meeting p:1568. [3] J.-B. Madeleine et al. (2011) JGR Planets, 116:E11010. [4] A. Colaitis et al. (2011) EPSC-DPS Joint Meeting p:1061. [5] F. Forget et al. (2006) Science 311:368. [6] J.-B. Madeleine et al. (2009) Icarus 203:390.

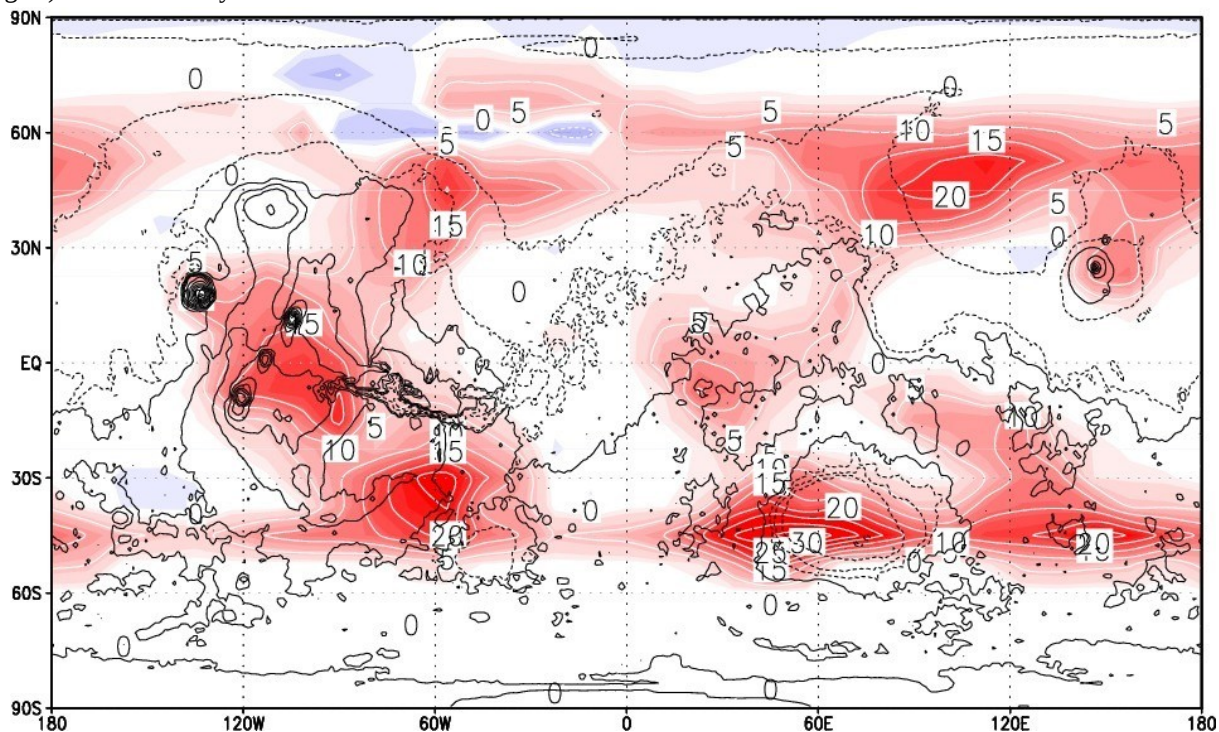


Figure 2: Mean surface temperature change due to the recent inclusion in the model of the radiative effect of clouds. Some glacial regions, such as the northern mid-latitudes or the Tharsis volcanoes, are warmed by up to 20K, resulting in the sublimation of ice deposits in many places. The results are averaged over the $L_s=150-180^\circ$ period, and the simulation is run under paleoclimatic conditions. The obliquity is set to 45° , and the orbit is circular. The northern polar cap is assumed to be the only source of water, and the dust conditions are clear (dust optical depth of 0.2).