

A GCM RECENT HISTORY OF THE NORTHERN MARTIAN POLAR LAYERED DEPOSITS. B. Levrard, J. Laskar, *Institut de Mécanique Céleste et de Calculs des Ephémérides, Observatoire de Paris, 77, Avenue Denfert-Rochereau, 75014, Paris, France.* (blevrard@imcce.fr), F. Forget, *Laboratoire de Météorologie Dynamique, Paris VI, 4, pl. Jussieu, T. 15-25, 75252 Paris Cedex 05-France,* F. Montmessin, *Space Science Division, MS 245-3, NASA/Ames Research Center, Moffett Fild CA, 94035.*

Introduction: The polar layered deposits are thought to contain alternate layers of water and dust in different proportions resulting from the astronomical forcing of the martian climate. In particular, long-term variations in the orbital and axial elements of Mars are presumed to generate variations of the latitudes of surface water ice stability and of the amount of water exchanged in the polar areas.

At high obliquity, simplified climate models [1] and independent general circulation simulations suggest a transfer of water ice from the north polar region to tropical areas [2, 3], whereas at lower and present obliquities, water ice is expected to be stable only at the poles. If so, over obliquity cycles, water ice may be redistributed between the surface water reservoirs leading to their incremental building or disintegration depending on the rates of water transfer. If only a relative limited amount of the available water is exchanged on orbital timescales, this may provide an efficient mechanism for the formation of the observed polar deposits.

Within this context, GCM simulations of the martian water cycle have been performed for various obliquities ranging from 15° to 45° and for a large set of initial water ice locations to determine the rate of water exchange between the surface water reservoirs as a function of the obliquity. Propagating these rates over the last 10 Ma orbital history gives a possible recent evolution of these reservoirs.

Recent obliquity history: The martian obliquity is chaotic between 0° and 60° [4] but regarding the uncertainties on the present precessional martian parameters, the chaotic behaviour is only significant beyond ~ 10 Ma. Over the last 10 Ma, a new accurate obliquity solution has been recently computed (Figure 1) [5]. It shows the presence of a low mean obli-

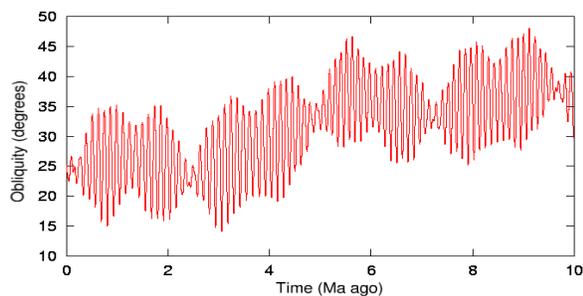


Figure 1: **Evolution of the martian obliquity over the last 10 Ma.** From [5].

uity regime ($\sim 25^\circ$) during the recent 0-5 Ma interval before a marked transition toward a higher mean obliquity regime $\sim 35^\circ$ with frequent excursions beyond 40° . Since it may represent a critical obliquity for the stability of a northern pure

water cap [2], the dissymmetric behaviour of the obliquity between the two regimes may have had a large impact on the recent northern terrains history.

Model description: We used the GCM developed in the French laboratory (LMD) for terrestrial climate simulations, which has been modified to incorporate physical parameters consistent with Martian processes and constants [6]. The model resolution is 48 longitudinal points-32 latitudinal points and 25 vertical levels. It provides a full simulation of the martian water cycle which includes the transport and seasonal exchange between surface water ice, atmospheric vapor and water cloud ice [6, 7]. The local albedo is set to 0.4 wherever an ice layer thicker than $5 \mu\text{m}$ is predicted by the model, which permits ice-albedo feedback process. In all the simulations, the eccentricity has been set to zero and the total available amount of CO_2 is kept constant with obliquity changes with respect to the present value. No permanent CO_2 ice cap or south water reservoir are initially present. All the runs start with a dessicated water vapor and cloud ice reservoir and surface water ice is thus the only initial water source. The stability of water-ice and the rate of movement of water are determined when the water cycle reaches an apparent steady state. In that case, the water vapour and cloud ice budgets comes to an interannually repeatable state. Radiative effects of vapor and clouds that might be important at high obliquity are not considered and largely unknown processes in other orbital conditions (dust storm frequency, cap albedo, atmospheric pressure) may affect the present results.

Results: In a first set of simulations, the stability of a north polar ice cap is studied for obliquities ranging from 15° to 45° with a 5° step. As in [2], we found that the residual nature of the north polar cap is lost between 35° and 40° . The annual loss rate of the northern polar water enhances with the obliquity due to increasing summer sublimation. It reaches $\sim 2.7 \text{ cm/yr}$ for 40° and $\sim 6.9 \text{ cm/yr}$ for 45° . We found that water ice mainly accumulates in the equatorial areas of the Tharsis Montes (Arsia, Pavonis, Ascraeus and Olympus Mons) where it becomes stable. However, unlike [2], no accumulation of water has been found in the northern high latitudes for an obliquity equal to 35° . Moderate changes in the initial cap size do not significantly affect these results. At lower obliquities, formerly stable low-latitude deposits become unstable with respect to the poles. In a second set of simulations, the water ice cap has been removed and the stability of an initial water source located on Arsia and Pavonis Mons has been investigated for the same range of obliquities. No change to polar albedo and thermal inertia has been made. Interestingly, we found an increasing accumulation of water in the latitudes higher than $\sim 60^\circ$ both in the north and south polar areas. This may be correlated with the existence of massive water deposits inferred in the near-sub surface by the Mars Odyssey

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Gamma-Ray Spectrometer (GRS) at these latitudes [8]. At the lowest obliquity 15° , the maximum accumulation rate is close to 0.15 cm/yr at the north pole, whereas it reaches ~ 0.05 cm/yr at the south pole. Note that these rates are one order of magnitude smaller than the previous opposite situation. It may illustrate an important dissymmetric evolution of the northern cap during the two obliquity regimes. We are presently undertaking additional simulations to estimate the speed of water exchange for other initial water-ice locations and final results will be reported at the meeting.

Conclusion: Considering the present evolution of the water reservoirs on the $15^\circ - 45^\circ$ recent obliquity excursion, our results suggest two significant conclusions. First, we found that for obliquities higher than 40° , the annual loss rates of the northern polar cap towards tropical areas are about one order of magnitude higher than the opposite situation (only tropical sources at obliquities lower than 40°). If no interaction with the dust cycle (possible formation of a residual lag deposit which inhibits the sublimation of water ice from the surface)

is considered, the model thus predicts (1) a possible quick disintegration of a ~ 3 -km thickness polar cap during the high obliquity excursion of the 5-10 Ma recent time interval (2) a recent averaged accumulation of the northern cap during the lower mean obliquity regime ($\sim 25^\circ$) of the 0-5 Ma interval from equatorial areas and also probably at the expense of the south polar area. Second, the slow rates of water accumulation in south and north polar areas on orbital timescales may provide, coupled with dust accumulation, a possible mechanism for the formation of ~ 10 -50 m thickness polar layers.

References: [1] Jakosky, B.M. and Carr, H.H. (1985) *Nature*, 315, 559-561. [2] Mischna, M.A. et al., 2003, *JGR*, in press. [3] Haberle, R.M. et al., 2003, this issue. [4] Laskar, J. and Robutel, P. (1993) *Nature*, 361, 608-612. [5] Laskar, J., Levrard, B. and Mustard, J.F., (2002) *Nature*, 419, 375-377. [6] Forget F. et al. (1999), *JGR*, 104, 24155-24179. [7] Montmessin, F., Ph.D dissertation, 2002, Université Paris VI. [8] Boyton, W.V. et al., 2003, *Science*, 297, 81-85.