



HAL
open science

Stability of (Sub)Surface Water Ice on Mars

L Lange, F Forget, P Y Meslin, E Vos, J B Clément, Joseph Naar

► **To cite this version:**

L Lange, F Forget, P Y Meslin, E Vos, J B Clément, et al.. Stability of (Sub)Surface Water Ice on Mars. Tenth International Conference on Mars, Jul 2024, Pasadena, United States. pp.LPI Contribution No. 3007, 2024, id.3117. insu-04710519

HAL Id: insu-04710519

<https://insu.hal.science/insu-04710519v1>

Submitted on 26 Sep 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Stability of (Sub)Surface Water Ice on Mars. L.Lange^{1,*}, F.Forget¹, P.Y.Meslin², E.Vos¹, J.B.Clément¹, J.Naar^{1,3}

¹Laboratoire de Météorologie Dynamique, CNRS, Paris, France; ²Institut de Recherche en Astrophysique et Planétologie, Toulouse, France, ³Laboratoire atmosphères et observations spatiales, Guyancourt, France.

*lucas.lange@lmd.ipsl.fr

Introduction

Widespread exposures of water ice on the Martian surface and subsurface have been reported in the literature, holding the keys to understanding Mars' past and present climates. Some of the key questions associated with these observations are: 1) When such massive ice deposits have formed? 2) Are they stable today? 3) Can water ice deposits on the surface melt during the recent past of Mars? We will discuss these questions in the conference in light of the literature and the work carried out as part of the *Mars Through Time* project (PI: F. Forget).

Subsurface Water Ice (SSI):

Massive reservoirs of subsurface water ice have been discovered at high latitudes ($>55^\circ$) by the Mars Odyssey Neutron Spectrometer (MONS) neutron spectrometers [1,2,3]. The widely accepted theory to explain their geographical distribution and depth is that this ice is in equilibrium with near-surface water vapor [4,5,6]. However, recent impact craters revealed the presence massive amount of ice down to 35°N in the first meter of the Martian soil [7,8]. Thermal infrared monitoring of the subsurface also suggests the presence of such ice down to $\sim 35\text{-}40^\circ\text{N}$ [9]. Models need to double/triple the current humidity to explain the stability of subsurface ice at such low latitudes [5, 10] (e.g., Figure 1). There are two possibilities to resolve this paradox: 1) this ice is currently unstable, formed during a recent past (Naar *et al.*, *this issue*, Clement *et al.*, *this issue*), slowly retreating to its equilibrium depth (Vos *et al.*, *this issue*); 2) Models based on yearly-average near-surface humidity [5,6,10] use a too simplified criterion too explain the stability of subsurface ice. For instance, [11] have shown that including the effect of surface water frost could change the ice's stability depth by tens of cm compared to previous models. To further explore the limits of such models, we have developed a complete model implemented in the Mars Planetary Climate Model [12] to simulate the water exchange between the surface and subsurface and will present preliminary results at the conference.

The same problem arises for subsurface ice beneath pole-facing slopes. [13] suggested that water ice

should be stable down to 20°S on steep-pole facing slopes, and should regulate the seasonal condensation/sublimation of CO_2 . Yet, [10] have reappraised this limit and suggest that ice should be present only poleward of 30° latitude. Here again, ice is expected to be shallower than what is suggested by water-vapor equilibrium models. If the ice is indeed shallower, then it could play a role in the formation of gullies. [14] have suggested that the destabilization of surface material during the formation of a gully could warm subsurface ice, which could help fluidize the soil when it sublimates, contributing to the formation of gullies. We have developed a 1D model to study this effect and will also present the results at the conference.

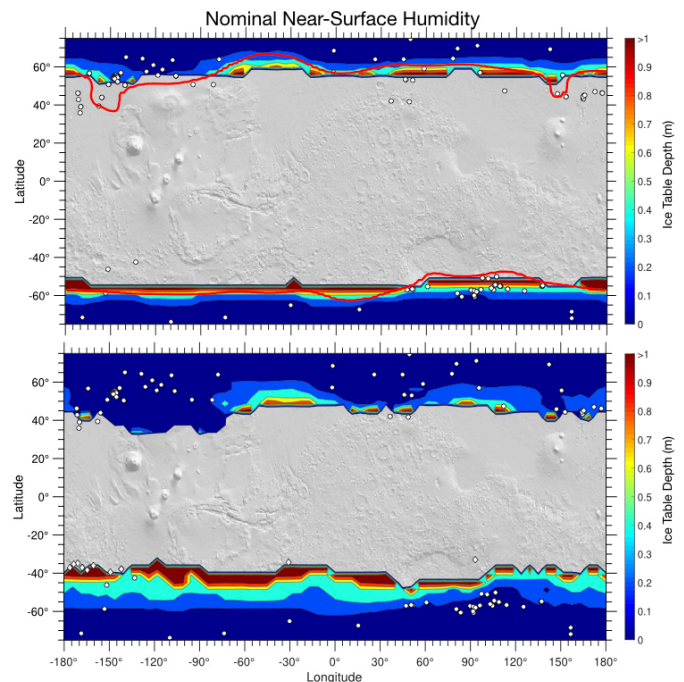


Fig. 1: Theoretical stability of subsurface water-ice with respect to diffusion for (a) flat surfaces (b) 30° pole-facing slopes, using a nominal near-surface humidity. The red curve is the observed 10% Water-Equivalent Hydrogen contour detected by MONS. White dots indicate exposed water ice along cliff scarps and impact craters, white diamonds indicate exposed water ice along gullies.

Surface Water Ice:

Water ice is found on the Martian surface at the poles all of the year, at mid-latitudes next to the seasonal CO₂ ice caps, and down to ~10°S on pole-facing slopes. These last detections on crater rims are of prime interest to constrain the mechanisms forming the gullies. Their similarity to terrestrial geomorphologies suggests that they are formed by liquid water. For example, [15] recently suggested that gullies are formed by the surface water ice on the surface during periods of high obliquity when pressure and temperature conditions are above the triple point of water. Yet even under these conditions, it is very unlikely to melt ice: due to latent heat-induced cooling, water ice cannot reach melting temperature [16,17, Forget *et al.*, *this issue*]. The only way to melt ice on the surface is if it is dusty (e.g., [18]). Under these conditions, a solid-state greenhouse effect appears, which can lead to ice melting [19, 20].

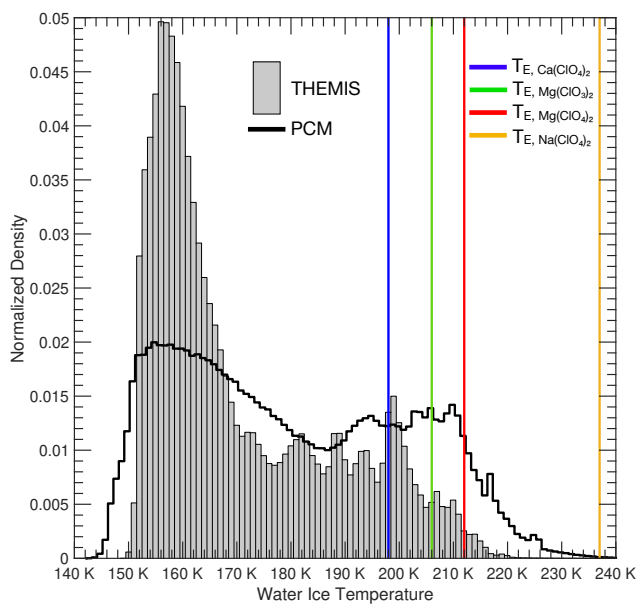


Fig. 2. Distribution of water ice temperature measured by THEMIS (grey histogram) and predicted by the Mars PCM (black curve). The distribution has been normalized by dividing each count by the total number of pixels. The eutectic temperature of Ca-perchlorate (198 K) is represented by the blue curve, the green curve is for the Mg-chlorate (206 K), the red curve is for the Mg-perchlorate (212 K), and orange curve is for the Na-perchlorate (237 K).

Using the visible and near-infrared images acquired by THEMIS, we have measured the temperature of water ice deposits observed on crater slopes (Figure 2). The

results of this study will be presented at the conference. For all observations, the ice deposits are too cold to allow melting. However, in some cases, frosts are warm enough for a few hours of the day to form brines if salts are present on the surface. However, because of the pressure and temperature conditions, these brines would be very unstable and would not seem to be able to form sufficient flows to form these gullies [21].

References: [1] Boynton, W. V., et al. (2002), *Science*, 297(5578), 81–85; [2] Feldman, W. C., et al. (2002, *Science*, 297(5578), 75–78; [3] Diez, B. et al. (2008). *Icarus*, 196(2), 409–421. [4] Mellon, M. T., and B. M. Jakosky (1993), *J. Geophys. Res.*, 98(E2), 3345–3364; [5] Mellon, M. T., et al. (2004). *Icarus*, 169(2), 324–340; [6] Schorghofer, N., & Aharonson, O. (2005). *J. Geophys. Res.*, 110(E5), E05003; [7] Byrne, S. et al. (2009). *Science*, 325(5948), 1674–1676; [8] Dundas, C. M., et al. (2023). *Geophysical Research Letters*, 50(2); [9] Piqueux, S. et al. (2019), *Geophysical Research Letters*, 46(24), 14290–14298. [10] Lange, L. et al. (2023), *Geophysical Research Letters*, 50, e2023GL105177; [11] Williams, K., et al. (2015), *Icarus*, 261, 58–65; [12] Forget, F. et al. (1999), *J. Geophys. Res.*, 104(E10), 24155–24175. [13] Vincendon et al., (2010), *Geophysical Research Letters*, 37(1), L01202; [14] Pilorget, C. and Forget, F. (2016), *Nature Geosciences* 9, 65–69. [15] Dickson, J. L. et al. (2023), *Science*, 370(6652); [16] Ingersoll, A. P. (1970), *Science*, 168 (3934); [17] Khuller, A. R., & Clow, G. D. (2024), *J. Geophys. Res.: Planets*, 129, e2023JE008114., [18] Khuller, A. R., & Christensen, P. R. (2021), *J. Geophys. Res.: Planets*, 126, e2020JE006539. [19] Clow, G. D. (1987), *Icarus*, 72 (1), 95–127. [20] Williams, K. E., et al. (2008) *Icarus*, 196 (2), 565–577. [21] Chevrier, V. F. et al. (2022), *The Planetary Science Journal*, 3 (5), 125.