Katabatic Winds, Geysers and Seasonal Water Frost During Northern Spring on Mars

T. Appéré (1), B. Schmitt (1), Y. Langevin (2), A. Spiga (3), S. Douté (1), A. Pommerol (4), F. Forget (3), B. Gondet (2) and J.-P. Bibring (2), (1) Institut de Planétologie et d’Astrophysique de Grenoble, Université J. Fourier, CNRS/INSU, Grenoble, France (thomas.appere@obs.ujf-grenoble.fr), (2) Institut d’Astrophysique Spatiale, Université Paris Sud, CNRS/INSU, Orsay, France, (3) Laboratoire de Météorologie Dynamique du CNRS, Université Paris 6, CNRS/INSU, Paris, France, (4) Physikalisches Institut, Universität Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland.

Abstract

We report on dynamical phenomena occurring during northern spring on Mars: the formation of a water ice layer above seasonal CO$_2$-rich ice and selective removing of this water ice layer by katabatic winds in spiral troughs and geysers on the circumpolar dark dunes. It may lead to inhomogeneous accumulation rates of water ice over the North permanent cap.

1. Introduction

The North permanent cap of Mars is a nearly 2 km thick stack of layers made of ice and dust mixtures. It shows numerous spiral troughs oriented counter clockwise, presumably formed by erosion, transport and deposition by katabatic winds [1]. The cap is surrounded by circumpolar dark dunes; they contain gypsum-bearing sediments coming from the permanent cap and transported by katabatic winds [2]. During northern fall, the CO$_2$ gas of the atmosphere condenses on the surface of the polar regions down to 45° of latitude. The resulting CO$_2$ ice deposit contains a small amount of water ice and dust [3]. The winter and spring retreat of these seasonal deposits has been monitored by the OMEGA imaging near-IR spectrometer aboard Mars Express. It provides new insights on the dynamical processes occurring during this sublimation phase.

2. The role of katabatic winds on the North permanent cap

Data from the OMEGA instrument makes possible to map the distribution of both CO$_2$ ice and H$_2$O ice near-IR signatures during northern winter and spring [4]. Surprisingly, the water ice signature dominates most of the seasonal deposits by mid spring while surface temperature is indicative of abundant CO$_2$ ice. It is particularly obvious on the plateaus of Gemina Lingula, Olympia Planitia and the North pole. This early disappearance of the CO$_2$ ice near-IR signature indicates that CO$_2$ ice is hidden by an optically thick cover, either of dust or water ice. A water frost layer overlying CO$_2$ ice is consistent with the observations of both high albedo and strong H$_2$O ice signature over these regions. Comparison between OMEGA spectra and radiative transfer modeling in layered media [5] shows that this water frost cover is made of ~200 µm grains, likely included into CO$_2$ ice during its fall condensation and released by its spring sublimation. The CO$_2$ ice signature remains hidden on the plateaus until the complete sublimation of the CO$_2$ ice. On the contrary, the CO$_2$ ice signature suddenly increases in the spiral troughs and scarps of the North permanent cap and in the circumpolar dark dunes field at L$_s$ ranging from 40° to 70° (see Figure 1a). Winds have been simulated for that range of L$_s$ with the LMD Martian Mesoscale model [6]. It indicates strong downslope katabatic winds on the permanent cap, particularly in regions where the CO$_2$ ice signature increases (see Figure 1b).

Dedicated simulations at high spatial resolution (2.2 km) have been done for the Rupes Tenuis region which topography enables the formation of strong katabatic winds (see Figure 2c). These winds result in an increase of the atmospheric temperature (Figure 2d). The late increase of the CO$_2$ ice signature is correlated with a decrease of the H$_2$O ice signature (Figure 2a and b), which is consistent with the removing of the top water ice layer previously hiding the CO$_2$ ice signature. Stronger winds are simulated where the CO$_2$ ice signature increases, despite one can notice a spatial shift at the bottom of the main slope. It may be due to a turbulence effect which spatial resolution of the simulation cannot take into account.

The water ice layer formed on top of the seasonal
Figure 1: (a) Localization of regions where late increase and early disappearance of the CO₂ ice signature are observed; (b) Mesoscale simulation of katabatic winds. Color bar: friction velocity from 0 to 0.8 m.s⁻¹. Brown area corresponds to the circumpolar dark dunes field. The red box corresponds to the Rupes Tenuis region analyzed in Figure 2.

CO₂-rich ice is thus removed by the action of katabatic winds in the spiral troughs and scarps of the North permanent cap by mechanical disruption or sublimation, but remains undisturbed on top of the plateaus of Gemina Lingula, Olympia Planitita and the North pole, where almost no wind blows.

3. Geysers disrupting the water ice cover

Late increase of the CO₂ ice signature observed in the circumpolar dark dunes field does not systematically correlate with strong katabatic winds; a different process may be involved in this region. It may be linked with the host of sublimation-driven features observed by the HiRISE camera [7]. Geysers form by release of pressurized CO₂ gas carrying dust. These jets could disrupt the H₂O ice cover hiding the CO₂ ice signature, resulting in the reappearance of the CO₂ ice signature. OMEGA spectra acquired at reappearance of the CO₂ ice signature are well fitted by a CO₂-rich layer overlaid by a thin layer of dust, thus confirming the proposed scenario. Analysis of CRISM observations is ongoing to investigate this process.

4. Conclusion

These dynamical phenomena witness a very active surface-atmosphere water cycle during northern spring and strong wind interaction that may lead finally to inhomogeneous accumulation rates of water ice over the North permanent cap.

Figure 2: Late increase of the CO₂ ice signature in Rupes Tenuis region. Variation of (a) CO₂ ice signature and (b) H₂O ice signature between Ls 48° and 50°. Mesoscale simulation of katabatic winds: (c) Friction velocity and (d) Atmospheric temperature at 10 m above ground.

References


