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Seasonal Water Frost: Minor Component But Major Role During the Spring Retreat of the Northern Seasonal Deposits on Mars

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

Abstract

We report on the spring evolution of the seasonal CO_2 ice and H_2O frost on the northern hemisphere of Mars. The sublimating CO_2 ice is gradually covered by a water ice layer, which thickness and equivalent grain size have been retrieved. Katabatic winds blowing in spiral troughs and scarps of the North permanent cap scatter this water ice layer, resulting in heterogeneous accumulation rates of seasonal water frost by the end of spring. It probably takes part in the present evolution of the North permanent cap.

1. Introduction

The advance and retreat of the seasonal ice deposits is one of the main driving forces of the Martian climate. During fall and winter, up to 30% of the CO_2 atmosphere condenses at 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, with a much larger amount of water ice in the northern deposits than in the southern deposits [1]. With the return of sunlight and positive energy balance, the deposits gradually sublimate. Observations of the OMEGA imaging near-IR spectrometer aboard Mars Express make possible to monitor the spatial distribution of both CO_2 ice and H_2O ice spectral signatures during their northern spring retreat [2], and to determine the coexistence mode, abundance and grain size of the CO_2, H_2O and dust components of the deposits. These information are essential to better understand the surface/atmosphere interactions during spring, which should help to constraint both CO_2 and H_2O cycles and may lead to improve the Martian climate models.

2. Accumulation of water frost on top of sublimating CO_2 ice

One of the key characteristics of the northern seasonal deposits is a water ice annulus about 2° wide surrounding the CO_2-rich deposits during spring [2]. It is very likely the source of the water vapor annulus observed by TES above the edge of the retreating deposits [3]. By mid spring, the H_2O ice spectral signature dominates most of the northern seasonal deposits while surface temperature is indicative of abundant CO_2 ice. This surprising configuration is due to the gradual formation of a water ice layer on top of sublimating CO_2 ice. It is made of water ice grains a few hundreds of microns in diameter included into CO_2 ice during its fall condensation and released by its spring sublimation, and of water vapour coming from the sublimating water ice annulus, transported northward by baroclinic waves activity and cold-trapped at the surface of CO_2 ice in the form of $\sim$10 μm grains.

The build-up of the water ice layer has been analysed on the plateau of Gemina Lingula. Six OMEGA spectra acquired on the plateau at various solar longitudes have been fitted by synthetic spectra modelled with a radiative transfer code in layered media [4]. The first spectrum (L_s=11.5°) gives the composition of the bulk of CO_2 ice: 99.954 wt% of CO_2 ice (30 cm grains) + 0.04 wt% of H_2O ice (350 μm grains) + 0.006 wt% of dust (16 μm grains). The five other spectra witness the build-up of the water ice layer, which thickness reaches 650±200 μm at L_s=95° (Figure 1). The equivalent grain size of the layer increases from 70±10 μm at L_s=30° to 170±20 μm at L_s=60°. It shows that the proportion of large water ice grains released by the CO_2 ice sublimation increases at the expense of small grains coming from cold-trapping of water vapour.

Moreover, it is possible to compute the mass of H_2O ice released by the CO_2 ice sublimation by multiplying the decrease of the CO_2 ice column density inferred from Neutron Spectrometer (NS) measurements [5] by the fraction of H_2O ice included into CO_2 ice. This mass is then converted into a thickness, which is very close to the total thickness of the top water ice layer inferred from OMEGA data despite large uncertainties (Figure 1). It indicates that the water ice layer is mostly made of grains released at the CO_2 ice sublimation on the plateau of Gemina Lingula.

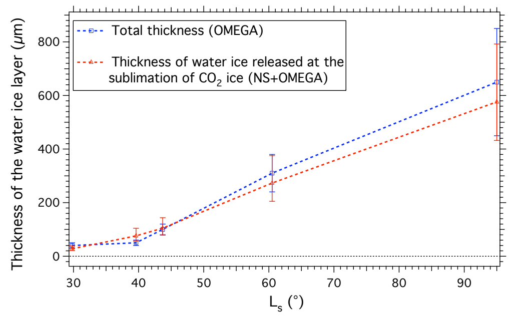

Figure 1: Temporal evolution of the thickness of the water ice layer covering the sublimating CO_2-rich ice on the plateau of Gemina Lingula. Blue squares: total thickness obtained by the inversion of OMEGA spectra. Red triangles: thickness of water ice released at the CO_2 ice sublimation inferred from NS and OMEGA data (bulk H2O abundance).

At lower latitude, close to the Phœnix landing site, a decrease of the water ice layer grain size is observed as the water ice annulus approaches this area. It is consistent with an increasing proportion of water vapour cold-trapped at the surface of CO_2 ice as the amount of available water vapour increases.

3. Effects of the aeolian activity on the seasonal deposits

While the CO_2 ice spectral signature is hidden on the plateaus of the North permanent cap by mid spring, it remains prominent in the spiral troughs and scarps of the permanent cap. The topography of the cap enables the formation of strong downslope katabatic winds. The presence of CO_2 ice on sloping terrains reinforces near-surface temperature hence katabatic acceleration. The aeolian activity in the North polar region during spring has been simulated with the LMD Martian Mesoscale model [6]. Strong katabatic winds are simulated at locations where the CO_2 ice signature persists. These winds are likely responsible for the scattering of the water ice layer on the slopes of the permanent cap, thus allowing the CO_2 ice signature to show up.

Strong and sudden increases of the CO_2 ice signature are also observed in the sloping terrains and their vicinity. They may be due to a temporary enforcement of the katabatic winds activity caused by transient low pressure systems.

The water ice layer covering the CO_2-rich ice during spring is thus scattered by katabatic winds in the spiral troughs and scarps of the North permanent cap while it remains undisturbed on top of its plateaus. This phenomenon may have consequences on the local or regional water ice balance and thus on the present evolution of the permanent cap.

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.

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