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# Mobility of Water Ice During the Retreat of the Seasonal Deposits on Mars

**T. Appéré** (1), B. Schmitt (1), Y. Langevin (2), A. Spiga (3), S. Douté (1), A. Pommerol (1,4), F. Forget (3), B. Gondet (2) and J.-P. Bibring (2), (1) Laboratoire de Planétologie 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) Physikzalisches Institut, Universität Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland.

## Abstract

We report on peculiar 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 [1]. It may lead to inhomogeneous accumulation rates of water ice over the North permanent cap.

## 1. Introduction

Seasonal deposits are one of the most important martian meteorological processes. Determination of the exact mixing between its $CO_2$ ice, $H_2O$ ice and dust components as well as spatial and temporal distribution of the seasonal ices should help to constrain both $CO_2$ and $H_2O$ cycles and may lead to improve the Martian climatic models. They may also provide clues to understand the current and past climatic cycles through inter-annual evolutions. Before the Mars Express mission (ESA) the evolution of the seasonal deposits have been essentially monitored by the albedo and temperature changes of the surface [2, 3]. The OMEGA imaging spectrometer aboard Mars Express allows to directly monitor the abundance, physical state and distribution of the $CO_2$, water and dust components of the deposits through their visible and near-infrared spectral signatures. We report on the mobility of water ice during the martian year (MY) 28 spring retreat of the seasonal ices.

## 2. Local evolution of the seasonal condensates

The temporal evolution of three regions of interest was monitored in term of albedo, $CO_2$ ice band depth at 1.43 $\mu$m and $H_2O$ ice band depth at 1.50 $\mu$m. The first region is located on Vastitas Borealis plains, at 64°E, 71°N and exhibits the typical evolution of the seasonal deposits: we observe the progressive disappearance of $CO_2$ ice, leading to the $H_2O$ ice annulus deposit followed by its sublimation.

The second region, located on Gemina Lingula, exhibits an atypical behavior with the disappearance of the $CO_2$ ice signature several degrees of Ls before the TES crocus line reaches the region. The crocus line corresponds to latitudes and longitudes where the surface temperature rises above 165 K for a given Ls [3]. This surface temperature typically corresponds to a surface covered by 81% of $CO_2$-rich ice at 150 K and 19% of dusty $H_2O$ ice at 205 K. Therefore we observe the disappearance of the $CO_2$ ice signature while the surface temperature still indicates the presence of abundant $CO_2$ ice. We refer to this process as "early disappearance of the $CO_2$ ice signature" (EDCS).

The third region, located on a plateau of the North permanent cap, exhibits first the progressive disappearance of the $CO_2$ ice signature and then its sudden reappearance (see Figure 1). We refer to this process as "late increase of the $CO_2$ ice signature" (LICS). We observe that the progressive disappearance of the $CO_2$ ice signature is correlated with an increase of the $H_2O$ ice band depth and the LICS event is correlated with a sudden decrease of the $H_2O$ ice band depth.

## 3. EDCS and LICS events

We propose a scenario for both the early disappearance and late increase of the $CO_2$ ice signature. At the beginning of northern spring, a thick layer of $CO_2$ ice contaminated by $H_2O$ ice and dust particles covers the northern regions. Soon after spring sunrise, the incident solar flux sublimates $CO_2$ ice but not the $H_2O$ ice grains trapped in it. A fine grained $H_2O$ ice layer gradually forms above the $CO_2$-rich ice, hiding its spectral signature. Radiative transfer model in layered media [4] using optical constants of $CO_2$ and $H_2O$ ices [5, 6]

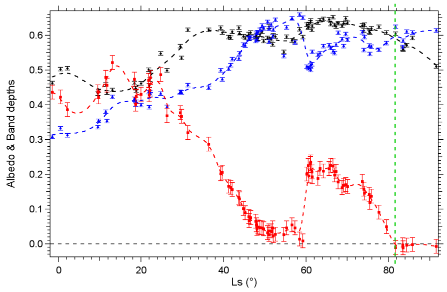

Figure 1: Late increase of the $CO_2$ ice signature. Black: albedo. Blue: $H_2O$ ice band depth at 1.50$\mu$m. Red: $CO_2$ ice band depth at 1.43$\mu$m. Green dashed line: Ls of the TES crocus line for this region.

shows that a 300 $\mu$m thick layer of $H_2O$ ice is sufficient to completely hide the $CO_2$ ice band at 1.43 $\mu$m. Some water vapor coming from the sublimating water ice annulus at lower latitudes may also be cold trapped on top of the $CO_2$-rich ice and contributes, from above, to the building of this $H_2O$ ice layer. It would explain the early disappearance of the $CO_2$ ice signature (EDCS) and the increase of the $H_2O$ ice signature (1).

Several sols later, an event removing the overlying $H_2O$ ice layer leads to a sudden increase of the $CO_2$ ice signature (LICS) and to a decrease of the $H_2O$ ice signature. An alternative solution would be that LICS events correspond to $CO_2$ ice condensed during the night and observed in the early morning before it has sublimated. But local times (LT) at which observations are made are not compatible with such a process.

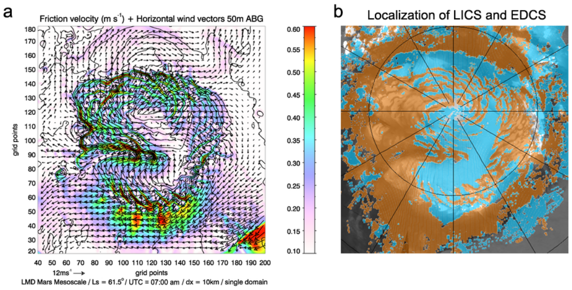

Figure 2: (a) Mesoscale simulation of katabatic winds. Color bar: friction velocity from 0.1 to 0.6 m/s. (b) Localisation of regions where LICS (orange) and EDCS (blue) are observed.

We hypothesize that wind can be the process responsible for the removing of the water ice layer overlying the $CO_2$-rich ice. The topography of the North permanent cap, except the central plateau, is well-suited to entail the formation of katabatic winds. We used the LMD Martian Mesoscale model [7] to simulate those winds at Ls 61.5° and LT = 7:00 am with a grid spacing of 10 km (see Figure 2).

Almost no wind is modeled on flat terrains such as the top of Gemina Lingula or regions near the North pole. This is also where EDCS mostly occurs and rarely LICS events are observed. On the contrary, North polar cap terrains where strong katabatics winds blow correspond to regions where sudden LICS events are observed. It is consistent with wind as the process responsible for the removing of the $H_2O$ ice layer overlying the $CO_2$-rich ice.

## 4. Conclusion

The main difference between northern and southern deposits is the much larger amount of water ice in the northern seasonal deposits. This leads to peculiar phenomena such as LICS events and EDCS but also to a very active surface-atmosphere water cycle that may lead finally to inhomogeneous accumulation rates over the North permanent cap.

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