PECULIAR PHENOMENA OF SUBLIMATING SEASONAL DEPOSITS DURING NORTHERN SPRING ON MARS

T. Appéré[1], **B. Schmitt**[1], [1]*Institut de Planétologie et d'Astrophysique de Grenoble, Université J. Fourier, CNRS/INSU, Grenoble, France (thomas.appere@obs.ujf-grenoble.fr)*, **Y. Langevin**[2], [2]*Institut d'Astrophysique Spatiale, Université Paris-Sud XI, CNRS/INSU, Orsay, France,* **A. Spiga**[3], [3]*Laboratoire de Météorologie Dynamique, IPSL, CNRS/INSU, Université Pierre et Marie Curie, Paris, France*, **S. Douté**[1], **A. Pommerol**[4], [4]*Physikalisches Institut, Universität Bern, Silderstrasse 5, CH-3012 Bern, Schwitzerland*, **F. Forget**[3], **B. Gondet**[2] **and J.-P. Bibring**[2]

Introduction:

Seasonal deposits are one of the most important martian meteorological processes. Observations from the OMEGA imaging spectrometer aboard Mars Express make possible to determine the composition of the northern deposits, i.e. CO_2 ice with minor inclusions of H_2O ice and dust, and to monitor the spatial and temporal distributions of both CO_2 and H_2O ices [1]. In particular, it has been shown that a water ice annulus about 2° wide surrounds the receding CO_2-rich deposits during spring [1, 2]. TES measurements also shows that an annulus of water vapor grows above the edge of the retreating seasonal deposits during spring [3]. This water vapor very likely comes from the sublimation of the water ice annulus and may be cold-trapped on the CO_2-rich deposits at higher latitude. A better understanding of the dynamics of water ice and vapor during spring 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. We report on peculiar phenomena occurring during the martian year (MY) 28 spring retreat of the seasonal deposits.

Early disappearance of the CO_2 ice signature:

The temporal evolution of three regions of interest was monitored in term of albedo, CO_2 ice band depth at 1.43µm and H_2O ice band depth at 1.50µm. The first region is located on top of Gemina Lingula. The CO_2 ice spectral signature observed during early spring progressively vanished until L_s 60° and has completely disappeared at L_s 65° on this region (Figure 1). However, a surface temperature of 155K is measured by THEMIS at the same L_s, indicating the presence of abundant CO_2 ice. We thus conclude that CO_2 ice is overlaid by an optically thick cover, either of dust or of water ice. A water frost layer overlying CO_2 ice is consistent with the observations of both high albedo and strong H_2O ice signature on this region (Figure 1).

We propose a scenario for the formation of this optically thick water frost layer. 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 ~200µm 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 modeling in layered media [4] using optical constants of CO_2 and H_2O ices [5, 6] shows that a 200µm thick layer of H_2O ice is sufficient to completely hide the CO_2 ice band at 1.43µm as well as the other CO_2 ice bands between 1 and 4 µm. 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. Radiative transfer modeling shows that for 10µm cold-trapped H_2O ice grains a 60µm thick layer is sufficient to completely hide the CO_2 ice bands.

An overall brightening of the northern seasonal deposits has been reported by previous observers [7]. The formation of a H_2O ice layer over CO_2-rich ice certainly contributes to this brightening since this configuration leads to an increase of the albedo of typically 20-50% depending on the upper layer H_2O grain sizes [1].

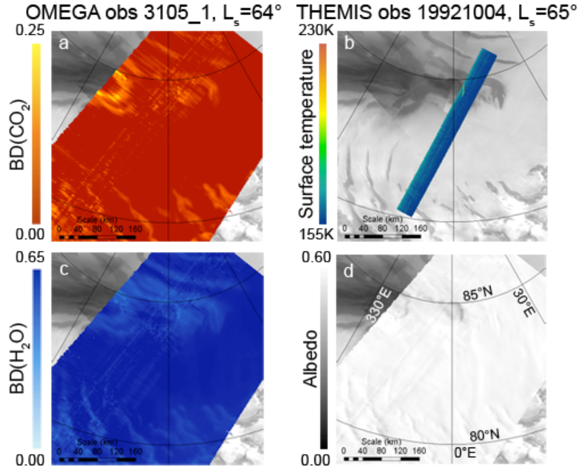

Figure 1: Early disappearance of the CO_2 ice signature. (a) CO_2 ice band depth at 1.43µm. (b) Surface temperature from a THEMIS observation. (c) H_2O ice band depth at 1.50µm. (d) Albedo.

The CO_2 ice spectral signature does not reappear on top of Gemina Lingula until the end of the retreat of the seasonal deposits. Therefore, the CO_2 ice remains hidden below the upper water ice layer until its complete sublimation.

Late increase of the CO_2 ice signature:

The second region, located on Rupes Tenuis, exhibits first the progressive disappearance of the CO_2 ice signature but then it suddenly reappears (Late Increase of the CO_2 ice Signature, or LICS) (Figure 2). The increase of the CO_2 ice band depth is correlated with a decrease of the H_2O ice band depth. It is consistent with the removing of the overlying water ice layer previously hiding the CO_2 ice signature. An alternative solution would be that the reappearance of the CO_2 ice signature corresponds 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.

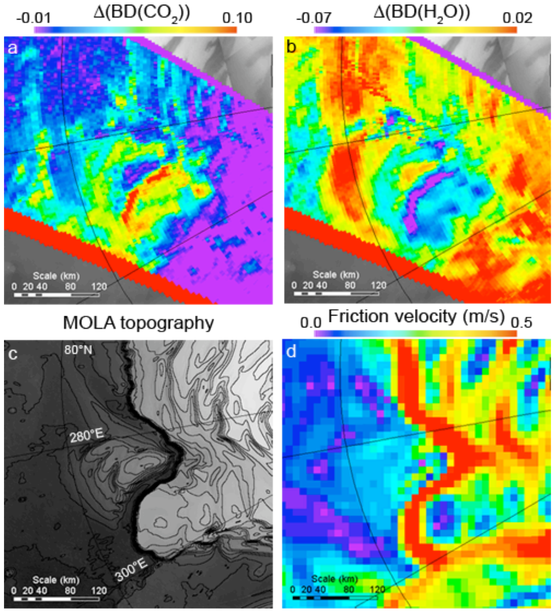

Figure 2: Late increase of the CO_2 ice signature on Rupes Tenuis. Variation of (a) CO_2 ice signature and (b) H_2O ice signature between L_s 48° and 50°. (c) MOLA topography. (d) Mesoscale simulation of katabatic winds.

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 [8] to simulate those winds at Ls 61.5° and LT = 9:00 am with a grid spacing of 10 km (Figure 2). Strong katabatic winds are simulated in this Rupes Tenuis region, particularly where the CO_2 ice signature strongly reappears. It is consistent with wind as the process responsible for the removing of the H_2O ice layer overlying the CO_2-rich ice.

The third region, located in the Olympia Undae dark dunes field, exhibits a late increase of the CO_2 ice signature between L_s 42° and 48° (Figure 3). The increase of the CO_2 ice signature is correlated with a decrease of both the H_2O ice signature and albedo. Katabatic winds could be once again responsible for the removing of the H_2O ice layer overlying the CO_2-rich ice. But low friction velocities are simulated on this region. Moreover, the occurrence of LICS events is correlated with the dark dunes field location. Therefore, the reappearance of the CO_2 ice signature seems linked with the nature of the dunes itself rather than to an atmospheric process such as wind. HiRISE observations acquired at the same location and L_s show a host of sublimation-driven features, such as dark fans of fine material transported from below the seasonal ice layer to the top [9] and bright fans of CO_2 frost coming from the decompression and adiabatic cooling of pressurized CO_2 gas released from below the ice layer [10]. Deposition of CO_2 frost is consistent with the reappearance of the CO_2 ice signature. Moreover, the H_2O ice layer overlying the CO_2-rich ice may be either hidden by the CO_2 frost or scattered by the fans, consistently with the decrease of the H_2O ice signature. Analysis of CRISM observations is ongoing to verify these hypotheses.

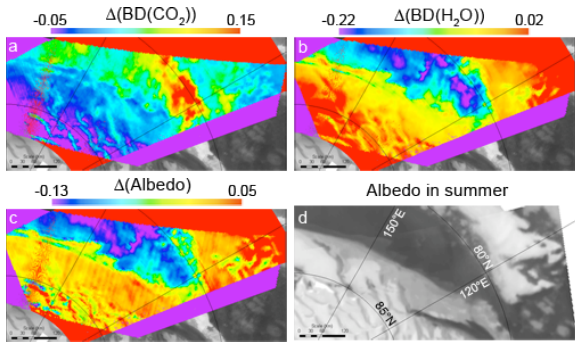

Figure 3: Late increase of the CO_2 ice signature on Olympia Undae. Variation of (a) CO_2 ice signature, (b) H_2O ice signature and (c) albedo between L_s 42° and 48°. (d) Albedo in summer.

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 early disappearance of the CO_2 ice signature followed locally by its late reappearance. Several different processes could be at the origin of these phenomena and the understanding of their origins can shed some light on the microphysical evolution of ice deposits. These phenomena already witness a very active surface-atmosphere water cycle and strong wind interaction that may lead finally to inhomogeneous accumulation rates of H_2O ice over the North permanent cap.

References: [1] Appéré. et al (2010), *JGR*, submitted; [2] Bibring et al. (2005) *Science* 307, 1576-1581; [3] Pankine et al. (2010) *Icarus* 210, 58-71; [4] Douté S. and Schmitt B. (1998) *JGR E* 103, 31367-31390; [5] Quirico E. and Schmitt B. (1997) *Icarus* 127, 354-378; [6] Grundy W. and Schmitt B. (1998) *JGR E* 103, 25809-25822; [7] James P.B. and Cantor B.A (2001) *Icarus* 154, 162-180; [8] Spiga A. and Forget F. (2009), *JGR* 114, E02009; [9] Hansen C. J. et al. (2010) *LPI Contribution* 1533; [10] Kieffer H. H. et al. (2000) *LPI Contribution* 1057.