KATABATIC WINDS, GEYSERS AND SEASONAL WATER FROST DURING NORTHERN SPRING ON MARS, T. Appéré¹, B. Schmitt¹, Y. Langevin², A. Spiga³, S. Douté¹, A. Pommere³, F. Forget¹, B. Gondet¹ and J.-P. Bibring¹, ¹Institut de Planétologie et d’Astrophysique de Grenoble, Université J. Fourier, CNRS/INSU, Grenoble, France (thomas.appere@obs.ujf-grenoble.fr), ²Institut d’Astrophysique Spatiale, Université Paris-Sud, CNRS/INSU, Orsay, France, ³Laboratoire de Météorologie Dynamique du CNRS, Université Paris 6, CNRS/INSU, Paris, France, and ⁴Physikalisches Institut, Universität Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland.

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, 2]. The cap is surrounded by circumpolar dark dunes; they contain gypsum-bearing sediments coming from the permanent cap and transported by katabatic winds [3]. During northern fall, the CO₂ gas of the atmosphere condenses on the surface of the polar regions down to 45° of latitude. The resulting CO₂ ice deposit contains a small amount of water ice and dust [4, 5]. 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.

The role of katabatic winds on the North permanent cap: Data from the OMEGA instrument makes possible to map the distribution of both CO₂ ice and H₂O ice near-IR signatures during northern winter and spring [5]. Surprisingly, the water ice signature dominates most of the seasonal deposits by mid spring while surface temperature is indicative of abundant CO₂ ice. It is particularly obvious on the plateaus of Gemina Lingula, Olympia Planitia and the North pole. This early disappearance of the CO₂ ice near-IR signature indicates that CO₂ ice is hidden by an optically thick cover, either of dust or water ice. A water frost layer overlying CO₂ ice is consistent with the observations of both high albedo and strong H₂O ice signature over these regions. Comparison between OMEGA spectra and radiative transfer modeling in layered media [6] using optical constants of CO₂ ice and H₂O ice [7, 8] shows that this water frost cover is made of 200 μm grains, likely included into CO₂ ice during its fall condensation and released by its spring sublimation. The CO₂ ice signature remains hidden on the plateaus until the complete sublimation of the CO₂ ice. On the contrary, the CO₂ ice signature suddenly increases in the spiral troughs and scarps of the North permanent cap and in the circumpolar dark dunes field at L₄ ranging from 40° to 70° (see Figure 1a). Winds have been simulated for that range of L₄ with the LMD Martian Mesoscale model [9]. It indicates strong downslope katabatic winds on the permanent cap, particularly in regions where the CO₂ 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). Two successive OMEGA observations acquired in this region at L₄ ~50° show an increase of the CO₂ ice signature correlated with a decrease of the H₂O ice signature (Figure 2a and b). It is consistent with the removing of the top water ice layer previously hiding the CO₂ ice signature. Stronger winds are simulated where the CO₂ ice signature increases, despite one can notice a spatial shift at the bottom of the main slope. The sudden change of the slope can result in the formation of an hydraulic jump, a phenomenon observed in Antarctica and called "Loewe's phenomenon". A wall of drifted snow is often observed at the location of this hydraulic jump [10]. Such a phenomenon could thus enhance the disruption of the top water ice layer-previous hiding the CO₂ ice signature, resulting in a stronger CO₂ ice signature increase at the bottom of the
These jets could disrupt the H$_2$O ice cover, resulting in the reappearance of the CO$_2$ ice signature. OMEGA spectra acquired at reappearance of the CO$_2$ ice signature are well fitted by a CO$_2$-rich layer overlaid by a thin layer of dust, thus advocating for the proposed scenario. Analysis of CRISM and HiRISE observations is ongoing to investigate this process (see Pommerol et al., this issue).

Conclusion: The main difference between northern and southern seasonal deposits is the much larger amount of water ice in the northern deposits. This leads to peculiar phenomena such as early disappearance of the CO$_2$ ice signature followed locally by its late reappearance. 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 3: Late increase of the CO$_2$ ice signature in Olympia Undae region. Variation of (a) CO$_2$ ice signature, (b) H$_2$O ice signature and (c) albedo between Ls 42° and 48°. (d) Albedo observed by MOC in summer.