WATER ICE, CO_2 ICE, AND ACTIVE PROCESSES ON POLE FACING SLOPES.

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Seasonal ice at low latitudes: Accumulation of surface water and CO_2 ice during cold seasons is locally observed at low and mid-latitudes on pole facing slopes, particularly in the southern hemisphere [1-4]. While these seasonal ices may be barely detectable using visible imagery due to contamination by dust, or due to transparency, very thin - µm thick - deposits significantly absorb near-IR photons, creating spectral features that can be easily observed in this wavelength range. Moreover, near-IR spectroscopy makes it possible to differentiate CO_2 from H_2O, while both ices appear "white" at visible wavelengths. A global survey of CRISM and OMEGA near-IR observations obtained from 2004 to 2010 revealed that surface ice is observed close to the equator in the southern hemisphere, down to 34°S for CO_2 ice and 13°S for water ice (Figure 1).

Subsurface ice: At first order, ice stability is controlled by two main parameters, surface temperature and volatile availability. While the pattern of water ice stability strongly depends on meteorological features [4], CO_2 ice – the main component of Mars atmosphere – necessarily condenses once the adequate surface temperature is reached. CO_2 ice is thus a tracer of surface temperature, which mainly depends on insolation but also depends on the subsurface thermal flux controled by thermal inertia [5]. The pattern of surface seasonal CO_2 ice stability revealed that shallow subsurface water ice is present below pole facing slopes in the southern mid-latitudes down to about 25°S [3], the exact stability limit being a function of slope angle and surface thermal inertia.

Slope activity: Current activity has been observed on pole facing slopes at mid-latitudes, notably within old gully channels [e.g. 6-9]. This activity includes modification of gullies morphology (such as channel widening), formation of color deposits, and observation of downslope movements of material. Resulting modifications can be perennial or ephemeral. Correlation with either winter and summer seasons have been highlighted [e.g. 8,9]. Various mechanisms are currently discussed and tested to explain activity on pole facing slopes. Proposed flow and erosion processes frequently require the presence of surface or subsurface water or CO_2 ice [6-9].

Objectives of current work: Here we use the near-IR imaging spectroscopy datasets OMEGA and CRISM to gather precise constraints about the presence, absence, and properties of ice at the exact locations where activity has been reported [10]. We then supplement these observational constraints with laboratory experiments [11] and energy balance calculation [12] to provide a comprehensive view of the mechanisms that could explain activity as a function of location or modification type.

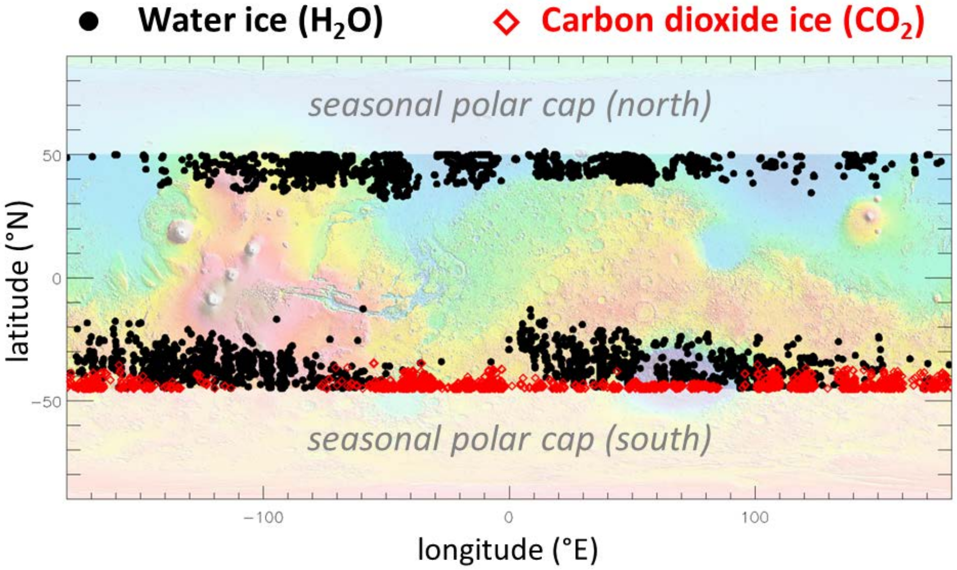

Figure 1: Map of surface seasonal water (black dots) and CO_2 (red diamonds) ice deposits detected with OMEGA and CRISM at low and mid-latitudes (between 45°S and 50°N, i.e. outside polar caps), shown above a background MOLA altimetry map. Adapted from [3, 4].

Results and Discussion: As a first example, we analyze an unnamed crater (38.9°S ; 223.7°E) where a gully channel widening, interpreted to occur in late winter due to the presence of CO_2 ice, have been reported based on HiRISE images [8]. About 10 CRISM and OMEGA observations cover this site in fall, winter and spring, which make it possible to constrain precisely the timing and composition of surface ice [10]. A CRISM observation obtained near winter solstice is shown on Figure 2. While both CO_2 and H_2O ice are detected in the near-IR, most of the bright ice seen in visible imagery is water ice and not CO_2 ice. At this location, CO_2 ice sublimates quickly and is no longer present after mid-winter [10]. As a consequence, the observed change does either occur under the action of a process not involving CO_2 ice, or does occur earlier in the season than reported by [8].

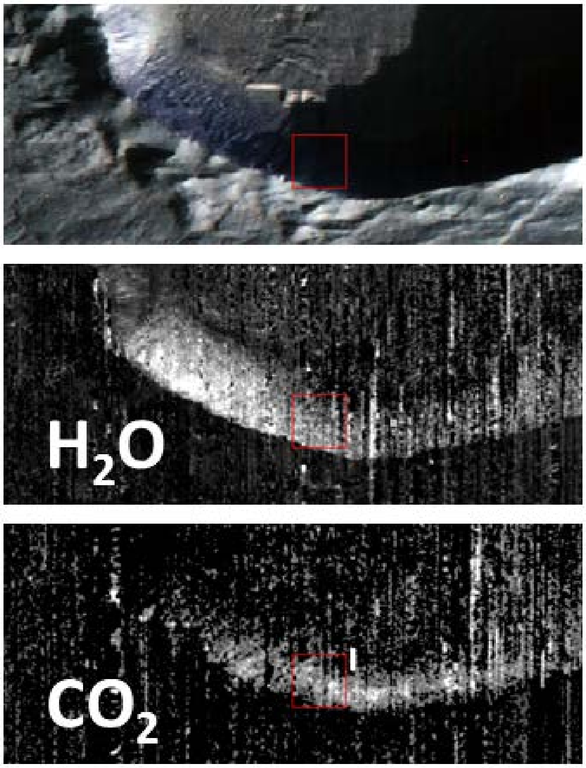

Figure 2: CRISM observation of an unnamed crater located at 38.9°S and 223.7°E, obtained in winter at Ls 100° (top: visible; middle: H_2O ice 1.5 µm band depth; bottom CO_2 ice 1.43 µm band depth). South pole direction is on top. The red box indicates the location of a gully channel widening previously reported by [8].

This example shows that CO_2 ice may be absent when gullies changes do occur. This situation is notably expected for other southern hemisphere active gully sites reported by [8] which latitudes (29°S, 32°S) are not consistent with the presence of CO_2 ice according to Figure 1. As a consequence, CO_2 ice mechanisms [e.g., 7, 8] may not explain all gully activity. On the other hand, thin (≤ 50 µm) deposits of water ice are observed at these latitudes (Figure 1). We have performed laboratory simulations at martian pressure of the behavior of surface water ice deposited on slopes when solar illumination increases in winter and spring [11]. We observe that transient liquid water forms at the interface between regolith grains and ice. As liquid is not stable at used Martian pressure, the transient liquid water quickly boils, which results in regolith grains movements and slope destabilization. Such a water-related mechanism could explain observed modifications at equatorward active gully sites where CO_2 ice is not detected.

Another active gully site is the Russel megadune (54.6°S, 12.4°E), where channels are observed to form currently during springtime [13, 14]. Seasonal CO_2 ice, with contamination by water ice, largely forms at this location included in the south seasonal cap. Activity there may be related to CO_2 ice processes [8] or may involve water ice [13, 14]. As surface seasonal water ice amount may be too low to explain observed activity, we aim at constraining locally the presence and depth of subsurface water ice using the timing of seasonal CO_2 ice condensation [3]. Preliminary results indicate that water ice is probably present in the subsurface of the dune, at shallow depth of about 5 to 10 cm.

References: [1] Schorghofer, N. & Edgett, K. S., Icarus, 180, 321 – 334, 2006. [2] Carrozzo, F. G. et al., Icarus 203, 406 – 420, 2009. [3] Vincendon, M. et al.., Geophysical Research Letters 37, 1, L01202, 2010. [4] Vincendon, M., Forget, F., Mustard, J, Journal of Geophysical Research, 115, E10, E10001, 2010. [5] Kossacki K. J. & Markiewicz, W. J., Icarus 160, 73-85, 2002. [6] Malin, M. C. et al., Science, 314, 1573, 2006. [7] Diniega, S., et al, Geology, 11, 9, 1047-1050, 2010. [8] Dundas, C. M., et al., Icarus, 220, 1, 124-143, 2012. [9] McEwen, A. S. et al., Science, 333, 740-743, 2011. [10] Vincendon, M., et al., EPSC, 193, 2013. [11] Massé, M. et al., 8th International conference on Mars, this issue, 2014. [12] Forget, F. et al., Workshop on Martian gullies: Theories and Tests, 8012, 2008. [13] Reiss, D. et al., Geophysical Research Letters, 37, 6, L06203, 2010. [14] Jouannic, G. et al., Planetary and Space Science 71, 1, 38-54, 2012.