MID LATITUDE CO_2 ICE DEPOSITS ANALYZED WITH CRISM AND OMEGA.

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Introduction: The near-IR orbital experiment OMEGA onboard Mars Express has detected seasonal CO_2 ice deposits in the mid-latitudes regions of Mars ([1], [2]). Small patches of seasonal frost with temperature consistent with CO_2 ice have been also observed in high-resolution visible MOC images [3]. Whereas the surface of Mars is totally covered by ice during a part of the year at latitudes higher than 45-50°, only patches of ice frequently linked with pole facing slopes have been found at lower latitudes. We will present a study of the CO_2 ice deposits observed by the CRISM and OMEGA imaging spectrometers. The distribution and properties of these deposit as a function of latitude, season, surface slope, thermal inertia, landform… for both hemisphere will be discussed and compared to the predictions of the LMD GCM [4] adapted to account for surface slopes [5].

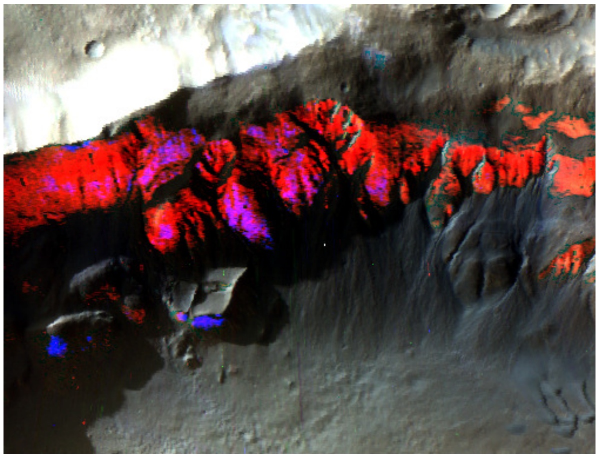

Figure 1: Example of CRISM high resolution observation (# FRT3266) of a pole facing crater rim (located at 38.88°S, 164.07°W) showing CO_2 ice (in blue, detections based on the 1.43 µm band). Water ice (1.5 µm band) is indicated in red. This observation was acquired at L_S 140.6°.

Data processing: More than 8000 spectral cubes have been obtained by OMEGA up to mid March 2009. The spatial resolution of these observations ranges from 0.3 km to 5 km. This dataset is automatically processed to detect points containing a 1.43µm band depth greater than 5%. This 5% limit results from the random noise of the OMEGA instrument and from the uncertainties of the atmospheric CO_2 gas band removal. We consider only observations with solar zenith angles lesser than 70°, as the noise strongly increases after that limit.

The CRISM dataset is composed of multispectral observations with a spatial resolution of 200 m and hyperspectral targeted observations with a spatial resolution ten times better. Due to the more complex structure of the noise of this dataset ([6], [7]), the selection of observations containing CO_2 ice is manually performed with a visual inspection of averaged spectra and spectral ratios. This approach also results in a 5% detection limit (in terms of 1.43 µm band depth) for most deposits considering their limited spatial extent (which limits the possibility of averaging spectra).

The link between the observed band depth and the amount of ice that condense at the surface is not straightforward as it depends on the structure of the ice (grain size…). We estimate that a 5% band depth requires a deposit with a thickness of at least a few tens of µm from laboratory measurements and modeling results [8, 9]. As observations of these CO_2 ice deposits are frequently obtained in shadowed regions with high solar zenith angles, the contribution of aerosols is high, which reduces the apparent band depth of surface components. According to Monte-Carlo modeling of the radiative transfer [10], a 10% band depth at the surface is required to obtain a 5% band depth in the final observation. Our detection limit thus approximately corresponds to a 200 µm thick CO_2 ice deposit at the surface. Thicker deposits can however be undetectable if composed of very small grains size [8], or if their extent is smaller than the pixel size. Latitude and season of deposits identified so far are shown in Figure 2.

Modeling: We use local 1D energy balance code from the LMD Global Climate Model [4] to predict the stability of CO_2 ice on the ground. Surface slopes are accounted for [5]. The ground is composed of two layers for which the thermal inertia and the depth of the interface can be adjusted. The model is run for three years so as to stabilize (the results of the last year are presented). We explore the effect of changing the properties of the ground, the atmospheric dust scenario, the slope angle as well as the slope orientation. An example of simulation is shown in Figure 3.

Results: In the southern hemisphere (Fig. 2), CO_2 ice deposits are observed up to 35°S, and between L_S 80° and L_S 175°. OMEGA and CRISM observations provide complementary L_S coverage. The higher spatial resolution of CRISM gives access to smaller deposits observed higher in latitude or later in the season. Modeling results strongly depend on the thermal inertia of the ground, as observed by [13] for flat surfaces. Grounds with higher thermal inertia store more heat during summer and do not reach temperatures cold enough for CO_2 ice to condense during winter. First modeling results indicate that the ice is expected to be easily stable in the southern hemisphere, i.e. no extreme conditions in terms of thermal inertia or slope angles are required to explain the stability range derived from the observations (Figure 3). Actual slopes on which CO_2 ice is observed (estimated using MOLA measurements) are in good agreement with modeling results: 28 of the 30 craters for which it has been possible to use MOLA profiles show slopes greater than 18°.

In the northern hemisphere, no CO_2 ice deposits have been detected so far for latitude lesser than 45°. Only a minor part of CRISM observations have however been processed for the moment in that region. First modeling results seem also to indicate that CO_2 ice is significantly less stable in the northern hemisphere. The differences between the northern and the southern hemisphere that are accounted for in the model are differences linked with the orbit of Mars (southern summers are warmer but shorter) and differences linked with the L_S dependent atmospheric dust amount. The smaller area of surfaces with high angle slopes in the northern hemisphere could also contribute to the absence of detections (available observations do not cover all these regions around the winter solstice).

Further work is now being carried out to refine the calculation of incoming radiation on slopes, notably by looking in more detail at the impact of atmospheric dust. Spatial variations of the ground inertia, as well as variations with latitude of the density and distribution of slopes, are also being explored.

References: [1] Langevin et al. (2007), *J. Geophys. Res.,* 112, E08S12 [2] Gondet et al. (2008), *Mars Water Cycle Workshop*. [3] Schorghofer and Edgett (2006), *Icarus*, 180, 321-334. [4] Forget et al. (1999). , *J. Geophys. Res.*, 104, 24155-24176. [5] Spiga and Forget (2008), GRL, 35, L15201 [6] Murchie et al. (2007), *J. Geophys. Res.*, 2007, 112, E05S03. [7] Parente (2008), LPSC 39, #2528 [8] Schmitt et al. (2005), LPSC 36, #2326 [9] Dupire et al. (2009), LPSC 40, # 1242 [10] Vincendon et al. (2007), *J. Geophys. Res.,* 112, E08S13. [11] Putzig et al. (2005), *Icarus*, 175, 325-341. [12] Ahronson and Schorghofer (2006), *J. Geophys. Res.,* 111, E11007 [13] Haberle et al. (2008), *Planet. Space Sci.*, 56, 251-255.

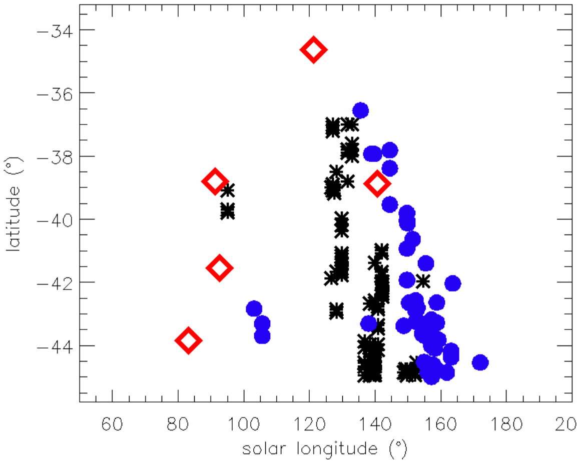

Figure 2: Latitude and season of observed CO_2 deposits (southern hemisphere). OMEGA detections are shown with black stars. Blue dots correspond to CRISM multispectral observations, and red diamonds correspond to CRISM high resolution observations similar to the example of Figure 1.

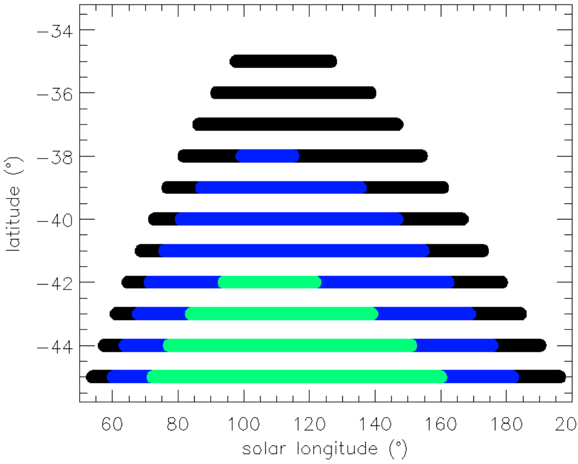

Figure 3: Modeled stability of CO_2 ice on pole facing slopes (black: 30° slopes; blue: 25° slopes; green: 20° slopes) in a latitude / solar longitude diagram (southern hemisphere). The ground is composed of a 10 cm thick soil of thermal inertia 260 SI that cover a layer with a higher inertia (2200 SI) according to ([11], [12]). The MGS atmospheric dust scenario is used.