RETREAT OF THE NORTH SEASONAL CAP OF MARS OBSERVED BY OMEGA AND CRISM.

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Introduction: Seasonal caps play an important role for surface-atmosphere interactions on Mars, as they trap up to 25% of the atmosphere during winter. While seasonal caps are mainly constituted of CO_2 ice, H_2O ice and dust play an important role in their evolution. Spectral imaging observations in the near infrared provide unambiguous information on the composition of the seasonal caps as CO_2 ice and H_2O ice present strong specific absorption bands between 1 µm and 4 µm. They are particularly well suited for investigating the retreat phases, which extend up to Ls 90° in the North (summer solstice) and up to Ls 310° in the South (mid fall), hence with good illumination conditions. The condensation phases are best studied in the thermal IR range (TES, THEMIS), as these instruments can observe during the polar night. The OMEGA imaging spectrometer on board Mars Express has observed the seasonal caps for nearly five years, covering the retreat of the Southern seasonal cap for two consecutive Martian years and that of the Northern seasonal cap for three consecutive Martian years. OMEGA observations have demonstrated a strong asymmetry between the North and the South polar caps during spring: H_2O signatures rapidly dominate in the North while they are restricted to isolated spots in the South, disappearing in late spring [1,2]. Dust contamination at the surface of the ice is responsible for the low albedo observed in the “cryptic region” [3,4], with contributions from venting processes [4] or from aerosol sedimentation [3,5]. The CRISM imaging spectrometer on board MRO has been in operation since November 2006, with observations of the retreat in the South and in the North during one full seasonal cycle. The high spatial resolution of CRISM provides new constraints on the extremely complex processes which occur during sublimation of the seasonal caps. In this contribution, we focus on the evolution of the northern seasonal cap as observed by OMEGA and CRISM.

Early stages of the retreat and formation of the H2O veneer: Shortly after equinox, H_2O ice signatures are observed all over the northern seasonal cap, extending 3 to 5° beyond the limit of CO_2 ice signatures. The existence of this outlying ring of water frost had been already inferred by TES from temperature measurements [6]. In 2006, the boundary of CO_2 ice signatures observed by OMEGA is fully consistent with that expected from temperature measu-

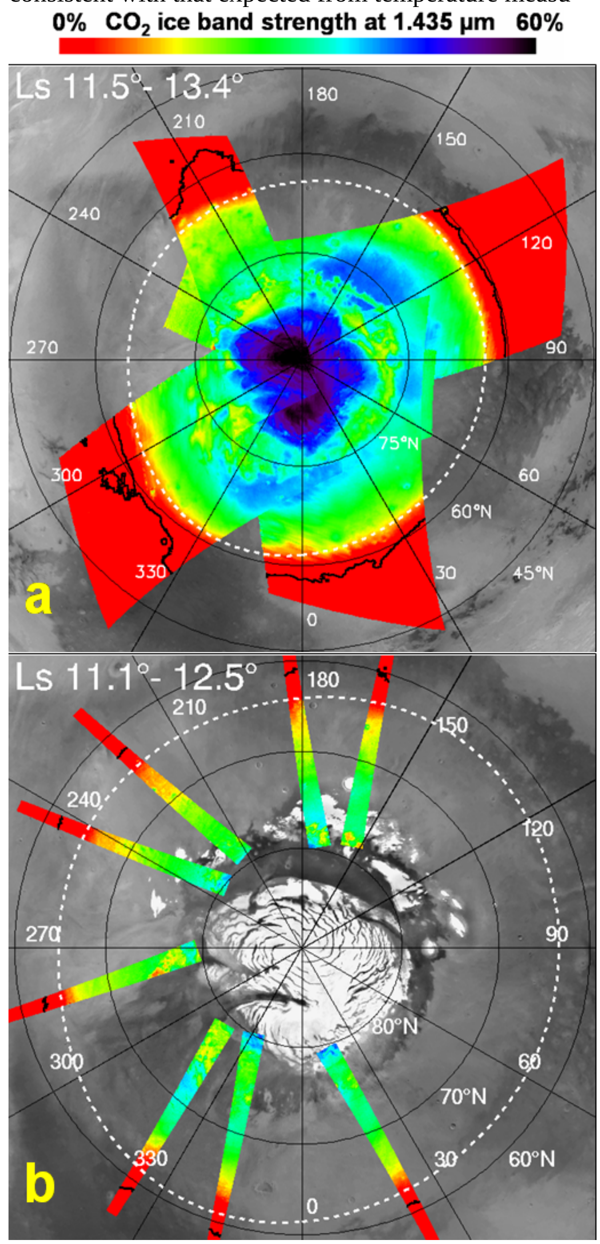

Figure 1: CO_2 ice signatures shortly after equinox in February 2006 (a) and January 2008 (b). The dashed line corresponds to the outer boundary of temperatures consistent with the presence of CO_2 ice [7]. The solid black line corresponds to the outer boundary of water

ice signatures. Weak outlying H_2O ice signatures correspond to ice aerosols in the polar hood.
ements by TES. In January 2008, the CO_2 ice signatures are significantly weaker, and the boundary has shifted by ~ 2° N (Fig. 1).

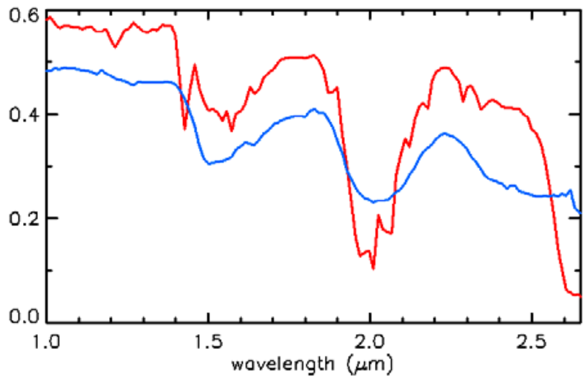

Figure 2: spectral signatures of the northern seasonal cap observed by OMEGA in early spring.

In early spring, the regions corresponding to the perennial cap (red spectrum in Fig. 2) are dominated by CO_2 ice contaminated by H_2O frost. The outer ring (blue spectrum) corresponds to a mixture of fine-grained H_2O frost and dust.

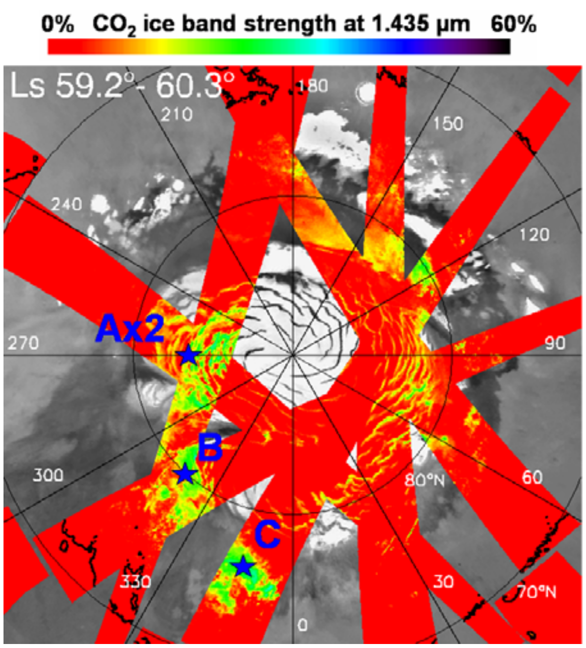

Figure 3 : CO_2 ice signatures observed by OMEGA at Ls ~ 60° in 2006. The solid dark line corresponds to the outer limit of H_2O ice signatures. Regions A, B and C where CO_2 ice signatures are observed to increase from Ls ~ 50° to Ls ~ 60° have been targeted for CRISM HR observations in 2008.

The northern seasonal cap in mid to late spring: After Ls 40°, most of the northern seasonal cap is dominated by H_2O ice signatures, which still extend down to 70°N. CO_2 ice signatures are only observed over a few patches (Fig. 3). While patches on the permanent cap are linked to north facing slopes of troughs, there are regions such as "C" on the figure with no clear link to topography.

In mid spring, the seasonal cap is still expected to be several 10 cm thick over the permanent cap. Given the limited supply of precipitable water, H_2O ice can only provide a thin surface veneer. As it must be optically thick so as to mask underlying CO2 ice signatures, grain sizes have to be small, which is confirmed by the relative strengths of the spectral bands at 1.25 μm, 1.5 μm and 2 μm (see Fig. 2). The most likely interpretation of the observed increases in CO_2 ice signatures is therefore that the H_2O veneer is removed by CO_2 sublimation in such areas, revealing underlying layers where CO_2 ice is still present.

A specific observation campaign combining OMEGA and CRISM has been implemented in early 2008 so as to investigate this anomalous process in terms of consistency between different martian years and relationship with albedo features or topography

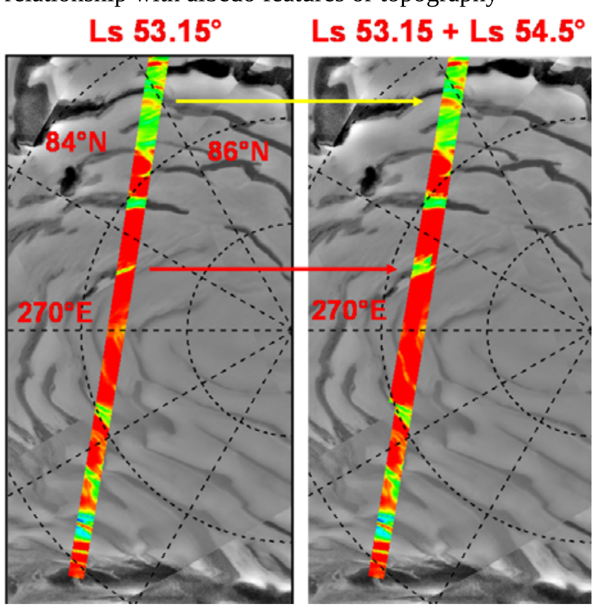

Figure 4: Observations of high latitude regions by OMEGA at 3 days interval in 2008 (same color code as Fig. 3). On the right, the second observation is superimposed on the first observation. Both shrinking (yellow arrow) and expanding (red arrow) patches with signatures of CO_2 ice are observed. The CO_2 signatures at 85°N, 210°E was not observed in 2006.

Observations of the anomalous CO2 ice signatures in 2008: Due to the northward motion of the pericenter of Mars Express from 2006 to 2008, the observations by OMEGA in 2008 were obtained at a higher resolution (0.5 km/pixel) than in 2006 (2 km/pixel). While the general pattern of patches with CO_2 ice spectral signatures is very consistent with that observed in 2006, CO_2 ice is observed in 2008 in a few areas where it was no observed in 2006 (see Fig. 4). Major changes in the extent of patches are observed over a 3 days interval at the same local time (2 PM). The signatures extend in troughs while decreasing in nearby regions on the top of the cap.

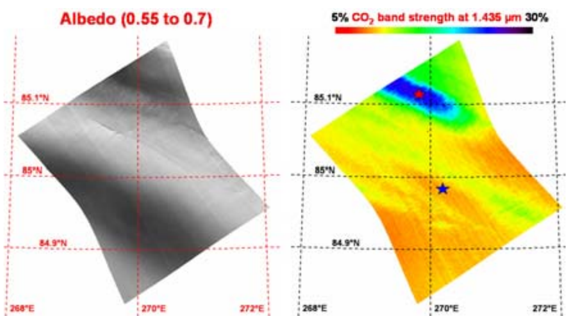

Figure 5: HR observation by CRISM of a high latitude region (region A of Figure 3) at Ls 70°. The red and blue stars show the locations of the spectra in Fig. 6.

CRISM HR observations have a resolution of 18 m/pixel. The patch with a CO_2 ice signature is clearly associated with the north facing side of a trough, as demonstrated by its lower apparent albedo, but a similar north facing slope at a lower latitude presents no CO_2 ice signature. The patches appear relatively homogeneous at a scale of a few 100 m. Spectra observed by CRISM (Fig. 6) are fully consistent with that observed by OMEGA on patches and regions not exhibiting CO2 ice signatures at the same L_s.

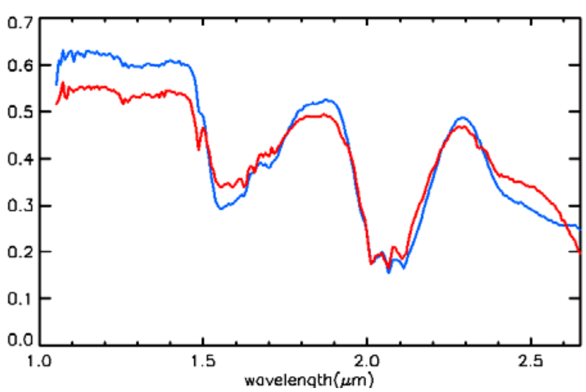

Fig. 6: CRISM spectra of regions with (red) and without (blue) CO_2 ice signatures at Ls 70°

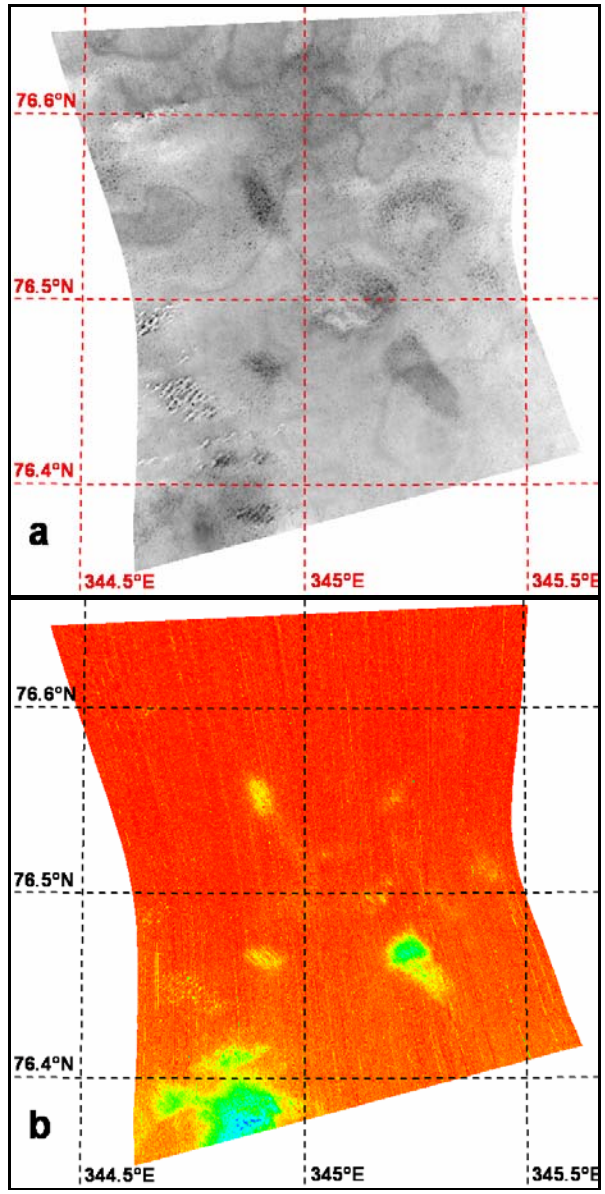

Figure 7: CRISM high resolution observations of Vastitas Borealis at Ls 64°; a: albedo (grey scale: 0.35 to 0.45); b: CO2 band strength (color scale: same as Figure 5).

Observations of regions of the seasonal cap outside of the perennial cap are presented in Figure 7. The albedo map (Fig. 7.a) shows a complex pattern with dark spots similar to that observed in the South due to venting processes [4], but with a much lower contrast (20%, compared to 50% in the south). There are patches exhibiting a CO_2 ice signature (Fig. 7.b) as expected for region C in Figure 3. They are relatively small which suggests that the H_2O ice veneer has reformed since L_s 50°. The comparison with the albedo map suggests that CO_2 vents responsible for the projection of dust as dark spots on the surface (lowering the albedo) may have played a role in the breaking-up of the H_2O frost veneer, as CO_2 ice signatures tend to be linked to low albedo regions, but the correlation is not straightforward. The relatively low overall albedo is similar to that of the H_2O frost deposit lagging behind the retreat of the seasonal cap, hence a contamination of surface frost by dust is likely. A venting process can hardly be considered for the flaking-off of the H_2O veneer over the perennial cap (regions A and B of Figure 3), as the high albedo of the underlying water ice layer hampers an effective sublimation process at the bottom of the CO_2 ice layer.

Conclusions: recent observations of the retreat of the northern seasonal cap with OMEGA/MEX and CRISM/MRO during northern spring have confirmed the non monotonic evolution of the spectral signatures, patches with CO2 ice signatures expanding at specific locations between L_s 50° and L_s 60°. These patches appeared at the same locations over two Martian years with a few exceptions. The sublimation processes in the North shows major differences with that in the South due to the much larger supply of water. The rapid evolution of spectral signatures and albedo patterns suggests a complex interplay between dust, seasonal CO2 ice, seasonal H_2O frost and the underlying surface (circumpolar dark terrains and perennial H_2O ice) during the sublimation process.

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