SEASONAL EVOLUTION AND ENERGY BUDGET OF THE SOUTH RESIDUAL POLAR CAP OF MARS FROM CRISM AND HIRISE OBSERVATIONS

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Introduction: The evolution of the CO_2 reservoirs is one of the key aspects to decipher the martian climate changes. On Mars, during winter, up to 30 % of the atmosphere (composed of 95 % of CO_2) condenses at the surface to form seasonal polar caps, which completely sublime in spring, except in the South where a residual cap, a few meters thick, persists during summer.

The evolution of the CO_2 icy surface is directly linked to its radiative properties: solar albedo and thermal emissivity. In particular, the albedo of the CO_2 ice has been shown to increase during spring as the insolation increases [e.g. 1]. Different mechanisms could potentially explain this behavior : ice cracking due to thermal stress, water ice deposition, dust transport at the surface, aerosol variations in the atmosphere, etc. Photometric effects could also possibly affect the albedo retrieval since it is generally derived from nadir acquisitions (lambert albedo).

Here we use both HiRISE/MRO high resolution images and CRISM/MRO VIS-NIR multi-angular hyperspectral data from the South residual cap to investigate this behavior and determine its energy budget through the retrieval of the directional-hemispheric surface ice albedo, i.e. the actual fraction of solar energy that is reflected by the ice.

Methods: HiRISE images of 6 different regions of the South residual polar cap have been acquired over MY32, covering the spring and summer seasons. Data acquired over the previous years also allow comparison of the overall morphology of the surface over several years. These images have a spatial resolution of ~25cm, thus allowing to detect potential cracks in the ice. Images from the RED channel were also corrected from the atmospheric aerosol contribution by using [2] method in order to determine the nadir reflectance factor of the icy surface at local/regional scale.

CRISM multi-angular hyperspectral data of the same regions (acquired over several years) were corrected from the aerosol contribution (mineral dust and H_2O ice) by using the Mars-ReCO approach [3,4]. This method uses the multi-angular nature of the data (11 different viewing geometries) to perform the joint characterization of both the aerosol contribution and the bidirectional reflectance distribution function (BRDF) over the CRISM spectral range (0.4-3.9 µm). In particular, it does not assume a lambertian behavior of the surface.

Results: After correction of the aerosol contribution, both HiRISE and CRISM data exhibit a continuous increase of the nadir reflectance factor until ~Ls270, followed by a decrease during the summer season. This trend is not restricted to certain areas or morphologies and is observed in all investigated regions so far (6 regions with HiRISE and 2 with CRISM) at both local and regional scale.

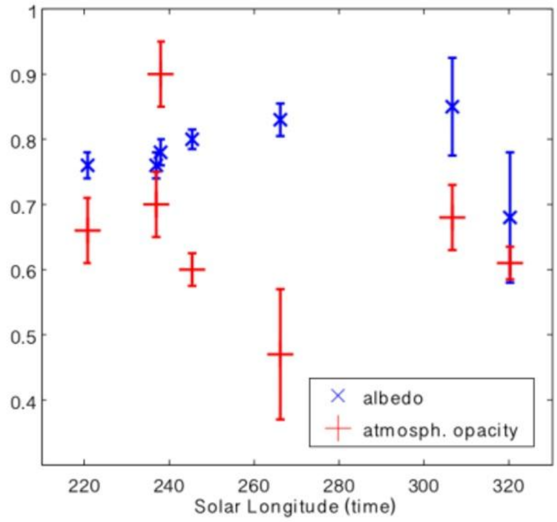

Fig.1 Conjoint temporal evolution of the atmospheric optical depth at 1000 nm and the surface directional-hemispheric albedo at 750 nm over an area located at -85.4° lat, 319.6° long (MY29).

Over spring and summer seasons, surface ice exhibits a photometric behavior rather close from lambertian, with forward and backward scattering lobes relative weight depending on the area. In particular, the various classes of spectro-photometric behavior that are observed appear to be linked to the composition, grain micro-texture, and surface roughness of polar materials. The directional-hemispheric albedo calculated at 750 nm is typically 10-15% higher than the reflectance factor measured at nadir and exhibits similar seasonal behavior which shows that photometric effects are not controlling the evolution observed at nadir (Fig.1).

In the meantime, no ice cracking can be observed in HiRISE images before ~Ls270. After that, a few cracks, a few tens of meters long typically, appear locally (Fig. 2) and could be linked to thermal stress. CRISM spectra do not show water ice contamination that is correlated with the albedo increase.

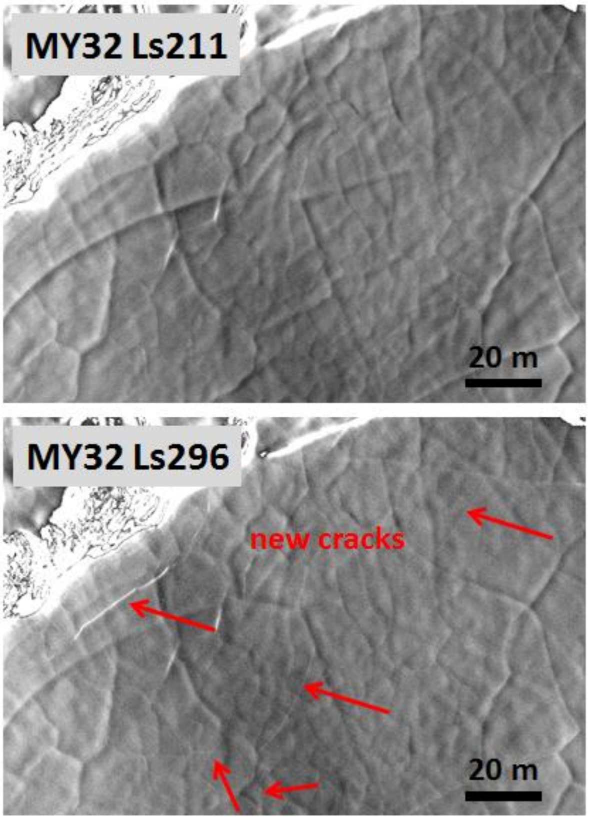

Fig.2 Temporal evolution of the ice surface morphology over an area located at -86.3° lat, 0.5° long. Cracks a few tens of meters long appear in early summer as shown in red.

Conclusion: A retrieval of the directional-hemispheric albedo of CO_2 icy surface of Mars, corrected from the aerosol contribution, has been made here for the first time. Important constrains on the surface physical properties, morphology and composition temporal evolution of the residual cap have also been obtained through HiRISE and CRISM data. In particular, our results suggest that most of the processes mentioned in the introduction (ice cracking, water ice deposition, aerosol content variations in the atmosphere) are not the main contributors to the observed evolution of the albedo of the residual cap. Ice cracking could however occur at small scale and not be observable by HiRISE. Other hypotheses like surface dust transport and the possibility to have an heterogeneous CO_2 ice layer condensing/subliming will be tested in the future.

References: [1] Paige and Ingersoll 1985, *Science* 228 1160-1168 ; [2] Vincendon et al. 2008, *Icarus* 196 488-505 ; [3] Ceamanos et al. 2013, *JGR* 118 1-20 ; [4] Douté and Ceamanos 2015, *IGARSS 2015* 1-4.