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Spring evolution of Martian south polar terrains: insights from high-resolution observations by HiRISE and CRISM.

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Abstract

We study the spring evolution of ten different areas in the south polar regions of Mars using high spatial resolution observations from the HiRISE/MRO camera and CRISM/MRO imaging spectrometer. We derive the temporal evolution of surface reflectance, CO_2–ice and H_2O–ice band strengths for selected areas. We observe common behavior with three steps: (1) initial darkening related to dust activity, (2) brightening and (3) final darkening during defrosting. Local and regional variability are also observed and discussed. Analyses of the HiRISE observations allow us to propose plausible mechanisms to interpret the evolution. In particular, we highlight the influence of meter-scale topography on the occurrence and modalities of jet activity.

1. Introduction

The sublimation of the seasonal deposits of volatiles during Martian spring results in strong temporal variations of the appearance of the southern polar regions terrains. The most spectacular manifestations of these processes are intense dust and CO_2 jet-like activities [5]. The high spatial resolution capabilities of the MRO instruments now offer the possibility of new analyses at an unprecedented level of detail. Results from the analyses of HiRISE images as well as complementary work on the physical modeling of the involved processes have recently been published [1,4,5]. We are now completing this work by extending the number of regions of interest and by including CRISM spectral information in our analyses.

2. Time-curves of spectral criteria

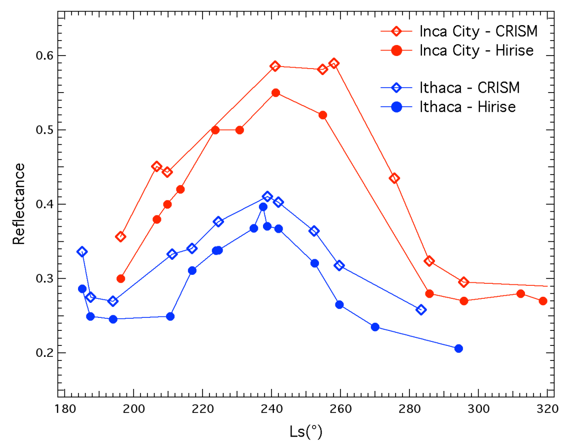

Figure 1: Temporal evolution of surface reflectance measured by HiRISE in the wide red visible channel compared to surface reflectance measured by CRISM at 1.14 μm in the regions of Ithaca and Inca City.

Figure 1 provides an example of the temporal variations of surface reflectance in the regions of Inca City and Ithaca. Both instruments show consistent evolutions of the spectral parameter but also a systematic shift of 10-15%, attributed to the relative uncertainties in the photometric calibration of each instrument (~10%). The strong brightening between Ls ~ 200° and Ls ~ 240° (so-called "step #2" for the rest of this abstract) is visible in both datasets as well as the final darkening ("step #3") attributed to the progressive defrosting of the surface. The first darkening step ("step #1") is barely visible from the three first points in Ithaca. This step is more obvious in other areas and on the time-curves of CO_2 band strength derived from CRISM. This behavior is globally consistent with the time-resolved maps built from OMEGA data [3].

We have also studied the behavior of H_2O-ice in a similar way. This spectral criterion shows a different behavior with either a continuous slow decrease in time or a plateau followed by a slow decrease. From the temporal evolution of spectral criteria, it is obvious that water ice systematically disappears from the surface before CO_2-ice. We are currently investigating different plausible mechanisms to interpret this observation.

3. Interpretation of HiRISE images

In order to interpret the temporal evolution derived from both HiRISE and CRISM datasets, we analyzed repeated HiRISE images of the same scenes. In early spring (Ls < 200°), we identify numerous bright features corresponding to meters-scale topography (channels, boulders…). These bright features are very often located close to the source of the dust fans. Our preferred interpretation of these observations is that these features remain bright because an active self-cleaning of the ice layer occurs here and gives rise to the jet activity.

At later times, around Ls ~ 190° – 210°, we observe the rapid development of halos around the dark dust fans, as already shown by [2]. From repeated HiRISE observations, it is obvious that the halos develop on areas that were previously covered by dust. CRISM spectra of the halos display clear CO_2 spectral signatures as well as a visible spectral slope very similar to the one of the mineral grains. Therefore, we interpret these halos as mineral particles sinking through the ice layer.

HiRISE observations during step #2 (as defined in section 2) usually display very little morphological change. This corresponds to the predominance of sublimation from the top of the ice layer as the atmosphere warms up. At this step, fine mineral particles embedded in the top layer of the ice deposits are released and could eventually be mobilized by surface wind. We see evidence for this mobility of dust from HiRISE images where dust tends to accumulate in topographic lows. Such a process could explain a puzzling positive correlation between surface reflectance and atmospheric dust opacity measured by the OMEGA instrument [6].

4. Summary and conclusions

We propose a three-step scenario for the evolution of south polar terrains at high latitude. Early dust jet activity is triggered by meters-scale topography and the presence of sun-facing slopes. Dark mineral grains emitted by this activity can sink through the ice layer, producing halos around large dust fans. This episode marks the transition between the predominance of a sublimation “from the bottom” where grains sink through the ice layer and sublimation “from the top” where dust grains can be released to the atmosphere. This last mechanism can explain the strong systematic brightening observed between Ls ~ 200° and Ls ~ 250°. Then, the surface darkens again due to progressive defrosting resulting in a patchwork of frozen and unfrozen areas.

Acknowledgements

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