Spatial variability and composition of the seasonal north polar cap of Mars

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The middle-spring Martian north polar cap (Ls ~ 40°) has been observed by PFS/MEX in illuminated conditions during orbit 452. The SWC spectra were used to study the cap composition in terms of CO_2 ice, H_2O ice and dust content. Significant spectral variation is noted in the cap interior, and regions of varying CO_2 ice grain sizes, water frost abundance, CO_2 ice cover and dust contamination can be distinguished. In addition, we correlate the infrared spectra with an image acquired during the same orbit by the OMEGA imaging spectrometer and with the altimetry from MOLA data (figure 1). Many of the spectra variations correlate with heterogeneities noted in the image, although significant spectral variations are not discernible in the visible. The data have been divided into five regions with different latitude ranges and strong similarities in the spectra, and then averaged. Bi-directional reflectance models have been run with the appropriate lighting geometry and used to fit the observed data, allowing for CO_2 ice and H_2O ice grain sizes, dust and H_2O ice contaminations in the form of intimate granular mixtures and spatial mixtures.

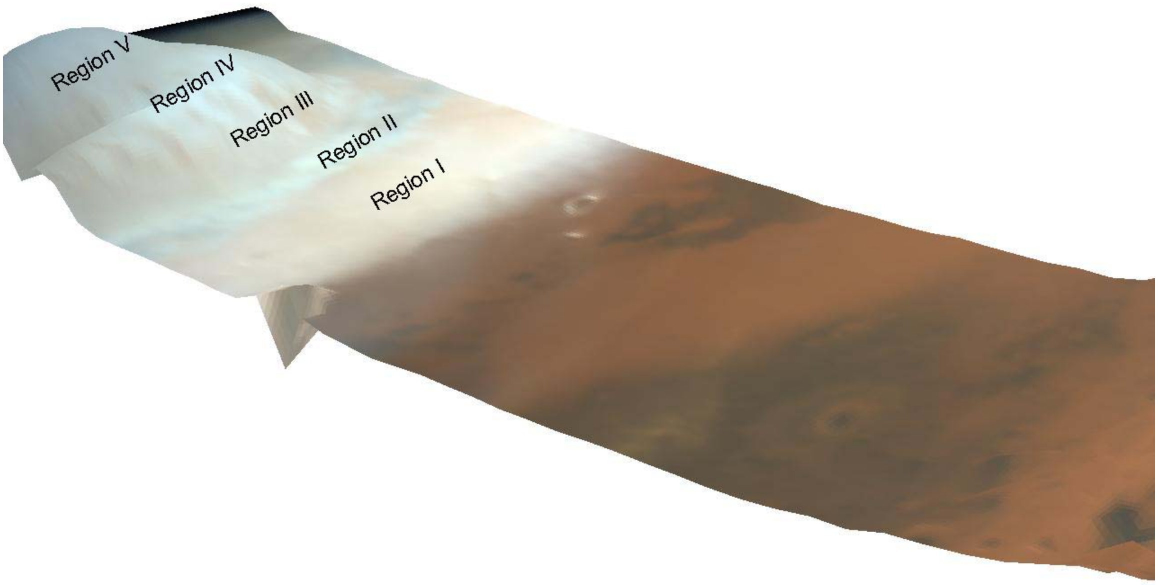

Figure 1. 3D surface plot of Martian north polar cap as seen by OMEGA during orbit 452. RGB colours have been obtained from the spectra in the visible range acquired by OMEGA. Altimetry is retrieved from MOLA data. The five regions investigated in this work are marked. Region I is at the cap edge and extends from 65°N to 72°N latitude. Region II is a narrow region [75°N ÷ 79°N] right at the feet of the north polar mountain. Region III is all along the shoulder of the mountain. It extends for 1.5 Km in altitude and by only two degrees of latitude. Region IV is close to the top of the mountain. The final region V is right at the top of the mountain.

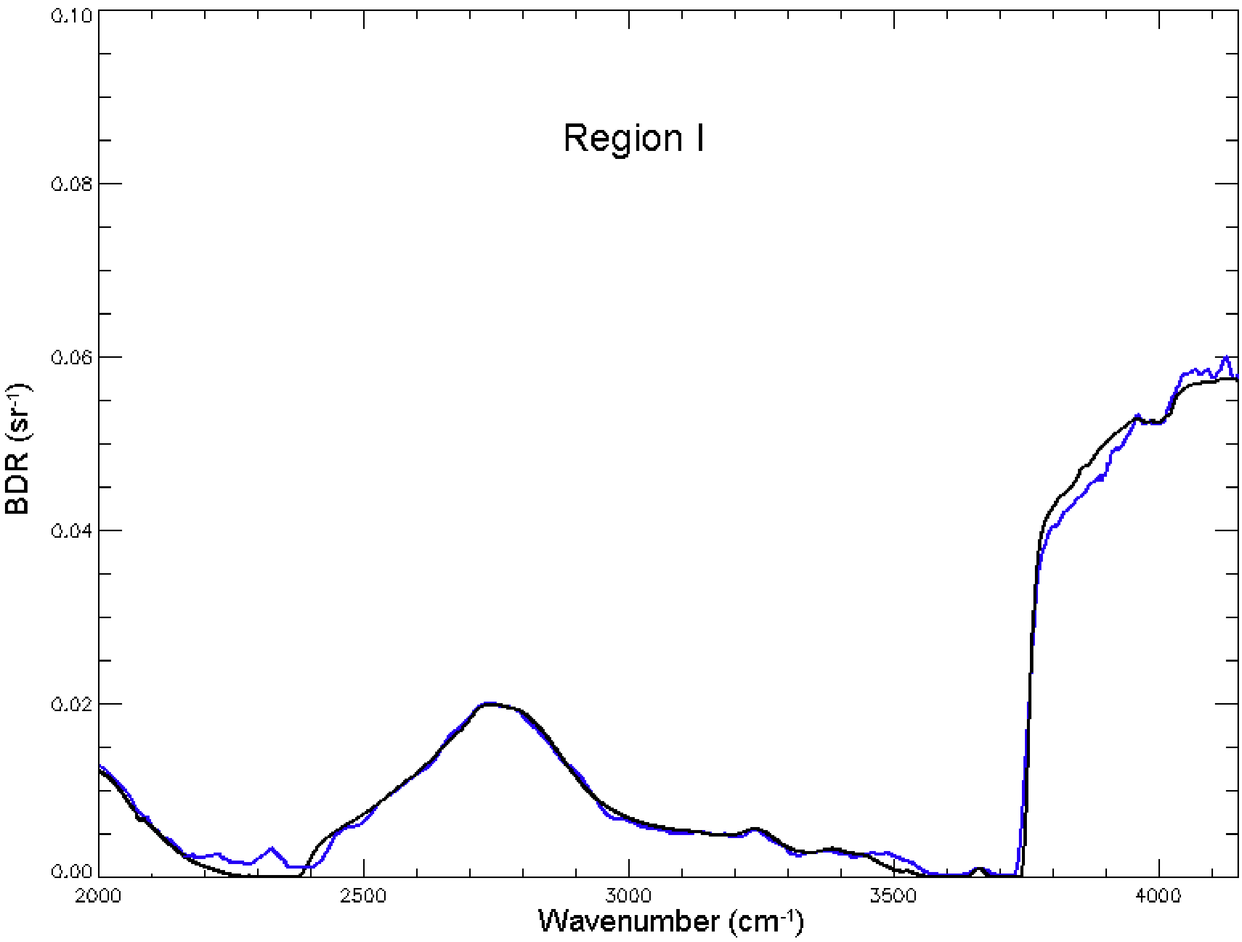

Figure 2. Best-fit of PFS spectra from Region I. The blue curve is the spectrum measured by PFS; the black curve is a BDR model of an intimate admixture of H_2O ice (20μm)_and 0.15 wt % of dust.

The cap edges are free of CO_2 ice, consisting of an admixture of H_2O ice and dust. The inner cap exhibits a layered structure with a thin CO_2 layer with varying concentrations of dark dust on top of an H_2O ice underneath ground. Layered structures are not accounted for on our current reflectance models. The ices beneath the top layer have been considered as spatial mixtures. The results are still very good everywhere in the spectral range, except where the CO_2 ice absorption coefficients are such that even a thin layer is enough to totally absorb the incoming radiation (i.e. the band is saturated). This only happens around 3800 cm^{-1}, inside the strong 2.7 μm CO_2 ice absorption band.
Region I (figure 2) is at the cap edge and extends from 65°N to 72°N latitude. No CO_2 ice is present in this region, which consists of relatively large grains of water ice (20 μm), highly contaminated by dust (0.15 wt%).

The adjacent region II is a narrow region [75°N ÷ 79°N] right at the feet of the north polar mountain. This region is well recognizable in the OMEGA image, where it appears to surround the whole mountain. It basically consists of a thin layer of 5 mm grained CO_2 ice covering a ground with the same composition as region I. The CO_2 ice features are barely visible in these spectra, except for the strong saturated 2.7 μm band. It is probably the result of several CO_2 ice landslips/avalanches previously occurred along the hard slopes of the contiguous mountain. A third interesting region (III) is found all along the shoulder of the mountain. It extends for 1.5 Km in altitude and by only two degrees of latitude and consists of dirty CO_2 ice, that is to say with a very high dust content. It is an admixture of CO_2 ice (3-4 mm), with several tens of ppm by mass of water ice and more than 2 ppt by weight of dust. We found an unexpected high increase of the retrieved surface temperature in this region, suggesting that it may be “warm” dust transported by winds circulation in the Martian atmosphere and recently deposited on-top of the ice rather than well mixed with it. Region IV (figure 3) is close to the top of the mountain; it is much brighter than region III, with a dust content ten times lower than the latter. CO_2 grain size is 3 mm and strong CO_2 ice features are present in the data, indicating a layer of CO_2 ice much thicker than that in region II.

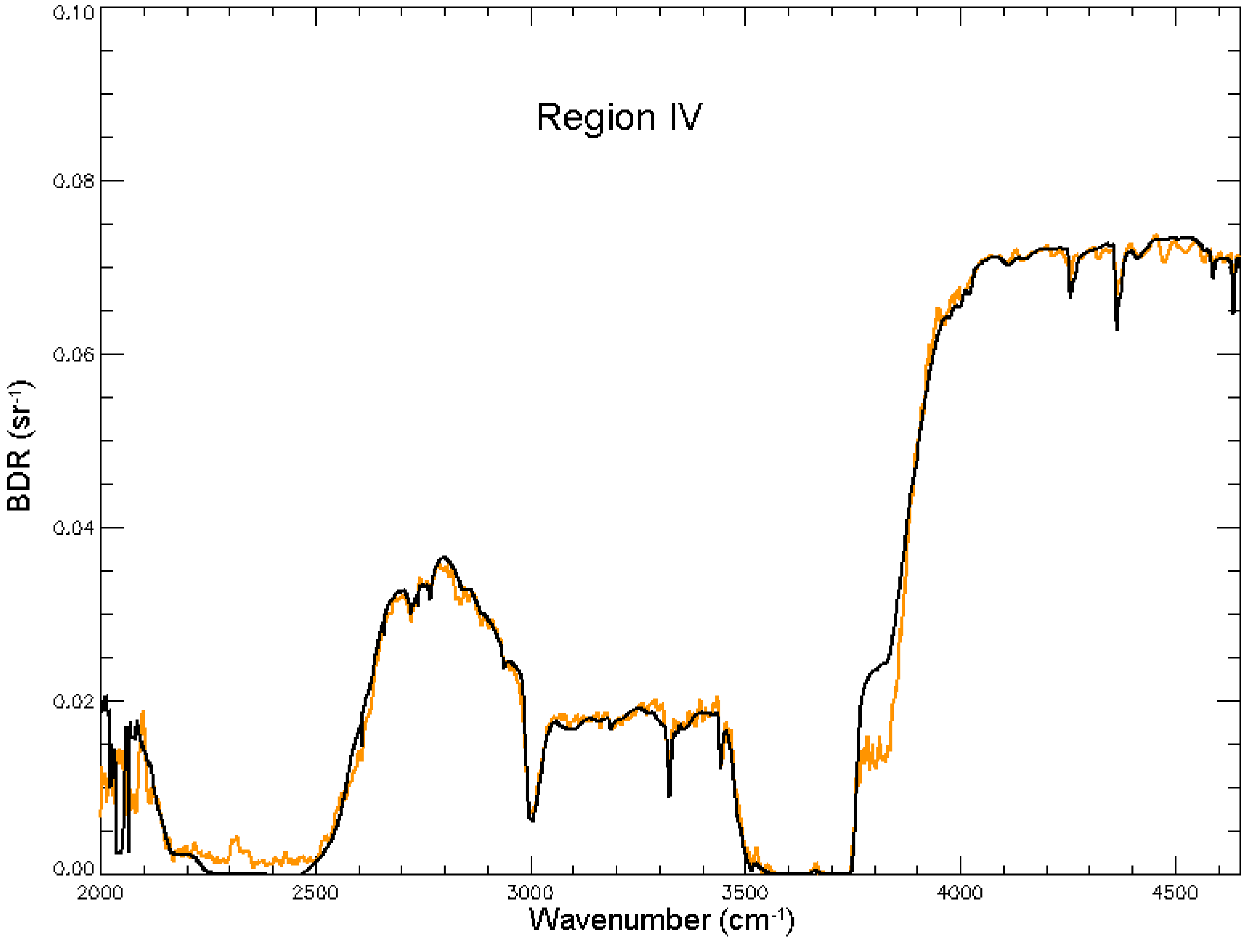

Figure 3. Best-fit of PFS spectra from Region IV. The Orange curve is the spectrum measured by PFS. The black curve is a BDR model that best-fit the spectrum. It consists of a spatial mixture of 50% of the same ice of region I and 50% of an intimate admixture of CO_2 ice (3mm)_contaminated by 0.02 wt % of dust and by 0.0018 wt % by H_2O ice.

The final region V is right at the top of the mountain. It is "pure" CO_2 ice (no dust) of 5 mm grain sizes, with 30 ppm by weight of water ice. The underneath ice (same as in region I) is barely visible, being present in the model only as a 15% spatial mixture, the CO_2 ice features are very strong and the 2.7 μm band is saturated.