OBSERVATIONS OF SURFACE ICES AND SEASONAL FROSTS WITH THE L AND V CHANNELS OF OMEGA / MEX

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Introduction:

After seven years of successful operation, the OMEGA Vis-NIR imaging spectrometer has demonstrated its ability to monitor surface ices, surface frosts and icy aerosols on Mars, with more than 10 published or submitted articles. The strong absorption features in the near IR range made it possible to discriminate CO_2 and H_2O ices within regions with high albedo [1,2,3,4], as well as identifying ices contaminated by dust [2,3] or covered by dust [4], which combine ice absorption features with an albedo similar to that of frost-free regions. The strength of the bands depends on the distance between scattering interfaces (grain size) which made it possible to follow the sublimation of seasonal H2O frost covering large-grained H2O ice on the north perennial cap soon after the northern summer solstice [5] and the complex evolution of granulometry during the sublimation of the southern seasonal cap, mainly constituted of CO2 ice [4, 6, 7]. Aerosols have a major impact on observed spectra, lowering the albedo and band strength [8], which makes it possible to monitor dust clouds over ice covered regions [9]. The Monte-Carlo model developed for recovering surface reflectances [8] has recently been adapted to high incidences [10], which makes it possible to obtain information on high latitude regions very close to or even beyond the terminator.

The OMEGA observations now cover nearly 4 full Martian years, from Ls 330°, MY 25 to Ls 208°, MY 28. The main emphasis of present and future OMEGA observations of interest for surface-atmosphere interactions is therefore the monitoring of seasonal and inter-annual evolutions [4, 7, 11]. CRISM, a VIS-NIR spectral imager on board MRO with a higher spatial resolution than OMEGA (20 m versus 300 m at pericenter) has been operating since late 2006. The much larger FOV of OMEGA for full spectral resolution observations (typically 60 x 800 km versus 12 x 12 km for CRISM) is clearly an asset for monitoring global evolutions at high latitudes. In late August 2010, the cryocooler dedicated to the C-channel of OMEGA failed. This led to the interruption of observations in this wavelength range (0.92 to 2.69 µm), which contains some of the most diagnostic absorption signatures of H_2O and CO_2 ices. Given the recent extension of Mars Express observations until 2012, it is of clear interest to identify the science goals which can still be achieved with the two remaining OMEGA channels : the visible channel (0.36 µm to 1.07 µm) and the long wavelength channel (2.53 µm to 5.09 µm).

Discrimination of H_2O and CO_2 ices

Seasonal frost and perennial ice uncontaminated by dust can be monitored on the basis of their high albedo [12], typically 50% or higher. This information is still available in the VIS range of OMEGA. Ices and frosts (either contaminated by dust or not) have a low brightness temperature (< 230 K), which is available from the L-channel of OMEGA (up to 5.1 µm). Discriminating between CO2 ice (~ 140 K) and H2O ice (~ 180 K) on the basis of temperature requires observations in the thermal IR with TES [13] or THEMIS [14]. However, the identification is not straightforward, as intermediate temperatures observed at the edge of the receding southern cap have been attributed to H2O frost [15] then to spatial mixing between CO2 ice-covered and ice free areas [4] on the basis of OMEGA spectral information.

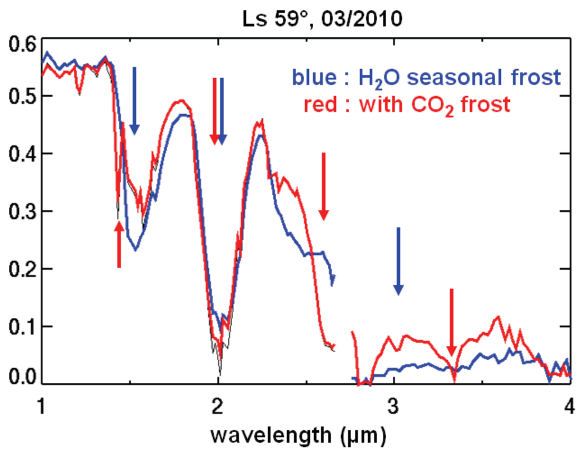

Figure 1: reflectance factor as a function of wavelength from the receding northern seasonal cap in late northern spring (L_s 59°) showing both H2O ice (blue) and CO2 ice (red) signatures

As demonstrated in Fig. 1, while the loss of the C-channel is clearly detrimental as diagnostic bands of H_2O ice at 1.5 µm and CO_2 ice at 1.435 µm and 2.65 µm can no longer be observed, it is still possible to identify CO_2 ice from the 3.3 µm band (red arrow on the right). The main impact is for very large grained ices (1 mm for H_2O ice, 50 mm or more for CO_2 ice) as reflectance factors become very low in both cases in the 2.8 to 4 µm wavelength range. As the emphasis is on seasonal and inter-annual variability, one can however rely on OMEGA observations from previous Martian years, as large-grained H_2O ice was only observed by OMEGA over the North perennial cap after the sublimation of seasonal frost.

As an example, a region at 357°E, 86.5°S (over the perennial southern cap) has recently been observed at L_s 201.2° with the VIS and L channel. The same region was observed at L_s 203° with all three channels two Martian years earlier (03/2007), exhibiting an unambiguous signature of slab CO_2 ice. In late 2010, the high reflectance factor in the visible, low reflectance factor from 2.5 to 4 µm and the low temperature could result from either slab CO_2 ice or large-grained H_2O ice. The comparison with earlier observation points towards CO_2 slab ice. The albedo in the visible is slightly lower in 2010 due to a higher incidence (81° instead of 77.2).

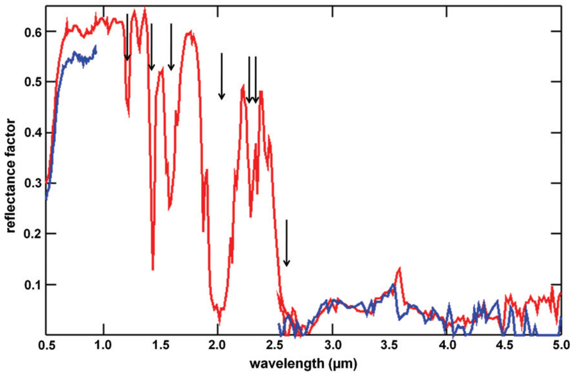

Figure 2: reflectance spectrum of a region at 357°E, 86.5°S in march 2007 (red) and in late 2010 (blue).

Another example of the potential of OMEGA with the VIS and L channels is given with a recent observation of the edge of the southern seasonal cap.

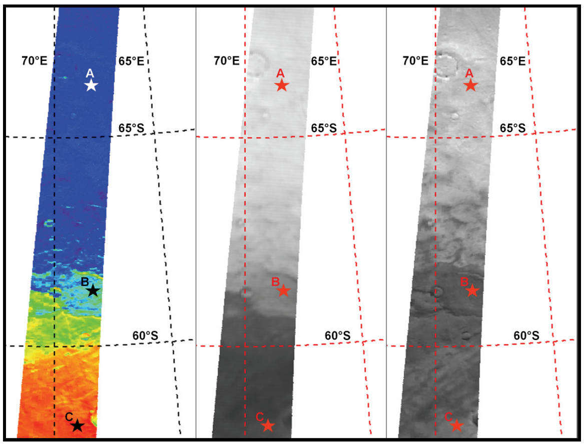

Figure 3: receding edge of the southern seasonal cap at L_s 203.7° in late 2010; right: temperature (blue : 200 K; red: 260 K); center: reflectance factor at 0.76 µm (grey scale, 0.1 to 0.4); right: reflectance factor at 3.75 µm (grey scale, 0.1 to 0.3). Three reference regions have been selected, corresponding to high (A), intermediate (B) and low (C) albedos at 0.76 µm

The temperature is (as expected) inversely correlated with albedo, the green region corresponding to spatial mixing between ice-covered and ice-free regions. The albedo at 3.75 µm lowers further South, indicating a gradient in ice composition.

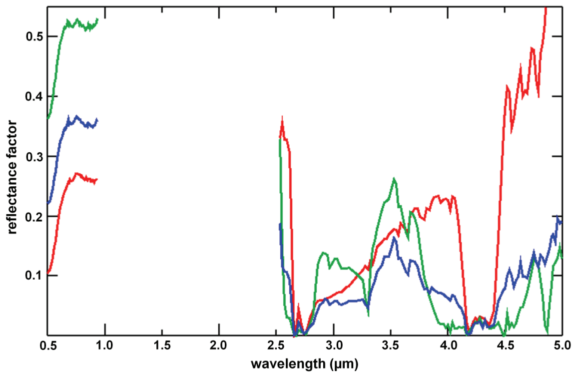

Figure 4: reflectance spectra of the three reference regions in Fig. 3; green: A; blue: B; red: C.

The red spectrum is typical of "hot" ice-free regions. The green spectrum exhibits a strong 3.3 µm CO_2 ice band, the lower reflectance at 3 µm being diagnostic of water ice aerosols around equinox [4]. Close to the edge, the lower intensity of the 3.3 µm band can be attributed to surface H_2O ice contamination, in line with previous OMEGA observations.

Conclusion

While the loss of the C-channel did impact OMEGA capabilities, the combination of the VIS and L channel as well as the reference provided by previous observations will make it possible to continue monitoring with OMEGA the seasonal and inter-annual variability of surface ices and icy aerosols on Mars

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