

**SURFACE WATER ICE AND AEROSOLS EVOLUTION OF 77°N, 90°E MARS CRATER DURING EARLY SUMMER BY OMEGA/MEX.** M. Vincendon<sup>1</sup>, Y. Langevin<sup>1</sup>, F. Poulet<sup>1</sup>, J.P. Bibring<sup>1</sup>, B. Gondet<sup>1</sup>, B. Schmitt<sup>2</sup>, S. Douté<sup>2</sup> and the OMEGA team. <sup>1</sup>Institut d'Astrophysique Spatiale, CNRS/Université Paris 11, Orsay, France, mathieu.vincendon@ias.u-psud.fr. <sup>2</sup>LPG, UMR/CNRS – Université Joseph Fourier, Grenoble, France.

### Introduction:

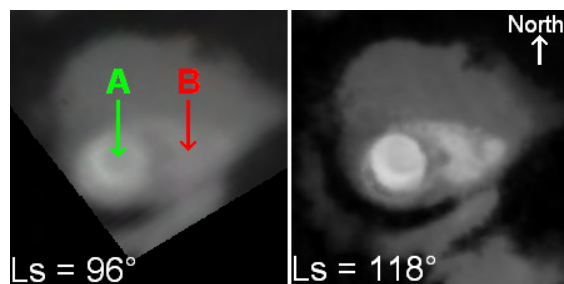
Observations of Mars North Pole surface temperatures by Viking/IRTM lead to the discovery of the main permanent cap component: water ice. The lack of H<sub>2</sub>O ice absorption features in the visible wavelengths makes water ice properties diagnosis ambiguous when using visible data, as has been previously notified by some authors [1, 2, 3]. An increase in visible albedo can be due to a deposition of water frost on ice-free or icy surfaces, a modification of ice grain size or a decrease in dust abundance inside the ice or above it (aerosols).

Repeated seasonal visible albedo increases of 77°N, 90°E crater during early 1970s summers (in particular between Ls=97° and Ls=117°) have been interpreted in [4] by water frost deposition on icy and ice-free surfaces. The same team has noticed in [5, 6] that recent MOC images of the crater do not show systematically the same visible albedo evolution during a similar period.

The visible and near IR imaging spectrometer OMEGA, on board Mars Express Mission, has provided the coverage of this crater during early 2004 summer. The strong absorption features of water ice in the near IR make it possible for OMEGA to unambiguously map surface water ice, and to investigate its properties. This study examines the [1 μm - 2.5 μm] spectral evolution of surface water ice in terms of aerosols, dust content and ice grains size evolution during early 2004 summer (Ls=96°-118°).

### Observations:

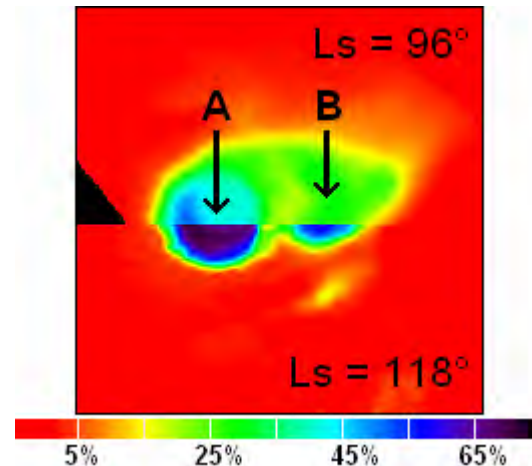
Reflectance evolution in the continuum between Ls=96° and Ls=118° shows a significant brightening in specific regions similarly to the result of [4] during a comparable period (Ls=97°-117°) (Figure 1, regions A and B).



**Figure 1:** OMEGA radiance factor at 1.085 μm (continuum) scaled from 0.1 (black) to 0.6 (white) of 77°N, 90°E icy outlier crater (~30km diameter). Regions A and B become brighter whereas other regions become darker.

The spatial layout of water ice in the crater area is mapped in Figure 2 thanks to the strong 1.5μm absorption feature of H<sub>2</sub>O ice. The ice boundaries are strikingly stable during the analysed period. This result shows that the albedo increase of region B in Figure 1 is not due to a deposition of ice frost on an ice-free surface.

As water ice is always present in region B, the increase in contrast observed in Figure 1 is most likely due to a diminution in aerosols optical depth between Ls=96° and Ls=118°.



**Figure 2:** Map of the strength of the 1.5 μm absorption feature of water ice (red: no ice). The top part of the figure was observed at Ls=96°, and the bottom part at Ls=118°. The extent of water ice surfaces is unchanging. H<sub>2</sub>O ice is already present in region B at Ls=96°.

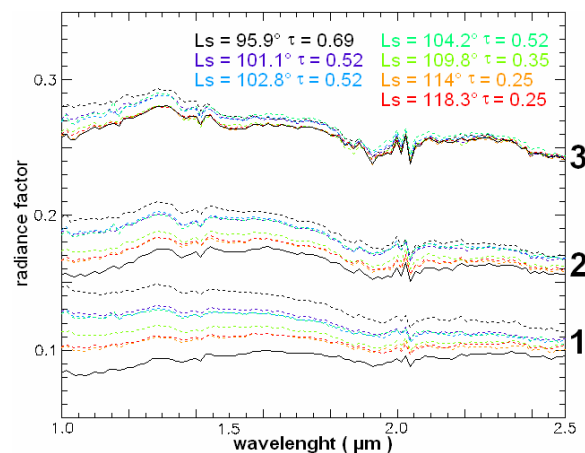
### Removal of aerosols effects:

In order to understand the role of aerosols in this region between Ls=96° and 118°, a Monte Carlo aerosols model has been developed. This model takes multiple, anisotropic and wavelength dependant scattering into account. The aerosol phase function is taken from a previous near-IR aerosols study [9] (asymmetry factor  $g = 0.63$ ), and is assumed to be constant between 1 μm and 2.5 μm in agreement with [9]. The extinction cross section is approximately 3 times the geometrical cross section. The aerosols single scattering albedo (SSA) is a critical parameter for correction of ice spectra: SSA determines the albedo level above which aerosols cause a drop in apparent reflectance. As ice spectra exhibit a broad range of reflectance, changing SSA value will markedly affect the shape of corrected spectra. For the chosen phase function, SSA has been strongly constrained using observations when the optical depth of aerosols was very high. A constant value of 0.97 for SSA is consistent with observations. This value is slightly larger than those published in [9] (SSA = 0.95 – 0.96) in our spectral range and for the same asymmetry factor. The wavelength dependence of aerosols cross section is inferred from the observations above ice-free surfaces of the crater area, and is consistent with [10]: optical depth at 2.5 μm is 40% of the one at 1 μm.

The only free parameter of the model is the optical depth at one wavelength. Observations at Ls=118° of a selected dark surface close to the crater with different solar

incidences ( $55^\circ$ ,  $71^\circ$  and  $79^\circ$ ) have been used to estimate the optical depth at this Ls. OMEGA data are scaled as radiance factor. The photometric properties of the Martian surface appear to differ from the Lambert law [7, 8], so comparing radiance factor at different incidences shows both aerosols and surface effects. We used observations of a dark area to restrict radiance factor changes with incidence linked with surface: the signal part coming from the surface, relatively to the one due to aerosols, is less important above a dark place. Moreover, photometric effects have been mainly observed on bright surfaces [7, 8]. The Monte Carlo model associated with these observations at different solar incidences enables us to obtain the optical depth at Ls= $118^\circ$  ( $\tau=0.25$  at  $1\ \mu\text{m}$ ), and therefore the surface spectra without aerosols at Ls= $118^\circ$ .

We have chosen three ice-free regions (Figure 3) of different albedo in the crater area to study the aerosols optical depth evolution between Ls= $96^\circ$  and Ls= $118^\circ$ . We have selected OMEGA data obtained by nadir pointing and with a similar incidence angle ( $\sim 55^\circ$ ) so as to avoid reflectance changes linked with surface bidirectional reflectance effects. A decrease by a factor 2.75 of aerosols optical depth between Ls= $96^\circ$  and Ls= $118^\circ$  is inferred from observations: for the three regions, the model gives approximately the same surface-only spectrum at the different Ls just by reducing progressively the value of the optical depth from Ls= $96^\circ$  to Ls= $118^\circ$  (Figure 3).

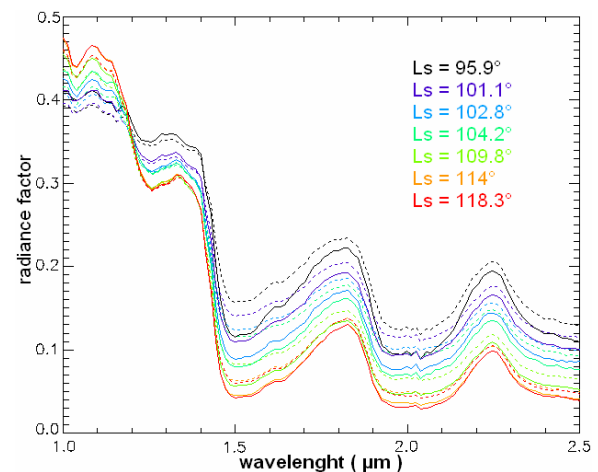


**Figure 3 :** Observed Ls evolution of 3 ice-free regions of different albedo in the crater area due to aerosols decrease (dotted lines) and surface model spectra of the 3 regions after aerosols contribution removal (black solid lines). Modelled optical depth  $\tau$  at  $1\ \mu\text{m}$  are specified, decreasing from 0.69 at Ls= $96^\circ$  to 0.25 at Ls= $118^\circ$ . All spectra are corrected for molecular absorptions of the atmosphere.

### Results and discussion:

The reflectance increase in the continuum of icy surfaces is linked with a complex evolution of the near IR spectrum with Ls (Figure 4). Ice spectra have been corrected from aerosols contribution using the model and the parameters previously determined (Figure 4). The strong resulting spectral evolution is due to physical changes in surface ice properties. This evolution has been modelled in terms of surface ice grain size and dust contamination changes inside the ice using a similar

method as the one described in [2], based on [11, 12] and ice optical constants from [13]. The best model fits are obtained with two ice grain sizes: large grains ( $600\ \mu\text{m} - 800\ \mu\text{m}$ ) and small ones ( $\sim 10\ \mu\text{m}$ ). Small grains dominated the spectrum at Ls= $96^\circ$ , constituting 50% of the volume. This fraction drops to 20% at Ls= $114^\circ - 118^\circ$ , where exposed ice is dominated by large grains. This result confirms those published in [2] on other northern cap areas: small grains of the seasonal frost sublimate away at the beginning of the summer. The conclusion is therefore the opposite of the one inferred from visible albedo in [4]. The dust contamination decreases from 11% at Ls= $96^\circ$  to 8% at Ls= $118^\circ$  assuming an intimate mixture. These values are model dependant, but not the decreasing trend. As aerosols contribution has been removed from ice spectra, the clean-up process associated with sublimation suggested in [2] for outlying ice-rich regions remains a possible interpretation.



**Figure 4 :** Time evolution of ice spectrum inside the crater (region A on Figure 1) after aerosols contribution removal (solid lines). Dotted lines are observed spectra.

### Conclusion:

Ice information contained in the near-IR enables OMEGA to observe ice frost sublimation of  $77^\circ\text{N}$ ,  $90^\circ\text{E}$  crater during early summer, whereas frost deposition was inferred from visible albedo considerations [4]. Aerosols and dust contamination of water ice play a substantial role during this period. Small variations of these parameters from one year to another can be a main contributing factor to annual variations of the visible albedo observed in [5, 6].

### References:

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