

OBSERVATION OF 3 μm HYDRATION FEATURE ON MARS FROM OMEGA-MEx DATA.

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Introduction: The OMEGA investigation, on board the ESA Mars Express mission, is to map Mars' surface at a 0.3- to 5-kilometer resolution using visible-infrared hyperspectral reflectance imagery. After numerous results on Mars surface diversity using the C channel (1.0 to 2.5 μm) [1], this paper reports a systematic reduction of the OMEGA data in the L channel (spectral range 2.5 to 5.1 μm). This global reduction gives the opportunity to study surface hydration through the 3 μm absorption band, which is indistinctly due to bending and stretching vibrations of water bound in minerals or adsorbed at their surface, and of hydroxyl groups [2]. Compared to previous studies based on ISM (Phobos spacecraft) [3] and IRS (Mariner 6 and 7 spacecrafts) [4], OMEGA dataset provides a larger coverage investigation, with a better signal to noise ratio, and a better spatial resolution. This type of hydration is very important to know how alteration currently plays, and should provide clues for the geologic and climatic history of Mars.

Thermal removal: A typical OMEGA spectrum can be modelled as the summation of two components: the reflexion of the solar light and the thermal emission, both being filtered by the atmosphere. In this study surface reflection is assumed to be lambertian. As Mars surface temperature may reach 300K, the L channel is in a range of wavelengths where thermal emission from the surface cannot be neglected. We need therefore to assess the temperature of each pixel and to remove the thermal emission to compare OMEGA albedo spectra to laboratory data.

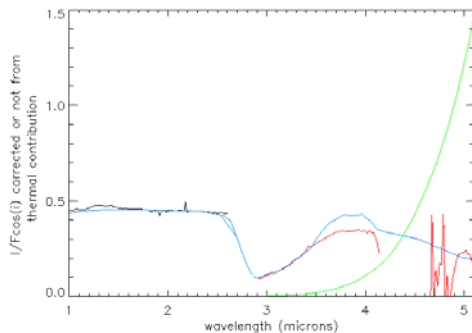


Figure 1: Illustration of the removal of thermal contribution ($T=273\text{K}$) to get albedo spectrum. Data have been removed from 2.6 to 2.9 μm because of total atmospheric absorption. Black curve: $I/F\cos(i)$, without correction from thermal contribution. Blue curve: average Martian albedo spectrum, used to assess thermal part at 5 μm . Green curve: derived estimation of thermal part divided by $F\cos(i)$. Red curve: resulting albedo spectrum corrected from thermal contribution.

The thermal part is evaluated at 5 μm , thanks to an estimate of the albedo at 5 μm by a linear combination of average albedo spectra of dark and bright soils, available at IAS. A least square fit to a theoretical black body gives the temperature of the pixel. To test the accuracy of the

method, results were checked by using the numerical simulation of the Martian Climate Database. Once the thermal part is obtained, we can get the spectrum of the surface albedo. The different steps of this method are plotted in Figure 1.

Methodology: With albedo spectra corrected from thermal emission, two methods were considered to assess hydration of the soil. First, hydration is estimated by an integration of the band depth (IBD) between a continuum and the spectrum from 3.0 to 3.7 μm :

$$IBD = \frac{1}{N} \sum_{\lambda_0=3.0\mu\text{m}}^{\lambda_w=3.7\mu\text{m}} \left(1 - \frac{\text{albedo}(\lambda)}{\text{continuum}(\lambda)} \right)$$

This method is similar to that used by [4]. Second, an estimate of the water mass proportion can be deduced from measurements done by [5], who measured albedo spectra of martian-like samples with several hydration rates (from 2% to 8%) in laboratory. The ratio between 3 and 3.7 microns of a mixture of Palagonite+Basalt is then compared to OMEGA spectra. This second method has the advantage of giving an absolute estimate, but it is likely more albedo- and compositional- dependent. These two methods are processed only for orbits ranged between 20 to 500 and 900 to 1200 for instrumental reasons, because the response of the L channel to calibration lamp is not constant for the other orbits. This problem is under investigation.

Results: Figure 2 shows the 3 μm IBD versus albedo for a data cube covering Mawrth Vallis region. The main sequence in this figure (red group) shows a general increase of hydration with albedo; such trend is observed in most of OMEGA cubes. This albedo dependence could be partly due to the method of measurement. From laboratory measurements, [6,7] indeed showed that IBD was correlated to albedo. Another method developed by [6] does not detect this albedo dependence, but it assumes different hypothesis such as Hapke modelling, same composition and same grain size that may be not valid for the Martian data. Therefore, we cannot totally exclude that the albedo-dependence is partly due to the methodology. It is well known that dark and bright units on Mars have different mineral compositions and different particle sizes. This leads us to propose that the albedo trend may result from a particle size effect: brighter albedo implies smaller particles, and smaller particles imply higher surface on volume ratio, so potentially higher capacity of water adsorption [8]. The method based on the laboratory measurements gives water massic percentages around 8% for bright soils of Mars (albedo about 0.40), and percentage around 3% for dark soils (albedo about 0.20). Again, this estimate depends on the method, and lower values for the bright units have been derived [6].

Figure 2 shows two exception groups. The yellow group corresponds to highly hydrated points. These points are in the outcrops of Mawrth Vallis, where a 1.9 μm hydration band associated to phyllosilicates is also

observed [9]. This deeper 3 μm band may be explained either by the enrichment of bound water in phyllosilicates, or by the potential hydrophilic property of phyllosilicates, able to adsorb more water.

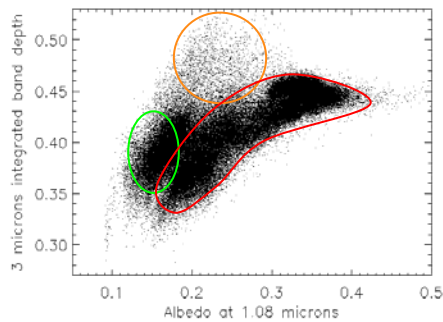


Figure 2: 3 μm integrated band depth against albedo at 1.08 μm for a given OMEGA data cube.

Secondly, the green group contains more hydrated pixels than the main sequence. This corresponds to points with lower altitudes than those in the red group. An analysis of all data from orbit 20 to 500 and 900 to 1200, between 50°N and 50°S, was conducted to study deeply this possible altitude effect. The result is shown on Figure 3, where mean hydration versus altitude is plotted for several ranges of albedo, in order to remove possible effects due to albedo. For albedos between 0.15 and 0.35 we can detect a small decrease of hydration with altitude. A possible explanation is the decrease of atmospheric pressure with altitude, including decrease of water vapor partial pressure on rocks and therefore depletion of the amount of adsorbed water [8].

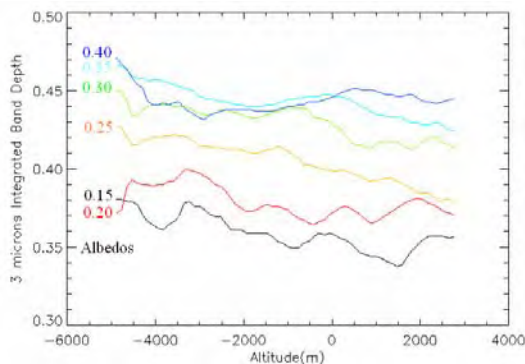


Figure 3: Average of the 3 μm integrated band depth versus elevation for albedos ranges: [0.125, 0.175], [0.175, 0.225], [0.225, 0.275], [0.275, 0.325], [0.325, 0.375] and [0.375, 0.425].

For most places of Mars, the hydration results for late orbits fit well that of former ones when they overlap. But for a few places, mainly in regions from 40°N to 60°N, some spectra do not show the same content of hydration suggesting a temporal evolution. The variations of the calibration level of the L channel require being cautious on such evolution and requires careful check of the detector temperature and lamp calibration values. Figure 4 shows one example amongst several of a geographical point where the 3 μm band depth has changed. The beginning of the spring (black curve, April 2004) is more hydrated than the beginning of the summer (red curve,

October 2004). For this point, the calibration spectra of the different cubes are the same, and the temperatures of the calibration lamp at the times of the observations are nominal. The temporal evolution of soil hydration is therefore not due to an instrumental effect. We have checked on TES results from 1999 to 2004 [10] that dust opacity and water-ice opacity are constant between the two observations. This suggests that the temporal evolution is not due to aerosols in atmosphere. We may explain it by the presence of water frost during winter, shown by OMEGA observations [1]. The winter frost has probably enriched the hydration of minerals as seen at the beginning of spring (after the end of the frost sublimation). During all spring and during the beginning of summer, the surface goes back to equilibrium with the atmosphere, decreasing its hydration as seen at the beginning of summer.

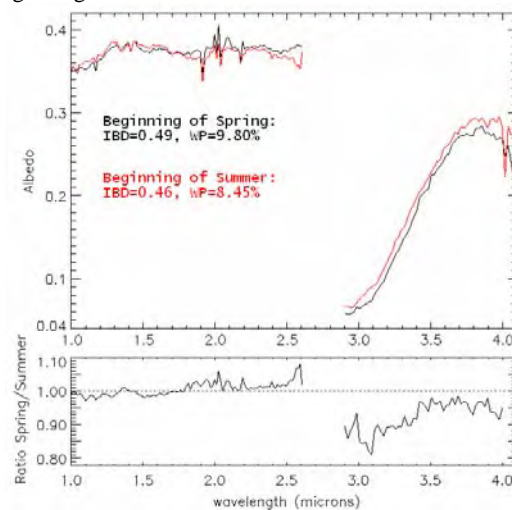


Figure 4: Top: Albedo spectra of the geographical point (212E, 47N), revealing a temporal variation of hydration from $L_s=17^\circ$ (black line, 2004/04) to $L_s=99^\circ$ (red line, 2004/10). IBD means Integrated Band Depth, WP means Water Percentage. Bottom: Ratio Spring/Summer.

Conclusion: In this study, we have shown that studying hydration through the 3 μm absorption band needs a more complicated pipeline than other studies using OMEGA data, including removal of thermal part. The developed tools have now to be adapted for all orbits. We have already inferred that hydration of the Martian surface seems to increase with albedo, to increase in places where phyllosilicates and clays are also observed, to decrease with elevation, and have a temporal evolution with Martian seasons.

References: [1] Bibring J.-P. et al (2005) *Science* 307, 1576-1581. [2] Cooper C.D. and Mustard J.F. (1999) *Icarus* 142, 557-570. [3] Bibring J.-P. et al (1990) *LPS* XX, 461-471. [4] Calvin W.M. (1997) *JGR E4*, 102, 9097-9107. [5] Yen A.S. et al (1998) *JGR E5*, 103, 11,125-11,133. [6] Milliken R.E. et al (2006), *this conference*. [7] Milliken R.E. et al (2005) *JGR E12001*, 110. [8] Zent A.P. and Quinn R.C. (1997) *JGR E4*, 102, 9085-9095. [9] Poulet F. et al (2005) *Nature* 438, 623-627. [10] Smith M.D. (2006) *private communication*.