ON THE ORIGIN OF THE INCREASE OF THE SURFACE AQUEOUS ALTERATION IN THE MARTIAN POLAR REGIONS. A. Stcherbinine[1,2], M. Vincendon[1], F. Montmessin[2]
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Introduction: The OMEGA experiment onboard the ESA Mars Express orbiter [1] had observed the Martian surface in the 0.38 - 5.1 µm spectral range from 2004 to 2010. Additional observations with a limited spectral coverage are still ongoing. The dataset contains thousands of hyperspectral cubes covering most of the Martian surface with a typical spatial sampling of 1 km. Repeated observations of the same region have been frequently obtained over the mission, in particular in the high latitudes where time sampling can be about 10° of L_s over most of the year [2]. This spectral range covers water-related spectral signatures of the surface, the most prominent being located at 3 µm [3-5]. Previous studies of the water content derived from the 3 µm band have shown an overall increase of water hydration in the polar regions, with modeled weight% increased by a factor greater than two in the northern polar latitudes, which presents the highest hydration state levels [4, 5]. The origin of this latitudinal trend is currently not fully understood, although various hypotheses have been previously suggested and discussed.

Summary of proposed explanations: Here, we present a synthesis of some effects that can be part of the explanation of this intriguing polar hydration increase, and that we plan to investigate.

Adsorbed water. The 3 µm feature has been previously linked to possible adsorbed water molecules at the surface (e.g., [4]). The increase of the intensity of hydration with latitude was then explained by an increase in the amount of adsorbed water in the colder polar latitudes covered by seasonal frost in winter [4]. While the kinetics of water adsorption/desorption on Mars is not precisely known, seasonal or diurnal variations may occur. Seasonal variations were initially reported [4], but later on not fully confirmed due to possible atmospheric contribution of the surface signal measured by OMEGA from orbit [5]. Due to the nadir observing geometry, both the surface reflection and the atmospheric transmission indeed affect the observed spectra, as both the ubiquitous dust and water ice clouds produce an absorption in the 3 µm range [e.g., 5-7]. The seasonal and diurnal variations of water ice clouds may notably impair the ability to detect surface time changes in the 3 µm hydration feature.

Surface alteration. This increase of hydration may also be related to water molecules more deeply bound to minerals or amorphous materials at the surface [5], in agreement with the potentially ubiquitous hydration of Martian soil and dust reported recently [8, 9]. The lack of observed clear seasonal or diurnal trends in the polar hydration has been thereby interpreted as suggestive of a possible increase of hydration in the surface material linked to long-term exposure to surface ice in the polar regions [5]. Such ice-related alteration processes may contain clues about ancient Mars

Exposed subsurface ice. The mid to high latitudes, where surface hydration is observed to increase, also contain near-surface perennial water ice in the permafrost [10]. Recently, it has been shown that erosion can create scarps, exposing this permafrost water ice at latitudes about 55°N [11]. Detected outcrops using CRISM and HiRISE are small-sized, thus roughly subpixel to OMEGA. Such exposed perennial ice patches may be more frequent and stable as the latitude increases, and the permafrost depth decreases. This may result in an average increase in the 3 µm feature at OMEGA resolution.

Preliminary study: In order to study the surface hydration, we compute the 3 µm Integrated Band Depth (IBD) between 2.9 and 3.7 µm, assuming a linear continuum between 2.35 and 3.7 µm [4]. As this absorption band is related to OH and H_2O molecules absorption, its depth can be related to the water content in the surface material [4, 5].

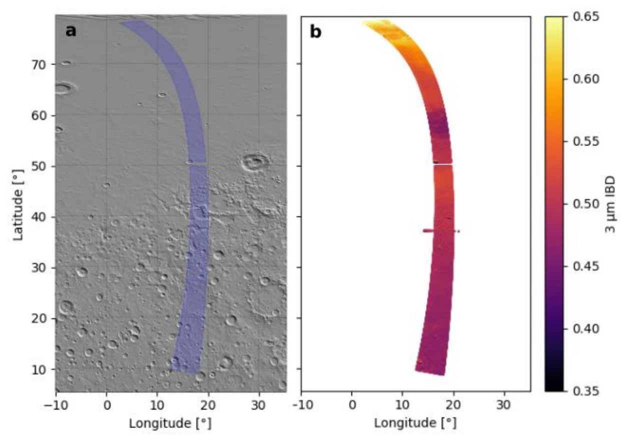

***Figure 1 – a**. Footprint of 3 OMEGA cubes (#2, 3 and 4) from Mars Express orbit 3747 (L_s = 147°), shown on a MOLA relief shaded map. **b.** 3 µm IBD variations associated with these observations.*

Figure 1 shows the 3 µm IBD variations from the equator to the north polar regions from an OMEGA observation during the northern summer (L_s = 147°). This illustrates the typical latitudinal hydration increase contained in the dataset and previously reported (e.g., [4, 5]) as we approach and finally cross the North permanent water ice polar cap.

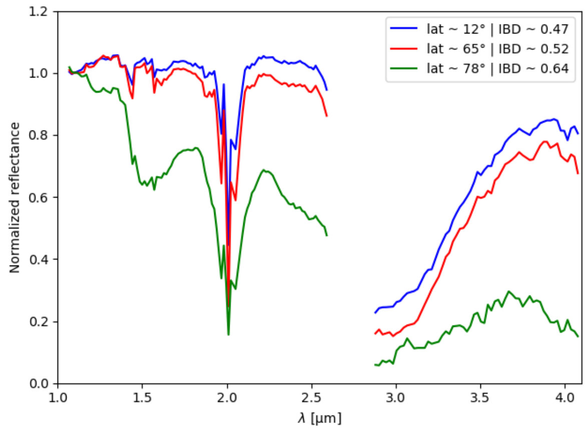

Figure 2 *– OMEGA reflectance spectra, corrected for thermal contribution, extracted from observations of Figure 1 at 3 different latitudes. Each spectrum is an average of 2000 OMEGA/MEx spectra. The spectrum at 78°N (green) contains a strong 1.5 µm feature indicative of surface water ice from the perennial cap. The two other spectra are taken outside the main polar cap. Spectra are not corrected for atmospheric (gas and aerosols) contribution.*

Figure 2 shows OMEGA spectra from the orbit 3747 taken respectively close to the equator (blue) and in the polar regions, one outside the polar cap (red), and one inside to illustrate the effect of water ice on spectra (green). In the two spectra obtained outside the cap, we observe that along to the increase of the IBD, the spectral slope between 1 and 2.5 µm increases with the latitude. Such an increase in the spectral slope may also be indicative of a particular surface composition [12]. We have thus looked for possible correlations between the 3 µm feature and this spectral slope.

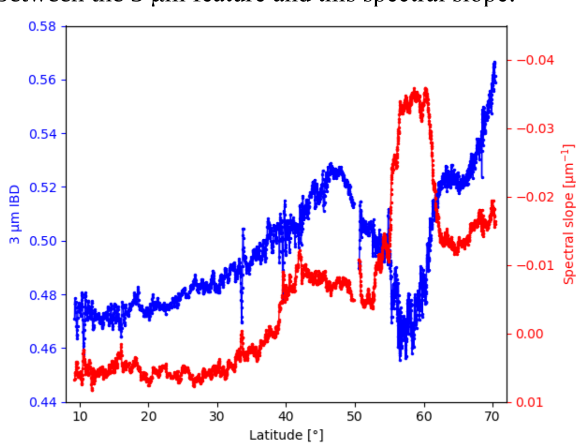

Figure 3 *– Latitudinal variations of the IBD (blue) and the 1 – 2.5 µm spectral slope (red), from the OMEGA observations of the orbit 3747.*

Figure 3 shows the latitude dependence of both the 3 µm IBD and the 1–2.5 µm spectral slope below 70°N (from OMEGA cubes #2, 3 & 4 of orbit 3747). We observe that from latitudes 10°N to 70°N (so below the North perennial cap and its main outliers), the IBD increases and goes from 0.47 to 0.56. We also note a global increase of the spectral slope with the latitude, even if it looks less regular than for the IBD. However, we also observe a local decrease of the 3 µm feature at 55°N that is linked to a reverse increase of the spectral slope. This is probably linked to the fact that the observation is crossing a low albedo terrain at this latitude [4]. Further investigations are thus required to better understand the relationship between the 3 µm feature, the spectral slope and the composition/albedo of the terrain.

Conclusion: We have initiated a study that aims at increasing the number of observational constraints related to the polar increase of surface hydration observed in the 3 µm spectral range. Our objective is to account for the various potential caveats (atmospheric hydrated dust, water ice clouds, exposed subsurface water ice) in OMEGA data analysis to bring new constraints about the plausibility of the primary two considered hypotheses: adsorbed water versus chemical alteration.

Acknowledgments: The OMEGA/MEx data are freely available on the PDS Geoscience Node https://pds-geosciences.wustl.edu/missions/mars_express/omega.htm.

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