

WATER-EQUIVALENT HYDROGEN CONTENT OF THE MARTIAN SURFACE. J. Audouard¹, F. Poulet², M. Vincendon¹, D. Jouglet², R. E. Milliken³, J-P. Bibring¹, B. Gondet¹ and Y. Langevin¹ ¹Institut d'Astrophysique Spatiale – Université Paris-Sud/CNRS Orsay France, ²CNES, Toulouse, France. ³Brown University, Providence, USA. Contact: *joachim.audouard@u-psud.fr*

Introduction: Early Earth-based telescopic [1] and orbital observations [2] of Martian surface reflectance recorded an absorption in the 3 μm spectral region. This absorption was later confirmed by ISM onboard the Phobos-2 spacecraft to be ubiquitous on Mars [3] and has been interpreted to be caused by H₂O molecules and/or hydroxyl groups as either structural, adsorbed, or water of solvation in surface components [1, 2, 3, 4, 5].

Depending on the mineral host, such “water” may be subject to temporal variations because of large variations in atmospheric relative humidity over time [6, 7]. If surface hydration is indeed exchangeable with the atmosphere, such changes could occur over seasonal and possibly on diurnal scales depending on kinetic controls [8, 9].

Recent Mars Science Laboratory *in-situ* analysis revealed an ubiquitous hydrogen signature of the surface (top μm) [10] and a bulk water-equivalent hydrogen content of a few weight percent (wt. % hereafter) for the top cm [11]. The SAM experiment measured a small release of water vapor at low temperatures (i.e. adsorbed water), with most water lost at higher temperatures in the Rocknest soil [11]. This hydration is mostly concentrated within the amorphous phase of the soils as hydrated crystalline phases were not observed to be major components in the CheMin X-ray diffraction patterns [12, 13]. It has been proposed by [10] that geographical variations of surface hydration observed from orbit could result from varying abundance of the amorphous component of the surface.

Using orbital spectroscopic data, our purpose is to build upon the work of [4,5] to provide more complete and improved estimates of the total water content of the Martian surface and to attempt to discriminate between structural and adsorbed components.

Dataset: We use OMEGA reflectance spectra, contiguous from 0.36 to 5.1 μm , which is well-suited to study the 3 μm absorption of the Martian surface [14]. The long wavelength channel is subject to variations of its On Board Calibration (OBC) level, measured at the beginning of every orbit with an internal lamp. New instrument transfer functions (ITF) derived by [15] can now be properly applied for quantitative analyses [16].

We thus reappraise the work of [4, 5] with a significantly increased dataset. Data corresponding to the 2007 global dust storm as well as data with Signal-to-

noise ratio in the 3 μm region lower than 20 is excluded from this study. A total of 6132 OMEGA data cubes were selected and processed for this study, spanning four full Martian years.

Method: OMEGA spectra are corrected from the atmospheric attenuation and the thermal contribution of the surface using the method of [16]. We select data that exhibit no water ice spectral signature at 1.5 μm using the water ice criteria of [17]. Water ice clouds significantly disturb the spectroscopic features of the surface in the 3 μm region and can be mapped with OMEGA data using a spectral slope criteria proposed by [17] and employed by [18]. We compute this ice cloud index for the selected dataset and present the results in Figure 1. Data with a cloud index lower than 0.8 are excluded from our final analysis.

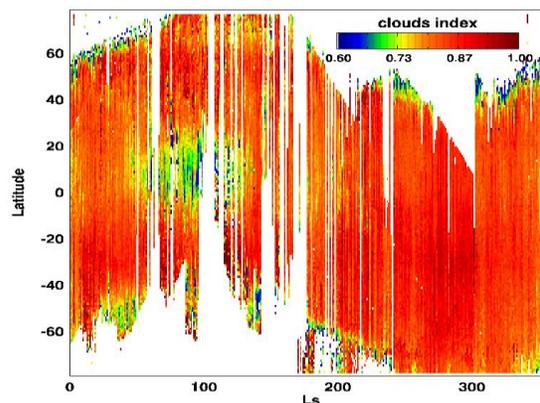


Figure 1. Average of the water ice clouds index for the selected OMEGA dataset as a function of latitude and solar longitude (L_s). [18] proposed a threshold of 0.8 as a proxy for water ice clouds. The equatorial aphelion cloud belt, as well as the high latitudes water ice clouds are clearly distinguishable in this diagram in yellow, green and blue. White means that no data is available for the corresponding L_s and latitude.

For every selected OMEGA spectrum we compute the effective single-particle absorption thickness (ESPAT) parameter at 2.9 μm following the methodology of [19]. Laboratory experiments [19] show that this ESPAT parameter is linearly correlated to wt.% H₂O for a large range of water content ($\sim <10$ -12 wt.%) and minimizes false correlations to albedo.

Finally, we use a 1-D energy balance code developed at the LMD [20] to predict the relative humidity of the near-surface atmosphere as a function of temperature, local time, latitude, pressure and season.

Results: The global map of wt. % 'water' derived from OMEGA data is presented in Figure 2. It confirms and extends previous partial mapping by [5].

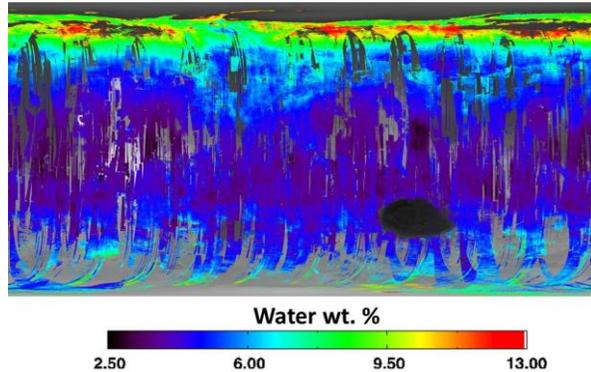


Figure 2. Global map of mean wt. % 'water' derived from OMEGA data overlaid onto MOLA topography with water wt. % = $4.17 * ESPAT_{2.9\mu m}$.

It is remarkable that:

- estimates wt. % water is strongly correlated with latitude (see Figure 3).
- northern high latitudes are more hydrated than southern high latitudes.
- wt. % water values are consistent with previous initial results [5] in this extended dataset.

This work should provide the community with robust surface hydration estimates for most of the Martian optical surface, which can be used to refine distribution of hydrogen at depth from GRS data and predict possible regolith-atmosphere exchange. Specifically, it will be shown that correlation of water content with predicted RH of the near-surface atmosphere shows a fundamentally different pattern between the two hemispheres, possibly caused by underground ice or water vapor transport in the atmosphere

The impact of volatiles (water ice clouds and airborne dust) as well as a possible bias (albedo, photometric effect) will be thoroughly discussed. Correlations with mineralogical maps of the surface will be presented in order to place these results in the context of surface composition determined in situ by the MER and MSL rovers.

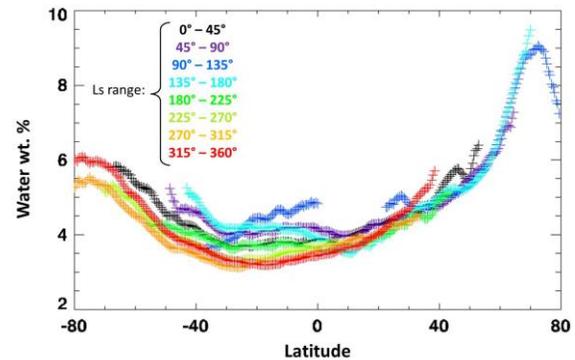


Figure 3. Latitudinal and seasonal variation of equivalent water wt. % of the Martian surface as seen by OMEGA.

This work enables us to quantify and discriminate between structural and mobile water-equivalent hydrogen constituting the total hydrogen content of the Martian surface.

References:

- [1] Sinton, W. M. (1967), *Icarus*, 6, 222–228.
- [2] Pimentel, G. C. et al. (1974), *JGR*, 79, 1623–1634.
- [3] Bibring, J.-P. et al. (1989), *Nature*, 341, 591–593.
- [4] Jouglet, D. et al. (2002), *JGR*, 112, E08S06.
- [5] Milliken, R. E. et al. (2007), *JGR*, vol. 112, E08S07.
- [6] Titov, D. V. (2002), *Adv. Space Res.*, 29, 2, 183–191.
- [7] Maltagliati, L. et al. (2011), *Icarus*, 213, 480–495.
- [8] Beck, P. et al. (2010), *JGR*, 115, E10011.
- [9] Chevrier, V. et al. (2008), *Icarus*, 196, 459–476.
- [10] Meslin, P.-Y. et al. (2013), *Science*, 341, 1238670.
- [11] Bish, D. L. et al. (2013), *Science*, 341, 1238932.
- [12] Leshin, L. A. et al. (2013), *Science*, 341, 1238937.
- [13] Blake, D. F. et al. (2013), *Science*, 341, 1239505.
- [14] Bibring, J.-P. et al. (2004), *ESA SP*, 1240, 37–49.
- [15] Jouglet, D. et al. (2009), *Planet. and Space Sci.*, 57, 1032–1042.
- [16] Audouard, J. et al. (2014), *submitted to Icarus*.
- [17] Langevin, Y. et al. (2007), *JGR*, 112, E08S12.
- [18] Madeleine, J.-B. et al. (2012), *JGR*, 117, E00J07.
- [19] Milliken, R. E. and Mustard, J. (2007), *Icarus*, 189, 574–588.
- [20] Forget, F. et al. (1999), *JGR*, 104, 24155–24175.