HYDRATION ON MARS: A NEW METHOD FOR RAPID ASSESSMENT OF EXTREMES. W. M. Calvin[1]
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Overview: A new method for determining variation in the strength of the 3-μm absorption feature is demonstrated with ISM data. The technique uses only two channels and corrects for the well-known albedo dependence seen in simple band ratios. Excess hydration is seen in locations in the Valles Marineris that correlate well with exposures of hematite and sulfates identified by TES and OMEGA. New regions are highlighted for exploration at higher resolution by CRISM.

Introduction: The appearance of a broad absorption feature on Mars at 3-μm has long been known and identified with hydration in minerals or potentially water loosely bound and in exchange with the atmosphere [1-3]. Variations in the strength of this feature have been identified in spectrometer data from Mariner 6/7 Infrared Spectrometers (IRS) [2], Phobos Imaging Spectrometer for Mars (ISM) [4], and most recently the OMEGA instrument on Mars Express [3,5]. Various methods for determining band strength have included band ratios, integrated band depth (IBD) and use of an "ESPAT" parameter derived from the single scattering albedo using Hapke theory [5]. Both ratios and IBD have a well known albedo dependence though variability is seen in hydration state among regions with similar albedo levels [2,4].

I have developed a new method for looking at relative hydration state for ISM data. Due to the lack of data longer than 3.1 μm neither the IBD or ESPAT models are possible. This method can be applied to CRISM survey mode data allowing rapid assessment of hydration extremes and prioritization of locations for targeted observations.

Method: The method relies on the reflectance level in two channels at 2.3 and 2.9 μm and that the apparent absorbance, -ln(r), is related to hydration state as shown by Yen et al. [6]. Four of the 11 available ISM cubes were used, three covering the Valles Marineris ("HEB", "VMC", "AUR") and one over Arabia ("ARA"). Data used are those calibrated and released by the ISM team and made available via electronic download.

Values are archived as radiance factor and no further geometry or atmospheric corrections are made. Because each image cube or "window" was acquired on a single orbit, the illumination and atmospheric conditions are similar for each spectrum in the cube, though these conditions vary between cubes. Therefore, each cube is fit separately. The –ln(r) at 2.9 μm is determined and plotted against the value at 2.2 μm. Figure 1 shows the channels used in the fit and Figure 2 shows an example of the $-\ln(r_{2.9})$ vs $r_{2.2}$ plot.

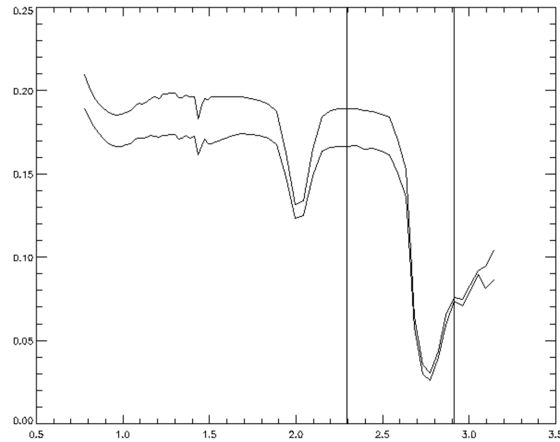

Figure 1: Channels used to map variation in surface hydration.

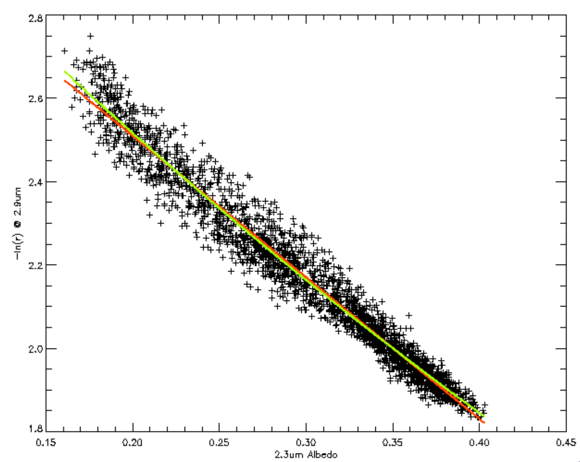

Figure 2: The strong albedo dependence of the apparent absorbance. The red line is a linear fit. The green line is a best fit second order polynomial used to correct for the albedo dependence.

Figure 2 clearly shows the strong dependence of the apparent absorbance on albedo. In order to remove this effect, the data are fit with a second order polynomial. A simple linear fit was also performed, but in all cases the second order polynomial provided a better fit, based on a lower χ-squared value.

The difference between the best fit polynomial and the data are taken and this difference is used to measure extreme values. Figure 3 shows that a histogram of the difference values is quite similar for each cube. Each appears Gaussian, clustered around zero, or no difference from the fit. This suggests that much of the surface is similar in hydration state, regardless of albedo, and some regions are either lower or higher than average. Figure 4 plots these albedo corrected hydration values in the Valles Marineris region over a Viking MDIM image. Increased apparent absorbance is seen as yellow and red points and regions much lower than average are blue and purple.

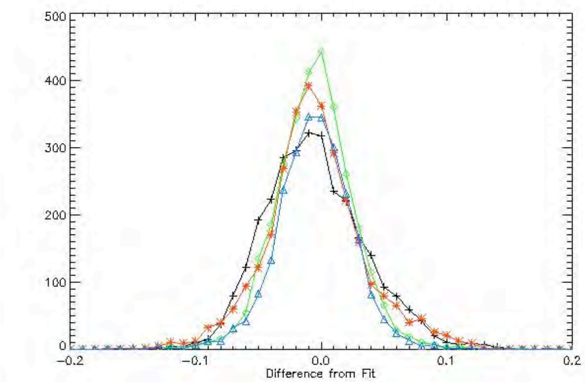

Figure 3: Histogram of the difference from fit for each of the 4 ISM cubes.

Results: This method clearly highlights regions of both East and West Candor Chasmae as having higher hydration than the average surface. Other localized regions showing increased hydration occur in the eastern end of Ius Chasma, northeastern Melas Chasma, in Noctis Labrynthus, on the plains adjacent to Echus Chasma, and in the southwestern corner of Juventae. Scattered individual high hydration pixels appear throughout Ganges and Capri Chasmae, but without much spatial coherence. In contrast, Hebes and the plains between Hebes and Candor are markedly lower in hydration than the average surface, as are locations in Echus, and most of western Ius and Tithonium Chasmae. In the Arabia cube (not pictured here) only a small region northeast of Aram Chaos, in the vicinity of Shardi crater, shows higher apparent absorbance. To the extent that the IRS and ISM data sets overlap these results are consistent with the normalized IBD results from Mariner 6 and 7 [2,10].

Discussion. Many of the regions identified as higher than average in hydration have been identified with other minerals indicative of aqueous processes. Christensen et al. [7] showed scattered patches of hematite in Ophir, Candor and Melas. Gendrin et al. [8] and Bibring et al. [9] and have identified various sulfates throughout the Valles Marineris region. These small locations identified in TES and OMEGA data correlate extremely well with those mapped in Figure 4. This suggests that other regions, such as Noctis Labrynthus and west of Echus would be good targets for high spatial resolution observations with CRISM.

This method should be easy to adapt to both OMEGA and CRISM survey mode observations on a global scale, in order to identify high priority locations for targeted observations.

References: [1] Pimentel, G.C., et al., *JGR, 79*, p. 1623, 1974. [2] Calvin, W.M. *JGR, 102 (E4)*, p. 9097, 1997, [3] Jouglet, D. submitted to JGR. [4] Murchie, S., *Icarus, 147*, p.444, 2000. [5] Milliken, R. et al. submitted to JGR. [6] Yen, A.S. et al., *JGR, 103 (E5)*, p. 11125, 1998. [7] Christensen, P.R. et al., *JGR, 106* (E10), 23873, 2001. [8]Gendrin, A. et al., *Science, 307*, p. 1587, 2005. [9]Bibring J.-P., et al., *Science, 312*, p. 400, 2006. [10] Baldridge, A. and W.M. Calvin, JGR, 109, E04S90, doi:10.1029/2003JE002066, 2004.

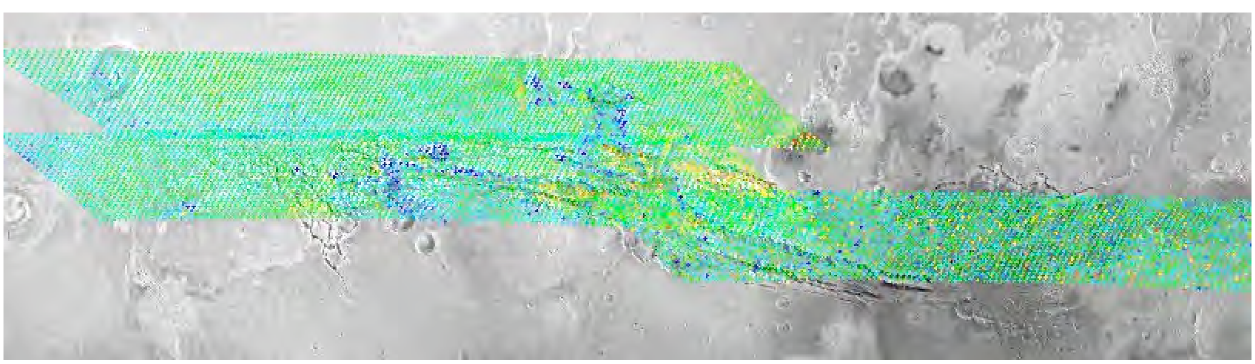

Figure 4: The apparent absorbance extremes over the Valles Marineris. The difference method highlights increased hydration(yellow and red) in East and West Candor and many other small patches. Areas with lower than average hydration (blue and purple) include western Ius and locations in Hebe and Echus.