CHARACTERIZING THE 3-D WATER DISTRIBUTION ON THE MARS SURFACE

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Introduction: The Mars Odyssey Mission carries a collection of three instruments whose main aim is to determine the elemental composition of the top layers of martian surface materials. Among them, the Mars Odyssey Neutron Spectrometer (MONS) has produced a wealth of data that has allowed a comprehensive study of the overall distribution of hydrogen on the surface of Mars [1]. In brief, deposits ranging between 20% and 100% Water-Equivalent Hydrogen (WEH) by mass are found pole-ward of 55 deg. latitude, and less rich, but still significant, deposits are found at near-equatorial latitudes. These results assume that the hydrogen distribution is uniform throughout the top meter of the martian soil. The Mars Reconnaissance Orbiter-Compact Reconnaissance Imaging Spectrometer for Mars (MRO-CRISM) has identified numerous locations on Mars where hydrous minerals occur (e.g.[2]). The information collected by MRO-CRISM samples the top few mm's to cm's of the martian soil. This independent information can, perhaps, help to impose additional constraints on the 3-D hydrogen distribution inferred from the MONS data. For instance, the absence of a correlation between the WEH wt% drawn from the MONS epithermal neutrons and the CRISM products at a location where the neutron data indicate high WEH implies the presence of a 3-D structure that is characterized by a top layer in which there is an absence of water, either in ice or hydrated mineral, and some buried layers where the concentration of hydrogen is higher than that expected from the MONS data alone.

However, MONS has a spatial resolution with FWHM of ∼550 km whereas MRO-CRISM has a spatial resolution of $\sim 20 - 200$m. Hence, associating WEH with geologic features and mineralogy observed independently, must assure the MONS instrumental smearing is properly understood and removed. Usually, in the presence of noise, this is an ill posed problem that requires the use of a statistical approach [3, 4]. Teodoro et al [5] have carried out a preliminary study of the martian polar regions applying such a methodology to Martian epithermal neutrons.

Here we present the most recent results of applying a Pixon image reconstruction approach to the Mars Odyssey epithermal neutron data coupled with information regarding the distribution of water and hydroxyls, including hydrous mineralogy. An exciting prospect is that this approach can provide more robust estimates of the real extent or the original volume of surface water needed to create evaporite deposits or other sedimentary units.

Pixon image reconstruction methods: In the presence of both some experimental noise, N, and instrumental blurring, B, the measured data, D, can be related to the input image, I, via

$$D = B * I + N, \tag{1}$$

where $*$ denotes the convolution operator. The main goal of an image reconstruction algorithm is to choose a reconstruction, I', that both avoids spurious complexity and produces a residual field,

$$R = D - B * I' \tag{2}$$

that is statistically equivalent to the anticipated experimental noise. The pixon reconstruction [3, 4] can be perceived as an "adaptive smoothing" technique with the scale of this smoothing set by the local information content in the data. Thus, each pixon, which can be thought of as a set of spatially correlated pixels, contains the same information content. The reconstruction therefore looks smooth in this pixon basis and the image entropy is maximised.

Example of a CRISM prior on a MONS reconstruction: In figure 1 we illustrate how one can use CRISM information to constrain the MONS count rates at a given locale of the Martian surface. In the top right panel, the pixon reconstruction without any prior constraints clearly shows the CO2 cap in the immediate vicinity of the south pole: red region centered a few degrees from the center. In the bottom panel we present a figure extracted from [6] delineating the same CO2 cap as derived from CRISM. Although the

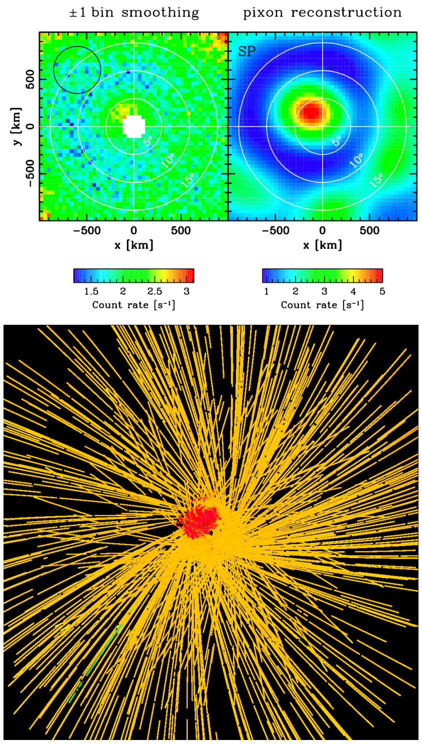

Figure 1: **Top left panel** MONS epithermal count rates data in 40×40 km bins. The dark circle in the top left corner represents the MONS point spread function. **Top right panel** Pixon reconstruction of the MONS data without a priori constraints. The red area is the CO2 polar cap. The three white circles in the two top panels represent −85°, −80° and −75° latitudes. **Bottom panel** South polar mosaic of CRISM MSP images from L$_s$ = 295-003 (see [6] for more details). The red region delineates the CO2 cap.

CRISM data also depicts the CO2 cap this has a slightly different shape. We are using this latter geometric information to improve upon the estimates of MONS count rates. The power of the technique detailed in the last two sections is that it can also quantify whether the proposed priors are demanded by the data (e.g. [7]) and which one is the best.

Very Preliminary Results and Conclusion: In figure 2 we present the cross-correlation between polydrated minerals by the CRISM Sindex [Sindex $= 1 - (R_{2100nm} + R_{2400nm})/R_{2290nm}$, where R_λ denotes the surface reflectance at wavelength λ, see [8] and references therein for further details] and the MONS WEH (as measured from the raw data, not pixon reconstructed). The scatter diagram between those two measurements in a latitude strip ($-90° <$ lat. $< -60°$) at the positions of 0.5° × 0.5° observed CRISM pixels. There appears to be a general correlation between these two parameters, indicating that besides the well-known deposits of water ice present at such high latitudes, part of the hydrogen seen by the epithermal neutrons is also locked in hydrated/hydroxylated minerals. However, the correlation is likely non-linear and the exact nature of the correlation is under investigation. Correlations with other CRISM and spectral parameters will allow us to draw conclusions about other hydrated/hydroxylated minerals as well as water ice. Thus the combination of the MONS and CRISM data-sets can constrain the 3-D distribution of water in the top meter of martian soils. This can be further refined using more detailed MONS maps as the ones resulting from a pixon reconstructions (with plausible priors demanded by the neutron data and suggested by CRISM), in which the instrumental blur has been removed without the introduction of spurious features.

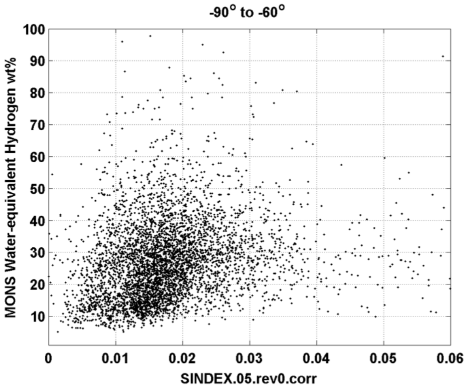

Figure 2: Cross-correlation between the MONS' WEH and Sindex in a in a latitude bin ($-90° <$ lat. $< -60°$). For more details see text and reference [8].

References: [1] W. C. Feldman, et al. (2004) *Journal of Geophysical Research (Planets)* 109(E18):9006 `doi:10.1029/2003JE002160`. [2] A. J. Brown, et al. (2010) in *Lunar and Planetary Institute Science Conference Abstracts* vol. 41 of *Lunar and Planetary Institute Science Conference Abstracts* 1278–+. [3] R. K. Piña, et al. (1992) *PASP* 104:1096 `doi:10.1086/133095`. [4] V. Eke (2001) *Mon. Not. R. Astron. Soc.* 324:108 `doi:10.1046/j.1365-8711.2001.04253.x`. [5] L. F. A. Teodoro, et al. (2010) in *Lunar and Planetary Institute Science Conference Abstracts* vol. 41 of *Lunar and Planetary Institute Science Conference Abstracts* 2742–+. [6] A. J. Brown, et al. (2010) *Journal of Geophysical Research (Planets)* 115(E14):0 `doi:10.1029/2009JE003333`. [7] L. F. A. Teodoro, et al. (2010) *Geophys. Res. Lett.* 37:12201 `doi:10.1029/2010GL042889`. [8] L. H. Roach, et al. (2009) *Journal of Geophysical Research (Planets)* 114(E13):0 `doi:10.1029/2008JE003245`.