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Characterizing the 3-D Water Distribution on the Mars Surface

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1 Abstract

The Mars Odyssey Neutron Spectrometer (MONS) and the Mars Reconnaissance Orbiter-Compact Reconnaissance Imaging Spectrometer (MRO-CRISM) have produced two data-sets that sample the top layers of the Martian soil in a complementary way: while MONS samples the top metre of the martian soil MRO-CRISM sample the top few mm's. We have devised a statistical approach that makes use these two complementary pieces of information to characterize the 3-D distribution of water on the Mars surface.

2. Introduction

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 metre 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 [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. In the presence of noise, this is an ill posed problem that requires the use of a statistical approach [3, 4]. The pixon reconstruction 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. [7] have carried out a preliminary study of the martian polar regions applying this methodology to epithermal neutrons without any prior constraints.

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 as identified by MRO-CRISM. A first application of such ideas is the use of the the geometrical shape of CO_2 cap in the immediate vicinity of the south pole [5] where water ice is absent in the top ten metres of crust. We are using this constraint to improve upon the estimates of MONS count rates.

As part of the exploratory work for this project we computed the cross-correlation between polydrated minerals by the CRISM $S_{\rm index}$ [$S_{\rm index} = 1 - (R_{2100nm} + R_{2400nm})/R_{2290nm}$, where R_λ denotes the surface reflectance at wavelength λ (see[6]) and references therein for further details] and the MONS

WEH (as measured from the raw data, not pixon reconstructed). 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 metre 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.

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