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Improved Spatial Resolution of Mars Odyssey Epithermal Neutron Data

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1 Introduction

When cosmic rays strike the surface of Mars, they generate neutrons from nuclei present in the top several metres of the surface materials by various nuclear reactions. The neutrons lose energy by interacting with the surrounding nuclei and their flux leaking from the planetary subsurface is thus an indication of the elemental composition of the top layer of the surface materials: macroscopic scattering and capture cross sections depend on the detailed composition of the soils and rocks.

For instance, hydrogen is especially effective at moderating neutrons because its mass is nearly the same as the mass of the neutron. Thus, hydrogen rich surface materials create a deficit of epithermal neutrons, and consequently the leakage flux of epithermal neutrons out of the subsurface is reduced in places where the hydrogen concentration is significant.

The Mars Odyssey mission carries a collection of three instruments whose main aim is to determine the elemental composition of the top layers of the martian surface materials. Among them, the Neutron Spectrometer has produced a wealth of data that has allowed a comprehensive study of the overall distribution of hydrogen on the surface of Mars (Feldman et al., 2004). In brief, deposits ranging between 20% and 100% Water-Equivalent Hydrogen (WEH) by mass are found poleward of ± 55 latitude, and less rich, but still significant, deposits are found at near-equatorial latitudes.

However, the Mars Odyssey Neutron Spectrometer (MONS) has a FWHM of $\sim$ 550 km. Hence, if one wants to associate WEH with geologic features and with mineralogy observed independently, then this instrumental smearing needs to be properly understood and removed. Usually, in the presence of noise, this is an ill posed problem that requires the use of a statistical approach (Piña et al., 1992).

An exciting prospect is to obtain more accurate WEH for certain locales where hydrous minerals have been found. This can, perhaps, help to constrain the real extent or the original volume of surface water needed to create evaporated deposits or other sedimentary units. Another rather interesting potential development is to study the distribution of subsurface water ice at lower latitudes. Although water ice is not stable at such latitudes recent impact craters have exposed buried deposits of nearly pure water ice at around 45° latitude (Byrne et al., 2009).

The talk presents the results of applying a pixon image reconstruction approach to the Mars Odyssey Epithermal Neutron Data.

2 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.e. a pixellised version of the real count rate field, 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 (Piña et al., 1992; Eke, 2001) combines simplicity with a residual field that is indistinguishable from that of the anticipated noise. Briefly, the data is smoothed using an “adaptive approach", 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. A variant of this algorithm has been successfully applied in planetary sciences to reconstruct maps of the hydrogen distribution in the vicinity of the lunar poles (Elphic et al., 2007; Eke et al., 2009; Teodoro et al., 2009).

3 Epithermal Neutron Data

In the present work we have made use of the newest epithermal neutron MONS dataset. This was collected between February 2002 and September 2009. The time series excludes times and places that are covered by CO_2 frost during the late autumn, winter, and early spring seasons (Maurice et al., 2007). Corrections were made based on models of atmospheric column density that vary with season and topography. Cosmic ray flux corrections were also applied.

4 Preliminary Results and Conclusions

By applying a specially developed pixon image reconstruction algorithm to the MONS epithermal dataset we clearly improve the sharpness of the features present in the noisy maps within 20° from the poles: some of the features that are barely apparent in the binned data are well delineated in the pixon reconstructions on length scales that are smaller than the MONS response function. The identification of large quantities of hydrogen in the top metre of the surface materials, indicated by very low epithermal neutron fluxes (Feldman et al., 2002), is very apparent in both polar neighbourhoods. Two other features, represented by an increase of the count rates, are also apparent in the north pole region: the mouth of the Chasma Boreale (a high counting rate region around longitude $\sim 310°$ E), and the northern dunes with latitudes ranging between $\sim 82.5°$ and $\sim 70°$ encompassing the arch spanning throughout the remaining quadrants of the map. As for the south pole, the southern CO_2 cap is depicted by the higher count rate in the reconstructed map.

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