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Tests of GCM pressure predictions for water ice stability using Mars Odyssey Neutron Spectrometer data

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Abstract

We have used the pixon image reconstruction technique on the Mars Odyssey Neutron Spectrometer epithermal neutron data to produce an improved global map of the hydrogen abundance on Mars. We will compare this to the predictions for surface hydration from the martian general circulation models, in order to provide both new constraints on, and tests of, the models.

1. Introduction

Much of our knowledge of the martian atmosphere is encapsulated in the General Circulation Models (GCMs): numerical simulations based on those developed for weather and climate forecasting on Earth. These models are constrained using the in-situ measurements of the martian atmosphere made by the various landers and rovers from the Viking missions to the present MSL Curiosity rover. However these measurements lack the spatial and temporal resolution to fully characterize the martian atmosphere.

The predictions of the GCMs have been compared with remotely sensed global data including that from the Thermal Emission Spectrometer (TES) [4] and the Mars Climate Sounder. The GCMs are found to be in agreement with most available observations and have been used to predict previously unobserved phenomena.

We propose another test of and constraint on the GCMs using the water equivalent hydrogen (WEH) distribution derived from the observations made by the Mars Odyssey Neutron Spectrometer (MONS). The stability of water ice on the surface of Mars is strongly dependent on atmospheric pressure and temperature. We will examine how the pressure variations predicted by the GCMs correlate with changing hydration as revealed in the MONS neutron data, noting that the form of the hydration (i.e. water ice or hydrated minerals) will affect the stability of the deposits and that this varies across the surface.

Previously, the utility of the MONS data in constraining the distribution of water, on scales similar to the GCM resolution (typically ~300 km), has been limited by its poor spatial resolution due to the large footprint of the MONS (its point spread function (PSF) has a full width at half maximum of

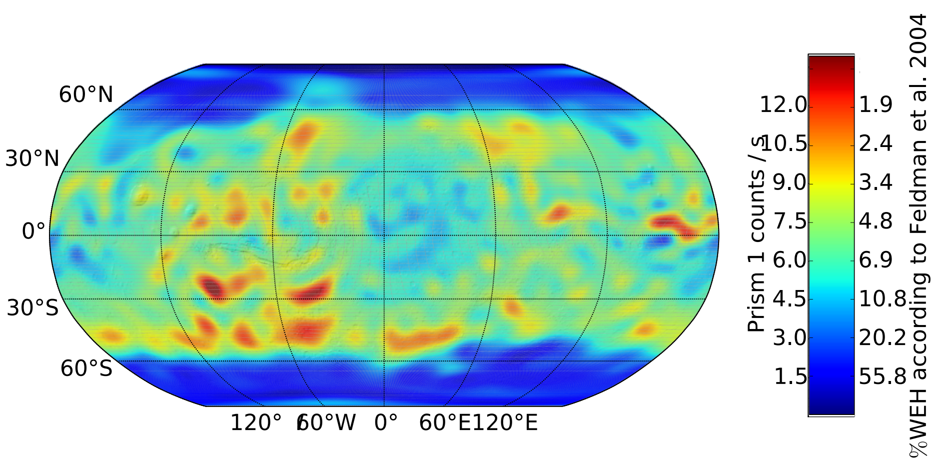

Figure 1: Robinson projection showing a pixon reconstruction of the MONS prism-1 data. Underlayed is a MOLA shaded relief map. The colour bar also shows the conversion to wt. % water equivalent hydrogen from Feldman et al. (2004) [2].

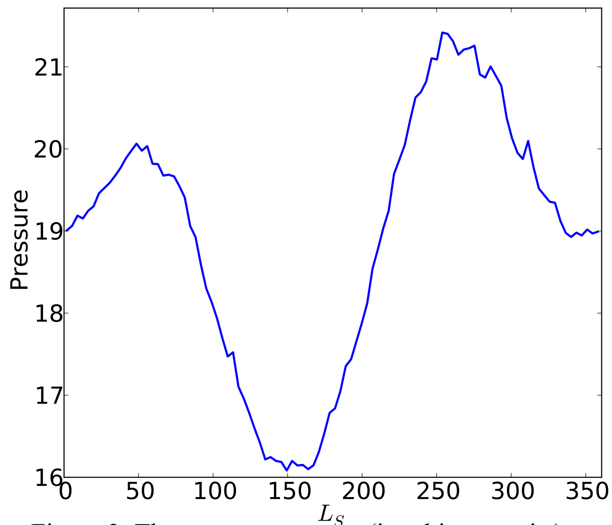

Figure 2: The average pressure (in arbitrary units) at 50°N in the LMD GCM against solar longitude, L_S.

~550km). Here we have used the pixon image reconstruction technique to improve the spatial resolution of this data set by suppressing noise and removing the effect of blurring with the PSF. At the poles this technique has been shown to give a spatial resolution of between 45-100 km [5]. Our reconstructed data set is available for the entire surface of Mars and will be compared to the predictions of the GCMs globally.

1.1 Image Reconstruction

The pixon method is a spatially-adaptive image reconstruction process that aims to deconvolve observed data from the PSF, to infer the simplest image consistent with the data [1]. Using this technique we have carried out the first global Bayesian reconstruction of a remotely sensed planetary data set, the result of which is shown in Figure 1.

The pixon method's adaptive smoothing algorithm works such that regions of the image with a higher signal to noise ratio are given the freedom to vary on small scales and those with low signal to noise ratio vary only on larger scales. This is done to create an image that has a spatially constant information content, which has the effect of precisely maximizing the entropy of the reconstructed image.

We use the frost-free prism-1 data (a measure of epithermal neutrons) from the MONS instrument of the three martian years from 2001, which has been corrected for altitude and look direction of the spacecraft and variation in environmental conditions [3]. We take only the data from where CO_2 frost is not present as it inhibits atmospheric exchange with the soil.

The conversion from epithermal neutron count rate to WEH is done using the relation in Feldman et al. (2004) [2].

2. Constraining the GCMs

GCMs depend on several important parameters associated with atmospheric and surface properties. One key property is the thermal inertia, which depends on the presence of water ice near the pole. Replicating the Viking and later missions atmospheric pressure histories requires taking into account near-surface water ice content and spatial distribution at high latitudes. In particular ice content is directly related to thermal conductivity and thermal inertia, and spatial variations of these govern the input and release of energy (and water vapour) seasonally. Therefore, the pixon reconstruction in the polar regions can be used to outline deviations from a uniform ice distribution poleward of 80°N which will influence local circulation and precipitation.

At all latitudes the pressures and temperatures predicted by the GCMs can be used to infer water concentrations in near-surface soil, which are measured globally in the MONS data. We will compare both the NASA Ames and Laboratoire de Météorologie Dynamique (LMD) models to our reconstructed data set. The variation in pressure with time in the LMD model is shown in Figure 2, this information can be used to predict surface water abundances globally, which we will then compared to the measured water abundances derived using the pixon reconstruction technique on the MONS data.

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