SEASONAL VARIATION OF THE MARTIAN POLAR CO_2 CAPS IN GCM PREDICTIONS AND MARS ODYSSEY NEUTRON SPECTROMETER DATA

J. T. Wilson[1], V. R. Eke[1], R. J. Massey[1], R. C. Elphic[2], W. C. Feldman[3], S. Maurice[4] and L. F. A. Teodoro[5], [1]Institute for Computational Cosmology, Durham University, South Road, Durham. DH1 3LE, UK (j.t.wilson@durham.ac.uk), [2]Planetary Systems Branch, NASA Ames Research Center, MS 245-3, Moffett Field, CA,94035-1000, USA, [3]Planetary Science Institute, Tucson, AZ 85719, USA,[4]IRAP-OMP, Toulouse, France, [5]BAER, NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035, USA.

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 either the spatial and temporal resolution or spatial coverage 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 and CO_2 ice on the surface of Mars is strongly dependent on atmospheric pressure, temperature and relative humidity. 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. We have also calculated the CO_2 ice abundance implied by the MONS data, assuming that there is no CO_2 frost present in summer.

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 ~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. This is the first application of the technique, on a global scale, to data split seasonally to show time variation. Our reconstructed data set is available for the entire surface of Mars and has a global resolution of ~290 km.

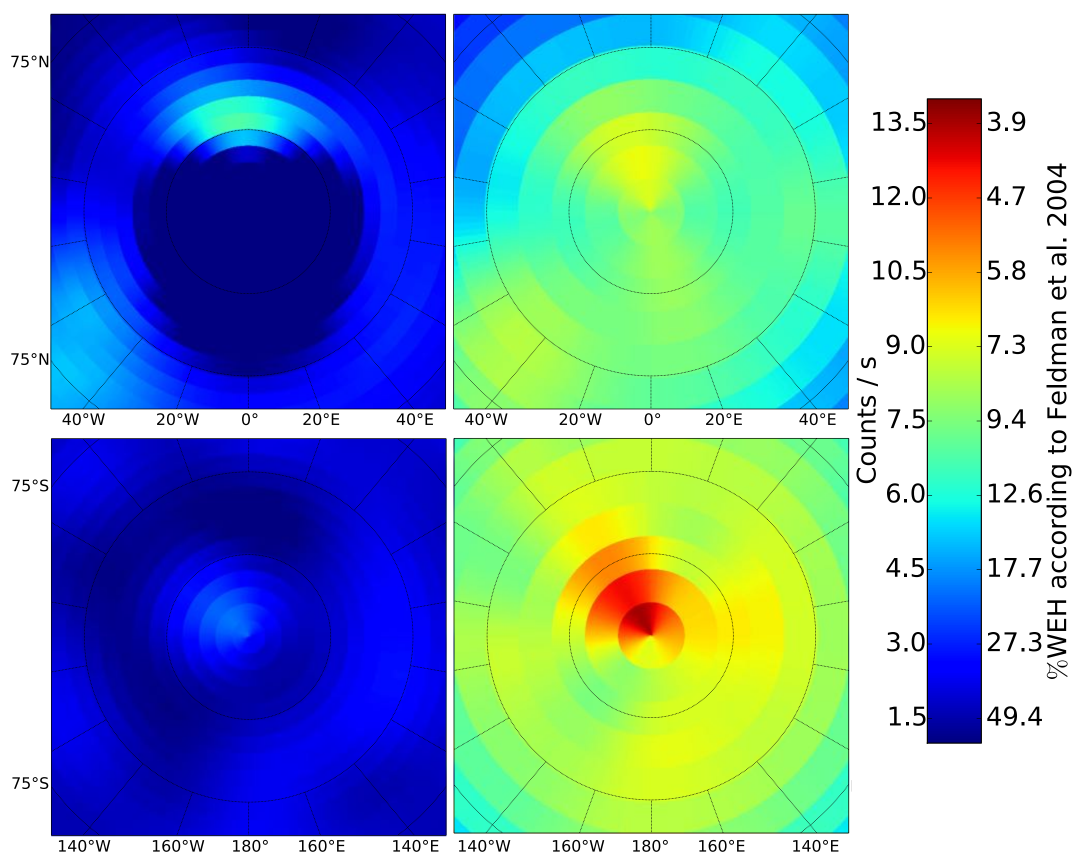

Fig. 1: Pixon reconstruction of the MONS epithermal data at the north (top) and south (bottom) during summer (left) and winter (right). The conversion from epithermal neutron count rate to WEH is done using the relation in Feldman et al. (2004) [2] and may not be appropriate in the winter when CO_2 is present and during summer in the south near the residual CO_2 ice cap centred on about 45° W. The dark blue at the north pole in summer represents 100 wt % WEH.

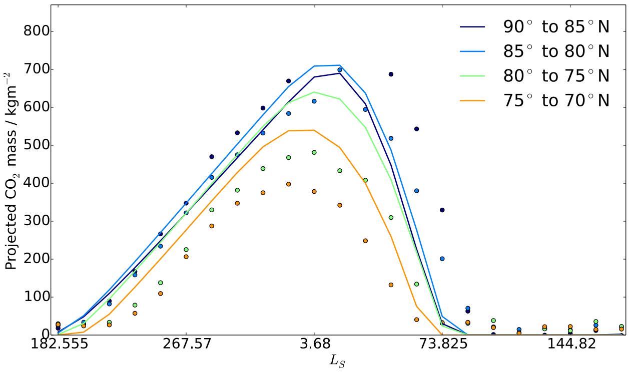

Fig. 2: A plot showing how the abundance of CO_2 varies with time, i.e. Martian solar longitude (L_S), at the north pole. The points are values derived from pixon reconstruction of MONS data using the method of [5] for conversion. The lines are the results of a GCM and the different colours correspond to different latitude bins.

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

The pixon method's adaptive smoothing algorithm works such that regions of the image containing more detail are given the freedom to vary on small scales and those without vary only on larger scales. This is done to create the simplest possible reconstruction that is still consistent with the data. This reconstruction is the one most likely to describe the true, underlying image.

We use the 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].

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.

Comparison of CO_2 Polar Cap advance and retreat: The abundance of CO_2 can be inferred from MONS data using the procedure described in Prettyman et al. 2009 [5]. Applying this technique to our improved resolution reconstructions allows for a more effective comparison of the GCMs to the data than using the raw MONS data. Fig. 2 shows a comparison of the GCM and reconstructed MONS polar CO_2 abundance, with broad agreement seen between the two data sets. However the GCM everywhere (greater than 5° from the pole) overpredicts the amount of CO_2. Additionally, there may also be slight differences in the timing of the onset and retreat of the cap.

The origin of these disagreements between GCM and MONS data may be the total CO_2 abundance, which is a parameter of the GCMs. Thus these results could provide an extra constraint on Martian climate models.

References: [1] Eke, V. (2001), A speedy pixon image reconstruction algorithm, *Mon. Not. R. Astron. Soc.*, 324, 108–118. [2] Feldman, W. C., et al. (2004), Global distribution of near-surface hydrogen on Mars, *J. Geophys. Res.*, 109, E09006. [3] Maurice, S., et al. (2011), Mars Odyssey neutron data: 1. Data processing and models of water-equivalent-hydrogen distribution, *J. Geophys. Res.*, 116, E11008. [4] Navarro, T., et al. (2014), Global climate modeling of the Martian water cycle with improved microphysics and radiatively active water ice clouds, *J. Geophys. Res. Planets*, 119, 1479–1495. [5] Prettyman, T et al. (2009) Characterization of Mars' seasonal caps using neutron spectroscopy, *J. Geophys. Res.*, 114, E08005.