

**Constraining the Mars General Circulation Model with realistic distributions of polar ice** Luís F.A. Teodoro<sup>1</sup>, Richard C. Elphic<sup>2</sup>, Jeffery L. Hollingsworth<sup>2</sup>, Robert M. Haberle<sup>2</sup>, Melinda A. Kahre<sup>2</sup>, Vincent R. Eke<sup>3</sup>, Ted L. Roush<sup>2</sup>, Giuseppe A. Marzo<sup>4</sup>, Adrian J. Brown<sup>5</sup>, William C. Feldman<sup>6</sup>, Sylvestre Maurice<sup>7</sup>; <sup>1</sup> BAER, NASA Ames Research Center, Moffett Field, CA 94035-1000 (luis.f.teodoro@nasa.gov); <sup>2</sup> Planetary Systems Branch, Space Sciences and Astrobiology Division, MS 245-3, NASA Ames Research Center, Moffett Field, CA 94035-1000, USA; <sup>3</sup> Institute for Computational Cosmology, Department of Physics, Durham University, Science Laboratories, South Road, Durham DH1 3LE, UK; <sup>4</sup> ENEA, Rome, Italy; <sup>5</sup> SETI Institute, Mountain View, CA 94043, USA; <sup>6</sup> Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ, 85719, USA; <sup>7</sup> Université Paul Sabatier, Centre d'Etude Spatiale des Rayonnements, 9 avenue Colonel Roche, B.P. 44346Toulouse, France

Much of our current knowledge about the climate and the global circulation of the atmosphere of Mars stems from measurements taken by landed missions from Viking through Phoenix. Their observations, however, lacked the temporal and spatial coverage required to fully understand the general circulation of the martian atmosphere. Thus for many years the details of the atmospheric circulation were studied using numerical general circulation models (GCMs). These have been successful in reproducing most of the available observations [1].

Recent spacecraft exploration of Mars has produced a wealth of data. More than ever, general circulation models are going to play a central role not only in analyzing the existing datasets but also in planning and execution of upcoming missions.

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 in the surface of Mars [2]. 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. [3]). 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

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 a low abundance of water, either in ice or hydrate 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 ~20 – 200m. Hence, associating WEH with geologic features and mineralogy observed independently, one must assure the MONS instrumental smearing is properly understood and removed. Usually, in presence of noise, this is an ill posed problem that requires the use of a statistical approach [4, 5]. Teodoro et al [6] 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 Pixion Odyssey epithermal neutron data coupled with independent information regarding the distribution of water and hydroxyls, including hydrous mineralogy. An exciting prospect is that this approach can provide estimates of the real extent or the original volume of surface water ice. Such estimates can then be used to constrain the Mars General Circulation Model.

**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

$$D = B * I + N, \quad (1)$$

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,

$$R = D - B * I' \quad (2)$$

that is statistically equivalent to the anticipated experimental noise. The pixion reconstruction [4, 5] 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 pixion, which can be thought of a set of spatially correlated pixels, contains the same information content. The reconstruction therefore looks smooth in this pixion basis and the image entropy is maximized.

**Example of a CRISM prior to 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 pixion reconstruction without any prior constraints clearly shows the CO<sub>2</sub> 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 delineating the same CO<sub>2</sub> cap as derived from CRISM. Although the CRISM data also depicts the CO<sub>2</sub> cap this has a slightly different shape. We are using the latter geometric information to improve upon the estimates of the MONS count rates.

**Constraining the Ames Mars GCM:** The Ames Mars GCM depends on several important parameters associated with the atmosphere and surface properties. One key property is the thermal inertia, which depends importantly 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. To the extent that these can be constrained by Mars Odyssey neutron measurements, the results of the GCM can be tied to physical parameters that characterize the near-surface materials 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 vapor) seasonally. Deviations from a uniform ice distribution poleward of 80°N may (see Figure 2) thus influence local circulation and precipitation. Perhaps more important is what the derived distribution of polar ground ice tells us about recent climatic trends.

**References:** [1] F. Forget, et al. (1999) *J. Geophys. Res.* 104:24155 doi:10.1029/1999JE001025. [2] W. C. Feldman, et al. (2004) *Journal of Geophysical Research (Planets)* 109(E18):9006 doi:10.1029/2003JE002160. [3] A. J. Brown, et al. (2010) in *Lunar and Planetary Institute Science Conference*

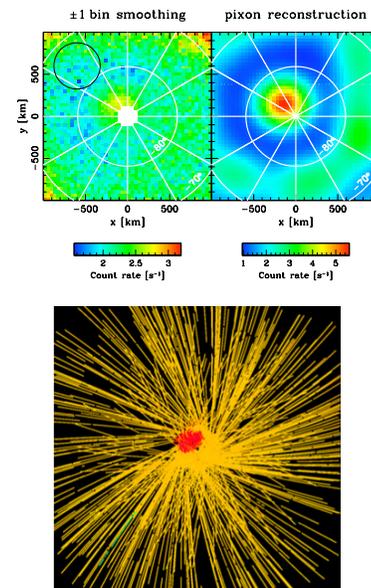


Figure 1: **Top left panel** Mons epithermal count rates data in 40×40 km bins. The dark circle in the top left corner represents the MONS point spread function. **Top right panel** Pixion reconstruction of the MONS data without prior constraints. The red area is the CO<sub>2</sub> polar cap. Whilst the dark blue regions indicate the presence of water ice. The two white circles in the two top panels represent -80° and -70° latitudes. **Bottom panel** South pole mosaic of CRISM-MSP images from L<sub>s</sub>=295-003 (see [7] for more details). The red region delineates the CO<sub>2</sub> cap.

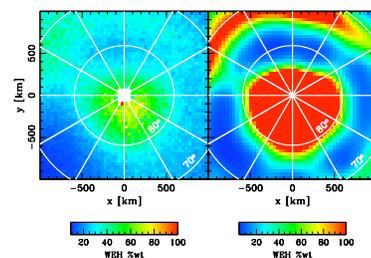


Figure 2: **Left panel** MONS WEH %wt data in 40×40 km bins. **Right panel** North Pole Pixion WEH reconstruction. The two white circles represent 70° and 80° latitudes.

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