GCM SIMULATIONS OF THE TROPICAL HYDROGEN DISTRIBUTION OBSERVED BY MARS ODYSSEY.

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Introduction: The age and nature of the tropical hydrogen deposits on Mars remain uncertain. Competing theories suggest that the deposits are composed of either ancient, hydrated minerals or recently emplaced water ice. We use the GFDL Mars GCM with a fully coupled atmosphere-regolith water cycle to explore which of these hypotheses is best supported by model results. Such a conclusion can be drawn from the resultant trends in subsurface ice evolution during various obliquity and polar cap conditions. Our results suggest that the tropical hydrogen distribution is best explained by recent emplacement of ice through either exposure of the south polar ice cap or by burial of tropical surface ice from the most recent high obliquity excursions.

Low vs. High Obliquity: The behavior of water in the martian regolith during contemporary (and lower) obliquities has been demonstrated before [1-4], and these previous results show that water ice is absent from the upper meter of the subsurface equatorward of ~50° latitude. This is the result of a greater annual average saturation vapor pressure in the tropics versus the poles under current conditions (Fig. 1).

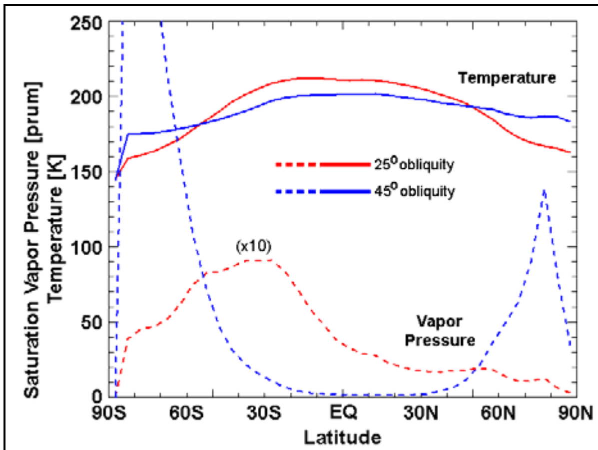

Figure 1: Zonally- and annually-averaged regolith temperature (solid lines) for 25° and 45° obliquity. Zonally- and annually-averaged saturation vapor pressure (dashed lines) for the same conditions. For both states, tropics are warmer than poles, however at high obliquity, average saturation vapor pressure is *lower* in the tropics, promoting ice formation in the tropics at the expense of the poles.

The solid lines in Fig. 1 indicate the zonally- and annually-averaged regolith temperature at 25° and 45° obliquity. In both cases (and, indeed, until obliquity surpasses 54° [5]), average temperatures are warmer at the equator than the poles. Nevertheless, for contemporary conditions, the maximum average saturation vapor pressure occurs in the low latitudes, while in the same region at high obliquity, it is a minimum. The root cause of this behavior lies in the annual temperature range at the two locations. Maximum polar summertime temperatures are higher at high obliquity than they are in the tropics for contemporary obliquity. Because of the strong non-linearity of saturation vapor pressure with temperature, this raises the annual average polar value above that of the tropics, and forces water out of the polar regolith and into the lower latitudes.

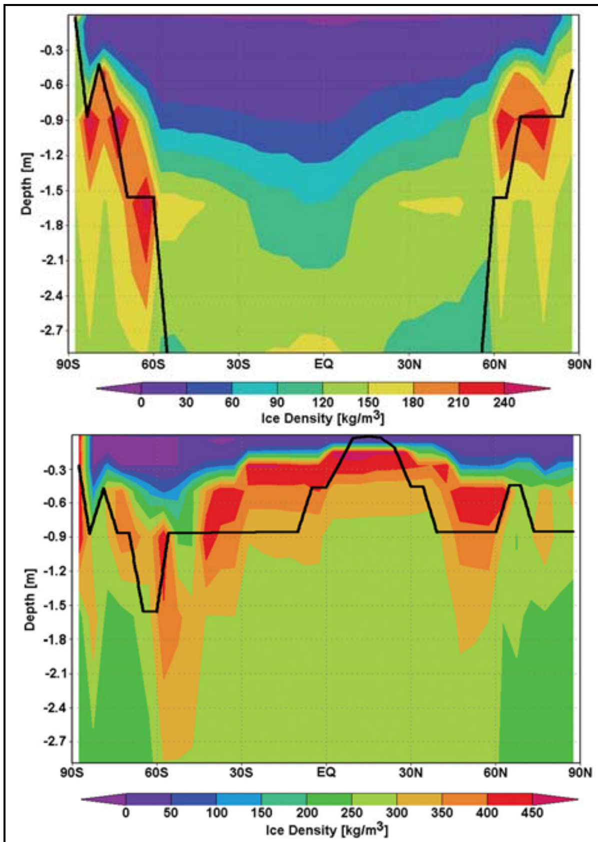

Figure 2: **(a, top)** Ice profile at 0° longitude for 25° obliquity simulation with initially ice-filled regolith. **(b, bottom)** Same as (a) but for 45° obliquity. Black lines indicate depth to local frost point in regolith. Both models after 8 model years.

We have run the full atmosphere-regolith model under both high and low obliquity conditions to observe this effect. In these simulations, ice-regolith feedbacks are neglected. For contemporary obliquity (Fig. 2a), after 8 simulation years with the regolith initially filled with ice, the resultant ice profile takes on the expected 'U' shape. The global distribution matches well with the thermal model of [5]. The black line represents the expected ice depth based on the overlying atmospheric frost point calculated by the model.

Figure 2b also has an ice-filled regolith, but is modeled at 45° obliquity. The frost point contour has an 'inverted-U' shape, approaching the surface in the tropics, and deepening with increasing latitude. In both cases, the ice that has been lost from the upper levels has either returned to the atmosphere, or migrated to deeper, more stable levels.

Subsurface Ice Distribution: The general Odyssey pattern (Fig. 3) is isolated around three major centers, with the highest retained abundances over the Tharsis bulge and Elysium plateau, and most of central and eastern Arabia Terra. We compare this distribution to results from the Mars GCM showing evolved, vertically-integrated water abundance for both high obliquity and low obliquity simulations (Figs. 4a and 4b, respectively). The high obliquity simulation is initialized with a dry regolith (under the assumption that the prior low obliquity period would have largely desiccated the low-latitude regolith). Warmer colors represent regions where water is entering the regolith at the fastest rate. Conversely, the low obliquity simulation has been initialized with an ice-filled, "wet" regolith (under the assumption that the prior high obliquity period would have at least partially filled the tropical regolith). Here, the warmer colors represent regions where extant water is being lost at the slowest rate. After eight years, the evolved water distribution in Fig. 4b seems to be the better match to the Odyssey distribution. The hydrogen-poor regions in Fig. 3 are also better matched by the contemporary model in Fig. 4b than the high obliquity model in Fig. 4a.

The results presented here strongly suggest geologically recent emplacement as the source of these tropical deposits. Even a cursory comparison between the model results in Fig. 4b and the Odyssey signature shows strong similarities in distribution. Of particular note is the enhanced signal in Arabia Terra in both figures, as well as the distribution on and around Tharsis. More broadly, if we trace along the hemispheric dichotomy boundary, we see that the model water is preferentially retained in the southern highlands, which is consistent with the GRS data. The source of this recent emplacement is uncertain, but may be due to either surface ice deposition and subsequent burial during the most recent high obliquity excursions, or very recent buildup of tropical ice when the south polar water ice cap was exposed, flooding the atmosphere with up to 100 prμm of water vapor [6].

References: [1] Mellon, M.T. and Jakosky, B.M. (1993), *JGR*, 98, 3345-3364 [2] Mellon, M.T. and Jakosky, B.M. (1995), *JGR*, 100, 11781-11799 [3] Zent *et al.* (1993) *JGR*, 98, 3319-3337 [4] Mellon *et al.* (2004) *Icarus*, 169, 324-340 [5] Ward, (1974), *JGR*, 79, 3375-3386 [6] Jakosky *et al.* (2005), *Icarus, in press.* [7] Feldman *et al.* (2004) *JGR*, 109 doi:10.1029/2003JE002160

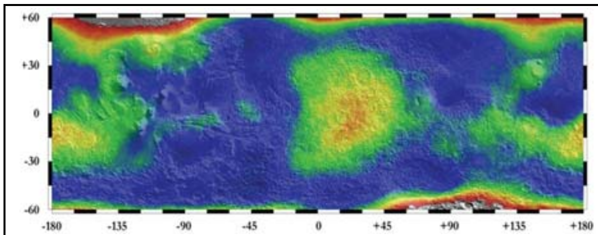

Figure 3: Odyssey tropical hydrogen distribution from Mars Odyssey GRS. Blue=2-4%, Red=10-12% by weight water equivalent hydrogen [7].

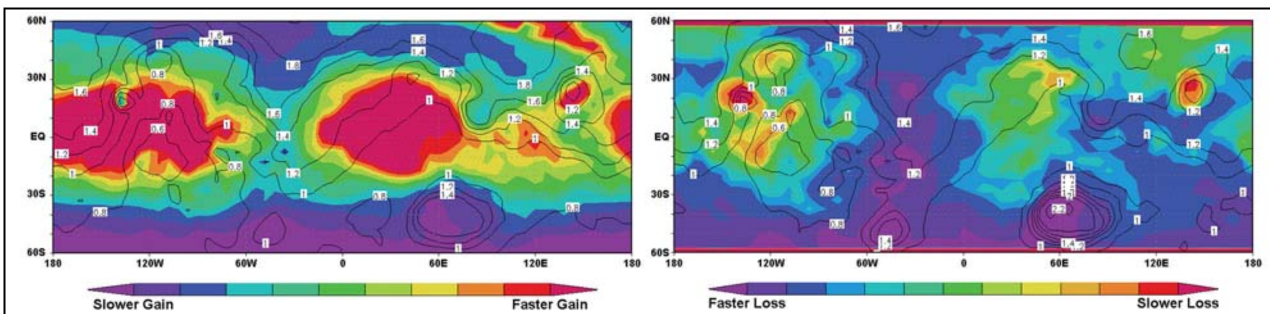

Figure 4: (a, left) Subsurface water distribution (ice+adsorbate+vapor) for 45° obliquity simulation with initially dry regolith. **(b, right)** Distribution for 25° obliquity simulation with initially ice-filled regolith. Both models after 8 years of simulation. Scale is qualitative; note differing interpretations in (a) and (b).