VERTICAL DISTRIBUTION OF WATER AT PHOENIX. L. K. Tamppari[1] and M. T. Lemmon[2], [1]Jet Propulsion Laboratory/Caltech, M/S 301-345, 4800 Oak Grove Dr., Pasadena, CA 91109, [2]Department of Atmospheric Sciences, Texas A&M University, College Station, Texas.

Introduction: Phoenix results, combined with coordinated observations from the Mars Reconnaissance Orbiter of the Phoenix lander site, indicate that the water vapor is non-uniform (i.e., not well mixed) up to a calculated cloud condensation level [1]. It is important to understand the mixing profile of water vapor because (a) the assumption of a well-mixed atmosphere up to a cloud condensation level is common in retrievals of column water abundances which are in turn used to understand the seasonal and interannual behavior of water, (b) there is a long history of observations and modeling that conclude both that water vapor *is* and *is not* well-mixed, and some studies indicate that the water vapor vertical mixing profile may, in fact, change with season and location, (c) the water vapor in the lowest part of the atmosphere is the reservoir that can exchange with the regolith and higher amounts may have an impact on the surface chemistry, and (d) greater water vapor abundances close to the surface may enhance surface exchange thereby reducing regional transport, which in turn has implications to the net transport of water vapor over seasonal and annual timescales.

Background: The Phoenix and Mars Reconnaissance Orbiter (MRO) spacecraft participated together in an observation campaign that was a coordinated effort to study the Martian atmosphere. One key aspect of this observation set was the means to compare the amount of water measured in the whole column (via the MRO Compact Reconnaissance Imaging Spectrometer for Mars [2] and the Phoenix Surface Stereo Imager (SSI) with that measured at the surface (via the Phoenix Thermal and Electrical Conductivity probe [3; TECP] which contained a humidity sensor). This comparison [1] showed the water vapor is *not* well mixed in the atmosphere up to a cloud condensation height. By comparing day and night observation sets, a well mixed assumption fails in both cases, and leads to the conclusion that water vapor must be exchanging with the surface diurnally.

However, a key unknown is how deep the exchanging layer is. For the Sol 70 case, MRO CRISM showed a change of ~12 pr μm from afternoon to early morning. While this magnitude change wasn't always seen in CRISM data, SSI sun-pointed data averaged in time-of-day over the course of the Phoenix mission show that there is a ~15 pr μm day-to-night difference.

The vertical distribution of atmospheric water vapor is important to understand adsorption/water cycling through the surface and, as such, is key to understanding the role of the regolith in supplying water to or sequestering water from the atmosphere (e.g. Jakosky *et al.*, 1997). This, in turn, is needed to understand the relative roles of the potential sources/sinks (e.g., surface and the exposed water-ice cap during northern summer) and hence the horizontal transport of water.

Method: We use the Phoenix SSI data taken with both water vapor and continuum filters. The 6 solar filters used include redundant 935-nm water band filters, each paired with one of two continuum filters (880 and 990 nm) in the dual filter wheel; and red and blue filters. The 935-nm band is narrow and specific to water vapor; liquid water and hydrates show absorption at longer wavelengths. We follow the methodology described by [5] for horizon pointed images, which involves comparing the actual radiance observed to output from a Monte Carlo model of water vapor absorption for different paths through the atmosphere (and therefore viewing geometries) under different water vapor mixing profile assumptions. We model scattering in the atmosphere with a spherically symmetric backward Monte Carlo model. This model is used due to the need for interpreting near horizon images in an atmosphere with a scale-height-to-radius ratio much larger than Earth's. In this backward Monte Carlo model, a photon is initiated at the camera to better bound the volume of integration. A photon is followed through many scattering events. In each event, the probability of the photon adding to the signal for that order of scattering is computed, and the probabilities of absorption or loss to space are computed. Absorption or loss to space trigger a reduction in statistical weight given to the photon rather than terminating that photon, in order to maximize accuracy for a given number of trials. The presence of water vapor decreases the mean single scattering albedo at each level, resulting, on average, in a smaller signal.

In our initial model runs, we focus on a particular diurnal cycle during the Phoenix mission: Sol 69-70 (L_s~108°). We assume a well-mixed boundary layer of varying heights, with water vapor following a condensation curve above that level.

Results: Below, we show an image set taken from near local noon on Sol 70 (SSI images ‘17DE’). The observation set included imaging near the horizon (opposite the sun) and near the sun. In each case, images were taken with the solar filter and in filters that are both in and out of the solar band. The percent absorption in the solar band, without the continuum, is retrieved from that set of 3 images. Figures 2 and 3 show the data as curves marked with triangles and diamonds. There are two curves because the observation set was repeated. The curve marked with squares show the model curve.

Figures 2 and 3 show that there is up to a few percent absorption (y-axis) due to water vapor in the data. The model curves show that, to first order, our model can achieve a few percent absorption as well. Our model is a two-layer mode that allows specification of the amount of water vapor in a well-mixed layer (prl), the altitude to which this water is well mixed (zwater), and the total water vapor column abundance (pr0). In addition, we specify the dust in a similar fashion, with a well-mixed lower layer and a total column abundance. These two mixed layers need not be the same. We use PHX LIDAR information to guide these mixed layer heights, and use MRO CRISM, PHX SSI, and MRO MCS data to guide our choices for water vapor total column abundance and dust optical depth.

Comparing Figures 2 and 3 shows an example of the sensitivity that we can expect. The model curve in Figure 2 was produced with a boundary layer height of 4.0 km, with nearly all of the 46 pr μm wate vapor within that layer, and dust, well mixed through the entire column, of τ(vis)=0.27. In Figure 3, the only change was to lower the altitude of the well-mixed water vapor layer to 2.0 km.

We will present updated results at the conference.

References:

[1] Tamppari, L. K., et al. (2009) *JGR, 115,* E00E17. [2] Murchie S., *et al*. (2007) *JGR, 112,* E05S03. [3] Zent, A. P., *et al.* (2009) *JGR, 114,* E00A27. [4] Whiteway, J. M., *et al.* (2009) *Science 325(5936)*, 68. [5] Titov, D. V., *et al.* (2000) *Plan. Sp. Sci. 48*, 1423-27.

Fig. 1. Sol 70 diurnal water vapor column abundance.

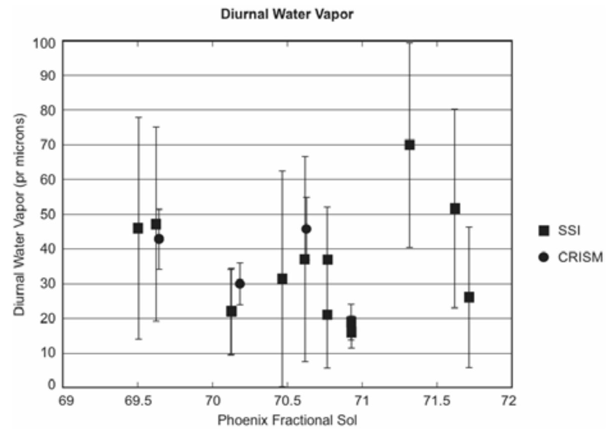

Fig. 2. Water vapor absorption and model for Sol 70 midday image sets. Parameters were: zwater=4.0, prl=45.0, pr0=46.0, τ=0.27. Triangles and diamonds show the image % absorption; squares show the model.

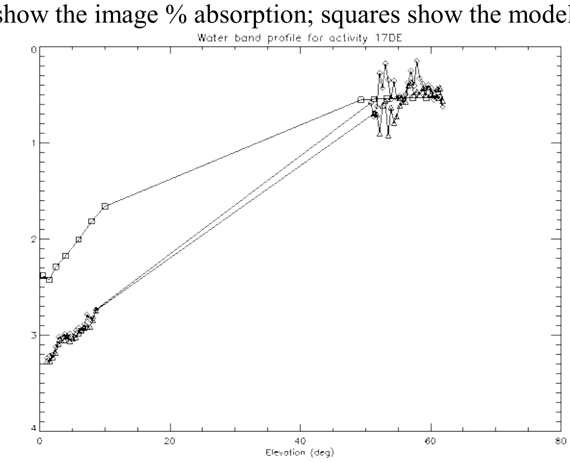

Fig. 3. Same as Fig. 2, but using zwater=2.0 km.