VERTICAL DISTRIBUTION OF WATER VAPOR IN THE MARTIAN POLAR ATMOSPHERE. A. A. Pankine[1] and L. K. Tamppari[2], [1]Space Science Institute (4750 Walnut Street, Suite 205, Boulder, CO 80301, apankine@spacescience.org), [2]JPL/Caltech.

Introduction: Seasonal and geographic variations of the water vapor in the Martian atmosphere over several Martian years have been observed by multiple orbiting spacecraft and are fairly well understood (e.g. [1], [2]). Vertical distribution of the water vapor in the Martian atmosphere is an important aspect of the Martian water cycle that is currently not well studied due to a lack of systematic observations. Most of the existing observations of the vapor vertical profile come from the observations of the planet limb (e.g. [3], [4], [5]), which miss most of the planetary boundary layer (PBL) (~ 10 km on Mars).

We use Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) daytime (2 pm) and nighttime (2 am) nadir observations to constrain vertical distribution of the vapor at the site of the Phoenix Lander [6] during northern summer. Our results suggest that water vapor is concentrated in the lowest 6-10 km above the ground and that the atmosphere is very dry above that height.

MGS TES data: MGS TES is a Fourier interferometer that collected far-infrared (~6-50 µm) spectra of Martian atmosphere and surface for almost 3 Martian years [7]. The daytime spectra were used to establish multi-year variability of the dust, water vapor and water ice cloud cycles [2]. The daytime spectra are not very sensitive to the vertical distribution of the water vapor, and the retrieval algorithm assumed that the mixing ratio of water vapor was constant below the condensation height of water ice clouds. If the same model of the vapor vertical distribution is used to retrieve nighttime vapor abundances, they turn out to be systematically higher than the daytime abundances, while the expectation is to find lower abundances at night (due to formation of ground frost and ground adsorption). Nighttime abundances are almost a factor of 2 higher in the Polar Regions during summer and on the slopes of the largest volcanoes. This difference between the daytime and night vapor abundances can arise due to a systematic under-estimation error of ~10K in the retrievals of nighttime atmospheric temperatures [8] in the lowest 10 km, but the error is too large and is not consistent with the radio science (RS) temperature retrievals [9]. The more likely explanation is that water vapor vertical extent is limited to lowest 1-2 scale heights (10-20 km) in the Martian atmosphere. Daytime and nighttime TES data can be combined to constrain the vertical distribution of water vapor.

Retrieval algorithm: The retrieval algorithm relies on the observation that daytime TES spectra are only sensitive to column abundances of water vapor, while nighttime spectra are also sensitive to its vertical distribution. The algorithm finds the vapor density profile that fits both the day and night observations. We assume that at night the vapor density profile is modified by formation of ice clouds where vapor pressure exceeds the saturation pressure, and by interaction with the surface (adsorption). The model vapor profiles for day and night are shown schematically in Figure 1. The retrieved parameters are the height of the 'wet' layer Hv and the mixing ratio of vapor in the 'wet' layer.

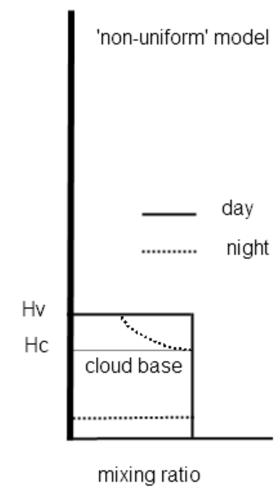

Figure 1. Model water vapor mixing ratio profiles for day and night. Hv – height of vapor, Hc – height of ice cloud base.

First, a daytime spectrum is used to calculate the water vapor index – which is essentially the difference between radiances within and outside two water vapor bands between 30 and 40 µm. A numerical model is then used to calculate water vapor indices for a range of vapor mixing ratios. Vapor mixing ratio is retrieved by comparing the observed and modeled indices. Nighttime index is then calculated using the daytime density profile modified by condensation of ice in the cloud. Vapor is also removed from the lowest model layer (~0.4 km) to simulate adsorption of vapor by the surface at night. Observed and calculated nighttime water vapor indices are compared and the vertical extent of vapor is adjusted to bring closer the observed and calculated nighttime indices. The daytime retrieval is repeated with the new Hv. The process repeats until both daytime and nighttime spectra can be matched with the same water vapor density profile. The solution for Hv and mixing ratio is unique (or does not exist in few cases).

Results: We apply the retrieval algorithm to the data collected by TES over the landing site of the Phoenix Lander (~234E, ~68N) from Ls=70-140°, because of the availability of in situ data [6] from the Lander (from a different year but same season) for comparison.

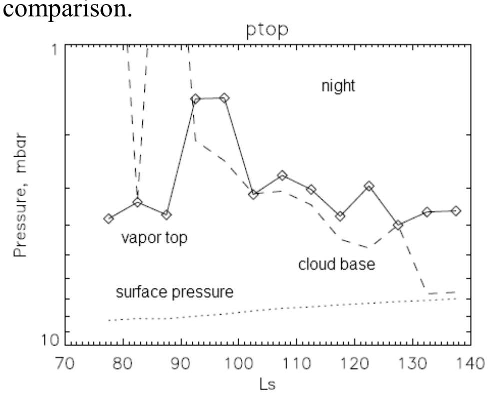

Figure 2. Pressure level of the top of the 'wet' layer (solid line, in mbar) and ice cloud base at night.

Figure 2 shows that the variation of the height of the 'wet' layer and of the ice cloud base with time during northern summer in Mars Year 25 (MY25). The height of the 'wet' layer remains roughly constant at 3-4 mbar (10-6 km), except for one episode at Ls=90-100°, when it increases to ~1 mbar level. The height of the ice clouds (dashed line) decreases from ~5 km at Ls=100° to the 0.4 km at Ls=140°, - roughly consistent with the observation of the Phoenix LIDAR instrument [10].

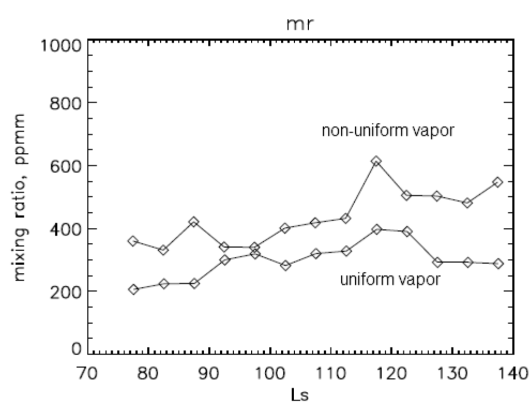

Figure 3. Comparison of the water vapor mixing ratios retrieved with the original TES retrieval [2] ('uniform vapor') and new retrieval ('non-uniform vapor').

Figure 3 compares vapor mixing ratios retrieved with 2 different models. The new retrieval produces higher mixing ratios, because the vapor is concentrated closer to the ground. Finally, Figure 4 compares water vapor density contours for the original retrieval [2] (top panel) and the new retrieval (bottom panel). The contours are in increments of 1×10^{-6} kg/m^3, the maximum contour in the bottom panel at Ls=115° is 1×10^{-5} kg/m^3.

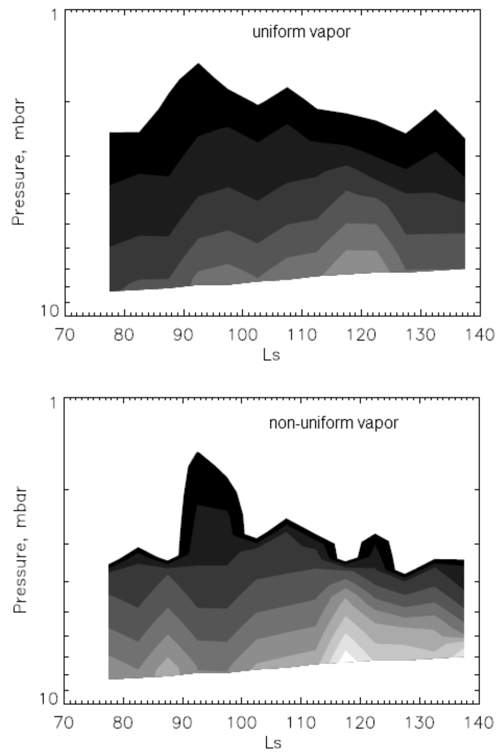

Figure 4. Water vapor density contours for retrievals with different models.

Conclusions: We have developed a new retrieval algorithm that allows to constrain the vertical extent of water vapor in the Martian atmosphere from combined daytime and nighttime MGS TES data. Application of the algorithm to the data from the northern polar summer suggests that the vapor is limited to the height of 6-10 km above ground. The method can be extended to TES data on global scale yielding maps of water vapor height variability.

References: [1] Jakosky B. M. and Farmer C. B. (1982) *JGR, 87,* 2999–3019. [2] Smith M. D. (2008) *Annu. Rev. Earth Planet. Sci., 36,* 191-219. [3] McConnochie, T.H. and Smith M.D. (2007). *In: 7th Int. Conf. on Mars*, Abstract #3345. [4] Smith M. D. et al. (2013) *JGR, 118*, 321–334. [5] Fedorova A. A. et al. (2009) *Icarus, 200*, 96–117. [6] Smith P. H. et al. (2009) *Science, 325*, 58-61. [7] Christensen P. R. (2001) *JGR, 106*, 23,823–23,871. [8] Conrath B. J. (2000) *JGR, 105*, 9509-9519. [9] Hinson D. P. et al. (2004) *JGR, 109*, doi:10.1029/2004JE002344. [10] Whiteway J. A. et al. (2009*) Science, 325*,68-70.