

ANOMALOUS H₂O CONCENTRATIONS OVER THARSIS: ANALYSIS OF EQUILIBRIUM MODELS A. P. Zent, SETI Institute and NASA Ames Research Center, Moffett Field CA, 94035; R. M. Haberle, NASA Ames Research Center, Moffett Field, CA 94035; J. R. Murphy, San Jose State University Foundation and NASA Ames Research Center, Moffett Field CA, 94035.

A one-dimensional model of regolith-atmosphere H₂O exchange has been published by Titov et al., [1] that purports to explain an apparent superabundance of H₂O in the atmospheric column above the Tharsis volcanoes. We show that their model cannot be expanded to three dimensions, and that alternative explanations, such as observation of a transient phenomenon, are preferred.

The Russian Phobos infrared imaging spectrometer returned over 40,000 spectra of Mars in the wavelength region 0.7 to 3.2 μm, with a spatial resolution of about 20 km. Titov et al. reported that variations in H₂O vapor bands near 1.8 and 2.5 μm reveal an anomalous concentration of H₂O vapor above the Tharsis volcanoes. They retrieved a mixing ratio of about 200 ppm, about 5 times higher than the mixing ratio over the surrounding plains.

Titov et al [1] advanced an hypothesis to explain the observed H₂O anomaly, in which the high abundance is explained by regolith-atmosphere water vapor exchange. They constructed a one-dimensional atmosphere-regolith exchange model which reproduced the high daytime column abundances derived from the Phobos observations. The model relied on vigorous daytime desorption from the volcanic regolith, which was postulated to have different adsorptive properties than the regolith of the surrounding plains. As such, their model implicitly represents an equilibrium solution.

While it is possible to construct a one-dimensional, equilibrium model that reproduces the observations, the model cannot be expanded to three dimensions without including additional processes. In three dimensions, the Titov et al. model must describe a transient state.

The equation describing the rate of change of the column abundance of H₂O in the martian atmosphere can be written as

$$\frac{d\psi}{dt} = \phi + \nabla\psi \cdot \vec{V} \quad 1$$

where ψ is the mass of H₂O in the column, ϕ is the flux of H₂O through the surface, and V is the wind vector. All horizontal transport of H₂O occurs through the atmosphere, and virtually all H₂O in the atmosphere+regolith column is stored as adsorbate [2]. In effect then, distinctly different column abundances can only be maintained over the volcanoes and surrounding plains if the integrated daily regolith-atmosphere exchange is zero. This in turn requires that

$$\int^{\text{sol}} \vec{V} dt = 0 \quad 2$$

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i.e., if there is no net diurnal circulation of the atmosphere. This would require a globally hydrostatic atmosphere, which is not permitted by observations. If there is any net diurnal circulation of the atmosphere, water will be transported down the gradient, away from the volcanoes. In consequence, the upper layer of the regolith will be severely depleted of H_2O in relatively short order. A simple calculation suggests that the down gradient transport in a 10 m s^{-1} wind field would remove around $2 \text{ pr } \mu\text{m}$ of H_2O per sol from the atmospheric column above the volcanoes. Therefore, a permanent H_2O anomaly above the volcanoes is not an equilibrium situation, and cannot persist.

The diurnal diffusion skin depth of a basaltic regolith, scaled for slowing by adsorption, holds approximately $8 \text{ pr } \mu\text{m}$ of H_2O at $P = 0.015 \text{ Pa}$ and $T = 215$ [2]; this amount could be carried away by advection in approximately 4 sols. Thereafter exchange with the atmosphere would be limited by diffusion upwards from below the diurnal diffusion depth. A similar calculation for higher adsorptive capacity regolith such as clay suggests that the diurnal diffusion skin depth could buffer an atmospheric anomaly for perhaps 70 sols. Even though the diffusion skin depth of clay is significantly less than for basalt, its higher adsorptive capacity gives it a greater capacity to buffer the atmosphere than basalt. This calculation suggests a possible explanation for the observed anomaly: the volcanic regolith may be equilibrating with the ambient atmosphere at a different rate than the surrounding regolith, producing an annual transient anomaly. More rigorous numerical modeling using the Ames General Circulation Model and the Boundary Layer H_2O Model [3], will test this possibility.

Alternative explanations for the apparent superabundance of H_2O above the volcanoes range from mundane to spectacular. The data reduction method employed by Titov et al. implicitly assumes that extinction due to aerosols does not affect the relative depth of the H_2O absorptions. In addition, the model assumes that mineralogical variations across the surface are not adequate to explain the variations in the depth of the H_2O band [4]. It is possible that problems with the data reduction give the illusion of excess atmospheric H_2O .

Finally, there is the remote possibility that a transient endogenic source of H_2O has been observed. Such speculation is not as farfetched as it might have been considered only a year ago. Observations of He in the martian atmosphere [5], as well as modeling of the Ne, Ar and N isotope ratios [6] suggest that degassing must be an essentially ongoing process on Mars.

[1]. Titov et al., *Planet Space Sci.* In Press, 1995. [2] Fanale and Cannon, *Nature*, **230**, 512, 1971, [3] Zent et al., *J. Geophys. Res.*, **98**, 3319, 1993. [4] Rosenqvist and Titov, *Bull. Amer. Astron. Soc.* **26**, 1124, 1994. [4] Kransnopolosky et al., *Icarus*, **109**, 337, 1994. [5] Jakosky et al., *Icarus*, **111**, 271, 1994.