CORRECTION FOR SCATTERING OPACITY OF MARTIAN ATMOSPHERIC WATER VAPOR ABUNDANCES

Ann Sprague, Donald Hunten, Richard Hill, Lyn Doose and Bashar Rizk
Lunar and Planetary Laboratory, University of Arizona
sprague@lpl.arizona.edu

It has been known since the work of Davies (1979) that spectroscopic measurements of H_2O abundance near the limb are affected by absorption and scattering by dust in the atmosphere. He suggested that this effect probably accounts for the apparent diurnal variations frequently seen in ground-based data of Barker (1976). Modeling of the phenomenon suggests that only water-vapor in the lowest 1000 m is likely to deposit on the surface during the night and re-appear during the day, and this is only about 10% of the vapor in a typical atmospheric column (Flasar and Goody, 1976). On the other hand, measurements from the Viking Landers do suggest deposition (Pollack *et al.*, 1977; Ryan *et al.*, 1982, Jakosky *et al.*, 1987).

Another point, perhaps even more interesting, is that measurements of the polar regions are likely to be systematically low, because these regions are always seen near the limb and will therefore be strongly subject to dust opacity.

We have developed a method to correct near-limb measurements for the dust scattering. Instead of the Monte-Carlo treatment used by Davies (1979), we use a doubling-adding code with a dust phase function determined by applying this code to data from Mars Pathfinder (Tomasko *et al.*, 1999). To determine the optical depth of the dust we use measurements of a CO_2 band at 869 nm, made almost simultaneously with the H_2O measurements at 819 nm (our instrument cannot observe both regions in a single exposure). The CO_2 abundance at any location and season is already known, and the variation of its absorption from limb to limb can therefore be interpreted to give the dust opacity. Results of computations for constant CO_2 and optical depths 0.3, 0.5 and 0.7 are shown in Figs. 1a and 2a (0.5 is a typical value for “clear” conditions). The points in Figs. 1a and 2a show measured apparent CO_2 abundances, and the wide gray lines represent the corresponding surface pressures, computed from the topography. (We intend to use this curve to correct the points when the procedures are fully developed.)

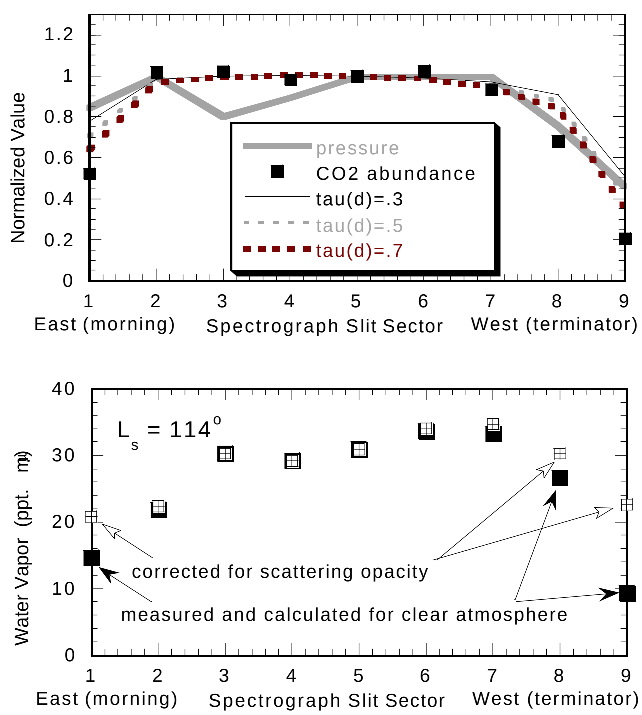


Fig. 1. (a) Top. Black points show CO_2 apparent abundances for nine areas along an East-West spectrograph slit, March 24 1999. Gray line is mean surface pressure for the same regions and the three similar curves are computed effects of dust (ratio of apparent to actual abundance) for opacities of 0.3, 0.5 and 0.7. All have been normalized to unity at the center, point 5. (b) Bottom. Water-vapor abundances for the same nine points, as observed (black points) and corrected for dust scattering (hollow points).

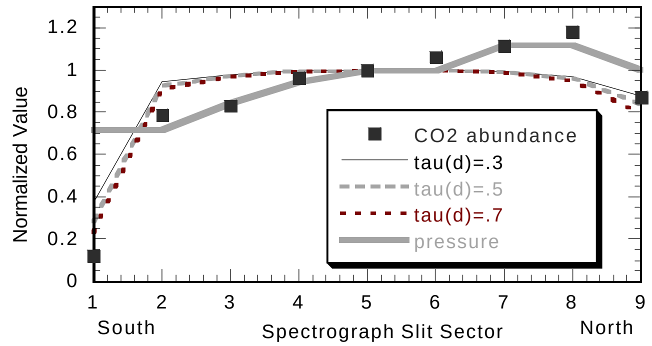
It can be seen that there is a general correspondence except near the limbs or terminator, where the effect of the dust becomes prominent. The three opacity curves do not differ by much except very near the limb or terminator; thus, the CO_2 measurements must be of very high quality to determine which one is correct. On the other hand, use of a mean optical depth of 0.5 is not likely to lead us far astray, and should be useful for the many previous data sets that have no accompanying CO_2 measurements. If the atmosphere is unusually dusty, it will probably be apparent and an adjustment can be made.

Figures 1b and 2b show water-vapor results corresponding to the CO_2 results in Figs. 1a and 2a. Black and hollow points are as observed and as corrected for scattering, respectively. Figure 1b, an East-West traversal with nine measurements at different local times across Mars near the equator, does seem to show significantly reduced water vapor in both morning and evening even after correction. The South-North data set in Fig. 2b shows a huge variation with latitude, typical for this season. The dust correction, as expected, is large for both polar regions.

For the current apparition we have in hand measurements of H_2O and CO_2 every two weeks from late September 1998 to late March 1999, covering L_s from 34 to 115 degrees. For the period around opposition the Doppler shift is too small, but we will start up again at the end of May. From the previous apparition we have H_2O coverage from October 1996 to February 1997 and May to July 1997; L_s 18 - 78 and 114 - 146 degrees.

Earlier results are summarized in Sprague *et al.* (1996); trends agree well with Viking data and measurements by other methods, but show considerable daily fluctuations. Also, as illustrated in Fig. 2b the polar abundances are likely to be systematically low (in this case 20%). We hope to apply the corrections discussed above, using the mean dust opacity of 0.5.

All this work by ourselves and other ground-based observers, and future extensions of it, provides baseline knowledge of the behavior of Martian water vapor, as well as measurements and theory supplementary to that of present and future Mars missions.



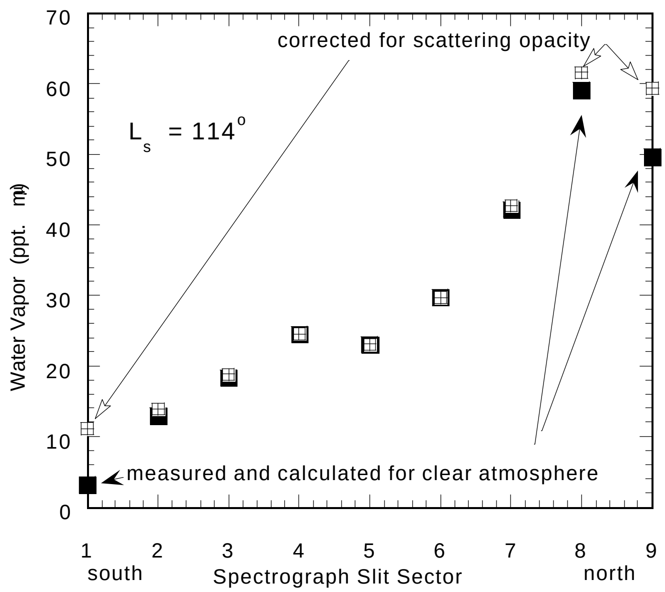


Fig. 2. Data and theory for a S-N traverse across Mars on March 25, 1999. (a) Top. CO_2 abundances and calculated opacities (same as in Fig. 1(a)). (b) Bottom. Measured H_2O abundances before and after correction for scattering opacity.

REFERENCES: Barker, E.S. (1976) *Icarus* **28**, 247; Davies, D.W. (1979) *JGR* **84**, 2875; Flasar, F.M. and Goody, R.M. (1976) *Planet. Space Sci.* **24**, 161; Jakosky, B.M. *et al.* (1987) *Icarus* **130**, 87; Pollack, J.B. *et al.*(1977) *JGR* **82**, 4479; Ryan, J.A. *et al.* (1982) *JGR* **87**, 7279; Sprague, A.L. *et al.* (1996) *JGR* **101**, 23,229; Tomasko, M.G. *et al.* (1999) *JGR* **104**, 8987.