LIMB-SOUNDING OF AEROSOLS WITH THE MARS GLOBAL SURVEYOR THERMAL EMISSION SPECTROMETER (TES).

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Introduction: The opacities of dust aerosol, water ice aerosol, and water vapor are routinely derived from Mars Global Surveyor Thermal Emission Spectrometer (TES) nadir-viewing radiance spectra, e.g., [1–5]. These retrievals, however, yield no information about vertical structure, and their accuracy diminishes as the surface temperature falls below 220 K [1]. We are developing a technique to measure the vertical distribution of aerosols and water vapor using TES limb-sounding observations. In contrast to the nadir case, the limb geometry allows accurate retrievals over cold surfaces (i.e., polar and nighttime), and contains information about the vertical structure of aerosols and water vapor. Aerosol scattering is a major contributor to the limb sounding radiance, and so we combine a full radiative transfer code with non-linear optimization in order to match the observed radiances.

By including aerosol scattering, we improve the absolute accuracy of the column opacities relative to the existing nadir based data sets. These data sets neglect scattering and so underestimate the actual optical depth by a variable amount that typically ranges between 20% and 30% [5], [6]. The accuracy of the nadir-based data sets is also limited by the need to assume a vertical distribution to account for the influence of vertically varying temperature on aerosol emission.

Expected Results: Limb-sounding retrievals will yield crucial new information about:

1. *Vertical mixing in the martian atmosphere and vertical variations in horizontal transport.*
2. *The diurnal cycle of water-ice clouds.* Comparison of the daytime and nighttime ice optical depth will reveal the extent to which the diurnal temperature cycle alters the distribution of water-ice cloud.
3. *The composition of the polar hood.* Existing TES retrievals show water ice in the illuminated low-latitude fringes of the polar hood [2], while the Mars Orbiter Laser Altimeter (MOLA) observes clouds in the dark interior of the polar hood [7], some of which have been interpreted as precipitating CO_2 aerosol, e.g., [8]. We will at minimum be able to map the distribution and opacity of water-ice clouds.
4. *The extent to which the polar vortex isolates the polar atmosphere.* [9] have studied the dynamics of the polar vortex as derived from TES-retrieved temperatures, and [10] have measured an enhancement of the argon mixing ratio in polar winter and discussed its implications for mixing across the vortex boundary. TES-based estimates of changes in dust content across the polar vortex boundary will help confirm or refute those authors' contention that the polar vortex is a significant barrier to mixing, and will help clarify when mixing does and does not occur.

The Mars Climate Sounder (MCS) on the Mars Reconaisance Orbiter [11] should yield information similar to the TES limb soundings, but with somewhat better spatial resolution. Since TES and MCS are very different instruments with significantly different observing strategies, comparison of their results will provide a sanity check for both data sets. (Detailed quantitative comparisons will of course be hampered by a lack of temporal overlap in the data sets.) The TES data set will also, of course, extend the record of vertically resolved atmospheric phenomena several martian years back in time relative to the MCS data set.

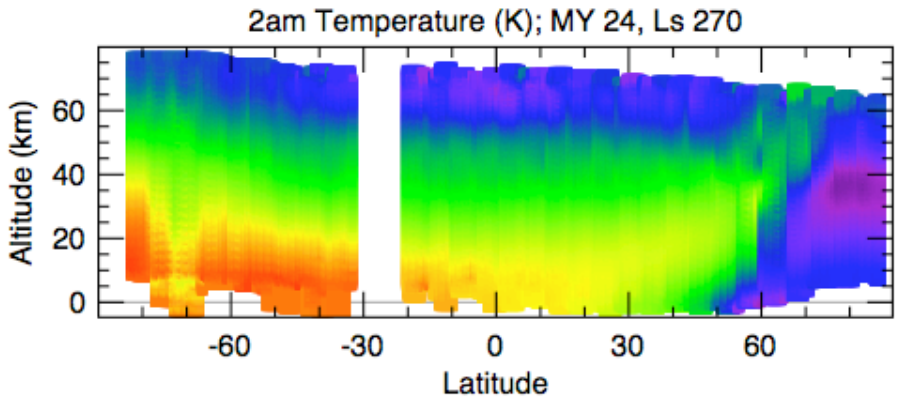
Method: The feasibility of TES limb retrievals has been demonstrated by [12]. We are developing an improved procedure which will map aerosol opacity as a function of latitude, longitude, alitude, and time for the entire period of TES mapping operations, a period of more than three martian years, with pole-to-pole coverage at local times of 2pm and 2am. Our procedure for measuring vertically resolved aerosol opacity is as follows:

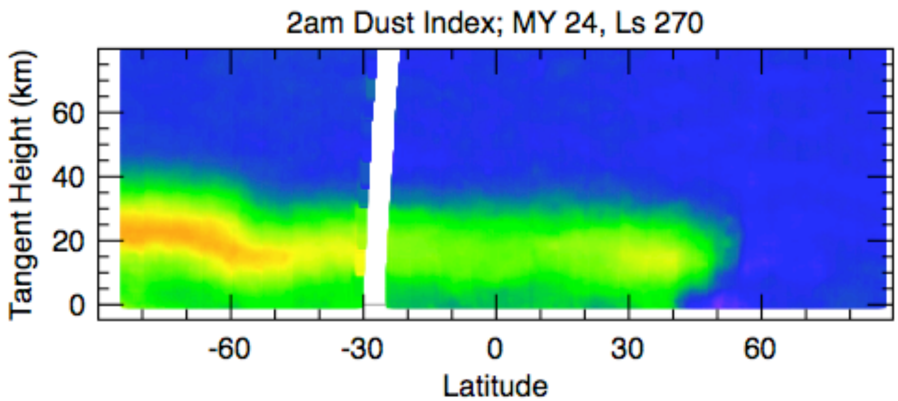
1. Obtain a set of TES thermal-infrared limb-pointed spectra.
2. Model the TES radiance spectrum as a function of the vertically resolved dust and ice optical depth. We will use the quasi-spherical discrete-ordinates radiative transfer model of [13]. Other than the optical depths, the important model inputs are TES-derived temperatures [14], and aerosol scattering parameters provided by [6].
3. Iteratively vary the dust and ice vertical distributions using the Levenberg-Marquardt algorithm to minimize the difference between the modeled radiance spectra and a set of TES limb-pointed spectra.

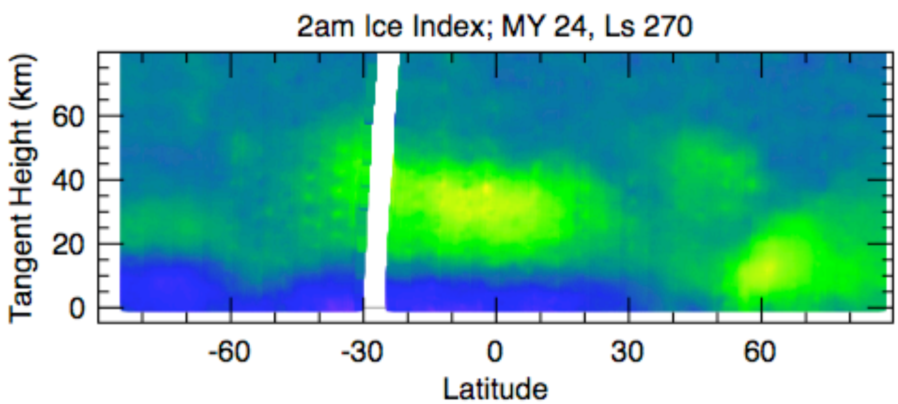
Example: The figure on the following page provides an example of the kind of information available from TES limb sounding. The dust and ices indices are simply the (scaled) height of a dust emission feature near 470 cm^{-1} and (scaled) depth of an ice absorption feature near 320 cm^{-1}. A dust or ice index data point is simply assigned an altitude based on the tangent height of the particular TES pointing from which it was taken. Since a given pointing samples a path through the atmosphere that crosses all levels at the tangent height and above, and since a simple index cannot capture the influence of the temperature profile or of aerosol scattering, the information provided is of course merely qualitative. Our modeling approach will replace the qualitative information with quantitative opacities.

The plots show latitude-height cross sections constructed from nighttime data in the L_s 269 – 271 period of the first martian year of TES mapping operations. use only nighttime (~2 am) data. The aerosol indices are boxcar smoothed with a width of 8 degrees in latitude, and 8 km in altitude, and averaged over all longitudes. The scale is arbitrary with red representing more aerosol (higher index value) and blue representing less. The temperature cross section is smoothed with a width of 4 degrees and 4 km, and uses TES temperature retrievals [14].

References: [1] Smith, M. D. et al. (2000) *JGR* **105**, 9539. [2] Smith, M. D. et al. (2001) *JGR* **106**, 23929. [3] Pearl, J. C. et al., (2001) *JGR* **106**, 12325. [4] Smith, M.D. (2002) *JGR* **107**, 2001JE001522. [5] Smith, M. D. (2004) *Icarus*, **167**, 148. [6] Wolff, M. J. and Clancy, R. T. (2003) *JGR* **108**, 2003JE002057. [7] Ivanov, A. B. and Muhleman, D. O. (2001). *Icarus* **154**, 190. [8] Colaprete, A. et al. (2003) *JGR* **108**, 17. [9] McConnochie T. H. et al. (2005) Submitted to *Icarus*, August, 2005. [10] Sprague, A. L. et al. (2004) *Science*, **306**, 1364. [11] McCleese, D. J. et al. (2007) *LPS XXXVIII*, Abstract #1338. [12] Smith, M.D. (2003) In: Proceedings of the 6th International Conference on Mars, Pasadena, CA. [13] Smith, M. D. (1994) Ph. D. Thesis, Cornell University, Ithaca, NY. [14] Conrath, B. J. et al. (2000) *JGR* **105**, 9509.


2am Temperature (K); MY 24, Ls 270
Altitude (km)
0
20
40
60
-60
-30
0
30
60
Latitude


2am Dust Index; MY 24, Ls 270
Tangent Height (km)
0
20
40
60
-60
-30
0
30
60
Latitude


2am Ice Index; MY 24, Ls 270
Tangent Height (km)
0
20
40
60
-60
-30
0
30
60
Latitude