FINAL REPORT

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Title: Cirrus Clouds on Mars: Data Analysis and GCM Modeling
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The goal of the investigation was to obtain a better retrieval of cirrus ice concentrations gain a quantitative understanding of the cirrus clouds in the upper atmosphere by analyzing The Thermal Emission Spectrometer (TES) data obtained by the Mars Global Surveyor (MGS). We study the global distribution of dust and ice for a Martian year to address the fundamental question of the importance of ice in the Martian atmosphere.

We introduced two new techniques in analyzing Martian spectrally resolved radiance data obtained by the Thermal Emission Spectrometer (TES): spectral empirical orthogonal function (EOF) analysis and the tri-spectral algorithm. Spectral EOF analysis allows us to obtain the variability of spectra and associated temporal and spatial patterns. The case study with TES 20°S -20°N data shows that the first principal component (PC1) dominates the total variance and is associated with surface or near-surface brightness temperature variations. The PC2 is associated with atmospheric variability, and a negative correlation between dust and ice absorptions can be clearly seen over many regions. The annual cycle is a major component of the PC1 temporal patterns. The fingerprint of the dust storm can be clearly seen in the PC2 temporal patterns in most areas except the highlands. Spectral EOF can be used for validation of the variability of Martian GCMs. The tri-spectral algorithm is based on the differences between three bands (dust, ice and a weak CO_2 absorption bands) to distinguish spectra sampled in different situations: water ice cloud, dust, and surface anisothermality. We use a line-by-line radiative transfer model coupled with multiple scattering to investigate the sensitivity of this algorithm to dust and ice optical depth as well as surface emissivity. The comparisons between results of this algorithm and the TES team's retrieved dust and ice opacity are consistent over all studies periods except during the peak of the dust storm. Our algorithm is complementary to the more sophisticated TES retrieval and can be used to screen large amounts of data to get an overview.

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Huang, X., J. Liu, and Y. L. Yung. (2003). "Analysis of Thermal Emission Spectrometer Using Spectral EOF and Tri-spectral Methods." *Icarus* **165**: 301-314.

Leroy, S. S., Y. L. Yung, M. I. Richardson, and J. C. Wilson. (2003). "Principal Modes of Variability of Martian Atmospheric Surface Pressure." *Geophysical Research Letters* **30**(13): art. No. 1707.

Nair, H., M. E. Summers, C. E. Miller and Y. L. Yung (2004). "The isotopic fractionation of methane in the Martian atmosphere." *Icarus*: In press

Conference Presentations

Leroy, S. S., Richardson, M. I., Yung, Y. L., and Wilson, R. J., Daily to Inter annual Variability of Mars' Surface Pressure, Fall AGU Meeting, Paper P61C-0358, 2002.

Yung, Y. L., X.-L. Huang and J. J. Liu, Analyzing TES Data Using the Tri-spectral and Spectral EOF Techniques, Birmingham DPS meeting. *Bull. Am. Astron. Soc.*, 2002.

Huang, X., J. Liu, Y. Yung, 2003, Spatial-Spectral EOF analysis of TES Data. Monterey DPS meeting. *Bull. Am. Astron. Soc.*, **35**, 936.

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Huang, X: I. Variability of outgoing thermal IR spectra and its application in GCM validation, II. The detection of clouds/aerosols in the outgoing thermal IR spectra, 2004, California Institute of Technology.