MARTIAN RADIATIVE TRANSFER MODELING USING THE OPTIMAL SPECTRAL SAMPLING METHOD. J. Eluszkiewicz, K. Cady-Pereira, G. Uymin, and J.-L. Moncet, Atmospheric and Environmental Research, Inc., 131 Hartwell Ave., Lexington, MA 02421, jel@aer.com.

Introduction: The large volume of existing and planned infrared observations of Mars have prompted the development of a new martian radiative transfer model that could be used in the retrievals of atmospheric and surface properties. The model is based on the Optimal Spectral Sampling (OSS) method [1]. The method is a fast and accurate monochromatic technique applicable to a wide range of remote sensing platforms (from microwave to UV) and was originally developed for the real-time processing of infrared and microwave data acquired by instruments aboard the satellites forming part of the next-generation global weather satellite system NPOESS (National Polar-orbiting Operational Satellite System) [2]. As part of our on-going research related to the radiative properties of the martian polar caps, we have begun the development of a martian OSS model with the goal of using it to perform self-consistent atmospheric corrections necessary to retrieve caps' emissivity from the Thermal Emission Spectrometer (TES) spectra. While the caps will provide the initial focus area for applying the new model, it is hoped that the model will be of interest to the wider Mars remote sensing community.

Overview of the OSS Method: The OSS approach is an extension of the Exponential Sum Fitting Transmittance method of Wiscombe and Evans [3] and consists of approximating radiances in each spectral channel as linear combinations of radiances computed at selected monochromatic locations. The spectral locations and their statistical weights are selected by comparing the resulting channel radiances against line-by-line (LBL) calculations performed over a wide range of atmospheric profiles. The training profiles are chosen to be representative of the expected variability, including atmospheric variability (temperature and composition), surface pressure, surface emissivity and reflectivity, and viewing and solar angles. The selection process can achieve any user-defined level of accuracy as compared with exact LBL calculations (typically < 0.05 K), but at a miniscule fraction of computational cost. Being monochromatic makes the OSS method applicable to non-positive instrument line shape (ILS) functions (interferometers) and different viewing geometries (e.g., down-, up-, and limb-looking). In addition, it greatly simplifies the computation of analytical Jacobians, makes possible the modeling of scattering effects in an accurate and computationally efficient way (because the algorithm obeys Beer's law), and provides a natural mechanism for parallel processing of the RT calculations. In our work with the OSS model, the LBLRTM model [4] serves as the line-by-line reference. The choice of LBLRTM gives direct access to on-going radiative transfer model validation studies [5] and, together with the monochromatic nature of OSS, enables the model to be quickly and rigorously updated for changes in the fundamental spectroscopic parameters.

Martian OSS Model: The training of the OSS model (i.e., optimal selection of monochromatic spectral points and weights) can be performed on any set of profiles that are representative of the global atmosphere and surface. In this initial phase of developing the martian OSS model, we have relied on profiles from a recent version of the GFDL MGCM [6] for this purpose. These profiles, originally supplied on the GCM's native terrain-following vertical grid, have been interpolated to a set of 20 fixed pressure levels between 10 and 0.01 mbar.

In Figure 1, we show three nadir-looking spectra generated using an OSS model for a set of 10 cm^{-1} channels covering the spectral range 300-1600 cm^{-1} (thus corresponding to an idealized "TES" instrument). These spectra correspond to a dust-free CO_2/H_2O atmosphere (with mass mixing ratios of 1 and 10^{-6} g/g, respectively) and temperature profiles shown in Figure 2. Figure 3 shows the RMS differences between OSS and LBLRTM for the set of 96 profiles used in the training, as well as the number of monochromatic points per channel necessary to achieve the prescribed level of accuracy. In this example the RMS errors are, by design, less than 0.05 K when evaluated on the training set. For an independent set of profiles, the RMS errors will be of the same order, provided the training (dependent) set is representative of the expected variability. Figures 4 and 5 are similar to Figures 1 and 3, but for an upward-looking instrument. The results shown in Figures 3 and 5 demonstrate the computational power of the OSS method: while the LBL model uses hundreds of thousands of monochromatic points to simulate a 10 cm^{-1} channel, the OSS model relies on less than a dozen monochromatic points to achieve a comparable level of accuracy.

Work Plan: The examples shown here are clearly preliminary and serve mainly to illustrate the potential of the OSS method in martian applications. Future plans include the development of a truly representative training set (including real profiles derived from TES spectra and variations in surface properties), a consideration of realistic ILS functions (e.g., TES, mini-TES, and any future instrument for which the OSS model may be of interest), the inclusion of dust, and the implementation of a multiple scattering version of the OSS model for Mars. Some of these results are expected to be available by the time of the meeting. In our ongoing work related to the polar caps, the OSS model will be used to retrieve dust optical properties and the caps' emissivity.

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References: [1] Moncet J.-L. et al. (2004) *Proc. SPIE 5425*, paper 5425-37. [2] AER, Inc. (2004) ATBD for Cross-Track Infrared Sounder, Vol. 2, Environmental Data Records. [3] Wiscombe W. J. and Evans J. W. (1977) *J. Comp. Physics, 24*, 416. [4] Clough S. A. and Iacono M. J. (1995) *JGR, 100*, 16,519. [5] Clough S.A. et al. (2005) *JQSRT, 91*, 233. [6] Wilson R. J. and Hamilton K. (1996) *J. Atmos. Sci., 53*, 1290.

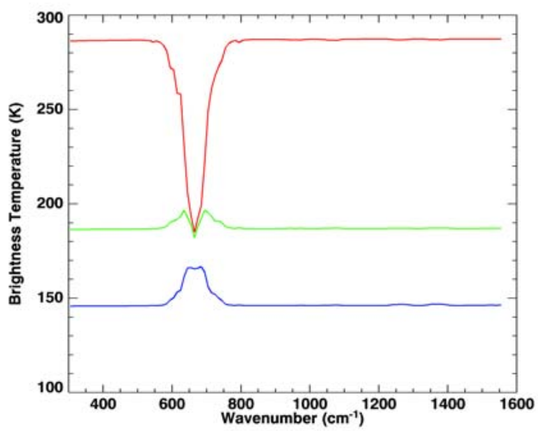

Figure 1: Examples of nadir-looking spectra at 10 cm^{-1} resolution simulated by the OSS model.

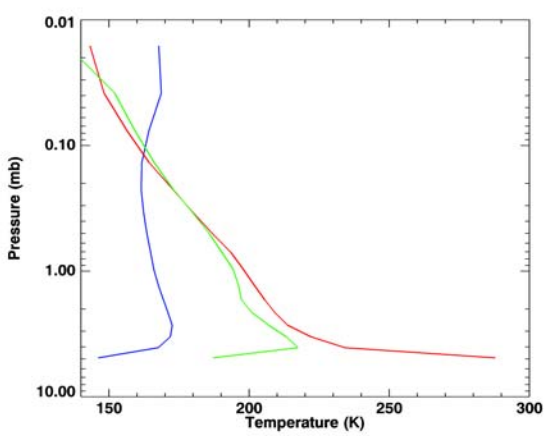

Figure 2: Temperature profiles used to generate spectra shown in Figure 1.

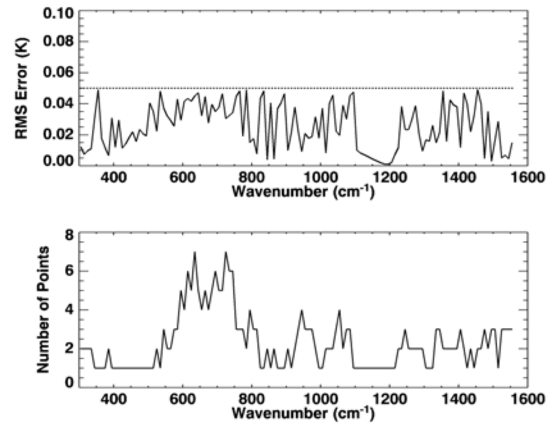

Figure 3: RMS error (vs LBL calculations over the entire training set) and number of spectral points in each 10 cm^{-1} channel for the nadir-looking OSS model.

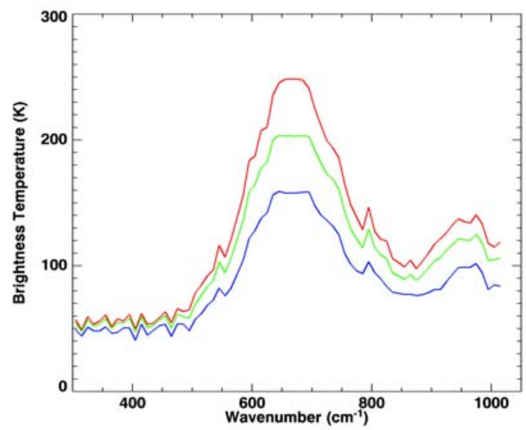

Figure 4: Similar to Figure 1, but for a notional 10 cm^{-1} instrument looking 30^{o} above the horizon.

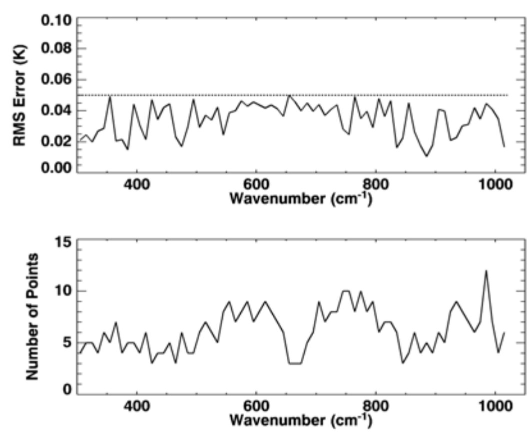

Figure 5: Similar to Figure 3, but for the upward-looking spectra.