A MICROPHYSICALLY-BASED APPROACH TO INFERRING POROSITY, GRAIN SIZE, AND DUST ABUNDANCE IN THE SEASONAL CAPS FROM ATMOSPHERICALLY-CORRECTED TES SPECTRA.

J. Eluszkiewicz[1] and T. N. Titus[2], [1]Atmospheric and Environmental Research, Inc., 131 Hartwell Ave., Lexington, MA 02421, jel@aer.com, [2]U.S. Geological Survey, 2255 North Gemini Dr., Flagstaff, AZ 86001, ttitus@usgs.gov.

Introduction: One of the highlights of the TES observations in the polar regions has been the identification of a "cryptic" region in the south where CO_2 appears to be in the form of a solid slab rather than a fluffy frost [1]. While the exact mechanism(s) by which the cryptic region is formed are still subject of some debate, it appears certain that a type of rapid metamorphism related to the high volatility of CO_2 ice is involved. The high volatility of CO_2 ice under martian conditions has several Solar System analogs (N_2 on Triton and Pluto, SO_2 on Io), thus making the martian cryptic region somewhat less cryptic and certainly non-unique among planetary objects. In an end-member scenario, both the formation and the spectral properties of the cryptic region (and of other areas in the seasonal caps) can be quantitatively modeled by considering sintering of an ensemble of quasi-spherical CO_2 grains [2]. This model includes the special case of instanteneous slab formation, which occurs when the grains are sufficiently small (in the submicron range) so that their sintering timescale is short relative to the deposition timescale (a situation analogous to the "sintering" of water droplets falling into a pond).

Physics of Sintering: Originally, the idea of annealed slabs of CO_2 in the martian seasonal caps was proposed based on an analysis of densification timescales [2]. Recently, we have also evaluated the role played by the non-densifying sintering mechanism caused by vapor transport (Kelvin effect). The main conclusion from this recent work is that the seasonal CO_2 deposits on Mars rapidly metamorphose into an impermeable slab regardless of the initial grain size. The slab forming by this mechanism is expected to contain quasi-spherical voids that then undergo slow elimination by the densifying mechanisms. This densification process *is* strongly grain-size dependent, which can be used to explain the persistence of both low- and high-emissivity areas (e.g., the cryptic region and Mountains of Mitchell, respectively). The proposed texture for the martian CO_2 deposits is consistent with both TES and other observations (in particular, the porous texture of the slab is consistent with the mean density of the seasonal deposits inferred from the MOLA data being less than the theoretical density of solid CO_2 [3]) and it has important consequences for the modeling of the physical properties of the martian seasonal frost. Specifically, the radiative properties of the frost (e.g., albedo and emissivity) are more prop-erly modeled by treating radiative transfer in a slab of solid CO_2 containing spherical voids (and other impurities such as dust grains) rather than by the usual model of spherical CO_2 and dust grains *in vacuo*. In the present study, this problem is tackled by finding the Mie solution for a spherical particle embedded in an absorbing host medium [4]. The Mie solution is then applied in a multiple scattering code [5] to compute the radiative properties of the martian CO_2 deposits.

Application of the New RT Model: The chief advantage of the new RT model is its connection to the microphysical model of the cap texture and, consequently, its predictive capability. In particular, the new model does not require the notion of meter-sized Mie boulders of solid CO_2 in order to explain the high emissivities in the cap spectra (e.g., in the cryptic region) but instead relates them to low porosity. The strong porosity dependence of the computed emissivity suggests that the density evolution obtained from the sintering model can be coupled with the radiative transfer calculations to predict the evolution of emissivities. Preliminary results presented at the 6th Mars Conference [6] have demonstrated the capability of the new model to mimic the observed evolution of the cap emissivity (represented as the depth of the TES 25-μm band, BD_{25}).

Modeling the Shape of TES Spectra: In addition to generating a semi-quantitative agreement with the evolution of BD_{25}, the new model is capable of providing a quantitative match to the shape of the TES spectra. For this more quantitative test, it is important to remove the component of the spectra related to atmospheric dust, which we accomplish using an approach based on the emission phase function (EPF) [7]. To date, 105 EPF-corrected spectra of the caps have been generated. An example of an EPF-corrected spectrum and the model spectra computed using the new RT model are shown in Figure 1. The refractive indices for solid CO_2 used in the calculations are as in [8], while the dusty spectra have been computed using optical constants for palagonite [9]. Application of the new model to match the TES spectra can in principle lead to maps of the porosity, void size, and dust content for the polar caps. In the example shown in Figure 1, a fairly good match to the observed spectrum is obtained for a slab containing 5-μm voids at 1% porosity with a

fractional abundance of 1-µm dust grains of 5 x 10^{-4} by volume (the presence of dust is responsible for the shift of the frequency of mimimum emissivity longward of 25 µm). Of course, the RT solution for these parameters is non-unique, and this will necessitate the development of a maximum-likehood inversion method utilizing *a priori* information. The results from the sintering model might in fact be used as an *a priori* constraint (i.e., in a given location, the solution for porosity at different times should be consistent with the porosity evolution predicted by the sintering model). In addition, several important factors neglected so far (e.g., variable cap thickness, nonuniform density distribution with depth, presence of a thermal gradient) should be included, some of which could further improve the agreement between the coupled microphysical/radiative transfer model and TES observations. Ultimately, the new model will provide a powerful observationally-based tool for the modeling of the coupled surface-atmosphere system on Mars.
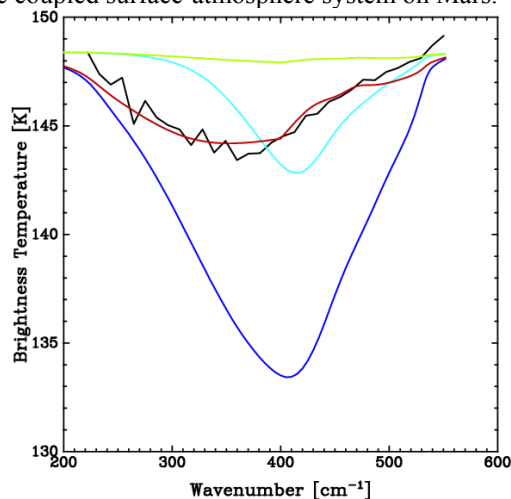

Figure 1: Black line: Observed spectrum. Dark blue line: computed spectrum with 5-µm voids, no dust. Light blue line: computed spectrum with 1-µm voids, no dust. Green line: Computed spectrum with 1-µm voids, 5 x 10^{-4} by volume of dust. Red line: Computed spectrum with 5-µm voids, 5 x 10^{-4} by volume of dust. All computed spectra assume a kinetic temperature of 146 K, slab thickness of 1 meter, 1% porosity, and dust grain size of 1 µm.

References: [1] Kieffer H. et al. (2000) *JGR 105,* 9653. [2] Eluszkiewicz J. (1993) *Icarus 103,* 43. [3] [3] Smith D. E. et al. (2001) *Science 294,* 2141. [4] Yang P. et al. (2002) *Appl. Opt. 41,* 2740. [5] Stamnes K. et al. (1988) *Appl. Opt. 27,* 2502. [6] Eluszkiewicz J. and T. N. Titus (2003) 6th Mars Conference (www.lpi.usra.edu/meetings/sixthmars2003/pdf/3046.pdf). [7] Titus T. N. and H. H. Kieffer (2001) 33rd DPS Meeting. [8] Hansen G. B. (1997) *JGR 102,* 21,569. [9] Roush T. et al. (1991) *Icarus 94,* 191.