CURRENT STATUS OF ATMOSPHERIC AND SURFACE RETRIEVALS IN THE MARS POLAR REGIONS. J. Eluszkiewicz and the AER Team, Atmospheric and Environmental Research, Inc., 131 Hartwell Ave., Lexington, MA 02421, jel@aer.com.

Introduction: The Mars polar regions and the global atmospheric circulation are intimately coupled through the CO₂ condensation/sublimation cycle driven by the polar energy balance [1-4]. The caps and the atmosphere also interact on the regional scale [5]. Signatures of these interactions may be expected in the surface and atmospheric properties retrieved from remote sensing observations, but polar retrievals to-date have been somewhat limited in scope. For example, the opacity product in the Planetary Data System (PDS) retrieved from Thermal Emission Spectrometer (TES) radiances is essentially non-existent when the surface temperature drops below about 220 K. This is principally due to the generally small thermal contrast between the atmosphere and the surface, particularly in situations when the surface has near-black-body emissivities [6]. This limitation has been addressed through a modification of the TES opacity retrievals [7], but this modification does not attempt a simultaneous retrieval of atmospheric temperatures, relying instead on the PDS profiles [8]. The latter have been obtained without specifically accounting for either dust or the polar surface emissivities (which are often very different from the non-polar emissivities) and they exhibit little vertical structure (see below). Surface emissivities are also not reported in the retrievals performed from the Planetary Fourier Spectrometer (PFS) data [9]. Polar atmospheric retrievals from the Mars Climate Sounder (MCS) limb radiances are emerging [10], but with a scarcity of concurrent surface observations and without a scattering parameterization.

Simultaneous Atmospheric/Surface Retrievals: In a pilot study [11], we performed simultaneous atmospheric and surface retrievals on a limited number of TES spectra in the northern polar ring data around 87°N during fall and winter. The retrieved quantities were atmospheric temperatures, spectral surface emissivities, and optical depths of atmospheric water ice and dust. For the atmospheric particulates, we ignored scattering, instead using their spectral absorption coefficients available from the PDS [6] and retrieving their optical depth. The impact of neglecting scattering is, in general, not large. For the small dust and ice optical depths we retrieve, the differences between non-scattering radiances and radiances computed using the scattering version of our radiative transfer code [12] are, on average, within the instrument noise level.

Figure 1 shows the atmospheric temperature profiles retrieved for locations characterized by near-unity emissivities (“low-BD₂₅” [13], panel a) and the so-called “cold spots” (“high-BD₂₅”) where emissivities are significantly lower than unity (panel b). Since cold spots are usually attributed to the occurrence of snowfall [5, 13-18], it is encouraging to see that the associated temperature profiles do fall below the CO₂ condensation line (plotted in green in Figure 1) more often than in the “low-BD₂₅” locations (where the CO₂ frost is likely to form directly on the ground). The super-saturated region in Figure 1 is confined to the lowest 20 km, consistent with the altitude range of previous detections of CO₂ clouds [19, 20].

![Figure 1](image_url)

Figure 1: (a) and (b): Atmospheric temperature profiles retrieved using AER’s algorithm for the low and high BD₂₅ spectra. (c) and (d) Their PDS counterparts. The solid red lines represent the mean retrieved profile in each case, while the green lines represent the profile of the CO₂ condensation temperature. For our profiles, the dashed blue and red lines represent a priori and a posteriori errors, respectively, around the mean profile.

The shape of our retrieved profiles in Figure 1 exhibits a warming between 1 and 0.1 mbar. While the reality of this shape is somewhat questionable, given the limited number of degrees of freedom and a very coarse vertical resolution [11], the small a posteriori errors in this altitude region indicate that the warming is real. The qualitative aspects of the shape in our temperature profiles around 1 mbar are consistent with the newest GCM runs that take into account interplays between cloud microphysics, convection, and large-scale dynamics [21]. Furthermore, the polar warming has also been detected in the PFS and MCS retrievals [9, 10], albeit without evidence of supersaturation and at somewhat greater heights (0.1 vs. 1 mbar).

For comparison, in panels (c) and (d) of Figure 1 we show the corresponding TES temperature profiles available from the PDS. As in our retrievals, the PDS profiles are generally colder for high-BD₂₅ locations,
but are significantly more linear above 1 mbar, particularly over the cold spots.

Of particular interest to the polar energy balance studies are the retrieved surface emissivities, shown in Figure 2. As expected, for the cold spots the emissivities do deviate significantly from unity in the 25-micron (400 cm⁻¹) "transparency band" of solid CO₂ [22] and their spectral shape is qualitatively consistent with simulated snow emissivities [16]. In contrast, for the low-BD₂₅ spectra, the retrieved emissivities are flat, but significantly less than unity (0.8-0.9), which is not supported by modeling. The cause of these spectrally uniform deviations from blackbody behavior remains to be investigated, but they might be caused by systematic errors not accounted for in our retrieval (with a zero-radiance-level correction applied to the TES spectra [13], the retrieved emissivities are somewhat closer to unity [11]). In any case, a comparison between the magnitudes of the a priori and a posteriori errors in Figure 2 reveals that there is enough information in the TES radiances to reduce the a priori errors on surface emissivity significantly. Furthermore, the estimated number of degrees of freedom is unity at each emissivity spectral point within the range shown in Figure 2, underscoring the ability of the retrieval to “move away” from the a priori. The retrieved dust opacities are generally low [11], consistent with the “flushing” of the wintertime polar atmosphere by precipitating snow, with a hint of lower opacities in the high-BD₂₅ case (suggesting more active flushing in the putative snowfall locations).

Future Plans: We plan to extend the study described in [11] to a comprehensive sample of TES polar measurements and establish the reasons for the AER/PDS differences via a detailed intercomparison of the respective retrieval algorithms (the PDS algorithm has been kindly provided by Michael Smith). We will attempt to remove the remaining artificial deviations from blackbody behavior by retrieving empirical correction factors necessary to yield blackbody emissivities while constraining Tskins to be close to Tfrass and fitting these factors using the correction software developed by Joshua Bandfield. The retrieved cap emissivities will be compared with frost emissivity models [13, 16, 23] and their (and the associated atmospheric temperatures’) spatial distribution and evolution used to provide insights on the frost formation mechanisms. The development of a limb-scattering code for Mars is also underway [24] and this will enable a quantitative assessment of scattering effects on the limb retrievals. Eventually, the new retrievals (both polar and non-polar) will be utilized in the Mars Data Assimilation System being developed at the University of Maryland.

Figure 2: Seasonal cap emissivities retrieved from TES spectra. The red solid and dashed lines represent the mean retrieved emissivity and its a posteriori errors and the blue solid and dashed lines represent the a priori emissivity and its errors.

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