Characterizing Reflectance Spectra of the Perennial Martian South Polar Cap via Radiative Transfer Modeling, A. E. Covington¹ and W. M. Calvin², ¹Dept. of Physics, University of Nevada, Reno, NV 89557 (avacovington@nevada.unr.edu), ²Dept. of Geological Sciences, University of Nevada, Reno, NV 89557 (wcalvin@unr.edu).

Introduction: The south polar ice cap of Mars is composed of dynamic ice deposits of water ice and CO₂ ice, which vary year-round with atmospheric processes and seasons [e.g. 1].

Each winter, CO₂ from the atmosphere condenses onto the south polar cap, and during the summertime, this seasonal CO₂ ice sublimes. Some of the CO₂ ice on the south polar cap is perennial, and lies atop and among complex layers and/or intimate mixtures of H₂O ice and non-ice surface material (Fig. 1, [1]). The exposed layer of perennial CO₂ ice is often referred to as the south polar residual cap (SPRC). As seasonal CO₂ ice begins to recede in early spring and until deposition begins again at the onset of autumn, parts of the SPRC become visible. Water ice has been identified in exposures surrounding the perennial CO₂ ice [3-5], leading to an inferred stratigraphic or “layer cake” model of CO₂ over water ice.

Recently, Cartwright et al. [6] utilized reflectance spectra from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) to map observations of the SPRC from Mars Years 28-33. They unexpectedly found CO₂ ice signatures extending beyond the bright residual ice and into surrounding material after seasonal frost removal in late summer. These results indicate that a “layer cake” model may not be sufficient to describe the distribution of ices in the SPRC. To better understand the composition of these ices, we use a forward radiative transfer model to constrain the grain sizes and fractional abundances of materials within the ices. Understanding the variation in composition between observed spectra will ultimately help shed light on the history of perennial CO₂ ice, and how atmospheric processes play a role in its evolution.

Radiative Transfer Modeling: In Cartwright et al. [6], 21 spectral endmembers were identified, representing a range of CO₂ ice, H₂O ice, and non-ice material mixtures. It is generally assumed that the non-ice material should be similar to airfall dust that is ubiquitous on the planet. Thus the term “dust” is commonly used for non-ice endmembers in theoretical models. The suite of 21 spectral types could be modeled using a linear combination of 5 endmembers (Figure 2), which were identified as seasonal CO₂ ice (C1), residual CO₂ ice (C6), dust (Dw1), and water ice with varying albedo (W1, W3).

Figure 1: The south polar ice cap of Mars as seen by the Mars Global Surveyor Mars Orbiter Camera [2]. A is high albedo CO₂ ice, B is water ice, and C is the surface of the polar layered deposits without ice signatures.

Figure 2: Spectra of five endmembers that can be used in a linear combination to recreate the 21 spectral types outlined in [6]. C1, C6 are CO₂ dominant, W1, W3 are H₂O dominant, and Dw1 is dusty water ice.

We have been using a Hapke radiative transfer model [7] and Matlab code modified from [8] to match the albedo and absorption features of each of these 5 endmembers to constrain the fractional abundances and grain sizes they contain. Grain size values used for the model were initiated using values from prior work [4, 9-12]. Here we focus on CO₂ endmembers C1 and C6.
Results: In contrast to prior studies, preliminary fits find a small grain size and high fractional abundance of water ice provides the best match to endmembers C1 (Fig. 3) and C6 (Fig. 4). Glenar et al. [10] used a grain size of 10-15mm for CO$_2$ ice, whereas others have found a CO$_2$ grain size ranging from 5-6.5mm, and an H$_2$O ice grain size of 200-300 micrometers [3, 4, 11]. In general, we find that a slightly smaller CO$_2$ grain size from 2-6mm works well. No prior model uses more than 0.006 wt% of water at grain sizes < 150 micrometers, but our models consistently use a much higher abundance of H$_2$O (4-30%) and smaller grain sizes on the order of tens of micrometers.

For C1 and C6, we have been able to match the overall reflectance level and the strength of the 2.3 µm doublet. Increasing the fractional abundance of water decreases the slope of the spectrum in from 2.25-2.5 µm, as well as pulling down the 1.5 µm region and diminishing the reflectance of between 2.75 and 3.35 µm. Note the model has had difficulty matching the reflectance level <1.35 µm, as well as >3 micron and most CO$_2$ features are still too strong.

In particular, subtle changes in slope between 3 and 3.6 µm suggest the need to revise the optical constants for Martian dust, which is the primary contributor to these regions. In [4] they used an area of the polar layer deposits without ice signatures as a “dust” model end member. Similarly we have extracted this type of spectrum from CRISM and are in the process of deriving new optical constants and updating the Hapke code. We will present our most up to date results at the meeting.

C1 Endmember Model

Figure 3: C1, which is the purest CO$_2$ endmember (orange), along with its model (yellow). The absorption feature at 1.4µm and 2.3 µm doublet are characteristic features of CO$_2$ that have been mapped well using the model. In the upper right corner, grain sizes and fractional abundance used for the model are listed.

C6 Endmember Model

Figure 4: C6, the most water-rich CO$_2$ endmember (dark blue), along with its model (light blue). In the upper right corner, grain sizes and fractional abundance used for the model are listed.

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