ANALYSIS OF MARS 1986 SEASONAL SOUTH POLAR CAP SPECTRUM

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During telescopic observations of Mars made in 1986 a spectrum was acquired of high southern latitudes in the 2.2- to 4.2 $\mu$m wavelength range [1,2]. This observation was made 7-8 June, 1986 at the NASA IRTF on Mauna Kea, during early martian southern spring ($L_s = 183^\circ$-$184^\circ$). A circular aperture 1.46 arc seconds in diameter was used. The observations have been absolutely calibrated to radiance factor [2]. Based on visual observation and eyepiece video recordings this observation sampled from about 50°S, near the northern edge of the seasonal south polar cap, to about 70°S, well within the seasonal cap. These positions are in good agreement with independent observations of south polar cap retreat in 1986 [3]. Since the seasonal cap is believed to be composed predominantly of CO$_2$ ice [e.g. 4,5,6,7,8] one would expect to identify spectral features due to solid CO$_2$, such as previously reported [e.g. 4,5]. Both terrestrial and martian atmospheric absorptions prevent measurements near 2.7 $\mu$m where CO$_2$ ice would exhibit its strongest absorption in our wavelength range [9,10]. However, there are other narrow strong absorptions of CO$_2$ ice in the wavelength region sampled, most notably a feature near 3.34 $\mu$m [3,4,9,10]. Yet our telescopic spectrum, shown in Figure 1, does not exhibit any observable feature at this wavelength.

The absence of a diagnostic CO$_2$ ice absorption is most likely indicative of a masking effect by one or more seasonal polar cap constituents, either coating the top of the CO$_2$ or intimately mixed with it. The first possibility was recently considered by Warren et al. [11], where a thin H$_2$O ice layer overlies a substrate composed of CO$_2$ ice. Their results indicate that a monolayer of 20$\mu$m-diameter H$_2$O spheres readily masks the 3.34 $\mu$m feature. It is not known whether their model can adequately match other aspects of our observed spectrum. For example, their results for the 20$\mu$m H$_2$O spheres exhibits a stronger 2$\mu$m H$_2$O ice band than the telescopic spectrum. In the second scenario we consider particulate surfaces where the individual components are physically admixed (i.e. intimate mixtures). In this modeling we have relied upon Hapke's treatment of the scattering of light by particulate surfaces [12,13]. We assume isotropic scattering of all components. Additionally, the reflectance of the mixture is calculated relative to a lambert surface with a reflectance 1.0, and both surfaces are viewed at 0° phase angle. We have included both two-component (H$_2$O and CO$_2$ ice, and palagonite and CO$_2$ ice) and three-component mixtures (H$_2$O ice, palagonite, and CO$_2$ ice). We used optical constants of H$_2$O and CO$_2$ ice from the literature [9,14]. We derived the optical constants of palagonite from its measured reflectance via Hapke's theories [15]. The palagonite is a fine-grained separate of weathered soil from Mauna Kea and has visible and near-IR reflectance similar to martian dust [16,17]; it is used here as a somewhat generic hydrated-silicate dust analog.

We investigated a range of both the abundance and particle diameter of the components in a mixture. Grain diameters were varied from 1 to 100$\mu$m for H$_2$O ice, from 1 to 1000$\mu$m for CO$_2$ ice, and from 1 to 5$\mu$m for the palagonite. The spectral behavior beyond 3.6 $\mu$m is poorly reproduced by any calculated mixture. This is not surprising as our models assume only reflected energy is contributing to the measured flux, whereas on Mars the thermal component becomes increasingly important at the longer wavelengths. Nevertheless we find it relatively easy to mask the 3.34 $\mu$m CO$_2$ ice feature with minor abundances of the other materials, and to simulate the general shape of our telescopic observation (see Figure 2).

In conclusion, we find that the absence of the diagnostic 3.34 $\mu$m CO$_2$ ice absorption in the telescopic spectrum of the seasonal south polar cap on Mars can be readily explained by the presence of additional components. This feature could be masked by either a thin layer of overlying H$_2$O ice, or by admixture of minor amounts of palagonite or palagonite and H$_2$O ice in the predominantly CO$_2$ cap. While admixture of water ice alone can mask the 3.34$\mu$m feature, palagonite (or perhaps some other hydrated silicate) appears necessary to properly reproduce the general observed spectral shape. Conversely, we can infer that when the 3.34$\mu$m CO$_2$ absorption has been previously observed for the S. polar cap [4,5] the CO$_2$ surface was quite free of dust and/or water ice contaminants.
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