ALBEDO OF SURFACE CO2 DEPOSITS IN MARS' RESIDUAL SOUTH POLAR CAP

P.B. James, Space Science Institute, Boulder, CO (pjames@cableone.net), **M.J. Wolff**, Space Science Institute, Boulder, CO, B. Bonev, CUA, Washington, D.C.

The existence of residual or perennial polar caps on Mars has been known for many years, starting with telescopic observations. Viking data determined that the residual south polar cap (RSPC) consists mostly of solid carbon dioxide (Kieffer, JGR 84,1979). The albedo of the surface CO_2 deposits controls directly whether there is net condensation or net sublimation of the surface frost deposits over a martian year and is therefore the crucial factor in determining the stability of the RSPC.

The observed "albedo" referenced in most previous analyses is the Lambert albedo, obtained simply by dividing I/F, determined from radiometrically calibrated imaging data, by the cosine of the incidence angle. This has the benefit that the Bond albedo, which is the factor that enters into energy balance, is equal to the measured Lambert albedo. The assumption that the surface phase function is that of a Lambertian diffuse reflector is undoubtedly only an approximation for real CO_2 frost deposits. More crucial is the fact that the measured I/F is at the top of the atmosphere, after radiation has passed through the atmosphere twice (i.e., not at the surface), and is not therefore the true surface albedo that enters into stability considerations. It differs from that quantity primarily due to the effects of atmospheric aerosols, which are quite variable.

The goal of this work is to determine the Lambert albedo of the surface of the RSPC during the summer season. We use spacecraft measurements of I/F (MARCI) and dust opacity (CRISM) as input to the discrete ordinate radiative transfer program DISORT (Stamnes et al., App Optics 27, 1988). Mid summer data from L_S=290° to L_S =330° in MY 28 and MY 29 are used here. No data exist after L_S = 325° in the latter year because of an extended MRO safing event; additional CRISM data in MY 30 have not yet been included in the analysis. We have also assumed the absence of atmospheric water ice in the RSPC region. Modeling of the CO_2 ice surface albedo by the late Gary Hansen (Bonev et al., P&SS 56, 2008) indicates that for visible wavelengths larger than 600 nm the albedo is between 0.8 and 0.9, depending on the grain size of the CO_2 and on the amount of dust contamination. The albedo values decrease at shorter wavelengths, with the precise behavior strongly dependent on the aforementioned parameters.

We used CRISM emission phase function (EPF) sequences to determine the optical depth histories of the RSPC in MY 28 and 29. The methodology that we have adapted for the retrieval of the dust column-integrated optical depths is based on that developed by Wolff et al. (JGRE 114, 2009). While the primary application in that work is the characterization of dust optical properties during the 2007 planet encircling dust event, a generalization to more diffuse loading cases is included. When this algorithm is applied to the EPF sequences from early November 2006 through December 2011, one obtains a database of approximately 24000 optical depth values. The database optical depths are referenced to a wavelength of 900 nm and a surface elevation of 0 m, i.e., the areoid. We corrected for topography using the Mars Orbiter Laser Altimeter topography (Smith et al., JGR 108, 2001) and the assumption of an exponential atmosphere with a scale-height of 10 km. The uncertainty associated with the dust optical depth for an individual bin is estimated to be max($0.1\tau_{dust}$, 0.1), which includes both the accuracy of the retrieval process and the scatter associated with multiple retrievals points in the bin. Retrieved opacities (at 900 nm) in MY 28 and My 29 are shown in Figure 1. The effects of the large dust storm in MY 28 are clearly visible.

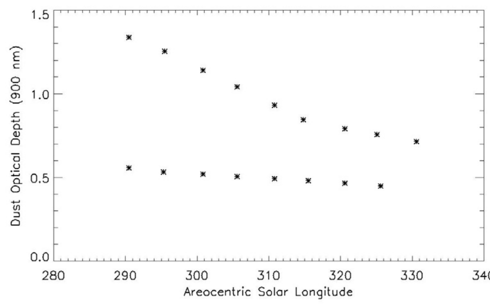

Figure 1: Dust optical depths in MY 28 (top) and MY 29.

Although there are no retrievals over ice-covered surfaces in the current version of the database, the small size of the RSPC encourages us to determine optical depths over the cap using those from the non-frost covered regions adjacent to it. The opacity employed in the atmospheric correction of the RSPC albedo values includes explicitly the enhanced elevation of the RSPC relative to the rest of the South Polar Region. This involves using the program DISORT to create surface albedo maps from the calibrated MARCI images. Figure 2 shows the retrieved albedos as well as the uncorrected

Lambert albedos -- (I/F)/cos(ina) -- for MARCI band 5 (725 nm) during the two Mars years.

The retrieved surface albedos in MY 28 and 29 are very similar despite very different histories of dust opacity in the two years. The high albedo at 725 nm in early summer is consistent with a fairly pure CO_2 surface with little dust contamination. A decrease in the surface albedo as the season progresses is consistent with an increase in the fraction of the roughly 100 km^2 test region in which the frost has totally or partially sublimed.

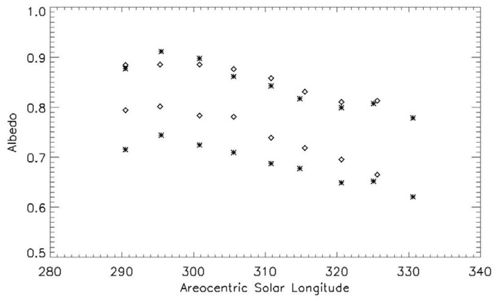

Figure 2. Albedos calculated from images that have been corrected for dust are shown for MY 28 (*) and MY 29 (diamonds). The bottom two curves show the albedos before dust effects have been removed.

I/F can be obtained from MARCI images in five visible wavelengths: 425 nm, 550 nm, 600 nm, 650 nm, and 725 nm. The 425 and 550 bands fall into the region where models of CO2 albedo indicate a rapid decrease. We find two very different behaviors for the wavelength dependence shown in Figure 3. The behavior at later values of Ls (right) is similar to the model predictions. But the albedo behavior of the short wavelength bands at earlier Ls is very different. With the prescribed dust opacity, the model requires cap albedos greater than 1.0 to reproduce the observed I/F. The similarity between MY 28 and MY 29 shows that this systematic bias is related to season and is not simply an error associated with the dust opacity. Specifically, our model is "missing" radiance at these shortest wavelengths in early summer. We studied the effect of using a slightly higher dust single scattering albedo in the blue to produce greater brightness due to the dust; this changes the recovered albedo in the right direction but by an insufficient amount. It seems more likely to us that our assumption that water ice opacity is negligible is incorrect. Clarification of the precise nature of this issue is ongoing.

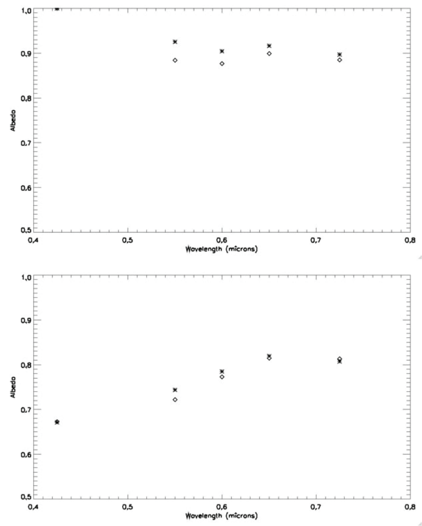

Figure 3: Albedos in the five visible MARCI bands for Ls = 300° (top) and 325°. Data are shown for MY 28 (*) and MY 29 (diamonds).

This work is supported by the Mars Data Analysis Program.