Evidence for the Possible Accumulation of Ice at the North Pole of Mars

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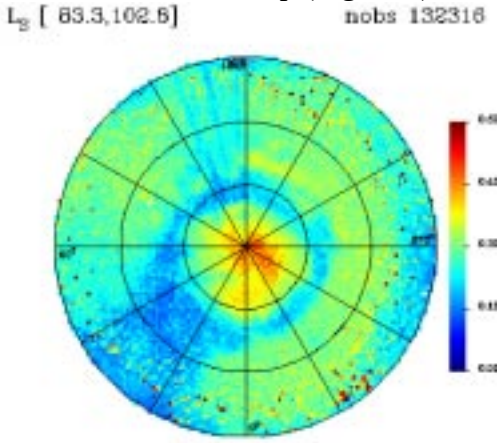
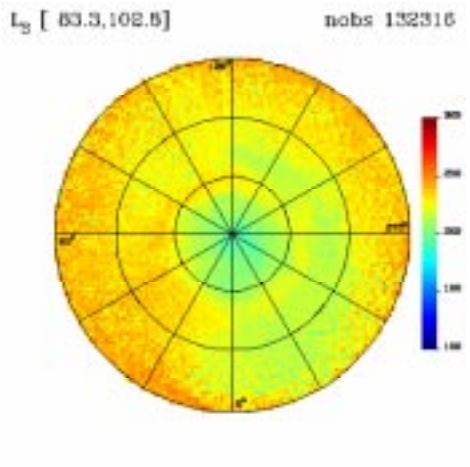
We have examined Viking Orbiter albedo, thermal, and atmospheric water vapor data acquired during Mars' northern summer season and compared these results with the imaging data from Mariner 9 and Viking Orbiters. Our results suggest that active seasonal processes have macroscopic effects that are observable from orbit. Albedo and imaging data suggest that the cap center has somewhat different characteristics than the cap edges. The maximum observed brightness of the peripheral regions examined was significantly lower than albedos measured at the center of the residual cap (Fig. 1, 2).



a)



b)

Figure 1. a) IRTM albedo map showing bright ice cap center and darker cap edges. b) IRTM t_{20} surface temperature data showing that carbon dioxide was not stable at this time in the summer season. "Nobs" refers to the number of observations present in each map. Map shows data binned in areocentric solar longitude. Data are binned in 2 degree by 2-degree intervals. Albedos range from 0.12 (blue) to 0.60 (red). T20 values range from 100 K (blue) to 300 K (red).

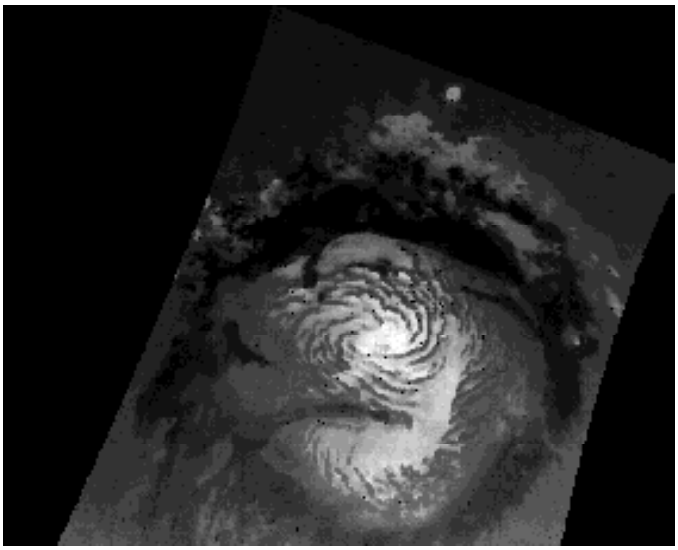


Figure 2. A Mariner 9 Orbiter wide angle image of the north polar region of Mars, acquired at L_s

= 101 in 1972 (668A10). Image is polar-projected and was corrected using a model Lambertian photometric correction function.

Because we find that the cap center always remains brighter than the cap edges, we believe the cap center is a region of active water ice accumulation due to cold trapping. Although there is no definitive evidence regarding ice flow in the northern hemisphere of Mars, Mars Orbiter Laser Altimeter data indicate that the cap center is the highest portion of the cap [1]. Therefore, if any regions are accumulating annual layers, the cap center is the most likely location. We also point out that the cap center has a favorable energy balance with respect to accumulation due to the increased brightness. [2] mapped the apparent thermal inertia and albedo of the north polar region of Mars. In the thermal inertia maps, the cap center at 90N, 250 - 270W has a lower thermal inertia than the surrounding portions of the cap. A lower thermal inertia indicates smaller or less annealed ice grains, which is consistent with the interpretation of younger, accumulating ice at the cap center.

We have assessed the amount of bright water ice that could account for the brightening in the late summer of the residual north polar cap. We used observed albedo data in conjunction with calculations using Mie theory for single scattering and a delta-Eddington approximation of radiative transfer for multiple scattering. For an optically-thick deposit, the minimum possible thickness can be determined from its albedo using radiative transfer theory if the particle sizes of the ice and dust are known. The brightened regions most likely consist of young ice deposited late in the summer. This indicates that the ice must be relatively fine-grained, but to produce the observed cap albedo, it must also be relatively dust-rich [e. g., 3]. To produce such an albedo change, the cap surface must be relatively smooth; highly varying topography would produce patchy ice coverage on observable lengthscales. We suggest that the late summer cap albedo increase could have been produced by a minimum of 10's of precipitable microns of ice and dust deposited on the surface. MAWD water data indicate that the martian atmosphere held an average of 10 pr μm. Therefore, it is plausible that the water vapor observed in the atmosphere in the MAWD data condensed as surface temperatures decreased in the summer season.

[1] Zuber *et al.*, 1998. *Science* **282**, 2053-2060; [2] Paige *et al.*, 1994. *J. Geophys. Res.* **99**, 25959 – 25991; [3] Kieffer, 1990. *J. Geophys. Res.* **96**, 1481 - 1493.