MARS POLAR COLD SPOTS OBSERVED BY MRO/MARS CLIMATE SOUNDER.

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Introduction: Using radiometric observations from the Mars Climate Sounder during southern winter, we report evidence that the brightness temperatures of polar cold spots (T_b < 135 K) at Mars' south pole are correlated with tropospheric, optically thick clouds. In limb observations coincident with nadir measurements of low brightness temperature regions, clouds appear as diffuse warm areas relative to the background. Using statistical methods, we confirm that transient cold spots appearing during polar night are correlated with the formation of clouds above the surface, which are likely composed of CO_2 ice. Areas where cold spots persist over the full range of solar longitude are also characterized by persistent clouds, the thickness of which is inversely correlated with nadir brightness temperature.

Theories of Cold Spot Origins: Since their discovery during the Viking era, radiometrically cold areas (below the CO_2 equilibrium temperature of ≈148 K at 6 mb atmospheric pressure) within the polar regions during the depths of winter have remained an enigma. Three primary explanations have been explored previously [1]:

(1) Depletion of atmospheric CO_2: Condensation of carbon dioxide could lead to enrichment in non-condensable phases, lowering P_{CO2} and allowing lower equilibrium surface temperatures [2].

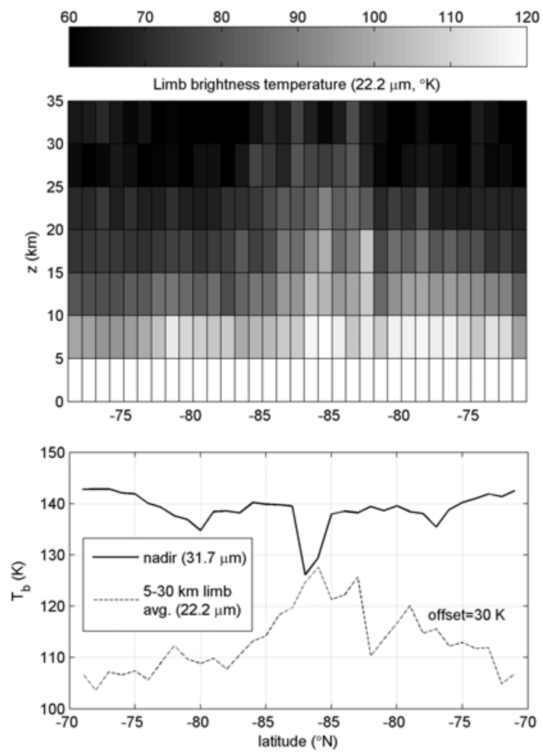
(2) Non-unit emissivity of surface CO_2: Formation of frost or freshly condensed snow could lower the emissivity of the surface [3].

(3) Carbon dioxide clouds: Optically-thick CO_2 clouds could result in lower measured brightness temperatures, as the cloud condenses at a lower atmospheric temperature and pressure above the surface [4, 5].

Instability to pressure gradients on relatively short time scales suggested by Hess [6] demonstrated that *(1)* is feasible only under very special circumstances. The spectral properties of CO_2 frost and clouds are similar such that it has been difficult to discriminate between *(2)* and *(3)* as viable hypotheses. In the present investigation, we use radiance measurements of both the atmospheric limb profile and nadir to better constrain the possible origin of the polar cold spots.

Observations of Cold Spots: The Mars Climate Sounder onboard the Mars Reconnaissance Orbiter (currently in orbit at Mars) recorded a series of nadir and limb radiance measurements in nine spectral channels, from ~1–40 μm wavelength. The observations used in this study spanned a range of solar longitude, L_s = 111 to 148, corresponding to southern winter. Radiances are converted to equivalent brightness temperatures using the radiometric response function of each filter and the Planck function. Observations are binned by latitude and longitude (1–5° bins) and L_s, and nadir brightness temperatures are compared to measured limb brightness temperature profiles. Figure 1 shows the correlation between clouds and nadir cold spots.

Figure 1



Results: We plotted limb brightness temperature profiles for the A5 channel (22.2 μm) for areas where measured nadir brightness temperatures (within three degrees of L_s) dropped below 137 K (or 140 K) in the B1 (31.7 μm) channel. Figure 2a compares these limb profiles (blue; shaded area indicates 1σ) to measurements at the same location, but during the period of maximum temperature for that spatial bin (red). During the period when the cold spot is present in the nadir data, brightness temperatures rise significantly at ~20–30 km altitude. This is interpreted as a cloud, whose brightness temperature in the nadir is indicative of the altitude of optical depth ~1, several kilometers above the surface. Figure 2b shows the location of the cold spots for each of the two cutoff temperatures.

Statistical analysis shows that the 22-μm brightness temperatures at ~30 km altitude are inversely correlated (R=-0.55, $p<10^{-14}$) with nadir 32-μm brightness temperatures (Fig. 2). A thorough analysis was performed to exclude any field-of-view effects due to surface radiance. We therefore conclude that the systematic increase in limb radiance is due to the presence of optically-thick clouds, likely composed of CO_2 ice particles.

Discussion and Future Work: Our results show that the brightness temperature of polar cold spots viewed from above correlates well (inversely) with the presence of clouds viewed at the limb. As discussed by other authors [1], this observation does not rule out the possibility of surface emissivity effects playing a significant role as well. The present work will be extended to include modeling of the effects of various scenarios on the radiances measured by MCS, in each of the available spectral channels. Implications for the global energy balance and seasonal deposition of carbon dioxide will be explored.

References: [1] Forget et al. (1995) *JGR 100*, 21,219. [2] Kieffer et al. (1977) *JGR 82*, 4,249. [3] Ditteon and Kieffer (1979) *JGR 84*, 8294. [4] Hunt (1980) *GRL 7*, 481. [5] Paige et al. (1990) *Bull. Am. Astron. Soc. 22*, 1075.

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