CO_2 Cycle: Two Martian Years of Polar IR Observations.

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Introduction: One-quarter of the Martian atmosphere is cycled through the polar caps,[1] condensing out in the fall and winter and sublimating in the spring and summer. This process of CO_2 exchange between the polar caps and the atmosphere dominates the current Martian climate.

The Mariner 9 and Viking missions significantly improved our understanding of polar processes and composition.[2] Perhaps the greatest result of these missions was the discovery of how little we actually knew about the Martian polar caps and the CO_2 cycle. Several of the questions raised by these early space missions are yet to be resolved. However, in 1997, Mars Global Surveyor (MGS) entered Mars orbit with the promise of answering old questions and raising several new ones. On board MGS was the Thermal Emission Spectrometer (TES). Even before MGS entered mapping orbit, TES was improving our understanding of polar processes, revealing the truly bizarre nature of solid CO_2 under Martian conditions.[3]

Currently, MGS TES has mapped 2 full Martian years of thermal behavior. These two years represent two endmembers of Martian climate behavior, one of the clearest years and one of the dustiest years observed on Mars. Figures 1 and 2 show TES bolometer brightness temperatures for the north and south polar regions. The difference in dust activity between the two years is apparent in Figure 2. An exploration of the defining differences between these two years should reveal clues as how the northern and southern polar processes couple with each other, as well as how seasonal processes couple with subsequent seasons.

CO_2 Snow and Ice: Early TES observations have provided evidence of CO_2 snowstorms,[4] as well as slab ice formations (e.g. the cryptic region[3]). Both winter polar caps are predominately CO_2 slab ice. Cold spots, which are most likely composed of fallen snow, occur mainly on the southern perennial cap and near topographical features on and around the northern perennial cap. We will compare the spatial and temporal distributions of cold spots and slab ice between the two Martian years. The dense repeat coverage of the polar rings[5 6] provides a unique opportunity to constrain the time scales on which cold spots grow and decay.

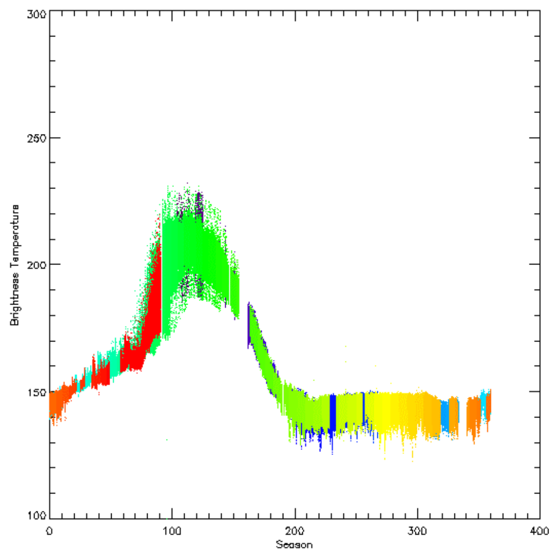

Figure 1: North polar ring TES bolometer brightness temperatures versus season (L_S). The data are color coded on the basis of time. The dark purple color indicates the beginning of mapping orbit, Ls = 104. Green data indicate the end of the first year and the beginning of the second year. The red color data points indicate the most recently acquired data.

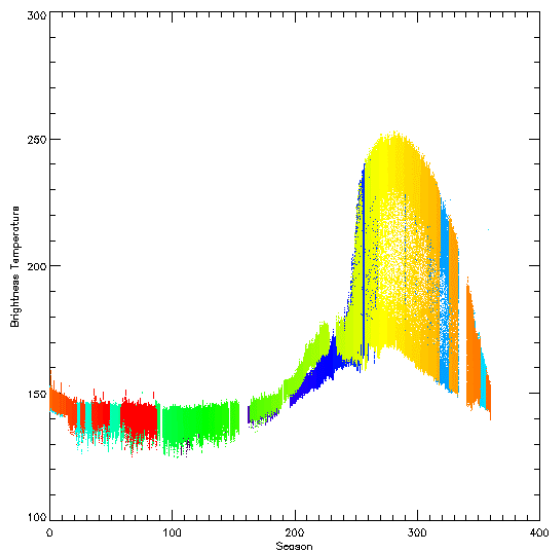

Figure 2: South polar ring TES bolometer brightness temperatures. The color code is the same as in figure 1. The difference in the temperatures between L_S 210° and L_S 240° is the effects of the second year being extremely dusty. The large distribution in temperatures from L_S = 250° through L_S= 350° is due to the polar ring intersection of both dry ice and exposed soil .

Recession Rates: Kieffer et al.[7] initially characterized the south polar recession rate in 1997 by fitting an arctangent curve to the temperature rise that occurs when soil is exposed. The inflection point of the arctangent curve was used to parameterize that season (L_s) when all of the CO_2 has disappeared, referred to as the crocus date. The 1997 analysis used a diurnally corrected 30-µm brightness temperature. For the 1999 and 2001 analysis, the "2 pm" 30-µm brightness temperatures were used. Since 1999 and 2001 data sets were analyzed using the same parameter and the two years represent a clear and a dusty year, we only compare these two years [Figure 3]. Dark areas, such as the "cryptic" region, remain ice covered approximately 4° to 5° of L_s longer in 2001 than in 1999. Bright regions, such as the Mountains of Mitchell, disappear approximately 4° to 5° of L_s sooner. A 10-day change in the crocus date is equivalent to having approximately 12 cm of ice still on the ground.

These observations are quantitatively consistent with modeling done by Bonev et al.[8] that shows the sublimation rate of bright regions is increased by additional downwelling thermal radiation from a hot dusty atmosphere. The sublimation rate of dark regions is depressed from a decrease in visible radiation incident on the surface.

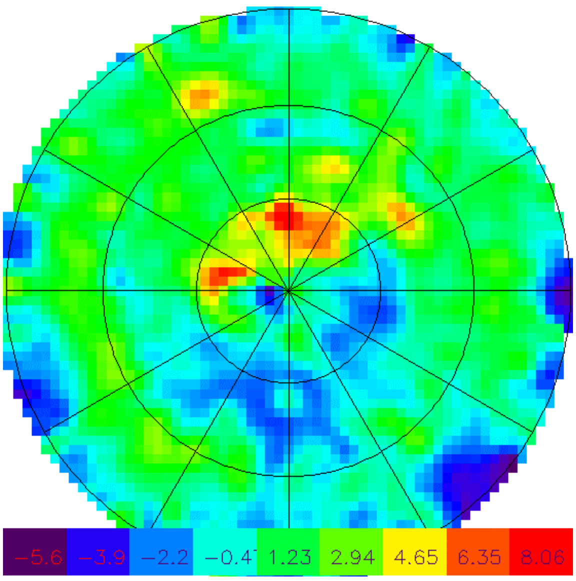

Figure 3: Difference in crocus dates between 1999 and 2001.

Mass Balance Rates: The TES bolometer channels measure the total reflected sunlight and the total emitted energy. These observations provide an excellent estimate of the total radiative balance for Mars at the instant and location of observations. Preliminary studies of mass balance rates using TES data in the north polar region have shown evidence of lateral transport of heat in the atmosphere [Figure 4]. More recent results from mass balance calculations from both the northern and southern seasonal caps will be presented.

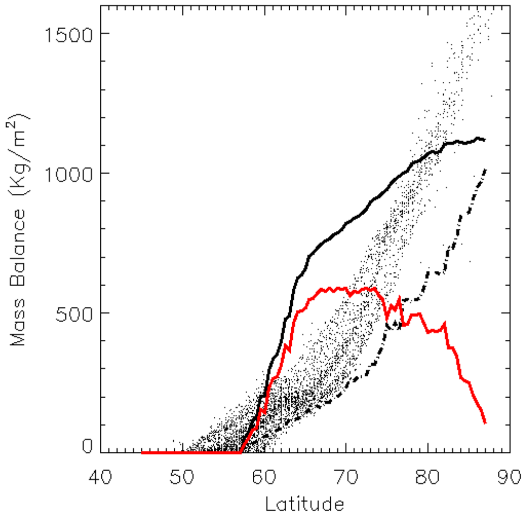

Figure 4: North polar seasonal cap mass budget.[9] The solid line is the condensation budget averaged over longitude. The dash line is the sublimation budget. The red line is the difference between the condensation and sublimation budgets. The dots are the estimated sublimation budget from individual 60km x 60km cells. The mass balance difference between the dashed line (zonal mean) and the dots (60km x 60km cell mean) are because two different methods were used to calculate the date when all of the CO_2 had sublimated.

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[1] J. E. Tillman et al., *J. Geophys. Rev.*, **98**, 10,963 (1993).

[2] P. B. James, H. H. Kieffer, D. A. Paige, The seasonal cycle of Carbon Dioxide in *Mars*, edited by H.H. Kieffer et al., Univ. of Ariz. Press, Tucson, 934, (1992).

[3] H. H. Kieffer et al., *J. Geophy. R.*, **105**, 9653, (2000).

[4] T. N. Titus et al., *J. Geophy. Rev.*, **106**, 23181 (2001)

[5] The polar rings are located under the tangent latitudes of the spacecraft orbit at ± 87˚.

[6] H. H. Kieffer, T. N. Titus, *Icarus*, **154**, 162 (2001).

[7] H. H. Kieffer et al., J. Geophys. Rev., 105, 9653 (2000).

[8] Bonev et al. *GRL*, in press (2002).

[9] H. H. Kieffer, T. N. Titus, *Icarus*, **154**, 162 (2001), Figure 7.