TRENDS IN THE SOUTH POLAR CAP OF MARS. K. N. Winfree[1] and T. N. Titus[2], [1,2] kwinfree@usgs.gov, U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ.

Introduction: Mars has a south polar perennial cap that is probably water ice (H_2O) covered by a veneer of carbon dioxide (CO_2) ice. Previous studies of summer observations of the south polar residual cap suggest that the thin veneer of CO_2 might be disappearing [1]. If indeed the CO_2 is disappearing, this effect should be apparent in inter-annual variation of the residual CO_2 areal coverage. If the areal coverage of the CO_2 ice in the summer is decreasing, this may suggest a warming trend at the south polar cap.

Inter-annual differences in the polar caps have also been observed by both terrestrial telescopes and orbital spacecraft. By analysis of thermal radiance as observed by Mars Odyssey Thermal Emission Imaging System (THEMIS), we are able to estimate the areal CO_2 coverage in mid-summer. By tracking inter-annual differences, we can monitor changes in the areal coverage of CO_2 ice.

Regions of Interest: There are several regions of interest available for observation of changes in either the thin veneer of CO_2 ice, or in the H_2O ice. They are seen in the following figure (1). Regions we selected for contiguous over lap among at least two stamps from two differing years. Stamp pairs (or sets) were also of the same orbit orientation; stamps had to be nearly parallel in order to achieve approximately equal contrast. Additionally, the regions must not be sampled at night, as the thermal contrast at that time is too low to quantify our three basic units of CO_2 and H_2O ice and volatile free regolith. Based on the observed temperatures, we can separate three distinct units as explained in the color/temperature map below.

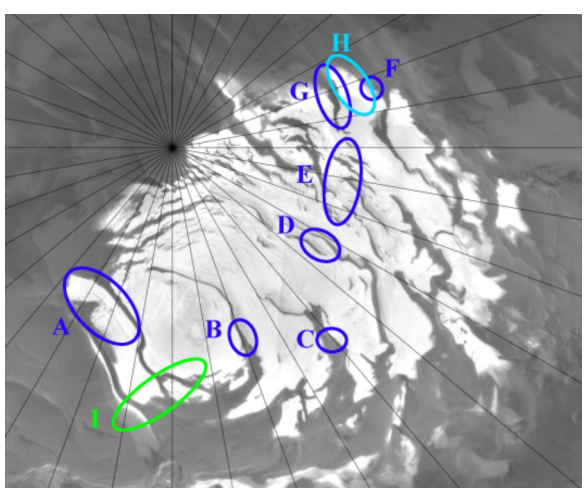

Figure 1: Figure 1: Shown here is the south polar cap of Mars.

All stamps shown below use the above color/temperature scale. CO_2 ice is stable between ~150K and ~165K on Mars (as observed by THEMIS; actually 142 – 148 K). H_2O ice is stable between ~165K and ~195K, though it cannot always be assumed that samples at this temperature imply presence of H_2O ice. Observed temperatures above ~195K are too great for volatiles to be present; these observations can be nothing but regolith.

L_s 320 ± 1° Season of Interest: This L_s is the most telling of our three seasonal samples. There are seven regions of interest. Here we compare THEMIS IR from Mars year (MY [2]) 26 with that of MY 27.

Region A, L_s 320. Two different stamp sets confirm a visible increase in CO_2 coverage in this region. Both show high thermal contrast with very distinct units of CO_2 ice (blue), H_2O ice (green), and volatile free regolith (red).

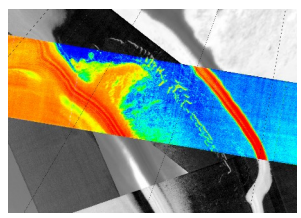

Figure 2.a: MY 26, I08935002

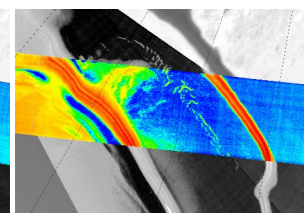

Figure 2.b: MY 27, I17284009

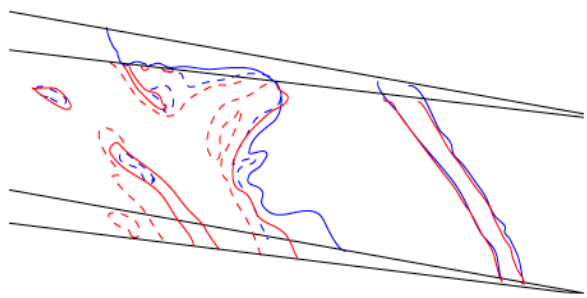

Figure 2.c: As seen here, in MY 27, there was an increase in both CO_2 and H_2O ice coverage. The solid lines outline the H_2O or regolith boundaries with CO_2 ice. Dashed lines outline regolith boundaries with H_2O ice. Years are colored as above, blue is MY 26 while red is MY 27. This standard is used for the remainder of the L_s 320 regional studies.

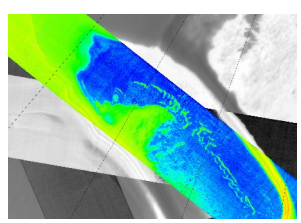

Figure 3.a: MY 26, I08934002

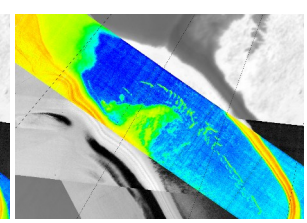

Figure 3.b: MY 27, I17283007

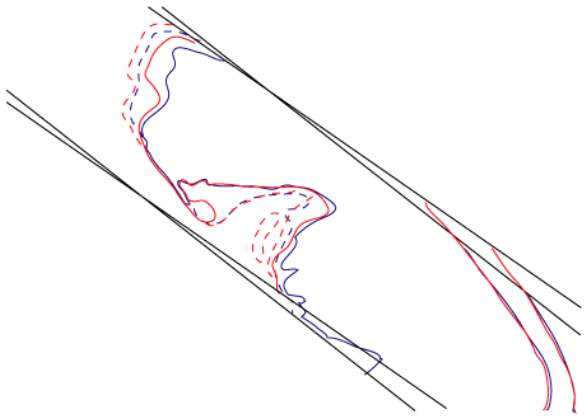

Figure 3.c: Though not as apparent as the previous figure, one can still see significant changes between MY 26 and 27 as outlined here. This is visible in the upper left hand extremities of this image. We can be assured that this is a significant change, and not a change in calibration of the instrument because of the relative increase in contrast as shown in figure 3.b compared with figure 3.a. We see more CO_2 (cold) and more defined hot regolith.

Region B, L_s 320. Though it does appear that we see a minor increase in H_2O coverage in region B, because of the low contrast and time of day as imaged here, we cannot confirm such changes. The same applies for region D (not shown).

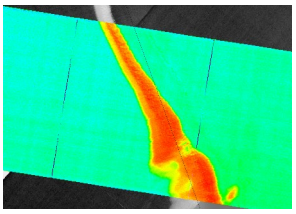

Figure 4.a: MY 26, I08935002

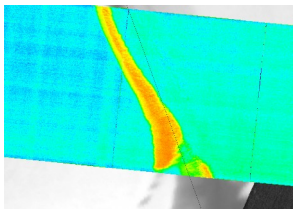

Figure 4.b: MY 27, I17284009

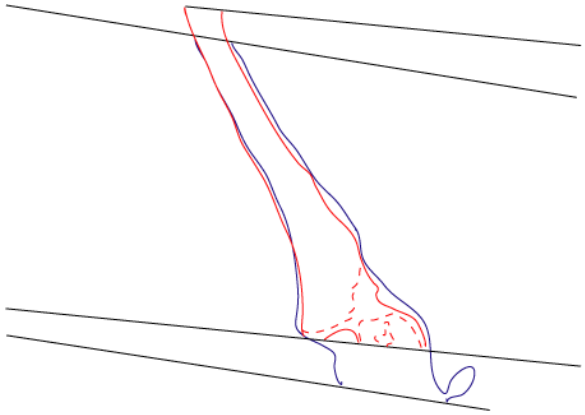

Figure 4.c: Though the outlines do suggest a change in areal coverage of suspected H_20 ice, we cannot confirm this localized effect. Figure 4.b is regionally cooler than figure 4.a, suggesting that any trends shown here may be superficial artifacts of instrument calibration.

Region C, L_s 320. Although this region does show an overall decrease in temperature, the observed changes to the interior region as outlined with dotted red lines in the middle of figure 5.c are dramatic enough that we likely do see an increase in CO_2 and H_2O coverage. The transition in that area is that from volatile free regolith to that of volatile present H_2O and/or CO_2 ices. The transition shows at least a 30K change, while the other areas in these images show no more than a ~8K change.

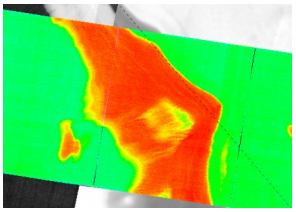

Figure 5.a: MY 26, I08935002

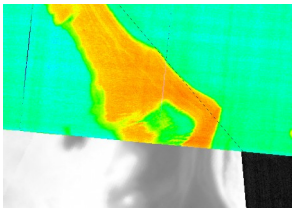

Figure 5.b: MY 27, I17284009

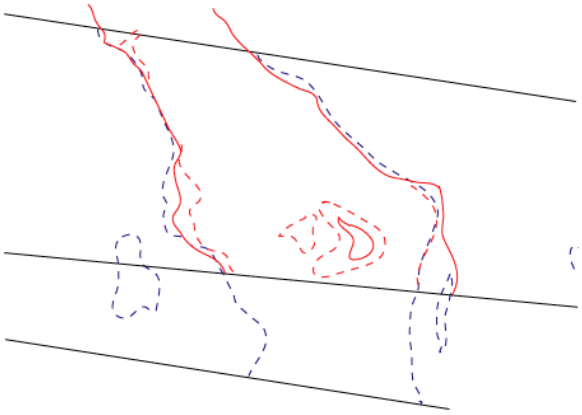

Figure 5.c: A significant increase in H_2O and CO_2 coverage is outlined by dotted red lines in the middle of this figure. The magnitude of this changes suggests that this effect may be real, and not an interseasonal or calibration effect.

Region E, L_s 320. Still in the interior of the cap, we do not see any significant changes in this region. The abundant selection of scarps, coupled with the lack of changes, gives strong reason to believe that changes to the ice coverage in this region are minimal if not nonexistent. This may suggest that the interior regions of the cap do not change much laterally, but rather that the depths of the ices are the most dynamic components. THEMIS IR images however do not resolve the ice structure depths.

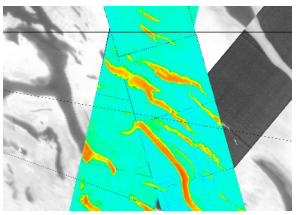

Figure 7.a: MY 26, I08939002, I08938002

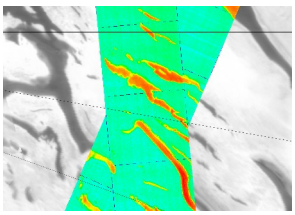

Figure 7.b: MY 27, I17300009, I17299007

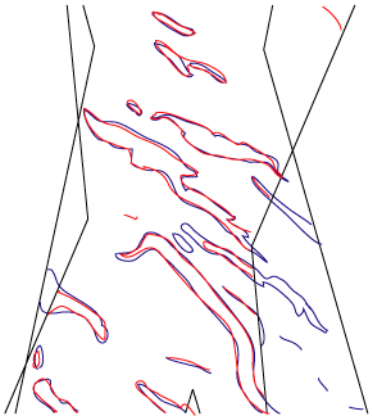

Figure 7.c: Though a few areas in MY 26 may have more defined H_2O ice coverage, over all, the two years show no signs of change.

Region F, L_s 320. Region F is probably the most pronounced of all the regions. Though the changes are dramatic enough that confirming registration is difficult, yet we can be assured by the rest of the image (not shown) that these are indeed aligned. This region is on the exterior edge of the cap.

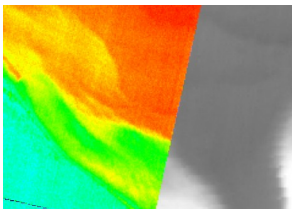

Figure 8.a: MY 26, I08939002

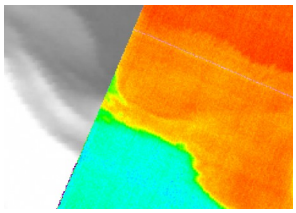

Figure 8.b: MY 27, I17299007

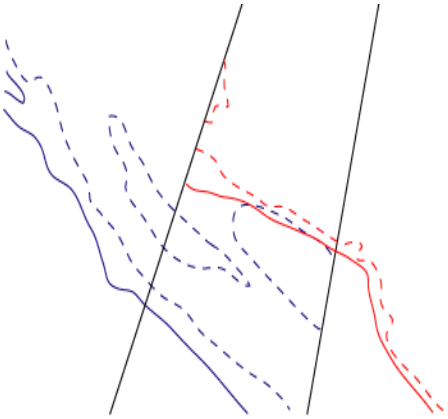

Figure 8.c: Here we have a decrease in H_2O islands, and an increase in overall CO_2 coverage.

Region G, L_s 320. Region G is also on the exterior edge of the cap. Just like regions A and C, ice coverage changes are visible between MY 26 and 27. At first look, it may appear that image I17300009 (MY 27) is colder overall, but analysis of the regolith peninsula shows that the whole image is not colder after all. Had the image been colder, we should have seen a change in the temperatures on that peninsula. Figure 9.c additionally shows that the peninsula does not change shape as significantly as the area towards the top of that figure.

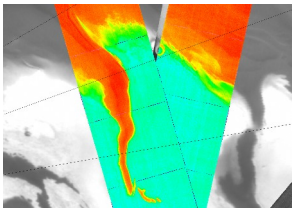

Figure 9.a: MY 26, I08939002, I08938002

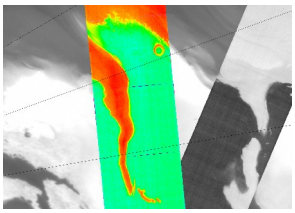

Figure 9.b: MY 27, I17300009

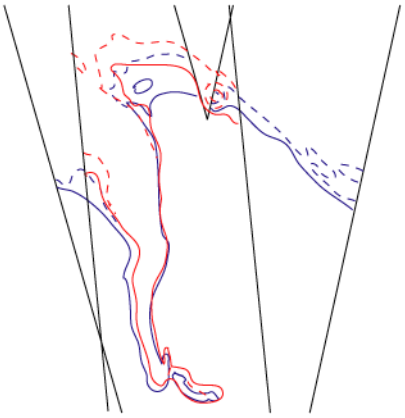

Figure 9.c: A significant change in ice coverage is visible at the top of this figure, while the regolith peninsula in the middle to bottom of the figure does not significantly change between the MY 26 and 27.

L_s 331 ± 1° Season of Interest: Data for MY 25 at L_s 331 is very limited. As such, only one region is appropriate for study. This region contains a single stamp from MY 25, with only one suitable partner from MY 27. No significant difference in ice coverage is apparent. It is however apparent that L_s 331 for each of these years is not necessarily at the same seasonal phase. Comparing this region and year with those of a slightly greater or lesser solar longitude may be in order. For example, the "winter" may have been a little later or earlier in MY 25 when compared with MY 27. This possibility will be studied in further research.

Region H, L_s 331. Initial inspection shows that there is some decay of the ice coverage in this region. However, the overlap between the two stamps is too minimal to justify any conclusion for this year, L_s, and region.

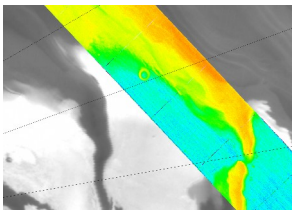

Figure 11.a: MY 25, I00826006

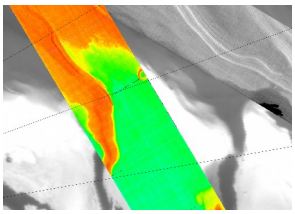

Figure 11.b: MY 27, I17538010

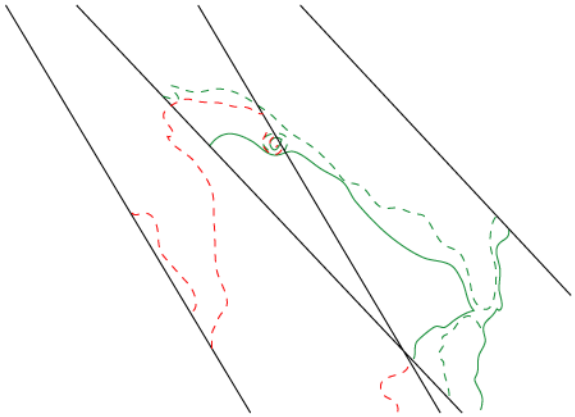

Figure 11.c: This region has very limited coincidental coverage. Study of the small area that does overlap shows a minor decrease in the H_2O coverage. Green lines outline MY 25 boundaries; red outline MY 27. This standard will also be used for L_s 333 studies.

L_s 333 ± 1° Season of Interest: Like L_s 331, supporting data from a secondary year is limited. There are several regions that overlap with another stamp from the other Mars year, but far less that have reasonably high contrast, and thus cannot be studied. The over lapping areas to the right in the below figure (not outlined) are on the night time side of the THEMIS IR image. Only two regions are available for study from MY 25 and 27 at L_s 333.

Region I, L_s 333. Variations between the two Mars years in this exterior region are insignificant. The bulk of the images show little to no change.

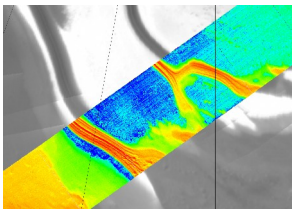

Figure 13.a: MY 25, I00910002

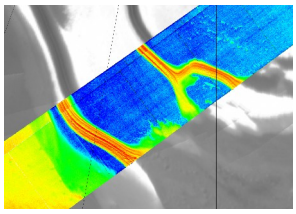

Figure 13.b: MY 27, I17585008, I17560013

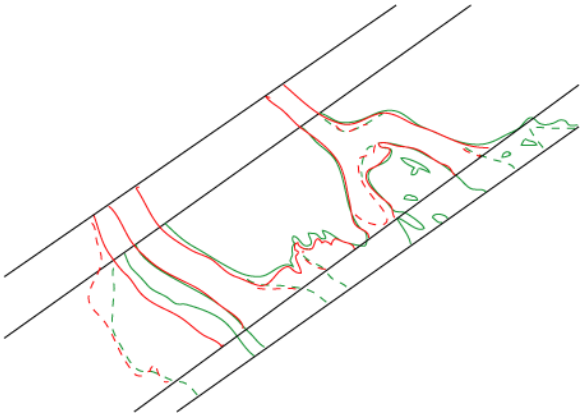

Figure 13.c: The most significant changes are on the left side of this figure. They are however, not dramatic enough to suggest a trend.

Region B, L_s 333. An interior region, though of a different year set that those compared around L_s 320, we see no notable changes between MY 25 and 27 once calibration of the images is taken into consideration.

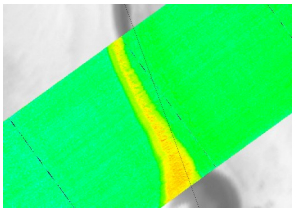

Figure 14.a: MY 25, I0091002

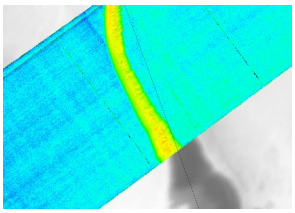

Figure 14.b: MY 27, I17585008, I17560013

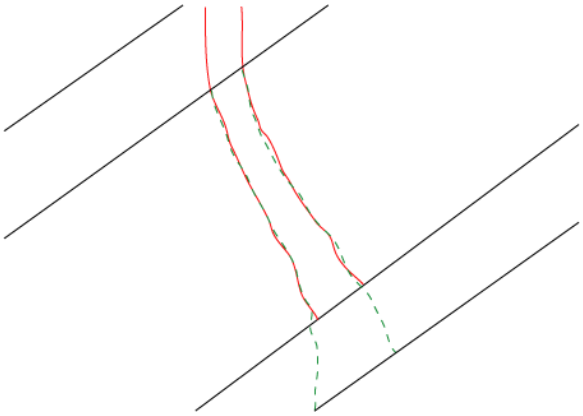

Figure 14.c: Where these two stamps overlap, the ice coverage outlines are nearly identical.

Conclusion: The south polar Martian ice cap does show signs of change between MY 25, 26, and 27. Instead of the warming trend previously suggested, an increase in areal coverage of both CO_2 and H_2O ice was observed between MY 26 and 27. These trends are however limited to the exterior edges of the cap. These results are consistent with those found in a smaller study by Winfree *et al* in 2006 [3].

Further Research: Continued research at the US Geological Survey in Flagstaff, AZ will result in a better inter-annual tracking of ice coverage. This should pin point when the cap is at its minimum and should be compared with other years at the same point in time. Additionally, a larger set of stamps will be considered with this study. 731 stamps between L_s 280 and L_s 349 for MY 25, 26, and 27 have been selected for this future research. Results will be presented at Seventh International Conference on Mars in July 2007.

References: [1] Malin, M. C. *et al* (2001) In *Science 294, 2146-2148.* [2] Clancy, R. T. *et al* (2000) In *J. Geophys. Res. 105, 9553-9572* [3] Winfree, K. N. *et al* (2006) Lunar and Planetary Science XXXVII