SEASONAL TEMPERATURE VARIATIONS ALONG THE CURIOSITY ROVER TRAVERSE IN GALE CRATER: A COMPARISON OF THEMIS REMOTE SENSING DATA WITH GROUND TRUTH

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Introduction: The weather on Mars is predictable. Seasonal changes in surface temperatures repeat from year to year. For example, near the south pole of Mars, in the CO_2 ice covered terrain, surface temperatures measured from orbit increase gradually during early spring, then show a sharp seasonal increase around Ls 250°. This sharp increase in surface temperature recurs around Ls 250° year after year [7].

In non-polar regions, surface temperatures are important because they are related to thermal inertia which in turn is used to derive particle size and compositional differences of the materials on the surface [1-4]. The Gale crater region of Mars provides us with the opportunity of comparing remote sensing data with on-ground measurements.

In this project we investigate the seasonal and diurnal variations in surface temperature along the Curiosity traverse in Gale Crater computed from thermal infrared images recorded by the Thermal Emission Imaging System (THEMIS) [5] onboard NASA's Mars Odyssey Spacecraft. This data is compared with published values of ground temperatures measured in situ by the Mars Science Laboratory's (MSL) Ground Temperature Sensor (GTS) [1] with the goal of verifying the reliability of remotely sensed surface temperatures measured from orbit.

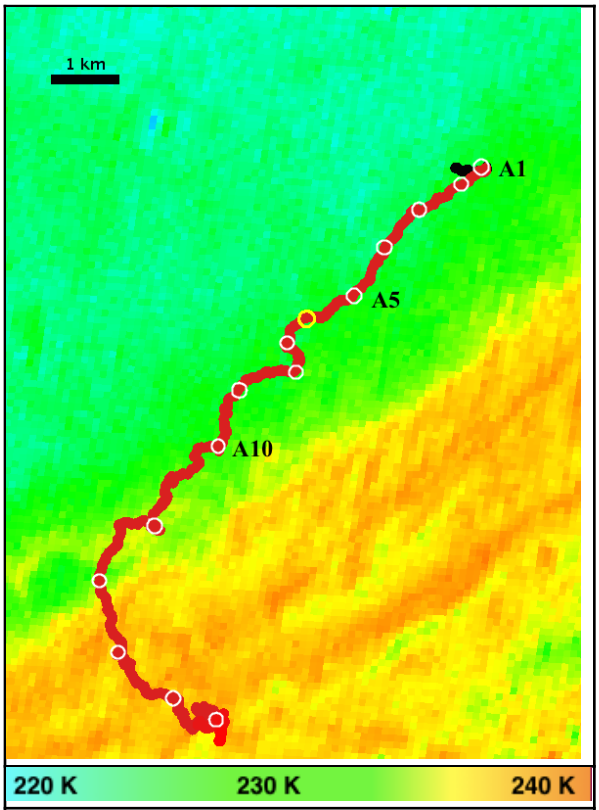

Figure 1. Thermal infrared THEMIS band 9 image (100 m per pixel) in false color from MY 32 Ls 31.5° at overlain with the Curiosity rover traverse, Gale crater. A1 @ 4.6°S,137.4°E. Colors represent temperatures.

Methods and Data: THEMIS infrared images (band 9: 12.57 μm) were analyzed to calculate surface temperatures along the Curiosity traverse for Mars years (MY) 31, 32, 33, and 34. Fig. 1 shows a THEMIS thermal infrared image in false color, overlain with the Curiosity rover traverse. The white circles are selected regions of interest (ROIs) along the rover traverse where surface temperatures were studied. ROIs A1, A5, and A10 are shown in Fig. 1. The average surface brightness temperature, T_B, was computed at different Ls values for Mars years (MY) 31, 32, 33, and 34 from infrared images using numeric map sampling in JMARS software [6,7].

GTS records ground temperature data along the Curiosity rover traverse. [1,2]. GTS ground temperature (T_G) data for mission sols 0 to 1337 used in this study was derived from the published work of Vasavada, et al. [1]. Minimum and maximum temperature values were sampled every 20 sols. Sols were converted to Ls using a script based on Mars' elliptical orbit **[8]**.

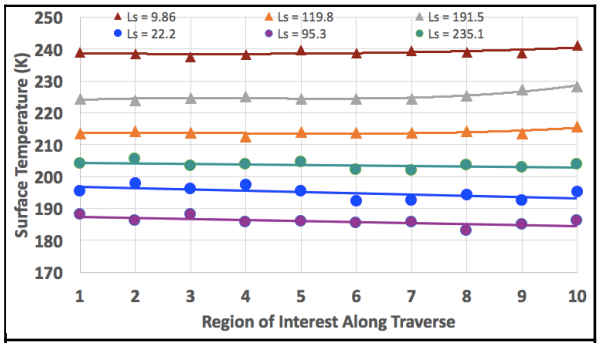

Figure 2. THEMIS Surface Temperatures T_B, at selected Ls values for MY 32 plotted by ROI # (A1-A10) along rover traverse. T_B does not vary significantly with location for a given Ls.

Results: Figure 2 shows THEMIS surface brightness temperatures T_B, at selected Ls values plotted by ROI # (A1-A10) along rover traverse. While T_B varies

with Ls, T_B does not vary significantly with location for a given Ls up through A10.

Seasonal Temperature Variations: Figure 3 shows seasonal variation of T_B with solar longitude Ls, along the Curiosity traverse for MY 32. Data for ROI's A1, A5, and A10 are shown in Figure 3. The bottom curve is a.m. temperatures from images recorded between 4 a.m. and 6 a.m. local time. The top curve shows the p.m. temperatures taken between 4 p.m. and 6 p.m. For MY 32, predawn (a.m.) temperatures vary from 185 - 205 K ± 3 K, while the p.m. temperatures vary from 215 - 240 K ± 3 K. Similar curves of seasonal temperature variation were plotted for Mars Years 31, 33, and 34, and the results will be presented in the poster.

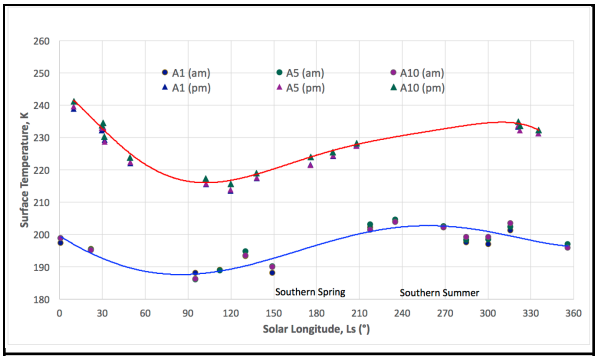

Figure 3. Variation of THEMIS surface brightness temperatures (T_B) vs. Solar Longitude (Ls) along the Curiosity traverse for MY 32. Circles represent a.m. temperatures and triangles p.m. temperatures.

Diurnal Temperature Variations: THEMIS images are recorded from orbit only during predawn (e.g. 4 a.m. to 6 a.m.) and evening (e.g. 4 p.m. to 6 p.m.) time intervals. The diurnal temperature variation which is the difference between the predawn and the evening temperatures, $\Delta T_B = T_B(\text{p.m.}) - T_B(\text{a.m.})$ depends upon the season. ΔT_B ranges from 25 K to 60 K and is smaller in the winter and larger in the summer. ΔT_B also depends on the local time of image capture.

Figure 4 shows a comparison of the THEMIS remote sensing temperatures, T_B for MY 31, 32, 33, and 34 with the REMS GTS ground temperatures, T_G, for sols 0-1337 of the Curiosity mission [1]. This time period corresponds to MY 31, Ls 150° to MY 33, Ls 150°. The solid symbols are T_B values and the open symbols are the T_G values. It is noteworthy that the predawn THEMIS T_B values (solid circles) agree with the GTS T_G minimum temperatures. However, the THEMIS T_B evening temperatures are 20-60 K below the diurnal maximums measured by GTS.This is because the ground temperature T_G attains its maximum value around 1:00 p.m., while the THEMIS data is recorded between 4-6 p.m when the surface is cooling.

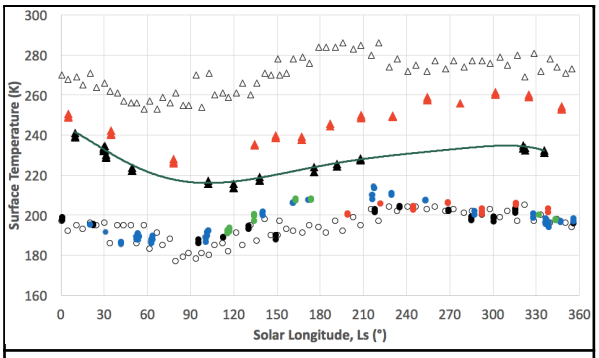

Figure 4. Comparison of THEMIS surface brightness temperature (T_B) (current work) with GTS surface temperatures (T_G) (Vasavada, et al.). THEMIS data: solid circles = a.m., solid triangles = p.m. GTS data: open circles = $T_{G(min)}$, open triangles = $T_{G(max)}$.

Comparing the THEMIS temperatures with the GTS diurnal variation at Bradbury Landing [1] shows that the p.m. temperatures are lower than GTS data which corroborates observations by Hamilton et al. [2].

Discussion: This study compares surface brightness temperatures derived from THEMIS IR images to ground temperatures measured in situ by the MSL's GTS. Surface brightness temperatures do not vary with location along the rover traverse, suggesting that a layer of dust occludes underlying differences in thermal inertia. The seasonal variations in temperature of 20 to 30 K observed from THEMIS measurements are consistent with the seasonal change in ground temperatures measured by GTS [1]. THEMIS a.m. temperatures recorded between 4 to 7 a.m. agree with the GTS diurnal minimum temperatures. This validates the reliability of surface temperatures measured from orbit. This also supports the use of pre-dawn (nighttime) temperature as the single temperature input in the calculation of thermal inertia [3,4].

Future Work: includes extending the temperature studies to ROIs A11-A15. Also, investigation of other bands of THEMIS infrared images and visible albedo variations in order to explore surface mineralogy..

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References: [1] Vasavada, A.R. et al., 2017. Icarus, 284, 372-386. [2] Hamilton, V.E. et al., 2014. JGR. 119, 745–770. [3] Edwards, C.S. et al., 2018. JGR.: Planets, 123, 1307–1326. [4] Fergason, R.L. et al., 2006. JGR., 111, E12004. [5] Christensen, P.R. et al., 2004. Space Sci. Rev. 110, 85-130. [6] Christensen, P.R et al., 2009. AGU Fall Meeting Abstracts, IN22A-06. [7] Angell, P. and Christensen, P.R. 2019. LPSC abstract 3199. [8] The Mars Climate Database Projects. Le Laboratoire de Météorologie Dynamique (LMD). 2008.