DIURNAL AND SEASONAL TEMPERATURE VARIATIONS ALONG THE MARS CURIOSITY ROVER TRAVERSE: A COMPARISON OF THEMIS REMOTE SENSING DATA WITH GROUND TRUTH

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Introduction: The surface of Mars heats up during the day and cools down at night. The diurnal variation in surface temperature, which is the change between the daytime maximum and night time minimum, depends on many factors such as the season, the topography of the place, the atmosphere, and the composition of the surface [1,2]. Surface temperatures are important because they are related to thermal inertia which is used to derive particle size and compositional differences of the materials on the surface [1-3].

This project investigates the diurnal and seasonal variations in surface temperature along the Curiosity traverse in Gale Crater computed from thermal infrared images recorded by the Thermal Emission Imaging System (THEMIS) [4] onboard NASA's Mars Odyssey Spacecraft and compares them to 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 brightness temperatures measured from orbit.

Methods and Data: THEMIS infrared images were analyzed to calculate surface temperatures along the Curiosity traverse for Mars years (MY) 32 and 33. 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_R, was computed at different Ls values for Mars years (MY) 31, 32, and 33 from infrared images using numeric map sampling in JMARS software [5, 6].

The GTS which is part of the Curiosity MSL's Rover Environmental Monitoring Station (REMS) has recorded temperature data along the Curiosity Rover traverse from landing until the present day [1]. This data is available in the NASA Planetary Data System. Hamilton et al. [7] analyzed the temperatures for the first 100 sols of Curiosity's traverse while Vasavada et al. investigated the first two Mars years of GTS data from landing at sol 0 until mission sol 1337. The ground temperature data set used in this study comes from the published work of Vasavada et al., [1].

Results: Figure 2 shows how the surface brightness temperatures, T_R, computed from THEMIS infrared images change with Ls, along the Curiosity traverse.

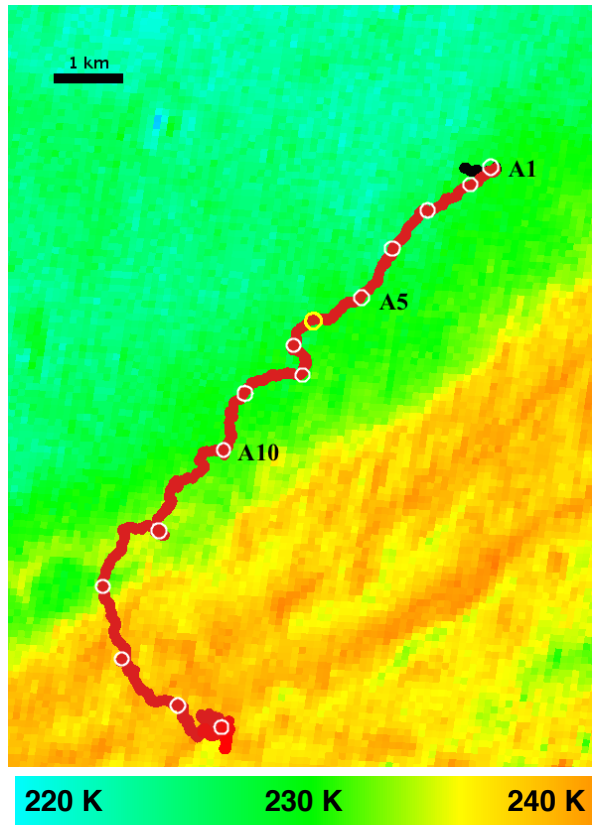

Figure 1. Thermal infrared THEMIS band 9 image in false color from MY 32 Ls 31.5° at 100 m per pixel overlain with the Curiosity Rover traverse. Image ID: I52390001, local time: 16.5 hours. Colors represent temperatures.

Only ROI's A1, A5, and A10 are shown in this plot. Morning (a.m.) and evening (p.m.) temperatures are separated into two data sets. 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. Variations in T_R for MY 33 are shown in Figure 3. It is interesting to note that MY 33 images were recorded between 6 a.m. and 7:30 a.m. and 6 p.m. and 7:30 p.m.

It can be seen that for MY 32, the seasonal variation in a.m. temperatures is from 185 K to 205 K, while the p.m. temperatures vary from 215 K to 240 K. For MY 33, the seasonal variation in a.m. temperatures is from 185 K to 215 K which is 10 K higher than the MY 32 values, however these MY 33 values were derived from images recorded at later times of day from

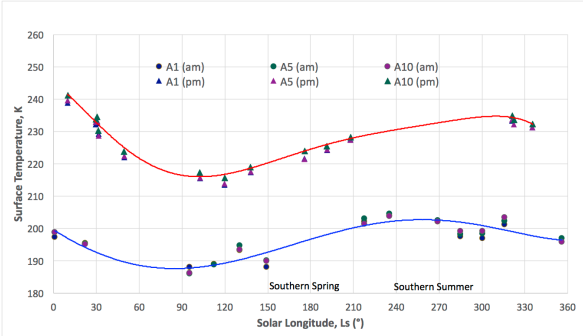

Figure 2. Variation of THEMIS surface brightness temperatures (T_R) vs. Solar Longitude (Ls) along the Curiosity traverse for MY 32. Circles represent a.m. temperatures and triangles p.m. temperatures.

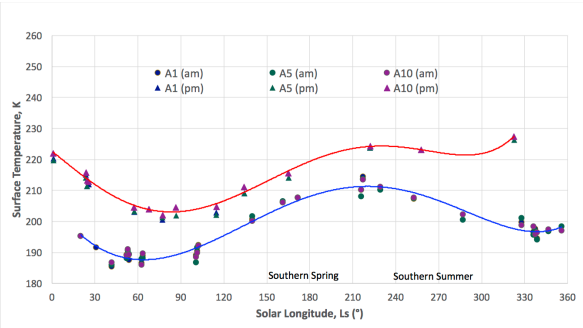

Figure 3. Variation of THEMIS surface brightness temperatures (TR) vs. Solar Longitude (Ls) along the Curiosity traverse for MY 33. Circles represent a.m. temperatures and triangles p.m. temperatures.

6 a.m. to 7:30 a.m. The p.m. temperatures for MY 33 are lower (200 K - 220 K) than the MY 32 values, also because the MY 33 images were recorded later between 6 p.m. to 7:30 p.m.

Figure 4 shows a comparison of the THEMIS remote sensing temperatures, T_R for MY 32, with the REMS GTS ground temperatures, T_G. The solid symbols are T_R values and the open symbols are the T_G values. Minimum and maximum T_G values were sampled every 20 sols from the published work of Vasavada et al. [1] for the first 700 sols after landing. The solar longitude, Ls, was calculated from the Curiosity MSL landing date in Mars Year 31, assuming a circular orbit (1 sol = 0.538° Ls).

It is noteworthy that the 4-6 a.m. THEMIS T_R values match the GTS T_G soly minimum temperatures. However, the THEMIS T_R p.m. 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. [1], while the THEMIS data is recorded between 4-6 p.m when the surface is cooling.

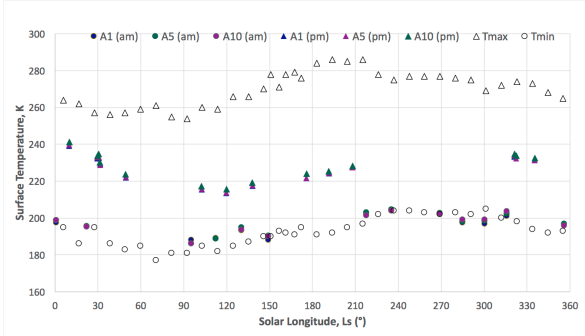

Figure 4. Comparison of THEMIS surface brightness temperatures, T_R, with REMS GTS diurnal surface temperatures, T_G. open circle: T_G(min), open triangle:T_G(max). GTS data from Vasavada et al. , [1].

Discussion: This study compares surface brightness temperatures derived from THEMIS IR images to ground temperatures measured in situ by the MSL's GTS with the goal of verifying the reliability of surface temperatures obtained by remote sensing. The THEMIS data shows that the surface temperature does not vary significantly with location across the Curiosity traverse. The seasonal changes in temperature observed from THEMIS measurements are about 25 K, consistent with the seasonal variation observed by GTS measurements. THEMIS a.m. temperatures recorded between 4 to 6 a.m. agree with the GTS daily minimum temperatures. This validates using the pre-dawn temperature as the single temperature input in the calculation of thermal inertia [2,7]. Since THEMIS imaging cadence is limited to two time intervals—4 to 6 a.m. or 4 to 6 p.m. it is valuable to see how the ground temperatures vary through the day from the ground-based GTS data.

Future Work: includes investigation of the information contained in the other bands of THEMIS infrared images and albedo variations to study surface compositions.

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