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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Motivation

Like Earth, the surface of Mars heats up during the day and cools down at night. Diurnal variation in surface temperature is the change between the daytime maximum and night time minimum. These diurnal variations 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 [1-4].

Objective

This study compares surface brightness temperatures derived from THEMIS infrared images to ground temperatures measured in situ by the Ground Temperature Sensor (GTS) on the Curiosity rover [1,2]. The goal is to verify the correlation between surface temperatures obtained by remote sensing and ground truth by evaluating diurnal and seasonal temperature variations.

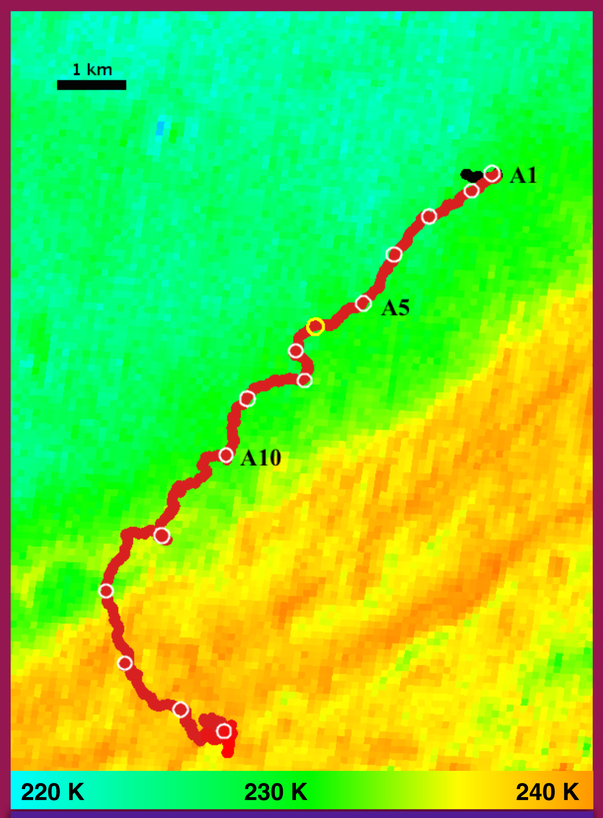

Figure 1: Thermal Infrared THEMIS band 9 (12.57 μm) image from MY 32 at Ls 31.5° at 100 m per pixel overlain with the Curiosity Rover traverse. Colors represent temperatures in this false color image. White circles are 100 m dia. ROIs labeled Al through A15.

Data Analysis: THEMIS

- ✳Thermal Emission Imaging System (THEMIS) is onboard NASA's Mars Odyssey orbiter.
- ✳THEMIS is a multispectral imager that records visible and infrared images from orbit [5].
- ✳THEMIS thermal infrared images (Fig. 1) were analyzed with JMARS software [6].
- ✳ White circles in Fig. 1 represent regions of interest (ROIs) along the traverse where THEMIS surface brightness temperatures (T_B) were studied.
- ✳Temperatures (T_B) for these ROIs were plotted versus the solar longitude (Ls) of each image.
- ✳About 200 images were analyzed at various Ls values in Mars years (MY) 31, 32 and 33 [6-7].
- ✳1° of Ls is about 1.86 sols (Mars days) [8].
- ✳THEMIS images are recorded from orbit only during predawn (e.g. 4 a.m. to 6 a.m.) and afternoon (4 p.m. to 6 p.m.) time intervals.

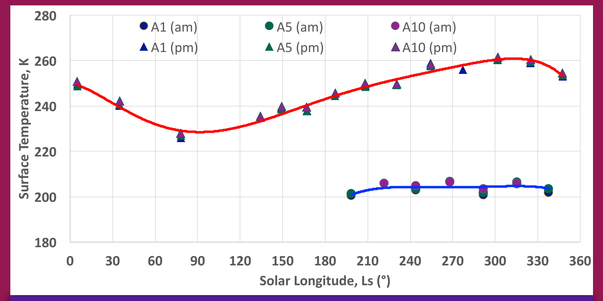

Figure 2. Seasonal variation of THEMIS surface temperatures (T_B) with solar longitude (Ls) along the Curiosity traverse for MY 31. Circles: a.m. (predawn) T_B (3:30 a.m. - 5 a.m.). Triangles: p.m. (afternoon) T_B (3 p.m. - 5 p.m.).

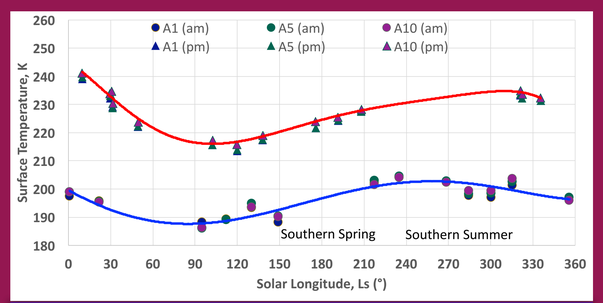

Figure 3. Seasonal variation of THEMIS surface temperatures (T_B) with solar longitude (Ls) along the Curiosity traverse for MY 32. Circles: a.m. (predawn) T_B (4 a.m. - 6 a.m.). Triangles: p.m. (afternoon) T_B (4 p.m. - 6 p.m.).

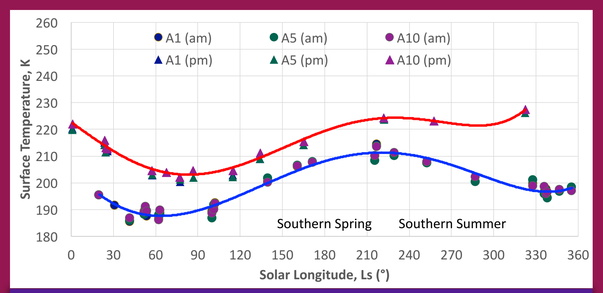

Figure 4. Seasonal variation of THEMIS surface temperatures (T_B) with solar longitude (Ls) along the Curiosity traverse for MY 33. Circles: a.m. (predawn) T_B (6 a.m. - 7:30 a.m.). Triangles: p.m. (afternoon) T_B (6 p.m. - 7:30 p.m.).

Data Analysis: GTS

- ✳ GTS records ground temperature data hourly along the Curiosity rover traverse [1,2].
- ✳ GTS ground temperature (T_G) data set is derived from published work of Vasavada et al., [1].
- ✳ GTS data for Curiosity mission sols 0 to 1337 is shown in Figure 5. Sols were converted to Ls using a script based on Mars' elliptical orbit [8].

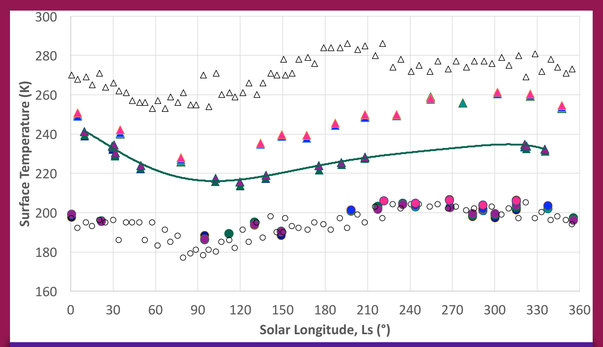

Figure 5: Comparison of THEMIS surface temperature, T_B, (MY 31 and MY 32) with GTS surface temperatures, T_G for 0 to 1337 sols. THEMIS data: solid circles: a.m., triangles: p.m. GTS data: Vasavada et al., 2017. open circle: T_G (min), open triangle: T_G (max).

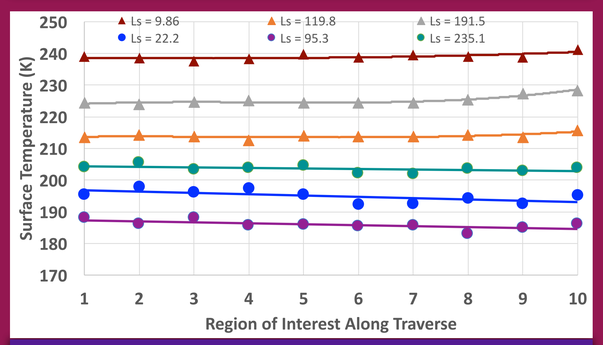

Figure 6: THEMIS surface temperatures, T_B, at selected Ls values plotted by ROI # (A1-A10) along rover traverse. T_B does not vary significantly with location for a given Ls.

Results

- ✳Figures 2, 3, and 4 show seasonal variations in T_B for MY 31, 32, 33.
- ✳Figure 5: Comparison of T_B with T_G

Seasonal Temperature Variations:

- ✳GTS Seasonal: ~25 K (Vasavada et al.)
- ✳THEMIS Seasonal: 20 K to 30 K
- ✳Predawn (a.m.) T_B varies 190 K to 205 K (± 3K)

Diurnal Temperature Variations:

- ✳GTS Diurnal, ΔT_G: 60 K to 90 K.
- ✳$\Delta T_B = T_B$(p.m.) - T_B(a.m.) = 25 K to 60 K. Smaller ΔT_B: winter. Larger ΔT_B: summer.
- ✳THEMIS a.m. temperatures agree with GTS diurnal minimums, T_{min} (Fig. 5, Fig. 7).
- ✳T_B p.m. lower than GTS data (Figure 7).
- ✳THEMIS (band 9) T_B does not vary significantly with location along Curiosity traverse A1-A10 (Figure 6).

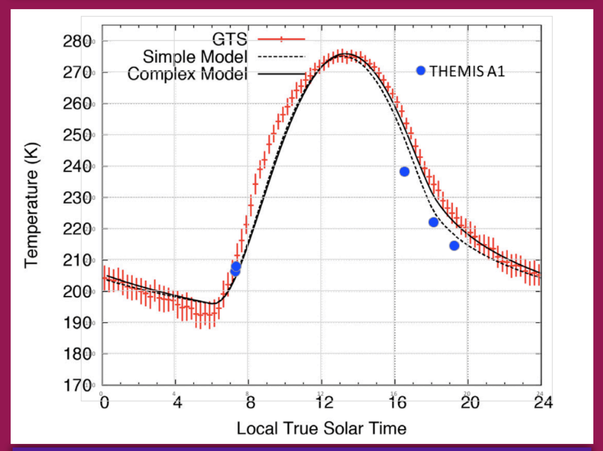

Figure 7: Diurnal variation in ground temperatures near Bradbury Landing for sols 30-37 (Vasavada et al.) [1] Red crosses: GTS data. Blue circles: THEMIS temperatures, Ls 166-171° at ROI A1 for MY 31-33.

Discussion

- ✳THEMIS temperatures recorded between 3 to 6 a.m. agree well with the GTS diurnal minimum temperatures. This validates the reliability of surface temperatures measured from orbit.
- ✳This also supports the use of predawn temperature as a single temperature input in the calculation of thermal inertia [3].
- ✳THEMIS p.m. temperatures lower than GTS corroborates observations by Hamilton et al. [2].

Future Work

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

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.

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