DEVELOPMENTS IN DERIVING BEST-FIT THERMAL INERTIA OF THE SURFACE OF MARS USING THEMIS IMAGES.

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Introduction: The Thermal Emission Imaging System (THEMIS) aboard Mars Odyssey has, since 2001, provided extensive coverage of the surface of Mars in 10 IR (6.78–14.88μm, at 100m/pix) bands. One quantity of interest is thermal inertia (measured in J m^{-2} $s^{-1/2}$ K^{-1} or tiu [1]), which represents a material's thermal response to changes in temperature of its surroundings. It is defined by taking the square root of the product of the density, thermal conductivity and heat capacity of a material. In a geologic context these quantities may be influenced by particle size, shape and degree of induration. Thermal inertia provides a level of thermophysical information allowing interepretation of ambiguous units. Typical values range from < 150 tiu for dust to > 1000 tiu for bedrock. Deriving thermal inertia from THEMIS (rather than TES) is especially desirable due to the high spatial resolution, which is commensurate with the scale of many light-toned outcrops that are of geologic interest. We enhance the method of [2] to derive best-fit thermal inertia and albedo of the surface of Mars by addressing issues regarding accuracy and spatial resolution.

Method to derive thermal inertia: By modeling martian surface temperatures using the thermal model of [3] diurnal temperature curves are calculated for a large range of surface albedo, thermal inertia, slope and azimuth. For the geographic region under study, we obtain pairs of overlapping day and night THEMIS IR images and spatially align them. Using band 3 (7.93μm) for daytime and band 4 (8.56μm) for night images, brightness temperatures are calculated, which loosely represent the diurnal thermal extremes. Topography is obtained for the region (previously from 128 pixel/degree MOLA data) and reprojected to THEMIS spatial resolution (100m/pixel). Slope and azimuth data are then calculated from the resulting DEM. A lookup table produced from the thermal model comprises a list of surface temperatures at the time of day of each THEMIS image calculated for a wide range of values for albedo, thermal inertia, slope and azimuth. The observed brightness temperatures for each overlapping pixel are then best-fit with this table to solve for thermal inertia and albedo.

Time offset of THEMIS images to daily thermal inflexions: To minimize error in the algorithm, we found that local time of acquisition of each THEMIS IR image must be very close to or at the diurnal thermal extremes. THEMIS images are often not. We produce a method for calculating the excursion from the diurnal thermal inflexion of a given THEMIS image using the thermal model (figure 1).

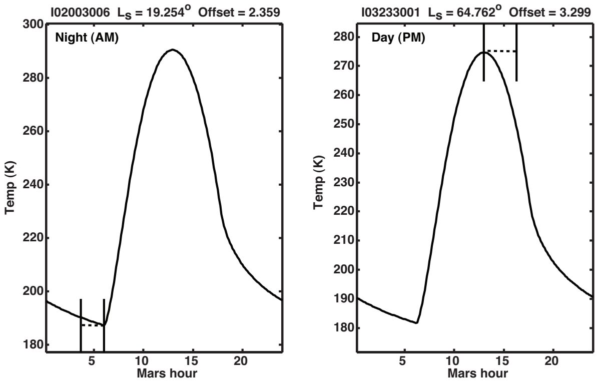

Figure 1: Modeled diurnal temperature curve at the L_s of a night (left) and day (right) THEMIS IR image. The offsets of the times of image acquisition from the appropriate thermal inflexion are marked with vertical lines.

'White Rock' is an indurated dust deposit centered at 25°E, 8.0°S with an independently measured thermal inertia of 232 ± 14 tiu [4]. We identified 5 daytime (PM) and 4 night-time (AM) THEMIS images as having good spatial coverage of the formation. Using the 20 possible image pairs to calculate thermal inertia of White Rock we plot the average value of thermal inertia obtained from all THEMIS pairs containing a particular image against the temporal offset of the image from the thermal inflexion (figure 2).

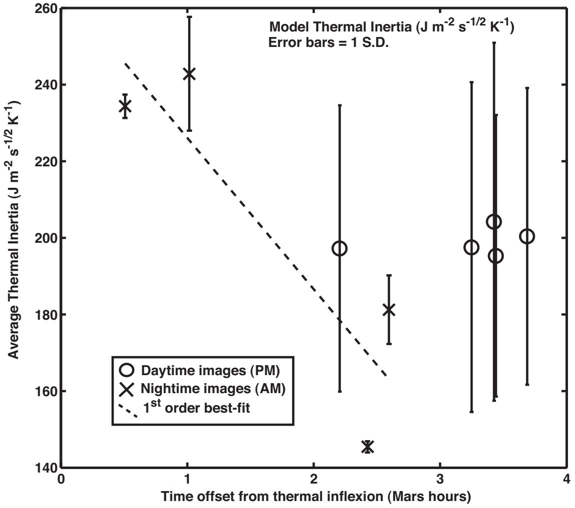

Figure 2: Mean thermal inertia values of 'White Rock'. There are 9 data points, one for each THEMIS image. The dashed line is a first order best-fit trend for the night images.

We find that apparent thermal inertia is inversely proportional to the offset of the THEMIS night image from the diurnal thermal minimum. Maximum accuracy is obtained when the night image is acquired within one Mars hour of the thermal minimum. We also note that night images are susceptible to high water-ice optical depths due to early morning clouds. These are seasonal variations and may be avoided by choosing images not acquired near the equator during the period L_s ~30° – 190°. This provides a rudimentary control on which data are appropriate for use to derive thermal inertia.

Spatial resolution differential between topography and THEMIS images: Surface temperatures can vary greatly with slope and azimuth in regions of high relief. The native resolution of MOLA 1/128th degree gridded data (~460m/pixel) is inferior to that of THEMIS IR images (100m/pixel). Regions of high slope or geomorphic features of a scale smaller than the MOLA native resolution are therefore not resolved, even though they may appear in THEMIS images. This results in misrepresentative values of thermal inertia when using MOLA topography. Therefore, we have incorporated HRSC topography into our methodology because HRSC DTMs have a native resolution of 200, 100 or 75m/pixel. This greatly improves the accuracy of best-fit thermal inertia and albedo values, most notably in high-slope regions. Many such regions also harbor geologic interest in the form of chaotic terrain, fluvial channels and light-toned/interior layered deposits (figures 3 and 4).

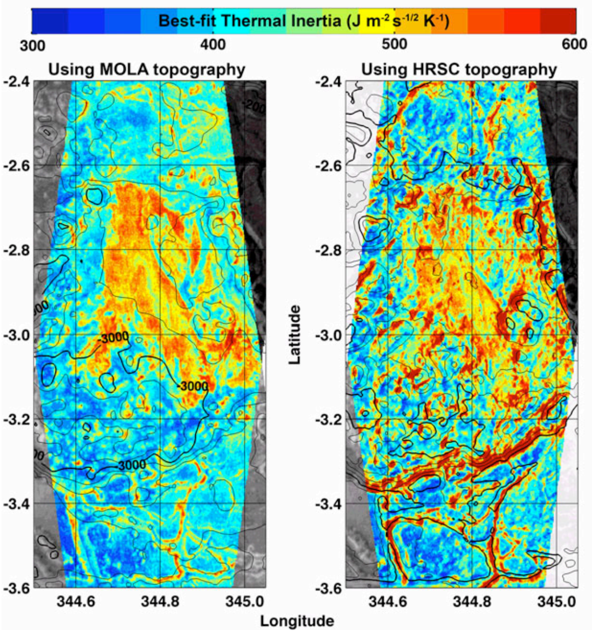

Figure 3: Thermal inertia maps of a region of chaotic terrain in Iani Chaos exhibiting a large central outcrop of light-toned layered rock of higher thermal inertia (480 – 600 tiu). Left: Derived using ~460 m/pixel MOLA topography. Right: Derived using higher resolution, 75 m/pixel HRSC topography (resampled to THEMIS resolution).

In Iani Chaos (figure 3) a light-toned layered outcrop is exposed within an ancient pseudo-circular region of chaotic terrain. Degraded chaotic mounds lie to the South-West of the relatively flat light-toned unit, while to the East and South large blocky mesas border kilometer-scale cliffs. These high slope regions typically do not exceed 440 tiu in the MOLA-derived thermal inertia map (figure 3, left panel). When HRSC topography is utilized (right panel), increased native resolution slope and azimuth data present a thermal inertia map that indicates high thermal inertia material (≥ 600 tiu) residing on many of these steep slopes. This could represent indurated, denser material or the exposure of a lateral extension of a unit similar to the light-toned material within the depression.

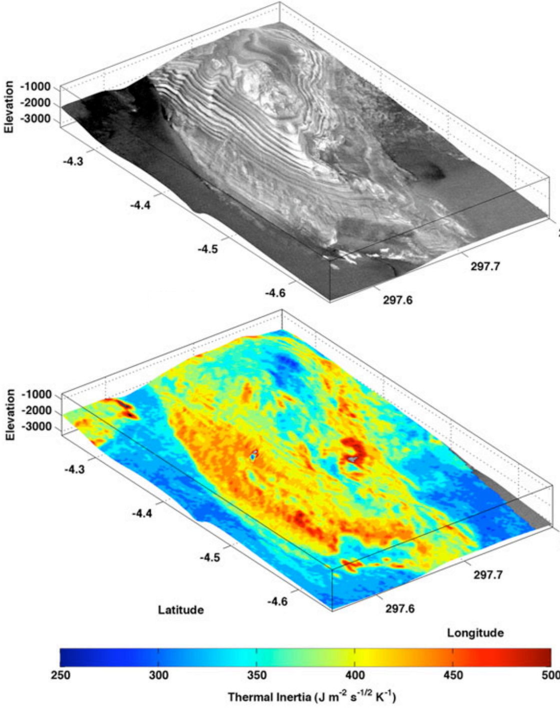

Figure 4: Interior layered deposit in Juventae Chasma. Documented by [2] as ILD 'B'. Top: HRSC image H1070_0001 nadir channel image draped on stereo-derived topography. Bottom: Thermal inertia derived using HRSC topography and THEMIS images I01307004 and I01450007.

We see similar improvements in figure 4, where 100m scale layering on an interior layered deposit in Juventae Chasma is discernable in thermal inertia, suggesting differences in bulk density/mineralogy.

References: [1] Putzig N. E. and Mellon M. T. (2007) Icarus 191 68-94. [2] Catling D. C. et al. (2006) Icarus 181, 26-51. [3] Kieffer H. H. et al. (1977) J. Geophys. Res. 82, 4249-4291. [4] Ruff S. W. et al. (2001) J. Geophys. Res. 106, 23921-23928.