Thermophysical Analysis of Gale Crater using TES and THEMIS observations.

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Abstract

We present an analysis of thermophysical properties within and surrounding Gale Crater using data from the Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) and the Mars Odyssey Thermal Emission Imaging System (THEMIS). THEMIS images provide higher spatial resolution ($\sim$100 m per pixel) but larger absolute uncertainty in temperature relative to TES ($\sim$3 km per pixel). We derive apparent thermal inertia from TES data and THEMIS images, using the TES results to analyse seasonal thermal inertia variations and the THEMIS results to analyse smaller scale spatial variations. We compare the variations to those found for horizontal mixtures and layers of different materials to better constrain the physical heterogeneity of surfaces in and around Gale Crater.

1. Introduction

Thermal inertia (I) is a bulk property that controls how a volume of material stores and conducts heat. Theoretically, the surface temperature of an object with negligible thermal inertia would respond instantaneously to radiative forcing, depending solely on incident radiation and the object's albedo (A). In reality, geologic material has non-zero conductivity (k) that spreads heat into its interior, while its density (ρ) and heat capacity (c) allow it to store heat. Together, these three properties comprise the thermal inertia:

$$I \equiv \sqrt{k\rho c} \tag{1}$$

We use the SI derived unit of thermal inertia, tiu:

$$tiu \equiv Jm^{-2}K^{-1}s^{-1/2} \tag{2}$$

The temperature of a surface is determined by a balance of the upward radiated heat from the surface with downwelling heat flux due to solar insolation, atmospheric radiation, subsurface heat conduction, and any other heat sources. In the case of Mars, another heat source that must be considered is latent heat due to seasonal CO2 condensation and sublimation. For geologic materials under Martian surface conditions, thermal inertia generally increases with grain size, providing a means to assess the physical properties of the near-surface using observations of temperature.

Together with surface brightness temperature, the TES instrument provided albedo (A) and atmospheric dust opacity (τ_D), which were used in our derivations of thermal inertia. Albedo within Gale Crater was seen to change from year to year, with changes occurring after major dust storms. THEMIS measurements taken after the failure of the TES spectrometer rely on seasonal forecasts of τ_D, and assume that A has remained unchanged since the last global dust storm of the MGS operational period. A complete description of the thermal-inertia derivation technique is described by [1] and references therein.

2 Surface Heterogeneity

In the technique used here to derive thermal inertia, the surface properties are assumed to be homogeneous within the area sampled by the measurement (i.e. within each 3-km pixel for TES and each 100-m pixel for THEMIS), both laterally and vertically to a few seasonal thermal skin depths. Because of its nonlinear relationship to temperature, the derived thermal inertia over heterogeneous regions will not be a simple average of thermal inertia in that region. In fact, when sampling the same pixel of a heterogeneous region, different values of derived thermal inertia may result depending on the season and the time of day. Such changes in derived thermal inertia between observations can be used to constrain the sub-pixel and subsurface distribution of thermal inertia. Fig. 1 presents maps of thermal inertia derived from TES nighttime measurements for two different seasons and demonstrates that Gale Crater is considerably heterogeneous, at least for the 20 pixel-per-degree TES sampling.

Model curves for seasonal apparent thermal inertia variations, under a few simple layering schemes, are produced and compared to derived apparent thermal inertia within Gale Crater. Preliminary analysis suggests that Gale Crater's bulk thermophysical properties may be too complex to be described by a simple two-component model of horizontally mixed or layer materials.

3 Themis Interpretation

In Fig. 2, we present a typical THEMIS derived thermal-inertia image in the vicinity of the landing site for Mars Science Laboratory (MSL) Curiosity, demonstrating the improved lateral resolution compared to the TES-derived results. Using our THEMIS results and supplementary information from the Mars Reconnaissance Orbiter Context Camera (CTX) and High Resolution Imaging Science Experiment (HiRISE) we will compare observed features with earlier THEMIS results by [2], with the geological mapping carried out by [3] and with later work using observations from MSL [4].

4. Summary

Analysing the seasonal variations in apparent thermal inertia allows us to place constraints on sub pixel heterogeneity of the surface, while the presence of MSL allows us to evaluate findings at one location with ground truths.

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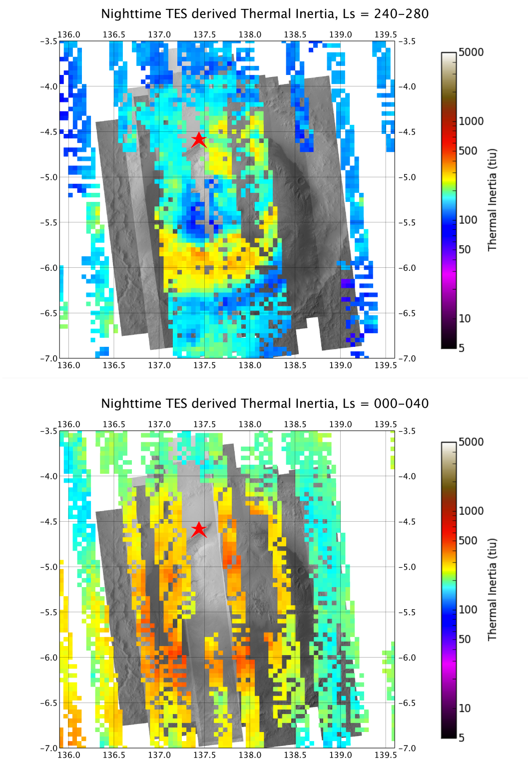

Figure 1: Derived thermal inertia from nighttime TES measurements for Top: $240° < L_s < 280°$, Bottom: $000° < L_s < 040°$. Plotted over a mosaic of MRO context camera images. The red star shows the landing location of MSL.

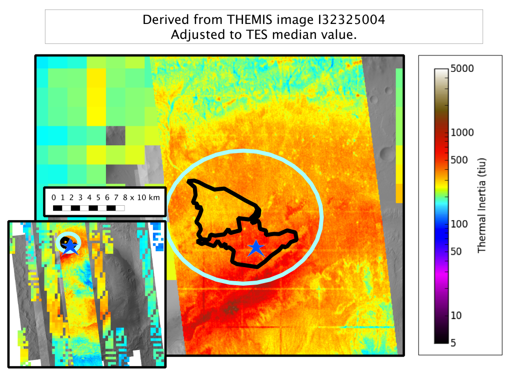

Figure 2: A detail of the thermal inertia derived from THEMIS image I32325004, plotted over the nighttime $200° < L_s < 240°$ TES derived thermal inertia, and the MRO context camera mosaic. Blue star shows the landing location of MSL. Ellipse shows approximate outline of landing ellipse. Black lines show mapped boundaries of Peace Vallis, differentiating between the Low and High thermal inertia fans described by [3].