A GLOBAL MAP OF THERMAL INERTIA FROM MARS GLOBAL SURVEYOR MAPPING-MISSION DATA. M. T. Mellon1, K. A. Kretke1, M. D. Smith2, and S. M. Pelkey1, 1Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, 80309, 2NASA Goddard Space Flight Center, Greenbelt, MD 20771.

Introduction: The Mars Global Surveyor (MGS) spacecraft has completed its primary mapping mission covering over one full martian year. The Thermal Emission Spectrometer (TES) onboard MGS has obtained high spatial resolution (approximately 3km x 6km) surface temperature observations from which thermal inertia has been derived. Seasonal coverage of these data now provides a nearly global view of Mars, including the polar regions, at this high resolution.

Background: Diurnal cycles in the martian surface temperature are strongly dependent on the thermophysical properties of the top few centimeters of the “soil”. Thermal inertia, a key property in controlling these cycles, is defined as a combination of thermal conductivity $k$, density $\rho$, and heat capacity $c$:

$$I \equiv \sqrt{k \rho c}.$$ 

It represents the ability of the subsurface to conduct and store heat energy away from the surface during the day and to return heat energy to the surface at night.

Deriving and understanding the thermal inertia of a surface can help to identify the small-scale characteristics of that surface. Fine grained and loosely packed material typically exhibits a low value of thermal inertia, while higher values are common for rocks and exposed bedrock. The thermal inertia of a region of the martian surface is generally related to properties such as particle size, degree of induration, abundance of rocks, and exposure of bedrock, including combinations of these properties within the field of view. Therefore, both global and local mapping of thermal inertia provides insight into the physical character of the martian surface and the geologic processes that have formed and modified that surface.

Observations: The MGS spacecraft is in a nearly circular 400 km polar orbit with equator crossing at approximately 2AM and 2PM local Mars time. The TES is primarily nadir pointing, making surface observations every 2 seconds during both day and night. The slight inclination in the polar orbit allows surface coverage between about 87° north and south latitudes.

The TES comprises three bore-sighted instruments: a spectrometer, a visible bolometer, and a thermal bolometer (see Christensen et al., 1992). Temperatures can be determined from the measured spectral radiance to obtain an estimate of the surface kinetic temperature and from the thermal bolometer to obtain a planetary brightness temperature. Each of six detectors, arranged 2x3, provide a nominal 3 km x 3 km resolution at the martian surface. However, due to difficulties in achieving the desired mapping orbit, the spacecraft now orbits opposite to its original design and TES image motion compensation is disabled causing the field of view of each detector to be smeared causing about 6 km downtrack.

In the present work, TES orbits 1583-11254 are used, which cover the range of Ls of 103° to 152° one full Mars year later. Data from orbits 4199-5410 were excluded due to the 1999 dust storms and globally high opacities. We will focus on thermal inertias derived from nighttime thermal-bolometer measurements.

Methodology: Thermal inertias are derived from individual TES temperature observations as described by Mellon et al. (2000). This method relies on finding the thermal inertia that produces model temperatures that best fit the observations. In short, a large number of diurnal temperature cycles are precomputed from a numerical thermal model for a variety of physical conditions to generate a lookup table. Each temperature observation is correlated with other data (e.g., latitude, albedo, time of day, etc.) and interpolated through this lookup table to find the best fitting thermal inertia.

Global Mapping: To map thermal inertia we employ a series of filters to remove the adverse effects of temporal variations in the atmosphere not yet accounted for in deriving thermal inertia. Specifically, we limit data to periods and locations of low dust and water-ice-cloud opacity (see Smith et al., 2001).

Figure 1 shows a global map of thermal inertia filled by interpolation between 80°N and 80°S latitude. Poleward of these latitude coverage falls off rapidly, due to a limiting combination of nighttime data (the sun below the horizon) and no seasonal CO2 frost (warm surface temperatures). Data meeting these criteria occurs only sparsely between 80°N to 83°N and 80°S to 86°S latitude.

The global view is similar to previous mapping efforts from MGS as well as Viking data. Several large areas of low thermal inertia occur which are interpreted as regional dust deposits. Other areas of moderate to high thermal inertia indicate coarser soil, surface rocks, and indurated soils to varying degree.

Significantly more spatial detail occurs in the present map. Extreme values in areas such as Valles Marineris, Isidis, and Argyre appear to be real surface characteristics, not evident in Viking thermal inertia (see Jakosky et al., 2000). Hellas, which exhibited high thermal inertias in pervious TES maps, is now lower as a result of eliminating high dust opacity data, and thus, more consistent with Viking maps.
Figure 1: Thermal inertia of the martian surface derived from MGS TES observations. Thermal inertia units are J m$^{-2}$ s$^{1/2}$ K$^{-1}$.

Figure 2 shows the north polar region. These thermal inertias are generally consistent with the Viking-based results of Paige et al., (1994). Moderate thermal inertias directly surround the polar deposits and the residual polar cap exhibits high thermal inertia between about 300°W to 50°W longitude and 77°N to 80°N latitude. The partial ring of high thermal inertia between ~90°W and ~300°W longitude shows significant variations between orbit tracks suggesting a residual atmospheric effect (not a surface characteristic) may be partly responsible for these observed values.

Figure 3 shows a similar map of the south polar region. These thermal inertias are also generally consistent with the Viking-based map (Paige and Keegan, 1994; Vasavada et al., 2000), but significantly more spatial detail is observed.

Overall TES thermal inertia are lower than most Viking-based values, which has been attributed to improved atmospheric modeling in deriving thermal inertia (Jakosky et al., 2000; Vasavada et al., 2000).

References: