HIGH RESOLUTION THERMAL IMAGING OF MARS

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One of the primary goals of the Viking Infrared Thermal Mapper (IRTM) experiments was to determine the thermal inertia of the surface (1). Global thermal inertia measurements provide a means of studying the spatial variations in effective particle sizes across the planet. As previously discussed, a wide range of surface properties, including the abundance of rocks and bonding of surface materials, can contribute to differences in thermal inertia (1; 2; 3; 4). Nonetheless, the thermal inertia does provide a means for assessing the properties of the martian surface materials, and for investigating surface processes.

In Palluconi and Kieffer's pioneering work, global thermal inertia determinations were made by fitting diurnal measurements of the surface to modeled curves of diurnal temperature variations to retrieve the thermal inertia. These determinations provide the most accurate measure of the inertia, together with the magnitude of the deviations of the surface from a simple model (see 5). However, to obtain diurnal coverage from the Viking spacecraft over a relatively small range of seasons it was necessary to bin observations into 2° x 2° latitude, longitude bins. Thus, the highest spatial resolution available from this method was 120 km x 120 km at the equator (2).

Using the map of Palluconi and Kieffer as a base, we have compared the thermal inertia obtained is this manner to that obtained by fitting the thermal inertia model to a single, pre-dawn observation. Histograms of the difference in thermal inertia determined for each method were computed for every Viking pre-dawn measurement, and show very good agreement between the two methods. This consistency is reasonable, given that the thermal inertia determination is very strongly sensitive to the pre-dawn temperature values. During clear periods, when atmospheric dust does not affect the pre-dawn temperatures, ~80% of the single point values fall within an inertia of ±1 (in units of 10^{-3} cal cm^{-2} K^{-1} $sec^{-1/2}$). This agreement indicates that pre-dawn measurements alone provide a reasonable estimate of inertia, and can be used to generate a map of thermal inertia at a substantially higher spatial resolution than by using the full diurnal analysis.

Data

A series of Viking 1 and 2 pre-dawn observations were used to construct a global thermal inertia map from ~-60° S to 60° N. The spatial resolution of these observations vary, but is ~30 km, with somewhat higher resolution in the southern hemisphere. They were collected into 1/2° x 1/2° latitude, longitude bins, consistent with the binning strategy of the Mars Consortium. The data used were obtained during 6 "walks" around the planet by the Viking 1 Orbiter, and 3 "walks" by Orbiter 2. Single-point thermal inertias were obtained using the Viking Standard Thermal Model described by Kieffer et al. (1). A subset of these data were discussed by Zimbelman and Kieffer (6). The data from each walk were binned together to create 9 images, each covering a range of latitudes at nearly all longitudes. Each individual sequence was analyzed and evaluated to eliminate any observations for which the thermal inertia values were affected by uncertainties in instrument calibration, atmospheric dust, or surface frosts. These resulting 9 images were then mosaicked together. In many areas overlapping coverage was acquired; in these cases the highest resolution observations were used. The final result in shown in Figure 1. Although observations at higher spatial resolution are available for specific regions (1) the data set described here provides the highest resolution, consistent data obtained pre-dawn during clear periods. As such it represents the best global thermal image available for Mars until observations can be obtained by the Mars Observer Thermal Emission Spectrometer experiment.

Discussion

The most striking feature of the thermal image presented in Figure 1 is the presence of small-scale structure in the surface properties not previously recognized on a global scale. Of particular interest are relatively high thermal inertia materials that occur within the volcanic province of Tharsis. These high inertia materials occur at the base of the scarp around Olympus Mons and its surrounding aureole. Detailed comparison of the location of these features indicates that they are located the feet of escarpments. Several possible explanations exist for the origin of these features. Two basic mechanisms can be envisioned for their origin. They may represent local, in-place changes to the surface character, such as bonding, or they represent localized accumulations of relatively coarse materials. The first mechanism appears less likely due to the small scale and high degree of correlation with local topography and morphology. A mechanism would be required to locally bond or alter material only in specific regions, while leaving material 50 km away unaffected. The second possibility appears more likely, either through local entrapment of a coarse, mobile surface fraction, or through the accumulation of coarse talus at the base of the escarpments.

The thermal inertia image also shows other regions with subtle thermal inertia differences that can be associated with surface morphology. Of interest for volcanic terrain analysis are the discrete changes in thermal inertia in the Lunae Planum region. These changes in surface properties suggest that a spatially non-continuous process has acted to produce the present surface. Aeolian mixing of material is not a good candidate in this particular case; differing degrees of bonding of material of possibly different ages is a possible explanation. Some additional features of interest include the high-inertia zones associated with crater streaks in Oxia Palus, high-inertia materials in the rim and walls of large craters in Arabia, and high-inertia, intra-crater deposits in the summer hemisphere (7).

These data provide a new view of varied and heterogeneous martian surfaces and surface processes. They suggest that Mars will display increased variability in surface characteristics as the resolution of the observations increases. Thus, localized processes appear to operate in addition to global-scale processes that have been proposed to produce the "continental-scale" inertia variations (3). Additional analysis of these variations will provide more information on local surface processes and surface evolution in volcanic terrains, and may help to separate primary and secondary surface properties.

References

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