

THERMOPHYSICAL PROPERTIES OF MARTIAN HIGH LATITUDE SURFACES DERIVED FROM SEASONAL TEMPERATURE MEASUREMENTS. J. L. Bandfield, Department of Earth and Space Sciences, University of Washington, Seattle (joshband at u.washington.edu).

Introduction: Martian high latitude surfaces have thermal properties consistent with an extensive high thermal inertia layer within a few centimeters of the surface. This subsurface permafrost will have a thermal inertia similar to solid bedrock that is much higher than the more porous dry particulate regolith cover [e.g. 1-6]. The layered nature of the regolith makes it impossible to describe its thermophysical properties using a single thermal inertia value. This layered nature of the regolith makes it necessary to revisit the derivation of high latitude thermophysical properties.

Data and Methods: The analyses of the surface temperatures assume that any buried high thermal inertia layer is a solid mixture of regolith and ice with a thermal inertia of $2290 \text{ J m}^{-2} \text{ K}^{-1} \text{ s}^{-0.5}$, (MKS units are used throughout this abstract). The model assumes a relatively simple two layered geometry of relatively dry soil cover on top of a semi-infinite high inertia layer that is assumed constant throughout the measurement field of view. More complicated systems are likely to be common on Mars, but the data set does not have the leverage to converge on a unique solution based on more complex geometries.

This study utilizes the estimated surface kinetic temperature derived from Thermal Emission Spectrometer data. Spectral, rather than bolometer, measurements were used because they are less susceptible to atmospheric effects. Observations were restricted to emission angles less than 30° , $50\text{--}80^\circ$ latitude (north and south), and 0100–0300 local time. The data were averaged in bins of 2° latitude, 4° longitude and 4.5° L_s .

The KRC thermal model (H.H. Kieffer, manuscript in preparation) was used to predict surface temperatures. This model allows for customization of a wide variety of parameters such as changes in subsurface thermophysical properties and atmospheric aerosol properties.

Thermal inertias derived from measurements with low angles of solar incidence are not as accurate as those derived from nighttime temperature measurements because of the dominant influence of slope, albedo, and atmospheric aerosol characteristics and their associated uncertainties. For this reason, descending orbit observations at local times of 1300–1500 were avoided. The model was set to run for two Martian years before outputting surface temperatures for the third year.

Each latitude/longitude bin of seasonal surface

temperature data was fit individually using a nonlinear least squares fitting routine. All modeling parameters were fixed except surface cover thermal inertia and depth of the permafrost layer. The seasons used for fitting were restricted to summer and early fall seasons. In addition, all surface temperatures below 160K were not used for fitting because of the proximity to CO₂ condensation temperatures. These restrictions as well as the use of only 0100–0300 local time data isolated the model and data from conditions of significant modeling uncertainty.

Top layer inertias were allowed to vary from 60–800, corresponding to diurnal skin depths of ~ 0.3 to 11 cm. The model permafrost layer has fixed thermophysical properties (including a thermal inertia of 2290), but was allowed to vary from 1.15 to 20.3 diurnal skin depths. As a result, the model and fitting routine is sensitive to permafrost at 0.3–6 and 12–220 cm depths for surface cover thermal inertias of 60 and 800 respectively.

Uncertainties are dominated by systematic errors in derivation and modeling of surface temperatures at mid-latitudes. The seasonal energy cycle is relatively weak at lower latitudes and the model does not account for lateral heat transport from lower latitudes. Uncertainties are discussed in detail in 6.

Results: Surface cover thermal inertia, active layer thickness, and error maps are displayed in Fig. 1. There are clear correlations between the different data sets and derived parameters. For example, between $\sim 50\text{--}65^\circ\text{N}$, relatively low albedo surfaces are associated with relatively high surface cover thermal inertias, neutron derived water ice depths, and surface temperature derived active layer thicknesses. Similar spatial correlations are also apparent in the southern hemisphere maps, although the nature of the surface cover thermal inertia and the permafrost/water-ice distributions are significantly different from the northern hemisphere maps.

Average RMS errors are 1.93 K and 2.30 K in the north and south respectively. This excludes regions of permanent water or CO₂ ice, which will not be well fit by the model.

Discussion: Obtaining accurate thermophysical properties at high latitudes is essential for prediction of seasonal CO₂ and H₂O frost cover as well as for predicting theoretical water ice stabilities. This is a difficult determination because of a rather weak diurnal energy cycle and the influence of subsurface ice itself on the apparent thermal inertia at these latitudes.

Several studies have derived apparent thermal inertia for high latitude surfaces. Despite some quantitative differences due to the models and type of data used, these studies show that thermal inertia in the northern hemisphere is generally higher than in the southern high latitudes.

This work finds a similar pattern of surface cover thermal inertia. The southern hemisphere has average surface cover thermal inertias of 159, 208, and 251 at 70–80°, 60–70°, and 50–60°S respectively. This is in-between the relatively high values derived by 7 and low values of 8. Putzig et al. [9] have lower thermal inertia values between ~70–80°S and higher thermal inertia values at ~50–60°S. It is interesting to note that the southern rim of Hellas basin has high values of thermal inertia up to ~500 by 9, but is a region of low surface cover thermal inertia (~200) and relatively shallow permafrost here. This will have a significant effect on predicted seasonal frost cover, surface temperatures, and water ice stability depths predicted by vapor diffusion models.

Where surface cover thermal inertia generally decreases poleward in the south, the pattern is more complex in the north. Elevated thermal inertia values of ~300–400 are typical of low albedo regions such as Acidalia near 50–65°N. This is about 50–150 units lower than those of 10 and 9.

One of the reasons that the term “apparent thermal inertia” is used for polar studies of surface thermo-physical properties is that it is impossible to characterize a layered surface with a single value. Thermal inertia derived assuming a vertically homogeneous surface will not be constant based on season [e.g., 11]. The work presented here is an improvement on previous studies because it explicitly accounts for vertical heterogeneity (albeit in a simplistic manner) and the surface cover thermal inertia values are likely more representative of the top layer of regolith. This can lead to a significant improvement in the prediction and modeling of surface temperatures and seasonal frost cover.

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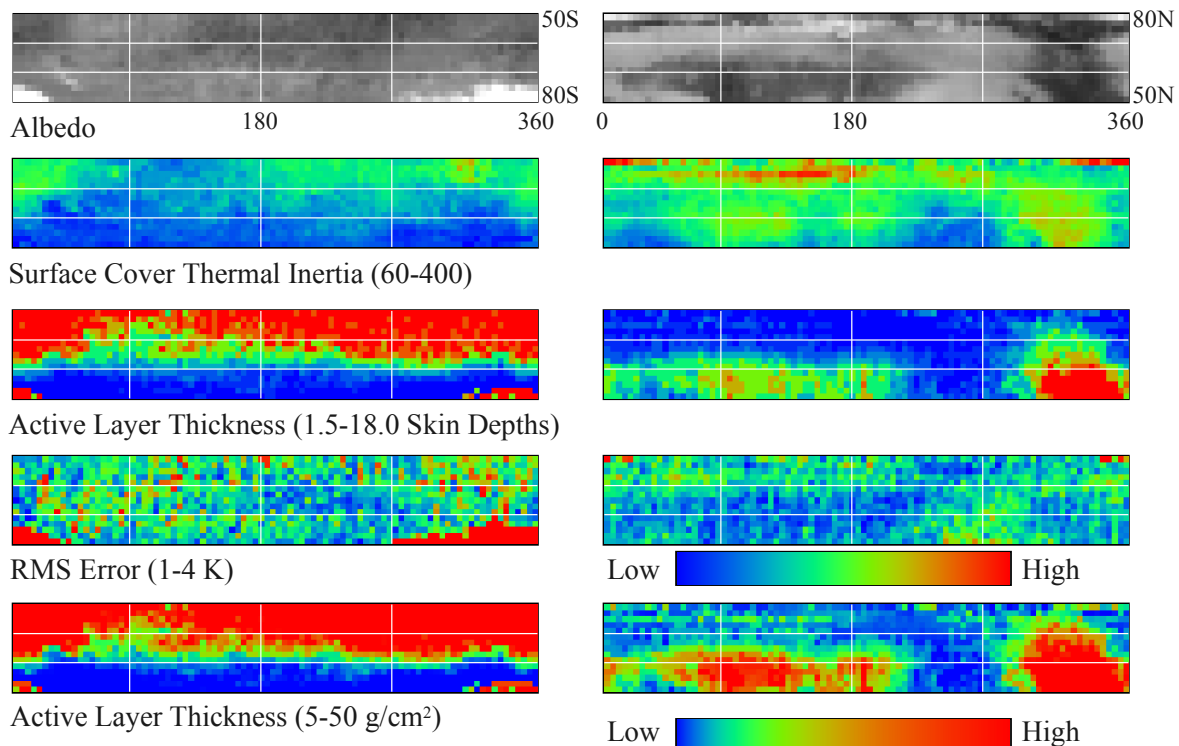


Figure 1. Albedo, surface cover thermal inertia, active layer thickness, and RMS error maps are shown for 50–80°N/S at all longitudes. The bottom set of maps are in burial depth assuming a 1.5 g/cm³ surface cover bulk density and use the bottom logarithmic color scale.