EFFECT OF GROUND ICE ON APPARENT THERMAL INERTIA ON MARS. M. A. Chamberlain and W. V. Boynton, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, 85721, U.S.A., mc@lpl.arizona.edu.

Introduction: The most recent thermal inertia maps of Mars have been produced with data from the Thermal Emission Spectrometer (TES) onboard the Mars Global Surveyor (MGS) [1]. Thermal models developed by [2-4] are used to convert surface temperatures observed by spacecraft to the thermal inertia of the ground. These models assume uniform thermal properties with depth. A multi-dimensional look-up table generated by the thermal model is used to match observed nighttime temperatures to thermal inertia. Latitude, season, time of day, dust opacity, surface pressure and albedo are other dimensions of the look-up table.

Thermal inertia values in recent TES maps in northern polar regions are variable between adjacent orbit tracks; this has been attributed to variable atmospheric conditions and observations taken near local dawn [1]. Also, thermal inertia values in the north from [1] are substantially higher than values by [5] particularly around 75° N.

Ground ice has been expected in the polar regions of Mars [6], and has now been detected [7]. The presence of ground ice will change the thermal properties at depth. The top, dry layer will have a thermal inertia that is much less than a buried, ice-rich layer. Where the ice is deep, say below the annual skin depth, the temperature observed at the surface will be the same as if the ice were not present and the inferred thermal inertia will be the thermal inertia of the top layer. However, if ice is close to the surface the thermal inertia inferred from the ground temperature is influenced by the depth and properties of the ice-rich layer, and by the season that the temperature is observed. The effect of ground ice has also been discussed before by [8] as a possible reason for seasonal thermal anomalies. Estimates of depth to ground ice in polar regions is of the order of the skin depth of the diurnal thermal wave [9].

Perhaps the presence of ground ice may be responsible for some of the discrepancies in the thermal inertia maps. I show the results of some models here to illustrate the effect of ground ice on the apparent thermal inertia.

Models: To determine observed surface temperatures I use a thermal model designed to emulate the model used to generate the look-up table used in producing the recent thermal inertia map. The model used is 1-D; the depth resolution near the surface is a fraction of the diurnal skin depth and increases exponentially with depth. The transmission of sunlight and energy exchange with the atmosphere is calculated using a scheme described by [2]. Thermal properties of the ground are modified to simulate ice-rich ground at an adjustable depth. The 2 am temperatures are plotted in figures below to coincide with the local time of the TES observations.

Sample results and discussion: I chose a latitude of 68.5° N to evaluate the effect of ground ice. To demonstrate the effect of ground ice on inferred thermal inertia, I produce surface temperatures for 2 sets of models. The first set contains models with varying thermal inertia and no ice (i.e. uniform with depth), while the second set has constant thermal inertia in the top layer and varying ice depth.

Figure 1 shows 2 am temperatures over the local summer for ice-free ground and different thermal inertias. A list of significant inputs is included in the caption. Observed temperatures increase monotonically with thermal inertia in all seasons.

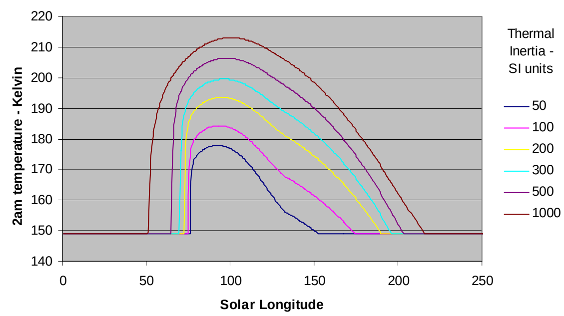

Figure 1 Variation in 2am temperatures for ground with different thermal inertia. There is no ground ice; albedo = 0.20, latitude = 68.5 N, P_{surf} = 6.1 mbar, dust opacity = 0.3. (S.I. units for thermal inertia are $JK^{-1}m^{-2}s^{-1/2}$).

Figure 2 shows temperature profiles when the thermal inertia of the top dry layer is held constant (200 S.I. units) and the depth to ground ice is varied. The diurnal skin depth of this top layer is 2.7 cm, annual skin depth is 69.8 cm. In Figure 2 there are seasons where there is a minima in observed temperature as the depth to ice is varied. When ice is closest to the surface, the ground responds as if it has a higher thermal inertia which raises the average and observed temperature. However, there is a point when ice passes below the diurnal skin depth where deeper ice also raises the observed temperature due to increased daytime heating of the low thermal inertia surface layer.

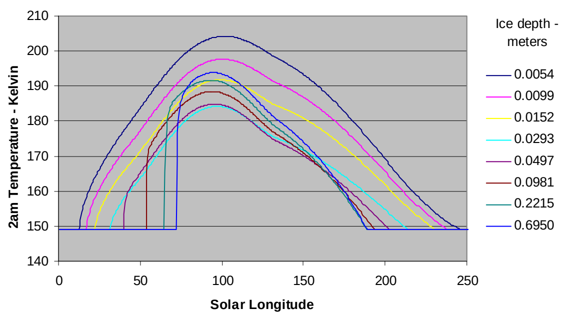

Figure 2 Variation in 2am temperatures for ice at different depths. Dry layer thermal inertia is 200 S.I. units; the ice-rich layer has properties of ice-cemented soil and a thermal inertia of 2200; other properties as for Fig. 1.

Figure 3 shows 2 am temperatures of ground with ice near the stable depth (based on the depth when the average water vapor density above the ground ice equals the density in the atmosphere, as used in [9]) and temperatures from the series of models with no ice. Comparing the temperatures gives us what thermal inertia would be inferred when ground ice is not considered. It can be seen that there are times when ice can reduce or increase the apparent thermal inertia by of the order of 100 S.I. units relative to the thermal inertia of the top layer. The extent of this variation should be a function of the properties of the ice-rich layer used, though this has not been explored yet. Interpolation is used to generate the apparent thermal inertia values at different seasons and is shown in Figure 4.

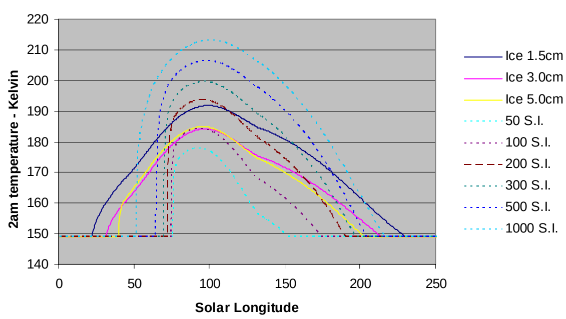

Figure 3 2am temperatures from a model with ground ice near the expected depth (data from Fig. 2) plotted against temperatures of models with no ice (from Fig. 1).

Conclusions: Ground ice can lower or raise the surface temperature observed by spacecraft, and hence the inferred thermal inertia, depending on the depth of the ice and season of the observation. The corrections to the thermal inertia shouldn't change the regions identified in present thermal inertia maps of Mars, though it would modify their values. On one hand, including ground ice in the models complicates the results, on the other hand they also show that tracking surface temperatures over the season has potential to determine other model parameters.

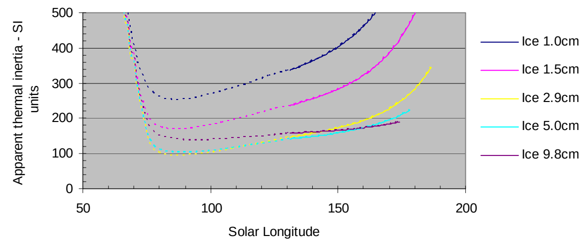

Figure 4 Seasonal values of apparent thermal inertia inferred from surface temperatures from models with different ice depths. Thermal inertia values are interpolated from model results shown in Figure 1. Values are not shown when the surface temperature is less than 160 K, and the dashed region shows seasons when the sun is still above the horizon at 2am local time.

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References: [1] Putzig N. E. et al. (2004), *Icarus,* in press. [2] Haberle R. M. and Jakosky B. M. (1991), *Icarus, 90*, 187-204. [3] Jakosky B. M. et al. (2000), *JGR, 105*, 9643-9652. [4] Mellon M. T. et al. (2000), *Icarus, 148*, 437-455. [5] Paige D. A. et al. (1994), *JGR, 99*, 25959-25991. [6] Leighton R. R. and Murray B. C. (1966), *Science, 153*, 136-144. [7] Boynton W. V. et al. (2002), *Science, 297*, 81-85. [8] Paige D. A. and Scherbenski J. M. (2003), *Mars Conf. VI*, Abstract no. 3265 . [9] Mellon M. T. et al. (2004), *Icarus, 169*, 324-340.