THERMOPHYSICAL ANALYSIS OF THE NORTH POLAR ERG ON MARS. N. E. Putzig[1], M. T. Mellon[2], K. E. Herkenhoff[3], and R. J. Phillips[1]. [1]Southwest Research Institute, Department of Space Studies, 1050 Walnut St, Suite 300, Boulder, CO 80302 (contact: nathaniel@putzig.com), [2]University of Colorado, Laboratory for Atmospheric and Space Physics, Boulder, CO, [3]United States Geological Survey, Astrogeology Team, Flagstaff, AZ.

Introduction: We are conducting an investigation into the reported anomalously low thermal inertia of the north polar erg on Mars, incorporating daytime observations and forward modeling of heterogeneity. Near-surface heterogeneity and normal basaltic sand may explain the thermal behavior of the erg, obviating the need for exotic sand-sized agglomerations of dust.

Background: The polar regions contain an array of geologic features that are crucial to understanding Mars' past and present global climate. The most prominent feature is the layered deposits that are believed to be largely composed of water ice and to result from cyclical climate variations over a broad range of time scales [1, 2]. After seasonal CO_2 frosts sublime, the layered deposits remain capped by bright residual water ice and surrounded by a dark annulus (Fig. 1a) of dune-forming materials known as the polar erg.

The dune morphology and the color and low albedo of the north polar erg materials are quite similar to those of dunes seen at lower latitudes [3] that have been interpreted to be composed of sand-sized basaltic materials [4, 5, 6]. The lower-latitude dunes exhibit intermediate values of thermal inertia (~ 250 tiu, where tiu = J m^{-2} K^{-1} $s^{-1/2}$), consistent with sand-sized grains. In contrast, the north polar erg has much lower values (~ 75 tiu), which has been interpreted to require that the materials be much finer grained [7, 8].

A widely accepted solution to this discrepancy is the bonding of fines into larger, low-density aggregate particles that are capable of forming dunes [9, 10]. The agglomeration of dust particles presumably occurs as they are weathered out of the layered deposits [1, 2, 10], and these sand-sized composite grains are subsequently transported within the erg by saltation. Recent studies associate the dune materials to a newly identified unit at the base the polar layered deposits [11, 12].

Thermal inertia and heterogeneity: A potential alternative explanation for the low apparent thermal inertia of the erg materials is surface heterogeneity, the anomalous thermal effects of which have been investigated in recent model studies [13, 14]. In particular, some configurations of near-surface layering may produce values of apparent thermal inertia at certain times of day and season that are substantially lower than the intrinsic thermal inertia of both the surface layer and its substrate [14]. If true for the polar erg, then it may be surfaced by ordinary basaltic sand, and the low values of apparent thermal inertia could then be attributed to an effect of surface heterogeneity rather than to sand-sized agglomerations of dust.

Large diurnal and seasonal variations in apparent thermal inertia (up to a few hundred tiu) derived from Mars Global Surveyor Thermal Emission Spectrometer (TES) data suggest that heterogeneity is a major factor in the global thermal behavior of the martian surface, and the polar regions show thermal characteristics that are broadly consistent with layered surfaces (Figs. 1b, 1c) [15]. A key element in this analysis is the use of both nighttime and daytime results, particularly for the polar regions where the seasons free of CO_2 ice largely overlap those when the Sun is predominantly above the horizon.

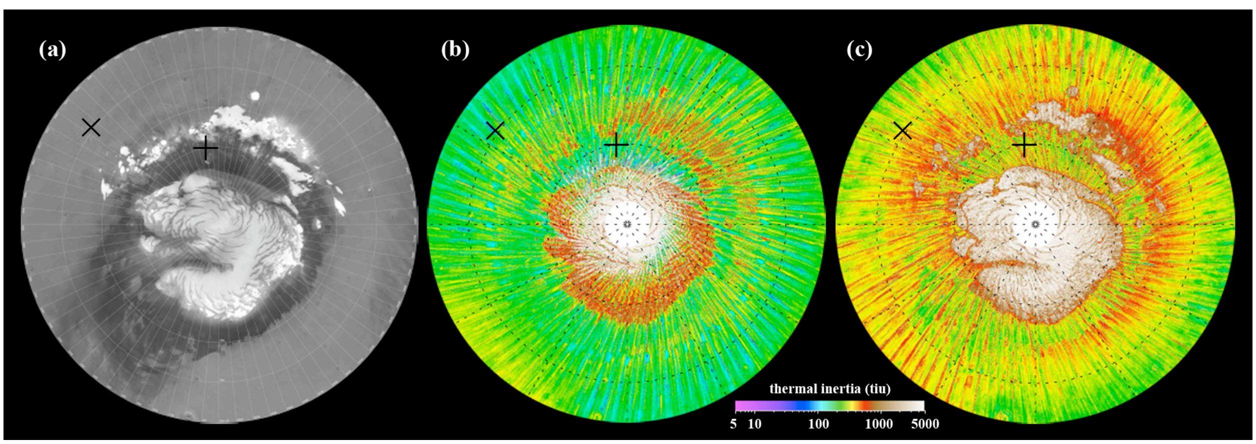

Figure 1. North polar region, 65–90° N, 0°W at bottom. (a) Mars Orbiter Camera wide-angle image mosaic; north polar erg is the irregular, dark annulus surrounding bright layered deposits. NASA/JPL/MSSS. (b, c) TES annual-median apparent thermal inertia near (b) 2 AM and (c) 2 PM [15]. Orbit-track-aligned streaks are due to seasonal variations. × is proposed Phoenix Lander site (Fig. 2). + is HiRISE image center (Fig. 3) within Olympia Undae (area of lower thermal inertia at 120-210° W, 78-83° N).

A comparison of seasonal TES results with those from models of sand (223 tiu) overlying 'rock' (2506 tiu) at the proposed Phoenix Lander site [16] is shown in Fig. 2. The rock value is also representative of the ground ice expected at this site. For the models with sand thicknesses approaching or exceeding a diurnal skin depth ($\geq \delta_S/26$), the 2-AM annual-mean apparent thermal inertia will be substantially less than that of the sand. Thus, analyses that focus solely on nighttime observations—or even those such as the Viking studies that take the annual mean of values fit to diurnal temperatures—may underestimate the inherent thermal inertia of the surface materials in this scenario.

Heterogeneity in the Erg: At the higher latitudes where the polar erg is located, the seasonal range of useful TES data becomes quite limited and the season-to-season changes in apparent thermal inertia are even larger than at the Phoenix site. To resolve these short-term, rapid changes, we will remap the north polar region with a finer seasonal increment—originally chosen at 10° L_S to optimize global results [15]. Our goal is to distinguish whether models having dust-sized surface materials (or agglomerations thereof that allow dune formation) or those having typical sand-sized surface materials provide the best match to the observed thermal behavior. We expect consistency with an ice-cemented substrate beneath a dry surface layer, and our analysis techniques may allow us to constrain the upper-layer thickness to within a few centimeters.

For some geometries, horizontal heterogeneity may have thermal behavior similar to that of layering [15].

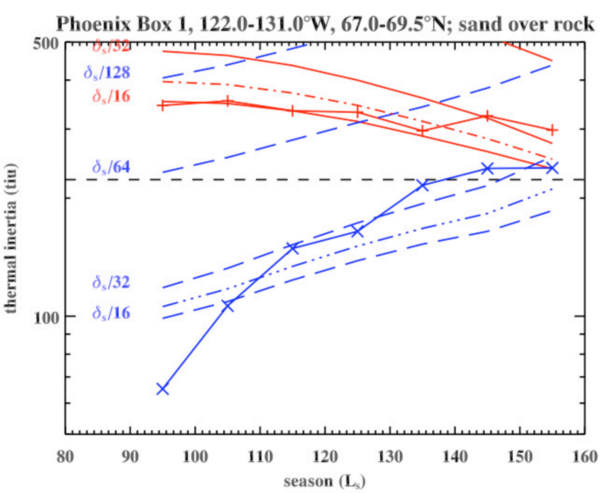

Figure 2. Seasonal 2-AM (blue) and 2-PM (red) apparent thermal inertia from TES (×, + symbols) and from layered models of sand over rock (or ground ice) at the Phoenix site (× in Fig. 1). Horizontal dashed line is sand (223 tiu). Curve labels are upper-layer thickness in fractional seasonal skin depth, δ_S (70 cm for sand). Best-fit model (dot-dashed curves) has a sand thickness of ~ 4 cm. Seasonal range is limited by transient CO_2 frost. From Putzig and Mellon [15].

In the erg, Mars Reconnaissance Orbiter High Resolution Imaging Science Experiment (HiRISE) images show bright deposits between individual dune crests (Fig. 3), which may be relatively consolidated and thus have higher thermal inertia than the surrounding dune materials. Also evident are diverging dune slopes, which will experience differential heating both diurnally and seasonally. Since their scales are well below that of TES (~ 3 km), both the horizontal material mixtures and the divergent slopes may have large effects on TES-derived apparent thermal inertia [13]. It will thus be essential to account for any contributions of horizontal heterogeneity when attempting to relate the thermal behavior of the erg to the presence of ground ice beneath a veneer of unconsolidated materials.

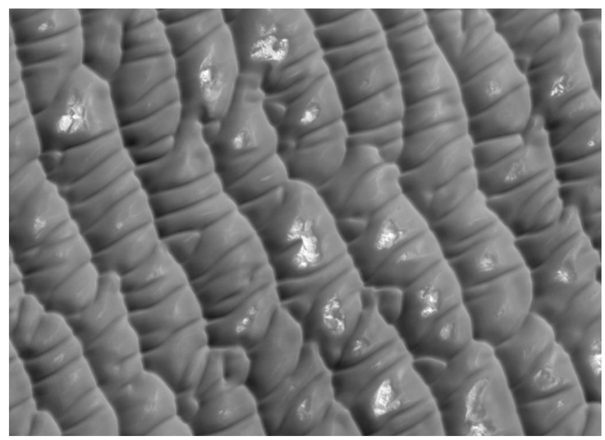

Figure 3. Portion of HiRISE image PSP_001736_2605 (center at 80.19° N, 168.77° W; + in Fig. 1), showing an area in Olympia Undae with bright deposits between dune crests. Illumination is from lower left. Image is 4.6 km wide. NASA/JPL/University of Arizona.

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