INVESTIGATING THE POLEWARD TREND OF SOUTHERN DUNE FIELD STABILIZATION ON MARS USING THERMOPHYSICAL OBSERVATIONS.

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Synopsis: Dune fields in the Martian southern hemisphere have morphologies indicating a poleward progression toward stabilization starting at 50-60° S. Separately, a near-surface layer of ground ice is expected to span the hemisphere from ~50° latitude to the pole. We hypothesize that the southward increase in stabilization may be caused by an ice table that is shallower at higher latitudes, a linkage that would allow dune morphology to be used as a tracer of local climate. Thermal inertia measurements and multi-layer thermal modeling can indicate near-surface properties including ice table depth. We have begun an investigation of the thermal properties of the largest 171 southern dune fields with well-defined characteristics. Analysis of both composition and topography has not explained thermal inertia measurements, indicating there is more to the picture than initially suspected.

Background: Recently, evidence has accumulated for a ubiquitous, high-latitude layer of water ice below the Martian surface. Material excavated by fresh, mid-latitude craters has revealed ice within decimeters of the surface [1]. Neutron spectrometry data from Mars Odyssey indicates deposits of 20–100% water-equivalent hydrogen by mass within a meter of the surface poleward of ±50° latitude [2]. Temporal variations in apparent thermal inertia in the northern polar erg have been shown to be consistent with decimeters of dry sand overlying ice-cemented sand [3].

A mapping of 1190 dune fields poleward of 50° S [4] found that sharp-crested dunes are located almost exclusively north of 60° S, and more rounded dunes are primarily south of this line, progressing to flat sand sheets near the pole (Fig. 1). This indicates dunes south of 60° S have experienced increased stabilization and are less reflective of current aeolian activity.

Ice, the Leading Suspect: This southward smoothing of dune fields beginning near 60° S is tantalizingly coincident with the southward rise in Odyssey-detected ice beginning near 50° S. Since interstitial ice retards bedform migration [5], it is proposed [4] that the transition in dune morphology is directly related to a transition in depth of subsurface ice, i.e., it is shallower in more poleward regions. Presumably, a shallow ice table would cement dunes in place, leaving them subject to non-aeolian erosion that rounds and flattens them.

High-resolution images do not reveal any craters on these frozen dune fields, indicating the dune surfaces are young, perhaps less than 100 years old [6]. This youthful appearance suggests that, if dune stability is controlled by a progressively shallower ice table, dune morphology is a direct indicator of current climatic conditions.

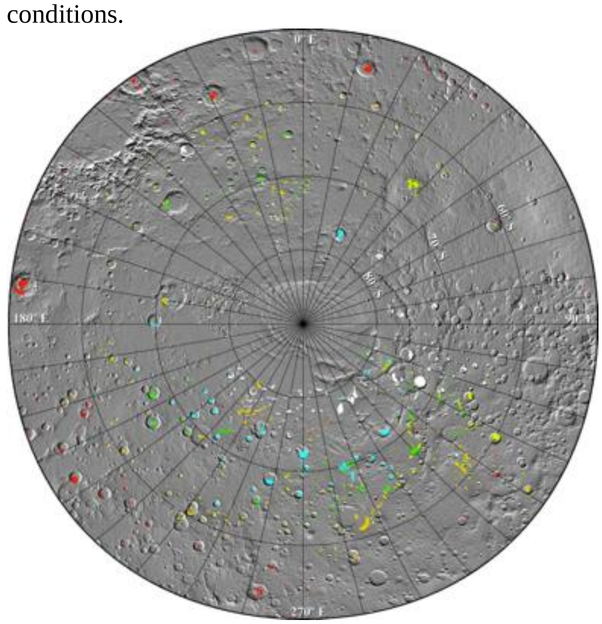

Figure 1. MOLA shaded relief map of the region poleward of 50° S in an oblique equidistant projection. Marked are 1190 dune fields in six morphological classes from [4]. Moving southward, sharp-crested dunes (red) give way to rounded dunes (e.g. green) and then to flat sand fields (white).

Investigating with Thermal Inertia: We investigate the ice table depth through comparison of thermal inertia measurements to thermal modeling results.

Thermal Inertia: Thermal inertia is a bulk material property. For typical materials on the Martian surface, it is dominated by thermal conductivity [7], which is determined by properties such as particle size and porosity, making materials such as dust, sand, and rock easily distinguishable. We determine apparent thermal inertia from individual temperature measurements by the Mars Global Surveyor Thermal Emission Spectrometer (TES) and the Mars Odyssey Thermal Imaging System (THEMIS) using a lookup table which matches temperature to thermal inertia at particular times of day, seasons, latitudes, and atmospheric and surface conditions [8, 9].

Thermal Modeling: Once we have determined a dune field's thermal inertia over the course of a Martian year, we compare with predictions from various model surfaces. For a heterogeneous surface, apparent thermal inertia varies with time of day and season [10, 11], so observed variations can be matched to a combination of materials (e.g. dust, sand, ice) in a certain configuration (horizontal mixture or vertical layering) with a certain surface slope. Vertical layering is key, as this includes dry sand layered in some thickness over ice. This technique was used, for instance, to accurately predict subsurface ice depth at the Phoenix landing site [12] and at the northern polar erg [3].

First Looks: We performed an initial analysis on two dune fields, in Hussey crater (233.1° E, 53.1° S) and in the inter-crater plains at 293.7° E, 49.8° S (Figs. 2 & 3). Under the subsurface ice hypothesis, we might expect thermal inertia measurements at these two sites

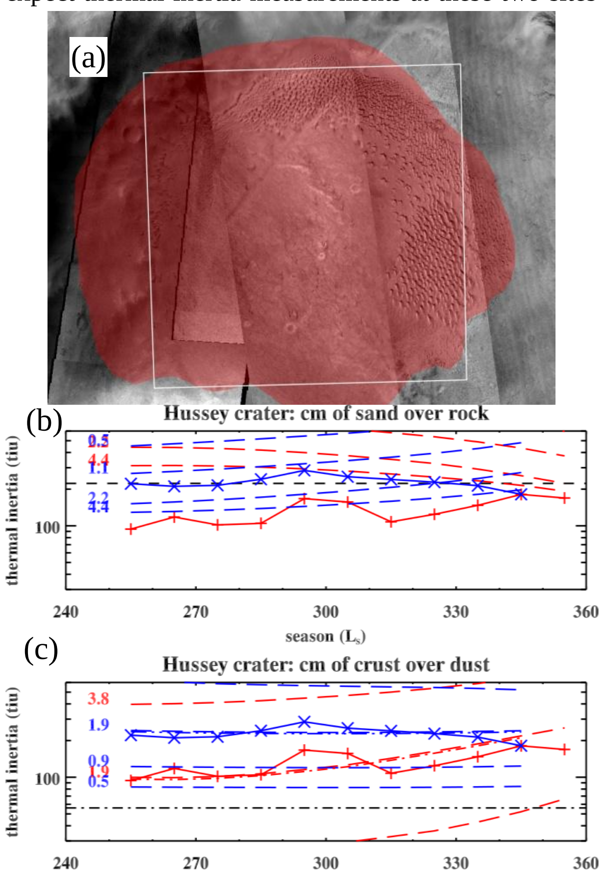

Figure 2. ***(a)*** *THEMIS visible images showing Hussey crater dune field (in red as defined in [13]), with our analysis performed within the white box.* ***(b)*** *and* ***(c)*** *show seasonal apparent thermal inertia for separate two-layer models (with rock used as thermally equivalent to ice). In each, values at 2AM (blue) and 2PM (red) from TES (symbols, solid lines) are compared with those from models (dashed lines) labeled with top-layer thicknesses in cm. Seasons are limited to those when CO_2 ice is absent. The data are broadly anti-correlated with the sand (225 tiu)-over-rock (2506 tiu) model, but follow well the crust (889 tiu)-over-dust (56 tiu) trends.*

to be consistent with a sand-over-ice model (where the model's "rock" is thermally equivalent to ice). However, both sites are consistent instead with a couple of centimeters of crust overlying dust. We found similar results in a preliminary analysis of two more-poleward, more eroded sites, where shallower ice would be expected. Further, dune slope modeling does not remove this discrepancy [14]. These results suggest additional complexity not captured in the models, but they do not rule out the presence of deeper ground ice.

Future Plans: Of the 1190 dune fields mapped in [4], 171 are larger than 0.25° across (5 pixels in TES data) with a high-confidence morphological classification. We hope analysis of the remaining 167 will help complete our picture. Additionally, we are developing models with 3+ subsurface layers, which we hope will resolve ice under more complex layering scenarios.

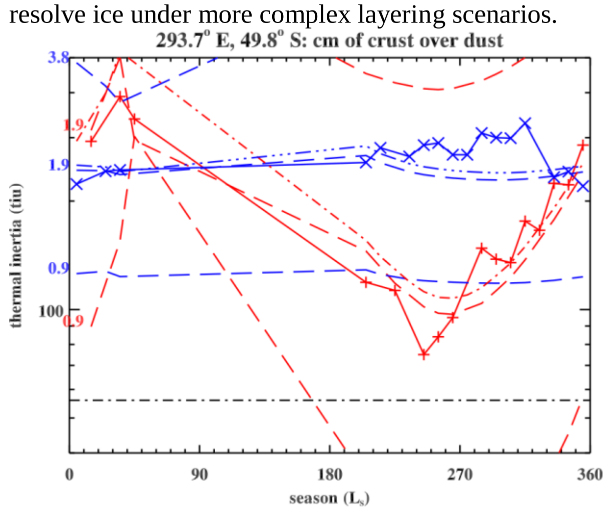

Figure 3. TES and modeled thermal inertia for the dune field at 293.7° E, 49.8° S, colored and labeled as in Fig. 2. As with the Hussey Crater dune field (Fig. 2), a crust-over-dust model provides the best fit whereas a sand-over-ice model (not shown) exhibits an anti-correlated behavior.

References: [1] Byrne, S. et al. (2009) *Science*, 325, 1674-1676. [2] Feldman, W.C. et al. (2004) *JGR*, 109, 13. [3] Putzig, N. E. et al. (2014) *Icarus*, 230, 64-76. [4] Fenton, L. K. and Hayward, R. K. (2010) *Geomorphology*, 121, 98-121. [5] Bourke, M. C. et al. (2009) *Geomorphology*, 109, 148-160. [6] Butcher, A. and Fenton, L. (2011) *LPS XLII*, Abstract #2091. [7] Jakosky, B. M. (1986) *Icarus*, 66, 117-124. [8] Mellon, M. T. et al. (2000) *Icarus*, 148, 437-455. [9] Putzig, N. E. et al. (2004) *LPS XXXV*, Abstract #1863. [10] Mellon, M. T. et al. (2008) in: *The Martian Surface*, Bell, J. F., ed. (2008) Cambridge Univ. Press. [11] Putzig, N. E. and Mellon, M. T. (2007) *Icarus*, 191, 52-67. [12] Putzig, N. E. and Mellon, M. T. (2007) *Icarus*, 191, 68-94. [13] Hayward, R. K. et al. (2014) *Icarus*, 230, 38-46. [14] O'Shea, P. et al. (2015) *AGU IIL*, Abstract P43A-2092.