APPARENT THERMAL INERTIA TRENDS FROM MARS ODYSSEY THEMIS AND IMPLICATIONS FOR SELECTED REGIONS OF MARS A. A. Ahern[1] and A.D. Rogers[1], [1]Stony Brook University Department of Geosciences, Earth and Space Science Building, Stony Brook, NY 11767, *alexandra.ahern@stonybrook.edu.*

Motivation: Constraints on the physical nature of Martian surface materials can provide greater insight into the origins of geologic materials and important sedimentary, effusive volcanic, pyroclastic, and surface-atmosphere exchange processes that have occurred in Mars' past. Additionally, characterization of the Martian surface will assist in future mission planning and has the potential to tie rover and orbital data together for a more cohesive understanding of Mars surface geology.

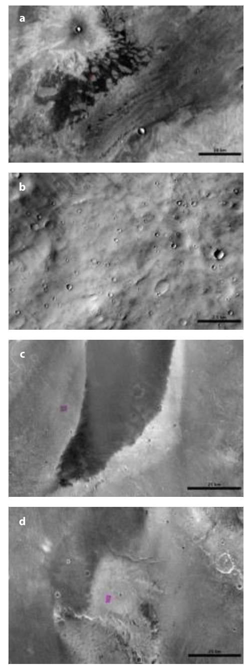
Background: Thermal inertia (I) is the intrinsic property of a material that quantifies how efficiently that material can store, conduct, and then reradiate heat. It is given by:

$$I = \sqrt{k\rho c}$$

where k is the thermal conductivity, ρ is the bulk density, and c is the specific heat, and is measured in $J/m^2Ks^{1/2}$, or thermal inertia units (tiu). Thermal inertia is the most important material property controlling both diurnal and seasonal surface temperature variations [1]. At Mars atmospheric pressure, thermal inertia is dominated by the effects of conductivity, which is determined by the physical characteristics of the near subsurface up to a thermal skin depth [2] [3]. Such physical properties could include grain size (for unconsolidated sediment), degree of induration, cementation, vesicularity, porosity, or degree of fracturing.

Most orbital derivations of thermal inertia are given as an apparent thermal inertia, using a single nighttime temperature and assuming that the surface is made of an entirely physically uniform material both laterally and into the subsurface. This was done out of necessity due to limited availability of local time coverage. However, may be occurring within each pixel of a it is highly likely, based on our current understanding of Mars geology, that materials with different thermophysical properties are mixed laterally or layered vertically at subpixel resolutions in most areas (e.g. variable dust cover, dune fields, bedrock exposures, duricrusts). However, changing apparent thermal inertia trends over both diurnal and seasonal scales [e.g. [4] may be able to provide clues as to the physical nature and styles of heterogeneity present at the surface of Mars.

Fortunately, the longevity and evolving local times of the Mars Odyssey Thermal Emission Imaging System (THEMIS) mission has enabled collection of 9 Mars years' worth of surface temperatures at varying local times and seasons. Specifically, pre-sunrise (3-6 AM) and post-sunset (6-8 PM) local Mars times provide the best opportunities for measuring surface temperatures and computing thermal inertia values from those temperatures, since albedo effects are minimized and surface temperature contrast is greatest at these times [5] [6].



1a: Cerberus Fossae high thermal inertia lava unit in THEMIS Day IR. The red polygon represents the location sampled for thermal inertia data.

1b: CTX image of putative duricrust surface in Noachis Terra.

1c: Thermophysical boundary between Oxia Palus and Arabia Terra in THEMIS Night IR. The lavender polygon represents the sampling area for thermal inertia data in putative duricrust.

1d: Thermophysical boundary between Arabia Terra and Meridiani Planum in THEMIS Night IR. The lavender polygon represents the sampling area for thermal inertia data in putative duricrust.

Figure 1: Locations for apparent thermal inertia trends presented in this paper.

Regions: In this study, we have identified regions of interest in the following four categories: (1) lithified materials ("bedrock") with distinctive spectral character (e.g. chlorides, feldspathic, and olivine-bearing units), (2) putative duricrusts, (3) widespread, distinctive, yet poorly understood surfaces (e.g. dark draping units in Mawrth Vallis/Meridiani Planum; "thin mesa units" [7]), and (4) past and future landing sites. Each of the 18 locations we have thus far examined have specific questions as to their physical properties, but all seek to answer the larger questions of material origins and Mars surface processes.

Specifically, we present results from the Cerberus Fossae region, where some of the youngest and most competent lavas on Mars are thought to be present [8] (Fig. 1a). However, relatively high albedo values also suggest a thin dust cover over these basalts. Another location of interest is a monitoring site in Noachis Terra, where duricrusts have been proposed to explain based on their combined intermediate TES TI and intermediate albedo values [1][6] (Fig. 1b). Additionally, we show trends from the thermophysical boundary around Oxia Palus, Arabia Terra, and Meridiani Planum with the hypothesis that differing thermal properties of adjacent units indicate duricrusts and dust deposits. (Fig. 1c).

Methods: For each of region of interest, we created sampling polygons within each of the relevant units from which to retrieve surface temperatures. These surface temperatures come from overlapping THEMIS projected brightness temperature observations in the pre-sunrise (3-6 AM) and post sunset (6-8 PM) local times. We also retrieved higher spatial resolution albedos from the THEMIS VIS sensor and appropriate atmospheric dust opacities corresponding to the THEMIS observations from [9]. The THEMIS surface temperatures are then converted to apparent thermal inertias using the KRC model [10]. Apparent thermal inertia trends can shed light on the styles of heterogeneity present within a sampling region. For example, diurnal drops in apparent thermal inertia indicate vertical layering, in which a lower thermal inertia material overlies a higher thermal inertia material (e.g. a dust or loose sand covering over competent bedrock). A rise in apparent thermal inertia throughout a Martian day is indicative of a higher thermal inertia layer over a lower thermal inertia material (e.g. a duricrust or lag deposit scenario) (Fig. 2). Each of these sampling polygons can then be tested against a variety of modeled physically-heterogenous scenarios to determine the most likely thermophysical nature and configuration of near-surface (>1 m) materials, which is a further extension of this work.

Results: The Cerberus Fossae lavas are thought to be competent, young, effusive flows, but relatively high albedo values compared to basalts suggest some amount of dust cover. Diurnal thermal inertia trends in that region seem consistent with these hypotheses, with a significant drop from AM to PM apparent thermal inertias (Fig. 3a). The long-term duricrust monitoring site in Noachis Terra appears to show the opposite trend, possibly corroborating the duricrust hypothesis in this location (Fig 3b). However, at other putative duricrust sites, such as at the thermophysical boundary of Oxia Palus/Arabia Terra or Arabia Terra/Meridiani Planum, the trends seem to be opposite, with a lower thermal inertia material overlaying a higher thermal inertia material (Fig 3c). This could indicate that the surface is different than expected but could also be due a thin cover of dust over a thick duricrust. Further model comparisons will hopefully shed light on why this trend occurs.

Conclusions: Thermal inertia is a useful tool in understanding the physical properties of the Martian near-surface, which is a crucial piece to the puzzle of learning the geologic history of Mars. Apparent thermal inertia trends are the first step towards assessment of heterogeneity and will guide future work in which we will directly compare overlapping THEMIS temperature observations with a variety of heterogeneous surface temperature models.

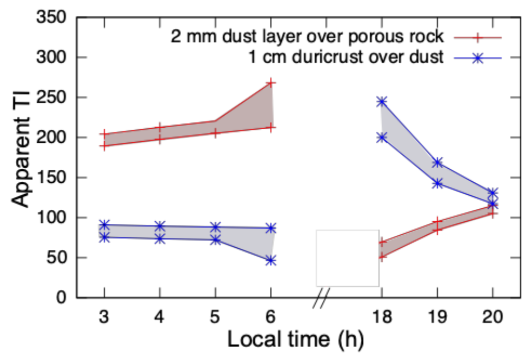
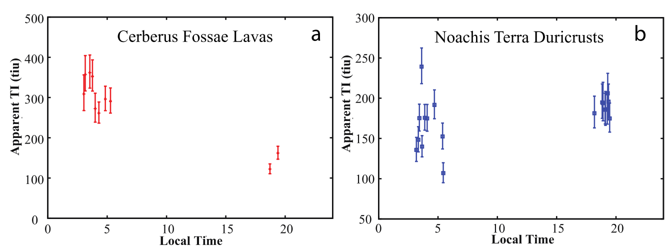


Figure 2: Predicted trends in apparent thermal inertia (TI) for two vertical layering scenarios: thin dust (2mm, TI=55) over porous rock (TI=600) and duricrust (1 cm, TI=800) over dust (TI=55), at Oxia Palus. Red and blue shading represents the seasonal variability in apparent TI. Homogeneous surfaces (not shown) should exhibit no change in apparent TI as a function of local time. The new Mars Odyssey local time provides a useful constraint on thermophysical mixing scenarios.



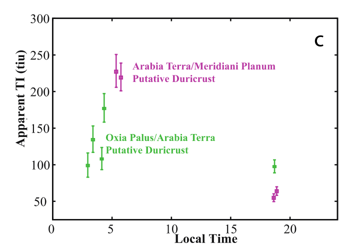


Figure 3: Apparent thermal inertia trends for (a) Cerberus Fossae lavas, (b) Noachis Terra putative duricrusts, and (c) the putative duricrusts along the thermophysical boundary near Oxia Palus/Arabia Terra/Meridiani Planum.

References: [1] Putzig, N. And Mellon, M. (2007) *Icarus, 191*, 68-94. [2] Wechsler, A.E. et al. (1972) Thermal Characteristics of the Moon, 215-241. [3] Jakosky, B.M. (1986) *Icarus, 66*, 117-124. [4] Audouard, J. et al. (2015) *Icarus, 233*,194-213. [5] Kieffer, H.H. et al. (1977) *JGR, 82*, 4249-4291. [6] Fergason, R.L. et al. (2006) *JGR, 111, E12004*. [7] Malin, M.C. and Edgett, K.S. (2000) *Science, 290*, 1927-1937. [8] Jaeger, W.L. et al. (2007) *Science, 317*, 1709-1711. [9] Montabone, L. et al. (2015) *Icarus, 251*, 65-95. [10] Kieffer, H.H. (2013) *JGR:Planets, 118*, 451-470.

Acknowledgements: This work was funded by the Mars Odyssey Project.