

QUANTIFYING THE AREAL PERCENTAGES OF DUST, SAND, AND LAVA OUTCROPS IN DAEDALIA PLANUM, MARS. C. M. Simurda¹, M. S. Ramsey¹, and D. A. Crown², ¹Department of Geology and Environmental Science, University of Pittsburgh, 4107 O'Hara Street SRCC, Room 200, Pittsburgh, PA, 15260 (Simurda_C@pitt.edu), ²Planetary Science Institute, 1700 E. Fort Lowell Road, Suite 106, Tucson, AZ, 85719.

Introduction: Mantling of the Martian surface by dust and sand can hinder remote investigation of the underlying bedrock, particularly in the Tharsis region [1]. It is vital to identify the degree of eolian mantling that obscures a study site in order to attempt an accurate investigation of the bedrock spectral signature. One approach to this problem is using thermal infrared (TIR) data to investigate the particle size of the mantling material and the composition of the underlying rocks.

Derived from TIR data, thermal inertia (TI) represents the resistance of a material to changes in temperature. TI can be used to identify particle size because thermal conductivity, a main component of TI, is dominated by grain-size, particularly under Martian conditions [2]. Martian thermal conductivity models suggest that low TI regions can be representative of a mixture of coarse plus fine-grained material [3]. The surfaces of certain lava flows in Daedalia Planum consist of large outcrops of lava with sand infilling low-lying regions and an optically thin, spatially heterogeneous dust layer covering these surfaces (Figure 1).

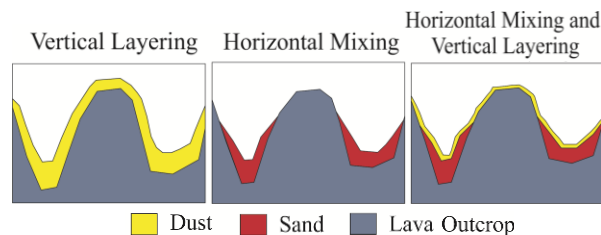


Figure 1. Possible scenarios for Martian surficial deposits: (A) uniform dust cover; (B) sand in low-lying regions and no dust; and (C) sand deposited in low-lying regions with dust covering both surfaces.

This study focuses on identifying the areal percentages of dust, sand, and lava outcrops by using a thermal model to predict the temperature and TI of a predetermined surface which is then matched with the thermal data collected for each flow. To separate the spectral signatures of these components, multiple datasets are examined here to investigate lava flows in Daedalia Planum previously considered too heavily mantled for this type of study.

Background: The lava flow field in Daedalia Planum originated from the SW flank of Arsia Mons

and is predominantly basaltic in composition, making it an ideal location to study the effect of variations in dust, sand, and lava outcrops at the surface [4-6]. This area also has extensive coverage by multiple datasets, including HiRISE, CTX, and THEMIS, and geologic mapping has been completed [7-9]. A previous study examining both VIS and TIR datasets to quantify the thermophysical variability of these lava flows demonstrated the presence of different combinations of dust, sand, and lava outcrops on the surface [7]. Rough flows with a thermal response of low day and high night brightness temperatures were determined to have the highest potential for lava outcrops with minimal amounts of mantling (Figure 2).

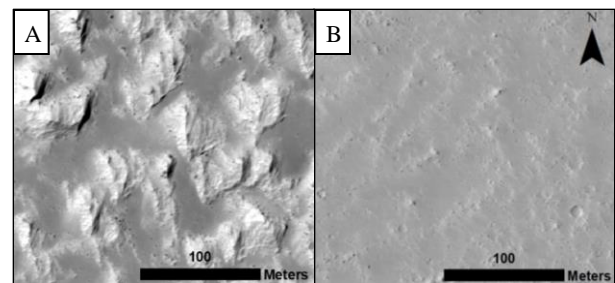


Figure 2. HiRISE images of (A) rough and (B) smooth lava flow surfaces in Daedalia Planum (ESP_036731_1570; ESP_036586_1560). Note that rough lava flows display locally high standing, bright outcrops with transverse eolian ridges indicative of sand in adjacent low-lying regions.

Methods: To investigate the potential variations of dust, sand, and lava outcrops at the surface, THEMIS data were used to quantify the thermophysical properties of the lava flows and visible data were used to identify the physical surface structures. Regions of interest (ROIs) were placed along 48 flow lengths to derive TI and brightness temperatures for both day and night [10]. These data were used to understand differences in thermal response between neighboring flows and any changes along flow lengths. Furthermore, having at least two brightness temperatures, with maximum time difference between them, a diurnal thermal model can be fit to them to investigate the surface properties.

To understand the THEMIS-derived thermal response, the KRC thermal model, named for the variables thermal conductivity, density, and thermal

capacity used to calculate TI, was used to generate two-component diurnal and seasonal temperature curves [11]. This model uses defined material properties and location parameters to calculate the surface temperature over either a diurnal or seasonal cycle. Three idealized surface components were defined, all having a basaltic composition with the following different particle sizes: dust (56 tiu), sand (223 tiu), and rock (2200 tiu). A series of model runs were completed with single and two-layer vertical systems (Figure 3).

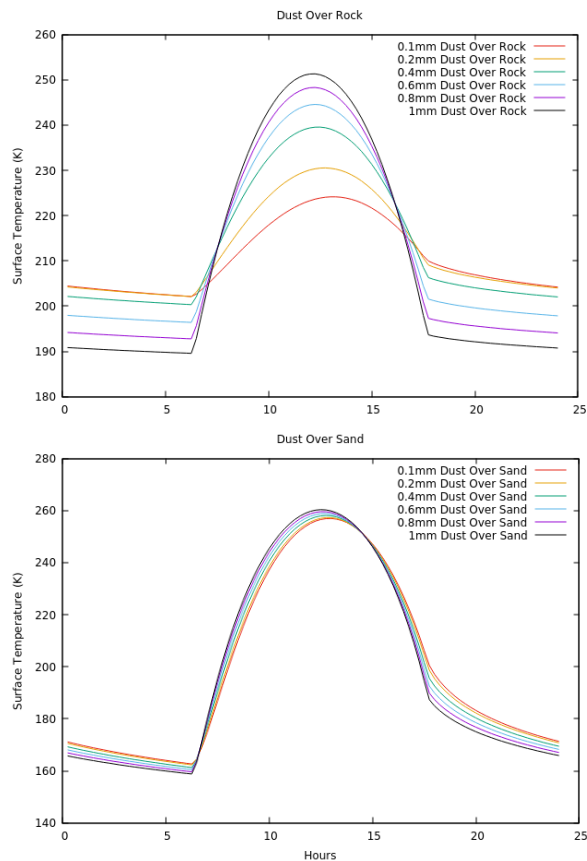


Figure 3. Diurnal temperature curves produced using the KRC model to demonstrate the effect of increasingly thicker dust cover over lava outcrops and sand. Note the impact on the thermal cycle of the lava outcrop is greatly influenced by thick layers of dust.

To produce the complex mixed component scenarios that are more realistic of these surfaces, a two-endmember, user developed, linear horizontal mixture code written in IDL was developed. This combines different areal percentages of the vertical components. A look-up table (LUT) was compiled to include all of the vertical layering runs and horizontal mixture combinations. The THEMIS-derived thermal responses were matched to the KRC-produced diurnal

curves to identify the areal percentages of dust, sand, and lava outcrop on the surface. To further limit the potential areal combinations, the TI of each potential mixture was matched with the TI calculated from night THEMIS data [10] and the flows were examined to visually identify exposed lava outcrops in CTX and HiRISE images to finally constrain the amount of dust, sand, and lava outcrops.

Results and Discussion: Initial comparison of simplified single-layer, horizontally mixed results and THEMIS data of the targeted rough flows strongly suggests the presence of up to 40% rock (lava outcrops) on the flows. If lava outcrops were mantled, the THEMIS data would only match the results of model runs with 0% rock abundance. This comparison also demonstrates that the most realistic scenario includes a horizontal mixing model of two-layered vertical endmembers with dust over sand and dust over lava outcrops. Analysis of the two-layered horizontal mixture models with THEMIS-derived thermal responses of targeted rough flows reveals that many have 40-45% lava outcrops and 55-60% sand with a ~1.5 mm thick dust covering. Additionally, the visible qualitative assessment of surface morphology and quantitative TI estimates support this conclusion.

Summary: This new thermophysical modeling method reveals that lava flows in Daedalia Planum are not completely (or uniformly) dust mantled and some flow surfaces contain over 40% observable outcrops. Combined visible surface morphology analysis and thermophysical modeling of the temperature and TI responses demonstrate the ability to identify the areal percentages of dust, sand, and lava outcrops on Mars. With this information, the spectral signatures of the exposed outcrops can now be specifically targeted and separated from the sand and dust in low-lying areas. We expect these spectral results will constrain any compositional changes between flows and variations in the emplacement process over time. This method also has applications to other less explored sites on Mars considered too dust-covered.

References: [1] Malin M.C. et al. (2001) *JGR*, 106, 429-23, 570. [2] Presley M.A. and P.R. Christensen (1997) *JGR*, 102, E3, 6551-6566. [3] Mellon et al. (2014) *8th Intern. Conf. on Mars*, abs. 1107. [4] Crumpler L.S. et al. (1996) *Geol. Soc. Spec. Publ.*, 110, 725-744. [5] Lang N.P. et al. (2009) *JVGR*, 185, 103-115. [6] Edwards C.S. et al. (2010) *JGR*, 116, E10008. [7] Simurda C.M. et al. (2018) *LPSC XLIX*, abs. 1792. [8] Crown D.A. and M.S. Ramsey (2017) *JVGR*, 342, 13-28. [9] Crown D.A. et al. (2015) *LPSC XLVI*, abs. 1439. [10] Ferguson R.L. et al. (2004) *JGR*, 111, E12004. [11] Kieffer H.H. (2013) *JGR*, 118, 451-470.