How Mantled are the Daedalia Planum Lava Flows?

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Introduction

Mantling by eolian material (i.e., dust and sand) hinders spectral investigations of the Martian surface. However, checkboard mixing of larger lava outcrops mixed with eolian material in low-lying regions may also occur. Therefore, it is critical to identify the degree of mantling and/or mixing of fines and lava outcrops on the surface to determine whether the spectral signature of the bedrock can be discerned. To achieve this goal, thermal properties can be used to identify particle and block size distribution due to the grain-size dependence of thermal conductivity [1]. Since thermal conductivity models suggest that the detection of coarse grained particles are obscured by fines, low thermal inertia regions may be explained by a mixture of coarse plus fine grained material rather than a continuous layer of fines [2]. For blocky lava flows, a surface may represent either checkerboard mixing, or a thin layer of dust coating the surface, or both. Multiple datasets, with both high spatial and spectral resolutions, are used to identify possible mixing relationships on the flow surfaces and determine which flows may have checkboard mixing surfaces in order to possibly determine the spectral signature of the lava.

Location

Daedalia Planum contains one of the main flow aprons originating from the SW flank of Arsia Mons (figure 1), the southernmost Tharsis shield volcano [3-4]. These flows have a predominately basaltic composition [5]. The study area was selected for its coverage by multiple datasets, extensive lava flow fields, and flow field mapping [6-8]. Additionally, recent detailed geologic mapping using the visible datasets suggests the presence of rugged outcrops of lava distinct from the mantling material [8].

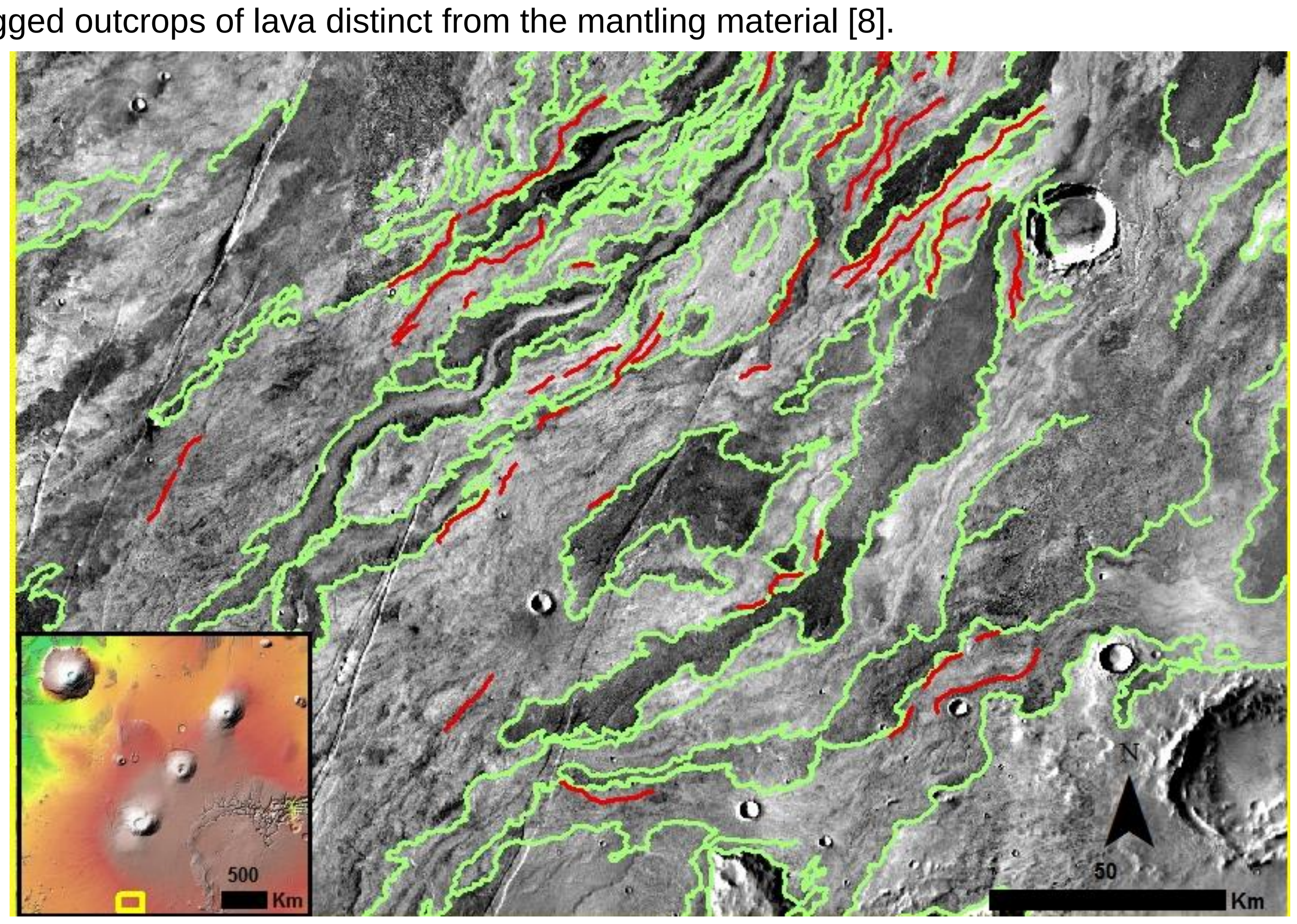


Fig.1. THEMIS IR day brightness temperature mosaic with lava flow margins (green) and channels (red) by Crown et al. [8]. MOLA color inset with yellow rectangle outlining the study area included for context [9].

Datasets

Lava Flow Boundaries and Surface Textures

- MRO ConTeXt Camera (CTX)
- MRO High Resolution Imaging Science Experiment (HiRISE)

Thermophysical Properties

- Thermal Emission Imaging System (THEMIS) IR Brightness Temperature Day and Night
- THEMIS Derived Thermal Inertia (TI)
- Thermal Emission Spectrometer (TES) Dust Cover Index

CTX and HiRISE images were used to visually identify flow boundaries, determine local flow superposition relationships, and characterize surface morphology. Through this method, elongate flows were identified as having either rugged (bright in the visible) or smooth (dark in the visible) surfaces [7-8].

For the thermophysical analysis of these flows, specific limitations were placed on the THEMIS infrared (IR) database search to select the best quality data [10]. Thermal inertia (TI) derived from THEMIS IR night data were compared with THEMIS IR day and night brightness temperature data to determine the thermophysical response of the identified flows over a diurnal cycle (figures 3-5) [11-12].

Methods

Over 450 regions of interest (ROIs) [500m x 500m] were defined to assess the variability of TI and brightness temperature within and between individual flows (figure 4). This is an expansion in the total ROIs collected and a decrease in the ROI area compared to previous studies [10]. Statistical analysis (including ANOVA) of the ROI data was performed. To investigate the thermophysical characteristics of the flows, four categories were defined based on day and night THEMIS IR brightness temperature data (table 1). Finally, the THEMIS defined category, thermal inertia, and flow type defined by Crown et al. 2015 [8] were compared to identify areas with potential unmantled exposures.

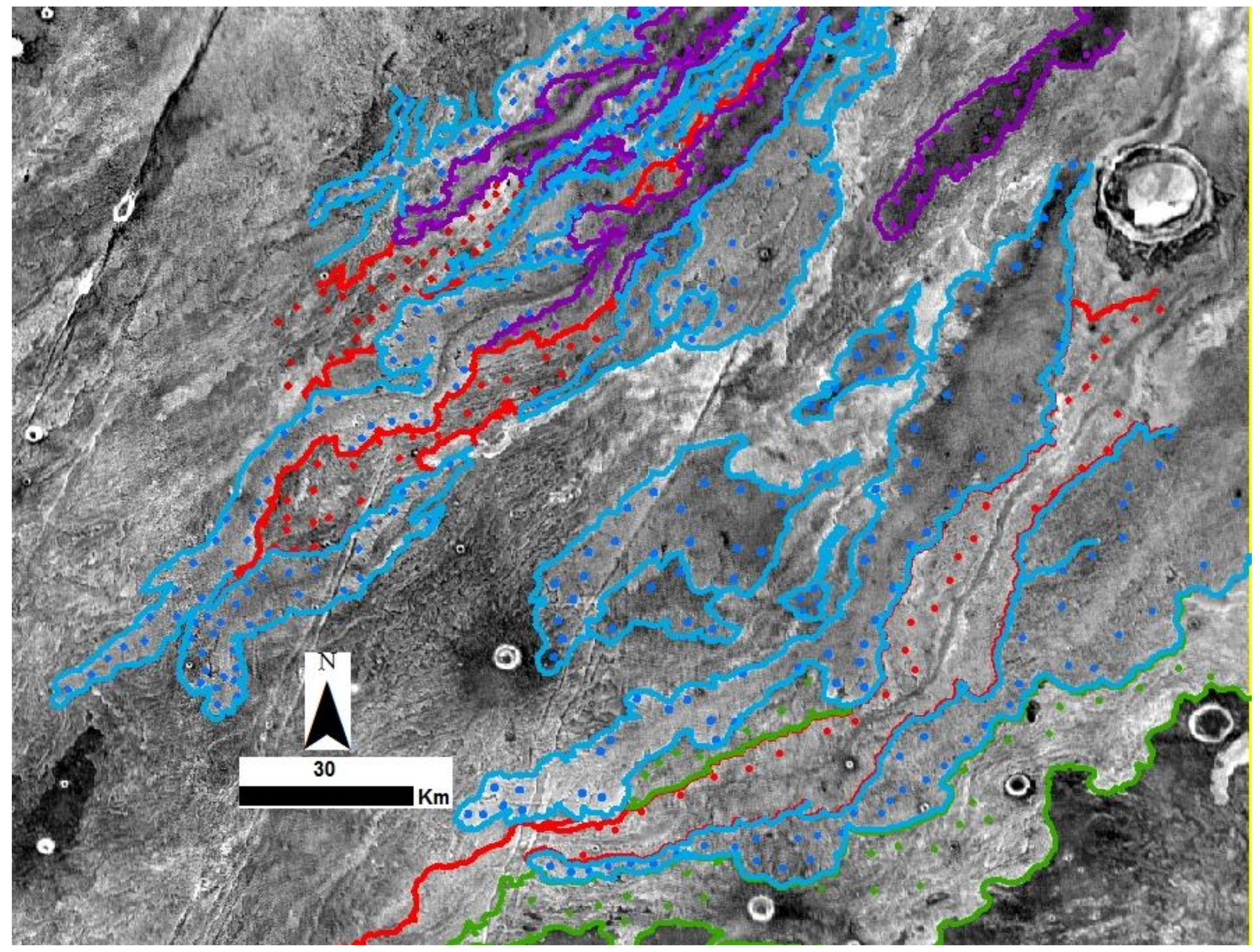
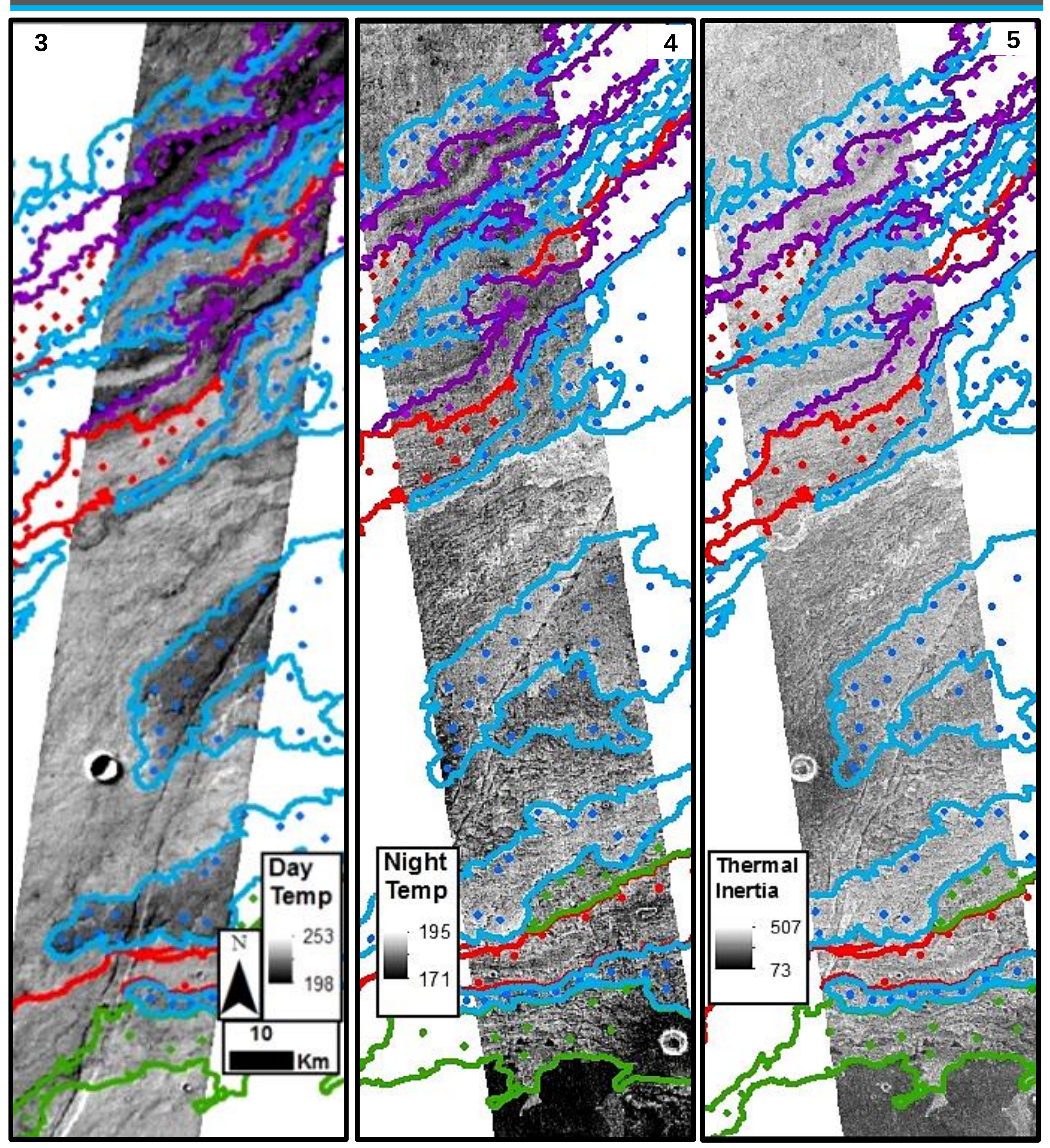


Fig.4. ROIs (colors corresponding to the flow categories in table 1) overlain on the THEMIS IR day brightness temperature mosaic [11] and flow boundaries [6-8].

Categories	IR Day Temperature	IR Night Temperature
A	High	High
B	High	Low
C	Low	High
D	Low	Low

Table 1. Four categories based on THEMIS-derived day and night brightness temperature data.

Comparison of Thermophysical Properties

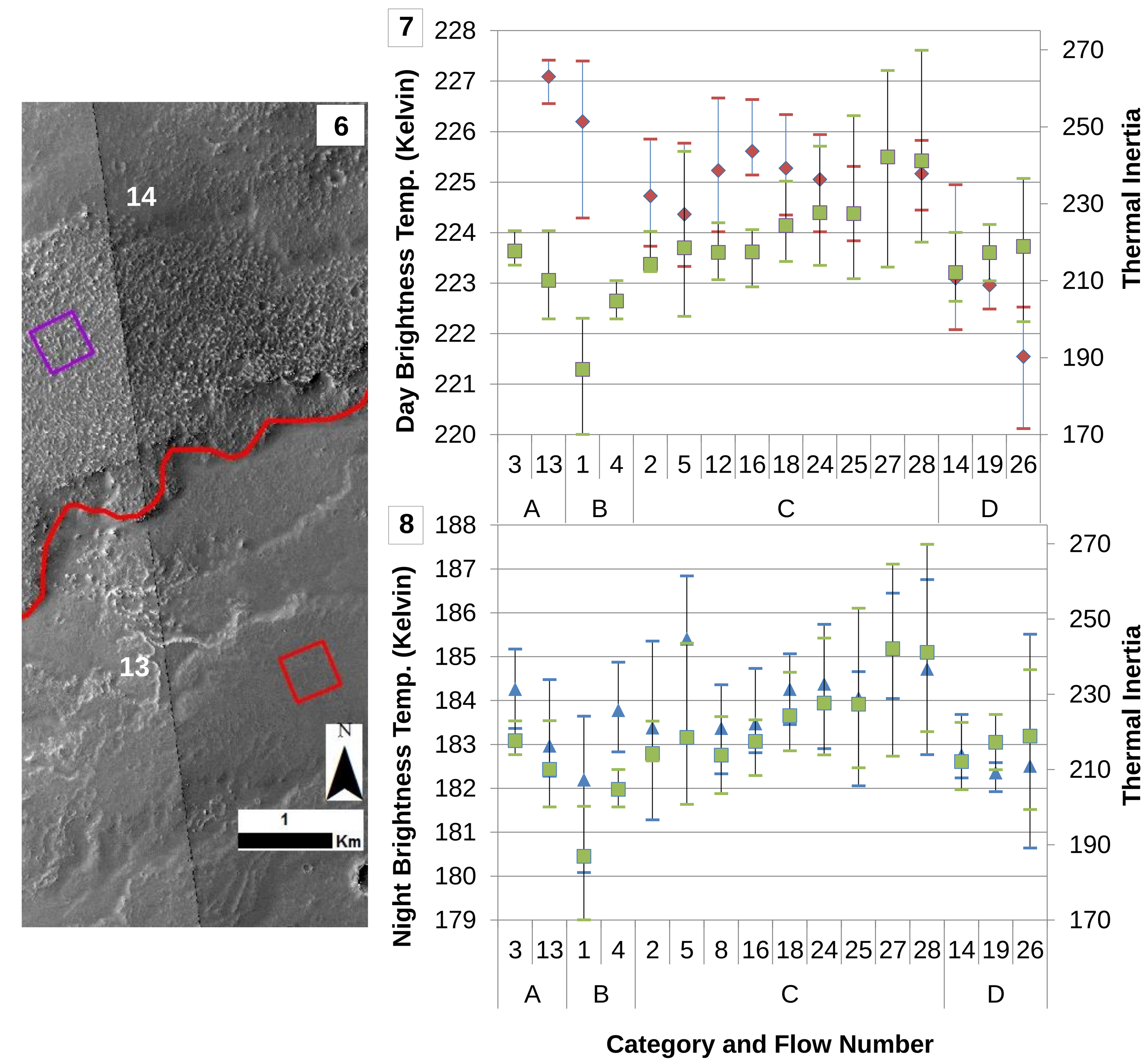


Figs.3-5. (3) THEMIS IR day brightness temperature, (4) THEMIS IR night brightness temperature, and (5) Thermal Inertia derived from THEMIS IR night [11] showing flow variability. The colors of outlined flows and ROIs correspond with the four categories in table 1 and the boundaries are defined by Crown et al. [6-8].

Results

The extent of the TI and brightness temperature variation in the lava flow field suggests the presence of different roughness element distributions or linear mixing of mantling and lava outcrops. If the area was completely covered with an optically thick layer of dust, the brightness temperature and TI should only vary as a result of shadowing effects based on slope topography that limits the maximum temperature reached by the fine material.

Twenty-one flows identified as either category D, having low day and night brightness temperatures, or category C, having low day and high night brightness temperatures, always display a rugged surface morphology. This extensive statistical analysis of the lava flows suggests that the THEMIS data may be detecting signatures from the lava outcrops as well as the eolian material in low-lying regions of rugged flows (figures 6-8). The identification of flows with potentially exposed lava outcrops now enables TI modeling to determine the percentage of rock plus fines that would produce the calculated TI values for the category C and D lava flows. This will ultimately determine whether or not it is possible to deconvolve the signature of only large outcrops.



Figs.6-8. (6) CTX image of neighboring flows (smooth – flow 13 and rugged – flow 14) with ROI areas shown. Average thermal inertia (green squares) with minimum and maximum range plotted against (7) day brightness temperatures (red diamonds) and (8) night brightness temperatures (blue triangle) for the flows.

Summary and Future Work

Analyses of surface thermophysical properties and flow morphology reveal that individual flows in Daedalia Planum respond differently to diurnal heating, suggesting that the area is not completely (or uniformly) mantled. The next phase of the work will be to model the TI response of rugged category A and C flows to determine the mixing percentages of outcrops plus fines on the surface. This will be accomplished by populating a look up table of possible components calculated using the krc model [13] and identifying potential mixing combinations that would produce the calculated TI values. Identified areas of outcrop will then be targeted to extract the spectral and thermophysical signatures using the defined mixing percentages. Thus, these results will constrain any changes in the down-flow composition and ultimately the emplacement process over time. Such an approach will be applicable to other lava flow regions on Mars.

Acknowledgements

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