BRIGHTNESS TEMPERATURE VARIATIONS AND ANISOTHERMALITY OF LAVA FLOWS NEAR ARSIA MONS. T. Peterson[1] B. E. McKeeby[2], M.S Ramsey [1], [1] Department of Geology and Environmental Science, University of Pittsburgh, 4107 O'Hara Street SRCC, Pittsburgh, PA, 15260 University of Pittsburgh, [2]Georgia Institute of Technology, North Ave NW, Atlanta, GA 30332 (typ12@pitt.edu).

Introduction: Anisothermal surfaces produce spectrally non-uniform brightness temperatures (BT) with higher temperatures present at shorter wavelengths [1]. The magnitude of BT differences is proportional to the magnitude of sub-pixel temperature mixing. Understanding the presence and degree of anisothermality on Mars is important because allows for the derivation of surface features below the spatial resolution of the instrument. In this work, anisothermality is detected by measuring the changing emitted radiance as a function of viewing angle and BT difference with respect to wavelength.

Correctly measuring a planet's emitted radiance and emissivity is critical to many aspects of planetary science including understanding surface evolution, compositional analysis, and landing site selection [2,3]. Furthermore, thermophysical properties such as thermal inertia aid in understanding surface layering, the presence of ice, and the particle size range [4]. Complications can arise in the interpretation of the surface emission, however. For example, a large range of surface roughness commonly results in an incorrect derived surface temperature that is necessary for retrieval of an accurate emission spectrum, and hence, the modeled surface composition [4]. Orbital instruments like the Thermal Emission Spectrometer (TES) and Thermal Emission Imaging System (THEMIS) are used to investigate compositional and thermophysical properties of the Mars surface for decades [3,4]. Surface roughness characterization is limited by the spatial resolution of these instruments (2 km/pixel for TES and 100m/pixel for THEMIS). Surface roughness below these spatial scales can produce temperature heterogeneities and mixing that alter the thermal infrared (TIR) emission spectrum [5,6]. Where sub-pixel thermal heterogeneities occur, the surface no longer behaves in a Planck like manner [4,9]. Therefore, standard temperature-emissivity separation methods are invalid as they assume a homogenous pixel surface temperature [7,8]. The result is a negatively sloped spectrum toward longer wavelengths. Like emissivity, brightness temperature (BT) is wavelength dependent, and can also be used to assess the degree of anisothermality [1,9].

Location: The selected THEMIS Routine Off-nadir Targeted Observation (ROTO) image data lies approximately 550 km south of Arsia Mons' base and within the Daedalia Planum flow field. This study area was selected as it contains previously identified thermal heterogeneities suggesting the presence of sub-pixel temperature mixing [3,7] and the young (~100 My) lava flows [10]. This dataset is one of only two ROTO's that have been completed to date. ROTOs provide TIR observations of the Martian surface collected in succession over only a week from varying viewing geometries.

Methods: This study utilizes an evening, -25° off-nadir THEMIS image (centered at -23.262ºN; 237.62ºE) of a region south of Arsia Mons. Previous studies have demonstrated that high emission angles better reveal anisothermal surfaces compared to nadir and intermediate geometries [9]. A decorrelation stretch (DSC) is one way to visualize these thermal variations in THEMIS images [9,7,11]. By removing highly correlated data between each spectral channel, color differences in DCS images reveal spectral differences despite the lava flows likely being the same basaltic composition. Here, a DCS of THEMIS bands 9-6-3 is used to show the presence of negatively sloped emission spectra, suggesting anisothermal surface conditions (Figure 1A). Although the DCS reveals thermal heterogeneities, warm atmospheric emission over the colder surface in certain parts of the image limits the ability to extract spectral slopes everywhere [7,9]. Therefore, a brightness temperature analysis utilizing high signal to noise and atmospherically transparent spectral wavelengths is employed. BT images are also utilized to identify warm (>215K at THEMIS band 9) surfaces (Figure 2B) where emissivity extraction may be possible [9]. In addition, the wavelength-dependent nature of BT data means that differences can also be used to investigate surface anisothermality. Here, by taking the difference of atmospherically transparent bands 3 and 9 (Figure 1C) we can identify areas with potential anisothermal surfaces [9].

Results: Results indicate variable surface properties across the scene. In the DCS shown in Figure 1A bluish-purple to teal colors suggest the presence of negatively trending spectral slopes towards longer wavelengths [9]. These appear to correlate with various flow like features and are more pronounced in the colder terrains (Figure 1B). BT differences between bands 3 and 9 (Figure 1C) indicate wavelength dependent temperature differences up to ~6 K. Differences of 4 K between the selected bands are colored green and correspond to the warmest regions shown in Figure 1B. BT differences of 6K are limited to steep sunlit surfaces (i.e. crater walls and large slopes). Interestingly, the colder flow surfaces in the northern part of the scene show minimal BT difference at this observation angle and overpass time.

Conclusions: BT differences in the range of 3-4 K suggest anisothermality within the lava flow plain studied here. This THEMIS image was acquired under evening viewing conditions with a solar incidence angel of 85°. Therefore, we expect some degree of surface shadowing within the image. Additionally, as the surface cools rocky material will retain its daytime heat longer whereas finer particle sized material will cool more quickly. Both scenarios can explain the observed anisothermality and further thermophysical modeling work is needed to differentiate these two hypotheses.

Next Steps: In the regions with suspected spectral slopes, the KRC thermophysical model (Kieffer, 2013) will be used next to determine the distribution of distinct thermal inertia units. In addition, TIR emission spectra will be extracted and modeled at each ROTO observation angle. By examining the observational dependent variations in BT and spectral slope, thermophysical surface properties such as surface roughness and thermophysical mixing can be inferred.

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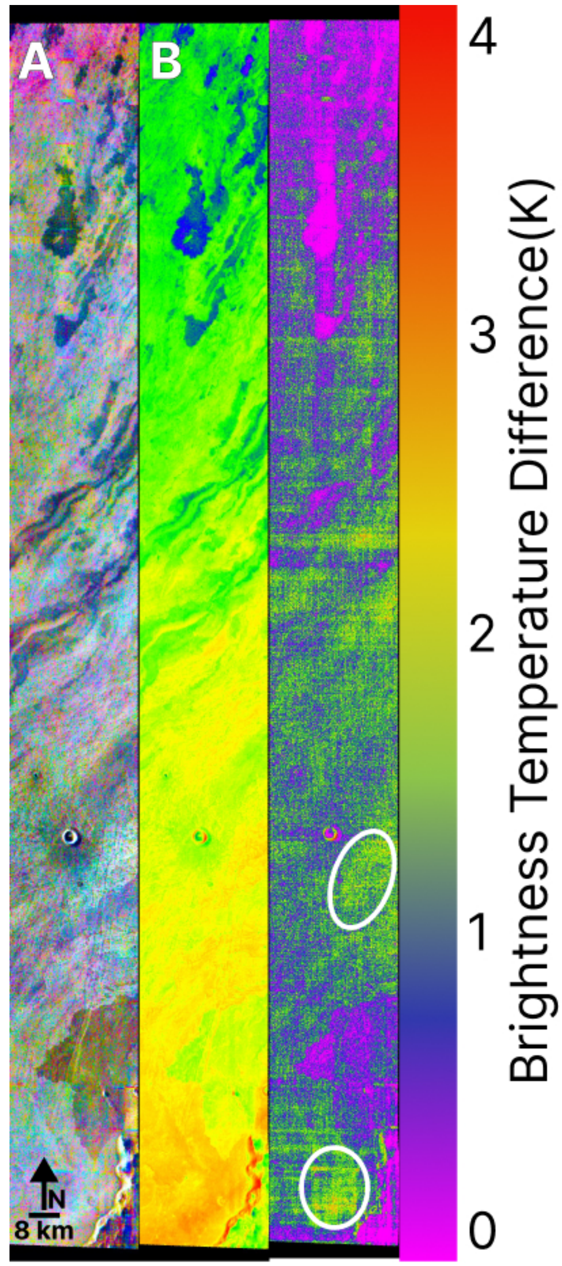

Figure 1. Three panel image of THEMIS ROTO image ID# I68172002. A) DCS radiance image using bands 9-6-3 showing the spectral variability across the scene. Bluish purple or teal colors represent regions with sloped spectra towards longer wavelengths. B) Brightness temperature image derived from band 9 radiance data showing the distribution of temperatures ranging from 187K (blue) to 228K (red). Study areas were limited to regions above 215K to avoid atmospheric temperature effects. C) Brightness temperature difference between bands 3-9. Warmer colors indicate greater difference in wavelength dependent temperature, suggesting the presence of surface anisothermality.