SUB-PIXEL TEMPERATURE MIXING ON THE B-TYPE ASTEROID (101955) BENNU. T. D. Glotch1, A. D. Rogers1, V. E. Hamilton2, P. R. Christensen3, C. W. Haberle3, J. P. Emery3, B. Rozitis3, and D. S. Lauretta4, 1Dept. of Geosciences, Stony Brook University, Stony Brook, NY, timothy.glotch@stonybrook.edu, 2Dept. of Space Science, Southwest Research Institute, Boulder, CO, 3School of Earth and Space Exploration, Arizona State University, Tempe, AZ, 4Dept. of Earth and Planetary Science, University of Tennessee, Knoxville, TN, 5Open University, Milton Keynes, UK, 6Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ.

Introduction: The Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) Thermal Emission Spectrometer (OTES) has observed spectral variability over the surface of Bennu [1–2]. Variations from the mean Bennu spectrum most commonly occur in the 800–1000 cm−1 range and at < ~400 cm−1. Previous work has demonstrated that thermal IR spectral variability can be caused by a number of factors unrelated to composition, including but not limited to particle size, albedo, and degree of space weathering [3–5]. Analyses of Diviner Lunar Radiometer long-wavelength thermal IR data demonstrated that surface anisothermality caused by surface roughness on the Moon leads to strong spectral variability that must be accounted for in any compositional analyses [6].

Bennu exhibits albedo variations [7], but its overall low albedo likely results in minimal variation in the surface thermal gradient, suggesting that the albedo also does not contribute to spectral variability.

On the other hand, we observe that OTES spectra calibrated to emissivity using a single temperature (Level 3 emissivity) display negative slopes towards lower frequencies and concave upward curvatures that are consistent with surface anisothermality, likely partially caused by shadowed surfaces in the OTES detector field of view (Figure 1). To address this, the OSIRIS-REx Team has implemented a multi-temperature emissivity calibration method [2] and is working to assess whether any residual effects are present in the spectra as a result of this method.

Calculation of Anisothermality Index: A primary goal of this work is to characterize the distribution and variability of anisothermal surfaces on Bennu. We start with the assumption that for a perfectly isothermal surface, the L3 and MT emissivity calibration routines would result in minimal differences between emissivity spectra calibrated using each method. Larger differences between the L3 and MT emissivity for any given spot result from sub-pixel temperature mixing. The degree of anistothermality can be visualized by dividing the MT emissivity spectrum by the L3 emissivity spectrum (Figure 2). We define the value at the peak of the average anistothermality ratio curve (at ~580 cm−1) for the Baseball Diamond 5 (BBD5) flyby as an “anistothermality index” that can be mapped across the surface of Bennu. The BBD5 data set was chosen as a test case because it includes observations with maximum brightness temperatures between ~240 and 340 K and solar incidence angles between ~0° and 90°.

We compare the index values for the BBD, Equatorial Station, and Reconnaissance surveys with a number of observational parameters to determine the cause(s) of sub-pixel temperature mixing on Bennu.

Global Anisothermality Trends: In every OTES data set examined for this work, anistothermality index values are lowest in equatorial regions and increase with latitude (Figure 3). This regional trend is likely dominated by the low solar incidence angles that generally accompany OTES observations near the equator and the higher emission angles at high latitudes. Solar incidence angles (and thus the proportion of
shadowed surfaces) increase as latitude increases. With the obvious exception of pre-dawn and night-time observations (incidence angles between 90-180°), the anistothermality index increases systematically as a function of incidence angle (Figure 4). However, anistothermality does not appear to be solely caused by surface shadowing that occurs with increasing incidence angle. Figure 5 shows that the largest anistothermality index values occur for BBD 5 and BBD7, which utilized an off-nadir scanning geometry. However, each of the

night-time and pre-dawn data sets have anistothermality index values that range from ~1.0 to 1.2. As anistothermality in these data sets cannot be caused by shadowing, we suggest that these values must be caused by other surface properties of Bennu. Possible causes of this anistothermality index variation include, but are not limited to, heterogeneities across Bennu’s surface in thermal inertia, particle size (mixtures of fine and coarse particulates), or the presence of a mineralogical graybody component (e.g., sulfide).

**Spectral Effects of Anistothermality:** As the BBD5 data set has the largest range of anistothermality index values among the data sets that we have examined, we use it to gain a better understanding of the effects of anistothermality on the thermal IR spectra of Bennu and the resulting mineralogical interpretation of the OTES spectra. Figure 6 shows averages of all BBD5 MT emissivity spectra with anistothermality index values < 1.1, < 1.2, and > 1.3. Average spectra with index values <1.1 and <1.2 are nearly identical, and the average spectrum isolated from the highest index spectra is also very similar. Overall, these data suggest that anistothermality does not have a strong effect on the shapes of the MT emissivity spectra. We will examine other data sets to determine if this conclusion is supported over a large range of local solar times and solar incidence angles.

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