THERMAL MODELING TO DETERMINE THE EXISTENCE AND NATURE OF LAYERED MATERIAL ON BENNU. A. J. Ryan[1], D. Pino-Muñoz[2], J. P. Emery[3], M. Delbo[4], B. Rozitis[5], R.-L. Ballouz[1], J. L. Molaro[6], M. Bernacki[2], J. Bandfield[7], C. Elder[8], M. Siegler[6], and D. S. Lauretta[1]. [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA (ajryan@orex.lpl.arizona.edu), [2]MINES ParisTech, PSL Research University, Centre de mise en forme des matériaux (CEMEF), CNRS UMR 7635, Sophia Antipolis, France, [3]Northern Arizona University, Flagstaff, AZ, USA, [4]Observatoire de la Côte d'Azur and Universitie Côte d'Azur, Nice, France, [5]Open University, Milton Keynes, UK, [6]Planetary Science Institute, Tucson, AZ, USA, [7]Space Science Institute, Boulder, CO, USA, [8]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA.

Introduction: The detection of layered material on Bennu, such as dust/sand/pebble coatings on the surface of rocks is of interest for geologic investigations and from a perspective of sampleability. The presence of a layer of cm-scale pebbles on a rock surface could for example be indicative of thermally driven exfoliation [1] or some other weathering or fallback process. The presence of layered material could also significantly bias our estimates of rock thermal inertia from data acquired by the OTES and OVIRS spectrometers onboard the OSIRIS-REx spacecraft, and as such could at least in part explain unexpectedly low thermal inertia values for Bennu and Ryugu [2,3,4,5].

Thermal analyses of Bennu and Ryugu so far have predominantly been performed with single-component thermophysical models with hemispherical craters to represent roughness [4,5]. Some work has, however, been done to study the effects of dust coatings. [5,6] showed that layers of dust as thin as 10–100 μm would significantly and noticeably affect the shape and phase of diurnal brightness temperature curves. However, neither study found compelling evidence for appreciable dust layers on Ryugu [5,6]. We seek to build upon the layered modeling work conducted by [5,6] by testing for the presence of thin layers of coarser, mm-to-cm-scale particles.

Methods: In order to model diurnal heating with very thin layers of particulate material, the individual particles must be treated explicitly in the model. We utilize a 3D finite element model for heat conduction and radiation [7]. Spheres are randomly dropped onto a smooth or rough surface to create a layer of particulates. The rough surface model geometry consists of a single hemispherical crater which is analogous to the craters utilized in global Bennu thermal inertia modeling [5]. Spheres are randomly dropped into the crater where they adhere to the walls and floor upon first contact. The crater is made sufficiently large compared to the sphere diameters so that the addition of the spheres does not significantly diminish the bowl-shaped nature of the crater.

The substrate rock in both the smooth- and rough-surface model is approximated as a continuum material to a depth of 20 diurnal skin depths. Heat flow through the solid materials is accomplished by means of an explicit heat diffusion solver, whereas surface-to-surface radiation between surface mesh elements is calculated using the Stefan-Boltzmann equation and added as an explicit term. The simulations are run through diurnal heating cycles until the maximum and minimum diurnal surface temperatures change by less than a defined threshold (currently ~0.05 K). All smooth-surface models are periodic in the x and y directions (where z is the direction of the surface normal) to minimize the size of the geometry and the computation time.

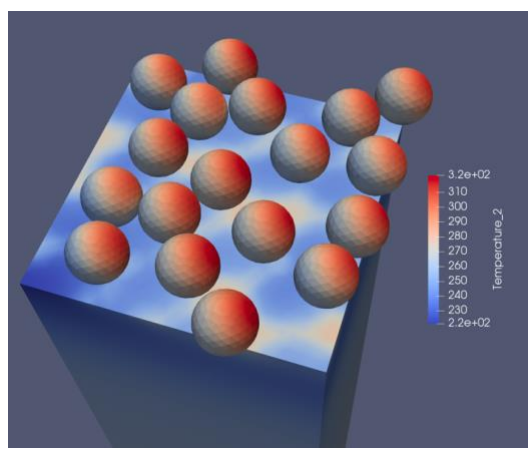

Figure 1. Temperature snapshot of diurnal heating of a loosely periodic monolayer of loosely distributed 1 cm diameter spheres on a smooth surface. The local time here is mid-morning when the solar source is positioned near the upper-right corner of the image. Note the visibility of thermal shadows to the left of the particles.

The smooth- and rough-surface models are run iteratively for different particle sizes (~0.1–5 cm diameter) with different layer thickness (monolayer and bilayer). The material properties, which are at present assumed to be the same for the rock substrate

and for the sphere material, are varied iteratively for each model geometry. Finally, diurnal brightness temperature curves produced from the layered model simulations are compared to diurnal curves created using the global Bennu thermal model [5] in order to determine which physical scenarios could possibly be present on the surface of Bennu.

References: [1] Molaro et al. (2019), this conference. [2] DellaGiustina, D.N., Emery, J.P., et al. (2019), Nature Astronomy, 3, 341–351. [3] Okada et al. (2019) EPSC-DPS Meeting, Abstract #268-1. [4] Grott et al. (2019) Nature Astronomy, https://doi.org/10.1038/s41550-019-0832-x. [5] Rozitis et al. (2019) EPSC-DPS Meeting, Abstract #548-1. [6] Biele et al. (2019) Prog. in Earth and Plan. Sci., 6, 48. [7] Ryan A. J. et al. (2018) 50th LPSC, Abstract #2512.

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