Regolith Thermophysical Properties: Experimental Thermal Conductivity Results and a New Full-field Thermophysical Model

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Thermal infrared observations of airless-body surfaces can be used to infer the physical properties of the surface regolith—namely, particle size distribution and rock abundance. This is of particular importance for active and future missions to asteroids, such as OSIRIS-REx, Hayabusa2, and Lucy, from a standpoint of scientific inquiry and mission safety. The main parameter that is typically determined from thermal measurements is the thermal inertia of the regolith. Thermal inertia is derived from the analysis of asteroid thermal infrared observations by applying thermophysical models (TPMs). To interpret thermal inertia values determined from TPMs, it is necessary to use theoretical or empirical models for heat flow through particulate materials in a vacuum.

I first focus on results from a laboratory experiment to determine the thermal conductivity of regolith simulants with particle diameters ranging from ~100 microns to 1.5 cm. I provide recommendations for how these results can be used for regolith particle size interpretations from airless-body thermal inertia values. I then present initial results from an ongoing effort to develop and apply a high-resolution, full-field, massively parallel particulate thermal model, wherein a finite element mesh framework is used to model heat flow through a three-dimensional bed of spherical particles. This model is specifically designed to accurately capture the two means of heat transfer through particulates: solid and radiative conduction. The model can be used to study many regolith properties that affect bulk thermal conductivity, such as packing density, particle-to-particle contact deformation size, temperature, particle thermal properties, and particle size distribution. Furthermore, full-field description of the topography of the regolith at the body surface will allow us to accurately model layering and shadowing under changing illumination conditions. This will be particularly useful for interpretation of thermal observations of Ryugu (and perhaps Bennu), where particle and rock dimensions have been observed that are on the order of the diurnal skin depth, given that this scenario invalidates the typical TPM assumption that the regolith can be approximated as a continuous material.