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# Temperature calculation of coarse-grained regolith surface on small bodies

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Remote-sensing thermal infrared measurements of planetary surfaces are of great importance to reveal physical properties of their surface regolith layers. Especially, grain size effectively controls the thermal conductivity of regolith, and therefore, the surface temperature profile. Thermal conductivity of regolith-like powdered materials under vacuum conditions is extremely lower than the intact rocks, which is attributed to heat constriction resistance around the inter-particle contacts. On the other hand, thermal conductance inside the grains is a few orders higher than that at the contacts. Therefore, the powdered media is inherently not uniform on the heat transfer. On planetary surfaces, if thermal skin depth is enough larger than the particle size, in other words, if the heat diffuses through enough contact points, a thermal model with homogeneous thermal conductance will be appropriate. However, it will not be appropriate for small bodies with fast rotating velocities, due to shallow thermal skin depth. For example, Muses Sea region on asteroid 25143 Itokawa is covered with centimeter-sized coarse regolith grains. On the other hand, diurnal thermal skin depth is about 10 centimeters or less, when using thermal inertia of 750 J $m^{-2}$ $s^{-0.5}$ $K^{-1}$ (global average from ground-based observations, Mueller et al., 2005) and rotational period of 12.13 hours. In such a case where the skin depth is slightly larger than the grain size, it is unknown whether the surface temperature can be modeled by homogeneous thermal conductance model. Concerning Hayabusa2 mission, an asteroid 162173 Ryugu has a rotational velocity about 7.62 hours. The thermal skin depth is a few centimeters, which is comparable to, or somewhat larger than, grain sizes (1-10 mm) estimated from ground-based thermal infrared measurements and a homogeneous thermal conductivity model (Mueller et al., 2016).

In this study, we computed surface temperature of fast-rotating asteroids using heterogeneous thermal models with different thermal conductance of grain insides and inter-particle contacts. We modeled packed grains as serial connection of $N$ slabs with thickness equivalent to the grain diameter $D$. Inside each slab, thermal conductance was determined from thermal conductivity of solid materials. At the boundaries of the slabs, we adopted thermal conductance $H = k/D$, where $k$ is effective thermal conductivity of bulk regolith determined from a model by Sakatani et al. (2017) as a function of $D$. Other parameters that affect the thermal properties (such as porosity, surface energy, thermal conductivity of solid material, and specific heat), excluding the temperature, were fixed at specific values. The results were compared with homogeneous thermal models and traditional constant thermal inertia models.