Full field modeling of heat transfer in regolith - A powerful tool to discuss thermophysical models

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A key challenge for solar system science is to establish a comprehensive understanding of the variety of processes that create, evolve, and shape the surfaces of small bodies.

This topic call for an understanding of a largely unexplored set of physical quantities (thermal inertia, roughness, regolith size, rock abundance) related to the nature of the surfaces of asteroids, which are still poorly understood.

This is, by example, extremely important for the NASA’ s space mission OSIRIS-Rex, which is on its way to meet the asteroid 101955 Bennu to return a sample of its regolith back to Earth. Its science team will take decision about the sampling site with the aid of thermal measurements interpreted in terms of regolith properties, such as abundance, grain size, and presence of rocks hazardous for spacecraft touch down. The main parameter that is determined from thermal measurements is the thermal inertia of the soil. Thermal inertia is derived from the analysis of asteroids thermal infrared observations applying the so-called thermophysical models (TPMs) in which thermal inertia is a parameter directly fitted to the data.

The challenge considered in these works is to treat the heat transfer in a multi-scale granular medium laid out on the complex, rough surfaces of asteroids. Recent development of numerical methods dedicated to High Performance Computing (HPC) in materials science are used to this purpose.

Main purpose of the considered developments is, thanks to a digital material framework, to define a new approach of asteroid thermal modeling, instead of the classical thermophysical models (TPMs) used up to now. Recent improvement of numerical modeling of complex massively multi-domain media in materials science is a great opportunity to develop a better understanding of the regolith properties from measurements of its thermal inertia. The proposed techniques are based on different high density packing algorithms (dropping and rolling, advancing front methods etc.), full field description of the objects and powerful FE simulations. Full field description of the topology is very promising in the current context in order to describe in a realistic way the top surface of the asteroids, which could be made of a mixture of rocks and regoliths, laid over a complex topography made of crates, rough terrains subject to rapidly changing illumination conditions. The figure illustrates an example of a representative digital regolith immersed in a FE mesh and a thermal calculation on it.

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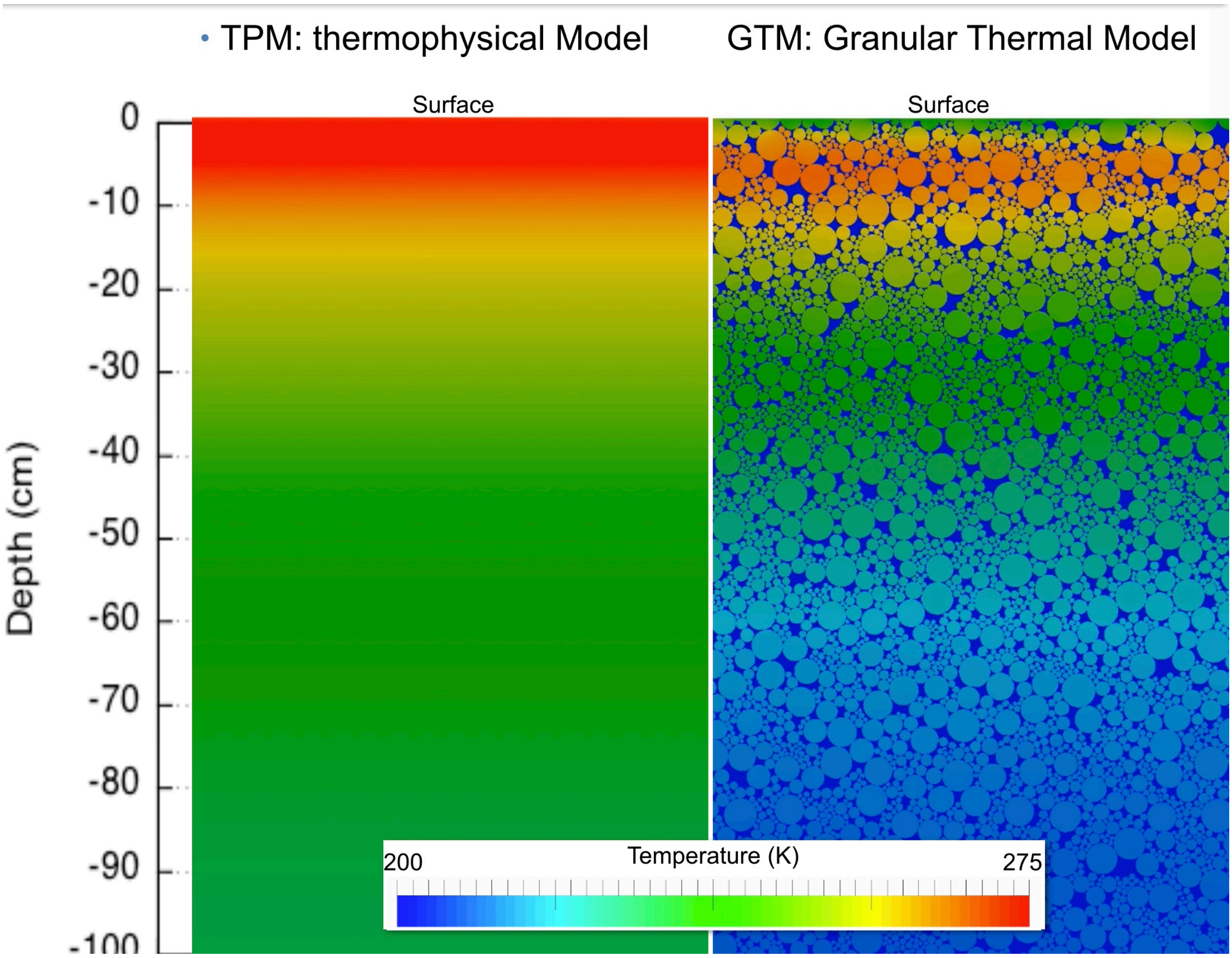
• TPM: thermophysical Model
GTM: Granular Thermal Model
Surface
Surface
Depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
200
Temperature (K)
275