Nature of Roughness of Ryugu Revealed by Thermal Simulation of High Resolution Digital Elevation Model.

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Introduction:

One of the main science objectives of the observations made by the thermal infrared camera (TIR) on board the Hayabusa2 spacecraft[1] is to deduce the thermal structure of the surface of asteroid Ryugu. So far, we found that the thermal inertia (TI) on a global scale with 5-20m resolution is widely uniform but strongly affected by surface roughness. In order to fit the temperature profile from dawn to dusk, an artificial roughness model was applied [2].

On the other hand, digital elevation models (DEM) with different resolution were constructed based on observations of the optical navigation camera (ONC) by the Hayabusa2 Shape Modeling Team. Higher resolution of the DEM reflects real surface roughness, and then, it is of our interest to investigate the relationship between observed TIR data and characteristic of roughness.

In this study, we performed thermal simulations using DEMs with different resolutions, and compared these with the observation data.

TIR Observation:

TIR has been collecting images of Ryugu since June, 2018 and more than 10000 images have been taken to date. Basically, three different types of observations have been conducted such as, (1) stational observation at 20km altitude (so called "home position"), (2) mid-altitude at 5km altitude, and (3) close-up observation for off-nominal descent operations such as touch down, lander deployments, and gravity measurement and so on. In order to analyze global thermal behavior, mid-altitude observation is suitable because the target subject was included within a image frame. This observation was conducted on Aug. 1, 2018, and then we used this data as reference.

Digital Elevation Model (DEM):

The Digital Elevation Model was constructed by the Hayabusa2 Shape Modeling Team. Representative global shape models consist of 3M and 200K polygons whose characteristic length (one side of triangle) is about 1m, and 5m respectively. In addition to these models, partial DEMs for special purposes were made in order to survey the safety of touch down operations. In this study, we used the L08B local DEM model which was made for the first touchdown, carried out on Feb. 21, 2019. The length of each polygon is about 10cm, one order finer than the 3M polygon model.

Thermal Simulation :

Temperature simulations were carried out using our original coded program which involves secondary radiation effects on the surficial polygon, and one dimensional thermal conduction from the surface[3]. We also simulated the expected images that will be obtained by TIR from orbital information. We applied a parallel projection in the rendering process from a 3D to a 2D image[3]. In this study, we assumed bond a albedo of 0.014, and an emissivity of 1.0 uniformly for all models.

Results and discussion :

Figure 1 shows an example of numerical simulation and observation image taken on Aug.1, 2018.

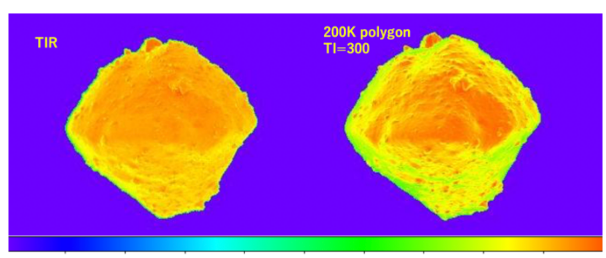

Fig.1 TIR image at 5km altitude taken on Aug 1, 2018 (left) and result of thermal simulation (right). The center area of Ryugu is approximately in a sub-solar position. The global shape model is the 200K polygon model and a thermal inertia of 300 J m^{-2} K^{-1} $s^{-0.5}$ was assumed.

The thermal inertia of the simulation was assumed to be 300 J m^{-2} K^{-1} s$^{-0.5}$ which is an averaged global value [2]. We found a large difference between observation and model., In particular, the simulated temperature at noon (around the center of the object) is higher, and more than 20K lower in the dusk and dawn region. That is, the temperature distribution of the real image is more uniform throughout dawn to dusk than that of the numerical simulation using this shape model. This phenomena should be a characteristic thermal behavior of rough surface[2] and 200k model could not reflect its thermal response.

Figure 2 shows a diurnal temperature profile at the first touchdown area at where the finest DEM was produced. The figure also shows the fitted curve obtained using the artificial roughness model[2]. There is little difference between the 3M and the 200K model. However, the result of the L08B model was drastically different and matches the observation data well. We note that this is the first time a good match of the diurnal temperature change between observation data and simulation data based on the "real topographic model" has been obtained.

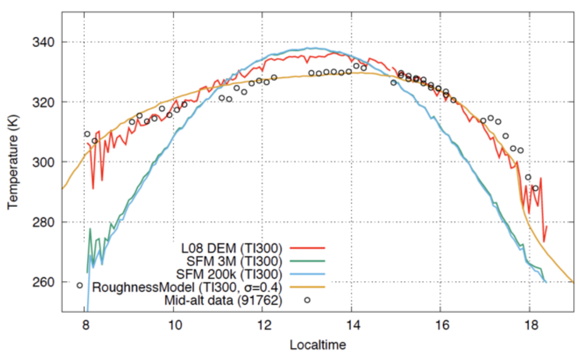

Figure 2. Diurnal temperature profiles for simulation result and observed data. Thermal inertia is 300 J m^{-2} K^{-1} s$^{-0.5}$ for all models. The fitted curve using an artificial roughness model[2] is also plotted.

In order to investigate the validity of the result, Figure 3 shows one of the closest images of TIR taken at an altitude of 8.5m when the final touch down operation sequence was conducted. We found that the surface is predominantly covered by boulders tens of cm to several tens of cm in size. In this sense, the thermal behavior of Ryugu seems can be explained as depicted by the finest DEM, dominated by roughness on scales of tens of cm.

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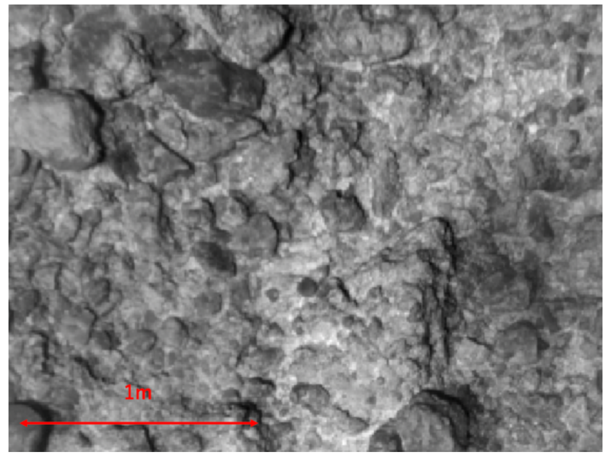

Figure 3. The closest TIR image of the surface of Ryugu at the first touch down area (21 Feb. 2019).

References:

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