ANNUAL EFFECT ON THE DIURNAL SURFACE TEMPERATURE TREND OF AN ASTEROID. H. Senshu[1], H. Maximillian[2,3], S. Tanaka[4], N. Sakatani[4], M. Kanamaru[5], Y. Shimaki[4], T. Arai[6], and T. Okada[4], [1]Planetary Exploration Research Center, Chiba Institute of Technology (Tsudanuma 2-17-1, Narashino, Chiba, JAPAN 275-0016, senshu@perc.it-chiba.ac.jp), [2]Deutsches Zentrum Für Luft- und Raumfahrt (DLR), Germany, [3]Planetology and Remote Sensing, Department of Geoscience, Freie Universität Berlin, Germany, [4]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (ISAS/JAXA), Japan, [5]The university of Tokyo, Japan, [6]Department of Life Engineering, Maebashi Institute of Technology, Japan.

Introduction: The surface temperature of an asteroid is controlled by the solar radiation. Thus, in studies on the asteroidal surface temperature, the balance between the solar radiation, the black body radiation into space, and the heat flux toward the subsurface region are solved numerically.

The solar radiation changes by the asteroid's spin and the asteroid's orbit around the sun. The rotational time scale is generally much shorter than the orbital time scale, such that it requires high numerical cost to simulate the diurnal temperature variation simultaneously including the orbital, i.e., seasonal, effect on temperature variation. Often, the orbital effect is omitted for simplification. Such a simplification can be justified for modelling thermal evolution of a planet and/or its satellite because the solar distance does not change so much for such bodies. However, it is not clear if it is applicable to asteroidal thermal evolution.

In this study we compare the thermal evolution of an asteroid derived from numerical simulations with and without orbital rotation effect.

Numerical Model: We carry out two types of numerical simulation about the thermal evolution of an asteroid: diurnal thermal evolution (DTE) model and annual thermal evolution (ATE) model.

In both models the asteroid is assumed to be a sphere spinning with the spin rotation axis and period which are same with that of (162173) Ryugu [1]. One dimensional thermal diffusion equation is solved numerically for each latitude, assuming the albedo and the emissivity are 0.05 and 0.95, respectively.

In DTE model the asteroid's position is fixed to the position of Ryugu on 3rd Oct 2018 (the solar distance and sub-solar latitude are 1.24 AU and -5.3 degree) and the spin rotational thermal evolution is simulated until an equilibrium state achieved.

On the other hand, in ATE mode we follow the surface temperature on the meridian (zero longitude) of the asteroid along the orbit until an equatorial state achieved, and finally we obtain the diurnal evolution of the day of 3rd Oct 2018.

The time-steps for these models are same (1 sec) and the thermal inertia is changed as a free parameter.

It is worth noting that the winter solstice on the northern hemisphere of Ryugu occurs the beginning of Aug. 2018. Thus, the day of 3rd Oct. 2018 is about 2 month after the winter solstice of the northern hemisphere.

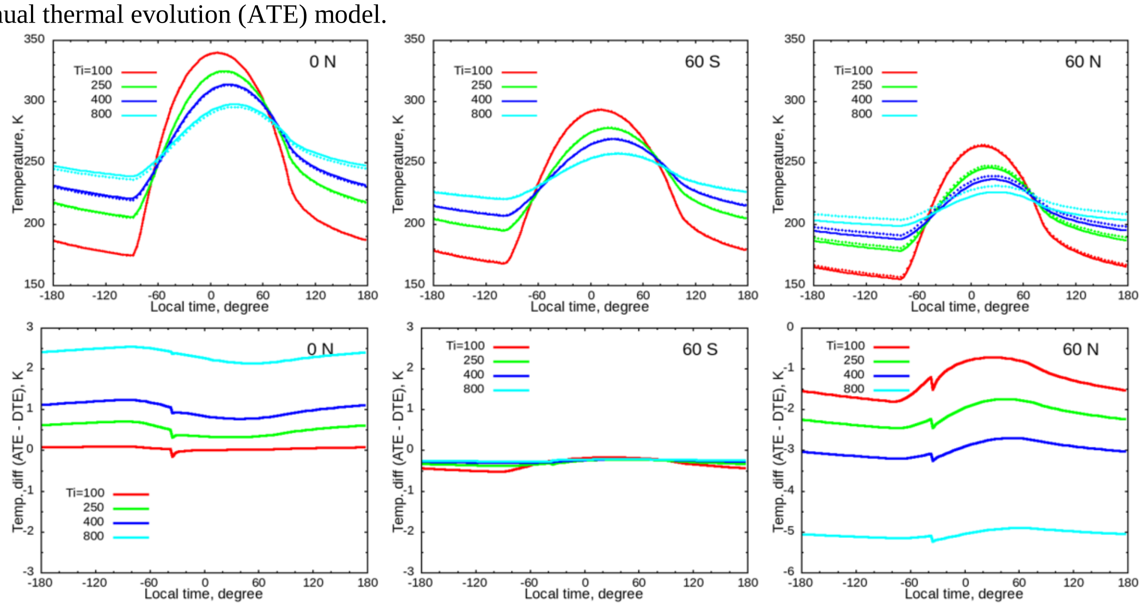

Fig. 1: Comparison of DTE (dots) and ATE (solid) model results. Upper panels show the diurnal temperature profile and lower panels show model discrepancy.

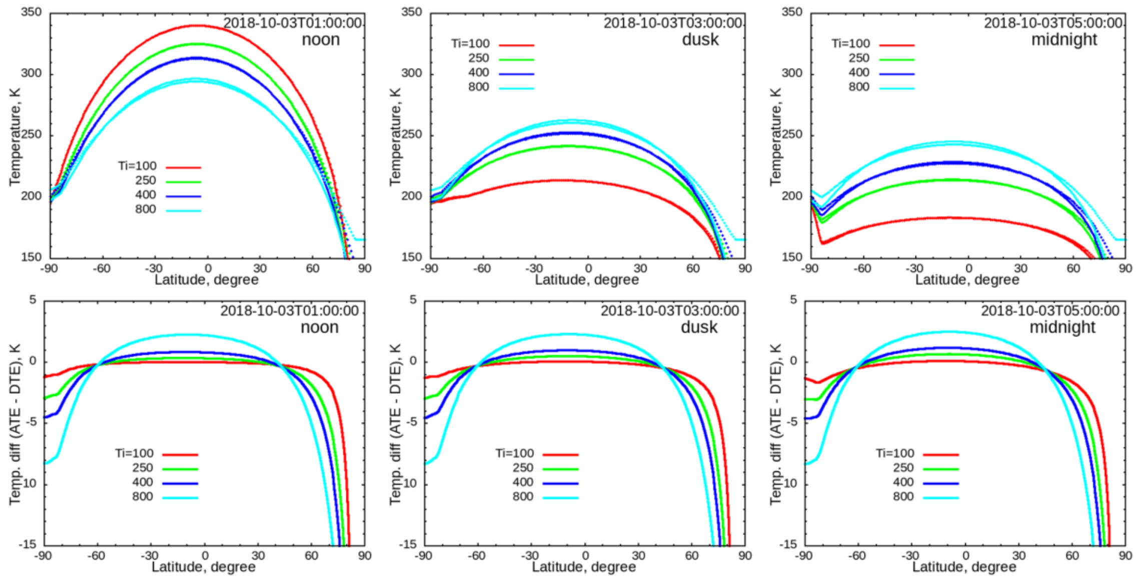

Fig. 2: Comparison of DTE (dots) and ATE (solid) model results as a function of latitude. Upper panels show the diurnal temperature profile and lower panels show model discrepancy

Numerical Results: Fig. 1 shows the diurnal temperature profiles at the equator, 60S and 60N for DTE and ATE models and their difference. As is shown in Fig.1 the temperate profiles of DTE and ATE models show similar temperature profile but there is a difference between them, and the difference is obvious for larger thermal inertia. ATE model becomes hotter than DTE model at the equator, but colder at higher latitude. The discrepancy is obvious for northern hemisphere.

Fig.2 shows the temperature difference between DTE and ATE models as a function of latitude at noon, dusk, and midnight. The model discrepancy becomes obvious when the thermal inertia becomes as high as 800 in MKSA unit. Conversely if we consider only low latitude region with moderate thermal inertia (e.g., less than 400 in MKSA unit), the model discrepancy is less than 1 degrees. The model discrepancy at higher latitude region shows asymmetric trend.

Discussion: The comparison between DTE and ATE models represent that the orbit rotation effect can be ignored if the target is low latitude region with thermal inertia less than 400 in MKSA unit. It is to be noted that if the asteroid is spherical and the observer is above the equator, more than 60% of the disk is in between 0S and 30N, and more than 80% is in between 45S and 45N.

However, in the case of (162173) Ryugu and (101955) Bennu, their shapes are known to be spinning top, which means the geometric latitude of almost all of their surface is around 45 degrees. Then the orbit rotational effect on the surface temperature becomes effective.

Our results also represent northern-southern hemispherical dichotomy in the model discrepancy. The dichotomy occurs because of seasonal effect: the northern hemisphere is the winter hemisphere and thus the subsurface region remains cold. The tendency that increases the model discrepancy with the thermal inertia can also be explained by the effect of the subsurface region.

In the previous study [2] we estimated the thermophysical parameters and surface roughness of (162173) Ryugu from the comparison of the diurnal temperature profile obtained by TIR on board Hayabusa2 [3] and numerical results from DTE model. We found appropriate parameters for the southern hemisphere while the northern hemisphere was difficult to fit. This might be because of the seasonal effect.

The temperature difference shown in this study is limited to only several degrees. However, it would affect the estimation of thermal moment and torque known as Yarkovsky and YORP effects.

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References: [1] Watanabe, S. et al. (2019) *Science, 364*, 268. [2] Shimaki, Y. et al. (2020) *Icarus, 348*, 113835. [3] Okada et al. *Nature, 579*, 518.