THE GLOBAL SURFACE ROUGHNESS OF 25143 ITOKAWA.

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Introduction: The Japan Aerospace Exploration Agency (JAXA) Hayabusa spacecraft explored near-Earth asteroid (25143) Itokawa from September to December 2005. During this period, the onboard laser altimeter (LIDAR) instrument collected over a million measurements of the spacecraft range to the asteroid surface [1]. We use these LIDAR data to calculate the global surface roughness of Itokawa. Such data provide inferences on how various geologic processes and surface attributes (i.e., regolith patches versus boulders) affect Itokawa at different baseline scales. The global surface roughness of Itokawa allows quantitative comparisons of the surfaces of Itokawa and (433) Eros, an asteroid that was characterized by a laser altimeter on the Near-Earth Asteroid Rendezvous-Shoemaker mission.

Three earlier efforts assessed the surface roughness of Itokawa [1-3]. In [1], an estimate was obtained for Itokawa's highlands and lowlands, while in [2] a more extensive study was performed using selected LIDAR returns in specific regions. In [3], a global assessment was performed using large longitudinal and latitudinal binned regions. In this study, we use a method well-tested at Mercury [4] and Eros [5], to expand on these previous efforts and produce more spatially accurate maps of the surface roughness of Itokawa for horizontal baselines ranging from 8 to 48 m.

Surface Roughness: We chose RMS deviation as our measure of surface roughness. RMS deviation is the root-mean-square of the change in detrended height for a specified horizontal baseline [6]. We can relate RMS deviation to the Hurst exponent, which describes a power relationship between RMS deviation and baseline (Figure 1), if the surface has self-affine behavior.

Altimetry Data: Due to the failure of three of the reaction wheels, the Hayabusa LIDAR tracks wandered across the surface of the asteroid [2]. This differentiates the Hayabusa data from other laser altimetry datasets as the altimetric tracks were not in straight lines and often twist on themselves or ‘zig' and ‘zag' across the surface. Since we needed to measure distance on Itokawa to calculate surface roughness, we explored several different measures of distance. We ultimately chose to measure distance using the radial distance of points from the point at which surface roughness is calculated. This method did not produce spatially different results from other distance-measure approaches when baselines were restricted to less than 50 m and were computationally the most efficient.

Results: Figure 2 shows a global surface roughness maps for Itokawa at the baseline of 8 m (the smallest baseline measured due to LiDAR spacing). Gray plates represent regions where there were insufficient data to calculate RMS deviation for that plate. These maps distinguish the lowlands (lower surface roughness values) from the highlands (higher surface roughness values). Large boulders on the western side of the asteroid possess high surface roughness values.

We compared the surface roughness at the baselines investigated to a map of block density (blocks greater than 5 m in diameter) generated with the block counts from [7]. We find a statistically significant correlation between surface roughness and boulder density for the 8 and 16 m baselines. A previous study of the global surface roughness of 433 Eros found that the surface roughness of Eros correlates with boulders at the 5 m baseline [5]. This implies that the topography of Eros and Itokawa are dominated by boulders at meter to tens of meter scale.

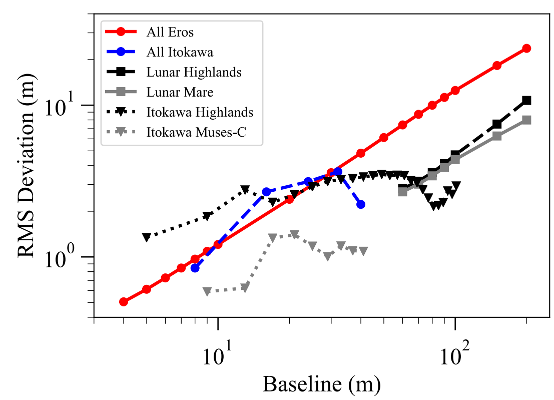

Figure 1. A deviogram of Eros, Itokawa and the Moon. The 'All Eros' and Lunar data are from [5], and the 'Itokawa highlands' and ‘Itokawa Muses-C' data are from [2]. We restricted our baseline to 48 m on Itokawa to avoid global curvature affecting our surface roughness measurements.

Deviograms (log-log plots of RMS deviation versus baseline) provide a quantitative way to compare the surfaces of different planetary bodies to one another. The deviogram of Itokawa looks different than the deviogram of Eros (Fig 1). Eros is self-affine (roughly a straight line in the deviogram) and has a similar Hurst exponent (0.97) to Mercury [4] and the Moon [8]. Itokawa, on the other hand, is not self-affine. We interpret the difference in deviogram behavior at long baselines to be due to the interior structure of Itokawa and Eros and the ability or lack of ability to support topography. Eros is believed to be a fractured monolith [9], while Itokawa is likely a rubble-pile [10]. On Eros, there is the underlying support for larger-scale topography (as seen in the many impact craters on the surface); Itokawa probably cannot support such large-scale topography due to its rubble-pile structure.

Conclusion: The surface roughness of asteroids may be a useful tool to understand both the interior structure and surface geology of asteroids. Although we have LIDAR coverage for Mars, Mercury, and the Moon, currently we only have laser altimeter data from two asteroids (Eros and Itokawa). In the next year, the two upcoming encounters by the OSIRIS-REx and Hayabusa2 spacecraft will generate high-resolution topography of asteroids (101955) Bennu and (162173) Ryugu. This new topography data will allow us to test our hypothesis on the relationship of surface roughness and interior structure, which, if true, will be a useful diagnostic of asteroid interior structure from topography data when the interior structure is unknown (such as flyby missions).

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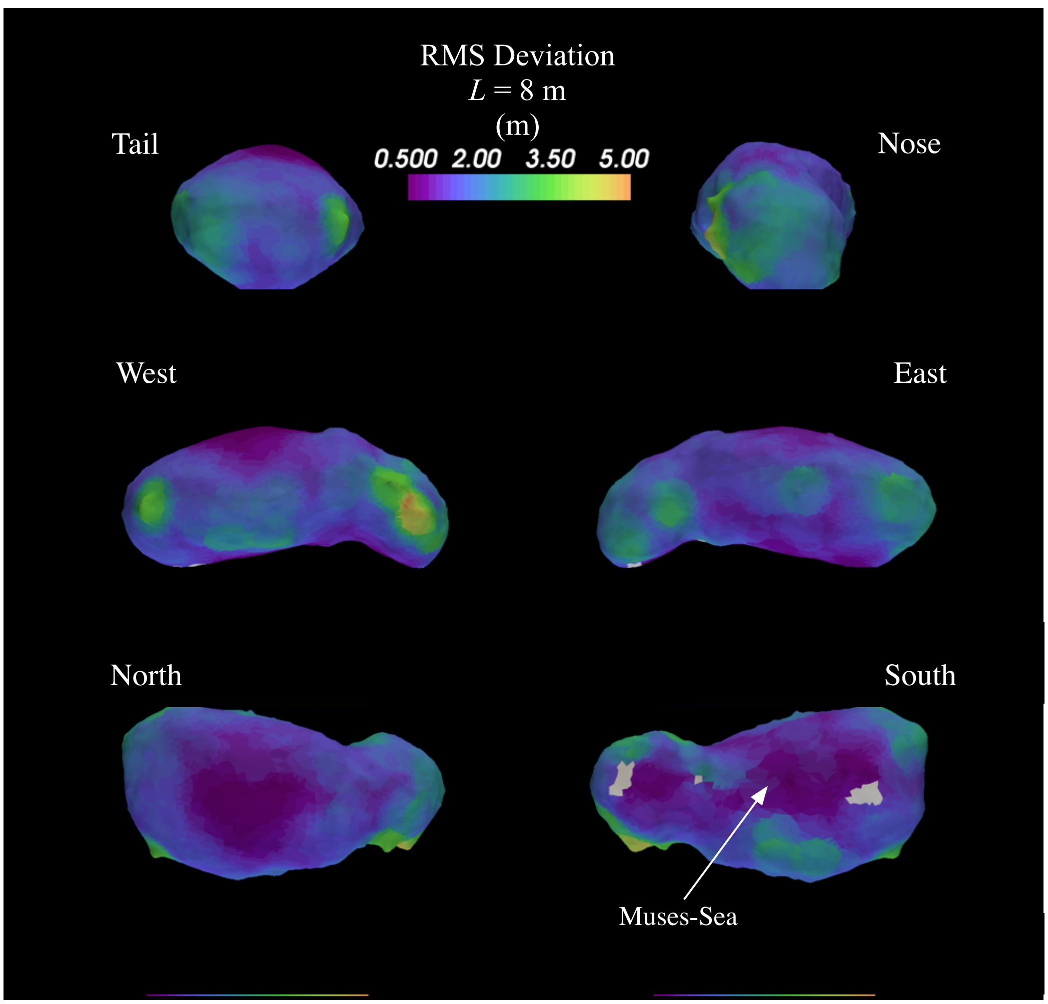

Figure 2. The global surface roughness of Itokawa for a baseline of 8 m. The regions of lowest surface roughness values correspond to the lowlands, while the highest surface roughness values correspond to large boulders.