Building a High-Resolution Shape Model of Bennu from OSIRIS-REx Lidar Data.

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Introduction: The OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer) [1] spacecraft collected lidar data from a near-terminator polar orbit of Bennu using the OSIRIS-REx Laser Altimeter (OLA) [2] to create a set of high-resolution topographic point clouds covering the entire surface of the asteroid. One of the goals of the OLA observations is to produce the highest-fidelity global shape model of Bennu created by the OSIRIS-REx mission.

Substantial differences were found between shape models produced using stereophotoclinometry (SPC) [3,4] from imaging data and those created using OLA data. Efforts to understand the nature of these differences were undertaken, and significant progress has been made in producing a well-registered OLA shape model.

Data Set: During July and August of 2019, OSIRIS-REx was in a near-terminator orbit at a range between 625 –730 m from the surface of Bennu.

During this phase, OLA collected 892 raster scans of the surface. Each raster scan took 330 seconds to complete and consists of approximately 3.2 million range measurements. Identical scan parameters were used throughout: a scanning mirror field of view of 183 × 174 mrad, with spot spacings of 0.1 mrad at a measurement rate of 10 kHz. At a range of 700 m, the spot size on the surface of Bennu was approximately 5 cm, the spacing between the spots ranged between 6 and 7 cm. About 2.8 billion lidar measurements of Bennu were taken during this time period.

Data Processing: Overlapping raster scans were strip-adjusted by identifying matching features using keypoints and keypoint descriptors [5]. Forty-two thousand sets of overlapping raster scans yielded 59 million keypoint matches. Keypoint pair residuals were globally minimized to register the raster scans and produce a self-consistent data set. OLA models with resolutions between 5 cm (Fig. 1) and 1 m are created from all 2.8 billion range measurements using a screened Poisson surface reconstruction method [6].

Mirror Calibration: A number of areas of poor registration (Fig. 2) were found when strip adjusting the data. A scaling issue with a factor of 1.0073 in one axis of the scanning mirror was found to be the cause. Further analysis of the mirror showed that the calibration at the four corners of the mirror needed refinement. Keypoint residuals calculated in mirror coordinates were used to calculate a correction polynomial to be implemented in the OLA processing pipeline. An improvement in registration of the strip-adjusted data is apparent when looking at the standard deviations of the radial component of the OLA returns (Fig. 3). The impact of the mirror calibration is currently being investigated and may be further refined.

Comparison to SPC: Comparisons between initial OLA shape models and SPC-derived shapes showed large differences in aspect ratio, with the OLA shape being larger at the poles and narrower at the equator by more than 1 m (Fig. 4).

The latest OLA shape using data with the updated mirror calibration matches the SPC aspect ratio but is approximately 20 cm smaller in radius (Fig 5). In both of these comparisons, 88-cm-resolution global shape models created using Poisson surface reconstruction were compared to an SPC model that incorporates some OLA ranges to help condition the SPC solution (SPCOLA) [7].

Conclusion: Initial attempts to produce a shape model from strip-adjusted OLA data highlighted issues with the OLA mirror calibration that resulted in poorly registered data and errors in the aspect ratio of the shape model of Bennu. Using only OLA data and the keypoint matches found during the registration process, an in-situ mirror correction polynomial was derived that resulted in a significant improvement in registration, and a shape model that matches the aspect ratio of an SPCOLA-derived shape.

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Figure 1. 5-cm-resolution shape model of a large boulder (approximately 40 m wide) called BenBen and the surrounding area (longitude, 127 deg; latitude, –47 deg).

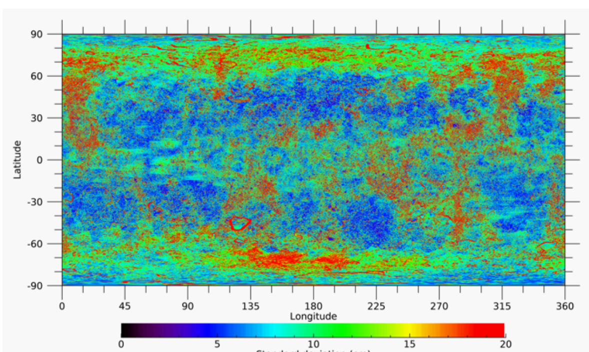

Figure 2. Standard deviation in 20 × 20 cm bins of strip-adjusted OLA returns before the updated mirror calibration.

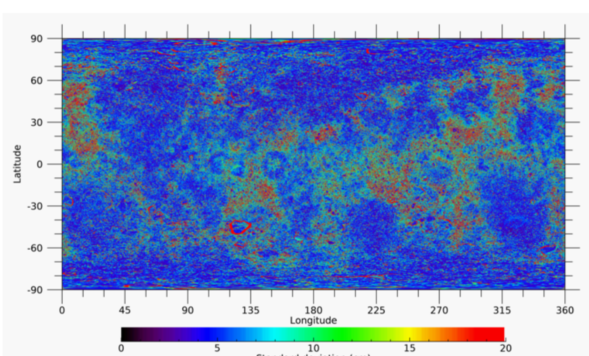

Figure 3. Standard deviation in 20 × 20 cm bins of strip-adjusted OLA returns after the in-situ mirror calibration.

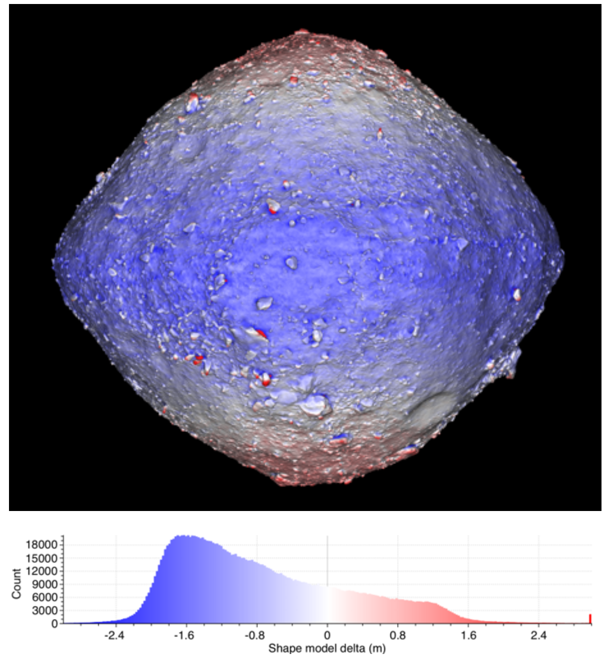

Figure 4. Global 88-cm-resolution OLA shape model created prior to the latest mirror calibration. The color indicates differences from the SPCOLA v54 shape.

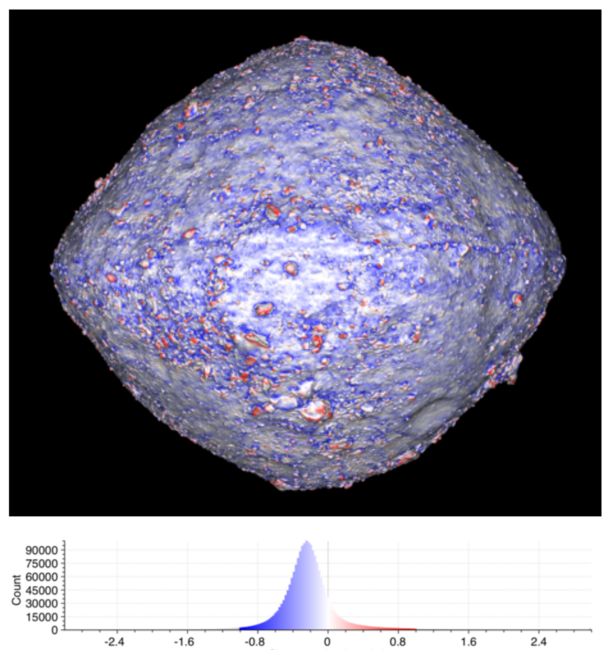

Figure 5. Global 88-cm-resolution OLA shape model created with the latest mirror calibration. The color indicates differences from the SPCOLA v54 shape.