NEW VIEWS ON BENNU FROM THE OSIRIS-REX LASER ALTIMETER. M. G. Daly[1], O. S. Barnouin[2], J. Seabrook[1], C. Dickinson[3], T. Haltigin[4], M. Perry[2], L. Philpott[5], M. M. Al Asad[5], R. W. Gaskell[6], E. Palmer[6], J. Weirich[6], E. B. Bierhaus[7], C. L. Johnson[5,6], K. J. Walsh[8], E.R. Jawin[9], D.N. DellaGiustina[10], B. Rizk[10], M. C. Nolan[10], W. Boynton[10], D. S. Lauretta[10]. [1]Centre for Research in Earth and Space Science, York University, Toronto, ON, Canada (dalym@yorku.ca), [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA, [3]MDA, Brampton, ON, Canada, [4]Canadian Space Agency, St. Hubert, QC, Canada, [5]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada (hsusorney@eoas.ubc.ca), [6]Planetary Science Institute, Tucson, AZ, USA, [7]Lockheed Martin Space, Littleton, CO, [8]Southwest Research Institute, Boulder, CO, [9]Smithsonian National Museum of Natural History, [10]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ.

Introduction: The objective of the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission is to return a sample from the 500-m-diameter asteroid (101955) Bennu [1]. The spacecraft is currently in close proximity to Bennu [2] as it conducts reconnaissance of the prime and backup sampling sites using onboard cameras [3], spectrometers [4,5,6], and the OSIRIS-REx Laser Altimeter (OLA) [7].

OLA is the world's first scanning laser rangefinder (or lidar) to fly on a planetary mission. Its high measurement rate of up to 10 kHz and programmable two-axis scanning mirror (~200 mrad x 200 mrad) allow for efficient global measurement of the topography of the asteroid with ground-track velocities ~20 cm/s.

Global Measurements of Bennu: From a polar orbit of radius 850 to 900 m during July and August of 2019, OLA measured the entire asteroid in a series of overlapping scans that each contained about 3.3 x 10^6 measurements at a spacing of ~7 cm x 7 cm (**Figure 1**). These measurements contain a variety of incidence angles and generally capture boulder sides as well as tops. This dataset contains almost 3 x 10^9 individual measurements and was assembled using techniques previously described [8, 9]. The resulting point cloud has ground-sample distances and ranging resolution of < 5 cm globally.

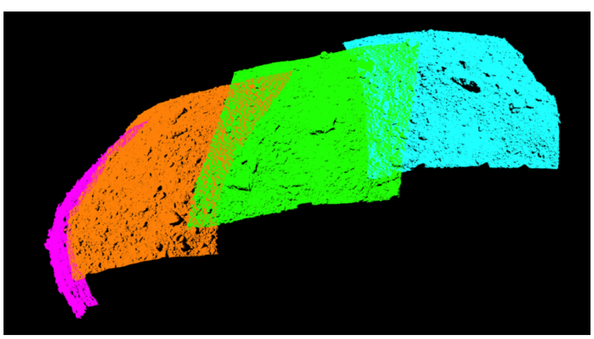

Figure 1: A series of overlapping 5.5 minute scans each containing more than 3.3 million measurements. were taken in each observation window while the spacecraft was in a near-terminator orbit. Approximately 900 of these were stitched together to form the global model of Bennu.

Bennu Global Model: The point cloud, although of extremely high detail, is difficult to interpret due to the variety of ground-sample distances and point-cloud transparency. We processed the point cloud at a variety of resolutions from 5 cm to a few meters by voxel-averaging the data (**Figure 2**). These data were then processed using the Poisson Surface Reconstruction Method [11]. These models of Bennu are the most complete and highest-resolution global asteroid models ever created.

Figure 2: A 20-cm version of the OLA global shape model rendered into an image [10] to reveal details of the topography. The look directions are (clockwise from the top left): +X, –X, +Z, –Z. The model extents are: X, 568.77 m; Y, 547.17 m; Z, 499.87 m.

New Views of Bennu: Bennu's general shape in our study is as described in [2], although we find that our model averages 30 cm smaller than that previously presented, which used stereophotoclinometry. This is a powerful shape modelling technique, but its results are highly dependent on imaging geometry. In Bennu's case, the details of the topography in the polar regions are compromised due to poor lighting conditions for imagery caused by low obliquity. As a laser altimeter, the solar-Bennu geometry is irrelevant for OLA, and the entire asteroid was measured at similar resolution – although polar coverage was greater due to the polar orbit in this observation phase.

Global Analyses. We will present global shape and topography analyses of Bennu. As an example, the improved geometric knowledge provides the ability to map the geological units on Bennu based on the scale of topographic change. **Error! Reference source not found.** bins the OLA data and plots the standard deviation of the heights in each bin. This image shows clear regional variations that correlate with the regions identified by mapping the surface using imagery.

Surface Features. We will also present new views of surface features on Bennu. The morphology of boulders on Bennu has been measured in fine detail, with surface textures clearly visible. Other detailed boulder morphology is clearly defined with features such as cracks, layering, and displacements visible in many locations. Micrometeorite craters are also present on some of these boulders. Craters are also clearly defined with structural features on rims, central depressions and uplifts measurable in fine detail. Linear surface features are also clearly measured in the dataset.

Taken together, the global shape and fine-scale topography provide an unprecedented dataset for the analysis of surface processes on Bennu. The detailed surface topography shows clear instances of mass movement on the surface [12,13]. This movement is often, but not always, associated with large slope discontinuities at crater rims, large-scale structural ridges or smaller linear features.

Conclusion. OLA topographic measurements provide a rich and unprecedented dataset for understanding the global and local processes that are active on Bennu. We will present a variety of these models – both globally and locally – to illustrate the depth of the dataset and the variety of surface features and processes visible on Bennu.

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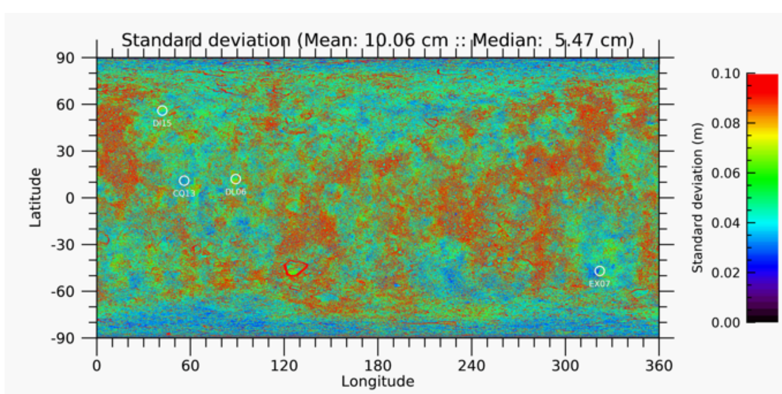

Figure 3: OLA data binned into 1/32 degree bins and the standard deviation of the returns in each bin are plotted thereby providing a measure of the quality of the model and the roughness of the asteroid.