Assessing the quality of topography from stereo-photoclinometry

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Introduction: Stereo-photoclinometry (SPC) has been used extensively to determine the shape and topography of various asteroids from image data. This technique will be used as one of two main approaches for determining the shape and topography of the asteroid Bennu, the target of the **O**rigins **S**pectral **I**nterpretation **R**esource **I**dentification **S**ecurity-**R**egolith **Ex**plorer (OSIRIS-REx) mission. The purpose of this study is to evaluate the quality of SPC products derived from the Near-Earth Asteroid Rendezvous (NEAR) mission, whose suite of imaging data resembles that to be collected by OSIRIS-REx. We make use of the NEAR laser range-finder (NLR) to independently assess SPC's accuracy and precision.

Determining Topography with SPC: SPC combines traditional stereo techniques with photoclinometry to derive the tilt of an asteroid's surface. The method models surface tilt at each pixel of a given image first by using stereo data to define a relationship between tilt and observed albedo. With this relationship in hand, the tilt of a piece of asteroid surface imaged at multiple emission and incidence angles are obtained using least squares methods that best duplicate the input images. Once the surface tilts are obtained, the shape of the surface across each image are determined by integrating over the resulting tilts. The individual surface maps are then collated together to produce a shape model.

The formal uncertainties (RMS) derived within SPC while generating the surface height maps and shape model of asteroids is typically on the order of $\sim$1 pixel. In the case of (433) Eros, this RMS uncertainty equals $\sim$3 m, while the best average pixel size used across the asteroid equals 3.2 m.

The Need to Assess SPC: A few studies have made cursory assessments of the SPC technique using an independent measurement of topography such as that provided by a laser altimetry. The OSIRIS-REx **Alt**imetry **W**orking **G**roup (ALTWG), which is responsible for all the shape model and topography generated by the mission, has decided that a detailed assessment of SPC is needed given this method's importance in quickly obtaining the shape and topography of Bennu. The ALTWG also will make use of the OSIRIS-REx laser altimeter (OLA). Products from both SPC and OLA will be generated independently to ensure redundant sources for these products in case an issue arises where one approach is no longer available. It also provides a means to mutually evaluate the quality of these products. These cross-checks are another reason why a good assessment of the expected quality of SPC is required: valid cross-checks with OLA require under-standing the true limits of SPC capability given the image quality employed.

Methods Used to Assess SPC and NEAR: The accuracy of SPC, i.e., the ability of SPC to accurately determine the absolute location of the asteroid's surface relative to its center of mass, is determined by comparing the range measurements derived from SPC between the spacecraft and the pixel 220,260 of the imager onboard the NEAR spacecraft for all images used to make the SPC shape model of Eros, and the NEAR laser rangefinder (NLR) obtained at approximately the same time. This pixel is the best known location of the NLR boresight.

For the purpose of understanding the precision of the SPC products, i.e., the point-to-point uncertainty of SPC, we use two techniques. One method requires identifying by hand the trajectory of the NLR boresight (pixel 220,260) in consequtive MSI images, and then comparing the directly measured NLR topography to an SPC-derived transect obtained along the same track with the topography generated by SPC. The second approach uses least-squares techniques to minimize the separation between individual NLR tracks and best resolution SPC topographic maps through along- and across-tracks displacements of the NEAR spacecraft. If required, a third approach will be employed to minimize the difference between SPC results and NLR using six degrees of freedom, including pointing errors in pitch, yaw and roll in addition to the along-across track adjustments.

Results: Preliminary results show that formal errors need to be thoroughly assessed, and that accuracy and precision of SPC results are closer to $\sim$2 pixels. Additional details of our findings will be presented.