MAPPING SMALL BODIES WITH STEREOPHOTOCLINOMETRY. R. W. Gaskell[1], [1]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719, rgaskell@psi.edu

Introduction: In the four years since it was first introduced at this workshop [1] the technique for construction of shape and topography of small bodies directly from imaging data, at a resolution comparable to that data, has matured. It has produced a model of Eros of unprecedented accuracy [2] and played a role in the Hayabusa encounter with asteroid Itokawa [3].

The basic data product is a set of overlapping digital topographc/albedo maps (L-maps) which tile the surface of the body. The slopes and albedo at each pixel in an L-map are determined by an estimation procedure called stereophotoclinometry (SPC) that minimizes the least square residuals between predicted and observed brightness in multiple images. The slopes are then integrated to produce the heights relative to a local coordinate system.

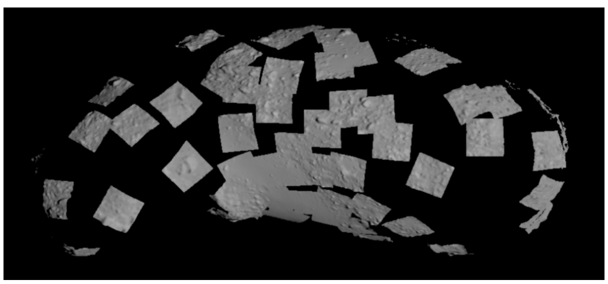

Figure 1: Some of the L-maps tiling Itokawa

The central pixel of an L-map represents a control point whose body-fixed location is determined in a simultaneous estimation with the camera location and orientation, constrained by apriori information, that minimizes the residuals between predicted and observed image space locations, limb locations and correlations between overlapping L-map topography. Laser ranging has now been added as a new data type [4].

Global Topography: The model for Itokawa was constructed from about 600 AMICA images and has 870 L-maps, each representing about 10000 vectors. From these, a standard 1.57 million vector global topography model (GTM) was constructed.

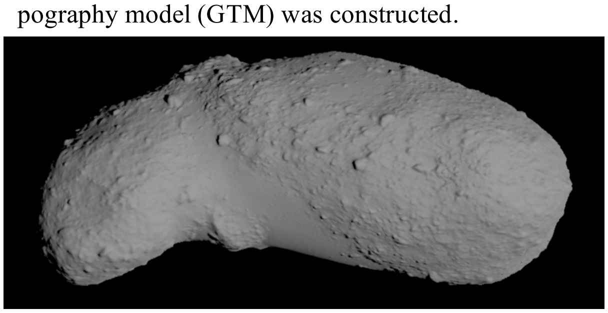

Figure 2: Itokawa Global Topography Model

Eros is currently tiled with about 9000 overlapping L-maps constructed from over 17000 NEAR images. From the resulting 90 million vectors, a standard Eros GTM was built.

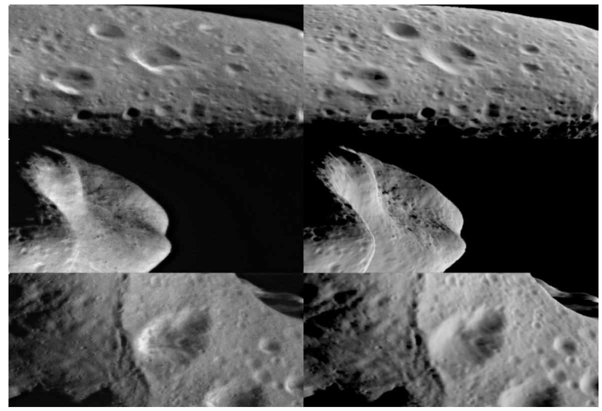

Figure 3: NEAR images and Eros GTM

The GTM provides a framework for estimating the surface gravity, gravity harmonics, and inertia tensor, assuming a homogeneous mass distribution. The current Eros GTM has a volume of 2507.79 km^3 and a surface area of 1137.98 km^2. The prime meridian is shifted 9.786° from the principal x-axis and the principal moments of inertia per unit mass are (15.1308, 73.0922, 74.3518) km^2. The Bouguer anomaly, the difference between measured and predicted harmonics on a 16 km sphere, has been reduced significantly from earlier shape estimates [5], suggesting that the interior of Eros is more nearly homogeneous.

The Itokawa GTM has a volume of 0.01773 km^3, a surface area of 0.40403 km^2, and principal moments of inertia per unit mass of (0.00631, 0.02128, 0.02235) km^2. The L-maps constructed from the narrow angle science camera were used in conjunction with wide-angle navigation camera images taken during the November 12, 2005 approach to the surface to determine Hayabusa's trajectory. This, in turn, was used to determine the mass of Itokawa to be [6] $GM=2.36 \times 10^{-9} \pm 0.15 \times 10^{-9}$ km^3/s^2, giving a density of about 2.0 g/cm^3.

Local Topography: The vast majority of L-maps on Eros have a resolution of 6 m/pixel. Some L-maps have lower resolution and provide context for the global fit, while others have higher resolution in order to better characterize regions of particular interest. Since the GTM has an average resolution of about 27 meters, it does not contain the full information provided by the ensemble of L-maps. High resolution topography maps (HRTMs) can be constructed from the L-map ensemble for areas of interest, such as the 6 meter resolution 1025x1025 pixel topographic map of Shoemaker Regio shown as a stereo pair in Figure 4, made from 444 L-maps.

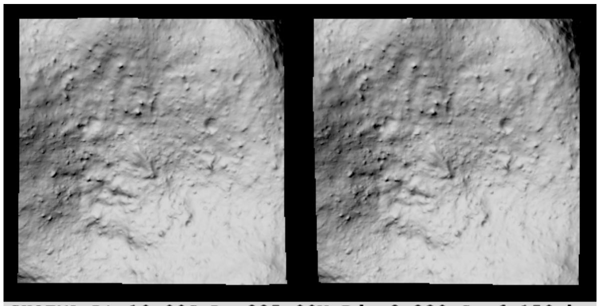

Figure 4: HRTM of Shoemaker Regio

Since HRTMs can be constructed with almost the resolution of the best images, they summarize that data with very little loss of information. These new representations can be recast in a variety of ways to assist in data analysis. Another map of Shoemaker Regio made by computing $\nabla^2 h$ from the HRTM data is shown in Figure 5. In this form, craters and boulders are much easier to identify, and this may eventually lead to an automated cataloging capability.

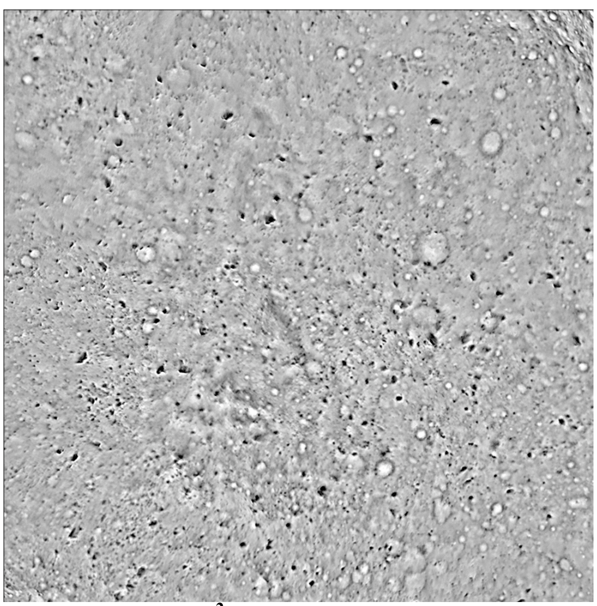

Figure 5: ∇^2h in Shoemaker Regio

HRTMs can also be used to display the original imaging data in three dimensions by resampling the data onto the map. A stereo pair of the Pencil boulder on Itokawa is displayed in Figure 6.

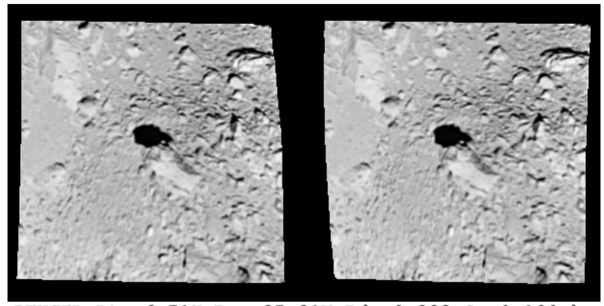

Figure 6: Pencil boulder on Itokawa

Ongoing Work: The recent completion of the set of 6 meter/pixel L-maps tiling the entire surface of Eros has made it possible to rapidly introduce higher resolution images into the data set at a rate of about 1000/wk. Data from each image is digitally correlated with illuminated pre-existing L-maps and the resulting image-space control point locations enable the rapid registration of the images. L-maps are then identified and located on the limbs, and the new imaging data is used to refine the L-map topography solutions and ultimately the GTM. The 9000 L-map centers are currently constrained by more than one million "observations", an average of more than 100 per control point, and are determined to about 2.1 meters per degree of freedom.

The laser ranging data for Itokawa and Eros is being incorporated both into the navigation solutions and the determination of the center of mass to center of figure offsets. In both cases, preliminary results suggest a small offset, consistent with a homogeneous mass distribution.

Finally, the Phobos model presented at the 2003 workshop is being used for radar studies of that body's interior [7]. When recent Mars Express images can be added to the Viking Orbiter data set, the model will become significantly more detailed, enabling better navigation and removal of surface reflections from the radar study.

References: [1] Gaskell R.W. (2003) ISPRS WG IV/9 [2] Gaskell R.W. et al. (2007) *LPS XXXVIII,* Abstract 1333. [3] Gaskell R.W., et al. (2006) *LPS XXXVII,* Abstract 1876. [4] Barnouin-Jha O.S. et al. (2006) *LPS XXXVII,* Abstract 1773. [5] Zuber M.T. et al. (2000) Science 289, 2097-2101. [6] Scheeres D.J. et al. (2006) AIAA paper 2006-6661. [7] Safaeinili A., et al. (2006) Geophysical Research Abstracts 8, 05330.