**DIGITAL ELEVATION MODEL OF THE DISCOVERY REGION ON MERCURY.** A.C. Cook[1], M.S. Robinson[2], T.R. Watters[1], and K. Edwards[3], [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560; [2]Department of Geological Sciences, Northwestern University, Evanston. Illinois 60208; [3]Q&D Programming, Hearne, Texas.

We have produced Digital Elevation Models (DEMs) [1], using three different patched-based stereo matchers applied to Mariner 10 vidicon stereo imagery, of the Discovery region on Mercury. DEMs were obtained with a range of correlation patch sizes and combined together to retain both good spatial resolution in regions of sharp topography, and adequate topographic S/N ratio in low texture regions.

Automated digital stereo matching is a process whereby a computer program finds corresponding pixels between two or more images. Patch-based stereo matching involves the autocorrelation between a small window region in one image, and a predefined search box at a predicted position in another image. After allowing for camera pointing and position errors, any shift between the predicted and autocorrelated position is assumed to be due to stereo parallax. By feeding the image coordinates through a stereo intersection camera model, planetary surface heights can be determined. A dense network of such points is known as a Digital Terrain Model (DTM). By interpolating between gaps one can form a near continuous raster image of heights known as a Digital Elevation Model (DEM). It is from this that analyitical measurements can be made such as topographic profiles, volumes, slopes etc.

**Artifacts:** Users of DEMs produced from stereo matching should be aware of the following: 1) objects smaller than the patch size, are spatially blurred. Fortunately this is not a problem on terrain with low frequency topography. 2) Image noise present in low texture areas, will induce spurious variations in the DEM topography, especially using small patch sizes. 3) Excessive salt and pepper noise in vidicon images, can cause the mis-identification of reseaus necessary for accurate image rectification. This gives rise to localized DEM height distortions between a reseau and its neighbors. 4) The precision of measurement of corresponding points between images can result in artificial boundary steps in the DEM. 5) Errors in camera position and orientation, depending upon their degree, can cause in order of increasing severity: (a) relative offsets in heights, (b) general DEM slope, (c) a low frequency mound due to the curvature of the planet.

**Method:** We used three stereo matchers: 1) Gotcha [2] from University College London, 2) Tracker3 from JPL, and 3) a recently implemented ISIS stereo matcher, based upon automated control point software. Reseau locations in the geometrically corrected images were checked manually.

To overcome the problems of the blurring effects of correlation patch, matching was performed using a range of patch sizes. In the Gotcha stereo matcher, we used patch sizes of between 6x6 to 18x18 pixels, in Tracker3, 3x3 to 15x15 pixels, and in the ISIS matcher, 7x7 to 21x21 pixels. A quality control threshold was used to reduce the number of bad matches. The resulting DEMs were stacked in to a data cube with the increasing patch size along the Z-axis. By stepping down in patch size, if an upward / downward height trend was detected, this was followed in the data cube, until it reversed, at which point the previous corresponding height was written to the appropriate output DEM pixel.

To reduce noise effects, a skew map was produced containing the median of skew values in 10x10 image pixel bins. Skew is the separation distance at the point of intersection of two stereo projected rays, one from each camera. The intersection defines the corresponding topographic point on the surface of the planet. Ideally the skew intersection distance should be zero, but camera pointing errors and precision of measurement make this otherwise. The largest patch size DEM was regarded as the most stable with respect to image noise, and hence a model for skew distribution. Skew values exceeding +/- 0.2 kms in smaller patch size DEMs indicated bad matched points and were removed.

In order to check independently the accuracy of the DEM, crater depth to diameter ratios (d/D) were determined and compared to Pike's relationship [3] for craters in the range of 30-175km in diameter (see Table 1). The ratios of these were found as follows: 1) the heights of 3-8 points were measured on each crater rim, depending on crater size, 2) floor heights were averaged over a 5x5 box, 3) crater diameters were measured from map projected images.

**Results:** The most robust and complete DEMs were produced using the Gotcha stereo matcher. Rim structures in craters as small as 17km in diameter were visible. The Tracker3 matcher produced slightly noisier DEMs, but could match to finer resolution, however it ran slowly with large patch sizes. The ISIS matcher was faster, but suffered from artificial topographic ripples, whose origin have yet to be determined. Concerning the camera positions and orientations, these had been recently recalculated [4] in a photogrammetric block-adjustment which was fitted to a sphere. There were hints from the skew map that these navigation data were still slightly out. The method of combining the DEMs from different patch resolutions preserves the sharpness of pits and ridges reasonably well. The crater d/D ratios are in good agreement with predictions, considering the relatively small sample of craters.

Table 1

| Crater | Lon (+veW) | Lat | Obsv. Depth (km) | Theor. Depth (km) | Diam. (km) | Obsv./ Theor. |
|---|---|---|---|---|---|---|
| A | 54.6 | -54.6 | 1.65 | 3.10 | 80 | 0.52 |
| B | 53.4 | -54.0 | 1.54 | 1.78 | 26 | 0.87 |
| C | 55.9 | -57.0 | 2.06 | 2.22 | 41 | 0.92 |
| E | 51.1 | -57.4 | 1.79 | 1.64 | 22 | 1.10 |
| F | 49.2 | -54.3 | 2.30 | 2.06 | 35 | 1.12 |
| G | 48.3 | -54.7 | 2.08 | 2.76 | 63 | 0.76 |
| H | 46.4 | -53.5 | 2.01 | 4.07 | 138 | 0.49 |
| I | 49.0 | -58.0 | 2.64 | 1.44 | 17 | 1.83 |
| J | 48.8 | -57.2 | 1.39 | 1.56 | 20 | 0.89 |
| K | 47.5 | -56.7 | 1.59 | 1.83 | 27.5 | 0.87 |
| L | 44.1 | -54.8 | 2.07 | 1.71 | 24 | 1.21 |
| M | 44.9 | -58.4 | 2.16 | 2.23 | 41 | 0.97 |

Average of ratio=0.96+/-0.35

**Future work:** Further work is needed to refine the combination of different resolutions DEMs together, in particular comparison with neighboring pixels. The origin of the topographic ripples in the ISIS matcher DEM will be identified and corrected. We are developing a feature-based matcher to better preserve the sharpness of DEM crater rims etc. Additional work needs to be undertaken on photogrammetry in order to improve the camera navigation for seamless mosaicking of adjacent DEMs. Finally we have started working on other areas of the planet in order to increase our crater statistics and investigate problems concerning the geologic history of Mercury.

**Acknowledgments:** To DLR (Berlin) / UCL (London) for the use of UCL's Gotcha software during the first author's stay in DLR. To Jean Lorre (JPL) for supplying the Tracker3 program. We would also like to thank the USGS for providing the ISIS software.

**References:** [1] T.R. Watters *et al.*, submitted to *Geology*, 1998. [2] T.Day *et al.*, *Int. Arch. of Photogramm. & Remote Sensing*, 29-B4, p801-808, 1992. [3] R.J.Pike., in *Mercury*, Univ. AZ Press, p165-273, 1988. [4] Robinson *et al.*, *LPSC XXVIII*, p1187-1188, 1997.

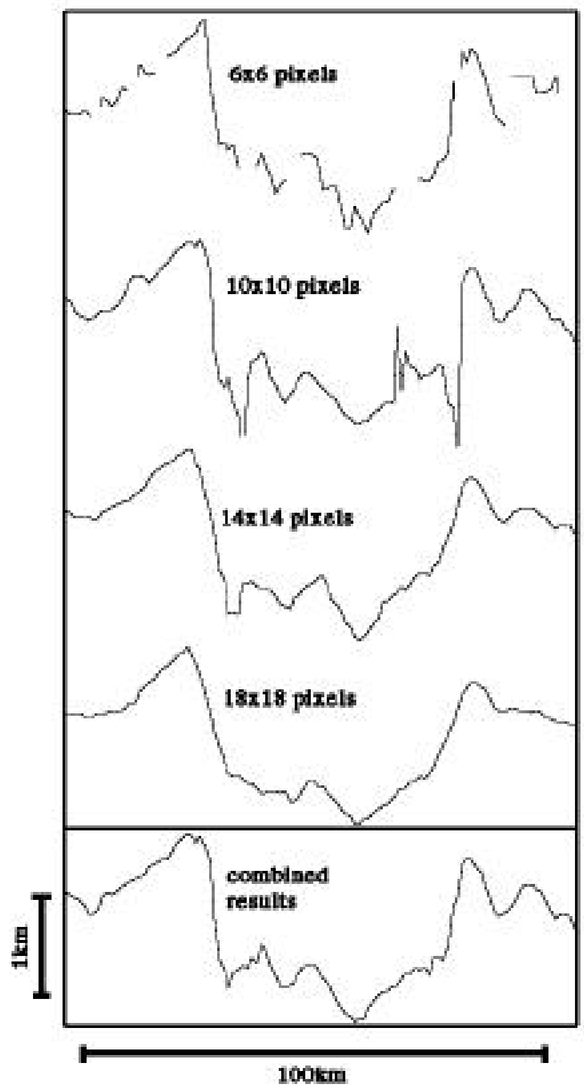


**Fig 1** Cross-sectional topographic profiles through crater G using different patch sizes, and the results of combining these.