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Topography of Mercury from stereo images: Regional terrain models from MESSENGER orbital mapping

Frank Preusker (1), Jürgen Oberst (1), James W. Head (2), Mark S. Robinson (3), Thomas R. Watters (4), and Sean C. Solomon (5).
(1) German Aerospace Center, Institute of Planetary Research, D-12489 Berlin, Germany (Frank.Preusker@dlr.de), (2) Department of Geological Sciences, Brown University, Providence, RI 02912, USA; (3) School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, USA; (4) Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, USA; (5) Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA.

1. Introduction

In March 2011 the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft entered orbit about Mercury [1]. The spacecraft is equipped with the Mercury Dual Imaging System (MDIS) [2] consisting of a wide-angle camera (WAC) and a narrow-angle camera (NAC) coaligned on a pivot platform. During its first Mercury solar day (~176 Earth days), MESSENGER acquired several thousand images to create a monochrome base map using the WAC for the northern hemisphere and NAC for the southern hemisphere, respectively, from its highly eccentric near-polar orbit. In September 2011, with the beginning of the second Mercury day, MESSENGER started acquiring a complementary image dataset under high emission angles (by tilting the camera) but similar Sun elevation and azimuth. The combination of both base maps enables us to analyze the images stereoscopically and to generate digital terrain models (DTMs). The DTMs are particularly important for the southern hemisphere, most parts of which are out of range of MESSENGER's Mercury Laser Altimeter (MLA).

2. Methods

The stereo-photogrammetric processing for Mercury is based on a software suite that has been developed within the last decade and has been applied successfully to several planetary image data sets [3-6]. The suite comprises photogrammetric block adjustment, multi-image matching, surface point triangulation, DTM generation, and base map production.

3. Image and Stereo Coverage

We selected images that have resolutions better than 600 m/pixel (~58,000 images in total) and have compiled the stereo coverage under "optimal" stereo conditions (Table 1).

Parameter	
Differences in illumination	0-10°
Stereo angle	15-60°
Incidence angle	0-70°
Emission angle	0-65°
Phase angle	5-180°

Table 1: Stereo conditions used for stereo processing.

For practical reasons we divided the stereo coverage into 15 tiles that conform to the quadrangle scheme proposed by Greeley and Batson [7]. From those areas, we selected one (Figure 1, H14 - Cyllene quadrangle) to carry out topographic surface reconstructions. The area is located in the southern hemisphere and is covered by about 1,300 stereo images with a mean resolution of about 230 m/pixel.

4. Results

Beginning with nominal navigation (pointing and position) data for the selected stereo images, we collected ~15,000 tie points for navigation data correction using a photogrammetric block adjustment. This step improved the three-dimensional (3D) point accuracy from ±700 m to ±50 m. Next, 1,585 individual matching runs were carried out to yield ~540 million object points. The mean ray intersection error of the ground points was ±55 m. Only triple-overlapping images were used for the matching. Finally, we generated a DTM with a lateral spacing of 250 m/pixel (~170 pixels per degree) and a vertical accuracy of about 30 m. This DTM covers about 6 percent of Mercury's surface and includes the western half of the Rembrandt basin and the large lobate scarp that cuts across its rim (Figure 1, upper right).

5. Summary and Conclusions

Now, with the completion of the second-day monochrome stereo base map, we have the opportunity to reconstruct most of Mercury's surface except for permanently shadowed areas near the poles. Laser altimeter profiles with their superior height precision will be used to remove ambiguities regarding absolute elevations and trends in long-wavelength topography. In addition, limb topography will be used to cross check absolute elevations for the southern hemisphere where no laser altimeter data are available.

Acknowledgements

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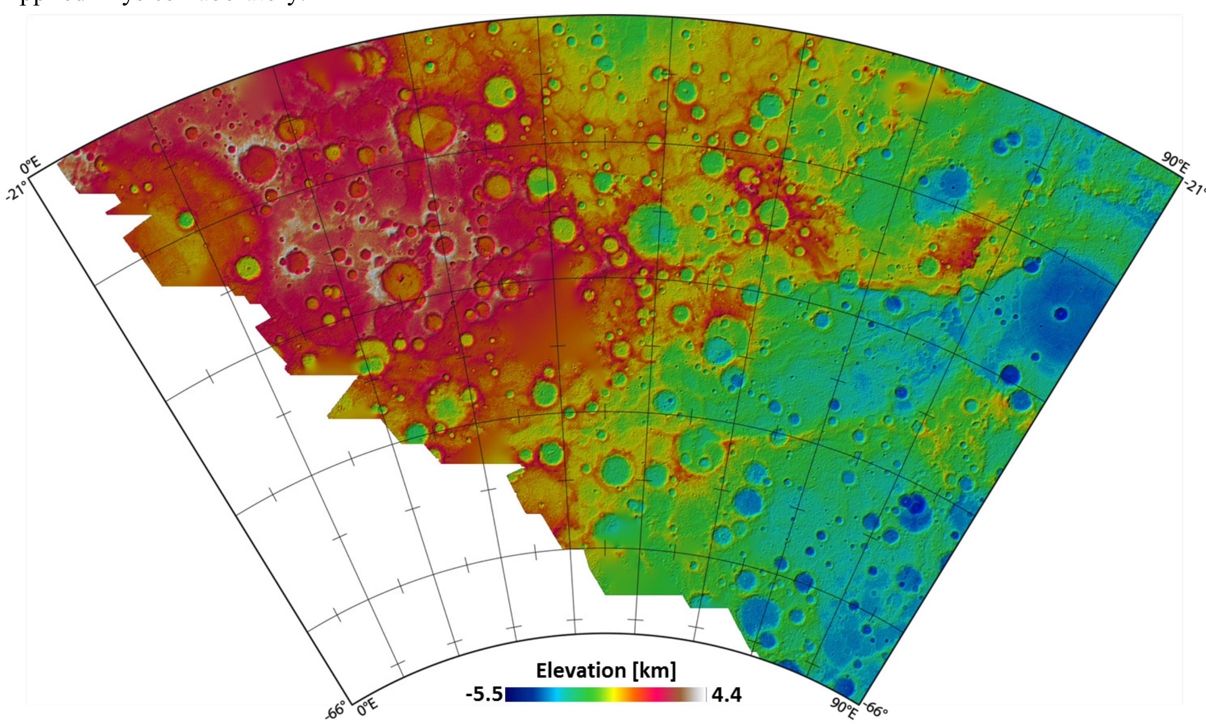

Figure 1: H14 – Cyllene quadrangle DTM (hill-shaded color-coded heights) with a lateral spacing of 250 m in Lambert (conformal) projection centered at 45°E. White areas are gaps in the current stereo coverage. Updated versions of this model and topographic data for other surface areas will be presented at the conference.