

High-resolution digital elevation models of Phobos derived from HiRISE stereo images

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Surface topography data of target bodies are essential for analyzing their surface/subsurface properties (e.g., calculations of spectrophotometric parameters [e.g., Fraeman et al., 2012], numerical simulations of radar echoes [e.g., Plettemeier et al., 2009], computation of dynamic height [e.g., Shi et al., 2012], measurements of morphometric parameters [e.g., Basilevsky et al., 2014], etc.), which leads to better understanding their composition, internal structures, and geological histories. The surface topography of Phobos has been characterized by using shape models and digital terrain models based on stereo-photogrammetric techniques [e.g., Gaskell, 2013; Willner et al., 2014]. These models are based on multiple images obtained by several spacecraft (e.g., Mariner 9, Viking Orbiter, Mars Express) and have spatial resolutions of up to 50-100 m and vertical accuracies of up to 10' s m [Willner et al., 2014], which enables the measurement of up to kilometer-scale topographic features. Although a set of the two high-resolution (~6 m/pixel) images of Phobos' s surface, taken by High Resolution Imaging Science Experiment (HiRISE [McEwen et al., 2007, 2010]) aboard the Mars Reconnaissance Orbiter, is an ideal stereo pair for deriving a high-resolution (20 m/pixel) digital elevation model (DEM) (Ivanov and Thomas, 2010), to date it has not been realized. Here we attempted to generate the three high-resolution DEMs from each stereo pair of the three HiRISE color channels (BG (~430–580 nm), RED (~570–830 nm), and IR (~790–1,000 nm)) having almost the same illumination and viewing geometry between different color bands. Radiometric and geometric image processing, creation of control network (a total of 30 points manually picked from 6 images at once), acquisition of ground control points, bundle adjustment, and map projection were performed using ISIS3 developed by the US Geological Survey. After applying the sub-pixel stereo matching and triangulation [Shean et al., 2016] to three stereo pairs of images map-projected to a set of global mosaic (~12.1 m/pixel; Wählisch et al., 2014) and a global digital terrain model (100 m/pixel; Willner et al., 2014), we successfully obtained three map-projected digital elevation models of the part of the sub-Mars hemisphere of Phobos, with spatial resolution of 20 m/pixel, expected vertical accuracy of ~4.2 m and high-resolution (~6.6 m/pixel) orthorectified images. These resolutions are at least a factor of four or five higher than those of previous shape models and digital terrain models. Using the new DEMs with a gravitational potential model, we are now working on extracting the topographic profiles of craters and other geological features as small as ~100 m, which will reveal, for example, depth-to-diameter ratios and the presence or absence of raised rims to constrain the physical properties of the regolith of Phobos, the effect of surface gravity of Phobos, and the origins of geological features.

Keywords: Phobos, digital elevation model, HiRISE