RELEASE OF HIRISE DIGITAL TERRAIN MODELS TO THE PLANETARY DATA SYSTEM. S. Mattson[1], R. L. Kirk[2], R. Heyd[1], A. S. McEwen[1], E. Eliason[1], T. Hare[2], R. Beyer[3], E. Howington-Kraus[2], C. Okubo[2], K. Herkenhoff[2], [1]University of Arizona (smattson@pirl.lpl.arizona.edu), [2]United States Geological Service, [3] NASA Ames.

Introduction: The High Resolution Imaging Science Experiment (HiRISE) flying on the Mars Reconnaissance Orbiter (MRO) since 2005, is returning the highest resolution orbital imagery of Mars to date (up to 25 cm pixel scale). HiRISE acquires stereo images by rolling MRO off-nadir on two different orbits to re-image a target under as similar lighting conditions as possible. Digital Terrain Models (DTMs) can be derived from such stereo that have a vertical precision of better than 25 cm, given a stereo convergence angle of 20º and unbinned source images [1]. HiRISE DTMs created at the U.S. Geological Survey Astrogeology Science Center and the University of Arizona Lunar and Planetary Lab, HiRISE Operations Center (HiROC), were released to the NASA Planetary Data System (PDS) for the first time in 2010 at http://hirise.lpl.arizona.edu/dtm/.

Prioritization and Timeline for PDS Release: Over 1900 stereo pairs have been acquired since HiRISE arrived in orbit around Mars in 2006. However, due to the intensive resources required to create terrain models, only ~100 DTMs have been produced so far. Not all DTMs produced by participating institutions will be released to the PDS. DTMs produced by the HiRISE team are released to the PDS one year from the date of completion. Exceptions to this policy are DTMs produced for contracted landing site studies (e.g. Phoenix Lander, MSL) which are released almost immediately.

Method: A HiRISE DTM is a gridded (raster) terrain model, constructed from two HiRISE stereo images as described in [2]. HiRISE is a pushbroom camera, with a focal plane array of 14 CCDs (10 panchromatic, or RED, across the full swath width), arranged to provide horizontally and vertically overlapping image strips [1]. Source data are taken from the stage in the HiROC downlink and image processing system that have been radiometrically and geometrically calibrated. The RED CCDs are processed with the ISIS 3 http://isis.astrogeology.usgs.gov/) application *noproj* which removes camera distortions and CCD offsets, and mosaics the 10 RED CCDs (full swath width). The mosaicked images are brought into the photogrammetry software SOCET SET (© BAE Systems, Inc.). In SOCET SET, the images are triangulated and registered to MOLA profiles [3]. Most HiRISE projects can be triangulated successfully to a solution with < 0.7 image pixels total RMS error. The images are then pairwise rectified, to put them in epipolar space. Automated terrain extraction algorithms in SOCET SET generate a terrain model at the specified post spacing. The model is edited for major blunders or artifacts if possible. Manual editing is extremely time consuming so major effort is put into making the input and solution as good as possible to minimize processing artifacts. The source images are then orthorectified to the DTM, at the same scale as the DTM, and at the full resolution of the original images. The output from SOCET SET is map projected.

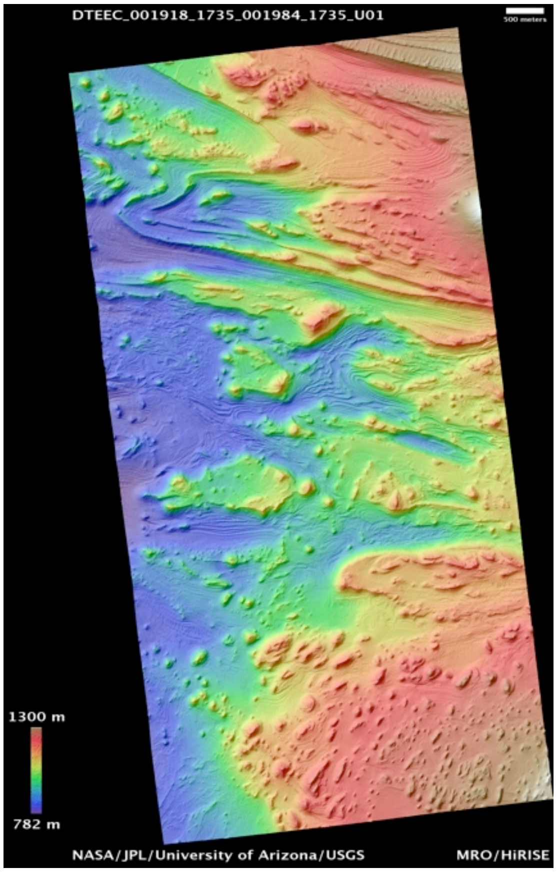

Figure 1. DTM colorized altimetry annotated browse image for DTEEC_001918_1735_001984_1735_U01, a DTM with 1m post spacing. Project location is in Candor Chasma.

The DTM and orthoimages are then exported and converted to ISIS cube format. The cubes are resampled twice, first to have square pixels in meters on the ground at the center latitude, as defined in the ISIS (and PDS) map projection, and then to convert to the PDS image object (.IMG) format with appropriate labels. The DTM pixels are in 32-bit Real values. Orthoimages are converted to JP2 format, as this image format is already in use in the HiRISE RDR products, and makes large files more manageable. The 8-bit DN values in the orthoimages can be converted back to I/F i.e. reflectance) values using the offset and scaling factors recorded in their respective labels.

Map Projection and Georeferencing: Cartographic definitions, map projection and PDS keywords for the DTMs and orthoimages are the same as those defined for the HiRISE RDRs [4]. Two map projections are used, depending on the latitude of the project. For images between -65° and +65° latitude, an Equirectangular projection is used, with planetocentric latitude type, projected onto a sphere of radius equal to the radius of the ellipsoid at the project center. To minimize scale distortions, the latitude of scale is determined to be the next lowest 5-degree latitude increment. Images above and below ±65° are in Polar Stereographic projection. As in the HiRISE RDR products, the JP2 images are encoded with a GeoTiff header, which is readable by many current georeferencing software packages.

Standard PDS Products: HiRISE stereo images are generally acquired in two modes – bin1 or bin2 – resulting in either ~25 cm/pixel or ~50 cm/pixel mapped image scale respectively. HiRISE DTMs are generated at 4 times the mapped pixel scale of the source images, resulting in products that are typically 1m/post or 2 m/post. Post spacing is equivalent to pixel scale, but refers to the horizontal grid spacing of the elevation "posts" in the DTM. Pixel values in the DTM are elevation values in meters above the Mars 2000 datum [3]. Source images are orthorectified to two scales – one at the equivalent mapped pixel scale of the HiRISE RDR product (i.e. 0.25 m/px for bin1, or 0.5 m/px for bin2), and at the matching pixel scale of the DTM (1 or 2 m/px). The DTM file is a PDS image object (file extension .IMG) with an embedded label. The orthoimages are produced as JPEG-2000 with GeoTiff encoding (.JP2 extension). The orthoimage labels are detached text files (.LBL extension). Label keywords and value definitions are described in detail in [4].

PDS Extras. Extras products are meant to provide a preview of the PDS data. The Extras files are reduced resolution JPEG images of each of the orthoimages and of the DTM, which is displayed as grayscale, shaded relief and color-coded elevation (altimetry) over shaded relief (fig. 1). Each Extra set consists of an annotated browse, browse and thumbnail size images, and a Readme text file. Annotated browse images contain the product ID, image credit, scale bar and color ramp for the colorized altimetry map.

Future Work: Some minor additions may be made to the README.TXT extra file such as including the naming scheme. Precision information may also be included (see below). Efforts are also being made towards ingesting products made at other institutions both within, and external to, the HiRISE team. Development is required to create tools to guarantee consistency of such products with the definitions specified in the SIS [4].

Precision/Edit Map. Development is currently underway to export the precision data from SOCET SET in some form of an image map. SOCET SET generates precision information, as well as Figure of Merit (FOM) data. The FOM map can be used to identify areas of the DTM that have been manually edited, as well as the correlation value of each post.

Color Orthoimages. In addition to the panchromatic visible RED wavelength images (570-830 nm), the HiRISE camera also acquires color data using filters in the blue-green visible (<580 nm) and near infrared (>790 nm) wavelengths [1]. The color portion of HiRISE covers approximately the center 20% of the full swath width. The orthorectified color will be a 3-band IR-RED-BG image, comparable to the HiRISE IRB RDR product.

Summary: The high spatial resolution and high signal-to-noise ratio of HiRISE data result in the most detailed and precise DTMs of the martian surface ever created from orbital data. Production of HiRISE DTMs and associated orthoimages is an intensive and time-consuming process. Methods are well established to create high-quality products in consistent data formats. Continual efforts are being undertaken to increase the number of DTMs produced and made available to the community, as they are an invaluable research tool. The HiRISE team is pleased to offer these products to the public via the PDS to enable quantitative geologic studies and aid in exploration planning.

References:

[1] McEwen, A.S. et al. (2007) *JGR-Planets* 112(E05S02). [2] Kirk, R. L. et al. (2008) *JGR-Planets 113(E00A24).* [3] Smith D. et al. (2001) *JGR-Planets 106(E10),* 23,689-23,722. A74. [4] Eliason E. S. et al. (2009) *MRO JPL Document #D-32006,* http://uahirise.org/pdf/HiRISE_RDR_v12_DTM_11_25_2009.pdf.

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