PRODUCTION AND ERROR ANALYSIS OF POLAR DIGITAL TERRAIN MODELS FROM HIRISE. S. Mattson[1], P. Russell[2], S. Byrne[1], R.L. Kirk[3], K. Herkenhoff[3], A.S. McEwen[1]. [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, USA (smattson@pirl.lpl.arizona.edu), [2]CEPS, Smithsonian Institution, Washington, D.C., USA, [2]Astrogeology Science Center, U.S. Geological Survey, Flagstaff, Arizona, USA.

Introduction: The high spatial resolution of Digital Terrain Models (DTMs) produced with stereo images from the High Resolution Imaging Science Experiment (HiRISE) camera on board the Mars Reconnaissance Orbiter (MRO) [1] can provide models with vertical precision in the tens of centimeters [2]. HiRISE image processing and DTM production are active areas of technical development. We discuss here concurrent efforts to improve both the production and interpretation of DTMs in the context of north polar scarps on Mars. Polar stereo images have unique considerations such as viewing angle, possible steep topography and variable seasonal lighting and frost conditions. By quantifying any processing artifacts and extending digital image processing techniques such as Fourier analysis to the interpretation of the topographic signature, HiRISE DTMs can be better used to study the climate history of Mars along with other data sets at many scales.

Stereo Pair Considerations: HiRISE stereo images are acquired on different orbits, and are targeted to provide an adequate (10-25º) convergence angle between the images. Targeting stereo on polar layered units is complicated by the steep terrain and the non-parallel orbit tracks for each stereo half, so stereo planning requires confirming that the stereo pair in question has a view of the desired features that is not too steep, does not obscure any part of the topography, and is not being viewed at a convergence angle that is out of range due to topographic effects. Polar DTM production is very sensitive to slight differences in lighting, particularly solar azimuth, and albedo differences such as frost pattern changes between stereo images. The elapsed time over which albedo is acceptably constant varies greatly with the season. The ideal stereo images will be acquired as close to each other in time as possible to minimize these differences.

DTM Production: The stereo images are preprocessed with the Integrated Software for Imagers and Spectrometers, v. 3 (ISIS 3) [3]. Mars Orbiter Laser Altimeter (MOLA) data [4] are prepared in the forms of an interpolated raster file and the laser shots as a shapefile. The HiRISE images are then triangulated within the commercial photogrammetric software SOCET Set (© BAE Systems, Inc.). The images and MOLA data sets are brought into the SOCET Set project in polar stereographic coordinates. The source stereo images are orthorectificed to the terrain model in SOCET Set. All products are exported and post-processed in ISIS 3. The process is described fully in [2]. Map projection at polar latitudes (>65º) is Polar Stereographic and conforms to standard HiRISE PDS product conventions [5,6]. DTMs produced with unbinned HiRISE images (nominally 25 cm pixel scale) have 1 m horizontal pixel scale, or post spacing. Vertical precision is ~30 cm or better, assuming a convergence angle of 20º [2].

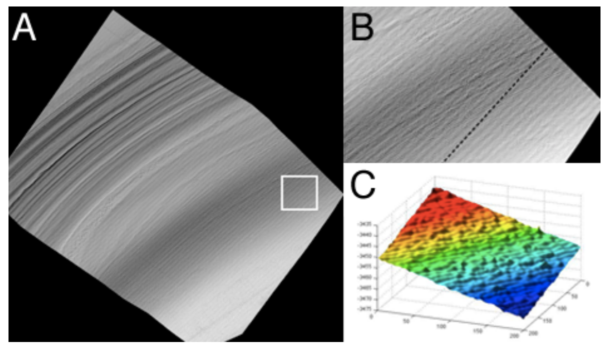

Figure 1. (A) Shaded relief image of HiRISE DTM DTEPC_018870_2625_018910_2625_A01. (B) Detail of A showing subtle artifacts visible as periodic ripples that run parallel to black dashed line. (C) Subset of the DTM indicated by the white box in A, showing the noise patterns characteristic to this DTM. Elevation range in C (indicated by color blue=low, red=high) is ~30 m.

Triangulating with MOLA: MOLA data are denser at high latitudes, but there can still be some ambiguity in tying HiRISE images to either the gridded data or to the actual laser shots, mainly because of the vast difference in resolution between MOLA and HiRISE and the small HiRISE footprints. As a result, the exact topographic correlation between MOLA and HiRISE is not always clear. Some intermediate resolution image data such as CTX could be beneficial in triangulating HiRISE to MOLA, as long as the appropriate stereo images exist at a given location. Despite the density of MOLA laser shots at the higher latitudes, there are small local differences in elevation values due to seasonal ice and frost accumulation over the lifetime of the MOLA data acquisition. The assumption used when tying image points to MOLA tracks is that the lowest elevation of a local set of tracks is the likely track acquired on frost and ice-free ground.

Effects of Image Quality on DTM: Spacecraft jitter and image noise can have some large and small effects on DTM quality. Jitter in HiRISE images is known to cause problems with stereo matching, due to geometric distortions. These distortions can increase y-parallax, which will interfere with stereomatching if motions are large enough (>~2 px amplitude) in the line direction. Increased y-parallax in stereo pairs generally causes noisy DTMs. Distortions in the x, or sample, direction affect the accuracy of elevation values. The HiRISE team has implemented a jitter correction algorithm [7] that is applied to minimize these distortions in stereo images as required. The correction is not always effective for smaller magnitude jitter, and may introduce undesirable effects. In those cases, the jitter correction algorithm is not used, and any minimal jitter effects are accepted.

HiRISE generally has a high signal-to-noise ratio (SNR) [1]. Images that have lower SNR due to haze, poor/faint illumination or darker albedo (conditions which may exist in polar images), may also result in poor stereo correlation. During pre-processing images for SOCET Set, images are downsampled from 16-bit to 8-bit. Whether or not reducing image bit depth emphasizes subtle calibration noise and how this may impact DTM production is under investigation.

Fourier Analysis: Fourier analysis has been used to analyze topography, and is especially appropriate for interpreting periodic layered structures [e.g. 8,9]. It is also a standard image analysis technique for characterizing and filtering noise in digital images. We use 2D Fourier analysis to characterize noise in a DTM (Fig. 2) in order to separate it from the topographic signal, in particular if these two patterns are nearly congruent, as in Fig. 1-B. In the case presented here, subsets of the DTM are transformed with a 2D FFT to analyze the orientation and frequency of the dominant noise signal, avoiding areas with stronger topographic signal in order to identify only the artifacts. Based on this analysis, the ripple artifact is characterized as having an angle of ~34.2º relative to the edge of the DTM file, with an amplitude up to 0.15 m and a period of ~8 lines (or ~8 m since this DTM is 1 m/post). Fourier analysis can also be used to understand the frequency of stratigraphy resolvable in HiRISE DTMs.

Conclusions: DTMs of polar scarps are being used to analyze the climate history of Mars (e.g. [10]). The analysis of small scale features resolved in HiRISE DTMs as well as correlation with larger scale features in other data sets (e.g. CTX, MOC, MOLA and SHARAD) relies on accurate positioning of the DTM, and the characterization of noise and jitter artifacts that may be present. Techniques used to understand image noise and its effects in the DTM also have applications to analyzing the topographic data in a quantitative sense.

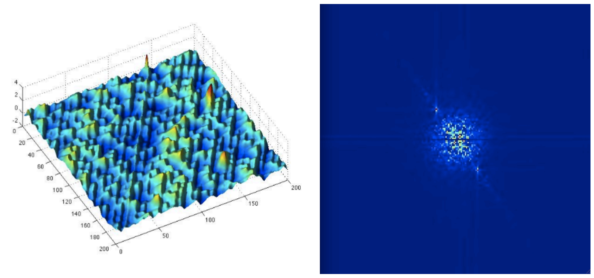

Figure 2. 2D Fourier transform magnitude diagram (right) of area shown in Figure 1-C, after detrending to remove overall topographic tilt (left). Bright points to upper left and lower right of center correspond to diagonal noise pattern. Brightness indicates higher amplitude. Distance from center indicates frequency of signal, where lower frequencies occur towards the center, and higher frequencies occur towards the edge.

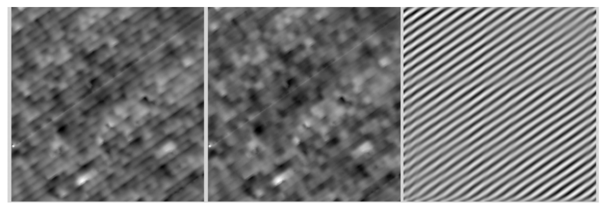

Figure 3. Cropped area as in Fig. 1-C displayed in grayscale (left); after performing the inverse FFT with a modified transform (middle); difference image (right) between the before and after correction images.

References: [1] McEwen A.S. et al. (2010) *Icarus,* 205, 2-37. [2] Kirk R.L. et al. (2008) *JGR-Planets 113,* E00A24. [3] http://isis.astrogeology. usgs.gov. [4] Smith D. et al. (2001) *JGR-Planets 106,* E210. [5] Mattson S. et al. (2011) *LPSC XLI*, Abstract #1558. [6] Eliason E. S. et al. (2009) *MRO JPL Document #D-32006*, http://uahirise.org/pdf/ HiRISE_RDR_v12_DTM_11_25_2009.pdf. [7] Mattson S. et al. (2009) *EPSC2009,* v.4, p. 604. [8] HRSC Co-Investigator Team and Milkovich S., et al. (2008) *Planetary and Space Science*, *56*, 2 pp. 266-288. [9] Perron J. T. et al. (2008) *JGR 113*, F04003. [10] Christian S., Holt J.W., Choudhary P., Fishbaugh K.E. (2010) *AGU Fall Meeting 2010,* #P34A-02.

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