



**HAL**  
open science

## **Revealing Active Mars with HiRISE Digital Terrain Models and Orthoimages**

S S Sutton, M Chojnacki, A S Mcewen, R L Kirk, C M Dundas, E I Schaefer, Susan  
J. Conway, S Diniega, G Portyankina, M E Landis, et al.

► **To cite this version:**

S S Sutton, M Chojnacki, A S Mcewen, R L Kirk, C M Dundas, et al.. Revealing Active Mars with HiRISE Digital Terrain Models and Orthoimages. 53rd Lunar and Planetary Science Conference, Mar 2022, The Woodlands, Texas, United States. <hal-03851152>

**HAL Id: hal-03851152**

**<https://hal.science/hal-03851152v1>**

Submitted on 14 Nov 2022

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

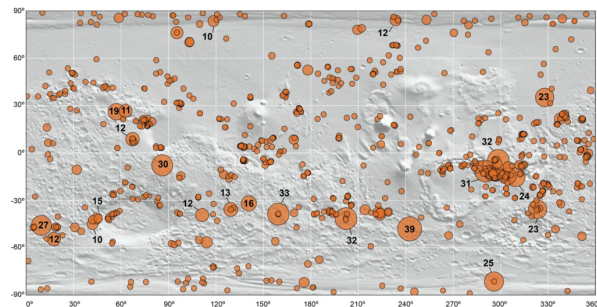


HAL Authorization

**REVEALING ACTIVE MARS WITH HIRISE DIGITAL TERRAIN MODELS AND ORTHOIMAGES.** S.S. Sutton<sup>1</sup>, M. Chojnacki<sup>2</sup>, A.S. McEwen<sup>1</sup>, R.L. Kirk<sup>3</sup>, C.M. Dundas<sup>3</sup>, E.I. Schaefer<sup>4</sup>, S.J. Conway<sup>5</sup>, S. Diniega<sup>6</sup>, G. Portyankina<sup>7</sup>, M.E. Landis<sup>7</sup>, N.F. Baugh<sup>1</sup>, R. Heyd<sup>1</sup>, S. Byrne<sup>1</sup>, L.L. Tornabene<sup>8</sup>, L. Ojha<sup>9</sup>, C.W. Hamilton<sup>1</sup>. <sup>1</sup>Lunar and Planetary Lab., U. of Arizona, Tucson, AZ, USA (ssutton@lpl.arizona.edu), <sup>2</sup>Planetary Science Institute, Lakewood, CO, USA, <sup>3</sup>U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ, USA, <sup>4</sup>Washington U., Dept. of Earth and Planetary Sciences, St. Louis, MO, USA, <sup>5</sup>LPG CNRS UMR 6112, Nantes Université, France, <sup>6</sup>Jet Propulsion Laboratory, California Inst. of Technology, Pasadena, CA, USA, <sup>7</sup>U. of Colorado, Laboratory for Atmospheric and Space Physics, Boulder, CO, USA, <sup>8</sup>Western U., Dept. of Earth Sciences, Inst. for Earth & Space Exploration, London, Canada, <sup>9</sup>Dept. of Earth and Planetary Sciences, Rutgers U., Piscataway, NJ, USA

**Introduction:** High resolution digital terrain models (DTMs) generated from High Resolution Imaging Science Experiment (HiRISE) [1] stereo pairs are one of the key data products used to support studies of active surface processes on Mars. The ability of the Mars Reconnaissance Orbiter (MRO) [2] to point repeatedly at a target, combined with the duration of the MRO mission (15 years, or 8 Mars years and counting), has allowed for details of the surface to be observed over many Mars seasons and years (**Fig. 1**).

A time series of images acquired over the same target, orthorectified to a corresponding DTM, enables pixel-scale evaluation of surface changes in three dimensions. We present here an overview of the processes used to generate HiRISE DTMs and orthoimages, with an emphasis on products created specifically for monitoring active landforms. Our intention is to provide information about the factors that affect the precision, accuracy, and effective resolution of HiRISE DTMs, and their use in change detection analyses.



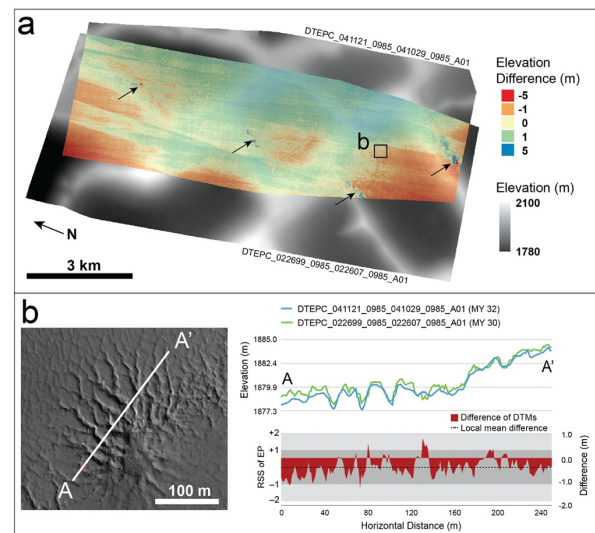
*Photogrammetric processing in brief.* Within SOcET Set, the majority of interactive steps take place during the Multi-Sensor Triangulation (MST) step. An initial relative correction is followed by controlling the stereo images in an absolute sense to geodetic control, if available. The quality of the solution achieved in MST largely determines the absolute accuracy of the DTM, and also influences how well the stereo matcher can extract elevation values from the stereo images, which affects internal precision. Additional images can then be tied to the stereo pair by remeasuring tie and control points, and solving in a relative sense. Following MST, the DTM is created at 1 or 2 m ground sample distance (GSD) in the terrain extraction stage. The DTM is evaluated for quality, and any interactive editing is performed, if necessary. The DTM and orthorectified images are then exported from SOcET Set to ISIS for post-processing to convert the files to standard PDS formats.

**Quality metrics:** An understanding of the quality of a DTM in terms of its vertical precision and horizontal resolution (e.g., [19]) is necessary to constrain the error on any quantitative analysis. Absolute positional accuracy and vertical precision are especially important for understanding the limits of what can be resolved in sequences of orthorectified images for time series analysis, or for measuring volumetric changes in multi-temporal DTMs of the same target (**Fig. 2**). Vertical precision is defined as the relative error of individual elevation values within a DTM. For HiRISE DTMs, the estimated vertical precision (EP) [20] is typically better than the GSD, and is on the order of a few tens of cm for a 1 m DTM, or  $\sim 1$  m for a 2 m DTM. While the GSD of a DTM can be chosen freely as a processing parameter, it sets a hard lower bound on the horizontal resolution of the DTM. The effective resolution of many DTMs, including those made in SOcET Set, is unlikely to be better than 3–5 image pixels, and is typically 10–20 image pixels [19].

**Conclusion:** HiRISE DTMs are the best and often only way to get accurate slope and height estimates at high-resolution from existing Mars datasets. HiRISE DTMs, along with orthorectified time series images, are necessary to make accurate and precise measurements of surface and volumetric changes on Mars, which are key constraints on models of present-day surface activity.

**Acknowledgments:** SSS was supported by NSF Graduate Research Fellowship Grant DGE-1746060, and by the HiRISE/MRO project. MC was supported in part by NASA MDAP Grants 80NSSC21K0040, 80NSSC20K1066, and by the HiRISE/MRO project. CMD was funded by MDAP 80HQTR19T0087. Work by SD was carried out at the Jet Propulsion Laboratory,

California Institute of Technology, under NASA contract 80NM0018D0004. SJC is supported for HiRISE-related work by the French Space Agency, CNES. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.



**Figure 2.** (a) Co-registered DTMs at the site dubbed Inca City ( $81.4^{\circ}$  S,  $295.8^{\circ}$  E), with overlapping area in color showing the difference map. Black arrows indicate interpolation artifacts in dark shadows. (b) Detail of orthoimage ESP\_041121\_0985, located at the small black square in (a), showing an araneiform with no apparent changes from the MY 30 stereo pair. Profile A–A' is shown from both DTMs. Gray shaded regions on the lower plot illustrate that the differences are less than  $\pm 2$  times the root summed squares of the EP (RSS EP) of both DTMs about the local mean difference.

**References:** [1] McEwen, A.S. et al. (2007) *JGR*, 112, E05S02. [2] Zurek, R. and Smrekar, S. (2007), *JGR*, 112, E05S01. [3] Bridges, N.T. et al. (2012) *Nature*, 485:339–342. [4] Chojnacki, M. et al. (2019) *Geology*, 47(5): 427–430. [5] McEwen, A.S. et al. (2011) *Science*, 333:740–3. [6] Ojha, L. et al. (2014) *Icarus*, 231. [7] Stillman D.E. and Grimm, R.E. (2016) *Icarus*, 302. [8] Schaefer E.I. et al. (2019) *Icarus*, 317. [9] Dundas, C.M. et al. (2017) *GRL*, 37. [10] Dundas, C.M. et al. (2012) *Icarus*, 220. [11] Diniega, S. et al. (2017) *Mars Geol. Soc.*, 467:95–114. [12] Portyankina, G. et al. (2010) *Icarus*, 205. [13] Portyankina, G. et al. (2017) *Icarus*, 282. [14] Landis, M.E. et al. (2016) *6th Mars Polar Science*, Abstract #6013. [15] Kirk, R.L. et al. (2008) *JGR*, 113. [16] Sides, S.C. et al. (2017) *LPSC XLVIII*, Abstract #2739. [17] BAE Systems (2011). [18] Sutton, S.S. et al. (2019) in *Planetary Rem. Sens. and Mapping*, 91–106. [19] Kirk, R.L. et al. (2021) *Rem. Sens.*, 13(17). [20] Kirk, R.L. et al. (2003) *JGR*, 108.