RECENT SURFACE WINDS OVER MARTIAN DUNES FROM RIPPLE DOCUMENTATION AND DIGITAL TERRAIN MODELS.
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Introduction: Sand dunes have been shown to preserve wind flow patterns in their ripple formations on both Earth [1] and Mars [2]. This investigation, supported by NASA MDAP grant NNX12AJ38G, was created to document properties of existing ripples on martian dunes in order to assess the recent wind flows over the surface [3]. Study sites are first evaluated for the clarity of their available HiRISE frames, which display many dunes and ripple patterns at up to 25 cm/pixel [2, 4], and their location (longitude and latitude). Frames with stereo pairs are also preferred because of their ability to create digital terrain models (DTMs) in 3D modeling software. Analysis efforts in two regions have begun with the use of geospatial information system (GIS) tools and DTM generation and study. The information from this analysis can provide insight into the modes of dune formation and add reasonable constraints to global circulation models.

Ripple Mapping: Using GIS, lines were drawn perpendicular to ripple crests across three adjacent ripples in order to document ripple wavelength from line length and inferred wind direction from azimuth by the rule of maximum gross bedform-normal transport [5]. Because it is not possible in most areas to infer a unique wind direction, line orientations have a 180 degree ambiguity [6]. The spacing between measurements is about 50 meters, but this number may decrease in areas where ripples change wavelength and direction in a small distance and increase where ripple patterns are obscured. Figure 1 is an example of these lines drawn on a dune in one HiRISE image.

DTMs: DTM creation software uses two stereo images along with absolute height reference points to create a 3D scene of the area. The SOft Copy Exploitation Toolkit (SOCET SET) used by the USGS has the ability to create a DTM with 1 meter post spacing from 25 cm/pixel resolution HiRISE images and MOLA track data [7]. Further interactive terrain editing, such as area editing by interpolation, may alter the product quality. Unfortunately, dunes present more processing challenges than other types of terrain. Although many stereo pairs of dunes exist, the images must be taken close enough together in time such that the dune has not moved significantly. In areas with clearly defined ripples, differences between the images may make finding tie points difficult, which can affect the accuracy of the DTM. Tie points are also difficult to find in smooth areas such as on dune faces. Artifacts such as 'snow angels' are created, and these post values are not reliable [7]. A further consideration is that 1 meter posts are generally too coarse to resolve ripple-scale features. However, they are still useful in defining dune-scale structure.

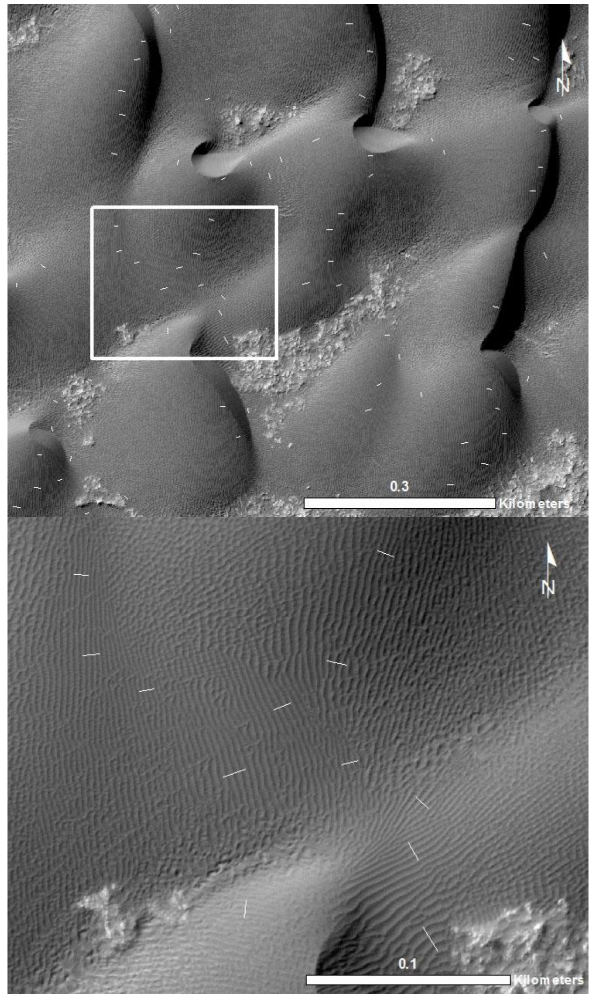

Figure 1: Ripple mapping of HiRISE frame ESP_025645_1455, shown at two scales. The top image, centered at -34.25N, 138.47E, shows a partial view of the HiRISE frame with a white box outlining the location of the bottom image. Note that areas with clear ripple definition for tens of meters contain measurements while areas with overlapping patterns have been intentionally avoided.

Terra Sirenum: The first study site is within a crater in Terra Sirenum. The site is represented by HiRISE image ESP_023928_1205 and a DTM was created using SOCET SET with stereo pair ESP_024060_1205 (Figure 2). The dominant grouping of measurements is in the SE, where 64% of measurements lie in the SSE direction (between 146 and 169 degrees). This high percentage in one cardinal direction suggests that we can extrapolate ripple values to represent wind flow over an entire dune field, subject to the availability of measurements. It also does not distinguish between primary wind ripples and those influenced by dune topography. For example, ripples near the crests of the linear dunes seem to display wind aligned with the dune's long axis (also SSE dominant) while ripples on the NE faces do not. This could be evidence for possible transverse winds, eddies, or another mechanism. The DTM shows that the dune height along the long axis is not constant, although there is only a single peak along the dune short axis. Such 'peaks and saddles' have been shown to be characteristic of meandering transverse dunes [8]. Though this region displays linear dunes with peaks and saddles, they do not seem to meander, and more investigation is needed to determine if they are transverse.

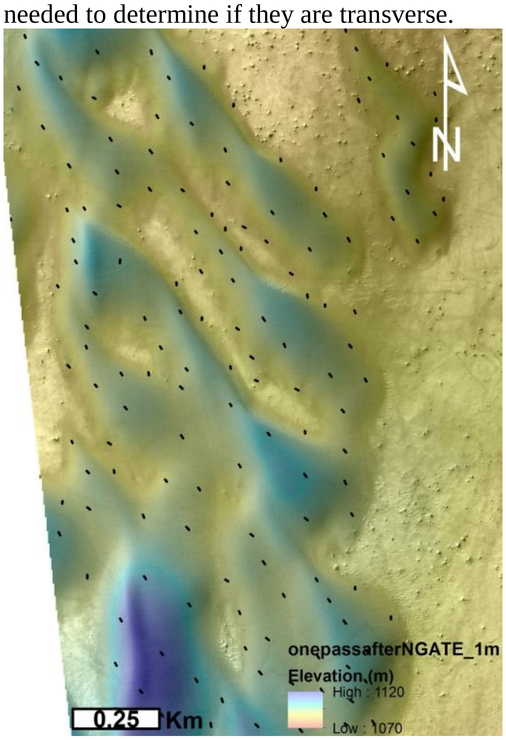

Figure 2: Subscene of HiRISE DTM created with frames ESP_023928_1205 and ESP_024060_1205. Ripple measurements documented in ArcGIS are overlaid.

Iaxartes Tholus: The second study site investigated here is an intra-crater field in Iaxartes Tholus, as seen in HiRISE image ESP_018925_2520 and stereo pair ESP_018938_2520. A publicly released DTM was created by staff at the USGS (Figure 3). An initial impression of this site is that it is a field of complex dune morphologies. The ripples do not show one dominant wind direction; 77% of measurements are split between the NE, ENE, and E directions. However, some features look like asymmetrically elongated barchans modified by gentle and strong winds, as modeled by Bagnold [9], or perhaps transverse dunes which developed elongated horns, as modeled by Tsoar [8]. Looking closer at the ripple measurements for individual features, some seem to follow the barchan curvature, though further analysis is warranted.

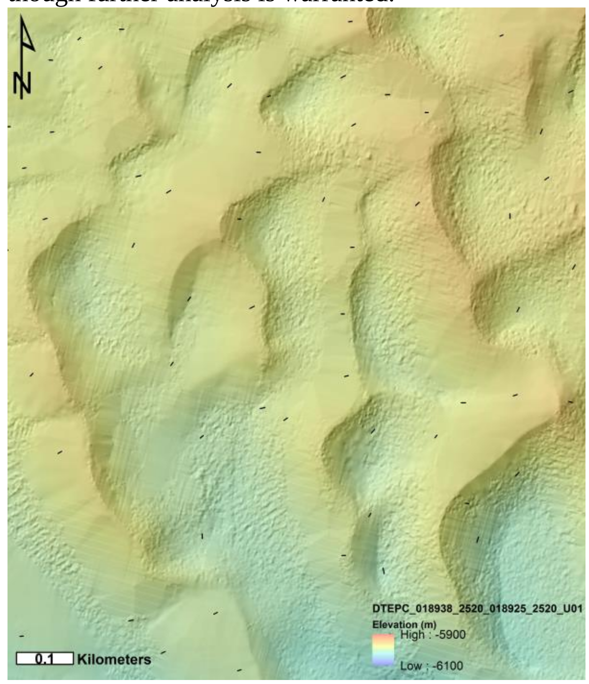

Figure 3: Subscene of released HiRISE DTM for frames ESP_018925_2520 and ESP_018938_2520. Ripple measurements documented in ArcGIS are overlaid.

Summary: Ripples and dune-scale topography have both proven to be important in assessing sand dune morphology. Ripples, while small-scale features, can record the latest wind flow over a dune surface. DTMs can provide a valuable relief representation when data are seemingly inconclusive as well as provide support for interpreting wind regimes. These two regions of Mars provide a starting point for quantitative martian ripple analysis and interpreted morphologies, which eventually should lead to constraints for regional and global wind models.

References: [1] Neilson J. and Kocurek G. (1987) *Geol. Soc. Am. Bull., 99,* 177-186. [2] Ewing R. C. et al. (2010) *J. Geophys. Res., 115,* E8. [3] Zimbelman J. R. (2011) NSPIRES NNH11ZDA001N-MDAP, MDAP proposal. [4] McEwen A. S. et al. (2007) *J. Geophys. Res., 112,* E5. [5] Fenton, L. K. et al. (2014) *Icarus, 230,* 5-14. [6] Sharp R. P. (1963) *J. Geology, 71,* 617-636. [7] USGS (2013) *Photogrammetric Processing of Planetary Stereo Images Using ISIS3 and SOCET SET,* http://astrogeology.usgs.gov/search/details/Docs/Photogrammetry/Primer/docx [8] Tsoar H. (1983) *Sedimentology, 30,* 567-578. [9] Bagnold R. A. (1941) *Physics of Blown Sand and Desert Dunes*.