Documentation of Sand Ripple Patterns and Recent Surface Winds on Martian Dunes

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Abstract 1518

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]. This information will provide insight into the modes of dune formation and add reasonable constraints to global circulation models.

Sand Transport Background

Observations of dune and ripple scale sand movements on Mars were first made by the Spirit rover [4]. Today, the High Resolution Imaging Science Experiment (HiRISE) camera provides unprecedented views of sand dunes and ripple patterns [2] with resolution as high as 25 cm/pixel [5]. However, the methods of sand transport are still debated. Wind speeds have yet to be measured in many areas and the complex structures and crest positions of dunes may be created by multiple wind directions or seasonal wind variations. Terrestrial studies have revealed that ripple-scale patterns are a better indicator of recent wind flows which modify the principle crests [1]. The preservation of ripples in HiRISE images offers the opportunity to document these recent wind flows on Mars.

Site Selection

Martian dune study sites are evaluated by the clarity of their available HiRISE frames and their location (longitude and latitude). Frames with stereo pairs are also preferred because of their ability to create digital terrain models (DTMs). The resulting 14 frames studied to date are shown in Table 1, Figures 1 and 2.

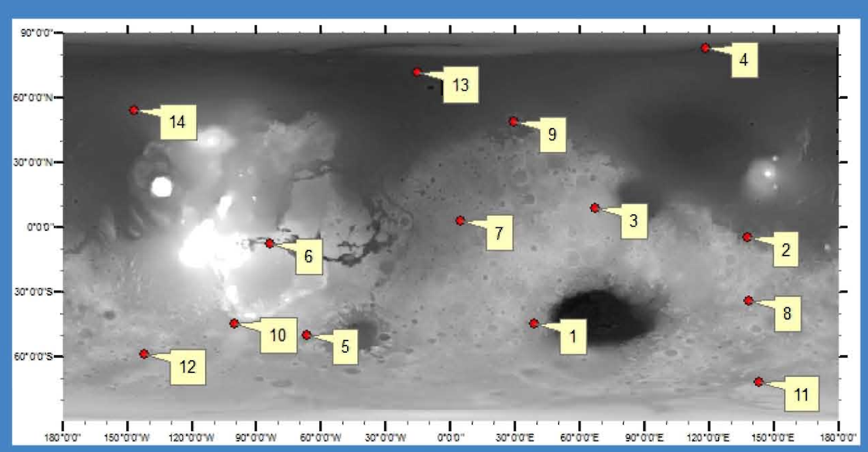

Figure 1: MOLA topography map of Mars with numbers indicating the location of each study site. Numbers correspond to those used in Figure 2 and Table 1.

Site	Method	Region	HiRISE frame ID	Lon E	Lat
1	JMARS	Hellespontus	PSP_007663_1350	38.779	-44.859
2	JMARS	Gale Crater	PSP_009571_1755	137.497	-4.463
3	JMARS	Nili Patera	ESP_017762_1890	67.321	8.779
4	JMARS	North Polar	PSP_010019_2635	118.543	83.505
5	JMARS	Aonia Terra	ESP_013785_1300	293.1	-49.804
6	JMARS	Lus Chasma	ESP_027341_1720	276.387	-7.718
7	JMARS	Arabia Terra	ESP_016459_1830	4.553	3.12
8	ArcGIS	Terra Cimmeria	ESP_025645_1455	138.437	-34.23
9	ArcGIS	Lyot Crater	PSP_009746_2290	29.287	48.864
10	ArcGIS	Icaria Planum Crater	ESP_029478_1350	259.932	-44.482
11	ArcGIS	South of Promethei Terra	ESP_022731_1080	143.002	-71.68
12	ArcGIS	Terra Sirenum	ESP_023928_1205	218.035	-59.098
13	ArcGIS	Iaxartes Tholus	ESP_018925_2520	344.658	71.906
14	ArcGIS	Milankovic Crater	ESP_018930_2350	213.42	54.576

Table 1: Information for the 14 study sites where dune ripple measurements have been recorded. 'Method' refers to the GIS software used for documentation. Lon (E) and Lat describe the center of the HiRISE frame.

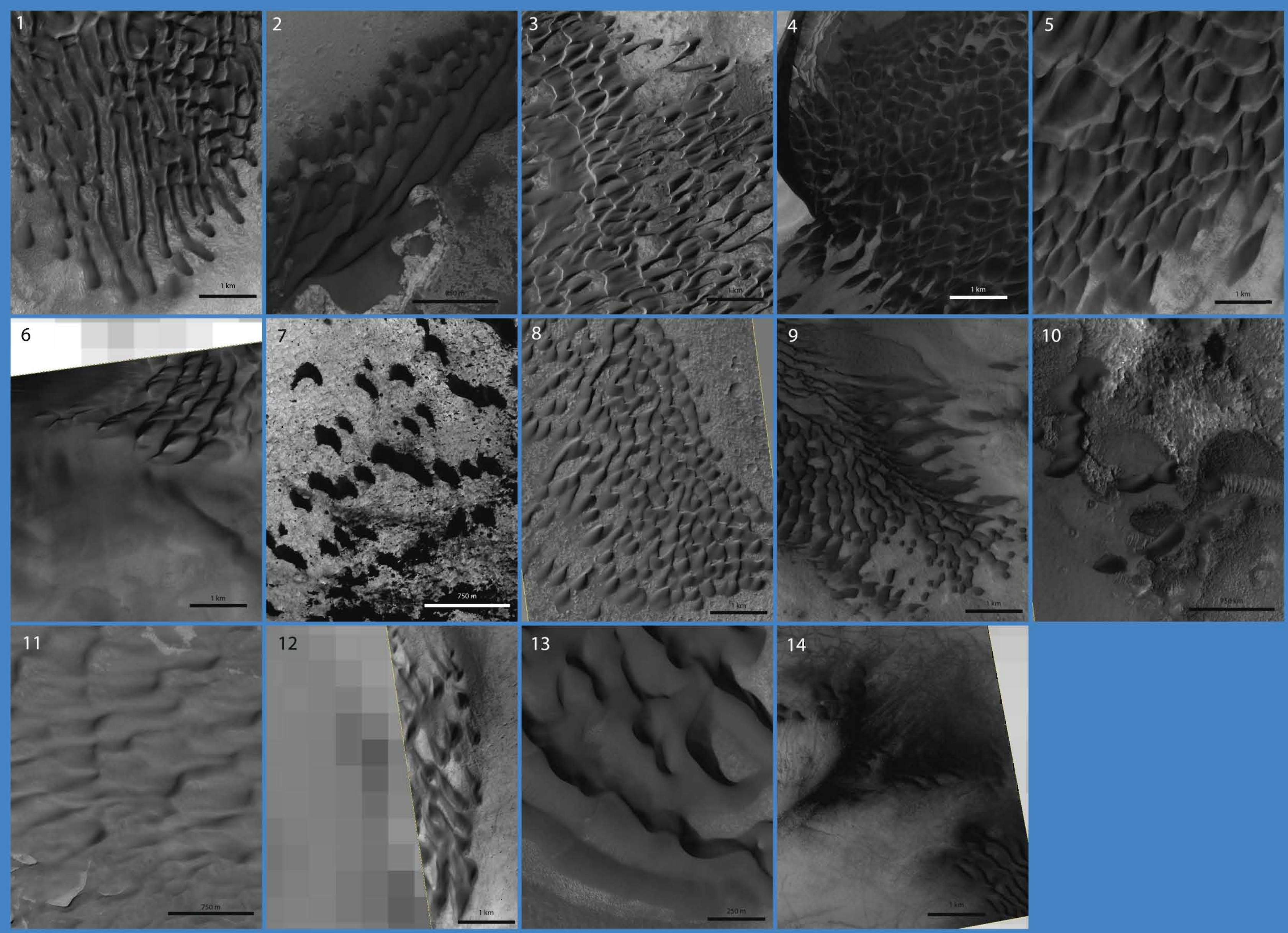

Figure 2: The first 14 study sites where dune ripple measurements have been recorded. Each image is numbered according to its listing in Table 1. A global map of the site locations is provided as Figure 1.

Ripple Mapping

Ripple documentation was completed in either the Java Mission-planning and Analysis for Remote Sensing (JMARS) geospatial information system (GIS) [6] or ESRI's Arc GIS. In both systems, 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 [7]. Because it is not possible in most areas to infer a unique wind direction, line orientations have a 180 degree ambiguity [8]. The spacing between measurements is about 50 meters. This number may decrease in areas where ripples change wavelength and direction in a smaller distance and increase where ripple patterns are obscured. Figure 3 is an example of these lines drawn on a dune in one HiRISE image, while Figure 4 is an example of prevalent types of patterns.

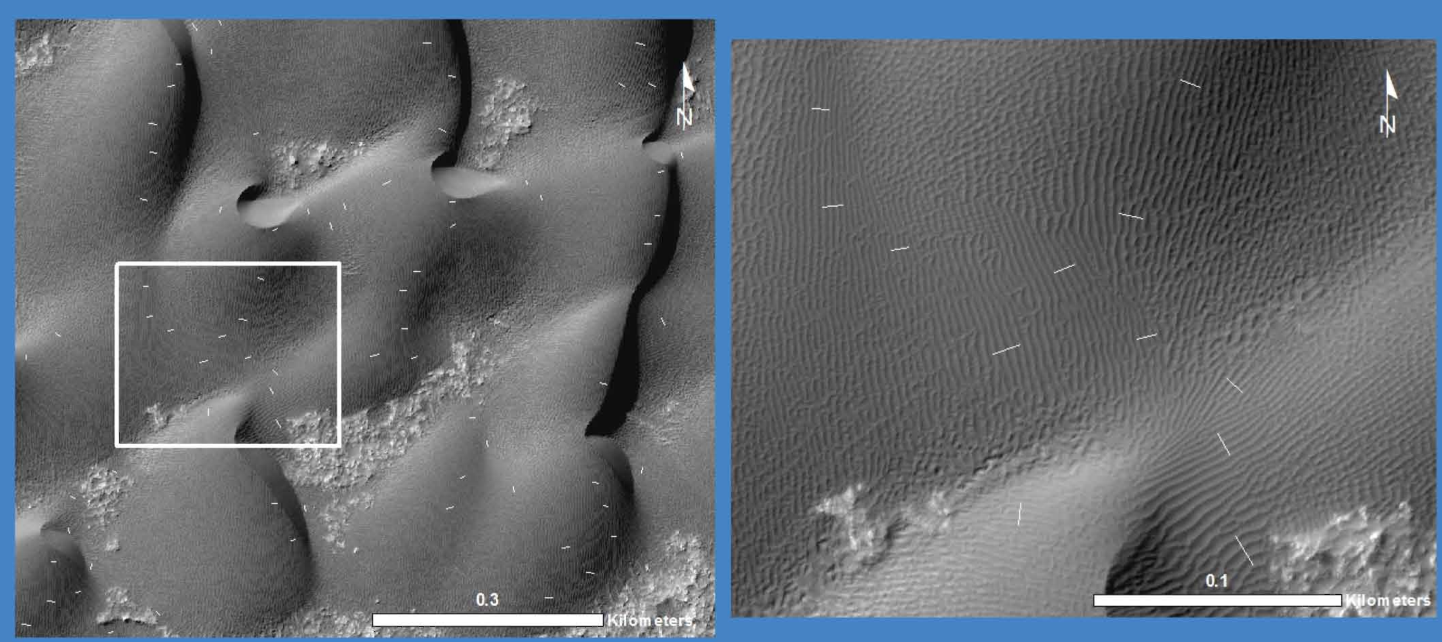

Figure 3: Ripple mapping of HiRISE frame ESP_025645_1455 shown at two scales. Scale bars in kilometers are included in each image. The left image, centered at -34.25N, 138.47E, shows a partial view of the HiRISE frame with a white box outlining the relative location for the right image. Note that areas with clear ripple definition for tens of meters contain measurements while areas with overlapping patterns have been avoided.

Figure 4: A partial view of HiRISE frame PSP_007663_1350 with three labeled ripple zones which indicate flow parallel to the dune axis (Zone 1), a linear termination zone (Zone 2), and a more complex area of overlapping ripples (Zone 3). This image is centered at -45N, 38.8E.

DTMS

Following participation in a USGS training class, the SOftCopy Exploitation Toolkit (SOCET SET) was used to create a DTM for one HiRISE stereo pair including dunes (Figure 5). A post spacing of 1 meter can be obtained from images with 25 cm/pixel resolution and further editing may alter the product quality.

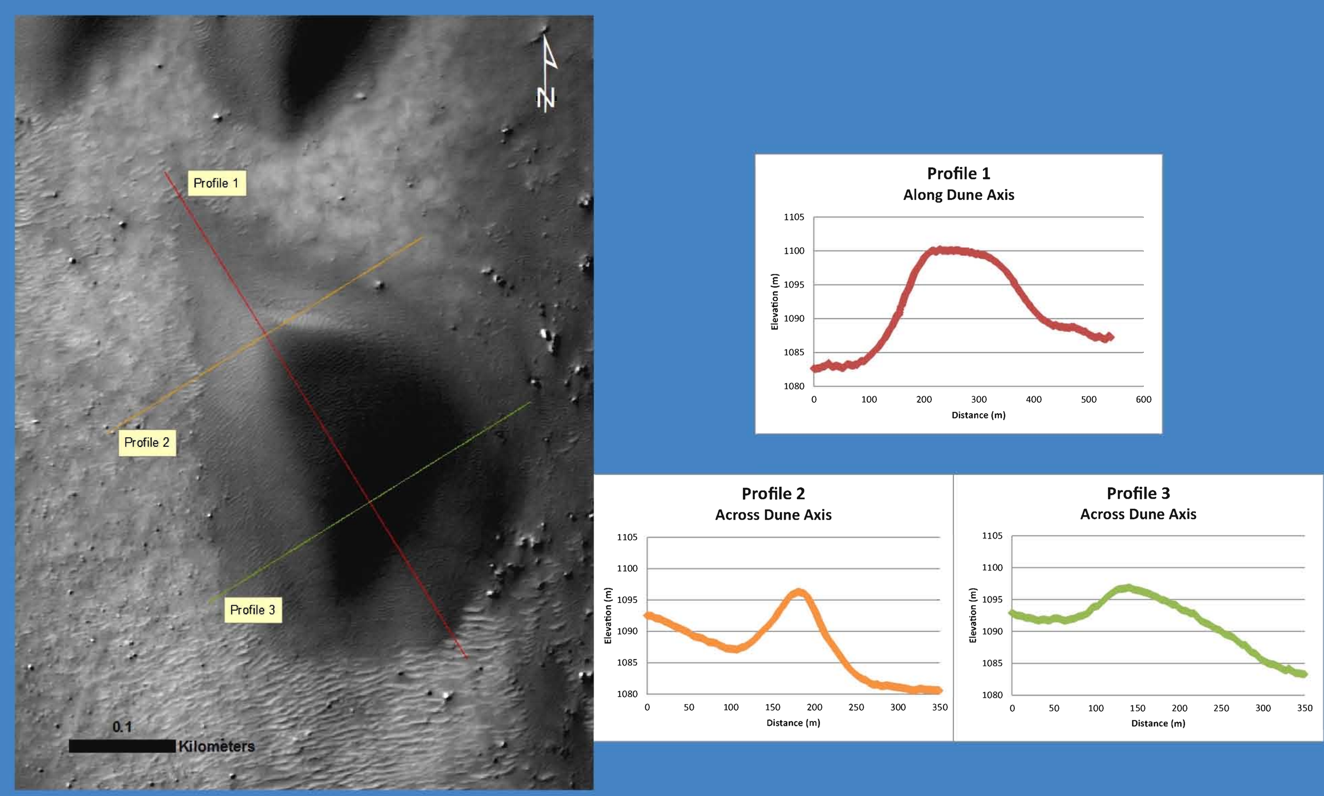

Figure 5: Dune topography derived from a DTM created with HiRISE stereo pair ESP_023928_1205 and ESP_024060_1205. The lines drawn on the orthorectified image correspond to the profiles on the right.

Results

- The survey for martian study sites confirms that there are many types of dunes in areas with adequate sand supply (Figure 2).
- The relationships seen between dunes and their surface ripple orientations include flows parallel to the dune axis and linear termination zones (Figure 4), which indicate the possibility of downwind elongation as seen in terrestrial studies [9].
- Unclear and overlapping ripple patterns (Figure 4) may indicate multiple dominant or seasonally varying winds.
- DTMs created from stereo pairs (Figure 5) provide information about dune structure, though with high post spacing and artifacts they may be too coarse for ripple analysis.
- Further study should expose additional ripple patterns of interest and allow for more terrestrial comparisons.

References

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