Wind Ripple Orientations at Forty Locations Distributed Around Mars

CEPS/NASM, MRC 315, Smithsonian Institution, Washington, D.C. 20013-7012; zimbelman@si.edu
*Department of Earth and Planetary Sciences, Harvard University, 20 Oxford St., Cambridge, MA 02138

Introduction

Wind ripple orientations were measured at forty locations widely distributed around Mars (Fig. 1). Ripples are ubiquitous on martian sand dunes, but here dunes with large slip faces were intentionally avoided. The goal was to use wind ripples as local indicators of surface winds [1, 2], with the caveat that steep slopes on dunes can induce secondary flow [3] or alter ripple direction through gravity-driven reorientation [4]. Here we present a first assessment of ripple orientations at the forty sites.

Background

Ripple orientations and their movement on Mars can be studied using images from the High Resolution Imaging Science Experiment (HiRISE) camera [5]. This instrument provides unprecedented views of martian sand dunes with resolution of 25 to 50 cm/pixel, sufficient to resolve large sand ripples like those recently examined by Curiosity [6, 7]. Dune crests and ripples mapped by Neis- son and Kocurek [8] showed that ripple patterns are a good indicator of recent surface wind flow which modified the principle dune crests, a technique applied here to ripples on dunes across Mars [9]. Recently an argument was made that the orientation of large ripples on some martian dunes may result from the composite effect of multiple wind directions, so that caution should be exerted when inferring surface wind direction from ripple patterns [10]. Here we attempt to address this situation through a combination of the mapping of both the ripple orientations and wind flow that can be inferred from the dune morphology present in the study region [11], using Context Camera (CTX) data [12] for the regional mapping [13].

Methodology

Ripple orientation was measured on HiRISE images chosen to show ripples on small dunes lacking prominent slip faces [9]. A line was drawn perpendicular to adjacent ripple crests, avoiding areas with superposed multiple patterns; drawn lines are reproducible to ±2°. Line orientation was obtained from map-projected HiRISE images using JMARS (for the first 7 sites) and ArcGIS (for the remaining 33 sites). Orientations are all 0° to 180° clockwise from north, but due to ambiguity of possible ripple migration direction, these orientations could be mirrored for 180° to 360°. Statistics were obtained using functions available in Excel. CTX images were used to derive regional maps of dune types present at each site [13].

Results

An initial analysis of the first seven sites revealed three orientation histogram types [11], a pattern maintained through all forty sites (Table 1, last column). Twenty-one sites (53%) show a clear unimodal pattern (like Fig. 2), fifteen sites (37%) have a bimodal pattern (like Fig. 3), and four sites (10%) have a non-systematic, nearly random pattern (like Fig. 4).

The first four statistical moments of a distribution provide a measure of the mean and standard deviation (column 6) of the data; the third moment (column 7), is the degree of asymmetry around the mean; and kurtosis, the fourth moment (column 8), gives the peakedness or flatness relative to a Gaussian distribution (K=3) [14]. Median (column 4) is the value for which larger and smaller values are equally probable, and mode (column 5) is the value where the distribution is a maximum [14]. Both the median and mode are useful for comparison to the mean, but mean is the parameter to which we compare other statistical variables. Figs. 5 to 7). Bimodal distributions clearly have two modes (Fig. 3), and a mode is determined for the four other histograms, in these cases it represents a local maximum that may not have much relevance to the distribution pattern as a whole (Fig. 4).

Unimodal distributions with a relatively small standard deviation (<20°) tend to have similar mean, median and mode (e.g., Table 1, sites 2, 7, 24). Not surprisingly, bimodal distributions generally have the largest standard deviation values. Negative skewness indicates the distribution is asymmetric toward values smaller than the mean (sites 1, 8, 33), while positive skewness indicates skewness toward values larger than the mean (sites 4, 29, 37). Kurtosis <3 indicates a flattened peak (sites 1, 10, 25) while K>3 are more sharply peaked (sites 7, 17, 39), relative to a normal distribution. There is no obvious correlation between the statistical parameters and their location on Mars (Figs. 8 to 10). The azimuths represented by the mean of the ripple orientations are roughly consistent globally (Fig. 11).

Regional mapping of each study site using CTX images [11] continues, providing useful context for interpreting the ripple orientation data, as well as an independent indication of the dominant wind direction based on the dominant type of sand dunes found at each study site (Fig. 12). Synthesis of these data should result in a global "snapshot" of surface wind flow patterns over sand. A manuscript describing the results should be submitted by early spring 2018. We are confident that the results will be useful for assessing wind flow over individual sand dunes, with the caveat that some ripple orientations may be a composite of multiple winds [10]. Both the local and regional products should provide a glimpse of wind flow patterns at settings widely distributed around Mars.

Acknowledgement: This work was supported by NASA MDAP grant NNX12AJ88G.

References: