Abstract 1478

Surface Slope Effects for Ripple Orientations on Sand Dunes in Lopez Crater, Terra Tyrrhena Region, Mars

J.R. Zimbelman and M.B. Johnson
CEPS/NASM, MRC 315, Smithsonian Institution, Washington, D.C. 20013-7012; zimbelmanj@si.edu; johnsonmb@si.edu

Introduction

Ripple orientations have been documented using High Resolution Imaging Science Experiment (HiRISE) images of sand dunes at widely distributed sites across Mars, in order to identify the most recent wind directions at these locations [1]. Howard [2] derived an expression for how surface slopes on a sand dune can deflect ripple orientation with respect to the formative wind. Howard's equation was applied to measured ripple orientations on sand dunes in Lopez crater (14.55°S, 97.77°E), where a Digital Terrain Model (DTM) was derived from stereo HiRISE images. Results indicate that ripple deflection is not large when areas on and around slip faces are avoided.

Methodology

A DTM with one meter posting was produced using SOCET SET at the Astrogeology Branch, USGS-Flagstaff in June 2014 (Figs. 1 and 2). Stereo HiRISE images ESP_026609_1655 and ESP_026675_1655 were obtained only six Earth days apart under excellent illumination conditions, which greatly facilitated automated feature matching, something that has proved to be difficult for martian sand dunes. A slope map was derived from the DTM (Fig. 3), from which the direction and magnitude of the local maximum slope was obtained for locations where ripple orientation was documented; these data became the input to Howard's equation [2], which provided a quantitative evaluation of the magnitude and orientation of ripple deflection from the formative wind direction at the surface of the dune.

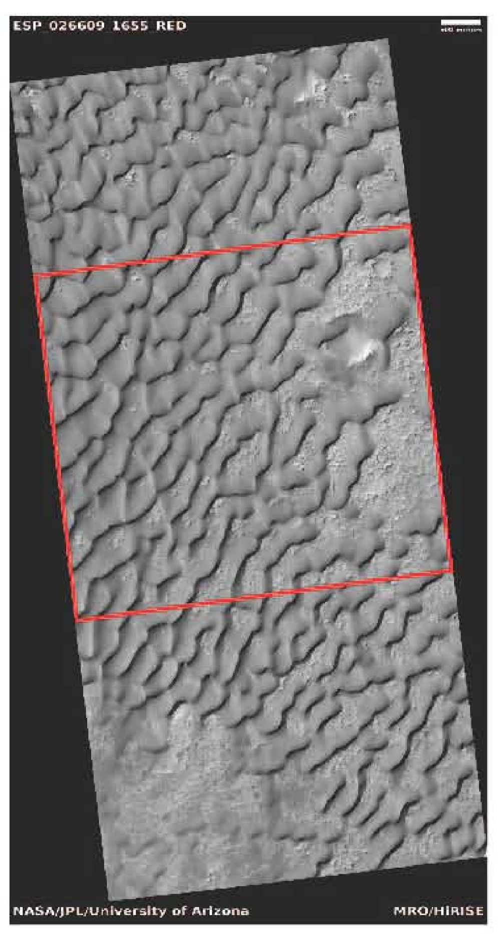

Figure 1. Browse version of HiRISE image ESP_026609_1655, showing a portion of the dune field on the floor of Lopez crater. The red box indicates the location of the area shown in Figs. 2 and 3. This image makes a stereo pair with HiRISE image ESP_026675_1655.

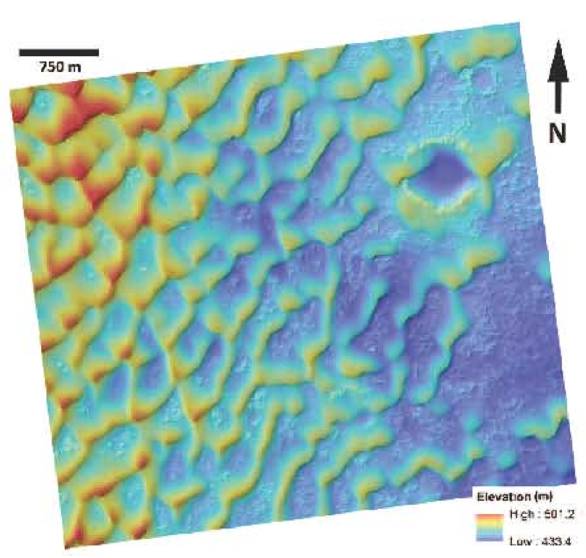

Figure 2. Digital Terrain Model (DTM) derived from a portion of a HiRISE stereo pair (see Fig. 1). The floor of the crater rises to the west at this location, but the relief of individual sand dunes is relatively constant across the area shown. DTM was produced through use of SOCET SET software at the Astrogeology Branch of the USGS-Flagstaff.

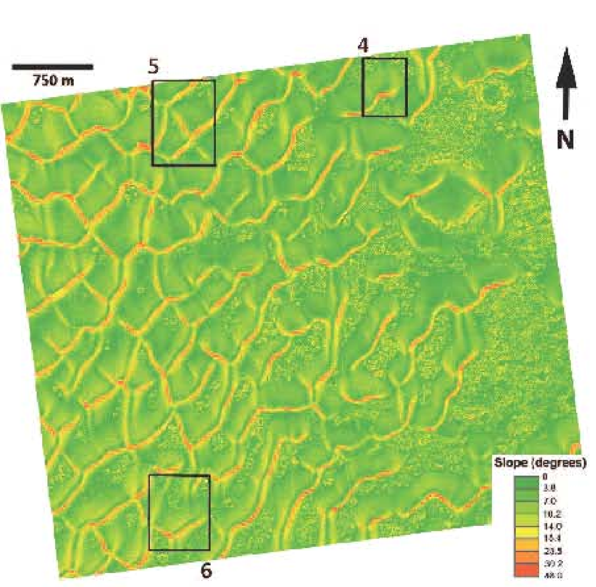

Figure 3. Slope map derived from the DTM shown in Fig. 2. The relatively constant east-dipping floor of the crater across the entire scene has little effect on individual dune relief. Steep areas on the dunes correspond to slip faces, some of which show strong shadows where oriented perpendicular to the solar insolation direction, but slip faces are less apparent when oriented along the insolation direction. Boxes show the locations of Figs. 4 to 6.

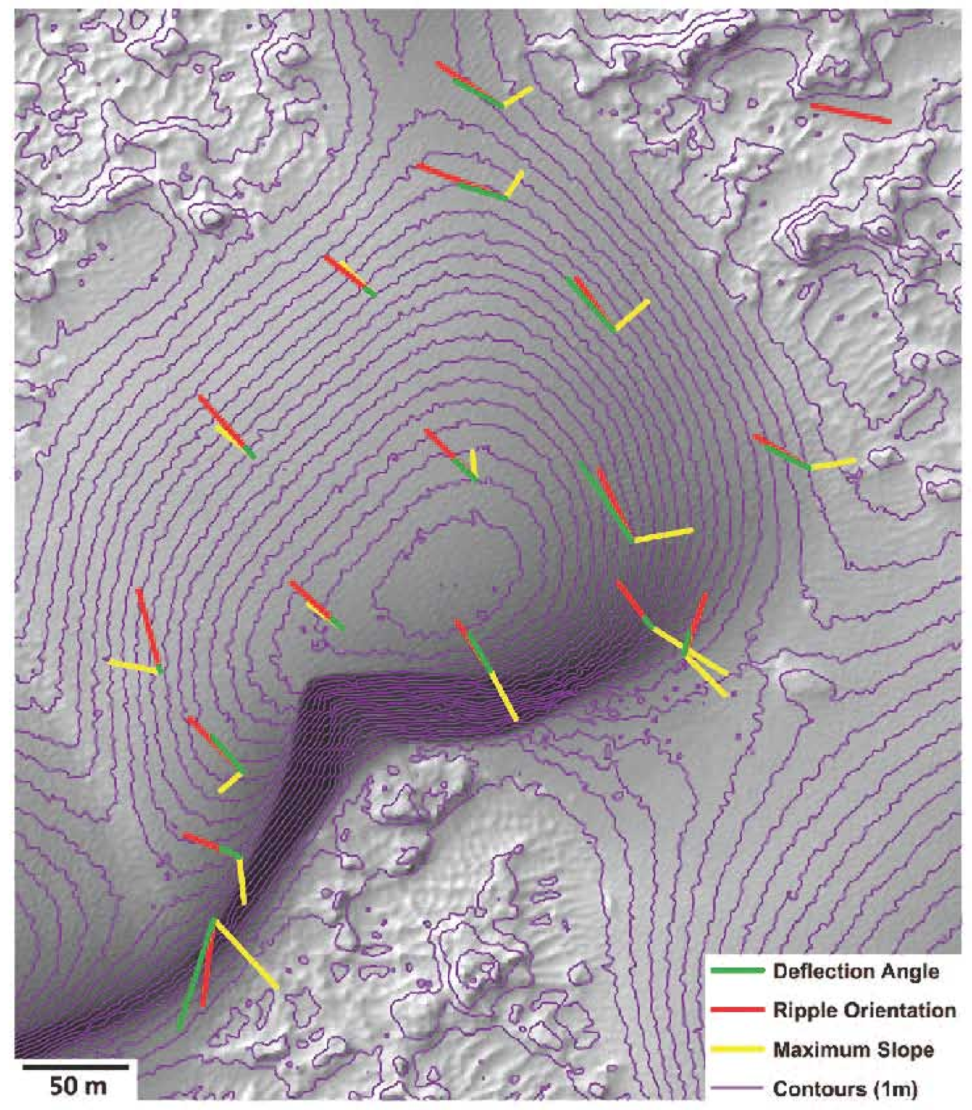

Figure 4. Wind ripple patterns on a dune near the eastern margin of the Lopez dune field [3] (see Fig. 3 for location). Red lines: measured orientation perpendicular to ripple crests; line length is scaled to 10X the ripple wavelength (at image scale). Yellow lines: direction of steepest local gradient; line length is scaled to 5X the surface slope (in degrees, at image scale). Green lines: calculated direction of surface wind after including the slope-induced deflection [2]; line length is scaled to 5X the deflection angle (in degrees, at image scale). Purple lines: 1 m topographic contours.

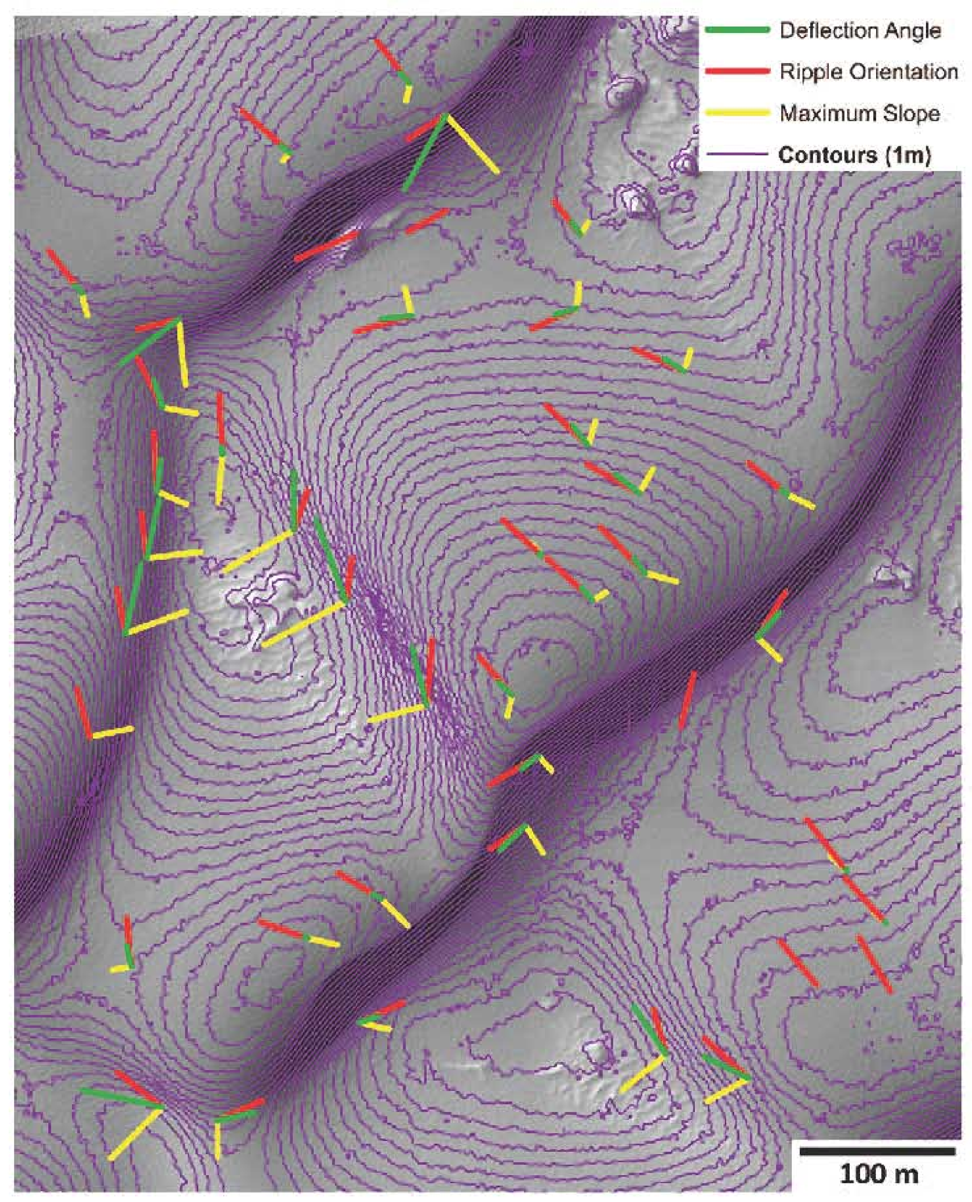

Figure 5. Wind ripple patterns on a dune near the western margin of the Lopez dune field (see Fig. 3). Line color scheme is the same as that used in Fig. 4, except that yellow line length is scaled here to 3X the slope (in degrees), and green line length is scaled here to 2X the deflection angle (in degrees).

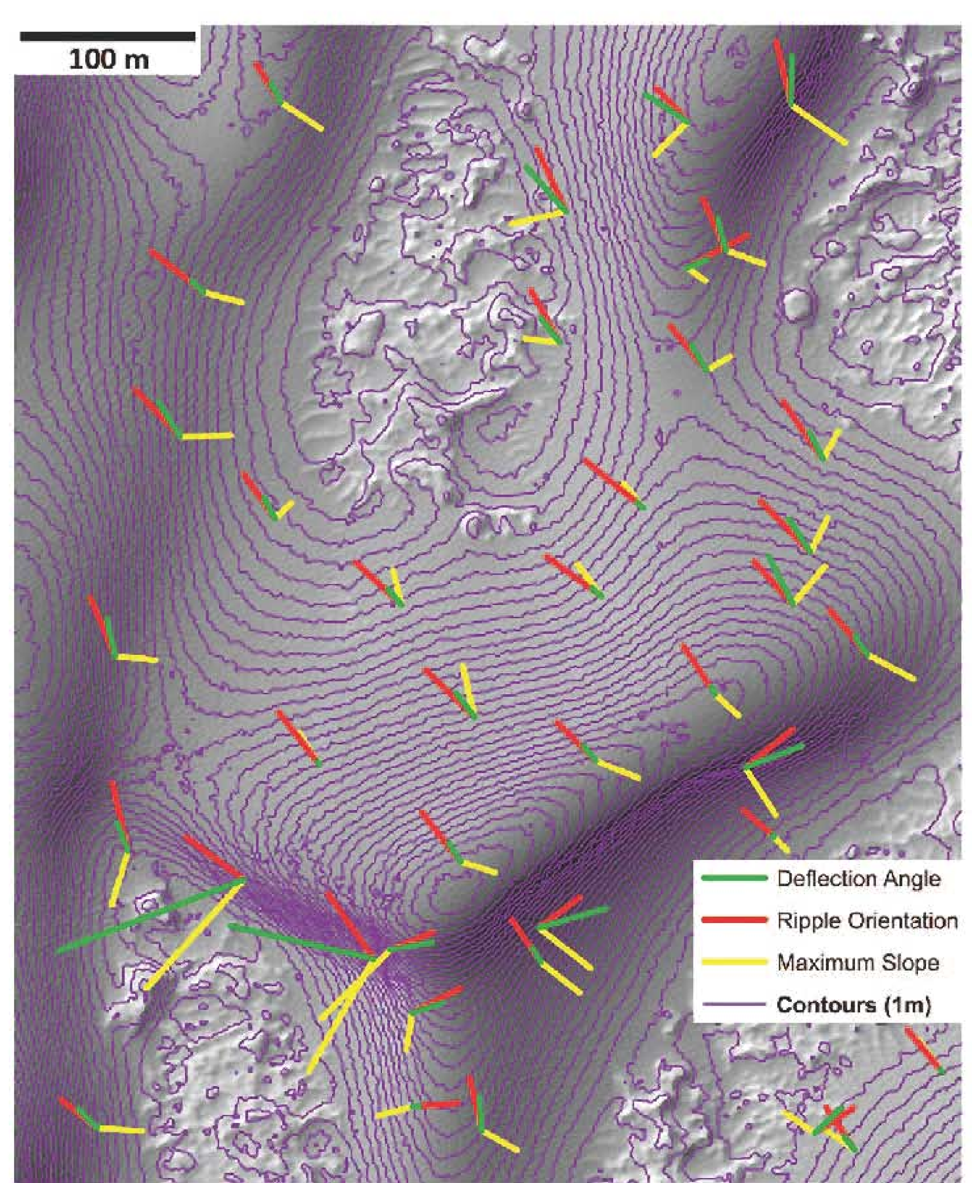

Figure 6. Wind ripple patterns on a dune near the southwestern margin of the Lopez dune field (see Fig. 3). Line color scheme is the same as that used in Fig. 4, except that yellow line length is scaled here to 3X the slope (in degrees), and green line length is scaled here to 2X the deflection angle (in degrees).

Results

The slope map (Fig. 3) revealed that 34% of the DTM has slopes between 0 and 5°, 41% has slopes between 5° and 10°, 21% has slopes between 10° and 20°, and 4% has slopes >20° (associated with slip faces). Three areas (boxes in Fig. 3) were examined in detail to determine deflection angles [2] (Figs. 4-6), the results of which should be applicable across the entire Lopez dune field. For a dune near the eastern margin of the dune field (Fig. 4), the dune has slopes <6° over nearly the entire surface (excluding the slip face), which resulted in deflection angles <5° [3]. This result is illustrated graphically by the close correspondence of red lines (measured ripple orientation) with green lines (calculated deflection angle), even where the maximum slope direction (yellow lines) is at a large angle with respect to the ripple orientation. Results changed only slightly for dunes near the western margin of the dune field (Figs. 5 and 6), where dunes have surface slopes up to 10°, resulting in maximum deflection angles <17°, but the ripples still serve as very good indicators of the most recent wind direction.

Discussion

Results for the magnitude of predicted deflection of ripples [2] applied to the Lopez crater sand dunes support the premise that ripples on sand dune surfaces are useful indicators of recent wind patterns. Application of ripple mapping to Mars [1] is an outgrowth of previous studies where wind ripples provided a record of recent near-surface wind on sand dunes on Earth [4]. Taken together, both the small effect of calculated slope deflection (reported here) and the experience from terrestrial ripple mapping support the use of ripple patterns to infer recent wind directions for sand dunes on Mars [e.g., 5]. The DTM revealed the presence of some slip faces oriented nearly parallel to the insolation direction (e.g., steep slopes running NW-SE across Fig. 5), where calculated deflection angles are comparable to those obtained for ripples on slip faces revealed by shadows. Deflections at both types of slip face locations approached values of 27°, so that ripple mapping to determine wind direction should not be carried out close to or on slip faces.

Conclusions

Three-quarters of the area covered by sand dunes within Lopez crater have surface slopes <10°, where deflection angles are <17°. Therefore, ripples are very good indicators of the most recent surface wind over dunes on Mars, as long as areas either on or near slip faces are avoided.

Acknowledgement: This work was supported by NASA MDAP grant NNX12AJ38G.

References: [1] Johnson M. B. and Zimbelman J. R. (2015) LPS 46, this conference. [2] Howard A. D. (1987) Geol. Soc. Am. Bull., 88, 853-856. [3] Zimbelman J. R. and Johnson M. B. (2014) Am. Geophys. Union, Fall meeting abstract EP43B-3564. [4] Nielson J. and Kocurek G. (1987) Geol. Soc. Am. Bull., 99(2), 177-186, doi: 10.1130/0016-7607(1987)99<177. [5] Ewing R. C. et al. (2010) J. Geophys. Res. Planets, 115, E8, doi: 10.1029/2009JE003526.