TEMPORAL INVARIANCE OF WIND ORIENTATIONS AS RECORDED BY AEOLIAN FEATURES IN PROCTOR CRATER.

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Introduction: The importance of wind action among contemporary surface processes on Mars has become well known since the first dunes were observed in spacecraft images. Wind circulation patterns determine the location and magnitude of sources, sinks, and transport pathways of particulate materials. The winds also dictate the morphology of aeolian features, such as yardangs and dunes. Because of this coupling between surface materials and the atmosphere, the study of one is not complete without the study of the other.

With the advent of mesoscale atmospheric models, the circulation of a small region can be examined in detail for the first time. These models can be used in concert with spacecraft data, and in particular MOC NA (Mars Orbiter Camera Narrow Angle) images, which provide detailed wind orientations at the scale of tens of meters. Comparing the two provides not only a verification of the mesoscale model and the GCM to which it is coupled, but also an understanding of the source of the winds that influence the surface. This in turn can lead to a better understanding of landscape morphology and the sources and sinks of mobile material.

In this work, we apply the Mars Mesoscale Model 5 (Mars MM5) to Proctor Crater to determine how the observed aeolian features correlate with predicted wind orientations. The various aeolian features on the crater floor have different relative ages, such that the comparison of each type of feature with the current wind regime provides an understanding of how wind circulation patterns have changed since the oldest remaining aeolian features formed.

Study Area: Proctor Crater is a 150 km diameter crater located in Noachis Terra, in the southern highlands of Mars and roughly 900 km west of Hellas Planitia (see Fig. 1). It contains numerous aeolian features, including a 35 X 65 km wide dark dunefield that is prominent in Figure 1. Generally visible only in MOC NA images, small bright dune-like features that are interpreted as transverse bedforms cover most of the Proctor Crater floor. In addition, dark filamentary streaks that are interpreted to be dust devil tracks form each summer. Each type of feature is aligned with its formative winds, giving an indication of the prevaling wind orientation at the time it was last active.

The Mars Mesoscale Model 5: To model the winds over Proctor Crater, we applied the Mars MM5 (Mesoscale Model Version 5), developed from the PSU/NCAR MM5 [1]. The Mars MM5 uses boundary and initial conditions provided by the GFDL Mars GCM [2]. It is nonhydrostatic, uses terrain-following sigma-coordinates, and applies the same radiation scheme as the GFDL Mars GCM. Recent topography, albedo, and thermal inertia maps are used to model the surface. The model uses a boundary layer scheme from the Medium Range Forecast (MRF) to represent the transfer of momentum from the atmosphere to the surface.

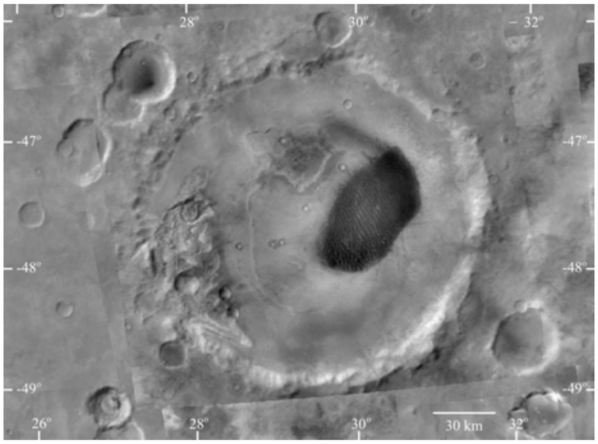

Figure 1. MOC Wide Angle mosaic of Proctor Crater

We ran the model for seven ten-day time periods distributed through the Martian year. We used 24 vertical levels from the surface to ~50 km and a horizontal spatial resolution of 10 km. The model timestep was 5 seconds, although data output was recorded 12 times each day (every 2 hours).

Aeolian Features in Proctor Crater:

Dark Dunes. Inspection of MOC NA images shows that the interior of the dark dune field in Proctor Crater is dominated by large (1-2 km wide) reversing transverse and star dunes [3]. Near the edge of the dunefield, the sand layer thins and the large dune ridges become barchanoid dunes with slipfaces that are easy to interpret, as they are always oriented downwind (see Figure 2).

Measurements were made of the orientations of these slipfaces. A rose diagram of the results is shown in Figure 3a. The dune slipfaces show three dominating wind orientations. The primary orientation, which is present throughout the dune field, indicates winds from 239º ± 18º (mean ± standard deviation), or WSW. The secondary orientation indicates winds from 110º ± 18º, or ESE, and these slipfaces are present in all but the easternmost portion of the dune field. The final, tertiary orientation indicates winds from 75º ± 9º, or ENE, and these slipfaces are only present on the eastern edge of the dunefield. These three slipfaces orientations implies that the dark dune field is located in a convergent wind regime [3], which is typical of terrestrial dune fields containing reversing transverse and star dunes [4].

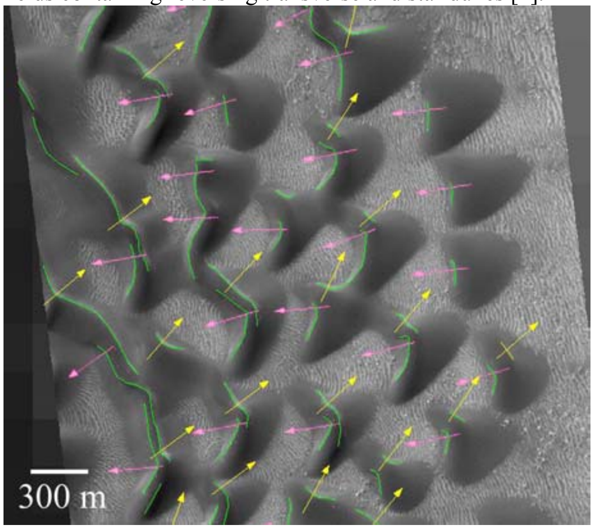

Figure 2. Dunes at the eastern edge of the dune field. Arrows indicate differing slipface orientations. Green lines indicate dune brinks.

Bright Duneforms. Small bright bedforms are distributed nearly uniformly across the floor of Proctor Crater. Where they come into contact with the large, dark dunes, they lie stratigraphically beneath them. Figure 4 shows the passage of large, dark barchans across a field of small bright bedforms, In the wake (upwind) of the dark dunes, the bright bedforms have been destroyed, implying that the migration of dark dunes also erodes away the previously existing bright bedforms.

Figure 3b shows the measured along-crest orientations of several hundred bright bedforms. The bedforms appear symmetrical at the scale of MOC NA images, with no obvious upwind or downwind slopes, and thus there is a directional ambiguity of 180º. All directions are therefore constrained to greater than 270º or less than 90º. There are two modal directions that appear in the wind rose: a primary one at 330-350º and a secondary one at 5º. If these bright duneforms

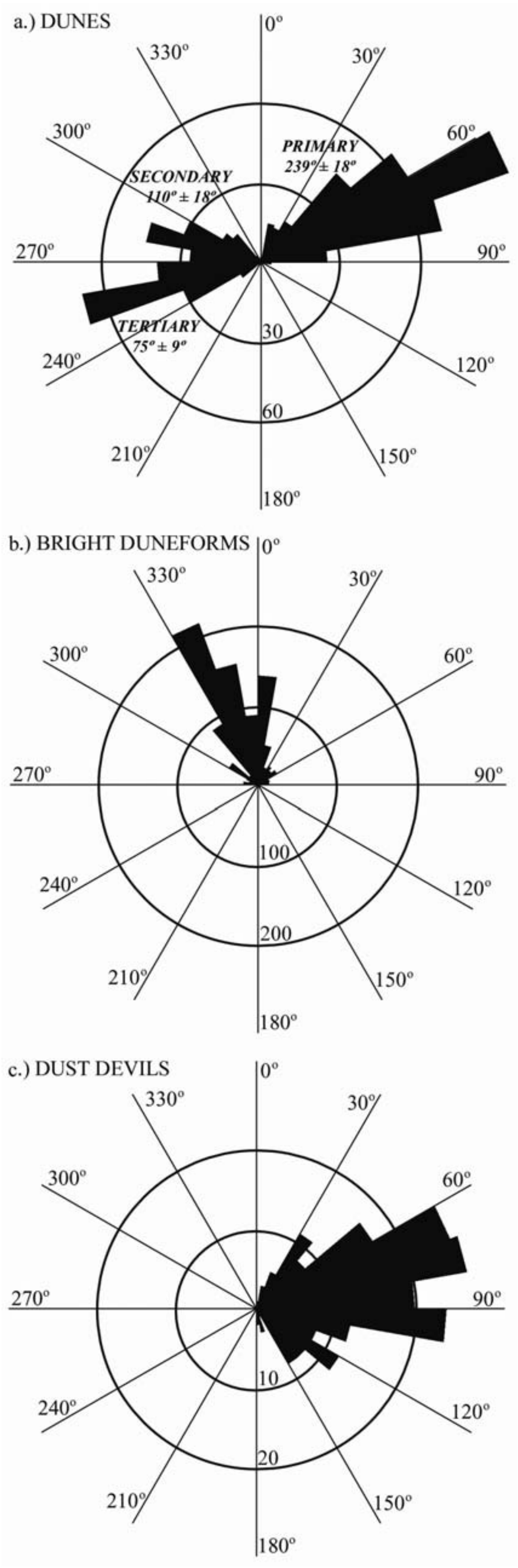

Figure 3. Wind roses showing the orientations of aeolian features.

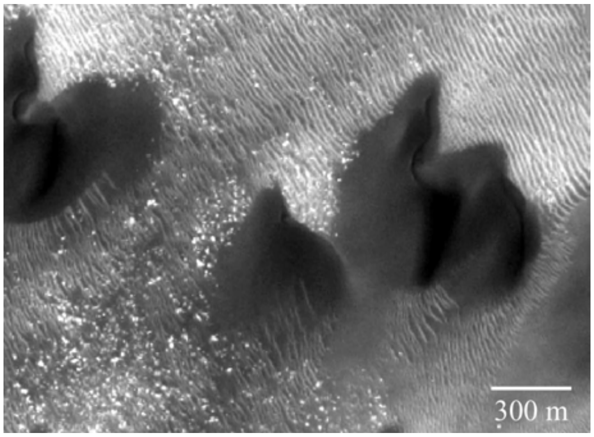

Figure 4. Migrating dunes erode smaller, bright bedforms

are oriented transverse to the winds that amost recently shaped them, as would be the case if they are granule ripples or small transverse dunes, then they reflect winds oriented ENE-WSW and ESE-WNW, respectively.

Dark Filamentary Streaks. Dark filamentary streaks form each summer and are erased each win MOC NA images of Proctor Crater. Figure 5 shows such streaks emanating from a dark patch, probably of sand. These tracks These tracks were probably created by dust devils that formed on the dark patch and moved downwind to the ENE.

Figure 3c shows the orientations of nearly two hundred such dark streaks. Because determining the upwind versus downwind direction is impossible from observing most dust devil tracks, all directions shown have been restricted to 0º to 180º. Tracks oriented at 0º or 180º are oriented north-south, and tracks measured at 90º are oriented east-west. One modal direction is evident in Fig. 5, with a spread from 60º - 100º, or generally ENE-WSW. Because of the tracks shown in Figure 5, we consider the predominant upwind direction to be from the WSW.

Model Results: The strongest daily winds shift in direction with the seasons (see Figure 6). Fall and winter winds come from the west and west-southwest. Spring and summer winds blow from the east-northeast, but they are weaker than their fall and winter counterparts. The fall and winter winds correspond well with the primary dune slipfaces, and they are most likely responsible for both the dune slipfaces and the orientations of most of the bright duneforms that are common on the Proctor Crater floor.

Dust devil tracks are also aligned with the primary wind, but they are generally only visible in spring and summertime images, indicating that this fall and winter wind is not responsible for creating the majority of dust devil tracks. Rather, they are produced by weaker winds from the WSW that blow only during the spring and summer (not shown in Fig. 6).

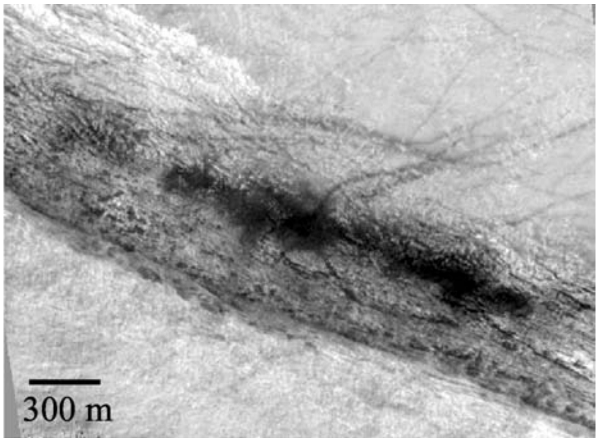

Figure 5. Dust devil tracks emerge from a small patch of dark material

The secondary winds, from the ESE, are absent from Fig. 6. It is not clear why the ESE winds do not appear as the strongest winds at some point of the year, but it may be that the model is not capturing small-scale processes that create these winds.

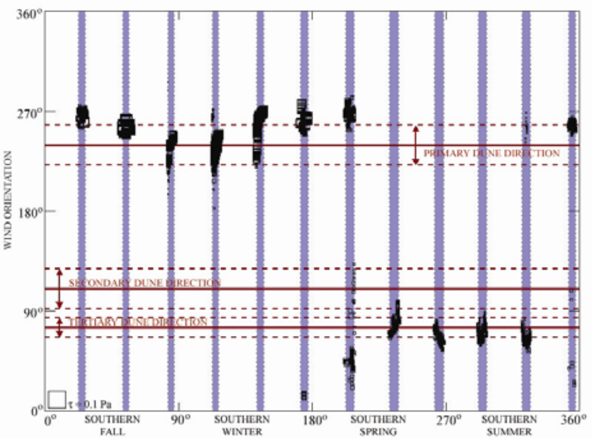

Figure 6. The highest-stres winds predicted by the mesoscale model over the Proctor Crater dunefield throughout the year.

Conclusions: Two of the three dune slipfaces are produced by the mesoscale model, indicating that the winds that last influenced the dunes are still active today. The bright duneforms, if transverse bedforms, are consistent with either the primary or the tertiary winds that influence the dark dunes, suggesting that the winds that produced the bright bedforms are also still active today. Finally, the dust devil tracks are oriented to summertime afternoon winds predicted by the model (although not shown in this abstract), and clearly indicate present-day winds.

All three types of aeolian features, regardless of their age, are consistent with present-day winds predicted by the mesoscale model. No shift in prevailing wind orientation is apparent in the aeolian features in the floor of Proctor Crater.

[1] Toigo, A. D. (2001) Ph.D. Thesis, Calif. Inst. Of Tech, 139 pp. [2] Wilson R. J. and Hamilton, K. (1996) *JAS, 53,* 1290-1326. [3] Fenton, L. K., Bandfield, J., and Ward, A. W. (2003) *JGR* (in press). [4] Wasson, R. J. and Hyde, R. (1983) *Nature, 304.*