Constraints on Mars’s recent equatorial wind regimes from interior layered deposits and comparison with general circulation model results

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Introduction

Aeolian features on Mars are transient on a range of timescales. The orientations of features such as dunes and yardangs are controlled by the prevailing wind regime over their respective intervals of formation. Statistical analysis of the orientations of young features allows probing of Mars’s recent wind regime and comparison with wind fields predicted by general circulation models (GCMs).

We collect statistical distributions of transverse dune trends and yardang azimuths at nine sites on Mars (Figure 1), and compare measured feature orientations to those predicted from interpretation of time-integrated wind vectors from the MarsWRF GCM (1, 7).

We focus on features atop interior layered deposits because their young surface ages (2) and erodible nature makes them applicable to determination of Mars’s modern wind regimes.

Results (Figure 4)

At each site we sampled the MarsWRF GCM (1,7) for each minute of a Mars year, giving a total of 96,5360 wind vectors, spread uniformly throughout the year.

For each point we extracted zonal (u) and meridional (v) wind velocities, the friction velocity, \( u^* \), and the atmospheric density, \( \rho \), (required to construct wind stress, \( \vec{\tau} \), using \( \vec{\tau} = \rho u^* \)).

\( u \) and \( v \) were interpolated to an altitude of 1.5m using similarity theory (the lowest model altitude was 10m). Wind speeds at 1.5m were deemed representative of those that control transport via salivation.

GCM vector frequencies are plotted in angular bins (Figure 4, third row down) and weighted by various formulations of wind stress. We also consider various values of saltation threshold friction velocity \( u^* \), the minimum value required to keep grains in saltation.

Transverse dune crests developed by a temporarily dynamic wind field tend not to align normal or parallel to the direction of sediment transport, but to trend such that the maximum gross bedform-normal transport, GBNT \( (\beta) \) is achieved (8).

GCM sampling & prediction of feature orientation

We calculate the angle clockwise from north where \( \beta \) is maximized (Figure 4, lower row), as well as for a secondary maximum (for Iani Chaos, green lines, top row).

Predicted dune crest orientations for maximum GBNT and maximum GBNT with various wind stress thresholds (dashed and dotted lines) are shown as red lines in Figure 4, upper row.

Conclusions

In 4 out of 7 sites, dune orientations are predicted within ~10° by the MarsWRF GCM by maximizing gross bedform-normal transport. Locations that do not match often show non-unidirectional wind fields or topographic variation.

Use of higher stress thresholds (0.016Nm\(^{-2}\)) produces better fits for dune populations at a number of locations, constraining the activation energy required for saltation.

Areas where features do not match GCM output are often more topographically variable (Candor Chasma, Iani Chaos) suggesting that the MarsWRF GCM is unable to resolve localized topographic wind forcing at these small scales.

Yardang populations approximately match the maximum GCM vector frequency at most sites, but at some they match secondary and tertiary directions, indicating the need for better understanding of the relationship between yardang erosion and wind fields.

Slight offsets between observed and predicted yardang orientations, coupled with matches between observed and predicted dune orientations (e.g. Gordii Dorsum), may indicate that yardangs are less in equilibrium with present day dune and wind fields (if dunes are active).

References