 # 2252

Possible Long-term and Short-term Wind Patterns Inferred from Mapping Martian Large Ripples and Sand Dunes

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Motivations

- Aeolian bedforms (sand dunes and wind ripples) have been extensively used to derive surface wind regimes on Mars.
- However, the distinction of different temporal (long-term vs. short-term) and spatial (global vs. local) scales of surface winds derived from these bedforms is unclear.
- Recent studies have utilized numeric modeling (global scale GCMs, mesoscale, and microscale airflow models) to analyze surface winds and compare the modeled winds with those derived from mapping of dunes and ripples.
- Results from these show discrepancies between mapping-inferred winds and modeled winds, which may be in part due to the lack of recognition of both temporal and spatial scales of winds.
- Since the knowledge of possible wind patterns is essential to understanding past and present climate on Mars, this study aims to classify the types of surface wind derived from different aeolian features.

Mapping Techniques

We compare mapping-inferred winds, derived from 3 techniques:
(1) Martian large ripples (LR) [Liu and Zimbelman, 2015]
(2) IMGBNT (inverse maximum gross bedform-normal transport) [Fenton et al. 2014]

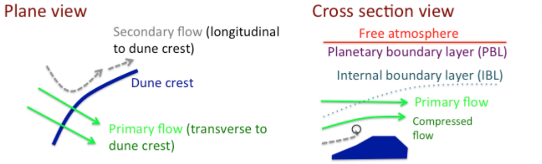
$$T_m = \max\left(\sum_{i=1}^{N} Q_i |\sin \alpha_i|\right)$$

Q_i: transport vectors, T_m: max gross bedform-normal transport
α: bedform crest orientation, Q_1 inferred from environment
→ solve for possible set of Q_2 based on Q_1 and observed α

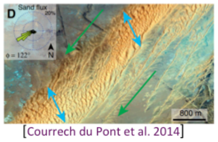
(3) Dune slipface (DS) [Fenton et al. 2003; Hayward et al. 2007; Silvestro et al. 2010]

Form-flow Interaction

Large bedforms such as dunes generate pressure gradients in near-surface flow field, which cause flow streamlines to diverge from their primary speed and direction [Walker and Nickling, 2002]→ secondary lee-side flow (may be correlated with dune crestline orientation). The compression of streamline also forms internal boundary layer (IBL) [Jerolmack et al. 2012]. The development of IBL controls the flow of wind.



Two Modes for Dune Orientation



[Courrech du Pont et al. 2014]

Dune alignment maximizes dune orthogonality to sand fluxes in bed instability mode, while dunes are aligned with mean sand transport direction in fingering mode.

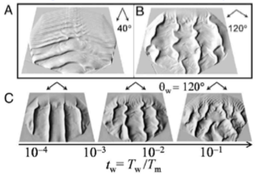
Dune Formation under Bimodal Winds

Parteli et al. [2009] presented numerical models for dune formation under bimodal winds.

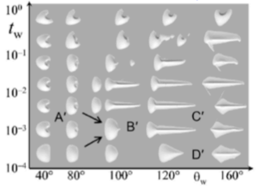
T_w: time of wind lasts in each direction,
T_m: reconstitution time, t_w: dune rescaled time
θ_w: angle of two wind directions

$t_w \ll 1$: winds shift faster than dunes can rework
$t_w \sim 1$: dune is reworked by one wind before the second wind begins
→ dune morphology depends on θ_w and t_w

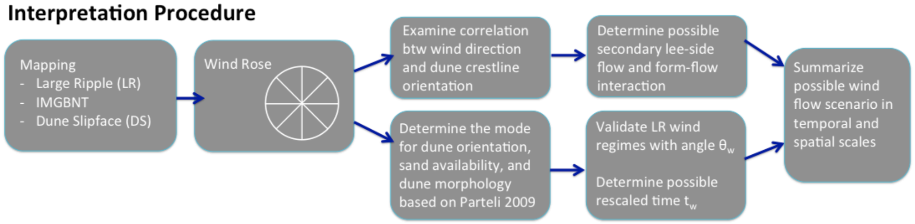
High/medium sand availability



Low sand availability



Interpretation Procedure



Mapping
- Large Ripple (LR)
- IMGBNT
- Dune Slipface (DS)

Wind Rose

Examine correlation btw wind direction and dune crestline orientation

Determine possible secondary lee-side flow and form-flow interaction

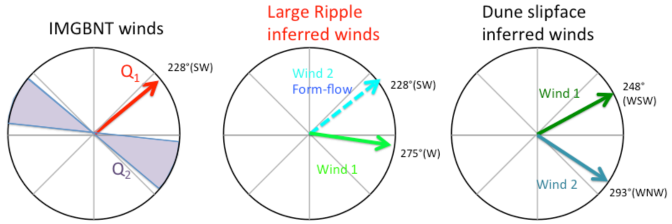
Determine the mode for dune orientation, sand availability, and dune morphology based on Parteli 2009

Validate LR wind regimes with angle θ_w

Determine possible rescaled time t_w

Summarize possible wind flow scenario in temporal and spatial scales

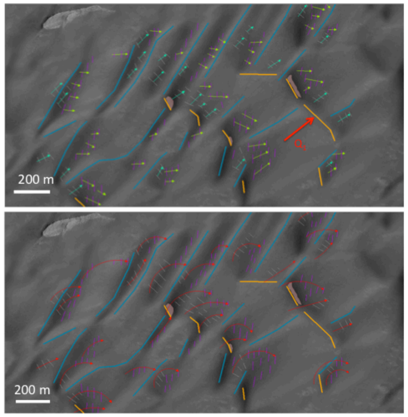
Case study-1: South of Promethei Terra



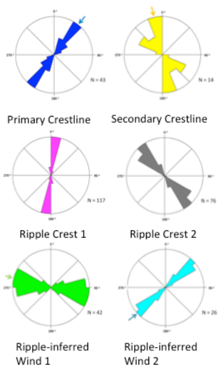
Interpretation summary:

Medium sand availability	Bimodal winds $\theta_w \sim 47°$	Possible long-term winds: Q_1: 228° (SW), Q_2
Fingering mode	Dune morphology: type A	Possible short-term winds: 275° (W), 228° (SW)
$\theta_w = \lvert Q_1 - Q_2 \rvert \sim 47°$	High t_w and T_w	Possible secondary lee-side flow: 228° (SW)

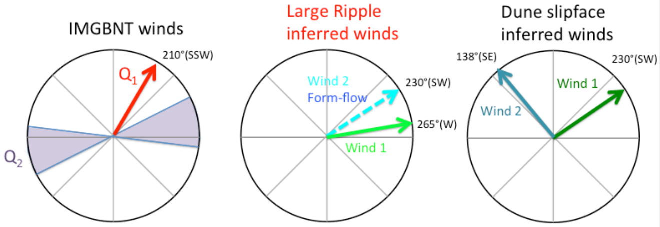
→ SW and W winds can be both long-term and short-term, could last thousands of years



Large ripple mapping



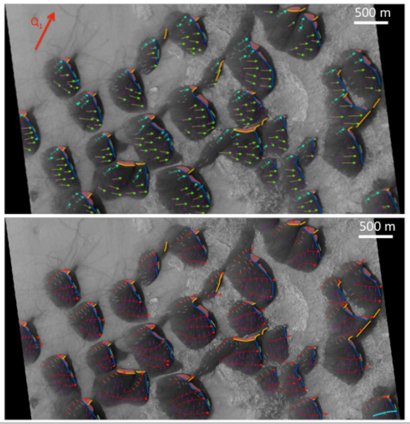
Case study-2: Wirtz Crater dunes



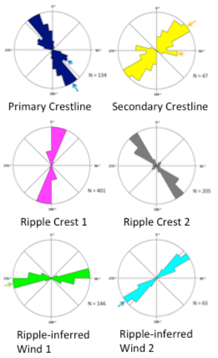
Interpretation summary:

Low sand availability	Bimodal winds $\theta_w \sim 110°$	Long-term winds Q_1: 210° (SSW), Q_2
Fingering mode	Dune morphology: type B′	Short-term wind: 265° (W), 230° (SW)
$\theta_w = \lvert Q_1 - Q_2 \rvert \sim 110°$	Low t_w (~ 10^{-3}) and T_w	Possible secondary lee-side flow: 230° (SW)

→ long-term winds form barchan-like dunes, short-term winds form large ripples, winds shift faster than dune can rework



Large ripple mapping



Discussions

- Ripple-inferred wind regimes are consistent with either dune crestline orientations or IMGBNT winds. The former implies the interaction between airflow and dune crest topography (form-flow), producing the secondary lee-side flows (longitudinal to dune crestline)
  → LR technique can derive secondary flow.
- IMGBNT Q_1 winds may better reflects large-scale, long-period wind dynamics.
- Dune slipface and large ripples may better reflect local-scale, short-period wind dynamics
  → DS technique is less effective in dune fields constructed by multidirectional wind flows.
- Comparison of wind regimes using numeric modeling (e.g., global scale GCMs, mesoscale, and microscale airflow models) should be evaluated accordingly.
- Derived short-term winds (from LR technique) and corresponding bimodal wind angle θ_w are consistent with resulting dune morphology modeled by Parteli et al. [2009].
- Comparison with bimodal wind model established by Parteli et al. [2009] reveals more information on wind regimes and possible wind flow scenario.

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References:

(1) Fenton et al. [2003] JGR, 108(E12). (2) Fenton et al. [2014] Icarus, 230, 5-14. (3) Hayward et al. [2007] JGR, 112(E11). (4) Liu and Zimbelman [2015] Icarus, 261, 169-181. (5) Silvestro et al. [2010] Geomorphology, 121(1), 84-97. (6) Walker and Nickling [2002] Prog. Phys. Geogr. 26 (1), 47–75. (7) Jerolmack, et al., [2012] Nat. Geosci.5, 206–209. (8) Courrech du Pont et al. [2014] Geology, 42.9, 743-746. (9) Parteli et al. [2009] Proc. of NAS, 106(52), 22085-22089.