Are Mars Aeolian Features Controlled by the Strongest Winds?

A Mesoscale Modelling Investigation

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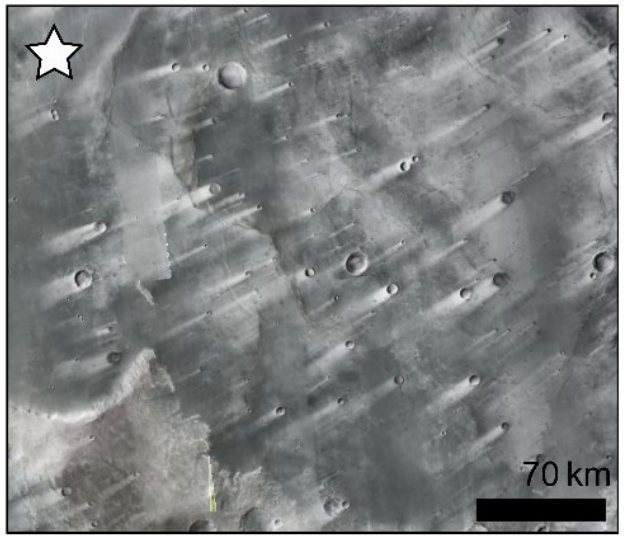
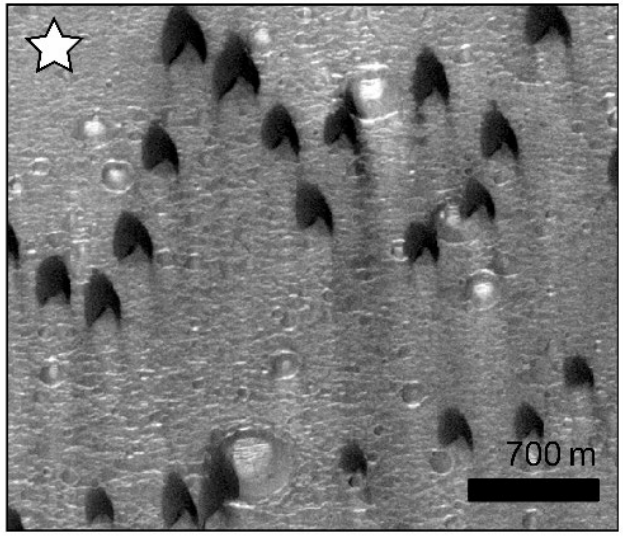
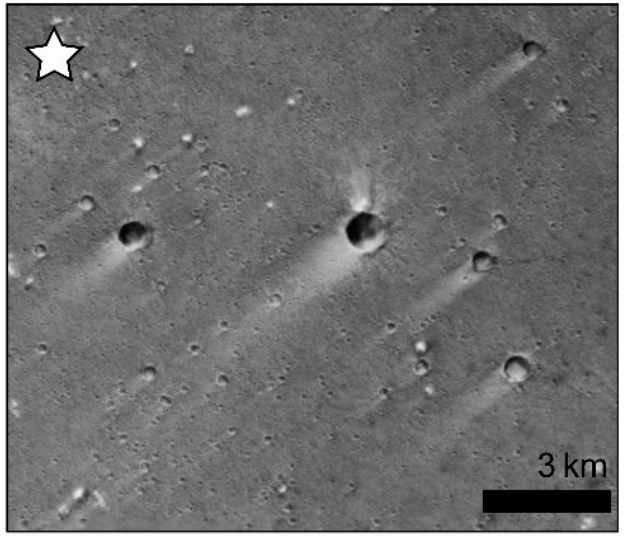
Sometimes yes. Sometimes no.

Introduction







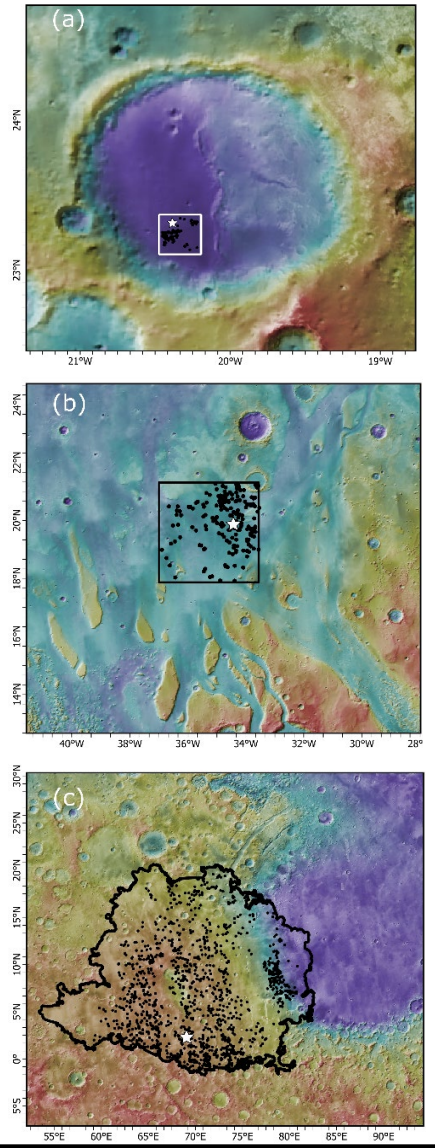
- Aeolian features (wind streaks, barchan dunes) are widespread on Mars
- Orientations tell us something about the present-day local winds
- **Common assumption:** ***Aeolian geomorphology is created by some % of the 'fastest winds'.***
- Compare aeolian orientations to local-scale wind models to see if it really is the 'top 5% of wind speeds'

Mesoscale modelling

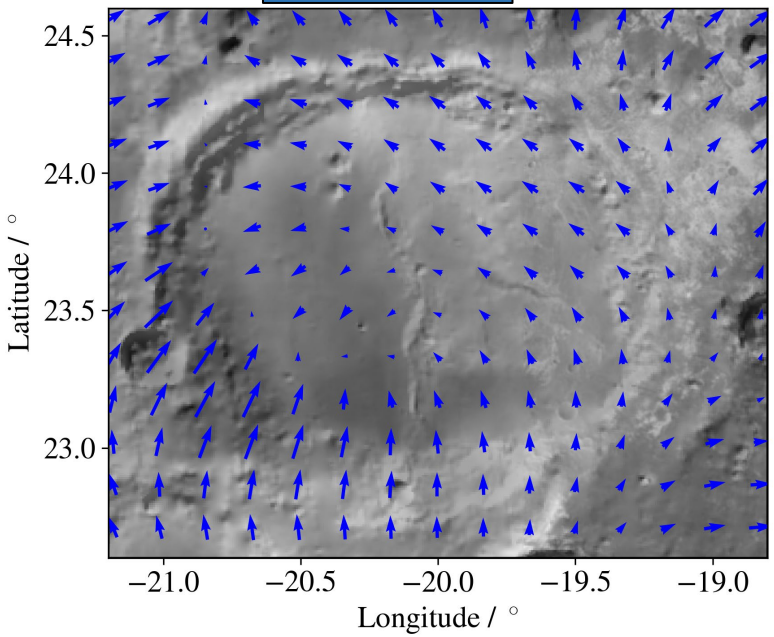
Oyama crater

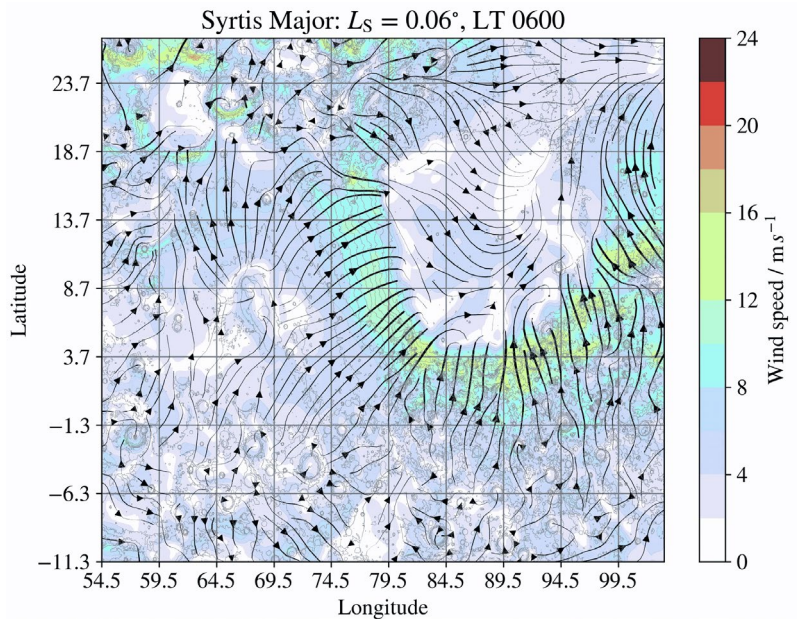
Ares Vallis

Syrtis Major



Mesoscale





- We used a mesoscale model to simulate the winds at three sites where wind features were mapped: Oyama crater, Ares Vallis and Syrtis Major. Mesoscale resolution allows for fine-grained comparison of small-scale wind features that are unavailable at GCM scale.

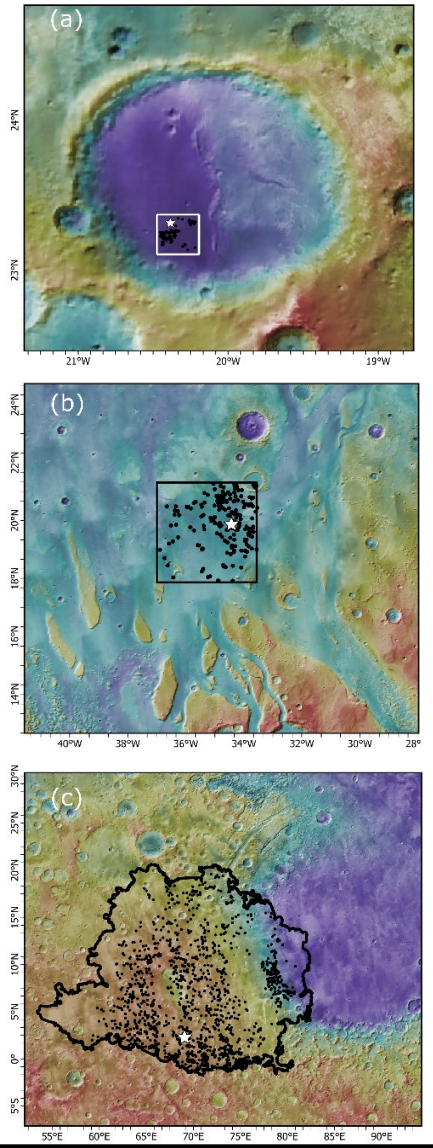
- 217 × 217 horizontal grid. Horizontal resolution: 10 km (Oyama crater, Ares Vallis), 14 km (Syrtis)
- 40 unevenly spaced vertical levels from the near-surface up to ~50 km
- 12 diurnal simulations at each domain, initialized at 12 different times of year, separated by 30° of solar longitude.
- Each simulation spanned 12 sols, including a 2-sol spin-up.
- Boundary conditions were taken from OpenMARS and reflected assimilated dust and temperature for Mars Year 35.

Mesoscale modelling

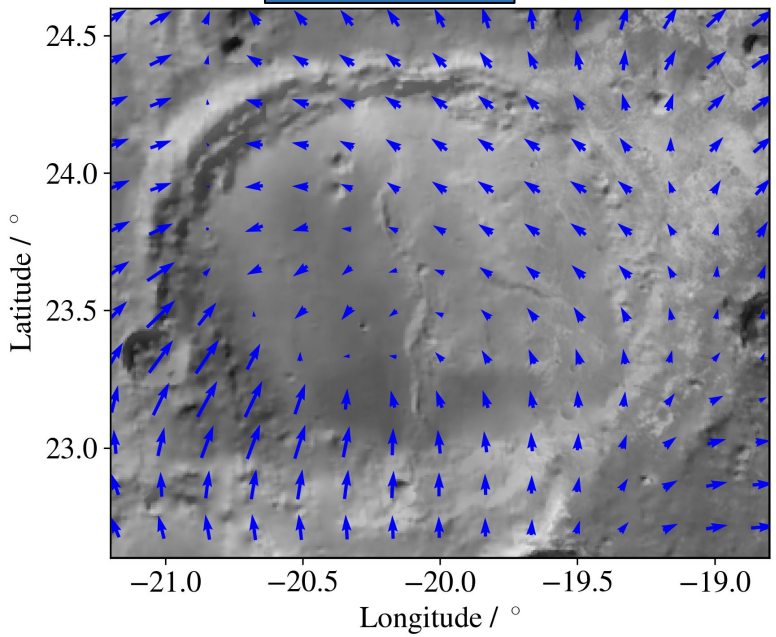
Oyama crater

Ares Vallis

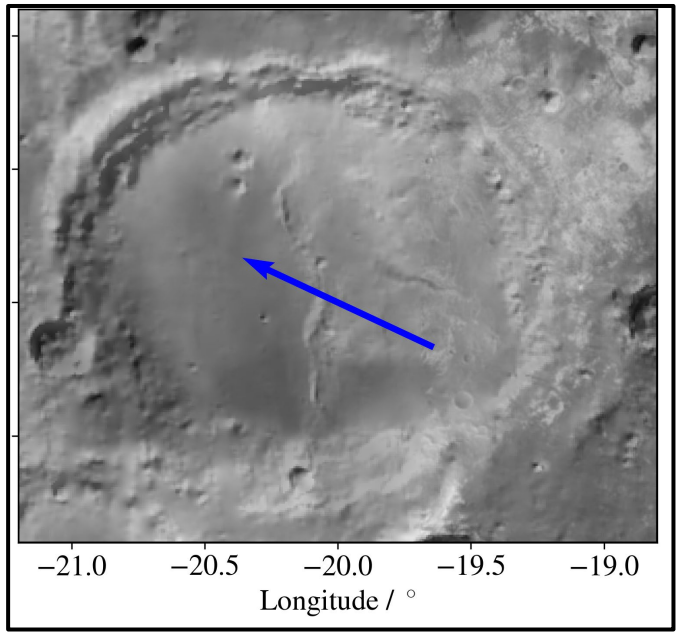
Syrtis Major



Mesoscale



GCM



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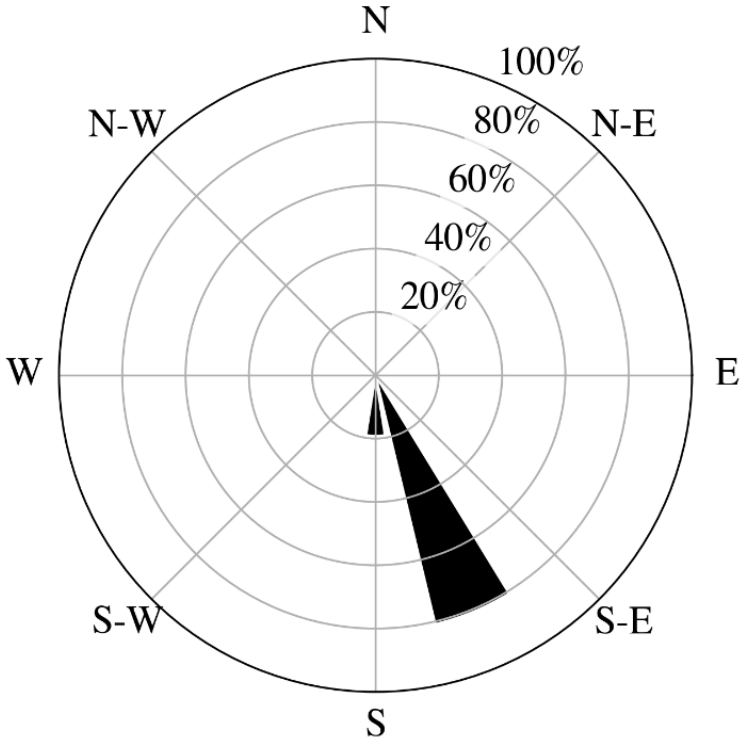
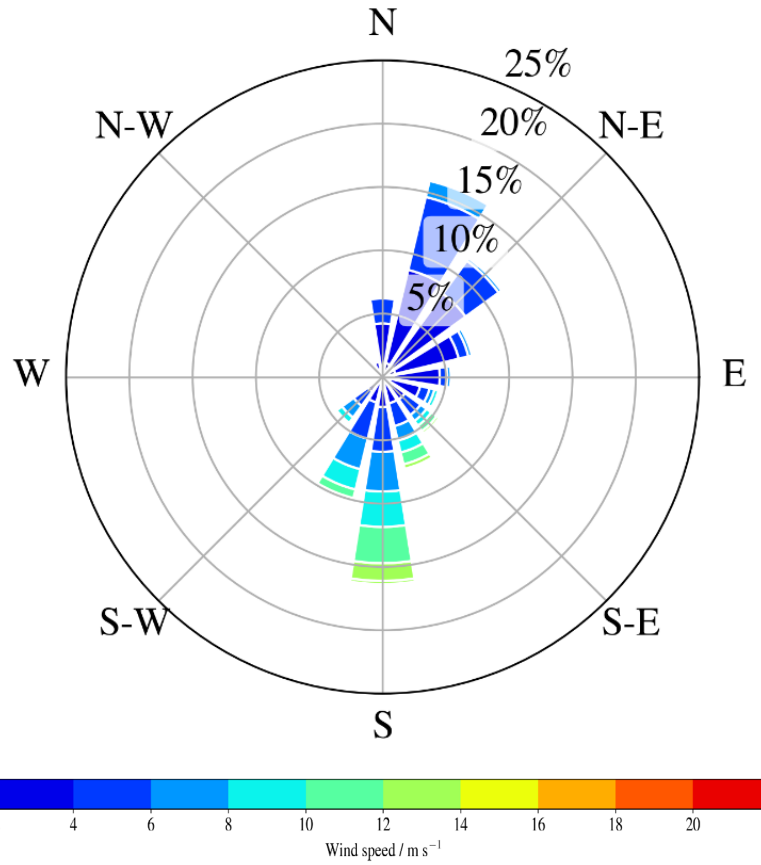
Method: How to compare observations and models?

Observed wind streaks



Mesoscale model winds



Modelled wind rose:

Angle = direction wind is 'blowing towards'.

Radial length = % of winds blowing in that direction.

Colour = wind speed.

Observed wind streak plots:

Angle = orientation (pointing towards)

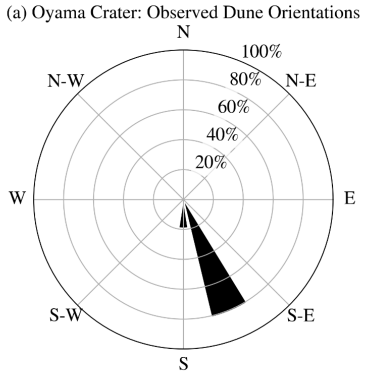
Radial length = % wind streaks pointing in that direction.

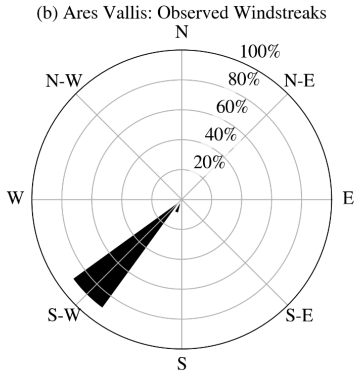
Results: Wind rose comparisons at all sites

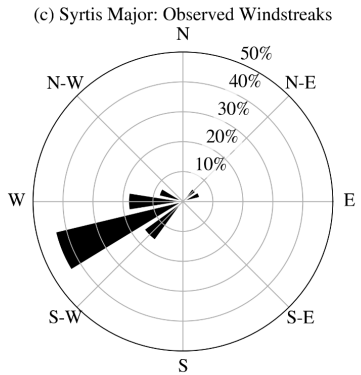
Oyama crater

Ares Vallis

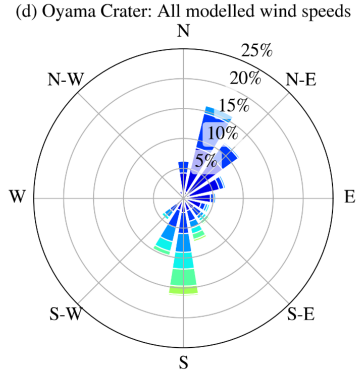
Syrtis Major

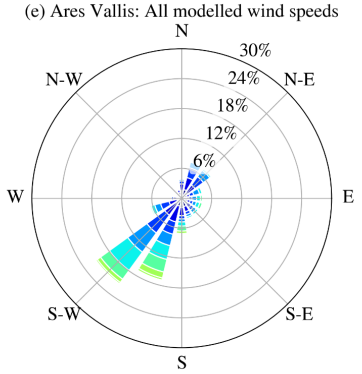






All winds





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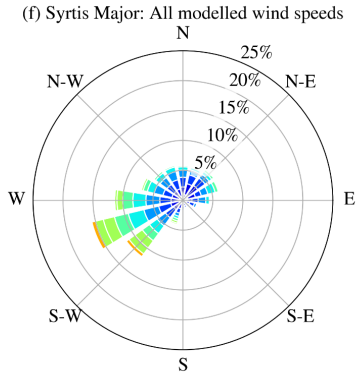
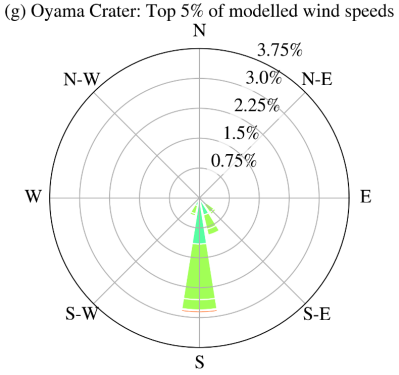
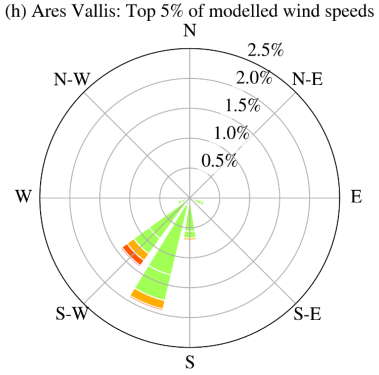


Top 5%





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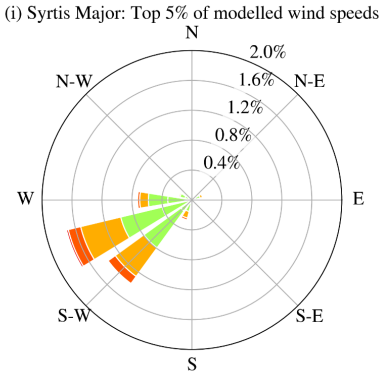
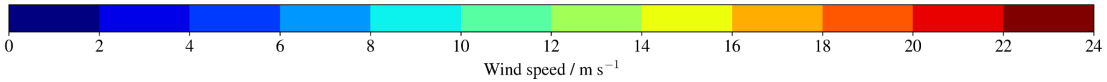


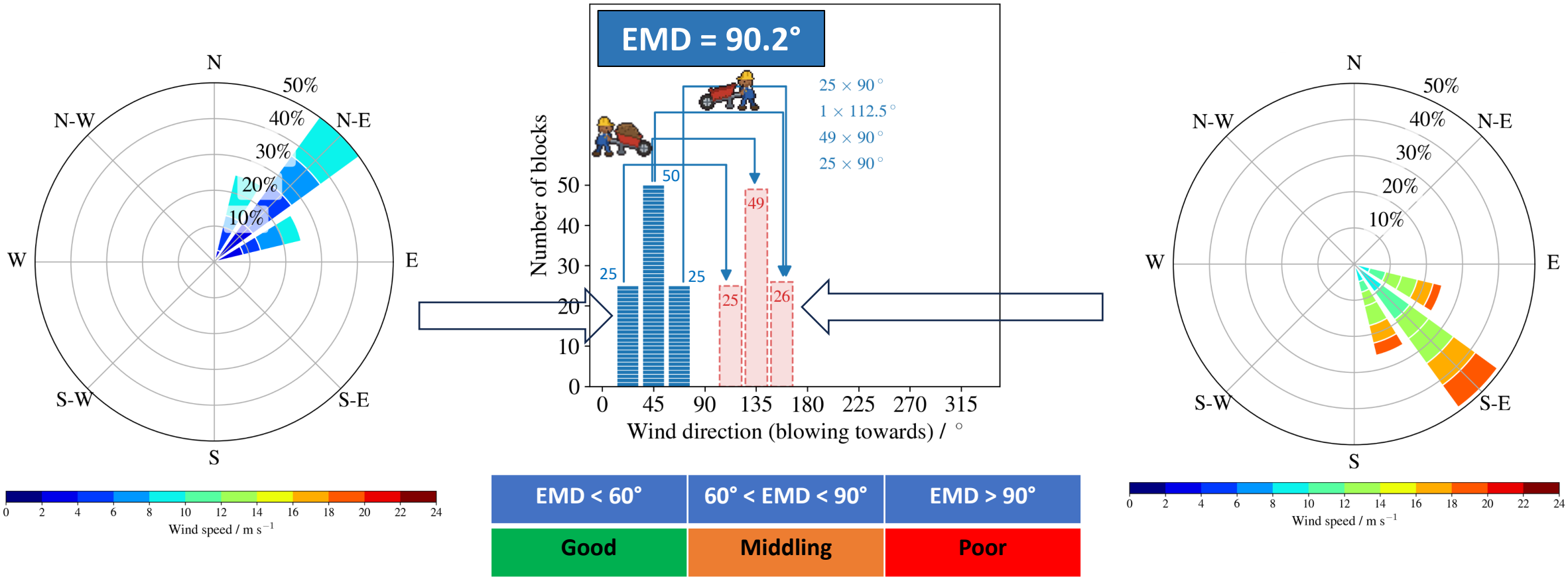


- Overall fit is reasonably good at all three sites. Broad validation of modelled winds?
- Filtering the top 5% of winds, the overall fit appears to gets visually better.
- Initial conclusion:

  Yes, the top 5% of winds seem correlated.

But can we be more quantitative?

Quantifying directional differences with the Earth Mover's Distance metric



- The **Earth Mover's Distance** measures the minimum number of steps to convert between (normalised) wind orientation histograms
- Thus, the EMD provides a quantification of the 'similarity' between wind rose orientations (but not magnitudes)

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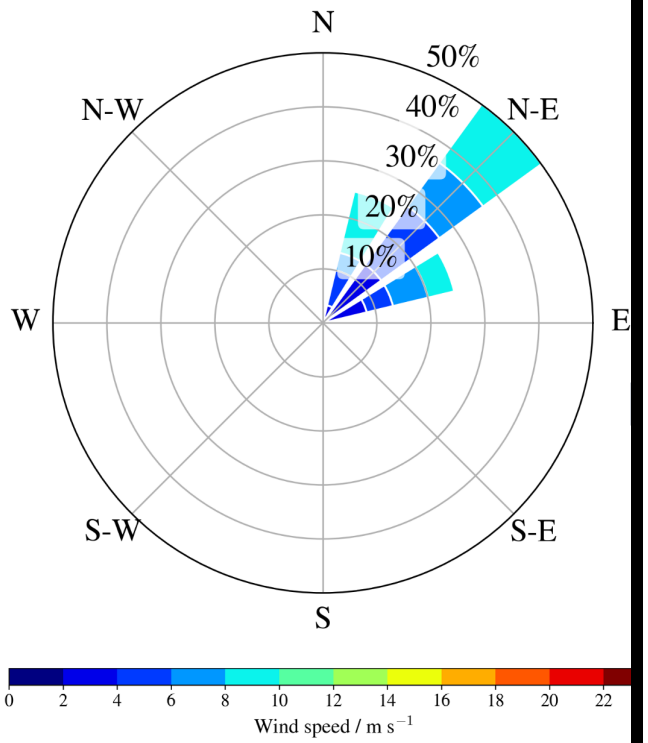
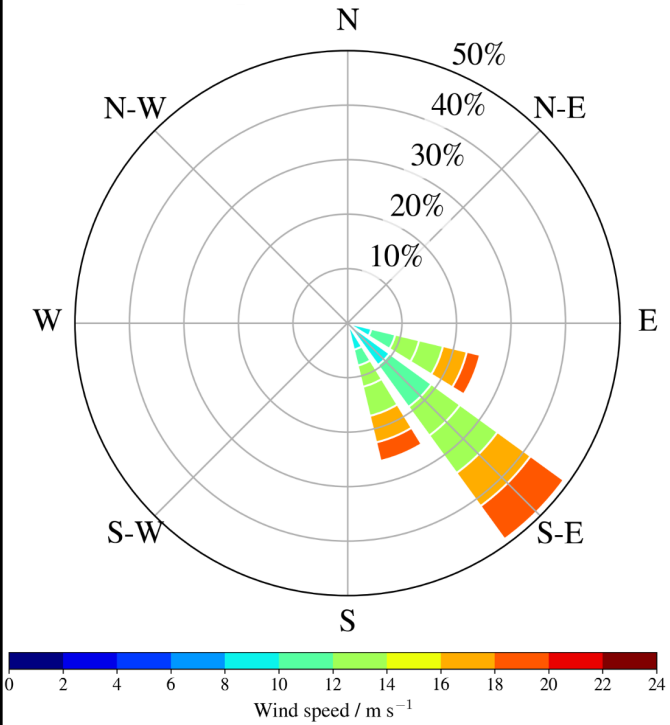


EMD is a measure of how much effort you need to expend to get from the left plot

to the right plot

The smaller the angular value, the better the correlation

We want small numbers.



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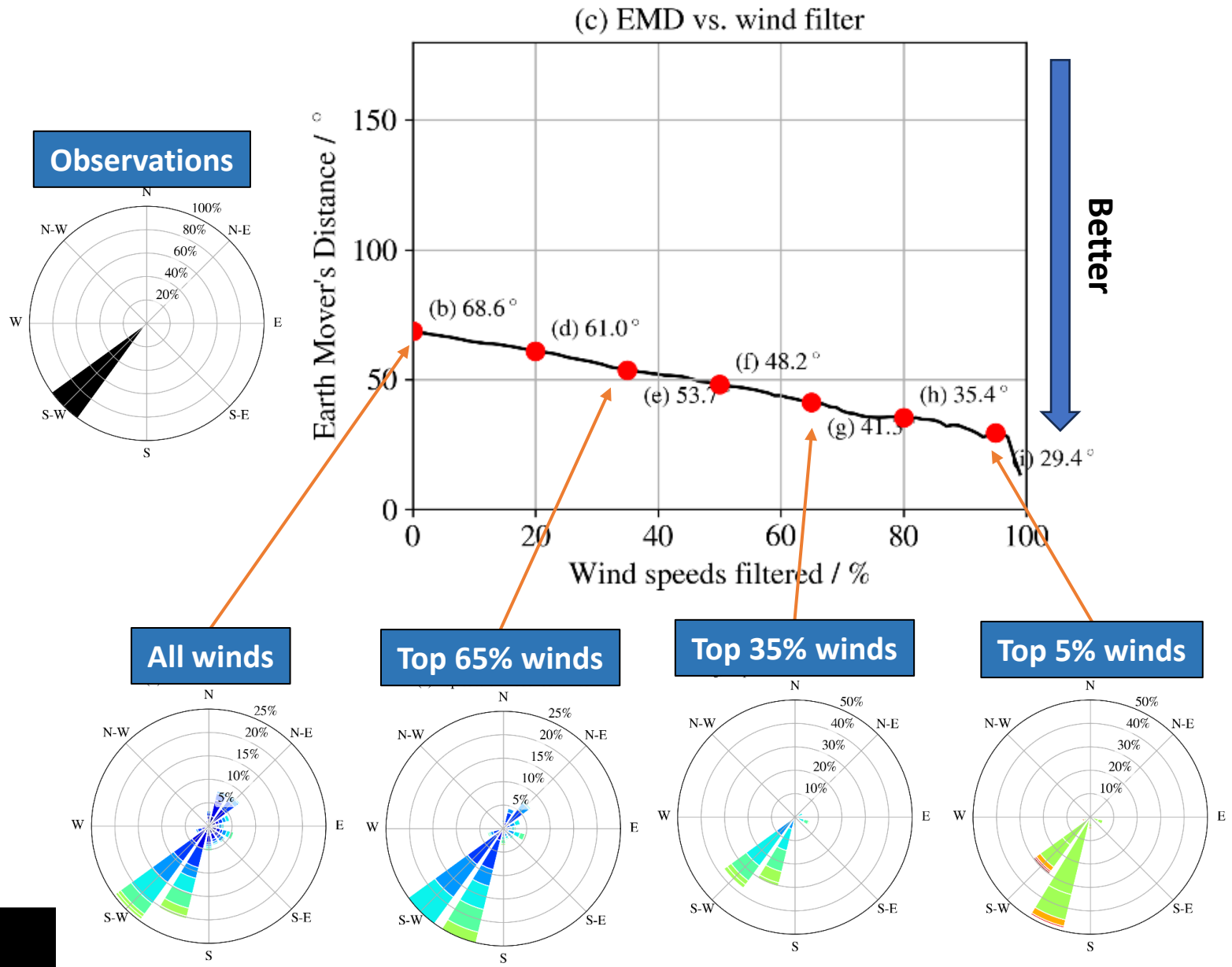
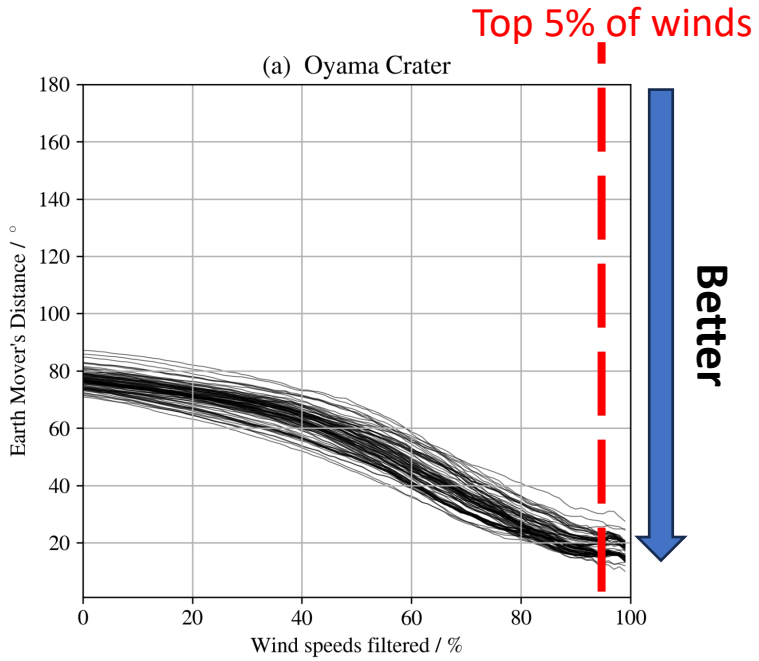
Applying the EMD: Ares Vallis



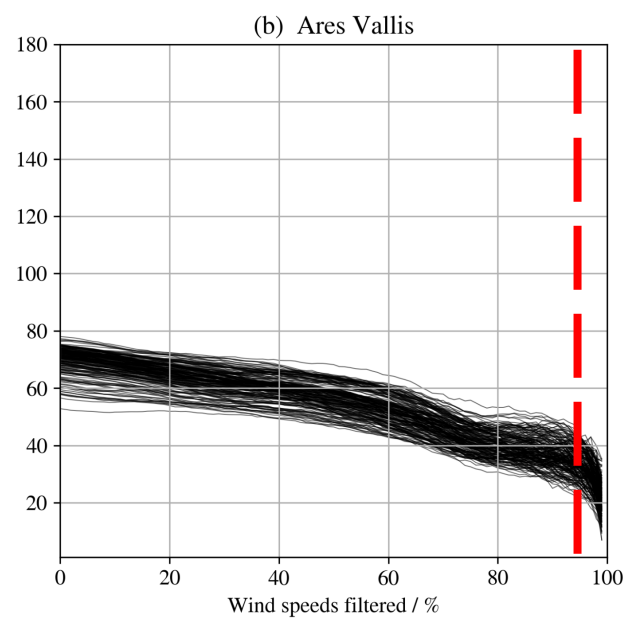
- EMD plot quantifies correlation as function of % of wind speeds.
- The lower the EMD the better the correlation
- As wind speeds increase, there is better correlation with orientation

EMD variation with wind filtering: all sites

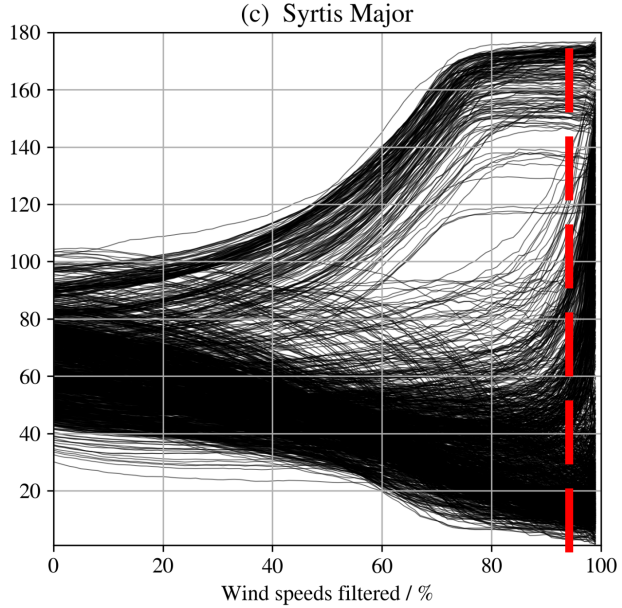
Oyama crater



Ares Vallis

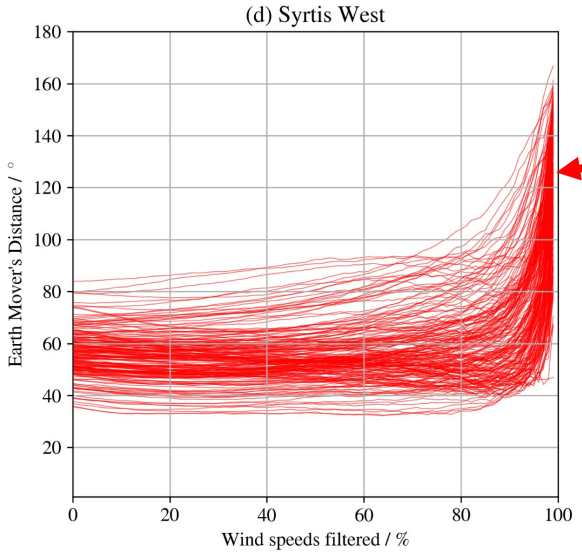


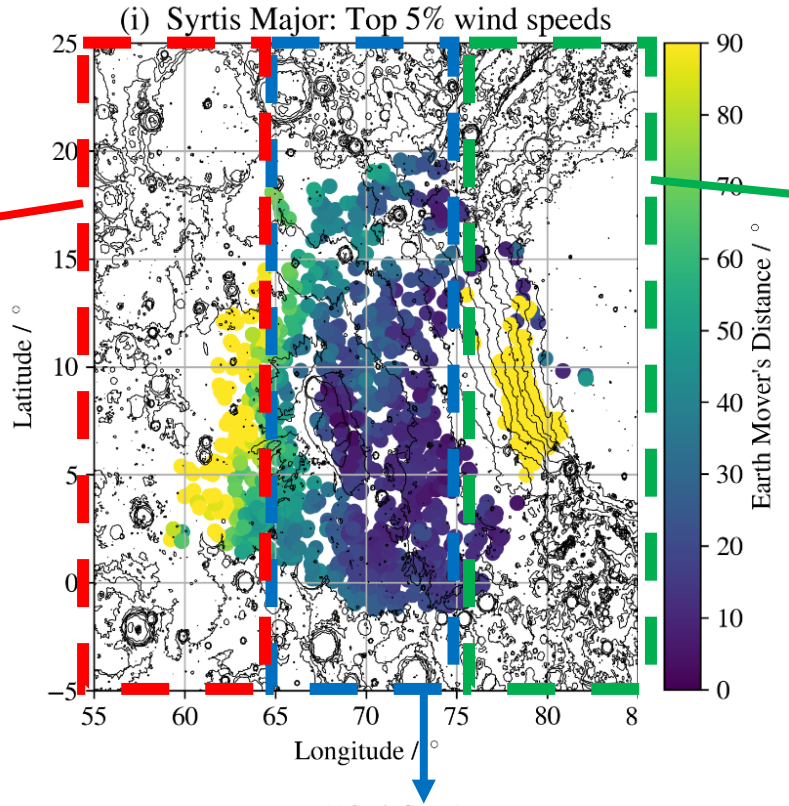
Syrtis Major

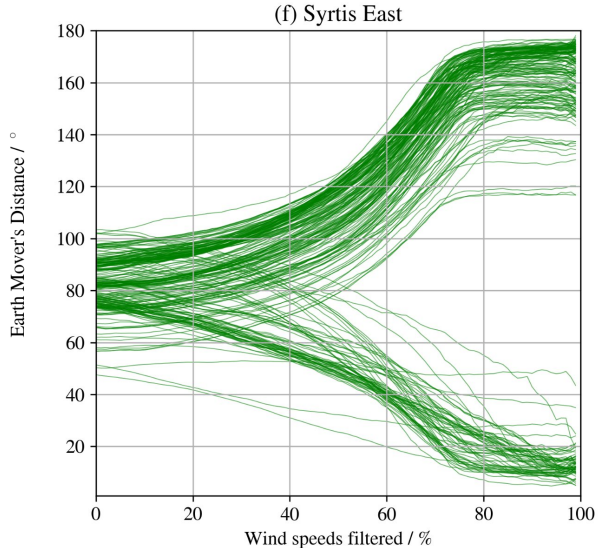


- In Oyama crater and Ares Vallis the EMD value decreases (better correlation) as weaker winds are filtered out, in line with expectations.
- Fastest winds are clearly important, but there is no obvious cutoff value.
- In Syrtis Major, the behaviour is completely different…

Deconstructing Syrtis

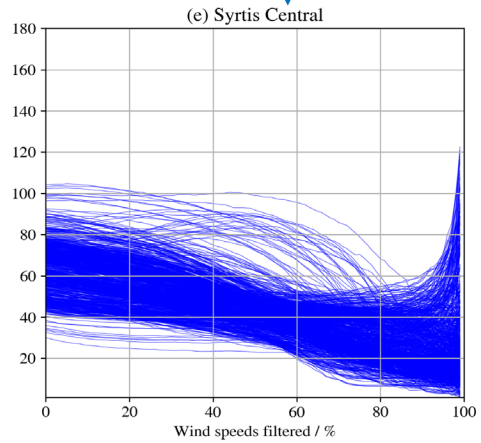






(Upslope winds)

West: correlation better with the weaker (prevailing) winds…



Central: Correlation better with stronger winds

East: mixture of up/downslope winds along the rim of Isidis.
Wind streaks are only in the downslope direction leading to a poor initial EMD value (~90°).
As the filtering selects for faster model winds, only the (stronger) upslope winds are selected, which are diametrically opposite to the observed wind streaks.
Wind streaks form downslope even though the strongest winds are upslope.

Conclusions

- Are wind streaks correlated with the strongest winds? **Sometimes yes, sometimes no.**

Our topographically simple cases showed good correlation of orientation-velocity

Our topographically complex case showed a wide range of correlation

- There is no obvious ‘threshold’ in correlation of wind speed (even in the best case).
- Local-scale analysis is crucial. Mesoscale modelling can help with this.
- The Earth Mover’s Distance is a very useful metric to quantify the differences between wind direction histograms.

If you are interested in local-scale winds: manish.patel@open.ac.uk