

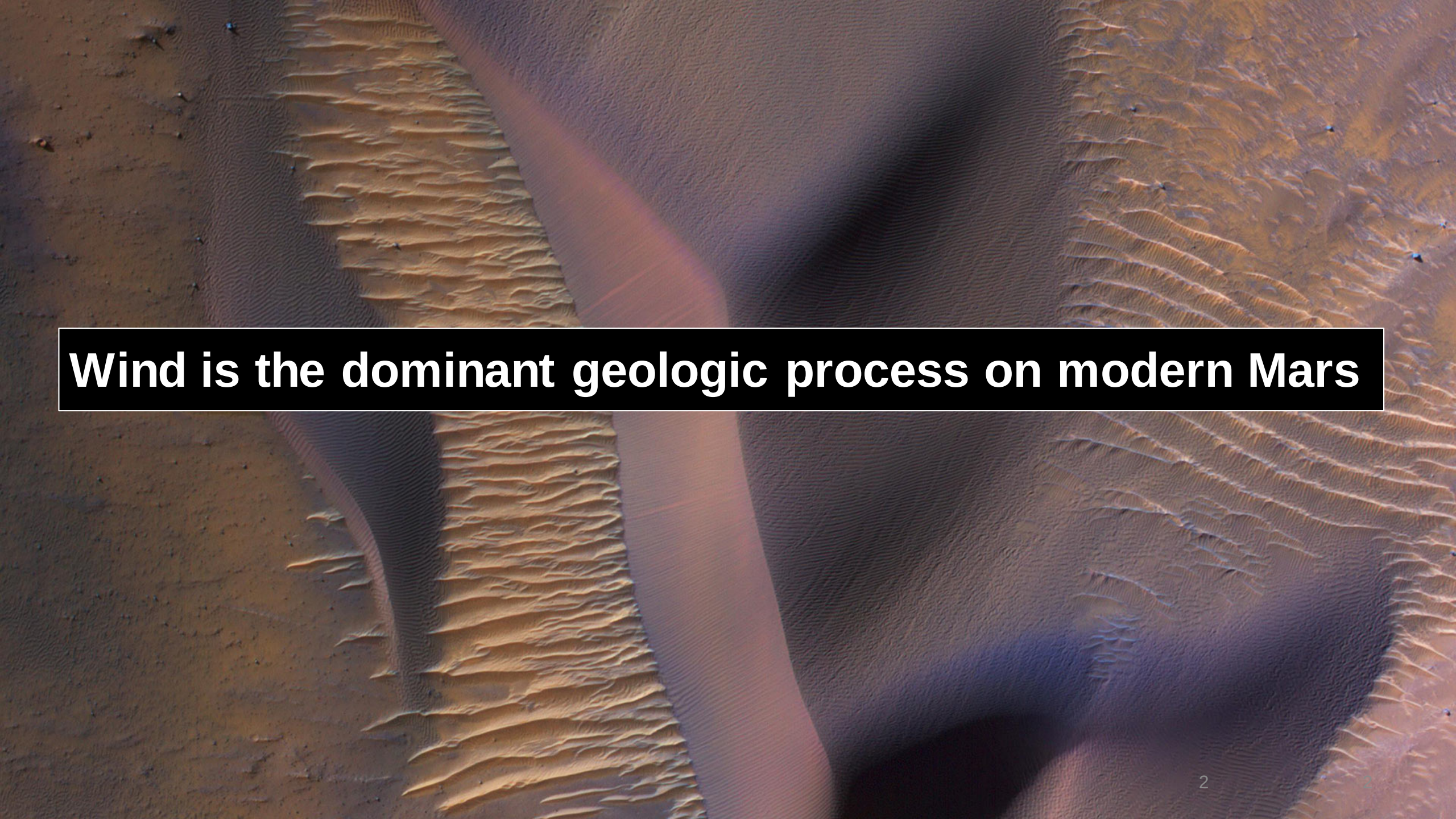


Wind, sand, and dust on Mars: **Key knowledge gaps related to the surface-atmosphere interface**

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UCLA

An aerial photograph of a Martian landscape featuring large, undulating sand dunes. The dunes are characterized by fine, parallel ridges and troughs, creating a textured appearance. The color of the sand is a reddish-brown, typical of Mars. A central, darker, shadowed area separates two main dune fields. The lighting creates strong shadows, emphasizing the three-dimensional structure of the dunes.

Wind is the dominant geologic process on modern Mars

Why study wind, sand, and dust?

Interactions between wind and surface leave behind evidence that tells us about modern climate conditions, but also the climate of ancient Mars

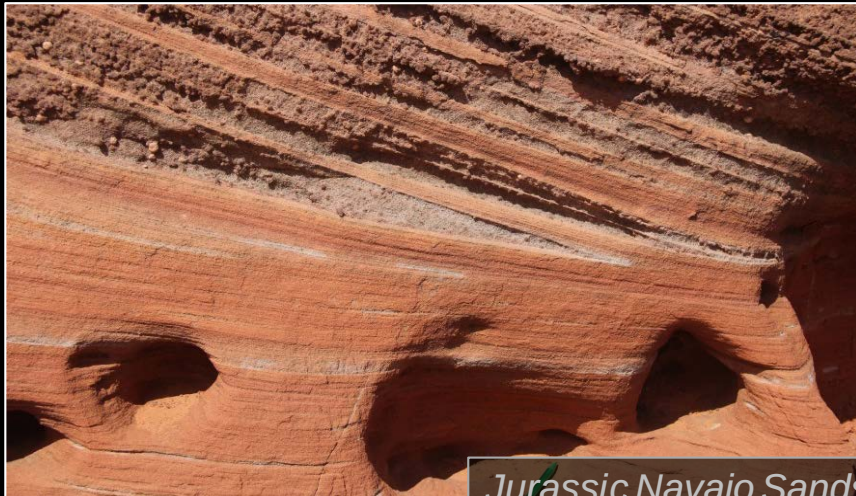
Earth

Modern



White Sands Dune Field

Ancient



Jurassic Navajo Sandstone

Mars



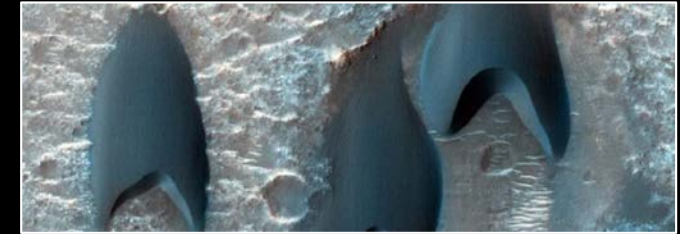
Namib Dune – Gale crater



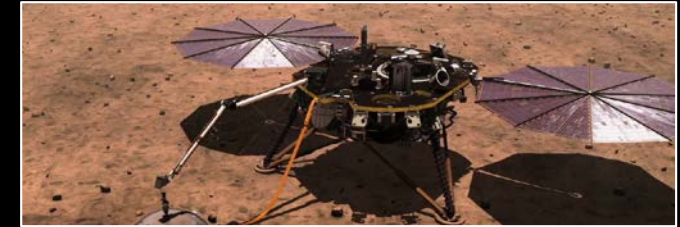
Stimson Fm – Gale crater

How do we study wind and sand transport on Mars?

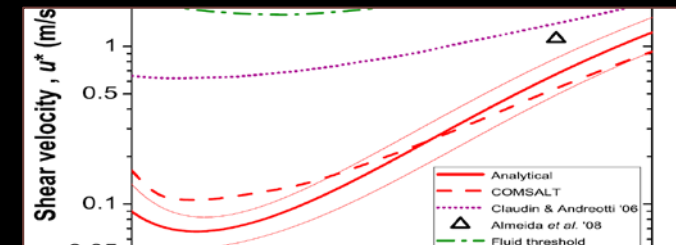
A) Geomorphic observation



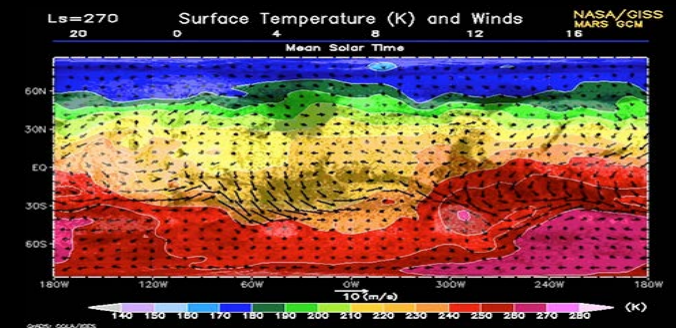
B) Direct measurement



C) Equations of motion



D) Atmospheric modeling



A) Geomorphic observation

(Earth)

Wind streaks



Ventifacts



Yardangs



Aeolian bedforms



Barchan dunes

Megaripples



Photo credits: Julie Laity, Sergey Shandin and Stanislav Sedov, GoogleEarth

Yizhaq et al., (2008)

A) Geomorphic observation

(Mars)

Wind streaks



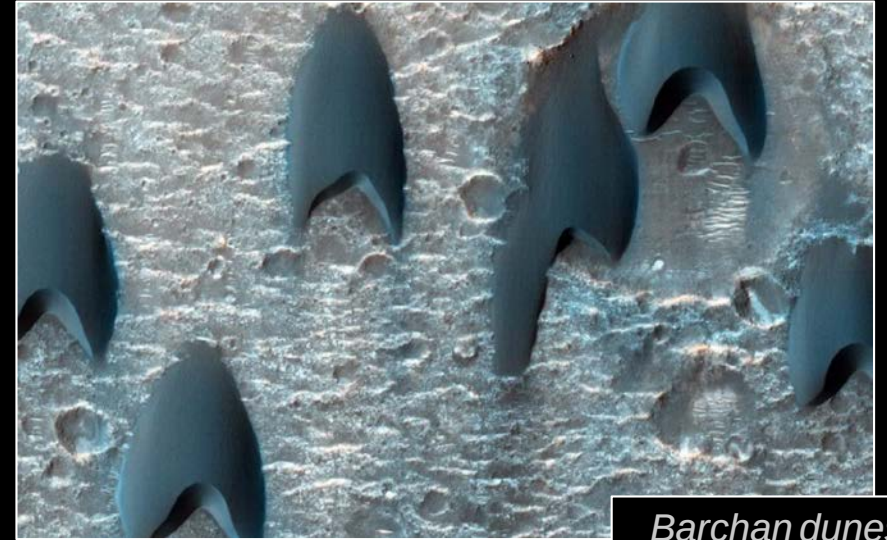
Ventifacts



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Barchan dunes

Transverse aeolian ridges



Photos credit: HiRISE – NASA/JPL/LPL/UofA

A) Geomorphic observation

(Mars)

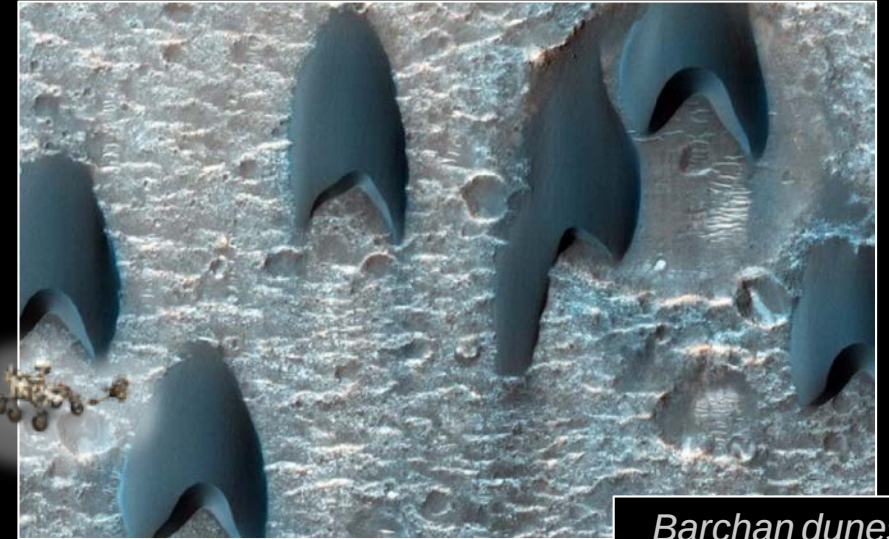
Wind streaks



Yardangs



Aeolian bedforms



Barchan dunes

Ventifacts



Transverse aeolian ridges



50 m

Photos credit: HiRISE – NASA/JPL/LPL/UofA

B) Direct measurement

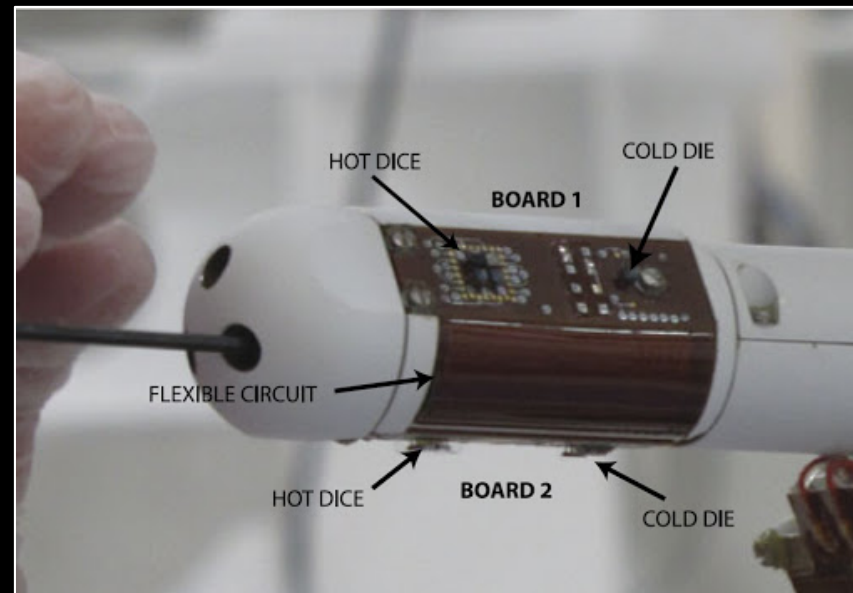
High frequency wind measurements characterize turbulence and gusts

Averaged and long term measurements describe typical conditions and seasonal change

Critical to understanding:

- Sand transport
- Dust lofting
- Atmospheric circulation
- Model validation
- Mission planning/risk mitigation

*Portable weather station
used in field studies -
NovaLynx*



*REMS boom on MSL
rover Curiosity –
NASA/JPL*



Phoenix

Viking 2



Viking 1



Pathfinder (Sojourner)



Mars 2020 (Perseverance)



InSight



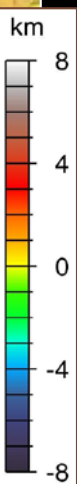
MER (Opportunity)

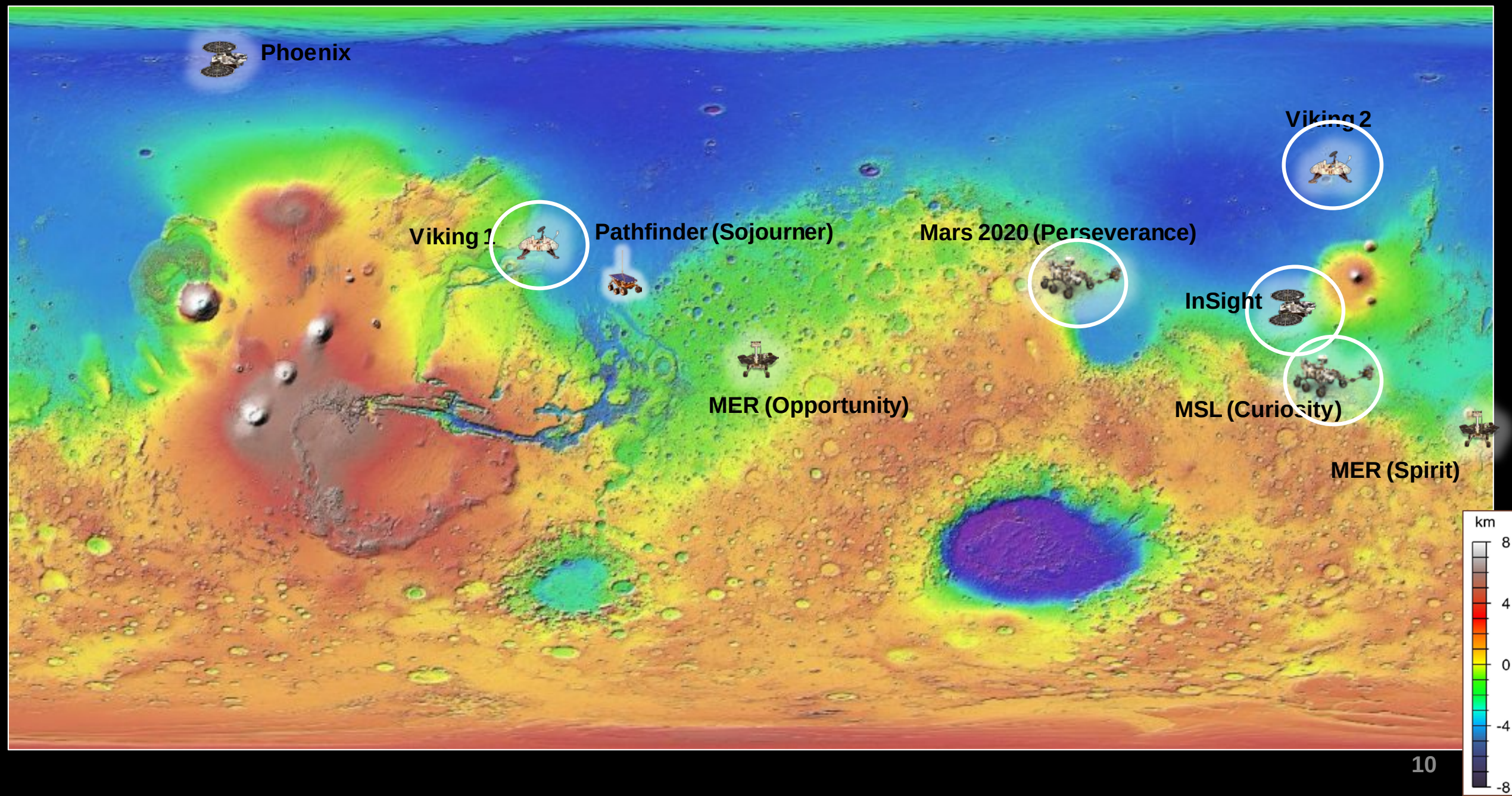


MSL (Curiosity)



MER (Spirit)

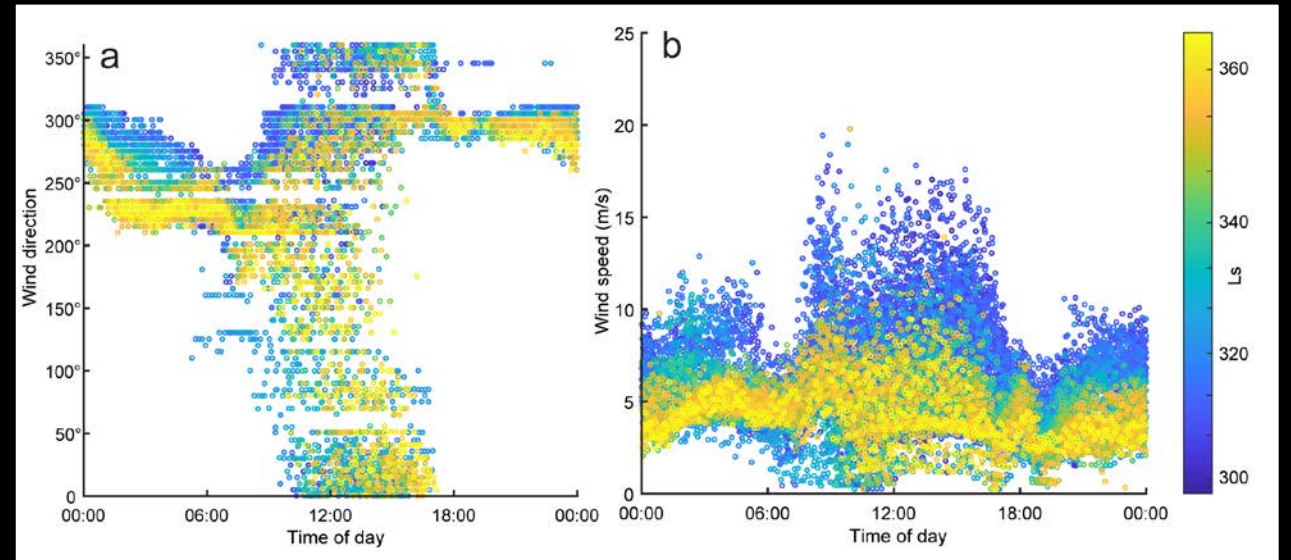
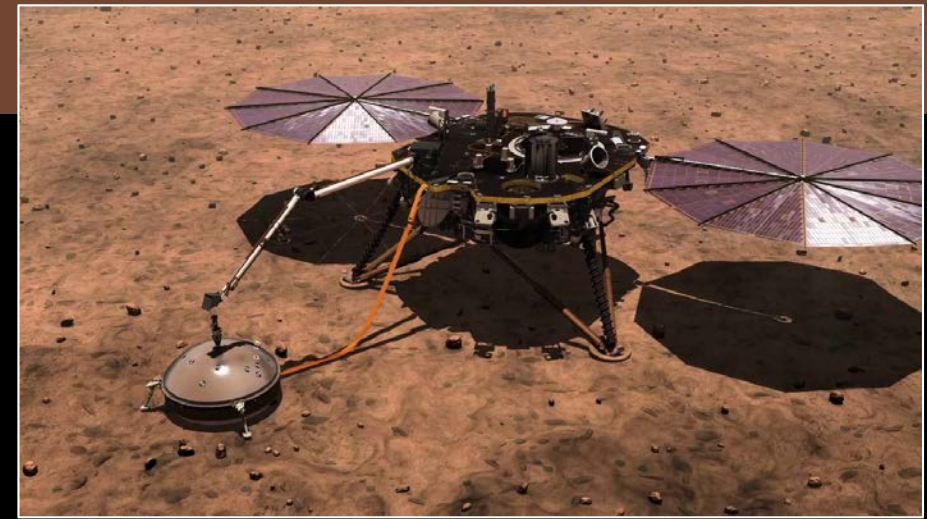




B) Direct measurement

Missions have provided some data from the surface

Not enough to fully understand the atmosphere



Day & Rebolledo, 2019; Banfield et al., 2020

Key Knowledge Gap #1:
Measurements of the wind near the surface and high in the atmosphere

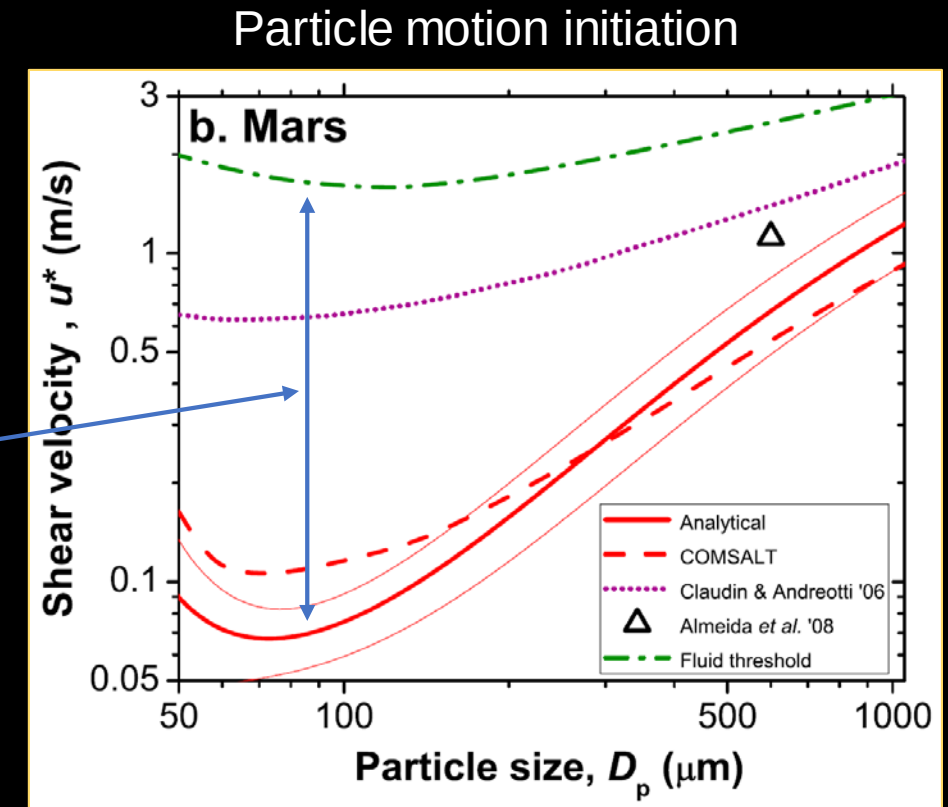
C) Equations of motion

Empirical equations on Earth work well to describe particle motion initiation

Theory has been adapted to Mars and includes larger difference between starting and continuing motion (hysteresis)

MSL observations have shown that sand moves below the theoretical minimum wind speed

Hysteresis



Kok (2010)

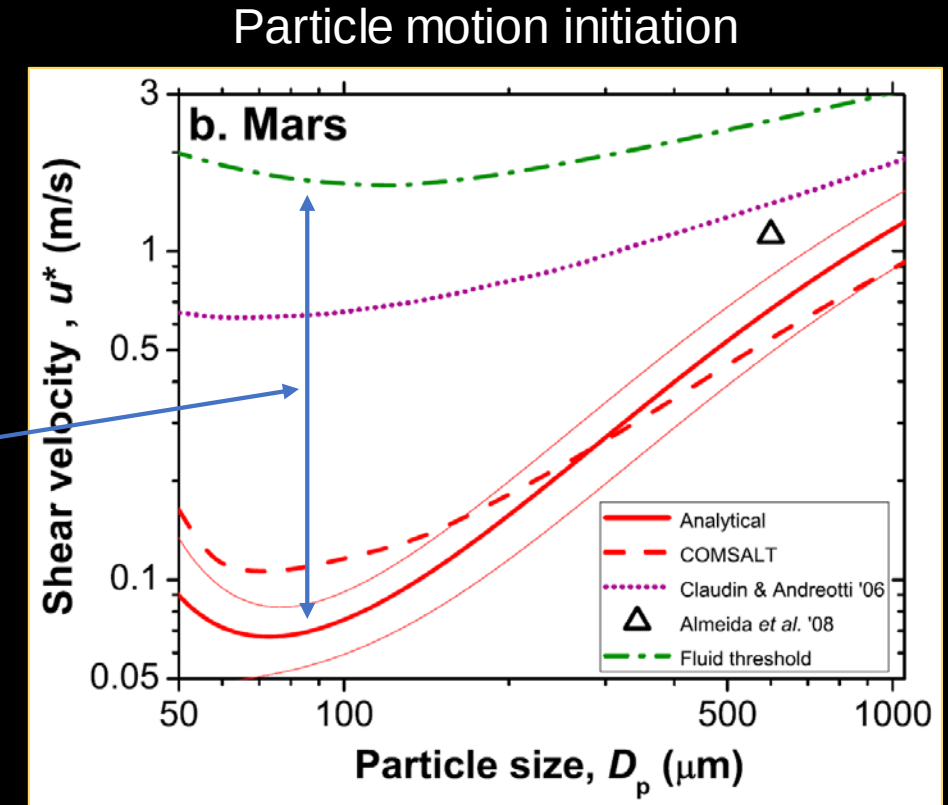
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Key Knowledge Gap #2:

Equations governing the motion initiation of sand and dust

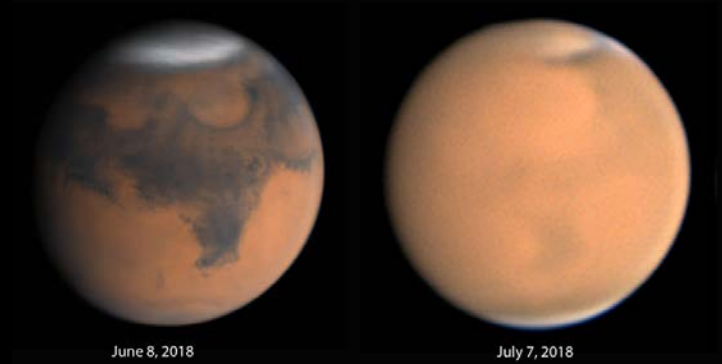
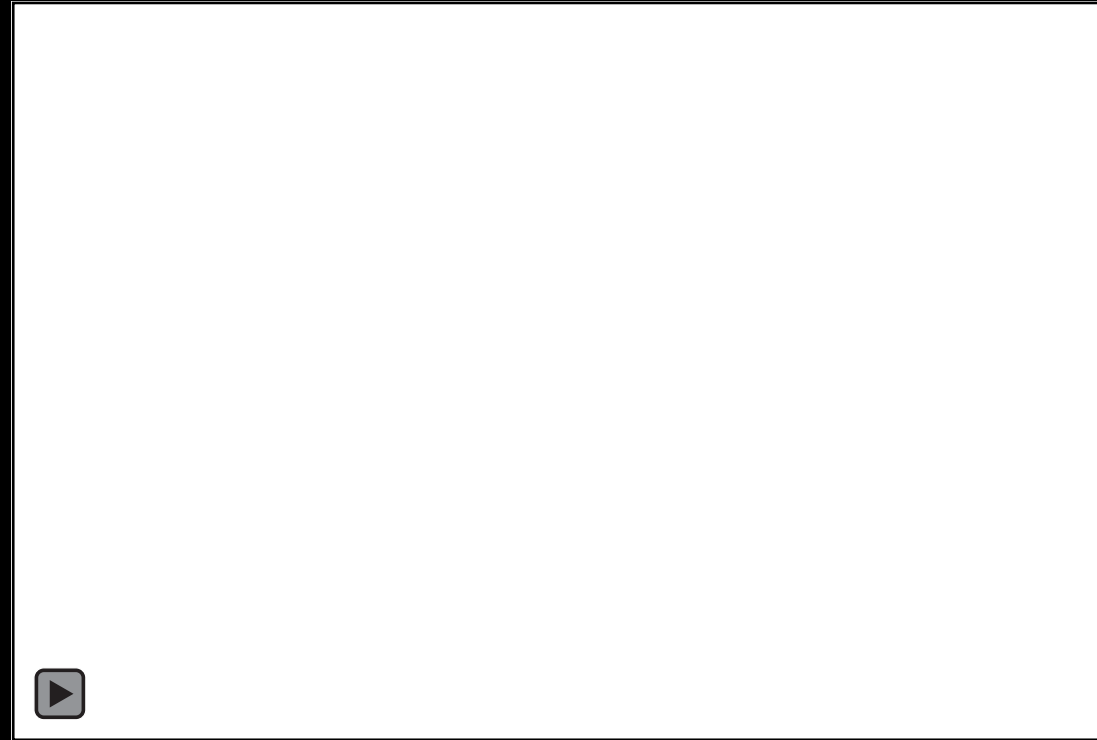
D) Atmospheric modeling

Global circulation and climate models provide a large scale picture of the surface-atmosphere interactions

Multiple, equally valid models exist and contradict one another

Many assumptions in models still need to be validated with measurements

Large disparity between 5 measurements of surface winds and global circulation



D) Atmospheric modeling

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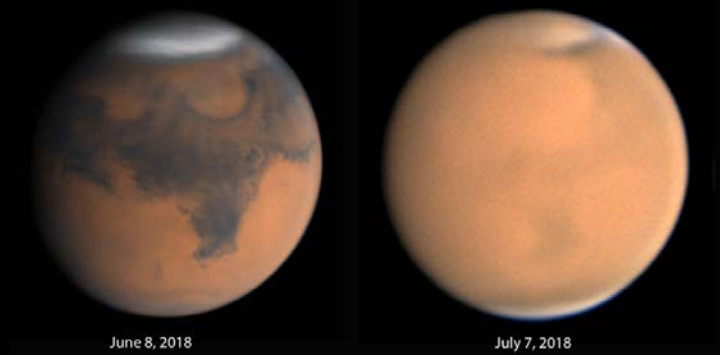
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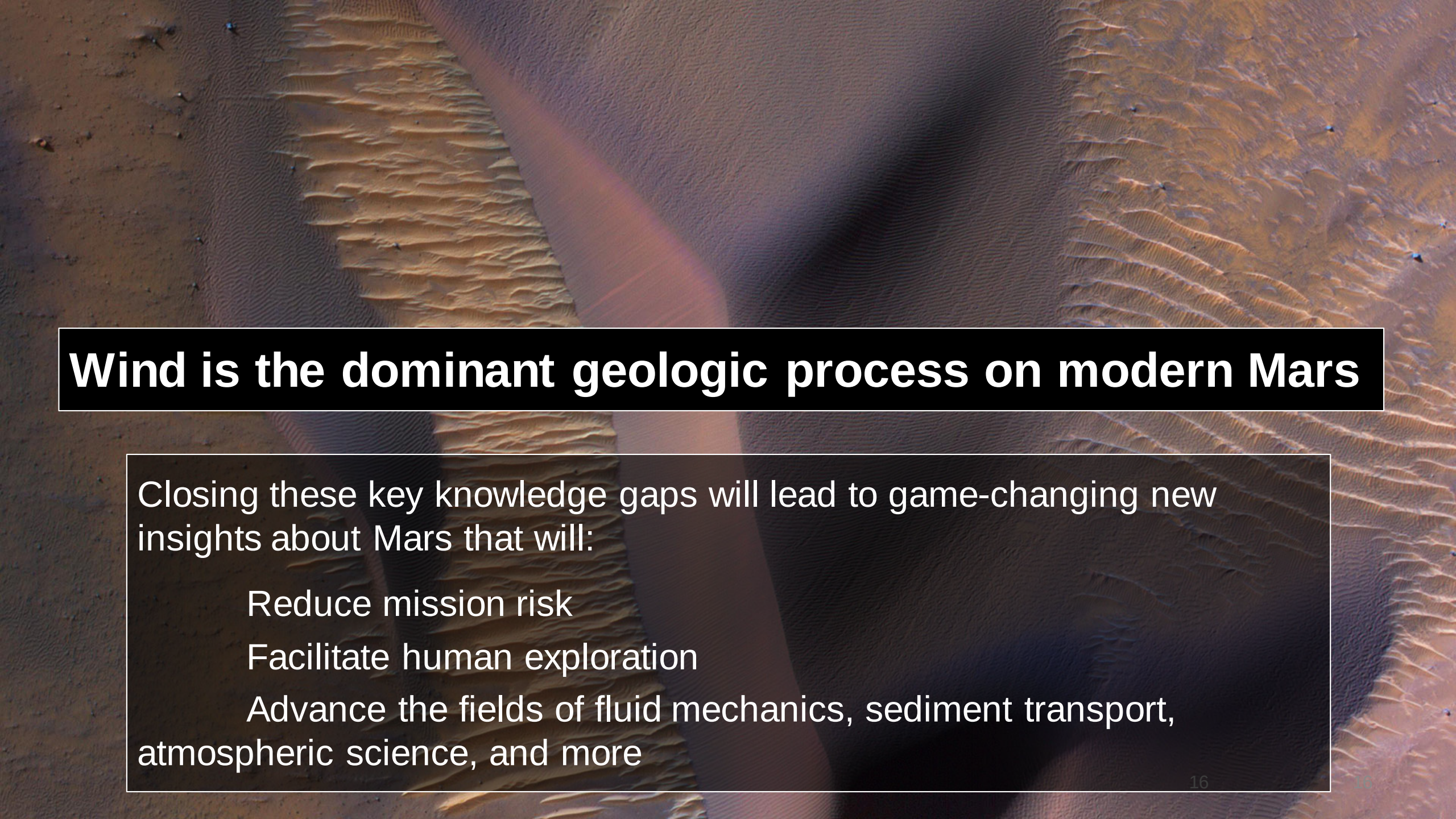
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Large disparity between 5 measurements of surface winds and global circulation

Key Knowledge Gap #3:

Models that accurately capture and predict Martian climate and storms



An aerial photograph of sand dunes on Mars, showing intricate ripple patterns and shadows that emphasize the three-dimensional structure of the terrain. The dunes are a reddish-brown color, typical of the Martian surface.

Wind is the dominant geologic process on modern Mars

Closing these key knowledge gaps will lead to game-changing new insights about Mars that will:

- Reduce mission risk

- Facilitate human exploration

- Advance the fields of fluid mechanics, sediment transport, atmospheric science, and more

Closing the gaps: Game-changing observations for the next decade

Key Knowledge Gaps

1) Measurements of the wind near the surface and high in the atmosphere

2) Equations governing the motion initiation of sand and dust

3) Models that accurately capture and predict Martian climate and storms

Needed observations

Wind and meteorological measurements on every mission to increase the diversity and timescale of data

Dedicated aeolian observations in regions of active sand saltation and dust lofting

Global wind measurements taken from orbit and surface measurements to validate model assumptions

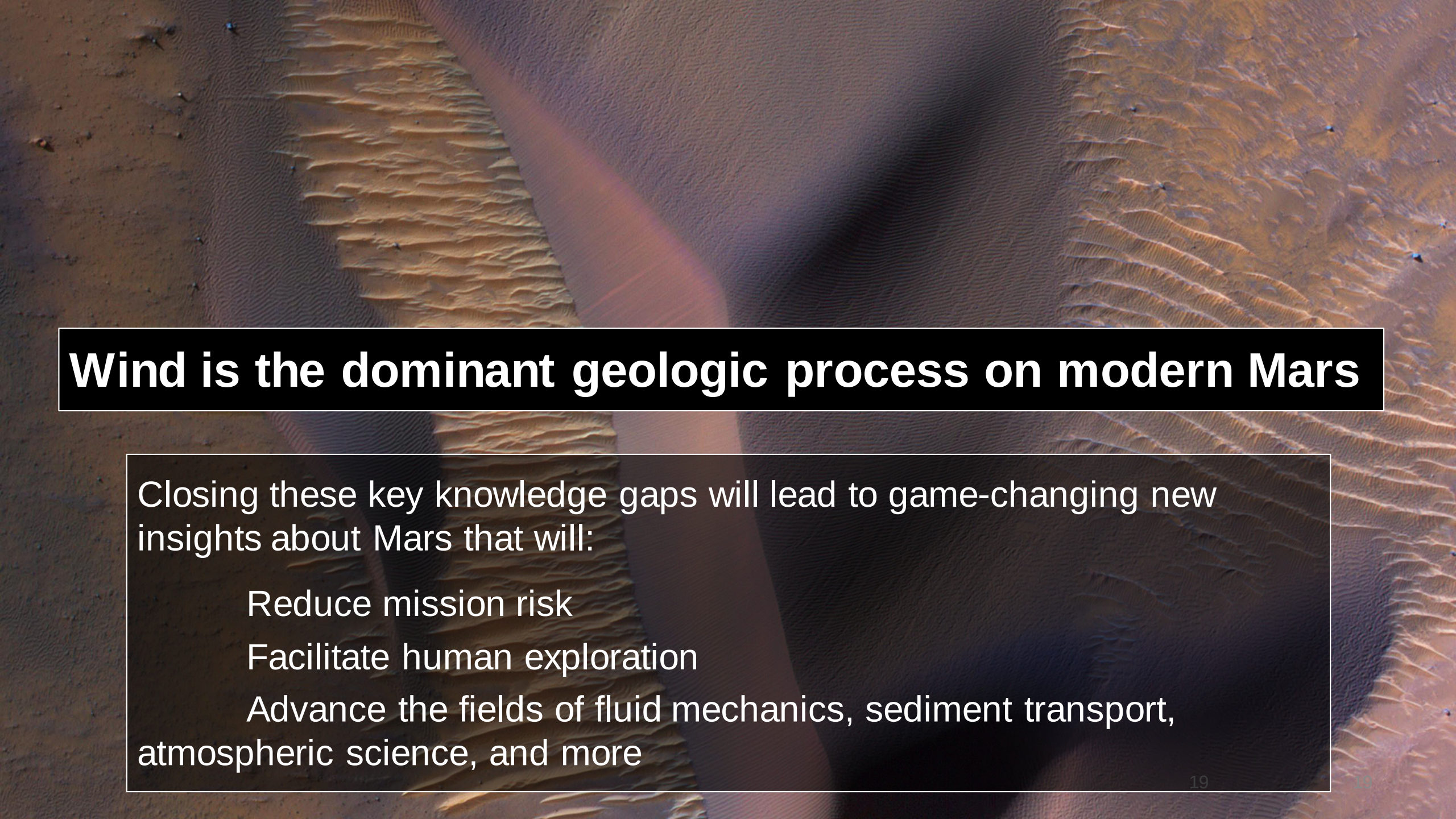
For more information, see relevant white papers and references therein:

Diniega et al., “A Critical Gap: In situ Measurements of Planetary Surface-Atmosphere Interactions Beyond Earth”,
https://mepag.jpl.nasa.gov/reports/decadal2023-2032/CriticalGapWP_Diniega_submitted.pdf

Guzewich et al., “The Mars Atmospheric and Polar Science Mission”,
<https://mepag.jpl.nasa.gov/reports/decadal2023-2032/GuzewichScottD.pdf>

Newman et al., “Toward More Realistic Simulation and Prediction of Dust Storms on Mars”, <https://mepag.jpl.nasa.gov/reports/decadal2023-2032/DustStormsWhitePaper.pdf>

Dundas et al., “Current Activity on the Martian Surface: A Key Subject for Future Exploration”, https://mepag.jpl.nasa.gov/reports/decadal2023-2032/Mars_activity_white_paper_final.pdf

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