Super-rotation and the 2018 Mars Global Dust Storm

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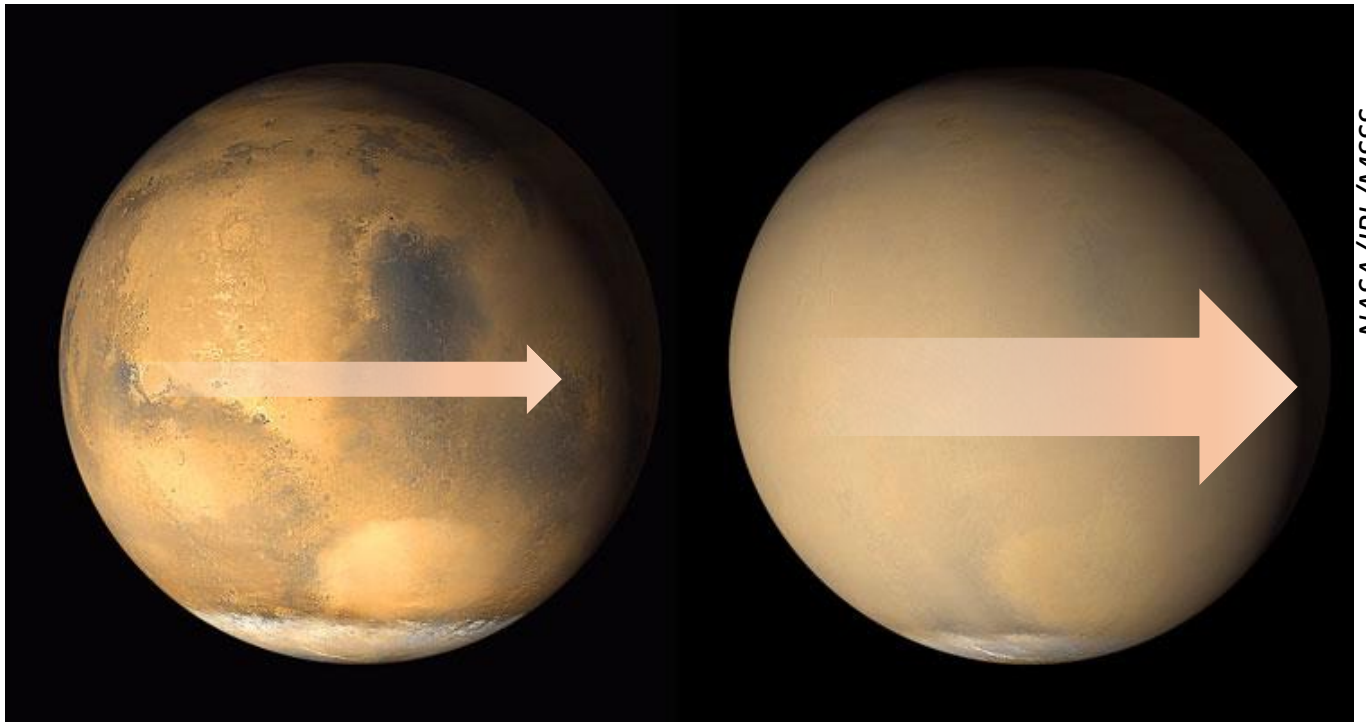
- Some of the most intriguing dust-driven phenomena on Mars are **Global Dust Storms** (GDS), which form episodically and can encircle the planet in a shroud of dust for several months.
- It is currently not well understood why these storms form from smaller pre-cursor storms in some Martian years, but not in others.



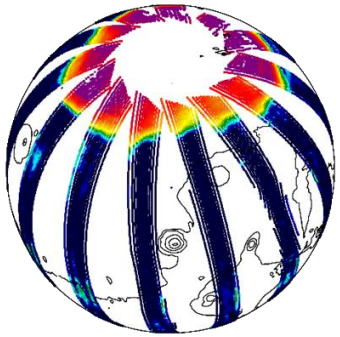
NASA/JPL/MSSS

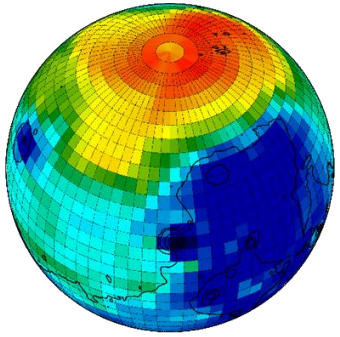
Non-dusty | Weak winds **Dusty | Strong winds**

- Dust-driven heating of the Martian atmosphere can lead to **super-rotation**, which is an excess of angular momentum as compared to an atmosphere in pure solid-body rotation. This results in strengthened prograde winds in the tropics.
- The presence of a super-rotating jet may have an impact on GDS formation by enabling the rapid transport of dust across the planet.

2018 Mars Global Dust Storm (GDS) & Data Assimilation

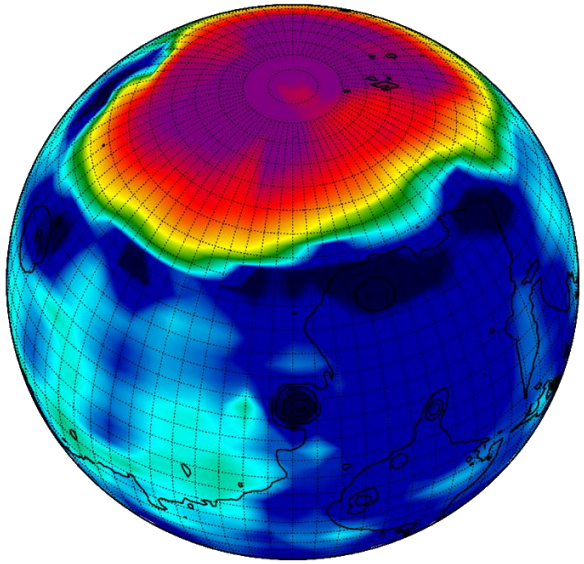
Observations





Model

Assimilation



Global super-rotation index S:

$$S = \frac{\iiint \rho u a \cos\phi \, dV}{\iiint \rho \Omega a^2 \cos^2\phi \, dV}$$

Solid body angular momentum

Atmosphere-only angular momentum

Local super-rotation index s:

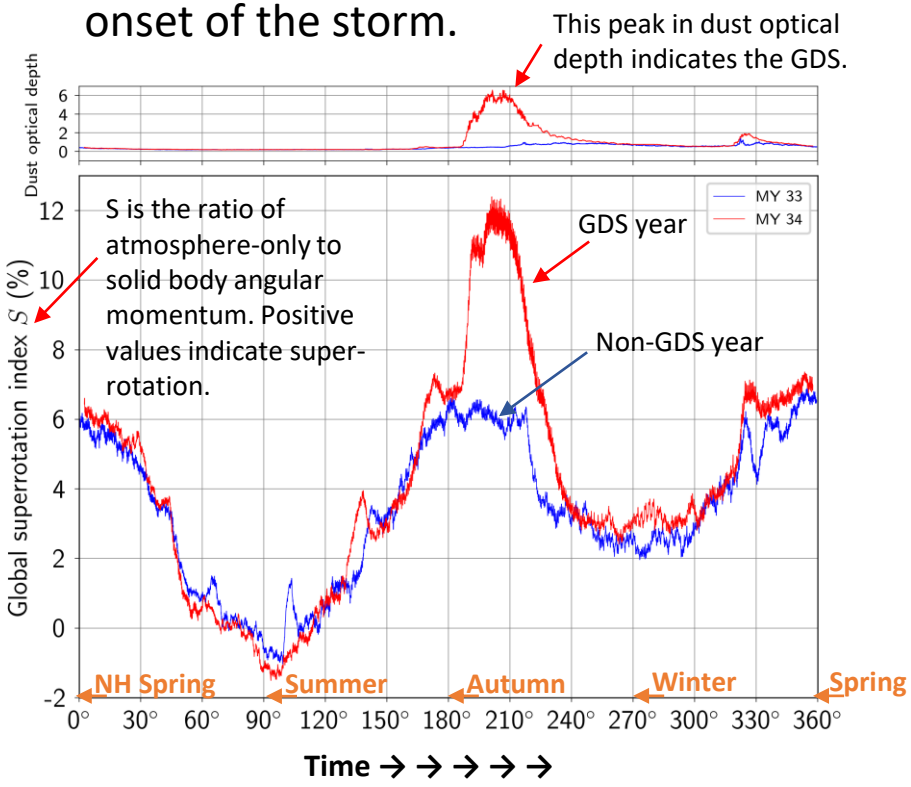
$$s = \bar{m}/\Omega a^2 - 1$$

Zonal mean angular momentum

- We used the Open University Mars climate model augmented with data assimilation to study super-rotation during the 2018 Global Dust Storm. Satellite measurements of temperature and dust by the Mars Reconnaissance Orbiter and ExoMars Trace Gas Orbiter were used to constrain the model field evolution.
- Global and local indices of super-rotation were used to quantify the amount of super-rotation during different phases of the storm.

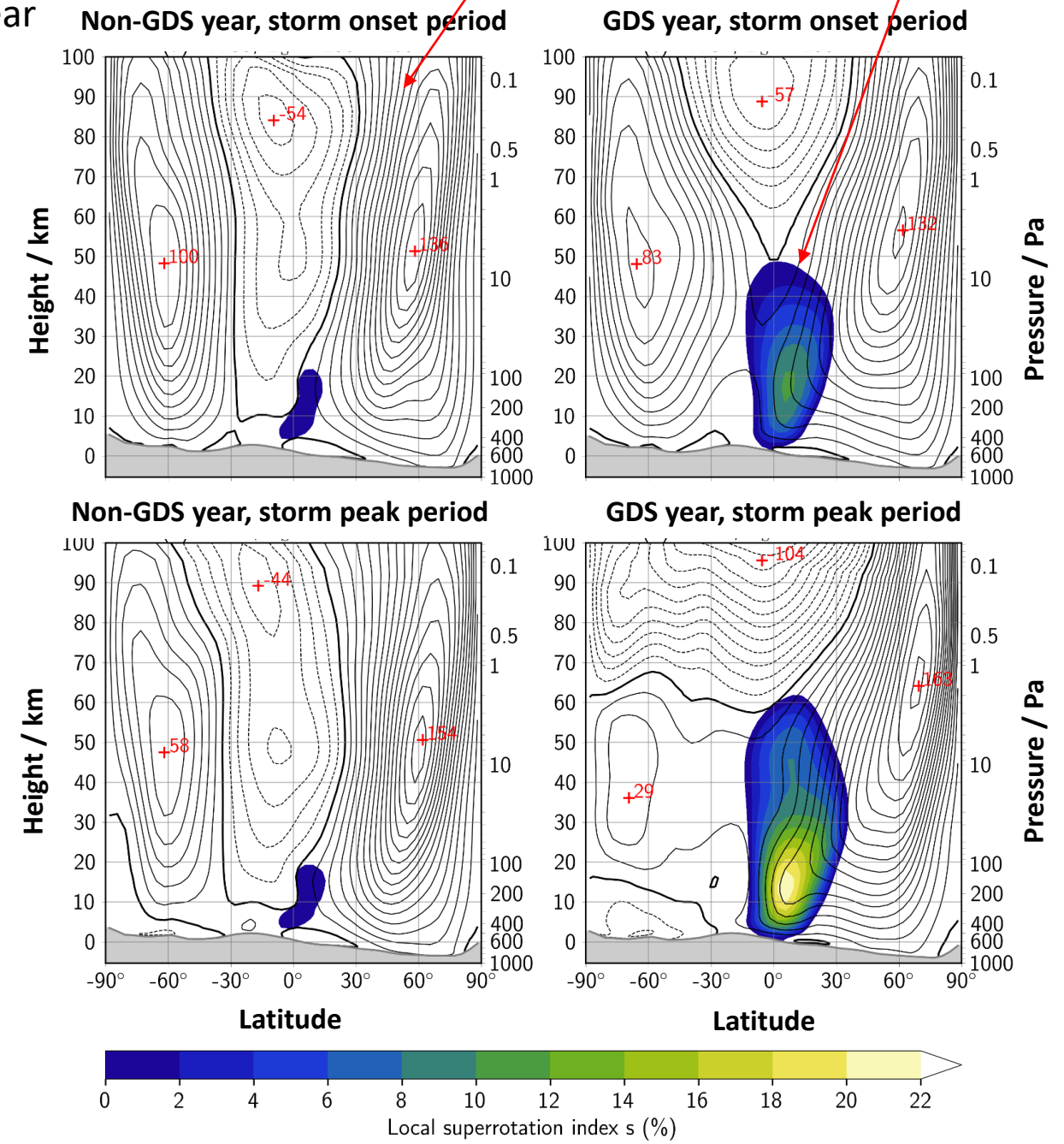
Results

- We compared the wind fields in the GDS year to a non-GDS year and found that super-rotation doubled during the GDS.
- The increased super-rotation was due to enhanced eastward winds dominating the tropical band up to 60 km.
- These enhanced winds facilitated the transport of dust across the globe at the onset of the storm.



Contours of zonal mean zonal wind. Solid lines are eastward winds, dashed lines are westward winds. Peak values in red.

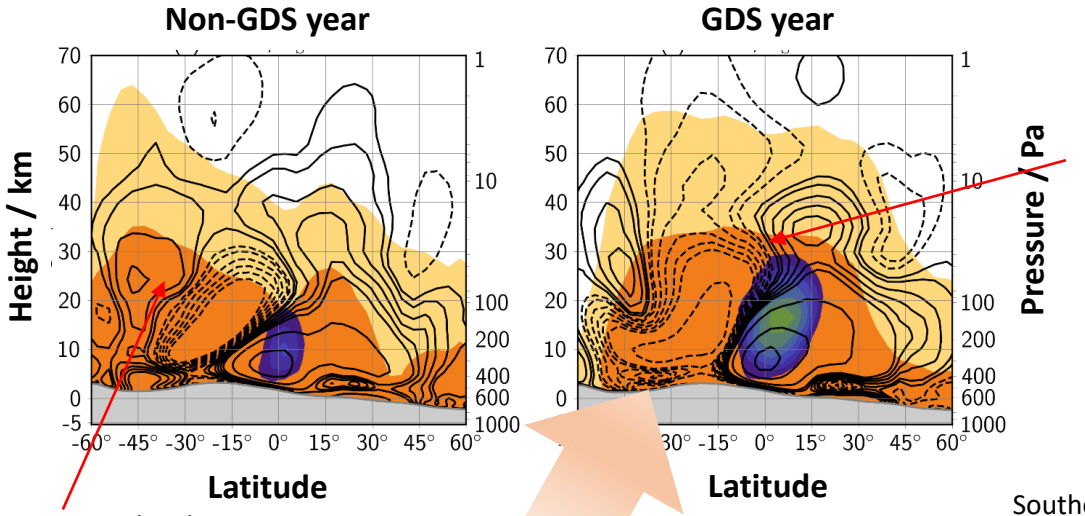
Filled contours are an index measuring local super-rotation.



- Super-rotation was enhanced in the GDS year even prior to storm onset. The cause was dust from the southern hemisphere encroaching into the tropics and altering the heating distribution.

- The resulting symmetrical circulation could efficiently transport dust vertically, which may have significantly contributed to the later rapid expansion of the storm.

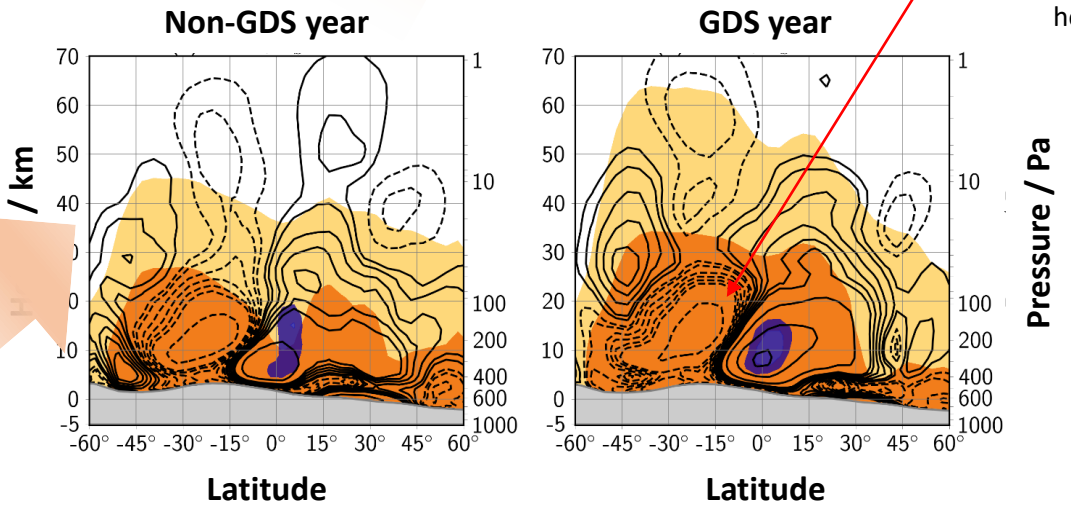
30 sols before storm onset



The circulation is more symmetric with a tropical upwelling branch closely aligned to the vertical. This enables efficient vertical transport.

Asymmetry in dust heating leads to a less symmetric circulation structure.

40 sols before storm onset

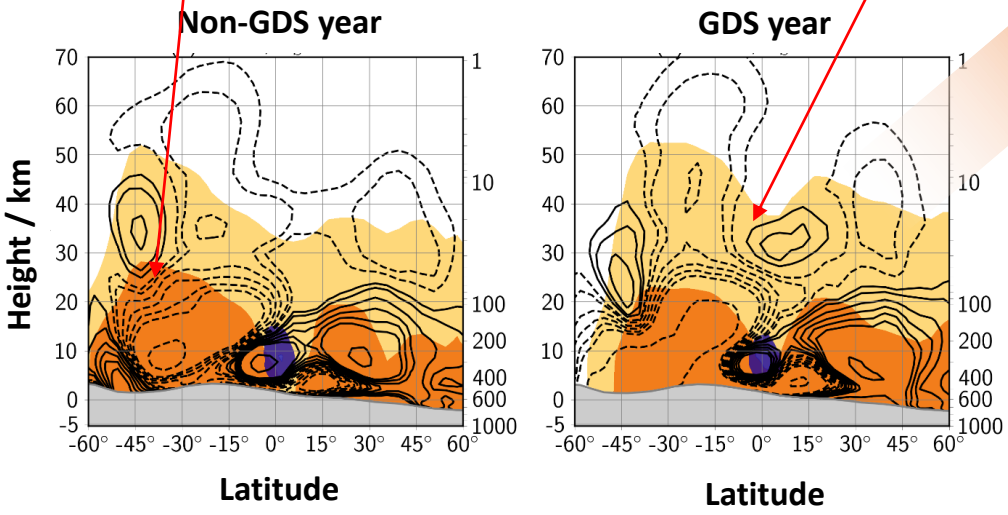


Southern hemisphere dust encroaches into the tropics, leading to latitudinally symmetric dust heating.

Contours of the meridional mass streamfunction. Solid / dashed contours represent clockwise / anti-clockwise motion.

Filled orange regions show the dust distribution.

50 sols before storm onset



Rajendran et al. “Enhanced Super-rotation Before and During the 2018 Martian Global Dust Storm”. Submitted to GRL. Preprint: https://doi.org/10.1002/essoar.10505331.2