The Non-local impact of Dust Storms on Martian Atmospheric Dynamics

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Objective: Impact of Martian Dust Storms on Dynamical Phenomena “At Distance” (Non-Local)

Case Studies:
1. 2001 Planet-Encircling Dust Storm (MY25, \( L_s \approx 186^\circ \))
2. 2003b Regional Dust Storm (MY26, \( L_s \approx 316^\circ \))

Dynamical Phenomena:

- Teconnection event
- Super-rotating westerly equatorial jet
- Polar vortex anomaly (and “sudden polar warming”)
2001 Planet-encircling Dust Storm

20 June 2001

31 July 2001

Mars Global Surveyor spacecraft MOC camera
Synopsis of the 2001 dust storm

Pre-storm events: baroclinic waves

$L_s \approx$ 169° → 180°
Explosive growth: strong updrafts

$L_s \sim 180^\circ \rightarrow 187^\circ$

LMD Mesoscale Model, 50 km horizontal resolution. Boundary conditions from data assimilation.

Synopsis of the 2001 dust storm
What happens at this time?
Questions

1. What is the origin of such a teleconnection event?

2. Is this a “teleconnection event”?

3. Does the advection towards the east of the dust lifted in Hesperia Planum cause the longitudinal displacement of surface pressure extrema?

4. Might there exist a ..?
Thermal tides

$L_s = 175.12$

$F_n$ values:
- 0.64
- 4.08
- 1.60
- 6.73
- 4.62

$L_s = 183.31$

$F_n$ values:
- 0.96
- 4.77
- 1.54
- 6.89
- 1.34

$L_s = 194.96$

$F_n$ values:
- 3.15
- 17.46
- 5.16
- 12.60
- 8.02
- 2.09
Teleconnection event

Amplitudes of diurnal + Kelvin components
Longitudinal anomalies of surface pressure:

Teleconnection event refers to weather anomalies being related to each other at large distances. (from L. Montabone)

Teleconnection atmosphere teleconnection pattern refers to climate anomalies being related to each other at large distances. (from Wikipedia)
Uniform and constant dust: \[ \tau = 0.4 \]

Longitudinal anomalies of surface pressure:

Amplitudes of diurnal + Kelvin components

Latitude = -18 degrees

Time

Pa
Teleconnection event

Model of the initial burst of dust in Hesperia Planum

Data assimilation

Gaussian dust storm

Ls = 183

Dust optical depth at reference pressure
Teleconnection event

Longitudinal anomalies of surface pressure:

Amplitudes of diurnal + Kelvin components

Latitude = -18 degrees

-14 Pa
Near surface wind stress

Data assimilation

Gaussian model
Hesperia Planum and the Tharsis region were connected at distance ("teleconnected") at short time scale via the thermal tides during the onset of the 2001 planet-encircling dust storm.

Such non-local effect developed in presence of localized atmospheric forcing (initial burst of dust in Hesperia Planum).

There was an effect of such a teleconnection on surface wind stress (therefore on potential dust lifting), but it can only partially explain the increase of surface wind stress in the reanalysis.

How important was eastward dust advection via atmospheric middle-altitude wind?

Can we explore the attribution problem (i.e. cause-effect relationship) for the initiation of secondary lifting in Tharsis? Effect of teleconnection vs effect of advection?
Work inspired by results in Lewis & Read, 2003

Zonal mean, daily averages
Local super-rotation index: Mars

\[ S = \frac{L_{atm}}{L_{rest}} - 1 > 0 \]
Local super-rotation index: Mars

\[ S = \frac{L_{atm}}{L_{rest}} - 1 > 0 \]

Autumn \( (L_S = 195^\circ - 225^\circ) \) in MY24 and MY25
Local super-rotation index: Earth

\[ S = \frac{L_{atm}}{L_{rest}} - 1 > 0 \]

ERA-Interim \( \bar{u} \) / m s\(^{-1}\) at 30 hPa
Westerly Equatorial Jet...on Earth

(Mars)

(Past)

Earth

2003b Regional Dust Storm: Impact on NH polar vortex

15 sols before

15 sols after
ありがとうございます。

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