High resolution general circulation model experiments of the Martian atmosphere

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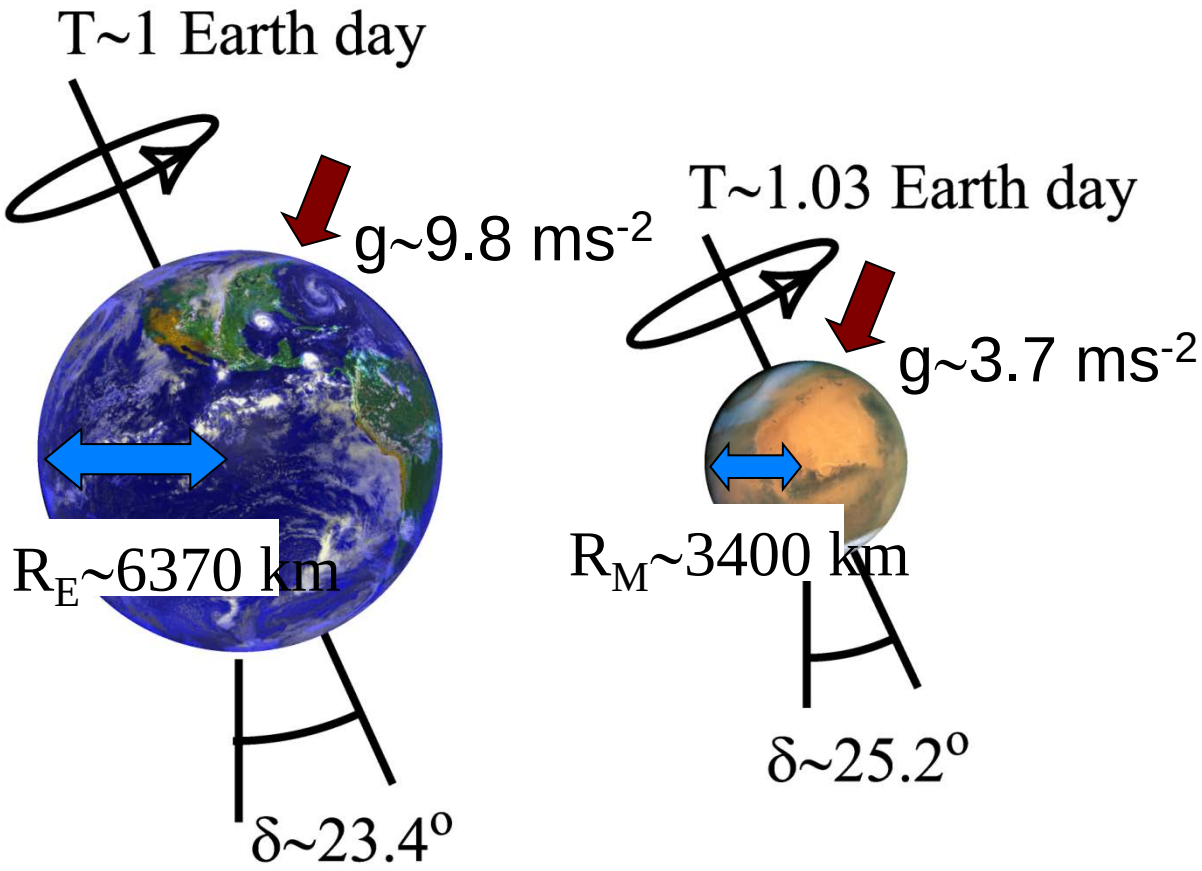
About Mars


T~1 Earth day
g~9.8 ms-2
RE~6370 km
δ~23.4º
T~1.03 Earth day
g~3.7 ms-2
RM~3400 km
δ~25.2º

Martian atmosphere / Martian surface environment

- Atmospheric major constituent
  - CO_2 > 95%
- Atmospheric mass
  - ~1/100 of Earth's atmospheric mass
    - Ps ~ 6-8 hPa
- Cold and dry surface environment
  - No liquid water on the surface
  - Averaged Ts ~220 K (-53 ℃)
  - Large diurnal variation
- Dust / dust storms
  - Atmosphere is strongly affected by
    - dust suspended in the atmosphere,
    - occurrence of dust storms.

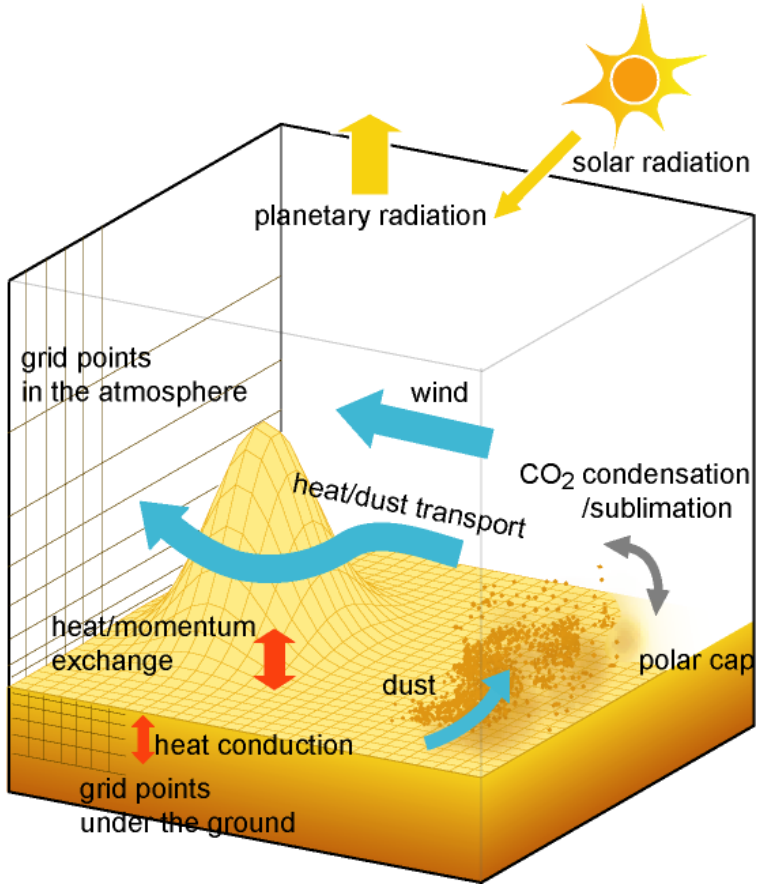
Fig. Mars observed by the Hubble space telescope

Fig. Martian surface observed by Mars Pathfinder

Purpose of this study

- We perform medium and high resolution ($\Delta x \sim 11$-90 km) experiments of Martian atmosphere by using a general circulation model (GCM)
  1. to survey the small and medium disturbances in the Martian atmosphere,
  2. to examine the effects of small and medium scale disturbances on dust lifting.

Model description



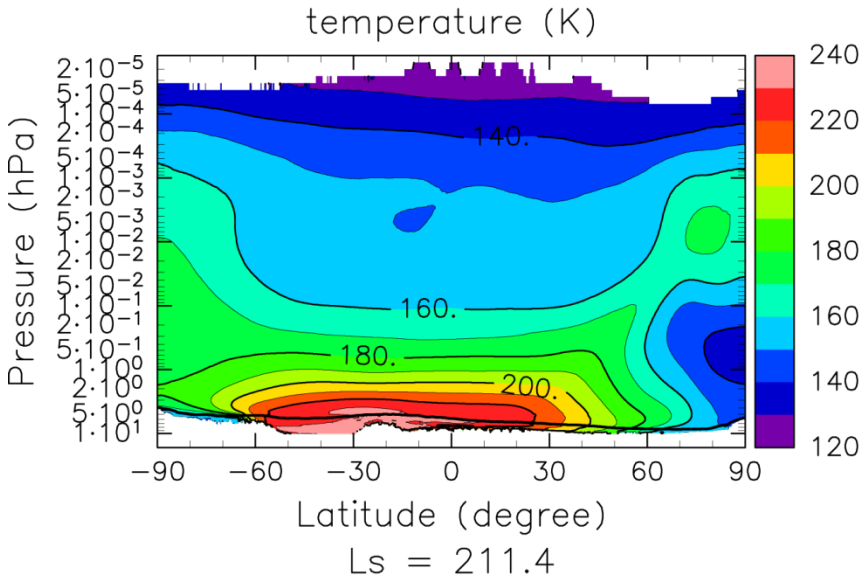
- Dynamics (AFES; Ohfuchi et al., 2004)
  - primitive equation system
- Physics (Takahashi et al., 2003, 2006)
  - radiation (CO_2, dust),
  - turbulent mixing (Mellor and Yamada, 1982)
  - thermal conduction in the soil,
  - mass exchange between atmosphere and polar cap,
  - dust lifting parameterization with a threshold following Newman et al. (2002),
    - dust devil parameterization is not included.

Experimental setup

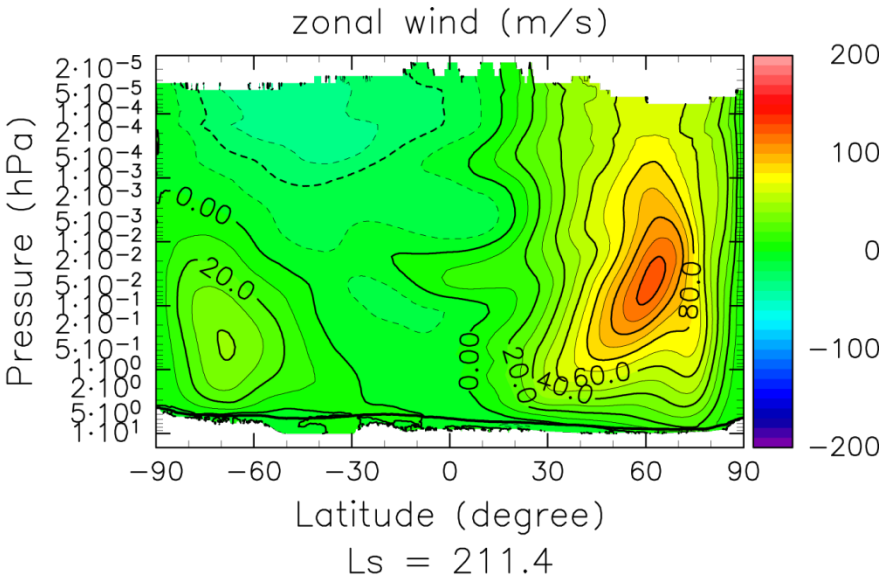
- Resolutions
  - T639L96, T319L96, T159L96, T79L96
    - horizontal grid size Δx~11, 22, 44, 89 km
    - 96 vertical levels up to ~90 km
- Dust condition
  - “passive dust experiment”
  - Dust optical depth is fixed to be 0.2.
- Seasonal condition and integration period
  - 40 Mars days at northern fall season from an initial condition of a snapshot of low resolution experiment
- Sensitivity test experiment with uniform surface properties
  - In these experiments, surface orography is flat, and surface albedo and thermal inertia are assumed to be constant.

- Experiments are performed on the Earth Simulator.

Zonal mean temperature and zonal wind in the T639L96 experiment

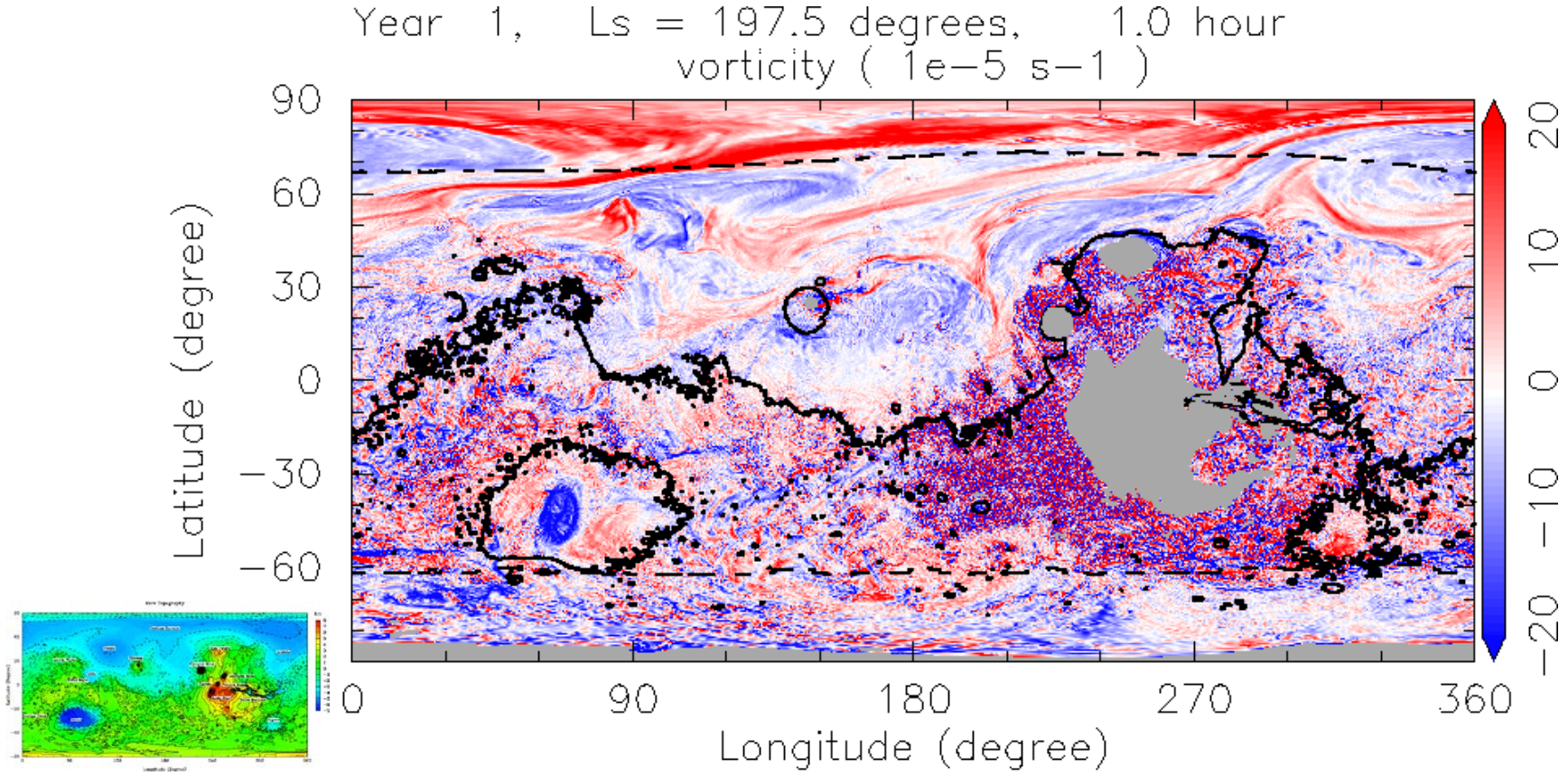


CONTOUR INTERVAL = 1.000E+01



CONTOUR INTERVAL = 1.000E+01

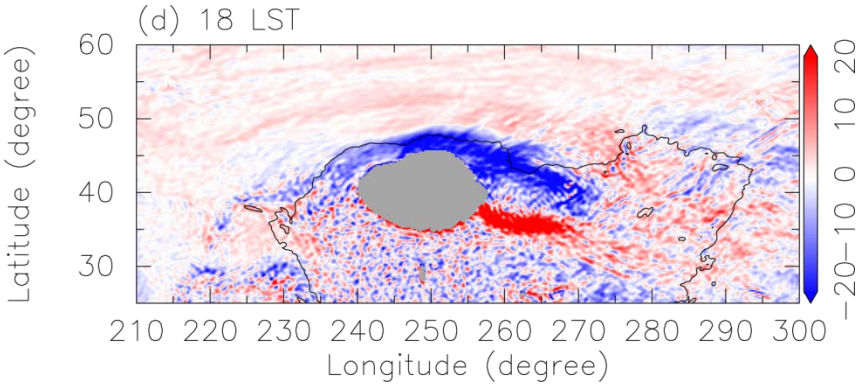
Vorticity distribution at 4 hPa
T639L96 (grid size~11 km)



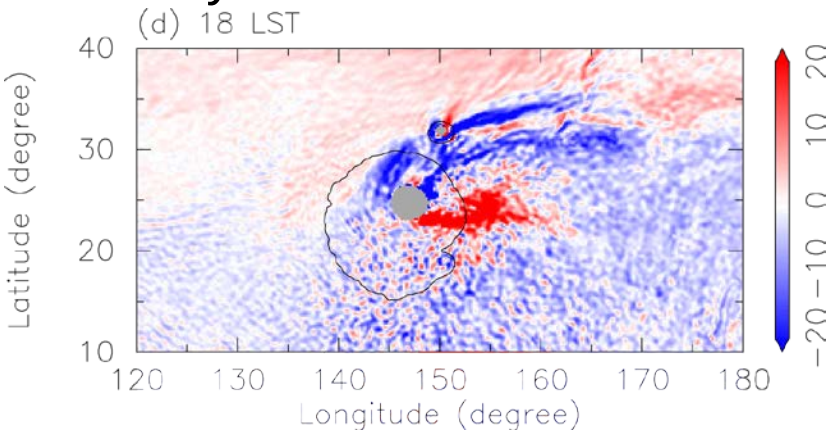
- A lot of disturbances ranging from planetary scale to ~10 km are represented.
  - A lot of small scale vortices, which would be caused by convective motions in the model,
  - Local orography related circulations.

Orography-related disturbances around Alba Patera, Elysium, and north of Hellas

Alba Patera at 18 LST

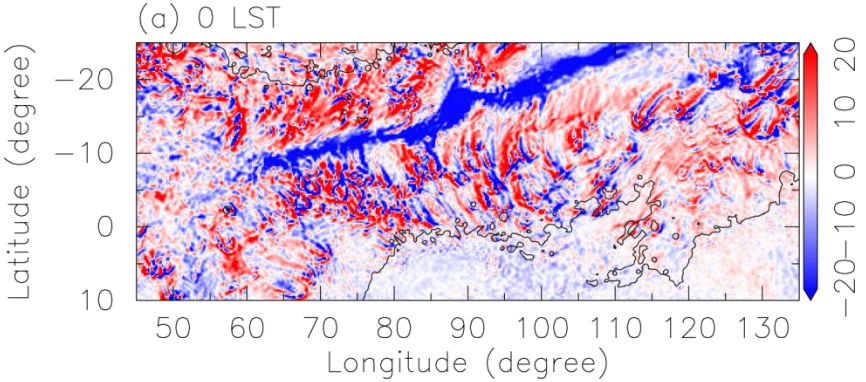


Elysium at 18 LST

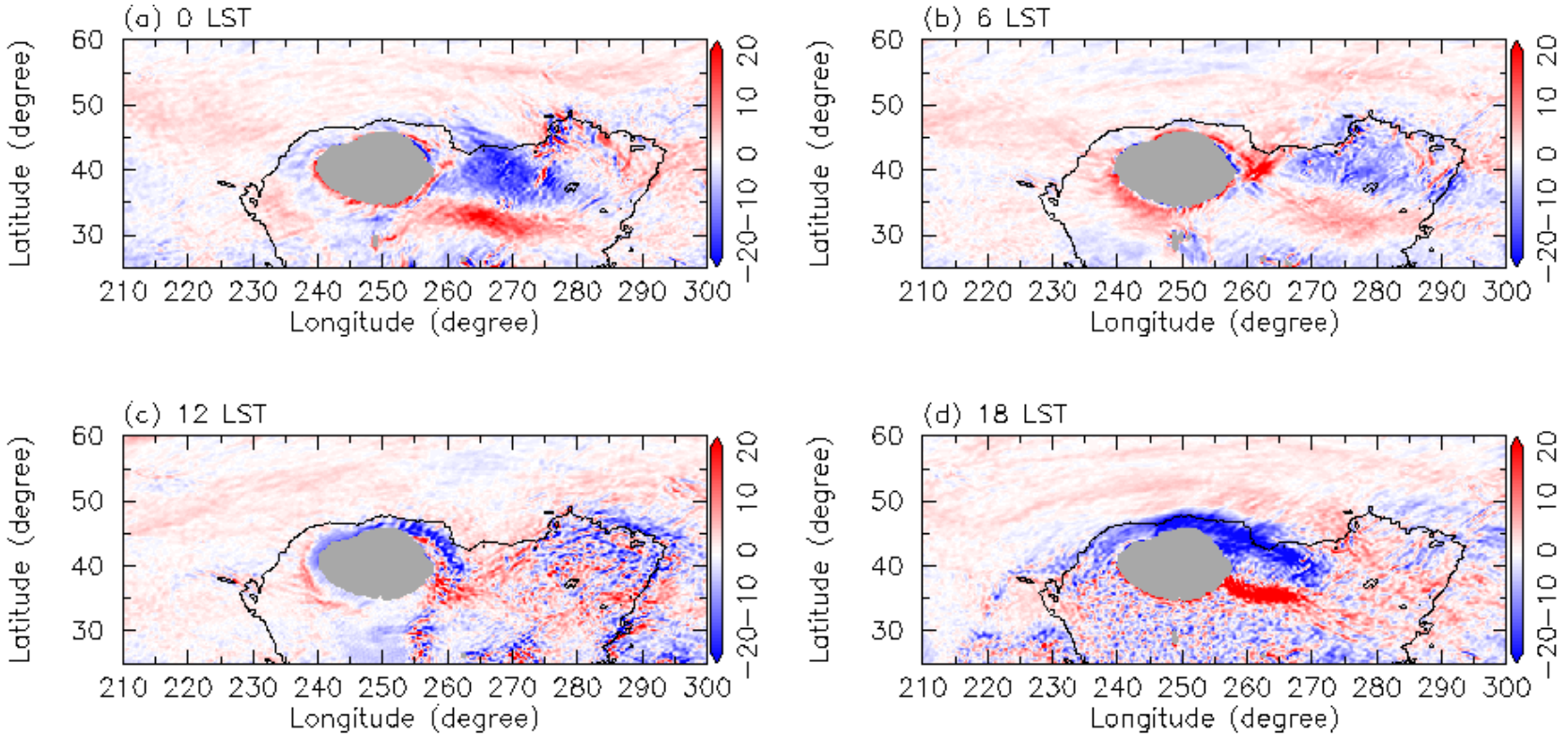


- Orography-related disturbances with horizontal scales of orography.
  - Clear diurnal variation is observed.
  - Interaction between the mean wind and mountain and diurnally varying slope wind around the mountain would cause these disturbances.

north of Hellas at 0 LST

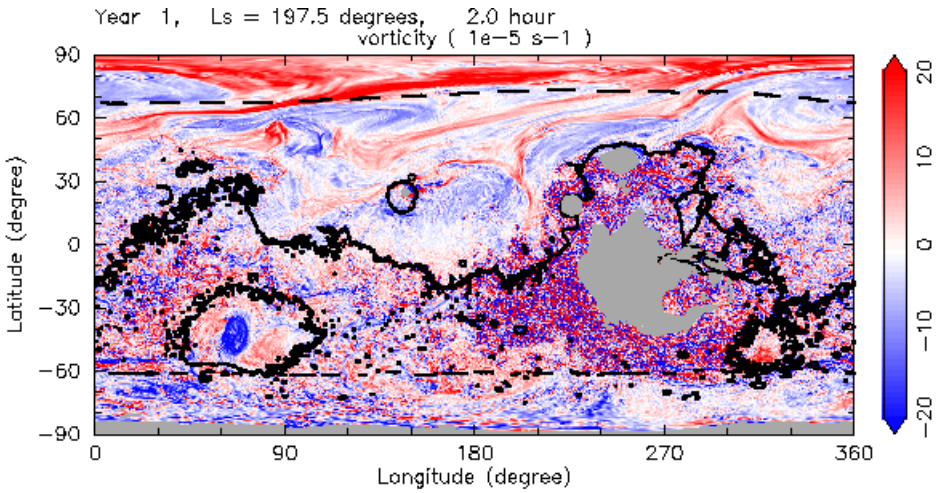


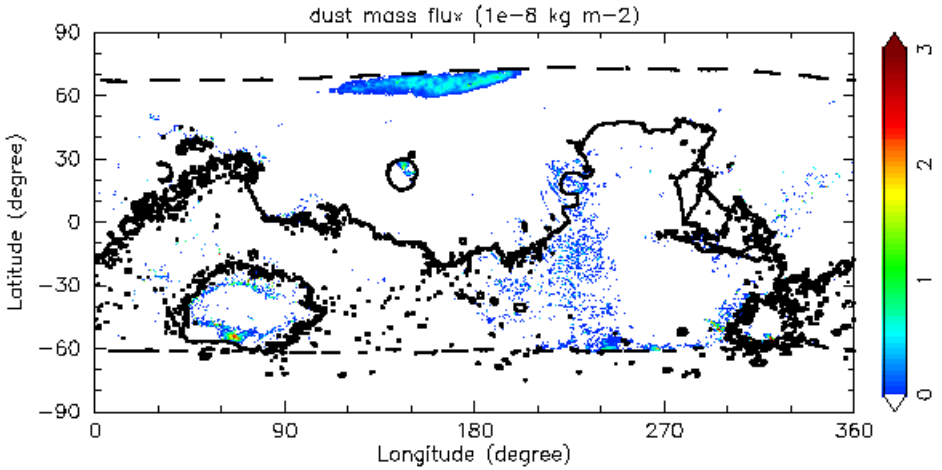
Vortices around Alba Patera
Composite plot of vorticity



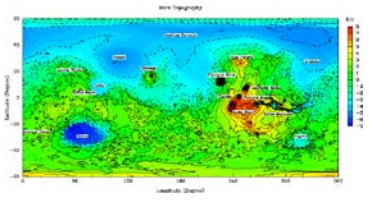
- Analysis indicates that this would be caused by
  - interaction between the mean wind and mountain (Alba Patera),
  - diurnally varying slope wind around the mountain.

Dust lifting in the model

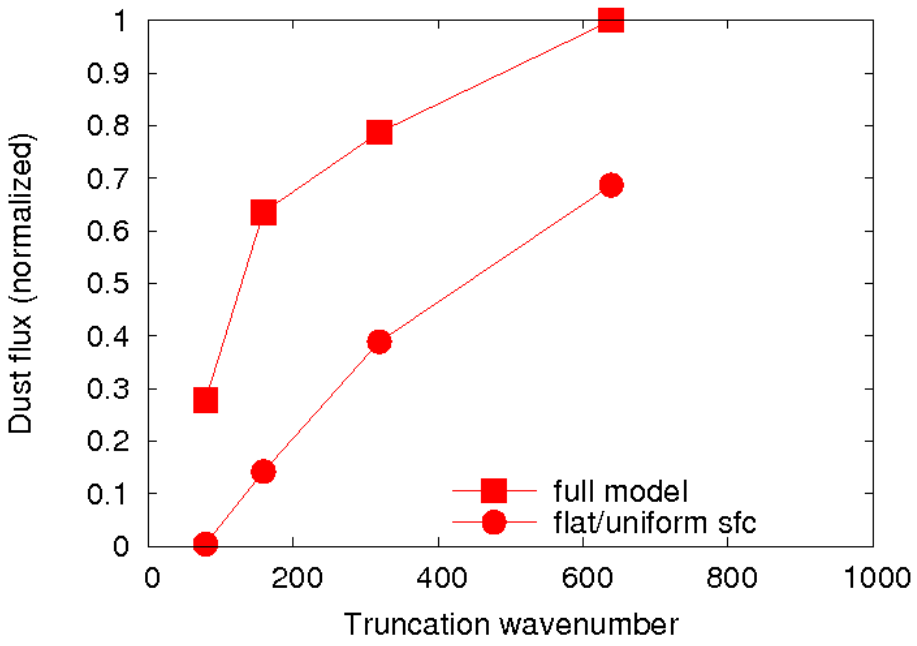




- Intense dust lifting events occur around fronts.
- Dust lifting associated with some characteristic orography is also observed.
- Small scale vortices seem to contribute on dust lifting too.



Resolution dependence of global mean dust flux



- In both cases with and without surface property variations, global mean dust mass flux increases with increasing resolution.
- Dust mass flux in the case with surface property variation is larger than that in the case without surface property variations.
  - Importance of orography-related circulation on dust lifting.

Summary

- High resolution GCM experiments of the Martian atmosphere are performed with the horizontal resolutions of T639L96, T319L96, T159L96, and T79L96 ($\Delta x \sim 11, 22, 44, 89$ km).
- The results show following disturbances:
  - baroclinic waves with clear frontal structures,
  - orography-related disturbances,
    - medium scale lee vortices,
    - a lot of streaks with horizontal resolutions of tens of kilometers,
  - small scale vortices in low latitude.
    - Modulation of these vortices are also observed.
- The horizontal size of small scale vortices has not converged even with T639 horizontal resolutions. The relationship between small vortices in the model and dust devils on real Mars is unclear.
- It is shown that small scale disturbances represented in the model contribute to dust lifting significantly.

- In future, I would like to examine wave activity in the high resolution simulations.