High resolution general circulation model experiments of the Martian atmosphere

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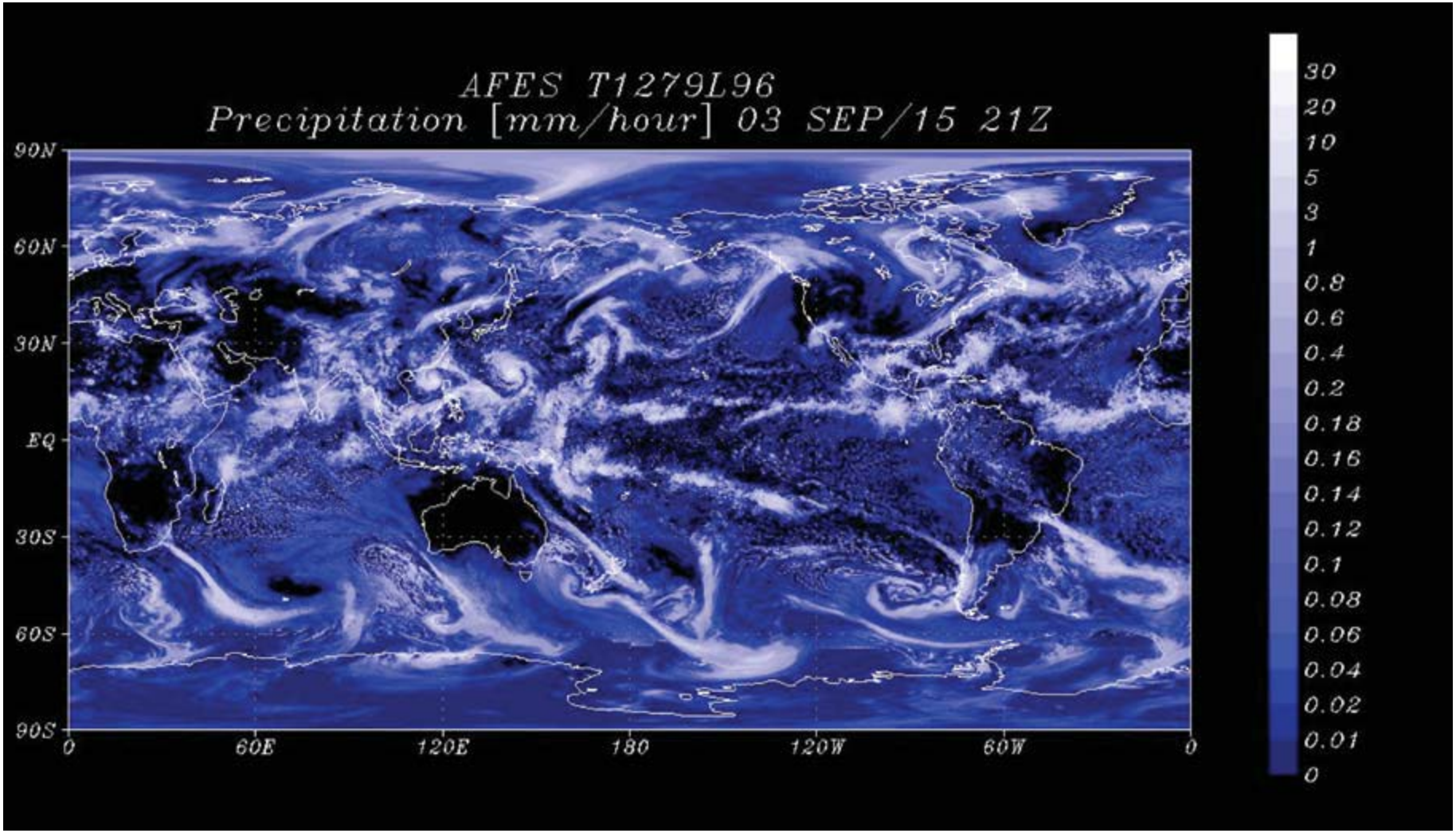
Purpose of this study

- We perform medium and high resolution (Δx~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.

- In the followings,
  - model description,
  - disturbances observed in the model,
  - dust lifting events observed in the model,

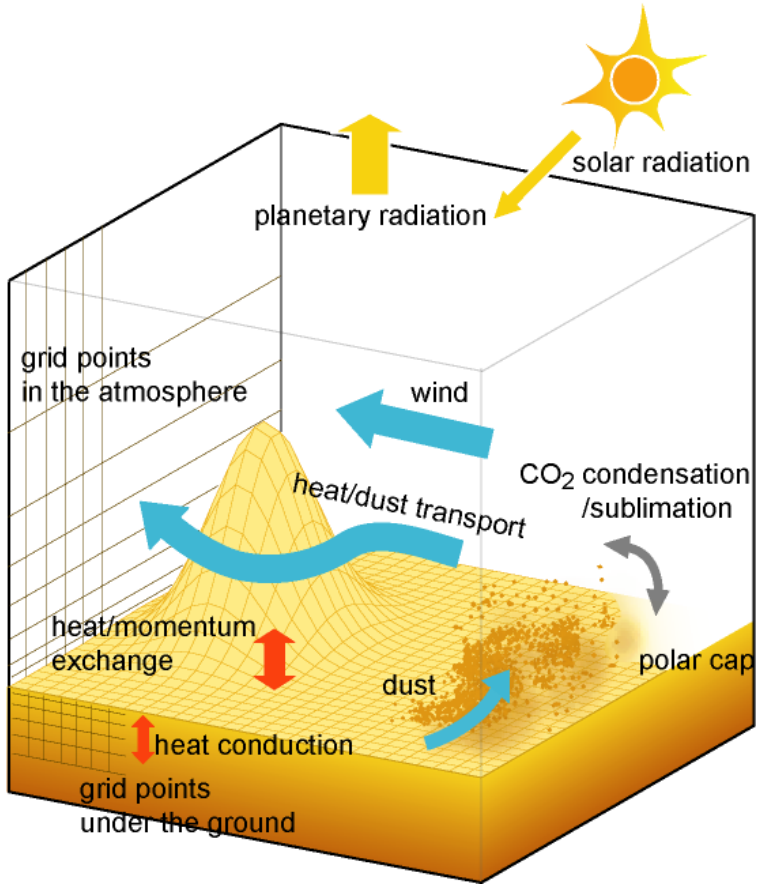
  are presented.

Introduction: Example of 10 km resolution experiment of the Earth's atmosphere



An example of a global 3-hourly precipitation field (Ohfuchi et al., 2004)

Model description



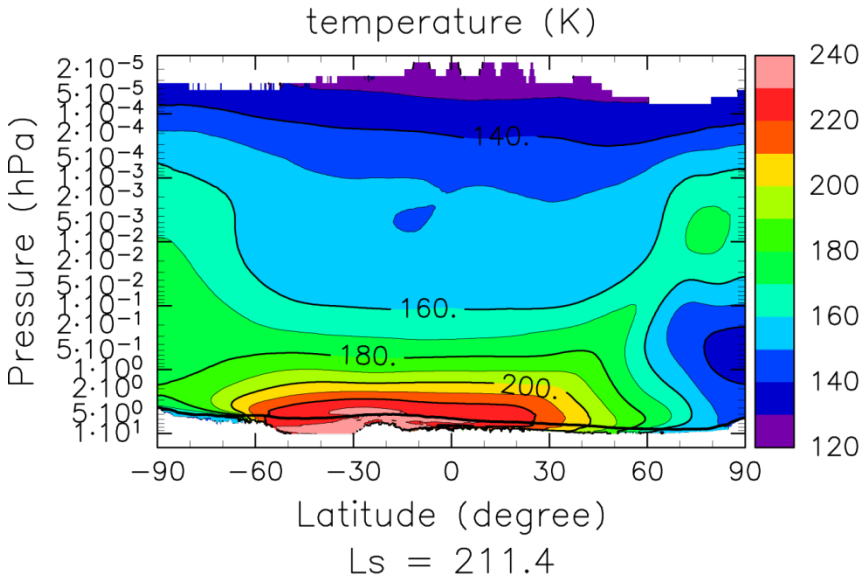
- Dynamics (AFES; Ohfuchi et al., 2004)
  - primitive equation system
- Physics (Takahashi et al., 2003, 2006)
  - radiation (CO_2, dust),
  - turbulent mixing (Mellor and Yamada, 1982)
  - thermal conduction in the soil,
  - mass exchange between atmosphere and polar cap,
  - dust lifting parameterization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

Experimental setup

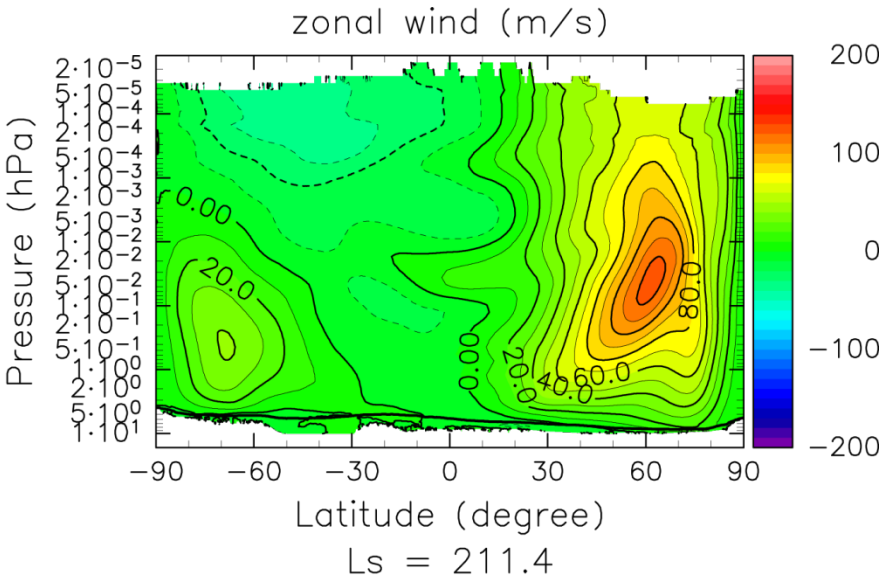
- Resolutions
  - T639L96, T319L96, T159L96, T79L96
    - horizontal grid size Δx~11, 22, 44, 89 km
    - 96 vertical levels up to ~90 km
- Dust condition
  - “passive dust experiment”
  - Dust optical depth is fixed to be 0.2.
- Seasonal condition and integration period
  - 40 Mars days at northern 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

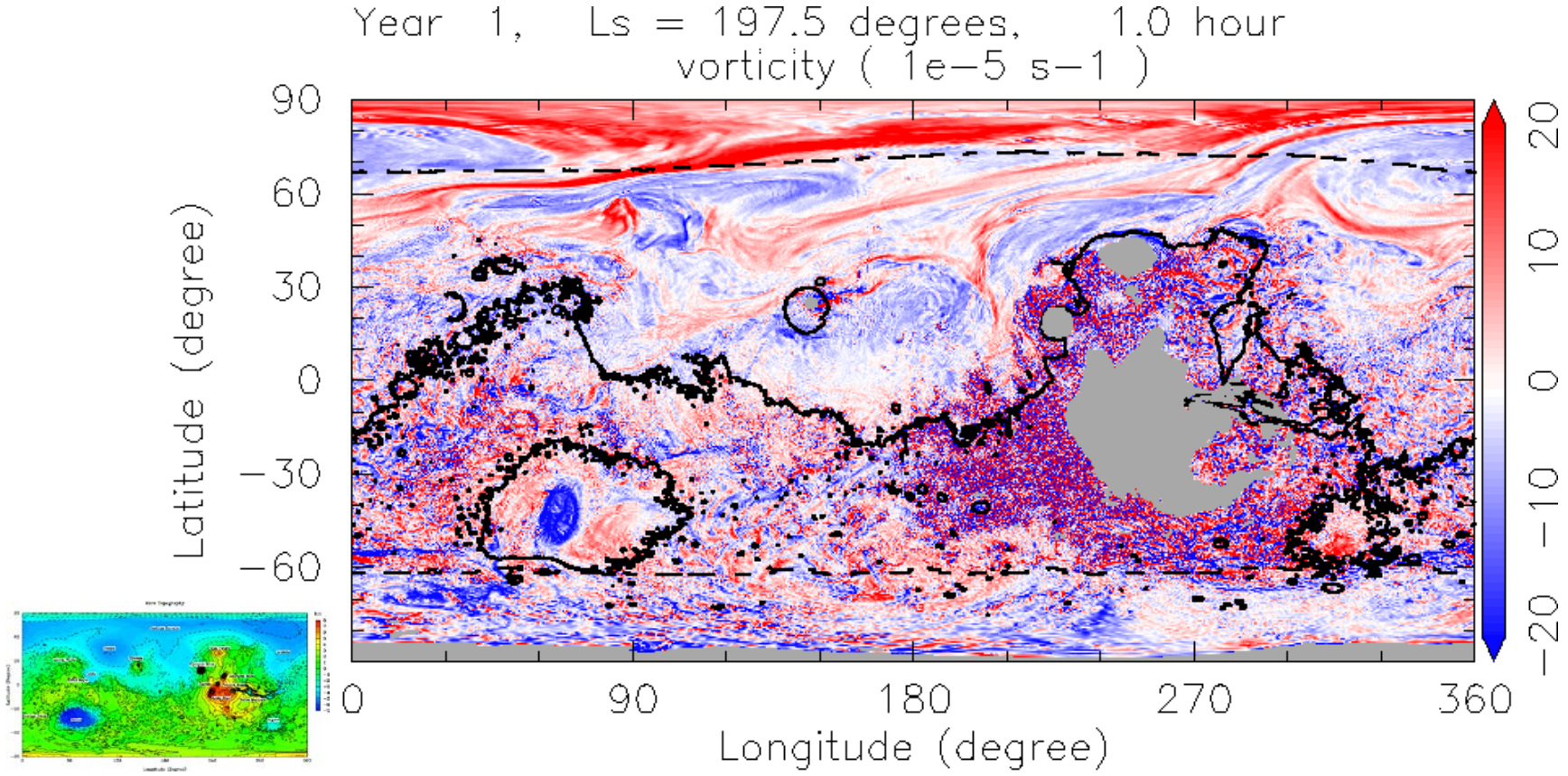


CONTOUR INTERVAL = 1.000E+01



CONTOUR INTERVAL = 1.000E+01

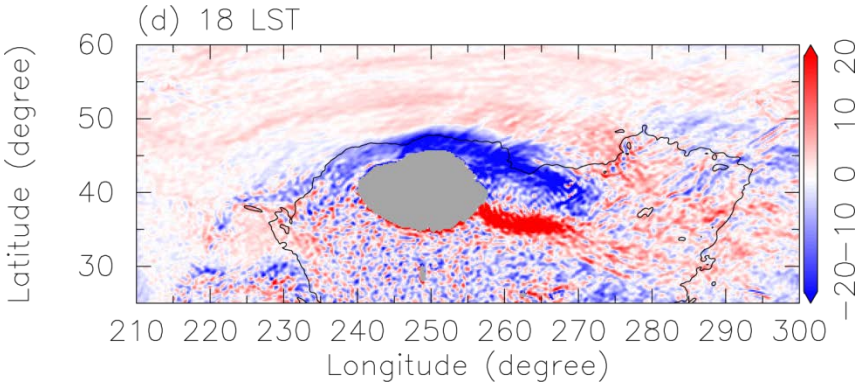
Vorticity distribution at 4 hPa
T639L96 (grid size~11 km)



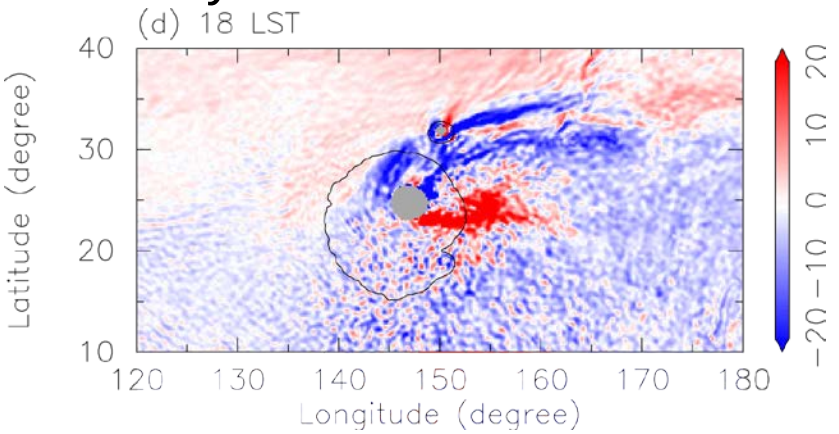
- A lot of disturbances ranging from planetary scale to ~10 km are represented.
  - A lot of small scale vortices, which would be caused by convective motions in the model,
  - Local orography related circulations.

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

Alba Patera at 18 LST

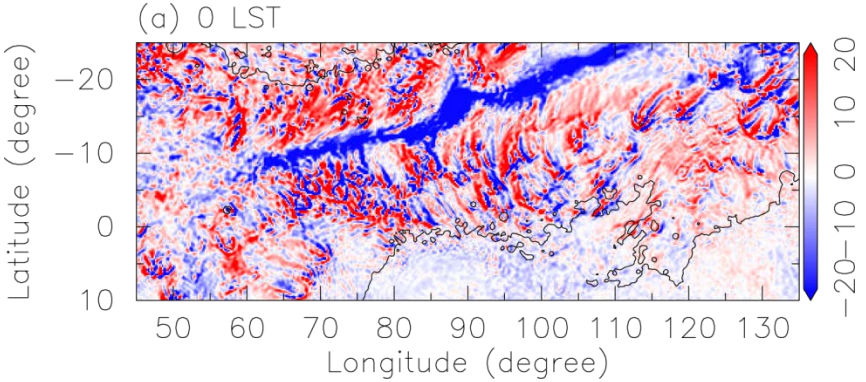


Elysium at 18 LST

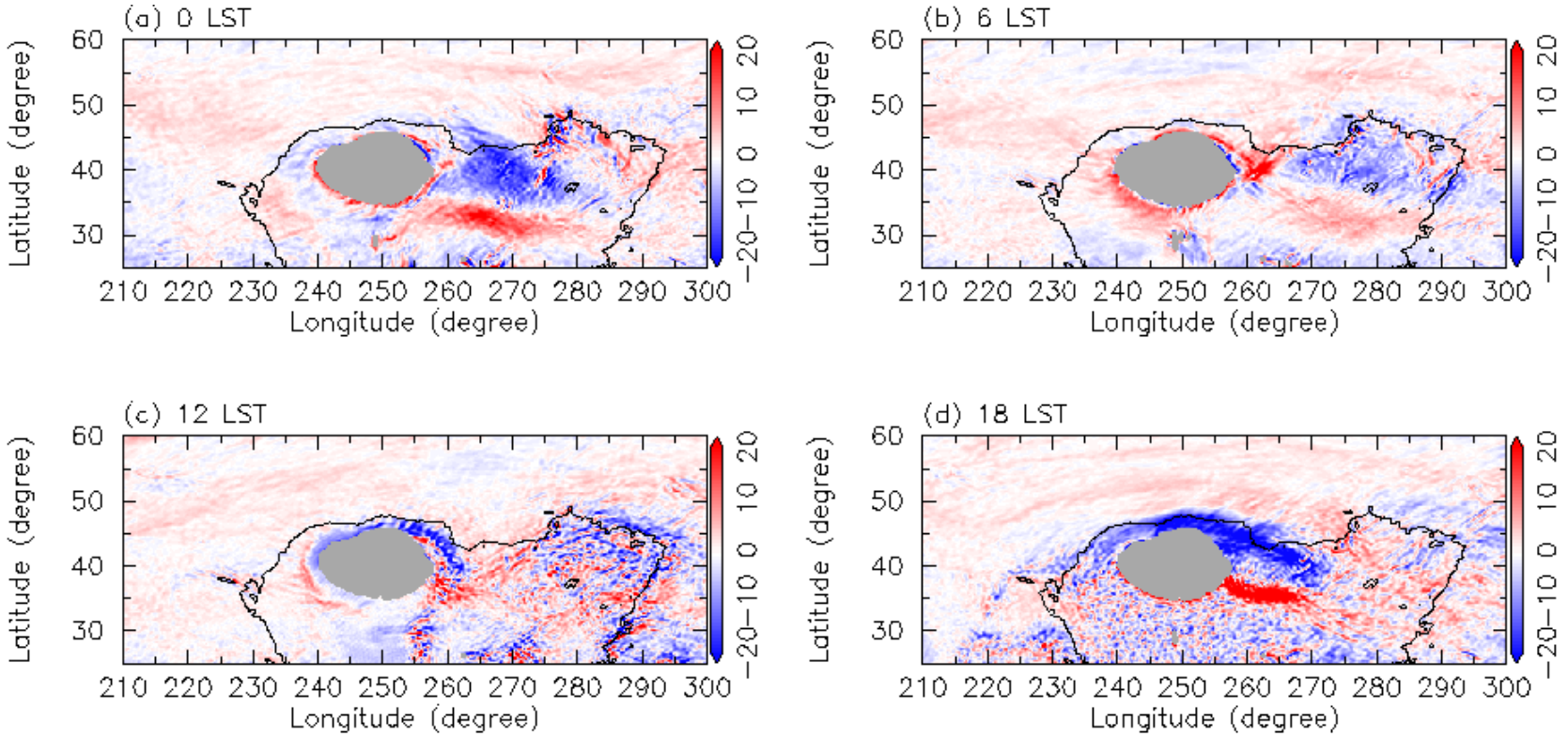


- Orography-related disturbances with horizontal scales of orography.
  - Clear diurnal variation is observed.
  - Interaction between the mean wind and mountain and diurnally varying slope wind around the mountain would cause these disturbances.

north of Hellas at 0 LST



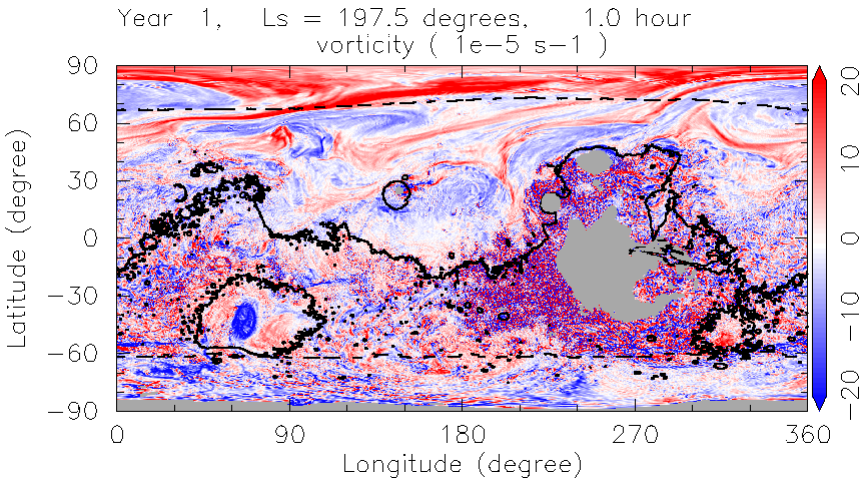
Vortices around Alba Patera
Composite plot of vorticity



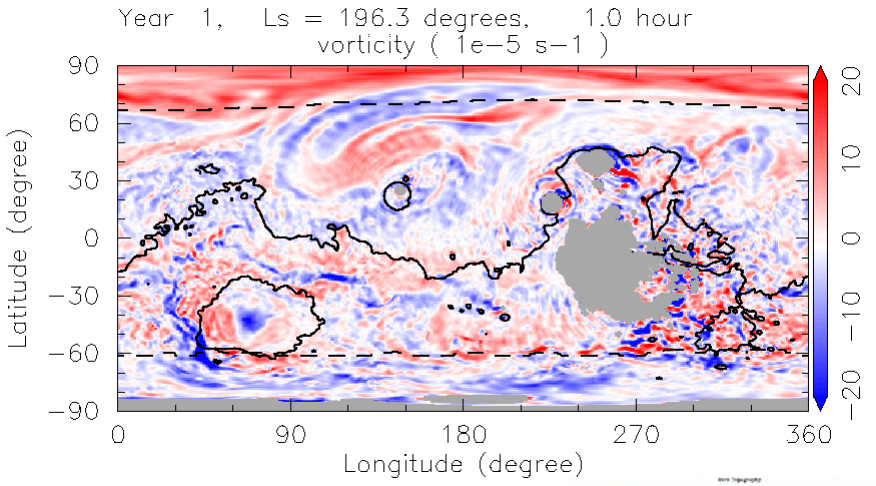
- Analysis indicates that this would be caused by
  - interaction between the mean wind and mountain (Alba Patera),
  - diurnally varying slope wind around the mountain.

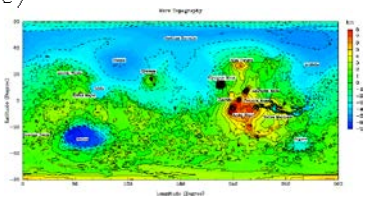
Comparison of vorticity distribution at 4 hPa T639L96 (grid size~11 km), T159L96 (~44 km)

T639L96



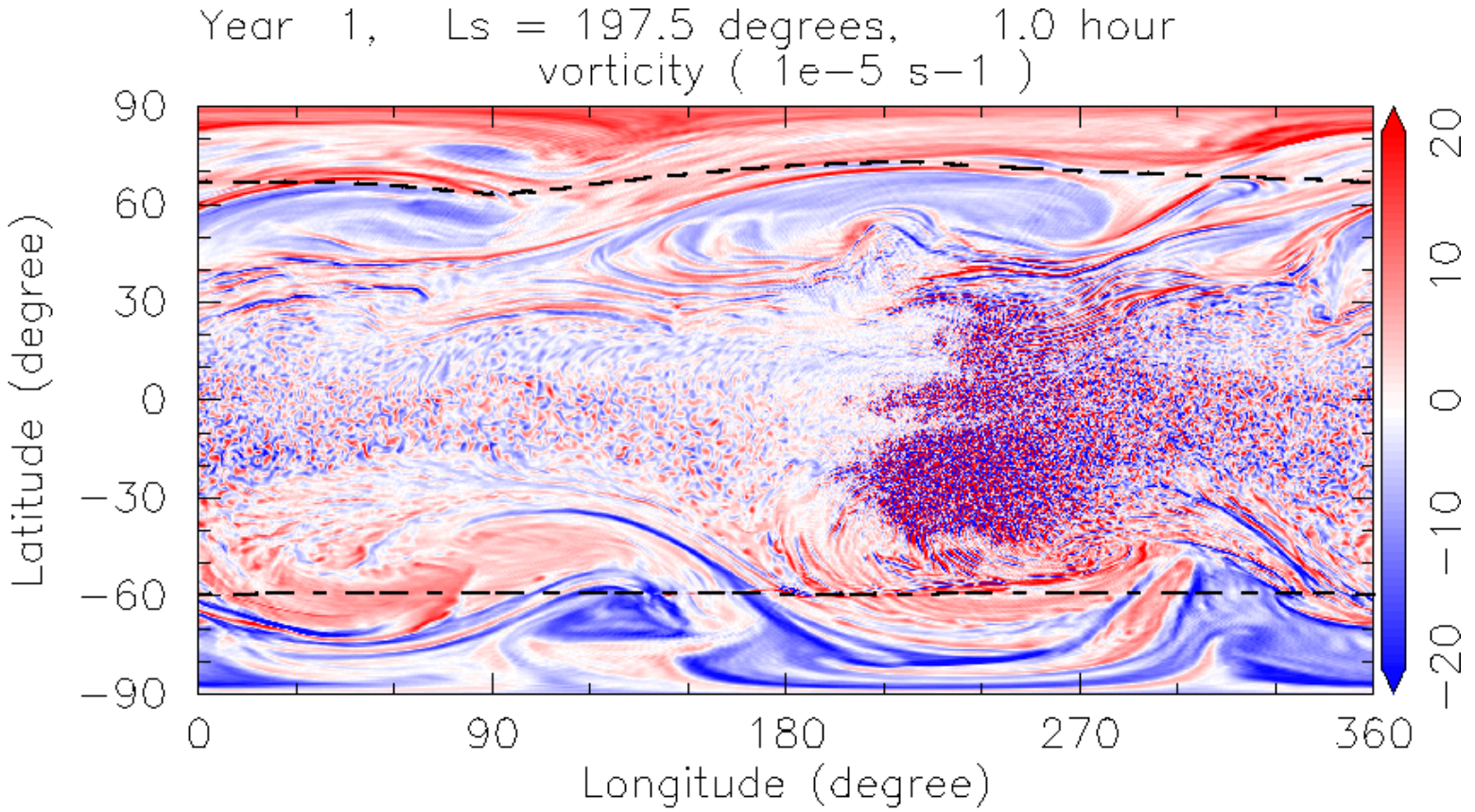
T159L96





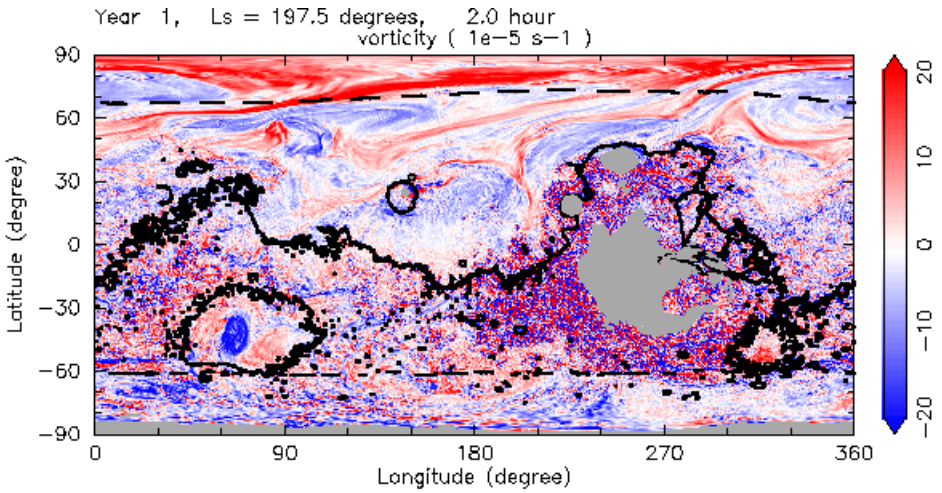
- Low latitude small scale vortices
  - Horizontal size decreases with increasing resolution.
    - Horizontal size does not seem to converge even in highest resolution (~11 km).
  - Vortices appears earlier local solar time with increasing resolution.

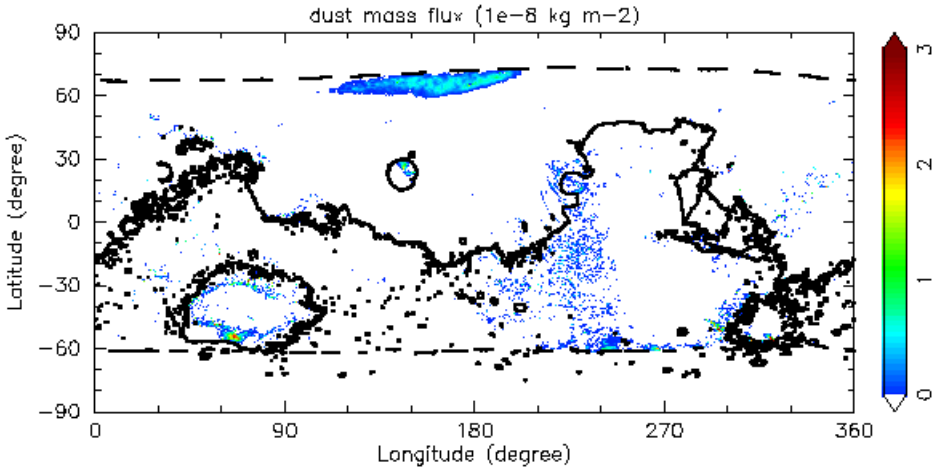
Vorticity distribution at 4 hPa
T639L96, No surface property variations



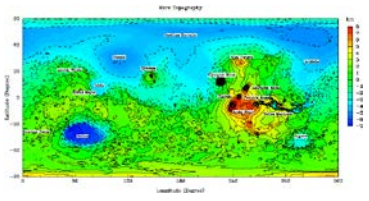
- Modulation of small scale vortices by large scale disturbance.
- Organization of motion is not observed.

Dust lifting in the model

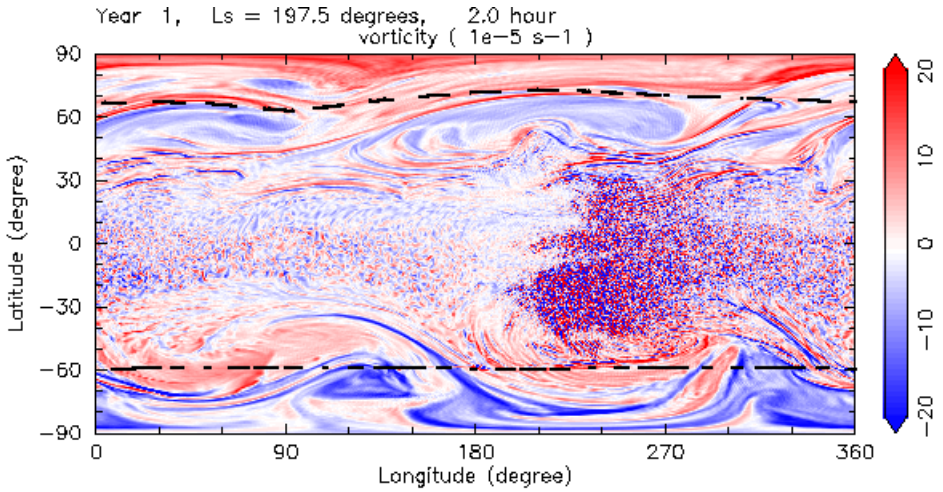


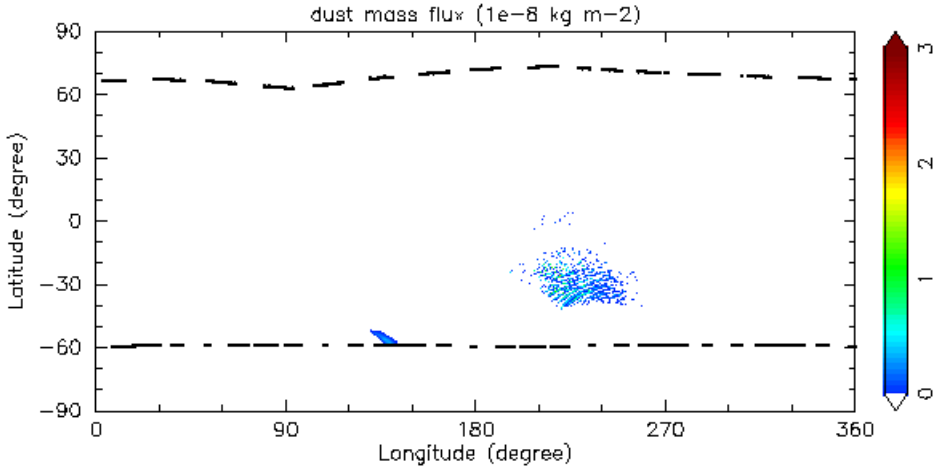


- Intense dust lifting events occur around fronts.
- Dust lifting associated with some characteristic orography is also observed.
- Small scale vortices seem to contribute on dust lifting too.



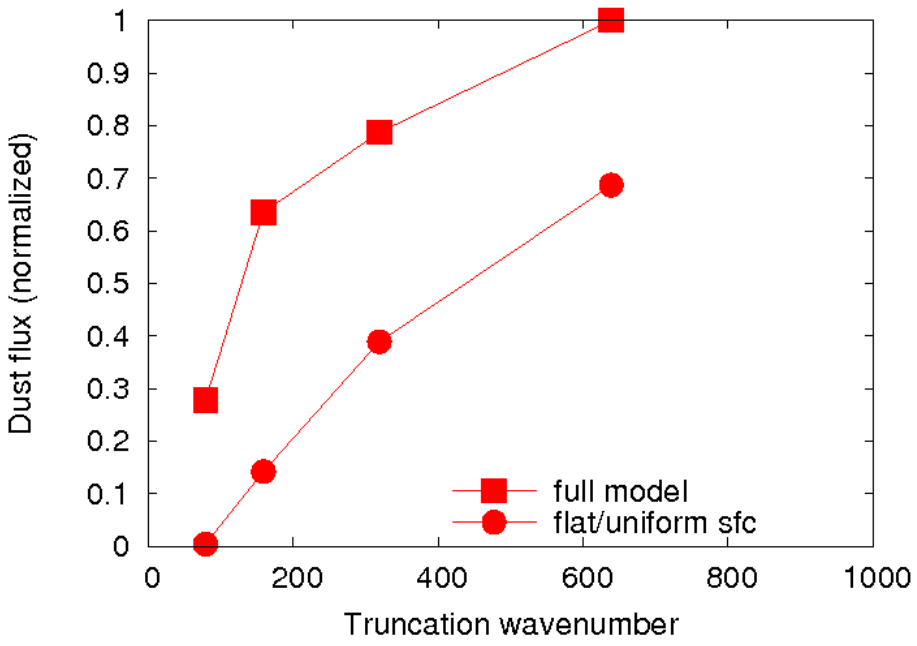
Dust lifting in the model with uniform surface properties





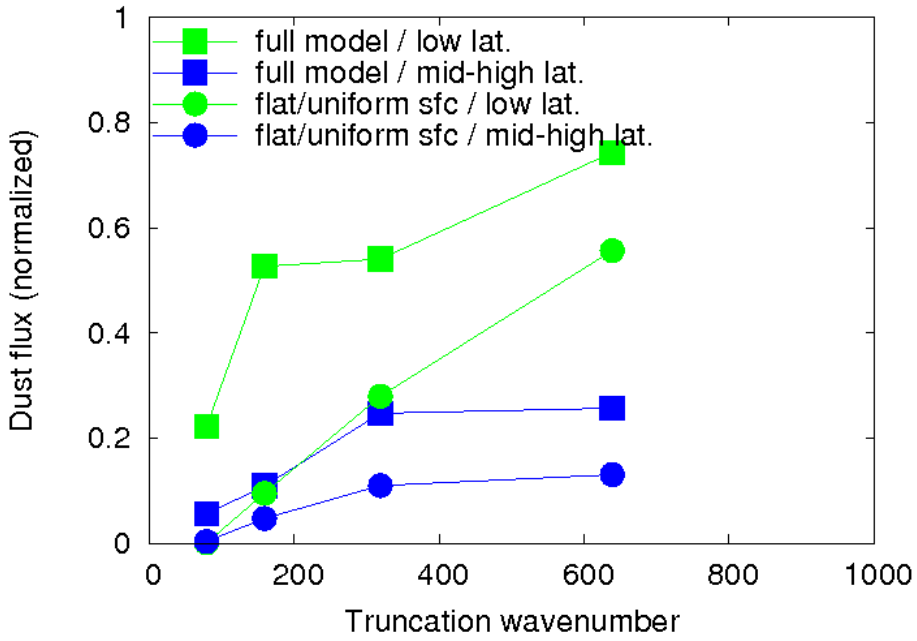
- Even without orographic variation, dust is lifted in the region where small scale vortices are generated.
- Intense dust lifting around fronts seem to occur at the timing when the small scale vortices are generated.

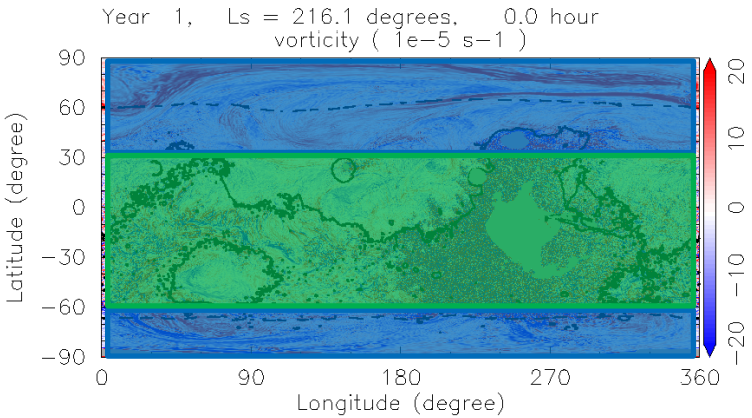
Resolution dependence of global mean dust flux



- 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.

Resolution dependence of dust flux in latitude bands





- Dust flux is nearly saturated in middle and high latitude, while it continues to increase even with highest resolution.

Latitude band used for analysis

Green : 60°S - 30°N

Blue : 90°S - 60°S

: 30°N - 90°N

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.