P138-002 **Room: 304** **Time: May 19 14:30-14:45**

Diurnally varying small scale vortices observed in the Mars general circulation model

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The numerical simulations by using the Mars general circulation models (GCMs) and regional scale models play important roles to understand the physical processes of phenomena in the Martian atmosphere. However, the actual features of small and medium scale disturbances, whose spatial scales are larger than thermal convection and smaller than baroclinic waves, have almost never been investigated so far, because of the insufficient model resolution and domain size. We have performed numerical simulations of the Martian atmosphere by using a Mars GCM with intermediate resolution (T79: about 79 km grid size) to investigate features of the small and medium scale disturbances and its effects on the dust lifting process on Mars. In this study, we perform Mars GCM simulations with higher horizontal resolution (T319: about 22 km grid size) than that performed so far, and examine the effects of horizontal diffusion on the features of medium scale disturbances observed in the previous simulations, and address the structures of the small scale disturbances that cannot be resolved in the previous simulations.

The model used in this study consists of the dynamical core of AFES, and the physical processes introduced from the Mars GCM which has been developed by our group so far. AFES is based on CCSR/NIES AGCM 5.4.02, and is optimized to perform high resolution simulations on the Earth Simulator. As for the physical processes, the radiative, the turbulent mixing, and the surface process are introduced from our Mars GCM. In addition, the dust lifting process and the gravitational sedimentation are implemented. The dust lifting process is the same as one of 'threshold-sensitive surface stress lifting' parameterizations proposed by Newman et al. [2002]. This parameterization is an GCM implementation of the process of dust lifting by the surface wind, whose characteristics is that dust is not ejected unless the surface friction velocity exceeds a certain threshold value. By the use of this GCM, we performed a simulation at northern fall season with higher resolution of T319L96, which is equivalent to about 22 km grid size.

The result of simulation with T319L96 resolution shows the formation of diurnally varying medium scale vortices in the lees of Alba Patera and Elysium. The horizontal scale of these medium scale vortices is 300-400 km, and is close to the minimum scale resolved in T79 horizontal resolution. However, the appearance and time evolution of the medium scale vortices observed in the T319 simulation is almost the same as those observed in the T79 simulation. This implies that the artificial horizontal diffusion in the model did not seem to affect the formation of medium scale vortices.

On the one hand, several small scale disturbances, that cannot be observed in the T79L48 intermediate resolution simulation, are also observed in the T319L96 high resolution simulation. For example, in low latitude region, a lot of small scale vortices whose horizontal scale is 100-150 km are observed. The region of these vortex generation moves westward, and the vortices are generated in the afternoon and dissipated in the night. It is considered that these vortices are generated as a result of vorticity stretching by the local thermal convection represented in the T319 resolution simulation. Another disturbance is a movement of horizontal shear line in the western flank of the Tharsis plateau. The horizontal shear line ranges about 1500 km and moves westward and downward. The shear line moves in the morning periodically with a period of one Martian day. It is supposed that the diurnally varying slope wind or gravity waves excited by the diurnally varying solar heating would cause this phenomenon. These results imply the importance of the diurnal variation in generating the small scale disturbances on Mars, because of the dry surface and atmosphere system of Mars.