Small and medium scale disturbances observed in the Mars general circulation model

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Atmospheric dust affects the thermal and circulation structure of the Martian atmosphere. But, the mechanisms responsible for dust lifting from the ground into the atmosphere have not been well understood. Past studies using general circulation models (GCMs) reported that, except for some restricted geometrical regions with some favorable conditions, wind speed calculated explicitly at each grid point of GCM rarely exceeds the threshold value for dust lifting, and hence GCMs could not have sufficient amount of dust in the atmosphere. In recent years, it has been recognized that the effects of small and medium scale disturbances with horizontal scales smaller than about 300 km, the grid scales of those GCMs, are important to produce dust lifting, and dust lifting parameterizations considering those effects have been incorporated in GCMs. These models successfully reproduce seasonal variation of dust amount that is roughly consistent with observed ones. However, the actual features of small and medium scale disturbances in the Martian atmosphere have not been revealed yet. In this study, a GCM of the Earth's atmosphere, AFES, is adapted to Mars and numerical experiments are performed with higher resolutions than those used in previous studies to examine the structures of the small and medium scale disturbances and its effects on the dust lifting and transfer processes. Here, we focus our attention on the structures of small and medium scale disturbances observed in the simulation results, and argue about its generation mechanisms.

The model used in this study consists of the dynamical core of AFES, the semi-Lagrangian tracer transport scheme, 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, an active dust experiment is performed with the resolution of T79L48, which is equivalent to about 90 km grid size.

The numerical experiment shows that small and medium scale vortices are generated in the lees of several mountainous regions, such as the Alba Patera, the Elysium, and the Olympus at the northern spring and fall seasons. These vortices are generated/dissipated periodically with a period of one sol, and are generated in the afternoon and dissipated in the night. In the lees of above mentioned mountains, a large diurnal variation of wind is observed, while the diurnal variation of background wind averaged around the regions is not very large. The local daytime weak wind in the lee side as a result of the large diurnal variation of wind appears to be a direct cause of vortex shape formation. Further examination of diurnally varying wind field revealed that the daytime weak wind in the lee is caused by the upslope wind. Because the vortex generation can be observed in several regions as mentioned above, it is implied that the superposition of the local slope wind on the large scale background wind field of this kind is one of the common mechanisms to cause small and medium scale disturbances in the Martian atmosphere.