An estimation of surface dust flux with high-resolution large eddy simulations for the Martian atmosphere

*Kuriki Murahashi[1], Kouhei Suto[1], Seiya Nishizawa[2], Masaki Ishiwatari[1], Masatsugu Odaka[1], Kensuke Nakajima[3], Shin-ichi Takehiro[4], Ko-ichiro SUGIYAMA[5], Hirotaka Ogihara[1], Yoshiyuki O. Takahashi[6], Yoshi-Yuki Hayashi[6]

1. Department of Cosmosciences, Graduate school of Science, Hokkaido University, 2. RIKEN Advanced Institute for Computational Science, 3. Kyushu University, 4. Research Institute for Mathematical Sciences, Kyoto University, 5. National Institute of Technology, Matsue College, 6. Kobe University / CPS

1. Introduction

Dust in the Martian atmosphere has a great influence on the temperature structure. Dust is lifted from the ground by the wind in the atmospheric boundary layer. An important point of dust lifting is the existence of required minimum stress threshold value. In many studies using Martian atmospheric general circulation models (MGCMs), dust lifting by the subgrid-scale wind is parameterized. The amount of dust lifting has been to be considered insufficient by the evaluation of the averaged surface stress determined by the so-called bulk method using the global scale wind and temperature fields near the surface. Therefore, particular flow structures such as dust devils should be considered and averaged contribution of extreme values of surface stress associated with the flow structures should be evaluated (Kahre et al., 2006).

However, the occurrence of extreme values of surface stress and statistics of surface stress in the Martian atmospheric boundary layer have been only speculated theoretically and have not been investigated from an observational standpoint. Actually, in MGCMs using these parameterization schemes, interannual variability of the global dust storm has not been successfully produced (Mulholland et al., 2013). One of the reason may be the insufficient verification of the current parameterization schemes in the current Martian environment.

It is difficult to obtain accurate flow field in the subgrid-scale size of MGCM by observation in the case of Mars. However, high-resolution large eddy simulations (LESs) can represent the subgrid-scale flow field. The highest resolution MGCMs use the spatial resolution of ten-odd kilometers (Takahashi et al., 2011). Therefore, by examining the characteristics of the high-resolution LESs which have ten-odd kilometers calculation area, we expect to examine the parameterization scheme in MGCMs.

In this study, to consider the dust lifting parameterization scheme in MGCMs, we investigate the relationship between microstructures of wind fields and the surface stress. Also, we compare the results obtained from the calculations with various resolution. We use the data calculated by Nishizawa et al. (2016). Nishizawa et al. (2016) conducted LESs where several different grid spacing ranging from 100m to 5m were employed and examined the resolution dependence of vortex radius. The isotropic grid spacing of 5 m is the highest resolution among Martian LESs performed so far.

2. Data

We use the data calculated by Nishizawa et al. (2016) which utilized SCALE-LES ver. 3 developed by RIKEN / AICS. The values of model parameters are those of Mars. The model domain is 19.2 km ×19.2 km ×21 km. Five experiments with the resolutions ranging from 100 m to 5 m were analyzed. The heating rate and the surface temperature are given externally from vertical one-dimensional simulation by Odaka et al.

(2001). Horizontally periodic boundary conditions are adopted. Except for the 5 m resolution run, the vertical temperature profile of initial state is obtained from Odaka et al. (2001) and tiny random perturbations are added. For the 5 m resolution run, integration is performed for 1 hour from the result at 14:00 (local time) obtained by the 10 m resolution run. In this study, we use the data at 14:30 obtained with the 5 m resolution run. Surface stress is calculated using the same scheme as Nishizawa et al. (2016). Dust flux is calculated using the same schemes and parameters in Kahre et al. (2006).

3. Result

We previously reported that the wind stress values exceeding 0.03 Pa which is the threshold value of dust lifting appear only in the 5 m resolution result, which is the highest resolution. And we showed the distributions of isolated vortices which have strong surface stress (Murahashi et al., 2017). In this presentation, we show the results of analysis of the surface dust flux calculated by the schemes in MGCMs.

Keywords: Mars, Atmospheric Boundary Layer, High-Resolution Large Eddy Simulation, Dry Convection, Surface Stress, Dust Lifting