Dust lifting and advection simulated by a non-hydrostatic general circulation model in a Mars-like atmosphere

*Hiroki Kashimura[1], Hisashi Yashiro[2], Seiya Nishizawa[3], Hirofumi Tomita[3], Kensuke Nakajima[4], Masaki Ishiwatari[5], Yoshiyuki O. Takahashi[1], Yoshi-Yuki Hayashi[1]

1. Department of Planetology, Graduate School of Science, Kobe University, 2. Center for Global Environmental Research, National Institute for Environmental Studies, 3. RIKEN Center for Computational Science , 4. Department of Earth and Planetary Sciences, Flculty of Sciences, Kyushu University, 5. Department of Cosmosciences, Graduate school of Science, Hokkaido University

Scales of atmospheric motions in Earth range from a few meter scale to the planetary scale, and multi-scale phenomena interact with each other. This is a reason for promoting an atmospheric simulation with higher resolution. The situation must be the same in other planets such as Mars. In the Martian atmosphere, dust storms in various scales—from dust devils of tens to hundreds of meter scales, to local dust storms of several tens of kilometer-scale, and to global dust storm—have been observed. However, interactions between these scales are unknown. In addition, since Mars has a thin atmosphere and no ocean, the temperature difference between day and night is large and vertical convection should play an essential role in the Martian meteorology, but it is also unknown. To investigate these mysteries, global atmospheric simulations with horizontal resolution as high as few kilometers are required. Additionally, in order to explicitly simulate vertical convection, it is necessary to solve the governing equations without assuming the hydrostatic balance.

We are developing a non-hydrostatic global Martian atmospheric model (Martian SCALE-GM) which is suitable for large-scale parallel computation, targeting to perform high-resolution simulations described above on the supercomputer Fugaku. SCALE-GM (http://r-ccs-climate.riken.jp/scale/) is being developed by using the dynamical core of NICAM (Tomita and Satoh, 2005; Satoh et al., 2008; Satoh et al., 2014), a non-hydrostatic model using a finite volume method in the icosahedral grid systems (Tomita et al., 2001, 2002), that has been used for simulations of Earth atmosphere and climate, and by aiming at sharing of physical process modules with the regional model (SCALE-RM) and application to other planetary atmospheres. We are developing Martian SCALE-GM by incorporating constants and physical process modules of the Martian atmosphere. The Martian physical modules are taken from DCPAM (https://www.gfd-dennou.org/library/dcpam/), an existing pan-planetary atmospheric general circulation model (GCM). DCPAM is a traditional, hydrostatic GCM using a spectral method for horizontal discretization.

We have ported a Martian atmospheric radiation model (partially, Forget et al., 1999) and a soil model from DCPAM to SCALE-GM and performed a high-resolution calculation with 1.9 km grid-intervals by following settings. The atmosphere model has 36 layers, and distribution of dust is fixed with 0.2 optical depth. The soil model has 18 layers. Soil's heat capacity and thermal conductivity are set to 9.7×10^{5} [J K^{-1} kg^{-1}] and 0.076 [W m^{-1} K^{-1}], respectively. Surface albedo is fixed at 0.5. For the calculation of surface fluxes and vertical diffusion, BH91B95 (Beljaars & Holstang, 1991; Beljaars, 1995) and MY2.5 (Mellor & Yamada, 1982) are used, respectively. The initial condition is the 200 K constant temperature atmosphere and soil. Note that a high albedo was used and the topography and the moist processes were not included in the above calculation.

In this study, we introduced a parameterization of dust lifting (Kahre et al., 2006) and the gravity

sedimentation process (Lin & Rood, 1996) to the Martian SCALE-GM, and enable it to calculate dust processes of lifting, advection, and sedimentation. First we aimed to explore effects of the vertical convection and associated large surface stress that are expressed by non-hydrostatic high-resolition model to dynamical processes of the dust. We performed calculation with radiatively inactive dust (i.e., radiation do not depend on the dust distribution). The figure shows zonal-mean distribution of dust's mixing rate and the lifting rate averaged over 5 days after 26-day time-integration from the initial state, for horizontal grid-intervals of dx = 60 km, 30 km, and 15 km. A large amount of dust reaches high altitudes (upper panels) in the higher-resolution case. This can be because of the higher dust-lifting rate (lower panels) and more active vertical convection in the higher-resolution case. In our presentation, we will show and discuss the results of calculations with radiatively active dust too.

Keywords: Martian atmosphere, global simulation, non-hydrostati model