Model development for a global, high-resolution, and non-hydrostatic simulation of the Martian atmospheric circulation

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Scales of atmospheric motions in Earth range from a few meter scale to the planetary scale, and multi-scale phenomena interact with each others. This is a reason for promoting an atmospheric simulation with higher resolution. The situation must be 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 storm of a several tens of kilometer scale, and to global dust storm—have been observed. However, interactions among 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 important 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 post-K computer. SCALE-GM (https://scale.aics.riken.jp/) 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.

In this study, we are developing the Martian SCALE-GM with a careful comparison of the results of two GCMs by keeping in mind the differences in the governing equations and the discretization methods. For the first step, we changed the planetary and atmospheric constants to the Martian ones, and performed an idealized experiment (Mischna & Wilson, 2008) in which radiative processes are simplified to the Newtonian cooling and heating, with both GCMs. Then, we confirmed that the similar wind and temperature fields were obtain for both models. Next, we have ported the Martian radiative process modules in DCPAM to SCALE-GM. To check the ported programs, we performed a 1D-vertical radiative experiment simplified from the 1D Martian atmospheric experiment (Takahashi, http://www.gfd-dennou.org/library/dcpam/sample/2015-02-14_yot/Mars1D/) with both models. The results show a temperature difference of a few Kelvin in the upper atmosphere close to the model top. This would be due to the difference in the upper boundary in both models. In the presentation, we will report such progress of our development and the latest results obtained on the current K computer.

Keywords: Martian atmosphere, model development, global non-hydrostatic model, high-resolution

