Modeling of the General Circulation of the Martian Atmosphere: Current Status of the Mars GCM

Yoshiyuki Takahashi[1], Hitoshi Fujiwara[2], Hiroshi Fukunishi[3], Yoshi-Yuki Hayashi[4], Masatsugu Odaka[4]

[1] Science, Tohoku Univ., [2] Graduate School of Science, Tohoku University, [3] Department of Geophysics, Tohoku Univ., [4] Earth and Planetary Sci., Hokkaido Univ.

We present outline of the Mars general circulation model (GCM) which has been developed in our group by referring to the intercomparison results of Mars GCMs reported at the Mars atmosphere modeling and observation workshop which was held in Spain at January, 2003. We describe the simulated characteristics of the general circulation, especially the structure of the Martian Hadley circulation. In recent years, the time- and spatial resolutions of meteorological data, such as temperature, dust opacity, and column abundance of water ice cloud and water vapor, of the Martian atmosphere are improved by the Mars Global Surveyor (MGS) observations. Development of numerical models and study with them are now actively performed, since we are now ready to start quantitative discussion on the Martian general circulation based on the accumulation of these observational data. Under those circumstances, we have developed our own Mars GCM and performed some numerical experiments to study the global scale circulation structures of the Martian atmosphere and the physical processes that contribute to their formation.

The dynamical core of our Mars GCM is based on the primitive equation system. The absorption and scattering of solar and infrared radiation due to CO2 and dust are considered. The distribution of surface topography and albedo are given from the observational results presented so far. Condensation and sublimation of CO2 are considered in order to represent the atmospheric mass variation associated with formation and dissipation of the polar caps. The results of our Mars GCM simulations show the general characteristics of the retreat of the polar cap, the zonal mean circulation, and the migrating diurnal tide, which are consistent with those obtained by observations and other GCM studies.

At the Mars atmosphere modeling and observation workshop, the results of five Mars GCMs are compared with each other. The performance of five models are roughly similar; the results of our model is not greatly different from the others. The zonal mean circulation and temperature in the dust free case simulated by our Mars GCM is similar to those obtained by the other GCMs, although the zonal mean temperature in the lightly dusty condition simulated by our model is significantly higher than those of the others. It is recognized that, in order to reveal the cause of difference among the results of different GCMs, it is necessary to perform a comparative numerical experiment which specifies the physical parameters and the boundary conditions in more detail. For this purpose, our GCM is asked to improve the scalability to realize a calculation with the higher spatial resolution.

By the use of our Mars GCM, we have investigated the effects of topographic north-south elevation difference on the meridional circulation. Even at equinoxes, the meridional circulation below about 20 km altitude has an asymmetric pattern with respect to the equator owing to the north-south elevation difference of the ground surface. The mean meridional circulation below about 20 km altitude is driven by convective heating whose magnitude is controlled by the potential temperature of the surface mixed layer. The value of potential temperature tends to be higher in the southern hemisphere than that in the northern hemisphere, since the surface elevation is the higher in the southern hemisphere. Consequently, the magnitude of convective heating in the southern hemisphere is larger than that of the northern hemisphere, which results in the asymmetric mean meridional circulation. The result suggests that the large scale wind convergence associated with meridional circulation tends to occur in the southern hemisphere in the Martian atmosphere. It is consistent to the frequent occurrence of dust loading in the summer southern hemisphere.