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火星大気大循環モデルで表現される火星中層大気子午面循環
Meridional circulation of Martian middle atmosphere represented by a Mars general circulation model

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Observations by Mars Climate Sounder (MCS) onboard Mars Reconnaissance Orbiter spacecraft provided the meridional temperature structure of Martian middle atmosphere up to about 90 km altitude. These observations enable us to compare the model produced middle atmosphere with observational ones and examine the nature of Martian middle atmosphere. In this study, structure of Martian middle atmosphere is investigated by use of a Mars General Circulation Model (GCM).

A planetary atmosphere GCM, dcpam, is used in this study. Dynamical core of dcpam solves the primitive equation system by use of spectral transform method with the finite difference method in vertical direction. The included physical processes are the radiative process, the turbulent mixing process, and the surface processes. Further, a condensation scheme of CO2 is included. By the use of a "Mars mode" of this model, several experiments have been performed. In the experiments, the dust distribution in the atmosphere is prescribed. In the vertical direction, the Conrath-type distribution is assumed. In the horizontal direction, the optical depth is prescribed in two ways. Those distributions will be described below. The resolutions used for this study is T21L32, which is equivalent to about 5.6 degrees longitude-latitude grid and has 32 vertical levels. Under these conditions, the model is integrated for 5 Mars years from an initial condition of isothermal atmosphere at rest. The result during the last Martian year is analyzed.

The model is evaluated by comparing the temperature structure simulated by the model with that observed by the MCS. In the simulation, the dust optical depth is prescribed based on the "climatology", which has been created by averaging dust optical depth observed by Thermal Emission Spectrometer onboard Mars Global Surveyor spacecraft. It is found that the gross features of temperature structure observed by MCS are represented by the model, such as the strong latitudinal temperature gradient at southern middle latitude, and the latitude of highest near surface temperature. However, some differences can also be observed. One of that is the strength of temperature increase in southern middle and high latitude at about 1 Pa pressure level (~60 km). This temperature increase is caused by adiabatic heating in a descending branch of meridional circulation. The difference of this temperature increase between the model and observation implies the failure in representing strength of meridional circulation in the model. One of plausible explanations for the failure would be the lack of representation of the effects of subgrid scale atmospheric waves, such as gravity waves. Similar biases were observed in Earth's atmosphere models without (non-orographic) gravity wave drag parameterization.

In order to examine the driving mechanisms of meridional circulation in the middle atmosphere, three experiments are performed: (I) an experiment with Rayleigh friction in the middle atmosphere, (II) an experiment with diurnally mean solar insolation, and (III) an experiment with zonally averaged surface topography, albedo, and thermal inertia. Those three experiments are intended to examine the effects of subgrid scale atmospheric waves, such as gravity wave, thermal tides, and orographically related waves, such as topographic Rossby waves, respectively. The Rayleigh friction coefficient in the experiment (I) is chosen to reproduce the middle atmospheric polar temperature increase observed by MCS roughly. The difference in peak values of mass stream function at 1 Pa pressure level between each experiment and control experiment at northern winter are 0.2e8, 0.15e8, and 0.15e8 kg/s, respectively. This result implies that the subgrid scale atmospheric waves, the thermal tides, and the orographically related waves contribute to middle atmospheric meridional circulation by the similar degree.

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