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Dependence of the characteristics of an atmospheric general circulation on the planetary parameters from Earth to Mars

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We have been developing an atmospheric general circulation model (GCM) aiming at investigating general circulation of planetary atmospheres, such as the Mars, the Earth, the Venus, and ideal planets which may have some characteristics of exoplanets. Purposes of the model development are to enable us to investigate, with a common dynamical framework, possible varieties of general circulations of planetary atmospheres, and to understand underlying mechanisms that realize the varieties of circulations to extend our knowledge on planetary atmospheres. In the followings, the model which is being developed is described, and some preliminary results of experiments for the Earth- and Mars-like planetary atmospheres are presented.

An atmospheric GCM, dcpam (http://www.gfd-dennou.org/library/dcpam/index.htm.en), is developed with the basis of the Geophysical Fluid Dynamics (GFD) Dennou Club atmospheric GCM (http://www.gfd-dennou.org/library/agcm5/index.htm.en). Dynamical core of dcpam solves the primitive equation system by using spectral transform method with the finite difference method in vertical direction. The included physical processes are the radiative, the turbulent mixing, and the surface processes. Further, simple condensation scheme of CO_2, which does not consider mass change due to condensation, is included for Mars experiment. The radiation models currently implemented in the model are those for Mars' and the Earth's atmospheres. The radiation model for grey atmosphere is also prepared for experiments for ideal planets. In addition, the simple forcing for the dynamical core test of Held and Suarez (1994) and for an experiment of Venus-like atmosphere following Yamamoto and Takahashi (2003) are also implemented.

By the use of this model, several experiments have been performed. In the followings, preliminary results of sequential experiments from an Earth-like to a Mars-like planet are presented. Following six sequential experiments are performed: (I) the Earth experiment, in which Earth's topography and land-ocean contrast are used and planetary radius and length of day in a year are Earth's values, (II) same as (I) but without orographic variation, (III) same as (II) but without ozone heating, (IV) same as (III) but without water/moist processes in the system, (V) same as (IV) but with planetary radius of Mars' value, and (VI) same as (V) but with length of days in a year of Mars' value (669 days). In the experiments (I)-(III), the Earth's land-ocean distribution is used and the climatological sea surface temperature is prescribed on the ocean grid point. Those experiments are performed with the horizontal resolution of T42 and 16 vertical levels. The horizontal resolution of T42 is equivalent to about 2.8 degrees longitude-latitude grid. Under these conditions, the model is integrated for 20 years from an initial condition of isothermal atmosphere at rest. The result during last 10 years is analyzed.

In this study, we focus on the structure of Hadley circulation at solstitial seasons when the structure is asymmetric with respect to the equator. The results show that one of the most important differences in Hadley circulation is caused by existence or absence of water in the system, as expected. It affects intensity and vertical extent of Hadley circulation significantly. This is qualitatively interpreted by the difference in moist and dry adiabatic lapse rate, if the surface temperature does not change significantly. In addition, the difference in planetary radius appears to have some influence on the latitudinal width of Hadley circulation. An additional experiment with quarter of Earth's radius shows that the latitudinal width of Hadley circulation is larger than that in the experiment with Mars' radius. In the presentation, these features will be discussed with showing results of additional experiments.

Keywords: planetary atmosphere, Mars, Earth, general circulation model