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Development of a general circulation model for planetary atmospheres : Simulation of the Earth's atmosphere

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In the solar system, there are several planets which have atmospheres. Those planets show a various surface environments and general circulation structures. Recently, a lot of exoplanets have been discovered so far, and many of those exoplanets would have atmospheres and surface environment on such planets may be very different from those on planets in the solar system. We have been developing a general circulation model (GCM) for planetary atmospheres to investigate a variety of surface environment and general circulation structures. In this presentation, current status of model development is presented, and some results of simulations of Earth's atmosphere are shown. In addition, some results of experiments with several values of obliquity will be reported.

A planetary atmosphere 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. As physical processes, following processes/schemes are included: radiation processes for Earth's atmosphere and Martian atmosphere, turbulent mixing process, cumulus convection parameterization, and large scale condensation process. Amount of cloud liquid water is calculated by solving a prognostic equation with considering turbulent mixing, production by cumulus convection and large scale condensation, and a simple loss process with a constant life time. In the current model, cloud fraction in each grid box is assumed to be one. Surface temperature is calculated by solving a surface heat budget equation and heat diffusion equation in a soil. In our model, a budget model is included to calculate soil moisture. Sea surface temperature can be prescribed with input data or can be calculated with an assumption of a slab ocean.

By the use of this model, simulations are performed with several values of cloud liquid water life time to tune the model to the Earth. In these simulations, climatological distributions of sea surface temperature and ozone are prescribed. Those simulations are performed with a resolution of T42L22, which corresponds to about 2.8 degrees longitude-latitude grid and includes 22 vertical layers. By examining a global mean radiative flux budget at top of the atmosphere, an optimum liquid water life time, which produces minimum net flux at top of the atmosphere, is chosen. A result of simulation with the optimum liquid water life time is compared with observations. A comparison shows that difference in global mean longwave radiation flux, shortwave radiation flux, latent heat flux, and sensible heat flux between the model and observation is less than about 5 W m^{-2}, except for the surface shortwave radiation flux. Global mean surface shortwave radiation flux by the model is different from that by observation by about 12 W m^{-2}. On the other hand, the comparison in the zonal mean circulation between the model and observation shows that the model roughly reproduces characteristic features of zonal mean circulation and its seasonal variation in a real Earth's atmosphere. However, large differences are observed in intensity of meridional circulation, and distributions of zonal wind and temperature in stratosphere.

In the presentation, the details of comparison results will be shown. Further, the results of experiments with different obliquities will also be reported.

Keywords: planetary atmosphere, general circulation model, Earth