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Development of a general circulation model for planetary atmospheres: Single column model experiments

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We have been developing a general circulation model for planetary atmospheres, DCPAM (http://www.gfd-dennou.org/library/dcpam/), to investigate various structures of atmospheric general circulation and surface environments of planets in our solar system and exoplanets. In this talk, some single column model (SCM) experiments by use of the DCPAM are reported. These SCM experiments are useful to check implementation of the parameterizations and to investigate its nature. On the other hand, it is also useful to investigate how a parameterization based on the Earth's atmosphere observations behaves under planetary atmospheric conditions. This study is performed as a part of developing a common physical process library in partnership with groups in RIKEN AICS and Japan Meteorological Agency.

The DCPAM is a general circulation model for planetary atmospheres which some members of GFD Dennou Club have been developing. The model is composed of spectral dynamics based on primitive equation system and physical processes of radiation, turbulence, condensation, cloud process, and surface processes. Further, this model is designed to be used for axisymmetric two-dimensional and vertical one-dimensional experiments with almost no code modifications.

In this study, four kinds of SCM experiments to check parameterizations implemented in the DCPAM: (1) ICRCCM (InterComparison of Radiation Codes in Climate Models; Ellingson et al., 1991) experiment, (2) GABLS2 (GEWEX Atmospheric Boundary Layer Study 2; Svensson et al., 2011) experiment, (3) TWP-ICE (Tropical Warm Pool International Cloud Experiment) experiment (Davies et al., 2013), (4) Mars atmosphere boundary layer experiment. Below, experiments 3 and 4 are described briefly.

In TWP-ICE experiments, atmospheric structure formed by radiation, turbulence, and condensation under an observation-based forcing is investigated. In our TWP-ICE experiment, relaxed Arakawa-Schubert scheme (Moorthi and Suarez, 1992), non-convective condensation by Le Treut and Li (1991), and turbulence by Mellor and Yamada (1982) level 2.5 are used. Experimental results show that temporal variation of precipitation is roughly consistent with other SCM results (Davies et al., 2013). However, relative humidity in DCPAM is lower than those in other SCMs in lower troposphere. We will examine what causes this difference between our and other SCMs.

In Mars atmosphere boundary layer experiments, structure of Martian atmospheric boundary layer formed by radiation, turbulence, and surface processes under a prescribed large scale pressure gradient is investigated. We use turbulence scheme of Mellor and Yamada (1982) level 2.5 in this experiment. The boundary layer height and its diurnal variation represented by the model are roughly consistent with those of previous studies with two- or three- dimensional convection resolving model simulations (e.g., Odaka, 2001). For example, top of the boundary layer on Mars is located about 5 km with a typical atmospheric dust condition.

In future, we will use the SCM experiments as fundamental experiments for other planetary atmospheres.

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