A numerical study on dependence of the Earth's climate on solar constant with a general circulation model

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Solar constant is one of important parameters causing diversity of the planetary climate. Dependence of planet's climate on solar constant has been investigated with one-dimensional energy balance models (EBMs) and general circulation models (GCMs) (e.g., Ishiwatari et al., 2007). Previous studies showed appearances of globally ice-covered solutions, partially ice-covered solutions, ice-free solutions and runaway greenhouse solutions according to values of solar constant for a configureation of ocean-covered planet. Moreover, the coexistence of multiple states for a certain range of solar constant was also shown. In the previous studies, however, effects of land-ocean distribution and non-grey radiation and cloud were not considered. In this study, we use a non-grey radiation based on the atmospheric composition of the present Earth and the land-ocean distributions same as those of the present Earth, and show dependences of the Earth's climate on solar constant and examined changes of various physical variables according to solar constant.

We use a planetary atmospheric general circulation model (GCM), DCPAM5 (http://www.gfd-dennou.org/library/dcpam/). Dynamical process is calculated by solving the primitive equations with a spectral method. Vertical turbulent mixing process is represented by the Mellor and Yamada (1982) level 2.5 scheme. Cumulus convection is represented by Relaxed Arakawa-Schubert scheme (Mootrhi and Suarez, 1992) and non-convective condensation is represented by a scheme of Le Treut and Li (1991). For radiative process, the Earth radiative scheme (e.g., Chou et al., 2001) is used. On the land surface, the surface and soil temperatures are calculated by a soil heat conduction model, and the soil moisture is calculated by a bucket model (Manabe, 1969). To perform experiments with solar constants different from the present Earth, a slab ocean with depth of 60 m is used for ocean area. Resolution used in this study is T21L26. By the use of the model, we performed 12 experiments with various solar constants and various initial conditions to explore dependence of the Earth's climate on the solar constant. The given solar constant ranges from
1100 Wm^2 to 1500 Wm^2.

We obtained annual mean fields with various values of solar constants and the relationship between solar constant and ice line latitude. We examined existences of globally ice-covered solutions, partially ice-covered solutions, and ice-free solutions, which had been discovered by Ishiwatari et al. (2007). Further, we investigated initial condition dependence of the system with examining several partially ice-covered solutions with different ice lines under the same value of solar constant by the use of the general circulation model and the energy balance model.

Keywords: climate, solar constant, atmospheric general circulation model, energy balance model, globally ice-covered state, runway greenhouse state

