Multiple equilibrium solutions of a gray atmosphere model with ice-albedo feedback

Masaki Ishiwatari[1]; Kensuke Nakajima[2]; Shin-ichi Takehiro[3]; Yoshi-Yuki Hayashi[4]

[1] Graduate School of Environmental Earth Science, Hokkaido University; [2] Dept. of Earth & Planetary Sci., Faculty of Sci., Kyushu Univ.; [3] Earth and Planetary Sci., Kyushu Univ.; [4] Earth and Planetary Sci., Hokkaido Univ.

http://wwwoa.ees.hokudai.ac.jp/~momoko

Multiple equilibrium solutions of gray atmosphere are investigated for various values of solar constant. The models used are a one-dimensional energy balance model (EBM) and an atmospheric general circulation model (GCM). The value of surface albedo is set to 0.5 for the regions whose surface temperature is below the freezing point, and 0 for other regions.

The results of numerical calculation with EBM show that the equilibrium solutions are classified as follows:

* Ice-covered solutions.

Equilibrium solutions in which all of the surface is covered with ice.

* Stable partially ice-covered solutions.

Equilibrium solutions with ice line latitude between 30 degree and 70 degree. There exists no ice in the lower latitudinal region.

* Partially ice-covered solutions with large ice cap.

Equilibrium solutions with ice line latitude between 0 degree and 30 degree. The instability of the solutions is referred to as large ice cap instability.

* Partially ice-covered solutions with small ice cap.

Equilibrium solutions with ice line latitude between 70 degree and 90 degree. The instability of the solutions is referred to as small ice cap instability.

* Stable no ice solutions.

Equilibrium solutions with no ice. Global mean surface temperature increases with the increase of solar constant.

* Unstable no ice solutions.

Equilibrium solutions with no ice. Global mean surface temperature decreases with the increase of solar constant.

Under certain ranges of solar constant, some kinds of equilibrium solutions coexist: there are multiple equilibrium solutions. For instance, with the value of solar constant for the present earth, there exist an ice-covered solution, a partially ice-covered solution with a large ice cap, a stable partially ice-covered solution, a partially ice-covered solution with a small ice cap, and an unstable no ice equilibrium solution. Moreover, there is a range of solar constant where all kinds of equilibrium solutions mentioned above coexist.

Numerical calculations with GCM show that the overall features of dynamical structure of the solution branches are similar to those of EBM, although the range of solar constant for each kind of equilibrium solution to exist is changed.