A Climate regime diagram obtained by a general circulation model: Toward the investigation on presence condition for liquid water

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It is often discussed that the habitability of life requires the presence of liquid water on planet's surface. In this presentation, our numerical results obtained by general circulation model (GCM), related to the condition for the presence of liquid water,are shown, and future problems are discussed.

The occurrence conditions of the runaway greenhouse state and the globally ice-covered state are important for considering the existence condition of liquid water.The runaway greenhouse state emerges under the condition with the incident energy flux to planet larger than the upper limit of atmospheric radiation. In a runaway greenhouse state, all of surface water evaporate eventually, liquid water cannot exist on the planetary surface. A globally ice-covered state is a state in which all of the planetary surface are covered with ice, and liquid water does not exist on the surface. For the presence of liquid water on planet's surface, neither the runaway greenhouse state nor the globally ice-covered state should be prevented.

We obtained a climate regime diagram which shows possible climate states according to the value of solar constant, with performing GCM calculations of the runaway greenhouse state and the globally ice-covered state (Ishiwatari et al., 2007).The model utilized is a GCM with simplified physical processes including gray radiation.External parameters, such as rotation rate, radius of planet, and the meridional distribution of incoming solar flux, are given referring to the present Earth condition. The value of solar constant is varied. For intermediate values of solar constant, the GCM result indicates the existence of multiple solutions which include the runaway greenhouse state in addition to the globally ice-covered state and the partially ice-covered state.Under the decreased solar constant, only the globally ice-covered state are permitted.When the value of the solar constant is increased, only the runaway greenhouse state emerges. In our GCM, a partially ice-covered state with the ice line latitude of 22 degree is obtained.In this partially ice-covered state, ice area reaches lower latitude compared to the results of one-dimensional energy balance models(Budyko, 1969; Sellers, 1969).

The above mentioned results are obtained for model configuration based on the present Earth condition. In order to investigate the occurrence conditions of the runaway greenhouse state and the globally ice-covered state for ancient solar system and extra-solar planet systems, a number of calculations under various configurations are needed. Abe et al. (2005) already has performed a GCM experiment for ancient Mars, and has examined globally ice-covered states obtained with land-planet configuration. More search for possible climates through such GCM experiments and examinations of atmospheric structure obtained by the experiments are necessary. For the purpose, GCM with flexibility for changing the model configurations, and reduced models (ex. vertical 1-D model, axisymmetric 2-D model) used for describing GCM results, should be developed.