

Resolved Clouds on Snowball Planets

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Exo-terrestrial planets within the habitable zone have attracted scientists in astronomy and related fields, such as planetary science and astrobiology. Although the definition of the habitable zone is a region from the host star where a terrestrial planet can maintain liquid water on its surface over a geophysical timescale, we know that the surface environment has been dramatically affected by changes in the climate system from the history of the Earth. On the Earth's history, it has been thought that there were at least three global freezing events, called the snowball event.

One of remaining mysteries on snowball planets is how much clouds were covered and how the maintenance and/or deglaciation of the snowball climate could be affected by the cloud radiative forcing. While several studies have argued this issue using a general circulation model (GCM), we have yet to reach a robust conclusion partly because of uncertainties in the representation of clouds in a conventional GCM. In the present study, we use the Nonhydrostatic ICosahedral Atmospheric Model (NICAM), known as a global cloud/cloud-system-resolving model, to reveal atmospheric equilibrium states on snowball planets. Under an aqua-planet configuration with reduced solar constant, we conduct a $O(10)$ -year atmospheric simulation coupled to a slab ocean (1-m mixed layer depth) at 14-km horizontal mesh with explicit convection, and then we obtain the quasi-stable atmospheric circulations above the freezing sea surface. In this presentation, we show the climatological mean states of large-scale circulations, precipitation, and clouds, and evaluate the energetics quantitatively. Also, we will discuss whether the cloud radiative forcing has a significant impact on the deglaciation of the snowball.

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