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The Condition Dividing Aqua Planets and Land Planets: Effects of Water Amount on Planetary Climate

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Liquid water on the planetary surface is essential for habitability of the planet. There are two processes that determine water distribution on a planet: the transportation on the planetary surface, which depends on its topography, and the transportation through atmospheric circulation. A planet whose water distribution is controlled by the former transportation is called 'an aqua planet', and the planetary surface is always wet (Kasting. et al. 1993). A planet whose water distribution is controlled by the latter transportation is called 'a land planet' (Abe et al. 2005).

Since a planet with very small amount of water should have the characteristics of a land planet, Abe et al. (2011) performed numerical experiments with general circulation model (GCM) for such planets. They found that liquid water localizes in high latitudes and dry desert appears in low latitudes. They also found that the habitable zones of land planets are much wider than that of aqua planets. Thus, it is important to investigate the condition dividing aqua planets and land planets.

Abuku (2009) considered that a globally linked ocean is required for being an aqua planet. Using mathematical percolation theory, he found that the ocean is globally linked when the ocean covers about 50% of the planetary surface. He concluded that the dividing condition is 50% of the ocean coverage.

However, it is not clear that a globally linked ocean is really the dividing condition. Although lowland area becomes ocean in percolation theory, on a land planet liquid water localizes in high latitudes, which means that lowland area is not always ocean. Therefore we should perform GCM experiments for a planet with topography, and check his result. In this study, we made four kinds of random topography maps and systematically performed numerical experiments with the transportation of liquid water on the surface with various amount of water.

We found that the condition dividing aqua planets and land planets is not sharp, which has not been shown in Abuku (2009). The change from land planet to aqua planet gradually occurs as water content increases. We can classify the climate state into three types: land-planet state, aqua-planet state and the marginal state. We also found that the coverage rate of the ocean rather than water content is essential for that classification. The climate of the planet is like land planet for 0.3 of ocean coverage, aqua planet for more than 0.5 and marginal state for 0.3-0.5.

Keywords: habitable zone, land planet, aqua planet, GCM