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# Evolution from aqua planet to land planet by water loss ; the inner edge of habitable zone

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Liquid water on the planetary surface is thought to be important for the origin and evolution of life. Habitable zone (HZ) has been defined as the region from the central star where liquid water is stable in the planetary surface. Kasting et al.(1993) have estimated the width of HZ around various types of the main sequence stars for the Earth-like planets (called 'aqua planet') which possess the ocean with the present Earth's ocean mass. The inner edge of HZ is determined by water escape and the outer edge of HZ is determined by CO2 condensation. In the results, they estimated HZ ; 90% - 110% of the present solar radiation at 1 AU. Both of the inner edge and outer edge of HZ are controlled by the strong positive feedback mechanism of H2O. On the other hand, Abe et al. [2011,prep] have considered a hypothetical planet with very small amount of water (called 'land planet'). On a land planet, water circulation is limited in atmospheric circulation, and the distribution of ground water is completely determined by the local balance between precipitation and evaporation. Using GCM (general circulation model) they have calculated the inner and outer edges for a land planet. HZ for a land planet is located between 77% and 170% of the present solar radiation at 1AU. HZ on a land planet is about three times wider than that on an aqua planet. Therefore, the amount of water on the planetary surface is important for the width of HZ. Here, we focus on long term processes of water escape and calculate the evolution of water content on the planet. If the water is efficiently lost during stellar age (~10Gy), there is a possibility that an aqua planet changes to a land planet which means that the HZ becomes wider. In this case, the aqua planet inside or outside of HZ would become habitable planets as a land planet.On a hypothetical planet with various initial water contents and distances from central star, we calculate the evolution of water content on the planet and discuss planetary states by considering the hydrodynamic escape of water and star evolutions. In our results, in case of solar type stellar and a planet that initially possesses about 0.1ocean masses, planets change from the mode of aqua planet to the mode of land planet at about 0.7 AU. The planets are classified into "Water planets" (liquid water on the surface), "Steam planets" (runaway greenhouse state) and "Dry planets" (no liquid water on the surface). For the change from an aqua planet to land planet, the following two timescales are essential. One is timescale of loss of ocean by escape. Another is timescale of evolution of central star. When the timescale of loss of water is shorter than the timescale of the evolution of central star, the aqua planets become the land planets. On the other hand, when the latter is shorter than the former, the aqua planets become runaway greenhouse state (Steam planets or Dry planets). It's not always true that extrasolar terrestrial planets have the same amount of the present Earth's ocean mass. The exoplanets that has been discovered so far orbit various types of stars. Generally, the evolution of stars that are lighter than the sun is slow and the evolution of stellar that are heavier than the sun is fast. During the evolution of planets that orbit stars that are lighter than the sun, they could easily change from an aqua planet to a land planet because such planets experience the efficient hydrodynamic escape caused by the slow stellar evolution. On the other hand, the planet that orbits a star that is heavier than the sun becomes the runaway greenhouse state easily. In this presentation, we discuss the evolution of planetary states and the inner edge of the HZ by parameterizing stellar types, the distance form central star, planetary size and initial amounts of water on the planets.