Theoretical prediction of water contents of terrestrial planets with effects of water production in primordial atmospheres

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Because of a growing number of detected exoplanets with Earth-like insolation, it is now important to predict how common Earth-like aqua planets are beyond the solar system. Theoretical predictions so far consider only water delivery from icy or water-rich planetesimals and conclude that planets with Earth-like water contents are rare around M dwarfs, which are the main target of ongoing and near-future observations. On the other hand, a primordial atmosphere of nebular origin itself is capable of producing water through oxidation of the atmospheric hydrogen with oxides in rocky materials from incoming planetesimals or the magma ocean. Thermodynamically, normal oxygen buffers produce water comparable in mass to or more than hydrogen. Thus, the primordial atmosphere would likely be highly enriched with water vapor. However, the properties of such water-rich primordial atmospheres are poorly known. Here we integrate the 1D structure of such an enriched atmosphere and investigate the effects of water enrichment on the atmospheric structure and mass with focus on the water amount. We have found that the mass of the 80 wt.% H_2O atmosphere is larger by a few orders of magnitude than that for solar-abundance atmosphere, and that even a Mars-mass planet can obtain water comparable in mass to the present Earth oceans. Furthermore, by combining the atmospheric structure model and planetary population synthesis model, we have found that the produced water in the primordial atmosphere significantly affects the predicted abundance of terrestrial exoplanets with Earth-like water contents. For more precise predictions, however, detailed investigation about the water production processes such as material mixing in the atmosphere and magma ocean and ingassing of produced water into the magma ocean are required in the future.

Keywords: terrestrial planet, primordial atmosphere, water content

