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Tropopause of steam atmosphere and inner edge of habitable zone

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The inner edge of habitable zone is characterized by two specific limits. The first one is the runaway greenhouse limit at which the oceans evaporate entirely. The limit is estimated by the ratio of radiation limit to net incident solar flux. The second inner habitable zone boundary is water loss limit. If a planet would exist inner region of the loss limit, the planet could not retain water over a period of time sufficiently long to evolve life on the planet. The water loss limit is closely related to the tropopause temperature because the tropopause works as cold trap for water vapor.

Kasting 1988, Kopparapu et al., 2013 estimate two boundaries of inner edge of habitable zone for our solar system. The model pressure-temperature profiles consist of a moist pseudoadiabat extending from the surface up to an isothermal stratosphere. The stratosphere temperature is 200 K. Kasting et al., 1993 notes that this assumption (200 K stratosphere) has negligible effect on the runaway greenhouse limit, but may have a significant effect on the water loss limit. In this study, we calculate radiative transfer for the profiles consist of a moist pseudoadiabat extending from the surface up to top of atmosphere, and estimate tropopause temperature.

Our model pressure-temperature profiles consist of a moist pseudoadiabat (Nakajima et al., 1992) extending from the surface up to top of atmosphere. We assumed an Earh-mass planet with H_2O dominated atmosphere (H_2O and non-absorbed gas). Relative humidity is assumed to be unity. The surface temperature is varied from 250 to 400 K. The amount of non-absorbed gas is varied from 1e+3 to 1e+7 Pa. We use line data for water from the HITRAN2008 spectral database (Rothman et al., 2009), the continuum absorption from MT_CKD 2.5 continuum model (Mlawer et al., 2012) and ultraviolet absorption (Chan et al., 1993). Solar radiation is assumed as a black body radiation of 5800 K. A surface albedo is 0.2 in the wavenumer range from 3000 to 100000 cm^{-1}. A two-stream approximation (Toon et al., 1989) is used to calculate radiative transfer by line-by-line treatment with resolution of 0.01 $cm^{?1}$ wavelength in the range of 0 - 25000 cm^{-1} and resolution of 10 cm^{-1} in the range of 25000 - 100000 cm^{-1}. We estimate tropopause temperature from the heating rate profiles.

We estimate tropopause temperatures of around 150 K. The values are lower than that of previous studies are assumed. The lower temperature indicates that tropapause works stronger cold trap and the water loss limits locate nearer from the sum than that previously reported.

Keywords: steam atmosphere, radiative property, habitable zone, water loss limit