Two humidity regimes of stratosphere on a moist atmosphere

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An inner edge of habitable zone is characterized by runaway greenhouse limit and water loss limit. Kasting et al. (1993) and Kopparapu et al. (2013) estimated these limits by one-dimensional radiation transfer model. These studies assumed the isothermal atmosphere at 200K. This assumption, however, has a significant effect on the water loss limit because the limit is depend on the temperature of cold trap.Kasting et al. (2015) estimated the temperature profiles on planets with N_2, CO_2 and H_2O atmosphere by one-dimensional radiative-convective model. Their calculations suggest that the water loss limit can be estimated by an isothermal model, provided that one uses a stratospheric temperature of 150 K. Leconte et al. (2013) and Wolf & Toon (2015) calculated the temperature profiles by GCM and estimated that the stratosphere temperatures ware 140 ~ 150 K. These models used k-distribution method.Arking & Grossman (1972) estimated the temperature profiles of radiative equilibrium state by using an idealized semi-analytical non-grey radiative model. This study showed that in a non-grey atmosphere, the temperature increases with increasing mean opacity below a certain height and decreases with increasing mean opacity above that height. It also found that there is no lower limit to the temperature at the top of the atmosphere: it can approach zero arbitrarily closely as the width of the lines is decreased. This result implies that estimating temperature of upper part of atmosphere needs a high resolution calculation.In the temperature profiles estimated by previous studies, tropopause pressure is much lower than that in present-day Earth: 1000 ~ 1 Pa. On the other hand, these studies used the modified models from present Earth models. To estimate the temperature of higher tropopause, a radiative transfer model which calculates opacity of each wavelength accurately enough for estimating temperatures in lower pressure tropopause than that of Earth is required. We estimate the temperature by using such a one-dimensional, line-by-line radiative transfer model. The model atmosphere is assumed to consist of H_2O and N_2. The troposphere and stratosphere is assumed to be fully saturated and isothermal, respectively. The value of a heating rate in tropopause are calculated for various surface and tropopause temperatures. The wavenumber resolution of this model is 10^{-4} cm^{-1}, in 0 –3000 cm^{-1}; 10^{-2} cm^{-1}, 3000 –76576 cm^{-1}. The result shows the existence of two regime: one is dry regime, and the other is wet regime. In a dry regime, the tropopause temperature is about 120 K, that is independent of surface temperature. A wet regime, in which water vapor becomes a major constituent, appears when the surface temperature is higher than 345 K. The model atmosphere does not experience a water loss phase, instead skipping directly to a runaway greenhouse.

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