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Control mechanisms of the tropopause level and cloud top in Jovian atmosphere.

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The primary definition of the tropopause of a planetary atmosphere may be the level which divides the convective region and upper stably stratified region. On the other hand, the tropopause is often defined as the level of first temperature minimum which occurs in the temporal-mean vertical temperature profile above the surface. This definition makes it easy to find the tropopause altitude, but it may be an approximation of the true boundary between the two regions, because the stably stratified region possibly includes a layer with negative vertical temperature gradient. This approximation could work for the Earth atmosphere because the change in lapse rate around the tropopause level is sharp and therefore the difference from the primary definition is minimal, but being not sure whether it is applicable for another planet or not.

Equilibrium cloud condensation models (ECCMs, e.g. Weidenschilling and Lewies 1973) and cloud convection models (e.g. Sugiyama et al. 2011) assume that the Jovian atmosphere is enough convective in the region below a level about 0.1 bar, where the temperature minimum exists in the representative temperature profile retrieved by observations. However, we need to revisit it more carefully as mentioned above. In a radiative-convective model of Jovian atmosphere (Appleby and Hogan, 1984), the temperature minimum occurs at a level around 0.1 bar, while the radiative-convective boundary may occur at a much deeper level around 0.5-0.75 bar. It means that the generation of NH3 cloud by convection, a widely accepted picture for the Jovian uppermost cloud formation, may be indeed marginally possible because little NH3 would condense at such deeper level.

In order to understand how the tropopause level is controlled in the Jovian atmosphere, we utilizes a new numerical model of radiative-convective equilibrium in H2-rich atmosphere taking into account the up-to-dated gas absorption models and knowledge on the atmospheric composition. Our model is a 1D radiative-convective equilibrium model for a plane parallel atmosphere. In this model, the temperature of lower boundary (taken 10 bar) is given constant in accordance with the Galileo probe data. We only solve the transfer of long wave radiation with wave number range from 0 to 10,000 cm-1. Here, we use HITRAN2008 database(Ruthman et al. 2009) for line absorption for condensable gas species, and Borysow (1989, 2002) for continuum absorption due to H2-H2 and H2-He collision. The temperature of each atmospheric layer is changed step by step according to the calculated amount of radiative heating or cooling until it converges into the steady state, or radiative-convective equilibrium state with applying convective adjustment for the unstable layer. Atmospheric compositions are given within the range consistent with the Galileo probe experiment.

From our preliminary results, it is confirmed that the tropopause by primary definition is formed around 0.5 bar level almost independent on the mixing ratio of condensable species. Note that the temperature tends monotonically decreases with altitude for most cases because the solar heating is neglected in these calculations. If the solar heating was included, the tropopause level would likely shift deeper. Our obtained temperature profiles are compared with the NH3 condensation curves, showing that little NH3 condensation occurs within the convective region when given nominal NH3 concentration or below. On the other hand, a NH3 condensable layer spans above the tropopause. This implies that the uppermost cloud layer of Jovian atmosphere would be mostly composed of stratospheric cloud and/or convective cloud associated with upwelling penetrating stratosphere. Because the uppermost cloud play an important role in determining the planetary albedo, model development for cloud formation in the stratosphere would be essential to understand the radiative energy budget in the Jovian atmosphere.

Keywords: Jupiter, Atmosphere, Cloud, Tropopause, Radiative transfer