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Estimation of Cooling Rate for H2-He Atmosphere with Radiative Convective Equilibrium Model

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In planetary atmosphere, it is generally thought that vertical convection is one of the major power sources of any atmospheric circulations. Intensity of these convections is dependent on atmospheric cooling rate, and atmospheric thermal structure is maintained by the equilibrium of this cooling and heating by convection carrying energy from lower hot atmosphere. This mechanism can be also occurred in the case of Gas Giant Planets, such as Jupiter, which have a thick atmosphere mainly consisted of hydrogen molecules.

In our study, we computed the radiative features and tried to reveal how they are determined, with calculation of energy transportation by radiation and convection in H_2-He atmosphere. We assumed plane parallel atmosphere, and calculated radiative transfer with formulations based on Appleby and Hogan (1984) in range 0.002-2 bar supposing the present Jovian atmosphere. The atmosphere consists of H_2 and He, and we took into account the collision induced absorptions of these molecules (Borysow 1988, 2002) as opacity sources. We calculated radiative trasfer for each 10 cm^{-1} bin over range 10-990 cm^{-1}. The solar radiation is neglected. At lower boundary, temperature was fixed and the flux from lower atmosphere was given by diffusion approximation. After the calculation of radiative transfer, we determined if the convective instability occurs at each layer, and gave dry adiabatic temperature profile for the entire unstable layers. We repeated these sequences until the time variation of thermal structure becomes small enough. Then, we got the energy equilibrium thermal structure.

In our results, the calculated vertical profile of cooling rate is almost consistent with the previous study by Sromovsky et al. (1998) base on the data of Galileo probe. The profile has a peak at 0.7 bar. At this level, optical depth for all wavenumber becomes nearly 1, so emission can effectively go through outward to space. This is the reason why such a profile is maintained. The peak value of cooling rate is 0.016 K/day, and which is much smaller than the typical value of the Earth's tropopause. This is due to the much lower temprature of the Jovian atmosphere. We also found that cooling rate approaches zero toward lower boundary. This might mean that the lower boundary of troposphere exists around 2 bar.

Keywords: gas giant planet, atmosphere, cooling rate, radiation, convection