Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-02 会場:A03 時間:5月26日 12:15-12:30

The radiative cooling and the solar heating in Jovian troposphere
The radiative cooling and the solar heating in Jovian troposphere

高橋 康人 [1*] ; はしもと じょーじ [3] ; 石渡 正樹 [1] ; 高橋 芳幸 [2] ; 杉山 耕一朗 [4] ; 大西 将徳 [2] ; 倉本 圭 [1]
TAKAHASHI, Yasuto[1*] ; HASHIMOTO, George[3] ; ISHIWATARI, Masaki[1] ; TAKAHASHI, Yoshiyuki O.[2] ; SUGIYAMA, Ko-ichiro[4] ; ONISHI, Masanori[2] ; KURAMOTO, Kiyoshi[1]

[1] 北海道大学, [2] 神戸大学, [3] 岡山大学, [4] 宇宙科学研究所
[1]Hokkaido University, [2]Kobe University, [3]Okayama University, [4]ISAS

For Jupiter, the atmospheric energy balance is important to understand not only its characteristic atmosphere circulation but also the thermal history over 4.5 Ga. To estimate effects of solar heating and thermal radiation cooling, radiative transfer models are useful. Some previous studies discussed the heating rate in the stratosphere in order to analyze the mechanism of thermal inversion layer formation (Yelle et al., 2001), whereas that in troposphere has been little treated because the temperature profile can be simply explained by the adiabatic profile. However, the tropospheric thermal balance must be important because this region emits the major part of Jovian thermal radiation and allows cloud activities by generating the convective instability.

So far, we have been developing a radiative-convective equilibrium model to calculate the thermal structure of H_2-rich atmosphere. By using this model, here we examine how major condensable gases (H_2O, CH_4, NH_3) and isolation affect the cooling rate profile in jovian troposphere. For this purpose, we solve 1-D radiative transfer equation in a plane-parallel, non-gray, cloud-free atmosphere over 0-25,000cm^{-1} which covers both the planetary radiation and solar radiation. H_2-He collision induced absorption (Borysow 1992, 2002), H_2O, CH_4, NH_3, PH_3, H_2S and GeH_4 line absorptions (HITRAN2012), and Rayleigh scattering are considered as optical parameter. Canonical mixing ratios of these heavy species are given as three times the solar abundance, respectively. Depletion of condensable species due to condensation is also taken into account.

From our results, we found that the cooling is strongly affected by thermal emission from gaseous NH_3 associated with slight contribution from H_2 and He. The cooling rate profile shows a peak around 0.59 bar and its value is -2.3x10^{-7} K/sec. The calculation without NH_3 shows peak (-6.6x10^{-8} K/sec) around 0.8bar. H_2O and CH_4 have little contribution in upper troposphere, but their contribution increase in deep atmosphere (below 1bar). Solar radiation with wave number between 2,500-10,000 cm-^{1} (wavelength of 1-4 micron meter) significantly heats stratosphere, but its effect becomes weaker as pressure increases, then almost vanishes below 1 bar level. Solar radiation with higher wave number between 10,000-25,000 cm^{-1} (0.4-1 micron meter) almost uniformly heats the stratosphere (7.1x10^{-8} K/sec) and its effect also becomes weaker in the deep atmosphere. Those heating compensate the radiative cooling, and change the sign of heating rate from minus to plus below 1.2 bar level.

These results show that the cooling in troposphere is virtually dominated by NH_3. One might consider that our estimation depends on the abundance of NH_3 in the deep atmosphere, which is not well constrained at present. But the atmospheric cooling occurs basically in the upper troposphere where the NH_3 abundance follows the saturation vapor pressure curve. Therefore, the uncertainty in NH_3 abundance in deep atmosphere may have a limited effect on the cooling profile in troposphere. More significant factor may be the abundance of H_2S relative to NH_3. It is expected to be 1/3 if we assumed solar abundance, but the actual abundance is poorly constrained especially for H_2S. If the ratio becomes higher, the cooling rate profile is greatly changed because of loss of NH_3 gas owing to NH_4SH formation. It indicates that unknown H_2S abundance is an important factor that controls not only NH_4SH cloud formation but also convective activities in the upper troposphere.

Keywords: Jupiter, radiative transfer, thermal equilibrium, troposphere, cooling rate