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Numerical Modeling of Moist Convection in Giant planets

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It is now widely accepted that moist convection is a common phenomenon in giant planets atmosphere. The moist convection is thought to play an important role in determining the mean vertical structure of the atmosphere; the mean vertical profiles of temperature, condensed components, and condensible gases in the moist convection layer is thought to be maintained by the statistical contribution of a large number of clouds driven by internal and radiative heating/cooling over multiple cloud life cycles. However, the averaged structure of the giant planets atmosphere and its relationship to moist convection remain unclear. For the purpose of investigating the above problem, we developed a cloud resolving model and investigated a possible structure of moist convection layer in Jupiter′ s atmosphere with using the model (Sugiyama et al., 2009, 2011, 2014). In this presentation, we perform two-dimensional calculations of moist convection and demonstrate a possible structure in the atmospheres of Saturn, Uranus, and Neptune.

The basic equation of the model is based on quasi-compressible system (Klemp and Wilhelmson, 1978). The cloud microphysics is implemented by using the terrestrial warm rain bulk parameterization that is used in Nakajima et al. (2000). We simplify the radiative process, instead of calculating it by the use of a radiative transfer model. The model atmosphere is subject to an externally given body cooling that is a substitute for radiative cooling. Because the vertical profile of net radiative heating is not observed in giant planets except Jupiter, the layer between 2 bar level and the tropopause, which corresponds to the observed cooling layer in Jupiter, is cooled. The body cooling rate is set to be 100 times larger than that observed in Jupiter′ s atmosphere in order to save the CPU time required to achieve statistically steady states of the model atmosphere.

The domain extends 960 km in the horizontal direction. The vertical domains are 400 km for Saturn case and 600 km for Uranus case and Neptune case, which are based on the one-dimensional thermodynamical calculation (Sugiyama et al., 2006). The spatial resolution is 2 km in both the horizontal and the vertical directions. The temperature and pressure at the lower boundary is also based on the thermodynamical calculation. The initial temperature profile follows adiabatic from lower boundary to tropopause and is constant above the tropopause. The abundances of condensable gases used in the each calculation are taken at 0.1, 1, 3, and 10 times solar.

The results obtained in Saturn case with 1 times solar abundance of condensible gases are discussed below; the results of other planets and the dependency on the abundances of condensable gases will be demonstrated at the meeting. The major characteristic of vertical motion in the moist convection layer obtained in Saturn case is that downdrafts are stronger than updrafts; this characteristic is obviously different from that obtained in Jupiter case (Sugiyama et al., 2009). Sugiyama et al. (2009) demonstrates that the vertical motion in the moist convection layer of Jupiter is characterized by narrow, strong, cloudy updrafts and wide, weak, dry downdrafts. On the other hand, the characteristics of mean vertical structure are consistent with those obtained in Jupiter case. Due to the active transport associated with convection, considerable amounts of H_2O and NH_4SH cloud particles exist above the NH_3 condensation level, while the mixing ratios of all condensible gases decrease with height from the H_2O condensation level. The stable layer associated with the H_2O condensation level acts as a fairly strong barrier for vertical convective motion; the vertical profile of root mean square of vertical velocity has local minimum at this level.

Keywords: atmosphere of giant planets, moist convection, numerical modeling, cloud resolution model