Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS04-02 Room:105 Time:May 21 14:30-14:50

A 2D numerical simulation of atmospheric convection with condensation of major component under early Mars condition

Tatsuya Yamashita[1*], Masatsugu Odaka[1], Ko-ichiro SUGIYAMA[1], Kensuke Nakajima[2], Masaki Ishiwatari[1], Yoshi-Yuki Hayashi[3]

[1]Hokkaido university, [2]Kyushu university, [3]Kobe university

In the early Martian atmosphere, it is suggested that the major component has condensed in wide area, and scattering greenhouse effect of CO_2 ice cloud contributed to the warm climate (Forget et al., 2013). The scattering greenhouse effect depends on the cloud distribution, and convective motion would play an important role in formation and distribution of the cloud. However, the structure of atmospheric convection with condensation of major component is poorly understood.

Colaprete et al.(2003) suggests that the convection due to buoyancy associated with condensation of major atmospheric component occurs if critical saturation ratio (Scr) is greater than 1 and surrounding air is kept supersaturated. However, Colaprete et al.(2003) only simulates by using 1D cloud model. It is necessary to perform 2D fluid model simulation for further investigation.

We have been developing a two-dimensional cloud resolving model including condensation of major component and performing preliminary numerical simulations under polar night condition in present Mars (e.g. Yamashita et al., JPGU 2012). In this study, we perform numerical simulation under the early Mars condition and investigate dependencies of Scr and number density of condensation nuclei ($N*$) on the flow field and cloud distribution of the convection.

The governing equations are the quasi-compressible system with condensation of major atmospheric component(Yamashita et al., 2012). Cloud particle grows only diffusion process and we assume that supersaturation is maintained if cloud density is less than the threshold (10^{-6}kg/m^3). It is physically equivalent that we consider the critical radius of cloud particle that grows diffusionally. Instead of solving atmospheric radiative transfer equation, we give horizontally uniform cooling from 0 km to 50 km height and Newtonian cooling above 50 km height. The value of cooling rate is 0.1 K/day (Kasting 1991). The surface pressure is 2.0 x 10^5 Pa and the surface temperature is fixed at 273 K. The initial temperature profile follows dry adiabat below 20 km height, and saturation vapor pressure from 20 km height to 50 km height, and isothermal above 50 km height. We set the value of Scr as 1.0 and 1.35 (Glandorf et al., 2002), and we set the value of $N*$ as 5.0 x 10^8, 5.0 x 10^6, and 5.0 x 10^4 /kg (Forget et al., 2013). The computational domain is 100 km in the horizontal direction and 80 km in the vertical direction. The spatial resolution is 500 m in the horizontal direction and 400 m in the vertical direction.

In the case for Scr = 1.0, the horizontally uniform cloud layer emerges quasi-stationarily above the condensation level. Vertical velocity in cloud layer is much smaller than those below the condensation level, and it is 0.5 m/s at a maximum. These characteristics do not depend on $N*$. In the case for Scr = 1.35, cloud distribution depends on $N*$. As $N*$ is less than 5.0 x 10^8 /kg, condensation and non-condensation periods occur alternately. In the condensation period, vertical velocity in the cloud is 2-3m/s. In the non-condensation period, horizontally uniform cloud layer forms, and the cloud density is less than the threshold for condensation (10^{-6}kg/m^3). Vertical velocity in the cloud layer is 0.5 m/s at a maximum.

We conclude that the spatial and temporal structure of cloud convection with condensation of major component vary greatly with the values of Scr and $N*$, and there are two types of solutions, which are a quasi-stationary solution that cloud distribution and flow field do not change in time drastically, and a quasi-periodic solution that condensation and non-condensation periods occur alternately.

Keywords: condensation of major atmospheric component, carbon dioxide ice cloud, cloud resolving model, early Mars