Basic numerical experiments on two dimensional moist convection including condensation of major atmospheric component

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

[1] Department of Cosmosciences, Hokkaido Univ.; [2] Dept. of Earth & Planetary Sci., Faculty of Sci., Kyushu Univ.; [3] Department of Earth and Planetary Sciences, Kobe Univ.

We performed numerical experiments on convections of Martian atmosphere using two dimensional cloud convection model including condensation of major atmospheric component.

On present Mars, CO_2, which is the major atmospheric component, condenses and forms ice clouds in polar region or upper-level of equatorial region(Pettengill and Ford, 2000; Montmessin et al., 2006). It is thought that CO_2 condenses and forms ice clouds more widely on early Mars(Kasting, 1991). It is likely that early Mars was warm enough to allow the temperature to be above the freezing point of water. The scattering greenhouse effect of CO_2 ice clouds is proposed as one of the mechanism of warming mechanism(Forget and Pierrehumbert,1997; Mitsuda, 2007). Since this effect depend strongly on size of particles and distribution of clouds, direct numerical simulation of process of CO_2 cloud formation and flow pattern would help us presume possibility of scattering greenhouse effect. The previous works of cloud formation and flow pattern in the system which major component condenses include Colaprete et al.(2003) and Kitamori(2006). However, average states of flow were not investigated in these works. Colaprete et al.(2003) used one dimensional microphysical cloud model including vertical motion, entrainment, and radiative process, thus they don't describe convections explicitly. Although Kitamori(2006) used two dimensional cloud convection model, he made only a test calculation in which a buoyant plume rises.

In our model we use two dimensional quasi-compressible equations including the effect of condensation of major component as governing equations(Odaka et al., 2005). For simplicity, we assume that the atmosphere consists of only CO_2. We consider that cloud particles grow by diffusion. We consider both the case that gravitational fall of cloud particles is included and the case that it is not included. We consider radius and number concentration of condensation nucleus to be constant. We allow supersaturation to be realized and consider critical saturation ratio to be 1.0 or 1.35(Glandorf et al., 2002). Computational domain is 50 km, 20 km in a horizontal, vertical direction respectively. Grid interval is 200 m. Stress-free conditions are applied to vertical boundaries. In horizantal direction, periodic boundary conditions is adopted. Initial temperature profile is set to be isentropic(165 K)from surface to 4 km high, saturation temperature from 4 km high to 15 km high, and isothermal(135 K) above 15 km high, which is a profile observed along polar cap(Colaprete and Toon, 2002). Radiative forcing is set to be uniform heating from 0 km high to 1 km high, and uniform cooling from 1 km high to 15 km high. Initial disturbance of potential temperature whose maximum amplitude is 1 K is given in the lowest layer of the domain. We carry out time integration for ten days in each experiment.

We obtained the following results. First, each plume is difficult to intrude into cloud layer. Second, growth of convections is promoted by enhancement of downdraft owing to sublimation of clouds. Under our configuration, the difference of temperature between ascending air parcels and the environment doesn't occur, and ascending air parcels gain little buoyancy, then convections are thought to be weak in the cloud layer. And as downdraft comes to the surface, gravity currents are formed. It is thought that growth of convections is promoted by convergence of gravity currents. However, we consider only one specific initial temperature profile or radiation profile, then it is necessary that we calculate under various configurations for assuring generality of these results.