Development of a numerical model for Martian atmospheric convection including condensation of major atmospheric component

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One of the features of the Martian atmosphere is condensation of carbon dioxide which is major component of the Martian atmosphere.Condensation of carbon dioxide almost occurs near the surface in present Mars, while it occurs in the atmosphere in early Mars where atmospheric mass may be much larger than that of present Mars. According to numerical smulation by using one-dimensional radiative convective model with 2 bar carbon dioxide atmosphere, moist adiabatic layer associated with condensation of carbon dioxide emerges between several and 30 km hight and dry diabatic layer exists below the moist adiabatic layer. This structure is similar to that of the terrestrial atmospheric convection which moist convection layer associated with condensation of water vapor exists above shallow dry convection layer below near the surface. However, it is not evident whether the circulation pattern of Martian moist convection is also similar to that of terrestrial moist convection, because water vapor is one of minor components of the terrestrial atmosphere while carbon dioxide is major component of the Martian atmosphere.

In this study, we develop a two-dimensional model including condensation of major atmospheric component in order to simulate the Martian moist convection. The basic equation of the model is based on a quasi-compressible system including source/sink term associated with condensation/sublimation of major atmospheric component in the pressure equation. Atmospheric component is assumed to carbon dioxide only, and cloud is formed by condensation of atmospheric carbon dioxide when saturation ratio exceeds its critical value. The condensation rate is described as a function of saturation ratio and cloud particle radius following to Tobie et al. (2003). Time integration scheme is the time-splitting method where a large time step is used for low-frequency modes and a small time step is used for high-frequency mode associated with sound wave (Klemp and Wilhelmson, 1978). The source term associated with condensation in the pressure equation and the latent heating term in the thermodynamic equation are treated as high-frequency mode in order to calculate pressure and temperature changes associated with condensation appropriately.

As a preliminary experiment of the Martian moist convection, we perform numerical simulation of thermal bubble with condensation of major atmospheric component. Horizontal and vertical computational domain are 20 km, and grid intervals are 200 m. Basic state surface pressure and temperature are 7 hPa and 165 K respectively. The basic state temperature profile is dry adiabatic from the surface to 5 km hight, moist adiabatic from the 5 km to 15 km hight, and constant temperature profile above 15 km hight. The thermal is located at just above the surface initially and its temperature distribution is given by Gaussian which maximum amplitude is 2 K. The result of numerical simulations show that the amount of cloud and its distribution are sensitive to critical saturation ratio given as a external parameter.The buoyancy of thermal is lost when the thermal penetrates to the condensation layer, since the temperature of thermal is adjusted to the basic state saturation temperature. It suggests that vertical mixing is suppressed in the Martian moist adiabatic layer.