Development of a three dimensional non-hydrostatic model for Martian atmosphere and a numerical simulation of thermal convection

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Thermal convection in the Martian atmosphere is a major thermal transport process near the surface, and the horizontal temperature difference which results from the thermal convection influences on large scale circulation. Rafkin et al. (2001) develop a three dimensional non-hydrostatic model for the Martian atmosphere based on RAMS which is for terrestrial atmosphere (Pielke et al., 1992), and perform a numerical simulation of thermal convection in the Martian atmosphere with background wind and typical dust radiative heating. The result shows that the horizontal and vertical scales of convection cell in day time are about 3 km and 5 km respectively, and the vertical wind velocity associated with thermal convection reaches 10 m/sec. Toigo et al. (2003) perform a numerical simulation of thermal convection with typical dust radiative heating and investigate effect of background wind velocity on generation of vertical vortex like dust devils by using Mars MM5 based on another three dimensional non-hydrostatic model for terrestrial atmosphere, MM5 (Dudhia, 1993).

In these previous studies, background wind and radiative heating due to dust are introduced to their numerical models for comparisons with observational results. To reveal features of thermal convection in the Martian atmosphere, however, it is necessary to perform a numerical simulation without background wind and dust radiative heating. Odaka et al (1998) and Odaka (2001) perform such numerical simulations, though they use two dimensional anelastic model. In this study, we develop a three dimensional non-hydrostatic model based on the two dimensional quasi-compressible model developed by Sugiyama et al. (2006, JPGU) and perform a numerical simulation of thermal convection in the Martian atmosphere without backgound wind and dust raditive heating for validation of the numerical model.

The basic equation of the model is based on quasi-compressible system (Klemp and Wilhelmson, 1978). The subgrid scale turbulent parameterization and the surface heat and momentum fluxes are following to those of Odaka et al. (1998). The atmospheric radiative transfer is not calculated explicitly, and a horizontally uniform body cooling is introduced below 5 km height. The amplitude of body cooling is the same value of parameterized convective heating calculated by one-dimensional model (Haberle et al., 1993). The computational domain extends 20 km horizontally and 10 km vertically. The horizontal and vertical grid intervals are 200 m and 100 m, respectivly. The horizontal boundary is cyclic. The vertical velocity is set to be 0 m/sec at the upper and lower boundaries. The ground surface temperature is fixed to be 270 K. Initial atmospheric temperature profile is adiabatic (245 K) below 5 km height and isothermal (220 K) above 5 km height. Random potential temperature perturbation with maximum amplitude is 1 K are given at the lowest level grid point to cause convective motion. The model is integrated for 12 hours.

The horizontal scale of updraft region of simulated thermal convection is several km. The ratio of updraft area to downdraft area is roughly 0.5, and the upward wind velocity reaches 15 m/sec while the downward wind velocity is about several m/sec. The upward wind velocity and potential temperature deviation of convective plume are same order of magnitude as those simulated by using two dimensional version of our model, while the horizontal mean convective heating is smaller. At the lowest level of the three dimensional model (z = 50 m), isolated vertical vortexes whose horizontal scale is about several hundred m are developed frequently. This result suggests that the vertical vortexes like dust devils may be naturally developed accompanied with the convection motion without background wind.