A numerical simulation of the Martian atmospheric convection: response to diurnal forcing

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Possible behavior of the Martian atmospheric convection driven by diurnal thermal forcing is investigated numerically by the use of two-dimensional model which has a resolution enough to represent convective motions explicitly. The thermal forcing has a prescribed vertical profile determined by simplifing the results obtained by the one-dimensional models and the observations. The calculated time evolution of convection is qualitatively similar to the one-dimensional model results. When the convection is fully developed, the cell aspect ratio is 2:1, the potential temperature deviation reaches 1 K and the characteristic vertical and horizontal wind velocity is 10 m/sec and 5 m/sec respectively. These values may be easily generated by the realistic thermal forcing of the Martian atmosphere.

1. Introduction

The major thermal forcing of the Martian atmosphere is sensible heat from the surface and radiation. Since the radiative time constant is short and the surface thermal inertia is small, the diurnal variations of the radiative forcing and the surface temperature are very large. Observations of the Viking mission show that the magnitude of diurnal variation of the surface temperature is about 100 K. One-dimensional radiative convective model by Savijarvi (1991) shows that the radiative forcing has its maximum just above the surface. The amplitude of diurnal variation is 10 K/day at 5 km height and 100 K/day near the surface.

In the Martian lower atmosphere, convective motions would have large diurnal change due to the large diurnal variation of radiative forcing and surface temperature. However diurnal change of convective motions are unknown. One-dimensional models by Savijarvi (1991) and Haberle et al. (1993) estimate parameterized convective heat transport, but do not describe time evolution of convective motions. We will demonstrate here dynamical structure of the Martian atmospheric convection with the diurnal thermal forcing by the use of two-dimensional model which has resolution enough to represent convective motions explicitly.

2. Model

The governing equation of the model atmosphere is anelastic system. Calculation of turbulent diffusion coefficient follows Klemp and Wilhelmson (1978). The surface flux parameterization is given by Louis (1979). The model horizontal domain is 51.2 km and vertical domain is 10 km. Horizontal and vertical resolutions are 100 m. The diurnal variation of the surface temperature is given by simplified form of the result obtained by the Viking observations. The radiative forcing is given under 5 km, whose vertical profile and magnitude of diurnal change are given by following the results of Savijarvi (1991). Initial conditions of atmosphere are at rest and constant temperature(220 K). Calculation time is 3 days.

3. Results

The calculated time evolution of the thermal structure is qualitatively similar to the one-dimensional model results by Savijarvi(1991) and Haberle et al. (1993). The development of the convection is rapid and routhly follows the time evolution of radiative forcing. As the thermal forcing reduces, the convection becomes weak and terminates at sunset. The characteristic aspect ratio of convection is about 2:1. Potential temperature deviation in the convection layer reaches 1 K, when the convection is most active. At LT=12:00-16:00, when the convection is fully developed, the characteristic vertical and horizontal wind velocities are 10 m/sec and 5 m/sec respectively.

The value of potential temperature deviation is similar to potential temperature difference in thermal boundary layer. The calculated value of wind velocity is consistent with the potential temperature qdeviation. These values of wind velocity may be easily generated by realistic thermal forcing in the Martian atmosphere.