A numerical simulation of internal gravity wave generated by thermal convection in the Martian atmosphere

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http://www.gfd-dennou.org/arch/odakker/

1. Introduction

The major constituent of the Martian atmosphere, CO2, is dissociated to CO and O by ultraviolet radiation in the Martian middle atmosphere. The concentration of CO and O in the Martian middle atmosphere estimated by simple photochemical equilibrium, however, is much larger than that observed by spacecraft. In order to understand the observed concentrations of CO and O by using a 1D photochemical model, following two processes must be considered [1]: the HOx catalytic chemical reaction which promotes recombination of CO and O, and the vertical eddy diffusion which transports the source of HOx, H2O, from lower to upper atmosphere. The value of vertical eddy diffusion coefficient in the 1D photochemical model is from 10e+3 to 10e+4 m^2/sec at 40 to 100 km hight [2].

The vertical eddy diffusion may result from mixing due to wave breaking. One of the candidates responsible for the wave breaking is vertically traveling internal gravity wave which is generated by thermal convection in the lower atmosphere. However, the intensity of vertical mixing due to the internal gravity wave breaking is not examined well. In this study, we perform a direct numerical simulation of propagation of internal gravity wave generated by thermal convection in the lower atmosphere, and estimate the intensity of vertical mixing associated with the internal gravity wave.

2. Model

Numerical simulation is performed by using the 2D anelastic model developed by Odaka et al. (2001). The atmospheric constituent is assumed to be CO2 only and air-bone dust is not considered. Detail descriptions about the 2D model and it s physical parameters can be seen in Odaka et al. (2001).

The computational domain extends to 51.2 km horizontally and 50 km vertically and the model horizontal boundary is cyclic. Both horizontal and vertical grid interval are 200 m except in the lowermost 200 m hight, where the vertical resolution is enhanced. The solar flux at the top of model atmosphere diurnally changes under the condition of Ls = 100 at 20 N. Initial condition is motionless atmosphere which has horizontally uniform temperature. The vertical profile of initial atmospheric temperature is calculated by using 1D radiative convective model, which has the same representation of radiative and grand thermal process as that of the 2D model. The numerical integration is started at LT = 6:00 and performed for 24 hours.

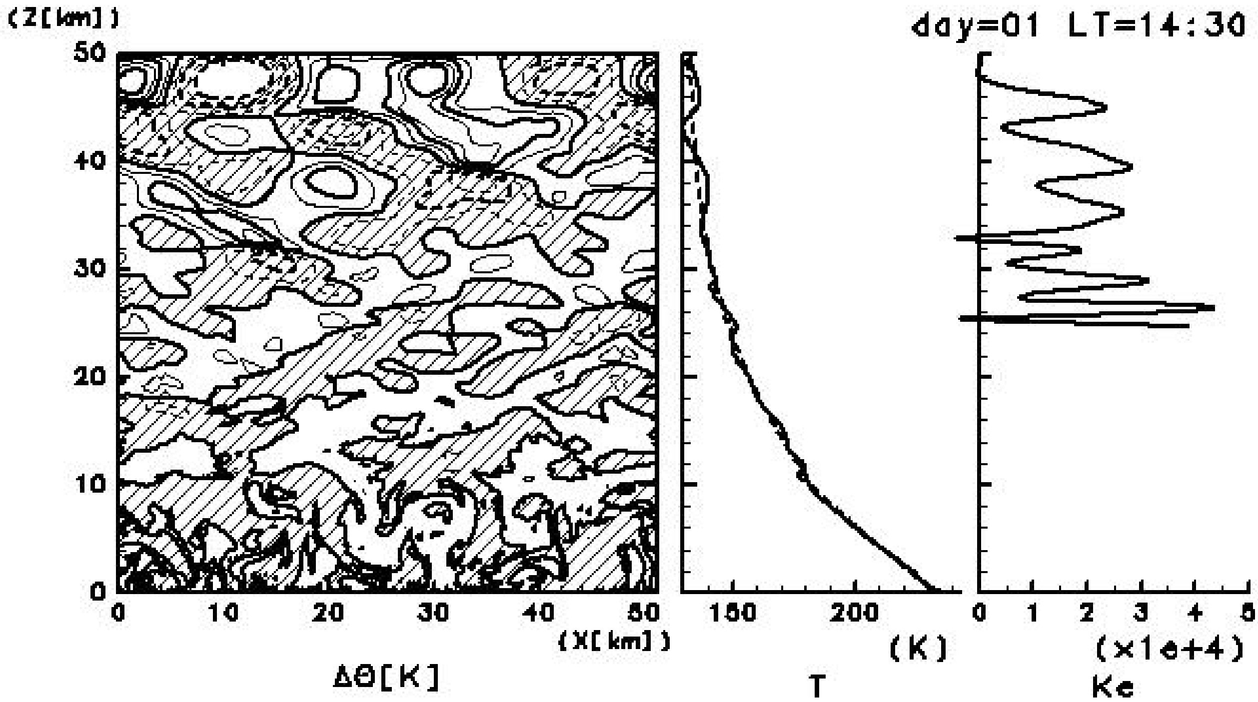
3. Results

Figure shows the numerical simulation results at LT = 14:30. The depth of the rmal convection layer is about 10 km at the time. The internal gravity waves which propagate in stratosphere are generated by penetration of the convective plumes to stratosphere. The horizontal and vertical wavelength of the internal gravity waves are from 15 to 20 km and about 10 km, respectively (left panel). The temperature deviation associated with the internal gravity waves is about 10 K around 40 km hight (middle panel).

By using the ratio of calculated value of vertical heat flux assoated with the wave motion to that of vertical profile of horizontal mean potential temperature, we can estimate the value of effective vertical diffusion coefficient, Ke. It is the vertical diffusion coefficient when the vertical diffusion is only responsible for the heat flux. The horizontal mean value of Ke above 25 km hight has the same order of magnitude of that used by the 1D photochemical model of Nair et al. (1994) (right panel). The result suggests that the the internal gravity wave generated by thermal convection in the Martian lower atmosphere contributes to the vertical mixing in the Martian middle atmosphere.

4. References

[1] McElroy, and Donahue, 1972: Science, 177, 986-988.
[2] Nair et al., 1994: Icarus, 111, 124-150.
[3] Odaka et al., 2001: Nagare Multimedia, http://www.nagare.or.jp/mm/2001/odaka/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30
20
10
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0
10
20
30
40
50
(X[km])
ΔΘ[K]
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200
(K)
T
0
1
2
3
4
5
(x1e+4)
Ke