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Modeling of the Venus atmospheric circulation with a new radiation transfer model

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Abstract

In order to investigate the Venus atmospheric circulation, a new radiative transfer model have been constructed. Preliminary results on the mean meridional circulation have been obtained by using a two-dimensional axisymmetric model combined with the grey radiative transfer model.

1. Introduction

Numerical simulations have been made actively for the Venus atmosphere in recent years [2, 3, 5, 10, 13]. In most general circulation models (GCMs) used in these simulations, the radiative process is represented by the Newtonian cooling. However, this approximation (or simplification)cannot be justified for the Venus atmosphere whose opacity is extremely large in the infrared region. In order to investigate the Venus atmospheric circulation, we must develop a radiative transfer model (RTM) applicable to the Venus atmosphere and incorporate it in a GCM.

2. A radiative transfer model

The Venus atmosphere consists of the vast amount of carbon dioxide (CO_2), which leads to high pres- sure and high temperature in its lower atmosphere. In this situation, representation of the CO_2 absorption lines is quite important for constructing an accurate RTM. In the present study, we calculated temperature distributions in the radiative and radiative-convective equilibrium states by using several line profiles so far proposed [1, 6, 9, 12]. It is noted that collision induced absorption (CIA) is also taken into account [7]. A RTM used in this calculation is based on the correlated k-distribution method. A wavenumber region of 0–6000 cm^{-1} is taken into account, which is divided into 30 channels.

Results can be summarized as follows: (1) Temperature profiles close to the observed one can be obtained for the line profiles proposed by [1] and/or [6], (2) A realistic RTM for the Venus atmosphere may be constructed by using these line profiles, (3) In the radiative equilibrium states, the temperature profiles are super-adiabatic from the surface to 10–80 km (the top level depends on the CO_2 line profiles), and (4) In the radiative-convective equilibrium states, a convective layer is formed from the surface to 30–50 km. The temperature at the surface strongly depends on the temperature at the cloud bottom. See [11] for more details.

3. Mean meridional circulation

Prior to numerical simulations by the GCM incorporated with the new RTM, we constructed a two-dimensional axisymmetric model combined with the grey radiative transfer model and examined the mean meridional circulation. In this simplified model, pressure dependence of the absorption coefficient is an important (unknown) parameter. In the following calculations, we examine two cases where (1) the absorption coefficient is constant (i.e., independent of pressure) and (2) that is proportional to pressure.

Figure 1 shows mean meridional circulation obtained for the case 1. In this case, a convective layer is confined to a layer adjacent to the surface. The meridional circulation extends from the surface to about 7 km. Vertical convection cannot be observed except in the lowest layer near the equator. The temperature deviation and meridional velocity are about 2 K and 2 $\mathrm{m\,s^{-1}}$, respectively. It is noted that the temperature distribution and meridional circulation obtained in this case can be explained clearly by the theory of the horizontal convection [4].

In results obtained for the case 2, convective motion is observed in the whole atmospheric layer (not shown). The meridional circulation extends to the upper layer. The temperature deviation and meridional velocity are about 0.05 K and 0.5 $\mathrm{m\,s^{-1}}$, respectively, which are considerably smaller than those obtained in

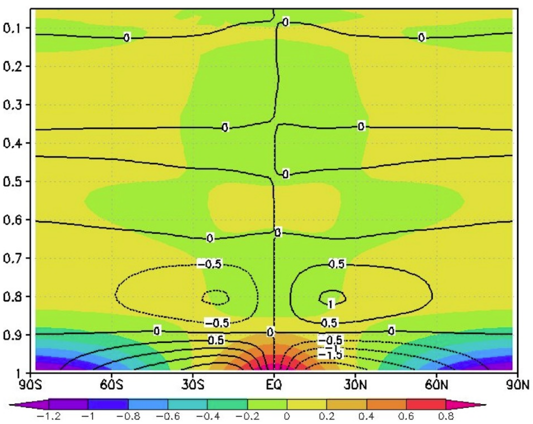

Figure 1: Mean meridional circulation obtained for the case 1. Horizontal and vertical axes are latitude and height (σ levels), respectively. Colormap and contour lines indicate temperature deviation (K) and meridional wind velocity ($\mathrm{m\,s^{-1}}$), respectively.

the case 1.

4. Concluding remarks

The results obtained in the present study are consistent with [8] which is based on the dimensional analysis proposed by Golitsyn. However, the meridional temperature deviation and meridional flow obtained by the GCMs (e.g., [13]) are considerably larger than those obtained in the present study. Moreover, there is a possibility that the meridional temperature deviation is balanced with the mean zonal flow even in the lower Venus atmosphere. In such a case, it may be expected that the meridional temperature deviation and meridional circulation can become larger and smaller, respectively.

In order to simulate the Venus atmospheric circulation and investigate the generation mechanism of the atmospheric superrotation, we are going to carry out numerical simulations with a three-dimensional GCM combined with the new RTM.

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