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Effects of mesospheric wind on the propagation of planetary-scale waves

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Abstract

General circulation in the Venusian mesosphere (70 - 110 km) is an important factor for the upward propagation of atmospheric waves. We have investigated effects of the mesospheric wind on the upward propagation of the planetary-scale waves generated in the Venusian cloud deck (50 – 70 km) with a General Circulation Model (GCM). Our GCM covers the altitude region between 80 km and about 180 km. We have performed simulations assuming three different wind velocity distributions at the lower boundary (LB). In case 1, the zonal wind velocity at the LB is 0 m/s. In case 2 and 3, the rigid body rotation with the equatorial wind velocity of 40 m/s and 80 m/s is assumed, respectively. The pressure and temperature at the LB is referred from the empirical model of the Venusian atmosphere (VIRA model) [1]. We imposed the Kelvin wave with the phase speed of about 110 m/s, which was observed from previous observations [2], at the LB. Our simulations show the propagation of the Kelvin wave up to around 130 km in all cases. However, the maximum amplitude of the zonal wind velocity fluctuation is smaller with the faster westward wind at the LB. The decrease of the wind velocity fluctuations is interpreted as the result of the vertical group velocity change of the Kelvin wave which is caused by the decrease of the intrinsic phase speed.

1. Introduction

In recent years, the importance of planetary-scale waves on the dynamics of the Venusian thermosphere has been recognized. Previous observation of the density in the thermosphere suggested the propagation of the planetary-scale waves originated in the cloud layer toward the thermosphere [3]. One of the important factors for the upward propagation of atmospheric waves is the general circulation in the Venusian mesosphere. A previous study [4] estimated the mesospheric wind velocity with the observed temperature distribution and the assumption of the cycrostrophic balance. They suggested that the mesospheric wind velocity could vary depending on the intensity of the superrotation at the cloud top (70 km). In order to understand the upward propagation of atmospheric waves, we must consider some different wind velocity conditions in the mesosphere. In this study, we performed numerical simulations assuming the three different wind velocity conditions at the LB and investigated impacts of mesospheric wind on the propagation of planetary-scale waves.

2. Model

We have developed a new GCM for the Venusian mesosphere and thermosphere, which includes the altitude region from 80 to about 180 km. The horizontal spatial resolutions in longitude and latitude are both about 5.6°. The vertical resolution is 0.5 scale height, which is equivalent to about 1.5 km at about 80 km altitude. We consider the eddy and molecular diffusion, viscosity, and heat conduction in our GCM. The eddy diffusion coefficient is given as in Bougher et al. [1988] except for a maximum value of 5.0×10^2 m^2/s at the tropopause. In this study, we imposed the Kelvin wave with the westward phase speed of about 110 m/s. The information about the Kelvin wave is referred from the previous observations with Pioneer Venus [2, 5]. In this study, we performed simulations with three different LB conditions. In all cases, the meridional profiles of temperature and pressure are referred from the VIRA model [1]. In case 1, the zonal wind velocity is 0 m/s at all latitudes and longitudes. The zonal wind distributions at the LB in the case 2 and 3 are assumed to be the solid body rotation with the equatorial velocity of 40 and 80 m/s, respectively.

3. Result

3.1 Background wind

In case 1, the calculated zonal-mean zonal wind is about 0 m/s at all grids. In case 2 and 3, the westward wind given in the LB decays with height rapidly and becomes about 0 m/s at around 90 km (Figure 1). Previous study suggested that the superrotation at the cloud top (about 70 km) can be maintained up to the thermosphere in the assumption of the cycrostrophic balance [4]. There is a possibility that the rapid vertical attenuation of the westward flow seen in our results is caused by the break of the cycrostrophic balance. In our simulations, the break of the cycrostrophic balance occurs at around 88km since the direction of the pressure gradient becomes equatorward above around 88 km.

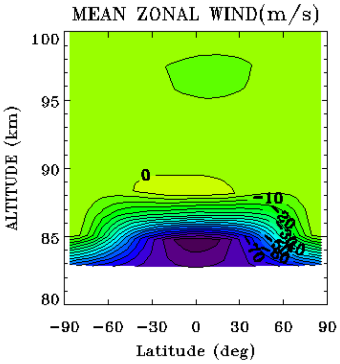

Figure 1: Zonal-mean zonal wind distribution calculated with the LB wind velocity of solid body rotation whose amplitude is 80 m/s at the equator.

3. 2 Upward propagation of Kelvin wave

In all cases, the Kelvin wave propagates upward up to about 130 km. However, the maximum intensity of the zonal wind fluctuation caused by the Kelvin wave is smaller when we assume the stronger westward flow at the LB. The change of the maximum amplitude of the Kelvin wave is caused by the change of the vertical group velocity. In general, the atmospheric wave with the smaller intrinsic phase speed has the smaller vertical group velocity. The atmospheric wave with the small vertical group velocity is attenuated effectively by wave damping processes (e.g., eddy diffusion and radiative damping). Since the Kelvin wave has the phase speed of about 110 m/s, the intrinsic phase speeds near the LB are 110, 70, and 30 m/s when we assume the LB wind velocity of 0, 40, and 80 m/s, respectively.

4. Summary and Conclusions

In this study, we performed simulations assuming the wind velocity distribution of the solid body rotation with the equatorial wind velocity of the 0, 40, and 80 m/s at the LB. In all cases, the zonal-mean zonal wind is about 0 m/s above around 90 km. This result indicates that the characteristic change of the wave propagation depending on the change of the LB wind velocity is caused below about 90 km. In all cases, the Kelvin wave propagates up to about 130 km. However, the maximum wind velocity fluctuation is smaller with the stronger LB wind velocity. The change of the wave amplitude is interpreted as the results of the vertical group velocity change.

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