Two dimensional numerical experiment of the Venusian gravity waves by using a cloud resolving model

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Atmospheric gravity waves influences the atmospheric circulation due to the heat and momentum transports associated with their propagation and breaking. Recently gravity waves are often observed in the Venusian atmosphere by optical and radio occultation measurements (e.g. Peralta et al. 2008; Ando et al. 2015). Convection in the Venusian cloud layer, which is located at 50 to 70 km altitudes, is thought to be one of the main sources of the gravity waves. We have investigated the convective motion and wave generation and propagation due to it by using two dimensional numerical model (Ando et al. JPGU 2014) and found that the reproduced gravity waves satisfy the dispersion relationship, but wave amplitude and energy depend on the resolution and numerical viscosity set in our model. In this presentation, we change the resolution and numerical viscosity and examine the shape of the energy spectrum obtained in each case to determine the appropriate resolution and numerical viscosity to reproduce the gravity waves. Furthermore, we show the energy spectrum distribution and calculate the acceleration rate associated with the momentum convergence in the vertical direction in the case where we use these appropriate values.

We use a cloud resolving numerical model “deepconv” (Sugiyama et al. 2009). The horizontal domain is 500 km, and the vertical domain corresponds to 35 to 135 km altitudes in the Venus atmosphere. There are no stress, vertical flow and potential temperature flux at the upper and lower boundaries. Side boundary is a periodic one. To prevent the wave reflection at the upper and lower boundaries, we introduce Rayleigh friction within 35 km down from top boundary and 5 km up from bottom boundary. To prevent generation of the mean zonal wind we also add <s>the</s> artificial friction to zonal wavenumber 0 component. Newtonian cooling is also introduced in our model on the basis of Crisp (1989). Initial vertical temperature profile is based on Ikeda et al. (2010), who derived the temperature distribution under the radiative-convective equilibrium. This profile has a neutral stable layer within the altitude rage of 48-54 km and a stable layer above and below it. We use net solar heating and infrared radiative cooling profiles based on Ikeda et al. (2010), assuming that they are horizontally uniform and do not change temporally. We assume that the atmosphere is stationary at the initial stage. To generate convective motion potential temperature perturbation with the maximum amplitude of 1 K at 50 km altitude, and we perform the numerical calculation for 15 Earth days. Horizontal resolution is constant of 200 m, and we use three vertical resolution cases (16, 32, 64 m) and four numerical viscosity cases (1×10^{-4}, 3×10^{-4}, 1×10^{-3}, 3×10^{-3}, 1×10^{-2} m s^{-2}).

As a result, in the case where vertical resolution is less than 32 m and numerical viscosity is less than 3×10^{-3} m s^{-2}, all the calculated spectral amplitude are almost equal. Within the altitude region of 66 to 98 km, where gravity waves propagate upward, the spectral amplitude decreases with the altitude. The spectral slope is about -2 within the horizontal wavenumber range of $10^{-4} < k < 10^{-3}$ (1/m) and -3 of $10^{-3} < k$ (1/m). In particular, the spectral slope in the former case is consistent with that empirically suggested on the basis of the observations of gravity waves in the Earth’s atmosphere. Furthermore, the acceleration rate in the horizontal direction associated with the wave dissipation increases with altitude, and it is ~1 m s^{-1} day^{-1} at 90 km altitude.

Keywords: Venus, Atmospheric gravity waves, Numerical calculation