Topographic waves in the Venus atmosphere

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Akatsuki observations show that large bow-shaped features extending about 10,000 km across the equator from the north polar region to the south polar region, whose zonal wavelength is estimated to be several thousand km at the cloud top level in the Venus atmosphere (Fukuhara et al., 2017). It has been pointed out that these features are gravity waves generated by the surface topography, because they stayed above Aphrodite terra for four Earth days without being advected by the atmospheric super rotation. The bow-shaped features have been also observed over Atla regio and Beta regio located in the equatorial region. Interestingly, the features have not been observed over Ishtar terra located in the north pole region. It has been also pointed out that the bow-shaped features are often identified in the late afternoon (Kouyama et al., 2017)

Young et al. (1987, 1994) investigated the vertical propagation of the gravity waves in the Venus atmosphere. Their results show that vertical winds observed by the VEGA-2 balloon could be explained by the gravity waves excited by Aphrodite. It should be noted, however, that the waves which have long zonal wavelength as seen in Akatsuki observations could not propagate up to the cloud layer. Recently, Lefevre et al. (2019) showed that the bow-shaped features could be formed at the cloud top level by the topographic waves by using a three-dimensional numerical model. Yamada et al. (2019) also showed that the gravity waves could reach the cloud top level and form the bow-shaped feature though the waves were excited thermally in their model. Though the topographic waves strongly depend on the zonal wind and the static stability of the atmosphere through which they propagate, the Venus deep atmosphere remains unclear because of the thick cloud covering the whole planet. Therefore, we investigated how the topographic waves depends on the zonal wind and the static stability in the lower atmosphere by using a regional nonhydrostatic model named Cloud Resolving Storm Simulator (CReSS). We modified CReSS for the Venus atmosphere, in which the radiative transfer process is simplified by Newtonian cooling and the solar heating is neglected. The vertical profiles of the zonal wind and the static stability are based on the previous observations. Numerical experiments are carried out by changing these profiles to take into account of their temporal variations and/or uncertainties. The range of zonal wind near the surface is between 1–5 m/s, and that of the static stability between neutral and weak stable stratification, based on Young et al. (1987). The preliminary results show that the vertical winds excited by Aphrodite have zonal and vertical wavelengths of 200-1200 km and 80-160 km, respectively. Though the horizontal wavelength is roughly consistent with the results of Lefevre et al., (2019), it seems that the vertical wavelength is not consistent. The horizonal resolution of 40 km may not be enough for the topographic waves excited by Aphrodite. It may be also interesting that the temperature deviations associated with the topographic waves have zonal and vertical wavelengths of about 1200 km and 20 km, respectively, which are different from those of the vertical winds. We will investigate how the topographic waves depends on the zonal wind and the static stability near the surface.