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Kelvin-like and Rossby waves in Venus' super-rotation simulated by a GCM

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Planetary-scale Kelvin-like and Rossby waves with long periods of 117 and 58.5 Earth days and with short periods of <10 Earth days have been observed in the Venus cloud layer (50-70 km height) where the super-rotation is fully developed. We review the dynamics of these Kelvin-like and Rossby waves in a Venus general circulation model (GCM) developed at the Atmosphere and Ocean Research Institute, the University of Tokyo (AORI).[1,2,3]

The most predominant long-period waves are thermal tides such as gravity waves at low latitudes similar to equatorial Kelvin waves (Kelvin-like waves) and tidal gyres such as Rossby waves at high latitudes. The gravity-wave tides are thermally forced at the maximum heating area around the cloud top, where diabatic heating generates eddy available potential energy. The Rossby-wave tides are formed in mid- and high-latitude regions, where diurnal barotropic energy conversion occurs around the zonal-mean jet core and semidiurnal baroclinic energy conversion occurs below the cloud layer far from the solar heating maximum (Figure 1).[3]

The most predominant short-period waves (7.5 Earth day waves in the GCM) comprise three types: a Rossby wave in the upper cloud layer, a Rossby wave around the polar tropopause, and an equatorial Kelvin-like wave around and below the cloud bottom. They are associated with baroclinic and barotropic energy conversions in the vicinity of the critical line. The pair of the Kelvin and Rossby waves at the cloud bottom is a major equatorward momentum transporter contributing to the super-rotation. The equatorial super-rotational flow is accelerated by the rotational zonal flow and meridional divergence (Figure 2a) and by the meridionally-tilting stream function around the (Figure 2b) at low latitudes.[2]

We suggest that the divergent/rotational wind structures and energetics of three-dimensional Matsuno-Gill response and Kelvin-Rossby instability might be important in discussing the dynamical coupling between Kelvin-like and Rossby waves in the super-rotations of Venus and Venus-like planets.

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References

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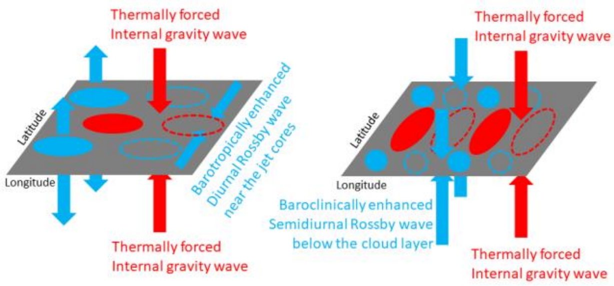

Figure 1. Schematics of three-dimensional structures of diurnal (left) and semidiurnal (right) thermal tides. The gray plane represents the longitude-latitude one at the maximum heating level (65 km) in the cloud layer and the thick arrows represent momentum fluxes of Kelvin-like gravity wave (red) and Rossby wave (blue).

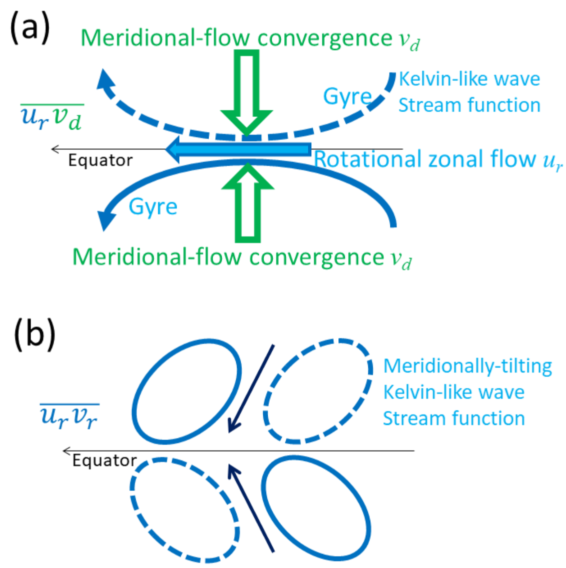

Figure 2. Schematics of the acceleration mechanisms of the equatorial super-rotation by equatorial 7.5 Earth day Kelvin-like wave at the cloud bottom.