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From Hadley Circulation to Superrotation: effects of equator-off heating on the transition of atmospheric circulation

Yasufumi Sekine[1], Hiroyuki Kurokawa[1*], Taishi Nakamoto[1]

[1]Earth and Planetary Sciences, Tokyo-Tech

The oblique angle of planetary rotation axis is thought as one of the most important parameters for the atmospheric circulation. We study the effects of equator-off heating on the transition from Earth-like Hadley cell to Venus-like superrotation. The effect of equator-off heating drives the seasonal variation of the atmospheric circulation.

We use a simple model; axisymmetric primitive equations on the spherical coordinates with the Boussinesq and Newtonian cooling approximation. The thermal Rossby number(RT), the horizontal Ekman number(EH), and the latitude at which radiative equilibrium potential temperature is maximum(f0), are treated as parameters. We construct the numerical calculation model and integrate until the steady-state is established, however for some sets of the parameters the steady-state is not established because of symmetric instabilities. A measure of a rigid rotation, Rg, and a measure of the intensity of superrotation, S, are introduced as Yamamoto et al. (2009). Also we attempt to describe the effects by analytic calculations.

We find that when f0 increases, Rg decreases, and larger EH is needed to transit from Hadley cell to a rigid rotation, because the zonal winds inside and outside the Hadley cells lose the component of a rigid rotation and gain the component of a non-rigid rotation. We make the expression of the divisional latitude between the summer and winter cells as a function of S, RT and f0 for large EH. S decreases with increasing f0 for large EH . In the case of two cells for large EH , the main upward transport of the angular momentum through vertical wind at the divisional latitude between the summer and winter cells is effective and the total transport of the angular momentum through vertical wind is upward because of the difference between the distribution of upward flow and that of downward flow.

Keywords: Atmospheric Circulation, exoplanets