Diversity of atmospheric circulations of tidally locked gas giant planets -- dependence on the incident radiation strength

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Thanks to recent development of observational instruments, the number of discovered exoplanets has been surprisingly increased. In particular, it is considered that there are many tidally locked gas giant planets, whose same hemispherical surfaces face to the central stars (hot Jupiter). General circulations of the surface atmospheres of such gas giants have been investigated using simplified and modified models for the Earth's atmospheric general circulation. One of the prominent characteristics of these simulations presented so far is a strong equatorial prograde jet (equatorial superrotation). However, the condition emerging a equatorial prograde jets is not well understood. Our purpose is to make clear the regimes of atmospheric general circulations of tidally locked gas giant planets through a series of numerical experiments using general circulation models where the parameters of the planetary atmospheres are widely varied, and understand diversity of atmospheric circulations of tidally locked gas giants. In this study, we investigate dependence on the incident radiation strength.

The atmospheric model used for numerical experiments is "DCPAM5" developed by GFD Dennou Club (http://www.gfd-dennou.org/library/dcpam/), which is a three-dimensional primitive model assuming hydrostatic balance in the radial direction. Dual band radiative transfer is adopted to express incident short wave radiation and outgoing long wave radiation. The incident radiation from the central star illuminates only the same hemisphere of the planet at all times. There is no heat flow through the bottom boundary. The parameters characterizing the planetary atmosphere in the model are based on those of the exoplanet HD209458b. Incident radiation strength is varied around the value of HD209458b. Time integrations are performed for various strength of incident radiation. When the incident radiation is as strong as that of the original HD209458b (10^6 W/m^2), strong equatorial prograde jet emerges which penetrates to about 1bar level. The equatorial jet is weakened and becomes shallow as the incident radiation is decreased. Finally, when the incident radiation is as weak as 10^3 W/m^2, equatorial zonal flows tend to retrograde and prograde high latitude jets become dominant. The newly found equatorial retrograde regime of tidally locked gas giants contrasts with that of equatorial prograde flow proposed so far.

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