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# The Atmospheric General Circulation of a Synchronously Rotating Planet and its Dependence on Rotation Rate

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Most exoplanets which have found exist in the visinity of the central star. Those planets are thought to be tidally locked by the central star, and to have fixed dayside and nightside on their surface. Near central stars with small mass and small luminosity (e.g. M star), a synchronously rotating terrestrial planet which has liquid water on the surface may exist.

Joshi et al. (1997) studied the atmospheric circulation of a synchronously rotating planet that has pure CO2 atmosphere by using General Circulation Model (GCM). Their results showed that the temperature in the nightside remains high in the case of the surface pressure is more than 100 hPa. However, no water was included in their model. In this study, we investigat the heat transport of a synchronously rotating planet whose atmosphere include water vapor by using GCM. We consider on the dependence of atmospheric circulation on planetary rotation rate to study how the temperature distribution is affected by the atmospheric circulation.

The model used in this study is dcpam (http://www.gfd-dennou.org/library/dcpam/index.htm.en), which is developed by our group. The ground surface is covered by ocean whose heat capacity is zero. The atmosphere absorbs only longwaver radiation, and absorption coefficient is constant. The condensable component is only H2O. The inclination and eccentricity are assumed to be zero. The planetary radius, average surface pressure, solar constant etc. are set to Earth's values. The number of grid point is 64 in longitude and 32 in latitude. The number of vertical layer is 16. The rotation rate is varied from zero to the Earth's value. Hereafter, Omega is used as a rotation rate normalized by the Earth's value.

Our parameter experiment with varying Omega show that the nightside averaged surface temperature is about 250 K and in the range of 10 K through all experiments. But the values of minimum surface temperature existing in the nightsides are changed in the range of 75 K according to Omega. This value is not a monotonic function of Omega. In the below, the details of atmospheric structure for various Omega are described.

In the case of Omega = 1, heat transport in mid-latitude is dominant. The maxima of the surface temperature is in not only a substellar point but also mid-latitude. Relatively high temperature is observed in a zonal region in the mid-latitude of nightside. Much precipitation by the baroclinic eddy is observed in this region. This result means latent heat transport and condensation heating of water is important to warm the nightside.

In the cases of Omega = 1/50 - 4/5, heat transport from the substellar point to eastward and the direct circulation across the poles are characteristic. For example, any point along the equator is more than 285 K in the case of Omega = 1/3. The global minimum surface temperature emerge in the latitude of 60-70 degrees of the nightside.

In the cases of Omega = 0 - 1/100, heat transport by the direct circulation (from nightside to dayside in lower layers, and from dayside to nightside in upper layers) is dominant. The global minimum surface temperature is in antistellar point. Average surface temperature in nightside is in 240 to 255 K range.

Keywords: synchronously rotating planet, rotation rate, general circulation model, heat transport, exoplanet