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Atmospheric General Circulations of Synchronously Rotating Terrestrial Planets: Dependence on Planetary Rotation Rate

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In order to investigate a variety of climates of synchronously rotating terrestrial planets, a parameter study on the dependence on planetary rotation rate Ω is performed by using a general circulation model (GCM) with simplified hydrologic and radiative processes. The planetary rotation rate is varied from zero to the Earth's value, and other parameters such as orbital parameters, planetary radius, solar constant are set to the Earth's values. The results show that there emerge four typical atmospheric states in ascending order of planetary rotation rate as follows:

1. States in which dayside-nightside direct circulations dominate
2. States in which weak super rotation emerges
3. States in which strong super rotation emerges and meridionally asymmetric patterns oscillate
4. States in which precipitation disturbances emerge in nightside midlatitudinal regions

The atmospheric state is gradually accompanied by a qualitative circulation change from state (1) to state (3) with increasing Ω from zero, although Merlis and Schneider (2010) which performed similar GCM experiments lump together cases with small planetary rotation rates under the term "slowly rotating atmospheres". For cases for planetary rotation rate with the values of 0.75-0.85 times of the terrestrial value, multiple equilibrium solutions of state (3) and state (4) are obtained. It is shown that, in addition to dry atmosphere (Edson et al., 2011), moist atmospheres on synchronously rotating planet also have multiple equilibrium solutions. Although circulation patterns and amount of sensible/latent heat transport from the dayside to the nightside changes with the change of Ω, summation of sensible heat transport and latent heat transport almost remains unchanged, and the dependence of dayside to nightside temperature contrast on Ω is small.