The transition to superrotation in stratospheric atmospheres

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Titan is the only satellite with the developed atmosphere and the stable liquid on the ground surface in the solar system. The history of the observation begins with the suggestion of the existence of the atmosphere in 1908. In the 1970's, the temperature structure and atmospheric composition of the Titan atmosphere have been clarified thanks to the progress of observation technology. Also, in the Cassini-Huygens mission, it visited the Saturnian system, made Huygens probes into the Titan atmosphere, and made high-precision observations. Ground-based submillimeter wave observation by the ALMA telescope is currently being carried out, and it is possible to observe at high resolution.
Observations clearly show the existence of superrotation, which is a high-speed zonal wind oriented to overtake the rotation on a global scale as a characteristic of the Titan atmosphere. The wind speed reaches 100 m/s eastward at about 10 degrees south latitude where Huygens entered, but it is difficult to investigate its mechanism from the viewpoint of insufficient observation data and complexity of atmospheric structure. Also, the theory which unified the generation mechanism of superrotation is not established, and various theories are advocated. Representative examples are the Gierasch mechanism proposed by Gierasch or the mechanism by thermal tidal waves proposed by Fels and Lindzen.
In this research, I conducted numerical experiments to generate superrotation by changing only the planetary radius using the Earth model. We used the numerical simulation model DCPAM5 of the planetary atmospheric general circulation developed by GFD Dennou Club. Primitive equations were used as the basic equation system of the model assuming a dry atmosphere. We used the model of Williamson et al.(1998) which added the pressure dependency of stratosphere to the Newtonian cooling process in Held and Suarez (1994). The calculation time was 1080 days where sufficient stationarity was confirmed, and we analyzed the time average of the physical quantities in last 360 days.
First, I output the temperature field, the mass transport distribution, zonal-mean zonal wind speed field, compare the structure of the atmosphere in the meridional space, and investigate the location and the condition. where superrotation is occurring. In the Earth model, eastward jet streams occurred in the mid latitudes of the troposphere and the stratosphere, but on the equator the westward winds are blowing. If the planetary radius is small, in the troposphere even in the equator the eastward wind is accelerated and superrotation has occurred. In the stratosphere, equator superrotation occurred in the lower stratosphere, but in the upper stratosphere the jet occurred only in the middle and high latitudes, and the high-speed eastward wind did not appear in the equator.
Next, in order to investigate the mechanism of keeping the angular momentum in the upper layer of the equator, the dispersion of the band-like disturbance of the temperature, the band-shaped disturbance spectrum of the east-west wind speed field were output, and the structure of the wave existing in the atmosphere was summarized. In the troposphere in the Earth model, many waves with a wave number of 4 or more existed in the mid latitudes, and angular momentum in the east direction was accumulated in mid latitude. However, as the radius of the planet is decreased, the waves with large zonal wavenumbers decrease, and global waves with the wave number of around one dominate. The behavior is similar in the stratosphere, in the Earth model, waves with large wavenumbers are present, although the waves are weaker in the troposhere as the planetary radius is reduced, only waves with small wavenumbers remain.
In the stratosphere the equator super rotation and the mid-high latitude jet occur in different altitude, and the mechanism for maintaining superrotation seems somewhat different from the mechanism in the troposphere.

