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Polygons formed on the surface of rotating water

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In the terrestrial and planetary atmospheres, vortices that exhibit a polygonal shape are occasionally observed even when the external conditions are nearly axisymmetric. Similar phenomena are also found in laboratory experiments in which water layer in a right cylindrical tank is driven by a rapidly-rotating bottom disk (e.g. Vistas 1990; Jansson et al. 2006; Vistas et al. 2008). However, their formation mechanism has not been clarified yet.
In this study, we have first performed a laboratory experiment in which the rotation rate of the bottom disk and the initial water depth are varied, and have investigated the dependence of the phenomenon on these parameters. When the bottom disk is set into rotation, the water is pressed outward by the centrifugal force and the central region becomes free of water. The shape of this region becomes a polygon with various numbers of corners depending on the rotation rate of the disk and the initial water depth. The number of corners of the polygon increases with increasing the rotation rate of the disk and with decreasing the initial water depth. The angular velocity of the polygon is found to be about 1/3 of that of the disk.
In order to explain the experimental result, we have examined a linear stability of a basic axisymmetric flow, which is obtained by solving the equation of motion without meridional circulation. A linearized vorticity equation for a two-dimensional infinitesimal disturbance superposed on the basic flow is solved to obtain instability waves. The dependence of the wavenumber of the fastest-growing wave on the rotation rate of the disk and the water depth is found to be similar to that of the laboratory experiment: the wavenumber of the fastest-growing wave increases with increasing the rotation rate of the disk and with decreasing the water depth. Furthermore, the phase angular velocity of the fastest-growing wave is about 1/3 to 1/2 of the angular velocity of the disk.
The unstable wave found in the linear stability analysis is caused by a horizontal shear instability of the basic flow, and thus the polygons observed in the laboratory experiments are likely to be caused by a shear instability.

Keywords: rotating fluid, laboratory experiment, shear instability