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Deformation of water surface rotating in a cylindrical tank

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In the terrestrial and planetary atmospheres, the axisymmetry of a vortex occasionally breaks and vortices with various structures are observed. Similar phenomena are observed on water surface in laboratory experiments in which water layer in a right cylindrical tank is driven by a rapidly-rotating bottom disk: the shape of the water surface is modified to be a polygon.

In this study, we have performed the laboratory experiments, focused on the range of the parameter values in which the axisymmetry breaks, and found two interesting phenomena. One is a vacillation in which the water surface oscillates greatly and becomes calm alternately. The other is a hysteresis in which there are two different states for the same rotation rate accordingly when it is increasing and decreasing. We investigated the dependence of these phenomena on experimental parameters: the initial water depth and the rotation rate. The oscillation occurs only in the condition in which the initial water depth is larger than a certain value. As the depth becomes larger, the rotation rate for the oscillation phenomenon becomes smaller, while that for the hysteresis phenomenon becomes lager.

We examined the experimental results using a simple dynamical model. In this model, the current velocity is represented only by two values; inner and outer velocities. The disturbance grows through instability of the axial flow. The exchange of momentum by the disturbance is taken into this model. We succeeded in reproducing the hysteresis as observed in the laboratory experiments with this simple model.

Keywords: rotating fluid, laboratory experiment, oscilation, hysteresis