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Effects of roughness on a vortex-like flow

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To investigate the influence of small-scale topographies on a large-scale geophysical flow, we carried out experiments in a cylindrical tank mounted on a turn-table. To simulate a rough boundary, regular grids of small cylinders were placed at the bottom of the tank. A vortex-like cyclonic flow was generated by the differential rotation of a smooth lid at the surface of the tank. The presence of rough elements increases the radial fluid transport in the bottom boundary layer, providing an additional Ekman friction for the core flow. As a consequence, the vorticity in the stationary core flow is lower than in experiments with smooth boundaries. Radial profiles of azimuthal velocity were inferred from measurements in the middle of the tank, and yield values of the mean drag associated with the cylinders. These experimental values are in good agreement with theorical predictions for the drag due the generation of inertia waves or wakes by the cylinders. However, a pattern of stationary bands also appears in the vertical vorticity field, propagates upwards in the same direction as the core flow, and gradually changes into a pattern of axi-symmetric rings far away from the bottom boundary. We show that these bands are inertia waves generated by divergent and convergent flows in regions near the bottom of the tank, where the cylinders are aligned with the geostrophic flow. As the rotation rate of the lid increases, the axi-symmetric rings become unstable and begin to generate turbulent motions in the outer part of the tank. These experimental results illustrate how, in addition to a mean drag effect, a distribution of rough elements leads to the formation of coherent structures in the core flow and may provide energy for turbulent motions.