CASTS TALKS

Special Program in Applied Mathematics and Applied Mechanics

High-resolution simulations of cylindrical gravity currents in a rotating system

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Cylindrical gravity currents, produced by a full-depth lock release, in a rotating system are investigated by means of three-dimensional high-resolution simulations of the incompressible variable-density Navier–Stokes equations with the Coriolis term and using the Boussinesq approximation for a small density difference. Here, the depth of the fluid is chosen to be the same as the radius of the cylindrical lock and the ambient fluid is non-stratified. Our attention is focused on the situation when the ratio of Coriolis to inertia forces is not large, namely 0.1 $\leq C \leq 0.3$, and the non-rotating case, namely C = 0, is also briefly considered. The simulations reproduce the major features observed in the laboratory and provide more detailed flow information. After the heavy fluid contained in a cylindrical lock is released in a rotating system, the influence of the Coriolis effects is not significant during the initial tenth of a revolution of the system. During the initial tenth of a revolution of the system, the Kelvin-Helmholtz vortices form and the rotating cylindrical gravity currents maintain nearly perfect axisymmetry. Afterwards, three-dimensionality of the flow quickly develops and the outer rim of the spreading heavy fluid breaks away from the body of the current, which gives rise to the maximum dissipation rate in the system during the entire adjustment process. The detached outer rim of heavy fluid then continues to propagate outward until a maximum radius of propagation is attained. The body of the current exhibits a complex contraction-relaxation motion and new outwardly propagating pulses form regularly in a period slightly less than half revolution of the system. Depending on the ratio of Coriolis to inertia forces, such a contraction-relaxation motion may be initiated after or before the attainment of a maximum radius of propagation. In the contraction-relaxation motion of the heavy fluid, energy is transformed between potential energy and kinetic energy, while it is mainly the kinetic energy that is consumed by the dissipation. As a new pulse initially propagates outward, the potential energy in the system increases at the expense of decreasing kinetic energy, until a local maximum of potential energy is reached. During the latter part of the new pulse propagation, the kinetic energy in the system increases at the expense of decreasing potential energy, until a local minimum of potential energy is reached and another new pulse takes form. With the use of three-dimensional high-resolution simulations, the lobe-and-cleft structure at the advancing front can be clearly observed. The number of lobes is maintained only for a limited period of time before merger between existing lobes occurs when a maximum radius of propagation is approached. The high-resolution simulations complement the existing shallow-water formulation, which accurately predicts many important features and provides insights for rotating cylindrical gravity currents with good physical assumptions and simple mathematical models. Reference: https://www.cambridge.org/core/services/aop-cambridge-core/content/view/9CA9F307136371B4B310C7F3522E8783/S002211201600598Xa.pdf/high-resolution-simulations-of-cylindrical-gravity-currents-in-a-rotating-system.pdf

