

Laboratory investigation on baroclinic instability of the river plume over a sloping bottom

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When the river flows into the coastal ocean, it forms a buoyant plume near the river mouth and serves as an important source of terrestrial materials in the coastal ecosystem. Considering only the buoyancy and the earth rotation, river outflow leaving the estuary typically has a two-part structure, a recirculating bulge near river mouth and a coastal current propagating in the downstream direction. The continuous river outflow makes the bulge to expand in size and to accumulate freshwater, and the bulge finally becomes unstable due to the baroclinic instability. To investigate the baroclinic instability in the bulge, we conducted a series of laboratory experiments to simulate an idealized river plume in the northern hemisphere under various Coriolis frequencies, density differences, and shelf slopes. River plume evolution was visualized using optical thickness method, and horizontal velocity fields were measured using particle imaginary velocimetry (PIV) method. Based on the vorticity field, we identified instabilities at different spatial and temporal scales in the recirculating bulge region. At the bulge center, an anticyclonic core continues to grow. Under the condition with a slopping bottom, a persistent coastal cyclonic gyre sits at downstream side of the river mouth, initiating the split of the anticyclonic core. The older core ultimately leaves the bulge system and transports a blob of freshwater downstream, while the new core starts to grow at the bulge center. In the gentle slope case, cyclonic eddies are generated on the front along the edge of the anticyclonic core, propagating downstream around the periphery of the bulge, squeezing the anticyclonic core, and finally peeling off the bulge. The bulge has multiple cores and is much more unstable in this situation. Our results show that the bulge stability is mainly controlled by the shelf slope and the inflow Rossby number. The generation of submesoscale cyclonic eddies on the front may extract the energy from the mesoscale anticyclonic core, and plays an important role in mass transport and frontal mixing.

Keywords: River Plumes, Baroclinic Instability, Submesoscale Processes, Laboratory Simulations