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Experimental Study of Three-Dimensional Obstacle Effect on Velocity Structure of Density Currents

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The density currents' velocity structure, which can be divided into a jet region (JR) and a wall region (WR, thickness h_r) according to their distinct dynamics, may be significantly modified as the current crosses an obstacle, thus leading to variations in the flow propagation process. However, there is a lack of direct observation of the response of different parts of the velocity structure to a three-dimensional obstacle due to the challenges in 3-D flow field measurement. To address this knowledge gap, a series of laboratory experiments have been devised to examine the separate influence of the WR and JR on mixing and propagation processes of density currents. A particle image velocimetry system and a high-speed camera are used to obtain the detailed velocity and vorticity fields with high temporal resolution. Compared with the no-obstacle counterpart that is uniform in the spanwise direction, the time-averaged current height (h_c) in obstacle cases gradually thickens in that direction, and both the WR and JR thicken accordingly. The ratio of the obstacle height (h_o) to h_c influences the velocity structure. Specifically, h_r/h_c upstream is larger than that downstream when $h_o>h_c$, and vice versa. It is noteworthy that the variation of h_r/h_c in the spanwise direction is nonmonotonic with h_o. Furthermore, the obstacle also influences the velocity profile upstream. The flow is obstructed on the center line when $h_o>h_c$. When $h_o<h_r$, the obstacle divides the wall region upstream into two parts above and below h_o, and the gradient of the velocity profiles of the upper one is larger than the lower one. The results suggest that the obstacle plays an important role in determining the dissipation on the interface between the JR and the environment, and changing the current's capacity on carrying the sediment since both the settling and resuspension of particles and sediment mostly happen in the WR. Our findings can improve understanding of the influence of submarine topography and provide a reference for underwater engineering.