Numerical simulation of intrusive gravity currents past obstacles in a continuously stratified ambient

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Abstract. Intrusive gravity currents are buoyancy-driven and environmentally-relevant flows. When an intrusive gravity current encounters topographic features, a rich set of phenomena is expected to occur. In this study, the flow of intrusive gravity currents past a bottom-mounted obstacle was investigated using the FLOW-3D computational fluid dynamics code. The large eddy simulation (LES) model was employed to gain more details about the flow field in this laboratory-scale study. The propagation dynamics of classical intrusive gravity current without topographic effect was first simulated and good agreement between the numerical model and experiments were found. An obstacle was then added to the problem and acted as a controlling factor of the downstream flow pattern. For short obstacles, the intrusion re-established itself downstream in a similar form. For high obstacles, the downstream flow was found to be a joint effect of horizontal advection, overshoot-springback phenomenon, and the Kelvin-Helmholtz instability. The relationship between the downstream constant intrusion speed and the dimensionless obstacle height $\widetilde{D}$ (obstacle height nondimensionalized by total fluid depth) can be subdivided into three regimes: (1) a retarding regime ($\widetilde{D} \approx 0 \sim 0.3$) where 30% increase in obstacle height leads to 20% reduction in intrusion speed, simply due to obstacle's retarding effect; (2) an impounding regime $\widetilde{D} \approx 0.3 \sim 0.6$) where the same 30% increase in obstacle height only leads to a negligible 5% reduction in intrusion speed, due to the accelerating effect of upstream impoundment and downstream enhanced mixing; (3) a choking regime ($\widetilde{D} \approx 0.6 \sim 1.0$) where the remaining 40% increase in obstacle height accounts for the remaining 75% intrusion-speed reduction, due to the dominance of the obstacle's blocking effect. The obstacle thickness was found to be irrelevant in determining downstream intrusion speed. The present work highlights the significance of topographic effects in stratified flows with gravitational forcing and provides a preliminary guidance for the engineering design of retarding facilities for intrusive gravity currents in a continuously stratified ambient.