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Why do some turbidity currents create upstream migrating bedforms while others do not?

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Turbidity currents are the dominant process for transporting sediment from continental shelves to the deep sea via submarine canyons. The small density contrast between turbidity currents and ambient seawater means that many of these currents are in the Froude-supercritical flow regime. Froude-supercritical flows in open channel flows form upstream migrating bedforms such as antidunes and cyclic steps. Turbidity currents have been shown to create similar upstream migrating bedforms in submarine canyons and on steep delta slopes, on a scale of tens of to hundreds metres; but curiously such bedforms are not always observed. Here, using a novel depth-resolved numerical model, we explore the physical controls on upstream migrating bedform development. Why do some turbidity currents create upstream migrating bedforms, and others do not?

A series of turbidity currents, with different initial concentrations, flow velocities, and thicknesses are simulated using a computational fluid-dynamics model. The sediment bed, initially with a random rugosity, is free to be reworked by turbidity currents. Contrary to expectations, we found that Froude-supercritical turbidity currents do not necessarily create upstream migrating bedforms. In isolation, the densimetric Froude number is a poor predictor for the formation of upstream migrating bedforms, unlike in open channel flows. Density stratification instead appears to be more important. The mixing intensity of the flow, as characterised by the gradient Richardson number, is used to quantify the degree of stratification and appears to be a primary control on upstream bedform migration. In the model runs, all flows that created upstream migrating bedforms where stratified, whereas none of the well-mixed flows created these bedforms. All flows that created bedforms had a denser basal layer with a densimetric Froude number above unity, and a mean velocity maximum over a threshold values (1.4 m/s in this case). Our results show that care should be taken when applying depth-averaged or open-channel-based models to upstream migrating bedforms related to subaqueous sediment density flows.