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A Critical Look at the Criticality of Sediment-Propelled Turbidity Currents

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Abstract

In nature turbidity currents are common, and in the deep marine are the principal sediment transporting agents that build up the largest sediment accumulations on Earth. However, these powerful currents are notoriously destructive, and therefore have been largely unexplored. Accordingly, researchers have turned to analyzing them in the lab. Here it is easy to form a suspended-sediment-propelled turbidity current but because of their inherently dense nature, these flows are not amenable to conventional sampling instrumentation. Therefore, most researchers have used variably concentrated saline currents with the implicit assumption, or explicit statement, that they faithfully mimic the dynamics of sediment-propelled currents. Based on that work, two end member kinds of (saline) currents were identified, and differentiated on the basis of flow criticality: subcritical flows have a high velocity maximum below which density is vertically uniform ("plug-like") and above which density decreases rapidly and shows minimal mixing with the overlying fluid; conversely, the velocity maximum of supercritical flows is located at the base of the current, density decreases exponentially away from the bed, and the current as a whole shows extensive vertical mixing. The question, therefore, is under similar hydraulic conditions, are the velocity and density profiles in saline currents representative of those formed in sediment-propelled turbidity currents? In this study, we created a variety of turbidity currents of varying velocity and sediment concentration. However unlike these other studies, this is the first to accurately measure the density profile (here a surrogate for sediment concentration) in natural, sediment-transporting turbidity currents using a medical grade CT scanner. Given similar hydraulic conditions, the two end-member profiles are controlled exclusively by particle size; specifically the velocity, density and mixing characteristics of fine-grained runs were similar to subcritical saline flows whereas coarse-grained runs were similar to supercritical saline flows. Such differences in density and velocity structure will profoundly influence the vertical distribution of momentum through the current, and the degree of vertical mixing, which has important implication for the conservation of flow energy, and therefore run out distance of turbidity currents in the deep sea.