Internal-wave controlled stratification determines seafloor gravity current run-out

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Seafloor gravity currents are flows generated by their density difference from the ambient ocean. Sediment-laden seafloor gravity currents, turbidity currents, can travel for thousands of kilometres, with multiple events forming some of the largest sedimentary landforms on the planet. Despite this, the physical processes controlling the dynamics of these flows remains poorly understood and the long run-out of these flows remains enigmatic. This is predominately due to a lack of observational data enabling scaling of experimental and theoretical models to describe large-scale natural flows.

Self-channelization and stratification, i.e. the vertical variation of flow velocity and density, of gravity currents is known to be fundamental to the long run-out of flows on the shallow slopes of real-world ocean basins. However, extant flow models imply gravity currents rapidly slow through basal friction and the entrainment of ambient fluid. Here it is shown that self-channelization and flow overspill eliminate the adverse hydrostatic pressure gradient associated with ambient fluid entrainment, which stall standard one-dimensional shallow-water flow models. Coupled to self-channelized flow overspill, flow stratification reduces suspended mass loss via overspill, therefore maintaining the driving force of the flow. Further, velocity and density stratification is shown to increase in the stability of flow solutions with decreasing bed slope. Although unstratified flow solutions only remain stable for steep slopes, >0.01 m/m, stratified flow solutions are shown to exist (and remain supercritical) even for very shallow sloped channels, <0.001 m/m.

Despite its importance, and unlike open channel flow, there exists no unified model for stratification of gravity currents on the seafloor. Existing models suggest that due to small-scale diffusive mixing in turbulent flows, flow velocity increases logarithmically away from the seafloor, and then decays with a quadratic exponential (Gaussian) profile like a free-jet. However, such theory is based on limited time- and length-scale experimental and numerical models. Here results are presented from direct observations of a (predominately) saline exchange-flow in the Black Sea and from saline and sediment laden gravity current laboratory experiments. Uniquely high-resolution field, and experimental, data has been obtained over a large range of time- and length-scales. The data suggests, that over long time- and length-scales, internal (gravity) waves drive systematic correlation of small-scale diffusive turbulent fluid motion resulting in unexpected self-organization in stratified gravity currents. This self-organisation influences, and is what ultimately controls, the run-out of seafloor gravity currents.

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