Dynamic stratification enables auto-suspension and thus the ultra-long run-out of sediment-laden buoyancy driven flows

*Robert Michael Dorrell[1]

1. University of Hull

Sediment-laden buoyancy driven flows, turbidity currents, are observed to traverse thousands of kilometers on the seafloor. Such behavior is predicated on auto-suspension, where sediment in suspension provides the motive force to drive the flow and the flow energy is expended keeping sediment in suspension. However, auto-suspension over such distances is enigmatic, as available flow energy is continuously dissipated through raising the centre of suspended mass of the flow. Thus, turbidity currents must ultimately stall and die. However, here a new model for turbidity current flow mechanics is proposed where the potential energy released in the deceleration of dynamically stratified turbidity currents provides sufficient energy to enable ultra-long flow run-out. The new model is validated against the first field-scale observations of a turbidity current traversing the entire length of a submarine canyon-channel system.

Here auto-suspension, and thus the ultra-long run-out of natural turbidity currents, is explained by depth-average dynamic weighting parameters, that appear in system scale shallow water models of turbidity current flow dynamics. In essence dynamic weighting is included to capture the fundamental process, that:

1) Whilst a flow decelerates, turbulent mixing decreases and thus stratification increases.

2) Whilst a flow accelerates, turbulent mixing increases and thus stratification decreases.

As stratification increases, with relative near-bed suspended sediment concentration increasing, the location of the velocity maximum becomes moves closer to the bed. As the velocity maximum is more closely aligned with the most concentrated region of the flow. Moreover, as the relative velocity is concentrated in a smaller region, closer to the bed. The paradoxical results of which is that with increasing stratification, downstream mass and momentum flux becomes more efficient.

As stratification increases the depth average hydrostatic pressure, decreases with the relative center of suspended mass being lowered towards the bed. The critical result is thus that whilst accelerating down steep slopes, where stratification increases, kinetic energy is transferred to, and stored as, potential energy. Yet whilst travelling over more gentle slopes, where the flow decelerates and stratification increases, the center of suspended mass is lowered releasing potential energy to drive the flow over long-distances.

Using dynamic models of flow stratification, turbidity currents traversing canyon-channel systems, over slopes down to 10^{-5} m/m may be predicted for the first time. Here temporally invariant flow, characteristic of the long-duration flows observed in real-world systems, is assumed. The model is applied to the Congo canyon-channel system. In both proximal and distal channel sections, modeled flow velocities match mean flow measurements of a 2004 turbidity current that traversed over 1000 kilometers of the canyon-channel seafloor system (Vangriesheim *et al.*, 2009). Sensitivity analysis shows weak dependence on initial flow conditions, if the flow has sufficient kinetic or potential energy to bypass the proximal

canyon, where it is fully confined. This suggests that flow tuning, through overspill, is a core control on the dynamics of partially confined flows within distal channel reaches.

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