

Multi-Stage Release Gravity Currents

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Recent research, postulating that seafloor density driven flow (turbidity current) deposits may provide a long-term geological record of seismic event frequency and aftershock history [Goldfinger, 2012], has motivated a series of novel experiments looking at the dynamics of multi-stage release gravity current experiments. The experiments have investigated the effect of multi-stage delays in the release of a denser than ambient saline fluid, generating pulsed flows to mimic sequential seafloor slope failure. To relate the experimental flow to real-world scales, the effect of key dimensionless parameters have been considered, including: initial release geometries; dimensionless delay times; ratios of motive to viscous forces. The experiments show that (turbulent) multi-stage release gravity currents merge, i.e. the front position of the second release overtakes that of the first (Figure 1a). That the gravity currents merge is of significant interest in determining how far from source pulsed flow signals may persist and where paleoseismic reconstruction from turbidity current deposits may be conducted.

Density driven flows are subject to frictional drag at their upper and lower boundary, generating a flow with an internal velocity maximum. This vertical variation in velocity means that flow near the centre of the flow is advected towards the head of the gravity current, implying that closely spaced multi-stage flows merge. However, the merging of all multi-stage flows is significantly enhanced by the dynamics of primary and secondary flow release. The initial collapse of primary generates significant entrainment of ambient fluid; this generates a vertically stratified flow whose density tends to that of the surrounding ambient. The secondary flow then forms an intrusion at a neutrally buoyant level within the primary flow, above the flow bed and beneath ambient fluid interface (Figure 1a). As the secondary flow is removed from frictional boundaries it experiences less drag and thus travels faster than the primary flow, enabling flow merging.

Interestingly, it is observed that as the delay time flows is increased, the front position of the primary flow begins to lag behind that of a single stage flow of equivalent volume and density (Figure 1b). This may be explained, as the initial volume of release from the multi-stage flow is smaller than the single stage flow, implying the flow exits the slumping phase of gravity current propagation sooner. Counter-intuitively however, it is later observed that multi-stage flows travel faster than a comparable single stage flow (Figure 1b). This is attributed to the protection that secondary flow intrusions are afforded by reduced basal and interface shear. Thus, in the multi-stage flows the intrusion suffers reduced turbulent mixing and ambient fluid entrainment. This enables multi-stage flows to transport higher solute concentrations, with associated greater velocities, over longer distances in comparison to otherwise equivalent single stage gravity currents.

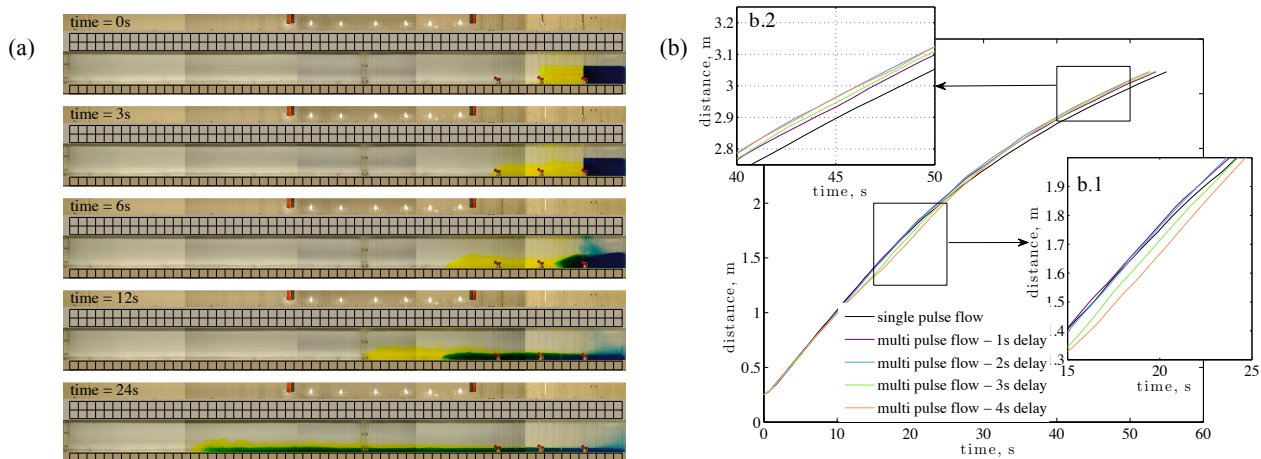


Figure 1. Evolution of a multi-stage gravity current (a), showing: initial flow division (t=0s); collapse of the primary (t=3s) and secondary (t=6s) flow releases; intrusion of the secondary release within the primary flow (t=12s); merging of primary and secondary flows Evolution of the front position (primary flow release) in space and time, as a function of delay time between primary and secondary release. Highlighted is the increasing initial lag of flow, compared with single release flow, with increasing delay time (insert b.1) and the long term increased velocity of the multi-release flows in comparison to the single release flow (insert b.2).

References

[1] Goldfinger, C. (2011). Submarine paleoseismology based on turbidite records. *Annual Review of Marine Science*, 3, 35-66.