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The three-dimensional turbulent structure of steady state gravity currents

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The structure of gravity currents has been extensively studied using both and laboratory and numerical methods. Much of the previous work has focused on lock-exchange type flows that typically result in an exaggerated current head and a distorted turbulence distribution. The work presented herein investigates steady state flows, primarily looking at the structure of the body of the flow. Within most natural flows the body of the flow forms the majority of the current. Similarly, the flow is typically assumed to be two-dimensional within experimental and numerical studies. This study aims to quantify the three-dimensional turbulent structure of steady state gravity currents.

A combination of three-dimensional direct numerical simulation (DNS), planar particle imaging velocity (PIV) and tomographic (volumetric) PIV has been used to investigate the body of pseudo-steady gravity currents, and more particularly the impact of Reynolds and Schmidt numbers on the formation of coherent turbulent structures. These structures are of interest due to their ability to control the distribution of mass, momentum and temperature, as well as their potential impact on erosion and deposition in particle laden flows. PIV was used to investigate a range of Reynolds numbers by considering various slopes with a constant influx, as well as a constant slope with varying influx. DNS, carried out using the spectral element code Nek5000, was used to investigate a range of Schmidt numbers, as well as a potentially wider range of Reynolds numbers than experimentally achievable, with a constant influx and varying slope. Multiple vortex identification techniques were utilised to identify the number and size of structures within the flow.

This study describes the three-dimensional turbulent structure of the body of pseudo-steady gravity current flow for the first time. Both the laboratory and numerical data reveal the complex three-dimensional flow present within gravity currents from a simple ducted domain. The results show that cross-stream and vertical flow velocities within these currents are of very similar magnitude. Turbulence structure is dictated by both the Reynolds and Schmidt number. The impact of these structures on the dynamics was then established: it was found that increasing the Reynolds number results in a greater number of smaller vortices, while increasing Schmidt number suppresses the formation of structures and reduces the thickness of the mixed layer.