EXPERIMENTAL INVESTIGATION OF ENTRAINMENT INTO A GRAVITY CURRENT

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Abstract Entrainment in the presence of a stable stratification is worthwhile studying since — among many other occurrences — it is the essential process governing geophysical flows such as oceanic overflows. For this purpose, a new experimental facility was designed and built. Results of a local analysis with respect to the turbulent/non-turbulent interface will be presented in an attempt to shed light on the role of density differences on interfacial dynamics.

MOTIVATION

The special case of entrainment in a stratified flow is relevant to many geophysical flows such as oceanic overflows that play an important role in global ocean circulation [3]. Despite its relevance, entrainment in the presence of a stable stratification has not been studied experimentally in terms of small scale aspects governing the physics close to the turbulent/non-turbulent interface (TNTI). In view of the fact that existing engineering concepts (e.g. by [2]) require fine tuning to every application case [1], we designed and built a new gravity current facility with the goal of gaining understanding of how stratification affects interfacial physics.

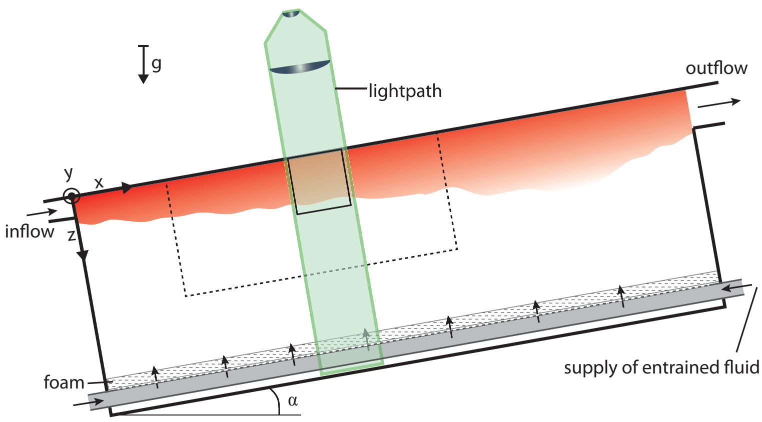
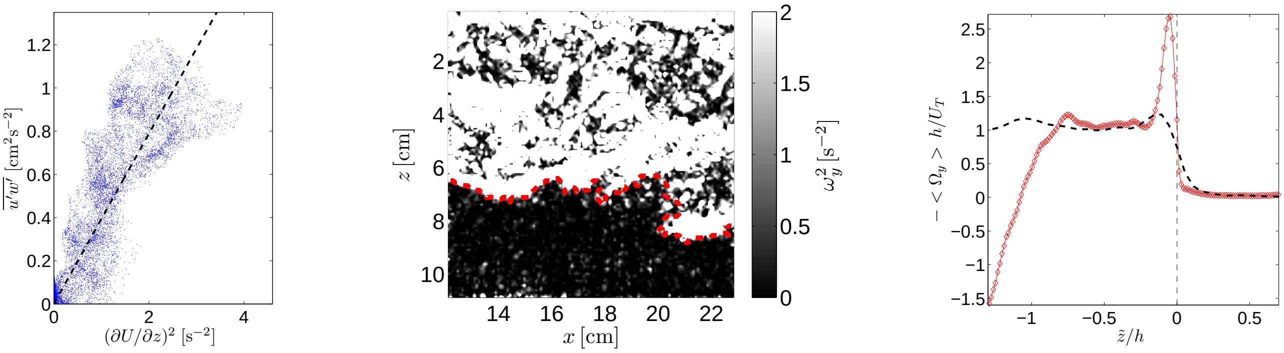


Figure 1: Sketch of the experimental facility including PIV measurement setup

OUTLINE

A schematic of the new gravity current setup that was inspired by a recent investigation by [4] is shown in Fig. 1. In this design, lighter fluid flows upwards along the top wall of a tilted tank entirely filled with denser fluid. Secondary flow is effectively suppressed by replacing entrained fluid along the bottom of the flow domain.

We present the successful implementation of the new gravity current facility. First measurements were performed in a flow at $Re \approx 4000$ and $Ri \approx 0.2$ using PIV and index matched liquids. Our results confirm the recent finding by [4] that shear stresses in the mixing region scale with the squared mean velocity gradient, i.e. according to a Prandlt mixing length model (see Fig. 2a). Further, Fig. 2b displays a contour plot of the instantaneous normal enstrophy component obtained from PIV measurements. A TNTI position was determined based on a threshold on enstrophy and is depicted by the dashed red line in the same figure. Flow quantities conditioned on the instantaneous interface position allow for a comparison to data obtained in a jet by [5]. Results such as the one for the conditioned vorticity in Fig. 2c indicate the existence of a strong interfacial shear layer with a thickness of about two times the Taylor microscale. The data further suggests the existence of strong density jump across this shear layer.



(a) (b) (c)

Figure 2: (a) Scatterplot of the Reynolds stress component $\overline{u'w'}$ plotted versus the squared wall normal gradient of the streamwise velocity. The black line represtens a linear fit to the data. (b) Snapshot of the normal enstrophy component as determined from PIV measurements; the dashed red line marks the TNTI defined by a threshold on vorticity. (c) Comparison of mean normal vorticity conditioned on the interface position of the gravity current (red diamonds) and a jet flow (data taken from [5])

As a next step, we will be measuring the density field via Laser Induced Fluorescence and use Particle Tracking Velocimetry which will provide a Lagrangian truly three dimensional velocity field. The Velocity and density fields will be captured simultaneously; in this way it will be possible to identify the exact effects of stratification on the local entrainment velocity and the shape of the turbulent/non-turbulent interface.

References

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