Turbulent entrainment by fountains and the implications for entrainment across density interfaces

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Abstract

Fountains are formed whenever a turbulent jet or plume crosses a density interface and becomes negatively buoyant, i.e. when the momentum flux of the flow across the interface is opposed by the buoyancy flux. We present experimental measurements for the turbulent entrainment by fountains in quiescent uniform environments [1]. The results span four orders of magnitude in the source Froude numbers, $0.004 \leq \mathrm{Fr}_0 \leq 25$, thereby examining the entrainment and mixing within all reported classes of fountain behaviour. We identify physically apparent scalings for the entrainment and mixing within a number of distinct Froude number bands and provide deterministic expressions for the entrained volume flux as a function of the Fr_0 and the source volume flux. At high Fr_0 our results broadly agree with those from studies of the entrainment by plumes and fountains in the presence of density interfaces [2, 5]. Our results at Low Fr_0 show significantly more entrainment than is reported by other studies examining the entrainment across density interfaces, e.g. [2, 3, 4]. We combine our results with a simplified model to account for the energy propagated by the interfacial waves that might form when a density interface is crossed by a jet or plume. Consideration of these interfacial waves in deep and shallow layers offer a possible source for some of the differences in the scaling laws for the entrainment across density interfaces that are reported within the literature.

References

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