Mixing in density currents flowing up a slope

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Abstract

Mixing processes associated to the propagation of unsteady gravity currents up a slope are investigated by laboratory experiments and Large Eddy Simulations (LES). Density currents were generated by the lock-exchange technique, consisting in the sudden release of a dense fluid into a lighter ambient fluid. Small inclinations θ of the bottom were considered ($\theta = 0°$, $\theta = 1.4°$, $\theta = 2.5°$ and $\theta = 5°$). Comparing both the front position and the shape of the density current, a good agreement was found between the laboratory measurements and the results of numerical simulations. Different flow regimes were observed: a slumping phase followed by an inertial phase and an eventual viscous phase [1]. The major effects of the inclined bottom on the flow dynamics, in comparison to the horizontal case, were: the decrease of the front velocity with the increase of the bottom upslope; a thinner profile of the dense current and a smoother interface between the dense and the ambient fluids. The formation of a reversed flow close to the bottom boundary, accumulating and stratifying close to the left wall of the inclined tank, was also detected in agreement with [2].

During the propagation of the density current, mixing occurs between the dense and the ambient fluids. Mixing processes were investigated following different approaches, revealing a decrease of mixing as the steepness of the bottom increases. Namely, two entrainment parameters were defined and the energy budget method of [3] was applied.

Finally, in order to investigate the regions of the gravity current in which turbulence is more pronounced and, consequently, in which mixing is more efficient, the budget of the turbulent kinetic energy k was analysed. High values of k were observed at the interface between the dense and the ambient fluids, particularly in the head region during the slumping phase and in correspondence of the Kelvin-Helmholtz billows. The terms of production and sink of k were investigated (figure 1): the production associated to the buoyancy fluxes B, the production P related to the velocity gradients of the mean flow and the dissipation ϵ. The analysis of k showed that all these terms decreased in time and with the steepness of the bottom boundary, indicating that both turbulence and the associated mixing were reduced by the up-sloping boundary.

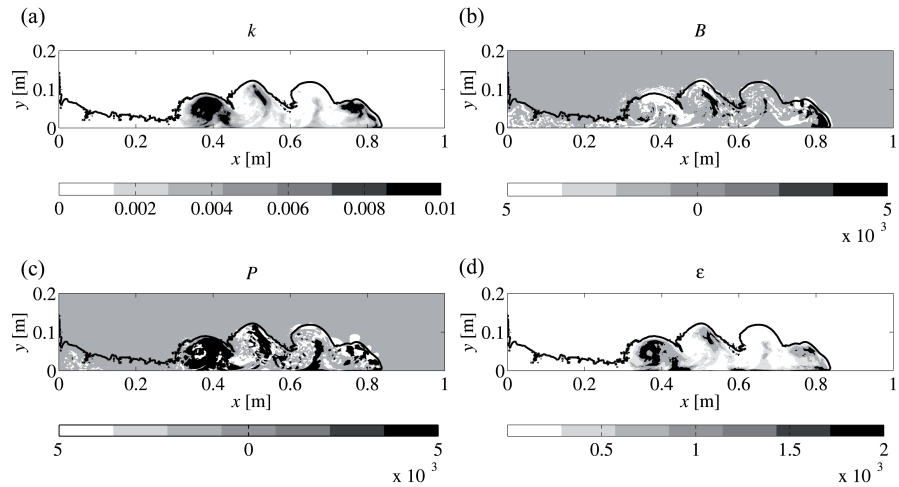

Fig. 1: Turbulent kinetic energy budget: (a) k; (b) B; (c) P; (d) ϵ.

References

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