Finite amplitude Kelvin-Helmholtz billows at high Richardson number

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Abstract

We study the dynamical system of a stratified mixing layer at finite Reynolds number and unity Prandtl number with hyperbolic tangent profiles in streamwise background velocity and density, forced in such a way that these background profiles are a steady solution of the governing equations. As is well-known, if the minimum Richardson number $R_{i_m}$ is less than a certain critical value $R_{i_c}$, the flow is linearly unstable to Kelvin-Helmholtz instability. We show that unstable, steady, two-dimensional, finite amplitude elliptical vortex structures, i.e. ‘Kelvin-Helmholtz billows’, exist above $R_{i_c}$. Bifurcation diagrams are produced using branch continuation, and we explore how these diagrams change with varying Reynolds number. In particular, we examine whether such finite amplitude Kelvin-Helmholtz billows can exist at $R_{i_m} > 1/4$, where the flow is linearly stable by the Miles-Howard theorem.