The Viscous Structure of Baroclinic Critical Layers in Stratified Shear Flow with Background Rotation

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Abstract

Stratified shear flows with background rotation are known to give rise to the spontaneous replication of zombie vortices when they are subjected to finite-amplitude perturbations. In direct numerical simulations, zombie vortices are produced at baroclinic critical points that are singularities of the underlying inviscid governing equations. In this investigation, a large Reynolds number asymptotic analysis is presented, which regularizes the critical point singularity via momentum and density diffusion within a critical layer of finite thickness. The formulation includes the effects of horizontal shear, stratification and background rotation. The predicted leading-order cross-stream structure in the baroclinic critical layer is shown to agree quantitatively with direct numerical simulations that include the effects of viscosity. The results are compared with those of classical viscous critical layer theory in shear flow instabilities.

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