Minimal seeds for turbulence in stratified plane Couette flow

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The stability properties of shear flows have received wide attention due to the important engineering applications of understanding how and when turbulence might emerge in a given flow geometry. Research has recently focused on identifying "minimal seeds," i.e. the initial perturbations to a laminar state with the smallest initial perturbation energy $E_0 = E_c$ that ultimately trigger the transition to turbulence. In unstratified plane Couette flow, Rabin et al. [1] identified such a minimal seed by searching for initial perturbations that maximised the gain in perturbation kinetic energy over some finite time, whilst Monokrousos et al. [2] identified such a minimal seed at a different Reynolds number, and in a different geometry, by searching for initial perturbations that maximised the time averaged dissipation of the perturbation kinetic energy over some finite time. We use the same variational method of "direct-adjoint-looping" (DAL) to identify minimal seeds for turbulence in stably stratified plane Couette flow, where a constant (stabilising) density difference is maintained across the flow. We investigate the relation between maximising the total perturbation energy gain and maximising the time averaged dissipation of perturbation energy in order to find minimal seeds. We show how the linear and nonlinear transient growth properties of stratified shear flows vary over a range of bulk Richardson numbers, along with categorising the types of minimal seeds for turbulence. We demonstrate that the minimal seed transition route to turbulence is strongly affected by presence of a stable stratification; the streamwise independent streaks prevalent in unstratified minimal seeds for turbulence that are a central component of Waleffe's [3] self-sustaining process are significantly affected by the stratification.

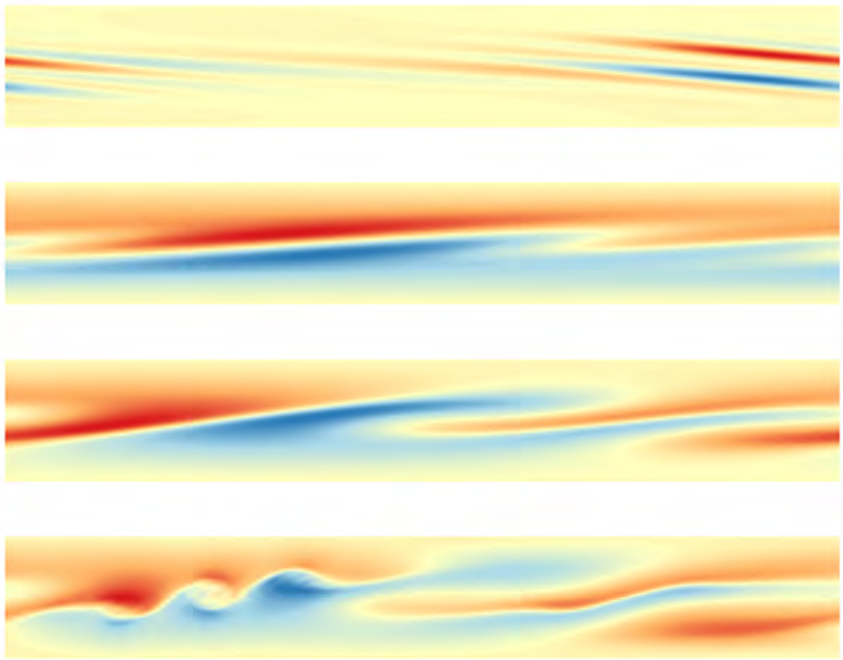

Fig. 1: Snapshots of the streamwise velocity of the flow evolution for the "minimal seed" for turbulence for bulk Richardson number $\mathrm{Ri_B} = 0.003$ at advective times $t = 0, 40, 200$ and 216.

References

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[3] Waleffe F *Phys. Fluids* **9**:883-900, 1997.

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