The intermittent dynamics in stratified plane Couette flow

E. Deusebio[1]*, C. P. Caulfield[1,2] and J. R. Taylor[1]

[1] DAMTP, University of Cambridge, CB3 0WA, Cambridge, UK
[2]BP Institute, University of Cambridge, CB3 0EZ, Cambridge, UK

Introduction

Turbulencein a stably stratified environment is a fundamental process of oceanic and atmospheric geophysical flows. For large static stability, the dynamics is characterised by large-scale temporal and spatial intermittency and turbulence might be virtually absent for long period of time and occur in strong bursts. Here, we characterise the complex dynamics arising from the interplay of laminar/turbulent regions in stratified plane Couette flows, focusing on the turbulent/laminar structures and the implications for turbulent transport and mixing efficiency.

Numerical simulations

Couette flow is a wall-bounded flow that develops between two solid walls which have a relative velocity and temperature difference. Two external dimensionless parameters control the dynamics: the bulk Reynolds number Re_b and the bulk Richardson number Ri_b. Here, we focus on the intermittent regimes by means of high-resolutions Direct Numerical Simulations (DNSs), using a well-validated pseudo-spectral code (see [1] for details on the numerical scheme). Figure 1(*a*) shows a summary of the simulations in the $Re_b - Ri_b$ plane, where the colour code represents the turbulent fraction. Simulations spanned more than two orders of magnitude in Re_b and values of Ri_b between 0 and 0.2. Figure 1(*b*) shows a snapshot of an intermittent simulations in which the co-existence of laminar and turbulent regions can be observed. We characterise the relaminarisation process and argue that the onset of intermittent dynamics occurs when the Reynolds number based on the Monin-Obukhov length scale, L, and the friction velocity u_τ, *i.e.* Lu_τ/ν, drops below 200 [2, 3]. This criterion also allows us to identify the boundary in the $Re_b - Ri_b$ plane separating fully-turbulent and intermittent dynamics. Solid and dashed lines in figure 1 represent the $L^+ = 200$ iso-contour predicted by two turbulence models, which provide reasonable agreement with the DNSs. We further study the energetics of the flow with a particular focus on the ratio between dissipation of kinetic and potential energy in laminar and turbulent regions, thus providing insights into the spatial variability of the mixing efficiency in strongly stratified turbulent flows.

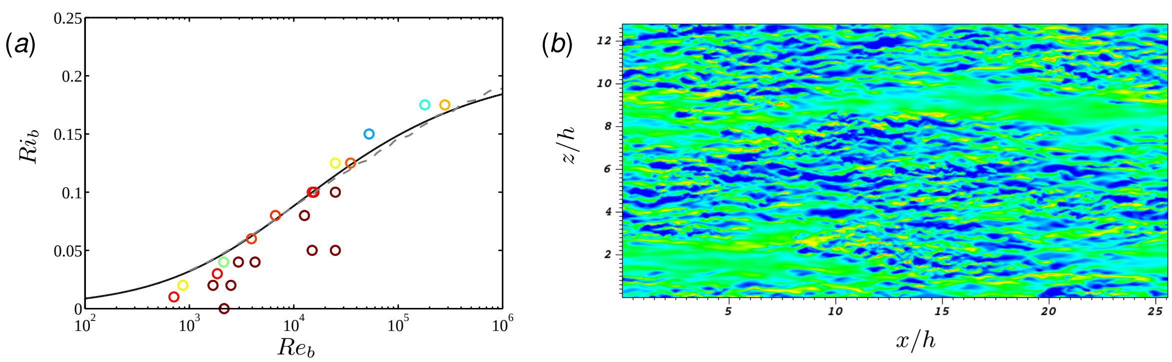

Fig. 1: (*a*) Summary of the simulations in the $Re_b - Ri_b$ plane. Colours represents the turbulent fraction, ranging from laminar (blue) to fully turbulent (red). Dashed lines: prediction of the iso-contour $Lu_\tau/\nu = 200$. (*b*) Snapshot of the streamwise velocity in a horizontal plane close to the upper wall for an intermittent simulation with $Re_b = 6.6 \cdot 10^3$ and $Ri = 0.08$.

References

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*corresponding author: ed441@damtp.cam.ac.uk