EUROMECH Colloquium 567
"Turbulent mixing in stratified flows"

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EUROMECH Colloquium 567 consisted of 3 invited lectures, 49 oral presentations and 12 posters over 3 days.

Colloquium themes

The main themes of the Colloquium are listed below.

Instability and transition The discussion was concerned with stability and transition in stratified shear flows. Results were presented of transient growth and minimal seeds using the direct-adjoint-looping method, coupled with direct numerical simulations. The role of stratification as characterised by the Richardson number was clearly identified by the way in which streamwise streaks prevalent in unstratified flows were significantly altered by stratification. The form of the stratification was also shown to be an important factor, with interfaces having high density gradients producing significant spatial variability in momentum, energy and mass fluxes. This, in turn, raises questions about the relevant length scales in stratified flows, the way in which overturns are characterised, and the importance of viscous forces as measured by the buoyancy Reynolds number.

Buoyancy-driven mixing and plumes Buoyancy-driven flows correlate buoyant fluid with vertical motion and so provide an effective means of vertical dispersion and mixing. This was studied in unsteady plumes generated by time-varying buoyancy fluxes, and in confined regions with an imposed unstable buoyancy flux. Both experiments and DNS results were interpreted in terms of dispersion closure models, where the dispersion coefficients depended on the buoyancy flux. These models work well even when the flow is multi-phase, such as in a particle-laden flow.

Field observations Oceanographic measurements made in a range of locations showed the importance of finite amplitude waves and other structures in causing mixing. Tidally forced events caused large shears and turbulence, as did other structures such as internal bores. At the associated high Reynolds numbers, the form of shear instabilities observed by acoustic backscatter were quite different from classical KH billows typically seen in laboratory experiments and DNS and there was a suggestion that sustained forcing plays an important role in some cases.

Effects of rotation Potential vorticity gradients can provide restoring forces that inhibit mixing in a manner similar to stable density gradients. These effects were nicely demonstrated in experiments on rotating plane Couette flow and in stratified Taylor-Couette flow. Intriguing finite amplitude structures were observed in these flows through the interaction with the horizontal shear and a restoring force. Equally, these flows also exhibit new instabilities such as stratorotational instability. Pancake vortices in rotating flows also exhibit a range of instabilities depending on their aspect ratio and relative vorticity.

Internal waves Internal waves are ubiquitous in stratified fluids and they interact with topography and generate turbulence and mixing. This was discussed in the context of breaking solitary waves on a slope, waves impinging on a slope at the critical angle, and through parametric subharmonic instability, whereby the energy in the primary wave is redistributed to a pair of waves with resonant wavenumbers and frequencies. These triadic interactions were also found to be very sensitive to background flow. Experiments and numerical studies showed that contributions to mixing can be significant in the right circumstances, and the predictions are supported by field measurements.

Diapycnal mixing A distinguishing feature of stratified turbulence is the resulting mixing across density surfaces. Papers at Colloquium 567 discussed field observations in the ocean and atmosphere, driven by convection or other mechanical driving mechanisms such as separation from buildings. The effects of strong stratification on these processes were discussed through analysis of high-resolution DNS and

LES and experiments on gravity currents. The efficiency of these various flows remains a major question, considered in a number of papers. These showed that details of both the large and small-scale features of the flows were important, since the efficiency depends on irreversible modification of the density field which is a molecular process. Consequently, the approximation often used in practice of a constant value for the mixing efficiency should only be used under severe caution.