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Scalar and momentum transfer processes across stratified sheared turbulent interfaces

J.C.R. Hunt[1]*, M. Moustaoui[2], A. Mahalov[2], T. Ishihara[3], J. Westerweel[4], M. Braza[5]

[1] Department of Earth Sciences, University College London, London WC1E 6BT, UK
[2] Mathematics Department, Arizona State University, USA
[3] Graduate School of Engineering, Nagoya University, Nagoya, Japan
[4] Mechanical Engineering, Delft University of Technology, Netherlands
[5] Institute of Fluid Mechanics of Toulouse, CNRS, 31400 Toulouse, France

Using recent DNS simulations (1), PIV data and local analytical models (2,3,4,), we consider well-developed inhomogeneous horizontal turbulent shear flows in the *x* direction lying beneath very thin external interfacial shear layers {*I*} located at $z = z_I$, that separate regions of strong and weaker turbulence.There are gradients of mean concentration C or normalised potential temperature (θ/θ_I) across the interface (the reference value of θ_I)and extending into the outer region {O}, where $z > z_I$). With gravity, the mean buoyancy frequency is determined by $N^2 = g\,(d(\theta/\theta_I)/dz)$. In the shear region {S} below the interface, the mean velocity is $<u_1>$ with significant mean shear $\Omega = d<u_1>/dz$.The relative dynamical effect of the buoyancy and shear is defined by $Ri = N^2/\Omega^2$. In the outer region {0} above {I} where $z = z_I + \tilde{z}$, there are two sub-regions ,{0_1} lying between the mean and fluctuating positions of the interface , ie $\tilde{z} < z_I'$ where viscous rotational eddies detrain from {I} leading to a local mean gradient ($d\tilde{U}/d\tilde{z}$). In {0_2} where $\tilde{z} > z_I'$, with weak stratification (Ri <Ri crit ~ 1) this layer above the primary interface {I},has rotational fluctuations which generate a separate interfacial shear layer $\tilde{U}(\tilde{z})$ and a second sheared interface {I_2} at $\tilde{z} \sim L$. With greater stratification ,where $Ri > Ri_{crit}$ significant internal shear waves are generated with a mean momentum flux upwards τ_0 (~1/4 τ_S). Within {I} there is a micro sub-layer (or 'super layer) of thickness $\ell_K \sim LRe^{(-3/4)}$ above the macro- layer $\ell \sim LRe^{(-1/2)}$.(1) , with mean jump in velocity $\langle \Delta U_I \rangle$, and similarly for C or (θ/θ_I) .

The interactions between regions {0},{I]},{S} determine whether the smaller scale Kelvin Helmholtz oscillations and small scale 'nibbling' turbulence in the layer, or whether larger 'engulfing' larger amplitude fluctuations of the interface dominate the entrainment processes which are quantified by integrating the conditional mean momentum/scalar transport equations in the moving frame of the interface , including the correlation between the fluctuating quantities. From these conceptual mechanisms and quantitative criteria, as verified by fully resolved simulations and PIV measurements, approximate unsteady numerical models have been developed for application in a wide range of engineering and environmental flows with greater generality than the usual similarity and eddy viscosity methods (5,6) .

References

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*corresponding author: euromech567@damtp.cam.ac.uk