The role of density interfaces in mixing strongly stratified turbulent flows

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Strongly stratified turbulent flows tend to self-organise into stacks of relatively deep and well-mixed density 'layers' separated by relatively thin 'interfaces' of enhanced density gradient[1]. Such structures offer a route for turbulence to grow and be sustained in a flow that otherwise would tend to suppress turbulent motions and are therefore of great importance when studying irreversible scalar mixing in strongly stratified flows. However, the presence of these statically-stably stratified interfaces is often overlooked in mixing parameterizations, the density overturns occurring in the well-mixed regions being usually used as a proxy for mixing. Considering statistically-steady, forced DNS data of stratified turbulence, Couchman et al. (2022)[2] questioned this hypothesis and showed that while density inversions are present in the well-mixed layers and account for large values of the turbulent dissipation rate of kinetic energy ϵ, extreme values of the scalar variance χ are found in the density interfaces, skewing the bulk statistics of the flux coefficient $\Gamma := \chi/\epsilon$ towards large values (see figure 1).

Considering DNS data such as the one initially reported by Almalkie and de Bruyn Kops (2012)[3] for various Prandtl Pr, horizontal Froude Fr_h and Reynolds Re numbers, we analyse here the temporal dynamics of the strongly stably-stratified interfaces as well as their statistics. Moreover, using agnostic clustering methods, we segment the flow into distinct regions with unique mixing properties, highlighting the underlying mechanisms giving rise to extreme mixing events. Practical conclusions regarding parameterizations of mixing in geophysical contexts are also drawn.

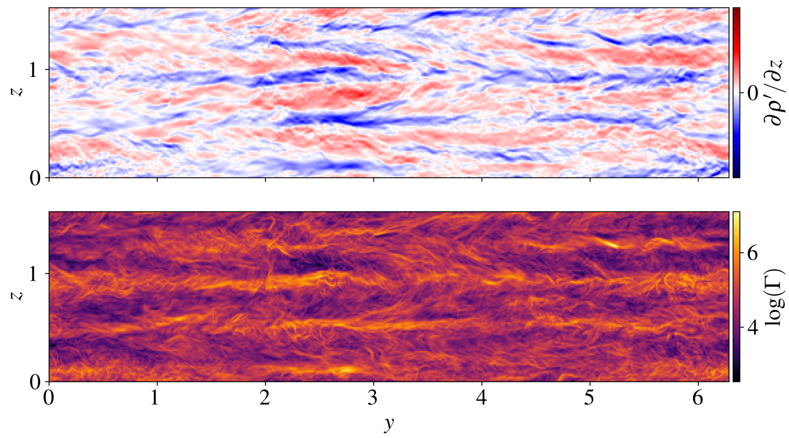

Figure 1: Ensemble averages of (Top) vertical density gradient $\partial\rho'/\partial z$ and (Bottom) flux coefficient $\log(\Gamma)$ for $Pr = 1$, $Fr_h = 1.66$ and $Re = 808$. All quantities are dimensionless.

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[1] Billant and Chomaz, *Physics of fluids*, **13**, 1645 (2001).
[2] Couchman et al., arXiv preprint arXiv:2210.16148, (2022)
[3] Almalkie and de Bruyn Kops, *Journal of Turbulence*, **13**(29) (2012)