Multiscale DNS modelling of turbulent destratification of open channel flow for Pr = 0.71 and 7

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This study aims to investigate the destratification process of a stratified open-channel flow with fluids with Prandtl numbers, Pr, equal to 0.71 and 7, after the removal of the heat source. For fluids with $Pr>1$, the temperature field creates steeper gradients than the momentum field. This means a coarser mesh can be used to adequately resolve the momentum and pressure equations. However, a much finer mesh is required for the temperature field, which considerably increases computational cost. It has been demonstrated in Figure 1a and elaborated by Kirkpatrick et al.[1] that increasing Pr results in lower molecular diffusivity, which requires a larger temperature gradient, thus increasing surface buoyancy and stability. For this reason, most previous direct numerical simulation (DNS) studies have considered fluid with $Pr \leq 1$, even for water, despite proven evidence of the effects of Pr on stratified turbulence. Therefore, in this study, to overcome the computation cost, an efficient multi-resolution scheme[2] is utilised to generate two different mesh resolutions for momentum and scalar fields and simulate the destratification process in an open-channel flow Pr = 0.71 and 7. Although Kirkpatrick et al.[1] demonstrated (Figure 1b) that the bulk destratification rate (D) is a function of Pr and friction Richardson number (Ri_τ), their proposed empirical approximation for D was only a function of Ri_τ due to their small range of Pr. Therefore, this study employs a multi-resolution DNS method to simulate destratification of fluids with $Pr > 1$, in order to:

- Investigate the breakdown of the initial stable stratification in three main regions of the flow, namely the near-wall, central and near-surface regions and compare the results with previous studies[1] which used $Pr < 1$.
- Evaluate the accuracy of empirical equations for D for fluids with $Pr > 1$.

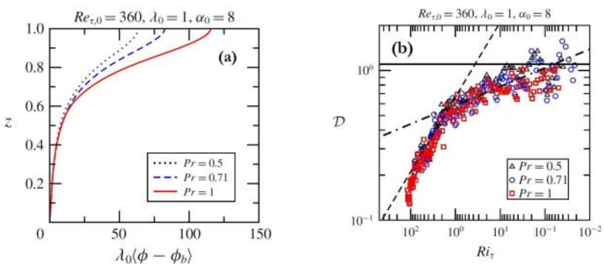

Figure 1: Results from[1]: (a) Equilibrium state buoyancy profiles; and (b) Normalised destratification rate (D) plotted against friction Richardson number (Ri_τ).

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[1] Kirkpatrick et al., *J. Fluid Mech.* **879**, 356 (2019).

[2] Jahani et al., *12th Australasian Heat and Mass Transfer Conference*, **A**04-60 (2022).