Mixing in Stably Stratified Wall-Bounded Turbulence

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Abstract. The focus of this study is to analyze stably stratified wall-bounded flows to highlight a number of pertinent issues that have implications for predicting turbulent mixing in environmental flows like the ocean and the atmosphere. By invoking the equilibrium assumption between the production rate of the turbulent kinetic energy (P), the dissipation rate of the turbulent kinetic energy (ε) and the turbulent potential energy dissipation rate (ε_{PE}) as $P \approx \varepsilon + \varepsilon_{PE}$, we first propose that the irreversible flux Richardson number $R^*_f = \varepsilon_{PE} /(\varepsilon + \varepsilon_{PE})$ can be approximated with the reversible form of the flux Richardson number $R_f = -B/P$ (where B is the buoyancy flux), especially for low gradient Richardson numbers. Second, we propose that the turbulent viscosity $\nu_t \approx 1/(1- R^*_f)\ \varepsilon /S^2$, where S is the mean shear rate. Tests using the direct numerical simulation (DNS) data of turbulent channel flow are performed to evaluate our propositions. The comparisons are excellent. Finally, by invoking the equilibrium assumption between the buoyancy flux (B) and the dissipation rate of the turbulent potential energy (ε_{PE}) as $-B \approx \varepsilon_{PE}$, we infer the turbulent diffusivity as $\kappa_t = \varepsilon_{PE} /N^2$, where N is the buoyancy frequency. The comparison of the proposed turbulent diffusivity with the exact turbulent diffusivity computed from DNS data is good especially in the near-wall region but the agreement deteriorates far away from the wall, indicating the breakdown of the equilibrium assumption which is attributed to the presence of linear internal wave motions in this far-wall region.