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Change in mixing efficiency in Taylor-Couette flow

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The mixing of the upper ocean is a long standing GFD issue. To investigate the mixing efficiency, we consider a stratified Taylor-Couette flow. The flow is anisotropic, and consists of annular ring-shaped vortex structures with horizontal axis, and, unlike most other experiments and simulations on mixing allows for the generation of inertial-gravity waves. The characteristics of the Taylor-Couette device employed are unconventional, with gap-width 5 cm of ratio 12.2 and inner diameter of 30 cm. Since the most unstable wavelength depend on gap-width and Reynolds number, the Taylor vortices in this device will have a larger diameter (about 5 cm). Typically, the effect of a linear stratification is to increase the threshold value for instability, or transition to another regime, and to decrease the aspect ratio of the Taylor vortices.

The mixing efficiency represented by the Richardson flux number, $Ri_f = ERi_o$ as a function of overall Richardson number $Ri_o = \Delta BL_H/U_H^2$, obtained for the turbulent regime. L_H is the vortex diameters, E is the adimensionnal entrainment rate, U_H is the maximum vortex velocity. The buyoancy jump is modelised by $\Delta B = g\Delta\rho/\overline{\rho}$. For larger Ri_o, the mixing efficiency systematically increases as predict by the model of Balmforth *et al* (1998). Though former studies suggest the influence of waves interacting with the shear layer as a possible mechanism to increase the mixing efficiency this has not been shown for such high Ri_o numbers. Observations reveal a mixing layer of approximately 5 mm thickness, with wave breaking fluid motions, while vortices above and below erase filaments of dense fluid from the upward moving layer induced by wave motions. For smaller Ri_o, the flow also showed filamentation generated by the same process, but the waves do not break in the interior of the pycnocline. This suggests that the increase in mixing efficiency at large buoyancy gradients is associated with a change in mixing mechanism from random scraping by large vortices to small scale overturning events. The mixing length being smaller, the entrainment is more efficient.