



Interactions of waves and eddies in stratified turbulence

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Most geophysical flows such as the ocean or the atmosphere are subject to stratified turbulence (ST) where Internal Gravity Waves (IGW), eddies, and large structures interact with each other to dissipate energy. All these structures are entangled and produce different phenomena as vertical turbulent mixing. While a global signature of an IGW has been observed in experiments (Savaro *et al.*, 2020) and simulations (di Leoni and Mininni, 2015), the mutual interactions between waves and eddies are less understood in full ST. Can we obtain a global overview of all interactions in ST? Can we evaluate separately the mixing due to waves and eddies?

To do this, we have developed a new technique based on spatio-temporal decomposition in 4D that allows to extract separately IGW, eddies and large scale parts and disentangle all interactions (Lam *et al.*, 2021). This technique is a spatio-temporal extension of Riley's decomposition (Riley *et al.*, 1981) which takes into account the modification of the IGW's properties due to a vertically sheared horizontal flow (large scale). From this decomposition, the equations governing the equilibrium of each part can be obtained as well as all interactions. Their mutual interactions are evaluated and analyzed via Sankey diagrams that provide a global picture of energy exchanges. We perform several Direct Numerical Simulations at low Froude number $Fr \ll 1$ but with varying buoyancy Reynolds number (Re_b) in order to study the regime's transition from $Re_b \ll 1$ to $Re_b \gg 1$. An illustration of this decomposition is shown in figure 1 for the buoyancy field from our DNS.

On the one hand, we observe for a moderate buoyancy Reynolds number $Re_b \sim 1$ that a significant part of energy is pumped from the IGW to the eddies whereas for $Re_b \gg 1$, the IGW and eddy dynamics seem to be separated and no global exchange is observed. On the other hand, the mixing coefficient used in oceanography to model turbulent vertical mixing can be split into two parts, IGW and eddy, and analyzed. At the largest $Re_b \gg 1$ considered, the mixing due to eddies is four times larger than that due to waves.

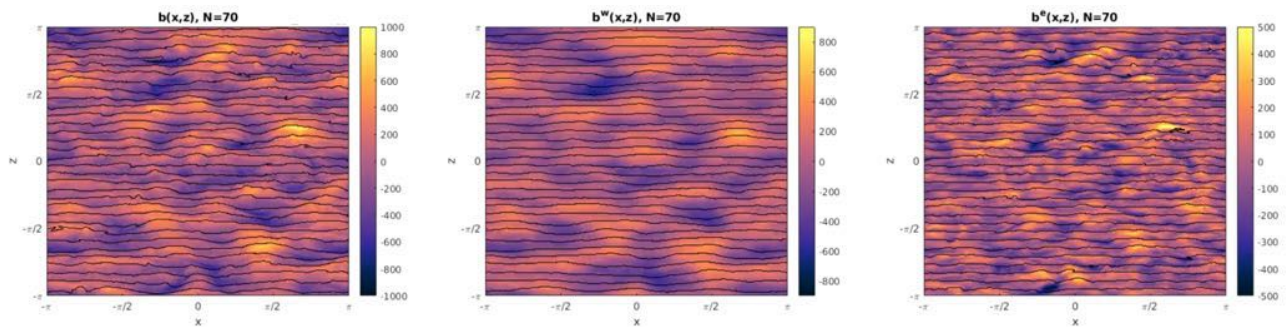


Figure 1: Illustration of vertical cut of buoyancy field b divided into two parts: the wave part b^w and eddy part b^e . The black line represent iso-values of density.

References

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