Internship proposal: Dispersion of a passive tracer in the deep ocean

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Background – The deep ocean is forced by energy and momentum exchanges with the upper layer of the ocean, and by flow interactions with the seafloor topography. Flow-topography interactions (FTI) span a wide range of processes, from the generation of internal waves –lee waves, internal tides and near-inertial waves– to the generation of submesoscale eddies. These processes impact the energetics of the ocean, and the transport and mixing of tracers, such as density and biochemical compounds. How these processes impact diapycnal mixing, i.e., mixing through density surfaces, is a question of particular interest, as diapycnal mixing is key in driving water mass transformation, ventilation, and the oceanic journey of dynamically passive tracers.

Diapycnal mixing occurs at small viscous scales (<1 cm), and is difficult to measure directly. Hence, several methods have been designed to infer the rate of diapycnal mixing, whose intensity is quantified by the diffusivity coefficient κ. In situ measurements of the velocity shear $\partial u/\partial z$ at high frequency (resolving centimetre scales, termed microstructure) allows to assess the turbulent energy dissipation rate ε assuming isotropy of the velocity field, which is tightly coupled to κ. This technique is considered to provide the most accurate measure of ε and κ.

Indirect techniques have been designed to measure diapycnal mixing in the ocean, and the most common technique is based on tracer dispersion, or dye-release experiments (Ledwell et al., 2000). It consists in releasing a passive tracer on a given range of isopycnals and monitoring the tracer spreading across isopycnals over time (Figure 1). The evolution of the tracer distribution has been modelled to determine κ (e.g., Ledwell et al., 1998).

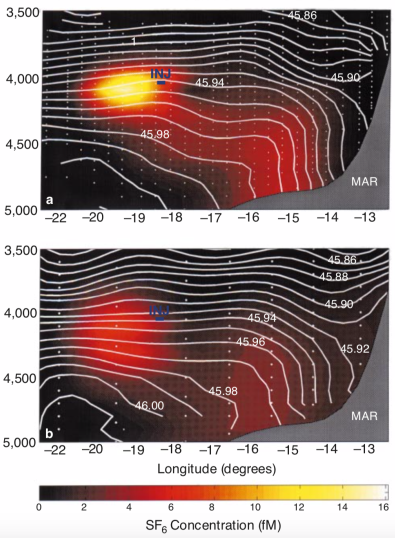

Figure 1: From Ledwell et al. (2000). Sections of tracer concentration and potential density from the valley where the tracer was released. (a) 14 months after release; (b) 26 months after release. The blue bar labelled 'INJ' marks the release site of the tracer.

Project narrative – The two above-mentioned methods revealed enhanced diapycnal mixing over areas of rough seafloor topography (Polzin et al., 1997; Ledwell et al., 2000), highlighting the crucial role of FTI in triggering small-scale turbulence. How these estimates compare and how the processes leading to dissipation are represented in state-of-the-art numerical models remain poorly tackled. Mashayek et al. (2017) reconciled those estimates in the Southern Ocean using a high-resolution numerical model, which paves the way for future investigation in other regions featuring strong FTI. The ANR-funded DEEPER project led by Jonathan Gula, seeks to understand the role of FTI on the circulation and dynamical balance of the ocean, through a series of realistic, high-resolution, numerical simulations (CROCO numerical model) spanning the Atlantic Ocean. As part of this project, Clément and Jonathan will design and run nested simulations over the Reykjanes Ridge, where microstructure measurements of turbulence are available (RREX project), to investigate the dynamical processes leading to turbulence and mixing. *The student will conduct the passive tracer experiment within these simulations, and design a framework to analyse the tracer dispersion and computation of diapycnal mixing coefficient.* Comparison of microstructure-derived, tracer-derived, and model-prescribed κ will help to assess the model ability to represent the turbulent small scales at play in turbulent mixing, and identify the missing processes / dynamical ingredients. The student will be mostly based at LOPS, and a visit to Ali Mashayek at Imperial College, London, in May-June will be planned.

Ledwell, J. et al. (2000). Evidence for enhanced mixing over rough topography in the abyssal ocean. *Nature*, 403(6766):179–182.

Ledwell, J. et al. (1998). Mixing of a tracer in the pycnocline. *J. Geophys. Res.*, 103(C10):21499–21529.

Mashayek, A. et al. (2017). Topographic enhancement of vertical turbulent mixing in the Southern Ocean. *Nature Commun.*, 8:14197.

Polzin, K. et al. (1997). Spatial variability of turbulent mixing in the abyssal ocean. *Science*, 276(5309):93–96.