Laboratoire de Mécanique des Fluides de Lille
Kampé de Fériet

Non-equilibrium turbulence in stably stratified boundary layer

Supervisor : Benjamin Luce (Assistant Professor)
Location : Build. M6, Av. Paul Langevin, Cité Scientifique, 59655 Villeneuve d'Ascq
Duration : 6 months, start in March/April 2025
Contact : benjamin.luce@univ-lille.fr
Requirements :

- Knowledge of fluid mechanics and/or numerical simulations (theory) at Master level.
- Basic knowledge of a programming language (C++ and/or python are best but not mandatory).

Density-stratified flows are a common occurrence in nature, with the atmosphere and the ocean being the most well-known examples. The stability of these flows is function of the temperature and the resulting buoyancy. One object of interest is the stably stratified atmospheric boundary layer, occurring when the ground surface is cooled, mainly at night or over snow and ice surfaces. These peculiar conditions are the set of complex interactions between internal gravity waves and weak shear turbulence. Despite numerous works on the topic (see [1], [2]) and even recent groundbreaking experiments [3], our understanding of the physical mechanisms for the intermittent turbulence generation is still lacking.
One of the question we could ask is how wave motions onset the transition to turbulence and how the latter modifies the existing waves. It is especially crucial to understand as the stable boundary layer is rarely in equilibrium, with temporal (sunset and sunrise) or spatial (thermally heterogeneous surfaces resulting in a different stability) transitions.
This, perhaps naive, question shall drive us toward a more generic yet ambitious question of the parametrization of such turbulence for forecasting models. The classical turbulence theory of Kolmogorov assumed a non-stratified and neutrally stable flow, the current closure models rely on this paradigm despite contradictory observations[4]. Worst, even Large Eddy Simulations are not entirely satisfactory on their ability to assure a correct representation of the flow[5]. This last point leads us to the object of the internship.

Preliminary organization of the work :

The intern will thus realized numerical simulations (DNS and LES) with the ERF code (https://github.com/erf-model/ERF), starting from what was done in[5], and the GABLS reference simulation. A grid convergence study will be carried out in LES with the objective to observe the loss of turbulent kinetic energy at finer grid with the goal to find a rational explanation of such behaviour.

Bibliography :

[1] L. Mahrt, « Stably Stratified Atmospheric Boundary Layers », *Annual Review of Fluid Mechanics*, vol. 46, nº Volume 46, 2014, p. 23-45, janv. 2014, doi: 10.1146/annurev-fluid-010313-141354.
[2] J. Sun *et al.*, « Review of wave-turbulence interactions in the stable atmospheric boundary layer », *Reviews of Geophysics*, vol. 53, nº 3, p. 956-993, 2015, doi: 10.1002/2015RG000487.
[3] N. Lanchon, D. O. Mora, E. Monsalve, et P.-P. Cortet, « Internal wave turbulence in a stratified fluid with and without eigenmodes of the experimental domain », *Phys. Rev. Fluids*, vol. 8, nº 5, p. 054802, mai 2023, doi: 10.1103/PhysRevFluids.8.054802.
[4] S. Zilitinkevich, E. Kadantsev, I. Repina, E. Mortikov, et A. Glazunov, « Order out of Chaos: Shifting Paradigm of Convective Turbulence », *Journal of the Atmospheric Sciences*, vol. 78, nº 12, p. 3925-3932, déc. 2021, doi: 10.1175/JAS-D-21-0013.1.
[5] B. Maronga et D. Li, « An Investigation of the Grid Sensitivity in Large-Eddy Simulations of the Stable Boundary Layer », *Boundary-Layer Meteorol*, vol. 182, nº 2, p. 251-273, févr. 2022, doi: 10.1007/s10546-021-00656-8.