PhD proposal

Internal gravity waves in periodic stratification

Supervisors: Severine Atis, Michel Fruchart and Germain Rousseaux

CNRS Research Scientists at Institut Pprime

severine.atis@cnrs.fr , https://severineatis.wordpress.com/ , http://germain-rousseaux.cnrs.fr

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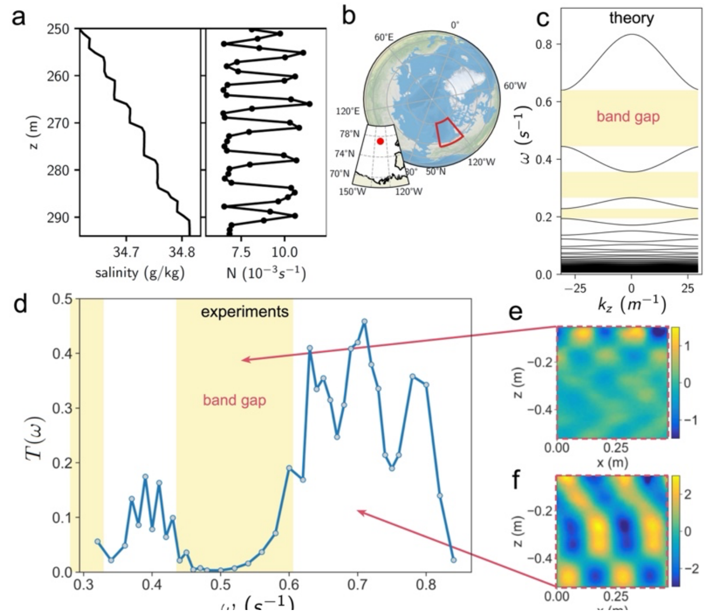
Context: Internal gravity waves are mechanical waves that propagate in the bulk of stratified fluids, such as the ocean or the atmosphere. They can transport energy and momentum far from the surface and over large distances and affect large-scale circulation patterns. When the density stratification is not uniform, internal waves can exhibit resonances, tunneling, and frequency-dependent transmissions. In the Arctic Ocean, global warming has been driving rapid ice cover loss, and led to an increased seasonal internal gravity wave generation by atmospheric perturbations. In this region, the interplay between heat diffusion and salt diffusion can lead to the formation of extended regions with spatially periodic density profiles known as thermohaline staircases (Fig. 1a and 1b). Periodic environments can strongly alter wave propagation and energy transfer phenomena (Fig. 1c), yet the effect of these periodically stratified thermohaline structures on internal wave transmission in the ocean are incompletely understood. We recently showed with preliminary laboratory experiments (Fig. 1d-f) the existence of internal wave band gaps and surface states in periodically stratified fluids. The occurrence of such banded internal wave transmission through periodic thermohaline structures could profoundly affect energy transport processes in the ocean, and their modeling poses a fundamental challenge that requires the development of pluri-disciplinary approaches.



a) Thermohaline staircases measured near b) in the Arctic Ocean. c) Predicted band structure for internal waves. d) Transmission function measured in laboratory experiments. e) Flow vertical component for a wave frequency in the band gap, and f) in the conduction band.

Goals: This research project proposes to develop a novel framework to investigate the interplay between internal waves and complex environments using methods inspired from condensed matter physics. Drawing analogies from a variety of systems describing wave-matter interactions, such as multi-layered photonic materials and topological insulators, we aim to identify the physical mechanisms that govern internal wave transport in complex geophysical environments, while exploring the existence of surface states and localization transition-like phenomena in fluids. Periodic density stratifications will be prepared in laboratory experiments using traditional double-bucket method to create non-uniform stratification by varying the mixing ratio of salt- and sweet-water periodically over time with a computer-controlled pump. The interplay between double-diffusive convection and internal wave band formation will be explored by controlling the temperature profile in addition to salinity differences in the tank. Flow velocity fields measurements will be performed using particle image velocimetry (PIV), along with filtering and spectral analysis methods to determine the internal wave dynamics. In parallel, we will perform numerical simulations combined with experimentally measured stratification profiles to determine the wave field in the linear approximation. The experiments will be carried out at Institut Pprime in close collaboration with Dr. Michel Fruchart at ESPCI (Paris) where the theoretical approaches are being developed.

Profile: Candidates must have a taste for experimental research and physical modeling, basic knowledge in Python or Matlab, with background in physics, fluid mechanics or soft matter.

Environment: Institut Pprime is one of the largest research laboratory in physics and engineering in France that possess a shared hydrodynamics facility located in Poitiers (1h10 from Paris by TGV). The intern/future doctoral student will benefit from the interdisciplinary research environment of the team CURIOSITY and regular interactions with collaborators at ESPCI.

Contact: please send a CV, cover letter, and the name and email address of at least one reference to:
severine.atis@cnrs.fr