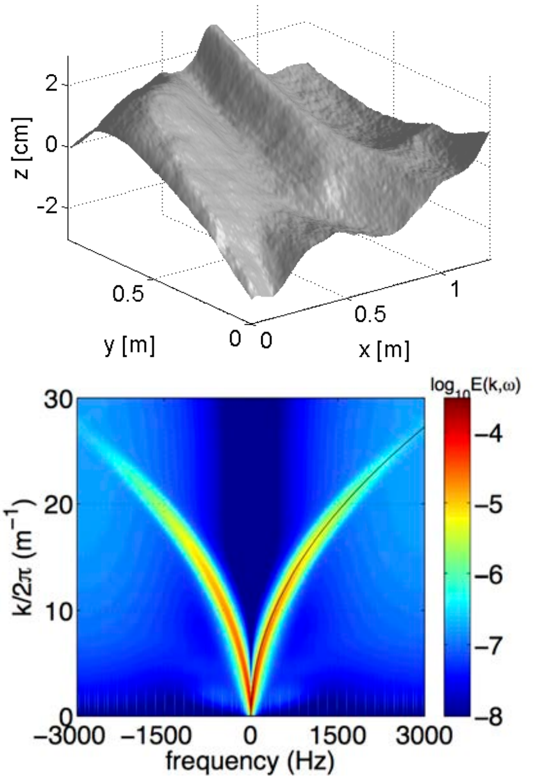
PhD thesis:
Experimental study of gravity wave turbulence in 1D: Is Weak Turbulence unstable ?

Supervision: Nicolas Mordant (Professor at Université de Grenoble),
Place: Laboratoire des Ecoulements Géophysiques et Industriels (LEGI)
Campus universitaire de Saint Martin d'Hères (Grenoble, France)
Funding: European Research Council (ERC)
Duration: Three years, start: Autumn 2015

General framework

The WATU project *"Wave turbulence: beyond weak turbulence"* is a 5-year research program supervised by N. Mordant and selected by ERC with a 2 millions euros funding to study the statistical properties of wave turbulence (begins in September 2015). Wave turbulence is a statistical state made of a large number of waves that are coupled by non-linear effects. The typical example of wave turbulence is that of oceanic waves (surface gravity waves) that develop a very wide spectrum of wavelengths from centimeter scale up to several tens of meters. Many other systems can lead to wave turbulence: non-linear optics in fibers, lasers, magnetohydrodynamic waves in solar winds, superfluid turbulence, confined plasmas as ITER...



Top: example of deformation of a vibrated steel plate measured at 10,000 frame/s.

Bottom: space-time Fourier spectrum of the flexion waves in such a plate. It displays frequencies from 1Hz up to several kHz.

Wave turbulence is specific in the fact that a statistical theory named "weak turbulence" has been developed in the 60's. This theory predicts in particular the time evolution of the Fourier spectrum of the waves. The predicted phenomenology resembles strongly that of the energy cascade observed in fluid turbulence: energy is injected at large scales and transferred to smaller and smaller scales until it is ultimately dissipated. Following this theory, the field of wave turbulence was the object of many theoretical developments that actually lack experimental support. The goal of the WATU project is to provide a strong effort so that to fill the gap between theory and experiment. We will gather advanced experimental information in the framework of weak turbulence as well as in the case of strongly non-linear waves.

During this project, we will be interested in several types of waves: elastic flexion waves in the thin vibrated plate (see figure), gravity or capillary waves at the surface of a fluid, internal gravity and inertia waves in a rotating and stratified fluid. All these waves exhibit various dimensionalities from 1D to 3D, non-linear coupling mechanisms involving 3 to 5 waves. Furthermore several kinds of cascades have been predicted and we will test their existence in the laboratory. From the experimental viewpoint, our goal is to develop measurement techniques so that to resolve the wave motion both in

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LEGI LABORATOIRE DES ECOULEMENTS GEOPHYSIQUES ET INDUSTRIELS time and space. In this way, we will be able to finely test the wave structure and the non-linear couplings in conditions of weak or strong turbulence. These experiments will also show various sizes: experiments in small containers or in the 36 m wave flume or in the Coriolis facility (13m diameter turntable).

Topic of the PhD thesis

In the present PhD program, we will focus on the case of 1D surface gravity waves. This situation is related to the case of the swell observed in the ocean that shows usually a quasi unidirectional propagation. Wave turbulence in 1D shows fundamental particularities that are somewhat exotic depending on whether the wave propagation is uni- or bi directional. Energy can cascade towards small scales or in contrast to large scales; weak turbulence can become unstable and lead to formation of solitons… Wave turbulence in 1D is a potentially very rich framework related to oceanic issues.

During this PhD, the graduate student will have to setup experiments in the 1D wave flume of the LEGI. This flume is 36 m long and it is currently used to study the sediment dynamics in the vicinity of the shore (see picture). The student will develop a new scheme to generate and control the waves and a 2D imaging system to record the free surface displacement in a way that is resolved both in time and space. For control purposes, additional ultrasonic local measurements of the surface displacement will be performed. It will then be possible to study in a very fine way, the weak or strong non-linear couplings between waves, and perform advanced comparisons between theory and experiments. The student will also be associated to the other studies of the WATU project, in particular to share the measurement and data analysis techniques and so that to compare results among various configurations.

36m wave flume in LEGI. It will be adapted during the WATU project to study 1D wave turbulence.

Prerequisite

The graduate student will have to perform significant data and image analysis that will benefit from the local HPC capabilities of the laboratory. He will have to get familiar with the mechanics of gravity waves to conceive and analyze the experiments.
Thus the applicant should have preferably a formation in non-linear physics and/or in fluid mechanics, with notions about turbulence. Skills in statistical data analysis will be appreciated as well as skills in experimental fluid dynamics.

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Information on LEGI: http://www.legi.grenoble-inp.fr

In order to apply, please send a CV and the name of a person for recommendation.

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