EXPERIMENTS ON THE INTERACTION BETWEEN HYDRODYNAMIC TURBULENCE AND FREE-SURFACE WAVES

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Abstract We investigate interaction between hydrodynamic turbulence and a free surface in a meter scale basin. An intense, homogeneous and isotropic turbulence is generated by an 8x8 array of jets pointing upwards at the bottom of the basin. We study free-surface deformations induced by hydrodynamic turbulence. In a second stage, we will study the mutual interaction between hydrodynamic turbulence and waves generated by an electromechanical shaker at the free surface: attenuation or amplification of free-surface waves by hydrodynamic turbulence and energy exchange in particular between hydrodynamic turbulence and wave turbulence.

INTRODUCTION

Understanding how hydrodynamic turbulence and a free surface interact is important as both play a major role in mass and heat exchange between oceans and atmosphere. Theoretical models have been proposed to describe part of these interactions [1, 2, 3] but few experiments studied free-surface deformations induced by turbulence [4, 5, 6]. With our new experimental setup, we aim to understand interaction mechanisms and energy exchange between hydrodynamic turbulence and free-surface waves.

EXPERIMENTAL SETUP

Hydrodynamic turbulence with no mean flow is generated by an 8x8 array of 64 jets pointing upwards at the bottom of a 40 cm x 40 cm basin (inspired by [7]). The basin is filled with water to a depth from 50 to 70 cm.
In this setup (Figure 1), water circulates in a closed circuit and the flow is produced by a centrifugal pump. The flow rate of the pump is controlled by a variable-frequency drive. The discharge head of the pump is connected to a distribution tank and 64 pipes link this tank with the bottom of the basin from underneath. The 64 jets are driven individually using solenoid valves to reach a random spatiotemporal forcing pattern and produce an intense, homogeneous and isotropic turbulence. Fluid velocity measurements (Laser Doppler Velocimetry, Particle Image Velocimetry) and free-surface deformation measurements (space and time-resolved Fourier Transform Profilometry, capacitive probe) are performed.

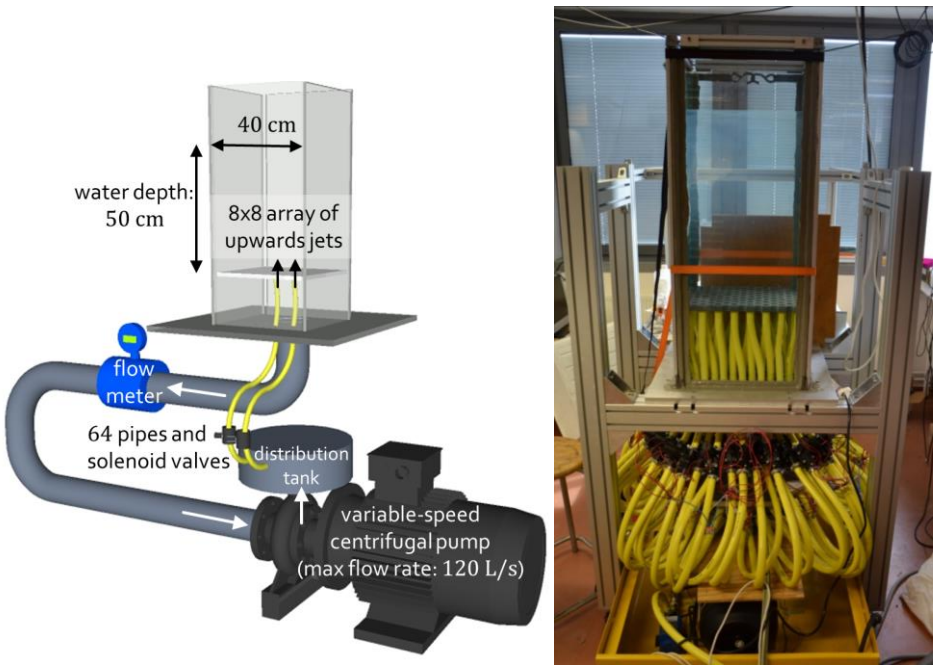

Figure 1. Sketch and photograph of the experimental setup.

FIRST RESULTS AND PERSPECTIVES

In a first stage, we study free-surface deformations induced by hydrodynamic turbulence. Figure 2 shows that free-surface deformations increase with the level of hydrodynamic turbulence. A weak level of turbulence induces a scarified surface. Then ripples and gravity waves appear for moderate turbulence (Figure 3 - left) and bubbles are entrained in the fluid when the turbulence level continues to increase (Figure 3 - right). The spatiotemporal properties of the velocity field and the free surface will be investigated to better understand the mechanism of wave generation.

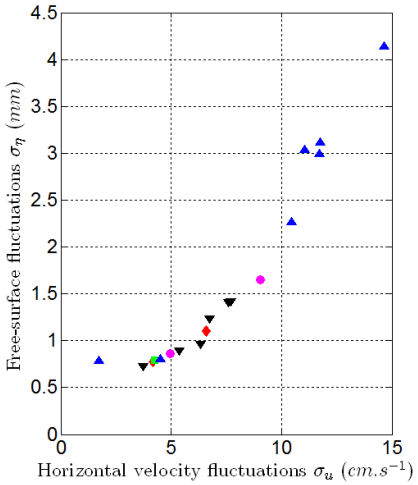

Figure 2. Standard deviations of free-surface fluctuations vs. velocity fluctuations (4 cm beneath the free-surface).

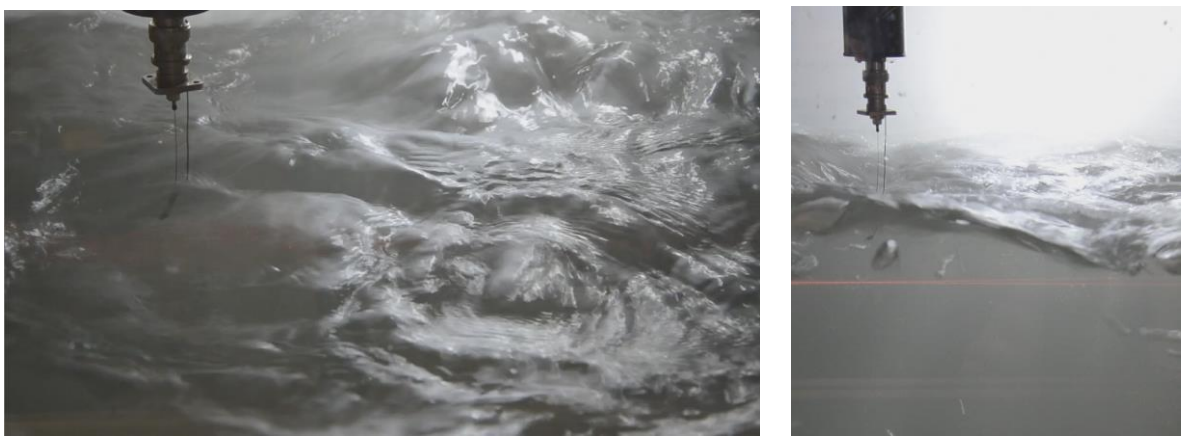

Figure 3. Generation of free-surface waves (left) and bubbles entrainment (right) by hydrodynamic turbulence.

In a second stage, an electromechanical shaker will generate gravity-capillary waves at the free surface. We aim to study attenuation [8, 9] or amplification of free-surface waves by hydrodynamic turbulence and energy exchange, in particular between hydrodynamic turbulence and wave turbulence (mixing of interacting nonlinear free-surface waves).

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