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# Total kinetic energy associated to wave and current evolution under accelerated wind conditions



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## Introduction

Most efforts in the study of the generation and evolution of wind waves have been conducted under constant wind. The balance of the transfer of different properties has been studied mainly for situations where the wave has already reached the equilibrium with the constant wind conditions. Besides, the effect of the vertical section of the drift surface current generation mix in the boundary layer has been poorly studied. The purpose of these experiments is to study the early stages of the generation of waves and surface drift currents under non-stationary wind conditions and to establish a balance in the exchange at the air-water interface for non-equilibrium wind conditions.

## Experimental design

A total of 9 experiments with a characteristic acceleration and deceleration rate of wind intensity were conducted in a large wind-wave facility of Institut Pythéas (Marseille-France). The wave tank is 40 m long, 2.7 m wide and 1 m deep. The air section is 50 m long, 3 m wide and 1.8 m height (Figure 1).

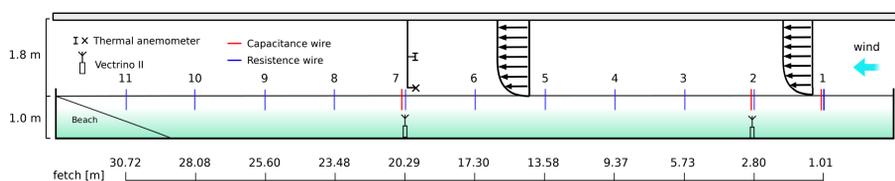


Figure 1: Layout of the wind tunnel and water tank.

The momentum fluxes were estimated from hot wire anemometry at station 7. Also, the free surface displacement was measured along the channel at 11 stations where resistance wires were installed. In gauge stations 1, 2, and 7 capacitance wires were also installed. The sampling frequency for wind velocity and surface displacement measurements was 256 Hz. Current sampling is performed with a profiling velocimeter located upward in the middle of the water column in station 2 or 7. The device measures the first 3.5 cm of the surface with a rate of 100 Hz and vertical resolution of 1 mm. During experiments the wind intensity was abruptly increased with a constant acceleration rate over time, reaching a constant maximum intensity of 13 m/s. (Figure 2).

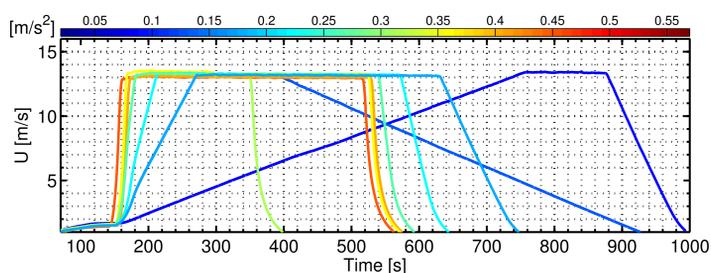


Figure 2: Time evolution of wind speed for 9 experiments with different acceleration rate.

## TKE-Balance

• TKE balance equation 
$$\frac{\partial k}{\partial t} + \frac{\partial F(k)}{\partial z} = P + P_s + B + \epsilon \quad (1)$$

• Shear production of mean flow 
$$P = - \langle wu \rangle \frac{\partial U}{\partial z} - \langle wv \rangle \frac{\partial V}{\partial z} \quad (2)$$

• Shear production of Stokes drift 
$$P_s = - \langle wu \rangle \frac{\partial U_s}{\partial z} \quad (3)$$

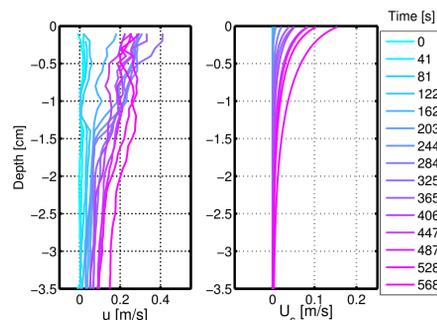
• Bouyancy production 
$$B = \beta g \langle w\theta \rangle \quad (4)$$

• Rate of viscous dissipation 
$$\epsilon = \frac{15}{2} \nu \overline{\left(\frac{\partial u}{\partial z}\right)^2} \quad (5)$$

• Turbulent kinetic energy (TKE) 
$$k = \frac{1}{2} \left( \overline{(u')^2} + \overline{(v')^2} + \overline{(w')^2} \right) \quad (6)$$

## Results

### Experiment 1 : 0.02 m/s<sup>2</sup>



### Experiment 2 : 0.10 m/s<sup>2</sup>

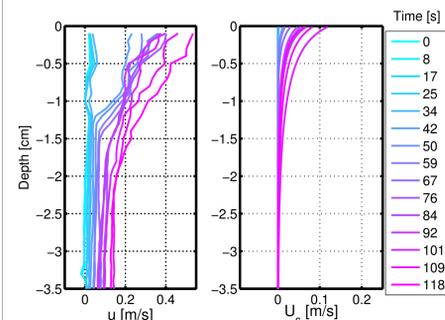
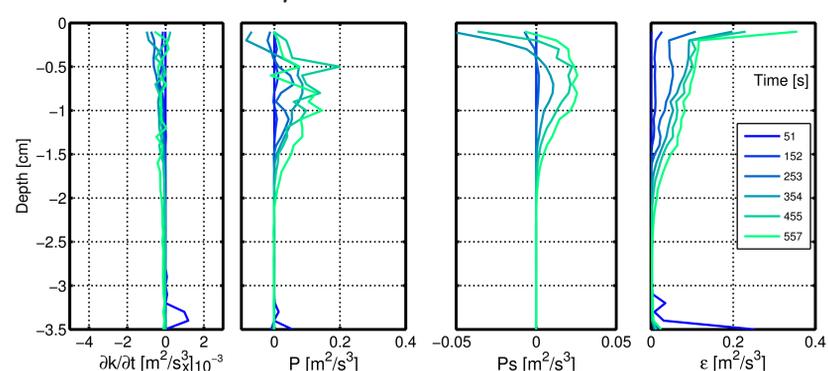


Figure 3: Time evolution of current horizontal velocity and Stokes drift during accelerated wind conditions for two different experiments.

### Experiment 1 : 0.02 m/s<sup>2</sup>



### Experiment 2 : 0.10 m/s<sup>2</sup>

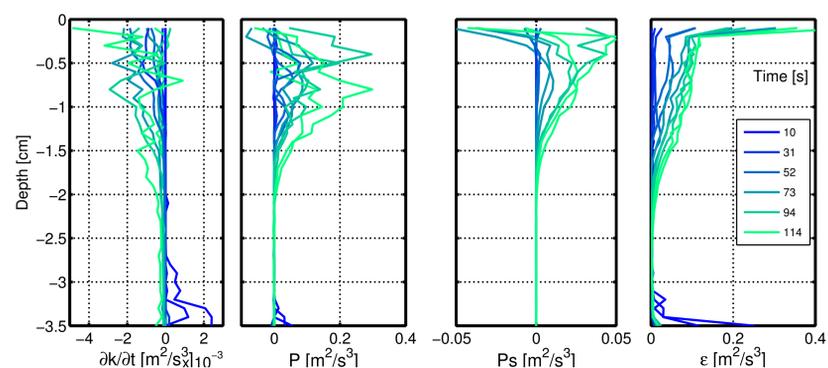


Figure 4: Time evolution of rate of turbulent kinetic energy, shear production of mean flow, shear production of Stokes drift and rate of viscous dissipation during accelerated wind conditions for two different experiments.

## Summary

- The energy injection from the surface current to deeper layers is higher for the higher acceleration experiment.
- However, the Stokes drift reaches higher magnitudes during the lower acceleration experiment.
- The rate of TKE presents values around zero during the acceleration wind period, showing a balance between the TKE production and TKE dissipation.
- The higher values of mean flow production, Stokes drift production and rate of viscous dissipation are presented in the experiment with higher acceleration rate.
- There is a difference of one order of magnitude between the mean flow production and Stokes drift production.

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