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# AIR-FLOW STRUCTURE IN THE VERY CLOSE VICINITY OF WIND GENERATED WATER-WAVES

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In the large wind-wave tank of IRPHE (40m long, 3m wide, 1m deep water and 1.7m high for the air, wind speed up to 14m/s) we conducted a set of experiments to measure the structure of the air flow in the very close vicinity of the water-surface above wind-generated waves. We estimated momentum transfers from air to water and we made direct measurements of form drag and viscous drag quantities for different conditions of wind and waves.

The total drag from air to water is equal to :  $\tau_{tot} = \rho_{air} \overline{uw} = \rho_{air} u^*{}^2$ , with  $\rho_{air}$  the air-density,  $u$  and  $w$  the horizontal and vertical components of the wind speed,  $u^*$  the friction velocity, and the bar denotes the time-average. The momentum flux does not vary with the altitude  $z$ , and at the water surface  $z = \eta$ , the total drag is equal to the sum of the viscous drag  $\tau_v$  and the form drag  $\tau_{form}$ :

$$\tau_{tot} = \rho_{air} u^*{}^2 = \tau_v + \tau_{form} = \rho_{air} \nu_{air} \left( \frac{\partial u}{\partial z} \right)_{z=\eta} + \left( \overline{P(\partial\eta/\partial x)} \right)_{z=\eta}$$

with  $P$  the static pressure,  $\partial\eta/\partial x$ , the slope of the water waves,  $\nu_{air}$  the air kinematic viscosity.

Wave characteristics were measured with a set of conventional capacitance wave gauges, and the total momentum transfer  $\tau_{tot}$  was determined with hot X-wire anemometer probes. Measured constant vertical profiles of  $\tau_{tot}$  demonstrated the existence of a constant flux layer above the water surface. In order to estimate the form drag and the viscous drag at the sea surface, we build two new microphysical devices:

1) the wind-speed vertical-profile was measured down to the surface with a specialist *kingfisher* apparatus: this device carries a single 5 $\mu$ m diameter hot wire and undertakes a rapid vertical wind profile downwards to the water surface. While acquiring horizontal wind speed data every 50 $\mu$ m, the hot-wire hits the water surface. An example of the vertical profile of the normalized phase-averaged wind-speed in the air-viscous layer (1mm above water surface) is shown on Fig 1. Viscous drag for different wind speeds are shown in Fig 2.

2) static pressure fluctuations at a constant curvilinear altitude above waves, were measured with an very sensitive piezo-pressure sensor (precision  $\pm 0.2 Pa$ ) located inside an Eliot disk antenna. This sensor was put on a new *wave-follower* device. A capacitance wave gauge output signal was connected to the wave-follower actuator command via a signal conditioning which controlled the gain, sensitivity, speed and acceleration of the following rod, thus resulting in an accurate constant elevation of the pressure probe above the surface (more details on the devices, sensors and results can be found in [1] and [2]). Examples of wave-phase-averaged static pressure field and form drag  $\tau_p$  are shown in Fig 3.

At the water surface, the wind-drift current is mainly induced by the viscous drag, and the wave height amplification is mainly induced by the form drag. The partition of the total drag into viscous drag and form drag was studied in [1]. Fig. 4 and 5 show examples of varia-

tion of the drags with wind speed and wave steepness  $ak$  ( $a$  amplitude,  $k$  wavenumber). Our work shows that wave coherent tangential stress may be more important at low  $ak$ .

We quantified also the associated growth rate of the surface wave fields. The systematic energy budgets for the interaction between wind and waves are detailed in [1] and will be presented during the oral session.

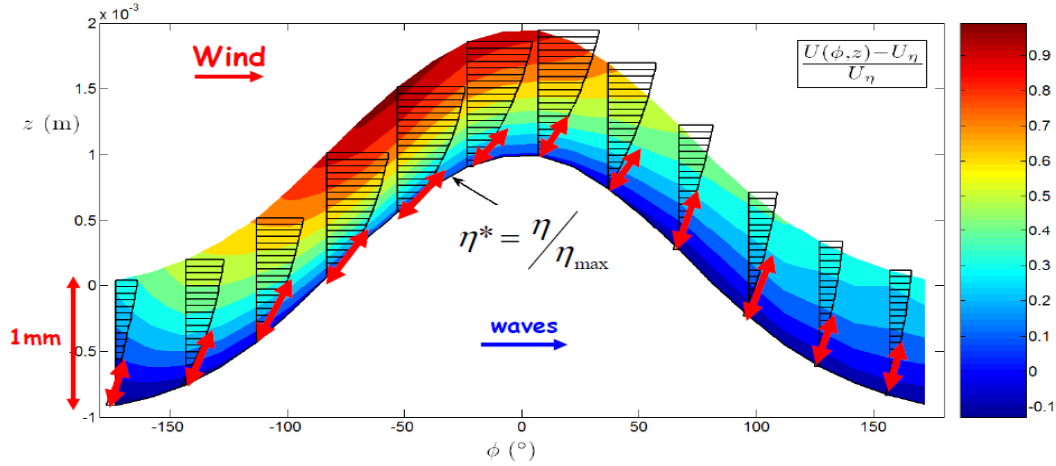


Fig 1. Results from the kingfisher device: vertical profile of the normalized phase-averaged wind-speed in the air-viscous layer (1mm above water surface). Wind speed 7m/s, mean wavelength  $L=0.48m$

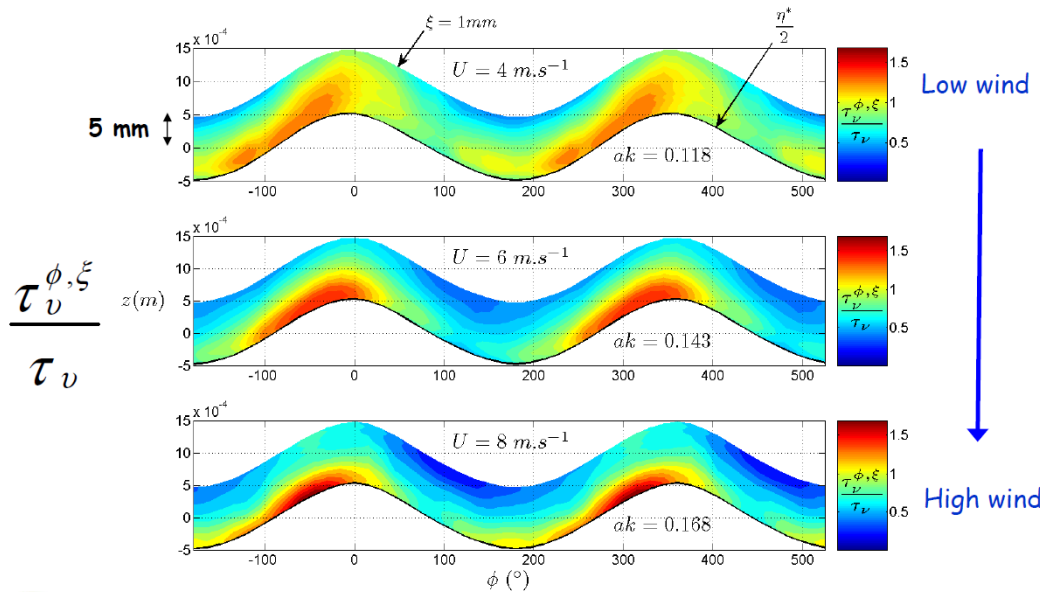


Fig 2. Normalized phase-averaged viscous drag above waves for different wind speed. Wind above the waves blows from left to the right.

## REFERENCES

1. Grare L., Peirson W., Branger H., Walker J., Giovanangeli J.P, Makin V. Growth and dissipation of wind forced, deep water waves // J. Fluid Mech. 2013. in press.
2. Grare L., Ocean-Atmosphere interaction study in the vicinity of water surface: application to wind waves and rogue waves // Ph. D. thesis, 2010, Aix-Marseille University, P 1-222, available on request by mail at [lgrare@ucsd.edu](mailto:lgrare@ucsd.edu)
3. Makin V., Branger H., Peirson W., Giovanangeli J-P. Modelling of laboratory measurements of stress in the air flow over wind-generated and paddle waves // J. Phys. Oceano. 2007. V. 37. P. 2824–2837.

4. Peirson W., Garcia A. On the wind-induced growth of slow water waves of finite steepness. J. Fluid Mech. 2008. V. 608. P. 243–274.

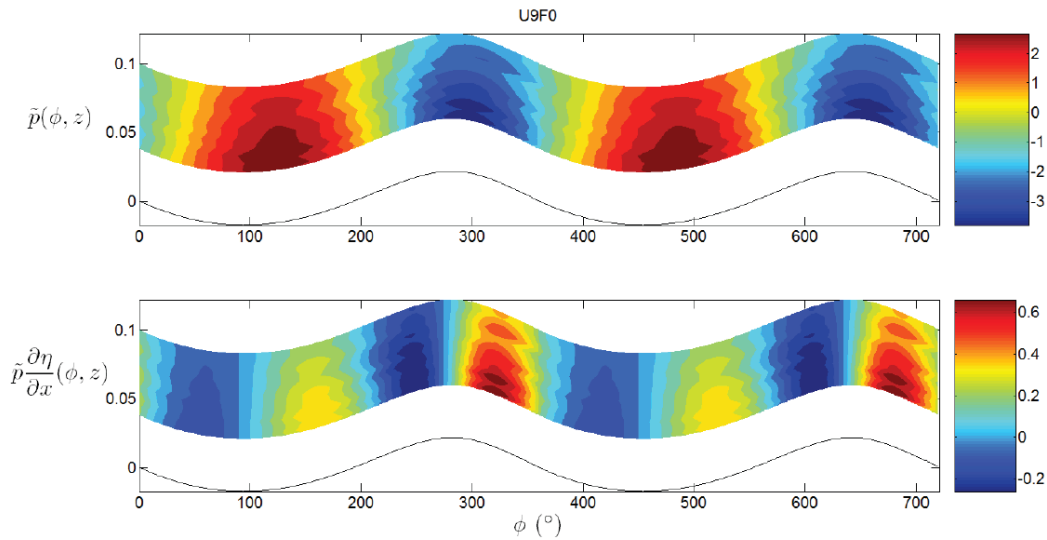


Fig 3. Examples of fluctuating phase-averaged static pressure field and form-drag measurements obtained with the Piezo sensor and Eliot antenna located on the wave follower. Units in Pa. Wind (9m/s) is blowing from left to right. Mean wavelength  $L=0.61m$

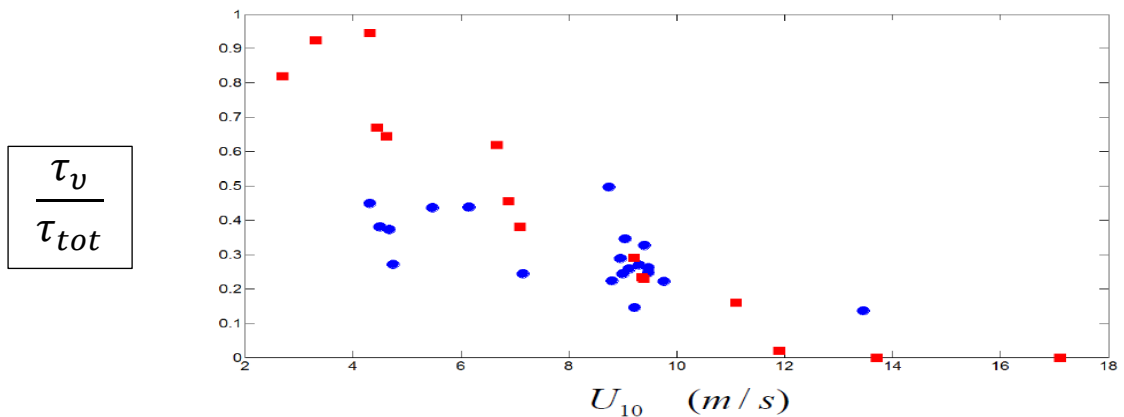


Fig 4: variation of the “viscous drag /total drag” ratio with wind speed. Blue dots: direct measurements, red squares: Makin’s model [3].

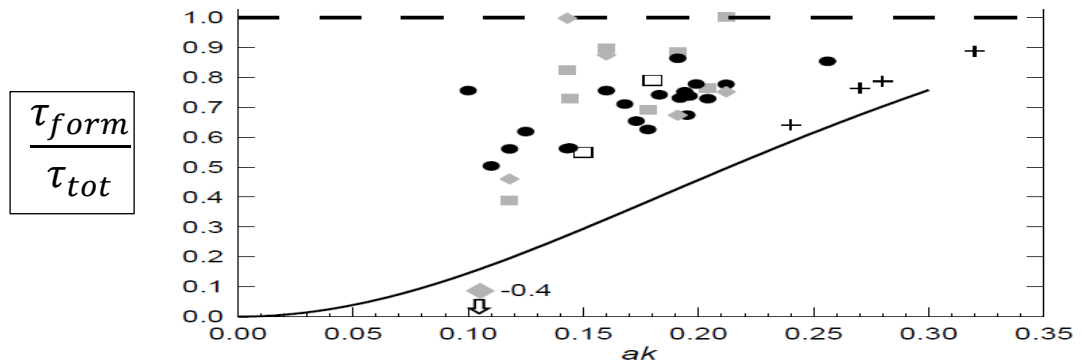


Fig 5: variation of the “form drag/total drag” ratio with wave steepness: black dots: direct measurements, other symbols: data from other studies (see [1]), black curve obtained from the net measurement of Peirson and Garcia [4].