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Detailed simulations of air-water interaction phenomena in ocean waves

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In the present contribution the flow induced in air by ocean waves is investigated. The air-water interaction problem is of obvious interest in the context of wind generated waves. However, the flow induced in the lower atmosphere layer by ocean waves has also important effects on the exchange processes between atmosphere and ocean and in some circumstances it influences weather conditions on large scales.

The problem is studied numerically by a two-dimensional Navier-Stokes solver which models the flow in air and water as that of a single incompressible fluid with density and viscosity expressed as a smooth function of the distance from the interface. The free surface is captured as the zero level set of the distance function. The distance from the interface is reinitialized every time step, so that the thickness of the transition region remains constant in time.

The method is applied to two problems characterized by quite different length scales and steepnesses. In both cases the limits associated to the numerical approach and possible effects on the results are discussed.

The first application is an attempt of investigating the role played by the flow in air on the dissipation rate of swells. The interest for such problem stems from some studies according to which the flow in air has an important effect on the dissipation of the steepest swells (Ardhuin et al, 2009). Motivated by the above findings, numerical simulations are performed in order to investigate the characteristics of the flow induced in air by swell with wavelengths in a range 50 to 300 m. Results are presented in terms of vorticity field in air with quantitative analyses of the vertical flux of horizontal momentum and of the viscous dissipation in the air phase. The thickness of the air layer which is influenced by the passage of the swell is also given.

The second study analyzes the flow induced in air by the evolution of modulated wave trains. In this case the fundamental wavelength is 0.6 m. Depending on the initial wave amplitude, rather steep waves are generated, which may eventually break. Independently of the breaking occurrence, the formation of steep waves due to the focusing of the different components is a rather fast process and this causes the separation of the air flow from the crest, with a corresponding generation of intense vorticity structures. Results are presented in terms of velocity and vorticity field in air, and the different dynamics induced in air by waves of different steepness are discussed. Some considerations concerning the thickness of the air layer affected by the wave are provided as well.

[1] F. Ardhuin, B. Chapron, F. Collard (2009) Observation of swell dissipation across oceans, Geophys. Res. Lett., Vol. 36.