Direct numerical simulation of non-breaking gravity waves: transition to turbulence in the wave boundary layer

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When progressive wind-waves approach the coast they interact with the sea bottom generating a boundary layer (BL) that is responsible for significant shoreward mass transport. The BL is driven both by the wave irrotational flow and by the viscous diffusion of momentum that ultimately gives rise to a near-bottom steady current[1]. Moreover, if turbulence eventually appears, the BL properties may significantly change. In the present contribution, the mechanism of transition to turbulence and the effects of turbulence on the Lagrangian transport are investigated by means of direct numerical simulation. In particular, waves characterised by period $T = 3.04$ s, wavelength $\lambda = 12.6$ m, height $H = 1$ m and water depth $h = 2$ m are considered. The incompressible Navier-Stokes equations are numerically solved in a Cartesian grid which extends, in the vertical direction, from the bottom, characterised by a smooth horizontal wall where no-slip condition is applied, for a distance equal to the 0.8 h. The dimension of the domain in the streamwise direction is equal to λ, while in the spanwise direction it is about 70 times the BL thickness δ. Periodic boundary conditions are imposed in the streamwise and spanwise directions, while the solution of the non-linear inviscid steadily-progressing wave problem is imposed at the top of the domain, which is computed using the procedure proposed by Fenton[2]. Second-order accurate fractional-step method is employed, with the spatial operators in the homogeneous directions discretised by a de-aliased pseudo-spectral method. While the flow is still evolving, figure 1 shows the three-dimensional vortical structures that predate the transition to turbulence. The preliminary results of the simulation will be shown.

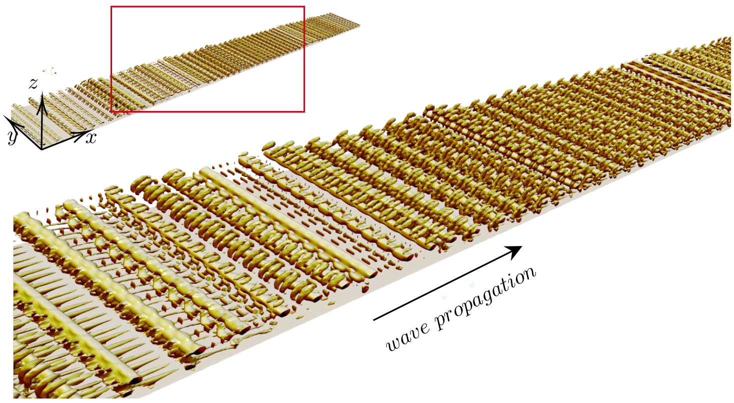

Figure 1: Three-dimensional vortical structures visualised by Q-criterion in the region of the bottom where the Reynolds number is maximum (in the inset $x \in [800, 1600]\ \delta$).

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[1] Longuet-Higgins, M. S. *Philosophical Transactions of the Royal Society of London* **245** 903 (1953)

[2] Fenton, J.D. *Advances in Coastal and Ocean Engineering*, **5** (1999)