THE DEPTH SEMI-AVERAGED MODEL: AN ALTERNATIVE APPROACH TO THE DESCRIPTION OF COASTAL DYNAMICS

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In the present work we show some novel applications of the depth semi-averaged model of Antuono et al. (2017) to the description of wave dynamics in the coastal region.

The above-mentioned model lies between the classic Boussinesq-type models and the more recent 3D models. It is composed by a subset of depth-averaged equations and by a Poisson equation for a depth semi-averaged quantity, namely the integral of the vertical velocity component from the free surface to a certain quote of the water column. This latter variable, called *Y*, is used to recover the vertical variations of the local velocity field and allows for the inclusion of the dispersion effects of wave propagation. Accordingly, the Poisson equation for *Y* is used in place of the Poisson equation for the pressure field, which is usually solved in non-hydrostatic models. Being a depth semi-averaged variable, *Y* is expected to represent the dynamics on characteristic lengths and times that are closer to those typical of wave propagation.

The advantage of such a formulation lies in the fact that the depth semi-averaged model is derived straightforwardly from the Euler equations without using any approximation. Further, it is possible to include the dissipation caused by wave breaking by deriving the model from the Reynolds Averaged equations and providing proper closures for the turbulent terms, as done in Antuono et al. (2022).

Starting from the latter work, in the present contribution we discuss applications for both breaking and non-breaking waves. In the latter case, we consider the experimental campaigns of Beji & Battjes (1993) and Dingemans (1994) who performed a series of experiments of regular wave propagation over a submerged trapezoidal bar. These results are used as benchmarks to check the accuracy of the model in representing dispersive and non-linear effects in intermediate and shallow water conditions. Conversely, the experiments of Chawla (1995) for regular monochromatic waves propagating over a circular shoal are used to assess the capability of the model in describing the interaction with complex two-dimensional seabeds. A comparison between the numerical outputs and the experimental measurements for the campaign of Beji & Battjes is displayed in Figure 1, whereas a snapshot of the evolution for the case of Chawla is shown in Figure 2.

For what concerns breaking waves, we consider the phenomenon of propagation over a uniform sloping beach described in Hansen & Svendsen (1979) and in Kimmoun & Branger (2007). A comparison between the latter experiments and the output of the model is shown in Figure 3, where the angled brackets indicate the ensemble mean while the bar symbol denotes the mean over the wave period. This proves that the model can represent the dissipation induced by wave breaking and by the consequent turbulent dynamics. In all benchmarks the model proves to be accurate and robust and to represent a valid alternative to the modeling procedure usually adopted by non-hydrostatic schemes.

Finally, as a proof of concept of an application to natural conditions, we consider the propagation of an irregular wave train in the region facing the dock of the Naples harbor, the Molo San Vincenzo. The reference sea conditions are those recorded at a buoy close to the dock, where the significant wave-height and period are Hp = 1.16m and Tp = 6.75s respectively. In the numerical simulations a slightly smaller wave height has been chosen for the input waves, in order to take into account the shoaling effects encountered during their propagation toward the dock. Figure 4 shows the seabed bathymetry in front of the dock and the positions of the free-surface probes at the inflow boundary and at the location of the buoy. Figure 5 displays a snapshot of the evolution of the free surface in the case of an irregular wave train from South-West. In this case the model is able to identify the regions where the wave elevation is more intense as a consequence of the interaction with the bathymetry and the reflection from the dock.

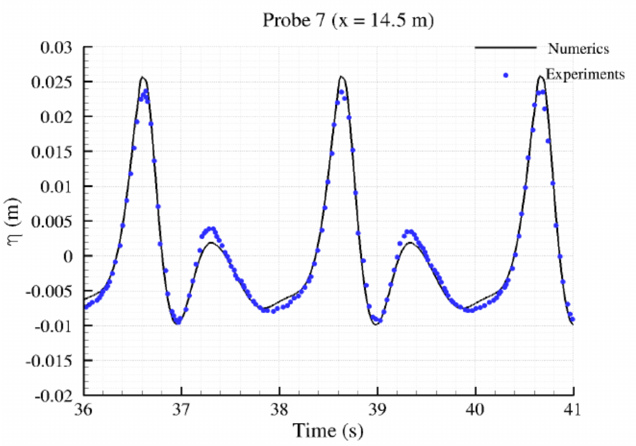

Figure 1 – Experiments of Beji & Battjes (1993). Comparison between the numerical outputs and the experimental measurements for the free-surface evolution at x=14.5 m.

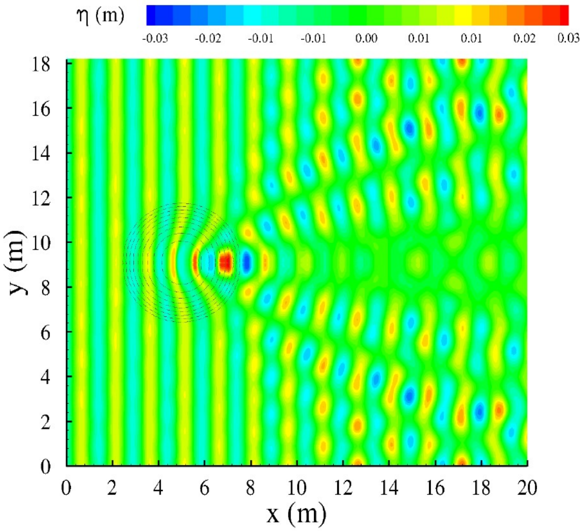

Figure 2 – Snapshot of the evolution of a regular wave train over a circular shoal (Chawla, 1995).

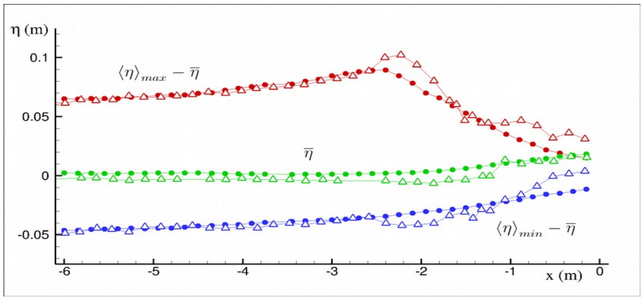

Figure 3 - Cross-shore distribution of crest, mean and trough elevations for the spilling breaking case of Kimmoun and Branger (2007). Comparison between numerical outputs (dots) and experiments (triangles).

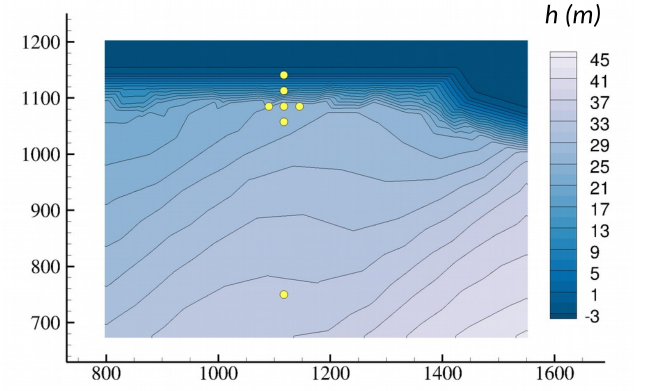

Figure 4 – Bathymetry of the San Vincenzo dock along with the positions of the free-surface probes (yellow dots).

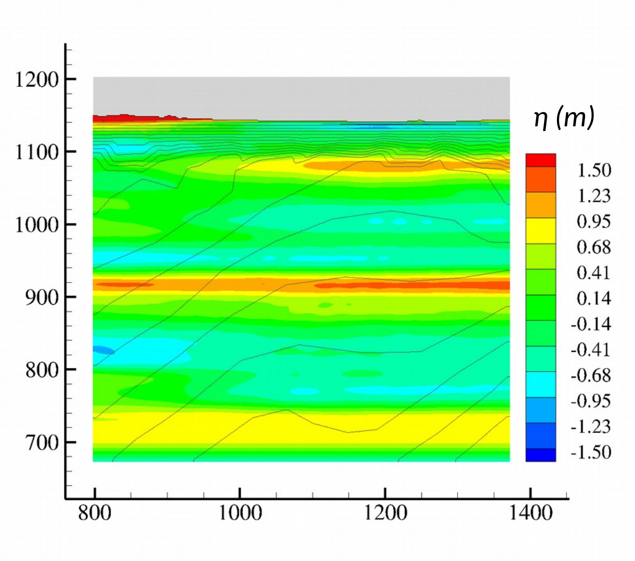

Figure 5 – A snapshot of the free-surface elevation for an irregular wave train from South-West.

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