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Numerical simulation of combined coastal inundation due to fluvial flood, storm surge and wave induced set-up/runup

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ABSTRACT

In the present work, the numerical simulation of coastal flooding is investigated considering the synergy of fluvial flooding, storm surge and wave induced setup/runup. Two approaches are developed: the first one is based on a linear wave propagation model and a breaking wave induced circulation and setup (based on the Shallow Water Equations), while the second one is based on a higher order Boussinesq-type intra-period nonlinear dispersive wave model which describes the propagation of breaking waves in the surf and swash zone. In order to simulate the wetting-drying process during inundation the dry bed boundary condition (in the two horizontal dimensions) is applied in both SWE and Boussinesq model. The first approach results to the estimation of coastal inundation due to breaking wave setup while the second one to nonlinear wave runup (also including wave setup). In both approaches fluvial flow is also described (applying the "dry bed" boundary condition), resulting in the compound coastal flooding due to synergy of river flow (and overflow), storm surge and wave setup/runup.

This work in considered as the first authors' step in understanding the hydrodynamics of such areas, which is critical for future research on the simulation of coastal morphodynamics under pressures from both the terrestrial and the coastal fields.

1. Modelling approach

1.1. Linear wave model

Wave transformation in the nearshore, including the compound wave field near coastal structures, can be simulated satisfactorily by a model based on the hyperbolic-type mild slope equation. Such a model is described in detail by Karambas and Samaras (2017). Breaking wave induced nearshore currents and setup are simulated by solving the depth and shortwave-averaged 2D continuity and momentum equations. Both models are extended in the swash zone according to Karambas and Samaras (2017). Coastal flooding is simulated using the "dry bed" boundary condition according to Militello et al. (2004).

1.2. Nonlinear wave model

An advanced model based on the numerical solution of the higher-order Boussinesq-type equations is used to simulate the propagation of non-breaking and breaking waves, according to Samaras and Karambas (2021). The above mentioned "dry bed" boundary condition, is also applied to simulate wave runup, while it is noted that wave-induced setup is automatically simulated in this type of models.

1.3. Storm surge and fluvial flow

Coastal flooding due storm surge is also simulated by the "dry bed" boundary condition. In both approaches fluvial flow is also described, applying the same boundary condition, resulting in the compound coastal flooding due to synergy of river flow (and overflow), storm surge and wave setup/runup.

2. Models Applications

Both the linear and nonlinear wave models described in the previous are applied to predict compound coastal flooding in a beach at a coast in Chalki Island (Greece), with the nonlinear (Boussinesq) model predicting a larger inundation area overall. The latter is expected since simulating wave runup, as done in nonlinear models, results in higher inundation than wave setup which is simulated in linear wave models (which is an important limitation). Figure 1 shows indicative results of the nonlinear wave model (Boussinesq model) due to the synergy of wave setup/runup and river flow/overflow (wave height= 1 m, period= 6 s, river velocity =1 m/s). The incorporation of swash zone hydrodynamics and fluvial flooding is the main advantage of the present approach over the existing ones which are based on linear wave model and a wave induced setup model. Unfortunately no data for the combined wave runup and river flooding hydrodynamics are available.

3. Conclusions

A higher order intra-period nonlinear dispersive wave model which describes the propagation of breaking waves in the surf and swash zone.and a linear wave propagation model in combination with a wave induced circulation and setup model can provide useful insights for the simulation of compound flooding in coastal zones comprising highly dynamic areas like river estuaries and natural streams' outlets.

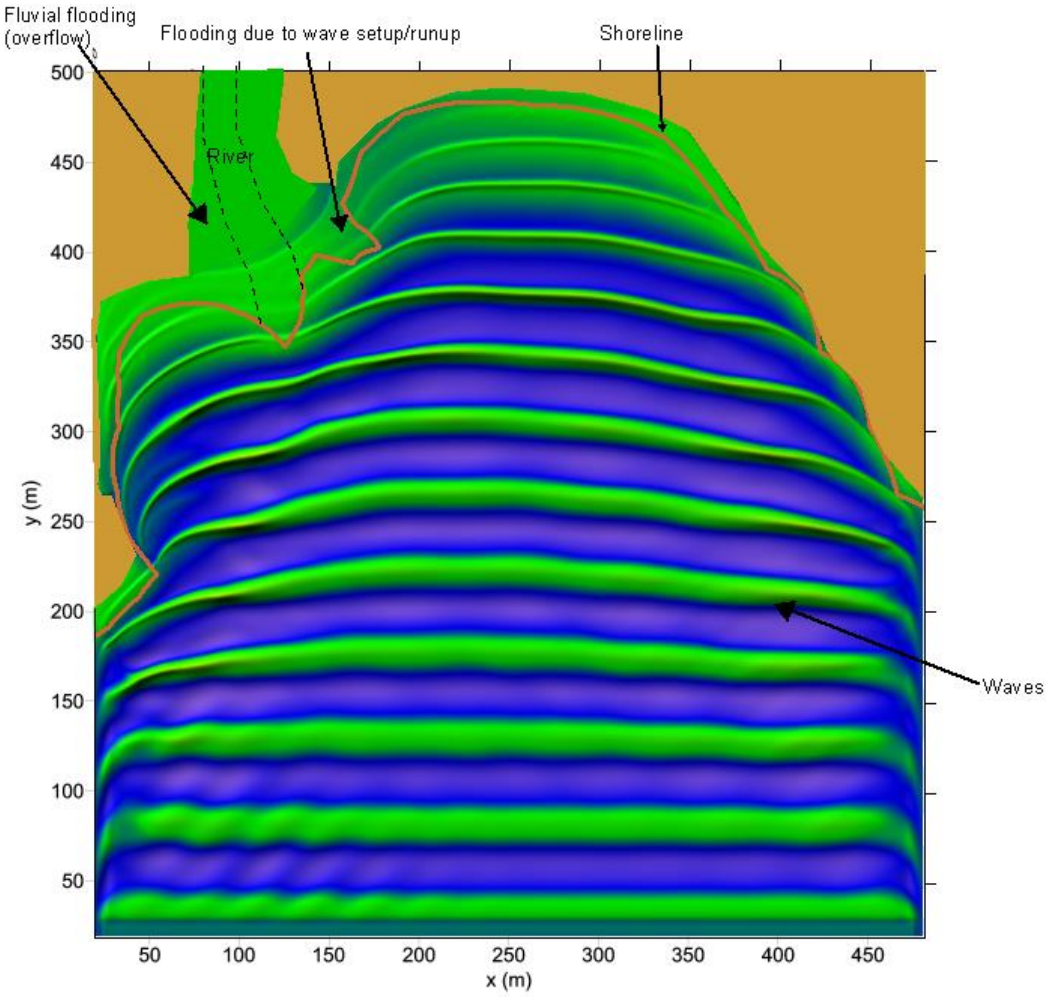

Fig. 1. Wave propagation and coastal inundation due to the synergy of wave setup/runup and fluvial flow (nonlinear wave model results). Green colour depicts water level above Mean Water Level.

References

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