Comparative assessment of non-linear deterministic models for coastal wave propagation and run-up on a vertical wall

Guillaume Coulaud[1,2], Michel Benoit[1,2], Maria Teles[1]

[1] EDF R&D Laboratoire National d'Hydraulique et d'Environnement (LNHE), 6 quai Watier, 78400 Chatou, France

[2] Laboratoire d'Hydraulique Saint-Venant (Ecole des Ponts, EDF R&D), 6 quai Watier, 78400 Chatou, France

guillaume.coulaud@edf.fr

When propagating over variable seabed, ocean surface waves experience transformations due to various physical processes, including shoaling, refraction, diffraction, reflection or depth-induced breaking. Dispersive and non-linear effects can also be of importance, depending on the relative water depth kh (k being the characteristic wavenumber and h the local water depth) and the wave steepness ka (with a the characteristic wave amplitude) respectively. Among the deterministic (or phase-resolving) class of wave models, depth-averaged models are commonly used as a cheaper alternative to the fully dispersive fully non-linear Euler equations. However, due to the simplifying assumptions made in their derivation regarding dispersion and/or non-linearity, their ranges of applicability in terms of kh and ka vary significantly and remain limited.

In this work, we compare various deterministic wave models, ranging from the non-dispersive non-linear shallow water equations to a fully non-linear potential-flow model [1]. Several depth-averaged weakly dispersive Boussinesq-type models (from Peregrine [2], Nwogu [3] and Wei et al. [4]), or Serre-Green-Naghdi equations (e.g. Cienfuegos et al. [5] and Clamond et al. [6]) are also considered.

The capabilities and limitations of the various models regarding dispersion and non-linearity are assessed on cases of propagation of non-breaking waves in one horizontal dimension with uniform or variable water depth. Extreme wave run-up on a vertical wall due to a dispersive shock-wave wave train is also investigated based on the test-case introduced by Benoit et al. [7]. This case allows a quantitative assessment of the performances of the various approximate models and highlight the importance of both dispersion and non-linearity.

References

1. J. Zhang & M. Benoit, Wave-bottom interaction and extreme wave statistics due to shoaling and de-shoaling of irregular long-crested wave trains over steep seabed changes, *J. Fluid Mech.*, **912**, A28 (2021).
2. D. H. Peregrine, Long waves on a beach, *J. Fluid Mech.*, **27**, 815–827 (1967).
3. O. G. Nwogu, Alternative Form of Boussinesq Equations for Nearshore Wave Propagation, *J. Waterway, Port, Coastal, Ocean Eng.*, **119**, 618–638 (1993).
4. G. Wei & J. T. Kirby & S. T. Grilli & R. Subramanya, A fully nonlinear Boussinesq model for surface waves. Part 1. Highly nonlinear unsteady waves, *J. Fluid Mech.*, **294**, 71–92 (1995).
5. R. Cienfuegos & E. Barthélémy & P. Bonneton, A fourth-order compact finite volume scheme for fully nonlinear and weakly dispersive Boussinesq-type equations. Part I: Model development and analysis, *Int. J. Numer. Methods Fluids* , **51**, 1217–1253 (2006).
6. D. Clamond & D. Dutykh & M. Dimitrios, Conservative modified Serre–Green–Naghdi equations with improved dispersion characteristics, *Comm. Nonlin. Sci. Num. Sim.*, **45**, 245–257 (2017).
7. M. Benoit & F. Dias & J. Herterich & Y.-M. Scolan, Un cas-test discriminant pour la simulation de la propagation et du run-up de trains de vagues de type tsunami, *Actes des 16èmes Journées de l'Hydrodynamique, 27-29 Novembre 2018, Marseille (France)*, (2018).