# Numerical modeling of depth-induced wave breaking: a review and comparison of low- to high-fidelity simulation methods.

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The numerical modeling of wave breaking in the coastal zone, subsequent energy dissipation and effects on the nearshore hydrodynamics remains a challenging task due to the complexity of the physical processes at play, including highly nonlinear free surface effects and deformations prior to breaking, air entrainment and droplets (two-phase flow), energy dissipation and high turbulence intensity associated with strong mixing in the water column, etc. Several modeling approaches have been proposed over the last 50 years, ranging from simplified (parametric) models to highly resolved two-phase CFD-type simulations.
The aim of this presentation is to review and compare several representative numerical models from five classes of increasing complexity, namely:

1. a parametric model, relying on the wave energy flux equation, including a dissipative term, formulated in analogy with a hydraulic jump for instance.
2. a weakly dispersive Boussinesq-type model, supplemented with a breaking criterion and a dissipative term activated after breaking initiation (e. g. Kazolea & Ricchiuto, 2018)
3. the two-layer model recently proposed by Gavrilyuk *et al*. (2016), where the surface layer modeling the breaking wave area is modeled with the nonlinear shallow water equations.
4. a fully nonlinear and dispersive potential flow model with a breaking dissipative term, formulated either in analogy with a hydraulic jump or an eddy viscosity-type term. These two dissipation formulations, combined with three breaking criteria have been implemented and validated in the whispers3D code (Simon *et al*., 2019).
5. a two-phase highly resolved solver using the neptune_cfd software, based on an Eulerian-Eulerian approach using a dedicated free surface interface tracking method (the Large Interface Method) and offering various ways of modeling the air phase. This code has been recently applied to model breaking waves impacting a vertical wall (Benoit *et al*., 2022). See also the presentation by Benguigui *et al*. (2023) at the B'Waves23 conference.

These modeling approaches will be briefly described and then compared with each other and experimental data in wave flumes for two cases with different seabed profiles and breaking-type conditions. This comparison allows to assess the merits and drawbacks of the various approaches. Furthermore, the possibility of using of higher-fidelity approaches (e.g. two-phase CFD) to improve lower-fidelity models (i.e. parameterized methods) will be discussed.

References:

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