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Wave-breaking onset in a High-Order Spectral model

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We examine the implementation of a wave-breaking onset parameter into two numerical models, HOS-ocean and HOS-NWT, which are computationally efficient, open source codes that solve for highly nonlinear wave fields in the open ocean and a numerical wave tank, respectively, using the High-Order Spectral (HOS) method. Due to the assumptions of solving for potential flow, the HOS solvers assume a single-valued free surface and therefore cannot produce breaking waves. The goal of implementing a wave-breaking mechanism into the HOS models is to approximate the broken free surface as a single value. By doing this, we can increase the application range of the models including calculating more extreme sea states, which is important when predicting dynamics of offshore vessels, predicting loads on marine structures and the general physics of ocean waves, for example.

In nature, a steep wave may grow to surpass some limiting threshold leading to a collapse of the water surface as a broken wave. Energy from the wave is transferred through the generation of currents and turbulence, and changes occur in the spectral distribution of energy before and after a wave breaks. To implement a wave-breaking mechanism into the HOS models, first a wave-breaking onset parameter needs to be identified, and second, a strategy for dissipating and distributing the energy after the wave has broken needs to be determined.

To calculate wave breaking onset in the HOS solvers, a dynamic wave-breaking criteria is proposed, following the work of Barthelemy, et al. (submitted). The criteria assumes that if the ratio of local energy flux velocity to the local crest velocity surpasses a limiting threshold, the wave will break. Calculation of the local crest velocity is non-trivial, and therefore partial Hilbert transforms are used. When calculating this wave-breaking parameter in the HOS model, it successfully distinguishes between an "unbroken" wave and a "broken" wave, evidenced by the manifestation of high frequency components in the surface elevation and modal distribution of a "broken" wave. These high frequency components are likely an artifact of a wave which in nature would overturn, but since the HOS models solve for a single-valued free surface, these high frequencies develop instead.

Comparisons are made between the calculated breaking onset parameter and corresponding local wave crest steepness for breaking and non-breaking waves generated with the HOS models and existing laboratory experiments and numerical calculations with good agreement. Further research will be done regarding the dissipation and distribution of energy after the wave has broken, with special attention paid to the spectral redistribution of energy.