Velocities Profiles and Energy Beneath Near-Breaking Waves

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ABSTRACT
Ocean wave breaking is a poorly understood but important air-sea coupling process that plays a critical role in sea state forecasting and the determination of peak loads on many ocean engineering structures. Ocean wave breaking is predominantly a three-dimensional (3D) process. Understanding of the onset and strength of 3D wave breaking is very limited and no general prediction can be made on the timing, location, scale and strength of wave breaking occurrences at present. The present study uses a Numerical Wave Tank (NWT) to reproduce various 2D experiments and then extends the simulation to 3D converging waves. Waves are generated by a snake paddle in a non-periodic domain with finite depth. We explore a new combination of methods to access to a high resolution velocity profile in steep crests approaching breaking. The accuracy of the estimated velocities is demonstrated in comparison with experiments. Unanticipated development of the velocity profiles occurs close to the point of breaking. Investigations are continuing to determine the robustness and potential significance of this kinematic behavior.

KEY WORDS: Deep water waves; Boundary element methods; Projection and Angular and Radial Transformation method; Breaking waves; Energy focusing.

INTRODUCTION
In the open ocean, wave groups and wave breaking are key characteristics of the dominant waves. Both the physics of the breaking process and predicting its onset are of fundamental importance in determining structural loadings on ships and platforms, operational states for maritime transport and exchanges between ocean and atmosphere.

Many criteria for predicting the onset of breaking of deep water waves have been proposed based on field observation, laboratory experiments and numerical simulation. Conventional understanding and parameterization of breaking onset in deep water has been limited to thresholds based on either (i) geometric considerations (i.e. waves break if they become too steep, or if the surface modulation becomes locally too large), or (ii) kinematic constraints (waves break if critical water speeds or accelerations occur at the wave crest). However, these approaches have: (a) largely failed to yield robust thresholds [Melville, 1996]; (b) avoided addressing the elusive underlying dynamical processes; and (c) provided no reliable predictive capability for either actual (phase-resolved) waves in the physical domain, or for averaged wave fields in the spectral domain used in present wave model forecasts.

Recent numerical and laboratory studies [Banner and Tian 1998], [Song and Banner 2002], [Banner and Peirson 2007] (hereafter BP07) of idealised 2D wave groups have shown that the occurrence and strength of breaking is closely related to the rate of increase of the energy at the maximum of the wave group energy envelope, rather than to local properties of the individual waves that break, as has been assumed in the past. The key aspect of this approach is that the steepest wave grows within a wave group as energy is focused into that wave by nonlinear interactions. A parametric growth rate was found that predicted breaking initiation when this growth rate exceeded a robust threshold. Unlike previous geometrical or kinematic strategies, this dynamical approach was shown to provide an advance warning of breaking onset of up to several carrier wave periods. BP07 showed that the energy convergence rate at breaking was a reliable predictor of the subsequent energy loss during the breaking processes. This new approach has been independently validated for idealised 2D waves by [Tian et al. 2008] and [Tian et al. 2010].

A challenging issue in quantifying wave energy fluxes is capturing the near-surface velocity profiles close to highly curved free surfaces which are the primary contributors to the total wave kinetic energy as well as the peak drag on structures and their appurtenances.

The purpose of this contribution is to highlight some of our recent computational and measurement results in the investigation of 3D effects. Specifically, we highlight development of numerical techniques essential for reliably capturing the near-surface velocities.

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