Modeling the optical signature induced by wave breaking using a Boussinesq model

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Bubbles and foam generated by breaking waves are primary surface signatures that have profound effects on remote sensing applications. Recent studies showed that wave breaking-induced bubbles and foam significantly increase LiDAR backscatter and affect LiDAR data processing, reducing the accuracy of airborne LiDAR measurements(Wang et al., 2022). Over the past several decades, significant efforts have been made to improve the understanding of wave-breaking mechanisms and their connection to optical signatures, such as bubbles and foam, in both the deep ocean and the nearshore field(e.g., Reul and Chapron, 2003, Carini et al., 2015). Following the traditional studies of whitecaps in the deep ocean, research on nearshore breaking-induced bubbles and foam has garnered increasing attention due to the growing investigations of surfzone dynamics and the associated sediment transport with shoreline erosion. However, numerical studies on this topic are rare due to the heavy computing costs associated with existing multi-phase numerical methods. In this study, we proposed to develop a surface signature component in the phase-resolving wave model, FUNWAVE-TVD. FUNWAVE-TVD is a depth-integrated two-dimensional model for modeling wave propagation, breaking, and wave runup in a nearshore domain. Since previous observations have indicated that the foam's decay time can be employed to estimate the timescale of the subsurface bubble plume (Masnadi et al., 2021), we utilize bubble/foam (BF) as a representative model component in the depth-integrated model. The model incorporates the formulated BF layer, which floats on the carrying waves, and grows and decays according to a data-based empirical formula.

We consider a relatively simple system in which there is no momentum transfer between the liquid phase and the BF phases. The BF content is treated to be a single and inert component. The governing equation for the BF content (thickness) was derived based on the mass conservation equation described by Carrica et al. (1998) and the source/sink formulas given by Reul et al. (2003).

The model was calibrated using the results from the VOF-type two-fluid model (Shi et al., 2010). It was then applied in a field-scale domain at U.S. Army Corps of Engineers Field Research Facility (FRF), Duck, NC, where optical data in either visible band (ARGUS) or Infared (IR) band were collected during 2010 Surf Zone Optics (SZO) experiments in September 2010. Figure 1 demonstrates a snapshot of modeled BF thickness at FRF. The model results were also compared with the IR imagery along the cross-shore IR transect (red dashed line, Chickdell et al., 2022). Detailed model development and validations will be presented at the conference.

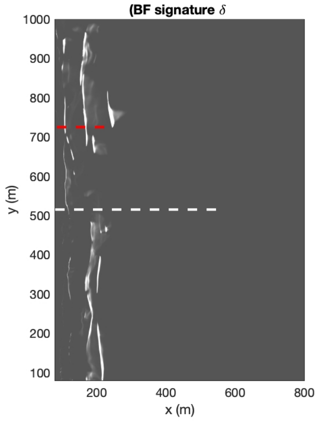

Figure 1: Snapshot of modeled BF thickness. The white dashed line represents the FRF pier location, and the red dashed line is the IR image transect used to compare the IR imagery.