UNSTRUCTURED WAVEWATCH III DEVELOPMENTS FOR MULTISCALE MODELING

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WAVEWATCH III

The US Army Engineer Research and Development Center (ERDC) is working collaboratively with the National Oceanic and Atmospheric Administration (NOAA), BGS IT&E GmbH, and the French Naval Hydrographic and Oceanographic Service (Shom) to extend the spectral wave modeling with WAVEWATCH III (WW3) (WW3DG 2019) from global and basin scales (e.g., ERDC Wave Information Studies hindcasting and NOAA forecasting) to local, nearshore processes into the surf zone. WW3 is undergoing rapid community development (Alves, et al. 2023). The unstructured, implicit solution option in WW3 provide flexibility and efficiency to resolve complex shorelines and high-gradient wave zones to drive nearshore circulation, wave setup, and wave-driven sediment transport with multi-scale spatial coverage over approximately three orders of magnitude. A hybrid approach to parallelization uses spectral partitioning for advection in geographical space and domain decomposition for spectral advection and the source term integration. The advection part of wave action equation is integrated fully implicitly, and a new convergent action limiter derived from Komen et al. (1994) and Hersbach and Janssen (1999) is applied. This paper describes model enhancements and validation.

BASIN-SCALE DEVELOPMENTS

WW3 advancements at large scale focus on improvements in efficiency and scalability that allow higher resolution in physical and spectral space and methods to reduce the so-called garden sprinkler effect (GSE). The new parallelization algorithm and implicit solver allow minimum resolution on the order of 10s of meters with multi-million node unstructured grids providing computational scalability and accuracy as good or better than the explicit scheme (Abdolali et al. 2020). A new diffusion tensor is implemented in WW3 to alleviate the GSE. This term is a function of latitude, mesh resolution, deep water wave speed, water depth. Within this study, we evaluate this implementation for Hurricane Lee, 2023, where the current operational systems (i.e., GFSv16) show a significant GSE in the wave products.

NEARSHORE COASTAL DEVELOPMENTS

Several additional capabilities have been implemented in WW3 to support nearshore applications. These include a lateral boundary conditions, dissipation by vegetation, triads, infra-gravity wave estimation, and extensive validation over a range of forcing conditions.

Neumann lateral boundary conditions are implemented in WW3 as an option for local application driven by offshore measurements or nested application where multiple nearshore simulations are made (e.g., to evaluate project alternatives) that don't require rerunning the parent grid simulation. The no-flux boundary significantly reduces shadow zone on the boundary for oblique wave incidence.

Modeling wave transformation and attenuation due to NNBF structures such as wetlands, submerged aquatic vegetation, or mangroves requires flexible gridding for complex coastal and estuarine shorelines and dissipation source terms for vegetation. Unstructured WW3 is modified for wave dissipations due to vegetation and validated for wave dissipation in wetlands systems. Comparisons with field data in a Chesapeake Bay wetland are used to evaluate model performance (Figure 1) (Abdolali et al. 2022). Changes in wave energy reduction due to elevated water levels resulting from storm surge are evaluated.

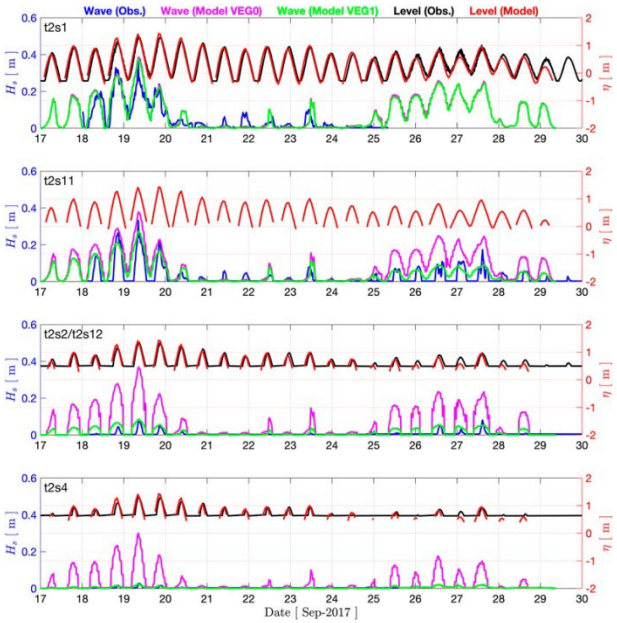

Figure 1. Wave model validation with vegetation for Hurricanes Juan and Maria in Magothy Bay, Virginia, USA.

Parameterized triad interactions in WW3 are based on Madsen & Sorensen (1993). Validation on the French coast near Ré Island is performed by Shom based on a unique and dense cross-shore array of gauges with a 14-m buoy and shallower pressure gauges. Figure 2 shows a comparison of simulated 1D spectra without triads (top panel) and with triads (middle panel) compared to the field measurements (bottom panel).

Additional validation of WW3 is performed at the ERDC Field Research Facility (FRF) on the coast of North Carolina, USA, to assess model errors and uncertainty over a wide range of forcing conditions over long duration. The FRF has a cross-shore array of wind, wave, current, and water level measurements along with monthly bathymetry surveys to set up and evaluate coastal models. WW3 is evaluated for conditions spanning intense extratropic storms, hurricanes, swell conditions, and mixed sea-swell conditions, including Hurricanes Sandy, Irene, and Dorian.

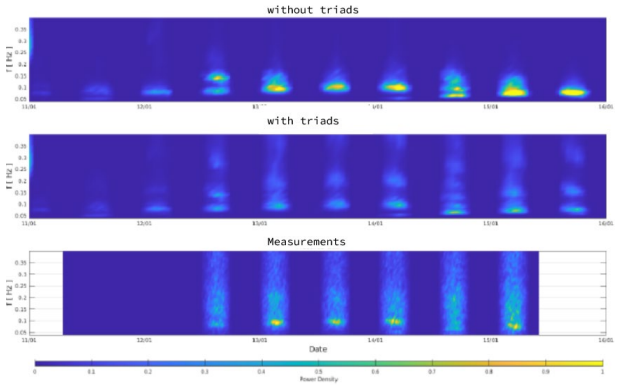

Figure 2. Wave model 1D spectra without triads (top panel) and with triads (middle panel) compared to the field measurements (bottom panel) on the rocky beach of Ars-en-Ré,Ré Island, France.

CONCLUSIONS

The enhanced unstructured/implicit WW3 provides combined large-scale wave generation and nearshore transformation for basin to regional to local application. WW3 is being integrated into Corps of Engineers circulation and sediment transport models.

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