An overview of multi-scale capabilities of the spectral wave model (WAVEWATCH III) for global and coastal applications. Case study: 2022 Atlantic Hurricane season

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Introduction

The third-generation spectral wave model, WAVEWATCH III (WW3), has undergone significant advancements in its unstructured components. These advancements have primarily led by the wave team at CHL/ERDC, in collaboration with both national and international partners within open-source community model development paradigm [1]. The adoption of unstructured mesh modeling has introduced several valuable benefits in contrast to traditional structured grids. It allows for greater flexibility in representing complicated geometries and enhances precision in regions with varying resolutions.

This recent enhancement of WW3 includes the implementation of modern parallelization algorithms based on Geographical domain decomposition and updated physics [2]. These updates encompass various aspects of wave modeling, such as wave-vegetation interaction [3], triad interaction, and depth breaking. As a result, the model can now run globally with refinements in coastal regions down to resolutions as fine as a few meters. These improvements have led to increased computational efficiency and modeling accuracy, especially in enhancing the model's downscaling capabilities for complex coastal applications.

Notably, the advanced capabilities of WW3 have already been applied in several studies, while others are currently undergoing testing. These applications span a wide range, including global/regional-scale: USACE/ERDC Wave Information Studies (WIS) and NOAA Global Forecast System (GFS), as well as specific coastal applications like the NOAA Great Lakes [4], FRF testbed in Duck, NC, the Oregon State testbed, and Basque Country, France. There are also plans to further integrate WW3 into other coupled applications with global and regional coverage, supporting both deterministic and probabilistic numerical [5] guidance within frameworks like the Unified Forecast System (UFS) and CSTORM.

This presentation aims to provide an overview of the model's development, highlighting select application studies. Particular emphasis will be placed on the 2022 hurricane season in Atlantic and Gulf of Mexico (GoM) basins, during which a rich set of observations is available, ranging from stationary NDBC buoys to moving Lagrangian drifter buoys and satellite altimeters. These observations will be instrumental in assessing the model's performance during this critical period.

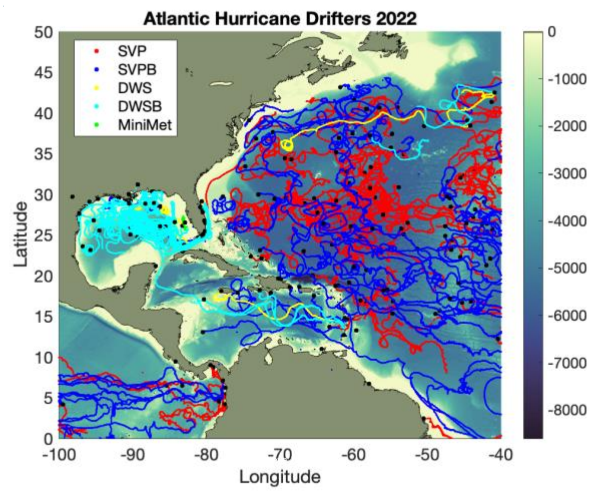

Figure 1 – the track of drifter buoys during 2022 campaign in Atlantic and GoM basins

Validation (2022 Hurricane Season)

During the 2022 hurricane season, which featured 13 named storms including Alex, Bonnie, Colin, Danielle, Earl, Fiona, Gaston, Hermine, and Ian, an array of nearly 100 Directional Wave Spectra Drifters (DWSD) and Directional Wave Spectra Buoy Drifters with Barometers (DWSBD) were strategically deployed in the Atlantic and Gulf of Mexico basins. These advanced instruments are equipped to collect real-time data on temperature, optional barometric pressure, and GPS coordinates, as well as the first five directional parameters (a_0, a_1, b_1, a_2, and b_2). Drifter buoys are adaptable and can be deployed from both ships and helicopters, with the flexibility to adjust their sampling rates as needed. Notably, in the GoM, drifter buoy measurements have significantly enhanced the data quality by contributing 30% more valuable information compared to stationary NDBC buoys (Fig. 1).

This study involves a comprehensive analysis, comparing drifter buoy data with data from the National Data Buoy Center (NDBC), satellite altimeters, and the WW3 model for various bulk statistics, including significant wave height (Hs), peak wave period (Tp), and wave direction (Wdir), as well as spectral analysis. The performance of the model will subsequently be assessed in coastal areas, utilizing a high-resolution unstructured mesh and incorporating the latest advancements in wave modeling techniques.

REFERENCES

[1] Alves, Jose-Henrique, Hendrik Tolman, Aron Roland, Ali Abdolali, Fabrice Ardhuin, Greg Mann, Arun Chawla, and Jane Smith. "NOAA's Great Lakes Wave Prediction System: A Successful Framework for Accelerating the Transition of Innovations to Operations", Bulletin of the American Meteorological Society, https://doi.org/10.1175/BAMS-D-22-0094.1

[2] Abdolali A., Roland, A., Van Der Westhuysen, A., Meixner, J., Chawla, A., Hesser, T., Smith, J.M. and M. Dutour Sikiric (2020), Large-scale Hurricane Modeling Using Domain Decomposition Parallelization and Implicit Scheme Implemented in WAVEWATCH III Wave Model, *Coastal Engineering*, 157, 103656, https://doi.org/10.1016/j.coastaleng.2020.103656

[3] Abdolali A, Hesser TJ, Anderson Bryant M, Roland A, Khalid A, Smith J, Ferreira C, Mehra A and Sikiric MD (2022) Wave Attenuation by Vegetation: Model Implementation and Validation Study. Front. Built Environ. 8:891612. doi: 10.3389/fbuil.2022.891612

[4] Ali Abdolali, Saeideh Banihashemi, Jose Henrique Alves, Aron Roland, Tyler J. Hesser, Mary Anderson Bryant, and Jane M. Smith (2023), Great Lakes Waves Forecast System on High-Resolution Unstructured Meshes, *Geoscientific Model Development*

[5] Ali Abdolali, Andre van der Westhuysen, Zaizhong Ma, Avichal Mehra, Aron Roland and Saeed Moghimi (2021) Evaluating the Accuracy and Uncertainty of Atmospheric and Wave Model Hindcasts During Severe Events Using Model Ensembles, *Ocean Dynamics*. https://doi.org/10.1007/s10236-020-01426-9