Spatiotemporal Sea-level Variability in Coastal Waters of U.S. East and Gulf Coasts

ASM Alauddin Al Azad, Reza Marsooli

Department of Civil, Environmental and Ocean Engineering, Stevens Institute of Technology, Hoboken, NJ

Poster Presenter: **ASM Alauddin Al Azad**, PhD Student, Email: aalazad@stevens.edu

Introduction

- Hindcast and reanalysis datasets provide temporally/spatially continuous sources of data for storm surge and wave climate studies.
- However, the resolution of such datasets is usually not sufficient to accurately resolve complex physical processes in coastal waters. For example, the spatial resolution of the ERA5 reanalysis is 30 km in the horizontal space, which is considered coarse for coastal waters, especially with complex bathymetry and geometry.
- A high-resolution coupled circulation-wave model (ADCIRC+SWAN) is developed to dynamically downscale the total water level and waves in the Western North Atlantic Ocean.
- The ADICIRC+SWAN model was forced with hourly surface pressure and wind fields, mean sea level, and direction-frequency (2D) wave spectrum of ERA5 reanalysis dataset at the boundary.
- Here, for the year 2018, we present the results of temporal variability in the monthly mean and extremes of residual water level and wave conditions. Additionally, we analyze the spatial variability of the annual mean of residual water levels and wave conditions.

Data and Methodology

- To generate downscaled water level and wave data in coastal areas, a high-resolution computational mesh for the Advanced CIRCulation model (ADCIRC-version 55.0) is developed.
- In the ADCIRC model we include:
  - Internal Tide Energy Conversion option to account for the effect of internal tide energy conversion by the interaction of deep ocean flows with bottom topography,
  - Quadratic Friction option to account for the sea floor friction.
- ERA5 reanalysis data are used to force the ADCIRC+SWAN model at its boundary using
  - Hourly ERA5 surface pressure and wind fields
  - Hourly ERA5 total water level time series
  - Hourly ERA5 direction-frequency (2D) wave spectrum data

Model Domain

- An unstructured triangular mesh is generated using OceanMesh2D (Roberts, K. J., et al., 2019).
- Mesh resolution is between 0.5 km and 1 km in coastal waters (up to a water depth of 300 m) and gradually increases to 20 km in the deep ocean.
- Bathymetry is based on the GEBCO's global 30 arc sec gridded data (vertical datum is mean sea level).

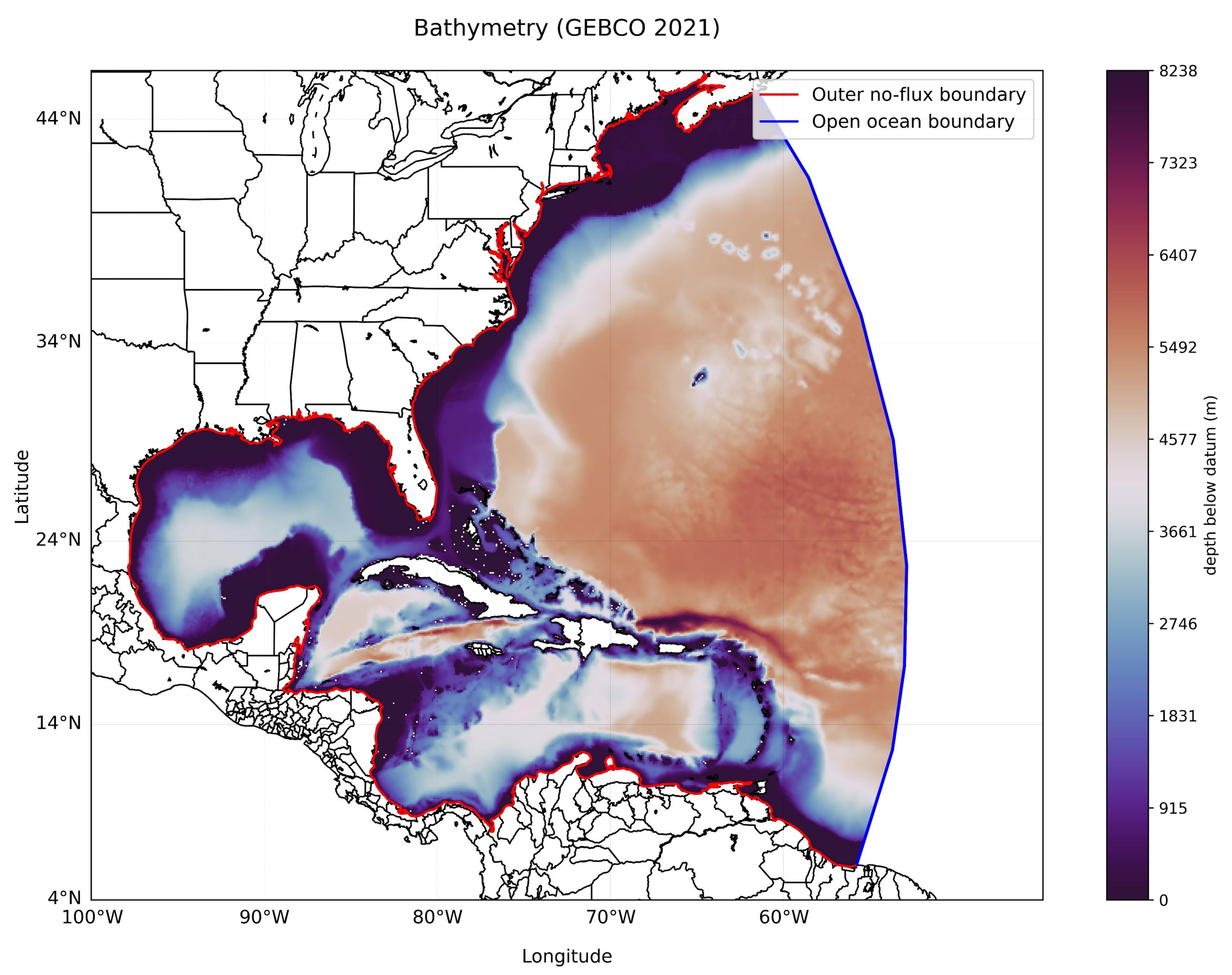

Figure 1: Bathymetry and boundaries of the model domain.

Validation of the ADCIRC+SWAN model

- For tide validation, the water level at the open boundaries for December 2016 is specified by eight major tidal constituents, sourced from the TPXO9-atlas. A sensitivity test was done considering bottom friction coefficient (CF), and internal tide friction (Non-local method: scale factor (C_Nyc), minimum depth (D - the depth which to cut off the internal tide friction). Best model setup is found for: CF = 0.0035, C_Nyc = 2.9, D = 100 m.
- For SWAN model, different wave physics packages Komen, Janssen, Westhuysen, and ST6 physics package have been evaluated to calibrate the model. Best model setup is found for Komen (1984).

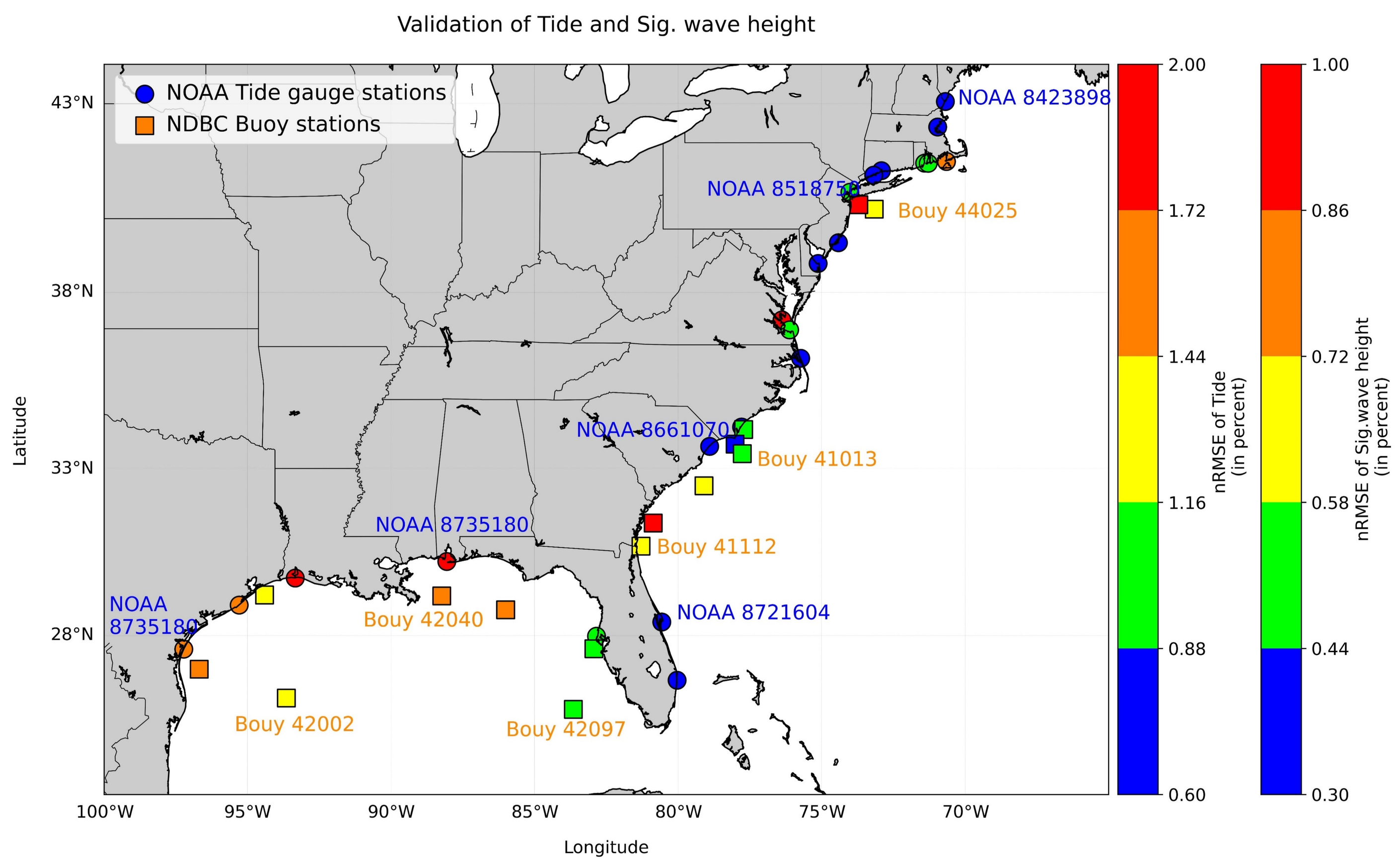

Figure 2: Normalized RMSE values comparing NOAA predictions with ADCIRC tide simulations at 22 tidal gauges, and significant wave height from ADCIRC+SWAN to data from 13 NDBC buoys.

Non-tidal Water level

- ERA5 surface pressure, wind speed, mean sea level, and direction-frequency (2D) wave spectrum dataset are used as ADCIRC+SWAN boundary conditions to simulate water levels and wave conditions of 2018.

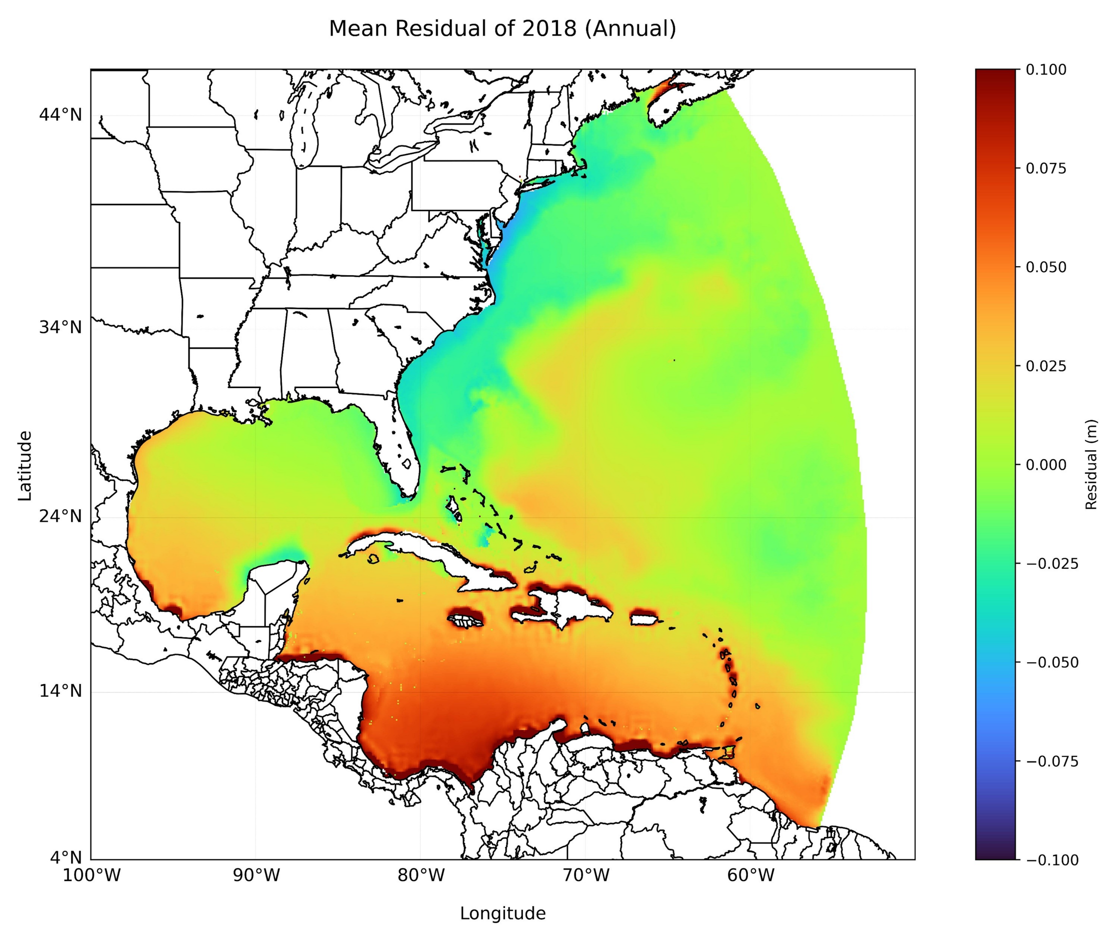

Figure 3: Spatial distribution of Annual mean of non-tidal water level.

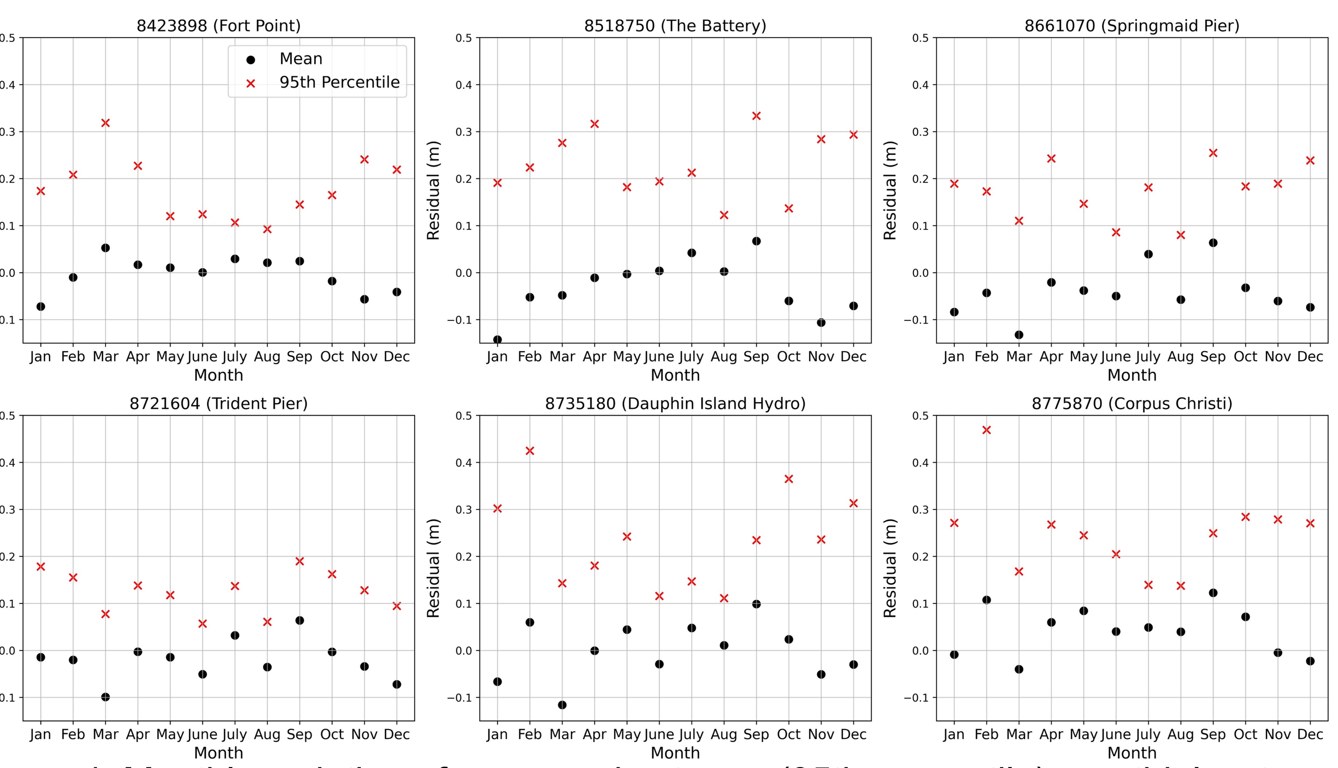

Figure 4: Monthly variation of mean and extreme (95th percentile) non-tidal water level.

Significant Wave Height

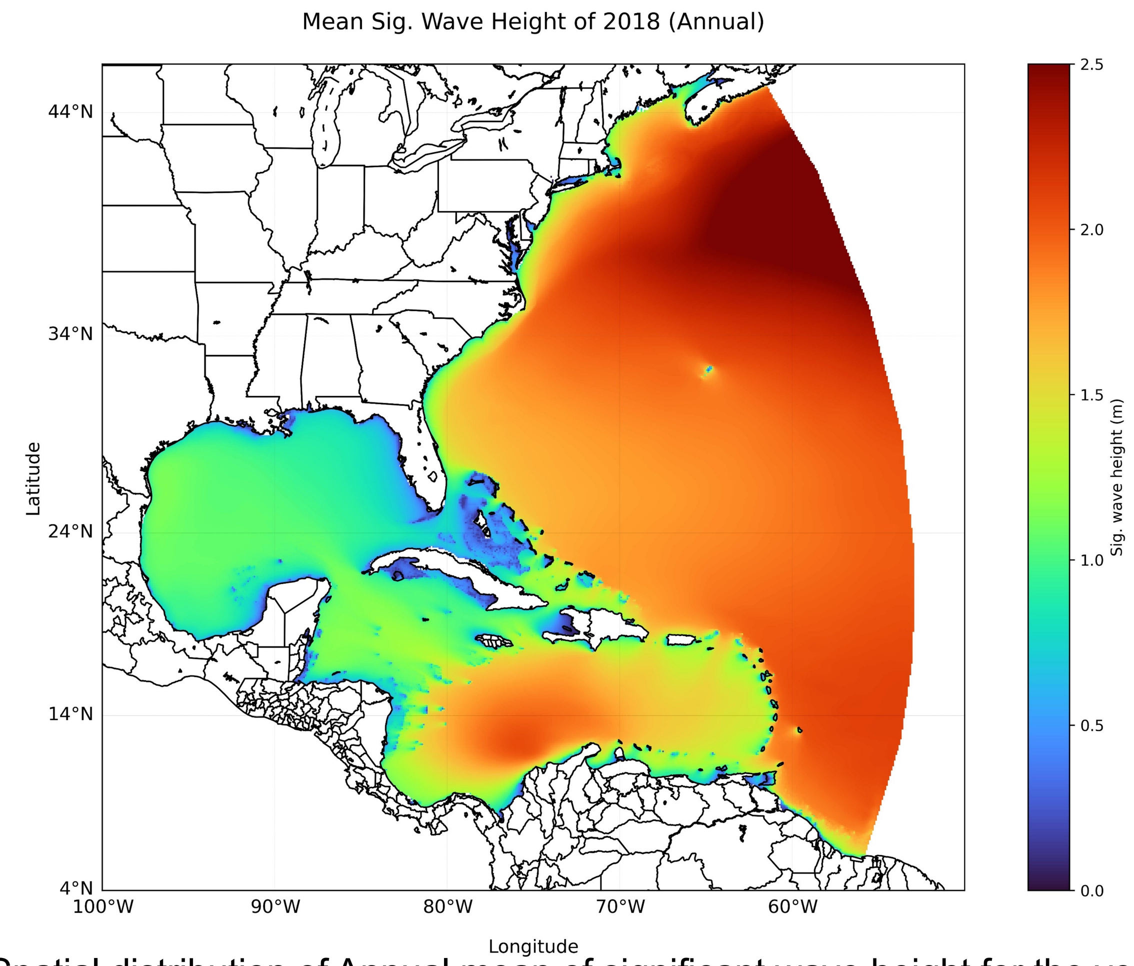

Figure 5: Spatial distribution of Annual mean of significant wave height for the year of 2018.

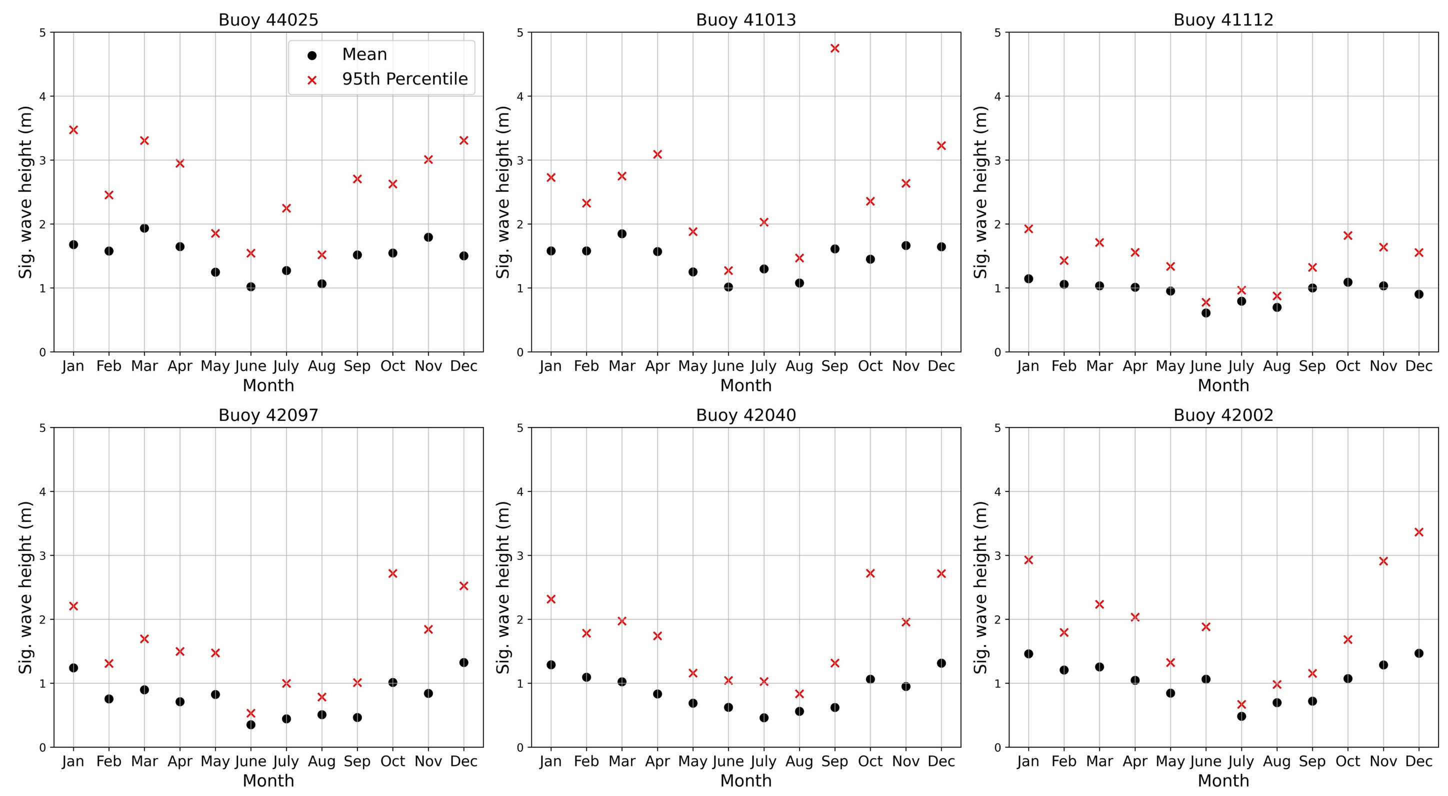

Figure 6: Monthly variation of mean and extreme (95th percentile) of significant wave height for the year of 2018.

Conclusion/ Future Steps

- A high-resolution ADCIRC+SWAN hydrodynamic model is developed for dynamic downscaling of water level and wave conditions in coastal waters of the western North Atlantic Ocean. The normalized RMSE values demonstrate that the model results are in good approximation with NOAA predicted tide and NDBC significant wave height data.
- The monthly variation of mean and extreme (95th percentile) residual water level follows the same trendline in most stations, with summer months showing a larger residual water level than winter.
- The monthly variation of both mean and extreme (95th percentile) significant wave heights exhibits seasonal variation, with larger wave heights in the winter months than in summer along the coast.
- The next steps of this study are to
  - evaluate a long-term dataset of water levels and wind waves for a historical period,
  - analyze the generated dataset to investigate the mean and extreme sea level and wave climate variability and change in coastal waters in decadal period.

References

- Luettich, R.A., Westerink, J.J. and Scheffner, N.W., 1992. ADCIRC: an advanced three-dimensional circulation model for shelves, coasts, and estuaries. Report 1, Theory and methodology of ADCIRC-2DD1 and ADCIRC-3DL.
- Roberts, K. J., Pringle, W. J., and Westerink, J. J., 2019. OceanMesh2D 1.0: MATLAB-based software for two-dimensional unstructured mesh generation in coastal ocean modeling.
- Egbert, Gary D., and Svetlana Y. Erofeeva. "Efficient inverse modeling of barotropic ocean tides." Journal of Atmospheric and Oceanic Technology 19.2 (2002): 183-204.