FUNWAVE: BRIDGING THE SHALLOW-TO-DEEP WATER WAVE GAP

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COASTAL INLETS RESEARCH PROGRAM

FY22 IN PROGRESS REVIEW

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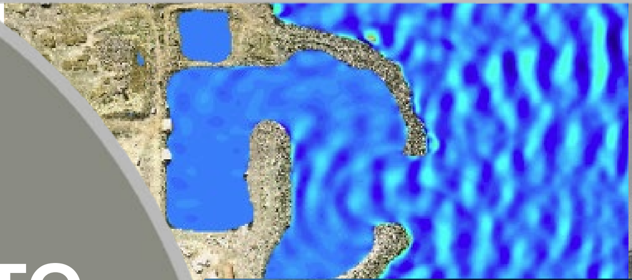
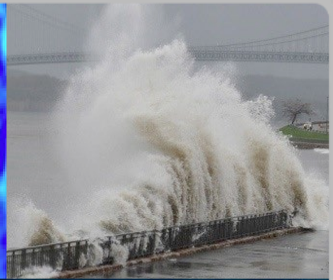
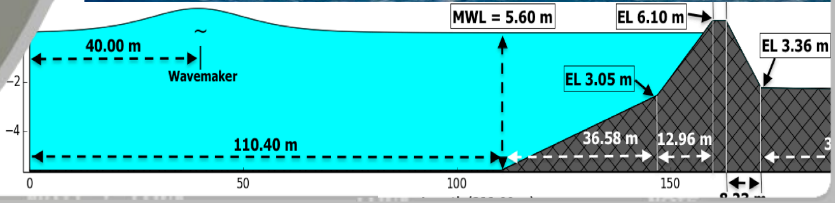






FUNWAVE

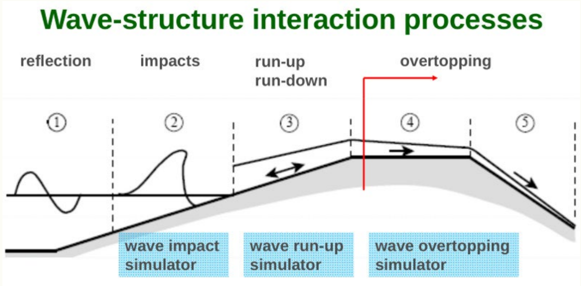
ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

COASTAL AND HYDRAULICS LABORATORY

FUNWAVE is a nearshore shallow-to-intermediate water phase-resolving Boussinesq-type numerical wave model that resolves many processes such as:

- ✓ nearshore wave propagation & transformation, including refraction, **<u>diffraction</u>** & nonlinear shoaling (Littoral Entry Operations)
- ✓ bottom friction & wave-induced current, nonlinear wave-wave & wave-current interactions
- ✓ wave breaking with **<u>runup</u>** & **<u>overtopping of structures</u>** (Flooding threats)
- ✓ **<u>harbor resonance</u>** and **<u>infragravity (IG) waves</u>** (Important for understanding austere ports of entry)
- ✓ **<u>vessel-generated waves</u>** & related sediment transport with morphology change
- ✓ landslide-generated tsunamis (regional and global ocean basin)
- ✓ (IMPROVED FY21) multi-grid nesting (MGN) with flexible grids for refined **two-way** coupled grids
- ✓ (NEW FY21) **- VER 2.0 -** High Performance Computing (HPC) Portal web-based access with GUI

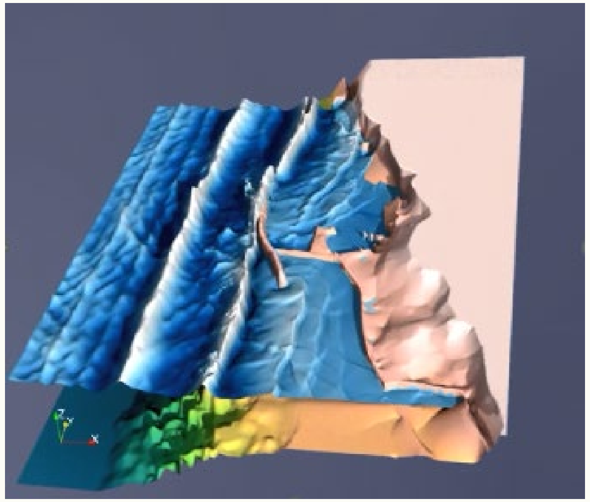
* **<u>underline/bold</u>** not available in phase-averaged models!



DOD HPC
DEPARTMENT OF DEFENSE
HIGH PERFORMANCE COMPUTING
PORTAL

Model Access: FUNWAVE has a comprehensive Wiki page with source code access via a version-controlled online repository and an extensive suite of test cases at <u>https://fengyanshi.github.io/build/html/index.html</u>

Bridging the Gap: Utilize FUNWAVE to pre-calculate surfzone wave dynamics swash zone <u>runup & overtopping</u> to provide rapid surrogate modeling between high-fidelity N-S equation models and phase-averaged ones.

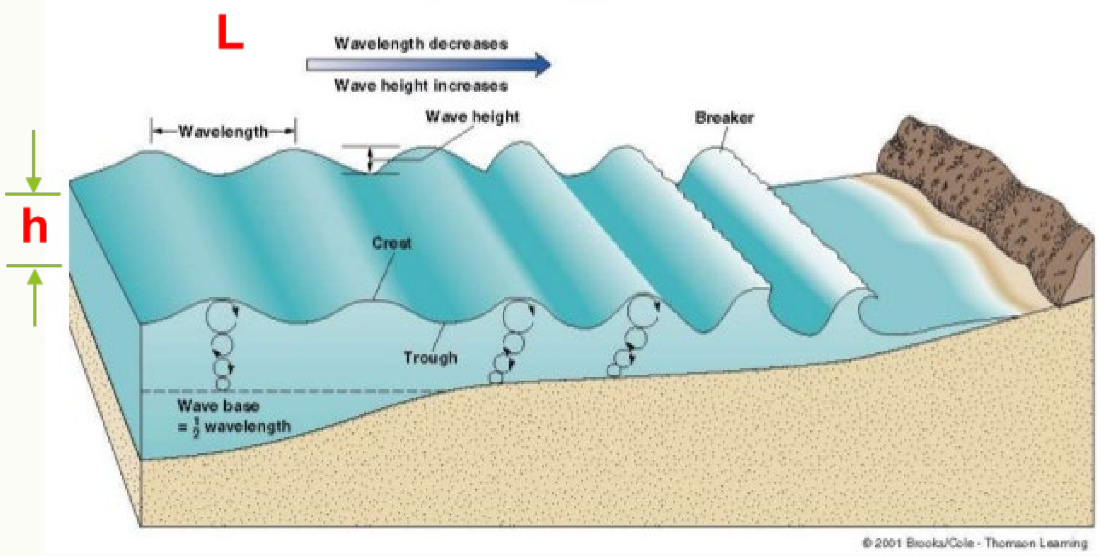


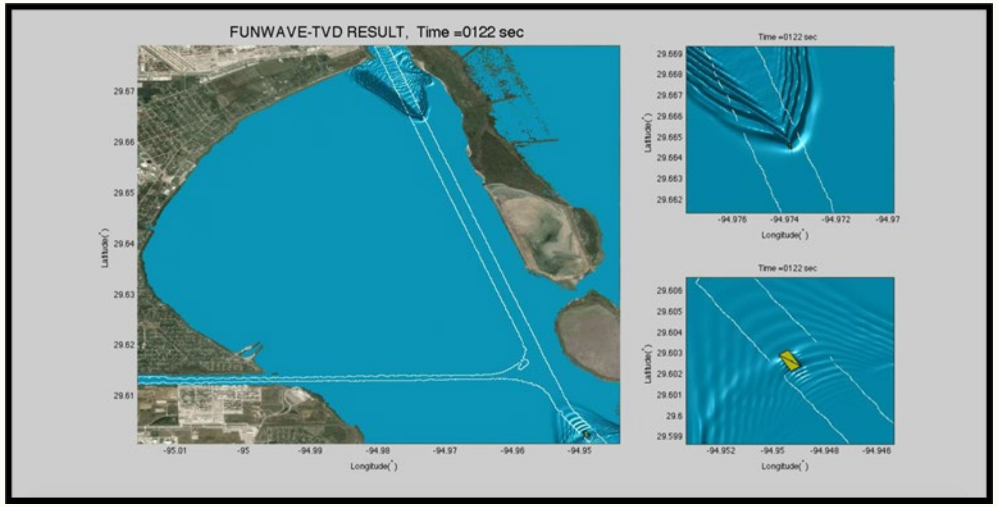
Motivation for current extensions

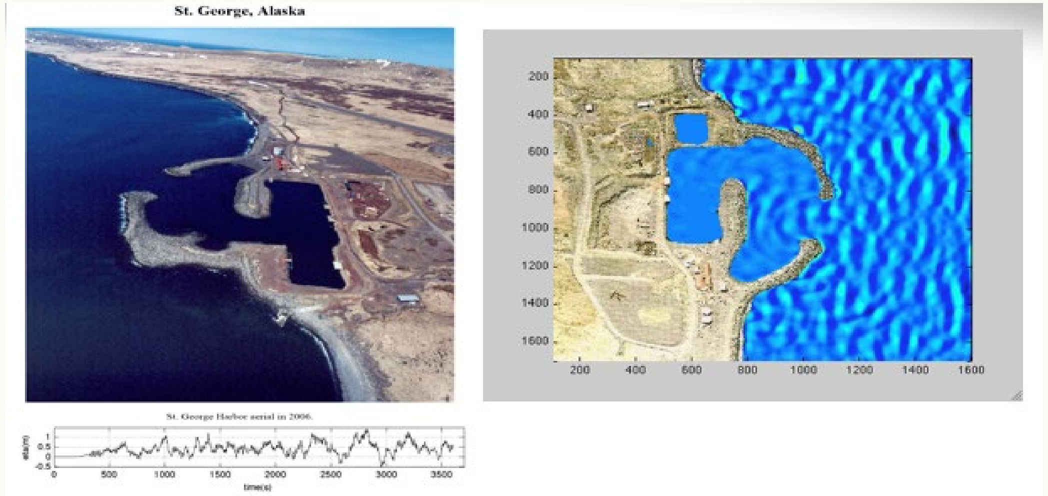
- **FUNWAVE is being applied to increasing more complex domains, with larger (space) and longer (time) simulations needing to adjust to variable water level.**

- **2nd Order (h / L) Boussinesq models are weakly dispersive**
  - **(Waves need to feel the bottom)**

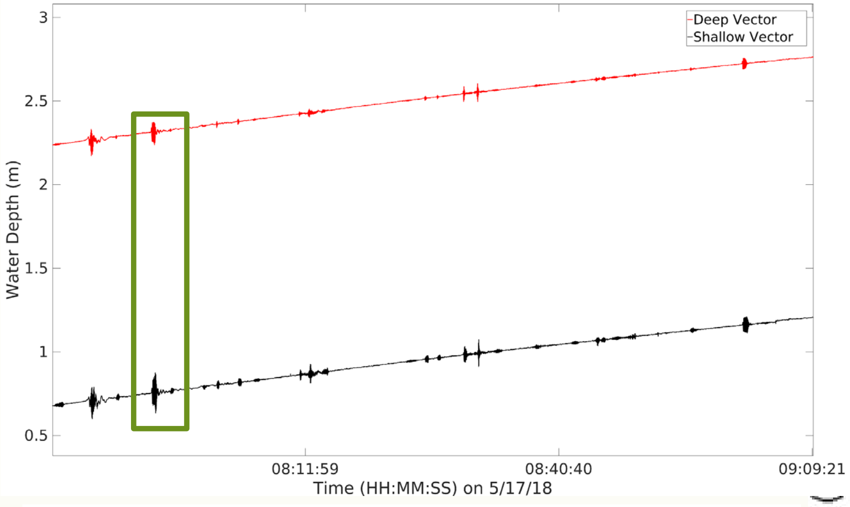
- **Need for surge/tidal forcing & tidal currents interacting with wind and vessel-generated waves at inlets [depth-limited wave breaking & sediment transport – erosion].**

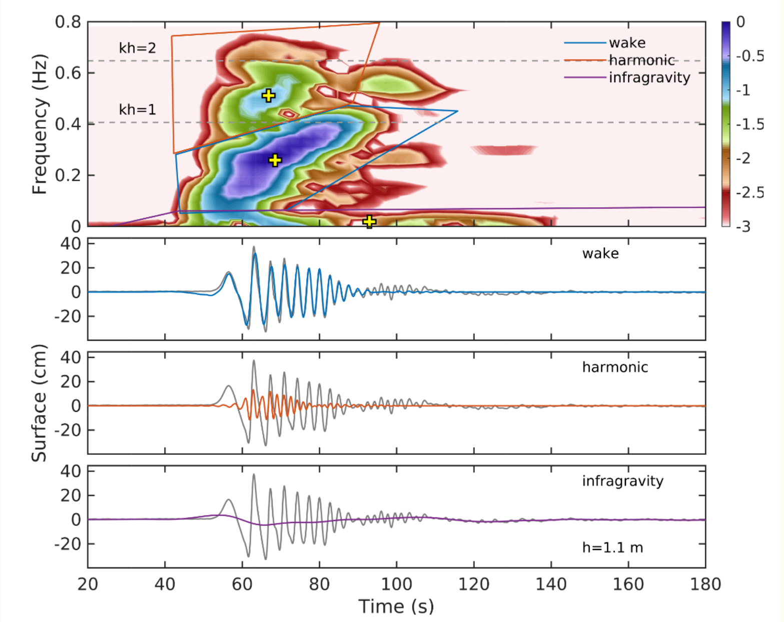


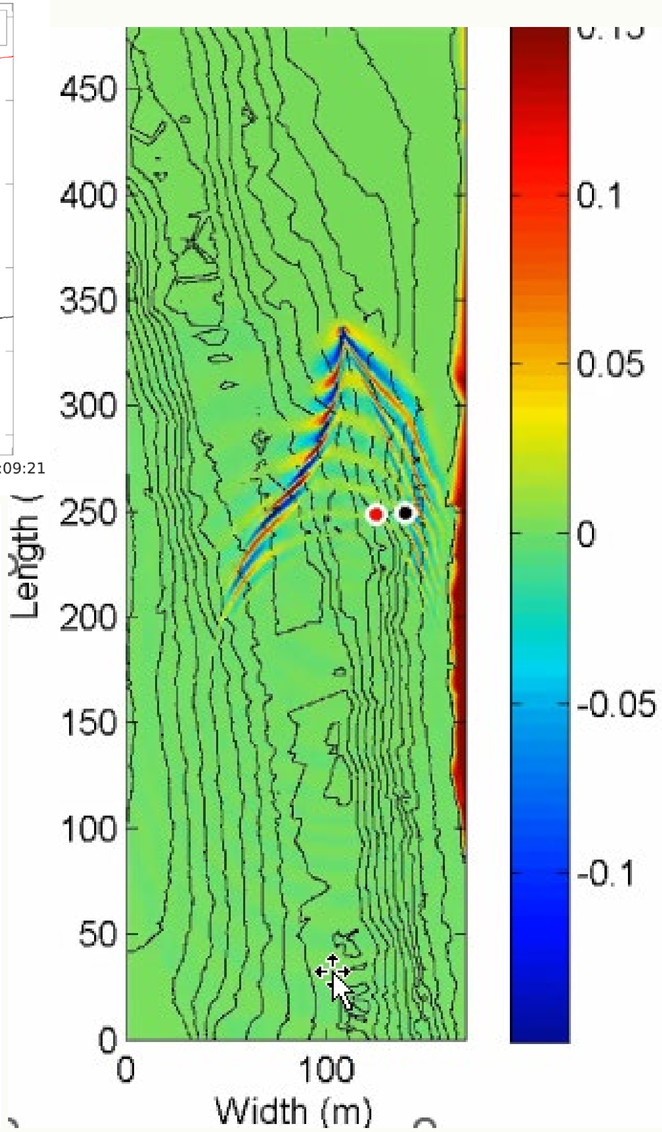


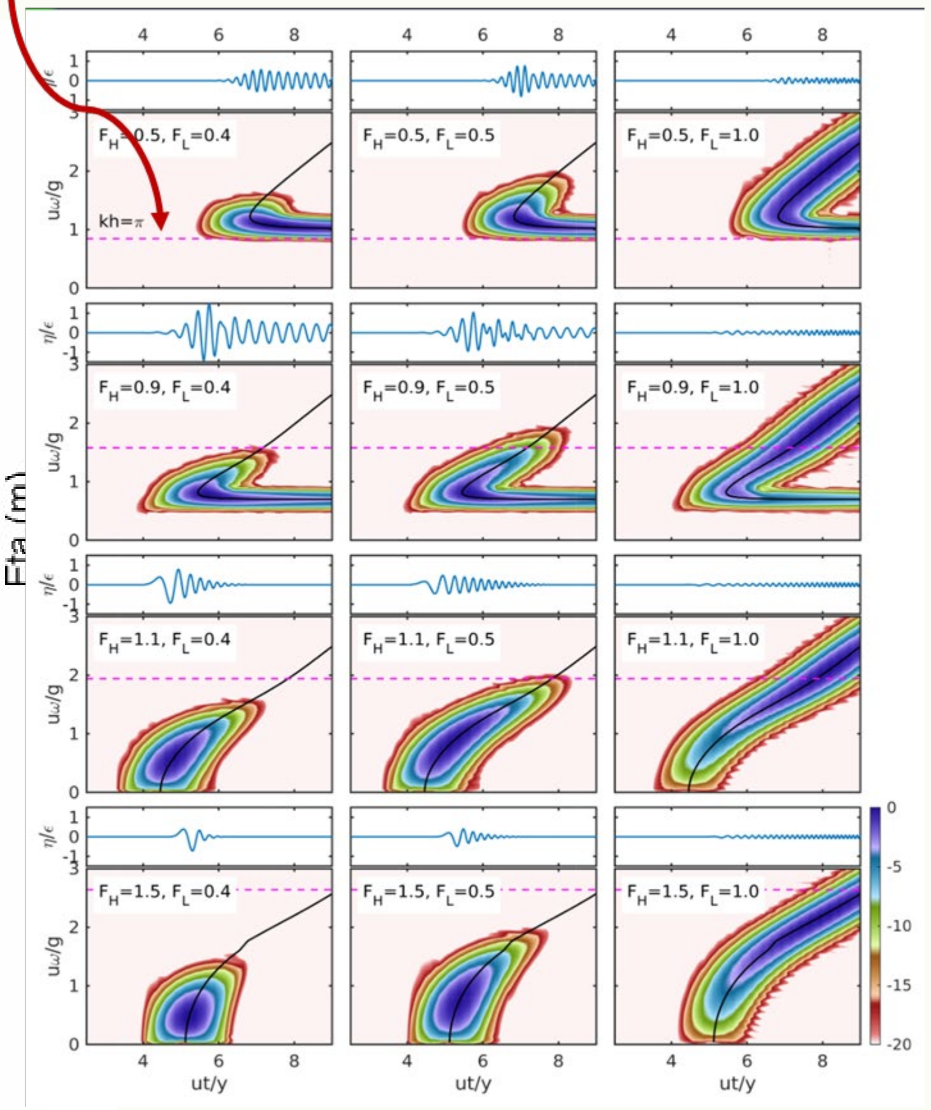


Vessel-Generated Waves in Confined Channels $(kh < \pi)$



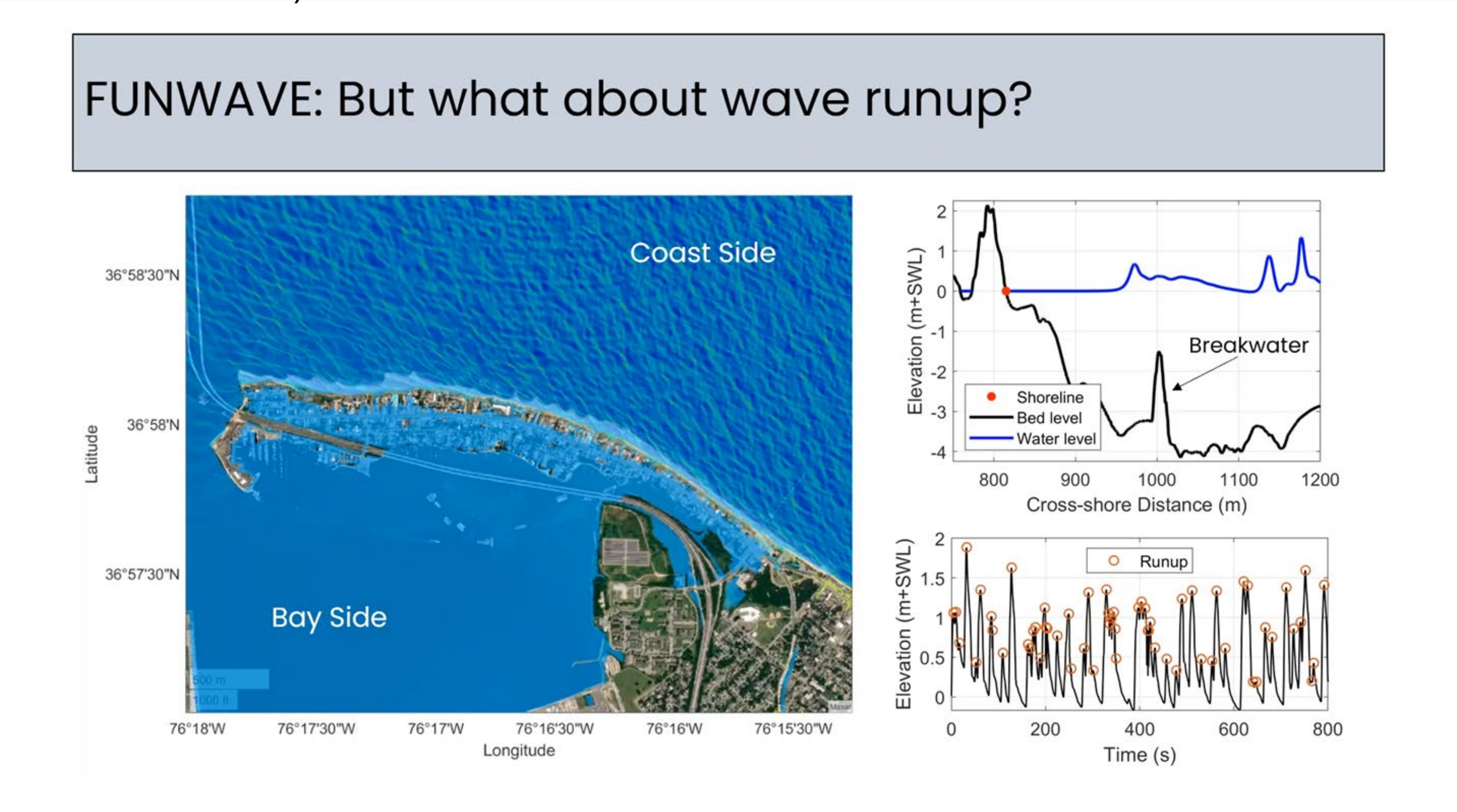






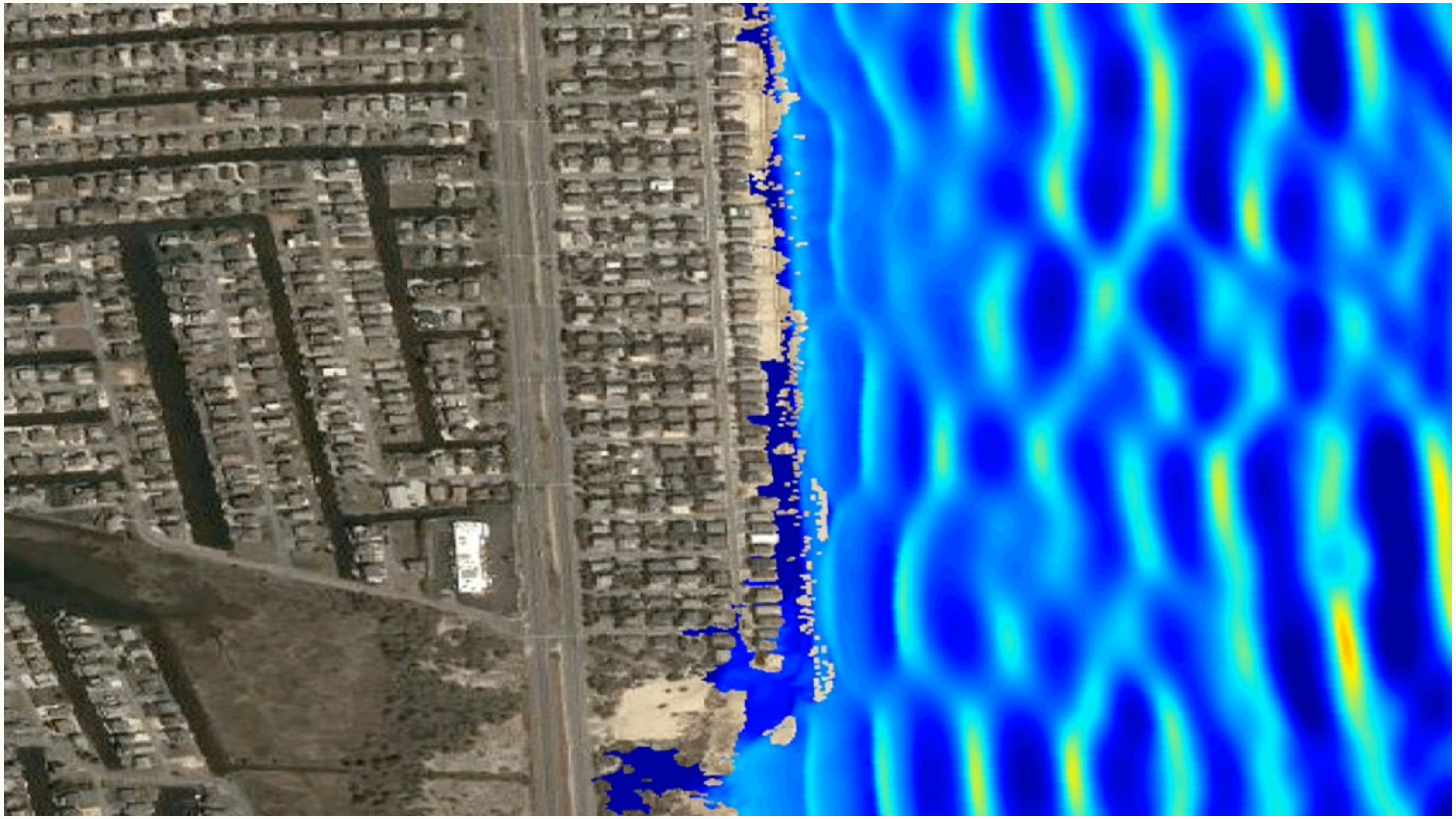
Tidal and Surge forcing

Simulation of wave impact on coastal inundation using the tidal and surge forcing condition
(Hurricane Irene at Norfolk)



Tidal and Surge forcing

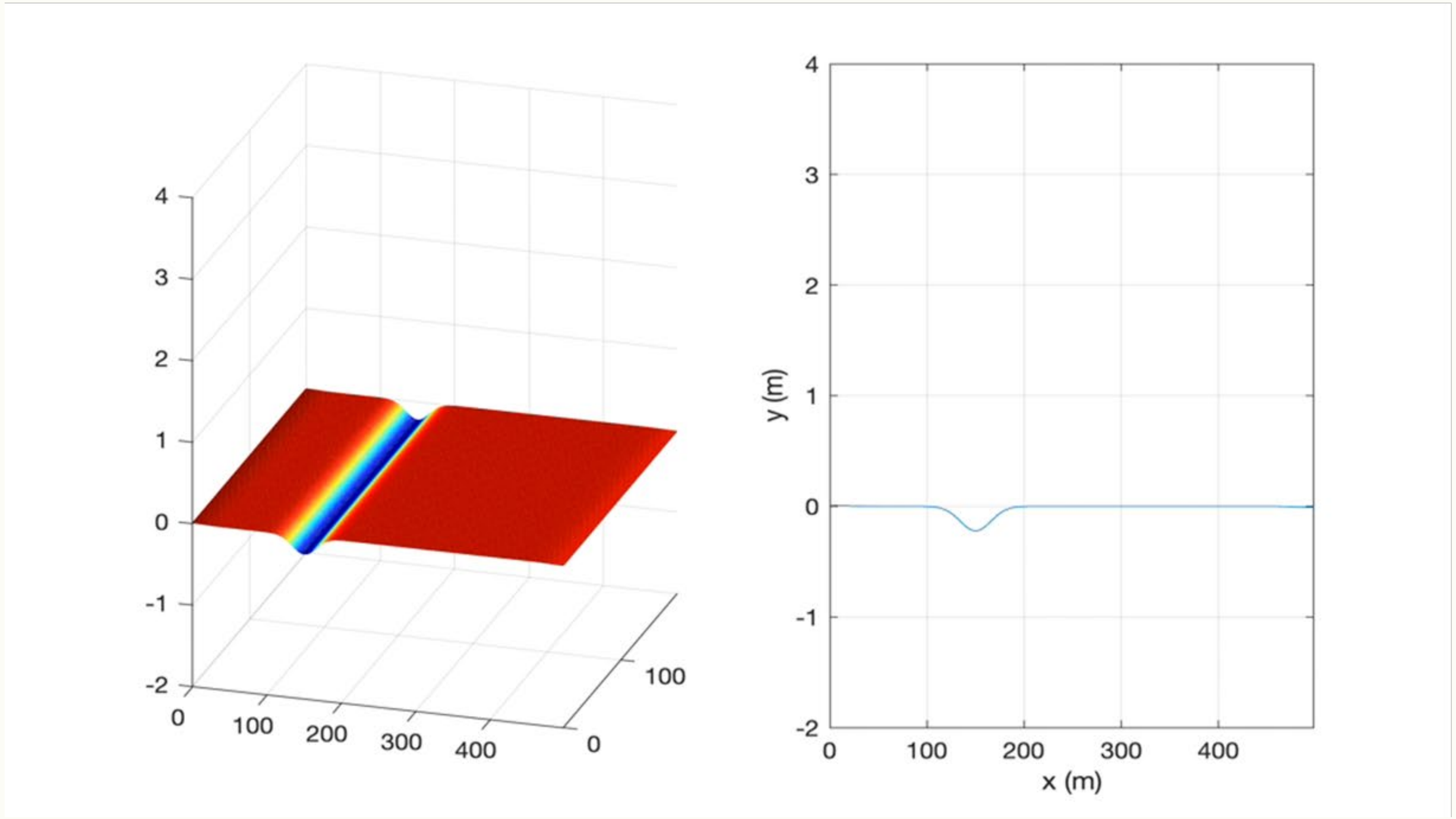
Modeling coastal inundation using the tidal and surge forcing condition



100-year storm at South Bethany Beach. Boundary condition from Hanson et al. (2013), ERDC/CHL TR-11-1

Tidal and Surge Forcing

Initial implementation of tidal and surge forcing in the current version of FUNWAVE-TVD. The forcing condition will be further developed in the fully-dispersive model based on the same theory and numerical techniques



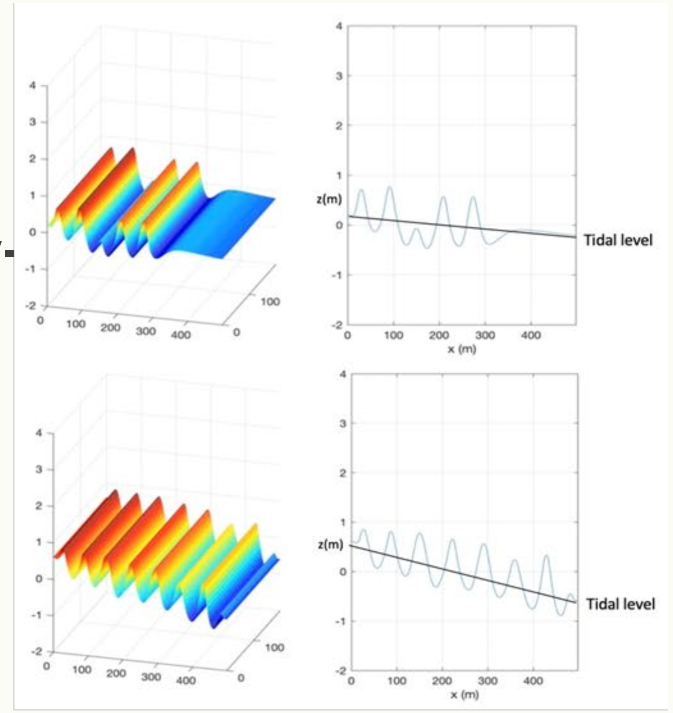
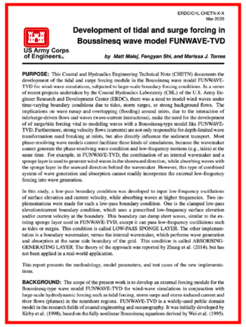


Figure 2. Case: tide abs 2bc data. Demonstration of 2D (left) and 1D (right) section views of surface elevation at time = 30.0 (top) and 90.0 (bottom) sec, respectively. Black solid lines denote tidal levels.


Development of tidal and surge forcing in Boussinesq wave model FUNWAVE-TVD

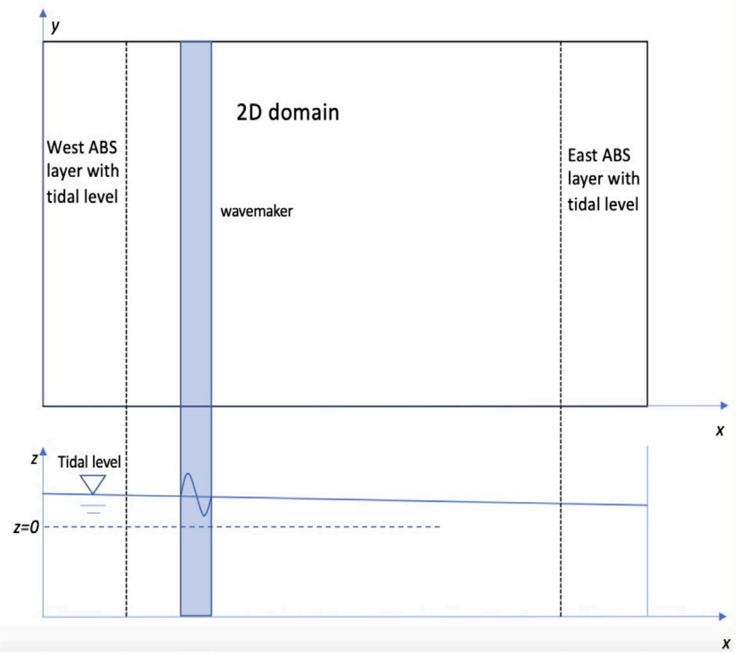
US Army Corps of Engineers

by Matt Malej, Fengyan Shi, and Marissa J. Torres

Malej et al., 2023, (in review) ERDC/CHL CHETN

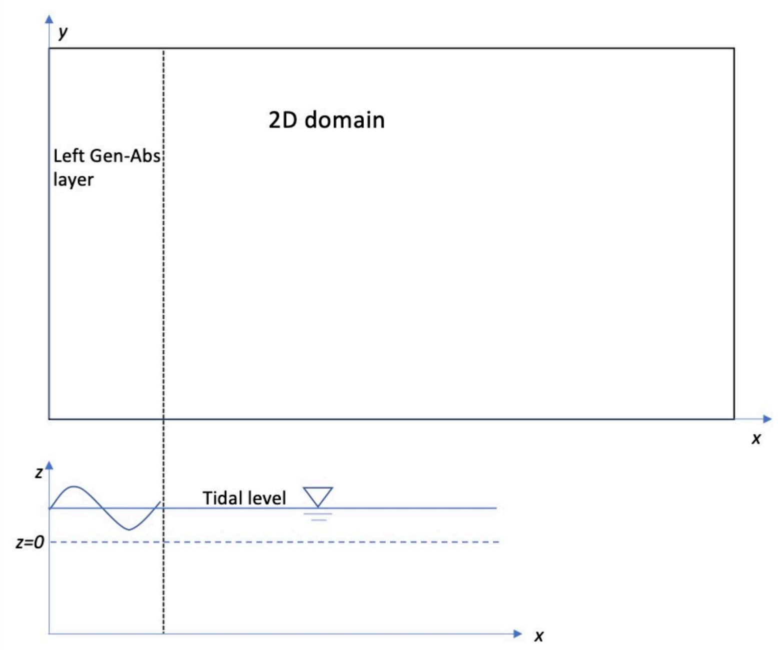
Tidal and Surge Module – Two Types

TYPE 1: ABSORBING (LOW-PASS) SPONGE B.C.

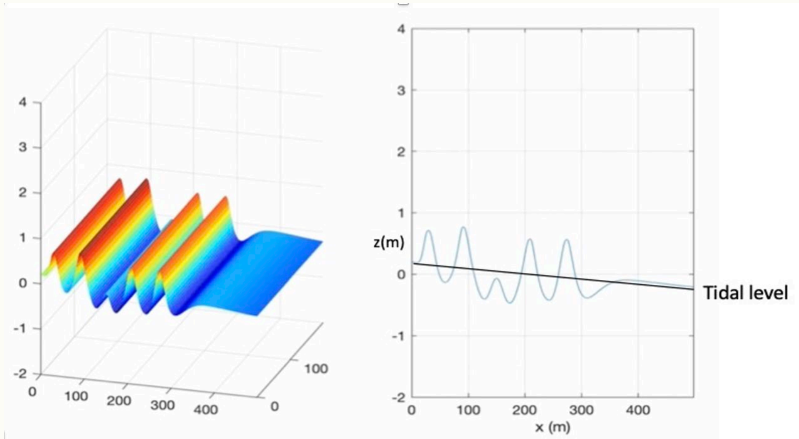


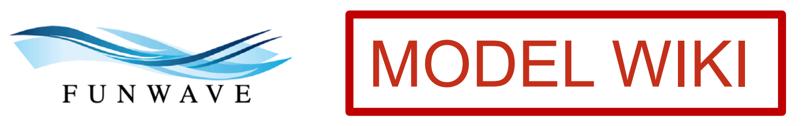
More robust, tides can be specified on all four sides of the domain

TYPE 2: ABSORBING-GENERATING B.C.



Includes a mechanism to absorb reflected waves, but may only be specified on the West boundary





FUNWAVE Documentation » DEFINITIONS OF PARAMETERS » Parameters for Central Module »

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Tide and Surge Boundary Conditions

SPECIFICATION OF TIDE AND SURGE OPEN BOUNDARY CONDITIONS

- TIDAL_BC_ABS: logical parameter for tidal absorbing boundary conditions, T – tide and surge at open boundaries, F – no tide or surge.
- TIDAL_BC_GEN_ABS: logical parameter for the combined tidal and absorbing-generating boundary conditions, T – ture, F – false.
- TideBcType: string parameter for data types. Default: TideBcType = CONSTANT
- TideWest_ETA: constant eta value at the WEST boundary.
- TideWest_U: constant u value at the WEST boundary, defalut: 0.0.
- TideWest_V: constant v value at the WEST boundary, defalut: 0.0.
- TideEast_ETA: constant eta value at the EAST boundary.
- TideEast_U: constant u value at the EAST boundary, defalut: 0.0.
- TideEast_V: constant v value at the EAST boundary, defalut: 0.0.
- TideSouth_ETA: constant eta value at the SOUTH boundary.
- TideSouth_U: constant u value at the SOUTH boundary, defalut: 0.0.
- TideSouth_V: constant v value at the SOUTH boundary, defalut: 0.0.
- TideNorth_ETA: constant eta value at the NORTH boundary.
- TideNorth_U: constant u value at the NORTH boundary, defalut: 0.0.

Summary

PROBLEM/ISSUE:

- Currently there are two major limitations in practical applications of the FUNWAVE model: (1) highly dispersive waves common in intermediate to deep-water regions and (2) external forcing associated with variable water level and large-scale processes, such as tides and storm surges.
- With growth in HPC resources FUNWAVE is being applied across increasingly larger spatial and temporal domains. This requires model flexibility and robustness in being able to resolve waves across wider spatial and depth scales with variable/changing water levels per single run.
- Common approaches to extend Boussinesq models from 2^{nd} to 4^{th} order in *kh* have been rendered computationally expensive and notoriously unstable.

Success/Impact: The new modules/products will enhance the predictive capability of simulating surface waves, ship-wakes and wave-induced processes, especially involving wave interactions with shorelines in larger temporal and spatial domains, allowing ERDC/CHL to remain state-of-the-art in wave modeling.
Transition and Sustainment: Several JP's will be published, along with validation & verification guidance materials that will be made available through formal written communications (TN, TR, and FUNWAVE Wiki updates).
VALUE ADDED/ROI: Improve the model accuracy and efficiency in simulating event-scale hydrodynamics, such as hazardous waves, coastal flooding, and ship-wake-induced coastal erosion; in line with the current Civil Works (CW) Strategic Focus Areas (SFA). Enhanced modeling capability for USACE.

DELIVERABLES/MILESTONES:

	Deliverable/Milestone
Year 1, FY22	**CHL TN**: development of the fully-dispersive model **JP:** theory and numerical schemes in new modules
Year 2, FY23	**CHL TN**: guidance on when to use higher-order module **JP:** ship waves in fully-dispersive deep-water regime **Tech Transfer:** new code release & benchmark tests
Year 3, FY24	**ERDC TR**: test cases of fully vs. weakly dispersive model **JP:** wind forcing and directional long infragravity waves **Tech Transfer:** Workshop for USACE & ERDC engineers

COLLABORATION PARTNERS: Districts engineers from: LRB, NWP, LRE, SAJ, POH, SPL, and SWG. Academia: University of Florida, University of Delaware, Georgia Tech, University of Rhode Island

Funding/Resources:

($M)	FY22	FY23	FY24	Total
Other/Prior Funding Source	0	0	0	0
Funding Requested	**$325K**	**$300K**	**$250K**	**$875K**
Estimated Additional R&D	0	0	0	0
Estimated Development/Test	0	0	0	0
Estimated Production/Fielding	0	0	0	0
Estimated Sustainment	0	0	0	0

Research Team & Roles

- Dr. Matt Malej (PI)
- Mrs. Gabriela Salgado-Dominguez (validation & verification)
- Mr. Michael Puhr (HPC FUNWAVE Portal App)
- Dr. Michael-Angelo Y-H. Lam (code development & optimization)
- Ms. Marissa J. Torres (HPC interface and tech transfer)