PRACTICAL MODELING AND WAVE RESPONSE GUIDANCE FOR COASTAL STRUCTURES USING FUNWAVE-TVD

Coastal Inlets Research Program
Technical Discussion
09 September 2025

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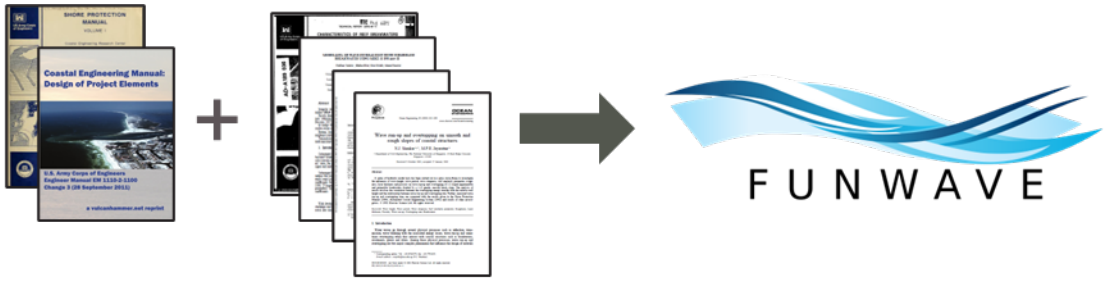
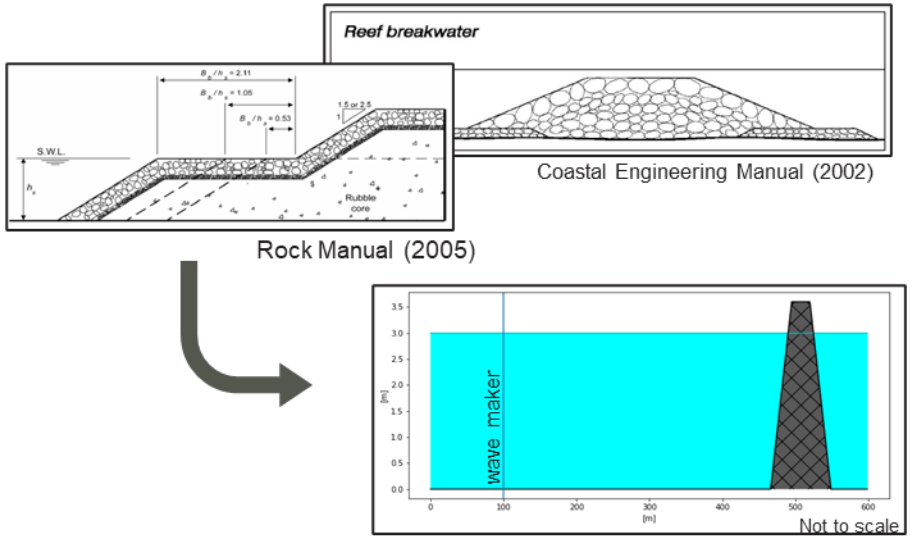
PROJECT OVERVIEW



Objective: To provide practical guidance for implementing impermeable coastal structures in FUNWAVE-TVD for the rapid environmental assessment of design alternatives in coastal engineering applications.

Goals:

- Define numerical parameter equivalents in FUNWAVE to replicate real breakwater design and its respective wave attenuation effects
- Enhance accessibility and usability of the model for users of all levels
- Help Nation stay resilient to coastal storms and floods by providing tools and resources to coastal practitioners



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DESCRIPTION AND RESOURCES

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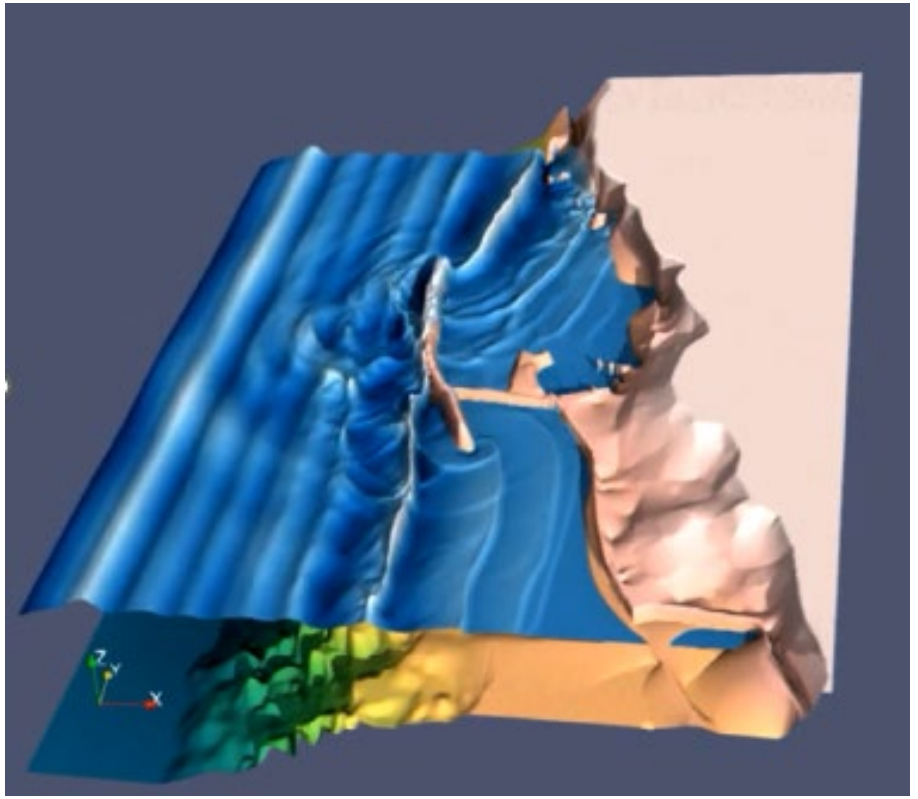
FUNWAVE

- A nearshore shallow-to-intermediate water phase-resolving Boussinesq-type numerical wave model that resolves many processes
- A bridge between computationally expensive high-fidelity Navier-Stokes equation models and phase-averaged models
- Quick turn around using parallel computing on high performance computers
- Collaborative effort with University of Delaware



Comprehensive Wiki

https://fengyanshi.github.io/build/html/index.html

OPEN SOURCE SOFTWARE

https://github.com/fengyanshi/FUNWAVE-TVD

DOD HPC DEPARTMENT OF DEFENSE HIGH PERFORMANCE COMPUTING PORTAL

https://portal.erdc.hpc.mil/erdchydro/#

PRACTICAL MODELING GUIDANCE

Numerical considerations:

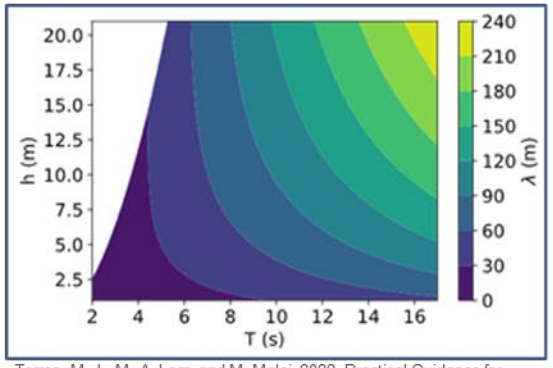
- Range of validity
  - Finite depth: $\lambda > 2h$ or $kh < \pi$
- Spatial resolution: points per wavelength
  - $DX < \lambda / 60$
- Spatial resolution: numerical stability
  - $DX / h > 1 / 15$

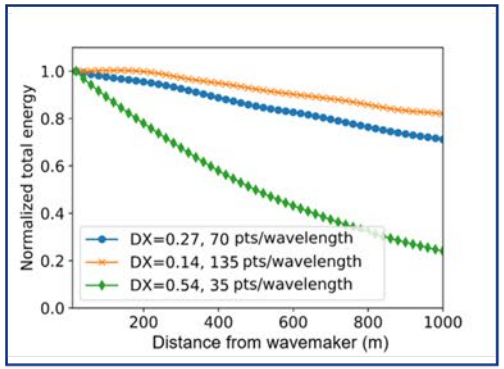
Potential sources of instability:

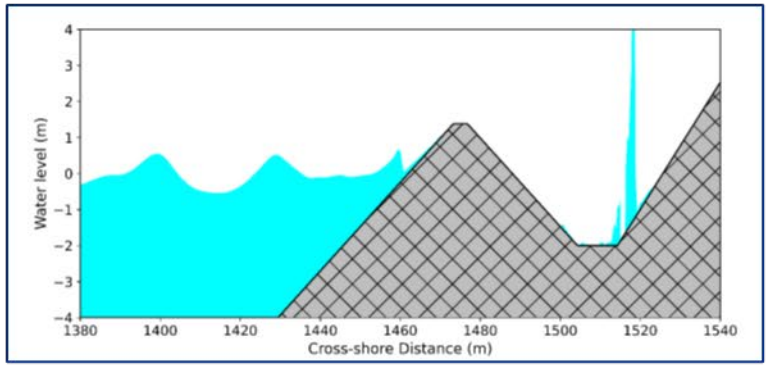
- Bathymetry
  - Apply localized or global smoothing to reduce or eliminate “jumps” in bathy
- Wetting/Drying
  - Sections of emergent topography experiencing intermittent or limited wetting events are susceptible to either BlowUp Time or NaN in Statistics failure mode

Troubleshooting recommendations:

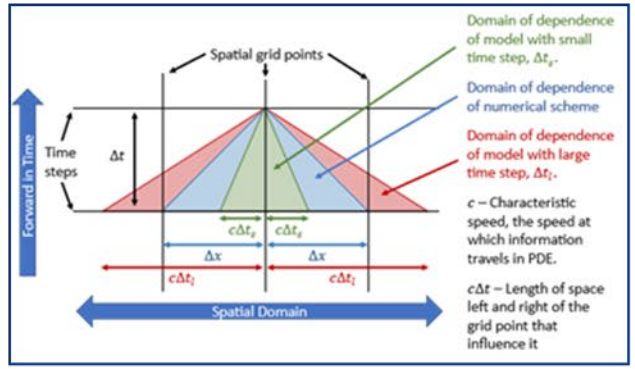
- CFL < 0.5
- Check LOG.txt statistics block
  - If the model “blows up”, an eta_99999 file will be printed.
  - If the model blows up in deep water, increase CFL.
  - If the model blows up in shallow water, check FroudeCap
- FroudeCap of 1.0 is considered critical.
  - Ideally: 1.0 < FroudeCap < 3.0







Torres, M. J., M.-A. Lam, and M. Malej. 2022. Practical Guidance for Numerical Modeling in FUNWAVE-TVD. ERDC TN-22-1. http://dx.doi.org/10.21079/11681/45641.



Torres, M. J., M.-A. Y. Lam, L. Cass, M. Malej, and F. Shi. 2024. Getting Started with FUNWAVE-TVD: Troubleshooting Guidance and Recommendations. ERDC TN 24-5. http://dx.doi.org/10.21079/11681/48631.

YEAR 1
APR FY22 – FEB FY23
Completed

YEAR 2
FEB FY23 – DEC FY24
Completed

YEAR 3
FEB/MAR FY25 – DEC FY26
Ongoing (Current & Upcoming)

Project schedule by MONTH FY

APR 22 | JUL 22 | OCT 23 | JAN 23 | APR 23 | JUL 23 | OCT 24 | JAN 25 | APR 25 | JUL 25 | OCT 25

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WAVE RESPONSE GUIDANCE

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- The problem was exceedingly more difficult than originally anticipated
- Full test matrix yields >10M simulations!
- Small batch (~5K) test suites to investigate sensitivity of response to certain input variables
- Today: wave reflection & transmission

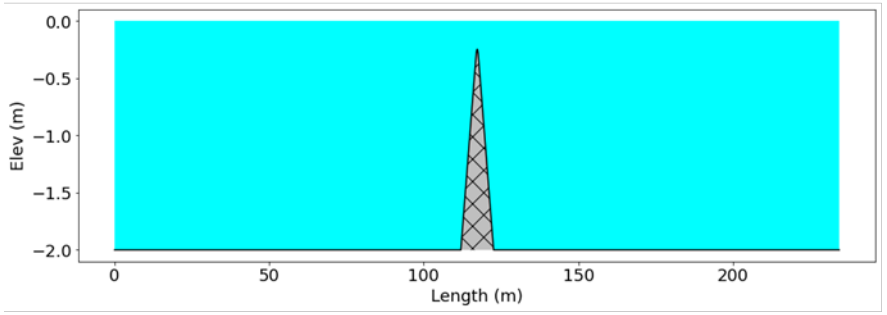
Wave Response	Dimension	Wave Climate	Structure Properties
Overtopping (q)	1D	Regular Irregular	Emergent Smooth / Rough Impermeable
	2D	Regular (normal, oblique) Irregular (normal, oblique)	Emergent Smooth / Rough Impermeable
Runup ($R_{2\%}$)	1D	Regular Irregular	Emergent Smooth / Rough Impermeable
	2D	Regular (normal, oblique) Irregular (normal, oblique)	Emergent Smooth / Rough Impermeable
Transmission (over structure; Kt)	1D	Regular Irregular	Submerged Smooth / Rough Impermeable / permeable
	2D	Regular (normal, oblique) Irregular (normal, oblique)	Submerged Smooth / Rough Impermeable / permeable
Reflection (Kr)	1D	Regular Irregular	Emergent / Submerged Smooth / Rough Impermeable
	2D	Regular (normal, oblique) Irregular (normal, oblique)	Emergent / Submerged Smooth / Rough Impermeable / permeable

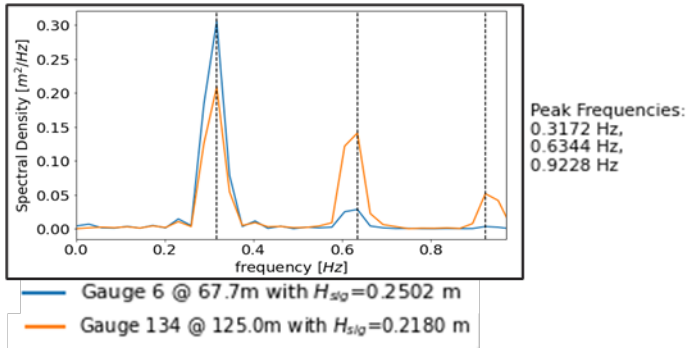
Project schedule by MONTH FY

PREVIOUS TECH DISCUSSION

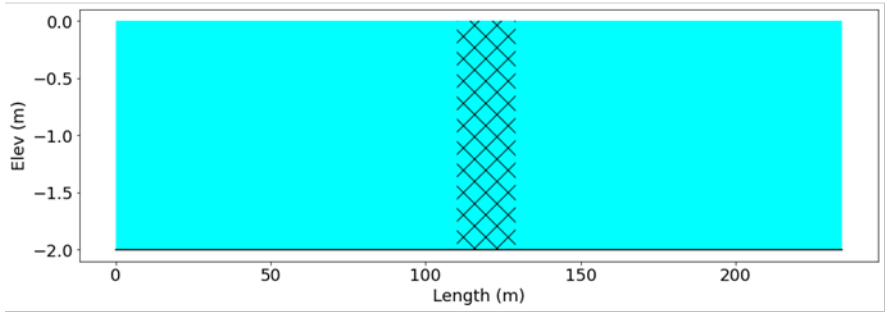
Compared wave transmission response across two structure placement methods

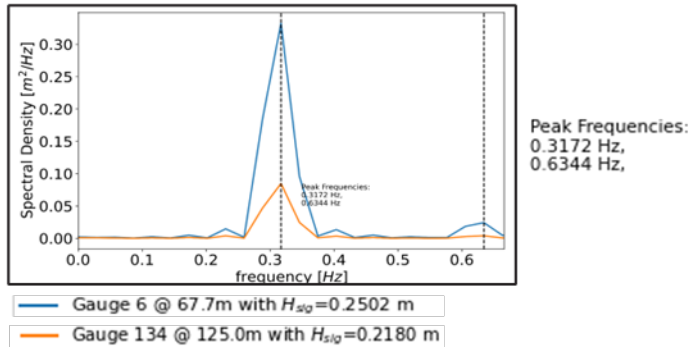
Bathymetry Modification (impermeable)





Breakwater file (permeable)





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WAVE TRANSMISSION

- Wave transmission relates the proportion of the incident wave transmitting past the structure

- For a rubble mound structure:
  - Overtopping transmission
    - Energy as a function of wave height propagating on the leeside of the structure (not an overtopping rate or volume)
  - Transmission through the structure
  - Diffraction around the structure

- Difficult to separate transmission via overtopping and transmission through the structure in physical modeling studies

$$K_t = {}^{E_t}/_{E_i}$$

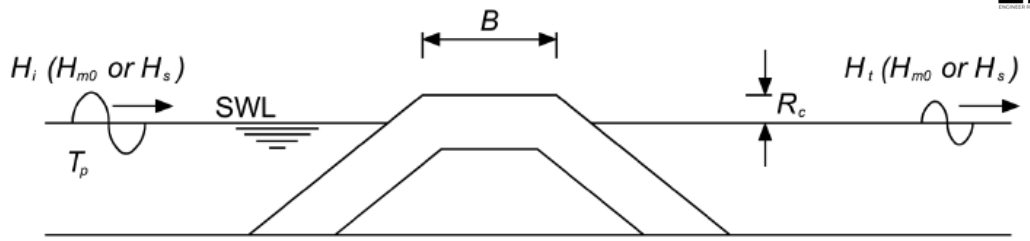
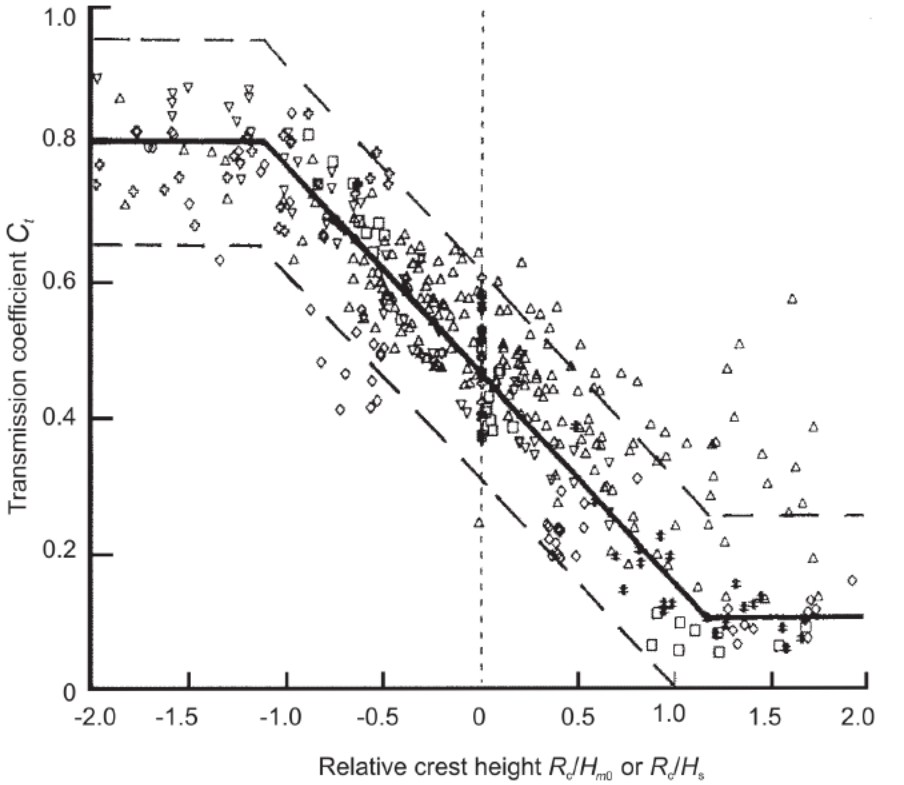


Figure 5.16 *Cross-section illustrating parameters influencing wave transmission*

Rock Manual (2005)



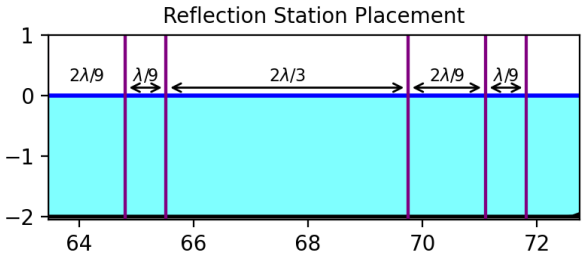
Rock Manual (2005)
CIRIA/CUR (1991)

WAVE REFLECTION

- Wave reflection relates the proportion of the incident waves reflected off the structure

- Following Goda and Suzuki (1976), expanded to three gages by Kobayashi and Cox (2012)

- Gage spacing, Δl:
  - 0.1*L and 0.2*L
  - Within one wavelength from toe
  - Outside one wavelength from toe



$$\left.\begin{aligned} E_I &= \int_{f_{min}}^{f_{max}} S_I(f)\ df, \\ E_R &= \int_{f_{min}}^{f_{max}} S_R(f)\ df. \end{aligned}\right\}$$

$$K_R = \sqrt{E_R/E_I}$$

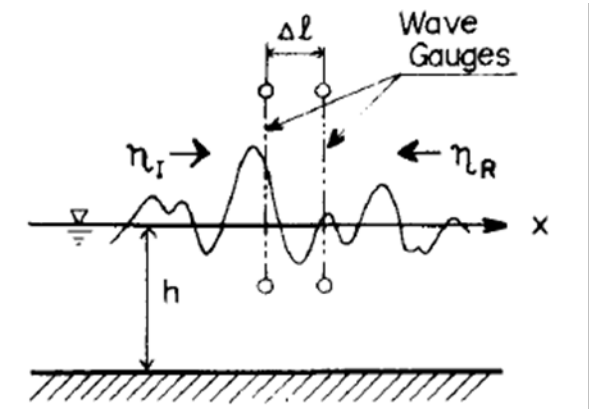


Fig. 1 Definition Sketch

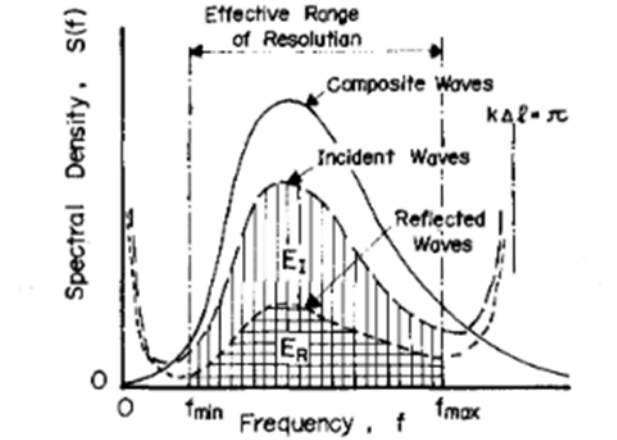


Fig. 5 Illustration of Spectral Resolution

Goda and Suzuki (1976)

TEST SUITE

Wave conditions:

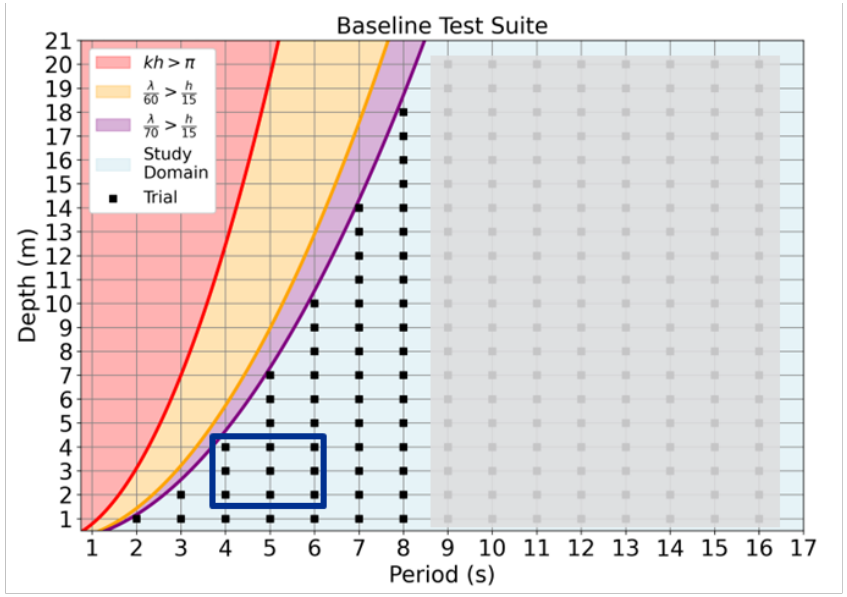
- Monochromatic

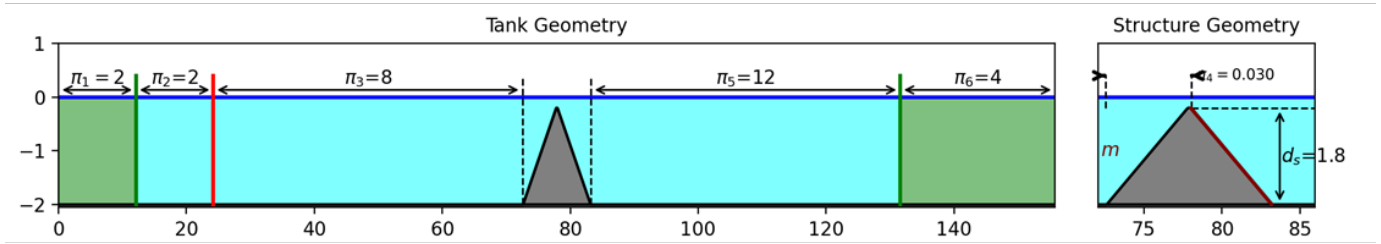
Constants:

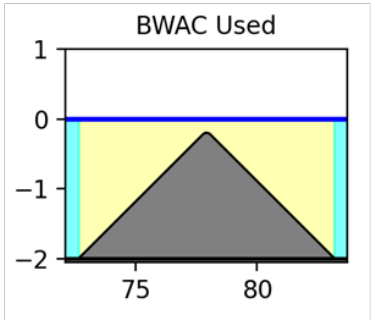
- Relative wave height – H/h = 0.1
- Relative freeboard – F/H = -0.2
- Relative crest width – B/L = 0.03

Variables:

- Coefficient of friction – Cd = log scale 0:1
- Sponge strength – Breakwater Absorption Coefficient = log scale 0:1
- Sponge width – same as toe-to-toe width of structure

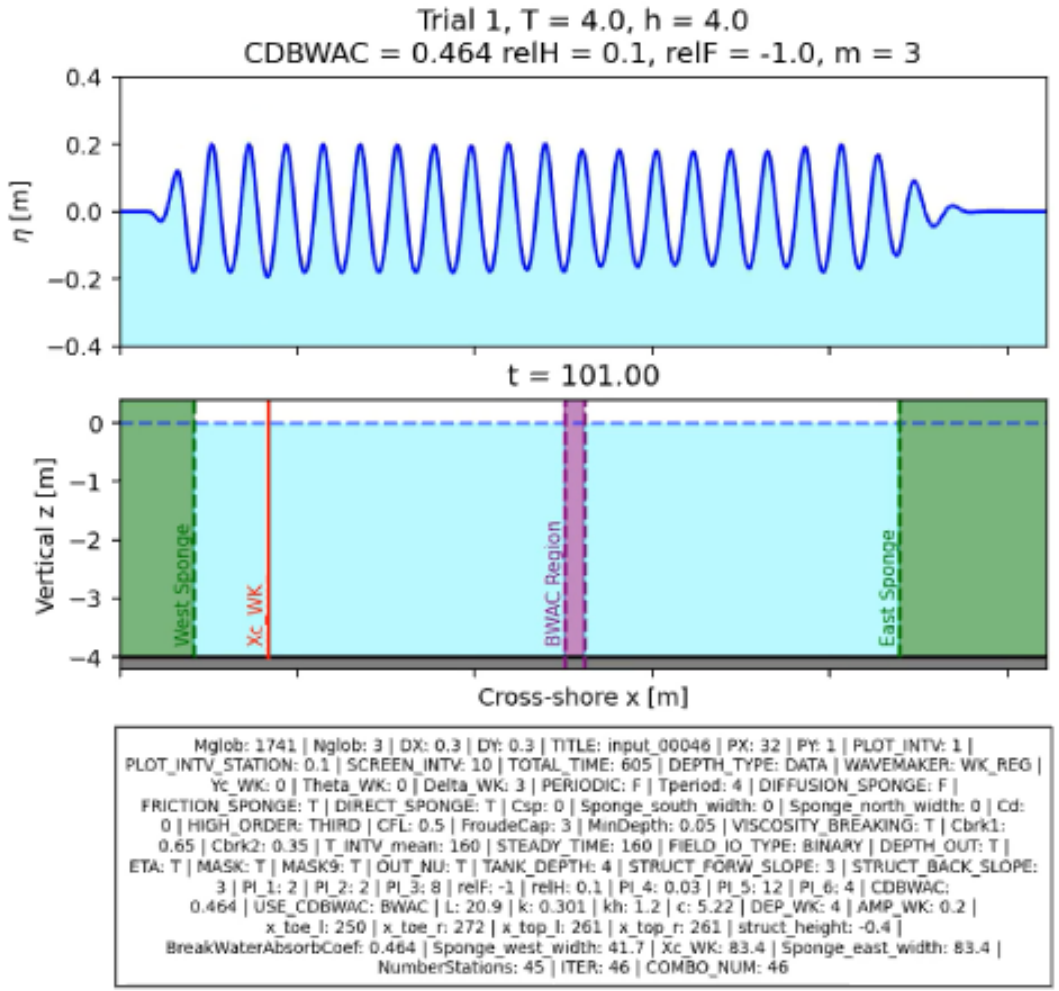


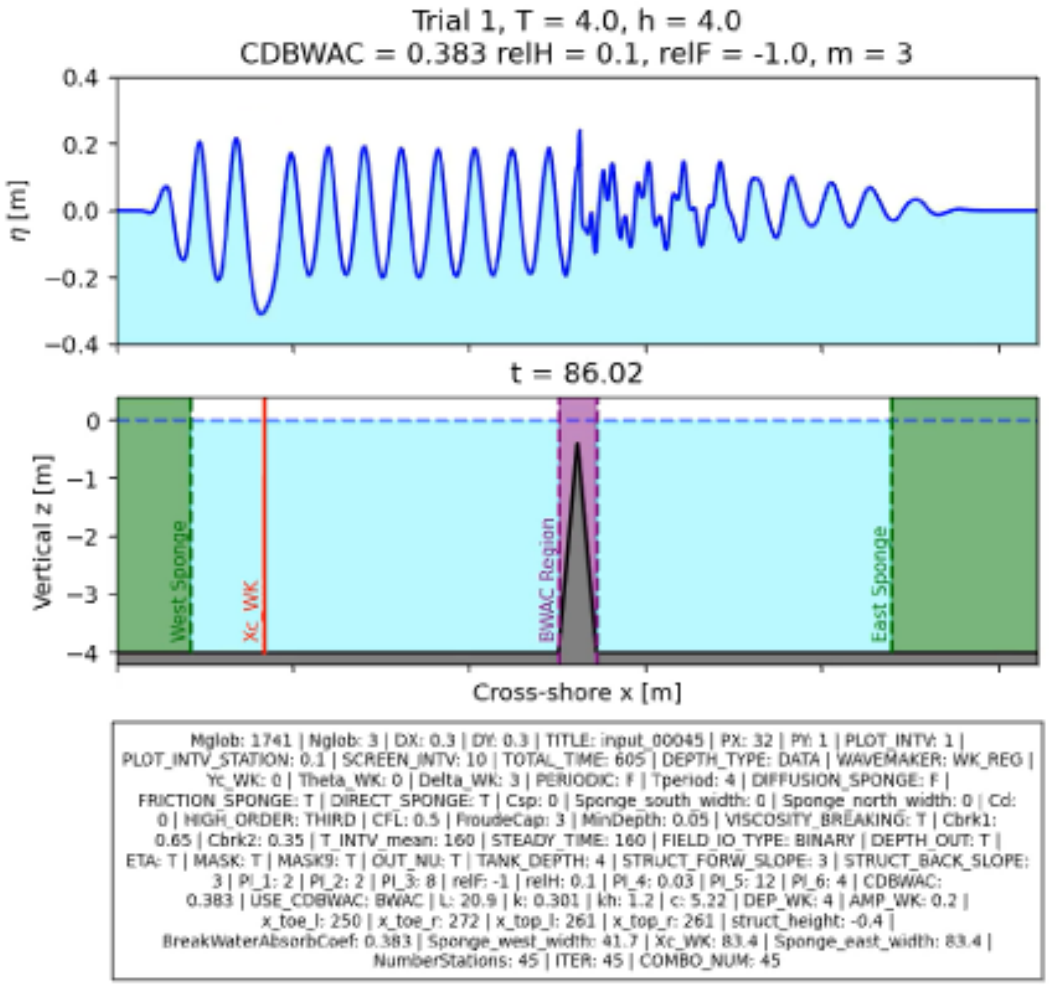




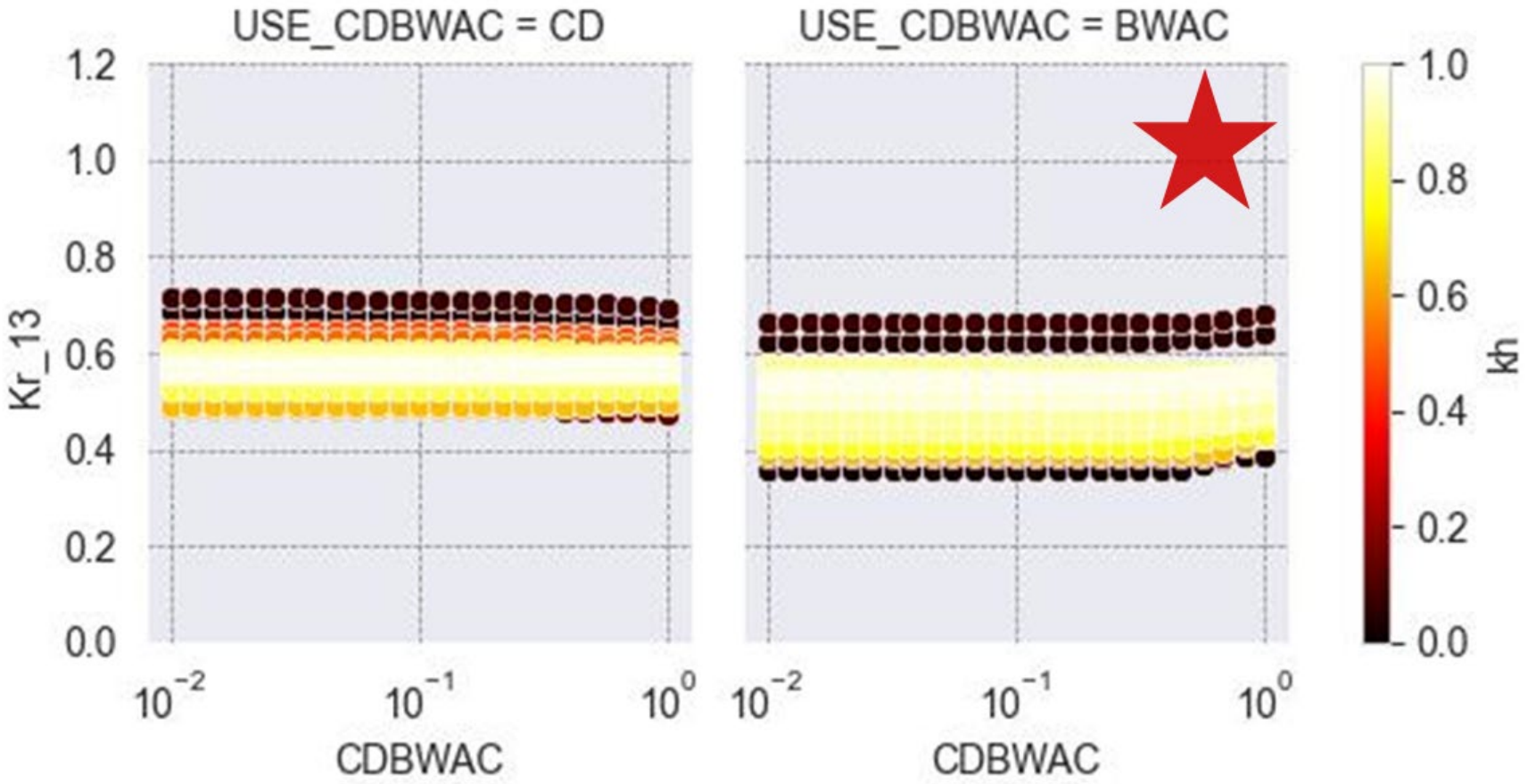
T – period (s)
H – wave height (m)
h – water depth (m)
B – crest width (m)
F – freeboard (m)
Cd – coefficient of friction
L – wavelength (m)

WAVE REFLECTION & TRANSMISSION



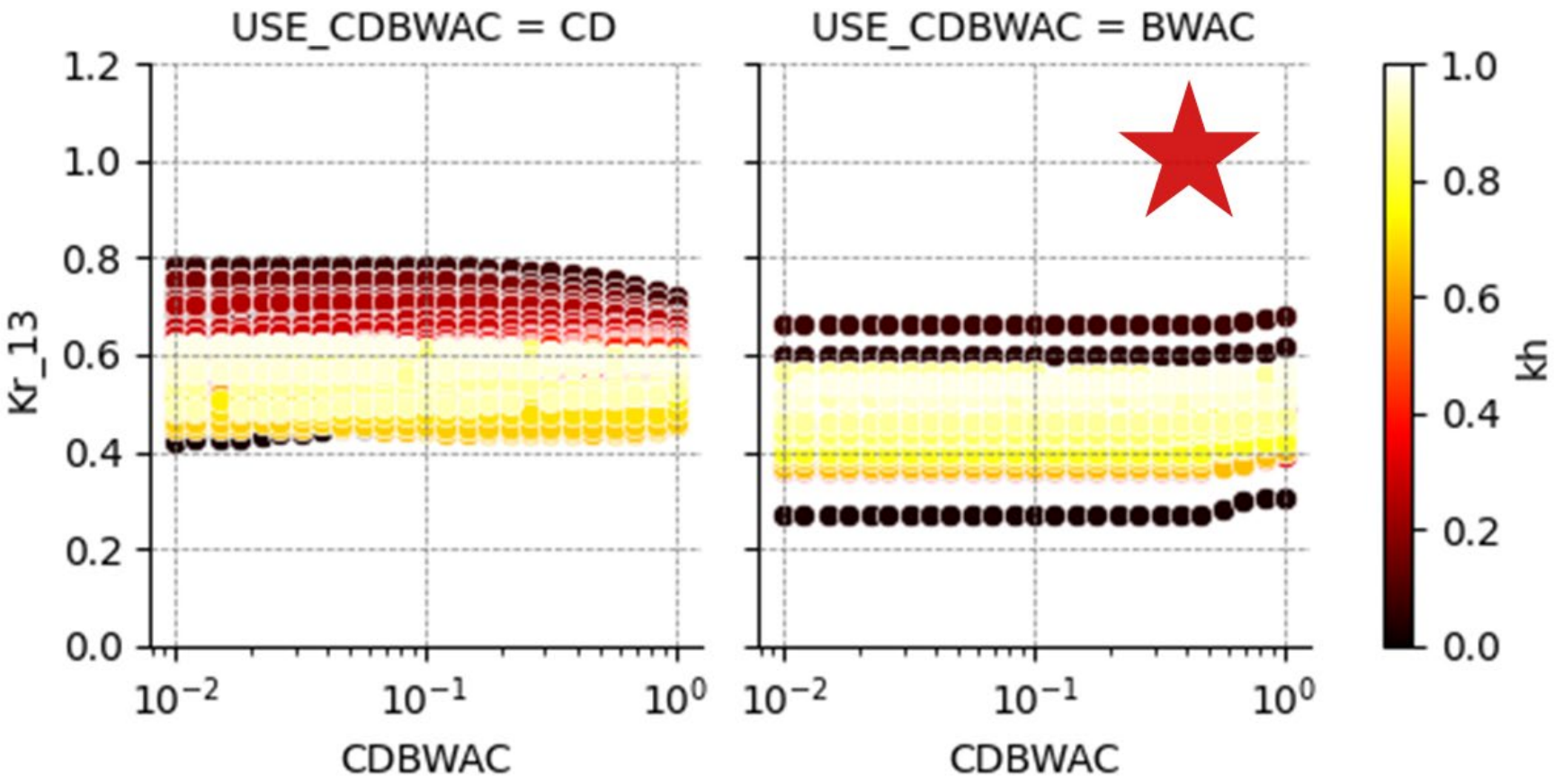


WAVE REFLECTION: EMPTY TANK



*This plot is incorrect and will be updated in a future presentation

WAVE REFLECTION: STRUCTURE



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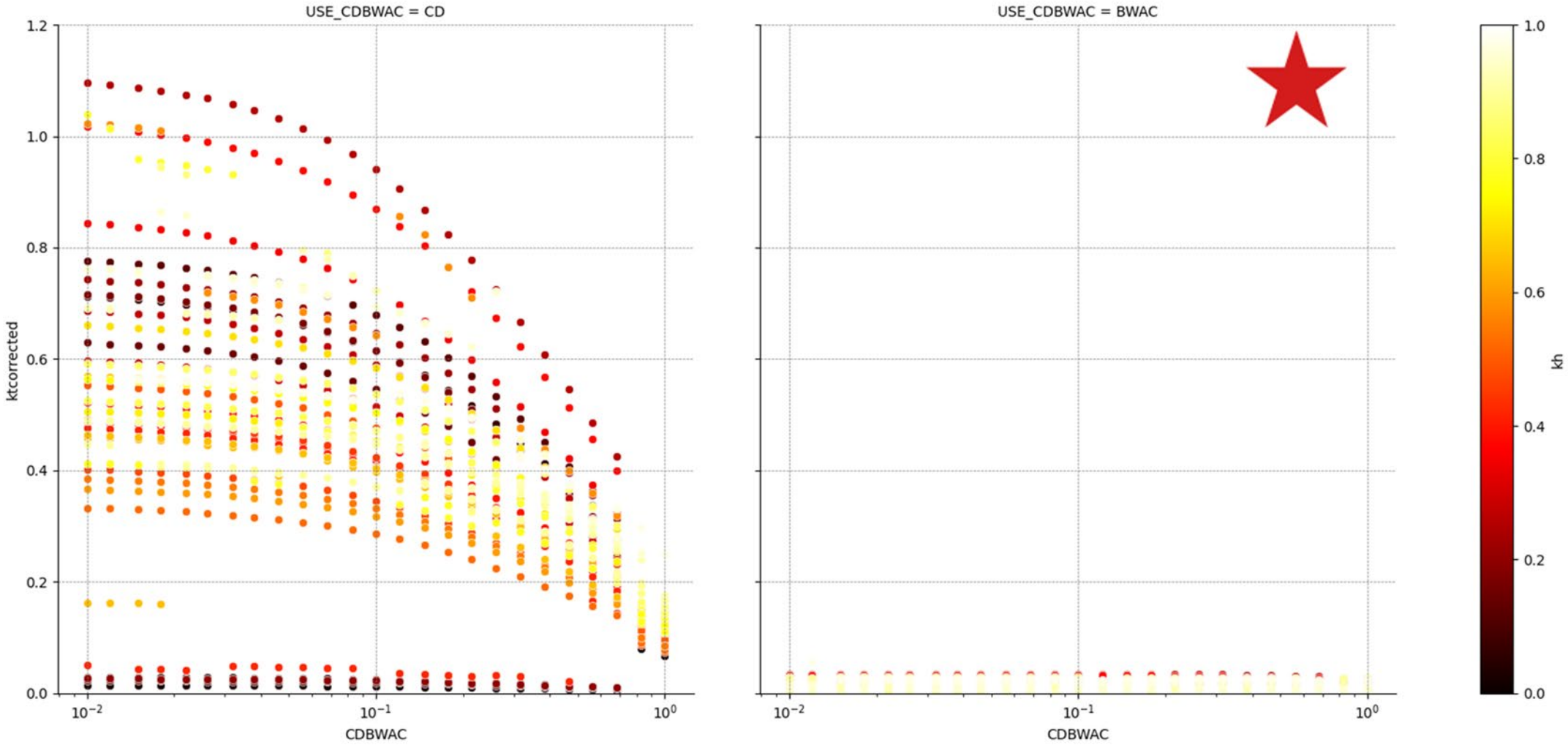
WAVE TRANSMISSION: STRUCTURE



*This plot is incorrect and will be updated in a future presentation

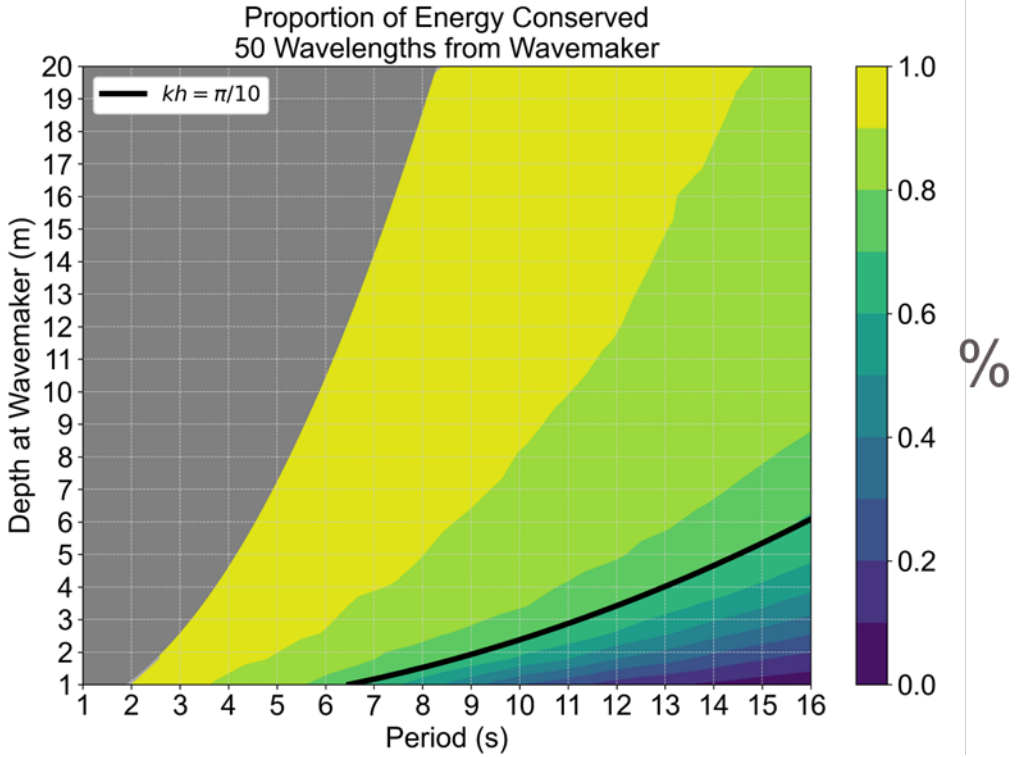
DISCUSSION

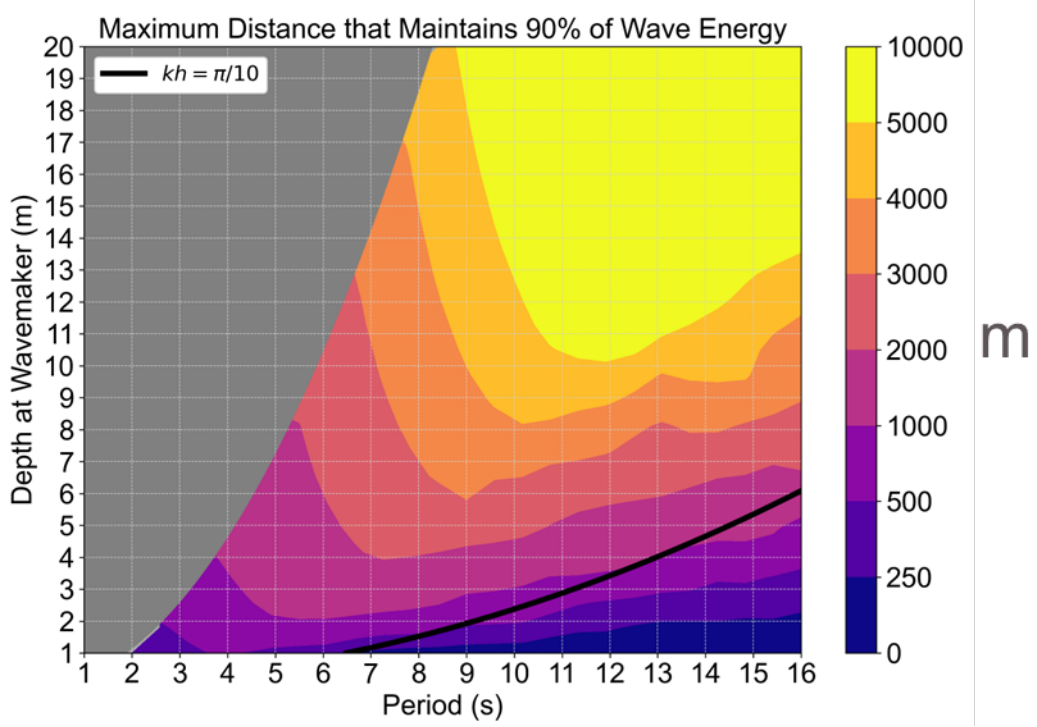
- Selection of time series for spectral analysis had minimal impact on response metrics
- Selection of reflection stations produced minimal changes
- Structure v. empty tank shows a greater band of reflection coefficients indicating increasing variability
- Slope or rate of change of the reflection coefficients increase/decrease more rapidly as Cd and BWAC increase?
  - *Requires an update in a future presentation when data has been corrected

ADDITIONAL GUIDANCE

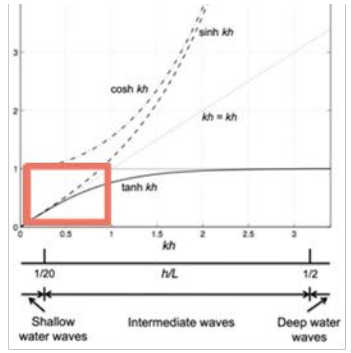
Normalized wave energy and distance – monochromatic waves, H/h = 0.1

- "Proportion of Energy Conserved" - ratio of energy at point X_n and X_0
- Energy transfer to higher harmonics, energy "loss" due to numerical scheme
- Traditional energy sinks possible due to breaking

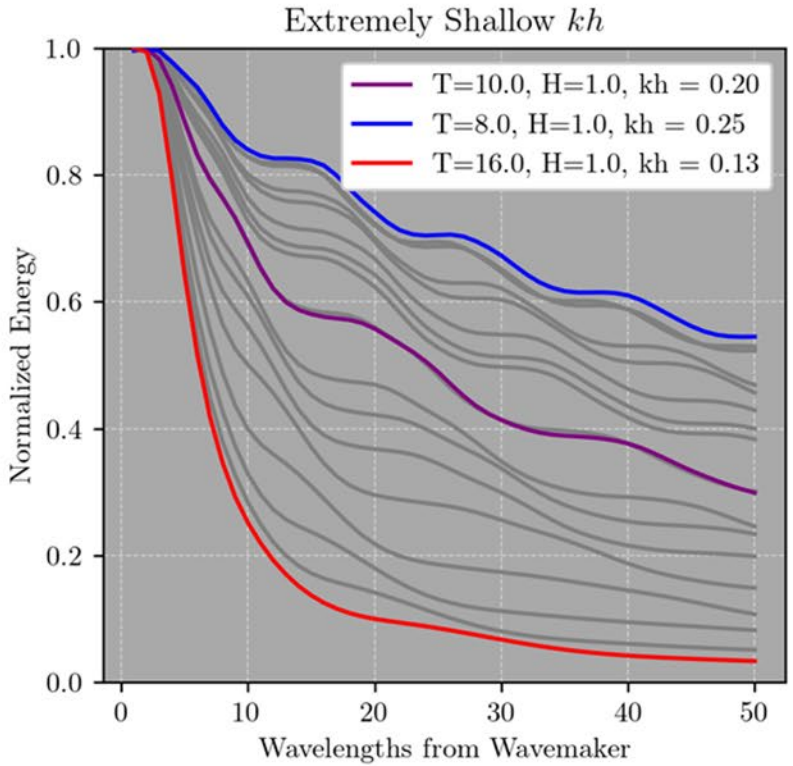


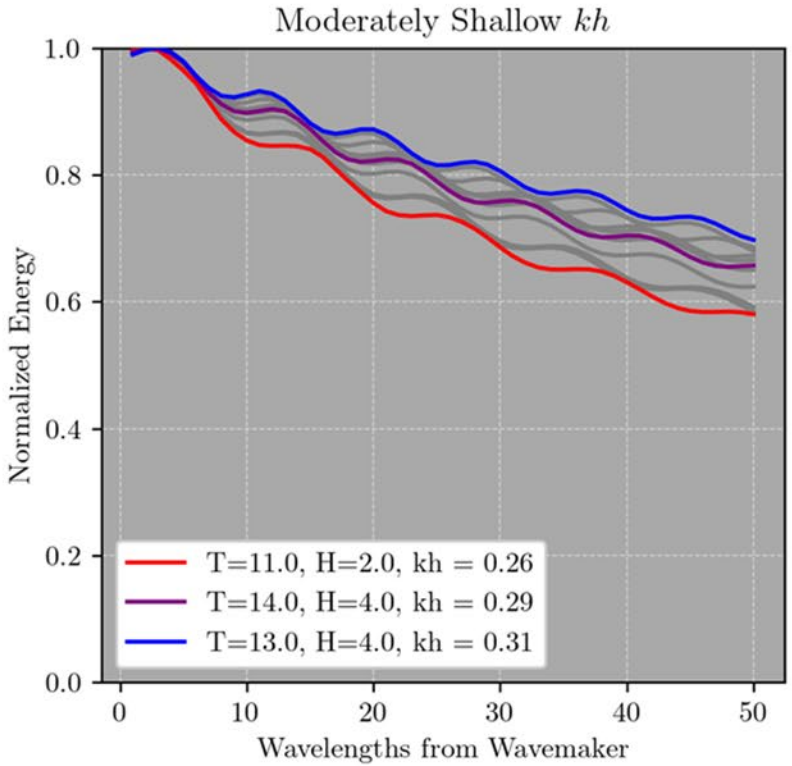


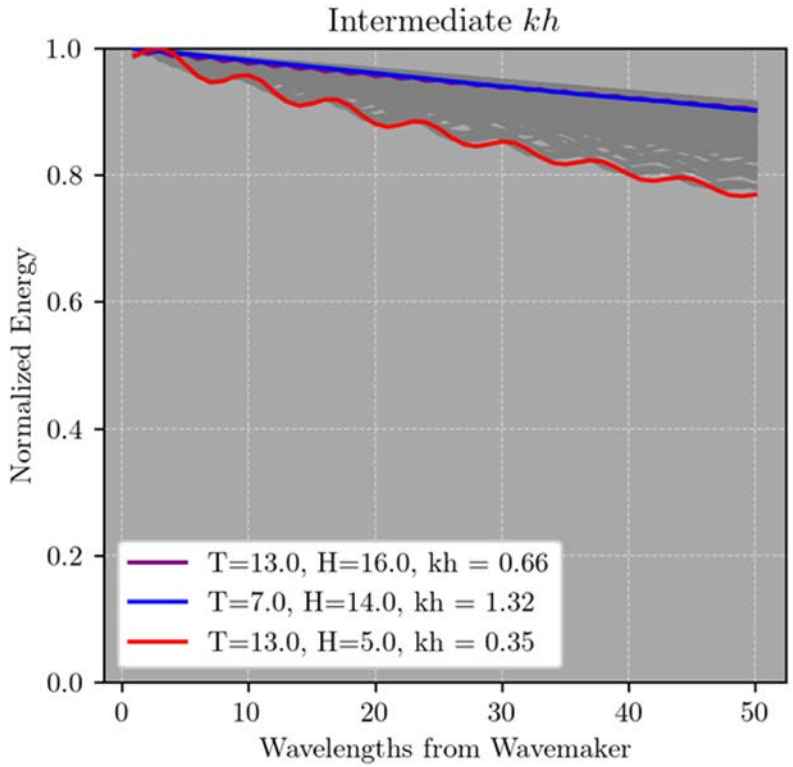
MORE GUIDANCE



Normalized wave energy and distance by kh







Less dispersion

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LOOKING AHEAD

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FY26 Q1

- Wave reflection & transmission
  - Expand range of friction values (CD and BWAC) between 1 and 2
  - Repeat modified test matrix for other relative freeboard, side slope, and sponge width conditions
  - Aggregate and analyze
- Wave runup & overtopping
  - Finish remaining small batch simulations over side slope, friction values, and incident relative wave heights
  - Aggregate and analyze
- Prepare comprehensive draft TR of sensitivity analysis for all wave response metrics – *exp. Apr 2026*
- Formalize and distribute post-processing scripts via GitHub or GitLab
- Archive FUN data

FY26+

- Assess remaining needs from ranked/relevant SoNs
  - 1278-2019 "Boussinesq modeling of wave transformation and interactions with permeable and submerged structures"
  - 1664-2021 "Enhanced user guidance and support tools for FUNWAVE-TVD, a Boussinesq-type numerical wave model"
  - 1739-2021 "Enabling Reliable Evaluation of Wave Interaction with Submerged Structures"
- Lessons learned suggest the need for internally managed model code: FUNWAVE-USACE
- Uncertain future – priorities and people
  - Administration and Lab priorities
  - Ongoing hiring freeze
  - Torres transition to PM role full-time?

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THANK YOU!

Shoutout to everyone who contributed to this work unit:

- Michael Y. Lam
- Gabriela Salgado-Dominguez
- Fabian Garcia Moreno
- Levi Cass
- Ryan Schanta
- Hailie Suk
- Abigail Stehno
- Steven Shi
- Amy Bredes

- Rachel Malburg
- Rod Moritz
- Matt Wesley
- Jessica Podoski
- Drew Condon
- Gabriel Todaro

- Matt Malej
- Tanya M. Beck

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