NEARSHORE PROCESSES/ MULTI-SCALE MODELING

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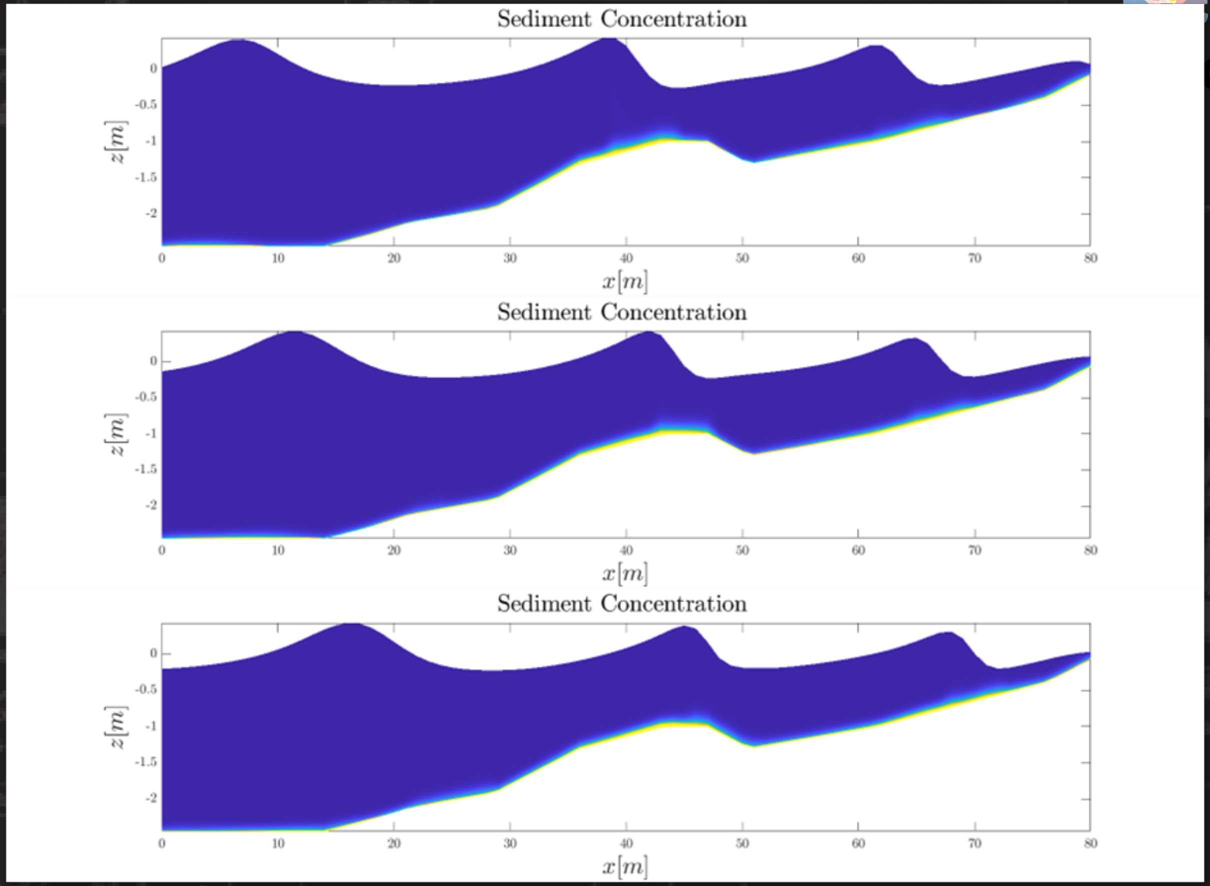

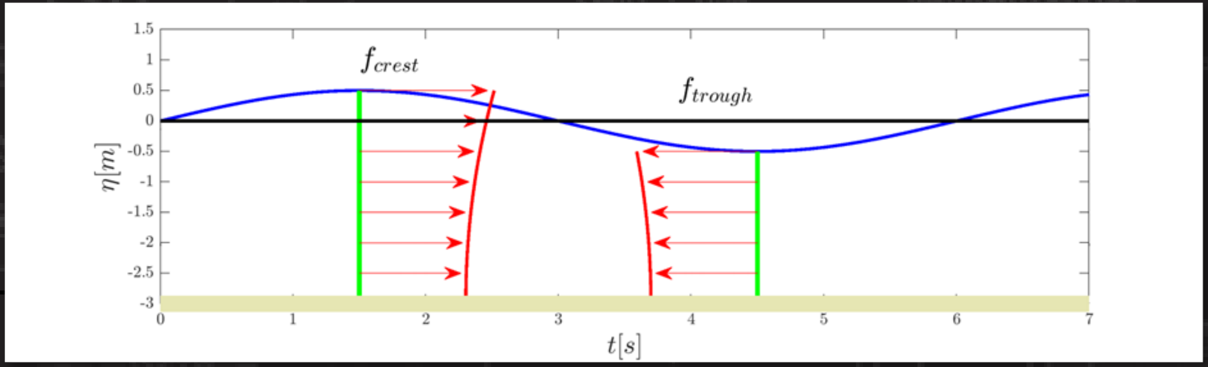

COASTAL INLETS RESEARCH PROGRAM
FY24 IN PROGRESS REVIEW

U.S. ARMY
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ERDC
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PROBLEM STATEMENT

- Nearshore waves, hydrodynamics, and sediment transport remain poorly understood. No comprehensive and general predictive technology exists for rational design and planning of coastal projects of relevance for USACE. Challenges include
- Navigation – sediment transport from open coasts to coastal inlets and channels
- BUDM – fate and evolution of nearshore nourishments
- FRM – design of flood protection dunes
- EWN – impact of NNBF

- 2024 BCER Initiative
- #1906: Quantification of Shoreline Response to Nearshore Berms
- #2101/2103 – Predictive Capability in Coastal Sediment Transport
- #2202 – CoPADD: Transition to New Coastal 3D Circulation Models for Water Quality and Sediment

FY24 was Year 1 of 3

Year over year advancements to date: 1 TD, 1 TR, conference presentations

AUTHENTIC PROBLEM STATEMENT

ERDC

- All practical process-based nearshore models estimate the phase-averaged wave-related terms: CMS, Delft3d, Xbeach, CSHORE
- Enormous resources (and 40 years) into making these estimates, yet two mature process-based nearshore morphology models:
- Inaccuracies in phase-averaged predictions for wave-dominated environments are attributable (usually) to a failure in 'closures'.
- Some success in hydro closures like radiation stress, but no general underlying algebraic description in nearshore transport to use as a theoretical basis
- Complex example: predicting residual of large oscillatory wave-driven processes: e.g. onshore-offshore transport—especially considering that we are not even directly modeling the wave-driven components

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Calibration and assessment of process-based numerical models for beach profile evolution in southern California

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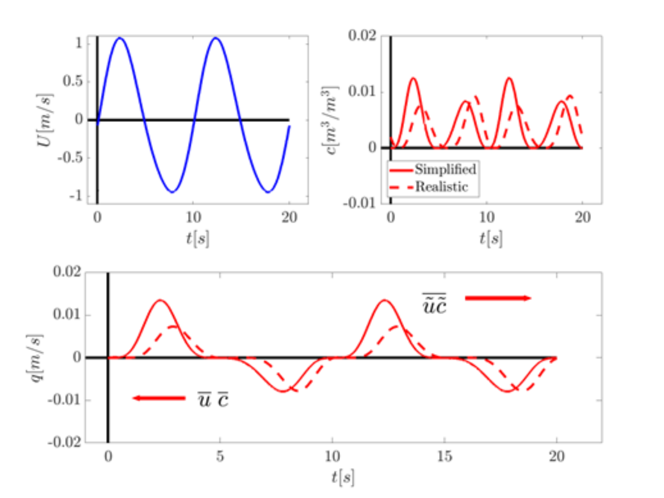
Abstract

Cross-shore profile … because the physics … sparse or unknown. … slopes are used to ca… CShore and XBeach… quantitatively evalu… along with Brier Ski… metric that evaluate… is tested with defaul… all profiles and events, however XBeach skill scores often remained low and in no case correctly predicted the offshore bar formation. Notably, XBeach is sensitive to the beach profile's calibration depth extent. Upper beach calibration produced significantly different skill than when the full profile was considered. CShore was tested using both the 'Atlantic' and 'Pacific' parameters. Both models predict profile change with limited skill. In their present forms, CShore and XBeach are unable to … beaches, but when calibrated may provide qualitatively useful beach face erosion estimates.

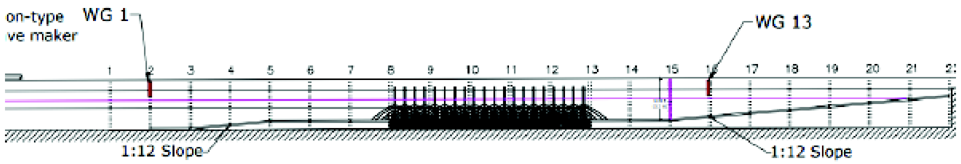


Is it hopeless? Perhaps the idea of collapsing closures (e.g., sediment transport) to a general simple algebraic expression is actually hopeless.

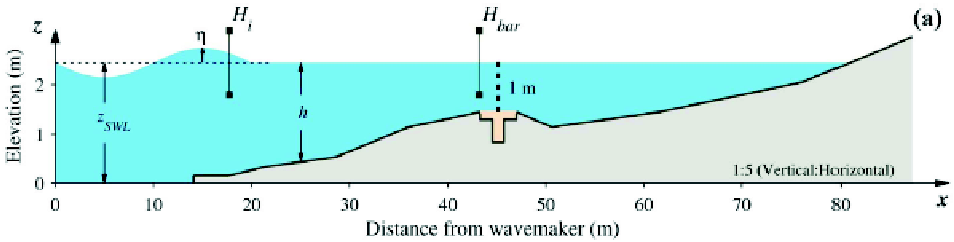
Consider some multi-scale alternatives (to guessing) that utilize finer-scale models to resolve the phase-dependent quantities

- Simple: Use phase-averaged quantities along with empirical procedure to determine details of wave-shape, apply representative hydrodynamics to equations governing relevant process (Two examples today)
- Complex: Build a well-populated 'library' of suitably accurate responses for use by ML (In development)

- OSU Vegetation Example



- BARSED Sediment Transport Example



NEW MODELING STRATEGY

Previously some proof-of-concept work making use of measured forcing data–of course, this is not a predictive system

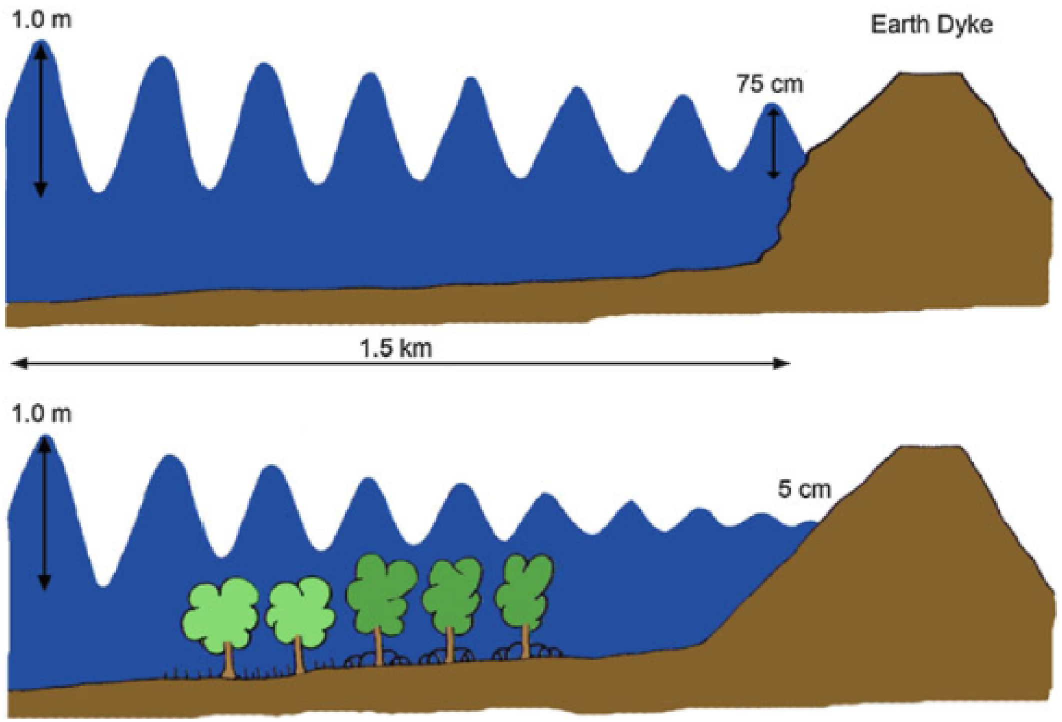
Consider, now, the simple hybrid approach where numerically-derived closures are computed and incorporated in the phase-averaged system:

- Deploy phase-averaged model: $h, H_s, (U, V)$
- Estimate skew, asym from $U_r(ka, kh) \rightarrow r, \phi$
- Invent time series of free surface and velocity
- Numerically evolve relevant physics, e.g. Vegetation forces or sediment concentration
- With detailed estimates of F, c, u, v, compute time-averages
- Incorporate 'closed' values in phase-averaged model

EXAMPLE WITH NNBF

Natural and nature-based features, as a topic, is fashionable at present

- Wave dissipation (robbing energy from the wave field), as induced by vegetation, is a practical and promising aspect of NNBF
- Many well-conducted laboratory investigations, and a few field campaigns
- The focus has been on development of predictive models for dissipation
- While reduced wave-heights, undoubtedly, have value in coastal protection, little research on the impact of these features on MWL



EXAMPLE WITH NNBF, EQUATIONS

Nearshore phase-averaged set:

- Energy

$$\frac{\partial E_f}{\partial x} = -D_B - D_f - \overline{\int_{zb}^{\eta} \rho \frac{C_D}{2} d_v N |u|^3 dz}$$

- Momentum

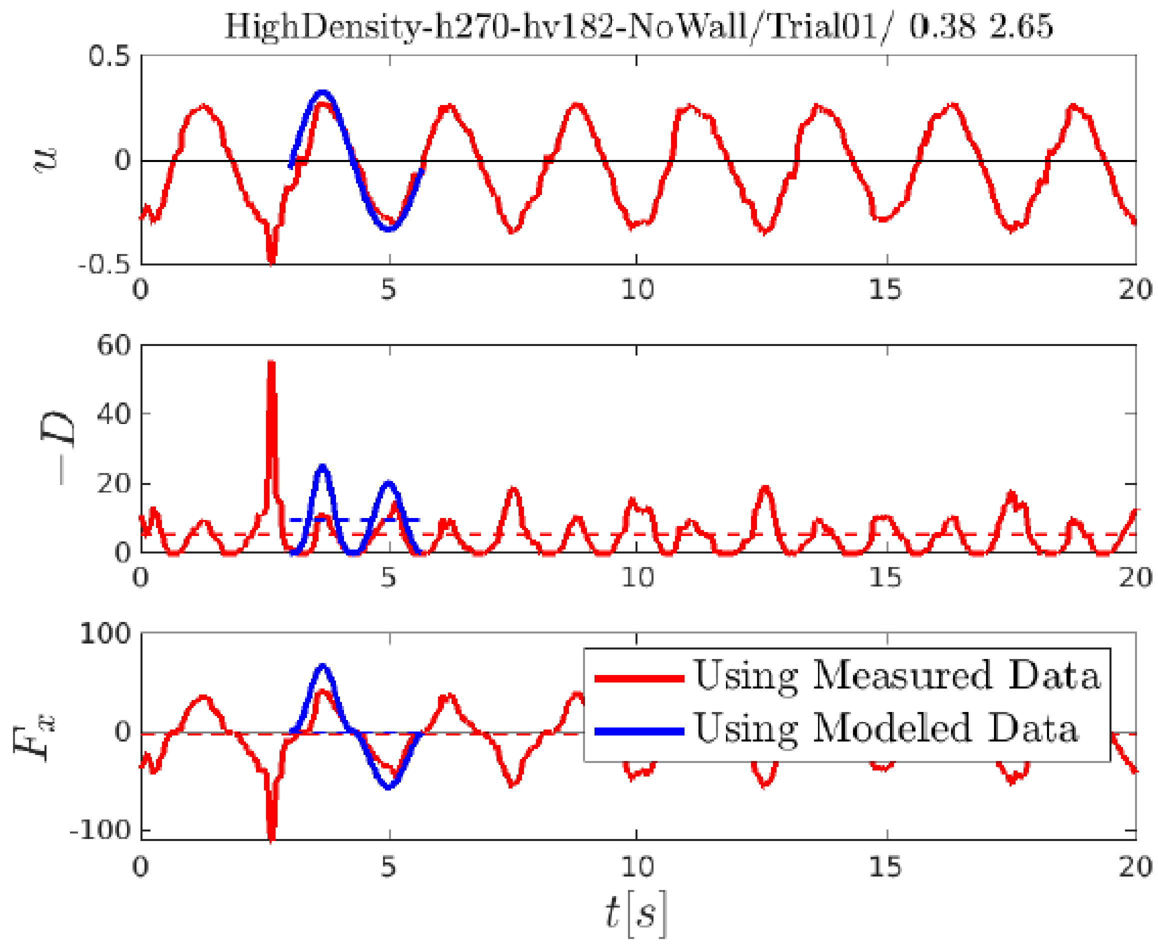
$$\frac{\partial S_{xx}}{\partial x} = -\rho g \overline{h} \frac{\partial \overline{\eta}}{\partial x} - \overline{\tau_b} - \overline{\int_{zb}^{\eta} \rho \frac{C_D}{2} d_v N |u| u dz}$$

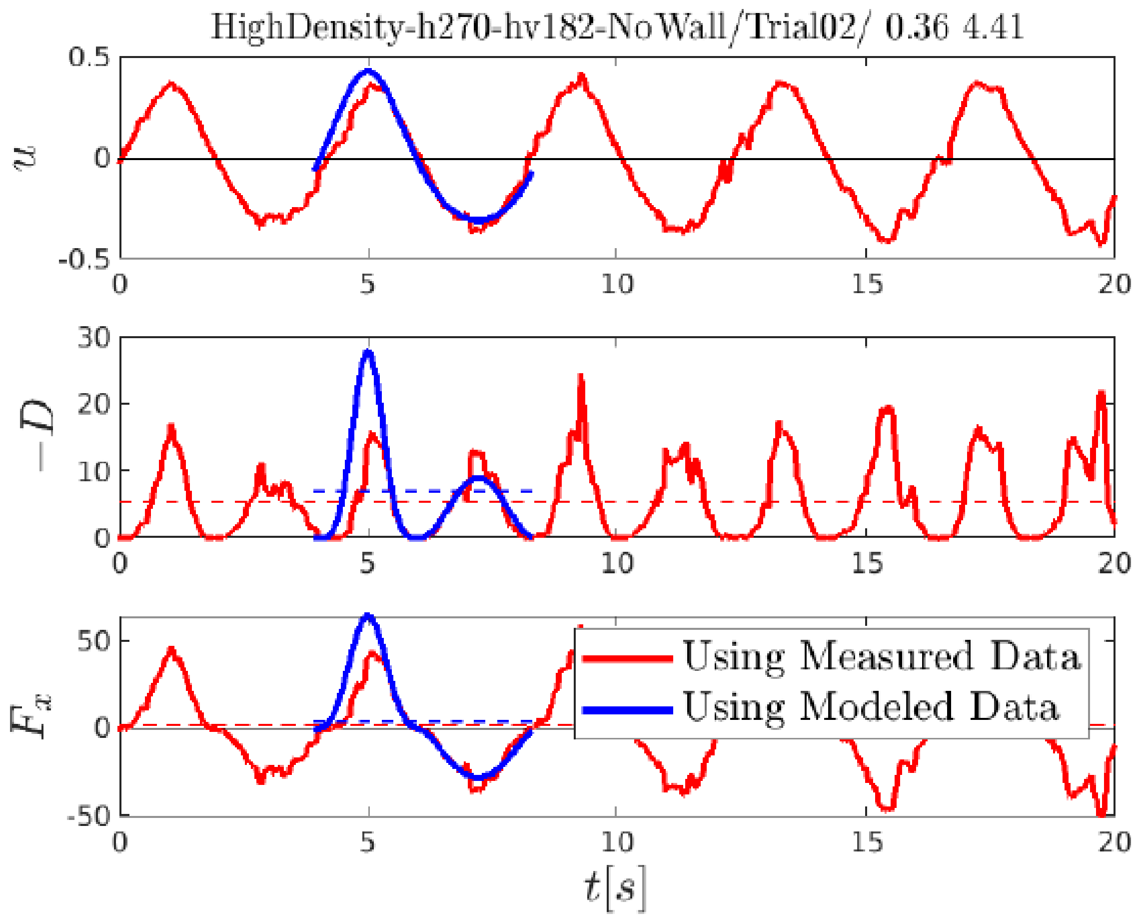
F

- Terms in blue derive from the same origin and a consistent model includes both
- Dissipation is always positive, and can be leading term in balance – as in this case
- Force, F is required for consistency, but not always important

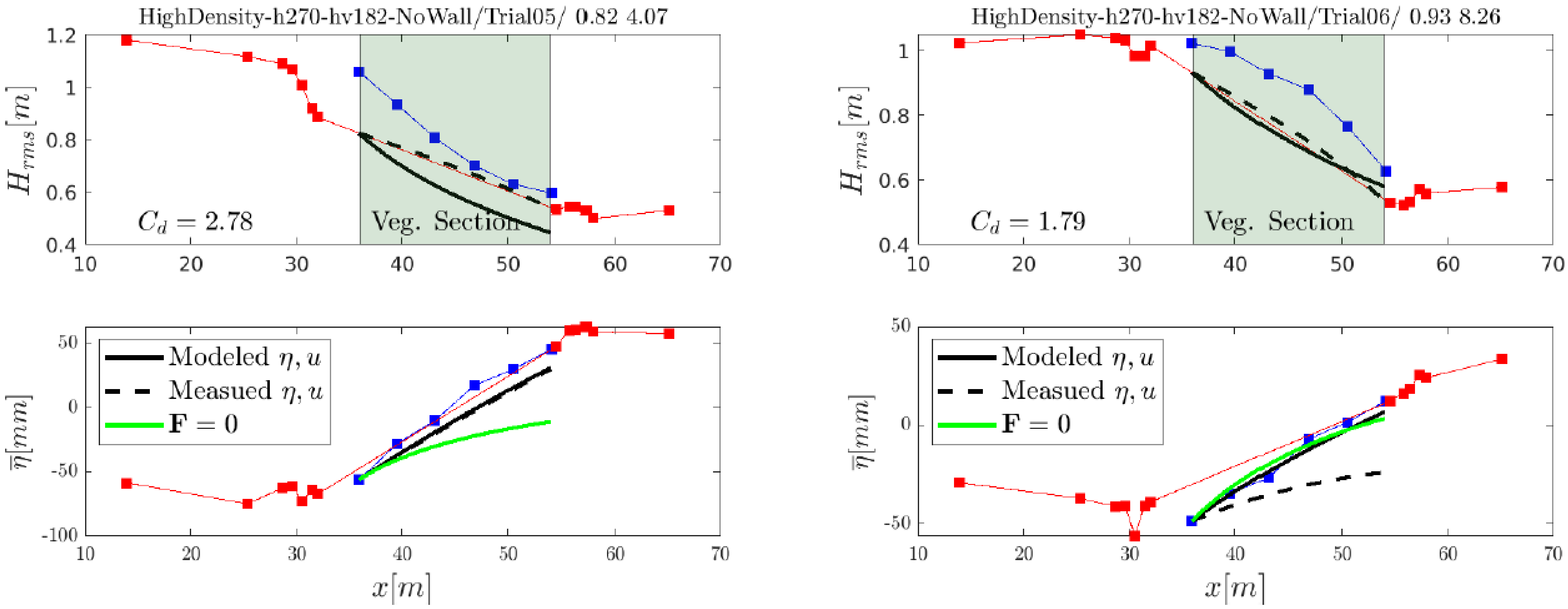
EXAMPLE WITH NNBF, COMPARISONS

ERDC

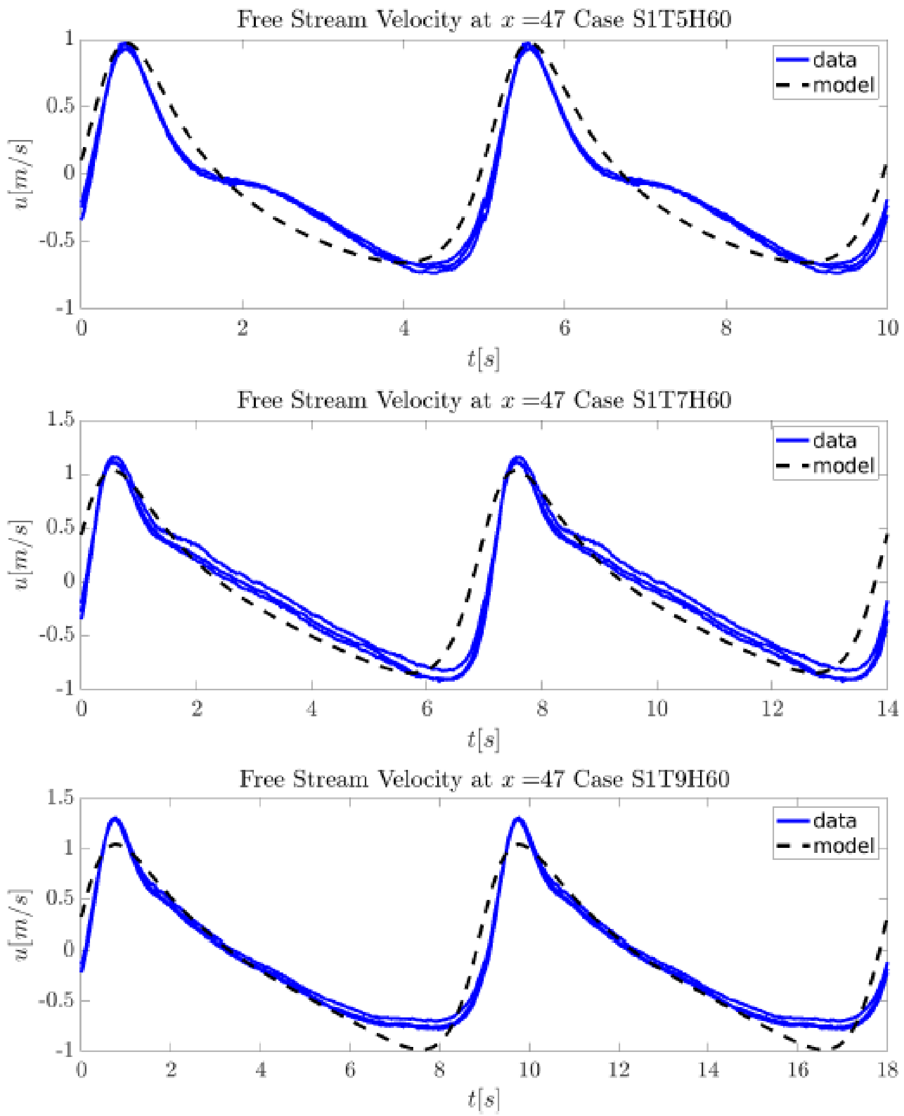


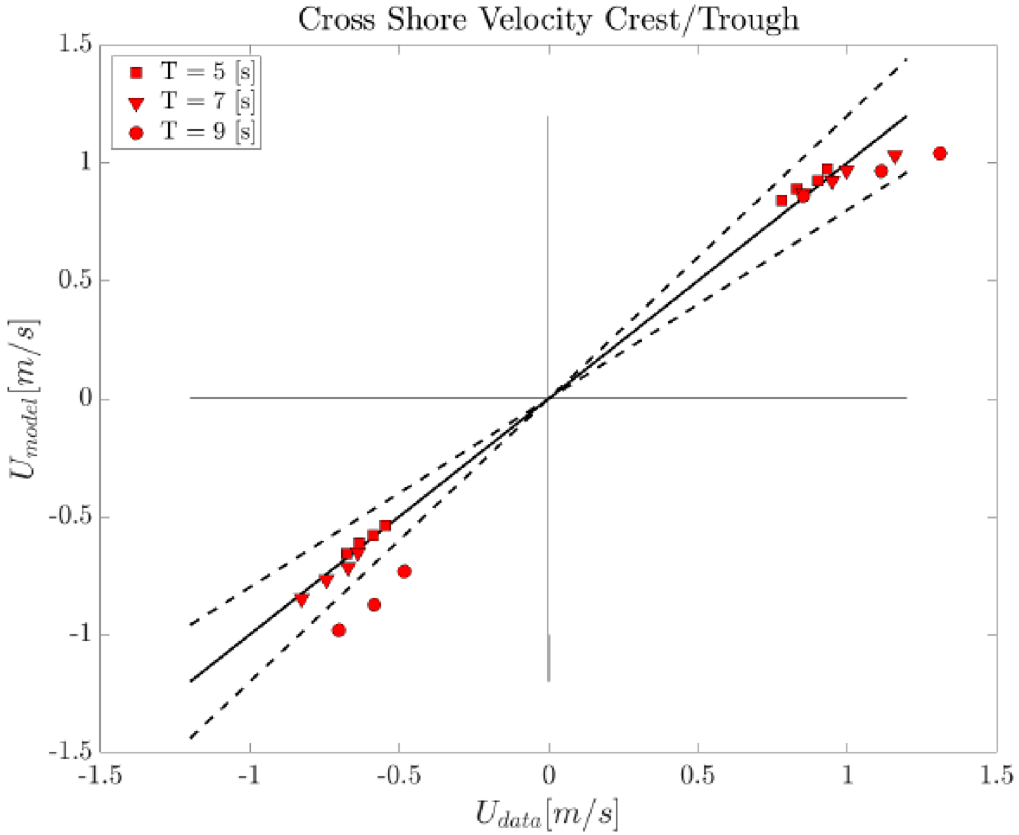


EXAMPLE WITH NNBF, MORE COMPARISONS



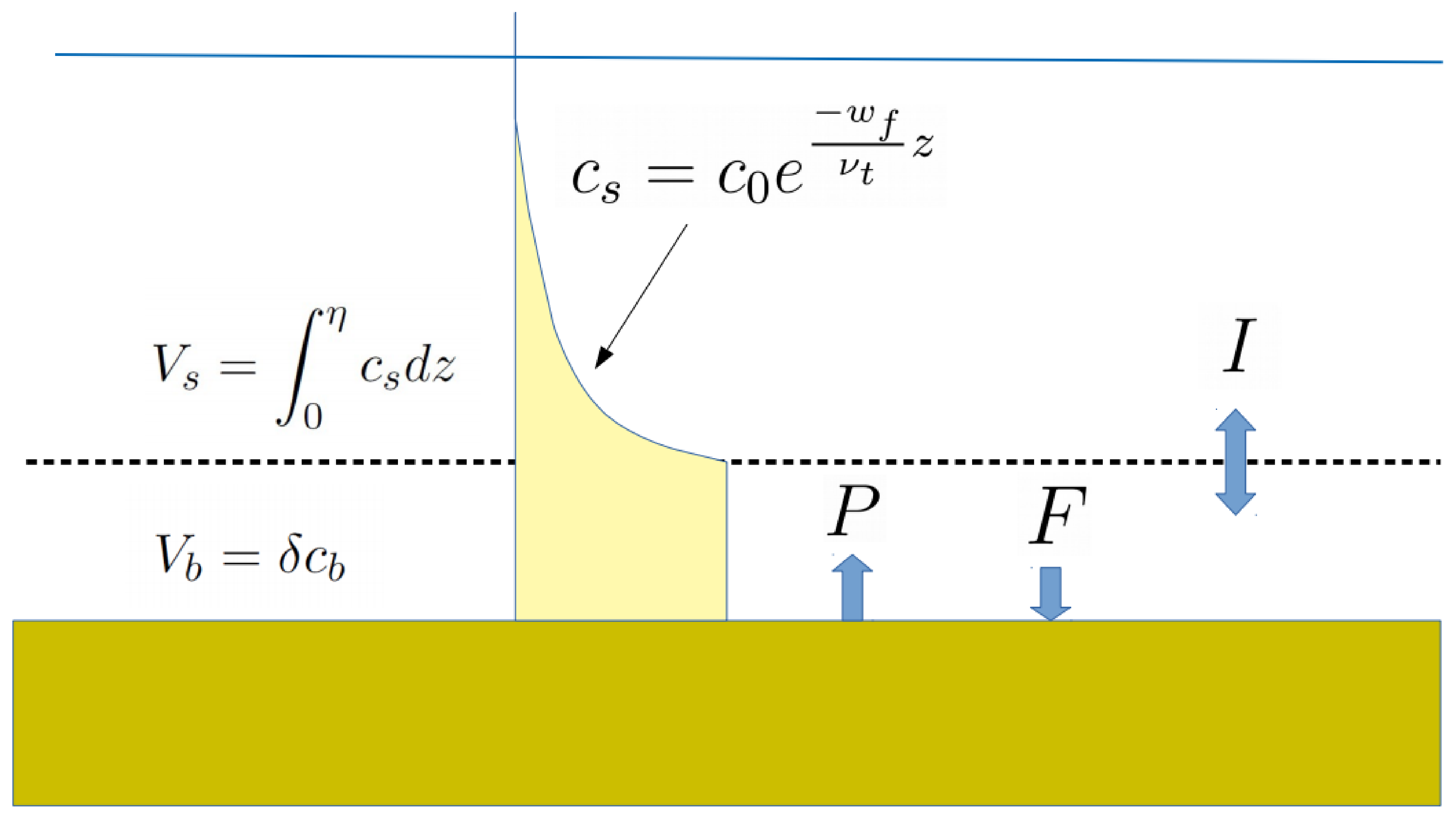
EXAMPLE WITH SEDIMENT TRANSPORT





EXAMPLE WITH SEDIMENT TRANSPORT

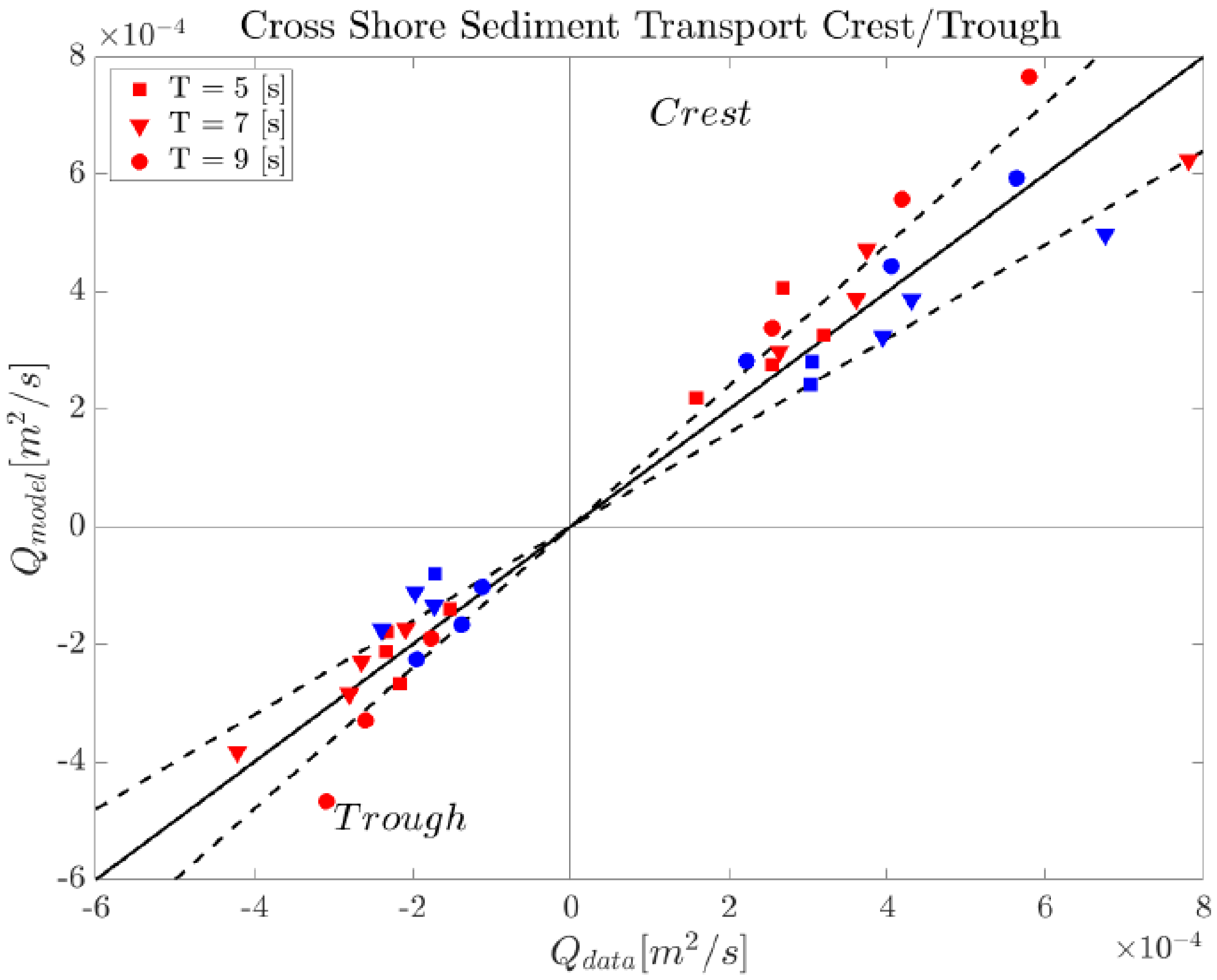
DIAGRAM



EXAMPLE WITH SEDIMENT TRANSPORT

GRAPH

- Crest/Trough based on Pos/Neg U_∞
- Provides some estimate of gross transport accuracy
- ν_s are tailored to these data
- Skewness included, but not asymmetry: $T_A(d^3)$



BEGINNING WORK ON 'COMPLEX' ALTERNATIVE

- Alternative option is creating a library of phase-resolved numerical predictions and using ML to
- Plan to employ XBEACH-NH and Funwave
- Significant work to be conducted as the sediment processes are largely absent/untested

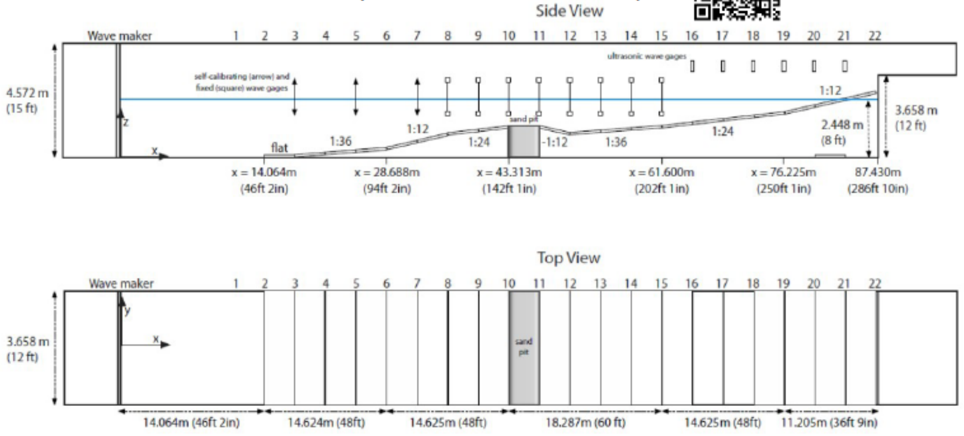
Summer Progress

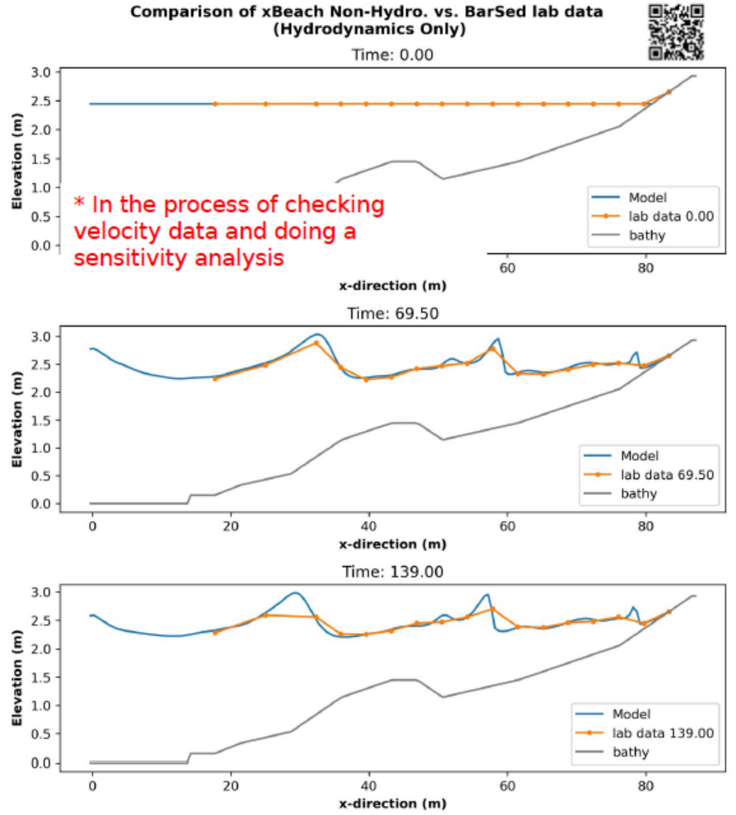
Broad Plan

1. Using wave resolving numerical model recreate lab experiment (Chose *xBeach Non-Hydrostatic*)
2. Using phase-averaged numerical model recreate lab experiment
3. Use phase resolving information to help better represent sediment transport in the phase averaged.

Current progress…

OSU BARSED Experiment (Mieras et al. 2017)

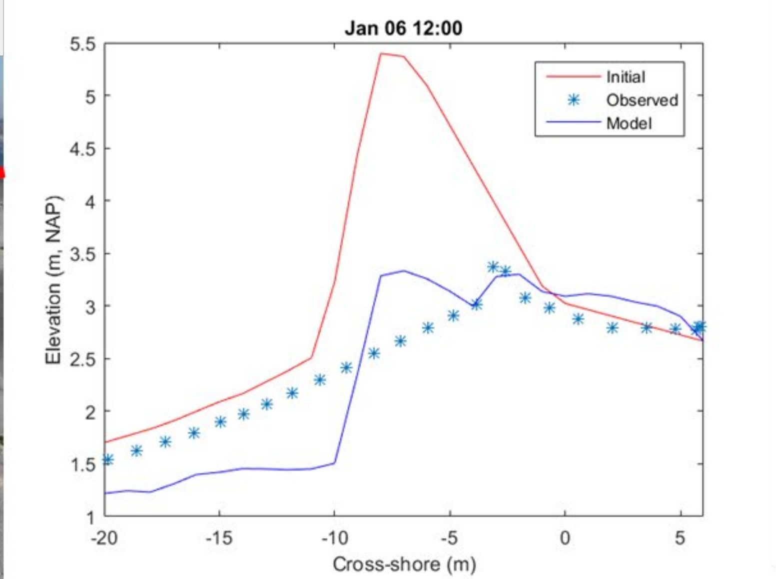


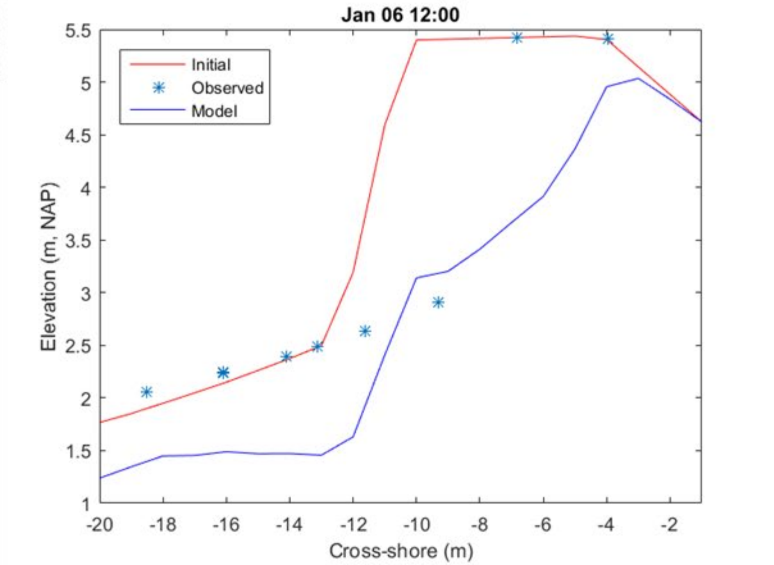


Run id	Period, T	Initial Depth, h0	Initial Wave Height, H0
(-)	Seconds	Meters	Meters
001	7	2.448	0.6

ORISE RESEARCH ON DUNE MORPHO CHANGE

- Dune change is a challenging closure problem
- ORISE for 3 months examined issues in modeling two measured morphologies
- Makes use of RealDune/ REFLEX experiments
- Measurements under calm, moderate, and storm conditions with dune erosion in the collision regime
- Mixed results using CSHORE model





SUMMARY

FY24 Major Advancements in Capability

- Initiated the predictive phase of the muti-scale modeling approach
- Reasonable model/data comparisons (sediment transport, vegetation impact) without reliance on measured data
- Started the ML approach

FY24 Major Products & Collaborations

- Runup TR published
- TD on modeling highly dissipative environments
- Multi-scale code submission
- ICCE Presentation
- VA Tech: collaboration on phase-resolving tech
- Northeastern: Collaboration on dune morpho change

FY25 Products & Advancements

- Take part in the design and execution of USCRP experiment
  - Sediment Transport Over the Nearshore Environment (STONE): Linking nonlinear wave effects across the shoaling and breaking zone (Morteza Derakhti UW + collaborators)
  - Breaking wave-induced rapid beach profile evolution in the inner surf and swash zones (Ryan Mieras UNCW + collaborators)
- ‘Application’ of model to laboratory experiments
- JP on multi-scale technique