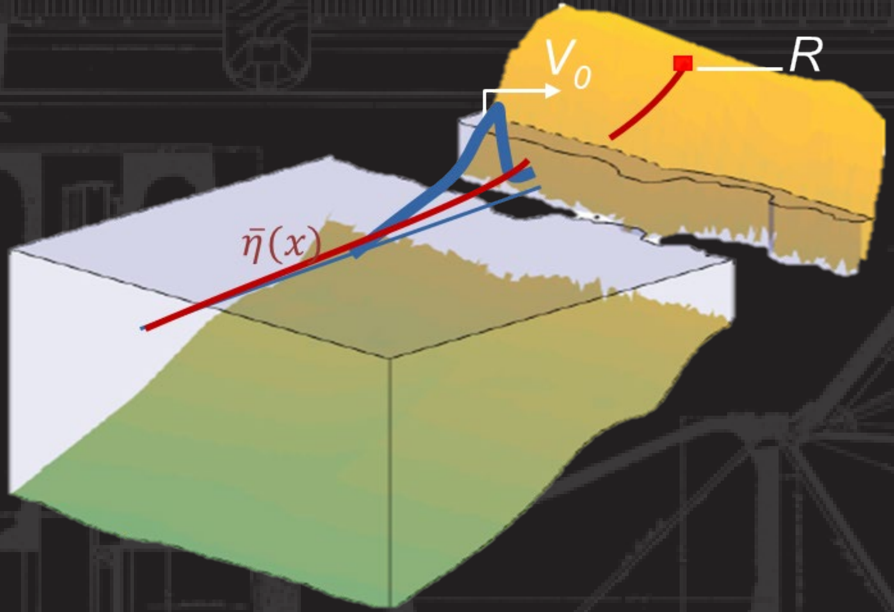
NEARSHORE PROCESSES/C2SHORE



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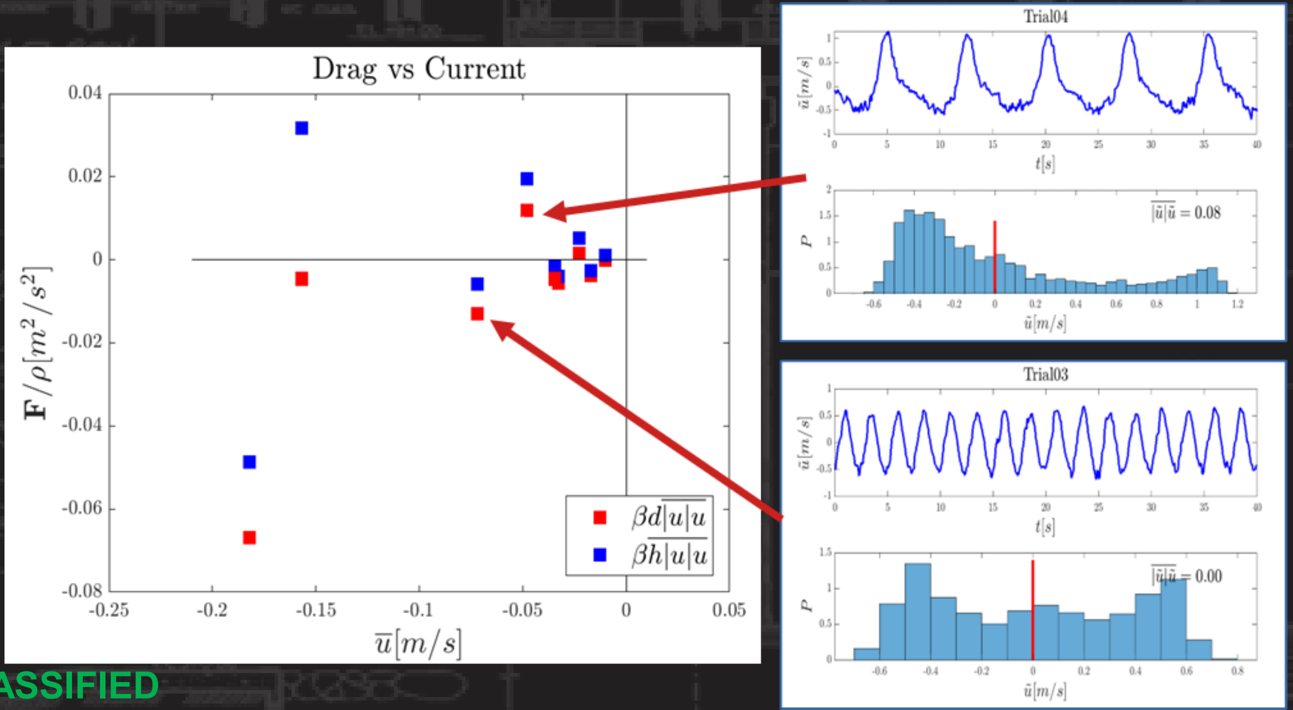
19 Apr 2024



COASTAL INLETS RESEARCH PROGRAM

FY23 IN PROGRESS REVIEW

U.S. ARMY

US Army Corps of Engineers®

ERDC

CIRP

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

FY23 was Year 3 of 3

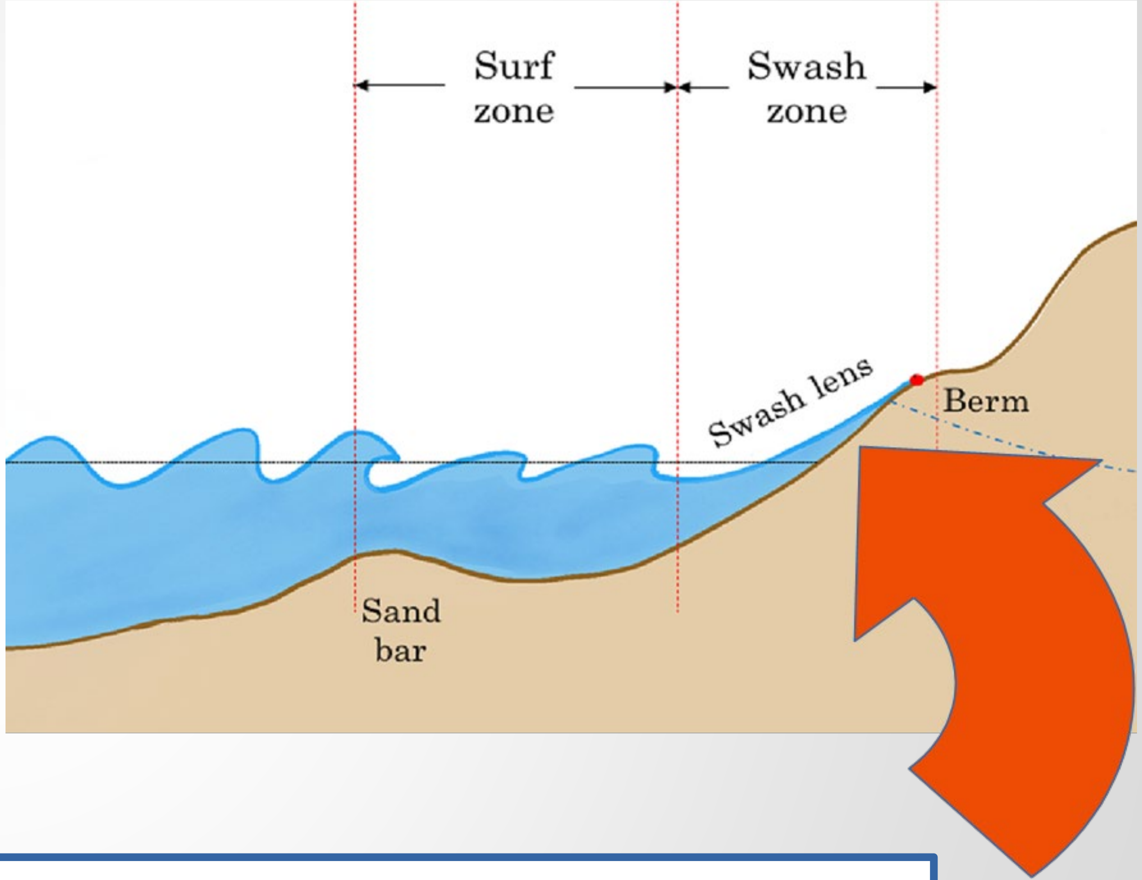
Year over year advancements to date: 1 TD, 1 TR (in review), 2 conference presentations (ASBPA, ICCE)

CAPABILITY AND STRATEGIC IMPACT

ERDC

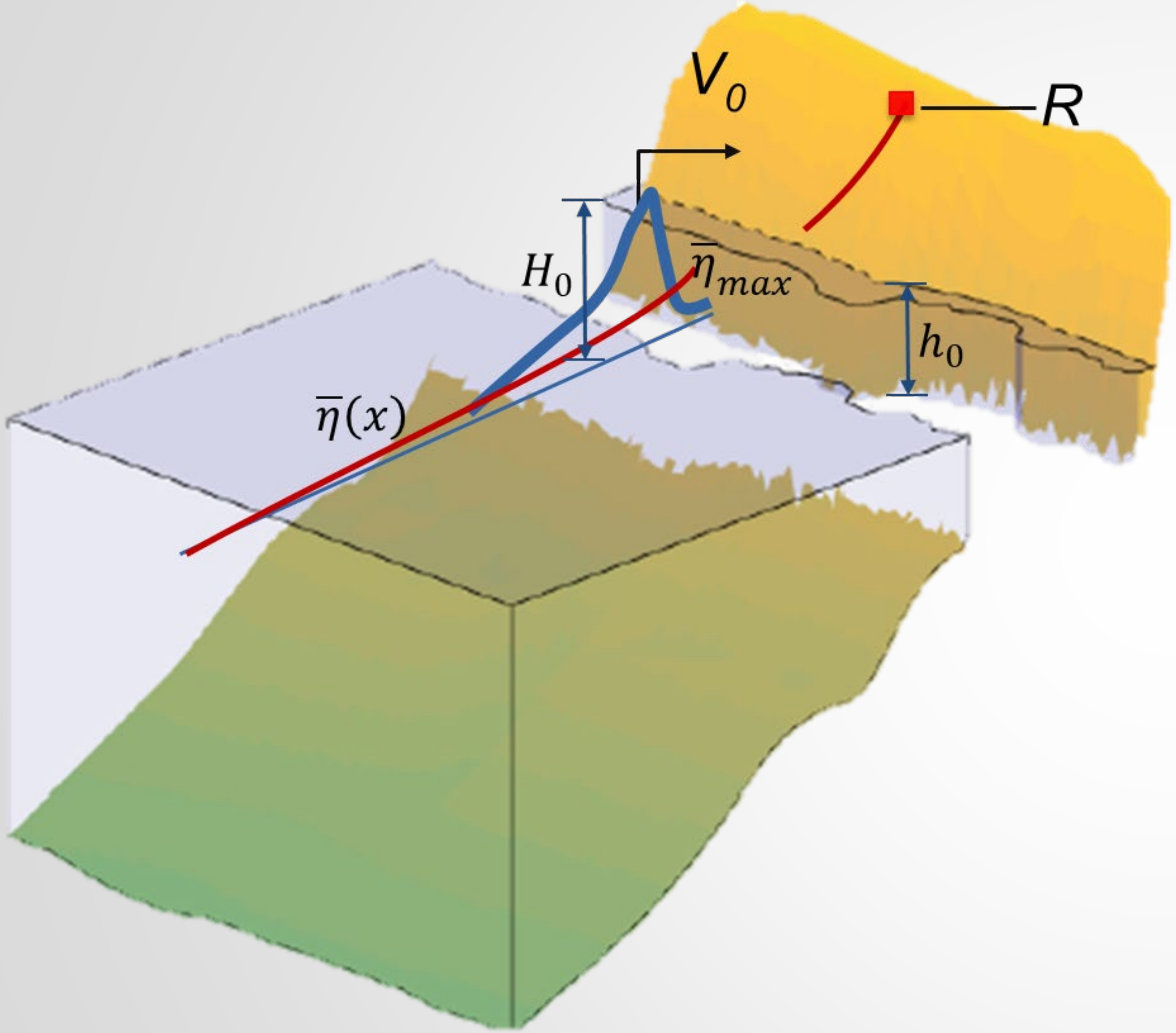
- Improved nearshore sediment transport for prediction of beneficial use, channel infilling, etc.

- New effort to properly include NNBF in both wave and circulation models.
- Consistent formulation permits prediction of benefit of dissipation elements (SAV, oyster, mangrove, etc.)



- New capability to model runup provides risk assessment, dune evolution; informs aeolian model coupling

RUNUP



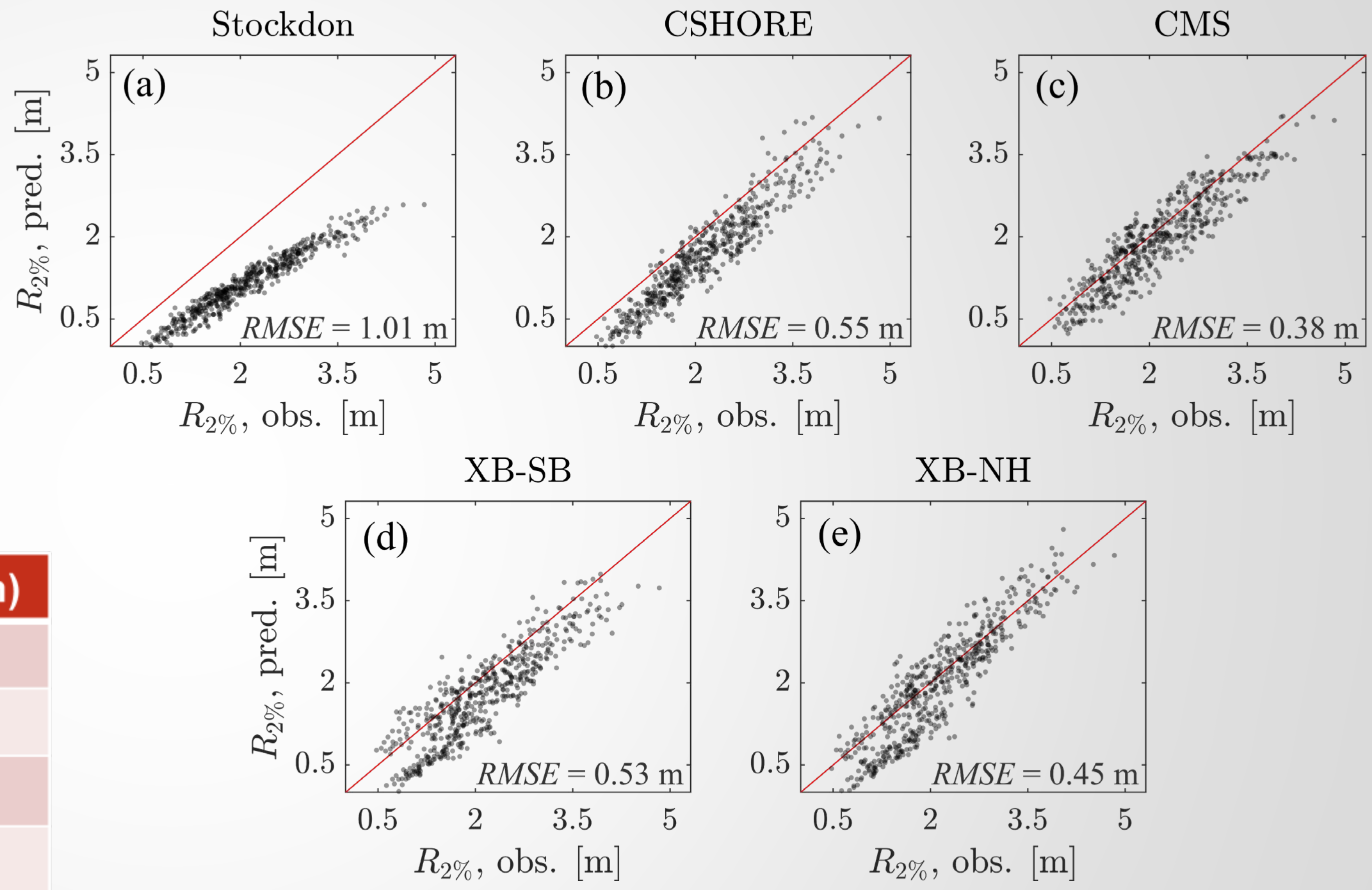
- Separate nearshore and swash domain, solve separately
  - Distinctly different WSL slopes indicate differing physics
  - Demarcation at point of max setup (not constant depth*)

- Swash solution governed by:
  - Simplistic momentum flux balance, closed with empirical parameter A_0 (= $R/2h_0$)
  - Bernoulli's velocity "head", Newtonian ballistics ($R = V_0^2/2g$)
  - Shallow water theory ($V_0^2 \sim gh_0 \sim gH_0$)

- Theoretical $A_0 = 4$, but can be adjusted to account for assumptions

RUNUP (CONT)

- Compare new CMS formulation for $R_{2\%}$ against 4 other models (3 numerical, 1 empirical)
- Validation set includes 533 unique observations of surf zone morphology, offshore wave and WL conditions, and runup statistics



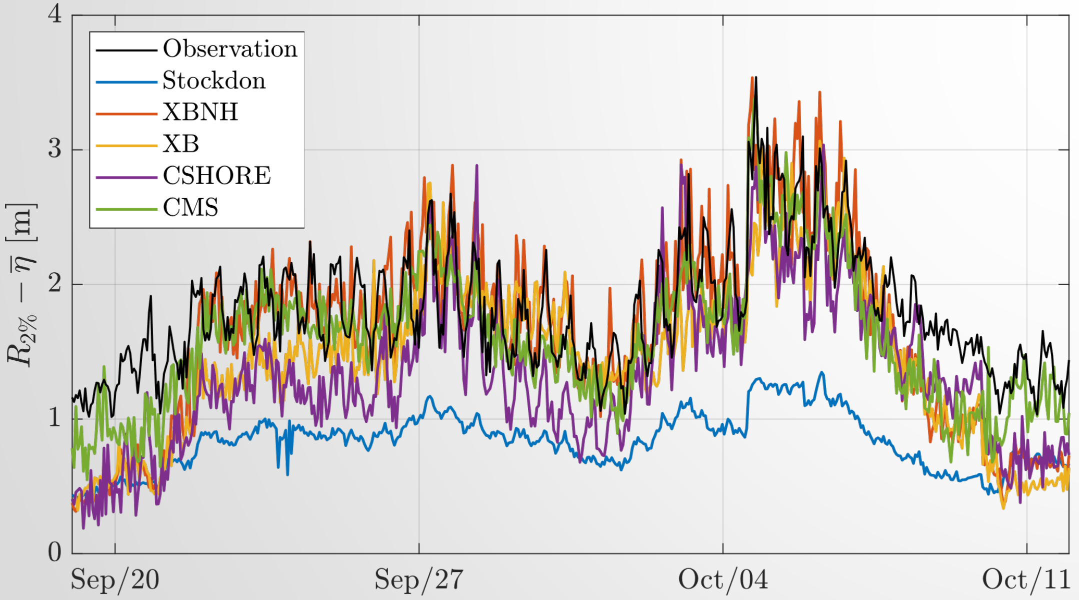
	Runtime	RMSE (m)
Stockdon, et al. (2006)	0.18 s	1.01
CSHORE	25.0 s	0.55
CMS – new $R_{2\%}$ formula	**4.1 min**	**0.38**
XBeach-Surfbeat	35.5 hr	0.53
XBeach-Nonhydrostatic	124.4 hr	0.45

RUNUP – KEY FINDINGS

ERDC

- Shoreface geometry/surf similarity parameter alone insufficient to capture observed tidal-scale variability in $R_{2\%}$
- Numerical models are needed to predict dynamic wave transformation over bar to the edge of the swash zone

Correlation (R^2) between $R_{2\%}$ and: Ib = 0.39, $H(x = x_b)^*$ = 0.53, $h(x = x_b)$ = 0.81, $H(x = 504m)$ = 0.90*



- New (rapid) CMS $R_{2\%}$ formulation is a valuable, critical step forward to predicting surf- and swash zone morphodynamics
- CMS wave heights comparable to or better than XBNH and XBSB in nearshore, but
- In swash zone, CMS wave heights *worse* than all numerical models tested; indicates A_0 is significantly tuning in addition to simply "closing" solution

		CSHORE	**CMS**	XBNH	XBSB
x = 403 m	RMSE [m]	0.17	0.13	0.31	0.43
	B [m]	-0.08	0.09	0.21	0.33
x = 453 m	RMSE [m]	0.15	0.24	0.3	0.54
	B [m]	0.13	0.22	0.23	0.45
x = 463 m	RMSE [m]	0.13	0.25	0.37	0.58
	B [m]	0.06	0.19	0.28	0.48
x = 494 m	RMSE [m]	0.2	0.17	0.23	0.25
	B [m]	-0.16	-0.09	0.12	0.13
x = 504 m	RMSE [m]	0.29	0.33	0.21	0.15
	B [m]	-0.26	-0.29	0.07	-0.07

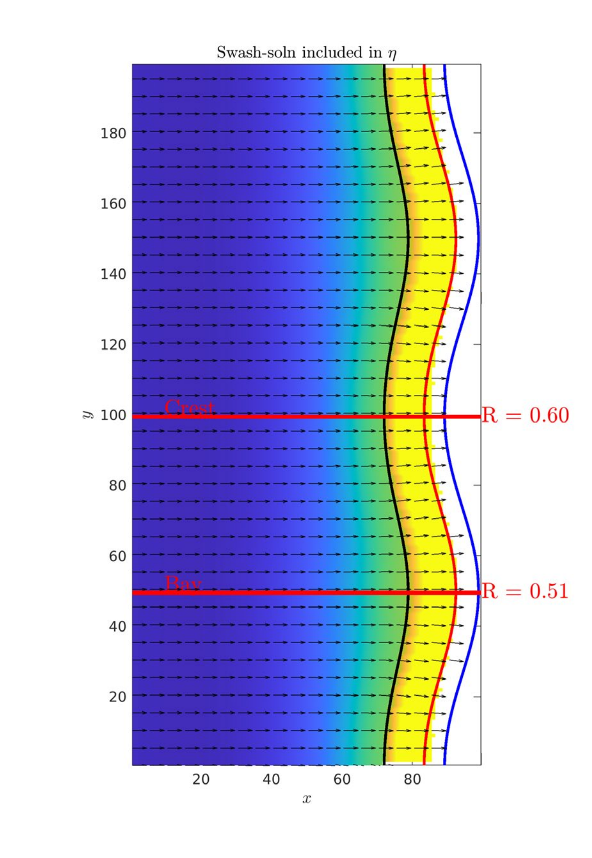
RUNUP – 2DH MILESTONE

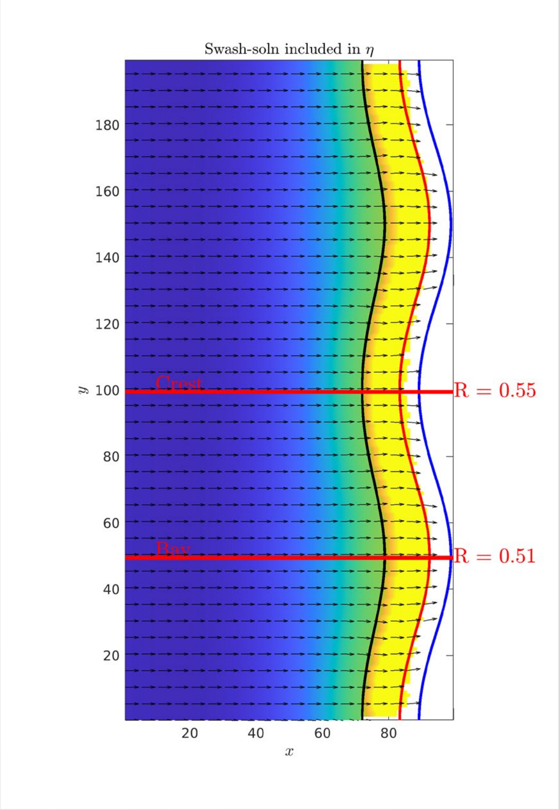
ERDC

1D longshore-uniform computations
- Demonstrates proper slope-dependence
- Doesn't include realistic momentum veering where velocities SHOULD veer away from crest

$$\frac{\partial h}{\partial x} = \frac{-\left\{\frac{\partial z_b}{\partial x} + c_f\right\}}{2A_0} - \frac{h}{2}\frac{\partial \alpha}{\partial y}\frac{\Delta y}{\Delta x}$$

CMS-2D swash
- Now include veering and momentum focus/defocus
- Runup reduced at ridges
- Formulation now requires predictor-corrector scheme
- Localized nature of CMS presents a challenge
- Data is required to verify simple formulation, but processing is challenging



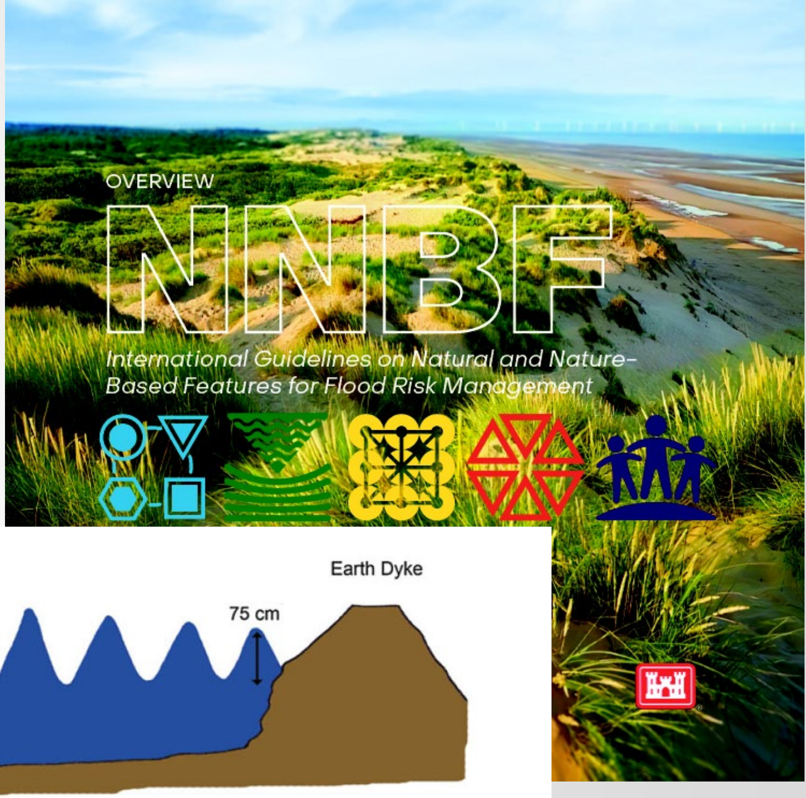


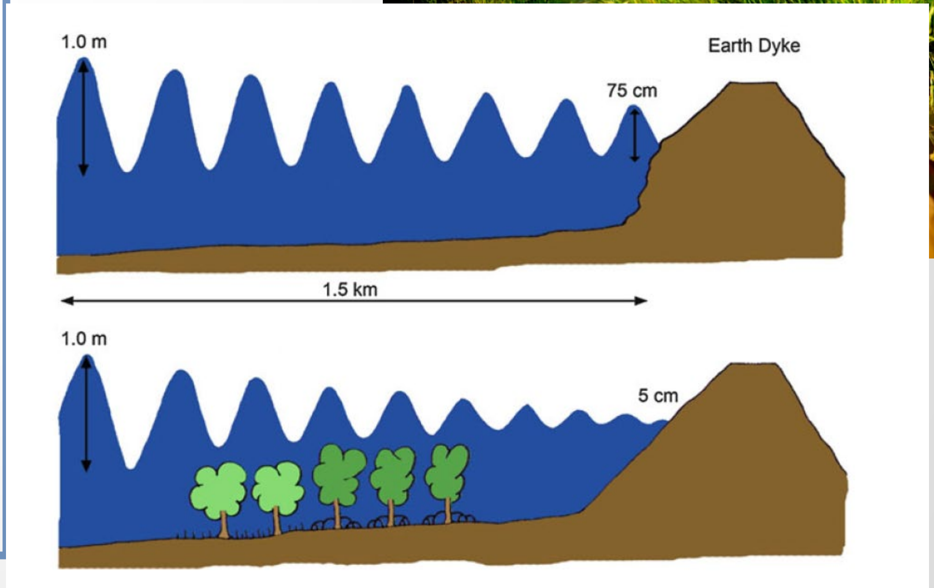
HAZARD REDUCTION by NNBF

- Recent emphasis on EWN and NNBF
- Fringing vegetation, such as mangrove stands provide a degree of coastal protection
  - ...The global annual avoided damages due to the presence of mangroves have been estimated at USD$65 billion....

But these studies are based on an incomplete view of the hazard and impact of vegetation

- Coastal hazard derives from waves and surge, and frictional dissipation impacts both
- a consistent modeling system includes impact of vegetation in both energy and momentum balances





CONVENTIONAL ENERGY BALANCE

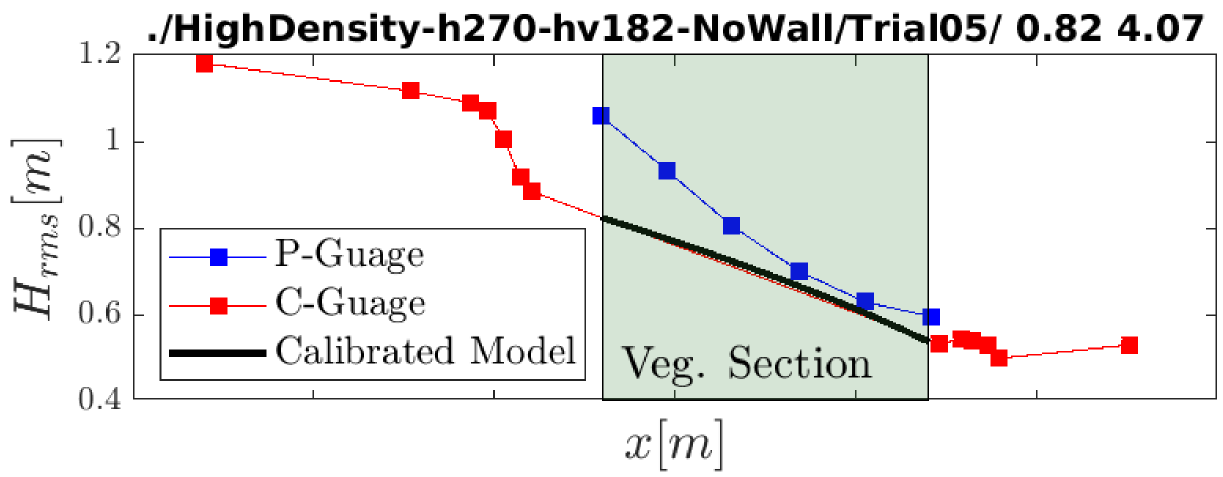
Energy loss in waves with depth- and phase-averaged energy balance

$$\frac{\partial E_f}{\partial x} = -\overline{\tau u} - \overline{\int_{zb}^{\eta} f u dz}$$

f = the incremental fluid force on the vegetation per unit area.

$$f = \rho \frac{C_D}{2} b_v N |u| u = \beta |u| u$$

- New OSU flume data with emphasis on investigating wave decay in artificial mangrove
- Free surface, pressure, velocities
- All of the vegetation unknowns are tailored to match the energy decay, making full use of the measured data



A Consistent Wave/Circulation Application

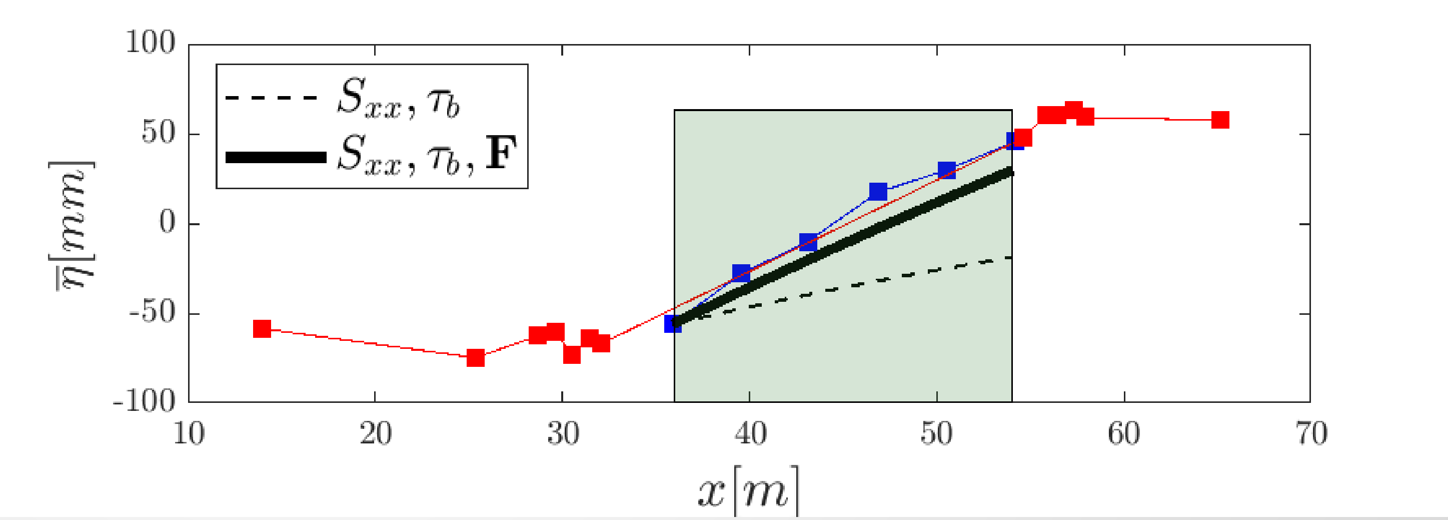
- While waves loose energy (thus providing coastal protection) the vegetation force results in larger free-surface slopes.

Note that we have something useful here:

$$D_v = \overline{\tau_v u} = \beta h \overline{|u|^3} \rightarrow \tau_v = \beta h \overline{|u| u}$$

Now we are well-positioned to examine the consistent momentum balance

$$\rho g \overline{h} \frac{\partial \overline{\eta}}{\partial x} = -\frac{\partial S_{xx}}{\partial x} - \overline{\tau} - \underline{\beta h \overline{|u| u}} \quad \leftarrow \mathbf{F}$$



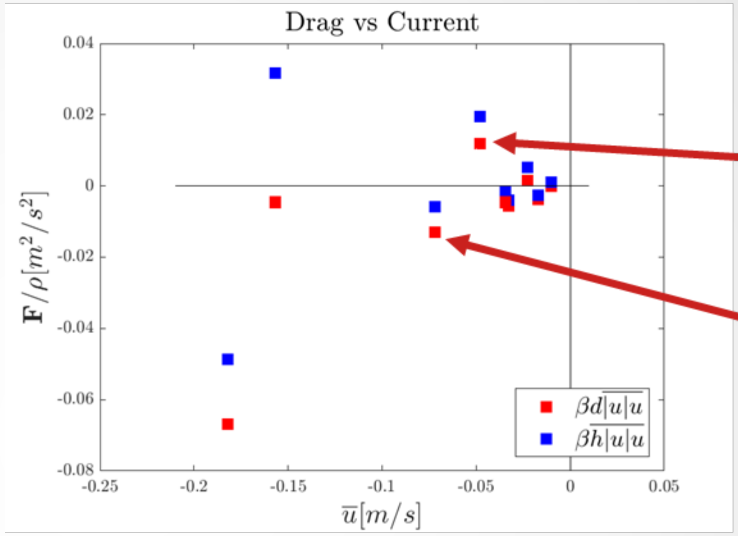
A Consistent Wave/Circulation Application (cont)

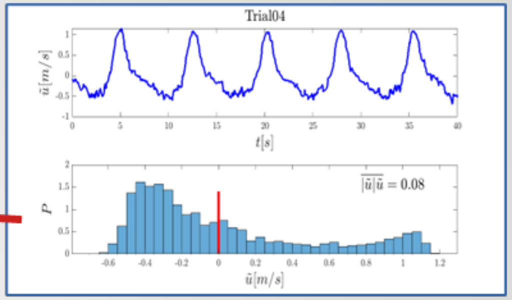
ERDC

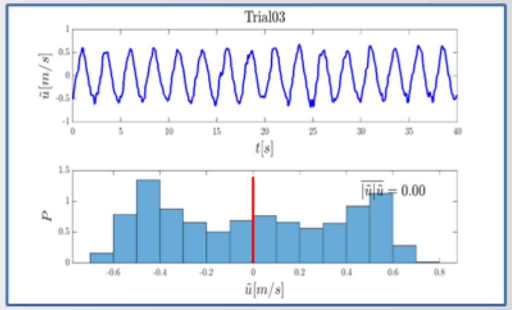
What contributes to non-zero $\mathbf{F}$?

- Non-zero current $\overline{u} \neq 0$
- Departure from symmetric u (skew) $\mathbf{F} \propto Sk$
- Impact of emergent vegetation: $f_{crest} > f_{trough}$, $\mathbf{F} = \overline{f} > 0$

	Setup $\overline{\eta}$
Current $\overline{u}$ $\Uparrow$	$\Downarrow$
Skewness $\Uparrow$	$\Downarrow$
Free-Surface Variation $\Uparrow$	$\Downarrow$







Based on steady mean water depth

Based on fluctuating water depth

This demonstration uses measured data and does not reflect the real fight! The real battle is formulating the methods to predict currents, skewness, free-surface effect. Inclusion in CMS is then relatively simple.

SUMMARY

FY23 Major Advancements in Capability

- Improved CMS-flow stability with corrected boundary pressure formulation
- Completed runup extension
- Initial testing of 2DH runup
- Initiated comprehensive effort to include impact of friction elements into CMS

FY23 Major Products & Collaborations

- New code version
- TR on runup (in review)
- 2-3 TD's on swash, setup in high-friction environments

FY24 Products & Advancements

- Two Related New Starts for SoN-N-1970:
  - Explore swash morphology change
  - Develop multi-scale modeling approach as a means to provide process-based closures in phase-averaged models could include