Modeling Total Water Levels on the Wave-Dominated US West Coast

David Honegger

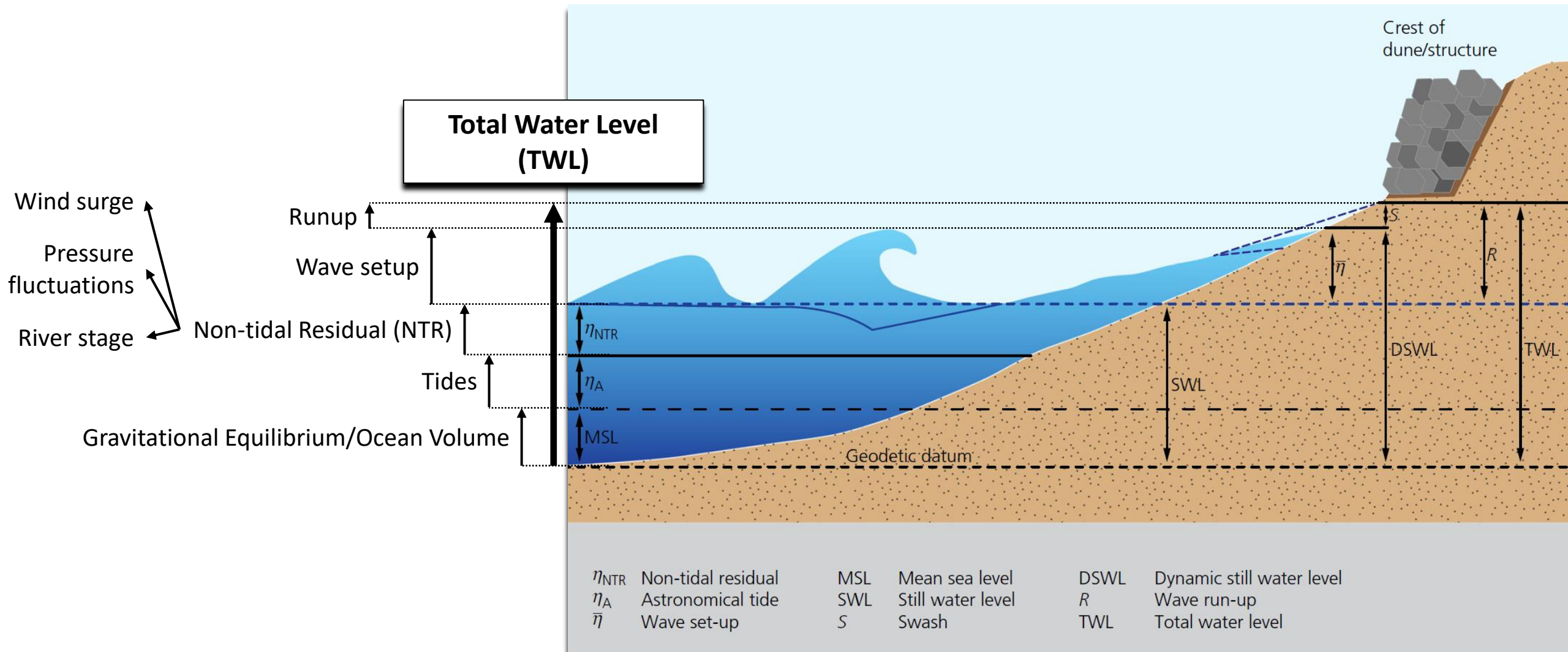**Carter Howe**

Dave Hill

Merrick Haller

Carson Williams
Peter Ruggiero
Jay Merrill
Randy Pittman
Jeff Wood
Margaret Conley
George Waldbusser
Marlena Penn
Jim Lerczak
Brett Hembrough
Bryson Robertson
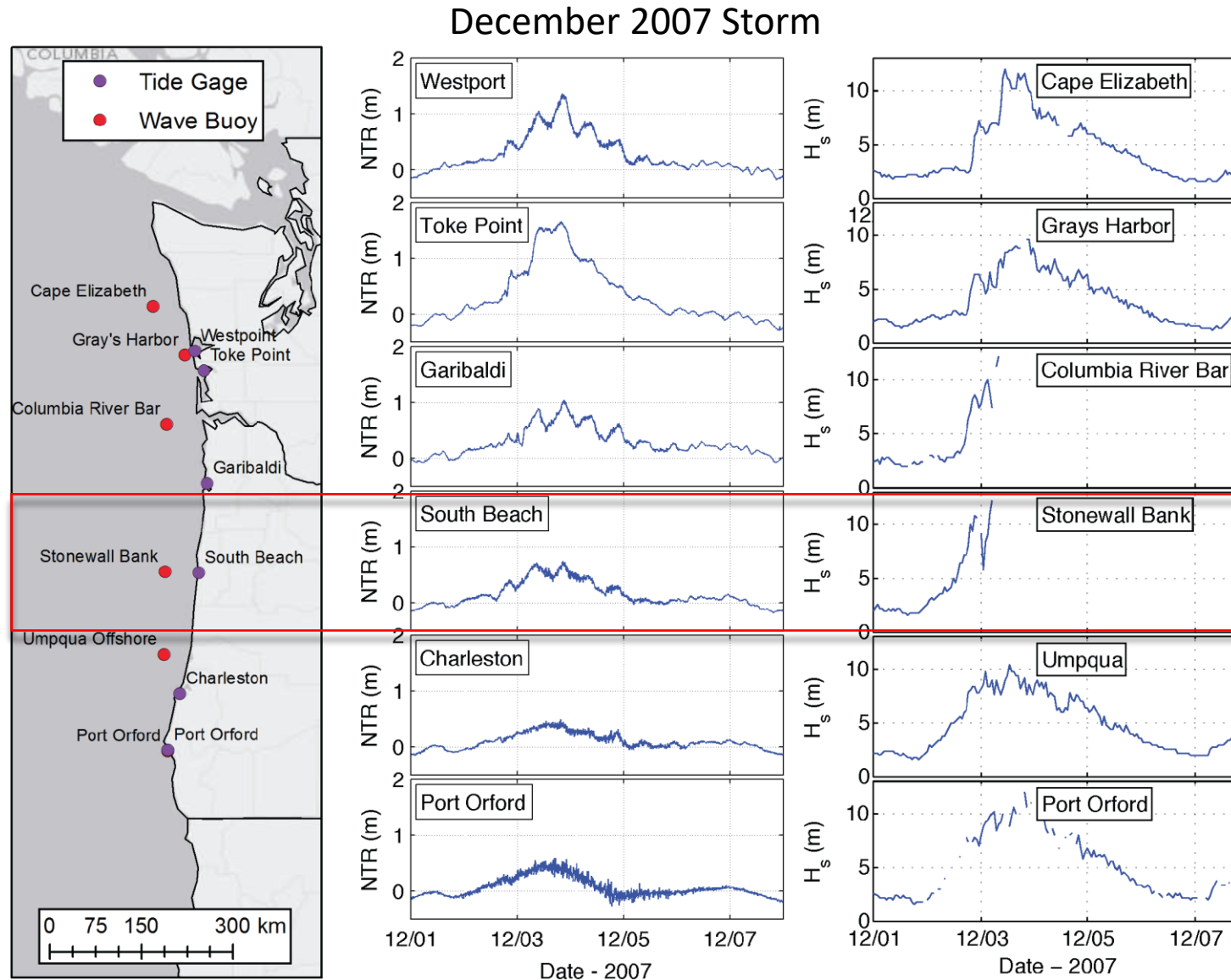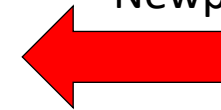Chris Massey
Ali Abdolali
Ty Hesser
Mary Bryant

04 October 2023

3rd International Workshop on Waves, Storm Surges, and Coastal Hazards

University of Notre Dame

Oregon State University

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Total Water Levels

Crest of dune/structure

Total Water Level (TWL)

Wind surge

Pressure fluctuations

River stage

Runup

Wave setup

Non-tidal Residual (NTR)

Tides

Gravitational Equilibrium/Ocean Volume

η_{NTR}

η_A

MSL

$\bar{\eta}$

S

R

SWL

DSWL

TWL

Geodetic datum

η_{NTR}	Non-tidal residual	MSL	Mean sea level	DSWL	Dynamic still water level
η_A	Astronomical tide	SWL	Still water level	R	Wave run-up
$\bar{\eta}$	Wave set-up	S	Swash	TWL	Total water level

Moritz et al., 2016, after Ruggiero et al., 2001

Wave-Dominated West Coast

December 2007 Storm

Offshore of Newport, Oregon

Cheng et al., *JCR*, 2015

Model Development
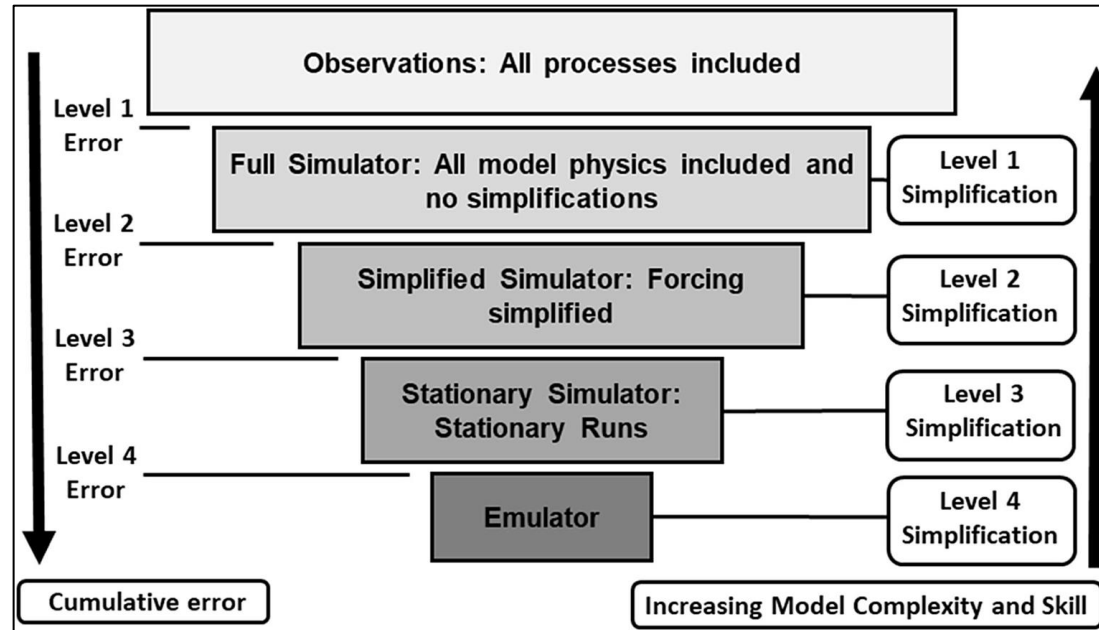
Parker et al., *Coast. Eng.*, 2019
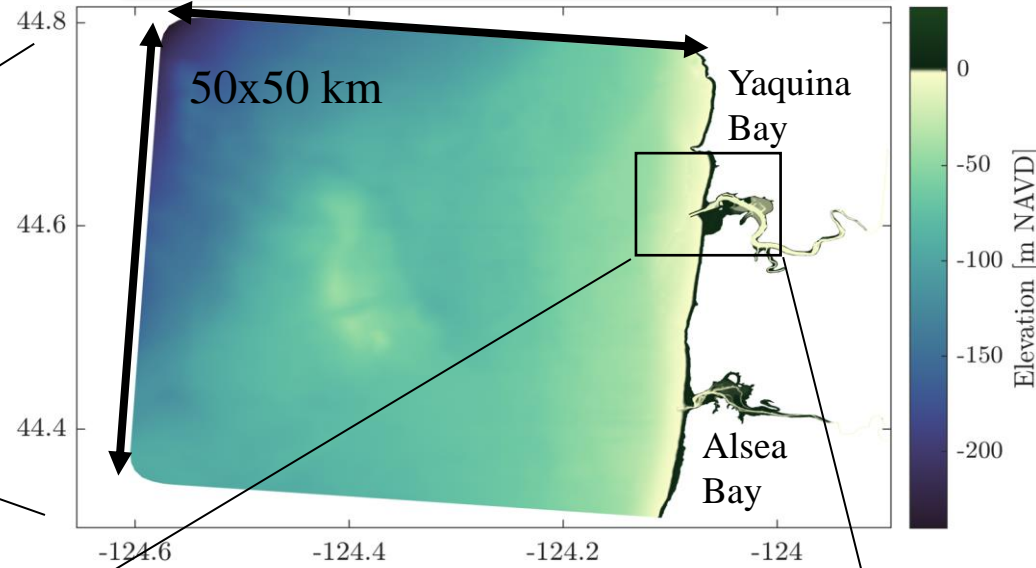
Process-based model
(ADCIRC, WW3, SWAN)

Statistics-based model
(built from high-fidelity simulations)

Well-represented
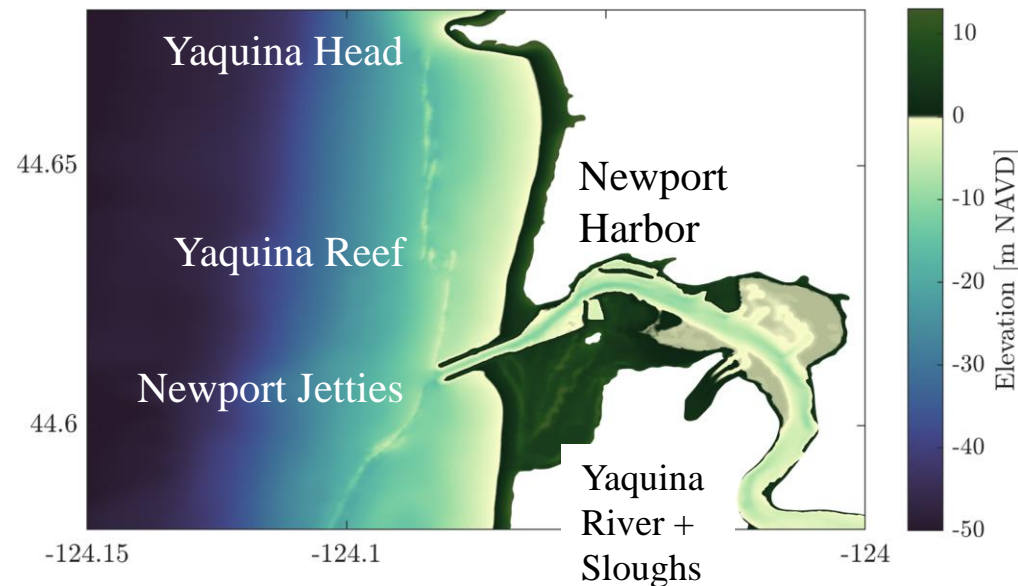physical processes

High-quality
observations

Model Testbed

Build testbed unstructured mesh

50x50 km

Yaquina Bay

Alsea Bay

Yaquina Head

Yaquina Reef

Newport Harbor

Newport Jetties

Yaquina River + Sloughs

Coastline
MHHW+10 m, tapered upriver

Triangular element resolution
1.5 km to 13 m

Bathymetry
Custom updates to
2021 NCEI CUDEM

Model Testbed

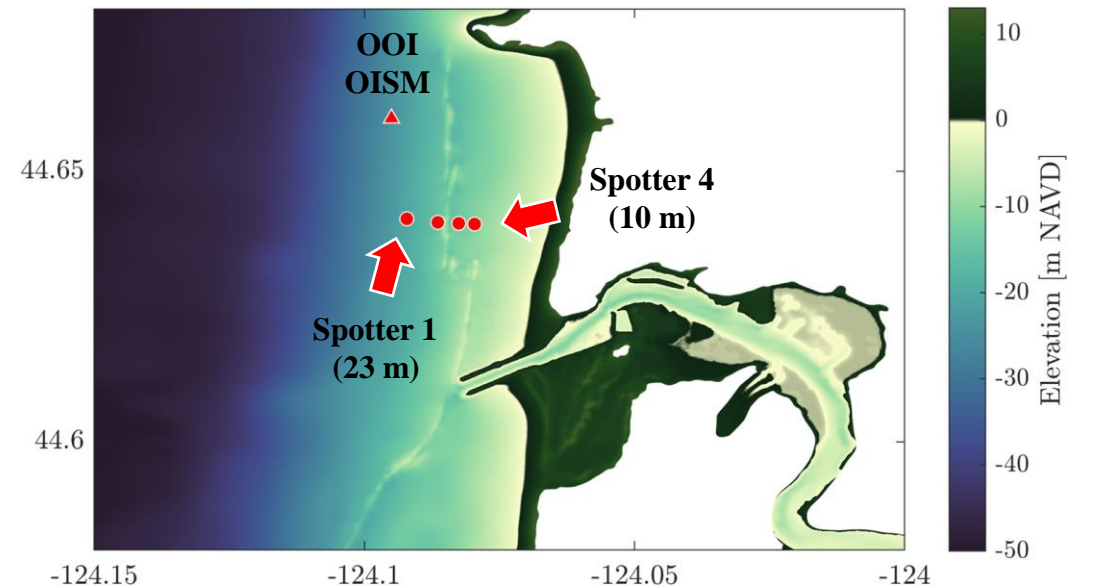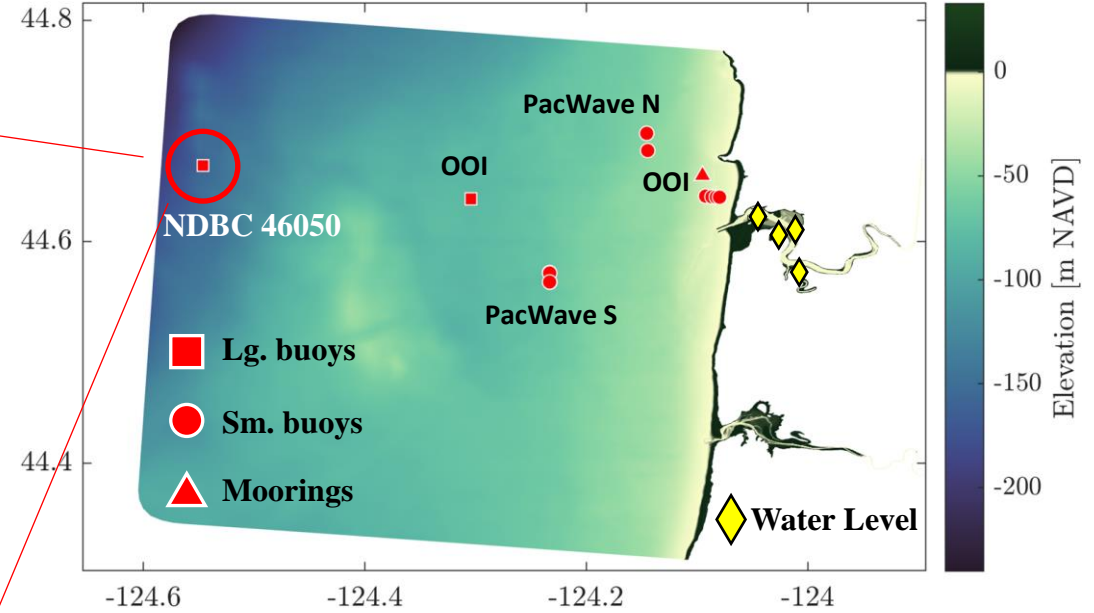**Enable various configurations, forcing**

NDBC, DOE/PNNL
hindcast **waves**

ENPAC15,
TPX09 **tides**

NDBC

USGS gage,
NWM **discharge**

NDBC,ERA5
winds, pressure

USGS gage,
NWM **discharge**

NDBC, DOE/PNNL
hindcast **waves**
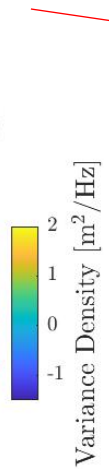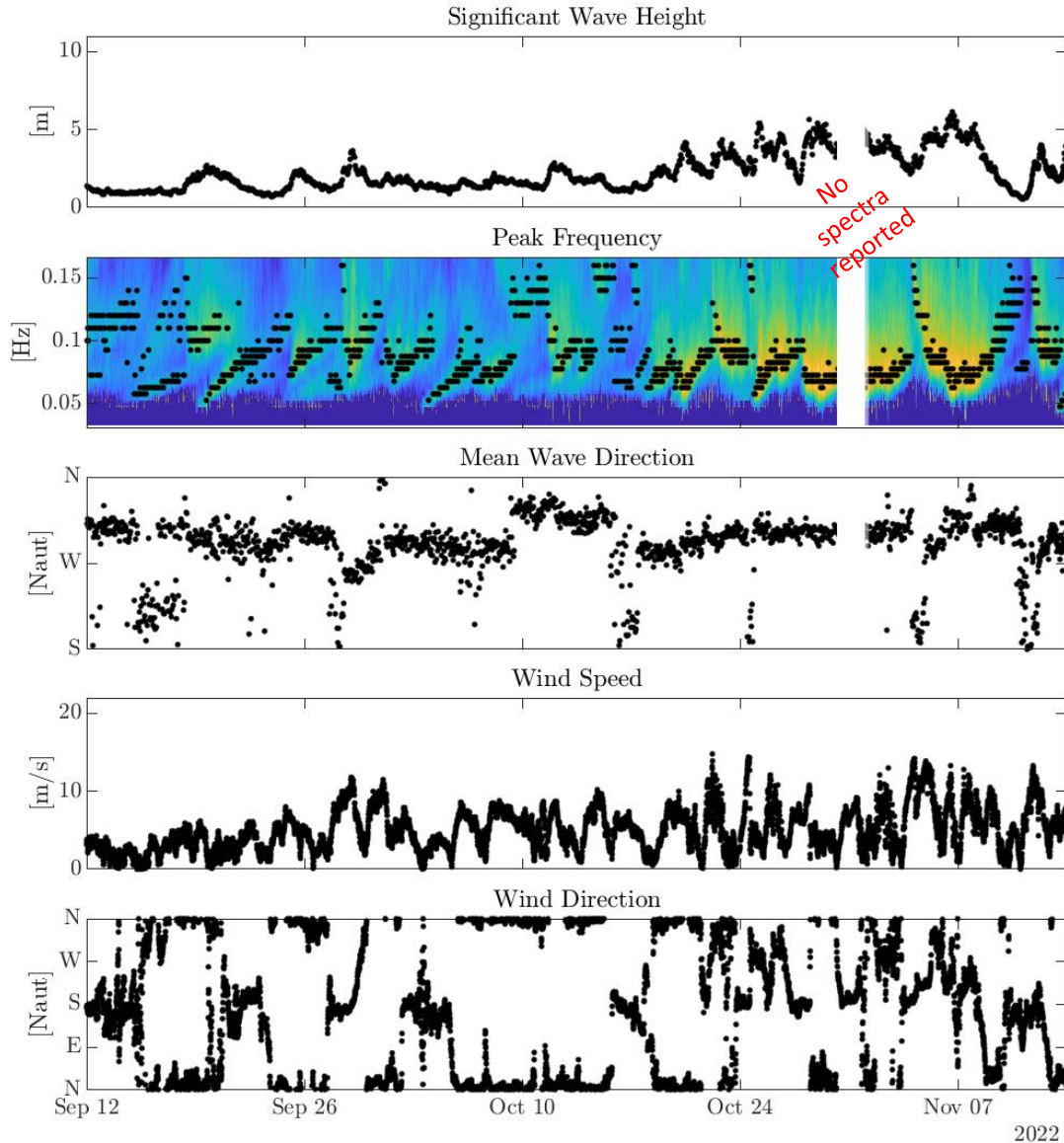
ENPAC15,
TPX09 **tides**
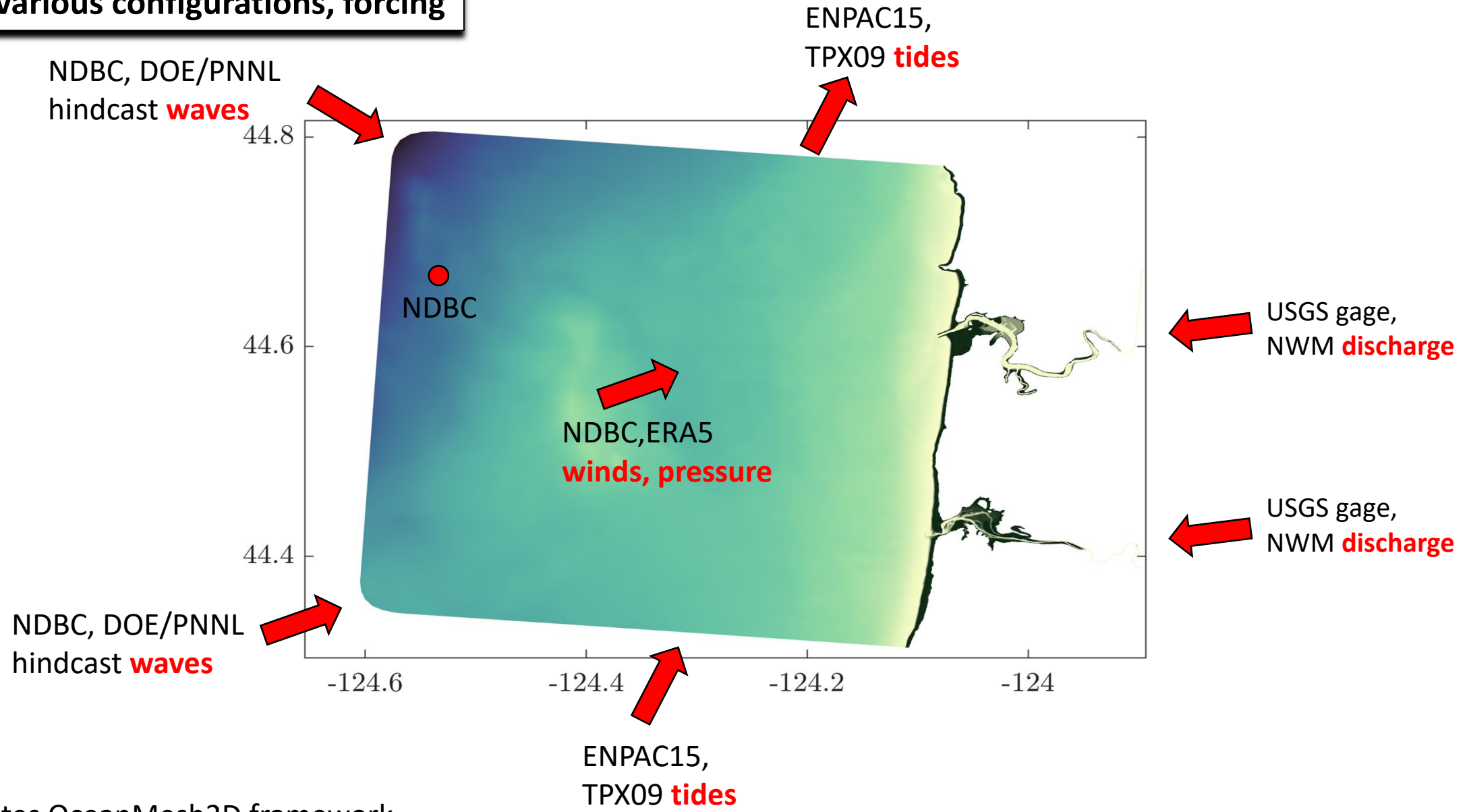
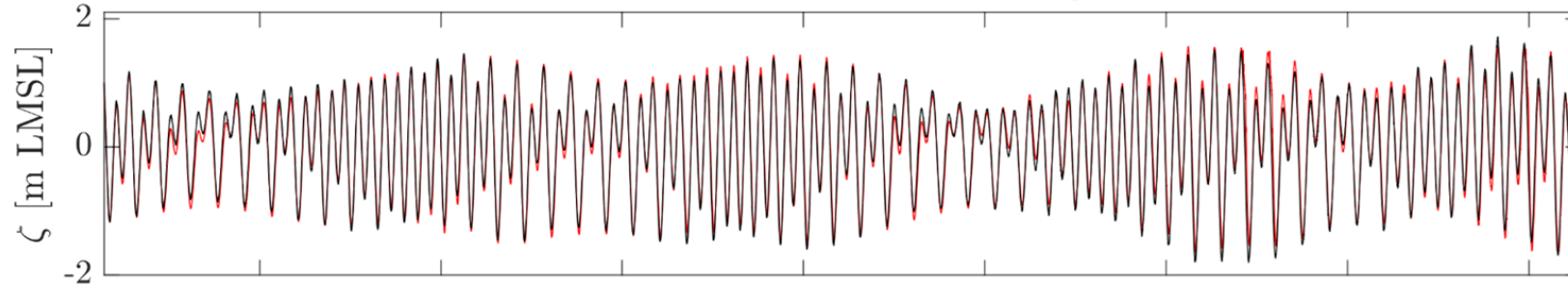Incorporates OceanMesh2D framework

Sample Configurations + Evaluation

Evaluate model performance

Sample Configuration + Evaluation
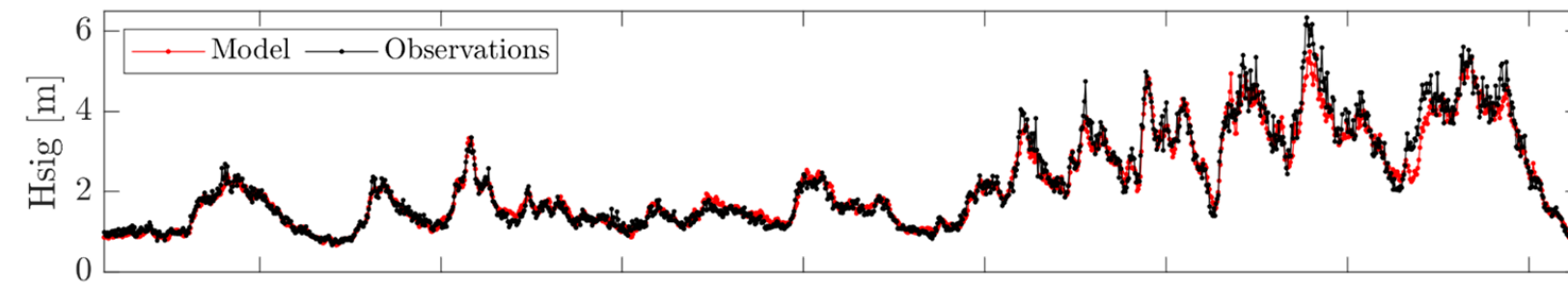
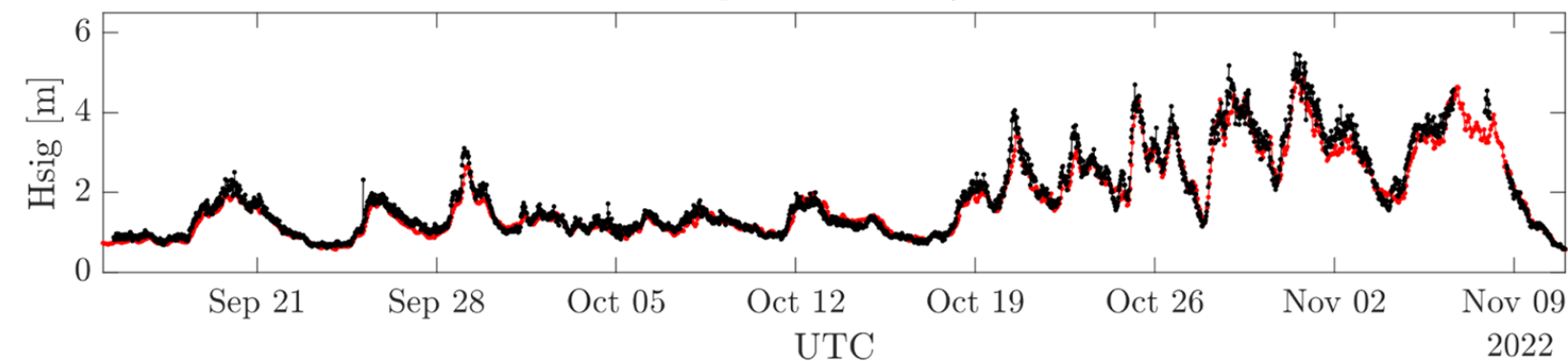Oregon State University
College of Engineering

Configuration
ADCIRC ⇔ SWAN
v55.01

Waves:	NDBC
Tides:	ENPAC15
Discharge:	Gage
Winds:	NDBC

Δt:	1 s
Δt_{SWAN}:	10 min
$\Delta t_{\mathrm{forcing}}$:	1 h

Directions:	36
Frequencies:	35 (0.0325 − 0.83 Hz)

Sample Configuration + Evaluation

Tidal Constituents
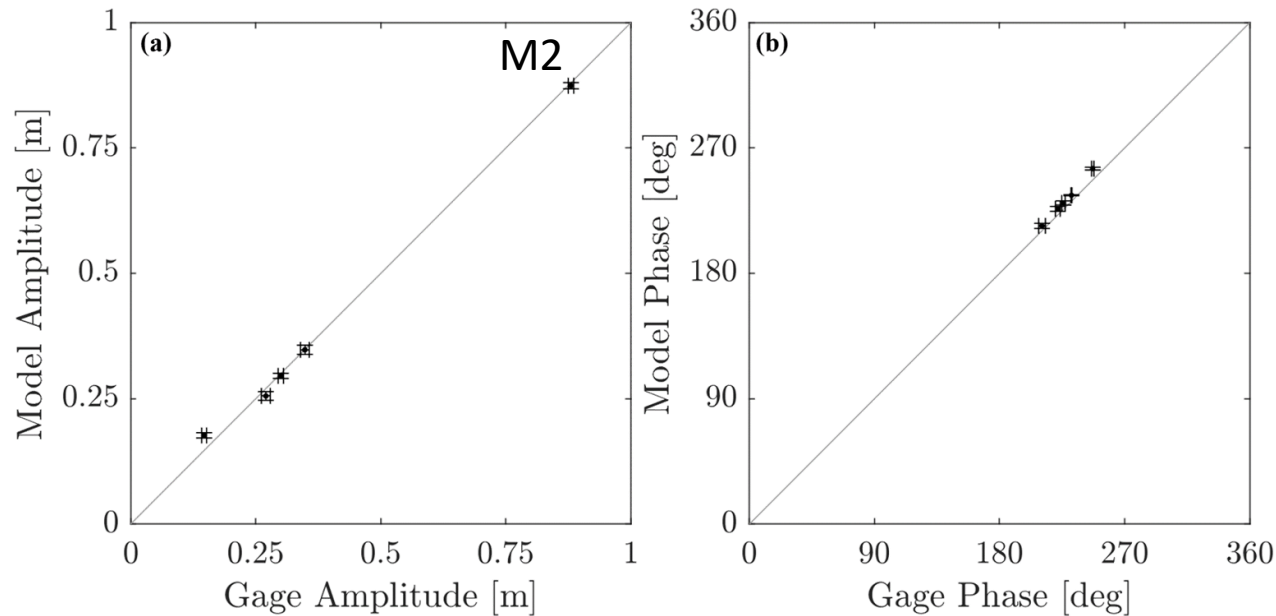
ENPAC15 Performance:
Within 10% amplitude error and within 10 deg phase error
(Szpilka et al., *J. Mar. Sci.*, 2018)

Next: Water levels at **7** additional backbay stations 2021-2024
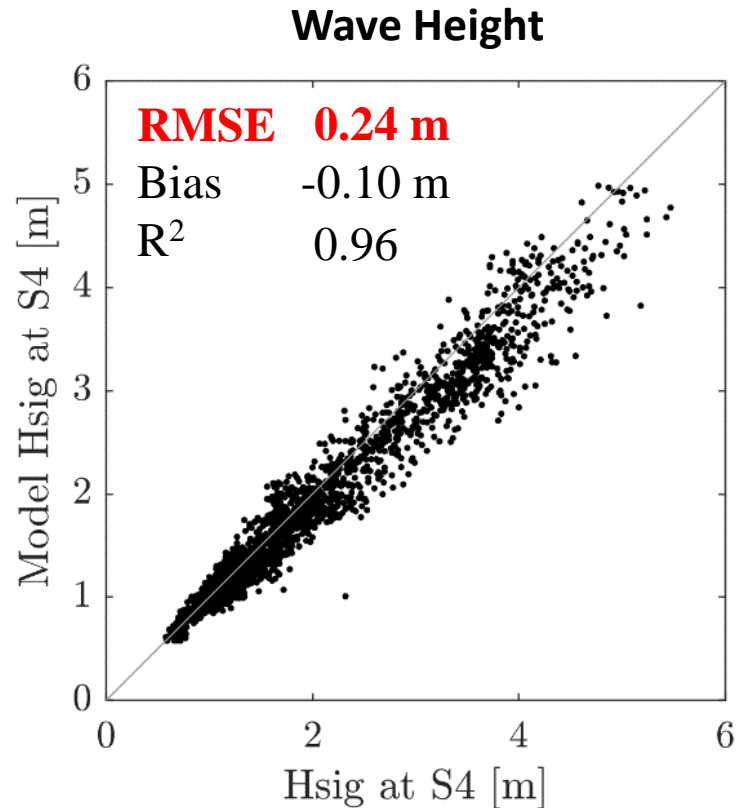
Configuration
ADCIRC ⇔ SWAN
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Sample Configuration + Evaluation

Wave Height

RMSE   0.24 m
Bias   -0.10 m
R^2 0.96

Model Hsig at S4 [m] (y-axis)
Hsig at S4 [m] (x-axis)

Configuration
ADCIRC ⇔ SWAN
v55.01

Waves:	NDBC
Tides:	ENPAC15
Discharge:	Gage
Winds:	NDBC

Δt:	1 s
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Directions:	36
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Nested multi-grid model performance

RMSE 0.27 m (Garcia-Medina et al., *WAF*, 2014)
RMSE 0.32 m (O'Dea et al., *Oc. Eng.*, 2018)

Next: Large storms with updated 25 m waves dataset 2014-2023

WW3 evaluation

Evaluate and exploit WW3 advancements

Shallow water physics
Domain decomposition
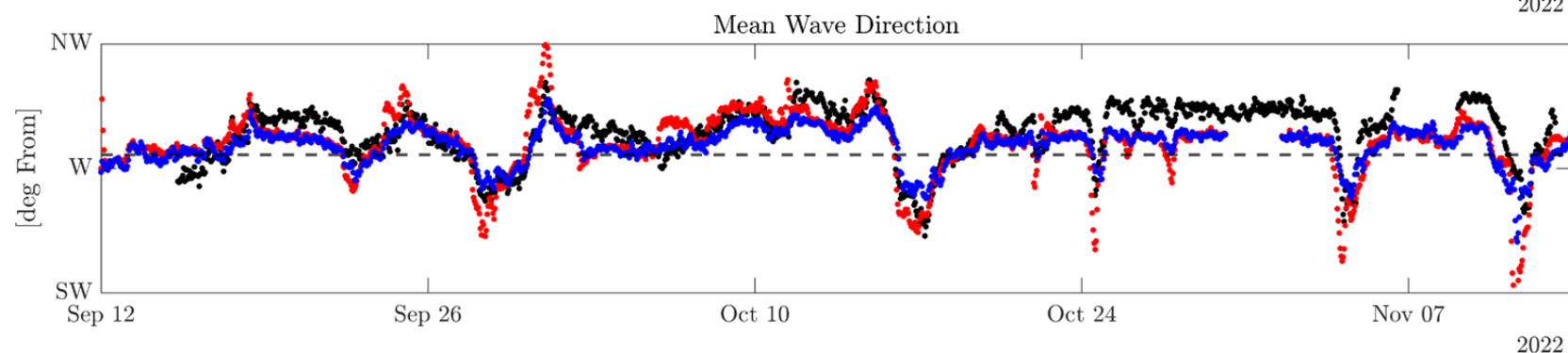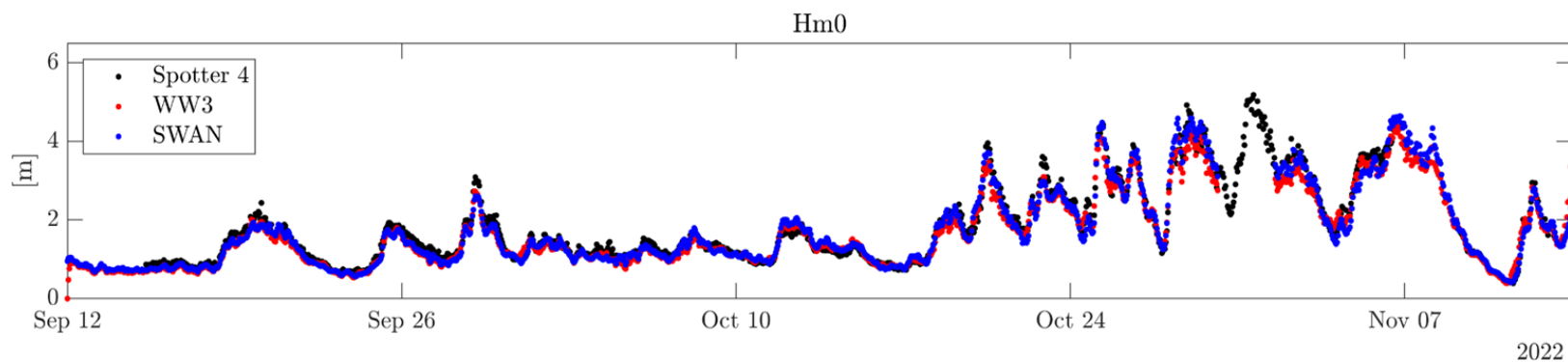ADCIRC coupling
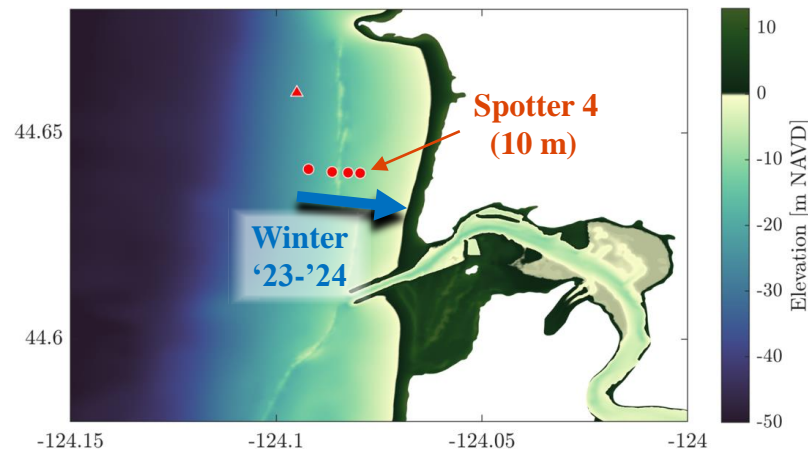
Configurations
SWAN v41.41
WW3 v6.07

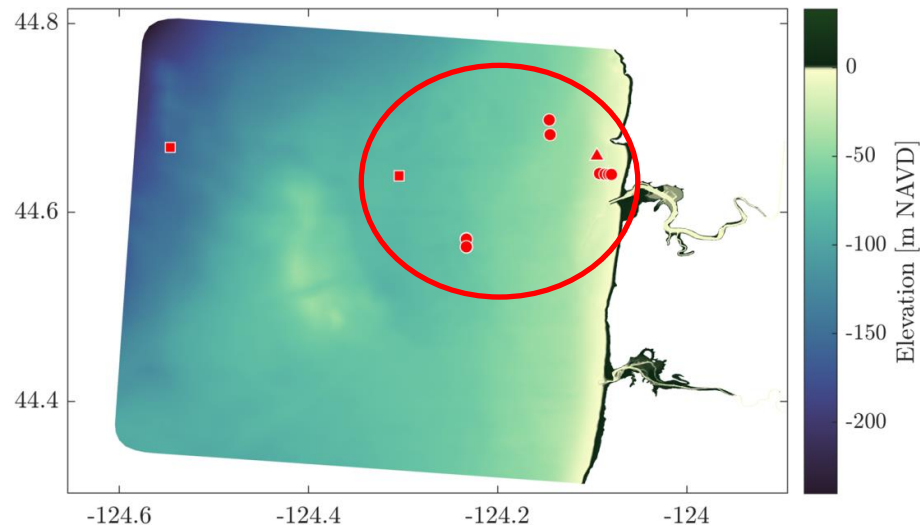Waves: NDBC
Winds: NDBC (ST6)

Δt: 10 min
$\Delta t_{\text{forcing}}$:   1 h
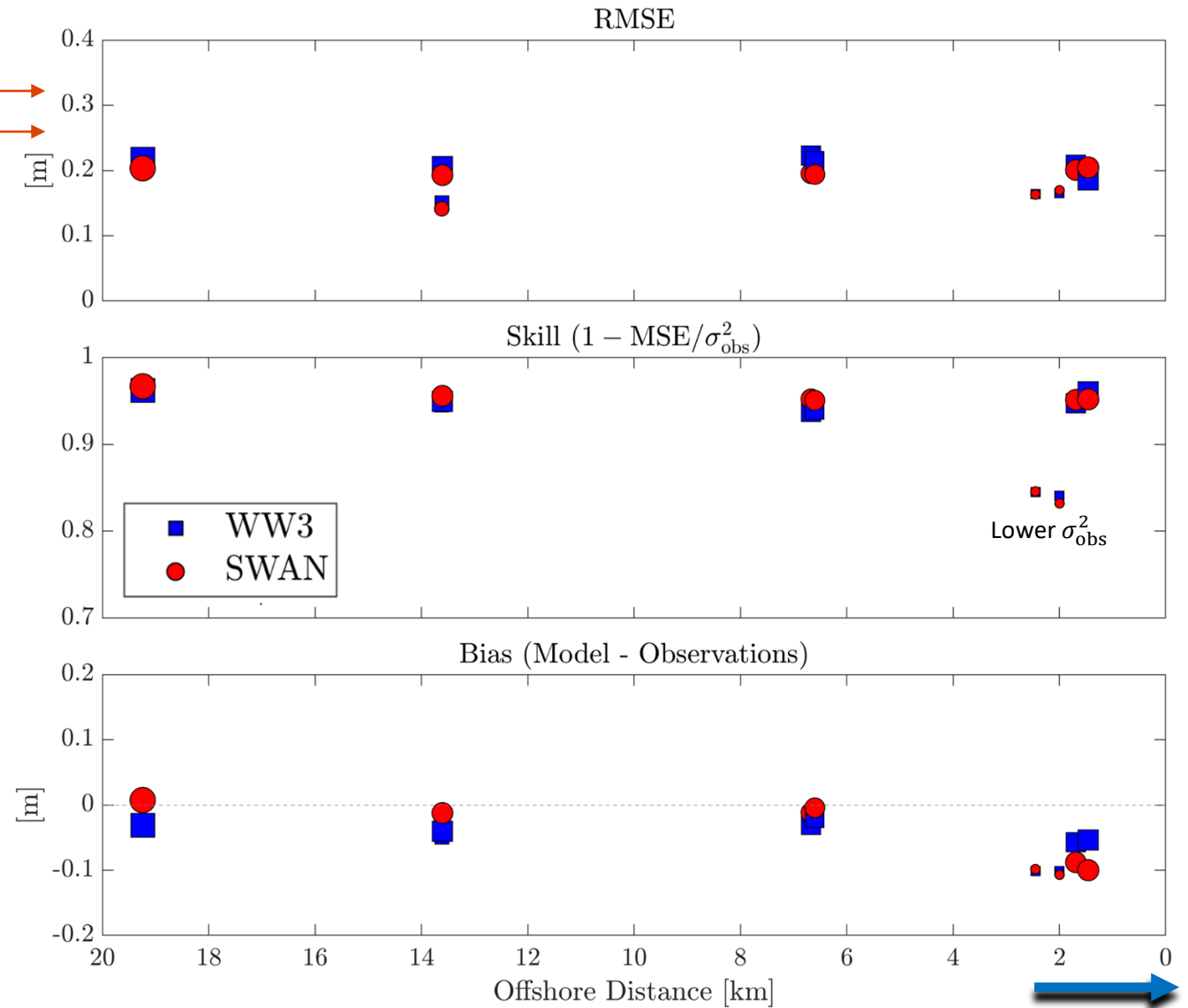
Identical spectral grids,
boundary forcing

WW3 evaluation

O'Dea et al., *Oc. Eng.*, 2018 →

Garcia-Medina et al., *WAF*, 2013 →

Negligible differences

- Δt: 5, 10, 20 min
- ST4, ST6 (defaults)
- Low tide vs high tide
- v6.07, v7.14

Summary

Testbed Development

- High-resolution mesh designed to capture challenging geometries

- Process-based coupled model performing well ➡

- Comparable WW3 ⇔ SWAN performance ➡
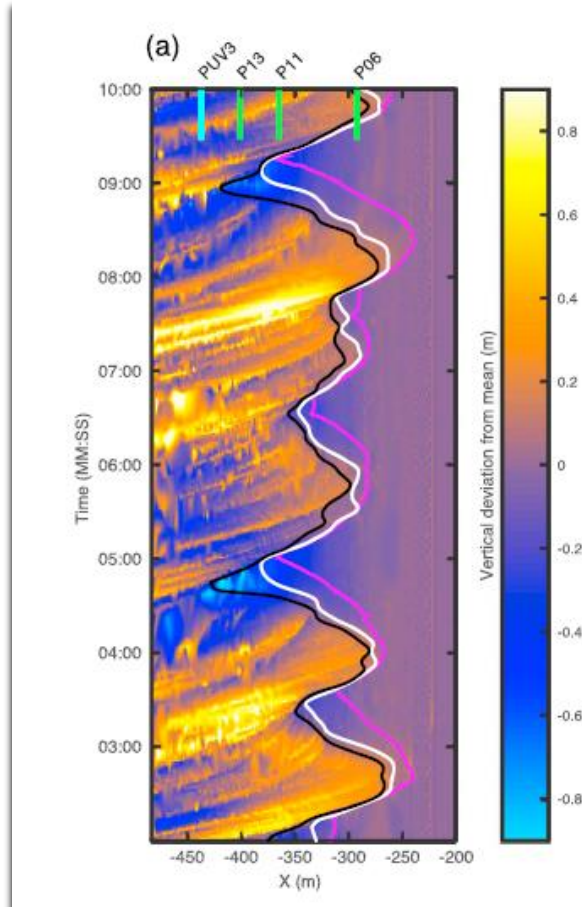
Coming up next ...

- Tougher tests will use "new" evaluation datasets

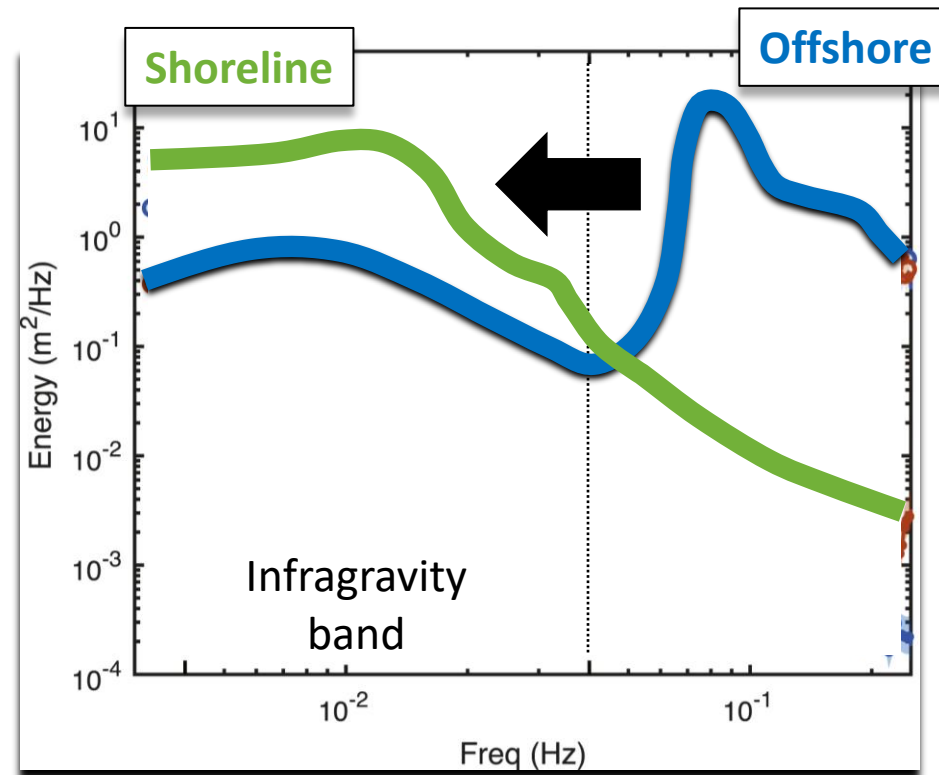- Tougher tests will use nearshore winter wave climate

Also ...

- Train statistical emulator

- Test reduced-physics approach

- Investigate approaches for infragravity processes

Supplementary Slides
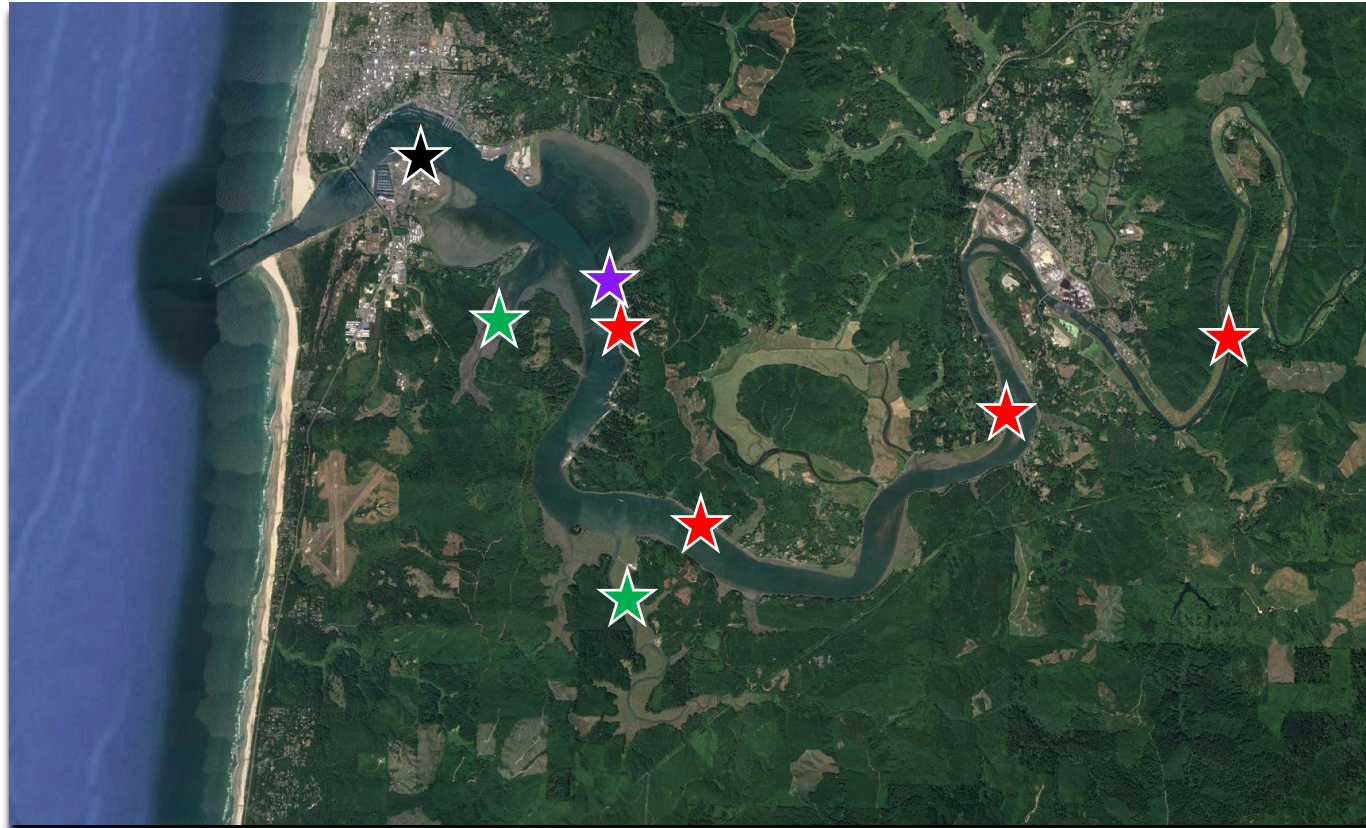
Infragravity energy

Fiedler et al., *GRL*, 2015

Modified after Fiedler et al., *Coast. Eng.*, 2018

Backbay water levels

Evaluate back-bay
water levels

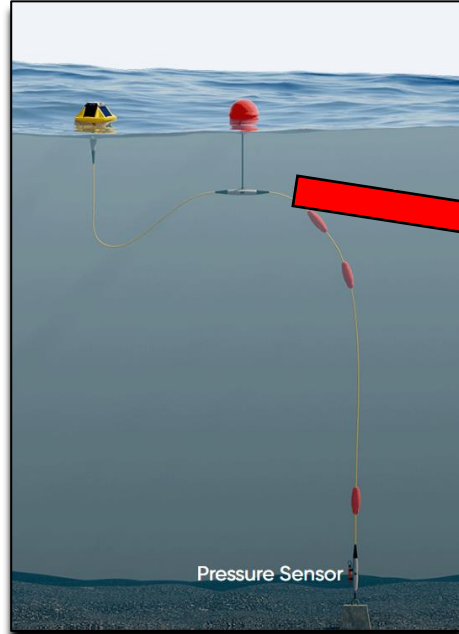Investigate potential
resonance

1967

2021

2021

2023

Jay Merrill
Margaret Conley
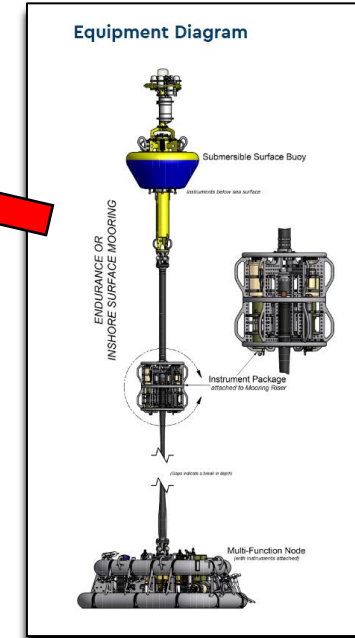Jim Lerczak
Marlena Penn
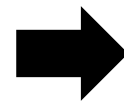George Waldbusser

Cross-platform quality control

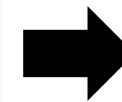**Moored Spotter**

ADCP

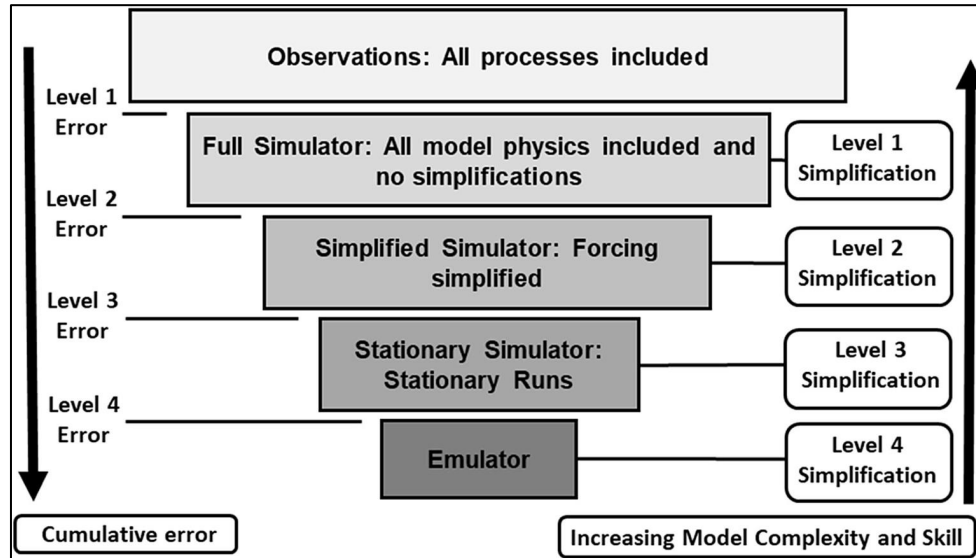Cross-platform QA/QC → H_{m0} RMS Difference **0.42 m → 0.12 m** → Evaluate large storm simulations 2014-2023

Building and testing less expensive options

Build out **storm emulator**
(Carter Howe, Dave Hill, Peter Ruggiero)

Evaluate **SFINCS** application
(Carson Williams, Peter Ruggiero)

Parker et al., *Coast. Eng.*, 2019

Leijnse et al., *Coast. Eng.*, 2021