USCRP

US COASTAL RESEARCH PROGRAM

Decadal Visioning Workshop 2024

THE FUTURE OF COASTAL PROCESSES RESEARCH

USCRP
US COASTAL RESEARCH PROGRAM

JUNE 11 – JUNE 13
Hilton St. Petersburg Bayfront – 333 1st Street, SE

Decadal Visioning Workshop

THE FUTURE OF COASTAL PROCESSES RESEARCH

2024

Examples of Applied Research Opportunities to Implement Solutions

Examples of Applied Research Opportunities to Implement Solutions

Session Objective: Give examples of applied research to spur thinking in breakouts.

PRESENTERS

- **Meg Palmsten**, Research Oceanographer, U.S. Geological Survey
- **Greg Dusek**, Senior Scientist, National Oceanographic and Atmospheric Administration
- **Kate Brodie**, Senior Research Oceanographer, U.S. Army Corps of Engineers

Meg Palmsten

Research Oceanographer, U.S. Geological Survey

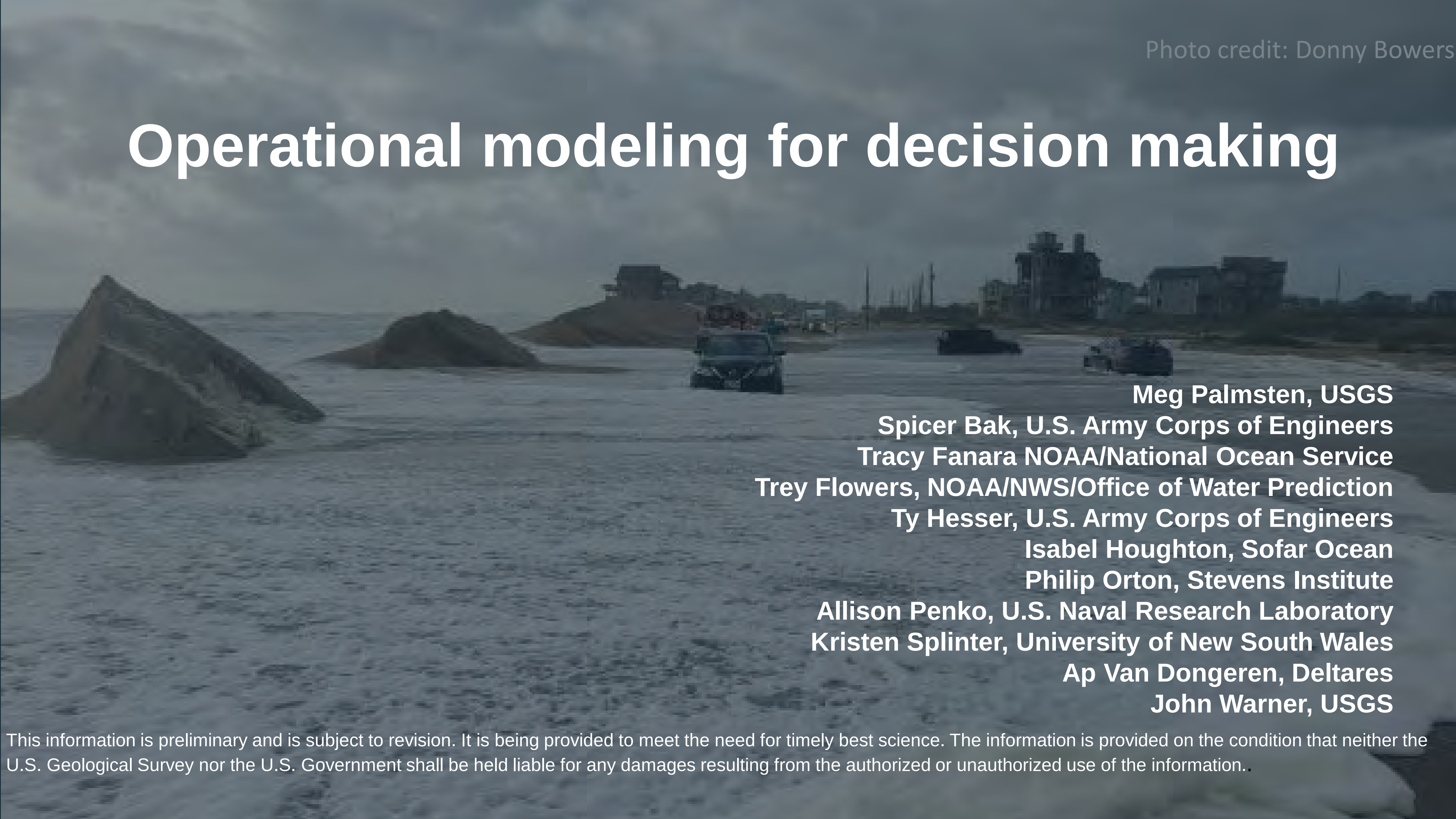


Photo credit: Donny Bowers

Operational modeling for decision making

Meg Palmsten, USGS
Spicer Bak, U.S. Army Corps of Engineers
Tracy Fanara NOAA/National Ocean Service
Trey Flowers, NOAA/NWS/Office of Water Prediction
Ty Hesser, U.S. Army Corps of Engineers
Isabel Houghton, Sofar Ocean
Philip Orton, Stevens Institute
Allison Penko, U.S. Naval Research Laboratory
Kristen Splinter, University of New South Wales
Ap Van Dongeren, Deltares
John Warner, USGS

Defining operational modeling

- Fast models at high resolution and short timescales
- Wave propagation and compound flooding
- Morphologic evolution and sediment transport
- Urban environment and human infrastructure
- Human and ecosystem health and safety
- Data assimilation
- Uncertainty
- Communication with stakeholders

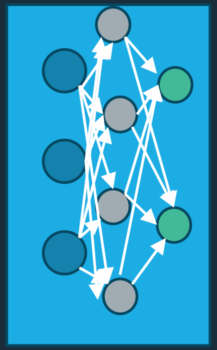
"coastal resilience…requires development of real time predictive models…"
Elko et al. 2015

Significant advancements: technology

Model coupling with open-source code

Computational power – cloud and operational high-performance computing

Improved data and model data access

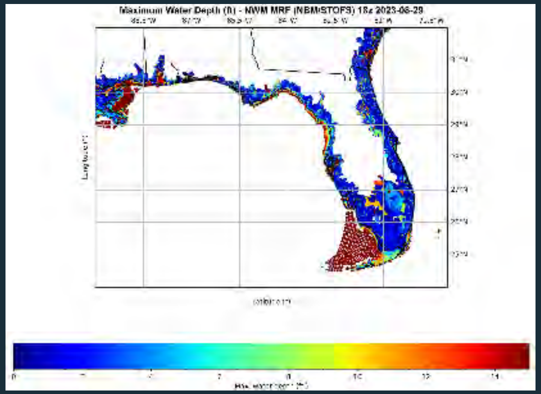


Meta-models and Machine Learning

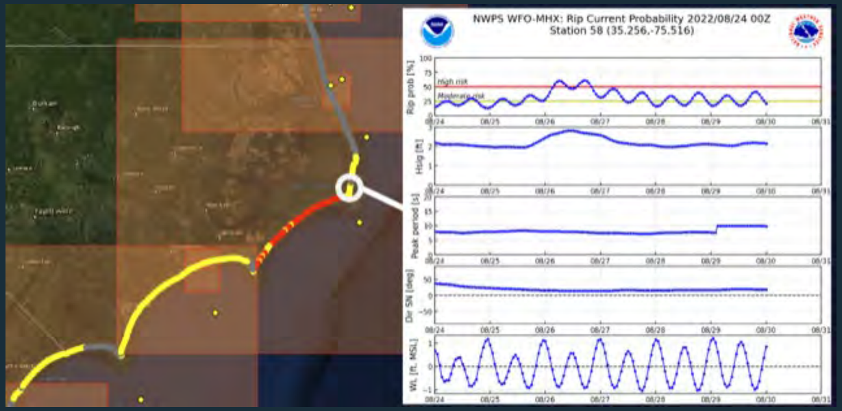
Better boundary conditions and longer lead times

Significant advancements: products

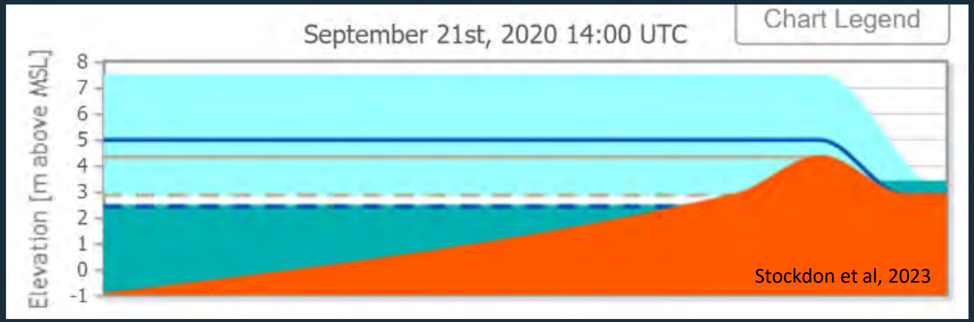
Compound Flooding
(National Water Model)



Rip Currents
(NOAA/Nearshore Wave Prediction System)

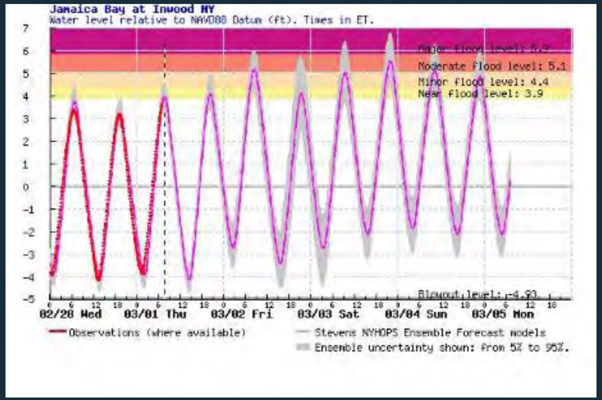


Dune erosion/Total Water Level and Coastal Change
(USGS/Nearshore Wave Prediction System)



Probabilistic information
(USACE Coastal Hazards
Rapid Prediction System)

Ensemble forecasts
(Stevens Ensemble Flood Advisory System)



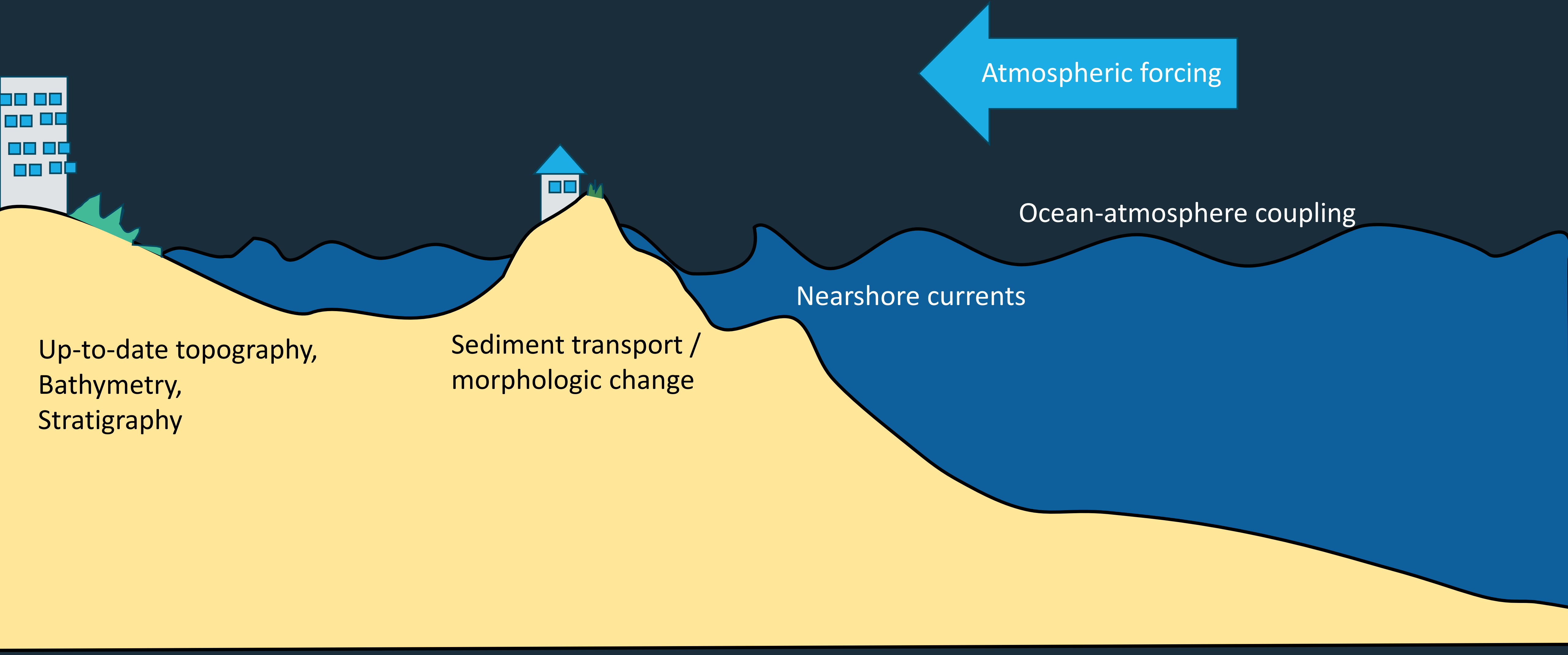
Impact Modeling
(NOPP Hurricane Coastal Impacts
Project/Deltares)

Significant advancements: impacts

After Hurricane Idalia, Gulfport, Florida
Photo credit: Erica Harris

- More information
- More time to react
- Actionable information by including uncertainties

Technical challenges: processes and data

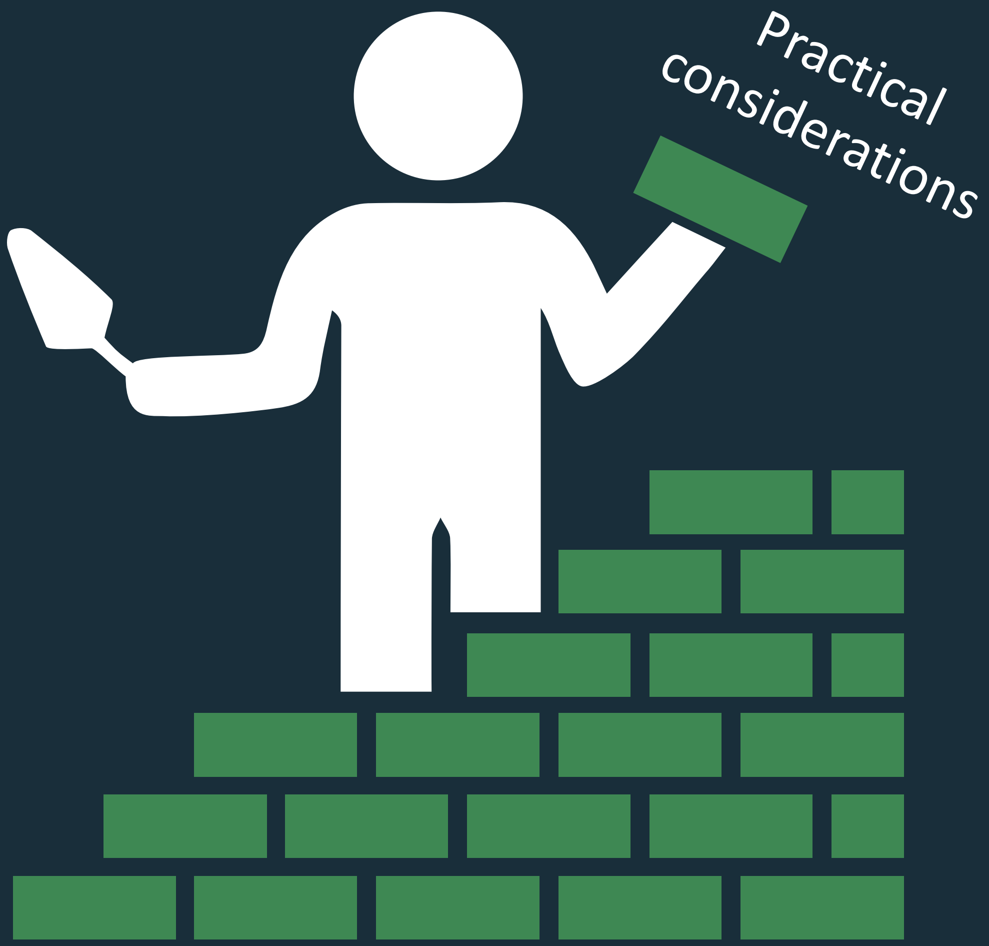


Technical challenges

01
Computational limitations
Runtime limitations
Improving model efficiency

02
Data access
Model data dissemination
Data and quality control in real time

03
Cybersecurity



Non-technical challenges and opportunities: research community

Non-technical challenges and opportunities: communication

- Explain forecast production
- Consider product design
- Convey uncertainty
- Consider language barriers

- Use relevant variables
- Engage with experienced science communicators
- Run mock events

Promising areas

- Data assimilation
- Multi-fidelity models
- Coupled systems
- Observations and data
- Model optimization and computing
- Machine learning
- Communications

What’s missing from nearshore operational models?

- What are the gaps?
- How do we co-develop useful products?
- What are the limitations? (technical and non-technical)

Greg Dusek

Senior Scientist, National Oceanographic and Atmospheric Administration

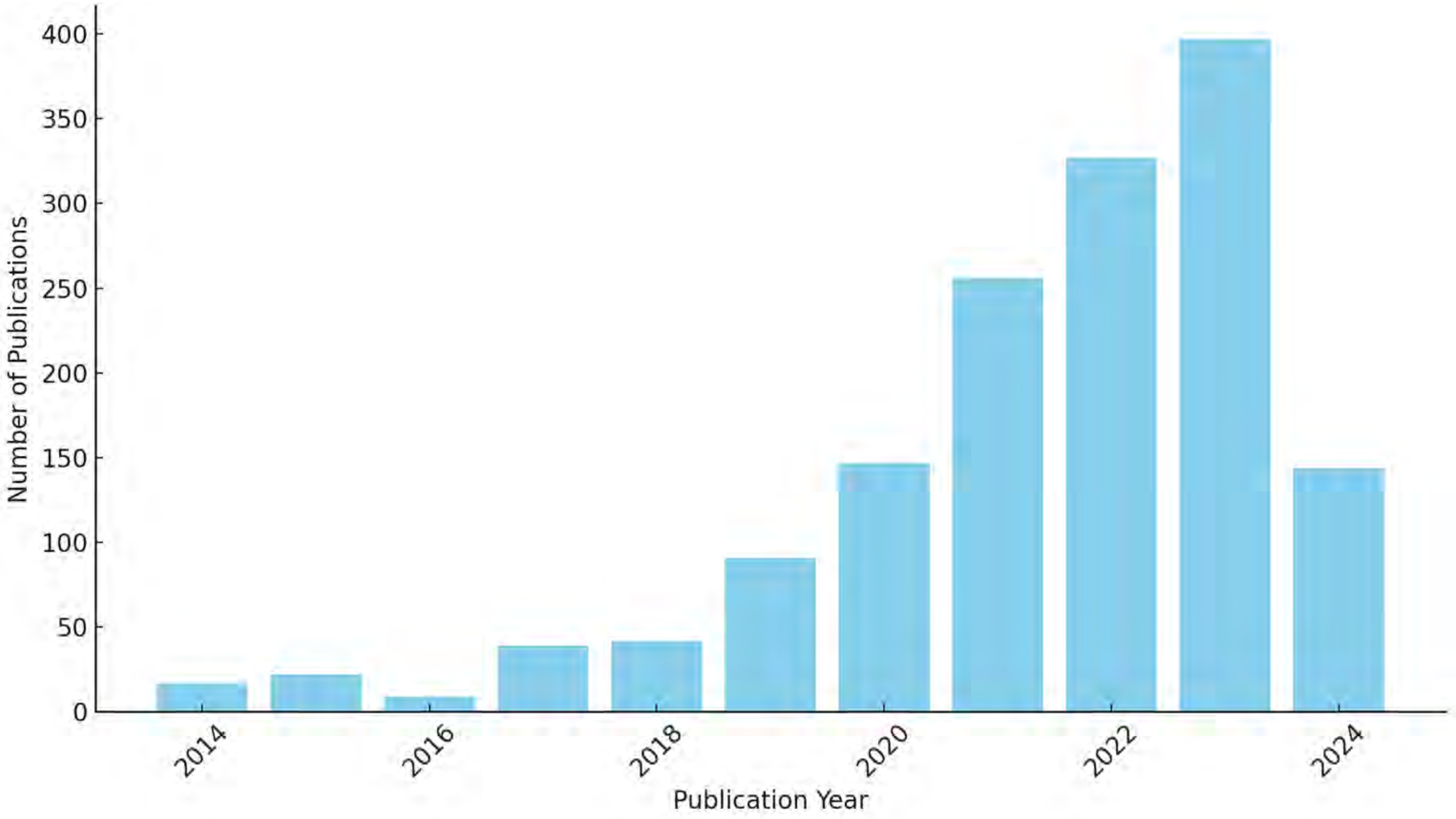
Coastal Applications of Artificial Intelligence

Greg Dusek

Senior Scientist
NOAA National Ocean Service

Applied Research Opportunities to Implement Solutions
2024 USCRP Decadal Visioning Workshop
June 12, 2024

Number of **Machine Learning** + **Coastal** publications per year



Data from Web of Science

November 30th, 2022 **Launch of ChatGPT**

Can you provide one sentence which describes how AI might transform coastal ocean research over the next decade?

AI is poised to revolutionize coastal ocean research over the next decade by enabling more accurate and efficient data collection, enhancing predictive models for climate and environmental changes, and facilitating real-time monitoring and management of marine ecosystems.

November 30th, 2022 **Launch of ChatGPT**

ChatGPT

Gemini

Claude

BY ANTHROPIC

LLaMA by Meta

Grok

What about if you were J.R.R. Tolkien?

In the coming decade, AI, much like a wizard wielding newfound power, shall transform the realm of coastal ocean research, bestowing upon us the ability to gather data with unparalleled precision, forge predictive models as reliable as the ancient tomes, and oversee the stewardship of marine ecosystems with vigilance akin to the watchful eyes of the Great Eagles.

Outline

Recent Federal Government focus on AI

How has AI been applied to coastal sciences?

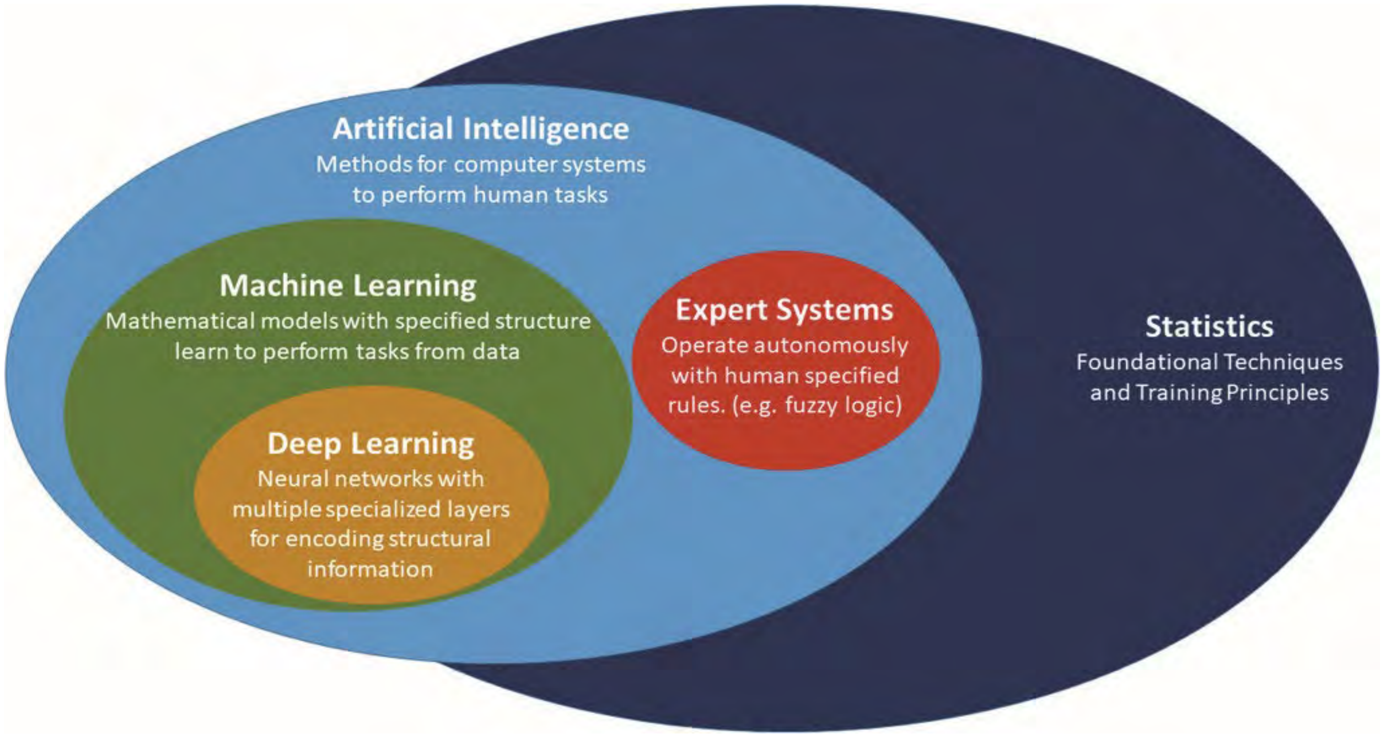
- Computer vision
- Prediction and forecasting
- Data analysis

AI Challenges and Limitations

Where are we headed with AI over the next decade?

What is **artificial intelligence**?

The ability for computational systems to perform tasks that normally require human intelligence



Haupt et al. (2022) The History and Practice of AI in the Environmental Sciences. Bull. Amer. Meteor. Soc., 103, E1351–E1370, https://doi.org/10.1175/BAMS-D-20-0234.1.

THE WHITE HOUSE

OCTOBER 30, 2023

Executive Order on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence

BRIEFING ROOM › PRESIDENTIAL ACTIONS

- National AI Advisory Committee
- Federal Gov AI use case inventory
- 2023 National AI R&D Strategic Plan
- OMB Policy to Advance Governance, Innovation and Risk Management in Federal Agencies’ Use of AI

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

How has AI been applied to coastal sciences?

Some great review articles!

Haupt et al. (2022) The History and Practice of AI in the Environmental Sciences. Bull. Amer. Meteor. Soc., 103, E1351–E1370, https://doi.org/10.1175/BAMS-D-20-0234.1

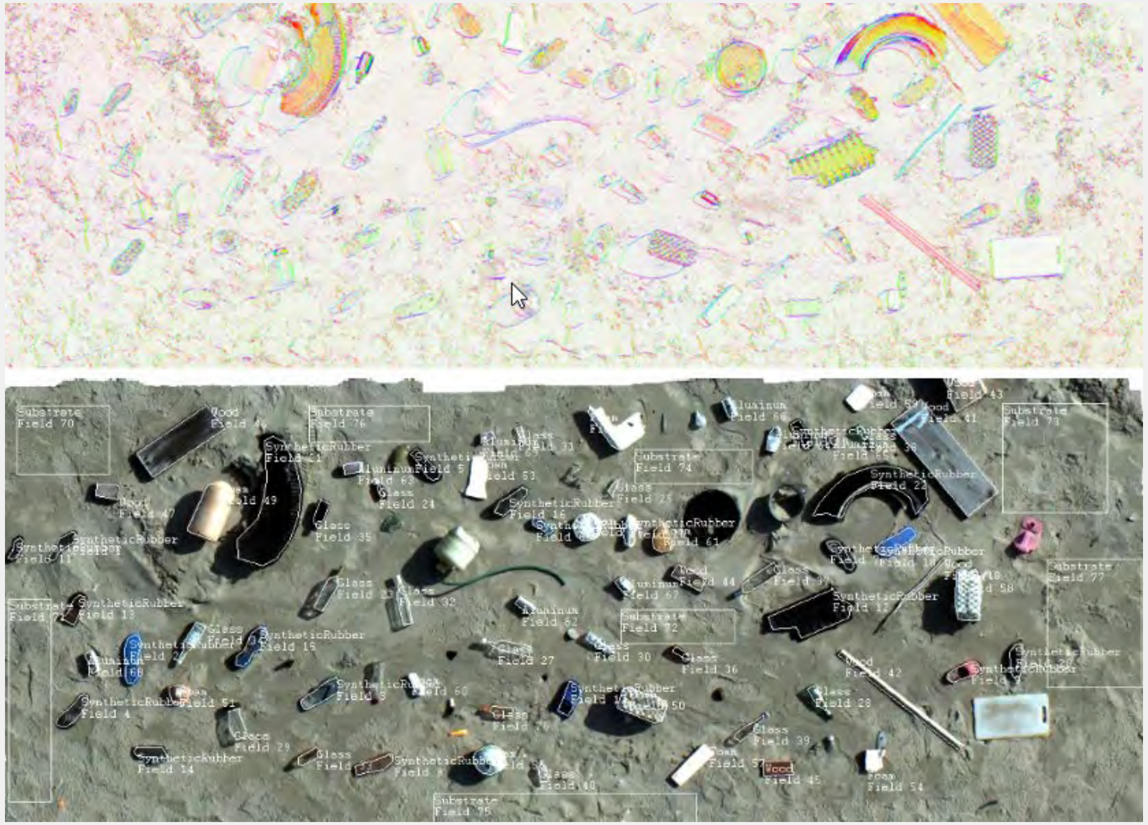
Goldstein EB et al (2019) A review of machine learning applications to coastal sediment transport and morphodynamics. EarthScience Reviews 194,97–108.

Vistousek et al. (2023) The future of coastal monitoring through satellite remote sensing. Cambridge Prisms: Coastal Futures, 1, e10, 1–18 https://doi.org/10.1017/cft.2022.4

Rubbens et al. (2023) Machine learning in marine ecology: an overview of techniques and applications. ICES Journal of Marine Science Volume 80, Issue 7, Pages 1829–1853, https://doi.org/10.1093/icesjms/fsad100

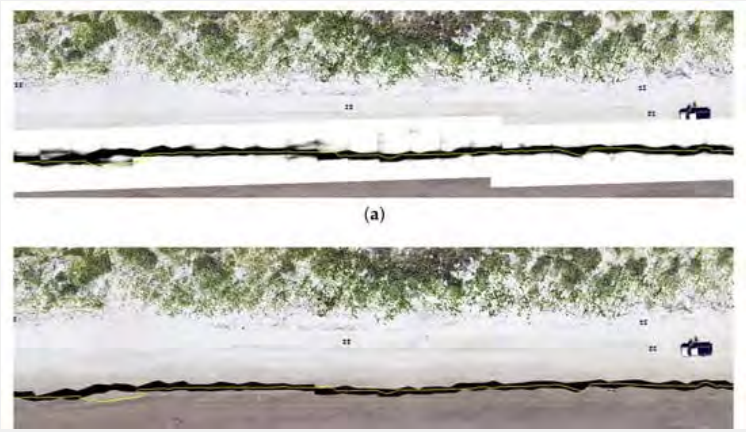
Computer Vision | **Detection**

Marine Debris Detection



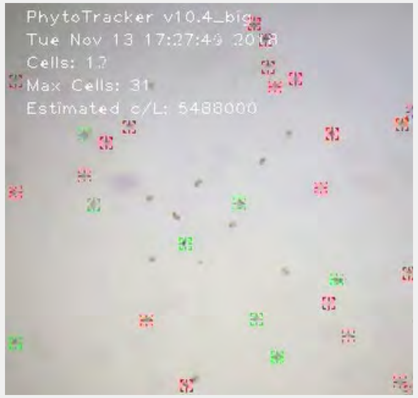
Parrish, C.E., et al. (2023) Uncrewed Aircraft Systems, Machine Learning, and Polarimetric Imaging for Enhanced Marine Debris Shoreline Surveys. Final Report. NOAA Technical Memorandum NOS NCCOS 312. Silver Spring, MD. 31 pp. doi: 10.25923/337h-k518

Wet/Dry Shoreline Detection



Vicens-Miquel M et al (2022) A Deep Learning Based Method to Delineate the Wet/Dry Shoreline and Compute Its Elevation Using High-Resolution UAS Imagery. *Remote Sensing*. 2022; 14(23):5990. https://doi.org/10.3390/rs14235990

HAB Detection



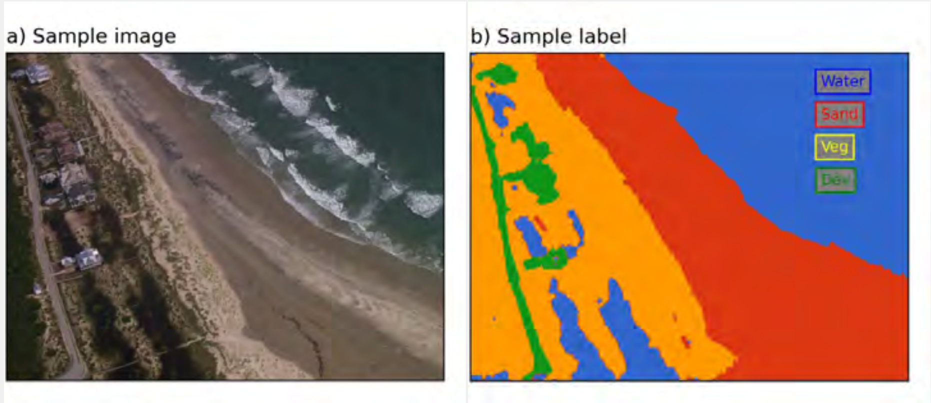
Hardison et al. (2019) HABscope: A tool for use by citizen scientists to facilitate early warning of respiratory irritation caused by toxic blooms of Karenia brevis. PLoS ONE 14(6): e0218489. https://doi.org/10.1371/journal.pone.0218489

Computer Vision | **Segmentation and classification**

Flood segmentation in webcam imagery

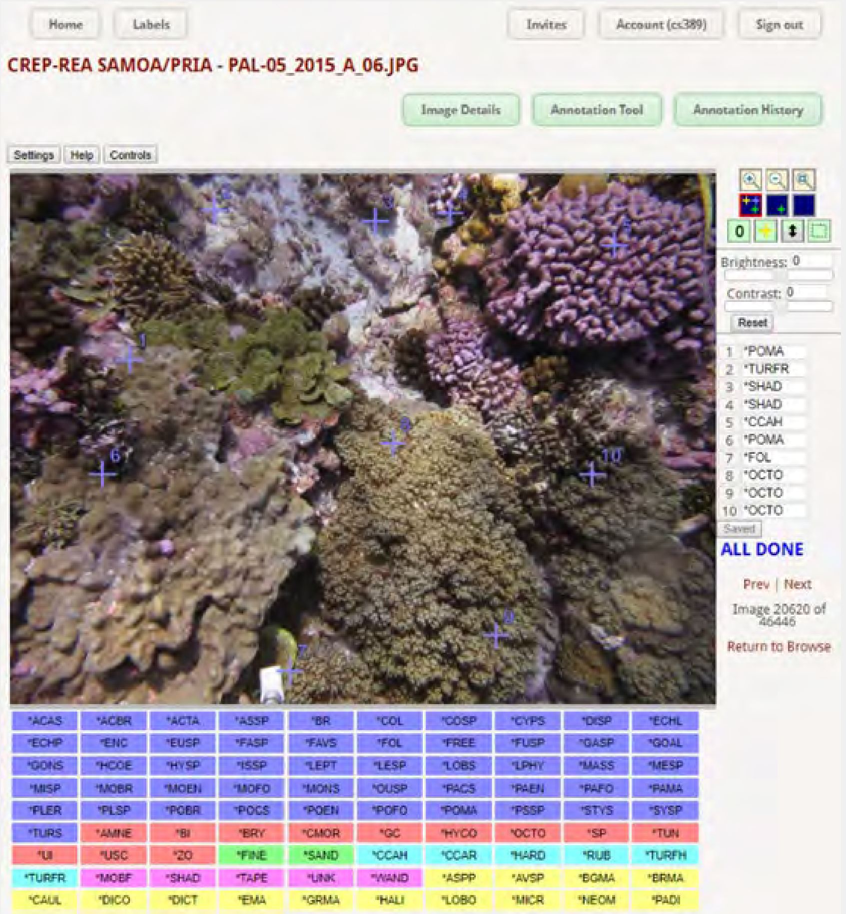
Wang et al. (2023) Urban flood extent segmentation and evaluation from real-world surveillance camera images using deep convolutional neural network. Environ Model Softw 105939. https://doi.org/10.1016/j.envsoft.2023.105939

Segmentation of earth surface imagery



Buscombe et al. (2022). Human-in-the-loop segmentation of Earth surface imagery. Earth and Space Science, 9, e2021EA002085. https://doi.org/10.1029/2021EA002085

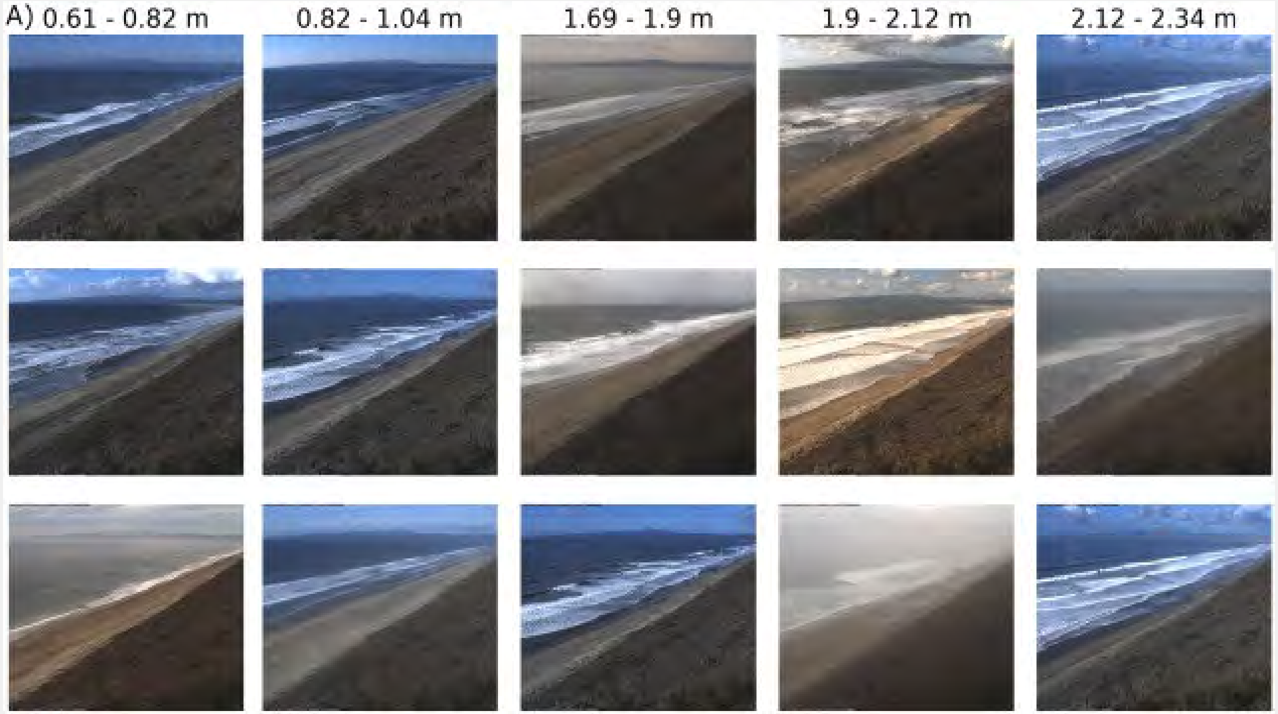
Point classification of benthic features



I. D. Williams et al. (2019). Leveraging Automated Image Analysis Tools to Transform Our Capacity to Assess Status and Trends of Coral Reefs. Frontiers in Marine Science.

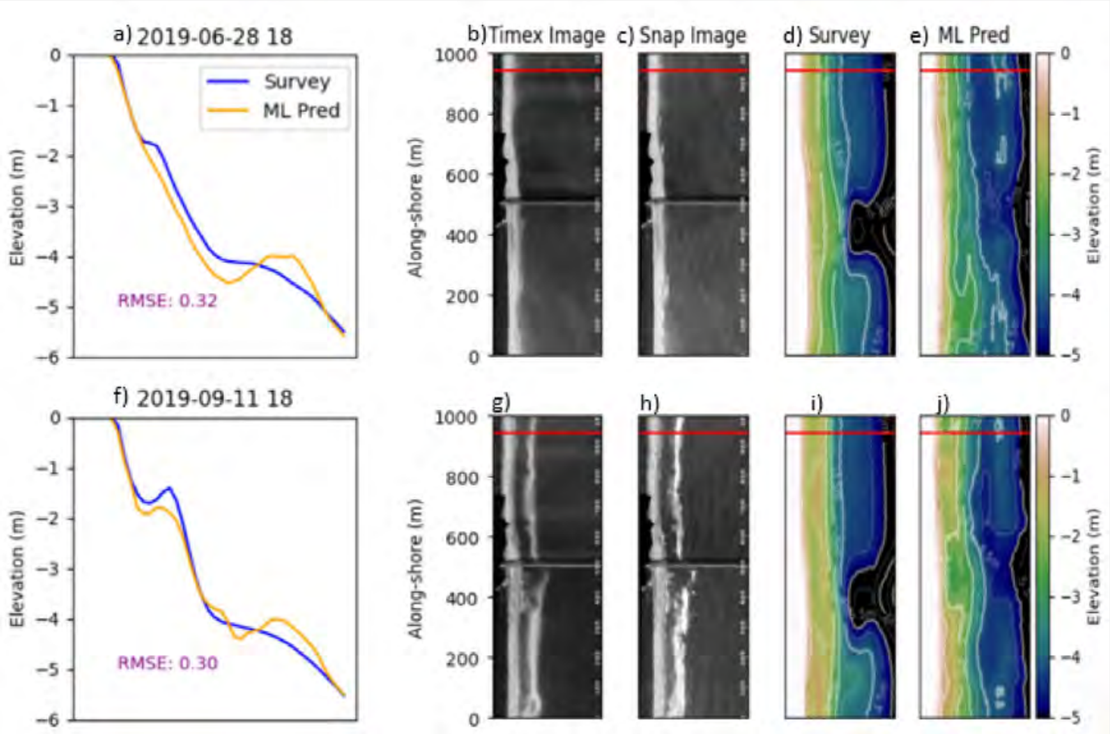
Computer Vision | **Regression**

Optical wave gauging



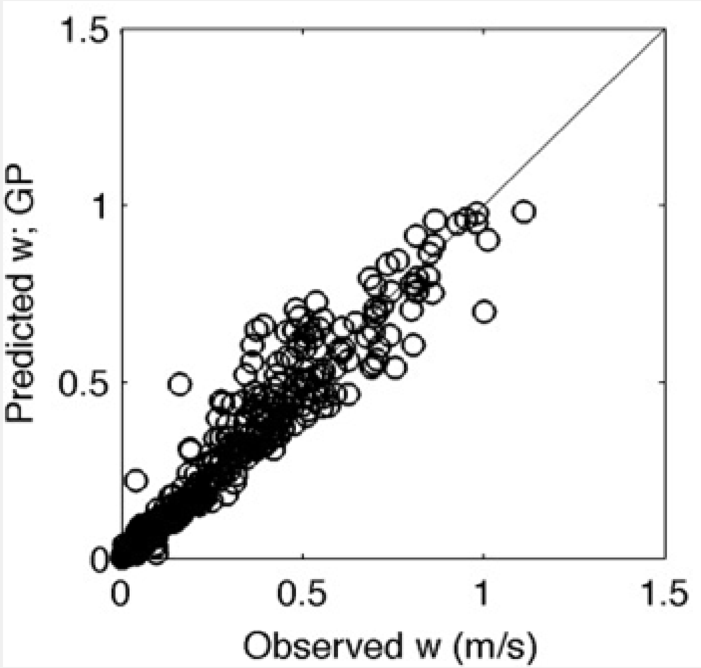
Buscombe et al. (2020). Optical wave gauging using deep neural networks. Coast Eng. 155, 103593. https://doi.org/10.1016/j.coastaleng.2019.103593. URL: http://www.sciencedirect.com/science/article/pii/S0378383919301243.

Surf zone bathymetry estimates from imagery



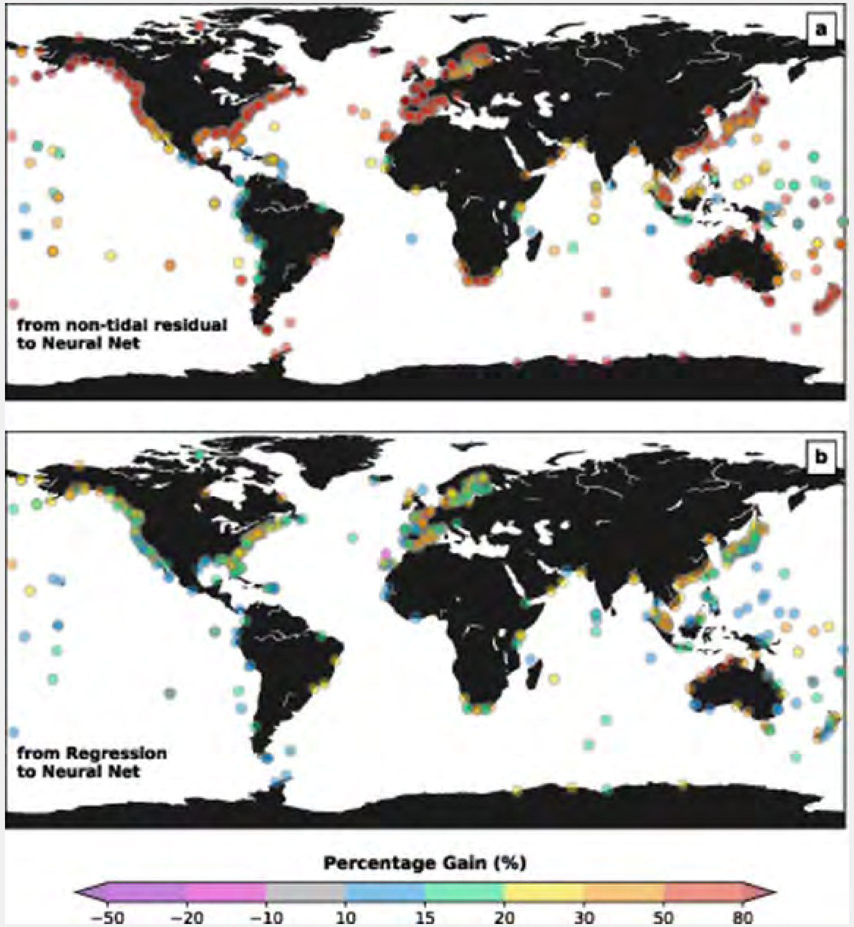
Collins et al. (2021). Development of a Fully Convolutional Neural Network to Derive Surf-Zone Bathymetry from Close-Range Imagery of Waves in Duck, NC. Remote Sensing. 13(23):4907. https://doi.org/10.3390/rs13234907

Predicting particle settling velocity



Goldstein, E. B., and Coco, G. (2014). A machine learning approach for the prediction of settling velocity. Water Resour. Res. 50, 3595–3601. doi: 10.1002/2013WR015116

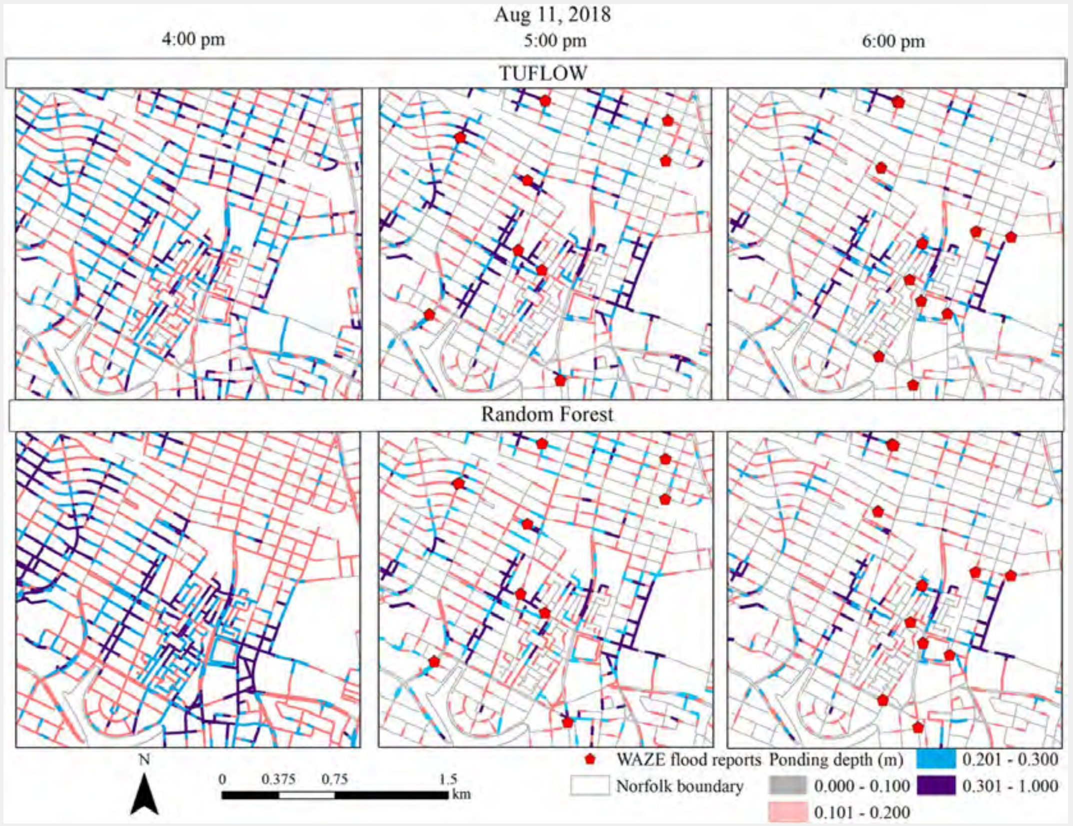
Prediction of non-tidal residual



Bruneau N. et al. (2020) Estimation of global coastal sea level extremes using neural networks. IOP Environ. Res. Lett 15, 074030. https://doi.org/10.1088/1748-9326/ab89d6

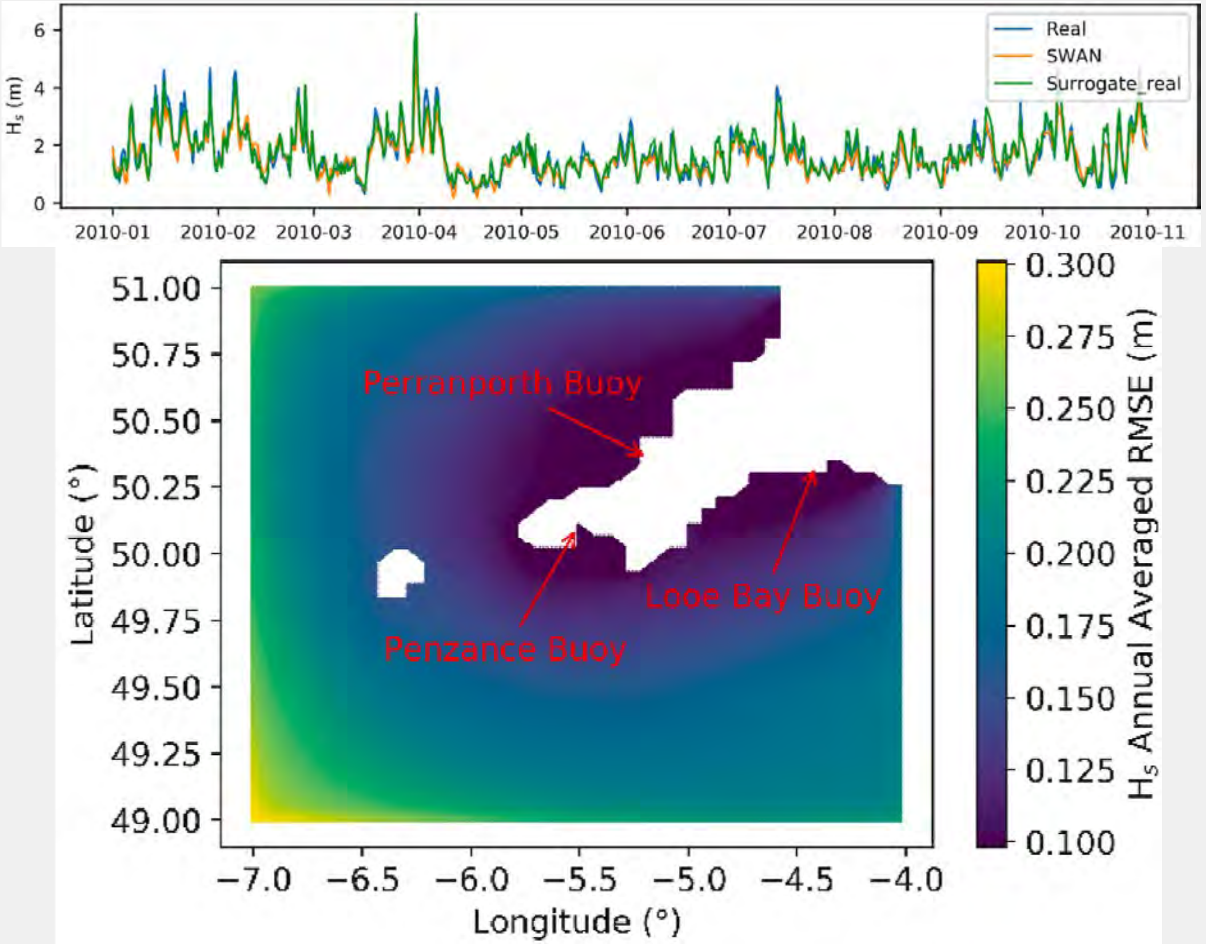
Prediction and Forecasting | **Surrogate models**

ML surrogate for overland urban flooding



Zahura et al. (2020). Training machine learning surrogate models from a high-fidelity physics-based model: Application for real-time street-scale flood prediction in an urban coastal community. Water Resources Research, 56, e2019WR027038. https://doi.org/10.1029/2019WR027038

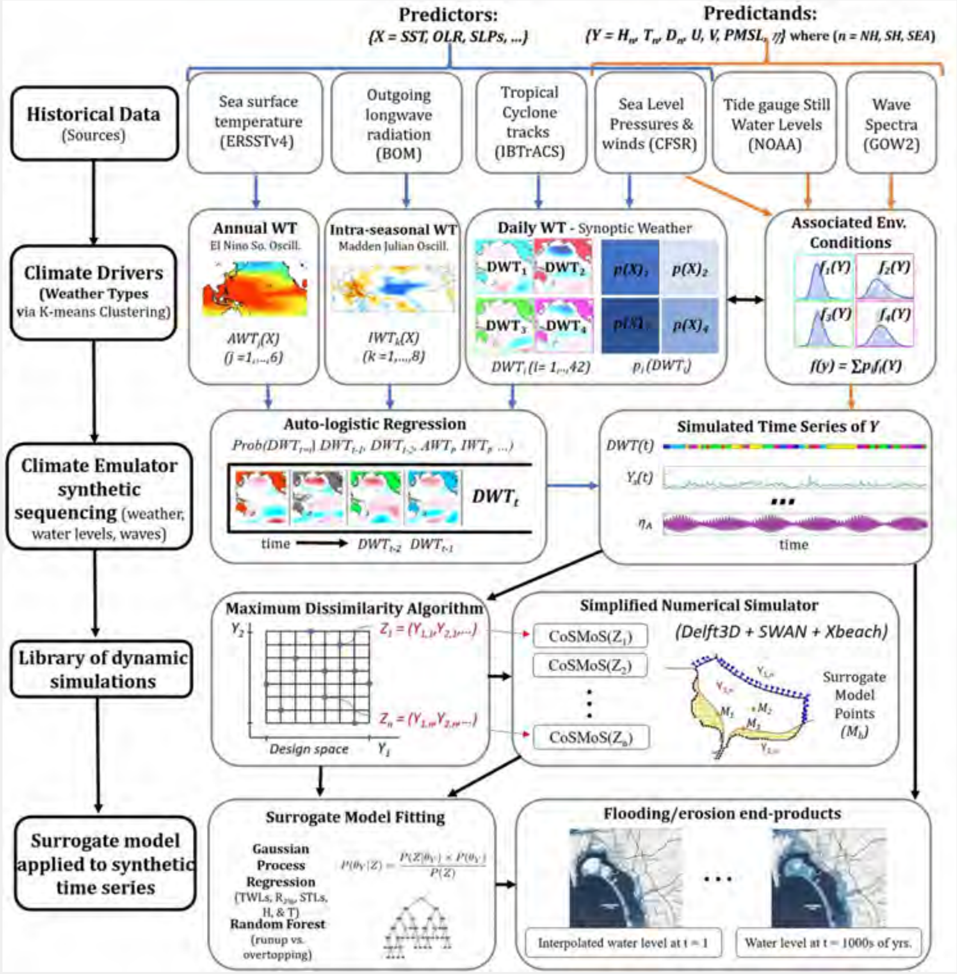
ML surrogate for wave model nowcasts



Chen et al. (2021) Using machine learning to derive spatial wave data: A case study for a marine energy site. Environ. Modell. Software, 142, 105066, https://doi.org/10.1016/j.envsoft.2021.105066.

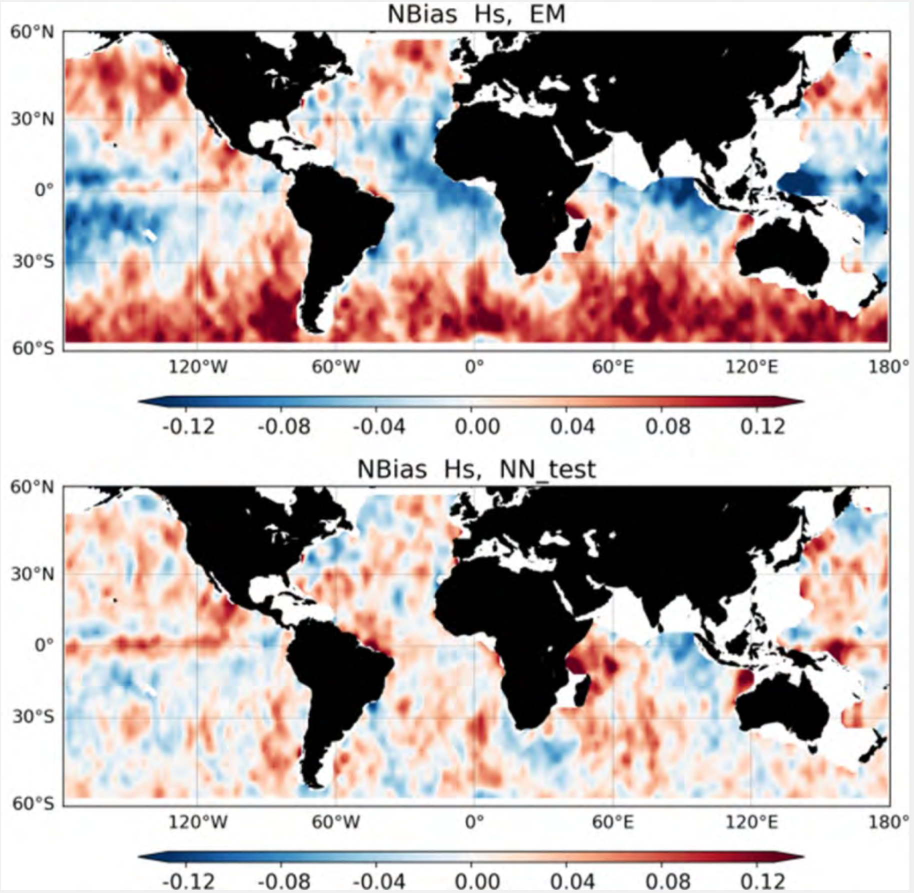
Prediction and Forecasting | **Hybrid models**

Predicting future coastal flood risk with a hybrid model



Anderson et al. (2021). Projecting climate dependent coastal flood risk with a hybrid statistical dynamical model. Earth's Future, 9(12), e2021EF002285. https://doi.org/10.1029/2021EF002285

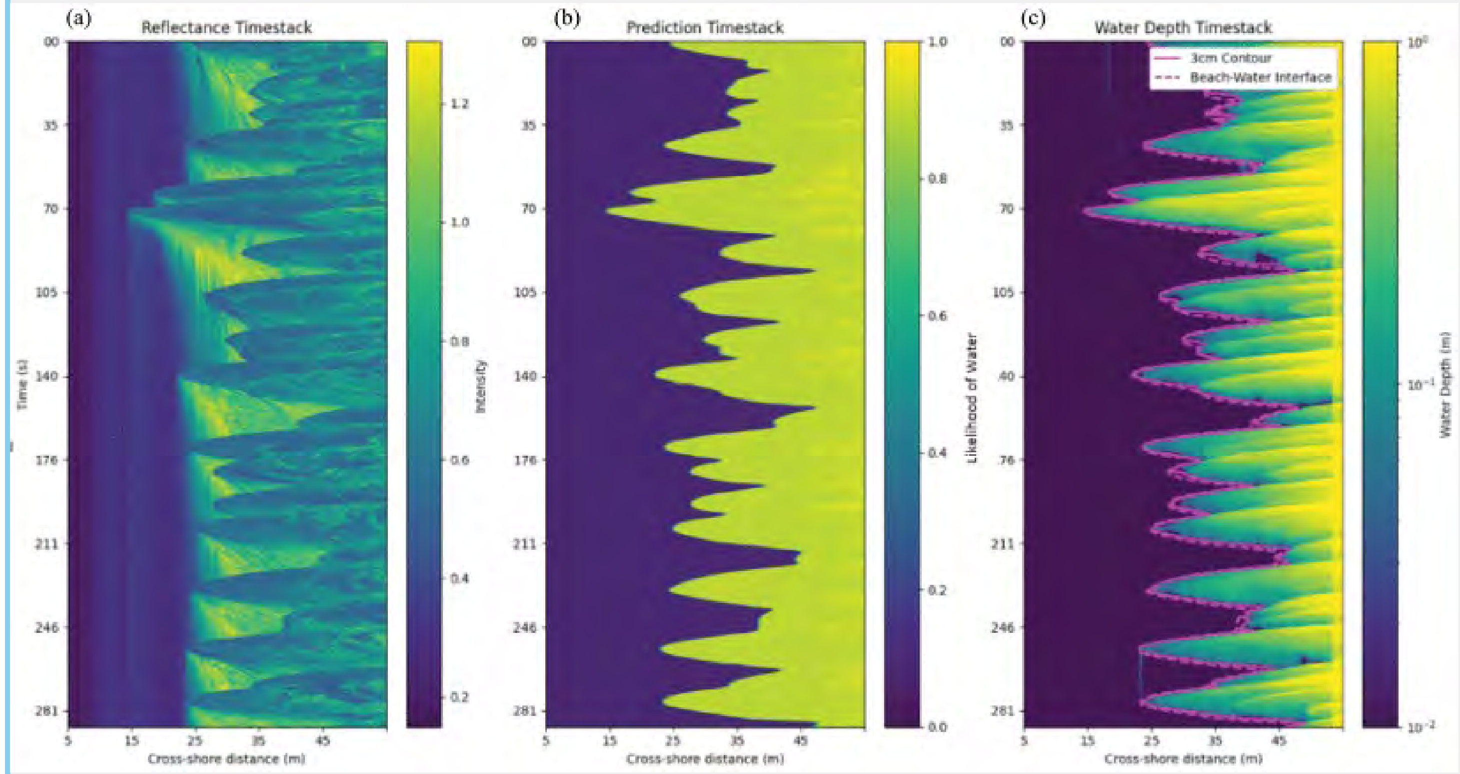
Improving numerical model ensemble averaging with ML



Campos et al. (2020). Improving NCEP's global-scale wave ensemble averages using neural networks. Ocean Model. 101617

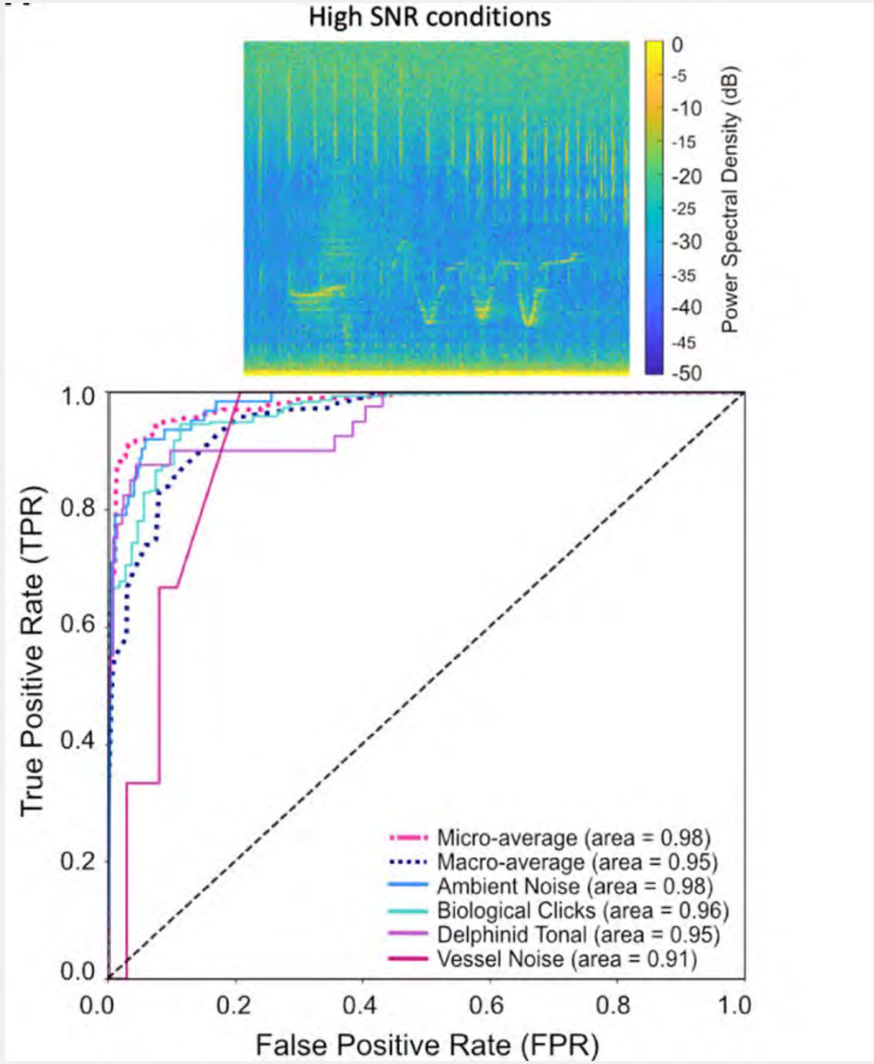
Data analysis | **Feature extraction**

Automated data extraction/boundary determination



Collins et al., (2023) Automated Extraction of a Depth-Defined Wave Runup Time Series From Lidar Data Using Deep Learning, in IEEE Transactions on Geoscience and Remote Sensing, vol. 61, pp. 1-13, 2023, Art no. 5700913, doi: 10.1109/TGRS.2023.3244488.

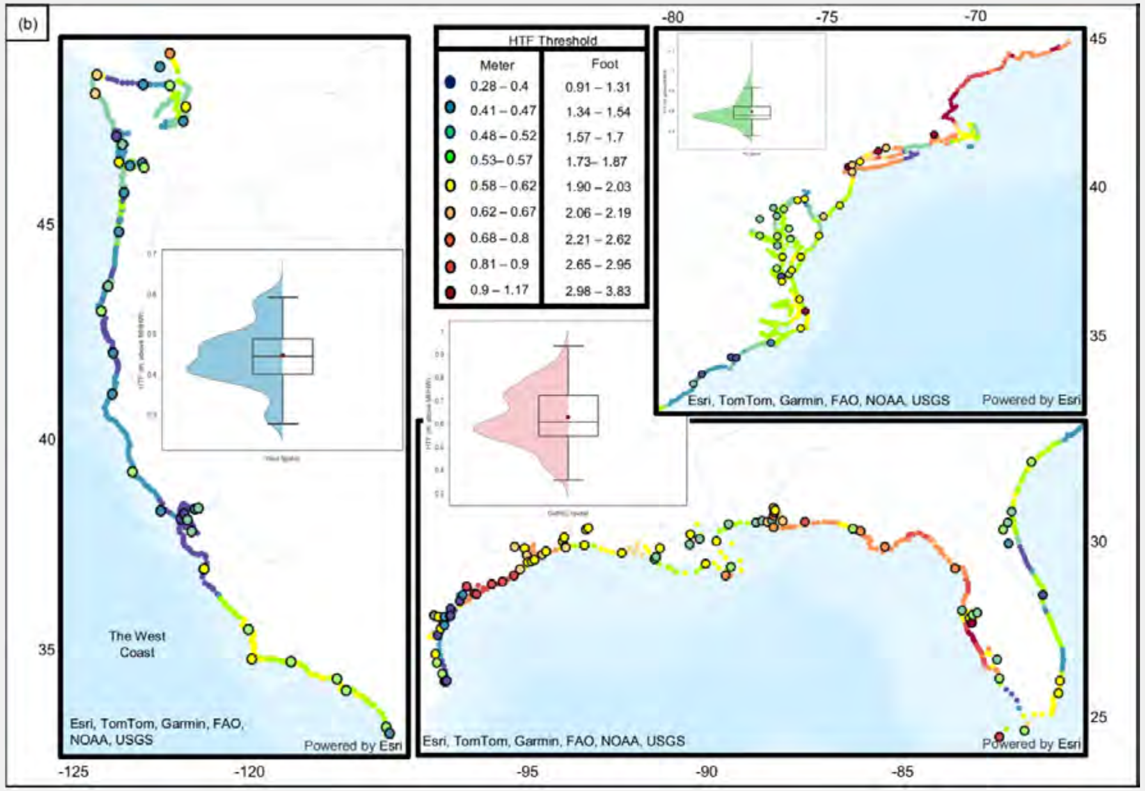
Detecting and extracting sound sources from acoustic data



White et al. (2022) More than a whistle: automated detection of marine sound sources with a convolutional neural network. Front. Mar. Sci. 9.https://doi.org/10.3389/fmars.2022.879145

Data analysis | **Recognizing patterns and anomalies**

Data clustering and pattern recognition for flood thresholds



Mahmoudi, et al. (2024) Establishing flood thresholds for sea level rise impact communication. *Nat Commun* 15, 4251 (2024). https://doi.org/10.1038/s41467-024-48545-1

Anomaly detection in optical flow fields

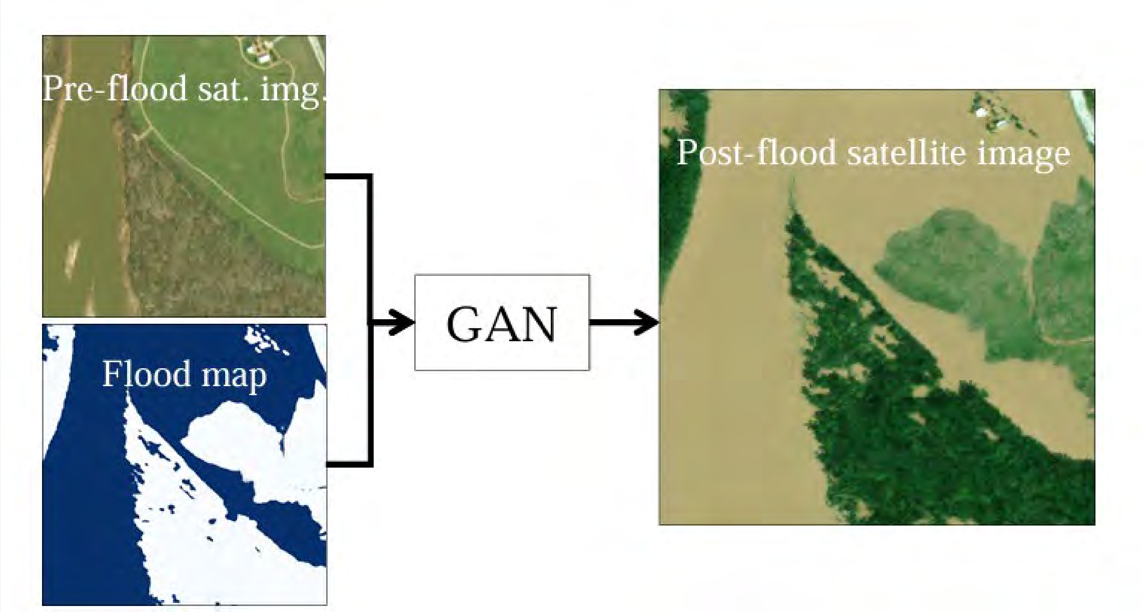
de Silva et al. (2023) RipViz: Finding Rip Currents by Learning Pathline Behavior, in *IEEE Transactions on Visualization and Computer Graphics*, doi: 10.1109/TVCG.2023.3243834.

Data analysis | **Data generation**

Super-resolution methods for remote-sensed imagery

Wang et al. (2022). A comprehensive review on deep learning based remote sensing image super-resolution methods. Earth-Sci. Rev. 232, 104110. http://dx.doi.org/10.1016/j.earscirev.2022.104110.

Image generation for flood visualization



Lütjens et al. (2023) Physically-consistent generative adversarial networks for coastal flood visualization. arXiv preprint arXiv:2104.04785v4.

Challenges and **Limitations**

Limits of data driven models

Data cleaning and labeling

Explainability

Compute and data storage

AI expertise and workforce development

Where are we headed with AI?

As a dynamic model replacement

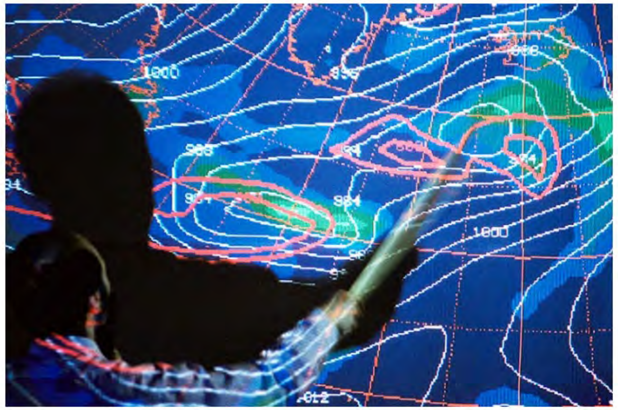
nature

NEWS | 14 November 2023

DeepMind AI accurately forecasts weather – on a desktop computer

The machine-learning model takes less than a minute to predict future weather worldwide more precisely than other approaches.

By Carissa Wong



Microsoft Research Blog

Introducing Aurora: The first large-scale foundation model of the atmosphere

Published June 3, 2024

By Wessel Bruinsma, Senior Researcher; Megan Stanley, Senior Researcher; Ana Lucic, Researcher; Richard Turner, Visiting Researcher; Paris Perdikaris, Principal Research Manager

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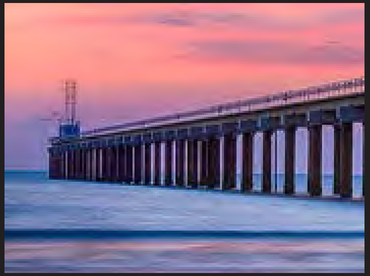
The possibilities of generative AI

- Data generation
- As an assistant
- How we interact with code
- Artificial General Intelligence?

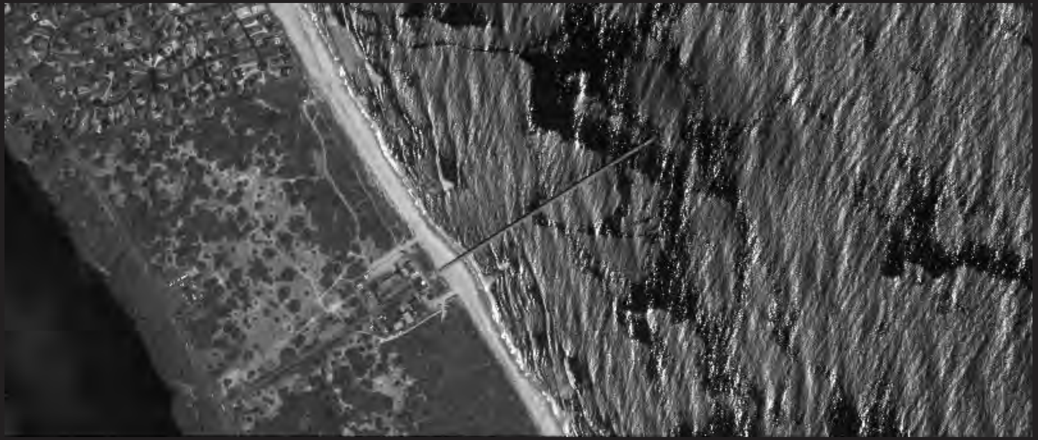
Kate Brodie

Senior Research Oceanographer,
U.S. Army Corps of Engineers




DECADAL IMPROVEMENTS IN COASTAL OBSERVATIONS INCLUDING SATELLITES, IN-SITU, AND REAL TIME DATA DELIVERY



Kate Brodie
Senior Research Oceanographer & Field Research Facility Technical Manager
US Army Engineer Research and Development Center


U.S. ARMY

US Army Corps of Engineers®

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

2014 FUTURE OF NEARSHORE PROCESSES RESEARCH

Observation Recommendations (Elko et al. 2014):

- Develop new sensors and observing techniques:

Remote Sensing Techniques	In-Situ Sediment Transport Observations	Morphology Evolution during Extreme Storms	Bio-geochemical Sensors	Low-cost, expendable sensor "swarms"
Yes. Lots.	*Still Hard.*	*Getting Better.*		*Kind of.*

- Expand long-term observing systems, conduct multiagency interdisciplinary field studies, and develop new citizen-science opportunities:

Fund (like UNOLS Ships) for Field Experiments at Coastal Observing Facilities	Multi-agency, multi-investigator, field experiments	New & Existing Long-term Observing Systems	Community Engagement & Citizen Science	Quantify anthropogenic impacts on coastal evolution
Not Yet.	*DUNEX; ONR*	*Some Expansion.*	*Some Growth.*	*Kind of.*

BIGGEST DECADAL ADVANCEMENTS

ERDC

2014 Data Starved → 2024 Data Rich

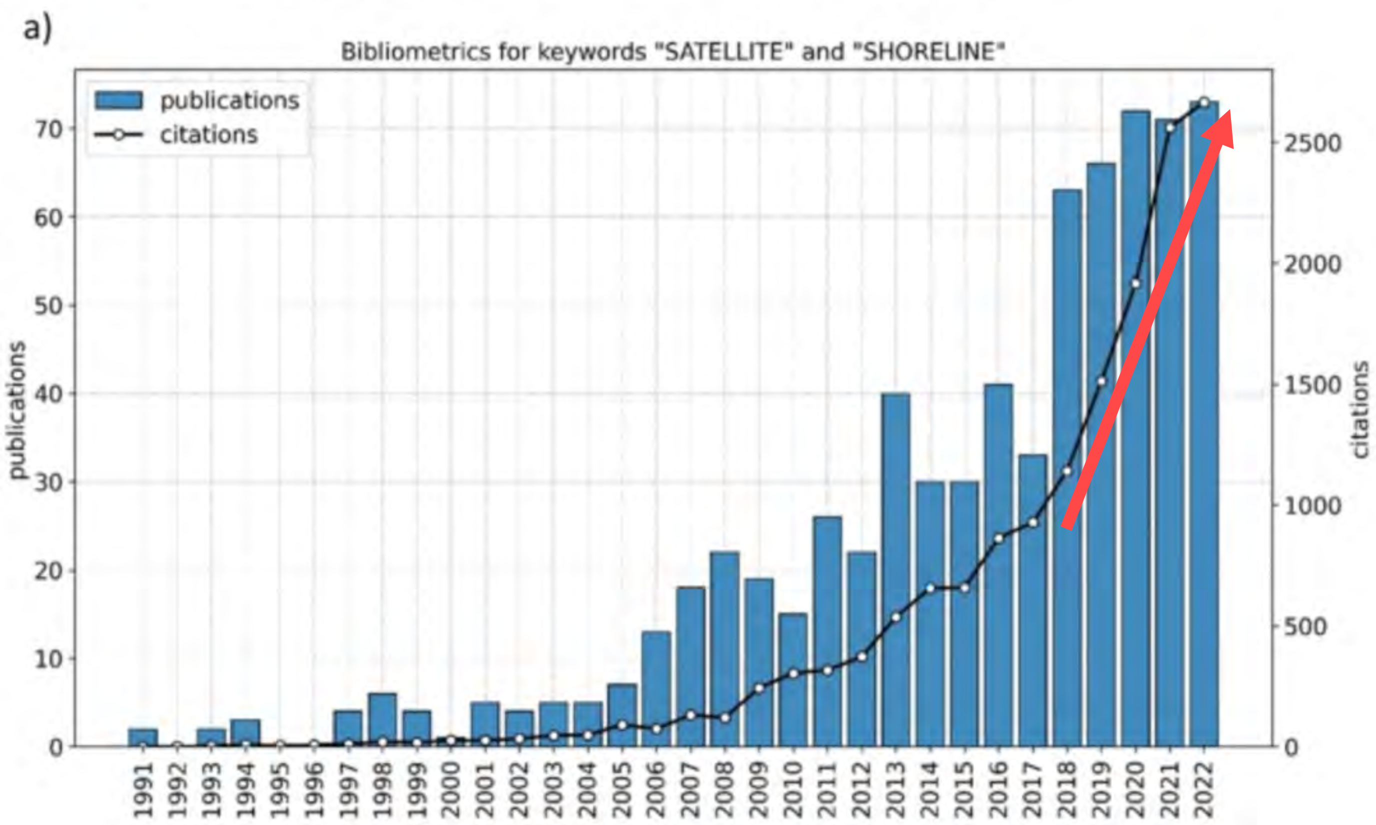
1. Large-scale, high-resolution coastal monitoring from satellites*
2. Operational use of close-range coastal imaging technology*
3. Sensor miniaturization, distributed sensing & in-water uncrewed systems*
4. Remote sensing renaissance for short-term process-focused experiments
5. Expansion of existing long-term monitoring efforts

*expansion of satellites & uncrewed systems as data collection platforms, and agency operational use of imagery was not well predicted in the 2014 report

1 SATELLITE-BASED SHORELINE CHANGE MONITORING

1047 citations!

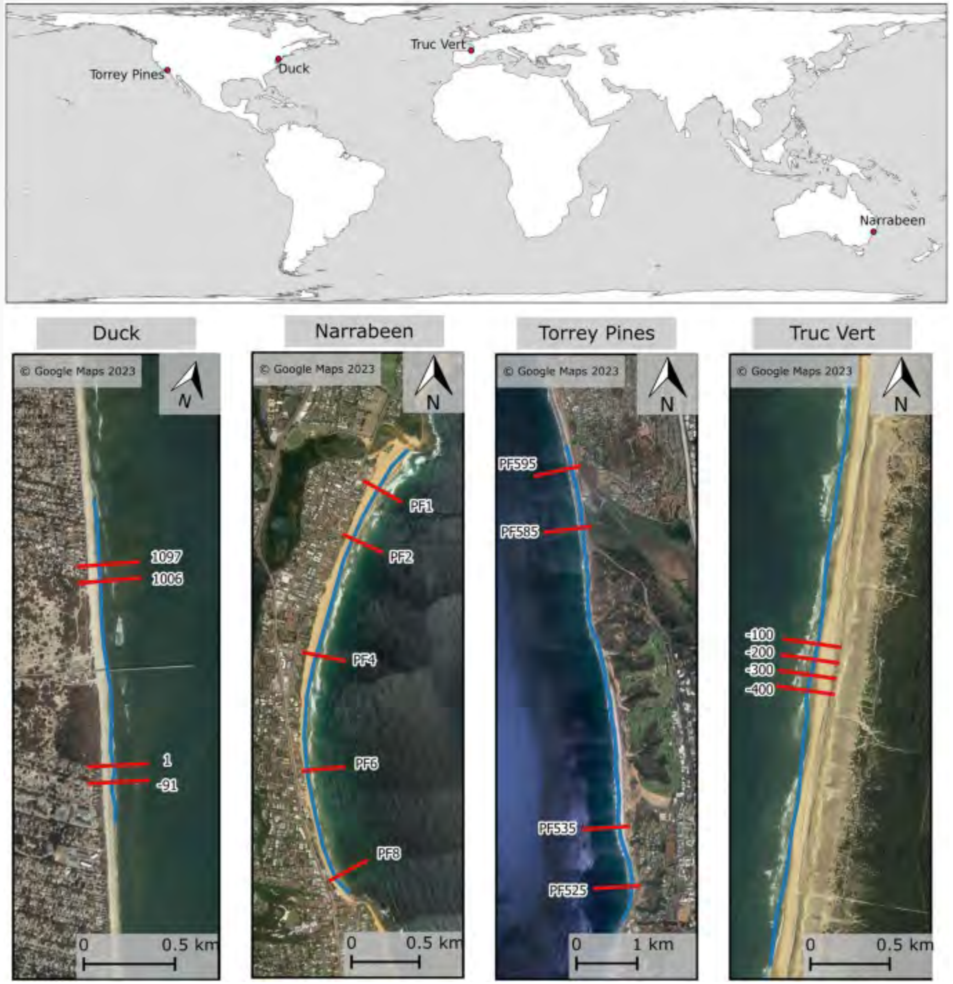
Fig. 1: Rapid evolution of satellite-derived shoreline methods.

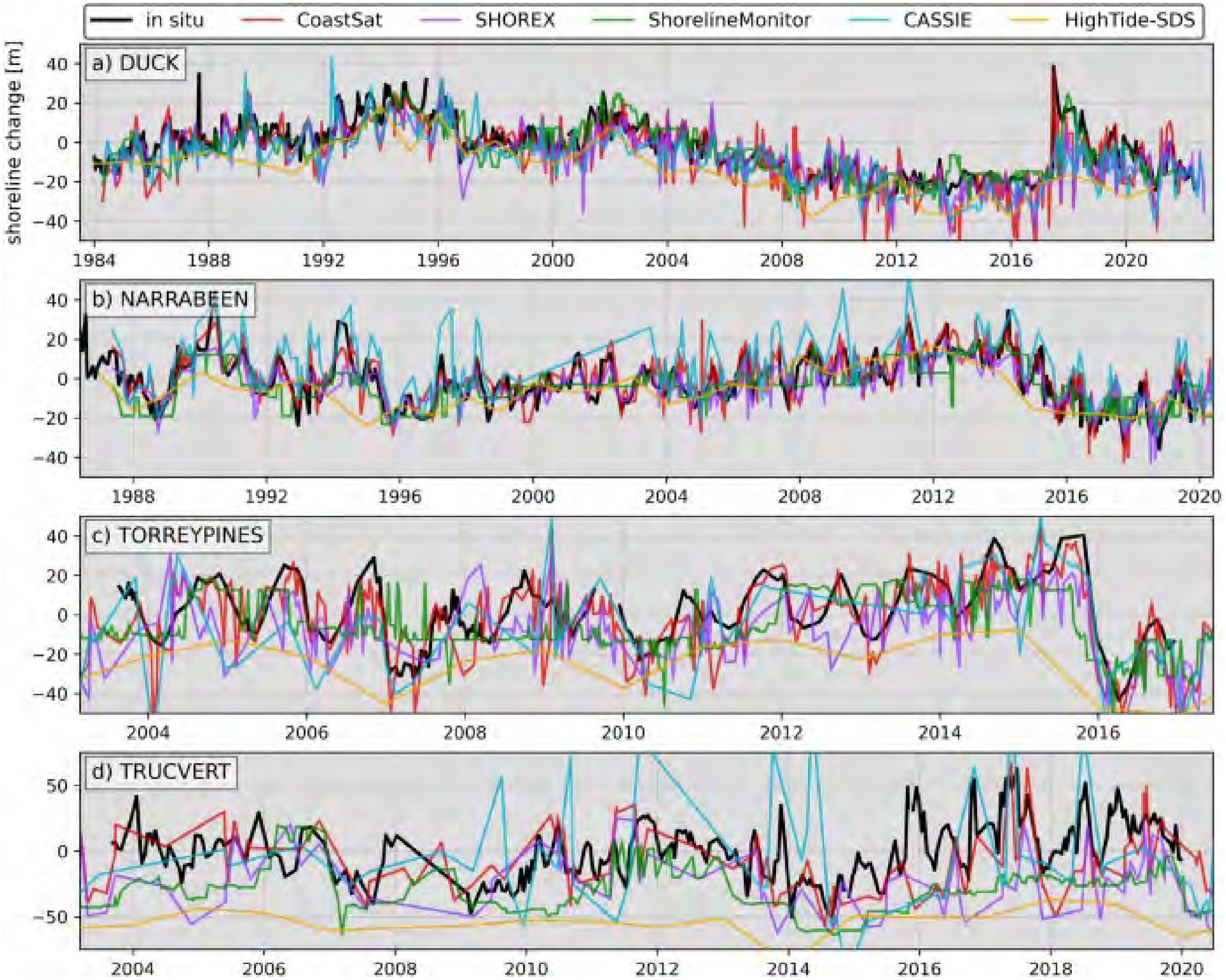


Vos et al 2023

1 SATELLITE-BASED SHORELINE CHANGE MONITORING

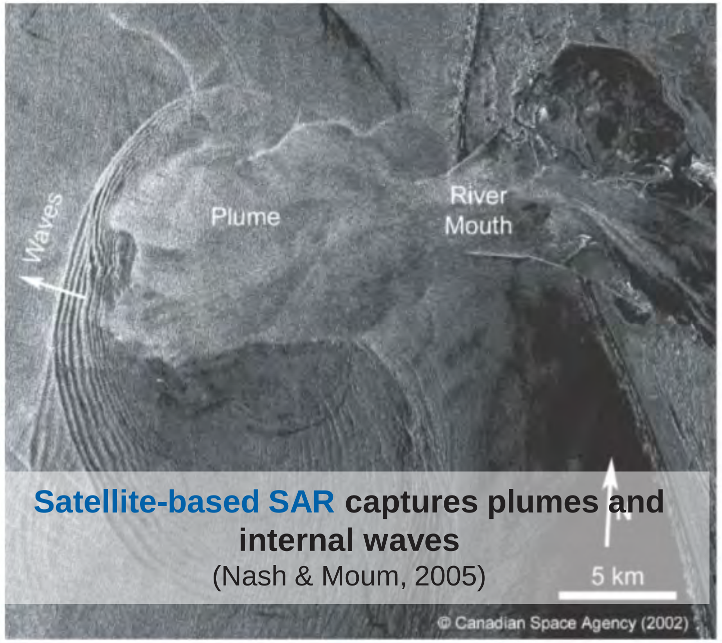
→ Collaborative open-source global community





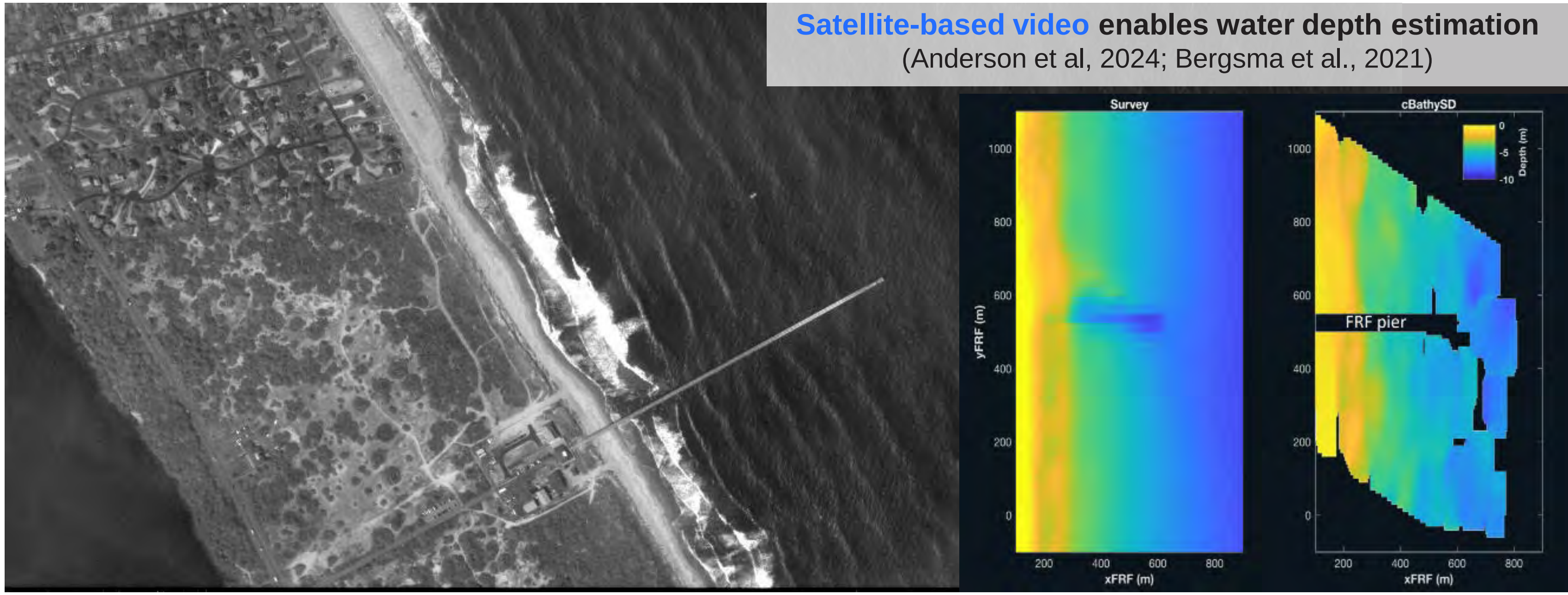
Vos et al 2023

1 OTHER SATELLITE APPLICATIONS

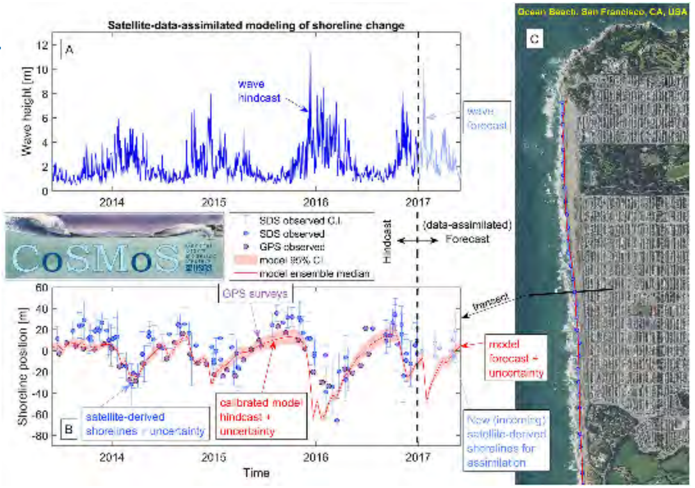


Satellite-based SAR captures plumes and internal waves
(Nash & Moum, 2005)

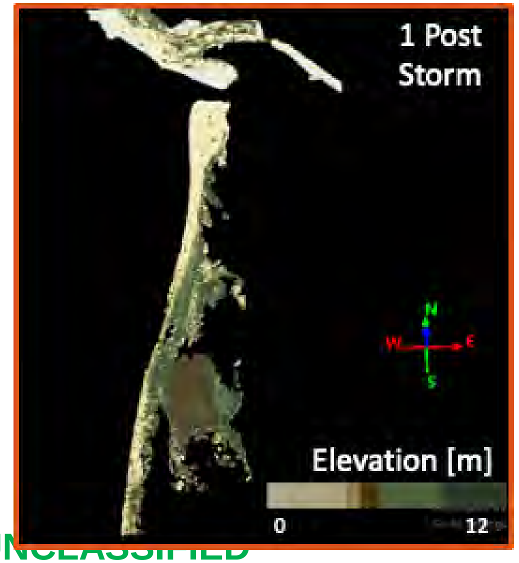
Satellite-based video enables water depth estimation
(Anderson et al, 2024; Bergsma et al., 2021)

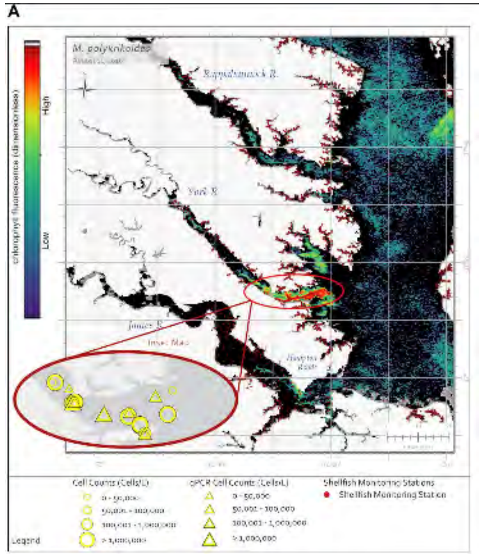


Satellite-data assimilated coastal-change modeling system
(Vitosek, 2023)



Satellite-derived topography for coastal-change monitoring
(Almar et al., 2022; Brown et al., In-Prep)

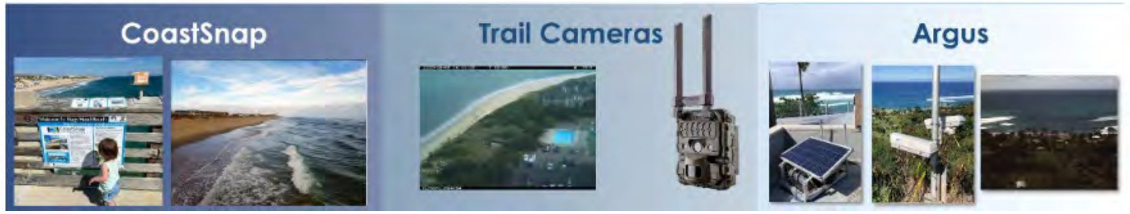




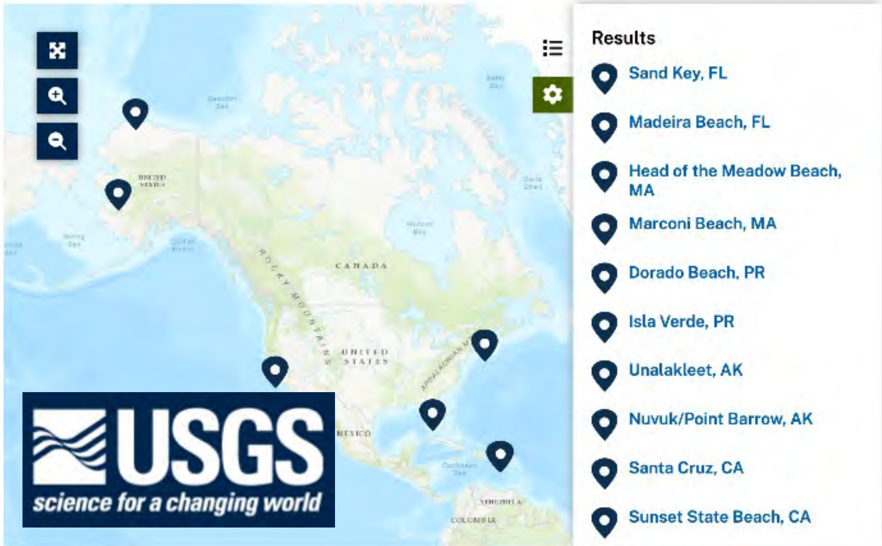
Satellite observations of Harmfull Algal Blooms (HABs) for water quality monitoring
(Wolny et al., 2020)

2 OPERATIONAL COASTAL IMAGING

IMPACT:
Real-time data on federal projects, to inform project condition and performance, channel shoaling, adaptive management strategies, monitor construction, water levels, waterway/resource use, ship traffic, etc.



IMPACT:
Low-cost observing platform to monitor and accurately forecast weather, ocean, ecological, and public health hazards including rip currents, beach usage, flood monitoring, etc.



IMPACT:
Monitoring coastal conditions in near real-time to support research and validate total water level predictions.

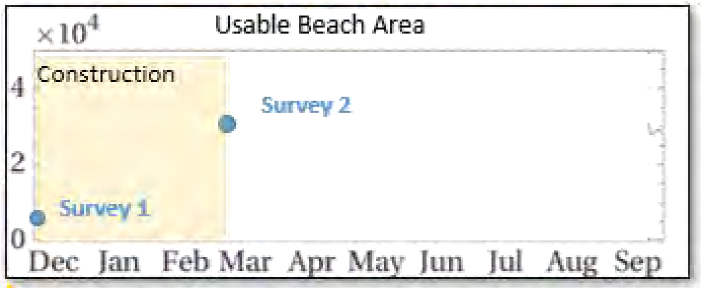
2 CorpsCam EXAMPLE APPLICATION

ERDC

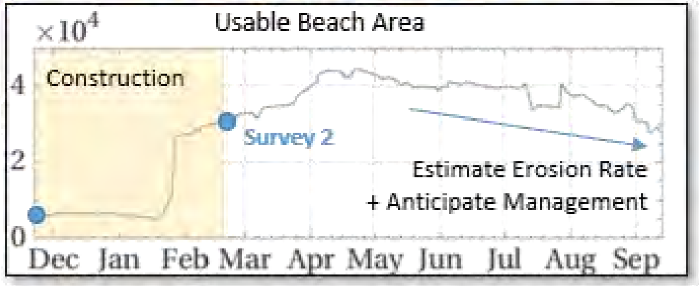
VIDEO IMAGING : HOURLY OBSERVATIONS, MAPS + ENGINEERING DATA

C A L I B R A T I O N

BEFORE CORPSCAM



WITH CORPSCAM

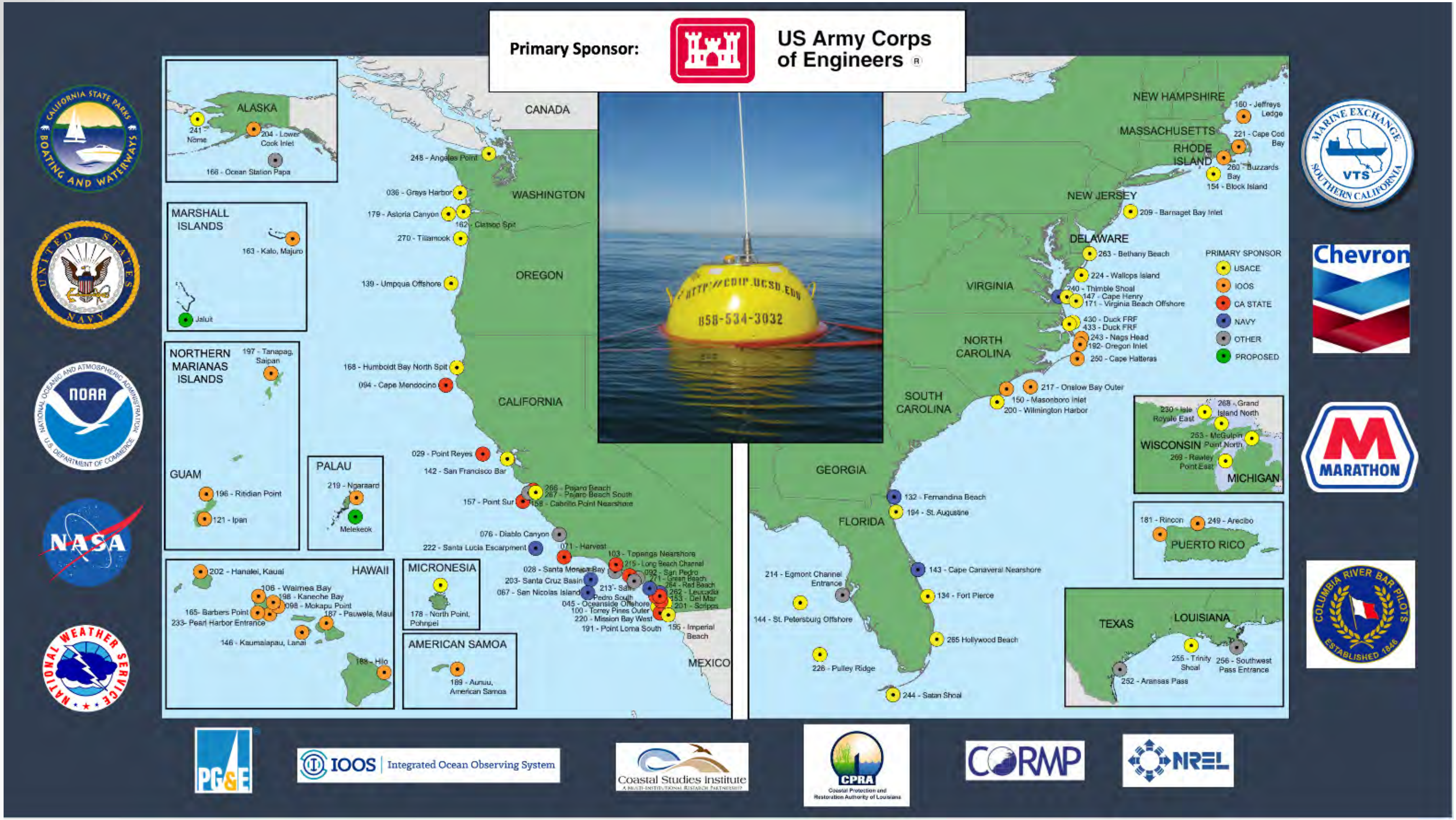


Remote | Autonomous | Quantitative | Holistic

Funded by the USACE Coastal and Ocean Data Systems Program

OPERATIONAL WAVE OBSERVATIONS

CDIP National Nearshore Buoy Network



IMPACT: Provides highly accurate real-time and historical nearshore wave observations Nationally that fill a gap between NOAA deep water observations and the shoreline.

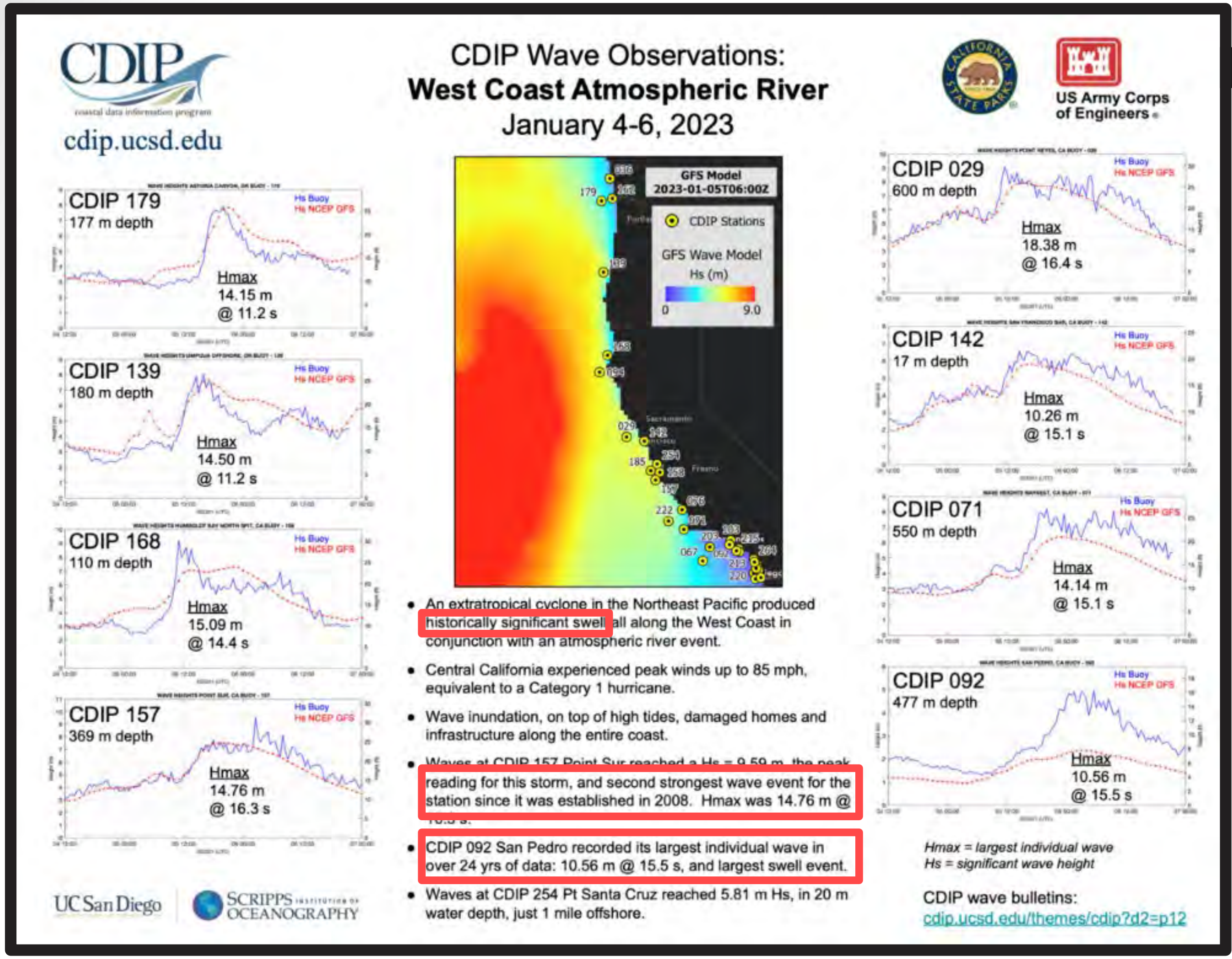
Operations: inform engineering analysis and design of federal projects, real-time port operations decisions, and storm-impact assessments.

Research: provide offshore boundary conditions that provide context for coastal change analysis and input/validation for nearshore & surf-zone models.

Funded by the USACE Coastal and Ocean Data Systems Program

WAVE BUOY NETWORK: APPLICATION EXAMPLE

Automated storm bulletins summarize impacts;
Identifies historic storm



SPL initiates navigation infrastructure inspection

USACE District identifies underwater damage that it otherwise wouldn't have known was there, demonstrating both the long-term and real-time value of buoy network.

- **Without the continuous long-term observations, this historic significance of this storm would have been unknown**
- **Without the realtime, automated data processing of this network, the District would not have known to immediately initiate inspection of it's infrastructure.**

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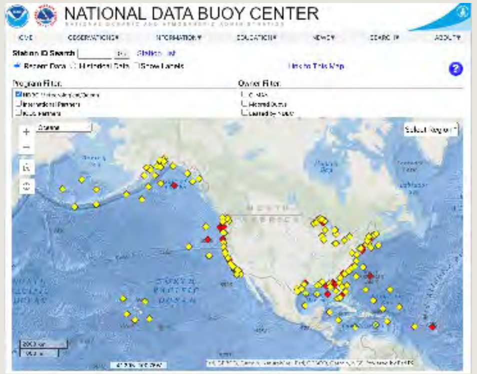
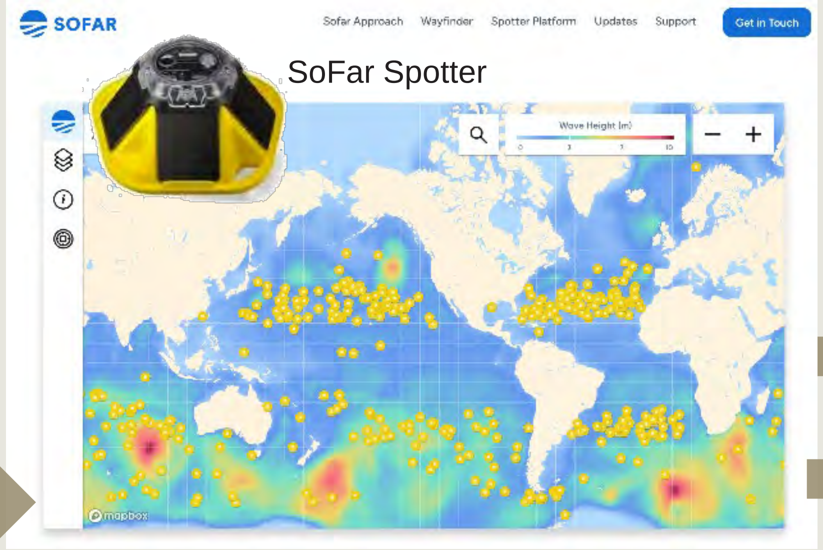
3 WAVE BUOY EVOLUTION

ERDC

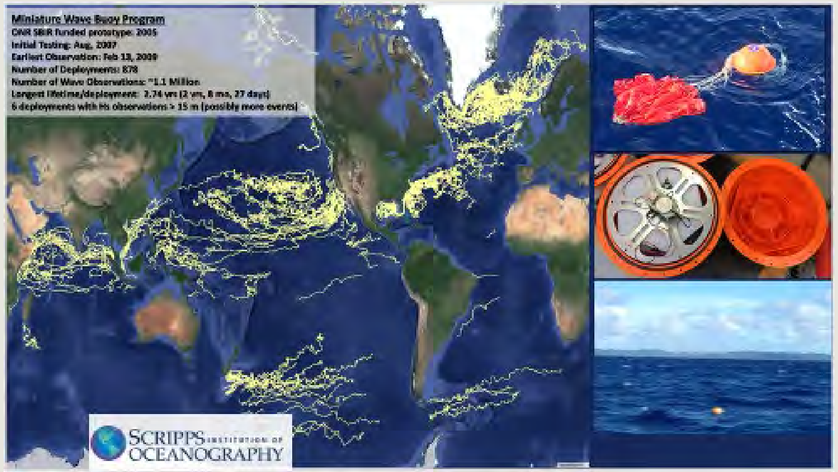
Fixed Networks



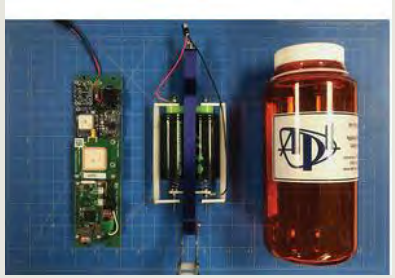
Small Drifting Buoys



SoFar Spotter



Miniature Wave Following Buoys



Thompson et al., 2023

Feddersen et al., 2023

Buoys of Opportunity

JaiaBot

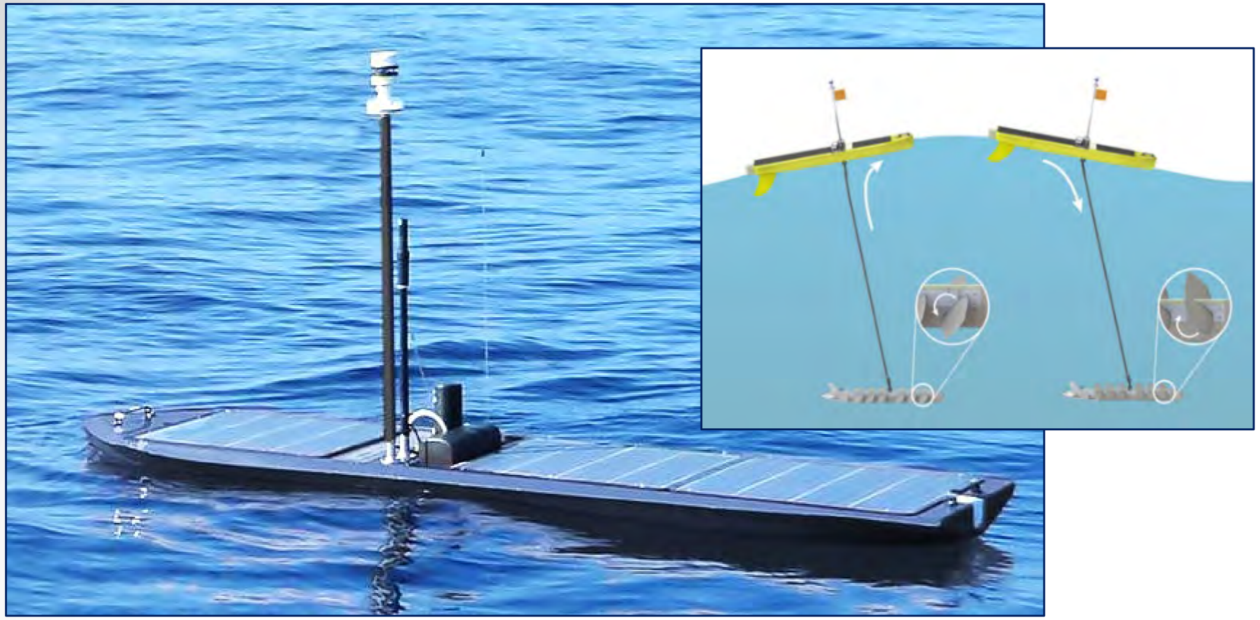
ONR/Penn State Eagle

Liquid Robotics Wave Glider

SubUAS Naviator

3 APPLICATION: BUOYS OF OPPORTUNITY

Liquid Robotics Wave Glider



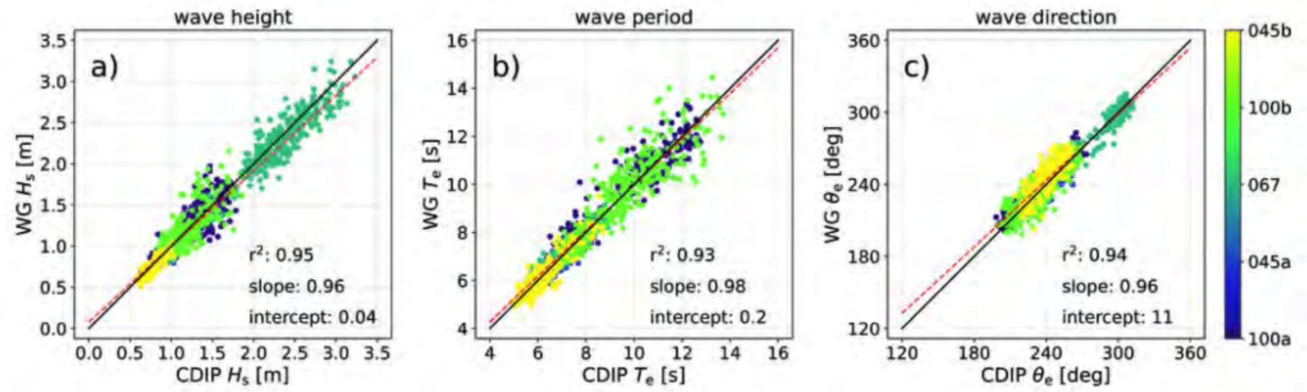


Fig. 8.

Amador et al., 2023

ONR Eagle

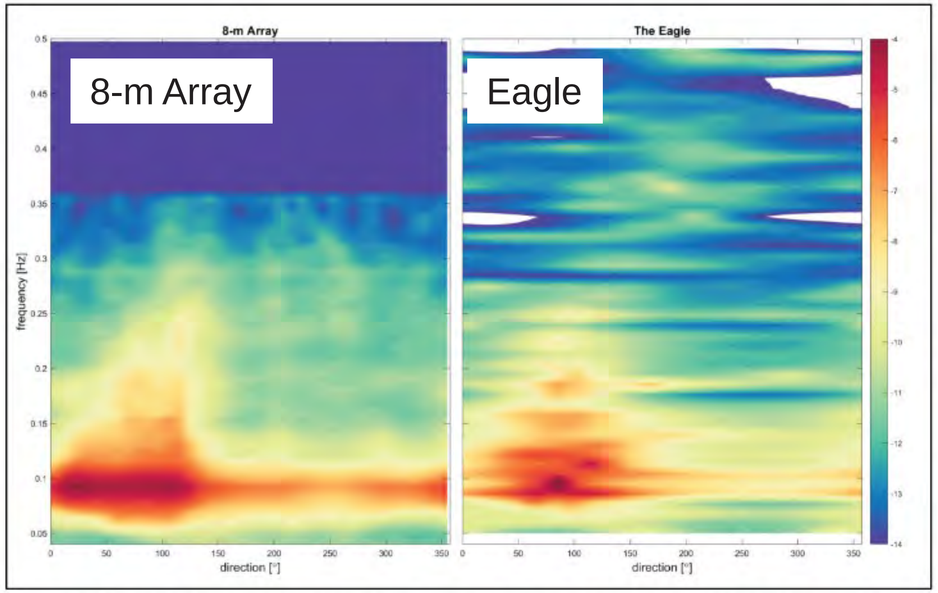


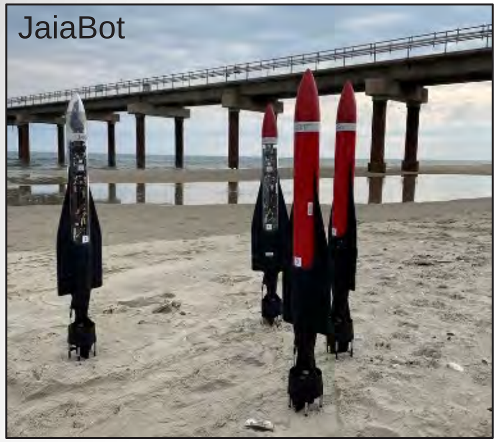
Figure 5. Direction-frequency spectra from the 8 m array (left) and the Eagle (right). The color scale indicates the spectral density [m^2/Hz/deg] on a log scale.

Collins and Brodie 2021

UNCLASSIFIED

3 UNCREWED SYSTEMS FOR COASTAL SURVEY

Uncrewed Surface Vessels


JaiaBot

Bak et al., 2022

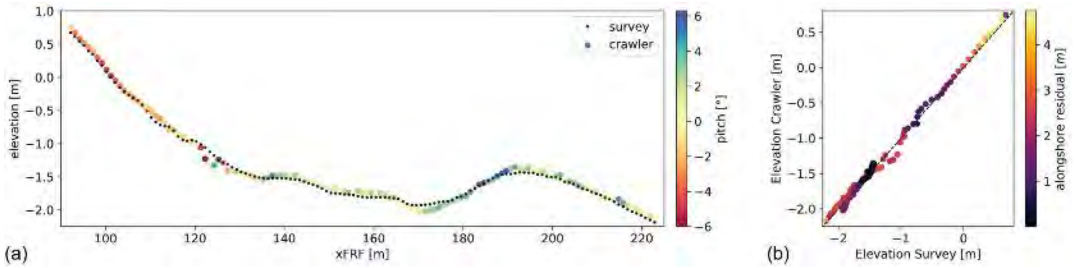

YellowFin

Francis and Traykovski 2021


Hydronalix Sonar Emily

Bottom crawler

Bak et al., 2023

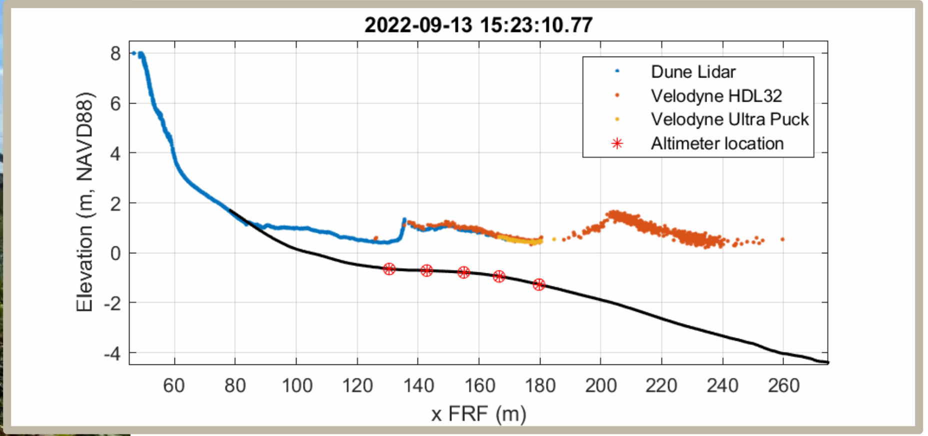



Bayonet 350

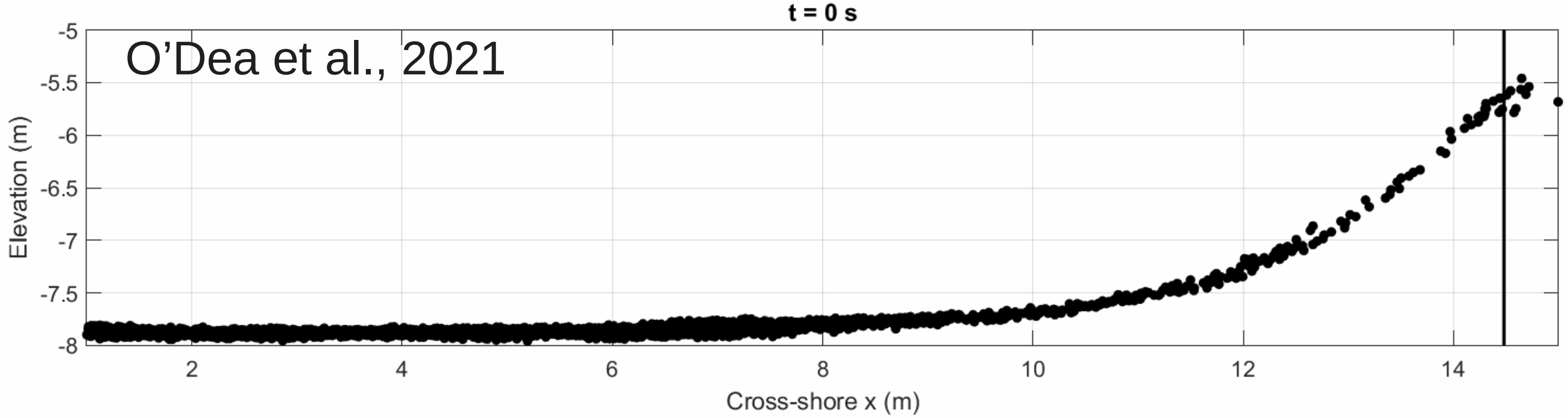
4 REMOTE SENSING OF COASTAL PROCESSES

→ Observations at process-relevant time-scales and spatial scales

Collaborative Experiment – September 2022



- Hydrodynamics: **high spatial-resolution wave resolving measurements** provide details of non-linear wave processes



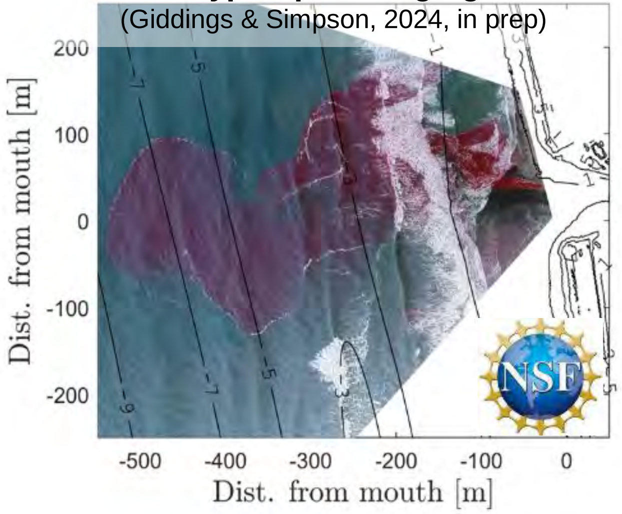
Funded by the USACE Coastal and Ocean Data Systems, ERDC Basic Research Program, OSD (R&E) LUCI Program

4 REMOTE SENSING OF COASTAL PROCESSES

ERDC

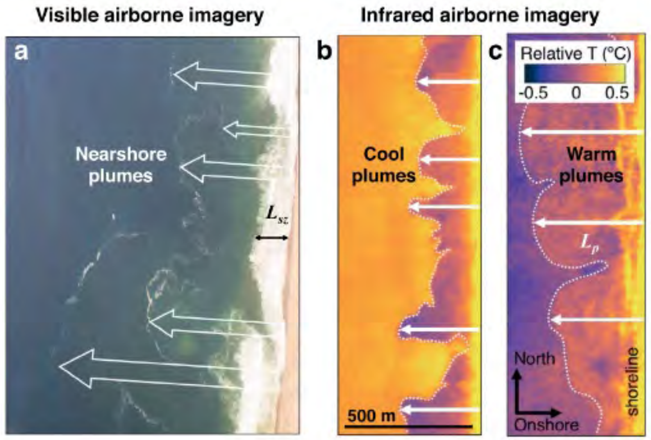
Dye studies of river plume-surfzone interaction using Drone RGB and Hyperspec imaging

(Giddings & Simpson, 2024, in prep)



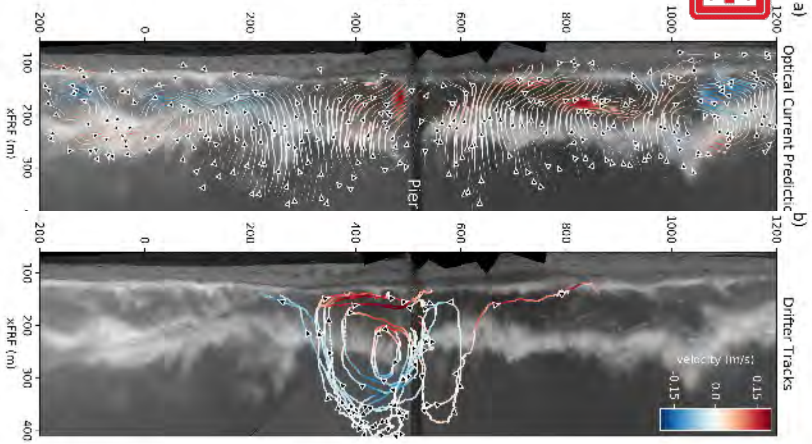
Warm/cool rip plumes using Airborne IR imagery

(Moulton et al., 2021)

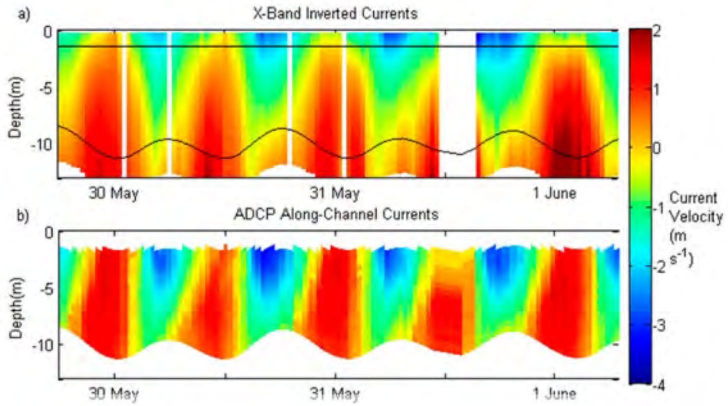


Optical flow and PIV algorithms developed for current tracking in Optical Wave Averaged Movies

(Anderson et al., 2021)

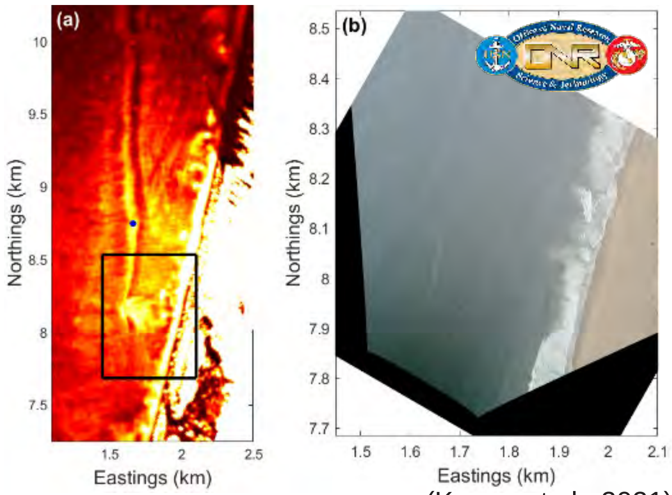


X-band radar and drone internal waves and rip currents

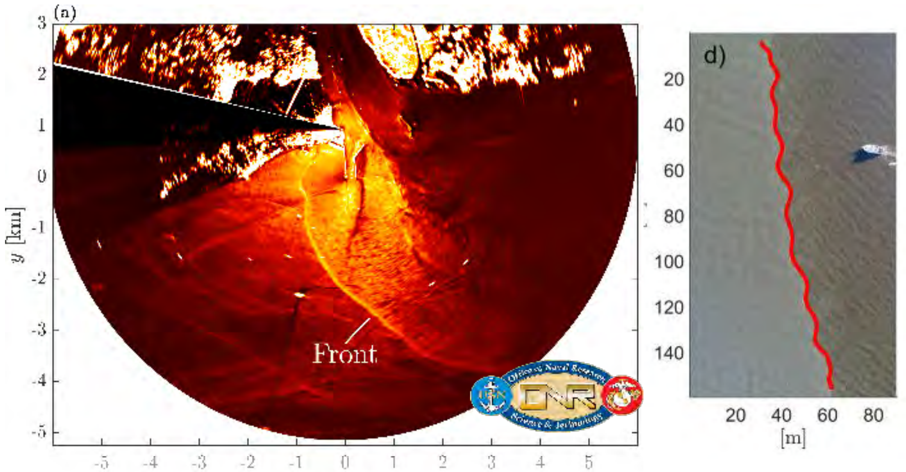


X-Band radar dispersion-based extraction of vertically-resolved currents at intermediate depths

(Campana et al., 2016)



(Kumar et al., 2021)



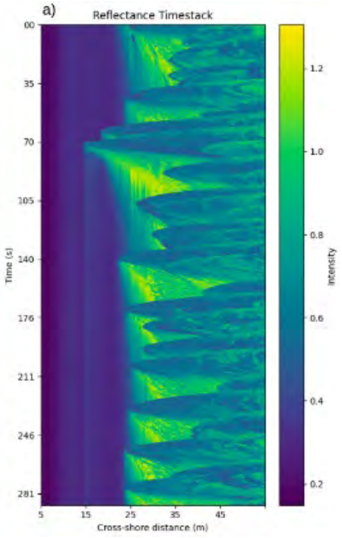
Time evolution of plume fronts at a range of relevant length scales from X-band radar and drones

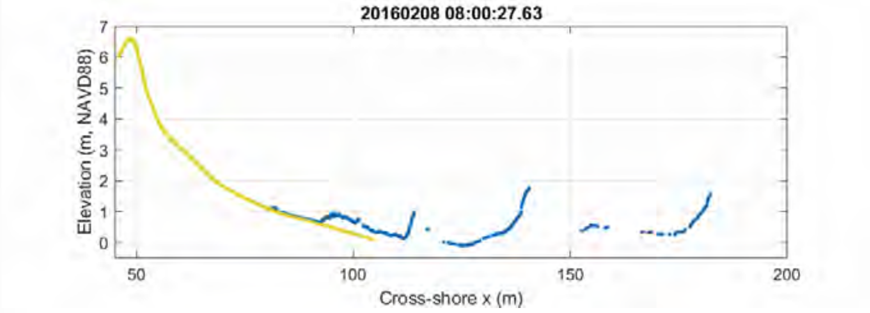
(Honegger et al., 2024) (Simpson et al., 2022)

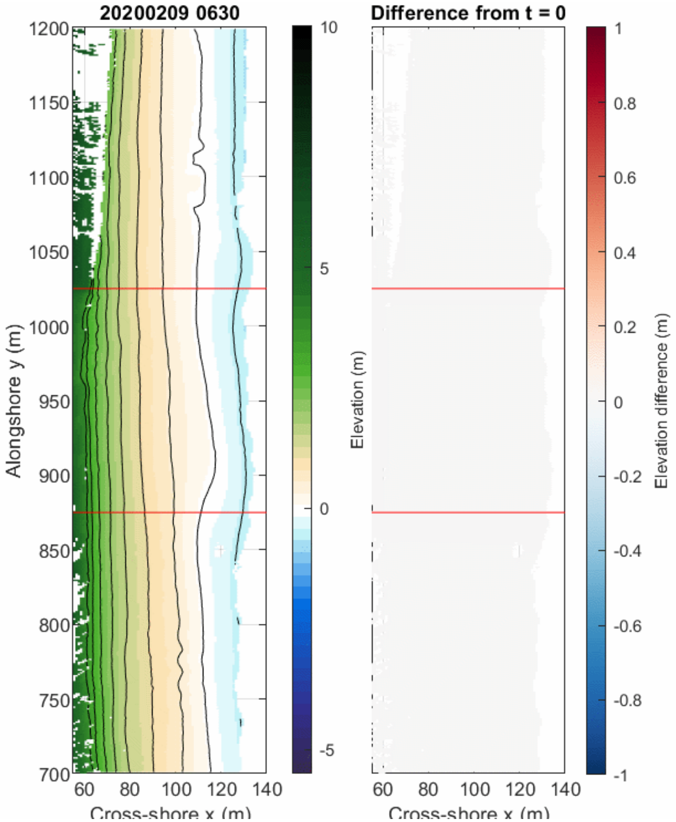
5 EXPANSION OF LONG-TERM MONITORING DATA

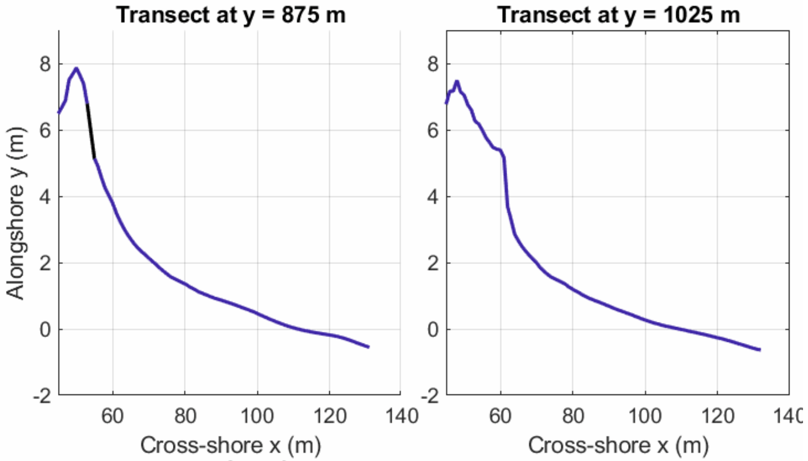
→ Observations can be made routinely at process-relevant time-scales and spatial scales

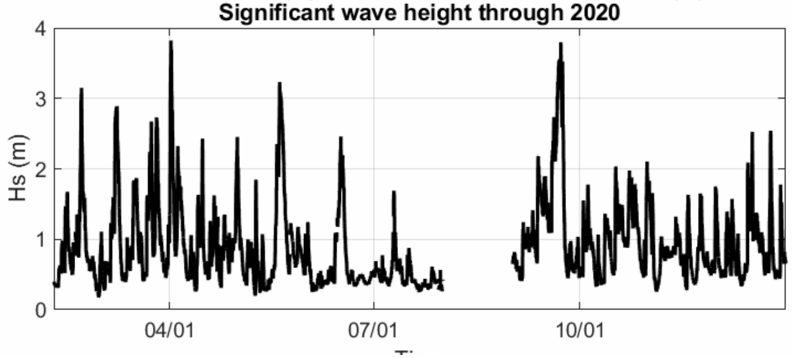
- Hydrodynamics: **high spatial-resolution wave resolving measurements**
- Morphology: **evolution at the time-scale of waves during storms; fully 3D**, regional spatial scales









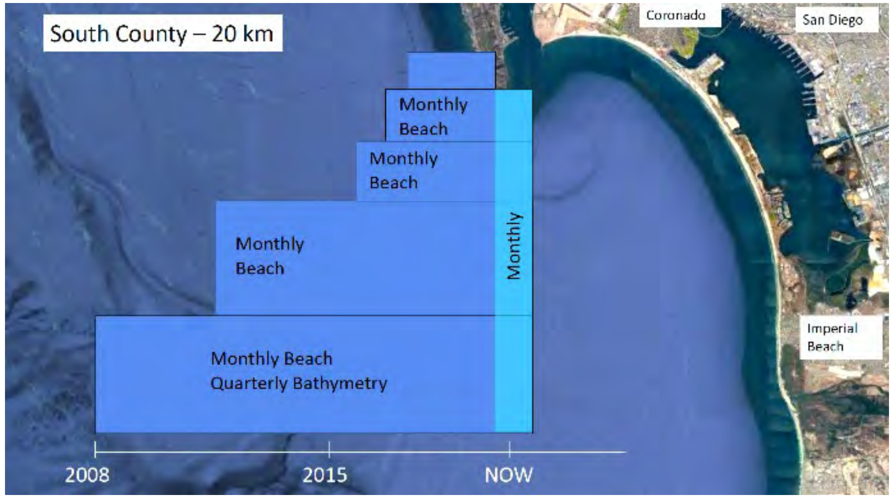


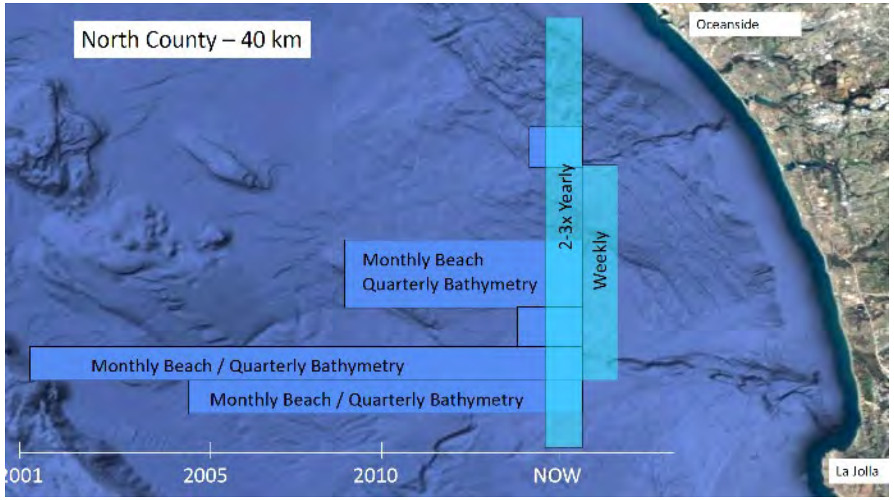
Funded by the USACE Coastal Field Data Collection Program

5 EXPANSION OF LONG-TERM MONITORING DATA

→ Observations can be made routinely at process-relevant time-scales and spatial scales
- Hydrodynamics: high spatial-resolution wave resolving measurements
- Morphology: evolution at the time-scale of waves during storms; **fully 3D, regional spatial scales**

Example: SIO Beach Monitoring Program (images courtesy A. Young)





Funded by the USACE Coastal and Ocean Data Systems Program

NEXT DECADE ADVANCEMENTS

2014 Data Starved → 2024 Data Rich → 2034 Information Rich

1

2

3

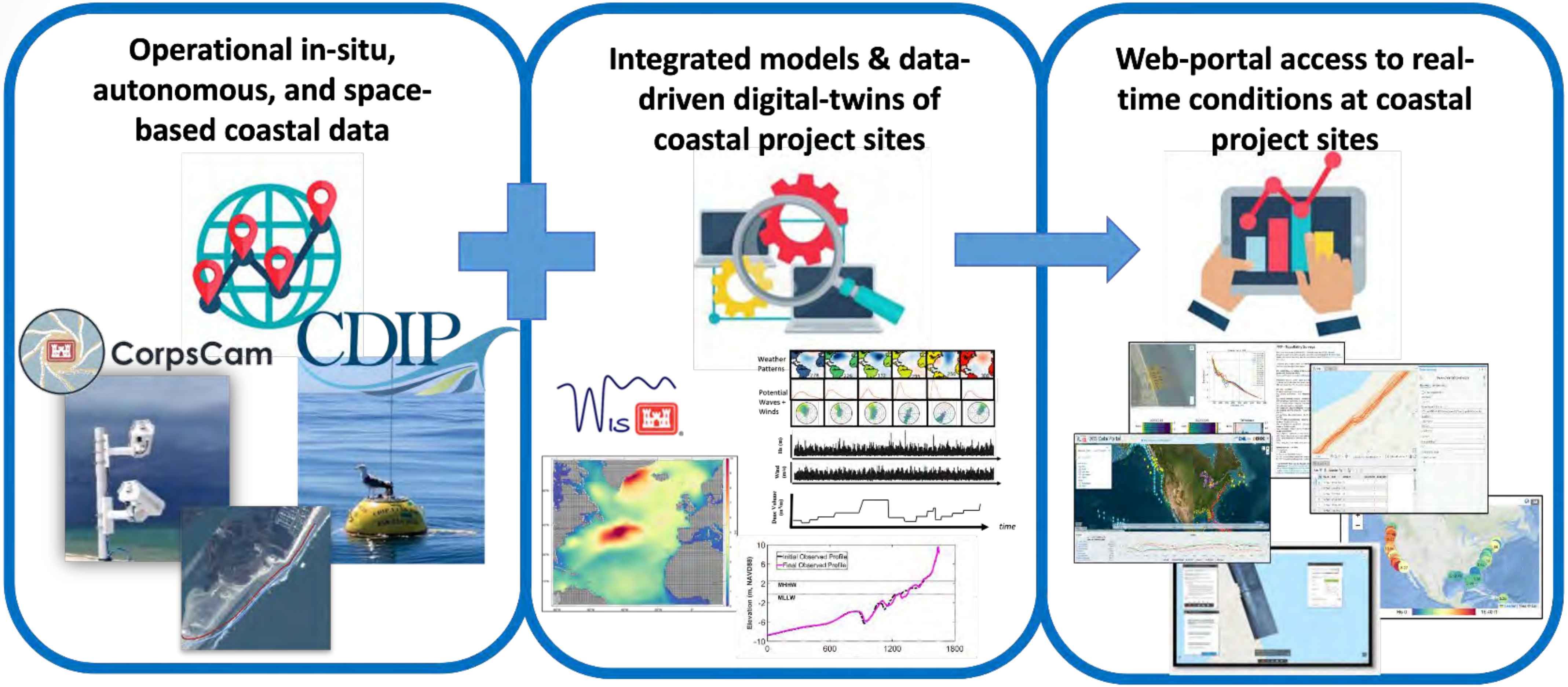
4

5

?

USACE VISON FOR OPERATIONAL COASTAL MONITORING

Coastal Ocean Data Systems will provide Decision Support Tools to USACE Engineers at National scales supported by layered, operational <u>monitoring</u> and <u>modeling</u> of coastal evolution through integrated <u>big coastal data</u>.



COASTAL PROCESSES R&D → OPERATIONS ROAD MAP

R&D Focus Areas

National-scale Operational Coastal Monitoring Technology

→ Helps provide answers now & informs engineering actions.

Probabilistic Multi-Scale Modeling Capabilities

→ Better communicates risk & uncertainty in our predictions.

Targeted Basic Research on Coastal Processes

→ Builds new understanding to improve future answers to targeted questions

Vision: Seamless integration of Academic Basic R&D, Agency Applied & Operational Tech. Development, End-User Operations

Multi-Echelon Support (Funding support, end-user & community input, Gov agency synchronization)

Cohesive strategy and development goals to meet Tactical & Strategic Goals.

Collaborative R&D integrating modeling and observation capabilities from academic partners, government researchers, commercial entities, and end-users

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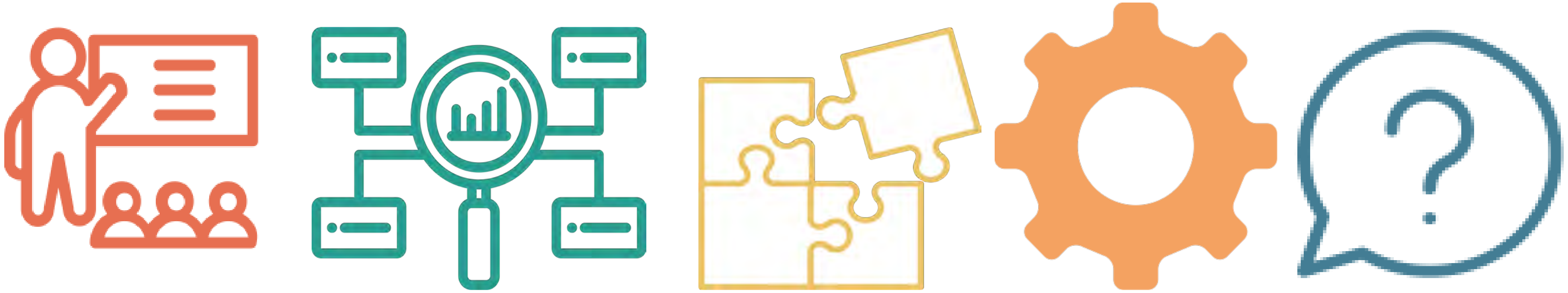
BREAKOUT #3

Tools and Approaches to Support Solutions

How the Agenda is Built

Working through challenges and solutions to actionable research

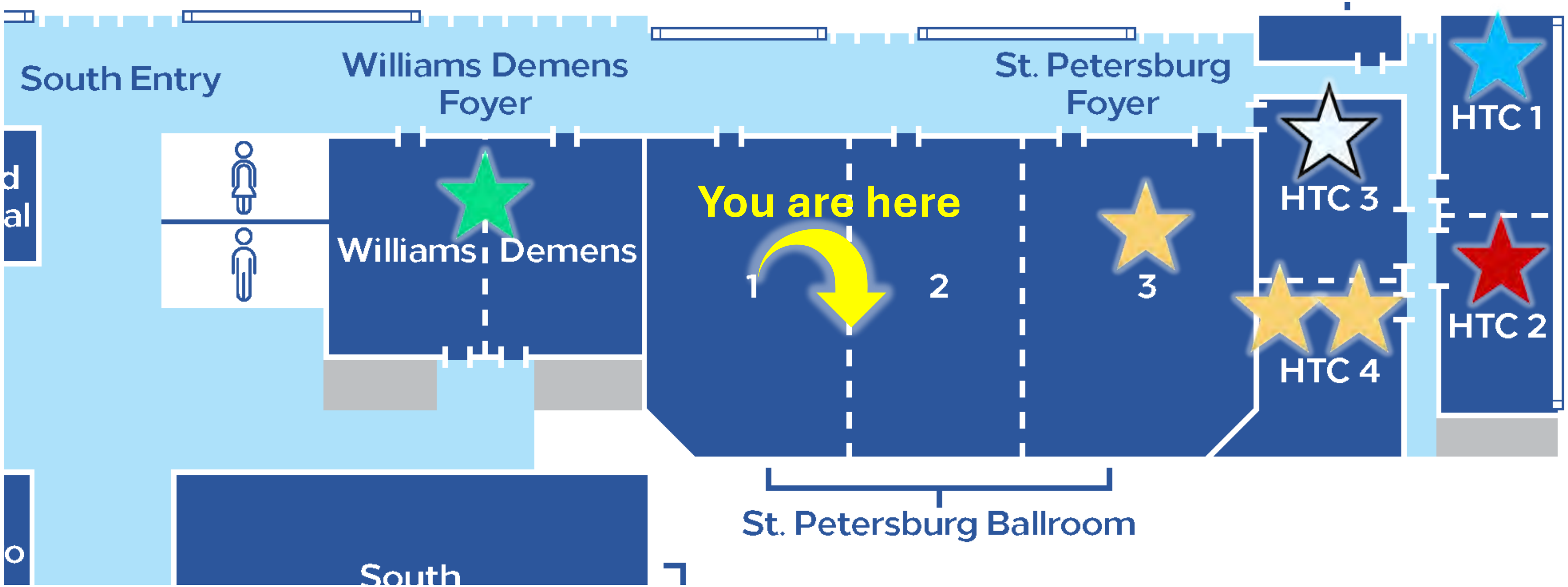


Presentations → *Community Needs* → *Co-Developed Solutions* → *Tools and Approaches* → *Research Questions*

Breakout Session Instructions

WHAT'S MY BREAKOUT ROOM?

Your badge has a star on it that corresponds to one of the following breakout rooms:



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JUNE 11 – JUNE 13

Hilton St. Petersburg Bayfront – 333 1st Street, SE

Decadal Visioning Workshop

THE FUTURE OF COASTAL PROCESSES RESEARCH

2024

Break

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2024

Research Example: Sediment Transport

Greg Wilson, Associate Professor, Oregon State University

Sediment Transport

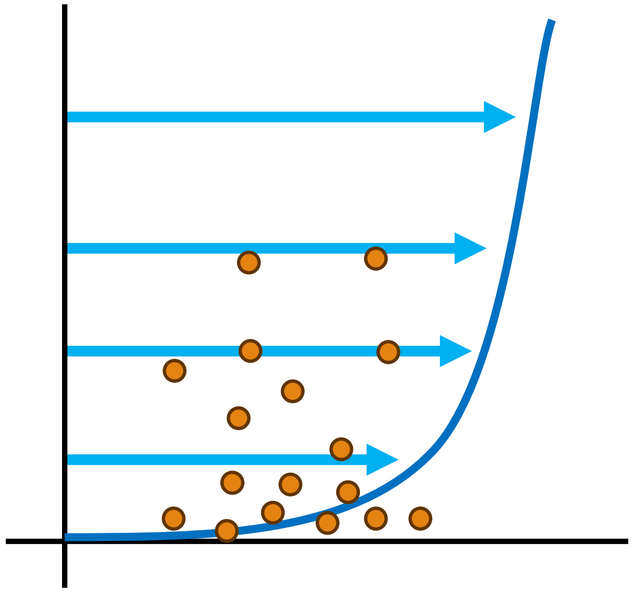
With Opinions From: Greg Wilson
Based on Research With: Jack Aldrich, Alex Hay, Steve Henderson, Pat Dickhudt

US Nearshore Decadal Visioning Workshop – June 14, 2024

Oregon State University
College of Earth, Ocean, and Atmospheric Sciences

Outline

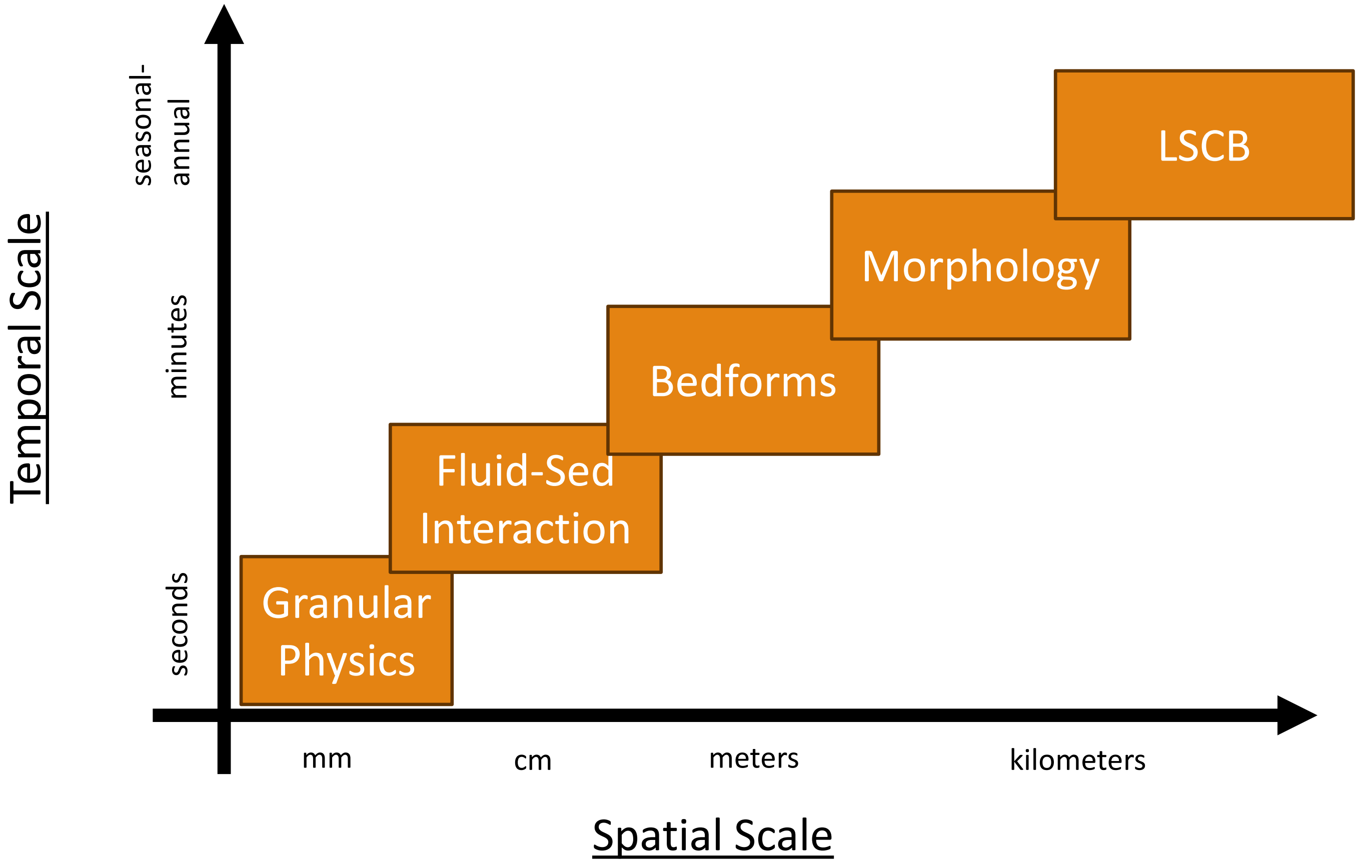
1. Research landscape – theory and applications across scales
2. Some recent research (fun)
3. Challenges & research gaps
4. ~~Path forward~~ (tomorrow morning)



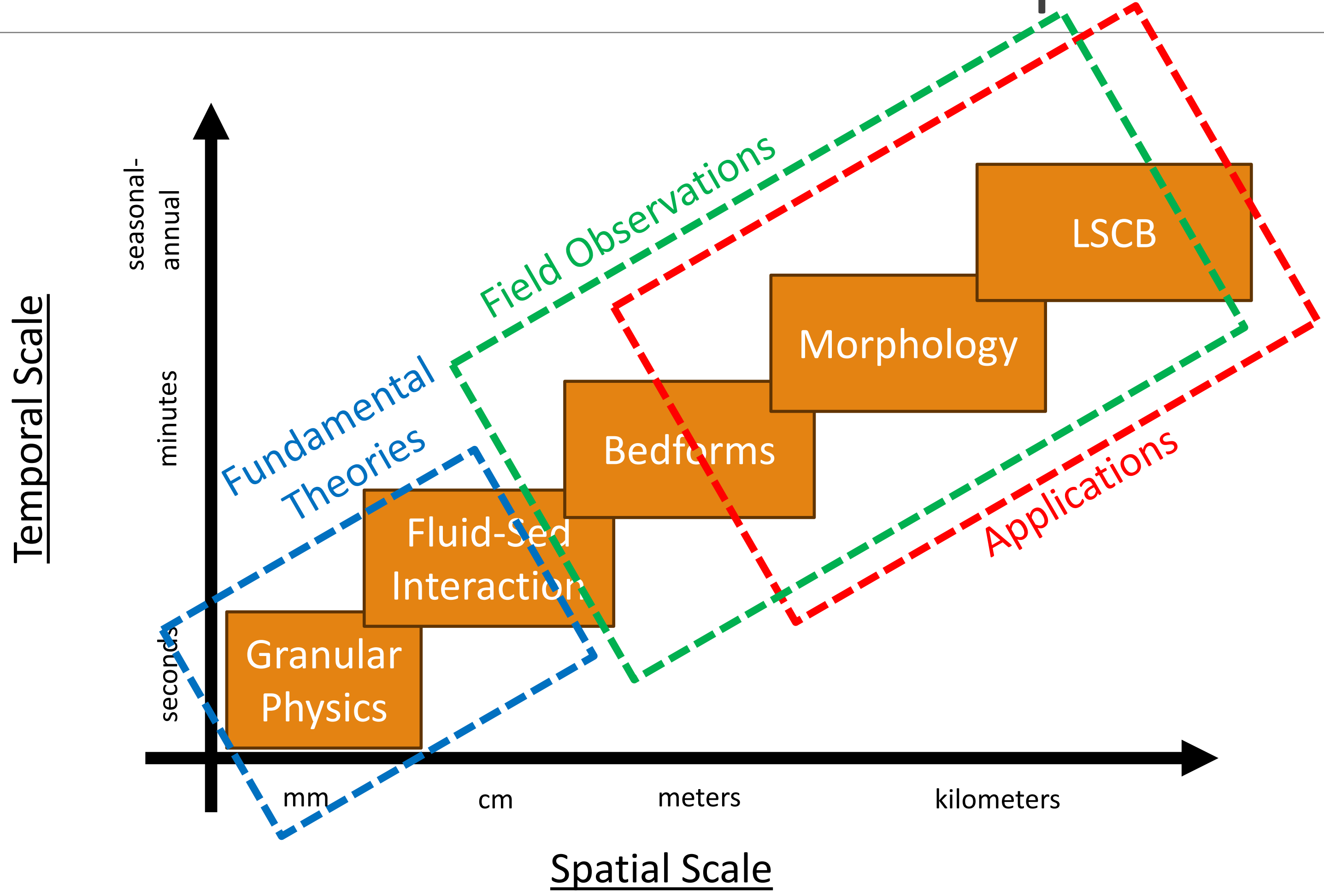
Scope: What is Nearshore Sediment Transport?

1. Mobilization of sand under nearshore waves and currents
2. Transport of sand, and subsequent changes to the bed
3. Feedbacks (coupling with nearshore hydrodynamics)

Scales of Sediment Transport



Scales of Sediment Transport



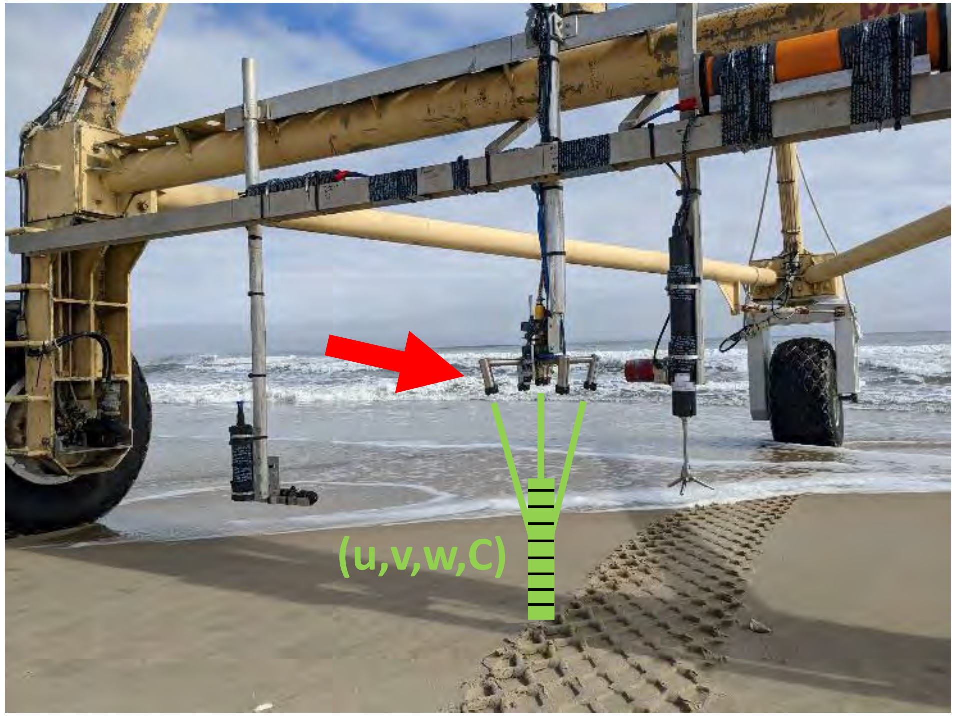
Blasstex – testing basic theories in the field

USCRP-Funded project: *Can we directly measure sediment transport processes and test models?*

<u>MFDop Instrument</u>:

- Brainchild of Alex Hay, Len Zedel & Nortek (~1995-present)
- Technical specs:
  - Vertical profile: z = 0 – 0.25 m, 4 mm bin-size
  - Sampling rate: 60 Hz
  - Approx. 1.4-2.1 MHz bandwidth
  - Up to 4 discrete frequencies (tone-burst sequence)

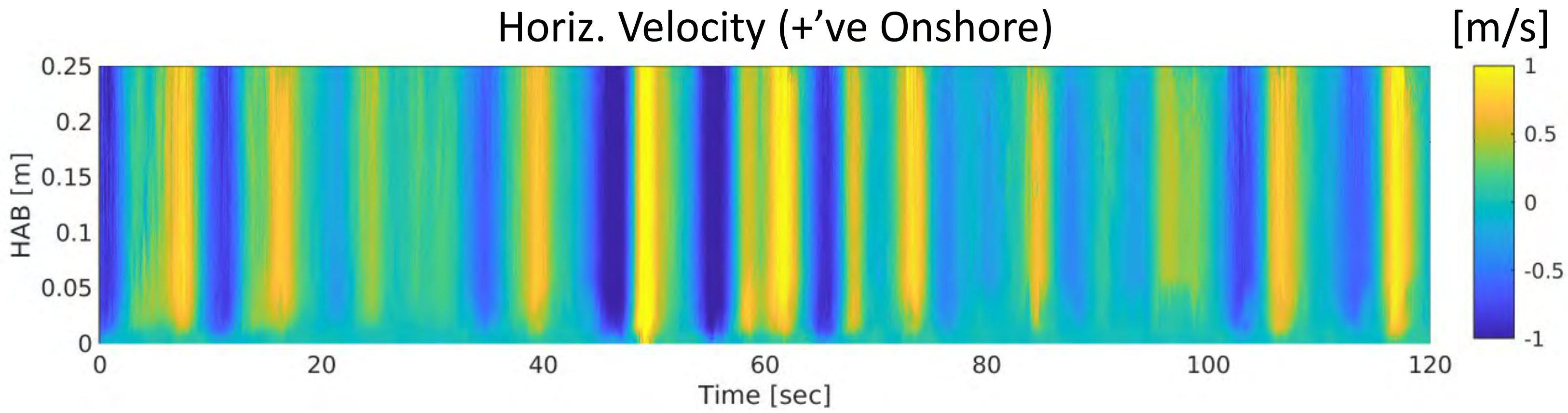
<u>Blasstex-2 frame</u>: MFDop, Aquascat (0.5,1MHz), Vector, bed-scanning sonar



Blasstex Field Data

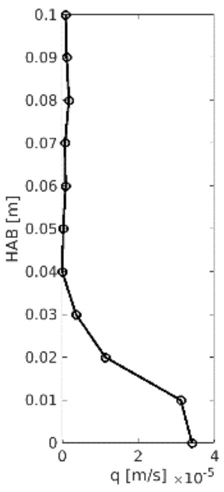
Waves near breakpoint

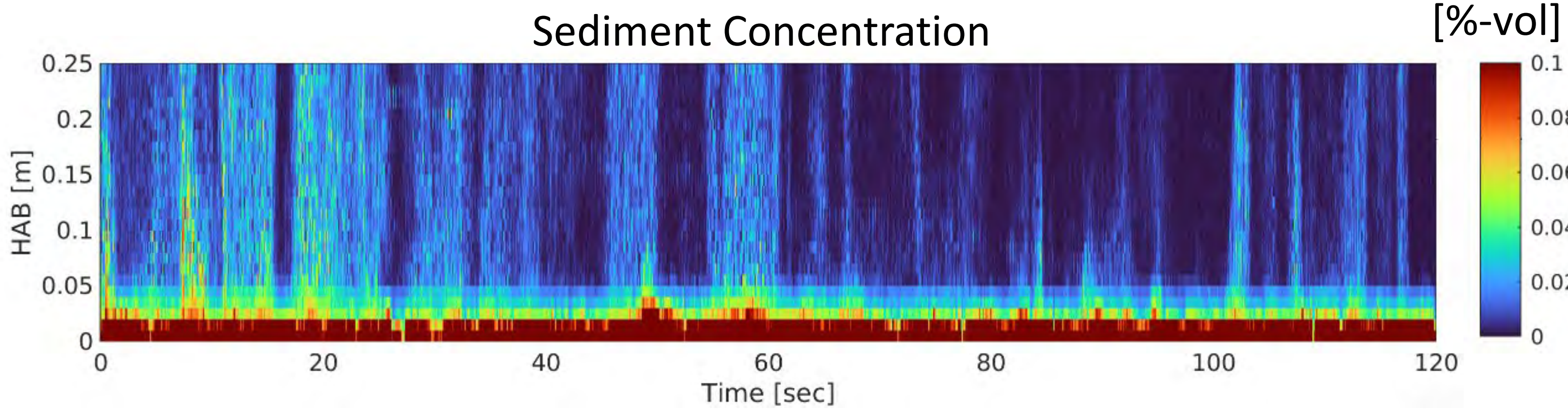
- H_{rms} = 0.8 m, h = 2.8 m, T = 11 s, A = -0.5, S = 0.3



Time-averaged sediment flux:

$$\langle q\rangle(z) = \langle u(z,t)c(z,t)\rangle$$

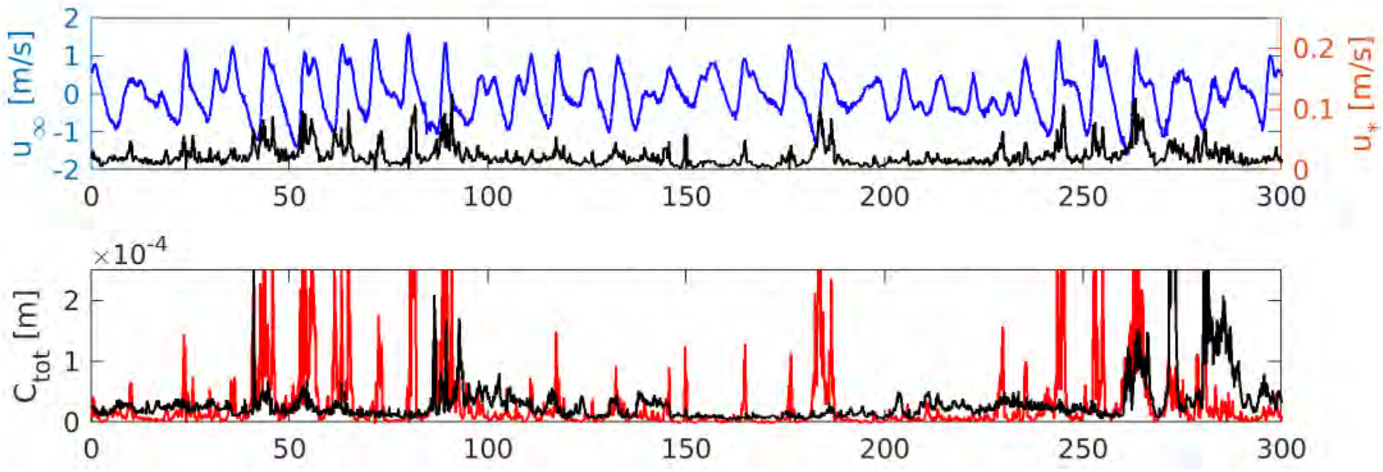




Model Validation

$$\langle C \rangle = \frac{\rho}{(\rho_s - \rho) g}\left[\frac{\epsilon_b}{\tan\phi}\langle u_*^2 \rangle + \frac{\epsilon_s}{w_s}\langle u_*^2 |u_\infty| \rangle\right]$$

- Time-dependent results
  - Black: Measured C(t)
  - Red: Model (using measured u_*)
- *Timing* of suspension events is good
- Errors come from sediment "burst" *magnitude*
  - Not every u_* event corresponds to a suspension event, and vice-versa

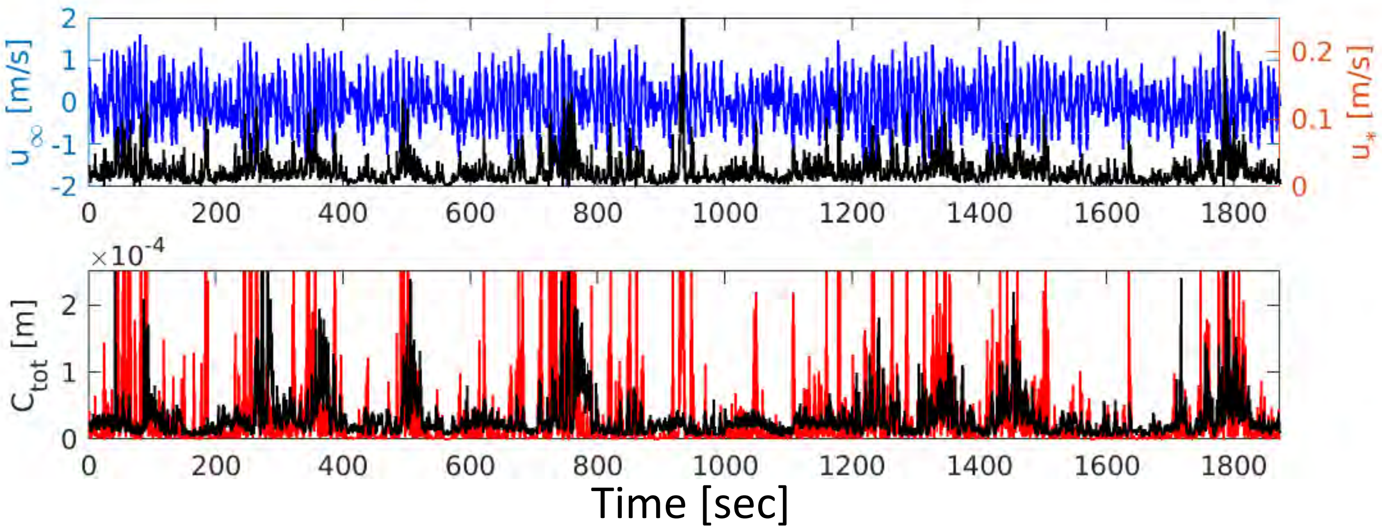


Time [sec]

Model Validation

$$\langle C\rangle = \frac{\rho}{(\rho_s-\rho)g}\left[\frac{\epsilon_b}{\tan\phi}\langle u_*^2\rangle + \frac{\epsilon_s}{w_s}\langle u_*^2|u_\infty|\rangle\right]$$

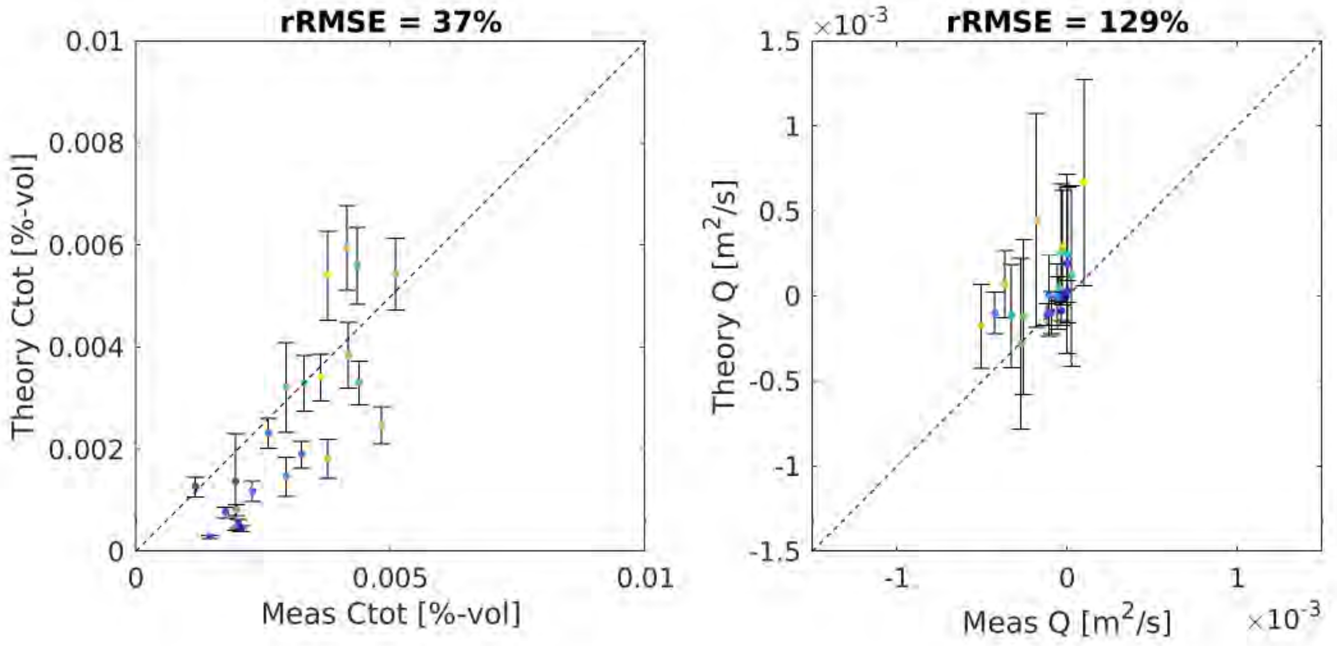
- **Zooming Out in Time:** Better correspondence can be seen, *on average*



Model Validation

- Depth- and time-averaged sediment concentration and transport
- Data includes range of skewness, asymmetry, breaking

→ After enough averaging, the model looks pretty accurate



Prospects for Observational Research

"The more we invest in funding sediment transport field measurements, the less we seem to understand about sediment transport." **(Anon, ca. 90's)**

- Why is this? Data suggests it's because of intermittency at small scales.
- *Lots of averaging* is required
  - Spatial: Must resolve full vertical profile
  - Time: Need to average over many waves. ~3.5x more than for wave stats
- Only recently have we been able to average through the noise, as necessary for testing theories

Sediment Transport as a Research Field

"You should work on sediment transport just as a hobby. Save your main research for something more mature and tractable." **(Anon)**

- What defines a viable/mature field of research?
  1. Rigorous theoretical basis (e.g., Navier Stokes Equations)
  2. Applications: Predictions of the theory (e.g., wave hydrodynamics)
  3. Observations: Testing of the predictions
- When a field has these things, we have a machine for solving problems
- Does sediment transport meet these criteria?

Reviews of Geophysics   Vol. 5, No. 3   August 1967

Longshore Current Velocity: A Review of Theory and Data

Cyril J. Galvin, Jr.

Lack of observations

Abstract. A proven prediction of longshore current velocity is not available, and reliable data on longshore currents are lacking over a significant range of possible flows. Theoretical studies have been based on over-simplified models, and empirical predictions have been hampered by lack of data. The empirically modified, momentum-flux theory now accepted as the best prediction is based on an untenable assumption and supported by inappropriate data. Regardless of their validity, however, all six of the testable equations agree fairly well with at least one of six sets of published data, and two agree with both of the better sets of data. These two equations may be used as empirical guides for velocity prediction in the absence of a proven theory. The best prospect for a generally valid velocity prediction appears to be an empirical correlation based on reliable data.

No rigorous theoretical basis

Theoretical Sediment Transport

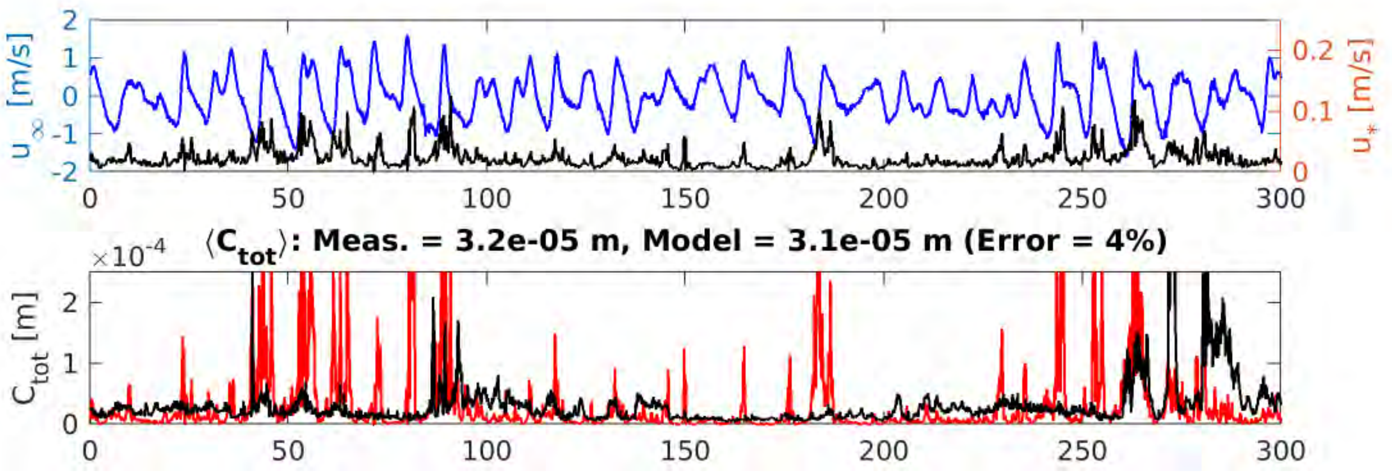
We have excellent **fundamental ideas** to draw upon...

- *High-resolution modeling (CFD, DNS, LES, ...)*
- *Rheology of granular mixtures, phenomenological approaches*
- *Stochastic advection-diffusion theory, intermittency*
- *Theories for emergent behavior and pattern formation*
- *Thermodynamics / Statistical Physics*
  - *Kinetic gases*
  - *Bagnold's energetics concept*

Observational Sediment Transport

Given adequate field observations, *many* clear **testable research questions** come to mind:

- "Is there enhanced transport under asymmetric wave crests?"
- "Does sediment respond instantly to waves, or is there a phase lag?"
- "Why is it so intermittent? Do our theories predict that?"
- "Do our equations for longshore transport (CERC) hold up?"
- etc. etc. etc.



Possible Breakout Discussions

- Teaching. How do we train (and recruit) students in sediment transport?
  - A series of practical formulas?
  - Fundamentals and theoretical underpinnings?
- What's the most optimal way to direct research funding?
  - Observational programs?
  - Theoretical development?
  - Graduate training?
- What would a "N. American School" of sediment transport look like?

Thank you

Thanks to Field Crews:

June Marion, Richard Cheel, Jason Pipes, Chris Thoburn, Jenna Hare, Luis Perez, Nathan Keane, Matt Conlin

OSU's MFDop Design/Fab Team:

Ben Russell, June Marion, Justin McCloud

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2024

Wrap up of Day 2

Linda Manning, President, The Council Oak LLC (Facilitator)

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THE FUTURE OF COASTAL PROCESSES RESEARCH