



Decadal Visioning Workshop 2024

**THE FUTURE OF COASTAL
PROCESSES RESEARCH**



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**

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

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



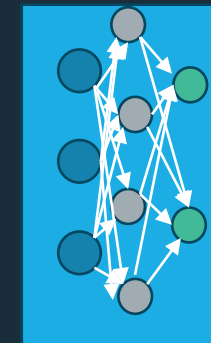
Model coupling with open-source code



Computational power – cloud and operational high-performance computing



Improved data and model data access



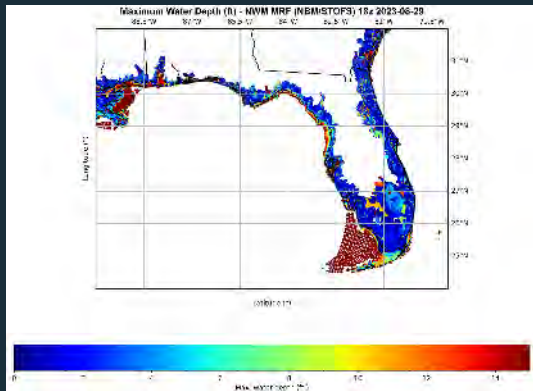
Meta-models and Machine Learning



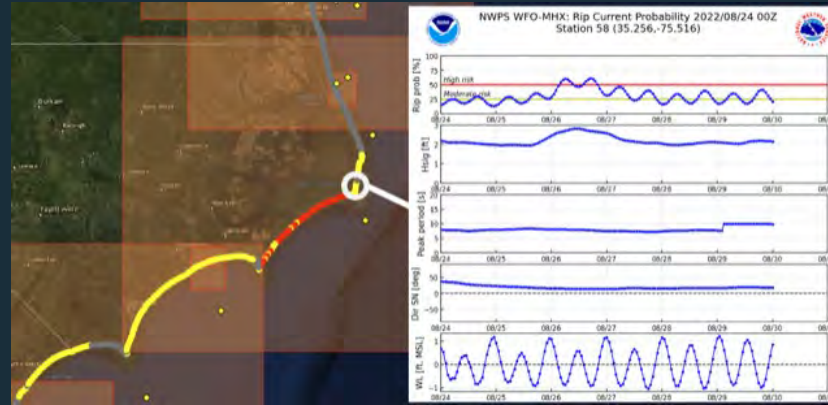
Better boundary conditions and longer lead times

Significant advancements: products

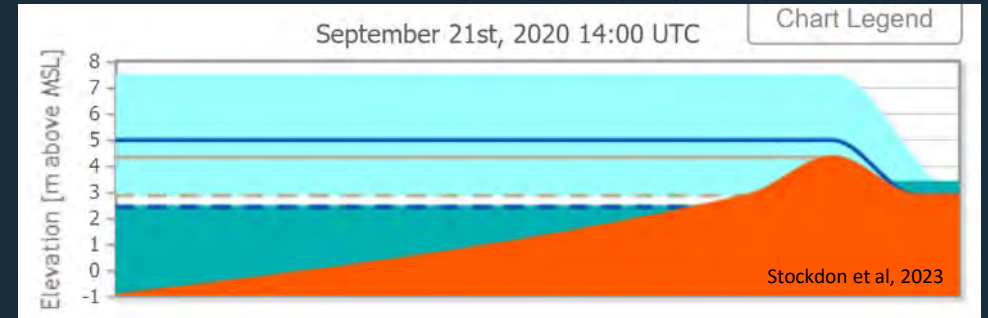
Compound Flooding
(National Water Model)



Rip Currents
(NOAA/Nearshore Wave Prediction System)



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



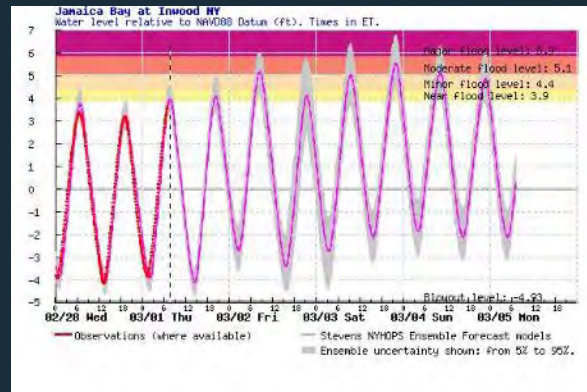
Impact Modeling
(NOPP Hurricane Coastal Impacts Project/Deltares)



Probabilistic information
(USACE Coastal Hazards Rapid Prediction System)



Ensemble forecasts
(Stevens Ensemble Flood Advisory System)



Significant advancements: impacts

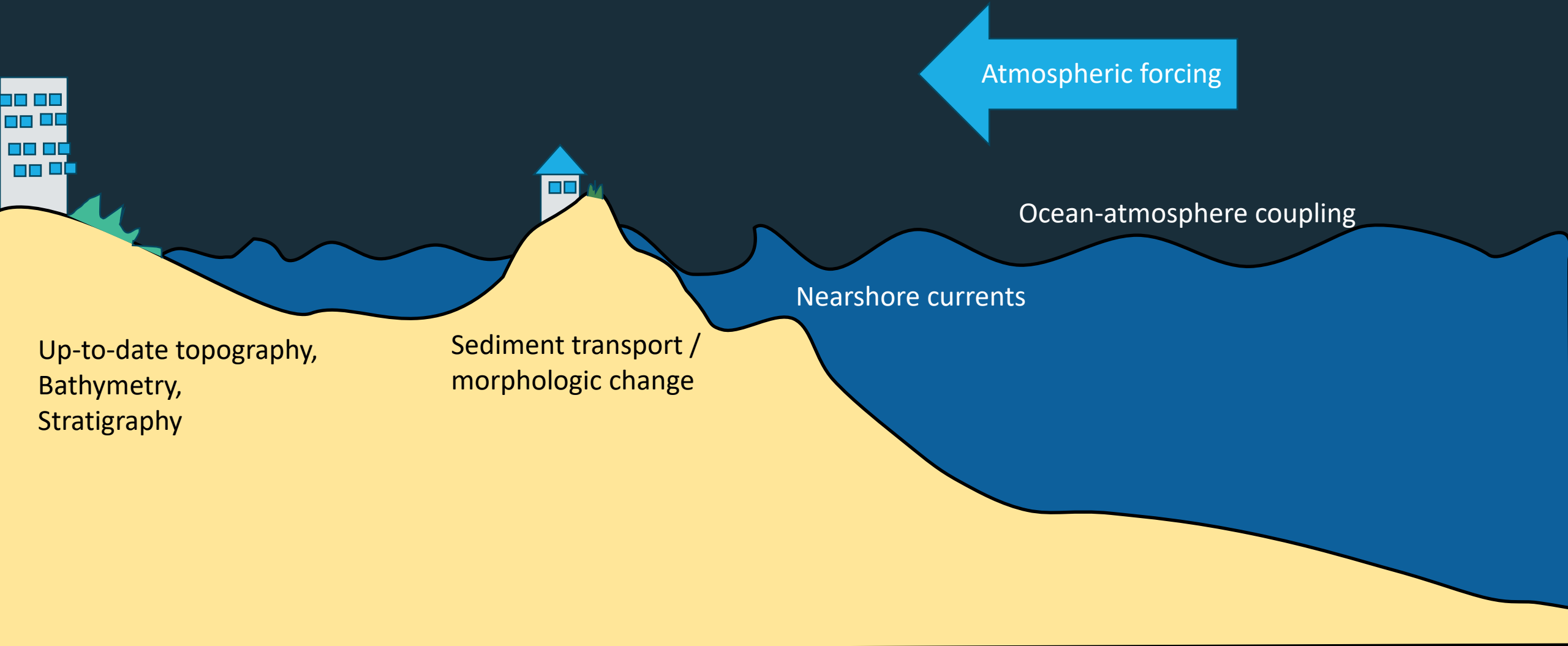


- More information
- More time to react
- Actionable information by including uncertainties

After Hurricane Idalia, Gulfport, Florida

Photo credit: Erica Harris

Technical challenges: processes and data



Technical challenges

01

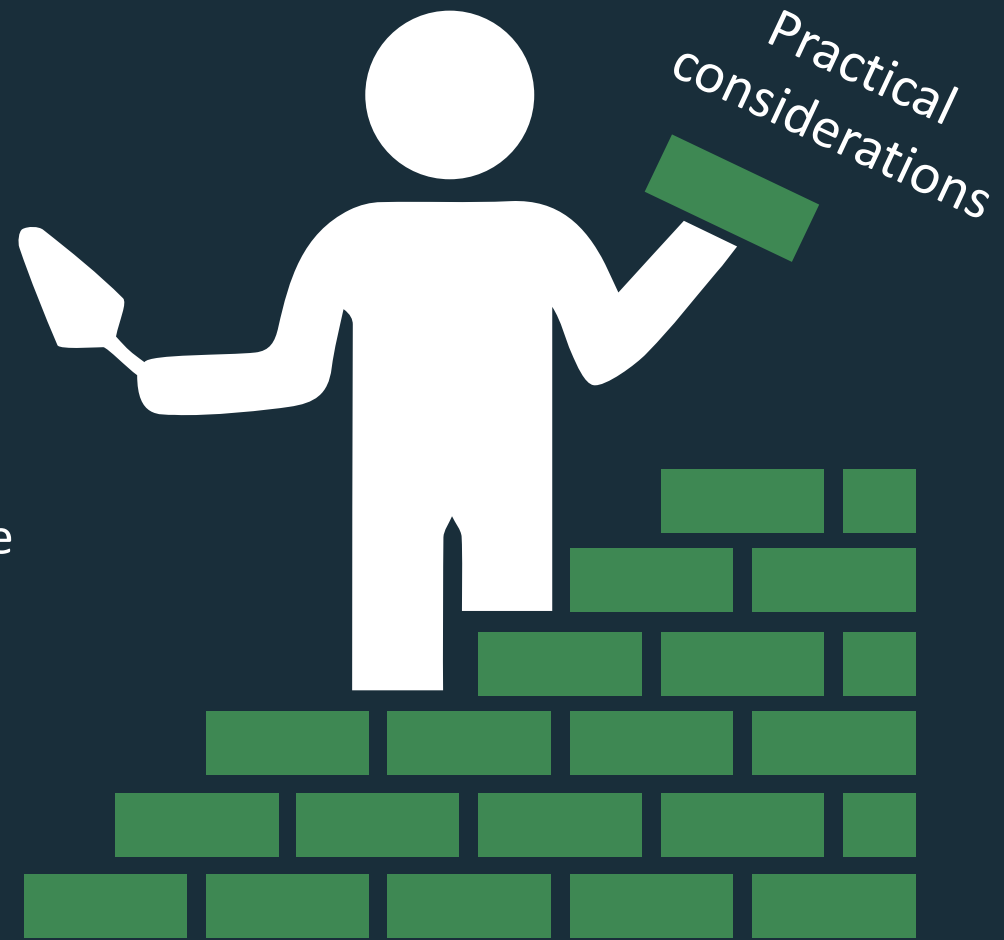
Computational limitations
Runtime limitations
Improving model efficiency

02

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

03

Cybersecurity



Non-technical challenges and opportunities: research community

Working collaboratively
to solve big problems

Communicating with
end users

Iterative R2O2R

R2O: Transitioning
developments



Workforce
development

Partnerships

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

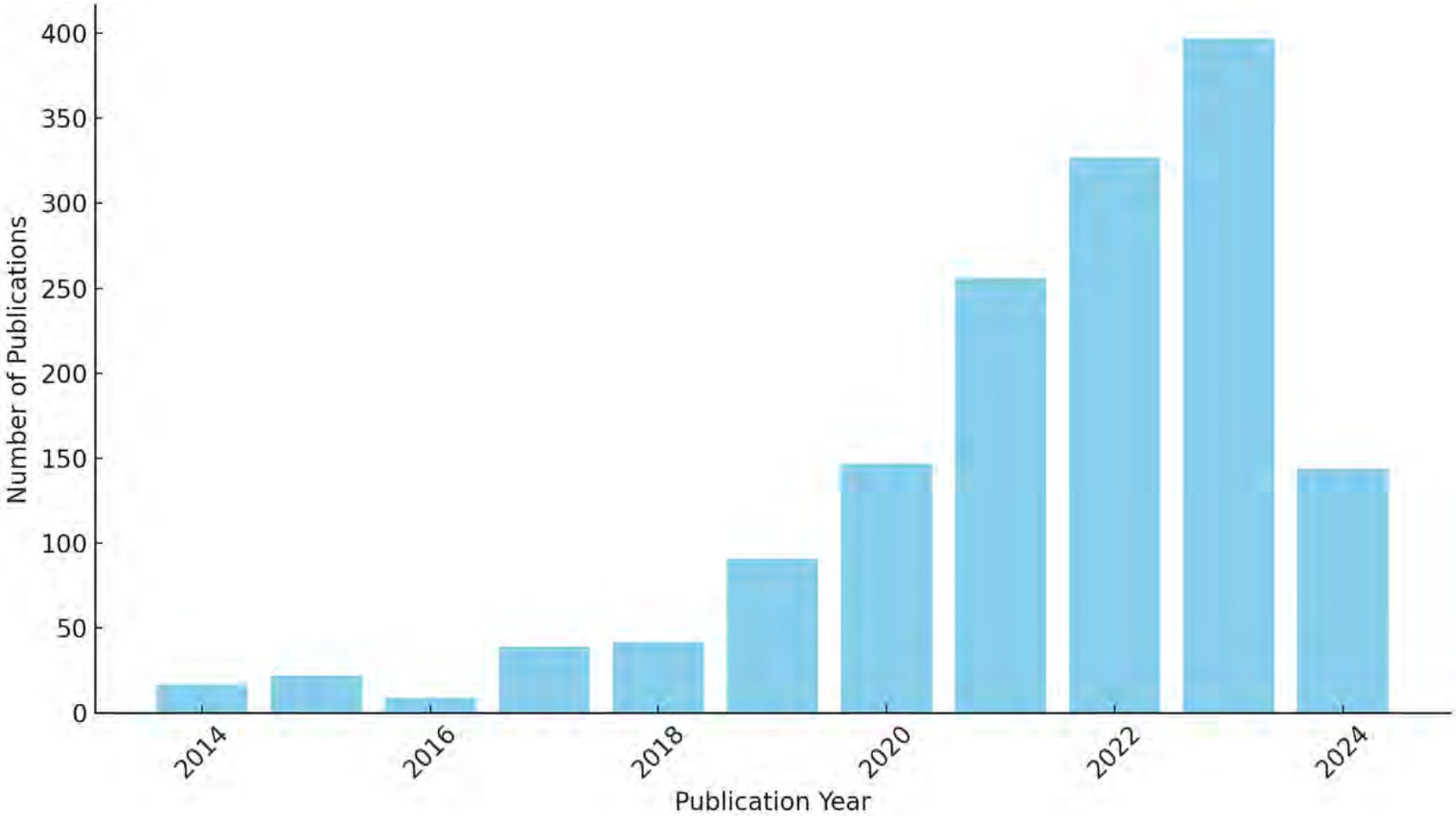
NOAA National Ocean Service

Applied Research Opportunities to Implement Solutions
2024 USCRP Decadal Visioning Workshop

June 12, 2024



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



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



ChatGPT

The Gemini logo, featuring the word "Gemini" in a blue sans-serif font with a small star above the 'i'. To the left of the text is the Google logo's four-colored 'G'.

The Claude logo, featuring a red starburst icon to the left of the word "Claude" in a black serif font.

BY ANTHROPIC

LLaMA
by  **Meta**



Grok

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**



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?

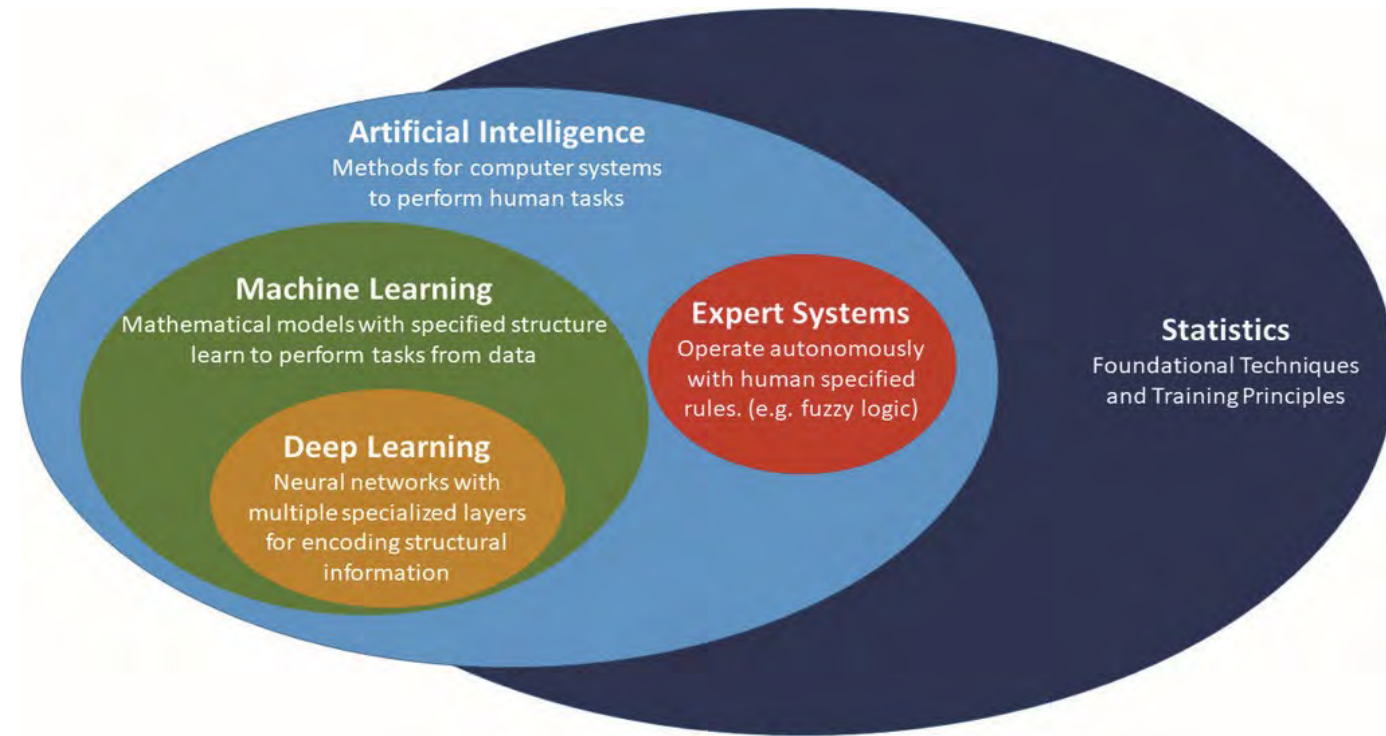
- Computer vision
- Prediction and forecasting
- Data analysis

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>.



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>

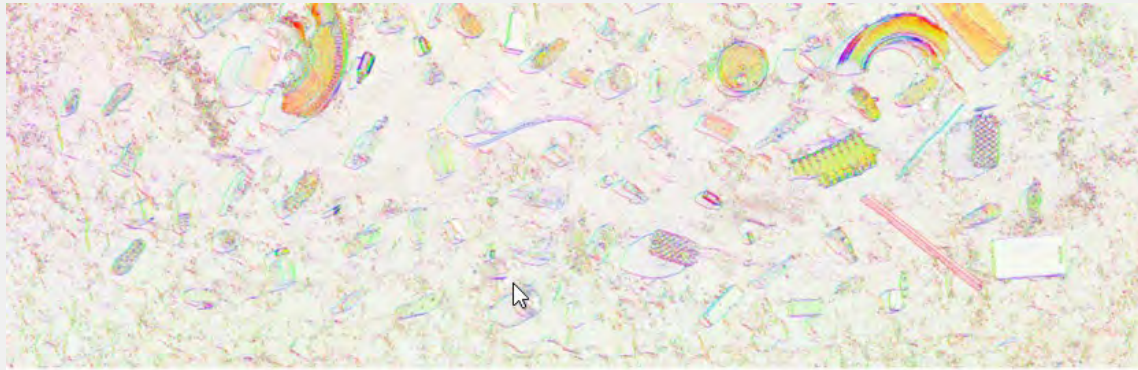
Goldstein EB et al (2019) A review of machine learning applications to coastal sediment transport and morphodynamics. EarthScience Reviews 194,97–108.

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>

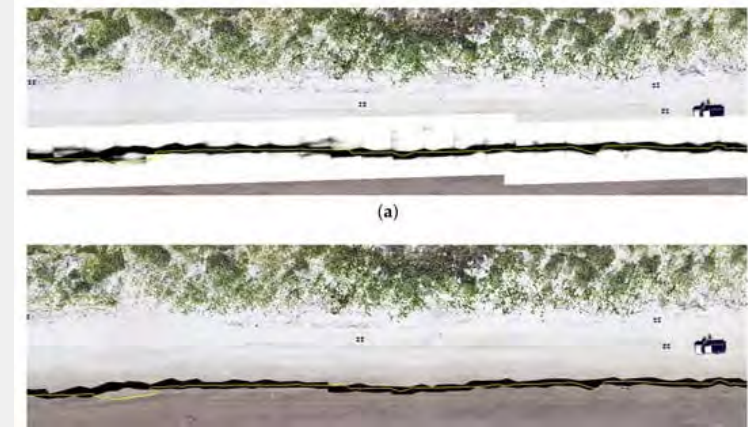
Computer Vision | Detection

Marine Debris Detection



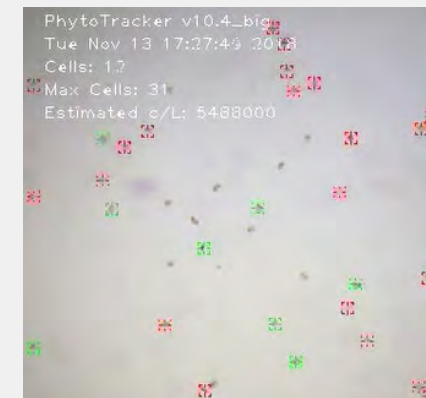
Parrish, C.E., et al. (2023) Uncrewed Aircraft Systems, Machine Learning, and Polarimetric Imaging for Enhanced Marine Debris Shoreline Surveys. Final Report. NOAA Technical Memorandum NOS NCCOS 312. Silver Spring, MD. 31 pp. doi: 10.25923/337h-k518

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>

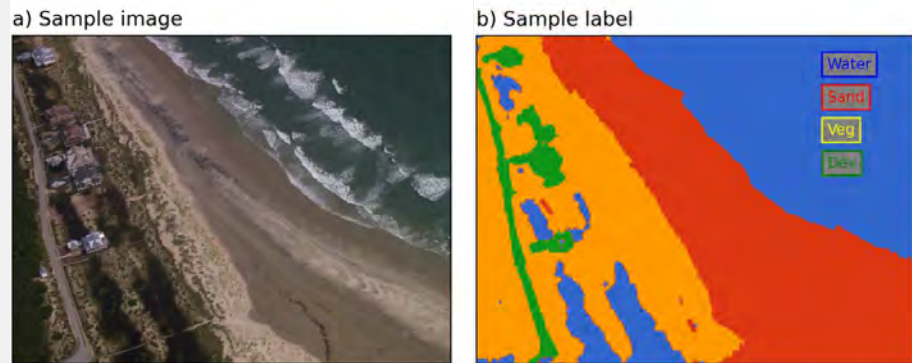
Computer Vision | Segmentation and classification

Flood segmentation in webcam imagery



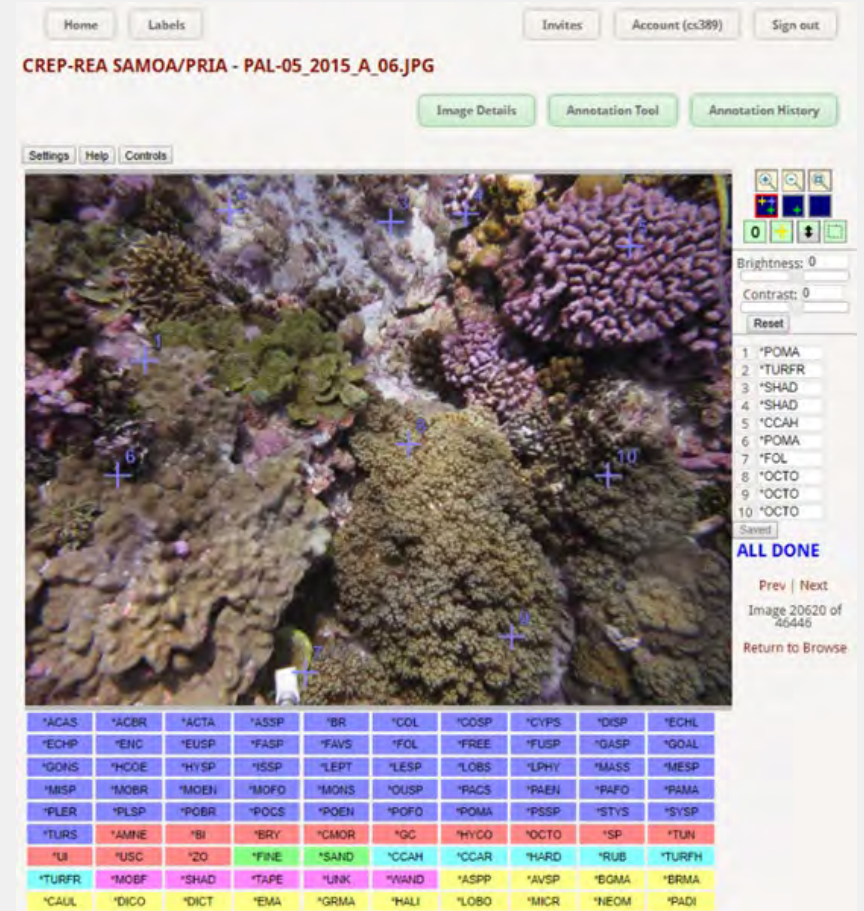
Wang et al. (2023) Urban flood extent segmentation and evaluation from real-world surveillance camera images using deep convolutional neural network. *Environ Model Softw* 105939. <https://doi.org/10.1016/j.envsoft.2023.105939>

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>

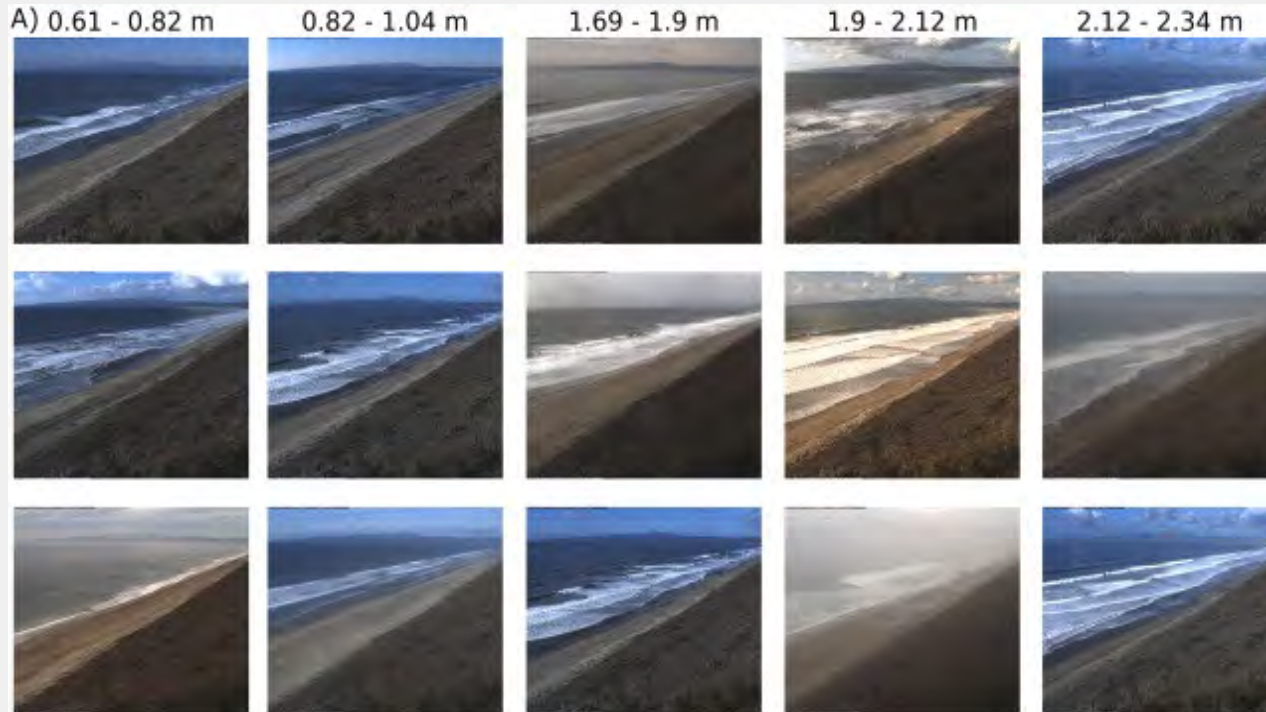
Point classification of benthic features



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*.

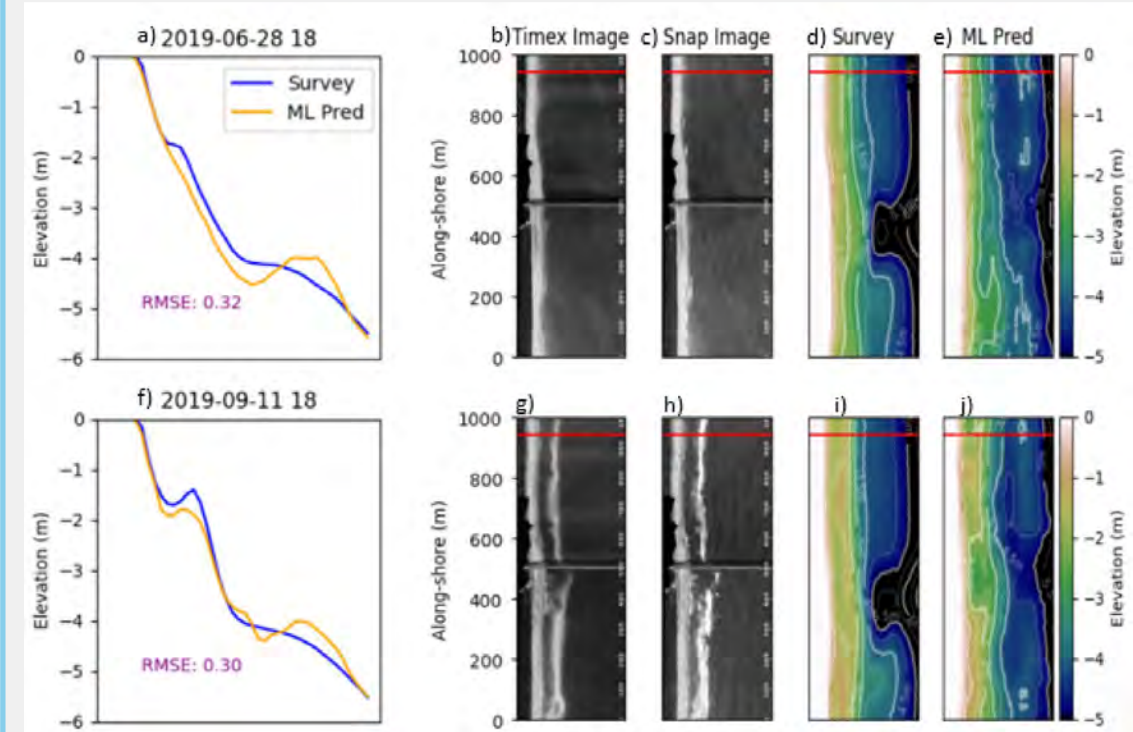
Computer Vision | Regression

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>.

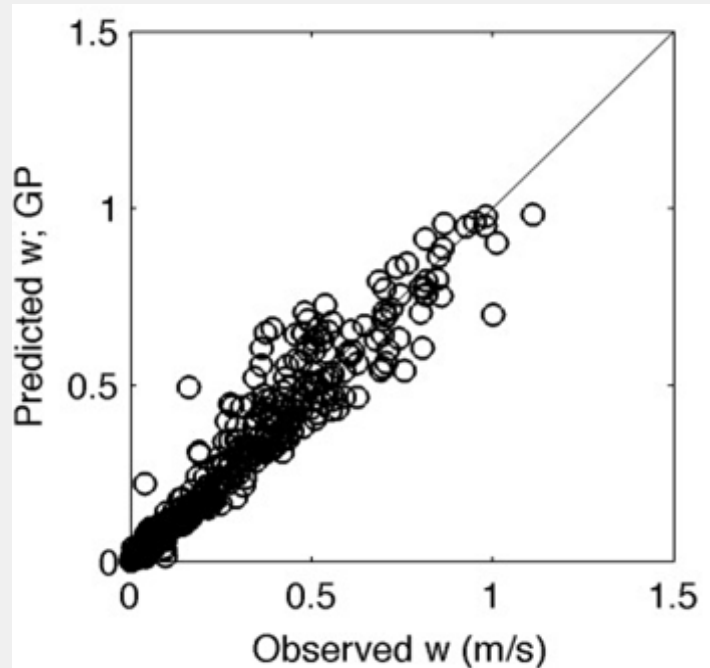
Surf zone bathymetry estimates from imagery



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>

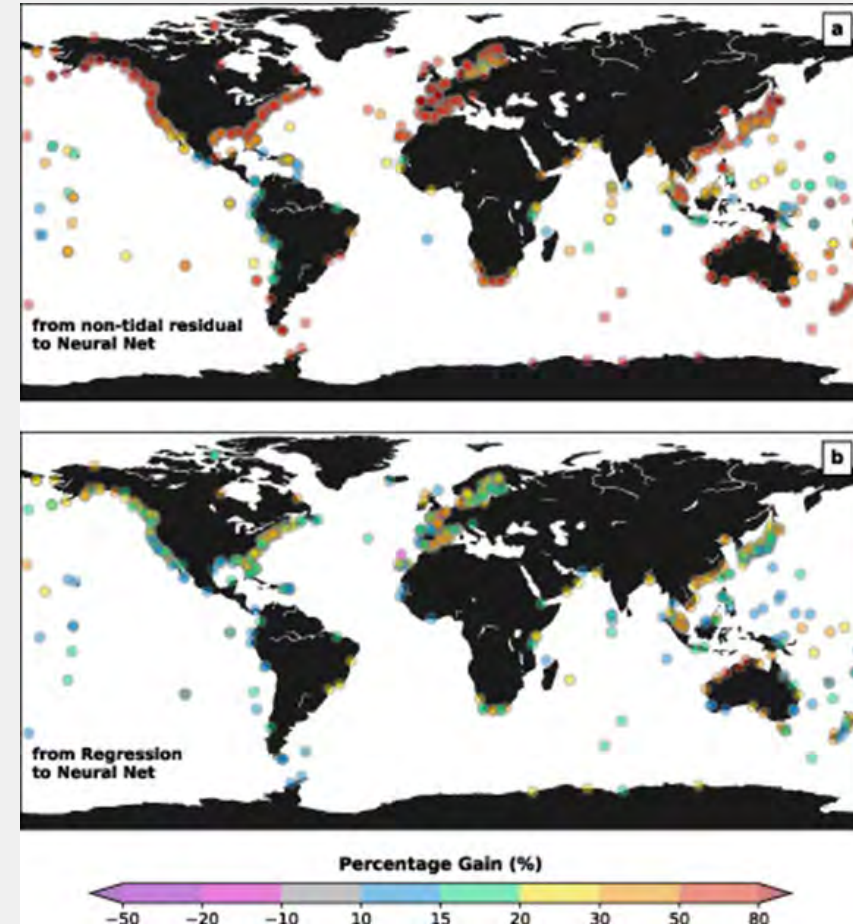
Prediction and Forecasting | Data driven models

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

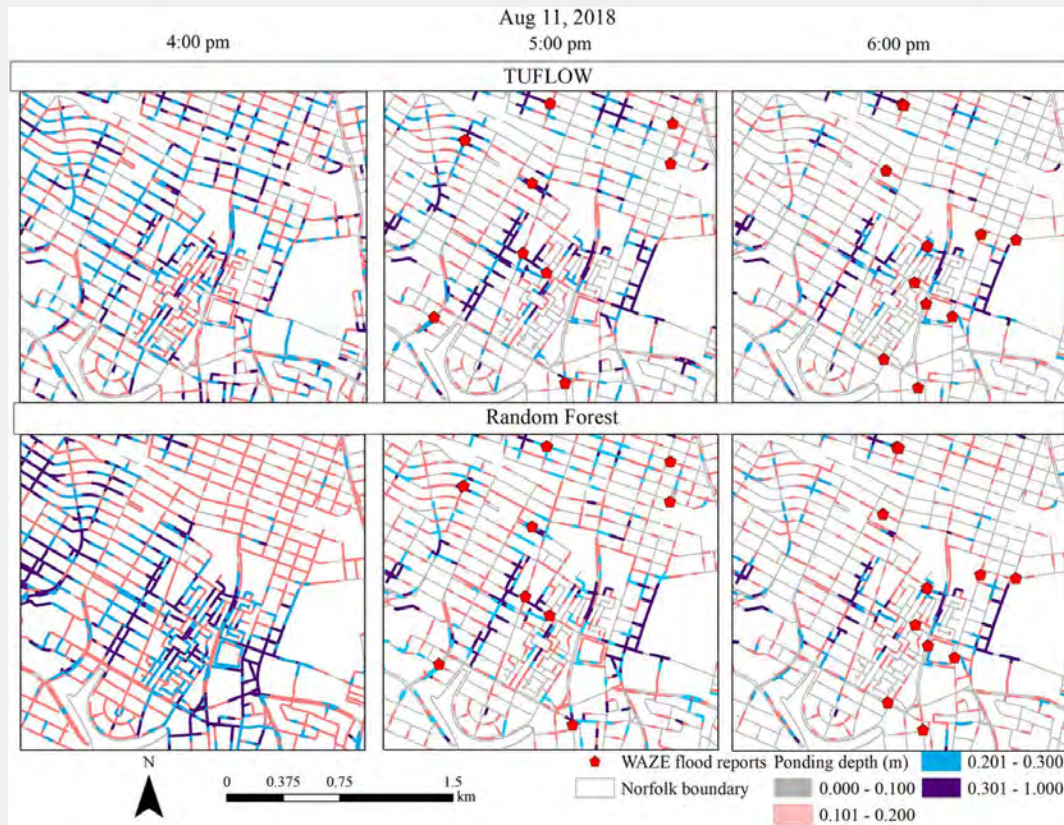
Prediction of non-tidal residual



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>

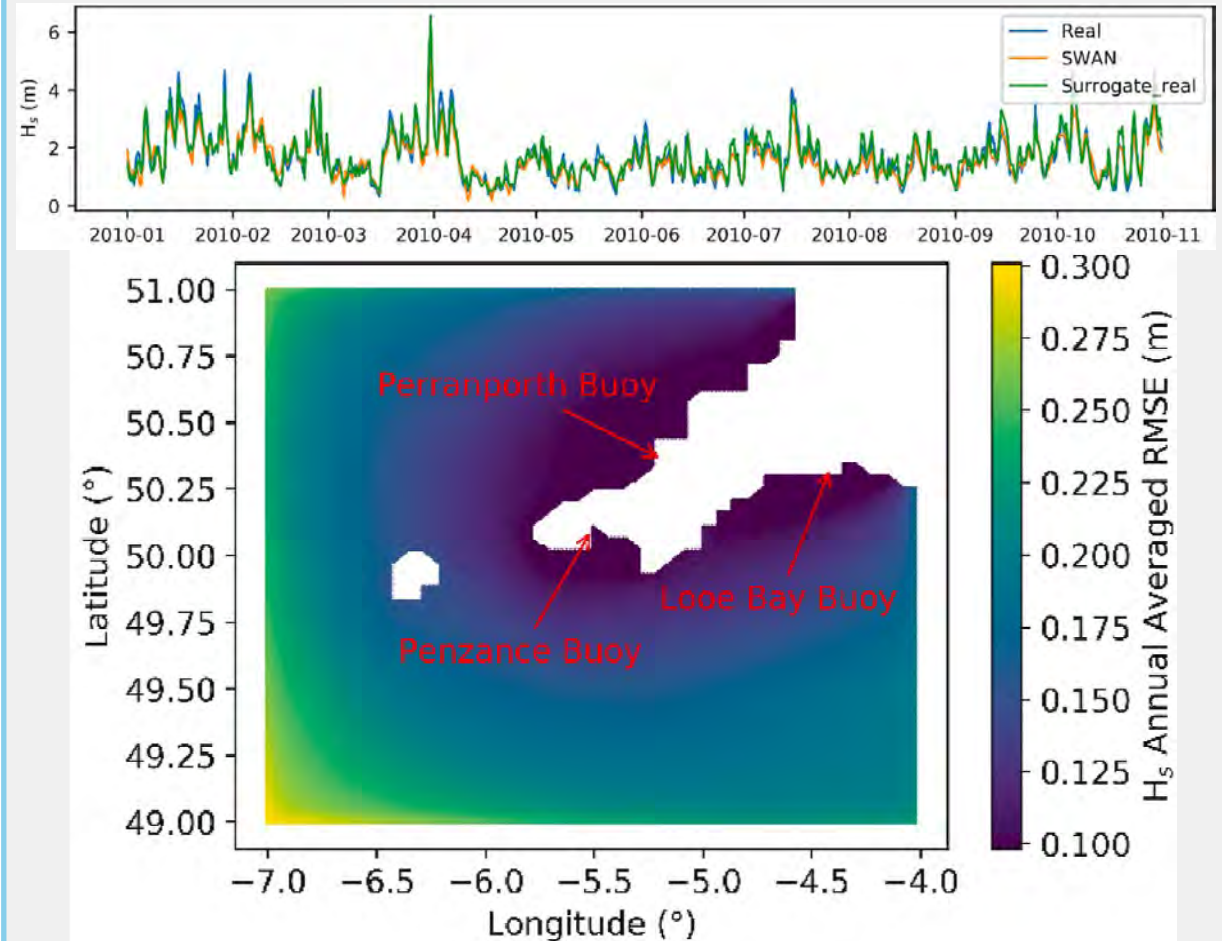
Prediction and Forecasting | Surrogate models

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>

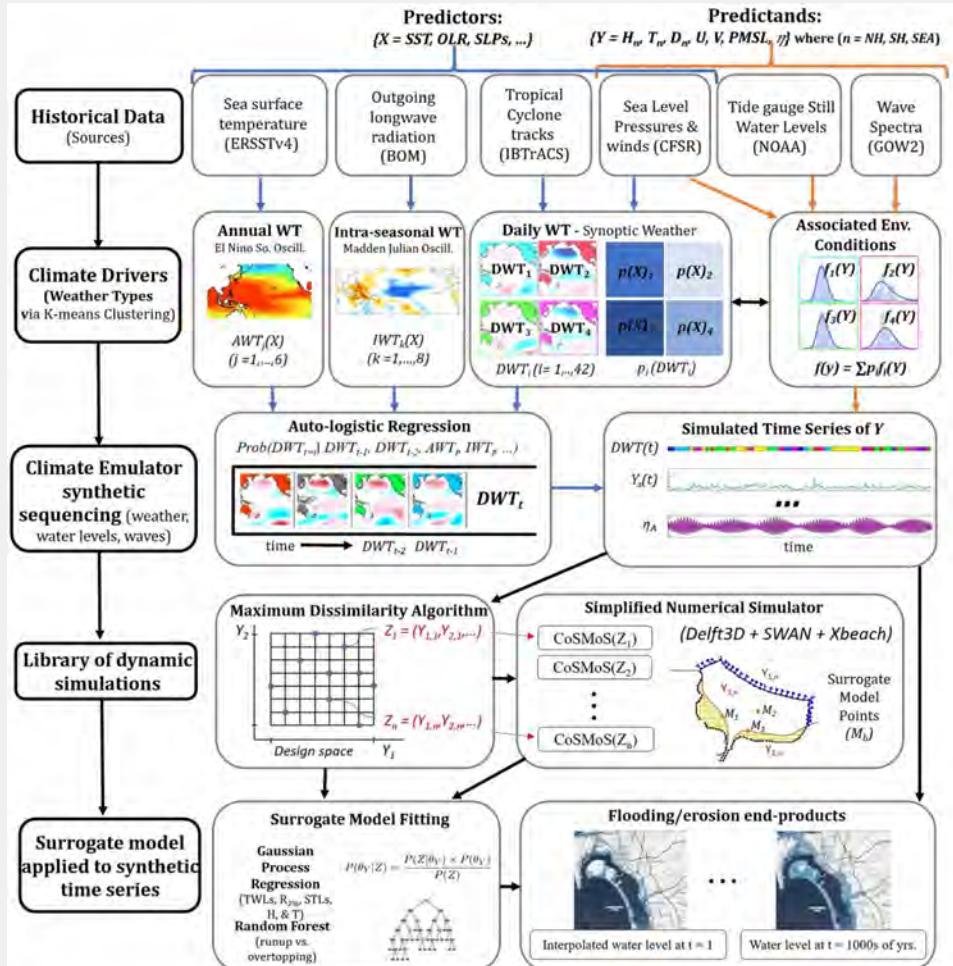
ML surrogate for wave model nowcasts



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>.

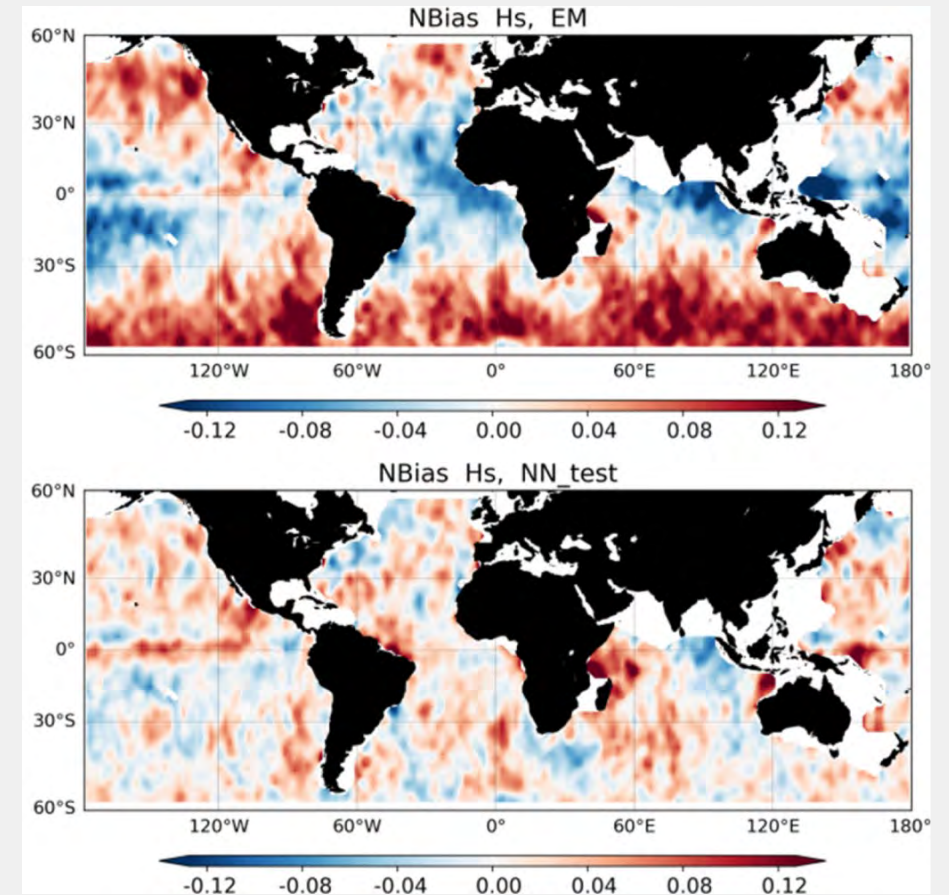
Prediction and Forecasting | Hybrid models

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>

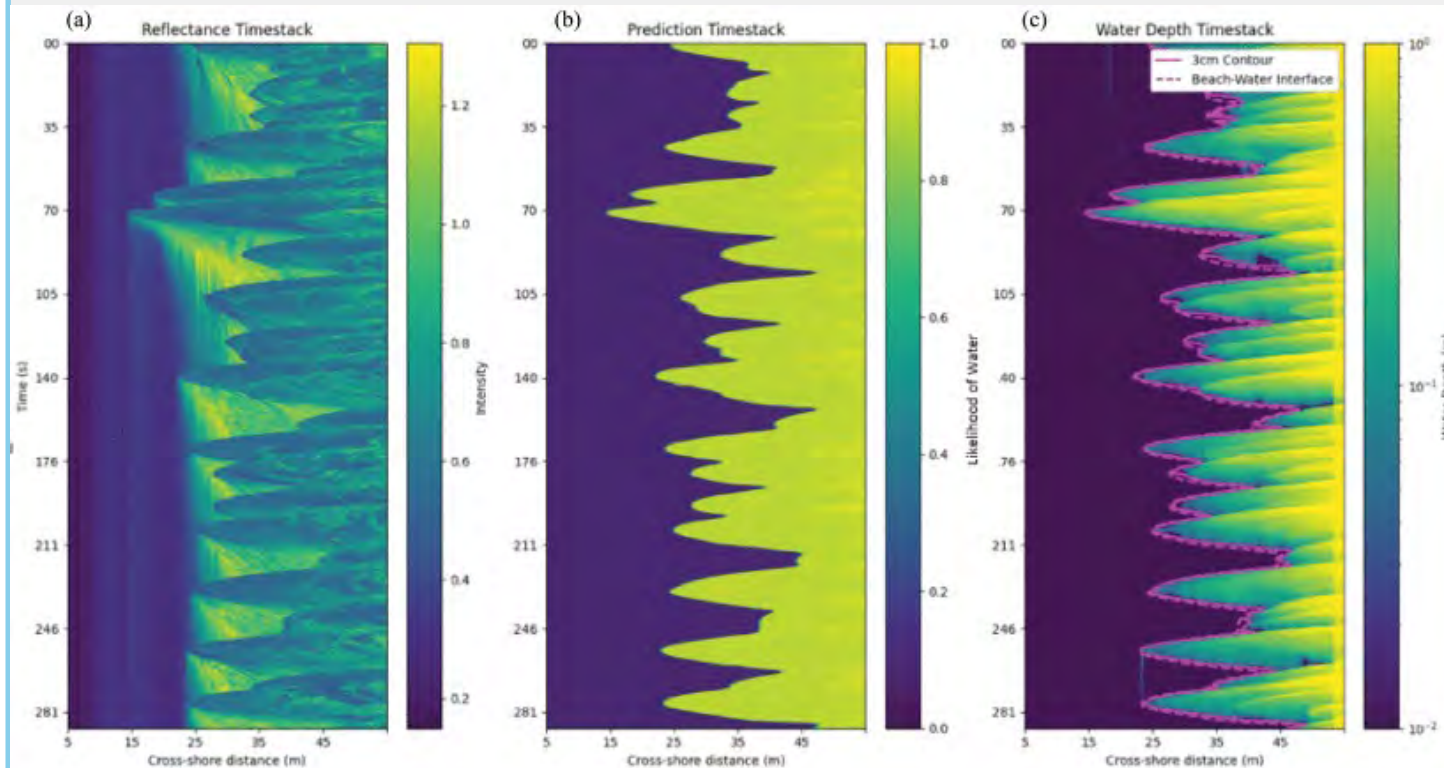
Improving numerical model ensemble averaging with ML



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

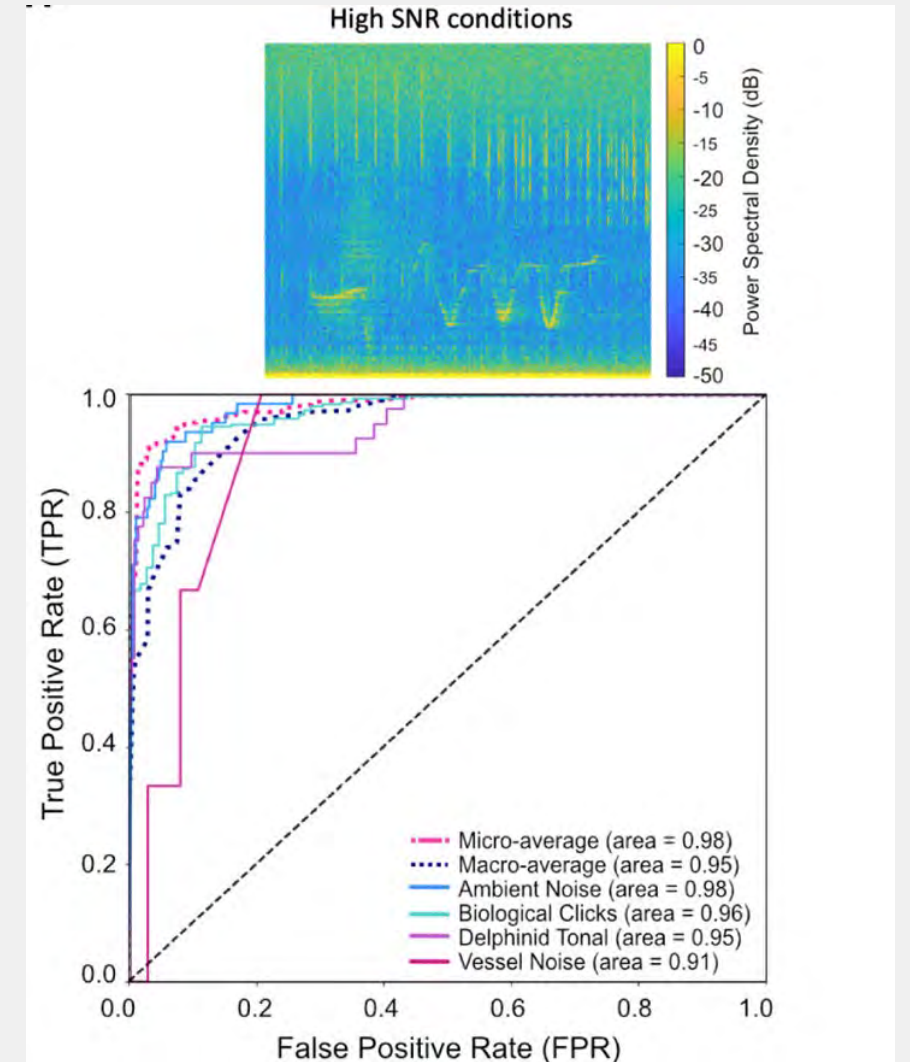
Data analysis | Feature extraction

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.

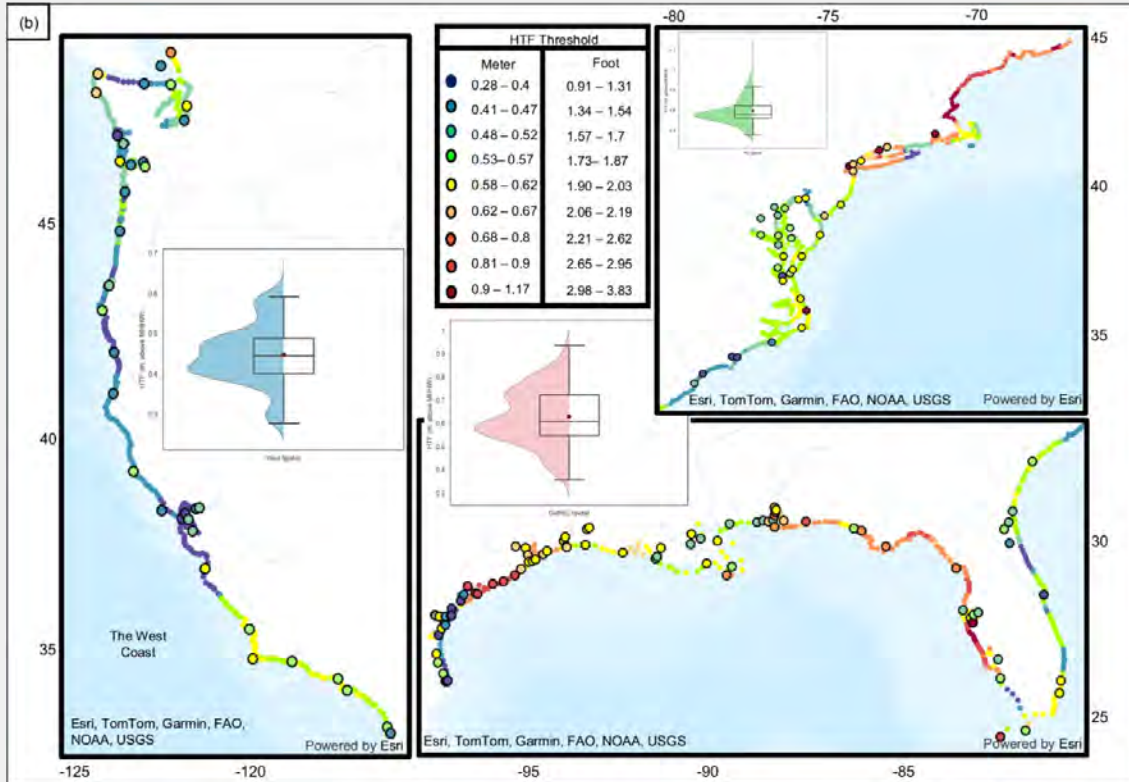
Detecting and extracting sound sources from acoustic data



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.

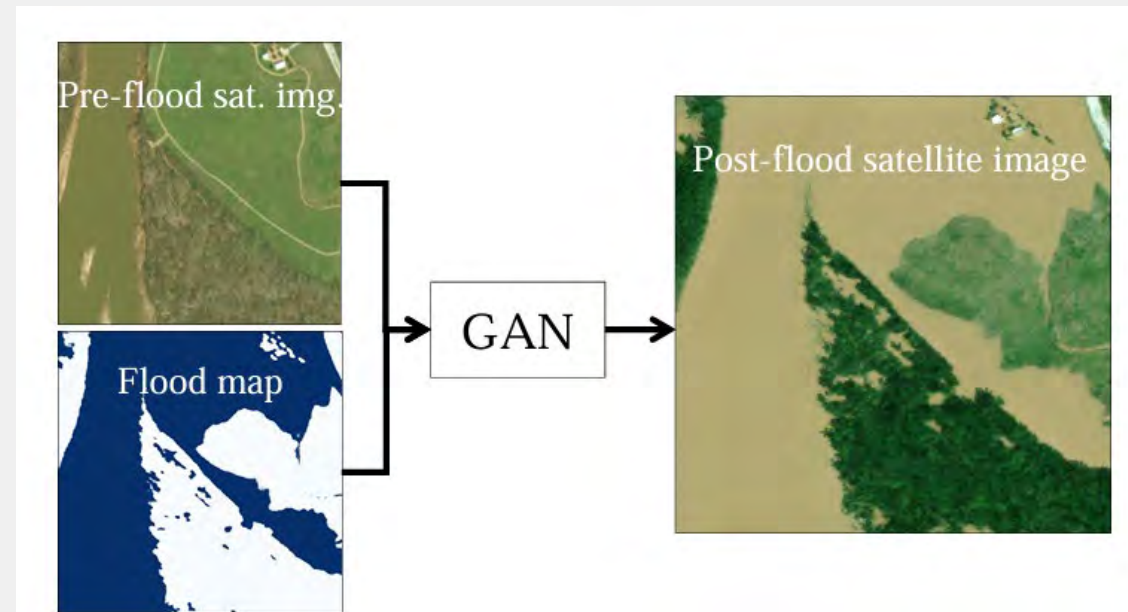
Data analysis | Data generation

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

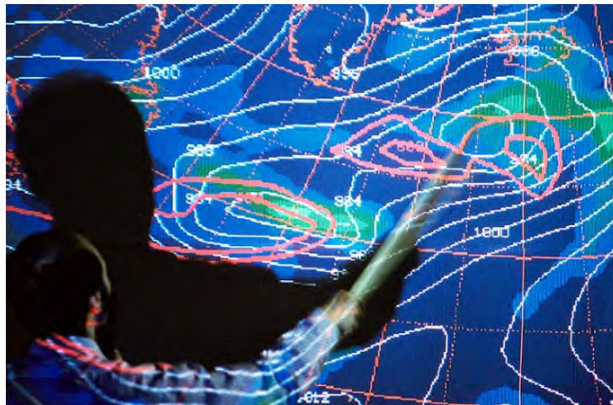
nature

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



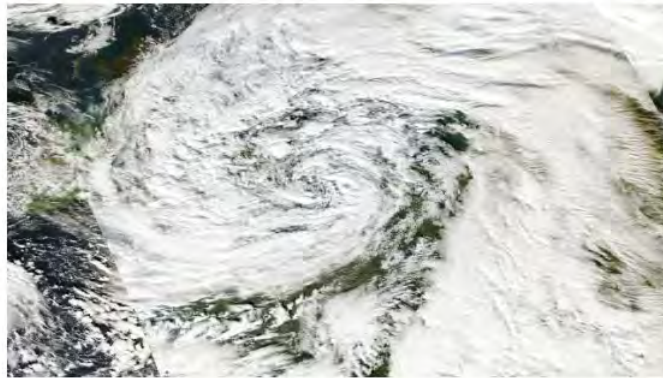
Microsoft Research Blog

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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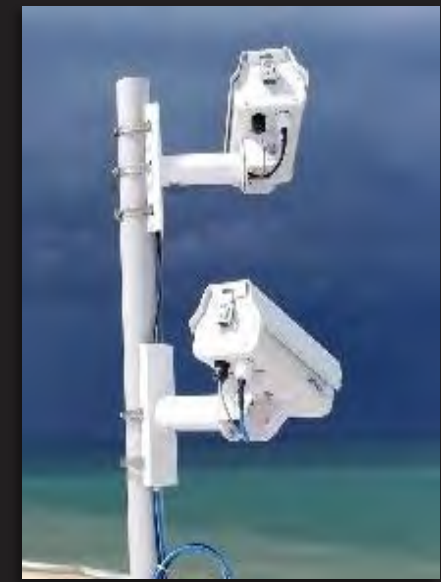
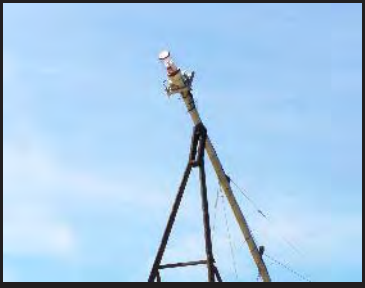
The possibilities of generative AI

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



Kate Brodie

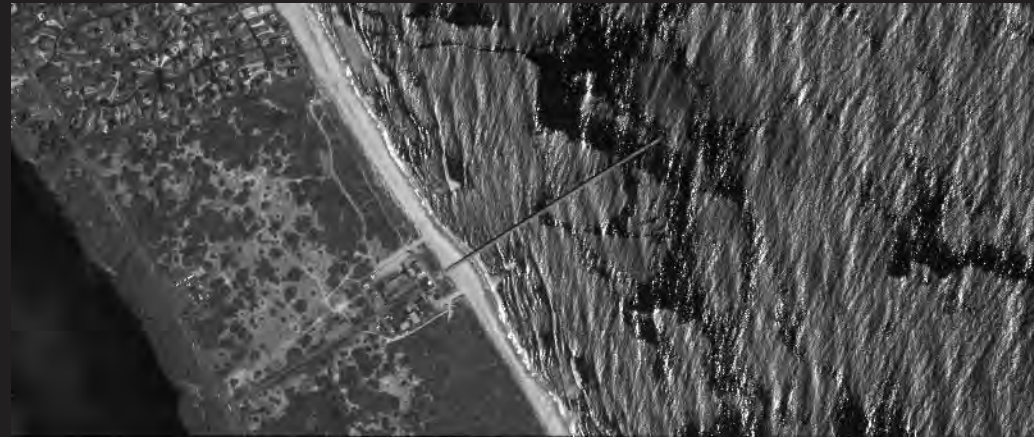
Senior Research Oceanographer,
U.S. Army Corps of Engineers



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

Yes. Lots.

In-Situ Sediment
Transport
Observations

Still Hard.

Morphology
Evolution
during Extreme
Storms

Getting Better.

Bio-
geochemical
Sensors

Low-cost,
expendable
sensor "swarms"

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

Not Yet.

Multi-agency,
multi-
investigator, field
experiments

DUNEX; ONR

New & Existing
Long-term
Observing
Systems

Some Expansion.

Community
Engagement &
Citizen Science

Some Growth.

Quantify
anthropogenic
impacts on
coastal
evolution

Kind of.



BIGGEST DECADAL ADVANCEMENTS



2014
Data
Starved

→

2024
Data
Rich

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

- 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



1

SATELLITE-BASED SHORELINE CHANGE MONITORING



1047 citations!

SCIENTIFIC REPORTS

OPEN The State of the World's Beaches

Arjen Luijendijk^{1,2*}, Gerben Hagenaars^{1,2}, Roshanka Ranasinghe^{1,2,3}, Fedor Baart¹, Gennadiy Donchyts^{1,2} & Stefan Aarninkhof¹

Received: 8 January 2019
Accepted: 5 April 2019
Published online: 27 April 2019

Coastal zones consist of diverse ecosystems. Despite the utility and of historical shoreline captured since 1994, presents a global scale therein. Applying pty shoreline are sandy, thus identified result Analysis of the satell eroding at rates exce sandy shorelines in m

Coastal zones have b value and diverse eco heavily populated an located in the coastal of coastal landforms, a coastline types, here v coastal part of world's and aesthetic that the agreee². Inevitably, assessments of the oce spatial planning, cost impacts along high va Despite the utility, assessment of their o available global scale have been derived is reported in literature shorelines, several ob barrier beaches (80% 79% of sandy shoreli name, best primarily b Robust estimation shoreline position. His involved traditional (photographs or lidar) now provide a powerf The method consist by image analysis of s forms, containing a co detection, having bot

¹Faculty of Civil Engin, Delft, The Netherlands; ²Delft, The Netherlands; ³Twente University, The Netherlands (a.luijendijk@tudelft.nl)

SCIENTIFIC REPORTS | (2019) 9:11111 | DOI:10.1038/s41598-019-41111-1



CoastSat: A Google Earth Engine-enabled Python toolkit to extract shorelines from publicly available satellite imagery

Kilian Vos¹, Kristen D. Splinter, Mitchell D. Harley, Joshua A. Simmons, Ian L. Turner

¹Water Research Laboratory, School of Civil and Environmental Engineering, UNSW Sydney, 110 Eng Street, Sydney, NSW, 2052, Australia

ARTICLE INFO

Keywords:
- single-beach regime
- shoreline analysis
- barrier
- coastal
- satellite remote sensing

ABSTRACT

CoastSat is an open-source software toolkit written in Python that enables the user to obtain time-series of shoreline position at any sandy coastline worldwide from 30+ years (and growing) of publicly available satellite imagery. The toolkit explores the capabilities of Google Earth Engine to efficiently retrieve, download and centroid 2 images cropped to any user-defined region of interest. The resulting images are pre-processed to remove clouds, pixels and enhance spatial resolution, before applying a robust and generic shoreline detection algorithm. This novel shoreline detection technique combines a supervised image classification and a sub-pixel resolution border segmentation to map the position of the shoreline with an accuracy of ~10 m. The purpose of CoastSat is to provide coastal managers, engineers and scientists a user-friendly and general toolkit to monitor and capture their coastlines. The software is freely available on GitHub (<https://github.com/kvos/CoastSat>) and is accompanied by guided examples (Jupyter Notebooks) plus step-by-step README documentation.

Software availability

Software name: CoastSat
Developer: Kilian Vos
Year first official release: 2018
Hardware requirements: PC
System requirements: Windows, Linux, Mac
Program language: Python
Program size: 1 MB
Availability: <https://github.com/kvos/CoastSat>
License: GPL v3.0
Documentation: README in (GitHub repository and guided example in the form of an editable Jupyter Notebook).

1. Introduction

The coastal region is the most heavily urbanised land some in the world (Gossl et al., 2017) and is regarded as a critical resource in view of its recreational, environmental and economic importance. Yet, ocean coasts are affected by variations in mean sea level, extreme waves, storm surges and river flow through a range of physical processes (Gossl et al., 2017; Turner et al., 2018). Recent intensification in mean wave energy (Fogelberg et al., 2018), extreme coastal wave energy (Stevenson et al., 2017)

and oceanic wind speeds (Young and Ribal, 2019), coupled with rising sea levels, suggest that coastal areas will be exposed to increasing hazards in coming decades (Liu et al., 2018). It is therefore critical for coastal managers and policy makers regulating coastal development to observe and quantify these changes along coastlines vulnerable to extreme as well as subtle changes in oceanographic forcing (e.g., Splinter et al., 2017; Harley et al., 2017; Masarik et al., 2016). Data scarcity, however, remains an ongoing challenge as long-term coastal monitoring programs, based on in situ measurements, are limited to only a few sites around the world (e.g., Splinter et al., 2015; Francis et al., 2013; Turner et al., 2014). Indeed, shoreline data is key to understand past beach behaviour (Splinter et al., 2018) and calibrate numerical models capable of predicting future shoreline changes (Splinter et al., 2013). Publicly available remote sensing data from Earth Observation Satellites provides a low cost solution to obtain long-term observations of coastline changes over the past three decades at many sites worldwide. Crucially, the advent of Google Earth Engine (Gorelick et al., 2017) has facilitated access to the growing archive of publicly available satellite imagery, providing the opportunity for global-scale analyses stretching back decades (e.g., Donchyts et al., 2018; Splinter et al., 2019; Splinter et al., 2018; Menachel et al., 2018).

Space-borne observations have been employed in a wide range of change detection applications, including the analysis of meandering

* Corresponding author. Water Research Laboratory, School of Civil and Environmental Engineering, UNSW Sydney, Australia.
Email address: k.vos@unsw.edu.au (K. Vos).

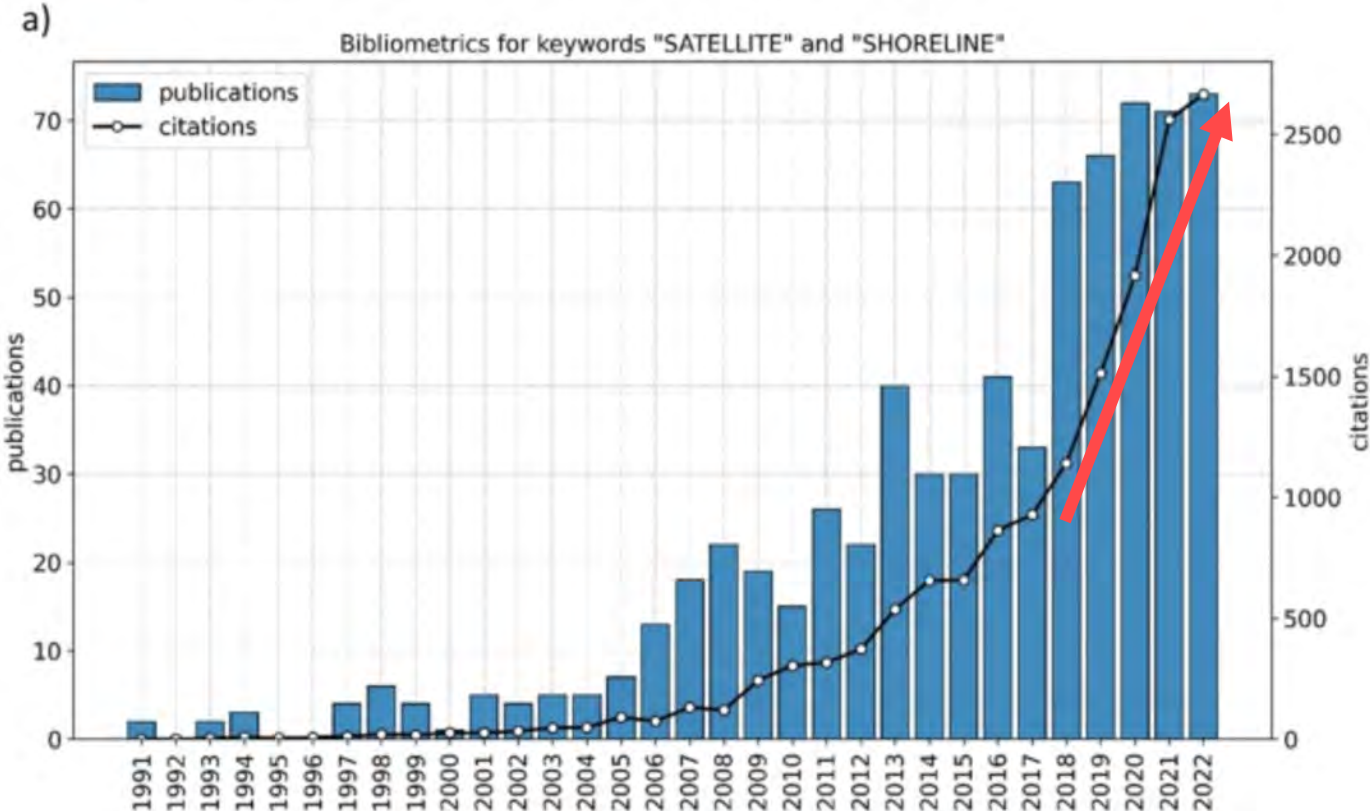
<https://doi.org/10.1038/s41598-019-41111-1>

Received 6 February 2019; Received in revised form 11 June 2019; Accepted 24 September 2019

Available online 26 September 2019

1364-8132/© 2019 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

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



Vos et al 2023

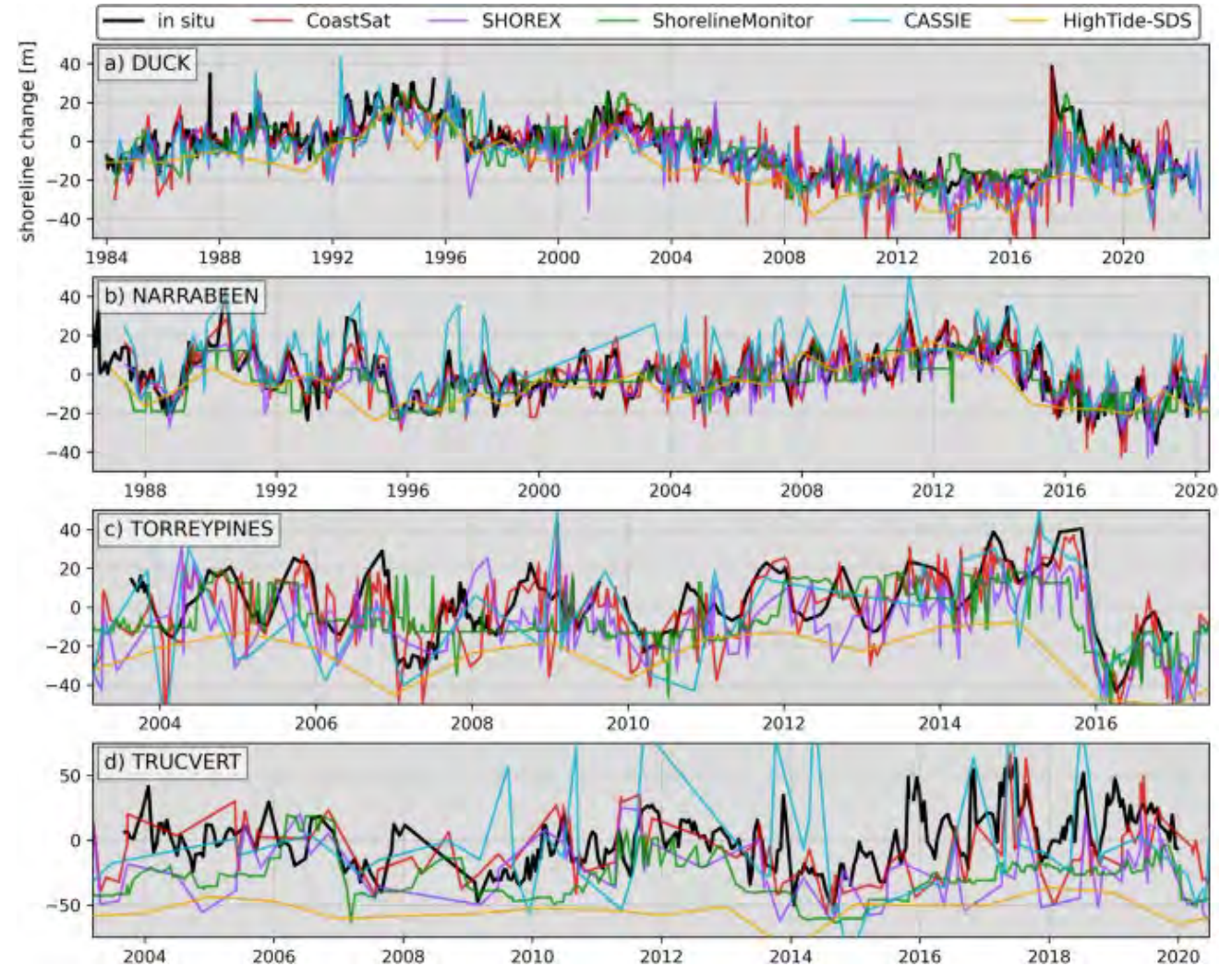


1

SATELLITE-BASED SHORELINE CHANGE MONITORING



→ Collaborative open-source global community

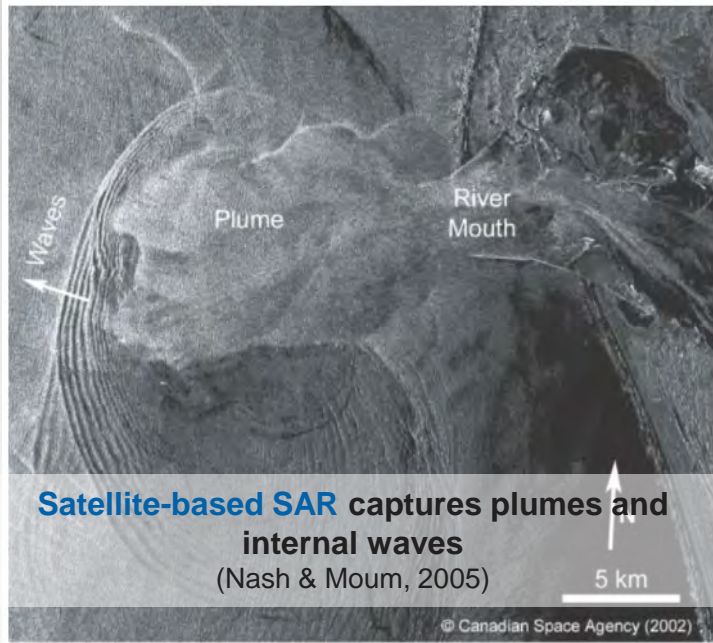


Vos et al 2023



1

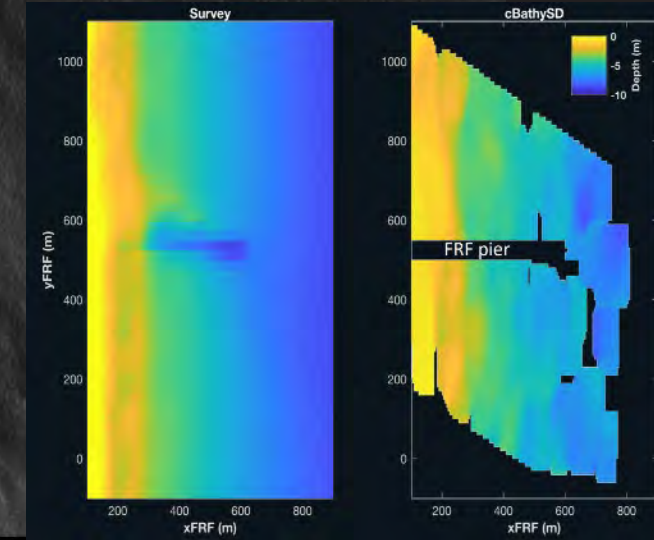
OTHER SATELLITE APPLICATIONS



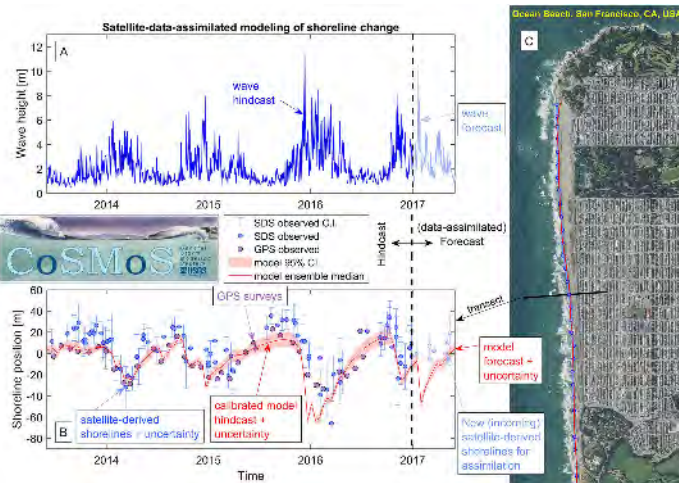
Satellite-based SAR captures plumes and internal waves (Nash & Moum, 2005)



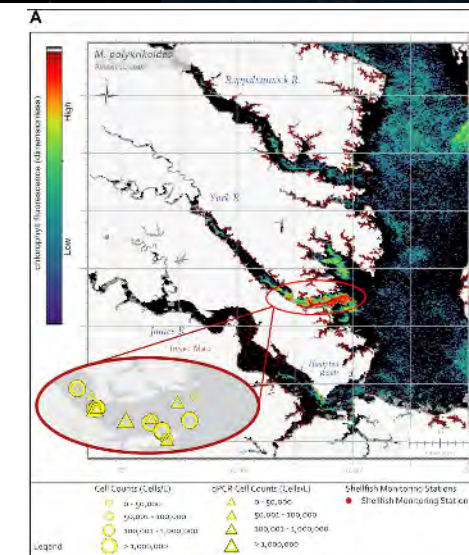
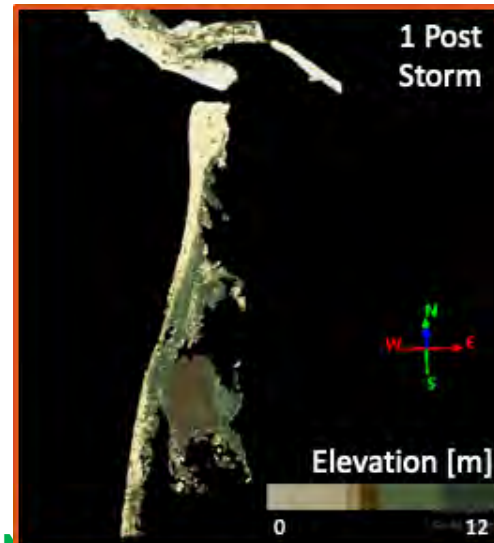
Satellite-based video enables water depth estimation (Anderson et al, 2024; Bergsma et al., 2021)



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 Harmful Algal Blooms (HABs) for water quality monitoring (Wolny et al., 2020)



2

OPERATIONAL COASTAL IMAGING

UNCLASSIFIED



CorpsCam

Real-Time Monitoring of Coastal Projects via Quantitative Video Imagery

<https://coastalimaging.erdcdren.mil/CorpsCam>

News About CorpsCam Stations Advanced Data Tools Media Contact

ERDC-CHL Field Research Facility
Location: Duck, NC

Northern Duck
Location: Duck, NC

Lynnhaven Inlet



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.

CoastSnap



Trail Cameras



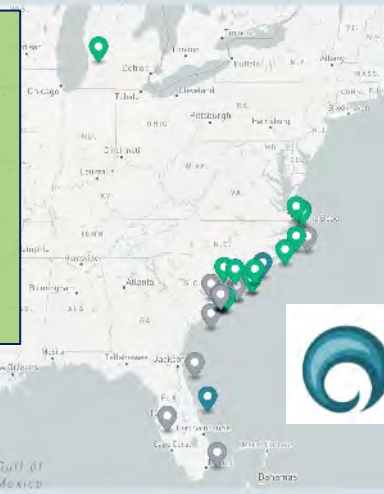
Argus



Cameras

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.



SECORA WebCOOS
Southeast Coastal Ocean Observing Regional Association



Results

- Sand Key, FL
- Madeira Beach, FL
- Head of the Meadow Beach, MA
- Marconi Beach, MA
- Dorado Beach, PR
- Isla Verde, PR
- Unalakleet, AK
- Nuvuk/Point Barrow, AK
- Santa Cruz, CA
- Sunset State Beach, CA

USGS
science for a changing world

CoastCams



IMPACT:

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

UNCLASSIFIED



2

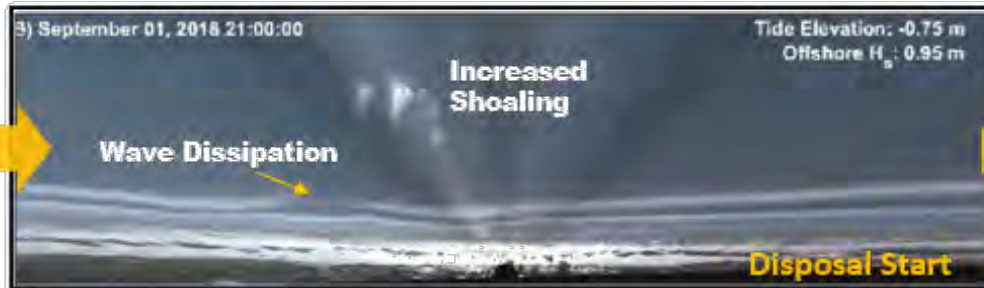
CorpsCam EXAMPLE APPLICATION



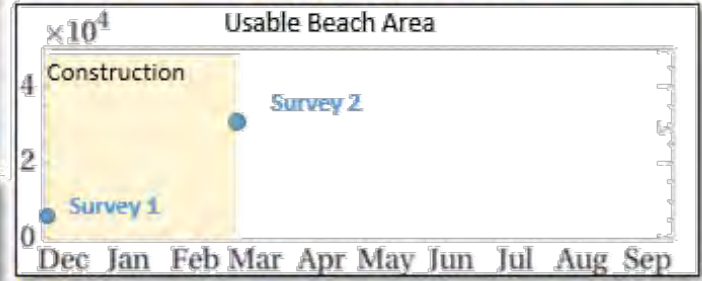
VIDEO IMAGING : HOURLY OBSERVATIONS, MAPS + ENGINEERING DATA



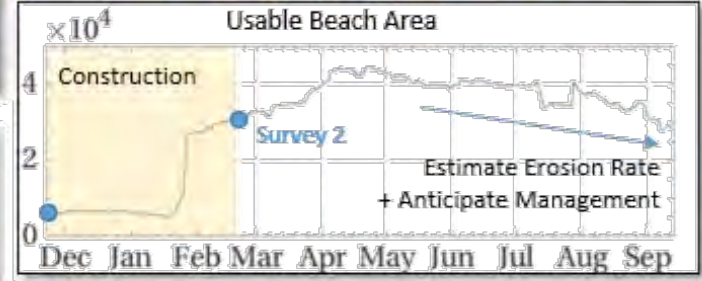
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BEFORE CORPSCAM



WITH CORPSCAM



Remote | Autonomous | Quantitative | Holistic

OPERATIONAL WAVE OBSERVATIONS



CDIP National Nearshore Buoy Network

Primary Sponsor:



US Army Corps of Engineers



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.

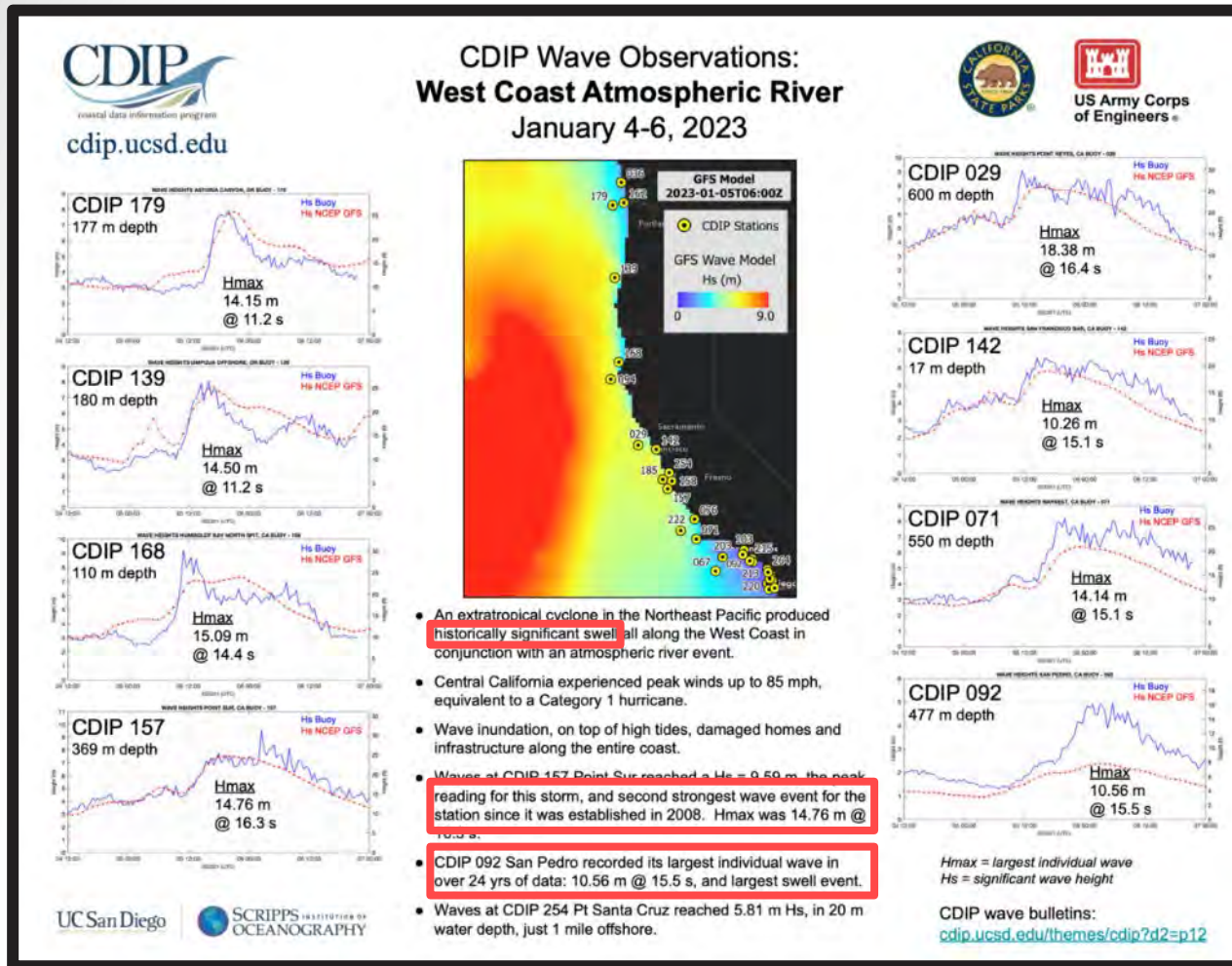




WAVE BUOY NETWORK: APPLICATION EXAMPLE



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.

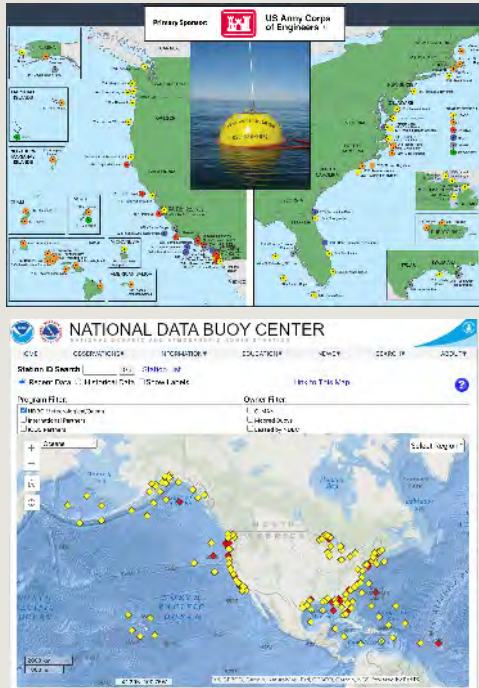


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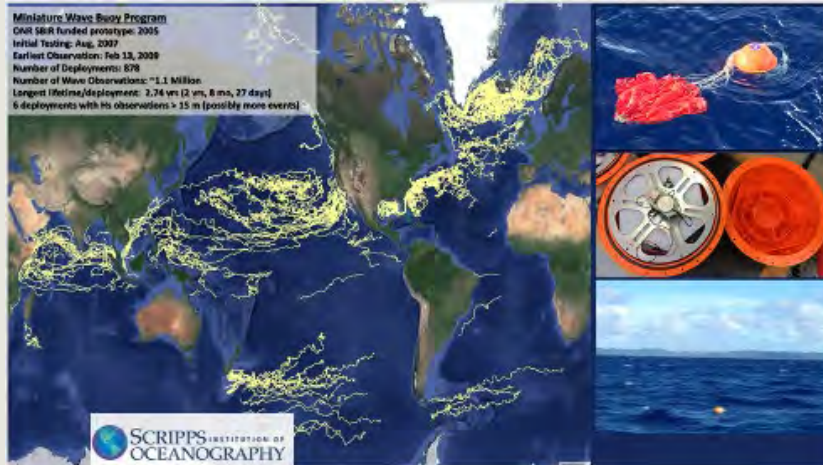
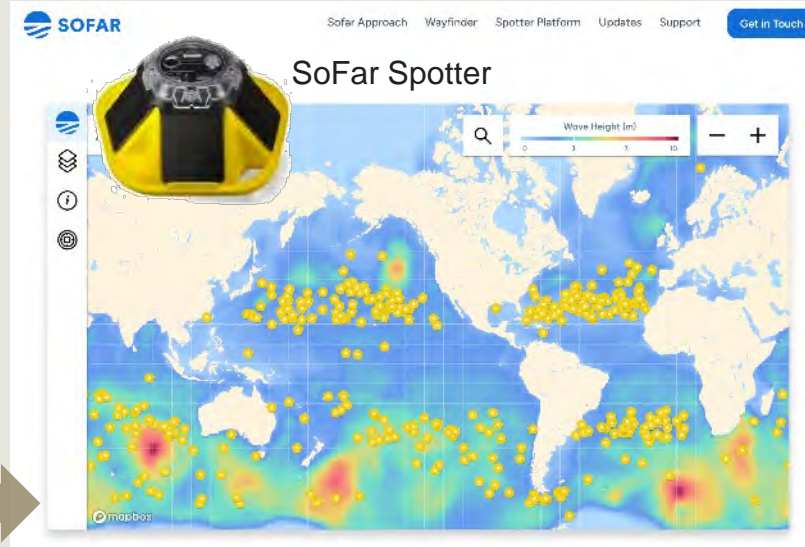
WAVE BUOY EVOLUTION



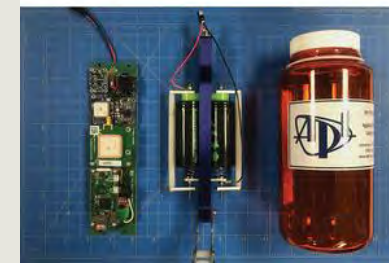
Fixed Networks



Small Drifting Buoys



Miniature Wave Following Buoys



Thompson et al., 2023



Feddersen et al., 2023

Buoys of Opportunity

JaiaBot



Liquid Robotics Wave Glider

ONR/Penn State Eagle



SubUAS Naviator

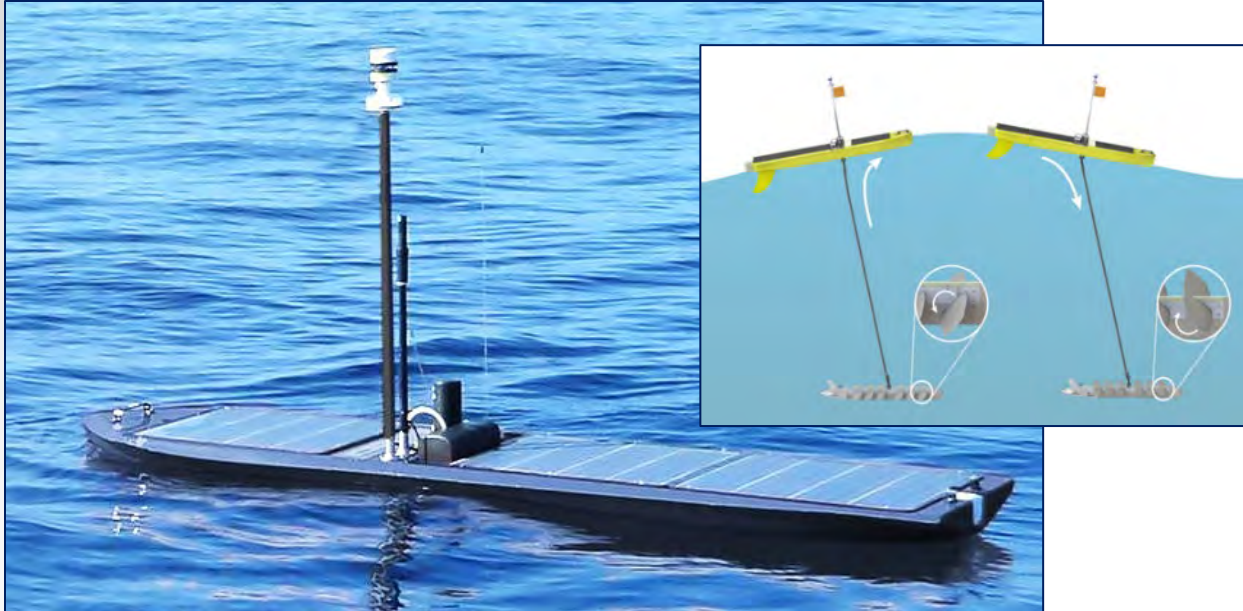


3

APPLICATION: BUOYS OF OPPORTUNITY



Liquid Robotics Wave Glider



ONR Eagle

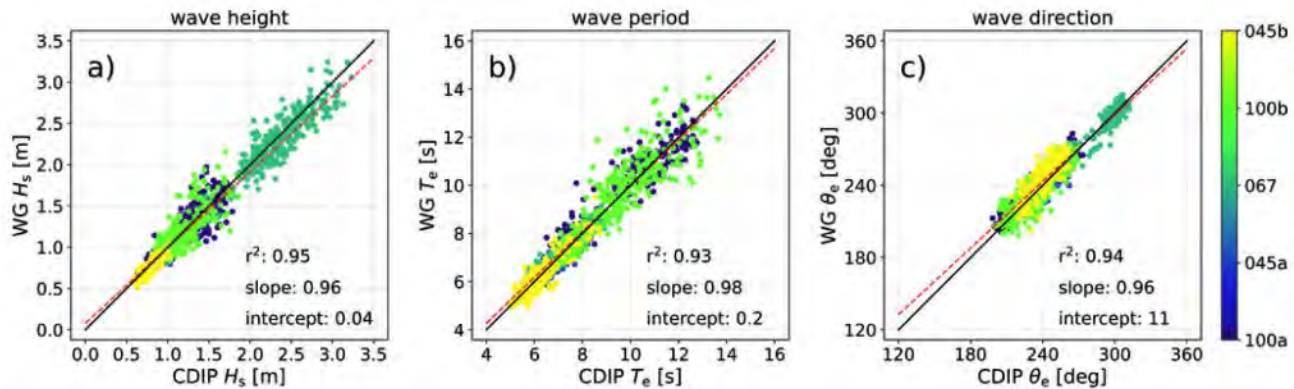


Fig. 8.

Amador et al., 2023

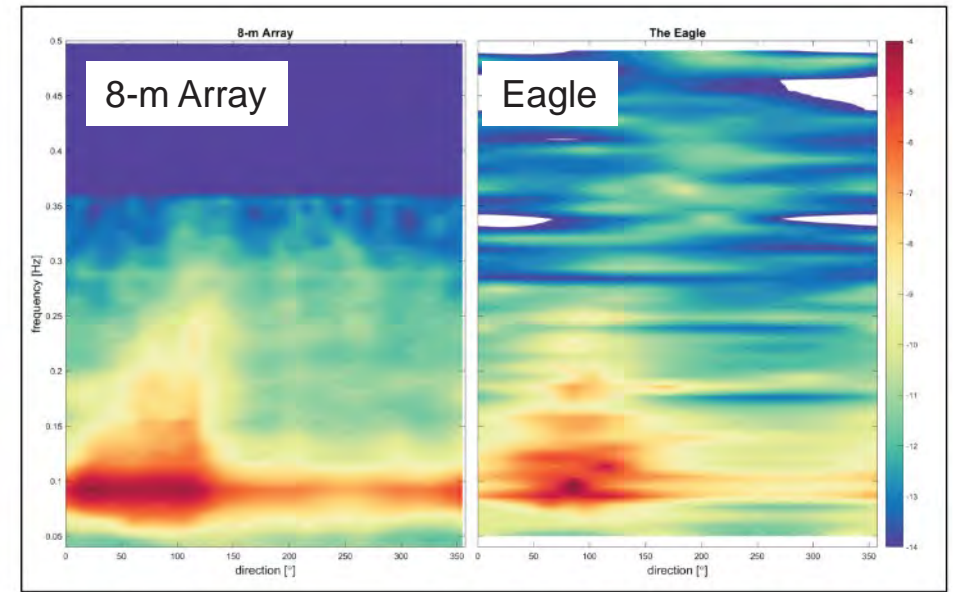


Figure 5. Direction-frequency spectra from the 8 m array (left) and the Eagle (right). The color scale indicates the spectral density [$m^2/Hz/deg$] on a log scale.



3

UNCREWED SYSTEMS FOR COASTAL SURVEY



Uncrewed Surface Vessels

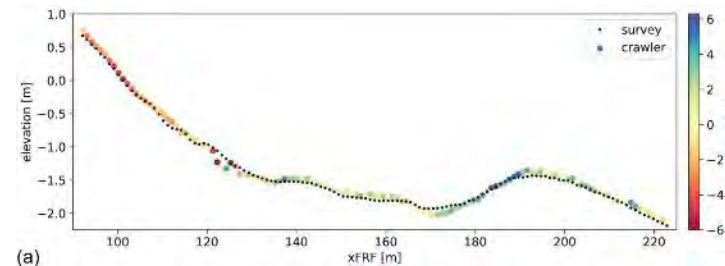


Bak et al., 2022

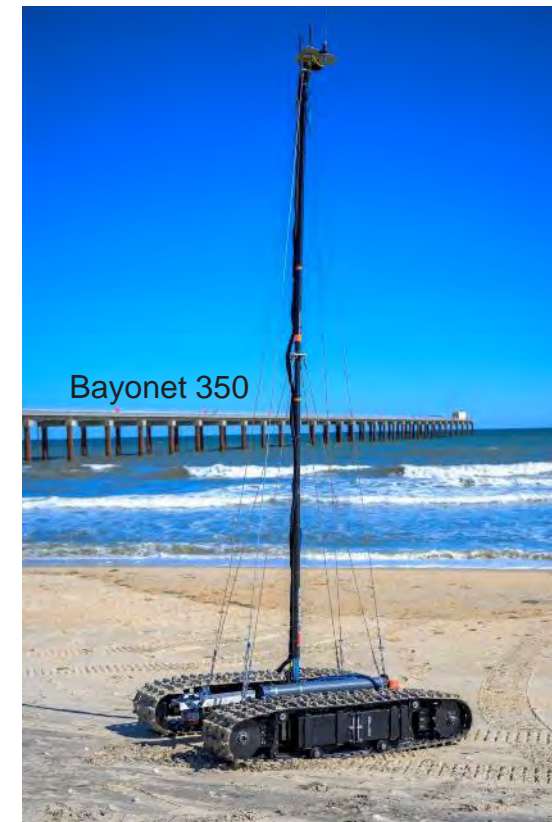
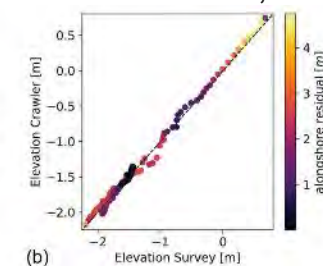


Francis and Traykovski 2021

Bottom crawler



Bak et al., 2023



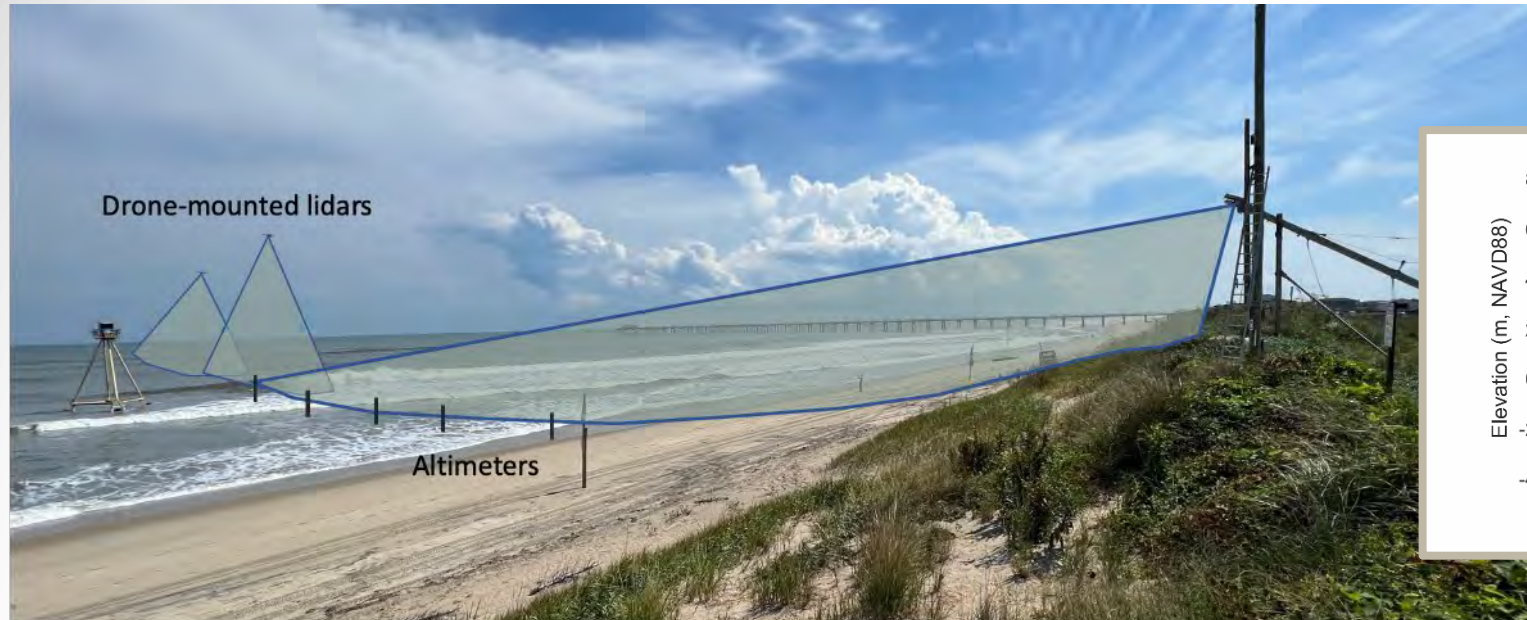


4

REMOTE SENSING OF COASTAL PROCESSES



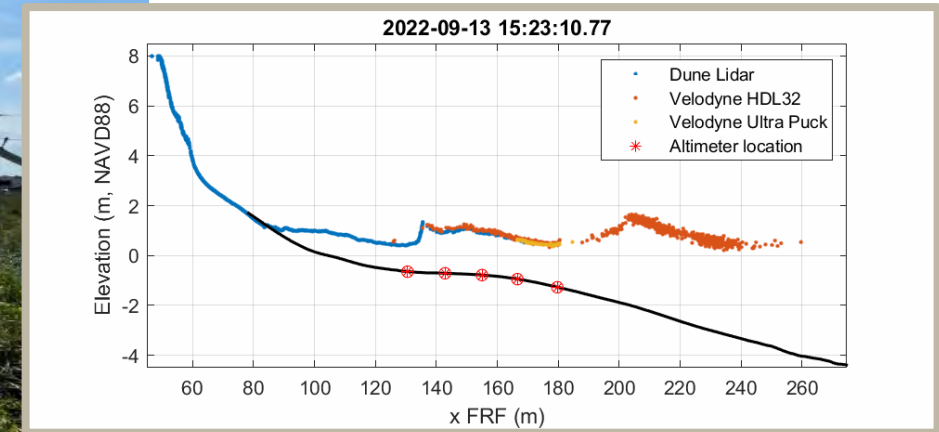
→ Observations at process-relevant time-scales and spatial scales



FRF
FIELD RESEARCH FACILITY

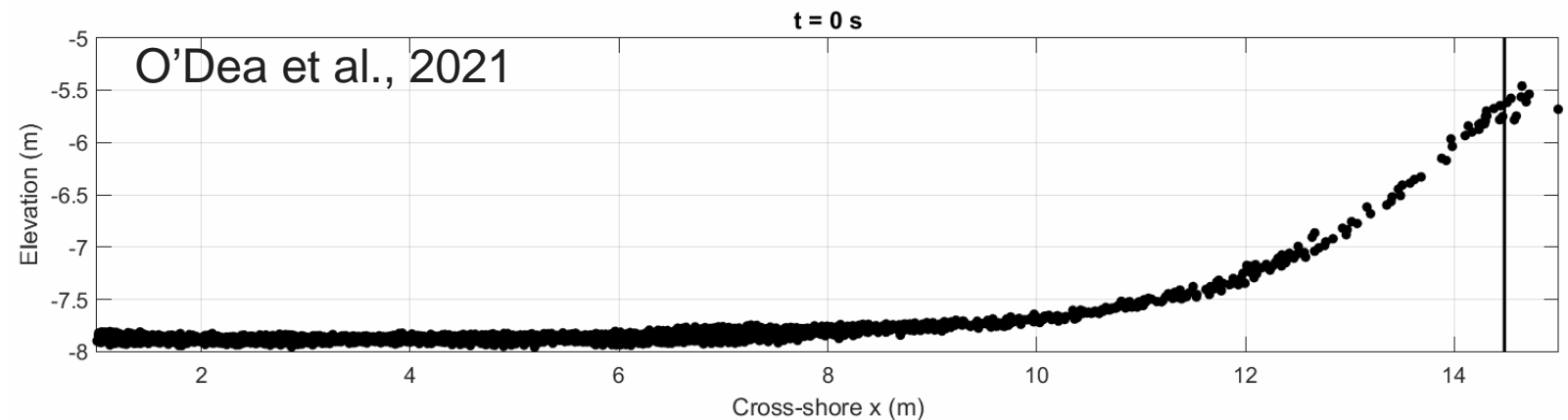


La Rochelle
Université



Collaborative Experiment – September 2022

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





4

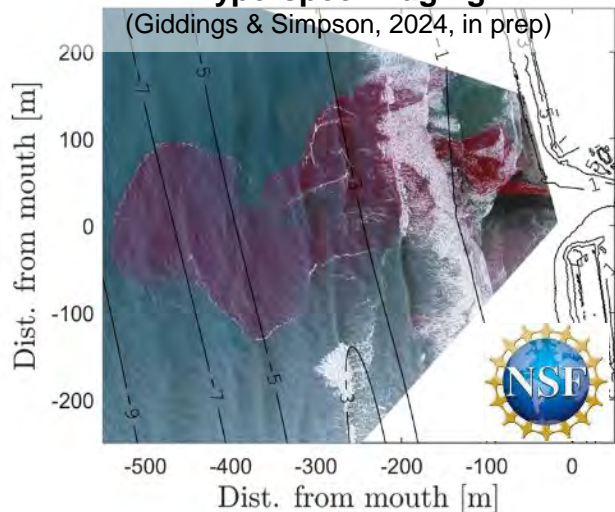
REMOTE SENSING OF COASTAL PROCESSES

UNCLASSIFIED



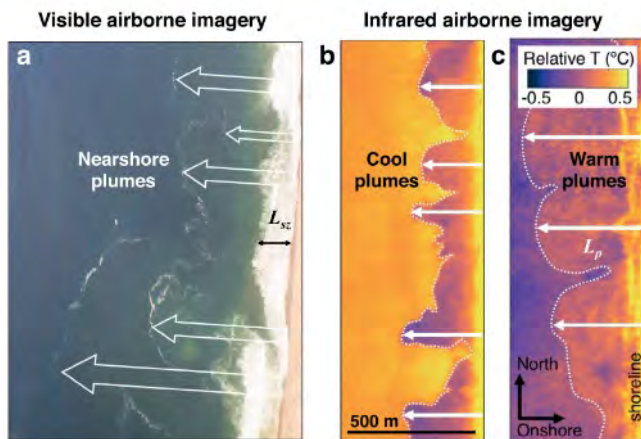
Dye studies of river plume-surfzone interaction using Drone RGB and Hyperspec imaging

(Giddings & Simpson, 2024, in prep)

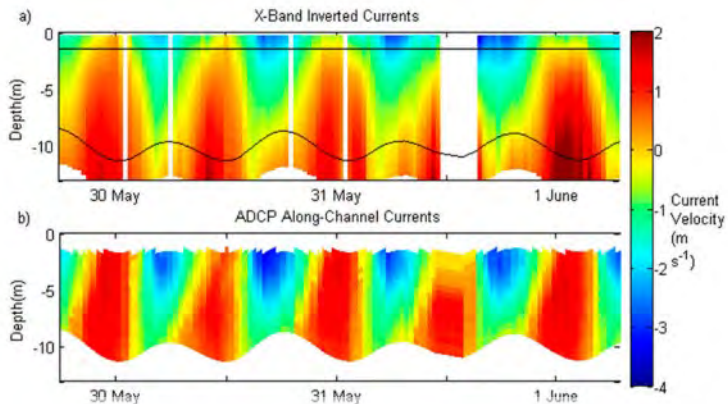


Warm/cool rip plumes using Airborne IR imagery

(Moulton et al., 2021)

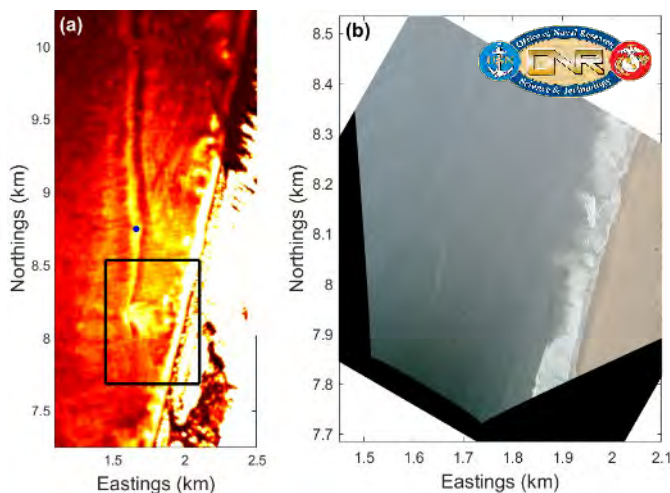


X-band radar and drone internal waves and rip currents



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

(Campana et al., 2016)

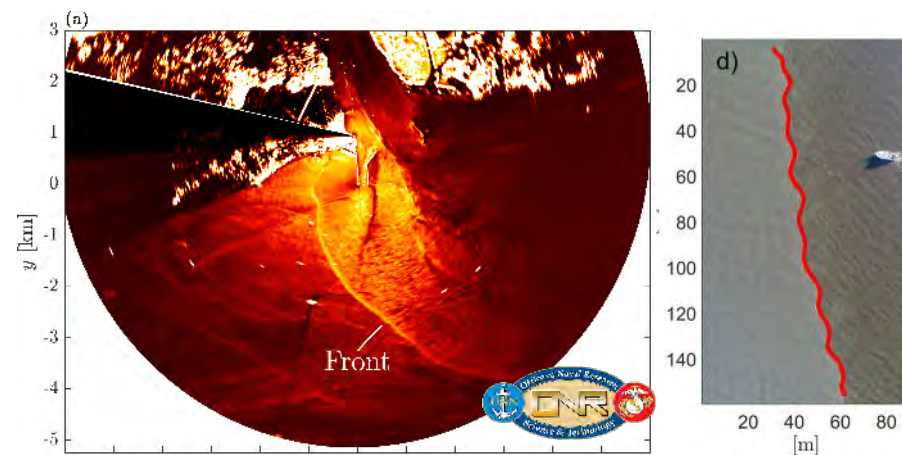
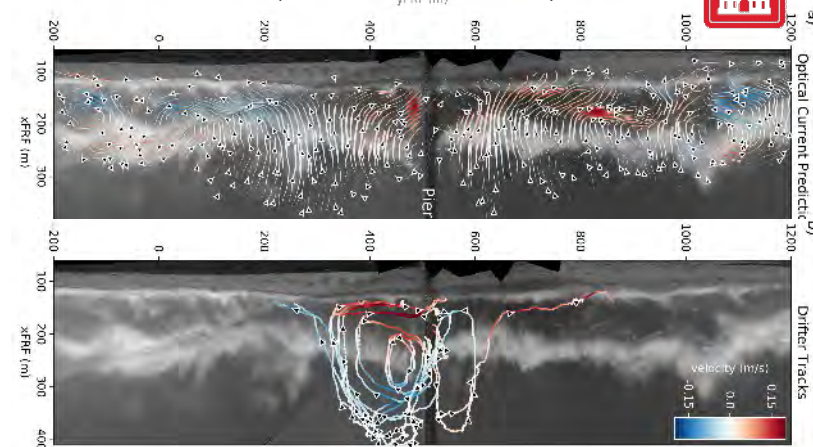


(Kumar et al., 2021)

UNCLASSIFIED

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

(Anderson 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)



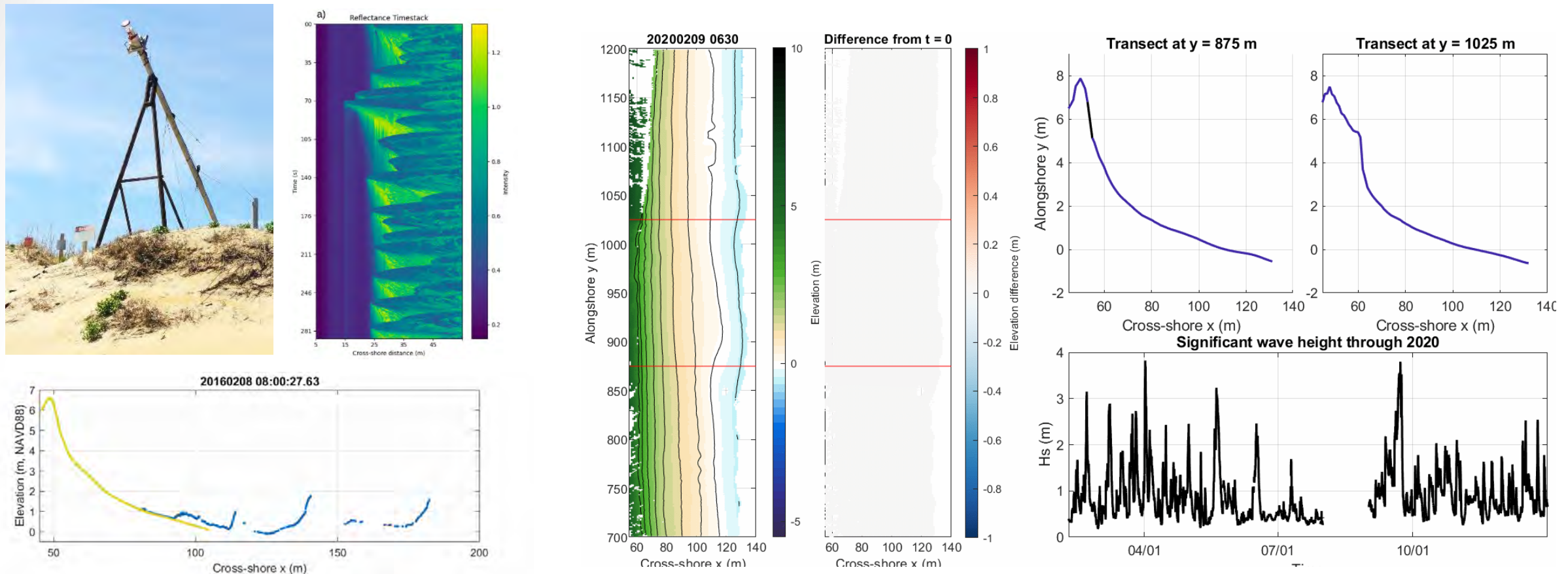
5

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





5

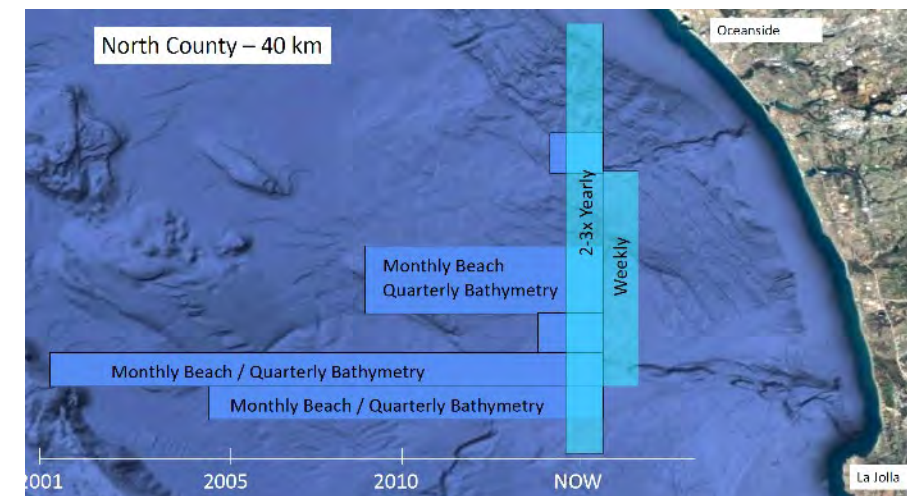
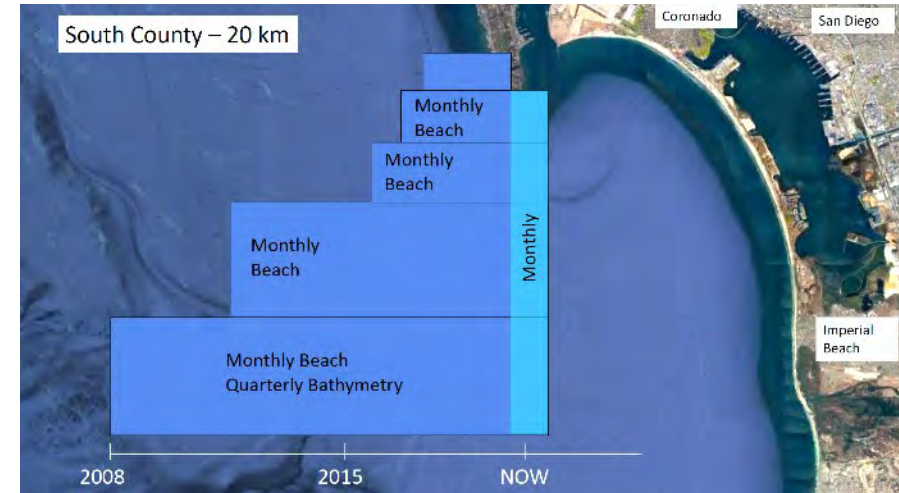
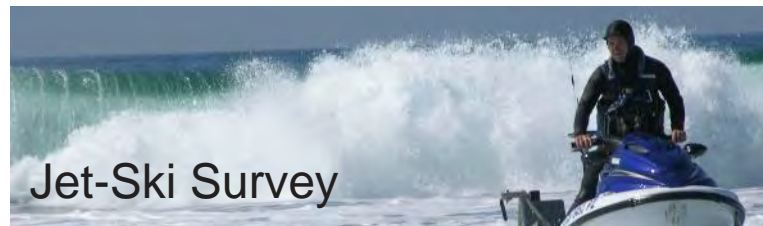
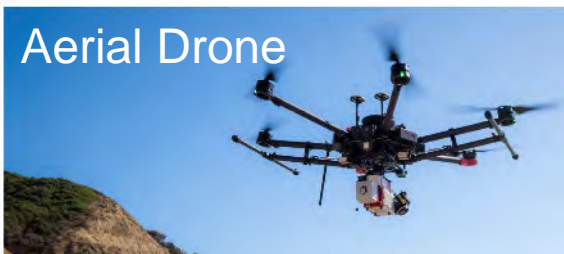
EXPANSION OF LONG-TERM MONITORING DATA



→ 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)





NEXT DECADE ADVANCEMENTS



2014
Data
Starved



2024
Data
Rich



2034
Information
Rich

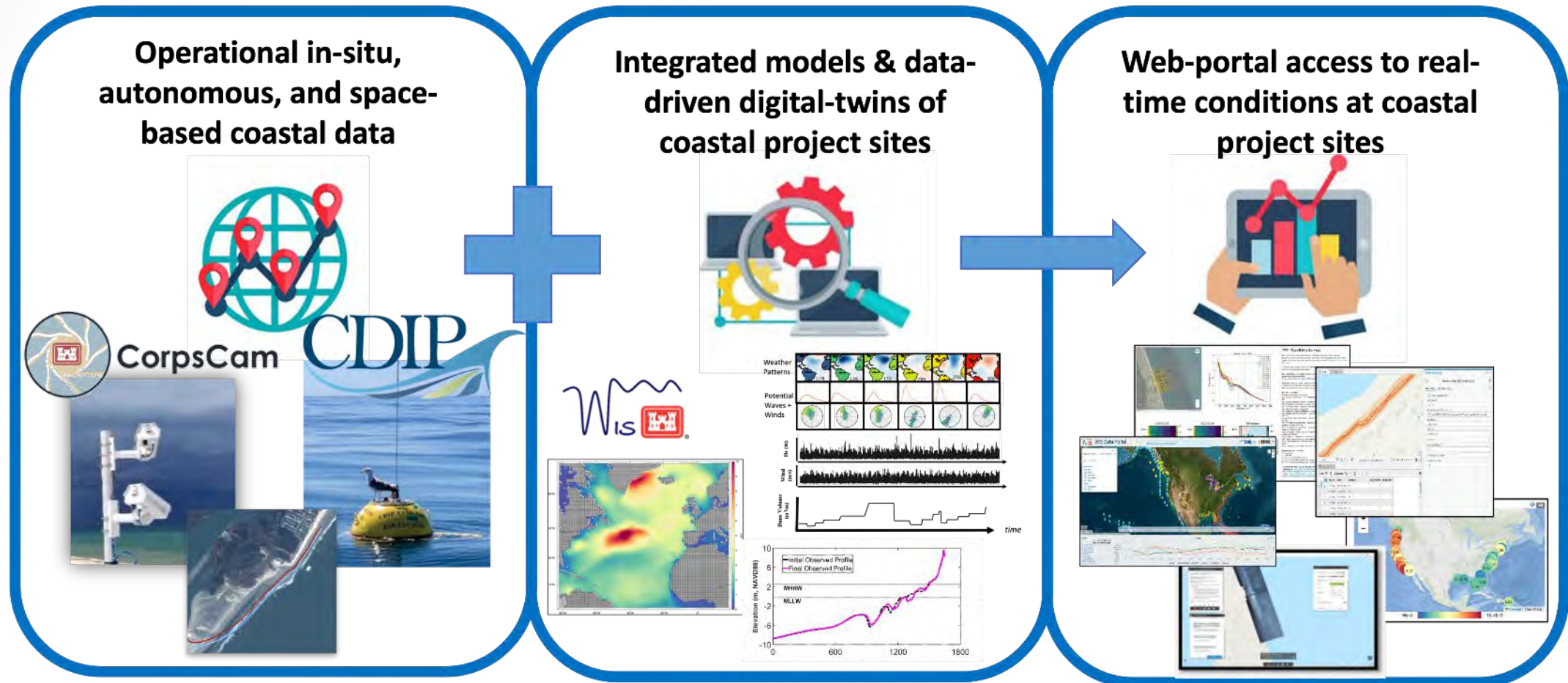




USACE VISION FOR OPERATIONAL COASTAL MONITORING



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





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

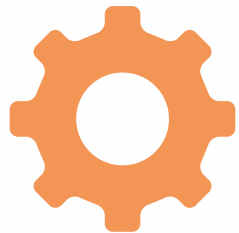
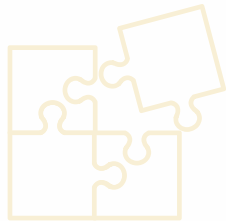


Challenges

Discuss what the community needs:
What challenges will we face in the next 10 years?

Co-developed Solutions

Discuss how we move forward:
How can we address these challenges?



Tools and Approaches

Discuss implementation strategies:
What ways will we achieve the solutions?

Research Questions

Discuss the gaps:
What basic research questions and data gaps need to be addressed in order for the tools and approaches to be successful?

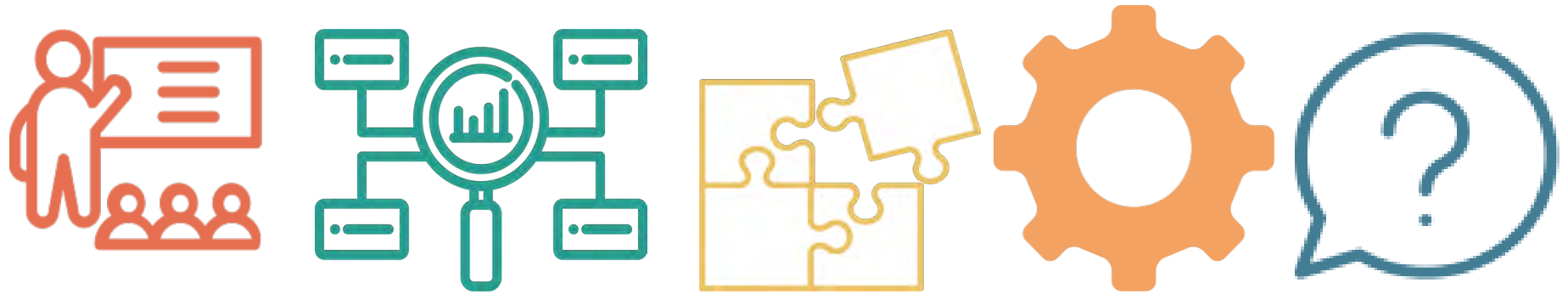


BREAKOUT #3

Tools and Approaches to Support Solutions

How the Agenda is Built

Working through challenges and solutions to actionable research



WHAT'S MY BREAKOUT ROOM?

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





JUNE 11 – JUNE 13

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

Decadal Visioning Workshop

**THE FUTURE OF COASTAL
PROCESSES RESEARCH**



2024

Break



Decadal Visioning Workshop 2024

**THE FUTURE OF COASTAL
PROCESSES RESEARCH**



JUNE 11 – JUNE 13

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

Decadal Visioning Workshop

**THE FUTURE OF COASTAL
PROCESSES RESEARCH**



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

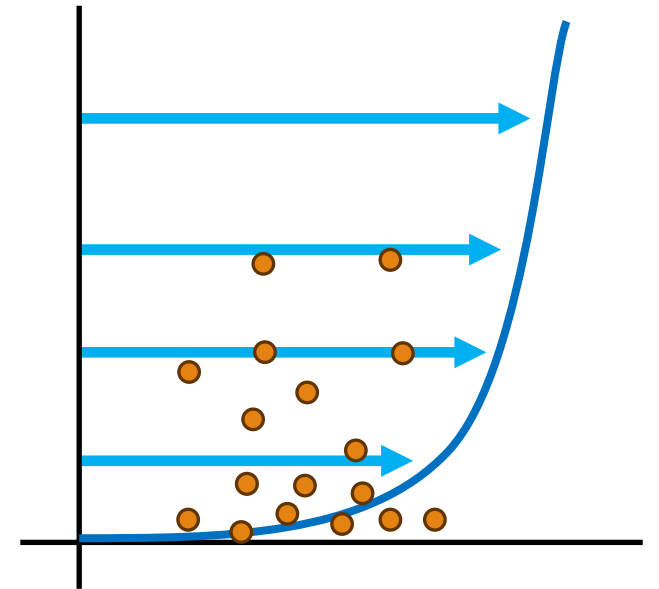
US Nearshore Decadal Visioning Workshop – June 14, 2024



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)

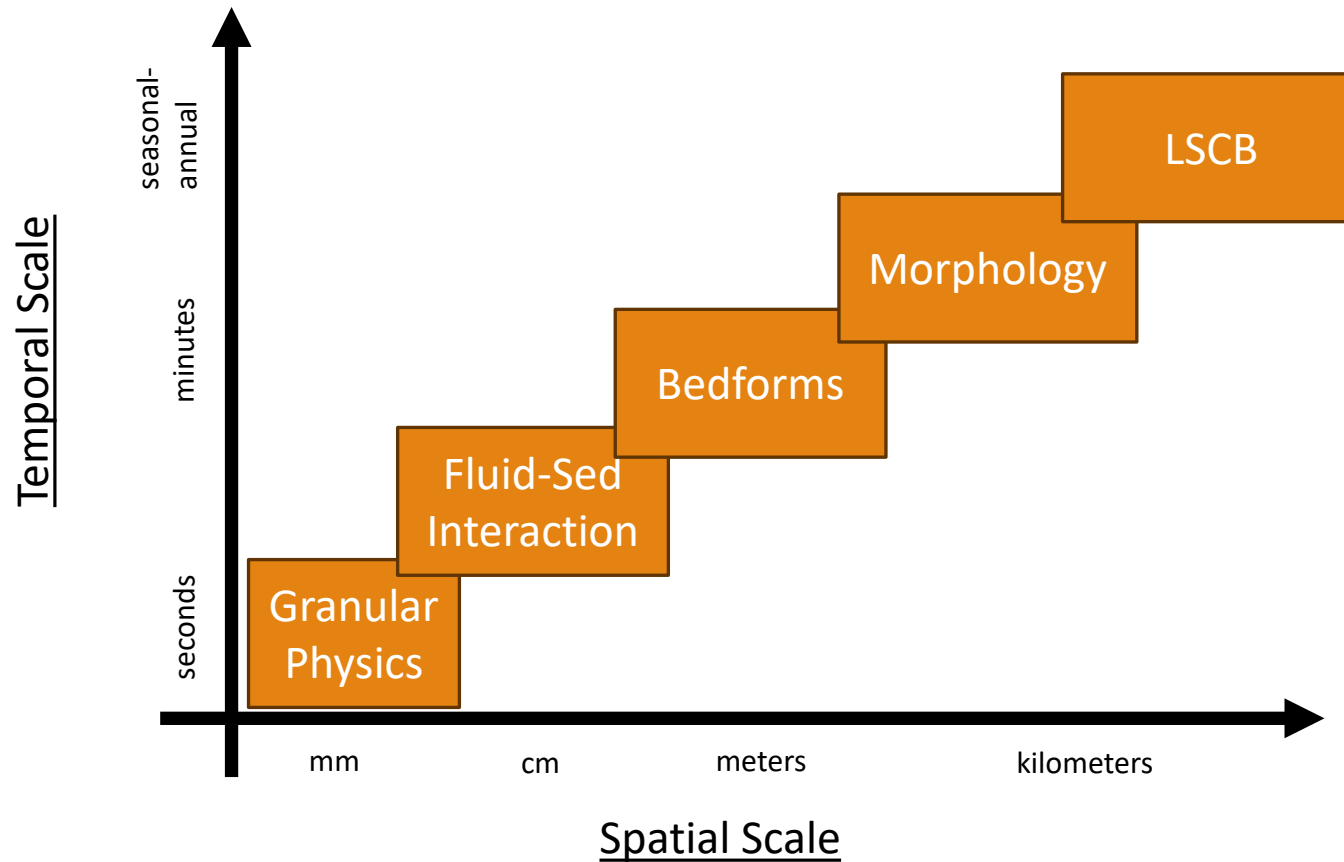


Scope: What is Nearshore Sediment Transport?

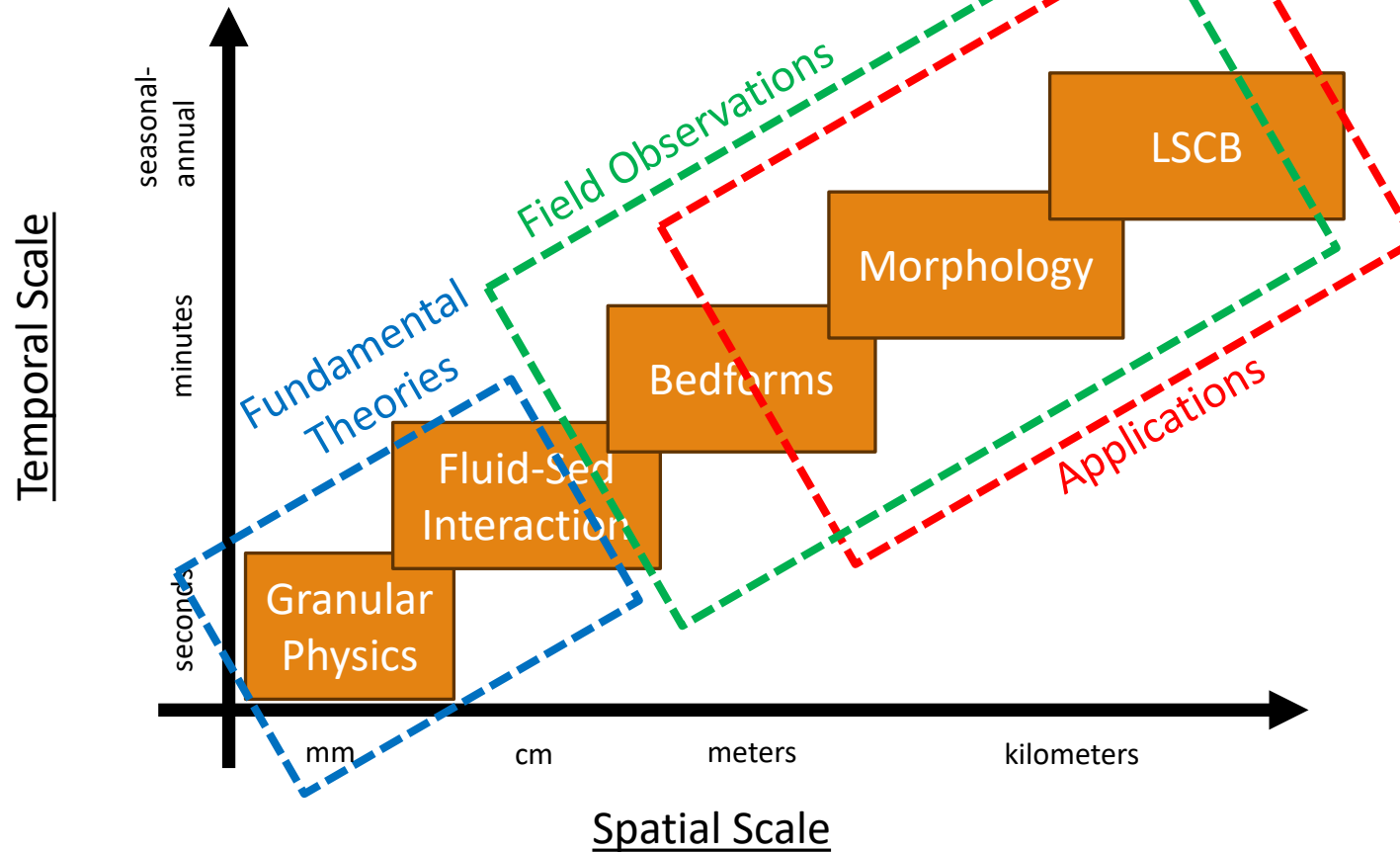
1. Mobilization of sand under nearshore waves and currents
2. Transport of sand, and subsequent changes to the bed
3. Feedbacks (coupling with nearshore hydrodynamics)



Scales of Sediment Transport



Scales of Sediment Transport



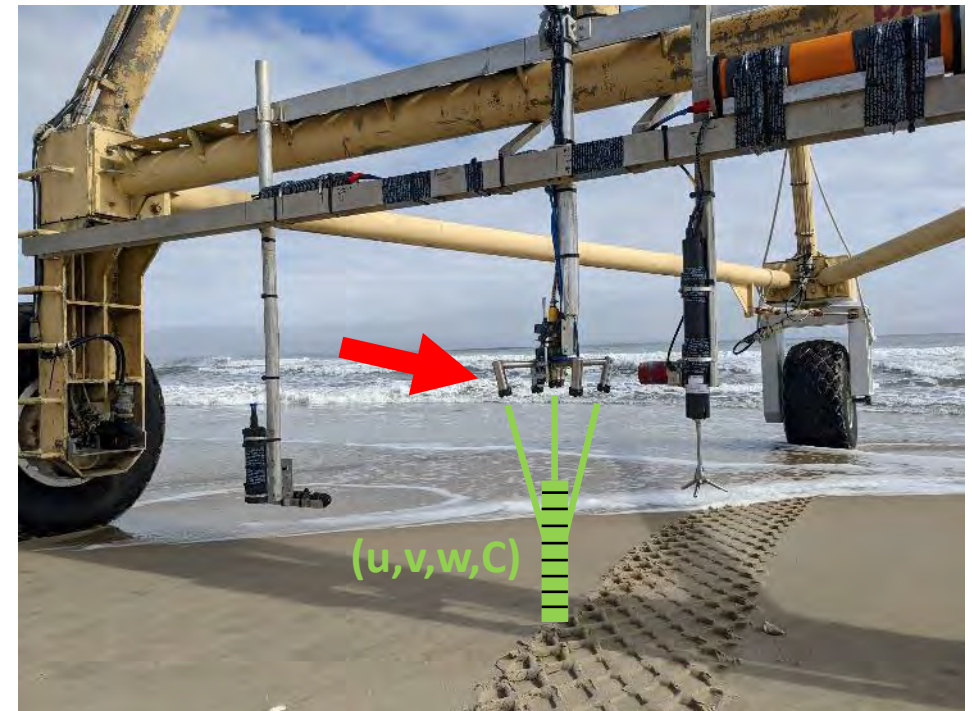
Blasstex – testing basic theories in the field

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

MFDop Instrument:

- 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)

Blasstex-2 frame: MFDop, Aquascats (0.5,1MHz), Vector, bed-scanning sonar



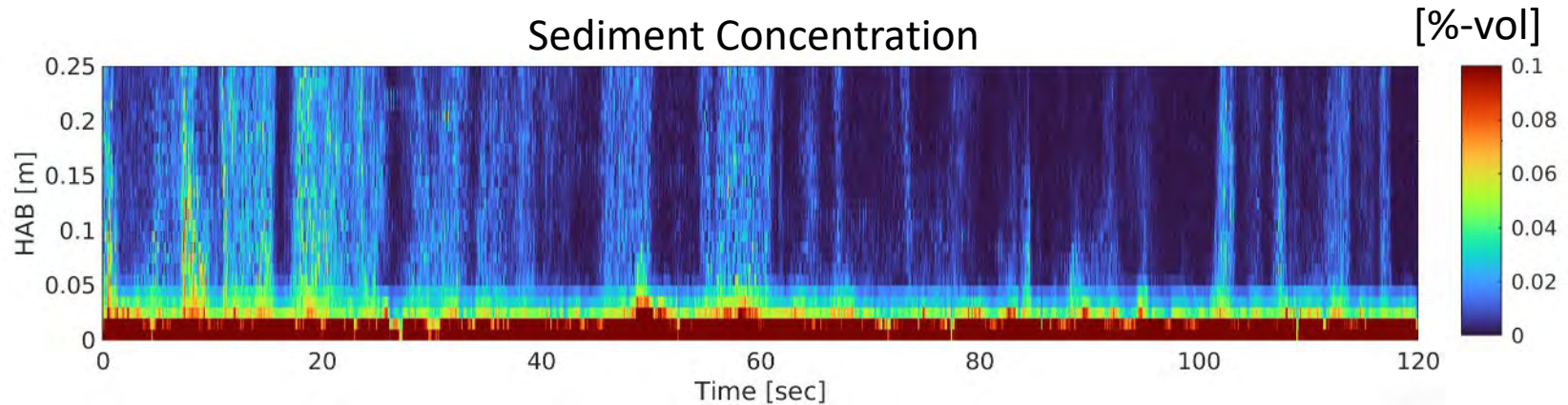
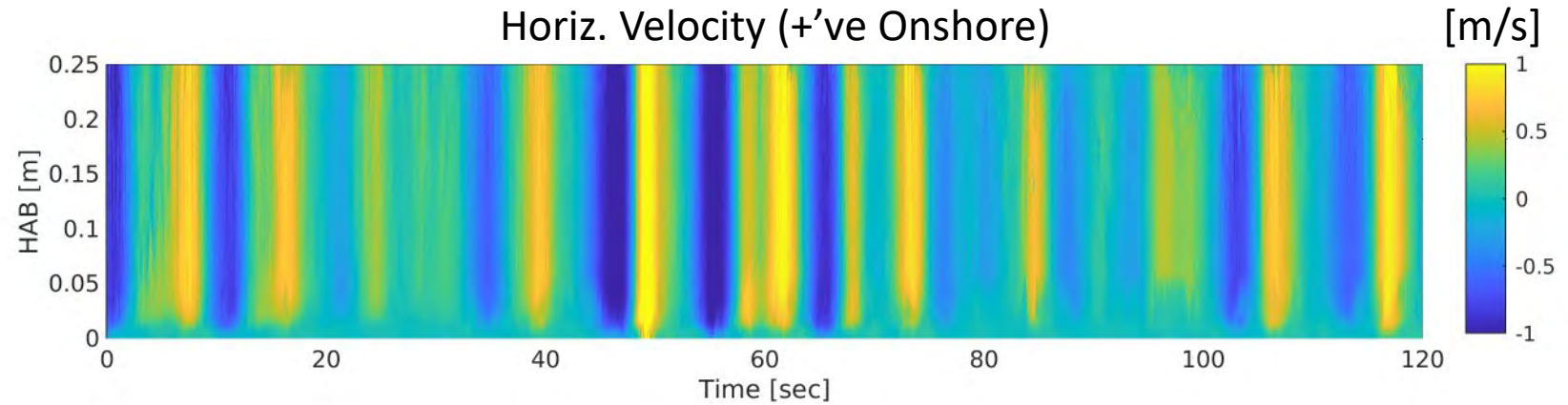
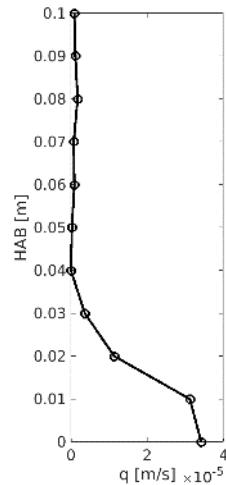
Blasstex Field Data

Waves near breakpoint

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

Time-averaged
sediment flux:

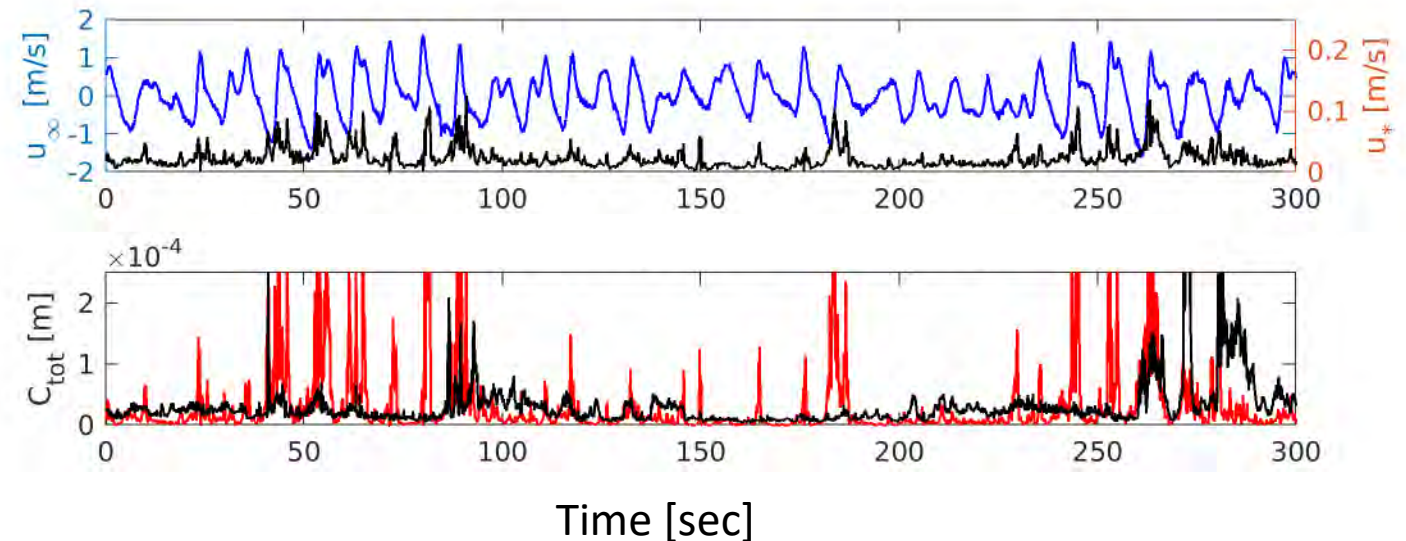
$$\langle q \rangle(z) = \langle u(z, t) c(z, t) \rangle$$



Model Validation

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

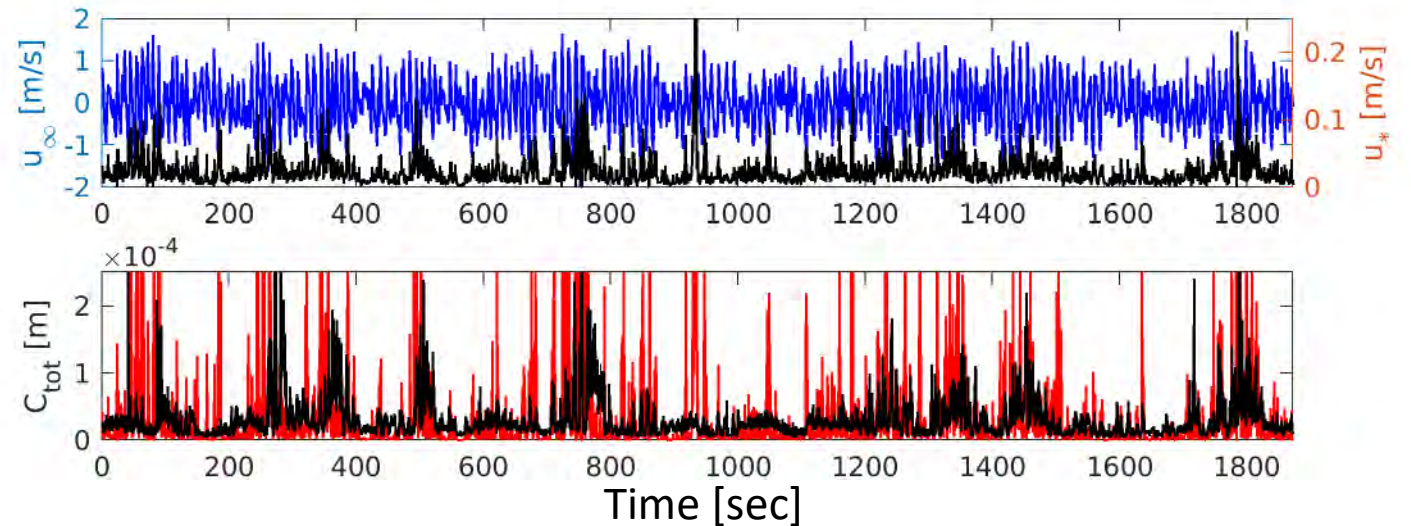
- Time-dependent results
 - Black: Measured $C(t)$
 - Red: Model (using measured u_*)
- *Timing* of suspension events is good
- Errors come from sediment “burst” *magnitude*
 - Not every u_* event corresponds to a suspension event, and vice-versa



Model Validation

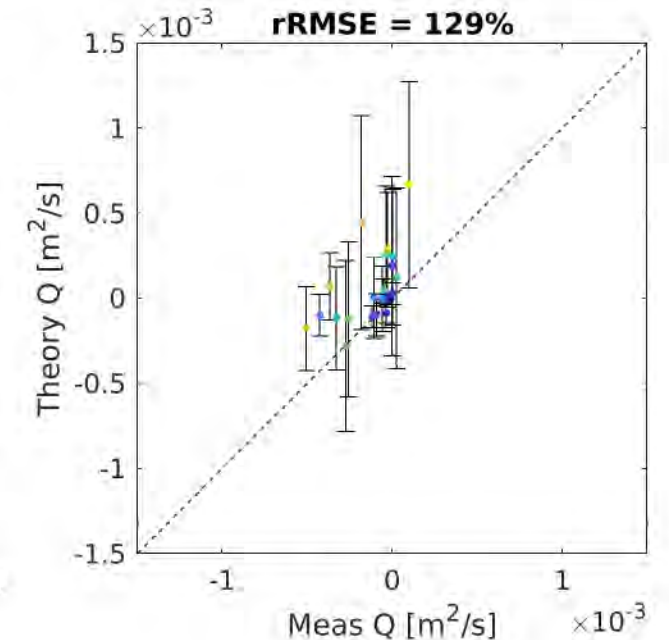
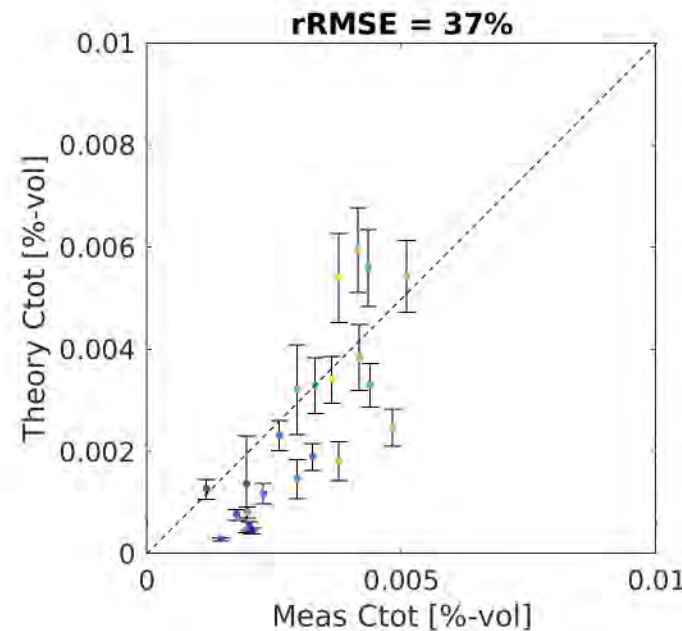
$$\langle C \rangle = \frac{\rho}{(\rho_s - \rho)g} \left[\frac{\epsilon_b}{\tan\phi} \langle u_*^2 \rangle + \frac{\epsilon_s}{w_s} \langle u_*^2 | u_\infty | \rangle \right]$$

- **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?

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

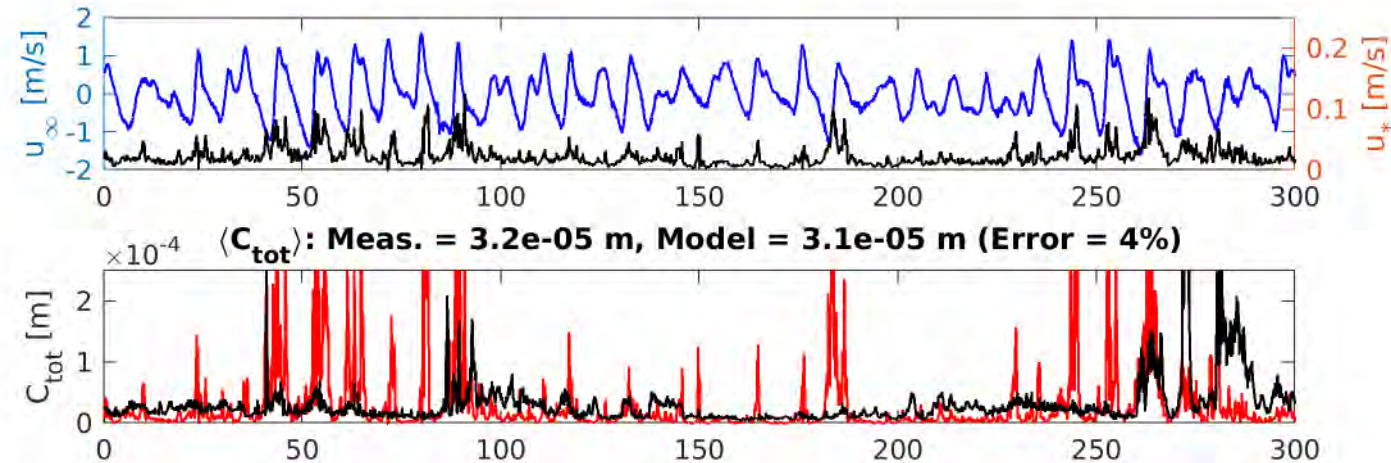
We have excellent **fundamental ideas** to draw upon...

- *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





JUNE 11 – JUNE 13

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

Decadal Visioning Workshop

**THE FUTURE OF COASTAL
PROCESSES RESEARCH**



2024

Wrap up of Day 2

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



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