Remote Sensing of Hazardous Inlet Shoals:
Insights from practitioners, the literature, and a pilot test

Justin Shawler, Aleks Ostojic,
Kaite McPherran, and Copeland Cromwell

Coastal Inlets Research Program Tech Discussion
October 29, 2024

CIRP

CHL COASTAL & HYDRAULICS LABORATORY

ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER

Project Team

Aleksandra Ostojic
Co-PI

Coastal geomorphology, remote sensing

Justin Shawler
Co-PI

Coastal geology, inlet processes

Kaite McPherran
Task Lead

Coastal geomorphology, inlet processes

Copeland Cromwell
SMART Scholar

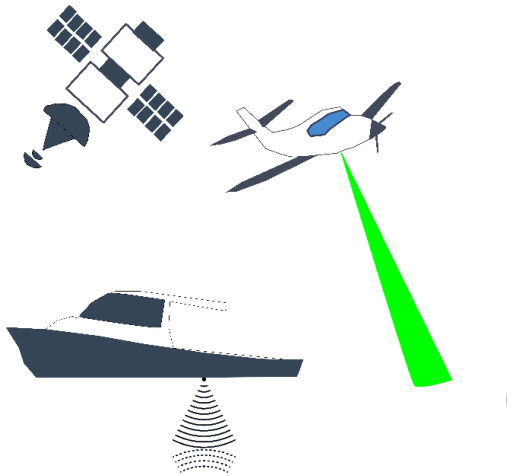
Coastal geomorphology, remote sensing

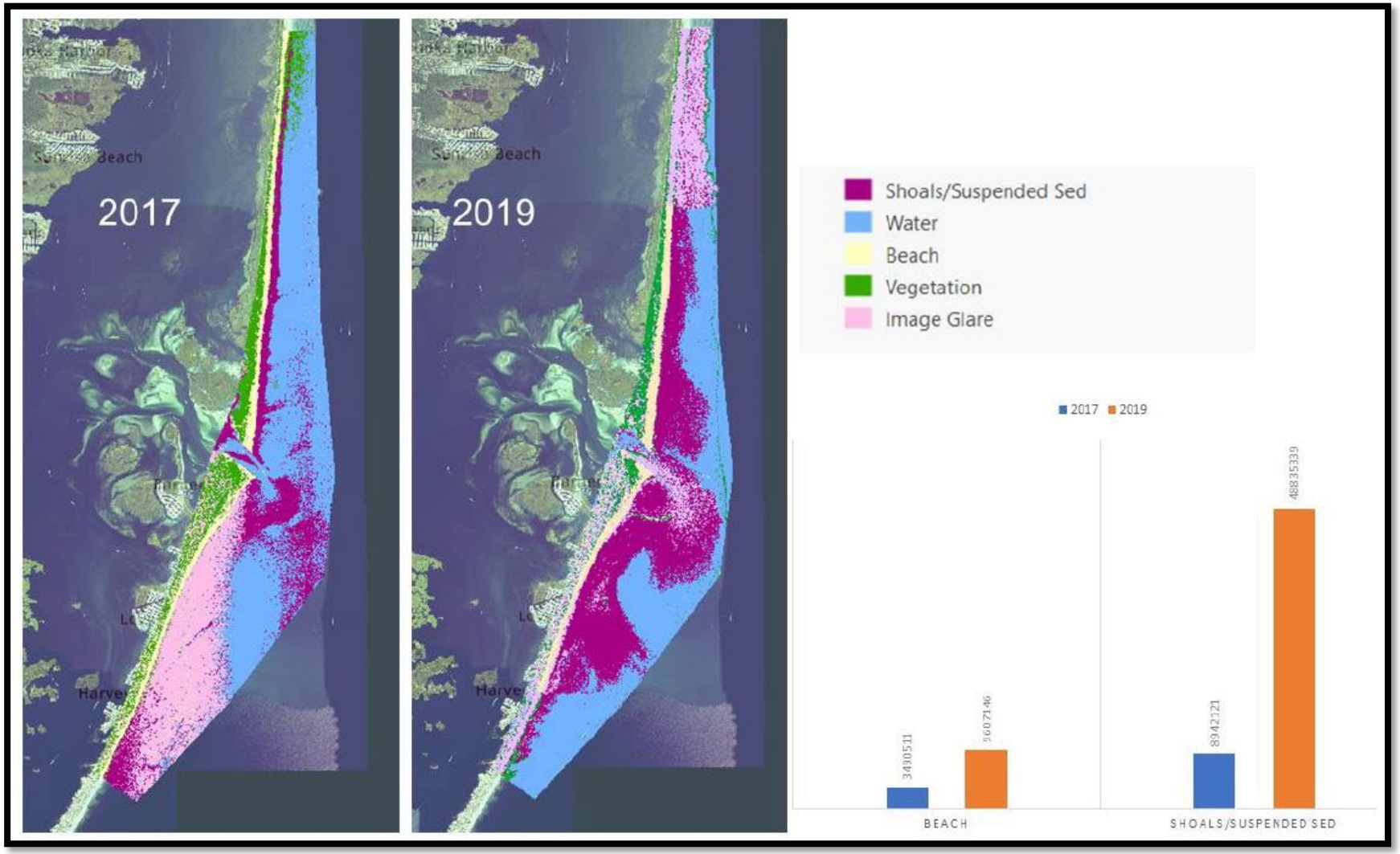
TBD (selection made)
<1 year position; post masters or higher

Python and GIS experience

Motivation

- **Barnegat Inlet Reimbursable Study**
- Identified data coverage gap
  - Footprint of hydrographic surveys are limited
  - National Coastal Mapping Program lidar and imagery = 5-year cycle
  - “Missing middle”
- Is satellite/aerial image classification a viable solution?



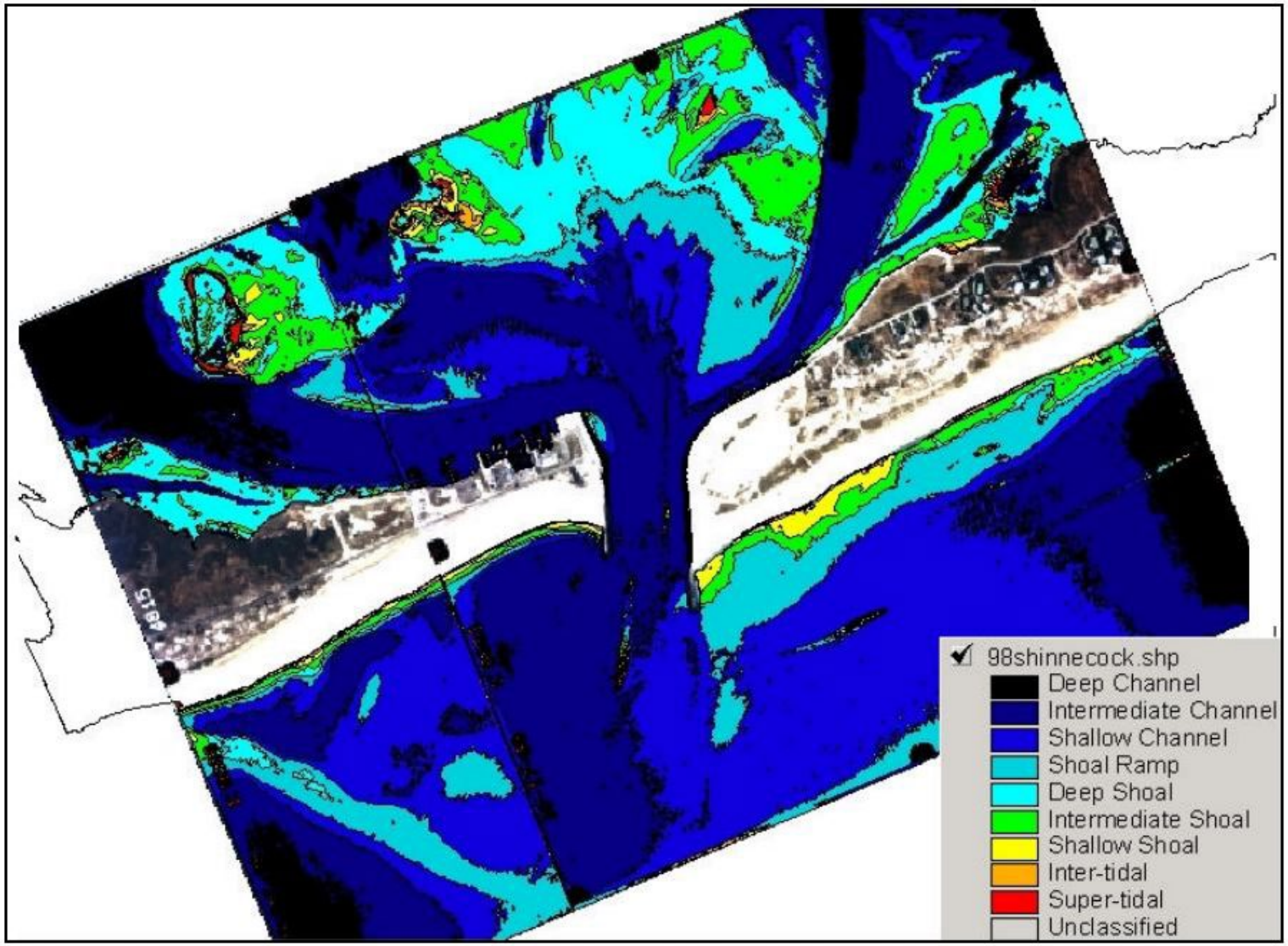


Motivation, cont.

ArcView Tool (INLETGIS)

K. Connell and G. Zarillo, 2004

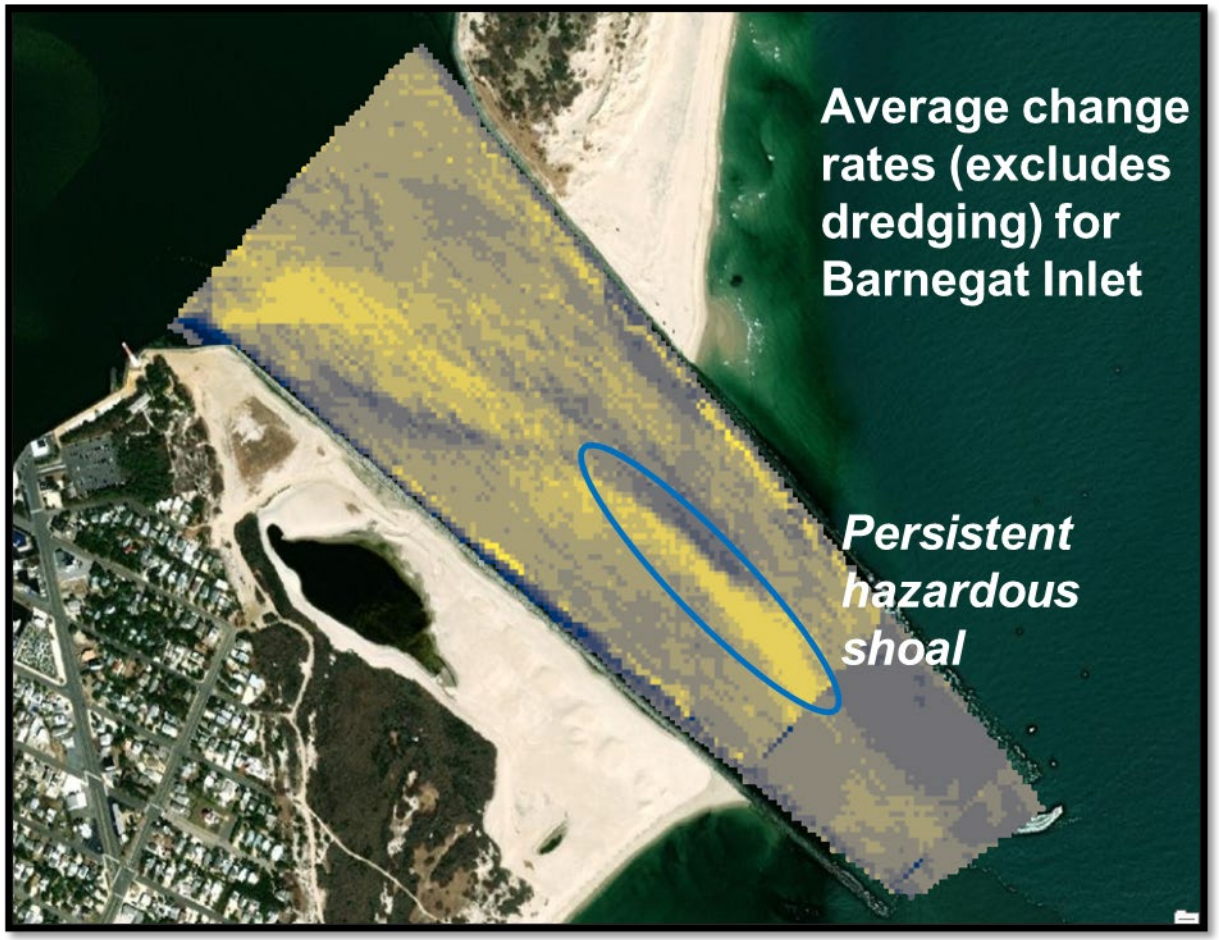
- Image Rectification
- Image Analysis
- Image Classification
- Shoreline Extraction
- Import XYZ Bathy Data



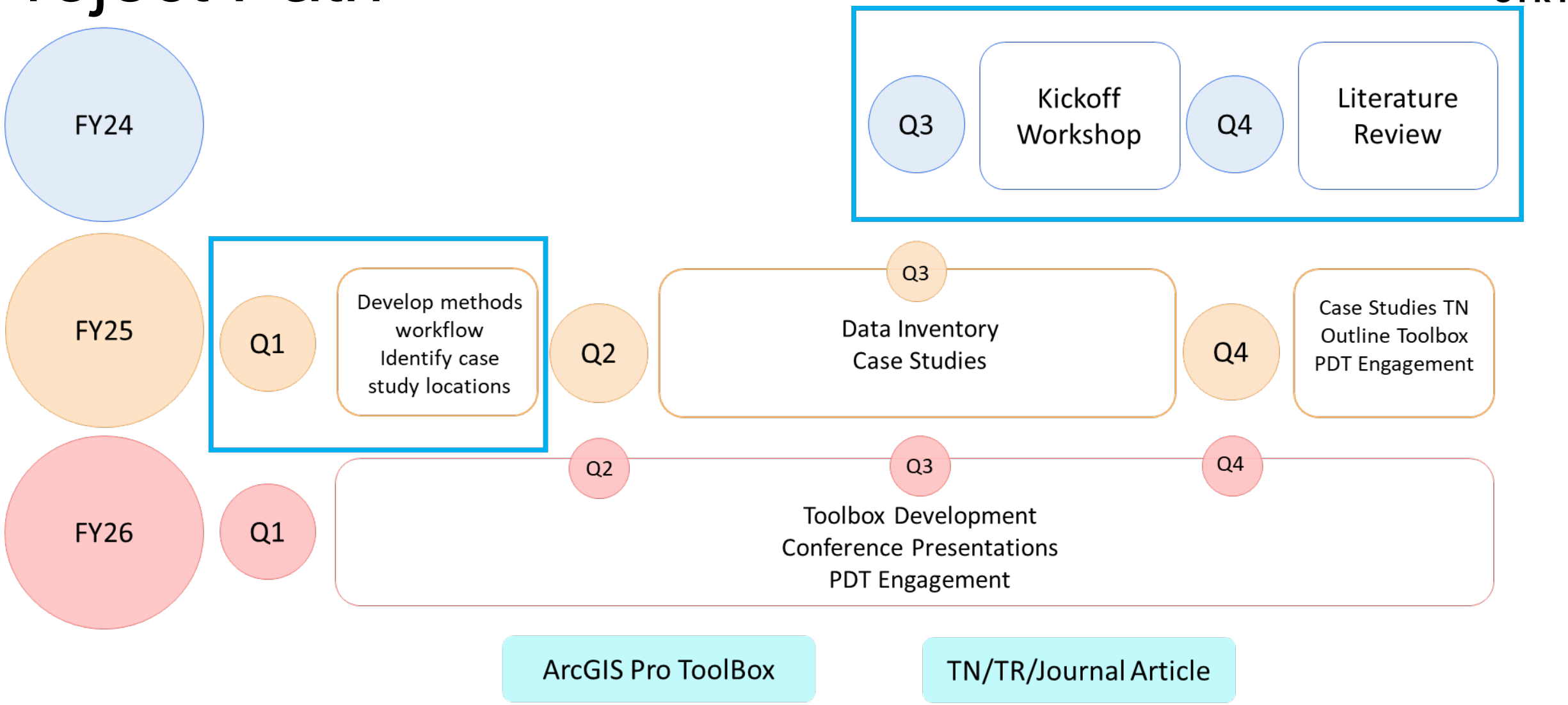
Added Motivation

- **SON 1923 (Chasten)**
- Inlet shoals pose hazards to navigation
- Understand/predict temporal changes
- New tools to monitor shoals

- **SON 2159 (Malburg)**
- Great Lakes channels
- Remote sensing and local tools
- Near real-time estimates of shoal formation and migration
- Influence of water levels on shoaling



Project Path

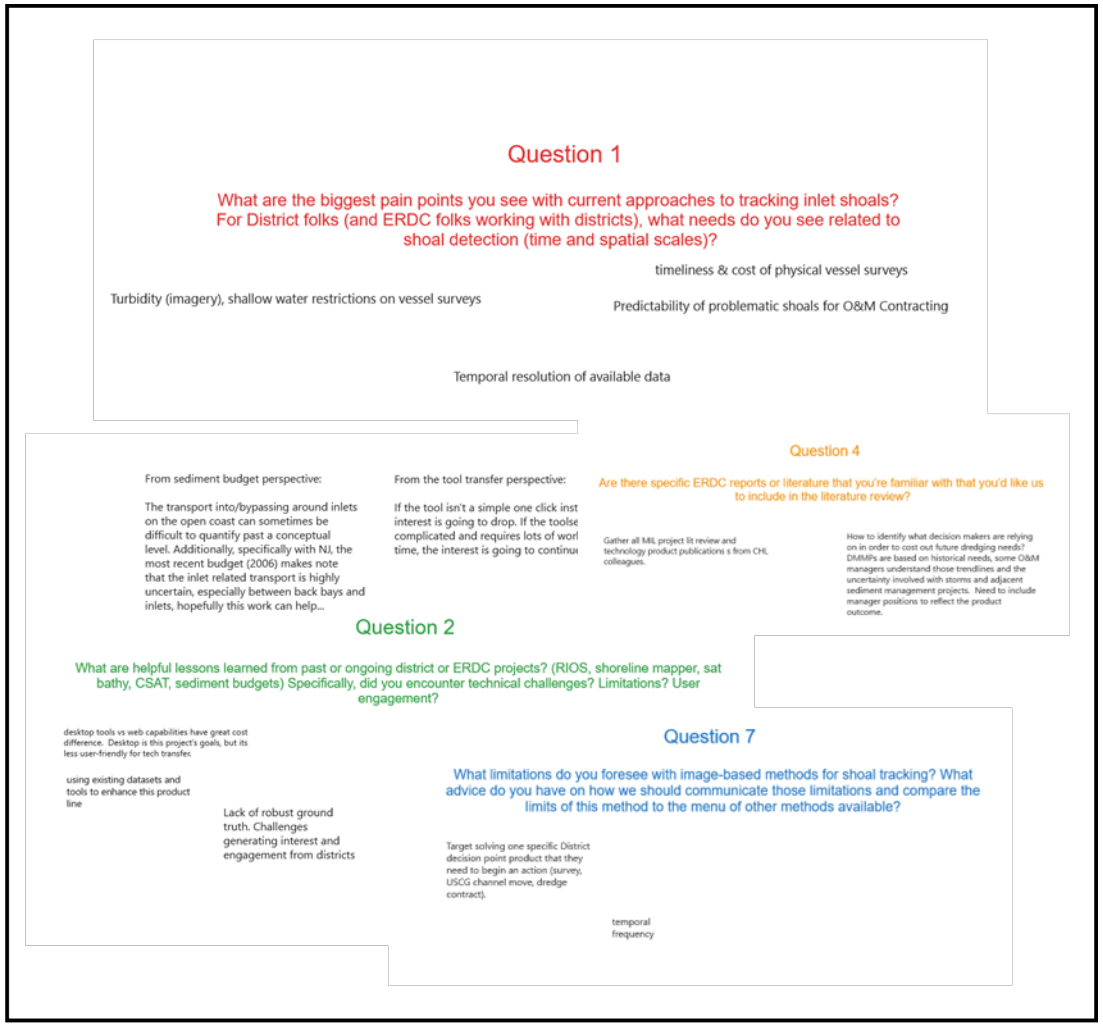


Kickoff Meeting with PDT

Districts:
Monica Chasten (NAP)
Elizabeth Godsey (SAM)
Rachel Malburg (LRE)

ERDC:
Kate Brodie,
Annika O'Dea, Ian Conery,
Shannon Brown, Sean
McGill, Charlene Sylvester,
Molly Reif

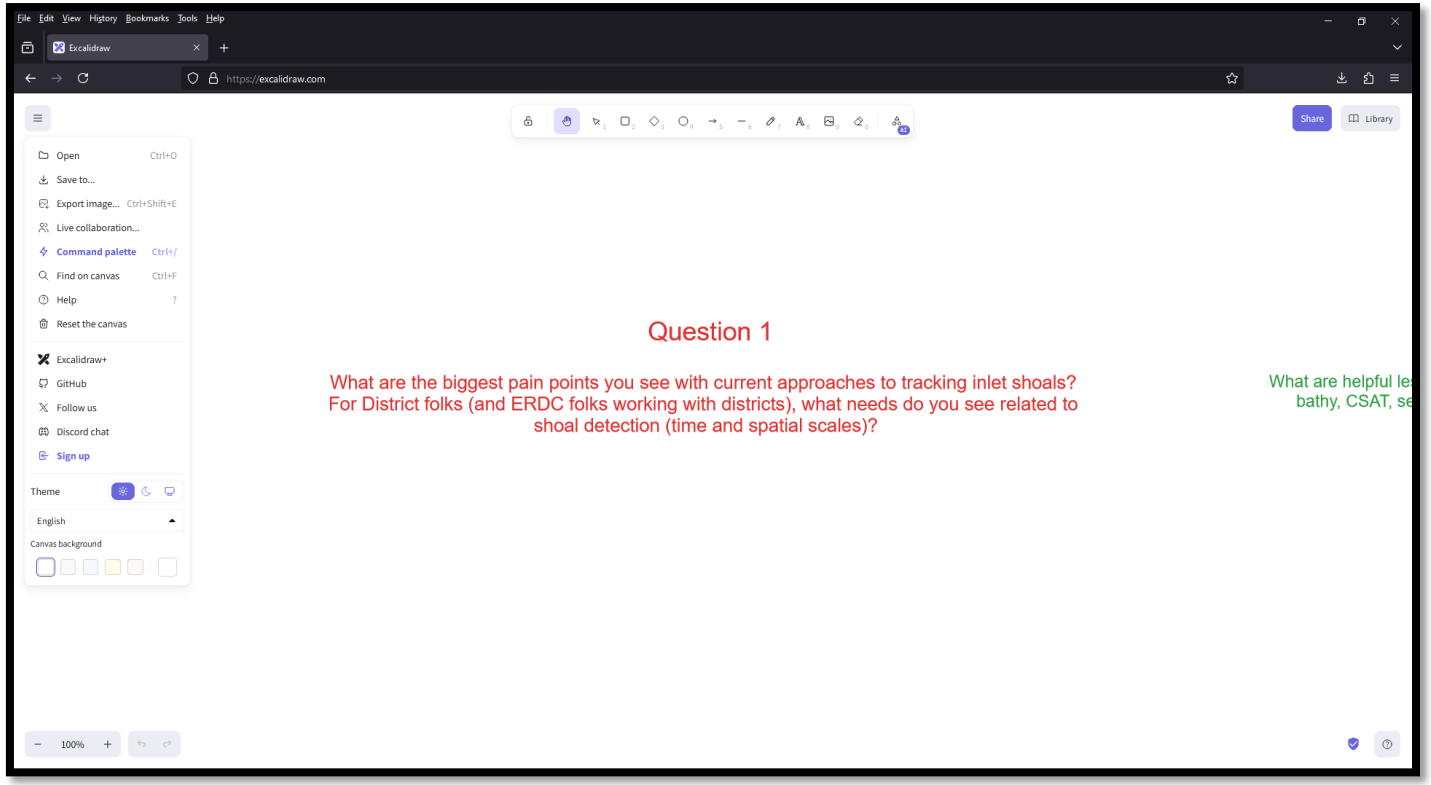
Workshop



- Whiteboarding during virtual workshop
- One-on-one and small group meetings

Feedback from PDT

- Multi-tiered approach to feedback
- Structured slide deck with background material followed by additional slides with questions
- Options for participation:
  - Verbal
  - Chat post
  - Anonymous white board using Excalidraw.com (simple, no accounts required for users)



Takeaways from Kickoff meeting with PDT

What if we could map the general trajectories of shoals in an inlet? Something along the lines of a shoal location probability/ shoal trajectory maps. Prediction of shoal trajectories? Track inlets/navigable water and shoals?

Planet can provide bi-daily imagery which could allow us to have a high temporal resolution that could allow us to select imagery with appropriate weather and wave conditions.

Spatial/regional variability in inlets. How can this tool be used in different regions. Can this tool be applied at W. Coast inlets? Perhaps a case study?

Shoals shifting too quickly to cost effectively monitor shoal conditions/location with current vessel surveys, lidar, etc.

Quarterly surveys desired.

Video looping of shoal migration as a qualitative product.

More workshops to engage districts – getting tools to the districts and better incorporating their use. Address disconnects between ERDC tools and district use. How to connect these tools with the district and show their applicability to district work.

Literature Review

60+ peer review articles, conference proceedings, reports, and theses/dissertations

Non-Satellite Based Tools for Inlet Shoal Monitoring

- Hydrographic Surveys
- Airborne Bathymetric Lidar
- Radar Inlet Observing System
- Imagery & Video (fixed camera, UAS, aerial)

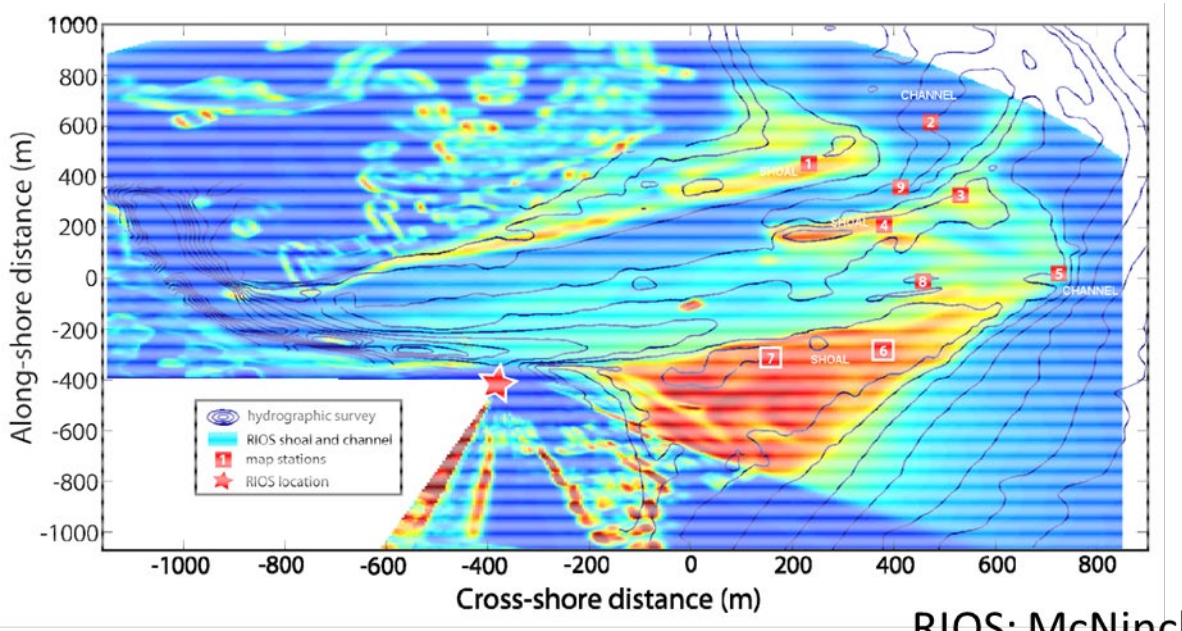
Satellite Approaches

- Satellite Derived Bathymetry
- ***Image Classification of Inlets & Similar Environments***
  - **Workflow will rely on these methods**

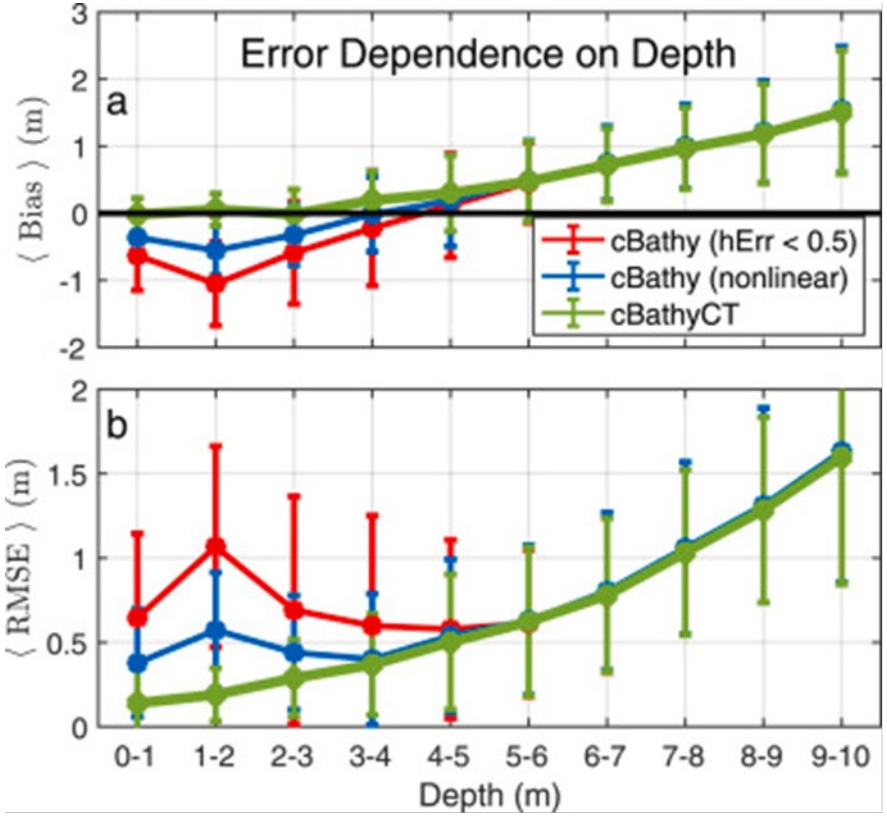
Literature Review – *Error*

Reliability of remotely inferred bathymetry:

- Qualitative/features are generally good
- Relative bathymetry and/or feature tracking common



RIOS: McNinch et all., 2012

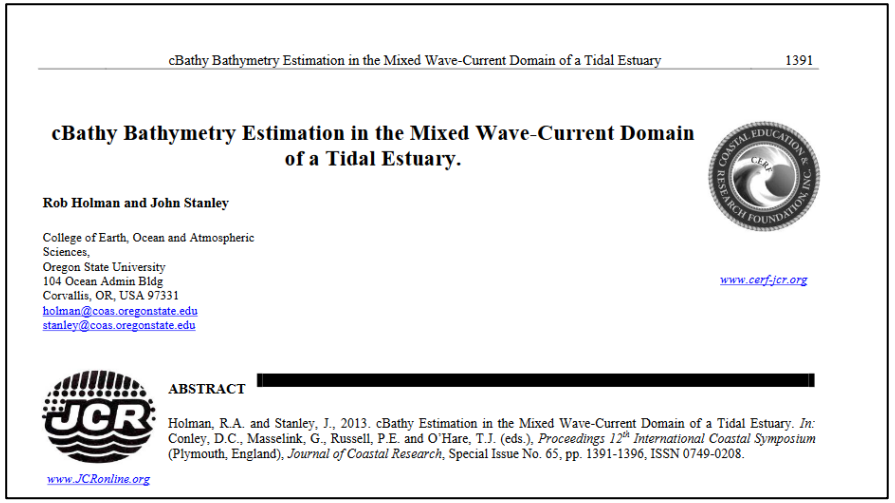


cBathy UAV: Lange et al., 2023 Coastal Engineering

Literature Review – *Challenges*

Wave celerity-based approaches are feasible but can be challenging due to complexity of inlet hydrodynamics

- **This project needs to fill gap where not feasible to use celerity-based approaches
- Working collaboratively with Conery/Brown work unit



cBathy Bathymetry Estimation in the Mixed Wave-Current Domain of a Tidal Estuary 1391

cBathy Bathymetry Estimation in the Mixed Wave-Current Domain of a Tidal Estuary.

Rob Holman and John Stanley

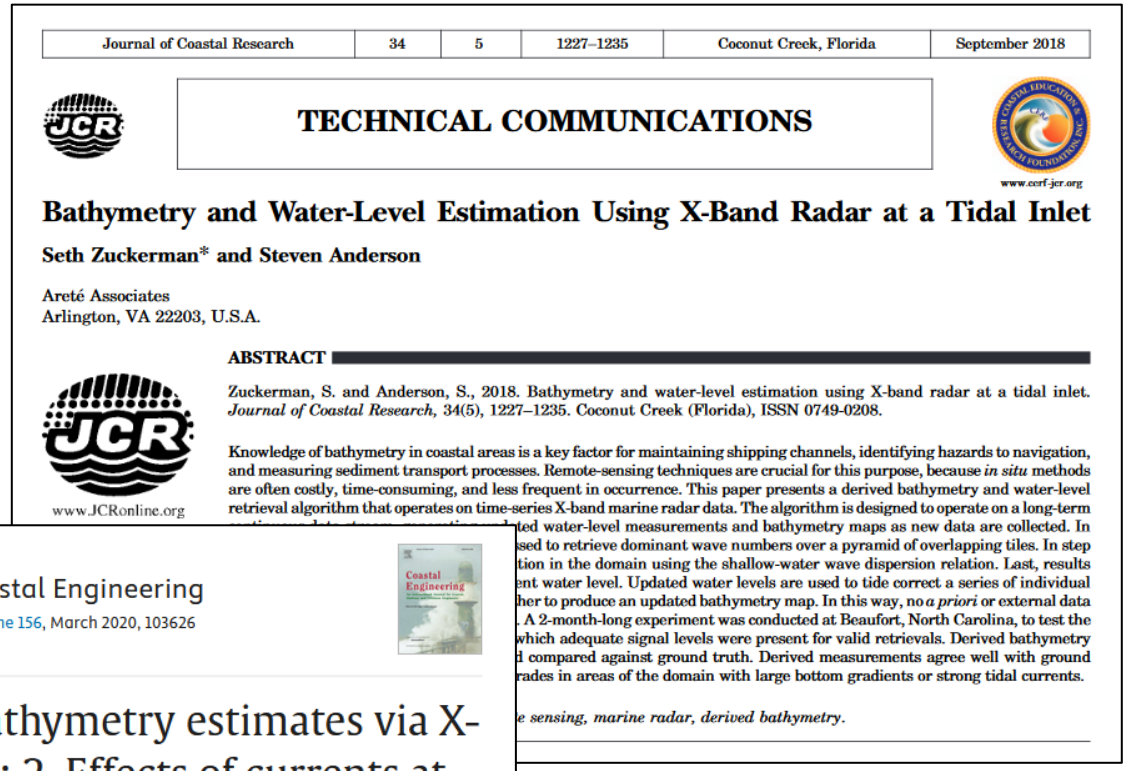
College of Earth, Ocean and Atmospheric Sciences,
Oregon State University
104 Ocean Admin Bldg
Corvallis, OR, USA 97331
holman@coas.oregonstate.edu
stanley@coas.oregonstate.edu

www.cerf-jcr.org

ABSTRACT

Holman, R.A. and Stanley, J., 2013. cBathy Estimation in the Mixed Wave-Current Domain of a Tidal Estuary. *In:* Conley, D.C., Masselink, G., Russell, P.E. and O'Hare, T.J. (eds.), *Proceedings 12th International Coastal Symposium* (Plymouth, England), *Journal of Coastal Research*, Special Issue No. 65, pp. 1391-1396, ISSN 0749-0208.

www.JCRonline.org



Journal of Coastal Research | 34 | 5 | 1227–1235 | Coconut Creek, Florida | September 2018

TECHNICAL COMMUNICATIONS

www.cerf-jcr.org

Bathymetry and Water-Level Estimation Using X-Band Radar at a Tidal Inlet

Seth Zuckerman* and Steven Anderson

Areté Associates
Arlington, VA 22203, U.S.A.

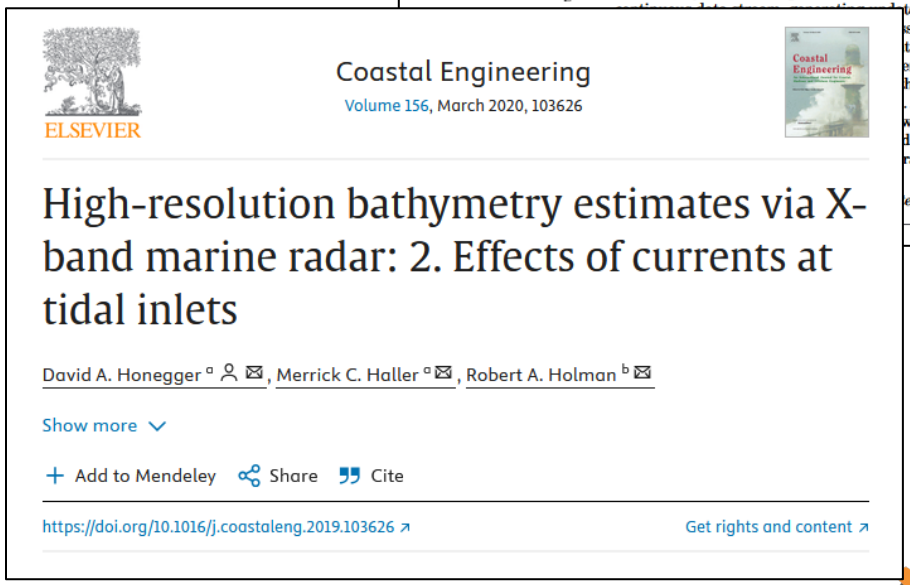
www.JCRonline.org

ABSTRACT

Zuckerman, S. and Anderson, S., 2018. Bathymetry and water-level estimation using X-band radar at a tidal inlet. *Journal of Coastal Research*, 34(5), 1227–1235. Coconut Creek (Florida), ISSN 0749-0208.

Knowledge of bathymetry in coastal areas is a key factor for maintaining shipping channels, identifying hazards to navigation, and measuring sediment transport processes. Remote-sensing techniques are crucial for this purpose, because *in situ* methods are often costly, time-consuming, and less frequent in occurrence. This paper presents a derived bathymetry and water-level retrieval algorithm that operates on time-series X-band marine radar data. The algorithm is designed to operate on a long-term ted water-level measurements and bathymetry maps as new data are collected. In sed to retrieve dominant wave numbers over a pyramid of overlapping tiles. In step tion in the domain using the shallow-water wave dispersion relation. Last, results nt water level. Updated water levels are used to tide correct a series of individual her to produce an updated bathymetry map. In this way, no *a priori* or external data . A 2-month-long experiment was conducted at Beaufort, North Carolina, to test the which adequate signal levels were present for valid retrievals. Derived bathymetry d compared against ground truth. Derived measurements agree well with ground rades in areas of the domain with large bottom gradients or strong tidal currents.

e sensing, marine radar, derived bathymetry.



ELSEVIER

Coastal Engineering

Volume 156, March 2020, 103626

High-resolution bathymetry estimates via X-band marine radar: 2. Effects of currents at tidal inlets

David A. Honegger [a], Merrick C. Haller [a], Robert A. Holman [b]

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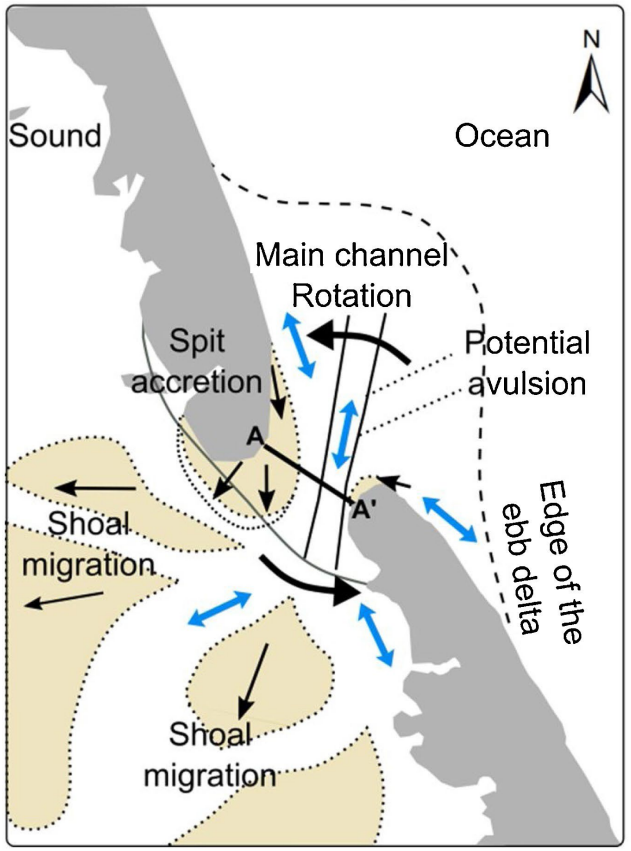
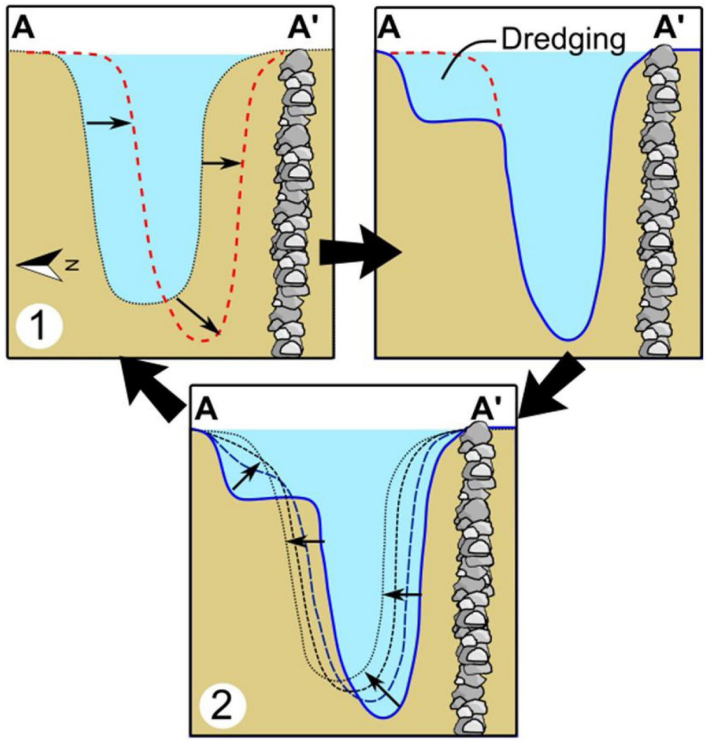
Literature Review – *Shoal Migration*

Shoal migration rates of
100 – 1000 m/yr

General evolutional patterns



Cyclic adjustment of the main channel
to dredging in the navigational channel



Velasquez-Montoya et al., 2020, Geomorphology

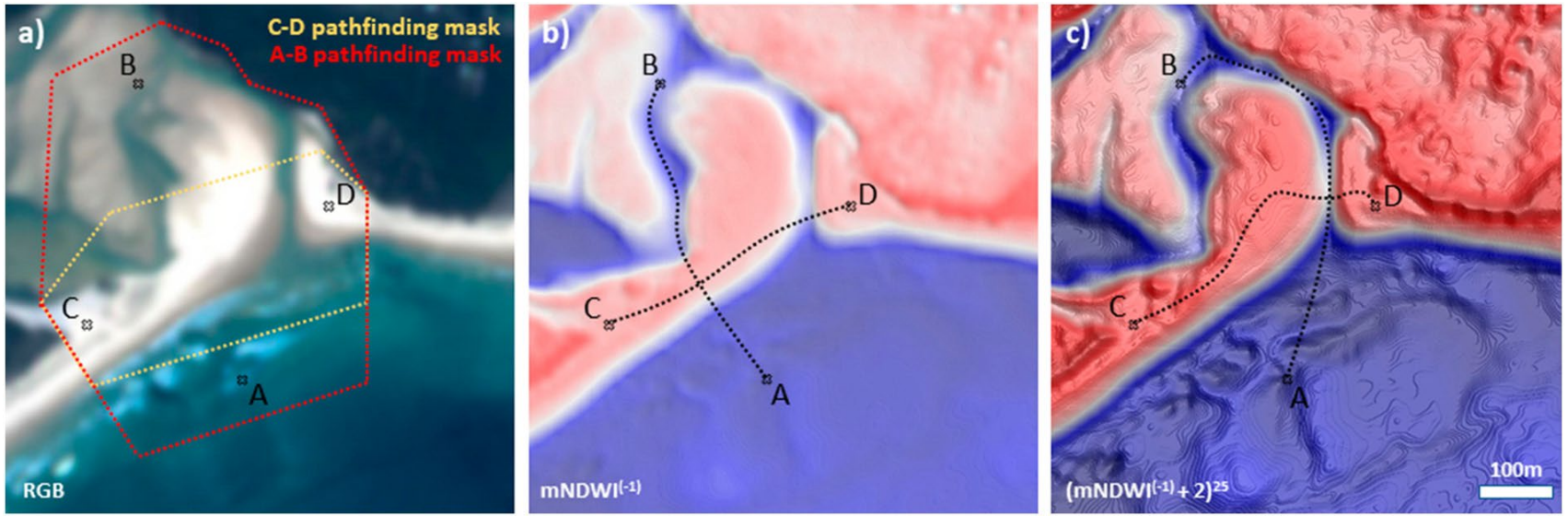
Literature Review – *Key Indices*

Normalized Difference Water Index (NDWI) and modified NDWI (mNDWI)

- CoastSat – 2nd step of shoreline detection
- InletTracker – thalweg migration

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

$$MNDWI = \frac{SWIR1 - G}{SWIR1 + G}$$

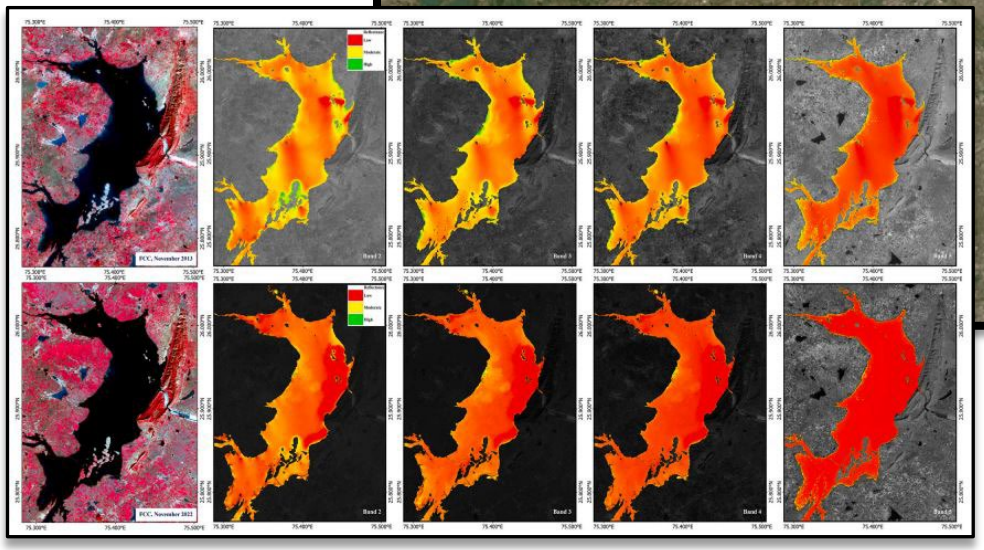


Literature Review – *NDWI Challenges*

Normalized Difference Water Index (NDWI) also used to track turbidity

Need to keep in mind

Potential to mistake turbidity for shoals



Singh et al., 2023, Environmental Research

Pilot Studies

East Pass Inlet

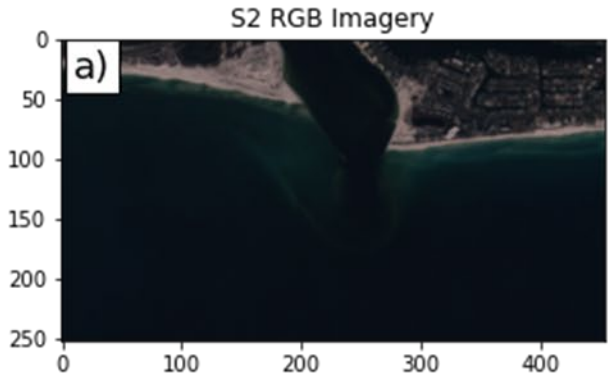
- FL Panhandle
- Good water clarity
- Decent ground-truthing data available
- Maintained and dredged since 1931
- History of thalweg migration/rotation

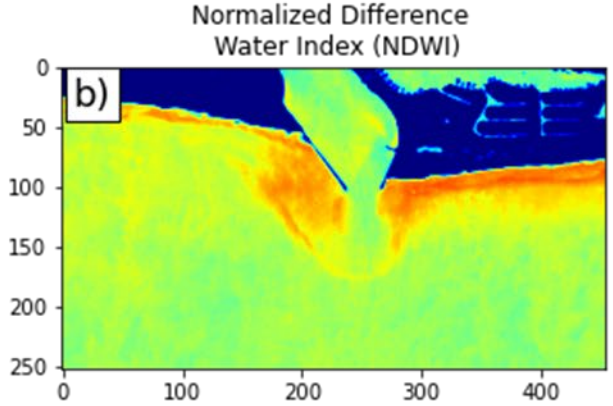
Barnegat Inlet

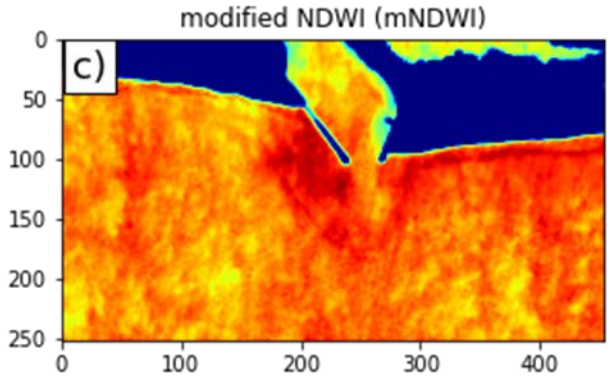
- NJ Coast
- Poorer water clarity
- Decent ground truthing data available
- Initial jetty construction in 1930s
- Ongoing dredging needs – persistent shoals

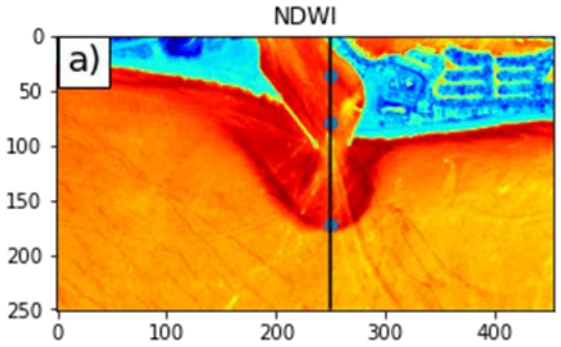
NDWI Application

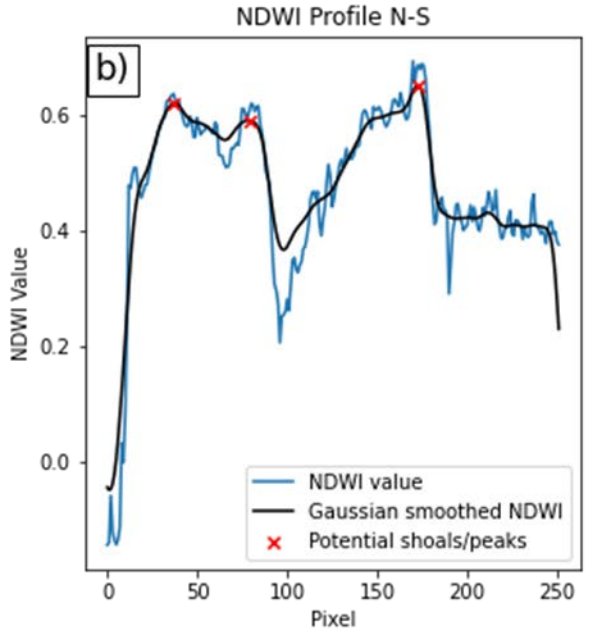
$$NDWI = \frac{Green - NIR}{Green + NIR}$$

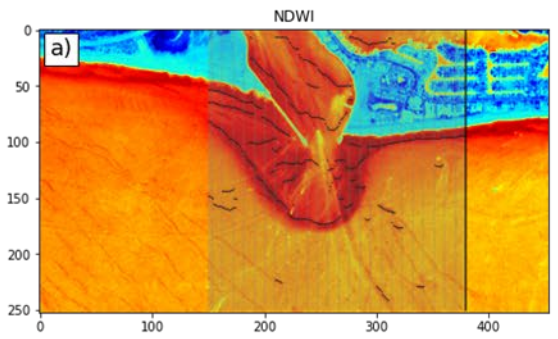


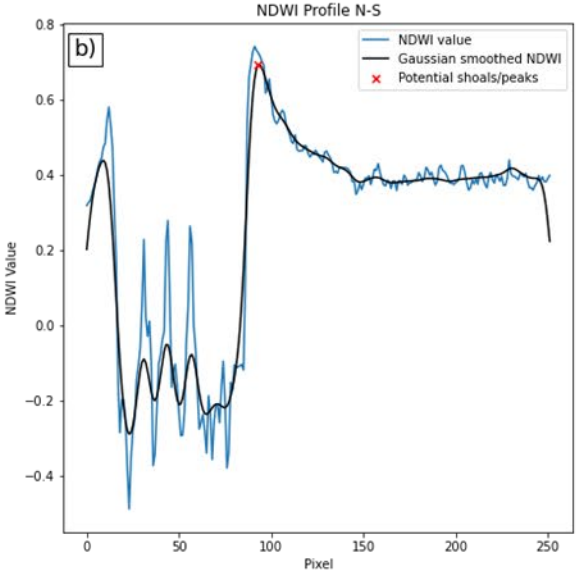




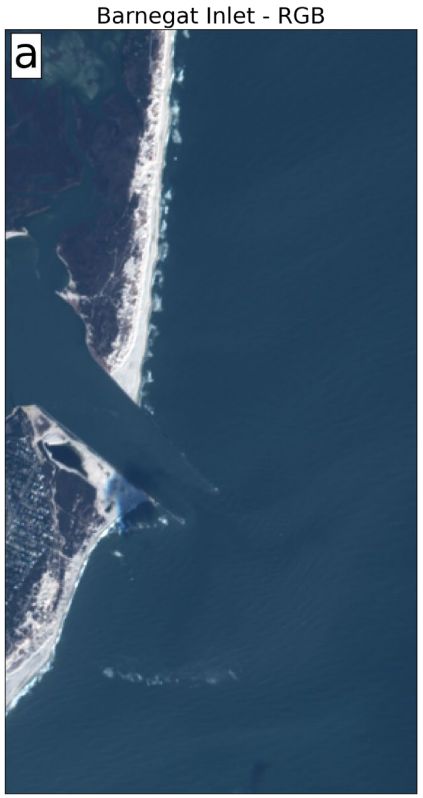


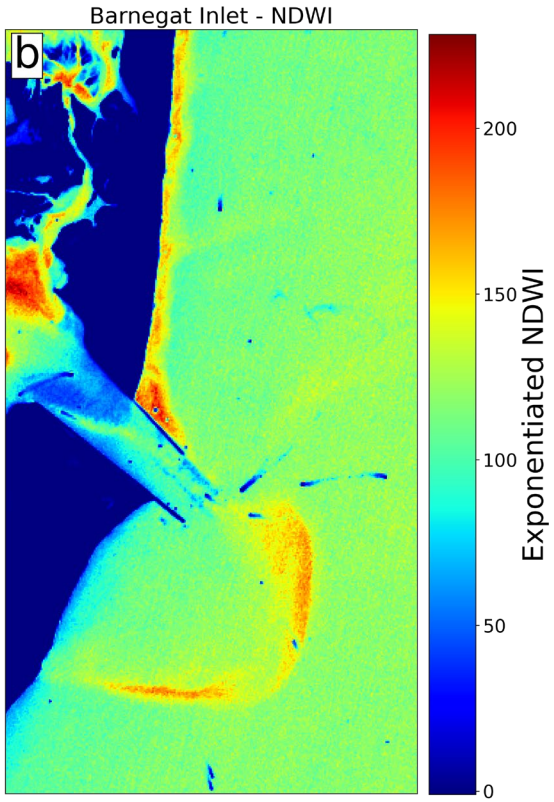


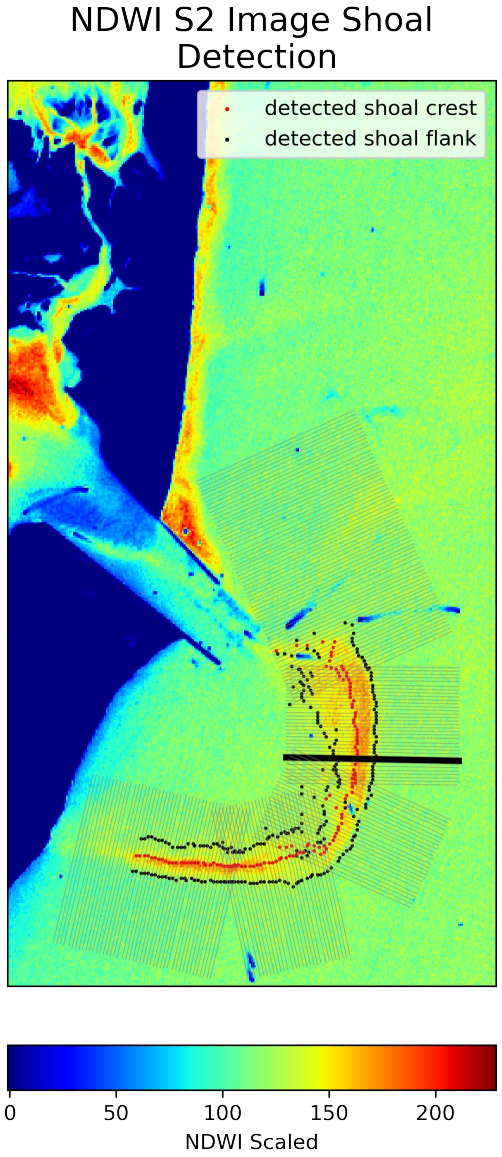




NDWI Application, cont.

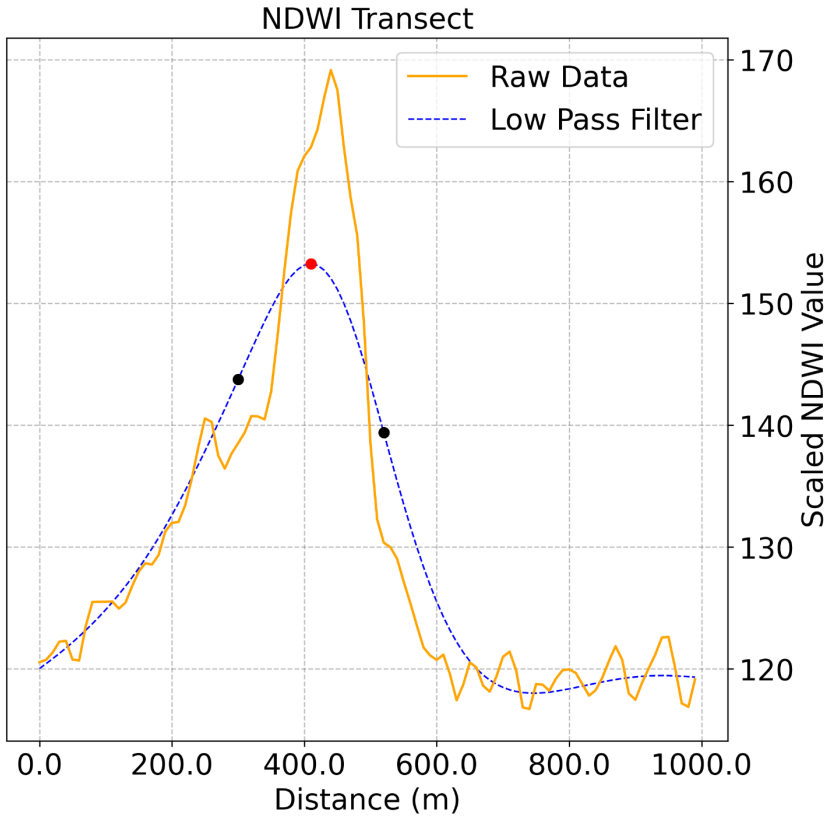






<u>NDWI is projected onto transects to identify shoals</u>

- Low pass filtering to remove wave and environmental “noise”
- Peaks and inflections in NDWI used to identify shoal crests and “flanks”.



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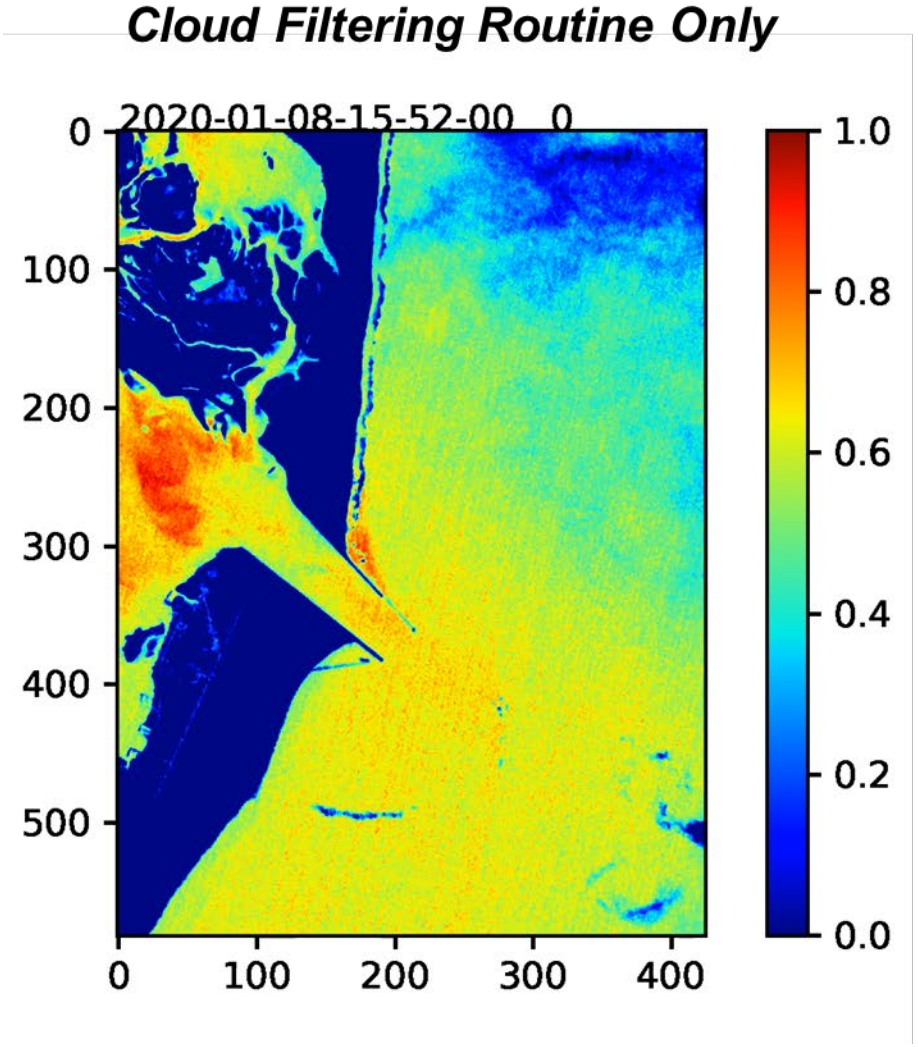
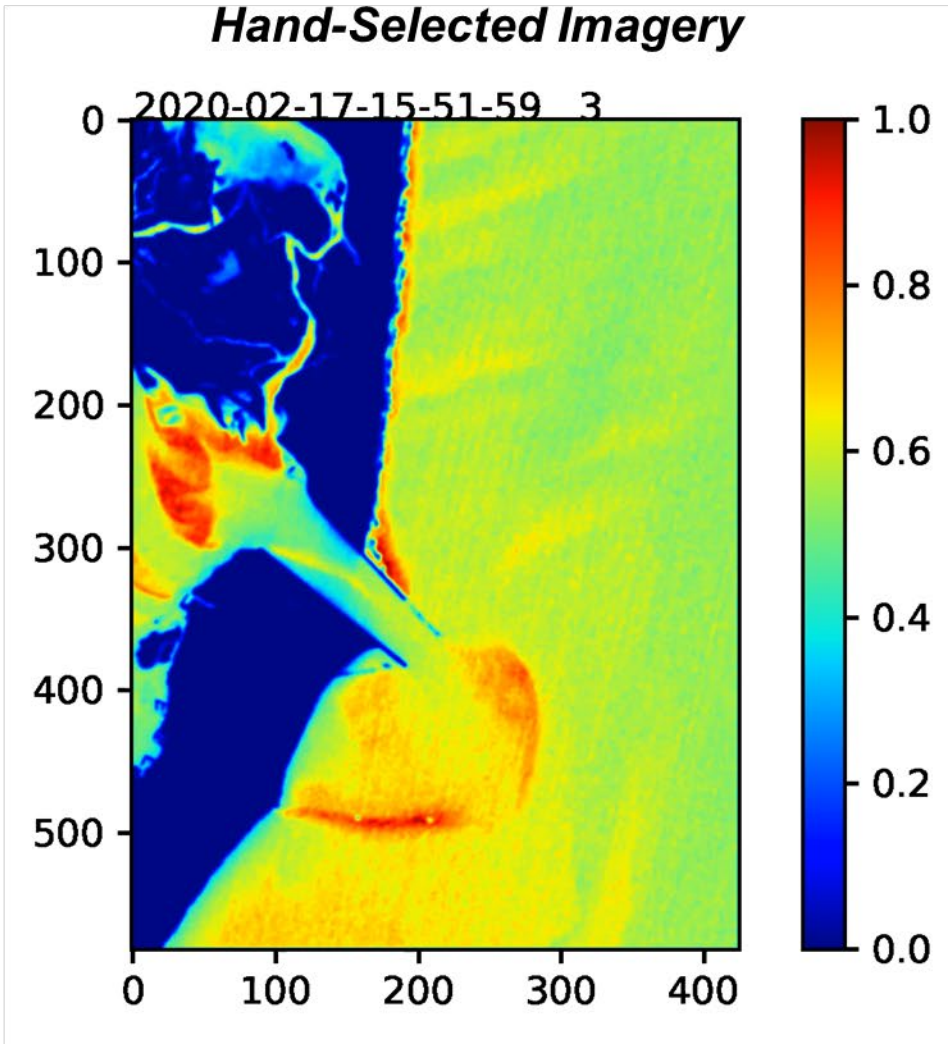
NDWI Challenges

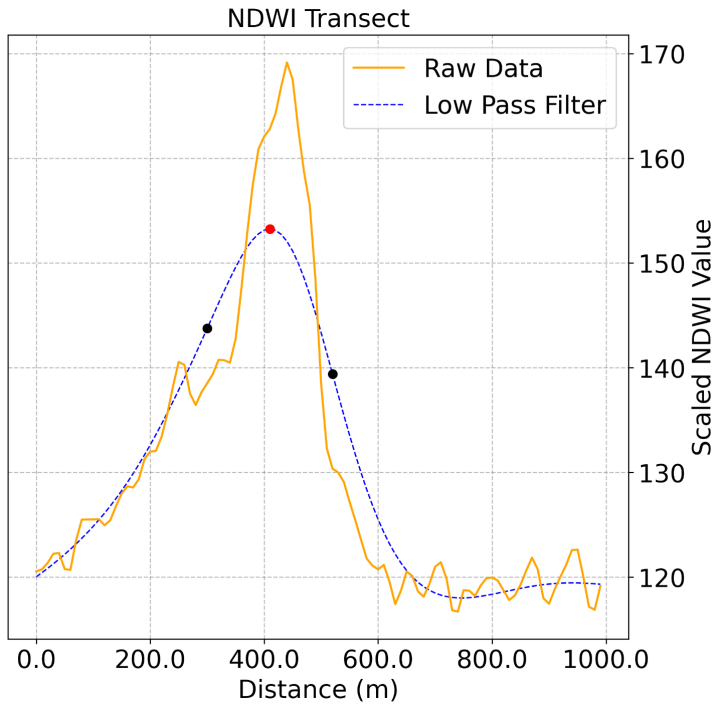
- Cloud cover
- Waves
- Turbidity
- Vessels





Final Products

Visualize and quantify change



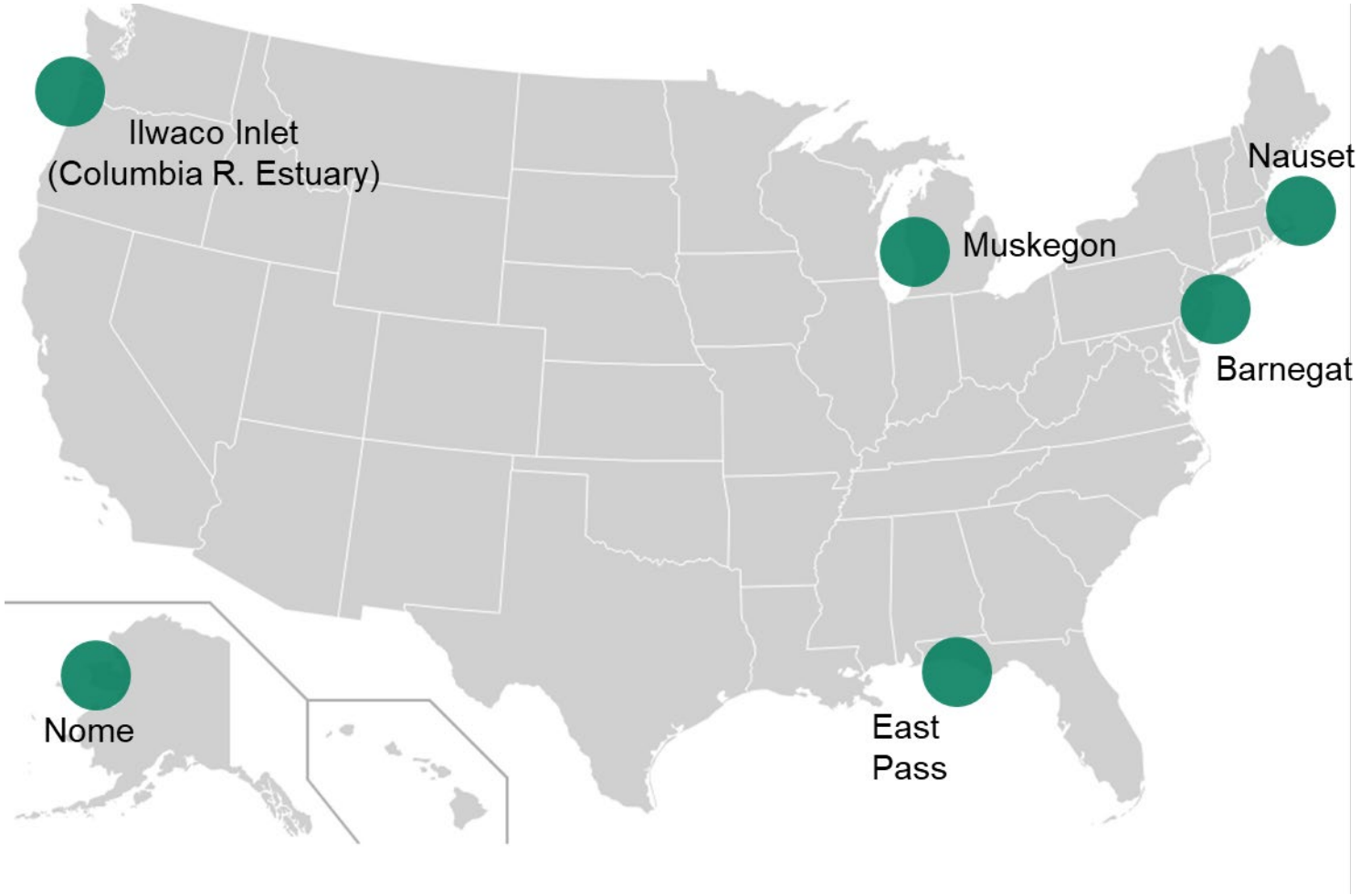
Summary and Conclusions

Key Highlights:

- PDT Engaged – example of gather input from multiple practitioners and technical experts
- Literature Review draft complete with key takeaways identified
- NDWI identified as common index from literature; tested at two distinct sites with reasonable success

Next Steps:

- Refine workflow and apply to case study sites (Map on right)
- Collaborate with Conery/Brown work unit to combine celerity and image-based approaches



Questions?

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