

# 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



# Project Team



**Aleksandra Ostojic**  
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Coastal  
geomorphology,  
remote sensing



**Justin Shawler**  
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Coastal geology,  
inlet processes



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Task Lead

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SMART Scholar

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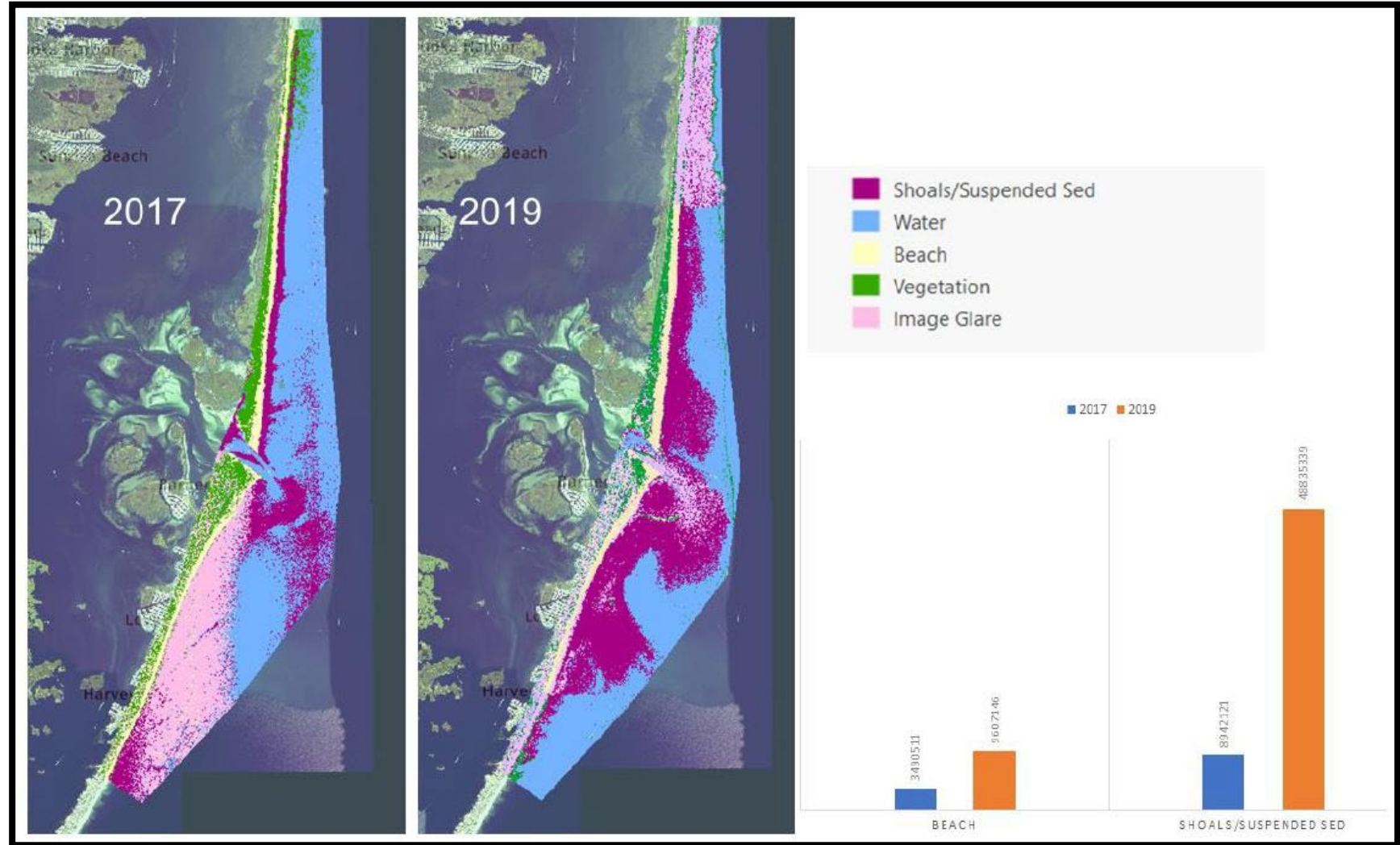
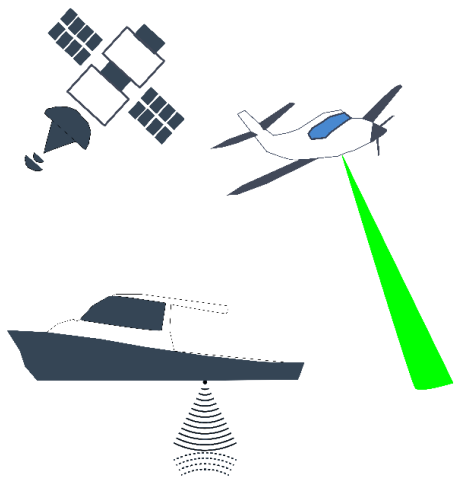


**TBD (selection made)**  
<1 year position; post  
masters or higher

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?



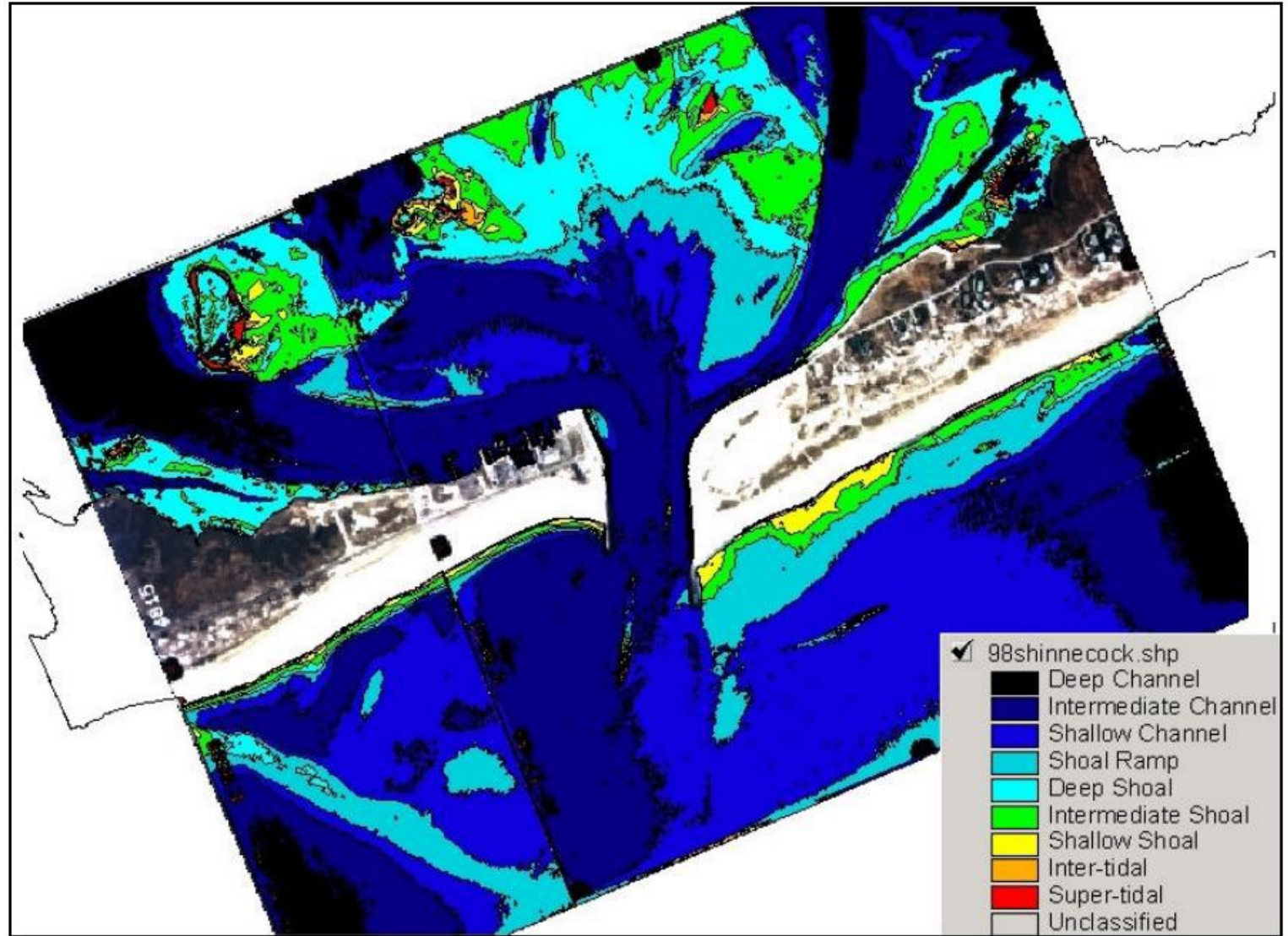
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# Motivation, cont.

## ArcView Tool (INLETGIS)

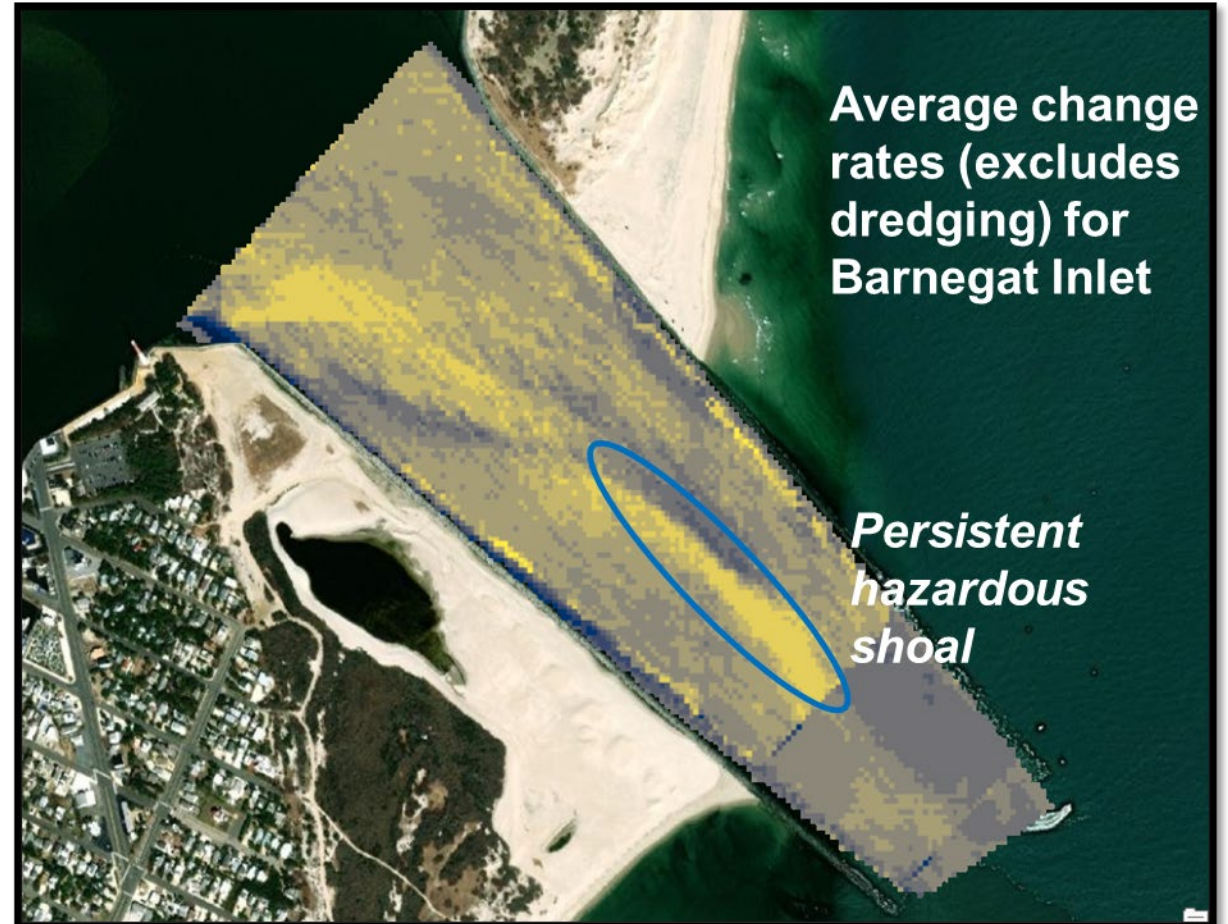
K. Connell and G. Zarillo, 2004

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



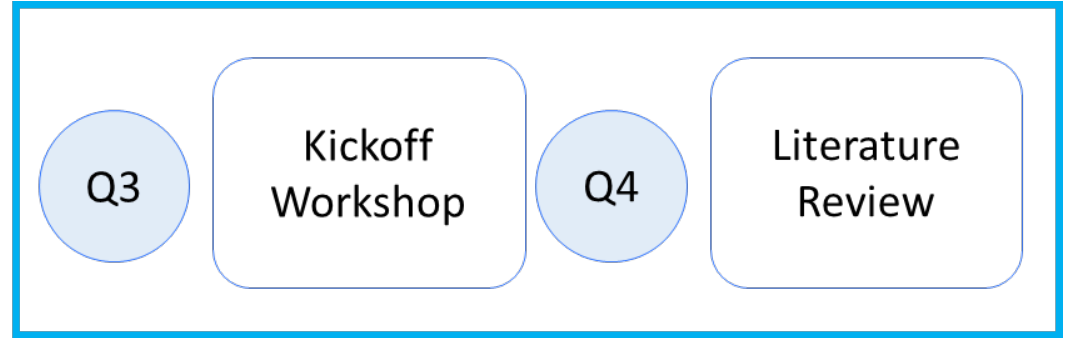
# Added Motivation

- **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

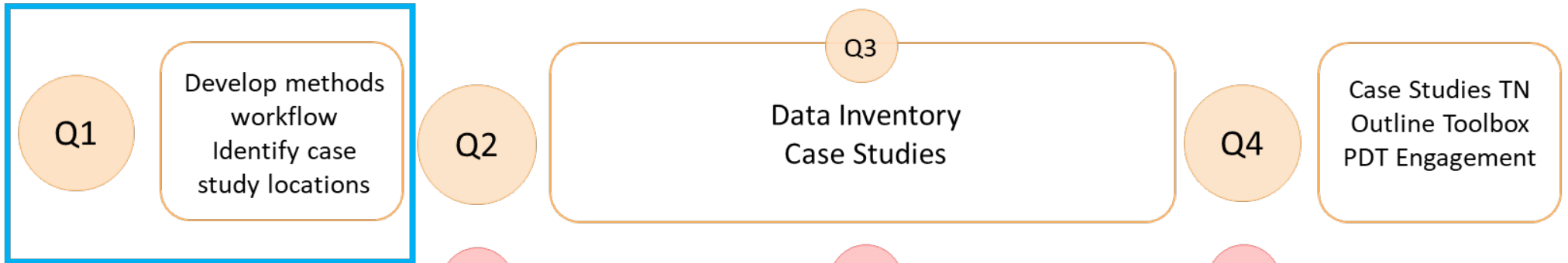


# Project Path

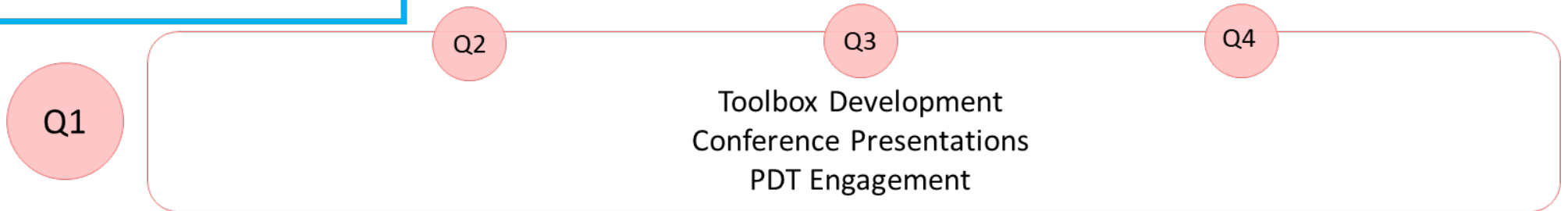
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FY25



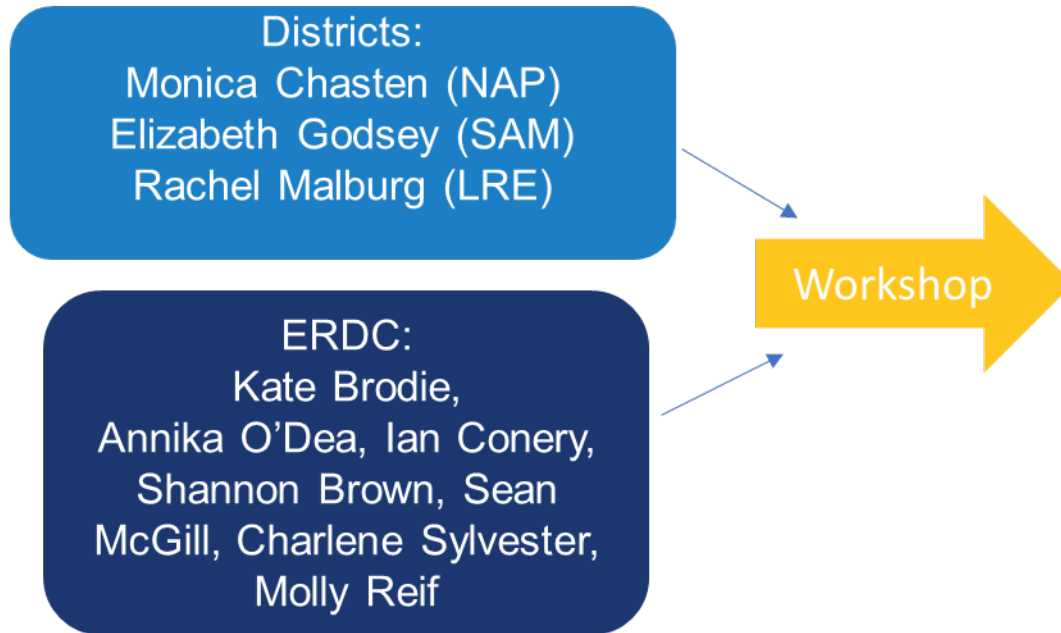
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ArcGIS Pro ToolBox

TN/TR/Journal Article

# Kickoff Meeting with PDT



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

**Question 1**

What are the biggest pain points you see with current approaches to tracking inlet shoals? For District folks (and ERDC folks working with districts), what needs do you see related to shoal detection (time and spatial scales)?

timeliness & cost of physical vessel surveys

Turbidity (imagery), shallow water restrictions on vessel surveys

Predictability of problematic shoals for O&M Contracting

Temporal resolution of available data

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**Question 2**

What are helpful lessons learned from past or ongoing district or ERDC projects? (RIOS, shoreline mapper, sat bathy, CSAT, sediment budgets) Specifically, did you encounter technical challenges? Limitations? User engagement?

desktop tools vs web capabilities have great cost difference. Desktop is this project's goal, but its less user-friendly for tech transfer.

using existing datasets and tools to enhance this product line

Lack of robust ground truth. Challenges generating interest and engagement from districts

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**Question 4**

Are there specific ERDC reports or literature that you're familiar with that you'd like us to include in the literature review?

From sediment budget perspective:  
 The transport into/by-passing around inlets on the open coast can sometimes be difficult to quantify past a conceptual level. Additionally, specifically with NI, the most recent budget (2006) makes note that the inlet related transport is highly uncertain, especially between back bays and inlets, hopefully this work can help...

From the tool transfer perspective:  
 If the tool isn't a simple one click inst interest is going to drop. If the tool is complicated and requires lots of work time, the interest is going to continue.

Gather all M&E project fit review and technology product publications from CHE colleagues.

How to identify what decision makers are relying on in order to cost out future dredging needs? DMBAs are based on historical needs, some O&M managers understand those trends and the uncertainty involved with storms and adjacent sediment management projects. Need to include manager positions to reflect the product outcome.

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**Question 7**

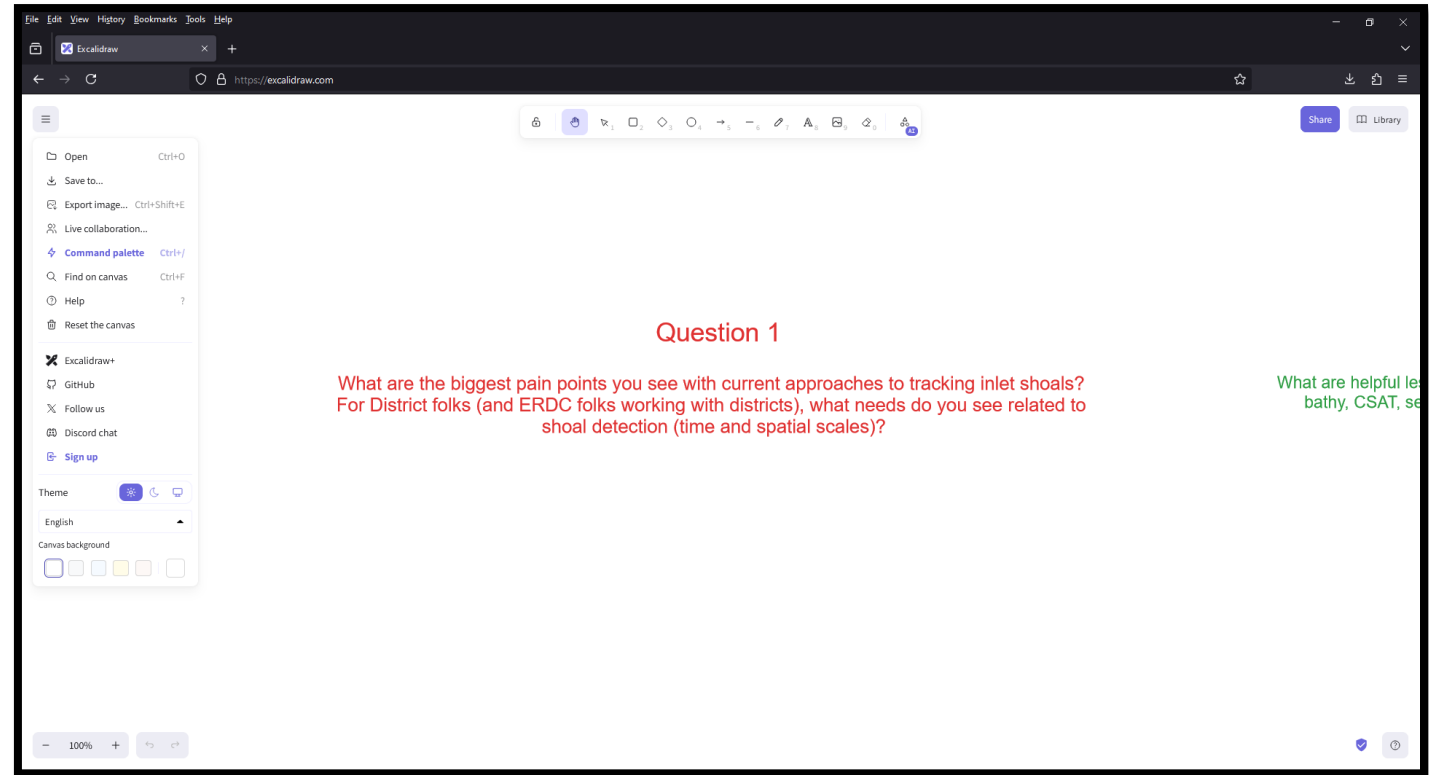
What limitations do you foresee with image-based methods for shoal tracking? What advice do you have on how we should communicate those limitations and compare the limits of this method to the menu of other methods available?

Target solving one specific District decision point product that they need to begin an action (survey, USCG channel move, dredge contract).

temporal frequency

# 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\*\****

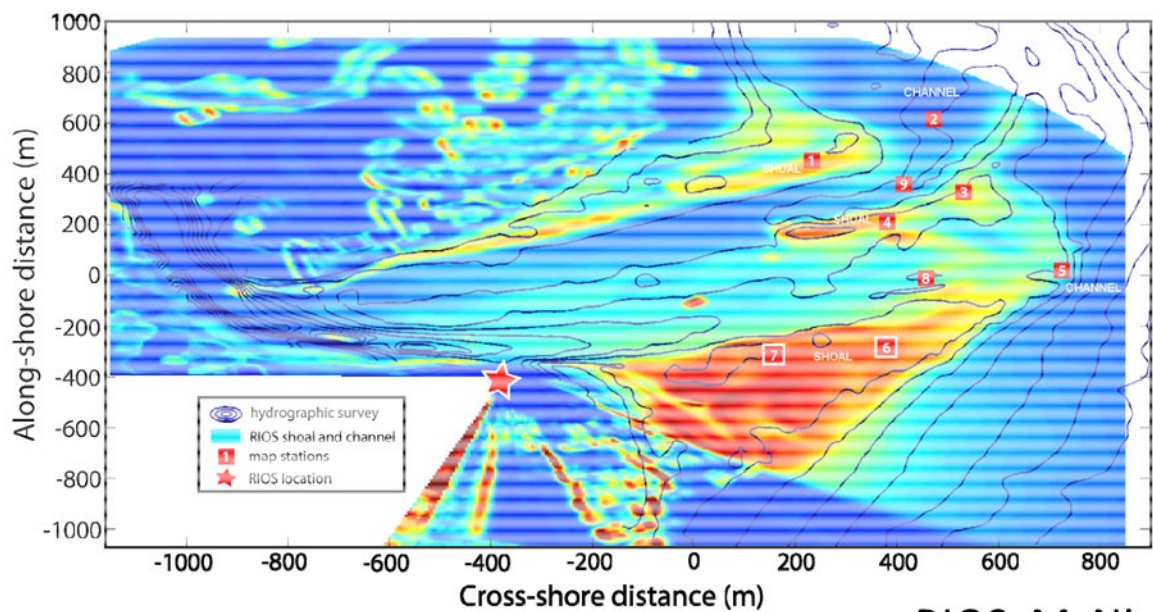


The image shows the cover of a report. On the left, a red vertical bar contains the text 'ERDC/CHL SR-YY-DRAFT' and 'Coastal and Hydraulics Laboratory'. The top right features the US Army Corps of Engineers logo and 'ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER'. Below that is the 'Coastal Inlets Research Program' logo. The title is 'Remote Sensing of Hazardous Inlet Shoals: A Literature Review'. The authors are 'Aleksandra Ostojic, Copeland Cromwell, Kaitlyn McPherran and Justin L. Shawler'. The date is 'Month Year'. A satellite image of an inlet is shown. At the bottom, it says 'Approved for public release; distribution is unlimited.'

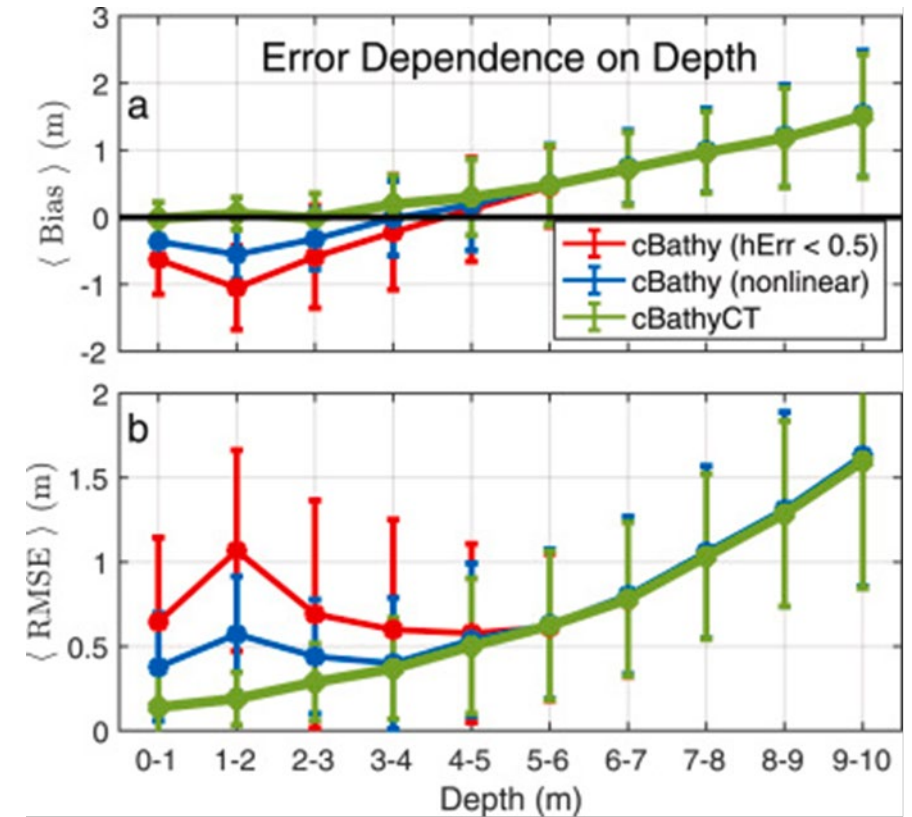
# Literature Review – Error

Reliability of remotely inferred bathymetry:

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



RIOS: McNinch et al., 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

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



## TECHNICAL COMMUNICATIONS



### 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.

**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

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](mailto:holman@coas.oregonstate.edu)  
[stanley@coas.oregonstate.edu](mailto:stanley@coas.oregonstate.edu)




[www.cerf-jcr.org](http://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](http://www.JCRonline.org)










## 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 <sup>a</sup>  , Merrick C. Haller <sup>a</sup>  , Robert A. Holman <sup>b</sup>  

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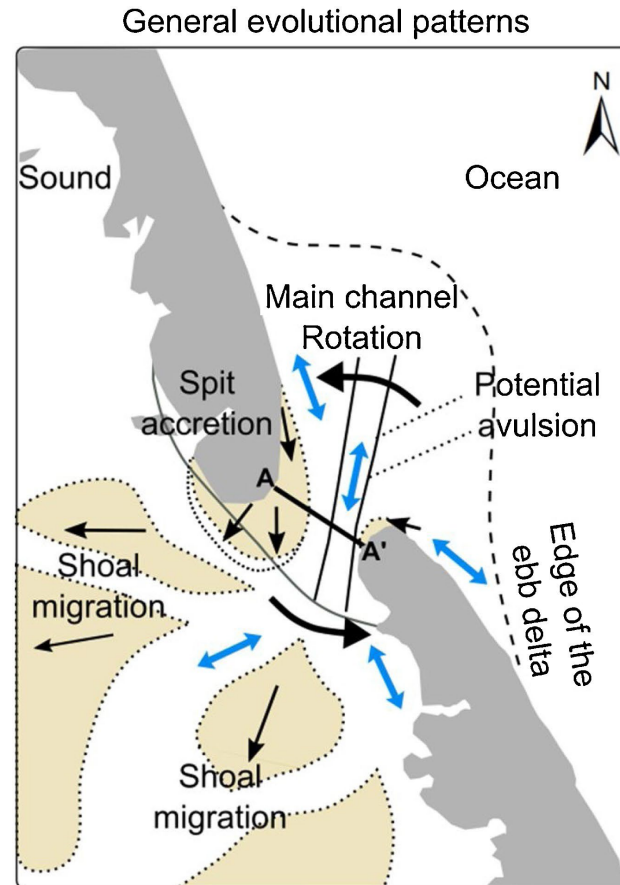
<https://doi.org/10.1016/j.coastaleng.2019.103626> [Get rights and content](#) 

led water-level measurements and bathymetry maps as new data are collected. In used 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 ent 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.

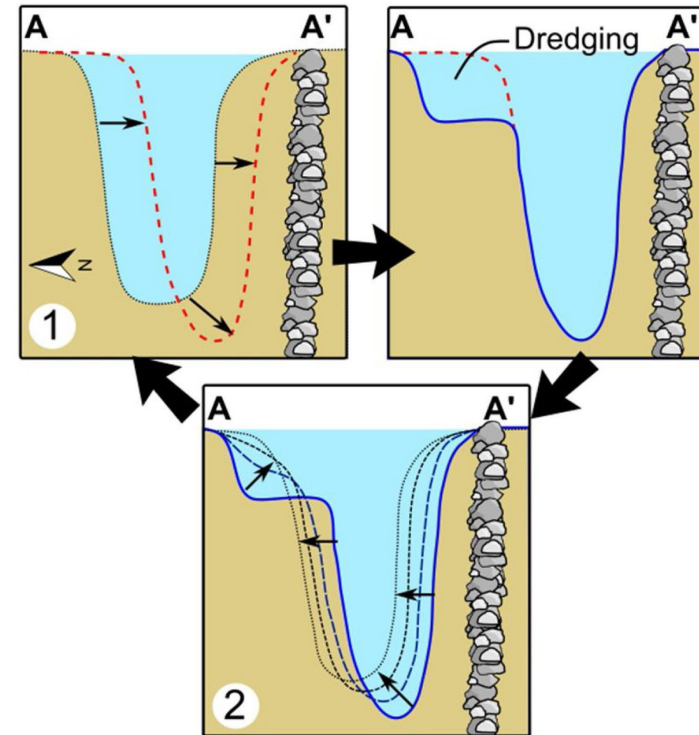
*e sensing, marine radar, derived bathymetry.*

# Literature Review – Shoal Migration

Shoal migration rates of 100 – 1000 m/yr



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



Velasquez-Montoya et al., 2020, Geomorphology

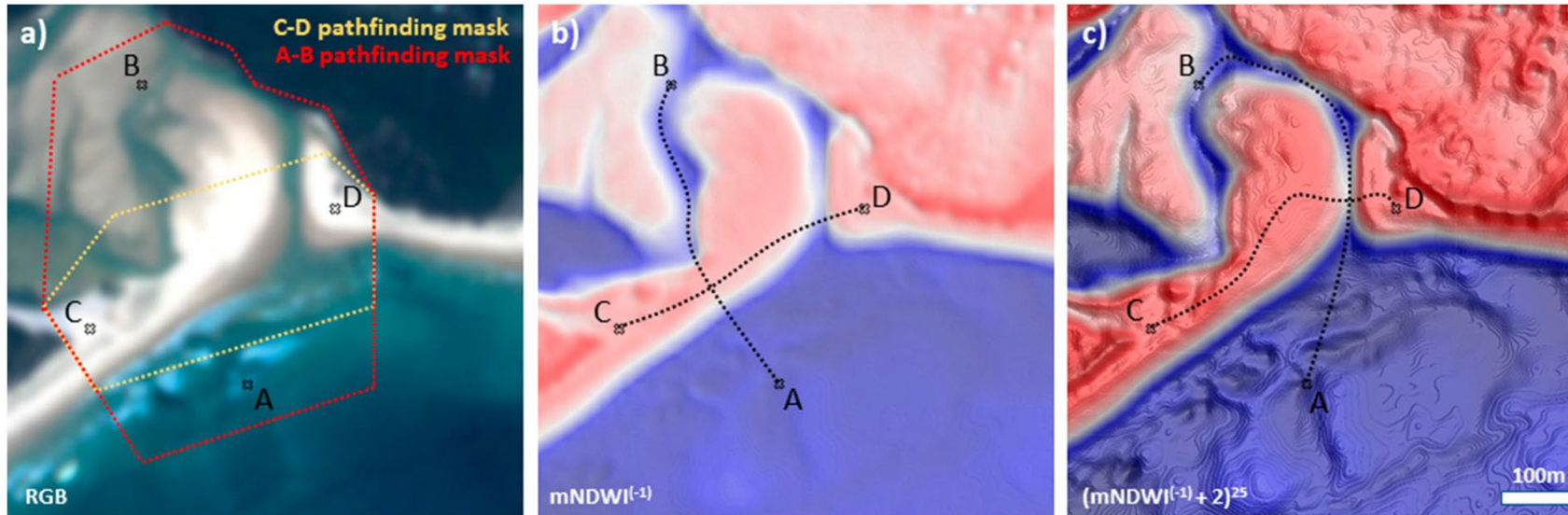
# Literature Review – *Key Indices*

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

- CoastSat – 2<sup>nd</sup> step of shoreline detection
- InletTracker – thalweg migration

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

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

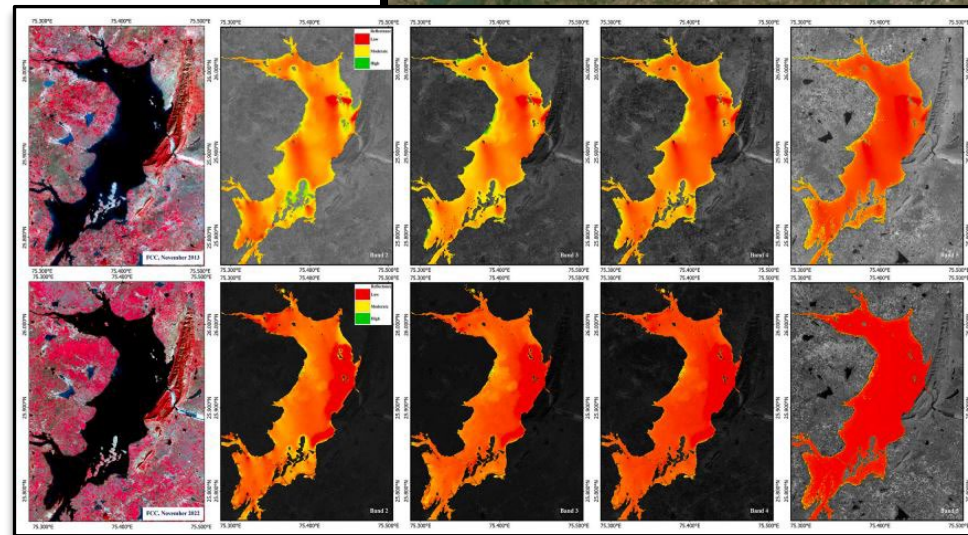


# Literature Review – NDWI Challenges

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

Need to keep in mind

Potential to mistake turbidity for shoals

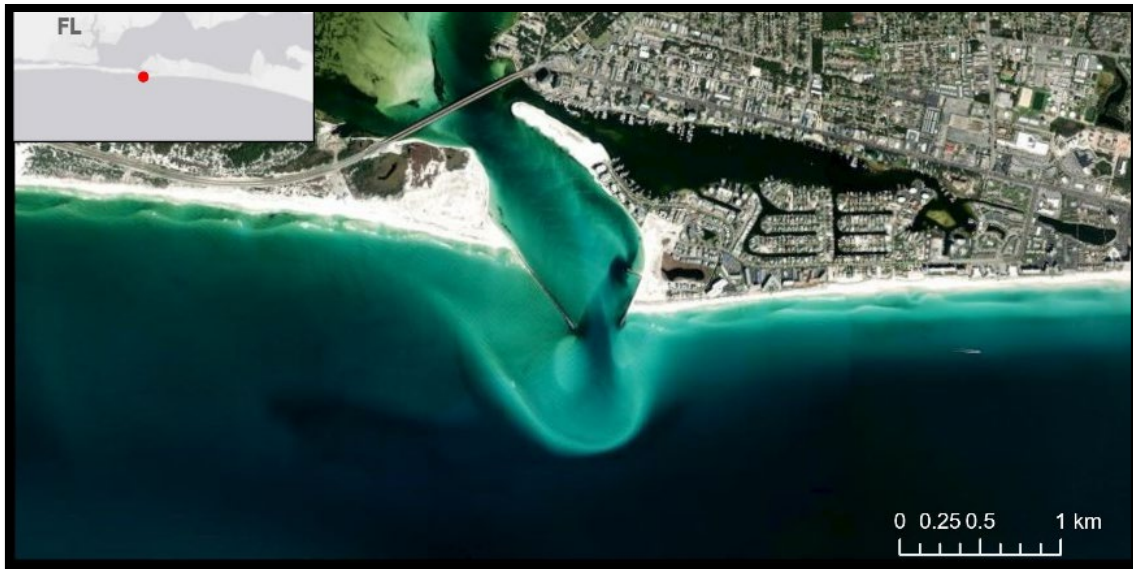


Singh et al., 2023, Environmental Research

# 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*

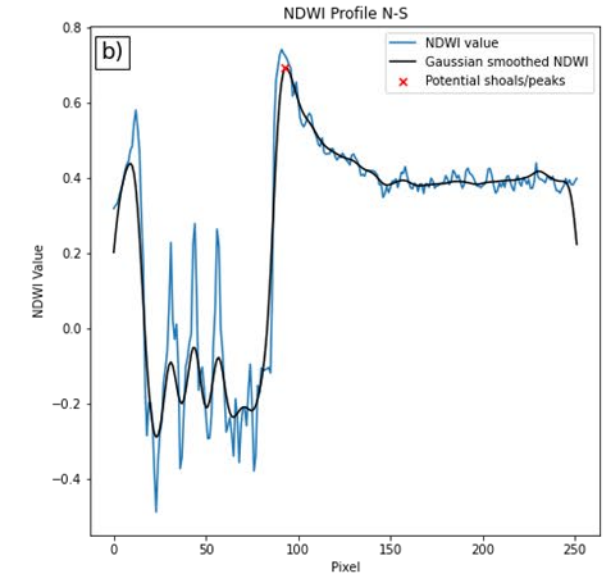
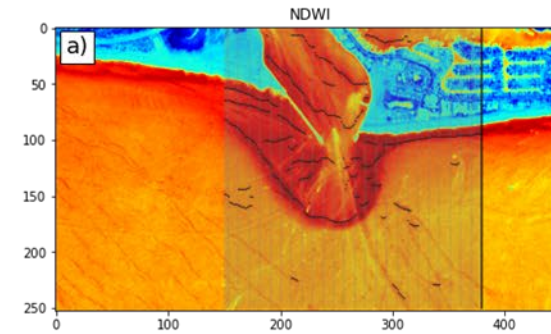
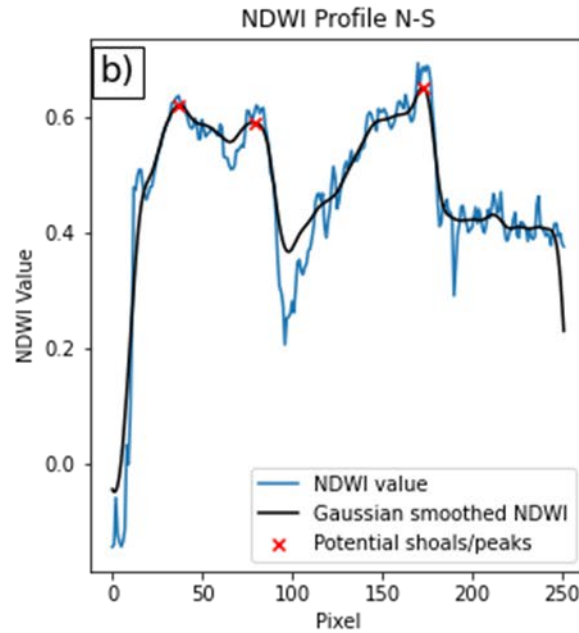
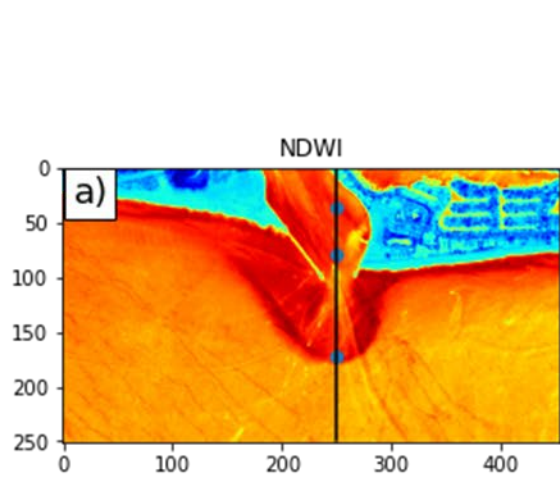
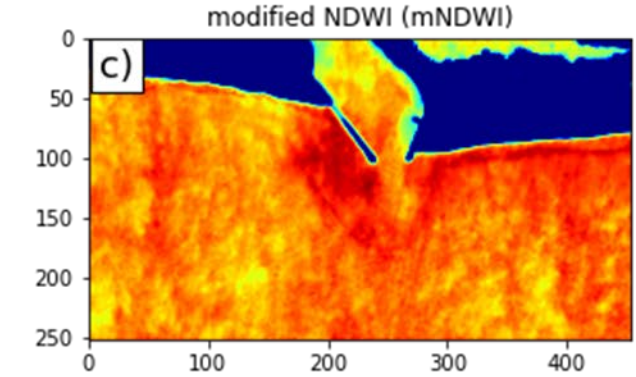
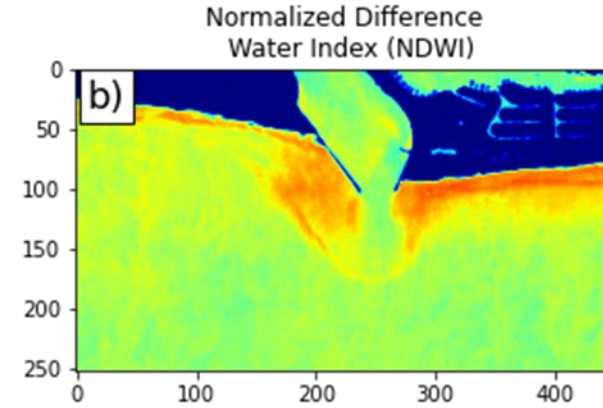
- NJ Coast
- Poorer water clarity
- Decent ground truthing data available
- Initial jetty construction in 1930s
- Ongoing dredging needs – persistent shoals





# NDWI Application

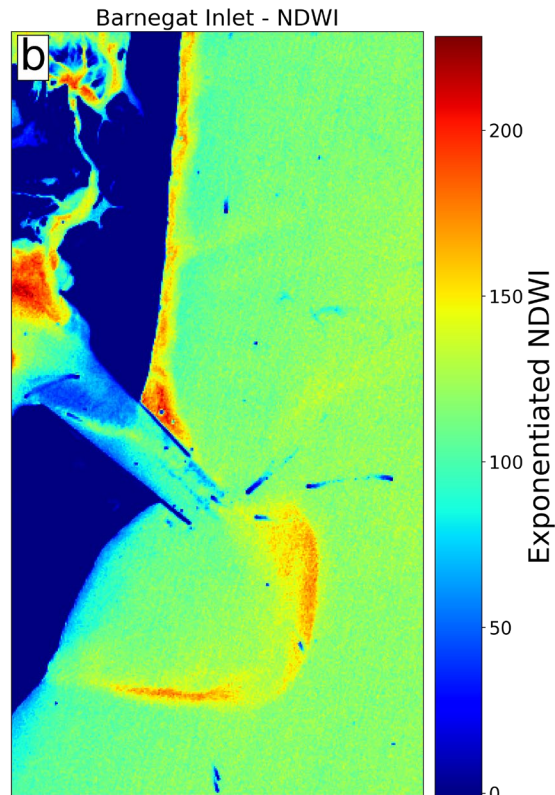
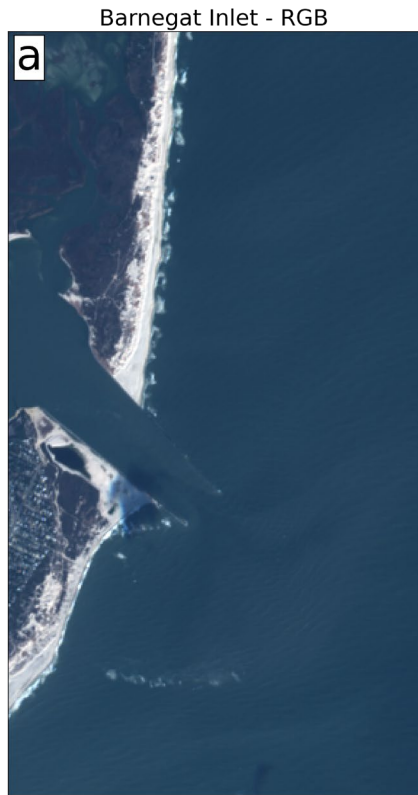
$$NDWI = \frac{Green - NIR}{Green + NIR}$$



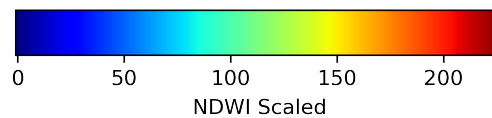
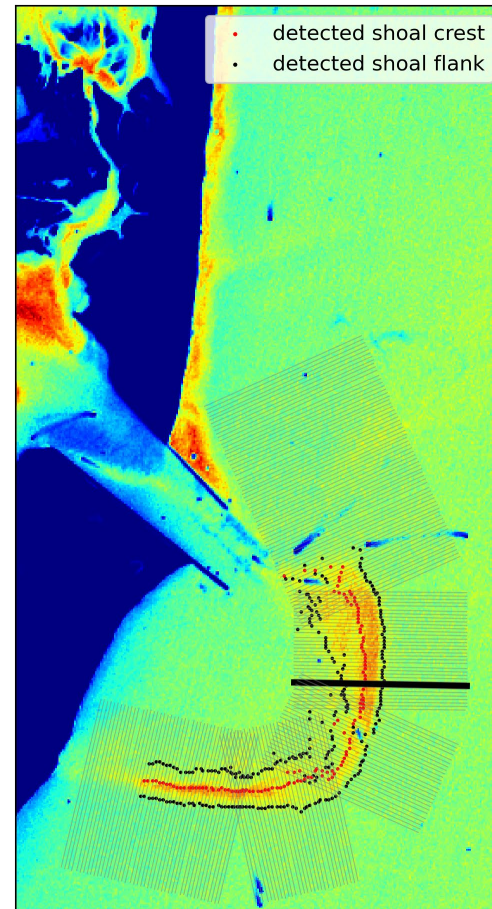
# NDWI Application, cont.

NDWI is projected onto transects to identify shoals

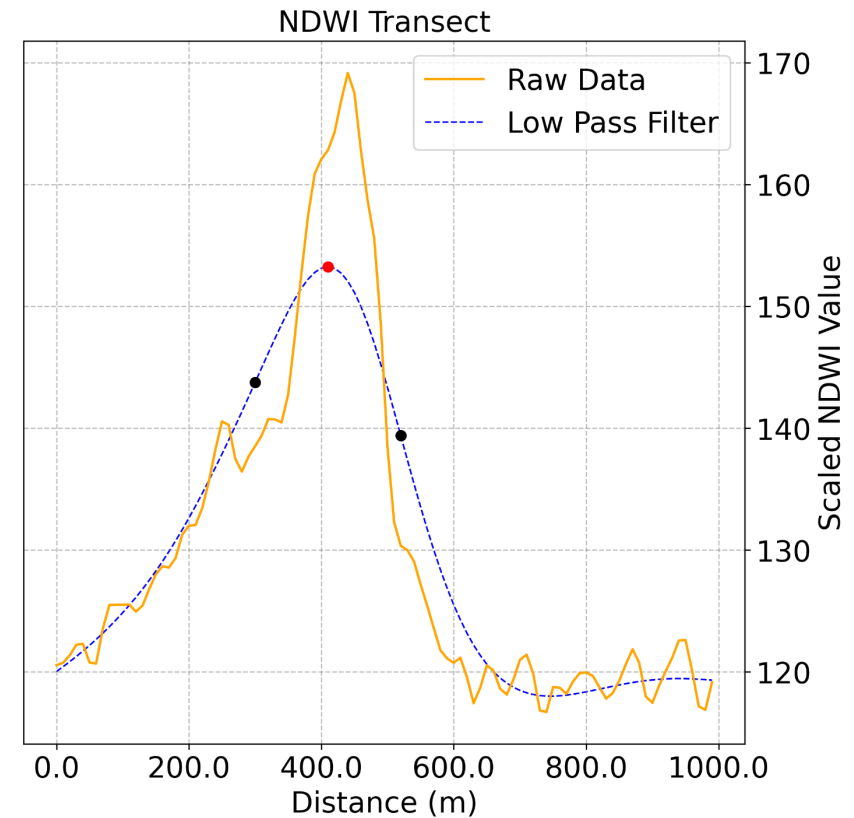
- Low pass filtering to remove wave and environmental “noise”
- Peaks and inflections in NDWI used to identify shoal crests and “flanks”.



NDWI S2 Image Shoal Detection



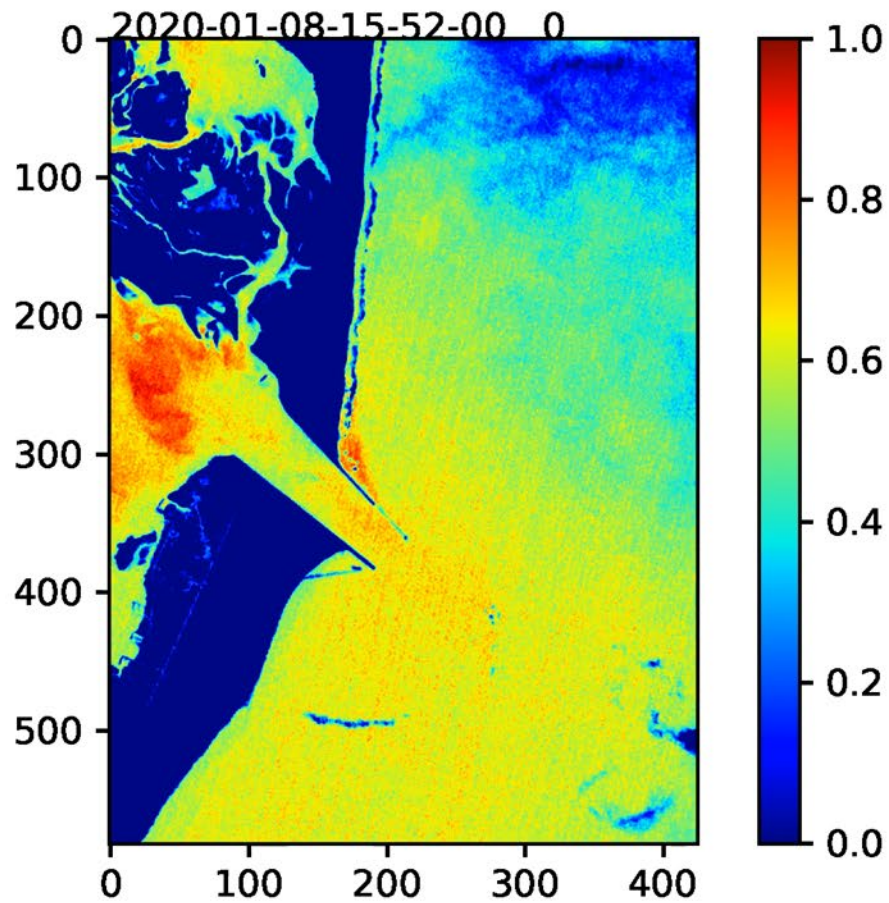
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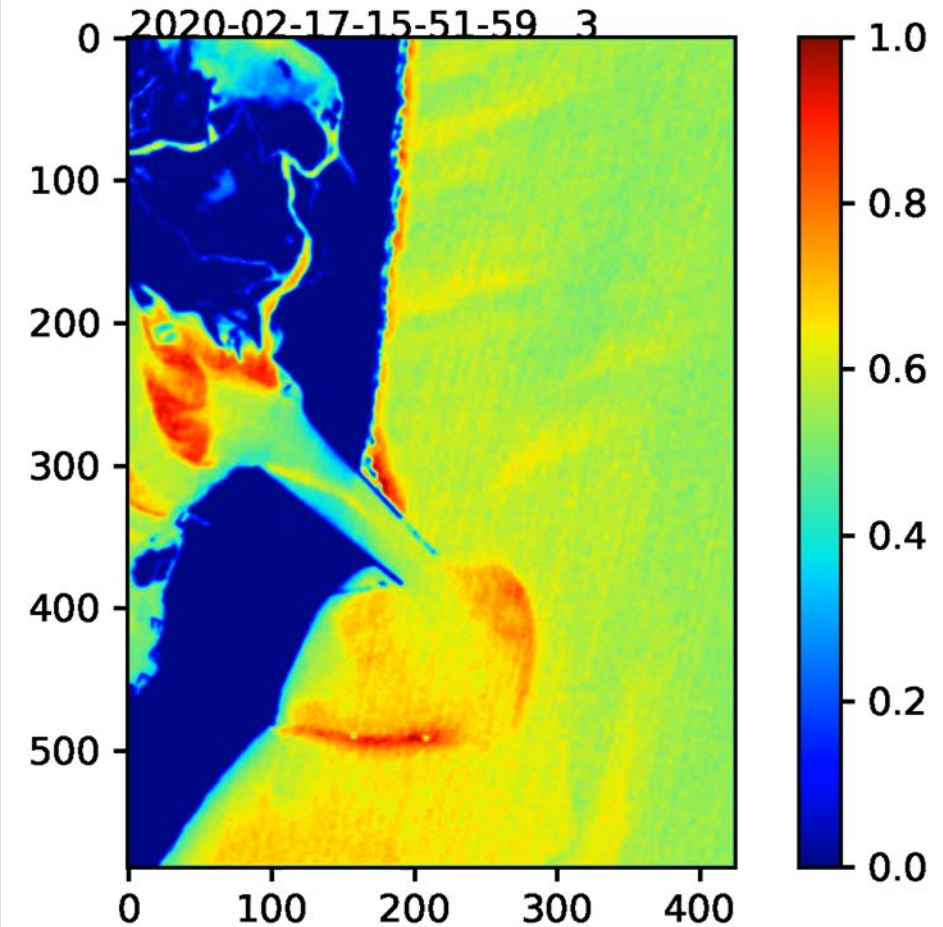
# NDWI Challenges

- Cloud cover
- Waves
- Turbidity
- Vessels

*Cloud Filtering Routine Only*

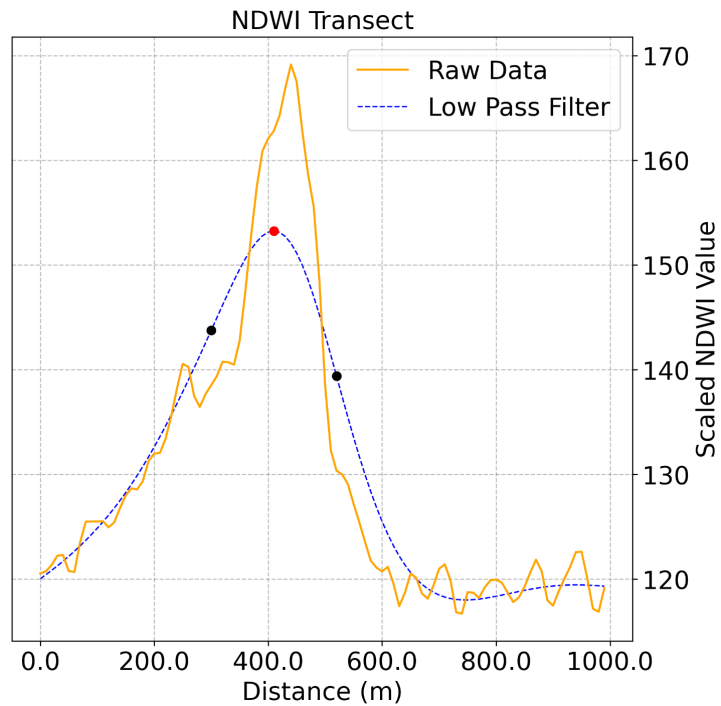


*Hand-Selected Imagery*



# 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

