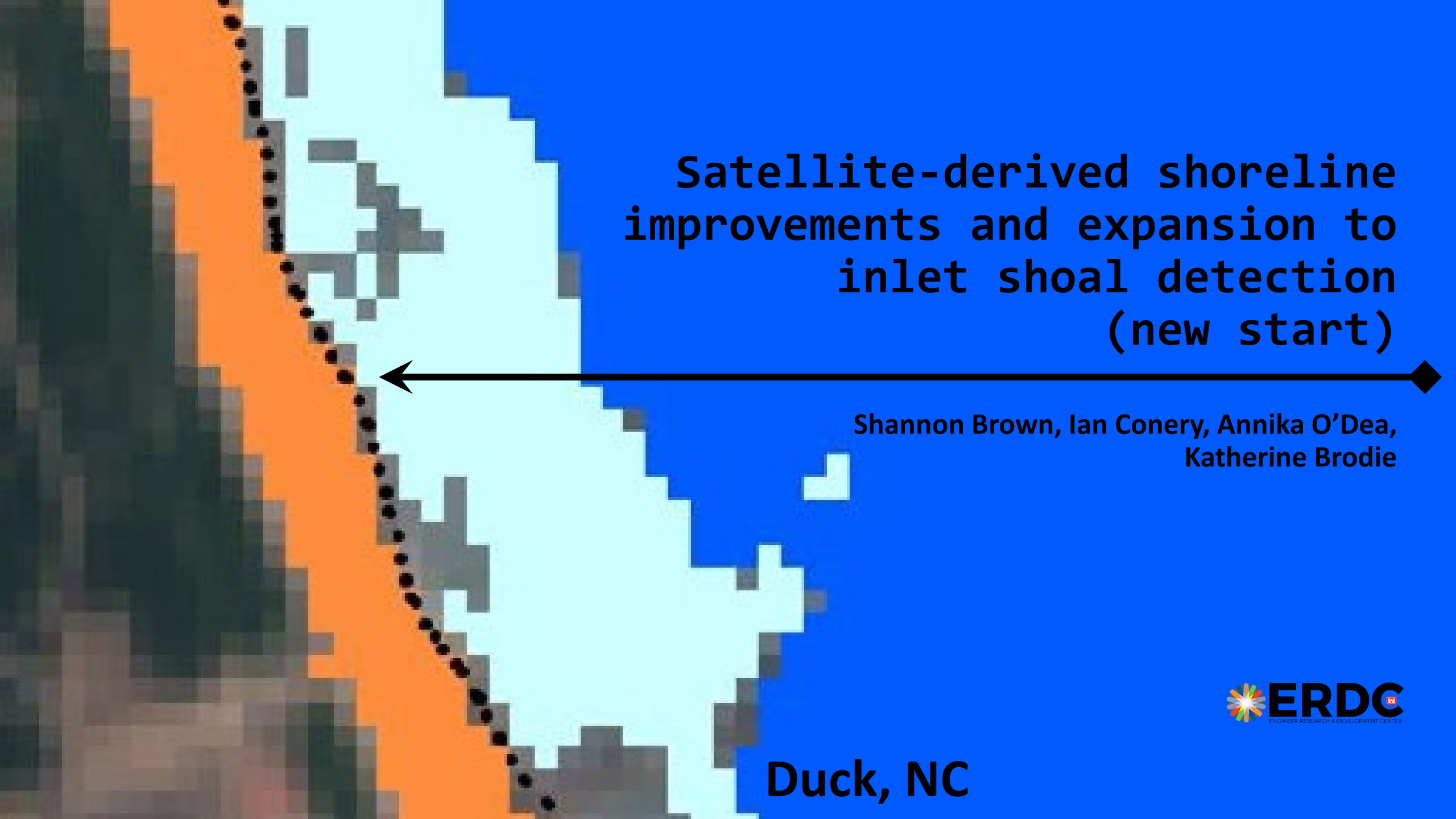

Satellite-derived shoreline improvements and expansion to inlet shoal detection (new start)

Shannon Brown, Ian Conery, Annika O'Dea, Katherine Brodie

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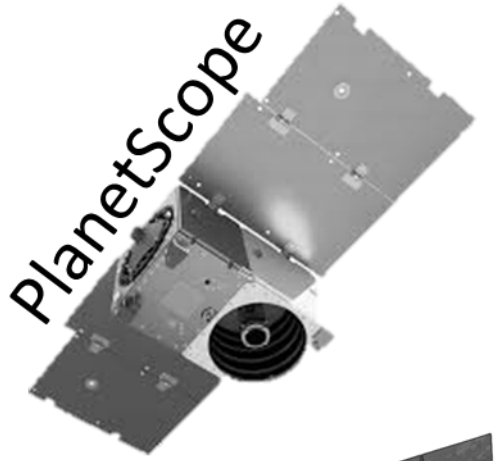
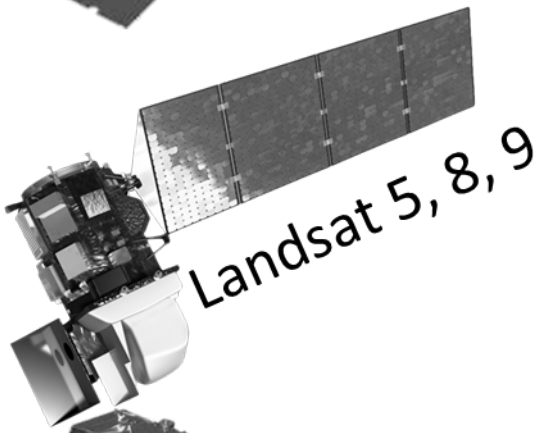
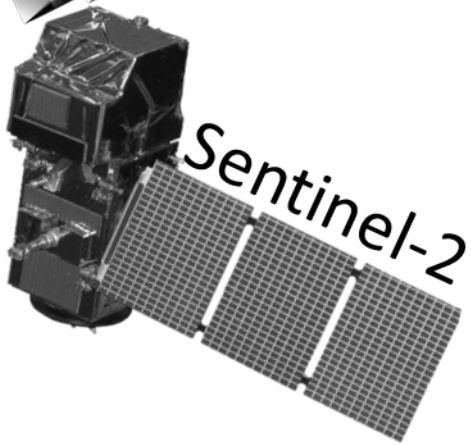
Duck, NC

CoastSat Satellite-Derived Waterlines



Commercially-available imagery available at a daily revisit since 2016





Publicly-available imagery available at a revisit rate of 5 – 16 days since 1984

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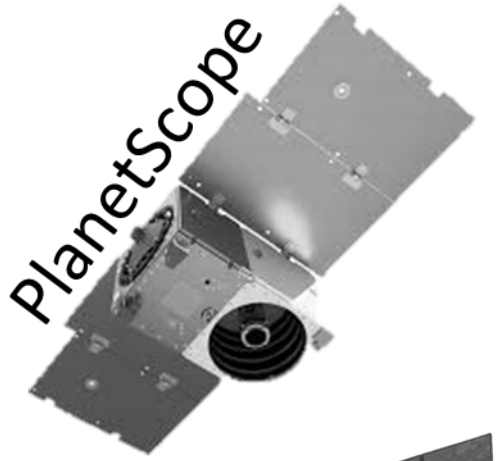
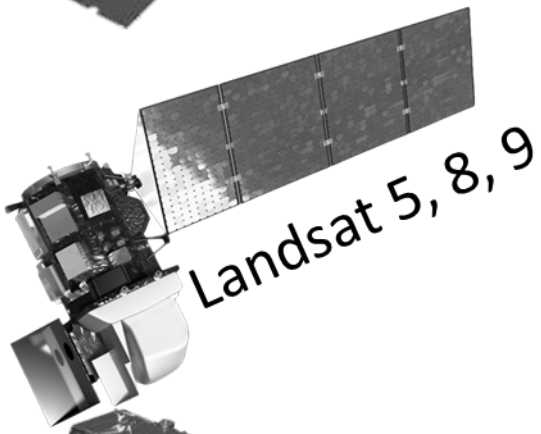
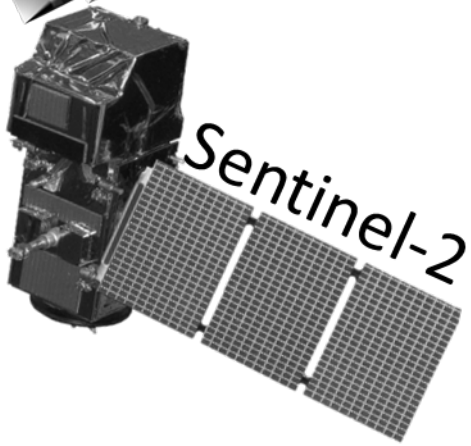
Waterline Extraction

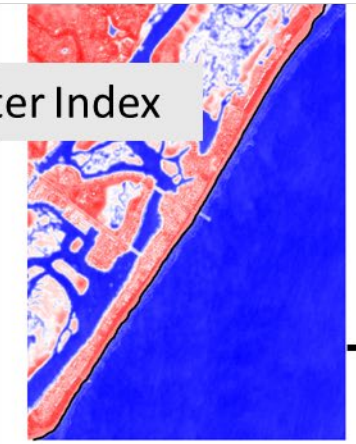




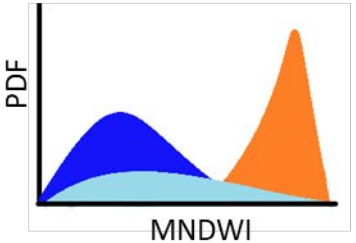


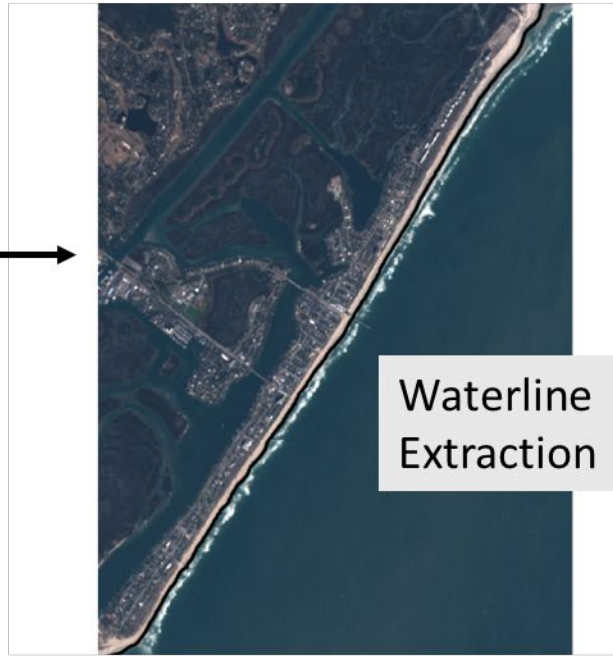
Supervised Classification

Water Index



Thresholding Algorithm





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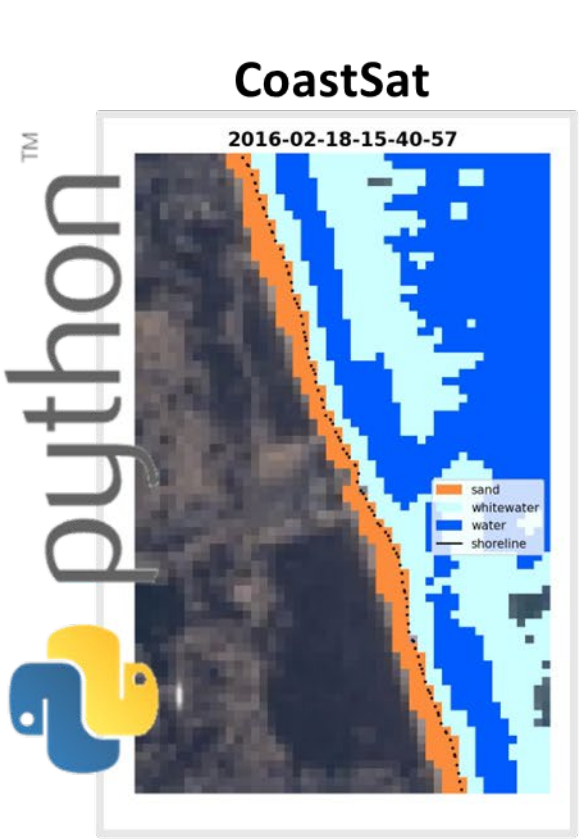
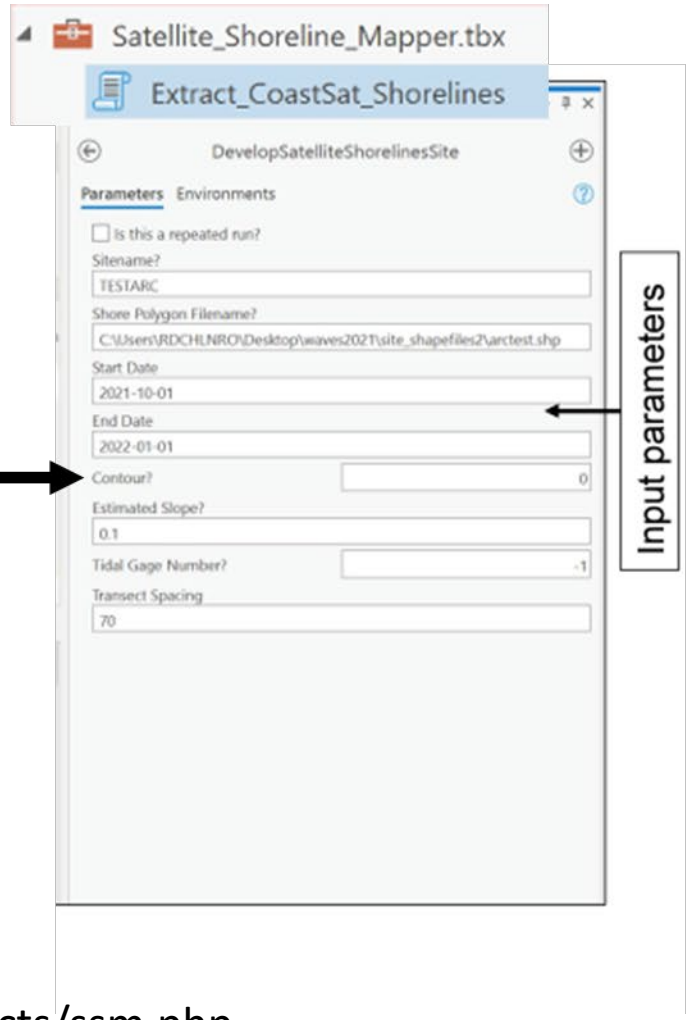
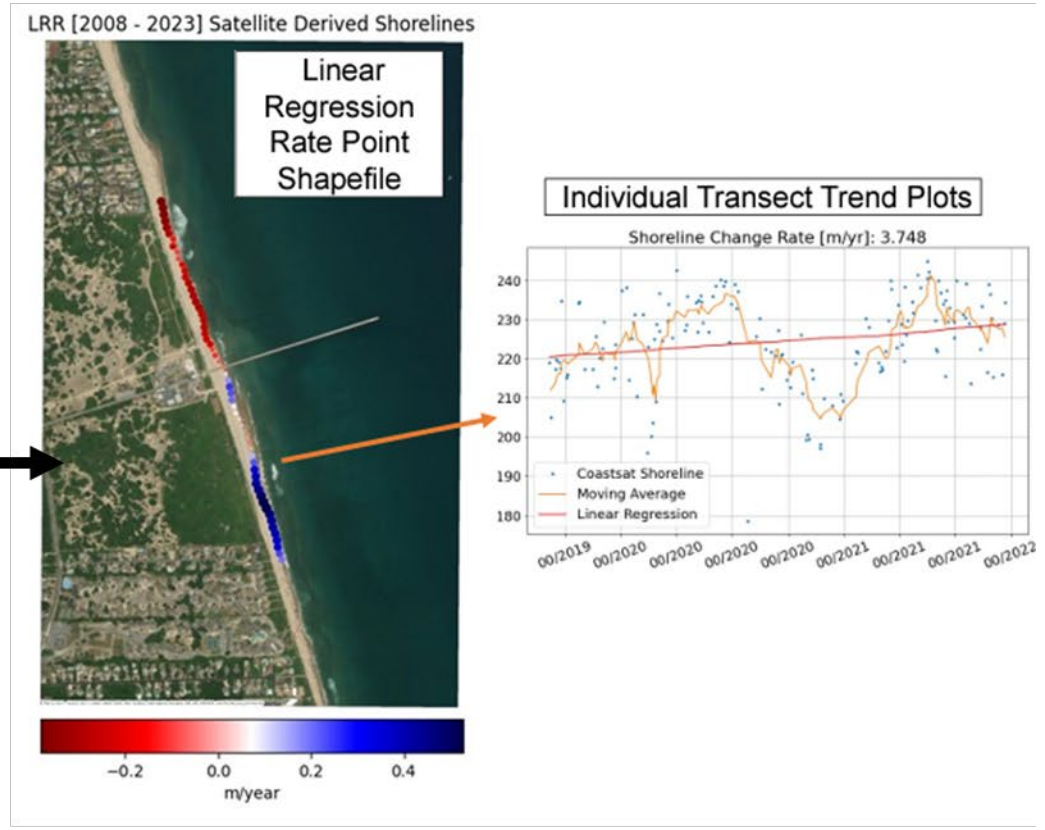
Satellite Shoreline Mapper







https://cirp.usace.army.mil/products/ssm.php

Ian.W.Conery@usace.army.mil
Shannon.M.Brown@usace.army.mil

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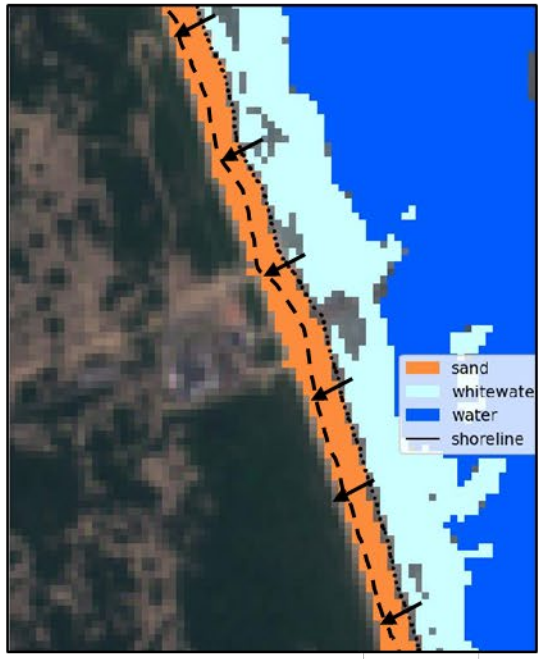
Water Level Correction

satellite-derived waterline
water/sand interface
(x,y)



elevation of reference contour

tide

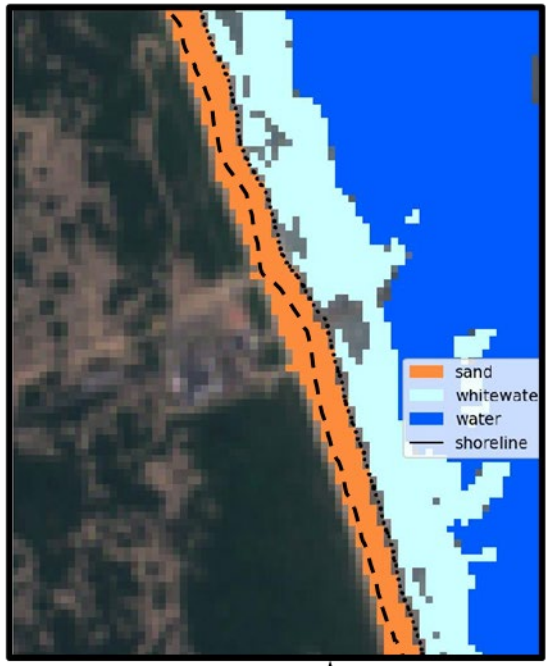
$$\Delta x = \frac{z_{ref} - z_{wl}}{m}$$

average beach slope

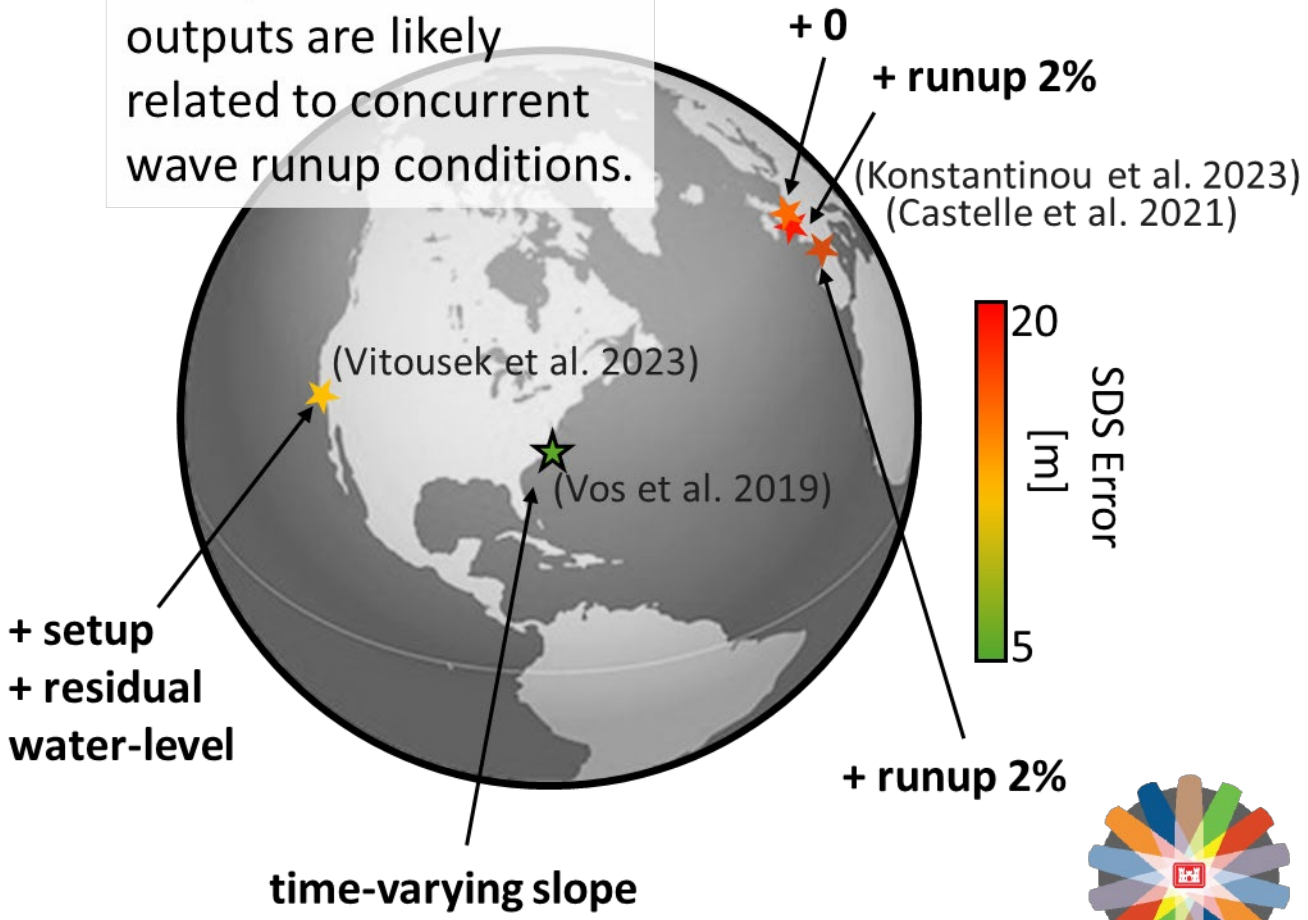
(Vos et al. 2019)

Water Level Correction, cont.

satellite-derived shoreline
(x,y,z)



Site-specific errors in outputs are likely related to concurrent wave runup conditions.



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Water Level Correction – 3 questions

satellite-derived waterline
water/sand interface
(x,y)

Three main Questions

What reference contour introduces the least error?

What is the optimal waterline elevation?

How much error does an average slope introduce?

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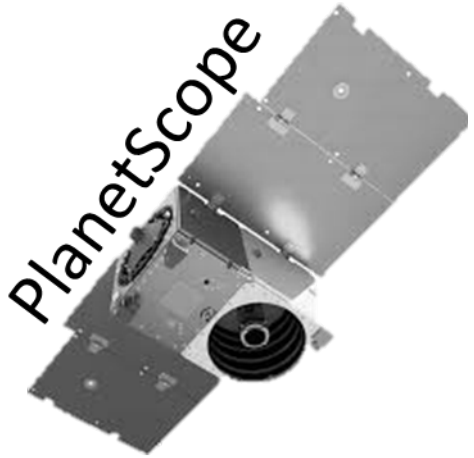
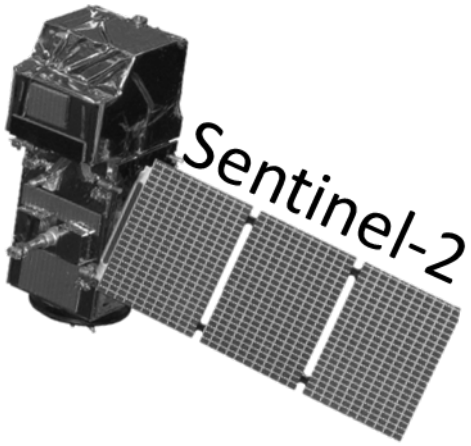
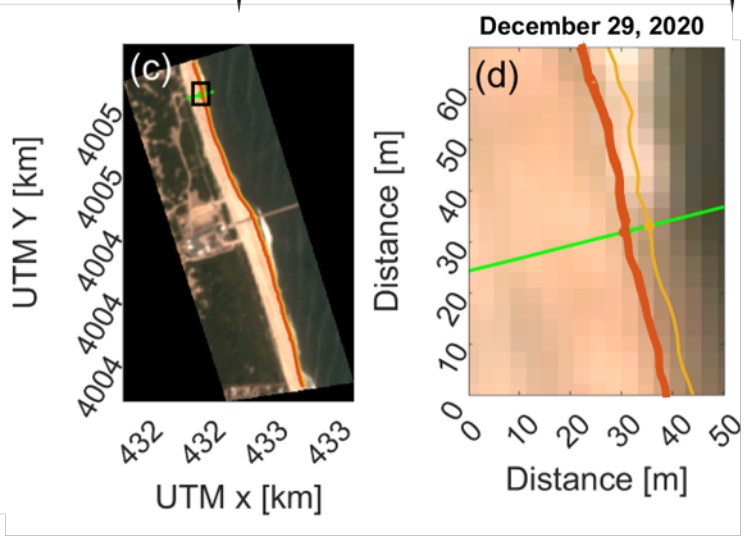
(O'Dea et al. 2019)

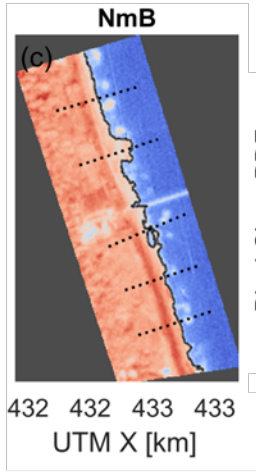
Satellite Imagery

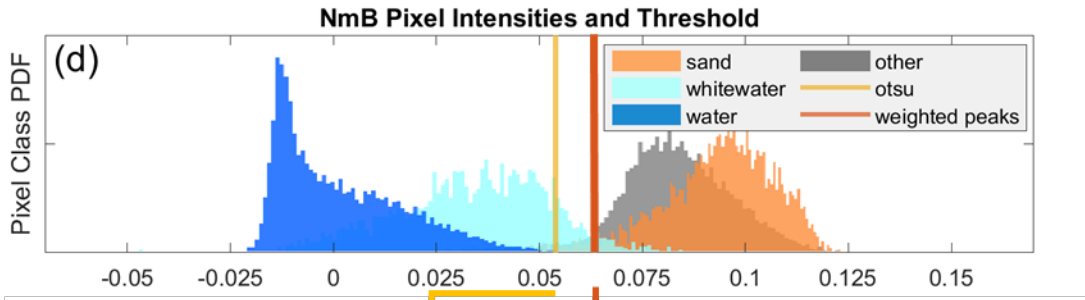
Comparing two image sources, two water indices, and two threshold algorithms





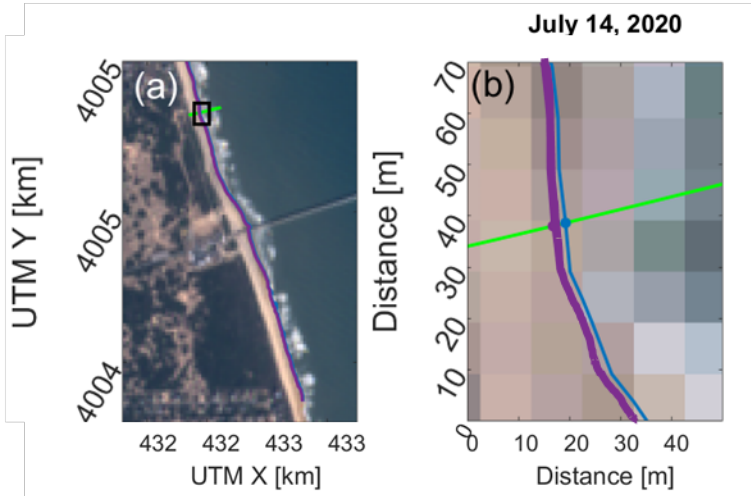


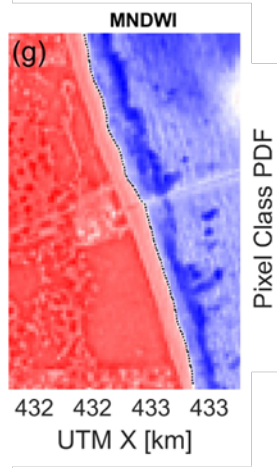


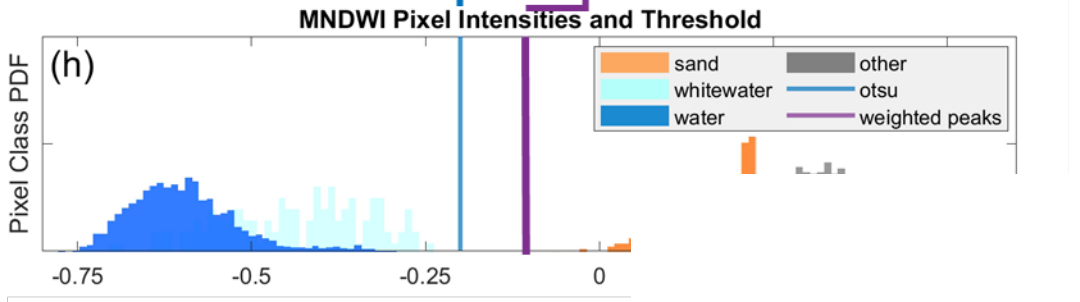


Otsu

weighted peaks



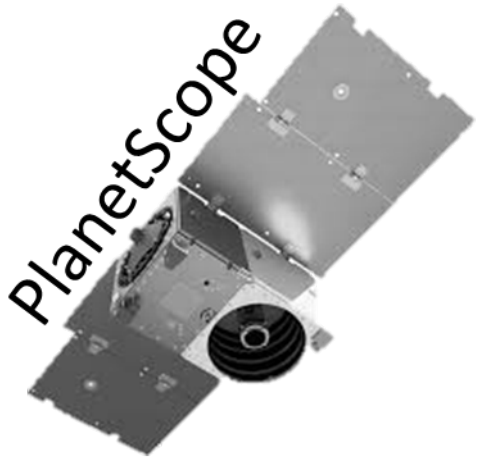


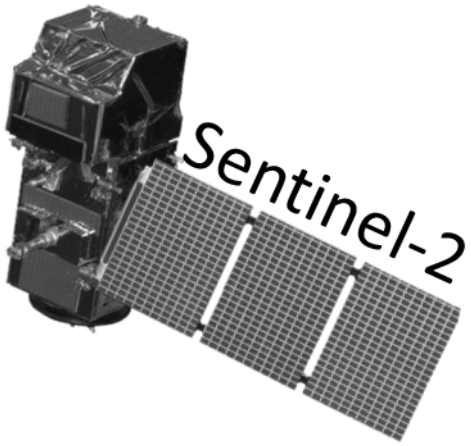


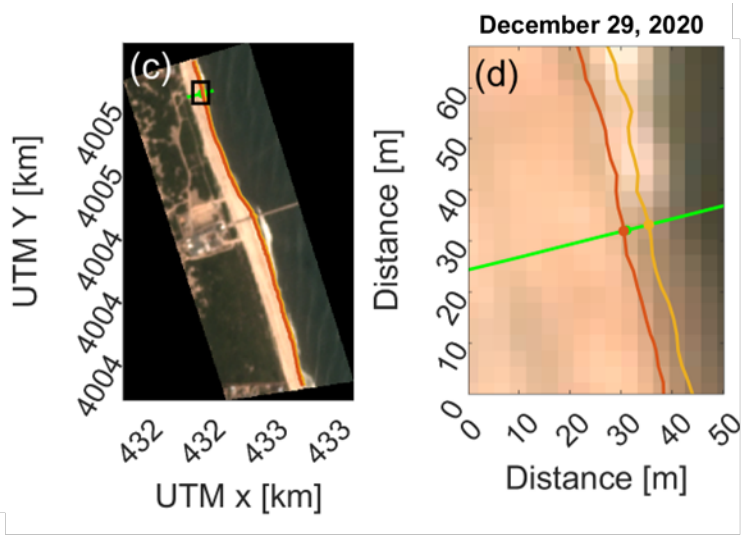
(Harley et al. 2019)

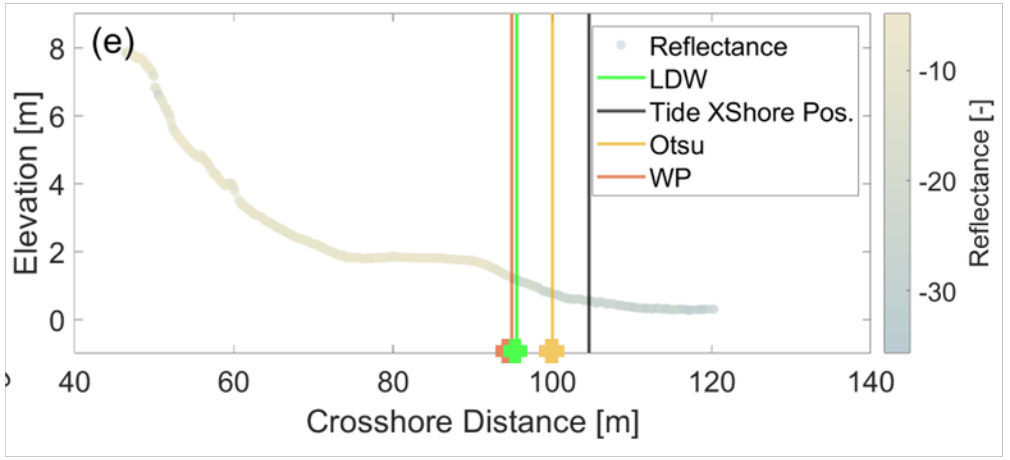
Comparing Data Types

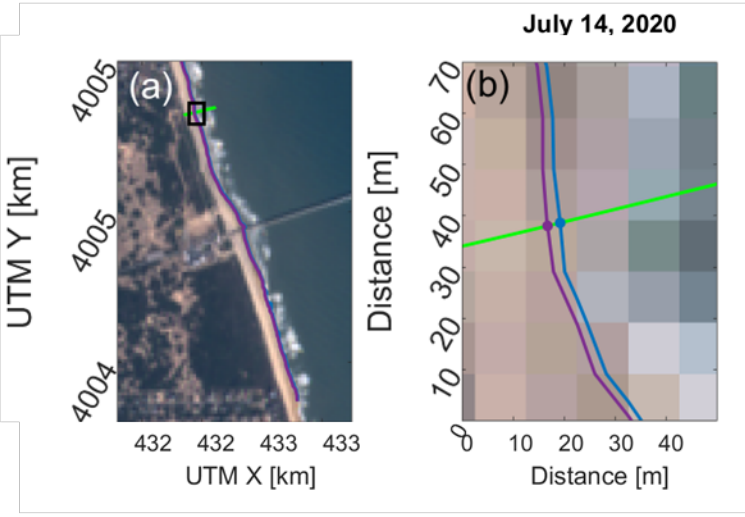
Can compare instantaneous waterline positions from SDW and LDW along lidar linescan

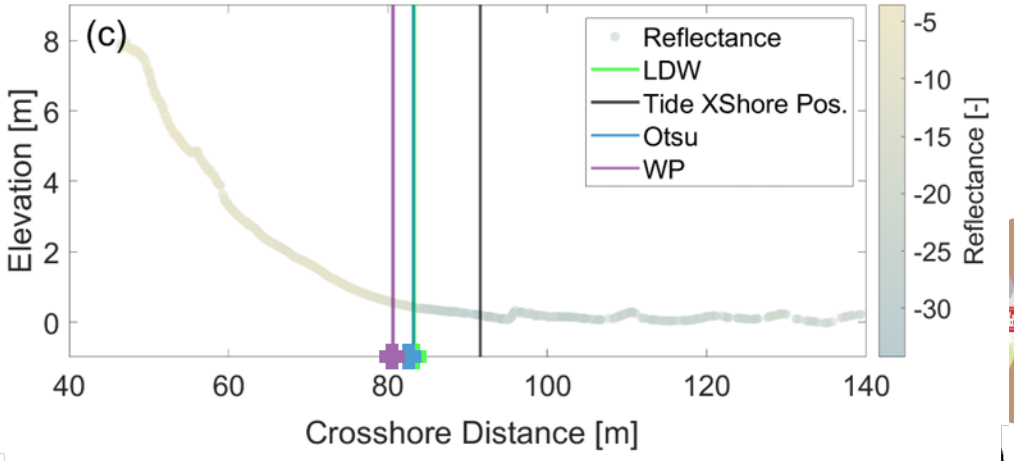












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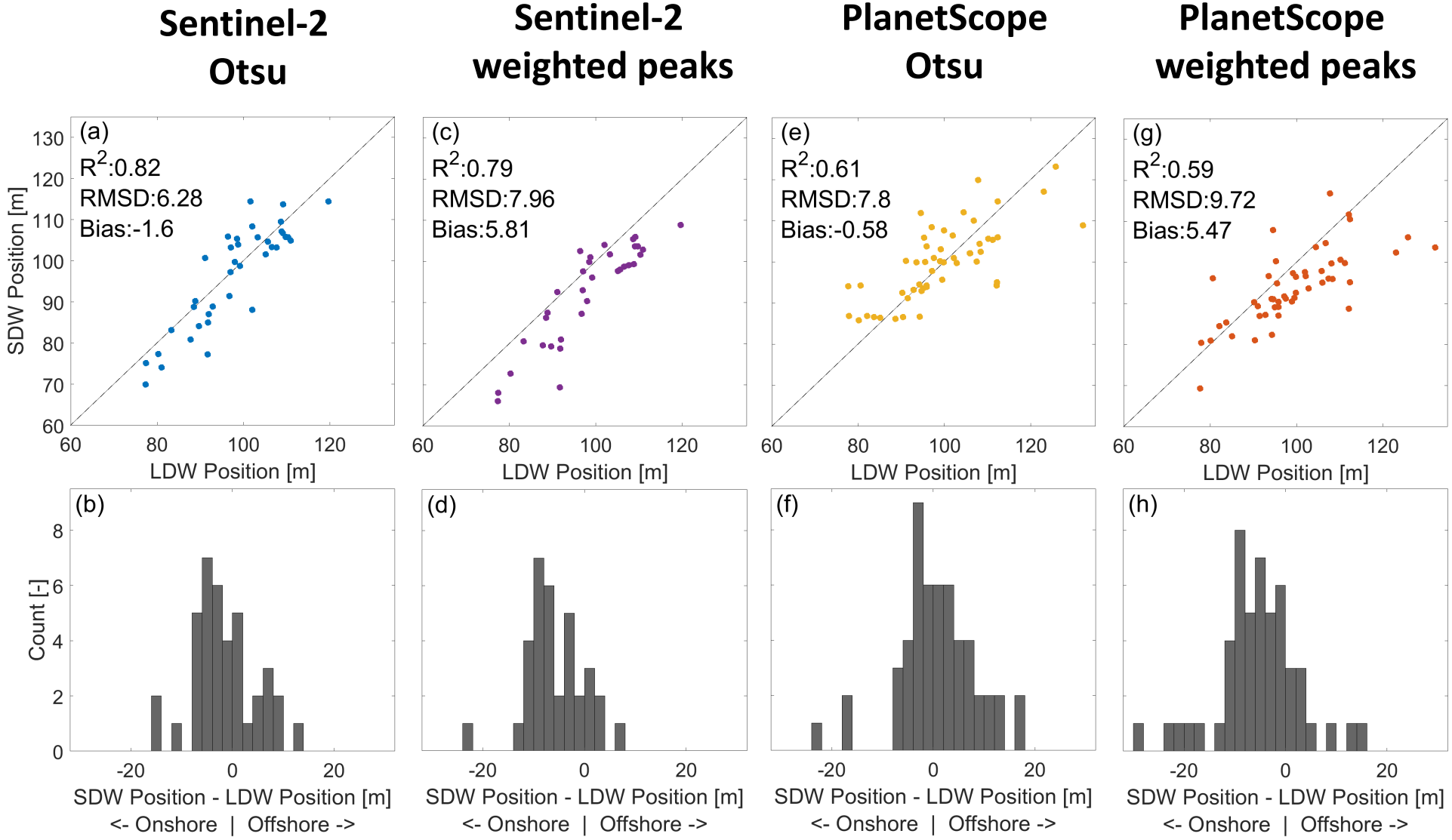
SDW vs. LDW



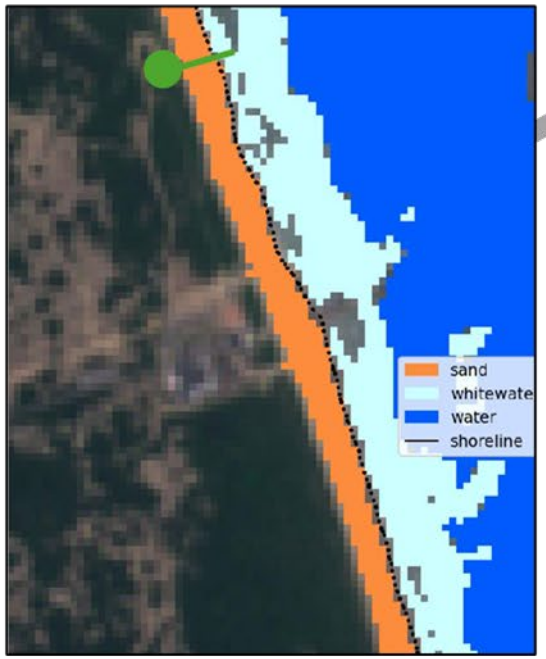
Sentinel-2 SDW correlate better with LDW than PlanetScope SDW

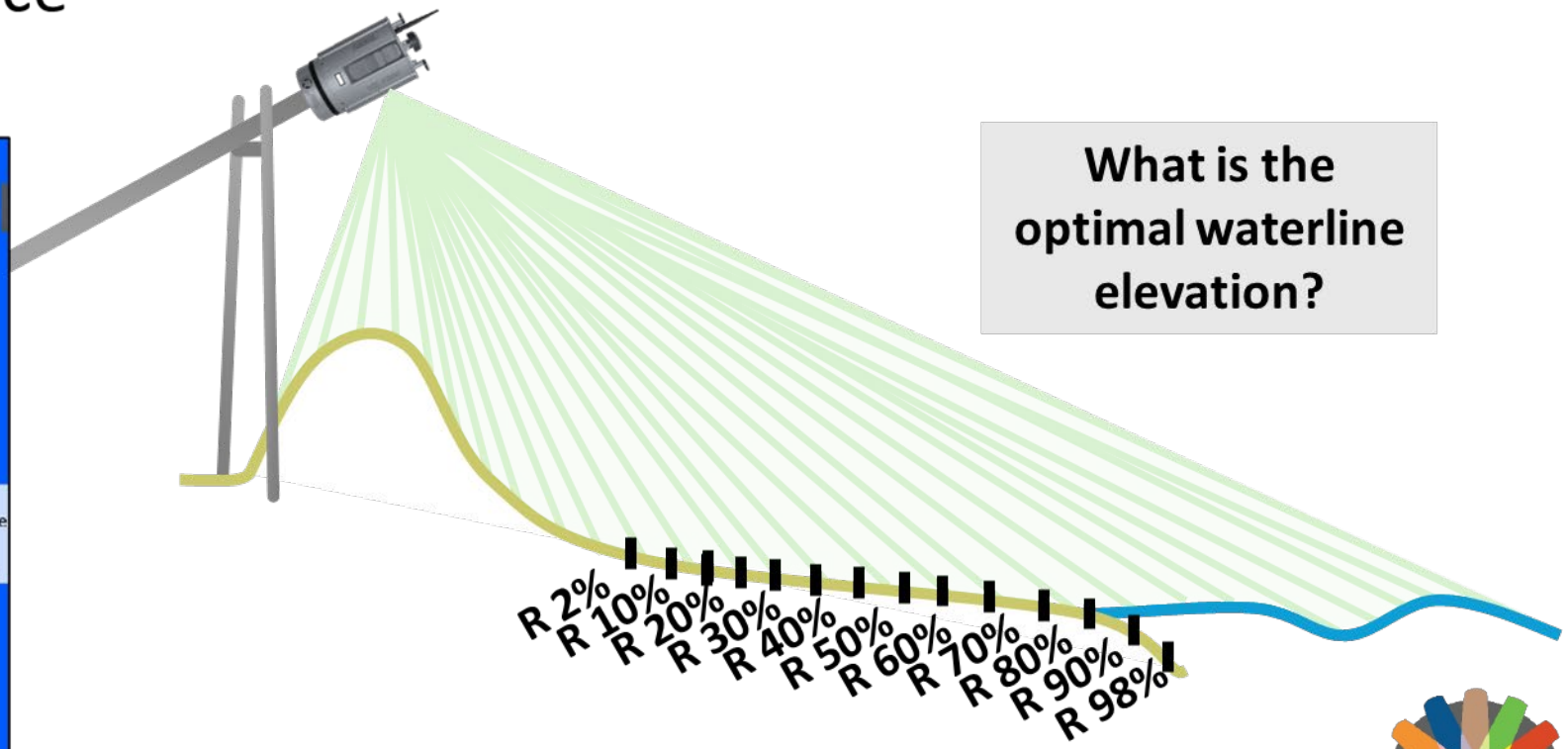
Otsu SDW had reduced error compared to weighted peaks SDW

Weighted peaks SDW had strong onshore bias

Water Level Correction – 1st question

satellite-derived waterline
water/sand interface
(x,y)

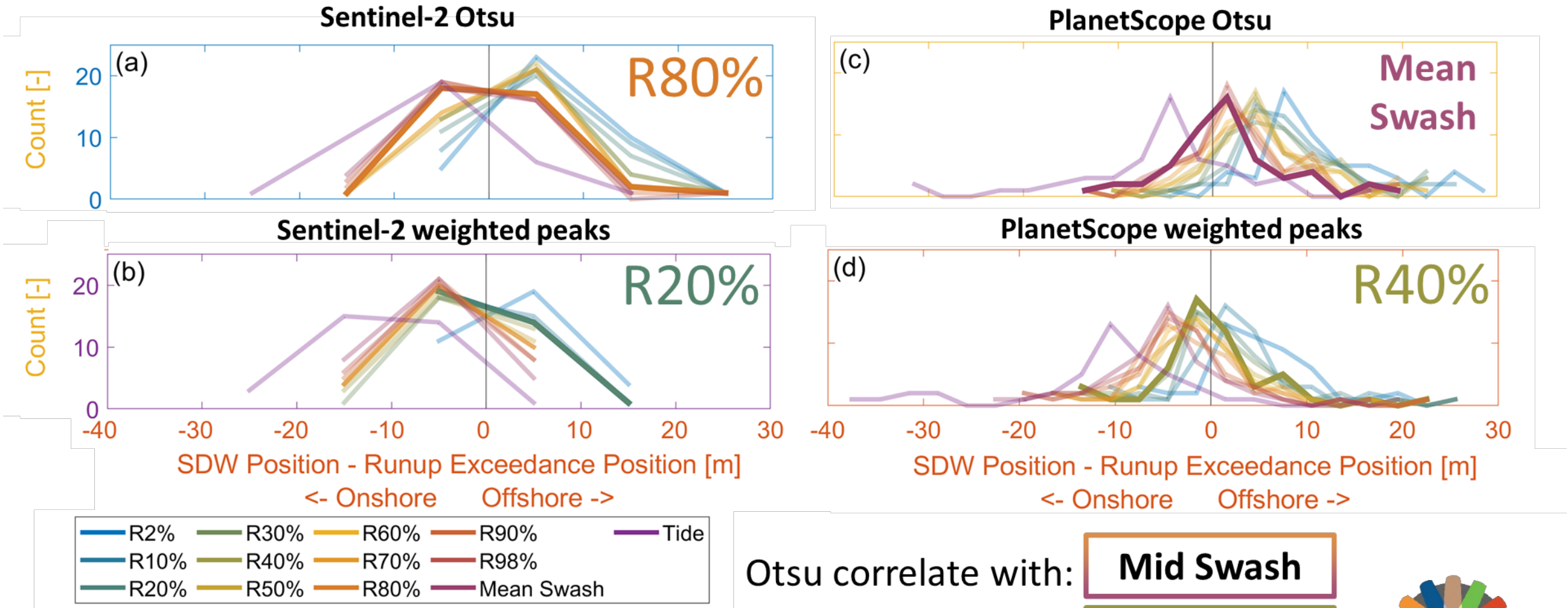




What is the optimal waterline elevation?

(O'Dea et al. 2019)

Measured Bulk Statistics



Otsu correlate with: **Mid Swash**

Weighted peaks correlate with: **Upper Extent**

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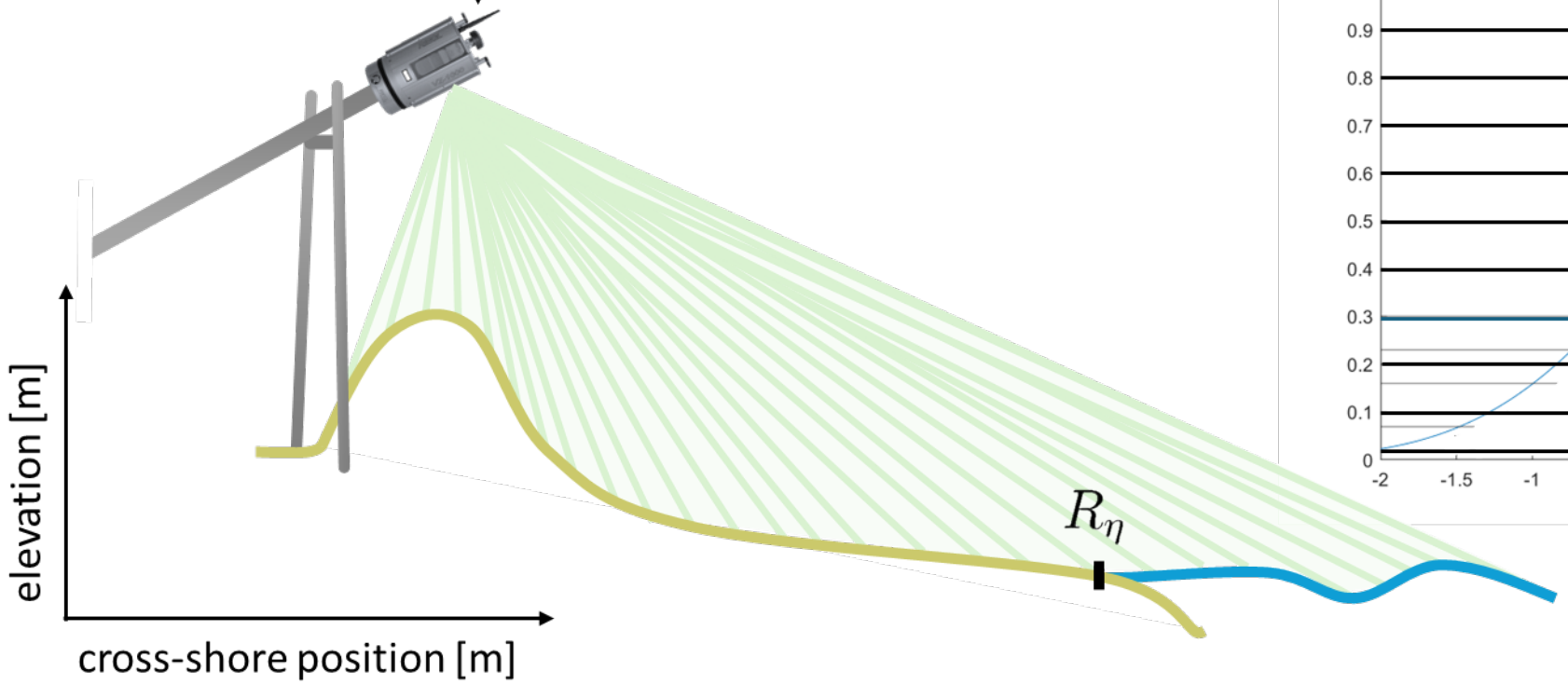
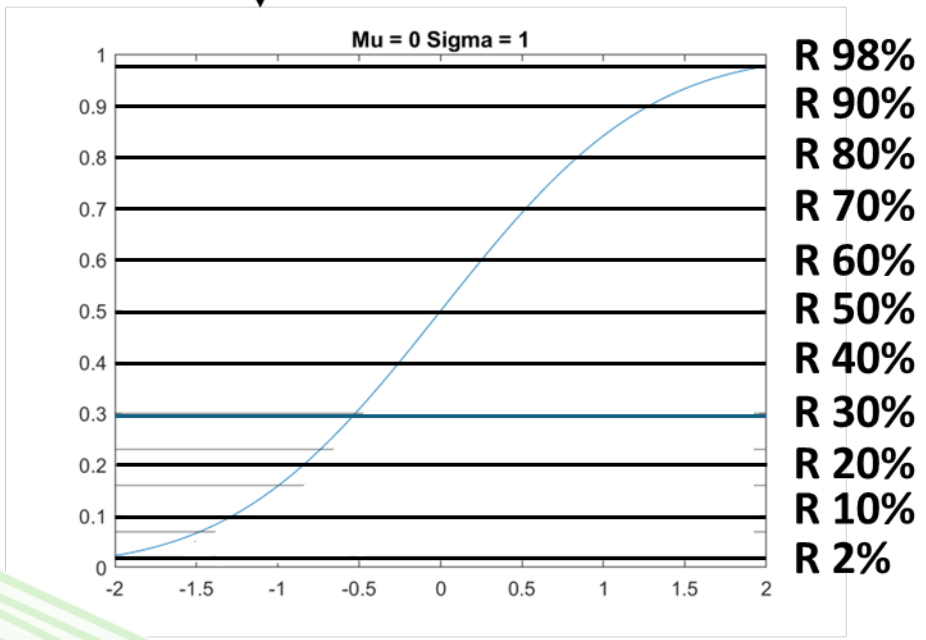
Bulk Statistics

Parameterized

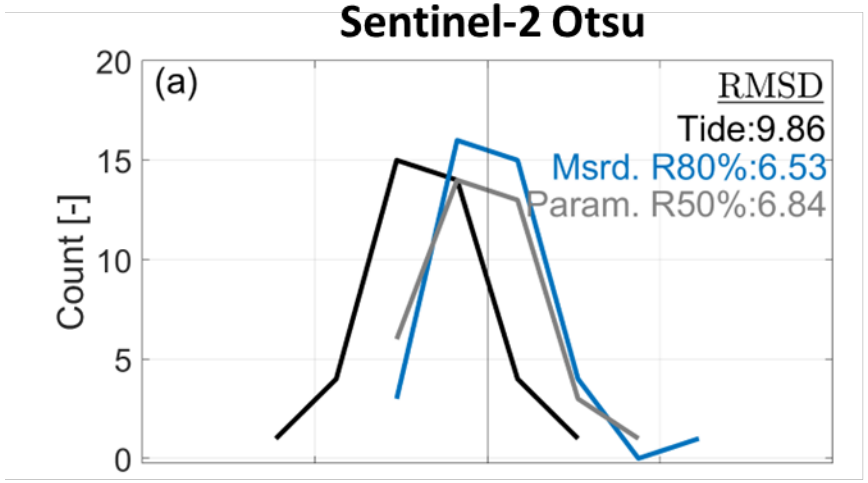
$$R_\eta = 1.1(<\eta> + \frac{[H_o L_o(0.563\beta^2 + 0.0004)]\cdot 5}{2}\frac{\eta_\sigma}{2})$$

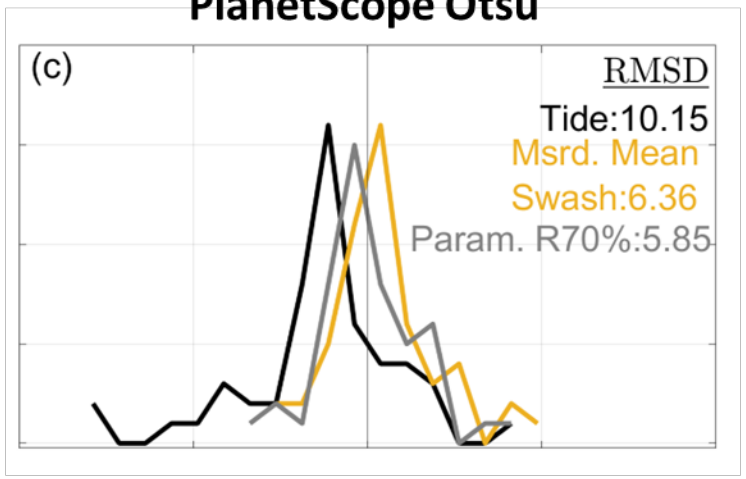


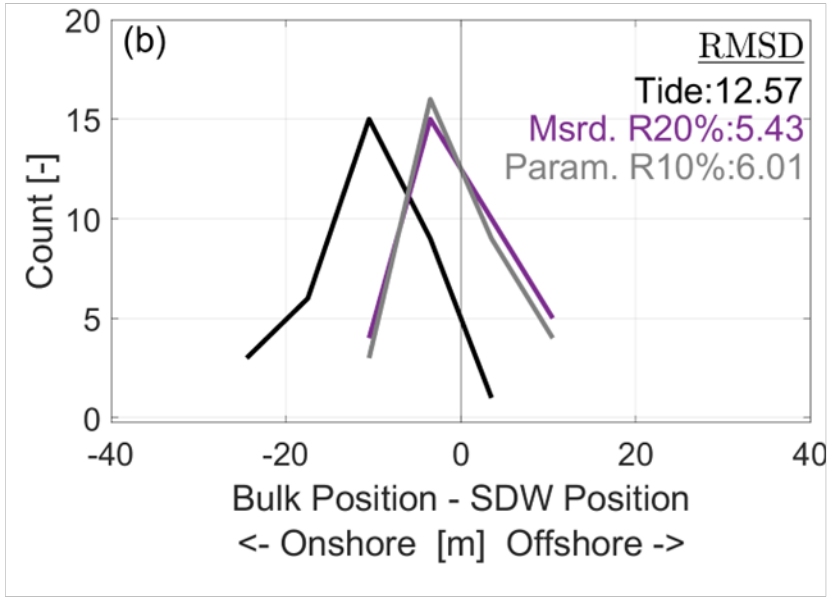


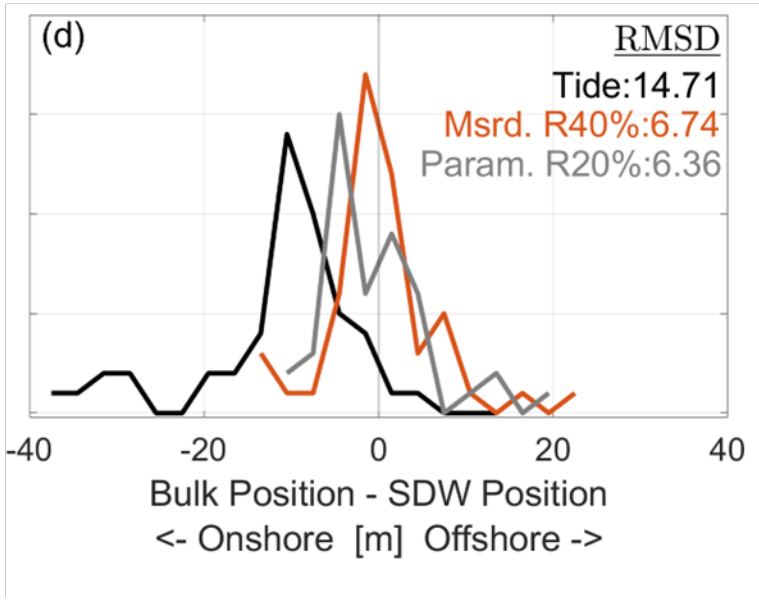
(Stockton et al. 2006; Palmsten and Holman 2012)

Bulk Statistics - comparison









Cross-shore positions of lowest RMSD measured and parameterized runup excursion both align better with SDW

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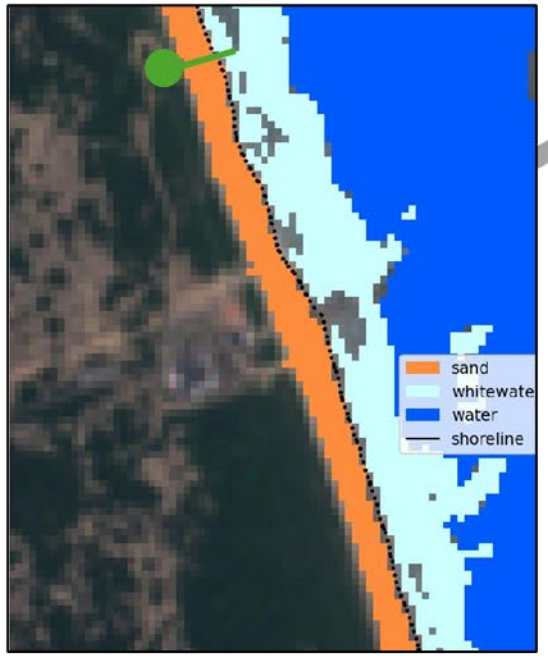
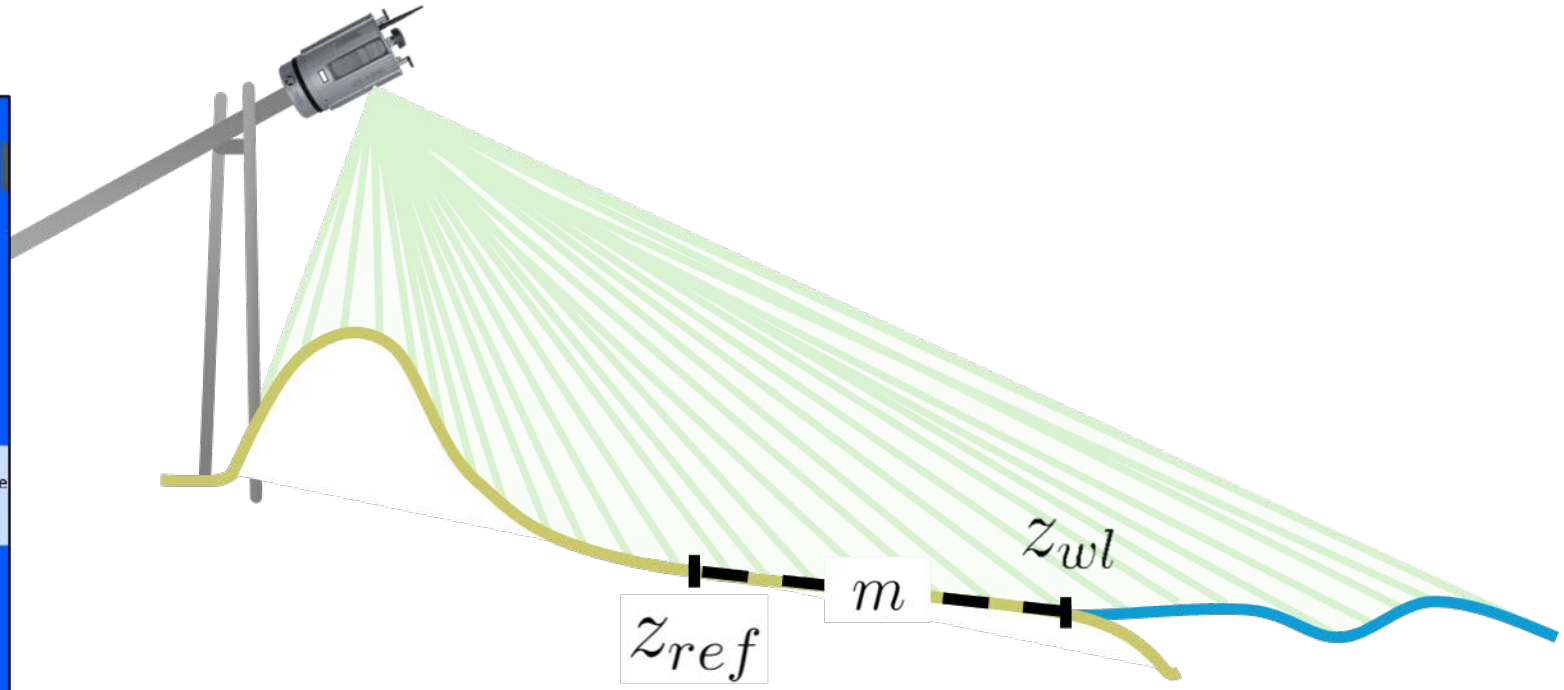
Water Level Correction – 2nd question

satellite-derived waterline
water/sand interface
(x,y)





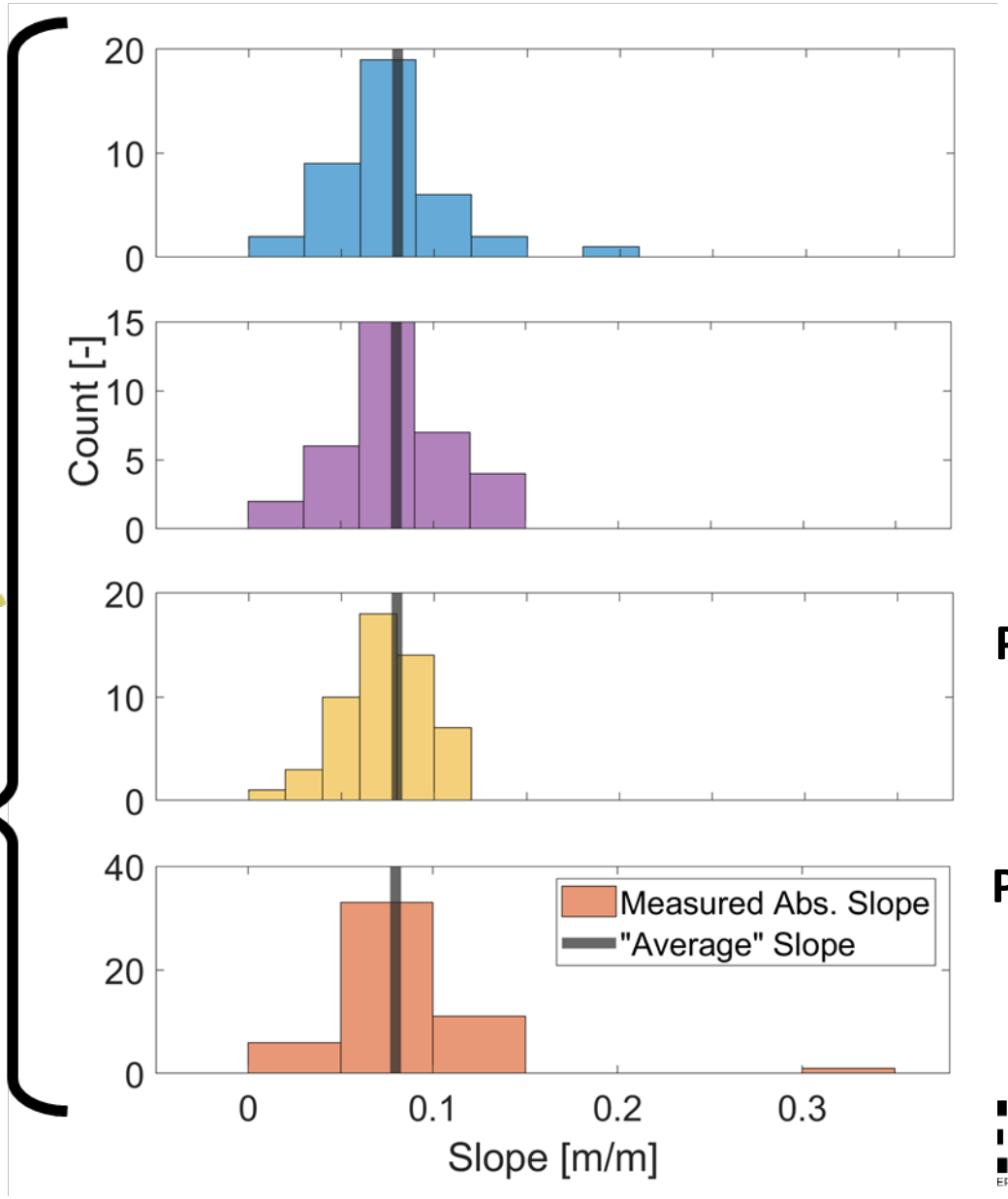
How much error does an average slope introduce?

(O'Dea et al. 2019)

Measured Slope

Calculated slope from position of 1m contour to the position of the SDW

measured slope has a wide variation, not captured using an average (0.08) slope



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Water Level Correction – 3rd question

satellite-derived waterline
water/sand interface
(x,y)

What reference contour introduces the least error?

$$\Delta x = \frac{z_{ref} - z_{wl}}{m}$$

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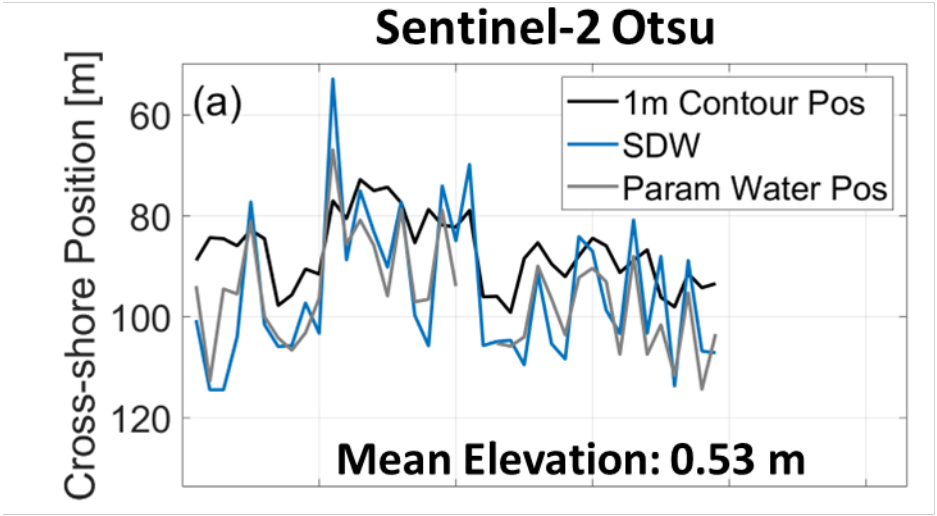
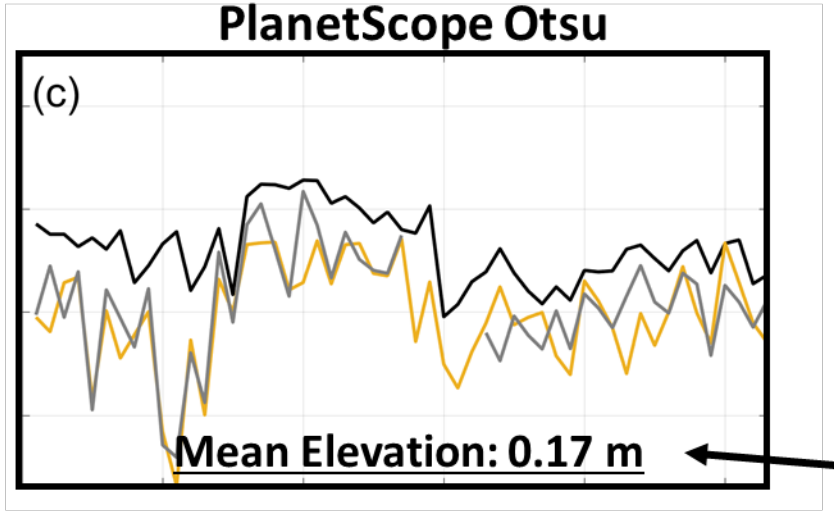
Reference Contour

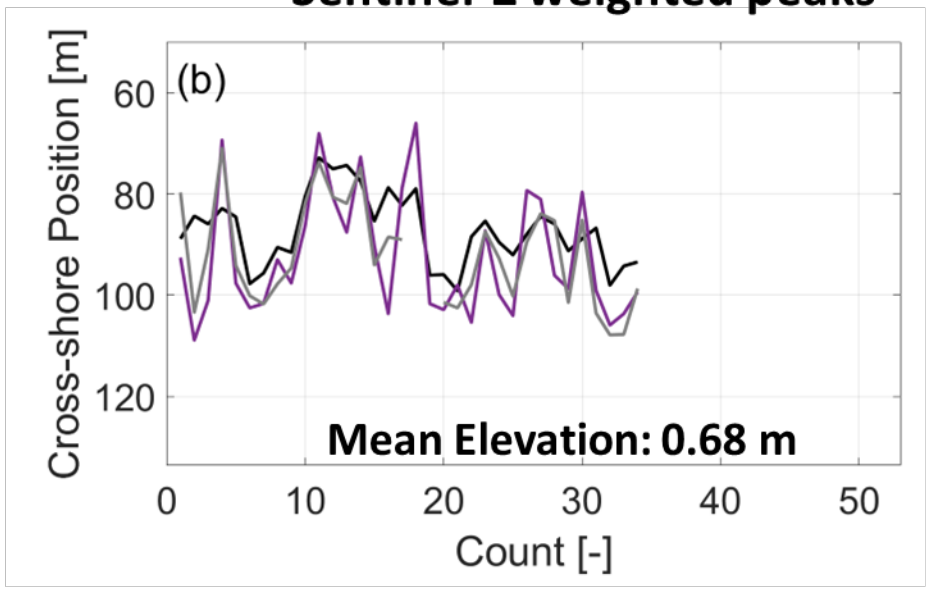


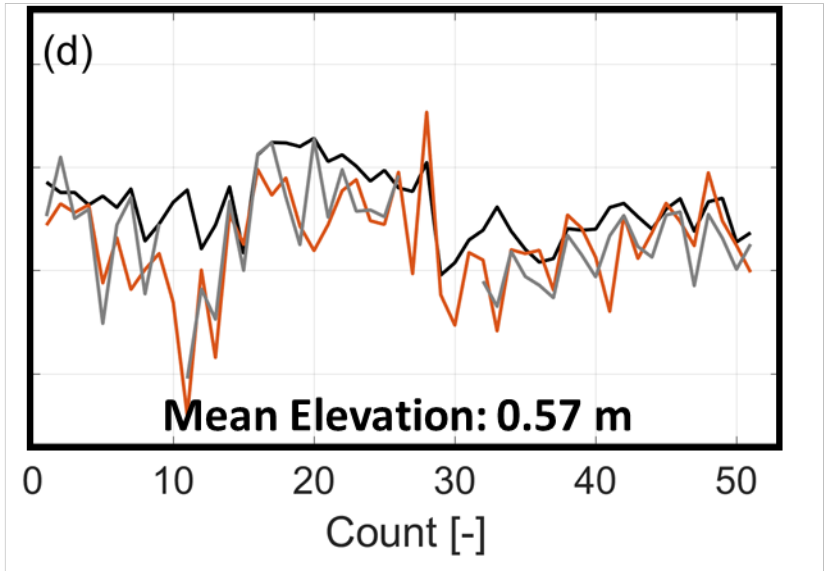


$$\Delta x = \frac{z_{ref} - z_{wl}}{m}$$

$$\Delta x = \frac{1 - 0.17}{0.08}$$

Furthest elevation difference to 1m contour





$$\Delta x = \frac{1 - 0.57}{0.08}$$

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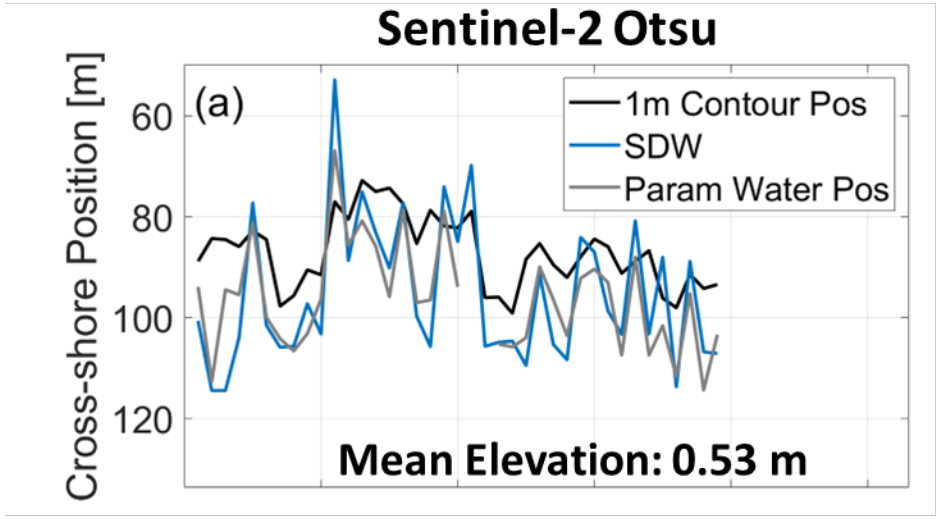
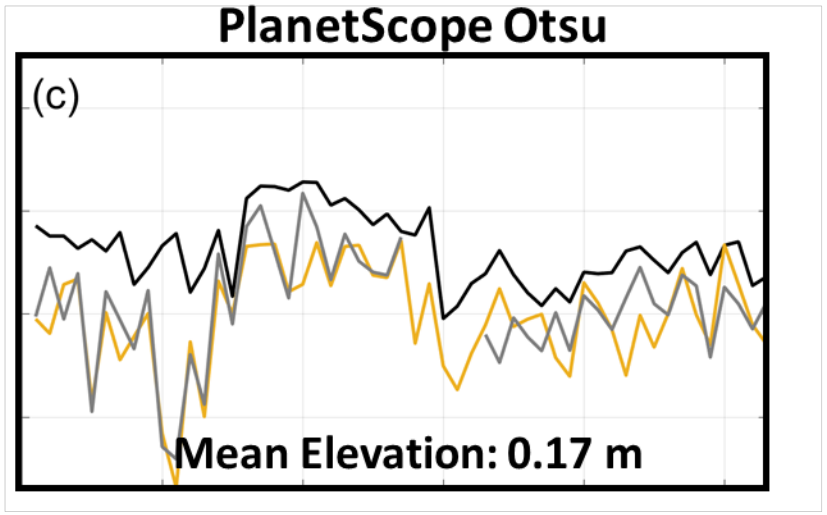
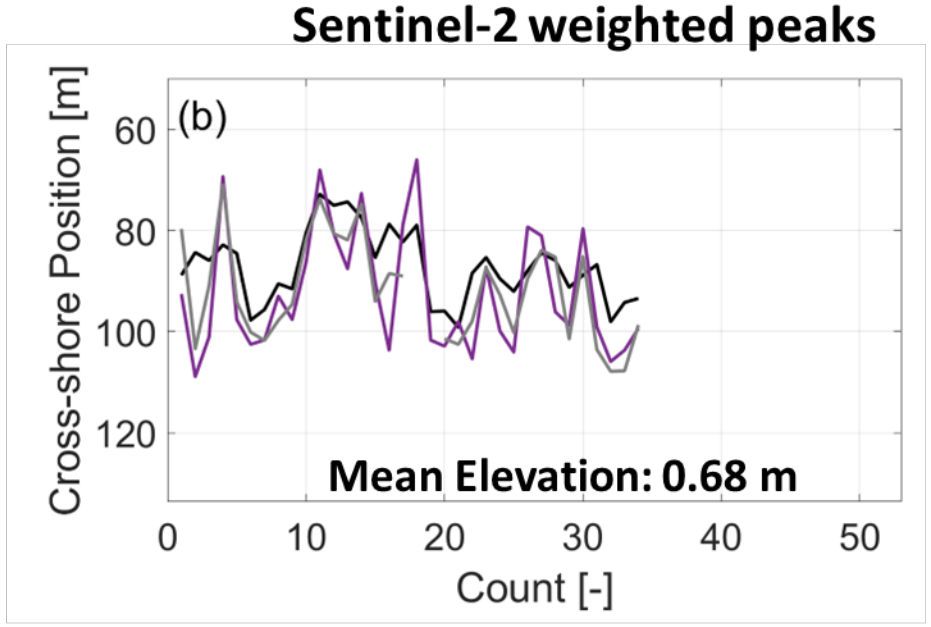
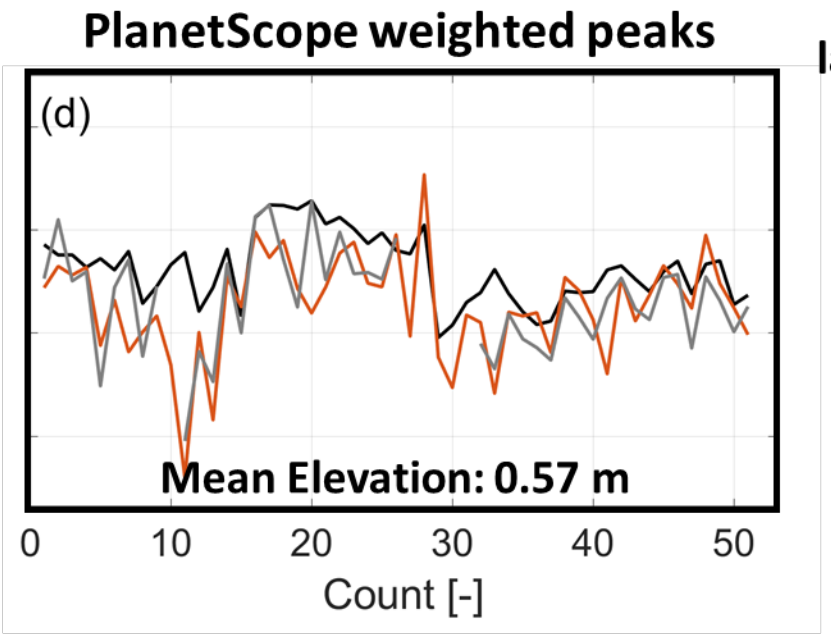
Reference Contour – cont.









$$\Delta x = \frac{z_{ref} - z_{wl}}{m}$$

$$\Delta x = \frac{1 - 0.17}{0.08}$$

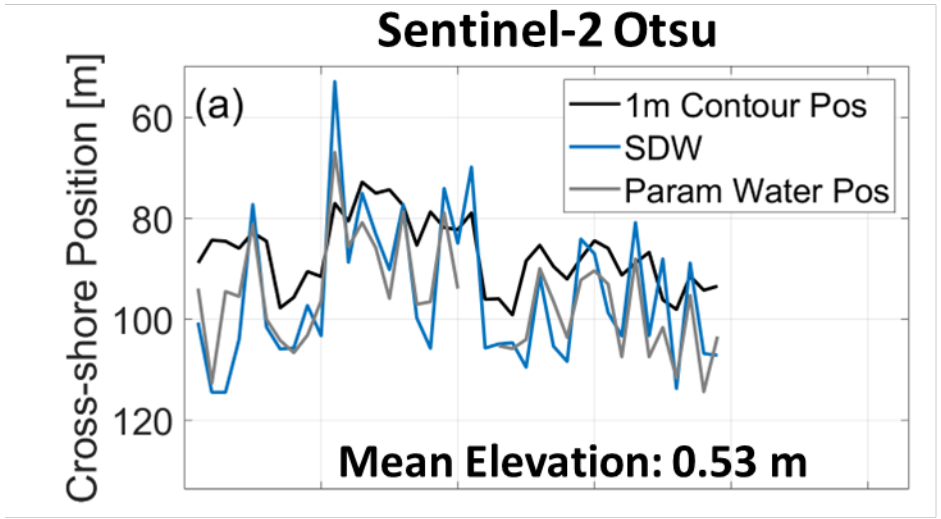
**** 0.08 is not always representative****

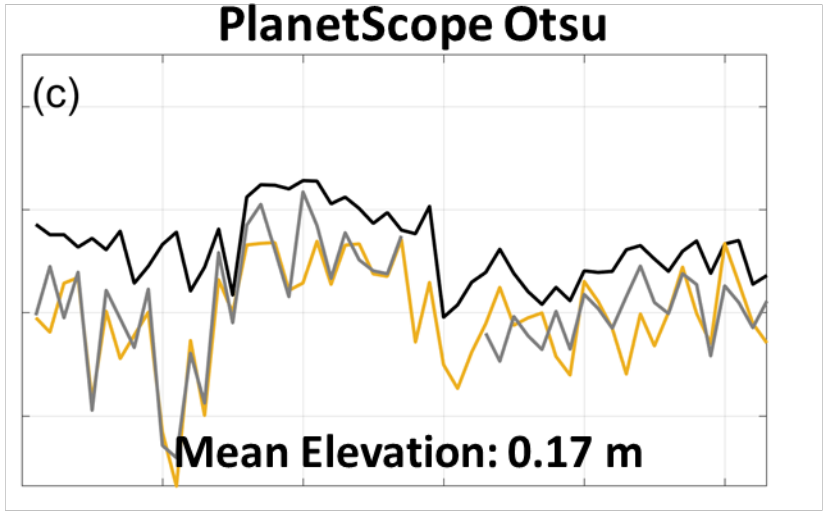
the larger the numerator, the larger the shift error introduced by the same slope error

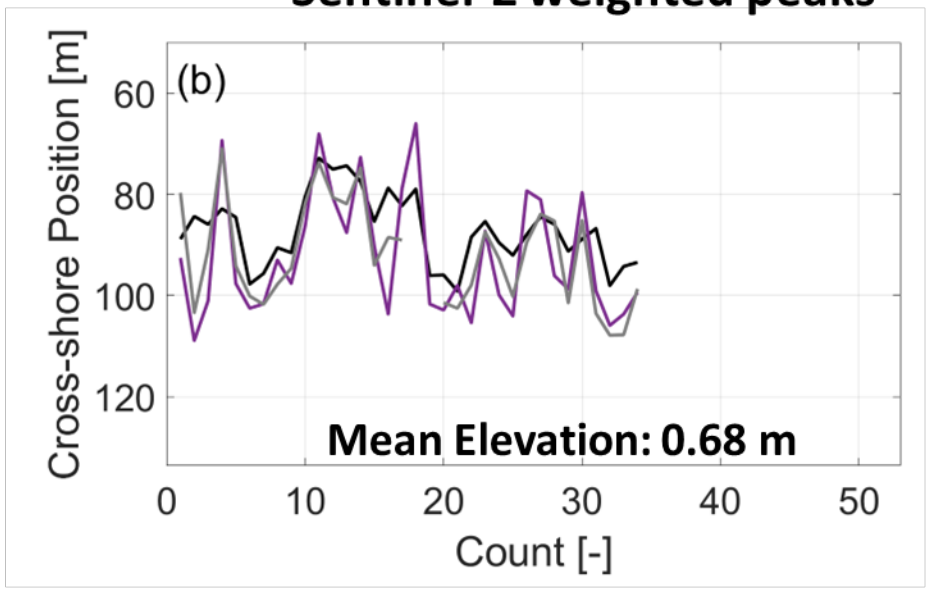
$$\Delta x = \frac{1 - 0.57}{0.08}$$

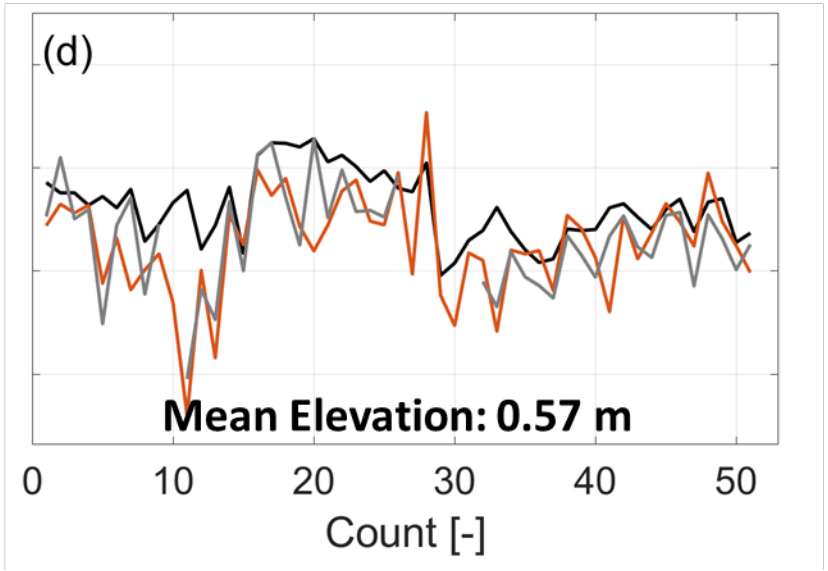
*** assuming the assigned waterline elevation error is minimal**

Reference Contour - complete









Otsu SDW are lower on the beach and should be shifted to the mid swash.

Weighted peaks SDW are consistently in the upper swash and should be shifted to an elevation within that zone.

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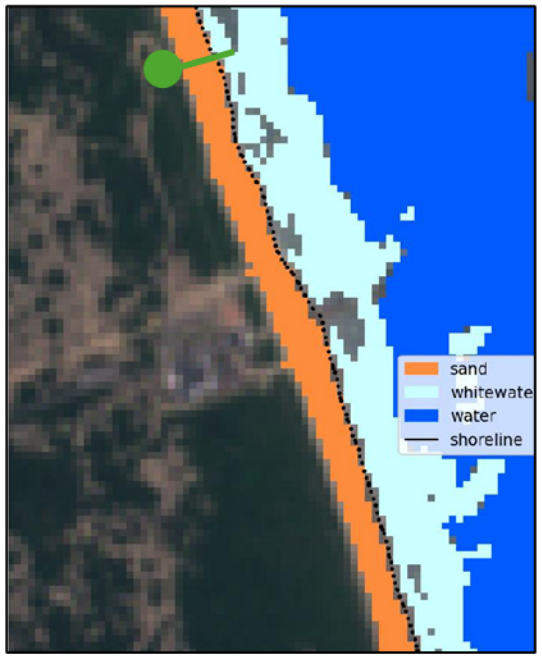
Water Level Correction – wrap up

satellite-derived waterline
water/sand interface
(x,y)



What reference contour introduces the least error?

- ***1 m contour***

What is the optimal waterline elevation?

- ***tide***
- ***lowest RMSD measured***
- ***lowest RMSD parameterized***

$$\Delta x = \frac{z_{ref} - z_{wl}}{m}$$

How much error does an average slope introduce?

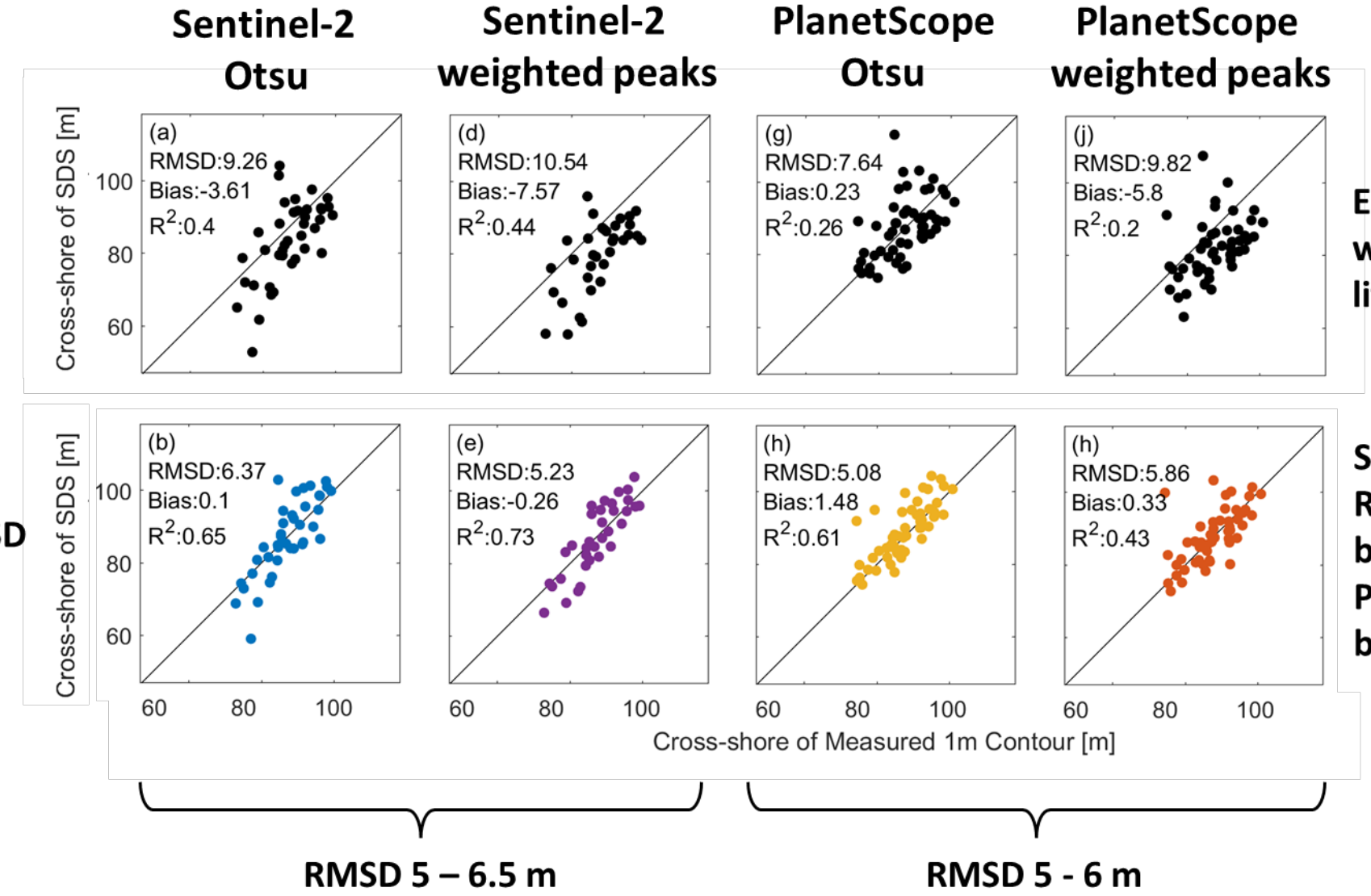
- ***average***
- ***measured***

(O'Dea et al. 2019)

SDS Accuracies - measured

z_{wl} = Tide
m = Average

z_{wl} = Lowest RMSD Measured
m = Measured



Errors consistent with previous literature

Sentinel-2 SDS RMSD reduced by ~30% and PlanetScope WP by ~40%

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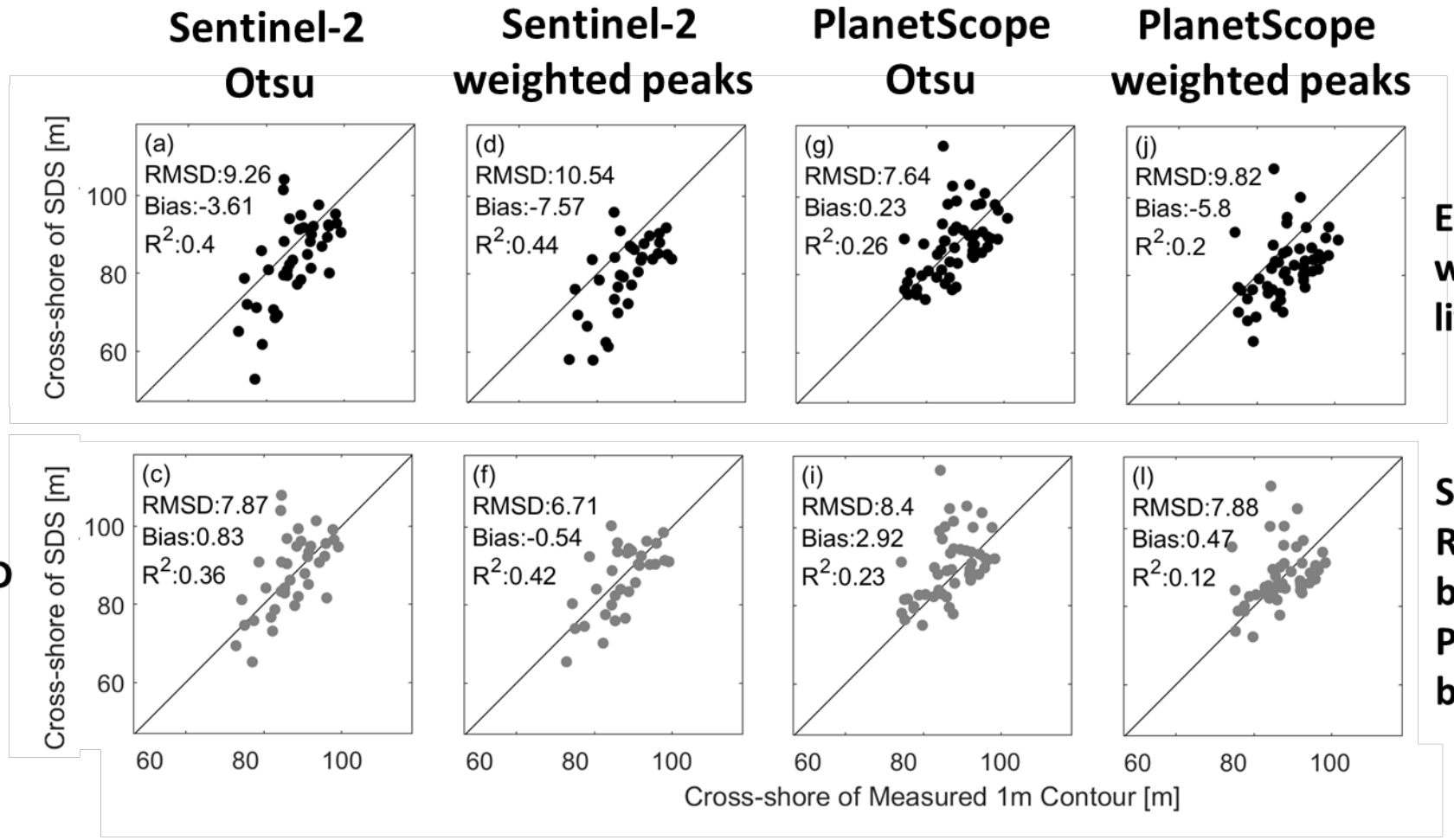
SDS Accuracies - parameterized

z_{wl} = Tide
m = Average

z_{wl} = Lowest RMSD Parameterized
m = Average



Errors consistent with previous literature

Sentinel-2 SDS RMSD reduced by ~35% and PlanetScope WP by ~20%

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Main Takeaways

1. CoastSat was used to extract 92 Satellite Derived Waterlines (SDW) from 2 image sources and 2 threshold algorithms

2. The Otsu waterline correlates better with the LDW and mean swash statistics, whereas the weighted peaks waterlines correlated with bulk statistics in the upper extent of the swash

3. By using the measured runup bulk statistic and measured beach slope when converting to SDS, SDS RMSD was reduced for this dataset

4. Using the parameterized runup bulk statistic improved SDS RMSD, even while using an average beach slope showing potential at less studied sites

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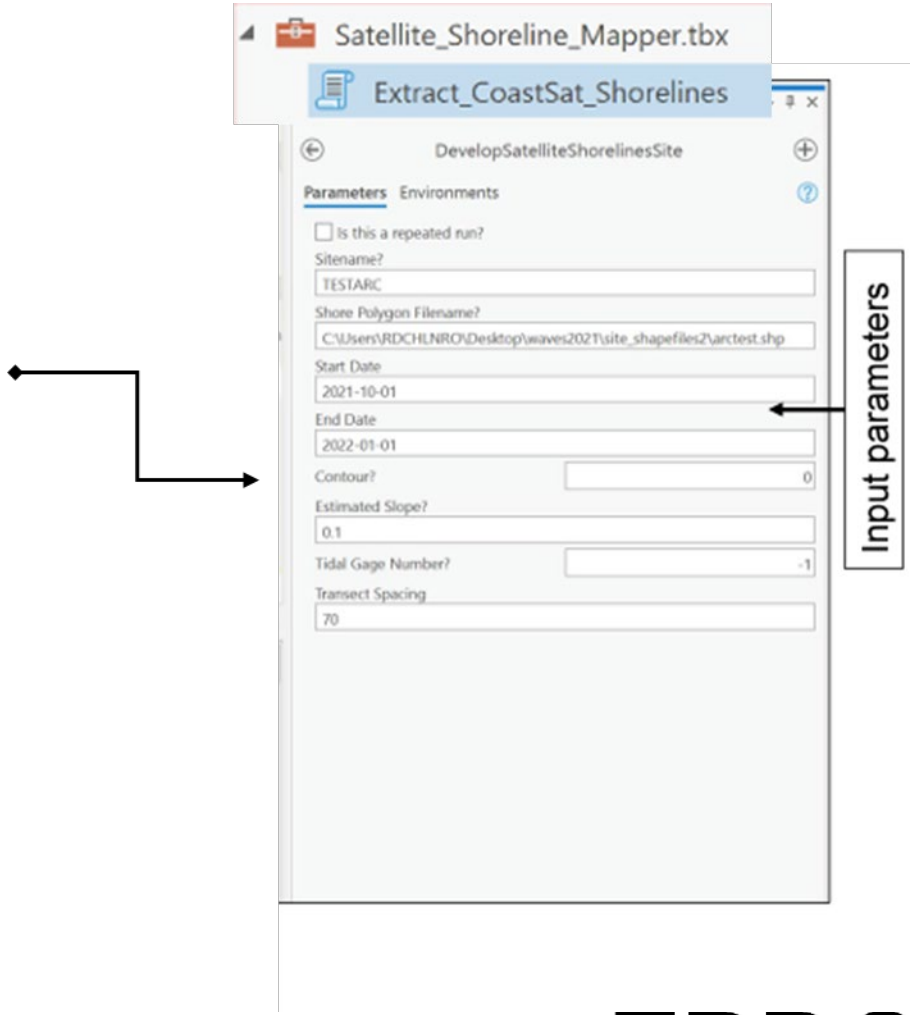
Management Application

The Satellite Shoreline Mapper tool uses the Otsu threshold algorithm

1. When using the current tool, set the **contour** input parameter to an elevation consistently in the mean swash.

2. Future version of SSM to include additional water level corrections above tide elevation to reflect these findings.



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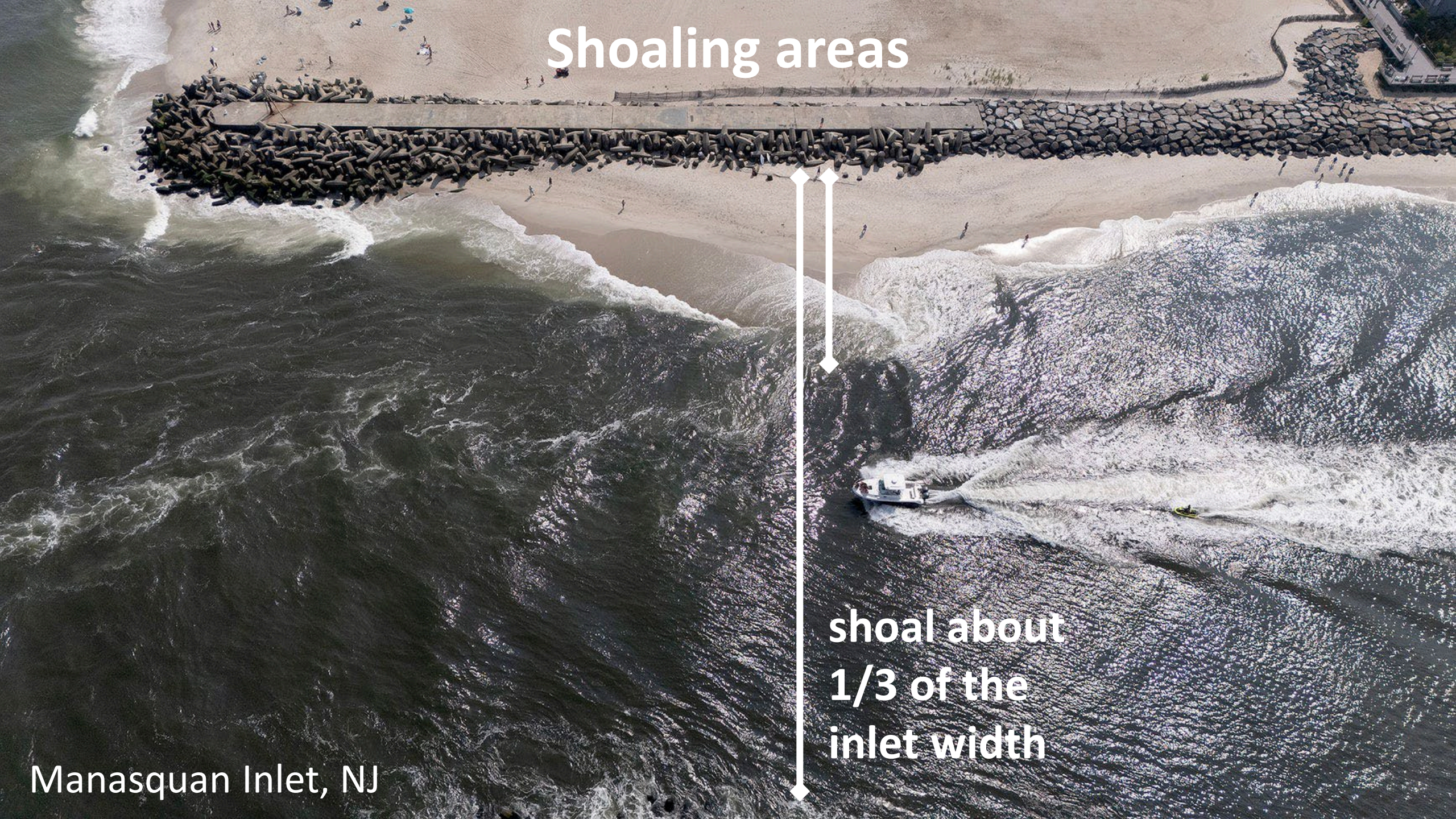

Shoaling areas
shoal about
1/3 of the
inlet width
Manasquan Inlet, NJ

Additional navigation hazards

Andrew Mills | NJ Advance Media

Andrew Mills | NJ Advance Media

Manasquan Inlet, NJ

Statements of Need

SON 1923 (Chasten)

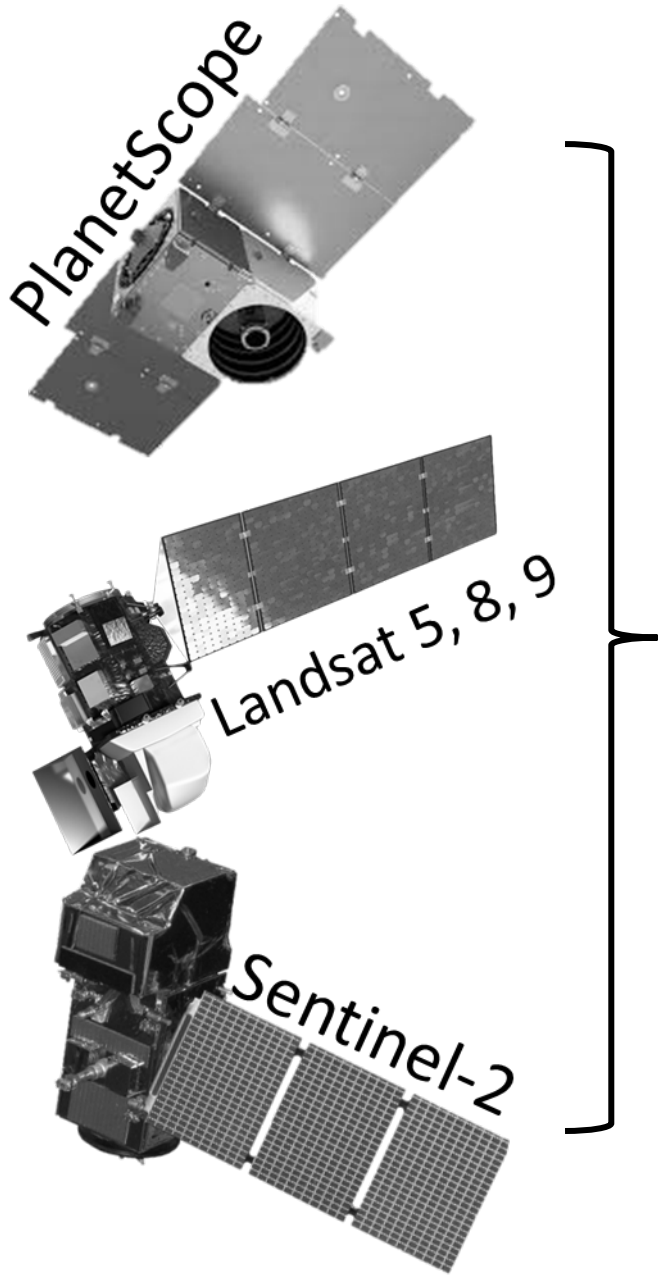
- Understand/predict temporal changes
- New tools to monitor shoals

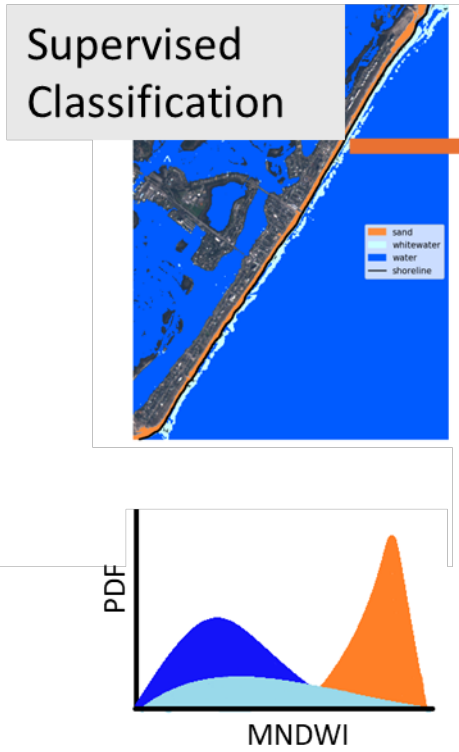
SON 2159 (Malburg)

- Great Lakes channels
- Remote sensing and local tools
- Near real-time estimates of shoal formation and migration

Manasquan Inlet, NJ

Satellite-Derived Waterlines





Currently identifies *whitewater* to reduce error.

But can we use this to inform hazardous shoals in wave-dominated inlets?

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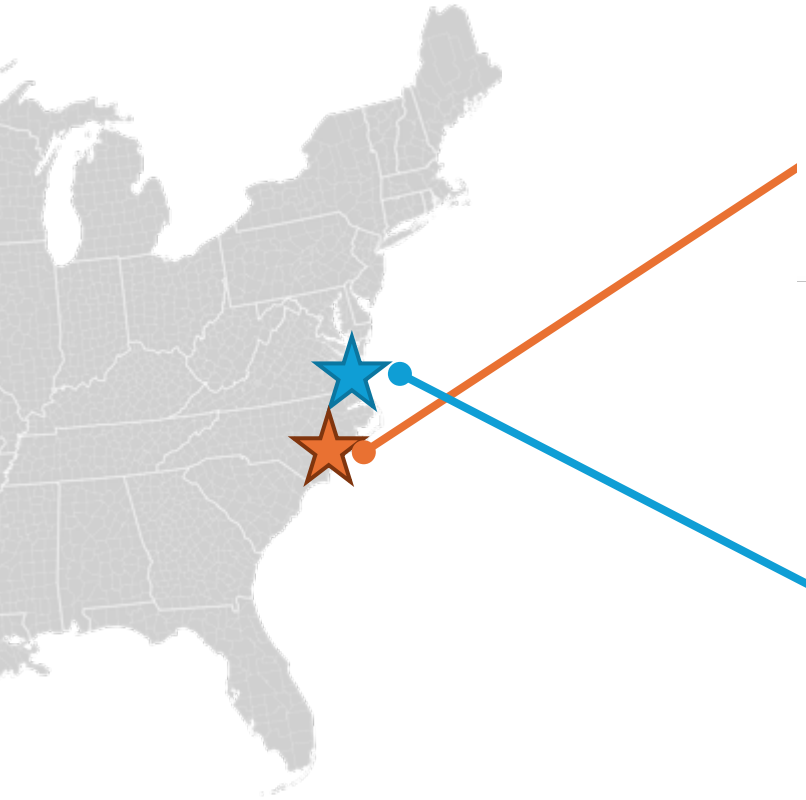
Approaches



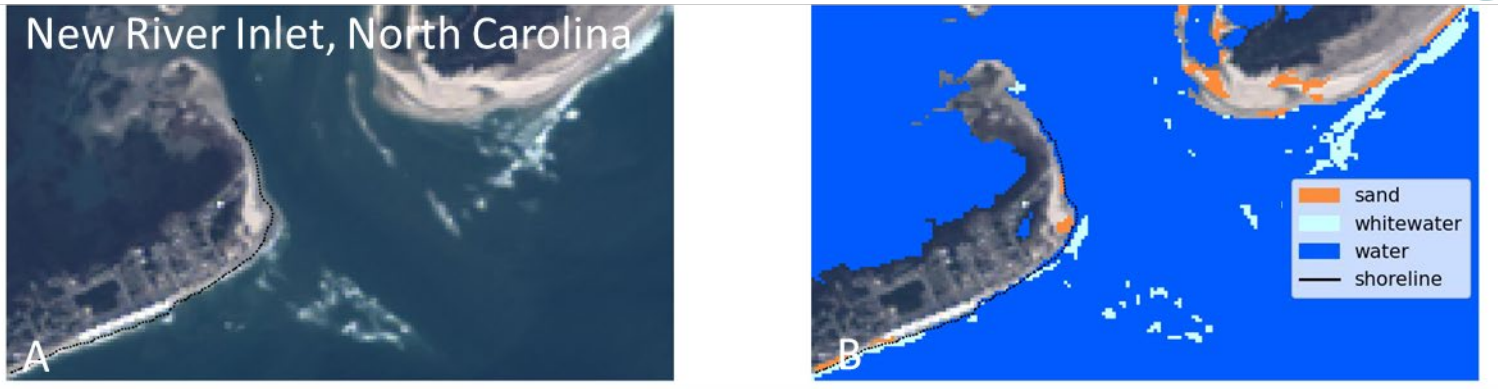


Figure 1. A) Sentinel-2 imagery of New River Inlet, North Carolina on January 30th, 2021. B) The classified image using CoastSat's supervised classification overlaid on the satellite image

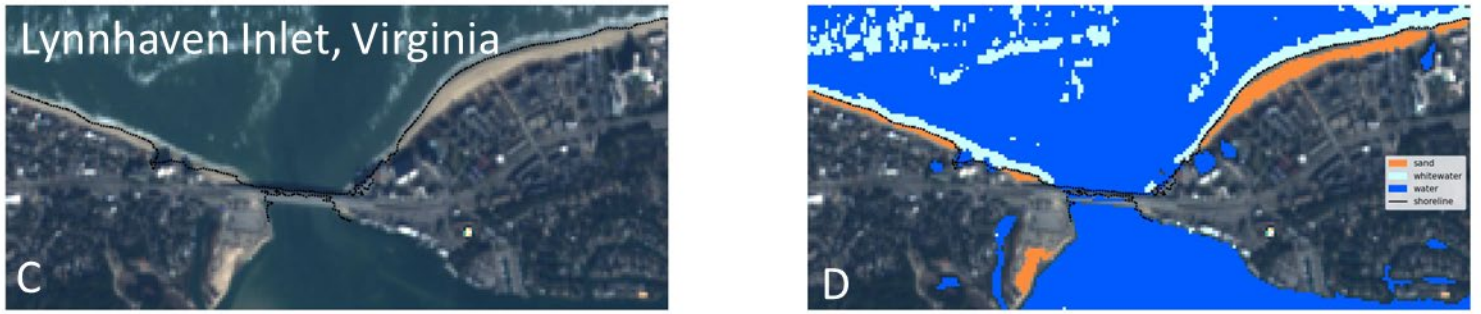


Figure 4. Each row depicts Sentinel-2 imagery of Lynnhaven Inlet, Virginia on the left and the classified image using CoastSat's supervised classification on the right A) January 30th, 2021. C) February 4th,2021 E) February 24th, 2021

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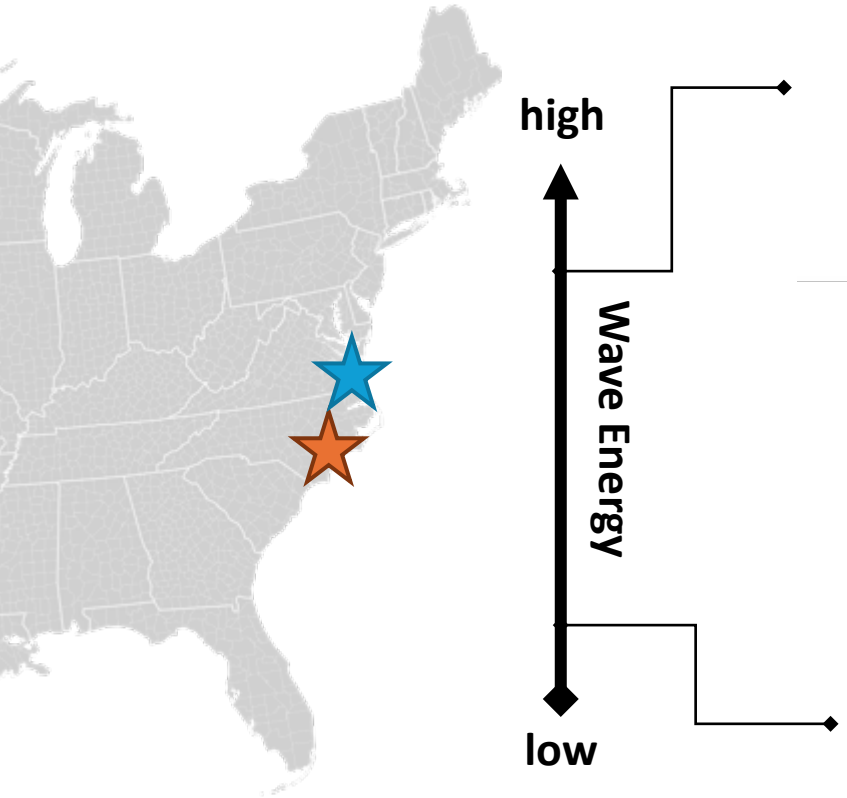
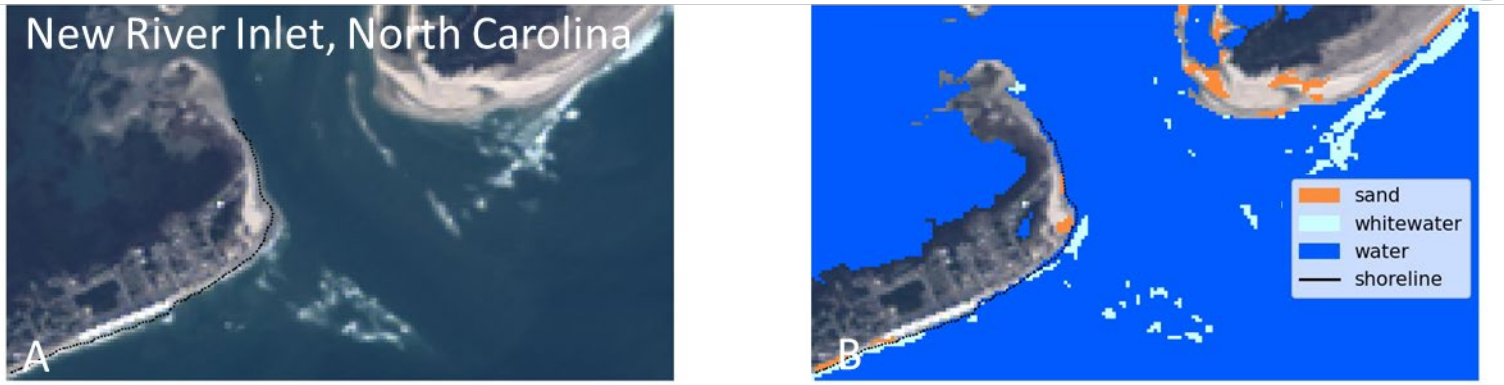
Approaches – wave energy





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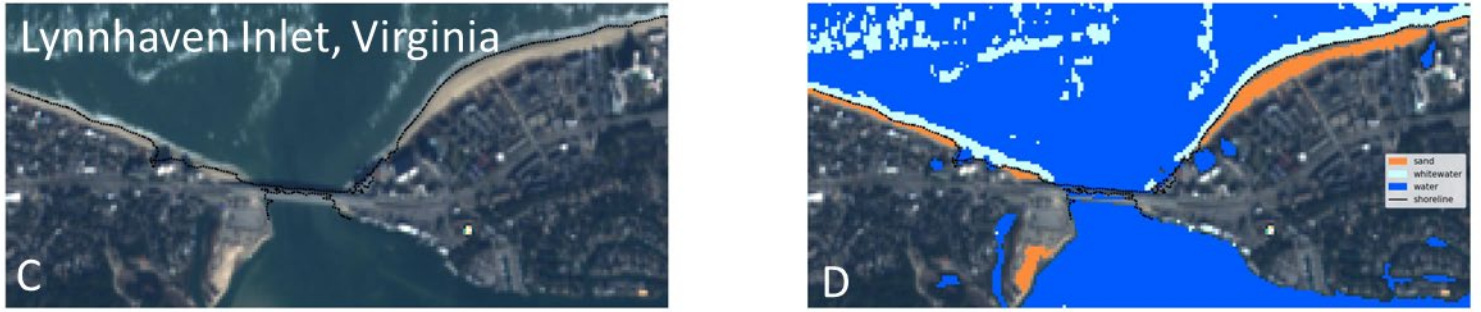

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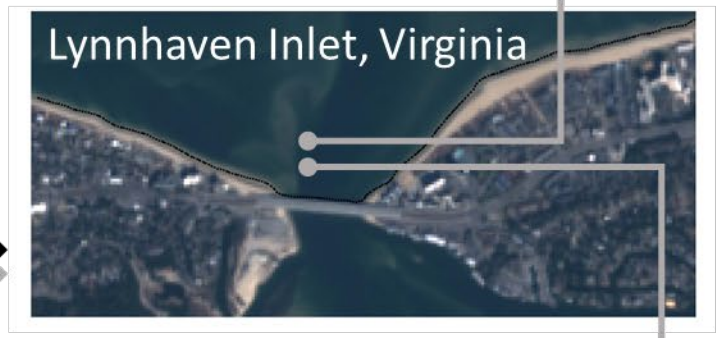
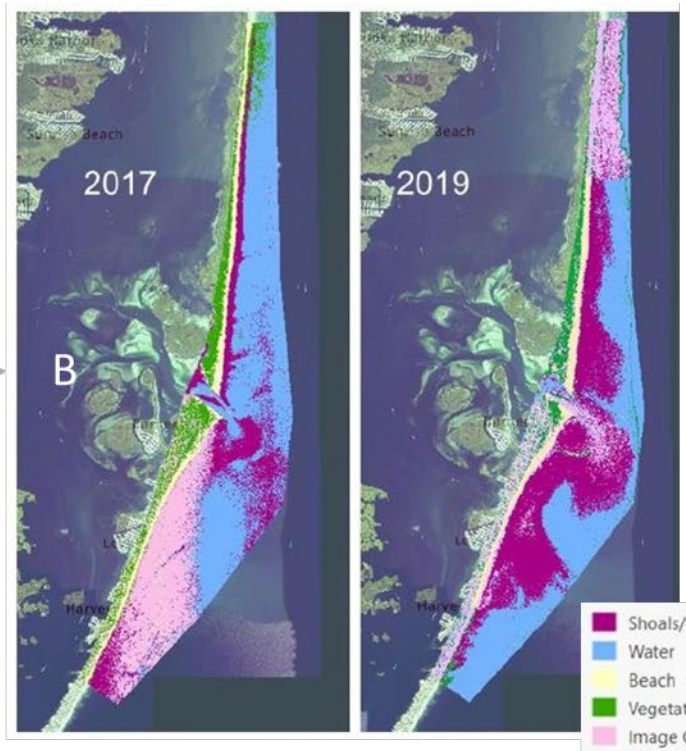
Approaches - discussion

Define site specific thresholds for when imagery is processed using this workflow and when it is processed using the multispectral delineation of hazardous shoal work unit led by Justin Shawler and Aleks Otsojic





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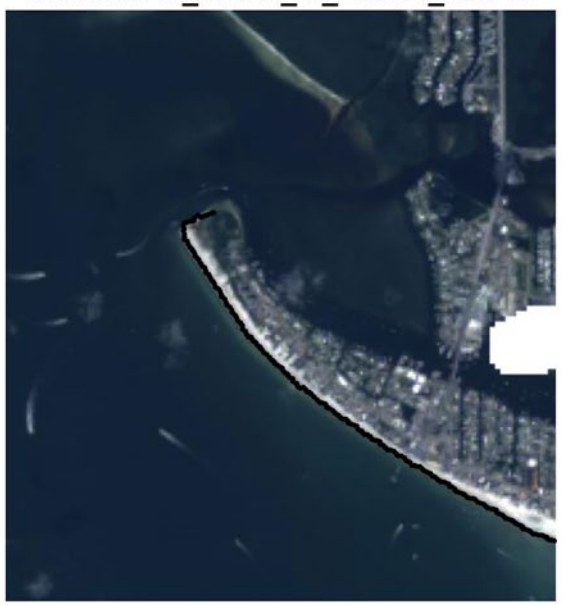
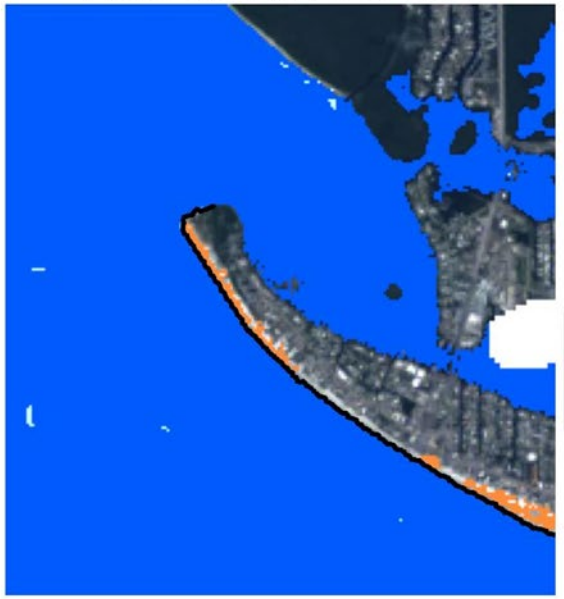
Matanzas Pass, FL

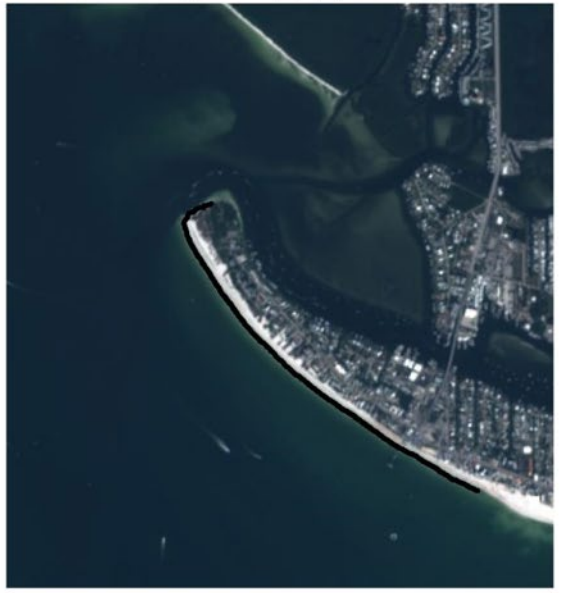
matanza_inlet_fl_2020_2024



2020-10-24-15-56-32



matanza_inlet_fl_2020_2024



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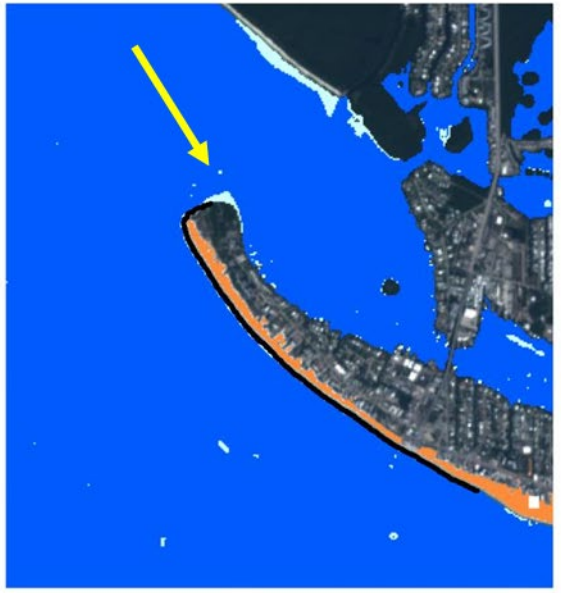

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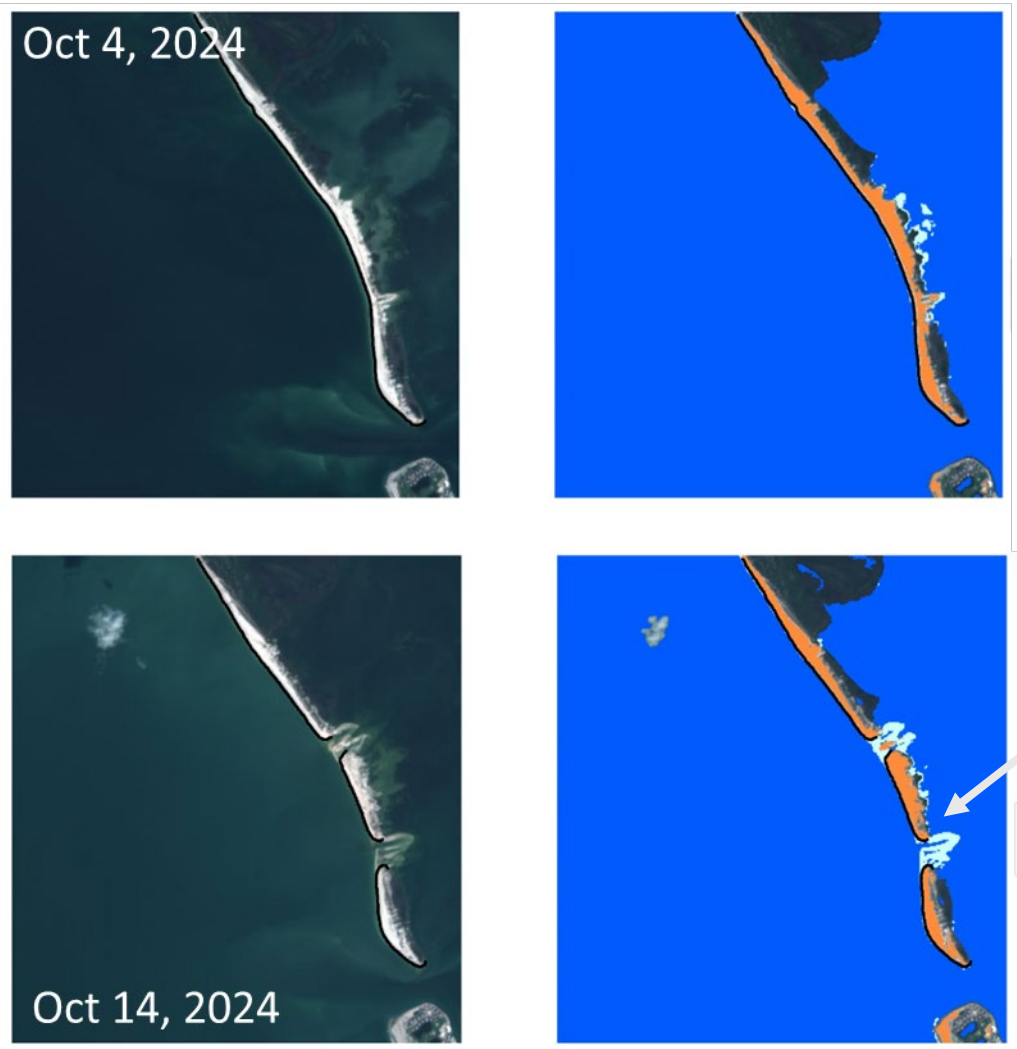
Hurricane Milton



Captured storm-induced breach events in North Captiva, FL

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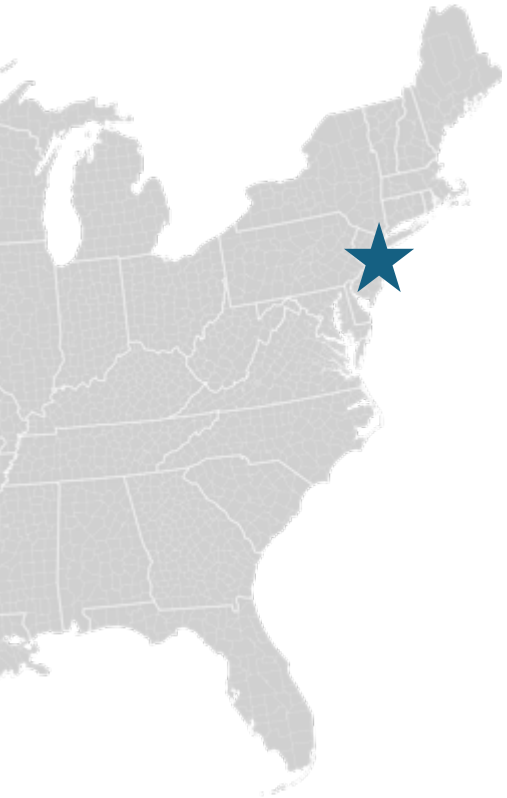
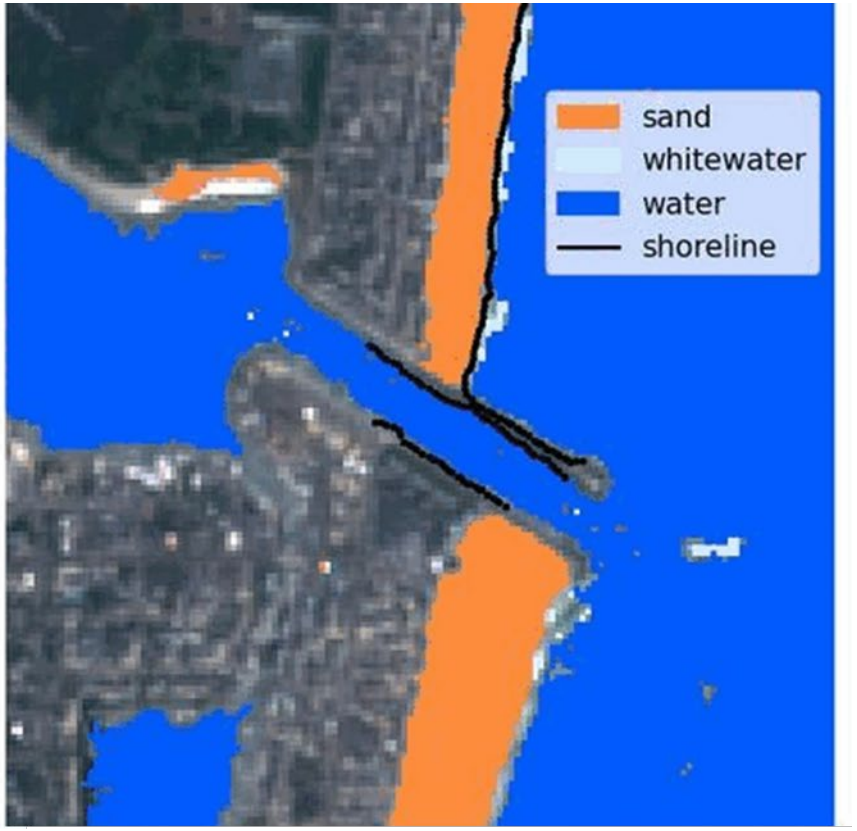
Manasquan Inlet, NJ





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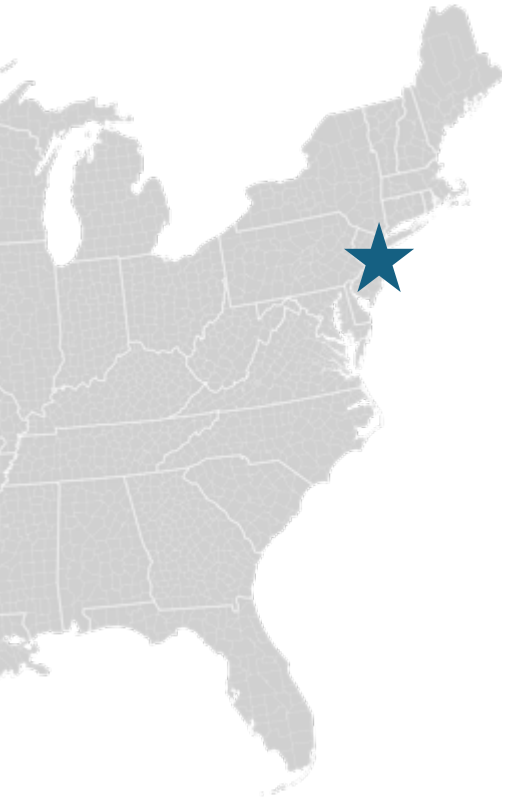
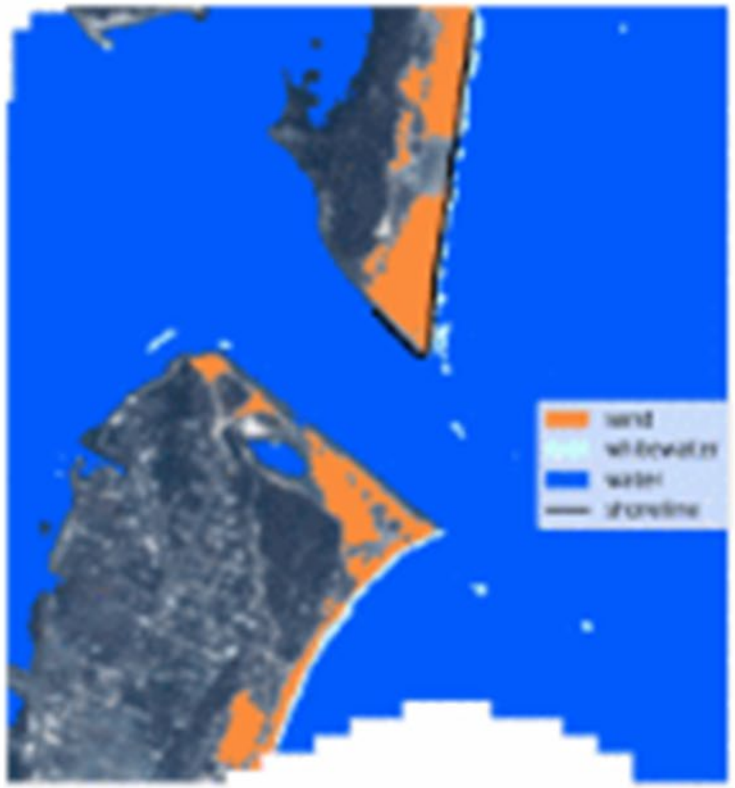
Barnegat Inlet, NJ





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Temporal Analysis

artifacts from cloud masking

4-year composite image of brightest pixels

bright locations indicate breaking waves and potential shoal locations

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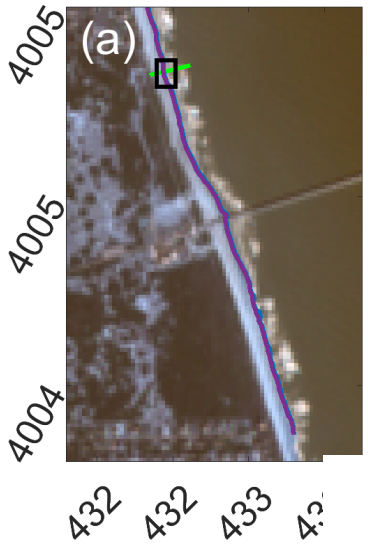
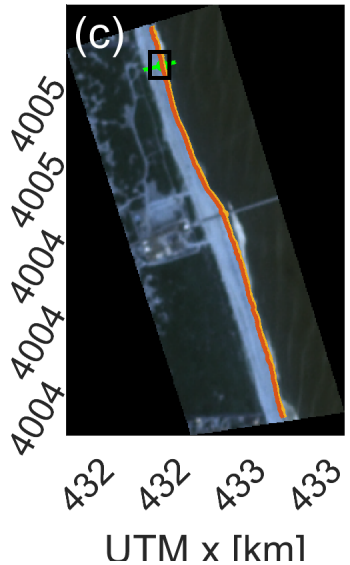
Testing Improved Classifier

CoastSat
10 - 15 m



CoastSat
PlanetScope
3 - 4 m, $$

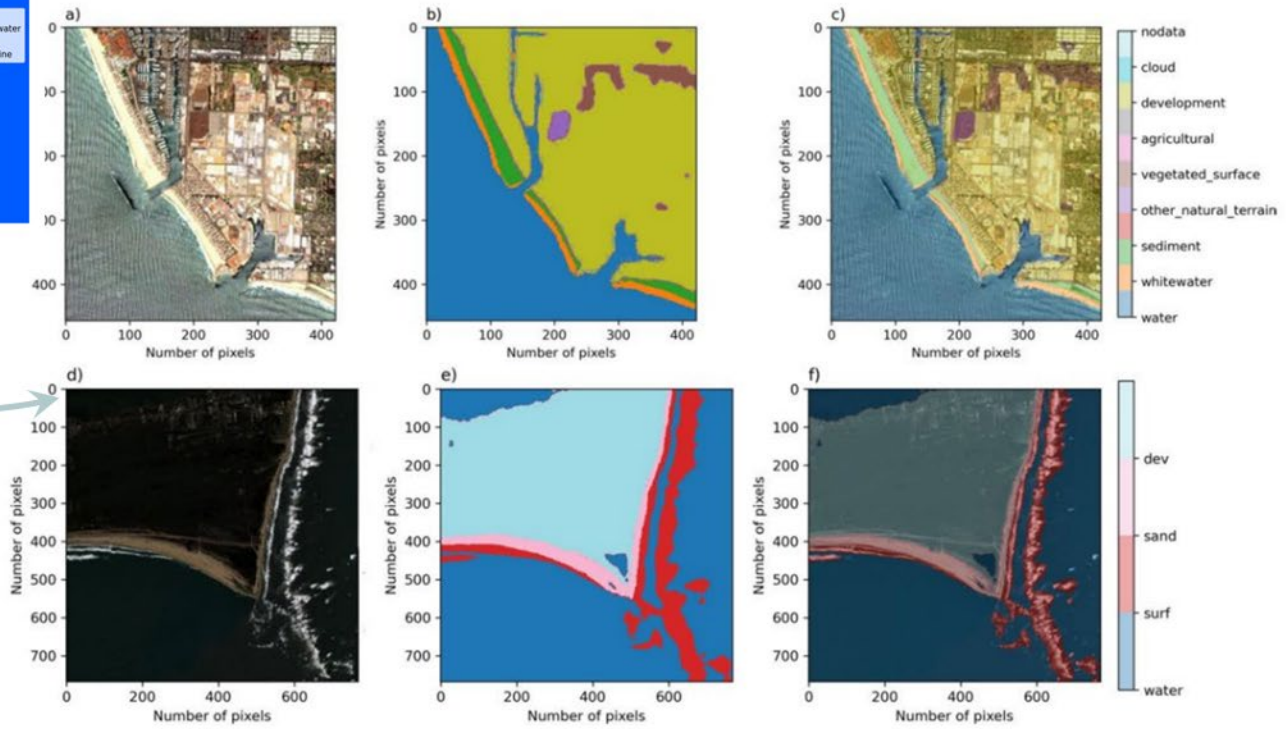


Supervised Classification

classifying sand, water, and whitewater

By using a supervised classification with more classes, can this workflow be used in additional environments?

Coast Train



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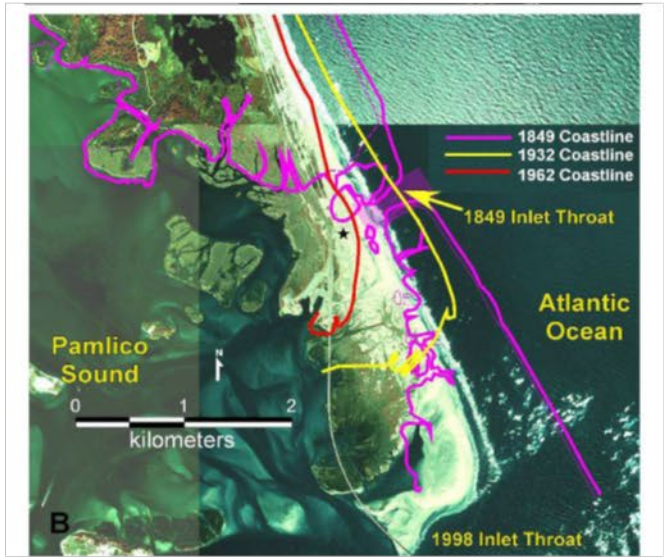
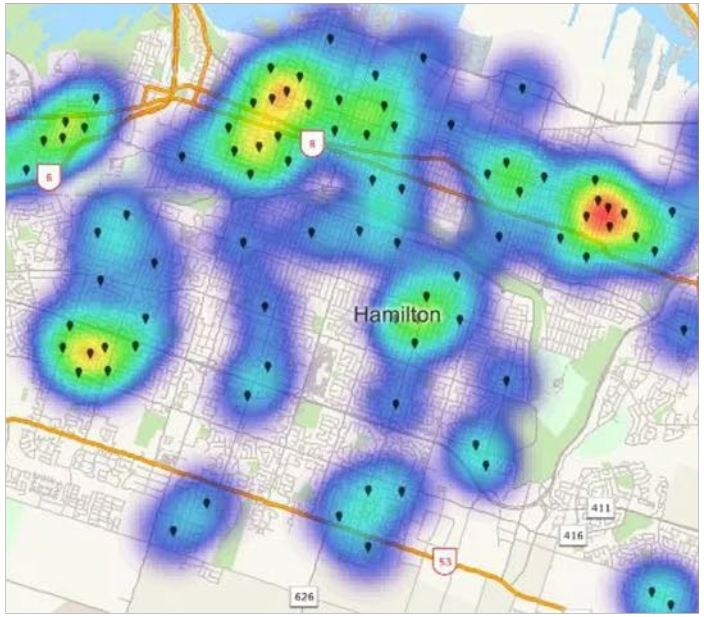
Potential Products

Add additional functionality in inlets

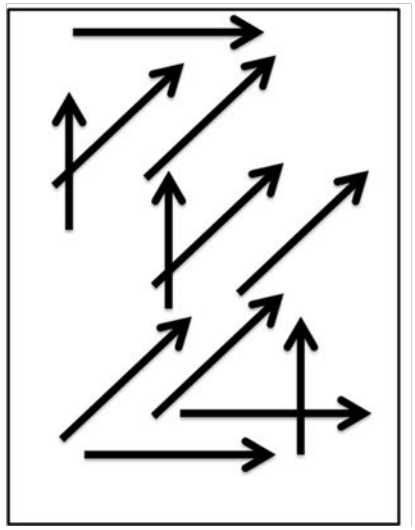
Inlet shoreline geometries





Weekly to decadal shoal recurrence heatmaps

Shoal directional vectors and migration rates



Ideas from field?

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Project Timeline

Month	Deliverable/Milestone
Sept., 2025	Single test site selection, shoreline and shoal extraction over 10 year period
Sept., 2026	Up to five site validation, depth contour selection, technical note
Sept., 2027	Tool integration/delivery and tech transfer through training workshop(s)
Sept., 2028	Shoal predictive model, technical report, conference proceedings or journal article

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Questions and Discussion

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ian.w.Conery@erdc.dren.mil

CIRP ERDC

Questions

- How might a tool like this impact your operations (e.g., survey and dredge timing)?
- What temporal frequency is ideal... weekly, monthly, seasonal?
  - Would time averaged products help?
- Would your district be willing to pay for higher resolution imagery/video?
- Are decadal historic trends useful or do you mostly care about current conditions?
- Any insight on good ground truth data?
- Desktop ArcTool vs web platform

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