# SATELLITE-DERIVED SHORELINES FOR COASTAL MONITORING

Ian Conery
Shannon Brown, Katie Devore, Mike Forte, Kate Brodie

District PDT members: Monica Chasten (NAP), Jonathan Waddell (LRE), Jessica Podoski (POH)

18 APR 2024

**COASTAL INLETS RESEARCH PROGRAM**

*FY23 IN PROGRESS REVIEW*

U.S. ARMY

US Army Corps of Engineers®

ERDC

CIRP

# PROBLEM STATEMENT

- **Existing coastal survey methods can be time-consuming, expensive and hazardous**

  …

  …

  - **to conserve limited operational resources (e.g., personnel and vessels), USACE Districts are often forced to narrow areas of interest or monitoring frequency, decreasing the likelihood of making data-driven management decisions**

FY21 SoN – Satellite Imagery for Coastal Monitoring (1731)

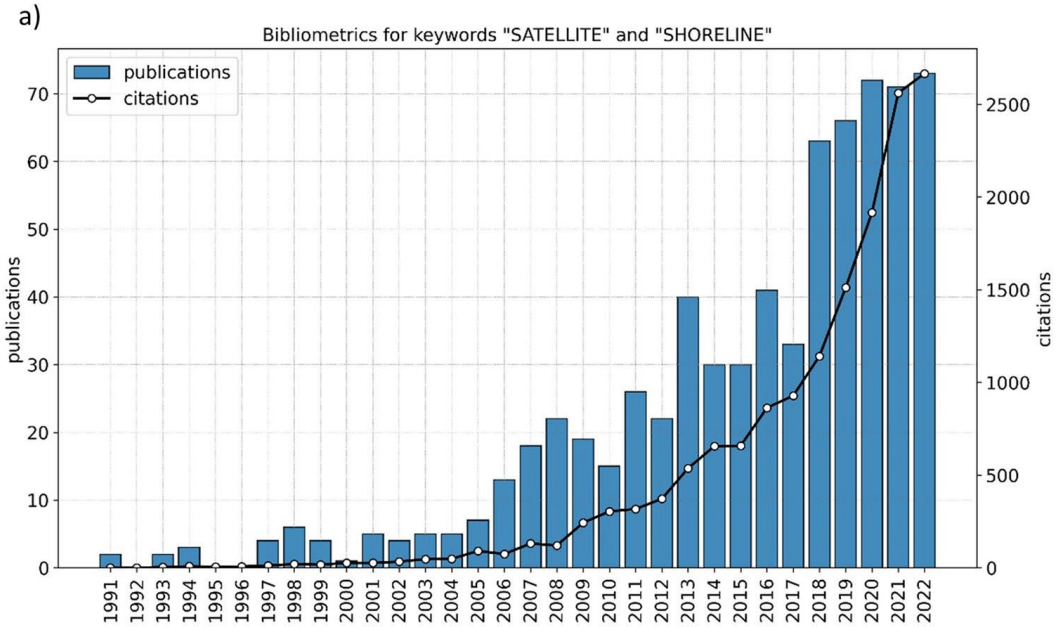
FY23 was Year 3 of 3

FY21: Algorithm accuracy evaluation; FY22: Tool development and report writing; FY 23: Tool refinement and tech transfer

# CAPABILITY AND STRATEGIC IMPACT

Satellite-based tool is expected to provide USACE Districts access to a ***new data source***, enabling wide-spread ***frequent*** coastal data with ***low cost*** and personnel commitment.

Adds ability to examine shoreline variability (short and long term), "***now state***" of coastline and help with preliminary planning for districts managing beach projects and storm impacts (e.g., nourishments, nearshore berms, dredging, etc.)



# PROJECT OBJECTIVES

**1)** Evaluate open-source satellite shoreline extraction algorithm accuracy at a range of test sites (CoastSat – UNSW; Vos et al., 2019) (FY21-22)

Mean horizontal difference from ground truth = **11.32** m; -3.51 m onshore bias

**2)** Assess how imagery can be used for management applications (FY21-22)

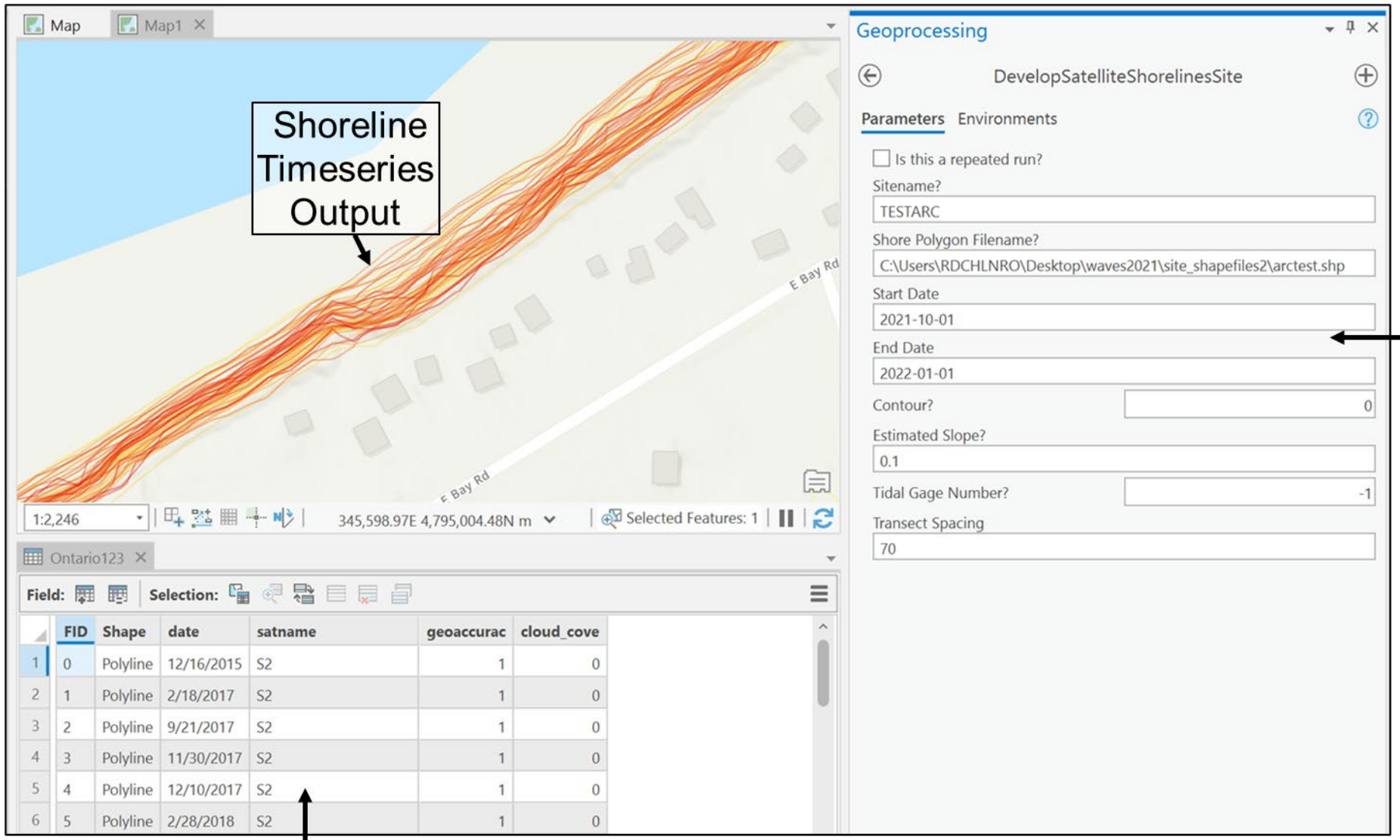
See technical report!

**3)** Create user-friendly ArcTool for USACE District use (FY22-23)

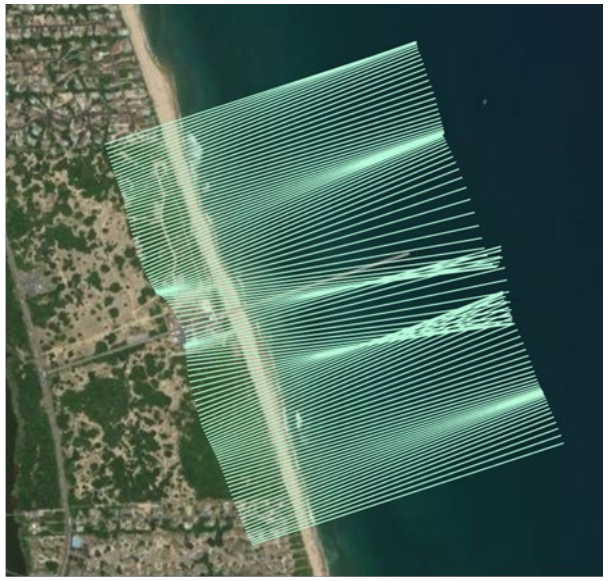
https://cirp.usace.army.mil/products/ssm.php

**4)** Journal Article (FY23-24)

# ERDC Satellite Shoreline Mapper (SSM)



# Tool improvements



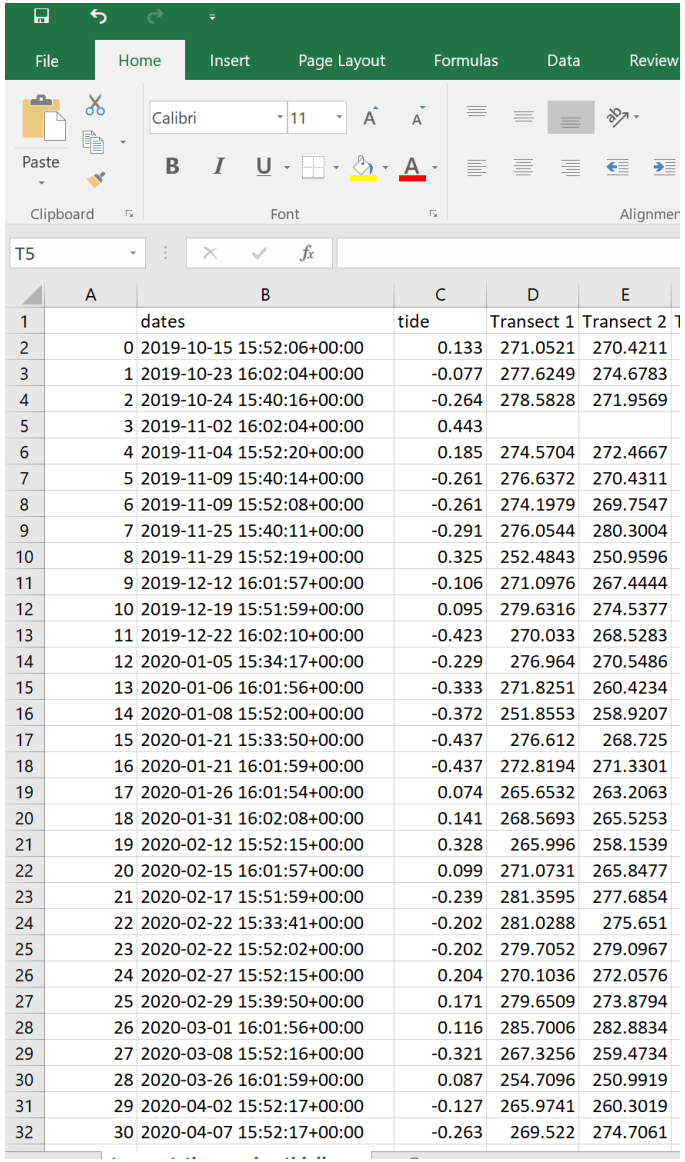
- Transects
- Shapefile tidal shift
- Created useful plots
- Sentinel 2 cloud threshold
- CoastSat slope over short intervals
- Blue border

Improvements on wrapper

Update/Improve
CoastSat Algorithm

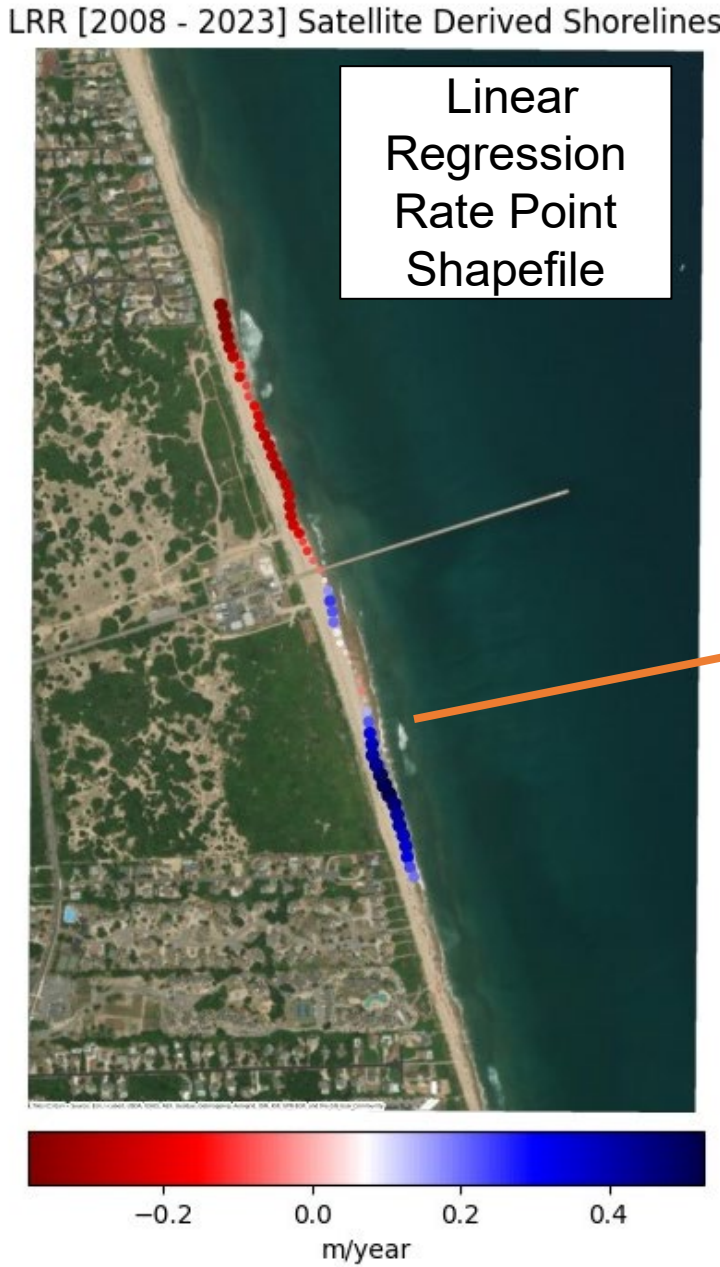
# Tool Products

## Summary .csv

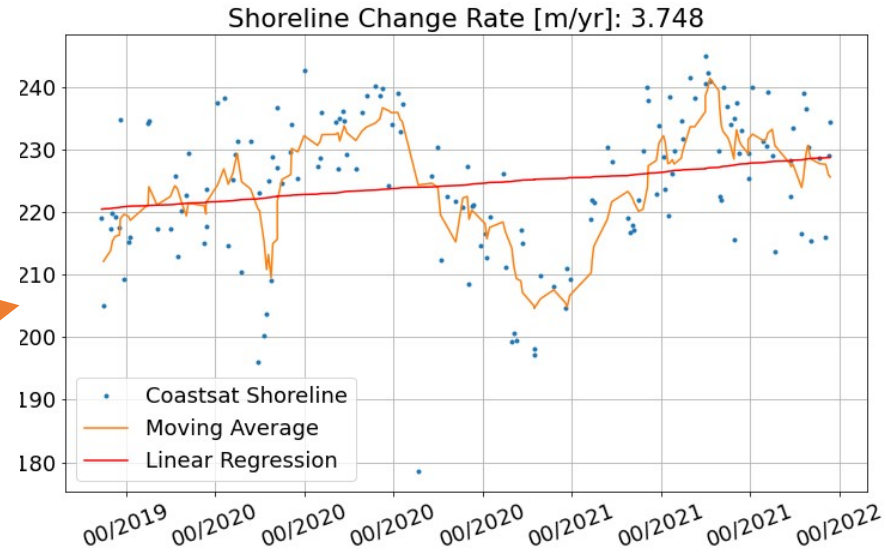


| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | | dates | tide | Transect 1 | Transect 2 |
| 2 | 0 | 2019-10-15 15:52:06+00:00 | 0.133 | 271.0521 | 270.4211 |
| 3 | 1 | 2019-10-23 16:02:04+00:00 | -0.077 | 277.6249 | 274.6783 |
| 4 | 2 | 2019-10-24 15:40:16+00:00 | -0.264 | 278.5828 | 271.9569 |
| 5 | 3 | 2019-11-02 16:02:04+00:00 | 0.443 | | |
| 6 | 4 | 2019-11-04 15:52:20+00:00 | 0.185 | 274.5704 | 272.4667 |
| 7 | 5 | 2019-11-09 15:40:14+00:00 | -0.261 | 276.6372 | 270.4311 |
| 8 | 6 | 2019-11-09 15:52:08+00:00 | -0.261 | 274.1979 | 269.7547 |
| 9 | 7 | 2019-11-25 15:40:11+00:00 | -0.291 | 276.0544 | 280.3004 |
| 10 | 8 | 2019-11-29 15:52:19+00:00 | 0.325 | 252.4843 | 250.9596 |
| 11 | 9 | 2019-12-12 16:01:57+00:00 | -0.106 | 271.0976 | 267.4444 |
| 12 | 10 | 2019-12-19 15:51:59+00:00 | 0.095 | 279.6316 | 274.5377 |
| 13 | 11 | 2019-12-22 16:02:10+00:00 | -0.423 | 270.033 | 268.5283 |
| 14 | 12 | 2020-01-05 15:34:17+00:00 | -0.229 | 276.964 | 270.5486 |
| 15 | 13 | 2020-01-06 16:01:56+00:00 | -0.333 | 271.8251 | 260.4234 |
| 16 | 14 | 2020-01-08 15:52:00+00:00 | -0.372 | 251.8553 | 258.9207 |
| 17 | 15 | 2020-01-21 15:33:50+00:00 | -0.437 | 276.612 | 268.725 |
| 18 | 16 | 2020-01-21 16:01:59+00:00 | -0.437 | 272.8194 | 271.3301 |
| 19 | 17 | 2020-01-26 16:01:54+00:00 | 0.074 | 265.6532 | 263.2063 |
| 20 | 18 | 2020-01-31 16:02:08+00:00 | 0.141 | 268.5693 | 265.5253 |
| 21 | 19 | 2020-02-12 15:52:15+00:00 | 0.328 | 265.996 | 258.1539 |
| 22 | 20 | 2020-02-15 16:01:57+00:00 | 0.099 | 271.0731 | 265.8477 |
| 23 | 21 | 2020-02-17 15:51:59+00:00 | -0.239 | 281.3595 | 277.6854 |
| 24 | 22 | 2020-02-22 15:33:41+00:00 | -0.202 | 281.0288 | 275.651 |
| 25 | 23 | 2020-02-22 15:52:02+00:00 | -0.202 | 279.7052 | 279.0967 |
| 26 | 24 | 2020-02-27 15:52:15+00:00 | 0.204 | 270.1036 | 272.0576 |
| 27 | 25 | 2020-02-29 15:39:50+00:00 | 0.171 | 279.6509 | 273.8794 |
| 28 | 26 | 2020-03-01 16:01:56+00:00 | 0.116 | 285.7006 | 282.8834 |
| 29 | 27 | 2020-03-08 15:52:16+00:00 | -0.321 | 267.3256 | 259.4734 |
| 30 | 28 | 2020-03-26 16:01:59+00:00 | 0.087 | 254.7096 | 250.9919 |
| 31 | 29 | 2020-04-02 15:52:17+00:00 | -0.127 | 265.9741 | 260.3019 |
| 32 | 30 | 2020-04-07 15:52:17+00:00 | -0.263 | 269.522 | 274.7061 |

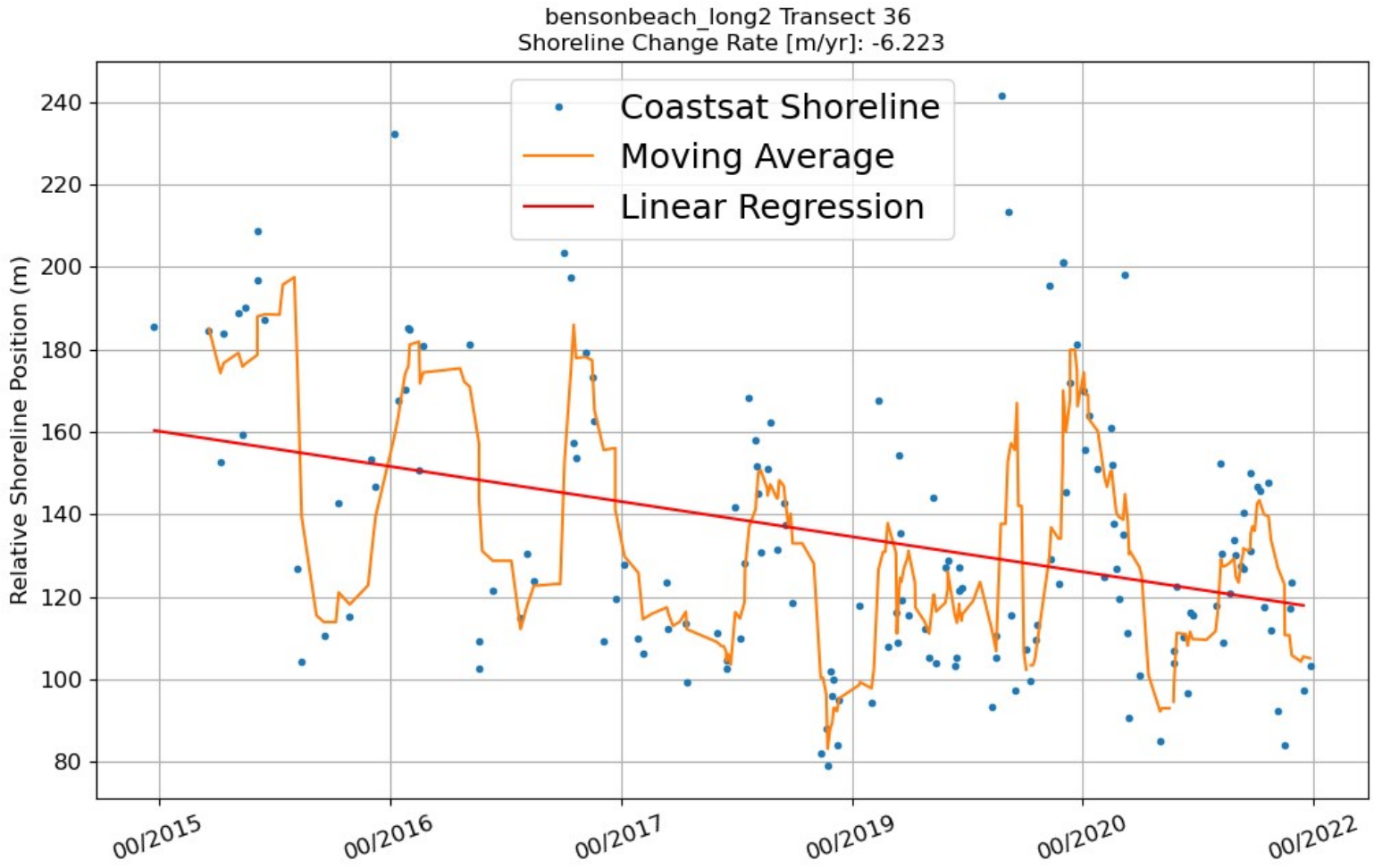
## Linear Regression Rate Point Shapefile



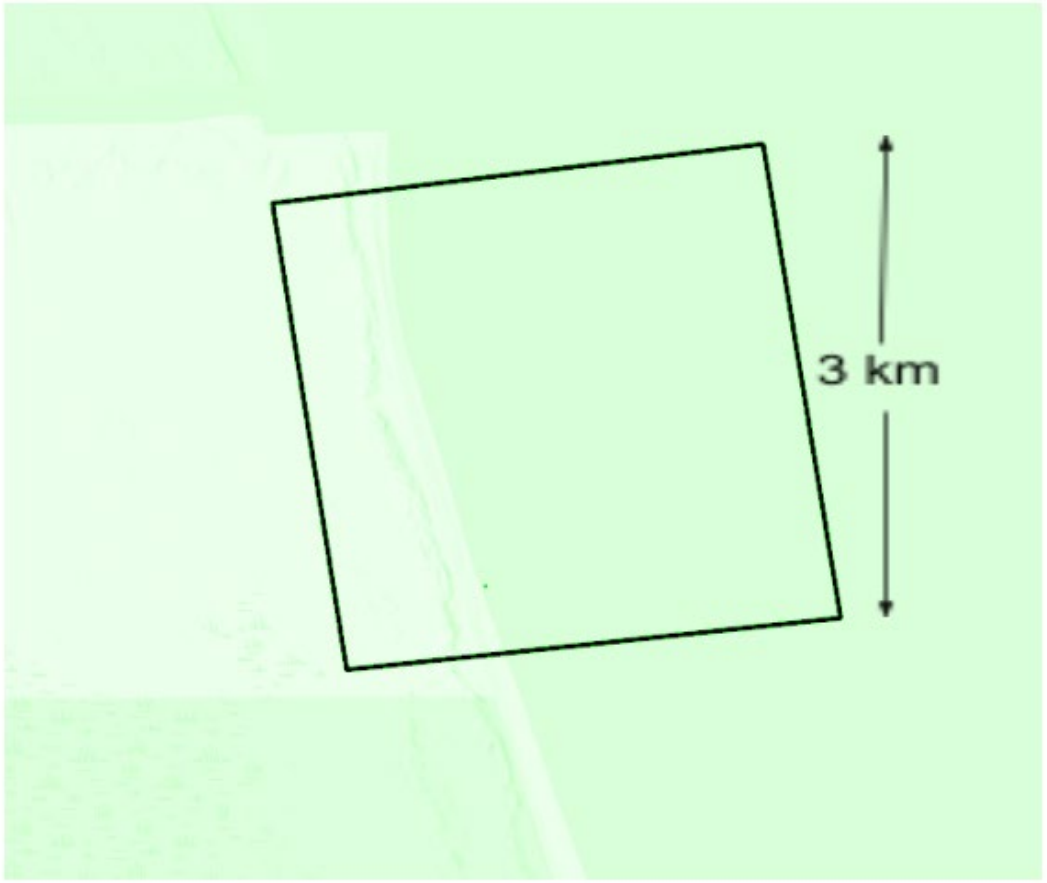

## Individual Transect Trend Plots



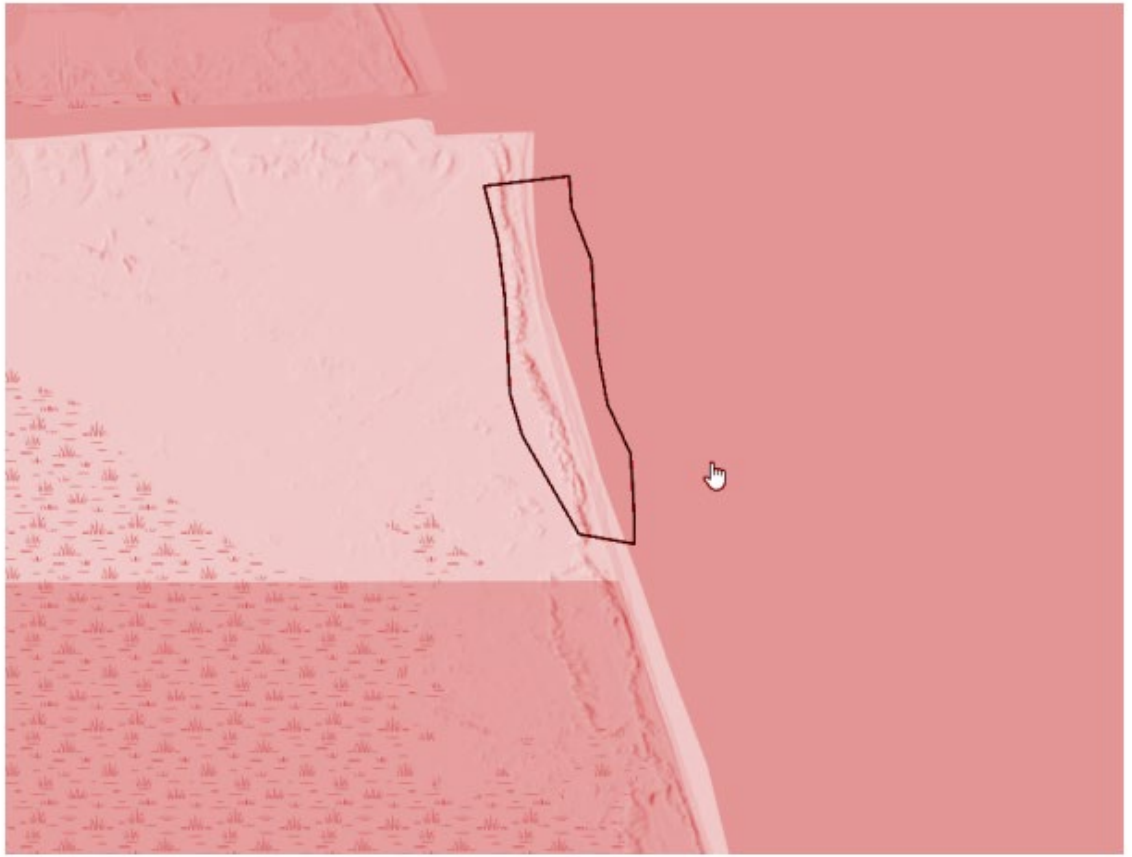
Satellite Derived Shorelines Linear Regression Rate
2015-2021

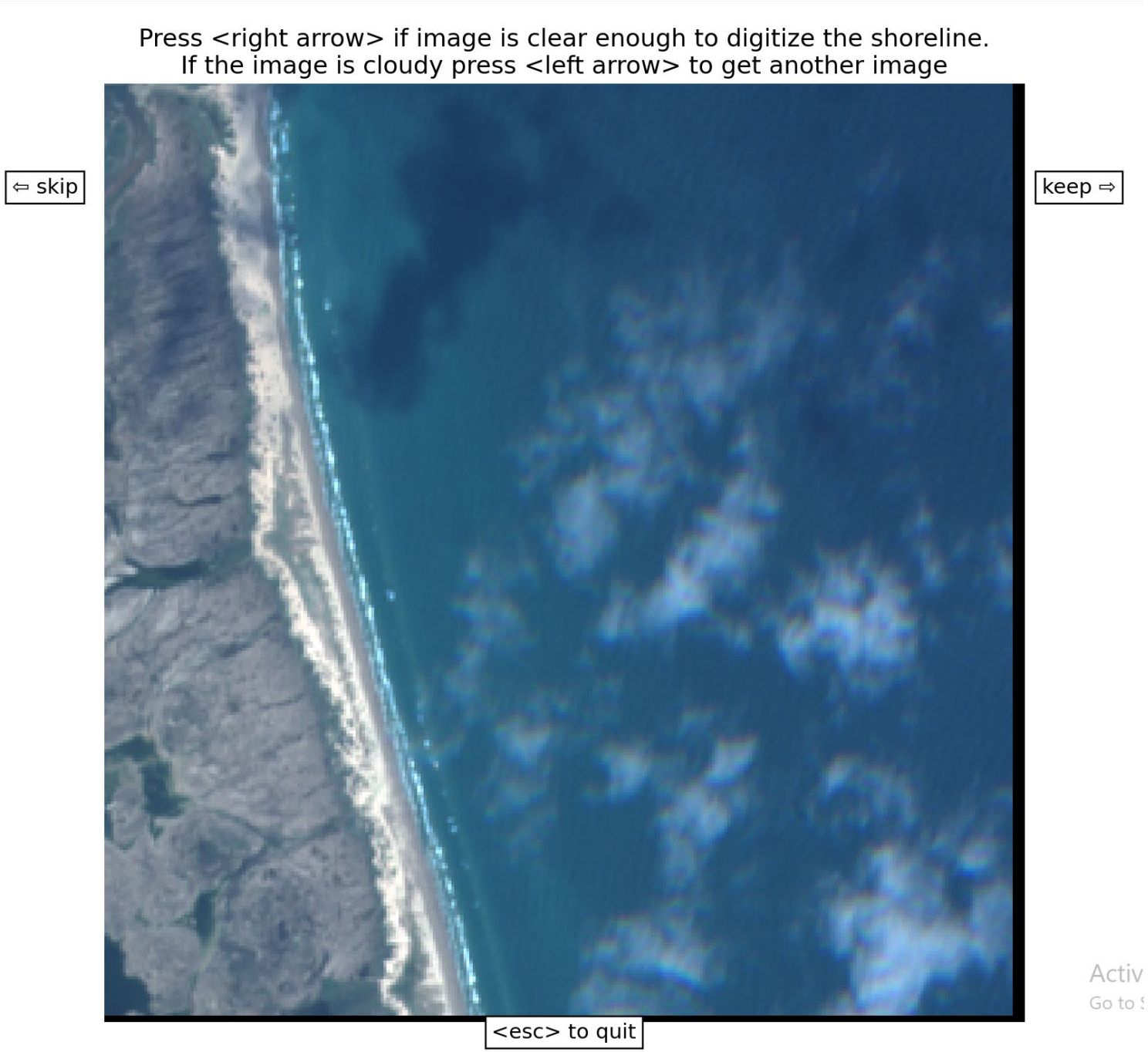
# Creating AOI Shapefile




Bad shapefile example:

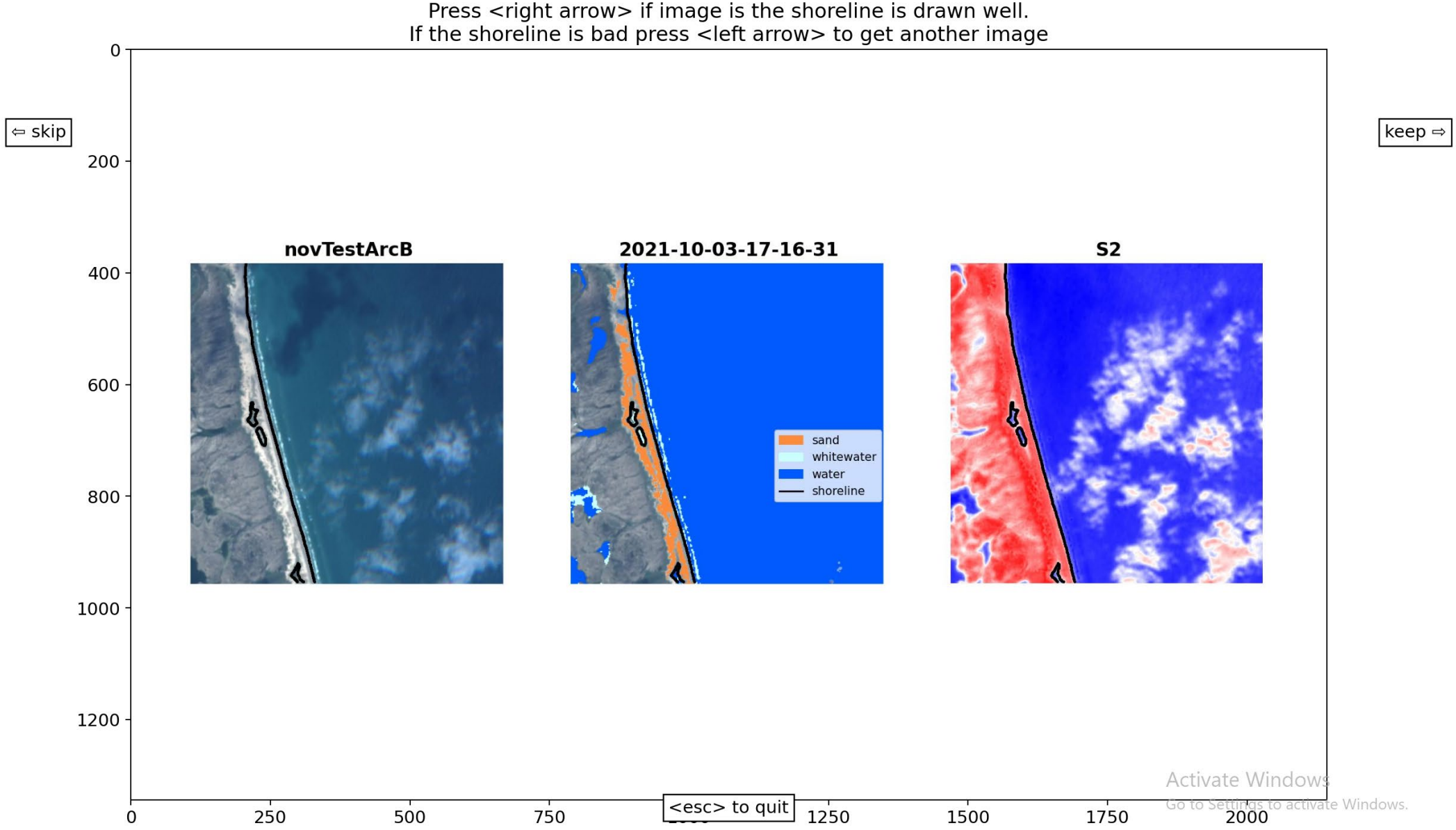


# Creating Reference Shorelines

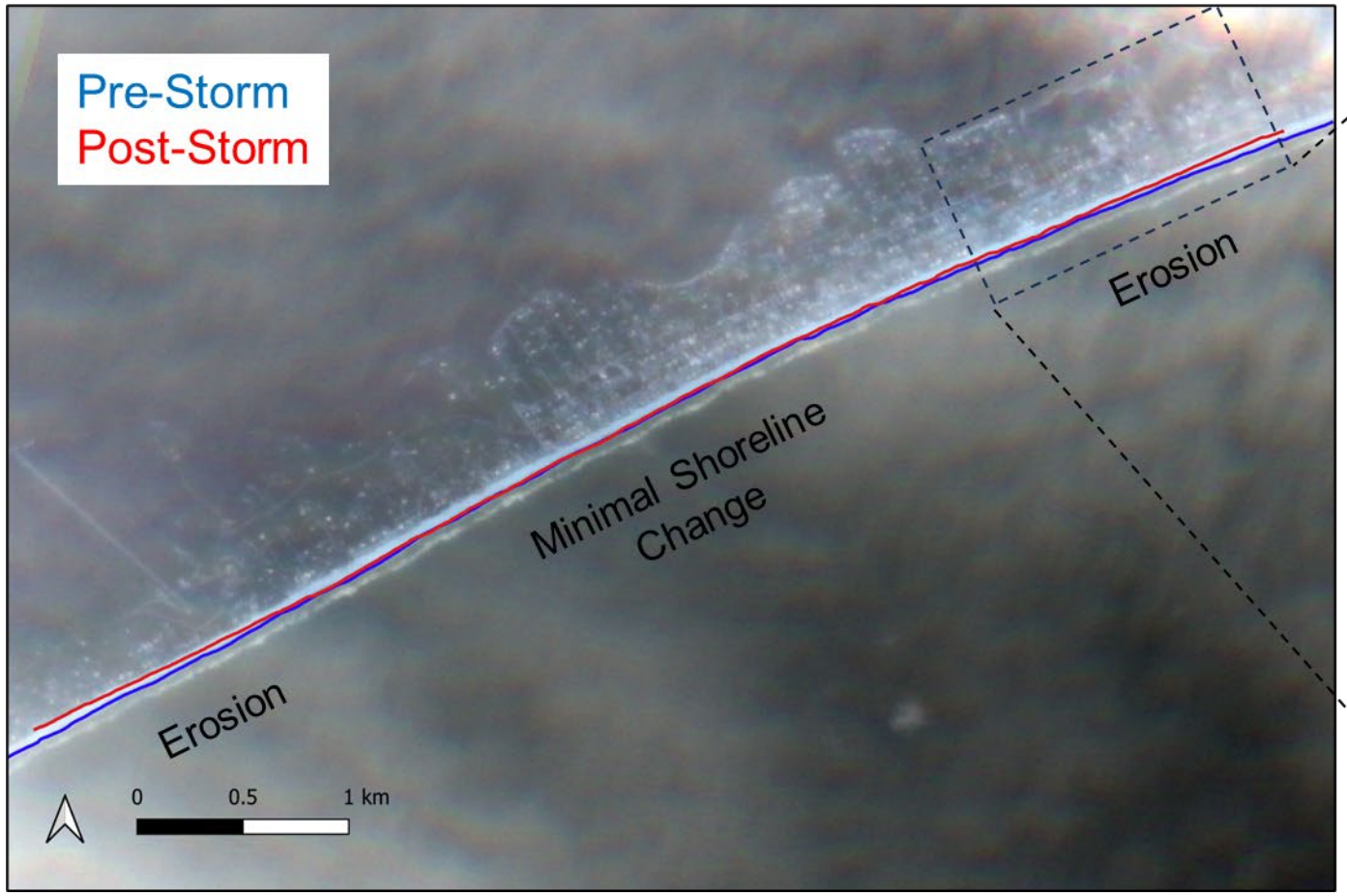


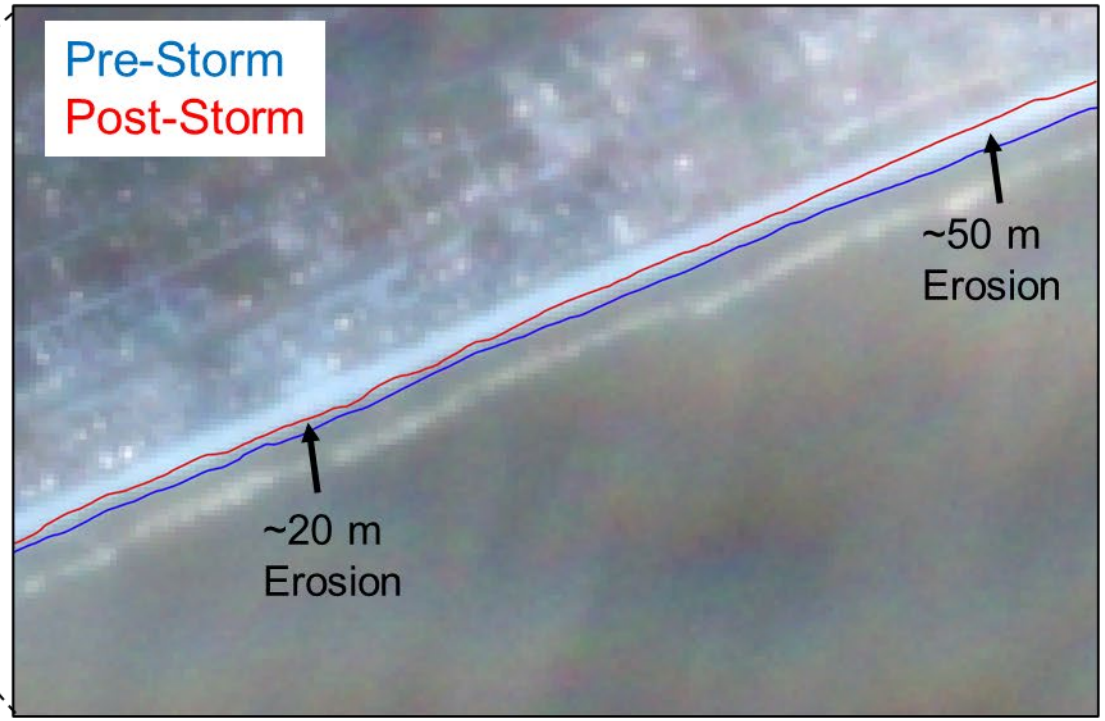
# Creating Reference Shorelines

# Image Sorting



# *Applications of ERDC Satellite Shoreline Mapper* : Rapid Storm Impact Assessment
## Hurricane Idalia, Aug. 30, 2023: St. George, FL




**BLUF**: Automated algorithms detected shoreline in pre (3 days) & post-storm (4 days) imagery, indicating up to 50-m of erosion and dune collision along eastern end of study site, minimal change in the center, and 20-m of beach erosion (half the pre-storm beach) to the west.

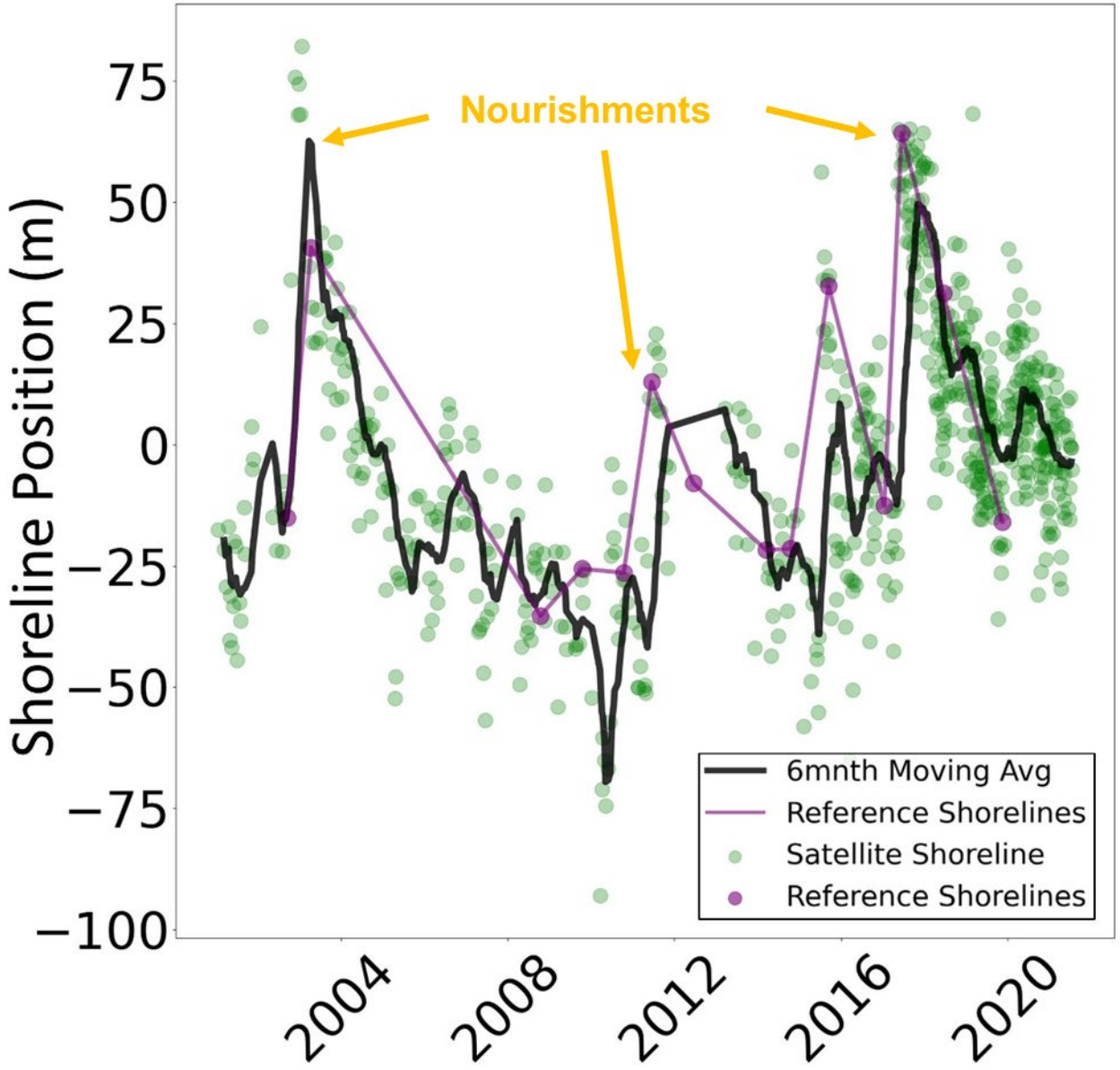
# *Applications of ERDC Satellite Shoreline Mapper* : Decadal Trends and Nourishment Monitoring, Avalon, NJ

**Example takeaways:**

- After 2003 nourishment, equilibration occurred resulting in shoreline recession at a rate of ~37.6 m/yr; likely attributable to active 2004 hurricane season which included impacts from four storms: Bonnie (August), Charlie (August), Gaston (August) and Ivan (September).

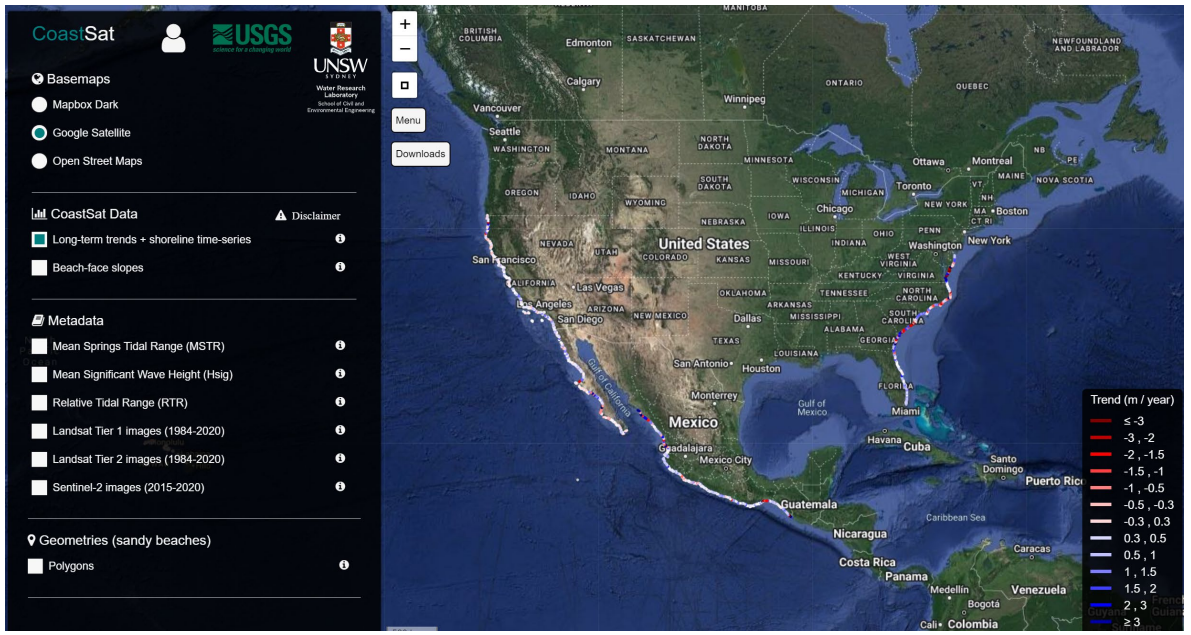
- Prior to the next major nourishment in 2011, the erosion from Hurricane Barry in May 2007 is clear (8 m shoreline retreat).

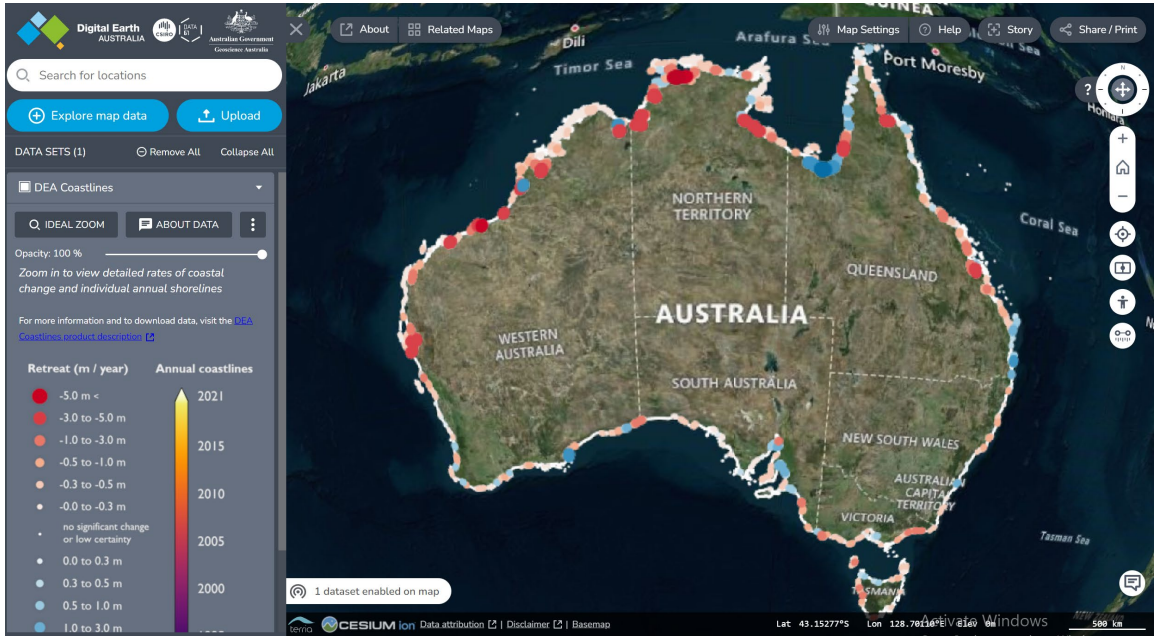
- The last notable nourishment of 1,636,685 CY was conducted in 2017. Over the next 2.25 years, the beach equilibrated to pre-project width, at a recession rate of 23.2 m/yr.



# FUTURE ENVISIONED PRODUCT

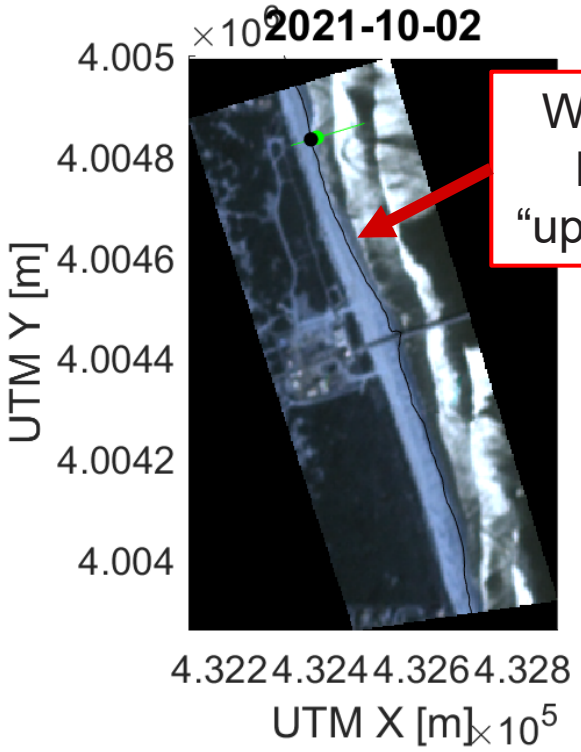
- **Vision:** Build a continuously updated national repository of satellite-derived shoreline position along our Nation's coastlines accessible via web portal
  - Allows historical shoreline available for all US Coastlines with each satellite pass (5 to 16-day interval)
  - In parallel a rapid response data pipeline can be setup for acute events where commercial satellites are tasked as priority and resources are directed.
    - Produces:
      - Shoreline change, beach width (e.g., shorelines cross-referenced with Dune position from JALBTCX)
      - Flooding extent
      - Flooding depth estimates (extent cross-referenced with latest topo DEM)



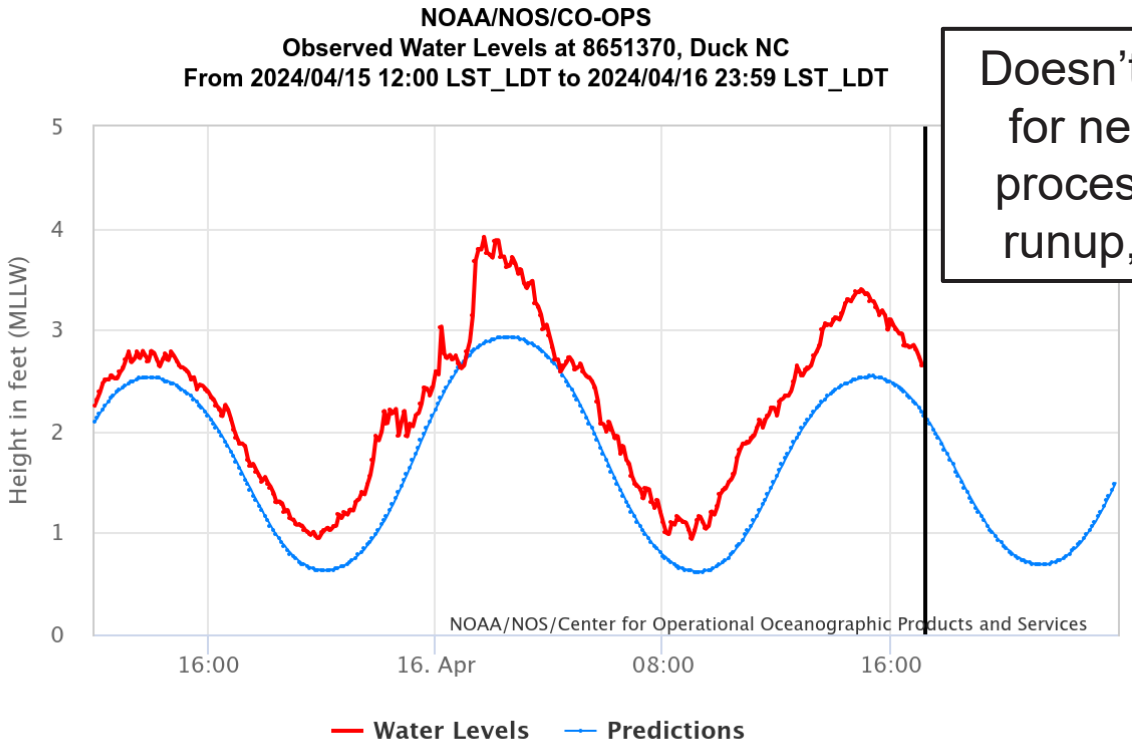



# Water Level Correction


Elevation Based Shoreline



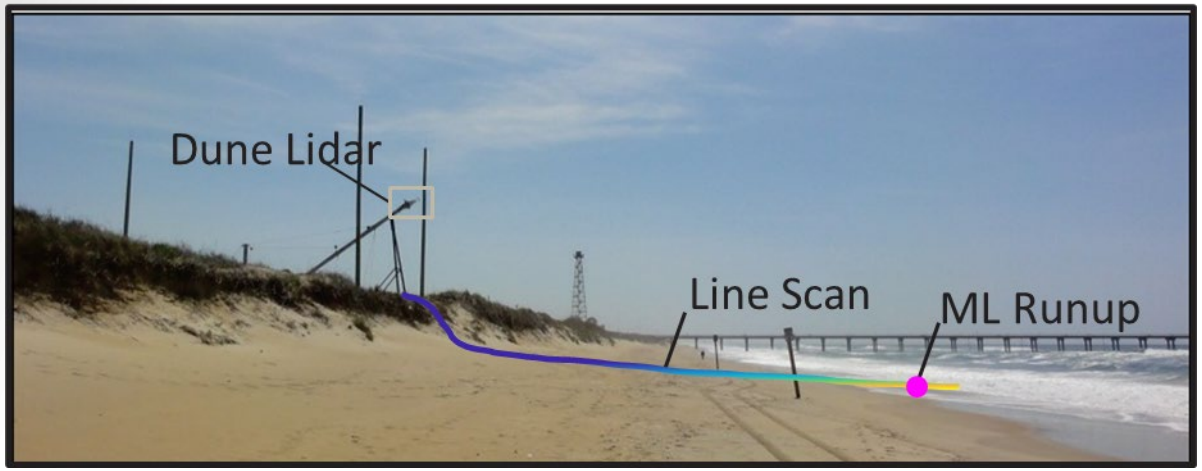

Water/Sand Interface "upper swash"



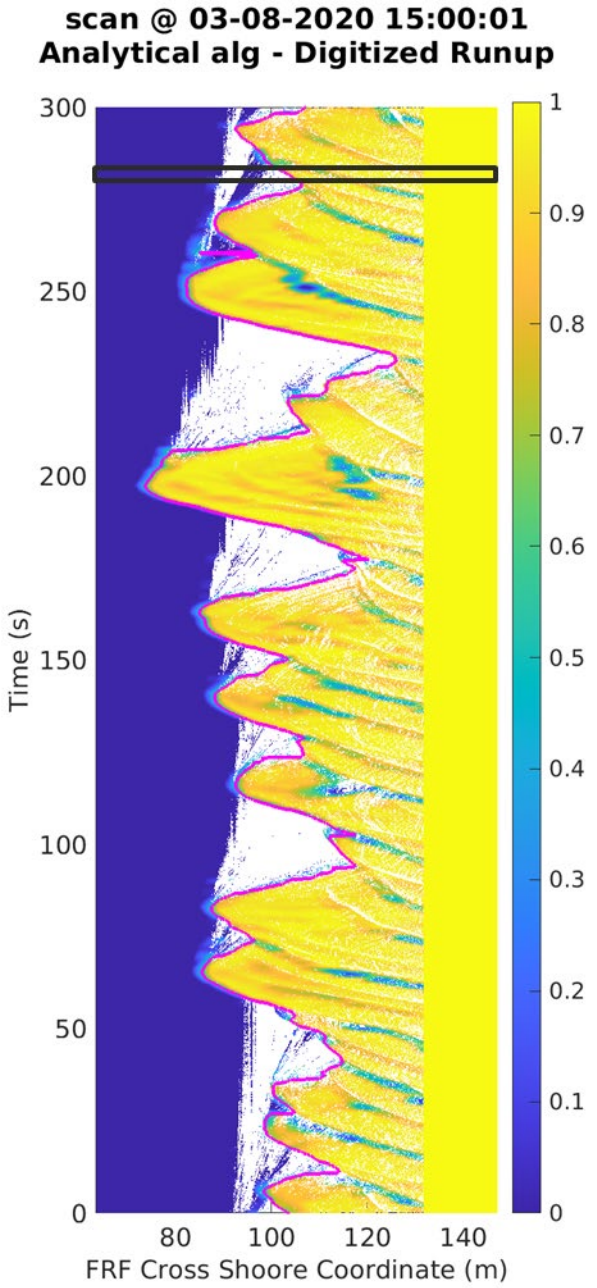

Doesn't account for nearshore processes (i.e. runup, setup).

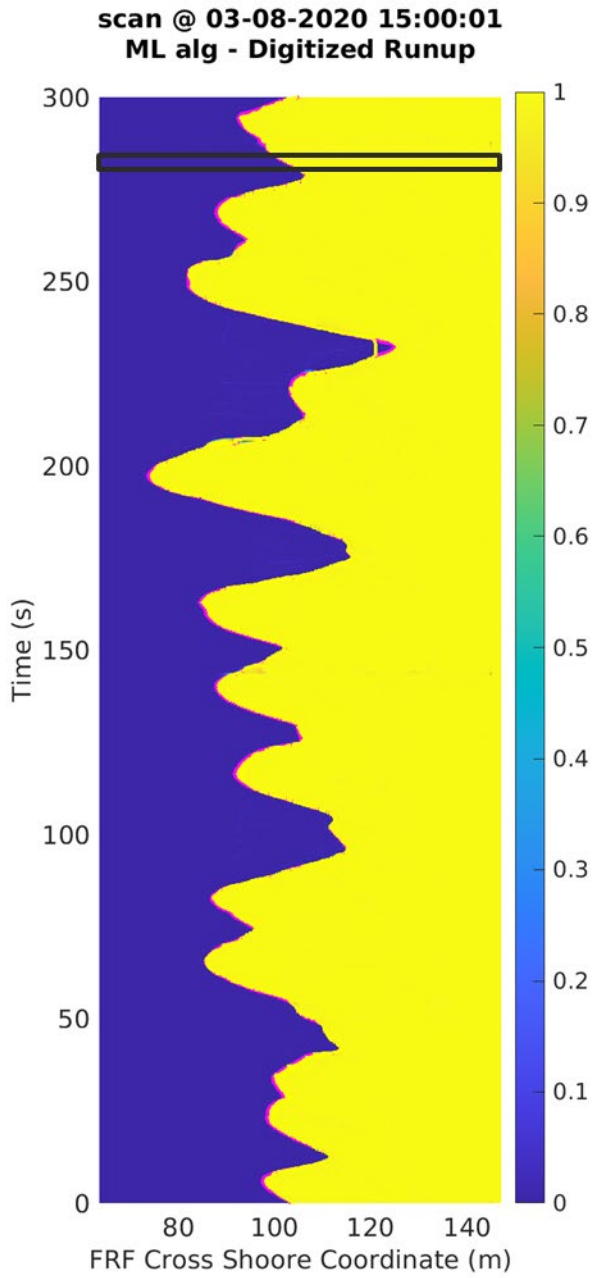
# Dune Lidar

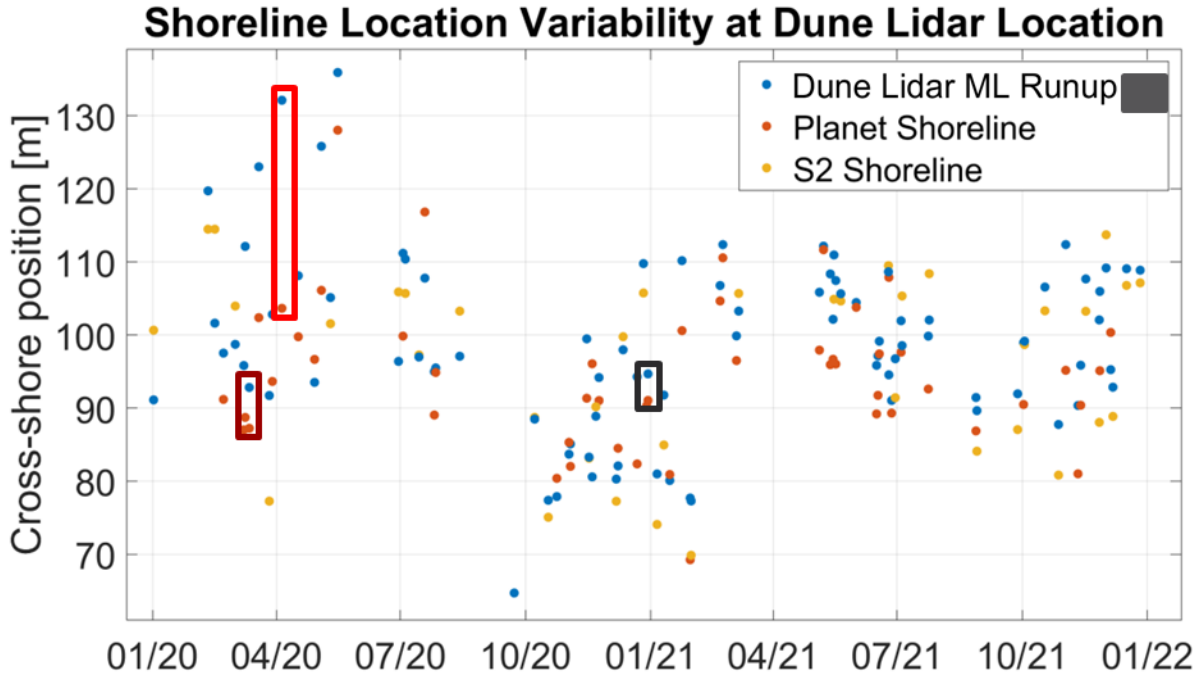
Reigl VZ-1000 |Collecting 7 Hrtz

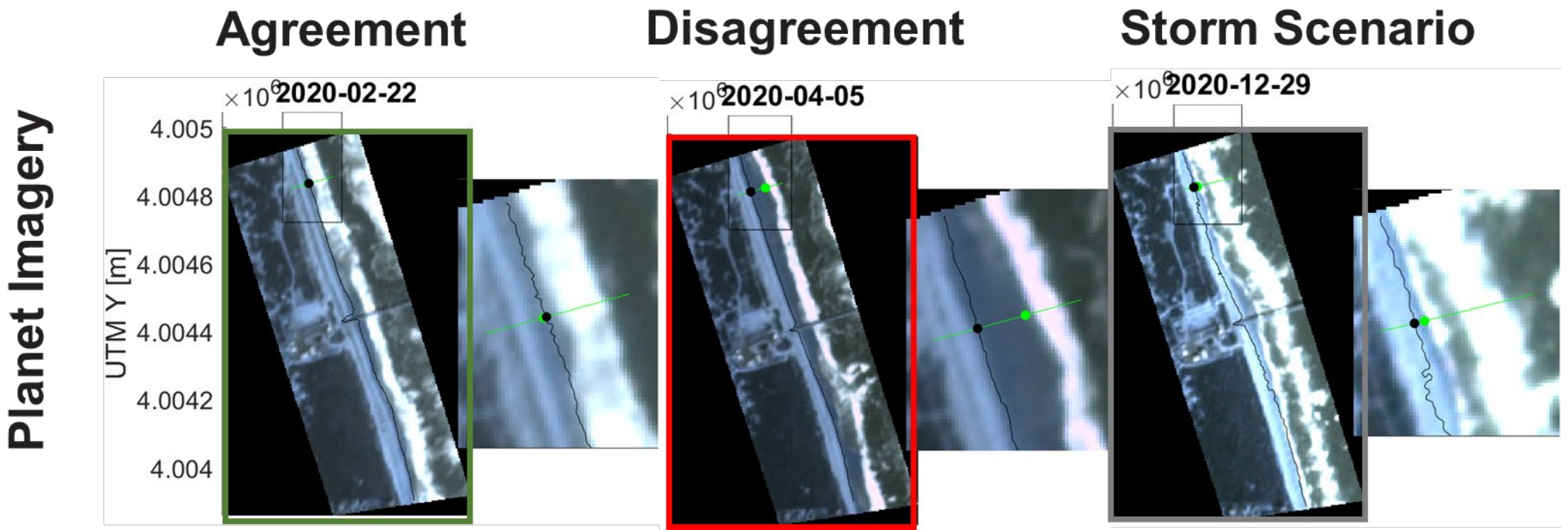


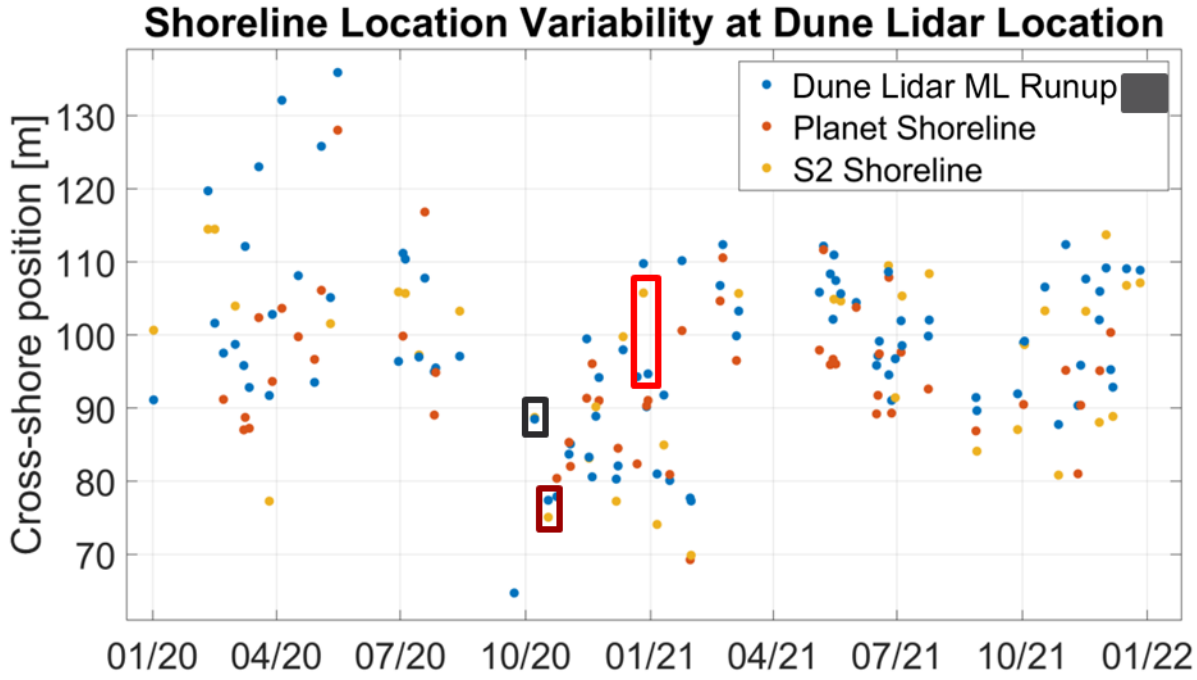

Can now compare coincident water level elevations and CoastSat shoreline location to better define “upper swash”.



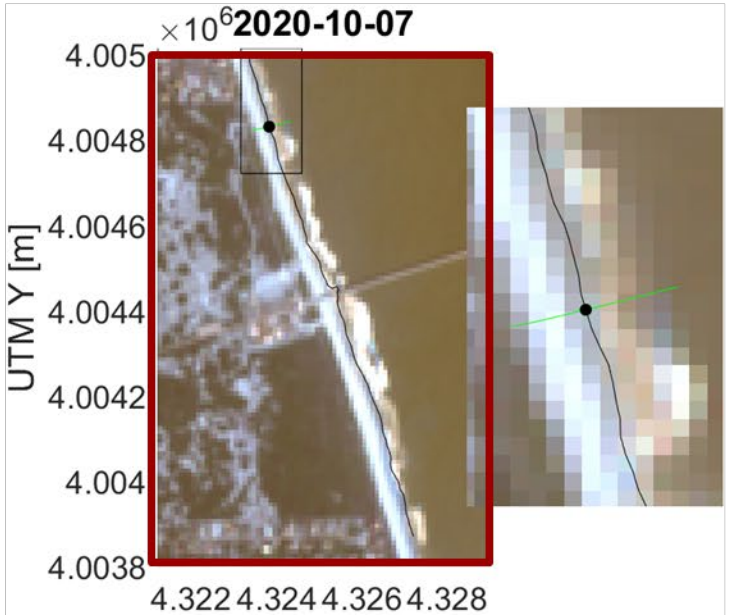

Shoreline Location Variability at Dune Lidar Location
Dune Lidar ML Runup
Planet Shoreline
S2 Shoreline
Cross-shore position [m]
130
120
110
100
90
80
70
01/20
04/20
07/20
10/20
01/21
04/21
07/21
10/21
01/22


Agreement
Disagreement
Storm Scenario
Planet Imagery
2020-02-22
2020-04-05
2020-12-29
×10^6
UTM Y [m]
4.005
4.0048
4.0046
4.0044
4.0042
4.004

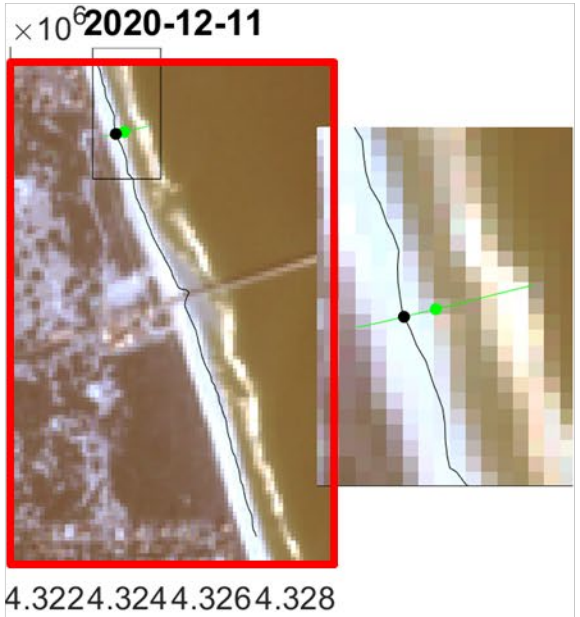



Sentinel-2 Imagery

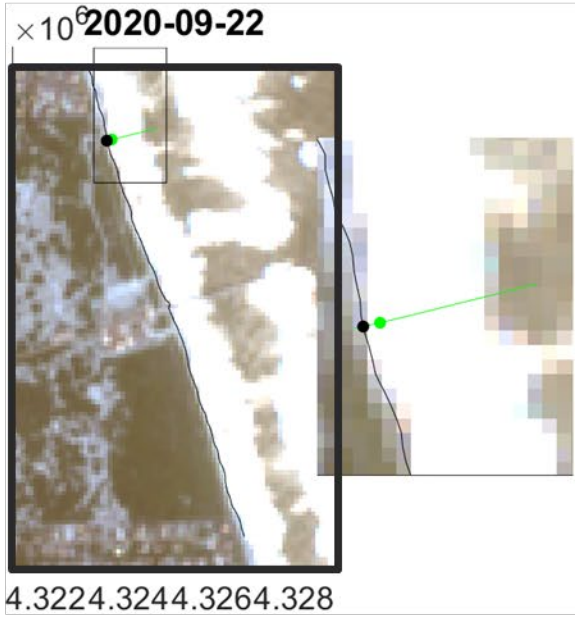
## Agreement



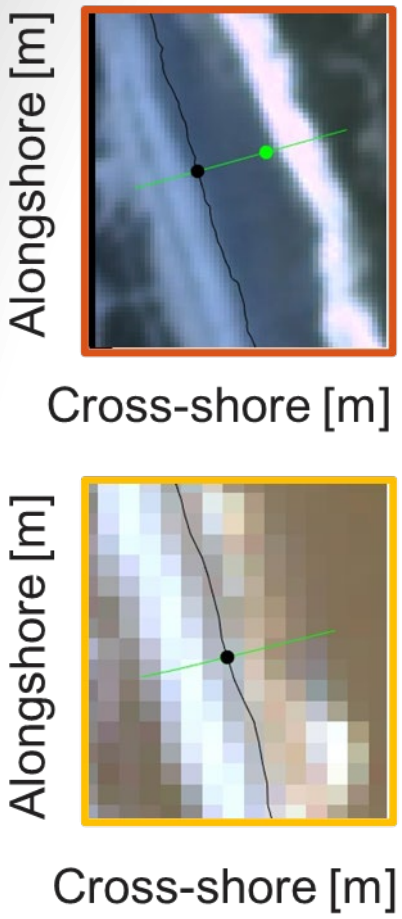

## Disagreement

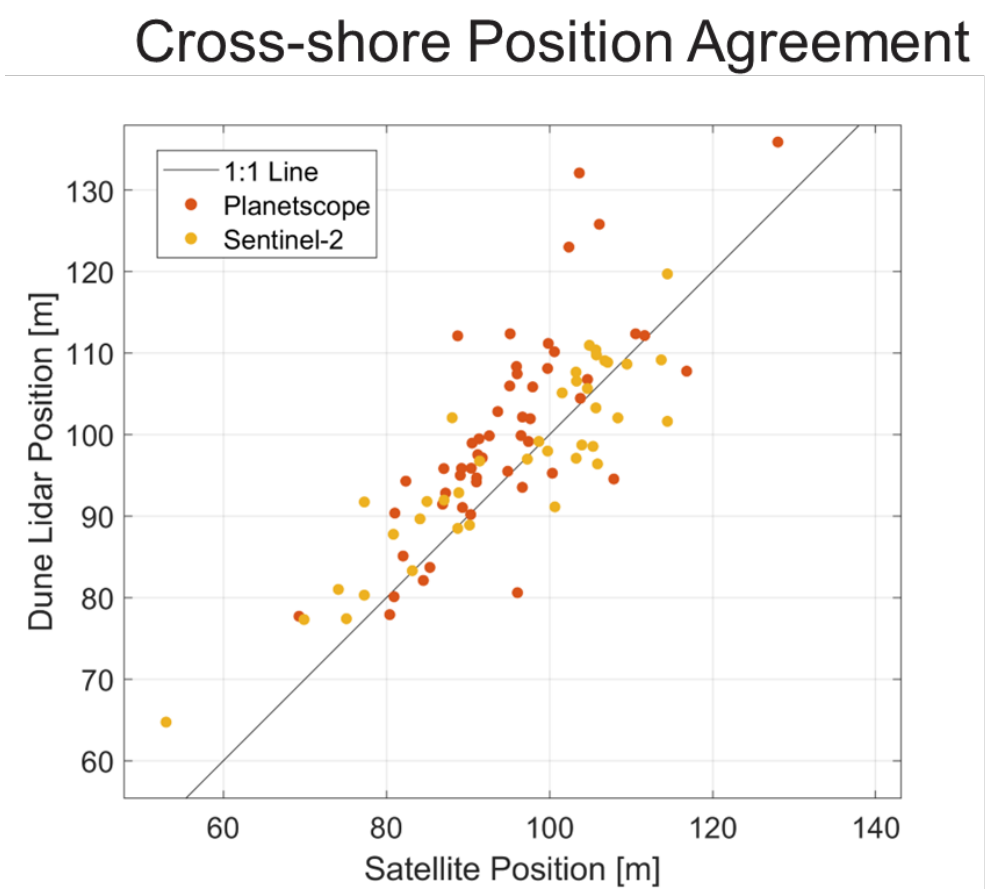


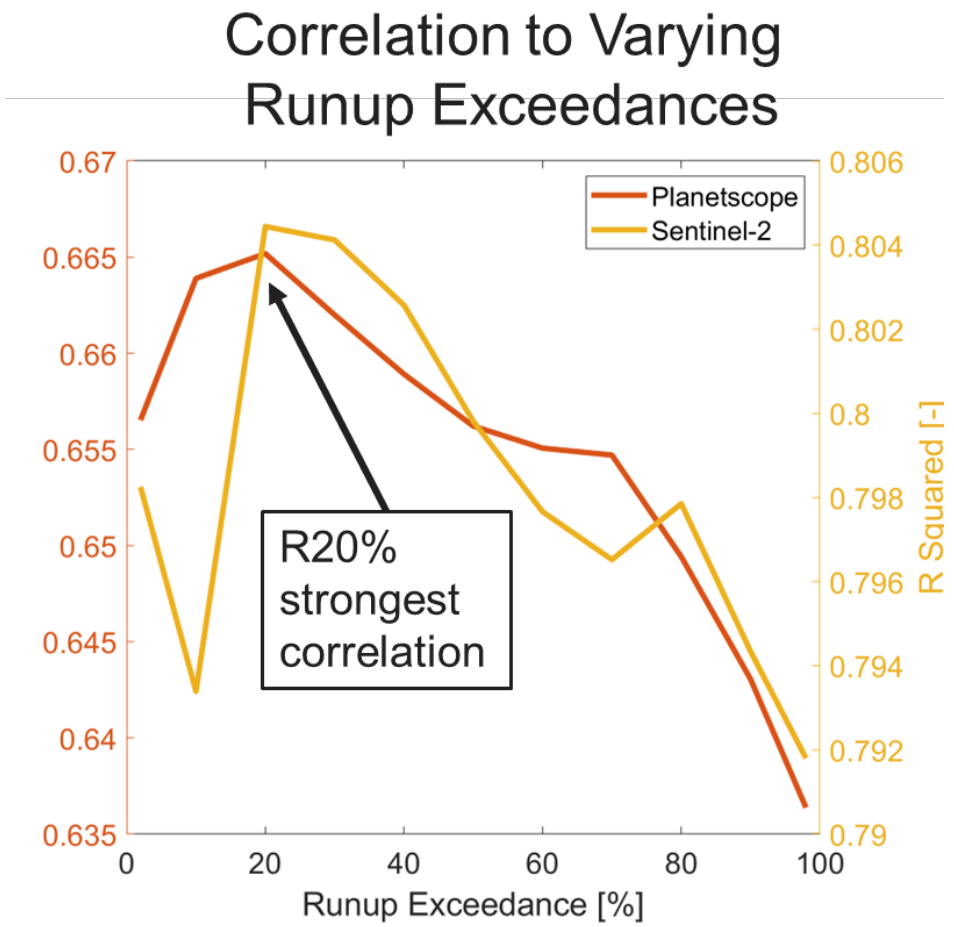

## Storm Scenario



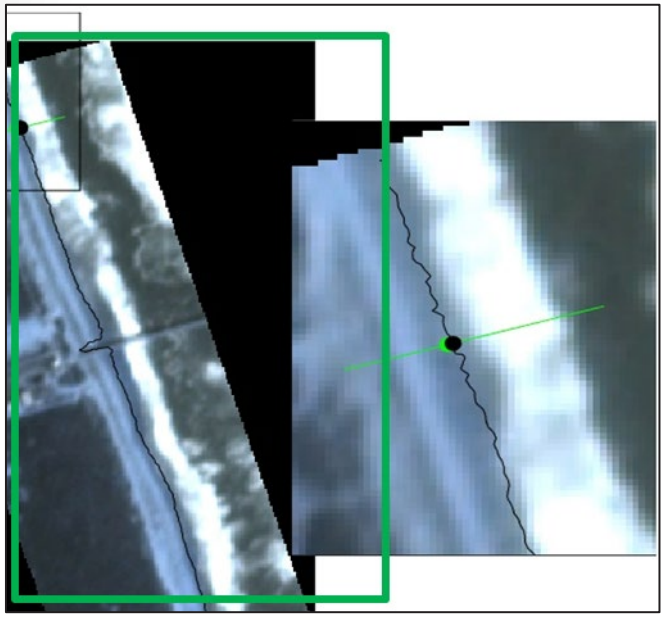
# COMPARING PLANETSCOPE AND SENTINEL-2

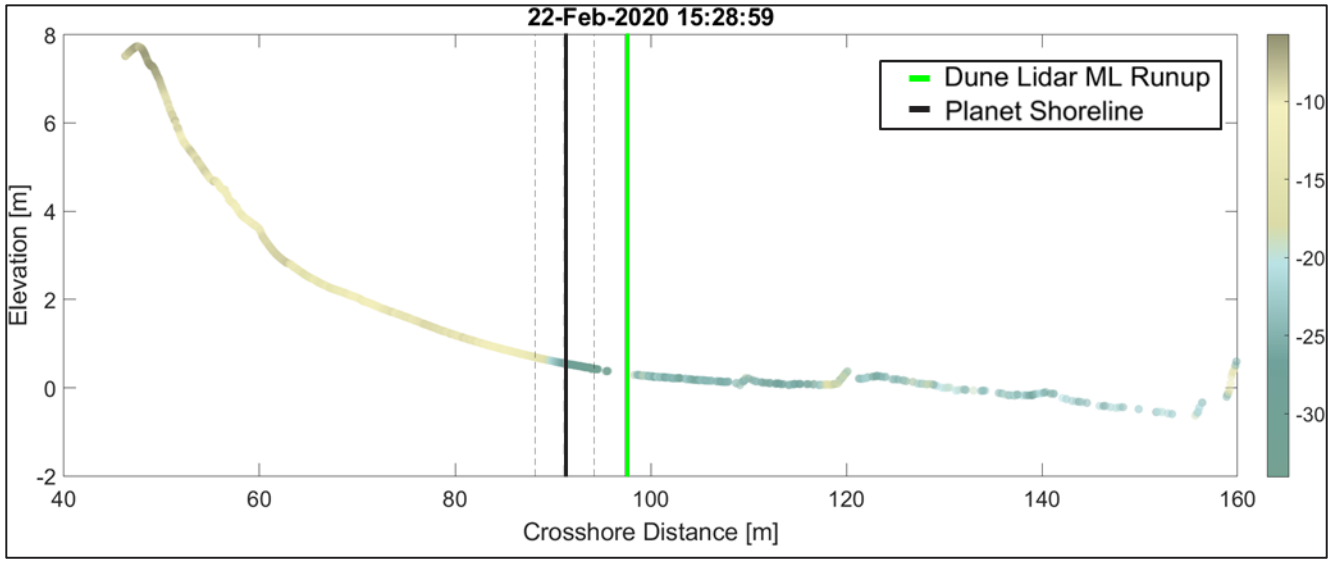


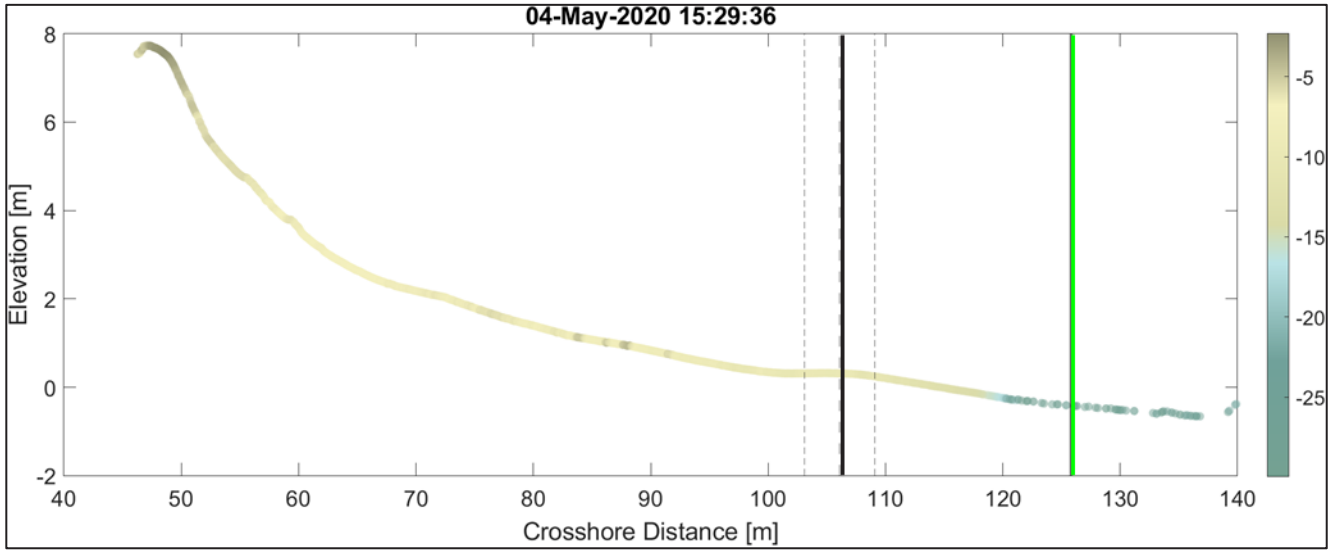



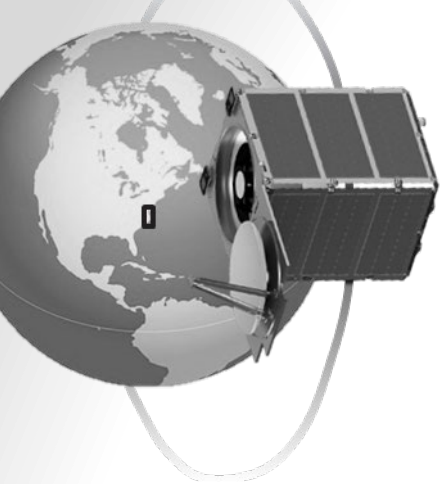
# Reflectance

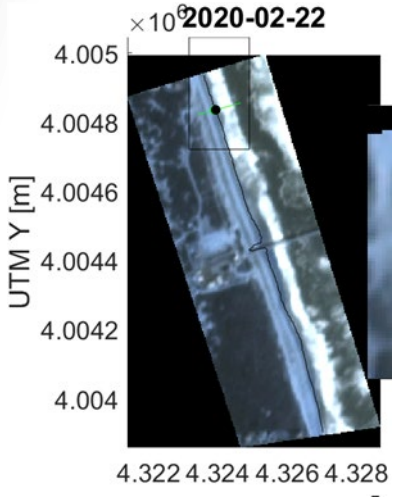


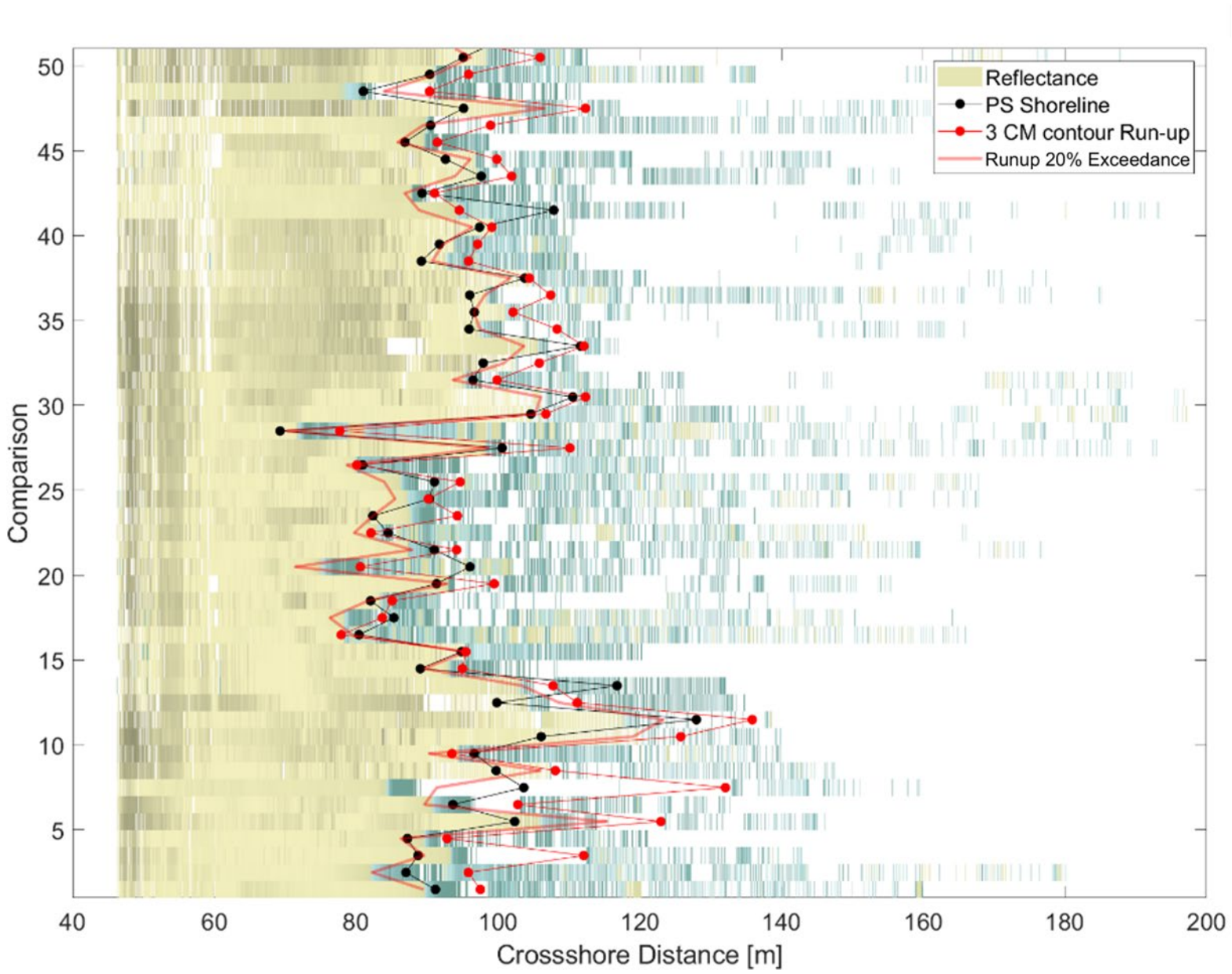


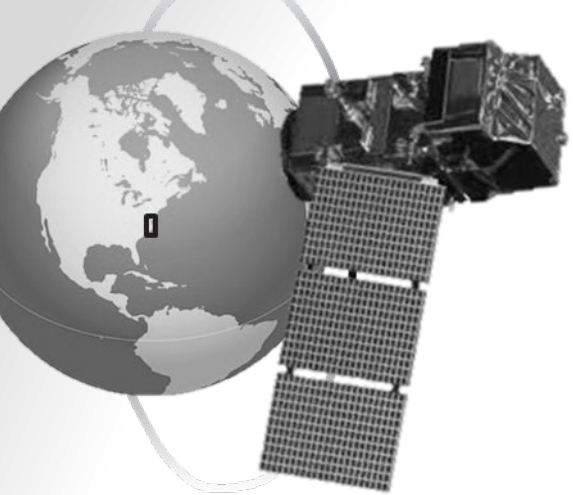
# Planetscope

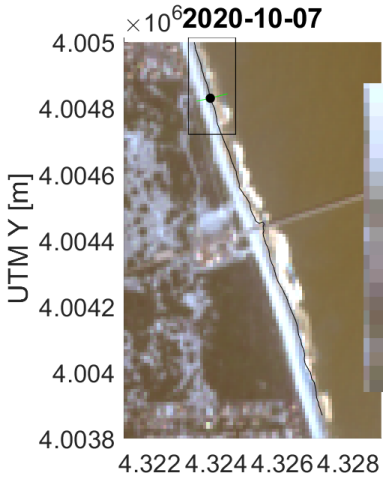


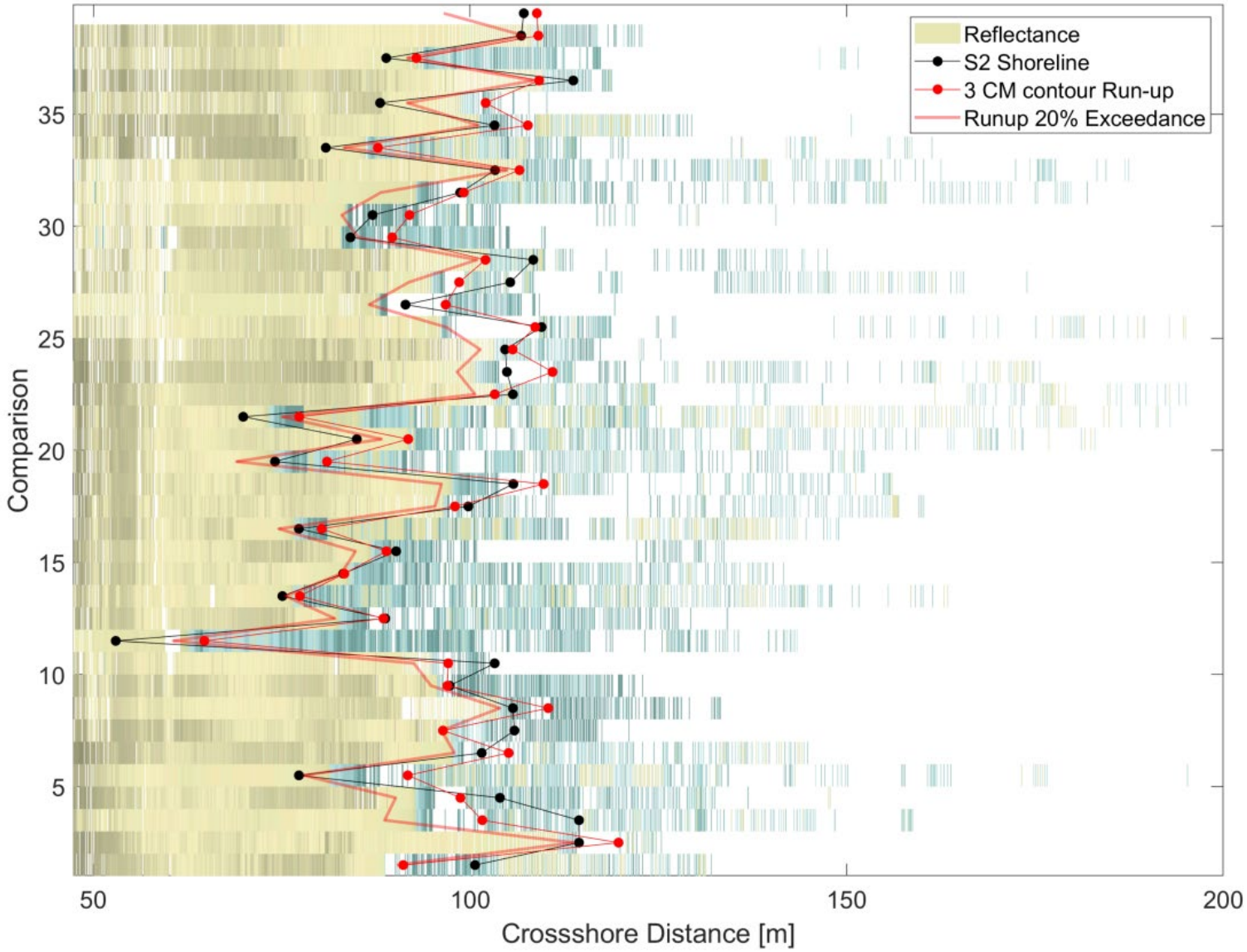


# Sentinel-2




×10^6 2020-10-07
4.005
4.0048
4.0046
4.0044
4.0042
4.004
4.0038
UTM Y [m]
4.322
4.324
4.326
4.328


Reflectance
S2 Shoreline
3 CM contour Run-up
Runup 20% Exceedance
Comparison
35
30
25
20
15
10
5
50
100
150
200
Crossshore Distance [m]

# SUMMARY

## FY23 Major Advancements in Capability

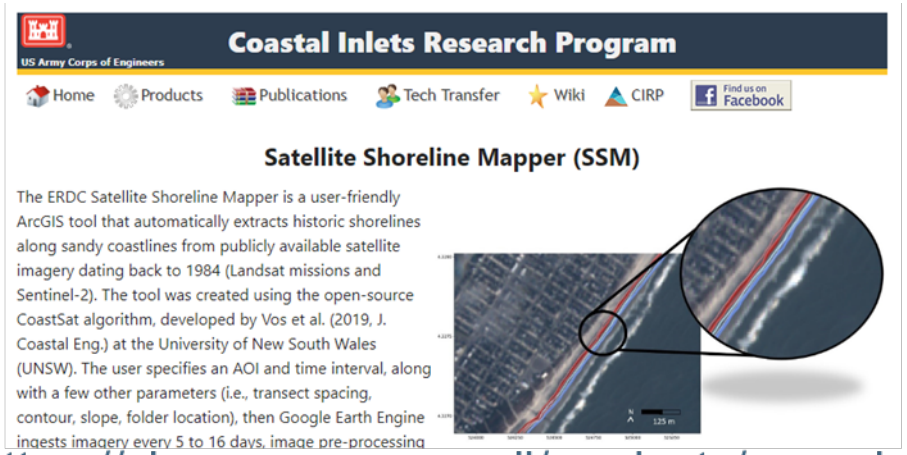
- Improvements to SSM workflow
  - Transect generation
  - Shapefile tidal shift
  - Sentinel-2 cloud mask
  - Small AOI fix
- Expanded SSM automated output analysis plots/tables

## FY23 Major Products & Collaborations

- SSM user manual and SSM tool release
- Internal ERDC SSM tool testing and feedback implementation
- Coastal Working Group (CWG) SSM workshop and tech transfer to district users
- CIRP TD
- Coastal Prospect Course Presentation

## FY24 Products & Advancements

- Streamline SSM install process
- Submit runup journal article




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