Prediction of Dune Erosion and Inlet Formation during Hurricanes Helene and Milton

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ADCIRC Users Group Meeting 20225
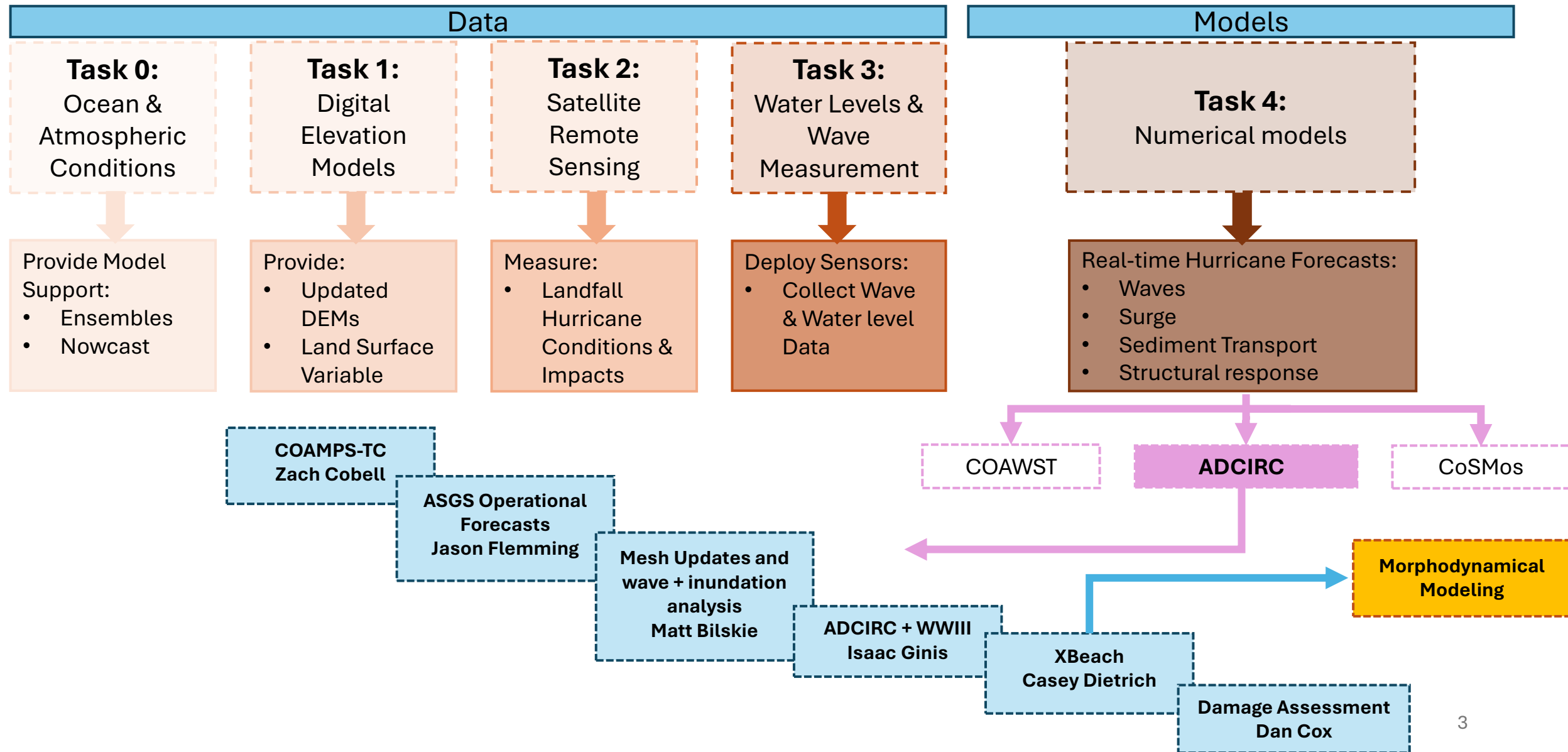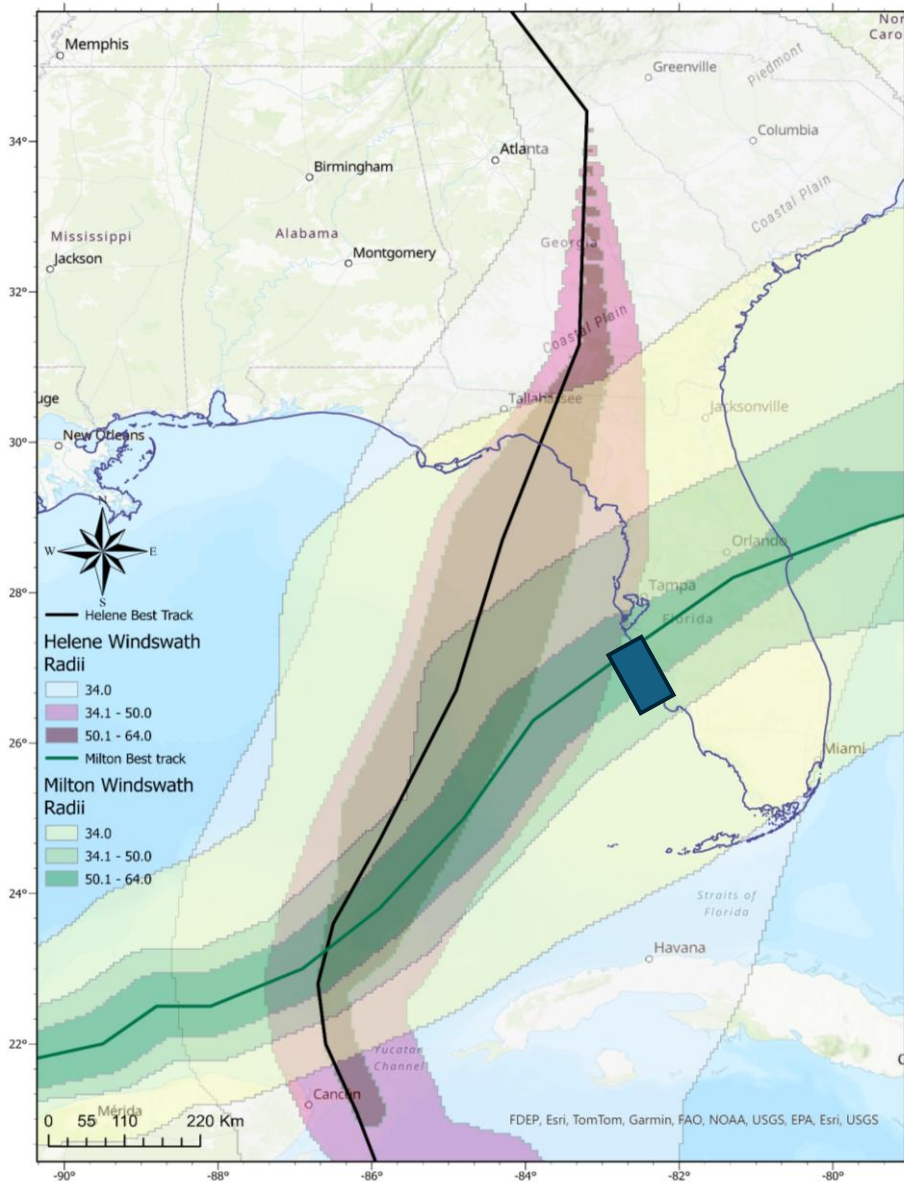
05/13/2025

Background

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NOPP Project

Research to enable predictive capabilities to improve predictions that serve and protect coastal communities

# Consecutive Storms, Hurricanes Helene and Milton

Hurricane Helene:
- Intensity: a category 4 cyclone with 140 mph (220 km/h)
- When: Made landfall on the 26th of September 2024 at around 11 pm
- Where: 10 miles west-southwest of Perry, Florida, in the Big Bend region
- Storm surge of 6-15 ft (1.8-4.5 m)
- It caused 221 deaths and property damage of $78 billion

Hurricane Milton:
- Intensity: a category 3 cyclone with 120 mph (193 km/h)
- When: Made landfall on 9th October at 8:30 PM EDT
- Where: near Siesta Key
- It caused 25 deaths and property damage of $34.3 billion

Midnight and Milton Pass were Formed After Each Storm

Midnight Pass

Hurricane Helene
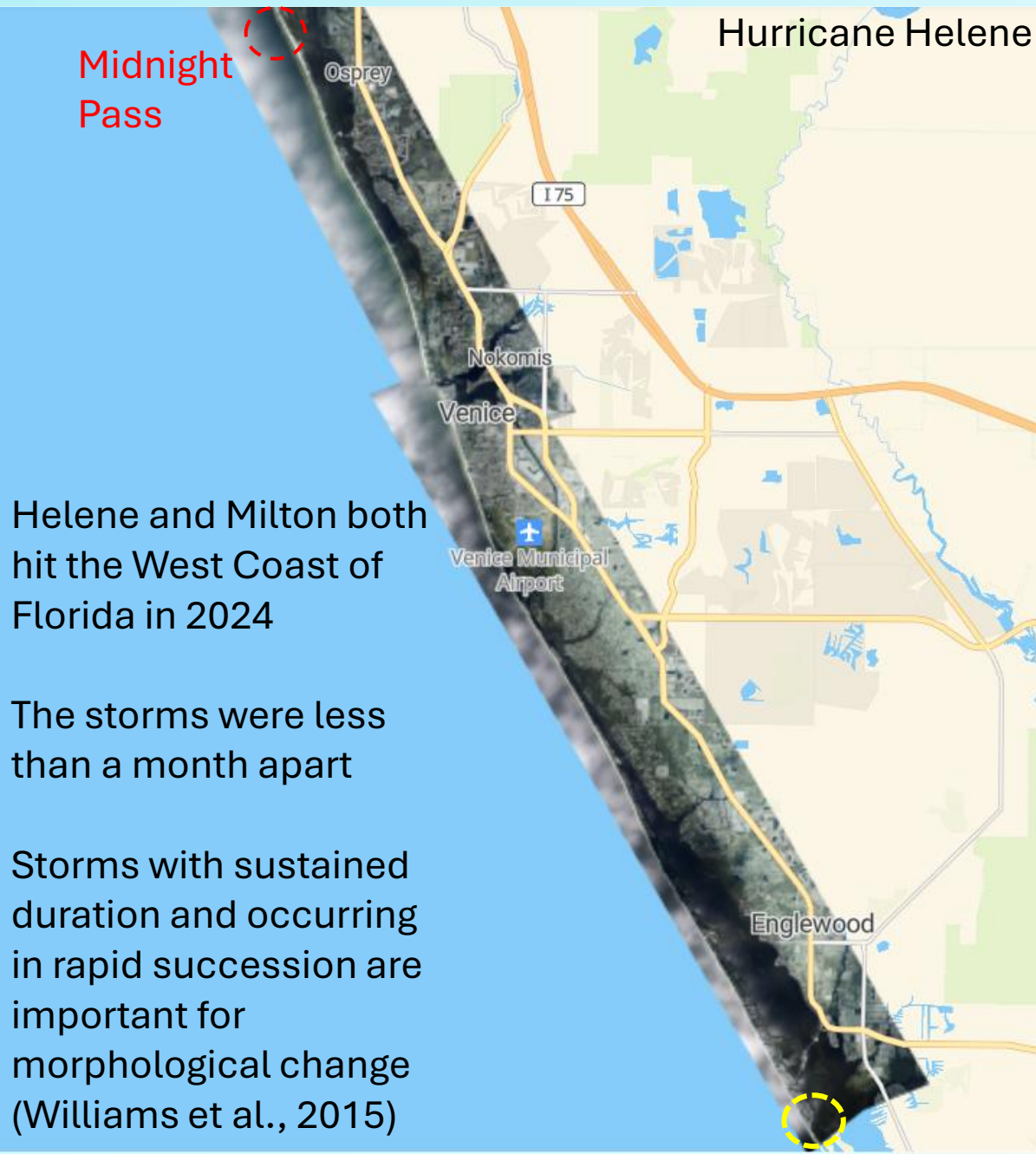
Helene and Milton both hit the West Coast of Florida in 2024

The storms were less than a month apart

Storms with sustained duration and occurring in rapid succession are important for morphological change (Williams et al., 2015)
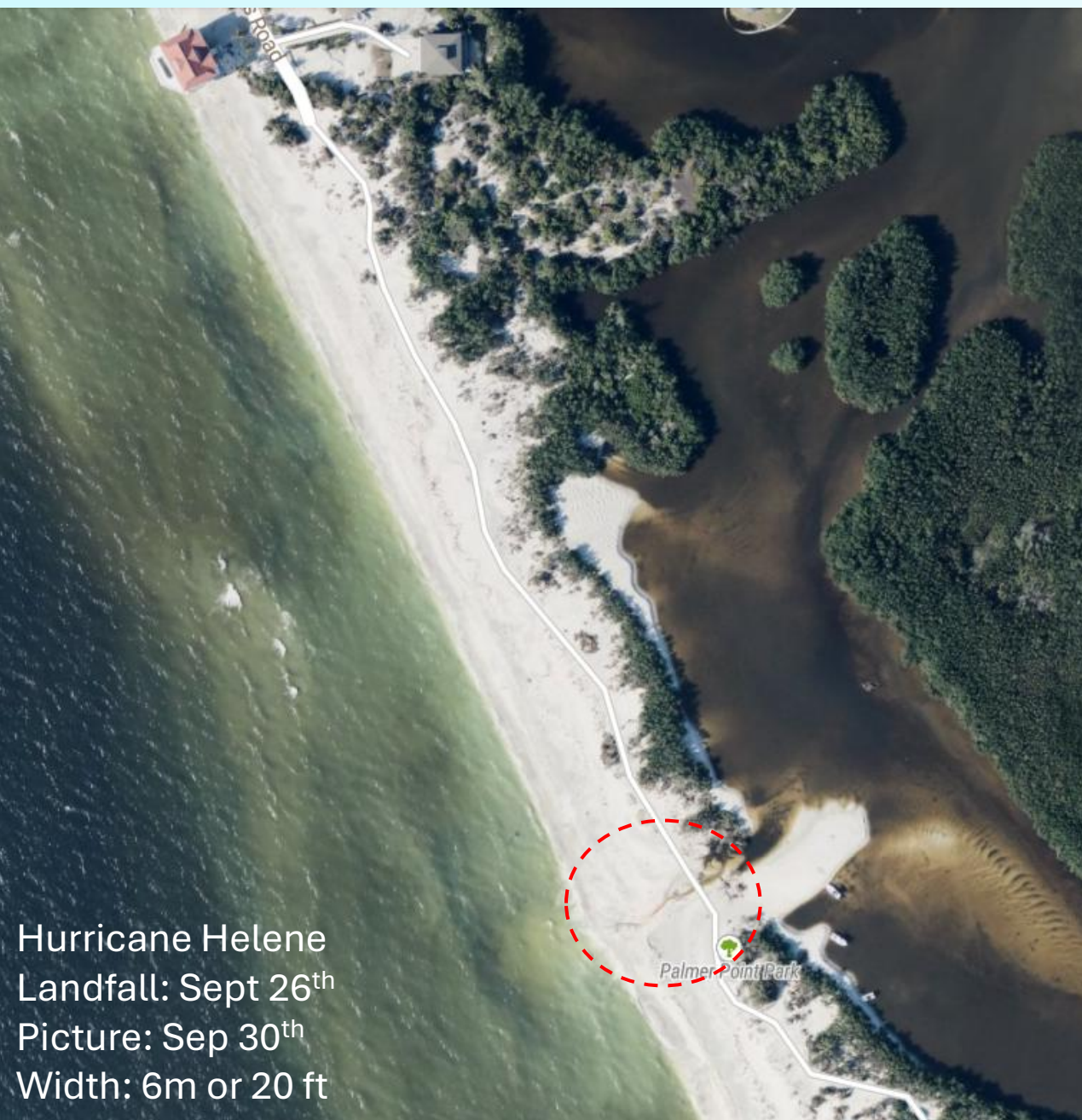
Hurricane Milton

Opened during Hurricane Helene and reopened after Hurricane Milton

Milton Pass opened during Hurricane Milton

Midnight Pass and Milton Pass are 37 km (23 miles) apart

Milton Pass

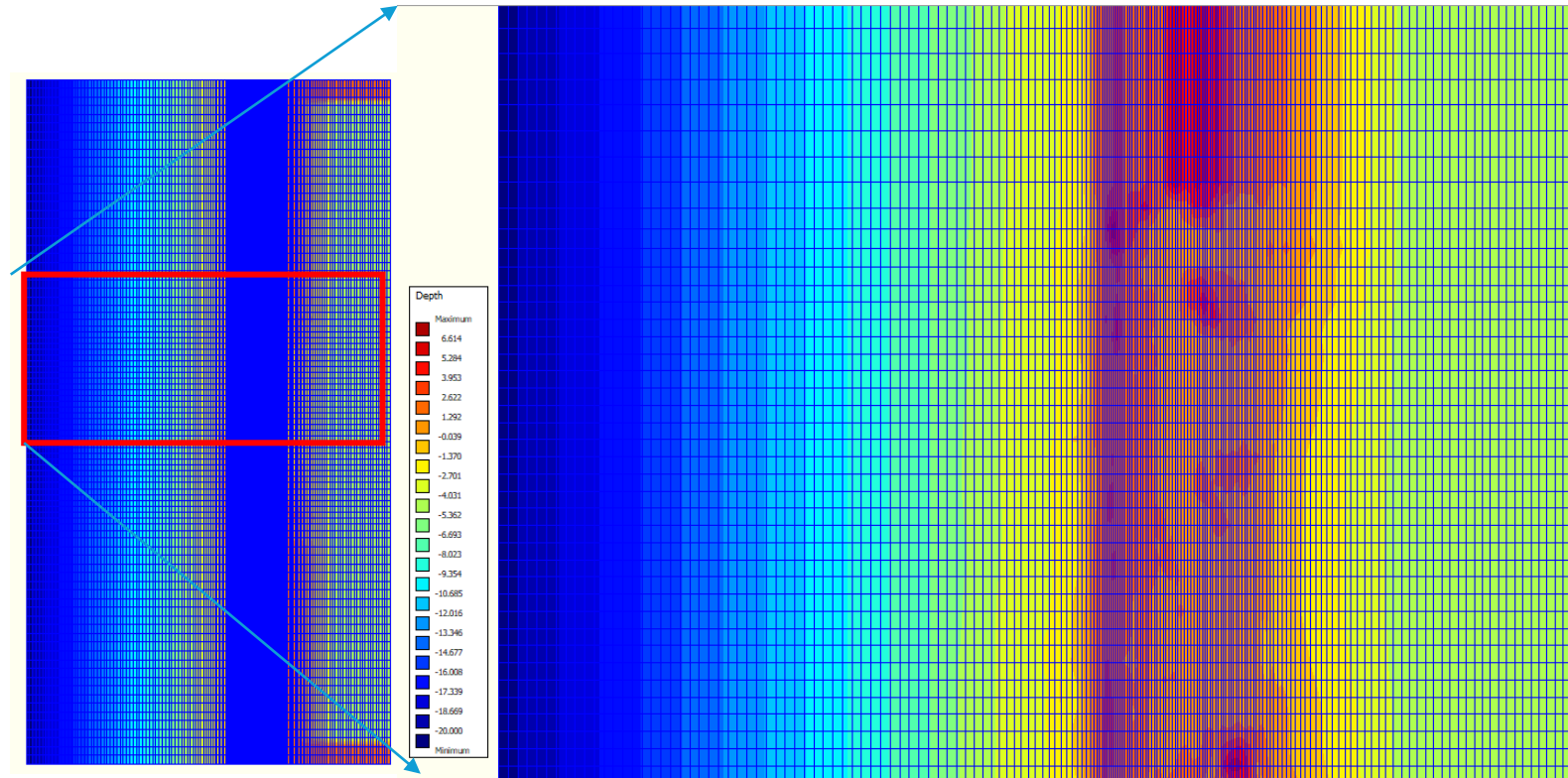# Midnight Pass Grew Bigger After Hurricane Milton

Hurricane Milton
Landfall: Oct 9th
Picture: Oct 11th
Width: 20 m or 65.5 ft

Hurricane Helene
Landfall: Sept 26th
Picture: Sep 30th
Width: 6m or 20 ft

Milton Pass was Opened After Hurricane Milton

Hurricane Helene
Landfall: Sept 26th
Picture: Sep 30th

Milton Pass opened
on the south-end of
Manasota Key

Hurricane Milton
Landfall: Oct 9th
Picture: Oct 11th
Width: 122 m or 400ft

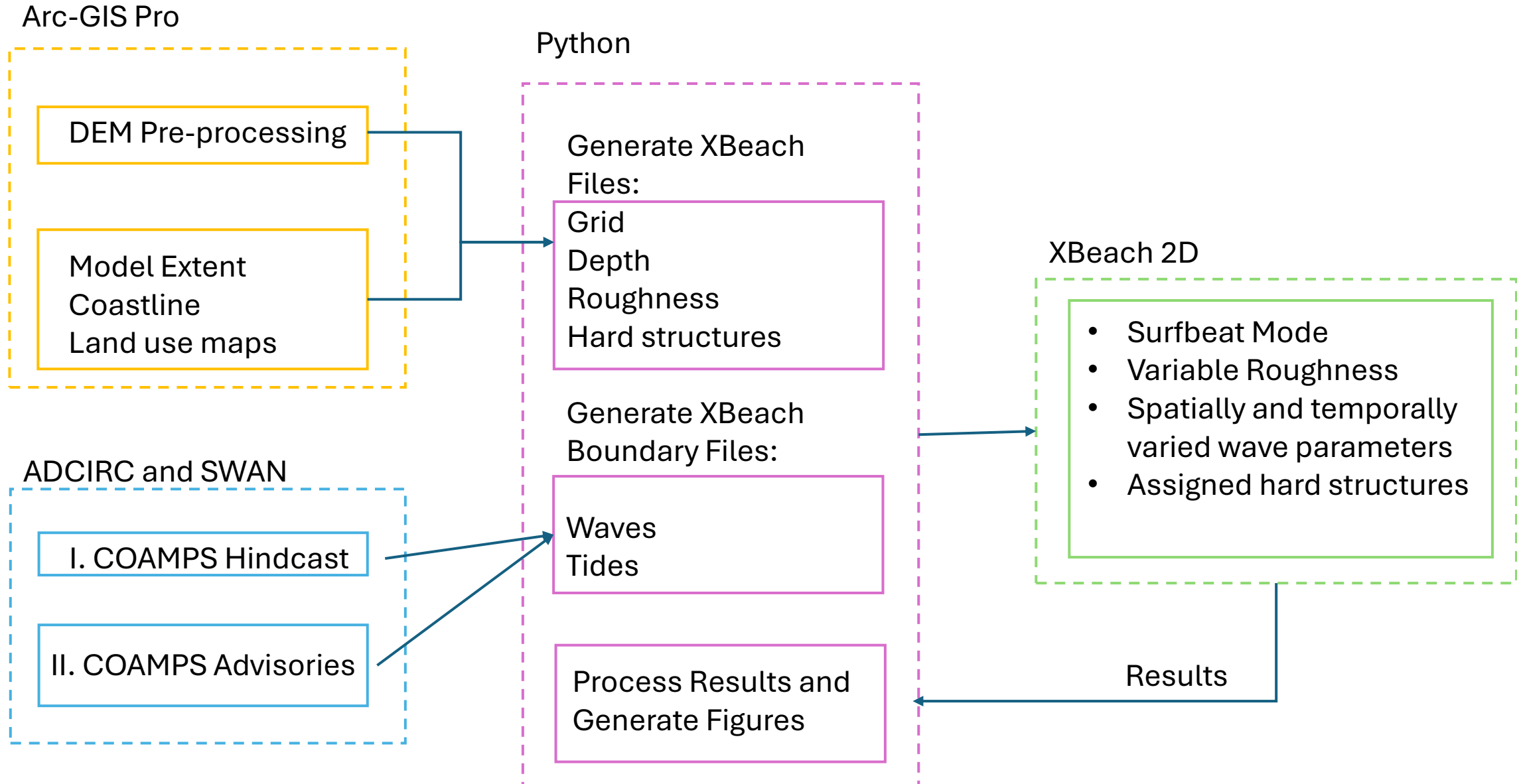# XBeach, the Morpho-dynamic Model of Choice

- Free to download and use.

- Process-based models → incorporate physics

- Always improving- incorporates

   a large range of coastal features like coral reef-lined coasts, gravel, and vegetated coasts

- Can be used in:
   - stationary wave model (wave averaged)
   - surfbeat mode (time averaged)
   - non-hydrostatic mode (phase-resolving)

- XBeach 2D
   - Used to simulate dune erosion and inlet formation.
   - Considers alongshore sediment transport

- Drawbacks:
   - More time expensive than a 1D model
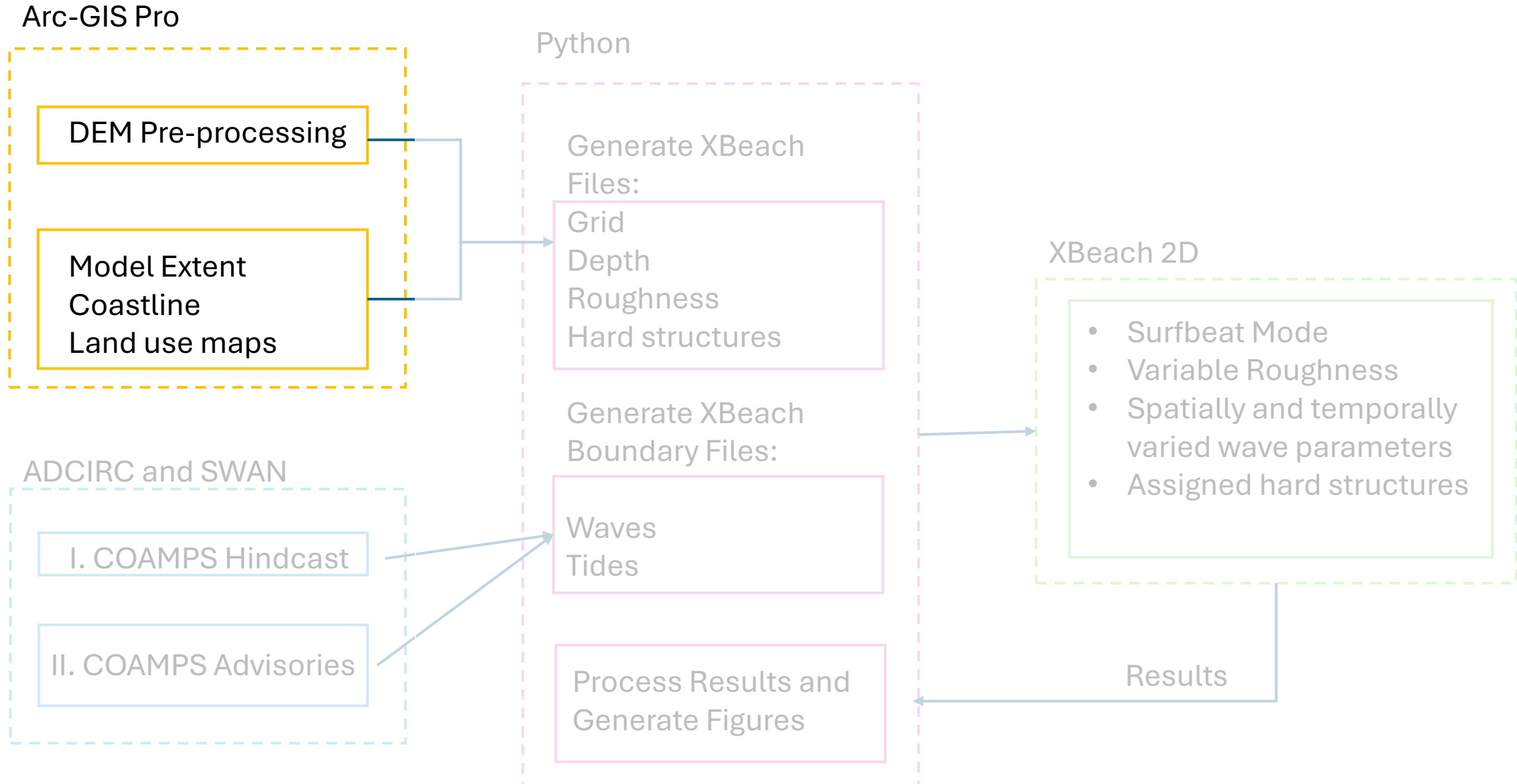   - Deposition at the lower beach face

Current Work:
'Forecasts' of Breach Formation

Modeling Scheme

Handling Geospatial Data

Arc-GIS Pro

Python

DEM Pre-processing

Model Extent
Coastline
Land use maps

Generate XBeach
Files:
Grid
Depth
Roughness
Hard structures

XBeach 2D

- Surfbeat Mode
- Variable Roughness
- Spatially and temporally varied wave parameters
- Assigned hard structures

ADCIRC and SWAN

I. COAMPS Hindcast

II. COAMPS Advisories

Generate XBeach
Boundary Files:

Waves
Tides

Process Results and
Generate Figures

Results
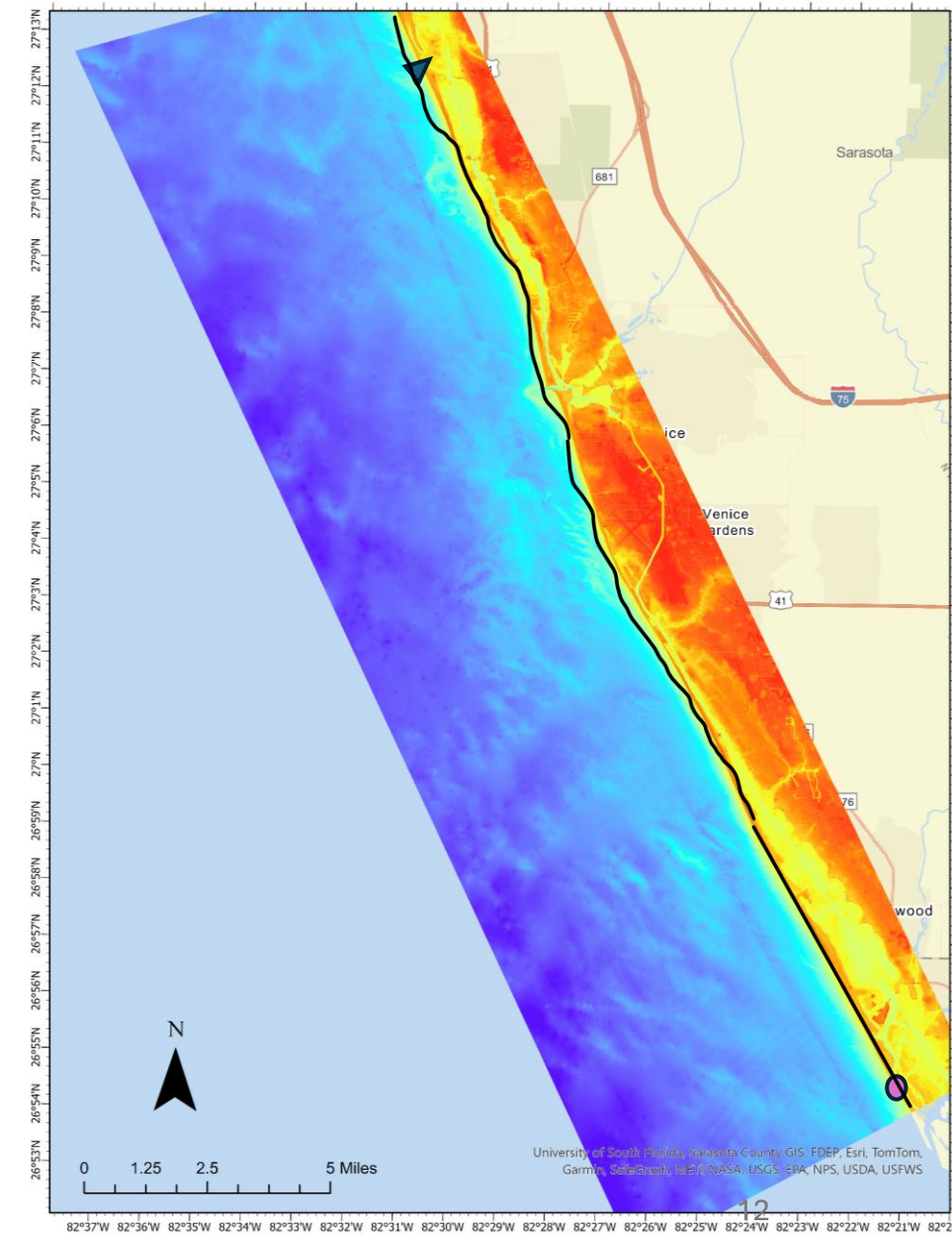
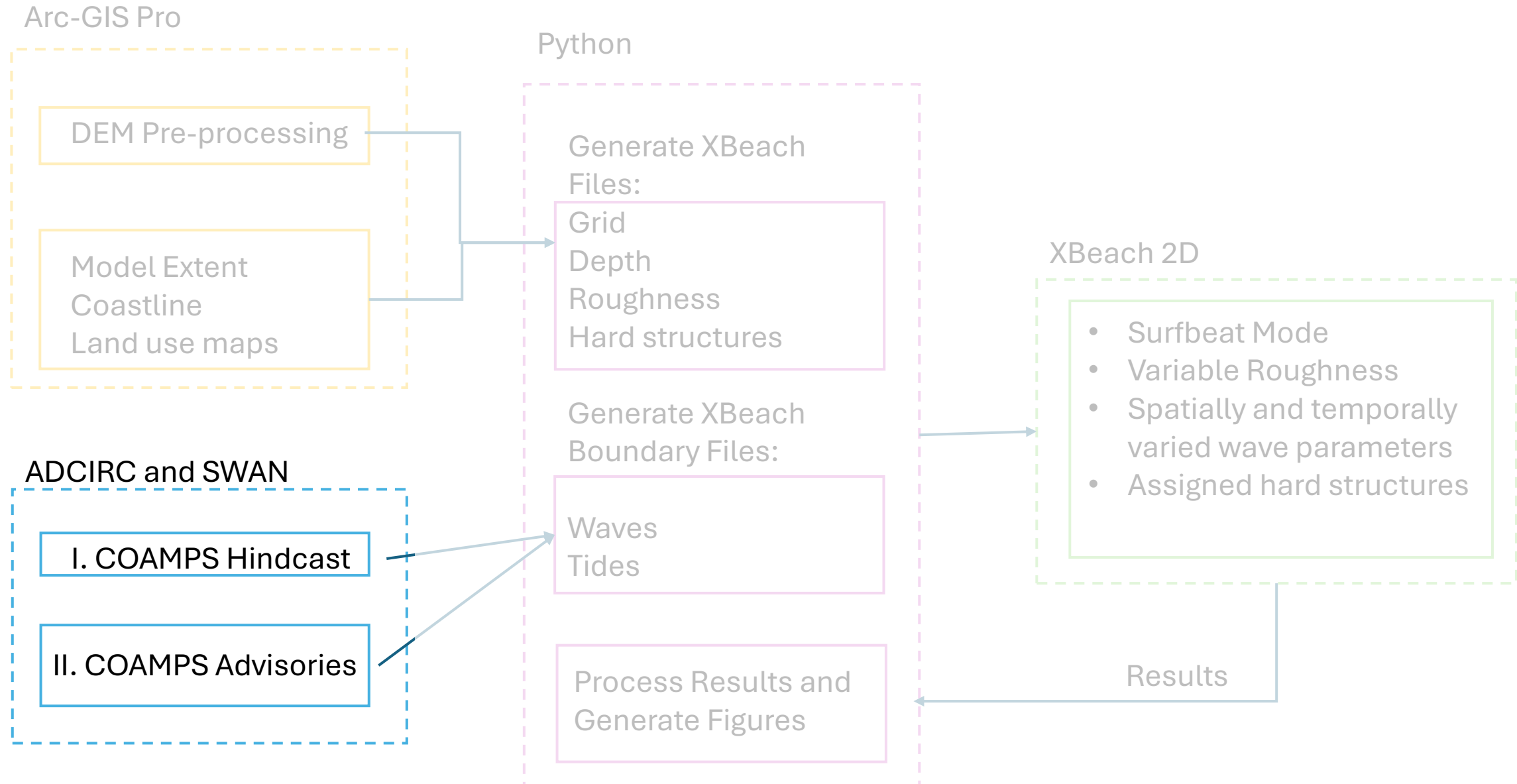# The Bathy-Topo After Pre-processing
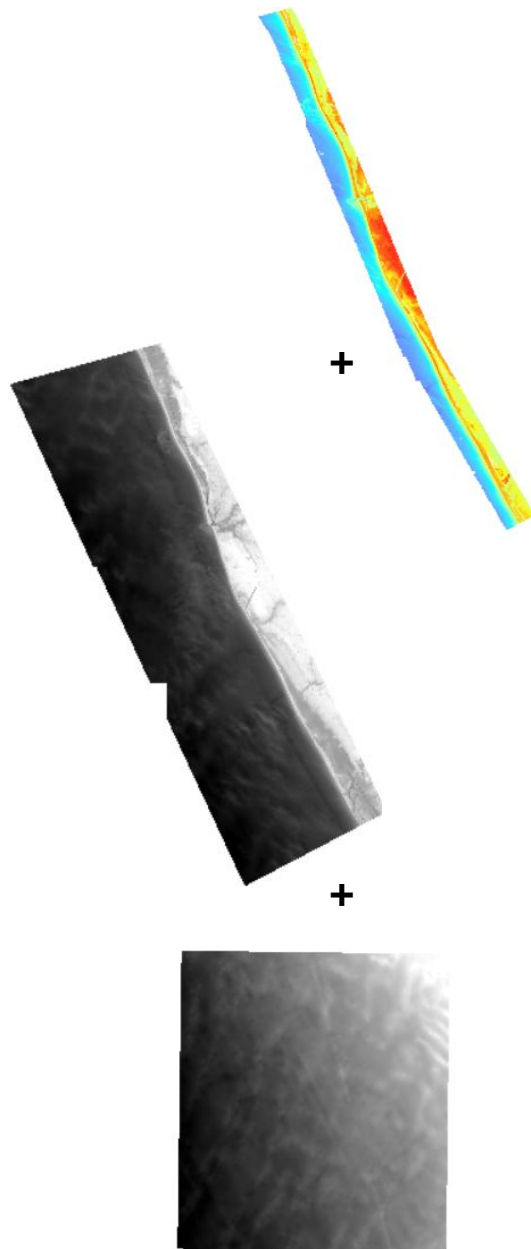
Merging
Clipping
Projecting
Smoothing
Resizing
Filling gaps

Boundary Data From ADCIRC+SWAN Coupled

Arc-GIS Pro

DEM Pre-processing

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Generate XBeach Boundary Files:

Waves
Tides

ADCIRC and SWAN

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Process Results and Generate Figures

Results

Spatially and Temporally Varying Wave and Tide

Offshore
Boundary
Points 2 km
apart

ADCIRC + SWAN → Hindcast and Forecast Simulation

Mesh Module
Water Surface (eta)
19 08:00:00

1.0
0.8
0.6
0.5
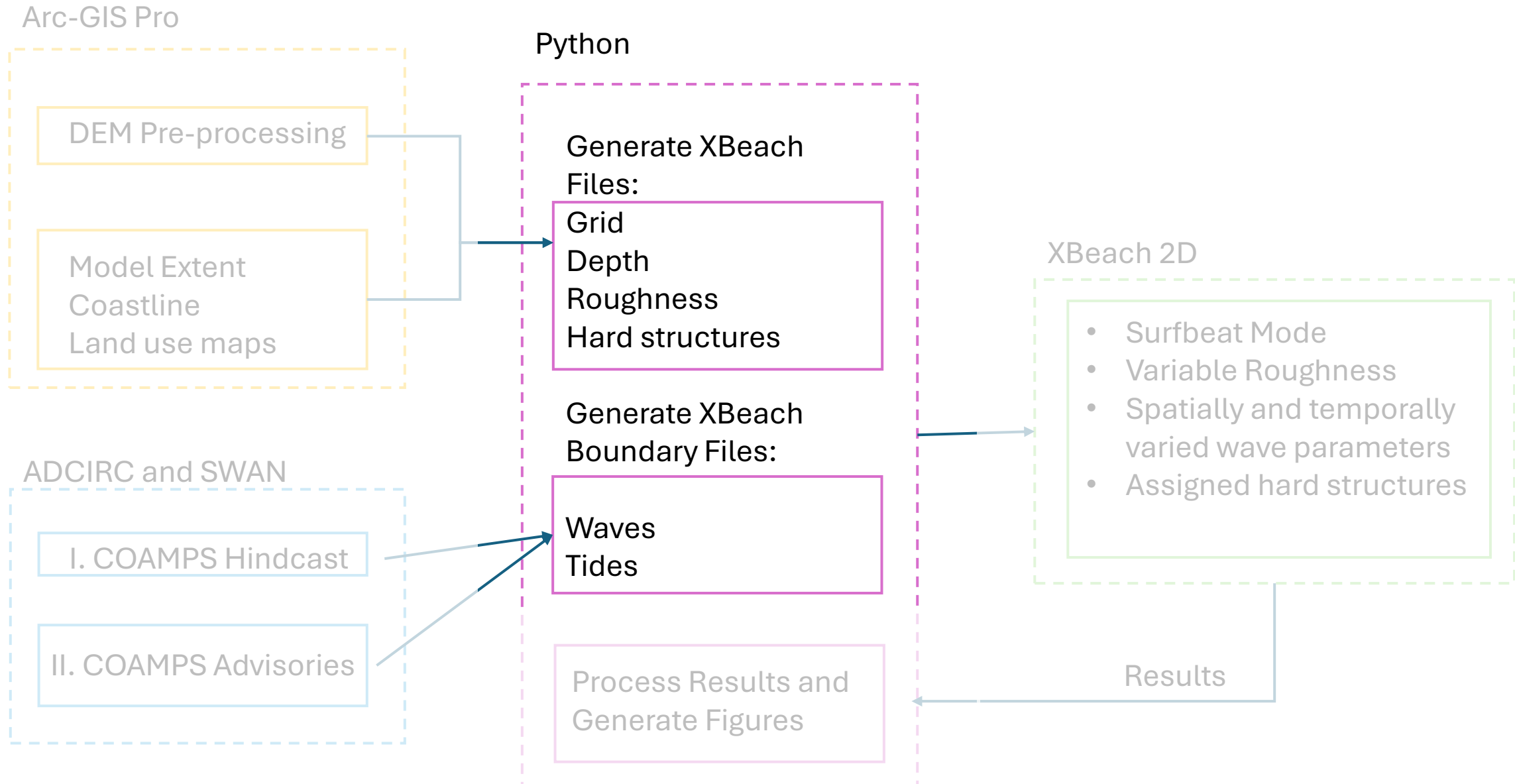0.3
0.1
-0.1
-0.3
-0.5
-0.6
-0.8
-1.0
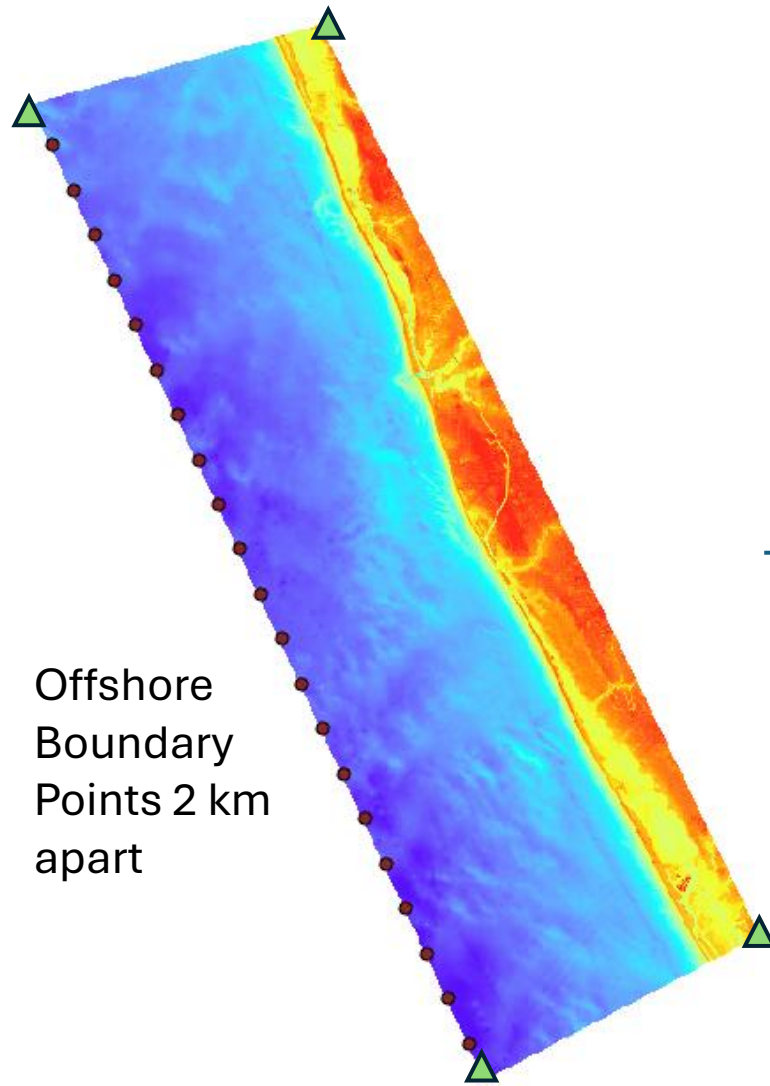
● = wave-parameter points

▲ = tide points
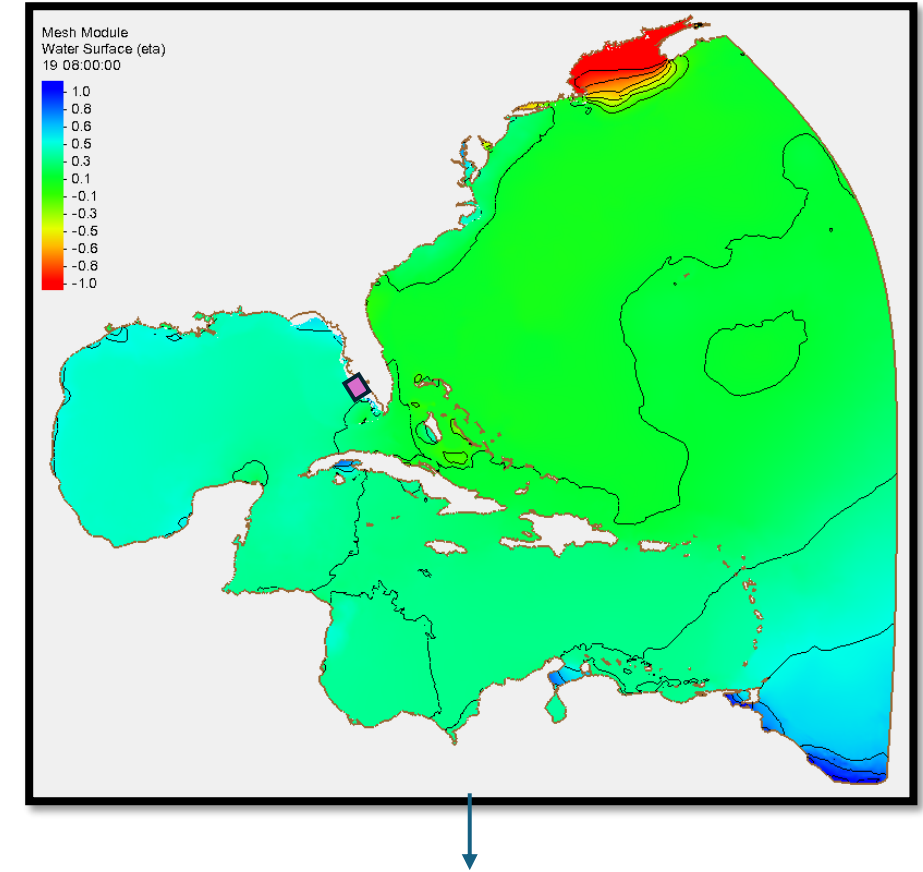
Extracted:
- Wave height
- Wave angle   Wave parameters
- Wave period
- Water level   Tide

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Generating Model Files in Python

Arc-GIS Pro

DEM Pre-processing

Model Extent
Coastline
Land use maps

ADCIRC and SWAN

I. COAMPS Hindcast

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Generate XBeach Boundary Files:

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Process Results and Generate Figures

XBeach 2D

- Surfbeat Mode
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Results

Python For User-Specified Grid Formation

Offshore Boundary

41 km

Follow the Coastline
Variable spacing:
      1m spacing, 65m from either side of the coastline
      1-20m spacing, gradual increase from 65m of
Coastline to model grid edge
Padded at either lateral side by 200m to avoid instability
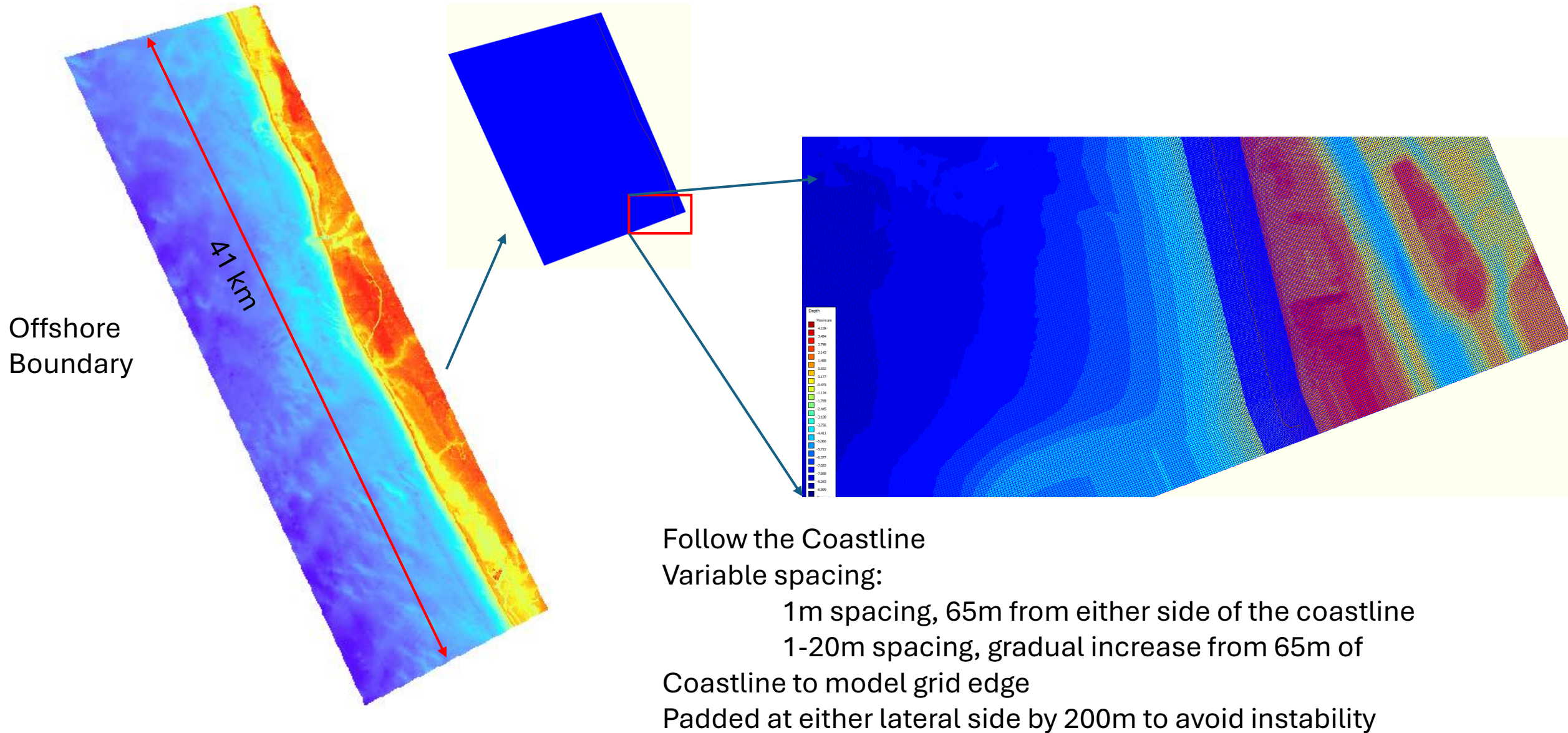
Running XBeach2D and Processing Results

Arc-GIS Pro

DEM Pre-processing

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Generate XBeach Files:
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Process Results and Generate Figures

XBeach 2D

- Surfbeat Mode
- Variable Roughness
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Results

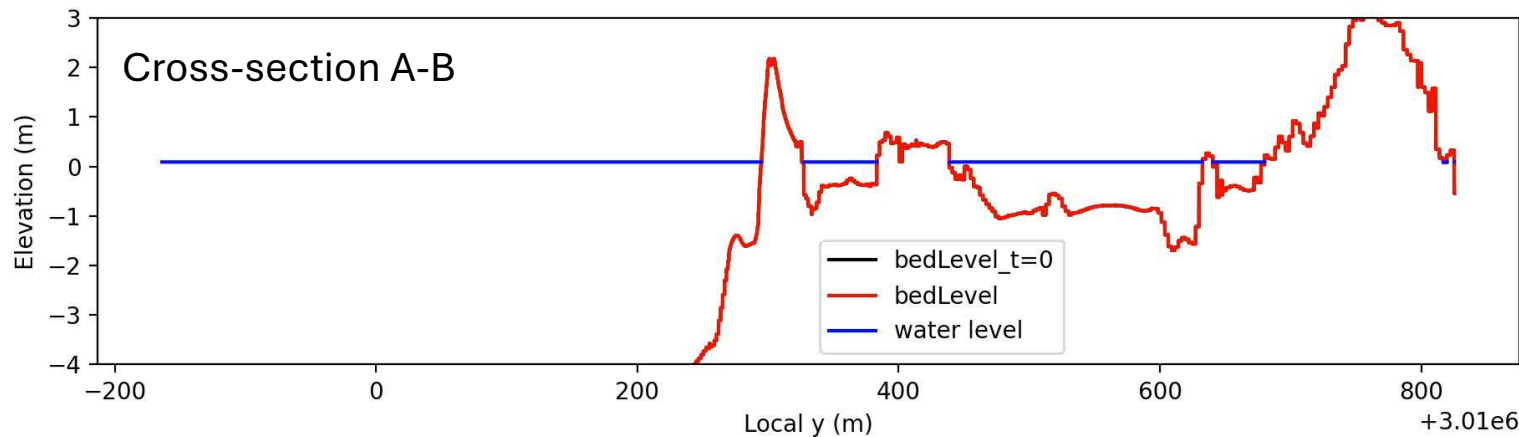# Midnight Pass Formation in the Model
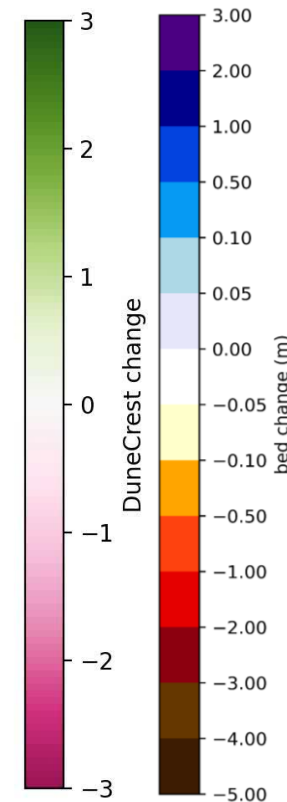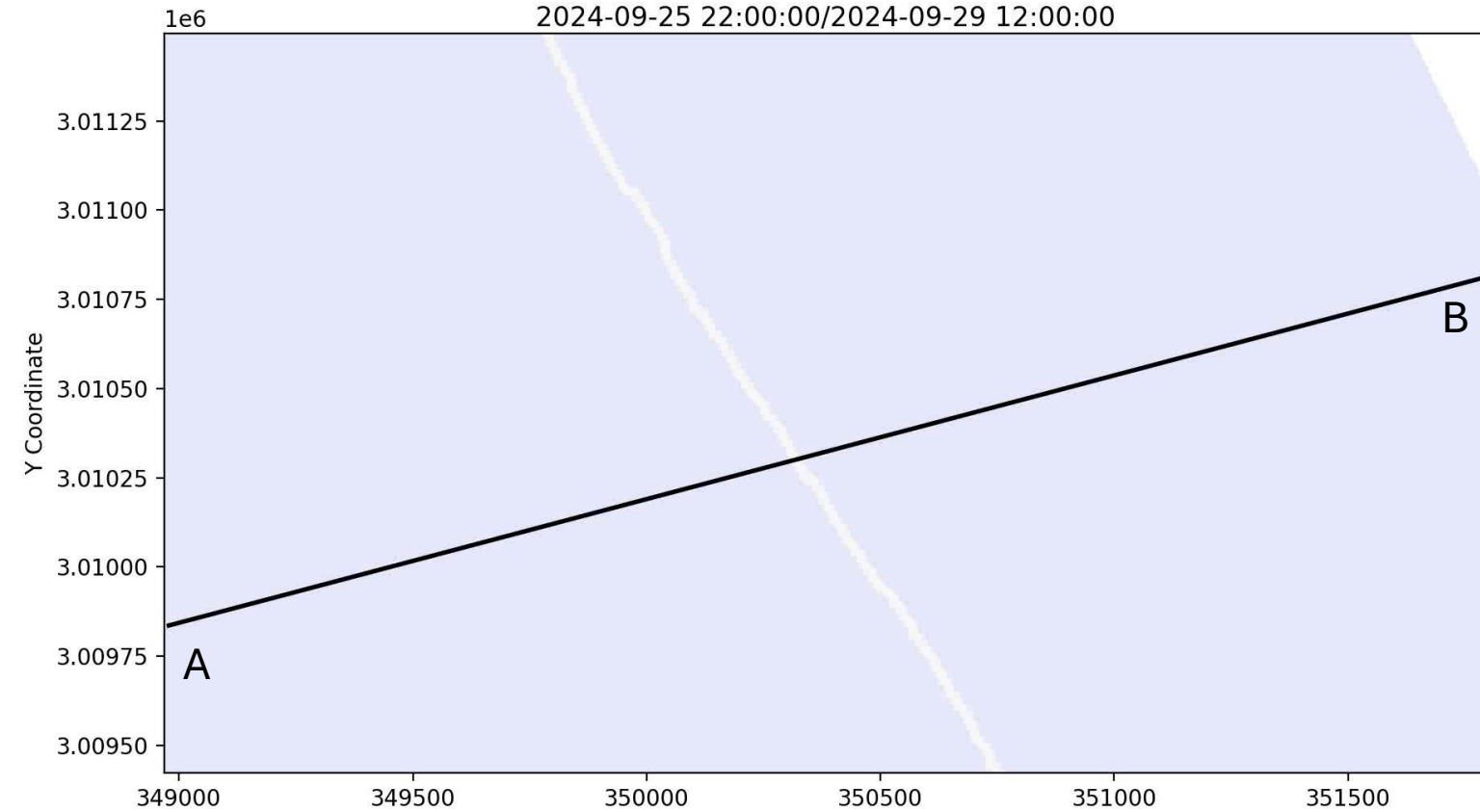
Zb = change in bed elevation
- Warm: erosion
- Cool: deposition

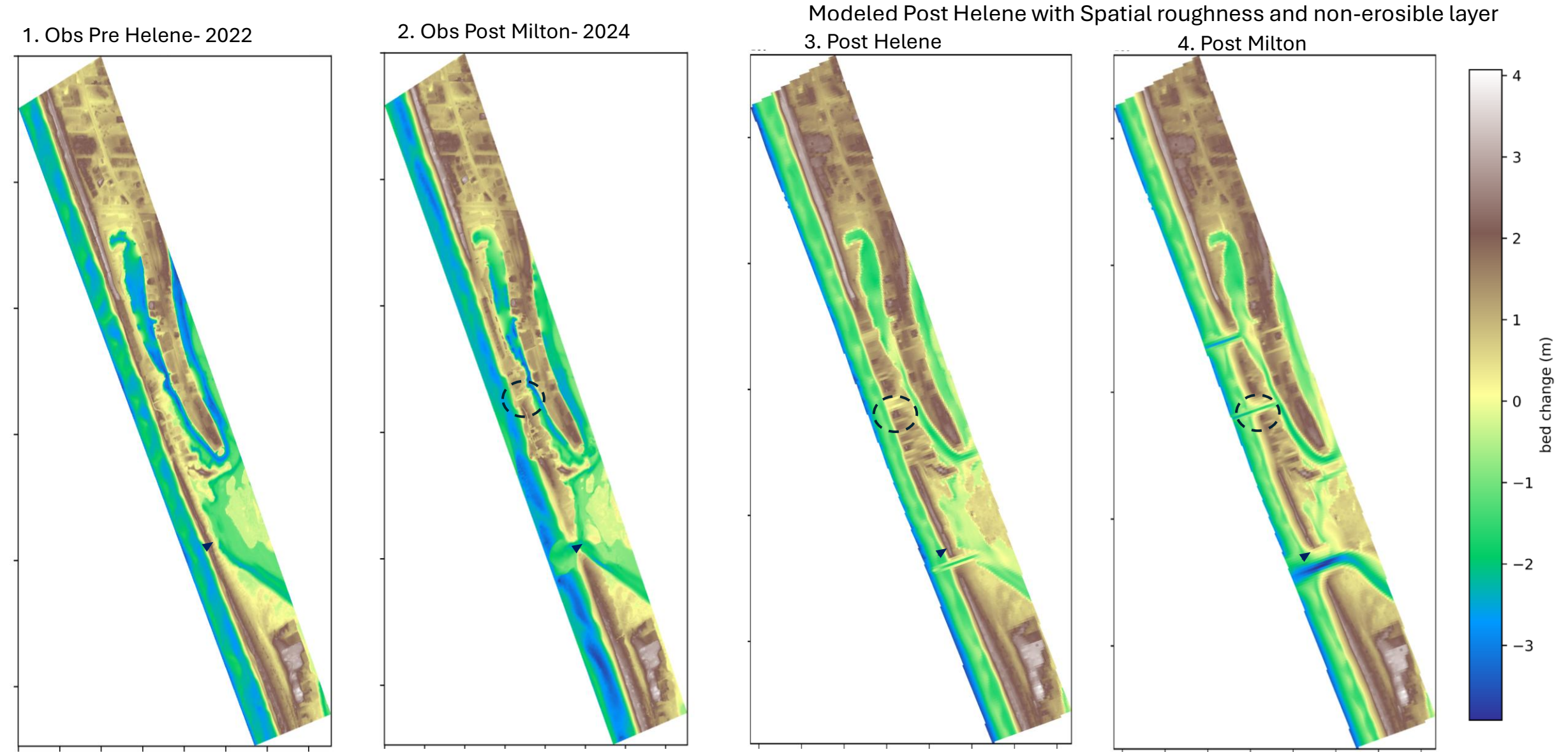Green → magenta: change in dune crest elevation

- Green: deposition @ dune crest
- Magenta: erosion @ dune crest

- An inlet is observed in the model 8m away from the observed inlet

- Multiple dune crest erosions are also observed but only one inlet formation

# Model Results for Helene – Spatial Plots of Erosion

Results from ADCIRC Forecast Advisory of 2024/9/24 12:00 hr

1. Obs Pre Helene- 2022

2. Obs Post Milton- 2024

Modeled Post Helene with Spatial roughness and non-erosible layer
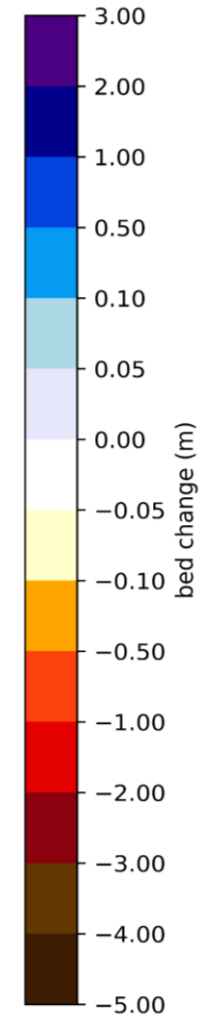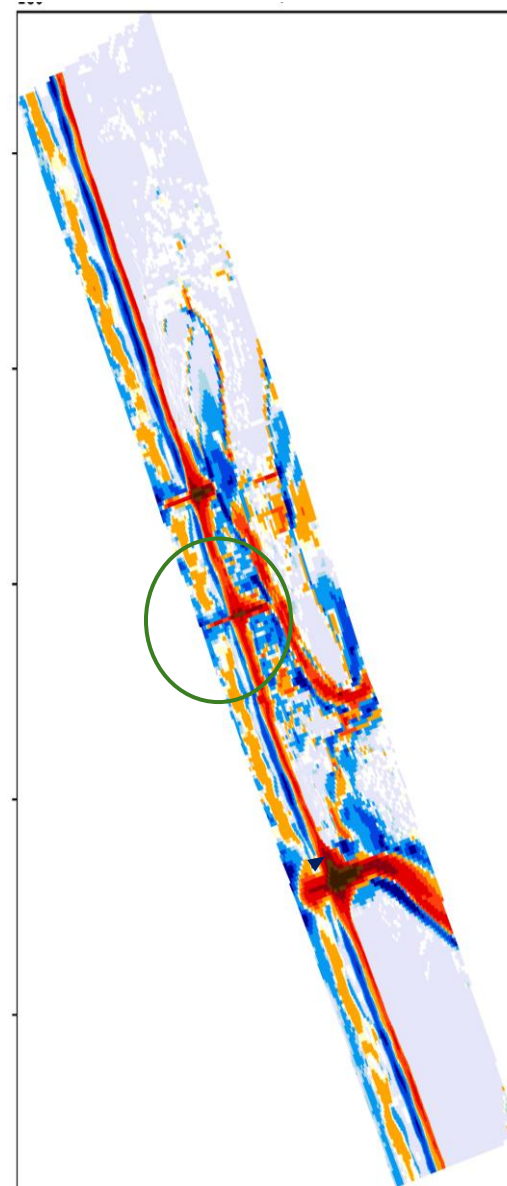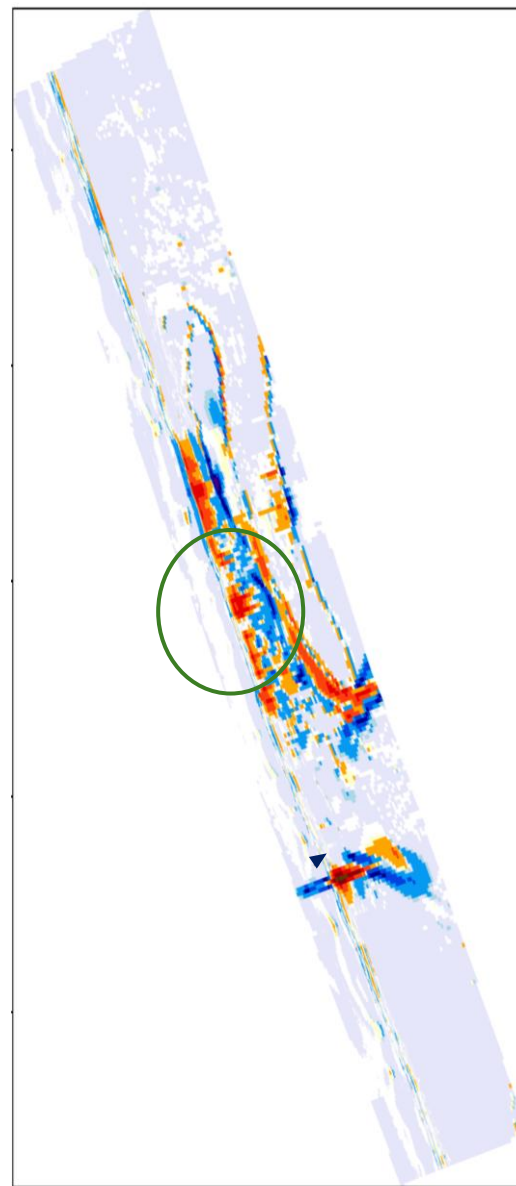
3. Post Helene

4. Post Milton

- An inlet elevation is around -2m in observed, and -2.5m in modeled

Difference in Elevation- pre and post Hurricane Helene

Observed elevation change after Milton
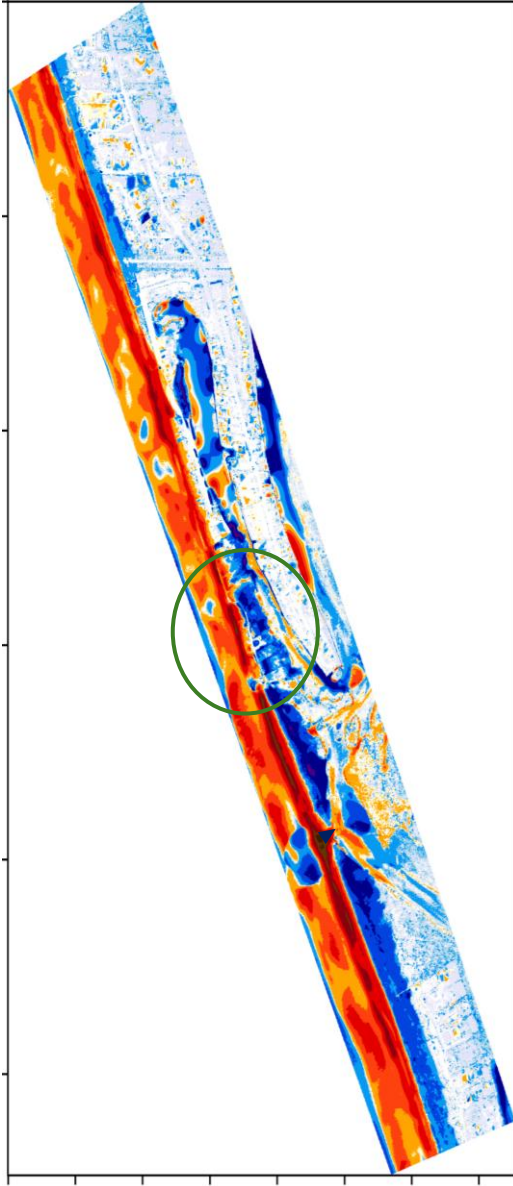
After Helene: spatial roughness + non-erodible layer

- The elevation of the Midnight Pass is around -4m to -5m
- Erosion in the beach face

- Multiple dune breaches

Ongoing/Future Work:
What can we learn about breach formation?

XB2D Simulated Dune Breach and Improve Simulation

De Vet et al., 2015:

- 2 km stretch of the Fire Island coastline in New York, USA, particularly focusing on a breach formed near Pelican Island due to Hurricane Sandy in 2012.
- Improve the accuracy of XBeach simulations by refining bed roughness parameters and wave skewness/asymmetry to provide better predictions of morphological changes

- Implemented variable roughness to show improved modeled erosion.
- Identified parameters relevant to overwash and collision regimes:
  - bed roughness
  - wave skewness and asymmetry

- The study never quantified the levels of these parameters to understand the breach location or extent
- The breach location did not match but was not investigated as to why.

Pre-Sandy LIDAR data

Post-Sandy LIDAR data
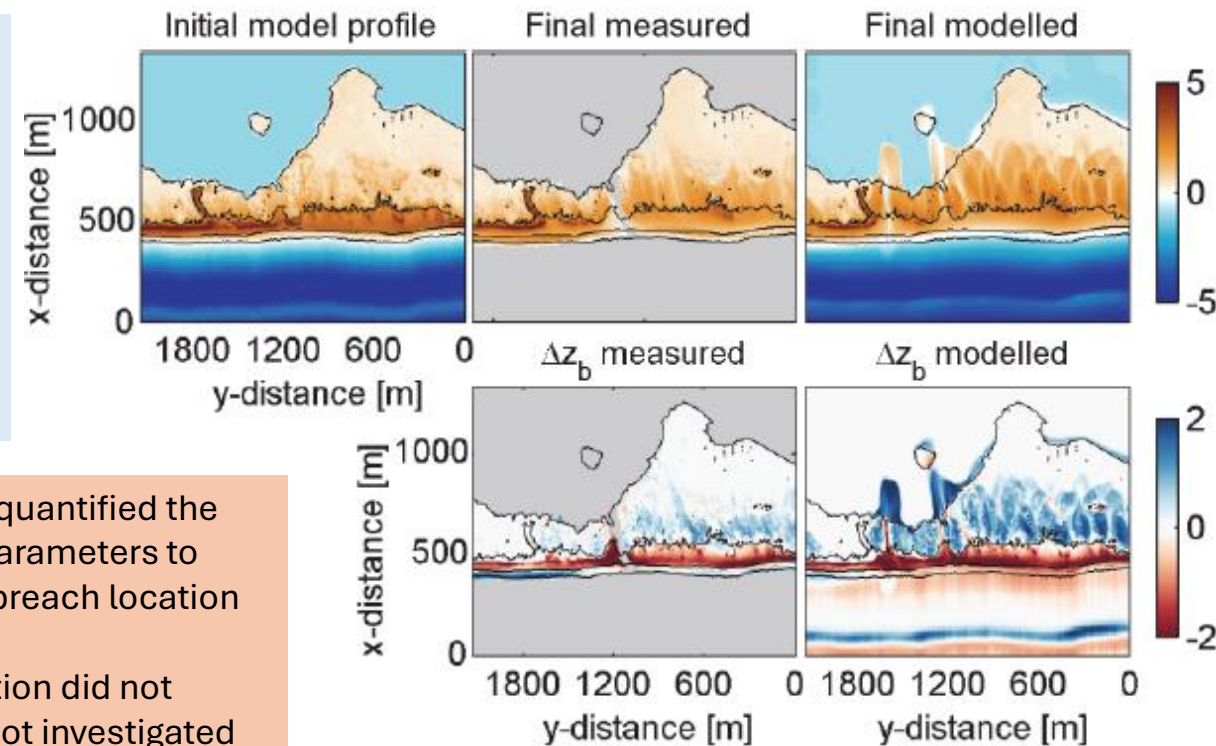
Improved Bed Roughness did not Simulate Correct Breach
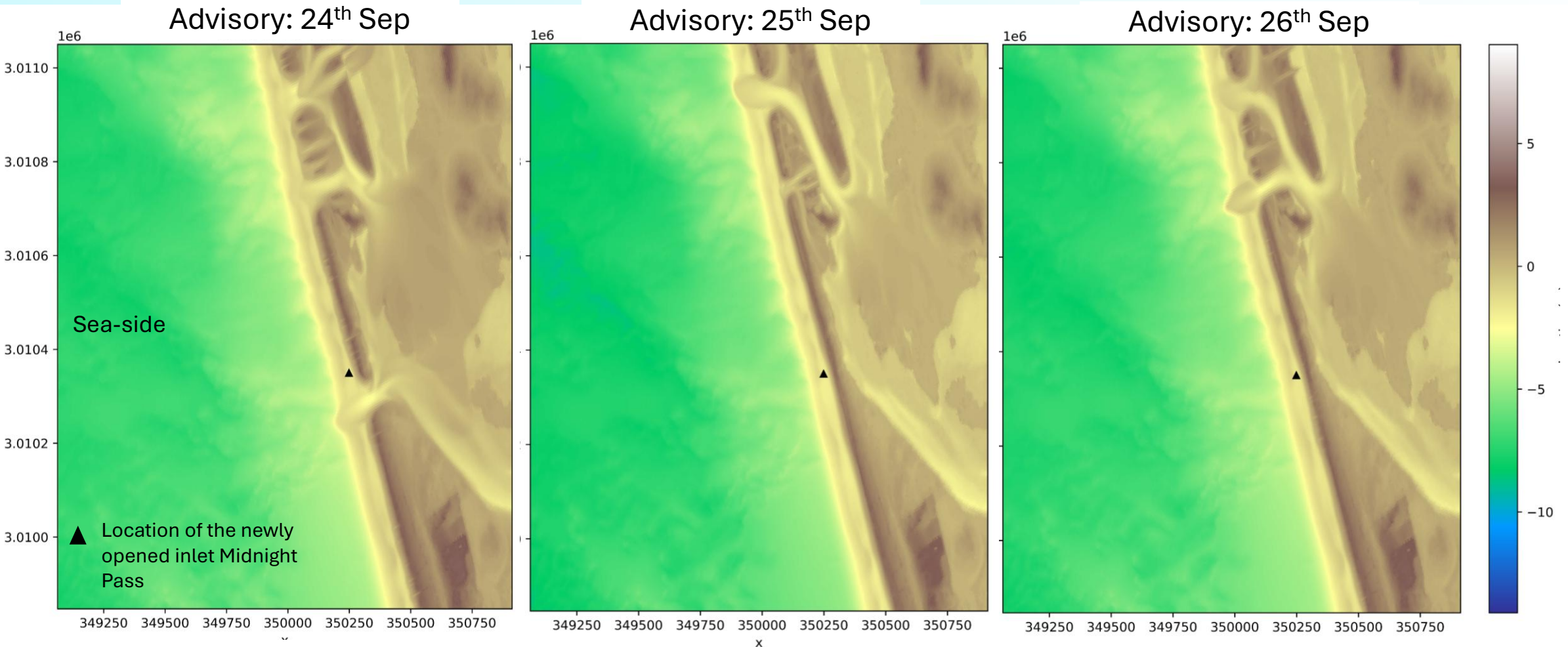
Van Der Lugt et al., 2019:
- Fire Island (New York) & Matanzas (Florida)
- Studied Hurricane Sandy (2012) and hurricane Matthew (2016)

- Used dynamic roughness to improve modeling.
- Identified that even a 10% variation in Bay Side water levels leads to significant deviation of erosion.

- Showed erosion overestimation and multiple breaching.
- Inlet formation, but not at the lowest dune crest, but no explanation as to why

Obs: Pre-storm

Obs: Post-storm

Model: Post-storm
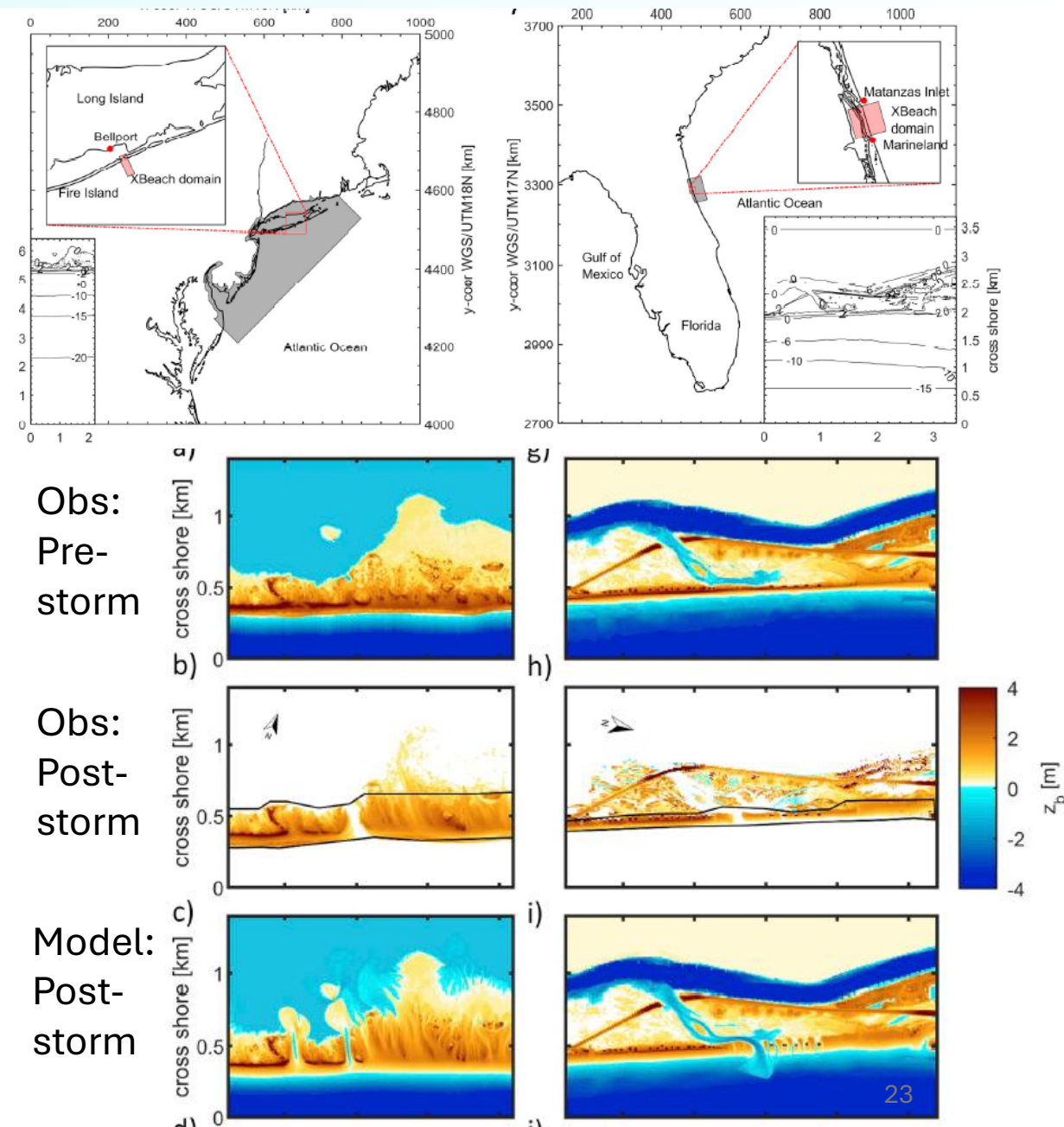
Midnight Pass Locations Differ at each Forecast Ensemble

The breach occurs to the north of the actual breach location by around 400m.

Which parameters affected the breach location?

    The difference in water level between offshore and Bay side (VanDerLugt et al., 2019)→ What is the ratio?

    Offshore wave height and angle affect the size of the breach (Houser eta al., 2008). → bathy remains the same at each ensemble.

Research Questions

I. What hydro conditions contributed to the opening of Midnight Pass after Helene and Milton?

- What wave parameter affects the width and depth of the pass?
- What hydro conditions cause inlet formation in certain locations of the coast?
- ➔ Hydro Forcing → Using COAMPS Hindcast → Still in process.

II. What hydro conditions differ in each forecast to cause the breach at different locations? -wave angle, wave height, period? Which has the most impact?

- What is the oncoming wave angle that affects breaching location and extent?
- What difference in the bay side and offshore water level causes the dune breach?
- Why are there multiple breaches in the model and not in real life?
- ➔ Hydro forcing → using COAMPS Forecast Advisory → Milton Still in Process

Conclusion

- Current work predicts formation of the inlet, Midnight Pass, within 8m of the actual location, of 10m width and 1m depth during Hurricane Helene

- Current also shows the widening and deepening of Midnight Pass after Hurricane Milton, with 30m width and 4m depth

- The model predicted erosion and deposition in approximately the same areas but showed multiple dune breach

- Future work include investigation into location of inlet for different wave conditions

Thank you
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