

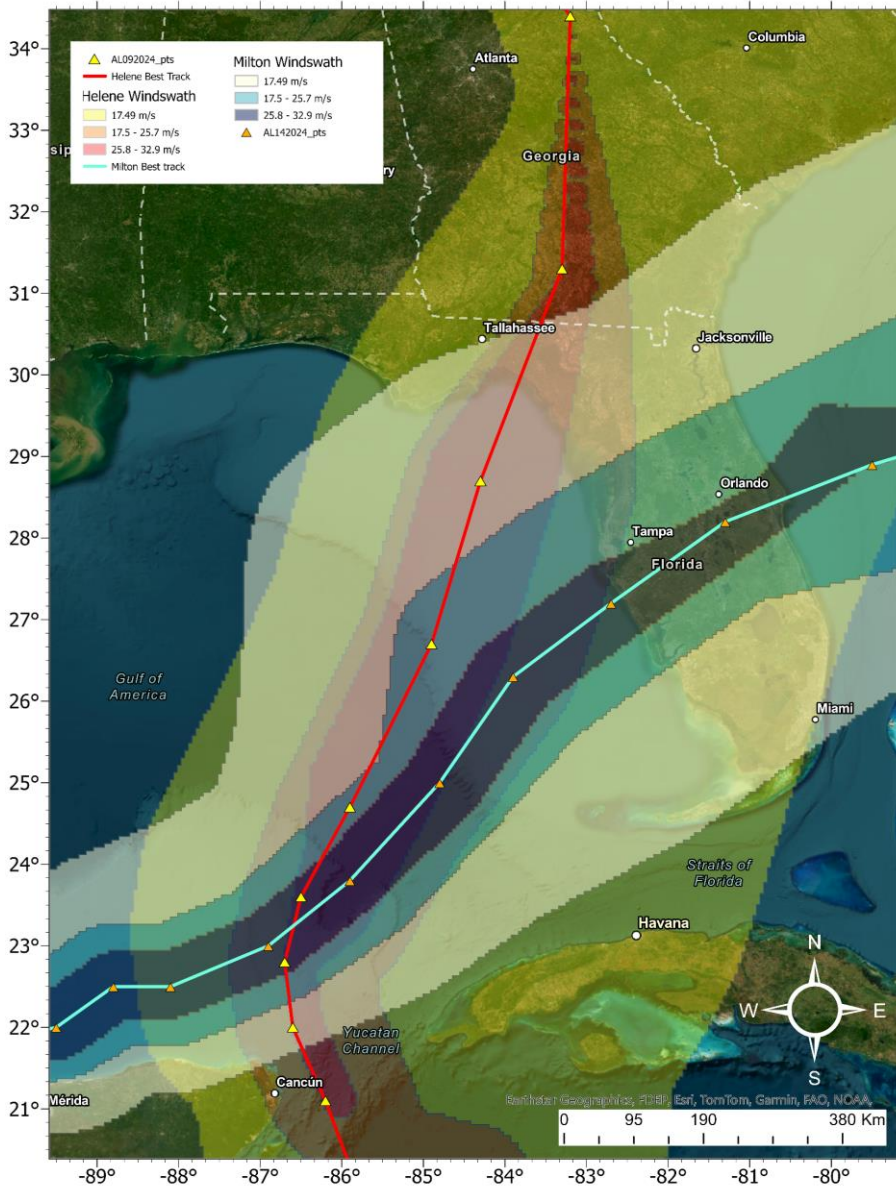


WAVE AND SURGE CONTRIBUTIONS TO MILTON PASS FORMATION DURING HURRICANES HELENE AND MILTON

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The Two Massive Storms Less Than Two Weeks Apart



Hurricane Helene:

- **Category 4** cyclone at landfall
- **Sustained wind** of around **140 mph (220 km/h or 62.6 m/s)**
- Made landfall at 0310 UTC on the 27th of September
- It landed 10 miles west-southwest of Perry, Florida
- It caused 250 deaths across Florida, Georgia, South Carolina, North Carolina, Tennessee, Virginia, and Indiana, and property damage of around 59.6 billion USD (Cooper, 2024)

13 days later

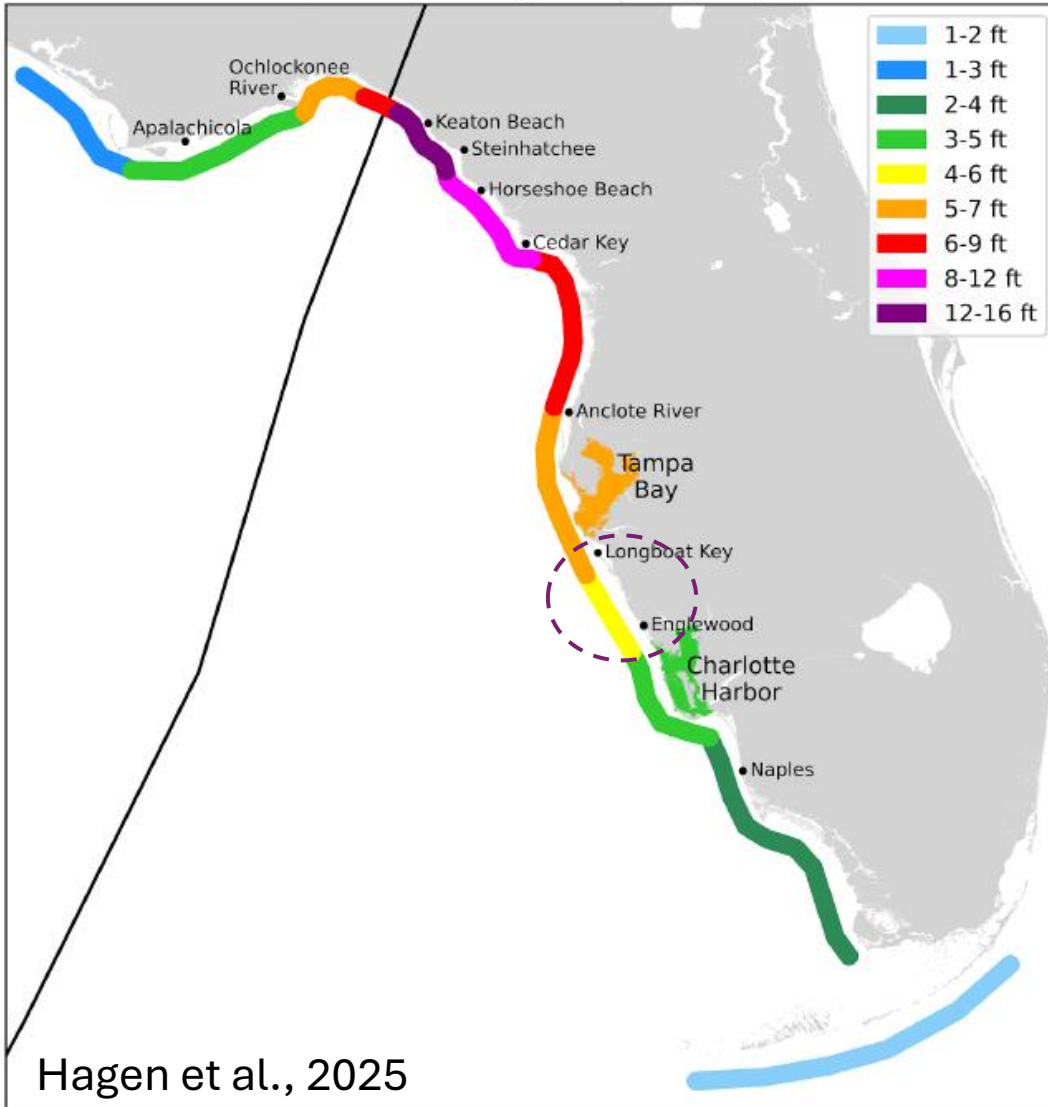
Hurricane Milton:

- **Category 3** cyclone at landfall
- **Sustained wind** of around **115 mph (194 km/h or 51.4 m/s)**
- Made landfall at 0300 UTC on the 10th of October
- It landed on Siesta Key, Florida
- It caused 9 deaths and damage of up to 34.3 billion USD in 2024 (Beven et al., 2025).

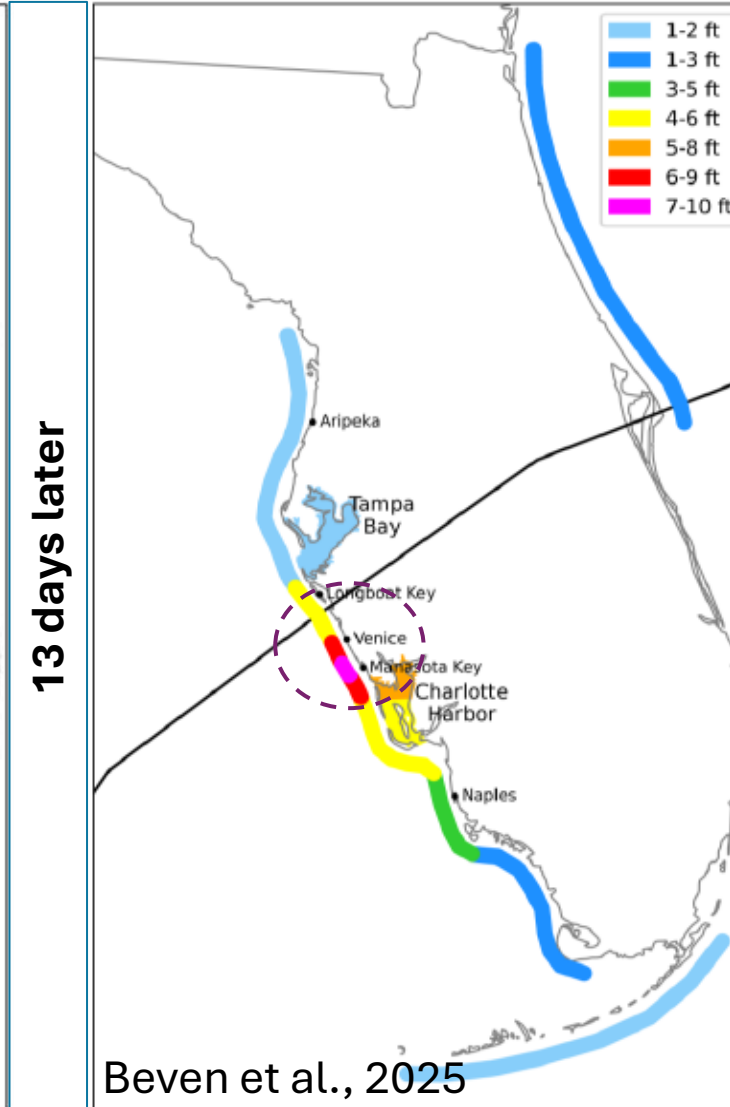
Exposed the same stretch of coast to high storm surge in quick succession

Same Stretch of Coast Exposed to Massive Storm Surge

Hurricane Helene
NHC Storm Surge Analysis (AGL)



Hurricane Milton
NHC Storm Surge Analysis (AGL)



During **Helene**, the **40 km coast** between Siesta Key and Manasota Key was exposed to **1.2-2.1 m of Storm Surge**.

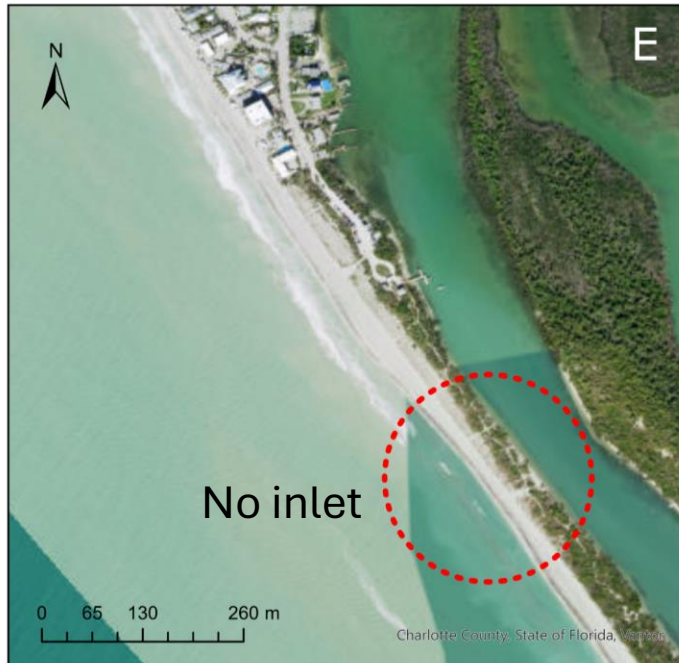
During **Milton**, the **same stretch of coast** was exposed to **1.2-3 m of Storm Surge**

Consecutive hurricanes created two separate breaches along the same barrier coast

The Resulting Erosion and Breach

November 2022

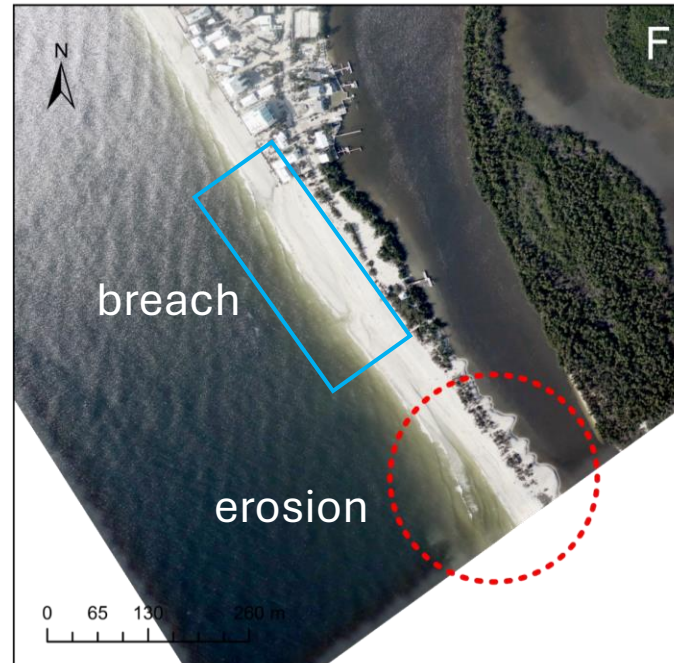
~2 years before Helene's landfall



Aerial imagery of the southern end of Manasota Key, FL

September 2024

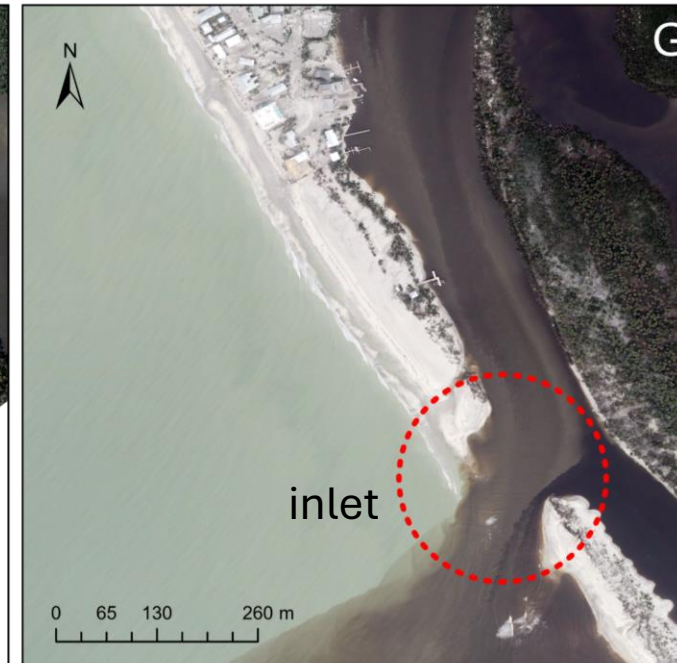
3 days after Helene's landfall



Aerial imagery of the area collected from NOAA
Beach erosion and coastline breach

October 2024

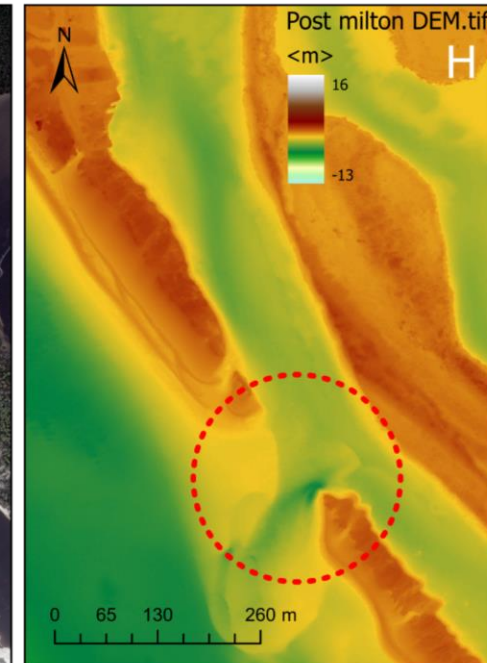
2 days after Milton's landfall



Aerial imagery of the area showing **Milton Pass**
It formed with a width of 160 m and a depth of 4.5 m

November 2024

~2 months after Milton



DEM at Milton Pass.
LiDAR DEM collected from NOAA has a spatial resolution of 1m

Understanding why barrier breaches form at specific locations during hurricanes is critical for improving coastal hazard prediction and understanding storm-driven landscape change.

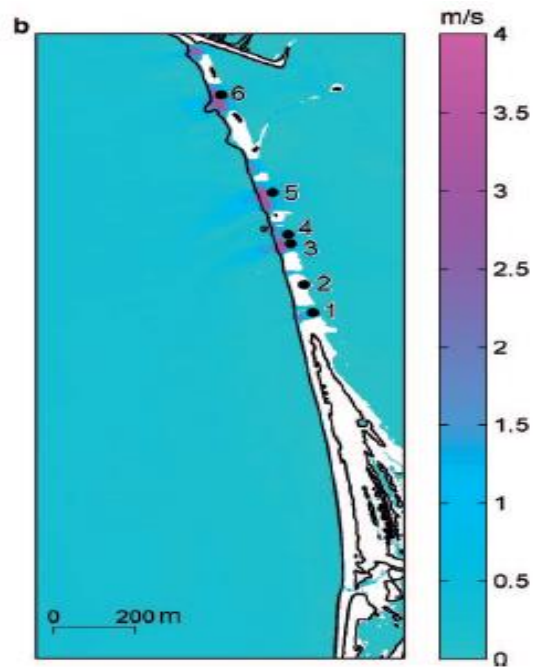
Research Question

How did hydrodynamic forcing and antecedent morphology interact to control the location and timing of inlets, particularly during consecutive storms?

Antecedent topography had a minimal effect

Muller et al., 2017:

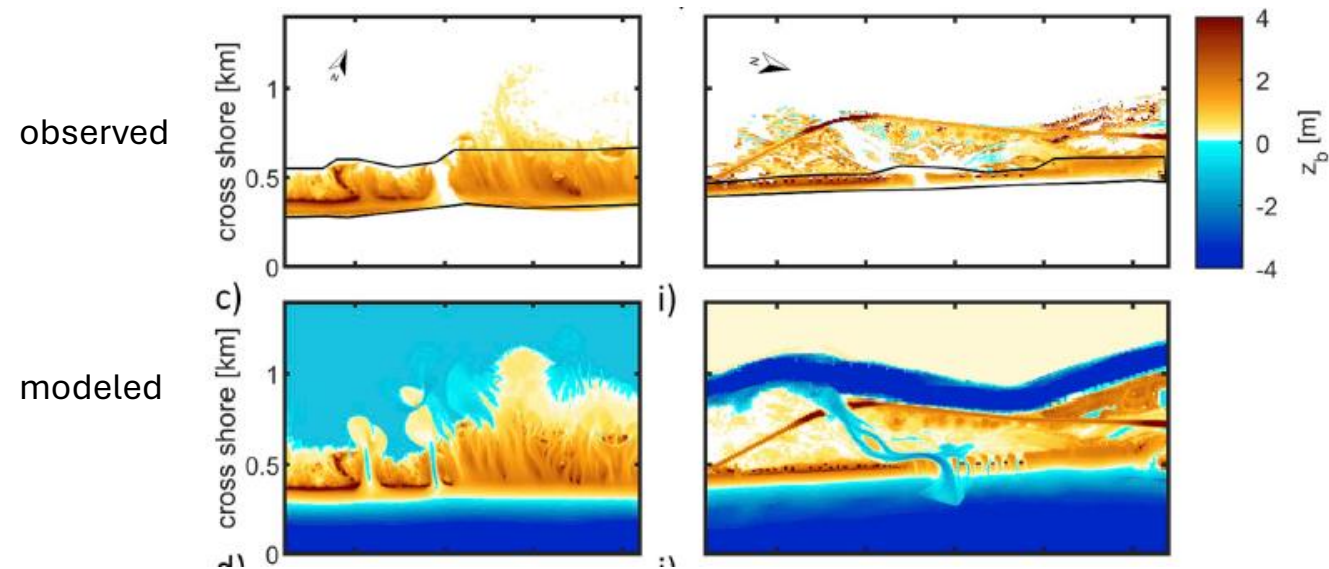
- Les Boucholeurs, located between La Rochelle and Bordeaux, France
- Xynthia (2016)



Correctly predicted the breach locations 6,5 and 3 → , but not 4, 2, and 1
Used post-storm bathymetry

Van Der Lugt et al., 2019:

- Fire Island (New York) & Matanzas (Florida)
- Studied Sandy (2012) and Matthew (2016)

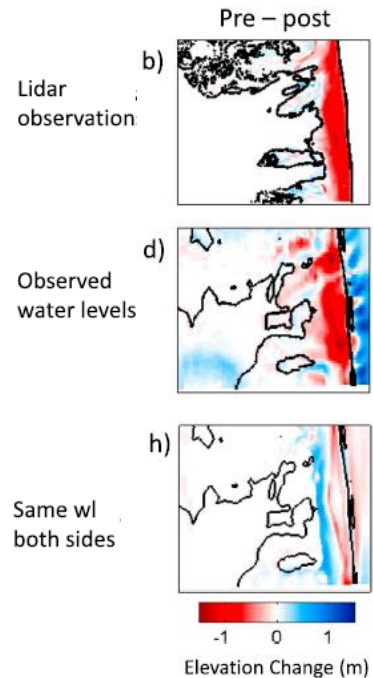


Showed multiple breaches
Inlet formed, but not at the lowest dune elevation

Parameters relevant to storm-induced inlet formation

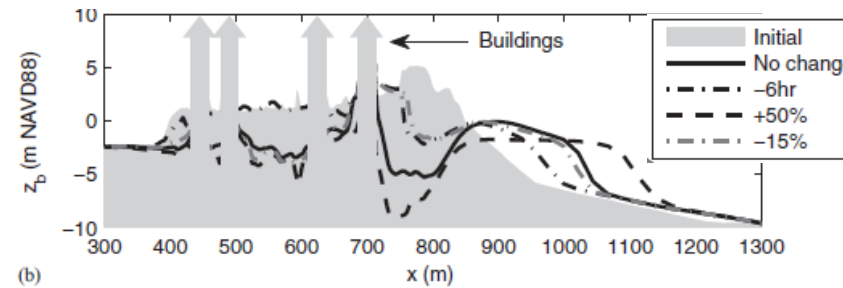
Sherwood et al., 2014

The **water level gradient** across the barrier island regulates the overwash direction



Smallegan et al., 2017

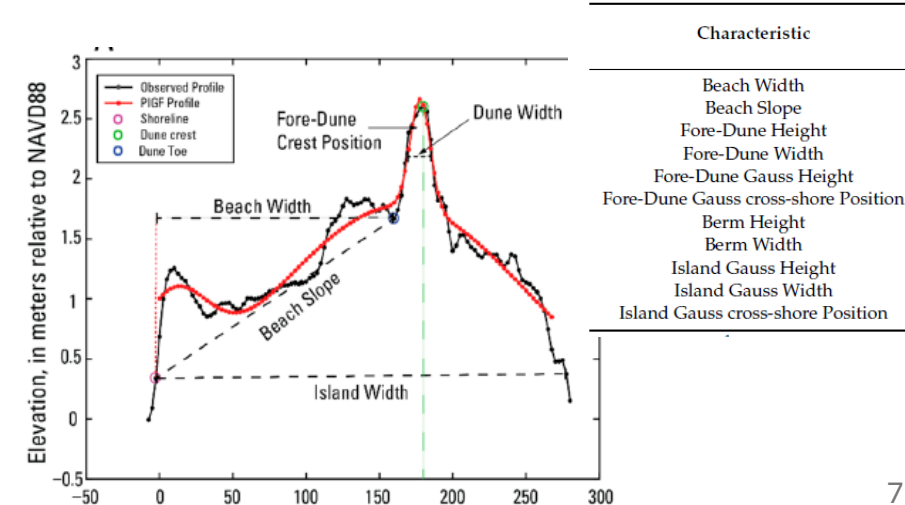
The **timing and magnitude** of the bay storm surge relative to ocean surges



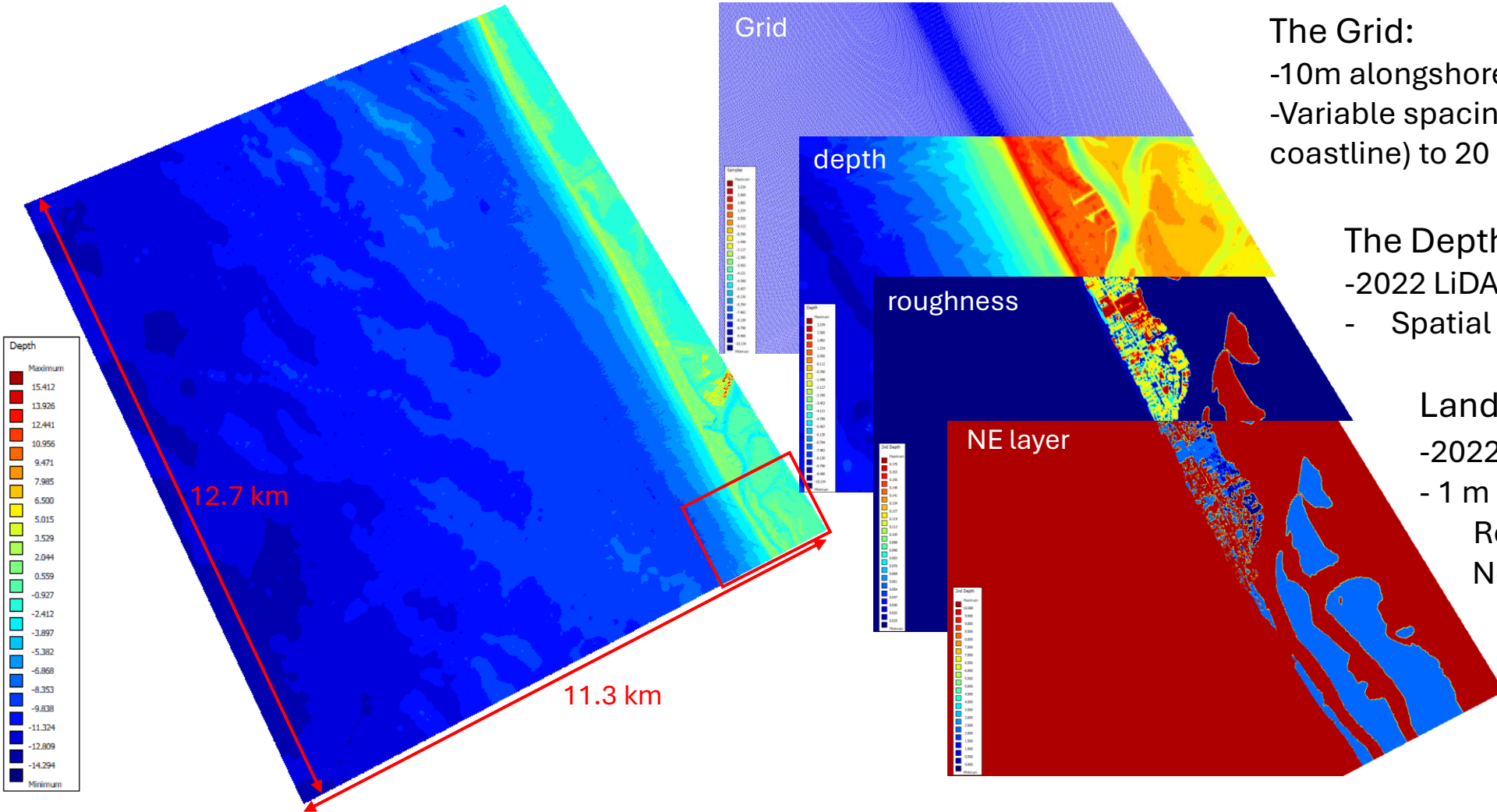
Relevant parameters identified:
Water level gradient → **timing and magnitude**
Beach width and dune height change

Mickey et al., 2020

erosion was most severe when **dunes** were **closer to the shore**, and the island's **base height decreased**



XBeach Model Details



The Grid:

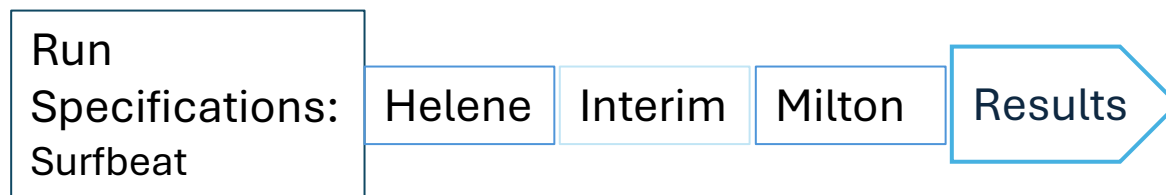
- 10m alongshore
- Variable spacing cross-shore from 1m (75 m of coastline) to 20 m (offshore)

The Depth:

- 2022 LiDAR DEM from NOAA + CuDEM
- Spatial resolution: 1m

Land Cover Map:

- 2022 land cover from NOAA
- 1 m resolution + 30 m resolution
- Roughness → land cover
- Non-erodible (NE) → landcover

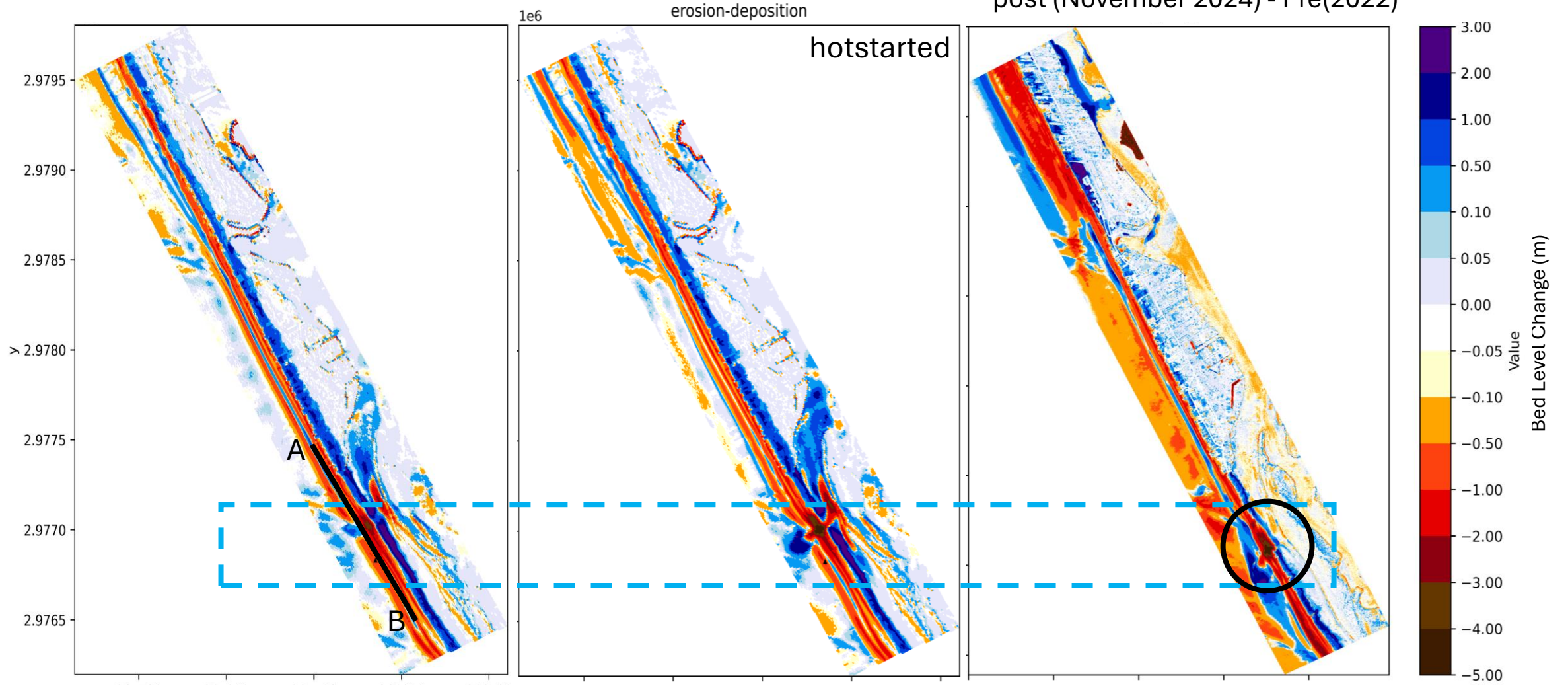


The Spatial Plot of Erosion at Milton Pass

Modeled: After Hurricane Helene

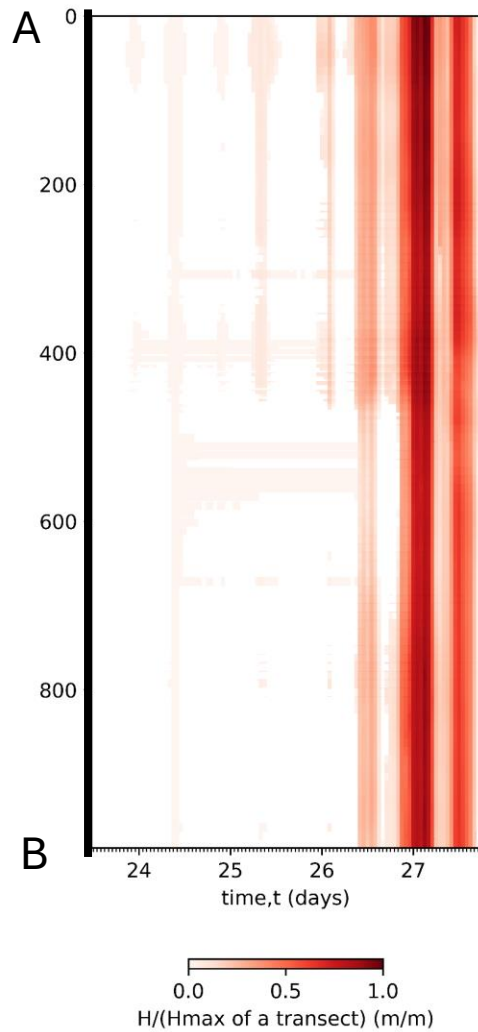
Modeled: After Hurricane Milton

Observed: After Hurricane Milton
post (November 2024) - Pre(2022)



An inlet after Hurricane Milton, 100 m away from the actual location, but with the same ~5 m depth

Highest Hs Along the Dune Toe-profile A-B



Plot of Normalized wave height, H , across the profile A-B:

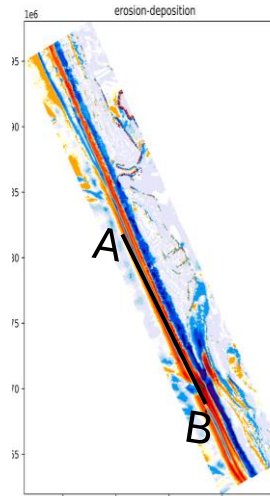
$$\frac{H}{H_{max}}$$

Where,

H = The wave height along A-B at time t

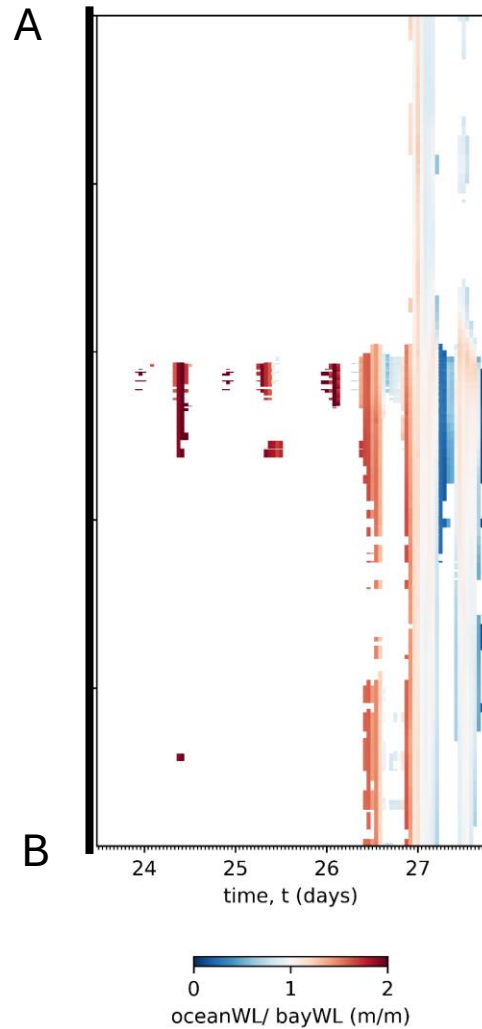
H_{max} = the max wave height for all time

The most red is the location of the highest wave height alongshore



A-B profile on the dune toe

Highest Water Level Gradient Along the Dune Toe



Plot shows water level gradient across the dune:

$$\frac{WL_{Ocean}}{WL_{bay}}$$

Where,

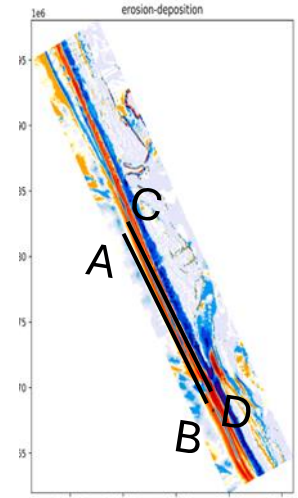
WL_{Ocean} = Seaside water level along profile A-B

WL_{bay} = Bay side water level along profile C-D

Most red shows the highest water level gradient from ocean to bay

Red → ocean side higher

Blue → bay side higher



A-B profile at dune toe

C-D at the bay side land

The Location Where the Sea Water Overtops Dunes

Plot shows water level gradient normalized by dune crest elevation

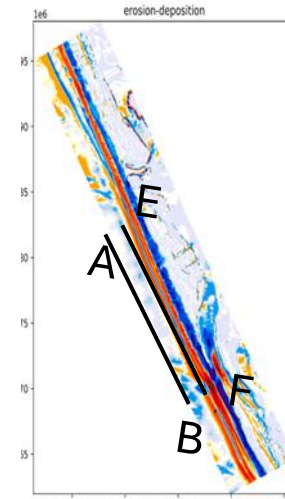
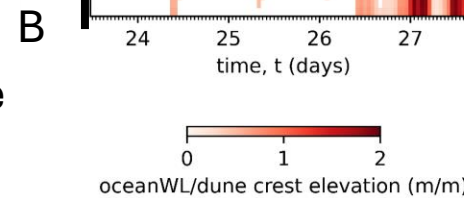
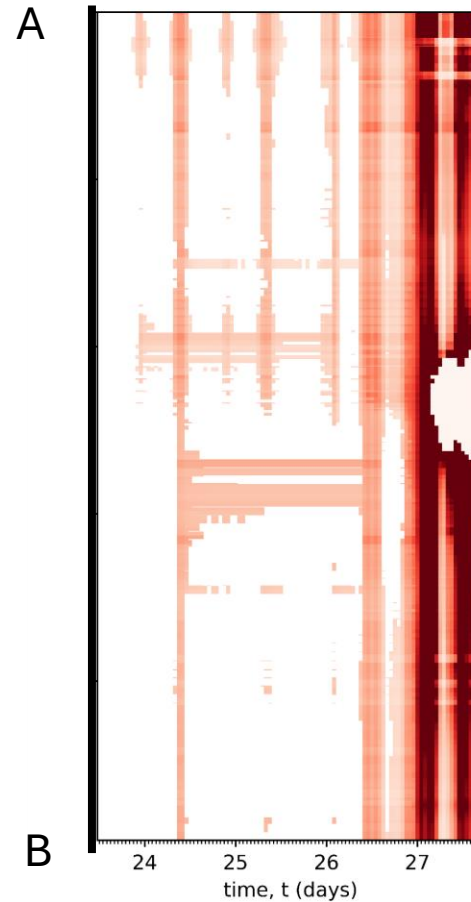
$$\frac{WL_{Ocean}}{DCE}$$

Where,

WL_{Ocean} = Seaside water level along profile A-B

DCE = Dune crest elevation at E-F

Most red where water from ocean continues to pass through after dune erosion



A-B profile
on dune toe

E-F profile on
dune crest

Location of the Erosion Alongshore

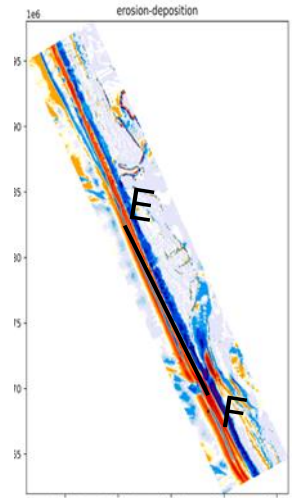
Plot shows Normalized dune crest elevation

$$\frac{DCE}{DCE_0}$$

DCE = Dune crest elevation along profile E-F at time t

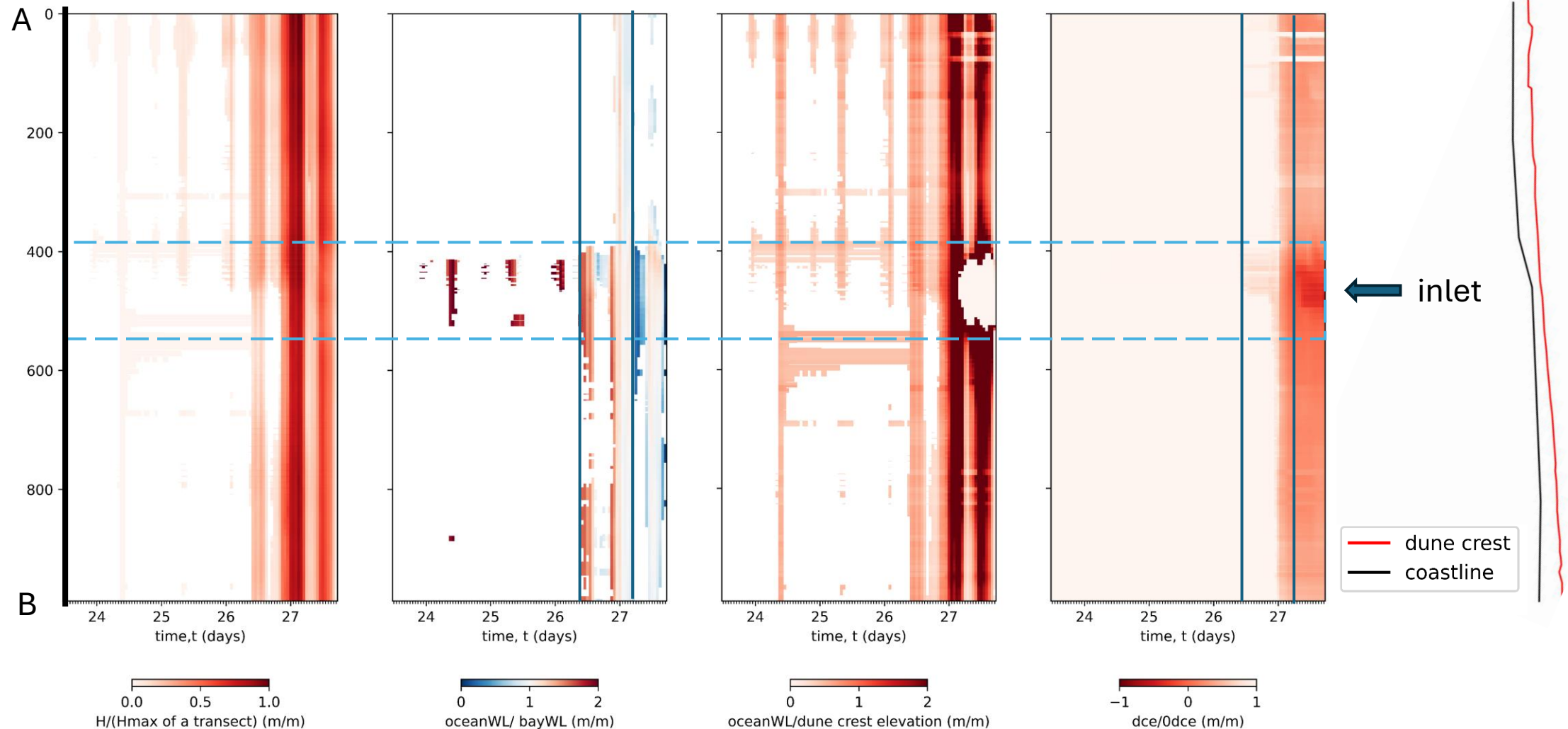
DCE_0 = Dune crest elevation at E-F at time $t=0$

Most red where dune crest elevation has reduced to open an inlet



E-F profile on dune crest

Understanding the hydro-drivers for Helene Hindcast

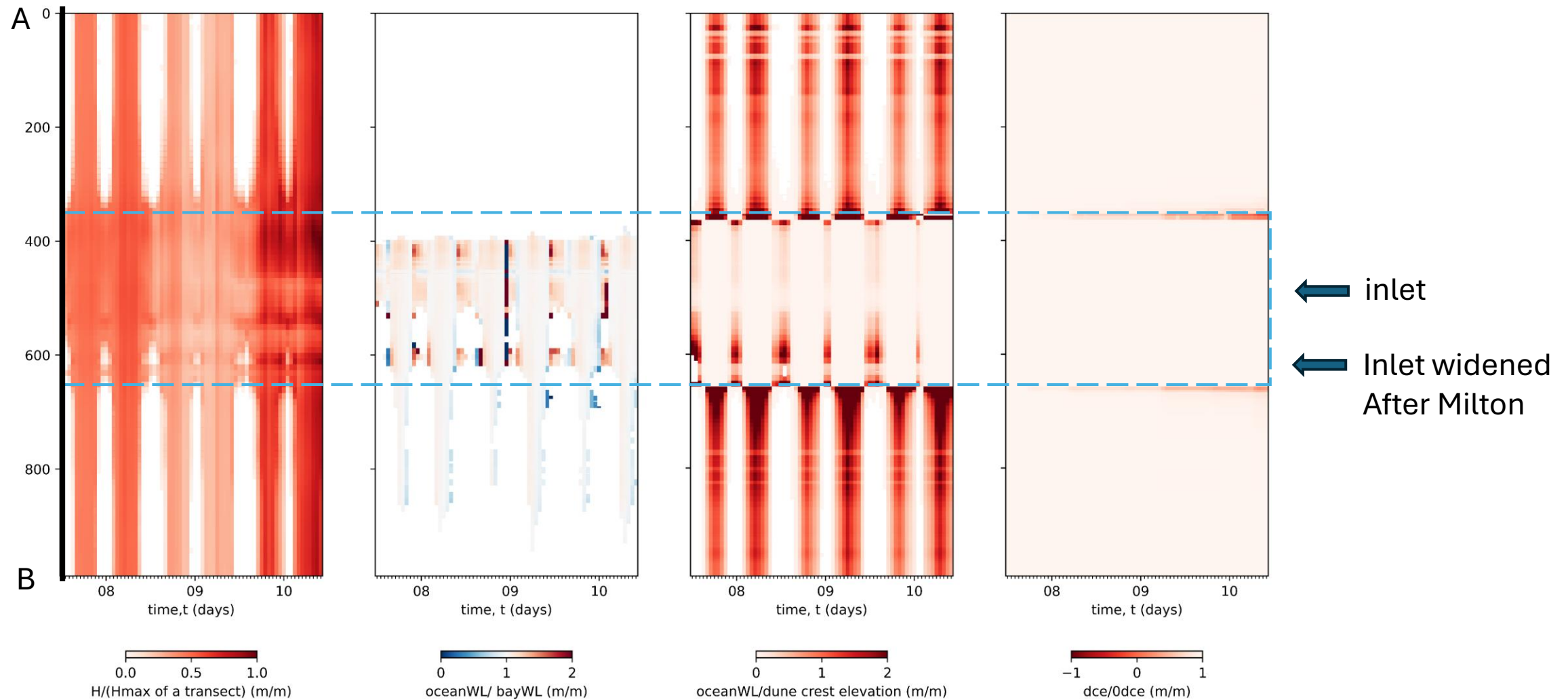


Erosion starts when the water level gradient is 1.5

Inlet starts forming when the water level gradient < 1 , i.e., Bay-side water level is higher

The location coincides with the significant wave height

Understanding the Hydro-drivers for Milton Hindcast



Inlet depth skewed, moves southerward.

Erosion coincides with the highest significant wave height location

Conclusion

- Inlet formation location coincides with the location of the highest wave height alongshore
- Dune erosion starts when the bay-side water level is high and comparable to the sea-side water level
- Inlet location coincides with the lowest beach width
- Inlet doesn't form at the lowest dune elevation
- Further investigation is needed with different storm conditions to see if the same patterns are observed



Thank you

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