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*The State of the Art and Science of Coastal Engineering*

# Morphological Modeling of Low-Dune Headland System Changes Due To Hurricane Forcing

LSU LOUISIANA STATE UNIVERSITY

**Cody L. Johnson, PhD candidate, research fellow**

*Louisiana State University*

Northeastern

**Dr. Qin J. Chen, Professor**

*Northeastern University*




# Overview

- Importance and objectives
- Project description
- Geomorphic context
- Modeling system
- Result and Analysis
- Conclusions
- Future work

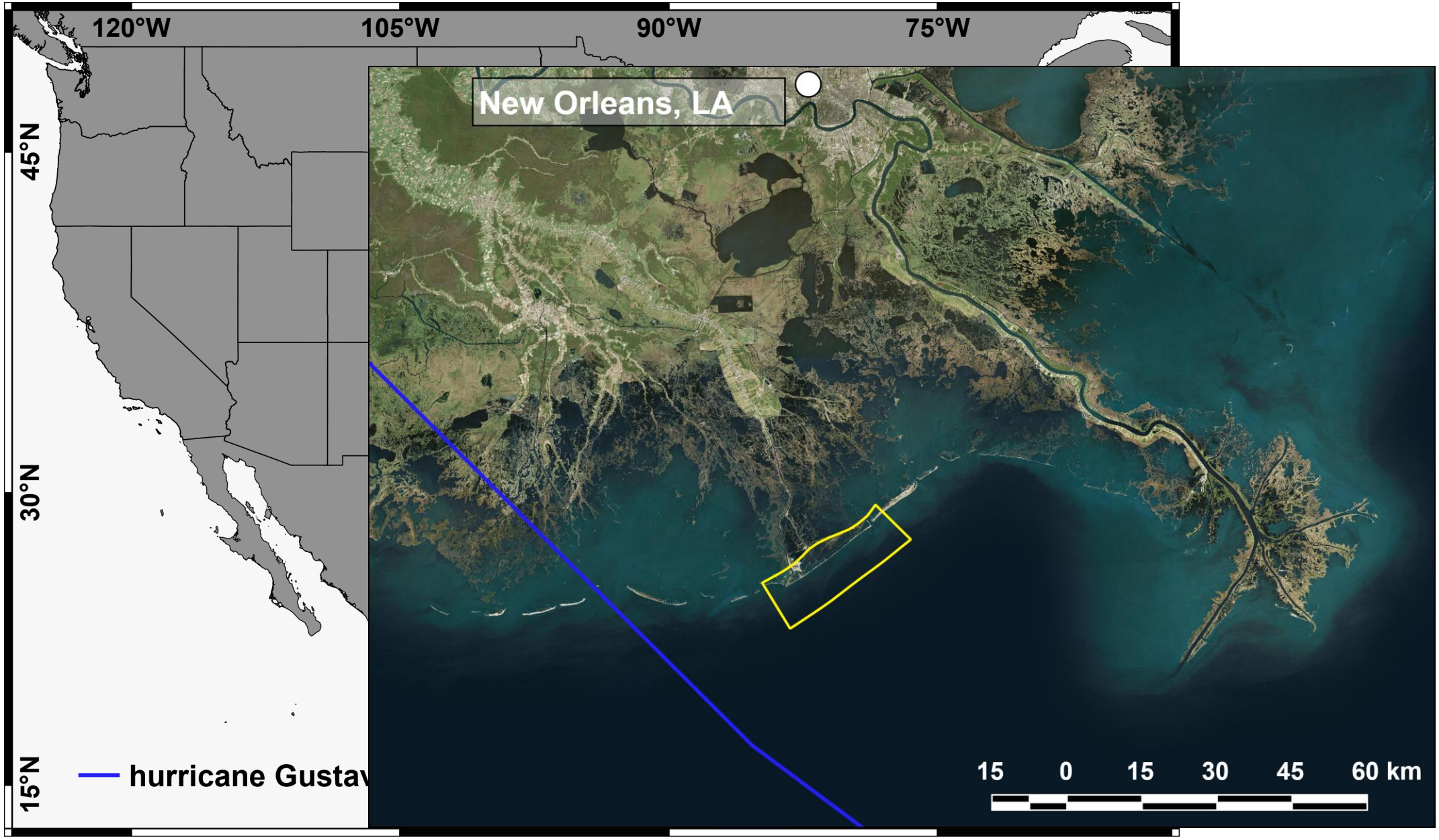

photo credit: Weeks Marine

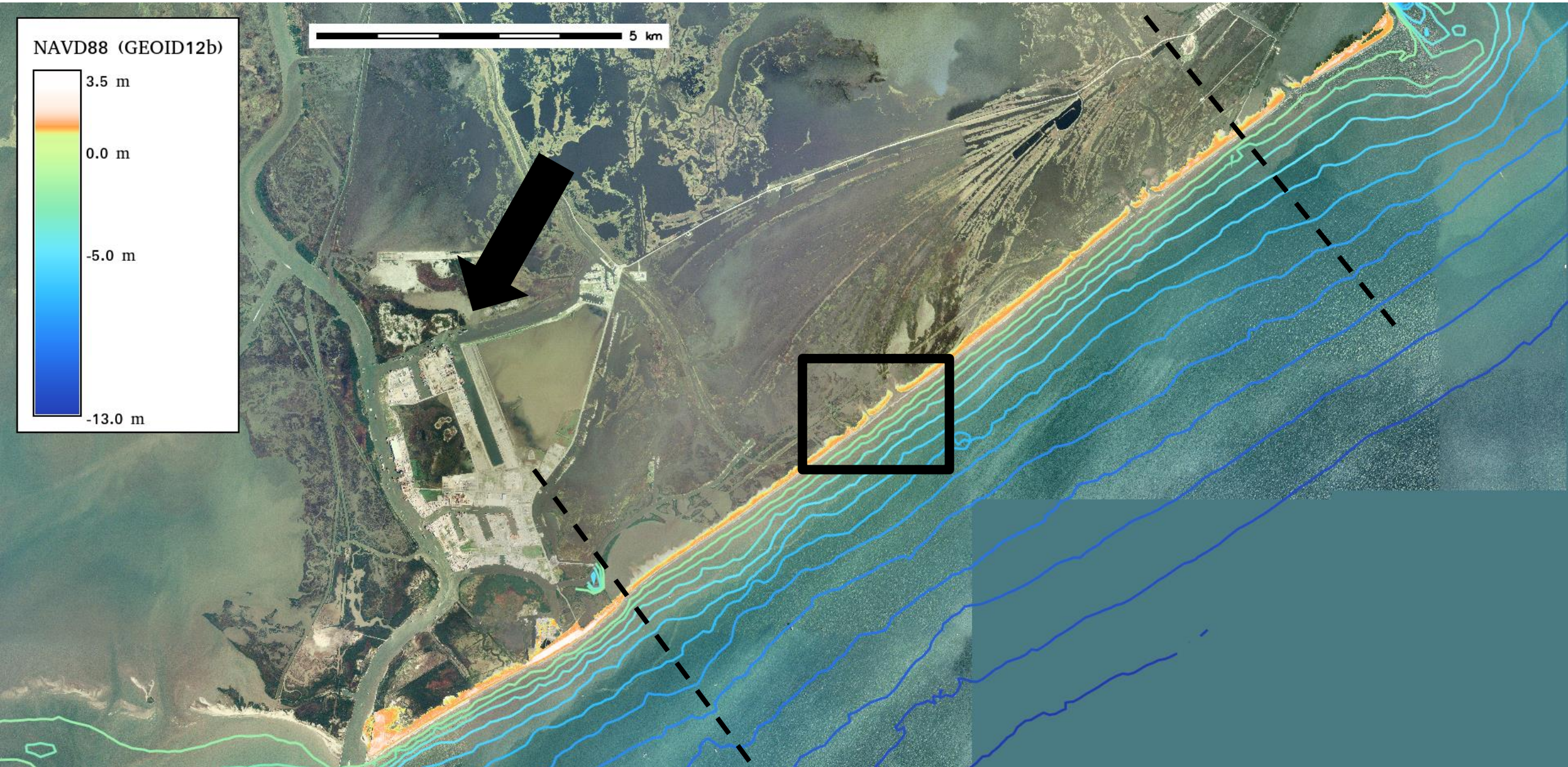
# Importance

- Hurricane driven morphological change threatens coastal sustainability
- Low-elevation sedimentary shorelines are primarily shaped by storm impacts
- Louisiana's fragile coastline protects valuable and strategic infrastructure
- Successful management of our coastal resources rely on predictive tools


# Research objectives

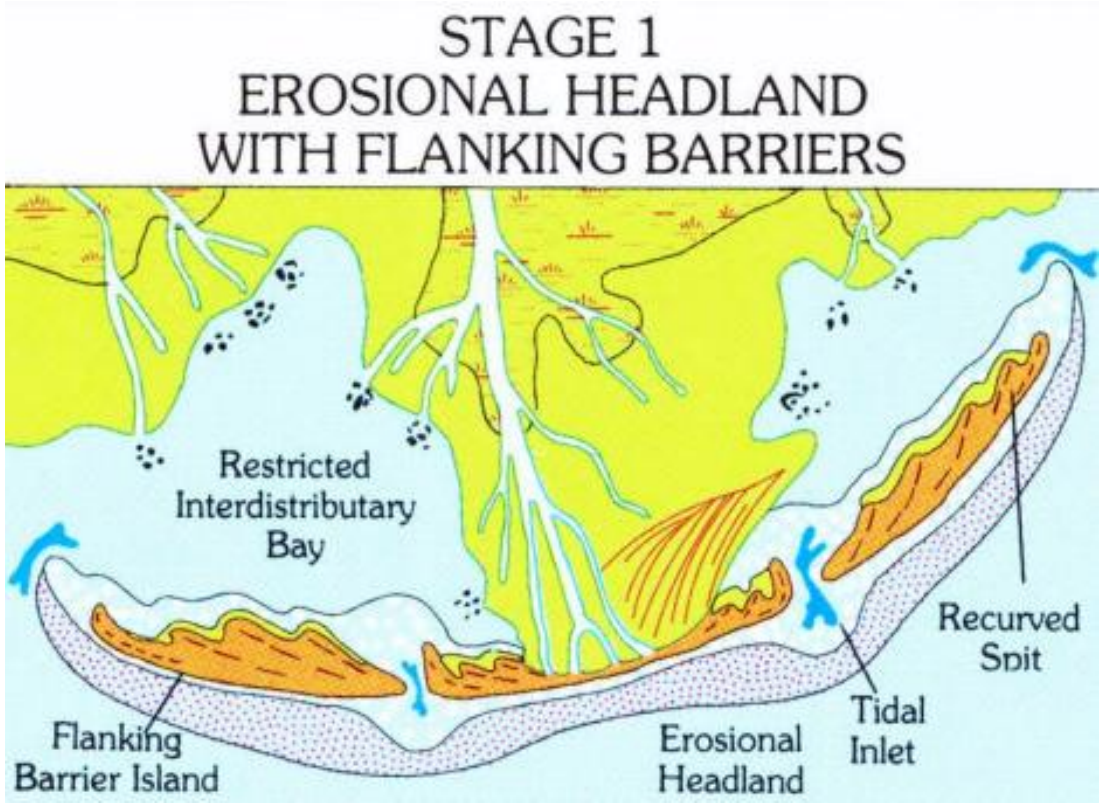
1. Simulate the morphodynamics of hurricane Gustav's (2008) impact to the low-elevation Caminada Headlands (CH), Louisiana
2. Investigate physical processes at work in the relationship between extreme erosion and hurricane driven hydrodynamics at CH
3. Setup modeling framework to forecast future hurricane impacts at CH given its recent restoration


120°W
105°W
90°W
75°W
45°N
30°N
15°N
New Orleans, LA
hurricane Gustav
15 0 15 30 45 60 km

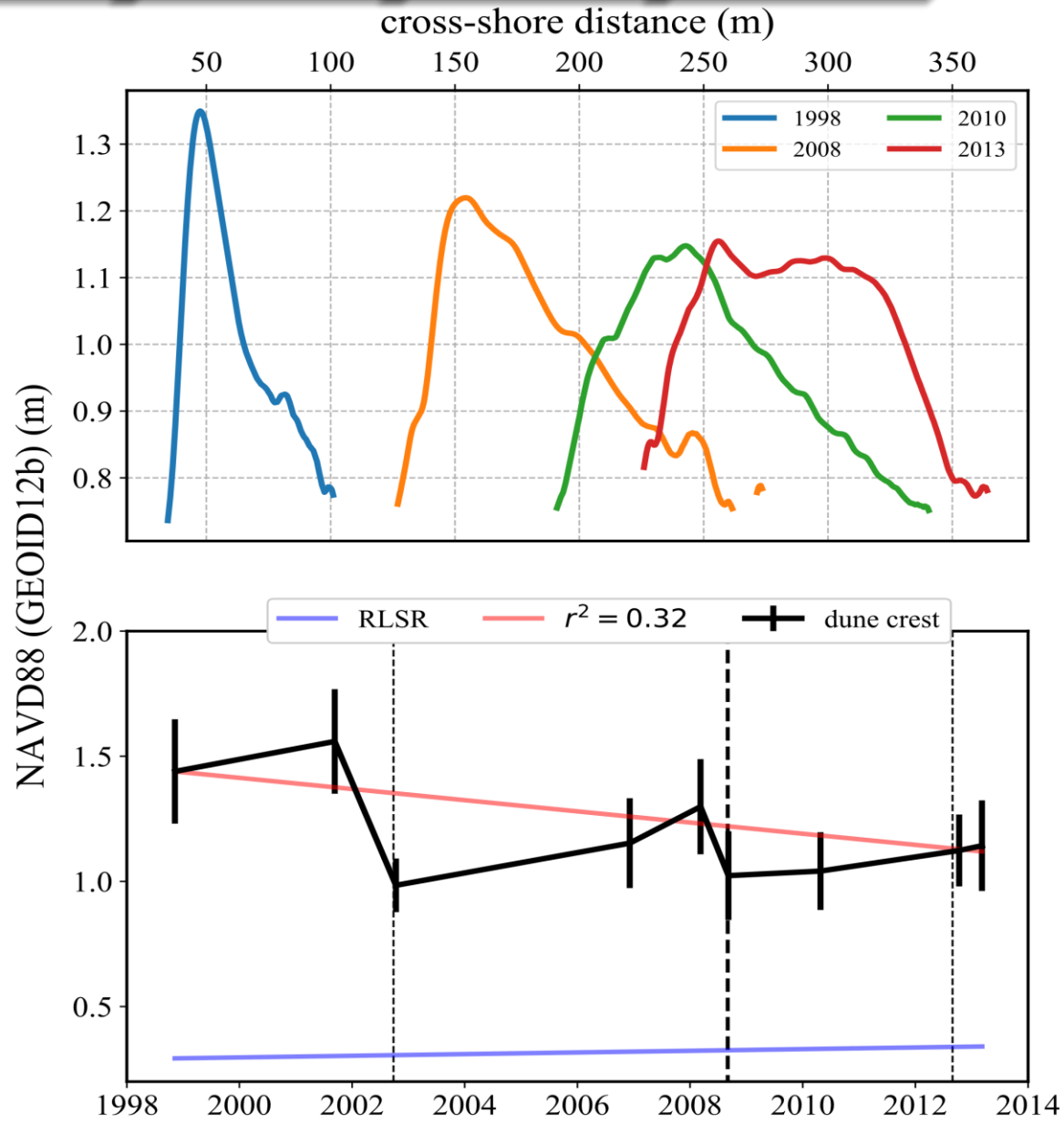

NAVD88 (GEOID12b)
3.5 m
0.0 m
-5.0 m
-13.0 m
5 km


NAVD88 (GEOID12b)
2.5 m
0.0 m
-6.0 m
1 km

# Delta Cycle

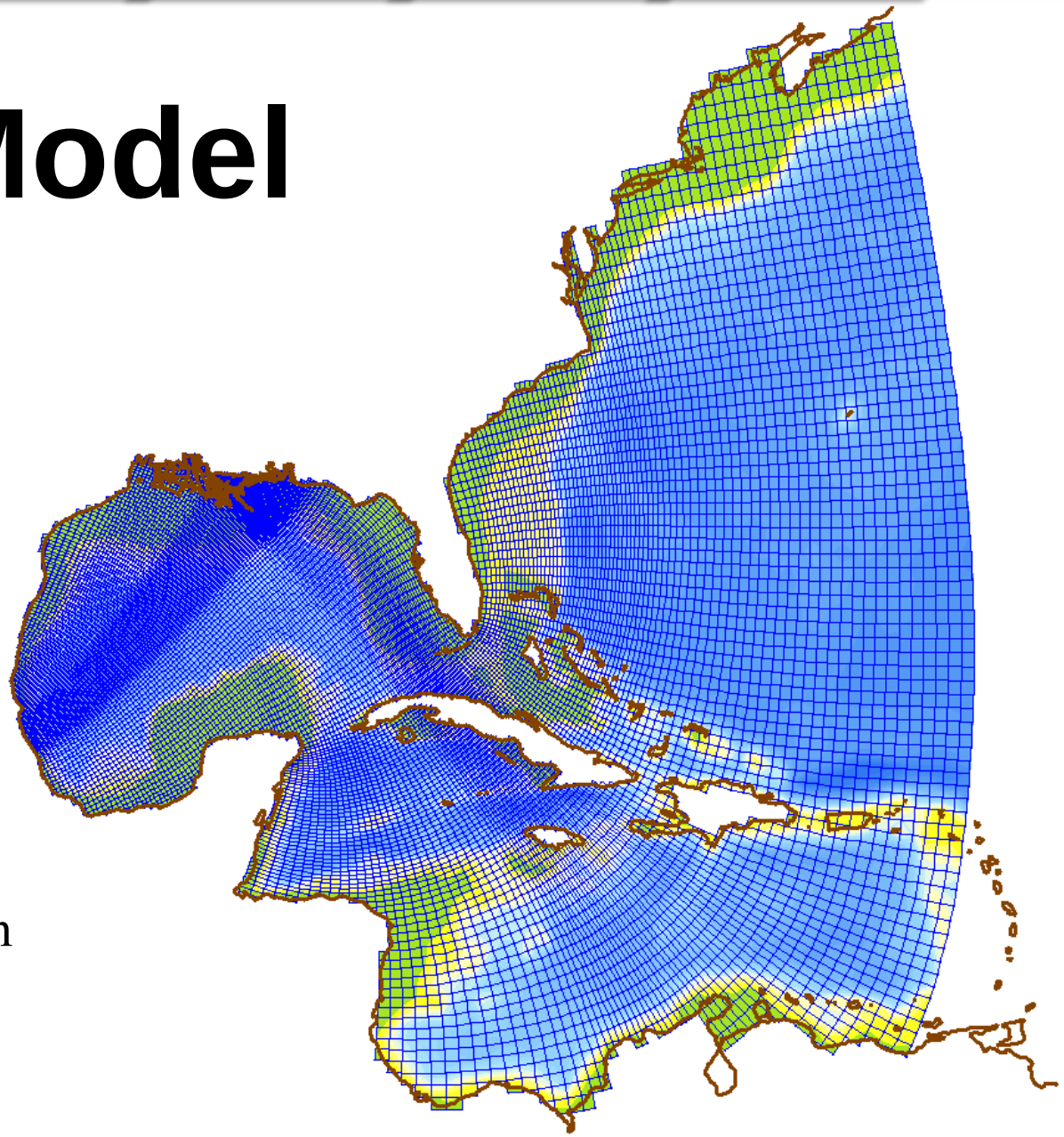



Penland et al. (1988). "Transgressive Depositional Systems of the Mississippi Delta Plain: A Model for Barrier Shoreline and Shelf Sand Development." Journal of Sedimentary Petrology.



# Basin Scale Model

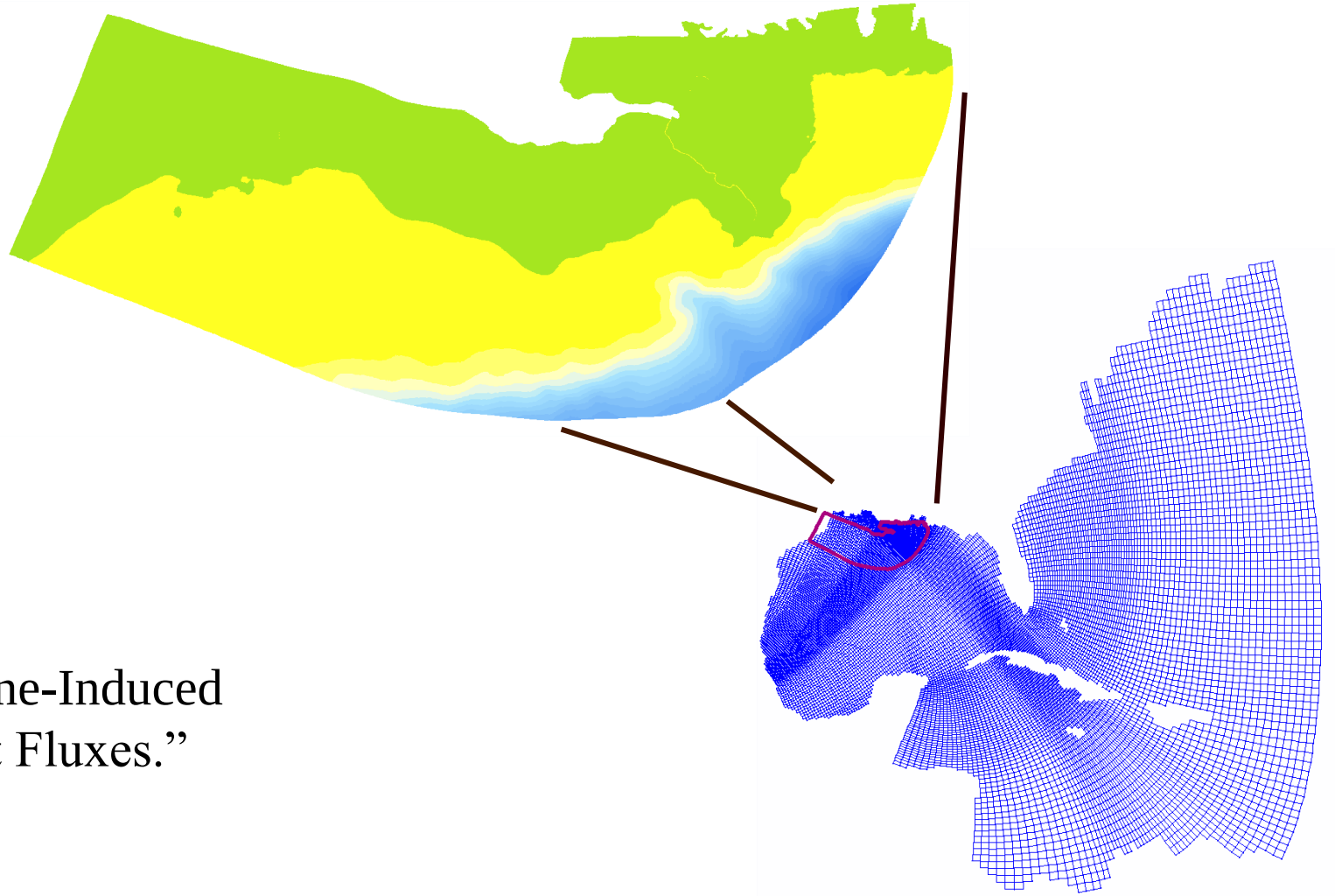
- Tier-1 of nested structure
- Coupled Delft3D-FLOW and SWAN
- 50 km – 10 km resolution
- 17,688 computational elements
- Fast and efficient runs



Hu et al. (2015). "A Numerical Study of Vegetation Impact on Reducing Storm Surge by Wetlands in a Semi-Enclosed Estuary." Coastal Engineering

# Regional Scale Model

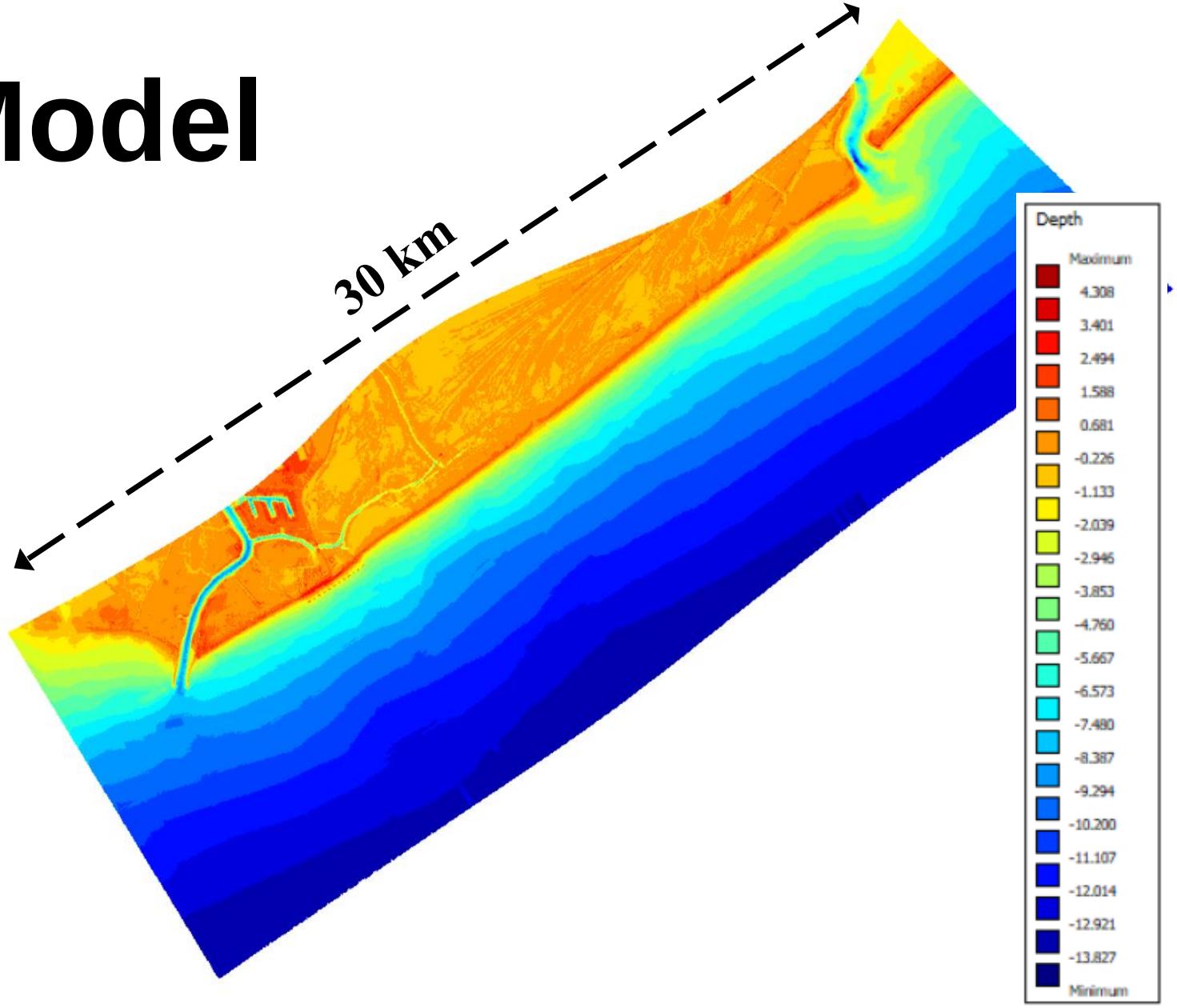
- Tier-2: nested in basin scale model
- Coupled Delft3D-FLOW + SWAN
- 3 km – 60 m resolution
- 430,620 elements



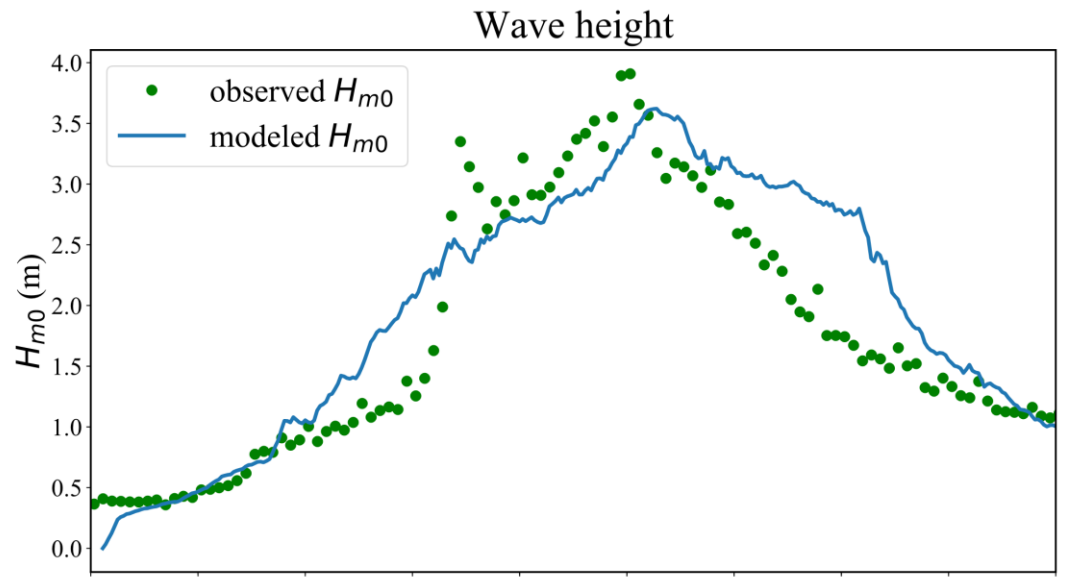
Liu et al. (2018). “Modeling Hurraicane-Induced Wetland-Bay and Bay-Shelf Sediment Fluxes.” Coastal Engineering.

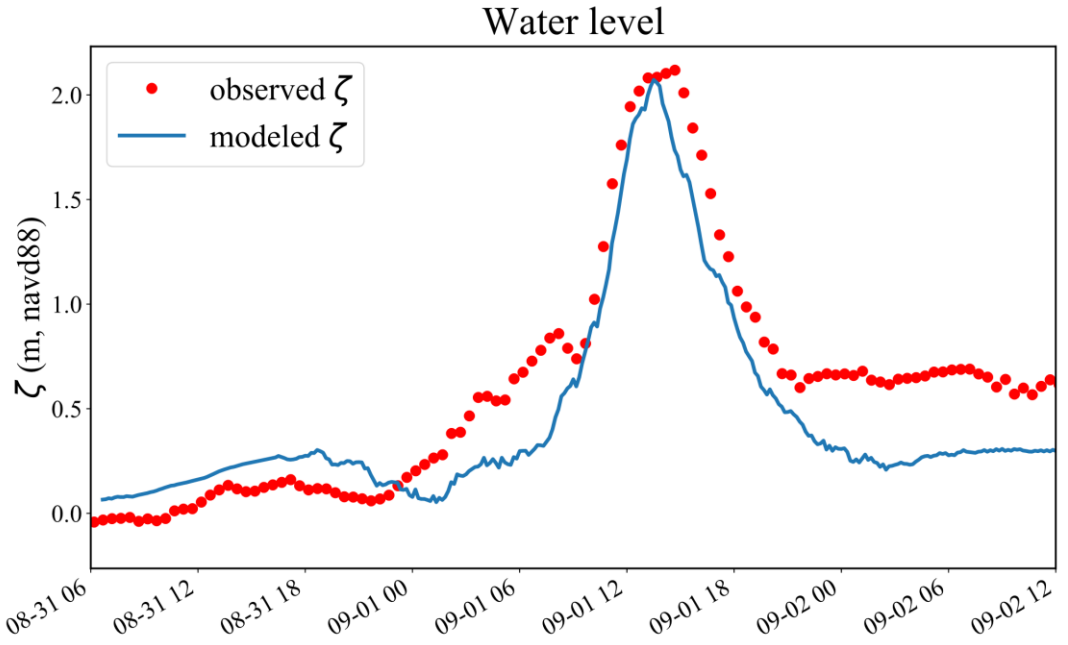
# XBeach Model

- Spatiotemporally variable boundary conditions
- Curvilinear grid
- 2 – 40 m resolution
- Inlets and back-barrier channels resolved
- Lidar, terrestrial RTK and single-beam bathymetric surveys
- 1,011,164 elements

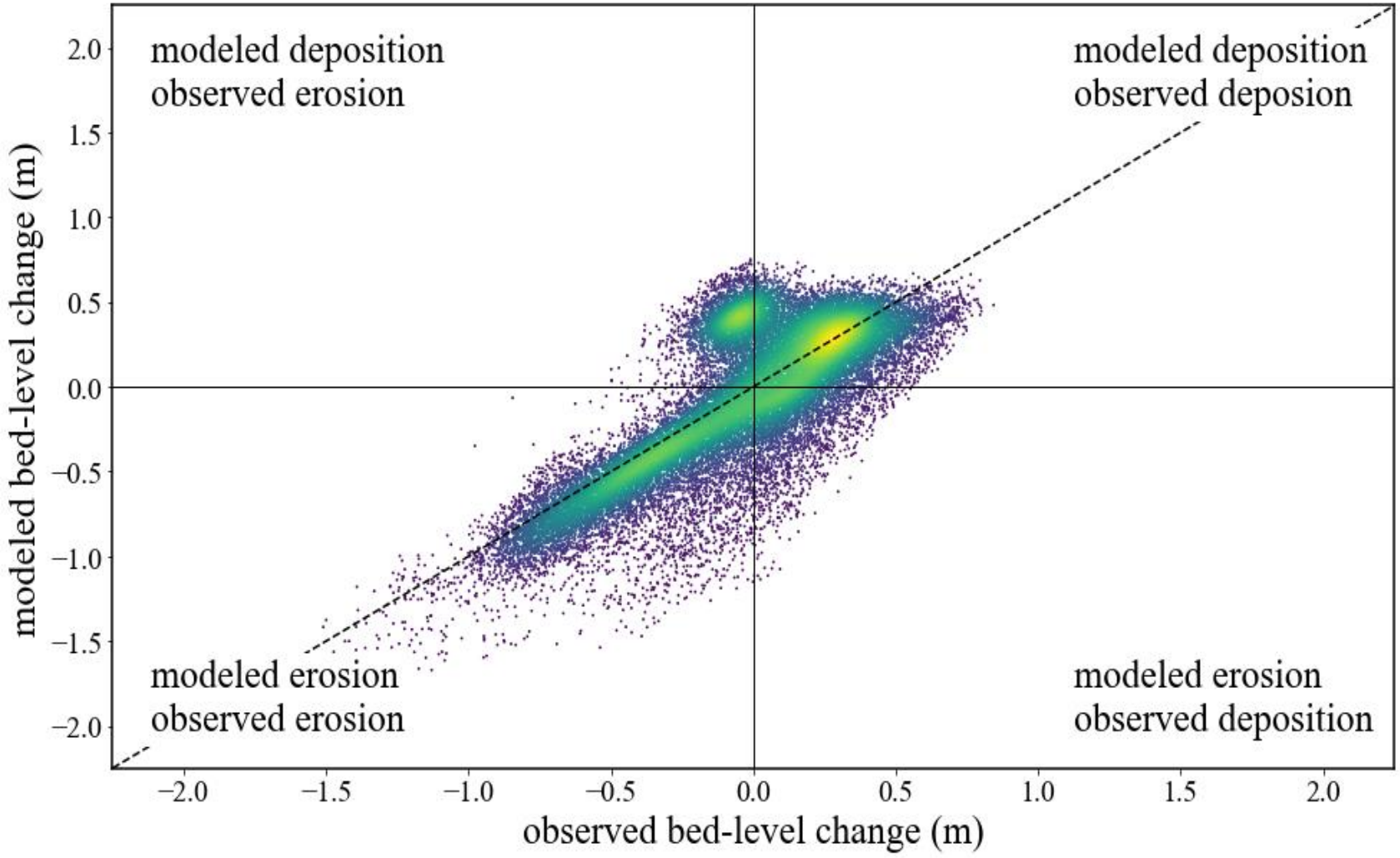


# Hydrodynamics

# Morphodynamics

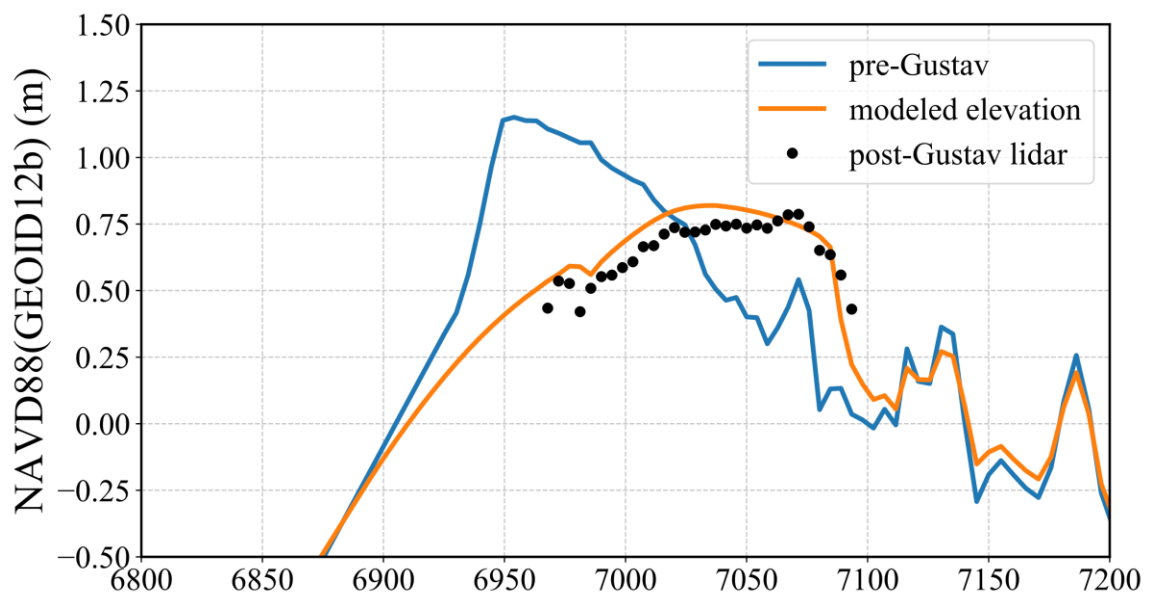


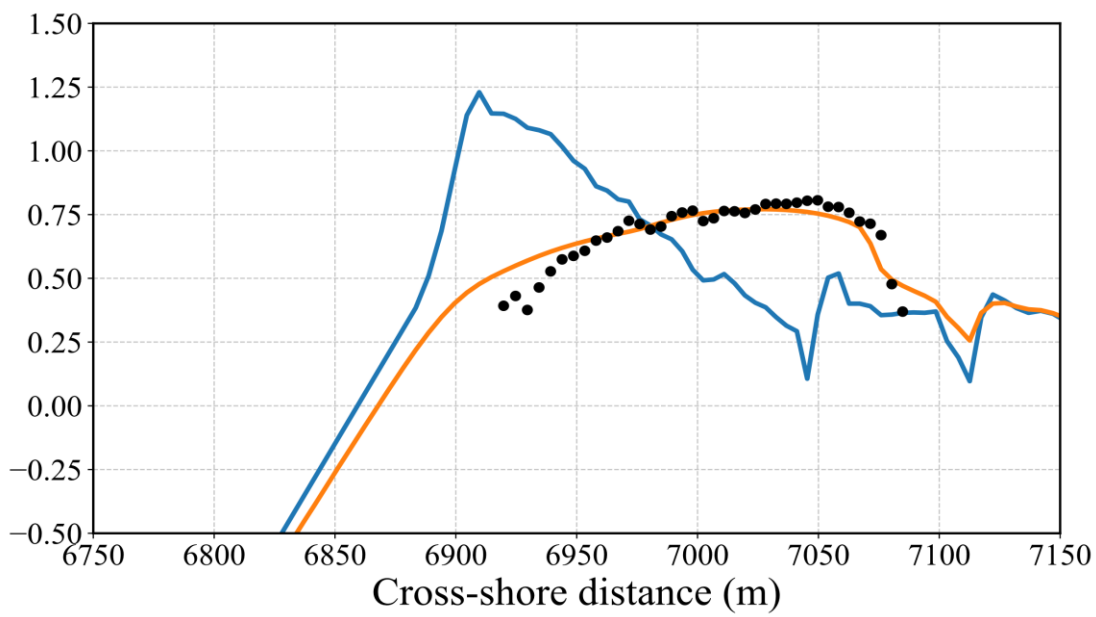

$$Skill = 1 - \frac{\sum_{i=1}^{N}(\Delta zb_{observed,i} - \Delta zb_{model,i})^2}{\sum_{i=1}^{N}(\Delta zb_{observed,i})^2}$$

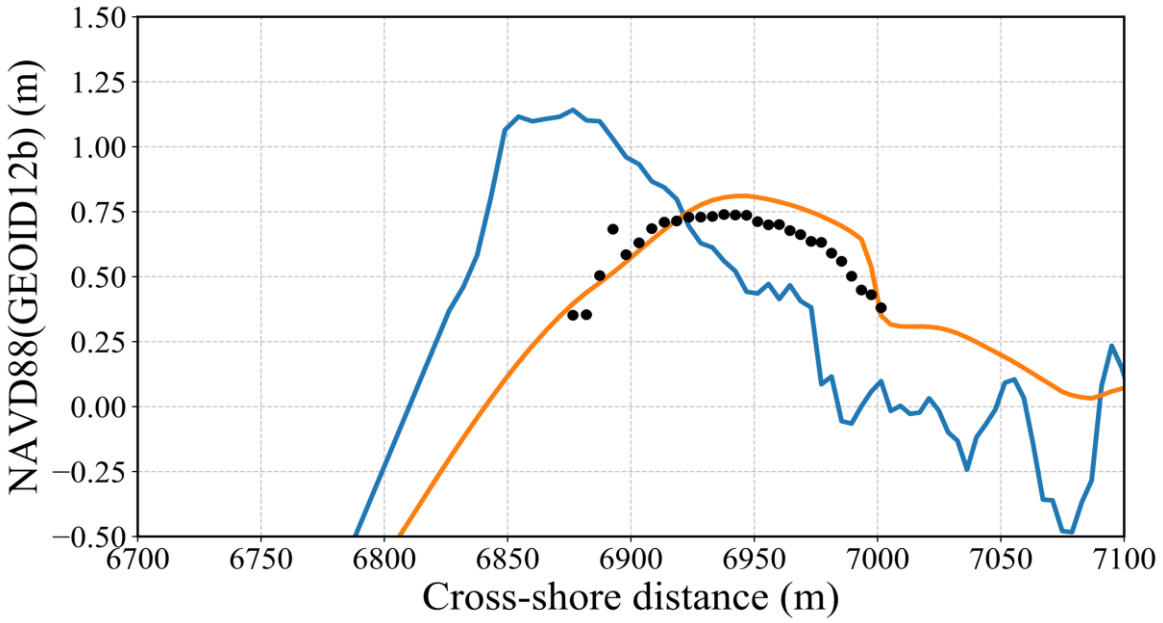
$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(zb_{model,i} - zb_{observed,i})^2}$$

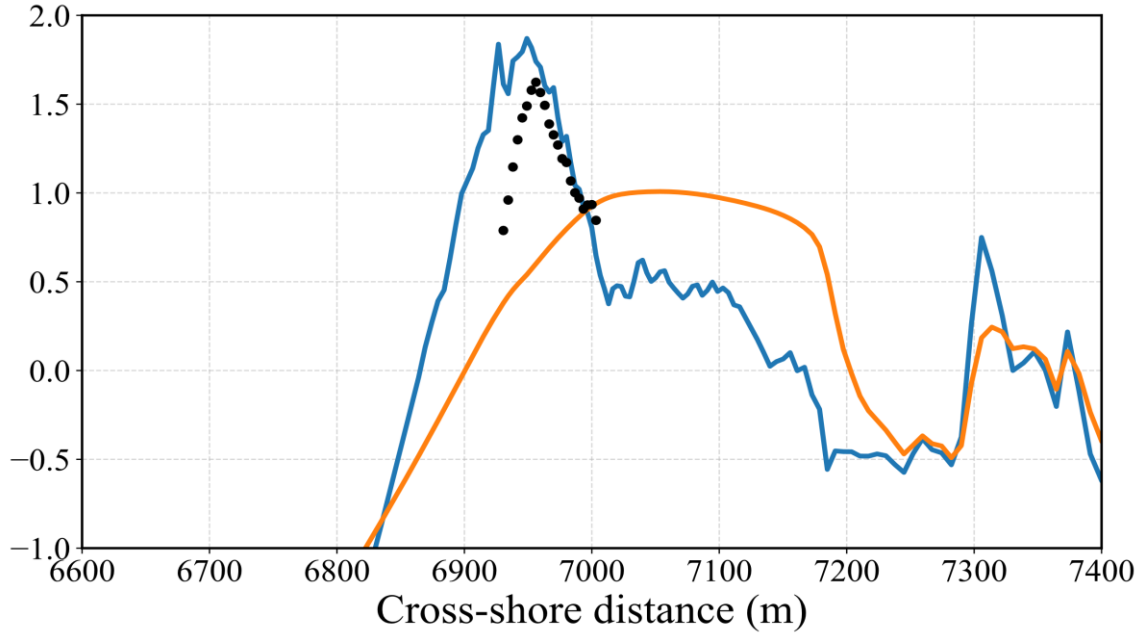
$$Bias = \frac{1}{N}\sum_{i=1}^{N}(zb_{model,i} - zb_{f,observed})$$

| Statistic | Value |
|---|---|
| RMSE (m) | 0.279 |
| Bias (m) | -0.029 |
| Skill | 0.405 |


pre-Gustav
modeled elevation
post-Gustav lidar
NAVD88(GEOID12b) (m)

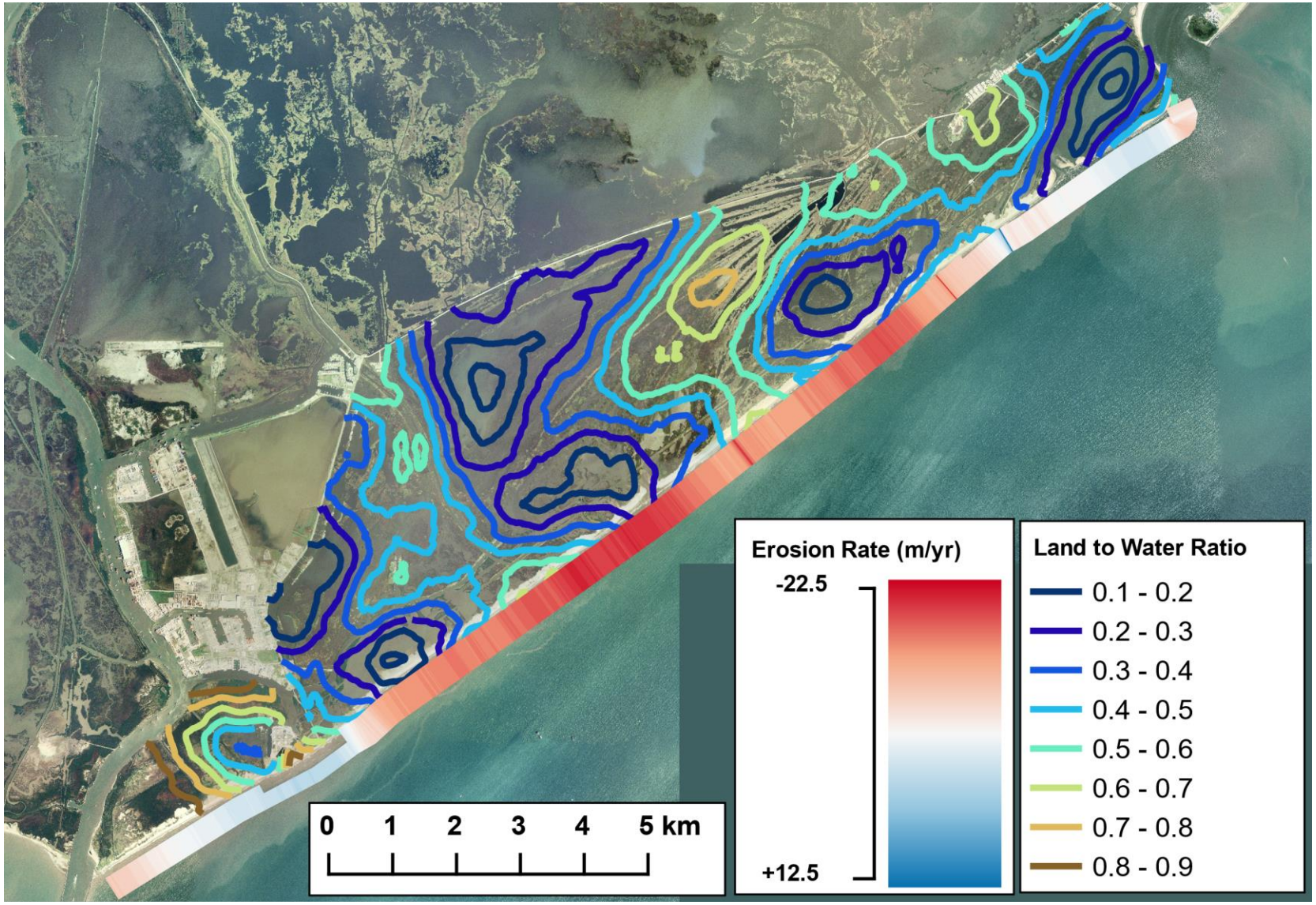

Cross-shore distance (m)

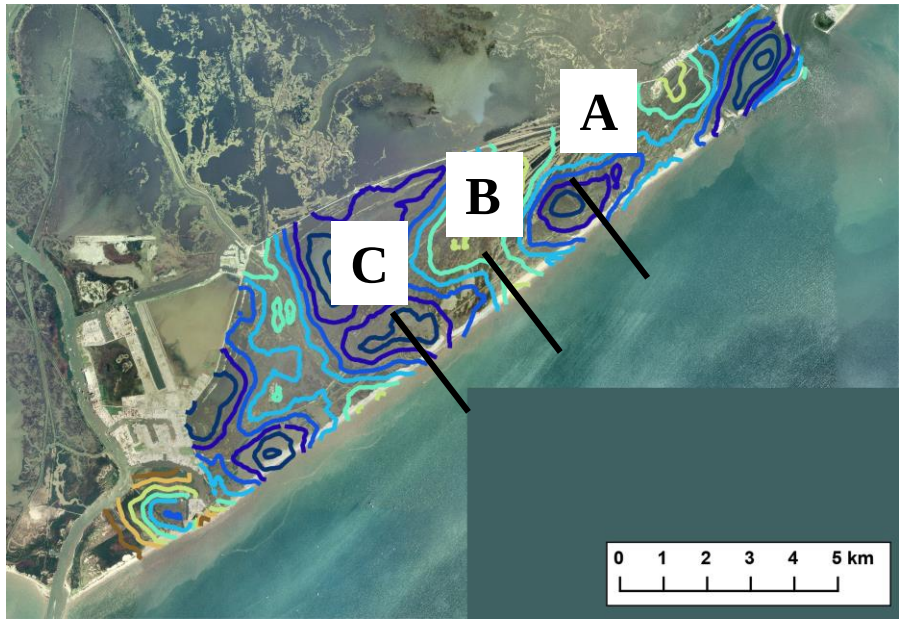

NAVD88(GEOID12b) (m)
Cross-shore distance (m)

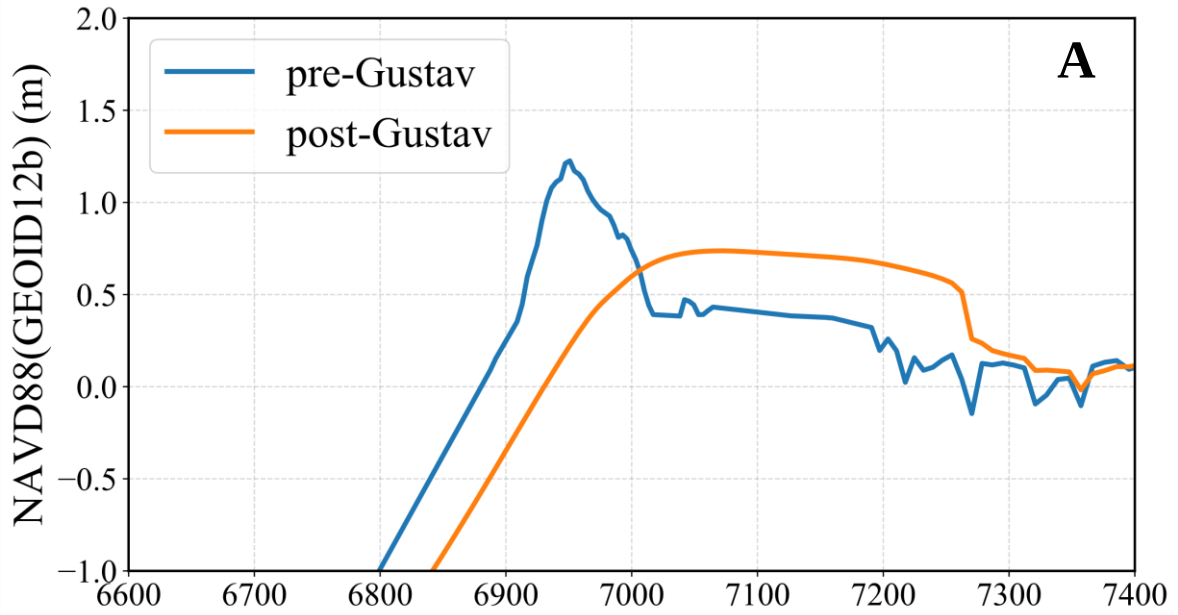

Cross-shore distance (m)

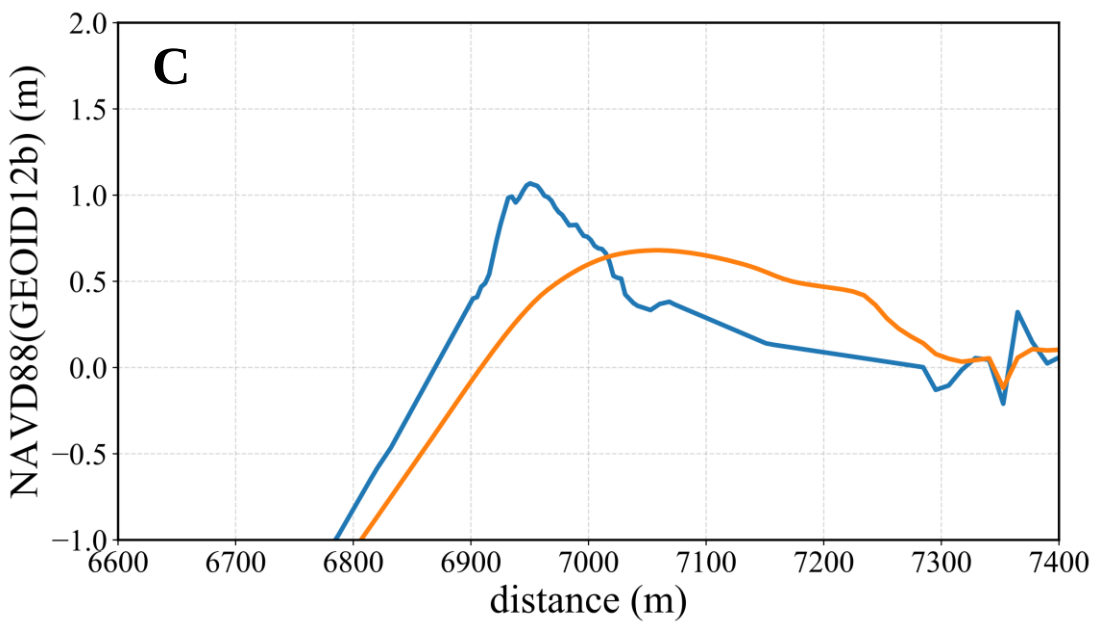
# Analysis

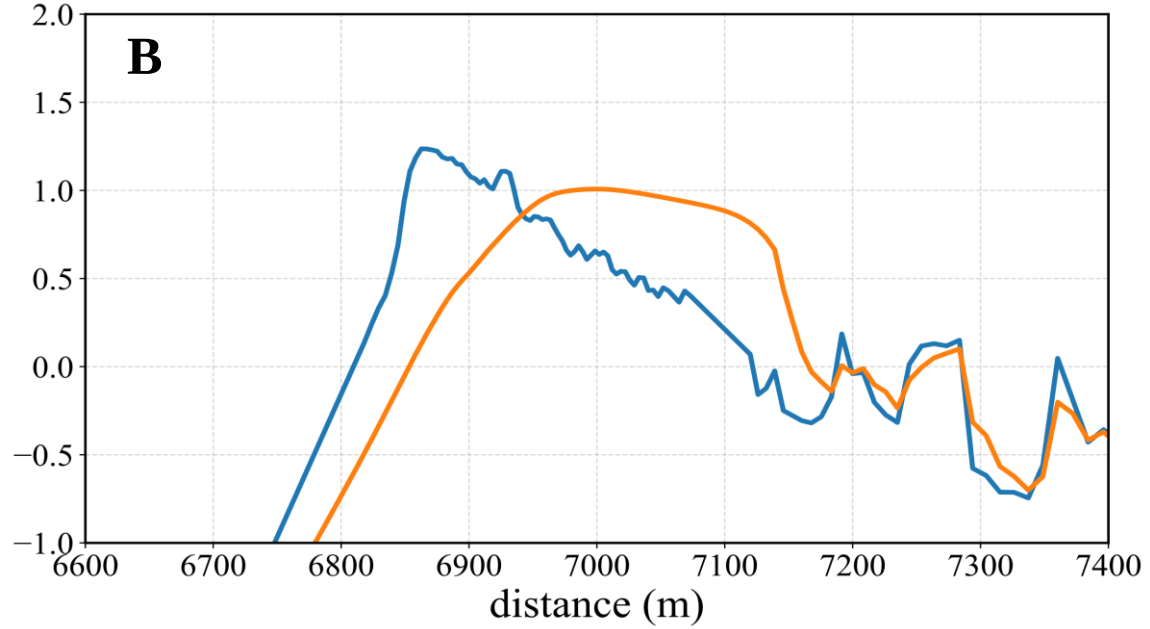
1. Erosion rate relationship to back-barrier open water
2. Cross-shore velocity distribution and sediment transport

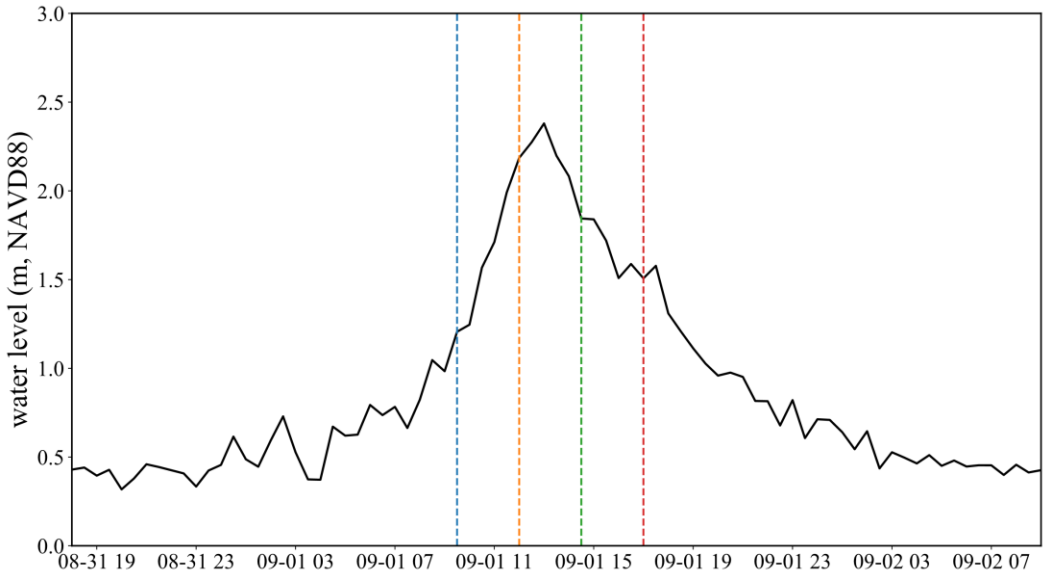


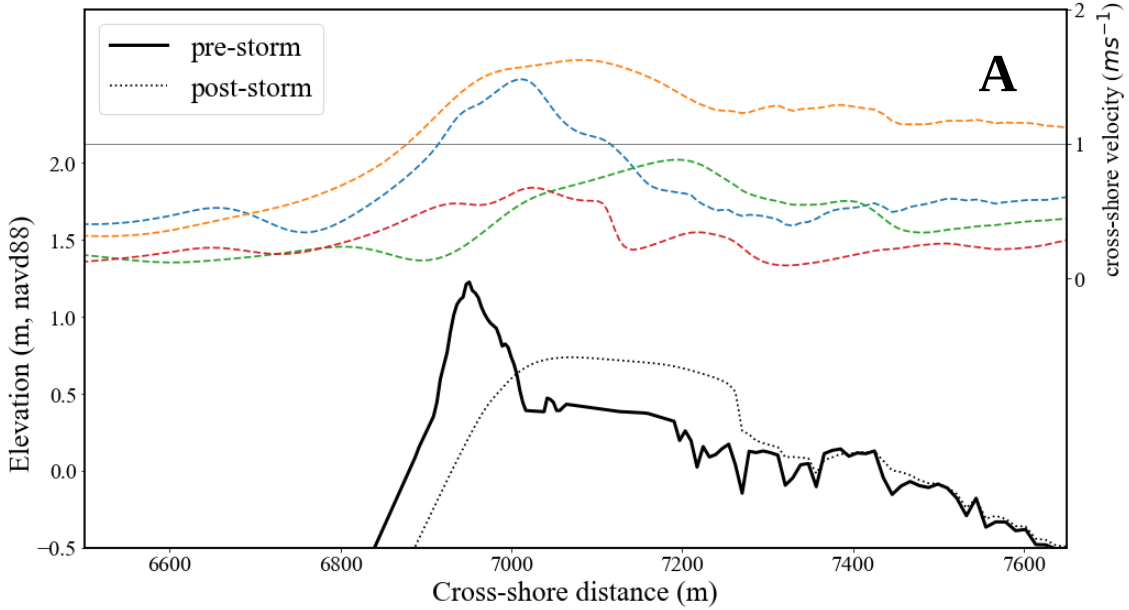

A
B
C
0 1 2 3 4 5 km

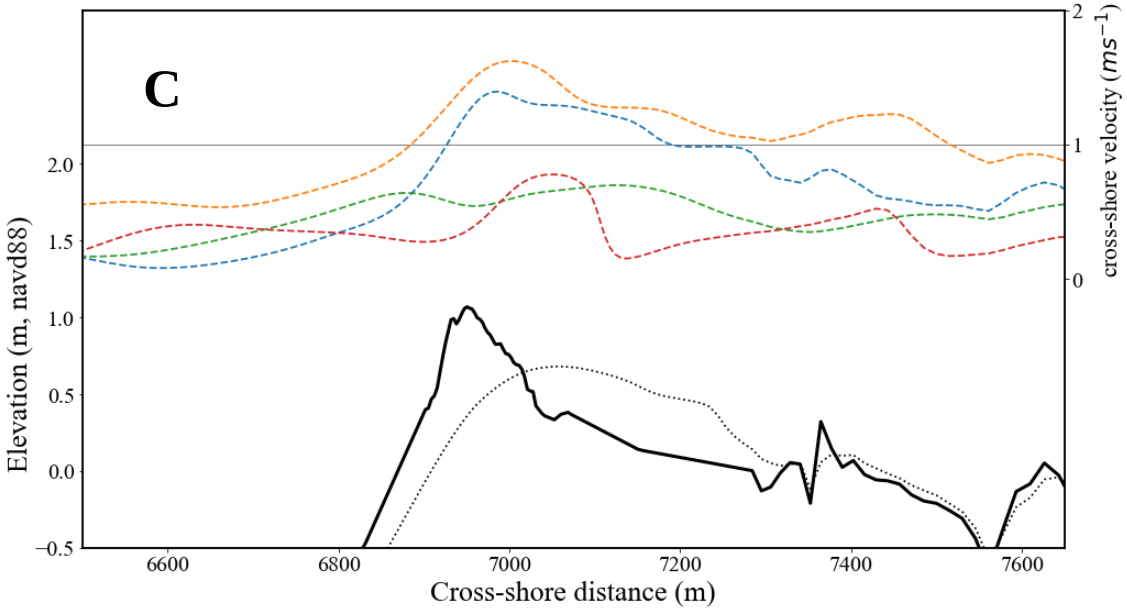

A
pre-Gustav
post-Gustav
NAVD88(GEOID12b) (m)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
6600
6700
6800
6900
7000
7100
7200
7300
7400

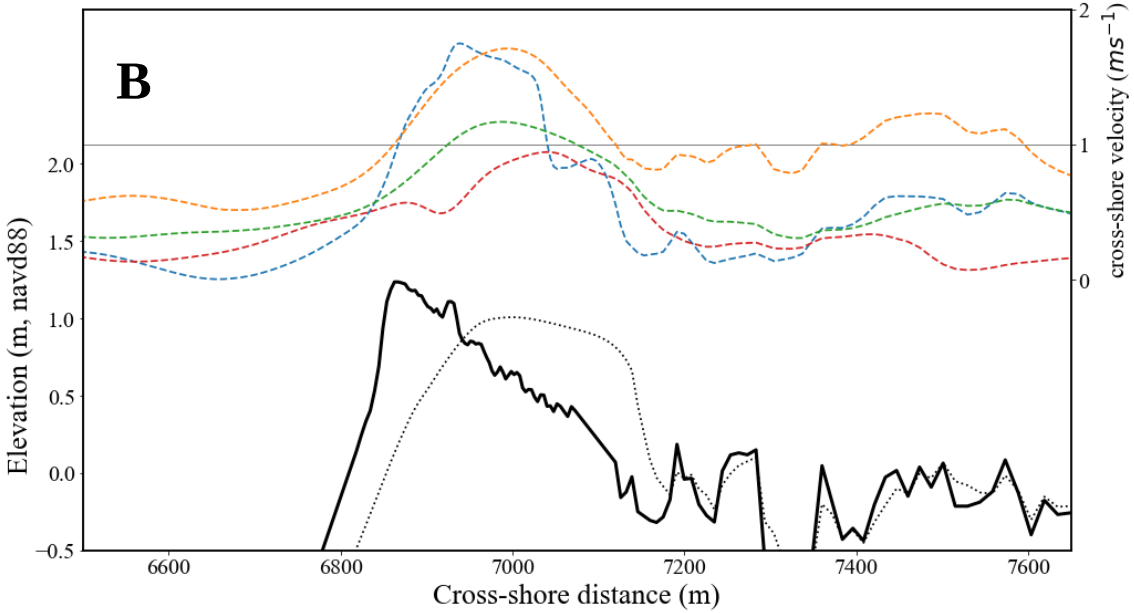

C
NAVD88(GEOID12b) (m)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
6600
6700
6800
6900
7000
7100
7200
7300
7400
distance (m)


B
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
6600
6700
6800
6900
7000
7100
7200
7300
7400
distance (m)


water level (m, NAVD88)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
08-31 19
08-31 23
09-01 03
09-01 07
09-01 11
09-01 15
09-01 19
09-01 23
09-02 03
09-02 07

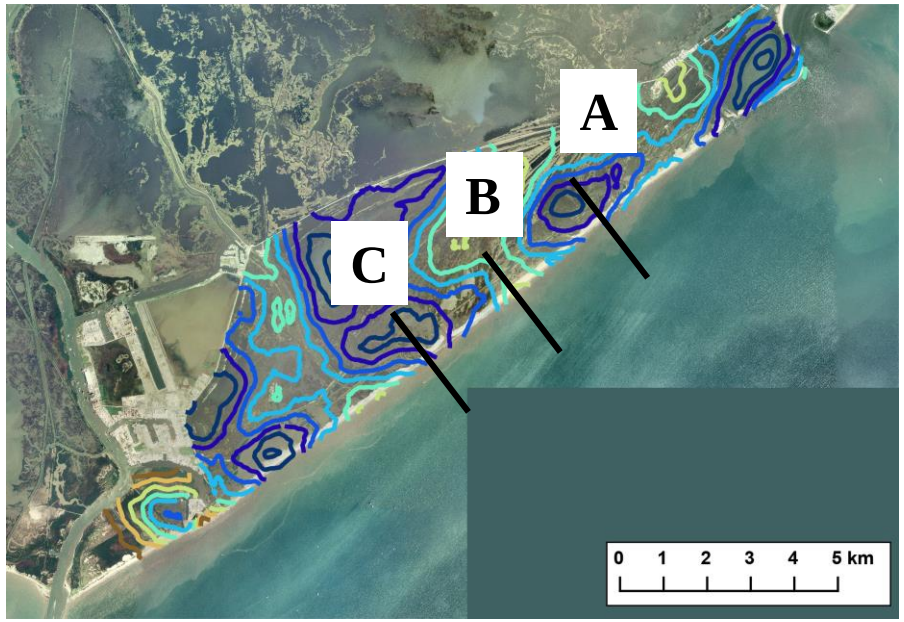

pre-storm
post-storm
A
Elevation (m, navd88)
cross-shore velocity ($ms^{-1}$)
Cross-shore distance (m)
6600
6800
7000
7200
7400
7600

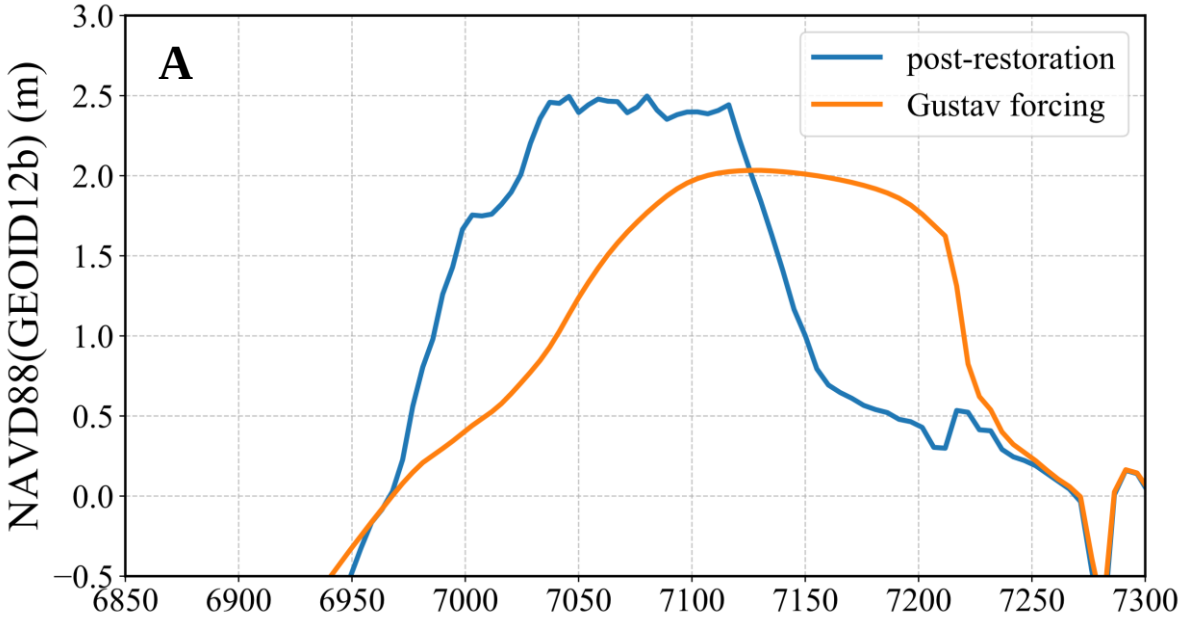

C
Elevation (m, navd88)
cross-shore velocity ($ms^{-1}$)
Cross-shore distance (m)
6600
6800
7000
7200
7400
7600

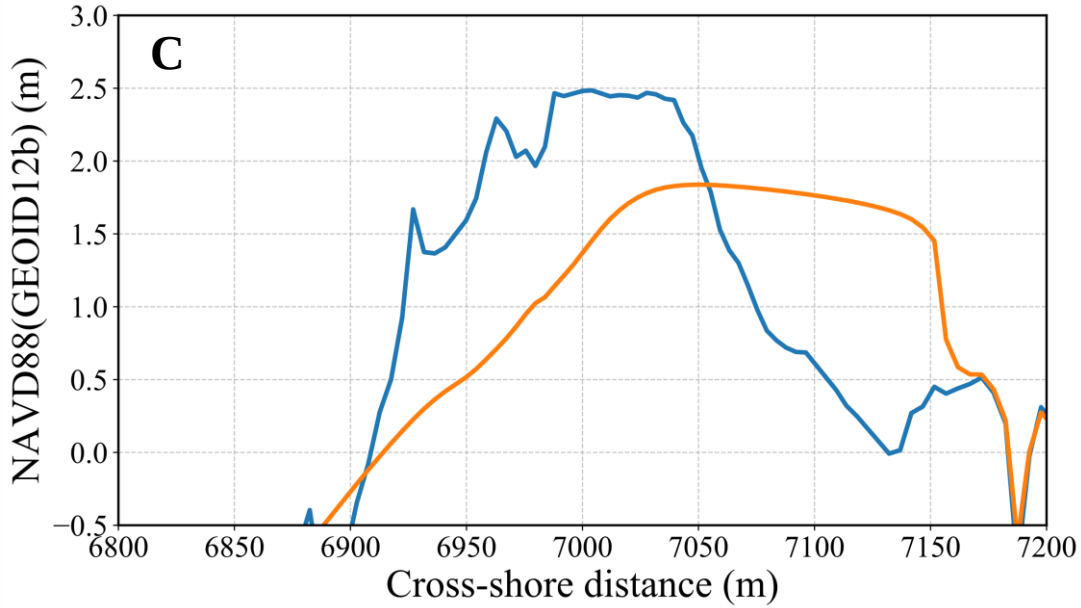

B
Elevation (m, navd88)
cross-shore velocity ($ms^{-1}$)
Cross-shore distance (m)
6600
6800
7000
7200
7400
7600

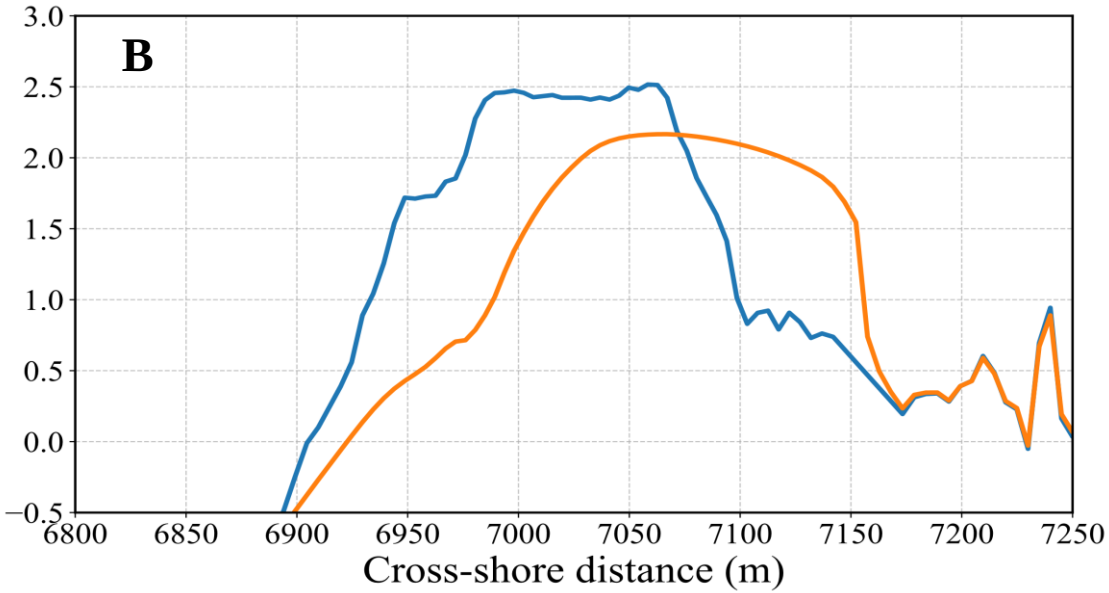
# Preliminary Conclusions

- Back-barrier accommodation space enables greater landward sediment transport for similar dune crest elevations
- For low-elevation dune systems, dune height may not be the controlling factor for storm impacts' influence on long-term morphological change


A
B
C
0 1 2 3 4 5 km


A
post-restoration
Gustav forcing
NAVD88(GEOID12b) (m)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
6850 6900 6950 7000 7050 7100 7150 7200 7250 7300


C
NAVD88(GEOID12b) (m)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
6800 6850 6900 6950 7000 7050 7100 7150 7200
Cross-shore distance (m)


B
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
6800 6850 6900 6950 7000 7050 7100 7150 7200 7250
Cross-shore distance (m)

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- LA Board of Regents
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