Morphological modeling of hurricane impacts on barrier islands

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IFMSIP: Increasing the Fidelity of Morphological Storm Impact Predictions

- Predicting the hurricane impact on U.S. barrier island morphology

- Improve accuracy of event-driven morphological predictions by
  - Best-estimate hydrodynamic forcing and initial conditions
  - constraining free parameter space
  - assessing sensitivity to variations in input

- Collaboration with partners: U.S. Geological Survey, University of Delaware, University of Florida and Naval Research Lab
- Funded by the Office of Naval Research, contract N00014-17-1-2459

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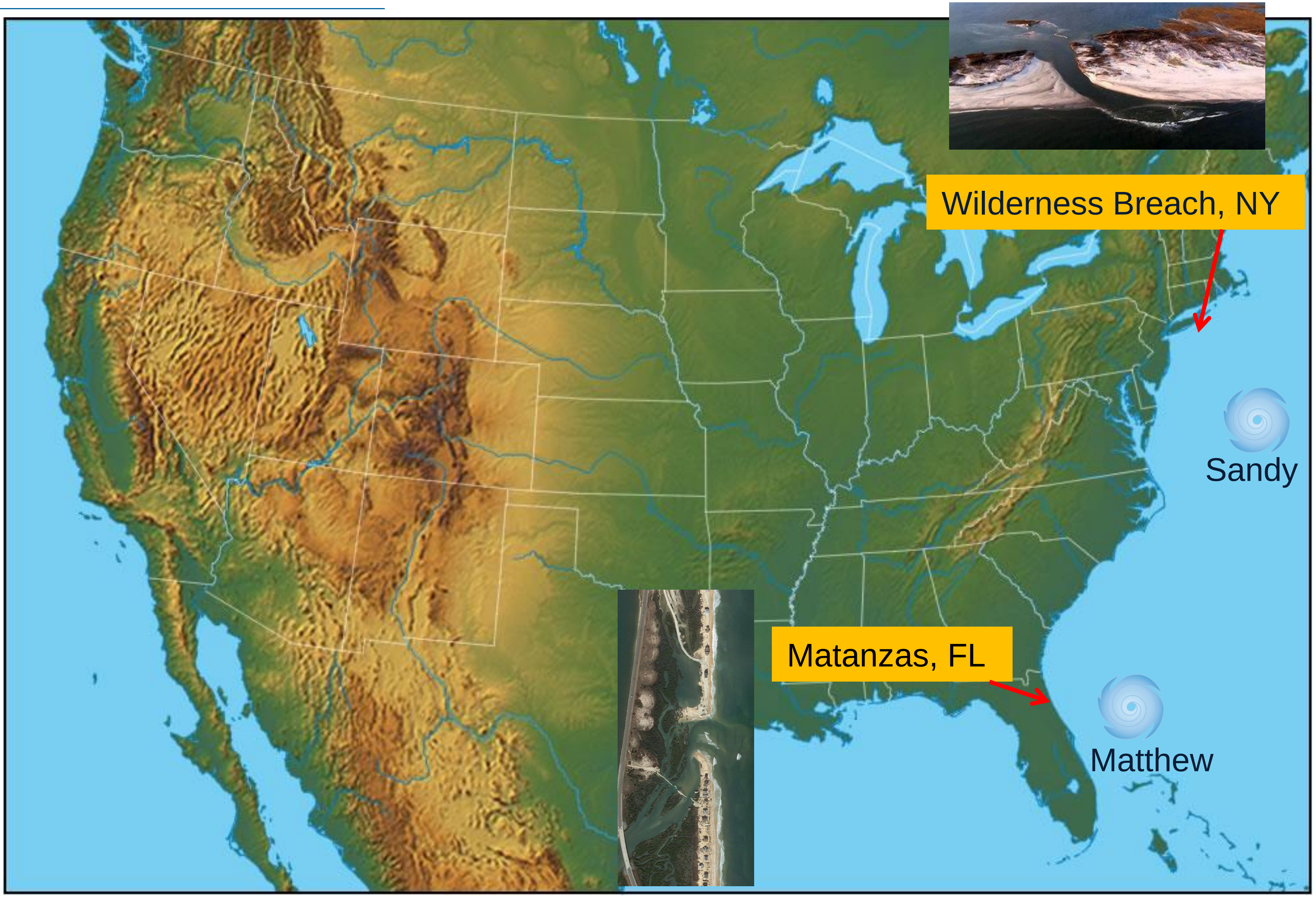
Two case studies considered: Wilderness Breach and Matanzas



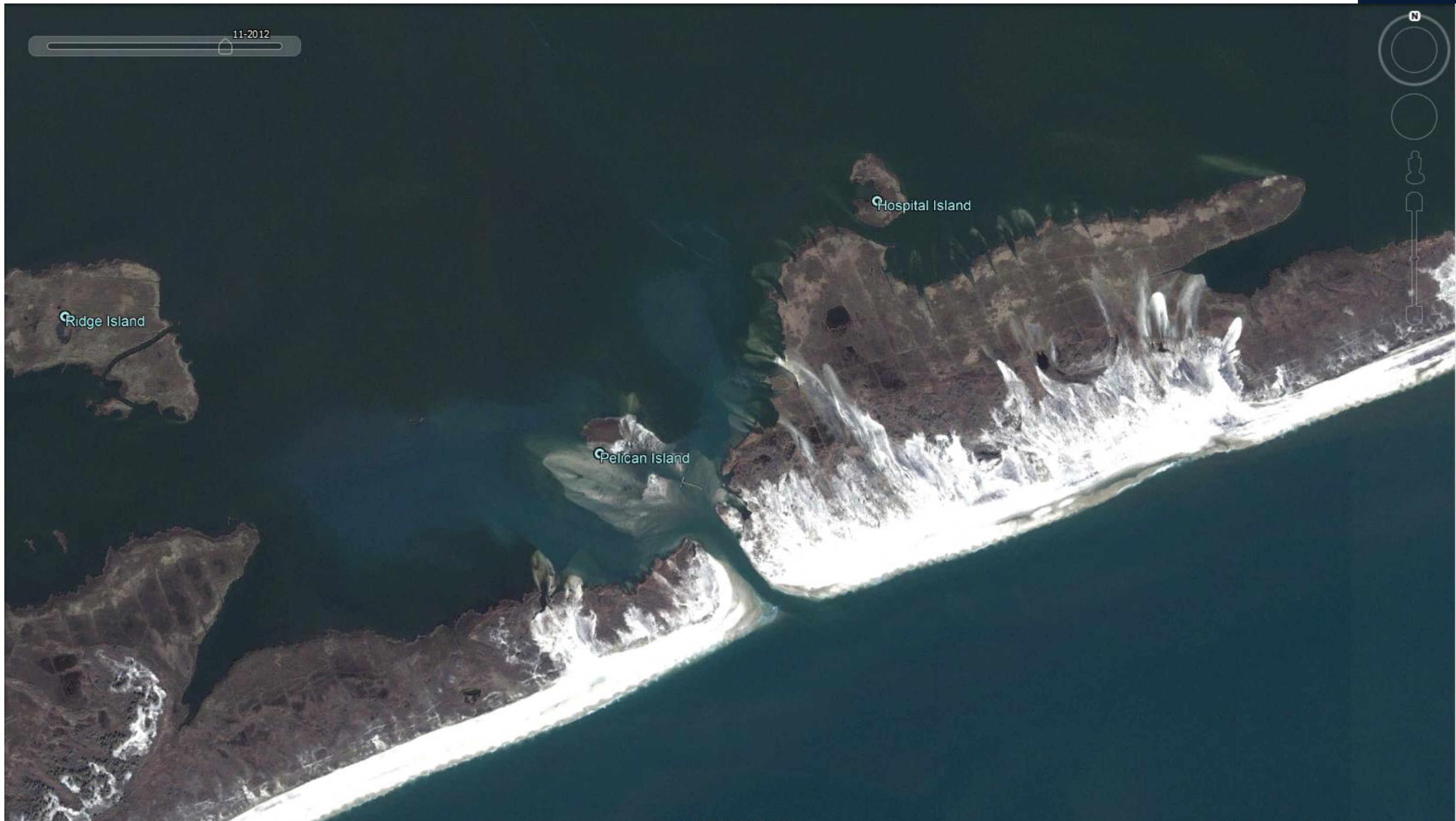
Matanzas and Wilderness Breach - before

Complex barrier island case with:

- Sandy beach
- Vegetated dunes
- Buildings and roads
- Back-bay marsh
- Adjacent tidal inlets

Matanzas and Wilderness Breach - after

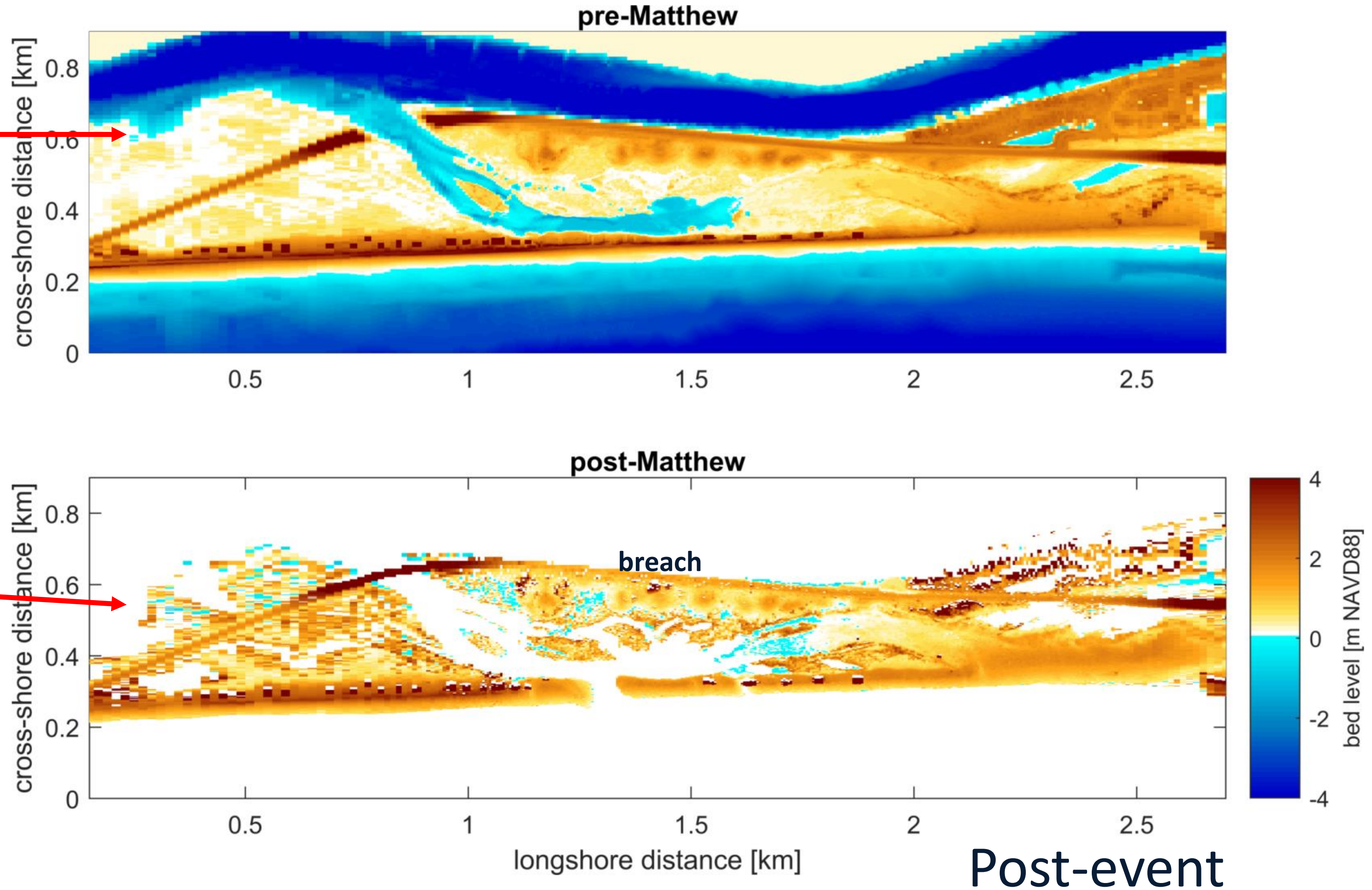
- Hurricane Matthew caused overwash, erosion and 120m wide breach
- Hurricane Sandy caused overwash, 4 m vertical erosion and 80 m breach



XBeach model inputs

- Topo/bathymetry:
  - Pre-event LIDAR
  - Post-event “Structure for Motion” or LIDAR

Pre-event

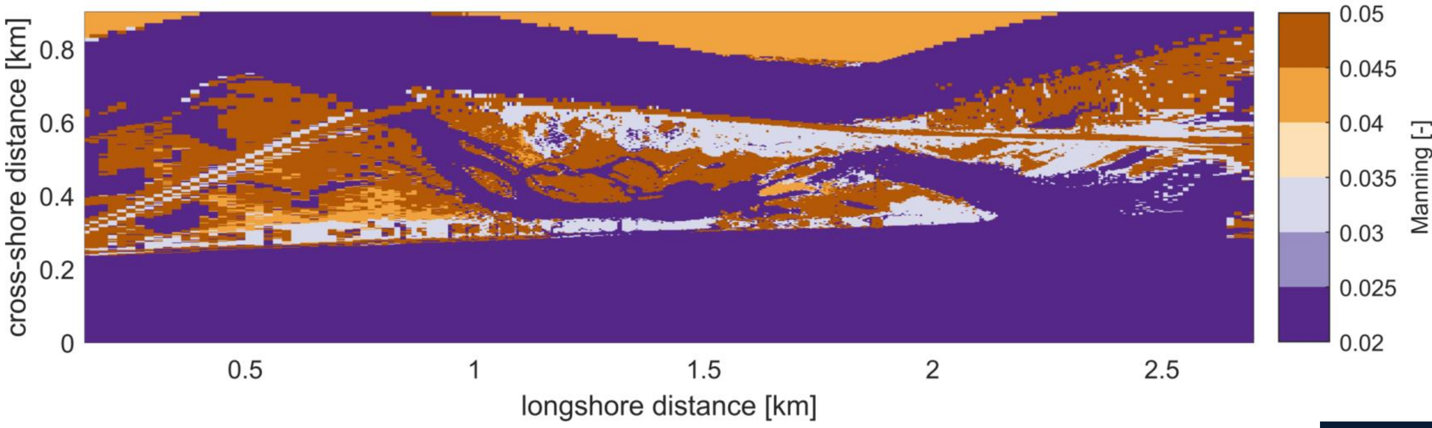


Post-event

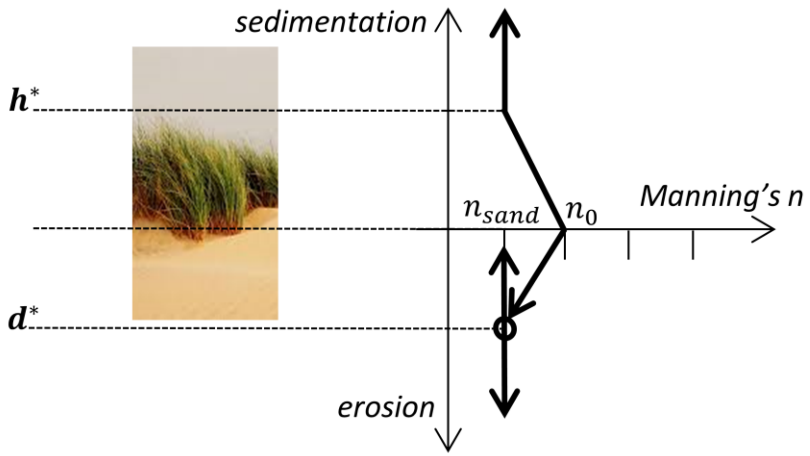
Temporal and spatial variation of vegetation roughness

- Spatial variation of roughness
  - Used pre-storm NAIP (National Agriculture Imagery Program) 1m x 1 m data
  - Each pixel classified using Conditional Random Field (CRF) method
  - Visually tag regions to Land Cover Classes
  - Converted Land Cover Classes to Manning's n roughness

- Temporal variation of roughness
  - Variation of Manning's n roughness due to burial or veggie erosion

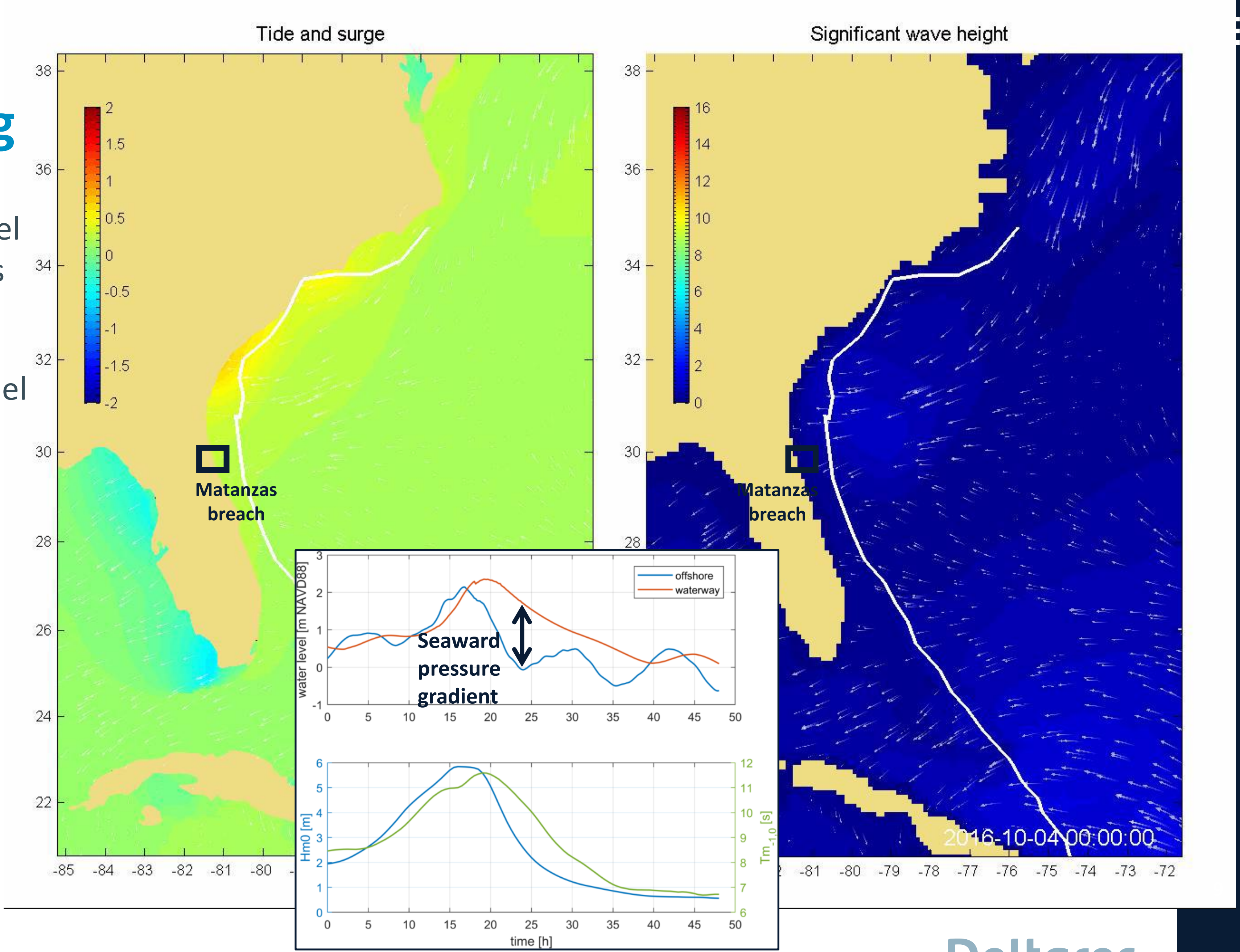


Classification	NLCD class name	Manning's n
Sand	Open Water	0.02
Wetland Vegetation	Emergent Herbaceous Wetlands	0.045
Water	Open Water	0.02
Dune Grass	Grassland/Herbaceous	0.034
Woody Vegetation	Shrub/Scrub	0.05
Anthropogenic coverage	Developed – Low Intensity	0.05



Hydrodynamic forcing

- NRL CoAmps Meteorological model provides wind- and pressure fields
- Drives Delft3D-Flexible Mesh model and SWAN model for NE Atlantic
- Provides boundary conditions to XBeach model



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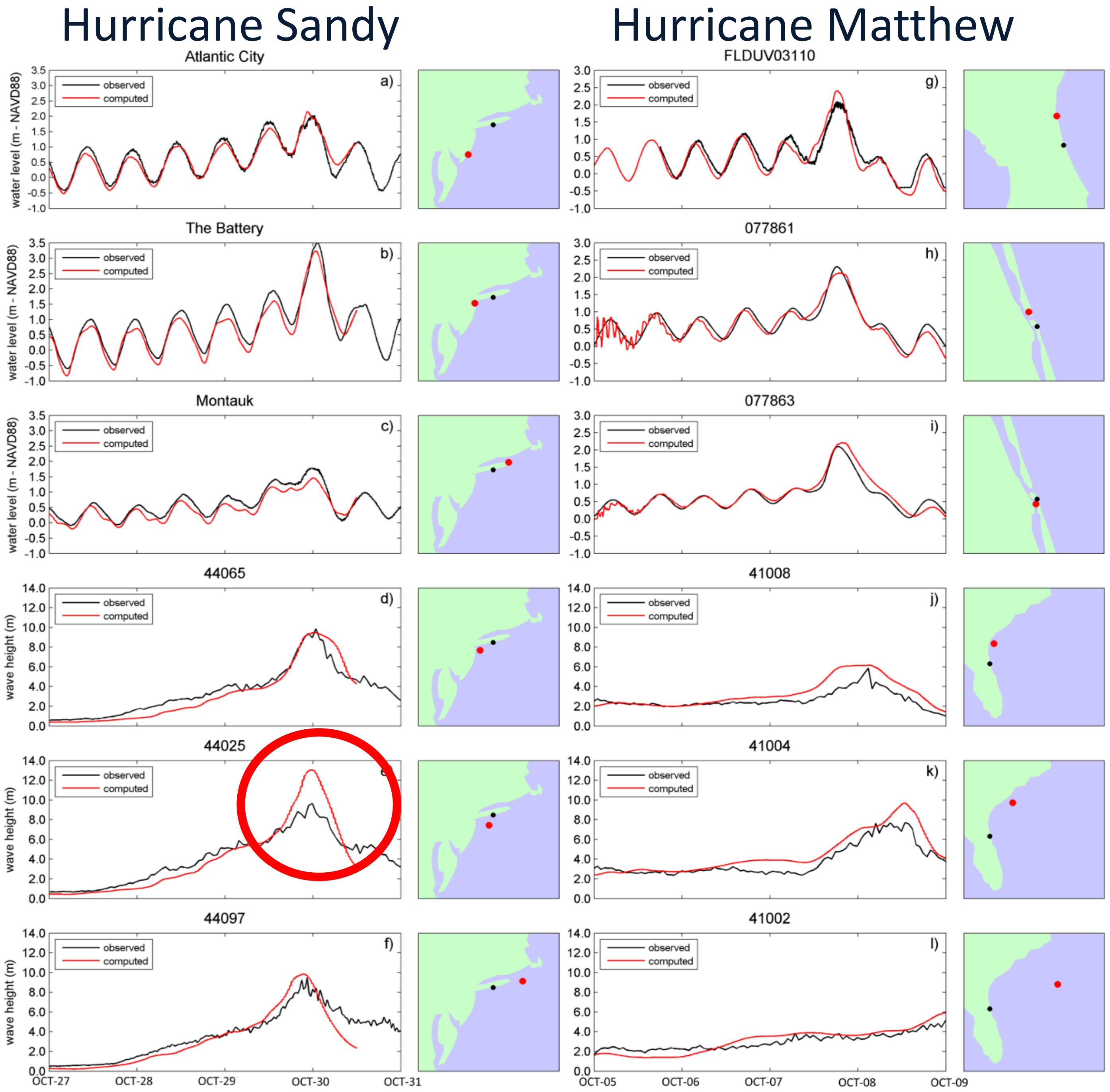
Hydrodynamic results

- Water level (top) predictions closely match the observations

- Wave heights at deeper water stations overpredicted,
- Difference is shown to have little effect on the Xbeach model boundary conditions.



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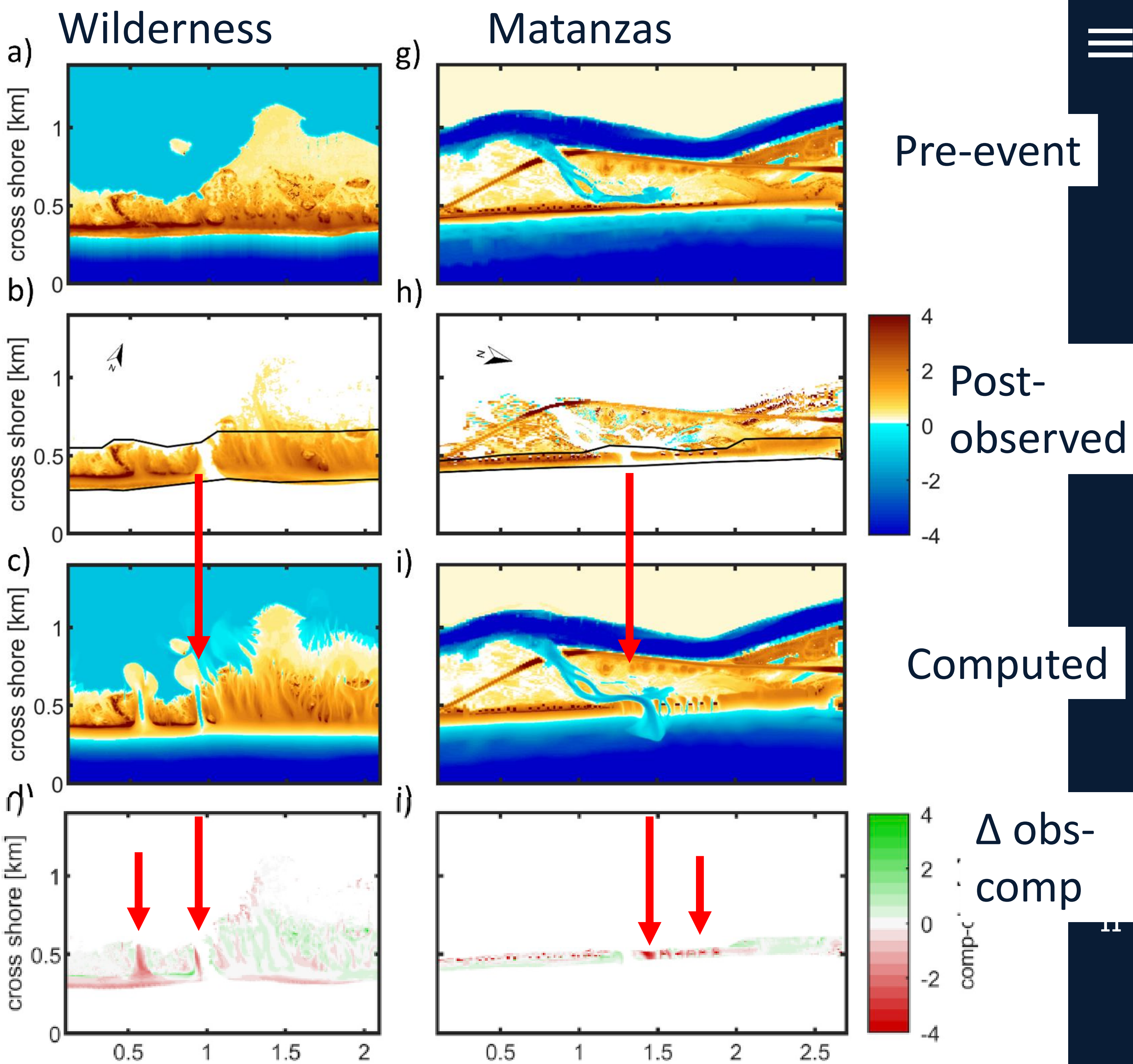
Morphological results

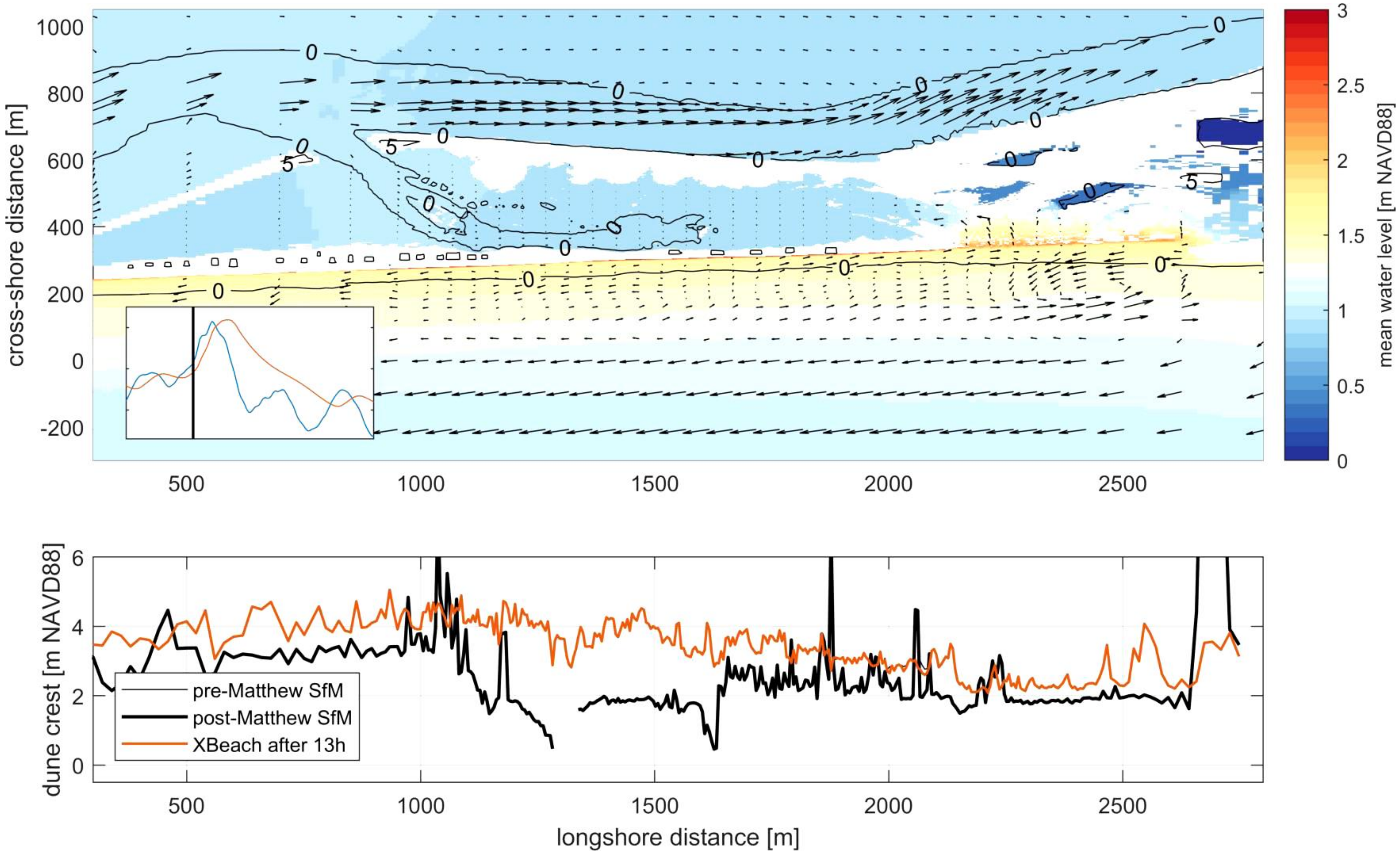
- Default “XBeachX” settings with “facua” calibrated on Wilderness case

- XBeach predicts breach formation(s)
  - But location is off by 100m
  - Secondary breaches predicted

  - Good agreement between computed and observed erosion volumes

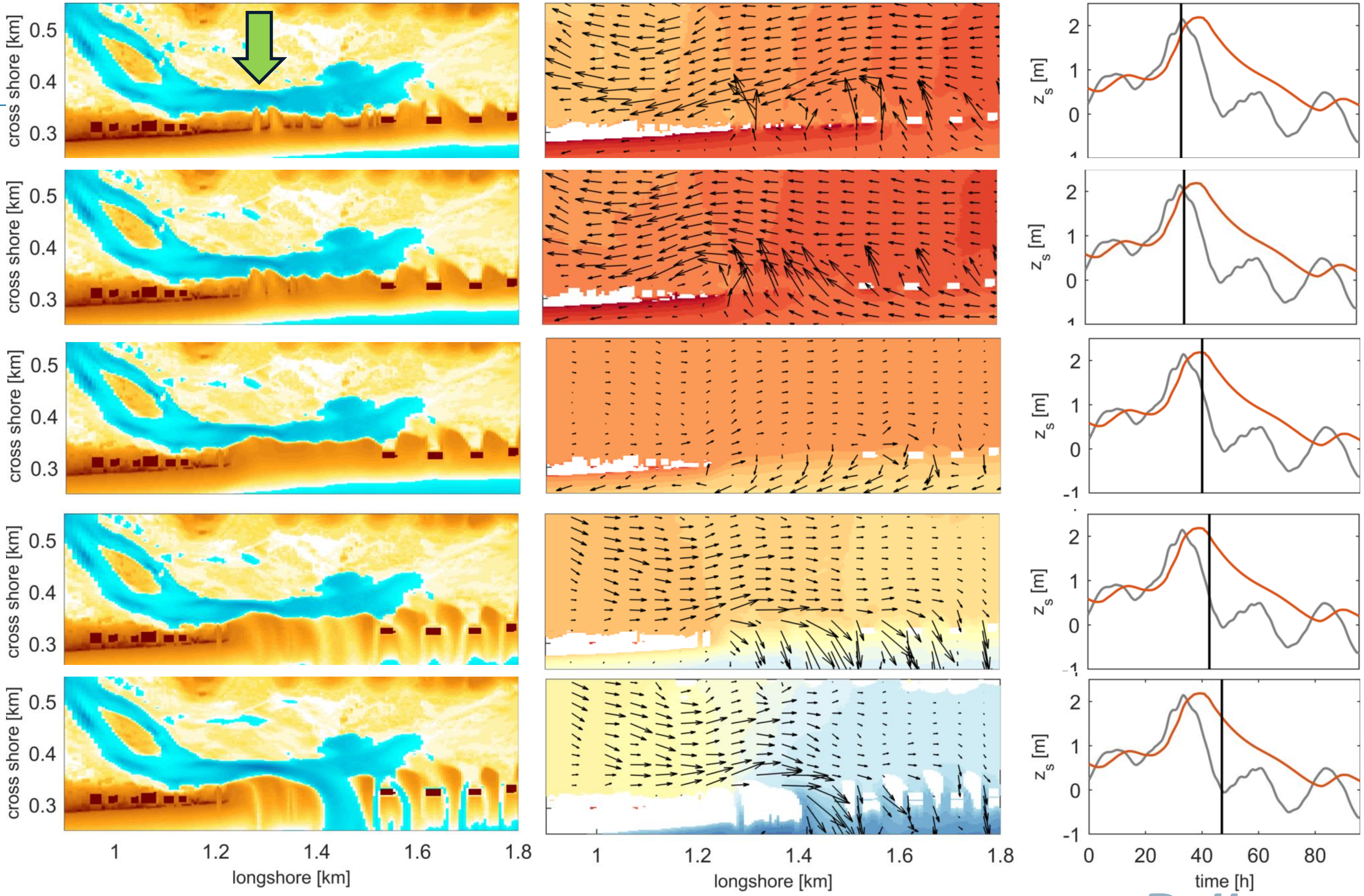


Why does the breach not occur in the right place at Matanzas?



Breaching

- Initial overwash at observed breach location
- uniform low dune with back-barrier deposit
- Dune lowering north of the observed breach
  - Suggests flow goes around back-barrier deposits



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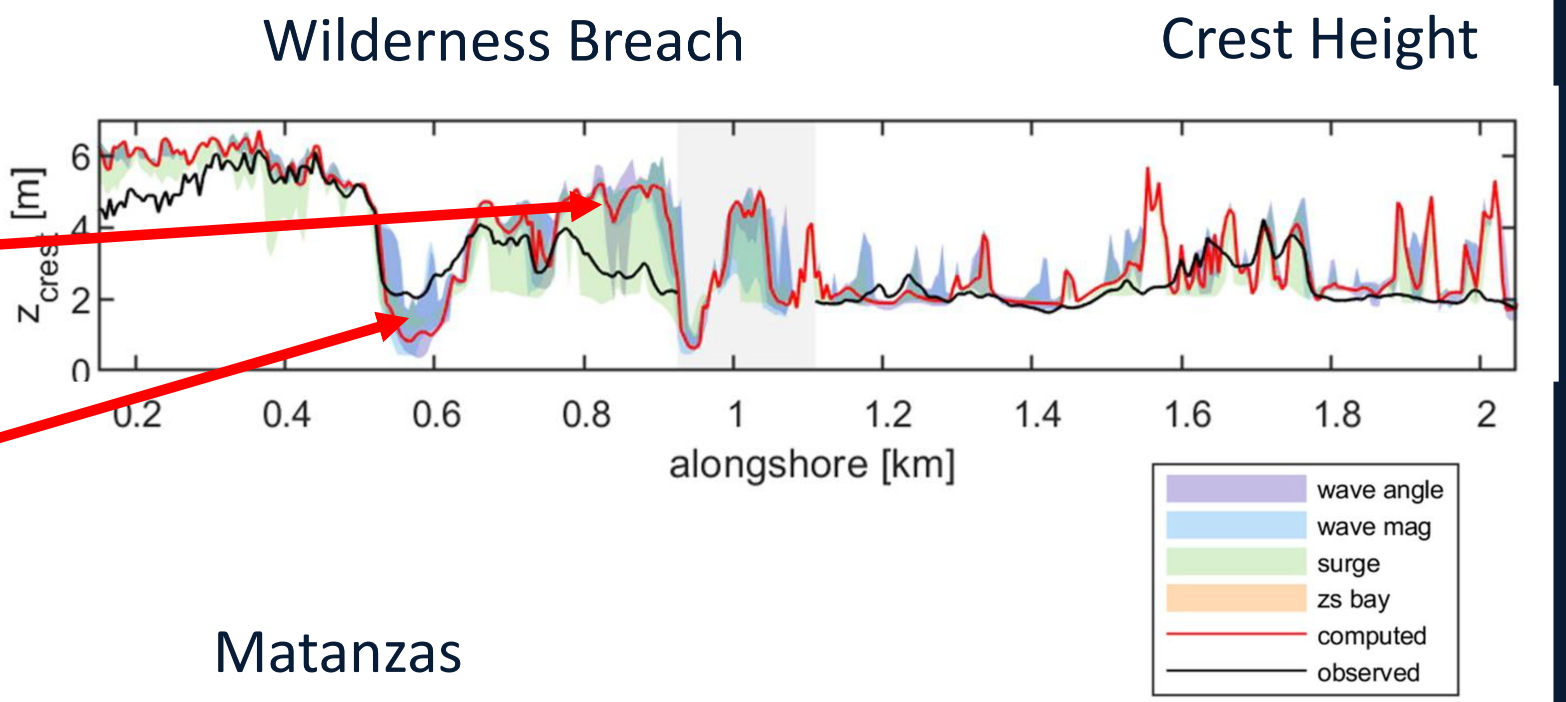
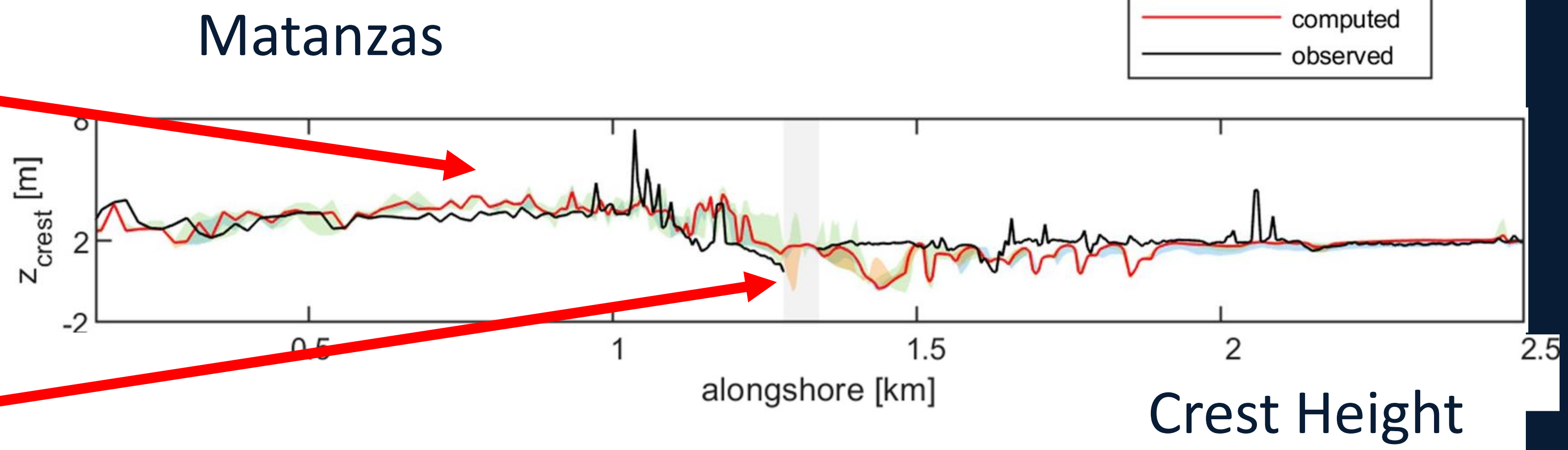
Sensitivity to input BCs

- Areas of large morphological change are sensitive to 10% variations in offshore surge
- Secondary breach are is sensitive to 10% variation in wave angle, wave height

- Largest impact by 10% offshore surge variations (surge level +/- 15 cm)
- 10% higher bay surge (+15 cm) results in a second breach at the observed location





Take home: morphological change sensitive to relatively small variations in forcing

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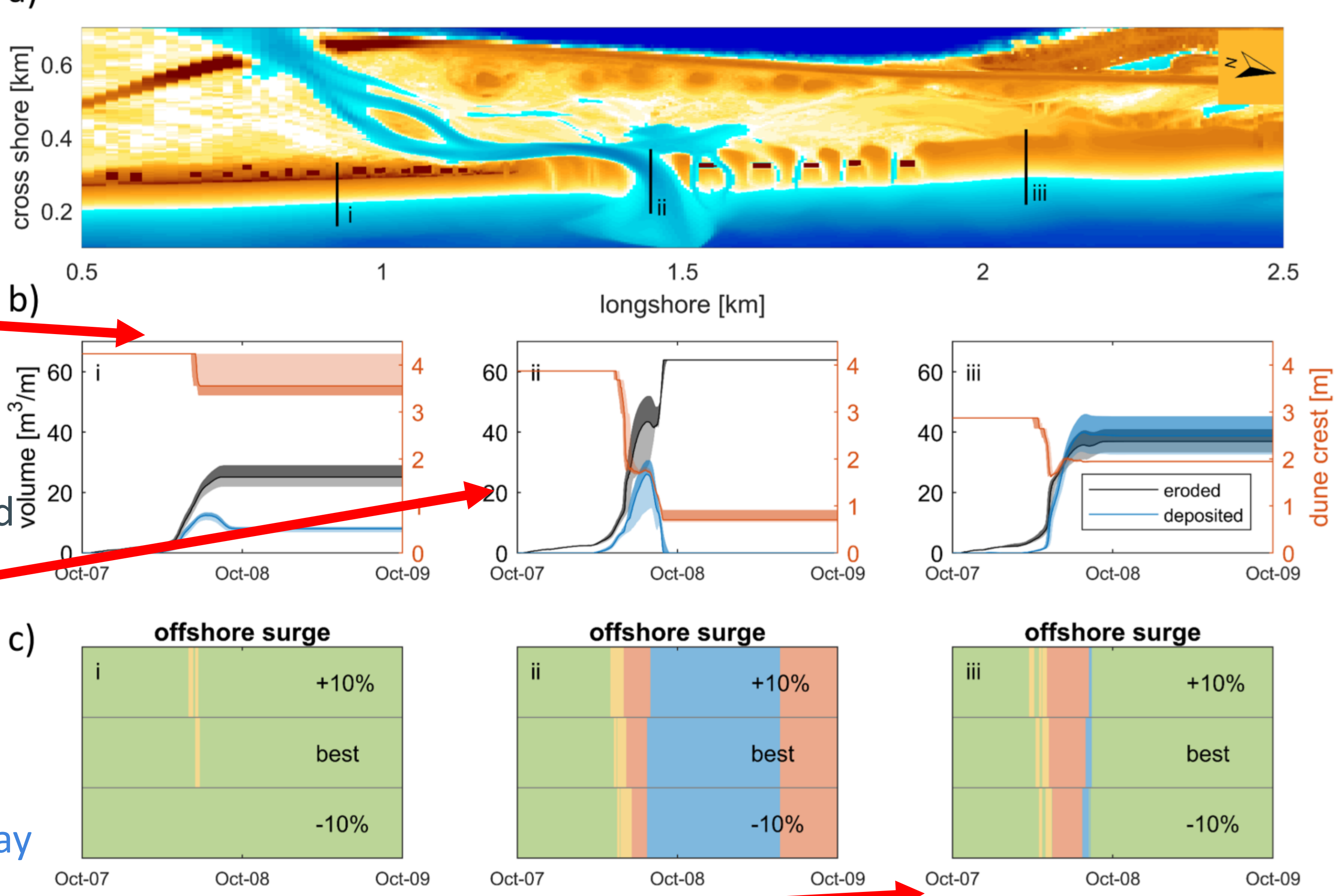
Sallenger
Regime changes

- Cross-section i:
  - Mostly in collision regime
  - Short interval of overwash
  - Morpho-change during overwash and 2nd collision regime
- Cross-section ii:
  - Earlier shift to overwash and inundation due to lower initial crest height
  - Morpho-change during inundation and bay surge
- Cross-section iii:
  - Lowest initial crest height: earlier shift to overwash and inundation
  - Deposition on crest prevents breaching
  - Brief period of bay surge, no morpho change



- Collision regime = max water level < dune crest
- Overwash = min water level < dune crest < max water level
- Inundation = min water level > dune crest
- Bay surge = inundation with flow reversal

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Conclusions

- XBeach model predicts dune erosion, deposition, and breach formation reasonably well
  - Used default settings with tuning of onshore sediment transport on one case.
  - Spatially-varying vegetation roughness from remote-sensed data with innovative classification
  - Temporally-varying roughness with new dynamics veggie erosion/burial module

- Breach formation occurs, but locations are off by 100 meters to observed breaches
  - Wilderness Breach: second breach predicted at site of relic breach, sensitive to input conditions
  - Matanzas: Breach area lowers uniformly but back flow forces out more to the North
  - Matanzas: breach location is function of dune crest height and deposition patterns during inundation

- Morpho results are sensitive to forcing conditions
  - Largest impact due to 10% offshore surge variations
  - 10% increase in waterway surge causes second breach at Matanzas at location of observed one
- Details: Van der Lugt et al. (2019), Estuarine, Coastal and Shelf Science 229 (2019) https://doi.org/10.1016/j.ecss.2019.106404

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