Modeling the Erosion on Hatteras Island During Hurricane Isabel: Toward XBeach Coupling with ADCIRC

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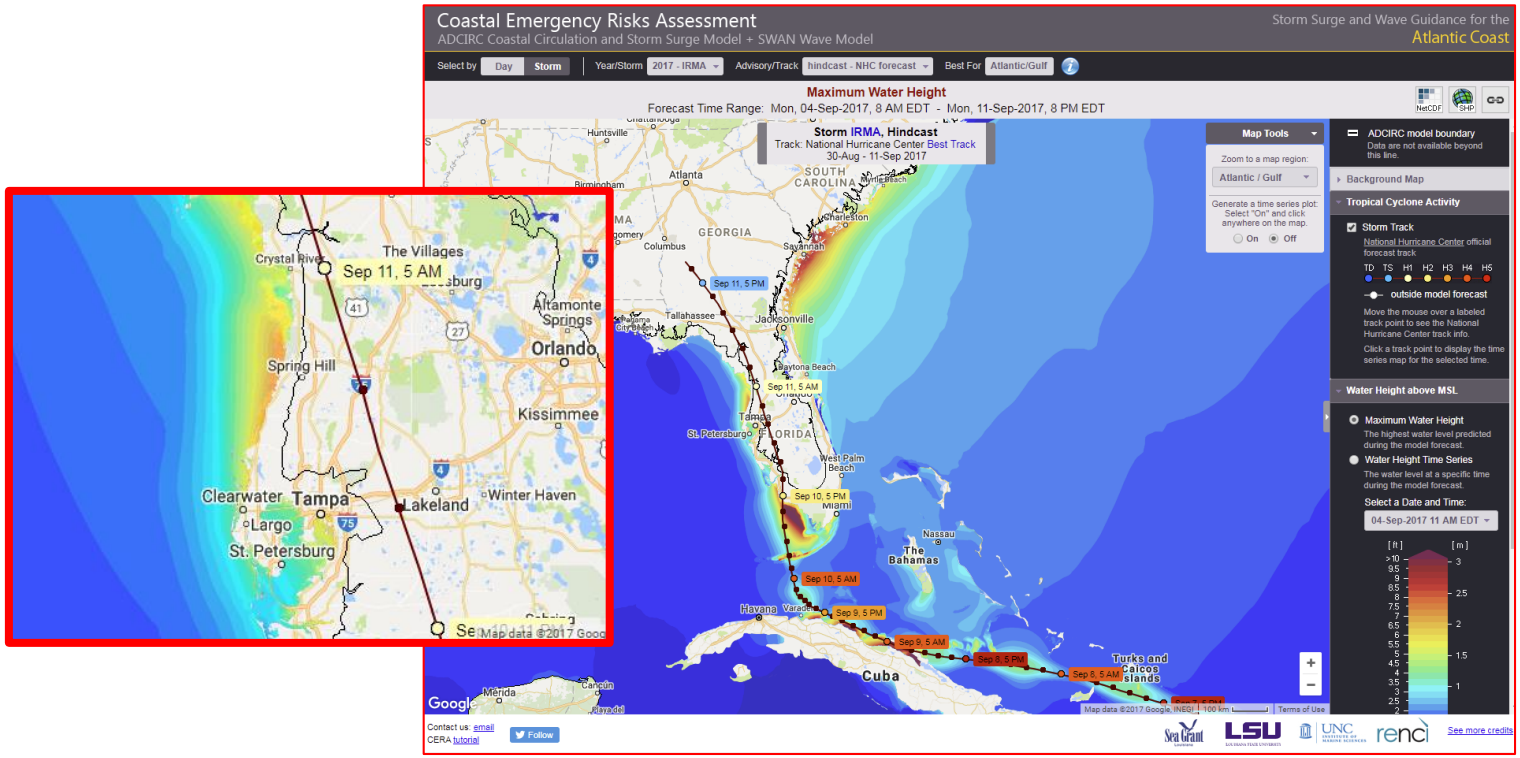
Motivations and objectives

Rodanthe, NC, Hurricane Isabel (2003)

St. Augustine, FL, Hurricane Matthew (2016)

Motivations and objectives

Real-time flooding predictions via www.ADCIRC.org



How will these flooding predictions be changed when we consider the morphodynamics of beaches, dunes and barrier islands?

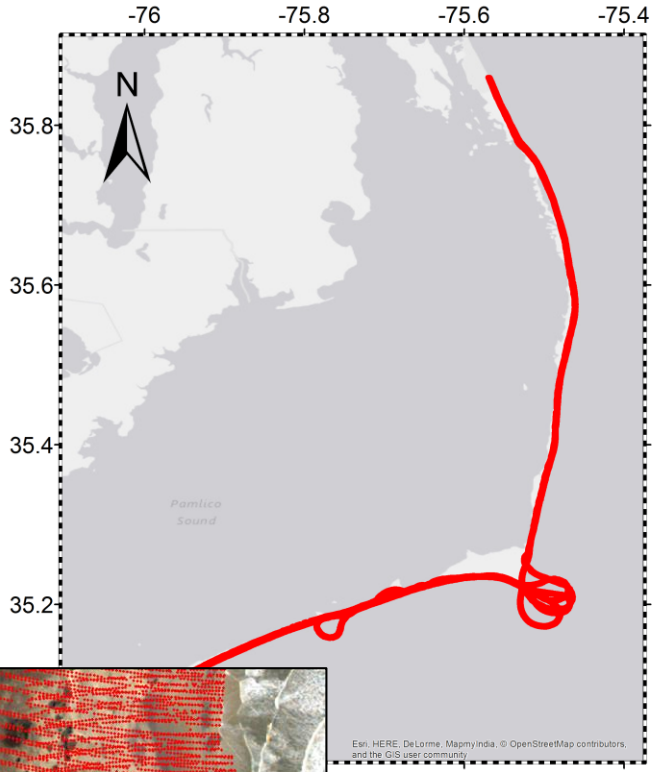
Motivations and objectives

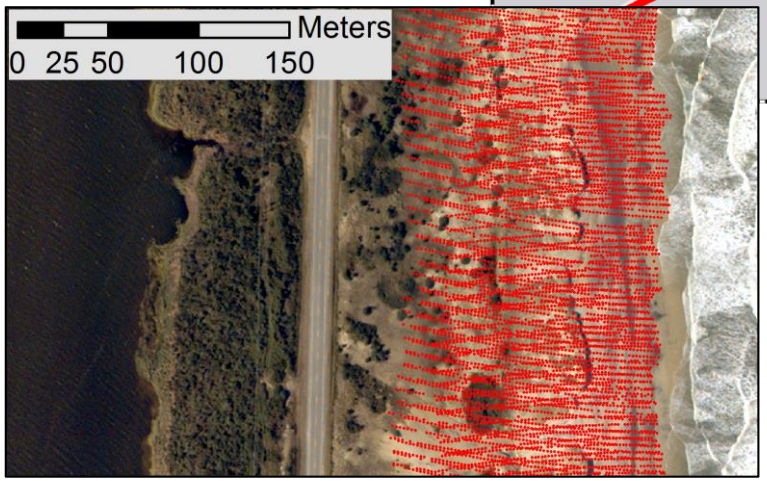
- Open source model
- Hydrodynamics and morphodynamics
- Topo/bathy evolution

- Objectives:
  - Expand the domain
    - Can we use XBeach on island-size domains, closer to what ADCIRC will consider?
  - Understand XBeach sensitivity to mesh resolution
    - What accuracy is needed for XBeach predictions?
    - How will the accuracy be affected for the overland flooding in ADCIRC?

Hurricane Isabel (2003)

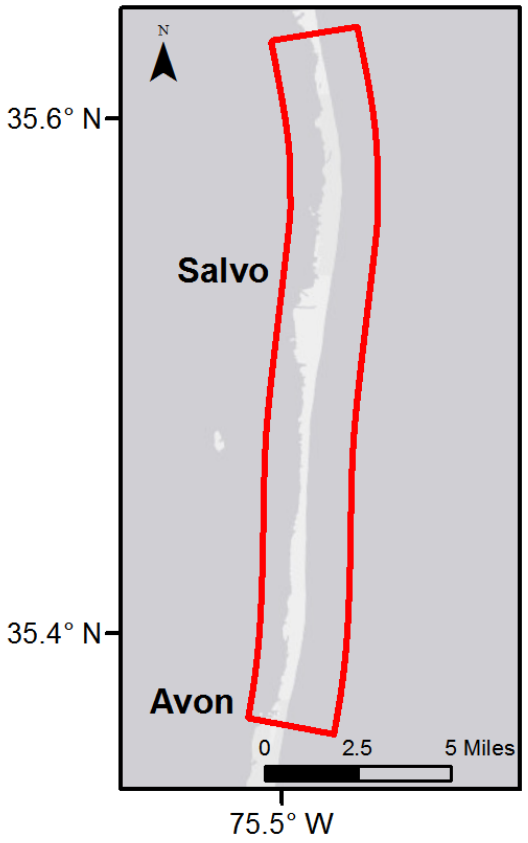
- Most powerful hurricane in 2003
- Made landfall on the Outer Banks on 18 Sep as Category 2 hurricane
- Caused overwash, dune breaching and infrastructure destruction
- Pre and Post storm data set available from NASA/USGS EAARL
  - 16 Sep 2003
  - 21 Sep 2003
  - High resolution (2m)
- Survey width: 250-300 m
- High resolution 2m

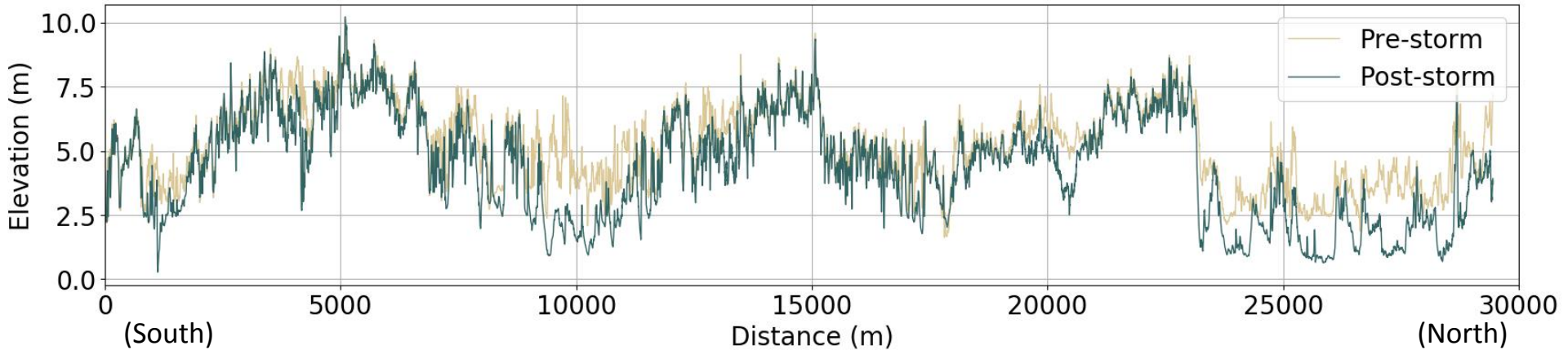




Study Area

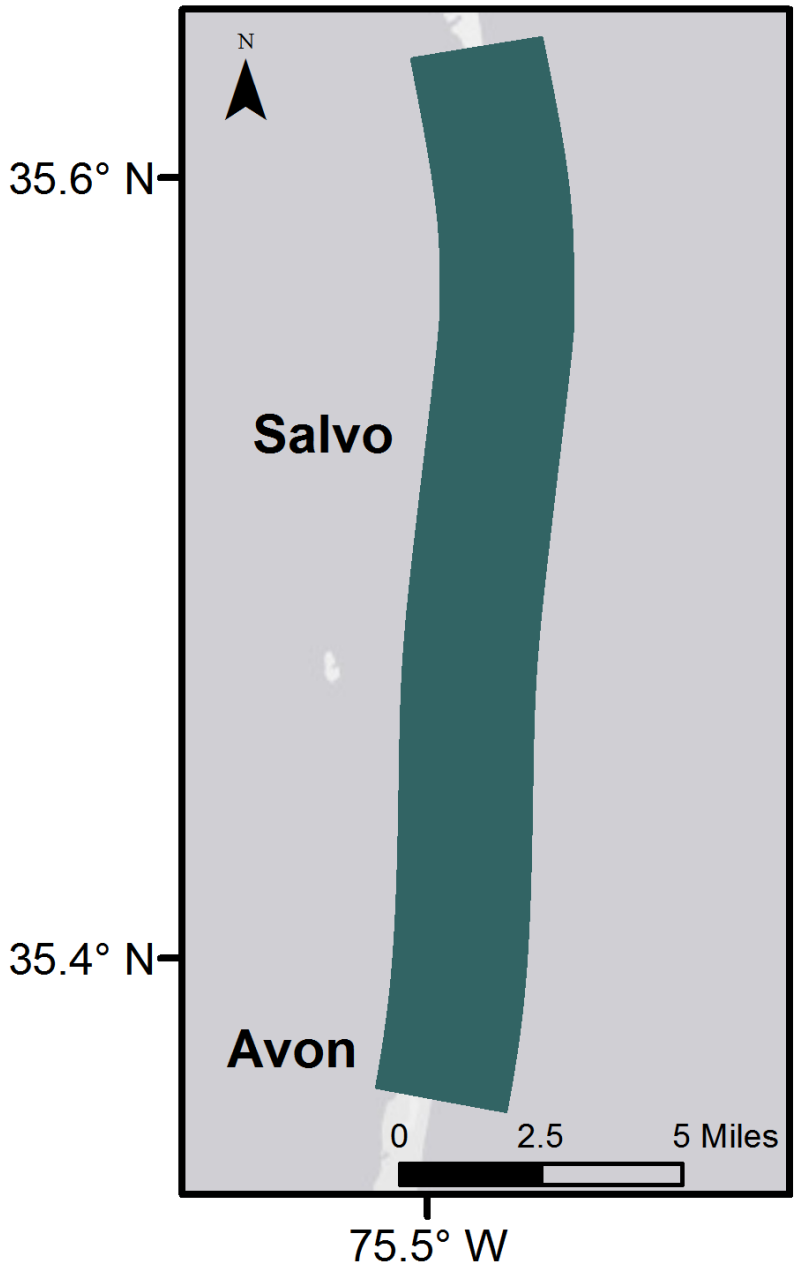
- The Study area between Avon and Salvo
- Distance of more than 30 km along shoreline
- Elevation change at pre-storm crest line
  - Average: 1 m
  - Maximum: 5.6 m
- Total of 25 major erosion events
  - All wider than 15 m





Generating Mesh

- Computational grid:
  - 2100 x 420 cells
  - Alongshore: 15 m
  - Cross shore: 3-35 m
- Combining data sets:
  - Pre-storm LiDAR with 1 m resolution
  - NC flood mapping DEM with 10 m resolution
- Not to over-parameterize the model
  - No vegetation
  - Two sediment classes
    - On the beach
    - On the dune
  - Minimal tuning
- Be able to expand to other regions



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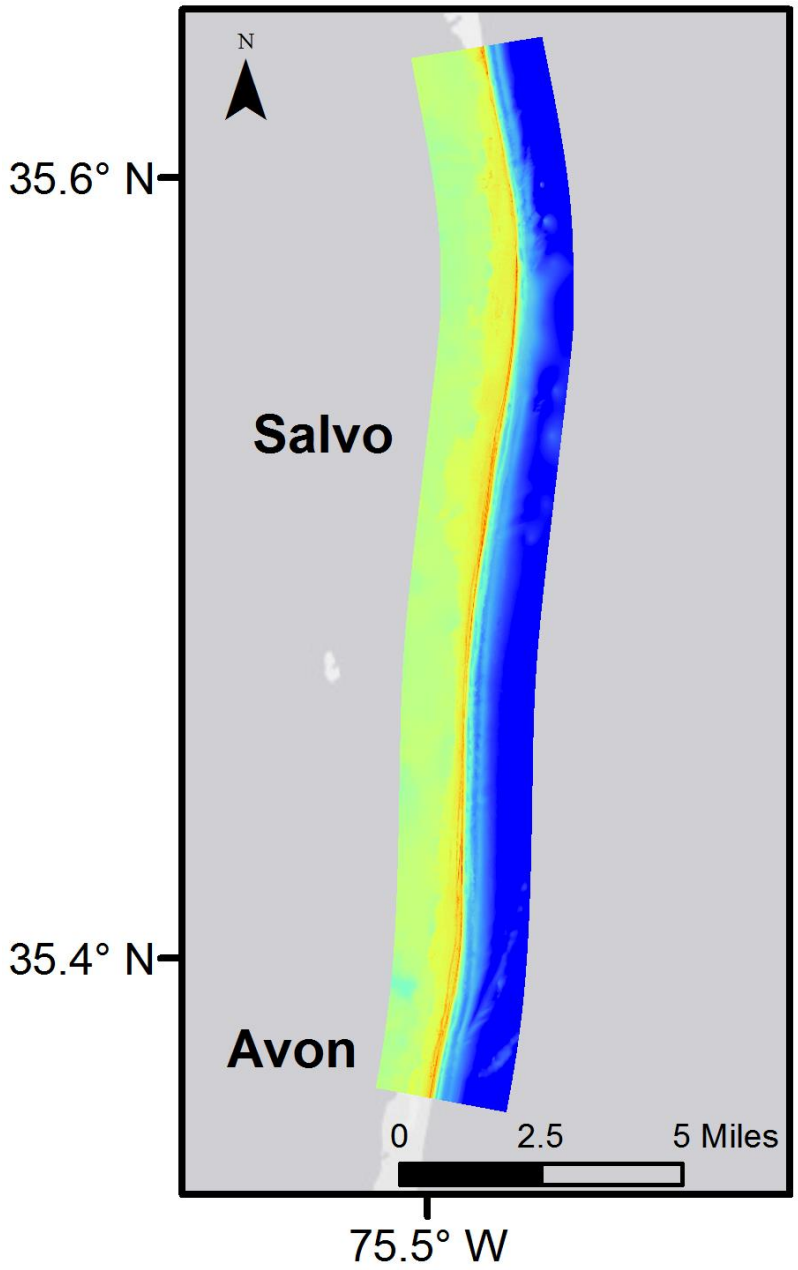
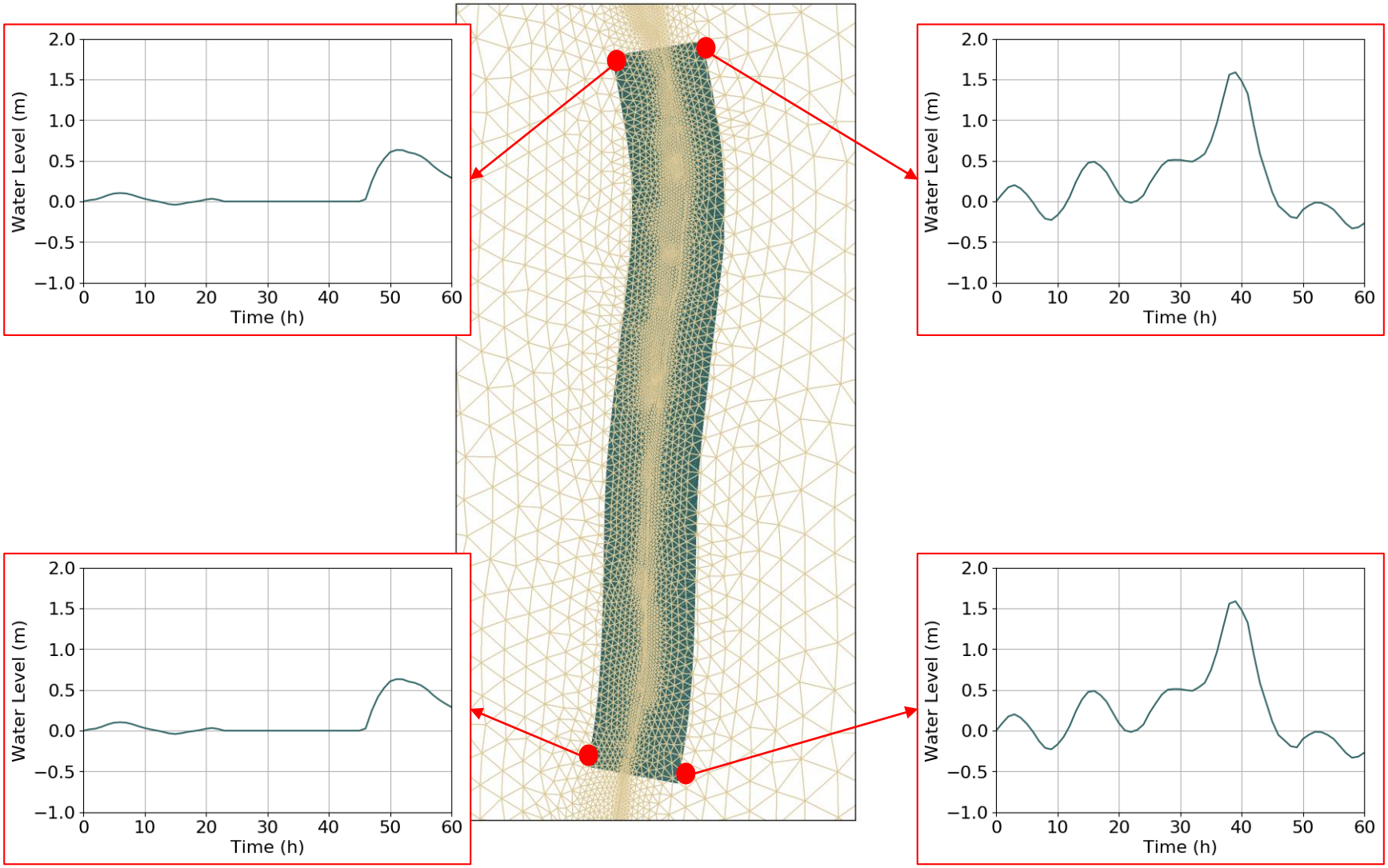
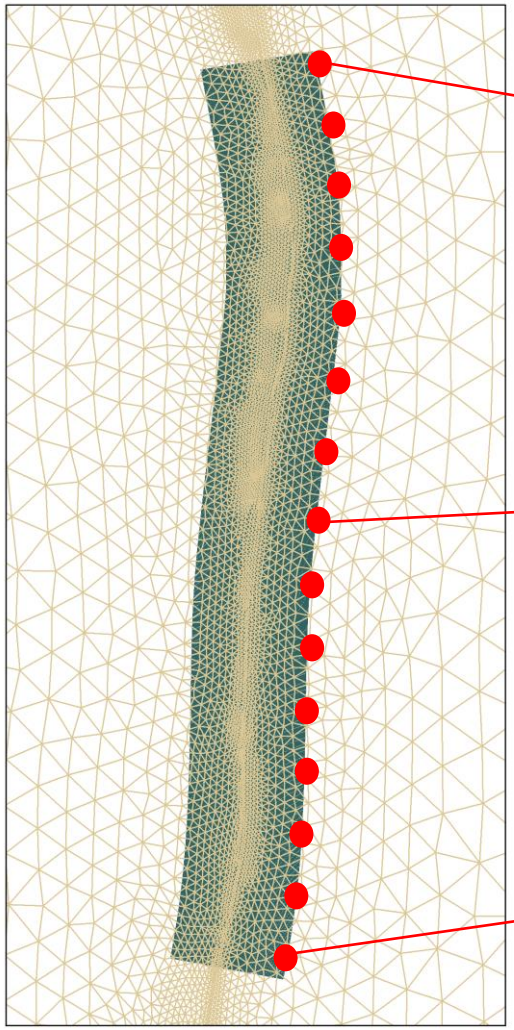
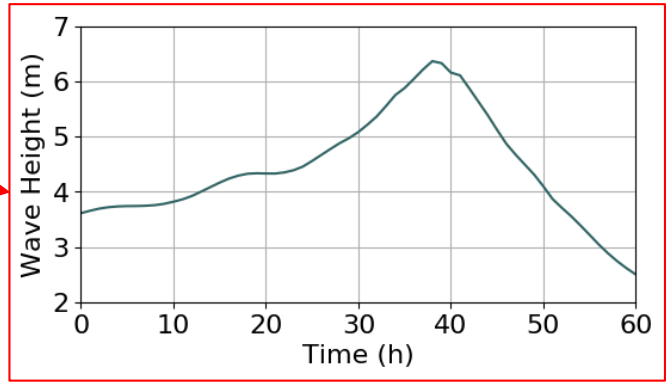


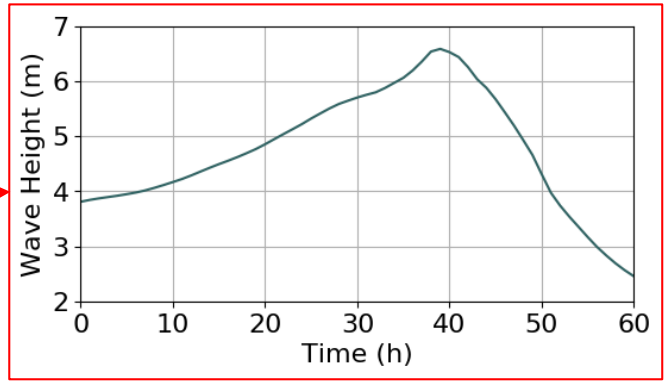
Model Setup – Water Levels

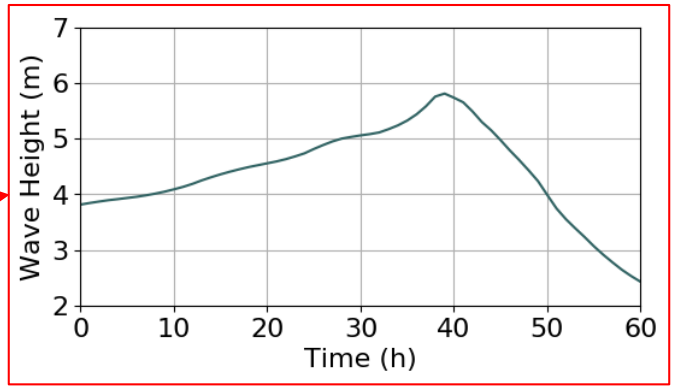


Model Setup – Waves





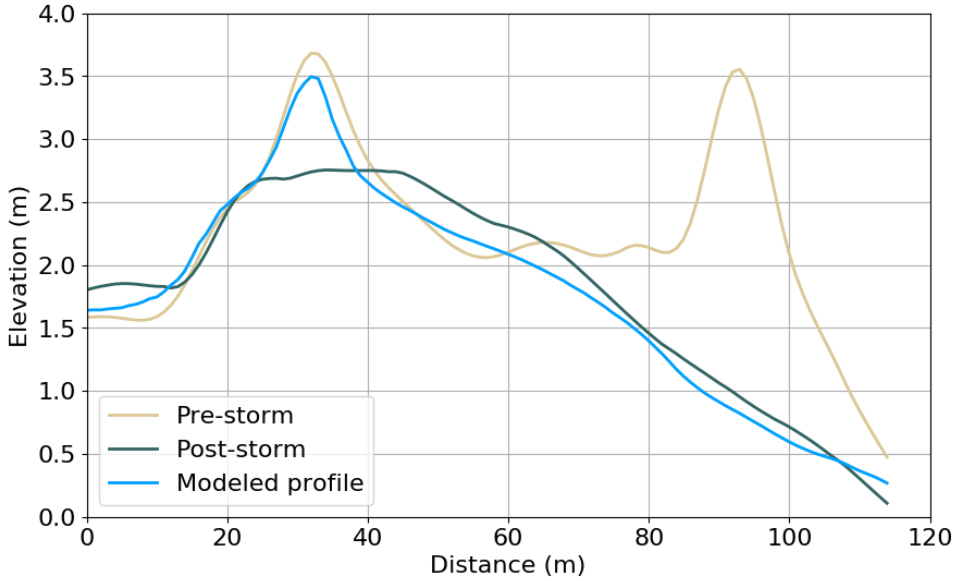


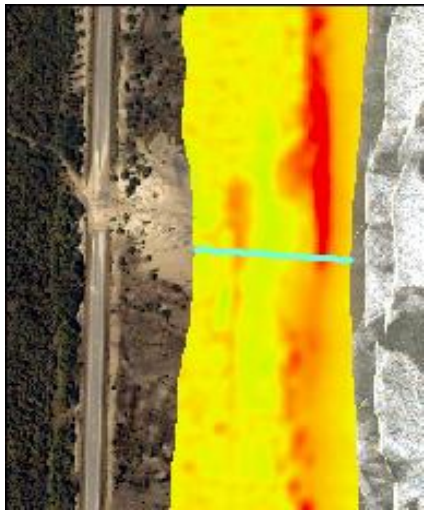


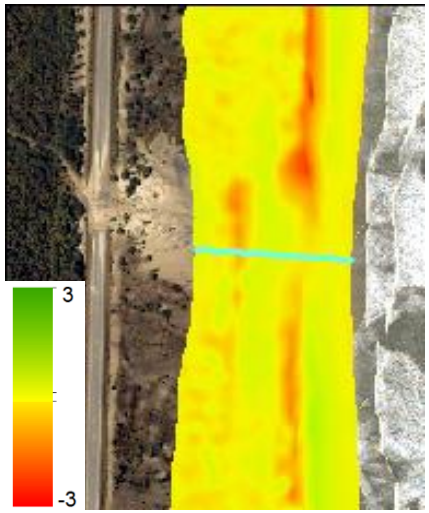
Model Results

Dune erosion event #1

- First dune removed
- Second dune is not impacted very much



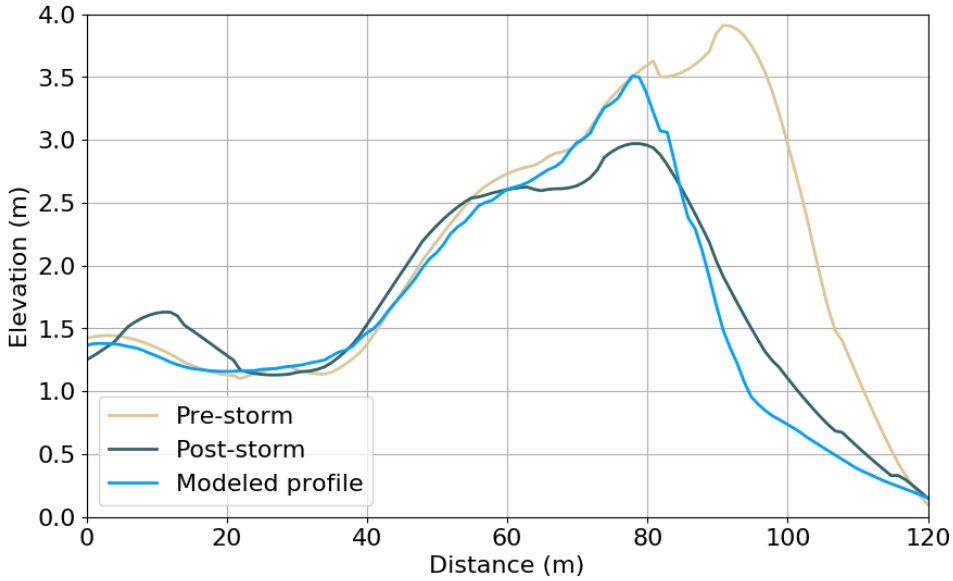


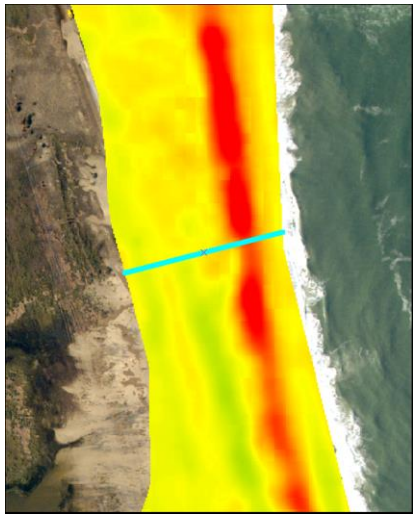


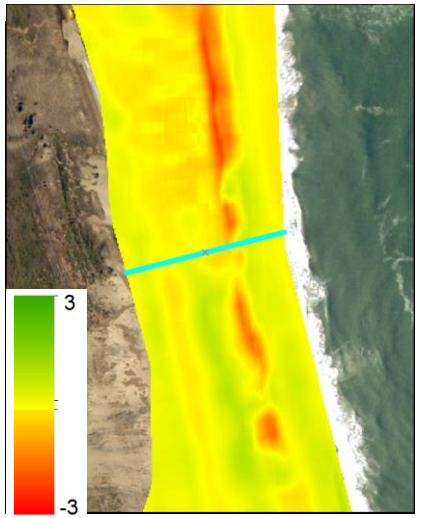
Model Results

Dune erosion event #2

- Partial erosion of the dune
- Over erosion on the beach



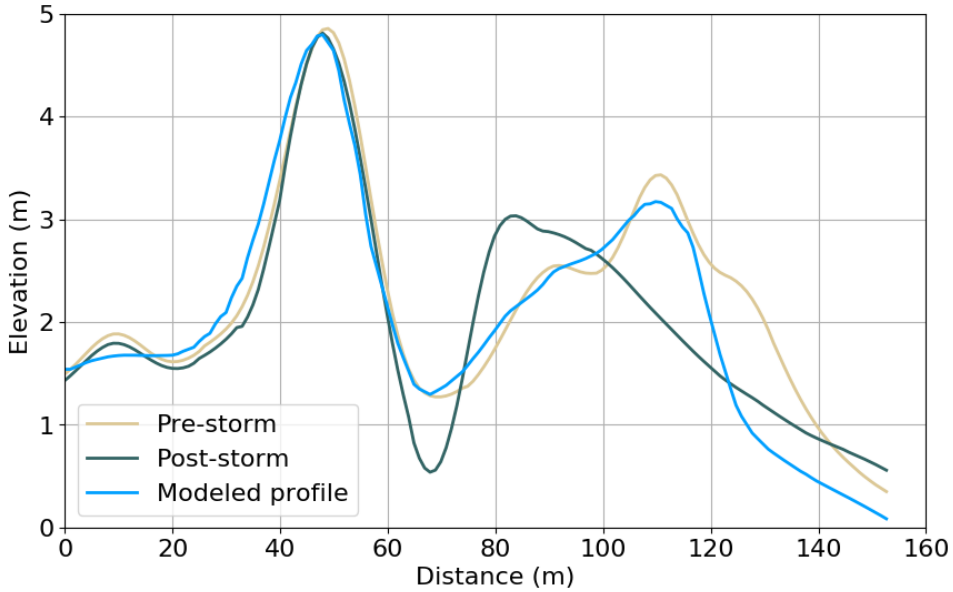


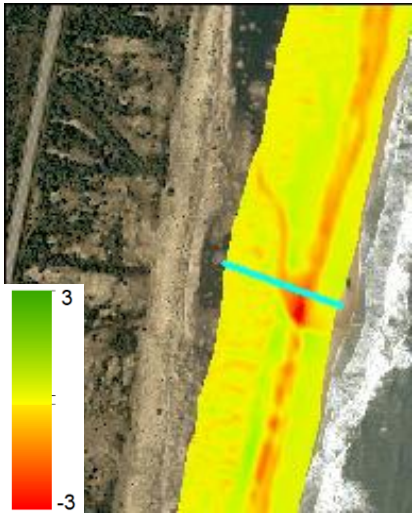


Model Results

Dune erosion event #3

- Challenges of modeling
- First dune is not removed
- Example of zero-erosion





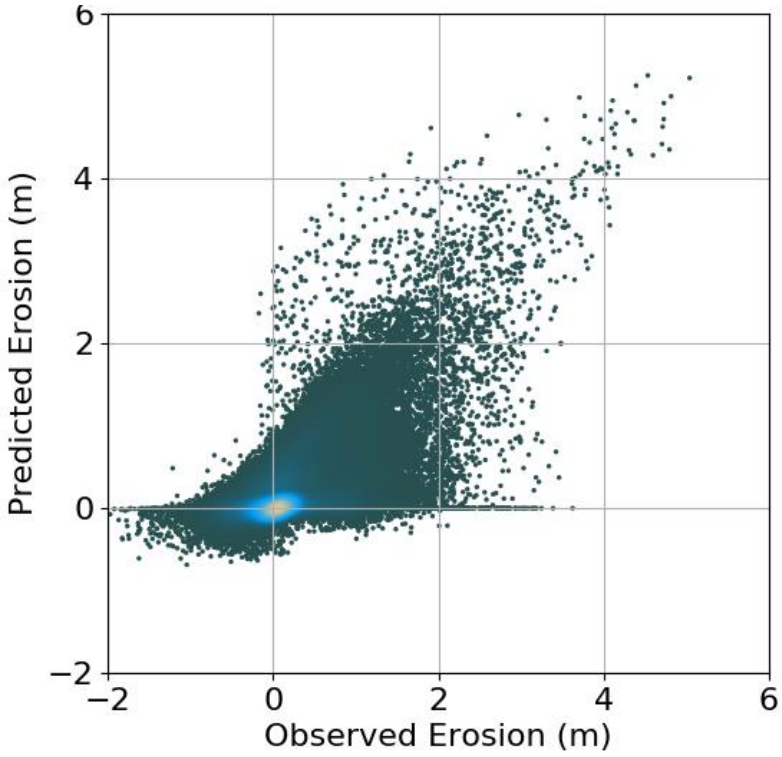
Model Results – Skill Score

Model Accuracy

$$Skill = 1 - \frac{\sum_{i=1}^{N} \left(dz_{b_{LIDAR,i}} - dz_{b_{XBeach,i}} \right)^2}{\sum_{i=1}^{N} \left(dz_{b_{LIDAR,i}} \right)^2}$$

- Skill Score
  - Compares measured to modeled elevation change
  - Skill score greater between 0.3 and 0.5 is “Good”
  - Modeled profiles match observation : scatter points close to 1:1

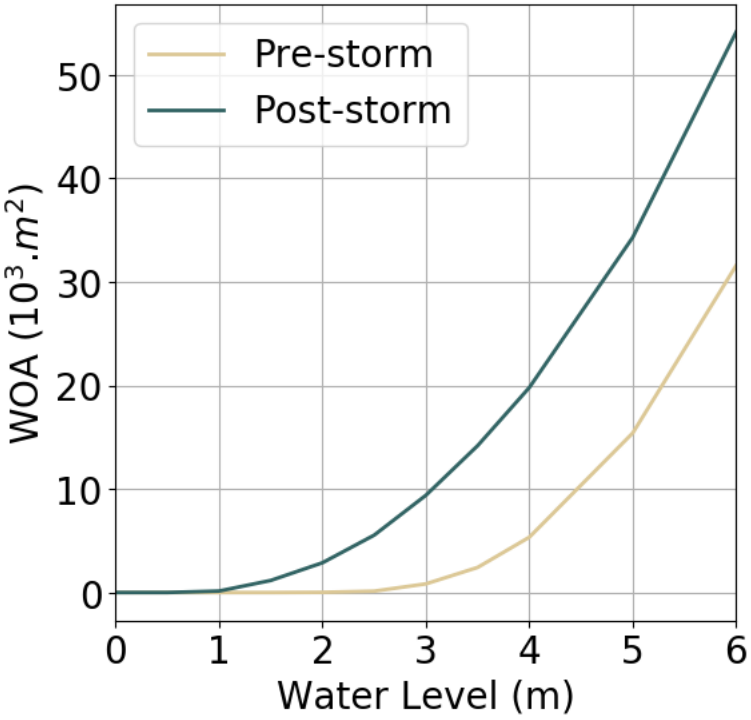
Skill score = 0.46

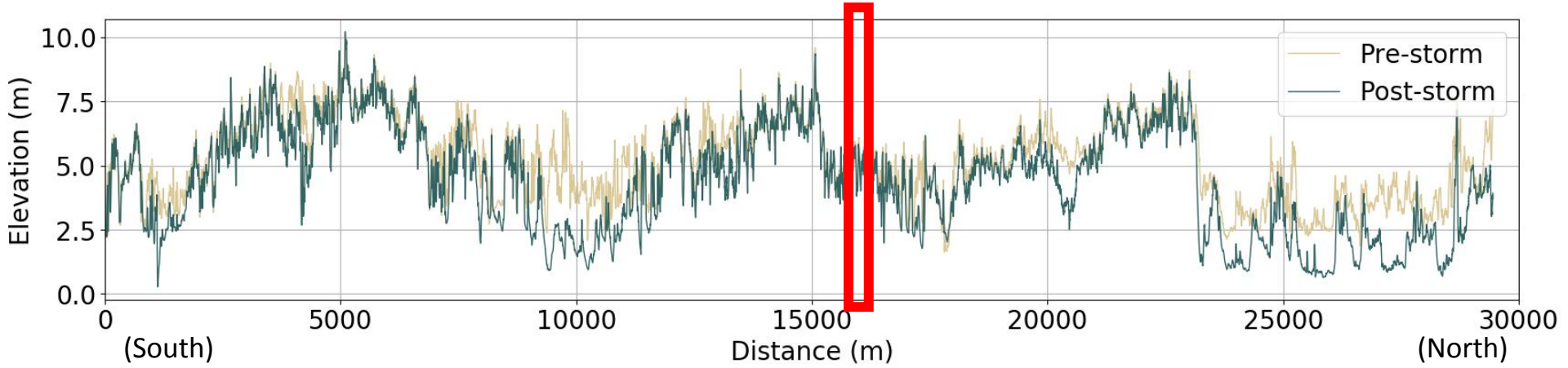


Model Results – WOA

Model Accuracy

- Water Overpassing Area (WOA)
  - Represents the amount of water that overtops the dune crest
  - Area between dune crest and water level

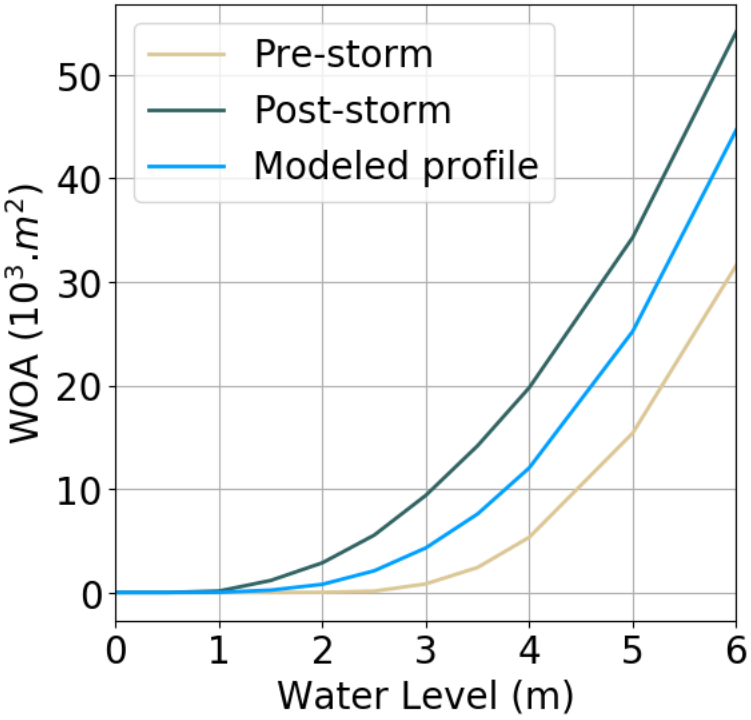


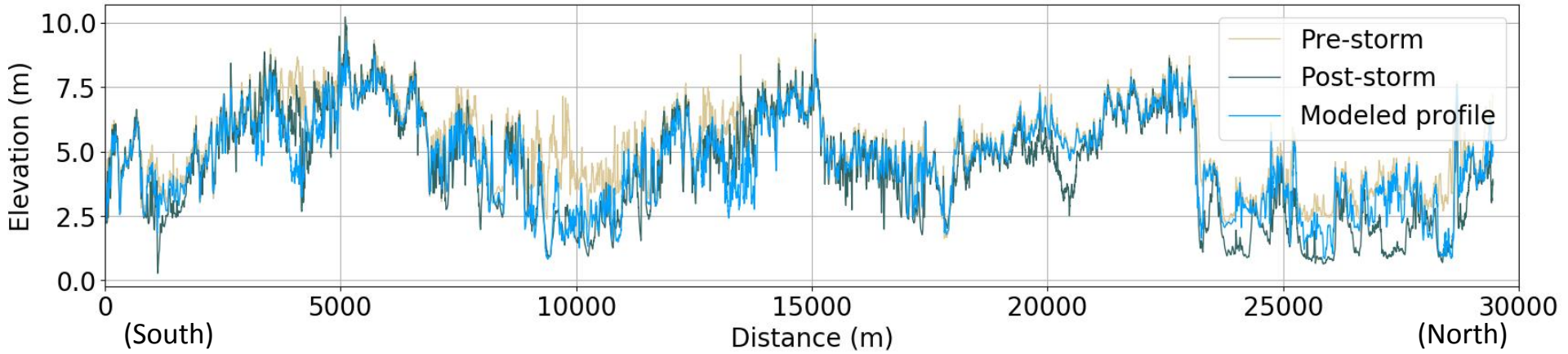


Model Results – WOA

Model Accuracy

- Water Overpassing Area (WOA)
  - Not a perfect estimate for WOA





Model results

- “Good” skill score
- Not a perfect match between post-storm and model WOA

- Mesh requirements for coupling:
  - How much coarse we can get ?
  - How skill score and WOA change with resolution?
  - Testing on smaller domain to save time

Mesh Resolution – XBeach vs ADCIRC

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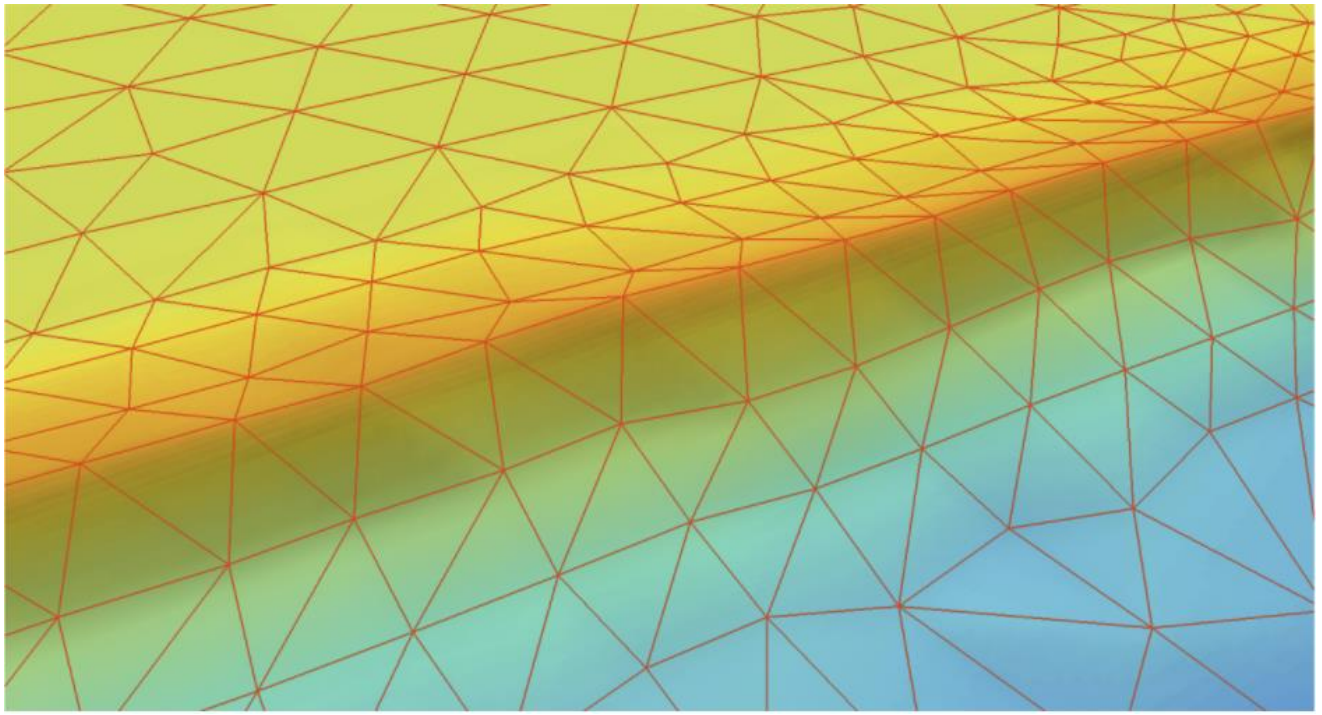

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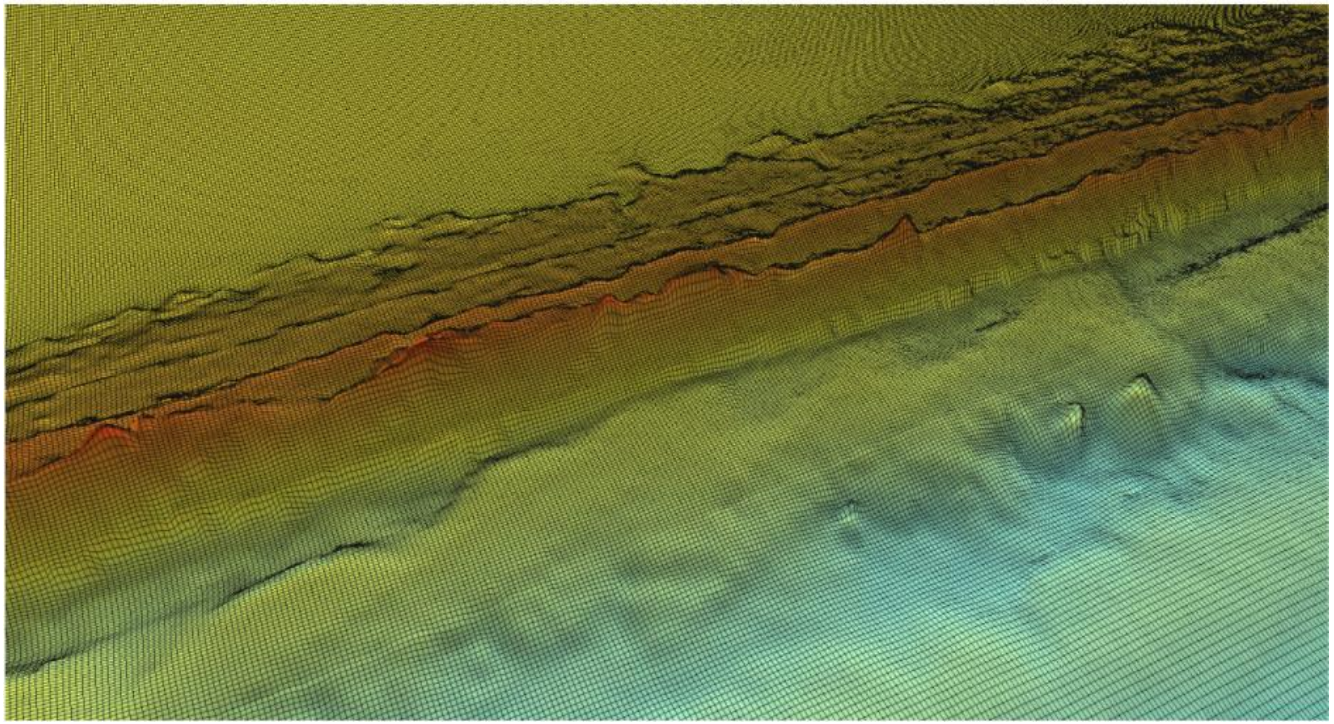

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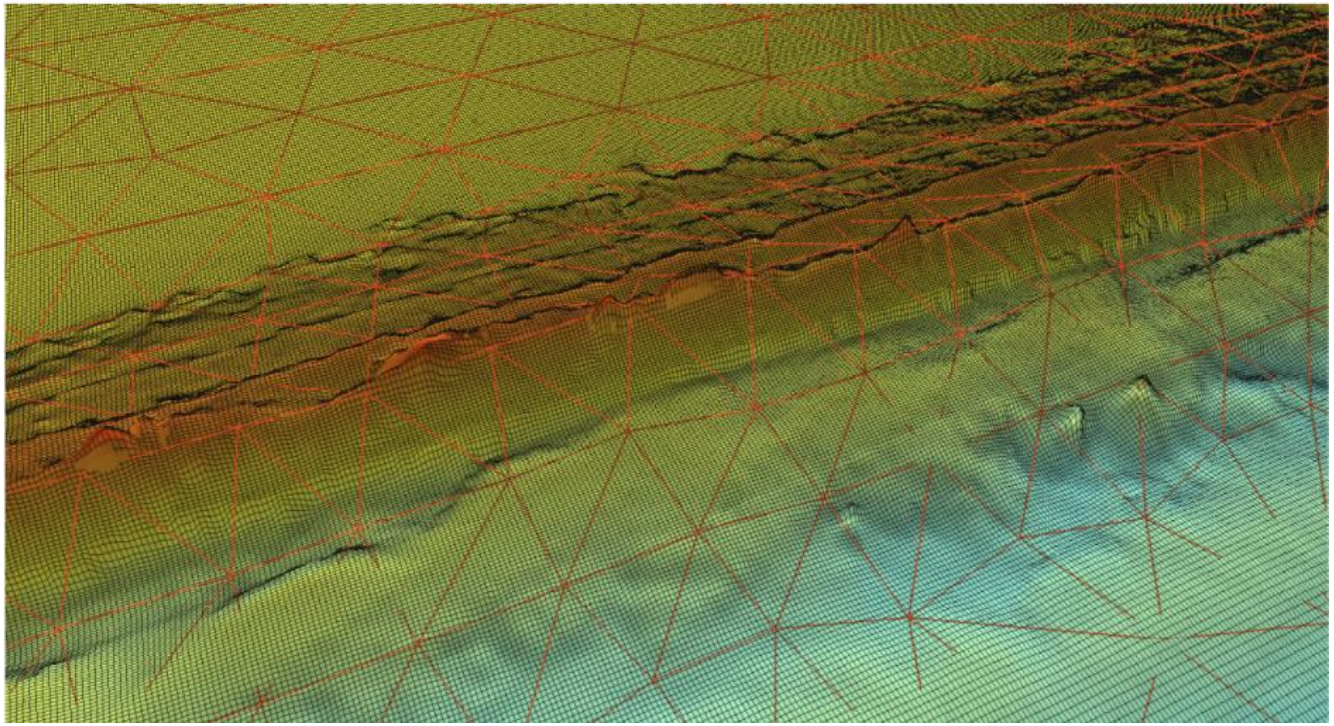
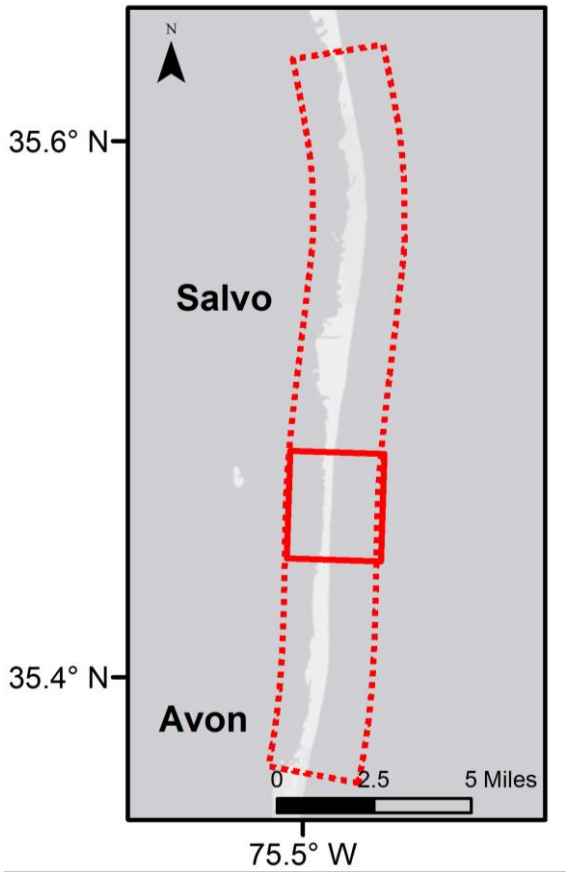


4km domain model

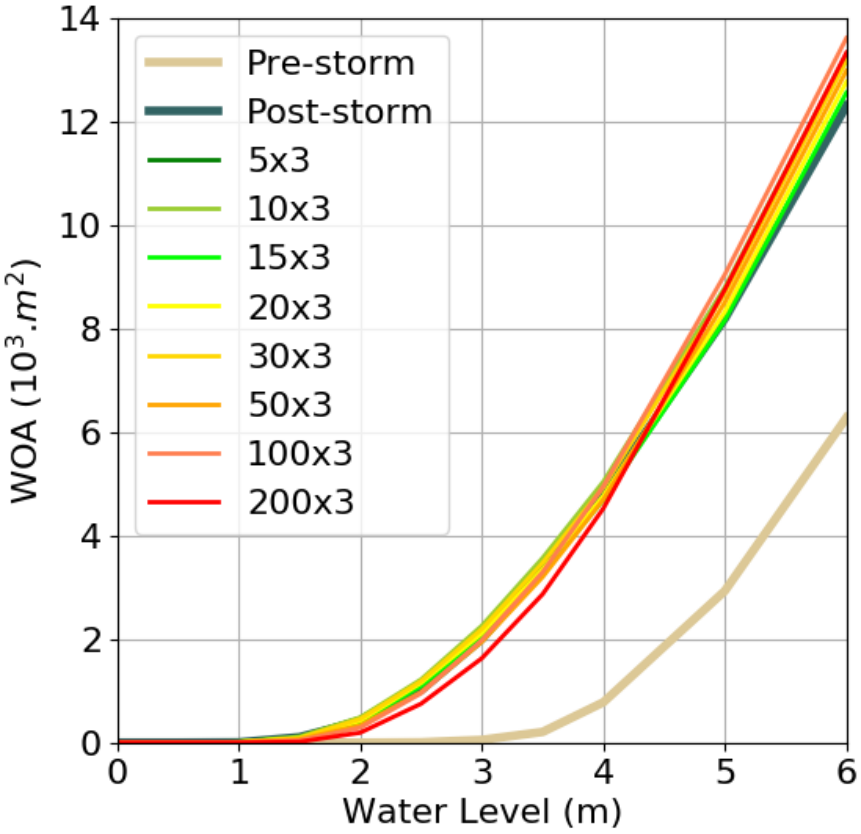
- Running test on 4 km sub-domain
  - Validating the results
- Mesh resolution sensitivity
- Changing grid spacing :
  - Alongshore
  - Cross-shore
  - Both directions



Mesh Resolution Sensitivity

- Changing grid spacing :
  - Increasing alongshore spacing
  - Cross shore spacing: 3 m

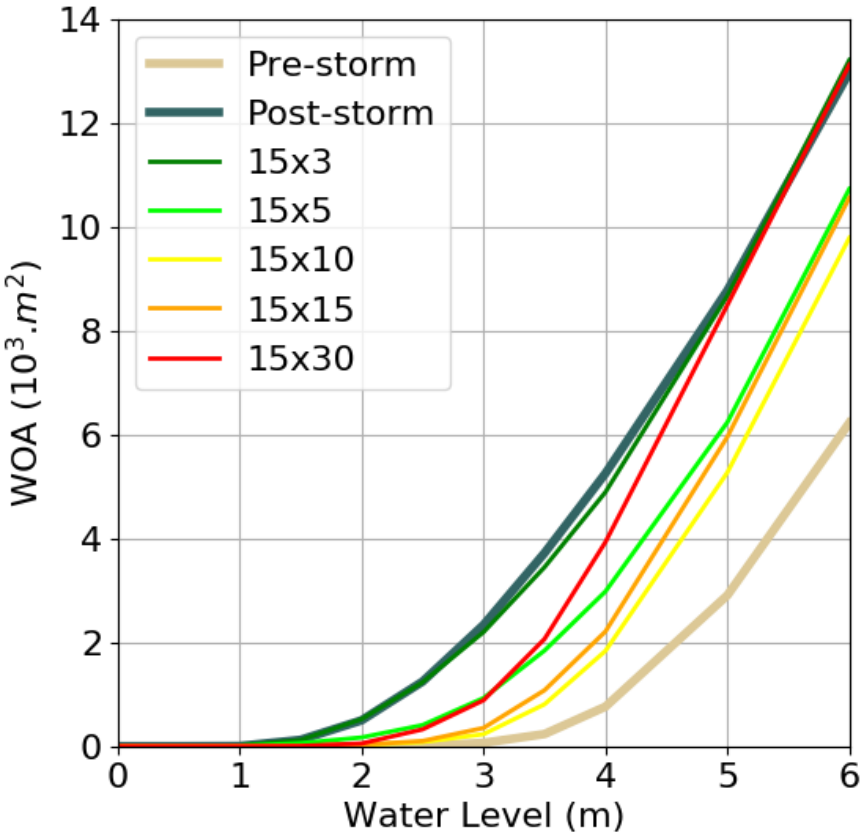
Mesh	Skill	Bias
5m	0.62	0.12
10m	0.60	0.12
15m	0.61	0.12
20m	0.59	0.12
30m	0.60	0.12
50m	0.61	0.12
100m	0.60	0.11
200m	0.62	0.12



Mesh Resolution Sensitivity

- Changing grid spacing :
  - Alongshore spacing: 15 m
  - Increasing cross shore spacing

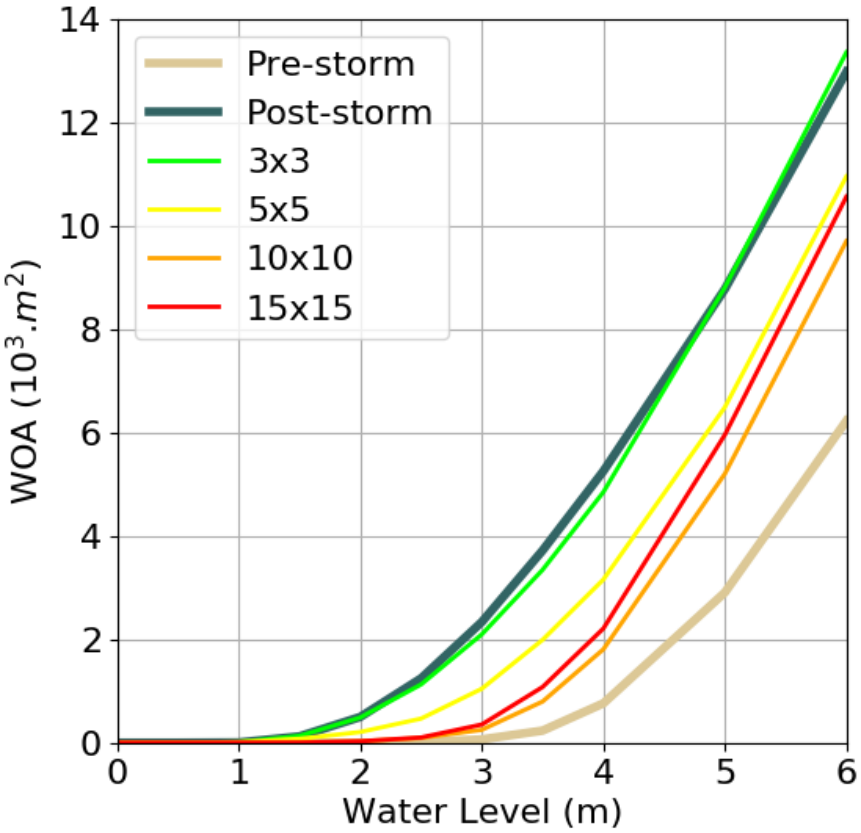
Mesh	Skill	Bias
3m	0.60	0.12
5m	0.50	0.05
10m	0.30	-0.03
15m	0.12	-0.11
30m	0.00	-0.06



Mesh Resolution Sensitivity

- Changing grid spacing :
  - Increase spacing in both directions

Mesh	Skill	Bias
3m	0.62	0.09
5m	0.55	0.04
10m	0.27	-0.06
15m	0.12	-0.11



Conclusion and Future Work

Mesh Sensitivity

- Alongshore:
  - Skill score is not sensitive to alongshore mesh spacing
  - WOA results also show a good match between modeled and post storm data
- Cross-shore:
  - Skill score drops as the cross-shore mesh resolution increases
  - WOA is similar for high and low resolution
- Skill Score is a good measure for domain-wide erosion
- WOA may estimate better the overtopping and flooding
- WOA might be better criteria for coupling XBeach with ADCIRC

Future Work

- Validating WOA sensitivity to mesh resolution in other regions
- ADCIRC mesh requirements
  - Increasing resolution in ADCIRC mesh
  - Update topography to improve flood prediction