Storm-Driven Erosion and Inundation of Barrier Islands at Dune- and Region-Scales

Alireza Gharagozlou[1]

JC Dietrich[1], A Karanci[1], MF Overton[1], RA Luettich Jr[2]

[1] Department of Civil, Construction, and Environmental Engineering, NC State University

[2] Institute of Marine Sciences, University of North Carolina at Chapel Hill

ADCIRC Users Group Meeting 2019 – Vicksburg, MS

Sea Grant North Carolina

US Army Corps of Engineers®

U.S. Coastal Research Program

NSF

Motivations

*NCDOT

* Daniel Pullen Photography

Cape Hatteras, NC Outer Banks, Florence Sep 2018

Motivations

ADCIRC

- Powerful tool for flooding and storm surge modeling
- Does not predict morphodynamics
- We explore a coupling with XBeach

XBeach

- Nearshore hydrodynamics and morphodynamics
- Small scale features (dune erosion, overwash, breach)

- XBeach mesh has higher resolution compared to ADCIRC mesh
  - ADCIRC: Typical minimum spacing of 20-100 m
  - XBeach: Typical minimum spacing of 1-3 m

Goals & Objectives

Goals:

- Predict storm-driven erosion over large domains
- Develop techniques for coarsening predictions and coupling back to flooding models

Objectives:

1. Validate XBeach erosion predictions on larger domains
   - Quantify model performance on 30-km of Hatteras Island during Isabel

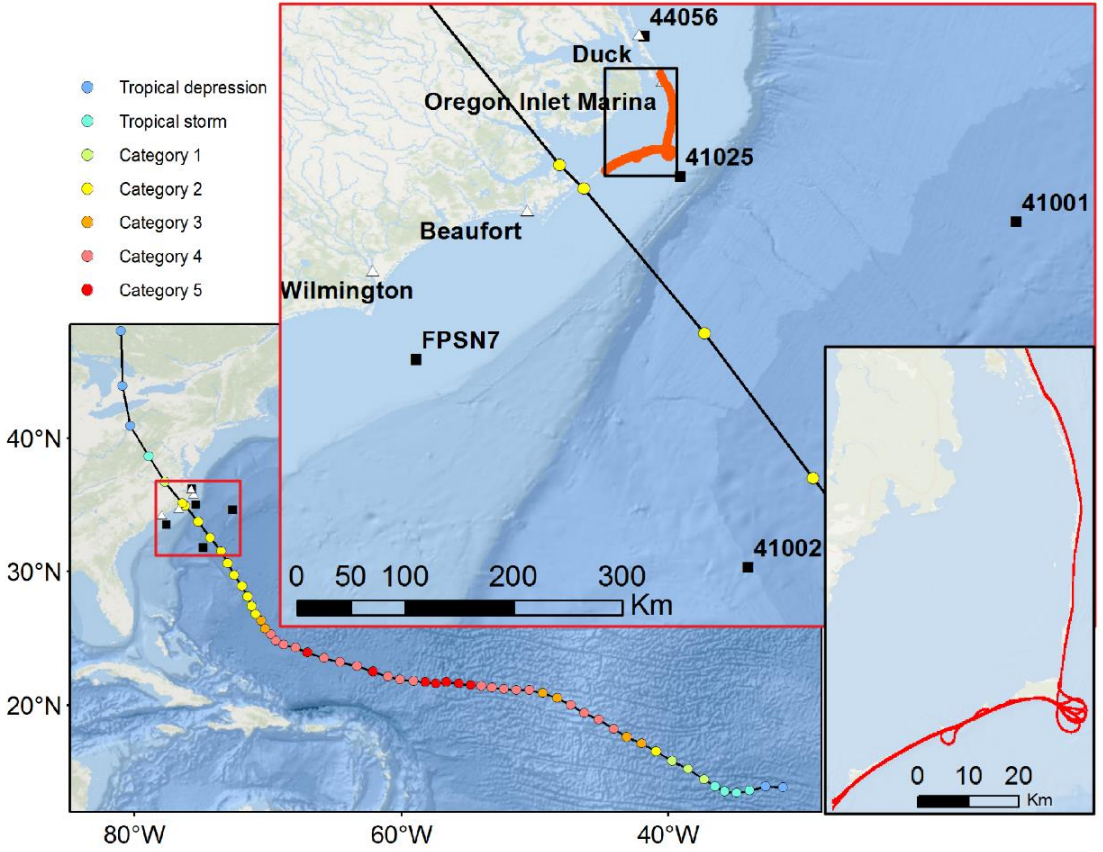
2. Evaluate XBeach accuracy at coarser resolution
   - What happens if we use a coarser mesh?

3. Loose coupling XBeach and ADCIRC
   - What are implications as a hydraulic control to stop or allow flooding?
   - How ADCIRC predictions change with updated topography?

Hurricane Isabel

- Survey width: 250-300 m
- High resolution LiDAR: 2m
- Covering large extent
- Erosion, overwash, and breaching
- Pre- and post-storm data:

  16 Sep — 21 Sep 2003



Study Area

Computational grid:

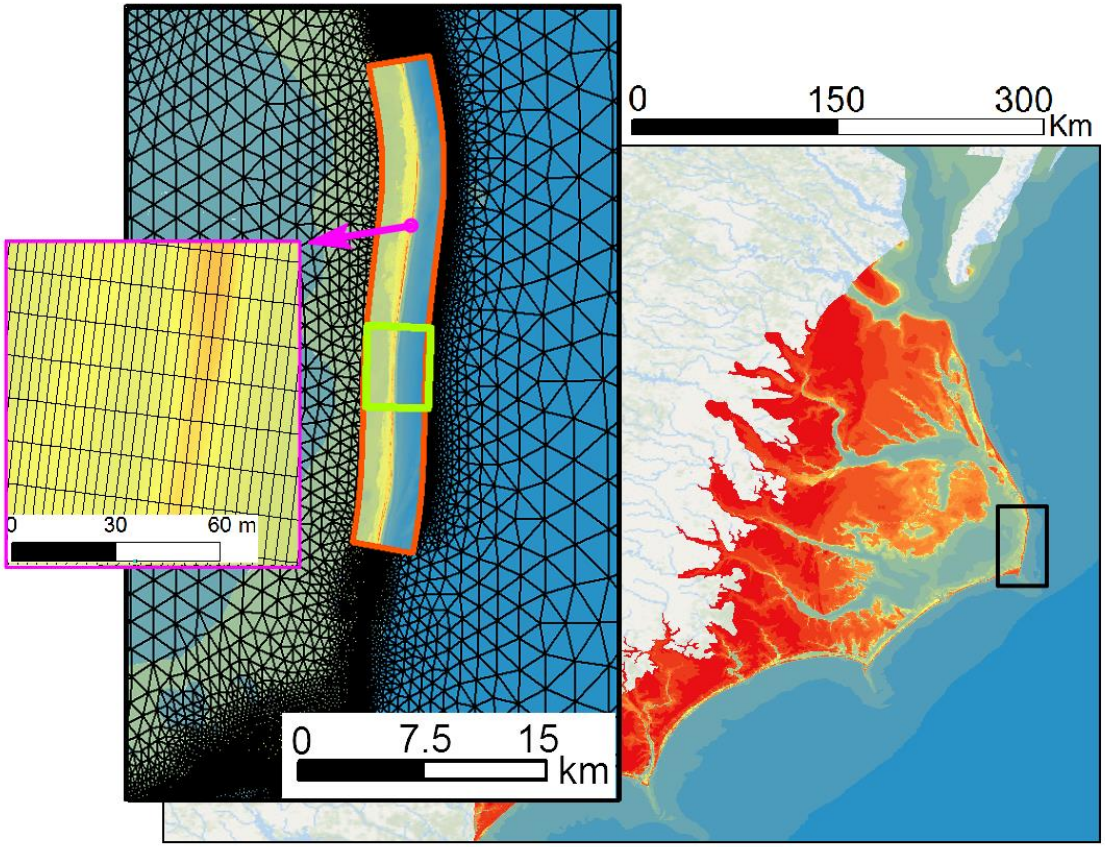
- Alongshore: 15 m
- Cross shore: 3-35 m

Topo/Bathy data:

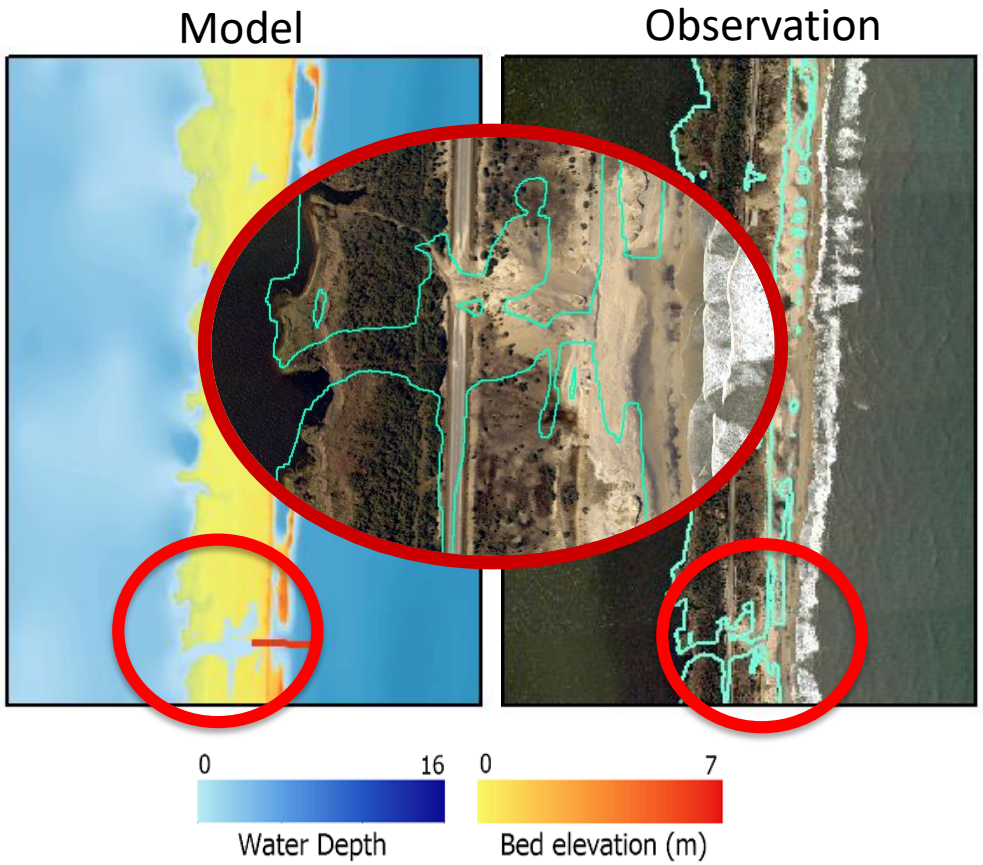
- Pre-storm LiDAR
- NC floodplain mapping DEM

Model setup:

- Simple model with minimal tuning
- To expand to other regions
- Waves and water levels from ADCIRC+SWAN



1. XBeach Validation

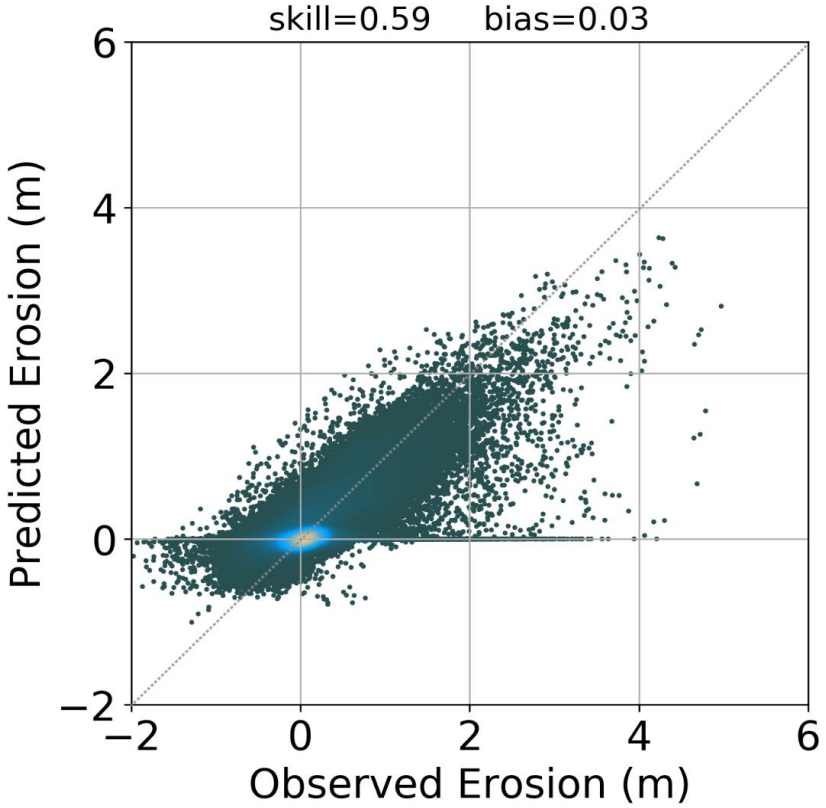


1. XBeach Validation

Skill Score

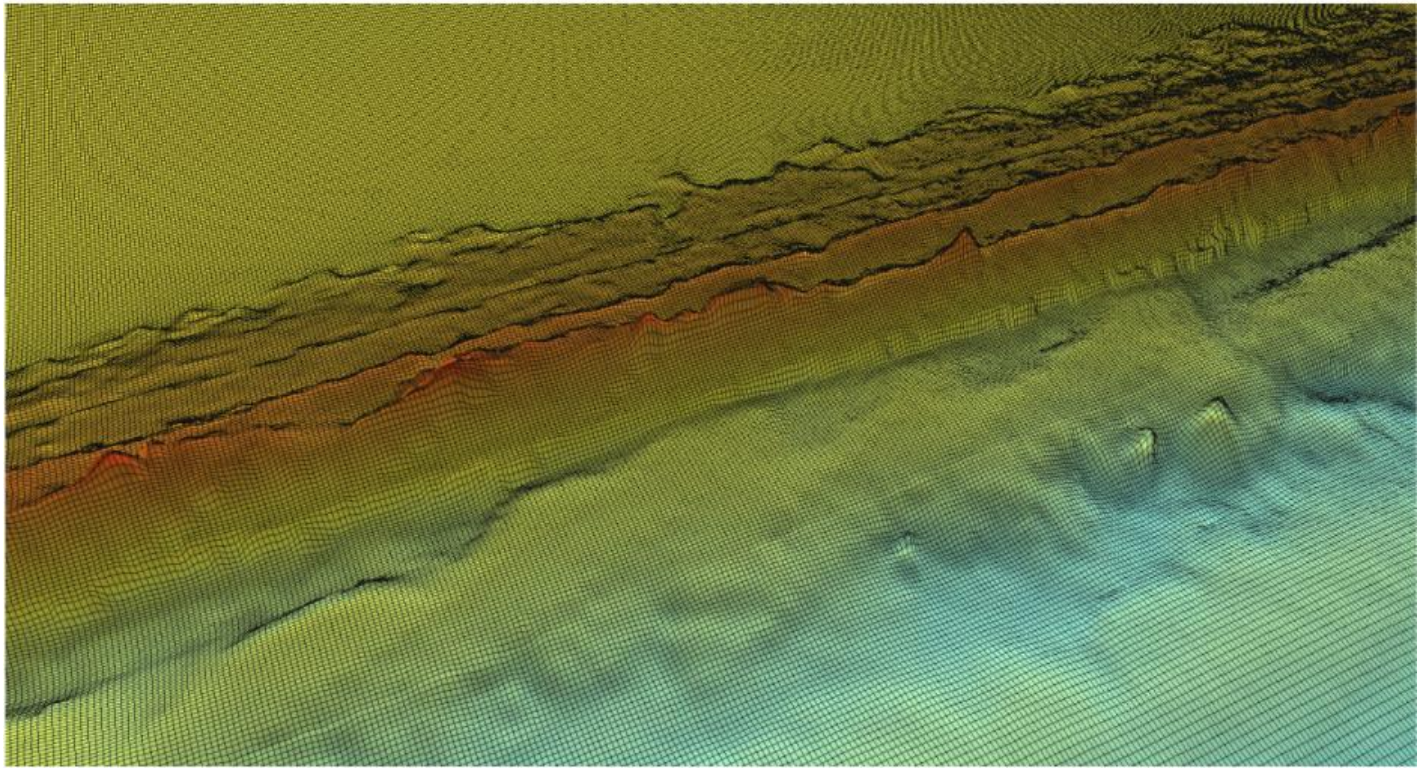
$$Skill = 1 - \frac{\sum_{i=1}^{N} \left(dz_{b_{LIDAR,i}} - dz_{b_{XBeach,i}} \right)^2}{\sum_{i=1}^{N} \left(dz_{b_{LIDAR,i}} \right)^2}$$

- Skill Score > 0.5 is “Excellent”
- Model Skill Score = 0.59

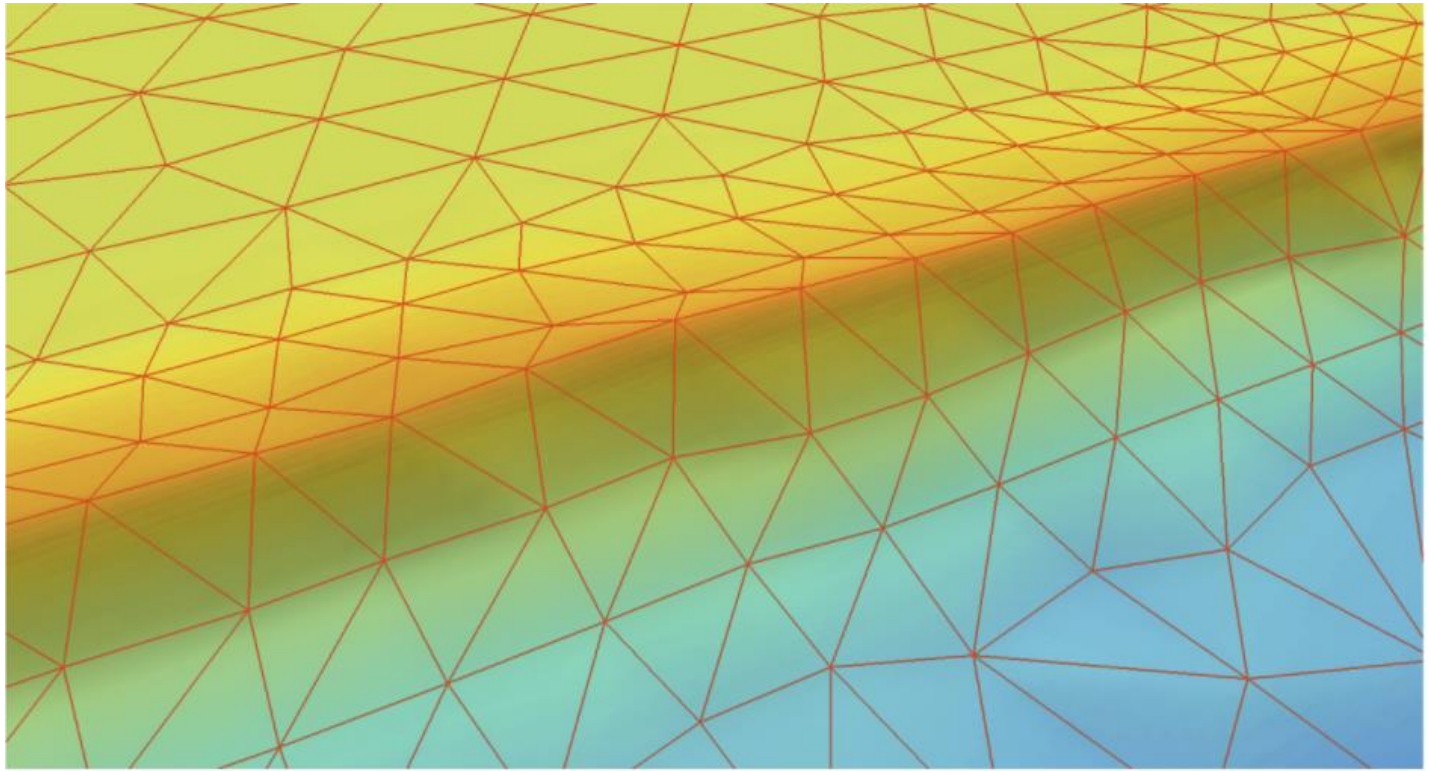


2. Resolution Sensitivity

2. Resolution Sensitivity

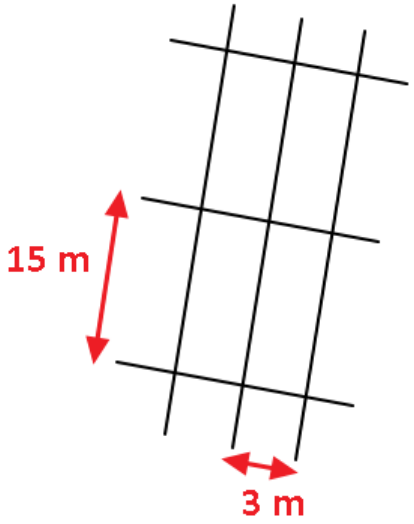


2. Resolution Sensitivity



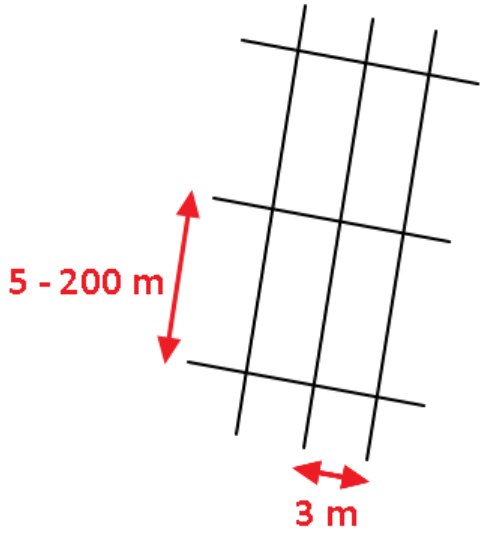
2. Resolution Sensitivity

- Changing mesh spacing
  - Alongshore
  - Cross-shore
- Sensitivity of Skill Score to resolution



2. Resolution Sensitivity

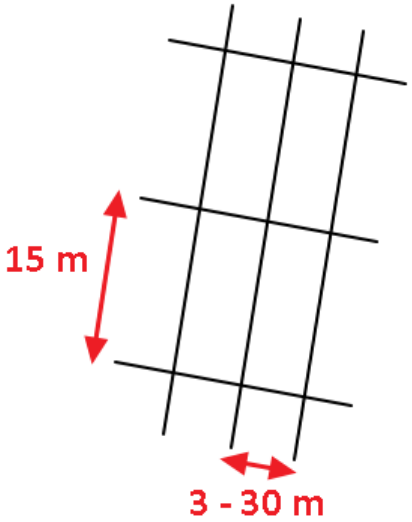
- Alongshore spacing



Mesh	Skill	Bias
5m	0.68	-0.06
10m	0.69	-0.07
15m	0.68	-0.06
20m	0.69	-0.06
30m	0.69	-0.06
50m	0.67	-0.05
100m	0.69	-0.03
200m	0.69	-0.03

2. Resolution Sensitivity

- Cross-shore spacing



Mesh	Skill	Bias
3m	0.68	-0.06
5m	0.60	-0.05
10m	0.51	-0.03
15m	0.27	-0.03
30m	0.07	0.33

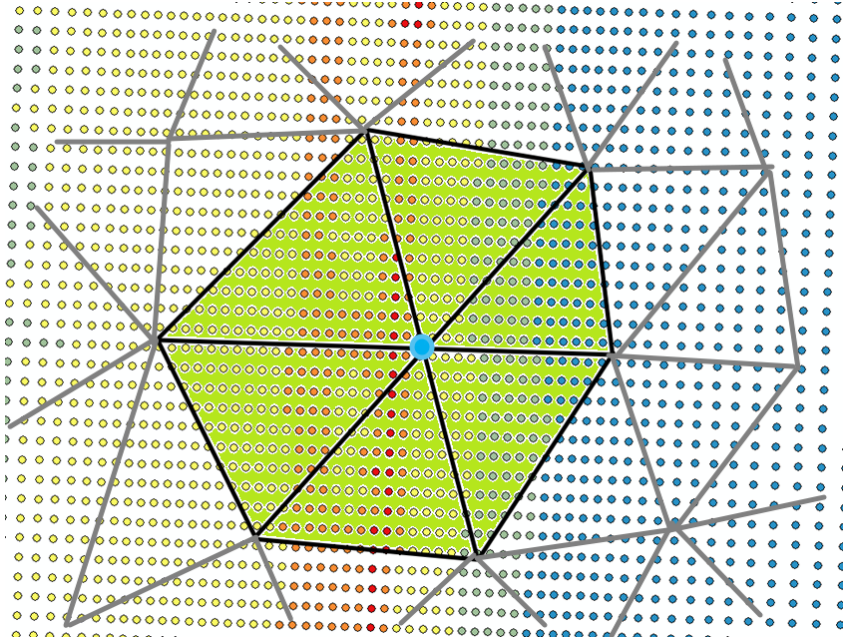
3. Loose Coupling

Refining ADCIRC mesh

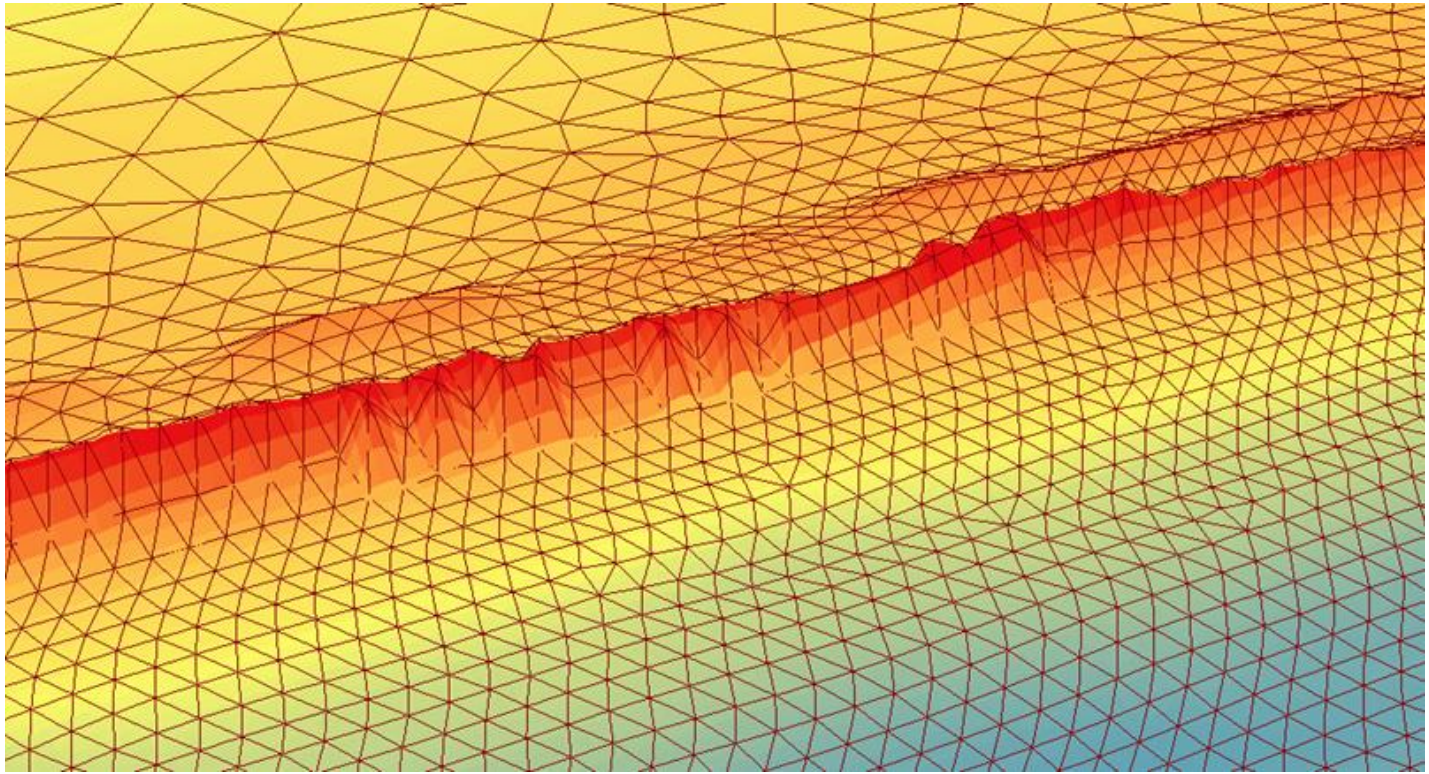
Upscaling bathy/topo:

- From a base data set (DEM or XBeach mesh)
- To a target mesh (ADCIRC)
    1. Pre-storm
    2. Post-storm
    3. XBeach prediction

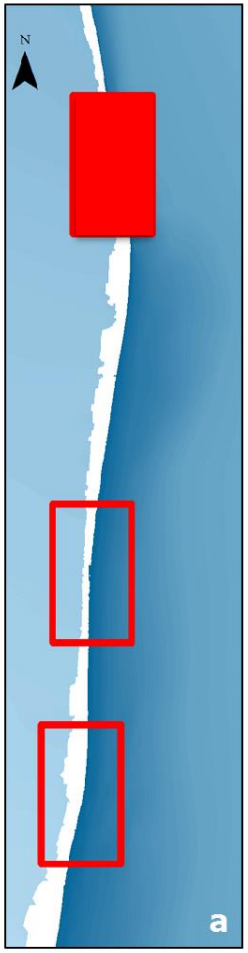
- Cell-area IDW interpolation
- Mapping the dune crest



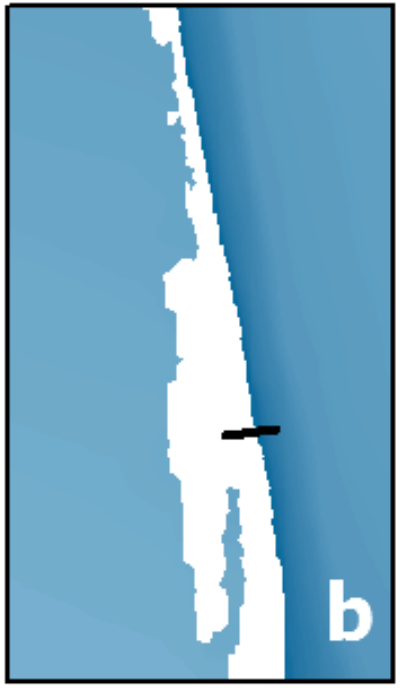
3. Loose Coupling



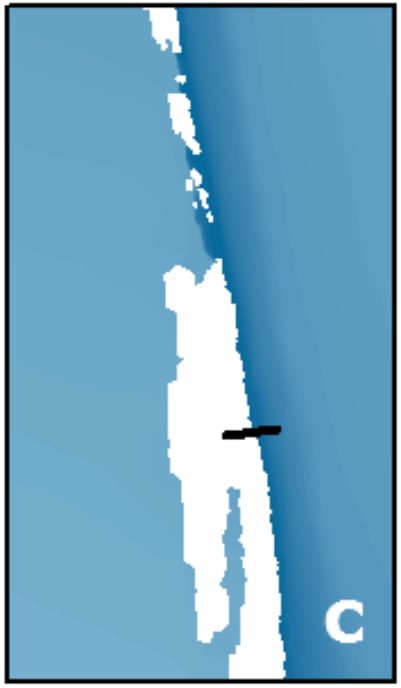
3. Loose Coupling



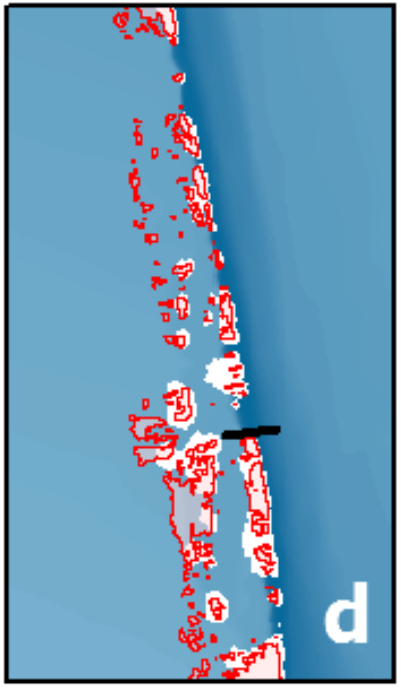
Pre-storm topo



Post-storm topo

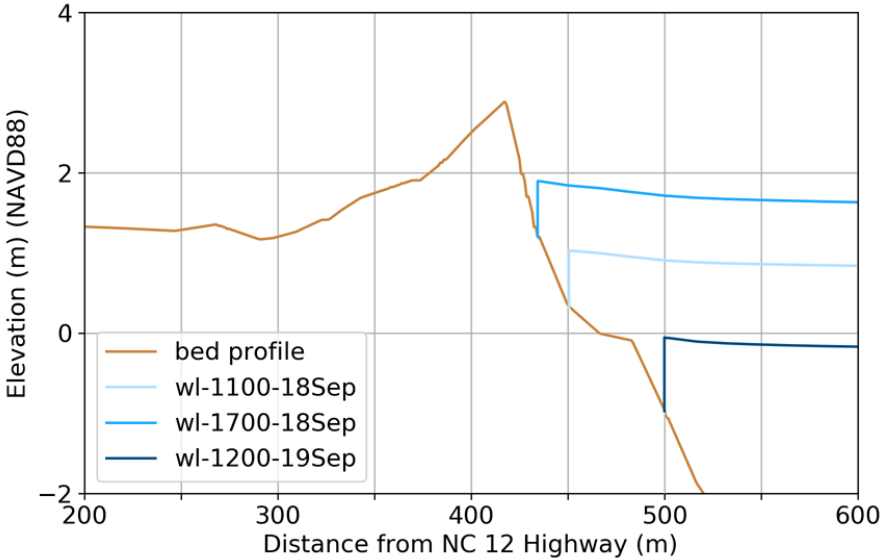


XBeach prediction

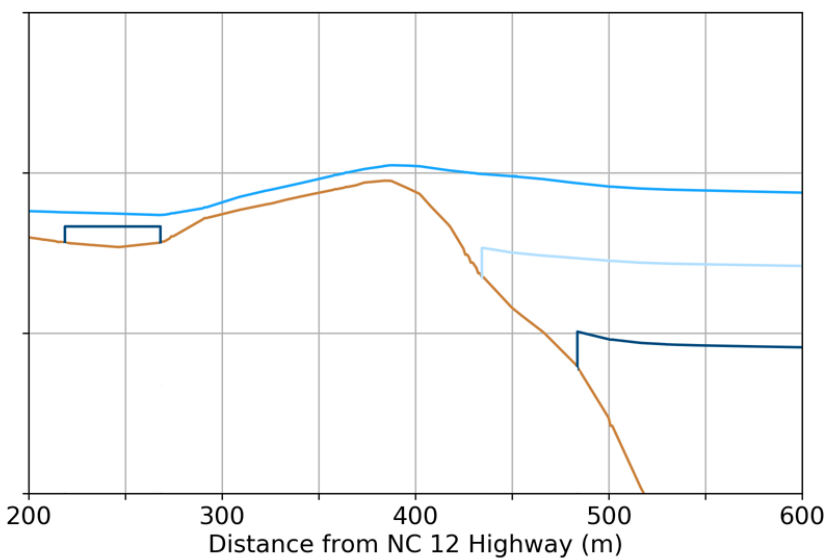


3. Loose Coupling

Pre-storm topo



XBeach prediction



Conclusion

1. XBeach performance:

- Model performance on 30 km domain is very encouraging
- Beach profile, Erosion events, flooding extents match post-storm observation

2. XBeach mesh resolution:

- Skill score is not sensitive to alongshore mesh spacing
- Skill score gets worse as the cross-shore mesh resolution increases

3. ADCIRC-updated topo/bathy:

- Beach and dune erosion contribute to flooding predictions
- Results match the prediction in XBeach and post-storm observation

Questions?