NC STATE UNIVERSITY

Interactions between Waves, Flooding, and Beach Morphology during Storm Events

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NC Beach Inlet & Waterway Association Annual Conference
Wrightsville Beach NC, 14-15 November 2016

Sea Grant
North Carolina

Waves, Flooding, and Beach Morphology

Overview

Project supported by NC Sea Grant:

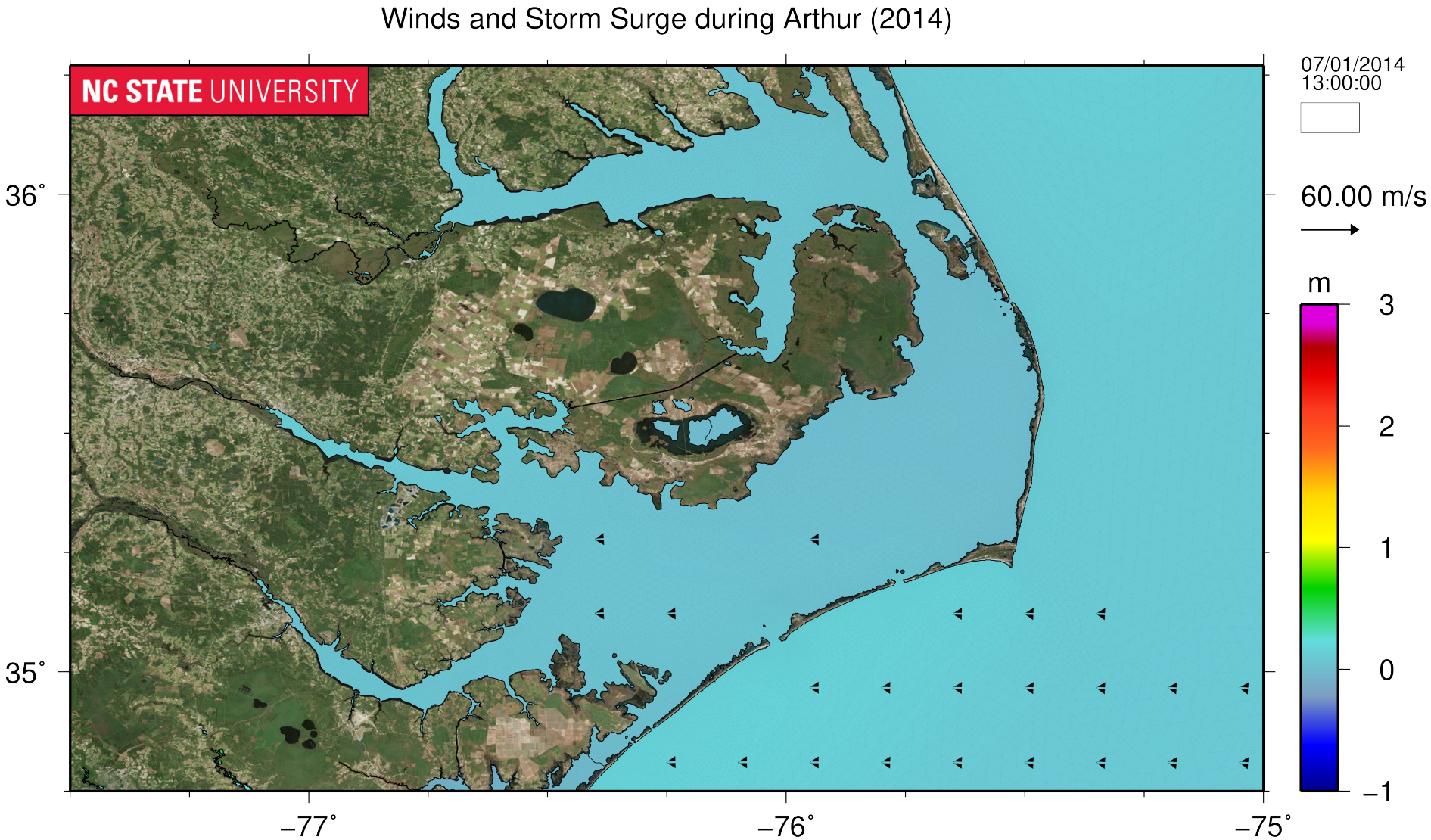
- Two years: Feb 2016 through Jan 2018
- Goal – To improve simulations of coastal flooding in regions where the beach and/or dune are highly dynamic during storms
- Objectives:
  1. Extend XBeach to applications at larger geographic extents
  2. Couple XBeach with ADCIRC to allow for dynamic feedback

Progress in the first 9 months:

1. Continue sharing guidance about waves and flooding during storms
   - Hermine (Sep 2016)
   - Matthew (Oct 2016)
2. Developing large-domain XBeach models for Hatteras Island

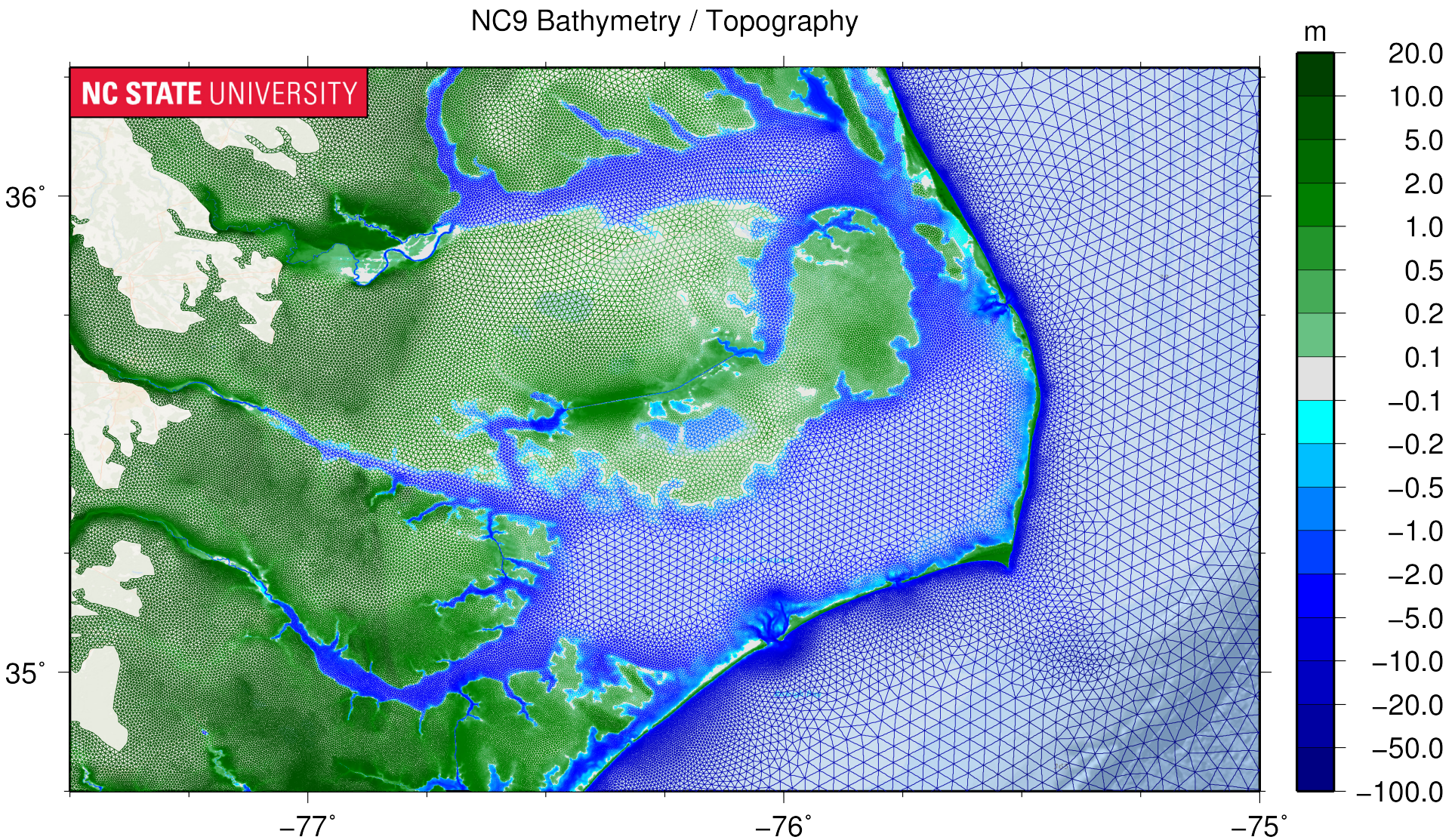
Real-Time Forecasting for Hurricane Waves and Surge

Example of Coastal Flooding



Real-Time Forecasting for Hurricane Waves and Surge

Finite-Element Mesh for NC Coast



Real-Time Forecasting for Hurricane Waves and Surge

ADCIRC Surge Guidance System (ASGS)

SWAN+ADCIRC can be employed in real-time via the ASGS

- **Everything happens automatically**
  - Models are initialized, run and processed by Perl scripts

Wind fields from two sources:

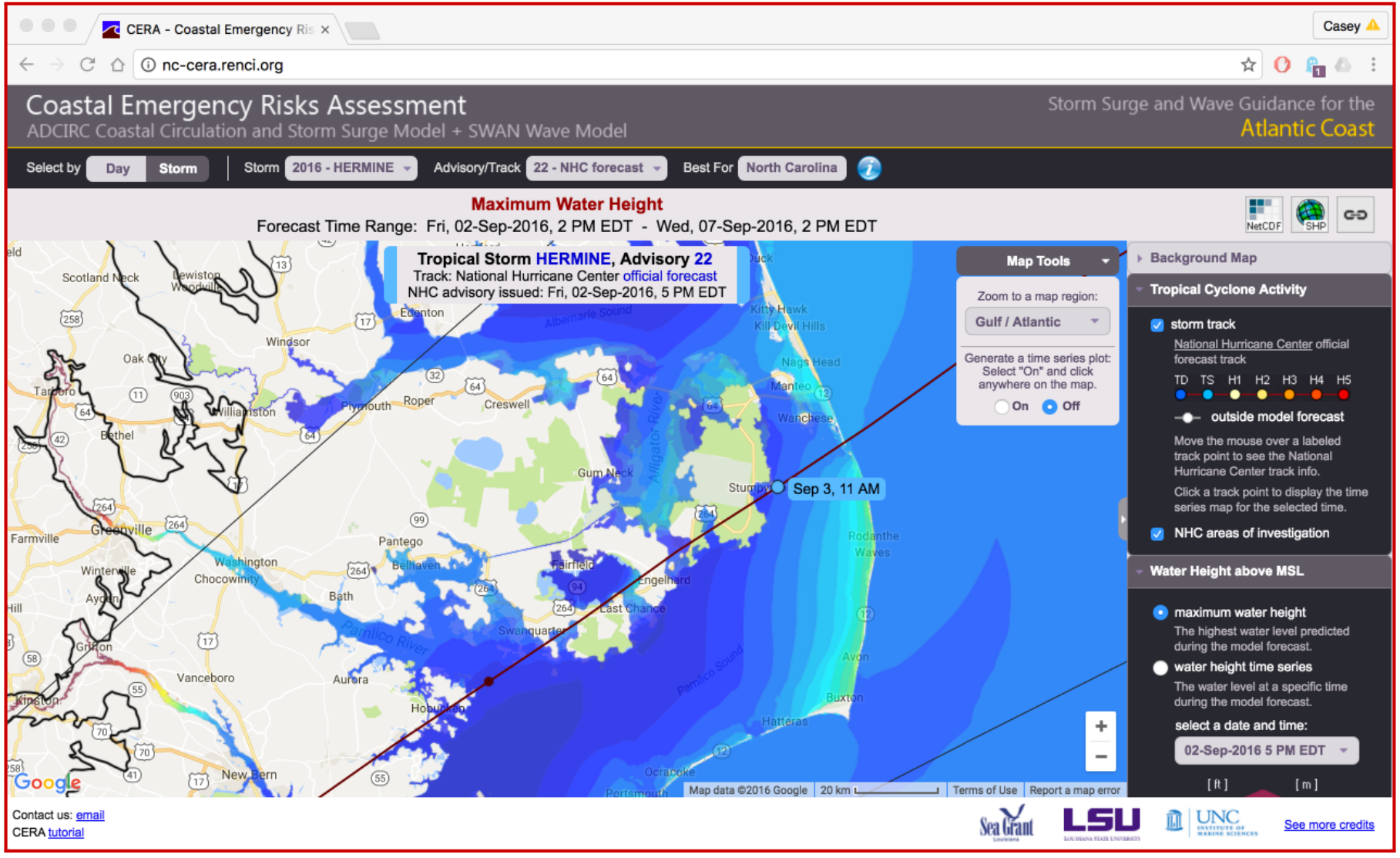
1. Under normal conditions:
   - Downloaded from NAM model output by NOAA/NCEP
   - Converted into format compatible with SWAN+ADCIRC
2. Under hurricane conditions:
   - Download advisories from NOAA/NHC
   - Generate wind field using parametric model (Holland, 1980)

Guidance can be shared in multiple formats:

- Raster images (JPG, PNG, etc.)
- Geo-referenced raster images (Google Earth, GIS)
- Web service (`nc-cera.renci.org`)

Real-Time Forecasting for Hurricane Waves and Surge

Coastal Emergency Risks Assessment (CERA): `nc-cera.renci.org`



Real-Time Forecasting for Hurricane Waves and Surge

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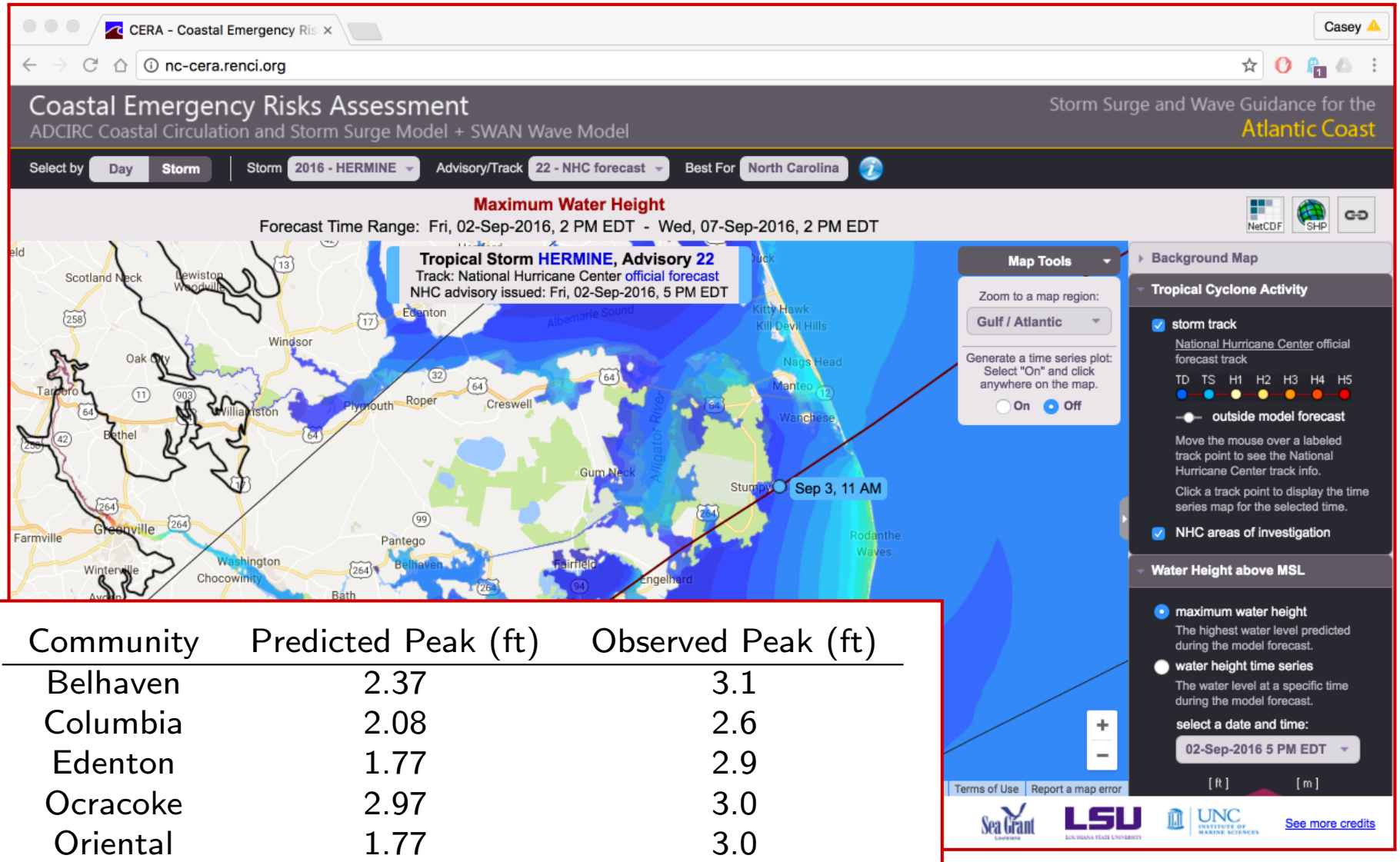

Community	Predicted Peak (ft)	Observed Peak (ft)
Belhaven	2.37	3.1
Columbia	2.08	2.6
Edenton	1.77	2.9
Ocracoke	2.97	3.0
Oriental	1.77	3.0

Real-Time Forecasting for Hurricane Waves and Surge

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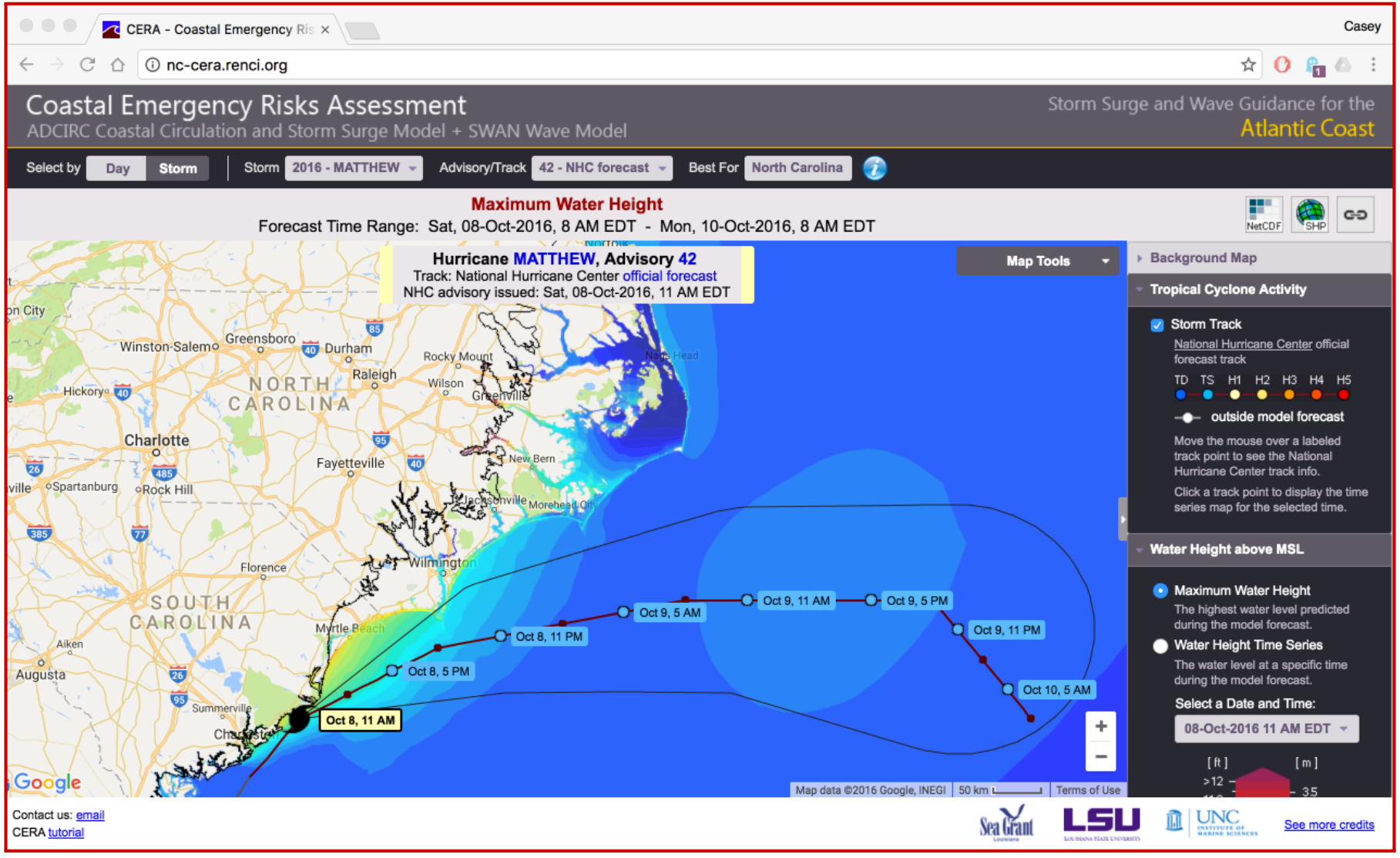
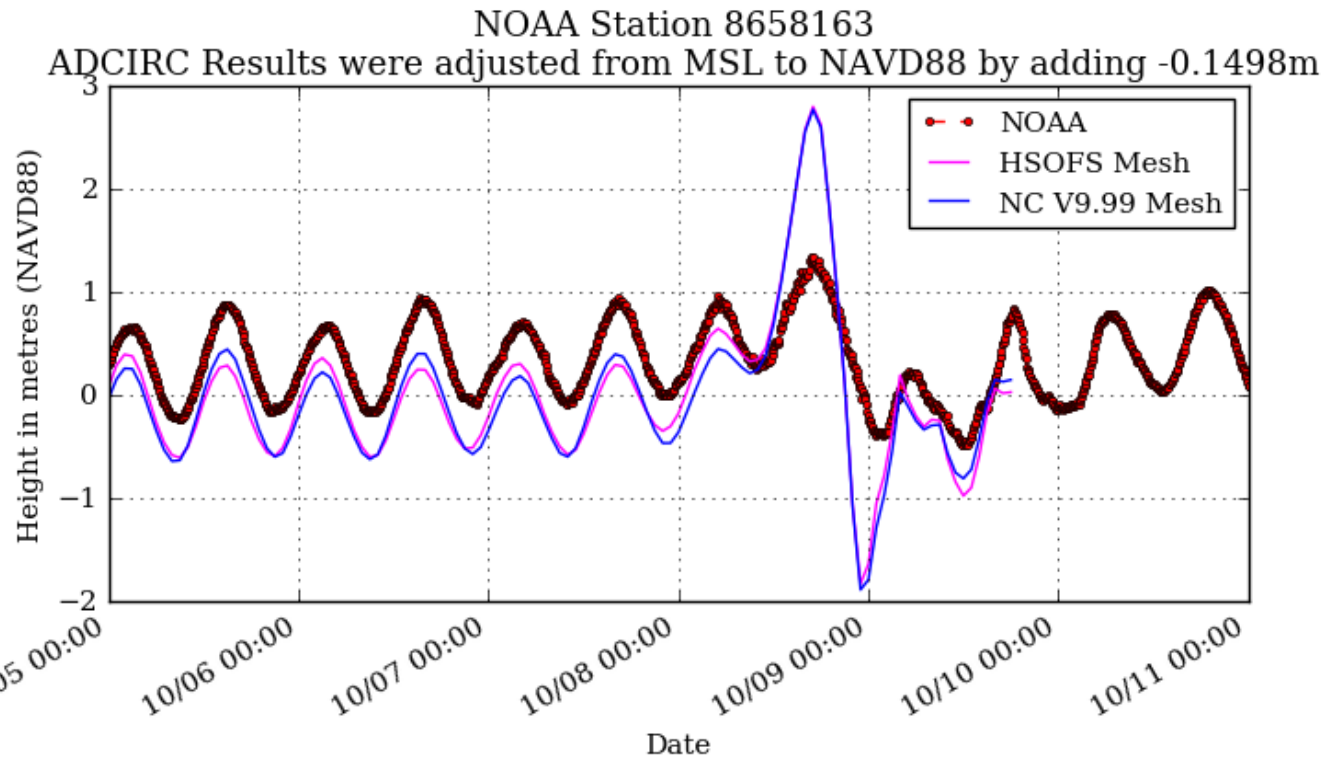


Real-Time Forecasting for Hurricane Waves and Surge

Water Level Predictions at Wrightsville Beach

Comparison of observations and predictions at NOAA 8658163

- Advisory 27 – 2100 UTC on Tuesday 4 October 2016

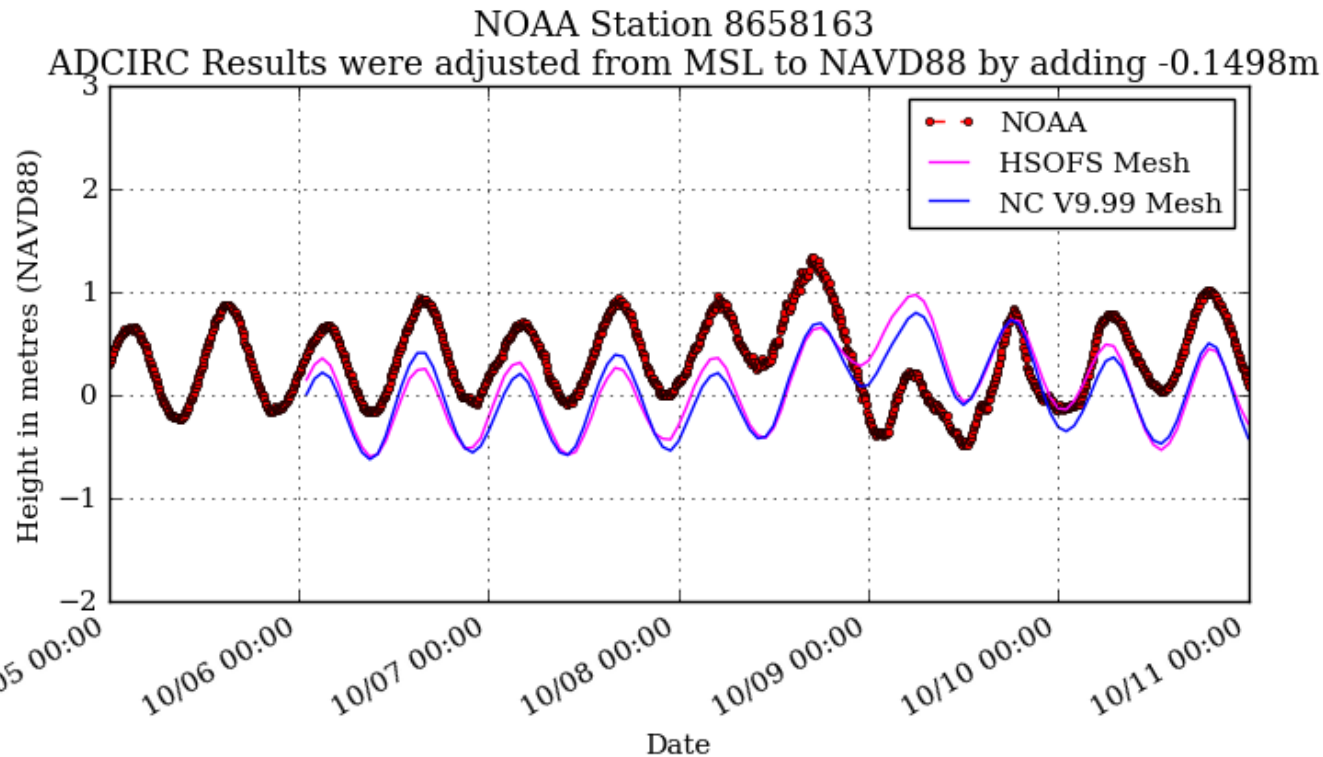


Real-Time Forecasting for Hurricane Waves and Surge

Water Level Predictions at Wrightsville Beach

Comparison of observations and predictions at NOAA 8658163

- Advisory 32 – 0300 UTC on Thursday 6 October 2016

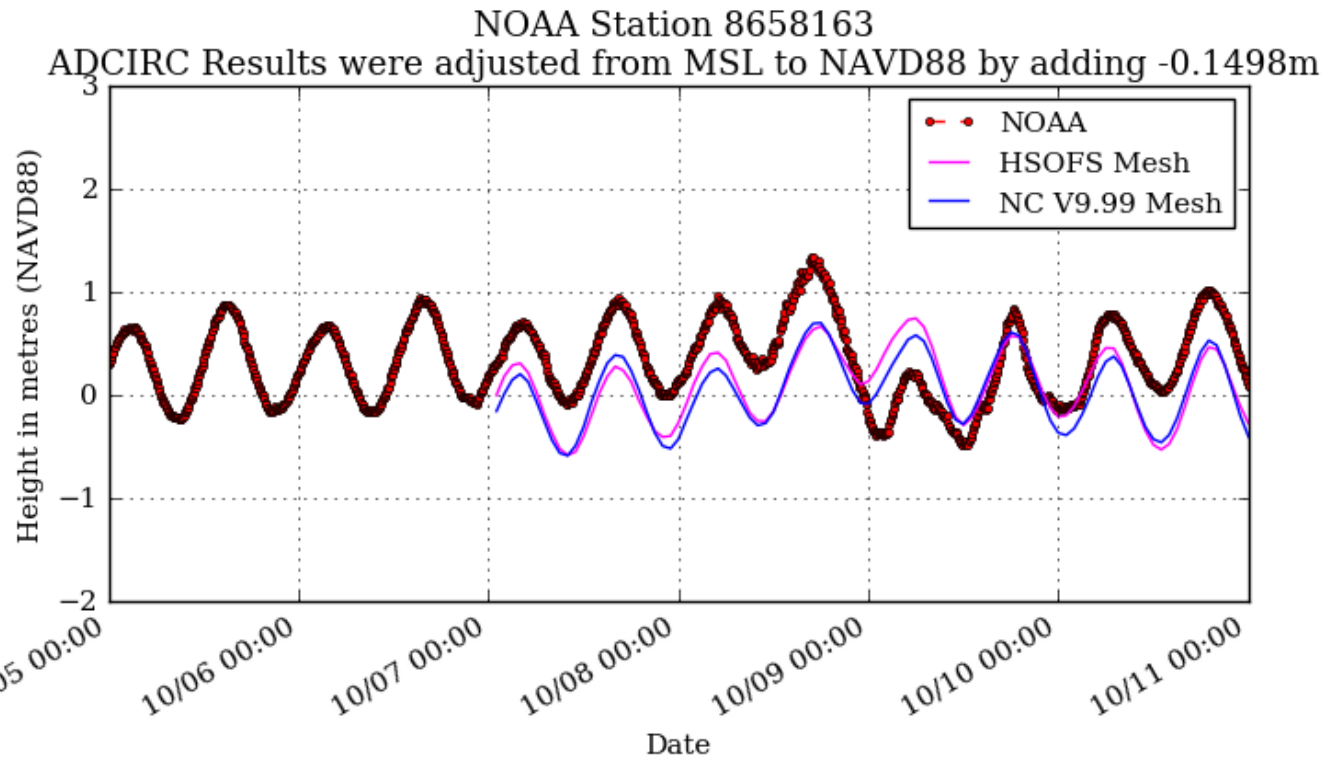


Real-Time Forecasting for Hurricane Waves and Surge

Water Level Predictions at Wrightsville Beach

Comparison of observations and predictions at NOAA 8658163

- Advisory 36 – 0300 UTC on Friday 7 October 2016



Coupling with XBeach for Morphodynamics

eXtreme Beach (XBeach): `xbeach.org`

Our forecast system is limited:

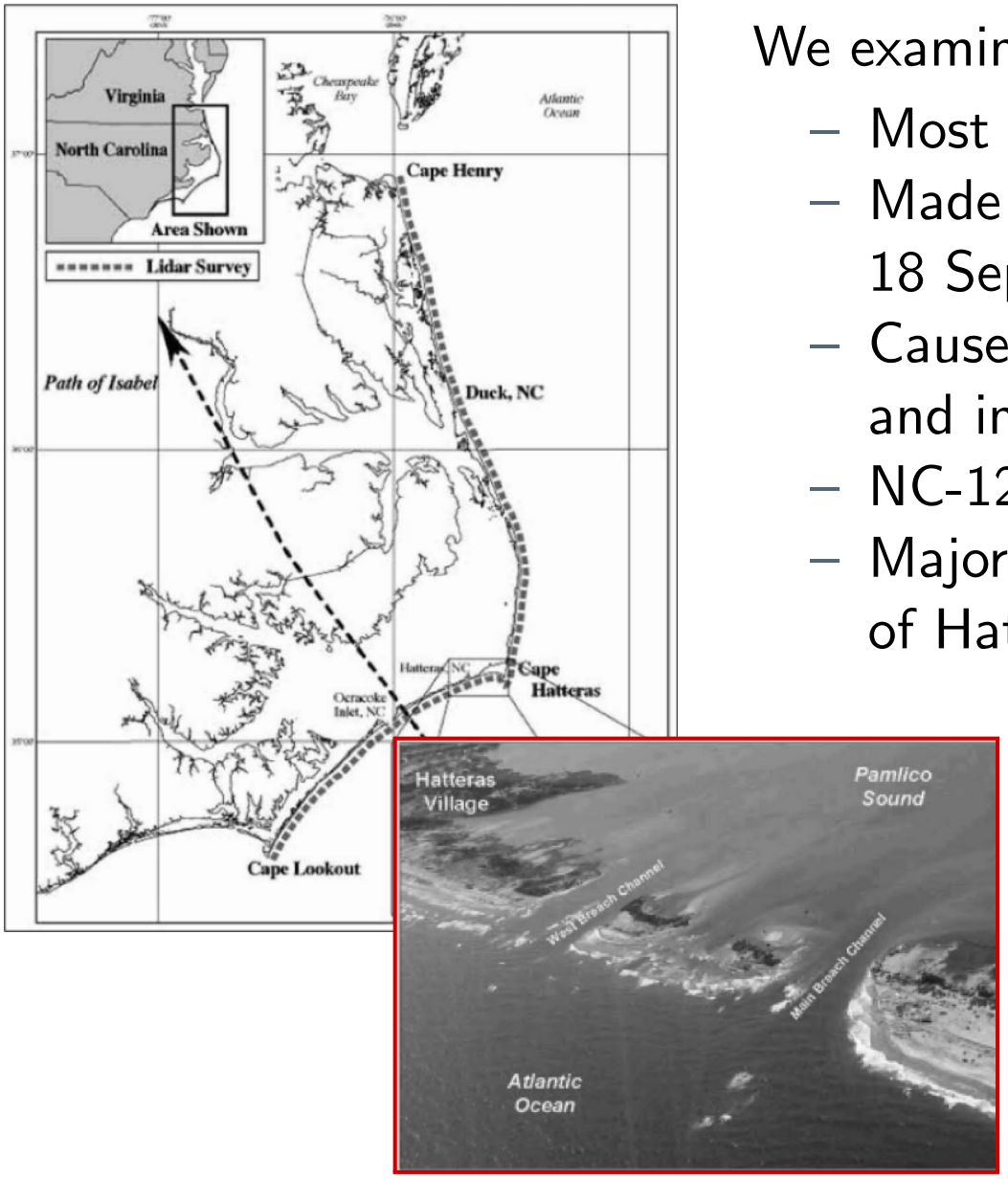
- Bathymetry and topography are fixed / constant
- No consideration of beach erosion, dune breaching, etc.
- Flooding impacts are limited behind the dunes

With support from NC Sea Grant, we are coupling with XBeach:

- Open-source model developed in the Netherlands
- Capable of simulating hydrodynamic and morphodynamic processes
- Applied typically at beach scales (a few kilometers)

Exploring Morphodynamics during Isabel (2003)

Hurricane Isabel (2003)



We examine storm impacts during Isabel:

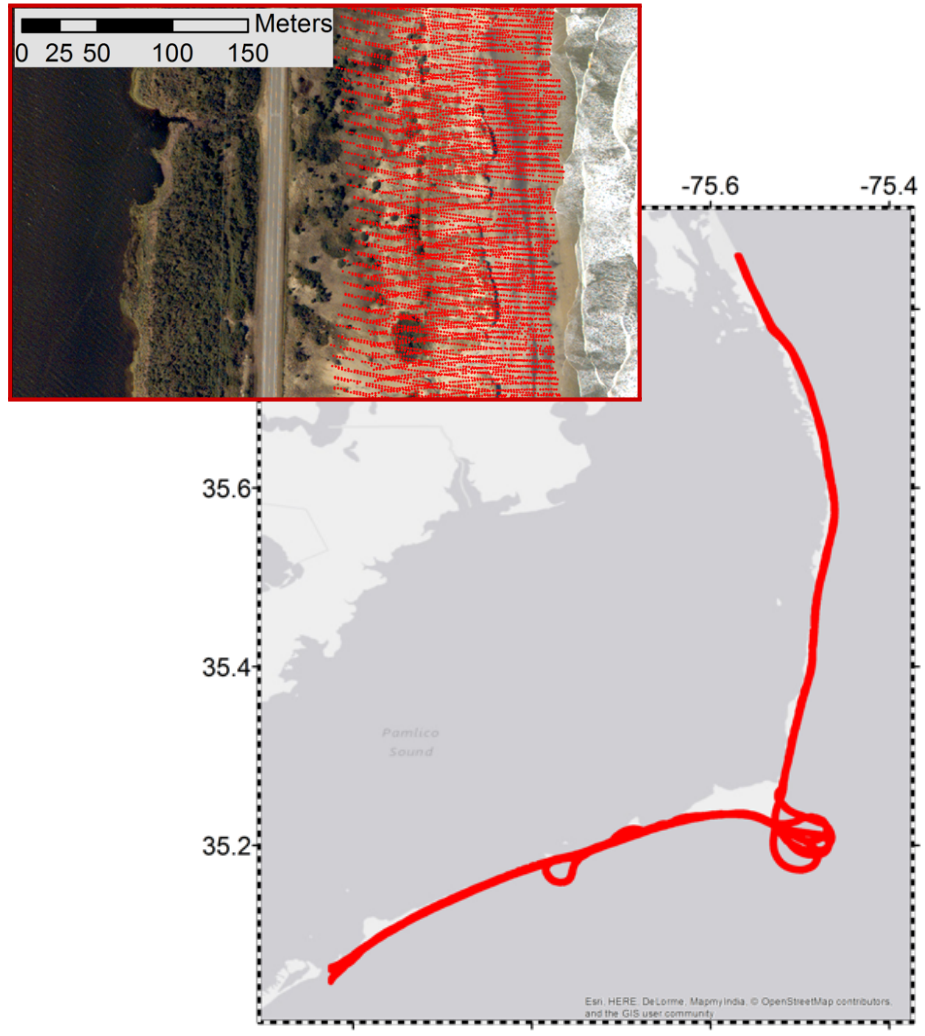
- Most powerful hurricane in 2003
- Made landfall on the Outer Banks on 18 Sep as Category 2 hurricane
- Caused overwash, dune breaching, and infrastructure destruction
- NC-12 closed at identified hotspots
- Major breaching occurred northeast of Hatteras Inlet

Exploring Morphodynamics during Isabel (2003)

Pre- and Post-Storm LiDAR Data

Available LiDAR data:

- Pre- and post-storm data sets available from the NASA / USGS Experimental Advanced Airborne Research LiDAR
  - 16 Sep 2003
  - 21 Sep 2003
- Coverage of Outer Banks from Ocracoke Inlet to Oregon Inlet
- Surveyed width of 250-300 m
- Resolution of 2 m
- Only the topographic data are used, due to water turbidity in bathymetric regions

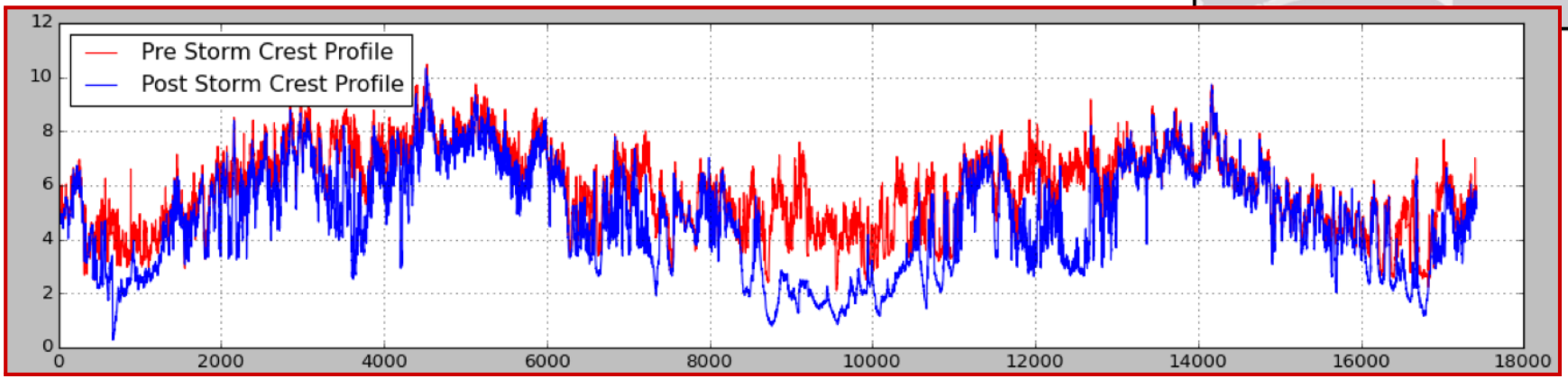


Exploring Morphodynamics during Isabel (2003)

Storm Impacts in Study Area

Alongshore crest elevation change:

- Study area between Avon and Salvo
  - Distance of about 18 km
- Elevation changes at pre-storm crest line
  - Average = 1 m
  - Maximum = 5.4 m
- Total of 20 major dune erosion events
  - All wider than 15 m

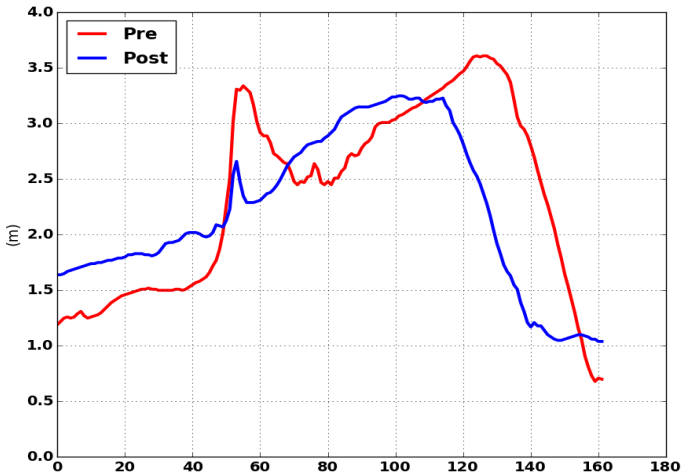


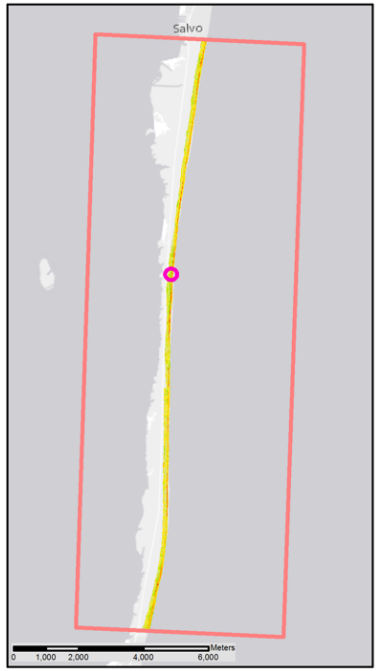
Exploring Morphodynamics during Isabel (2003)

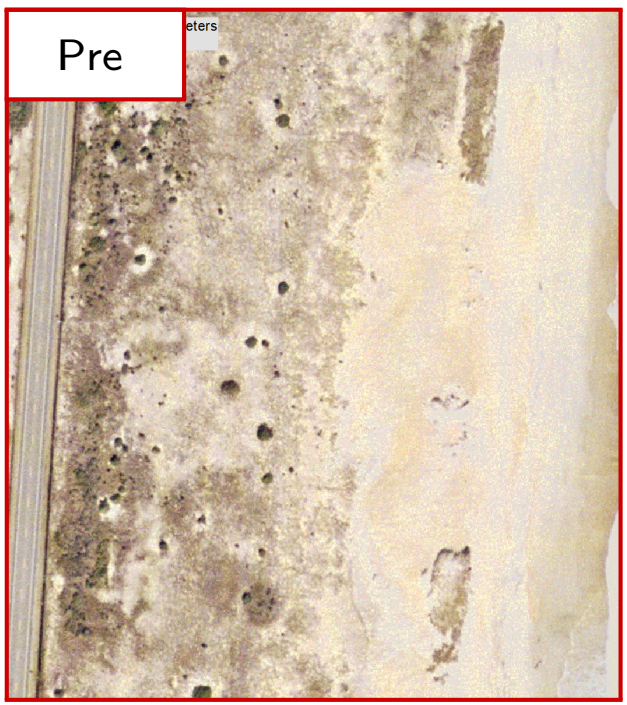
Examples of Major Dune Erosion Events

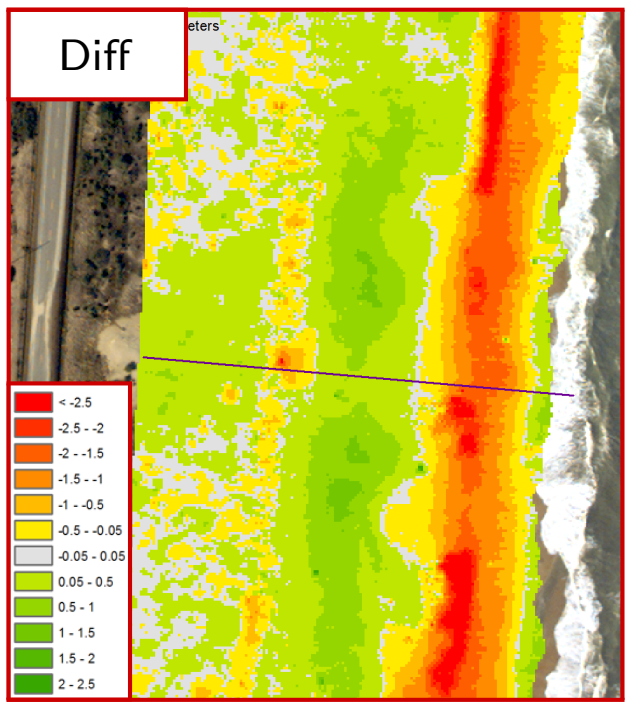
Dune Erosion Event #1:

- Removal of first dune
- Erosion of second dune
- Deposition between and behind dunes







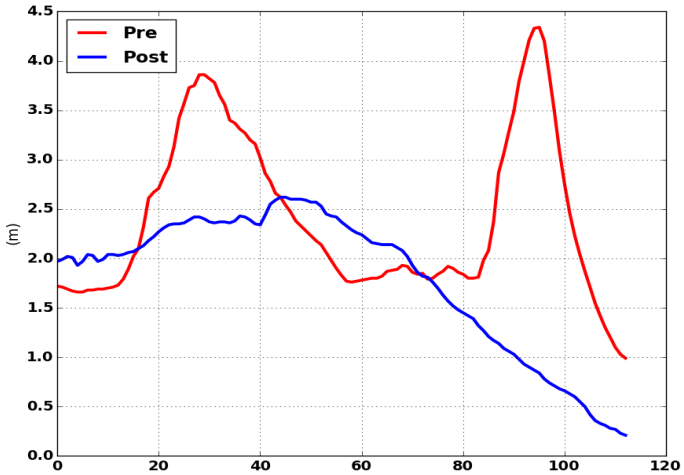


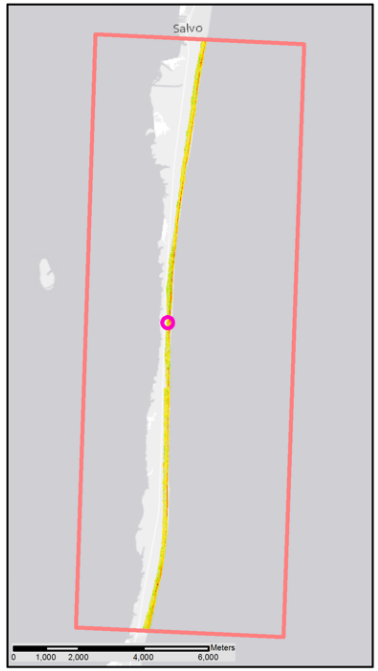
Exploring Morphodynamics during Isabel (2003)

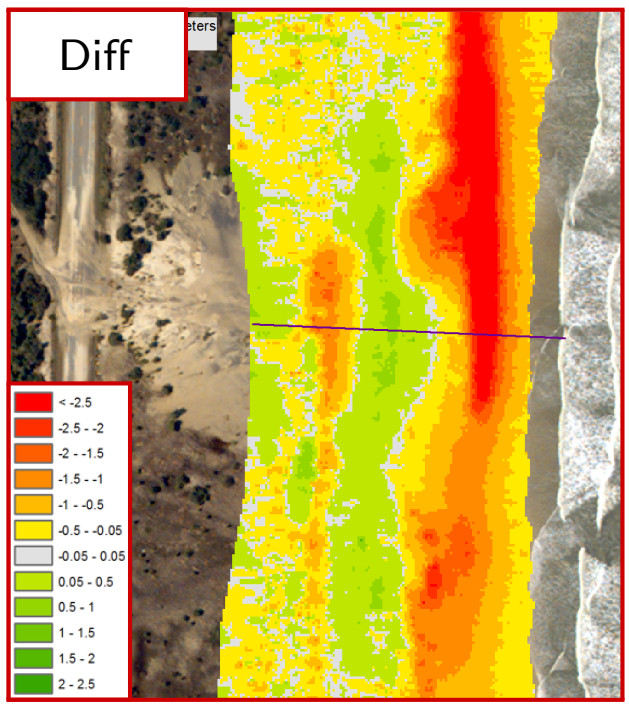
Examples of Major Dune Erosion Events

Dune Erosion Event #2:

- Removal of both dunes
- Deposition between and behind dunes
- Overwash extends to road







Initial Results with XBeach

Generating Mesh for XBeach Simulations

Combining data sets:

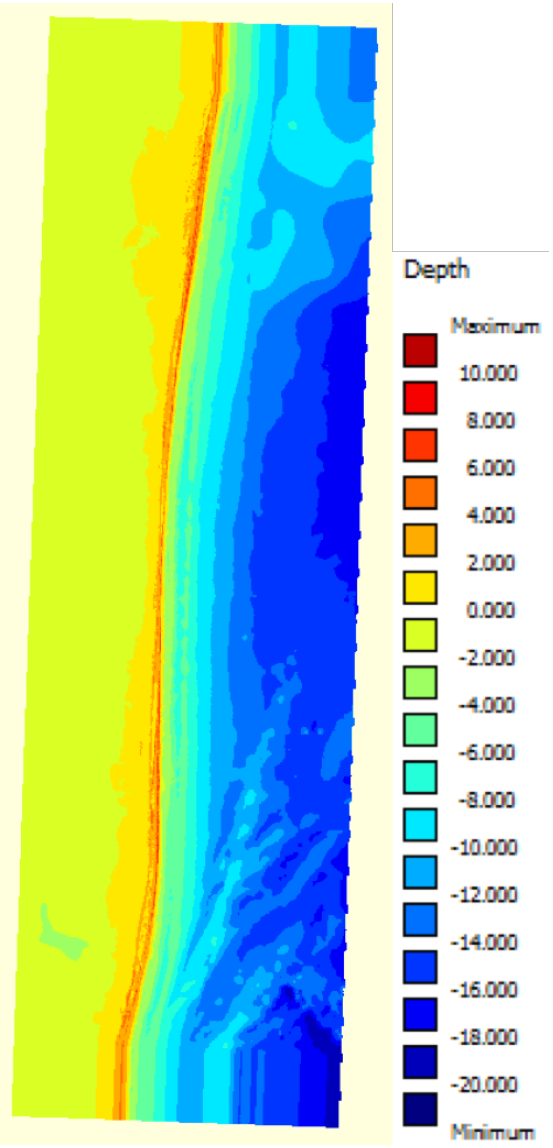
- Pre-storm LiDAR with 1 m resolution
- NC flood mapping DEM with 10 m resolution

Converting to computational mesh:

- Total of $1400 \cdot 720$ cells
- Cell widths:
  - Alongshore $= 15$ m
  - Cross-shore at offshore boundary $= 30$ m
  - Cross shore at shoreline $= 3$ m

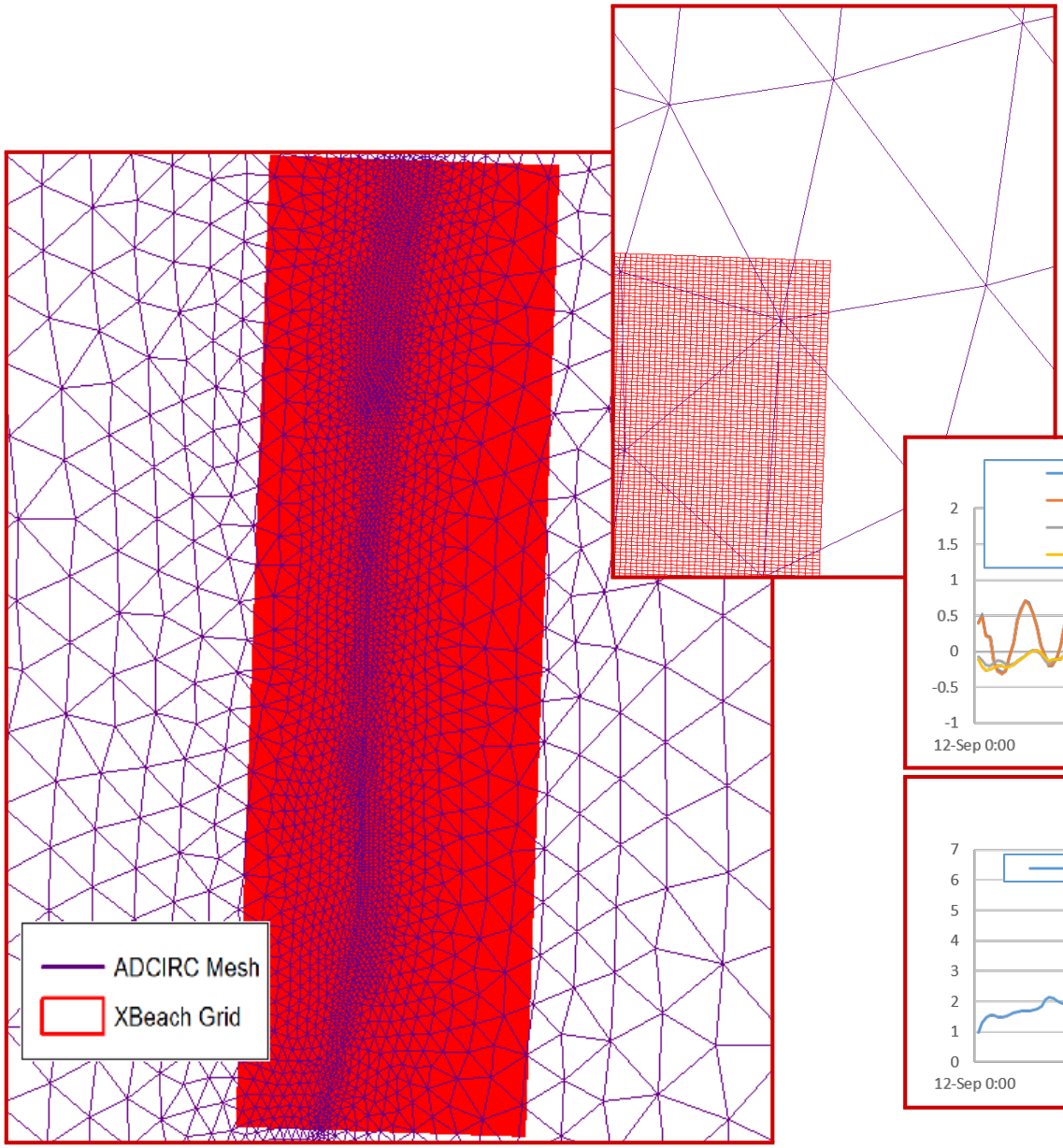
Need to assign values:

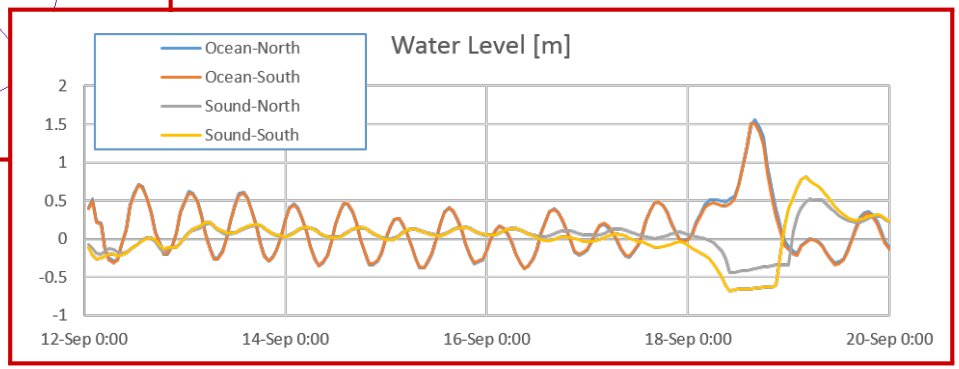
- Waves and water levels at boundaries
- Vegetation properties
- Sediment properties

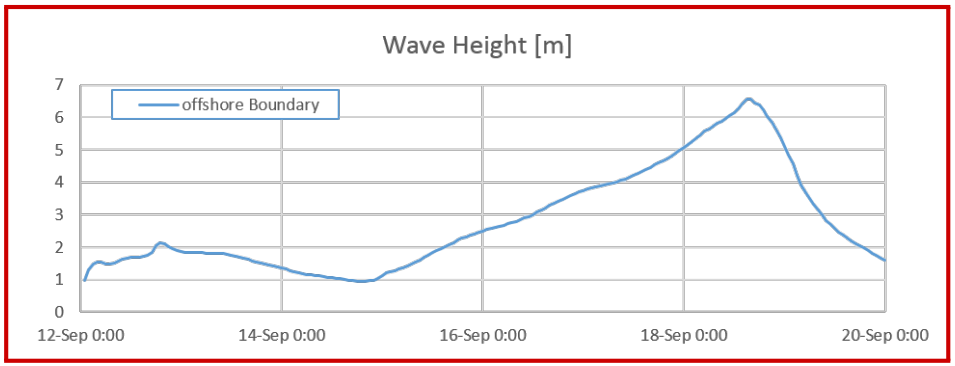


Initial Results with XBeach

Wave and Surge Boundary Conditions from SWAN+ADCIRC





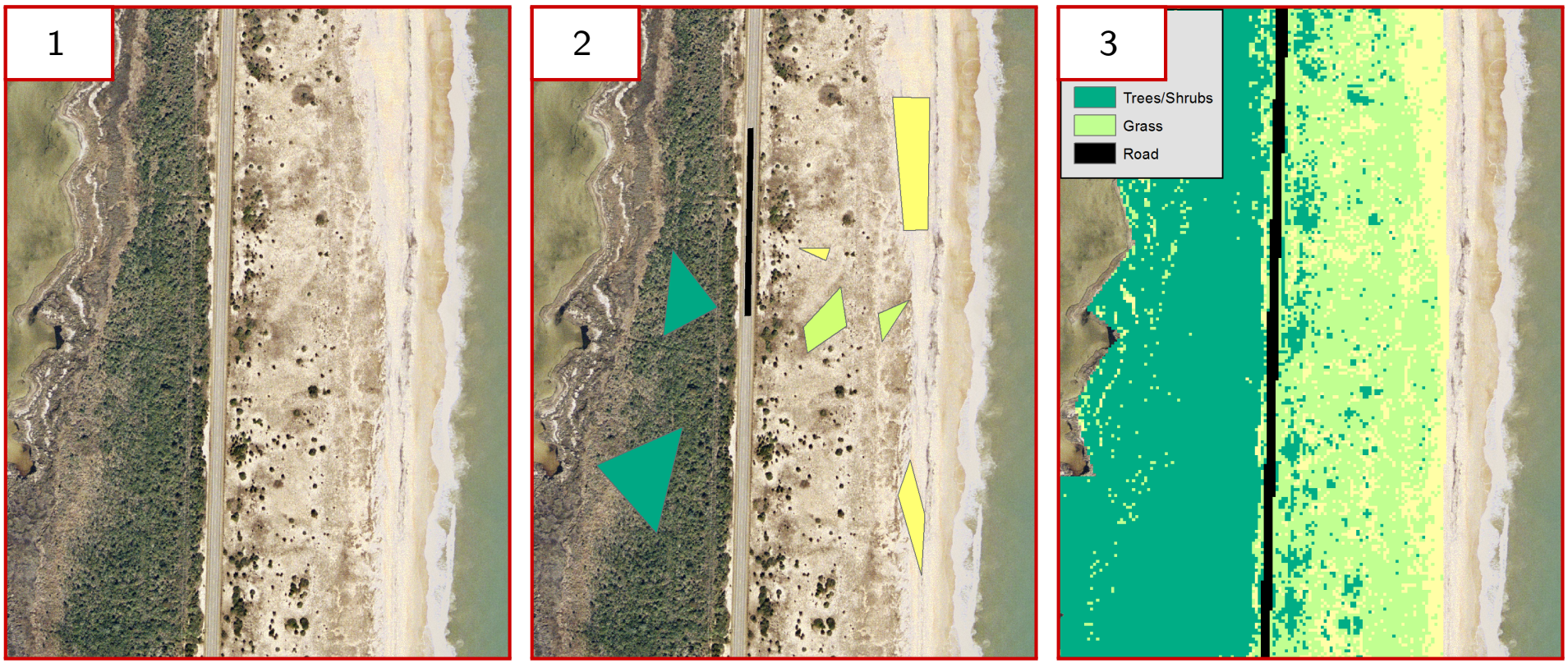


Initial Results with XBeach

Extracting Vegetation Classes

Obtaining the vegetation from pre-storm orthophotos:

1. Orthophoto showing land-cover characteristics
2. Delineating the sand, grass, trees/shrubs, and road
3. Converting to three vegetation classes for use in XBeach



Initial Results with XBeach

Water Levels during Isabel (2003)

Flooding and erosion simulated by XBeach:

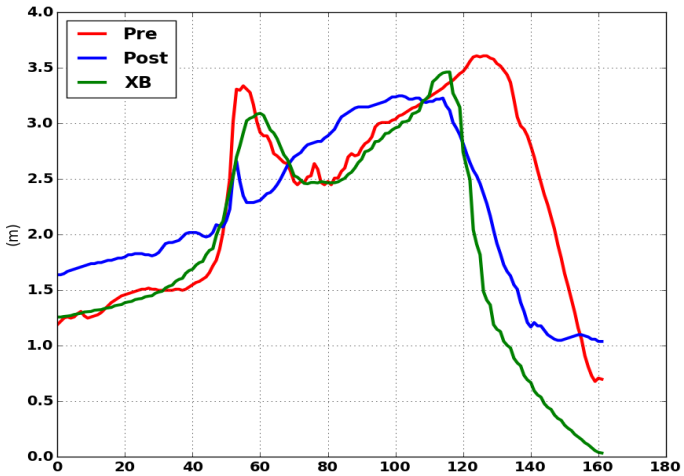
- Overwash of dunes on ocean side
- Flooding from sound side

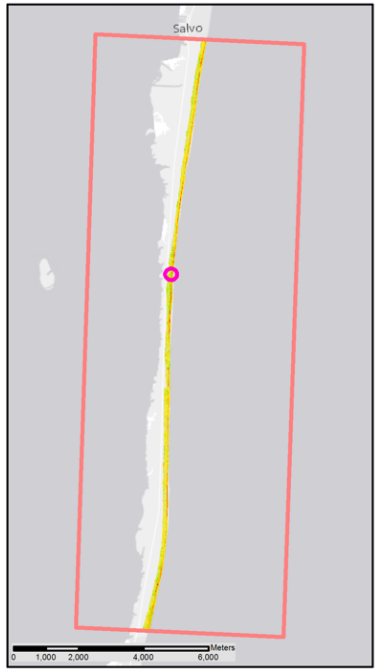
Initial Results with XBeach

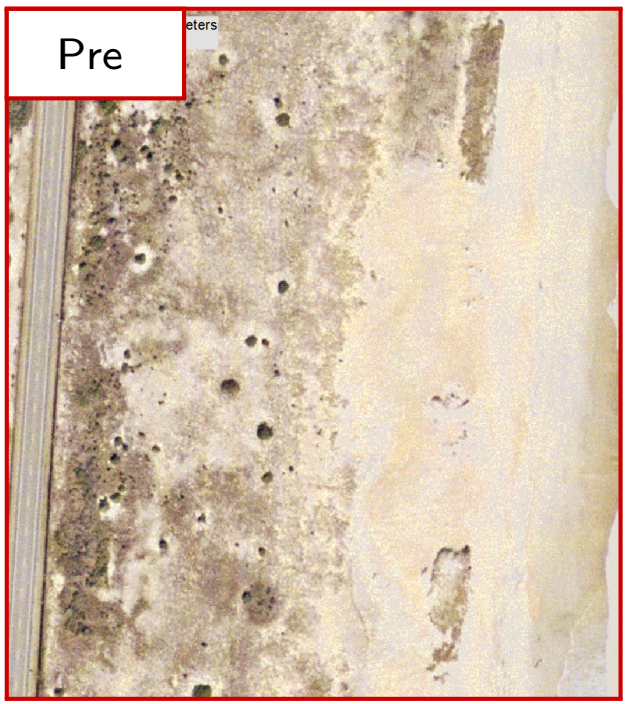
XBeach Profiles at Major Dune Erosion Events

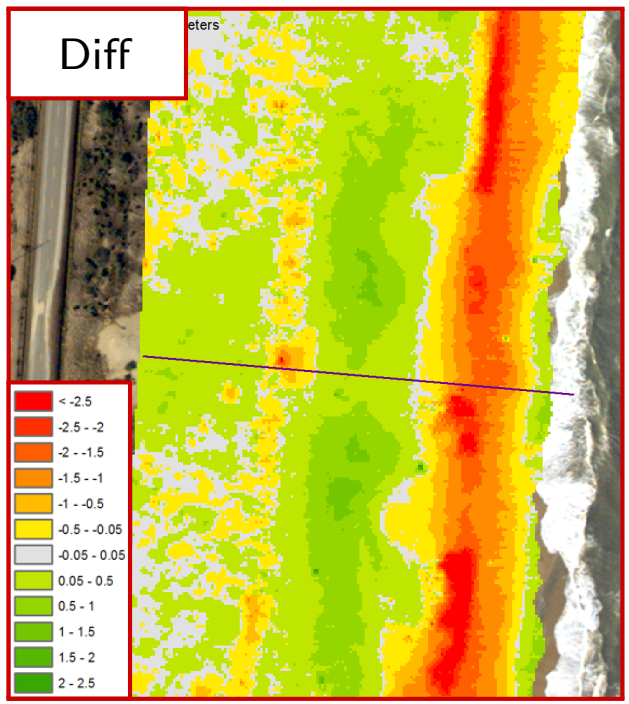
Dune Erosion Event #1:

- Too much erosion of beach and first dune
- No changes to profile behind first dune







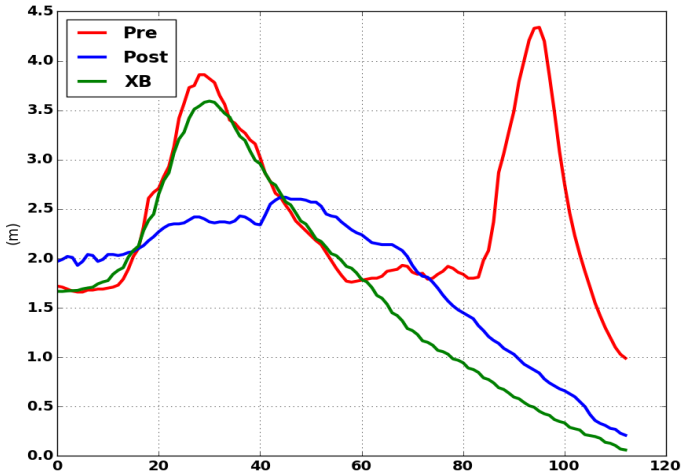


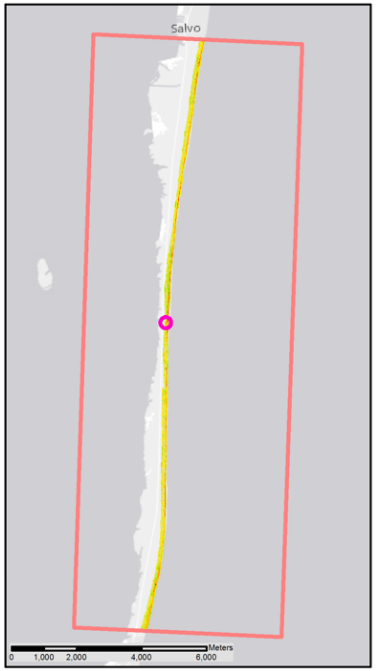
Initial Results with XBeach

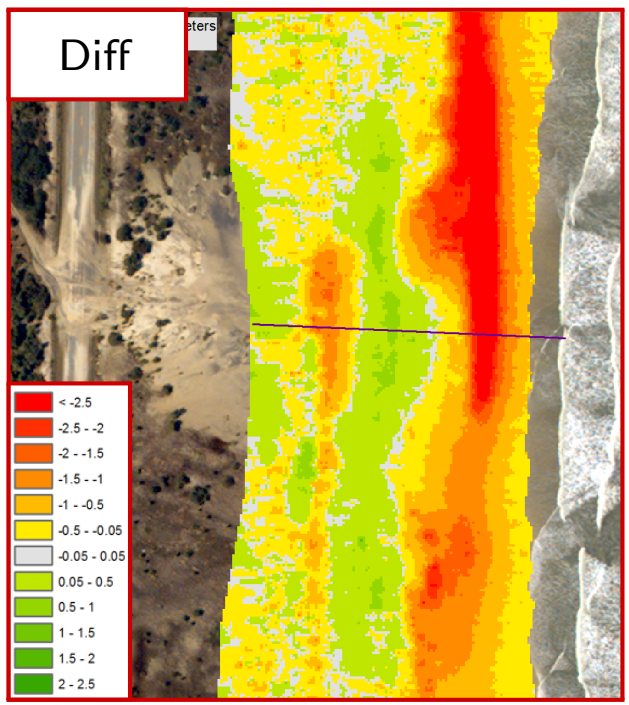
XBeach Profiles at Major Dune Erosion Events

Dune Erosion Event #2:

- Removal of first dune
- Too much erosion between dunes
- No change to profile at and behind second dune







Summary and Future Work

Waves, Flooding, and Beach Morphology

Real-time forecasting for coastal North Carolina:

- Available several times per day at: `nc-cera.renci.org`
- Hermine and Matthew (2016)

Working with XBeach to simulate beach and dune erosion:

- Preliminary results are encouraging
  - Developed model for large domain – 18 km of Hatteras Island
  - Too much erosion on beach and primary dune
- Need to couple with ADCIRC
  - Revised topography to improve flood predictions