Predictive Modeling for Storm Surge and Flooding Risks in Coastal North Carolina

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# Models for Hurricane Waves and Storm Surge Example of Coastal Flooding

Winds and Storm Surge during Arthur (2014)



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36°

35°

#### Models for Hurricane Waves and Storm Surge Finite-Element Mesh for NC Coast





# Real-Time Forecasting 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:

- Send directly to stakeholders (NC Emergency Management)
- Share publicly via web service (nc-cera.renci.org)

#### Real-Time Forecasting during Hurricane Hermine Coastal Emergency Risks Assessment (CERA): nc-cera.renci.org



### Real-Time Forecasting during Hurricane Hermine Coastal Emergency Risks Assessment (CERA): nc-cera.renci.org



# Real-Time Forecasting during Hurricane Matthew Coastal Emergency Risks Assessment (CERA): nc-cera.renci.org



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#### Real-Time Forecasting during Hurricane Matthew High-Resolution Mesh for North Carolina – NC9



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#### Real-Time Forecasting during Hurricane Matthew Large-Domain Mesh for the U.S. Gulf and Atlantic Coasts – HSOFS



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#### Best-Possible Hindcast of Hurricane Matthew Evolution of Winds Along US East Coast – HSOFS



# Best-Possible Hindcast of Hurricane Matthew Wind Speed Comparison from South to North



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#### Best-Possible Hindcast of Hurricane Matthew Evolution of Water Levels in North Carolina – NC9



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# Best-Possible Hindcast of Hurricane Matthew Water Level Comparison from South to North



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### Best-Possible Hindcast of Hurricane Matthew Quantifying the Effect of Mesh Resolution

How does mesh resolution affect the model performance?

- Comparison to wind speeds:

Mesh	Stations	RMSE (m/s)
HSOFS	108	1.944
HSOFS	33	2.260
NC9	33	2.367

- Comparison to water levels:

Mesh	Stations	RMSE (m)
HSOFS	310	0.295
HSOFS	90	0.264
NC9	90	0.240

Water level predictions are improving when we have better resolution

- How can we improve for future years?

# Supporting Coastal Resilience Areas for Future Work

How can we continue to support coastal resilience?

- Enable faster forecasts during storm events
  - Optimize how our models run on supercomputers
  - Utilize pre-computed simulations from similar storms
- Include more-accurate predictions
  - Expand how we include rainfall and riverine flooding
  - Consider density-driven flows and material transport
  - Couple with household decision-making on longer terms
  - Allow beaches, dunes, and barrier islands to erode
- Connect better with stakeholders
  - Tailor our guidance products for specific users
  - Link forecasts with infrastructure databases
  - Educate about strengths and weaknesses



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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





# Initial Results with XBeach XBeach Profiles at Major Dune Erosion Events Dune Erosion Event #1: - First dune removal modeled perfectly - No changes to profile behind first dune

Modeled Profile





2240



2190



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2090

2140

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Distance from offshore boundary [m]

#### Summary and Future Work

Predictive Models for Waves, Flooding, and Beach Morphodynamics

Real-time forecasting for coastal North Carolina:

- Available at: nc-cera.renci.org
- Hurricane Matthew (2016)
  - 47 advisories were issued during the storm
  - Flooding impacts along the U.S. East Coast
  - Hindcasts on meshes with difference coverage, resolution
  - Water level predictions within 1 ft

Working with XBeach to simulate beach and dune erosion:

- Preliminary results are encouraging
  - Developing model for Hatteras Island
  - Improving accuracy for complex erosion patterns
- $-\,$  Need to couple with wave and surge models
  - Revised topography to improve flood predictions

