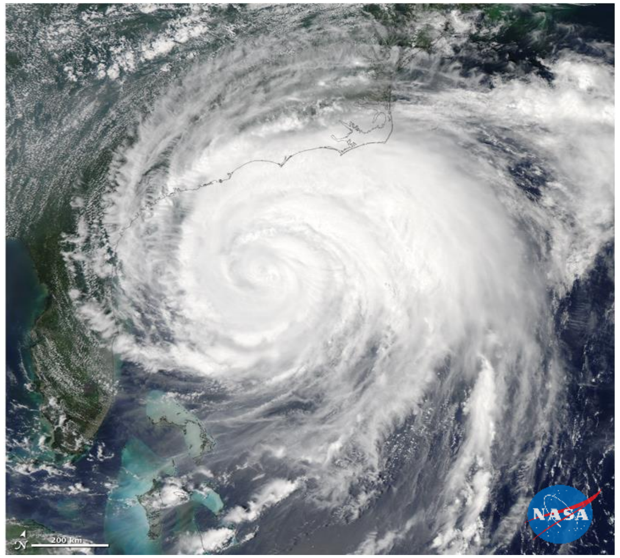
Washover Volume Analysis of Hatteras and Pea Island, North Carolina, USA over Centennial Timescales

Shara L. Gremillion[1], Davin J. Wallace[1], Eve R. Eisemann[2], Erin A. Culver-Miller[1], William R. Funderburk[1]
[1]The University of Southern Mississippi, [2]University of North Carolina Chapel Hill

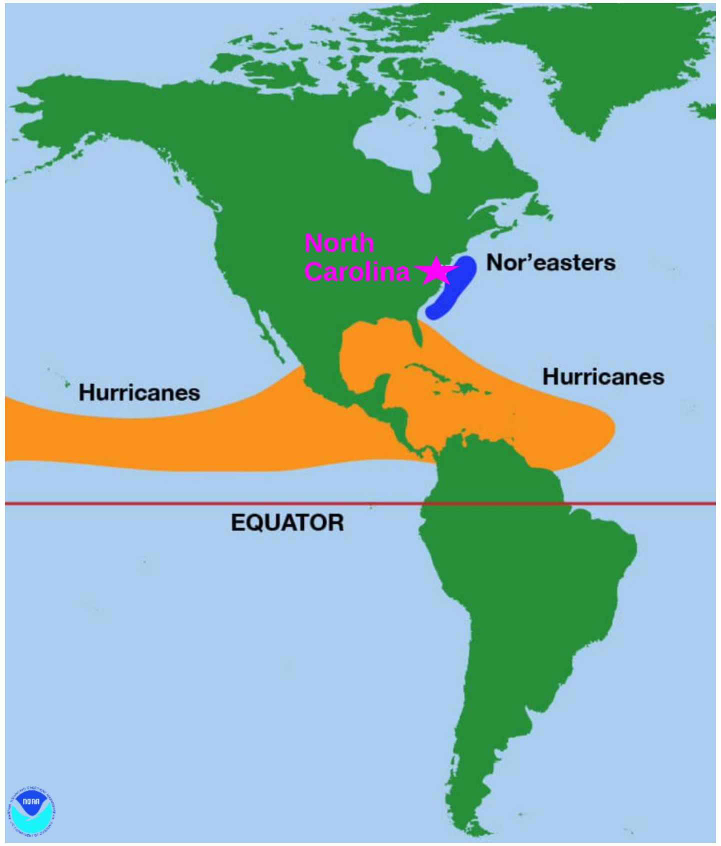
Prepared for:
American Geophysical Union Fall Meeting (Dec 2021)
Session: EP24A

Introduction: Storms



Hurricanes (tropical cyclones): Low-pressure systems, originating over tropical / subtropical waters

Nor'easters (mid-latitude cyclones): Low-pressure systems, originating in mid-latitude regions, winds dominantly from the east



Financial Impacts to US Taxpayers (1980-2020):

Source: NOAA Nation Centers for Environmental Information (Smith et al., 2021)

Hurricanes: ~ $997 billion
Nor'easters: ~ $48 billion
Total: ~ $1.05 Trillion

Robert F. Bukaty (AP Photo)

Ryan Mcbride (Getty Images)

Overwash Process→ Washover Deposits

- Hurricanes and nor'easters often produce overwash!
- **Overwash**: sand transported from the nearshore to the backshore.
- Sediments associated w/ overwash flows called **washover deposits.** Resulting "sheet-like" geometry called **washover fan.**

Washover deposits can be identified, mapped, & quantified using geologic, geophysical, & remote-sensing techniques.

Credit: North Carolina Dept. of Transportation (Nov 2021)

Pre-Hurricane Sandy

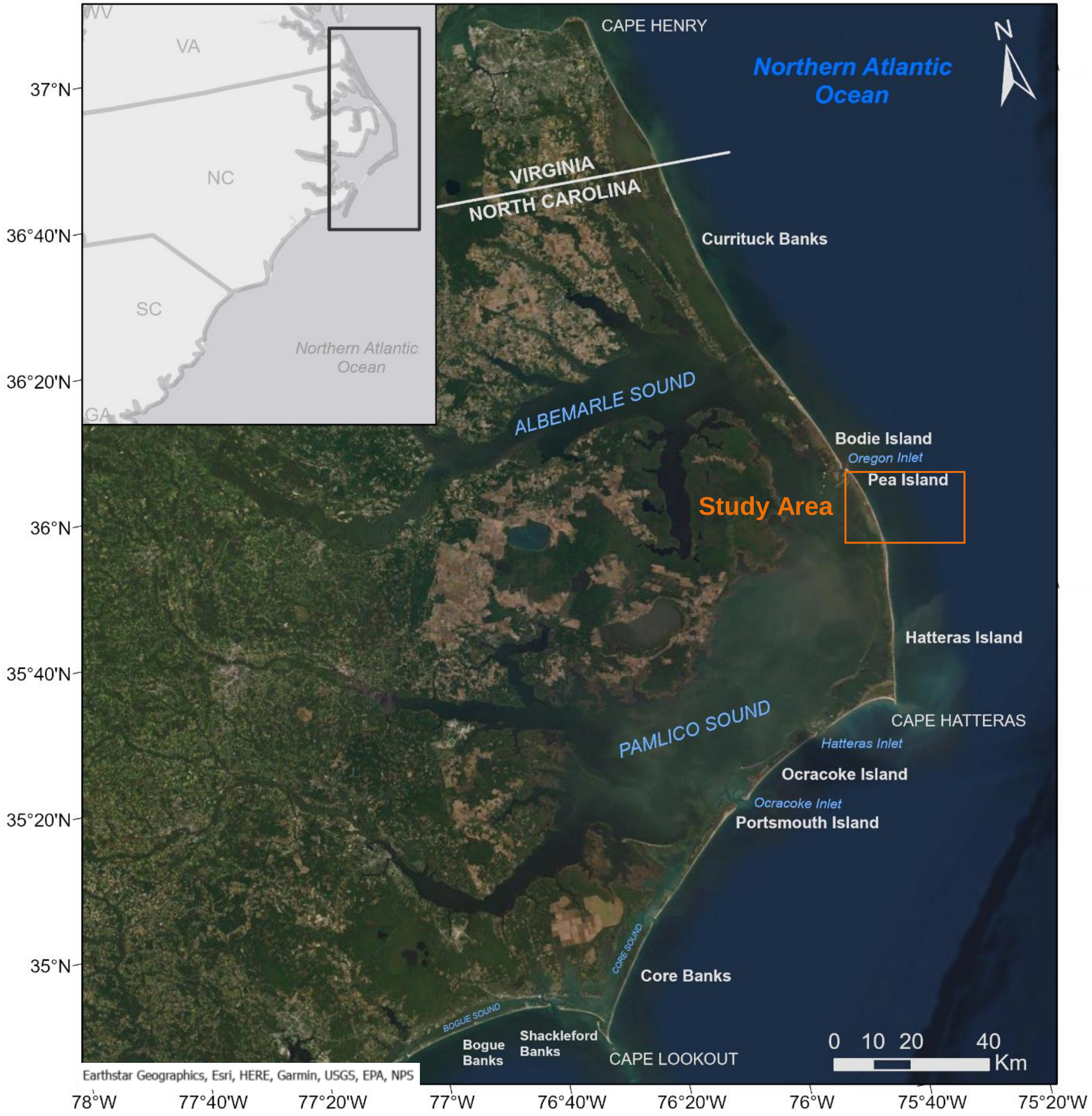
Pea Island, NC: Aug. 2011

→

Post-Hurricane Sandy

March 2013

Project Background / Regional Area



USCRP US COASTAL RESEARCH PROGRAM

DUNEX During Nearshore Event Experiment

https://uscoastalresearch.org/dunex

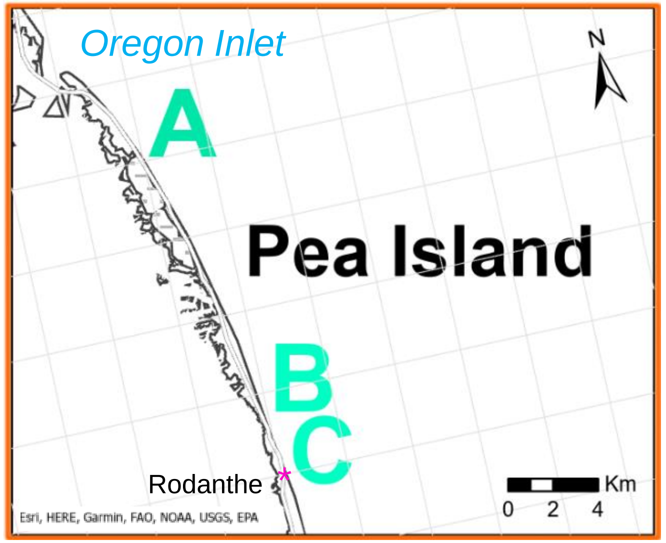
- "Multi-agency, -academic, and –stakeholder collaborative experiment to study nearshore processes during coastal storms."
- **USM Involvement**:
  - Academic partner
  - Research: Assess modern to historic hurricane & nor'easter washover deposits; consider future risks to vulnerable coastlines

Outer Banks (OBX) Island Chain:

- ~330 km long island chain, ~0.5 to 50 km offshore
- Moderate to high wave energy climate; significant wave heights ~1 m
- Semi-diurnal, micro-tidal (< 2 m) environment; tidal range ~1 m

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Study Site: Pea Island, NC

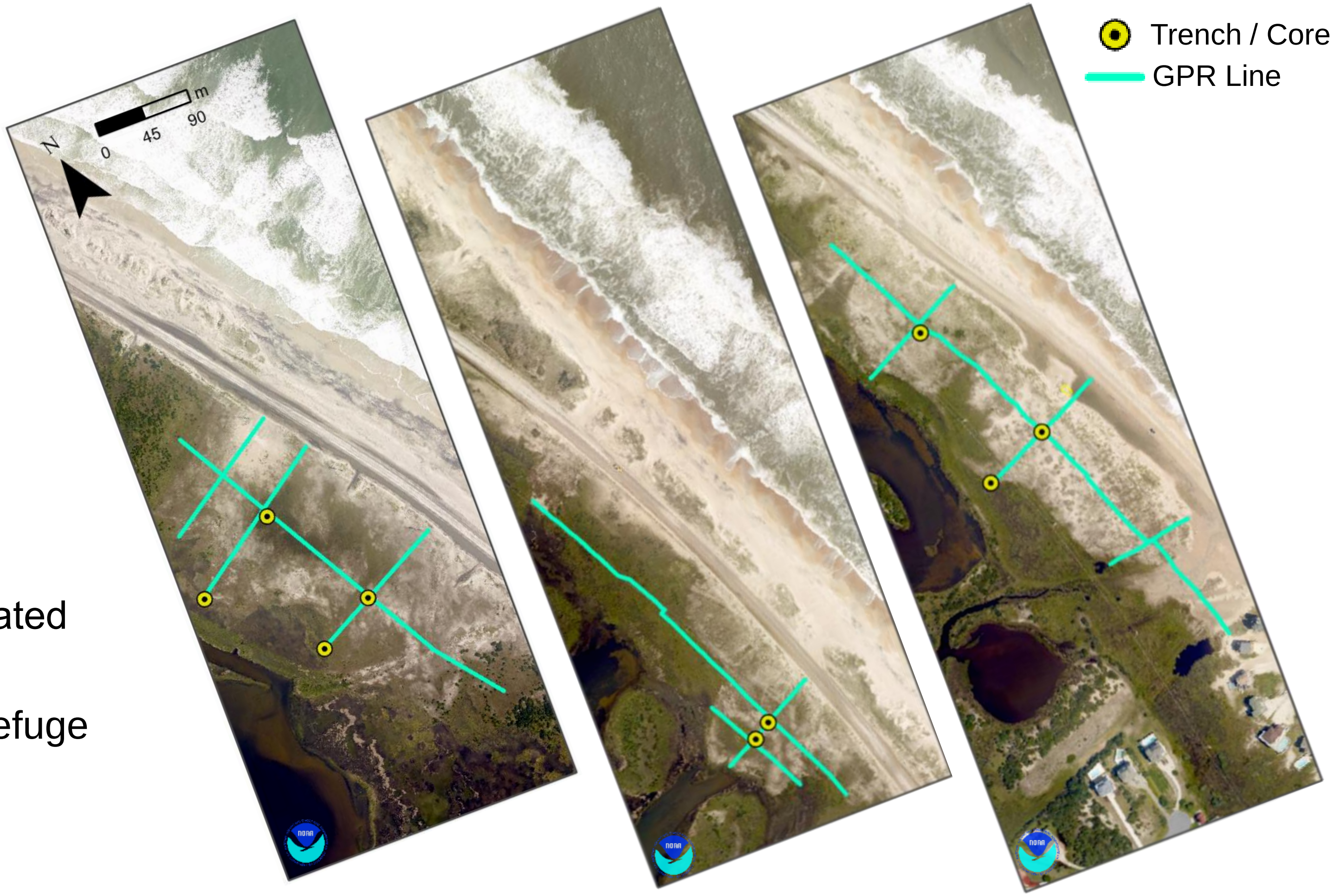


PEA ISLAND:

- Northern tip Hatteras Island; an “island” when separated from Hatteras by storm-induced breaches
- Mostly undeveloped, Pea Island National Wildlife Refuge
- Eroding by as much as 4 m/yr. (Riggs et al., 2009).
- 3 fan sites selected based on imagery analysis; considered “active”, natural laboratory

PREVIOUS RESEARCH (e.g.):

- Schwartz (1975)
- Ernst (2004)
- Gares & White (2005)



A. Northern Fan **B. Middle Fan** **C. Southern Fan**

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Research Questions

R_1: Can we correlate washover deposit area to known modern and historic hurricanes and nor'easters?

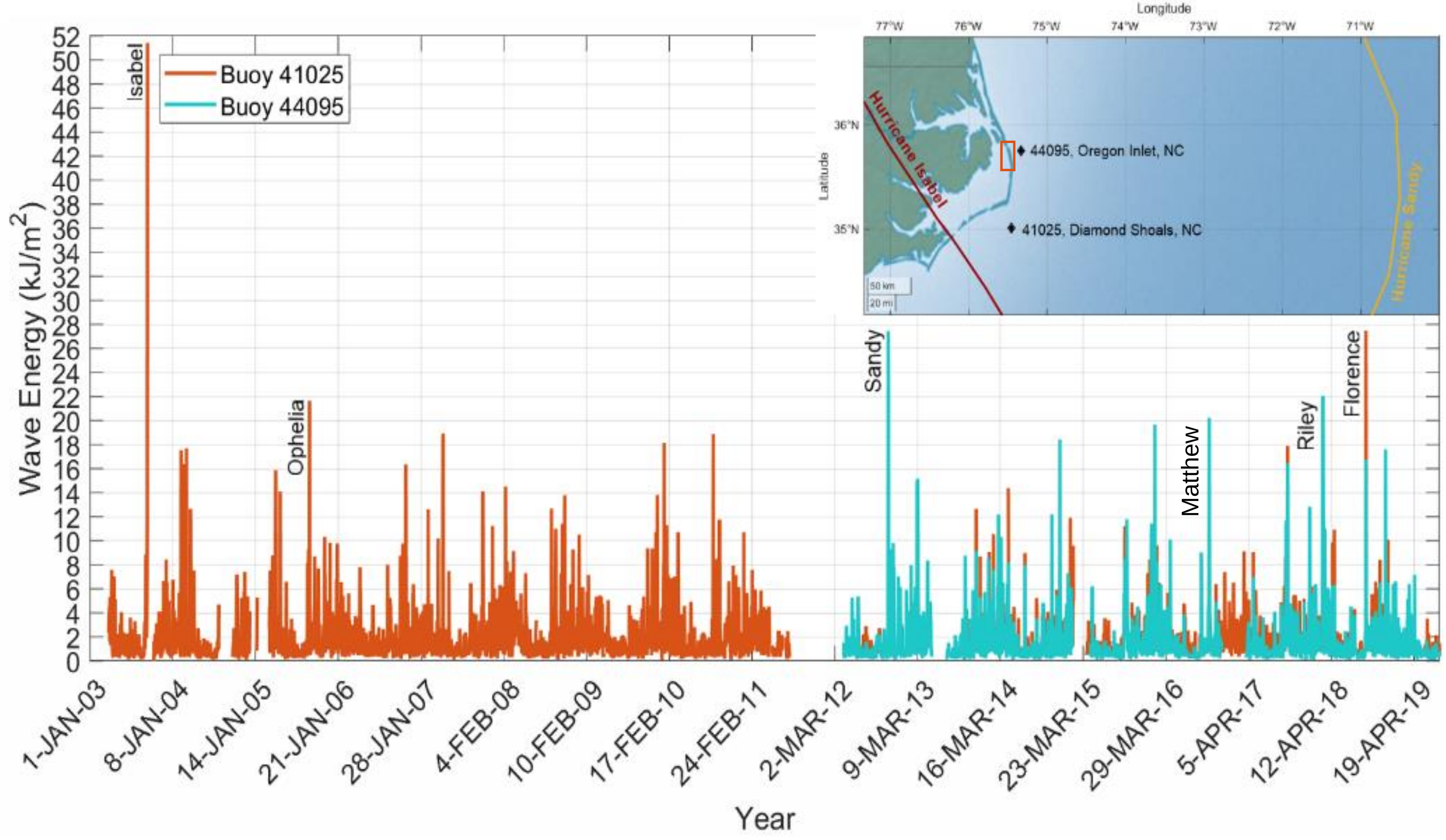
R_2: What is the variability in washover deposit thicknesses, grain-size characteristics, and volume of deposits associated with these storms?

R_3: Has washover sediment flux rate been accelerating/decelerating over the past ~500 years?

APPLIED METHODS TO CALCULATE STORM WASHOVER VOLUME

Methods: Remote Sensing for Storm Identification (2003-2019)

Significant Wave Height (buoy) → Wave Energy time-series



Hurricane Isabel (Sept. 2003)

Wind speed: ~104 mph
Storm surge: 1.4 m
Wave energy: 51.4 kJ/m²

Vet's Day Nor'easter (Nov. 2009):

Wind speed: ~35-45 mph
Storm surge: 0.8 m
Wave energy: 9.4 kJ/m²

Hurricane Sandy (Oct. 2012)

Wind speed: ~45 mph
Storm surge: 1.1 m
Wave energy 27.4 kJ/m²

Nor'easter Riley (Mar. 2018):

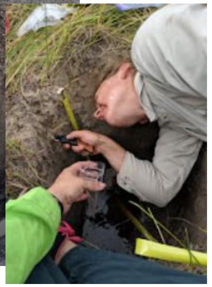
Wind speed: ~50 mph
Storm surge: not reported
Wave energy 22.1 kJ/m²

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Methods: Geologic Techniques

Field Data Acquisition:

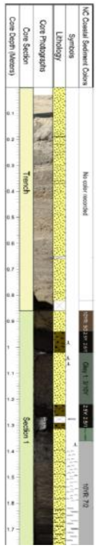
5 Trenches & 9 Cores


Lab Prep & Analysis

390 Samples: Particle-size analysis (<2 mm)

Graphical sediment logging



10 Organic samples: ^{14}C dating & calibration

WOODS HOLE OCEANOGRAPHIC INSTITUTION

NOSAMS NATIONAL OCEAN SCIENCES ACCELERATOR MASS SPECTROMETRY

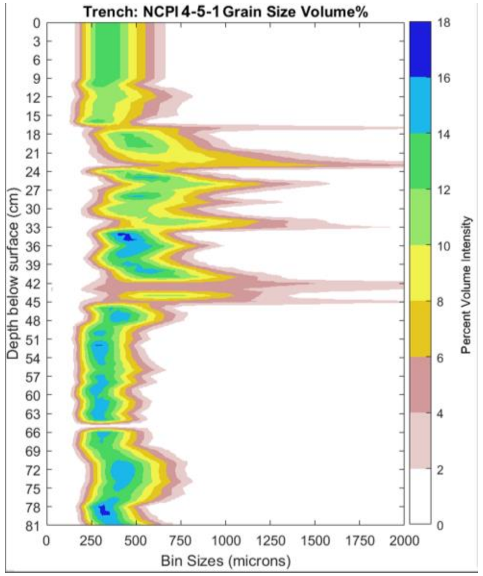
Bomb-spike

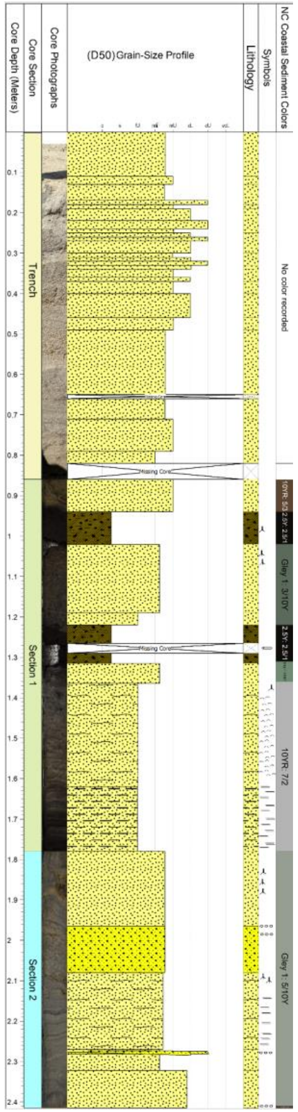
IntCal 20 curve

Output Products

Particle-Size Percent Volume Graph (left)

Core Log w/ D-50 grain-size (right)





THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Methods: Geophysical Techniques

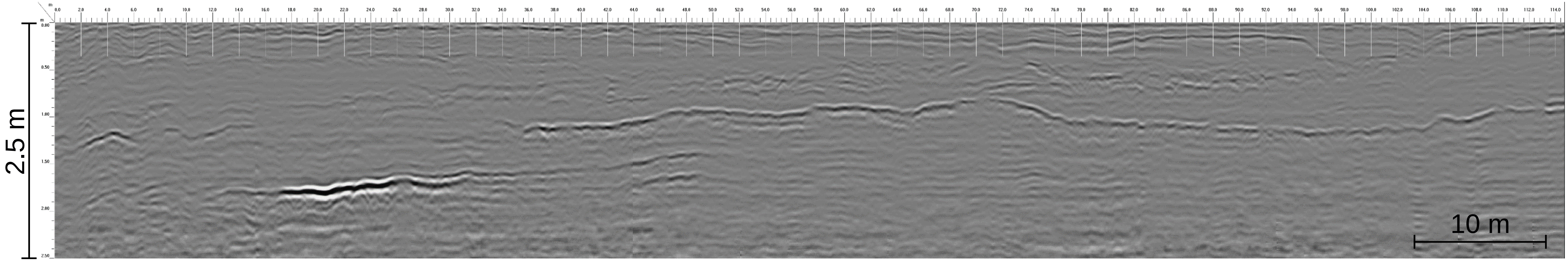
Ground Penetrating Radar (GPR)

Collected 2300 m, high-resolution data

Geophysical Survey Systems, Inc. (GSSI) SIR 3000 GPR, 400 MHz antenna

Trimble R10 Global Navigation Satellite System (GNSS) receiver + NC Geodetic Survey's Real Time GNSS Network

Output Product: GPR Radiograph (Uninterpreted Linescans)



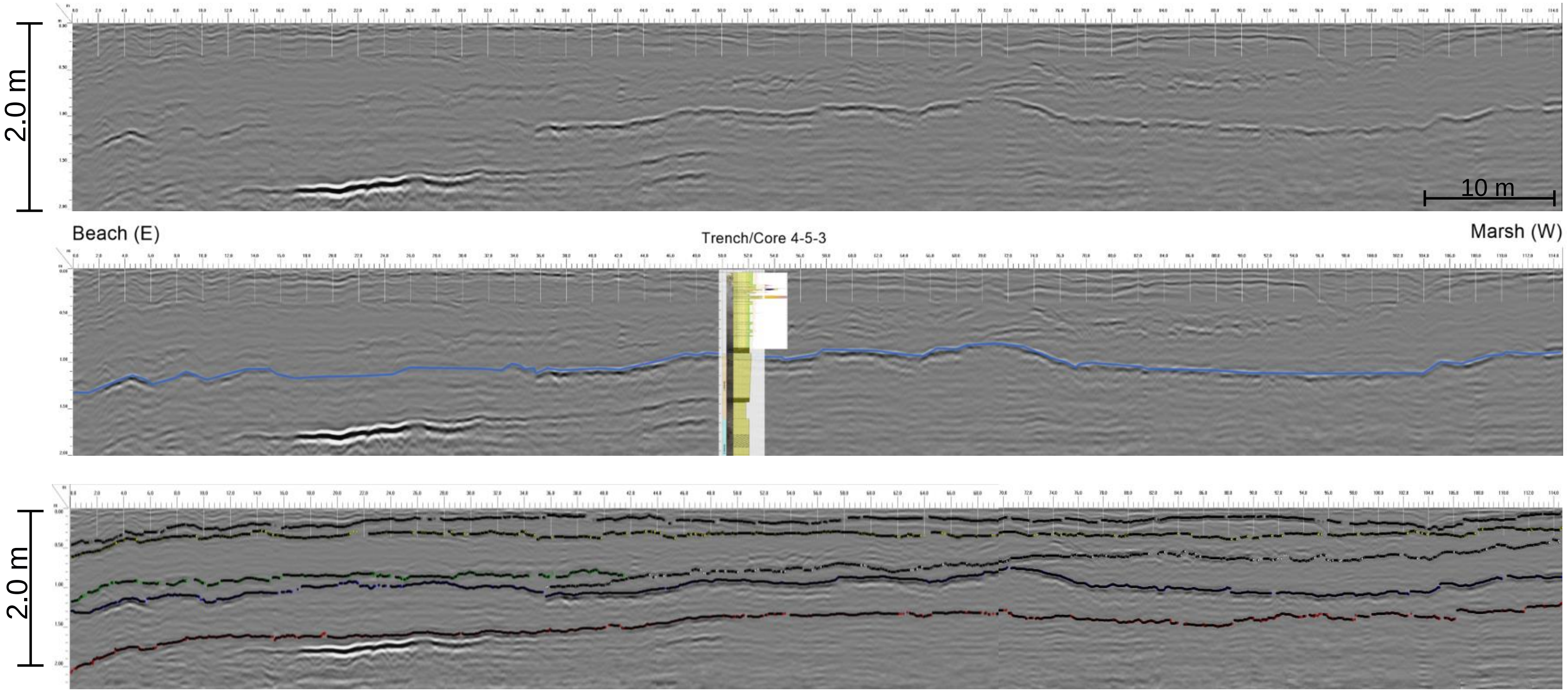
THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Methods: GPR Interpretation Process

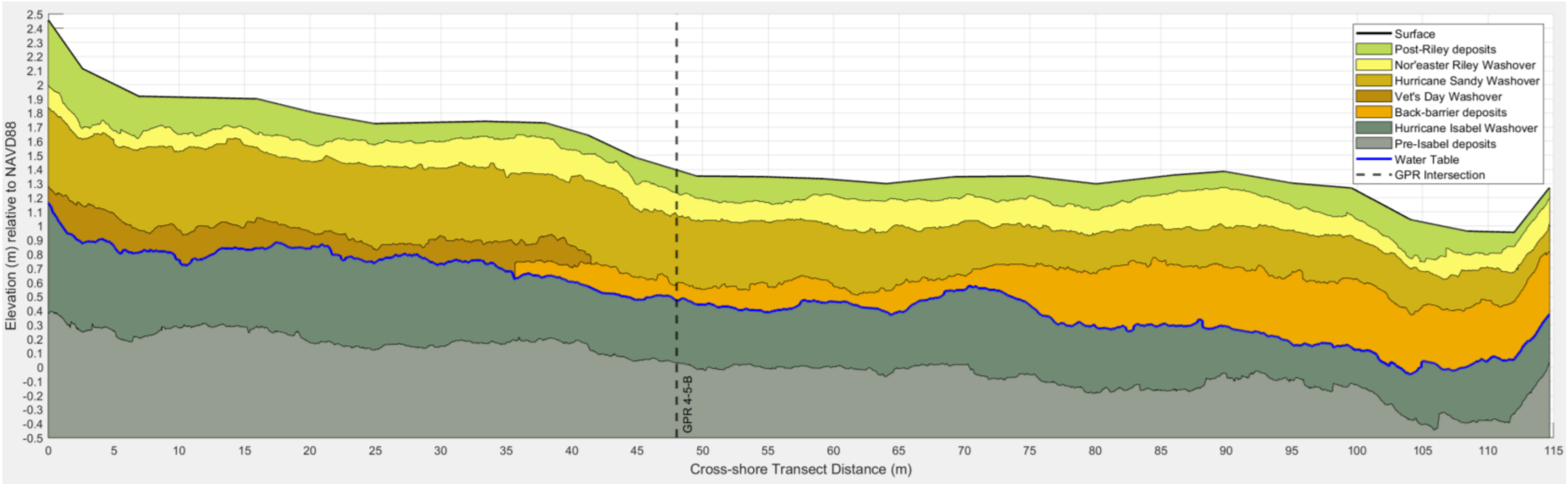
Start:
Uninterpreted radiographs

Correlate:
Grain-size plots, core logs, & imagery to high/med amplitude reflectors. Water table depth used as “ground truth”.

Interpret Stratigraphy:
GSSI’s RADAN 7 Software

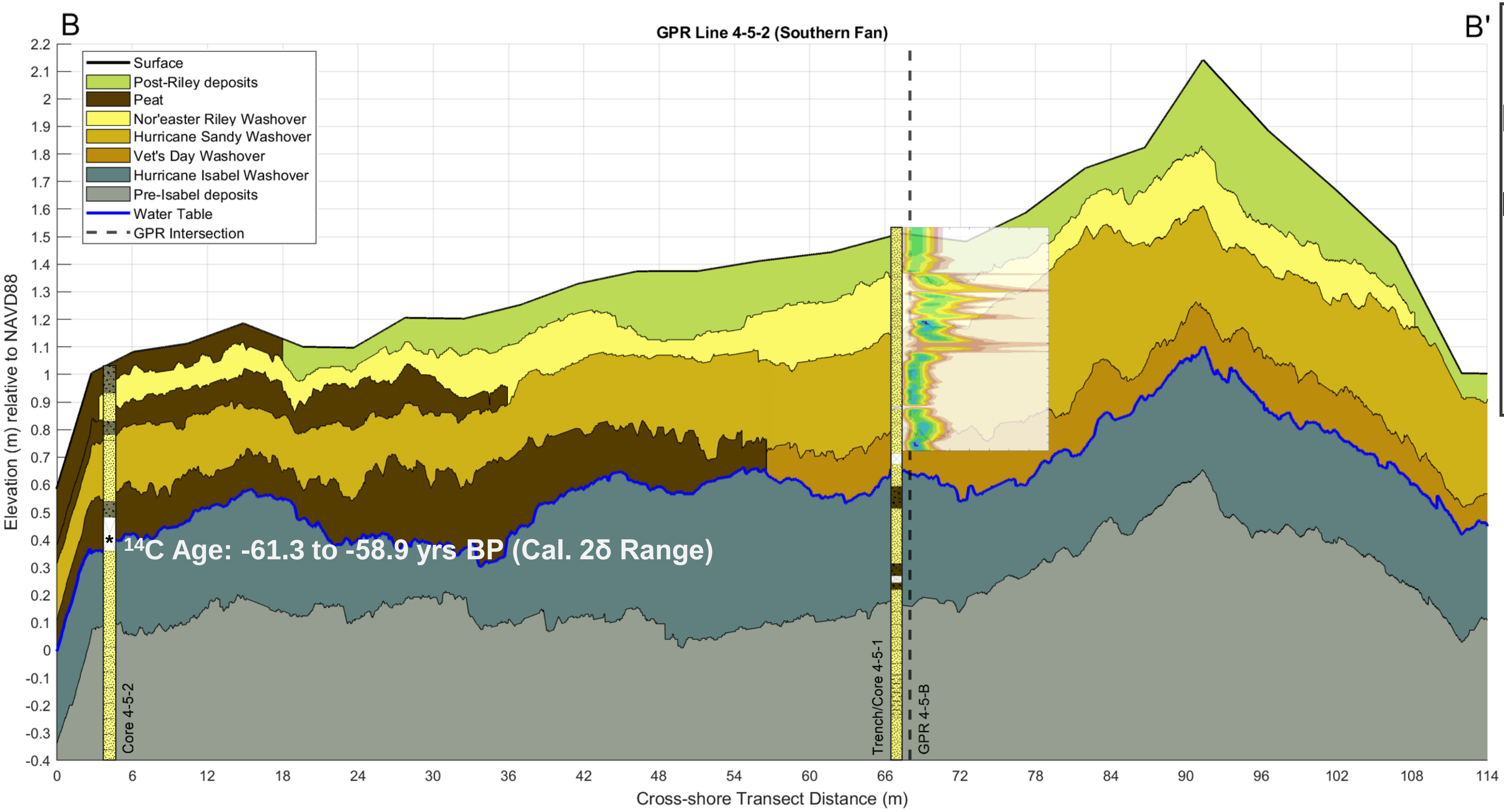


Visualize:
Surface Normalization
(elevation vs. distance)

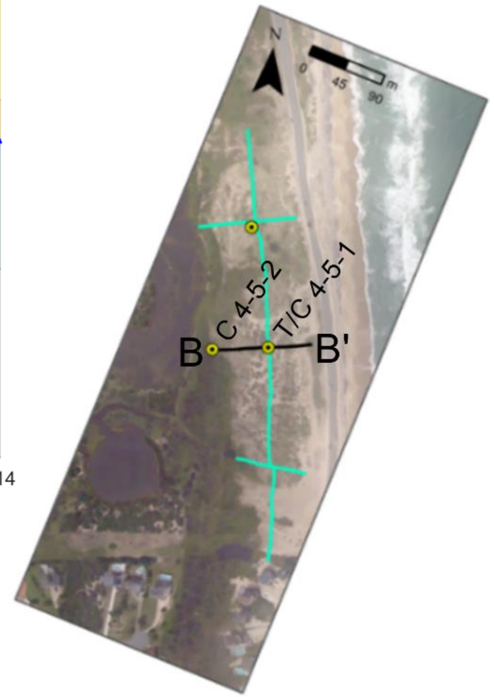


Calculate:
Individual Storm Layer Thicknesses
(shown in results section)

Results: GPR Full-Interpretation



Mean Storm Layer Thickness (m); Std. Dev. (m)		
Nor'easter Riley	0.13	0.05
Hurricane Sandy	0.31	0.10
Vet's Day Nor'easter	0.16	0.04
Hurricane Isabel	0.39	0.09



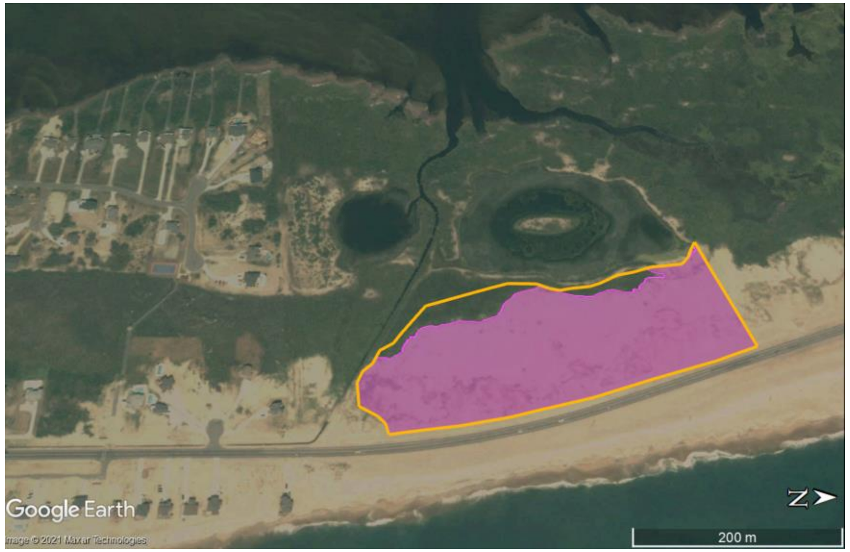
Trench/Core Lithology Key

- Sand
- Peat

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Results: Southern Washover Fan Areas

Hurricane Isabel (2003)
Washover Area: 43,460 m^2



Vet’s Day Nor’easter (2009)
Washover Area: 10,553 m^2

Common maximum area footprint delineated by orange perimeter

Hurricane Sandy (2012)
Washover Area: 35,559 m^2

Nor’easter Riley (2018)
Washover Area: 36,830 m^2

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Results: Washover Volume

MEAN STORM LAYER THICKNESS x TOTAL STORM WASHOVER AREA = TOTAL WASHOVER VOLUME

Southern Fan Storm Washover Statistics

Storm	Mean Layer Thickness (m)	Std. Dev. (σ)	+2σ	-2σ	Total Area (m^2)	TOTAL VOLUME (m^3)
Riley	0.136	0.046	0.229	0.043	36,830	4,999
Sandy	0.326	0.097	0.520	0.133	35,559	11,606
Vet's Day	0.174	0.058	0.290	0.058	10,553	1,834
Isabel	0.402	0.1	0.603	0.202	43,460	17,476

The storm washover thicknesses contribute significantly to volume variability, as the fans' areas are similar.

Project Status / Ongoing work

Repeat same methods for Northern & Middle fans:

- Identify storm impacts
- Measure washover fans' surface areas
- Interpret GPR stratigraphy
- Calculate storm layer thicknesses & volumes

Calculate sediment flux rates (all fans)

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Additional References

- Inman, D. L., & Dolan, R. (1989). The Outer Banks of North Carolina: Budget of sediment and inlet dynamics along a migrating barrier system. *Journal of Coastal Research*, 193-237.
- Leatherman, S. P., & Williams, A. T. (1983). Vertical sedimentation units in a barrier island washover fan. *Earth Surface Processes and Landforms*, *8*(2), 141-150.
- Riggs, S. R., Ames, D. V., Culver, S. J., Mallinson, D. J., Corbett, D. R., & Walsh, J. P. (2009). Eye of a human hurricane: Pea island, Oregon inlet, and bodie island, northern outer banks, North Carolina. *Geological Society of America Special Papers*, *460*, 43-72.
- Sallenger Jr, A. H. (2000). Storm impact scale for barrier islands. *Journal of coastal research*, 890-895.
- Schwartz, R. K. (1982). Bedform and stratification characteristics of some modern small-scale washover sand bodies. *Sedimentology*, *29*(6), 835-849.
- Smith, A., Lott, N., Houston, T., Shein, K., Crouch, J., & Enloe, J. (2021). US Billion-Dollar Weather & Climate Disasters 1980-2021. In *NOAA National Centers for Environmental Information* (p. 15). Asheville NC, USA.
- Thieler, E. R., Foster, D. S., Himmelstoss, E. A., & Mallinson, D. J. (2014). Geologic framework of the northern North Carolina, USA inner continental shelf and its influence on coastal evolution. *Marine Geology*, *348*, 113-130.

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

QUESTIONS

Shara L. Gremillion
shara.gremillion@usm.edu

In-person:

Tuesday, 14 December 2021

14:40 - 14:45

Convention Center - Room 228-230