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

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**Abstract**

Hurricanes (tropical cyclones) and nor'easters (mid-latitude cyclones) are high-energy storms often impacting the Outer Banks (OBX) barrier islands of North Carolina (NC), USA. Storm hazards include, but are not limited to, high speed winds, coastal flooding, storm surges, and increased precipitation. As a consequence of increased storm strength and frequency, loss of life, property damage, and erosion to beaches, barrier islands, and marshes have amplified over the past 40 years. In a recent report by the National Oceanic and Atmospheric Administration (NOAA), US taxpayers expended ~$1.05 trillion on hurricane and nor'easter impacts from 1980 to 2020. Identifying historical hurricanes and nor'easters in the geologic record as washover deposits can aid in the understanding of past events and prediction of future impacts to the OBX. Storm events yielding washover deposits can be identified, mapped, and quantified using various geologic, geophysical, and remote-sensing techniques. To identify both modern and historic coastal storms, nine sediment cores and 2300 meters of ground penetrating radar (GPR) data were collected, and five trenches were dug from the surface to the water table on three washover fans on Hatteras and Pea islands, NC. Grain size distributions were measured at centimeter intervals from trenches and sediment cores. GPR data were used to map spatial extents and measure sediment thicknesses in washover deposits down to ~1 m. Radiocarbon and short-lived isotopic dating techniques were employed to ascertain ages of washover deposits identified within cores. Additionally, historical surface analyses, hurricane tracks, and buoy data from NOAA were used to correlate washover deposits to known historic and modern hurricanes or nor'easters. To date, this project has identified several discrete washover events associated with Hurricane Sandy (2012) and several nor'easters across the northern (Pea Island) and middle/southern (Hatteras Island) study sites. Radiocarbon dating from plant material indicates these sites contain a ~500 cal yr BP record of washover deposition. The significance of this project is to evaluate differential impacts of nor'easters and hurricanes on the geomorphic evolution of Pea and Hatteras islands through the integration of data from multiple methodologies.

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Session: EP24A

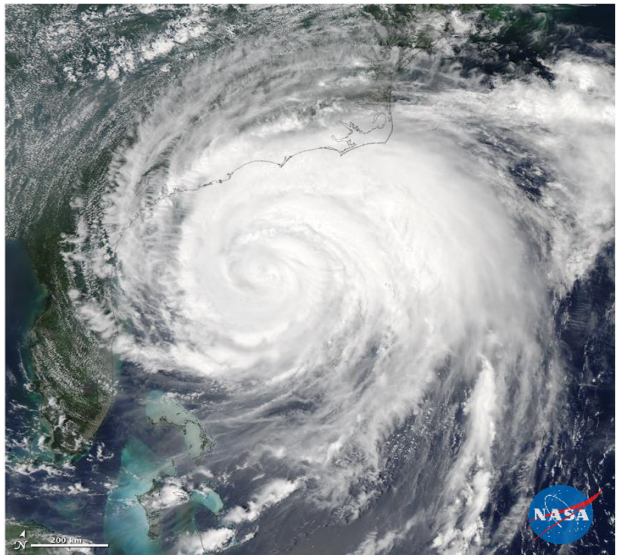
USCRP
US COASTAL RESEARCH PROGRAM

DUNEX
During Nearshore Event Experiment

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

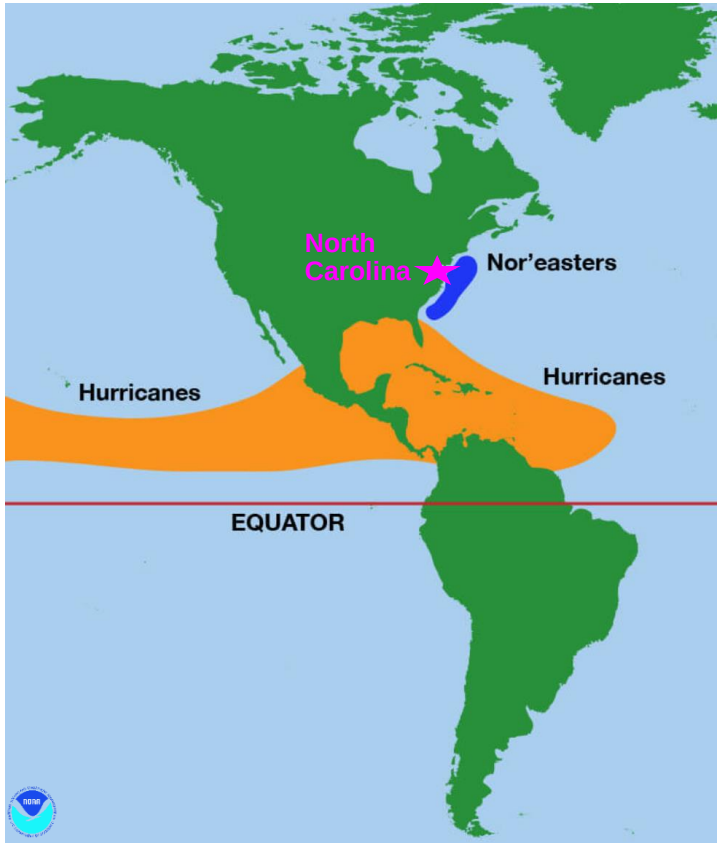
ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

# 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.

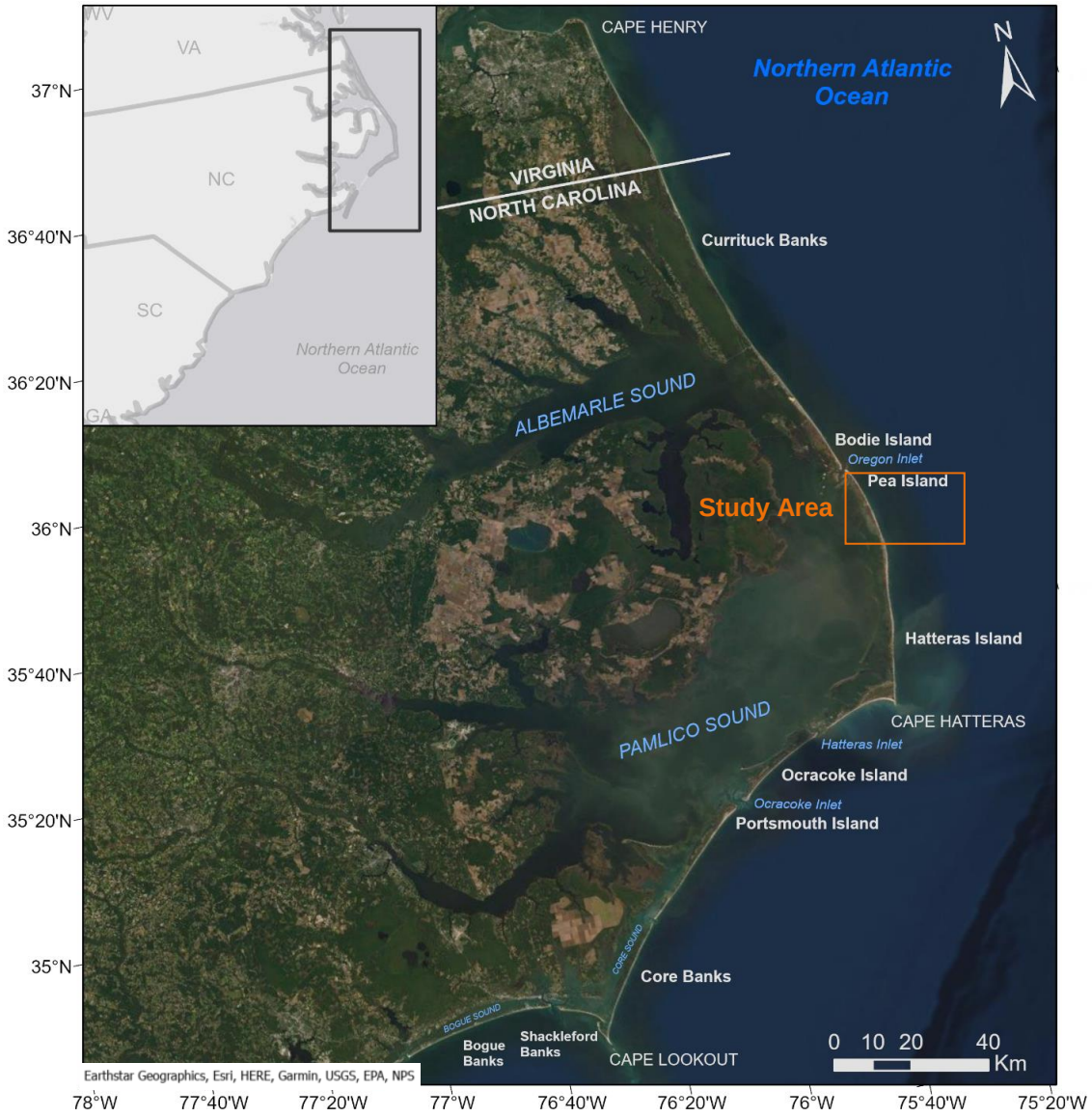

Pre-Hurricane Sandy

Pea Island, NC: Aug. 2011

Post-Hurricane Sandy


March 2013

# Project Background / Regional Area




USCRP US COASTAL RESEARCH PROGRAM

DUNEX During Nearshore Event Experiment

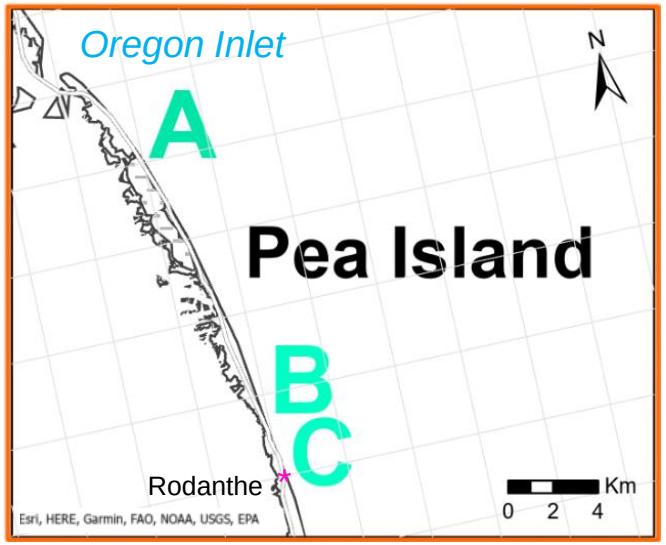
https://uscoastalresearch.org/dunex

- "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

# Study Site: Pea Island, NC

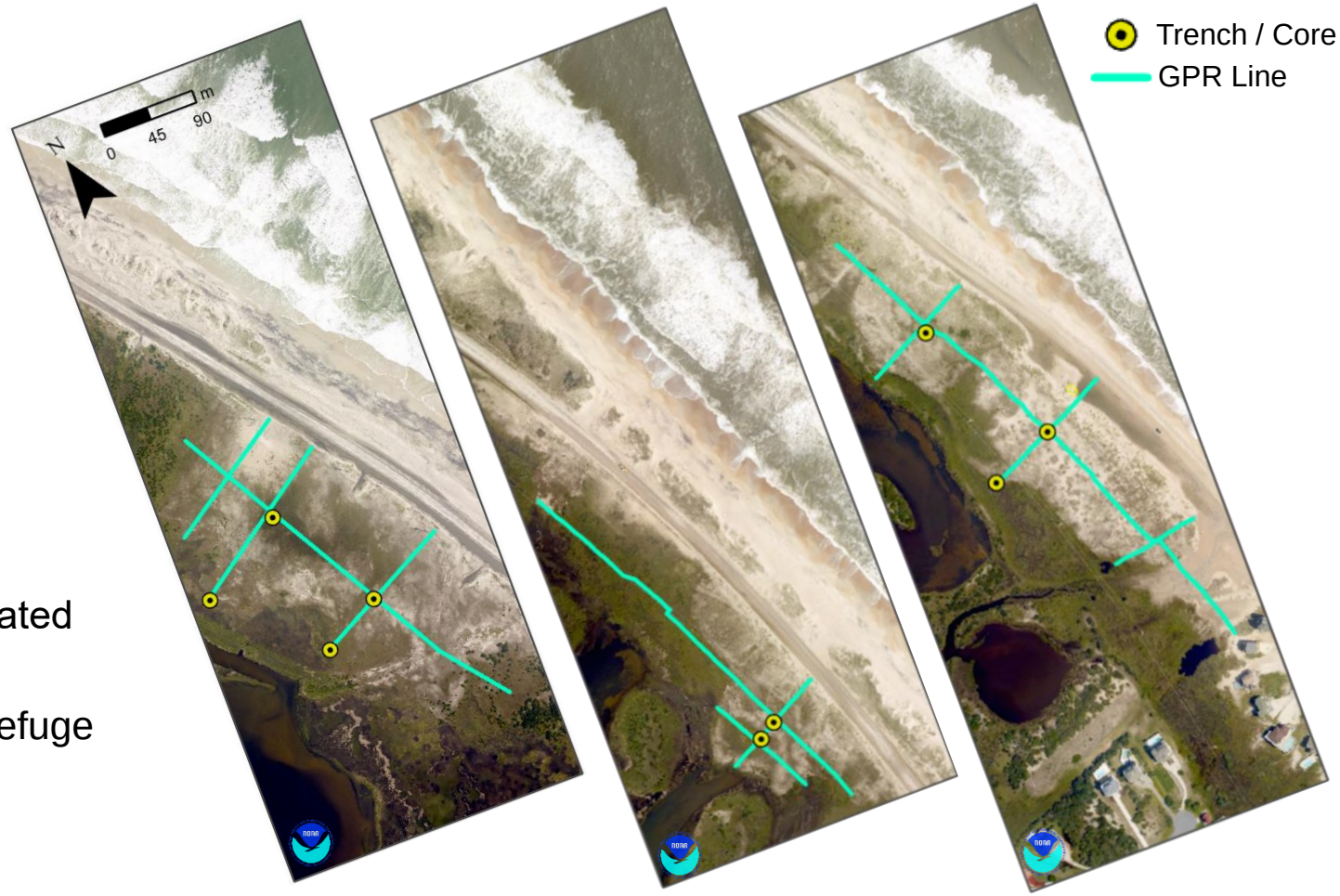



**PEA ISLAND**:

- 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**

# 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?

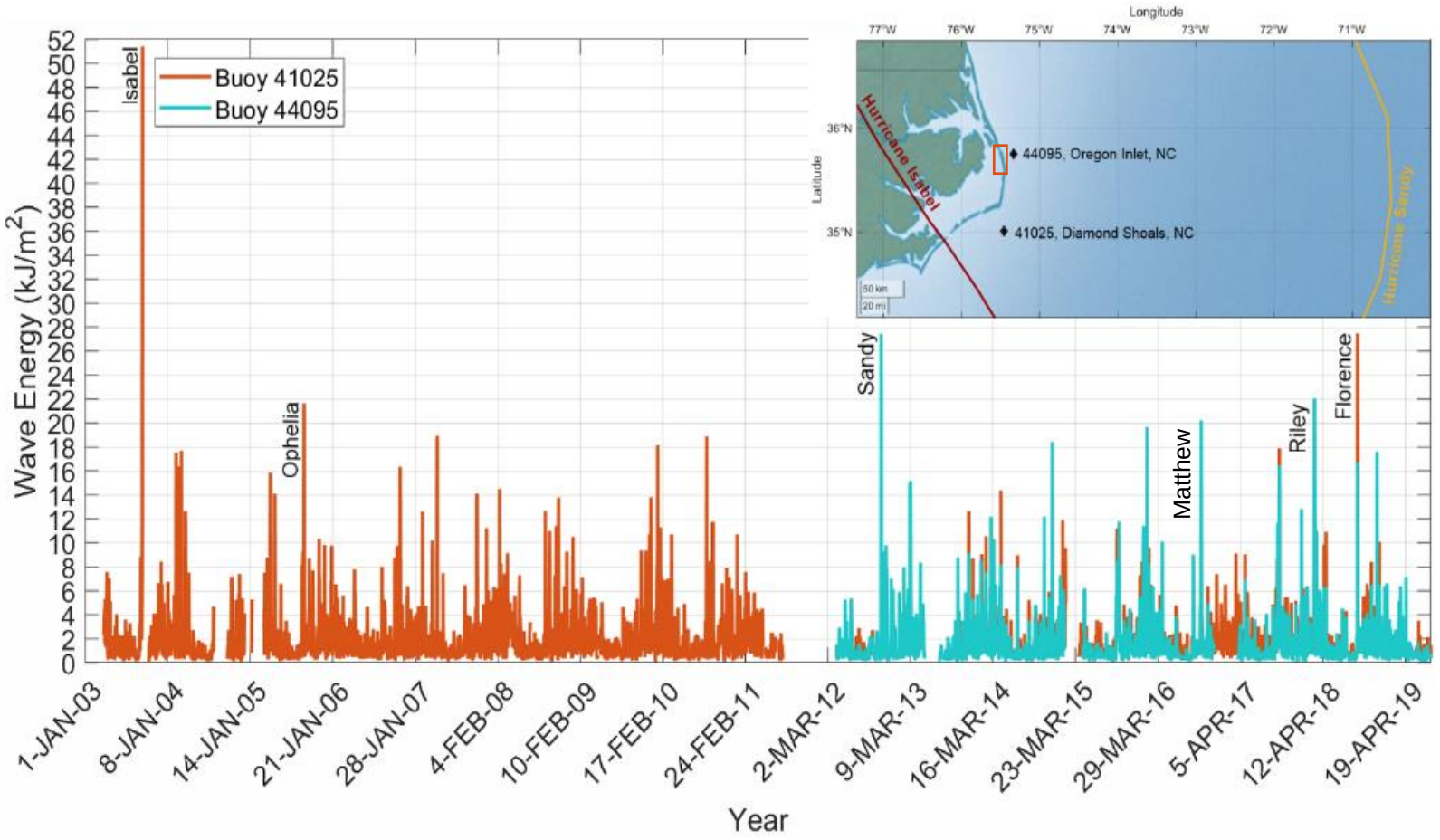
$R_3$: Has washover sediment flux rate been accelerating/decelerating over the past ~500 years?

**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/m$^2$

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

Wind speed: ~35-45 mph
Storm surge: 0.8 m
Wave energy: 9.4 kJ/m$^2$

**Hurricane Sandy (Oct. 2012)**

Wind speed: ~45 mph
Storm surge: 1.1 m
Wave energy 27.4 kJ/m$^2$

**Nor'easter Riley (Mar. 2018):**

Wind speed: ~50 mph
Storm surge: not reported
Wave energy 22.1 kJ/m$^2$

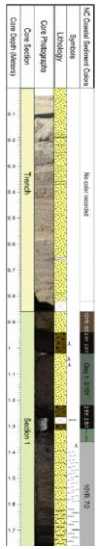
# Methods: Geologic Techniques

**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

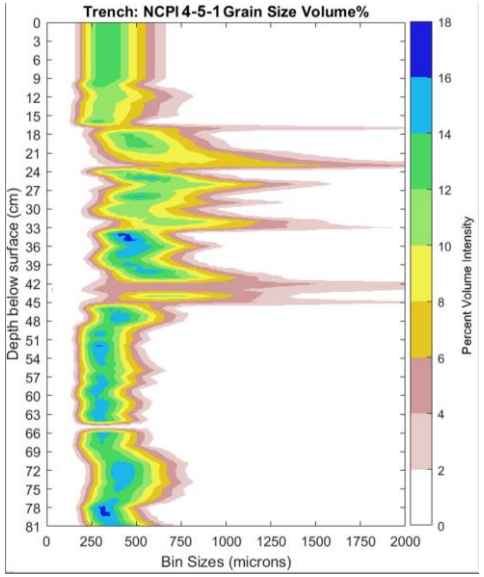
CHRONO

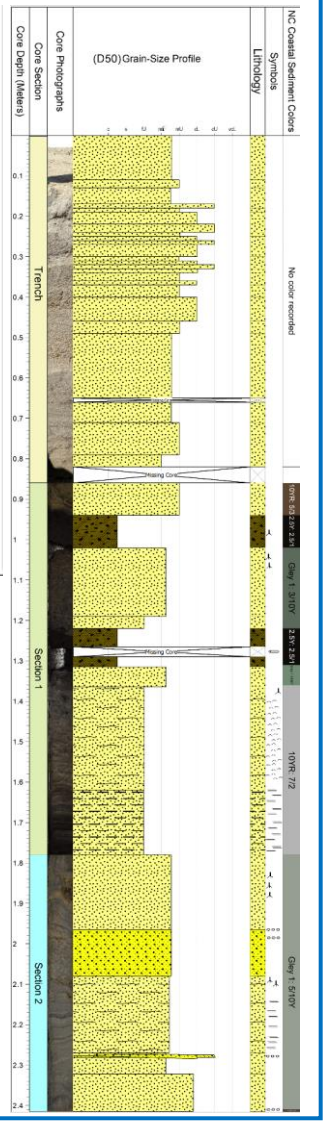
Bomb-spike

IntCal 20 curve

**Output Products**

Particle-Size Percent Volume Graph (left)
Core Log w/ D-50 grain-size (right)



# Methods: Geophysical Techniques

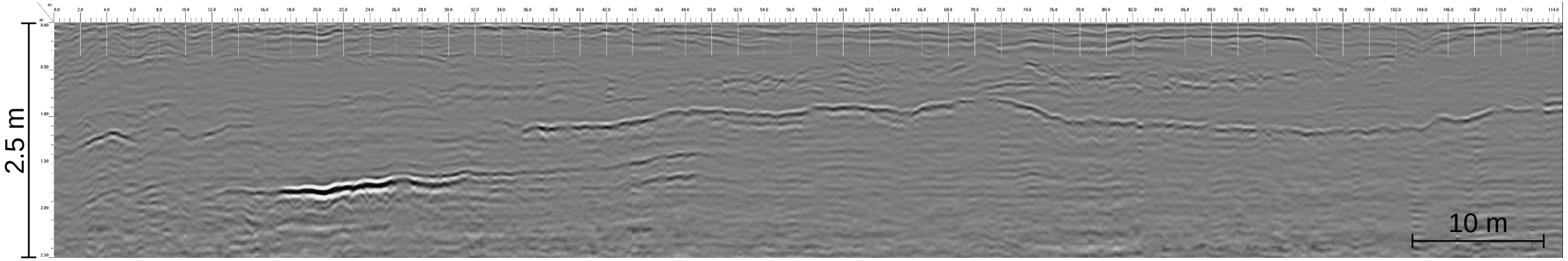
**Ground Penetrating Radar (GPR)**

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)



# Methods: GPR Interpretation Process

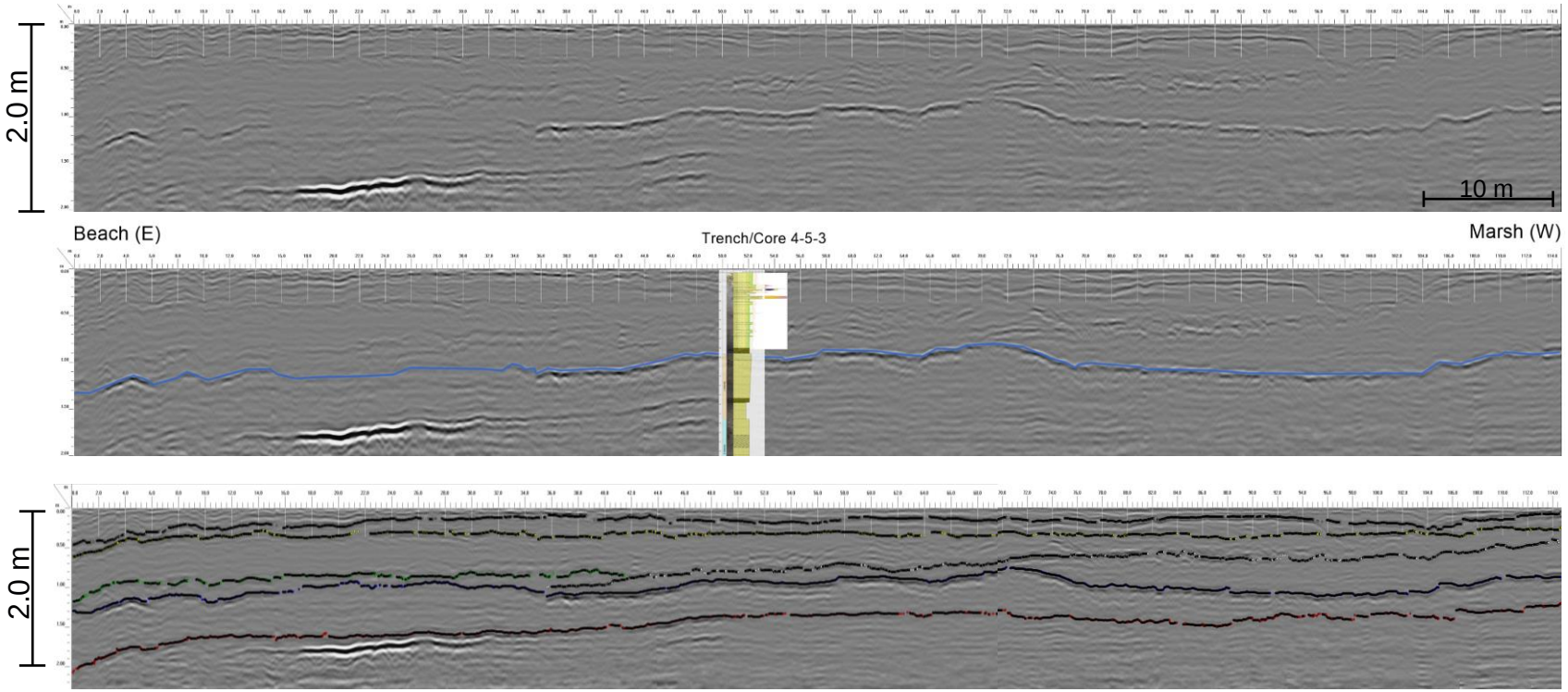
**Start**:
Uninterpreted radiographs

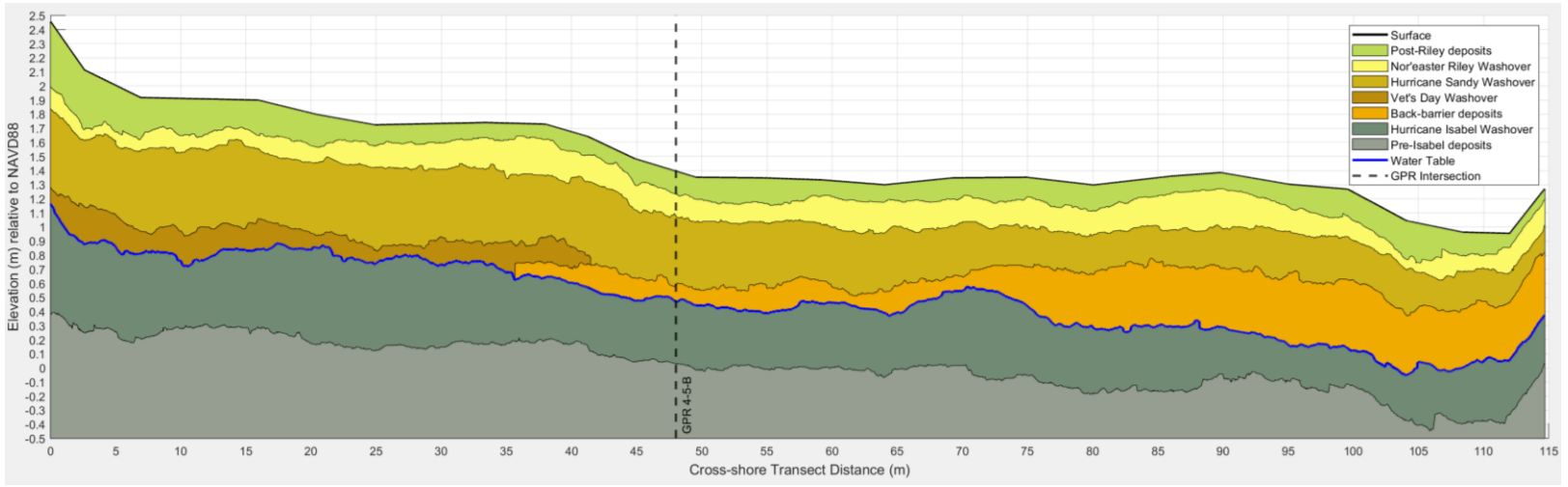
**Correlate**:
Grain-size plots, core logs, & imagery to high/med amplitude reflectors. Water table depth used as “ground truth”.

**Interpret Stratigraphy**:
GSSI’s RADAN 7 Software

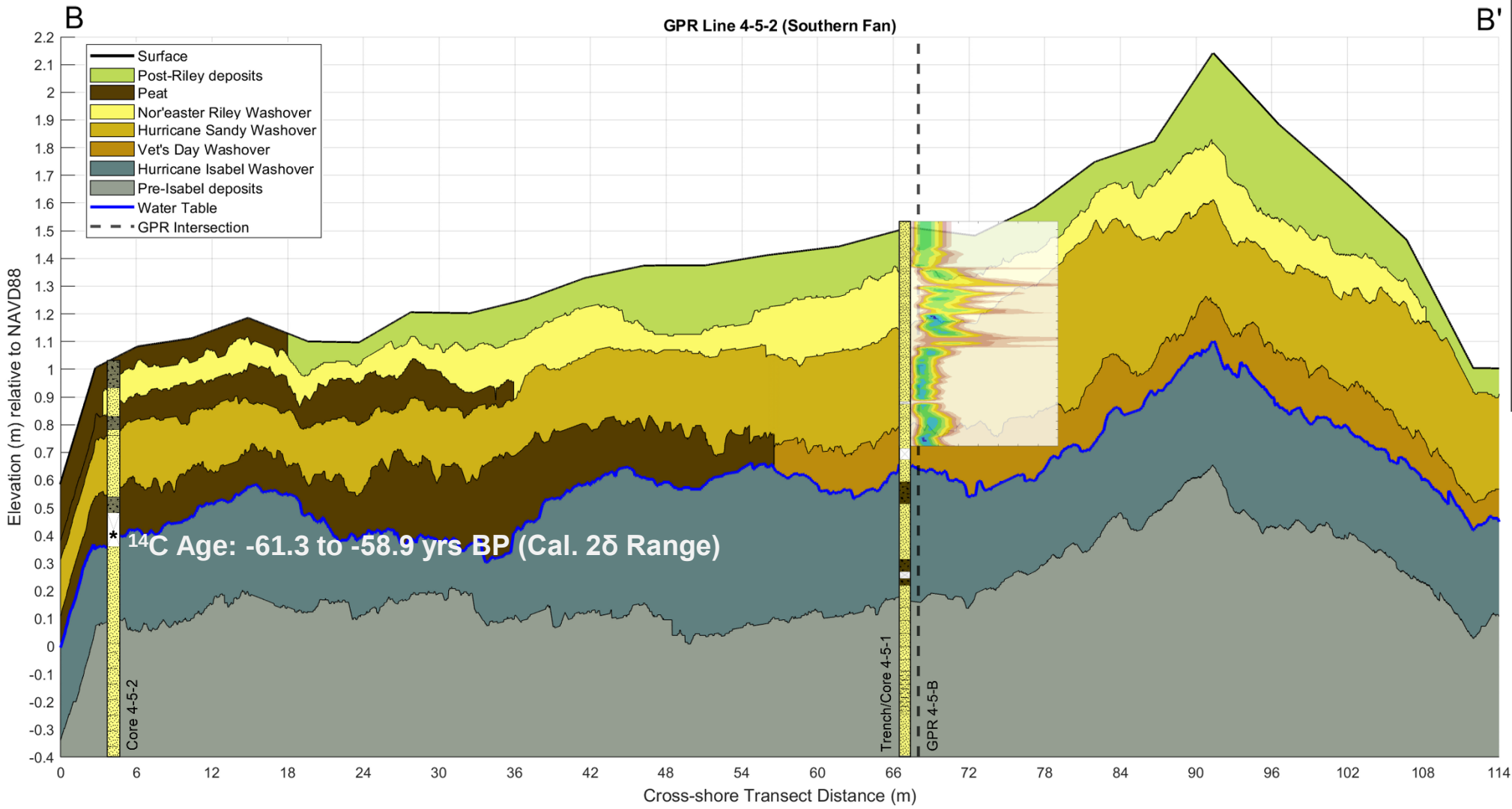
**Visualize:**
Surface Normalization (elevation vs. distance)

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

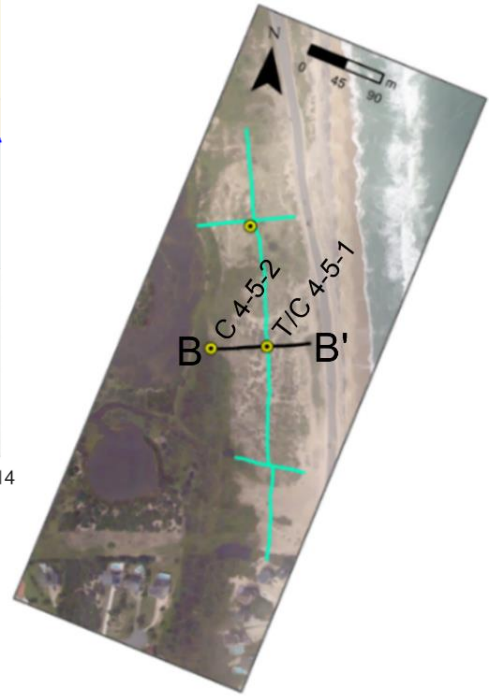


# Results: GPR Full-Interpretation




| 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 |

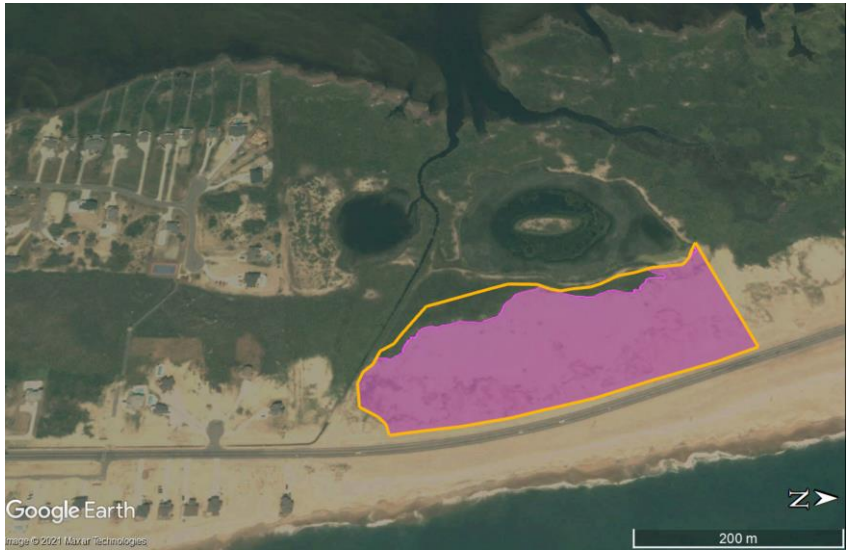



Trench/Core Lithology Key

- Sand
- Peat

# Results: Southern Washover Fan Areas

Hurricane Isabel (2003)
**Washover Area: 43,460 m²**





Vet's Day Nor'easter (2009)
**Washover Area: 10,553 m²**

Common maximum area footprint delineated by orange perimeter

Hurricane Sandy (2012)
**Washover Area: 35,559 m²**



Nor'easter Riley (2018)
**Washover Area: 36,830 m²**

# 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)

# Additional References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# QUESTIONS

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In-person:

Tuesday, 14 December 2021

14:40 - 14:45

*Convention Center - Room 228-230*