Sea-level Rise on Virginia's Barrier Islands: Is Climate Change a Factor?

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Environmental Studies Program/Geology
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RANDOLPH-MACON COLLEGE

Outline

- Background
- “Burning” questions (climate change/sea-level rise)
- A conceptual model
- Database
- Summary of salient results
- Management strategies

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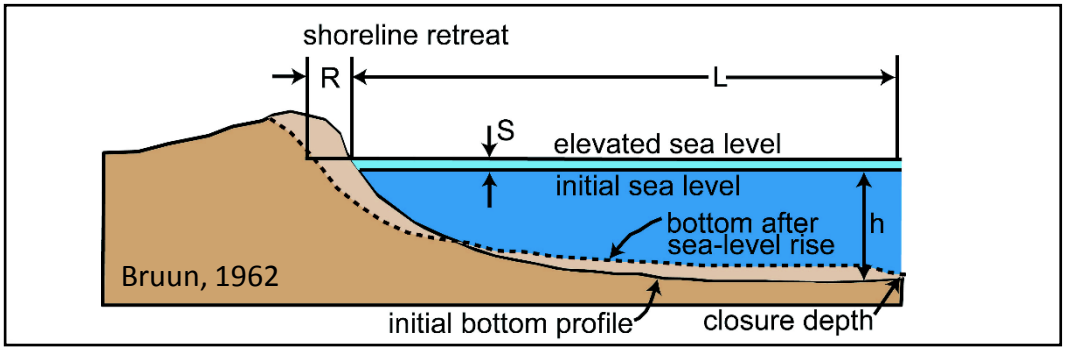
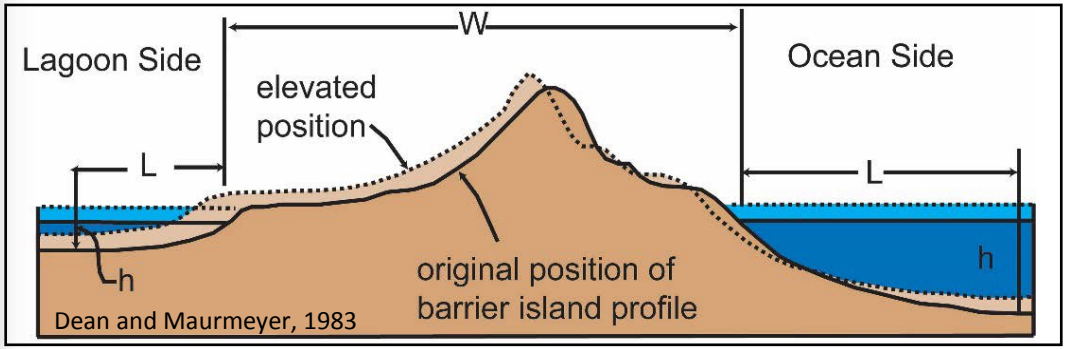
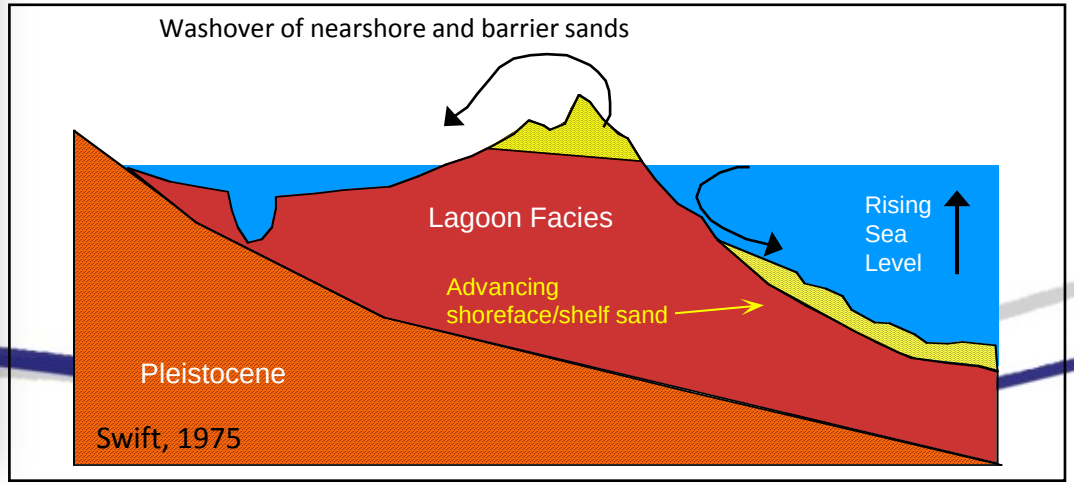
120 km

10 km


shoreline retreat
R
L
S
elevated sea level
initial sea level
bottom after
sea-level rise
h
Bruun, 1962
initial bottom profile
closure depth

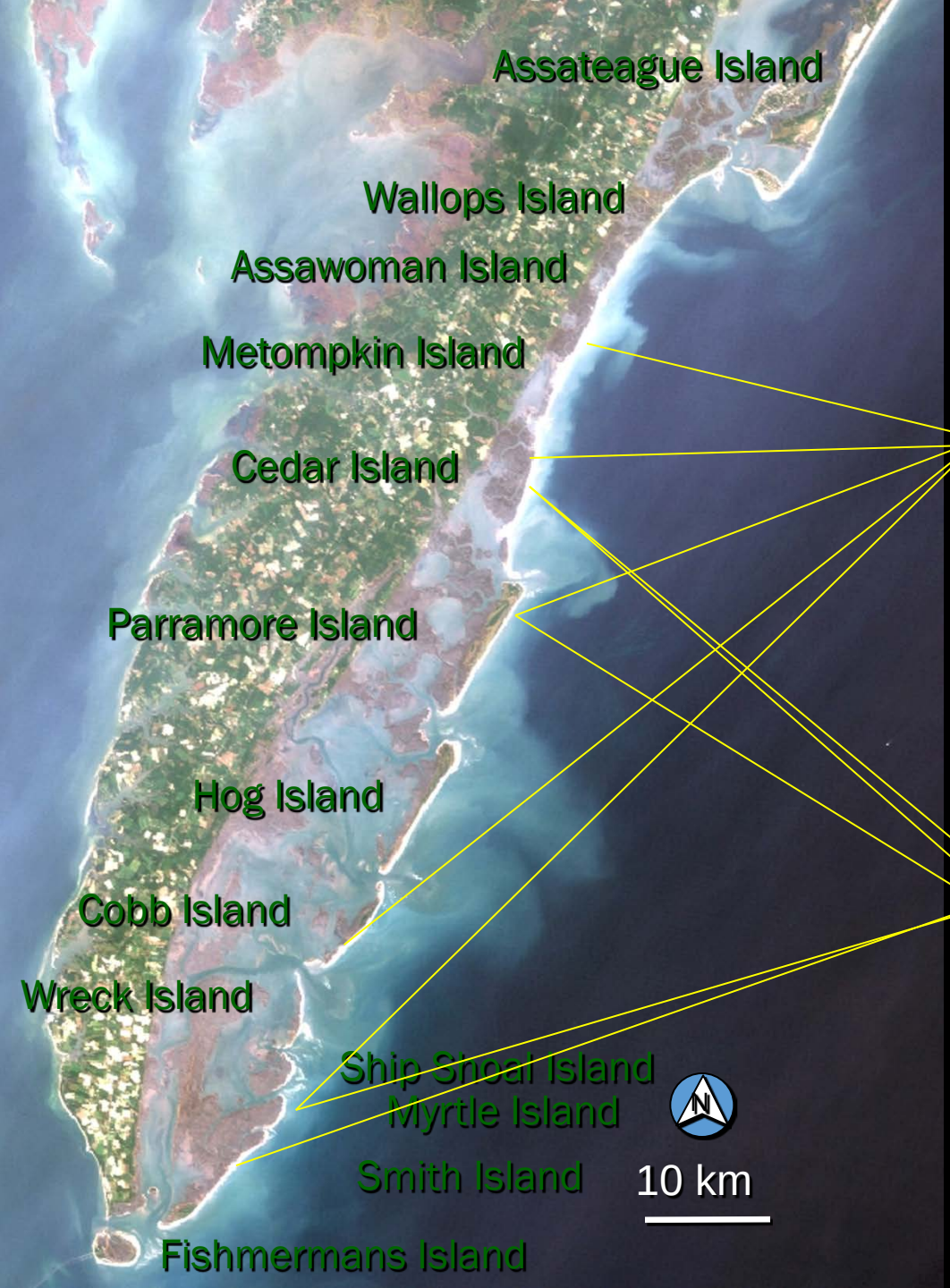

W
Lagoon Side
Ocean Side
elevated
position
L
L
h
h
original position of
barrier island profile
Dean and Maurmeyer, 1983


Washover of nearshore and barrier sands
Lagoon Facies
Rising
Sea
Level
Advancing
shoreface/shelf sand
Pleistocene
Swift, 1975

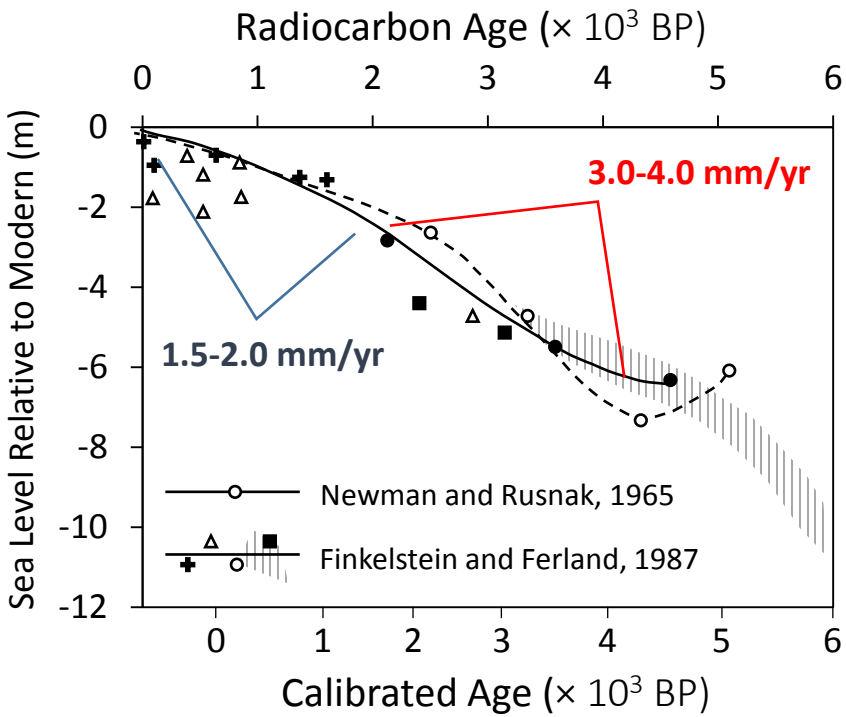
Climate Change Impacts along Virginia's Coasts?

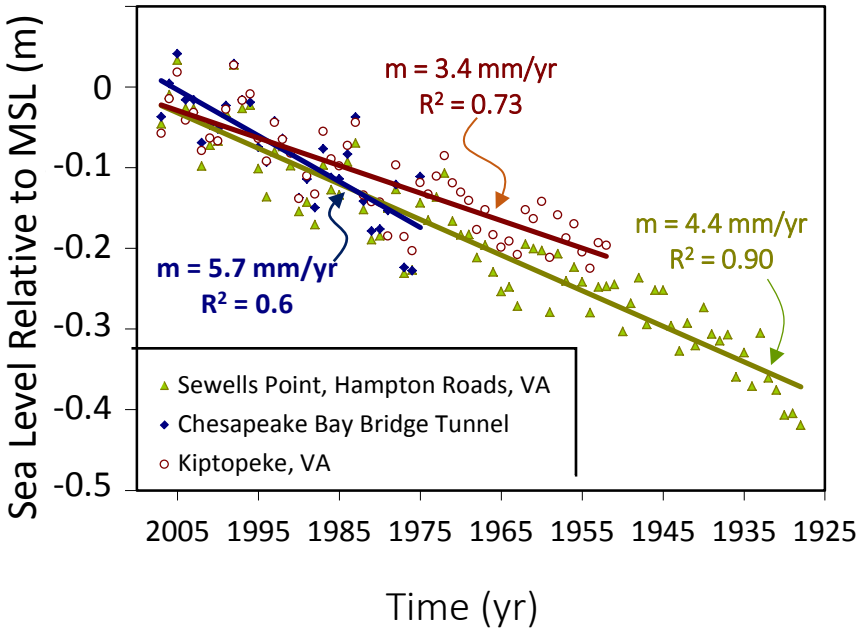
Ownership

Greenbackville Harbor
RT 679
RT 679
RT 175 East Side Boat Ramp
Wisharts Point Landing
Hallwood
RT 679
RT 689
Gargatha Landing
RT 680
RT 686
Parkers Creek Landing
Folly Creek Landing
RT 605
Wachapreague Town Dock
RT 605
RT 605
Quinby Harbor
Willis Wharf Harbor
RT 600
Red Bank Boat Ramp
RT 600
Eastville
RT 631
RT 600
Oyster Harbor Ramp
Cape Charles
Mockhorn Wildlife Area
RT 600
Kiptopeke
ESVA National Wildlife Refuge
Fisherman Island
Smith Island
Ship Shoal Island
Myrtle Island
Wreck Island
Little Cobb Island
Cobb Island
Hog Island
Revel Island
Parramore Island
Cedar Island
Metompkin Island
Assawoman Island
Wallops Island
Assateague Island
N
The Nature Conservancy
Call (757) 442-3049
Dept. of Game and Inland Fisheries
Call (757) 442-2429
Dept. of Conservation and Recreation
Call (757) 787-5576
U.S. Fish and Wildlife Service Refuges
Chincoteague – Call (757) 336-6122
Eastern Shore Call (757) 331-2760
Fisherman Island – Call (757) 331-2760
Wallops Island (NASA)– Call (757) 336-6122


Assateague Island
Wallops Island
Assawoman Island
Metompkin Island
Cedar Island
Parramore Island
Hog Island
Cobb Island
Wreck Island
Ship Shoal Island
Myrtle Island
Smith Island
Fishmermans Island
N
10 km

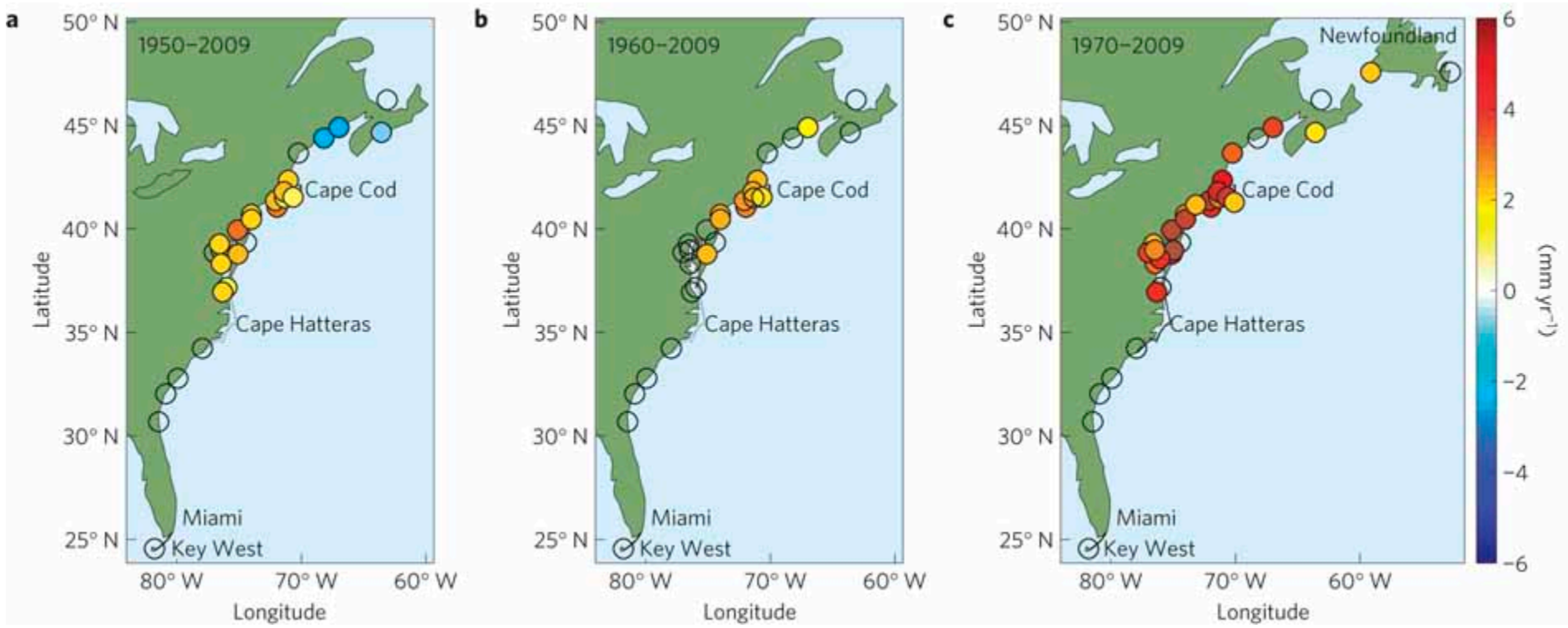
Sea Level


Radiocarbon Age (× 10³ BP)
0
1
2
3
4
5
6
Sea Level Relative to Modern (m)
0
-2
-4
-6
-8
-10
-12
3.0-4.0 mm/yr
1.5-2.0 mm/yr
Newman and Rusnak, 1965
Finkelstein and Ferland, 1987
Calibrated Age (× 10³ BP)


Sea Level Relative to MSL (m)
0
-0.1
-0.2
-0.3
-0.4
-0.5
m = 3.4 mm/yr
R² = 0.73
m = 4.4 mm/yr
R² = 0.90
m = 5.7 mm/yr
R² = 0.6
Sewells Point, Hampton Roads, VA
Chesapeake Bay Bridge Tunnel
Kiptopeke, VA
2005
1995
1985
1975
1965
1955
1945
1935
1925
Time (yr)

Sea-level Hot Spots

1950 - 2009 **1960 - 2009** **1970 - 2009**



Sallenger et al. (2012)

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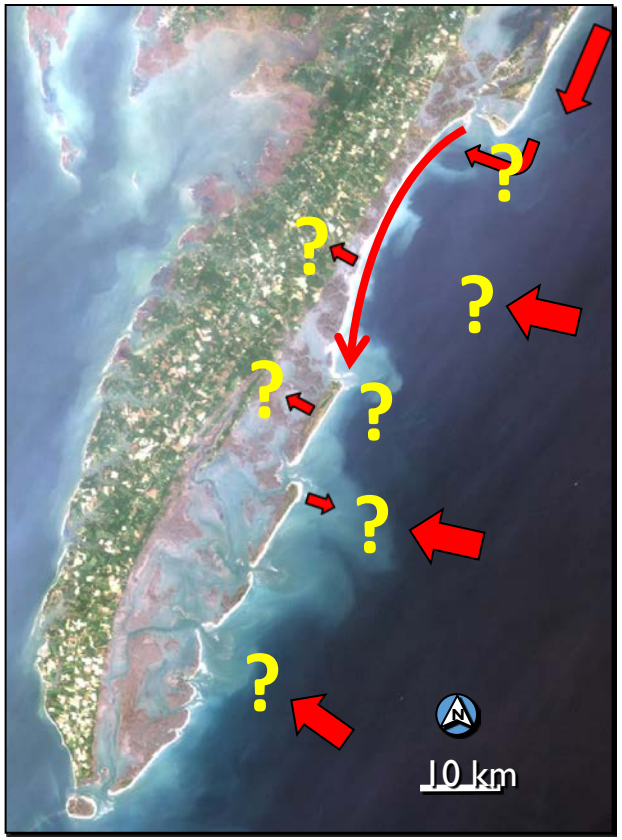
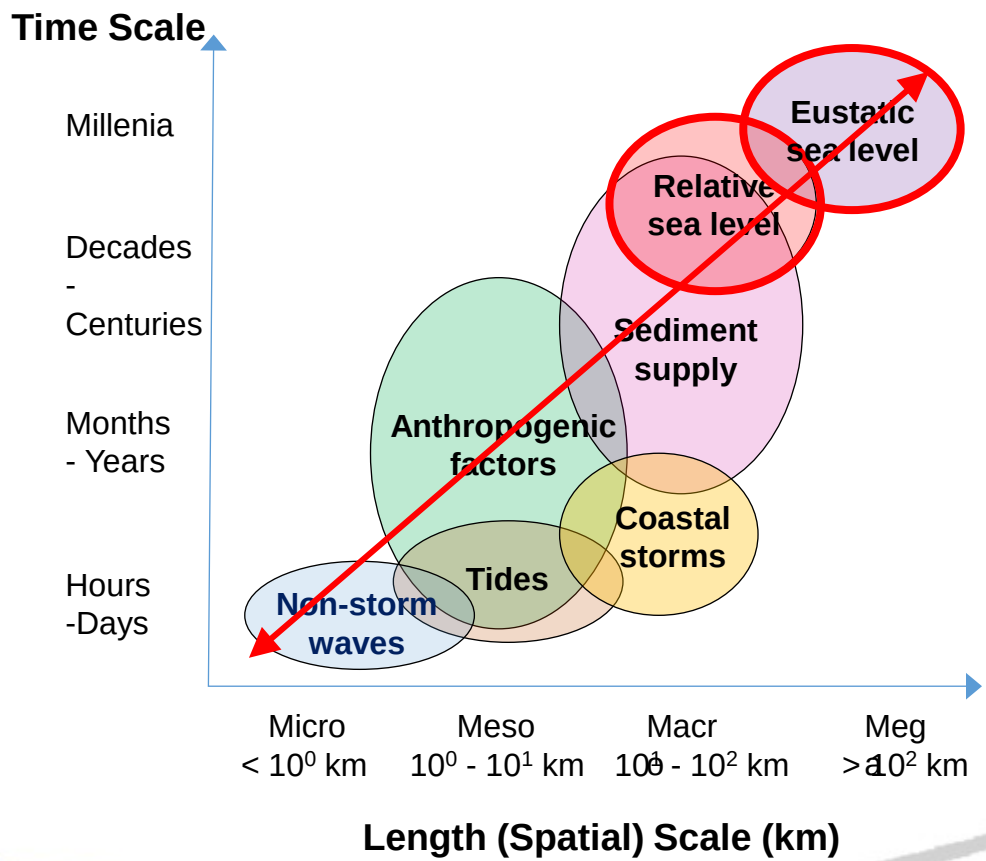
“Burning” Research Questions

- Where is the sand going?
- How much sand moves around?
- Over what time scales does sand move?
- What are the mechanisms that make sand move?
- Where are the reservoirs and what role do they play on the overall system?
- What happened to the barrier island in the past and what will happen to them in the future?



Research Questions: Short Version

- "Morphodynamics"
- Climate change?



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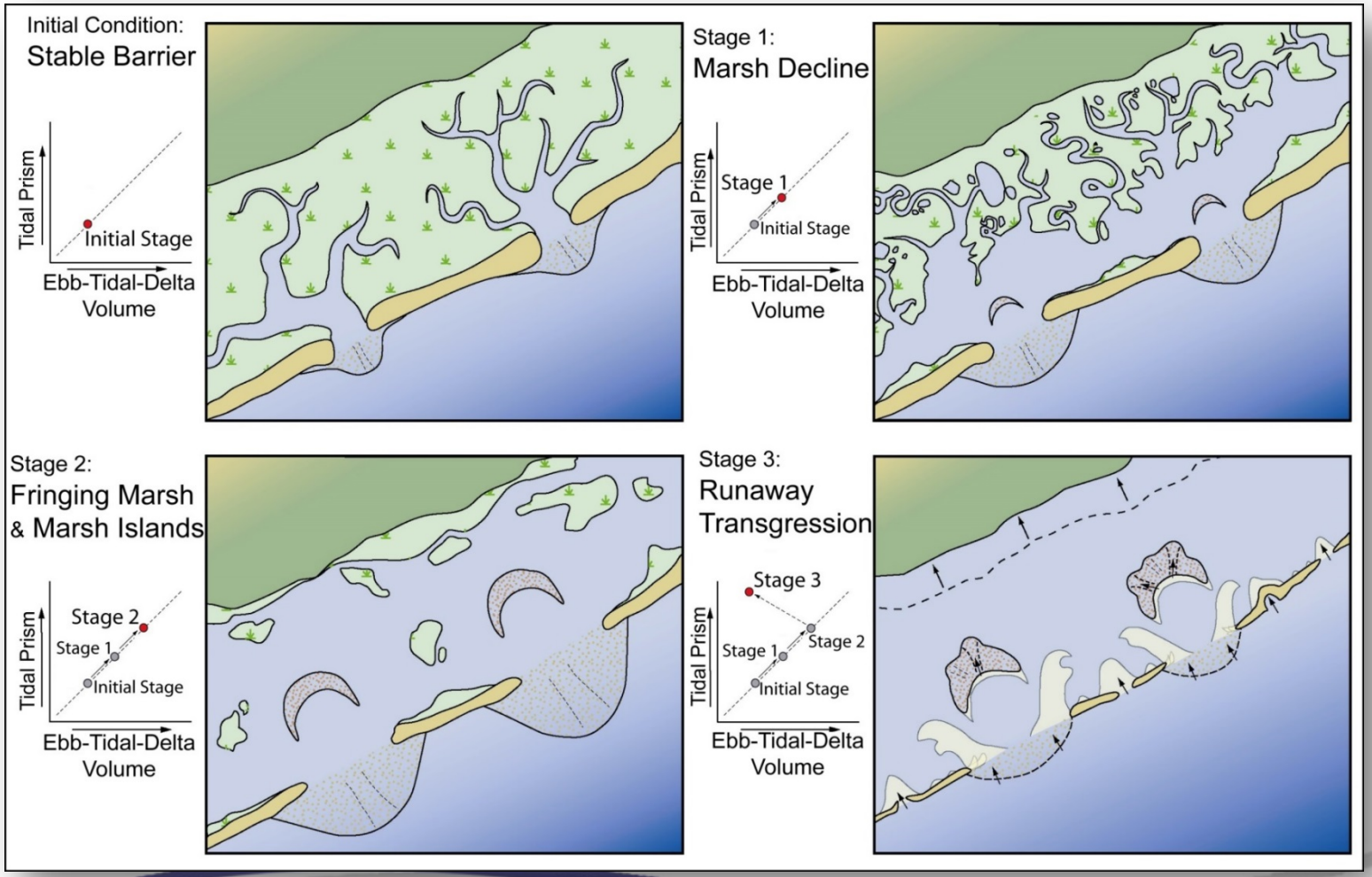
Conceptual Model ⇔ Hypothesis



(FitzGerald et al., 2007)

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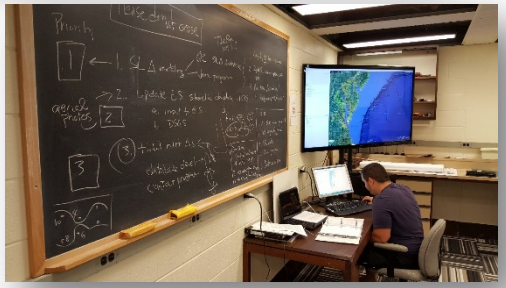
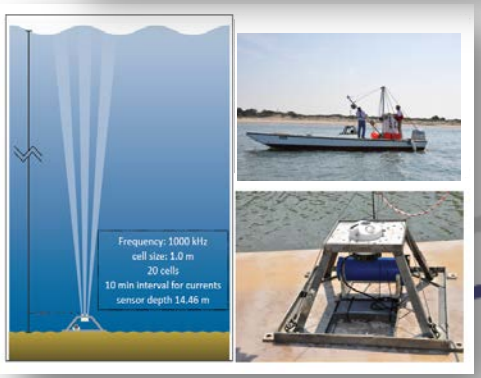
Database Used to Test Hypothesis

- Tidal prism changes (1800s-present)
  - ADCP surveys, empirical…
- Island, marsh, bay area changes
  - GIS analyses of aerial imagery
- Shoreline change (1800s-present)
  - Shoreline migration reversals (non-linear)
- Textural change (spatial)
  - Onshore, nearshore
- Geologic framework
  - Seismic reflection profiling
- Storminess (frequency and intensity)





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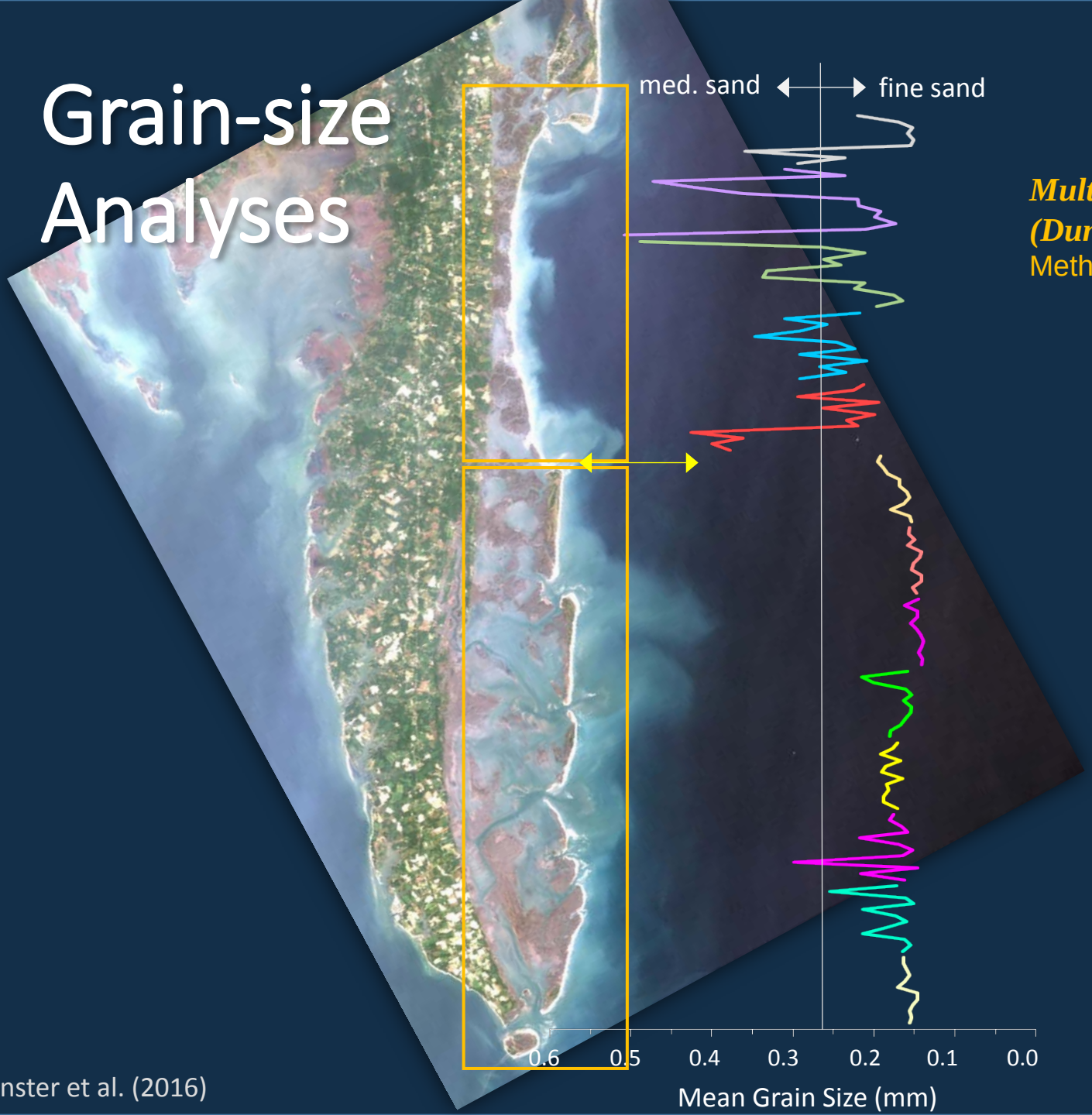
Grain-size Analyses



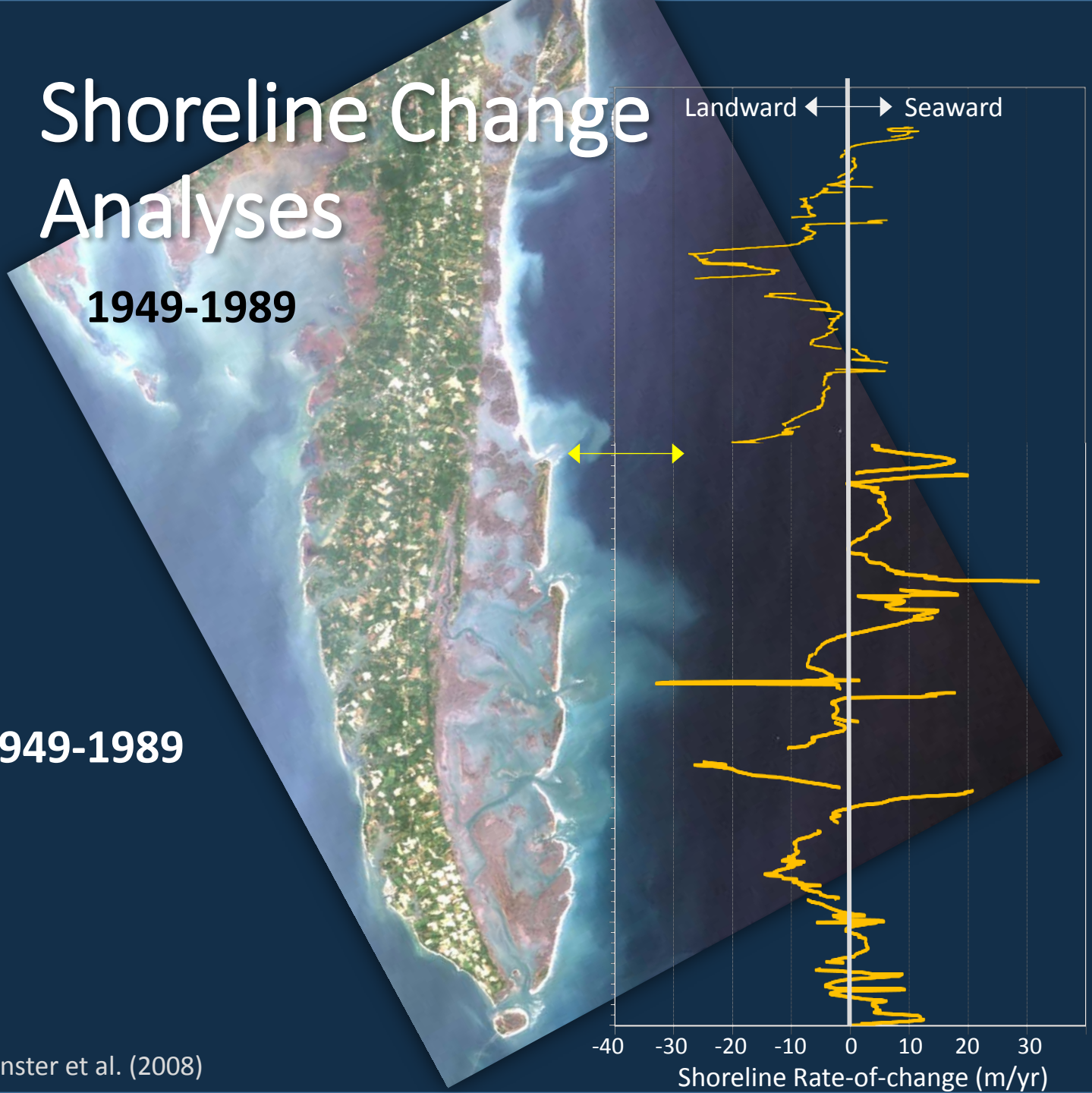
Multiple Comparisons (Dunn)

Method: 95% Dunn interval

Fenster et al. (2016)

Shoreline Change Analyses

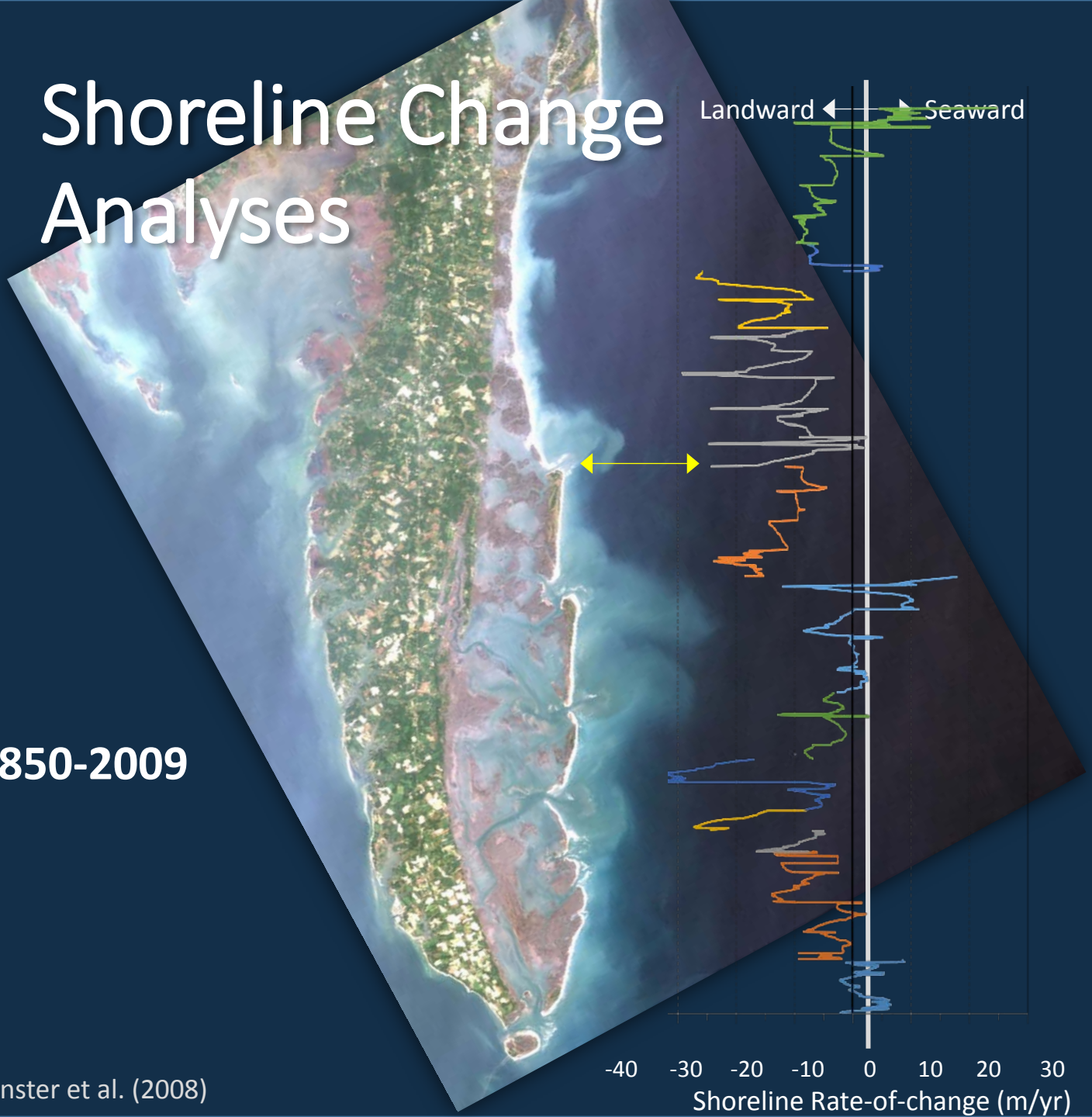
1949-1989



1949-1989

Fenster et al. (2008)

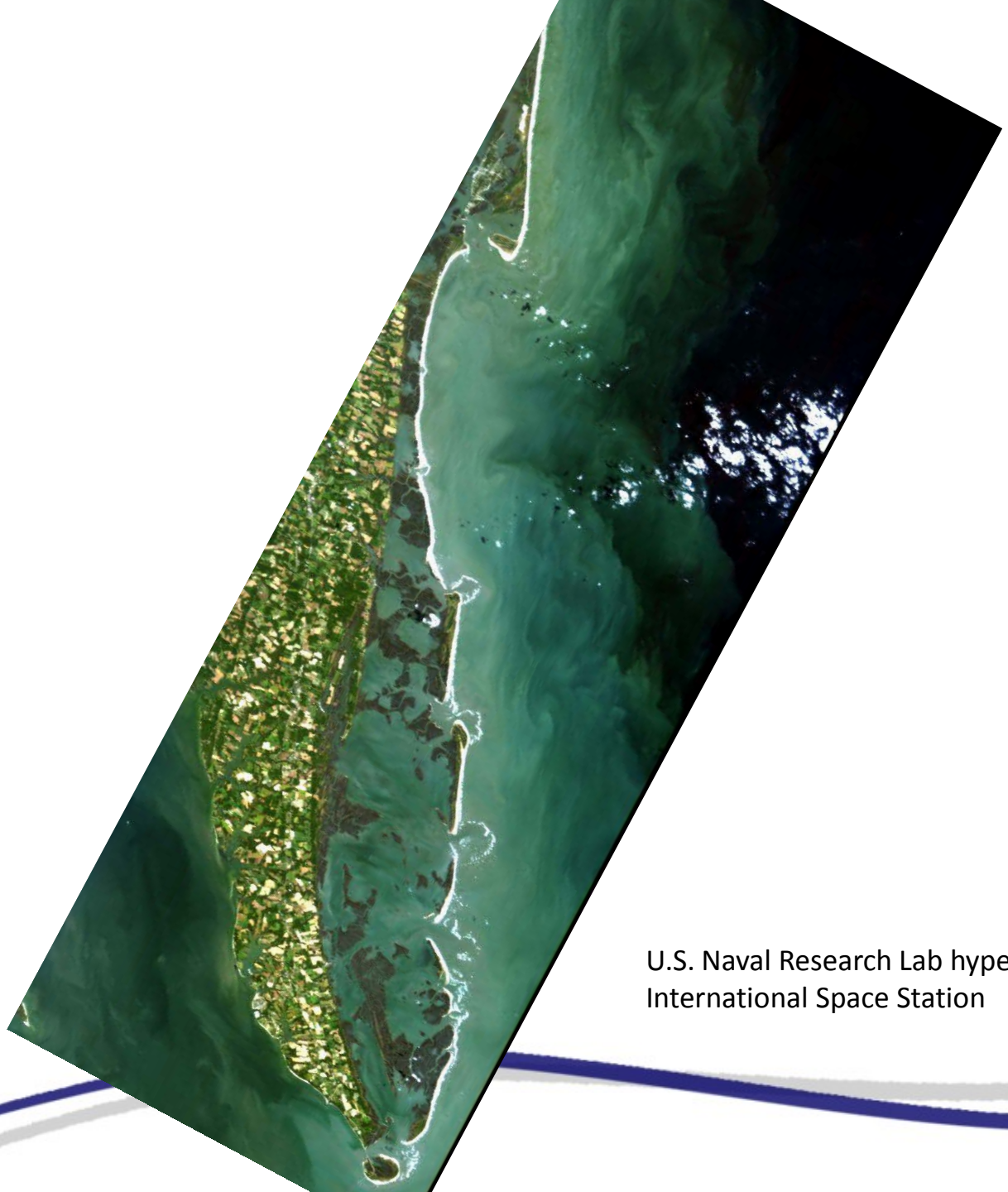
Shoreline Change Analyses



1850-2009

Fenster et al. (2008)

Assateague I.
Chincoteague I.
Fishing Pt.
Wallops I.
Arc of Erosion
Parramore I.
Fishing Pt.
Arc of Erosion
Parramore I.
Image NASA
Image © 2007 TerraMetrics
3191 m
Pointer 37°32'24.04" N 75°37'38.09" W elev 0 m
Streaming 100%

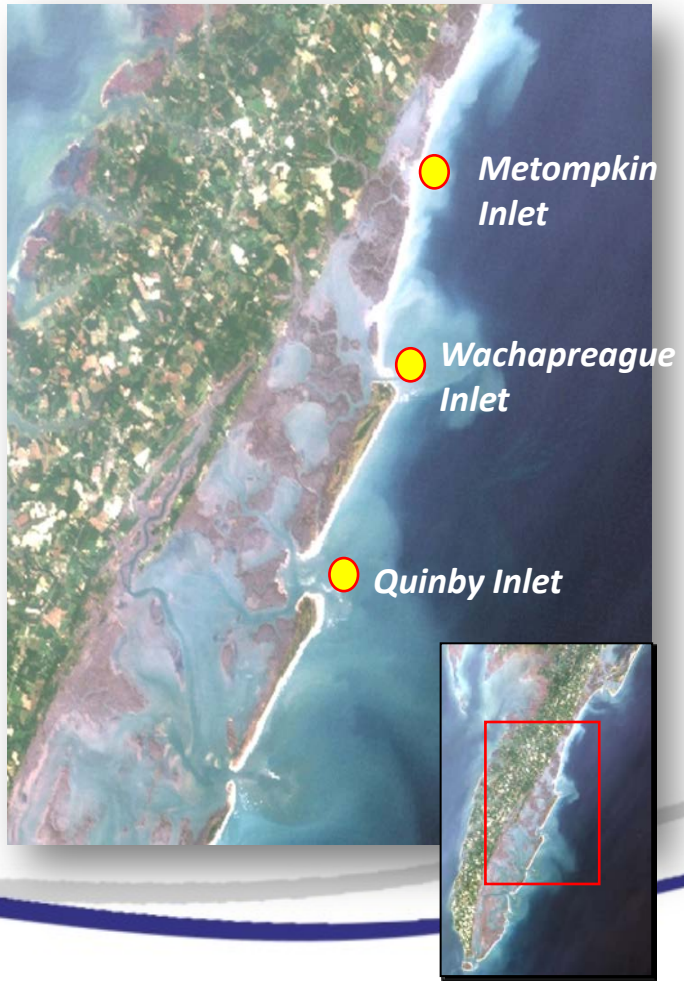


U.S. Naval Research Lab hyperspectral imager abroad the International Space Station

Tidal Prism – Dynamic Method

- Point measurements at 3 upward looking ADCPs ≈ 4 weeks

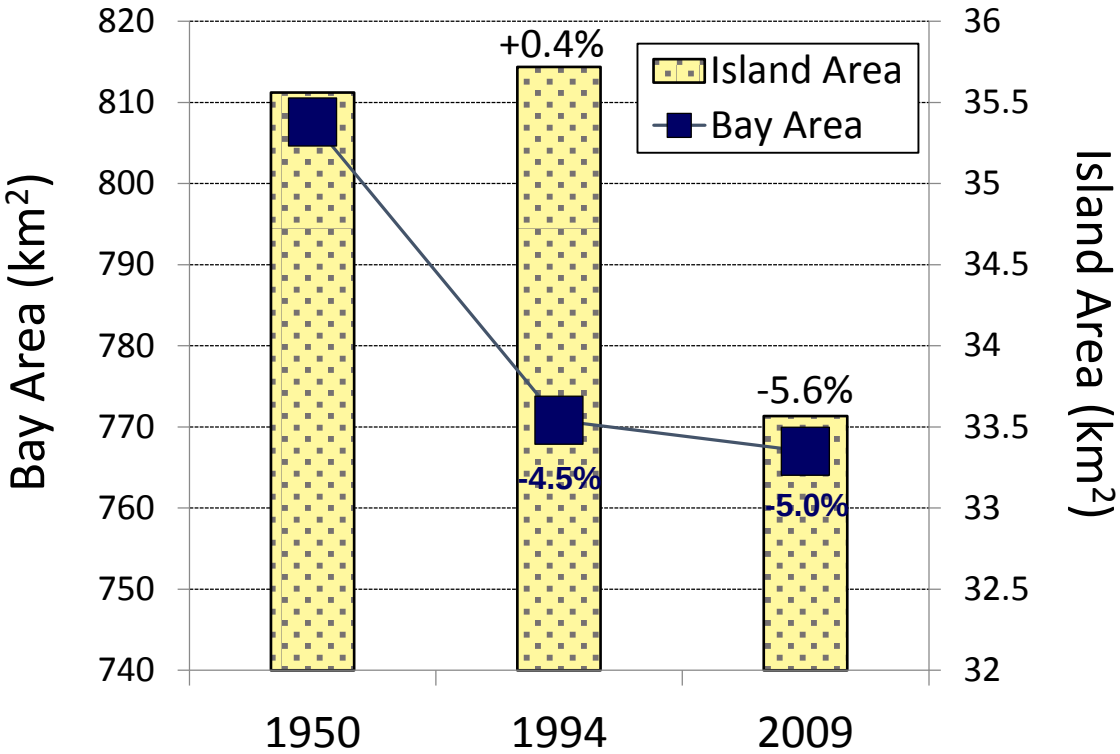
Inlet	Area	Tidal Prism	Flood vs. Ebb
Metompkin	↓	↓	Ebb
Wachapreague	↑	↑	Ebb
Quinby	↓	↓	Stable

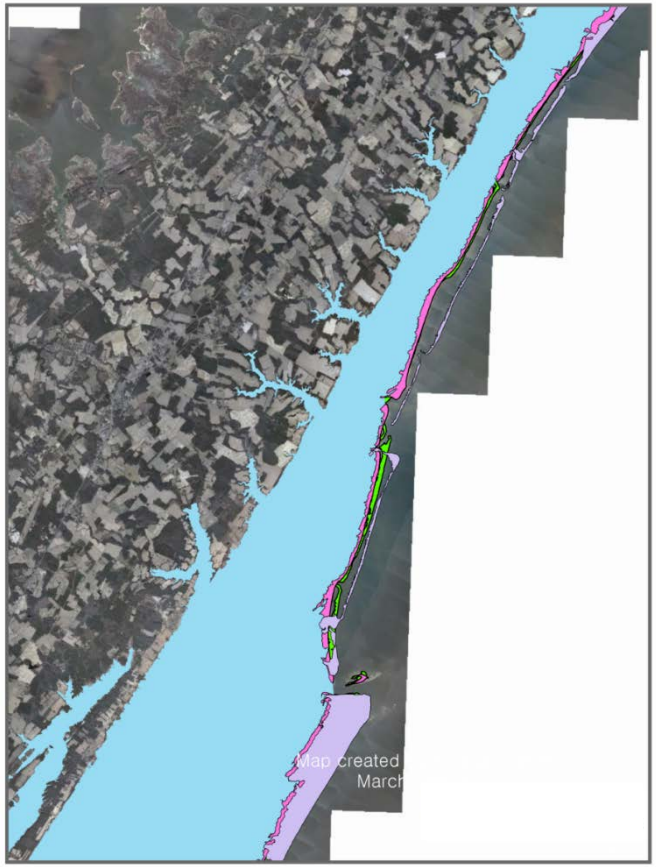


Fenster et al. (2011)

GIS Results

Tidal Prism = Bay Area + Tidal Range

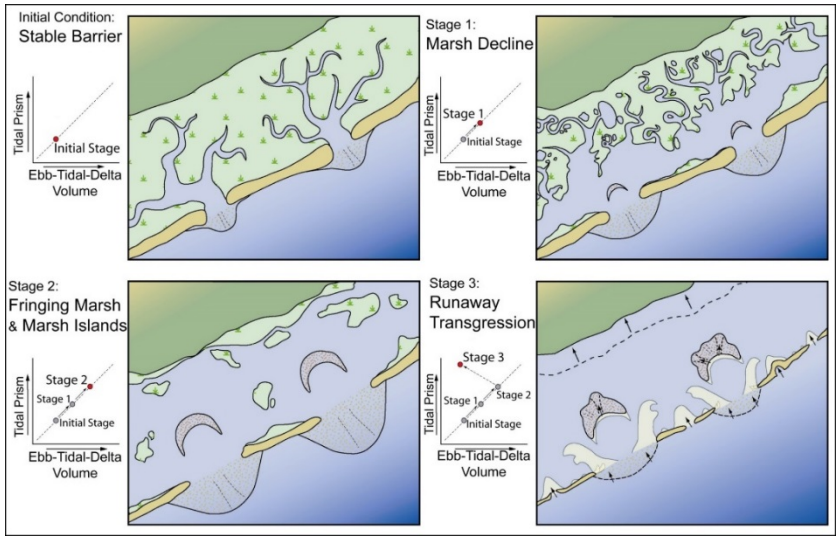




Fenster et al. (2014)

Climate Change? Summary of Results

- Yes
  - Grain-size trends
  - Shoreline migration rates
  - Inlet widths ↑
  - Island areas ↓
- No
  - Bay area ↓
- Questions
  - Ebb-tidal delta (growth or decay)?
  - Tidal inlet dominance (ebb or flood)?
  - Tidal prism?
  - Back barrier marsh area?



Overarching Conclusions

- Difficult to ascribe climate change processes to morphologic changes that have occurred along the Virginia barrier islands since 1800s
- Within noise of trends (signals)
- Storms (extratropical) and sediment budget (fluxes) seem to control morphodynamics over these time scales

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NASA: Wallops Flight Facility

Mutual Missions: TNC, U.S. FWS, NPS

The mission of:

the **U.S. Fish and Wildlife Service** is working with others **to conserve**, protect, and enhance **fish**, **wildlife**, plants, and their habitats for the continuing benefit of the American people.

the **National Park Service** shall promote and regulate the use of Federal areas known as national parks, monuments and reservations . . . … **to conserve** the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations

The mission of **The Nature Conservancy** is **to conserve** lands and waters upon which all life depends.

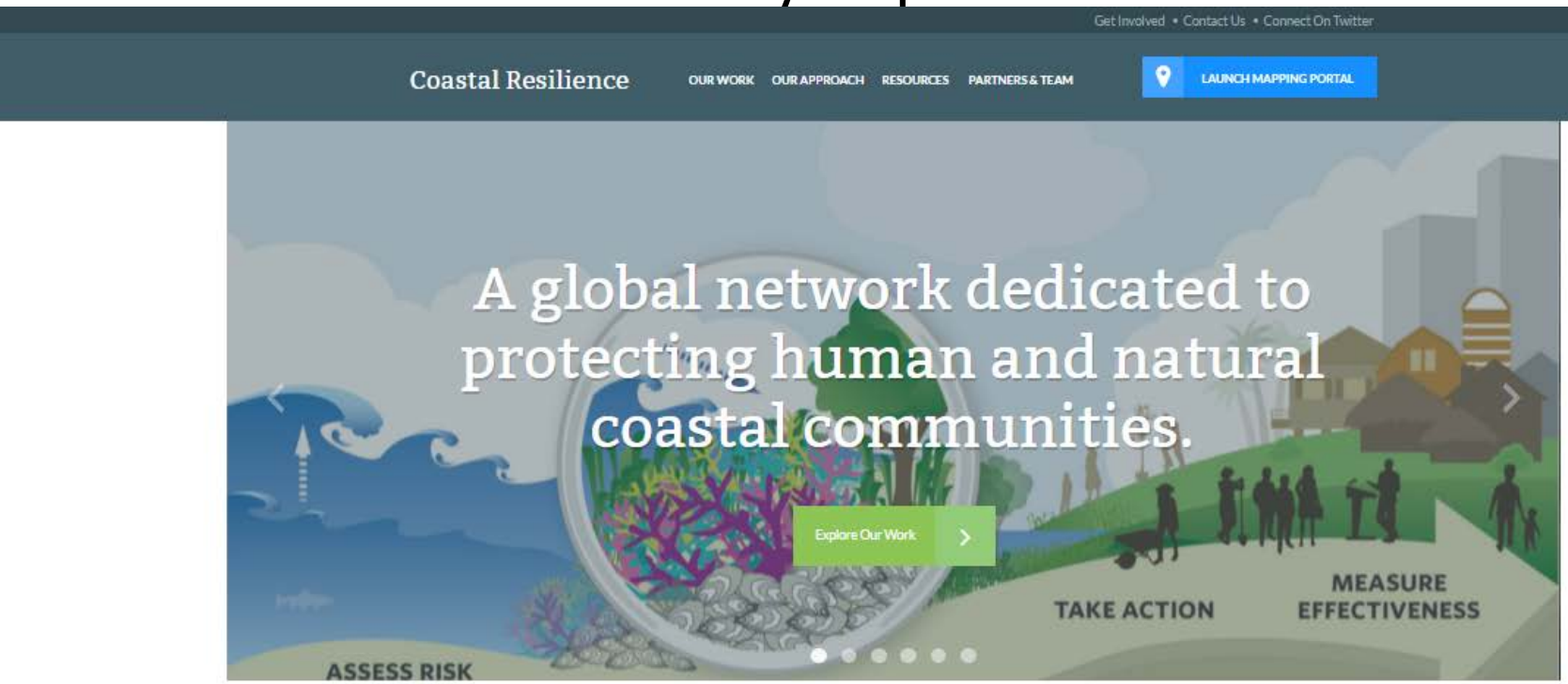
Enhancing Coastal Resilience on Virginia's Eastern Shore

- A NFWF HURRICANE SANDY COASTAL RESILIENCE PROJECT

University of North Carolina Chapel Hill
University of Virginia
Eastern Shore of Virginia Climate Adaptation Working Group
Accomack-Northampton Planning District Commission
The Nature Conservancy
Protecting nature. Preserving life.
Randolph-Macon College Ashland, Virginia
Duke University
U.S. Fish & Wildlife Service
NASA Wallops Flight Facility GSFC WFF
UNCW University of North Carolina Wilmington
natural capital PROJECT
The University of Southern Mississippi
National Fish and Wildlife Foundation
NFWF
Virginia's Eastern Shore A-NPDC
National Oceanic and Atmospheric Administration NOAA U.S. Department of Commerce
Association of State Floodplain Managers ASFPM
ARCADIS
Brosnan Institute for Risk Reduction brosnancenter.com
azavea
USGS science for a changing world
warren pinnacle consulting, inc.
University of California Santa Cruz

Coastalresilience.org

- A Global Community of practice

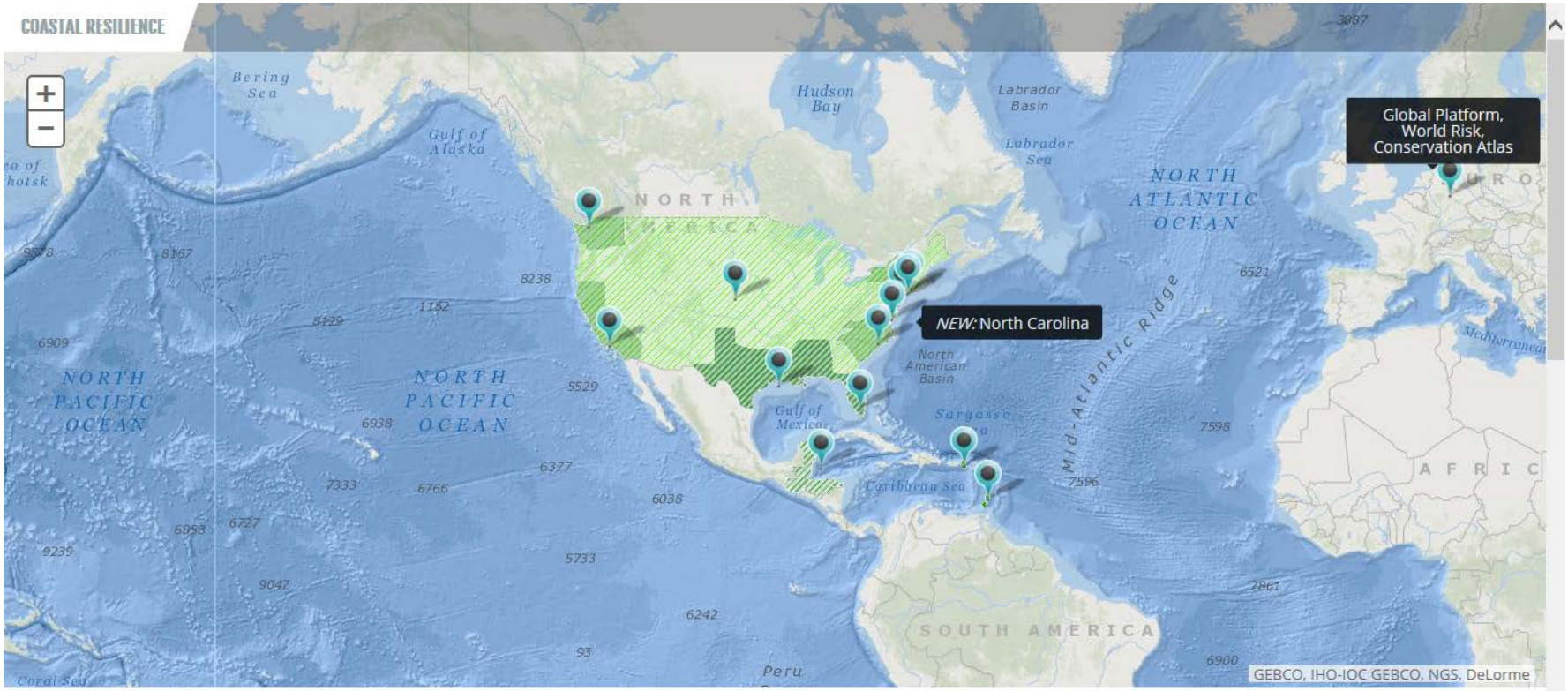


RESILIENCE MAPPING

The coastal resilience approach and mapping are informing restoration, adaptation and conservation decisions around the world.

Web-based mapping platform with apps

- MAPS.COASTALRESILIENCE.ORG



Coastal Resilience mapping portal

The Nature Conservancy — Protecting nature. Preserving life.™

natural capital PROJECT

NOAA

USGS — science for a changing world

isr

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

ASFPM

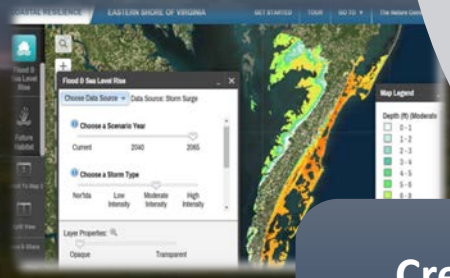
Engage communities

Promote nature based solutions

Demonstrate natural infrastructure projects

PROJECT GOAL

Provide science-based tools to develop locally-relevant climate-hazard mitigation actions that include nature-based solutions.

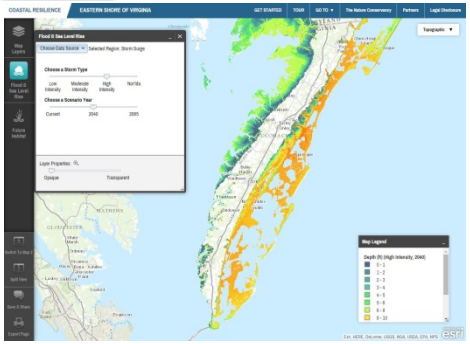


Create decision-support tool to deliver model outputs

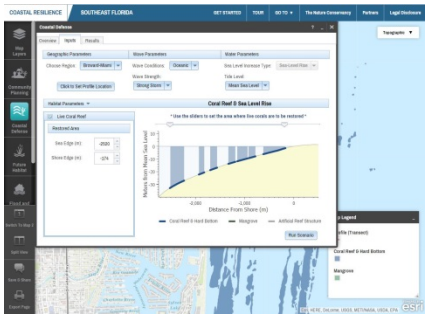
Research efficacy of natural infrastructure; use results to parameterize models

Plug-in web-based Apps

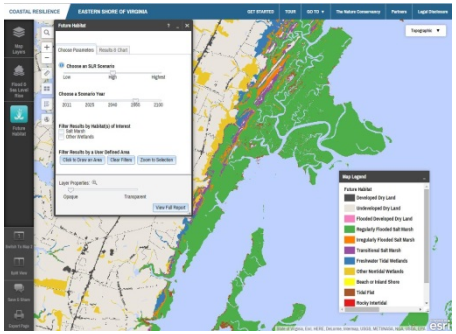
Flood & SLR



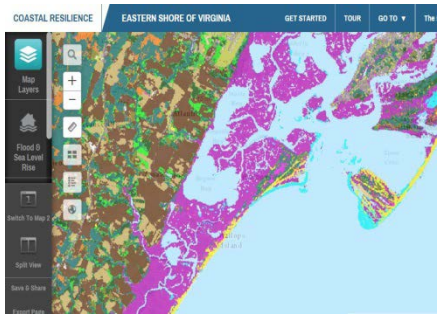
Coastal Defense



Future Habitat

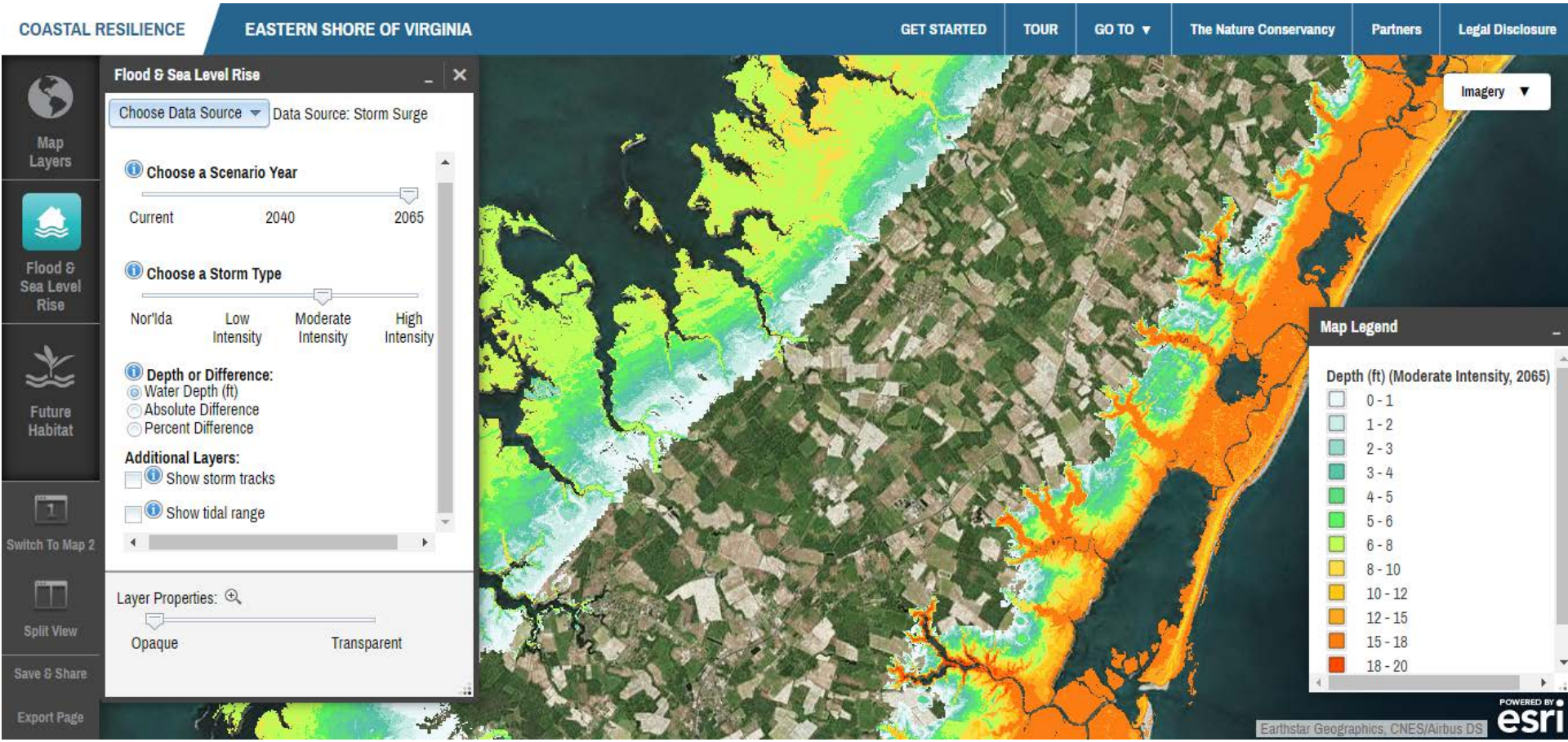


Shoreline Change



Flood & Sea Level Rise

- STORM SURGE



Down the Road…

- Additional research
  - Evolutionary history/chronology of the VBIs
  - Sediment budgets
  - Island, inlet, backbarrier dynamics
  - Storm response
- Proposal submitted to NASA in support of MACRI collaboration

Acknowledgements

- National Science Foundation through University of Virginia's Long-term Ecological Research (LTER) Program (Research Opportunity Awards)
- NASA's Wallops Island Flight Facility
- The Nature Conservancy
- Randolph-Macon College's Walter Williams Craigie Grant, Summer Undergraduate Research Fellowship
- Virginia Institute of Marine Science, Eastern Shore Lab, Wachapreague
- U.S. Fish and Wildlife Service
- Art Trembanis, Randy McBride, Allen Gontz

YAMAHA
150