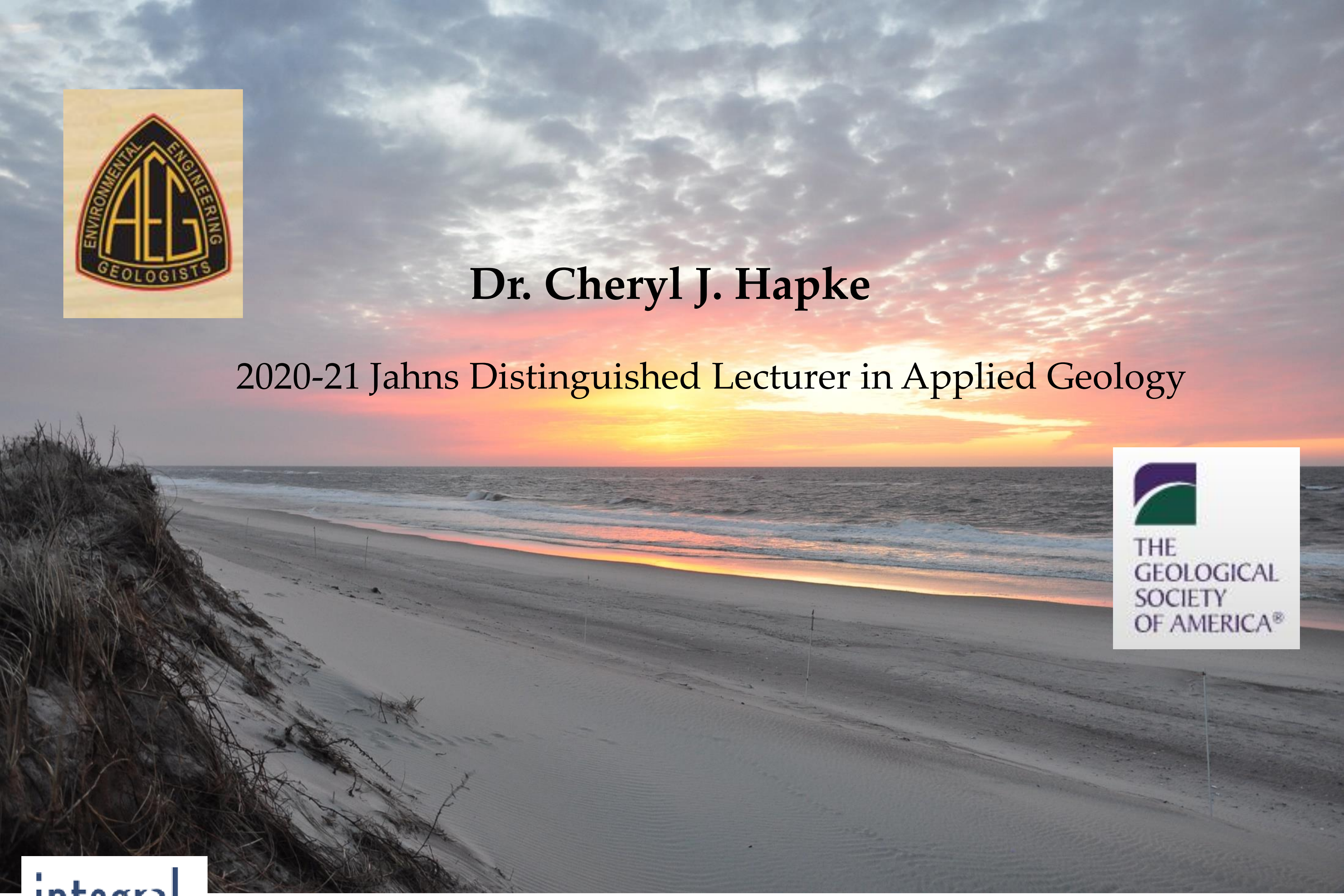

Dr. Cheryl J. Hapke

2020-21 Jahns Distinguished Lecturer in Applied Geology

Environmental Engineering Geologists

The Geological Society of America®

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University of South Florida College of Marine Science

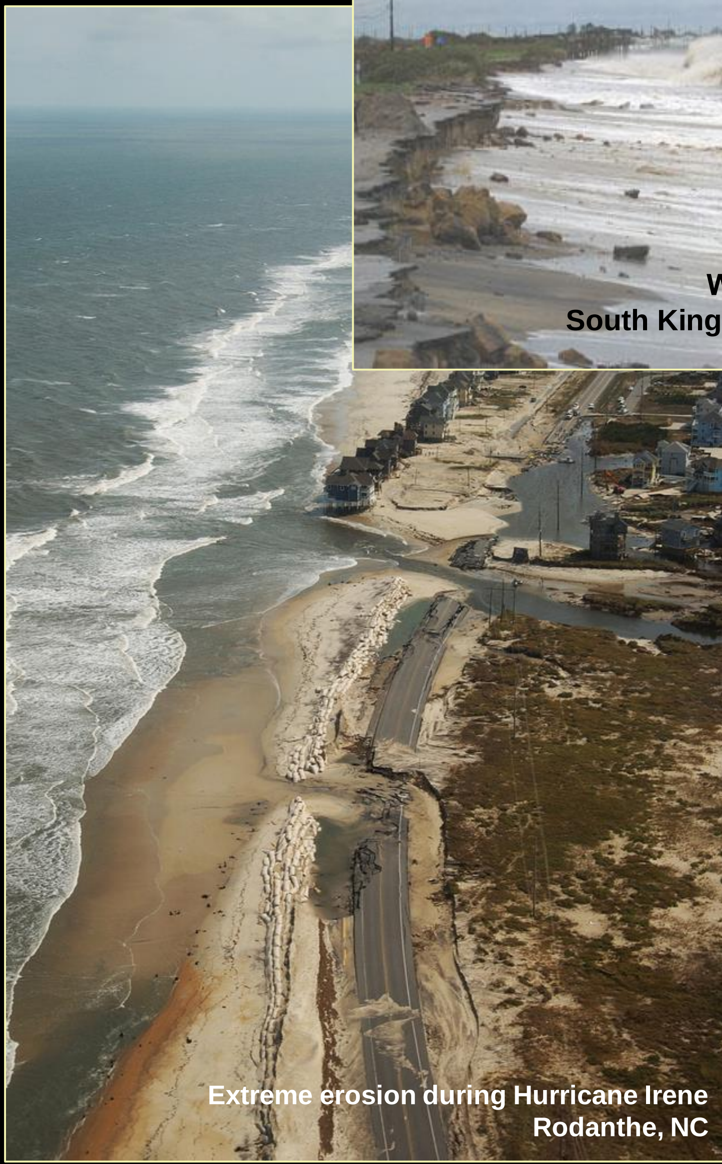
Human Influence on Large-scale Coastal Behavior: Evidence from the New England and Mid-Atlantic Coasts

Issues in the coastal zone

Coastal Change Hazards

Winter nor’easter
South Kingstown Beach, RI

Long-term cliff erosion
Pacifica, CA



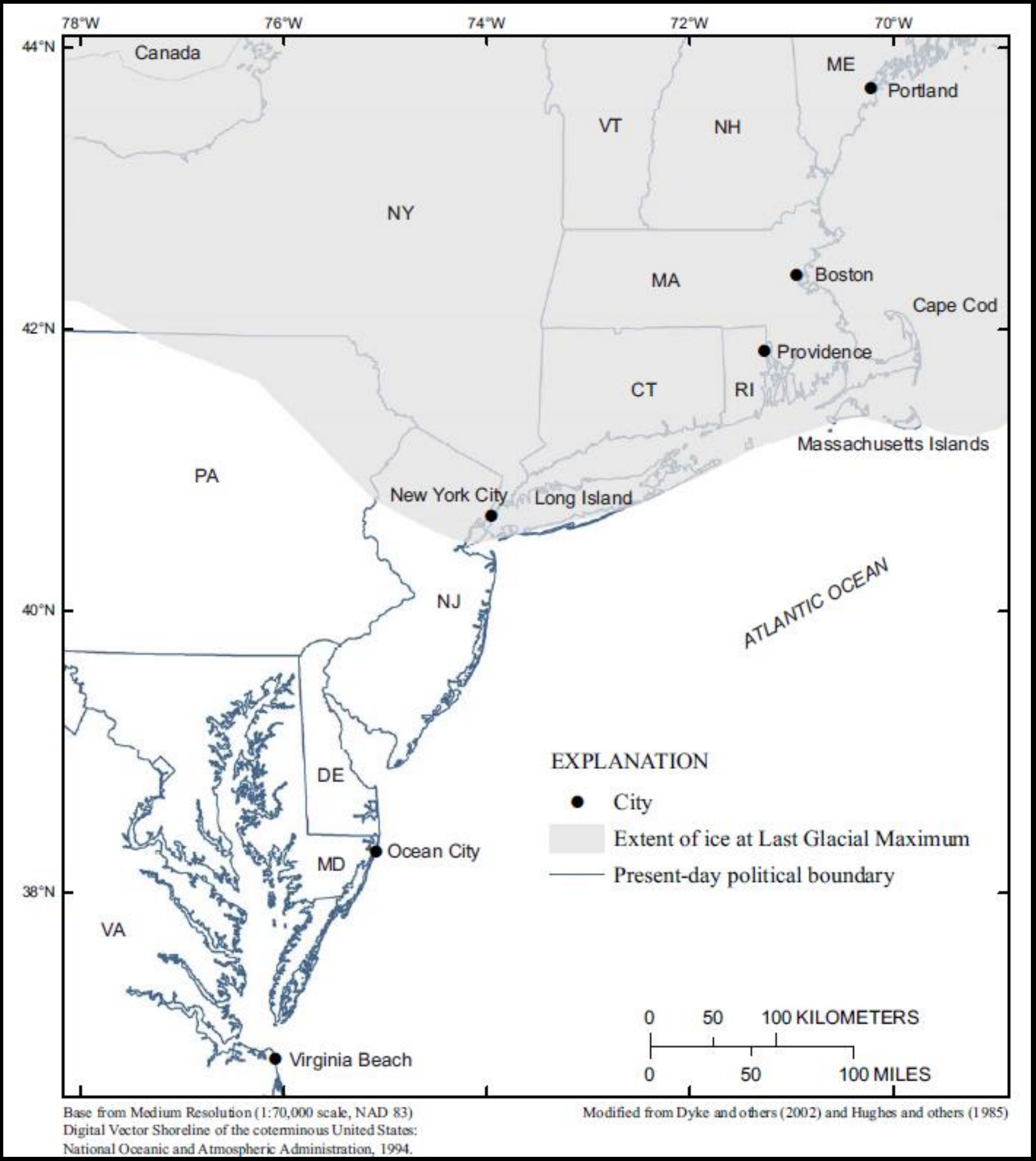
Extreme erosion during Hurricane Irene
Rodanthe, NC

Goal: Identify, quantify, and model the vulnerability of the U.S. shorelines to coastal change hazards

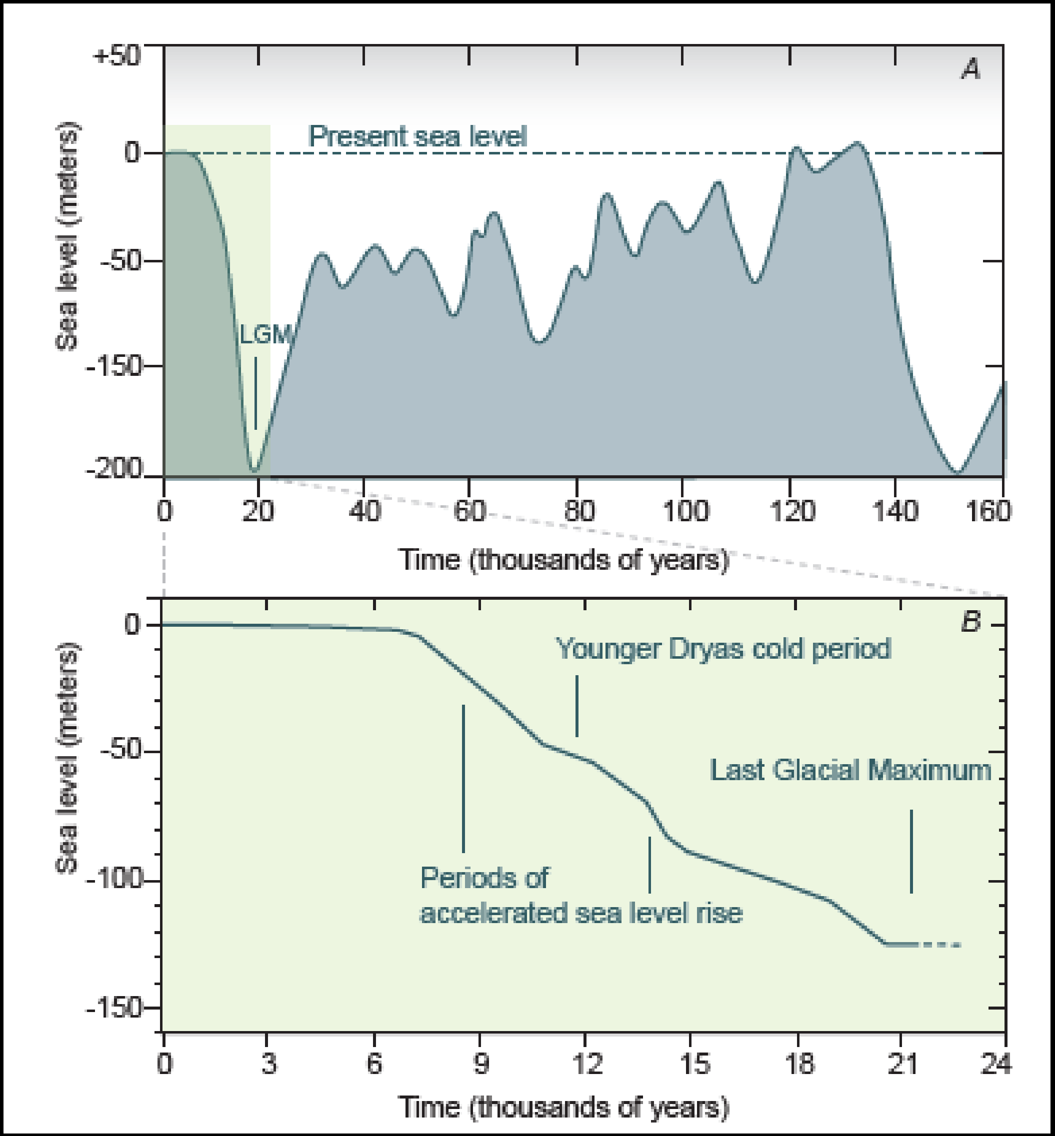
Ongoing Tasks

- Impacts of severe storms & hurricanes
- Long-term shoreline change
- Coastal vulnerability to sea level rise

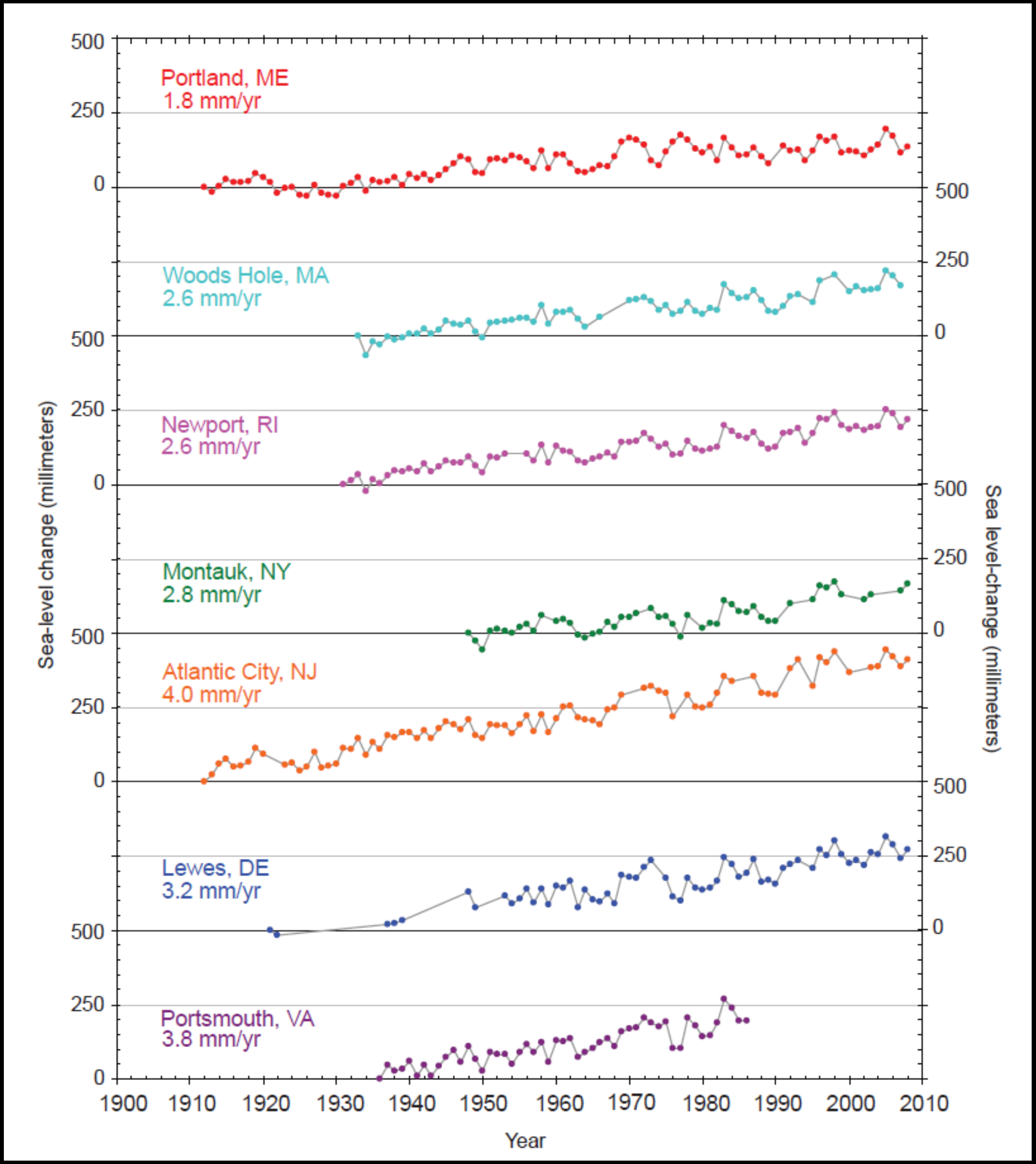
Physiographic/Geologic Settings



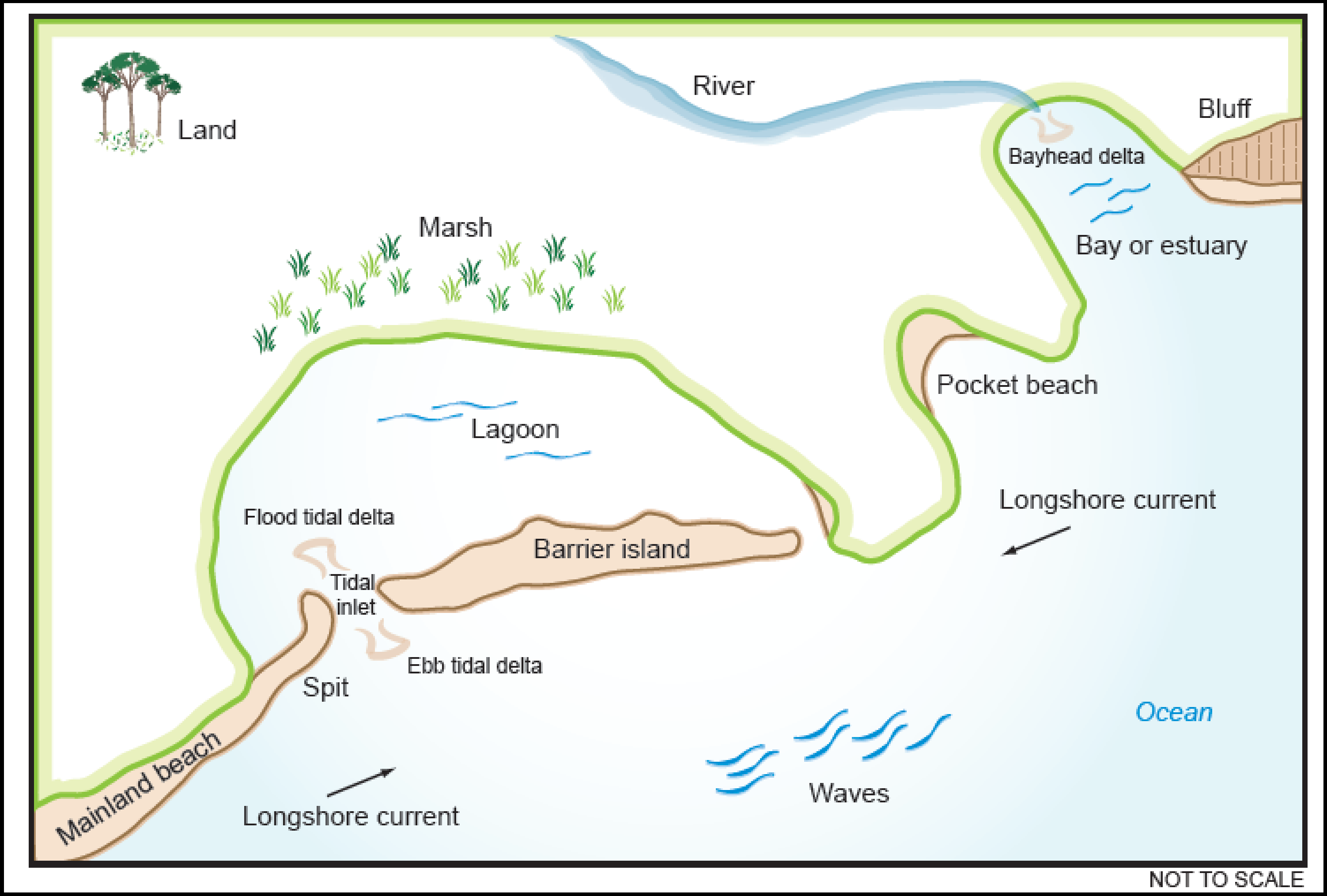
Long-term Sea Level Rise



Short-term Sea Level Rise



Coastal Landforms



Rocky coasts

- headlands
- pocket beaches

Maine
South shore MA and RI

Bluffed- backed coasts

Northern MA coast
Martha's Vineyard
Montauk

Linear barrier beaches

Mainland Beach

W. RI
E. Long Island
Various portions of Mid-Atlantic

Objectives

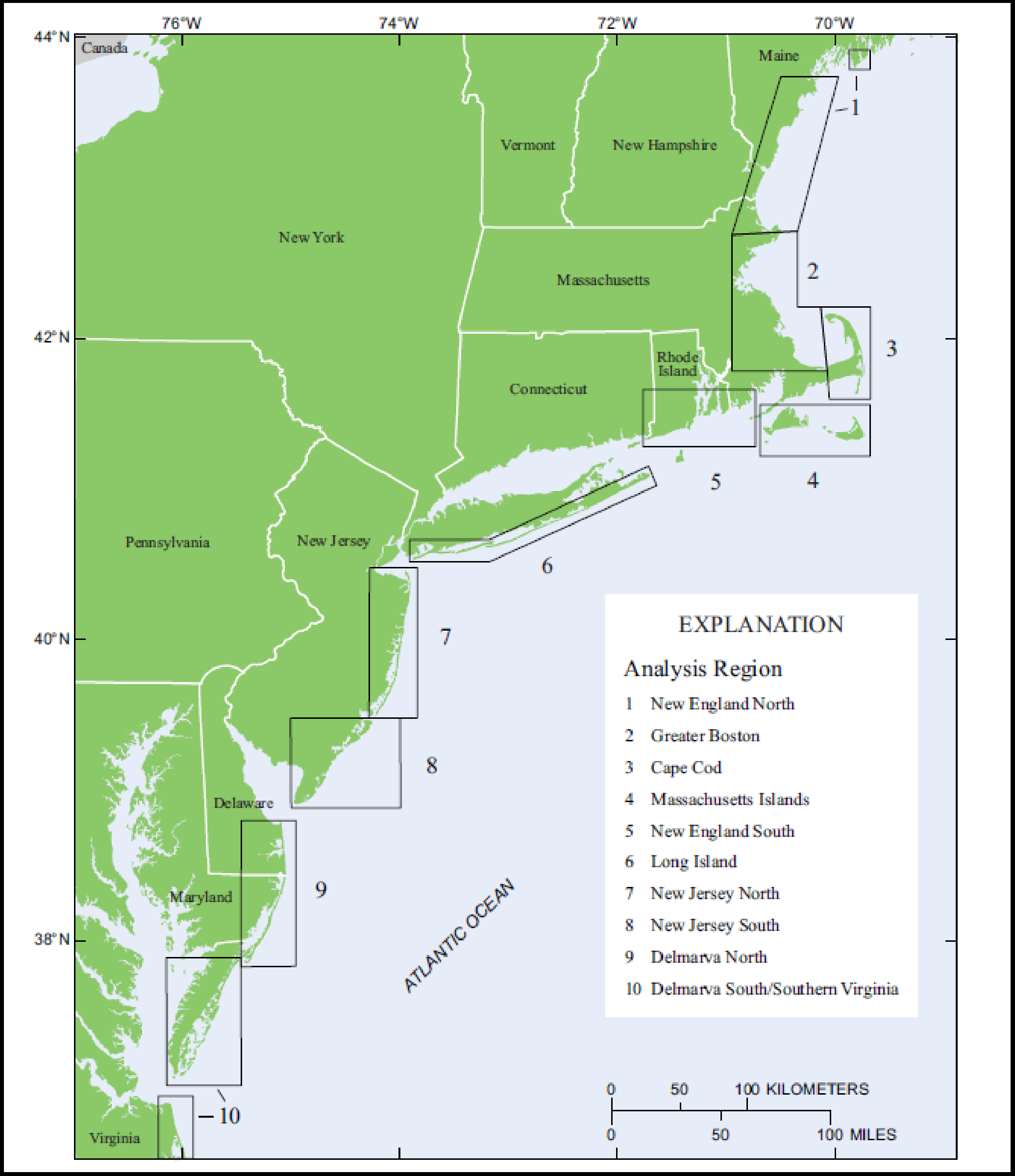
- **Measure long-term (~150 yrs) and short-term (~25-30 yrs) shoreline change**

- **On a large-scale (100s to 1000s of kilometers) what influences variation of rates?**
  - **Geomorphology**
  - **Geology**
  - **Sediment supply**
  - **Hydrodynamics**
  - **Human Activities**

- **How do rates of change vary as a function of coastal landform type?**
  - **rocky coast, beaches fronting bluffs, mainland beaches and barrier islands**

- **What is the influence of human activities on regional change rates?**
  - **jetties**
  - **level of development**
    - **sparse, moderate, heavy, dense, urban**

10 Subregions



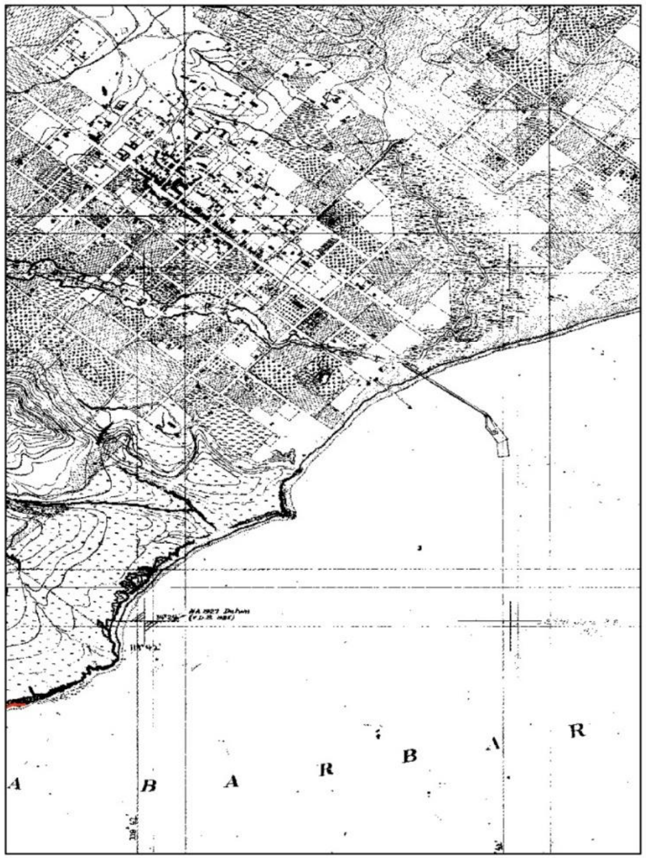
Data and Approach: New England and Mid-Atlantic

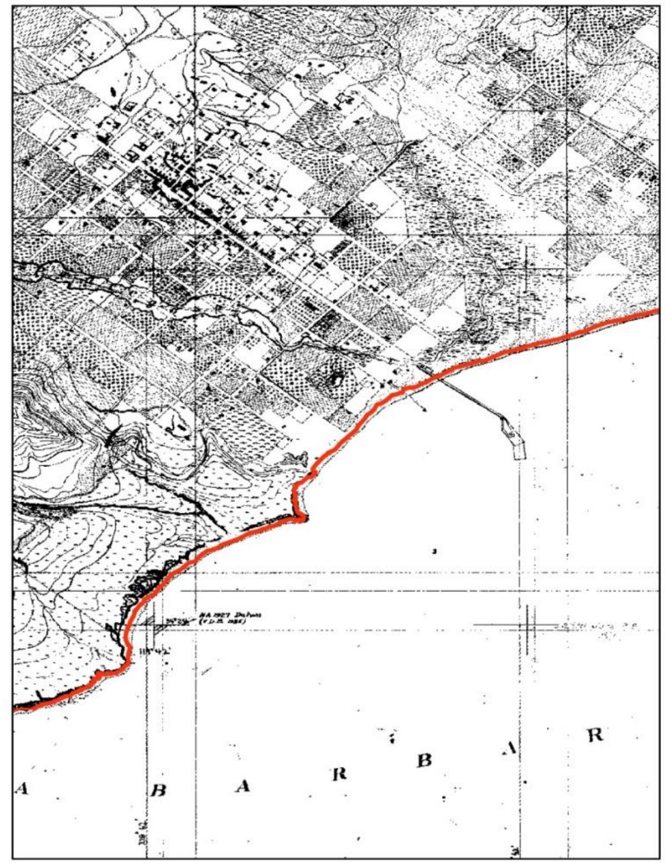
- Maine to VA/NC border
- Mid-1800s to 1960s: NOAA topographic survey maps (t-sheets)
- 1960s to 1990s: aerial photographs
- 1997/2000: lidar (light detection and ranging)
- Number of shorelines ranges from 2 to 55

- Coastal change rates calculated for long-term (~150 yr) and shorter-term (~25-30 yr)
- Over 21,000 measurements at 50 m intervals along the coast

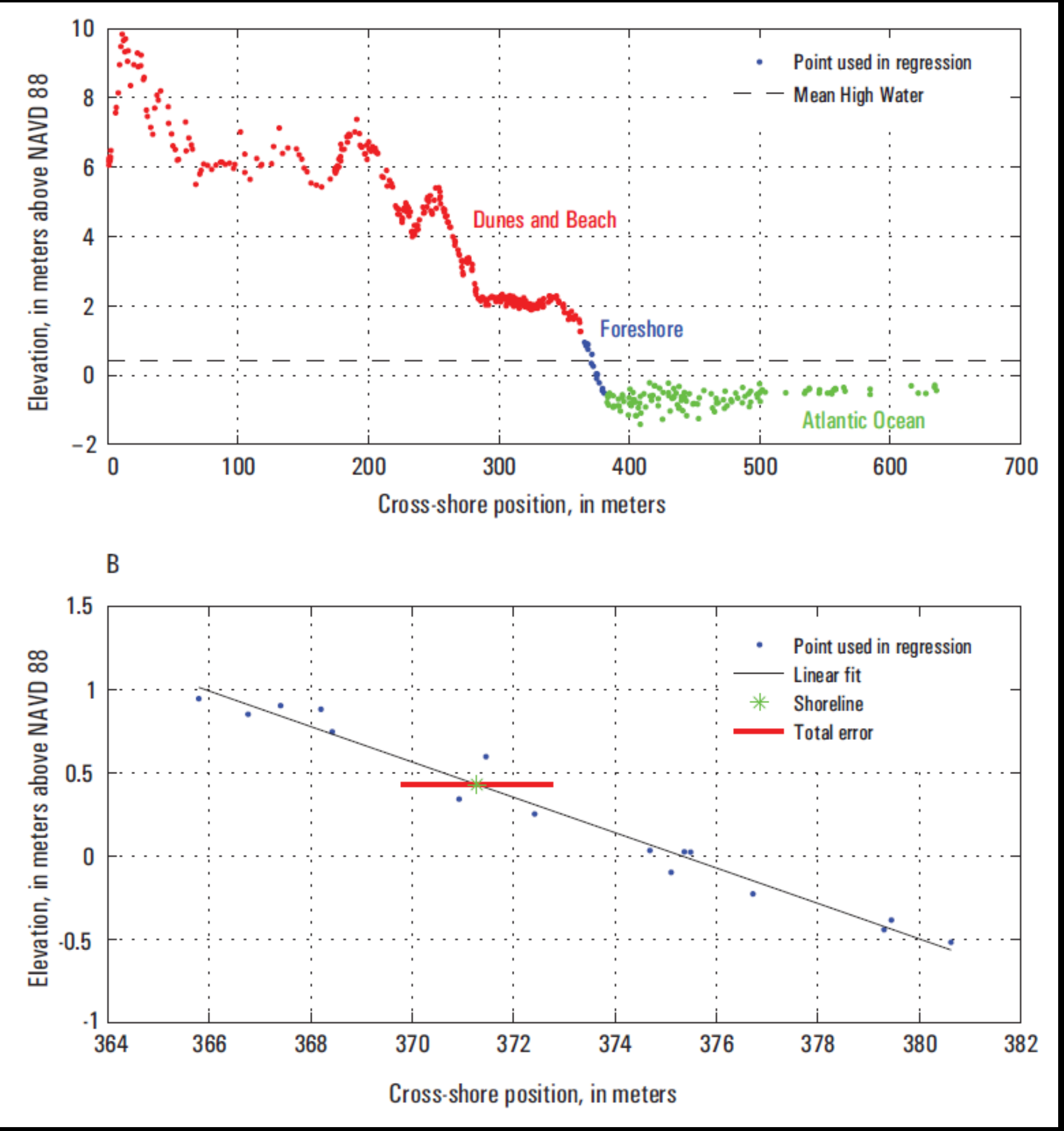
Hapke et al., 2011

T-sheet Shoreline

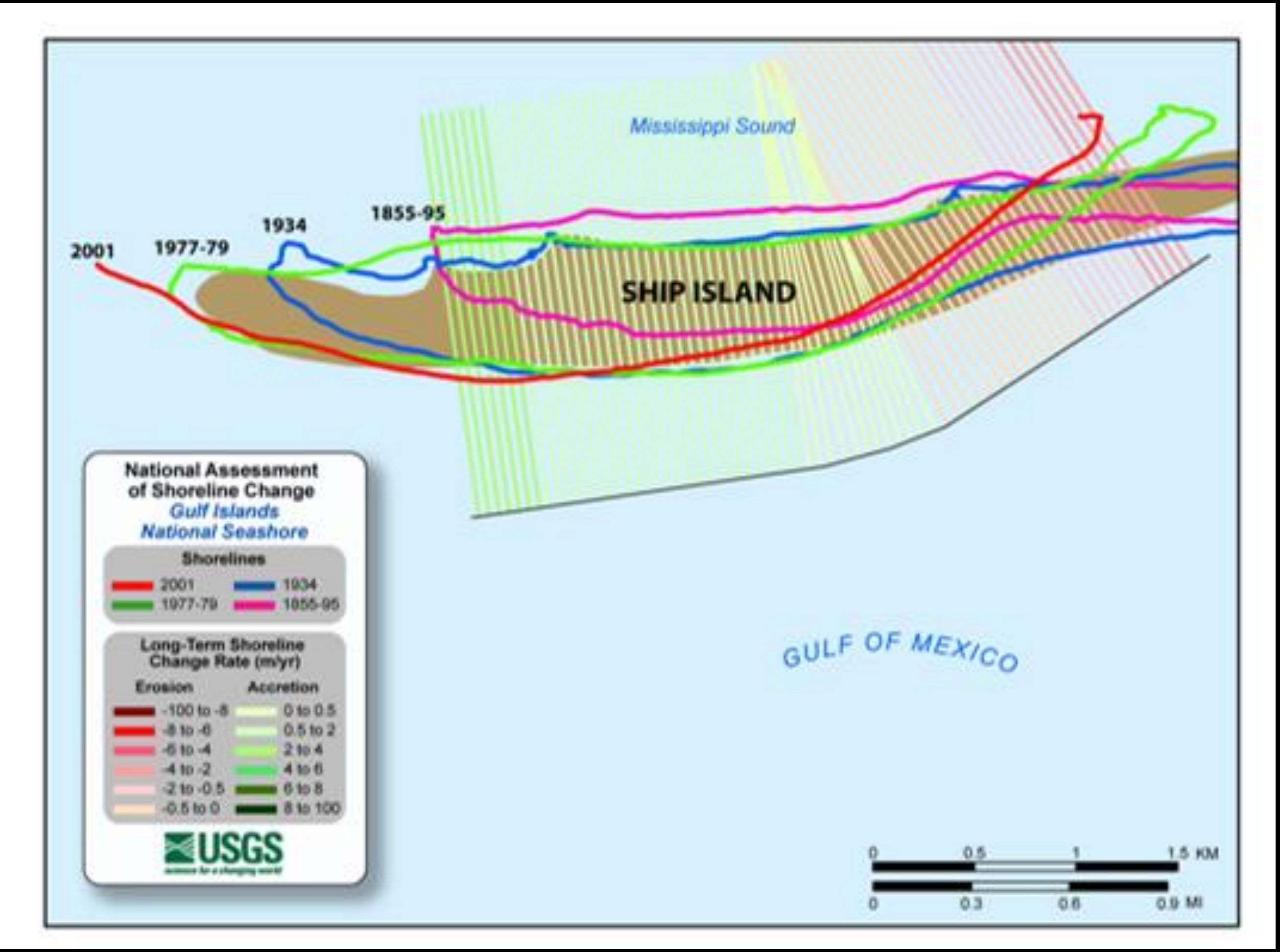




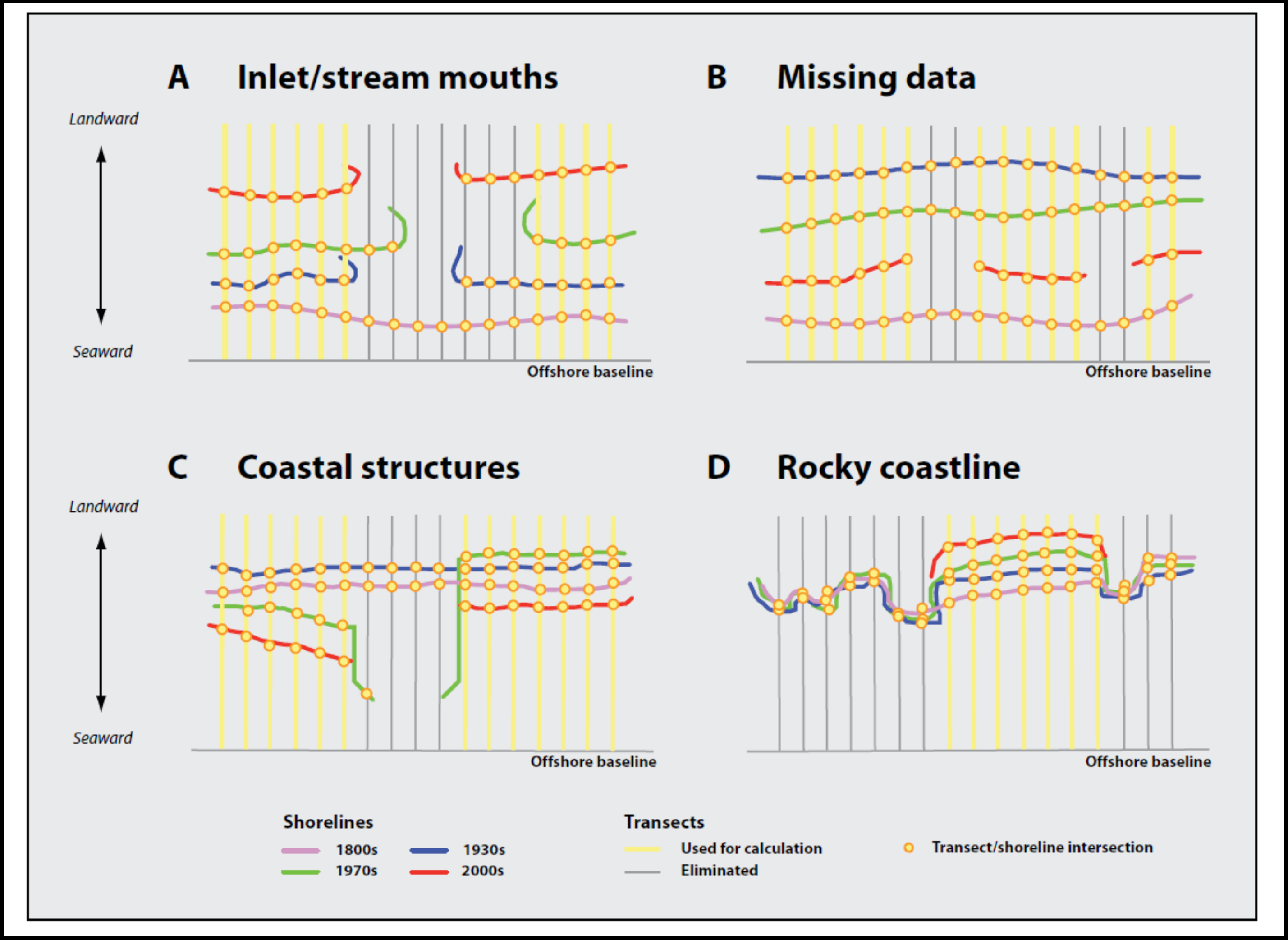
Lidar Data Shoreline Extraction



Shoreline Change Rate Calculations - DSAS



Data Gaps/Issues

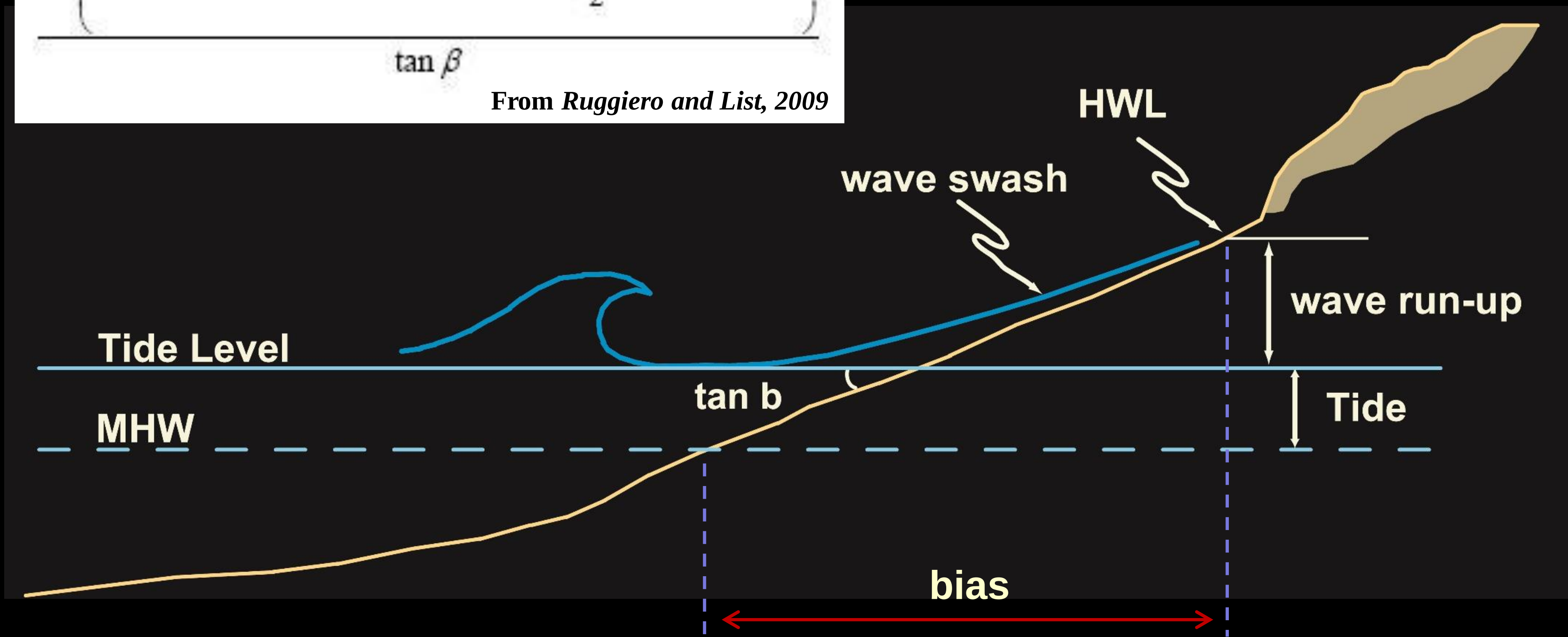


Proxy Datum Bias: MHW (lidar) vs. HWL (maps, photos, field)

$$Bias = (X_{HWL} - X_{MHW})_{offset} =$$

$$\frac{1.1\left(0.35\tan\beta(H_oL_o)^{(1/2)} + \frac{\left[H_oL_o(0.563\tan\beta^2 + 0.004\right]^{1/2}}{2}\right)}{\tan\beta}$$

From *Ruggiero and List, 2009*



Proxy bias and DSAS

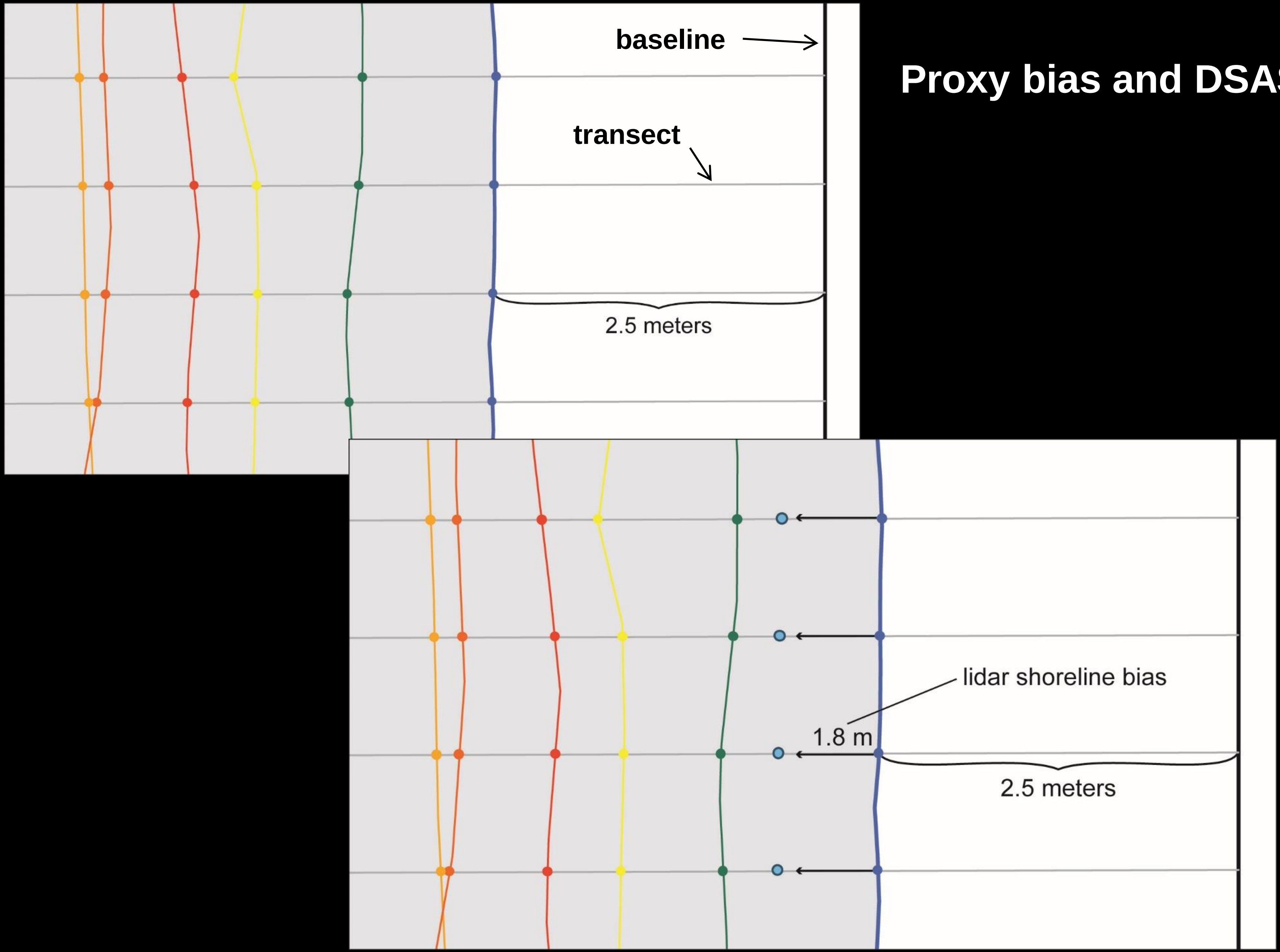
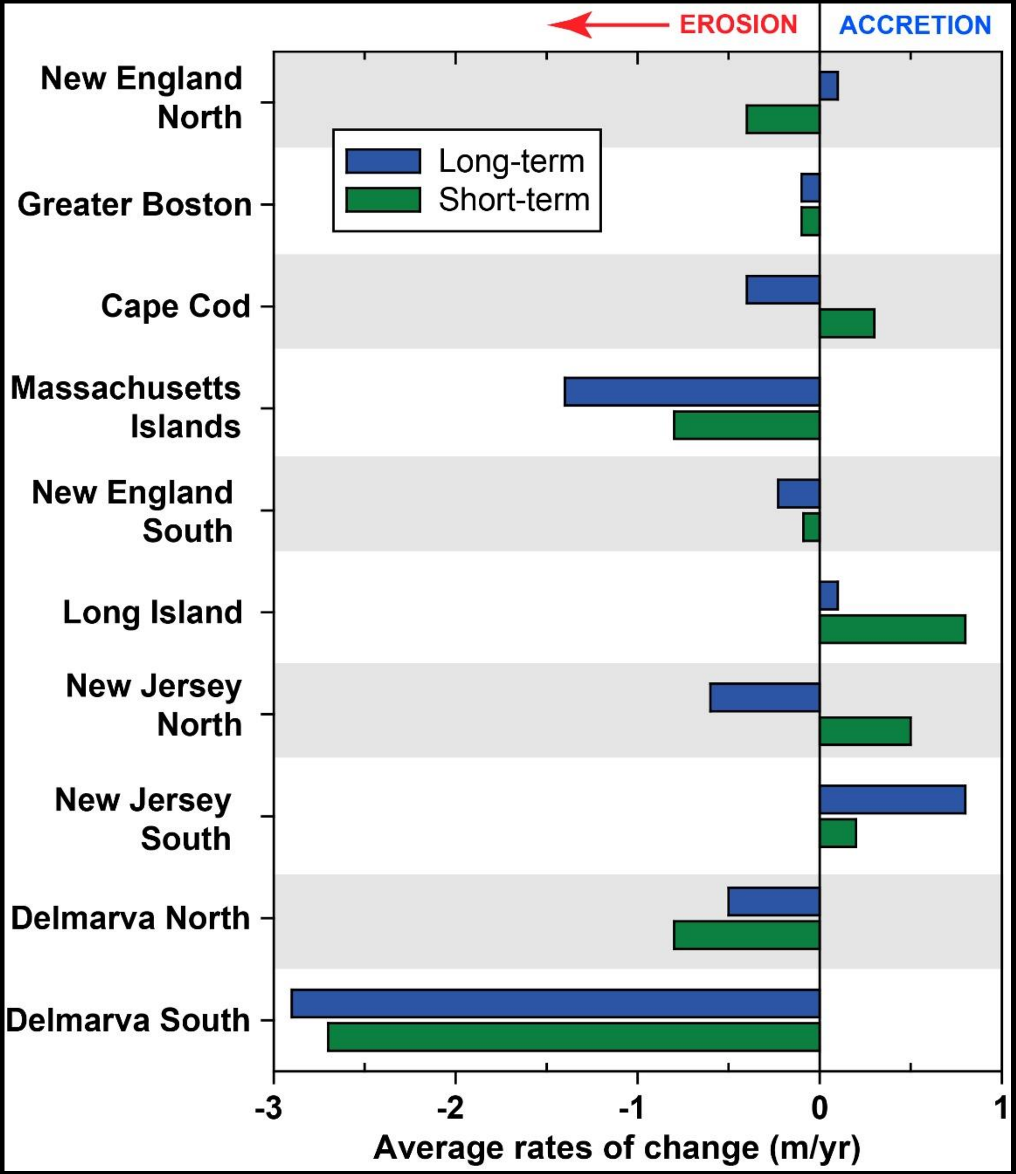
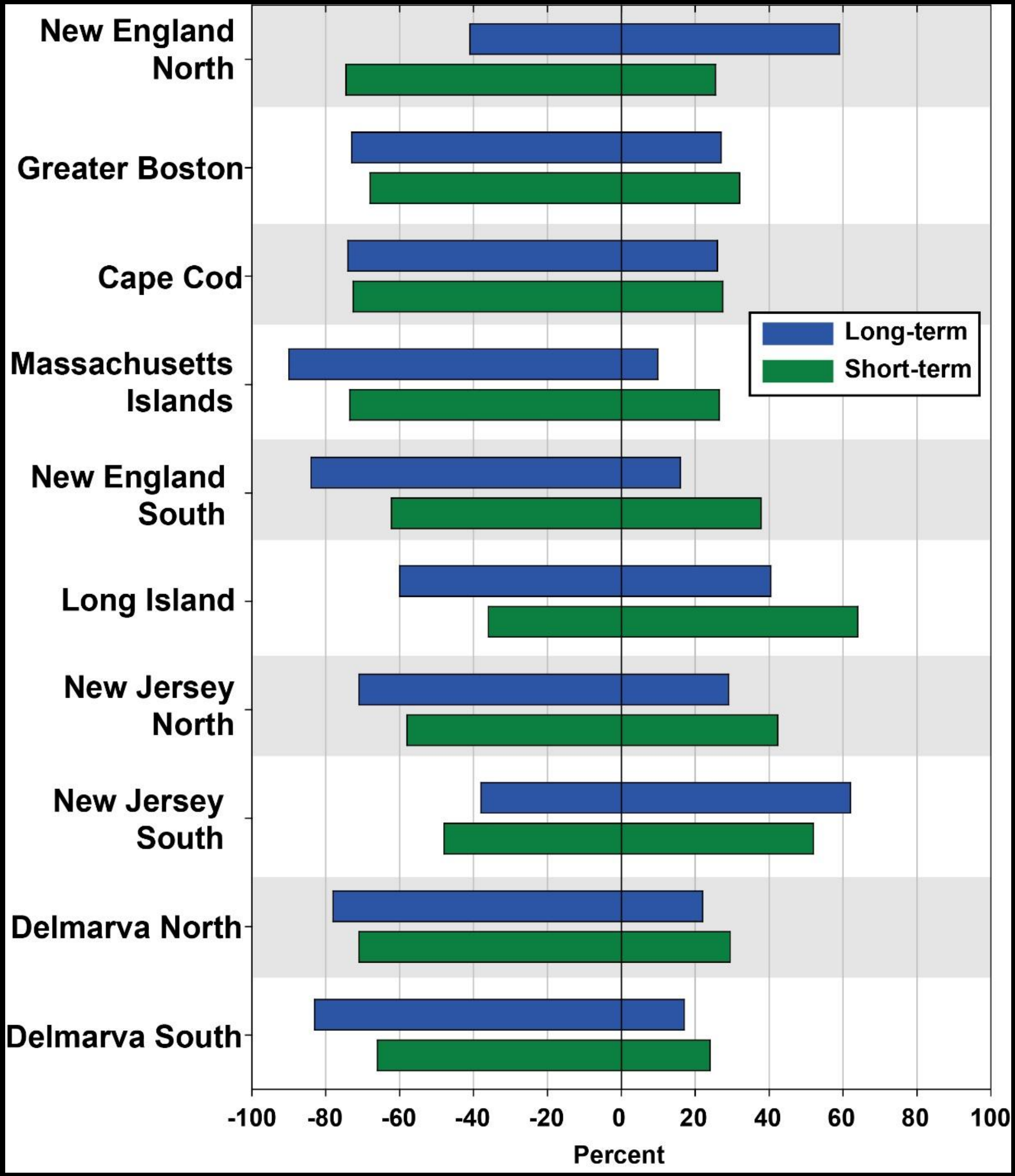


TABLE 1: Rate statistics for the shoreline change analysis

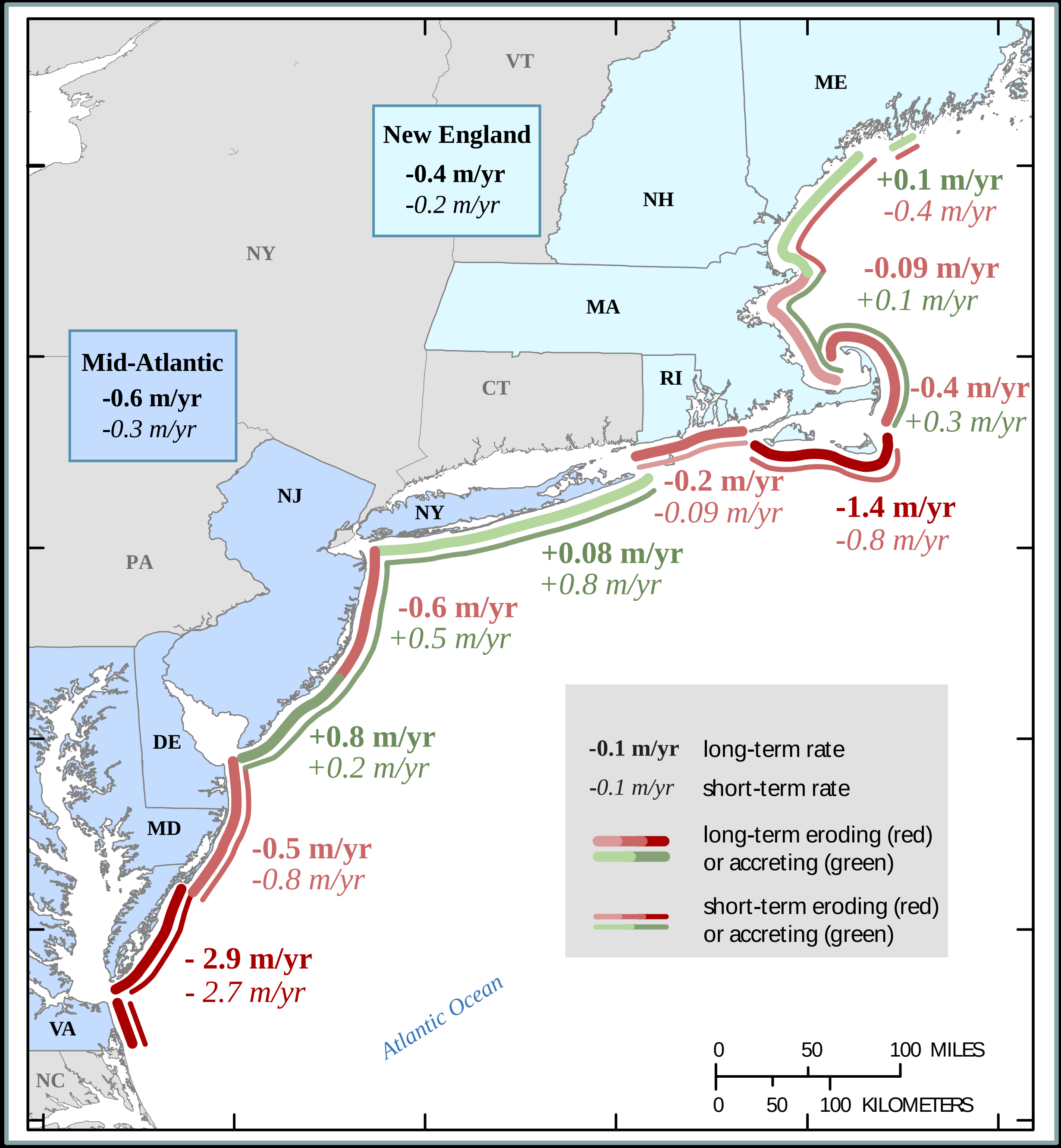
	Region	Long-term average rate (m/yr)	Long-term percent eroding	Long-term erosion rate (m/yr)	Short-term average rate (m/yr)	Short-term percent eroding	Short-term erosion rate (m/yr)
New England	New England North	0.1 ± 0.05	41	-0.2 ± 0.05	-0.4 ± 0.1	75	-0.9 ± 0.1
	Greater Boston	-0.09 ± 0.03	73	-0.2 ± 0.03	0.1 ± 0.06	68	-0.6 ± 0.06
	Cape Cod	-0.4 ± 0.5	74	-1.1 ± 0.5	0.3 ± 0.09	73	-2.9 ± 0.09
	Massachusetts Islands	-1.4 ± 0.09	90	-1.6 ± 0.09	-0.8 ± 0.1	74	-1.7 ± 0.1
	New England South	-0.2 ± 0.03	84	-0.3 ± 0.03	-0.09 ± 0.1	62	-0.4 ± 0.1
Mid-Atlantic	Long Island	0.08 ± 0.2	60	-0.6 ± 0.2	0.8 ± 0.09	36	-1.0 ± 0.09
	New Jersey North	-0.6 ± 0.2	71	-1.1 ± 0.2	0.5 ± 0.06	58	-0.9 ± 0.06
	New Jersey South	0.8 ± 0.3	38	-1.0 ± 0.3	0.2 ± 0.1	48	-2.2 ± 0.1
	Delmarva North	-0.5 ± 0.2	78	-1.2 ± 0.2	-0.8 ± 0.04	71	-2.1 ± 0.04
	Delmarva South/Southern Virginia	-2.9 ± 0.5	83	-3.7 ± 0.5	-2.7 ± 0.1	66	-5.6 ± 0.1
	New England totals	-0.4 ± 0.1	71	-0.5 ± 0.1	-0.2 ± 0.09	70	-2.5 ± 0.09
	Mid-Atlantic totals	-0.6 ± 0.1	67	-2.2 ± 0.1	-0.3 ± 0.1	54	-2.1 ± 0.1
	Regional totals	-0.5 ± 0.09	68	-1.4 ± 0.09	-0.3 ± 0.1	60	-1.5 ± 0.1



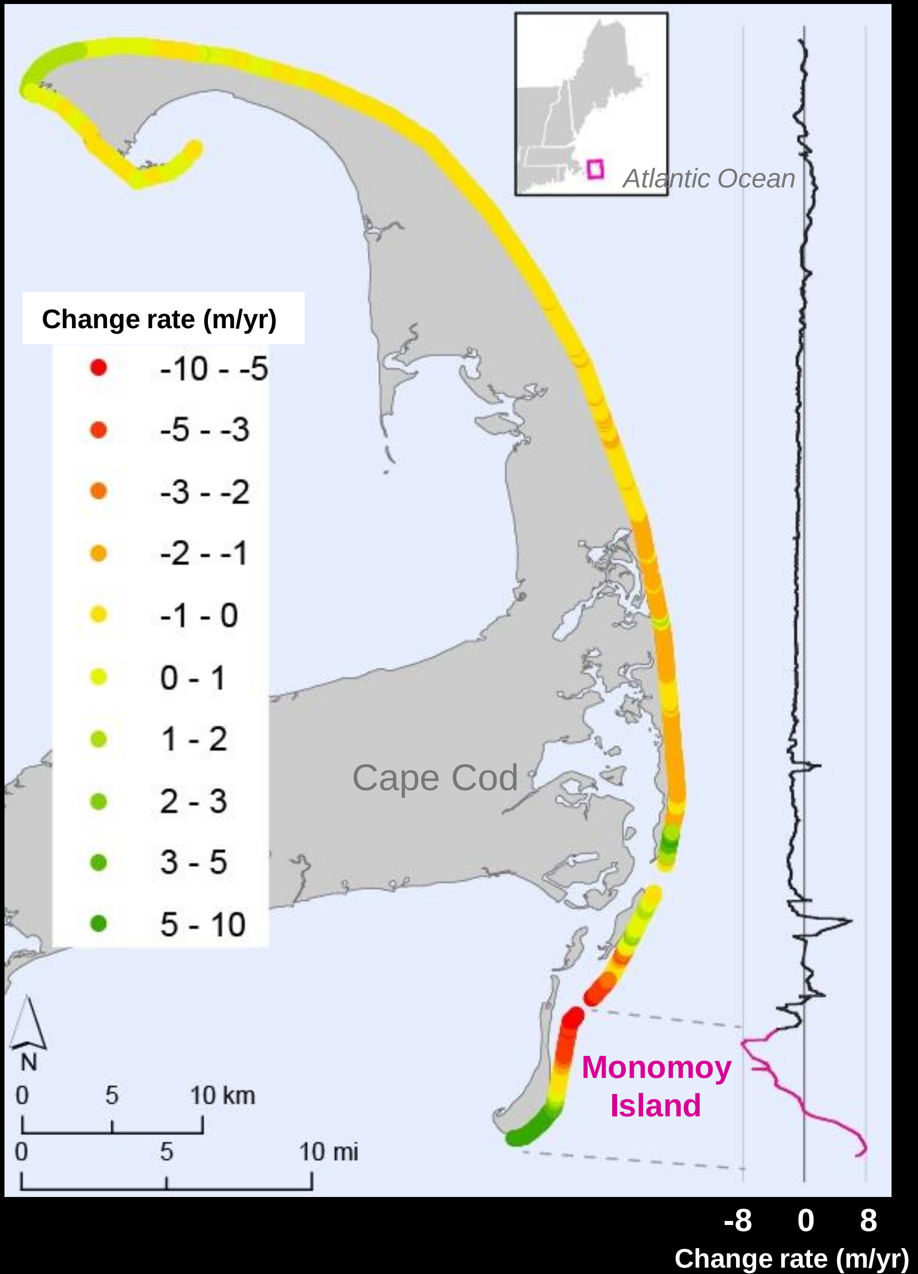
EROSION
ACCRETION
New England North
Greater Boston
Cape Cod
Massachusetts Islands
New England South
Long Island
New Jersey North
New Jersey South
Delmarva North
Delmarva South
Long-term
Short-term
-3
-2
-1
0
1
Average rates of change (m/yr)

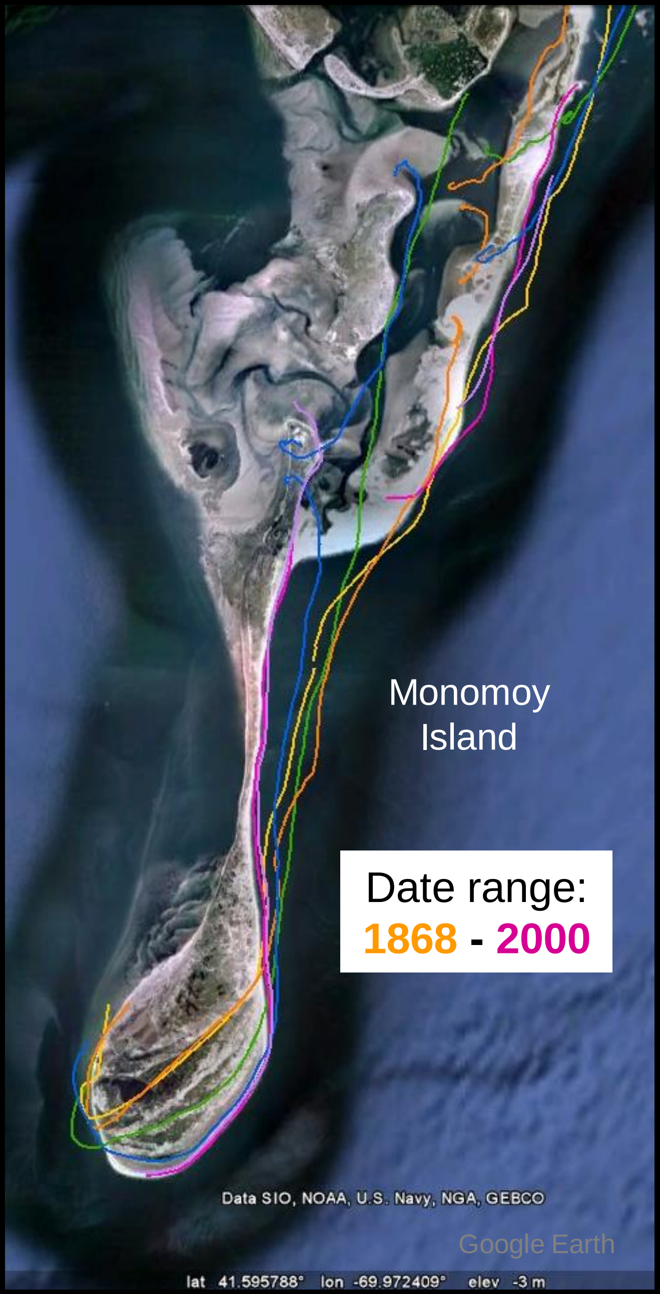


New England North
Greater Boston
Cape Cod
Massachusetts Islands
New England South
Long Island
New Jersey North
New Jersey South
Delmarva North
Delmarva South
Long-term
Short-term
-100
-80
-60
-40
-20
0
20
40
60
80
100
Percent

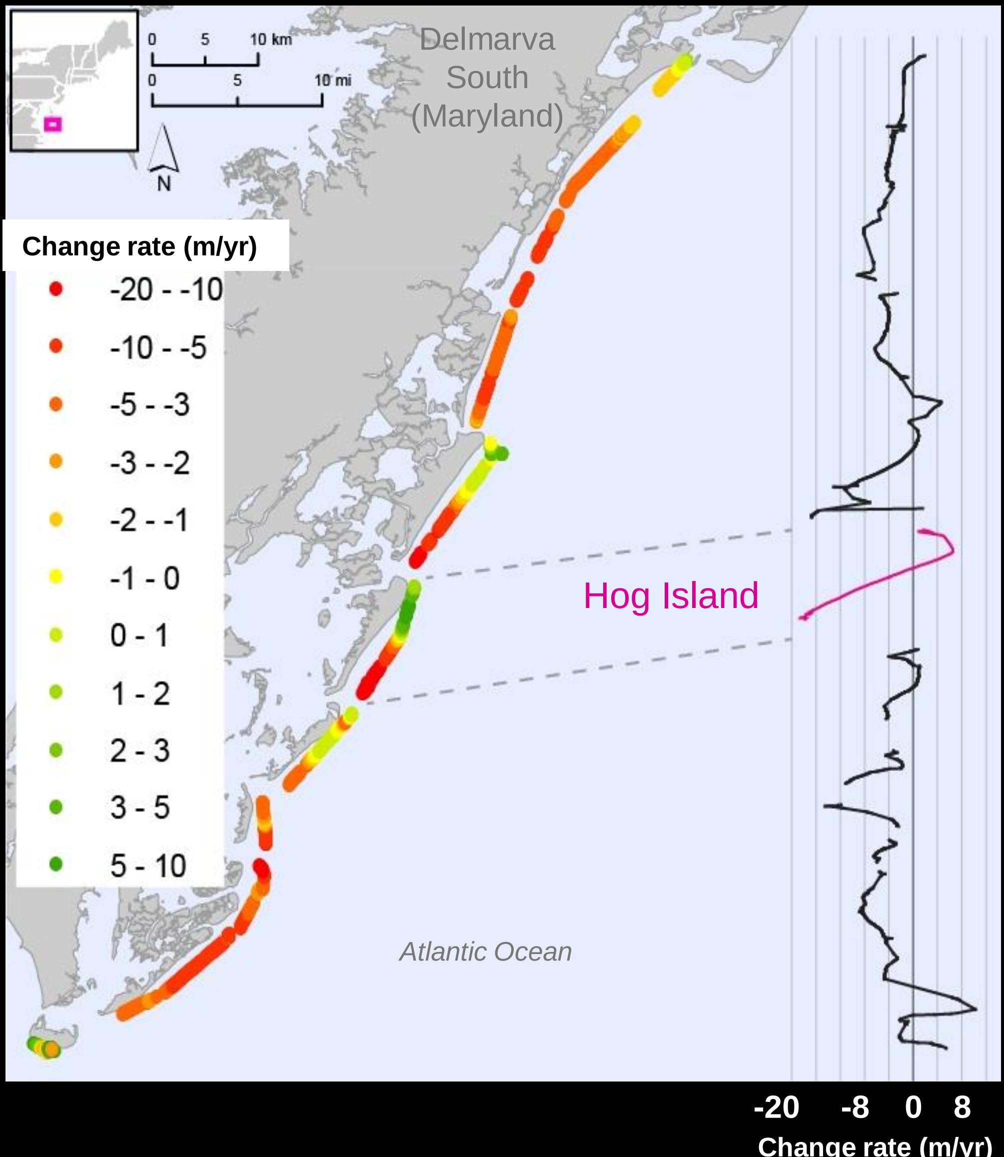

New England
-0.4 m/yr
-0.2 m/yr
Mid-Atlantic
-0.6 m/yr
-0.3 m/yr
VT
ME
NH
NY
MA
CT
RI
NJ
PA
DE
MD
VA
NC
+0.1 m/yr
-0.4 m/yr
-0.09 m/yr
+0.1 m/yr
-0.4 m/yr
+0.3 m/yr
-0.2 m/yr
-0.09 m/yr
-1.4 m/yr
-0.8 m/yr
+0.08 m/yr
+0.8 m/yr
-0.6 m/yr
+0.5 m/yr
+0.8 m/yr
+0.2 m/yr
-0.5 m/yr
-0.8 m/yr
- 2.9 m/yr
- 2.7 m/yr
Atlantic Ocean
-0.1 m/yr long-term rate
-0.1 m/yr short-term rate
long-term eroding (red) or accreting (green)
short-term eroding (red) or accreting (green)
0 50 100 MILES
0 50 100 KILOMETERS

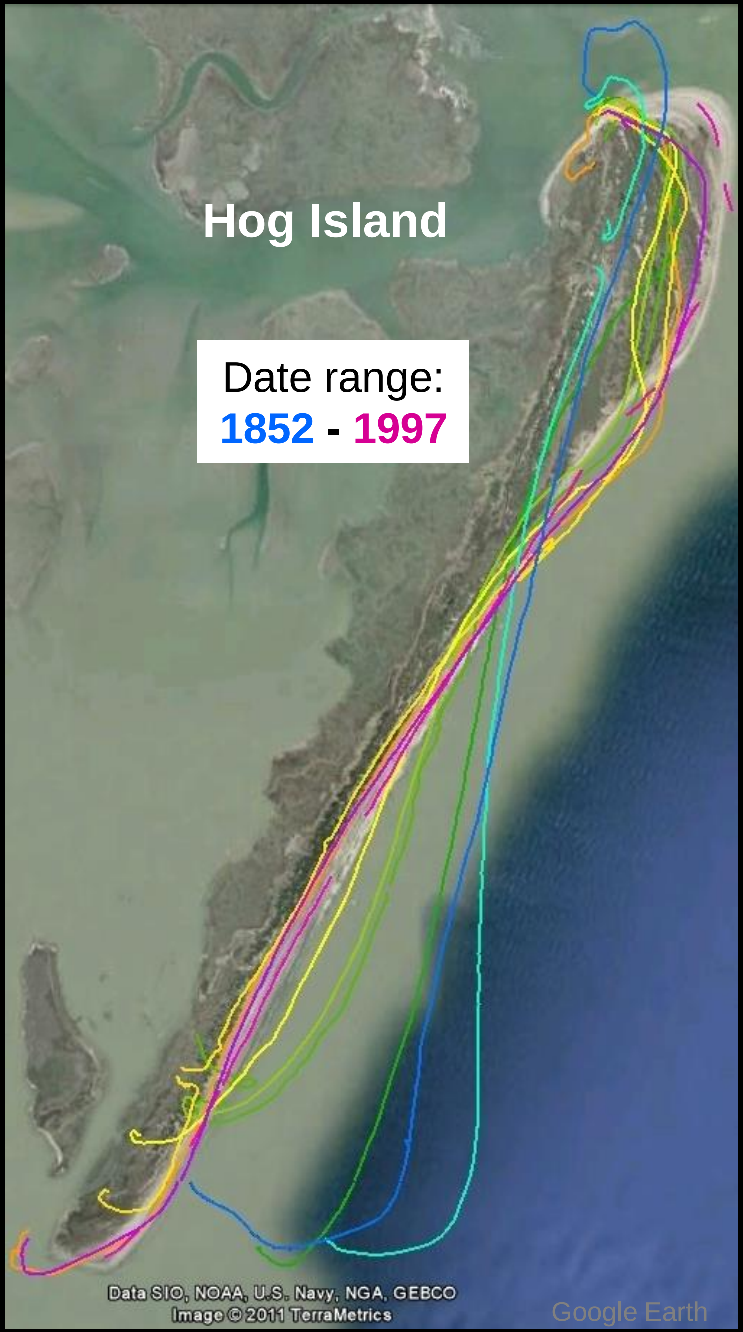
Long-term shoreline change on Monomoy Island NWR, Cape Cod





Long-term shoreline change on Hog Island, Virginia





Key Findings – Regional Shoreline Change

- Long-term coastal change rates calculated for 1,360 km of the New England and Mid-Atlantic coasts:
  - 68% of coast is eroding
  - Average rate of change = -0.5 m/yr

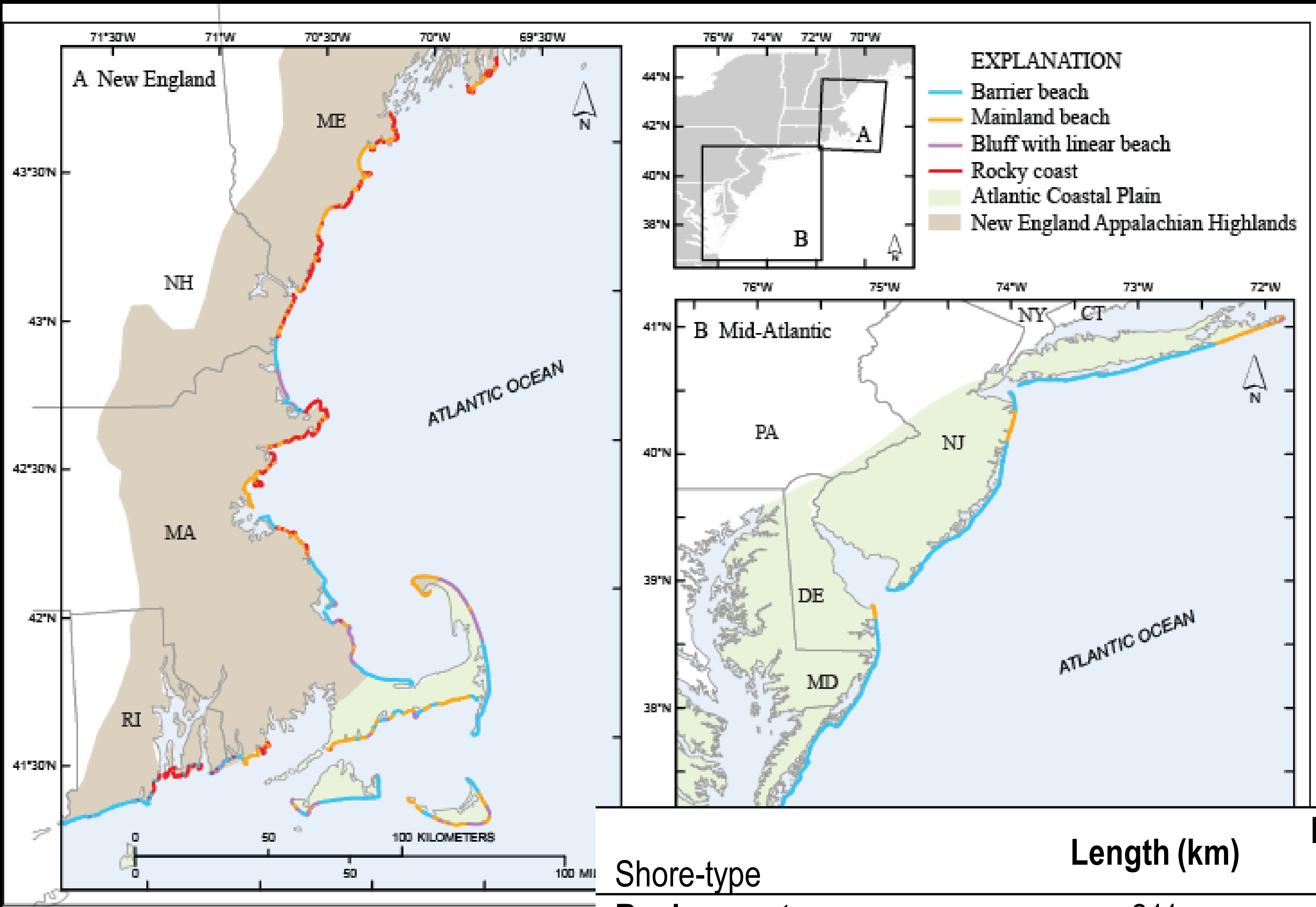
- Portions of the coast that are more heavily engineered have lower rates of erosion, especially in the past 25-30 years

  → Can this trend continue?

Next Up

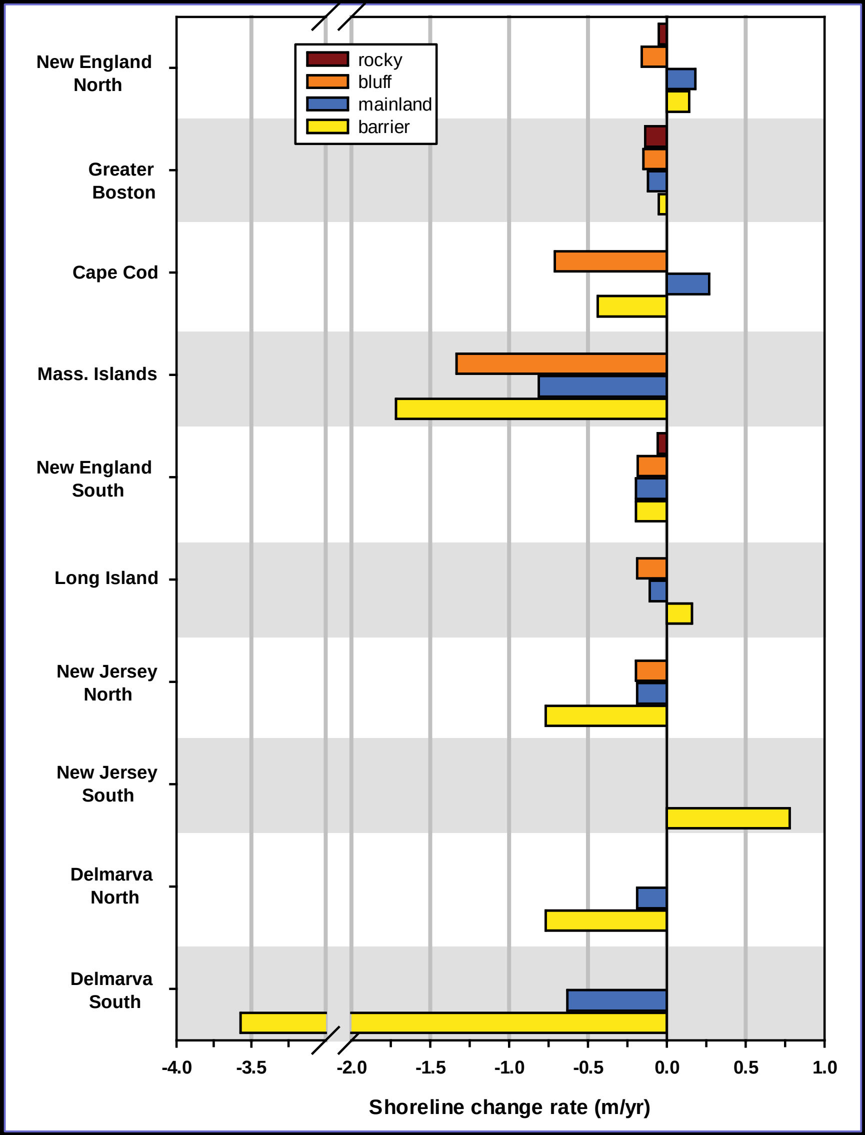
- Characterize Geomorphology of entire coast
  - Rocky
  - Bluff
  - Barrier Island
  - Mainland coast

- Characterize amount of development: sparse, moderate, dense, heavy, urban



Shore-type	Length (km)	Percent of total length
Rocky coast	211	15
Bluffs with linear beaches	104	7
Mainland beaches	340	23
Barrier beaches	805	55
Total length of coast	1460	100
Structures present	384	26

Rate Distribution per Landform Type



Geomorphic Type	Percent of coast	Long-term percent eroding	Long-term average rate (m/yr)
New England			
Rocky	5	69	-0.09
Bluff-backed	22	88	-0.69
Mainland	24	48	0.07
Barrier	49	74	-0.51
Mid-Atlantic			
Rocky	--	--	--
Bluff-backed	1	94	-0.19
Mainland	19	69	-0.40
Barrier	80	66	-0.70
Region Totals			
Rocky	2	69	-0.09
Bluff-backed	10	92	-0.65
Mainland	21	59	-0.18
Barrier	67	68	-0.64

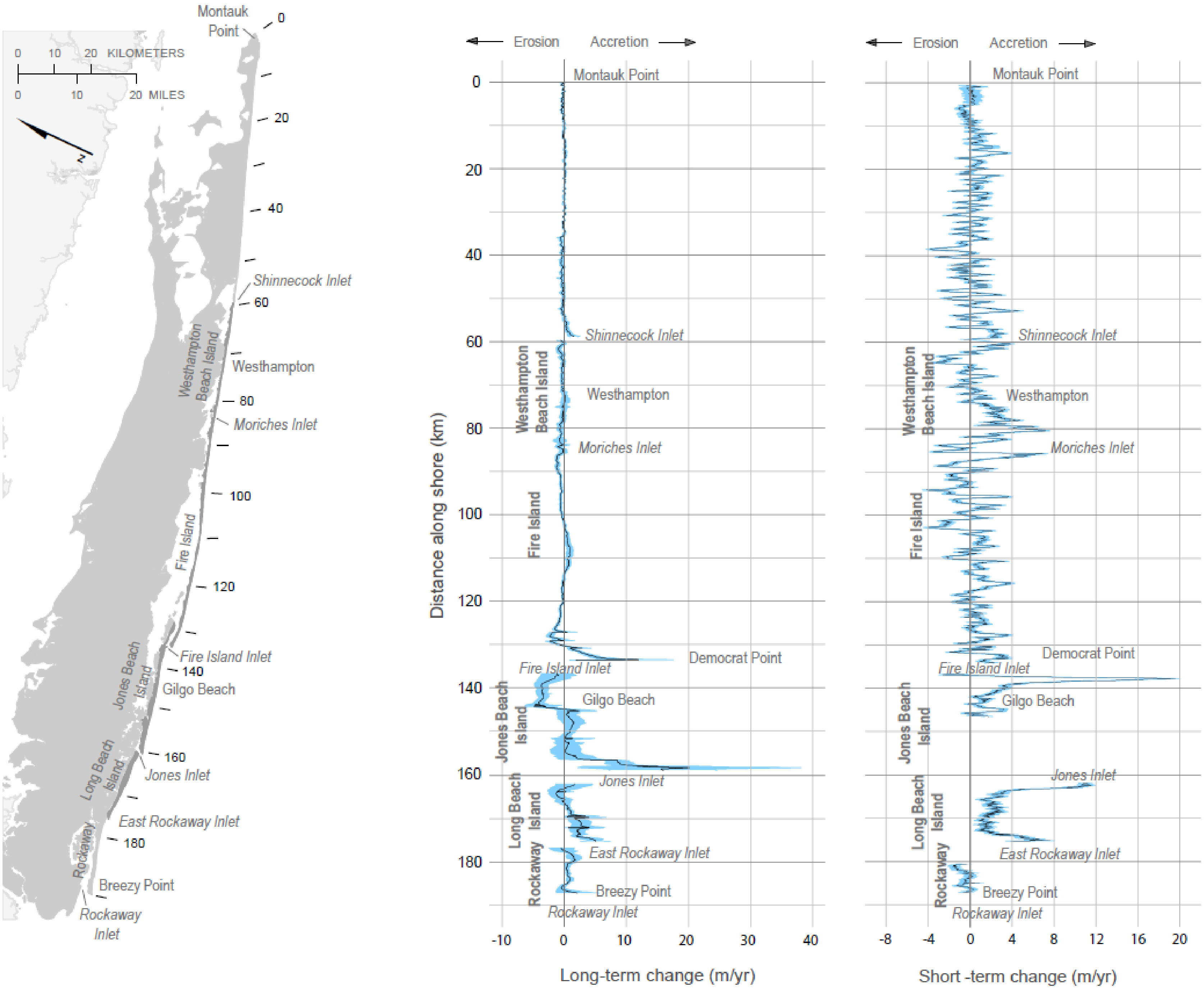
Key Findings – Geomorphic Analysis

- Dominant type of coast influences rates of change
    - New England (rocky coastline): -0.4 m/yr, 71% eroding
    - Mid-Atlantic (barrier beaches): -0.6 m/yr, 67% eroding

- Erosion rates of barrier beaches and bluffed coasts are the same

What are human influences on regional change?

→ Inlets and development


Montauk Point
0 10 20 KILOMETERS
0 10 20 MILES
N
0
20
40
Shinnecock Inlet
60
Westhampton Beach Island
Westhampton
80
Moriches Inlet
100
Fire Island
120
Fire Island Inlet
140
Gilgo Beach
Jones Beach Island
160
Jones Inlet
Long Beach Island
East Rockaway Inlet
180
Rockaway
Breezy Point
Rockaway Inlet
Erosion
Accretion
Distance along shore (km)
Democrat Point
Long-term change (m/yr)
-10
0
10
20
30
40
Short -term change (m/yr)
-8
-4
0
4
8
12
16
20

Influence of Engineered Inlets

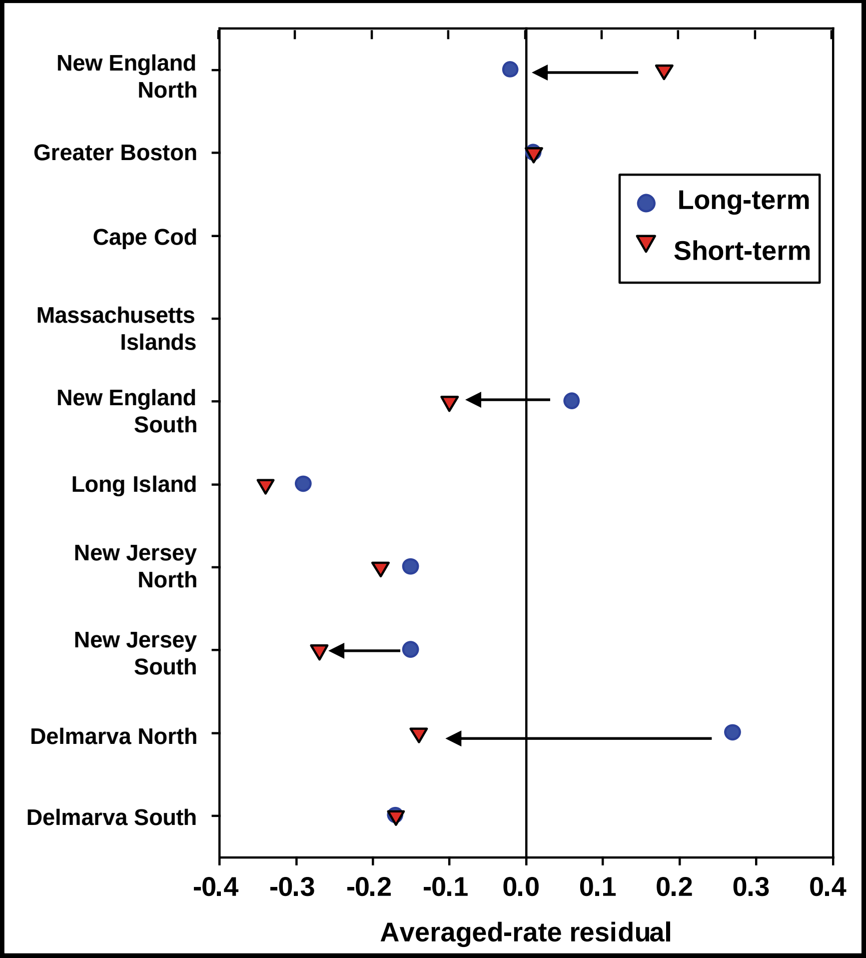
$$R = |\mu_j - \mu_r|$$

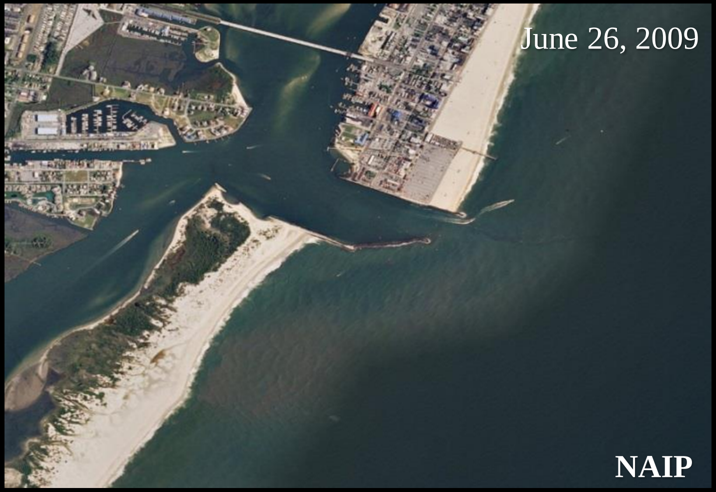
μ_j = averaged net rate

μ_r = averaged net rate without transects +/- 4 km of jetty

	Region	Engineered inlets	Long-term μ_j (m/yr)	Long-term μ_r (m/yr)	Long-term R	Short-term μ_j (m/yr)	Short-term μ_r (m/yr)	Short-term R
New England	**New England North**	**5**	**0.1**	**0.08**	**-0.02**	**-0.4**	**-0.22**	**0.18**
New England	**Greater Boston**	**5**	**-0.09**	**-0.09**	**0.01**	**0.1**	**-0.09**	**0.01**
New England	**Cape Cod**	**0**	**-0.4**	**--**	**-**	**0.3**	**--**	**--**
New England	**Massachusetts Islands**	**0**	**-1.4**	**--**	**-**	**-0.81**	**--**	**--**
New England	**New England South**	**4**	**-0.2**	**-0.17**	**0.06**	**-0.09**	**-0.19**	**-0.1**
Mid-Atlantic	**Long Island**	**6**	**0.08**	**-0.19**	**-0.29**	**0.8**	**0.46**	**-0.34**
Mid-Atlantic	**New Jersey North**	**3**	**-0.6**	**-0.75**	**-0.15**	**0.5**	**0.31**	**-0.19**
Mid-Atlantic	**New Jersey South**	**4**	**0.8**	**0.65**	**-0.15**	**0.2**	**-0.07**	**-0.27**
Mid-Atlantic	**Delmarva North**	**2**	**-0.5**	**-0.23**	**0.27**	**-0.8**	**-0.94**	**-0.14**
Mid-Atlantic	**Delmarva South/ Southern Virginia**	**1**	**-2.9**	**-3.07**	**-0.17**	**-2.7**	**-2.87**	**-0.17**

Influence of Engineered Inlets





$$R = |\mu_j - \mu_r|$$

Development Categories

sparse

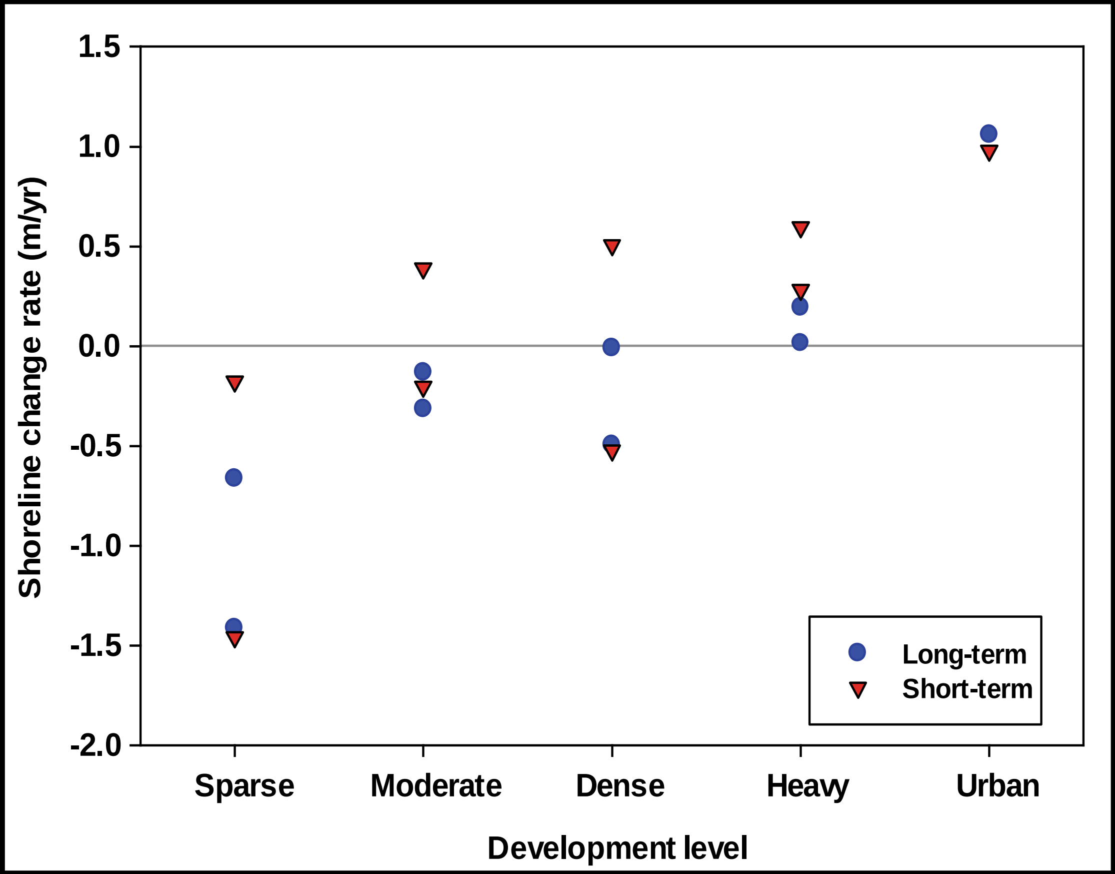
heavy

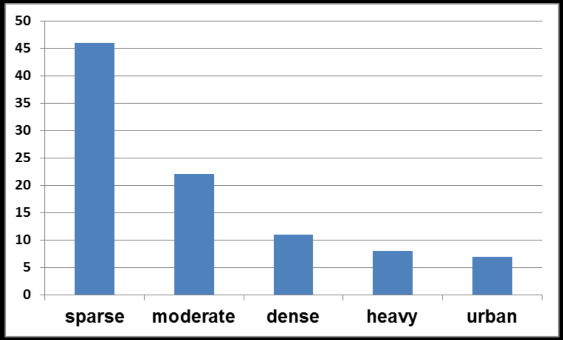
dense

urban

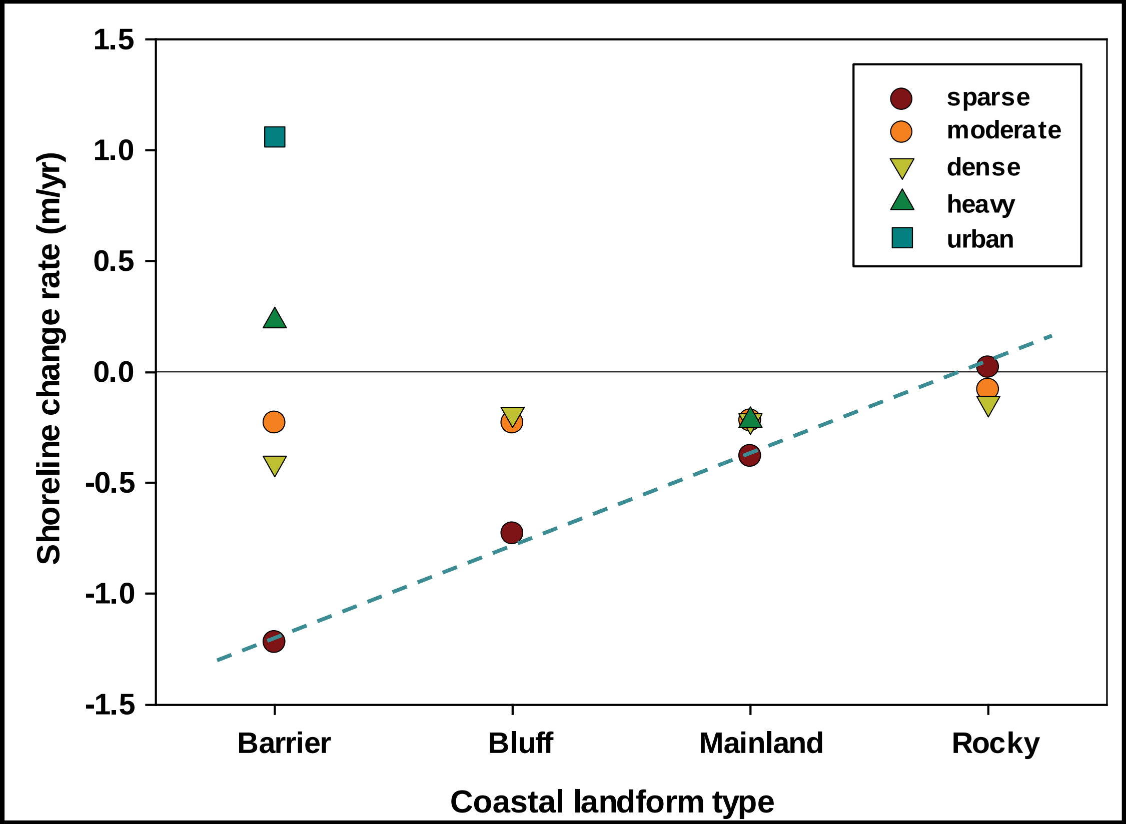
moderate

Influence of Development





Change Rate per Landform Type as a Function of Development



Conclusions

- **Majority of coast is eroding (68% long-term and 60% short-term)**
  - **reduction in the percentage of coast eroding in recent decades is attributed to human activities**

- **Rates of change in New England are less erosional than in the Mid-Atlantic**
  - **variability attributable to geomorphologic variability and level of development**

- **Change is higher along barriers and beaches fronting bluffs than mainland beaches**

- **Anthropogenic activities have a measureable impact on the regional shoreline change signal**
  - **Localized effect of engineered inlets**
  - **Other activities such as structures, nourishment**

- **Influence of development on shoreline change rate with respect to landform type:**
  - **Development overrides morphologic signal**
  - **Change rate predictable relative to geomorphology ONLY in sparsely developed areas**
  - **Rates of change only correlate to the geomorphology in sparsely developed areas (where the coastline responds naturally).**