Coastal Change and Vulnerability: Sea-Level Rise and Other Climate Change Effects

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Gloucester, MA

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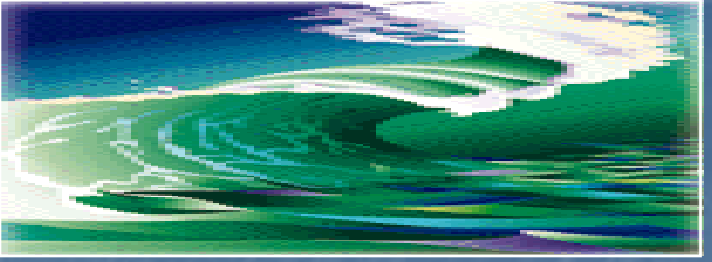


Sea-level rise, coastal change, hazards adaptation…

Outline

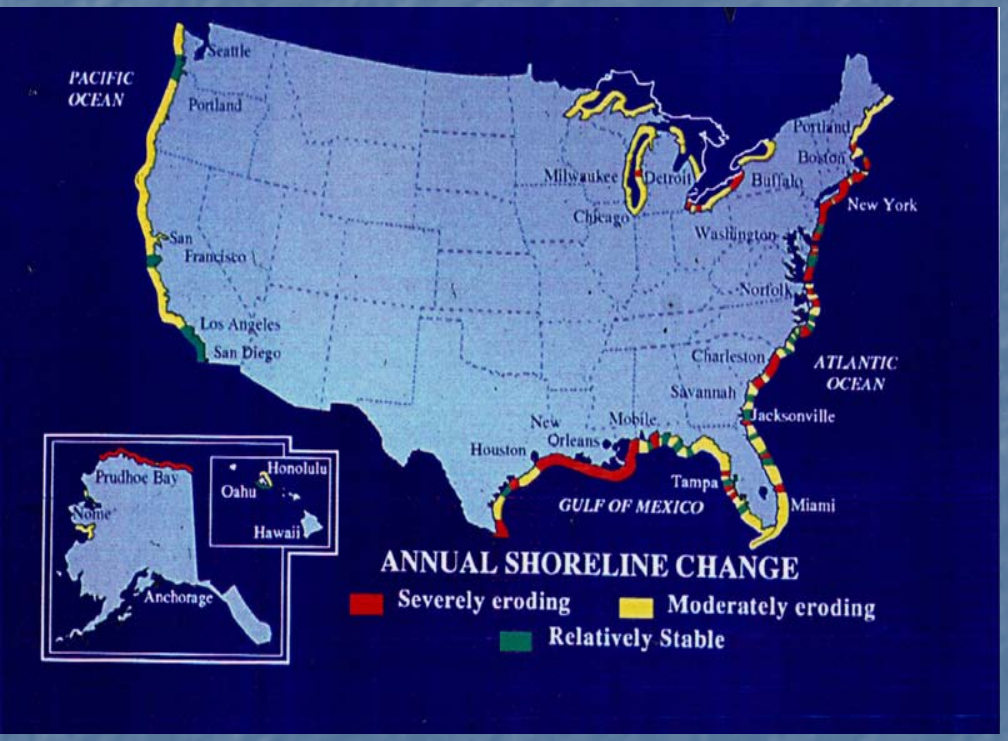
- Introduction
- Coastal-change processes, past sea-level change, human effects on coasts, effects of storms, coastal hazard risk and vulnerability
- The future of coasts and low-lying regions under global climate change: sea-level rise, increase in storminess, erosion, inundation, flooding.
- Planning for SLR in the Northeast by Feds, States, NGOs
- Questions and discussion

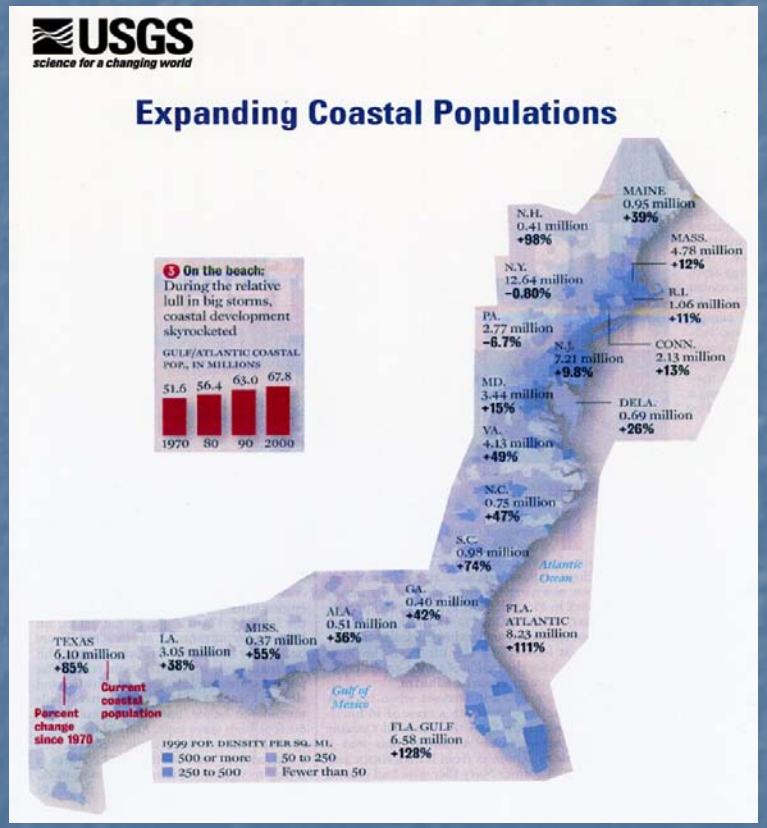
Coastal systems respond dynamically to many environmental factors and processes

Dauphin Isl., AL, post-Katrina/Rita

- Geologic framework and character
- Geomorphology, slope, elevation
- Sea-level change
  - global change
  - land subsidence & uplift
- Storm events
  - tropical storms / hurricanes
  - extratropical storms, nor'easters
- Daily coastal processes
  - waves, currents & winds
- Sediment budget
  - sediment sources and pathways
  - sediment sinks
- Human activity
  - coastal development & infrastructure
  - coastal engineering structures
  - beach & dune nourishment
  - dredging (channels, inlets, canals)
  - river modification (dams, levees)
  - fluid (oil-gas-water) extraction

America's Coastal Crisis – Coastal population and development are increasingly vulnerable to coastal hazards

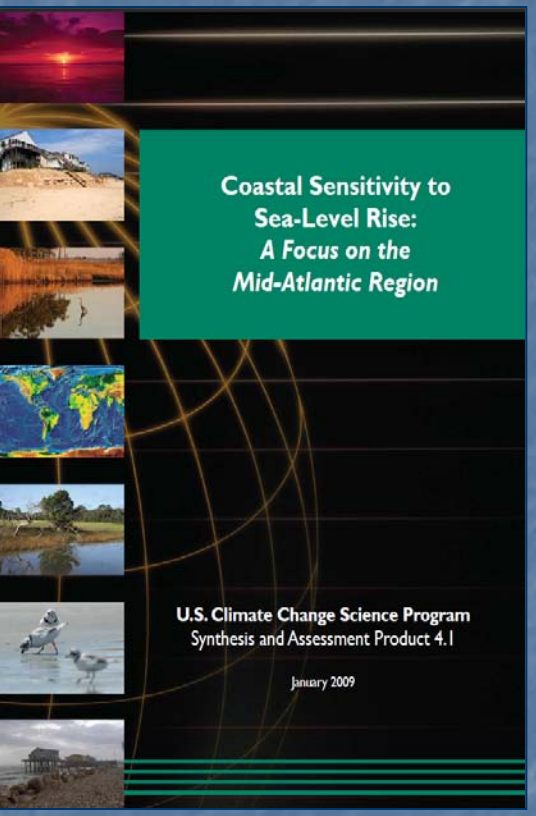




- Erosion affects all 30 coastal states
- 60-80 % of coast is eroding
- Erosion caused by complex processes
- Rates are highly variable in time & space
- Sea level change is highly variable

- Coastal populations have doubled
- ~50 % live along coasts
- Infrastructure about $9 trillion

U.S. Climate Change Science Program, Science and Assessment Product 4.1



CCSP 2009

I. The Physical Environment
1. Sea-Level Rise and Its Effects on the Coast
2. Coastal Elevations
3. Ocean Coasts
4. Coastal Wetland Sustainability
5. Vulnerable Species

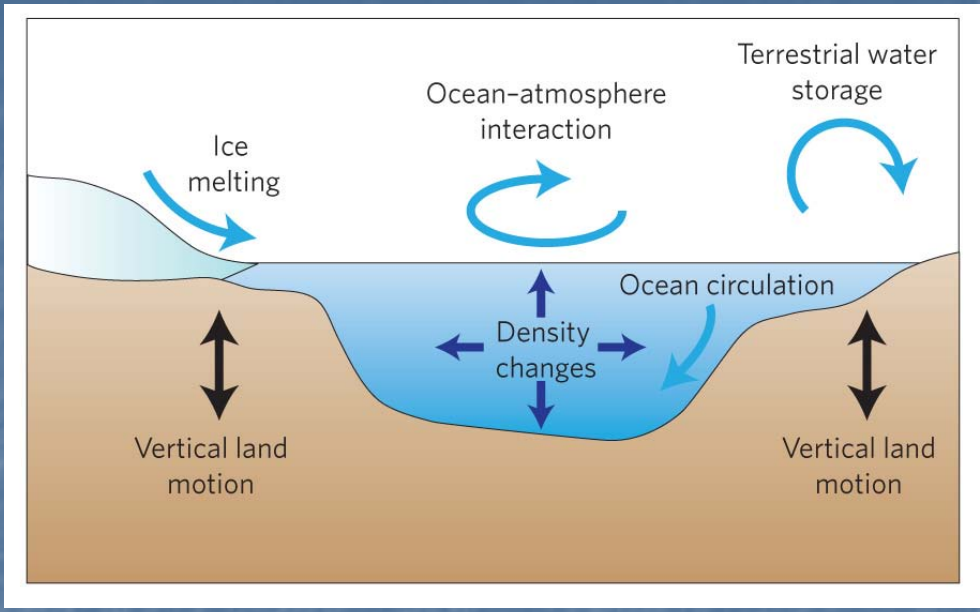
II. Societal Impacts and Implications
6. Shore Protection and Retreat
7. Population, Land Use, and Infrastructure
8. Public Access
9. Coastal Flooding, Floodplains and Coastal Zone Management Issues

III. Preparing for Sea-Level Rise
10. Implications for Decisions
11. Ongoing Adaptation
12. Institutional Barriers

IV. National Implications and a Science Strategy for Moving Forward
13. Implications of Sea-Level Rise to the Nation
14. Science Strategy

Appendix I: State and Local Information on Vulnerable Species and Coastal Policies
Appendix II: Basic Approaches for Shoreline Change Projections

Causes of Sea Level Change:



(Milne et al. 2009)

1. Ocean volume change

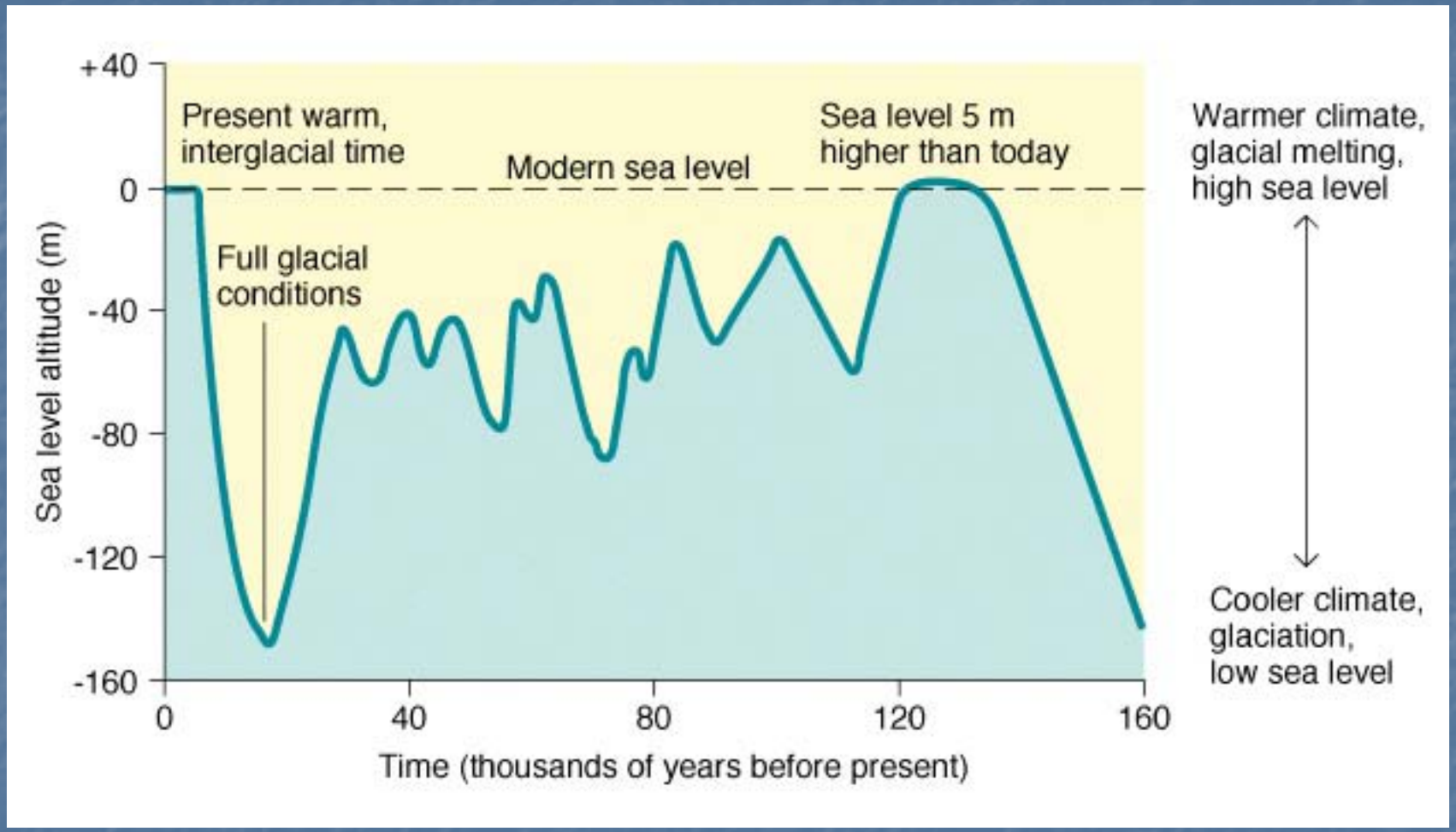
- melting land based ice sheets and glaciers
- thermal expansion
- freshwater storage

2. Changes in distribution of solid earth and oceans

- changes in ocean circulation
- vertical adjustment of the earth's crust
- gravitational effects
- adjustment of earth's rotation

** Need to recognize that there are large spatial variations in sea-level change. SLC rates are site-specific

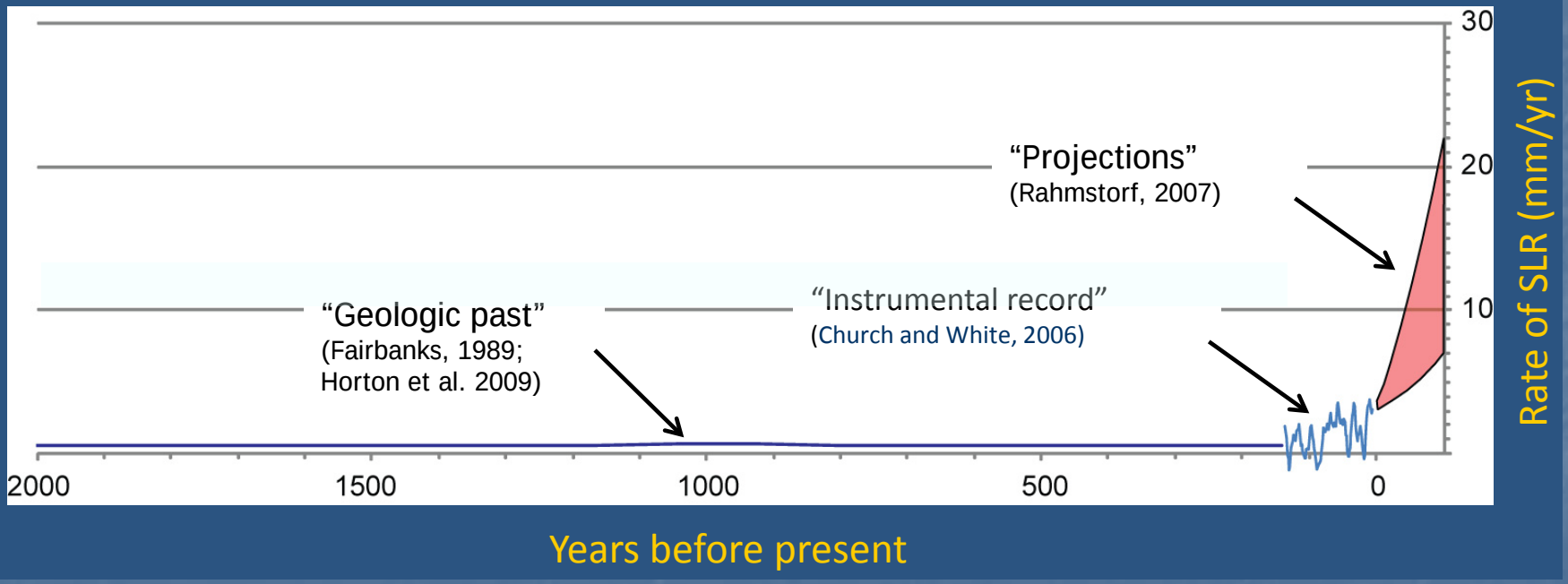
Global sea-level change over the past 160,000 years



- Sea level has been highly variable due to natural processes
- Sea level -120 m (400 ft) lower and +4-6 m (20 ft) higher than present

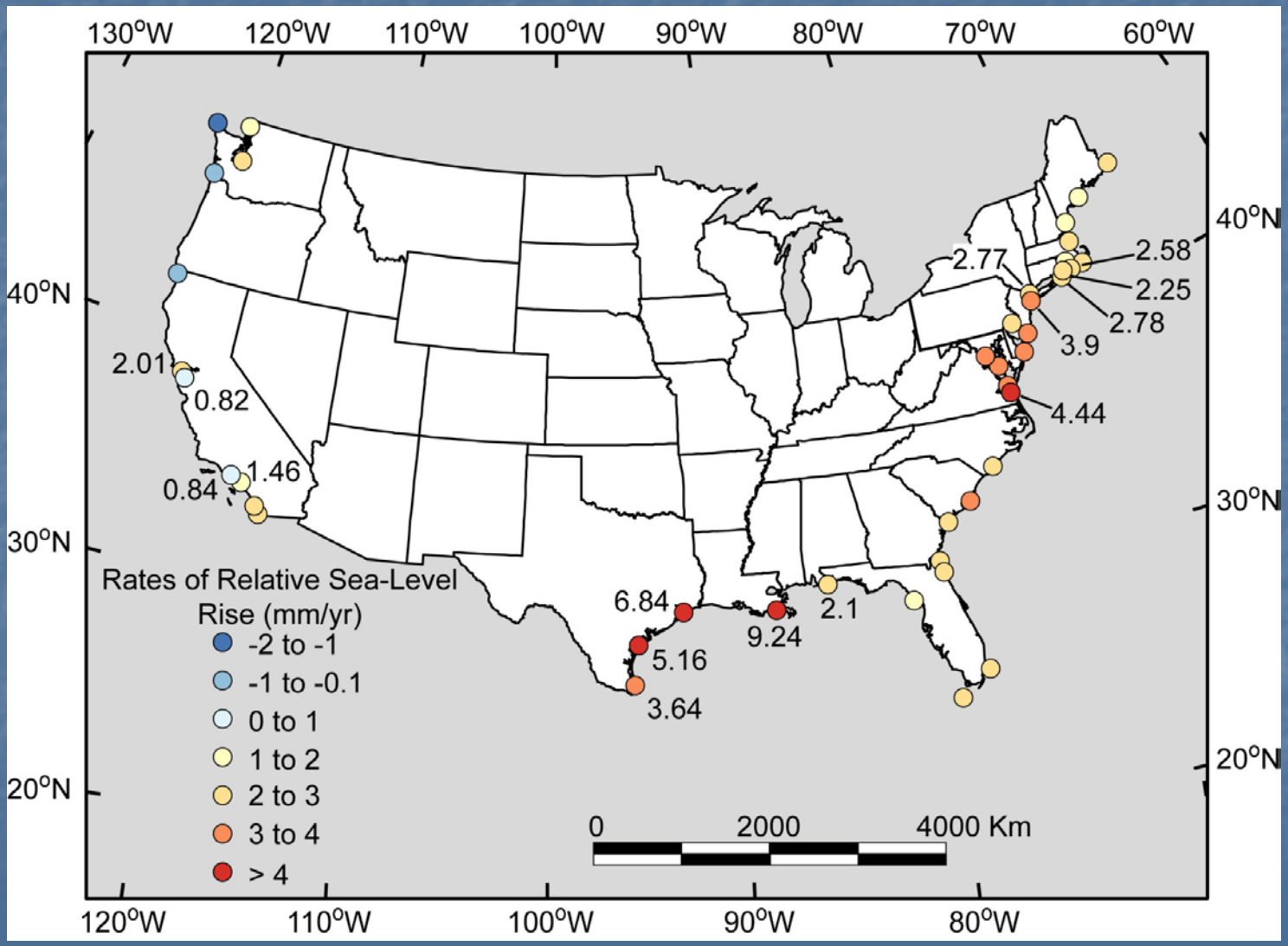
(Chappell & Shackleton, 1986; Merritts et al., 1998)

Past, present, and potential future average rates of sea-level rise: reliable prediction relies on understanding the recent, historic, and geologic record of sea-level change

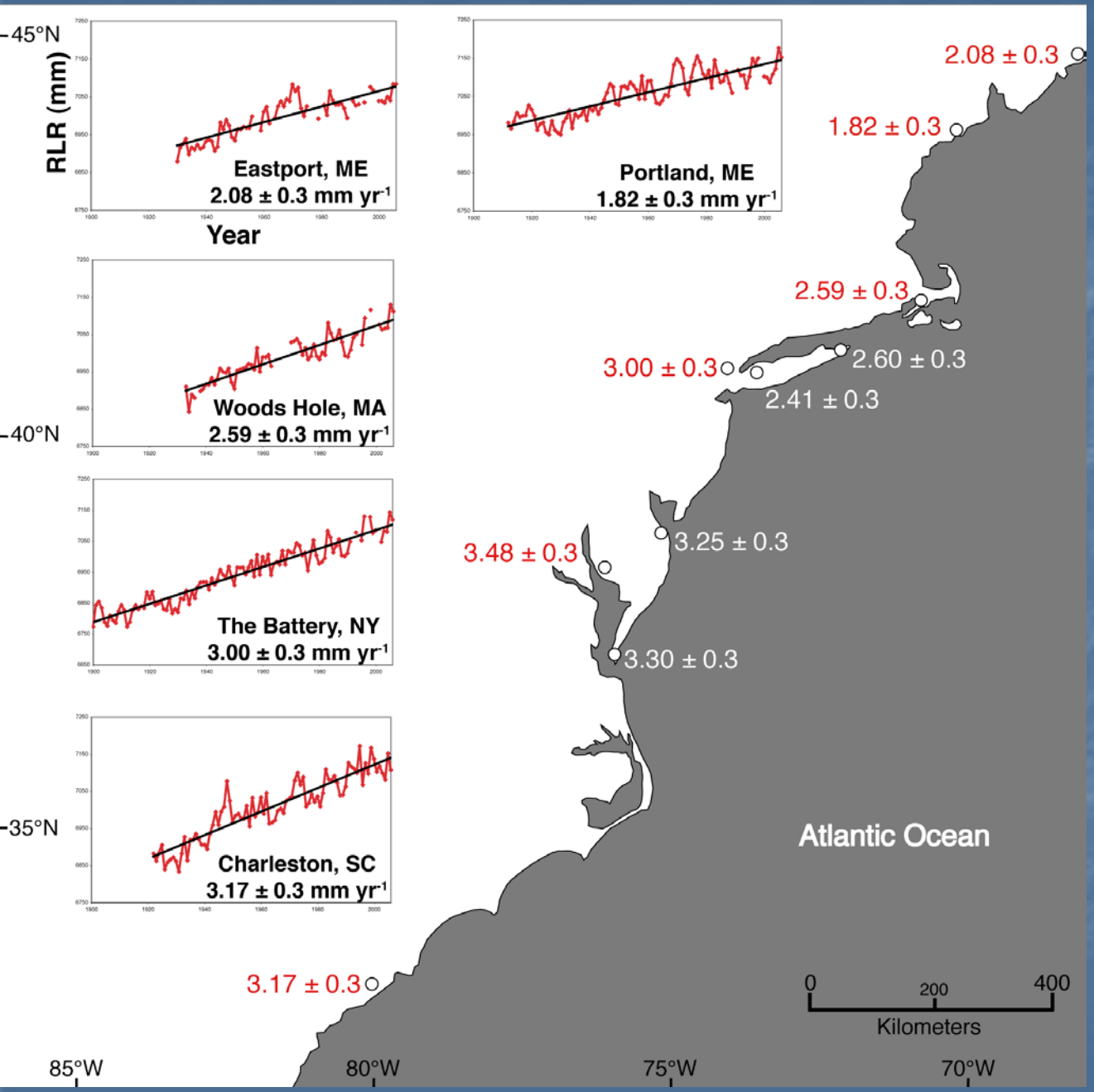


Geologic past: ~ 1 mm/yr ~19thC to 1990: 1.7 mm/yr 1992-2009: 3.3 mm/yr

NOAA tide gauge stations with records exceeding 50 yrs provide reliable rates of 'relative sea-level' change



Sea-level rise in the 20th century



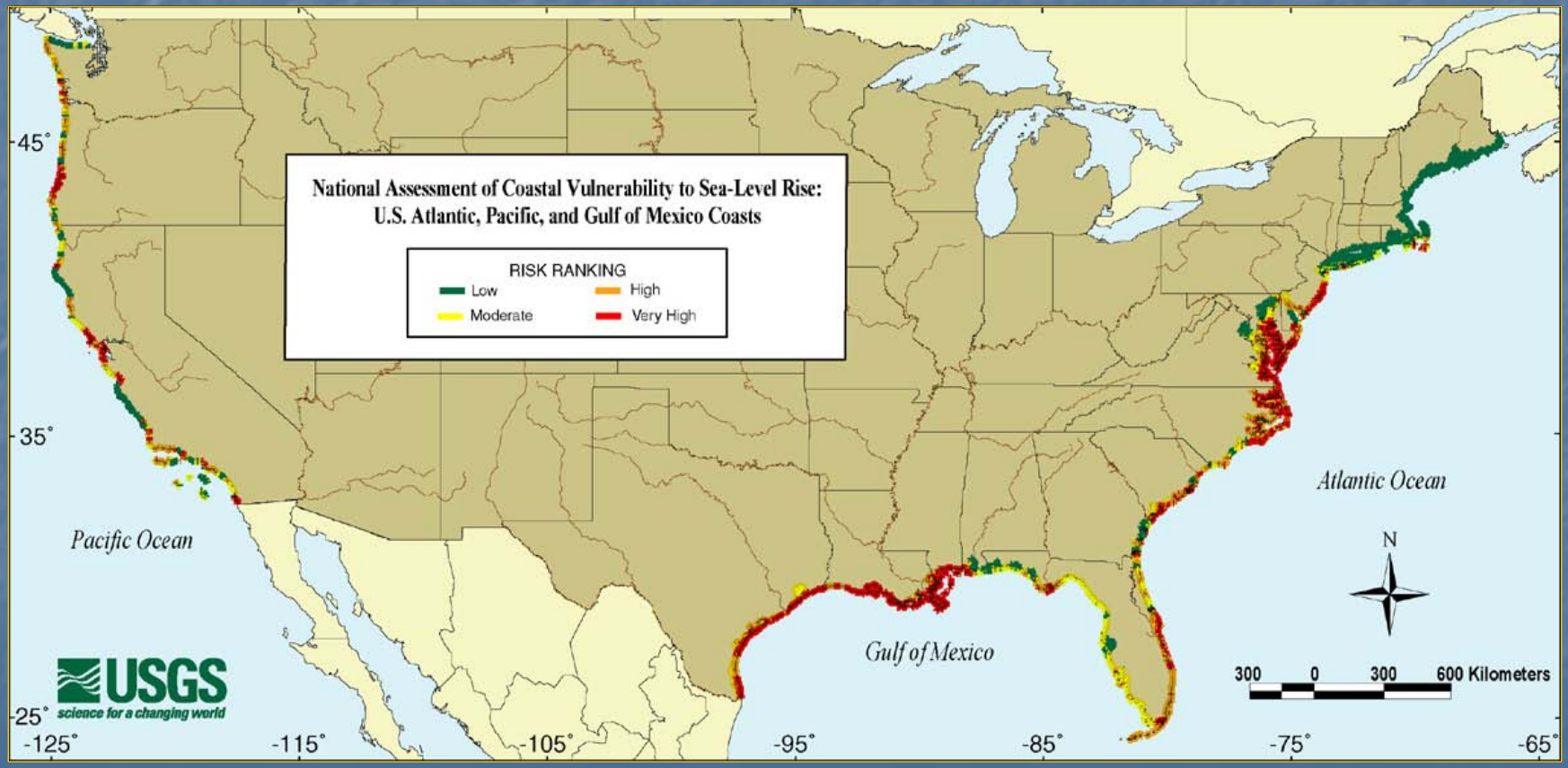
Tide gauges
2-6 mm/yr

Global rise last 4000yrs
<1 mm/yr

(Ben Horton et al)

Coastal Vulnerability to Sea-level Change: A Preliminary National Assessment

CVI based on 6 factors: tide range, wave height, regional slope, historic shoreline change rate, geomorphology, RSL rate



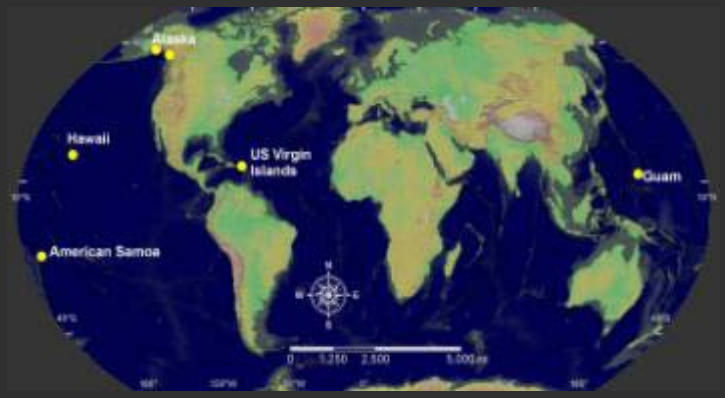
(from Thieler and Hammar-Klose 1999; 2000a; 2000b)

http://woodshole.er.usgs.gov/project-pages/cvi/

The USGS/NPS CVI project

CVI study sites in the Contiguous U.S.

CVI study sites in Hawaii, Alaska, and U.S. Territories



Cape Cod NS
Fire Island NS
Gateway NRA
Gulf Islands NS
Cape Hatteras NS

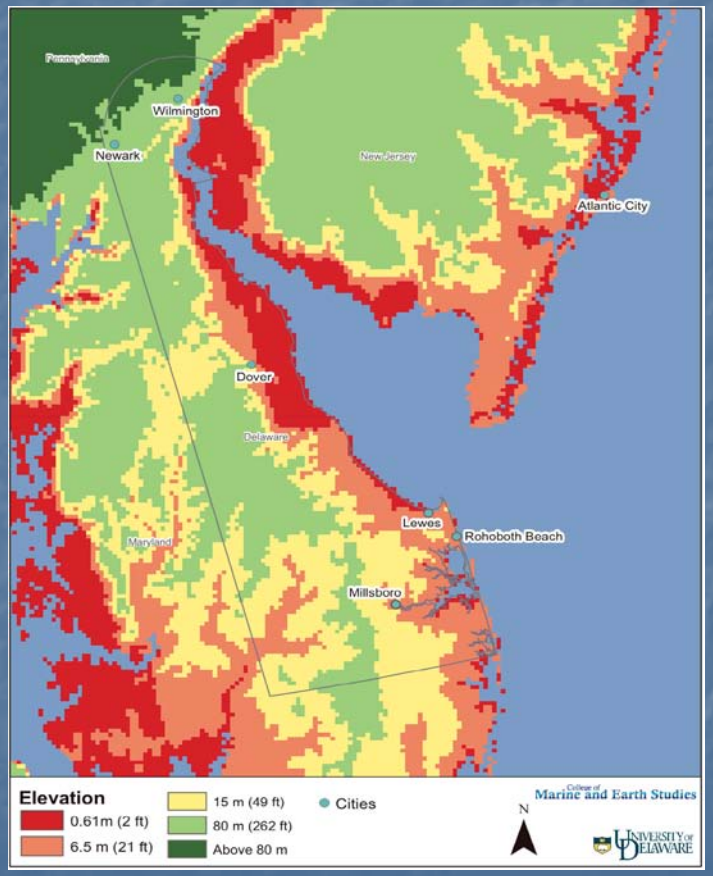
Cumberland Island NS
Assateague Island NS
Dry Tortugas NP
Padre Island NS
Channel Islands NP

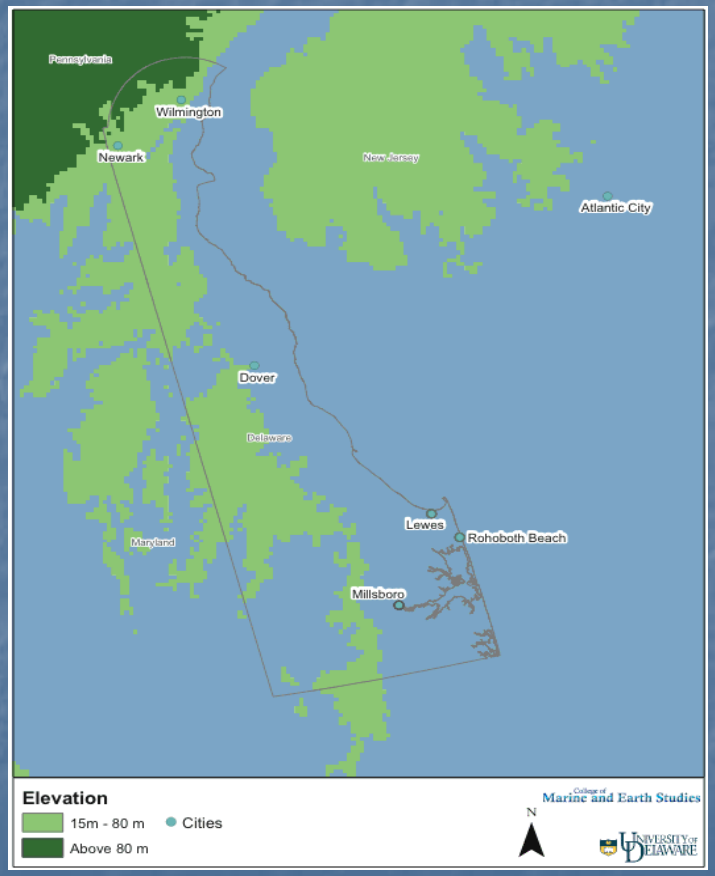
Golden Gate NRA
Point Reyes NS
Olympic NP
Apostle Islands NL
Indiana Dunes NL

Sleeping Bear Dunes NL
Kenai Fjord NP
Glacier Bay NPP
Kaloko-Honokohau NHP
NP of American Samoa
Virgin Islands NP
War in the Pacific NHP

http://woodshole.er.usgs.gov/project-pages/nps-cvi/

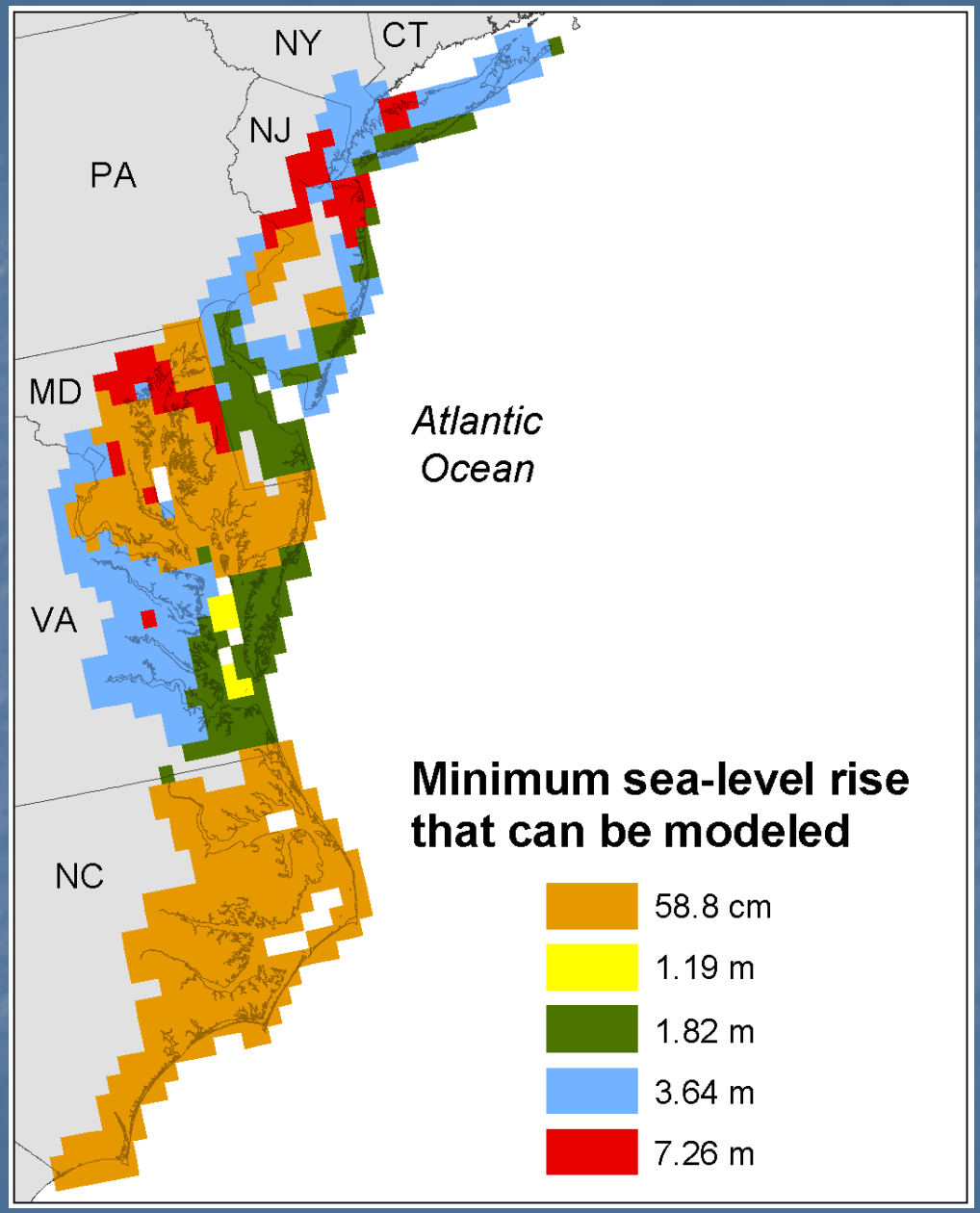
‘Areas of Delaware inundated by expected sea level rise in this century (red), by Greenland (orange), and by the West Antarctic (yellow). Light green are the areas that would be inundated by additional loss of the entire Antarctic, but the probability and time constant of this are very poorly estimated. Impact of sea level rise on Delaware, due to ice melt from Greenland and the West Antarctic combined. The remaining land areas are shown in green.’





Coastal Elevations

- Elevation is a critical factor in assessing potential impacts (specifically, inundation)
- Current elevation data do not provide the degree of confidence needed for quantitative assessments for local decision making
- Collection of high-quality elevation data (lidar) would be valuable



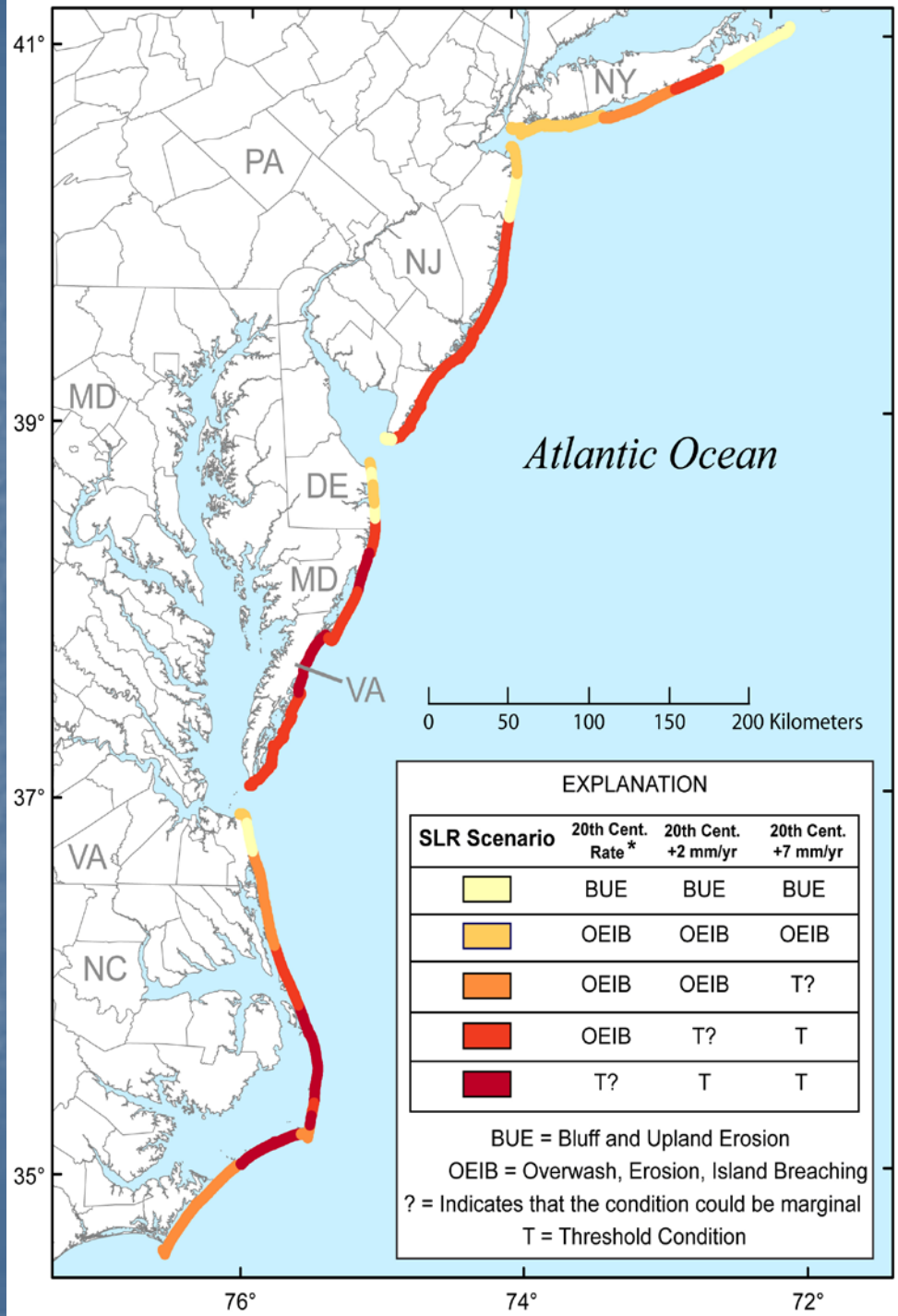
From CCSP/SAP 4.1 chapter 2

(Gesch et al., 2009)

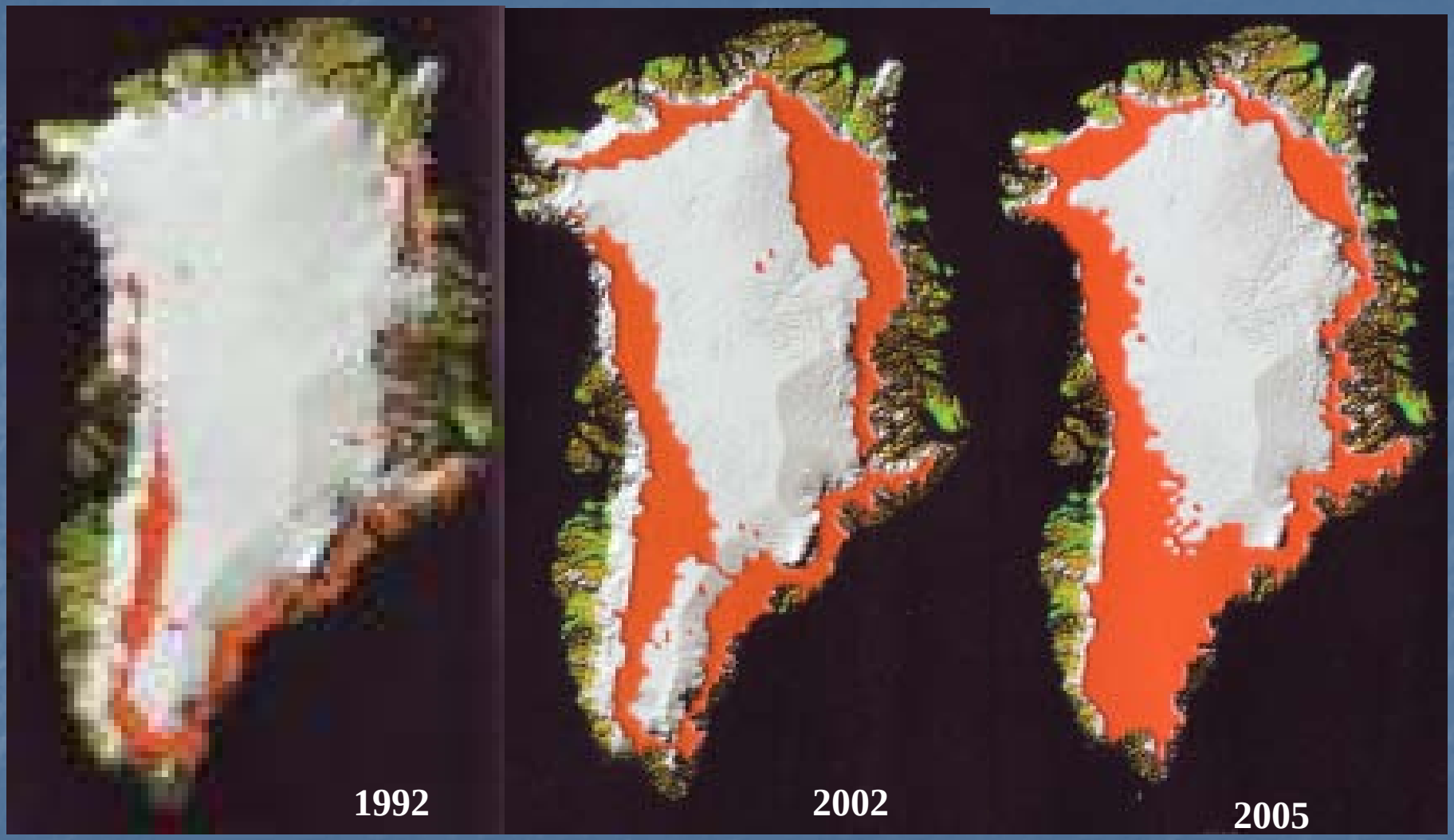
Ocean Coasts

(chapter 3, CCSP/SAP 4.1)

- It is *virtually certain* that erosion will dominate changes in shoreline position along the mid-Atlantic ocean coasts in response to sea-level rise and storms
- For higher sea-level rise scenarios, it is *very likely* that some portions of the mid-Atlantic coast will undergo large changes which will depend in part on local geologic and oceanographic conditions
- Some barrier island coasts will *likely* cross a threshold and become prone to more rapid landward migration or segmentation



Greenland ice sheet melting is accelerating!



Balanced ice mass by build-up in the center and melting at the coast.

Ten years later, in 2002, the summer melting was much greater.

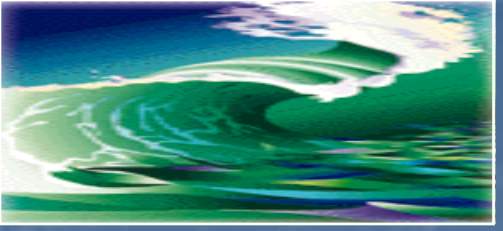
In 2005, melting accelerated dramatically. And continues.

Source: ACIA, 2004 and CIRES, 2005

Coastal Flooding in Charleston, SC
(urban environmental impacts)

- NOAA/NWS Charleston issues coastal flooding advisories for +2 m tides
- 2 m tides typically predicted to occur four times a year
- With 0.5 m SLR, this advisory could be issued 255 times a year

(NOAA/CSC)



Several federal agencies, NGOs, and NE states are planning for SLR

A Few Examples:

USGS: Research into climate change, geologic record of SLC; coastal change and vulnerability
NOAA: New Climate Change office, adaptation guidance website
USGS/NOAA: Dec 2009, community-based workshop on SLR, inundation effects
NPS/USFWS: SLR planning underway for coastal parks and refuges
EPA: Modeling effects on wetlands
USACE: Guidance memo of SLR planning; SLR committee in progress
FEMA: assessing SLR effects on Federal Flood Insurance Program; disaster response

TNC, WWF, CLF, Sierra Club: planning, assessing impacts, mapping habitats

Maine: 2 ft rise/100 yrs for sandy shores & dunes
New Hampshire: 2 ft rise by 2100
Massachusetts: Coastal Hazards Commission 2007 report and recommendations
Rhode Island: Climate Change and SLR draft report, May 2009
Connecticut: CT Coastal Hazards Portal web site
New York: ‘central range’ 12-23 ins; ‘rapid ice melt’ 41-55 ins
New Jersey: Planning under Gov Christie uncertain
Delaware: 0.5-1.5m by 2100 for ‘low to high’ sensitivity to SLR
Maryland: MD Coastal Program SLR Response Strategy report
Virginia: Lidar data collection in coastal zone

Conclusions

- Climate is complex. Earth is warming, climate is becoming more variable, less predictable. Unprecedented rate and magnitude of change are concerns for humans and ecosystems.

- Coastal systems are dynamic. SLR, storms, sediment supply are primary drivers of coastal change. Erosion, inundation and flood frequency likely to increase. Mid-Atlantic states are highly vulnerable due to land subsidence.

- Oceans are warming, ice sheets melting: SLR is accelerating. Future sea level ~ 1 m higher by 2100, higher locally . Greenland and West Antarctica rapid melting are concerns.

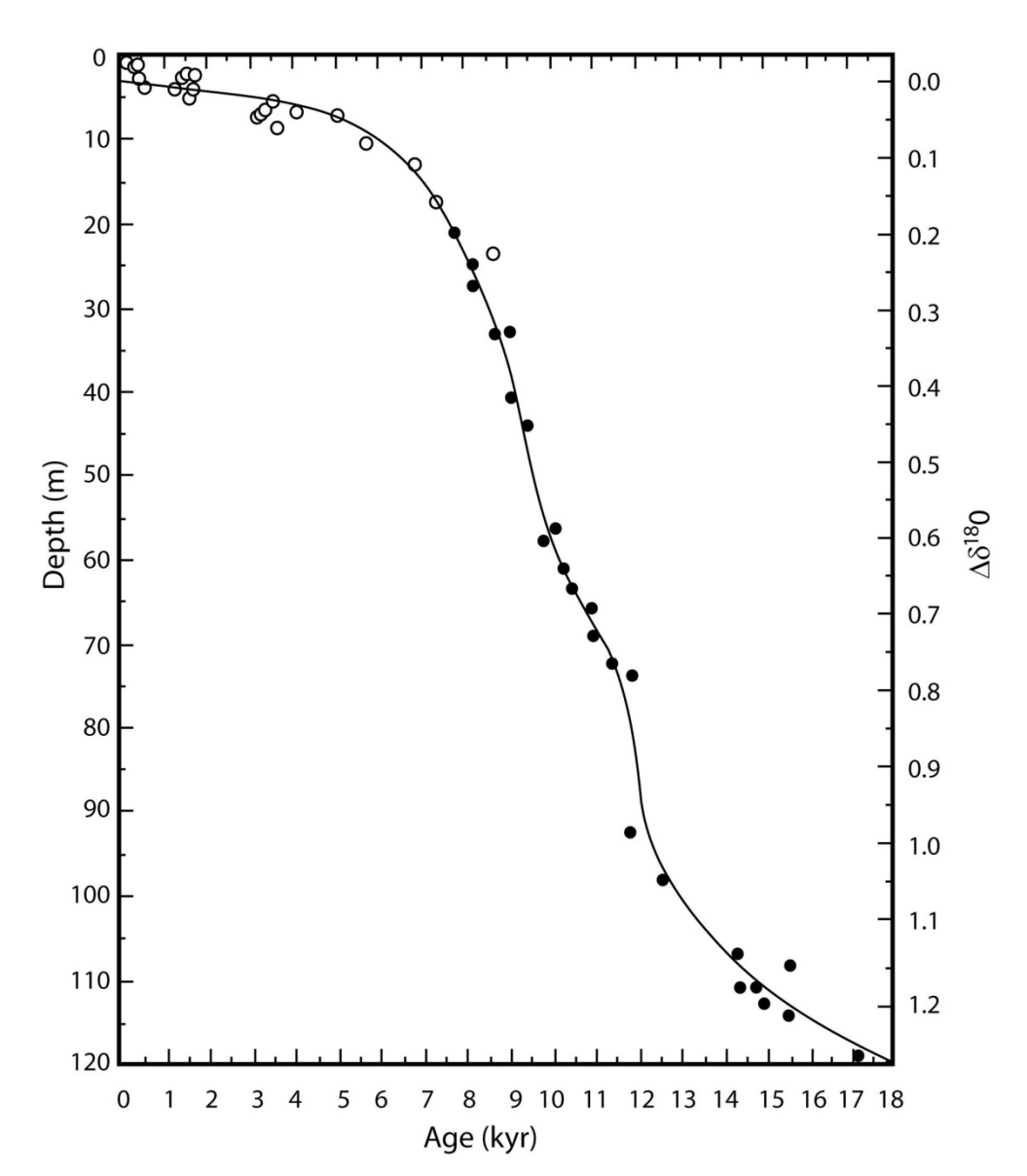
** Reduce vulnerability & enhance resiliency **

- **Increase science and monitoring:** integrate coastal/climate science in coastal zone planning, management and engineering

- **Adaptation:** plan for a range of SLR effects, use principles of “resilient” and “storm-smart” coastal planning tools; incorporate SLR in regulations and programs; restore natural processes

USGS

Sea-level rise over the last 18,000 years based on geologic record



Fairbanks 1989