Sea-level Rise and Storm Effects on the Florida Coast Under Changing Global Climate

Invited lecture
Miami-Dade Co. Climate Change Task Force

19 June 2009

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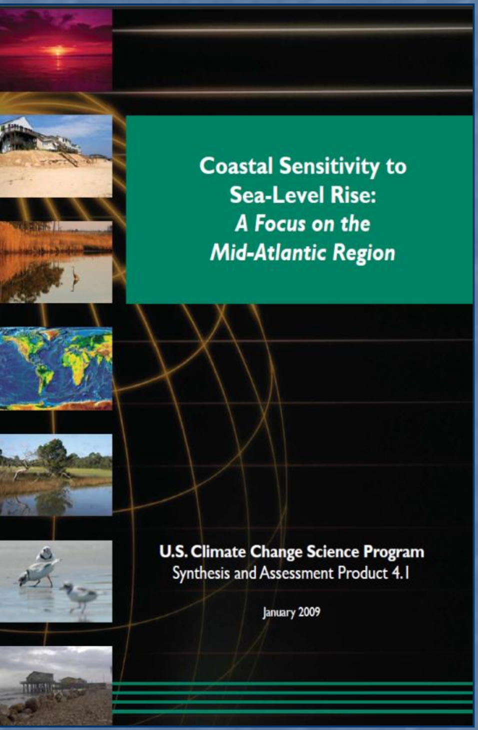
The Coastal Crisis….

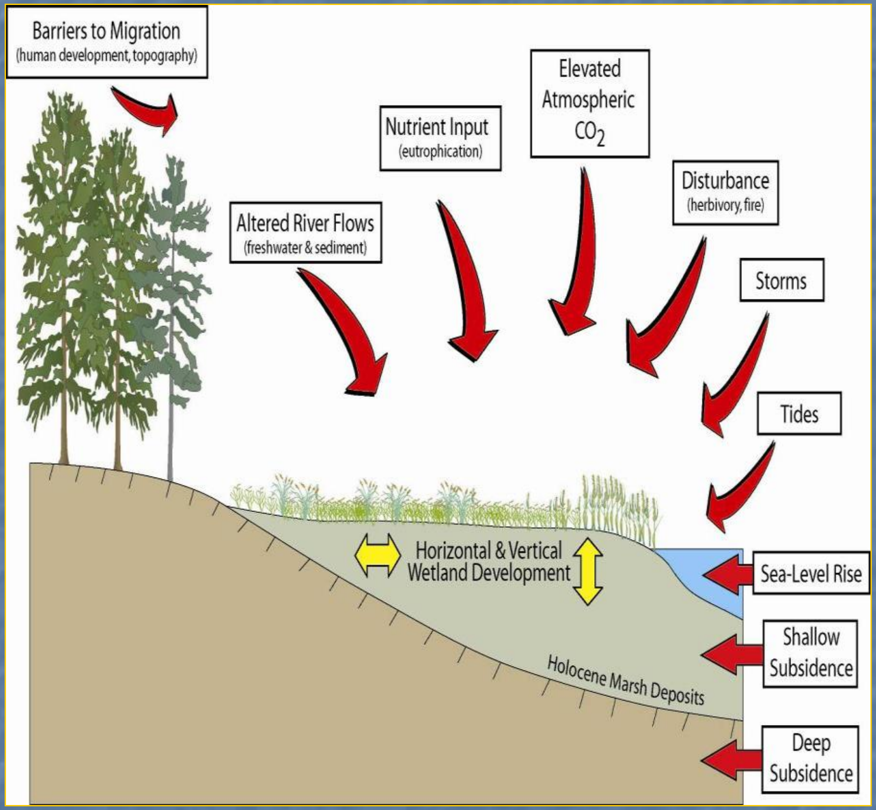
Outline:

- Summary of U.S. Climate Change Science Program SAP 4.1 report (2009)
- Coastal-change processes, past sea-level change history, human effects on coasts, effects of storms, coastal hazard risks
- The future under global climate change: sea-level rise, increase in storm activity, erosion, flooding…. coastal vulnerability to sea-level rise and storms
- Planning for sea-level rise to manage and protect coastal infrastructure and resources
- Questions and discussion

Climate Change Science Program, Science and Assessment Product 4.1



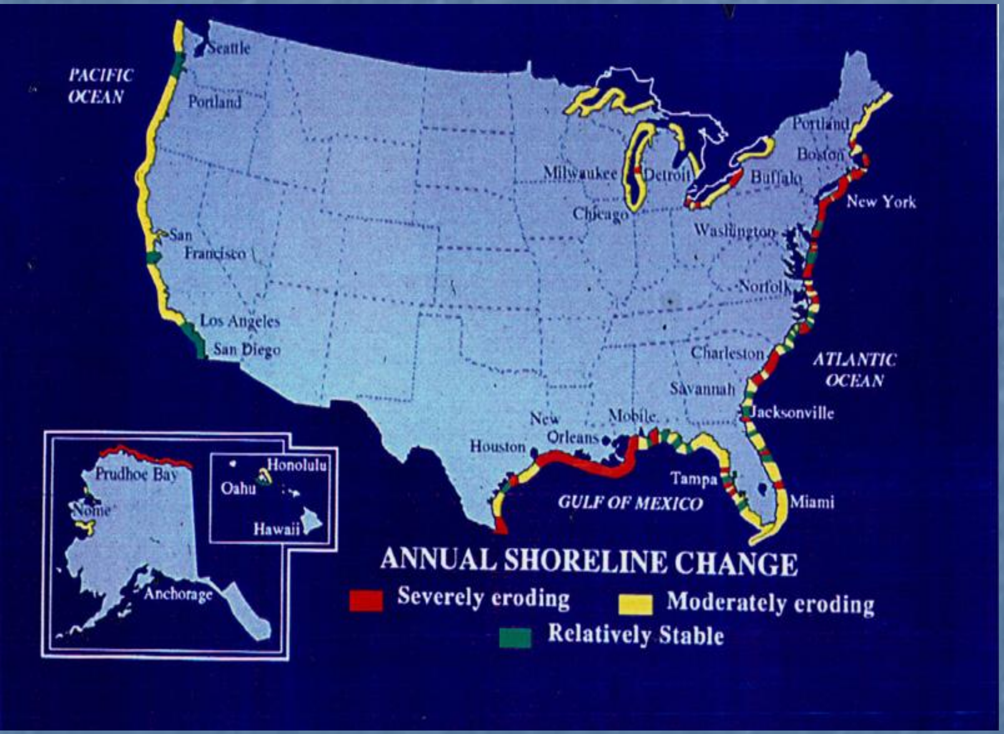
Coastal systems respond dynamically to environmental factors and processes



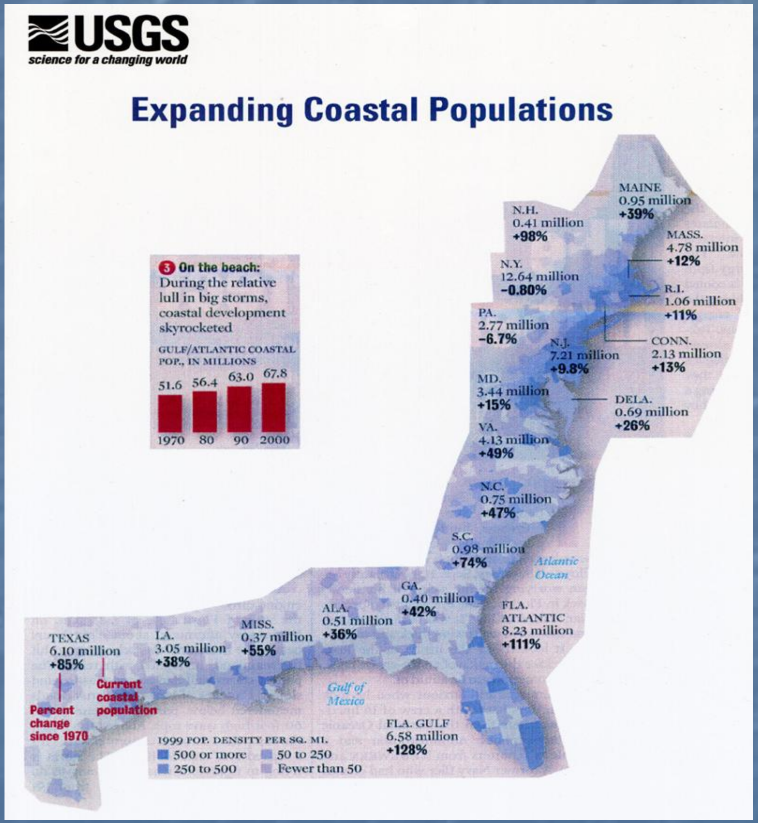
- Geologic framework and character
- Geomorphology, slope, elevation
- Sea-level change
  - global change
  - land subsidence & uplift
- Storm events
  - tropical storms/ hurricanes
  - extratropical storms

- Routine coastal processes
  - waves, tidal currents & winds
- Sediment budget
  - sediment sources
  - sediment sinks
- Human activity
  - coastal engineering structures
  - dredging channels, inlets, canals
  - river modification (dams, levees)
  - fluid (oil-gas-water) extraction
  - climate change (SLR, storms)

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



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

South Florida deemed highly vulnerability to sea-level rise (IPCC)

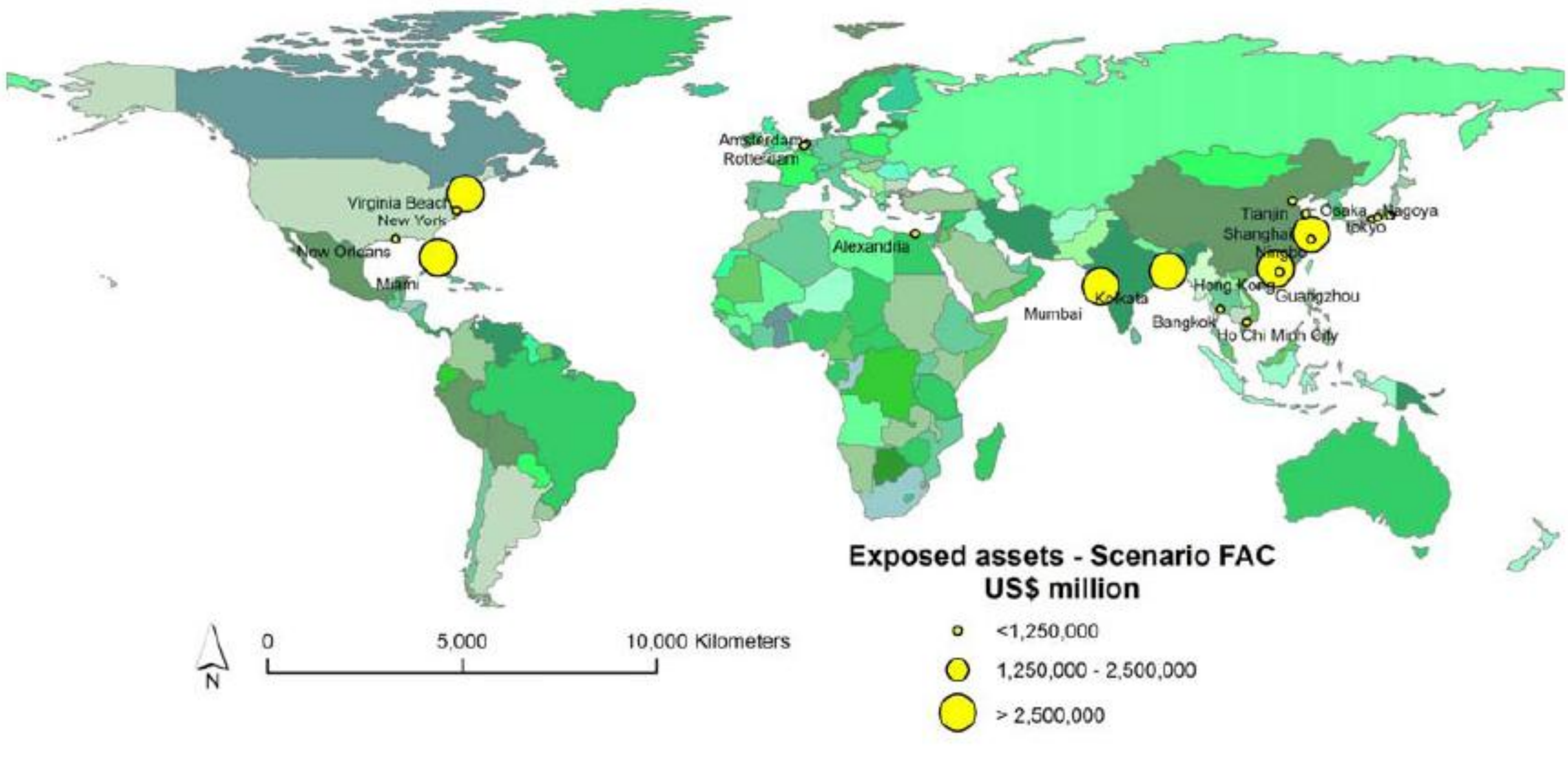
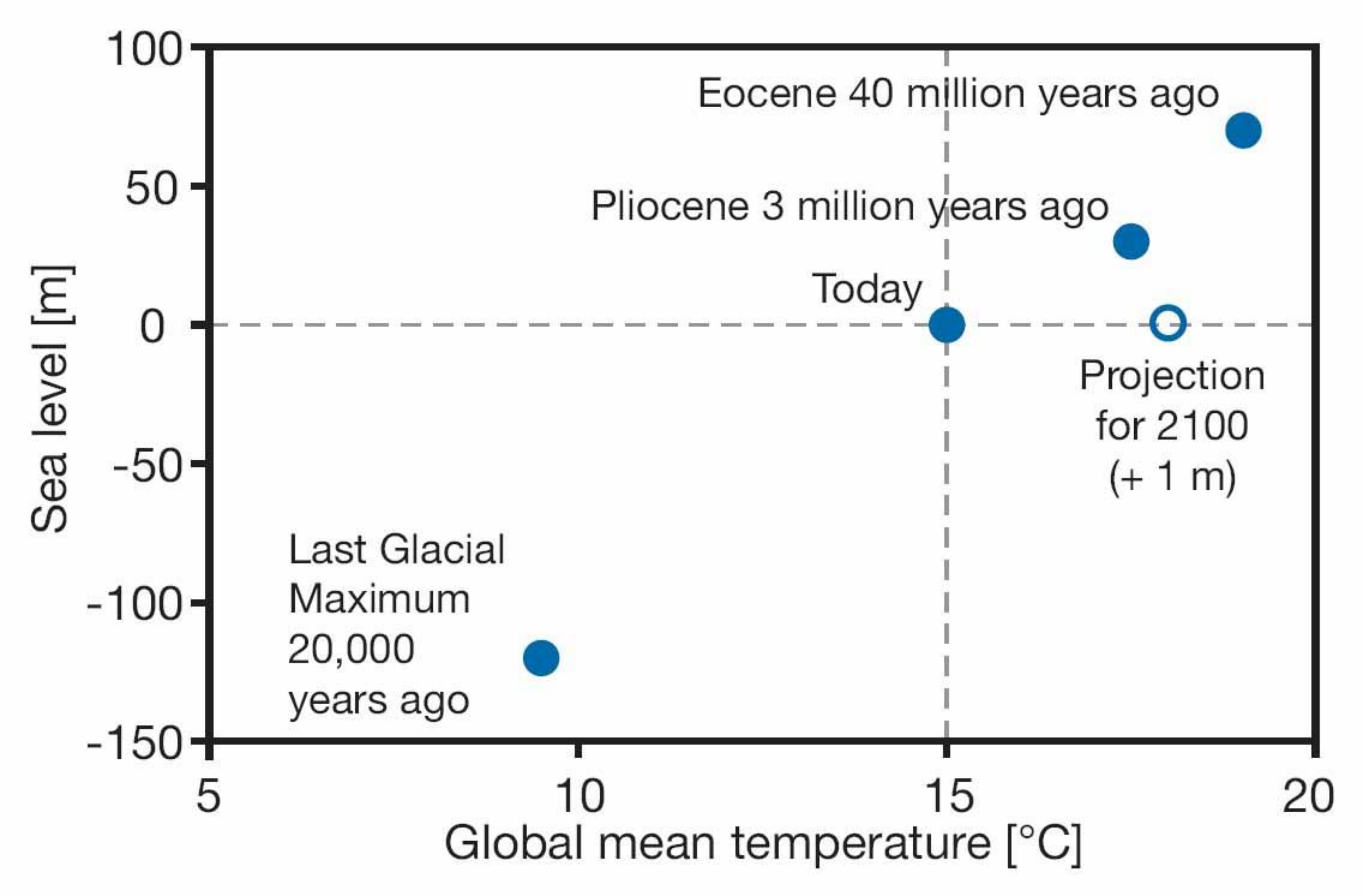
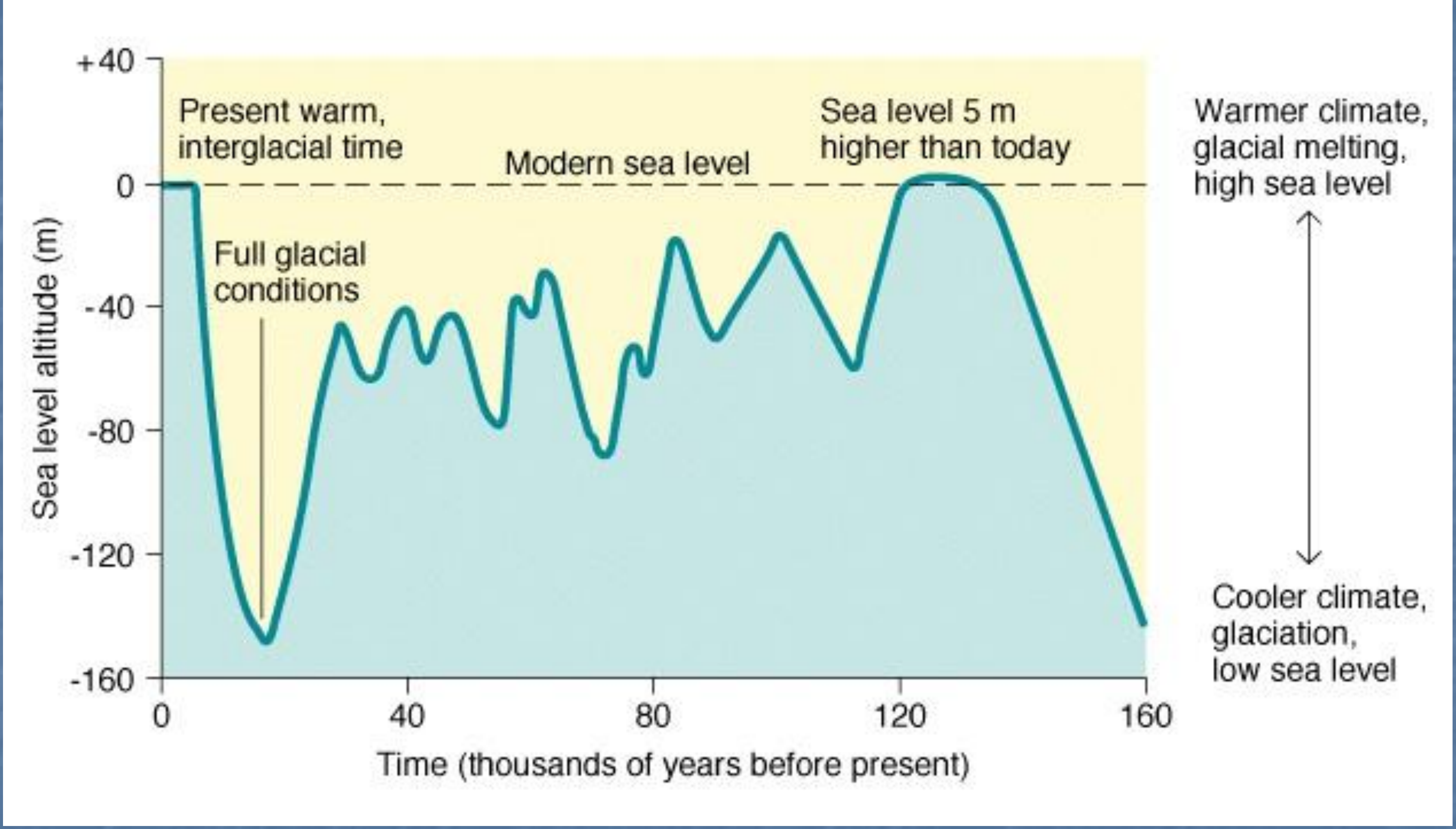


Figure 3: Map showing the Top 20 cities for exposed assets under the future climate change and socioeconomic change scenario
(Source: Nicholls et al (2007), OECD, Paris)

Global climate has been highly variable over the Earth's history



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



- **Sea level 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)

Sea-level rise caused by three factors:

- ***Thermal Expansion*** of the oceans as the atmosphere and waters warm.

- ***Addition of Water*** by the melting of land-based ice sheets, ice caps, and glaciers.

- ***Relative sea-level rise*** due to the changing elevation of coastal land (subsidence, glacial rebound, tectonic uplift).

Effects of increased sea-level rise and storm intensity

Greater potential impact

- Loss of coastal habitats and resources
- Increased coastal erosion
- Loss of recreation resources (beaches, marshes)
- Saltwater intrusion into aquifers, water wells, septic systems
- Elevated storm-surge flooding levels
- Greater, more frequent coastal inundation
- Increased risk to people and infrastructure

Overwhelming Scientific Consensus

The National Academy of Sciences (2005)

"The scientific understanding of climate change is now sufficiently clear…(we urge) prompt action to reduce the causes of climate change."

National Security and the Threat of Climate Change
CNA Corp (2007) for Dept of Defense
"The nature and pace of climate change are grave and pose grave implications for U.S. national security."

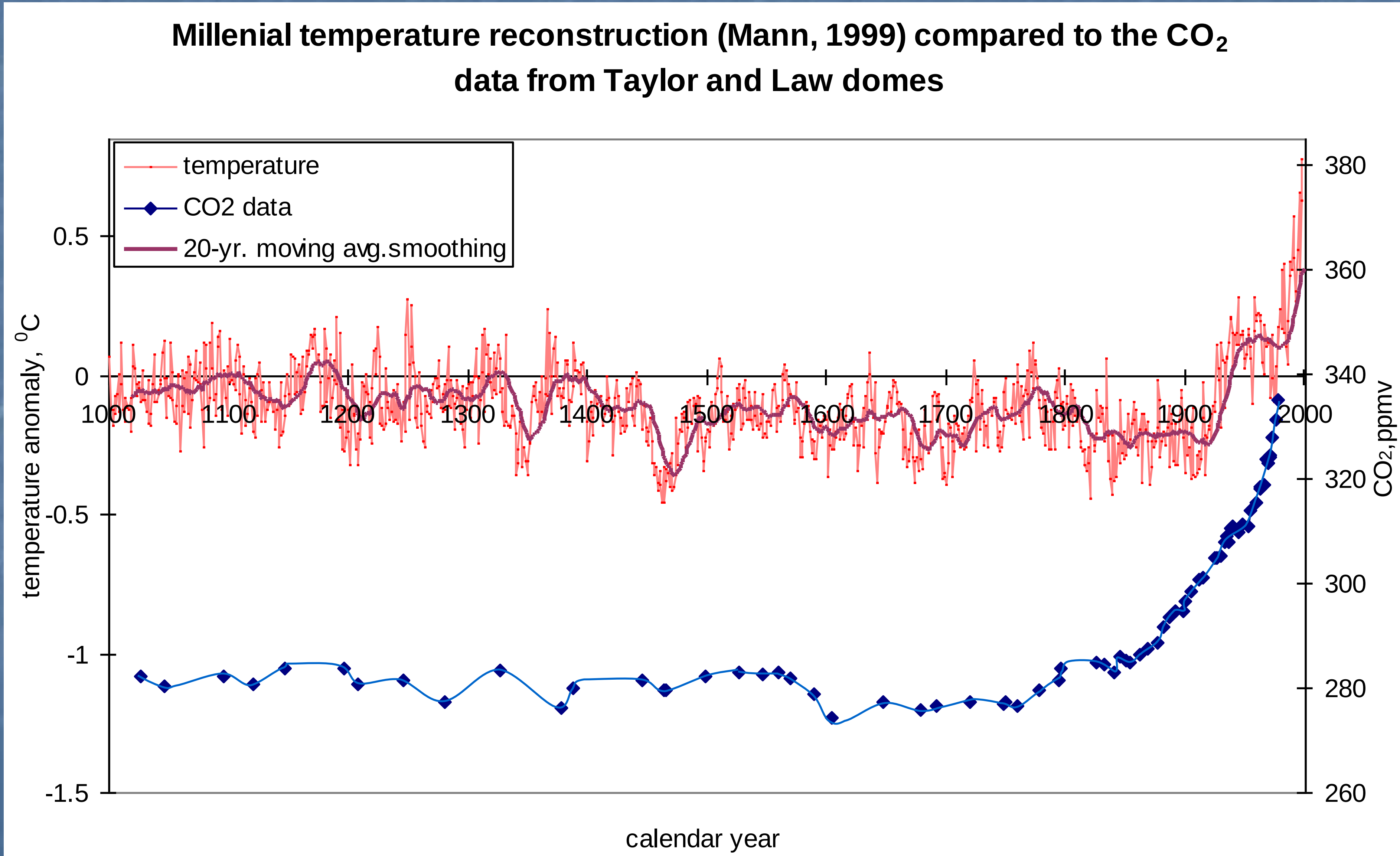
Intergovernmental Panel on Climate Change (2007)

"Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely (90%) … "unequivocally" due to the observed increase in anthropogenic greenhouse gas concentrations."

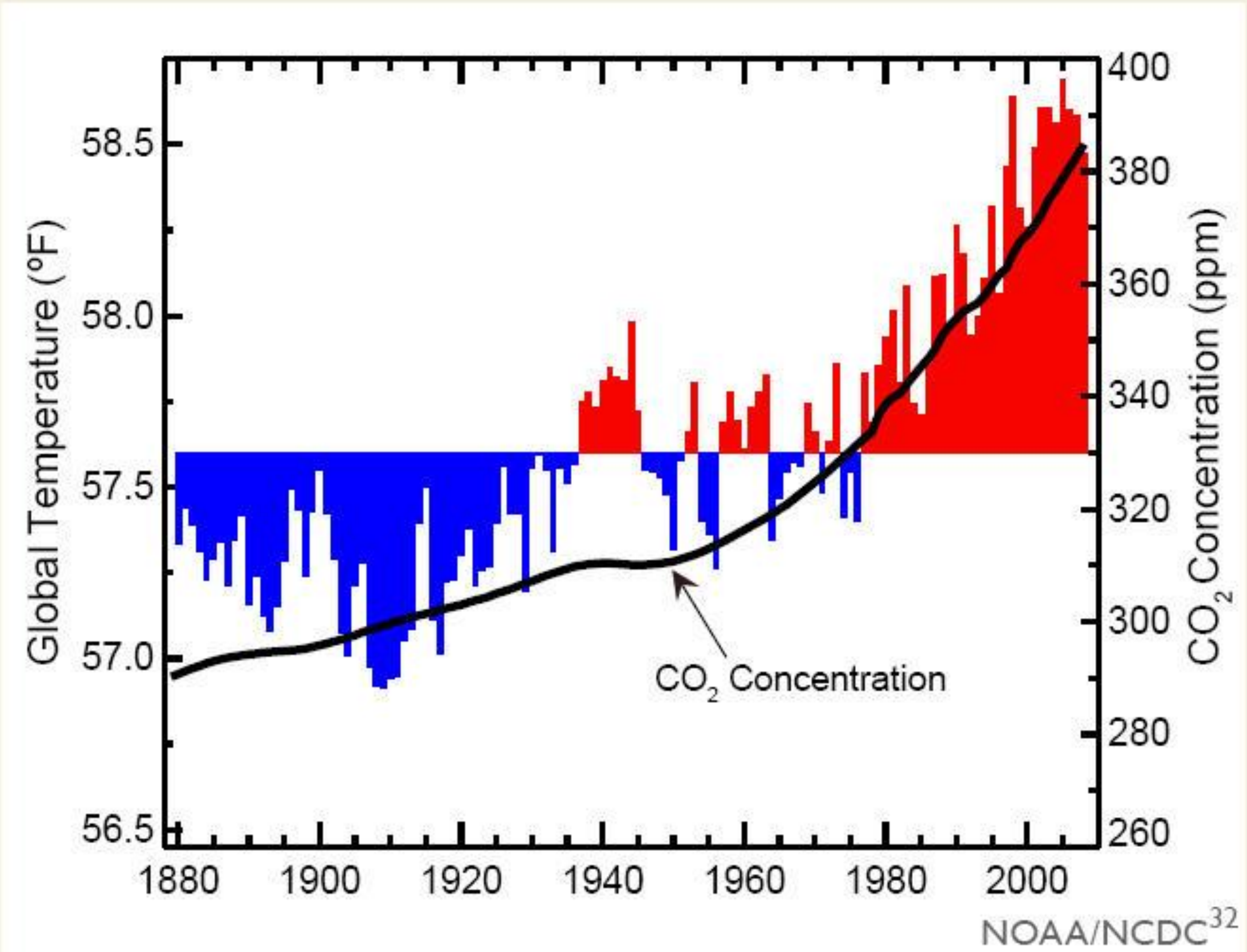
U. S. Climate Change Science Program, SAP 4.1 (2009)

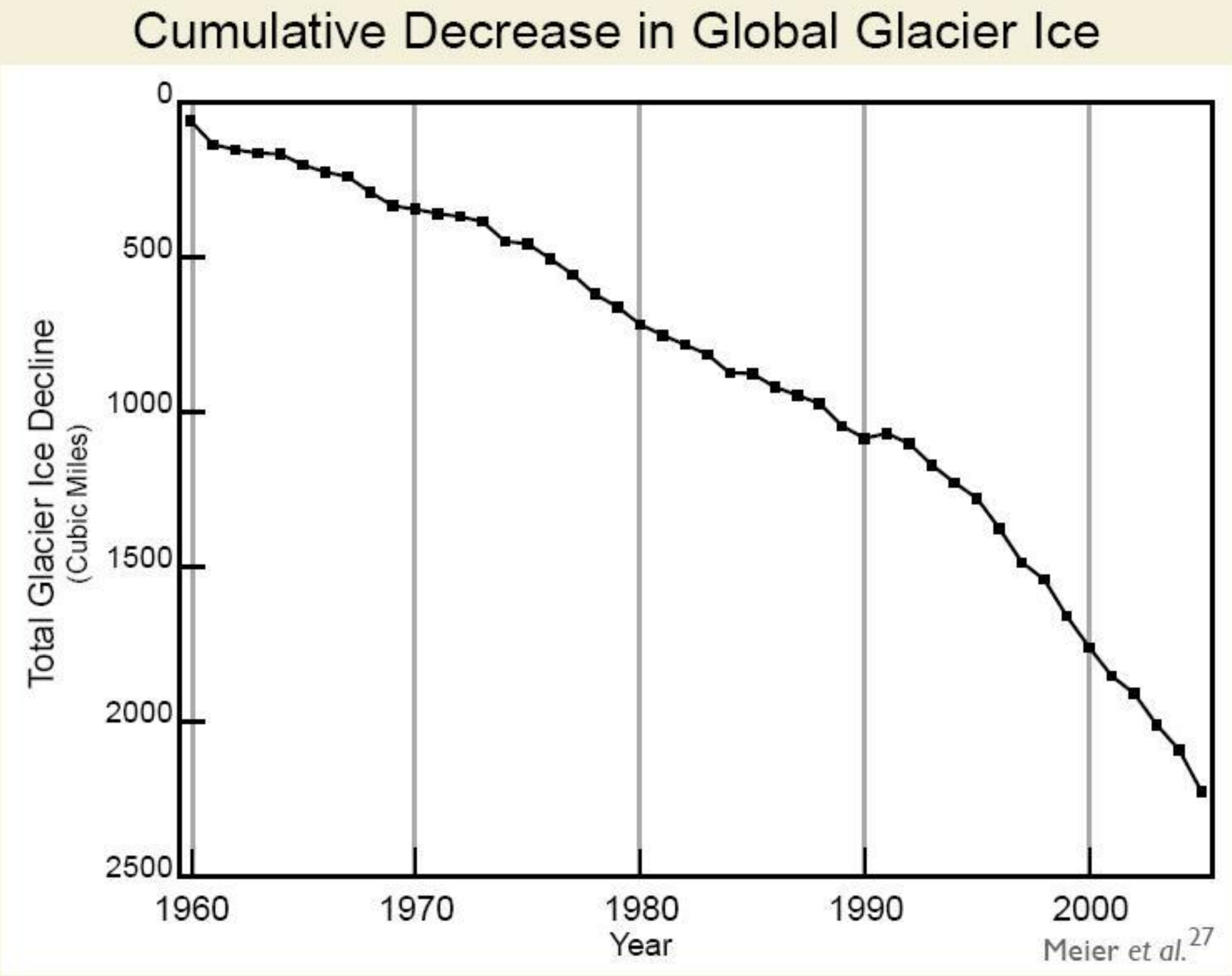
"Climate warming will raise sea levels and potentially increase storms, resulting in increased erosion, wetland loss, salt water intrusion. Actions and plans are needed at national and state levels for adaptation to future climate conditions."

Global temperature and CO2 record for the past 1,000 yrs based on tree ring and Antarctic ice core analyses



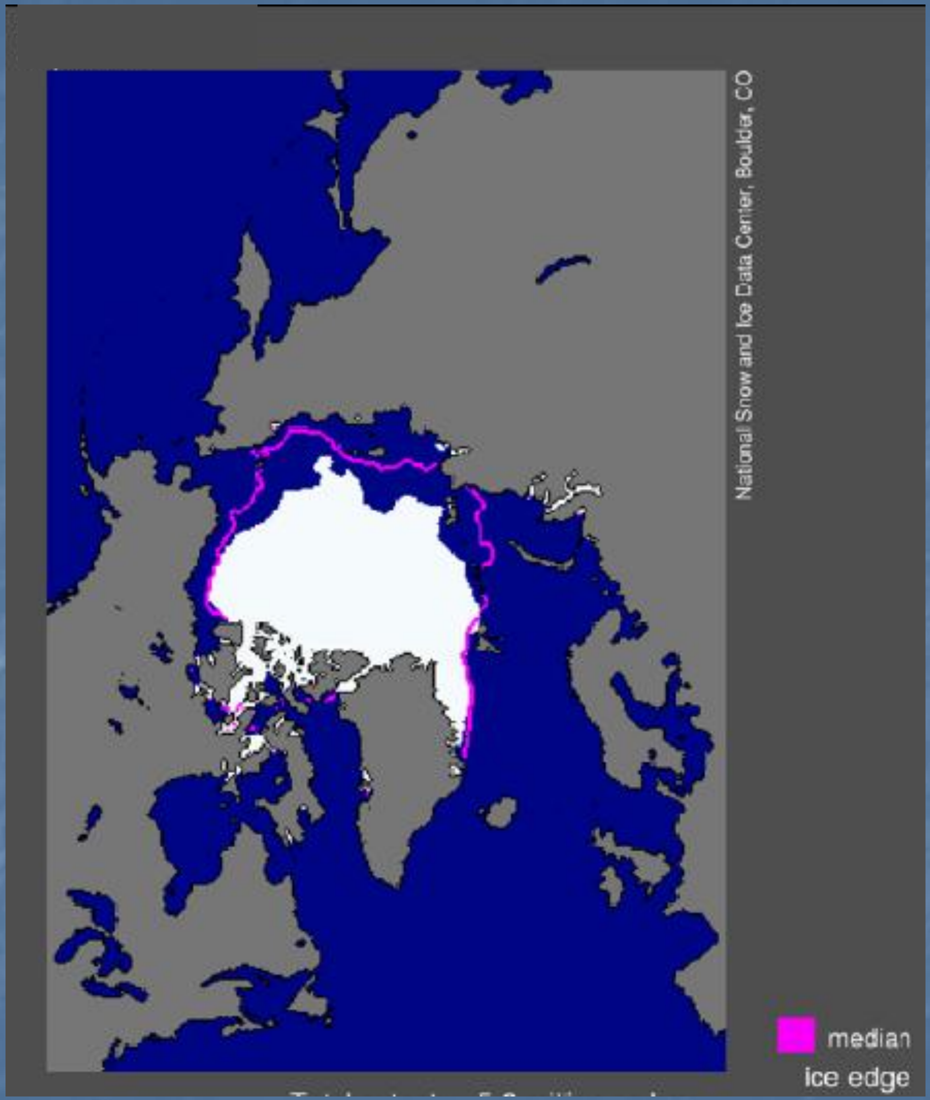
Global Temperature and Carbon Dioxide



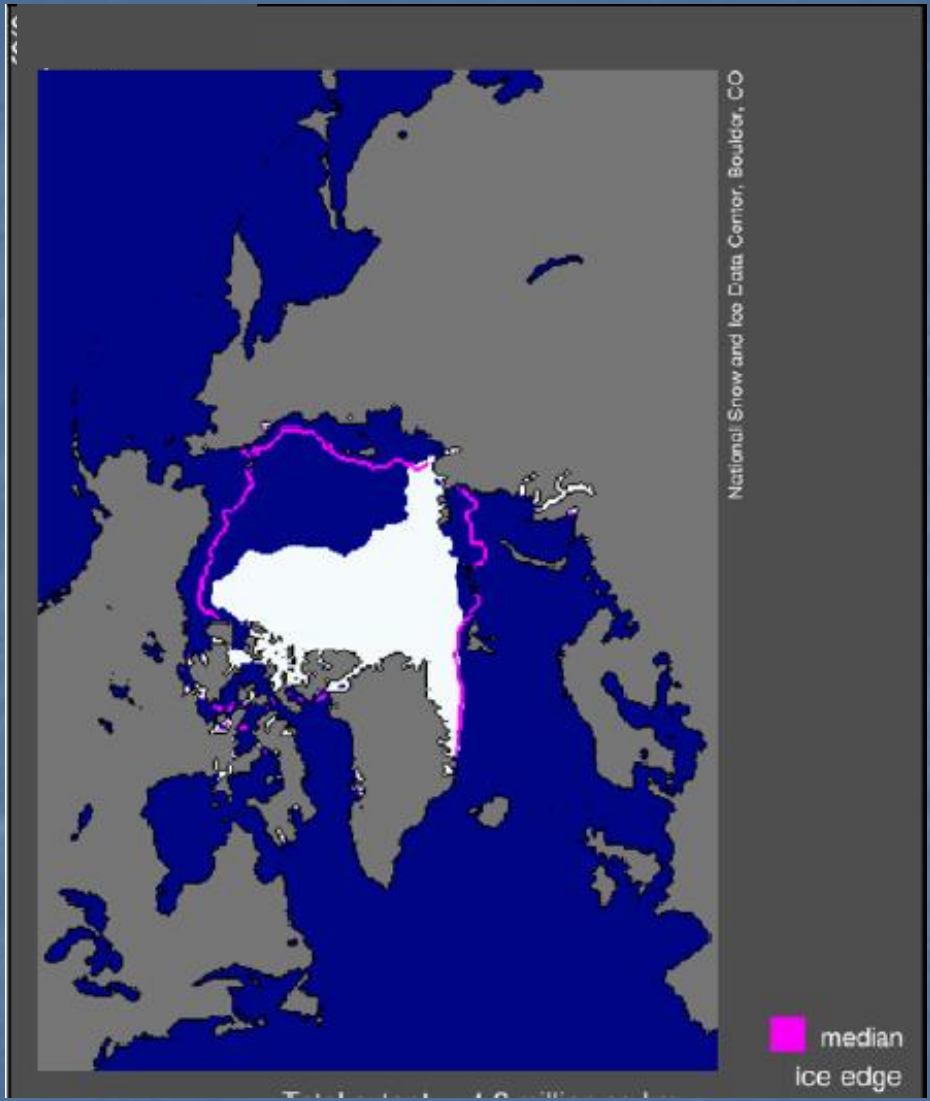


As temperatures have risen, glaciers around the world have shrunk. The graph shows the cumulative decline in glacier ice worldwide.

Arctic summer sea ice is rapidly disappearing… 2009?



September 2005



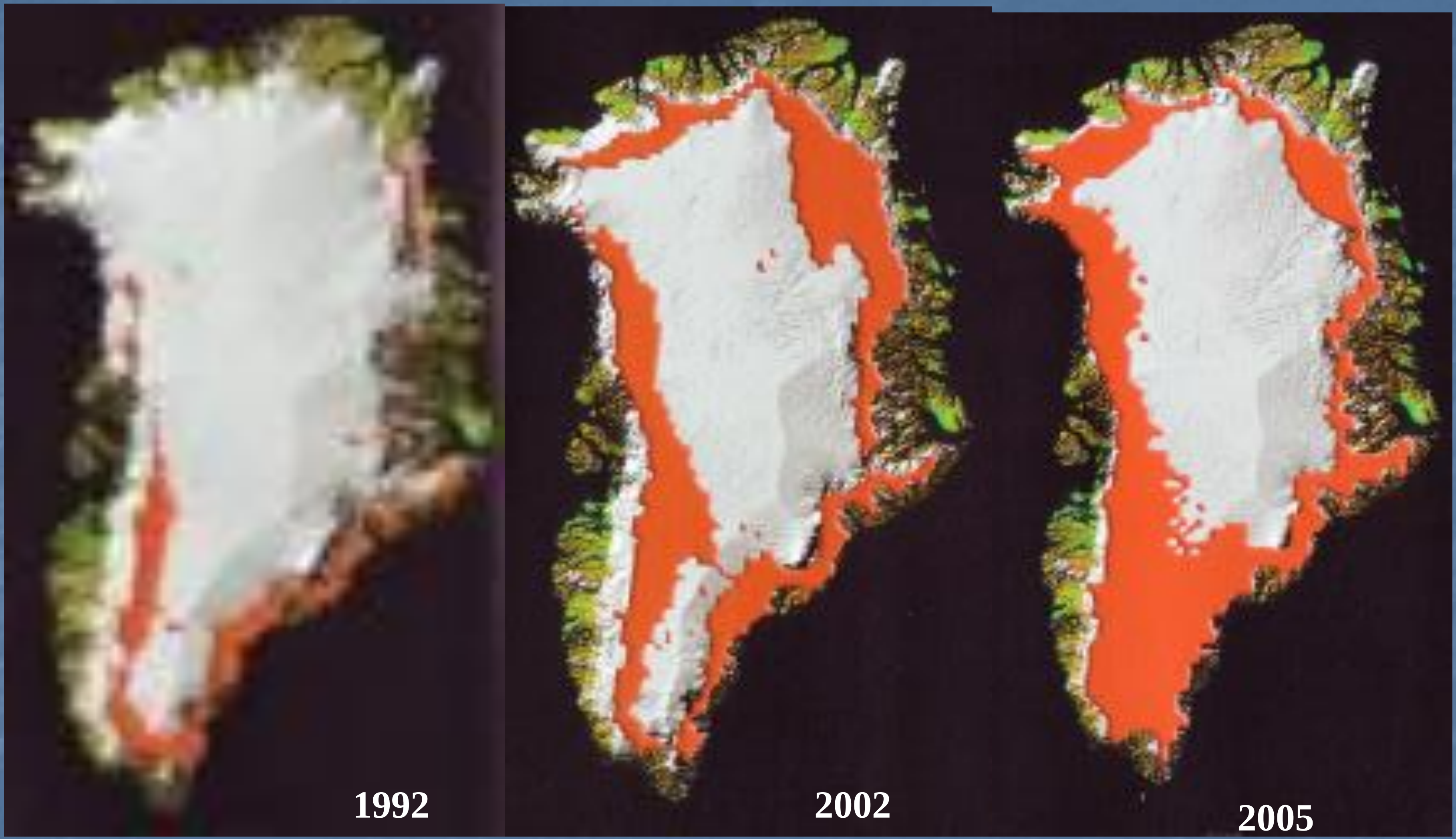
September 2007

US National Snow & Ice Data Center, 2007

Rapid ice melt on a Greenland glacier, October 20, 2006.

- Ice accumulates in the middle of Greenland and melts along the margins
- Until the 1990s, the two were roughly in balance
- In recent years the shift is strongly to greater melting at the surface and margins
- Meltwater lubricates the glaciers and increases rates of movement to the coast
- Greenland ice sheets contain equivalent of 6-7 m (20+ ft) of potential SLR
- Much of Greenland ice melted during last interglacial warm period

Greenland ice sheet melting is accelerating……



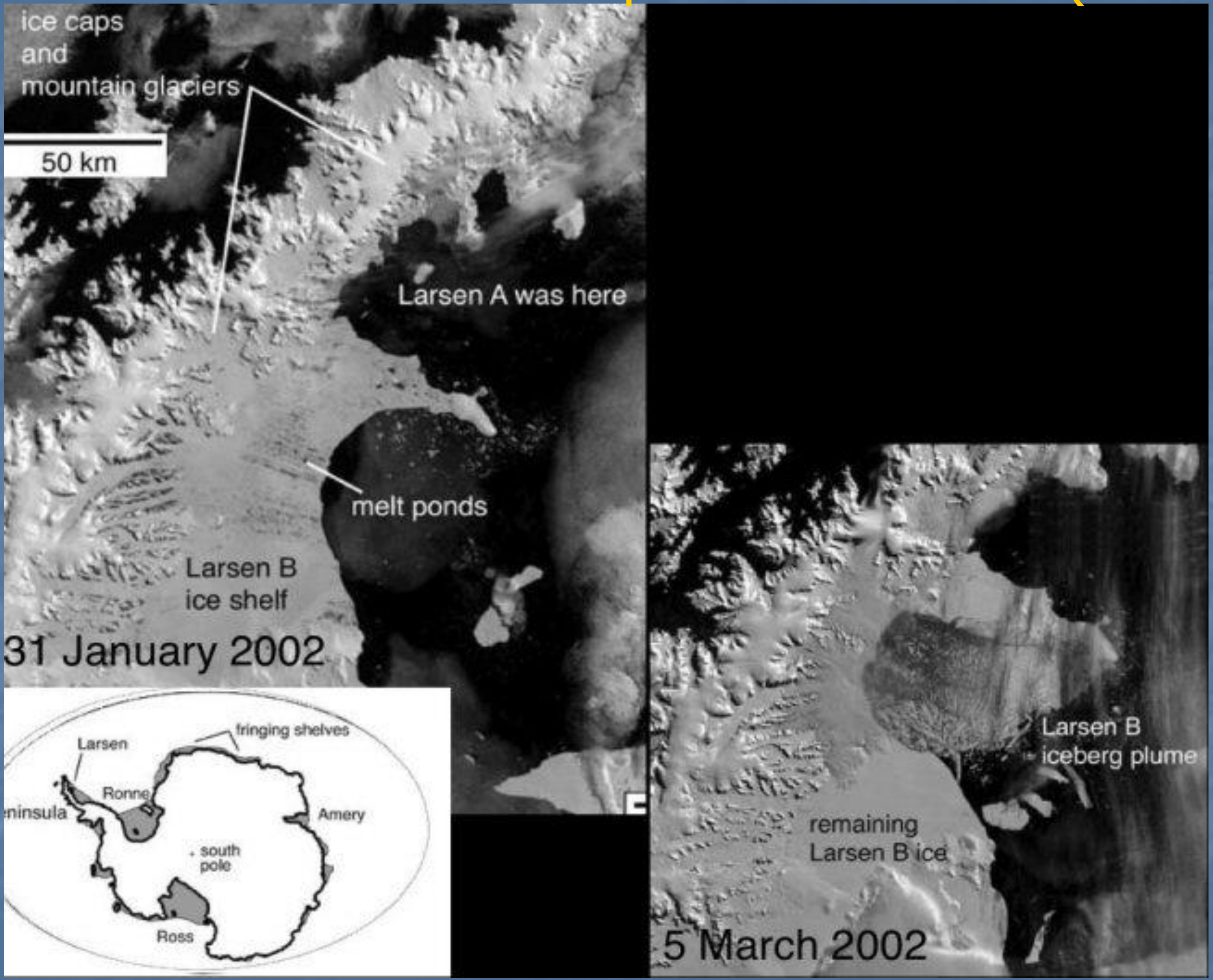
In 1992, scientists measured the amount of melting in Greenland as indicated by red areas

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

In 2005, melting accelerated dramatically yet again

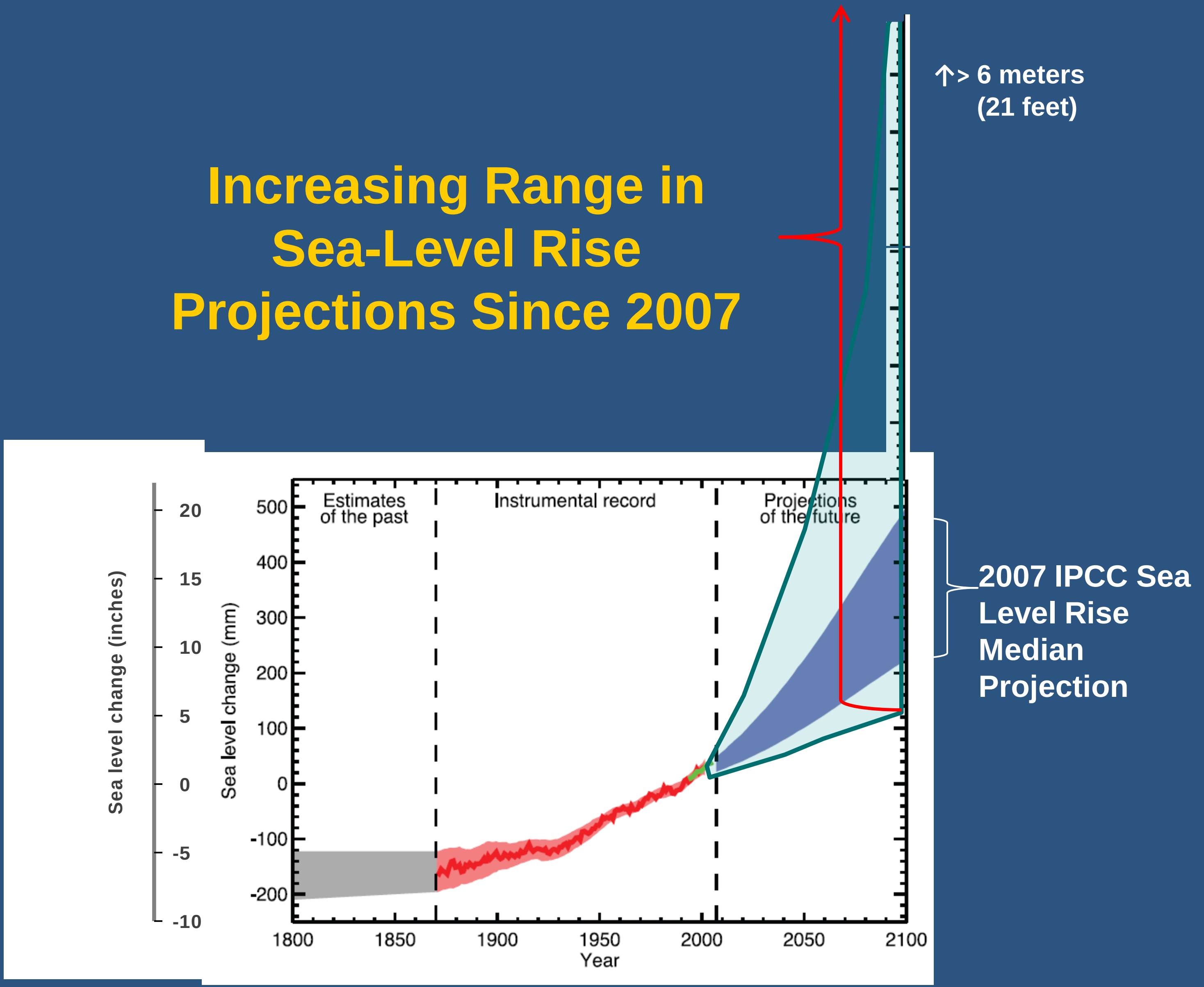
Source: ACIA, 2004 and CIRES, 2005

West Antarctic ice shelves are breaking off….
…….Antarctica ice contains equivalent of 73 m (240 ft) of SLR



Satellite photos from National Snow and Ice Data Center
http://nsidc.org/iceshelves/larsenb2002/

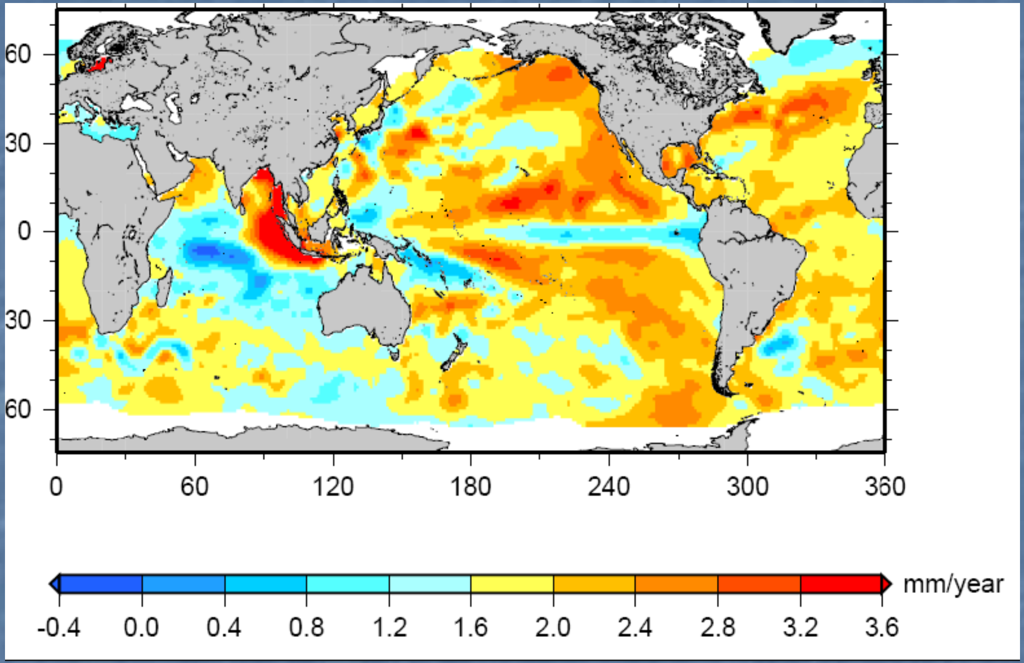
Increasing Range in Sea-Level Rise Projections Since 2007



Adapted from FAQ 5.1. Figure 1. Chapter 5: Observations: Oceanic Climate Change and Sea Level. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

fig from Patrick Gleason

Regional Variability in Observed Sea Level Rise (1955 to 2003)



(combined tide gauge and satellite altimetry record, source IPCC WG1 2007, updated from Church et al. 2004)

- **Sea level rise extremes will have greatest affect on low lying coasts – not the global or regional average change in sea level**
- **SLR may be 30-51 cm greater than global average for NE U.S. by year 2100 due to accelerated Greenland melting and shifts in ocean currents (NSF News, 28 May 2009)**

Protection and Retreat Options
(CCSP, SAP 4.1, 2009)

- Fundamental alternatives for responding to sea-level rise:
  - Shoreline armoring (hard structures, nourishment)
  - Elevate land, structures, beaches, wetlands
  - Strategic retreat landward to higher elevations

- Tradeoffs between different approaches:
  - Shoreline protection maintains existing land use
  - Protection may not be sustainable under high rates of SLR
  - Sediment suitable for nourishment and land elevation may not be available
  - Retreat allows natural processes to operate
  - Costs and social implications vary by region, by state, by locale
  - Higher rates of SLR may shift the balance toward retreat

SLR vulnerability mapping strategy

1) Determine a range of future sea-level rises for planning time frame (i.e. 0.5m by 2050; 1-2m by 2100)

2) Get accurate geo-referenced elevation (lidar) and coastal image data as well as infrastructure, economic and social data. Test and report vertical accuracy of lidar as a measure of uncertainty

3) Characterize the coast's geology and processes
to determine where inundation, erosion will be primary effect

4) Run various simulations based on different sea-level rises and different storm activity

5) Produce static maps of potential area impacts. Apply elevation uncertainty information in development of vulnerability maps and area statistics

The Resilient Coasts Blueprint- Principles

- Identify and fill gaps in scientific understanding and develop tools and methodologies needed for incorporating climate change into risk assessments and mitigation decisions
- Require risk-based land use planning
- Design adaptable infrastructure and building code standards to meet future risk
- Strengthen ecosystems as part of a risk mitigation strategy
- Develop flexible adaptation plans
- Maintain a viable private property and casualty insurance market
- Integrate climate change impacts into due diligence for investment and lending

From "Resilient Coasts" A Blueprint for Action (Heinz Center/Ceres, 2009)

Conclusions

- Climate systems are complex. Humans are altering global climate. Climate is becoming more variable, less predictable, warmer. Effects: sea-level rise, more storminess, more erosion, more floods and droughts. Rates of change are a concern
- Sea-level rise and storms are primary drivers of coastal change, both are increasing. Erosion and flooding will increase in magnitude and frequency
- Oceans are warming, SLR is accelerating due to thermal expansion and increased melting of glaciers and ice sheets. Future sea level likely ~1m higher by year 2100 . Greenland and West Antarctica rapid melting are concerns
- Warming ocean temps are increasing Atlantic storm intensity in addition to natural cycles of storm activity. Effects on storm frequency are still uncertain

Dauphin Isl, Alabama

Solutions

- Mitigation and Adaptation- cut carbon release with new technologies; conservation; improve science and monitoring; include climate science in coastal planning and management; keep plans flexible

USGS