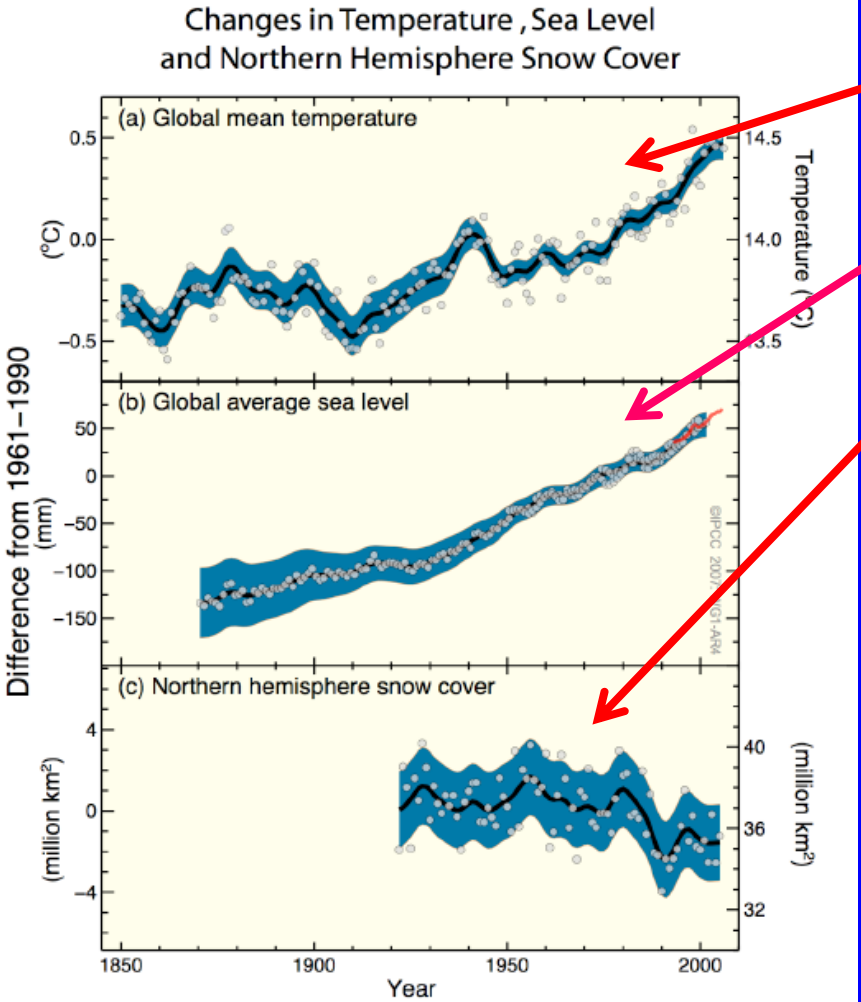
Sea Level Rise: From the Global to the Local

Michael Oppenheimer
Princeton University
At
Mid-Atlantic Governors' Ocean Summit
4 June 2009

Climate changes, and related sea level rise ***already underway:***



- Temperature
- Sea level
- Ice (glaciers) and snow
- Extreme heat(⇑), cold(⇓)
- Rainstorm intensity and drought (⇑)
- Tropical cyclones
- Ocean acidity

IPCC AR4 WGI SPM

Focus on global mean sea level: Already rising, accelerating

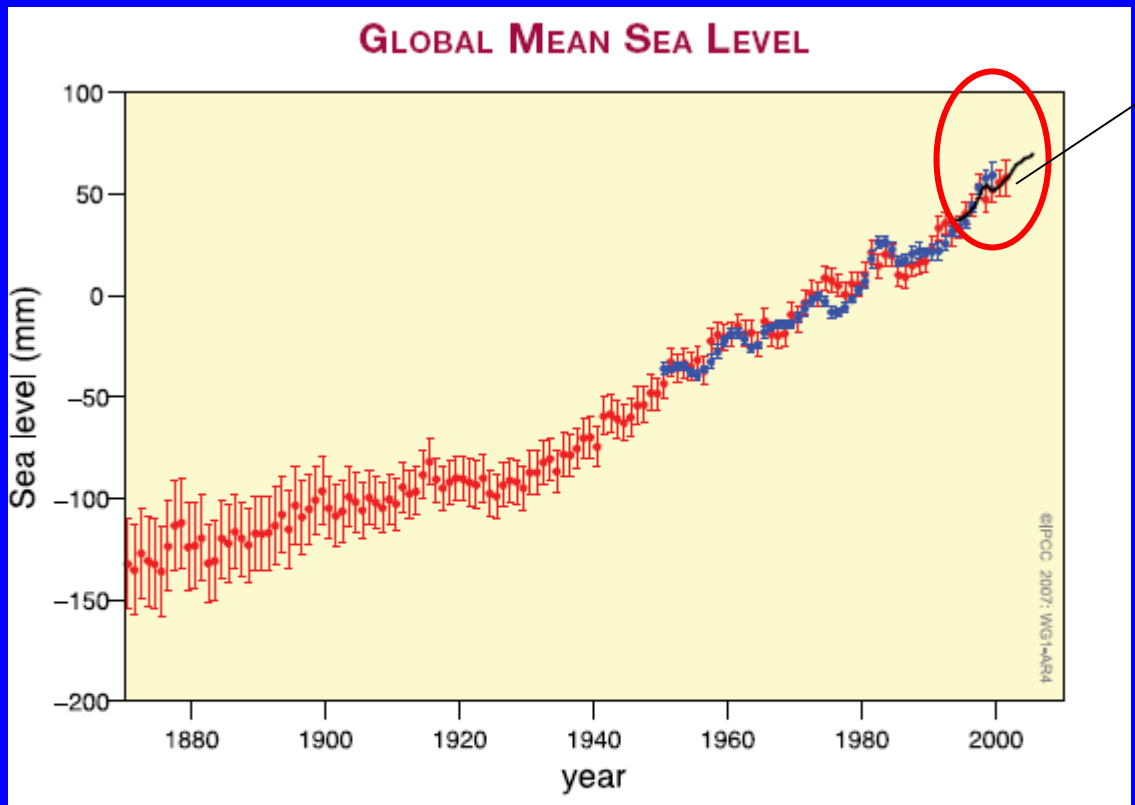


Figure TS.18. *Annual averages of the global mean sea level based on reconstructed sea level fields since 1870 (red), tide gauge measurements since 1950 (blue) and satellite altimetry since 1992 (black). Units are in mm relative to the average for 1961 to 1990. Error bars are 90% confidence intervals. {Figure 5.13}*

Current rate:
~3mm/yr

~0.2m/C
= 2mm/yr

Trends in total sea level

Trends in thermal expansion

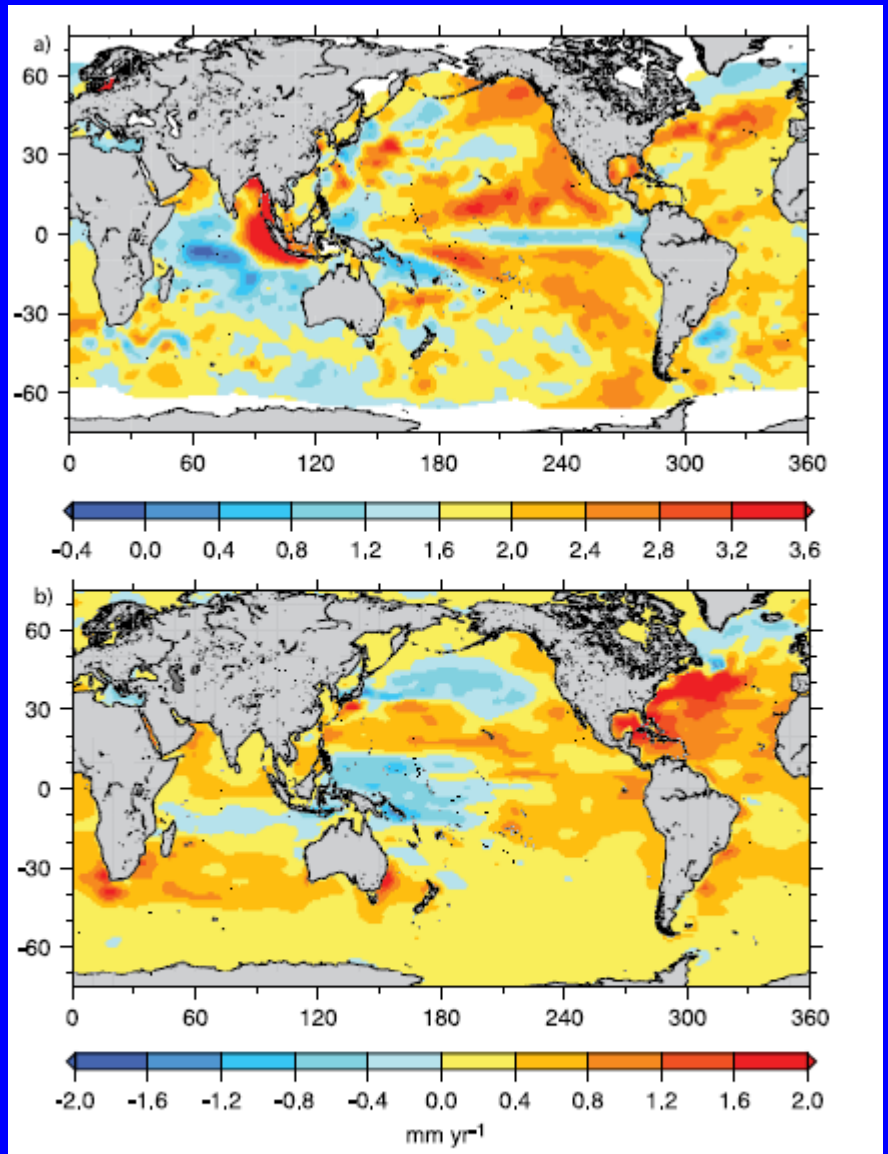


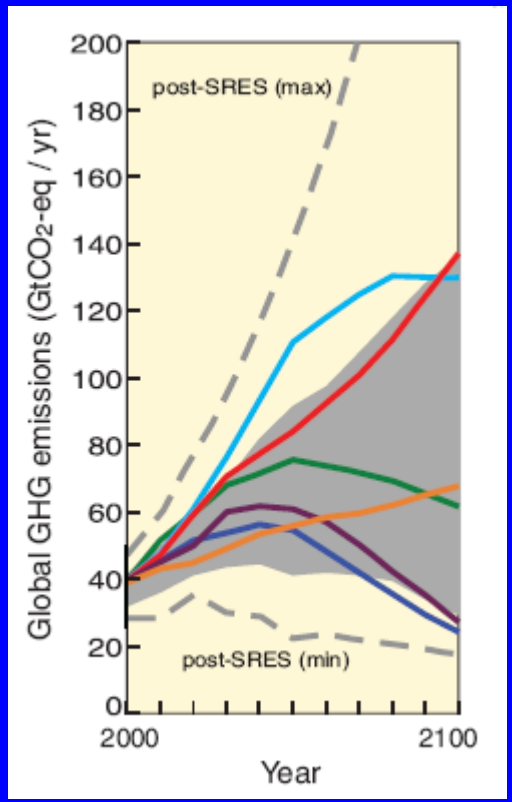
Figure 5.16. *(a) Geographic distribution of long-term linear trends in mean sea level (mm yr^{-1}) for 1955 to 2003 based on the past sea level reconstruction with tide gauges and altimetry data (updated from Church et al., 2004) and (b) geographic distribution of linear trends in thermal expansion (mm yr^{-1}) for 1955 to 2003 (based on temperature data down to 700 m from Ishii et al., 2006). Note that colours in (a) denote 1.6 mm yr^{-1} higher values than those in (b).*

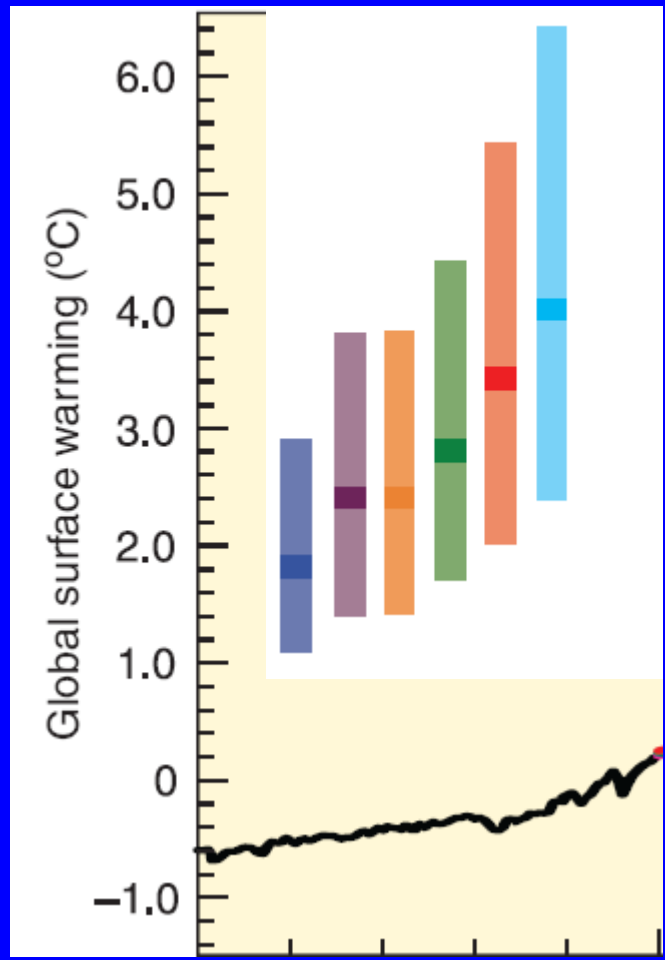
Trends differ regionally, due to regional differences in thermal expansion, local subsidence, sedimentation, etc.

AR4 WGI Ch 5

Problem: The World Is Warming, More Sea Level Rise to Come

Future emissions





Future Warming

Warming 1900 - 1990

IPCC AR4 SYR

Unanticipated ice sheet contribution to recent trend is worrisome

Table TS.3. *Contributions to sea level rise based upon observations (left columns) compared to models used in this assessment (right columns; see Section 9.5 and Appendix 10.A for details). Values are presented for 1993 to 2003 and for the last four decades, including observed totals. {Adapted from Tables 5.3 and 9.2}*

	Sea Level Rise (mm yr^{-1})			
	1961–2003		1993–2003	
Sources of Sea Level Rise	Observed	Modelled	Observed	Modelled
Thermal expansion	0.42 ± 0.12	0.5 ± 0.2	1.6 ± 0.5	1.5 ± 0.7
Glaciers and ice caps	0.50 ± 0.18	0.5 ± 0.2	0.77 ± 0.22	0.7 ± 0.3
Greenland Ice Sheet	0.05 ± 0.12[a]		0.21 ± 0.07[a]	
Antarctic Ice Sheet	0.14 ± 0.41[a]		0.21 ± 0.35[a]	
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	1.2 ± 0.5	2.8 ± 0.7	2.6 ± 0.8
Observed total sea level rise	1.8 ± 0.5 (tide gauges)		3.1 ± 0.7 (satellite altimeter)	
Difference (Observed total minus the sum of observed climate contributions)	0.7 ± 0.7		0.3 ± 1.0	

Notes:
[a] prescribed based upon observations (see Section 9.5)

Leads to large uncertainty in future rise

Continental Ice Sheets: A large hazard

~7m

~5m

~60m

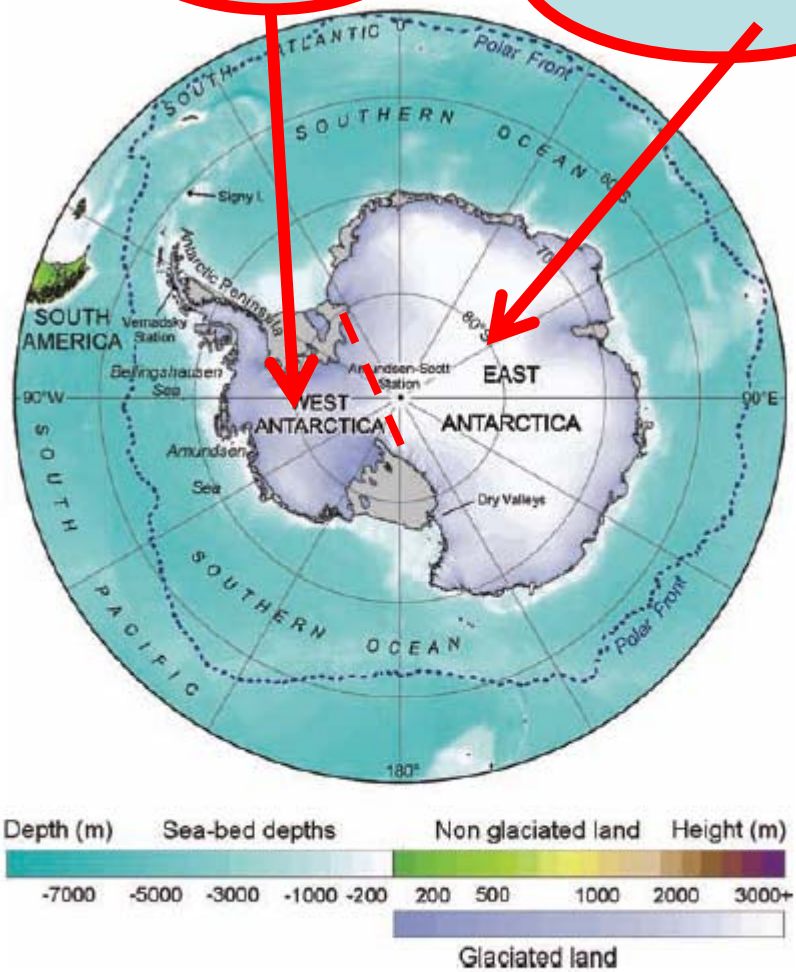
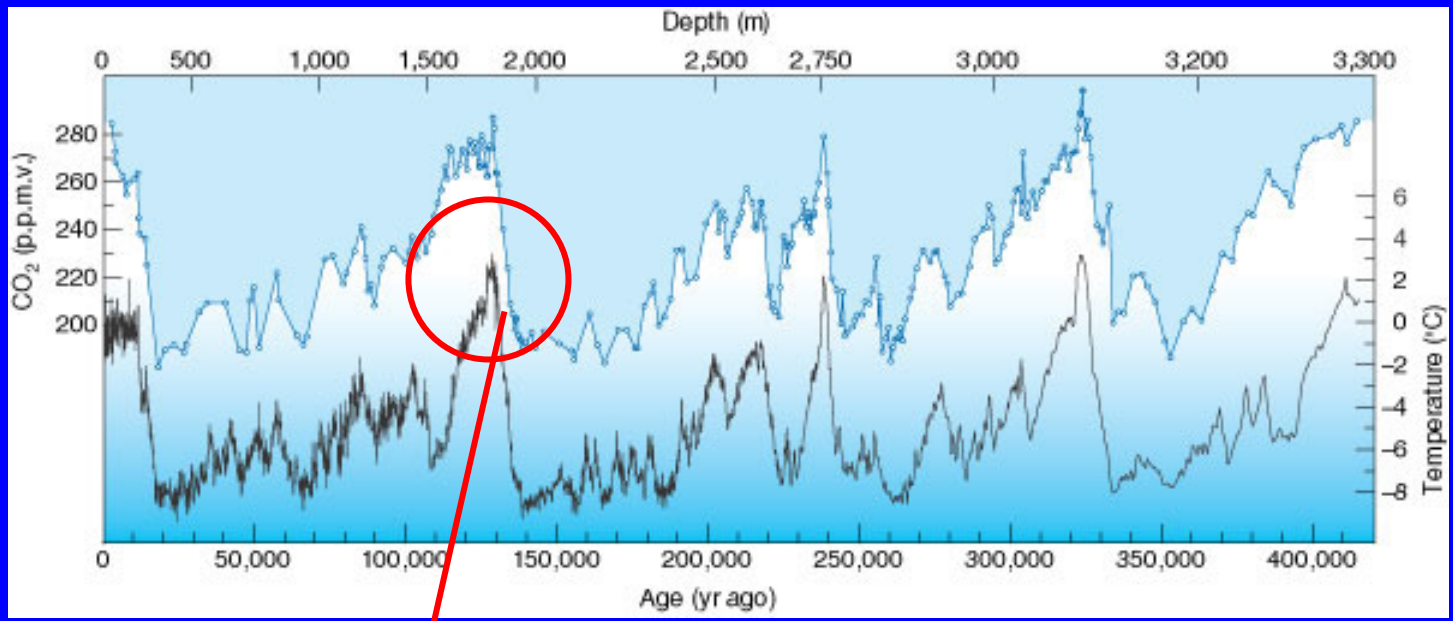


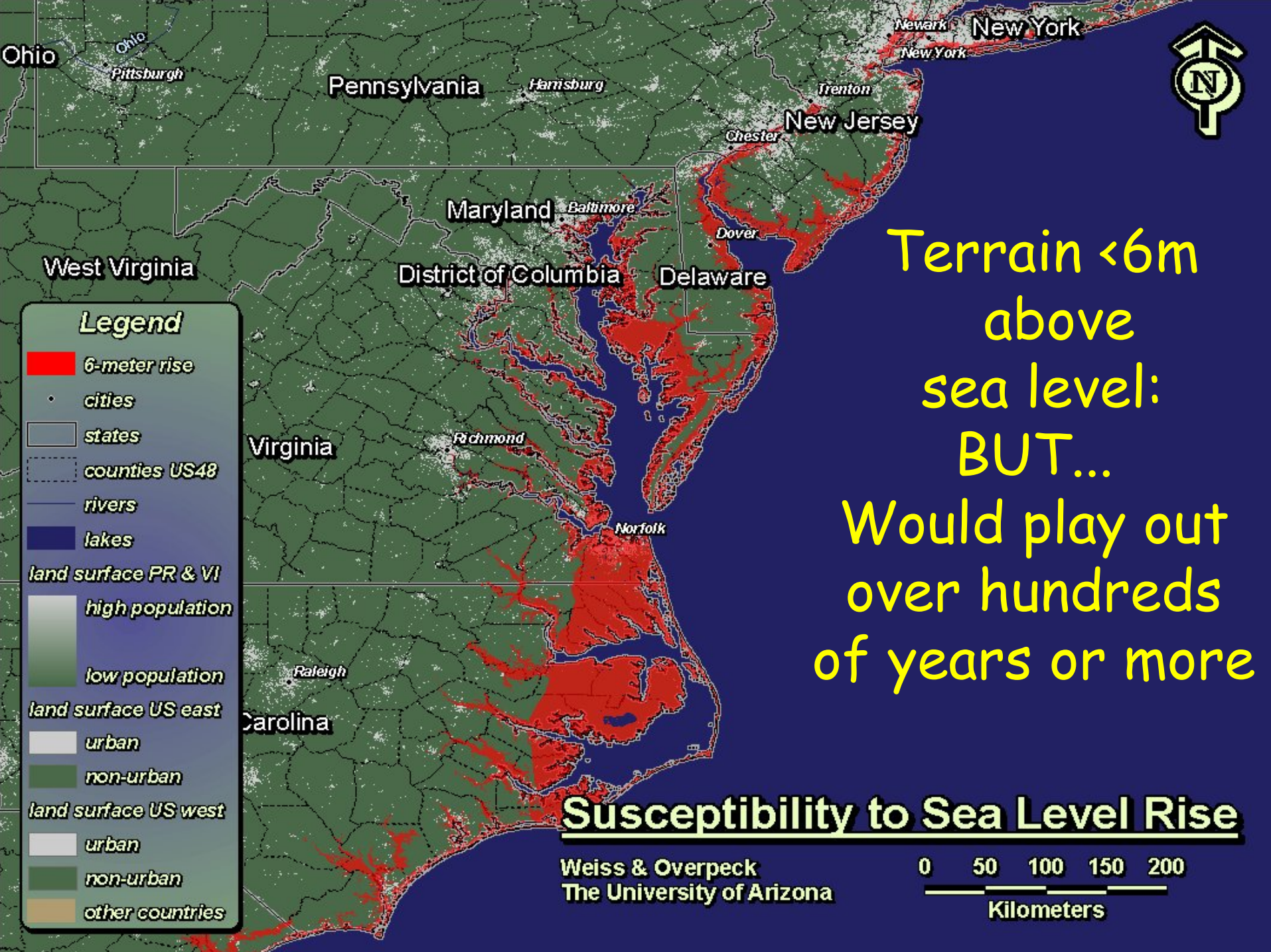
Figure 15.1. *Location maps of the North and South polar regions, including place names used in the text. The topography of glaciated and non-glaciated terrain is shown by using different shading schemes. The polar fronts shown are intended to give an approximate location for the extent of cold, polar waters but are, in places, open to interpretation and fluctuations. (This and other maps were drawn by P. Fretwell, British Antarctic Survey.)*

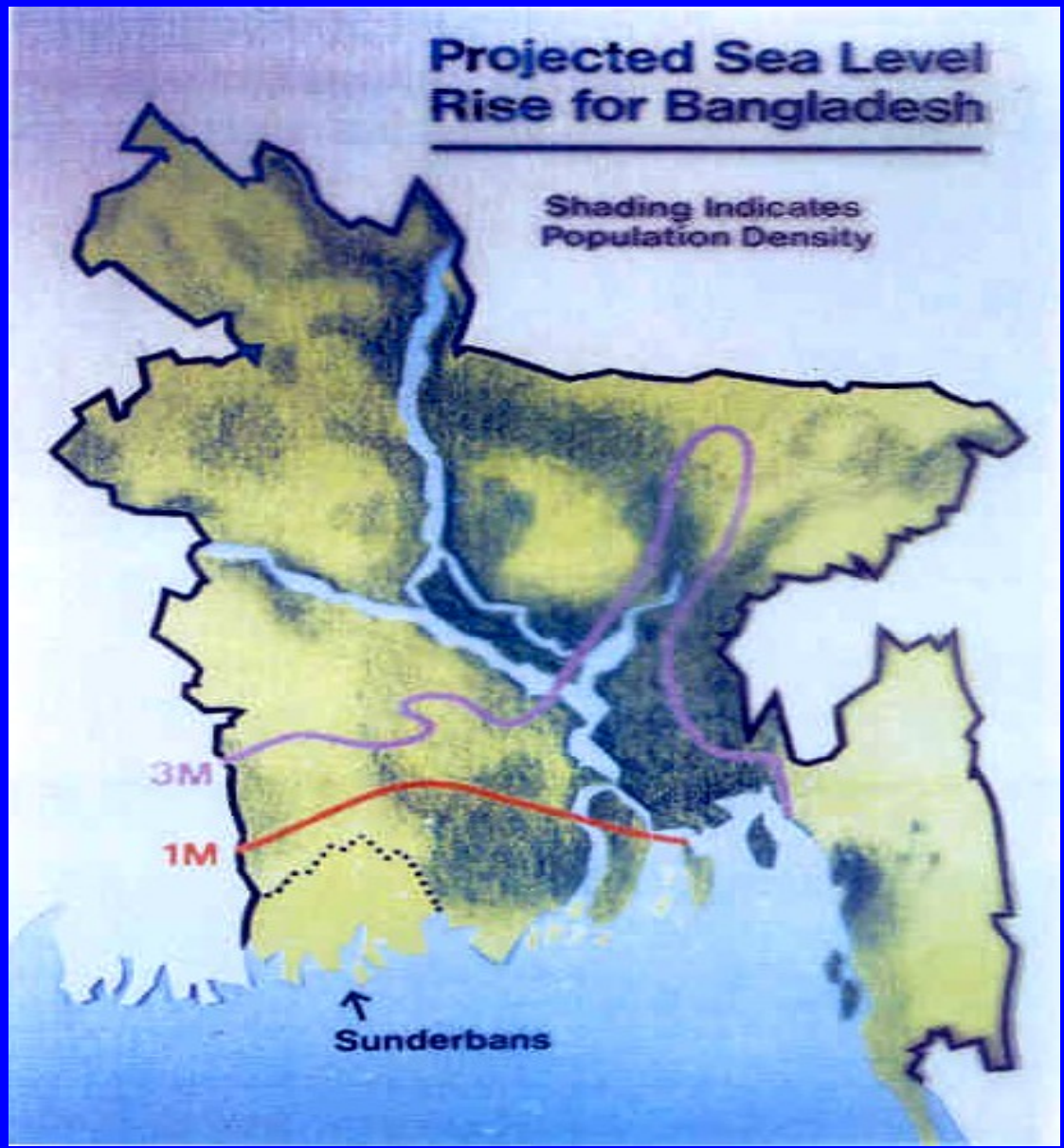
Nature/Vol. 419/12 September 2002, pg. 189

Could this really happen?



Last Interglacial (LIG): Poles 3-5^{0}C warmer....
Sea level 4-6m higher
with
Rates as high as 1m/century!


Ohio
Pittsburgh
Pennsylvania
Harrisburg
Newark
New York
New York
Trenton
New Jersey
Chester
Maryland
Baltimore
Dover
West Virginia
District of Columbia
Delaware
Virginia
Richmond
Norfolk
Raleigh
Carolina
Legend
6-meter rise
cities
states
counties US48
rivers
lakes
land surface PR & VI
high population
low population
land surface US east
urban
non-urban
land surface US west
urban
non-urban
other countries
Terrain <6m above sea level: BUT… Would play out over hundreds of years or more
Susceptibility to Sea Level Rise
Weiss & Overpeck
The University of Arizona
0 50 100 150 200
Kilometers

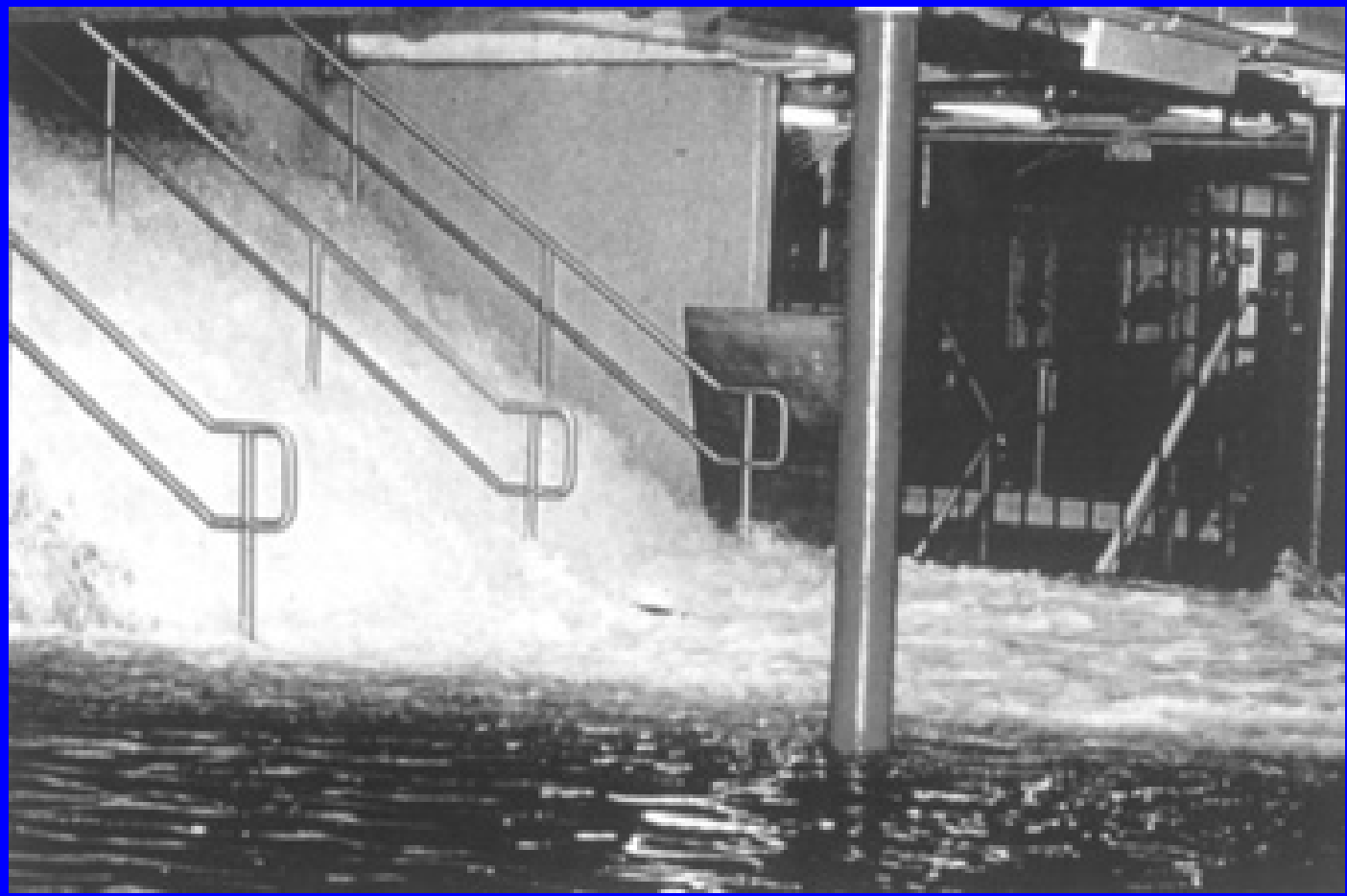


Even without large ice-sheet contribution, sea level rise of ~1 meter this century could prove disastrous in some regions

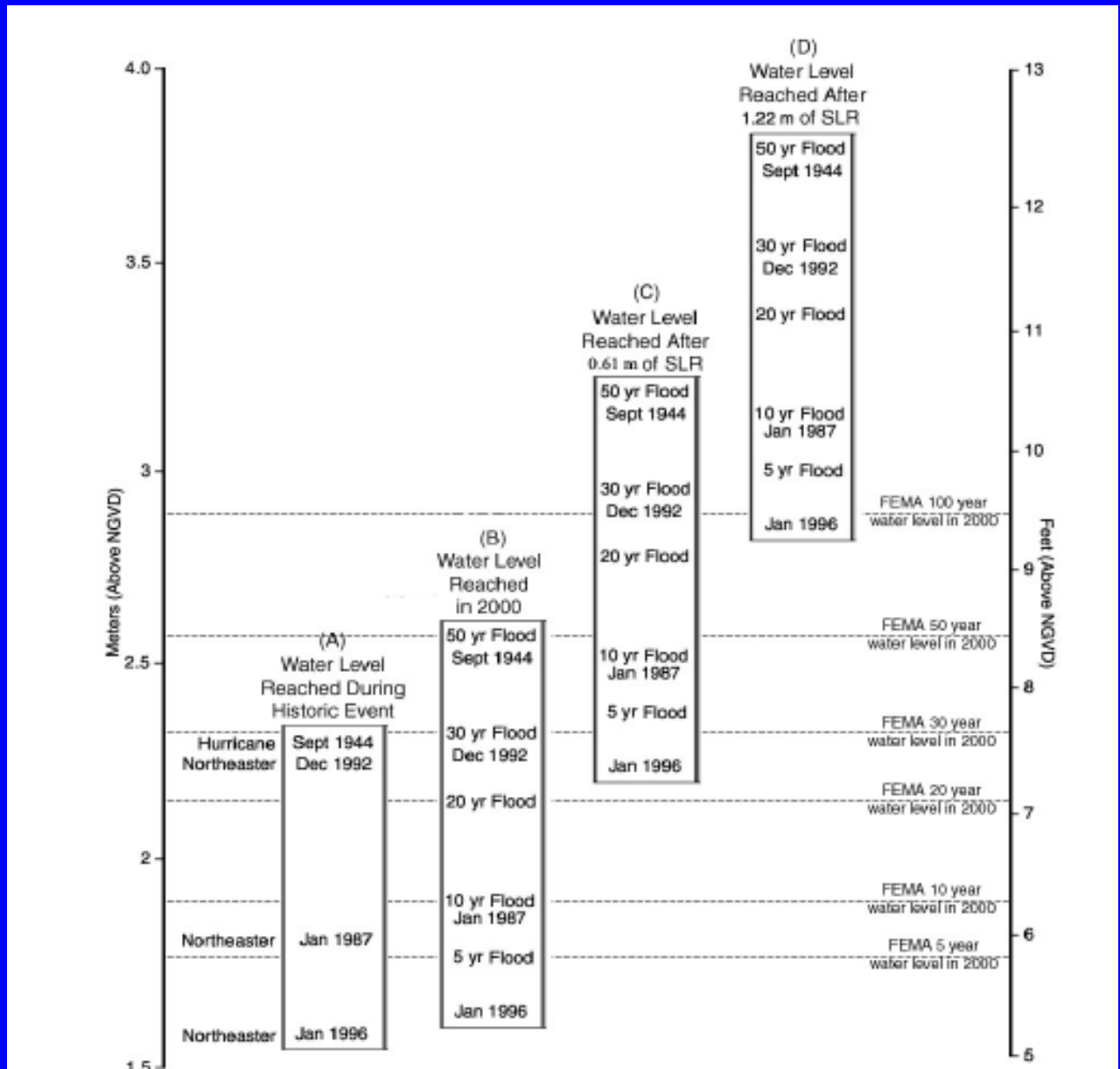
Courtesy J. Broadus


This is how we are preparing for the threat…
TAJ MAHAL
SHOWBOAT
Courtesy Norm Psuty

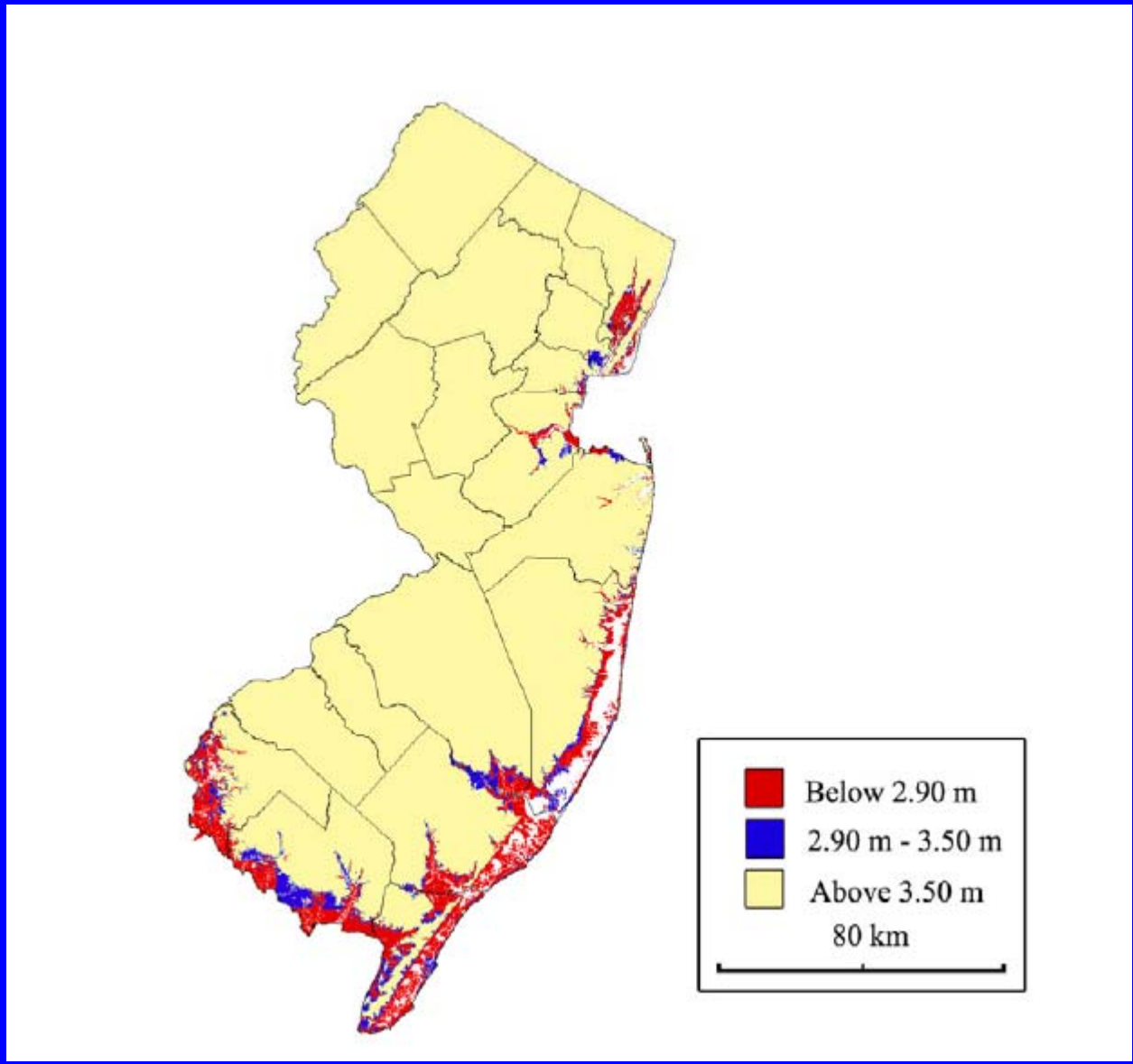
Hoboken PATH station, 1992 Nor'easter



Flood line for storm + 2-4ft rise



Storm-flood risk for New Jersey



Rosenzweig, Cynhtia and William D. Solecki, Climate Change and a Global City: The Potential Consequences of Climate Variability and Change, pg. 35, Columbia University 2001

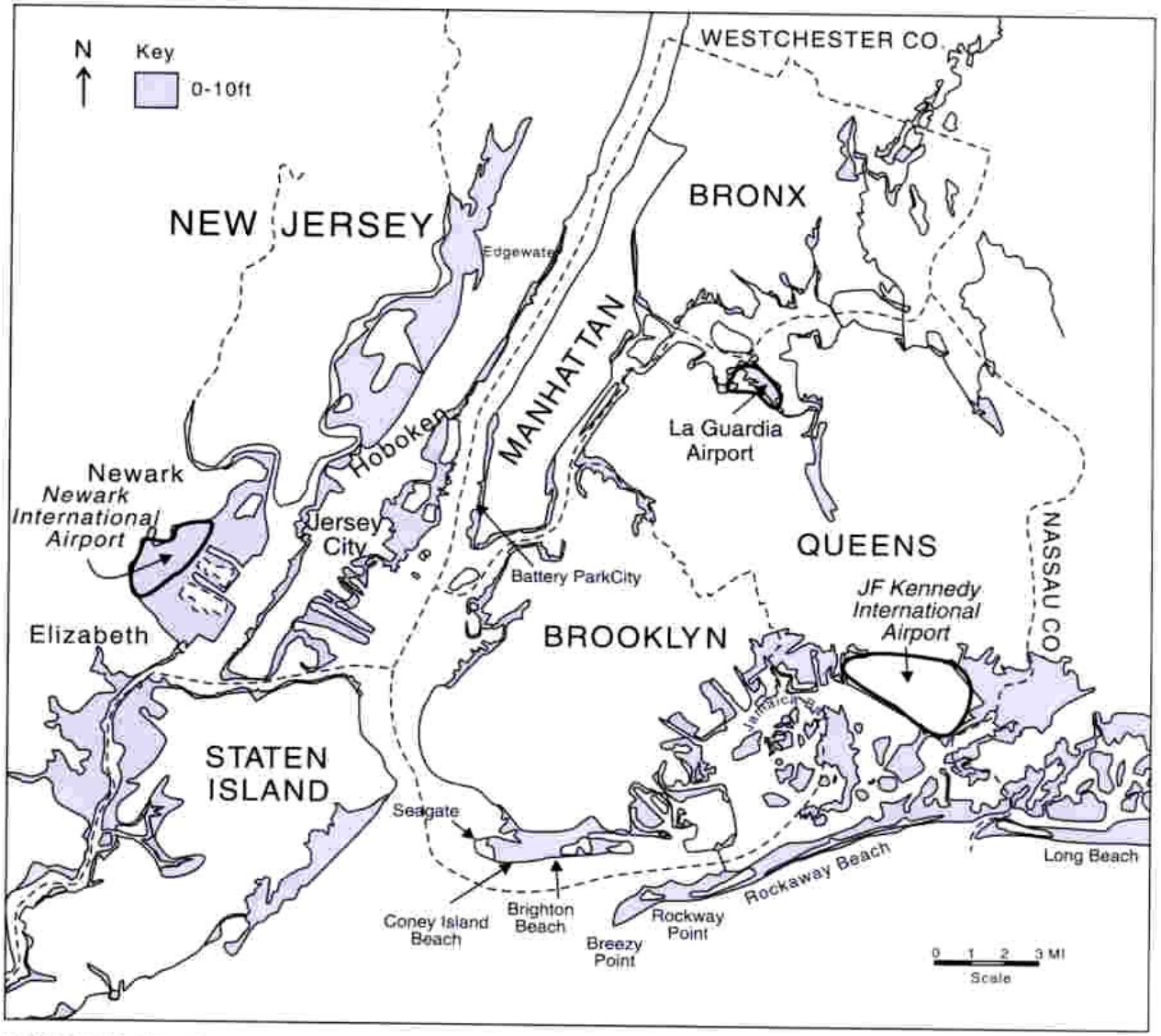
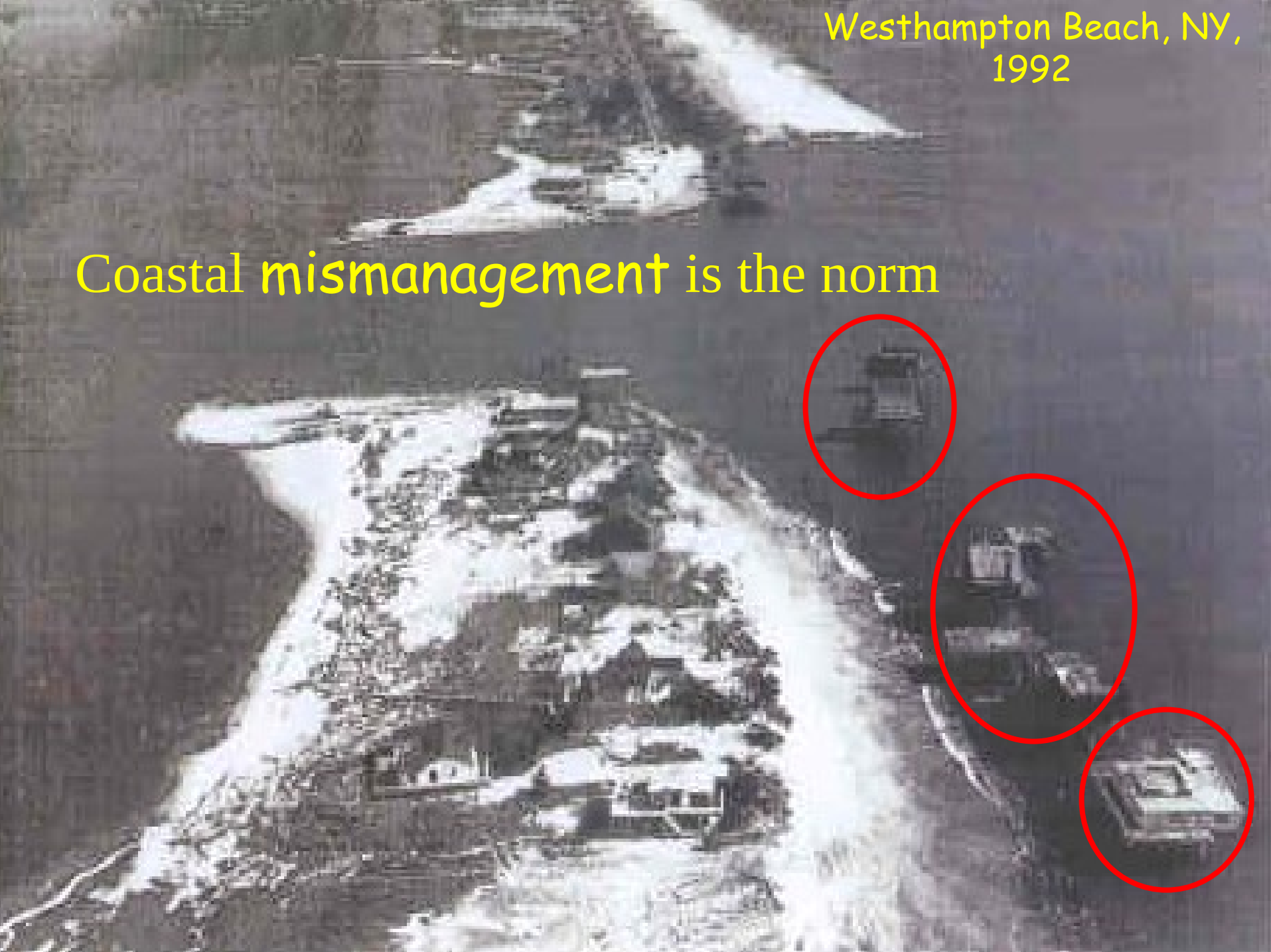


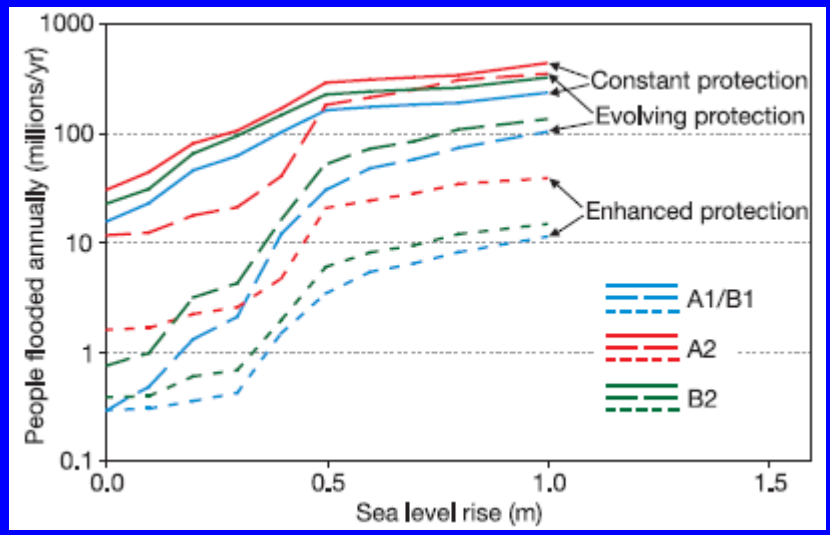
FIGURE 3-15 Flood risk zone, New York City metropolitan area.

Infrastructure at risk:

10-foot flood line=100yr return of flood


Westhampton Beach, NY,
1992
Coastal mismanagement is the norm

Planned adaptation would make a big difference



Needs:

>> Rational planning

>> Avoiding perverse incentives

>> Thinking through the politics

Figure 1. Estimates of people flooded in coastal areas due to sea-level rise, SRES socioeconomic scenario and protection response in the 2080s. (Source: IPCC Fourth Assessment Report, 2007)