Global climate change primer

December 5, 2007

Jay Gulledge, PhD
Senior Scientist
Program Manager for Science & Impacts
Pew Center on Global Climate Change

…and the kitchen sink

- Pew Center on Global Climate change
- Basic Science
- Man-made Greenhouse Gas Emissions
- Observed & Projected Impacts
- Policy Landscape
  - Economics
  - State Action
  - Business
  - Congress
  - President
  - International

Pew Center on Global Climate Change

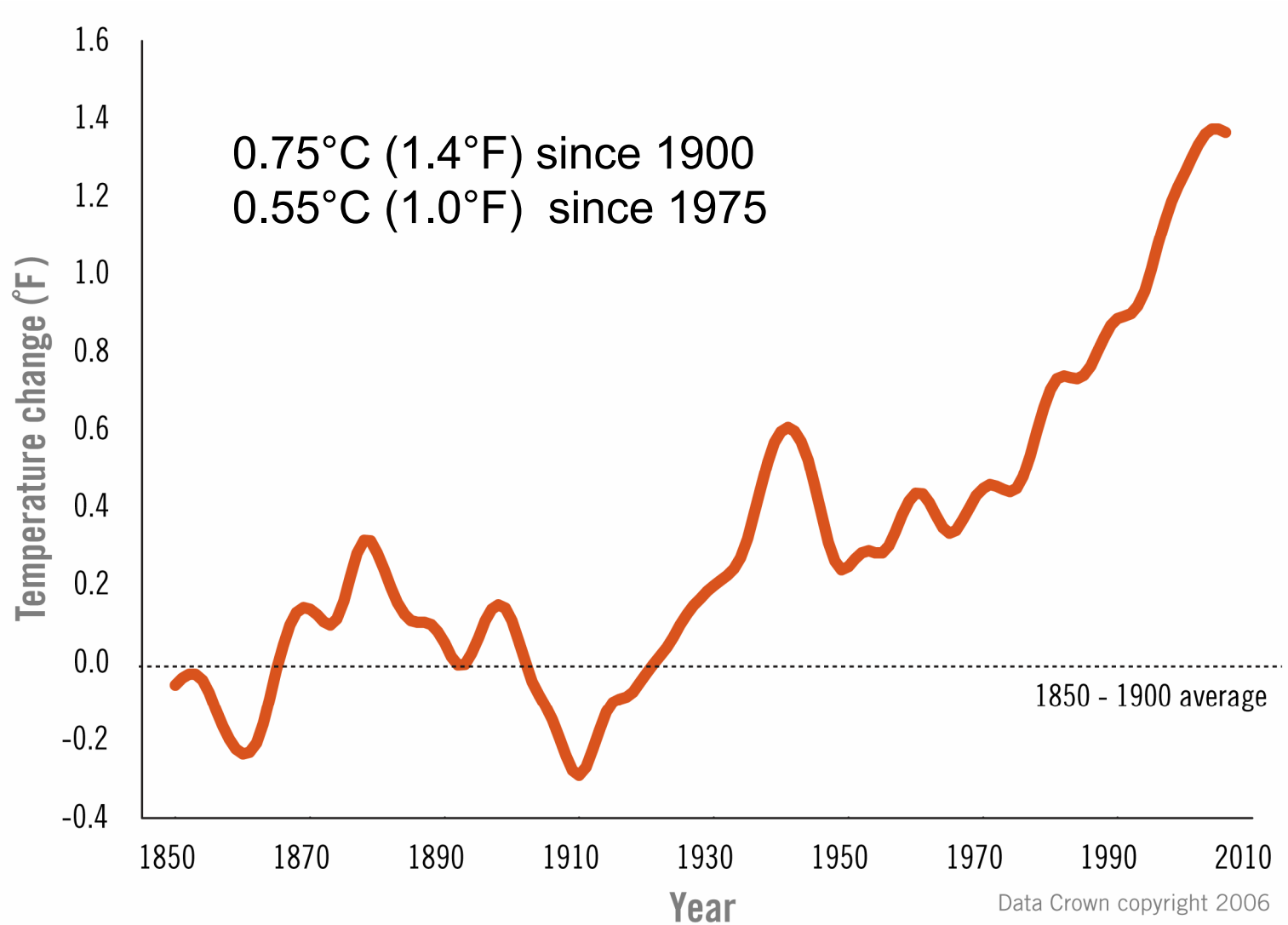
- Founded in May 1998
- Independent, non-profit, non-partisan
- Divided into five major program areas
  - Science & Impacts Studies
  - Domestic & International Strategies
  - Outreach
    - Business
    - States
  - Solutions
  - Communications

45 BELC Companies

PEW CENTER on Global CLIMATE CHANGE

ABB
AIR PRODUCTS
ALCAN
ALCOA
AEP AMERICAN ELECTRIC POWER
BOEING
bp
Bank of America
Baxter
citi
CH2MHILL
Deutsche Telekom
DTE Energy
DUPONT
Duke Energy
Exelon
Cummins
Entergy
GP Georgia-Pacific
GE
hp
Holcim
IBM
intel
Interface
John Hancock
LOCKHEED MARTIN
MARSH
NOVARTIS
ONTARIO POWER GENERATION
PG&E Corporation
PNM Resources
RIO TINTO
ROHM AND HAAS
SC Johnson A FAMILY COMPANY
SUNOCO
TOYOTA
TransAlta
TRAVELERS
United Technologies
Weyerhaeuser
Whirlpool CORPORATION
we energies

Global Surface Warming

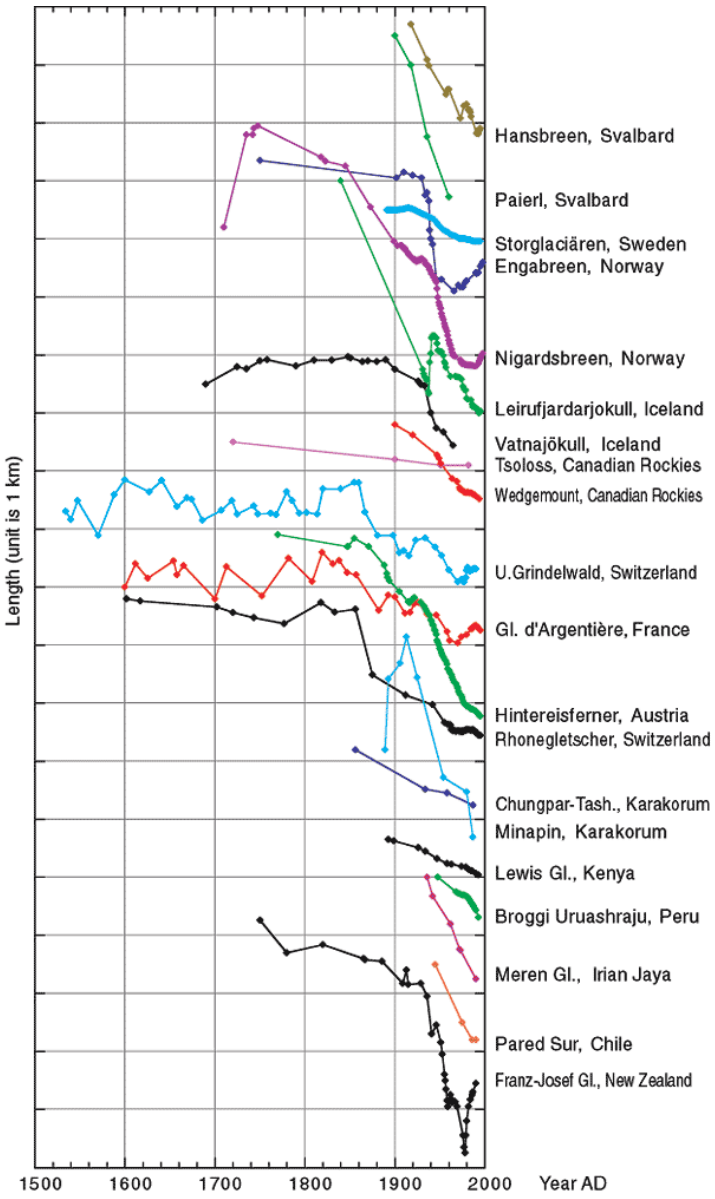


Brohan (2006) JGR

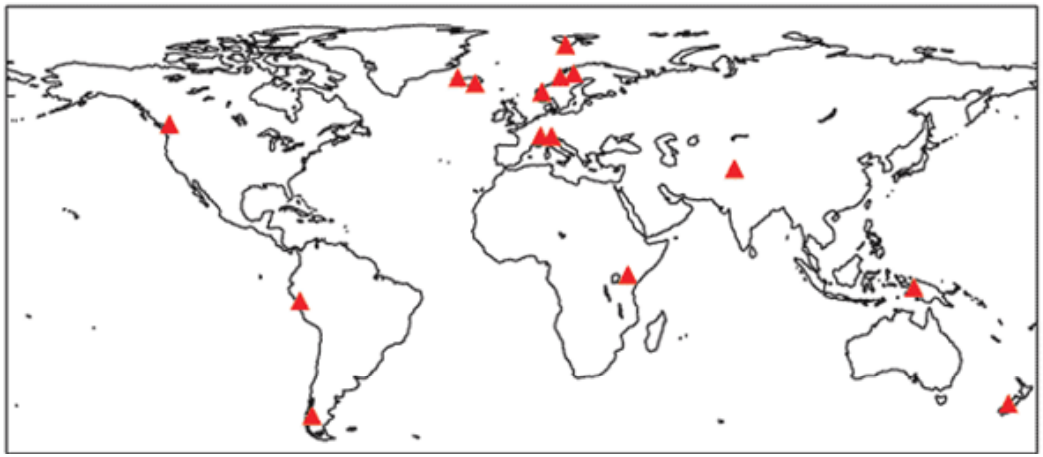
Global Ice Loss

NASA/Goddard Space Flight Center Scientific Visualization Studio; thanks to Rob Gerston (GSFC) for providing the data

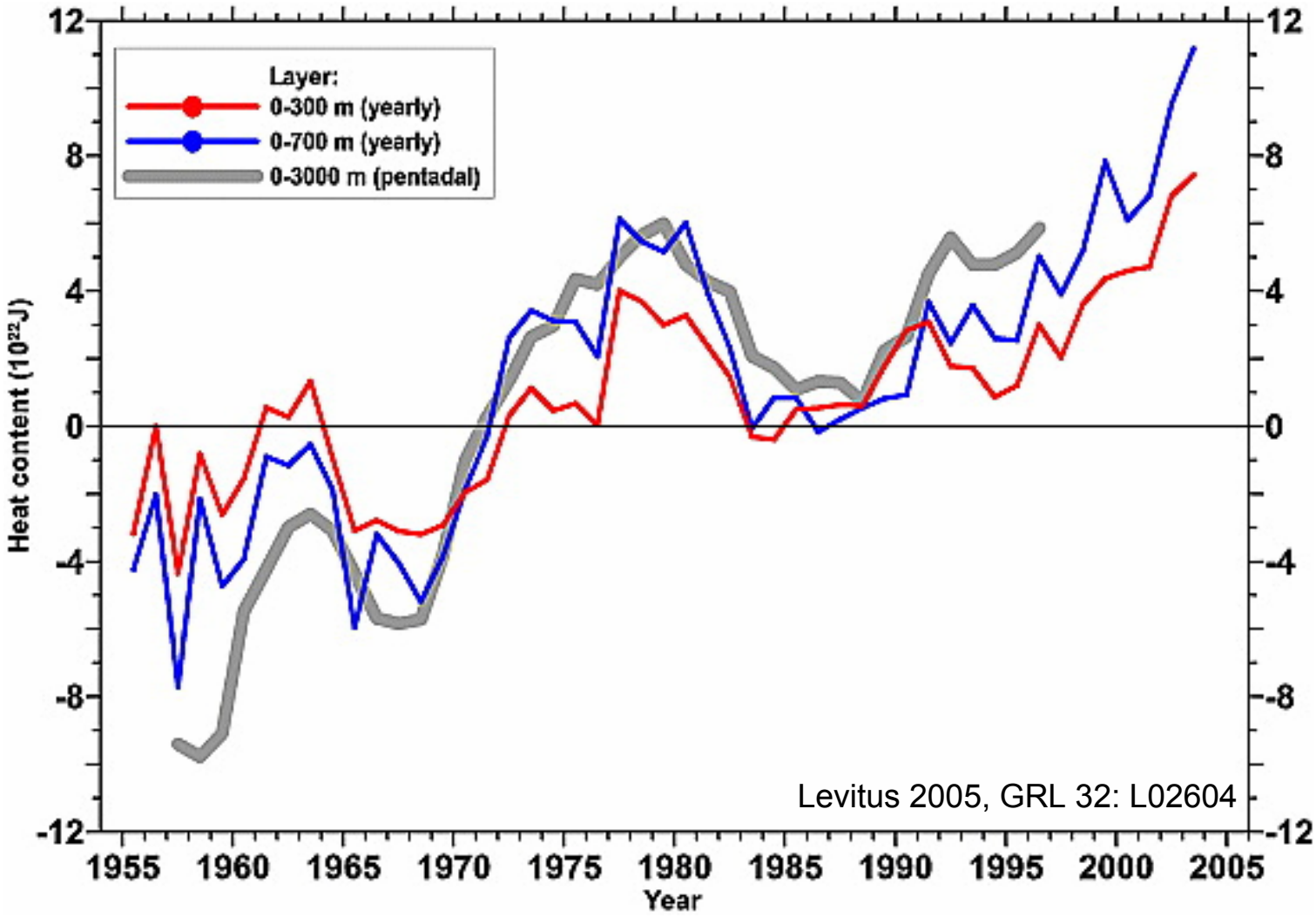
Global Ice Loss



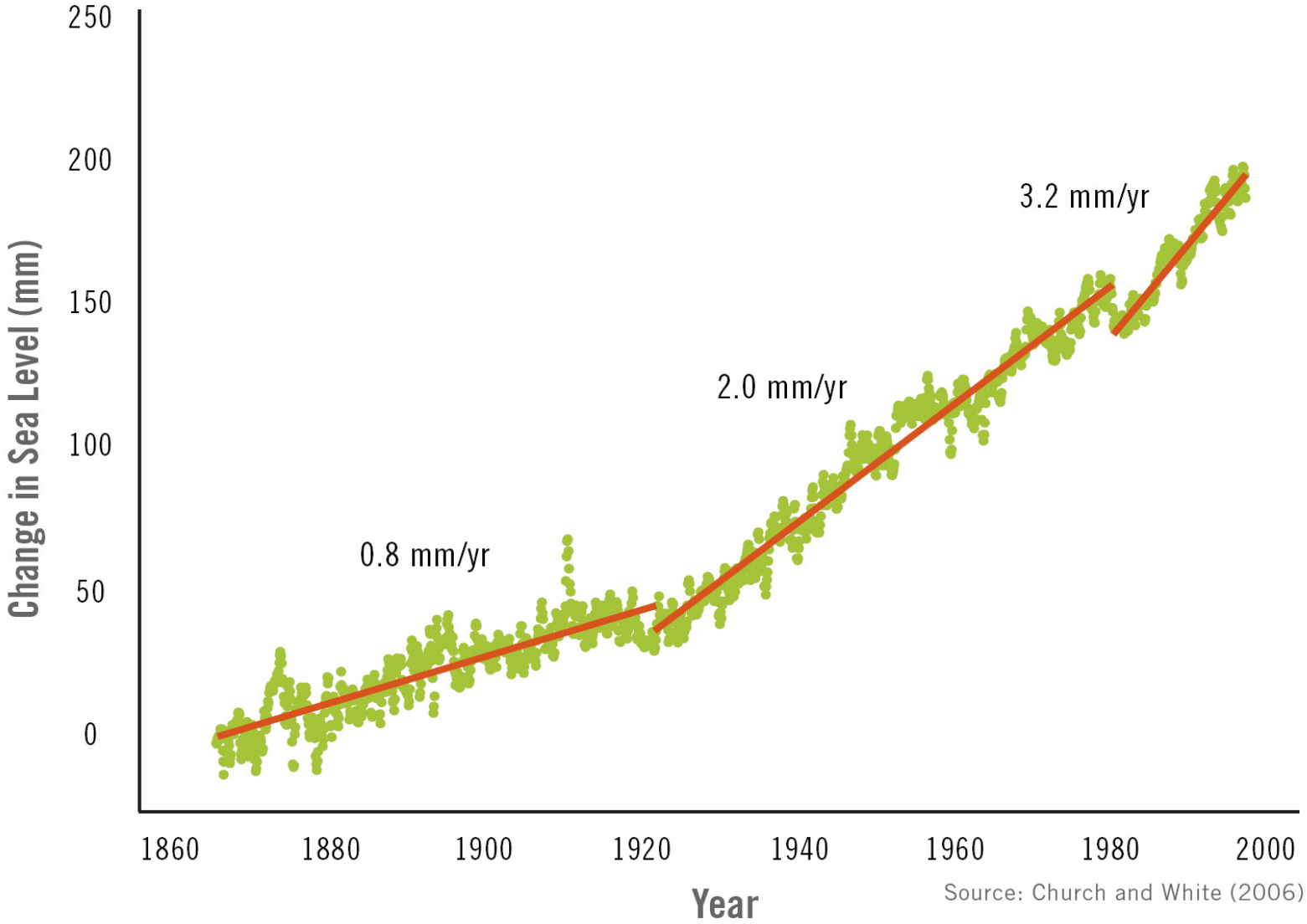
Mountain Glacier Trends



Ocean Heat Content



Accelerating Sea Level Rise



Source: Church and White (2006)

Global Warming "Unequivocal"

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."

- *IPCC 2007*

Why is the Temperature Rising?

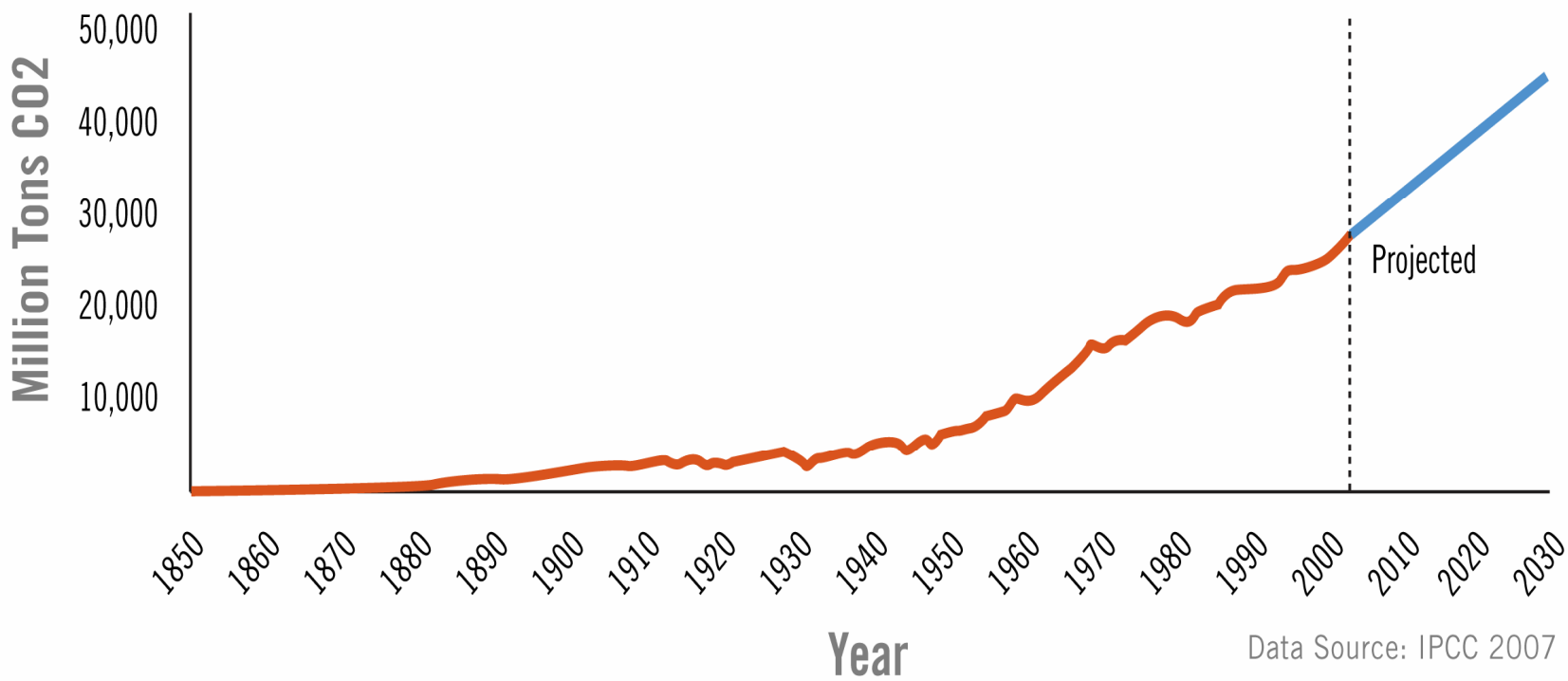
- Human activities?
- Natural variability?

"GHGs are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise"
- National Academy of Sciences 2001

"Studies to detect climate change and attribute its causes using patterns of observed temperature change in space and time show clear evidence of human influences on the climate system"
- U.S. Climate Change Science Program 2006

"Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely [> 90% certainty] due to the observed increase in anthropogenic greenhouse gas concentrations"
- IPCC 2007

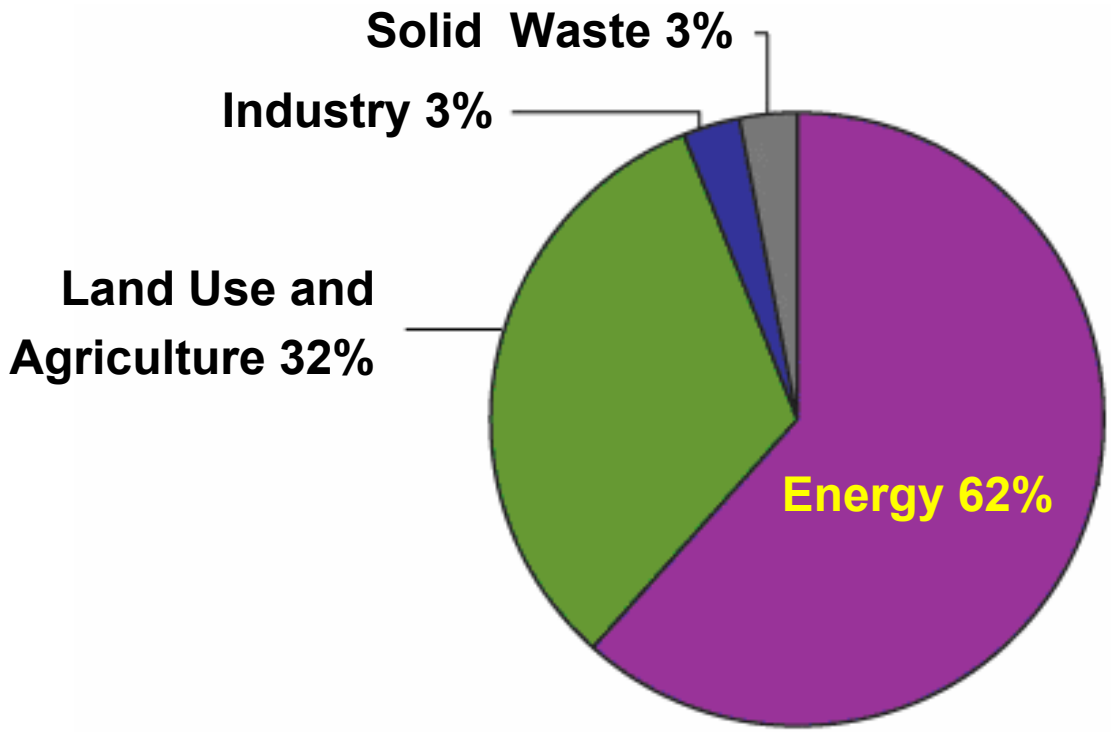
Man-made CO_2 Emissions



- The growth rate of manmade CO_2 emissions increased from 1.1% per year for 1990–1999 to more than 3% y^{-1} for 2000-2004.
- Since 2000, emissions have grown more rapidly than the most fossil-fuel intensive IPCC emissions scenario

Raupach et al., PNAS 2007

Global GHG Contributors

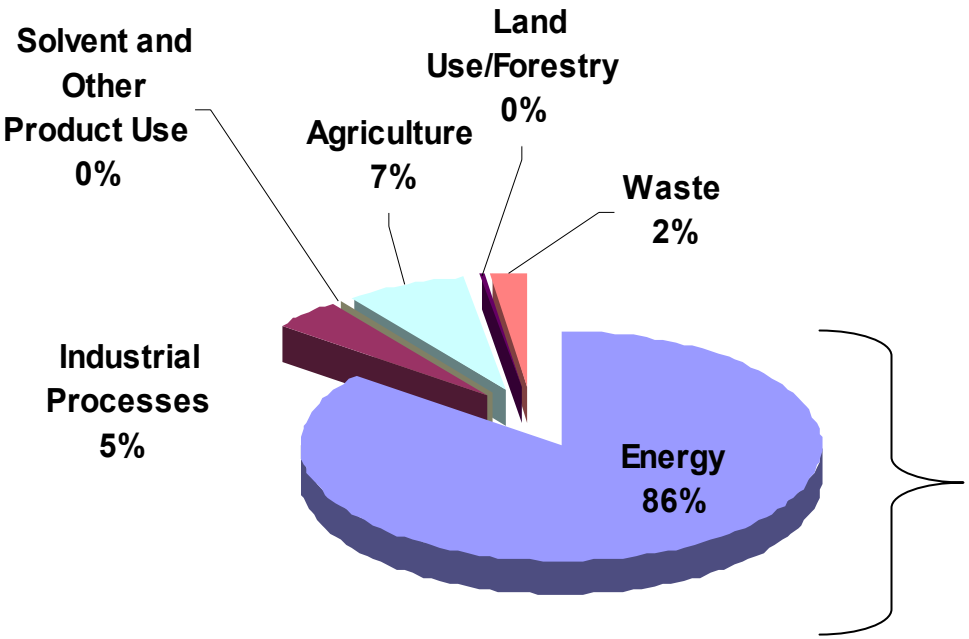


Total Emissions* = 41,382 Metric Tons CO_2 E

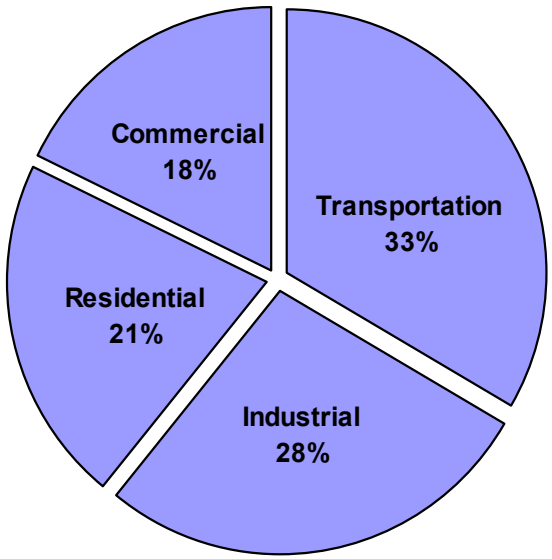
Source: US EPA

U.S. GHG Contributors

U.S. GHG Emissions by Sector



U.S. CO_2 Emissions from Fossil Fuel Combustion by End-use Sector



Source: INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990-2005 (April 2007) USEPA #430-R-07-002

Observed Physical Impacts

- 11 of the 12 warmest years on record occurred since 1995
- Warming of lakes and rivers
- Earlier peak discharge from glaciers in the spring
- Ice cover
  - Arctic sea ice: being lost at an unprecedented rate, reaching a record low area during summer 2005. Arctic Ocean could be ice free during summer by late this century - *IPCC 2007*
  - Greenland and Antarctica are losing ice
  - Mountain glaciers continuing worldwide retreat
- Drying of subtropical latitudes
- Increased global average rainfall and more heavy rainfall events in wet regions (extra precip often damaging)
- Accelerated global average sea level rise
- More acidic ocean water from dissolved CO_2

Rhone Glacier

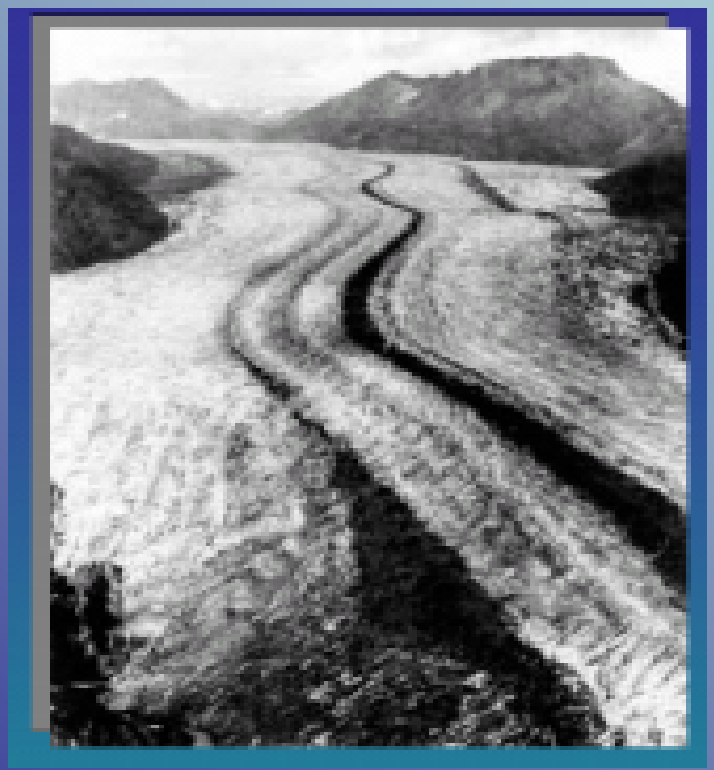
1856

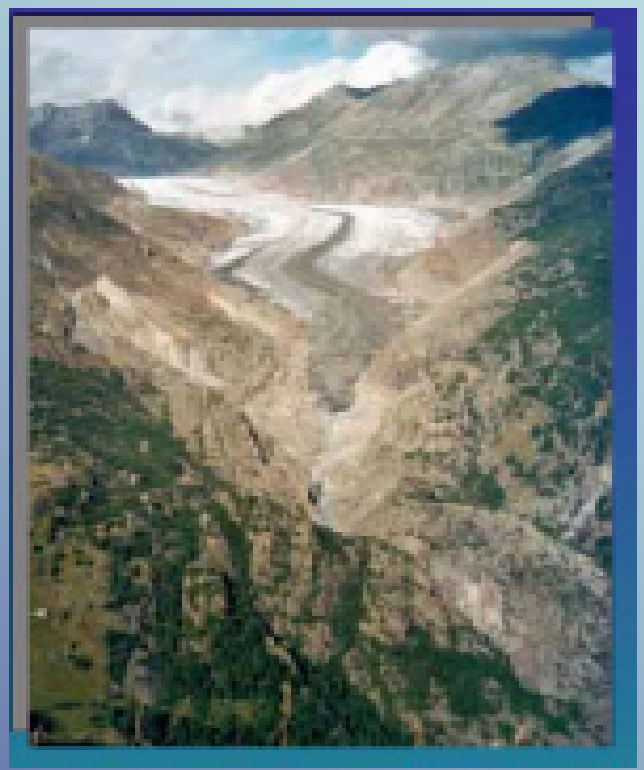
Rhonegletscher,
Switzerland

2000

Aletsch Glacier

Aletschgletscher, Swiss Alps, 1856 and 2001



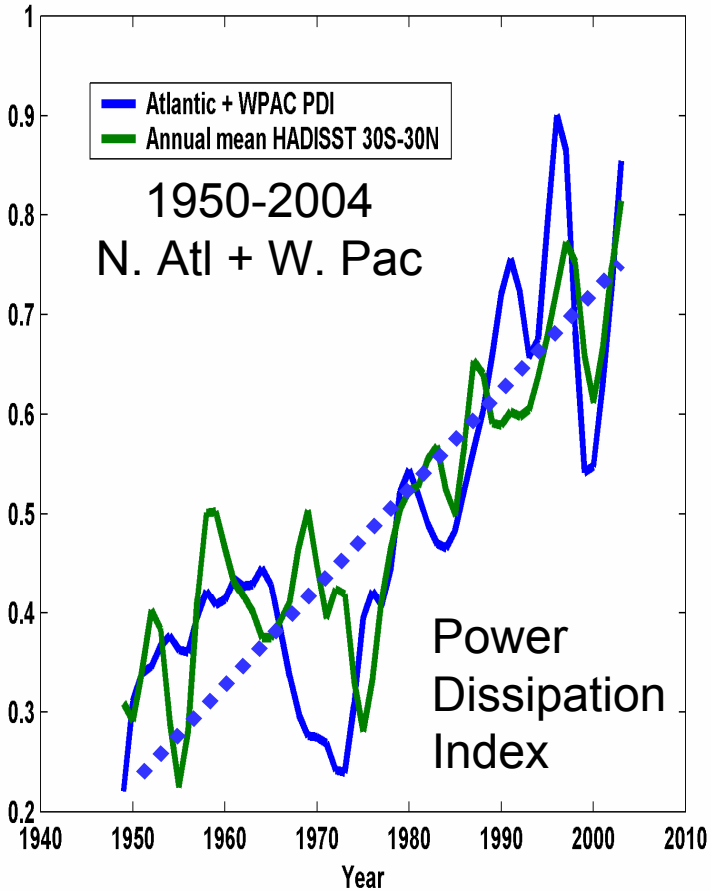


Because of delayed glacier response, this glacier will retreat an additional ~2000m even if no further temperature increase would occur (unrealized response)

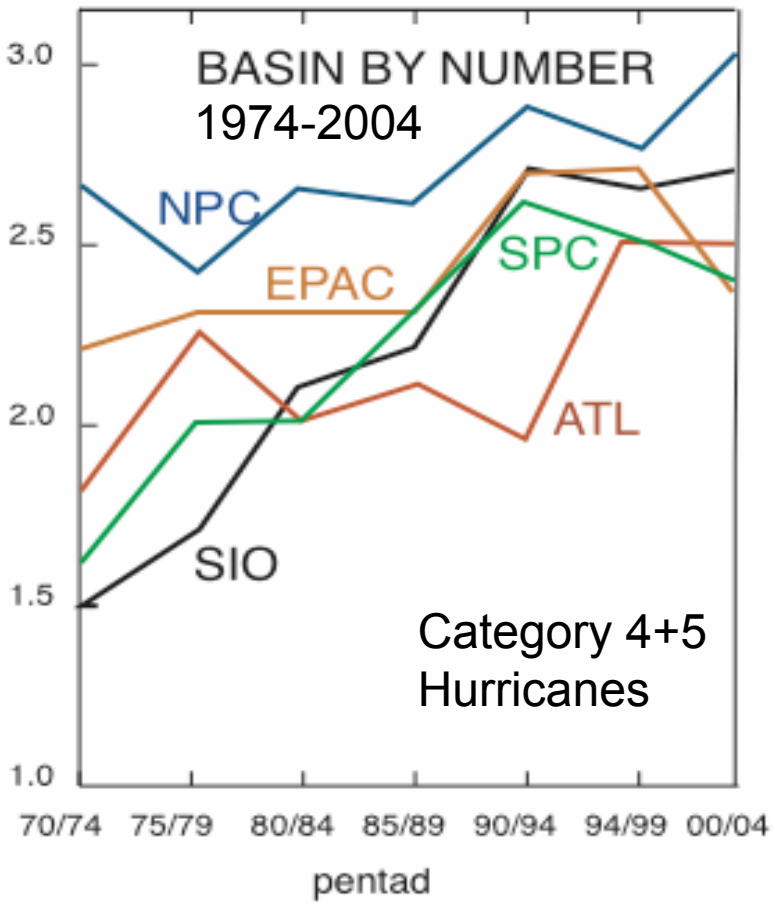
Observed Physical Impacts

Melting ice
in Greenland

Hurricane Intensification

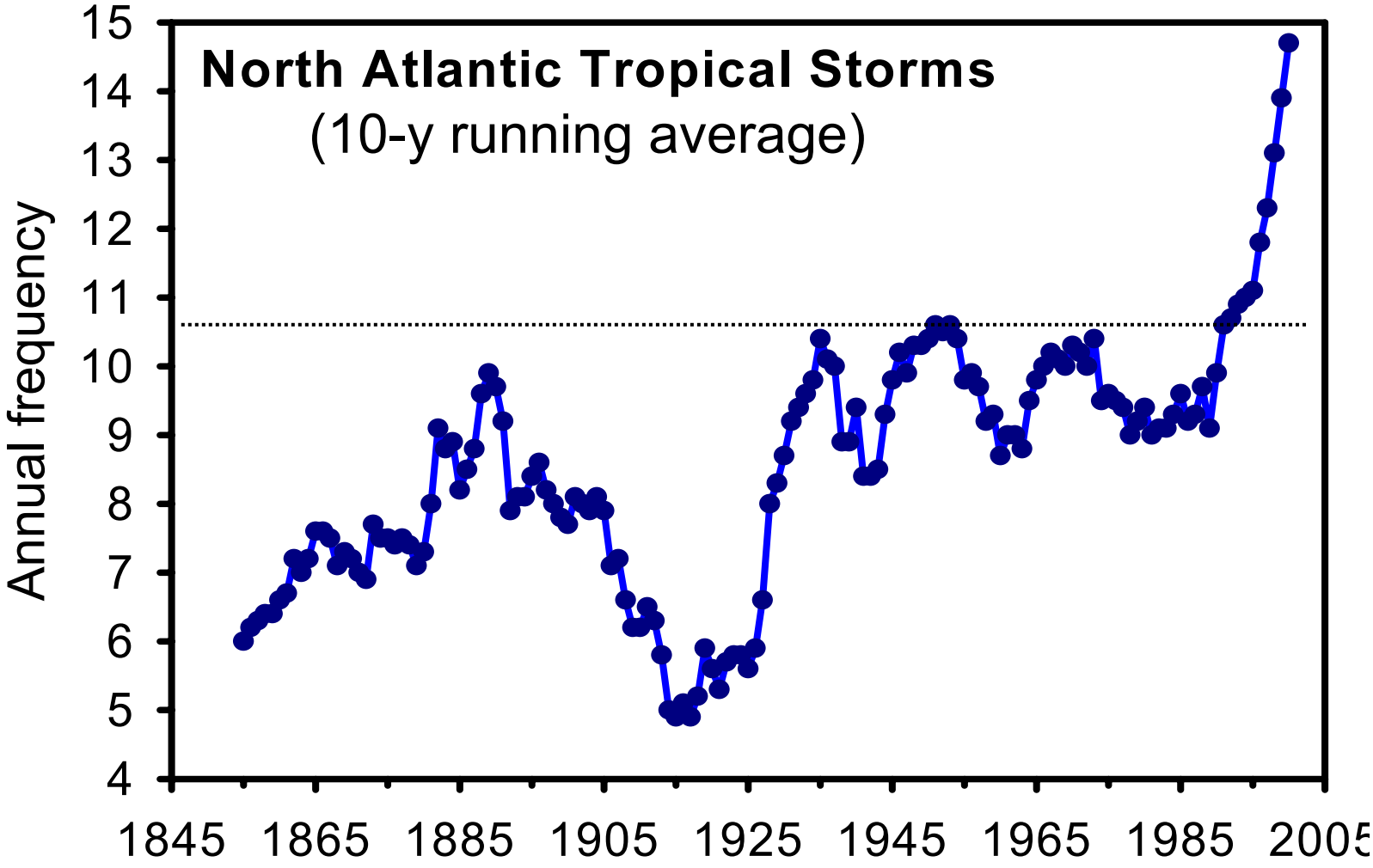


Emanuel 2005, Nature 436:686

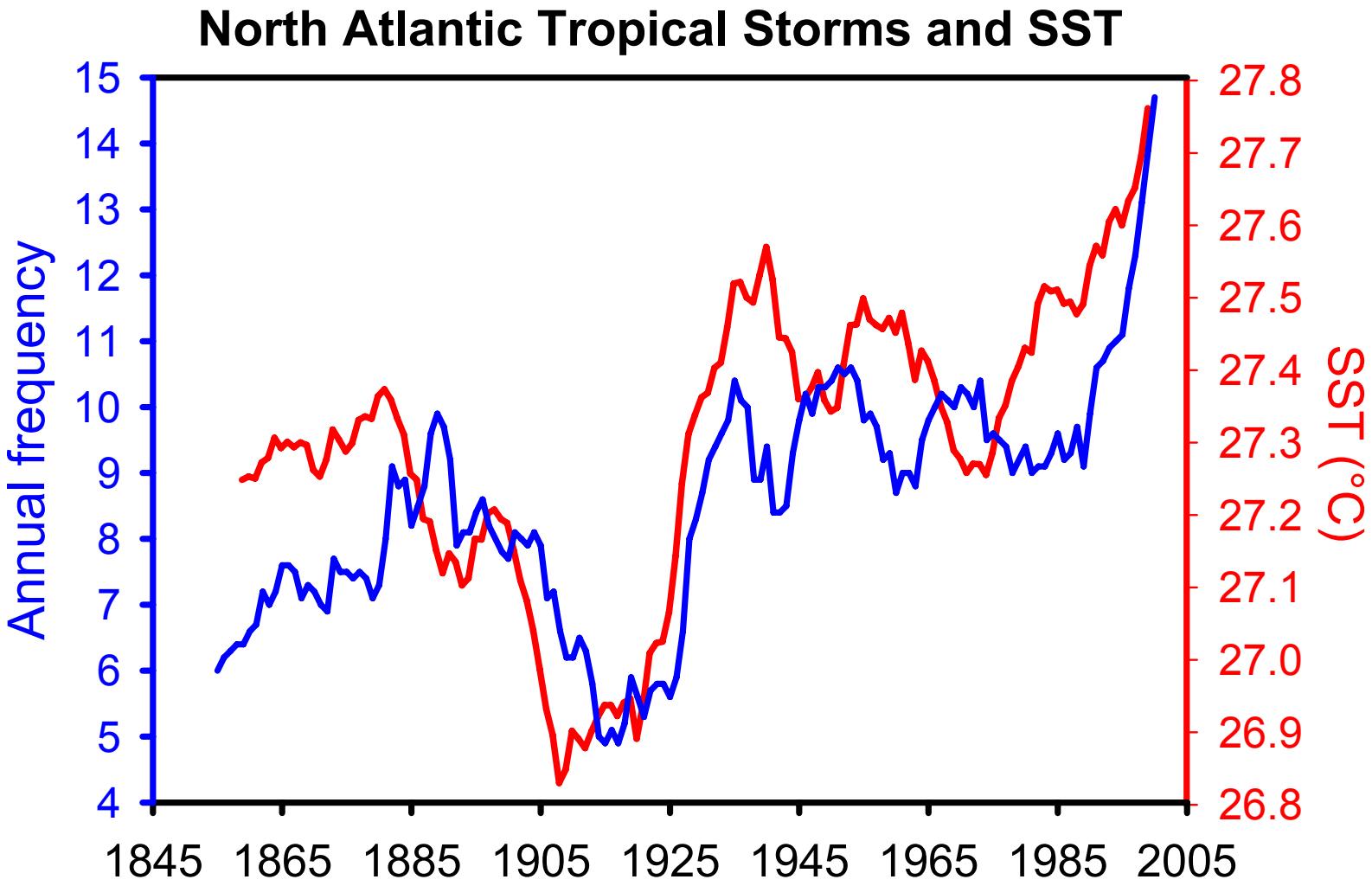


Webster 2005, Science 309:1844

North Atlantic Hurricanes

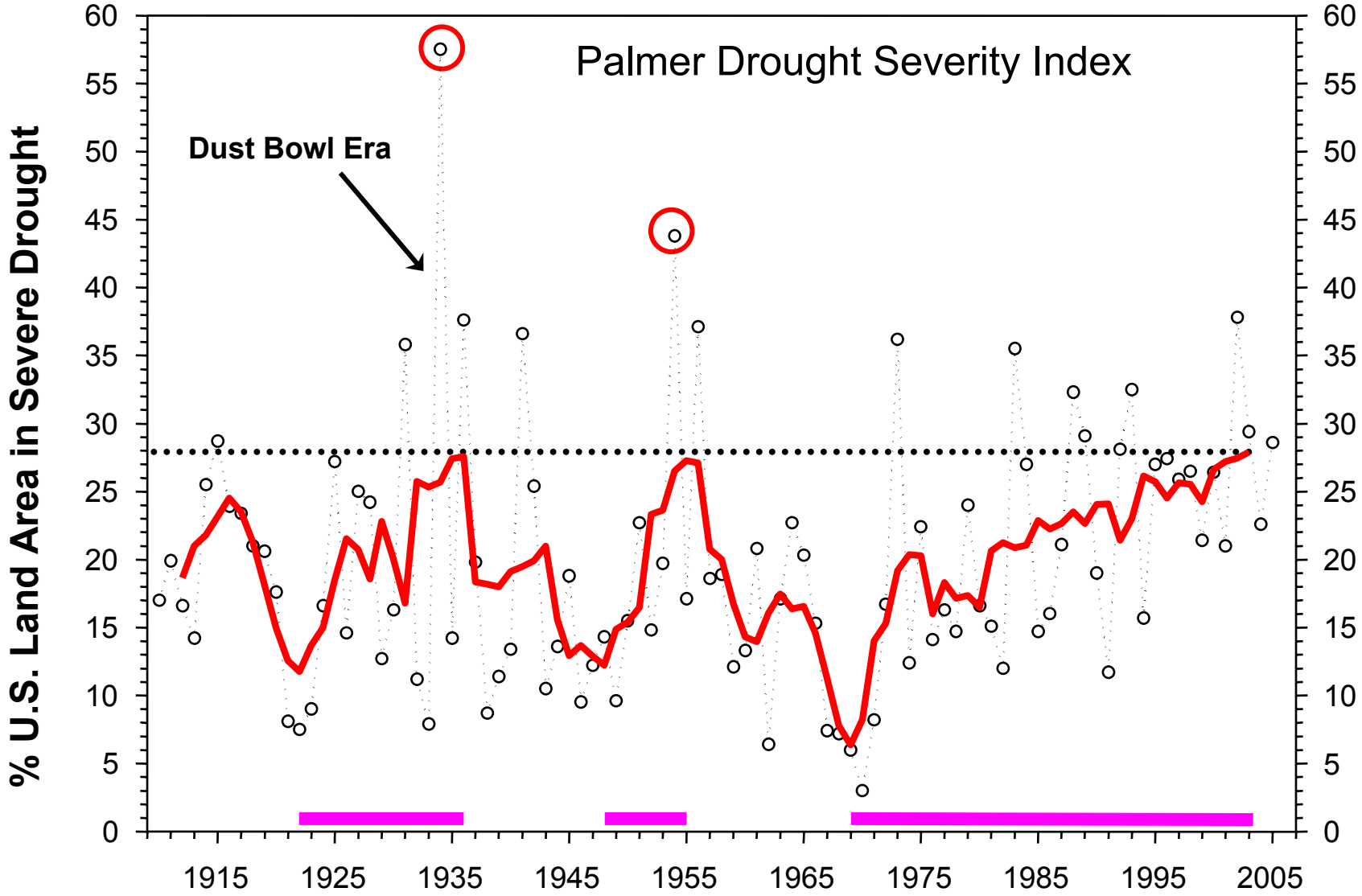


North Atlantic Hurricanes



Trop. storms: Nat'l Hurricane Center
SST: NOAA

Drought—Conterminous U.S.



Projected Physical Impacts

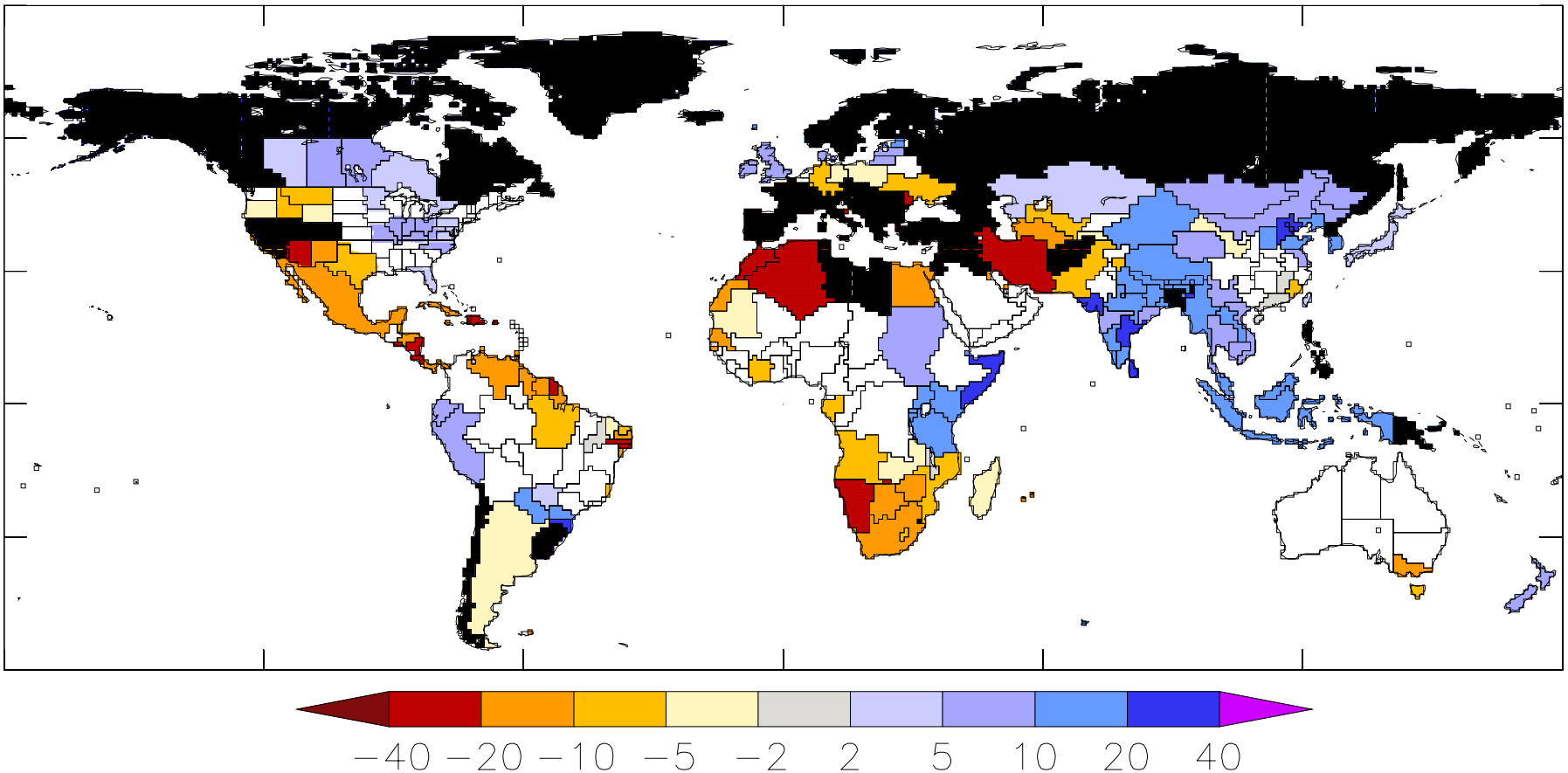
World

- Heavily populated and low-lying coastal areas at greater risk for flooding and storm damage
  - rising sea levels
  - more frequent and/or intense storms.
  - potential for intensified hypoxia
- Inland areas also affected by increased incidence of extreme weather events.
- Mountainous regions lose glacier volume, initially causing increased flooding, followed by dwindling river flows and water availability during parts of the year.

- IPCC 2007

Projected Physical Impacts

- Projected Changes in Annual Runoff for 2050



Milly (2005) Nature 438:347, updated

Projected Regional Impacts

North America

- Decreased water in the West (very high confidence)
- Increased wildfire (very high confidence)
- More frequent and intense heat waves in cities where they already occur (very high confidence)
- Coastal areas are especially vulnerable to the interacting effects of development, pollution, and climate change (very high confidence)

-IPCC 2007

Projected Regional Impacts

Latin America

- Tropical regions at risk of species extinctions
- Tropical forests replaced by more arid ecosystems
- Crop and livestock production decline in drier areas, soybean yields will increase in temperate zones
- Rising sea surface temperatures will damage coral reefs and shift fish stocks
- Changing precipitation patterns and glacier loss will affect water availability

Africa, Asia, the polar regions, and small islands

- the most vulnerable regions worldwide because of:
  - Larger degree of climate change projected (polar regions, small islands)
  - Existing climate stress and lack of resilience (Africa, Asia, and small islands)

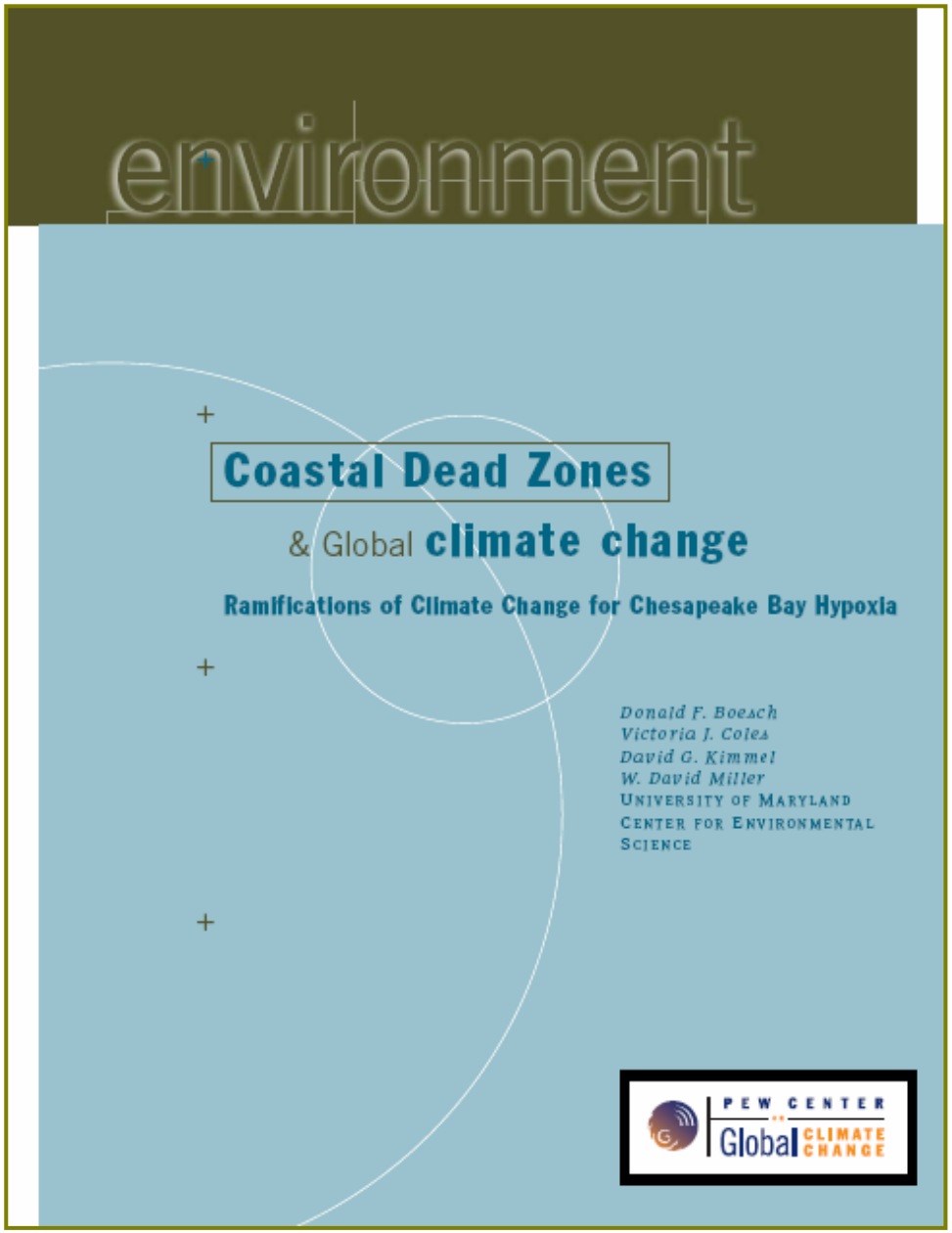
Pew Report: US Regional Impacts

Regional Impacts Case Studies

- **Chesapeake Bay Hypoxia**
  Don Boesch, Univ. of Maryland
- **Gulf Coast Wetland Loss**
  Robert Twilley, LSU
- **Midwest Heatwaves**
  Kris Ebi, ESS and
  Jerry Meehl, NCAR
- **Western Wildfires**
  Dominique Bachelet,
  Oregon State University

"Historically, risk management strategies have relied on the past as a guide to the future. But with global climate change, the future will no longer resemble the past."

Pew Report: US Regional Impacts

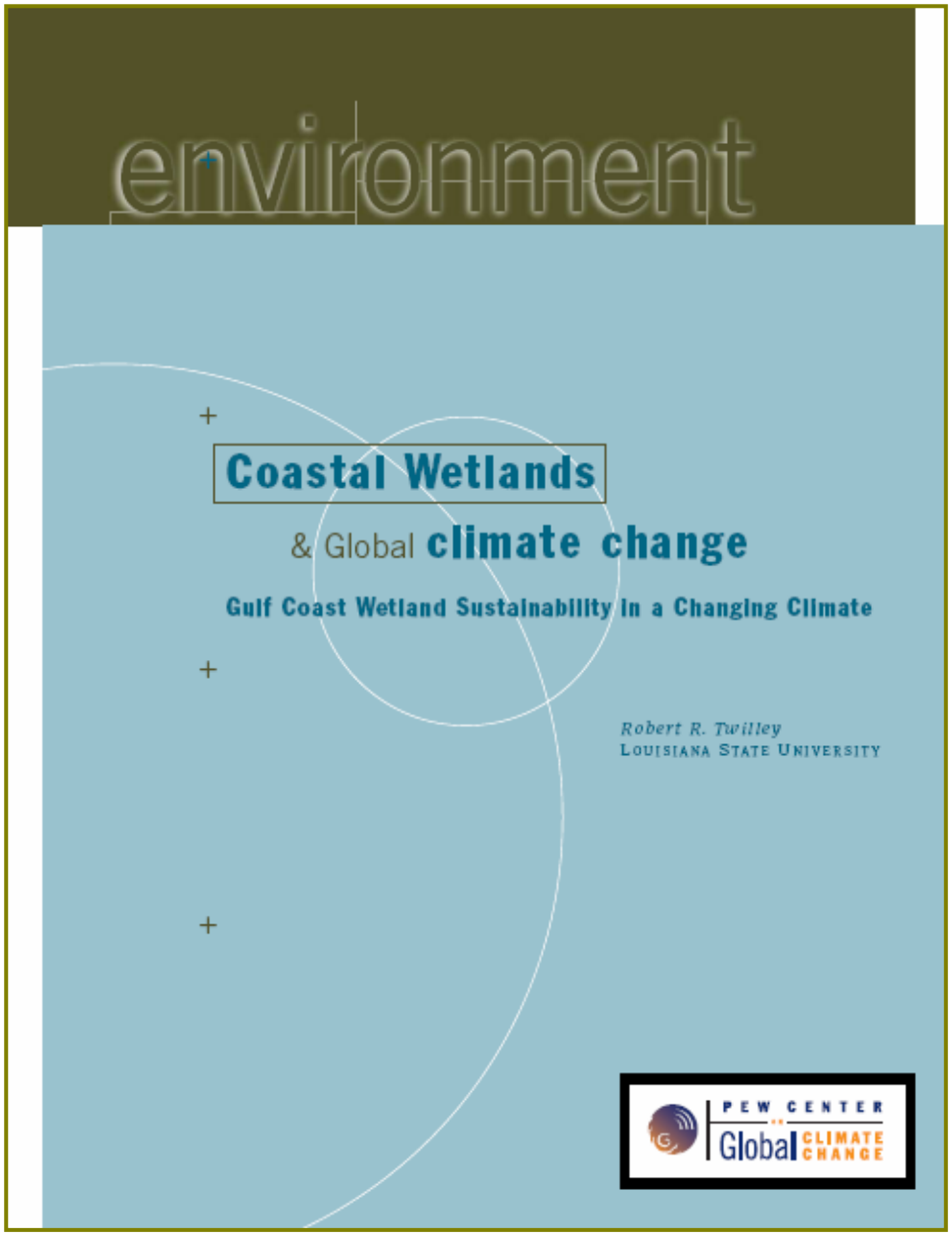


Chesapeake Bay Hypoxia

Don Boesch, Univ. of Maryland

- The bay has warmed by 2 °F and deepened because of sea level rise since 1950. Both factors favor hypoxia.
- In in future decades, increased precipitation, higher temperatures, and sea level rise will likely interact with development to increase the incidence of hypoxia in the bay.
- Regional climate change will complicate existing restoration efforts, but these efforts do not account for future climate change.
- The current restoration plan does not account for climate change.

Pew Report: US Regional Impacts

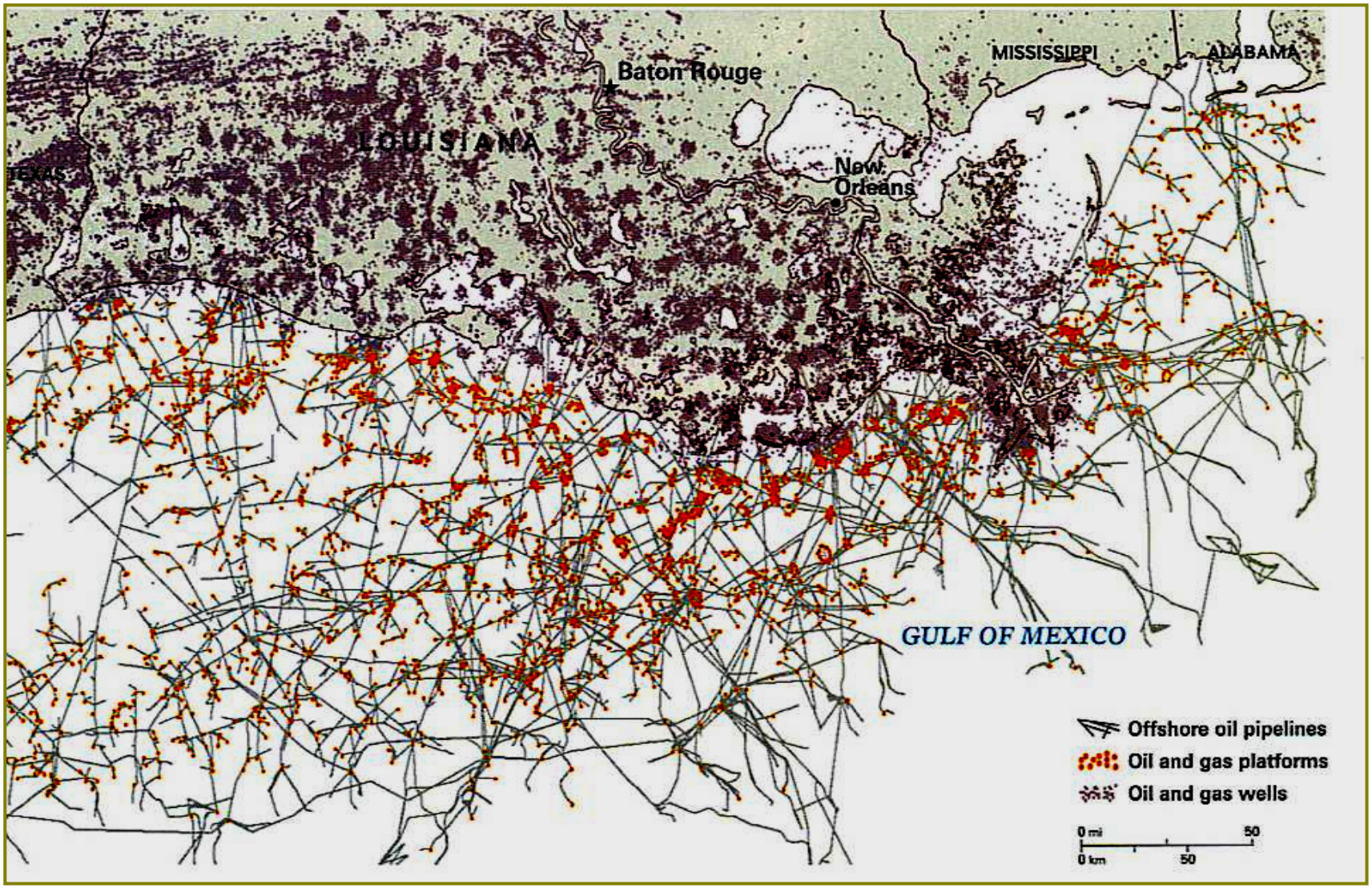


Gulf Coast Wetland Loss

Robert Twilley, Louisiana State Univ.

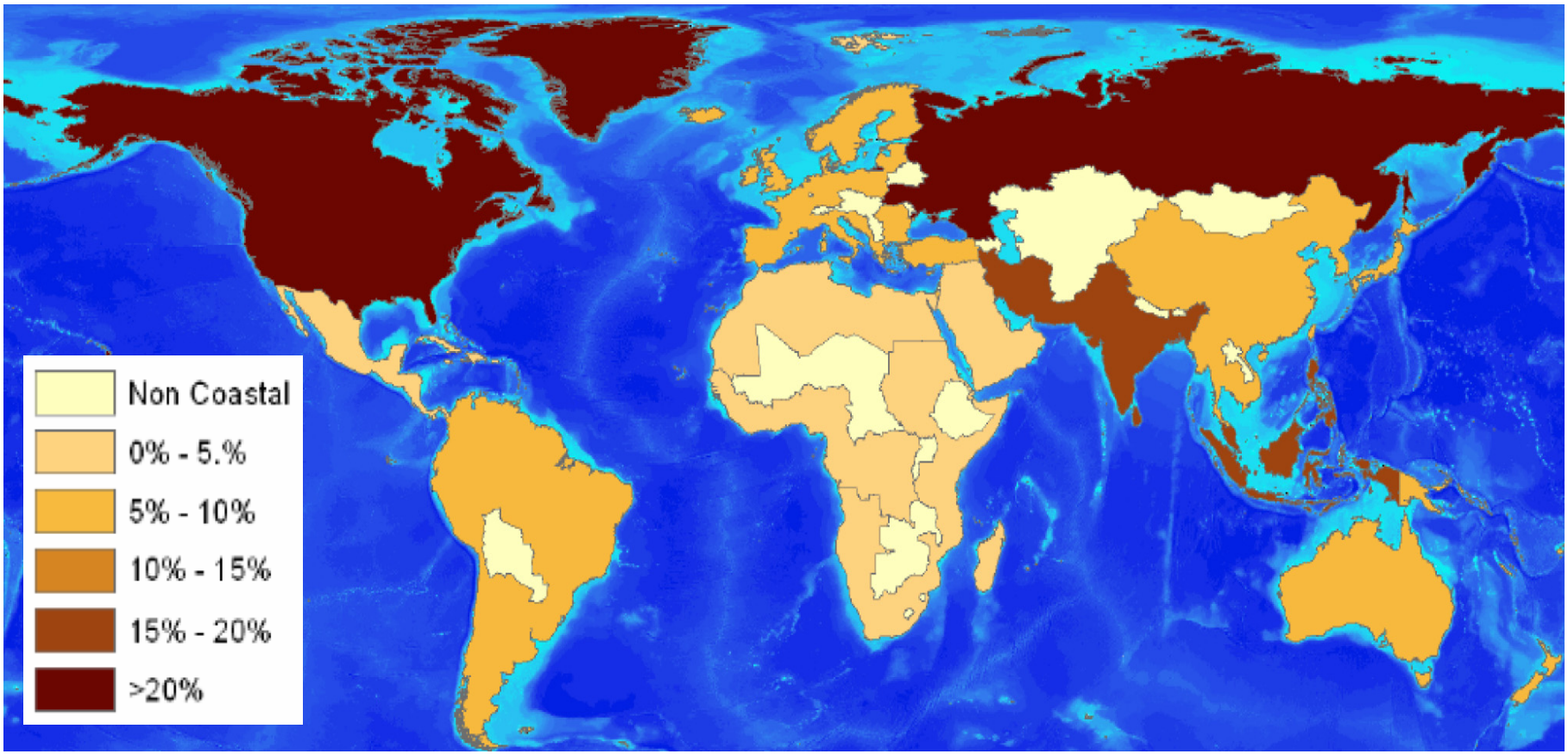
- Sustainability of Mississippi Delta wetlands and the Everglades is threatened by human activities that reduce natural soil elevation.
- Surviving future sea level rise and more intense tropical storms will require even faster rates of wetland elevation.
- Shoreline development also limits inland migration of wetlands as sea level rises.
- Sustainability requires restoration of natural soil building capacity.
- Current restoration plans do not account for future climate change.

Gulf Coast Infrastructure



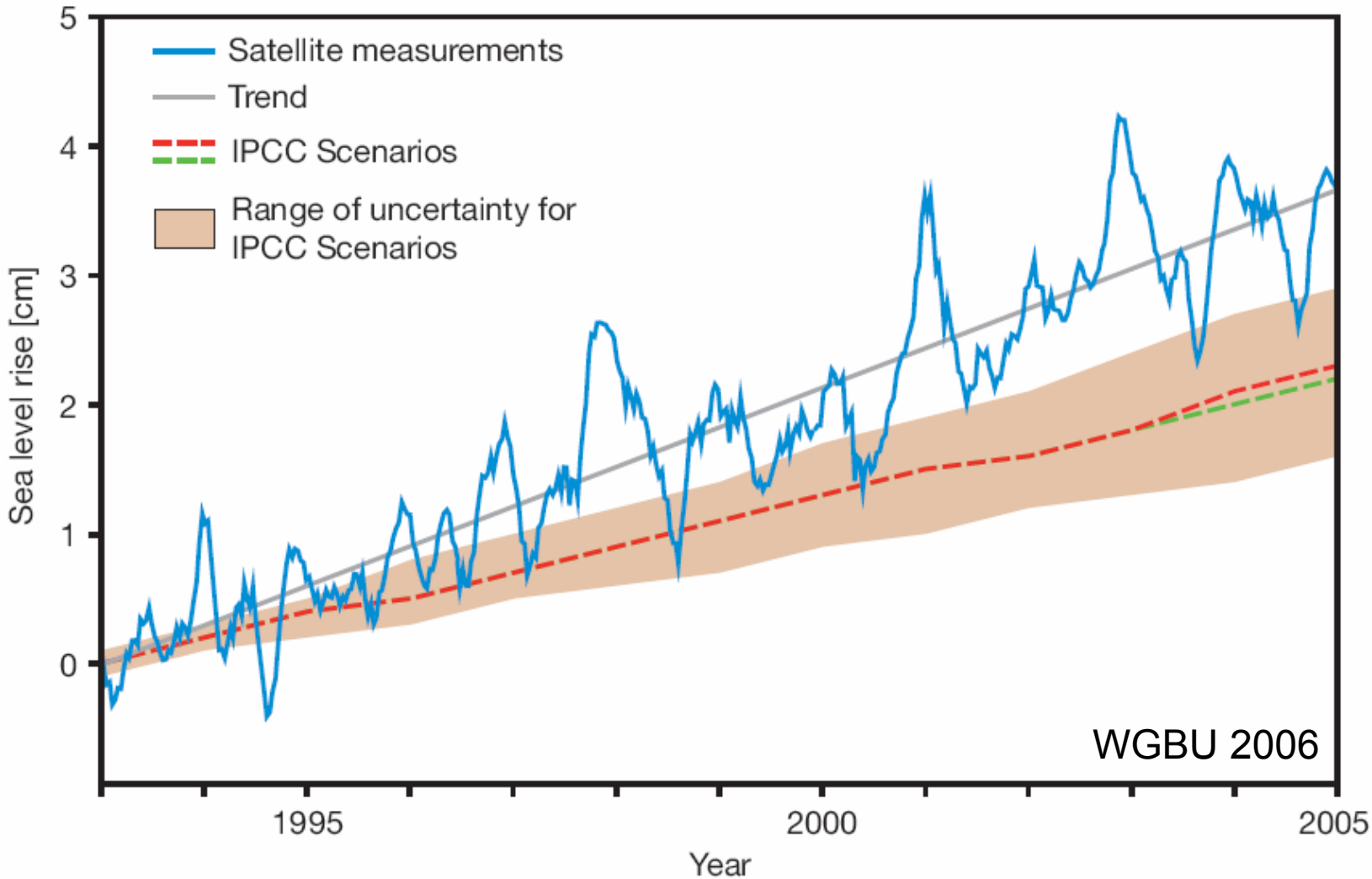
Vulnerability to Sea Level Rise

U.S. has the Largest Number of Low-lying Coastal Cities



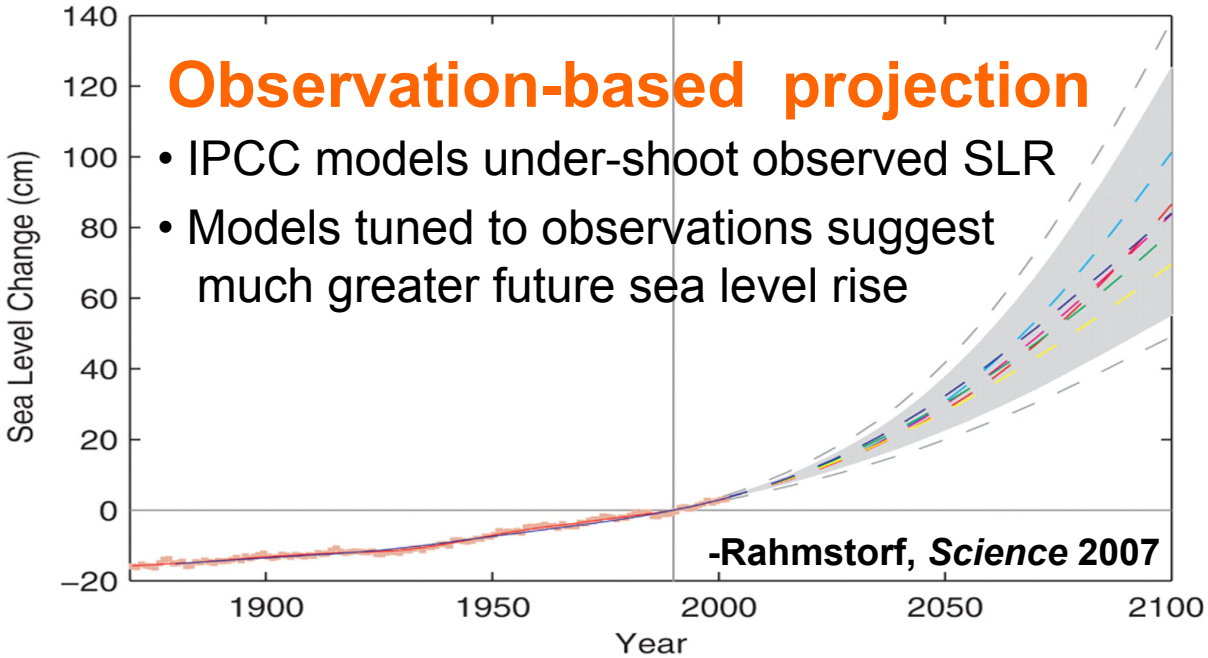
Impacts Underestimated?

Actual Sea Level Rise Underestimate by Models



How Much Sea Level Rise?

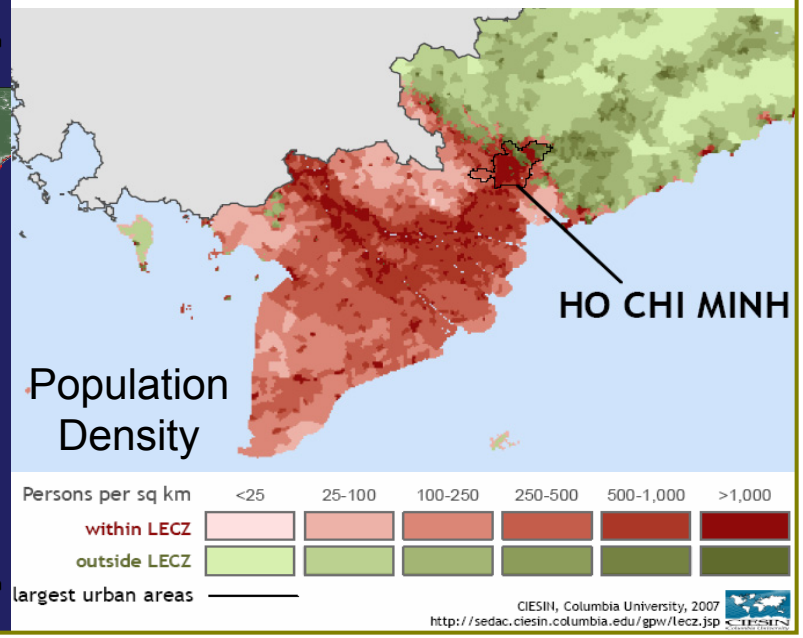
- Future sea level rise is impossible to predict now because of uncertain contributions of Greenland and Antarctica.
- The IPCC projects 0.28 - 0.59 m of sea level rise by 2100, but does not exclude higher rates.
- A more recent study suggests **0.5 - 1.4 m** by 2100.



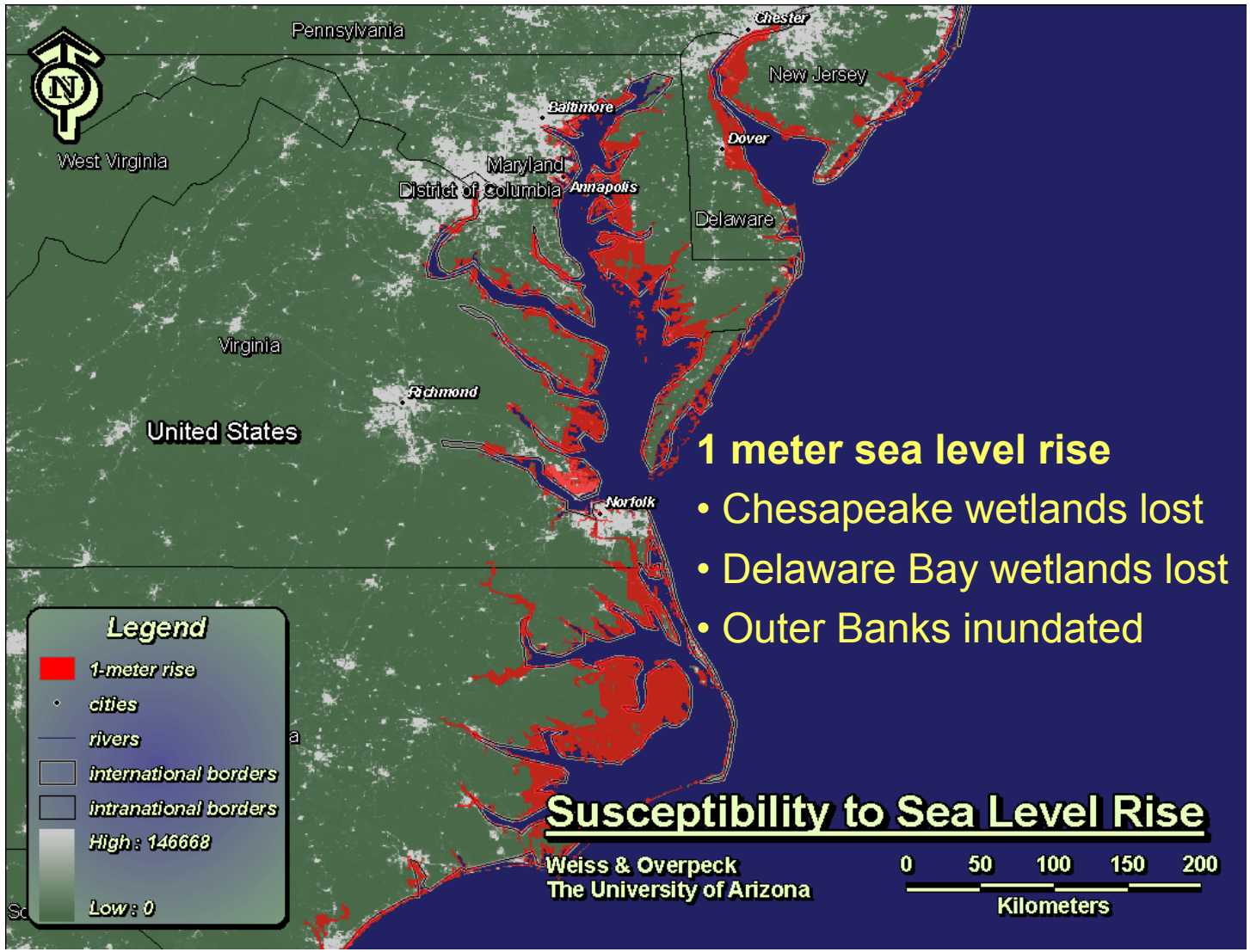
Mekong Delta Sea Level Rise

"Vietnam's rice bowl!"

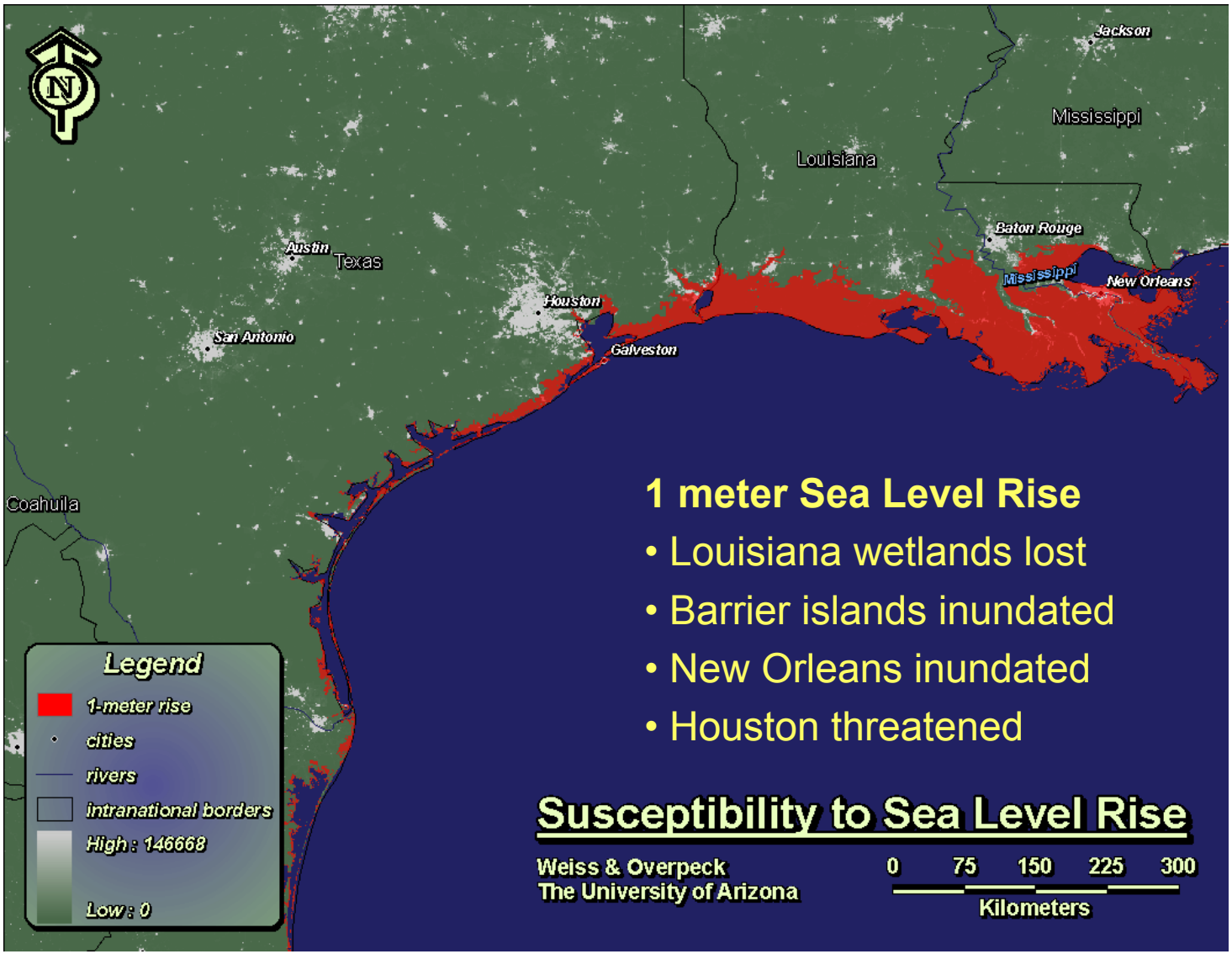
- Densely populated
- Major food production



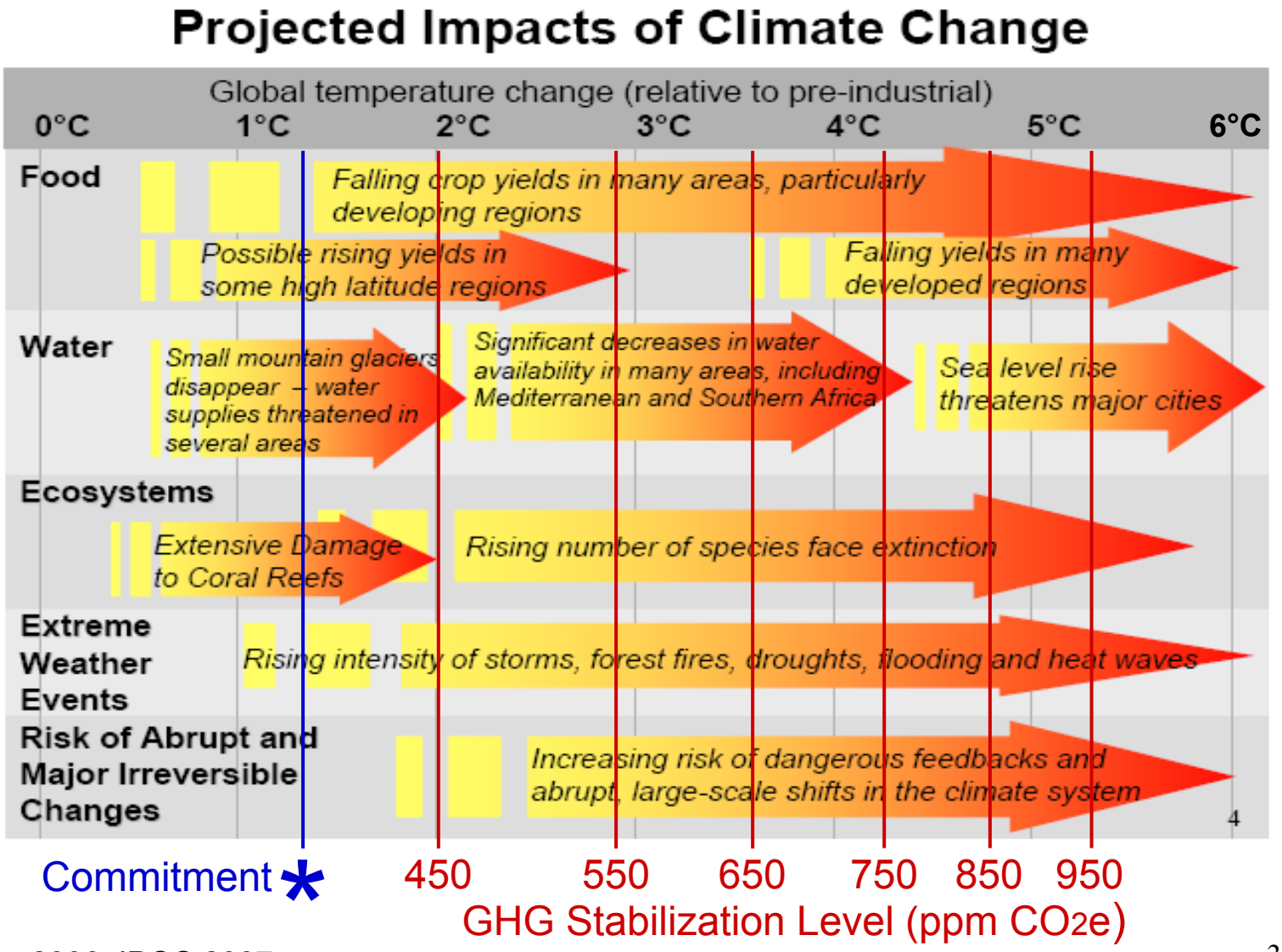
Mid-Atlantic Sea Level Rise



Louisiana / Texas Sea Level Rise



Avoidable Impacts

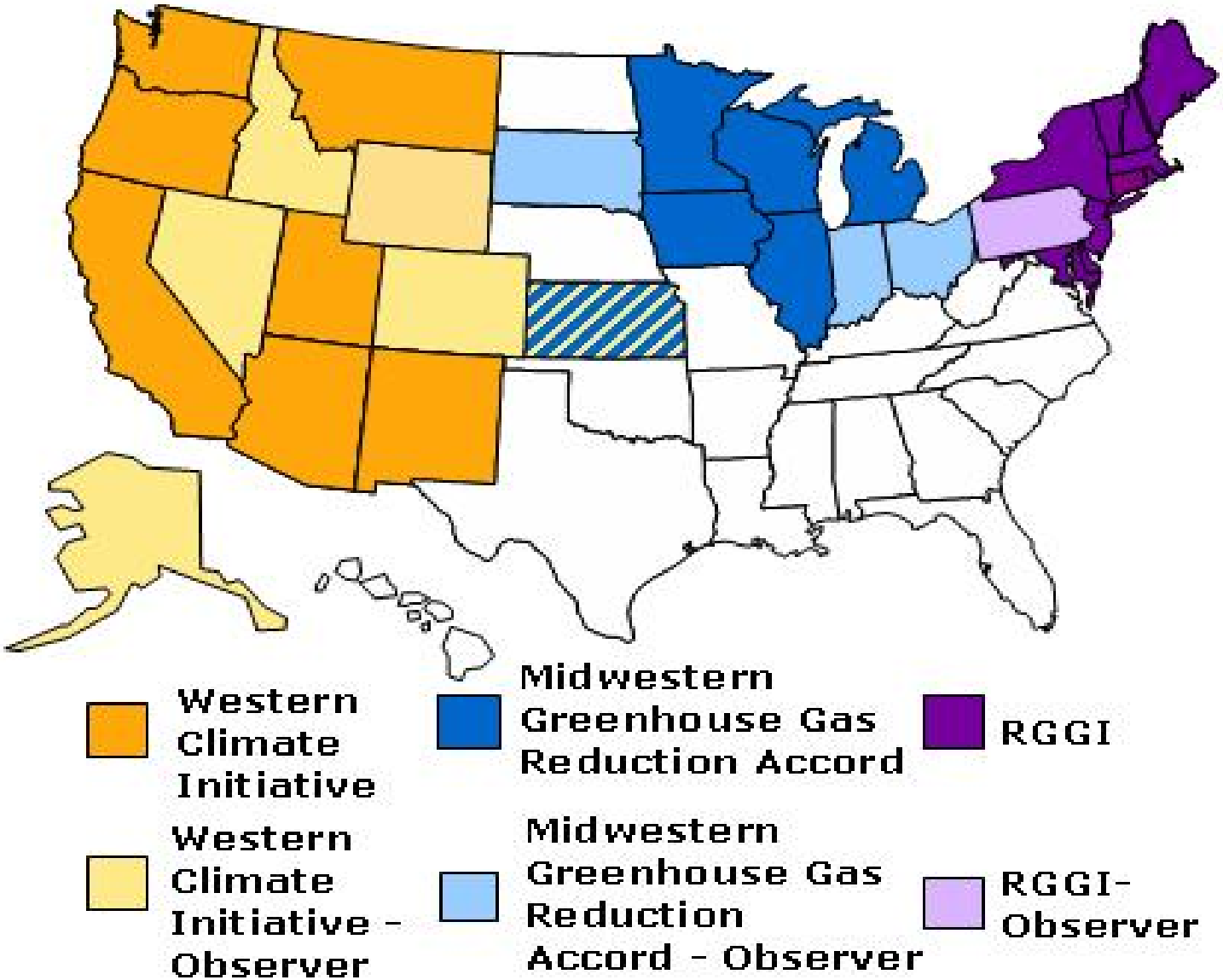


Stern 2006; IPCC 2007

Economics of Climate Policy

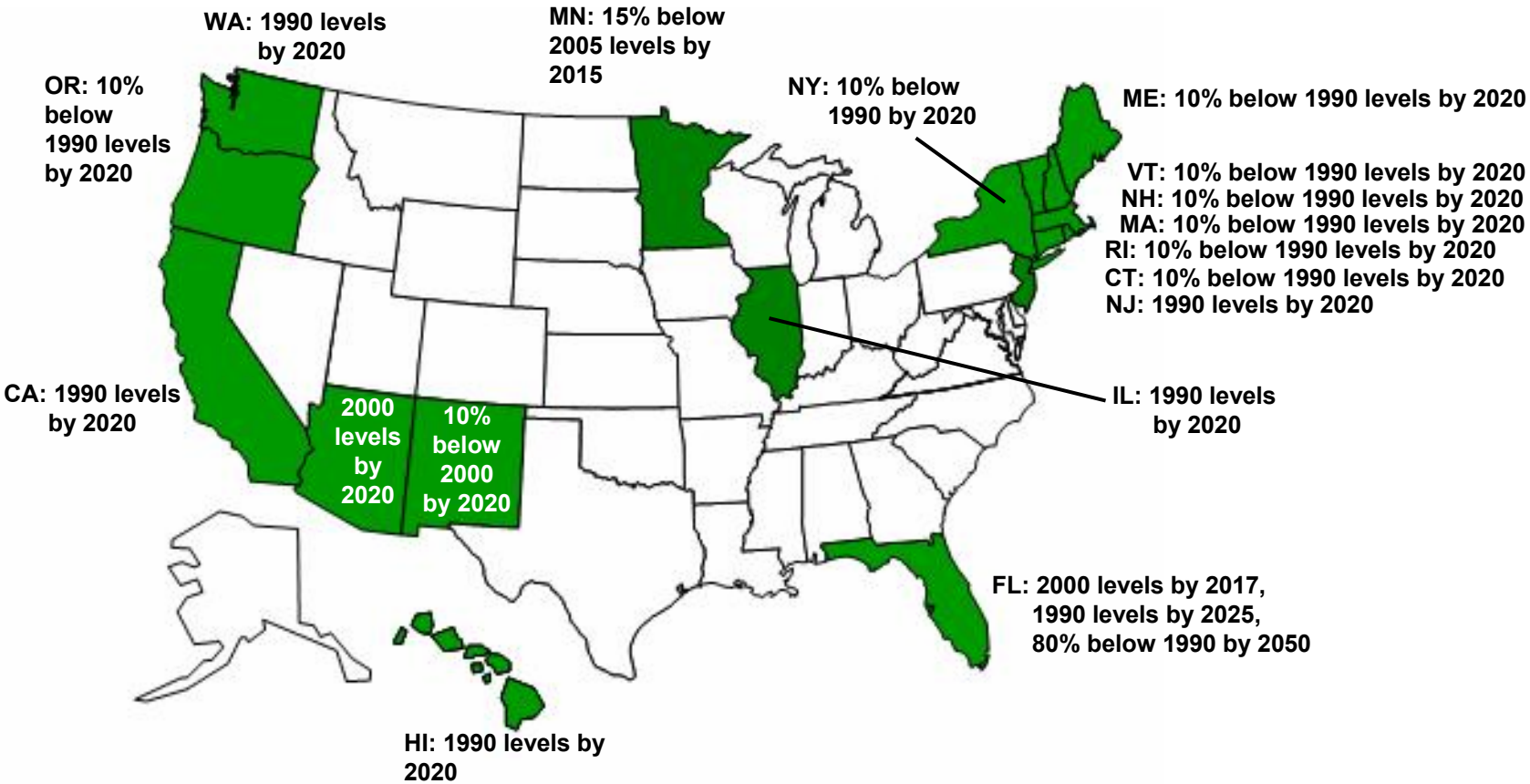
- Stern review (UK) – broad findings supported by work that shows costs of inaction exceeds cost of reasonable policy measures
- IPCC mitigation report – affordable policy options and technologies are available to stabilize emissions in 445-710 ppm CO_2e range but must start now
- Cap-and-trade programs successful in achieving environmental objectives cost-effectively
  - Experience with acid rain (SO_2 trading) program: reductions cost $125/ton, or less than half predicted permit price
- Our US experience (OMB 2003 study) shows the health benefits of a decade of EPA regulations were 4 – 7 times the costs

States Leading the Way



State GHG Emission Targets

State Near- to Mid-Term Targets

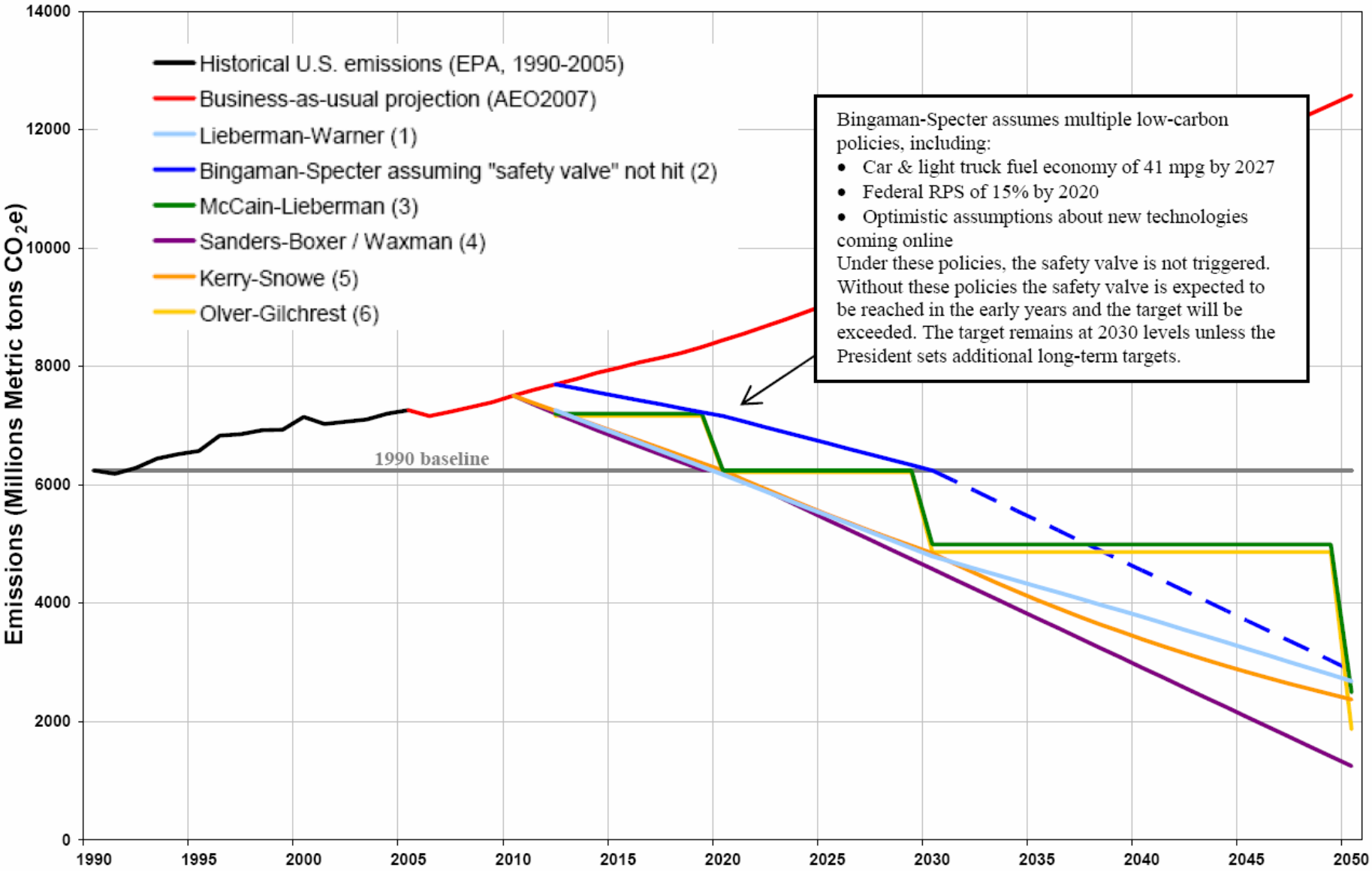


Businesses Leading the Way

US CAP Recommendations

- Targets
  - Between 100-105% of today's levels within five years
  - 90-100% of today's levels within 10 years
  - 70-90% of today's levels within 15 years.
  - Goal of 60-80% reduction by 2050 (atmospheric concentrations of 450-550 ppm)
- Economy-wide cap-and-trade system is essential to create market price signal for GHGs
- Additional policies/measures where price signal alone is not sufficient
  - Transportation
  - Power generation
  - Buildings and energy efficiency
- Technology research, development, demonstration, and deployment
- Need for renewed U.S. leadership in international efforts

Congress Following



Lieberman-Warner Bill

- Passed subcommittee (4-3) on Nov. 1
- Passed out of full committee (11-8) on Dec. 5
- Economy-wide cap-and-trade covering 6 GHGs
- Targets:
  - 2005 level in 2012
  - 15% below 2005 in 2020
  - 70% below 2005 in 2050
- Allocation by increasing auction: 24% in 2012, rising to 73% between 2036 and 2050
- Offsets and Other Cost Controls:
  - 15% limit on use of domestic offsets and international emission allowances
  - Borrowing up to 15% per company
  - Carbon Market Efficiency Board monitors the trading market
- Variety of bonus allocations and incentives for early action, carbon capture and storage, and technology development
- Funds for mitigating negative effects on the poor
- Three-year performance review by National Academy of Sciences

Not Following, Not Leading

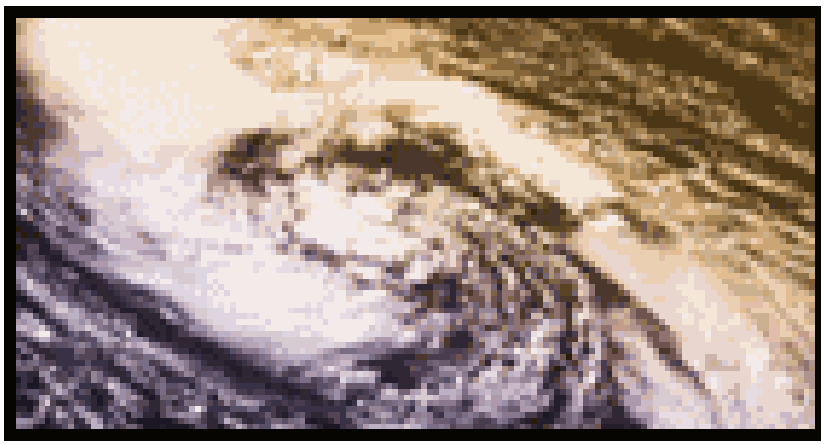
Bush Administration Policy:

- No Kyoto
- More scientific research
- Voluntary GHG intensity target
- Voluntary GHG reporting by companies
- Long-term technology development
- Nothing mandatory

International: Post Kyoto (2012)

- Two critical objectives
  - Engage the world's major economies—25 countries account for 85% of global GHG emissions
  - Provide flexibility for different national strategies and circumstances
- Recommended policy approaches
  - Targets and trading
  - Policy-based commitments
  - Sectoral agreements
  - Technology cooperation
  - ***Adaptation***

For More Information

Jay Gulledge
Senior Scientist
Program Manager for Science & Impacts
Pew Center on Global Climate Change
GulledgeJ@pewclimate.org

www.pewclimate.org