Global and Regional Climate Change

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Interstate Oil and Gas Compact Commission

2009 Annual Meeting

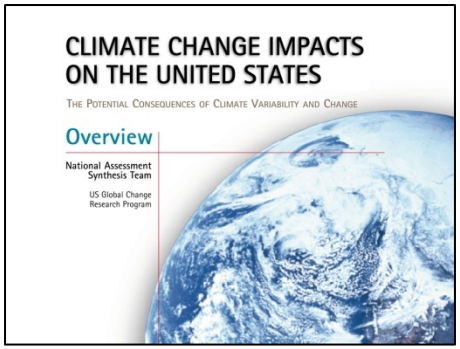
"Unconventional Potential: Setting Sensible State Policy"

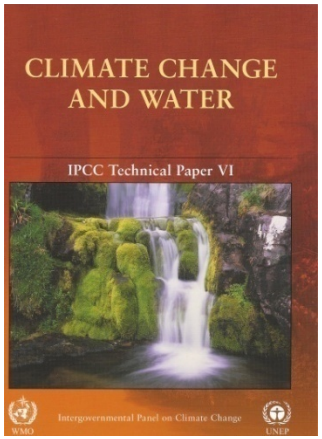
Biloxi, Mississippi
October 4-6, 2009

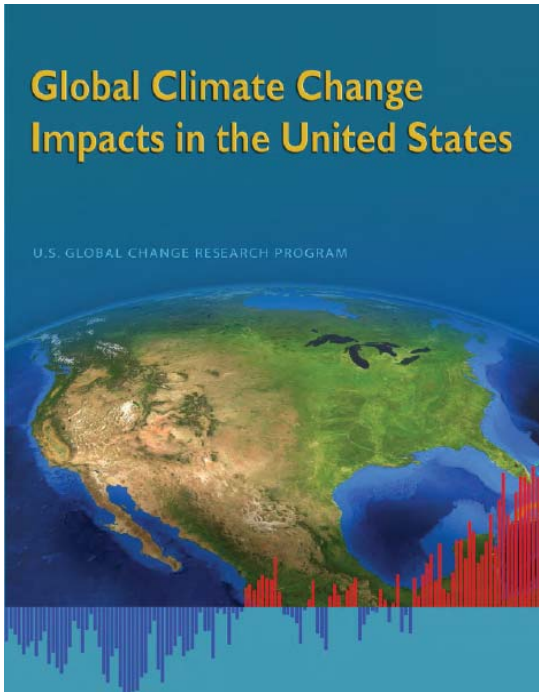
U.S. Department of the Interior
U.S. Geological Survey

U.S. Global Change Research Program

National, Regional, and Sectoral Assessments







(USGCRP 2009)

Main Sources

Intergovernmental Panel on Climate Change

UNEP

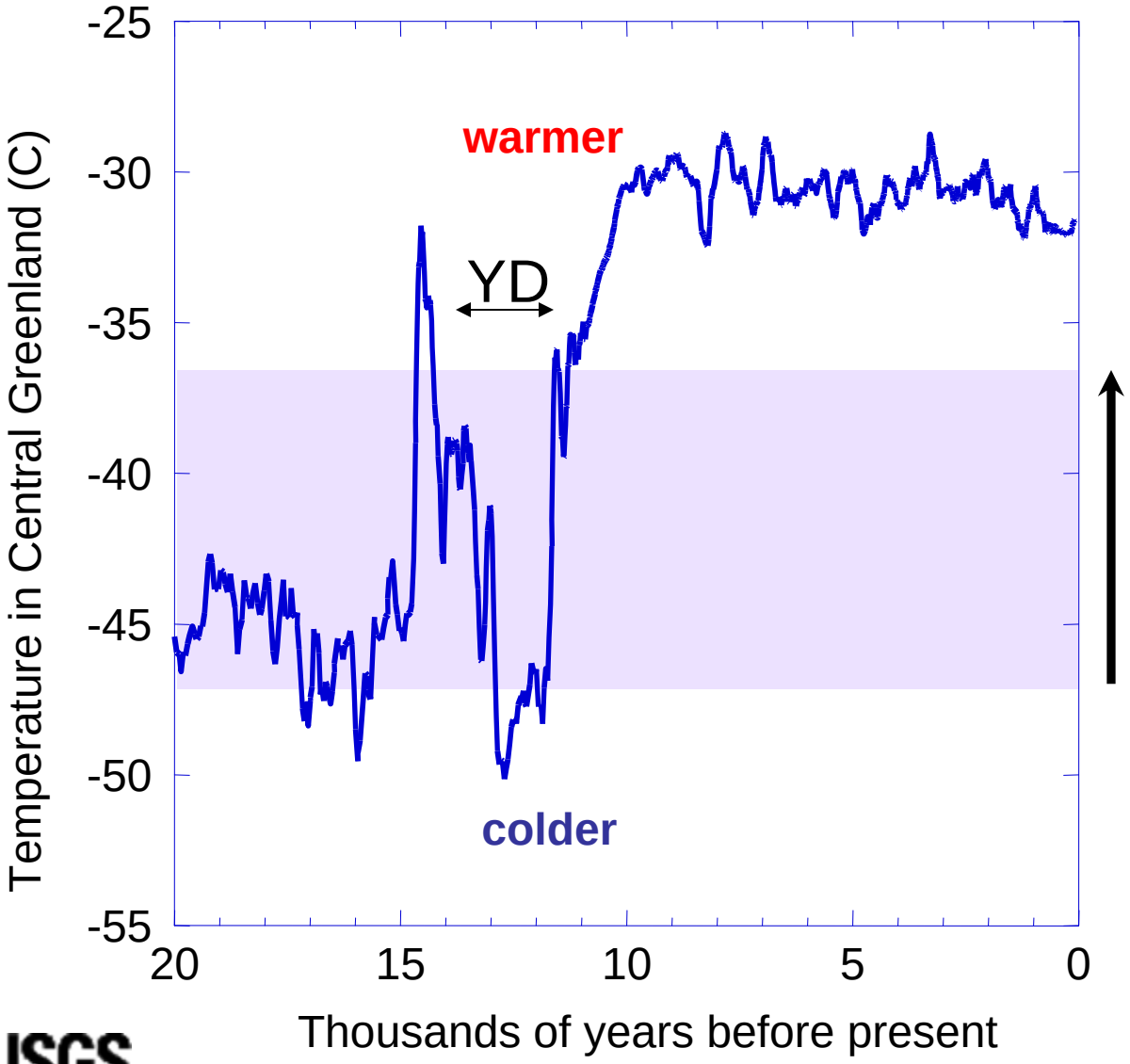
WMO

USGS

IPCC Working Groups:

- WG I - Physical Climate Science
- WG II - Impacts, Adaptation and Vulnerability
- WG III - Mitigation

Past 20,000 Years:



10° C increase in several decades at end of Younger Dryas interval (YD)

USGS

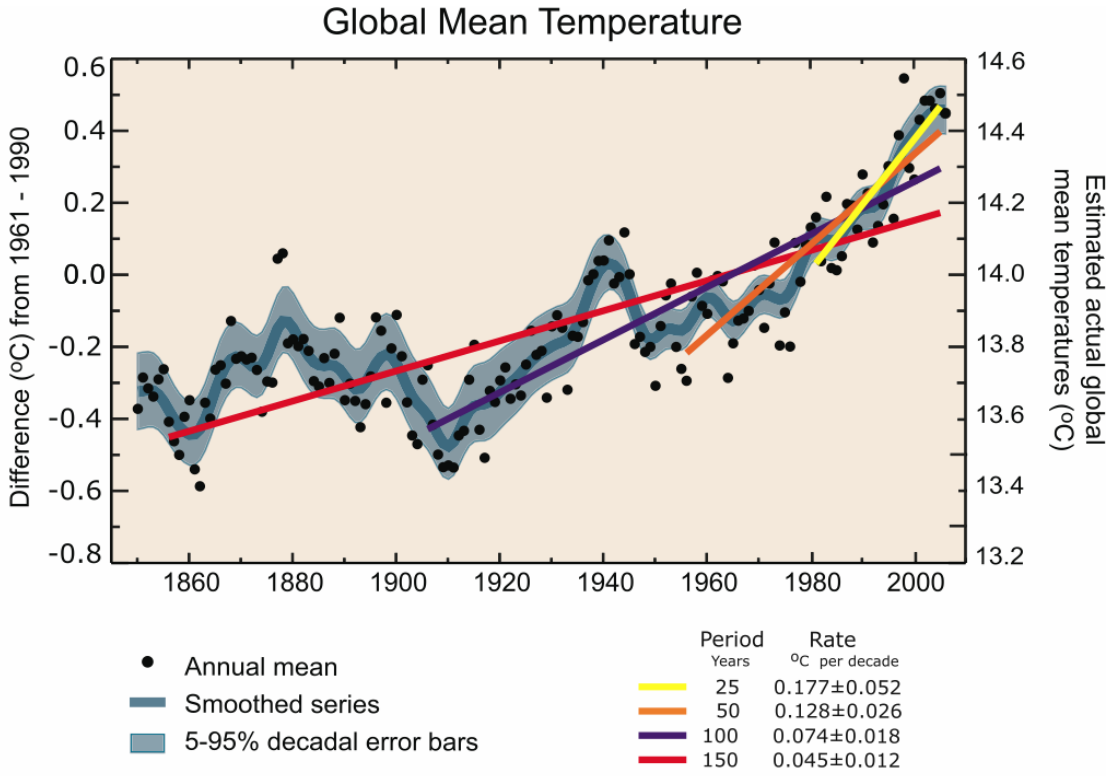
(based on Alley, 2000)

Past 100 years:

Atmospheric Change

- $C0_2$ increased 35%, methane increased 150% compared to pre-industrial levels (attributed to fossil fuel use & land use change)

- Global average temperature increased 0.74 ºC over past 100 yrs, 0.65 ºC over past 50 years

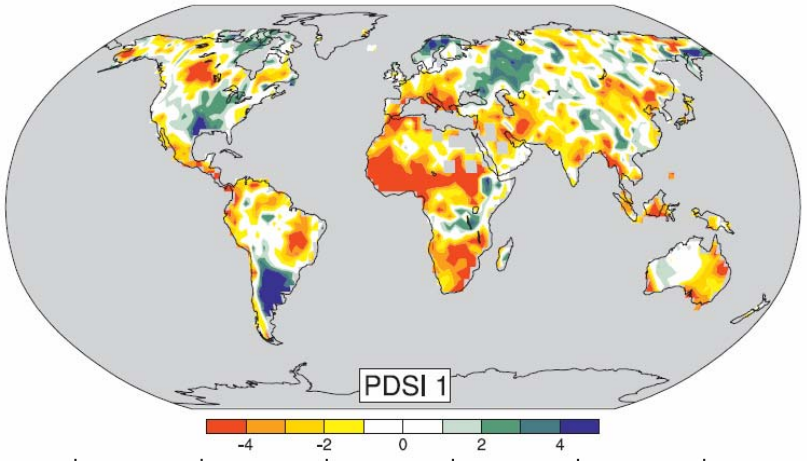


USGS

Atmospheric Change

- Atmospheric water vapor increased (consistent with T increase)
- Total volume and intensity of rainfall increased over most land areas -- but so did the number of dry days
- Intensified droughts have occurred over wider geographical areas, especially the tropics and sub-tropics, since 1970
- Severity of drought as measured by the Palmer Drought Severity Index (PDSI) rapidly increased from 1980 through 2002

Global Average Trend in Monthly Palmer Drought Severity Index (1900 to 2002)

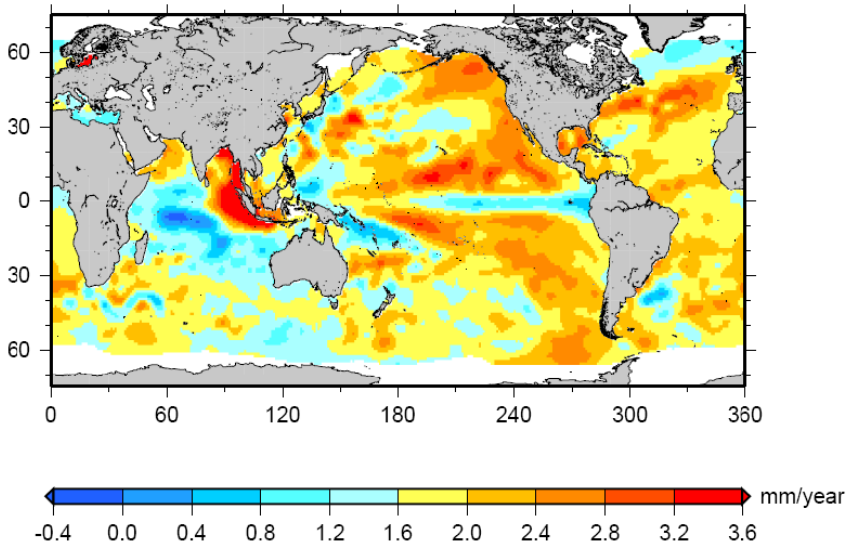


USGS

Ocean change:

- Ocean temperature increased from surface down to at least 3000 m
- Increase in N. Atlantic hurricane activity
- Increase in ocean acidity
- Global sea level rise
  - 1.7 mm/yr during 20th century
  - 3.1 mm/yr during 1993-2003 (acceleration or natural variability?)

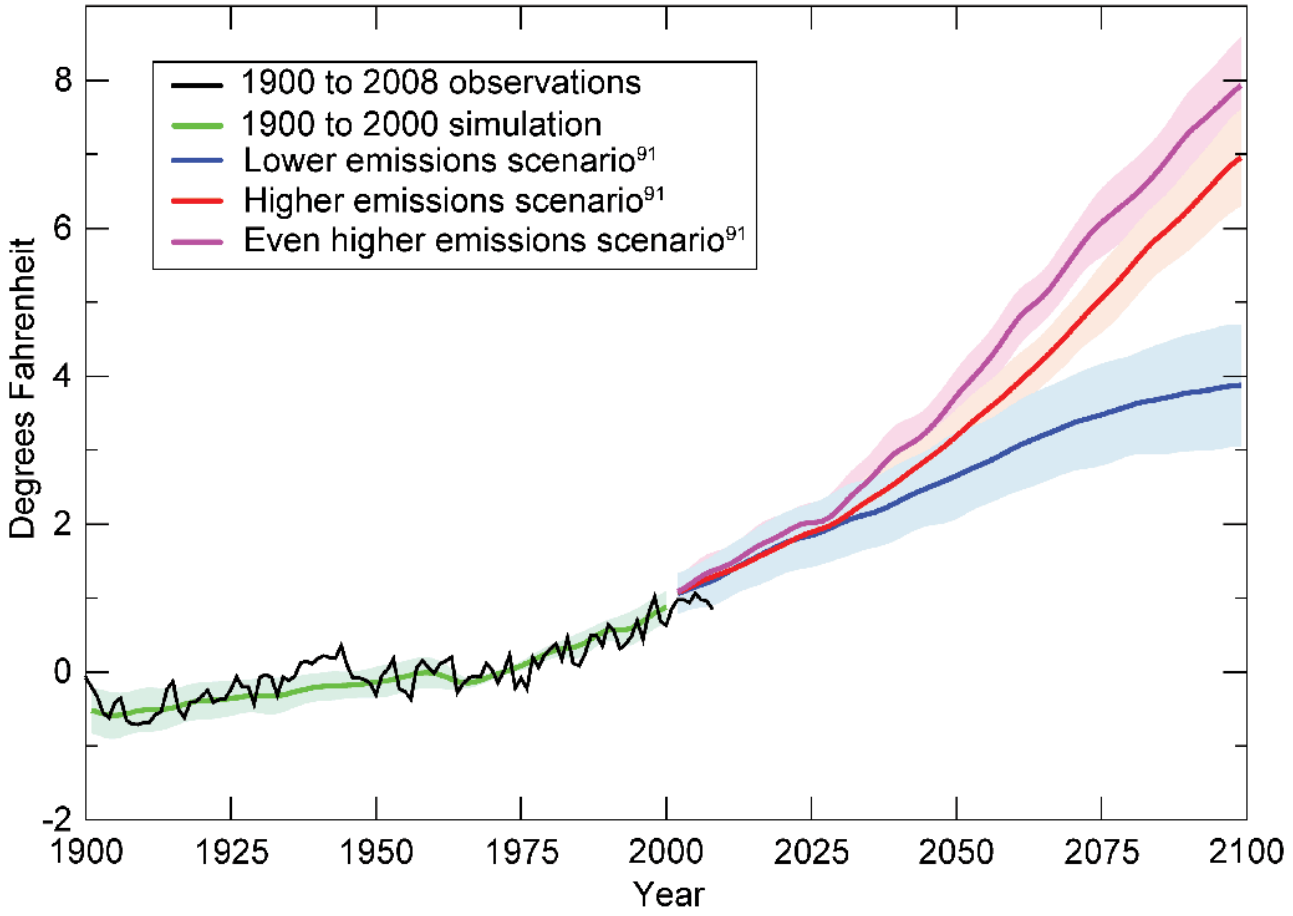
Geographic Variability in the Rate of Sea Level Rise (1955 to 2003)



USGS

Observed and Projected Global Average Temperatures

relative to the 1960-1979 average



(USGCRP 2009)

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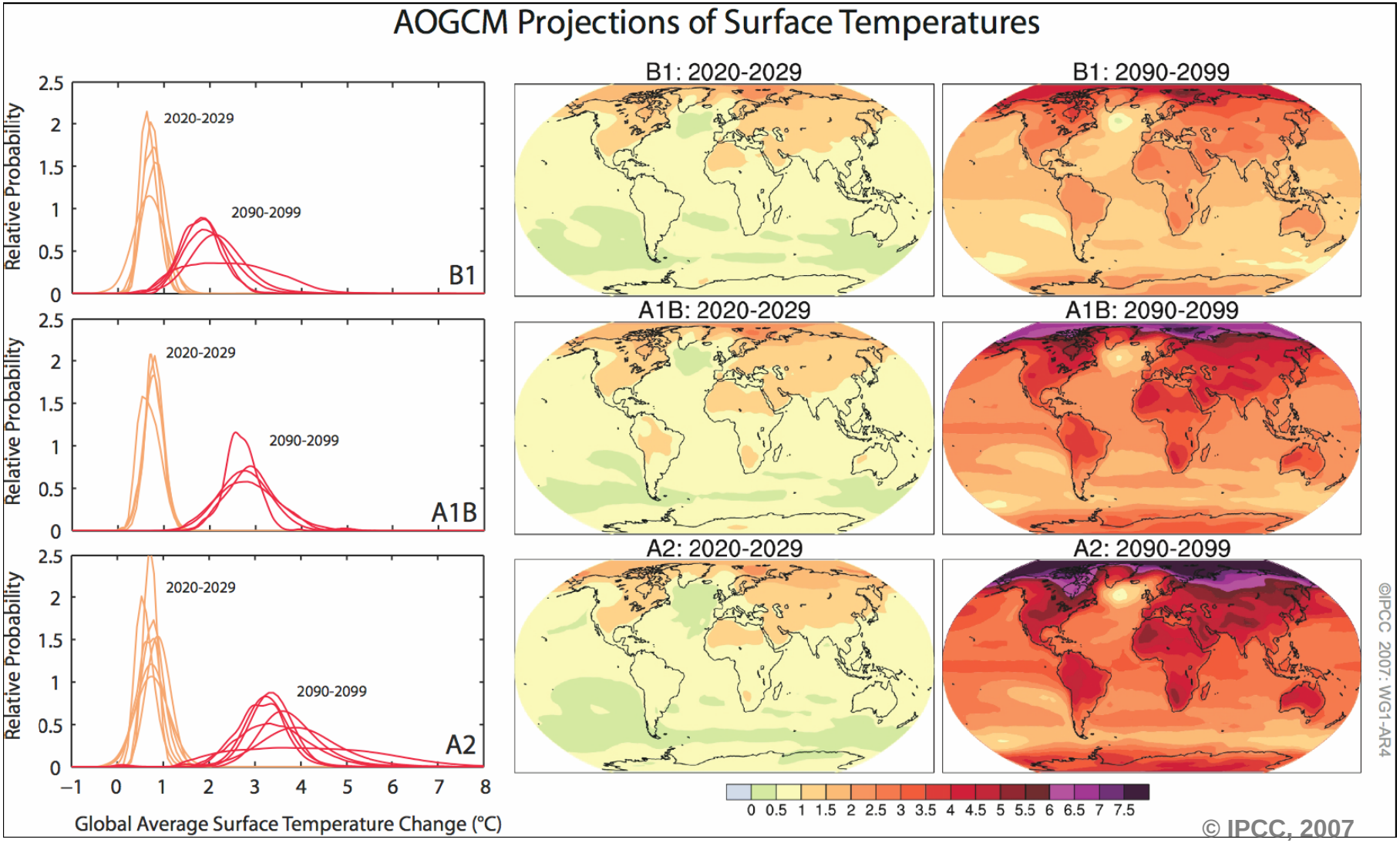
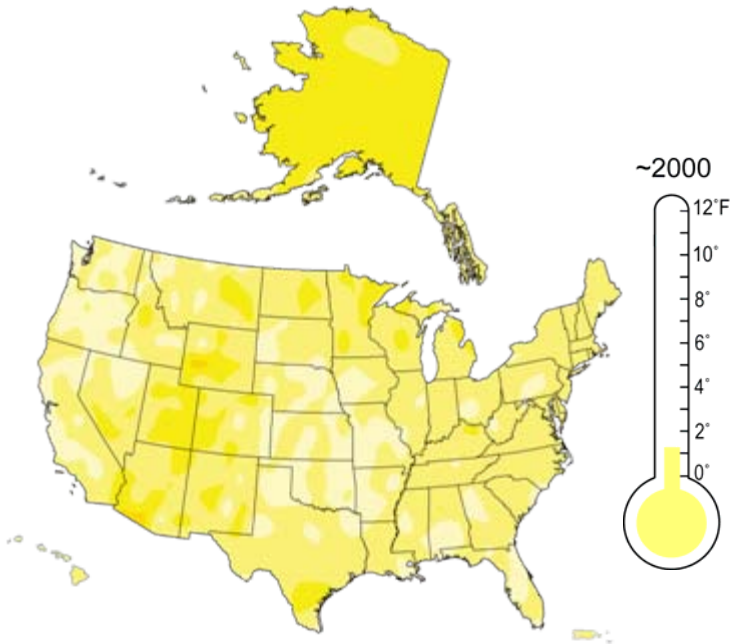


Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999 (for 3 SRES emission scenarios and from an ensemble of AOGCMs).

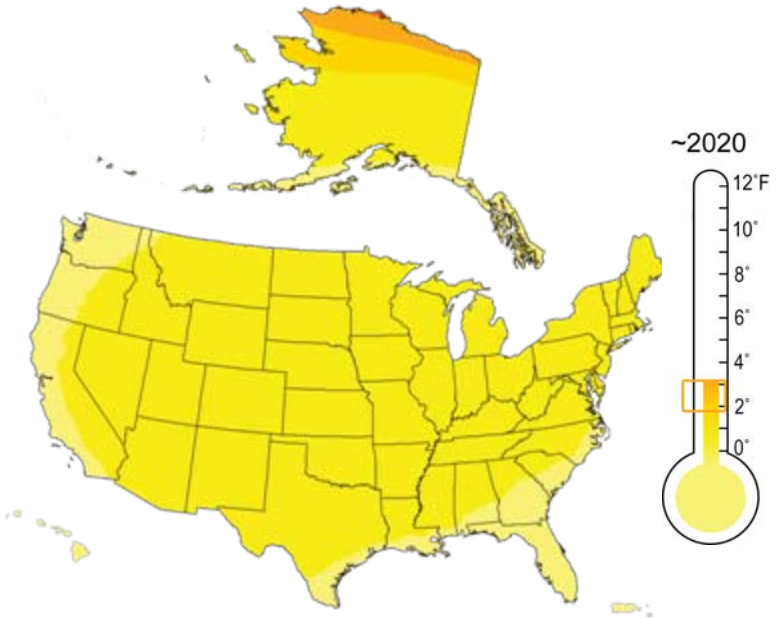
USGS

Change in U.S. Temperature (°F) from the 1960s and 1970s

Present-Day **(1993-2008)** Average Change
from 1961-1979 Baseline



Near-Term **(2010-2029)** Projected Average Change
from 1961-1979 Baseline

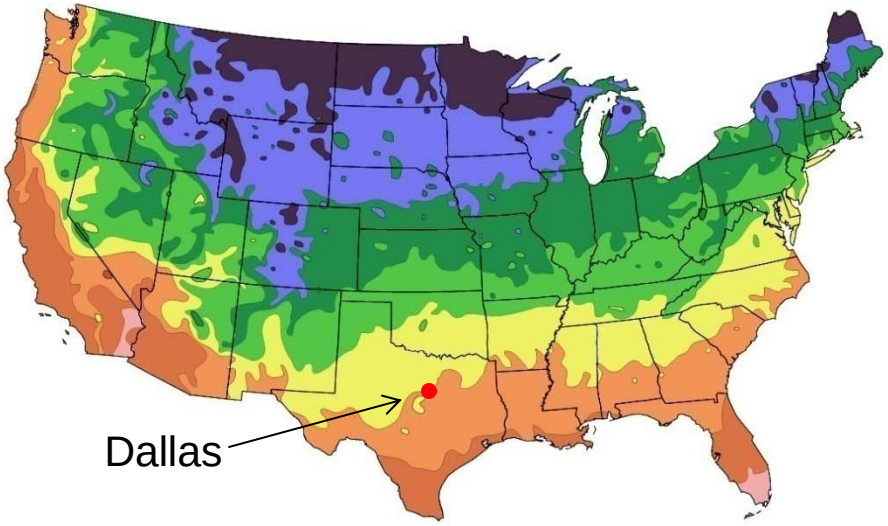


USGS

(USGCRP 2009)

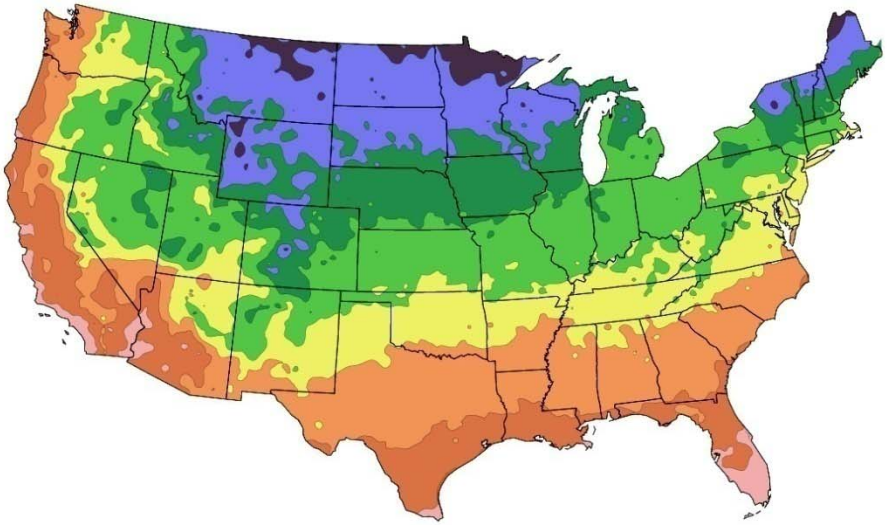
Shifting plant hardiness zones

1990 Map

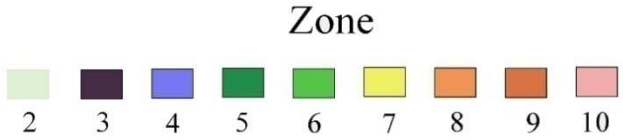


After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990

2006 Map



National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.



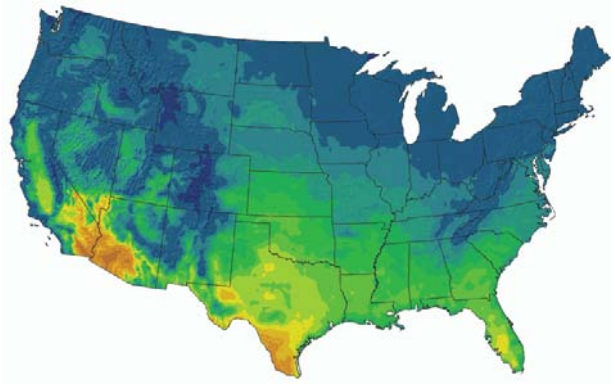
The plant hardiness zone for Dallas has *already* shifted to become more like Houston was in 1990.

USGS

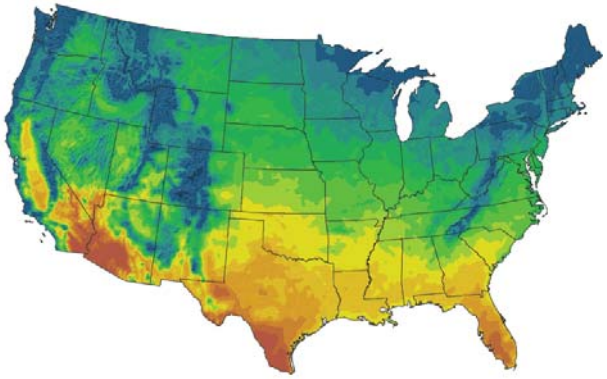
(Source: Katharine Hayhoe, Texas Tech)

Change in Number of Days Above 90°F

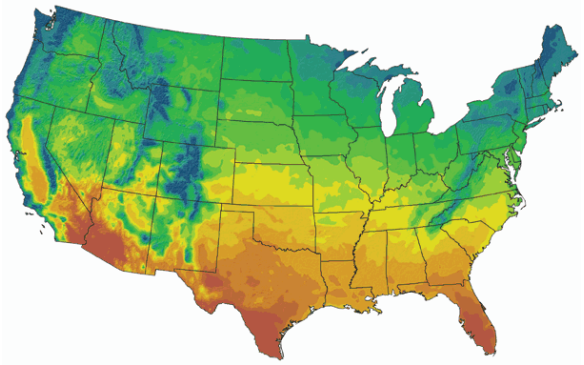
Recent Past
(1961-1979 Average)



Projected End-of-Century
Lower Emissions Scenario
(2080-2099 average)



Projected End-of-Century
Higher Emissions Scenario
(2080-2099 average)



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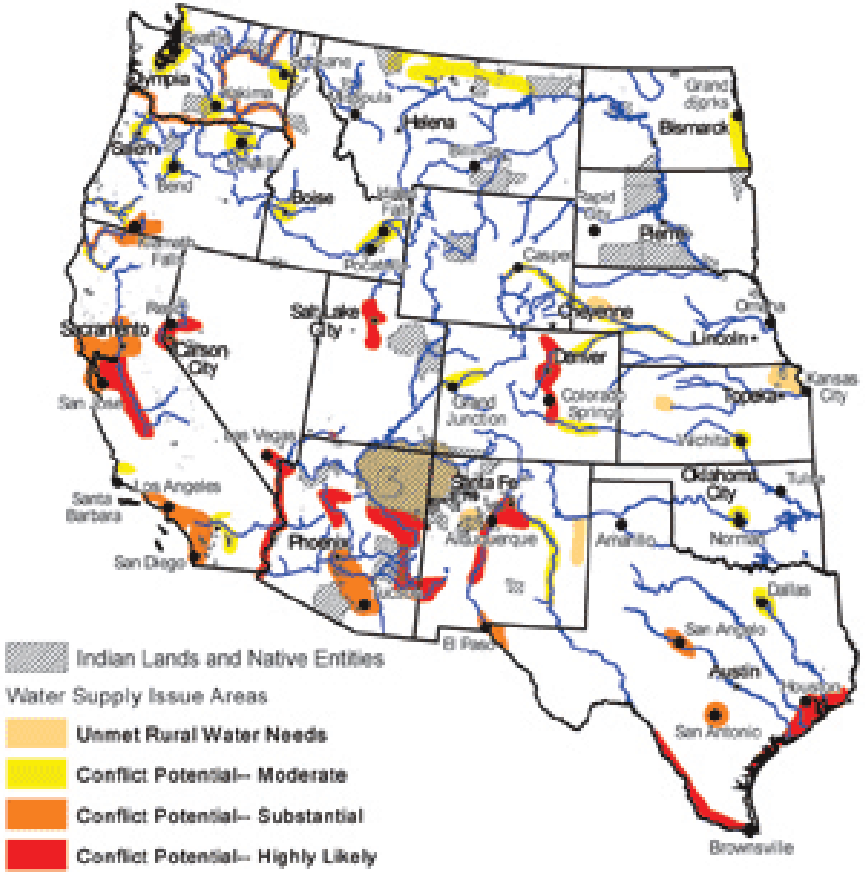
(USGCRP 2009)

Potential Water Supply Conflicts by 2025



Regions in the West where water supply conflicts are likely to occur by 2025 based on a combination of factors including population trends and potential endangered species' needs for water

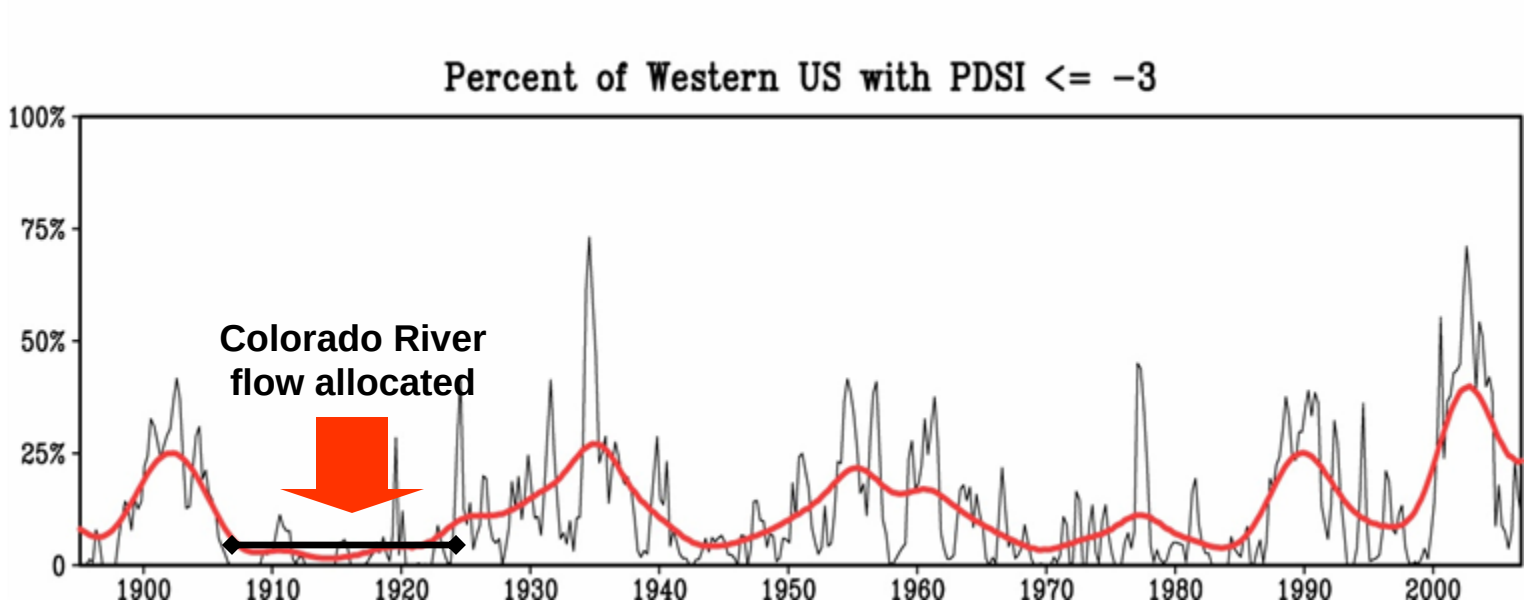
Red zones are where the conflicts are most likely to occur. This analysis does not factor in the effects of climate change, which is expected to exacerbate many of these conflicts

USGS

(USGCRP 2009)

- The drought of 1861-1864 played a major role in the introduction of the prior appropriation system of water rights
- Westward expansion and drought events brought structural adaptations including hundreds of reservoirs and irrigation projects to semi-arid environments
- Allocation of Colorado River water to states occurred during the wettest period (1905-1925) in over 400 years

Colorado River, Grand Canyon NP, 1905



USGS

(figure courtesy of Jon Eischeid, NOAA/CIRES)

Examples of Ecological Consequences

Droughts can rapidly restructure aquatic, terrestrial, and coastal ecosystems

In summer 2002, pinyon (*Pinus edulis*) began dying *en masse* from drought stress and an associated bark beetle outbreak

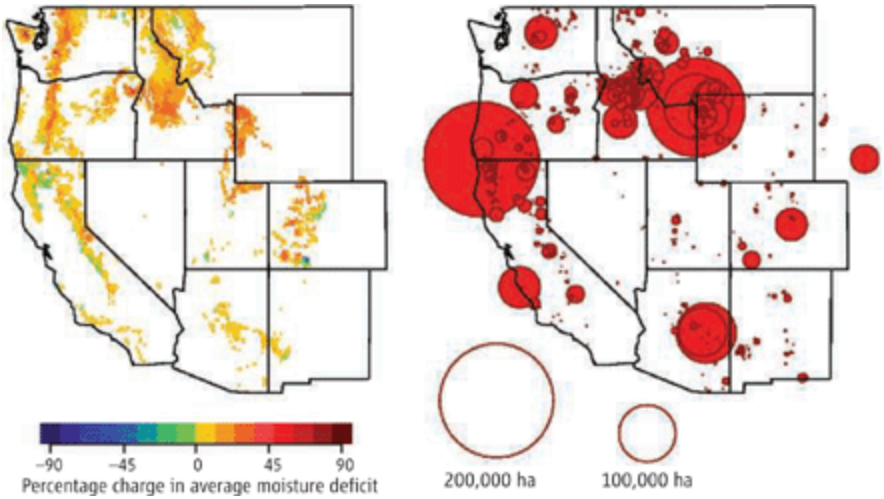
(Jemez Mts. near Los Alamos)

USGS

Examples of Ecological Consequences

Lower soil moisture leads to more intense, frequent, and widespread wildfires

Rill erosion on a burned hill slope after the Buffalo Creek Fire (Photo by John A. Moody)

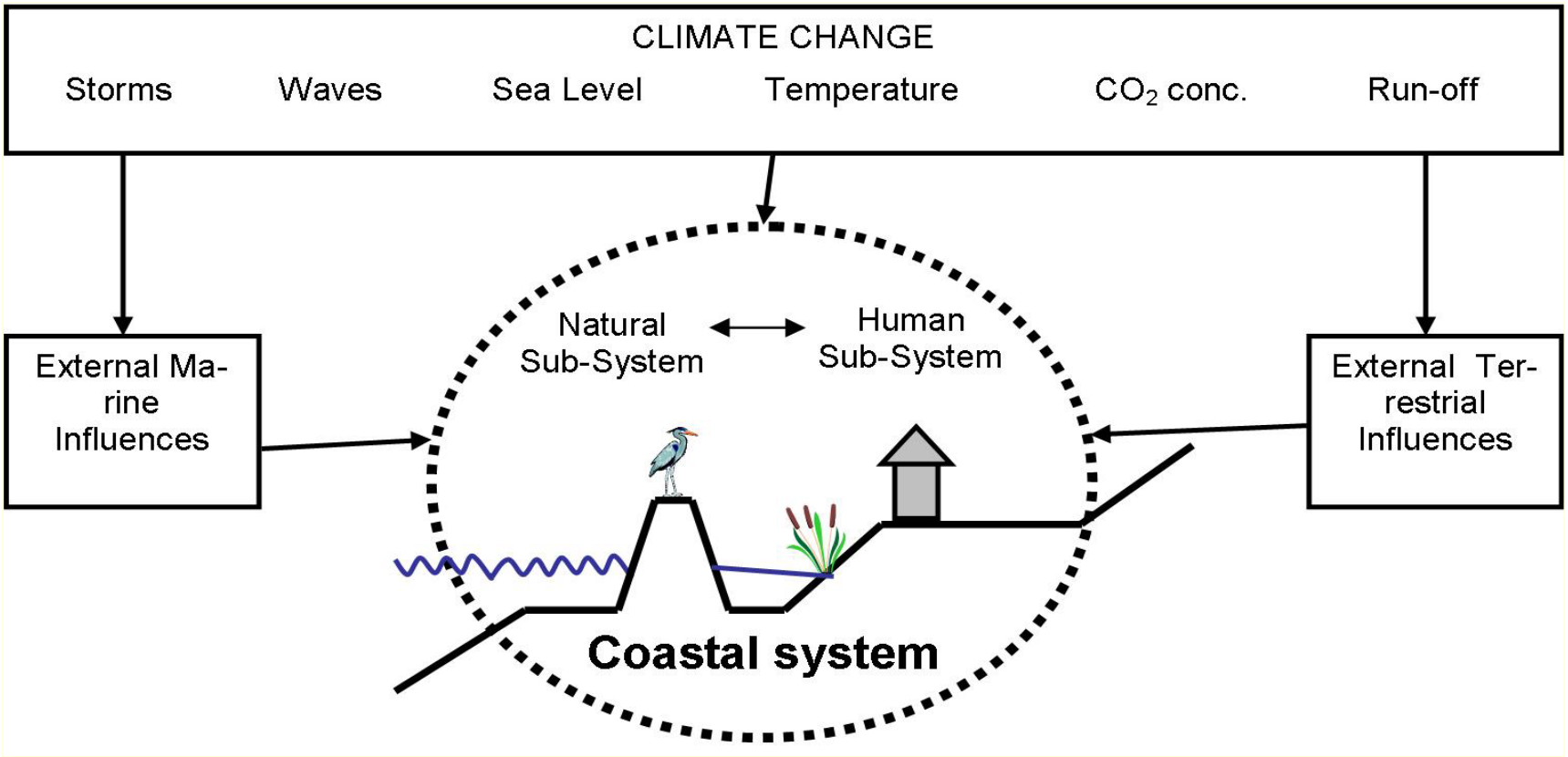


Source: Westerling, Hidalgo, Cayan and Swetnam, *Science* (2006)

Wildfires lead to erosion, flash flooding, and habitat loss

USGS

Climate Change Drivers in Coastal Systems



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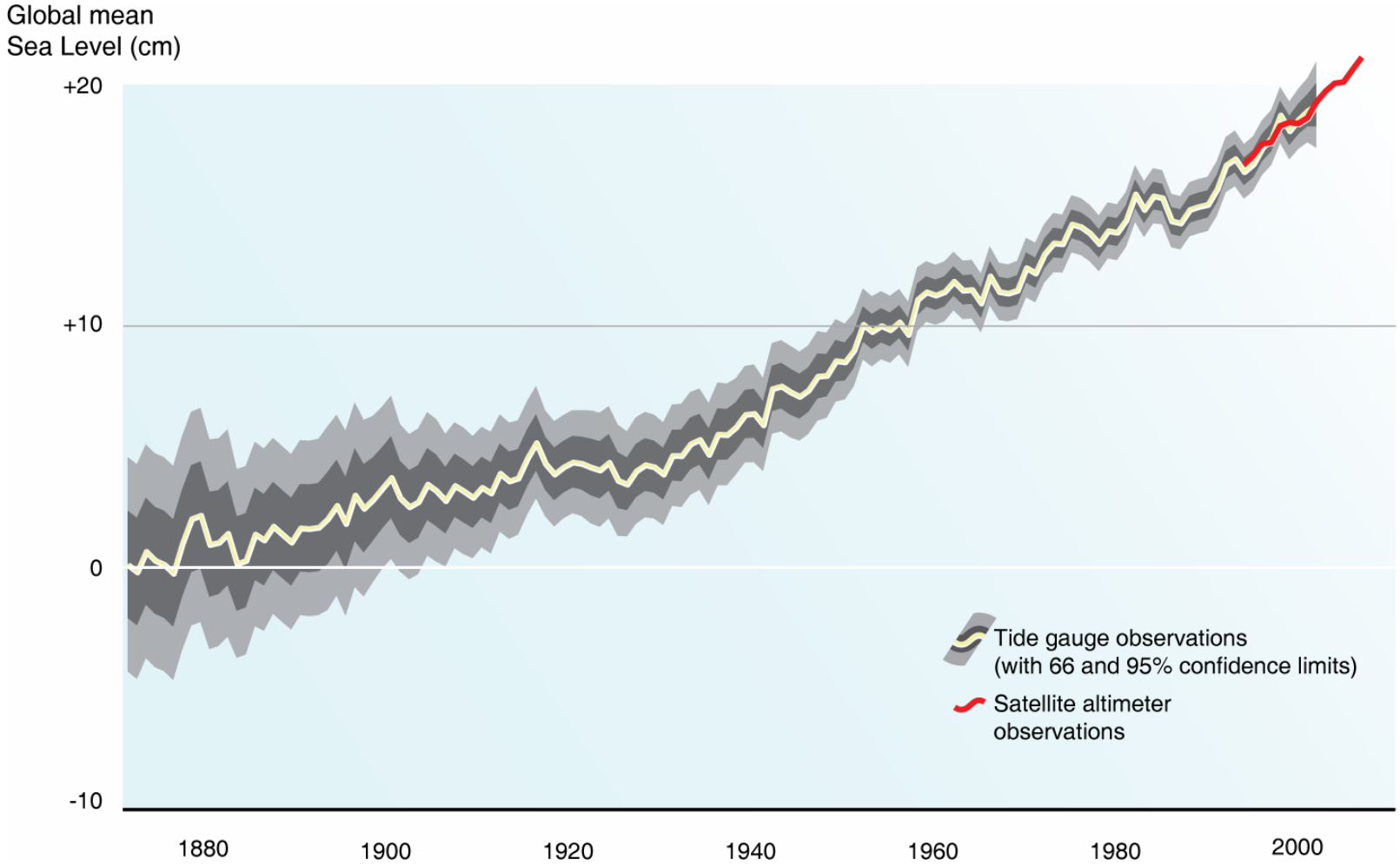
Global Mean Sea Level Rise, 1870-2006



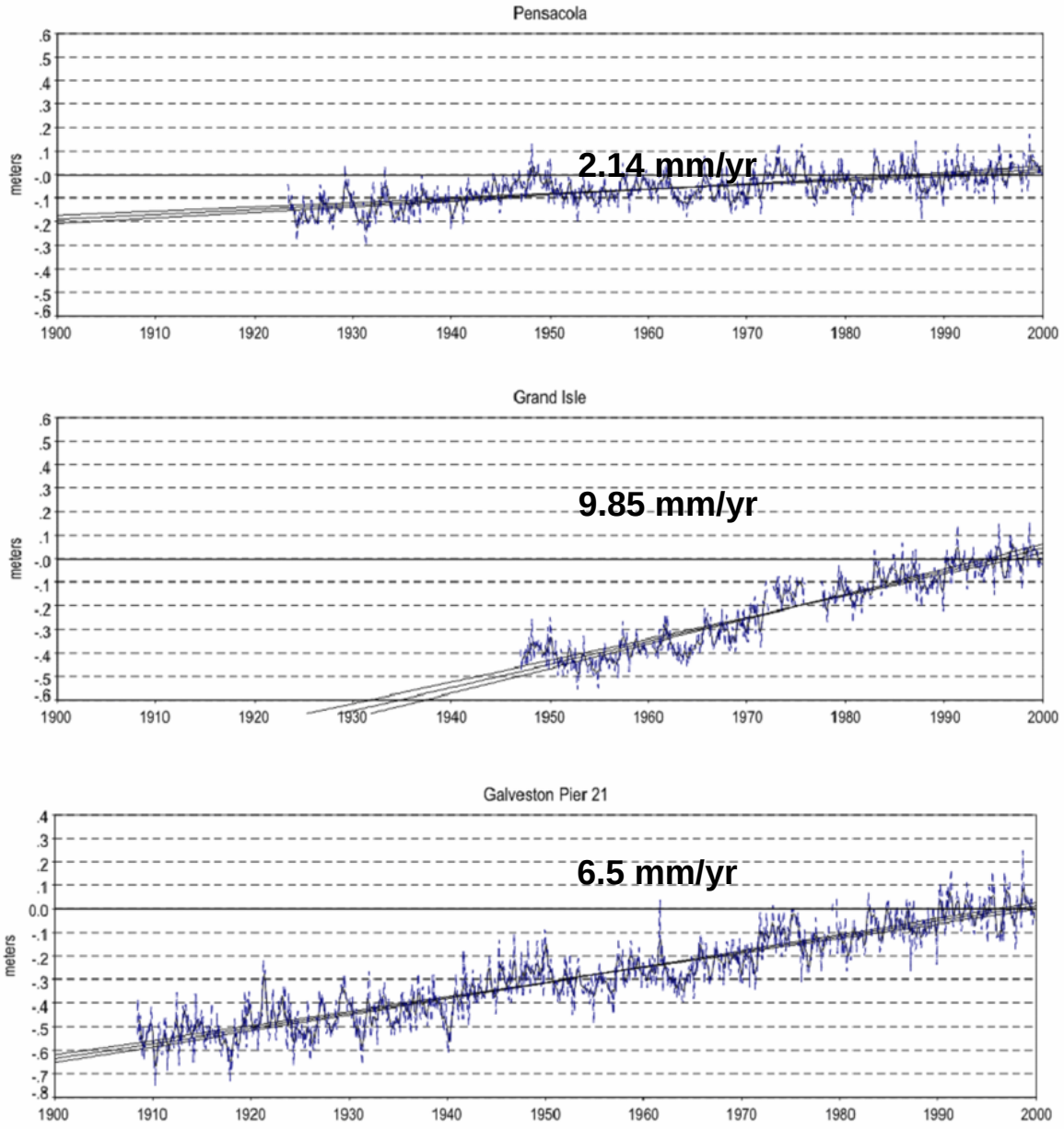
Church, J.A. and White, N.J. (2006)

http://maps.grida.no/go/graphic/trends-in-sea-level-1870-2006

USGS

“Relative sea level rise”

is a combination of global sea level rise and regional or local land surface elevation change (such as subsidence)

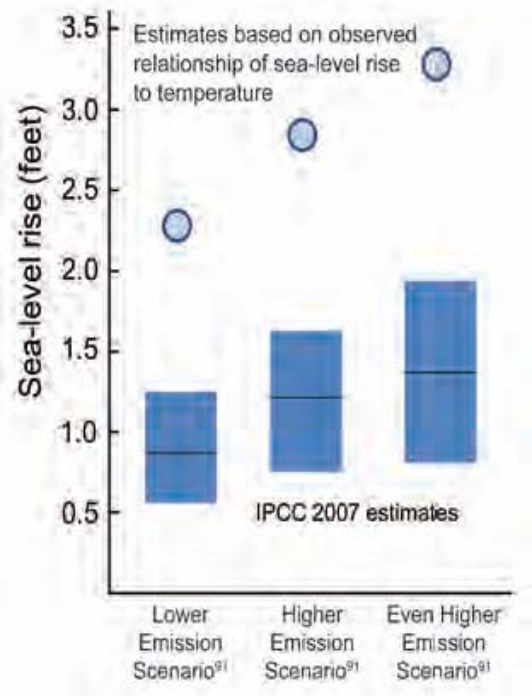


USGS

Historical Tide Gauge Data (1900-2000)

Melt area of the Greenland ice sheet increased on average by 0.7% per yr between 1979 and 2005

Disintegration would raise sea level 6-7 m



USGS

(USGCRP 2009)

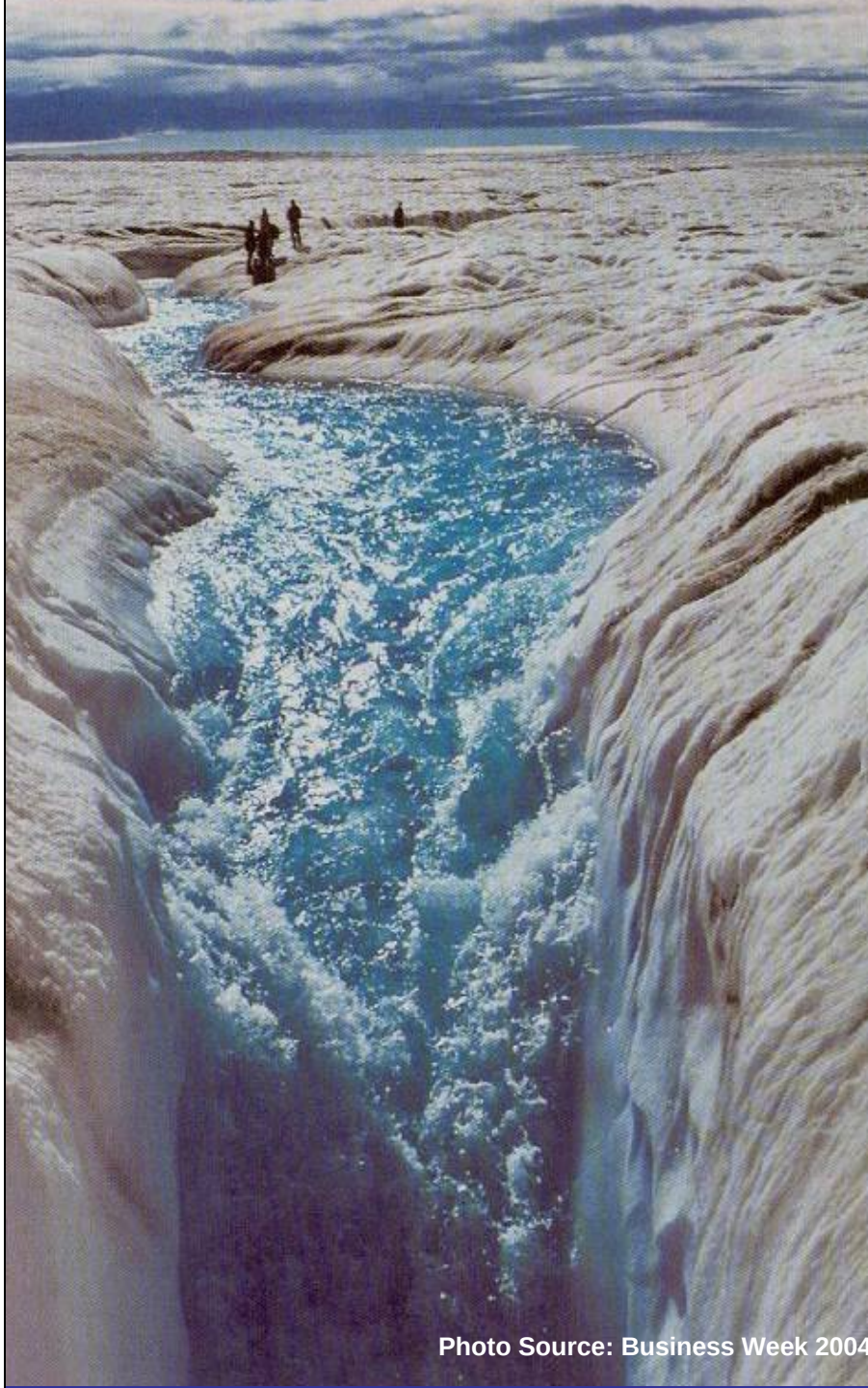
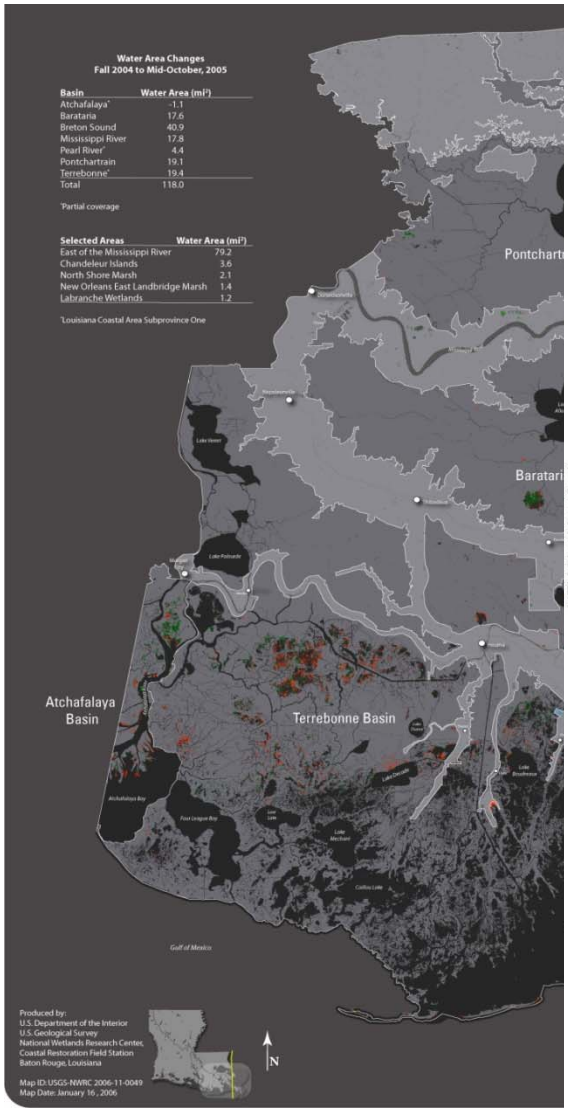
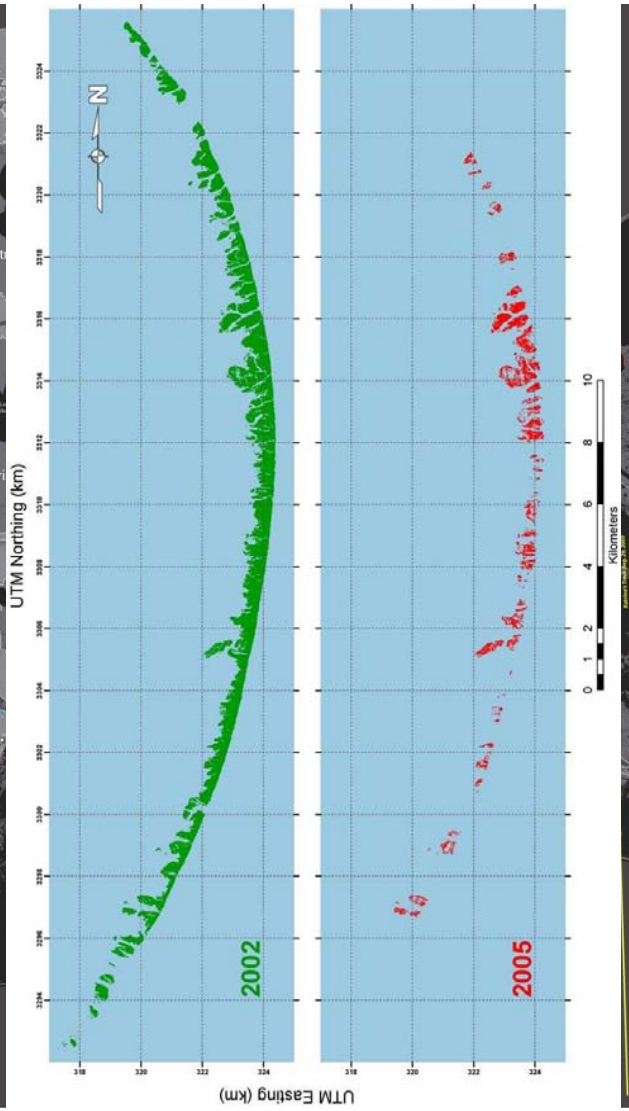
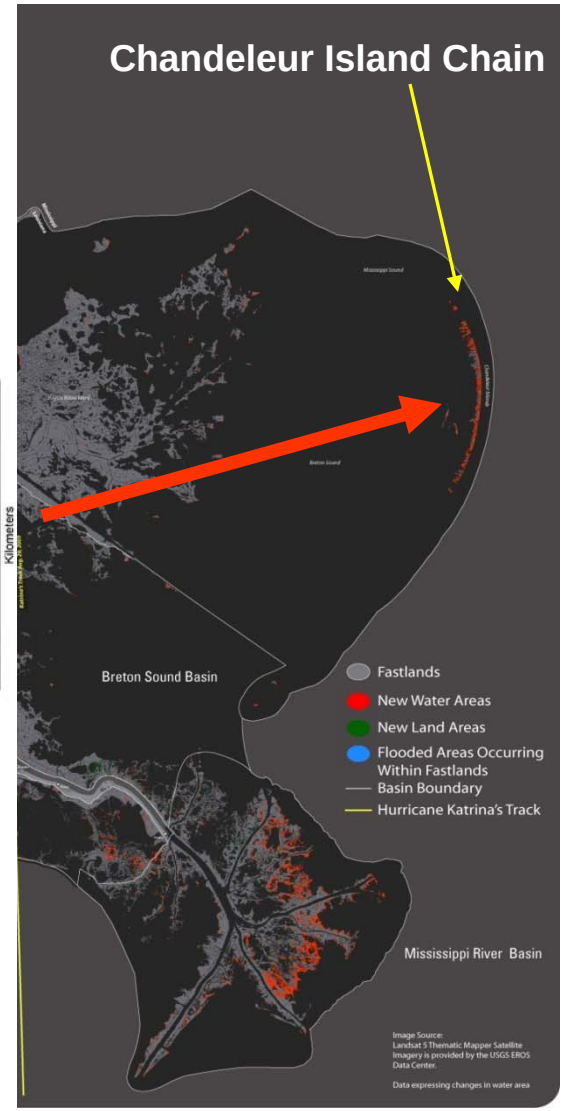


Photo Source: Business Week 2004

Hurricane Katrina converted 217^2 mi of Wetlands and Land to Open Water in Southeast LA



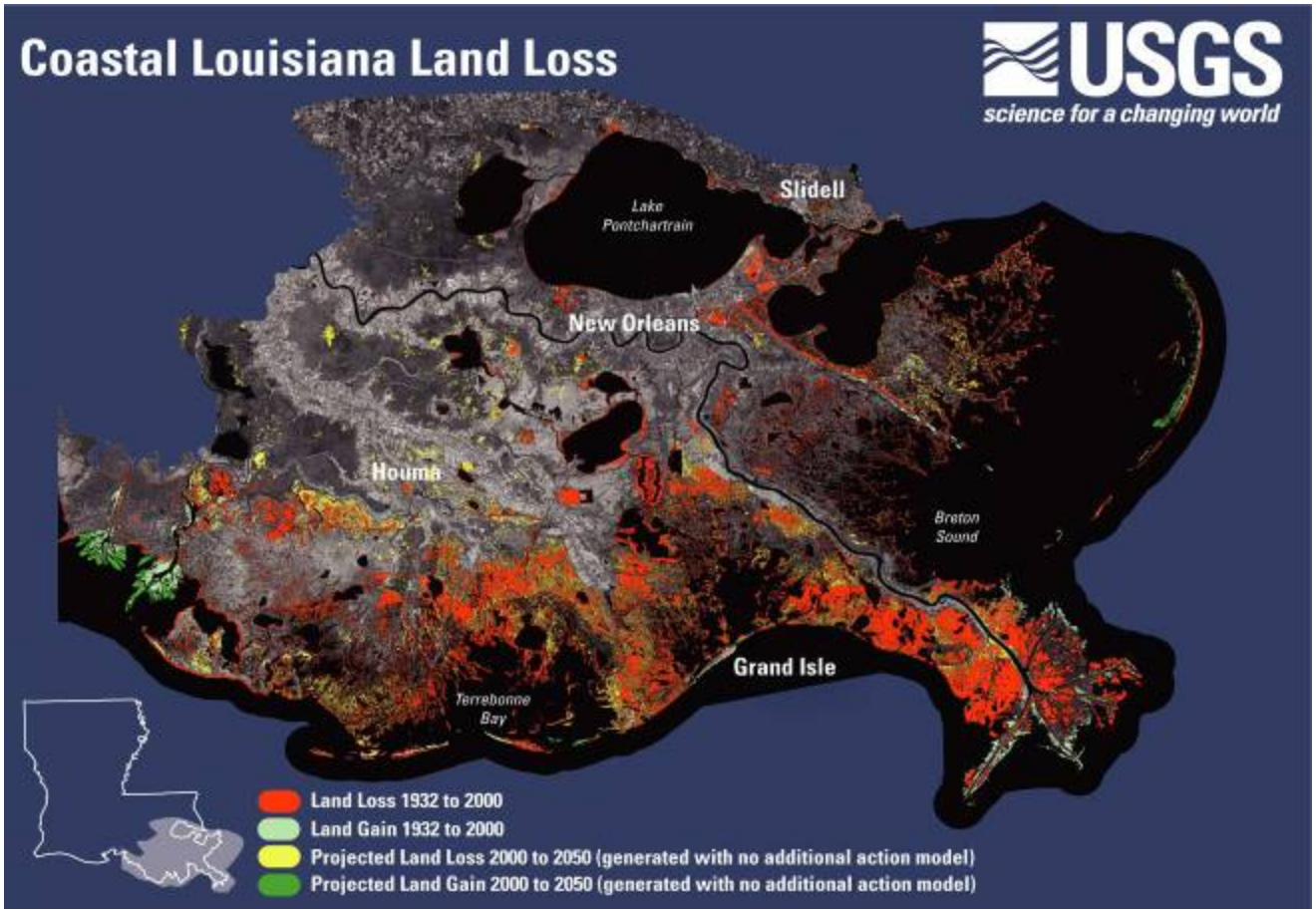




USGS

Examples of Ecological Consequences

As sea level rise accelerates -- shoreline erosion, wetland submergence, and salinity increase along low-lying coasts



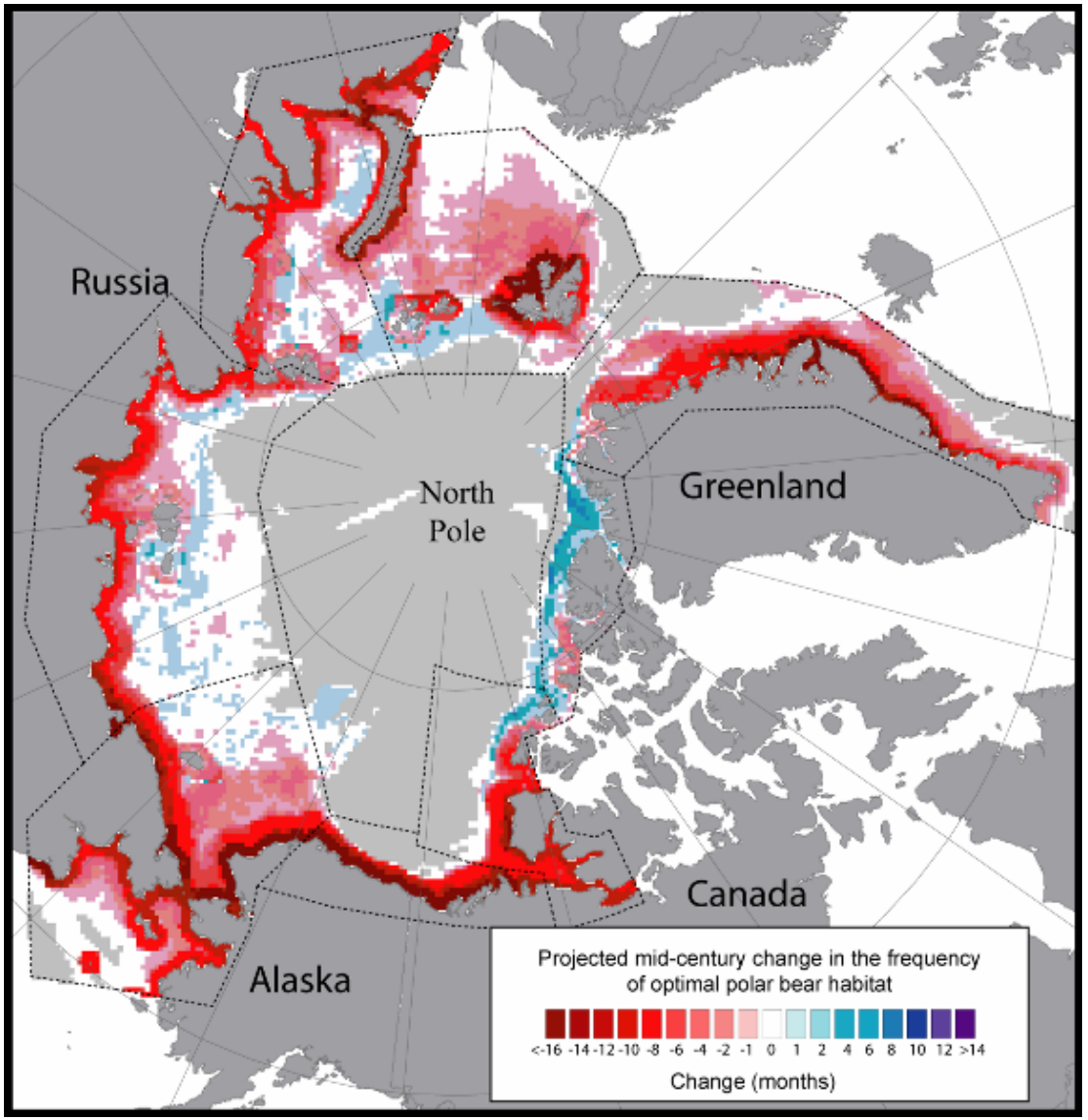
USGS

Examples of Ecological Consequences

As sea ice disappears

Change in optimal polar bear habitat

2041-2050 minus 2001-2010



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Examples of impacts on oil and gas operations

Onshore oil and gas facilities will likely be more difficult to permit, construct, and maintain

Port Fourchon, LA

USGS

Examples of impacts on oil and gas operations

Sea level rise and/or increase in tropical storm intensity will affect oil and gas infrastructure (offshore and onshore)

Rig damage during Hurricane Lilli

off the LA coast, Eugene Island area

USGS

Examples of impacts on oil and gas operations

Surface transportation systems that are essential to coastal onshore and offshore/OCS oil and gas development may be impassable more frequently or permanently

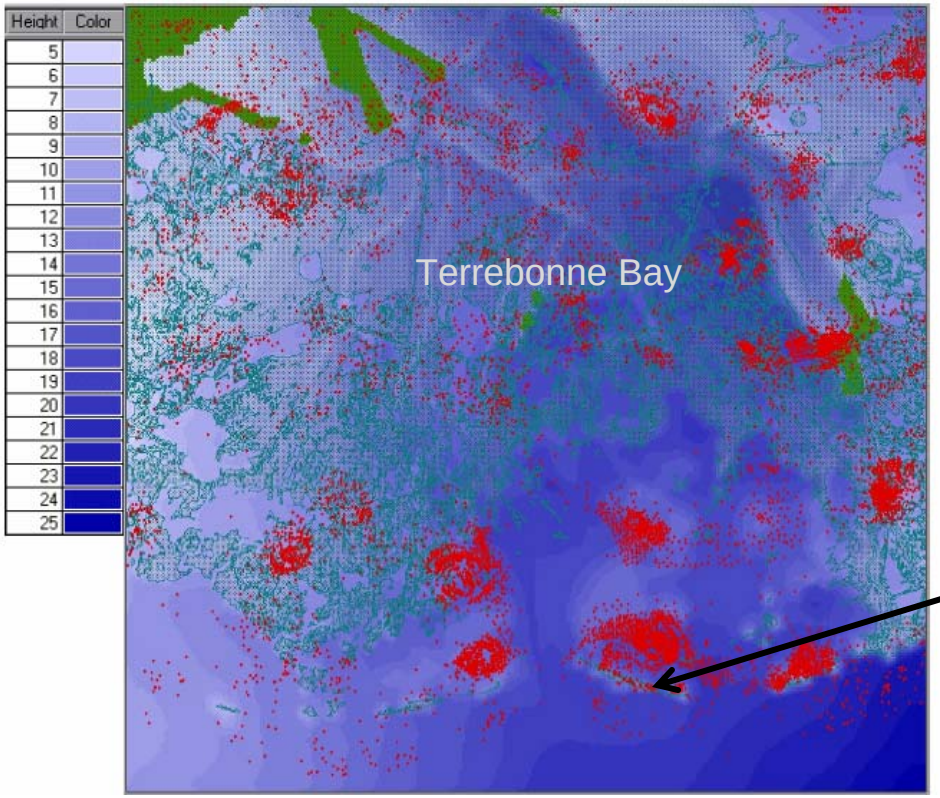
LA Highway 1, less than a foot above sea level, is a key highway that supports the offshore oil and gas industry in the Central Gulf Coast Region

USGS

Examples of impacts on oil and gas operations

Erosion of coastal barriers will affect wave energy and storm surge in oil and gas fields that were developed under more protected conditions

Simulation models indicate that storm surge during a category 3 hurricane increased typically 8-10 feet in this region of coastal Louisiana, concurrent with rapid deterioration of the coastal landscape (Stone *et al.* 2003)



Red dots are oilfield platforms in Terrebonne Bay, LA and adjacent nearshore waters

(Stone *et al.* 2003)

USGS

Examples of impacts on oil and gas operations

Exposed offshore pipelines are vulnerable to lateral and vertical displacement during storms, exposure to vessel traffic, or rupture by currents

Distribution of oil and gas pipelines superimposed on the 1990's Maximum Storm Surge Elevation and Maximum Significant Wave Height composite
(source Stone et al., 2003)

(Stone *et al.* 2003)

Examples of impacts on oil and gas operations

Permafrost decline is already affecting oil and gas facilities in coastal Alaska

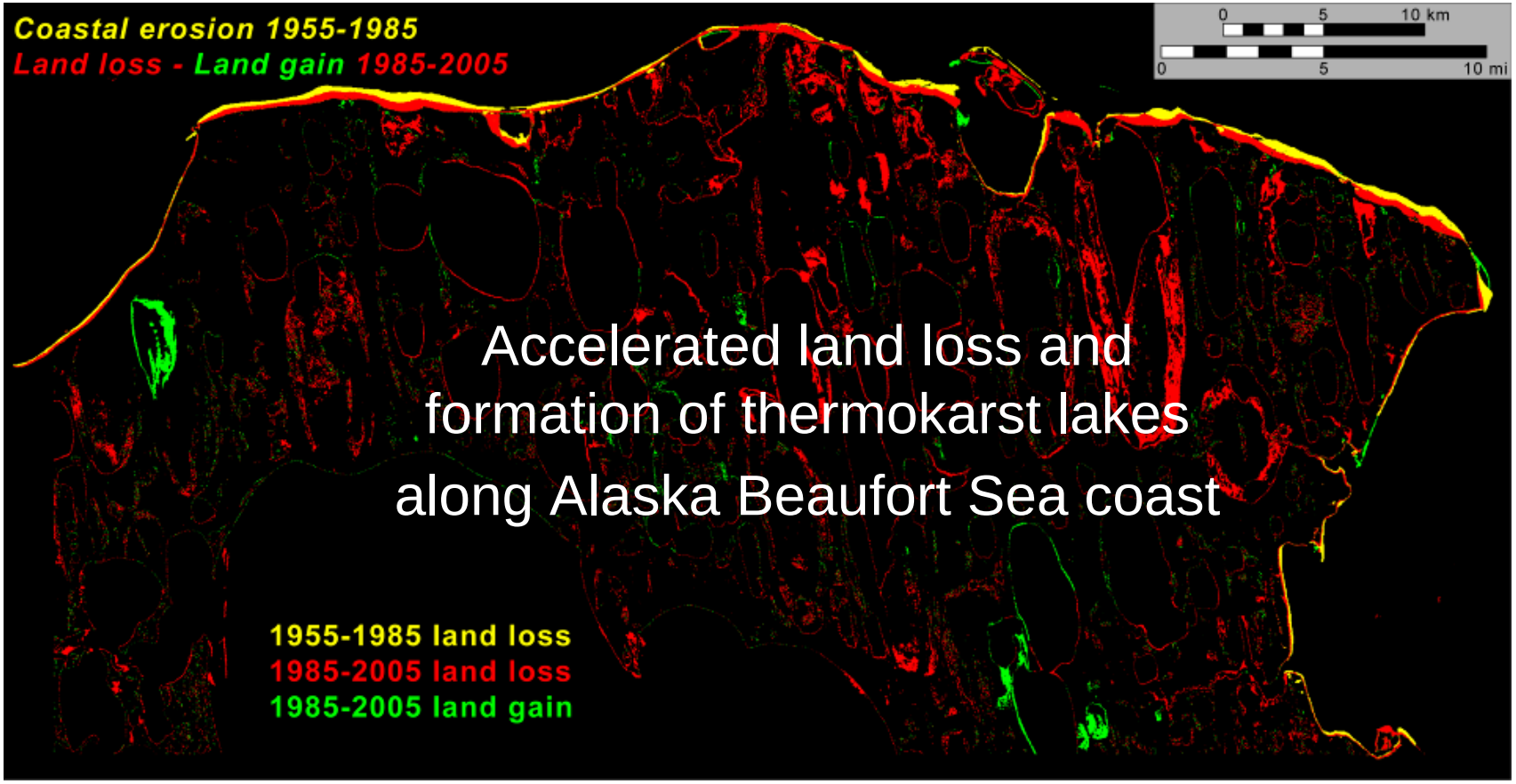
J.W. Dalton wellsite, National Petroleum Reserve AK

The U.S. Bureau of Land Management has identified about 30 old oil exploration wells that will soon be in danger of erosion. BLM has plans to plug these wells to prevent contamination

USGS

Examples of impacts on oil and gas operations

Hazards associated with the formation of thermokarst lakes in the coastal zone and the stability of shelf sediments due to thawing ice in sediments and the release of gas from clathrates



USGS

Examples of impacts on oil and gas operations

Navigation routes through the Northwest and Northeast Passages may be opened, even if ice simply thins to the point that shipping lanes can be mechanically maintained by icebreakers. Longer ice free season for exploration and development

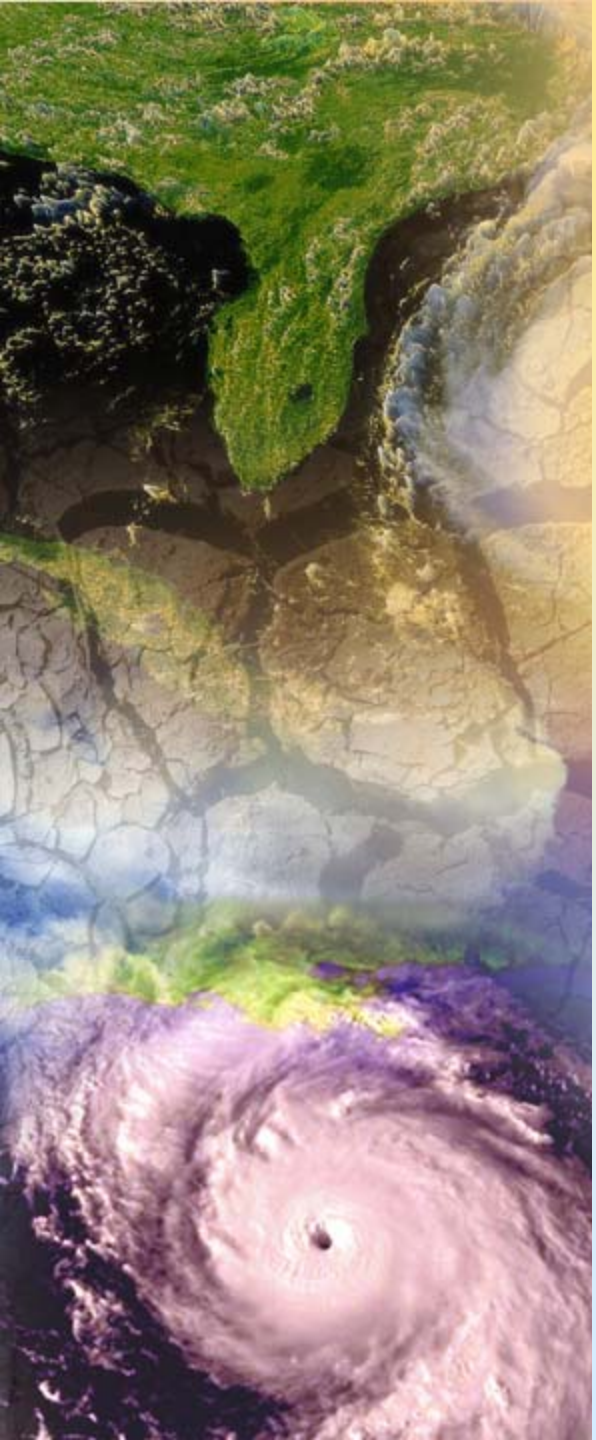
1979

Arctic Summer Sea Ice

source: NASA GSFC

2007

USGS



Mitigation

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Adaptation

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Climate Response