

Responding to a Changing Climate: Challenges and Opportunities

Eileen L. Shea

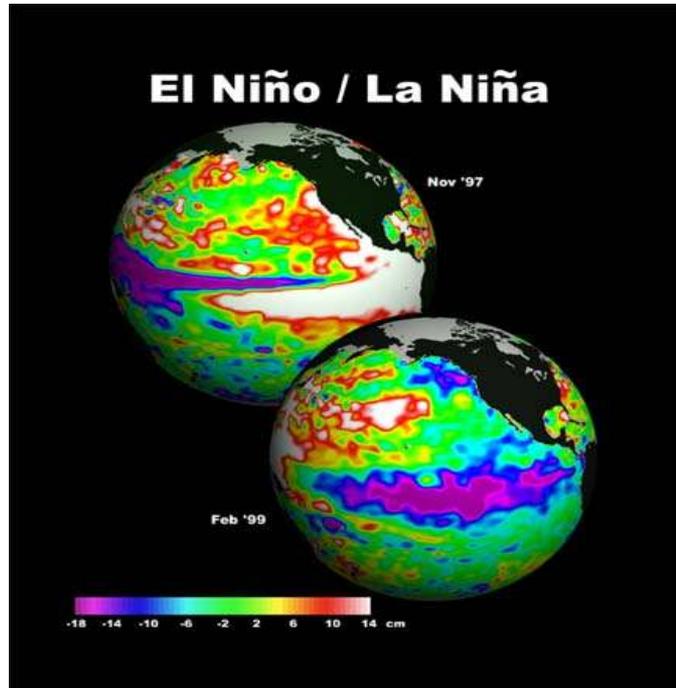
Chief, Climate Services & Monitoring
Division, NCDC, NOAA

MAFAC Meeting

May 24, 2011

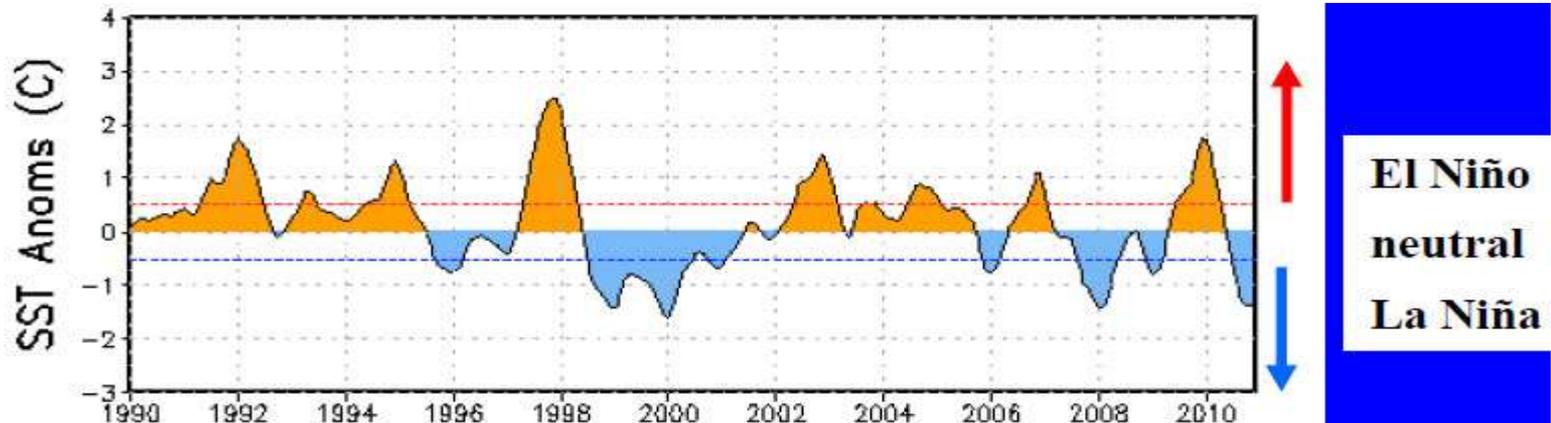
Key West, FL

What does El Niño have to do with the price of eggs?



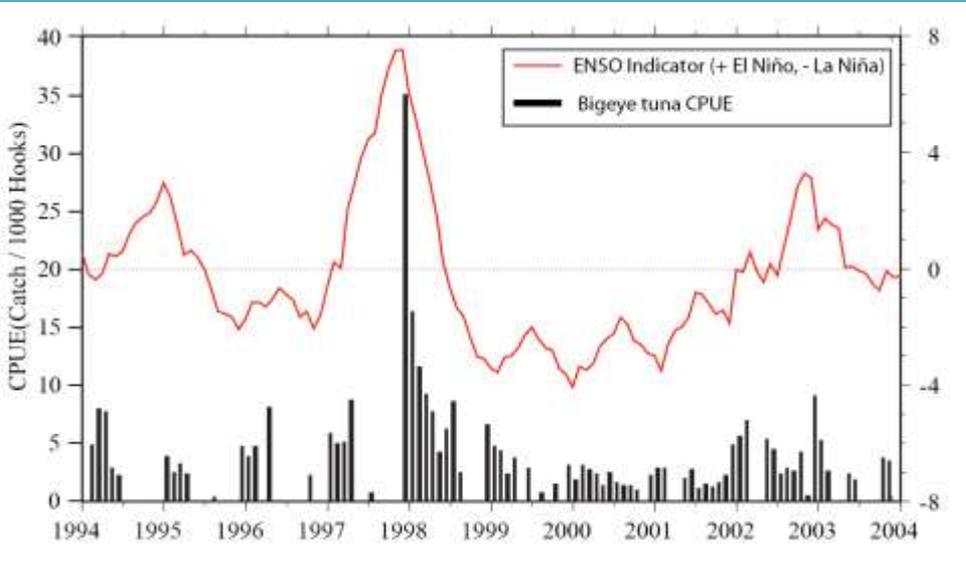
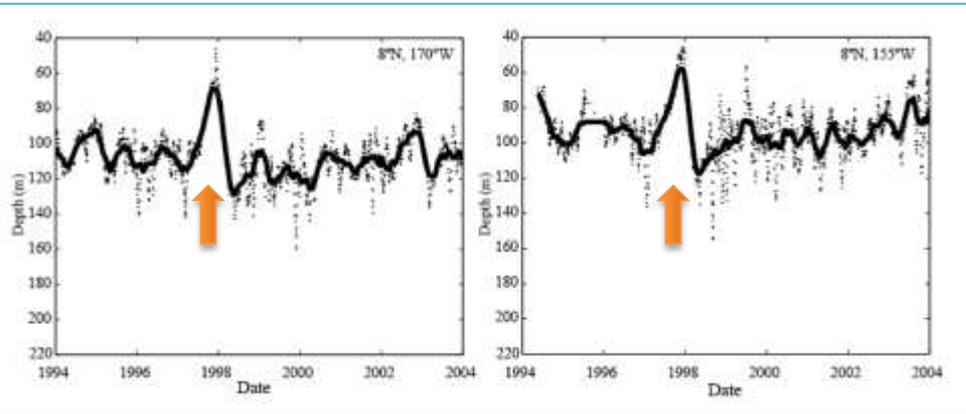
El Niño / La Niña

- Natural oscillation in the Pacific with near-global impacts
- Ocean and atmosphere connected

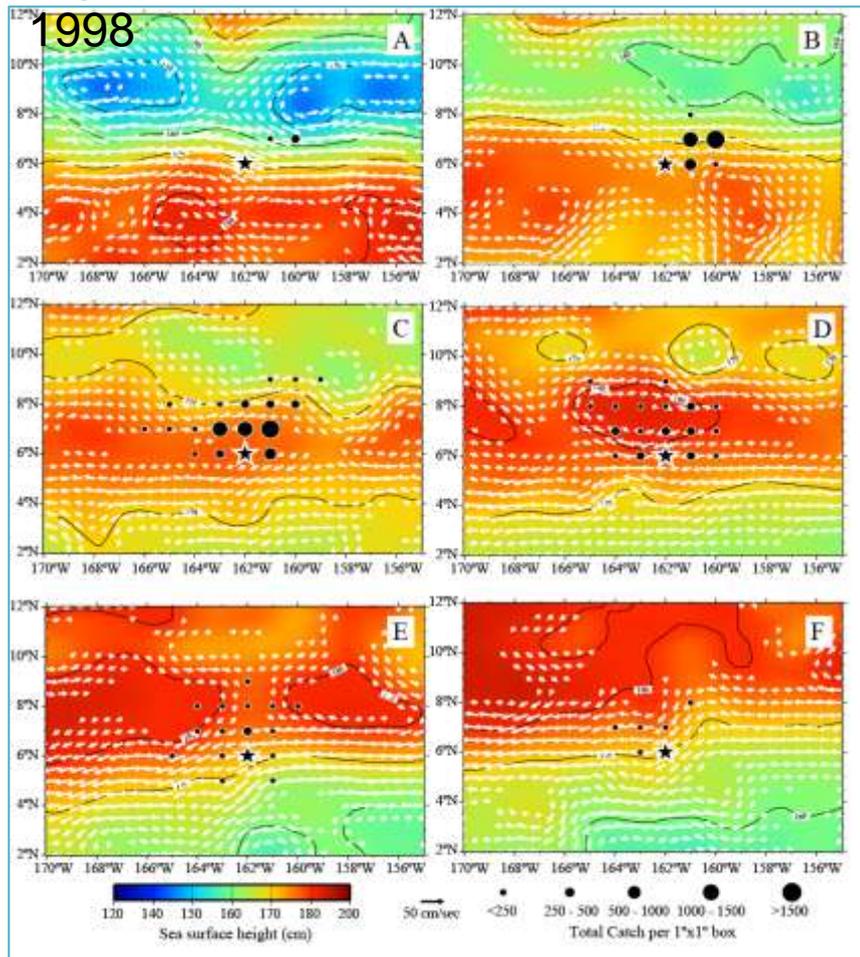


El Niño and the Hawaii-based pelagic longline fishery (Jeff Polovina)

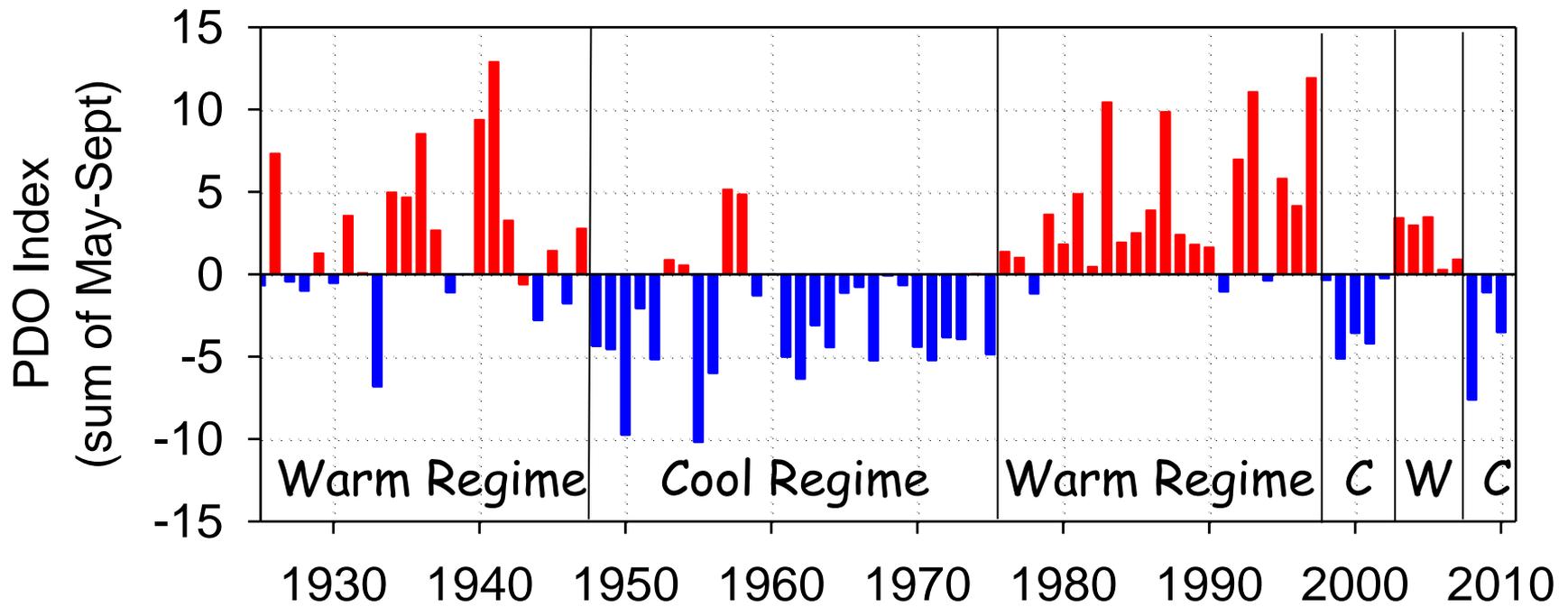
- I. **El Niño** brings warm pool waters from the west to the Palmyra Atoll region
- II. This results in a drop in Altimetry, **a rise in the thermocline depth**, yet warm SST
- III. Possible Mechanism: Movement of new recruits from warm pool spawning grounds to the east and a rise in the interaction with the fishery



Bigeye CPUE over altimetry Jan-June

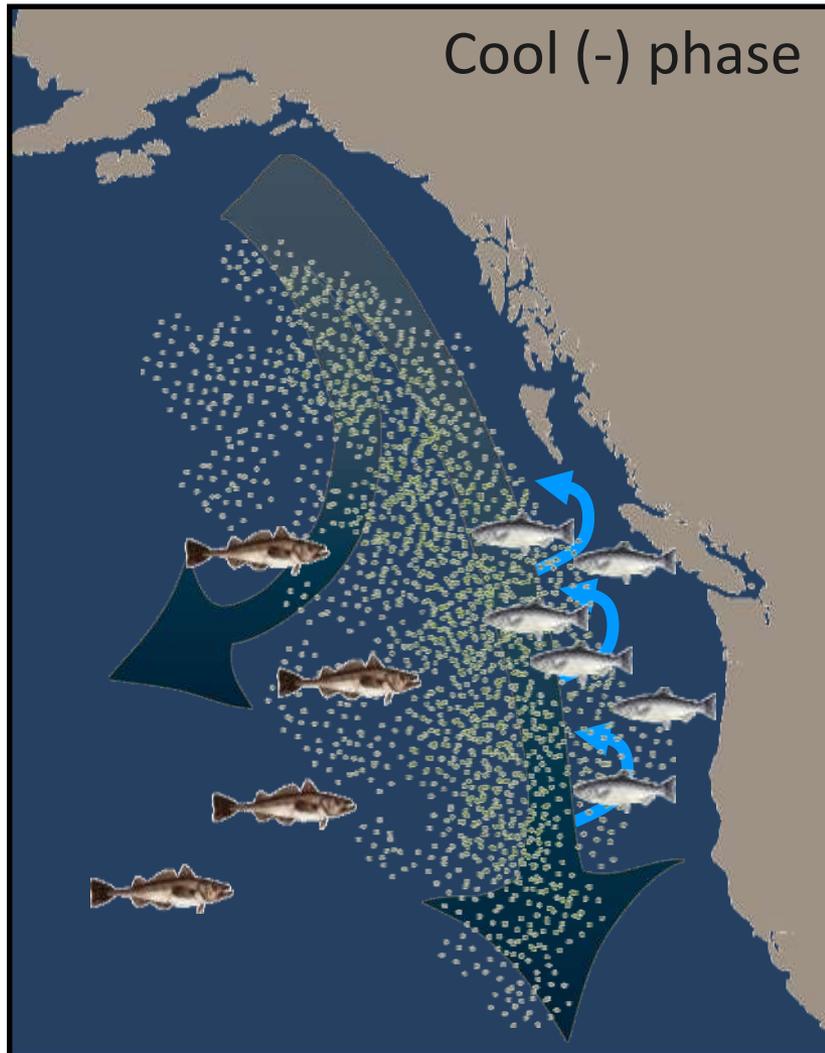


PDO: May-Sep Average, 1925-2010



- From 1925-1998, PDO shifted every 20-30 years between warm and cool regimes.
- However, we have had two shifts of four years duration recently: 1999-2002 and 2003-2006, and another shift in late 2007, thus we have a natural experiment to test the affects of PDO on marine food chains and salmon populations.
- Note 2008: most negative PDO since 1950s!!

The Pacific Decadal Oscillation



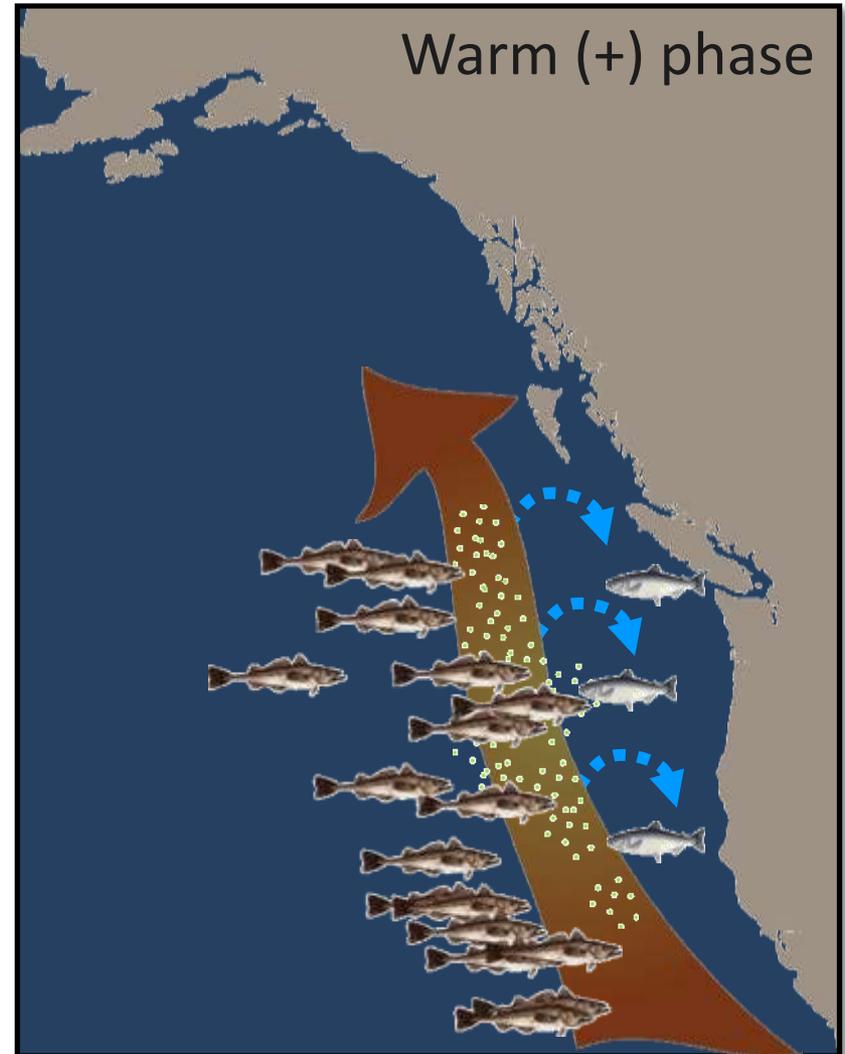
- Cold sea temperature
- Northerly currents
- Strong upwelling
- High productivity
- Lots of forage fish
- Low predation

Good survival

The Pacific Decadal Oscillation

- Warm sea temperature
- Southerly currents
- Little upwelling
- Low productivity
- Few forage fish
- High predation

Poor survival



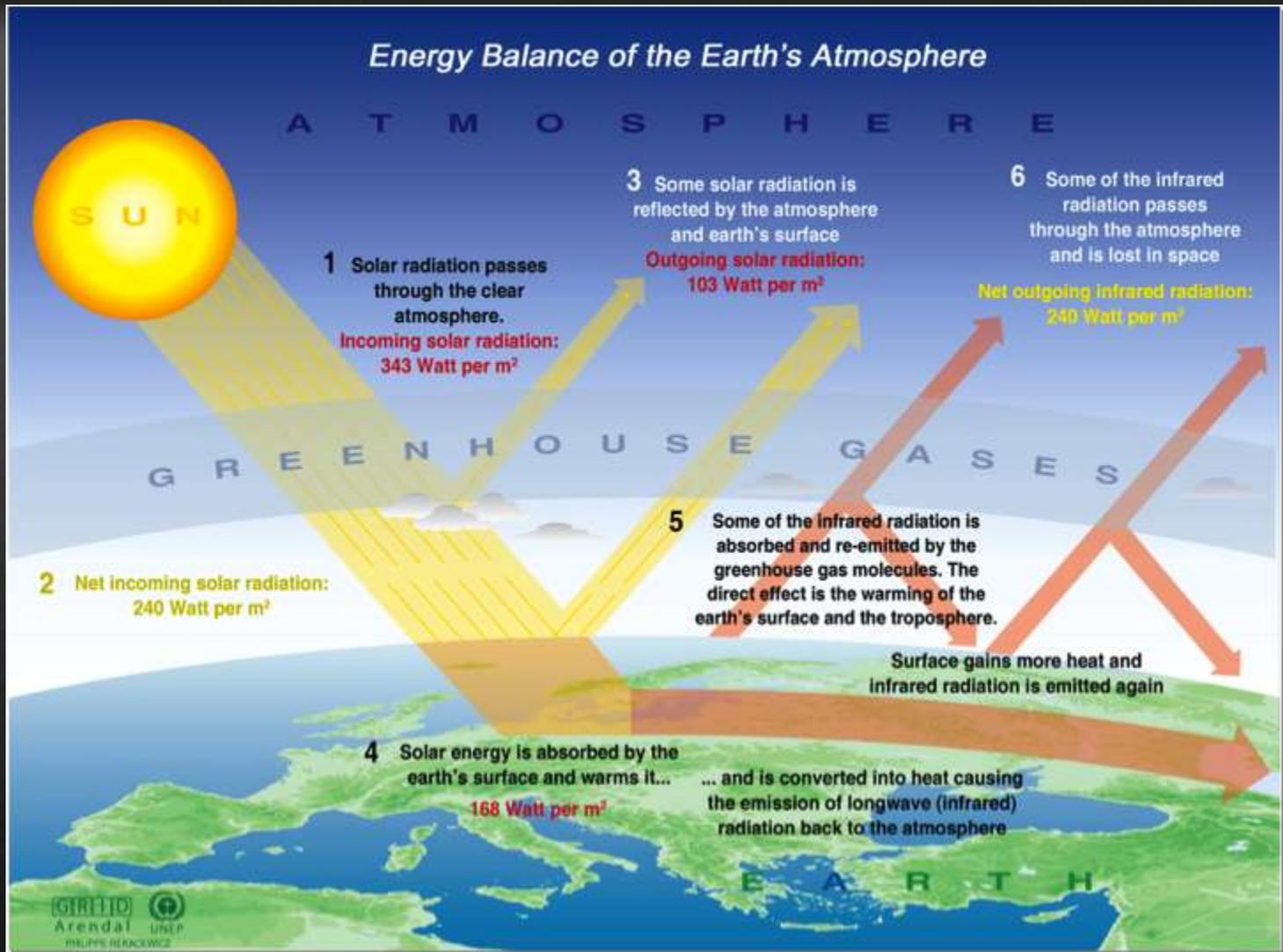
Ocean Conditions and Coral Bleaching (Billy Causey)

Can predict coral bleaching and stressful events:

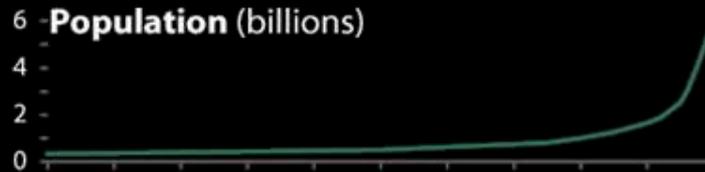
- Doldrum conditions for extended periods
- Low Cloud cover
- Minimal water circulation
- Elevated Sea Surface temperatures
- Consistent Predictability



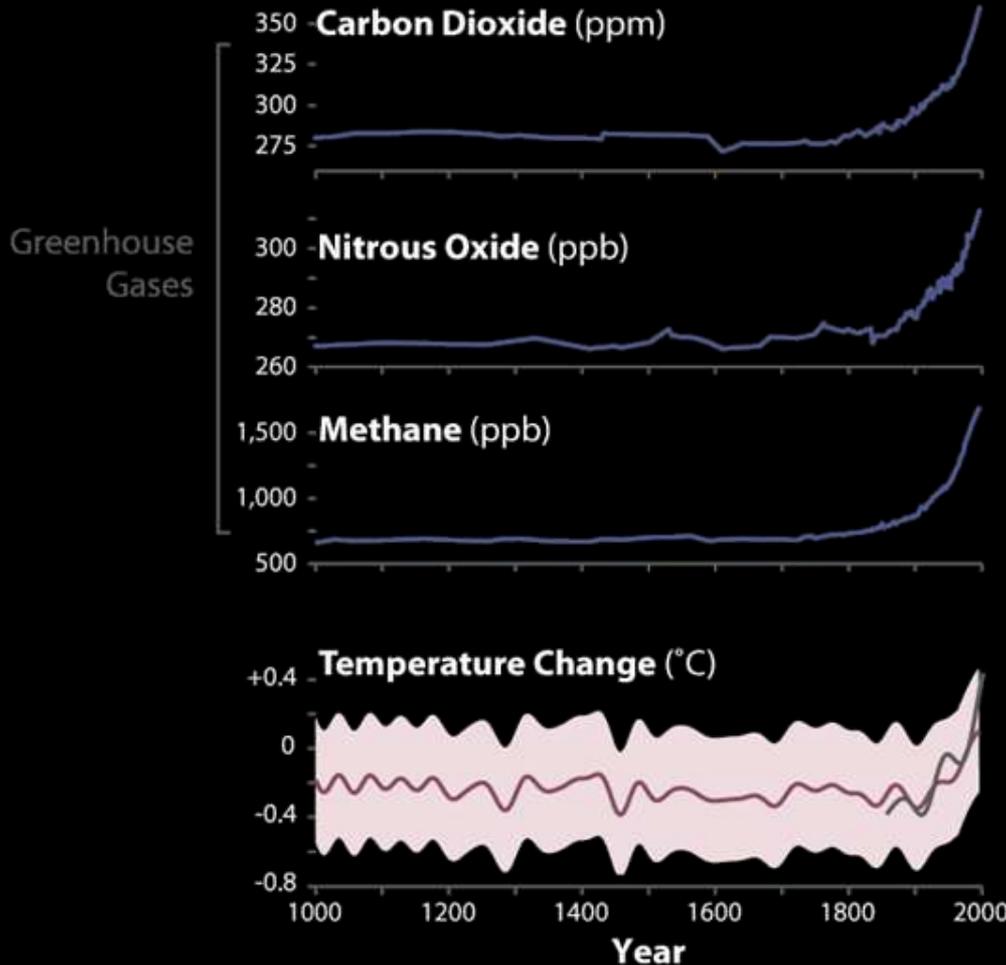
Heat Budget of the Earth's Climate System



Human 'fingerprints' on the climate system



Population doubled & then doubled again over the last century—from 1.65 billion to more than 6 billion inhabitants.

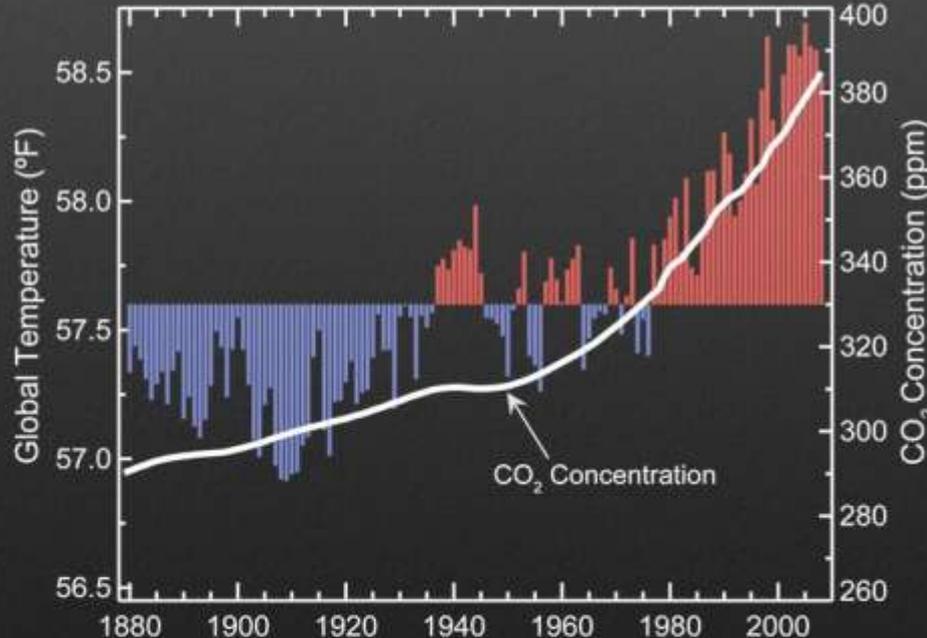


In that same time span, there was a rise in the three most abundant human-emitted greenhouse gases, mirroring the growth in human population. Isotopic analysis and carbon cycle models established that the increase in carbon dioxide was due to fossil fuel consumption.

With the rise in those greenhouse gases, Earth experienced an unusually rapid rise in its average temperature—increasing 0.7°C since 1880.

The Climate Is Already Changing

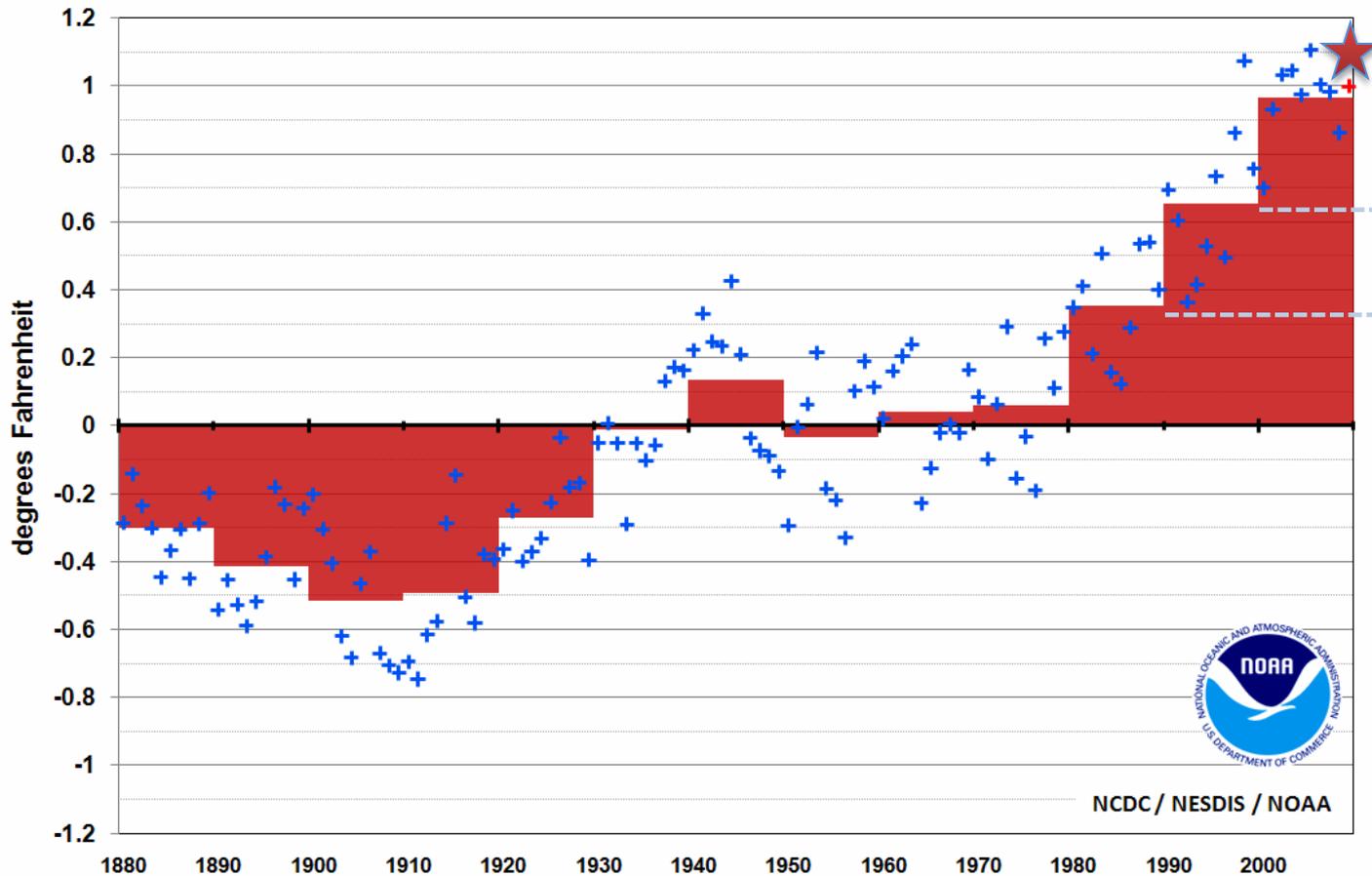
Scientific consensus shows that the Earth's climate is changing due to increased concentrations of greenhouse gases in the atmosphere



- Global average temperature and carbon dioxide concentrations have risen substantially since 1880
- Most of the warming in the past 50 years has been over land and in the Northern Hemisphere
- Year-round average temperatures in the U.S. have already risen 2°F over the past 50 years

1880-2009 Global Temperature

Annual Global (Land & Ocean) Temperature Anomaly
relative to 1901-2000 base period



2010

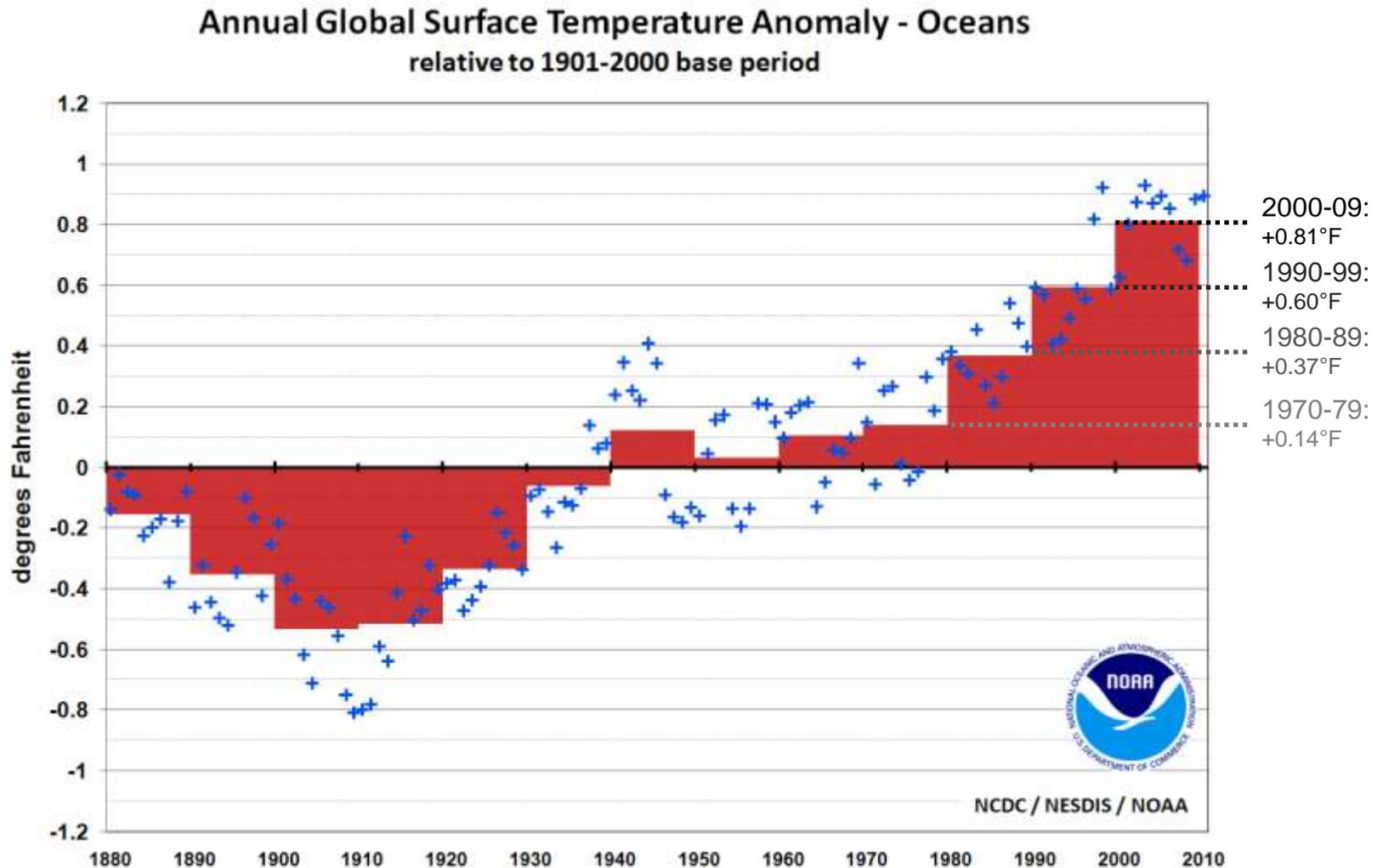
1990s warmest decade at the time. Every year of 2000s warmer than 1990s average.

1980s warmest decade at the time. Every year of 1990s warmer than 1980s average.



NCDC / NESDIS / NOAA

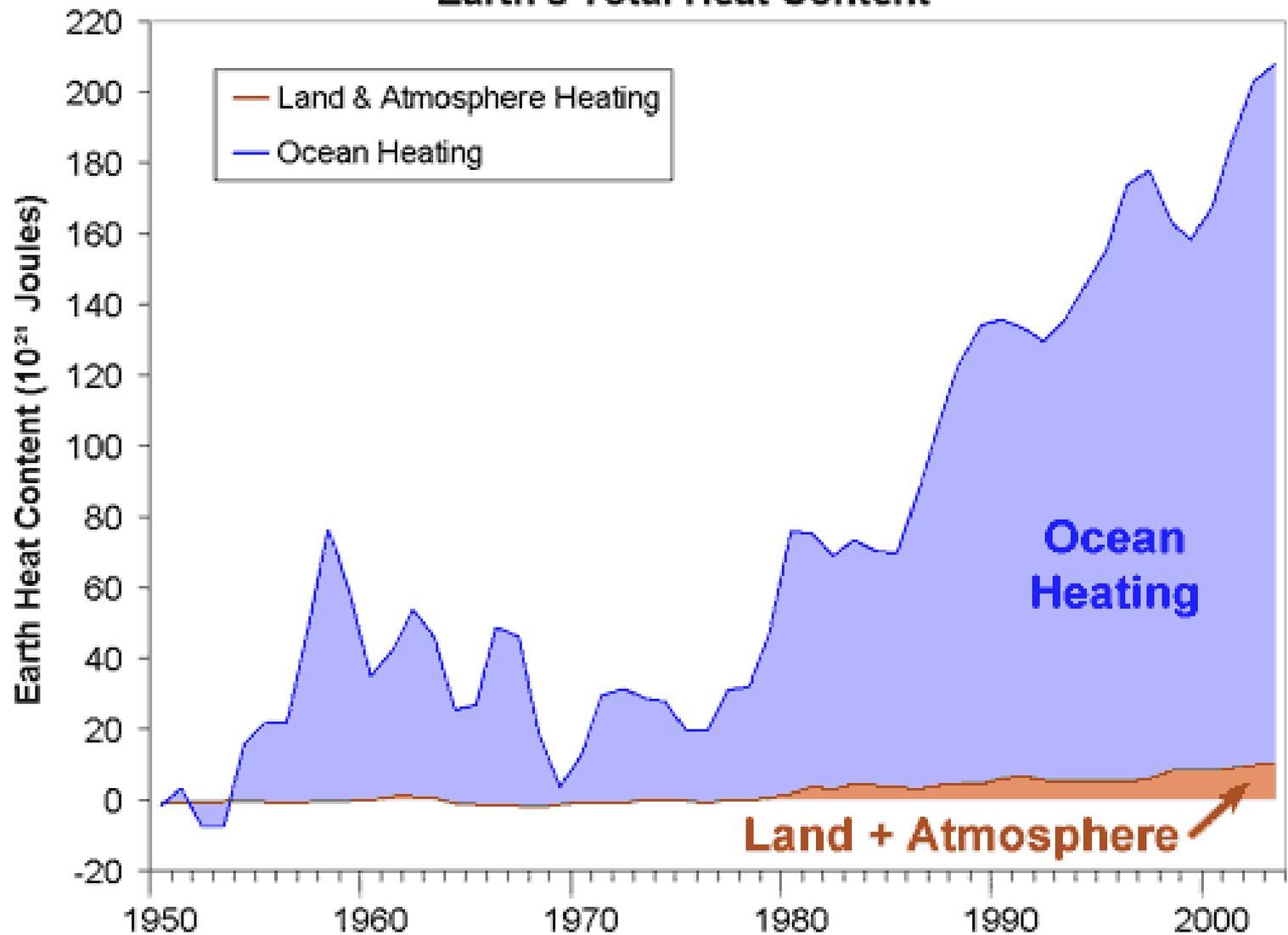
Global Sea Surface Temperature, 1880-



Data source:
Extended-Reconstructed Sea Surface Temperature (ERSST) v3b
NOAA's National Climatic Data Center

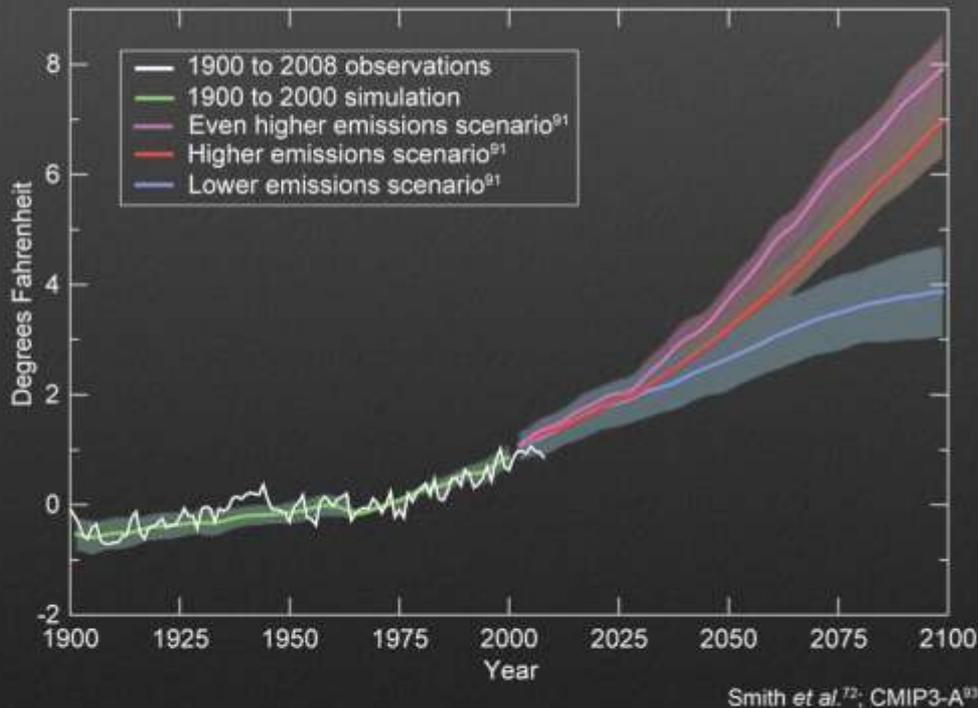
Heat content of the ocean is increasing

Earth's Total Heat Content



Future Climate Change

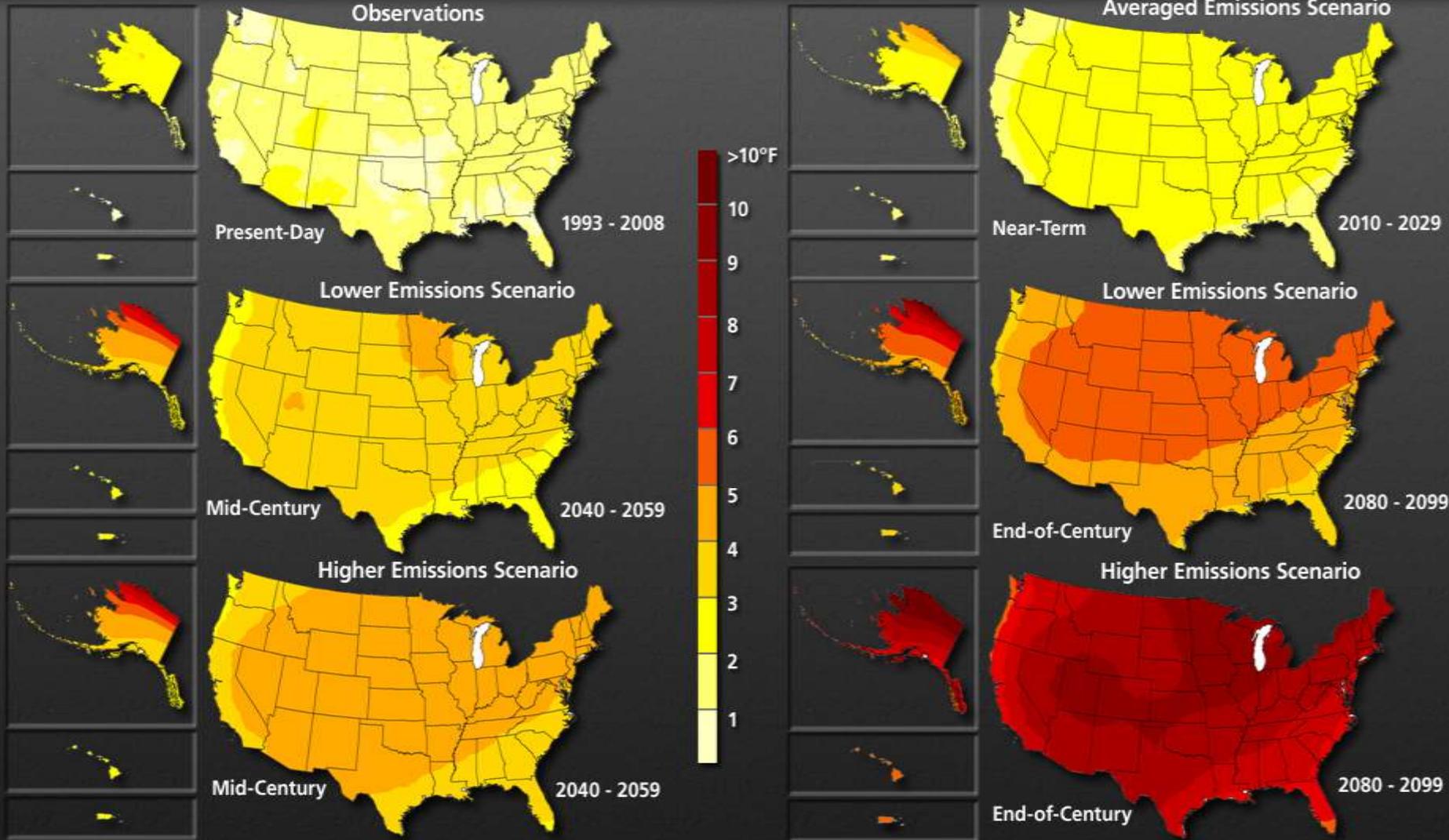
The future depends largely on choices people make now



- Actions to reduce greenhouse gas emissions will help limit future warming
- Even with strong emissions reductions, people will continue to feel the effects of climate change
- Adaptation and mitigation are inextricably linked

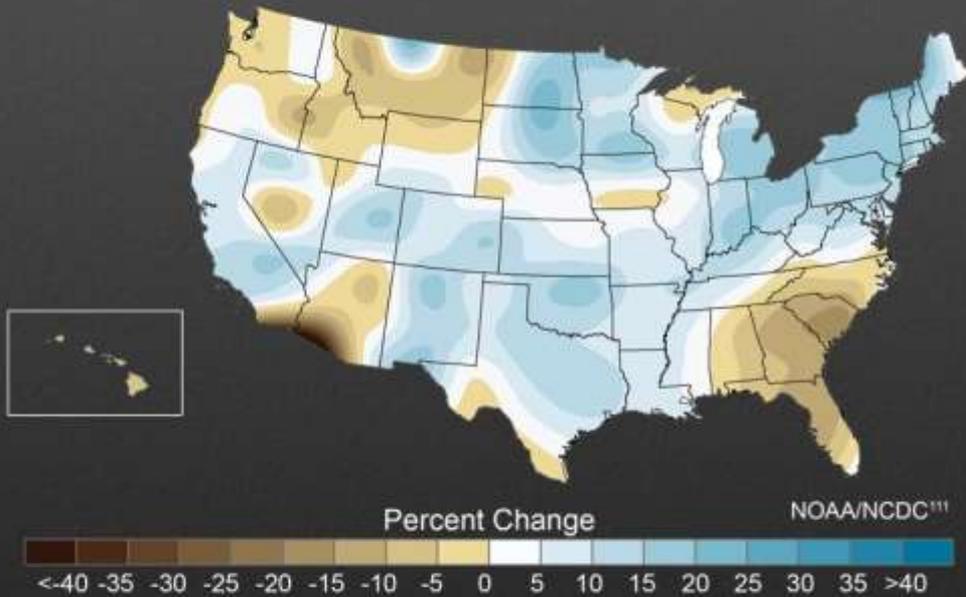
Observed and Projected Average Change °F

from 1961 - 1979 Baseline



Precipitation Changes

“Climate changes are underway in the United States and are projected to grow.” — USGCRP 2009



Wetlands drought, USDA

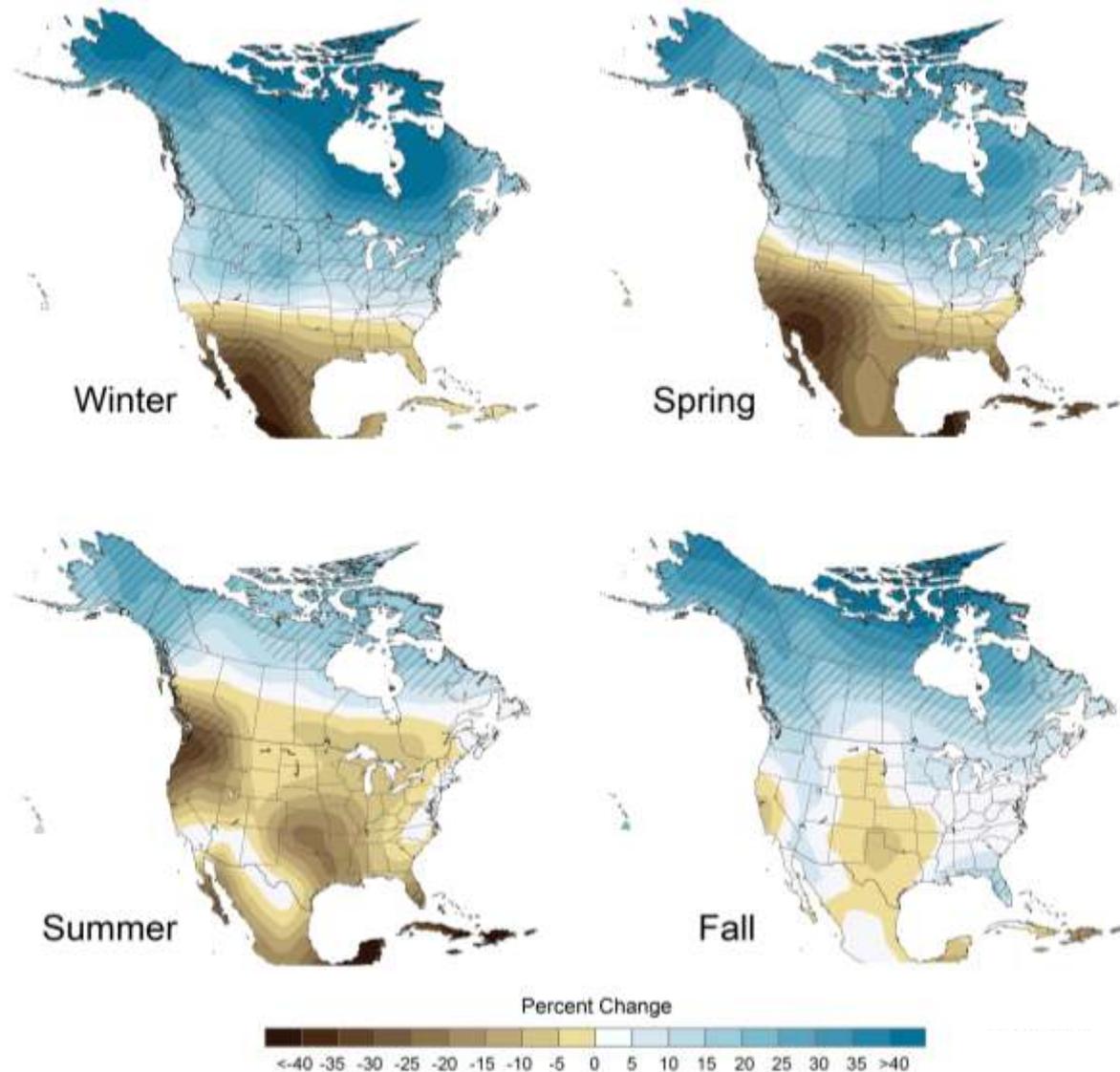


Iowa flooding, FEMA

U.S. average annual precipitation has increased by approximately 5% over the past 50 years, but the changes have not been uniform

Water resources will be affected by changing precipitation patterns and increasing temperatures.

Projected
Change in
Precipitation
by 2080-90s



Climate Change Impacts Are Not Distributed Evenly

For example...



Western drought, CA Dept. of Water Resources

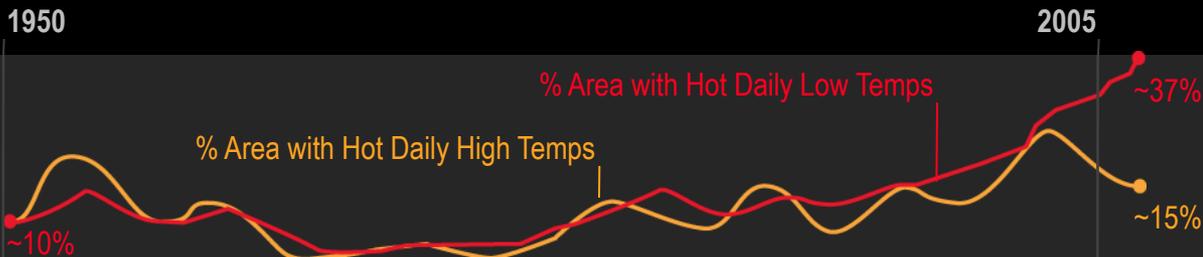


Midwestern flooding, NRCS

- Drought frequency has increased in the Southeast and much of the West
- Heavy precipitation has increased most in the Midwest and Northeast

Climate change brings extreme weather & climate

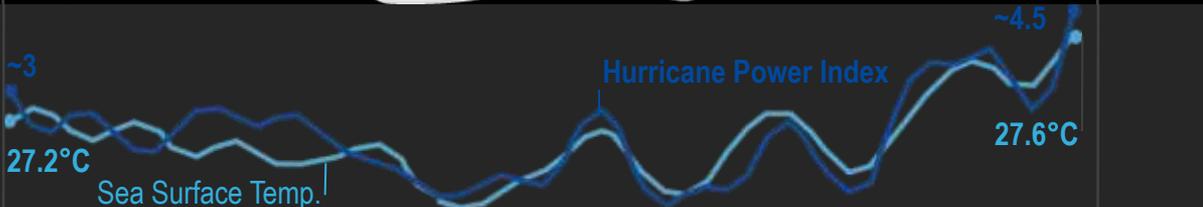
Increased Temperatures



Area in Severe Drought



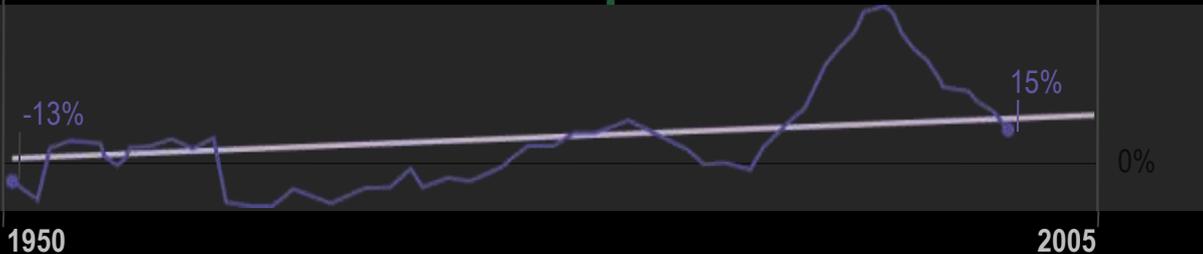
Atlantic Hurricanes



Wave Heights



Heavy Rain Events

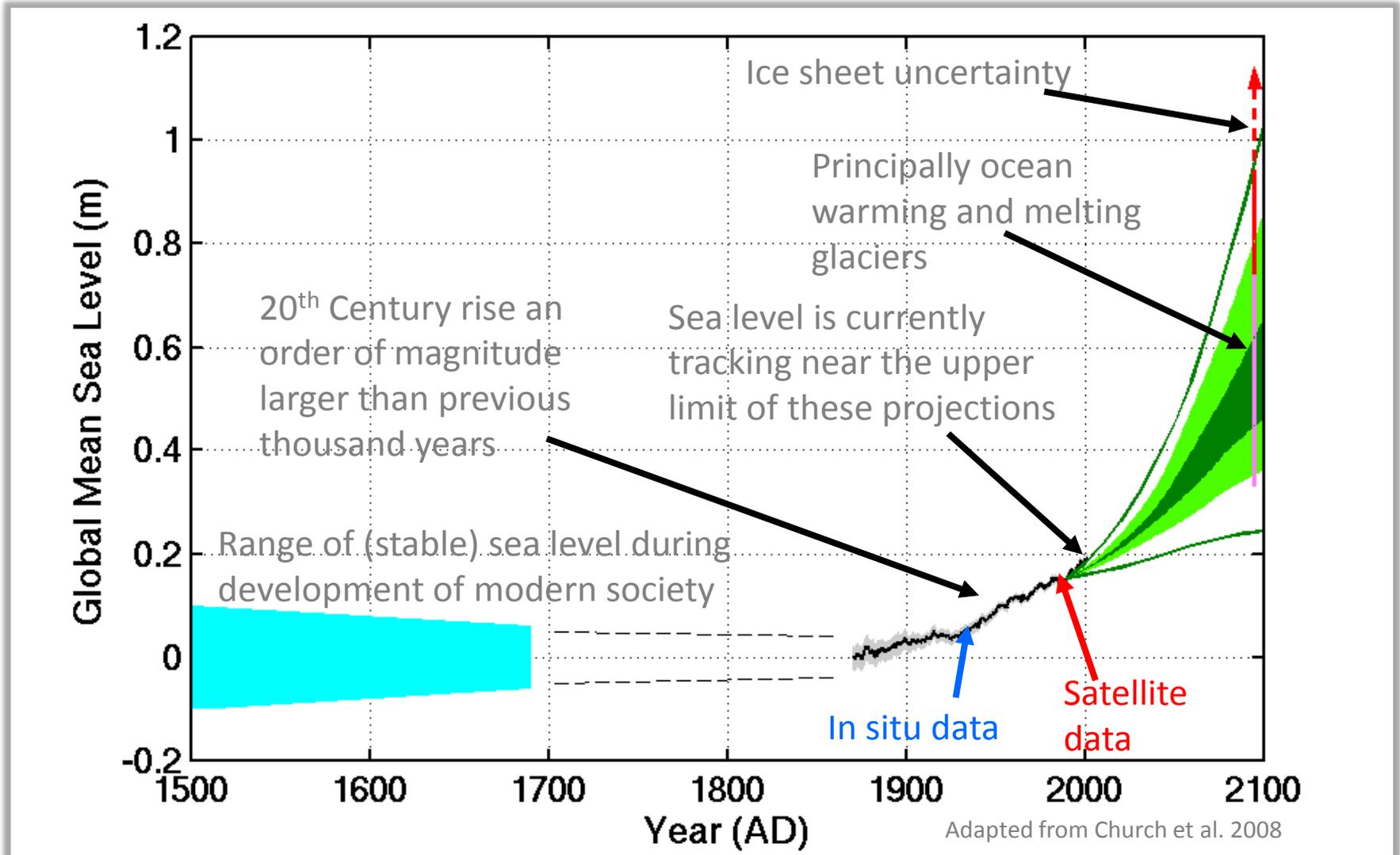


Island communities, infrastructure and ecosystems vulnerable to coastal inundation due to sea level rise and coastal storms

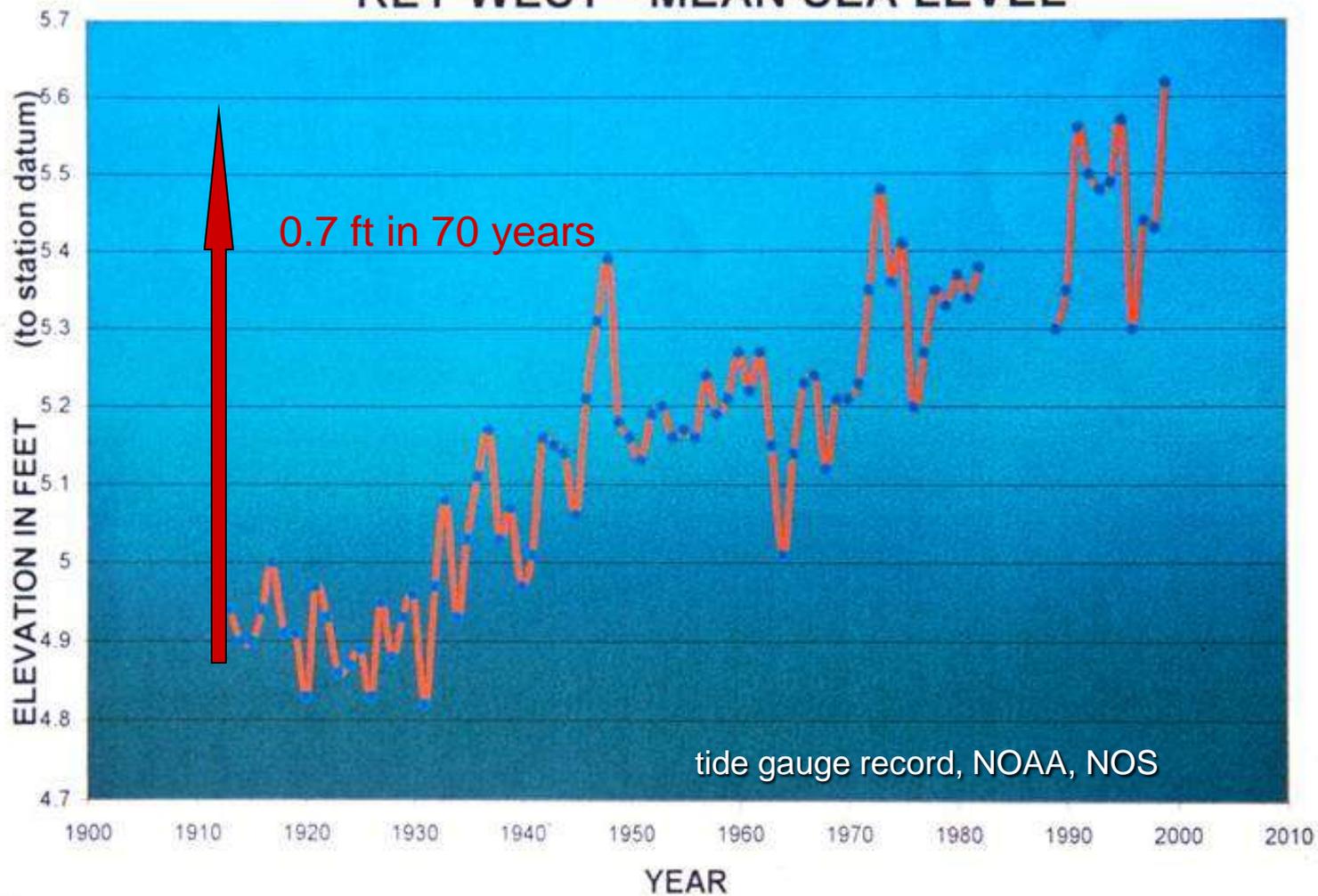


Coastal houses and an airport rely on mangroves' protection from erosion and damage due to rising sea level, waves, storm surges, and wind. in the U.S.-affiliated Federated States of Micronesia

Today's Sea-Level Rise is Unprecedented



KEY WEST - MEAN SEA LEVEL



Beginning in 1930, the rate of relative sea level rise increased about 8 fold over that of the past 2,000 years. It is presently rising at 30 cm (1') / 100 years!

Red Areas Show Inundation with 1-meter Sea Level Rise



Changing Climate Is Already Affecting Society

- Economy
- Communities
- Energy production/supply
- Human health
- Water availability
- Food production
- National security
- Tribal cultures
- Biodiversity
- Ecosystem services that people depend on for clean water, coastal protection, food protection, food production, and recreation



...and will challenge agency missions and operations

Vulnerability and Adaptive Capacity Vary Widely



NOAA



NOAA

- **Social/economic factors**

Economic status, race, gender, age, ethnicity, and health

- **Environmental factors**

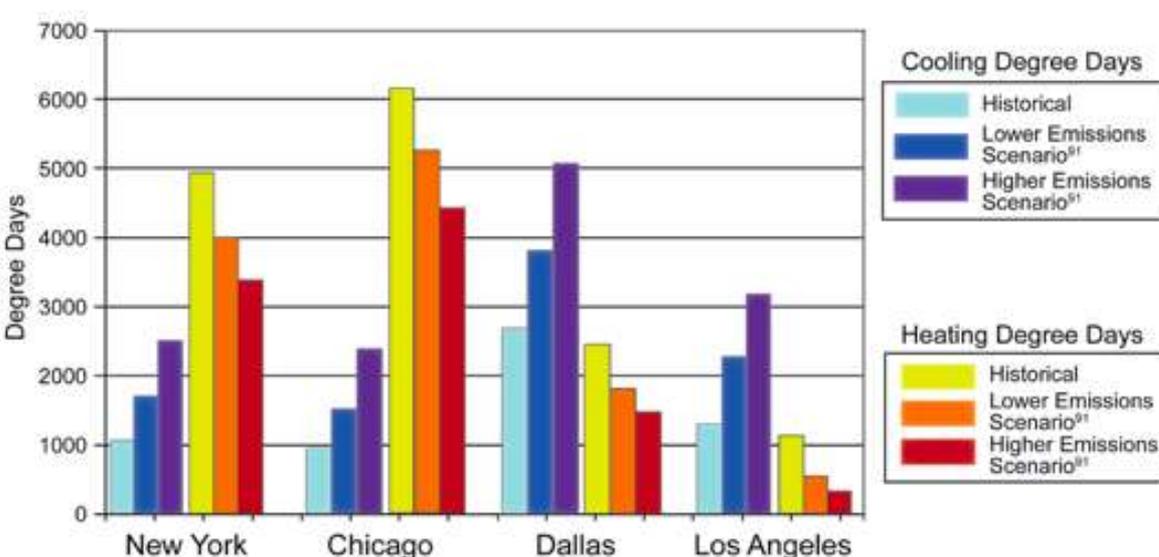
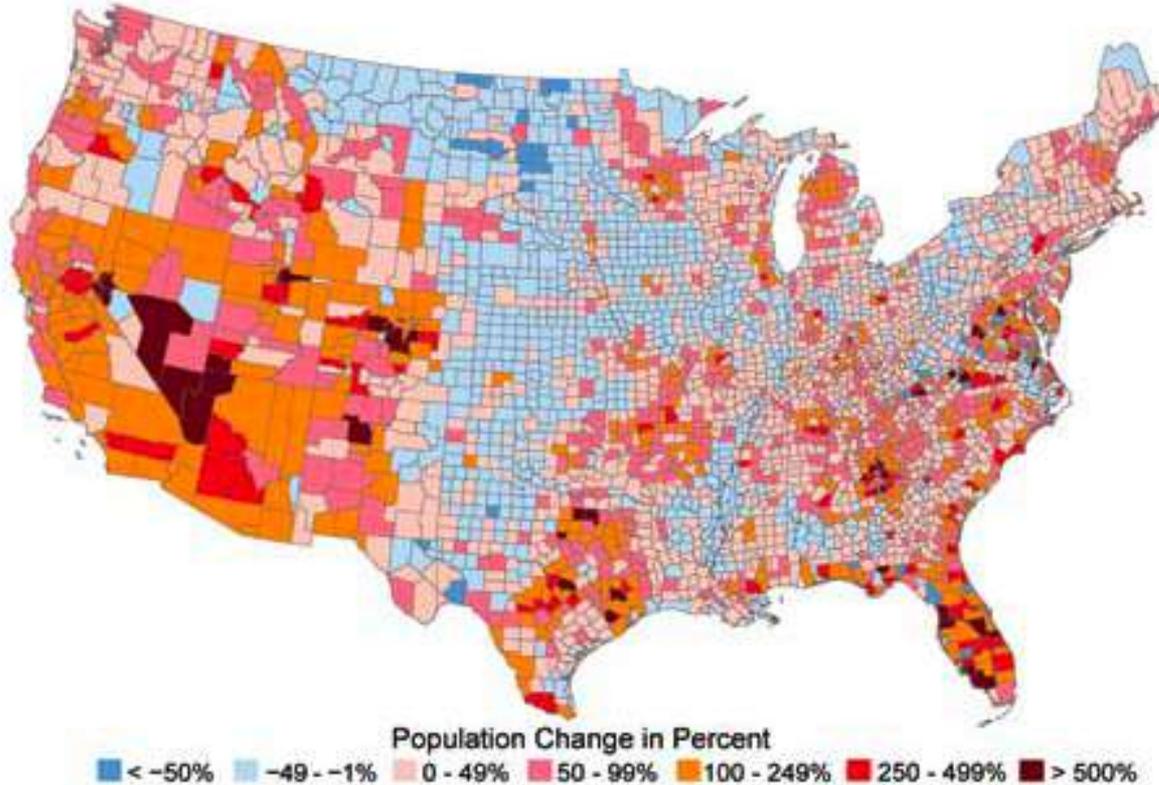
Pollution, over-harvesting, and habitat destruction



PublicDomainPictures.net

Climate change will interact with many social and environmental stresses

Population has been changing rapidly (1970-2008) with *more people moving into coastal regions and the southwest.*



Driven by changing climate & population, demand for energy the U.S. is shifting (2080-2099)

Climate change will interact with many social and environmental stresses

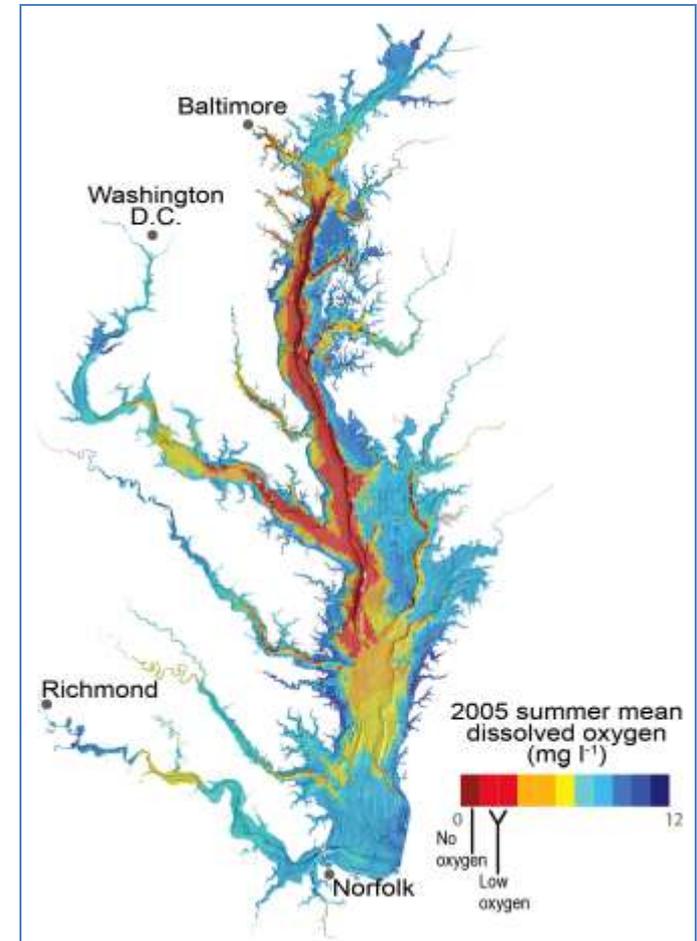
- Coastal dead zones likely to increase in size and intensity in Chesapeake Bay and N. Gulf Coast

Why?

- Warmer water (less dense)
- More spring runoff (more nitrogen rich water – fertilizer) leads to:
 - Excess algae and micro organisms
 - Settle on sea floor where they decompose and deplete oxygen from sea water

Adaptation Issue:

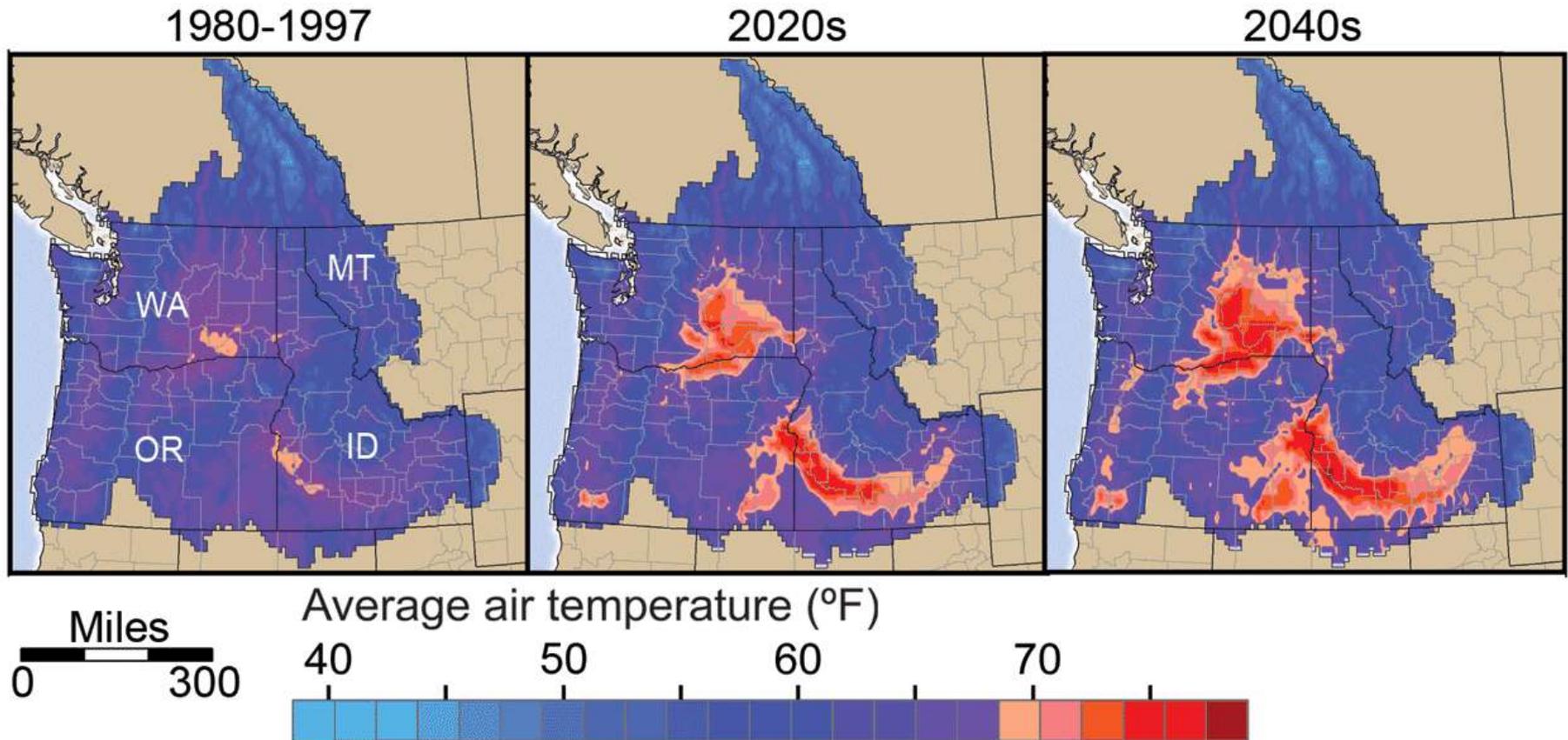
- Reduced runoff from agricultural fertilizer to curb amount of nitrogen rich water



Thresholds will be crossed, leading to large changes in ecosystems.

Decreasing Habitat for Salmon and other Coldwater Fish

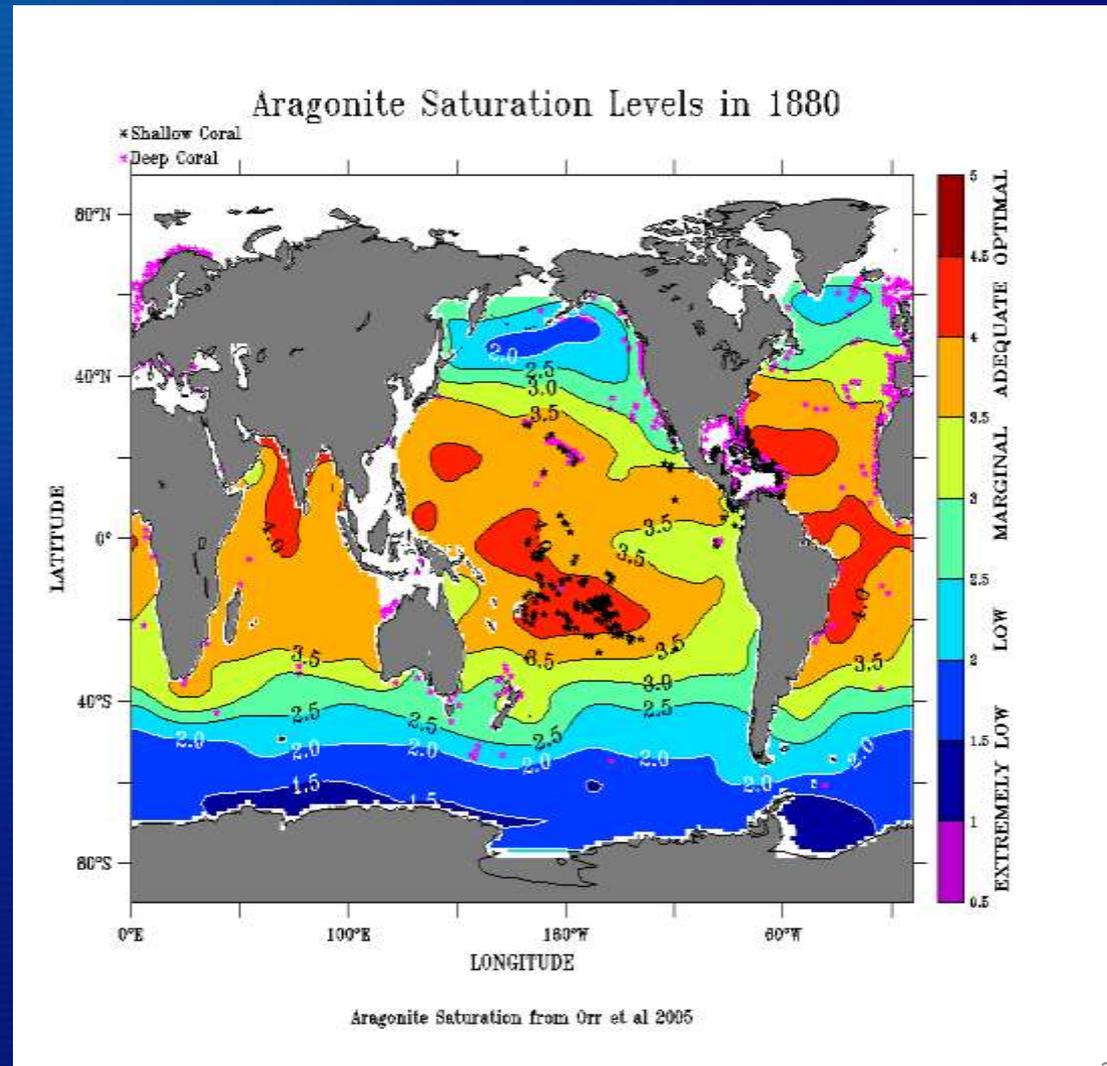
Based on a Higher Emissions Scenario



Key Finding: Thresholds will be crossed leading to large changes in climate and ecosystems

Coral calcification may decline 30% under CO₂ doubling

- Rising atmospheric carbon dioxide (CO₂) concentrations over the past two centuries have led to greater CO₂ uptake by the oceans.
- Increasing CO₂ in seawater results in:
 - Increasing acidity (decreasing pH)
 - Decreasing carbonate for organisms that build/maintain
 - calcium carbonate shells and other structures



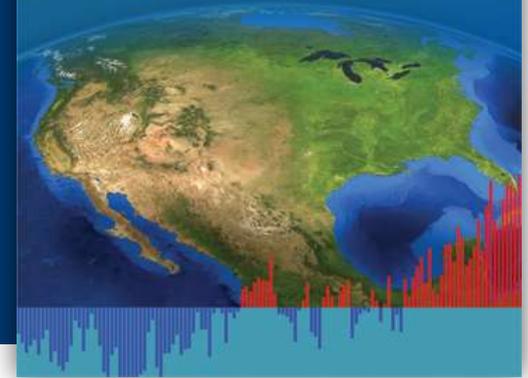
US Global Change Research Program (2009)

Marine Ecosystem Impacts:

- Ecosystem processes have been affected by climate change;
- Large-scale shifts in species' ranges, timing of seasons and migrations have occurred, and are very likely to continue;
- Coastal and near-shore ecosystems are already under multiple stresses, and climate change and ocean acidification will exacerbate these stresses;

Global Climate Change Impacts in the United States

U.S. GLOBAL CHANGE
RESEARCH PROGRAM



- **Sea level rise, increased coastal storm intensity, and rising temperatures increase vulnerability of coastal wetlands;**
- **Arctic sea ice ecosystems are already being adversely affect by the loss of summer sea ice and further changes are expected;**
- **Some of the ecosystem services will be threatened, while others will be enhanced**

<http://globalchange.gov/publications/reports/scientific-assessments/us-impacts>

Climate changes affecting coastal and marine ecosystems will have major implications for tourism and fisheries

- **Threats include:**

- Sea level rise
- Increasing water temperatures
- Increased storm intensity
- Coastal inundation and erosion
- Ocean acidification
- Incidences of coral disease
- Invasion of non-native species

- **Implications for:**

- Beaches and coastal development
- Natural storm protection (coral reefs, mangroves)
- Coral reef health
- Critical infrastructure
- Subsistence and commercial fisheries
- Coastal communities and culture

Primary Climate Change Issues for NOAA Fisheries Service

(Murawski, NMFS Chief Scientist, 2008)



- **Ocean warming:** impacts on populations of marine species' distribution, primary and secondary productivity, phenology, invasive spp.)
- **Sea level rise** (natural resource implications)
- **Ocean acidification** impacts on marine biota
- Attribution of **climate signals impacting ecosystems:** long term change vs. natural variability
- Impacts of **loss of sea ice** on living marine resources
- **Freshwater supply & resource management**

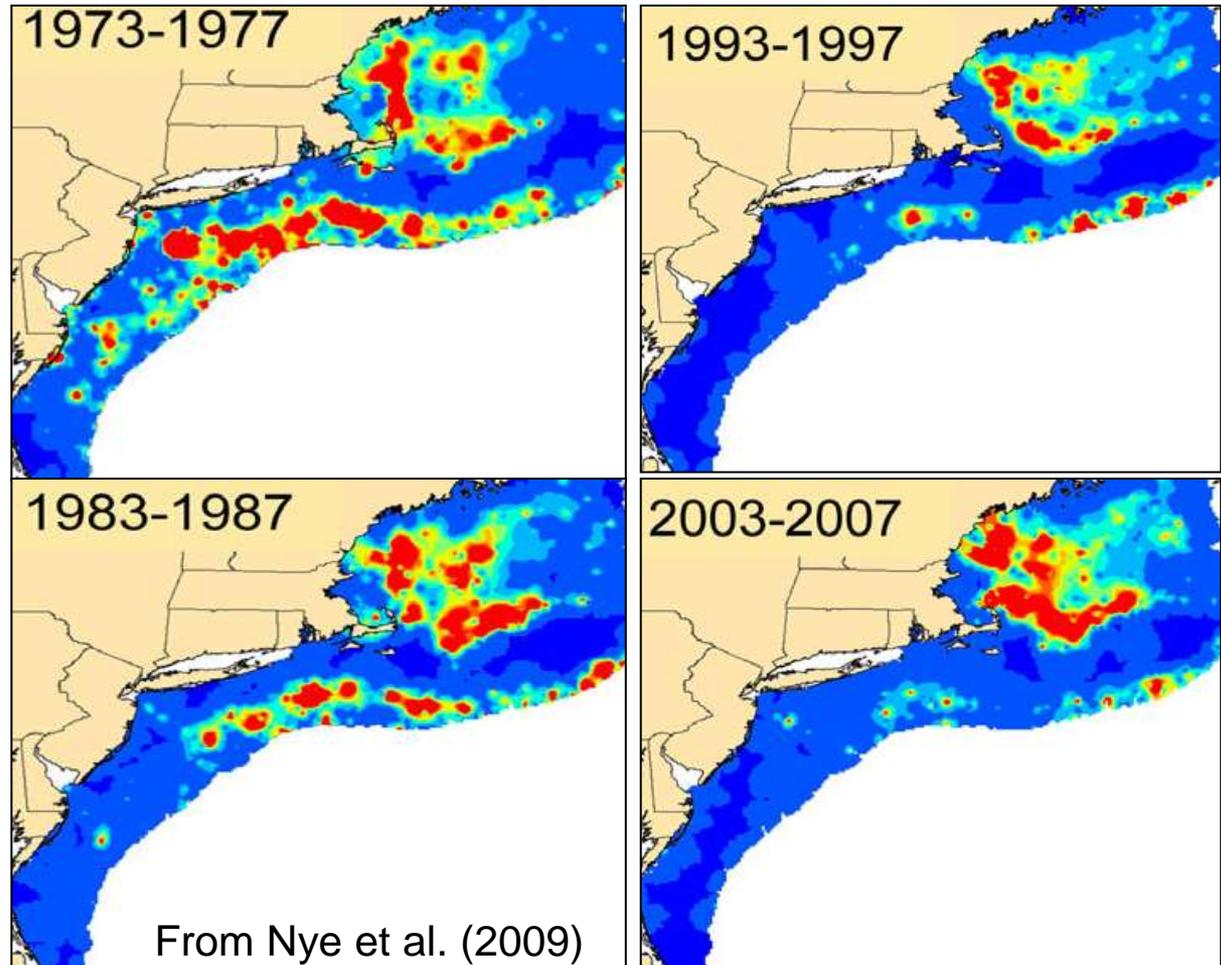
Northeast Fisheries and Climate Change

Observations and Projections

(Mike Johnson)

Water Temperature:

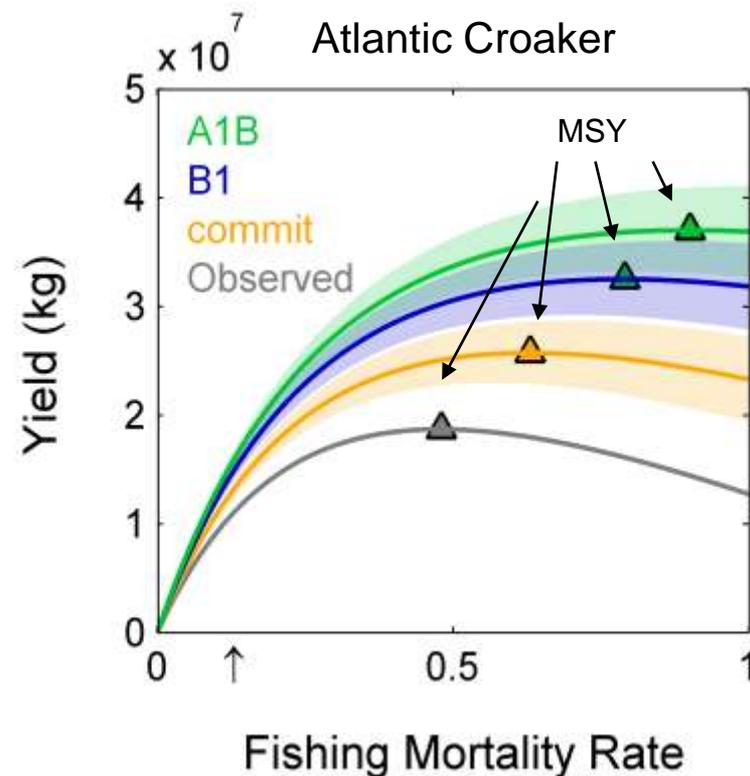
Poleward shifts in biomass and increases in depth distribution have been correlated with large-scale warming and climatic conditions for 24 of the 36 stocks examined in the Northeast (Nye et al. 2009)



Northeast Fisheries and Climate Change Observations and Projections (Mike Johnson)

Water Temperature

- Using a coupled population-climate model, Hare et al. (2010) forecast Atlantic croaker to spread northward into the Mid-Atlantic and southern New England and that yield will increase with increasing atmospheric CO₂ (Hare et al. 2010). Will croaker be a climate change “winner”?
- Nursery production of winter flounder will become increasingly synchronized at larger spatial scales leading to boom or bust scenarios (Manderson et al. 2008). Will winter flounder and Atlantic cod be climate change “losers”?



Ocean Acidification

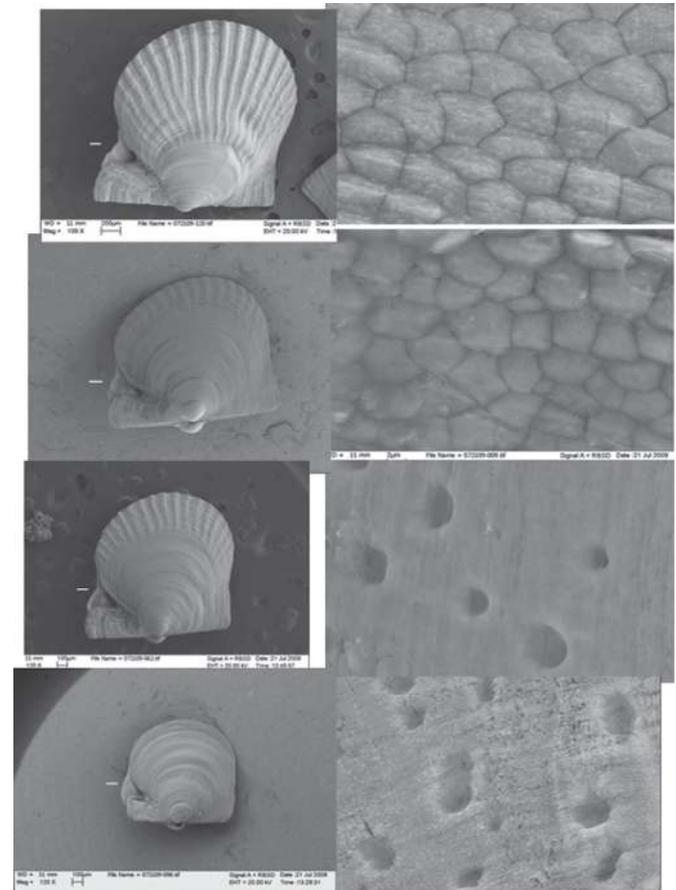
(Mike Johnson)

- Ocean Acidification has great potential for widespread changes to marine ecosystems (Feely et al. 2004, Feely et al. 2010; Fabry et al. 2008)
- Potential impacts on calcareous plankton, coral reefs (shallow/warm water and deep/cold water), bivalves and crustaceans, and food chains
- pH by mid-century are expected to reduce ocean sound absorption by ~40% (Hester et al. 2008): implications for marine mammals



Ocean Acidification Northeast Fisheries (Mike Johnson)

- Experimental studies indicate shellfish are negatively affected by present day ocean acidification, possibly contributing to declines observed in wild populations over this century (Miller et al. 2009; Talmage and Gobler 2010).
- Experiments with quahog and bay scallops grown under present day and projected future CO₂ concentrations resulted in lower larval growth rates, lower survival and higher malformed/eroded shells compared to pre-industrial conditions (Talmage and Gobler 2010).



Impacts of Climate Change

Climate change is apparent now across our nation.

Trends observed in recent decades include:

- rising temperatures,
- increasing heavy downpours,
- rising sea level,
- longer growing seasons,
- reductions in snow and ice, and
- changes in the amounts and timing of river flows

These trends are projected to continue, with larger changes resulting from higher amounts of heat-trapping gas emissions, and smaller changes from lower amounts of these emissions.

Responding to Climate Change

“Mitigation”

Options for limiting climate change

“Adaptation”

Responding to present and future climatic conditions

Take Home Messages



- The impacts of climate change are already occurring throughout the United States and will continue to occur in the future.
- Climate change impacts vary across sectors and regions.
- Choices about emissions now and in the coming years will have far-reaching consequences.
- Preparing for, and responding to, the impacts of climate change will require adaptation actions at all levels:
 - We are already committed to significant changes
 - Planning, monitoring, continuous evaluation & adaptive management essential to success
 - Requires public-private-academic partnerships at all levels

Some Key Opportunities For Input

- **National Fish, Wildlife and Plants Climate Adaptation Strategy**

- draft Dec 2011
- final July 2012



NATIONAL *fish, wildlife & plants*
CLIMATE ADAPTATION STRATEGY

- Opportunity to highlight needs and strategies to incorporate climate in marine resource management

- **National Climate Assessment**

- draft 2012
- final 2013
- Specific marine/coastal focus areas
- Regional reports



United States Global Change Research Program
National Climate Assessment

- **NOAA Climate Adaptation Plan (2012)**

- Agency Climate Adaptation Plans due by 2012
- NOAA-wide Team established
- Opportunity to highlight needs & strategies to incorporate climate change in NOAA marine resource management

Resources and Support

Resources:

U.S. Global Change Research Program. 2009

Global Climate Change Impacts in the United States

<http://www.globalchange.gov/usimpacts>

U.S. Global Change Research Program

Synthesis and Assessment Products

<http://www.globalchange.gov/publications/reports/scientific-assessments/saps>

National Academies of Science. 2010

Advancing the Science of Climate Change, America's Climate Choices

<http://americasclimatechoices.org/panelscience.shtml>

Adapting to the Impacts of Climate Change

<http://americasclimatechoices.org/paneladaptation.shtml>

NOAA's Climate Portal

<http://www.climate.gov>

