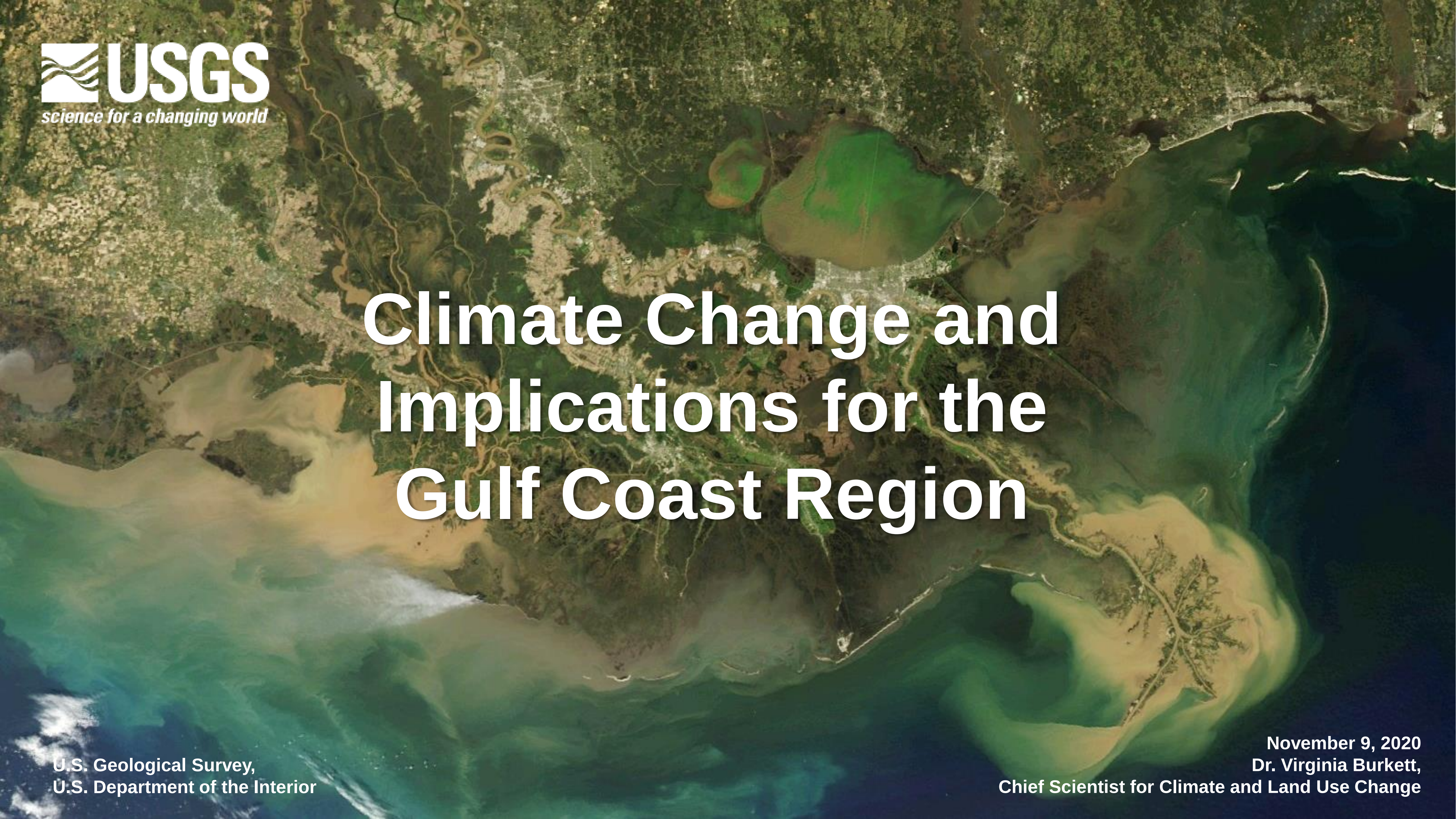

Climate Change and Implications for the Gulf Coast Region

November 9, 2020
Dr. Virginia Burkett,
Chief Scientist for Climate and Land Use Change

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

Outline

Louisiana Climate Initiatives Task Force

1. Basic concepts – weather and climate, how atmospheric chemistry influences temperature
2. Observed and projected change – global, National and Regional national
3. Impacts on the central Gulf Coast region – findings of the IPCC and the US Fourth National Climate Assessment
4. Adaptation and mitigation options
5. Scenarios of future change, with and without mitigation

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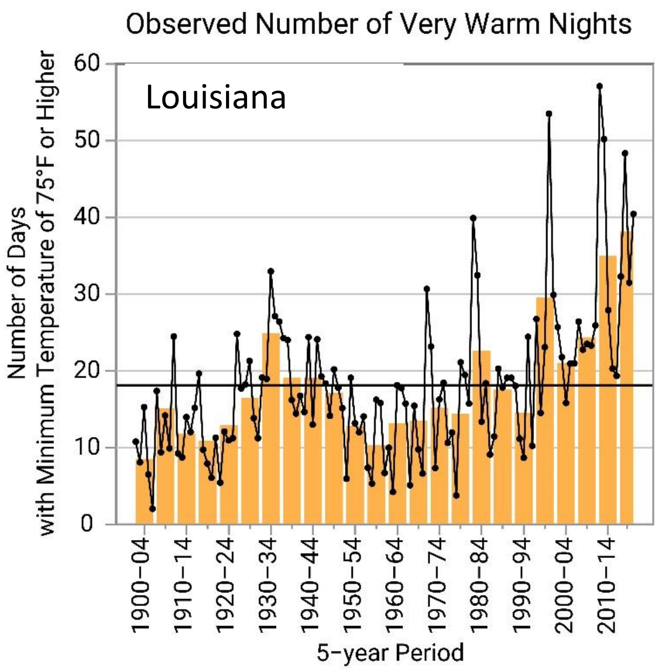
Difference between weather and climate

The difference between *weather* and *climate* is a measure of **time**.

- ***Weather*** is the condition of the atmosphere over a short period of time.
- ***Climate*** is how the atmosphere "behaves" over relatively long periods of time.

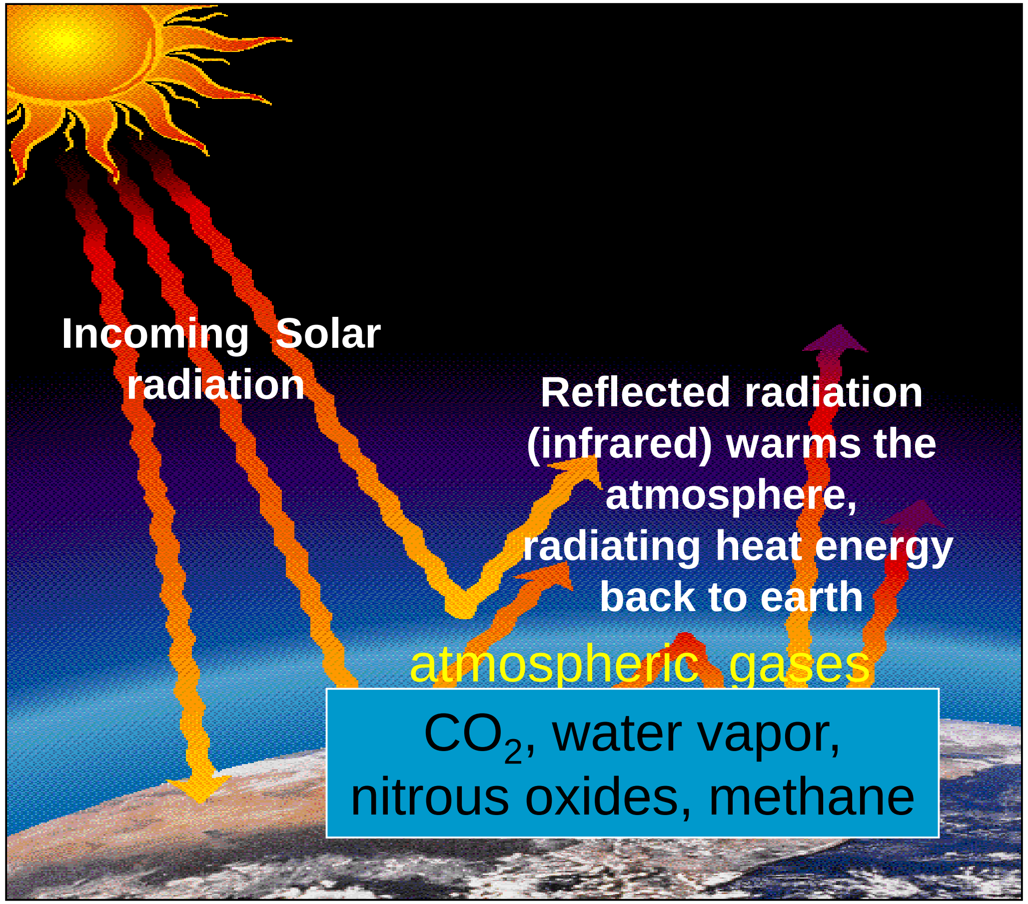
Climate is the average of weather over a period of time. It is not just the average, but the variability and the extremes. Climate is usually defined for different seasons or months and averaged over a period of 30 years.

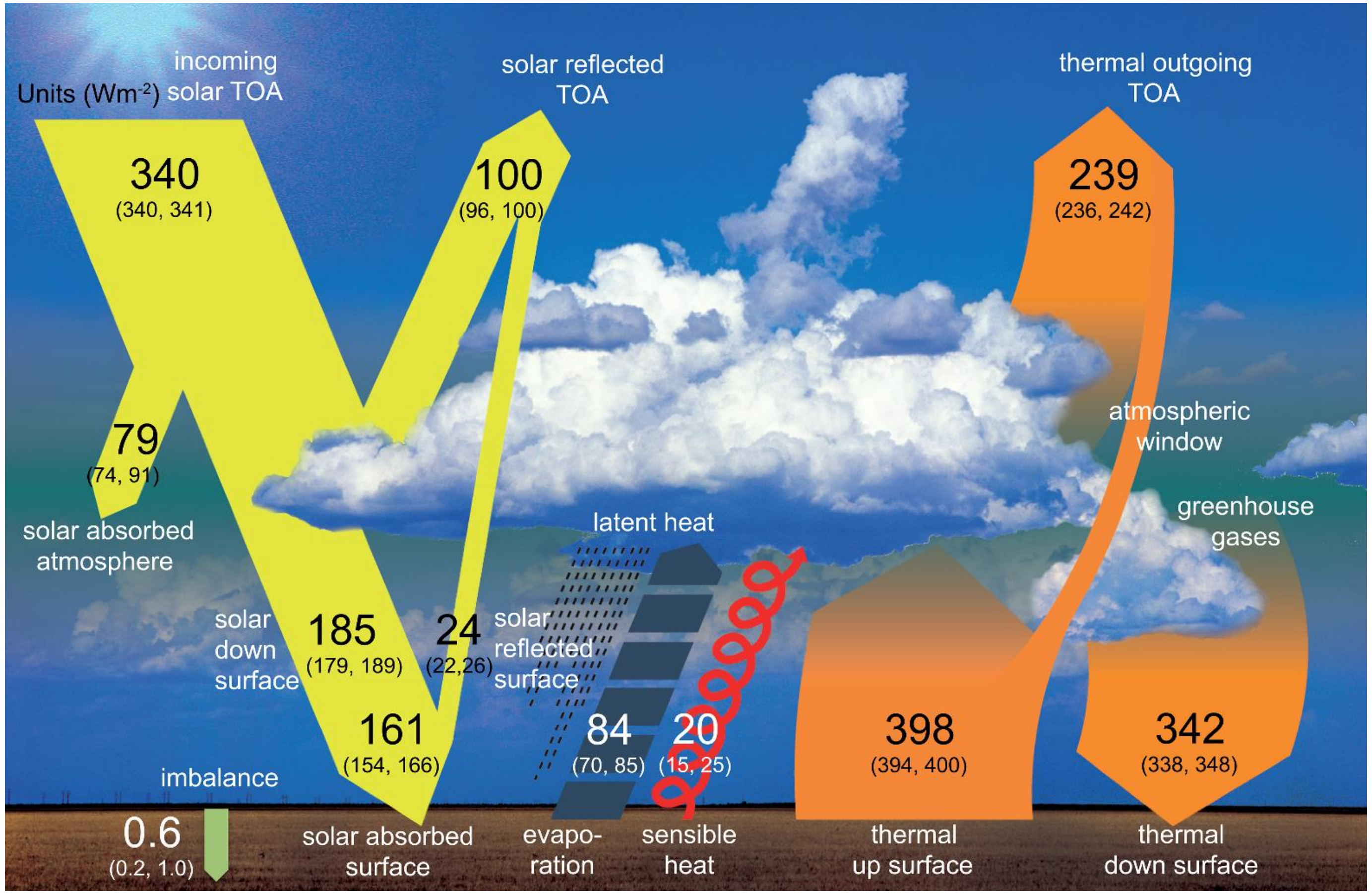
Climate change refers to a trend or "change in the state of the climate that can be identified (e.g. using statistical tests) and that persists for an extended period, typically decades or longer."



(NOAA State Climate Summary, 2018)

The Greenhouse Effect warms the Earth's atmosphere





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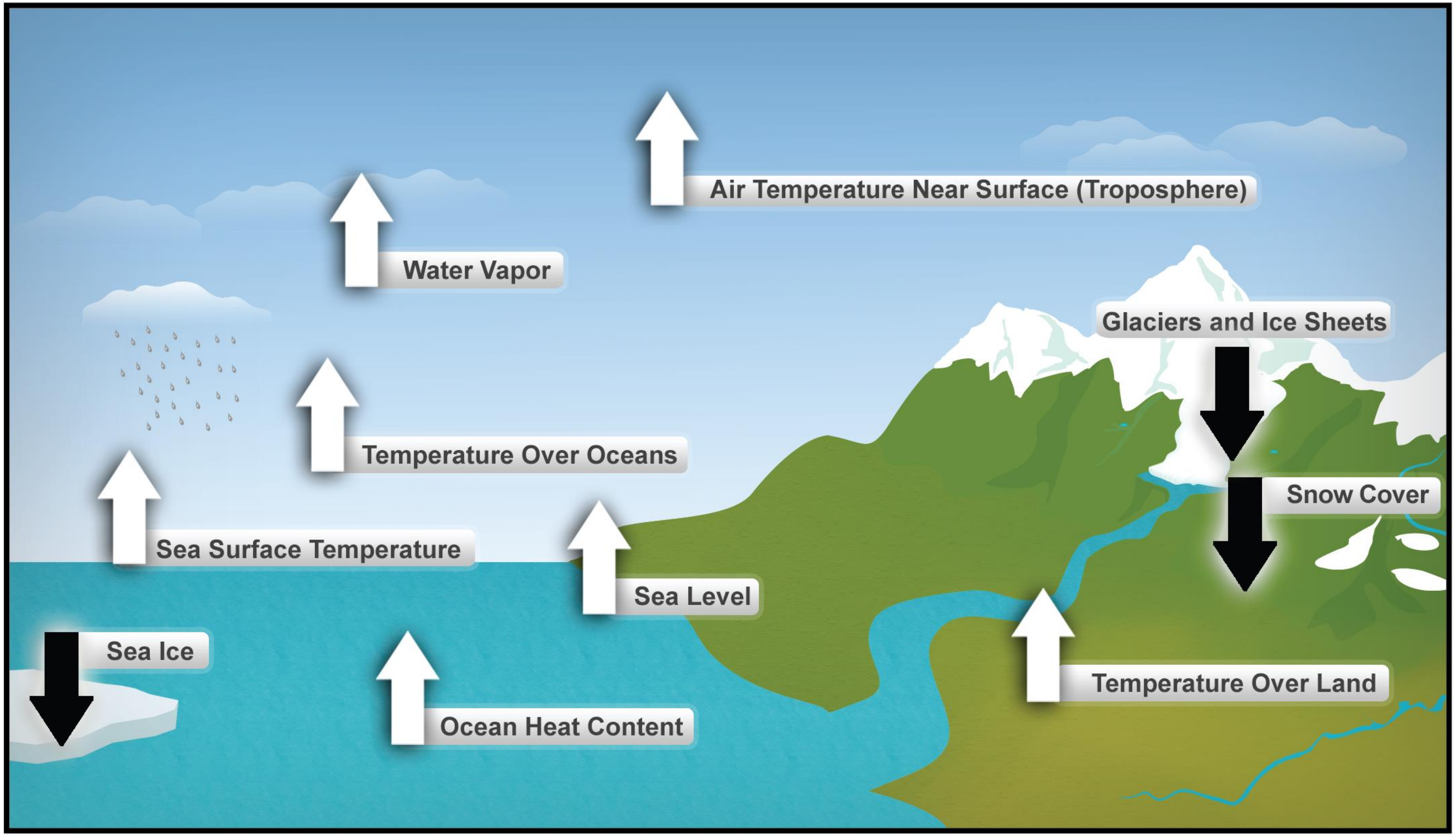
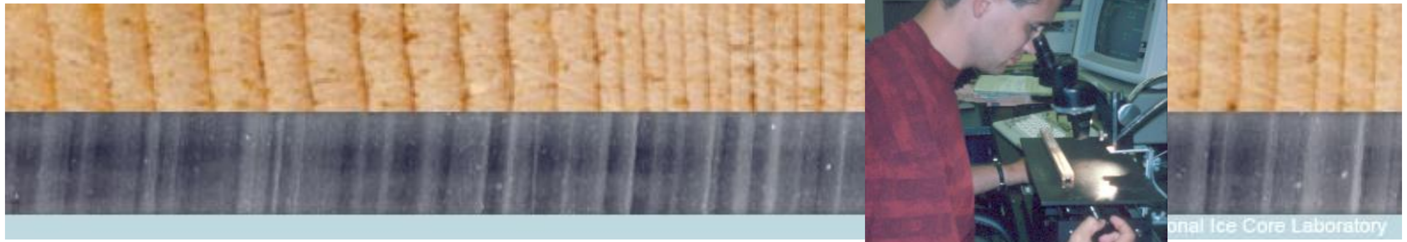
10 Indicators of a Warming World



Long-term Earth observations reveal climate variability and long-term warming trends.

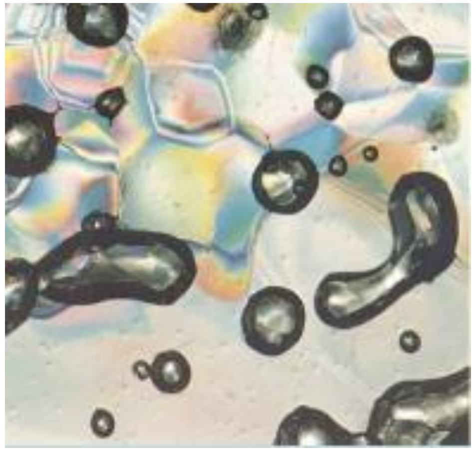
Ice cores help us document how the Earth's greenhouse gases and temperature have changed through time.



- Ice cores are read like tree rings
  - Summer ice appears light
  - Winter ice appears dark

- Air bubbles in the ice trap pollen and atmospheric gases

- Stable isotopes of oxygen (^{16}O, ^{18}O] and hydrogen [D/H]) provide a detailed record of temperature change



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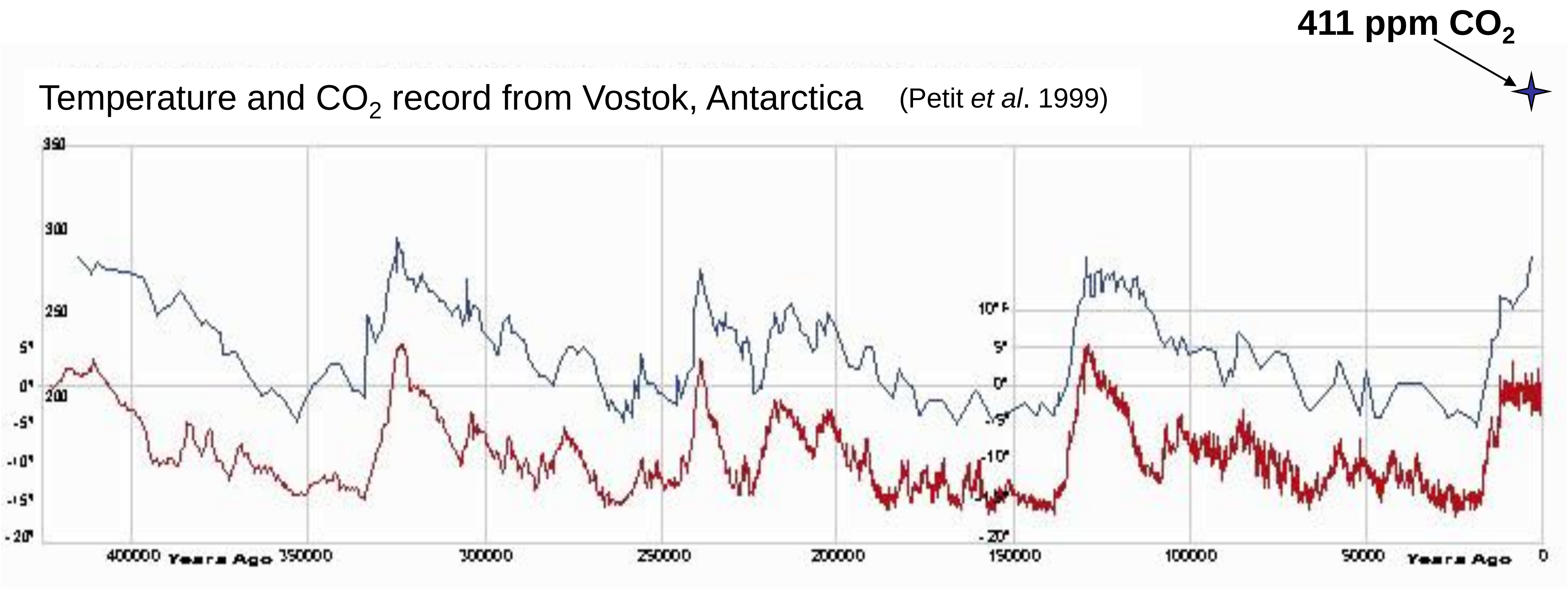
Ice Core record of past 420,000 years:



Upper, blue line = CO_2 level

Lower, red line = temperature

Orbital eccentricity affects the Earth-sun distance in a cycle that takes 90,000 -100,000 years

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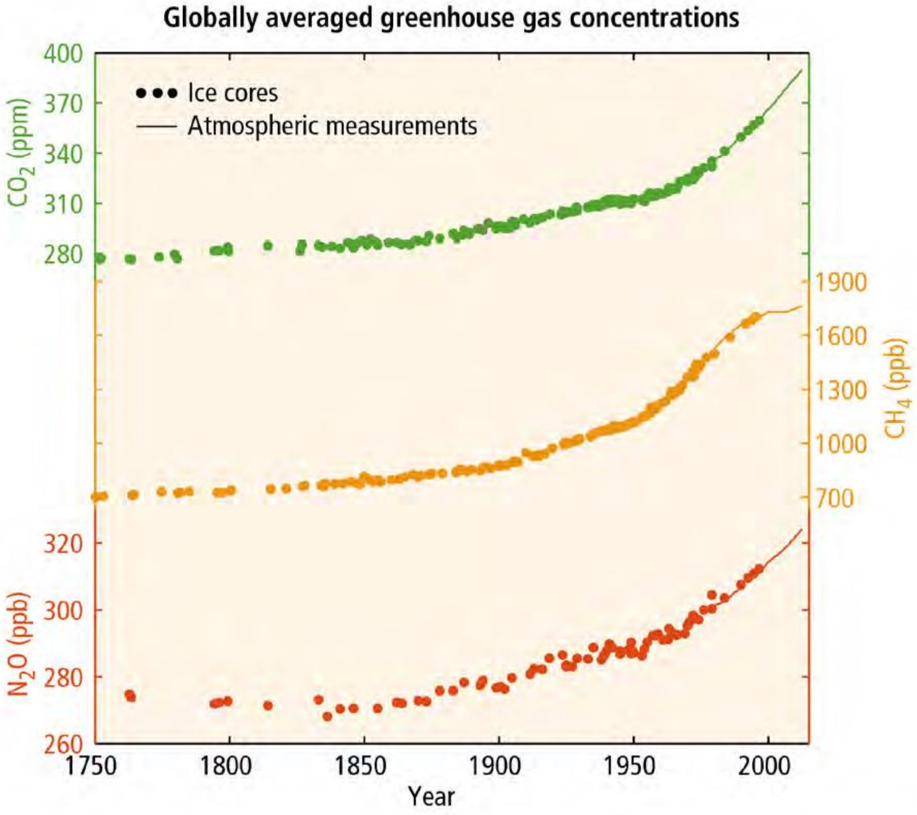
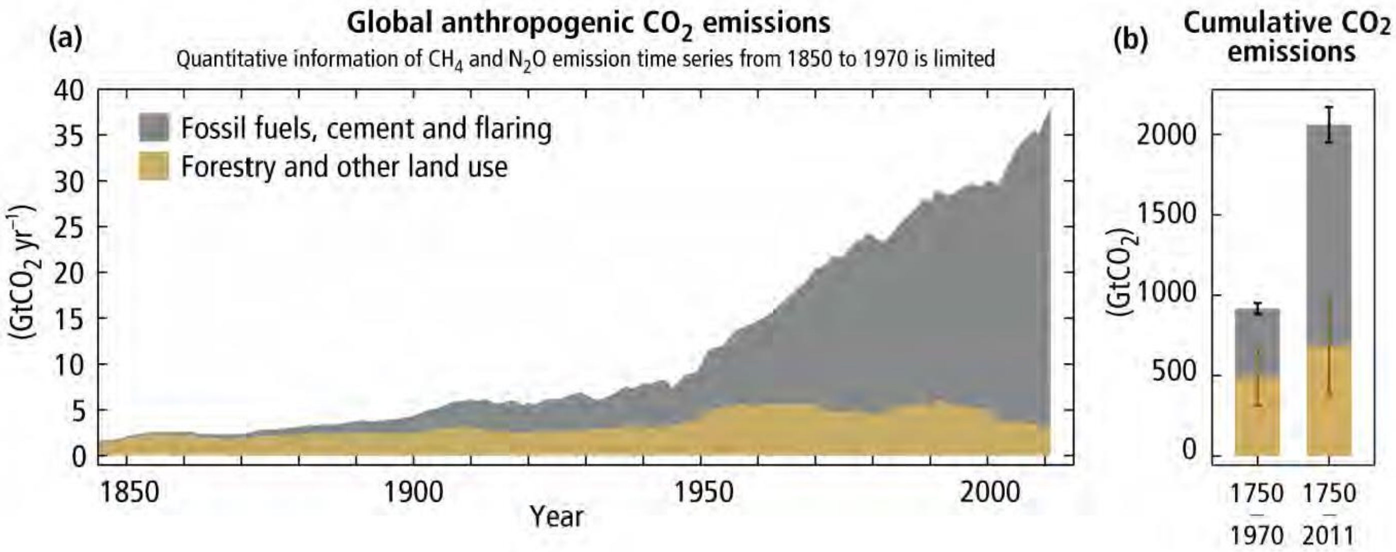


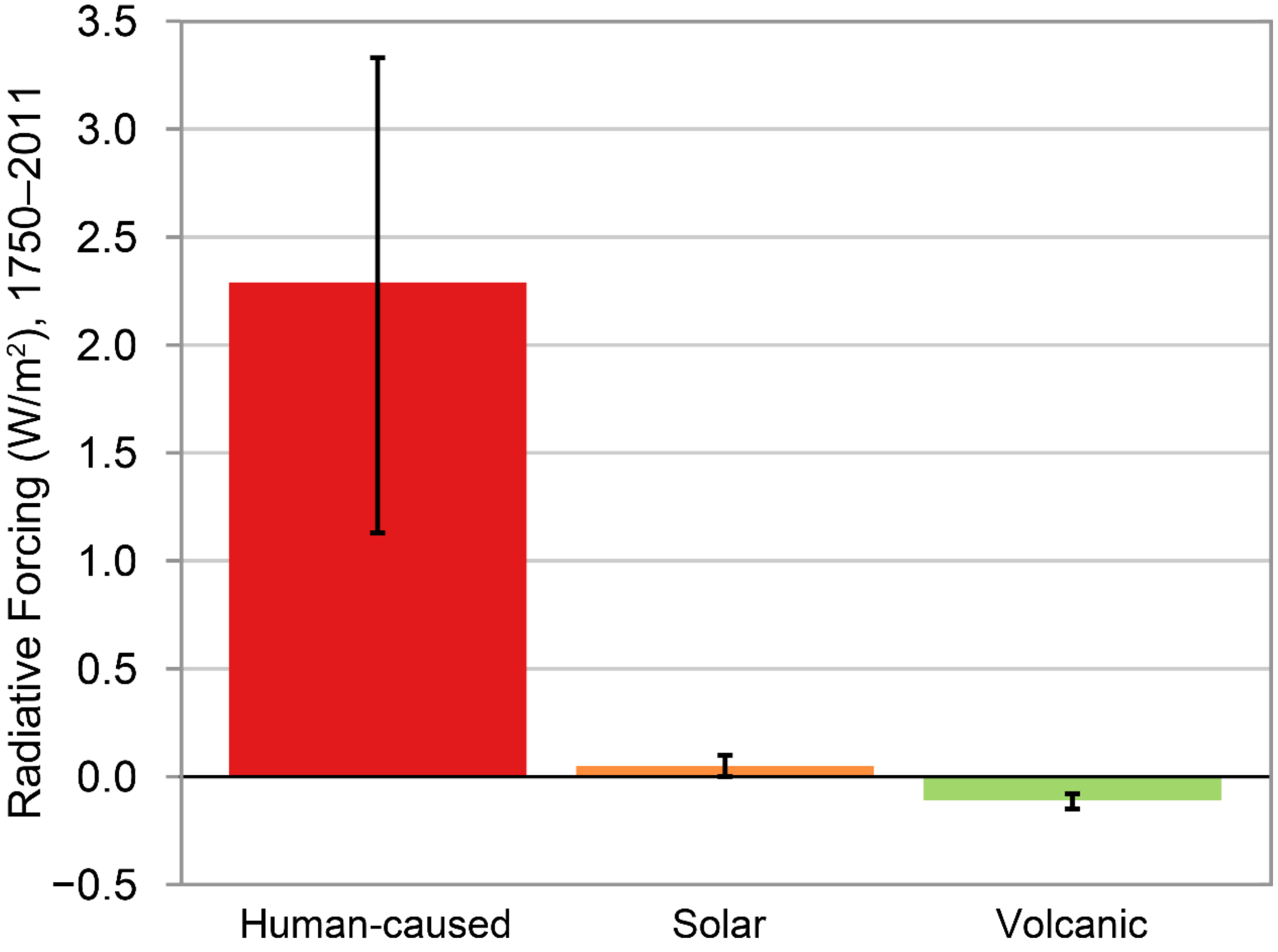
Atmospheric carbon dioxide level now is highest in at least 3 million years.

Since 1970 cumulative CO2 emissions from fossil fuel combustion, cement production (2.4% of total emissions) and flaring **have tripled.**



(IPCC AR5, 2014)

Human Activities are the Primary Driver of Recent Global Temperature Rise



"*We find no convincing evidence that natural variability can account for the amount of global warming observed over the industrial era….. Solar output changes and internal variability can only contribute marginally to the observed changes in climate over the last century, and we find no convincing evidence for natural cycles in the observational record that could explain the observed changes in climate. (Very high confidence)*" (NCA4, 2017)

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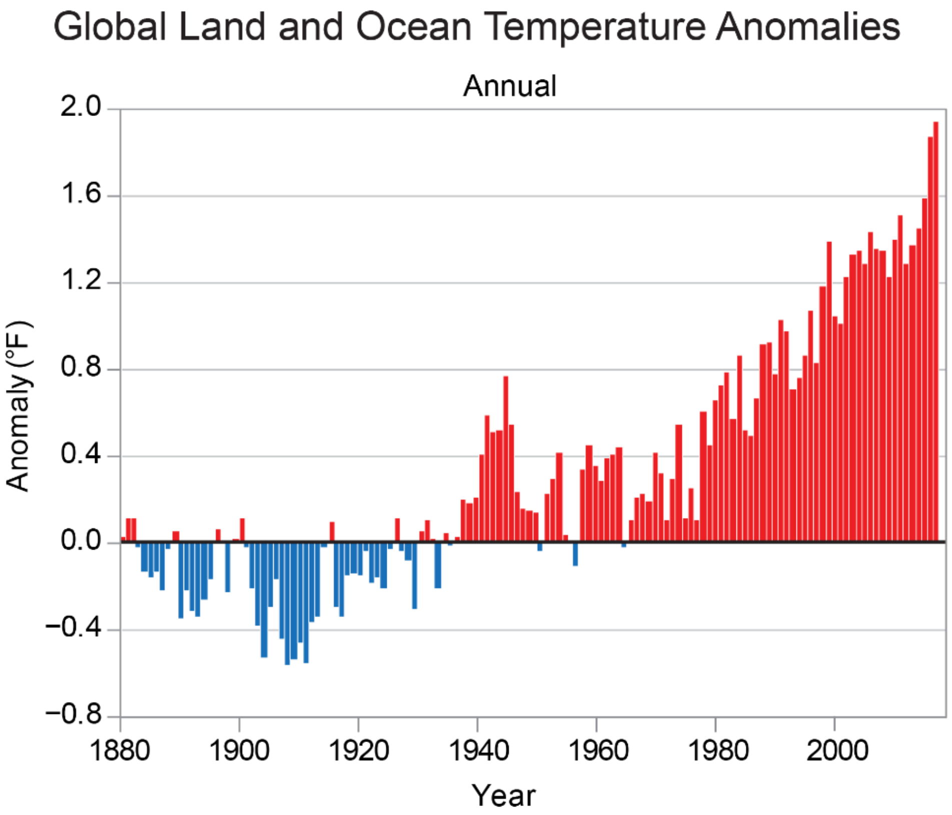
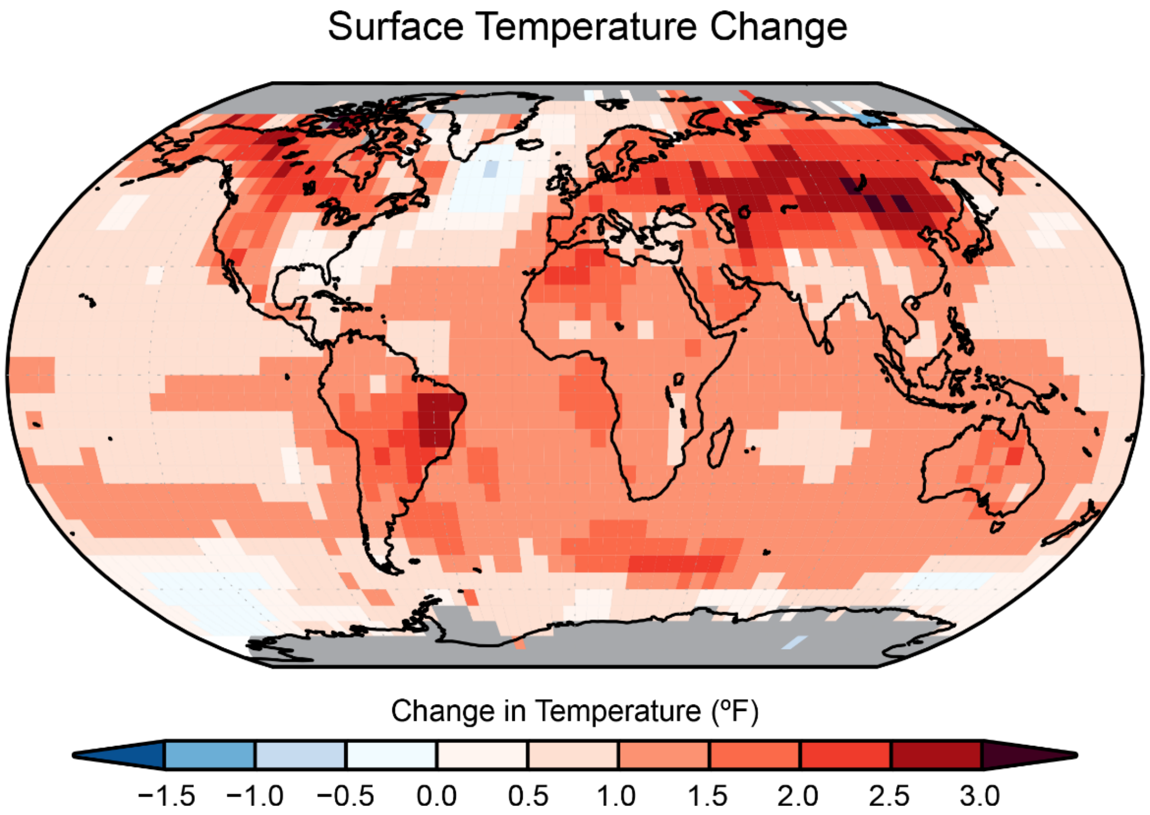
Global temperatures are rising -- rate varies among regions

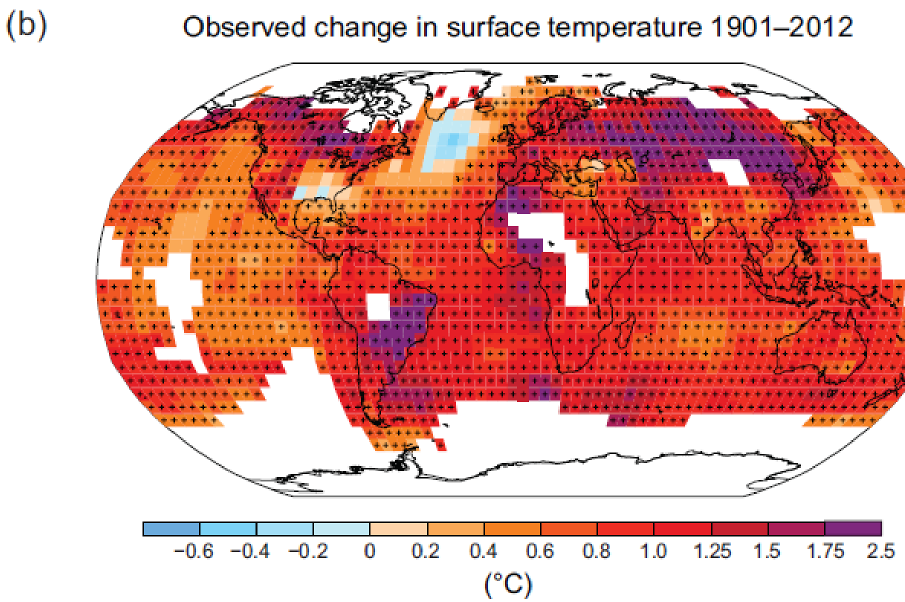


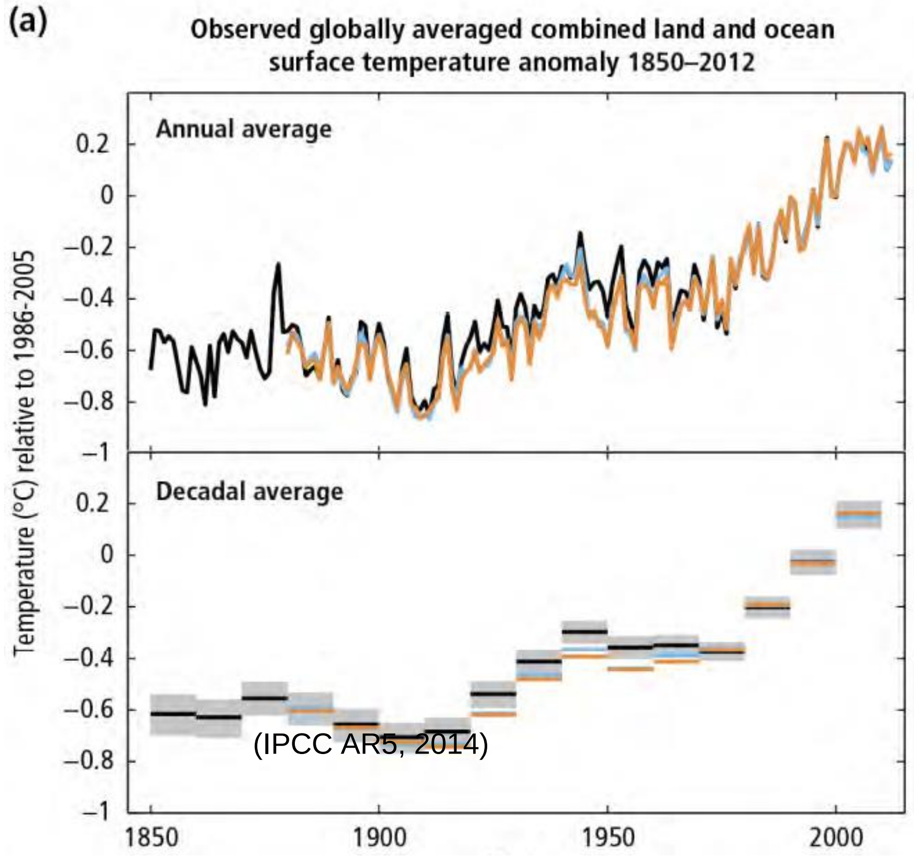


Global annual average temperature (from instrumental records over both land and oceans) has increased by **more than 1.2°F** (0.65°C) for the period **1986–2016** relative to 1901–1960; the linear regression change over the entire period from **1901–2016 is 1.8°F** (1.0°C) (*very high confidence*).

Fourth US National
Climate Assessment
Volume 1, November 2017

Accelerated warming - *last three decades have been successively warmer at the Earth's surface than any preceding decade since 1850. The period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere.*





Increase in Ocean Temperature - *On a global scale, the ocean warming is largest near the surface, and the upper 75 m warmed by 0.11 °C per decade over the period 1971 to 2010. It is virtually certain that the upper ocean (0−700 m) warmed from 1971 to 2010, and it likely warmed between the 1870s and 1971.*

(IPCC AR5, 2014)

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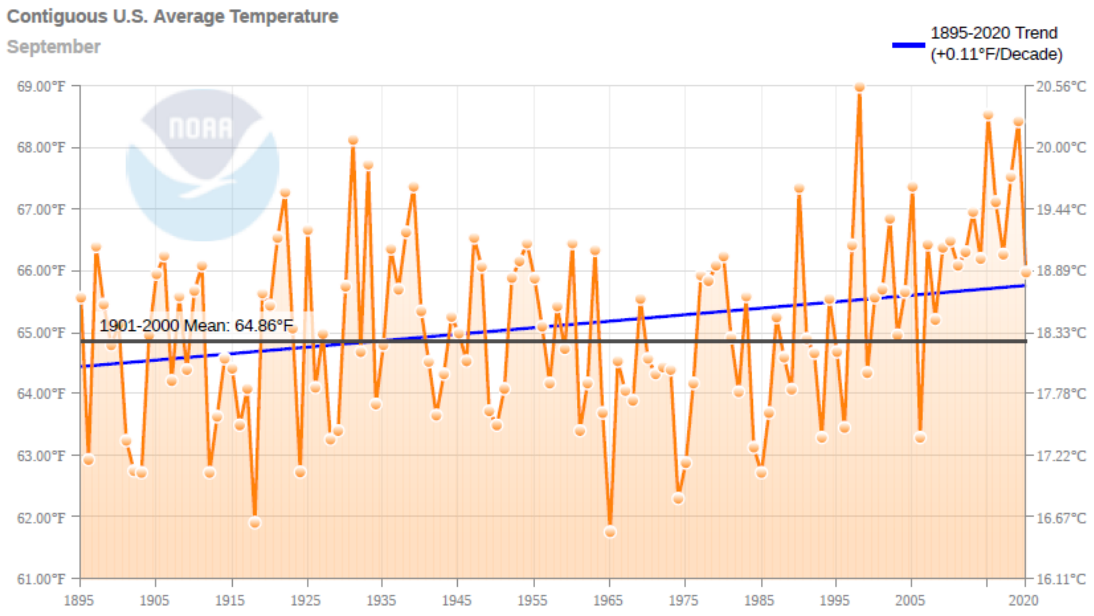
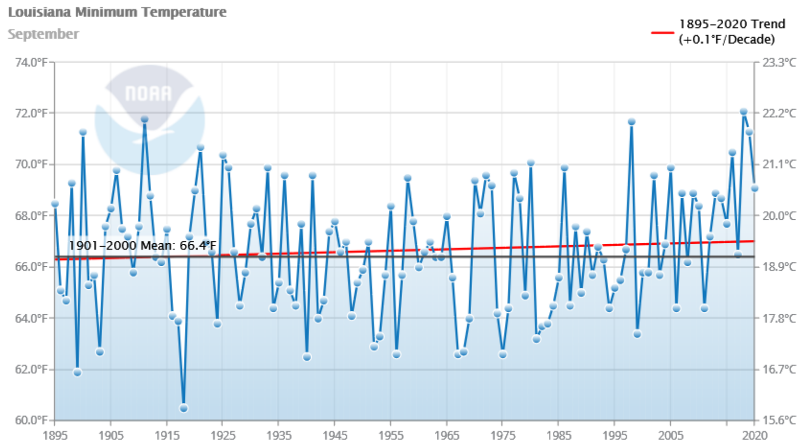
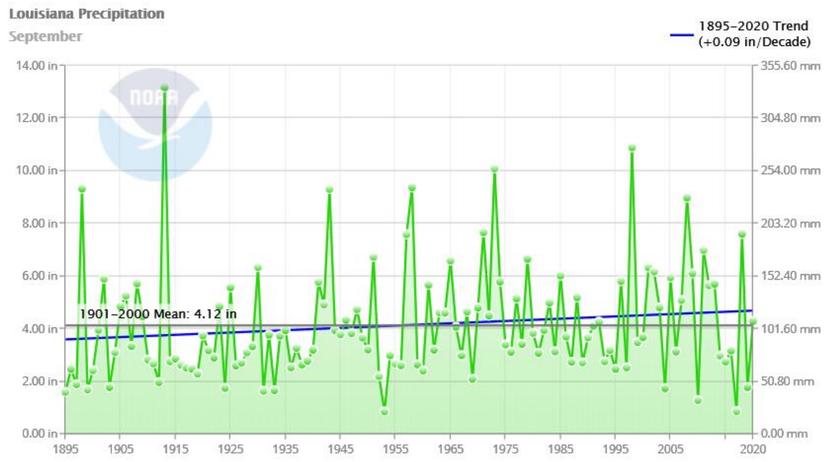
Contiguous US Average Annual Temperature (1895-2020)



Louisiana Minimum Temperature (1895-2020)



Louisiana Precipitation (1895-2020)



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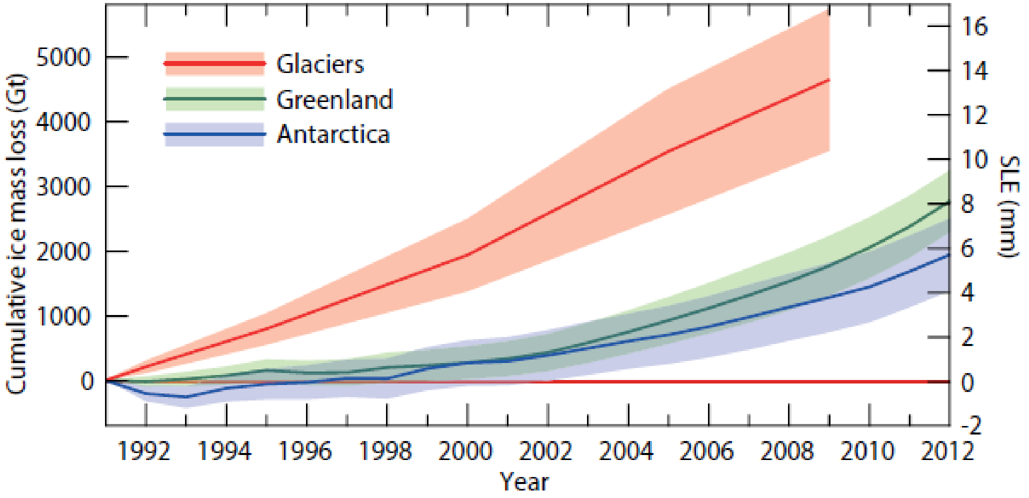
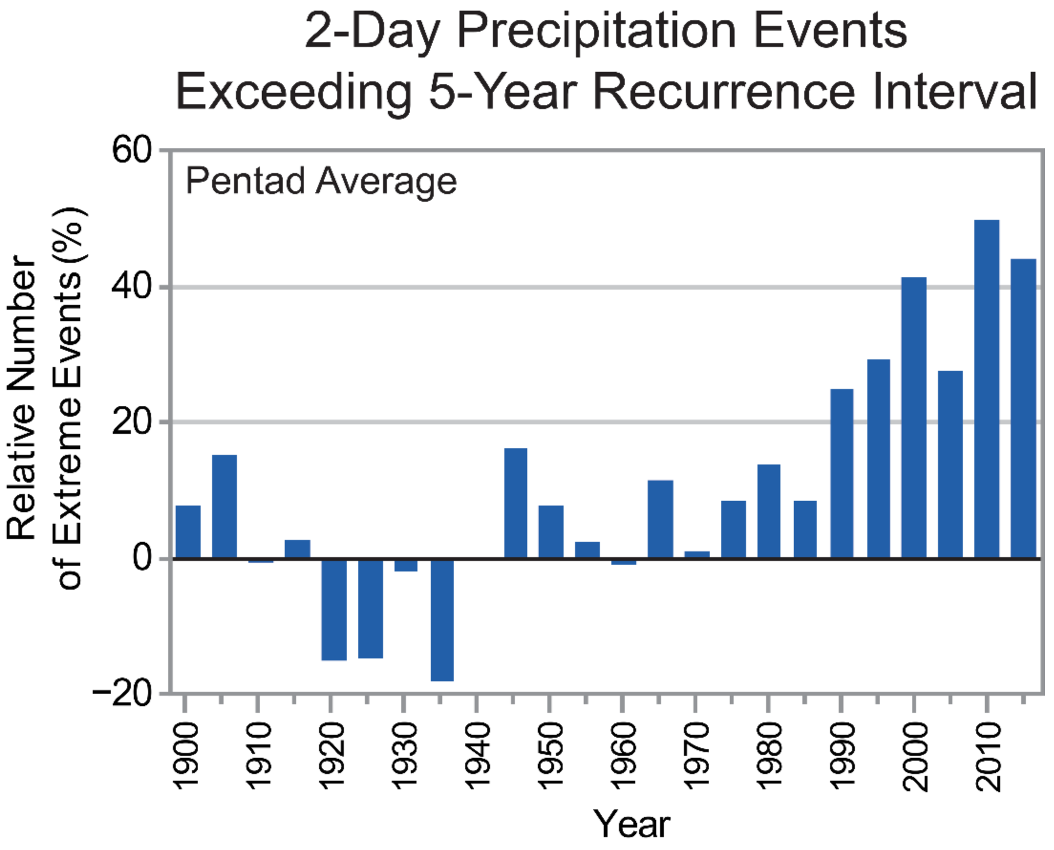
(NOAA, NCEI, 2020)

Land Ice Decline - Over the period 1992 to 2011, the Greenland and Antarctic ice sheets have been losing mass and at a larger rate over 2002 to 2011. Glaciers have continued to shrink almost worldwide.



(IPCC AR5, 2014)

Precipitation Change - Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901.



Fourth US National Climate Assessment Volume 1, November 2017

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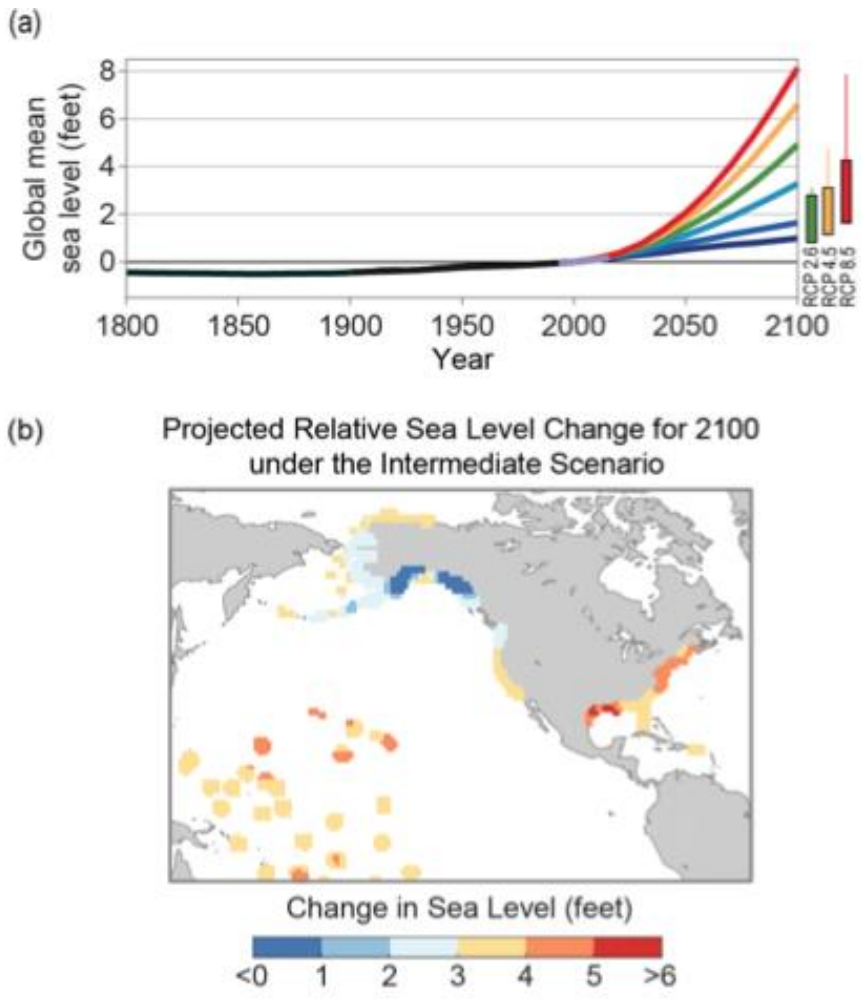
Sea Level Rise – a consequence of atmospheric warming caused by:

1) Thermal expansion of sea water as it warms
2) Transfer of water to the ocean from glaciers, ice caps and the Greenland and Antarctic Ice Sheets

- Global mean sea level (GMSL) has risen by about 7–8 inches since 1900, with about 3 of those inches occurring since 1993.

- Relative to 2000, GMSL is *very likely* to rise by 0.3–0.6 feet by 2030, 0.5–1.2 feet by 2050, and 1.0-4.3 feet by 2100.

- A GMSL rise greater than 8 feet by 2100 is physically possible, although the probability cannot currently be assessed.



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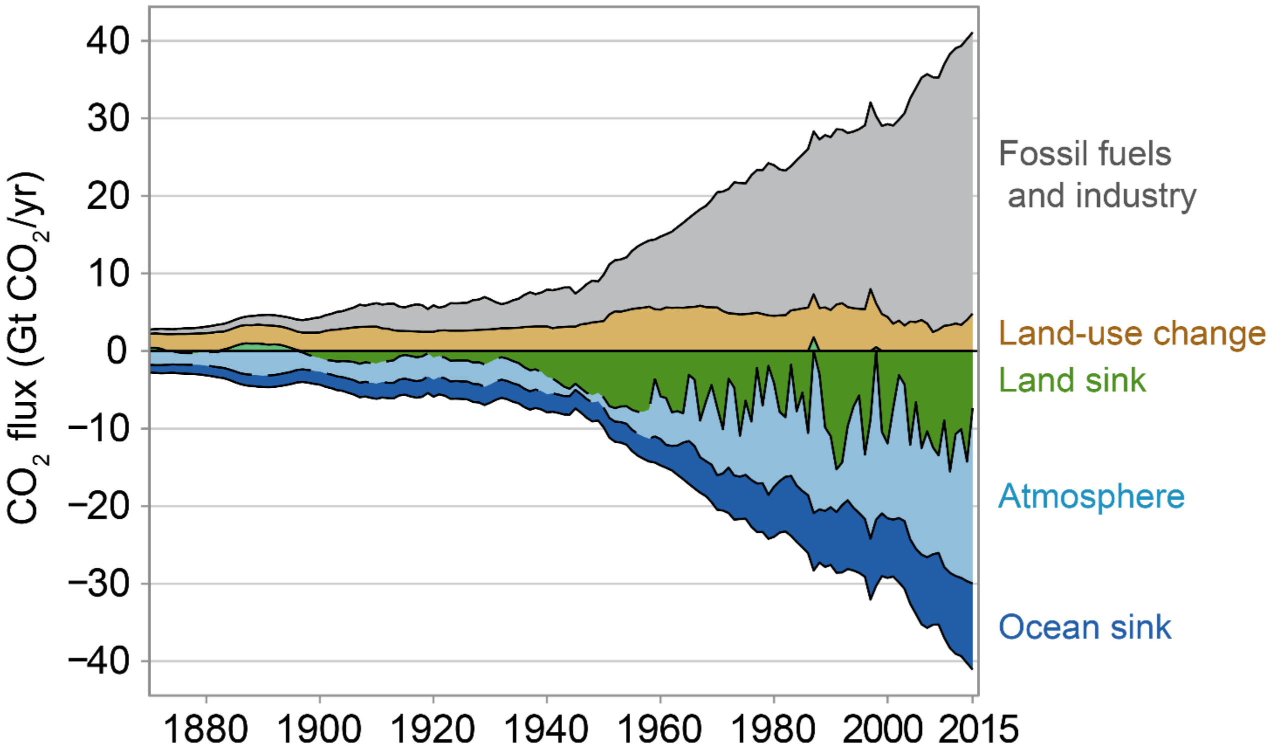
Oceanic uptake of CO_2 has resulted in acidification of the ocean; decreasing pH of ocean surface water by 0.1, a 26% observed increase in acidity.

CO_2 Sources and Sinks



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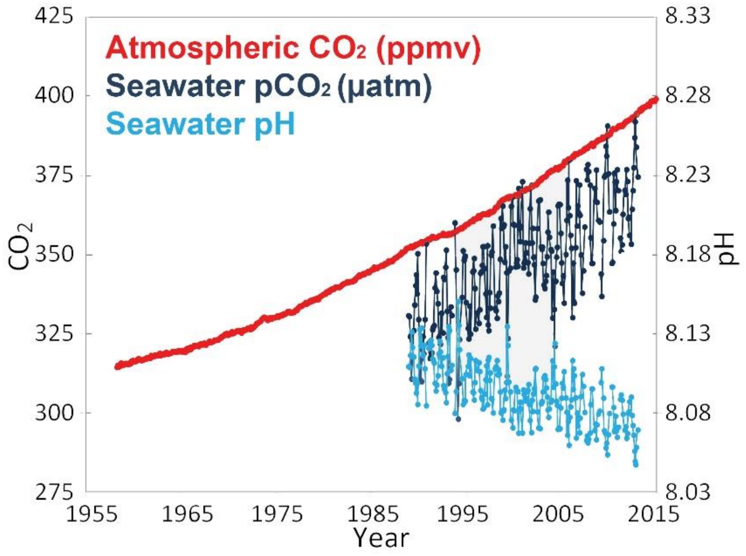

Time series of carbon dioxide and ocean pH at Mauna Loa, Hawaii

As ocean acidification increases, available **carbonate** ions bond with excess hydrogen, resulting in fewer **carbonate** ions available for calcifying organisms to build and maintain their shells and skeletons

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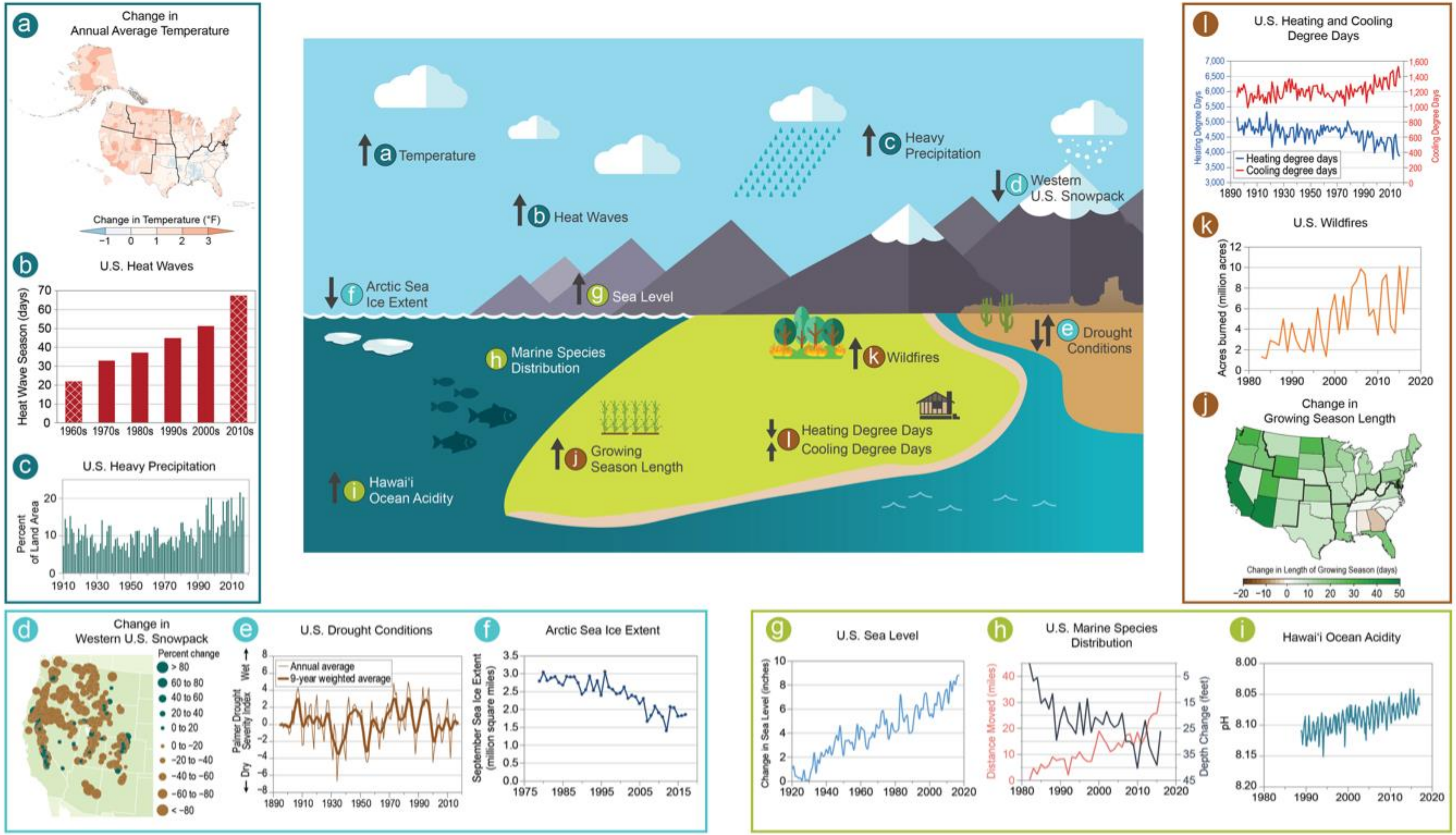
Summary of Observed Change – U.S.



Fourth US National
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Volume II, November 2018

IPCC and NCA - findings regarding North Atlantic hurricanes:

Past:

- substantial increase in intensity, frequency, and duration as well as the number of strongest (Category 4 and 5) storms since the early 1980s
- observed increases in hurricane intensity are linked, in part, to higher sea surface temperatures

Future:

- by late this century, models, on average, project an increase in the number of the strongest (Category 4 and 5) hurricanes
- greater hurricane rainfall in a warmer climate
- tropical cyclones are projected to increase in intensity although not in frequency

Hurricane Zeta, Grand Isle Levee, October 28, 2020 (Jefferson Parish)

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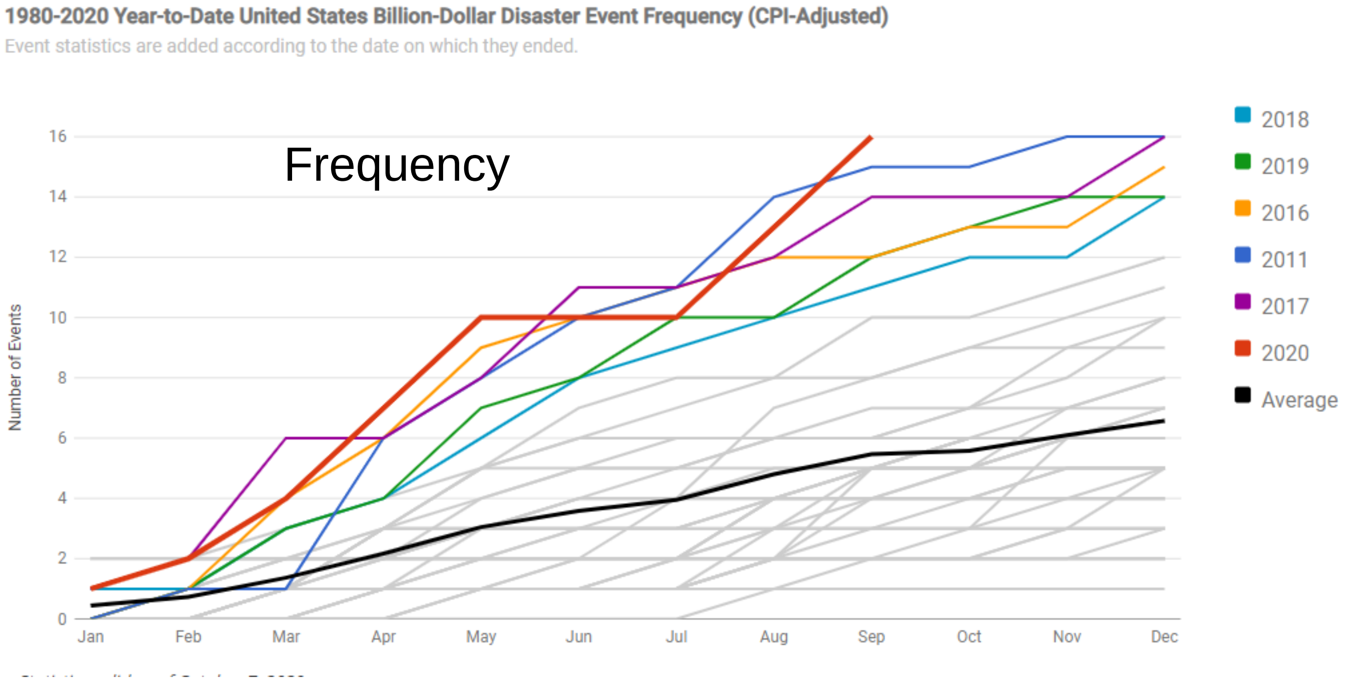
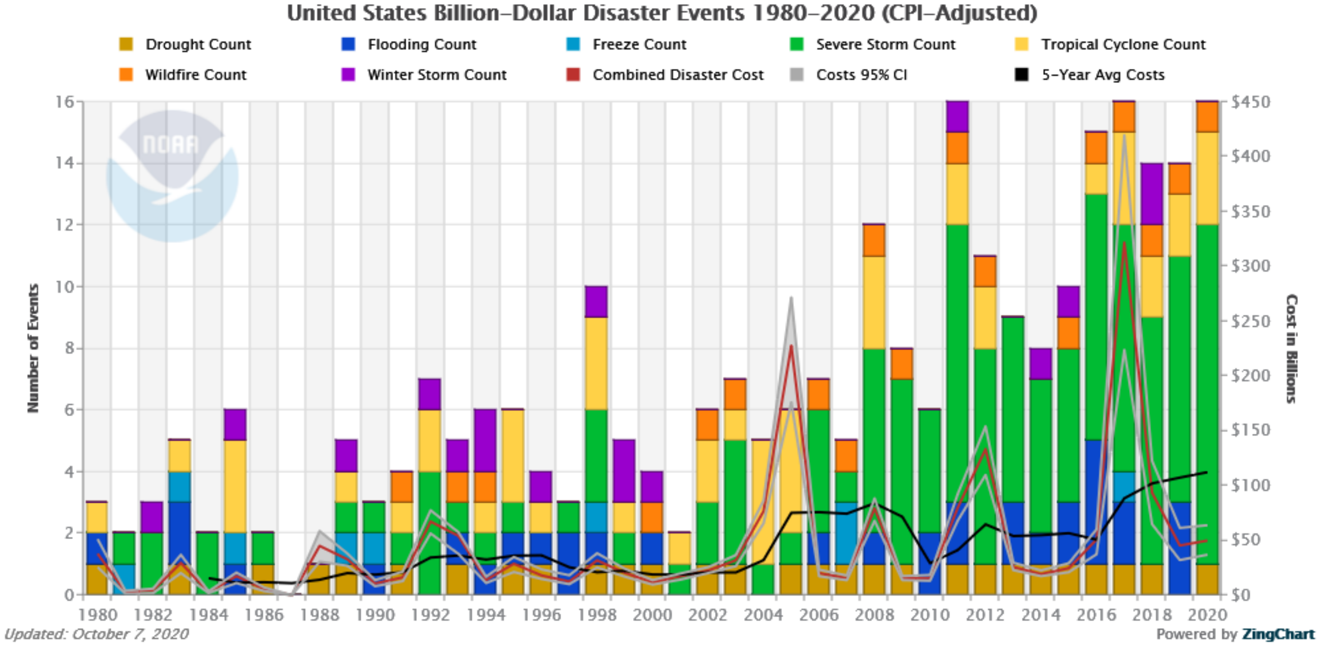
1980-2020 US Billion-Dollar Disaster Events

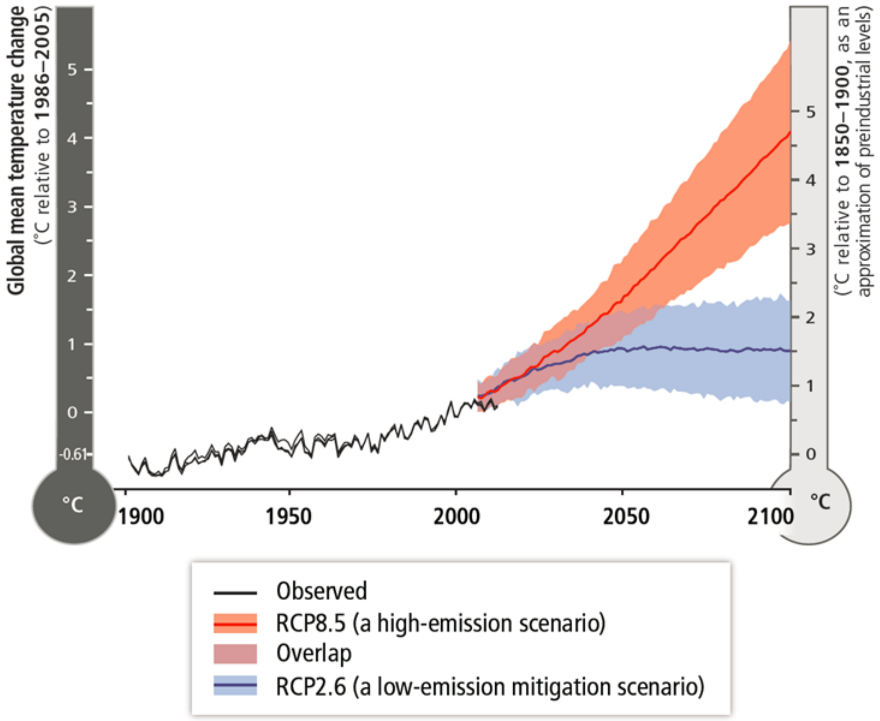


279 weather and climate disasters with overall damages/costs ≥ $1 billion during 1980 - 2020.
Total cost exceeds $1.825 trillion. Does not include Hurricanes Sally, Delta and Zeta.

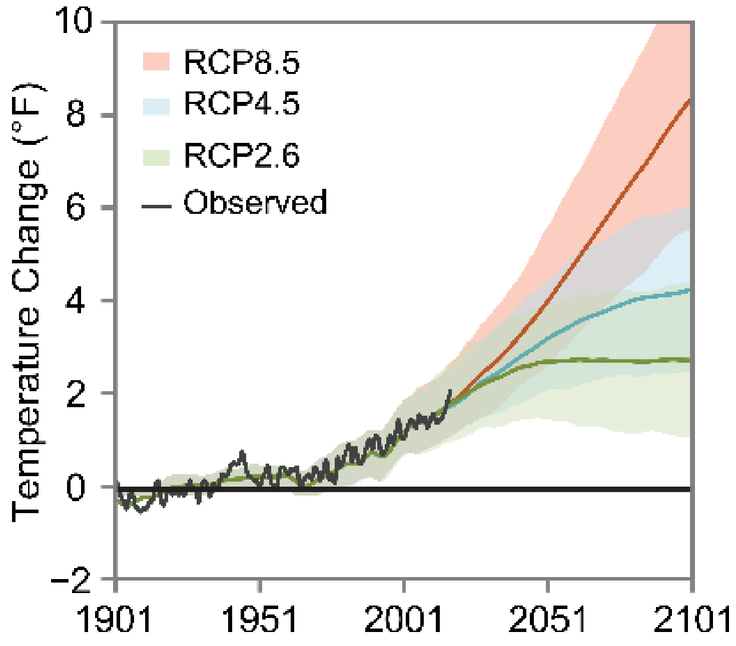


Source: US NOAA, NCEI, October 2020

Projected Global Temperature



(IPCC, 2014)



(NCA, 2018)

RCP = Representative Concentration Pathway, Radiative Forcing in units W/M^{-2}

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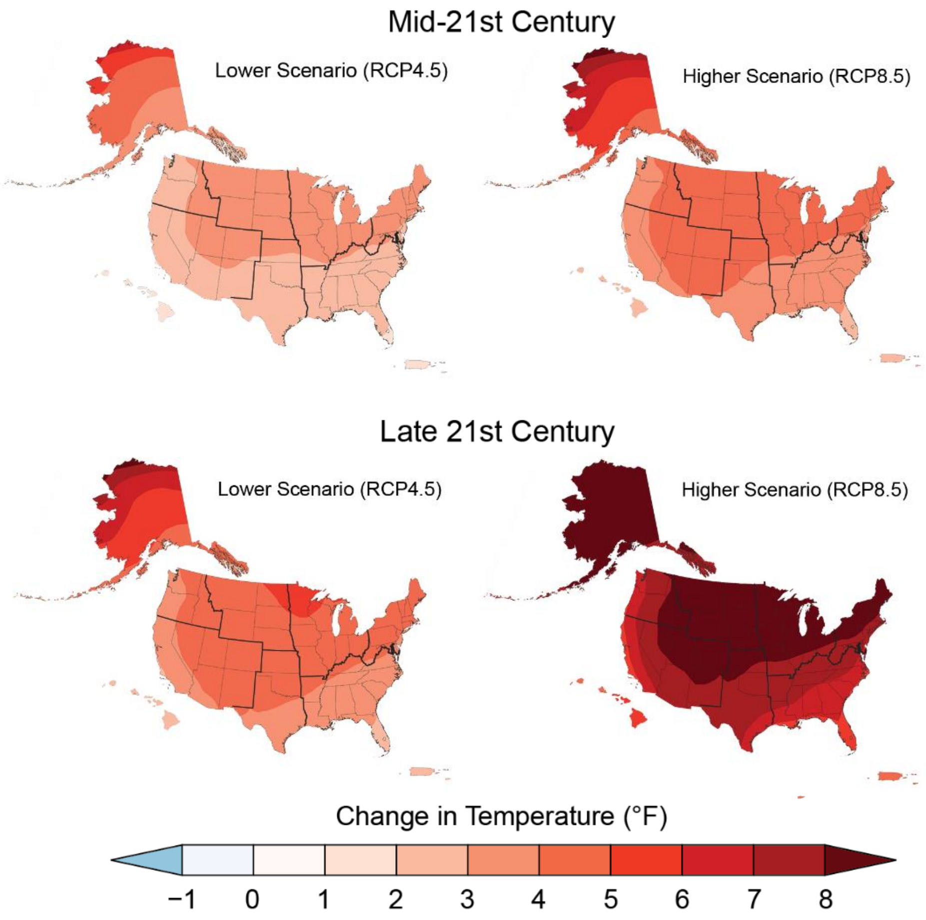
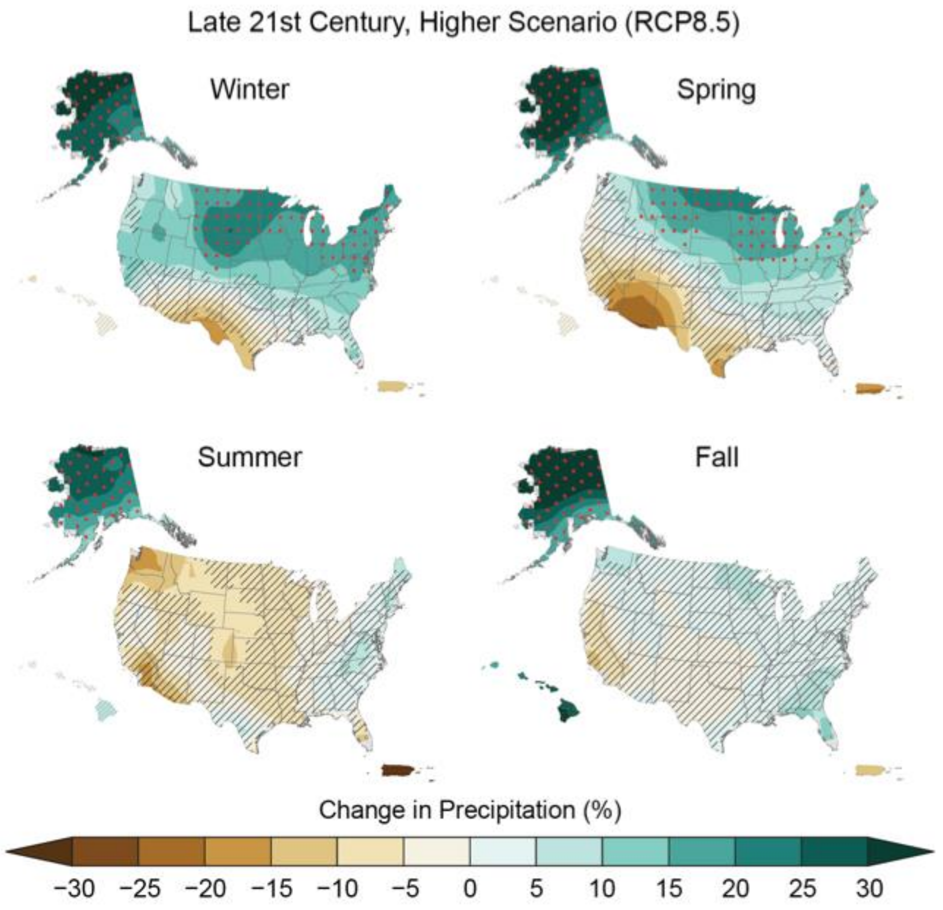
Projected US Climate Change

Annual Temperature



Seasonal Precipitation



Areas with red dots show where projected changes are large compared to natural variations; areas that are hatched show where changes are small and relatively insignificant.

Fourth US National Climate Assessment
Volume II, November 2018

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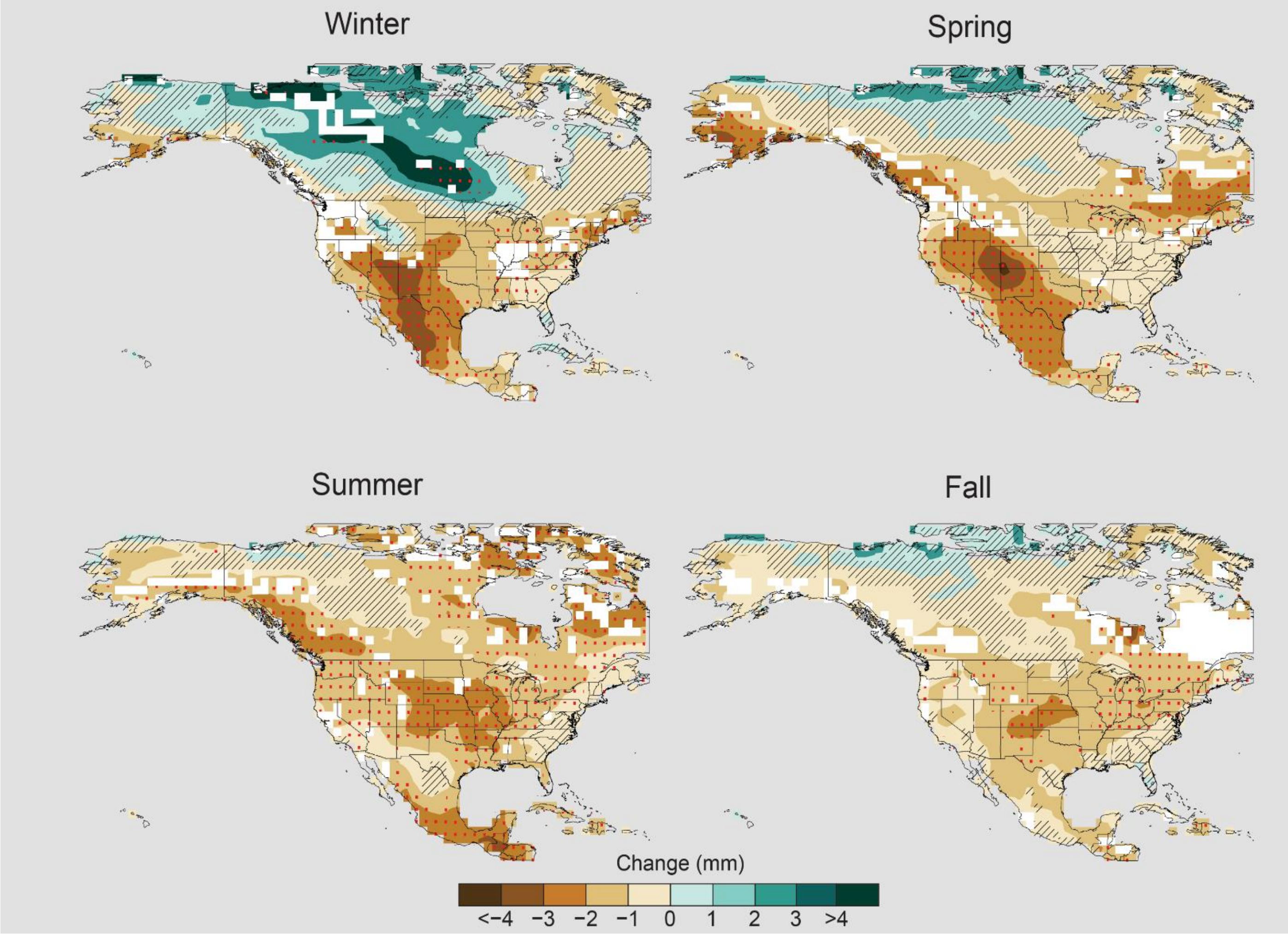
Projected change (mm) in Soil Moisture by end of century

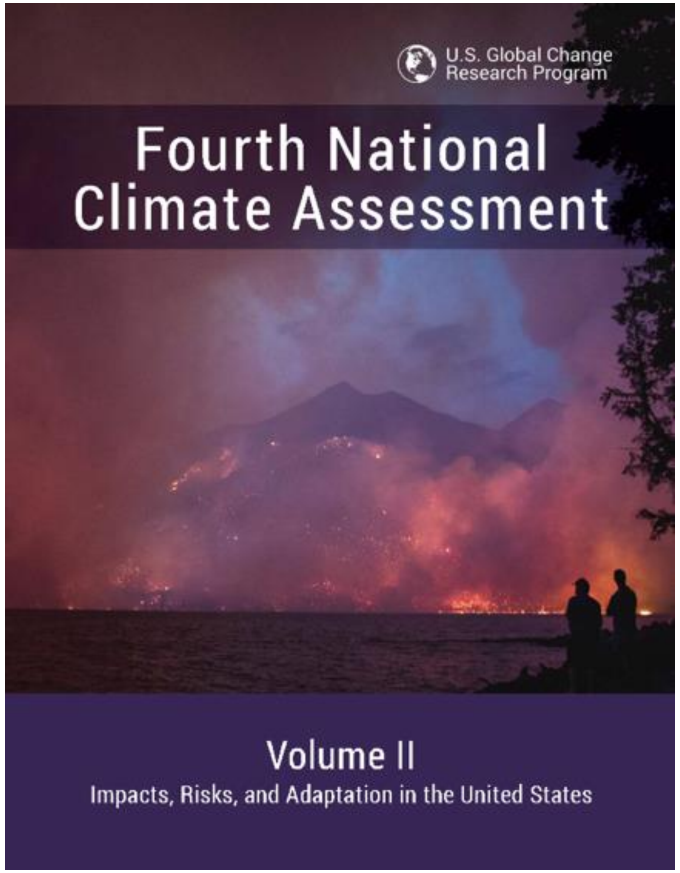


CMIP5 model projections (RCP 8.5) project drying in all seasons by 2100, even where precipitation is projected to increase, consistent with increased evapotranspiration due to elevated temperatures – profound implications for **agriculture, forestry and land carbon**. (NCA4 Volume I, 2017)

US National Climate Assessment

Key Findings (Impacts Volume, 2018)

- Earth's climate is now changing faster than at any point in modern civilization.
- These changes are primarily the result of human activities, the evidence of which is overwhelming and continues to strengthen.
- The impacts of climate change are already being felt across the country, and climate-related threats to Americans' physical, social, and economic well-being are rising.
- Americans are responding in ways that can bolster resilience and improve livelihoods.
- However, neither global efforts to mitigate the causes of climate change nor regional efforts to adapt to the impacts currently approach the scales needed to avoid substantial damages to the U.S. economy, environment, and human health and well-being over the coming decades.



Read and download NCA4 Volume 2 at
nca2018.globalchange.gov

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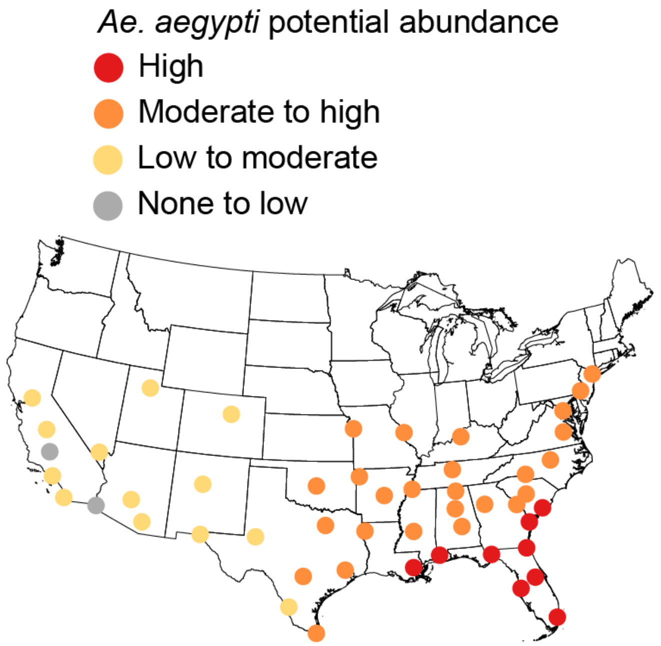
Southeast Key Message #1:
Urban Infrastructure & Health Risks

- **Rapid Population Shifts** – 12 of the 20 fastest growing metro areas are in the Southeast; a more urbanized region creates new vulnerabilities
- **Increasing Heat** – Birmingham, New Orleans, and Raleigh are seeing some of the most extreme increases in high heat events.
- **Infrastructure** – Flooding and SLR affect roads, bridges, municipal water supplies, etc.
- **Vector-Borne Disease** – expanded spatial extent and annual duration of certain vector-borne diseases
- **Air Quality –** Climate influence remains uncertain (clouds, rain, wind, etc.), but aeroallergens likely to increase in urban areas

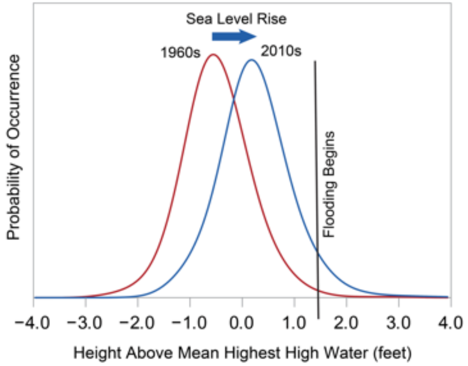


Current suitability for the *Aedes aegypti* mosquito in July. These mosquitoes can spread diseases, including dengue fever, chikungunya, and Zika fever. The Southeast is the region with the greatest potential mosquito activity. Warming temperatures have the potential to expand mosquito habitat and disease risk.

Southeast Key Message #2:
Increasing Flood Risks in Coastal & Low-Lying Regions

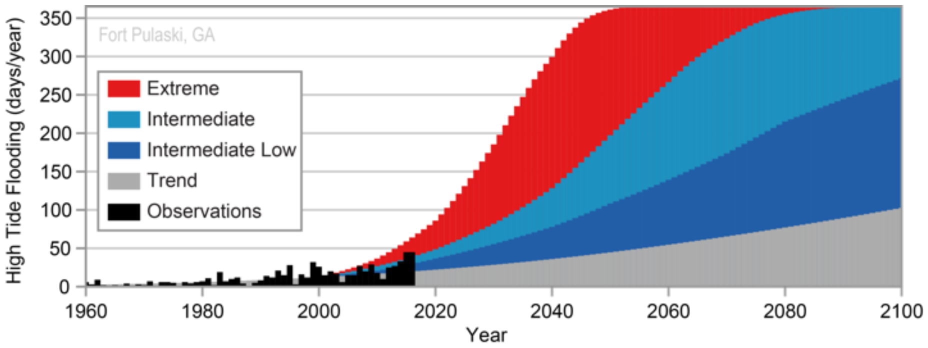
Observed

- NOAA tide gauges show as much as 1 to 3 feet of local relative SLR in the past 100 years (vs 8-9” globally)
- Annual occurrences of high-tide coastal flooding have increased 5- to 10-fold since the 1960s in several low-lying coastal cities



Projected

- By 2050, many Southeast cities are projected to experience 30+ days of high tide flooding regardless of scenario.
- More extreme coastal flood events are also projected to increase in frequency and duration.



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Southeast Key Message #3:
Natural Ecosystems Will Be Transformed

- **Warming Winter Temperature Extremes** – Plant hardiness zones shift; salt marsh → mangrove
- **Changing Patterns of Fire** – SE region has the most prescribed fire in the U.S., a practice that may become less effective with climate change and urbanization
- **Rising Sea Levels and Hurricanes** – Coastal inundation affects marine economies, port infrastructure, and communities
- **Drought and Extreme Rainfall** – Tree mortality and impacts on forest ecosystems that drive local economies (family farms)
- **Warming Ocean Temperatures** – shifts in fisheries and coral bleaching

In Louisiana and parts of northern Florida, future coastal wetlands are expected to look and function more like the mangrove-dominated systems currently present in South Florida and the Caribbean.

Increase in ocean temperature of 1-2° C above summer maxima causes expulsion of coraline symbiotic algae

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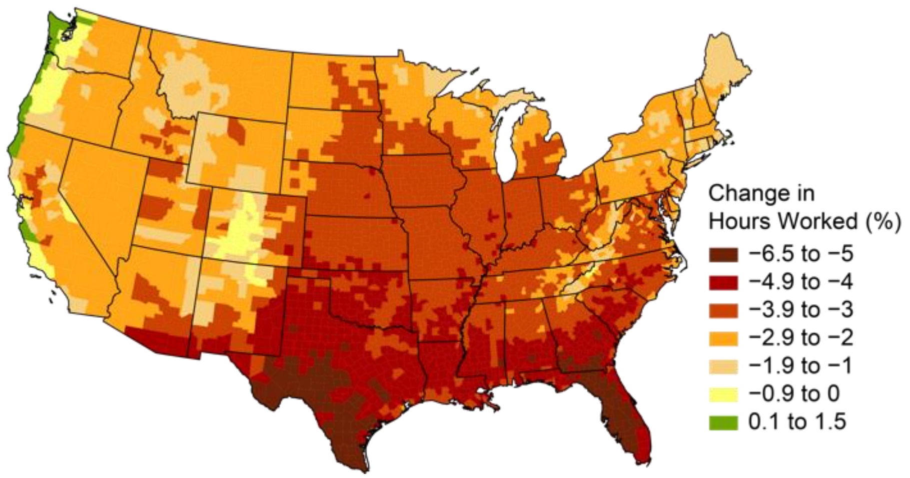
Southeast Key Message #4:
Economic & Health Risks for Rural Communities

- **Diverse Rural Regions** – Communities centered around energy production, agriculture, forestry, manufacturing, and tourism face unique risks
- **Risks to Agriculture & Forestry** – Freeze-free days, wildfire, invasive species, drought, extreme heat and precipitation
- **Heat, Health, and Livelihoods** – Outdoor jobs (construction, agriculture) and recreation (hunting, fishing)
- **Compounding Stresses and Constraints to Adaptation** – Poverty, low literacy, and limited capacity to respond can exacerbate impacts and inhibit resilience

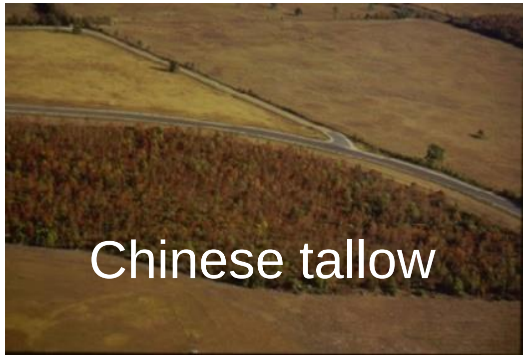


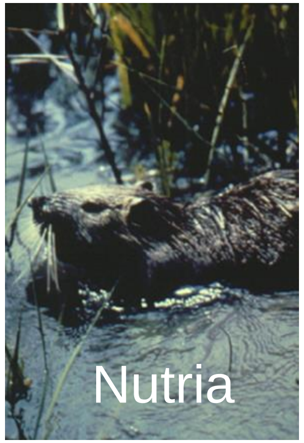
Estimated % **change in hours worked** in 2090 (vs 2003-07) under a higher warming scenario (RCP8.5).

Projections indicate an annual average of 570 million labor hours lost per year in the Southeast by 2090 in high-risk industries (i.e., agriculture, forestry, and fishing; hunting, mining, and construction; manufacturing, transportation, and utilities).

Examples of Coastal Impacts

1. **Warmer winters lead to changes in plant and animal species distribution and the spread of invasive species**


Chinese tallow


Nutria

2. **Lower soil moisture leads to more intense, frequent, and widespread wildfires and plant water stress**

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Examples of Coastal Impacts

3. As sea level rises, fresh and brackish water coastal ecosystems will become more saline

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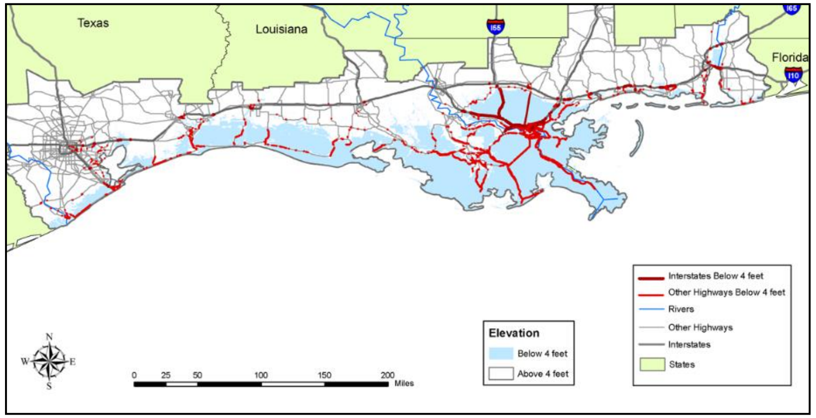
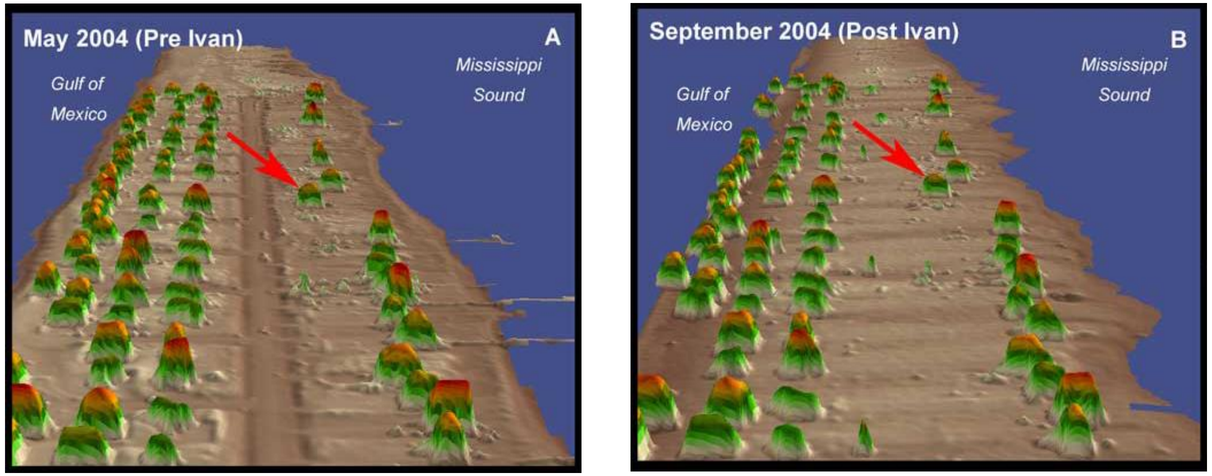
Examples of Coastal Impacts

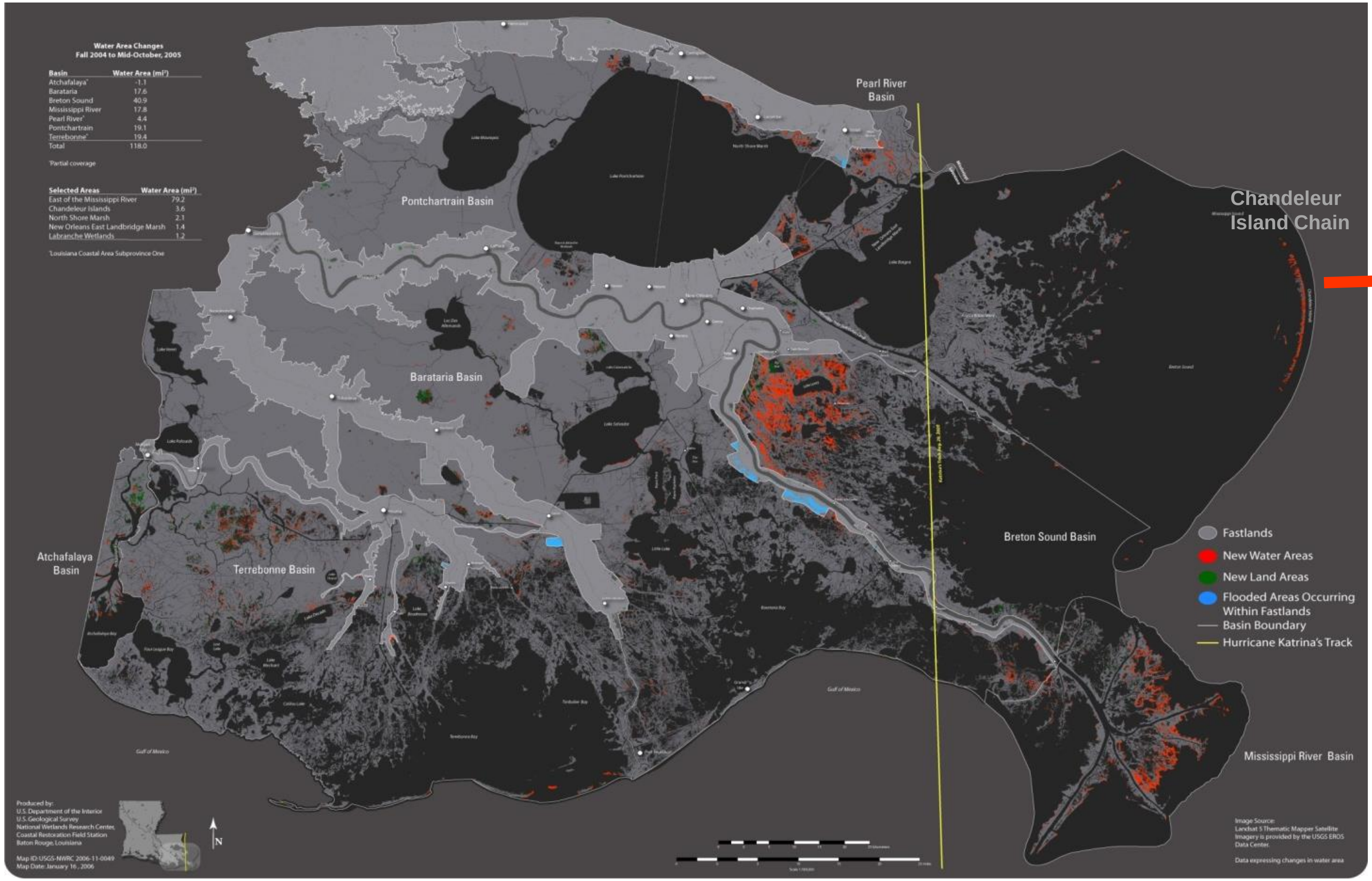
4. Coastal tidal and storm surge flooding increases due to sea level rise

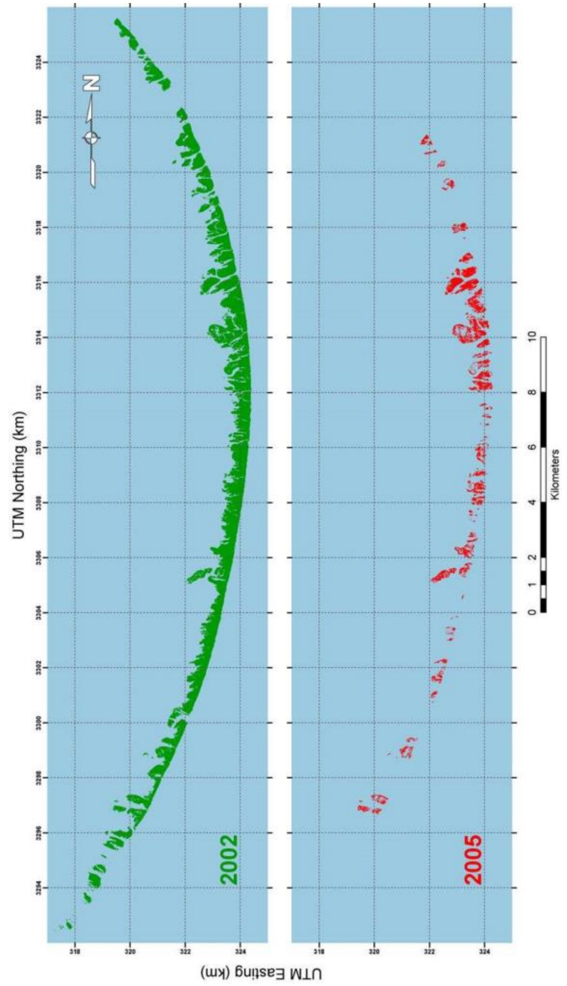


5. Low-lying coastal ecosystems will erode more rapidly if storms increase in intensity.



217 square miles of Louisiana coast were lost to open water during Hurricanes Katrina and Rita in 2005





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Tipping points in natural systems are generally poorly understood and difficult to predict – there will be surprises.

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Source of photos: Isle De Jean Charles band

Tipping points in community sustainability will also be crossed as risks increase in low-lying coastal regions

Risks from climate change impacts arise from the interaction between hazard (triggered by an event or trend related to climate change), vulnerability (susceptibility to harm), and exposure (people, assets or ecosystems at risk).

Climate change risks are generally greater for disadvantaged people and communities in countries at all levels of development.

ipcc INTERGOVERNMENTAL PANEL ON climate change

What can be done to reduce risks?

Adaptation

- Purposeful actions taken to reduce undesirable effects or enhance positive effects of climate change

Mitigation

- Reduce greenhouse gas emissions or enhance carbon sequestration (in the subsurface or in ecosystems)

Adaptation: 5 examples

1. Reduce non-climate stressors on coasts

2. Adapt infrastructure – floodproof existing structures, design the built environment to survive the changes that are likely

Adaptation: 5 examples

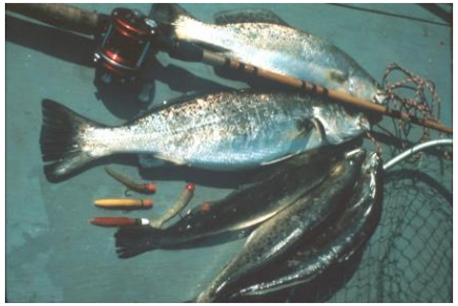
3. Retreat from low-lying coastal zones

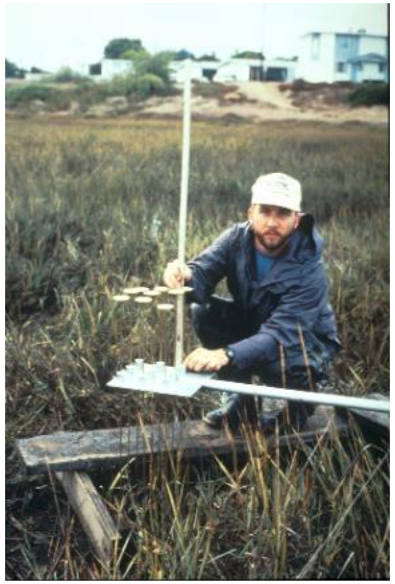
In some areas retreat may be the most cost effective option.

Biloxi MS after Hurricane Katrina

State, local, and tribal leaders discuss the relocation of the tribal community of Isle de Jean Charles, LA, in response to severe land loss, sea level rise, and coastal flooding.

4. Factor scientific understanding of natural processes and trends into management, inform by monitoring





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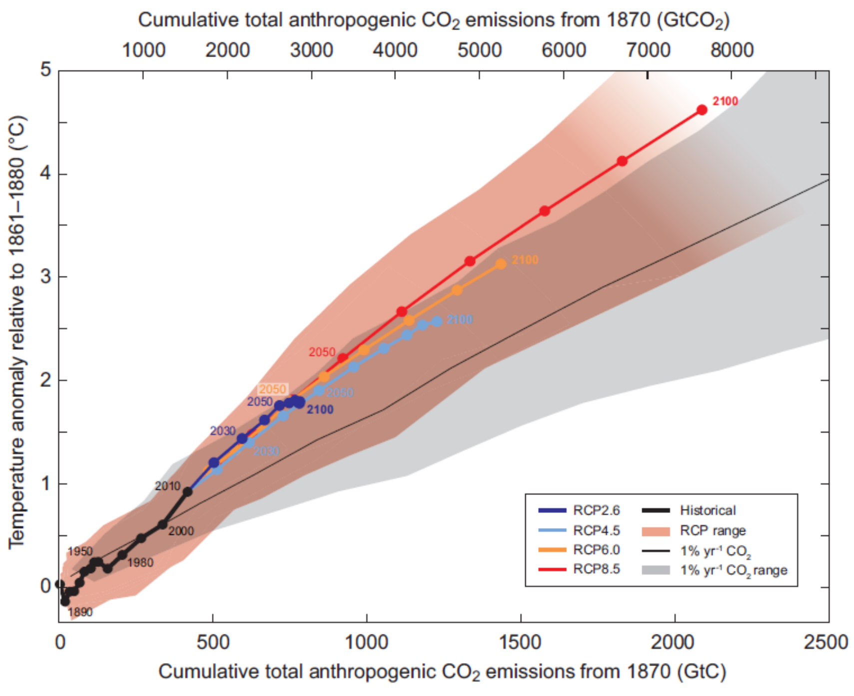
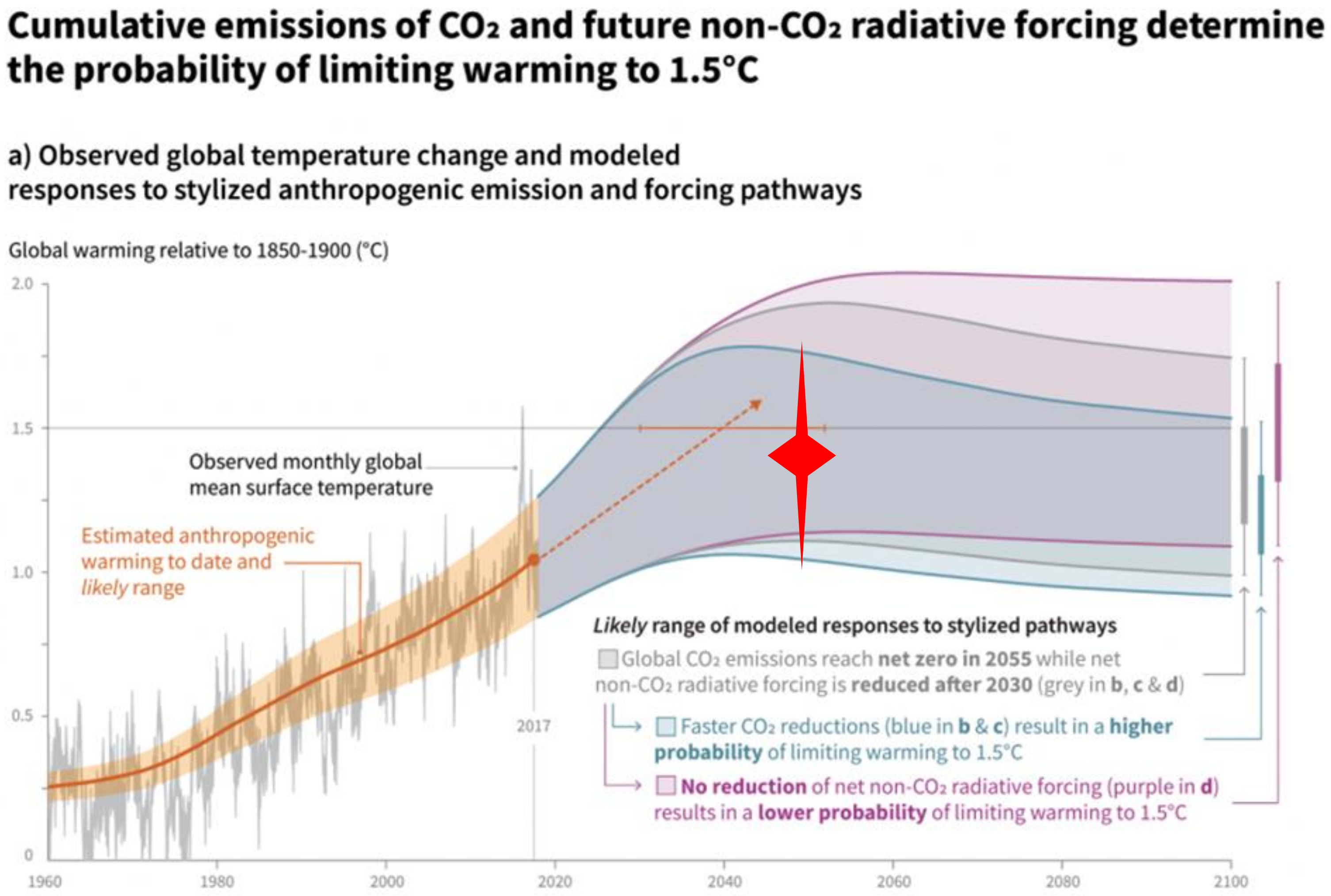
Adaptation: 5 examples

5. Increase the resilience and sustainability of coastal systems (natural and human)

Mitigation, or lack thereof, will determine rate of future warming

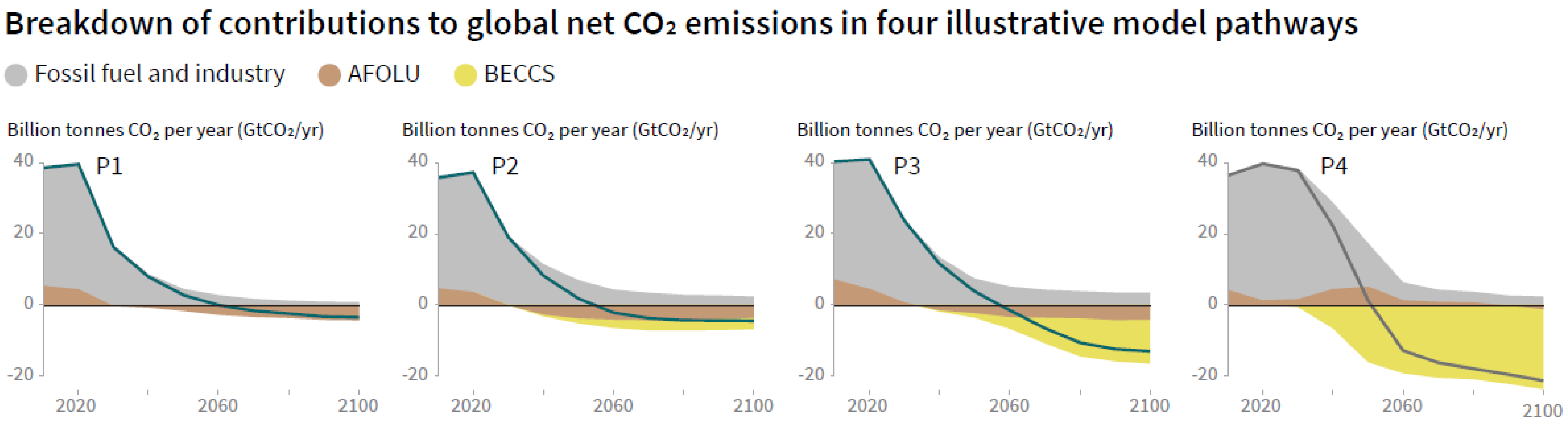


(IPCC WGI AR5, 2013)



(IPCC 1.5ºC Special Report, 2018)

IPCC 2018 illustration of pathways that limit warming to 1.5°C



- The IPCC 1.5C special report concludes: the only way to keep T increase to 1.5C and achieve sustainable development goals is
  - Decarbonization of the economy (emissions reduction)
  - Carbon dioxide removal and sequestration – via afforestation and other land use change, direct atmospheric removal (air capture), and BECCS (bioenergy with carbon capture and storage)

- Technological and scientific advances are needed urgently to underpin new mitigation technologies, to enhance adaptation, and to enable the economic transformation that could keep global T from increasing **3-5°**C by end of century.

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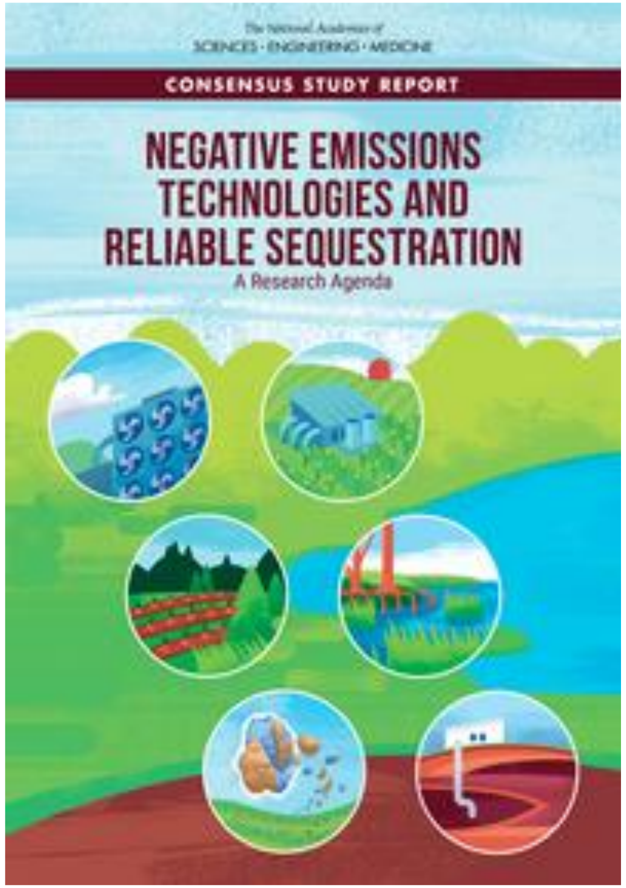
Avoiding a global temperature increase of 3-5°C (compared to preindustrial times) by 2100 will require a combination of 1) emissions reduction and 2) rapid advancement in negative emissions technology.

The implementation of negative emissions technology and carbon sequestration help offset fossil fuel extraction and use.

A recent National Academies' study (Pacala et al. 2018) on negative emissions technology and carbon sequestration and concludes:

"removing CO2 from the atmosphere and storing it has exactly the same impact on the atmosphere and climate as simultaneously preventing emission of an equal amount of CO2"

The US can emerge as a global leader in lead in the field of Negative Emissions Technology and carbon sequestration.



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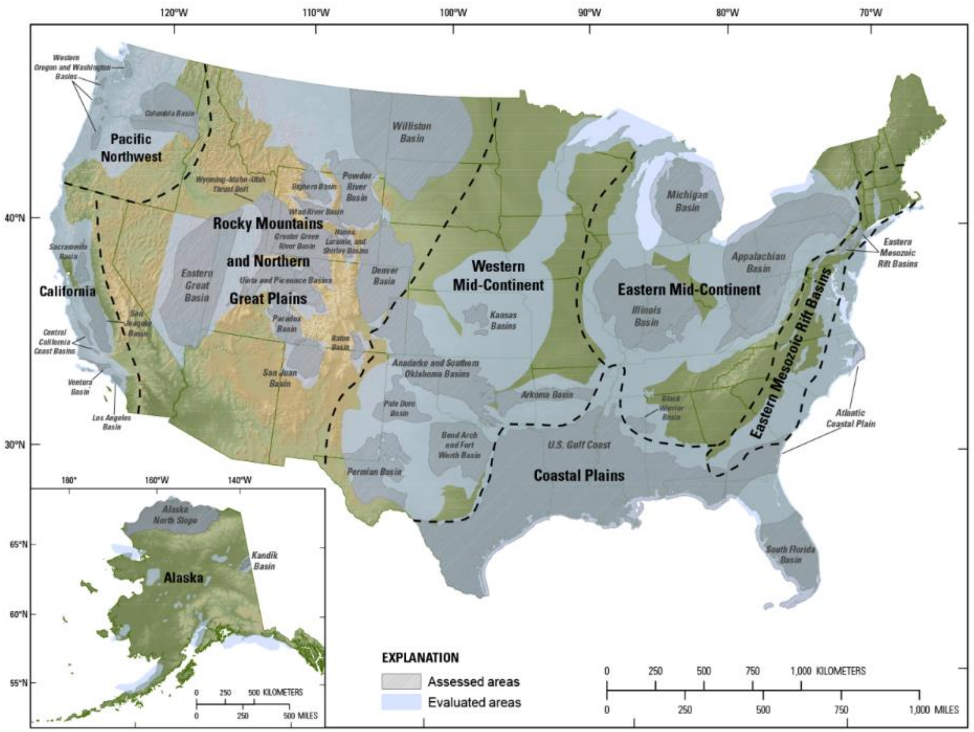
6 classes of Negative Emissions Technology research recommended by the National Academies (2018)

- **Coastal blue carbon** —Land use and management practices that increase the carbon stored in living plants or sediments in mangroves, tidal marshlands, seagrass beds, and other tidal or salt-water wetlands. (called "blue carbon" even though they refer to coastal ecosystems instead of the open ocean.
- **Terrestrial carbon removal and sequestration** —Land use and management practices, such as reforestation, and changes in agricultural practices that enhance soil carbon storage.
- **Bioenergy with carbon capture and sequestration** — Energy production using plant biomass to produce electricity, liquid fuels, and/or heat combined with capture and sequestration of any CO_2 produced.
- **Direct air capture** —Chemical processes that capture CO_2 from ambient air and concentrate it, so that it can be injected into a storage reservoir.
- **Carbon mineralization** —Accelerated "weathering," in which CO_2 from the atmosphere forms a chemical bond with a reactive minerals (particularly mantle peridotite, basaltic lava, and other reactive rocks), at the surface or in the subsurface, where concentrated CO_2 streams are injected and mineralizes in the rock pores.
- **Geologic sequestration** —CO_2 captured through BECCS or direct air capture is injected into a geologic formation, such as a saline aquifer, where it remains in the pore space of the rock for a long time. This is not a NET, but rather an option for the sequestration component of BECCS or direct air capture.

An example:
US National Assessment of Geologic Carbon Dioxide Storage Resources

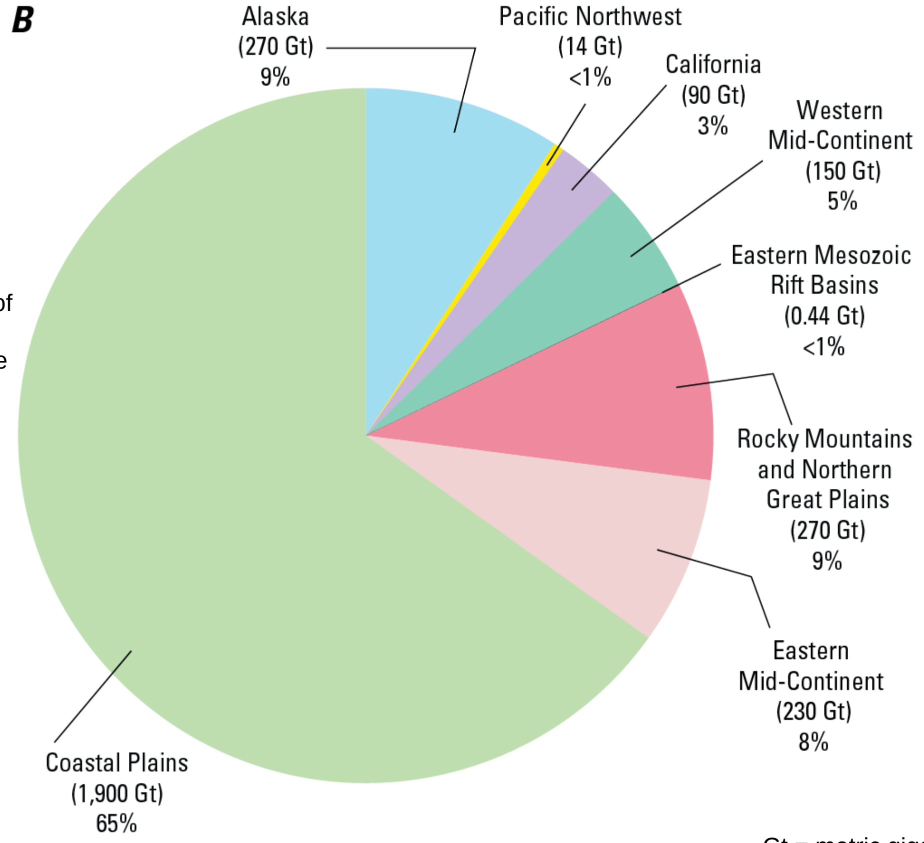
Coupled with wall to wall assessment of US ‘LandCarbon’ and how it can be managed.



The regions with the largest technically accessible storage resources are the Coastal Plains (mostly in the U.S. Gulf Coast), Rocky Mountains and Northern Great Plains, and Northern Alaska. US Gulf coast has 59% of the US storage capacity.

USGS Circular 1386
pubs.usgs.gov/circ/1386

USGS estimates of technically accessible storage resources for CO_2 in the United States by region



Gt = metric gigaton

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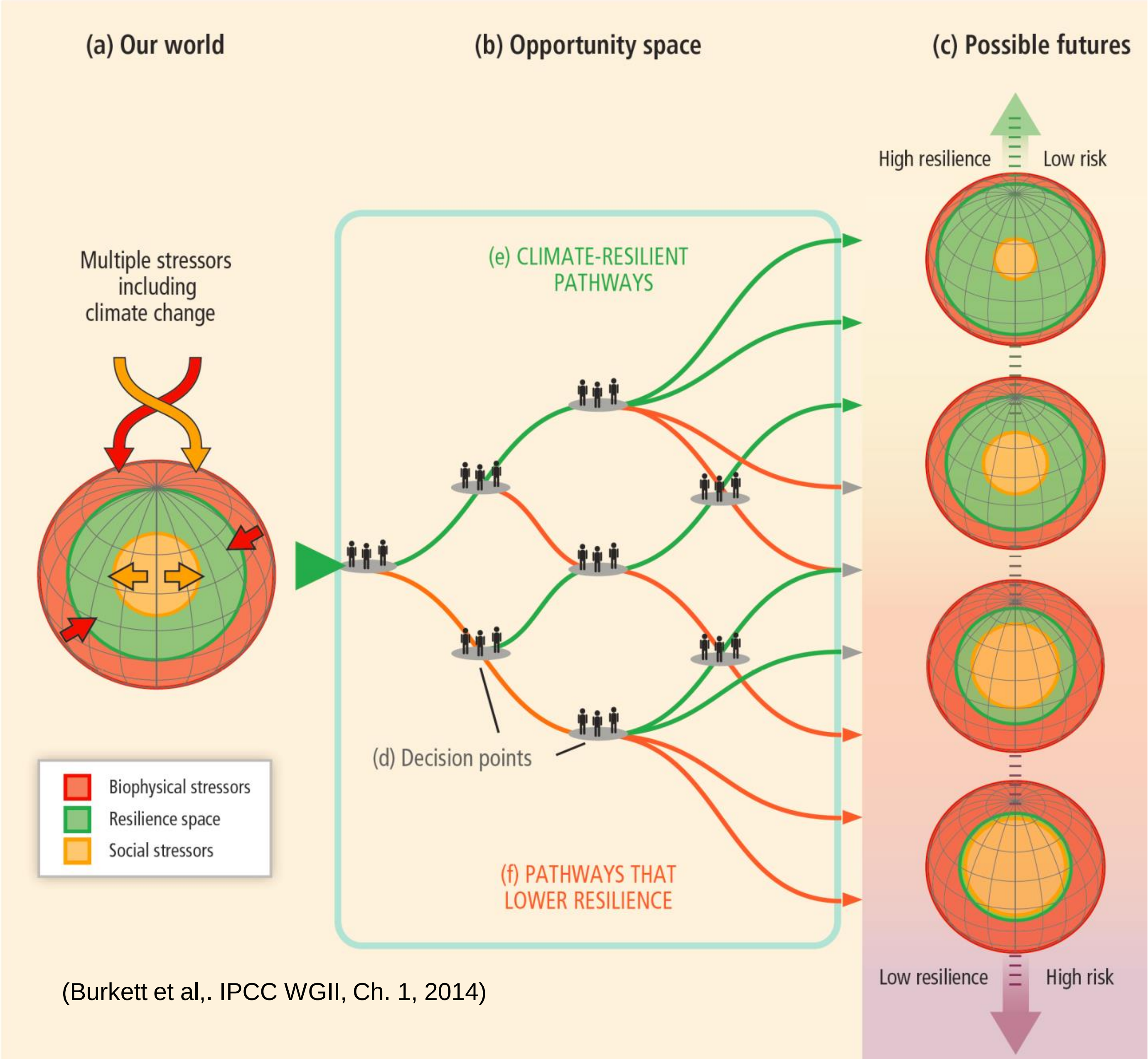
Opportunity space and climate-resilient pathways

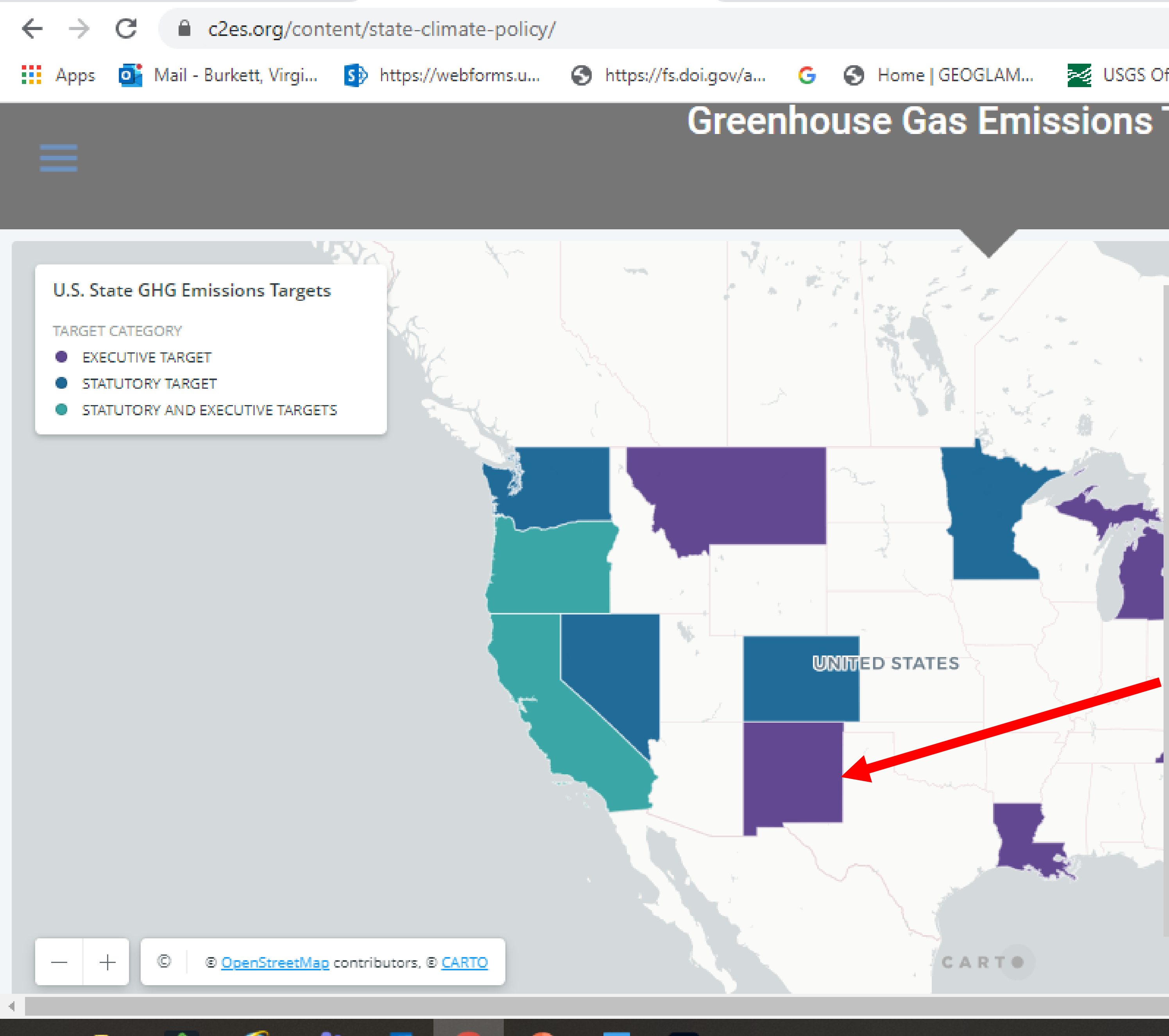


(Burkett et al,. IPCC WGII, Ch. 1, 2014)

23 states plus the District of Columbia have adopted specific greenhouse gas reduction targets to address climate change. Each state has adopted a target and baseline year that suits its circumstances.

One of the most common state policies is a **portfolio standard** that requires electric utilities to deliver a certain amount of electricity from renewable or clean energy sources. A renewable portfolio standard (RPS), adopted in 29 states, including Texas, require a certain percentage of a utility’s electricity to come from renewable energy sources.

Center for Energy and Climate Solutions, successor to the Pew Center on Global Climate Change, founded in 1998, tracks state climate action plans

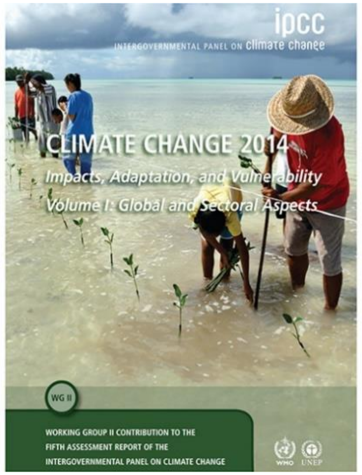


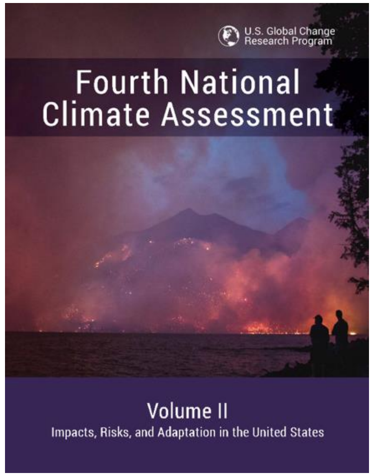
New Mexico Climate Strategy: Initial Recommendations and Status Update **(2019)**

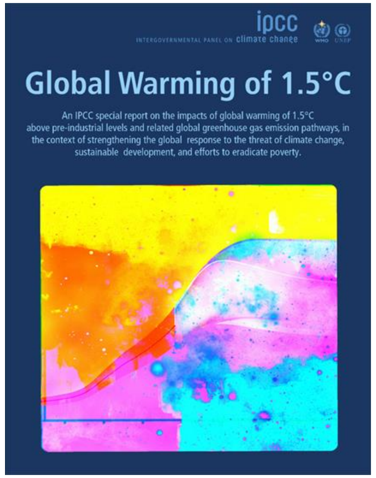
The report outlines proposals for the state to meet its goal of reducing GHG emissions by at least 45% by 2030 compared to 2005 levels. Key recommendations include prioritizing climate-focused forest and grassland management, boosting electric vehicle market penetration through an Electric Vehicle Climate Action Team, and expanding energy-efficient housing and appliances to low-income and disadvantaged people. New Mexico released a previous climate action plan in 2006

Acknowledgements – Primary Sources

- Intergovernmental Panel on Climate Change (IPCC), Fifth Assessment Report – Working Groups I and II
- Fourth National Climate Assessment Volumes I and II
- IPCC Special Report, Global Warming of 1.5°C







THANK YOU!

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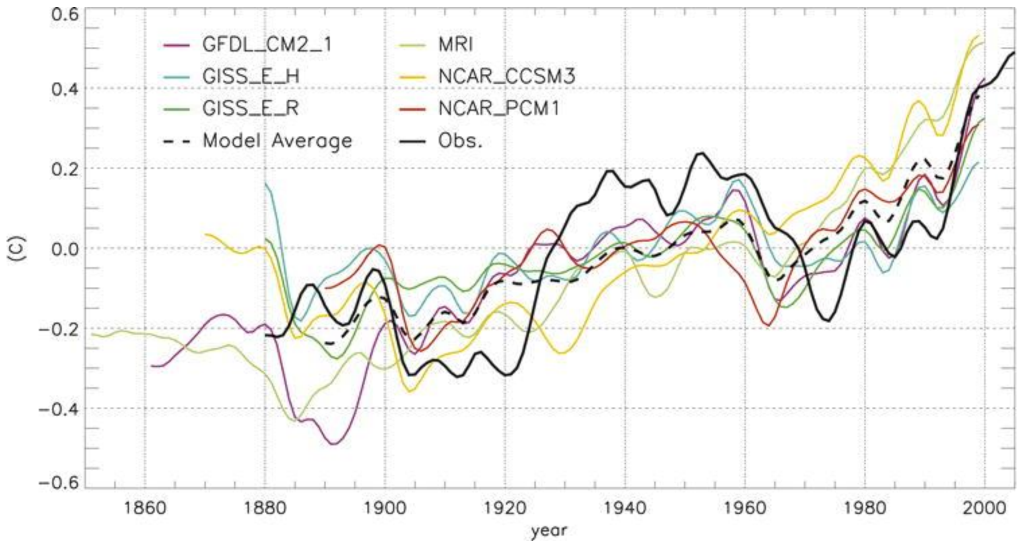
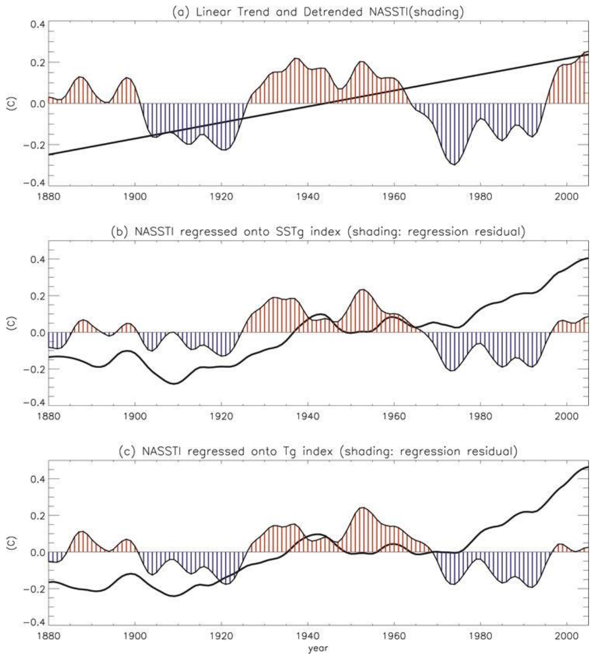
From: **Forced and Internal Twentieth-Century SST Trends in the North Atlantic***

J. Climate. 2009;22(6):1469-1481. doi:10.1175/2008JCLI2561.1



NASSTI averaged over the ocean grids from the equator to 60° N and from 7.5° to 75° W. Black solid line: observations; color lines: coupled ocean–atmosphere models of the IPCC twentieth-century simulations averaged over multiple realizations starting from different initial conditions; dashed black line: average of all models.



(a) The linear trend (solid black line) and detrended NASSTI (shaded). (b) NASSTI regressed onto the global mean SST (SSTg regression, solid black line) and the difference between the observed NASSTI shown in Fig. 1 and the SSTg regression (shaded). (c) NASSTI regressed onto the global mean surface temperature (Tg regression, solid black line) and the difference between the observed NASSTI shown in Fig. 1 and the Tg regression (shaded).

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A World of Agreement: Temperatures are Rising