

EXHIBIT 6



A Tutorial on Climate Change Science: The 4th National Climate Assessment

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Climate Science Special Report

Fourth National Climate Assessment (NCA4), Volume I

This report is an authoritative assessment of the science of climate change, with a focus on the United States. It represents the first of two volumes of the Fourth National Climate Assessment, mandated by the Global Change Research Act of 1990.

Recommended Citation

science2017.globalchange.gov

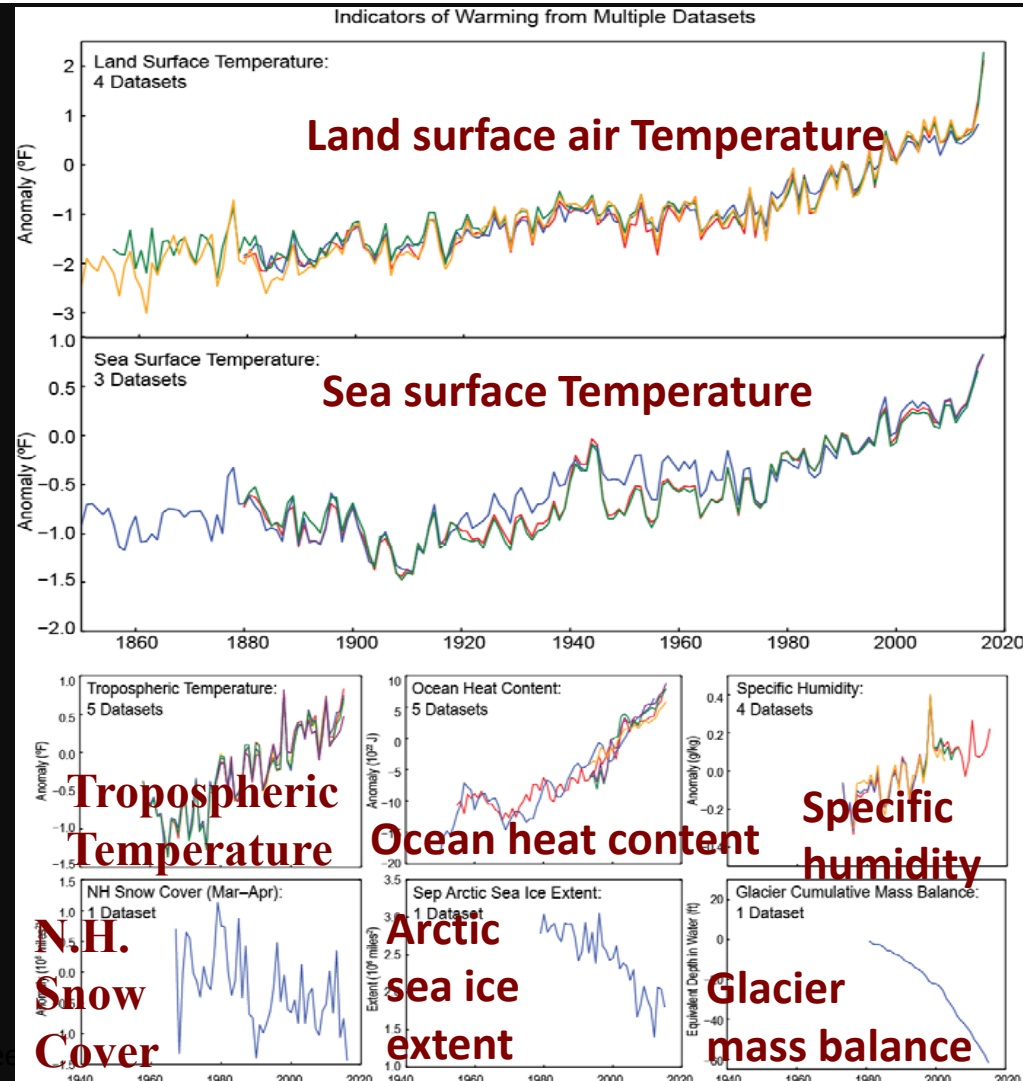
NCA Volume II on impacts expected to be published in Dec. 2018

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The Science: The Bottom Line

- Our climate is changing,
 - It is happening now;
 - It is happening extremely rapidly;
- Severe weather is becoming more intense;
- Sea levels are rising;
- It is largely happening because of human activities and associated pollution;
- The climate will continue to change over the coming decades.

Many Different Observations Show a Changing Climate

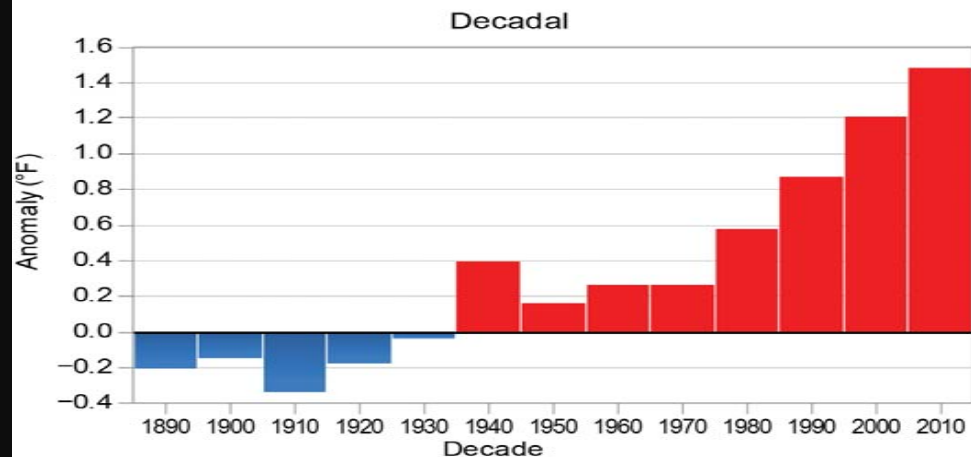
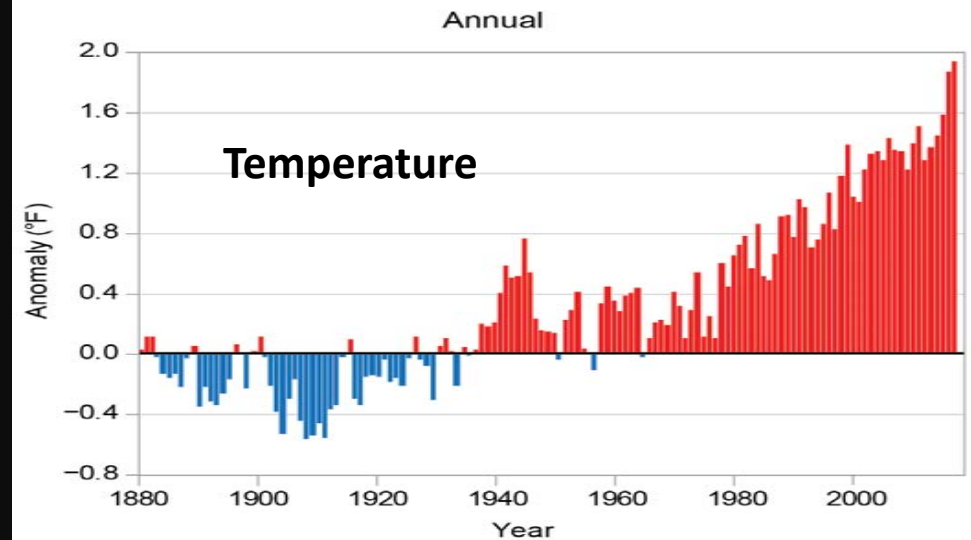


Global Annually-Averaged Temperature Record (NOAA, through 2016)

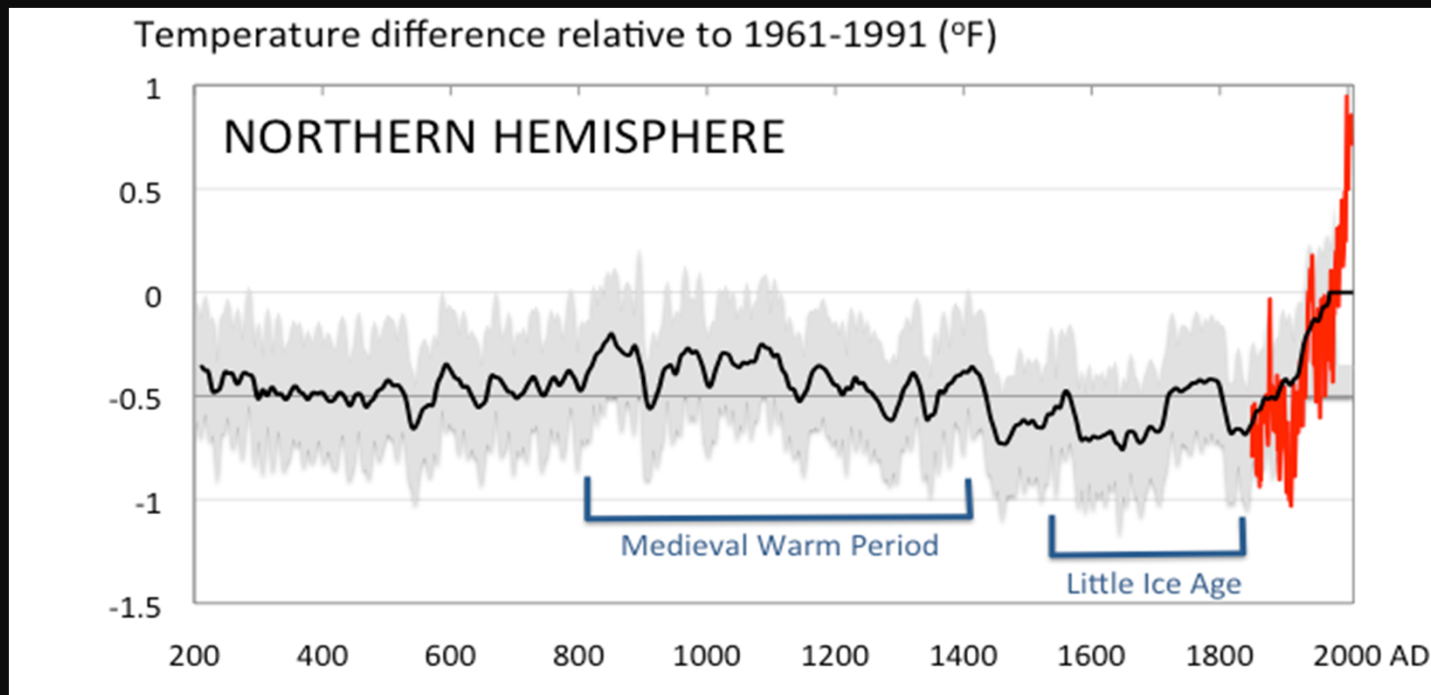
Globally, annually-averaged temperature has increased by 1.8 °F from 1901-2016

Date Graphs are relative to 1901-1960

Global Land and Ocean Temperature Anomalies



Conditions today appear to be unusual in the context of the last 2,000 years ...



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Updated from Mann et al., 2008 PNAS

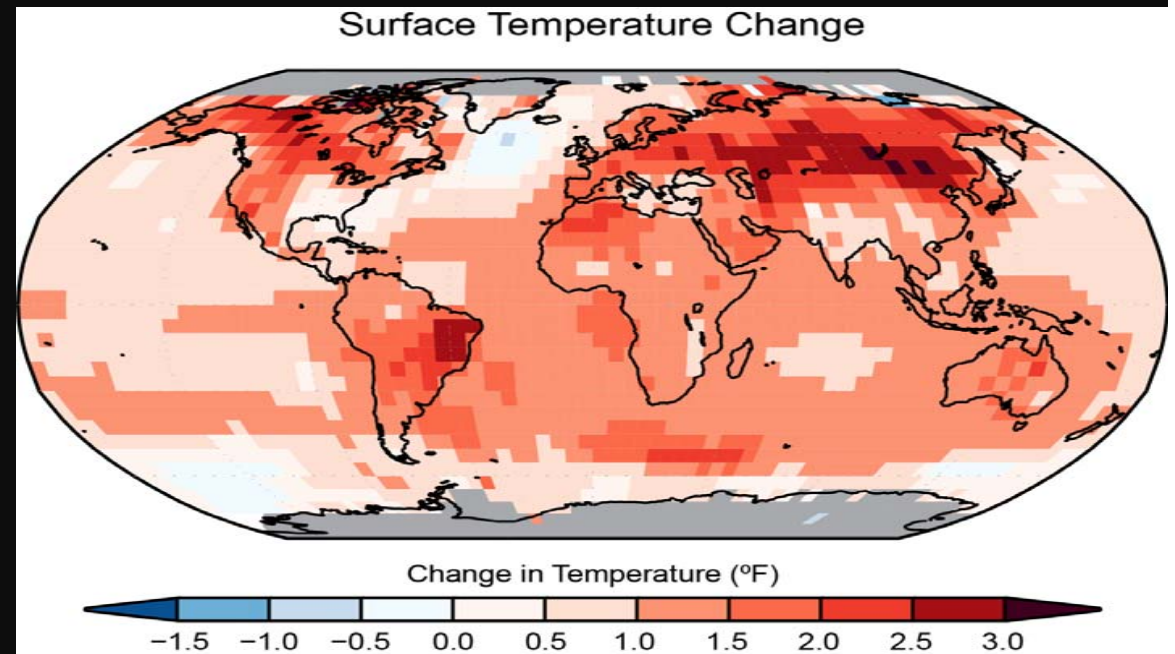
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Our Climate Continues to Change Rapidly

The global long-term warming trend continues.

2016 was the warmest year on record, 2015 is 2nd and far surpassed 2014, which is 3rd. 2017 is 2nd or 3rd warmest year on record.

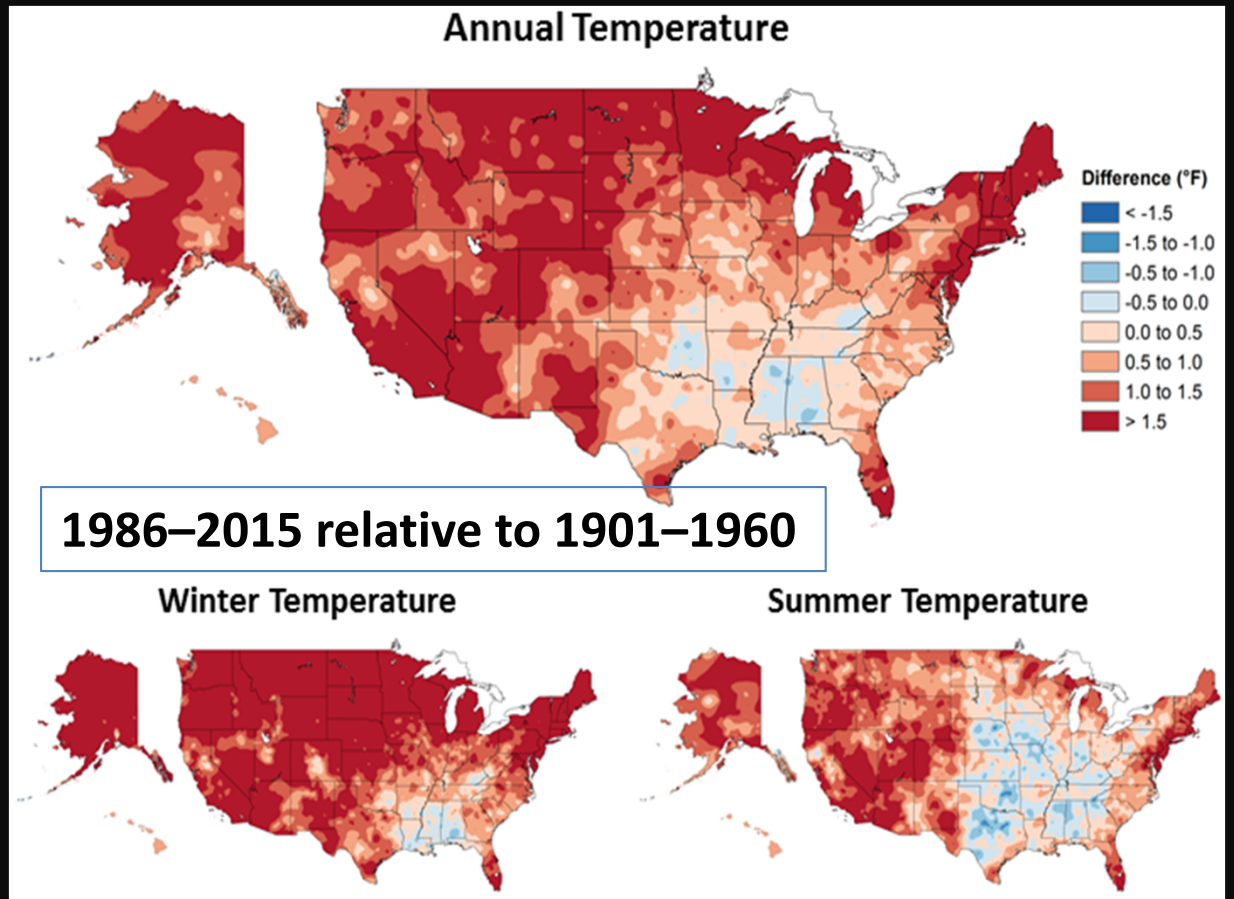
Seventeen of the last 18 years are the warmest years on record.



Temperature trends (change in ° F) for the period 1986-2015 relative to 1901-1960

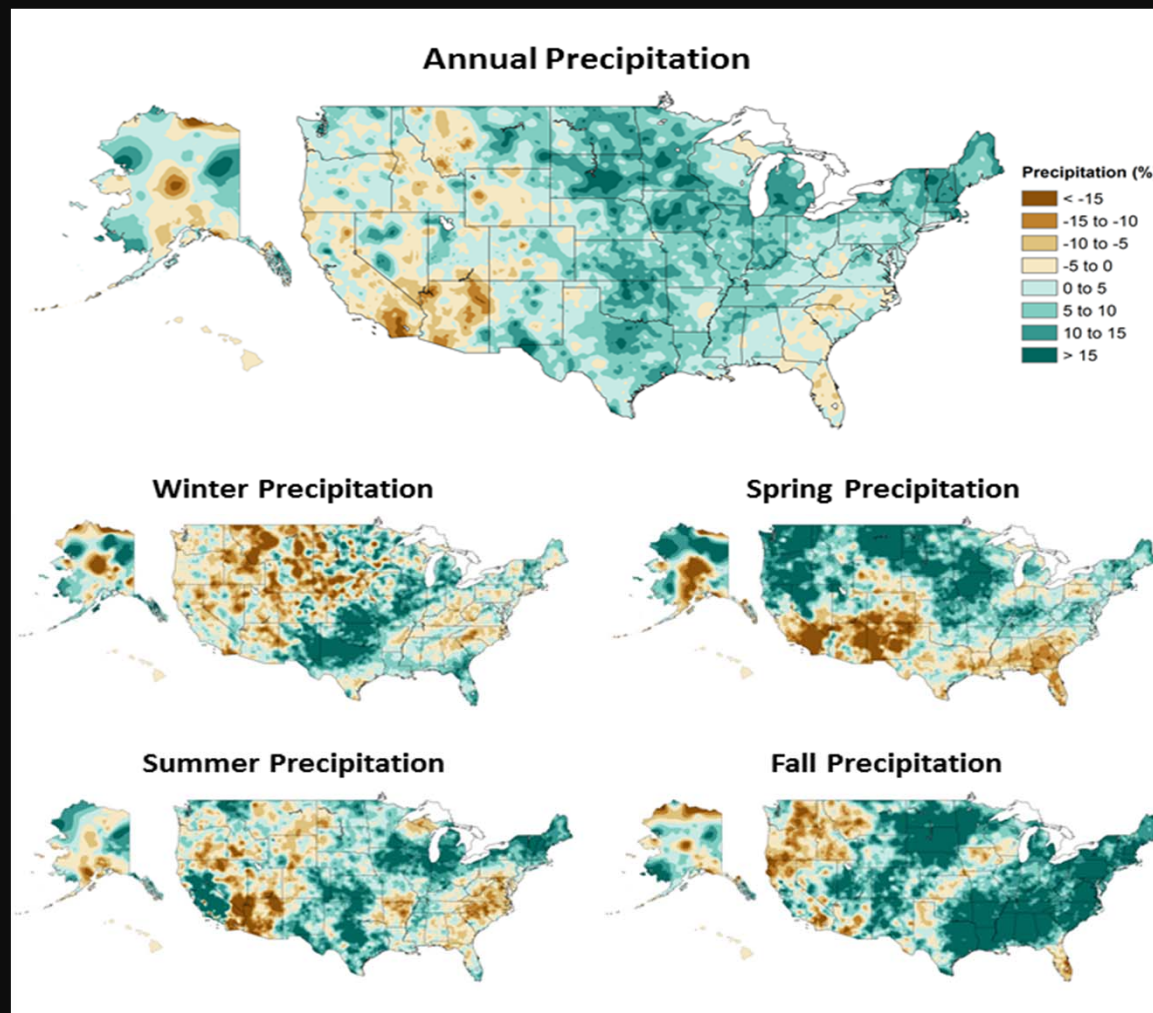
Observed U.S. Temperature Change

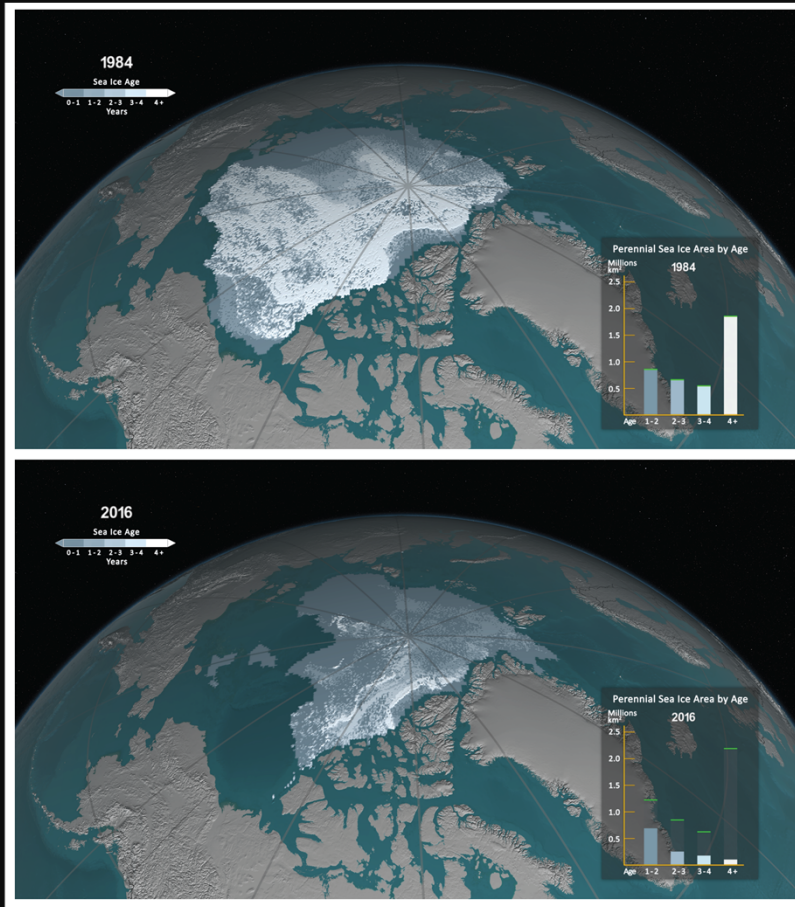
Over contiguous United States, annually-averaged temperature has increased by 1.8 °F from 1895-2016



Observed U.S. Precipitation Change

Annual precipitation has increased overall by 4 % in the United States. It has decreased in much of the West, Southwest, and Southeast.





The Arctic is on the Front Lines of Climate Change

Stark examples of rapid changes:

- Temperature warming at 2x rate of rest of world.
- accelerated melting of multi-year sea ice cover
- mass loss from the Greenland Ice Sheet
- reduced snow cover
- permafrost thawing

We are seeing changing trends in extreme weather and climate events

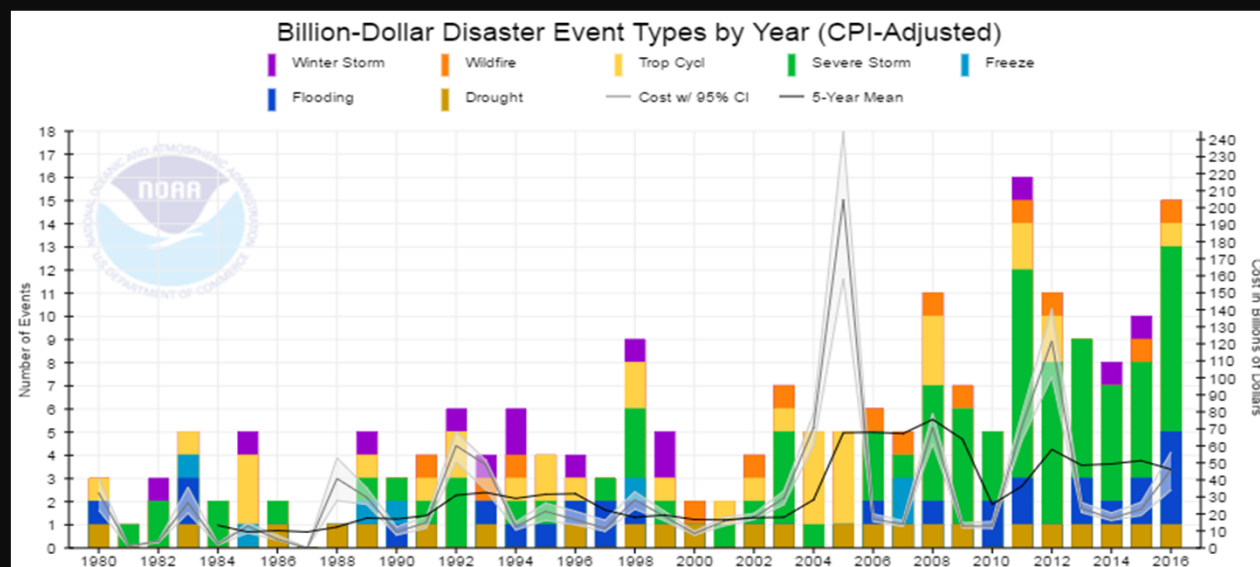


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NOAA analyses show increasing effects of Severe Weather on U.S. economy: Total of \$1.1 trillion since 1980

Every U.S. region has been affected by this growing trend.



**Billion-dollar
weather and
climate disasters
1980-
2016 (accounts
for inflation)**

Similar trend globally

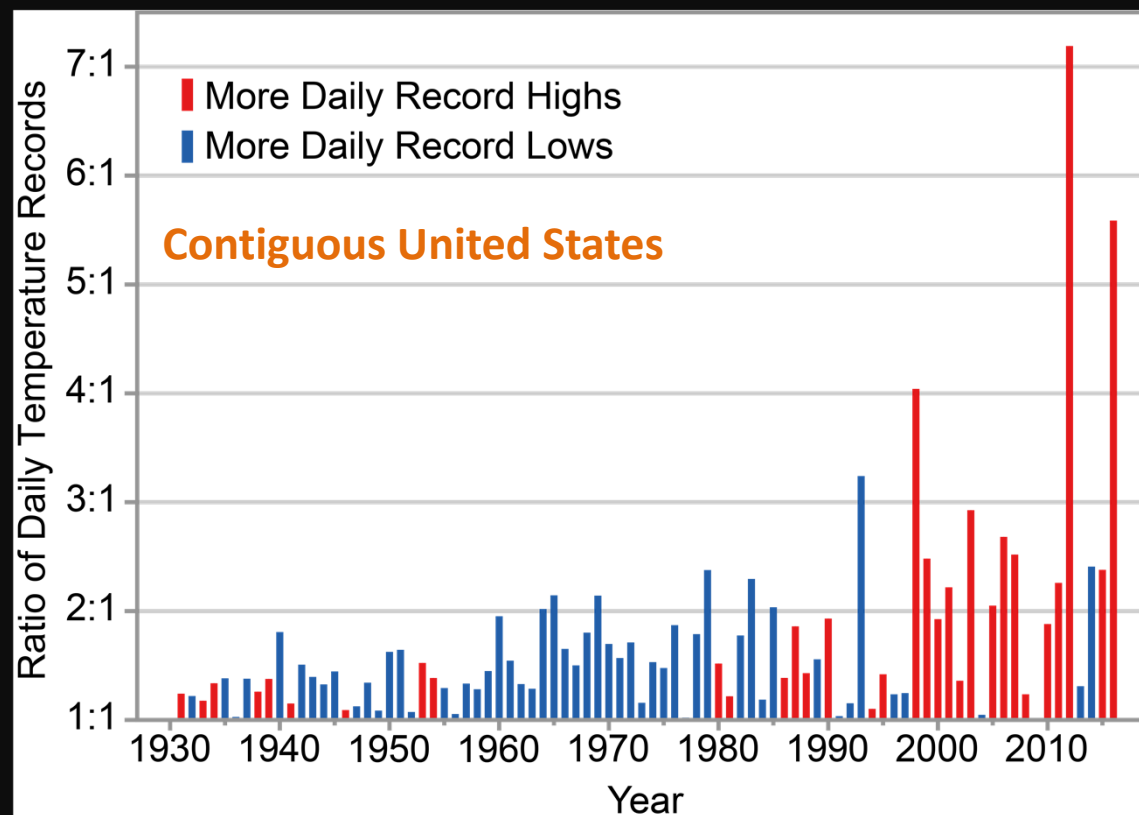
Extreme Events Show Important Trends Globally and in United States

- **Heat waves are increasing**
- **Cold waves are decreasing.**
- **More precipitation coming as larger events.**
- **Increasing risk of floods (esp. in NE, MW).**
- **Increasing intensity of droughts (esp. in SW, SE).**
- **Incidence of large wildfires has increased (West, Alaska)**
- **Increasing intensity of Atlantic hurricanes.**
- **Tornado activity more variable – increase in outbreaks.**
- **Hail may be coming more intense.**

These trends are expected to continue.

Record Warm Daily Temperatures Are Occurring More Often







The frequency and intensity of **extreme heat** events are increasing in most continental regions of the world, including the United States.



Pentad Average

Year	Relative Number of Extreme Events (%)
1900	8
1905	15
1910	0
1915	4
1920	-14
1925	-13
1930	-2
1935	-17
1940	0
1945	16
1950	8
1955	2
1960	0
1965	12
1970	2
1975	9
1980	14
1985	8
1990	25
1995	30
2000	42
2005	28
2010	50

A map of the United States where each state is colored based on the number of states in that region that have a specific number of states. The numbers are: 16 (Alaska), 9 (Washington), 10 (California), -11 (Hawaii), 29 (Montana, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Minnesota, Iowa, Missouri, Arkansas, Louisiana, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York, Vermont, New Hampshire, Maine), 42 (Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York, Vermont, New Hampshire, Maine), 55 (New York, Vermont, New Hampshire, Maine), 27 (Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Arkansas, Louisiana, Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York, Vermont, New Hampshire, Maine), and 12 (Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York, Vermont, New Hampshire, Maine).

<0 0-9 10-19 20-29 30-39 40+

Increasing Trends in Wildfires

- More than 9.2 million U.S. acres burned in 2017.
- The U.S. fire season is about 3 months longer than 40 years ago.
- The average fire is much bigger & hotter than before.
- In Alaska, even the tundra is experiencing wildfires.



Montana Sept 2017

Date

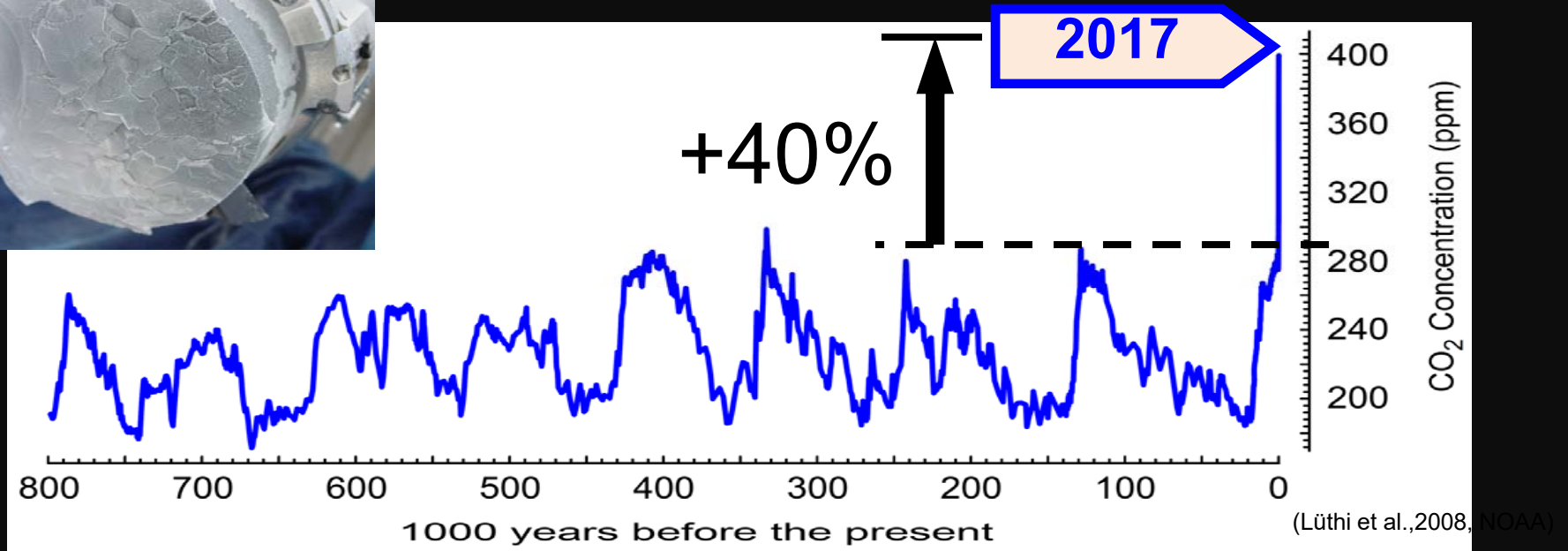
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What is Causing Observed Changes in Climate

- Many lines of evidence demonstrate that human activities are primarily responsible for the observed climate changes.
- There are no credible alternative explanations supported by the extent of the observational evidence.
 - Solar output changes and natural variability can only contribute marginally to observed climate changes.
 - There are no natural cycles in the observational record that can explain the observed changes in climate.

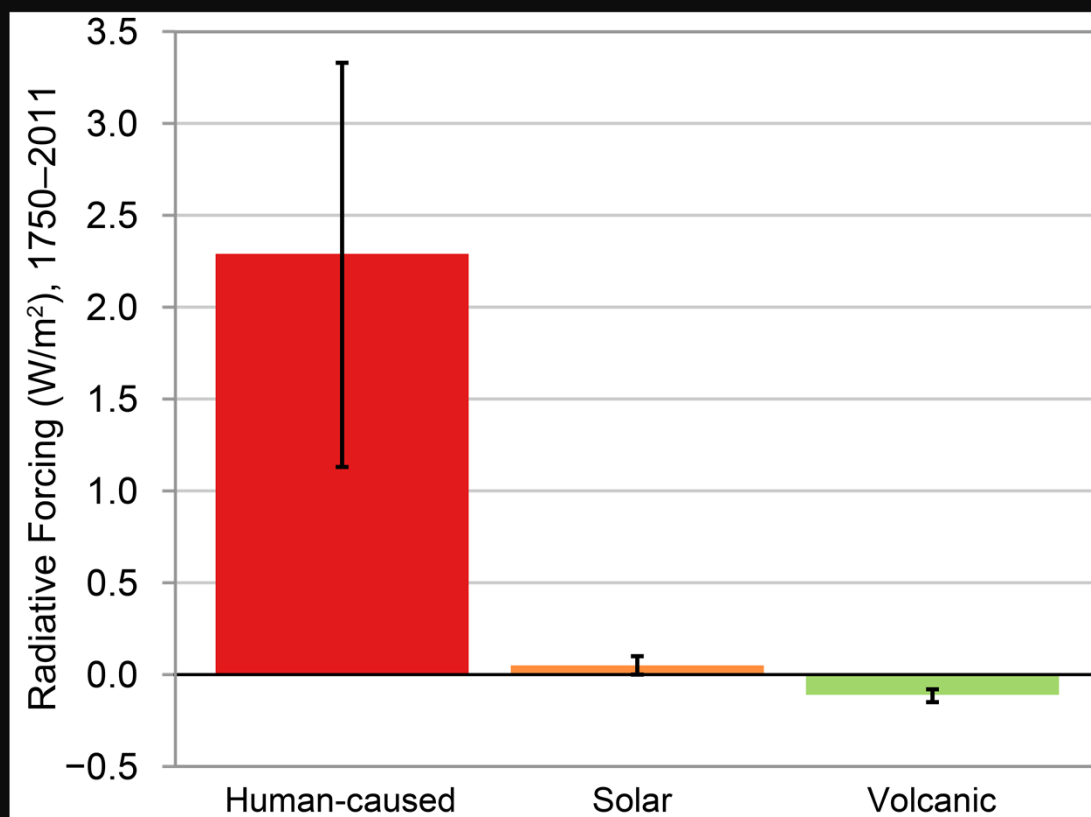


CO₂: Ice Core from Antarctica



The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years.

Human Activities Driving Climate Change

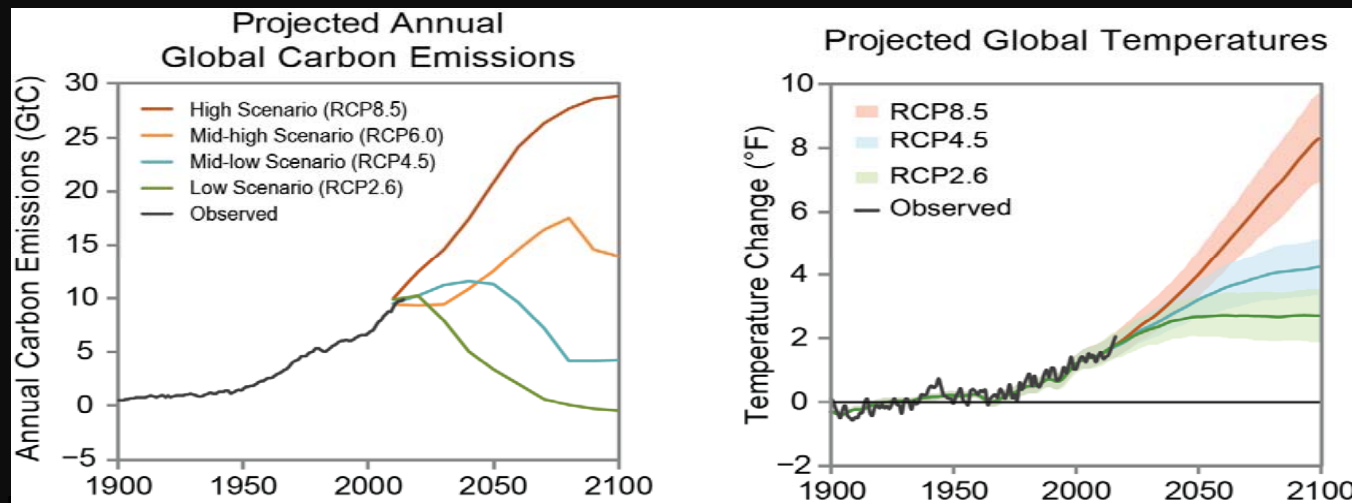


Contributions to radiative forcing on climate since 1750

It is extremely likely (> 95% certainty) that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century.

Climate will Continue to Change

- Globally climate is expected to continue to change over this century and beyond.
- The magnitude of climate change depends primarily on the additional amount of greenhouse gases emitted globally, and on the sensitivity of Earth's climate to those emissions.

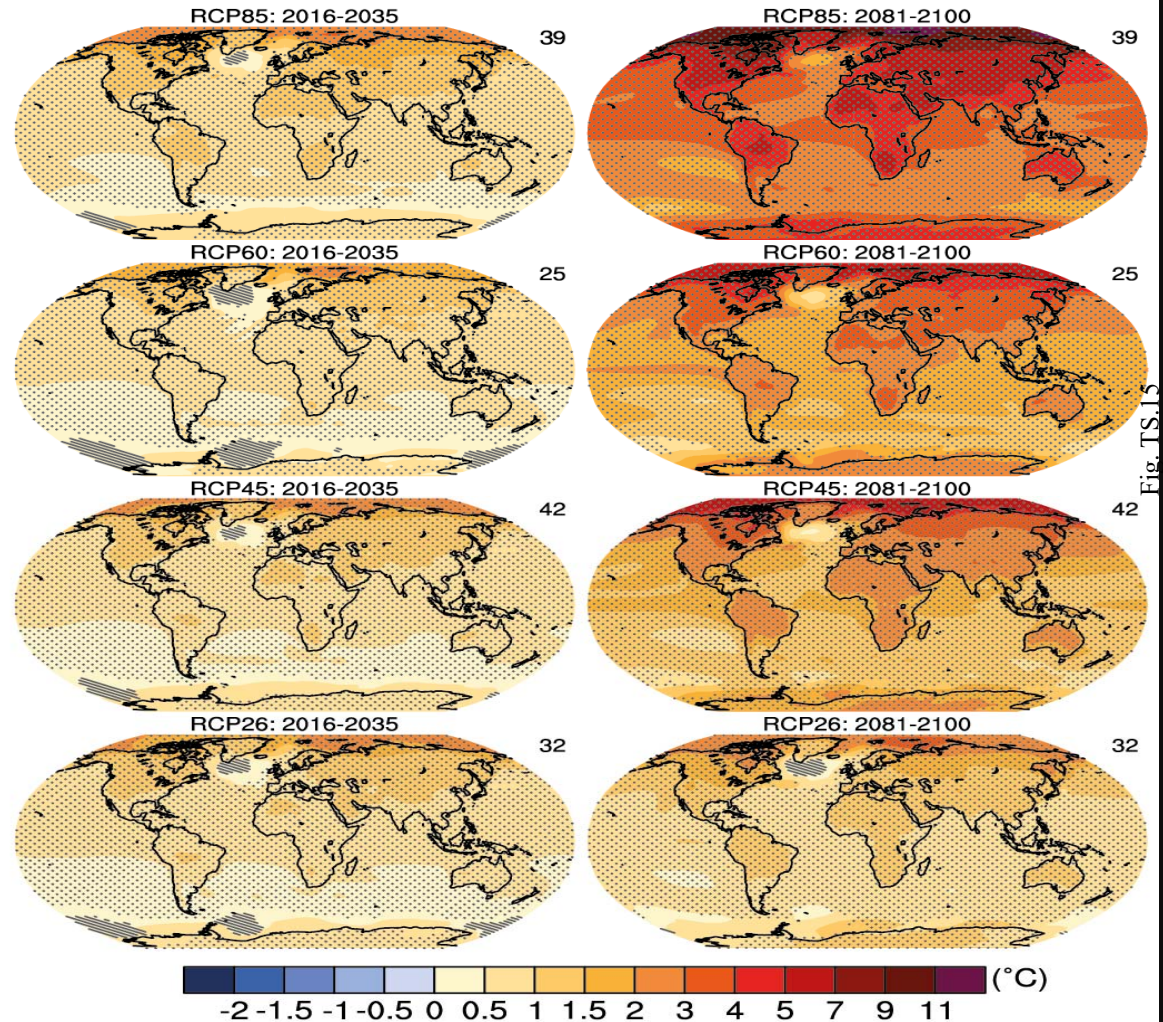


Global Temperature and Other Changes in Climate Depend on Future Emissions

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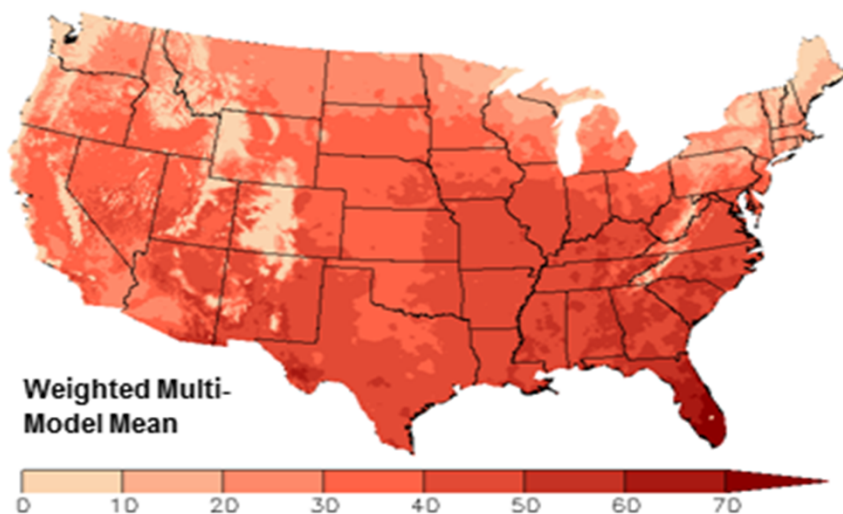
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Annual mean temperature change

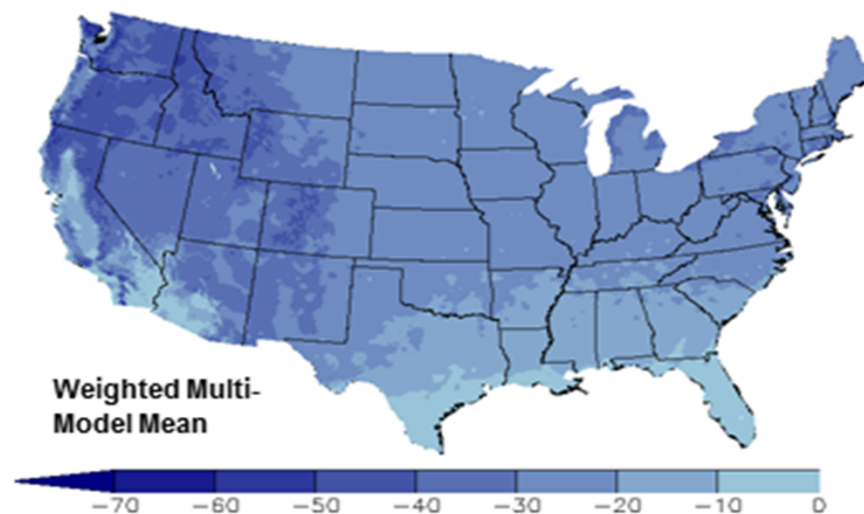


Projected Changes: Number of Days with $T > 90^{\circ}\text{F}$ and $T < 32^{\circ}\text{F}$ for 2036-2065 (relative to 1976-2005) for a High Emissions Scenario

Projected Change in Number of Days Above 90°F
Mid-21st Century, Higher Emissions



Project Change in Number of Days Below 32°F
Mid-21st Century, Higher Emissions



WIDESPREAD OBSERVED IMPACTS

The CHANGING OCEAN

- Sea levels have risen 7-8 inches since 1900
- Sea Level Rise Now Highest Rate in at least 2800 years
- Acidification of the Oceans
- Changing ocean circulation

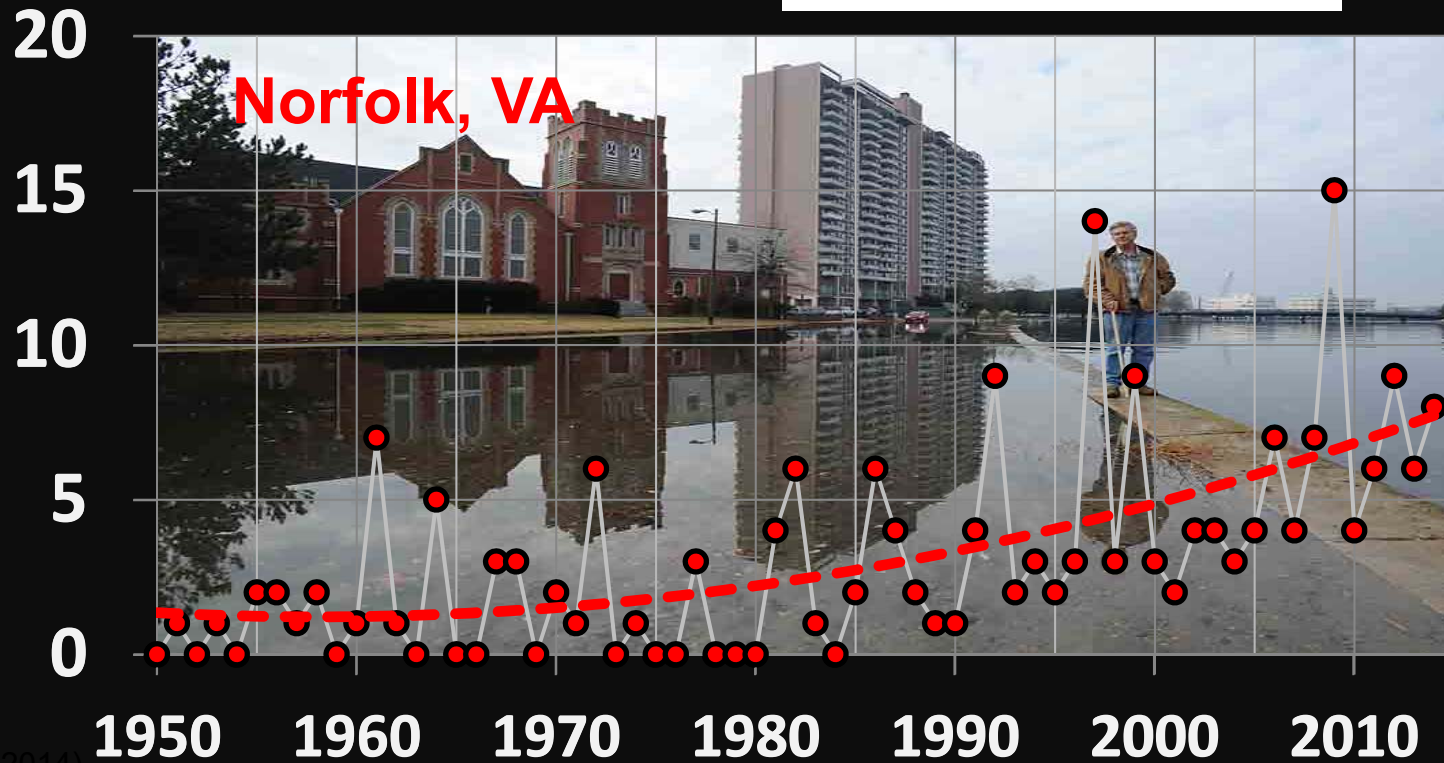
An Accelerating Trend of Tidal Flooding

—●— Historic

--- Quadratic Fit

Minor Flooding
(days/year)

Norfolk, VA

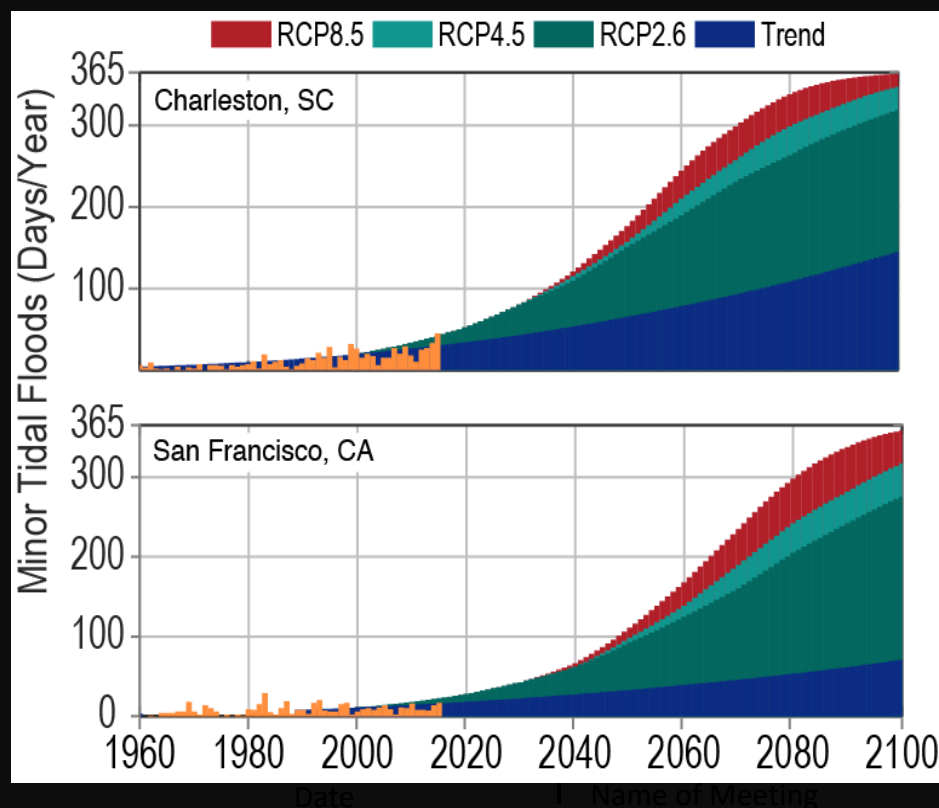


Sweet and Park (2014)

From Sweet et al. (2013)

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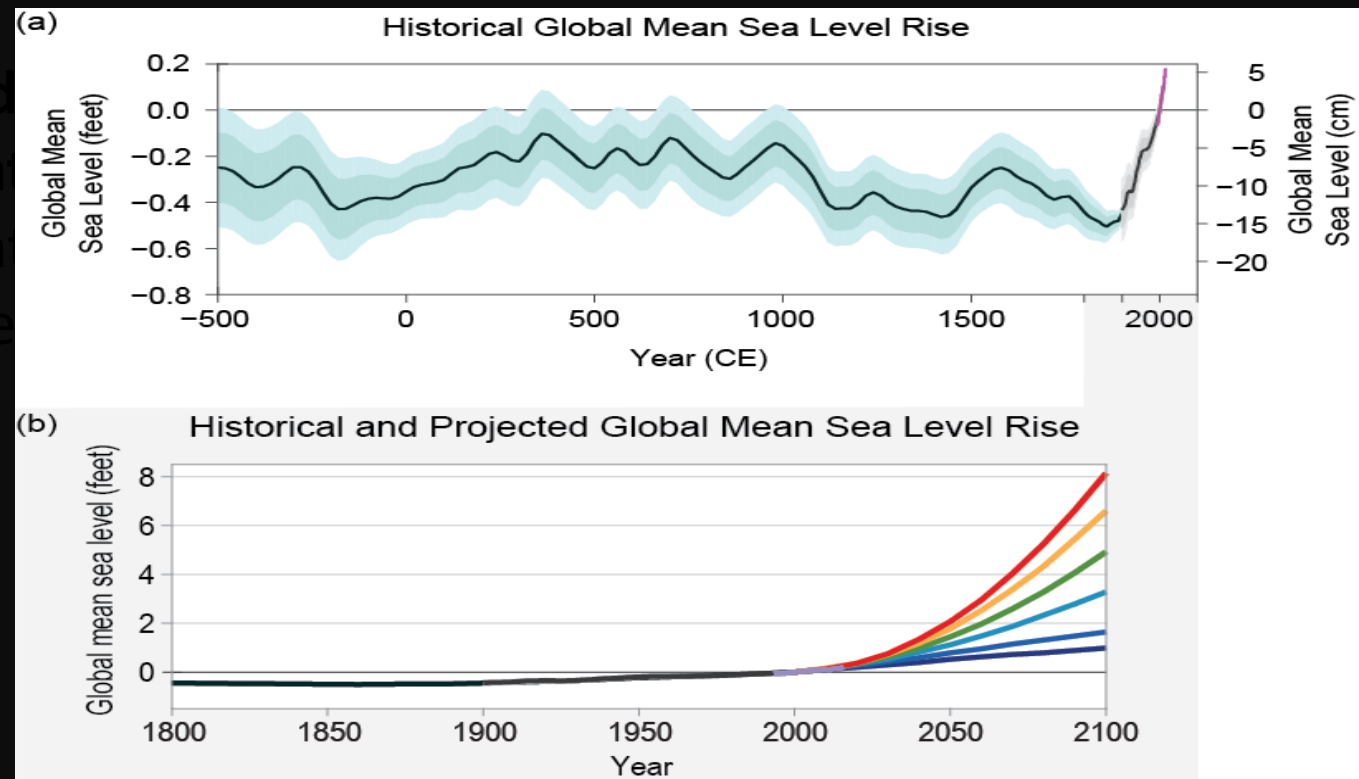
“Nuisance Flooding” is Increasing Across the United States



Past and Projected Changes in Global Sea Level

Best SLR estimate is another 1-4 feet by 2100.

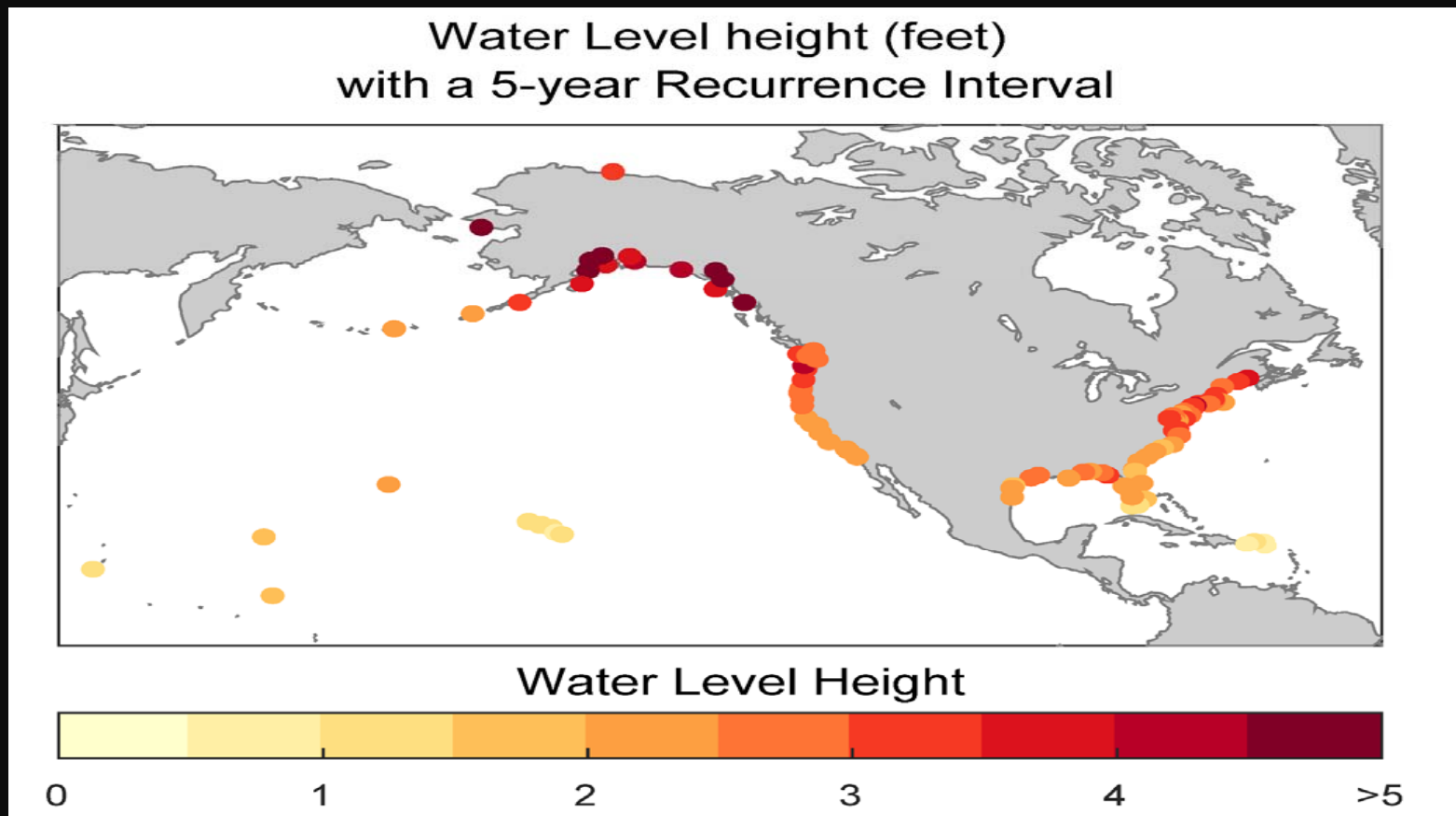
But could be as large as 8 feet.



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Future SLR: Coastal Flooding



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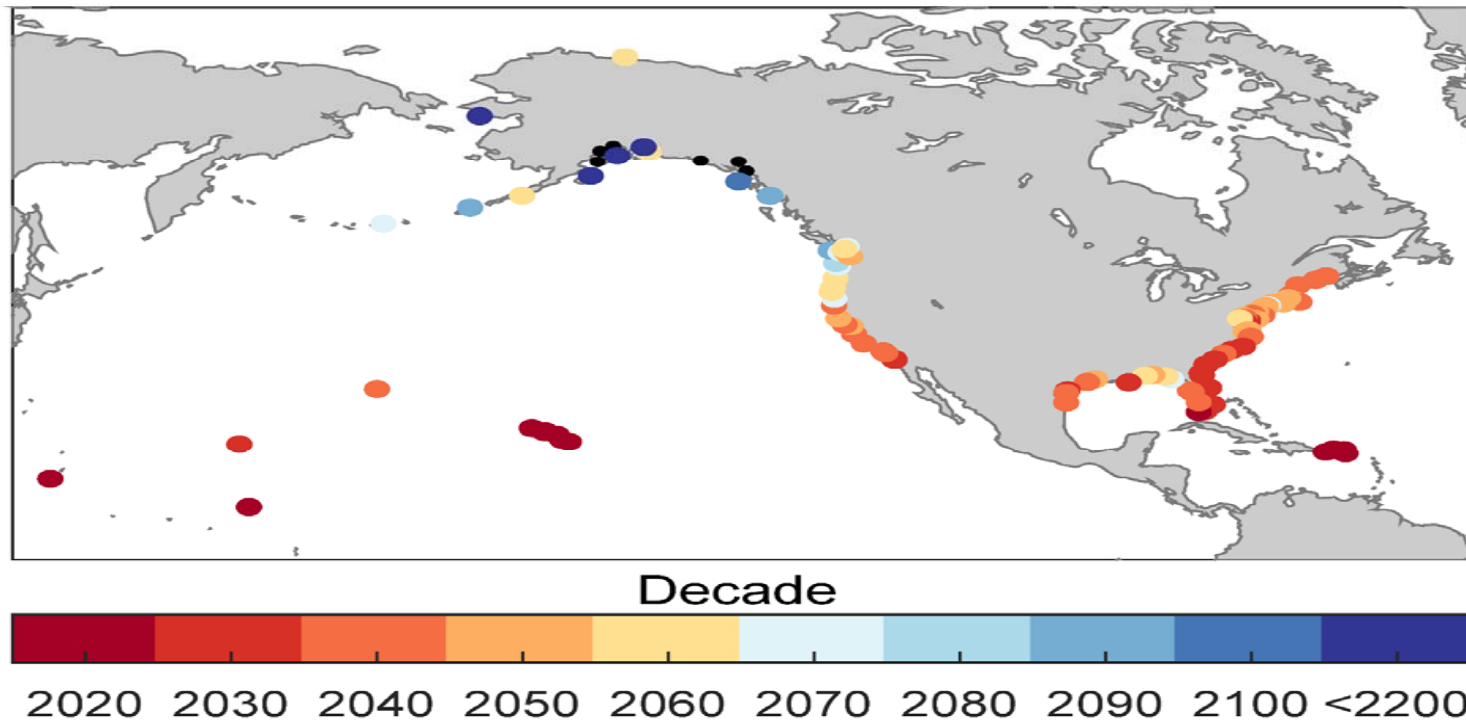
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Sweet et al. (2017): CSSR Chapter 12

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Future SLR: Coastal Flooding

Decade the 5-year Event Becomes a 0.2-year Event
under the Intermediate Scenario



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Sweet et al. (2017): CSSR Chapter 12

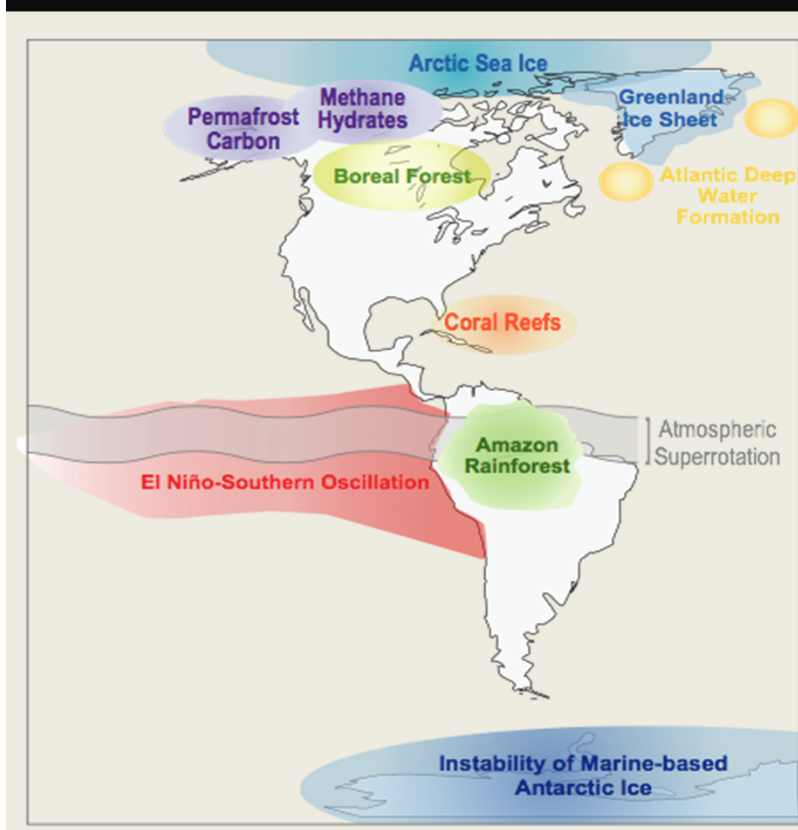
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Future SLR: Coastal Flooding

With only about 1.1 foot of additional local SLR, coastal flooding with moderate impacts that today trigger **NOAA coastal flood warnings** will increase 25-fold at majority of locations.

Under the Intermediate Scenario, this occurs by about 2040 (+/- 5 years) on average.

Potential Surprises: There is a Significant Possibility for Unanticipated Changes



- **Tipping elements** within the Earth system exhibit **critical thresholds**, sometimes called “**tipping points**”.
- They have the potential to enter into self-amplifying cycles that commit them to shifting from their current state into a new state
- State shifts can occur abruptly; or they may be locked in rapidly but take decades or centuries to play out