

Global Climate Change and the Implications for Oklahoma

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STATEMENT ON CLIMATE CHANGE AND ITS IMPLICATIONS FOR OKLAHOMA

OKLAHOMA CLIMATOLOGICAL SURVEY

"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."
— the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC).

That statement reflects the essence of a vast amount of observational data and climate research: the earth's climate has warmed on average during the last 100 years and will continue to warm through the 21st century. Further, ample evidence from observational data and climate modeling studies indicates that this global-scale warming is not attributable to natural variability. The Oklahoma Climatological Survey (OCS) has been mandated by the Oklahoma legislature to provide climate information and expertise which could be of value to the public, as well as to state policy- and decision-makers. In accordance with that directive, OCS has conducted a review of the current assessments of climate change research and concludes the following to be true:

- The earth's climate has warmed during the last 100 years; future warming is expected to continue.
- The earth's climate will continue to warm for the foreseeable future.
- Much of the global average temperature increases over the last 50 years can be attributed to human activities, particularly increasing greenhouse gases in the atmosphere.
- Oklahoma will be impacted.

Across the globe, a warming climate will be beneficial to some and detrimental to others. Anticipating how this climatic shift will impact Oklahoma is of vital importance to state decision-makers. The greatest impacts will be the exposure of Oklahoma's growing population and economy to water stress. Oklahoma's growing access to fresh water. Thus, due diligence in protecting our water resources and adapting to future climate variability is paramount if we are to maintain and improve the quality of life and the economy of Oklahoma.

The Science of Global Climate Change

The earth's climate is always changing. Evidence such as tree ring and ice core studies indicates large and sometimes abrupt climate changes have occurred in the earth's distant past, lasting centuries to millennia. These climate swings are attributed to natural variations such as changes in the output of the sun or shifts in the earth's orbit. Oklahoma has exhibited distinct climate periods attributable to natural variability in the last 100 years, from the decadal-scale droughts of the 1910s, 1930s and 1950s to an extended period of abundant precipitation during the 1980s and 1990s. Mounting evidence continues to indicate, however, that human activities have begun to impact the earth's climate through the release of greenhouse gases. Ice core studies show carbon dioxide and methane are at their greatest levels within the last 650,000 years. Due to the extended

Following climate change associated impacts to be projected range of warming remainder of the 21st century:

- Heat waves will increase.
- Droughts will increase.
- Storms will move poleward.
- Spring arrives earlier.
- Winter which leads to a longer growing season.
- Orchard crops leave the ground and bloom earlier.
- Specially during the risk of heavy rainfall events.

Even if climate does not evolve as expected, these steps will yield long-term benefits to Oklahoma's society and economy through reduced losses to existing climate and weather threats and cost-savings through reduced energy use. If climate does evolve as expected, Oklahoma will be better positioned to adapt to those changes without rapid social upheaval. Furthermore, building resilience to climate and weather events will help position Oklahoma at a relative advantage to neighboring states, especially in attracting businesses that are dependent upon a continuous water supply.

This statement is the first in a series issued by OCS which delineates the impacts, both beneficial and detrimental, of a warming climate system on the economy of Oklahoma and the quality of life for Oklahomans. Future statements will illuminate possible impacts to specific industries, such as water management and agriculture.

Oklahoma Statewide Winter Temperature History 1896-2006

Climate Change Impacts

The effect on the frequency of extreme temperatures in a warming climate.

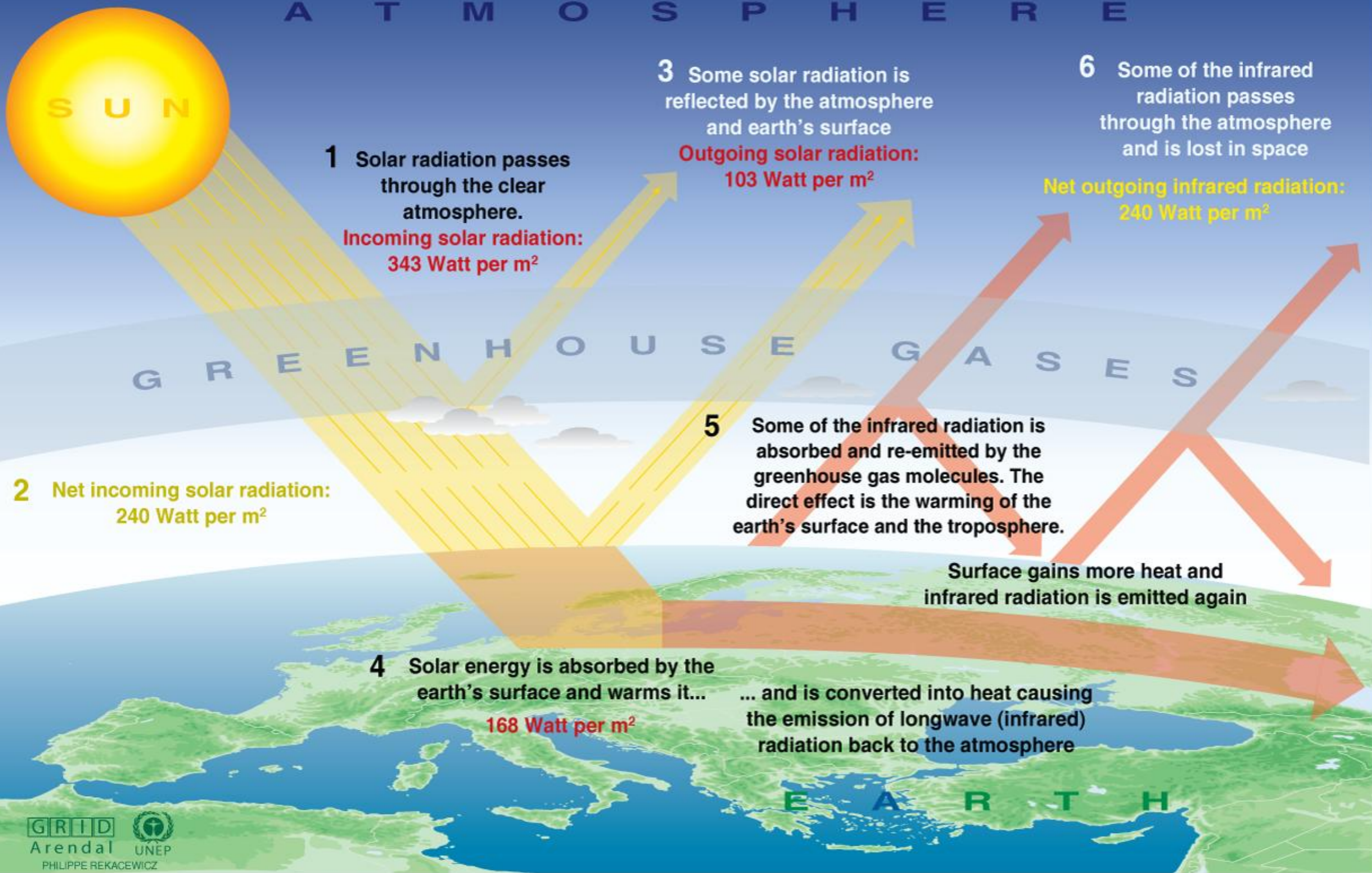
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OCS LEGISLATIVE MANDATES

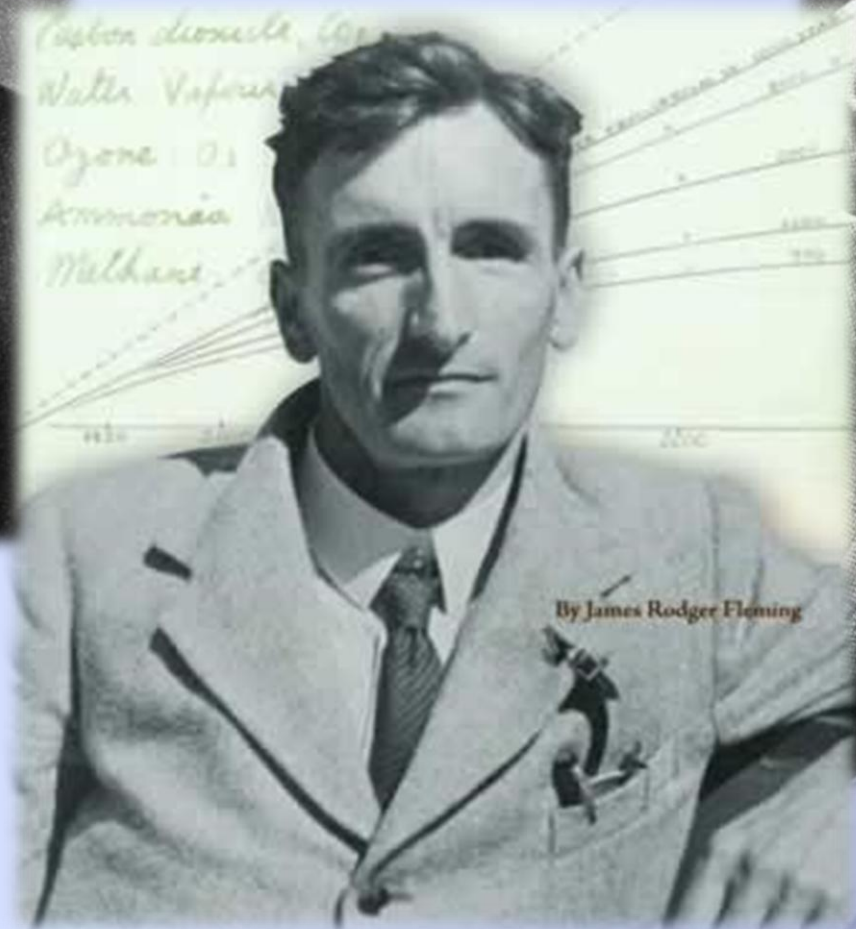
- **Conduct and report on studies of climate and weather phenomena of significant socio-economic importance to the state**
- **Evaluate the significance of natural and man-made ... changes ... and to report this information to those agencies and organizations in the state who are likely to be affected by such changes or modifications**

A Quick Background on Climate Change

The Greenhouse effect



Global Warming Is Not A New Theory



It's the confirmation of a prediction

- **1890s** – Nobel Prize winner Svante Arrhenius theorized about a warming climate due to the burning of coal.
- **1938** – Guy Stewart Callendar asserted that warming of the 19th century forward was due to a rise in CO₂.
- **1965** – Roger Revelle: “By the year 2000, the increase in atmospheric CO₂ ...may be sufficient to produce measurable and perhaps marked change in climate”

IPCC: Intergovernmental Panel on Climate Change

- Established in 1988 by United Nations
- Not to do research, but to synthesize and assess it
- Most recent report (Fourth Assessment Report) scientific experts from > **130** countries, > **800** authors, > **2500** peer reviewers
- Historically unprecedented: scale, scope, ambition.
- Summary approved by consensus (including representatives of the Bush Administration) at meetings of the IPCC.
- Next report will be released 2013-14

Broad Consensus: An Example

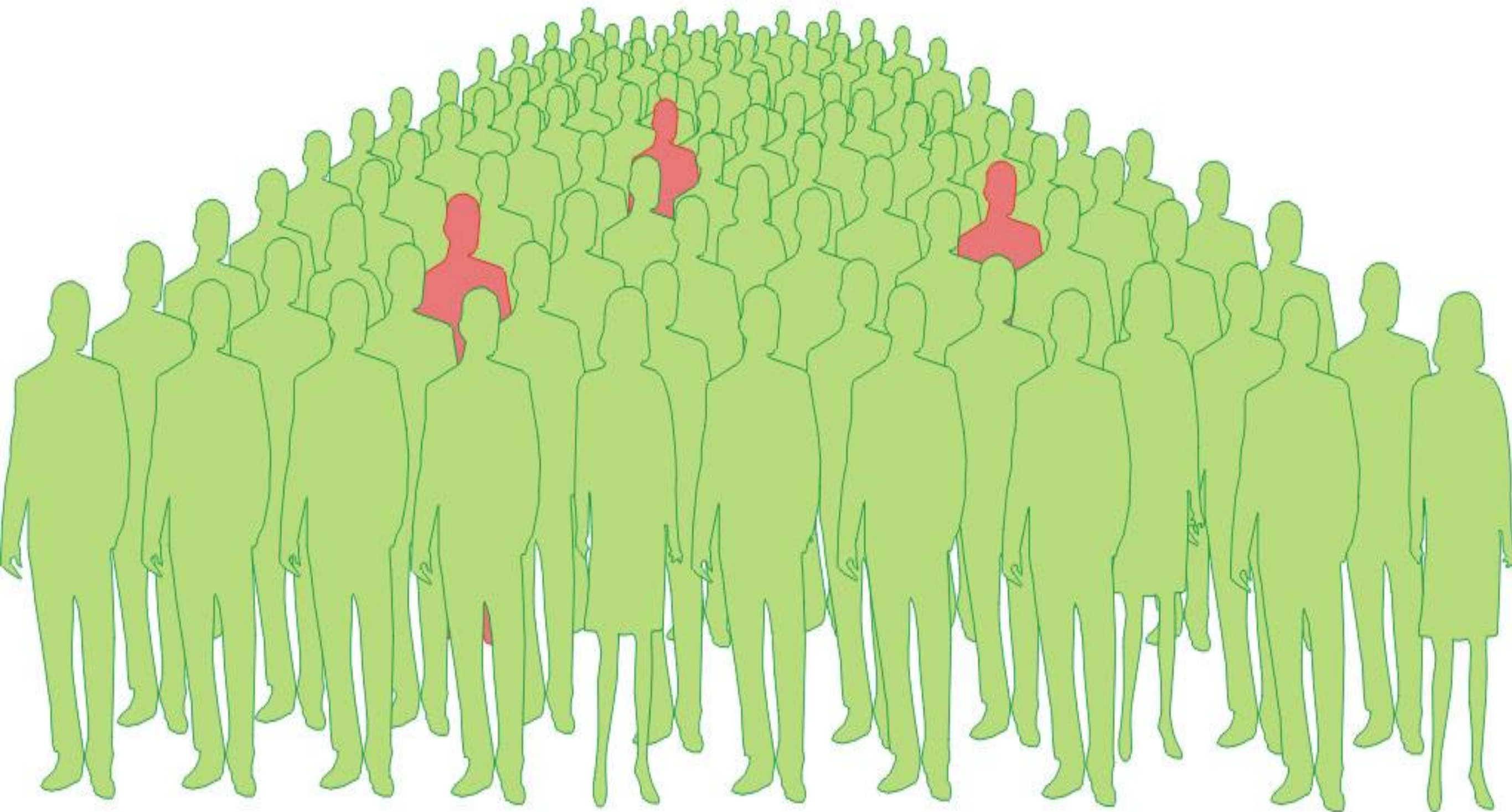
Letter to U.S. Senators, Oct. 11, 2009:

- **“Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver.”**
- **“These conclusions are based on multiple independent lines of evidence, and contrary assertions are inconsistent with an objective assessment of the vast body of peer-reviewed science.”**

- **American Association for the Advancement of Science**
- **American Chemical Society**
- **American Geophysical Union**
- **American Institute of Biological Sciences**
- **American Meteorological Society**
- **American Society of Agronomy**
- **American Society of Plant Biologists**
- **American Statistical Association**
- **Association of Ecosystem Research Centers**

- **Botanical Society of America**
- **Crop Science Society of America**
- **Ecological Society of America**
- **Natural Science Collections**
- **Alliance Organization of Biological Field Stations**
- **Society for Industrial and Applied Mathematics**
- **Society of Systematic Biologists**
- **Soil Science Society of America**
- **University Corporation for Atmospheric Research**

97 out of 100 climate experts think humans are changing global temperature



The following represents the VAST MAJORITY of scientific expertise on global climate change

Important to remember:

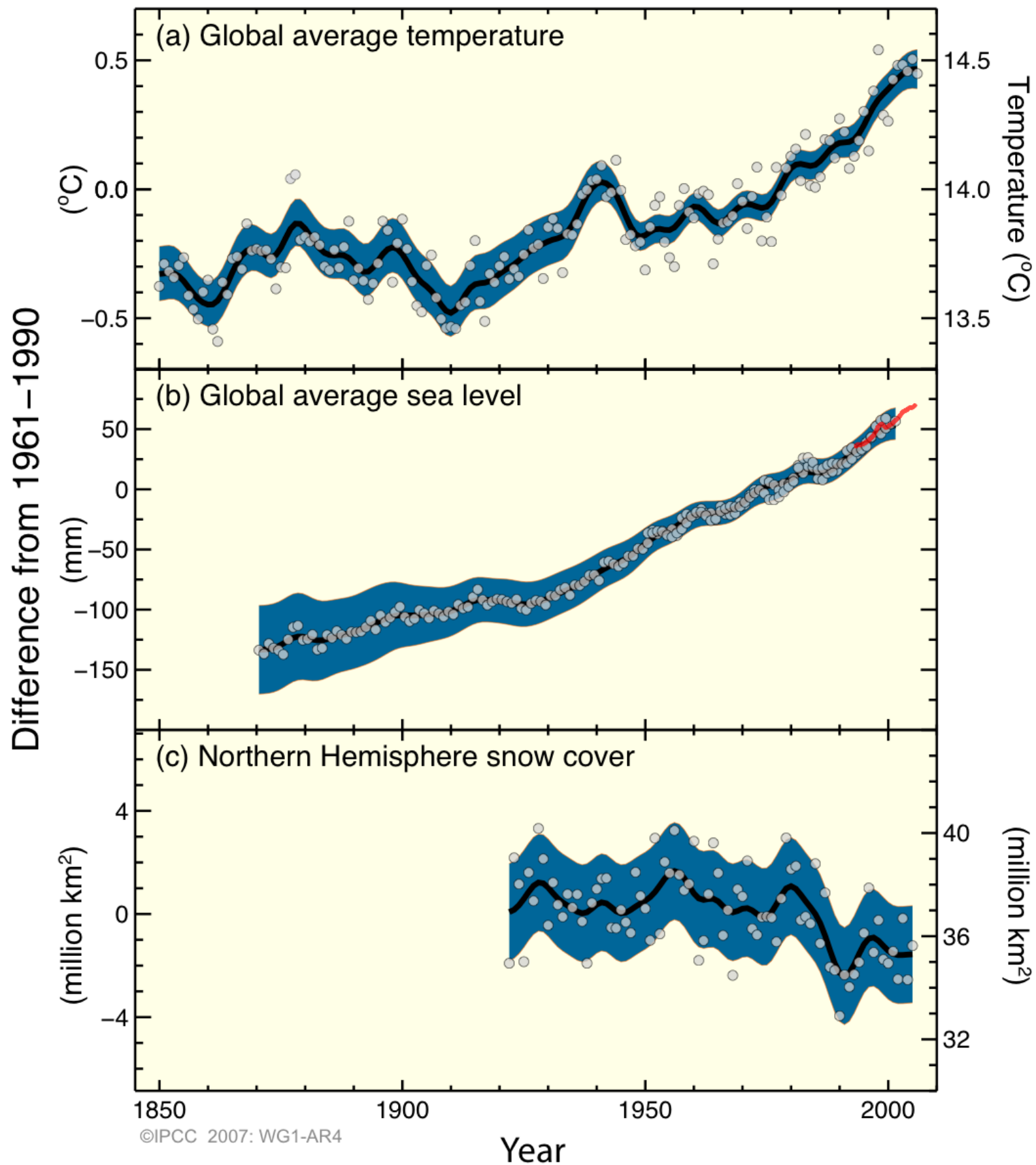
- **Think GLOBALLY and DECADEALLY**
- **Climate is in flux**
- **Temperature projections represent a RANGE of possible warming, dependent upon societal responses**
- **Uncertainty remains, especially in regional precipitation patterns**
- **Natural variability will still occur (i.e. cold years, wet and dry years)**

Oklahoma is NOT the canary in the coal mine!



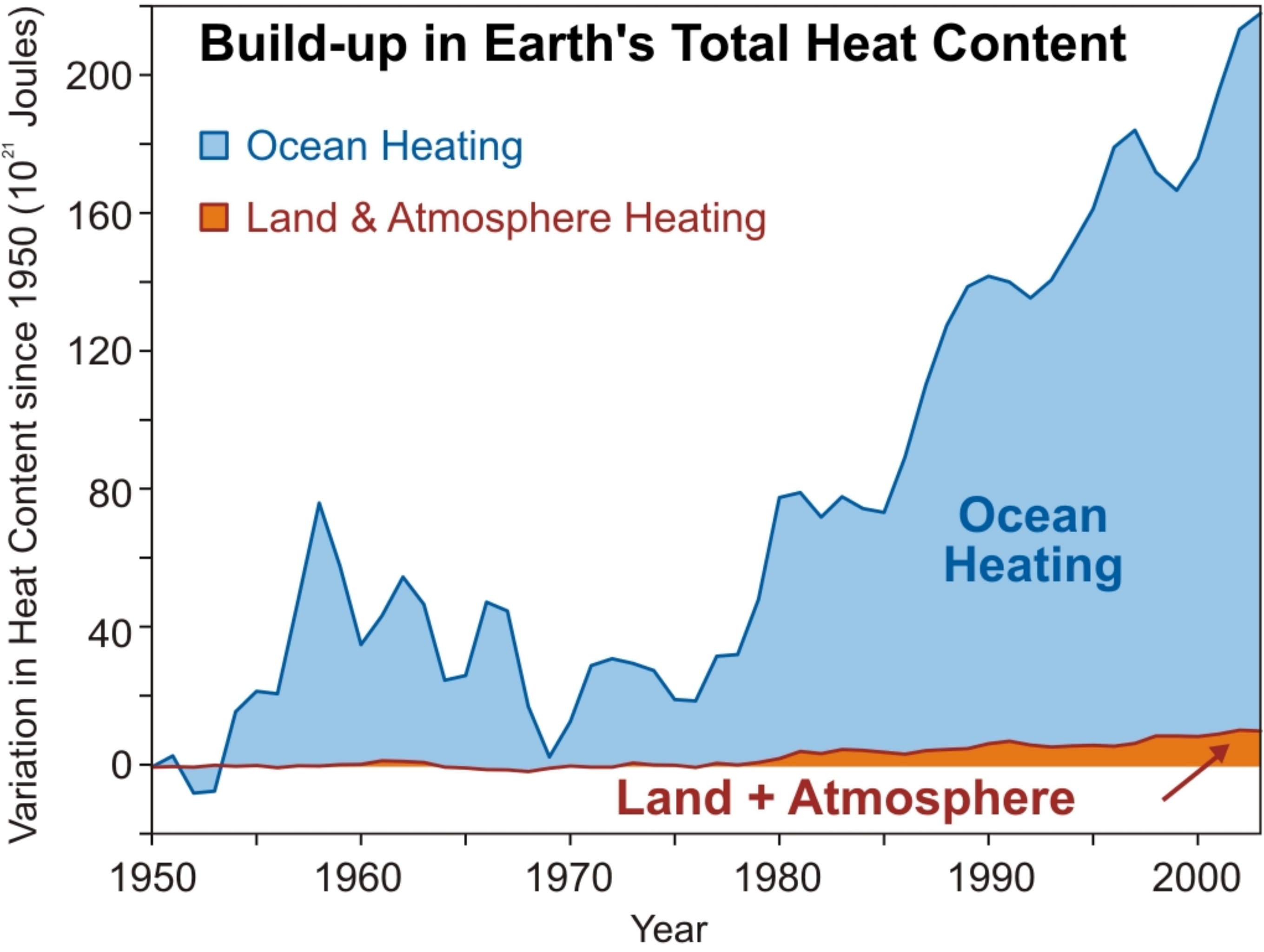
**Observational Evidence:
the Globe has warmed**

Changes in Temperature, Sea Level and Northern Hemisphere Snow Cover



‘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.’

Build-up in Earth's Total Heat Content



■ Ocean Heating

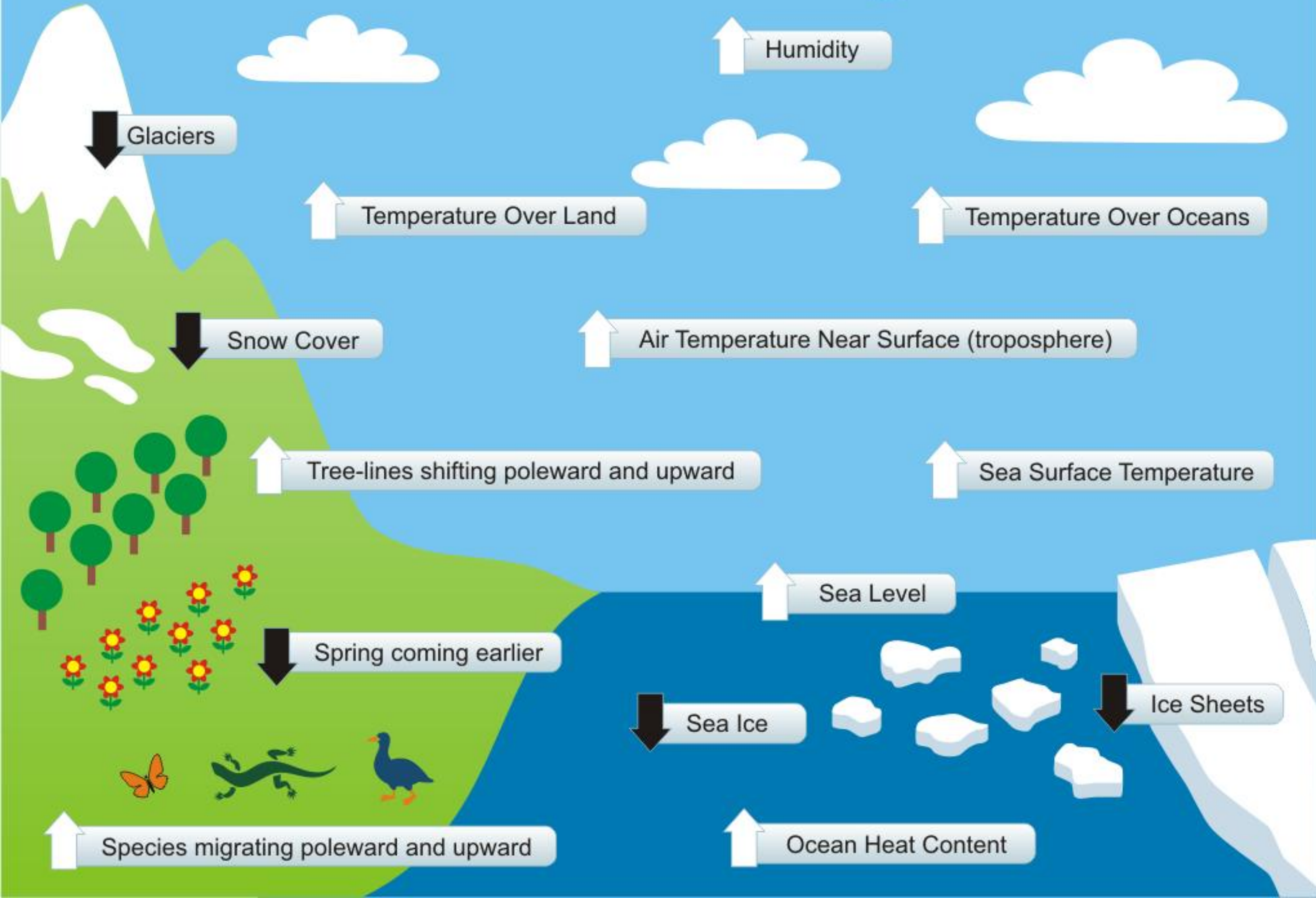
■ Land & Atmosphere Heating

Ocean Heating

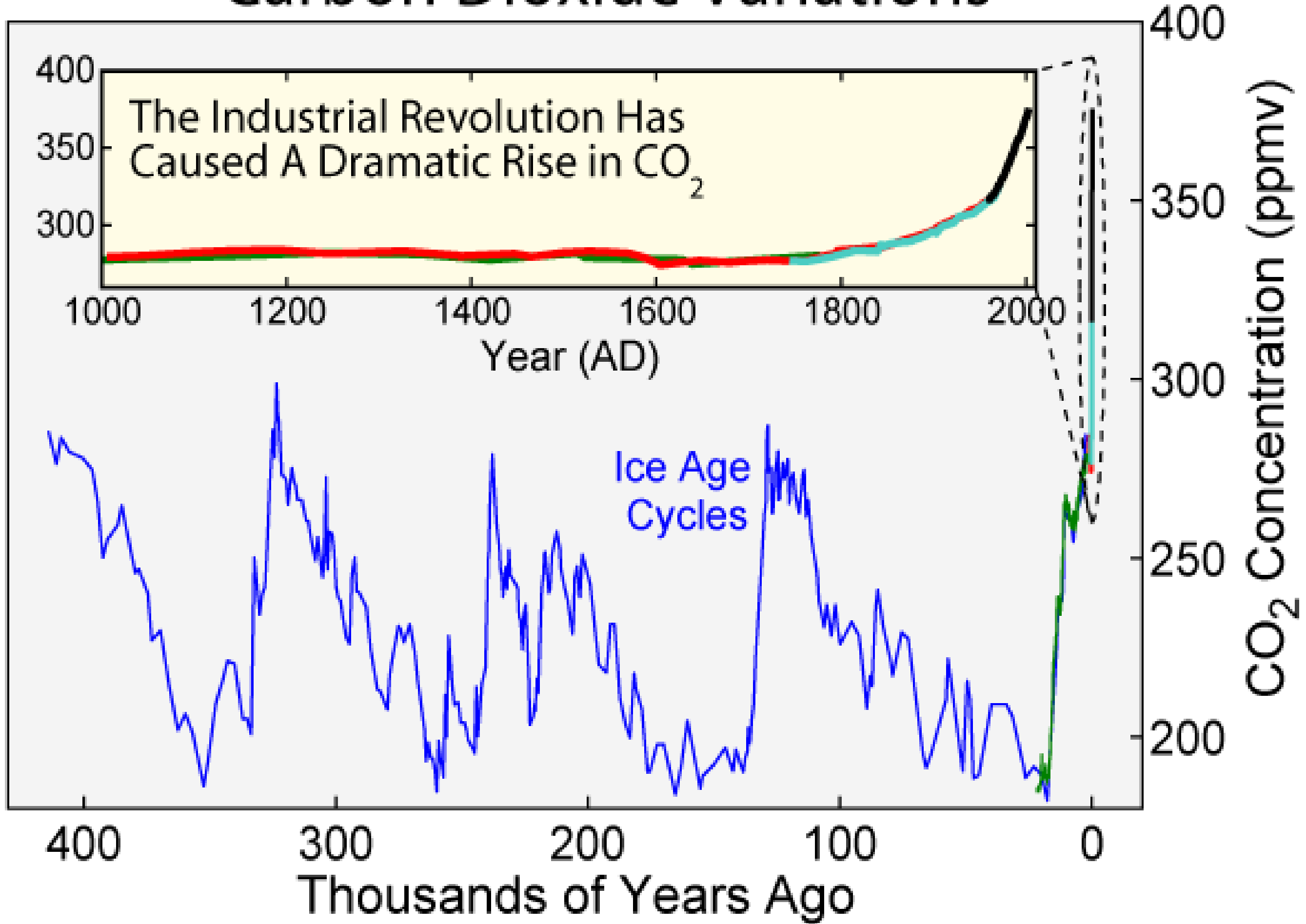
Land + Atmosphere

**Mother Nature has her
own thermometers**

Indicators of a Warming World

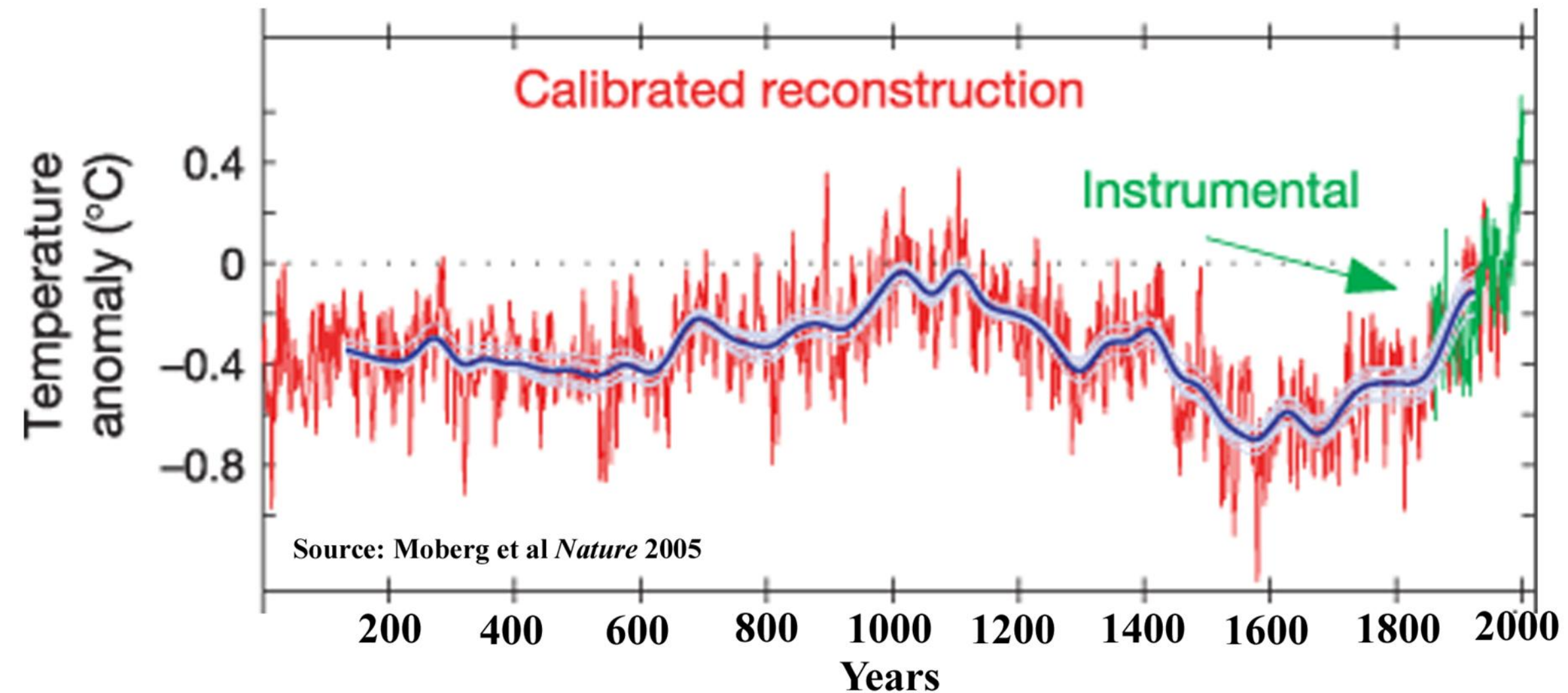


Carbon Dioxide Variations

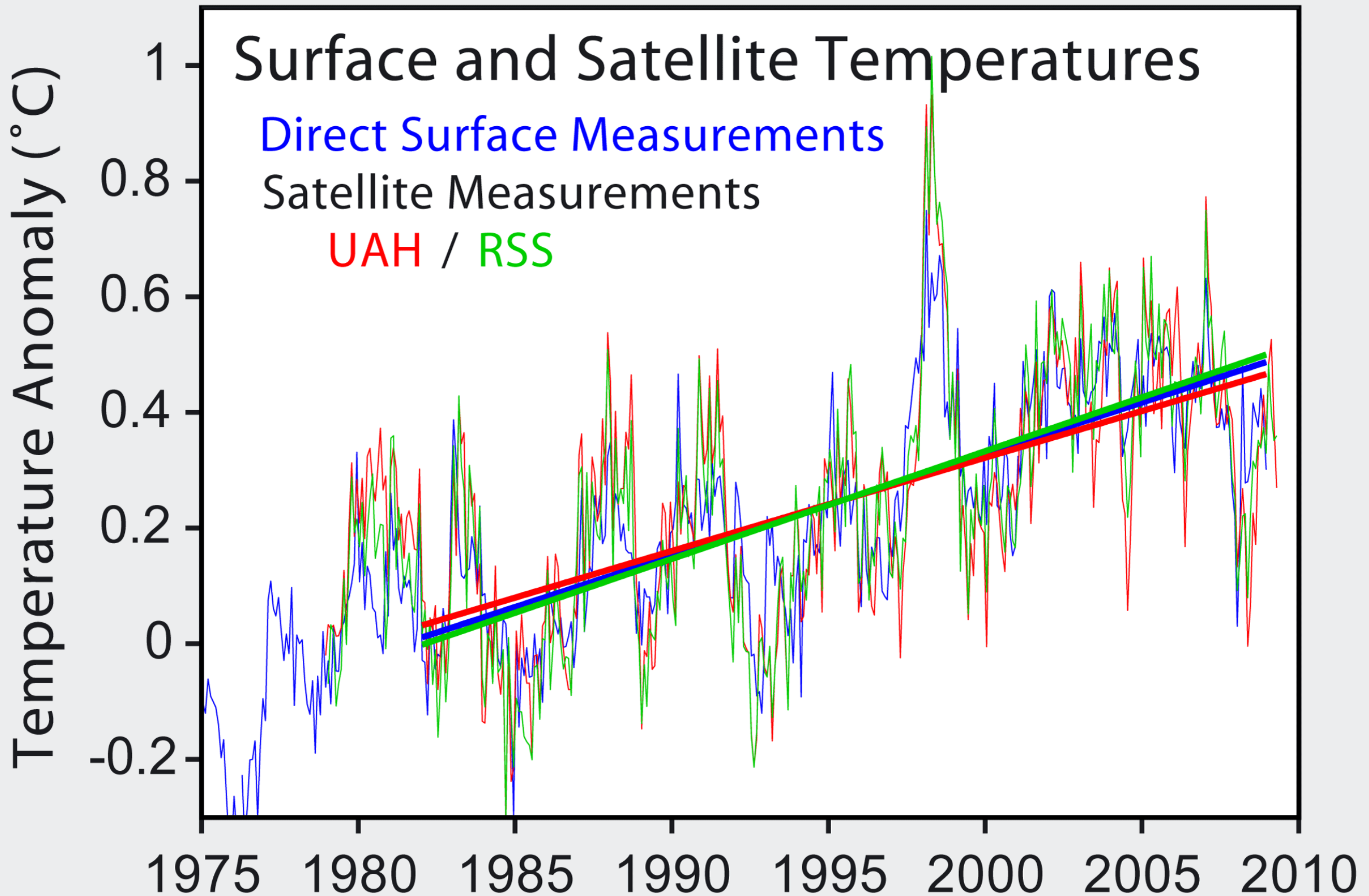


The warmth of the last half century is unusual in at least the previous 1300 years

2000 Year Northern Hemisphere Reconstruction of Surface Air Temperatures



Think DECADALLY

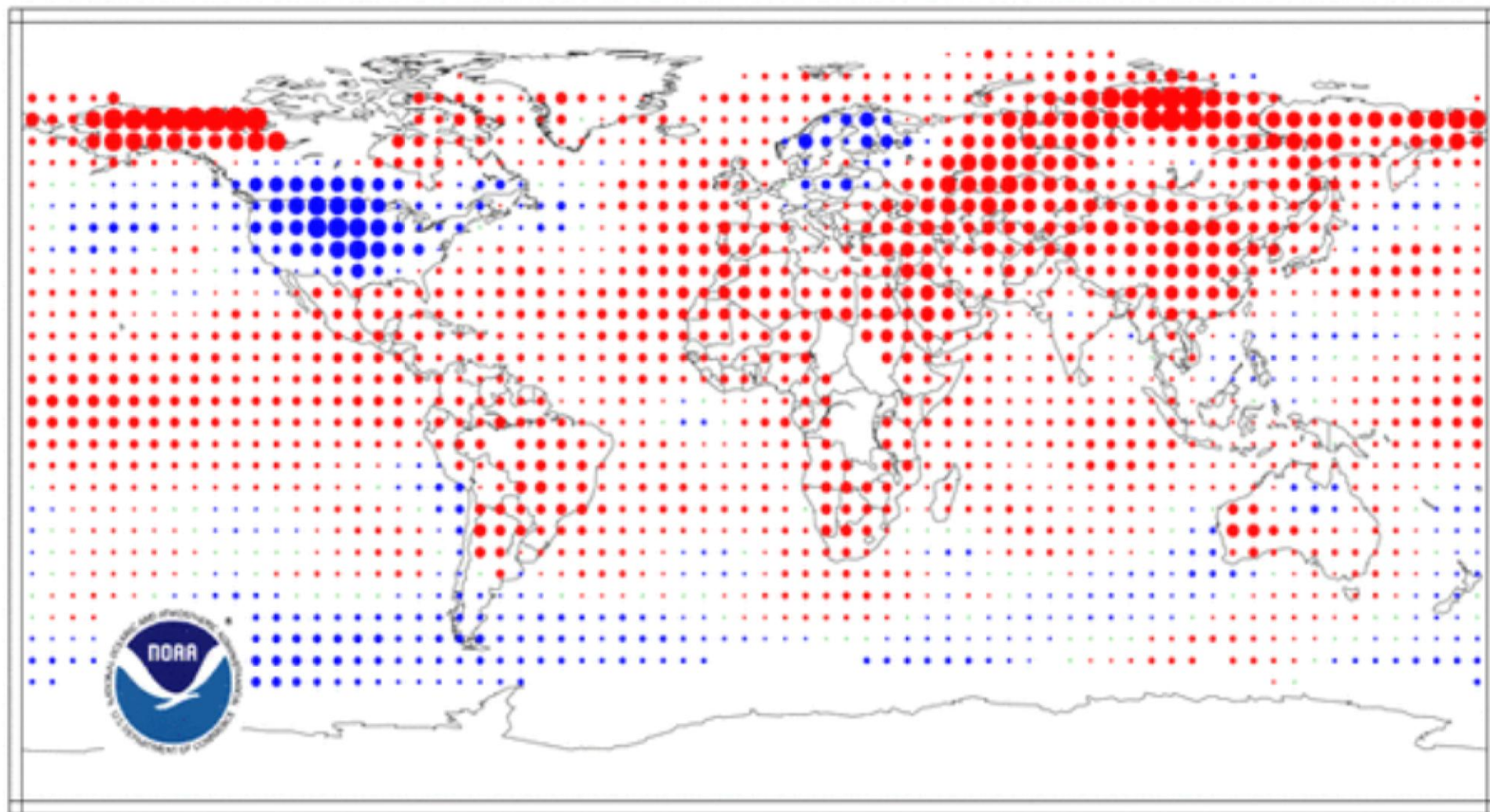


Think GLOBALLY

Temperature Anomalies October 2009

(with respect to a 1971-2000 base period)

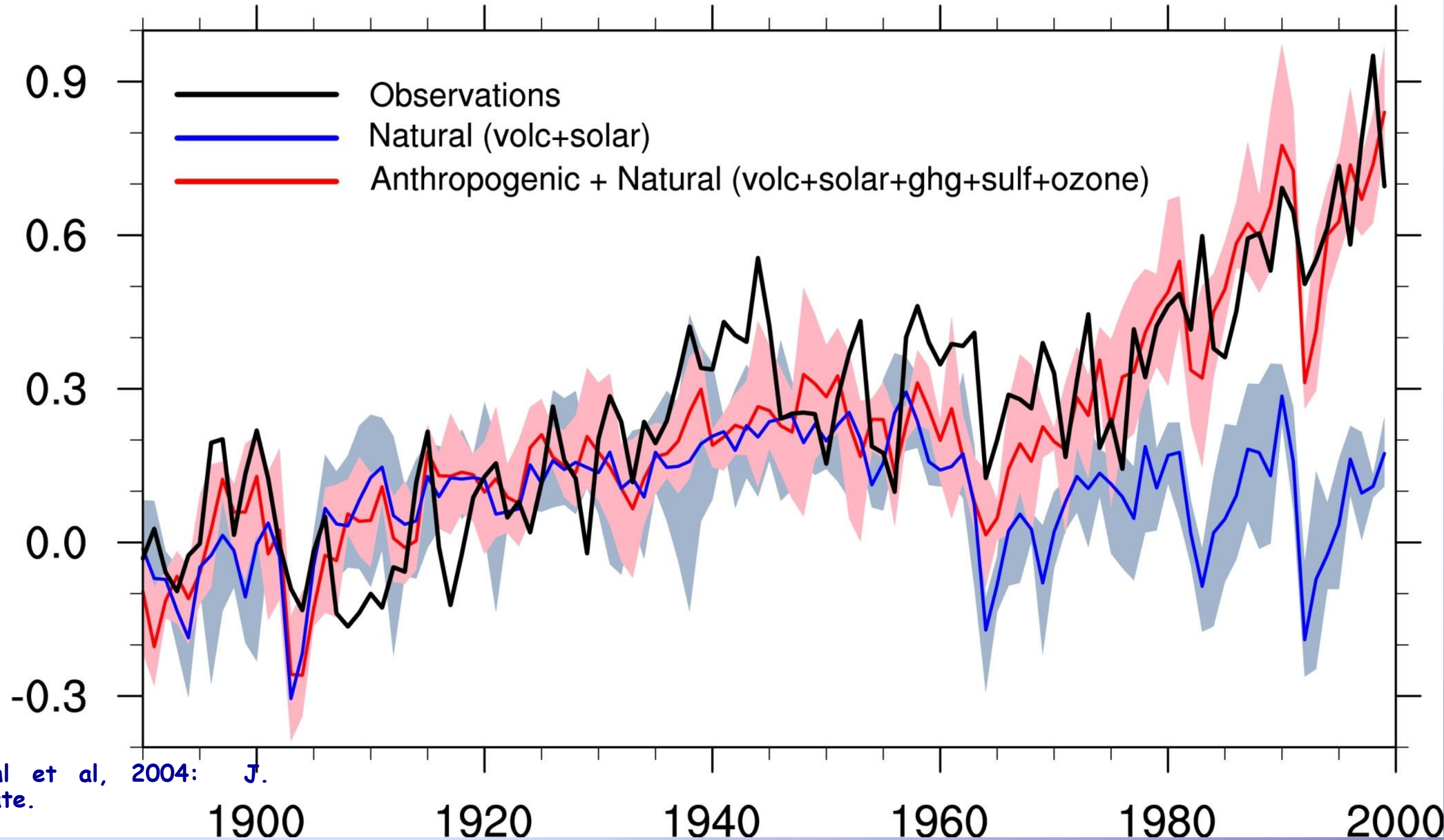
National Climatic Data Center/NESDIS/NOAA



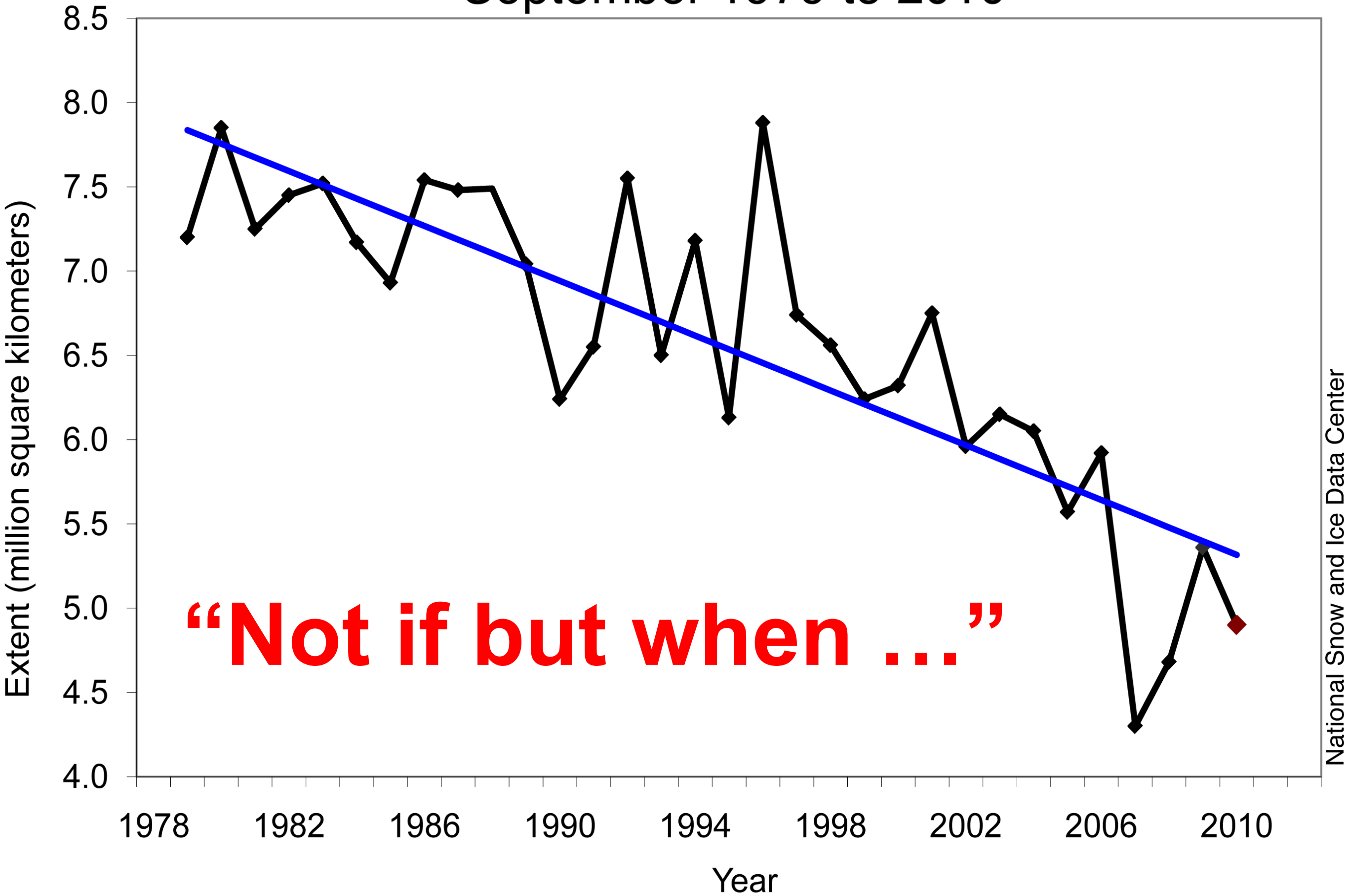
Degrees Celsius

Global Models: Natural processes do not account for observed 20th century warming after 1965

Global Temperature Anomalies
from 1890-1919 average

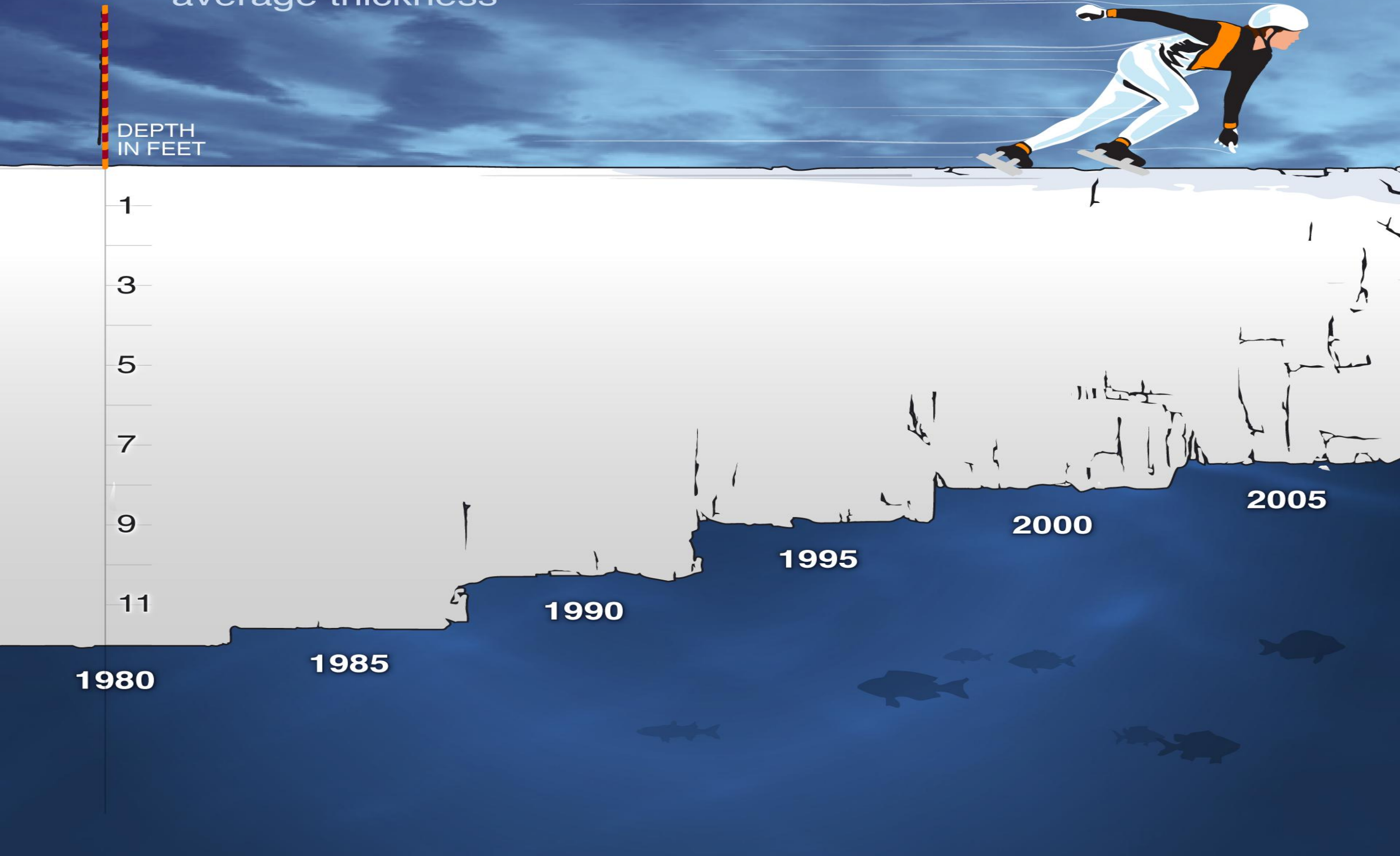


Average Monthly Arctic Sea Ice Extent September 1979 to 2010

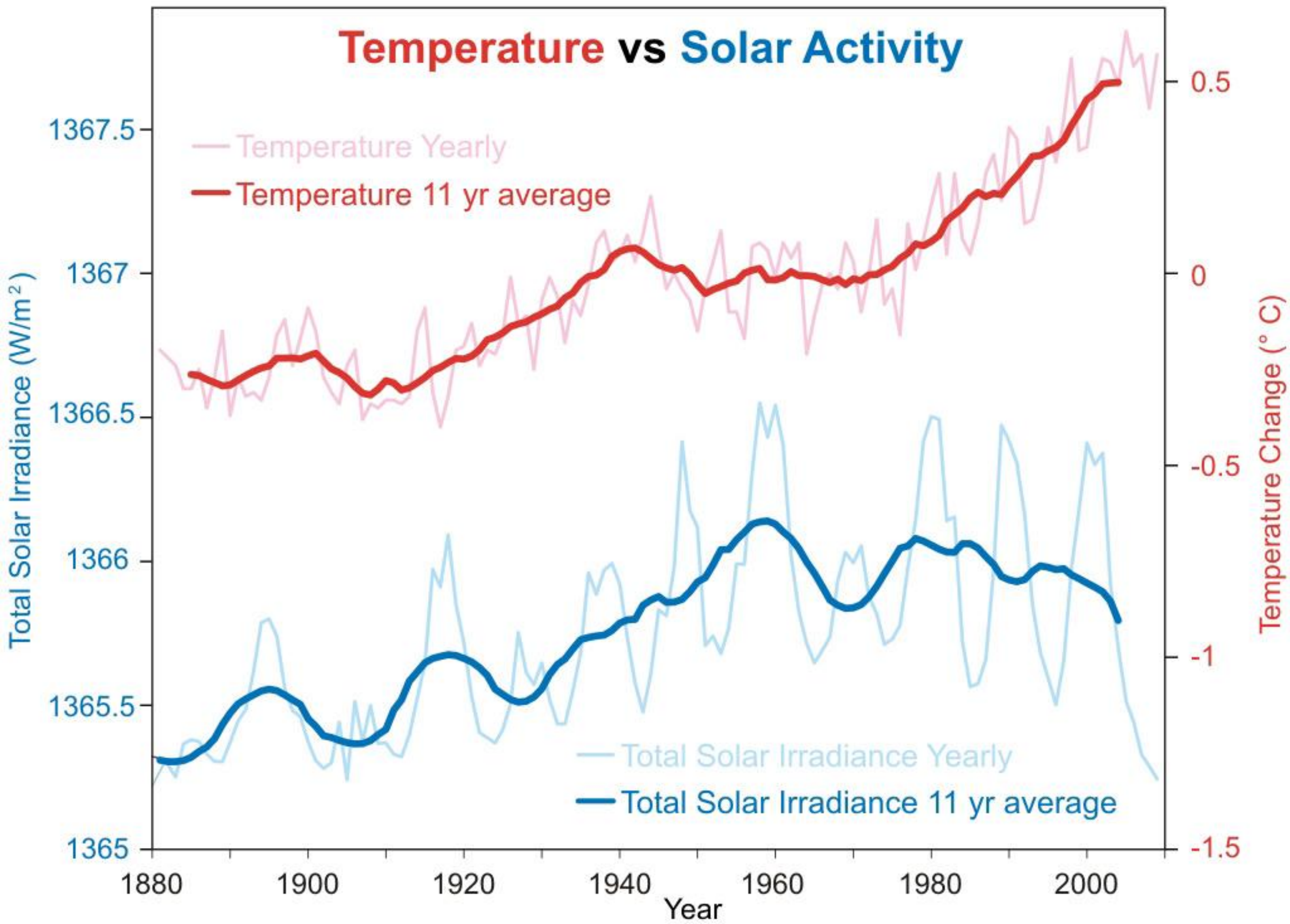


Thin Ice

Changes in winter Arctic sea ice average thickness



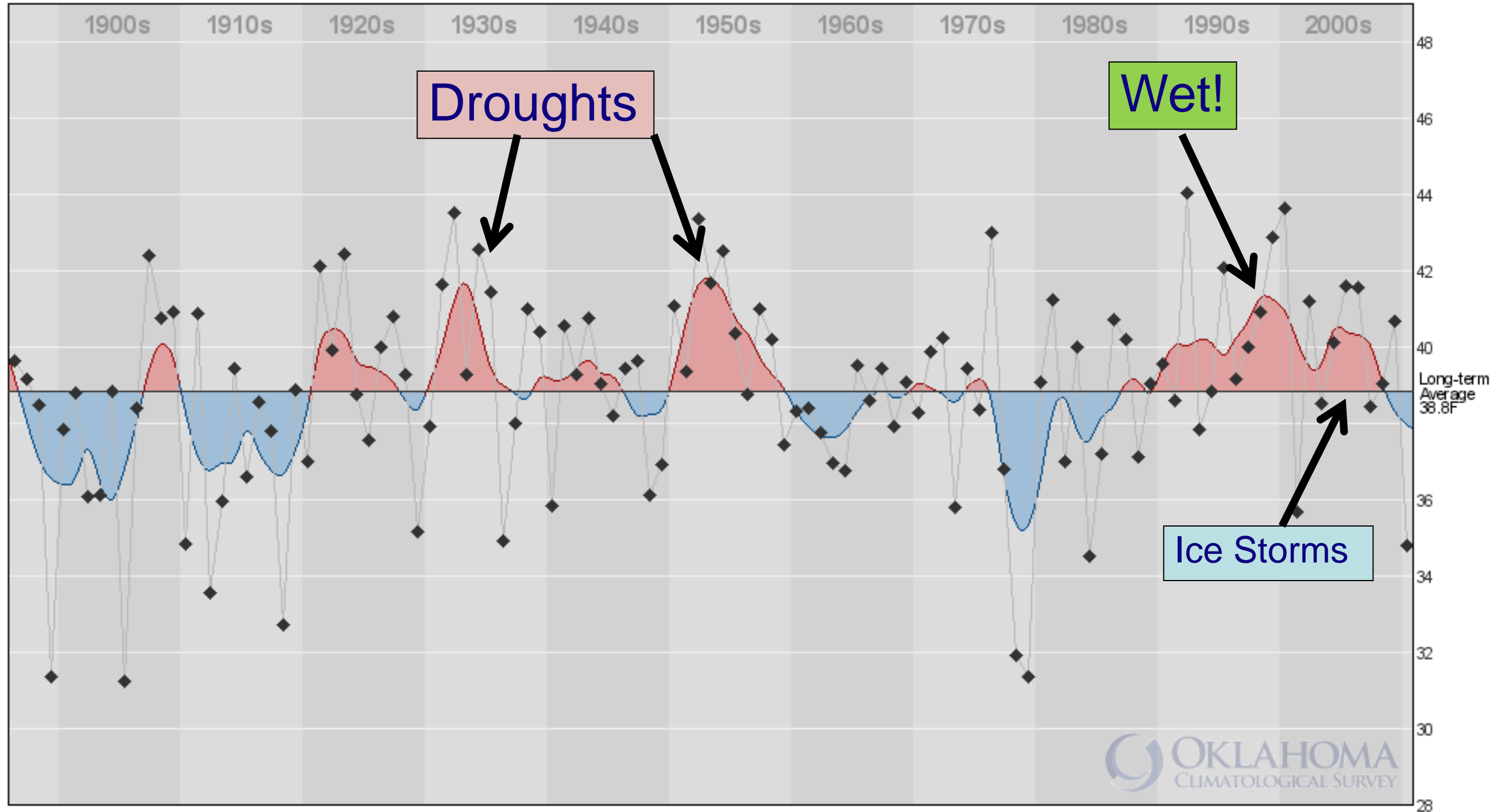
Temperature vs Solar Activity



Oklahoma's Changes?

- **Oklahoma's climate signal still dominated by natural variability**
- **Warmer, wetter winters**
- **Extreme precipitation frequency has increased**

Our winters have gotten warmer and wetter



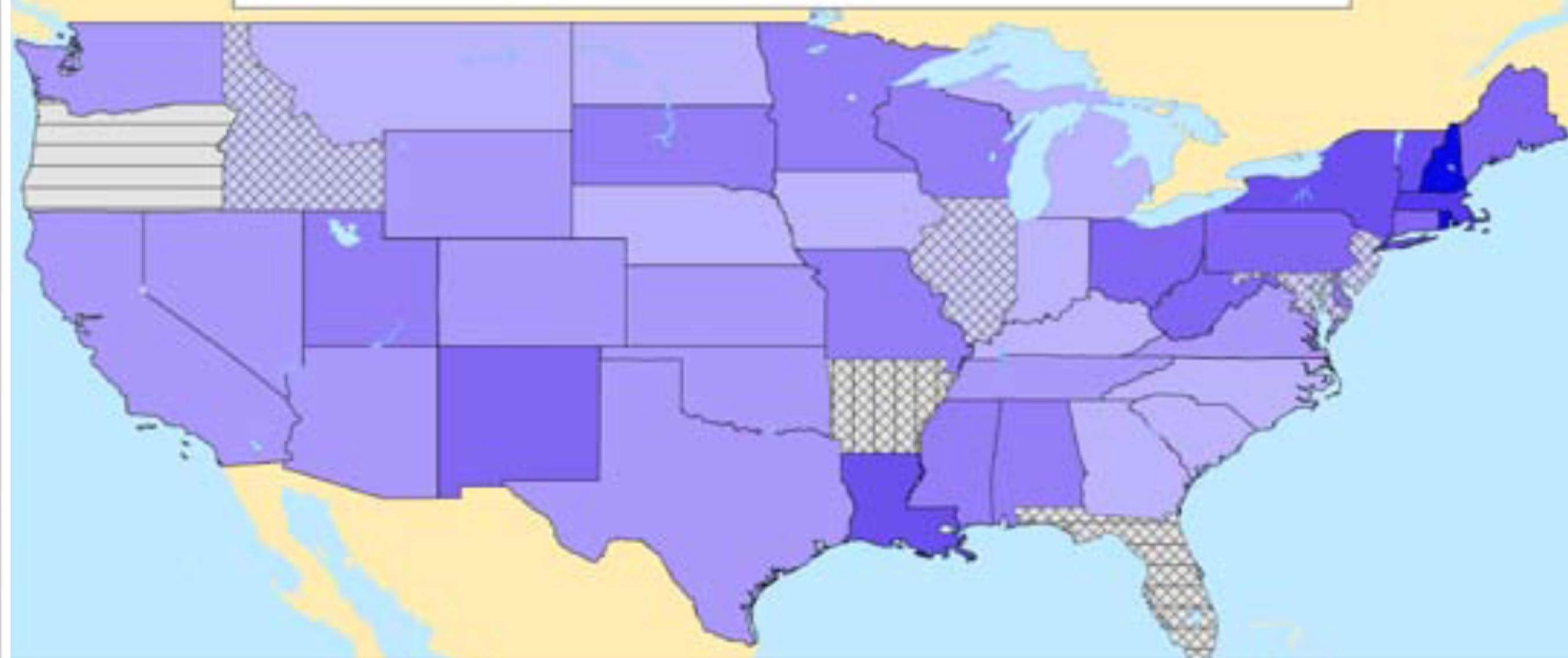
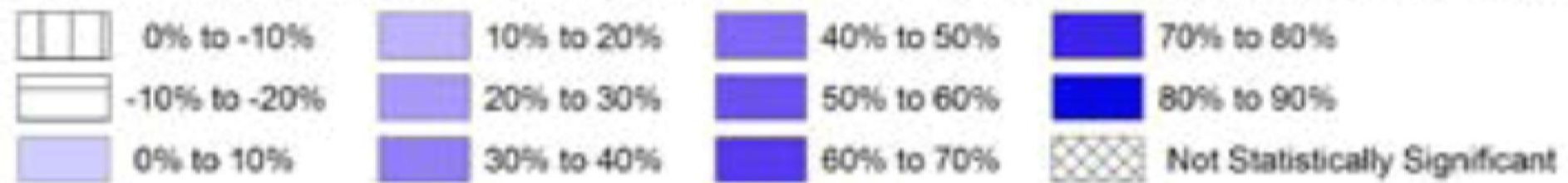
Winter Temperature History with 5-year Tendencies
Oklahoma Statewide: 1896-2010

- Warmer historical periods
- Cooler historical periods
- Individual Winter temperature value

Rainfall events have become more intense

- Oklahoma's value: 22%
- One-year recurrence-level storms (i.e. 59 largest storms)

Trend in the Frequency of Storms with Extreme Precipitation, 1948-2006



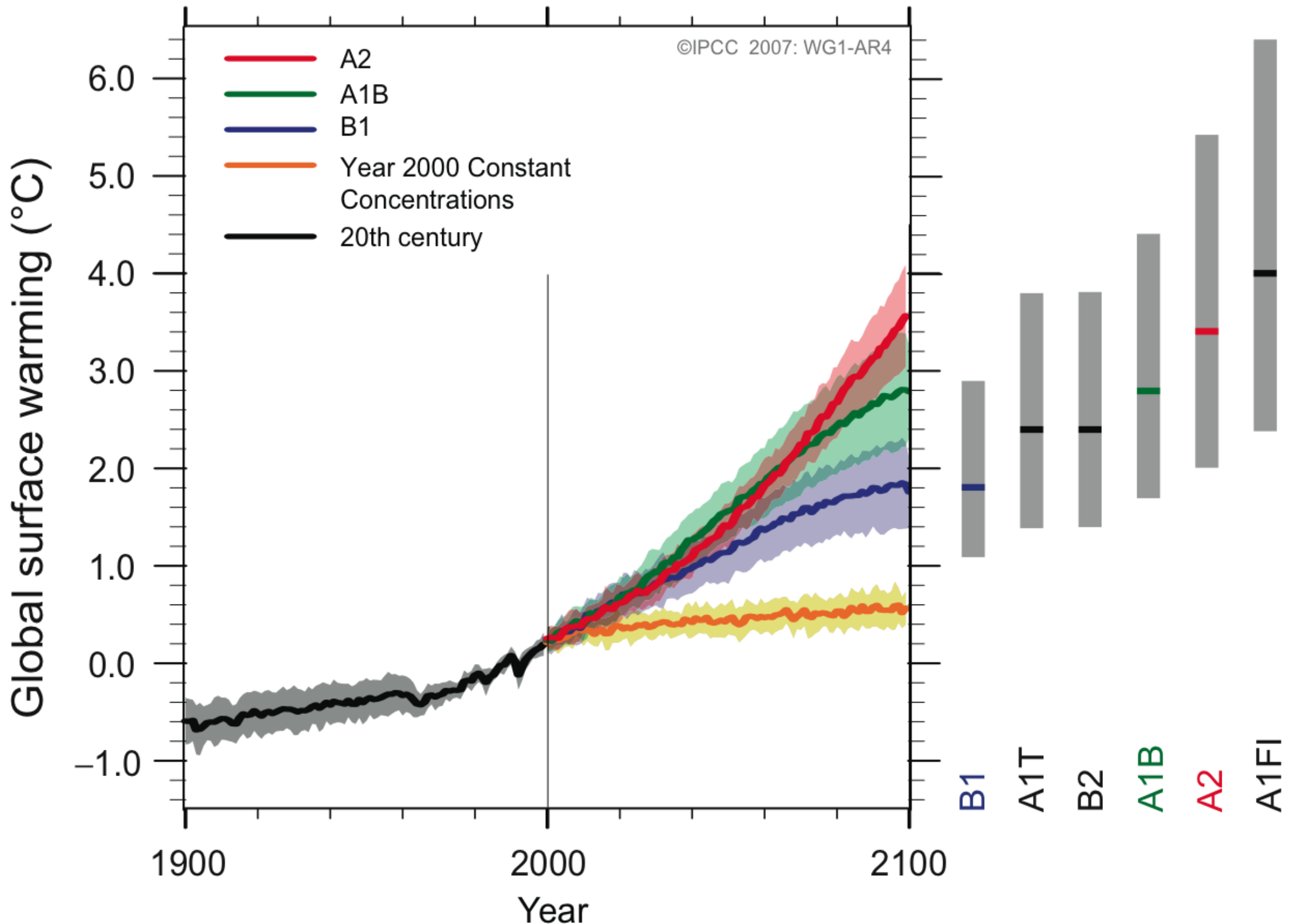
Climate Projections

IPCC Findings

- Higher confidence now exists in projected patterns of warming than exists for other elements such as rainfall
- Hot extremes and heat waves will increase
- Heavy precipitation event frequency will continue to increase
- Snow cover and sea ice continues to shrink
- Sea levels will rise
- Storm tracks are projected to move poleward
- Increasing acidification of the ocean
- Further 21st century emissions will contribute to warming & sea level rise for more than a millennium

Societal response is key

Multi-model Averages and Assessed Ranges for Surface Warming



Temperature Projections: A Range of Possibilities

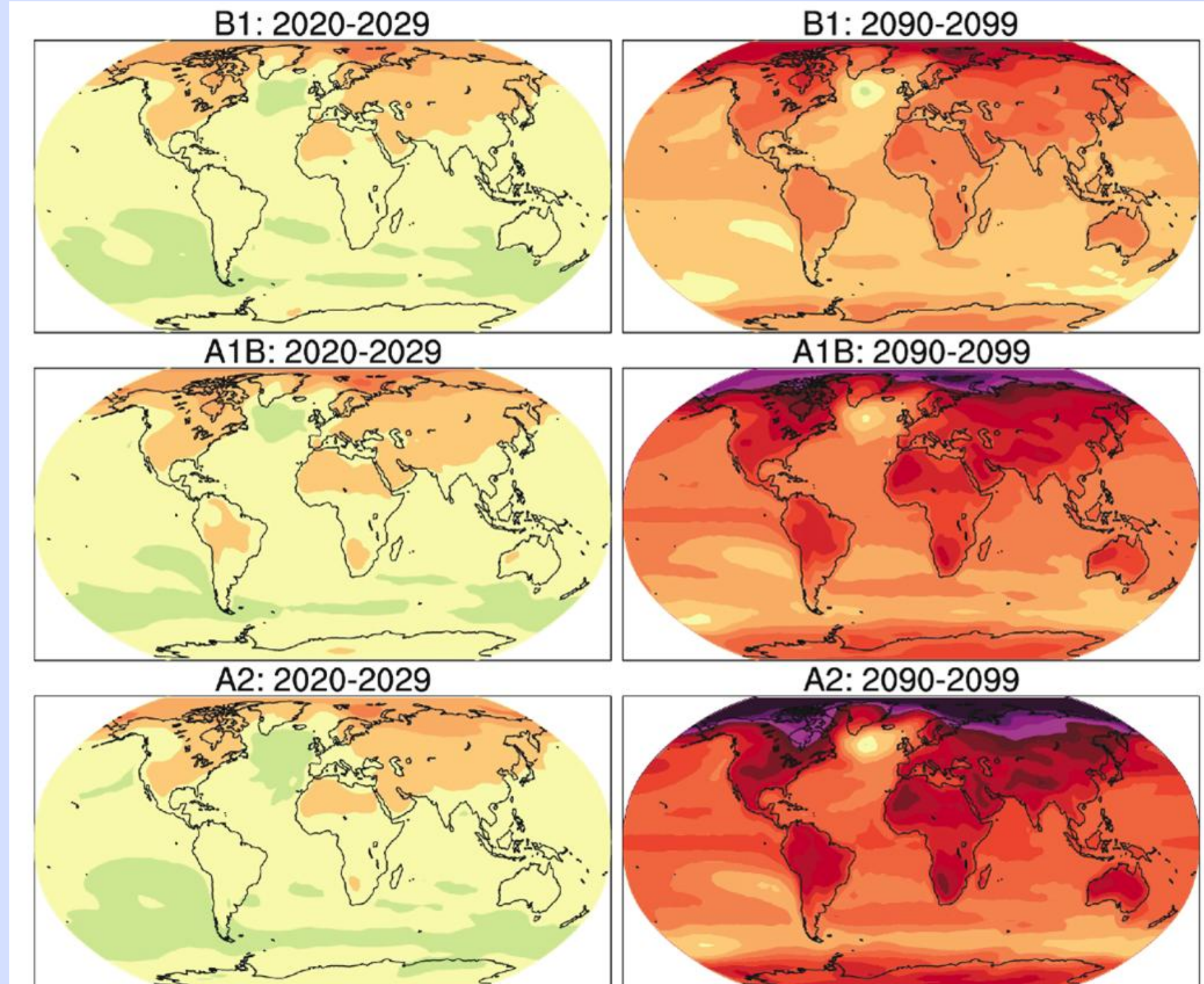
Societal Response



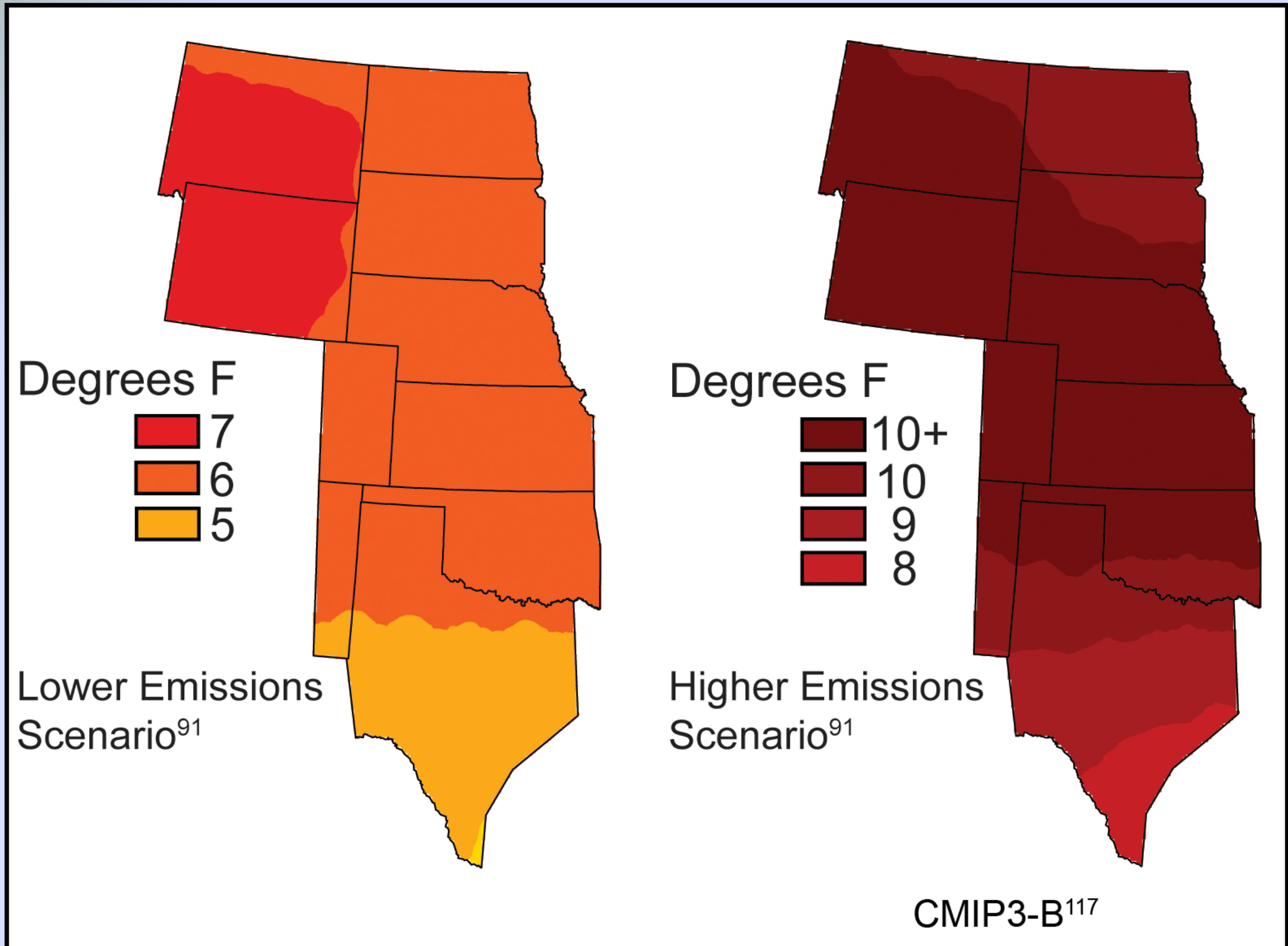
Green Response

Middle Road

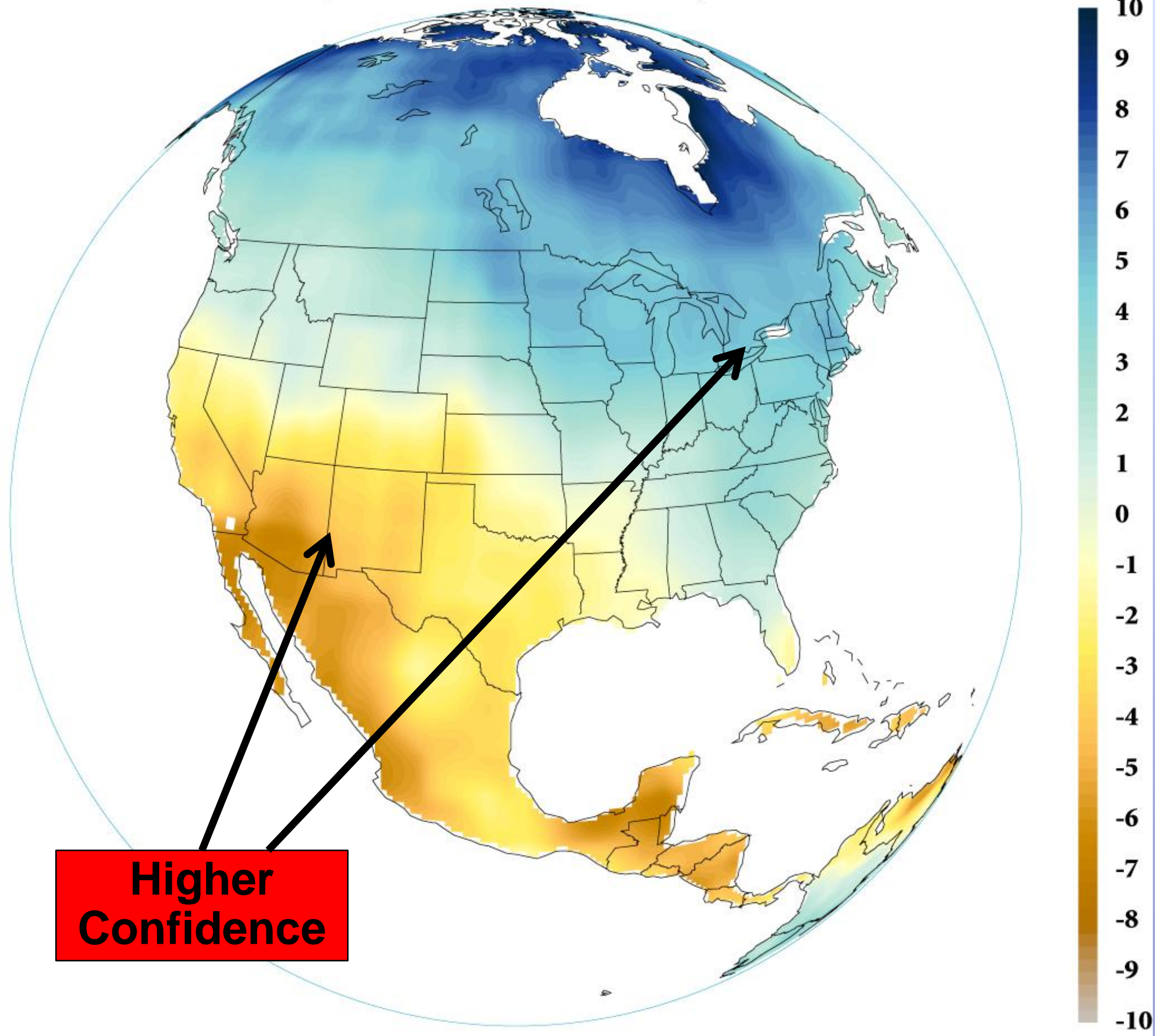
Maximum Growth



Summer Temperature Change: 2080-99

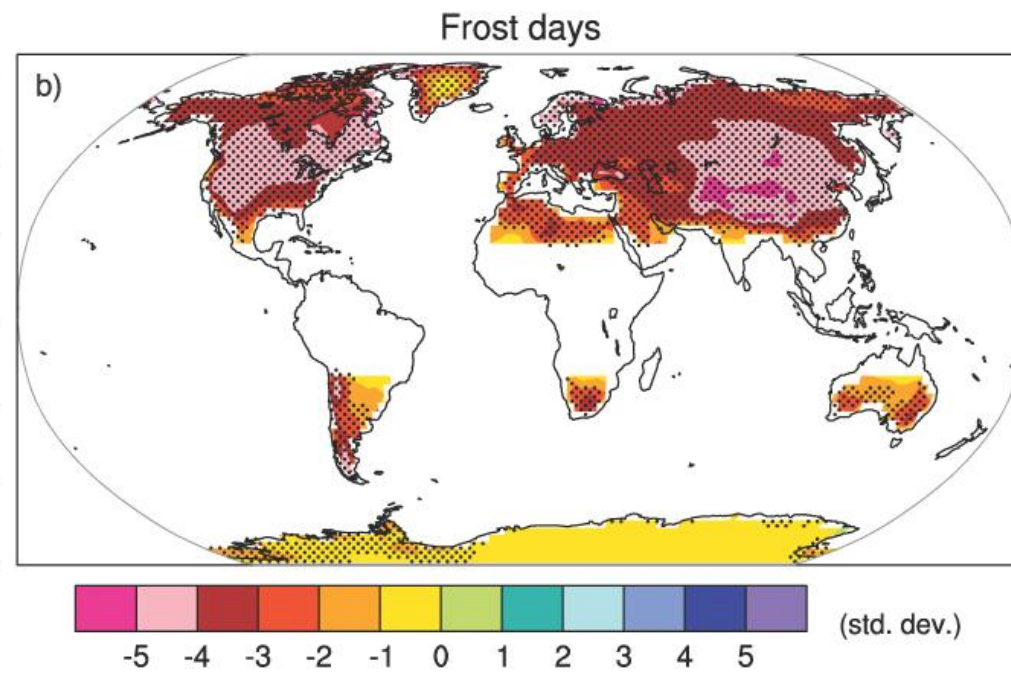
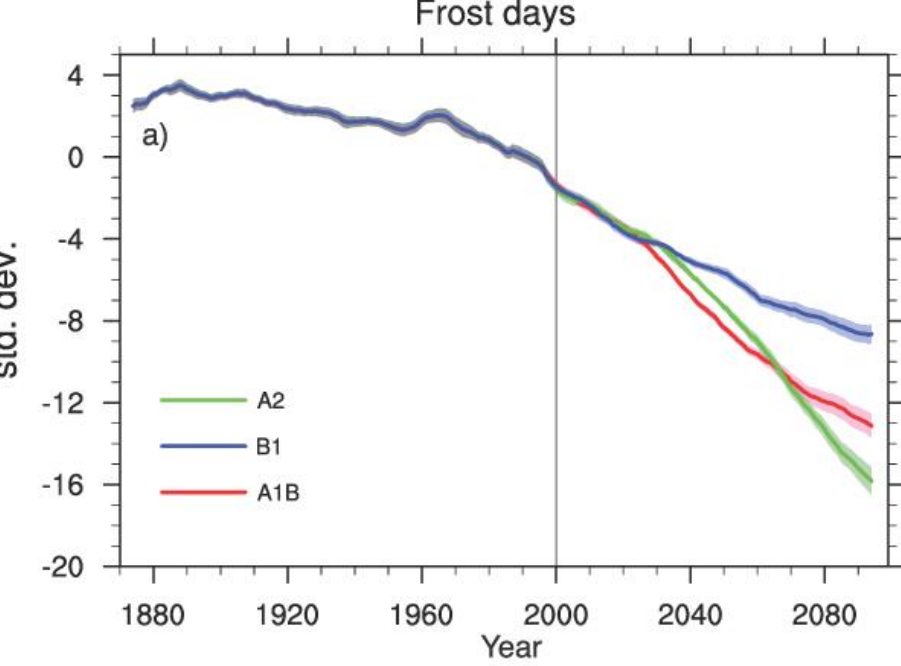


Projected Change in Precipitation 1950-2000 to 2021-2040 (Percent of 1950-2000)

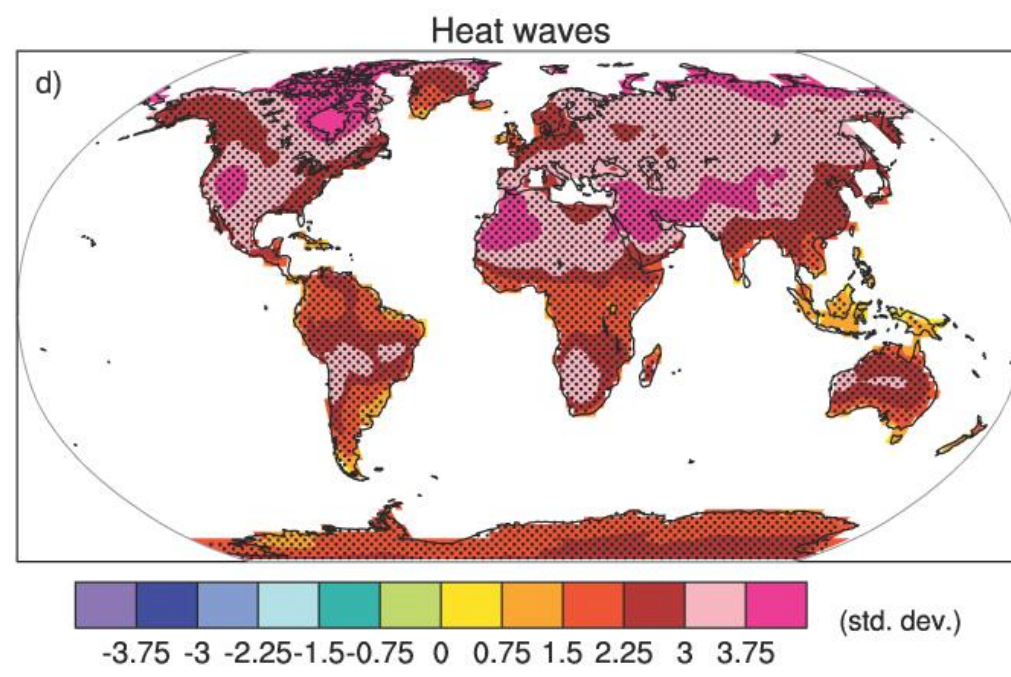
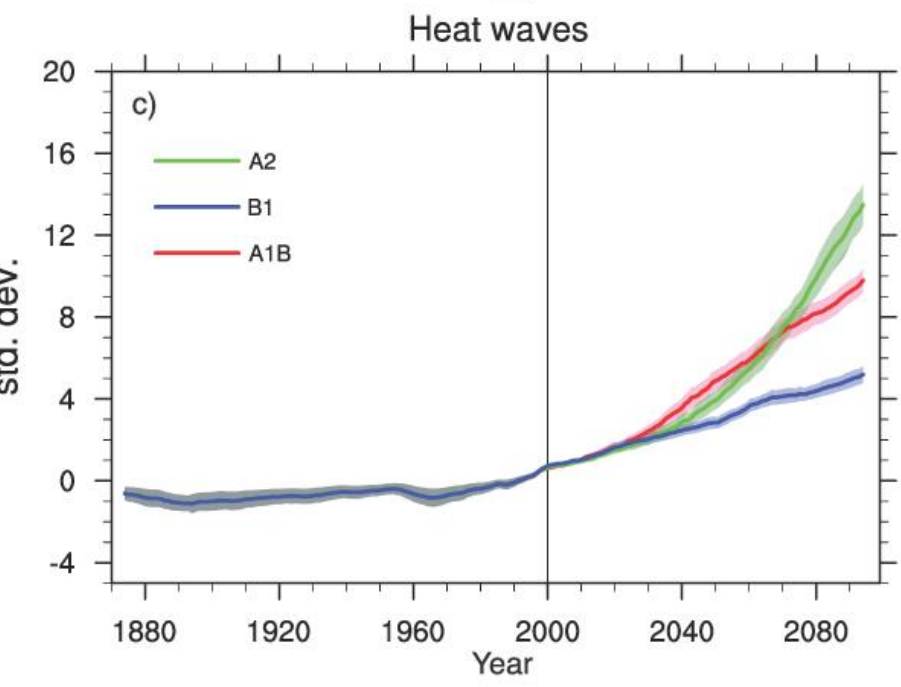


**Annual U.S.
precip will
increase in
the northeast
and decrease
in the
southwest**

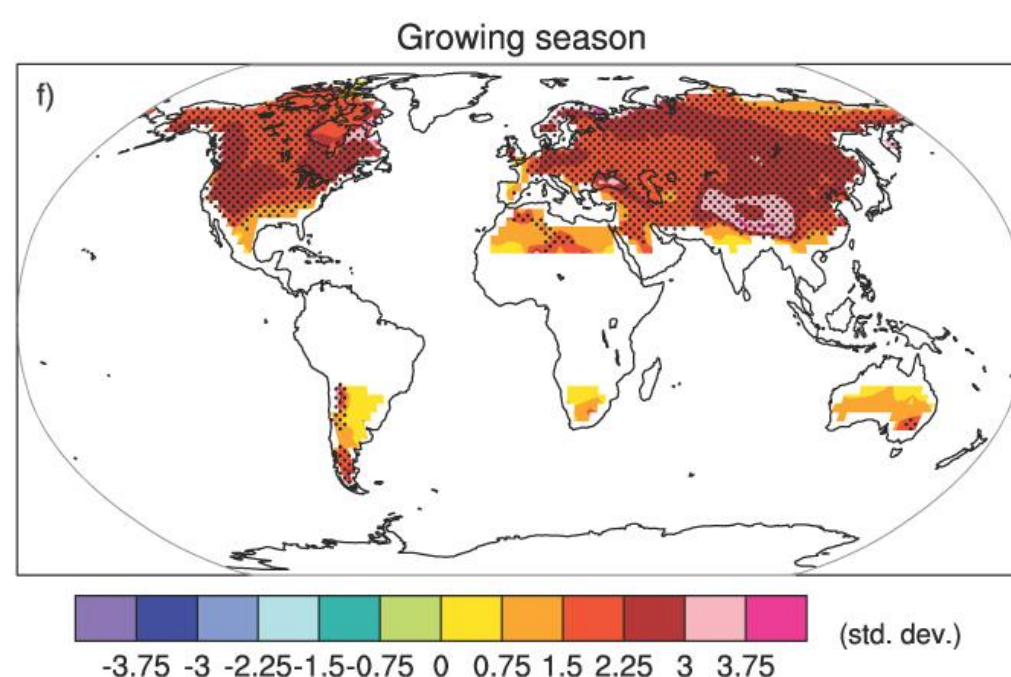
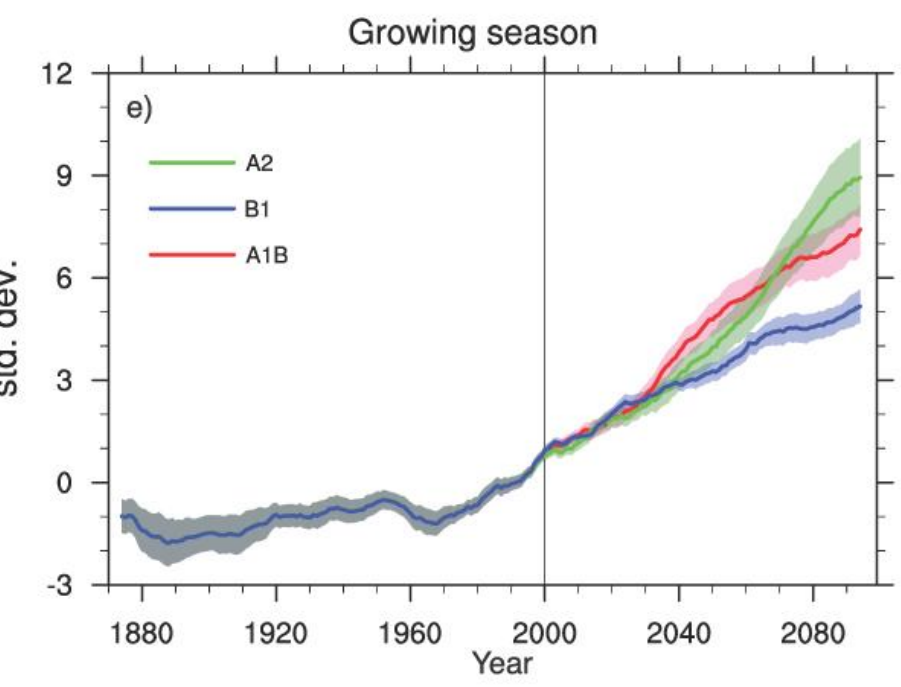
**Higher
Confidence**



Days with frost



Heat waves



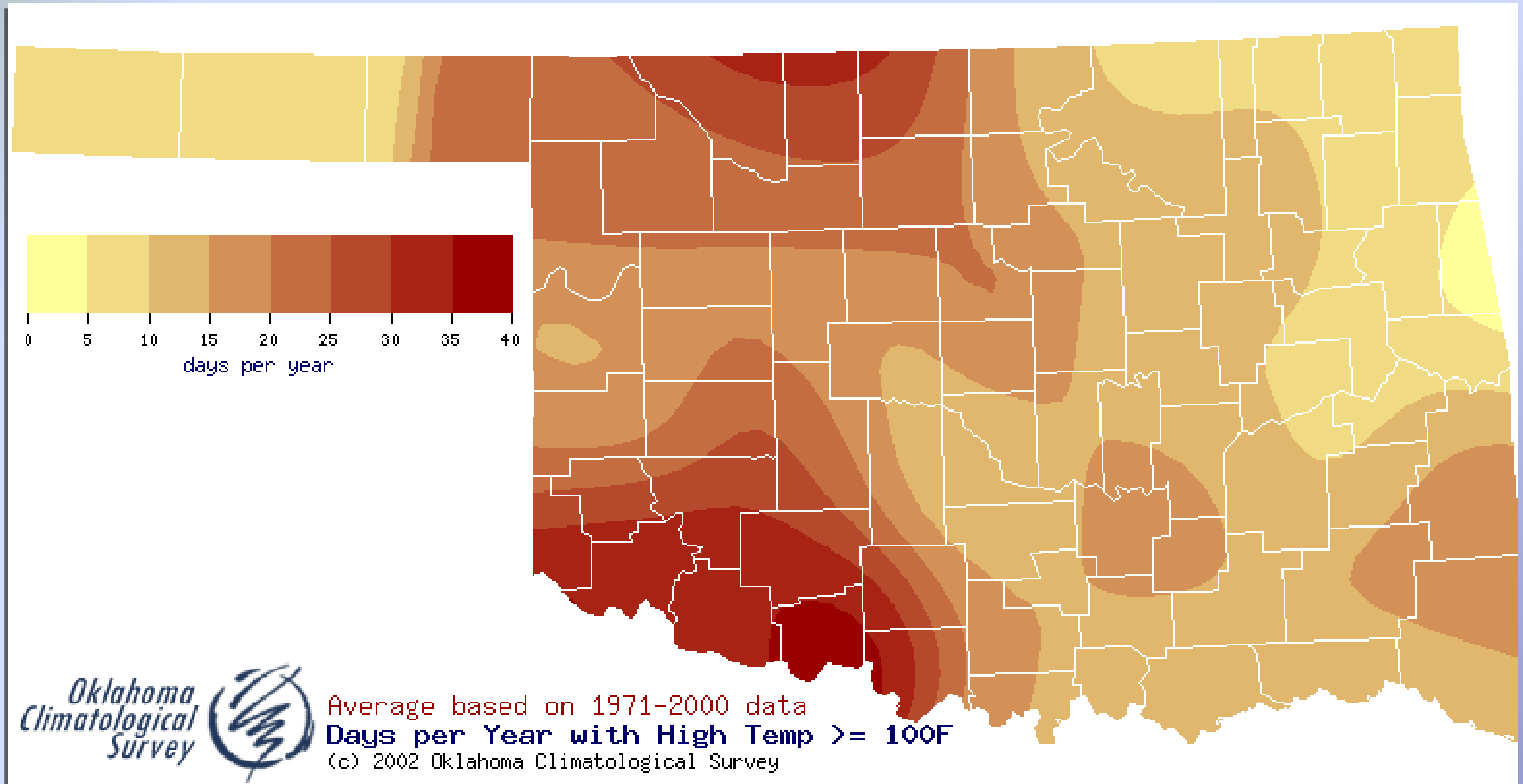
Growing Season

Projections for Oklahoma as we scale down

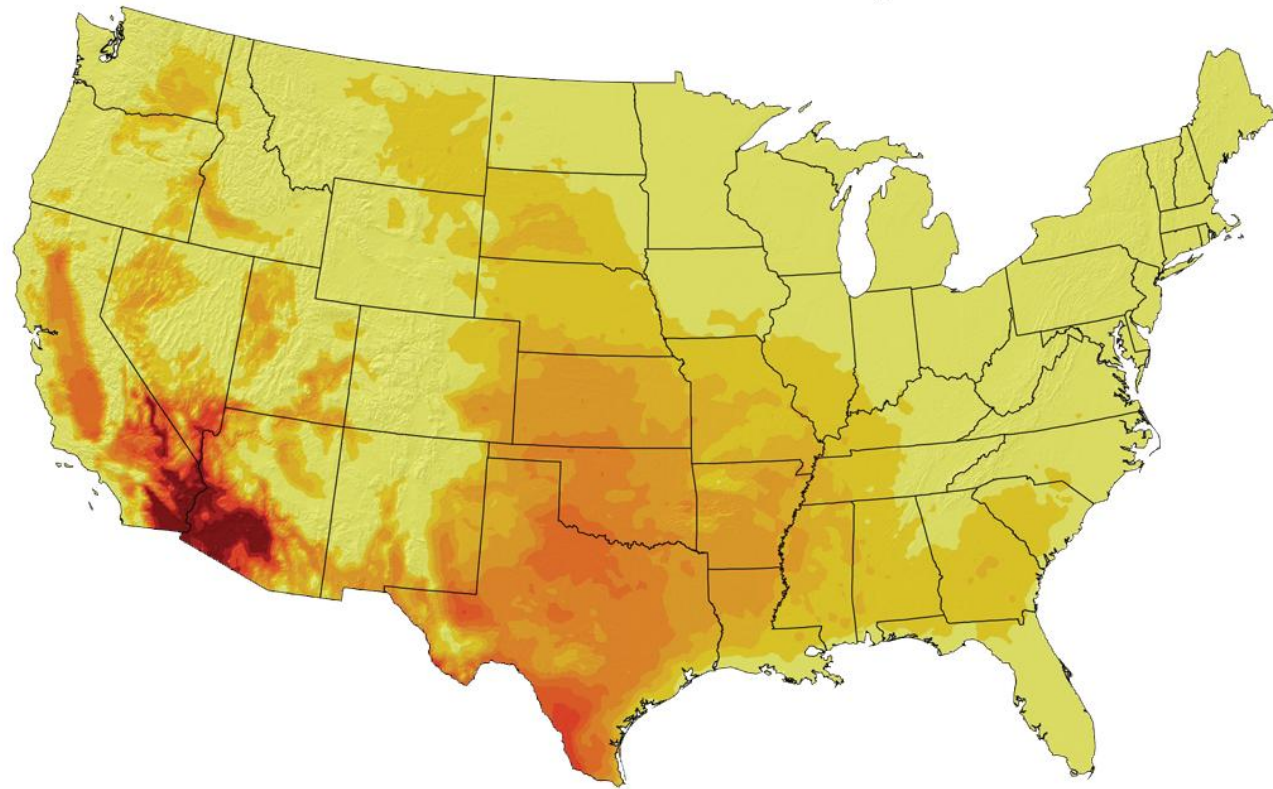
Temperature

- Annual warming by the 2020s
 - “Middle Road” scenario: 2-4°F
 - “Maximum Growth scenario: 2-4°F
- Annual warming by the 2090s
 - “Middle Road” scenario: 4-7°F
 - “Maximum Growth scenario: 10-12°F
- Summer becomes longer and spring weather arrives earlier
- Winters warm - longer frost-free periods and a longer growing season
- Earlier maturation of winter wheat and orchard crops leave them more vulnerable to late freeze events (think 2007 and 2009)

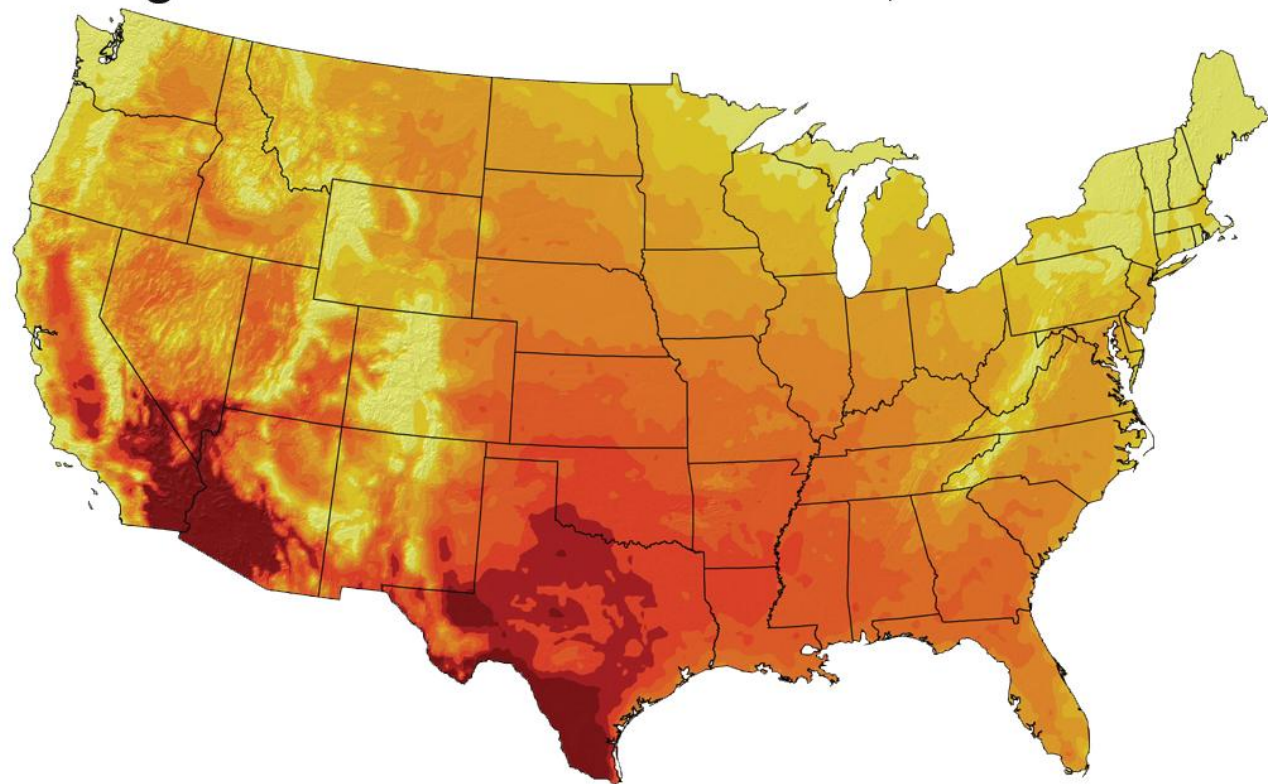
100-degree days (1971-2000)



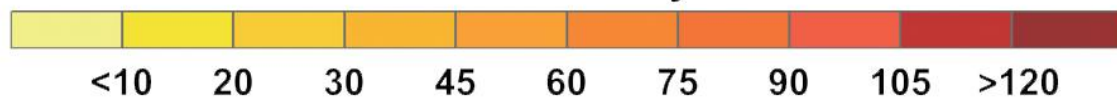
Lower Emissions Scenario⁹¹, 2080-2099



Higher Emissions Scenario⁹¹, 2080-2099



Number of Days



CMIP3-B¹¹⁷

100-degree days – Projections

Precipitation

- **Rain-free periods will increase, but individual rainfall events will be more intense**
- **Increased year-round evaporation from the ground and transpiration from green vegetation**
- **Drought frequency and severity increases**
- **The risk of wildfires increases, especially during summer**

Oklahoma's Water Future?

Fewer (but more intense) precipitation events:

- More runoff, more flooding
- Crop damage
- More pollution from runoff
- Increased erosion
- Possibly less water available, even if yearly totals increase

- The earth's climate has warmed during the last 100 years;
- The earth's climate will continue to warm for the foreseeable future;
- Much of the global average temperature increases over the last 50 years can be attributed to human activities, particularly increasing greenhouse gases in the atmosphere;
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The Science of Global Climate Change

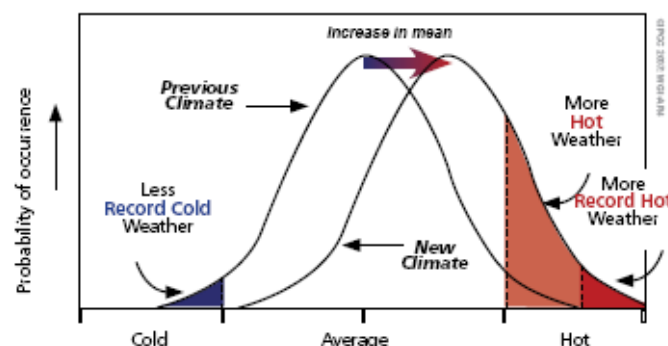
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Oklahoma statewide average winter temperatures since 1896. The warming trend evident since the late 1980s has occurred during an extended drought-free period.

periods required for these gases to be removed from the atmosphere, further emissions during the 21st century will cause additional warming for more than a millennium. In fact, even if greenhouse gas concentrations were held steady since the year 2000, the earth is committed to decades of warming from heat already absorbed by the oceans.

Global Climate Change Impacts for Oklahoma

The continued warming of the climate averaged across the globe will create a cascade of climatic shifts which could impact Oklahoma's climate. These shifts will not mean an end of year-to-year natural variability – hot years and cold years will continue, as will wet years and dry years. The projected changes will be seen at time scales averaged over a decade or more. Little is known of the effects climate change will have on severe weather. The ingredients required for severe weather involve complex combinations that do not exhibit clear changes in a warming climate. Further, global climate models are unable to accurately simulate small scale weather events like thunderstorms or tornadoes.



The effect on the frequency of extreme temperatures in a warming climate.

**Find out about climate change for
yourself at**

<http://www.ipcc.ch/>

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

Thank you!