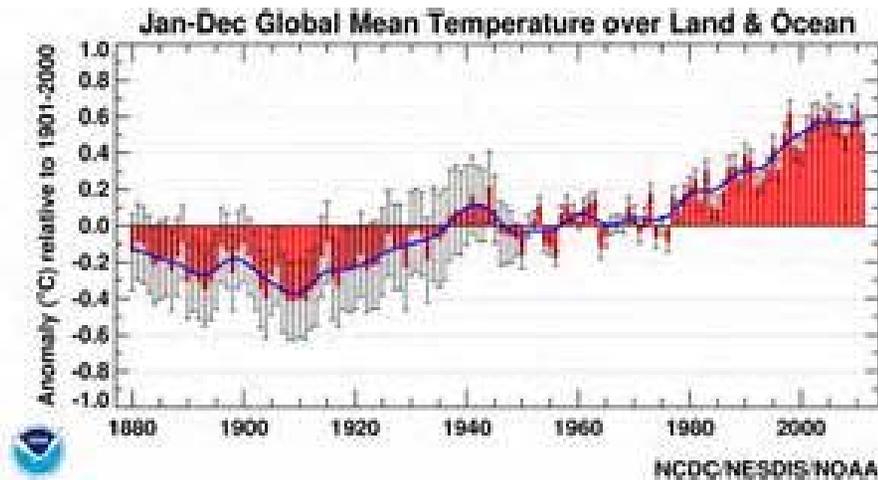

Climate, Climate Variability and Change: The Science

Anthony R. Lupo
Department of Soil, Environmental, and Atmospheric Sciences
302 E ABNR Building
University of Missouri – Columbia
Columbia, MO 65211

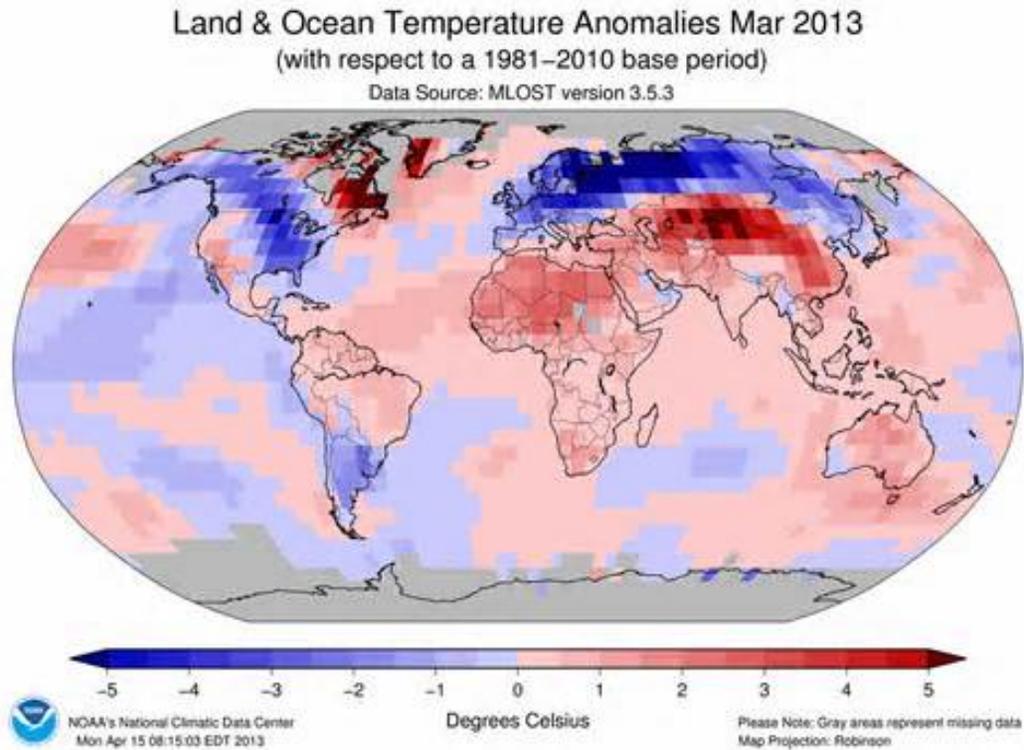
Situation Today.....

- What is happening..... Warming Pause?



Situation Today.....

- Winter 2013 – 2014:



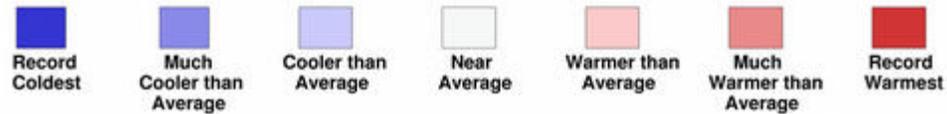
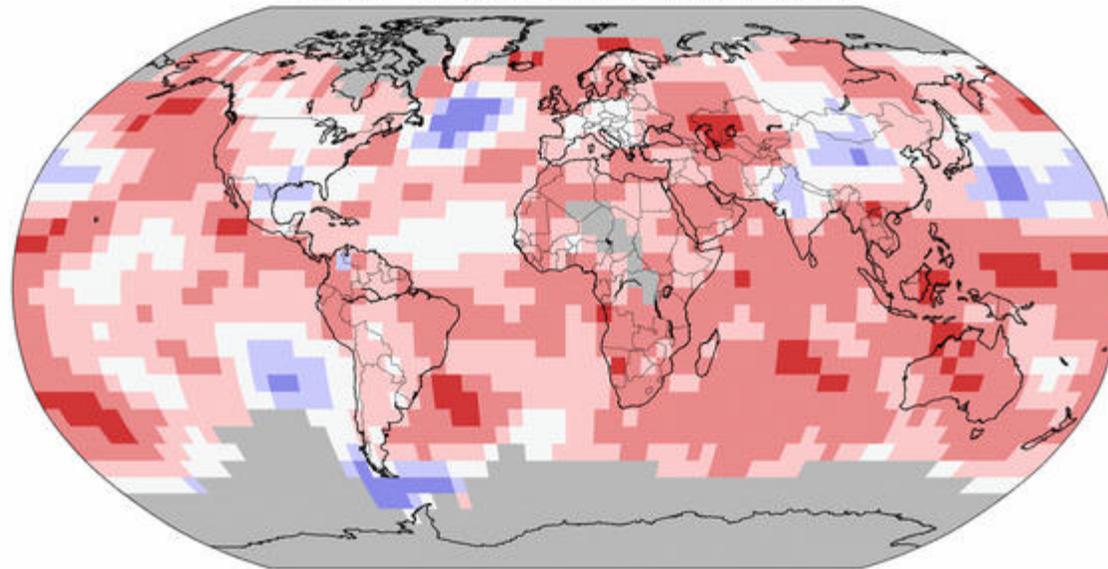
Situation today

- May 2014 hottest ever!?

Land & Ocean Temperature Percentiles May 2014

NOAA's National Climatic Data Center

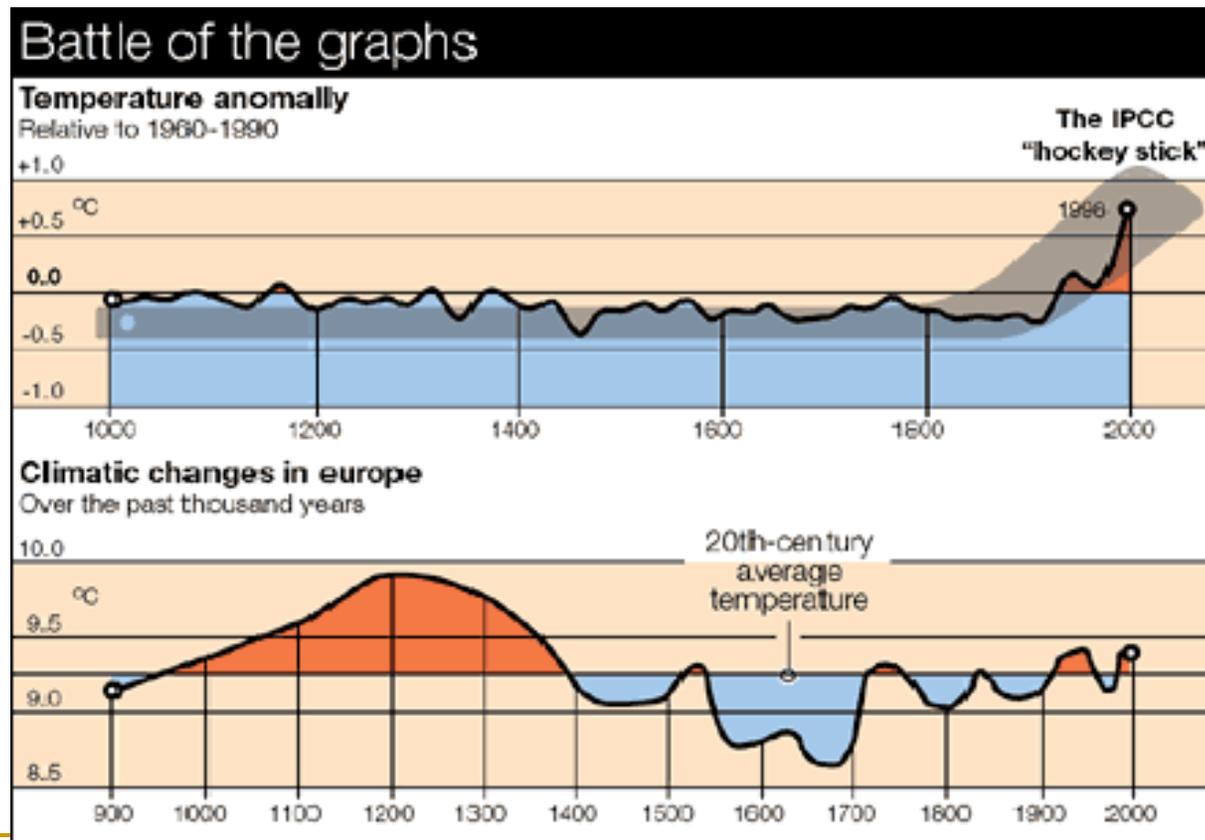
Data Source: GHCN-M version 3.2.2 & ERSST version 3b



Tue Jun 17 11:40:39 EDT 2014

Situation Today.....

- Observations versus the Hockey Stick



Situation Today.....

- IPCC Report – Working Group III 4/13/2014
 - We need to:
 - Cut emissions rapidly 40 – 70% by mid century, and this is conservative
 - Warming is worse than thought, 5- 7 F by 2100 a certainty.
 - Stop eating meat..
-
- Minimum of tripling of zero carbon fuels.

Situation Today.....

- June 2014 – EPA requires states to reduce overall CO₂ emissions by 2030 to 30% below 2005 levels.
 - June 23 2014, Supreme Court declares science is not disputable, the EPA has the authority to regulate CO₂.
-

Climate What is it?

- Climate? What is it?
- Weather → the day-to-day state of the atmosphere. Includes state variables and descriptive material such as cloud cover and precipitation, etc.
- We can get this material instantaneously

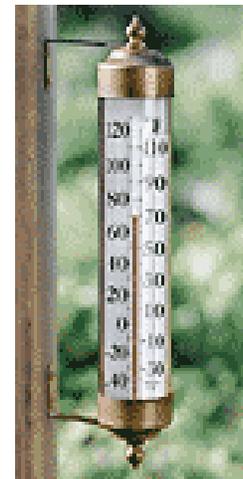


Climate: What is it?

- Climate → Is the long-term or time mean state of the earth-atmosphere system and the state variables along with higher order statistics. Also, we must describe extremes and recurrence frequencies.
 - In 'English': A long-term summary of what has happened.
-

Climate and Climatology

- Climate can, therefore, be descriptive and tell us something about, ‘what is possible’ in a given region.



The Answer!

- The World Meteorological Organization standard Climate averaging period is 30 years.
 - Two reasons: A) This is long enough to eliminate “year to year” variations in climate, and B) it’s not too long relative to human life spans!
-

Climate: What is it?

- Climatology is the study of climate in a mainly descriptive and a statistical sense. Climatologists study these issues, as well as changes in climate.
 - Climatology is, of course, a popular subject today because of the concern over climate change.
-

The Climate System / What is it?

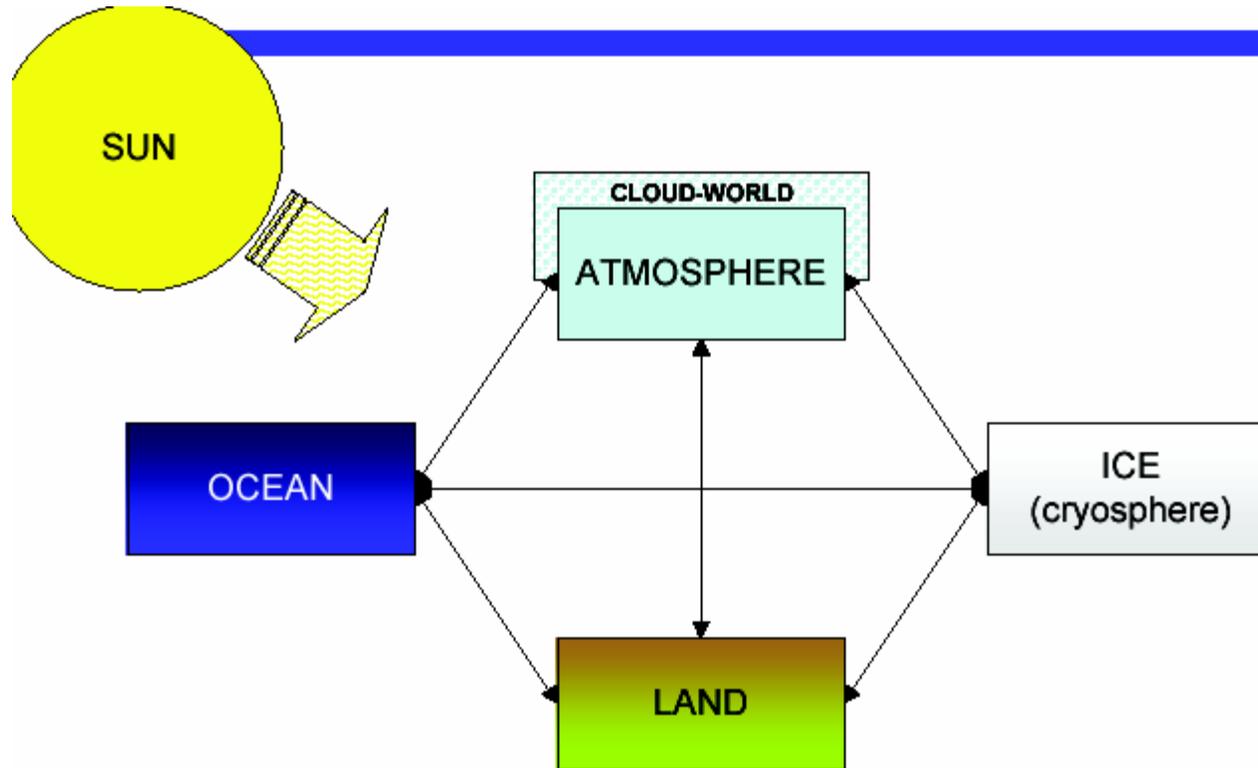
- The Earth-Atmosphere system is an integrated system of which the atmosphere is only one part!



The Climate System

- The other parts of the climate system are:
 - The Cryosphere (Glaciers, Antarctica)
 - The Oceans (and freshwater too)
 - The Lithosphere (dirt, continents)
 - The Biosphere (life → Plants and Animals)
-

The Climate System



The earth-atmosphere system, courtesy of
Dr. Richard Rood.
(<http://aoss.engin.umich.edu/class/aoss605/lectures/>)

The Climate System

- Each part of the climate system interacts with the other.
 - Each part generally evolves or changes more slowly, the atmosphere is a “quick response” system.
-

The Climate System

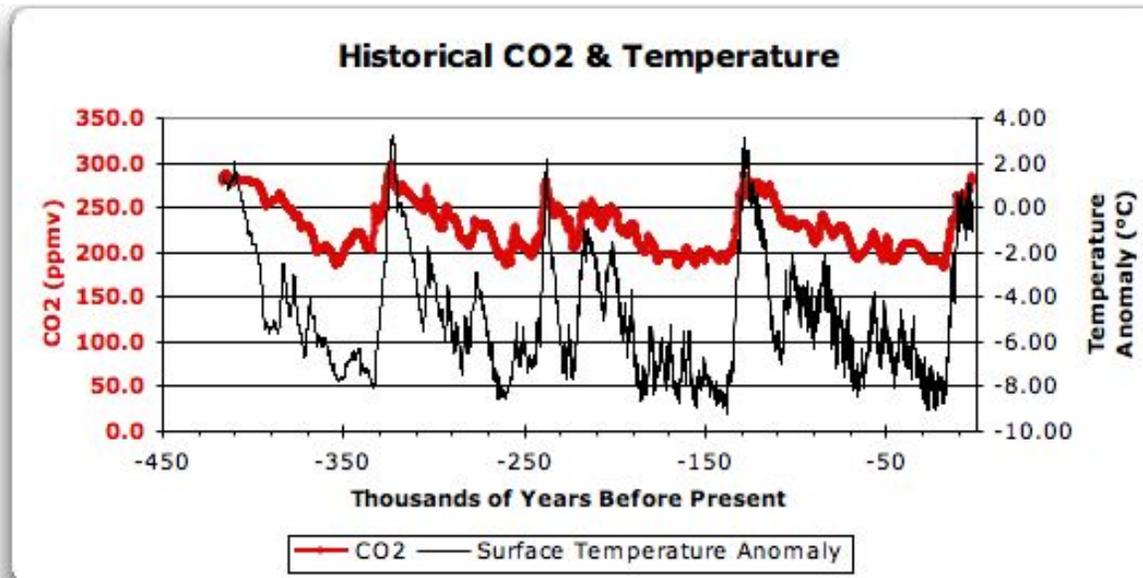
- We make two assumptions about the climate system:
 - That the energy that comes into the system equals the energy going out, and
 - That the mass within the system is conserved.
-

Global Warming: Attribution

- How do we identify humanity's contribution to climate?
 - First, we know there is a strong correlation between global temperature and CO₂ concentration,
-

Global Warming: Attribution

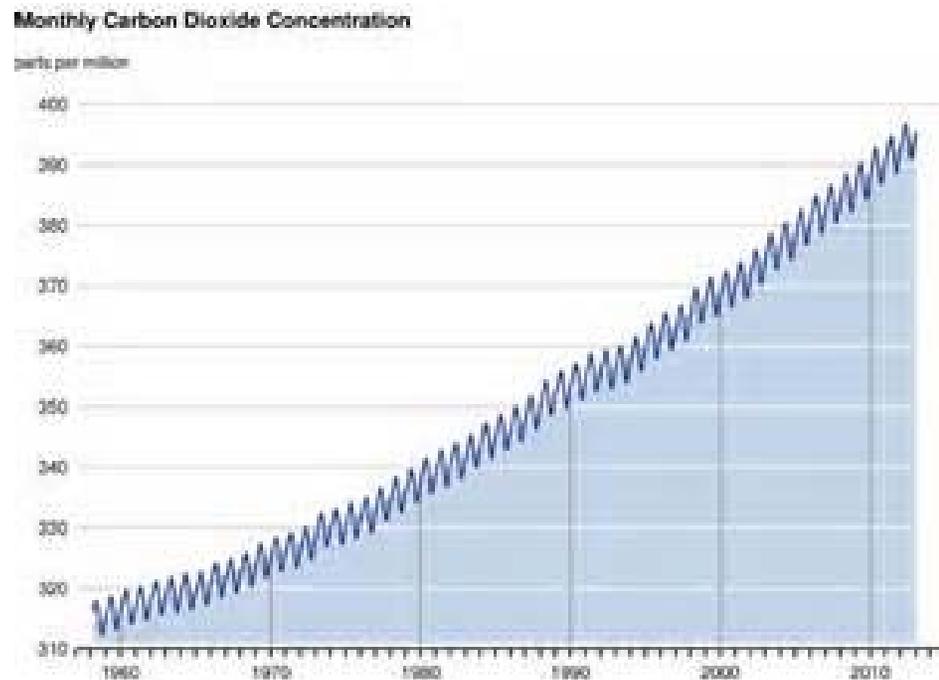
-but on a VERY long time-scale (tens of thousands of years)



- Graphic similar to this in “An Inconvenient Truth”

Global Warming: Attribution

- Of course we all have seen this diagram:



Global Warming: Attribution

- The rate of CO₂ increase has been steady up to the early 2000's, although there is some evidence it is dropping.

- “CO₂ – rising”

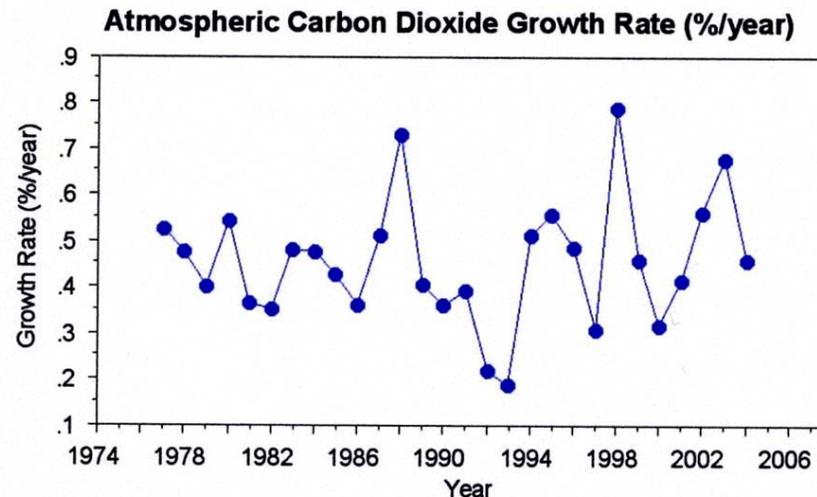
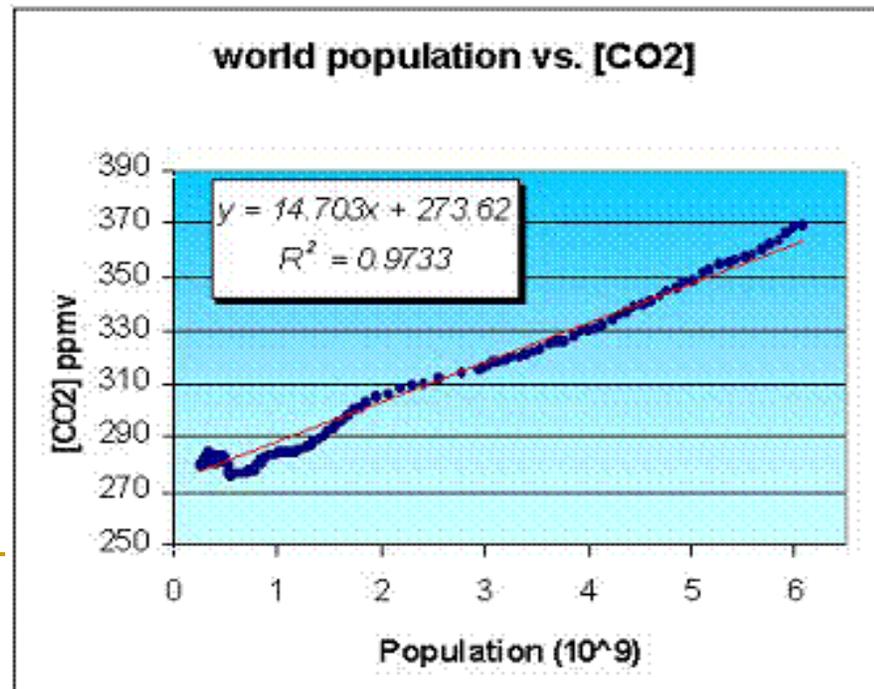


Figure 4. Observed annual growth rate of atmospheric carbon dioxide concentrations, %/year, during the past 30 years. There has been no significant trend in the growth rate during this time. The average value during that time has been 0.45%/year (values derived from data available from the Carbon Dioxide Information Analysis Center, <http://cdiac.esd.ornl.gov/trends/co2/sio-mlo.htm>)

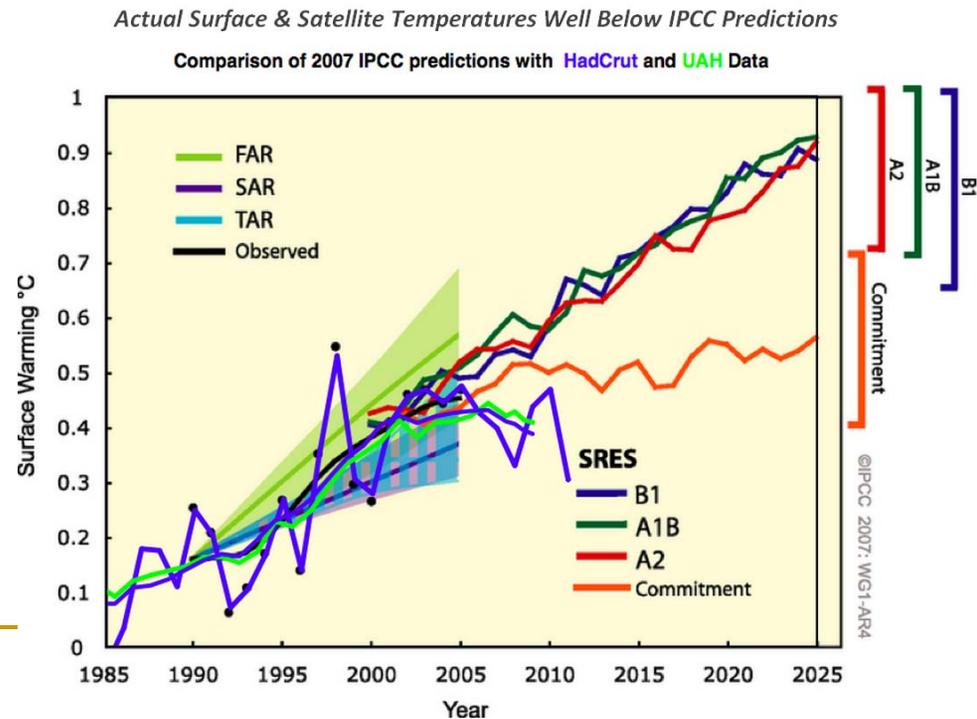
Global Warming: Attribution

- We can “fingerprint” CO₂ concentrations by it's mass (ratio of various isotopes) and there is no doubt that some of the increase in CO₂ is generated by humans (industry)

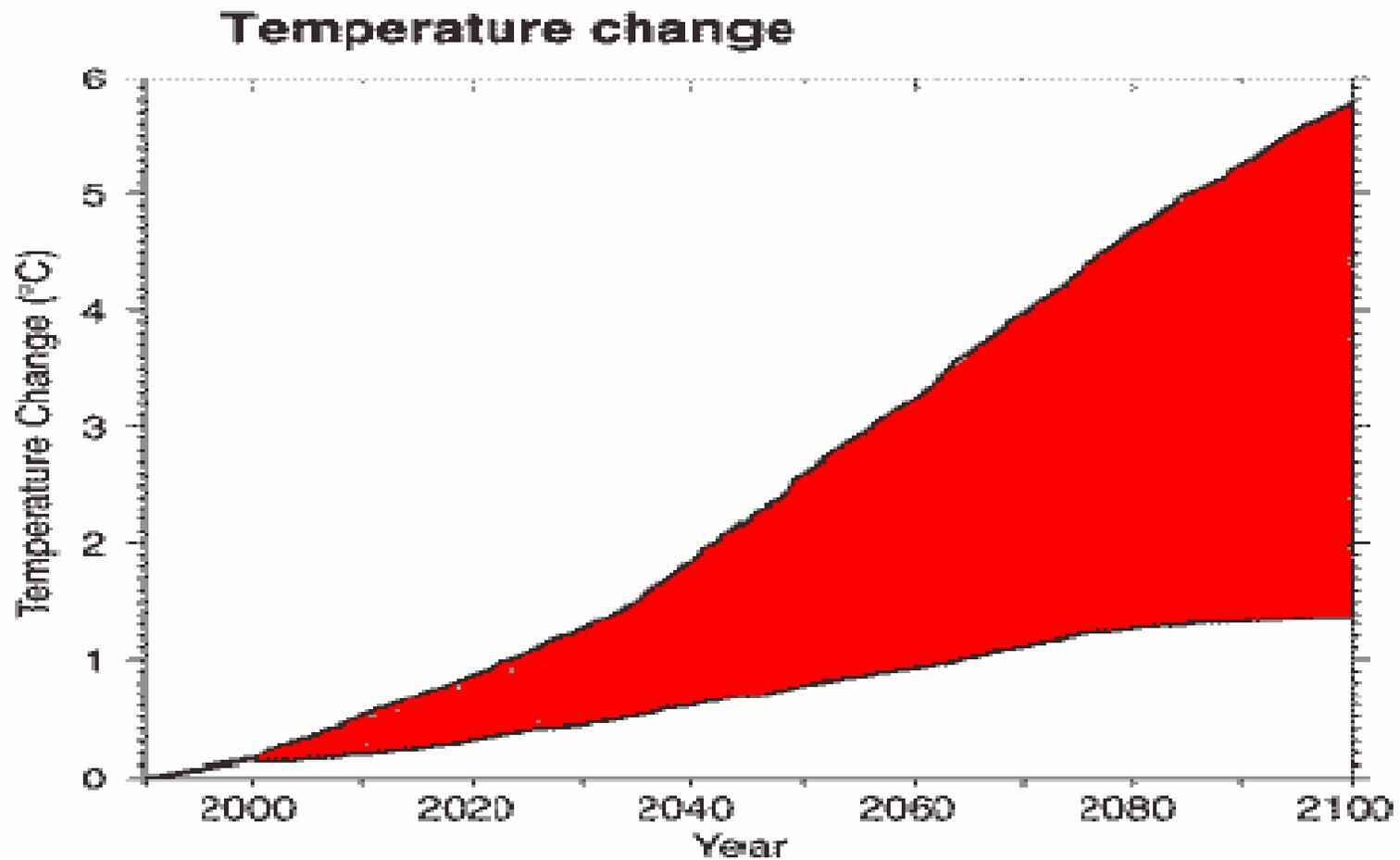


Global Warming: Atmospheric Models

- Also, we can use atmospheric models: (General Circulation models) and examine the impact of changing the CO₂ amount (Climate skeptics)



Model projections

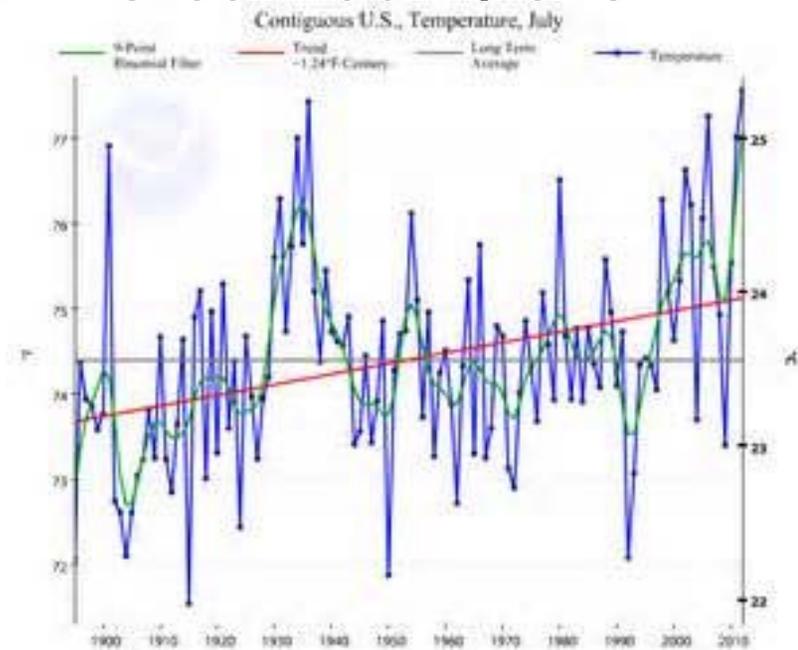
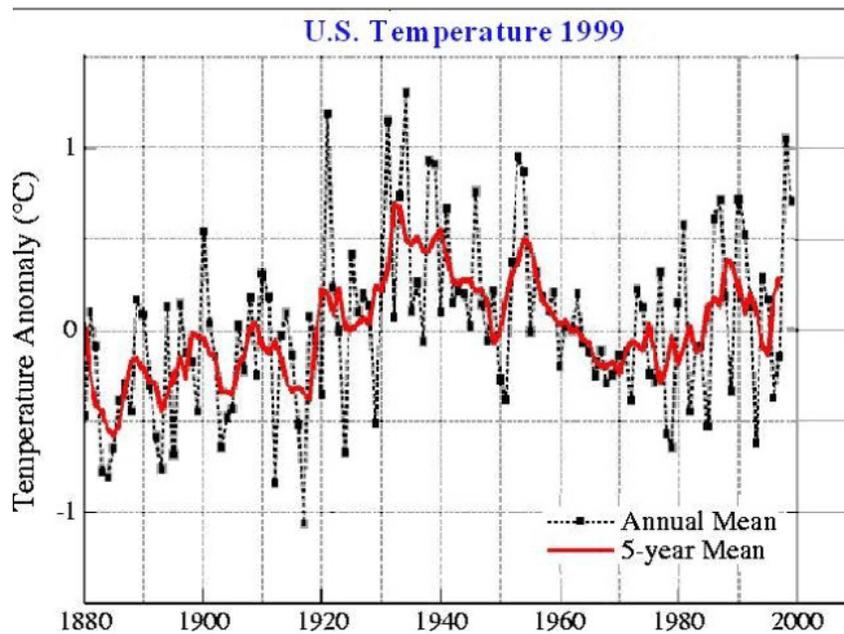


Model Projections

- Climate models project an increase in global temperature of 1.5° – 12° F by the year 2100.
 - This has brought worries about:
 - Increased heat waves
 - Droughts
 - Floods
 - Hurricanes
 - Storminess
 - Habitat loss
 - Etc.....
-

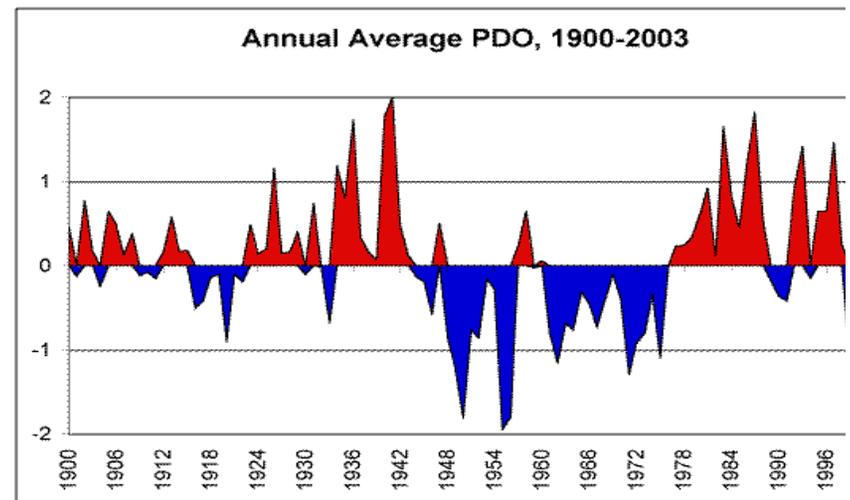
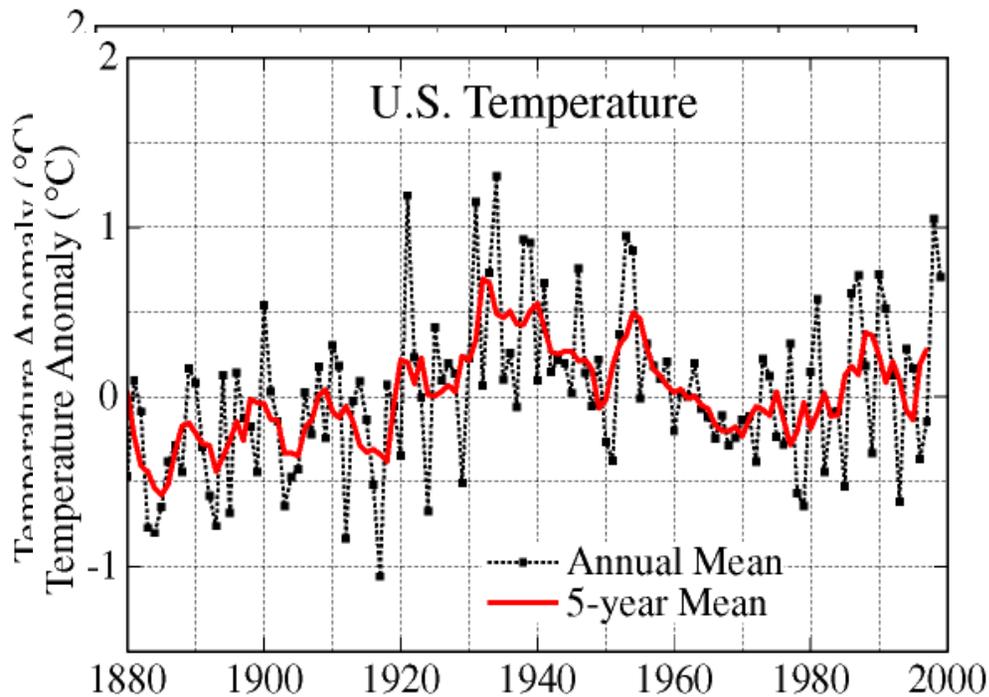
Global Warming: The case against?

- How do skeptics counter? They can show that temperature on various scales correlates to natural phenomenon. We can compare:



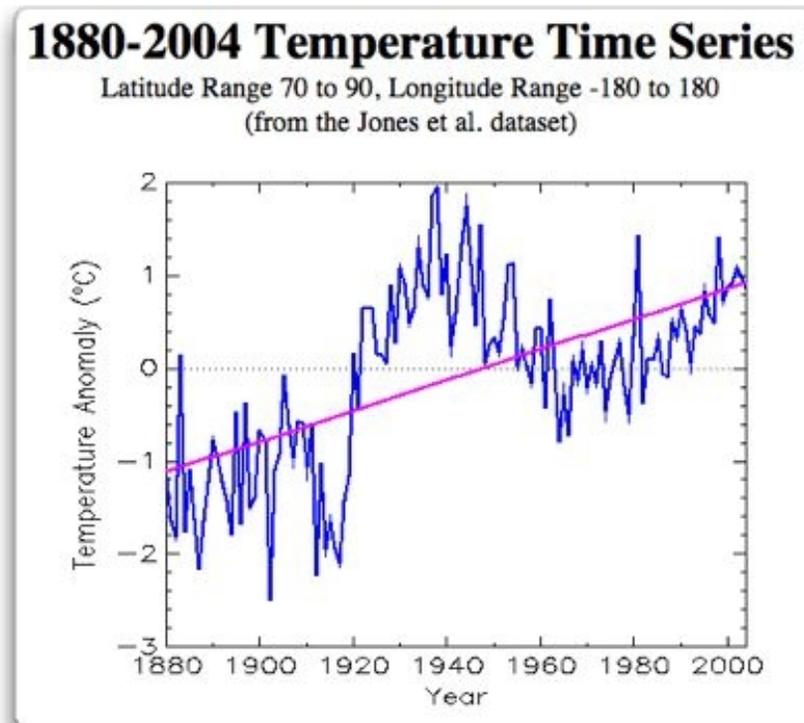
Global Warming: The cast against?

-US temperatures to temperatures in the Pacific region

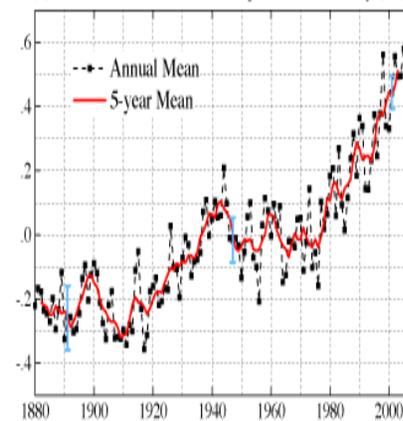


Global Warming: The case against?

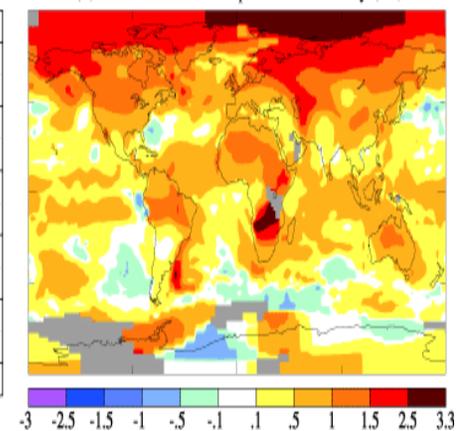
- More evidence? (Correlates to the Pacific Decadal Oscillation)
- (Jones et al. and NASA – GISS lab)



(a) Global-Mean Surface Temperature Anomaly (°C)

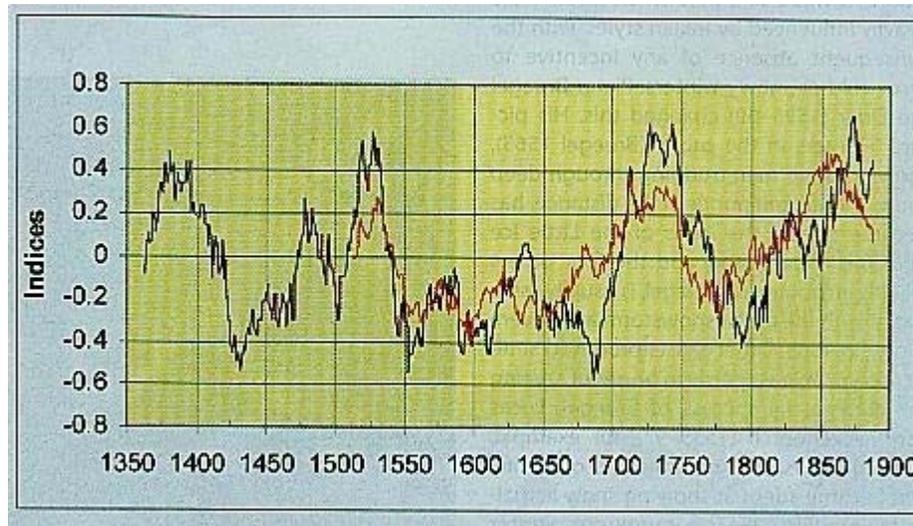


(b) 2005 Surface Temperature Anomaly (°C)



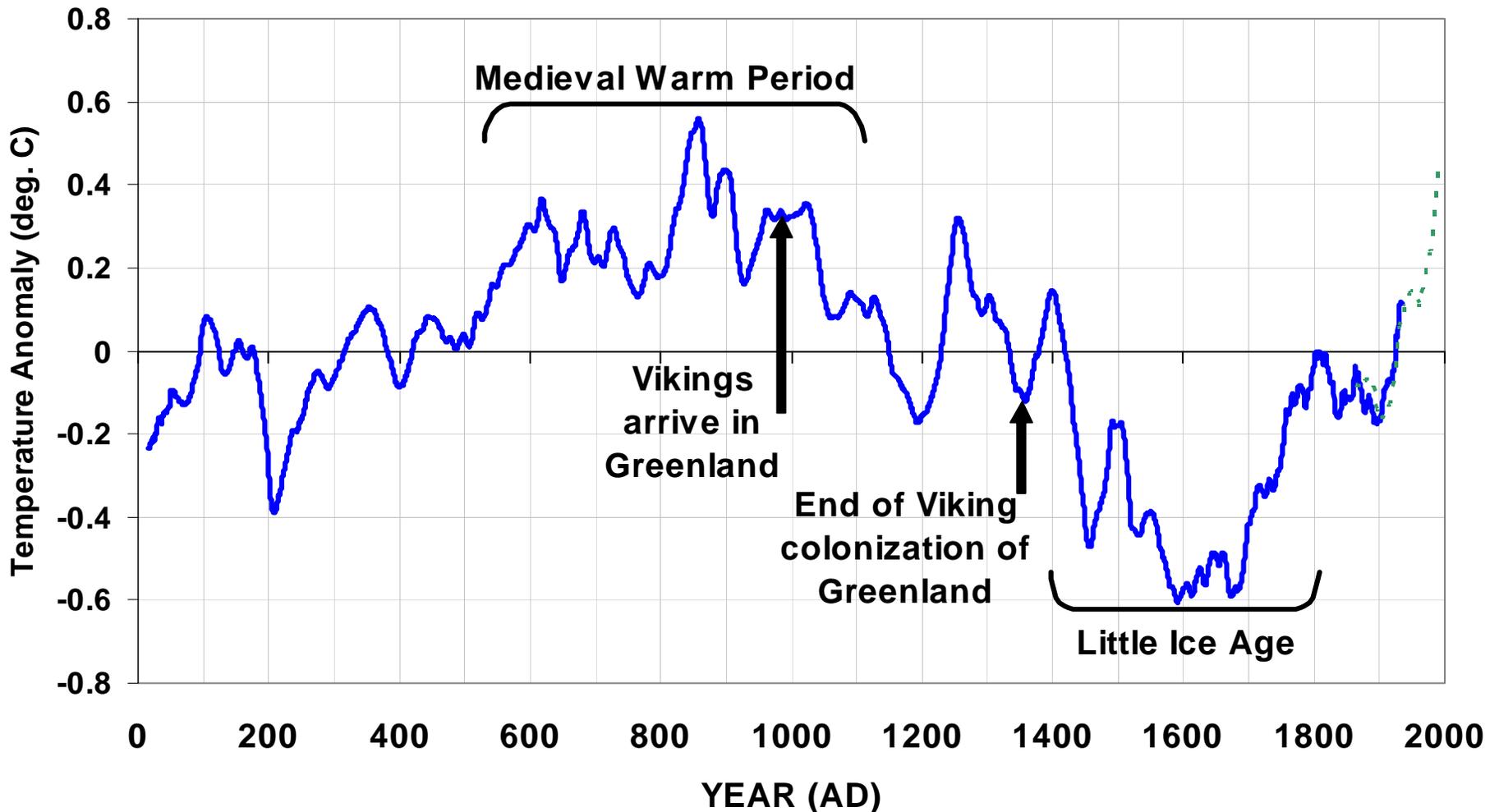
Global Warming: The case against?

- On centuries! (Correlates to the North Atlantic Oscillation)
- (Robinson et al. 2006, Weather)



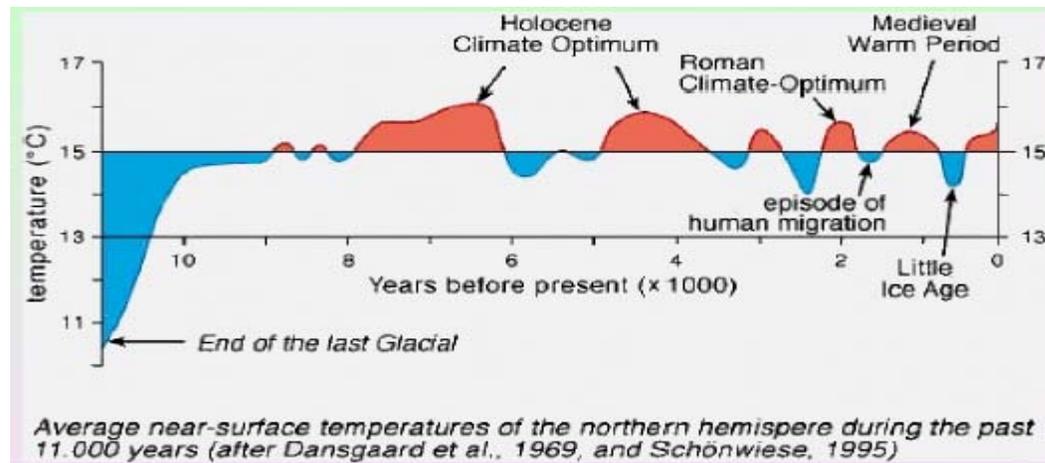
Natural climate variability: (Dr. Roy Spencer, NASA)

~100 Year Periods of Warming and Cooling have been Common Over the Last 2,000 Years. If recent warming is caused by CO₂, then what caused all the other periods Medieval Warm Period of warming and cooling?



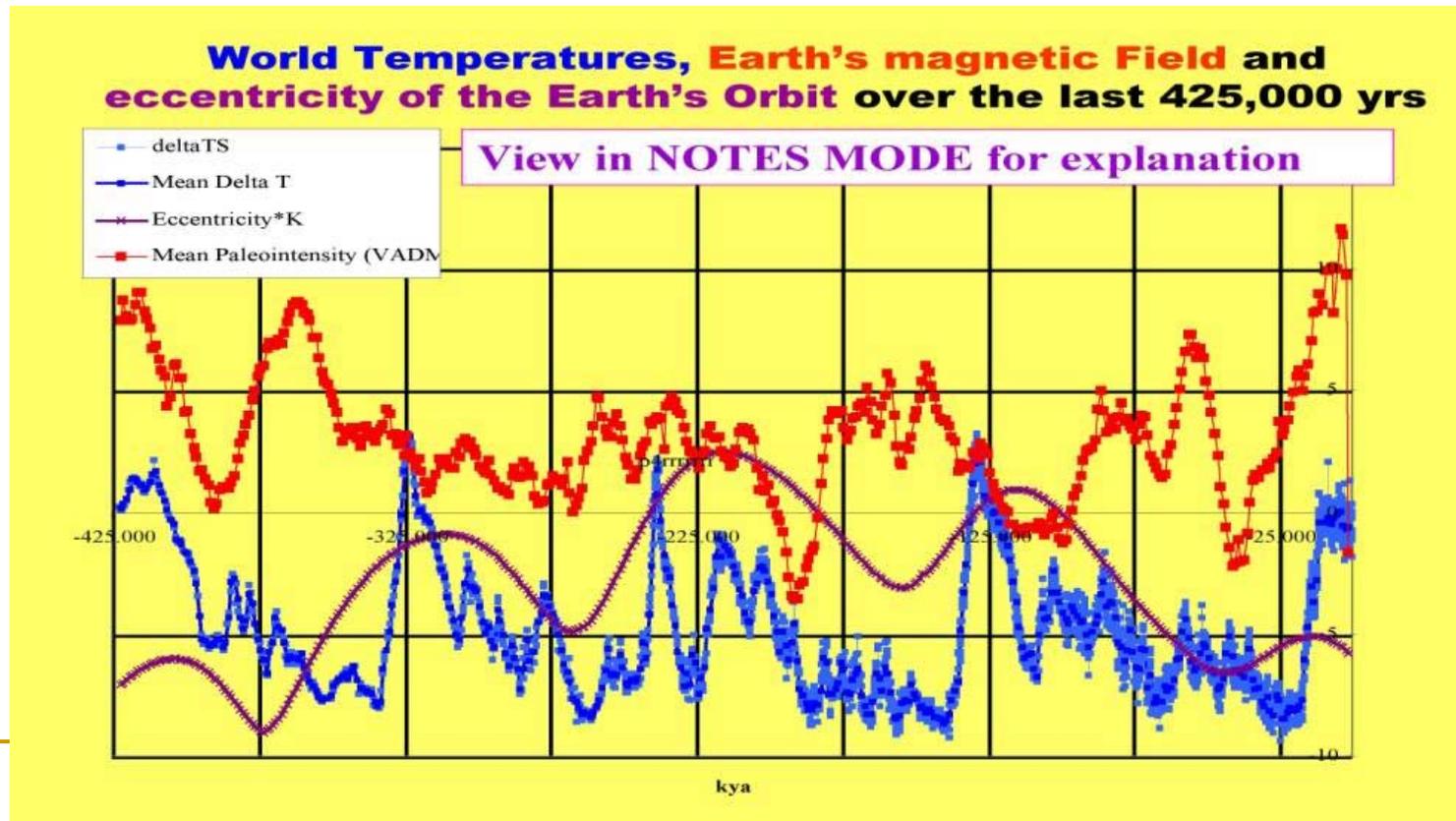
Climate change: The case against?

- And millenia.....



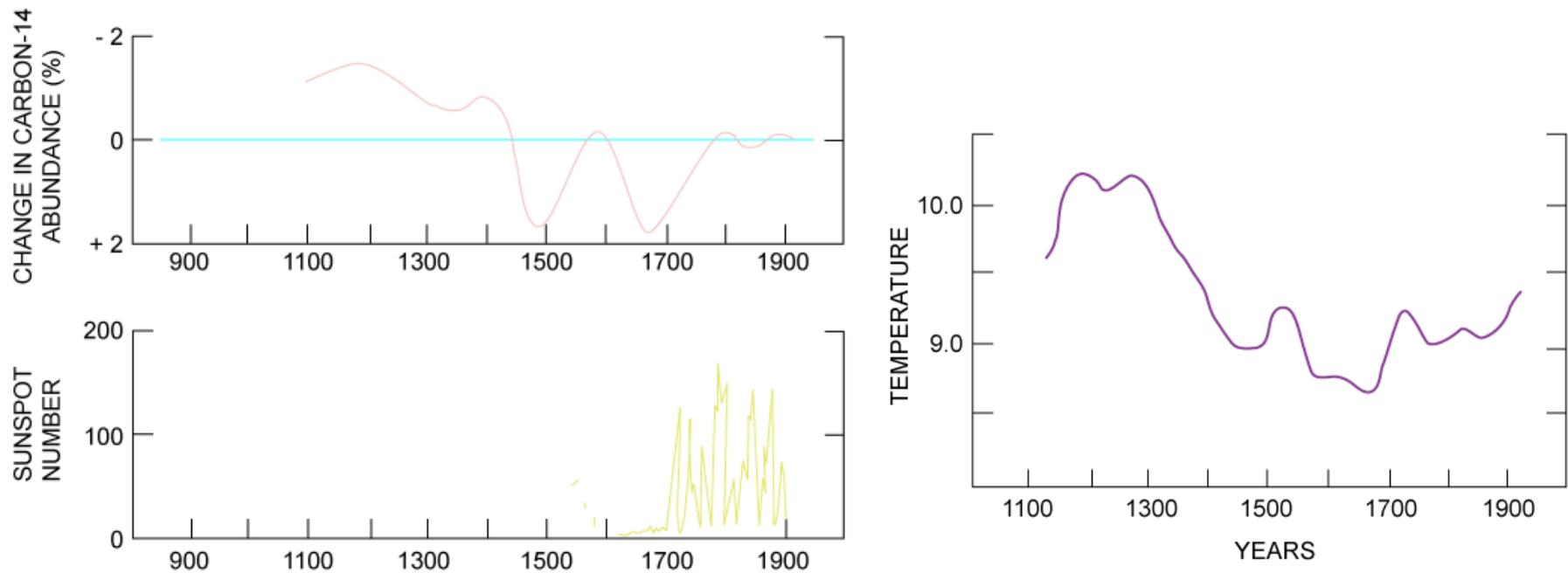
Global Warming: The case against?

- Solar forcing on ice age scales (Climate Skeptics):



Global Warming: The case against?

- Solar activity (Sunspots) (R.D. Tkachuck – Geophysics Research Institute):



Global Warming: The case against?

- Volcanism – scientists have shown that Volcanic forcing tends to cool climate, and the last 150 years have been relatively quiet!
 - Skeptics counter the model results with a barrage of issues.
 - IPCC is able to quantify these climatic influences and estimate their error.
-

Global Warming: The Case Against?

- Models are simply a hypothesis on how we think the atmosphere works. Three main flaws:
 - Incomplete / missing physics (at boundaries / clouds)
 - Numerics are inadequate
 - Observational error / not enough data!
-

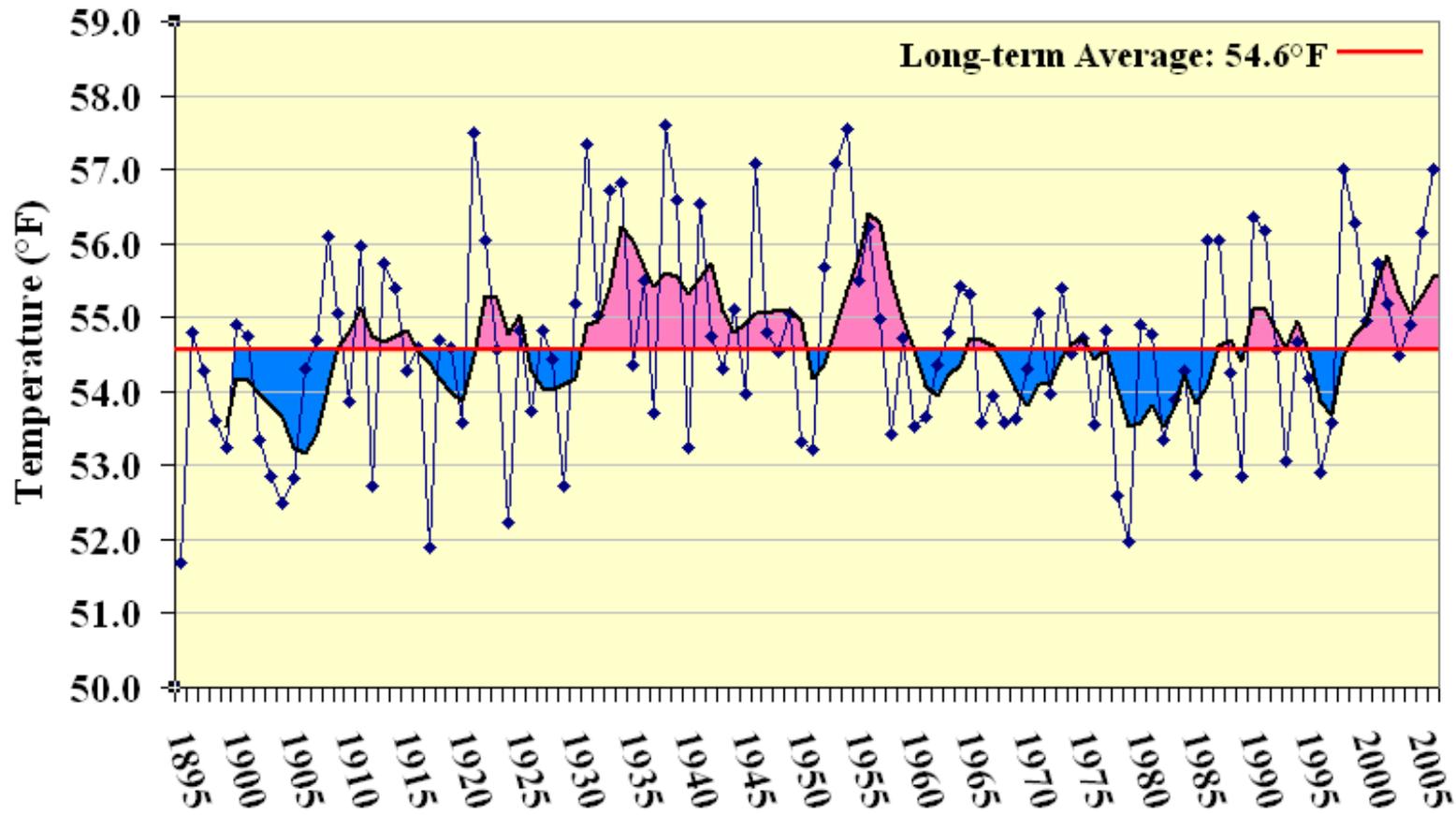
Climate Change: The case against?

- “Planet Climate model!”



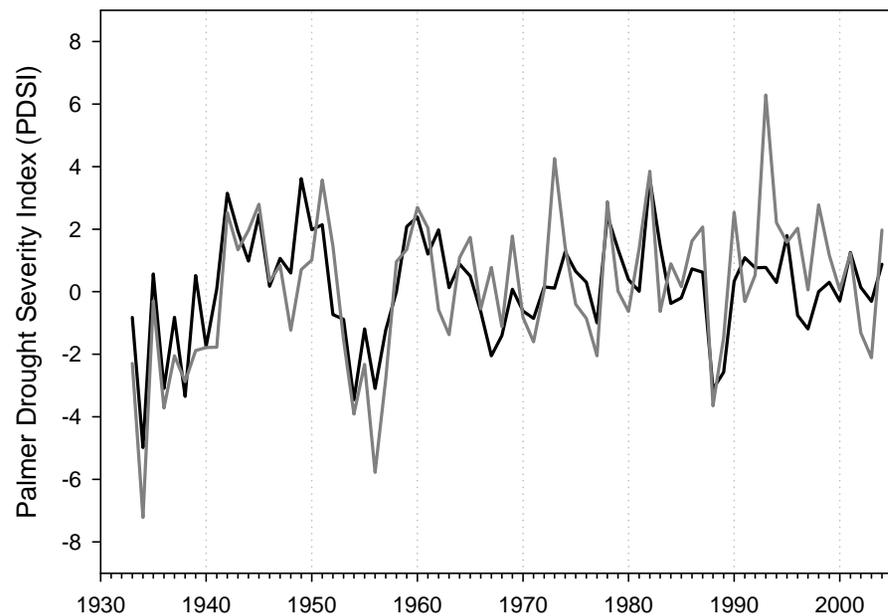
What has been observed?

- In Missouri..... (Missouri Climate Center)



What has been observed?

- Borrowed from the Missouri Tree-Ring Laboratory



Stambaugh, M.C. and R.P. Guyette. (in prep). 1000 years of tree-ring reconstructed drought in the Central United States.

What has been observed?

- Around the world..... (from Bulletin of the AMS)

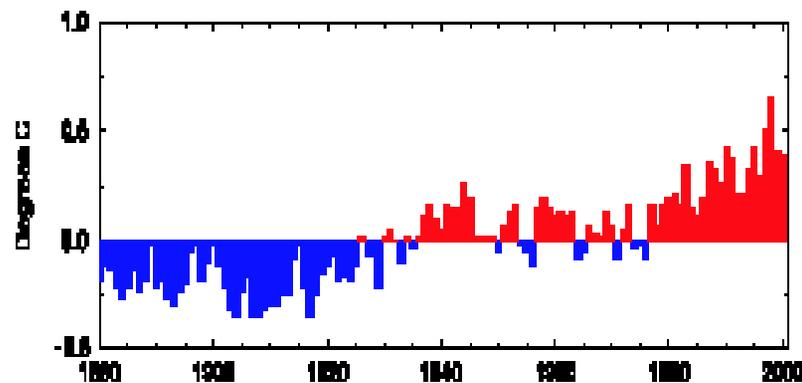


FIG. 8. Global mean annual surface temperature anomalies ($^{\circ}\text{C}$) 1880–2000. Anomalies are departures with respect to an 1880–1999 base period and include both land and sea surface temperature observations.

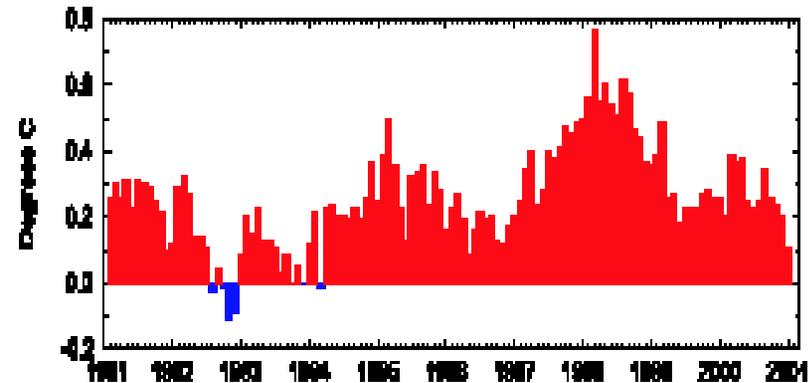
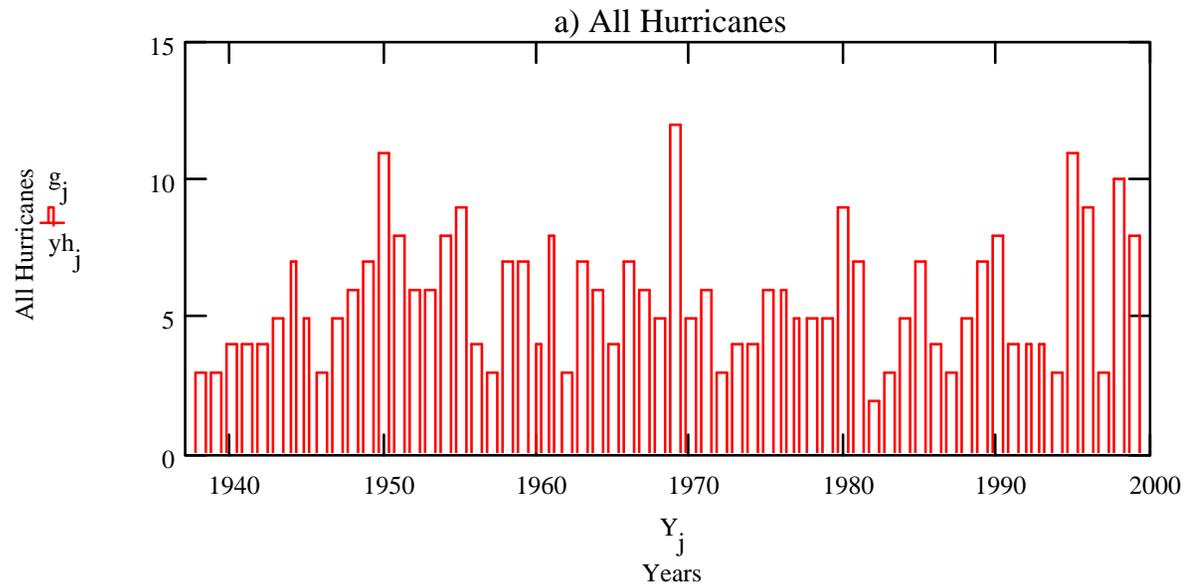


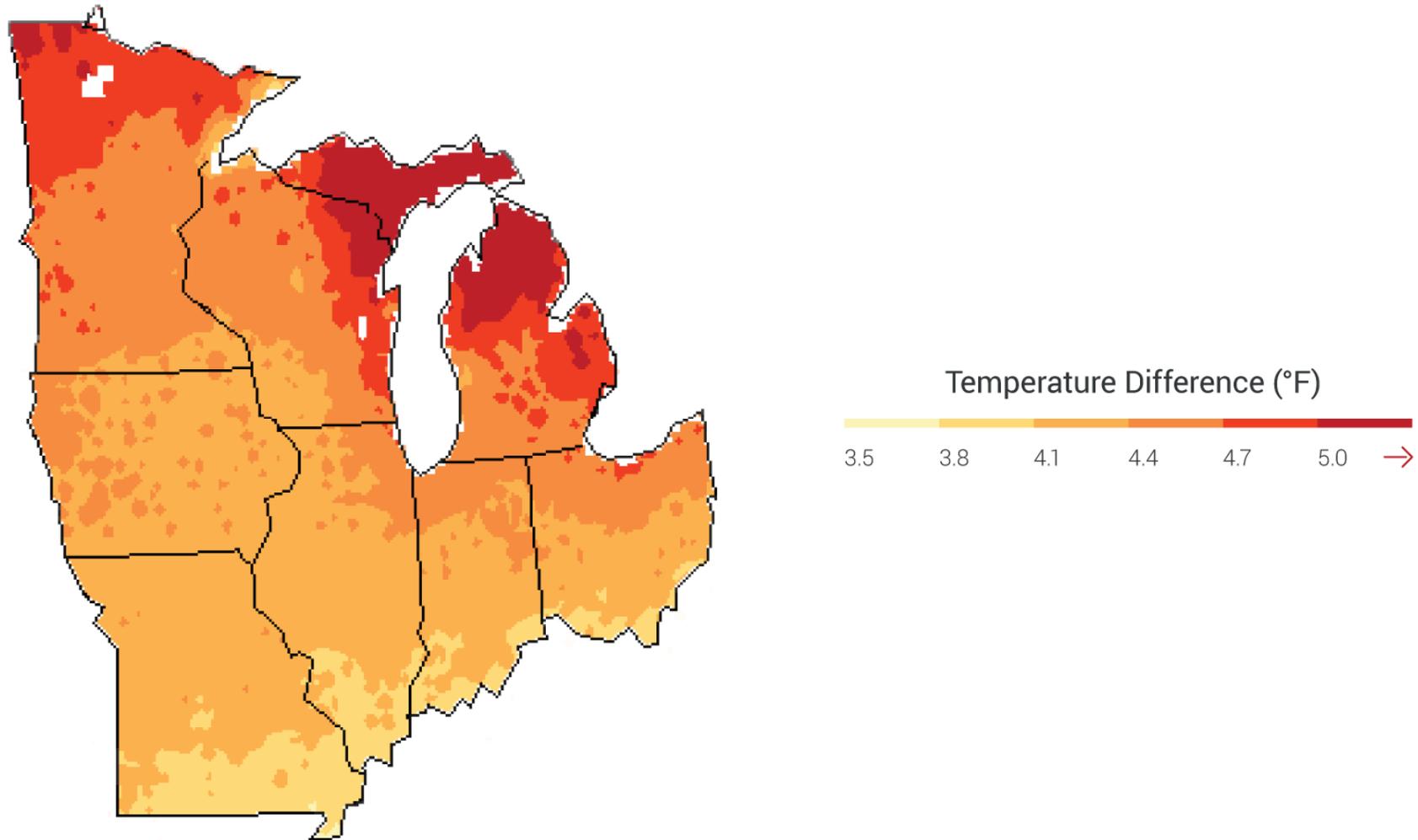
FIG. 9. Global mean monthly surface temperature anomalies ($^{\circ}\text{C}$) 1991–2000. Anomalies are departures from a 1961–90 base period and include both land and sea surface temperature observations.

Climate, Climate Change & Hurricanes

- Is global warming increasing the hurricane numbers?

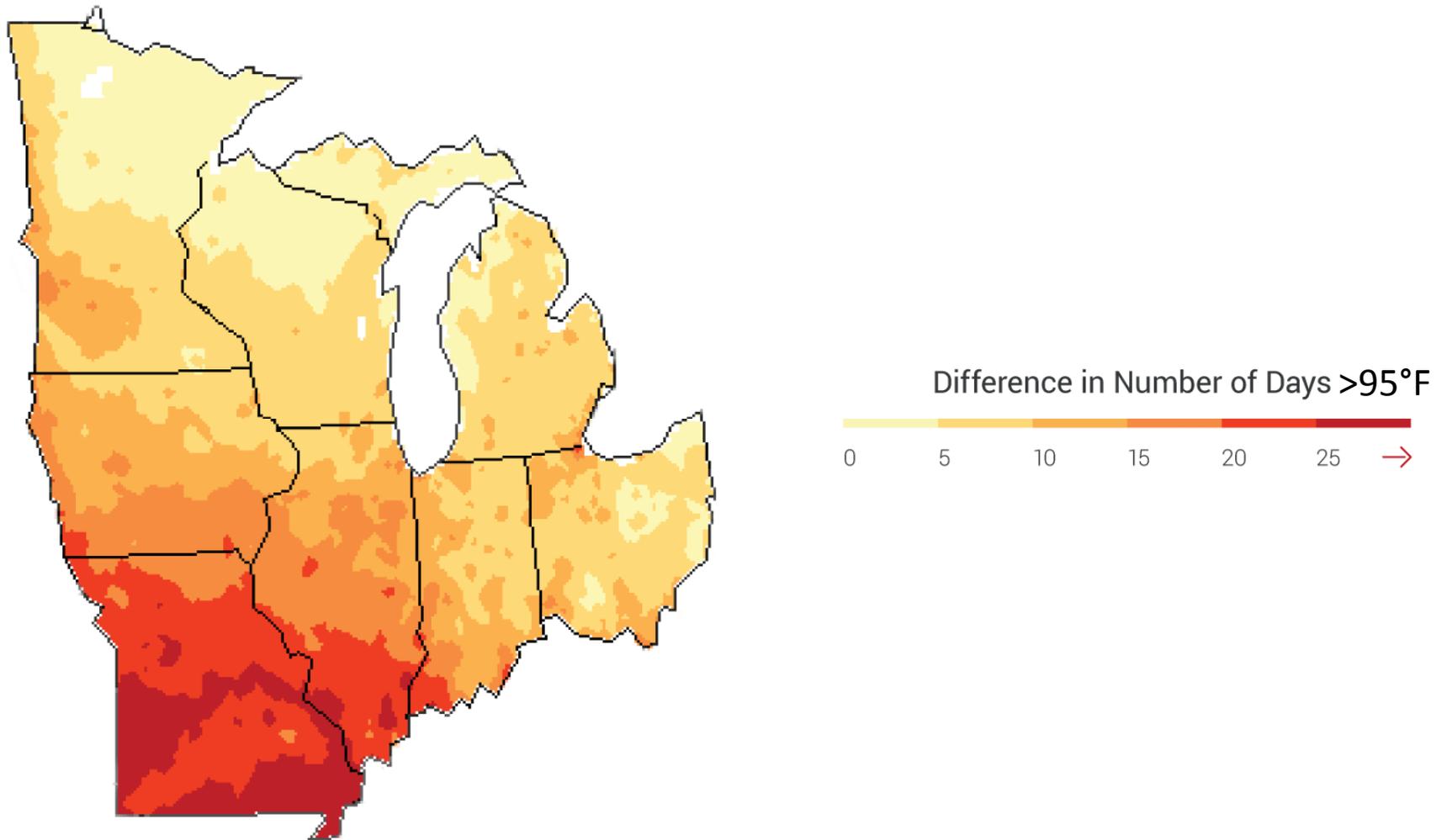


Temperature difference (°F) by 2041-2070*



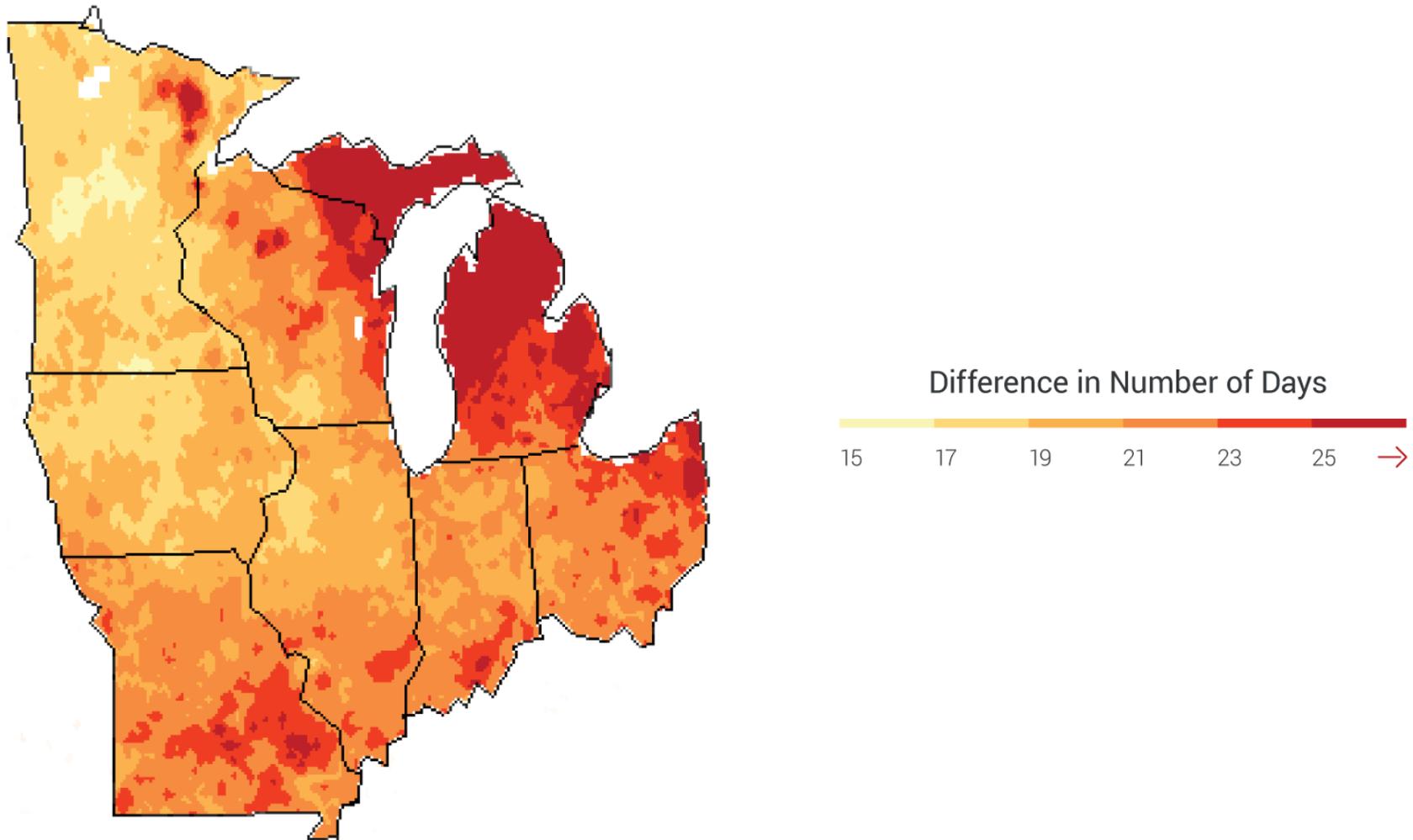
***Compared to 1971-2000 normals and using A2 scenario**

Difference in no. of days above 95°F by 2041-2070*



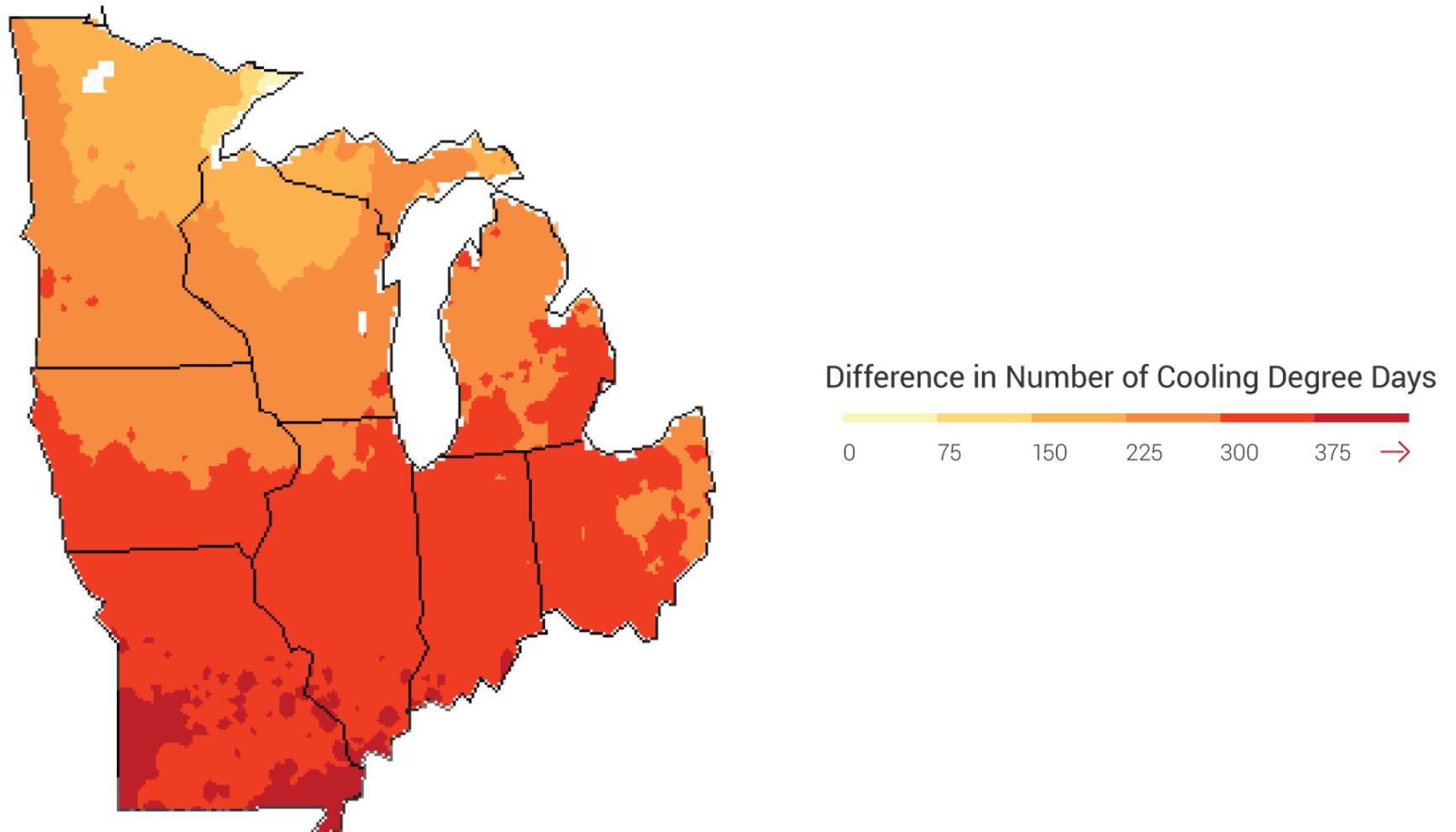
***Compared to 1971-2000 normals and using A2 scenario**

No. of frost free days by 2041-2070*



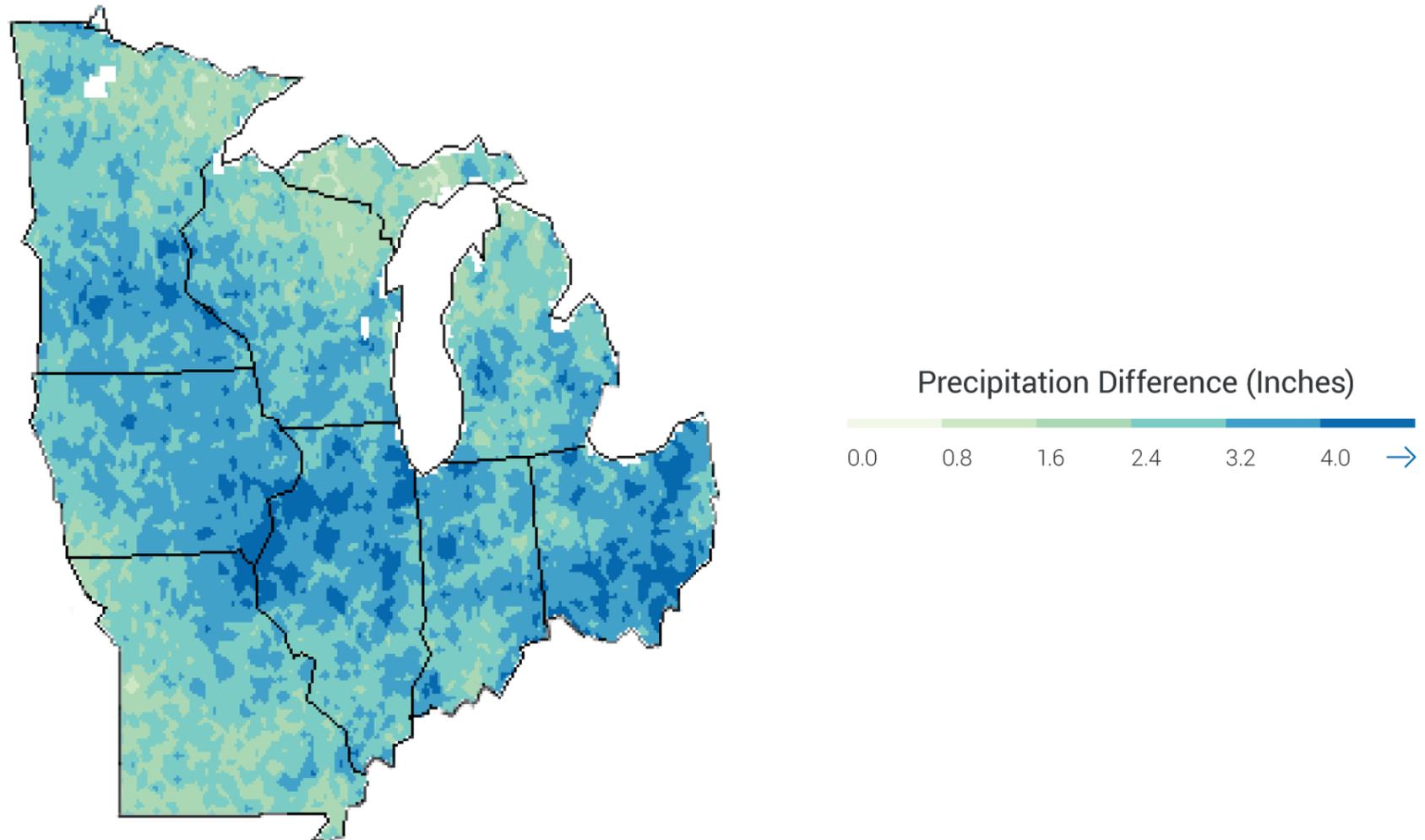
***Compared to 1971-2000 normals and using A2 scenario**

Difference in no. of cooling degree days by 2041-2070*



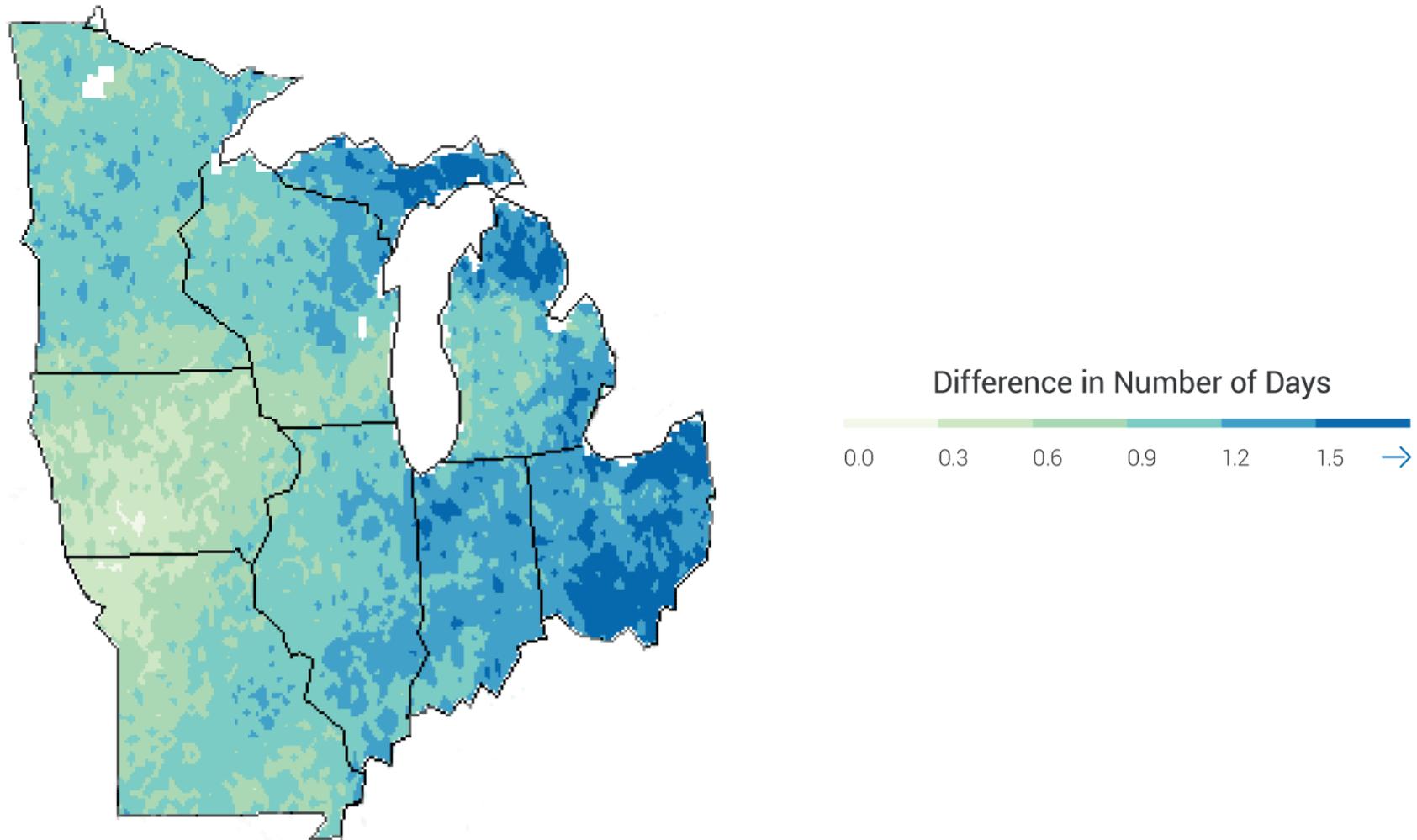
***Compared to 1971-2000 normals and using A2 scenario**

Precipitation difference (inches) by 2041-2070*



***Compared to 1971-2000 normals and using A2 scenario**

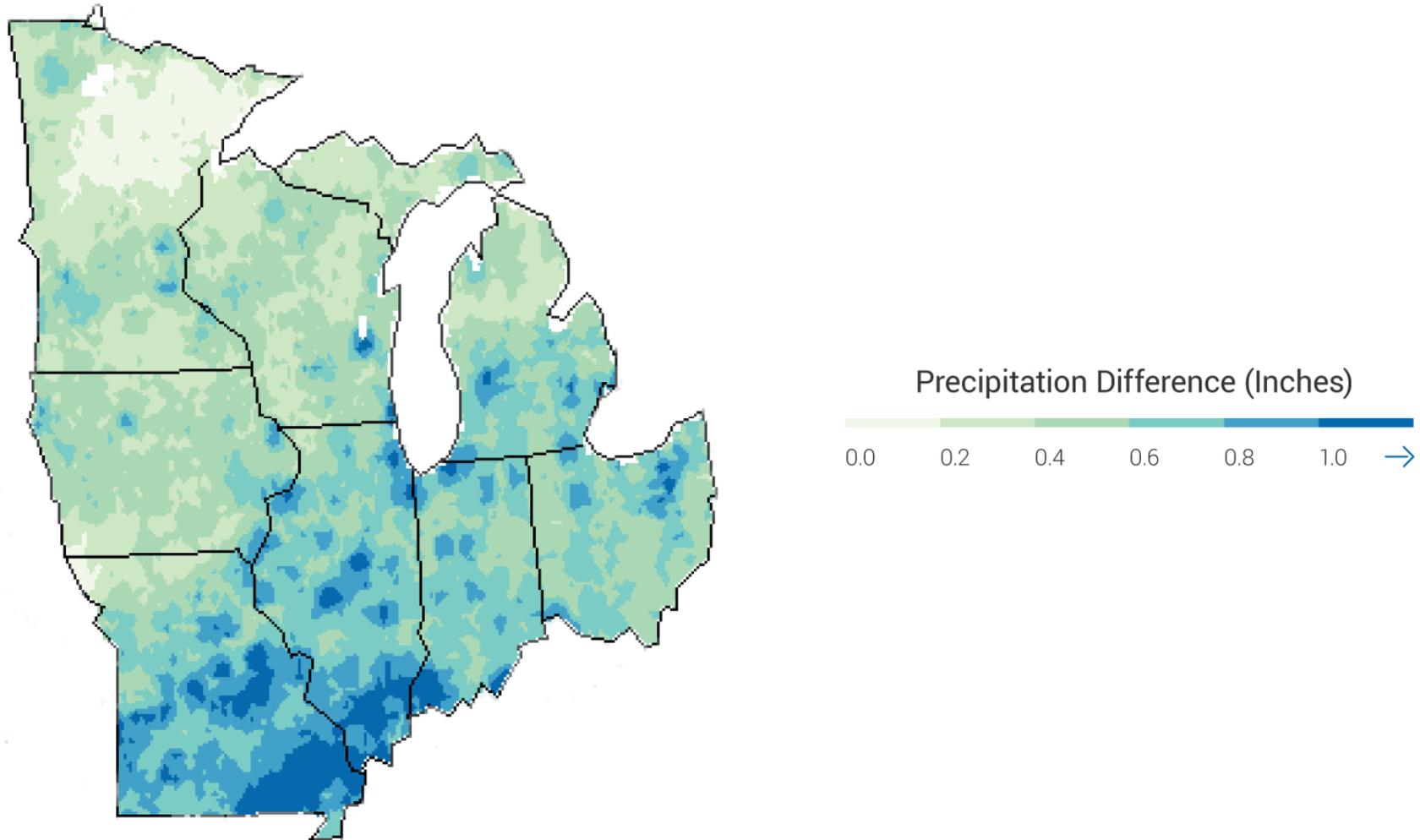
Difference in no. of days with heavy precip* by 2041-2070**



***Top 2% of all rainfalls each year**

****Compared to 1971-2000 normals and using A2 scenario**

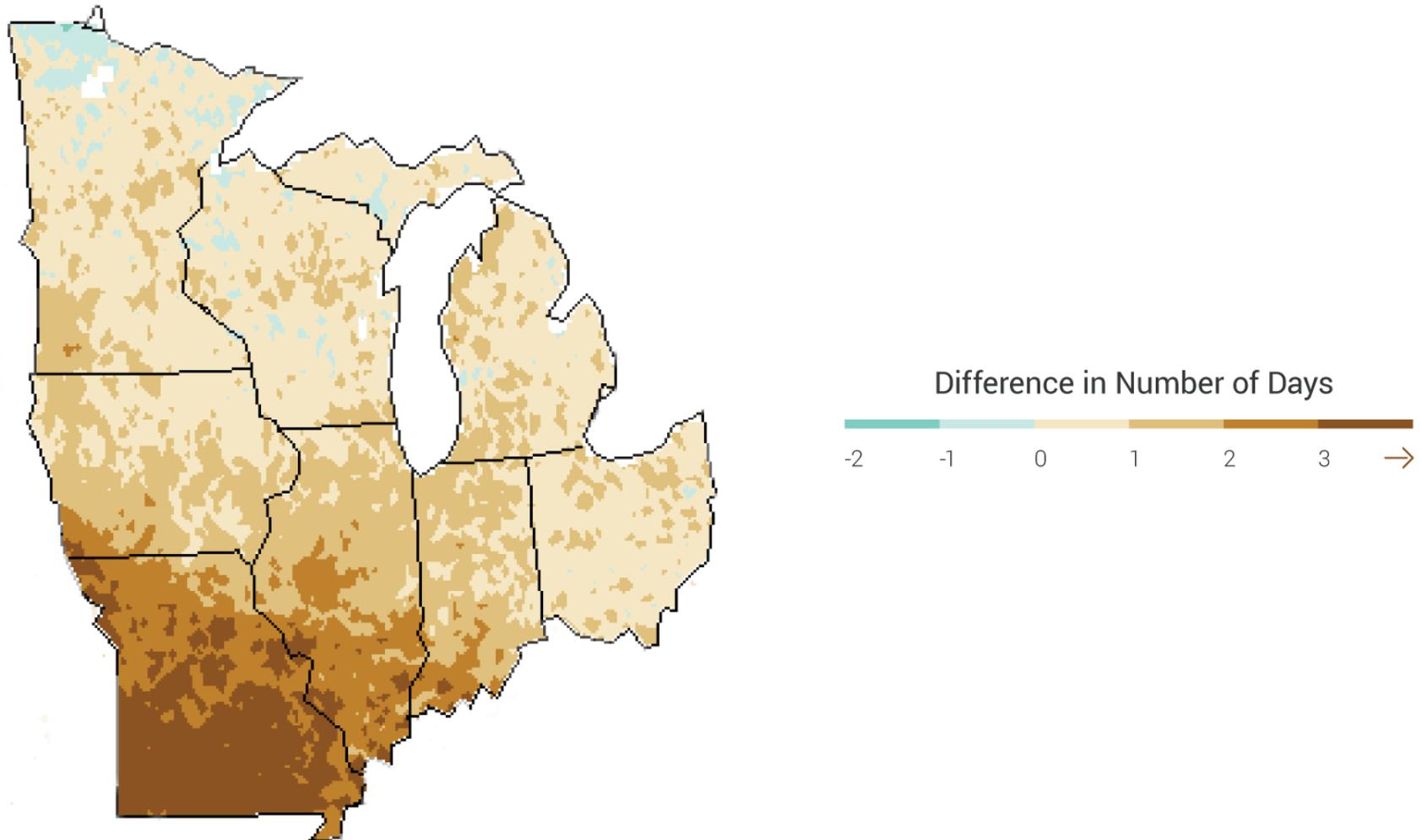
Wettest 5-day total* by 2041-2070**



* Increases in the amount of rain falling in the wettest 5-day period over a year

** Compared to 1971-2000 normals and using A2 scenario

Change in the average maximum number of consecutive days each year with less than 0.01 inches of precipitation by 2041-2070*



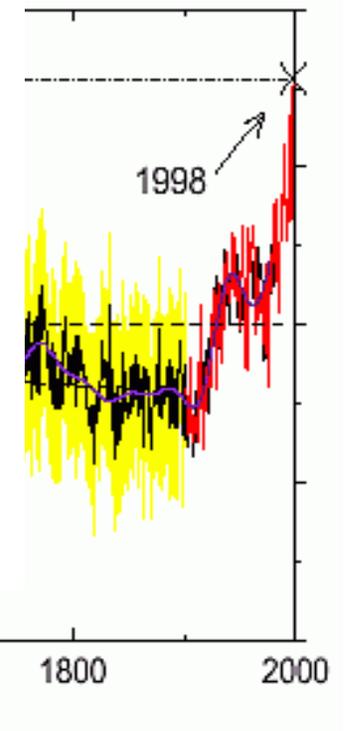
***Compared to 1971-2000 normals and using A2 scenario**

Climate Change: Global warming

- Recent contributions (1998)



to
et al.



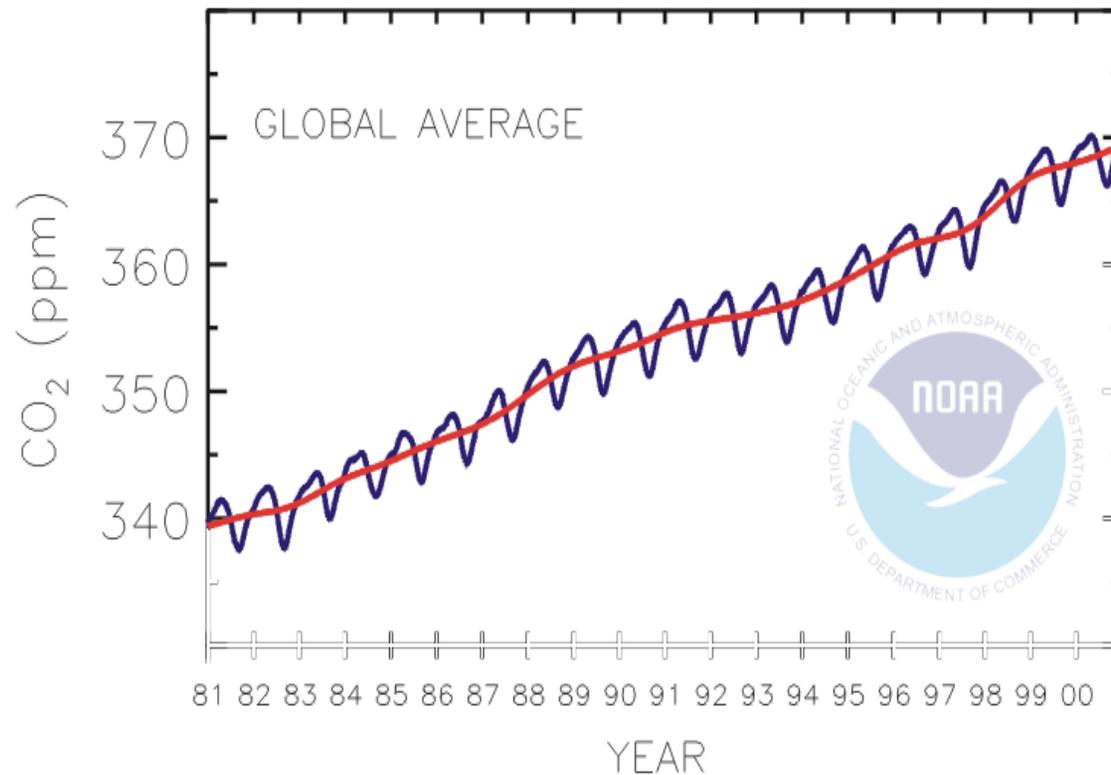
Global Warming

- Global warming as we use it here, means the contribution of humankind to the increase in carbon dioxide.
 - Sometimes called the “greenhouse effect”, but there is a natural “greenhouse effect”, so we’ll save this term of “nature’s contribution”.
-

Global Warming

- Can humans impact the climate?

Carbon Dioxide Measurements
NOAA CMDL Carbon Cycle Greenhouse Gases



Global Warming

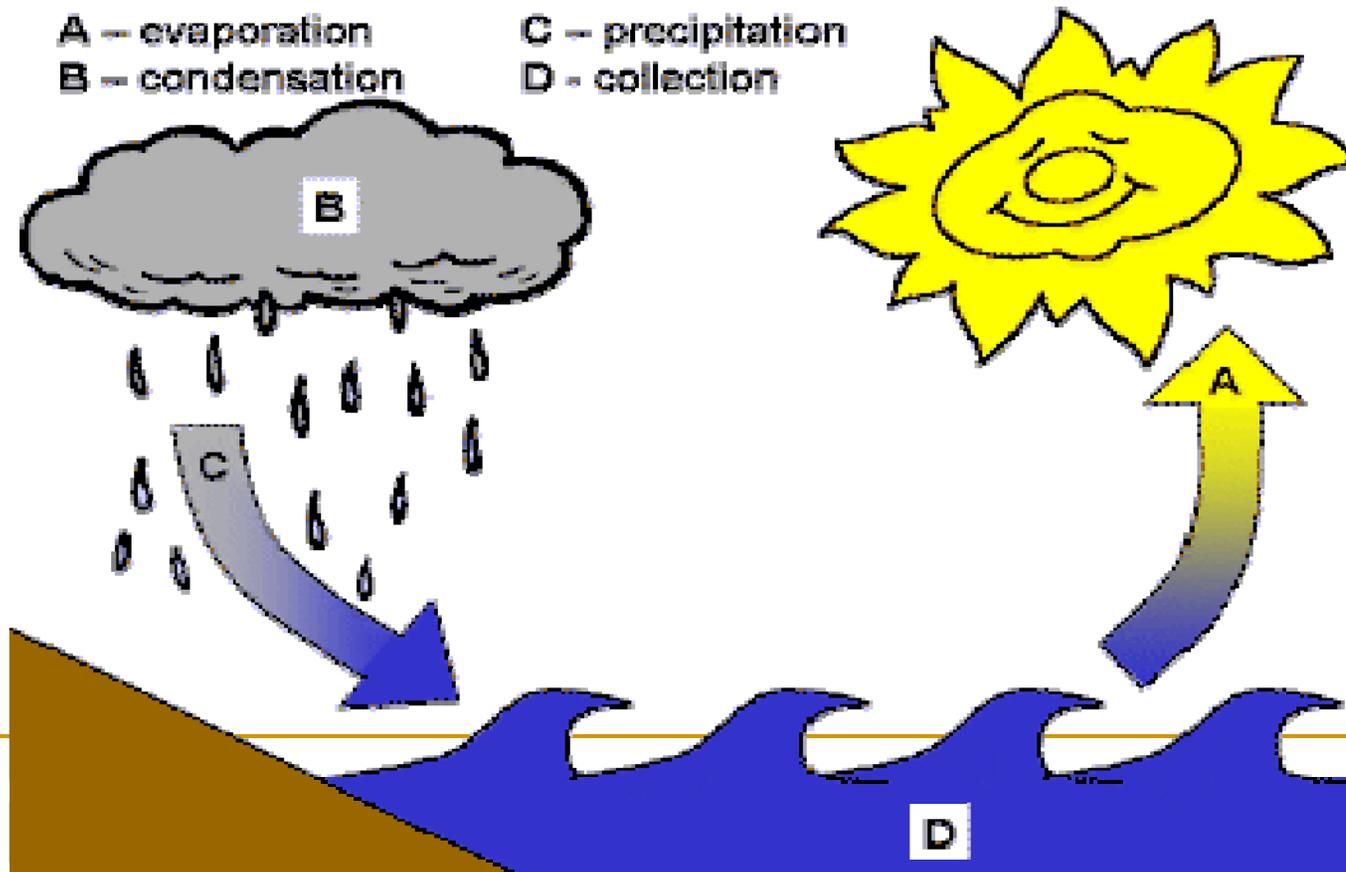
- The answer, I believe, is yes we can, but our contribution is small.
 - Global temperatures since 1860 have risen 0.6 – 1.2 degrees Fahrenheit. The margin of error is 0 – 0.5 degrees.
 - Maybe the temperatures have not risen?
(Only a small few doubt this)
-

Global Warming

- What keeps the planet warm?
 - Greenhouse gasses, such as water vapour and Carbon Dioxide trap heat in our atmosphere. Without these, earth's climate would be darn cold!
-

Global Warming

- We understand the water cycle
<http://www.kidzone.ws/water/>.



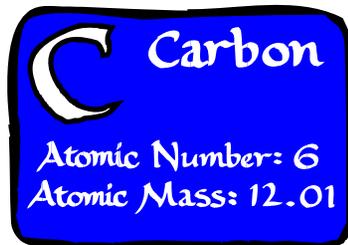
Global Warming

- Water vapor is the most potent greenhouse gas, many times more potent than Carbon dioxide

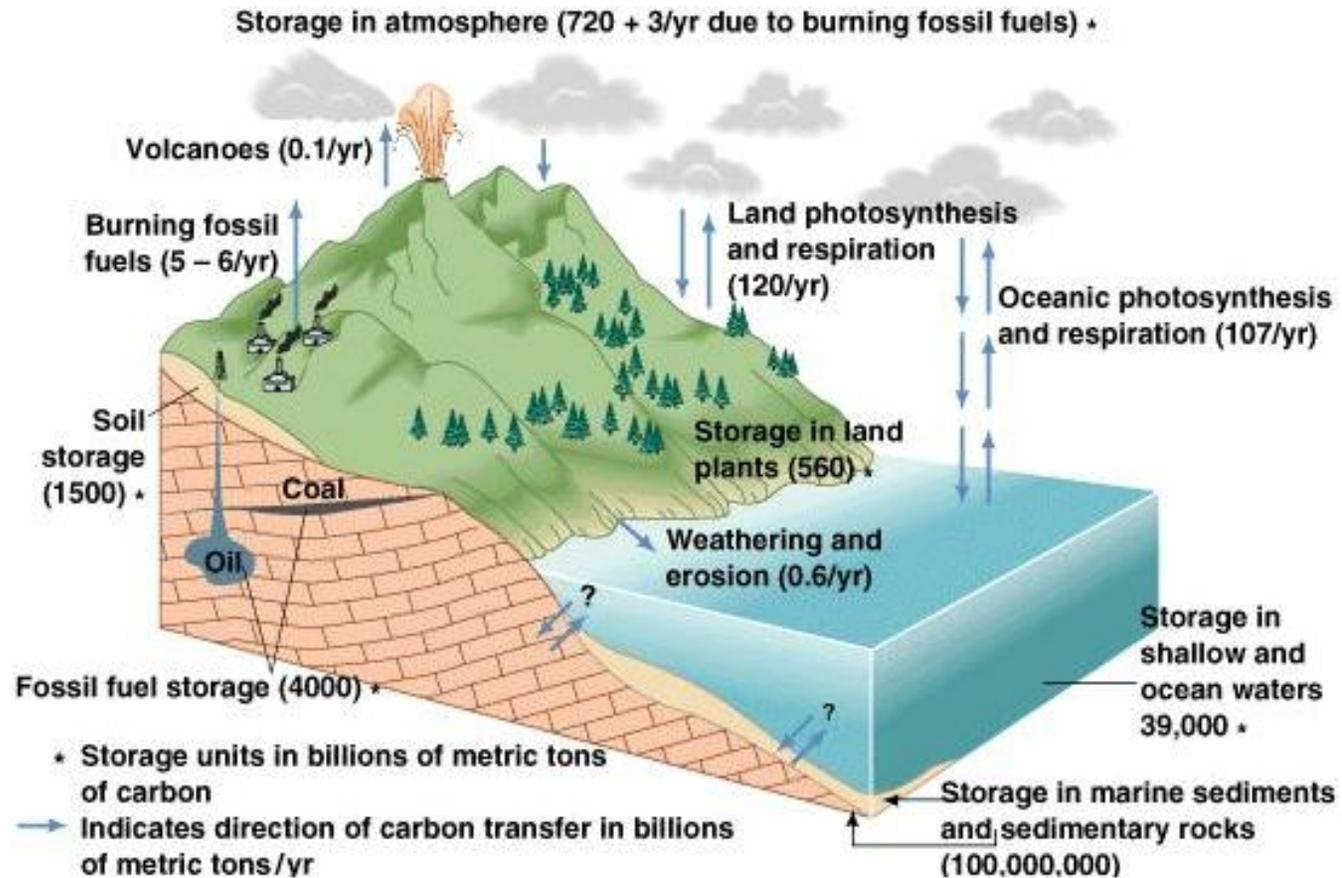
 - Water vapor is the real issue, but we don't understand what the future holds.....
-

Global Warming

- We don't understand future water vapor concentrations or the future distribution of cloudiness.

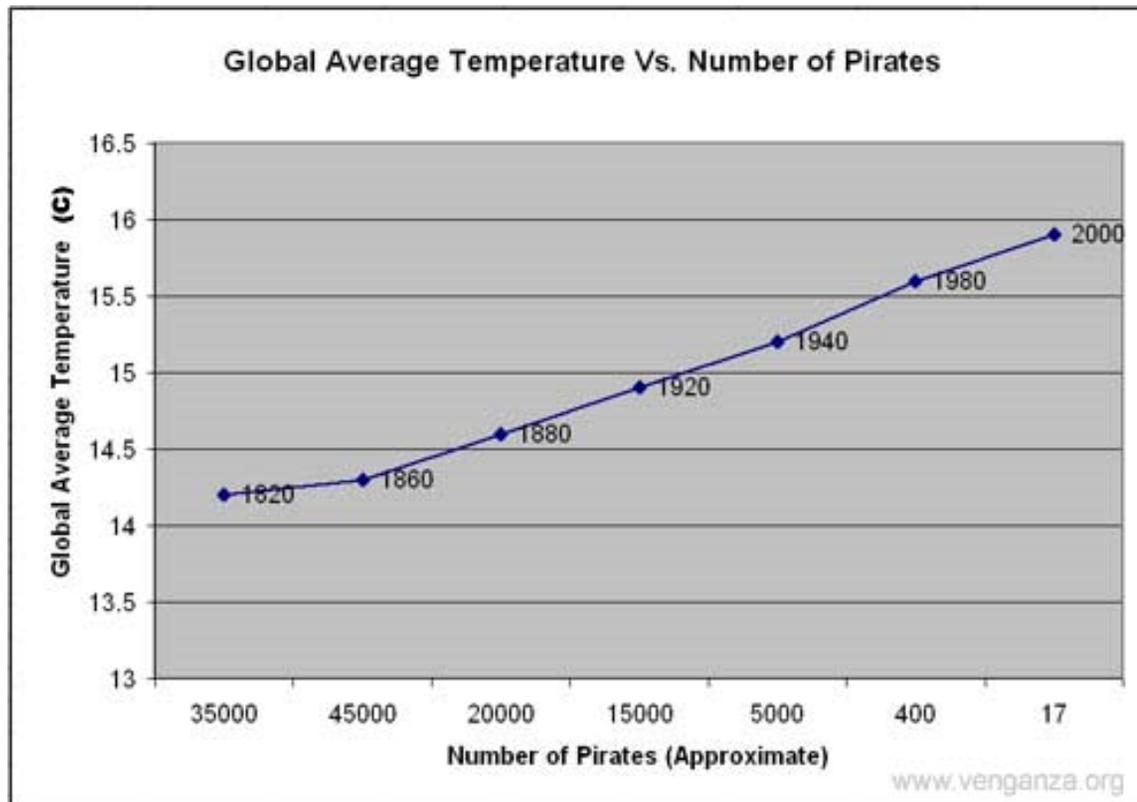


- Nor do we understand completely the Carbon Cycle! (But improvements are being made)
-



What can we do about climate change?

- A facetious solution..... (become a pirate!)



What can we do about climate change?

- If you believe in a significant anthropogenic component.....
- We can do plenty!
(conservation, and
Policy-wise)



What can we do about climate change?

- If you believe that nature is driving climate change in large measure.....
 - We can do nothing!
 - However, I believe we need to be good stewards
-

Let's wrap it up

- Global warming

- Yes, climate is warming
 - possibly humans are contributing, but to what degree?
 - there are many things about the climate still not understood.
 - what should we do about it?
-

Global Warming: Attribution

- Let the commentary and discussion begin!



Global Warming: Attribution

- Questions?
 - Comments?
 - Criticisms?
-

Global Warming: Attribution

- The End!

