https://www.youtube.com/watch?v=5t08CLczdK4

A Song of Our Warming Planet

Climate Change and Variability

John Harrington Jr.

jharrin@ksu.edu

Geography


RL
KANSAS
JUN
11
KANSAS
2136991
CLIMATE
AMERICA'S HEARTLAND

Climate Change and Energy: Basic Science, Impacts, and Mitigation

More than 60 Kansas scientists are collaborating on the *Climate Change and Renewable Energy* initiative, a massive research endeavor that has the potential to significantly affect the Kansas economy.

Climate Change Education Partnership Program

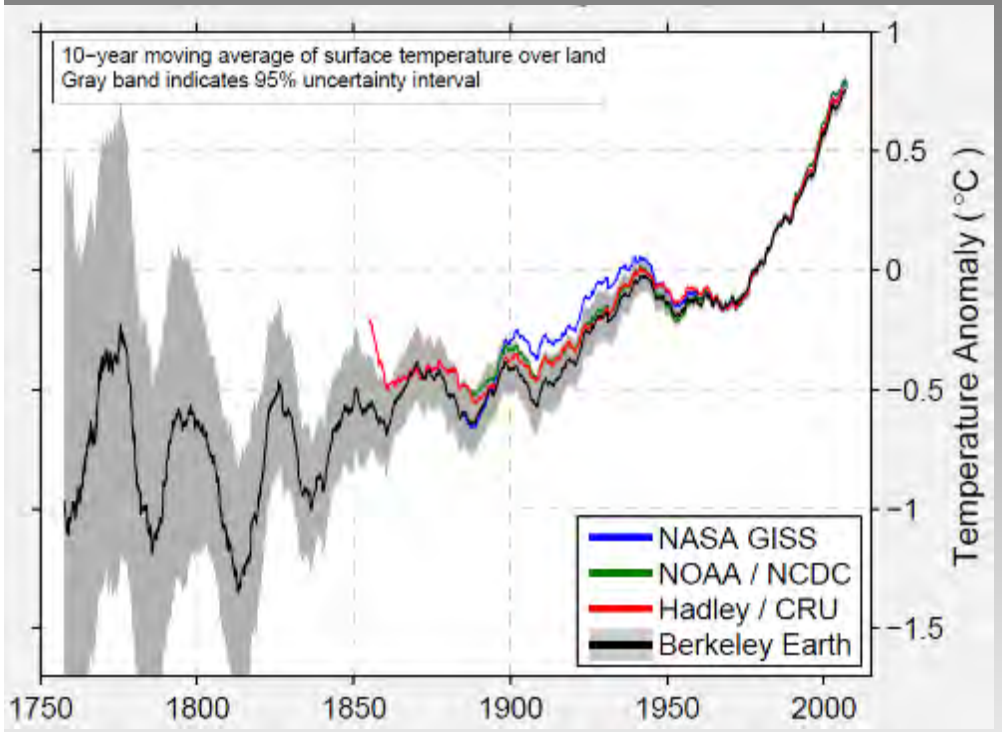
Increasing the adoption of effective, high quality educational programs and resources related to the science of climate change and its impacts.

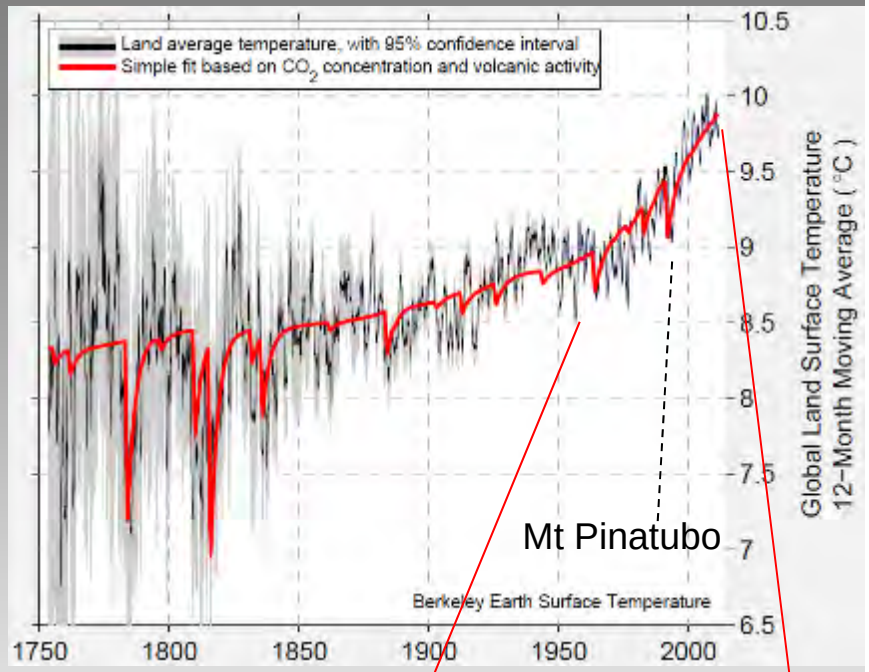
CCEP-I: Central Great Plains Climate Change Education Partnership

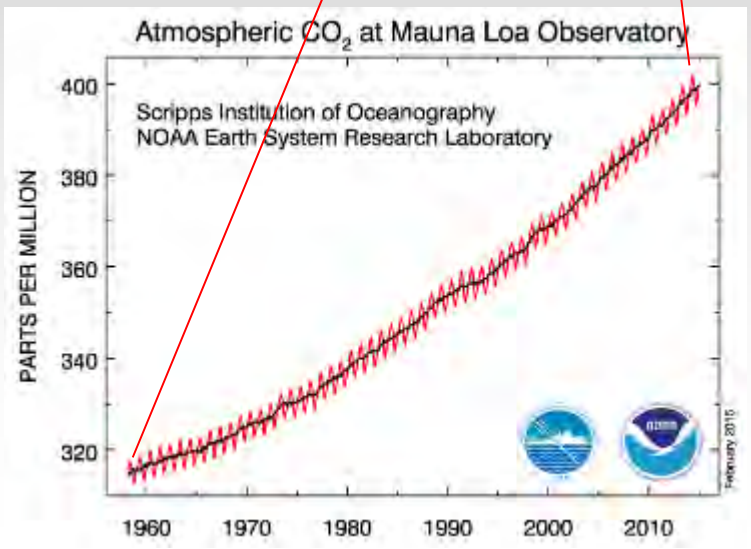
Ben Champion, Kansas State University - Enhance climate science education in agricultural and rural communities in the Great Plains

1 of 15 awards nationwide

Are the numbers changing?







Let's go into the Lion's Den

The findings from a Koch Bros funded study by the Berkeley Earth Surface Temperature (BEST) group

The planet is warming and it is driven by CO_2
Also - modulated with short-term volcanic cooling

Big ideas for this morning:

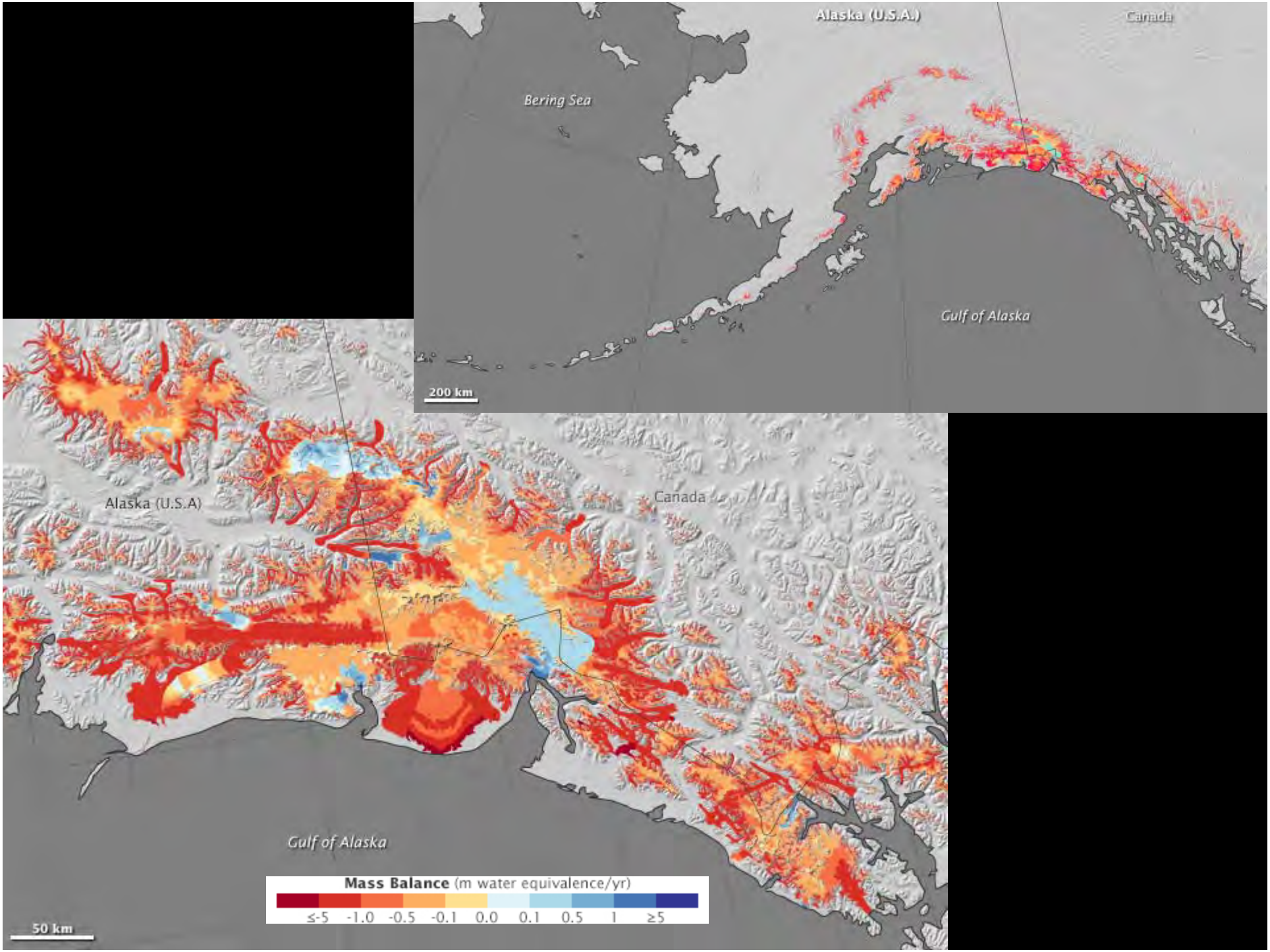
- Evidence of change
- Doubt/denial and the nature of science
- To understand what climate is (includes climate science and climate change)
- To understand some of the physics supporting a changing atmospheric/climate system

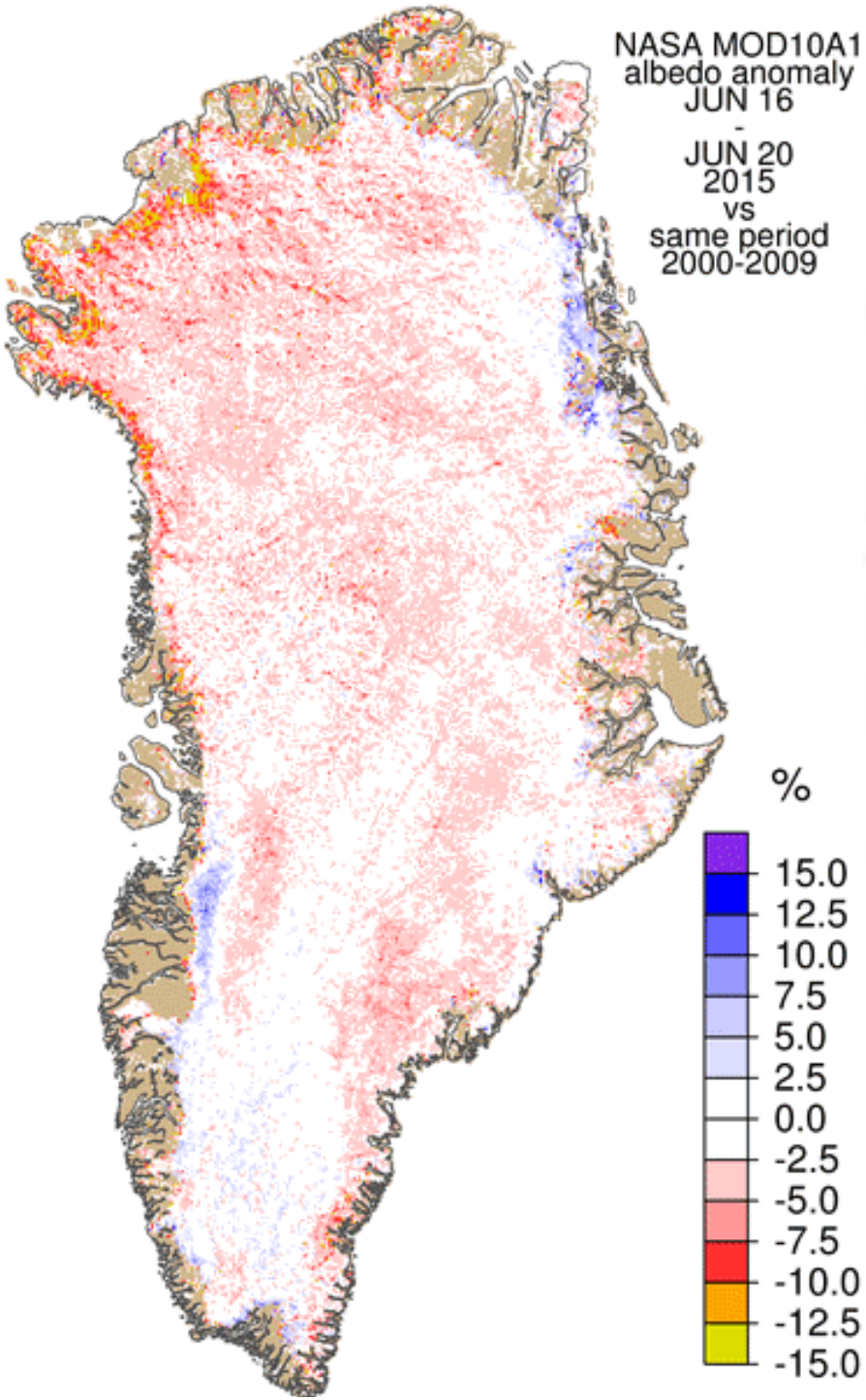
1941

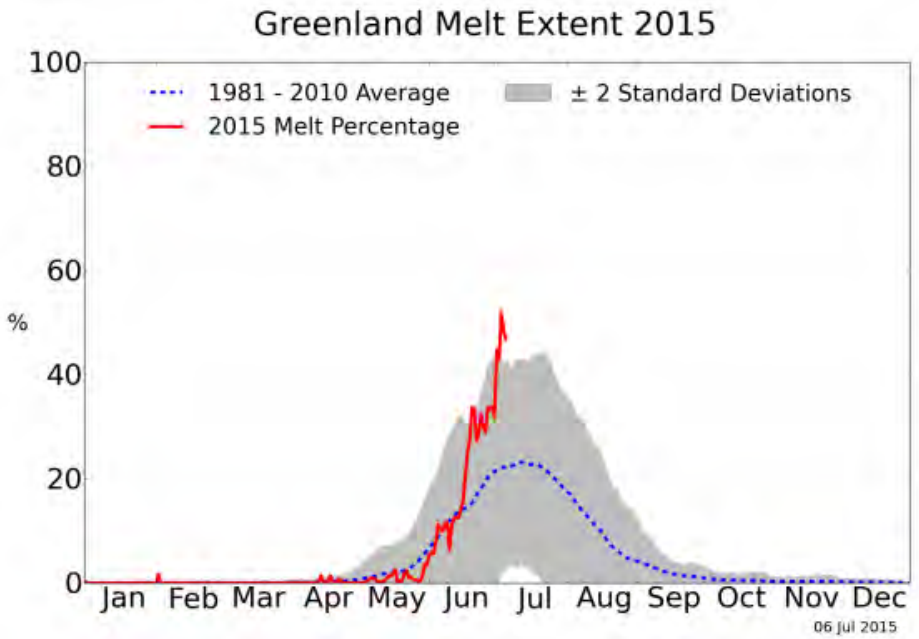
Glacier Bay
Alaska

2004

Columbia Glacier, Alaska

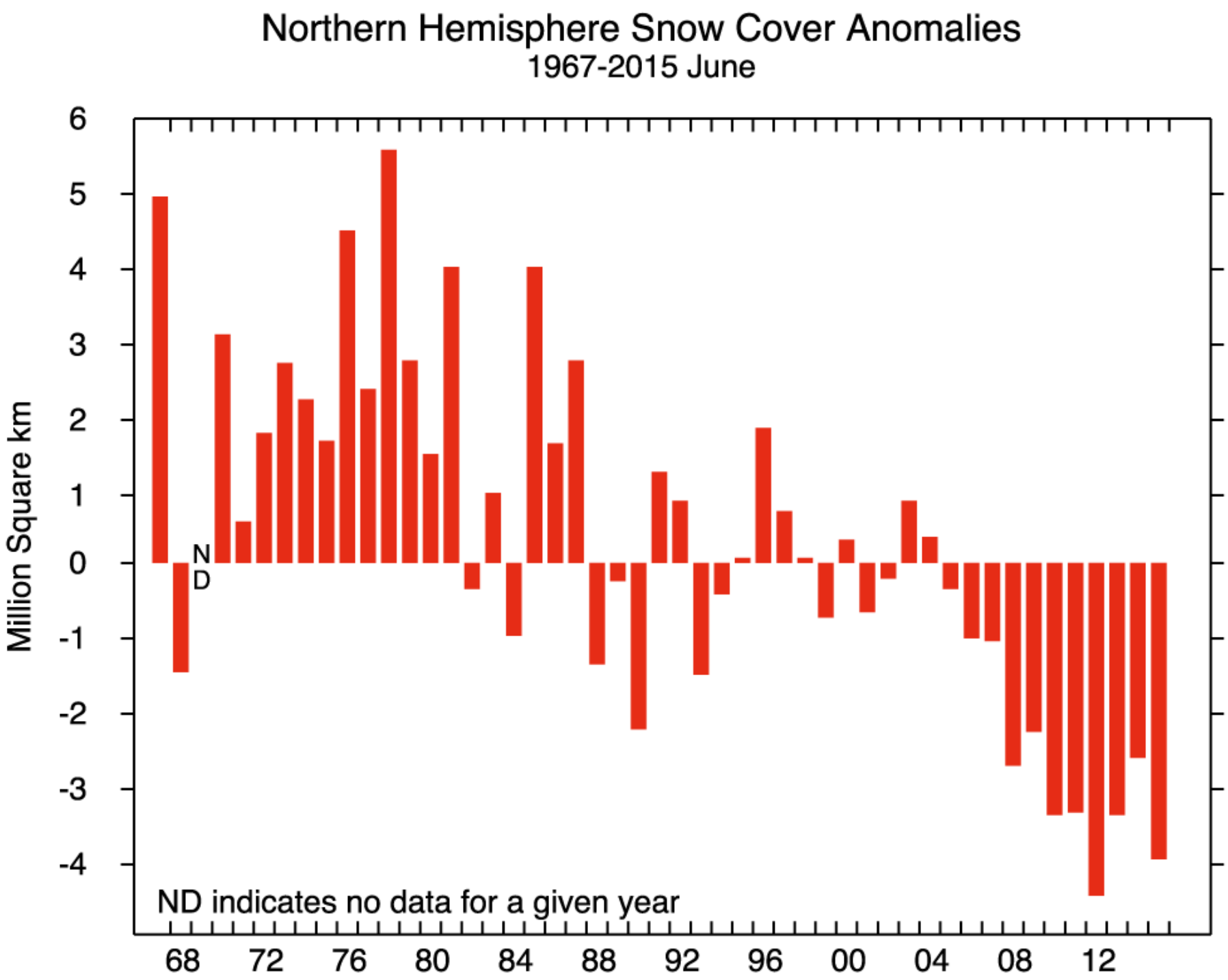

Alaska (U.S.A.)
Canada
Bering Sea
Gulf of Alaska
200 km
Alaska (U.S.A)
Canada
Gulf of Alaska
Mass Balance (m water equivalence/yr)
≤-5 -1.0 -0.5 -0.1 0.0 0.1 0.5 1 ≥5
50 km

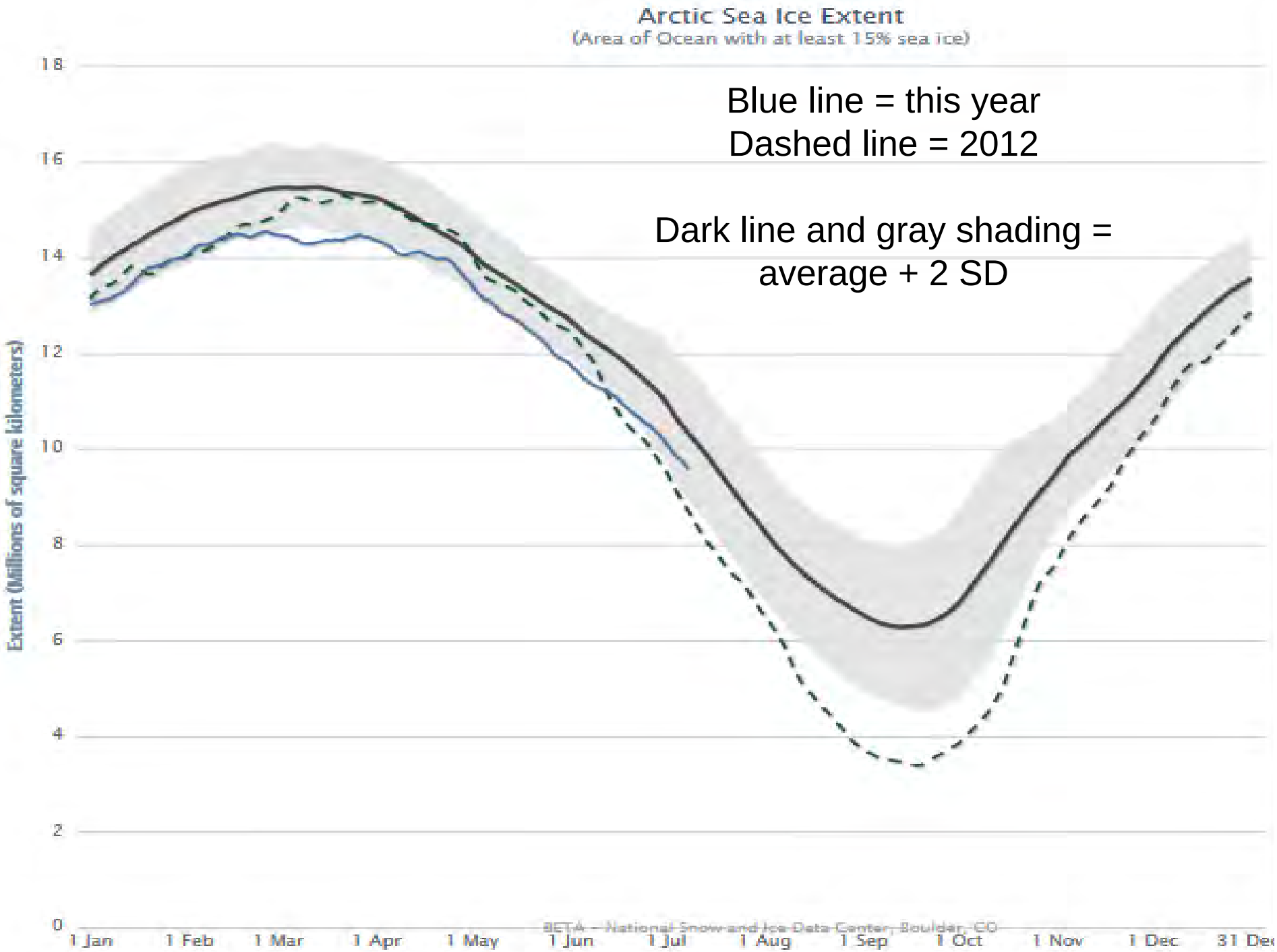




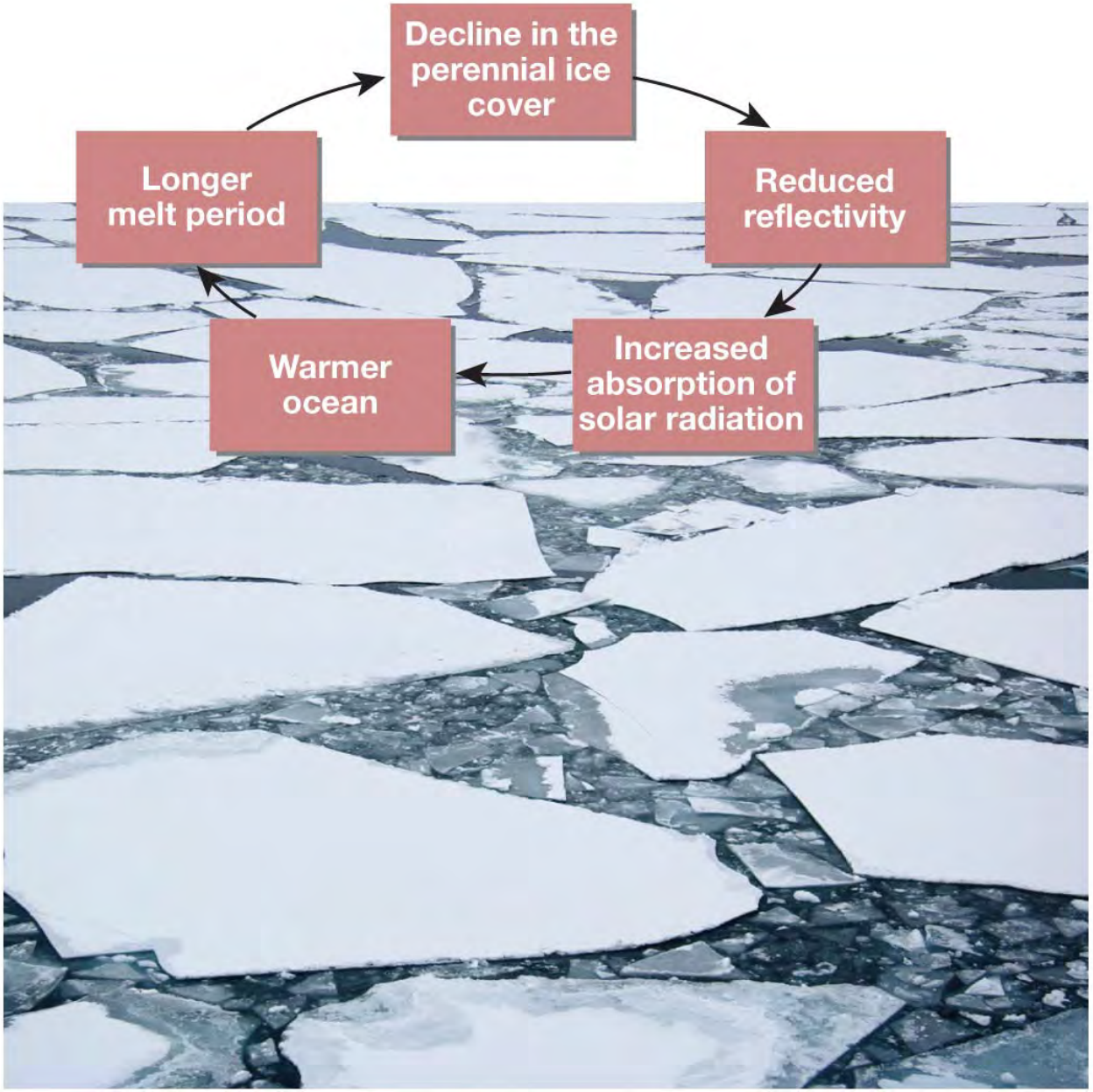
NSIDC / Thomas Mote, University of Georgia

A negative anomaly = a darker surface that melts faster


Northern Hemisphere Snow Cover Anomalies
1967-2015 June
Million Square km
6
5
4
3
2
1
0
-1
-2
-3
-4
N
D
ND indicates no data for a given year
68
72
76
80
84
88
92
96
00
04
08
12


Arctic Sea Ice Extent
(Area of Ocean with at least 15% sea ice)
Blue line = this year
Dashed line = 2012
Dark line and gray shading = average + 2 SD
Extent (Millions of square kilometers)
18
16
14
12
10
8
6
4
2
0
1 Jan
1 Feb
1 Mar
1 Apr
1 May
1 Jun
1 Jul
1 Aug
1 Sep
1 Oct
1 Nov
1 Dec
31 Dec
BETA – National Snow and Ice Data Center, Boulder, CO

Climate-Feedback Mechanisms



Ice – Albedo Feedback Loop
Arctic Climate Impact Assessment

Less of the globe covered by snow and ice

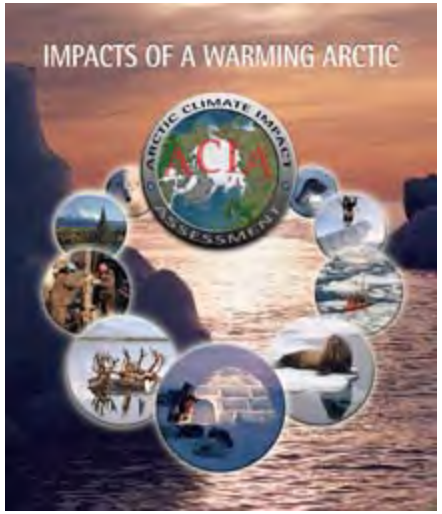
→ More solar radiation absorbed

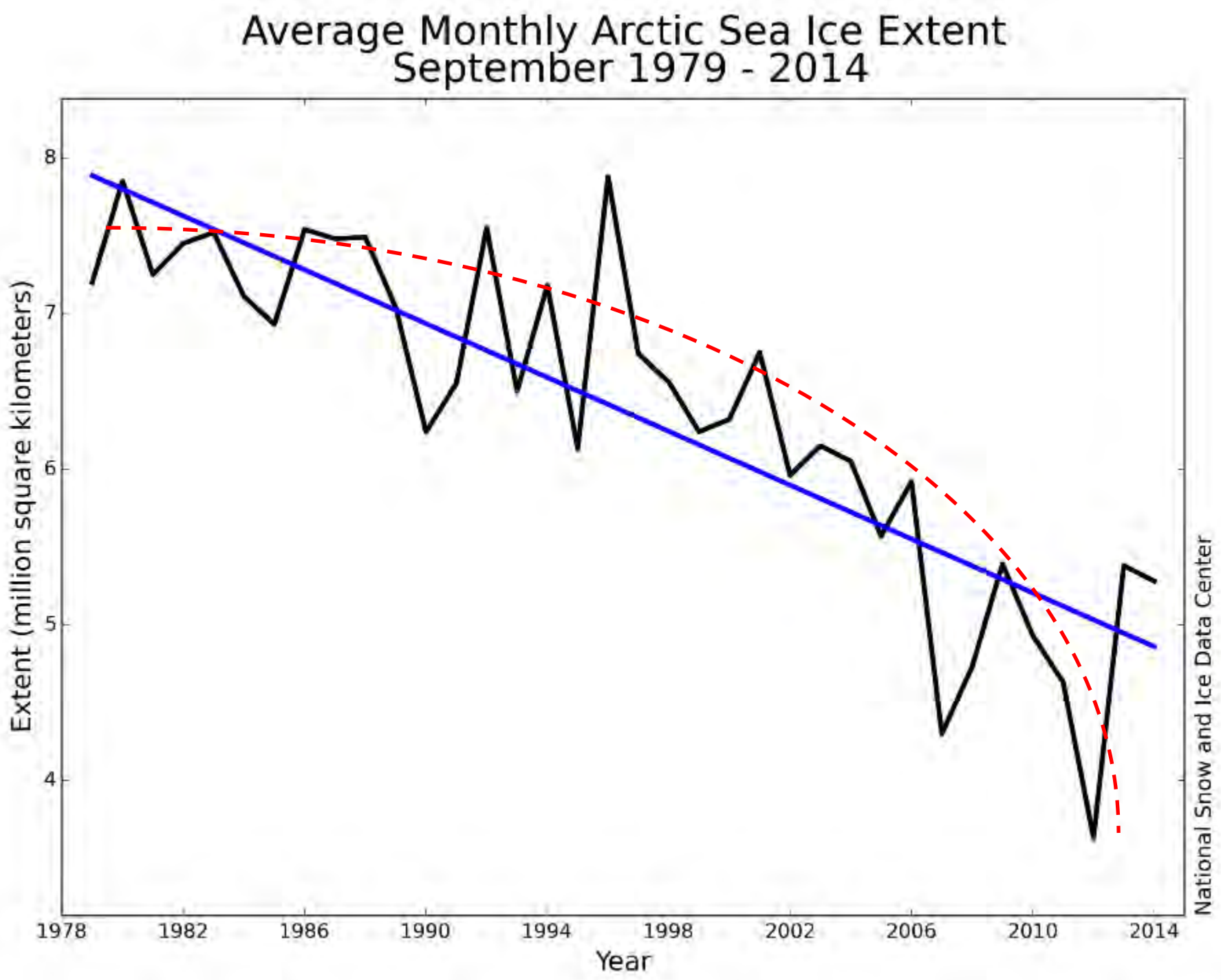
→ Warmer climate

→ Less of the globe covered by snow and ice

http://www.acia.uaf.edu/

Synthesis report available + CBS 60 Minutes ‘story’



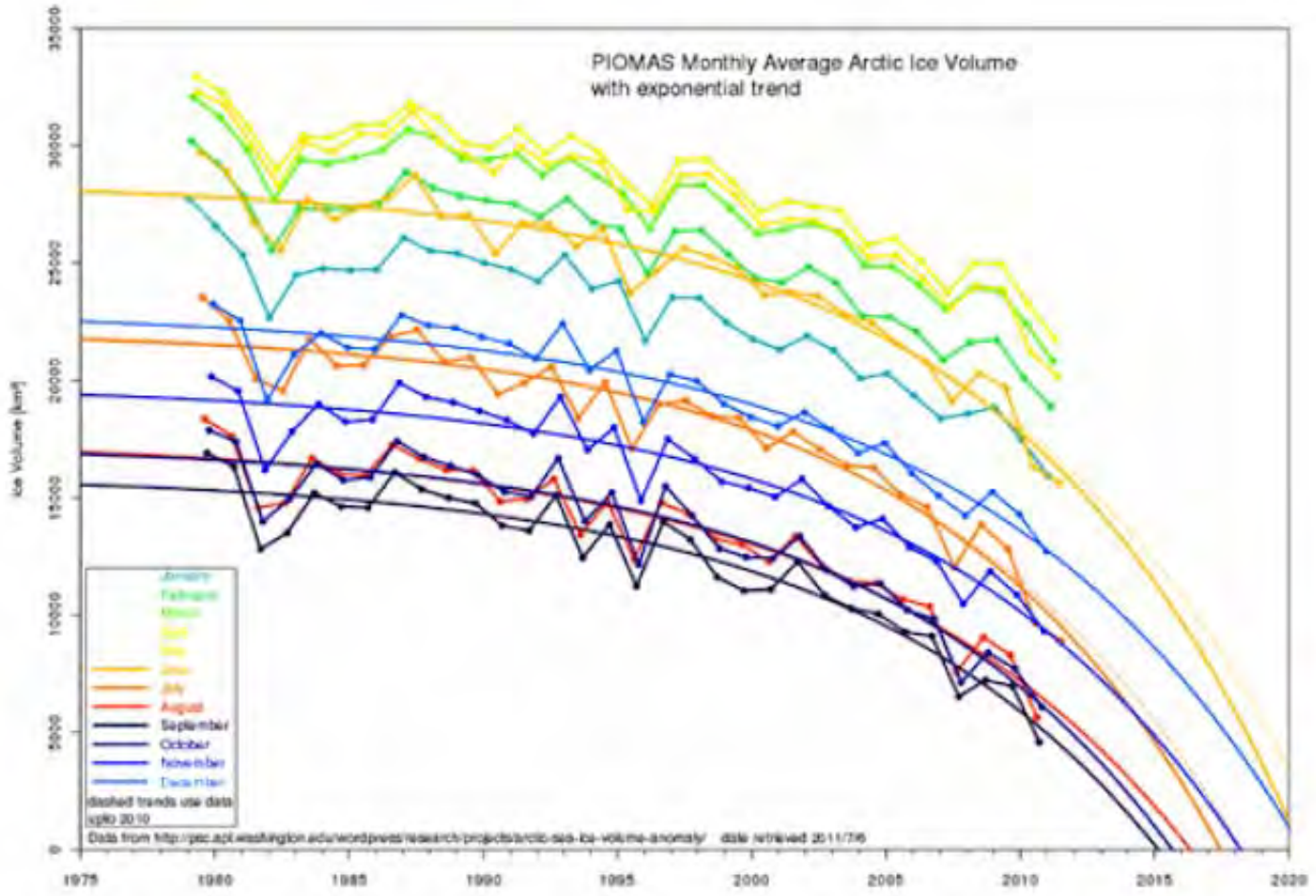

Average Monthly Arctic Sea Ice Extent
September 1979 - 2014
Extent (million square kilometers)
8
7
6
5
4
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year
National Snow and Ice Data Center

The Arctic “Death Spiral”

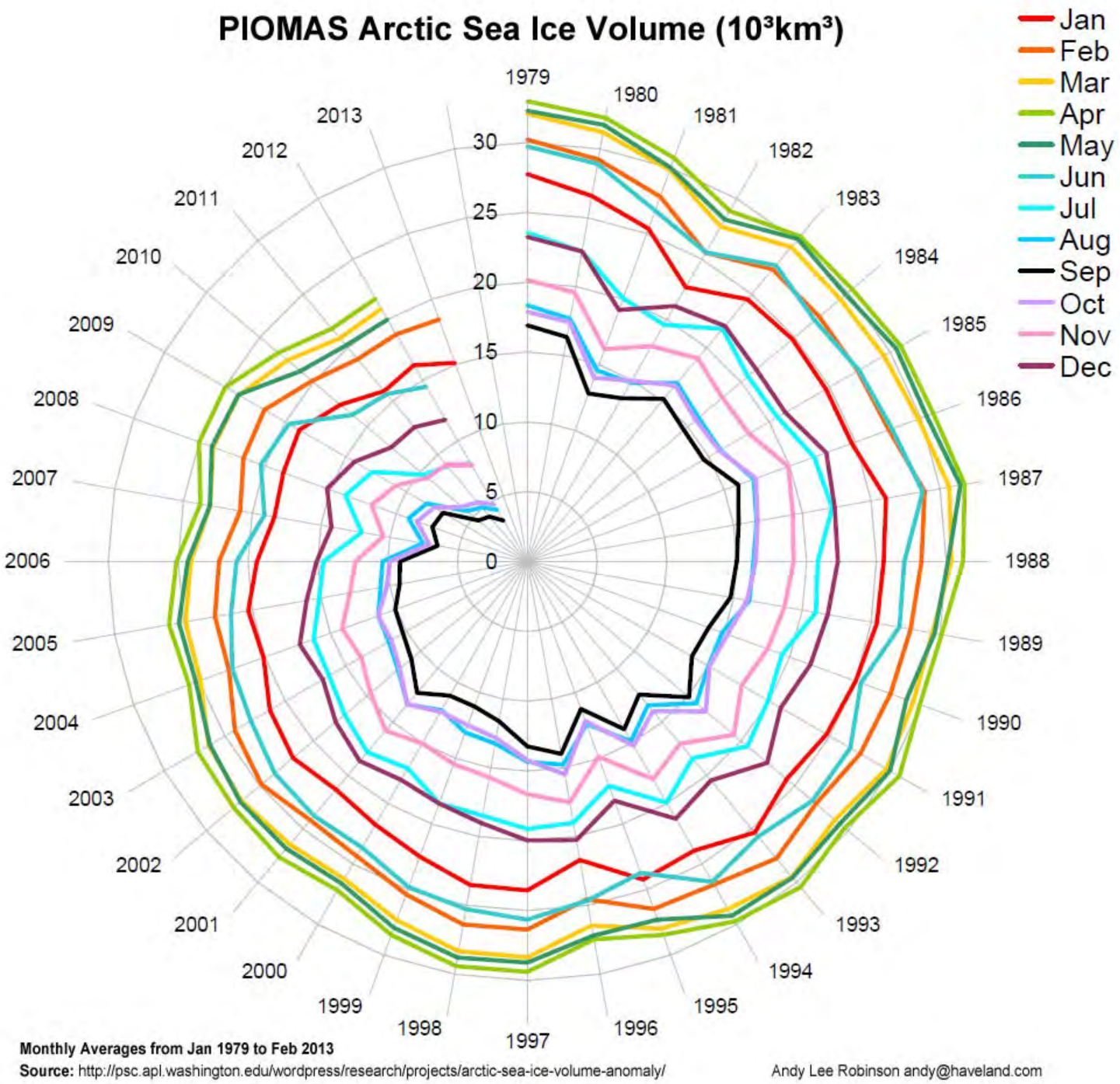
Mark Serreze 2010

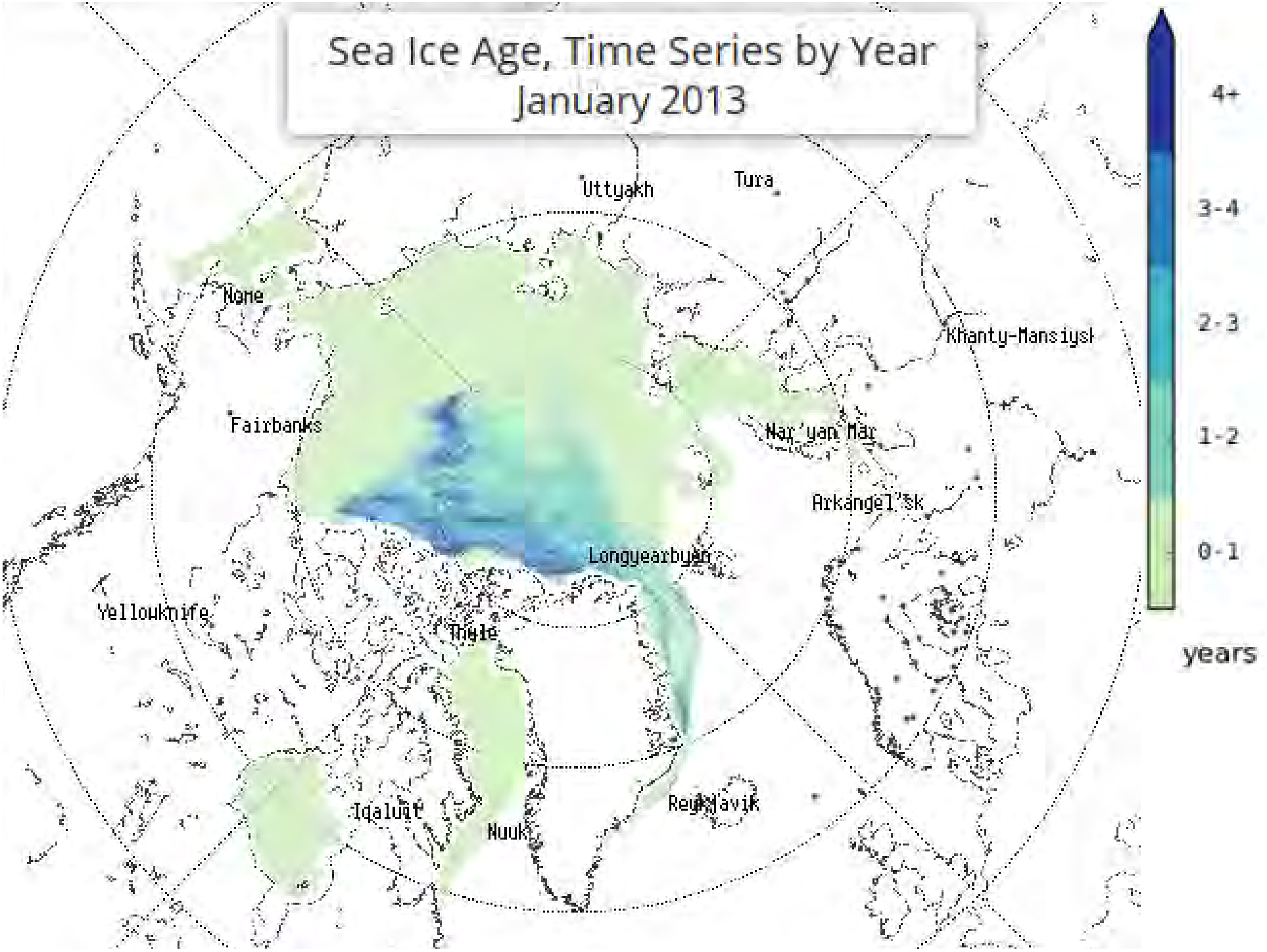
“There are claims coming from some communities that the Arctic sea ice is recovering, is getting thicker again. That’s simply not the case. It’s continuing down in a death spiral.”

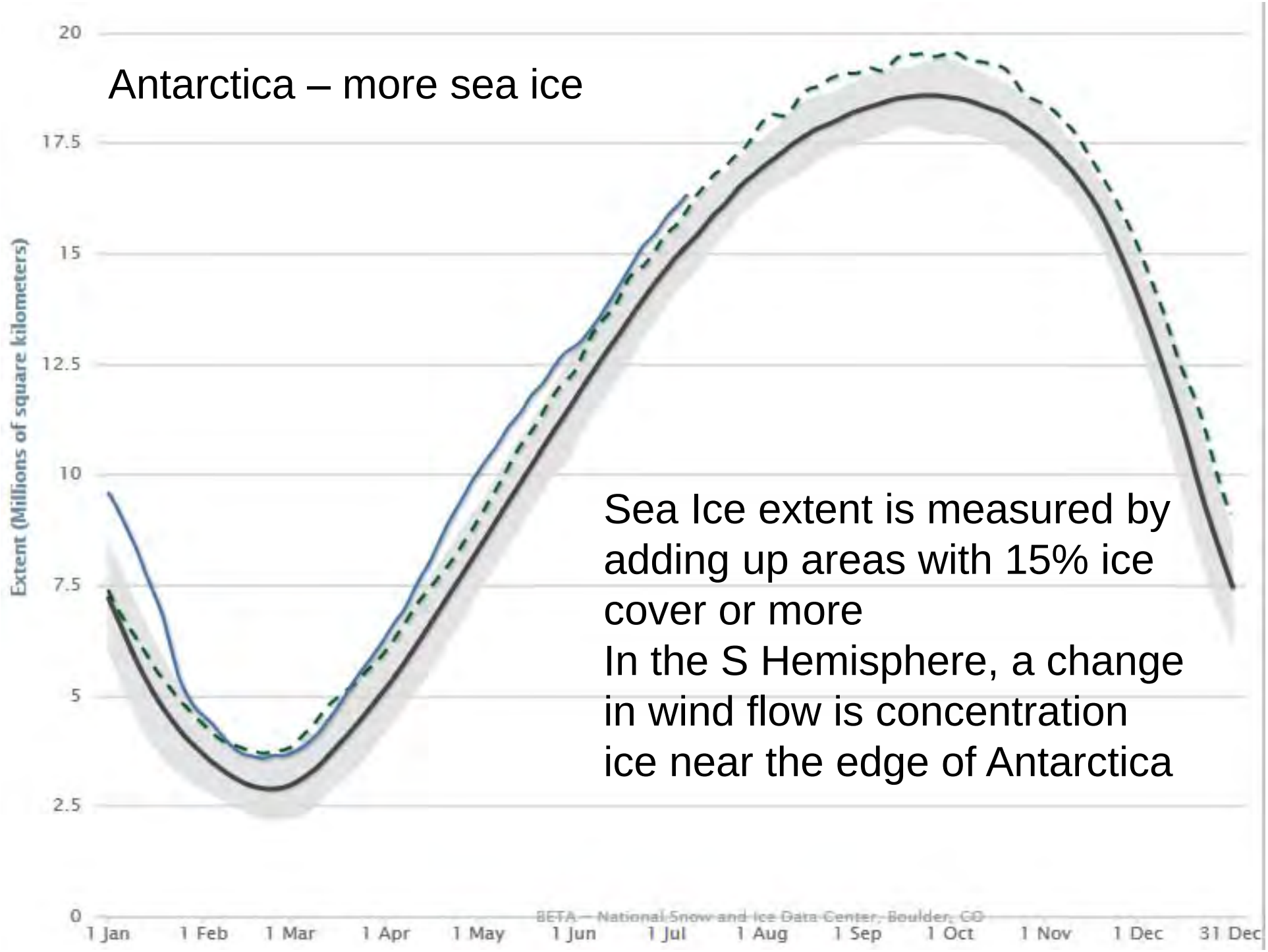
Into the
total perspective vortex?

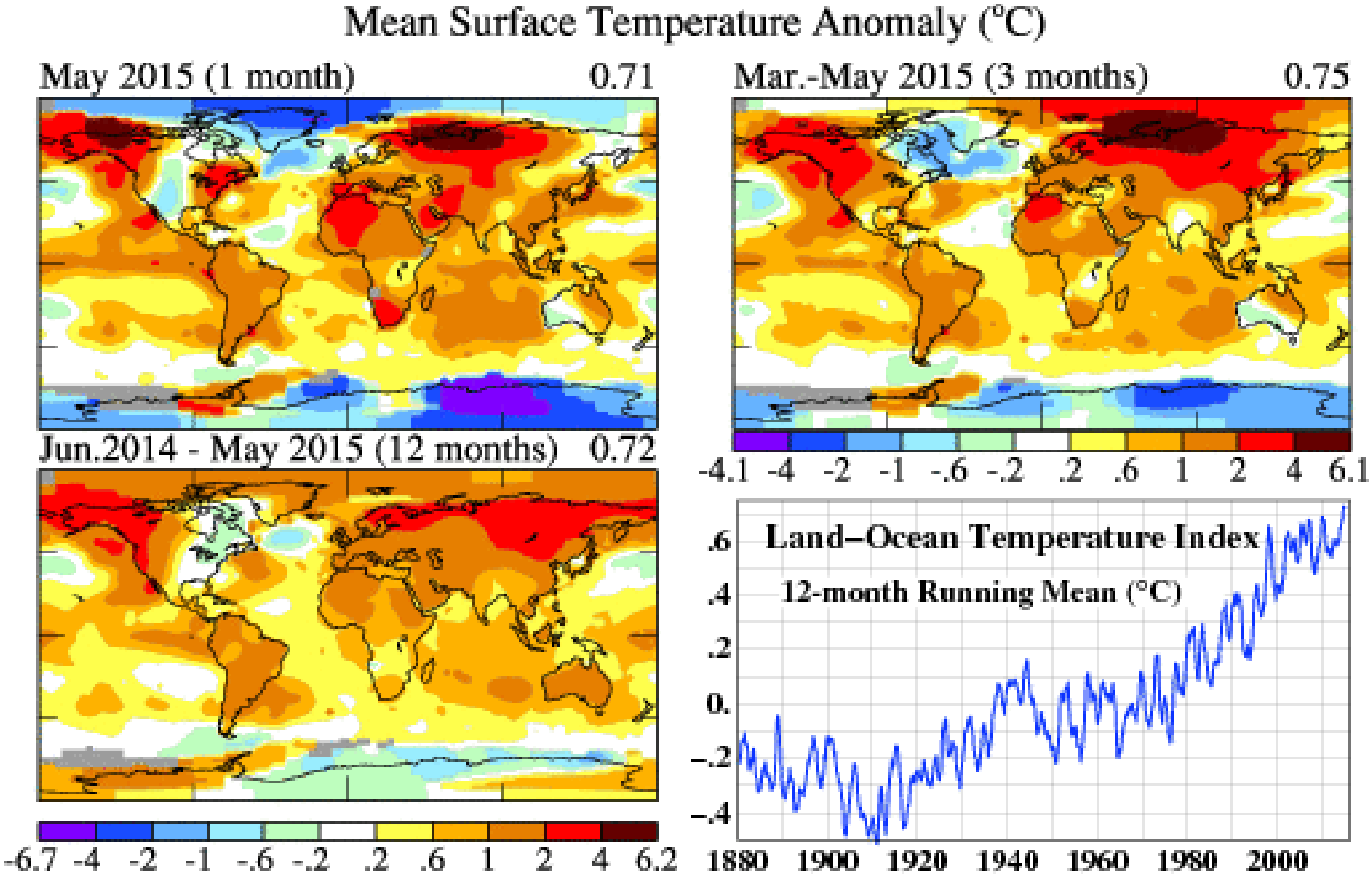


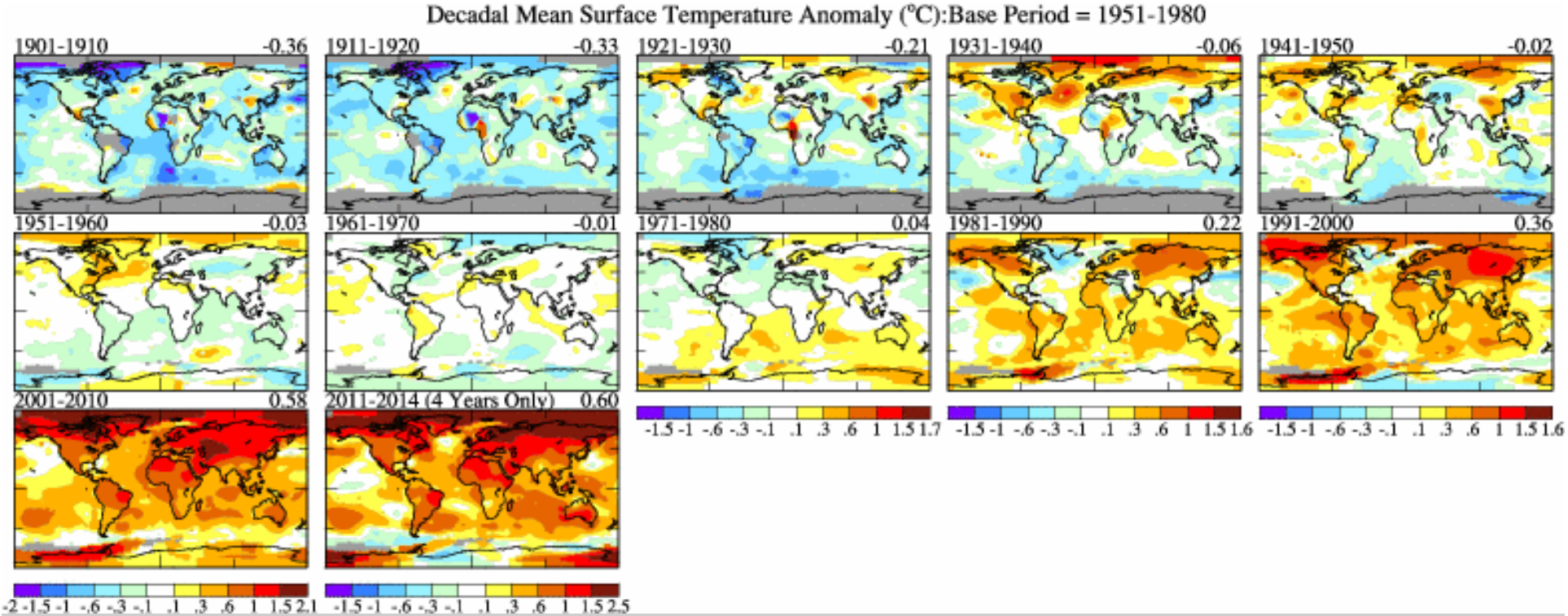
Arctic sea ice volume by month in cubic kilometers. The bottom (black) line is September volume. The plot makes projections with simple quadratic trend lines (details here), which likely oversimplify matters as we approach zero volume (especially for non-summer months). But reversal of the overall death spiral is highly implausible absent an even more implausible reversal of current climate policies — policies which are promoted by denier disinformation and sustained by media stenography.


PIOMAS Arctic Sea Ice Volume (10³km³)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
30
25
20
15
10
5
0
Monthly Averages from Jan 1979 to Feb 2013
Source: http://psc.apl.washington.edu/wordpress/research/projects/arctic-sea-ice-volume-anomaly/
Andy Lee Robinson andy@haveland.com


Sea Ice Age, Time Series by Year
January 2013
Uttyakh
Tura
Nome
Khanty-Mansiysk
Fairbanks
Nar'yan Mar
Arkangel'sk
Longyearbyen
Yellowknife
Thule
Iqaluit
Nuuk
Reykjavik
4+
3-4
2-3
1-2
0-1
years


Antarctica – more sea ice
Extent (Millions of square kilometers)
20
17.5
15
12.5
10
7.5
5
2.5
0
1 Jan
1 Feb
1 Mar
1 Apr
1 May
1 Jun
1 Jul
1 Aug
1 Sep
1 Oct
1 Nov
1 Dec
31 Dec
Sea Ice extent is measured by adding up areas with 15% ice cover or more
In the S Hemisphere, a change in wind flow is concentration ice near the edge of Antarctica
BETA — National Snow and Ice Data Center, Boulder, CO

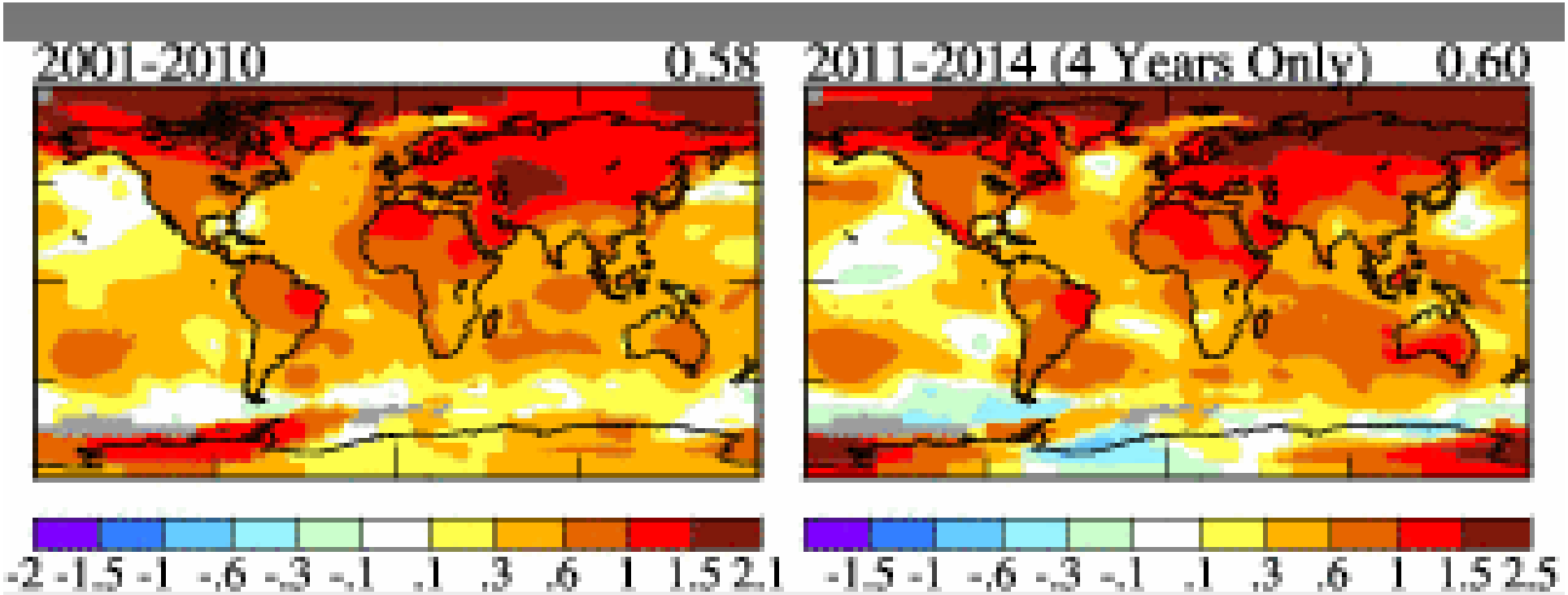

Mean Surface Temperature Anomaly (°C)
May 2015 (1 month) 0.71
Mar.-May 2015 (3 months) 0.75
Jun.2014 - May 2015 (12 months) 0.72
-6.7 -4 -2 -1 -.6 -.2 .2 .6 1 2 4 6.2
-4.1 -4 -2 -1 -.6 -.2 .2 .6 1 2 4 6.1
Land–Ocean Temperature Index
12-month Running Mean (°C)
.6
.4
.2
0.
-.2
-.4
1880 1900 1920 1940 1960 1980 2000
Base Period: 1951-1980



Too much information

Temperatures for each decade (starting 1900) compared with the 1951-1980 30-year ‘normal’ period

Warmer colors (red, orange, yellow) indicate that the planet is warmer now than 100 years ago



- Warmer over land, compared with the oceans
- Warmer at higher latitudes, esp. N. Hemisphere

APRIL 3, 2006 www.time.com AOL Keyword: TIME

SPECIAL REPORT GLOBAL WARMING

TIME

BE WORRIED. BE VERY WORRIED.

Climate change isn't some vague future problem—it's already damaging the planet at an alarming pace. Here's how it affects you, your kids and their kids as well

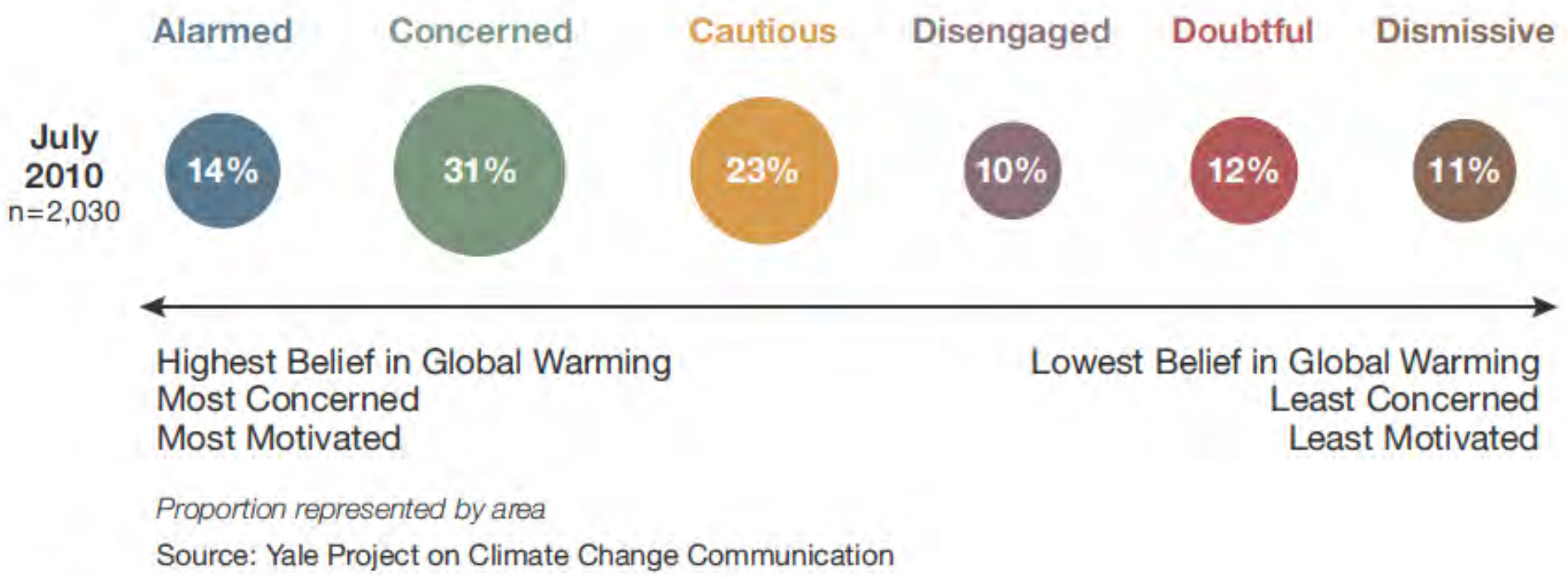
EARTH AT THE TIPPING POINT

HOW IT THREATENS YOUR HEALTH

HOW CHINA & INDIA CAN HELP SAVE THE WORLD—OR DESTROY IT

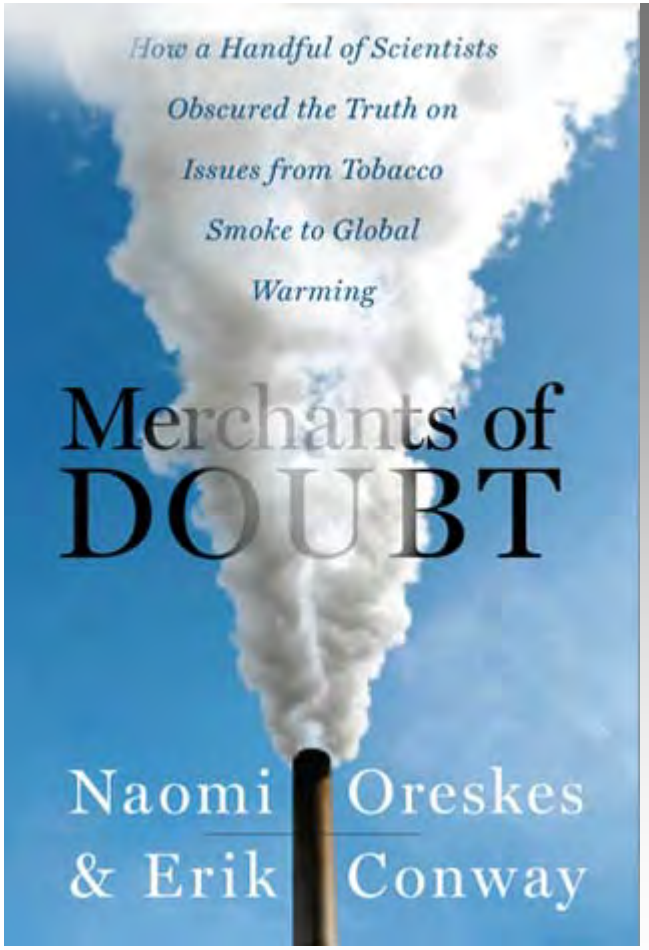
THE CLIMATE CRUSADERS

The Six Americas



http://environment.yale.edu/climate/files/Knowledge Across Six Americas.pdf

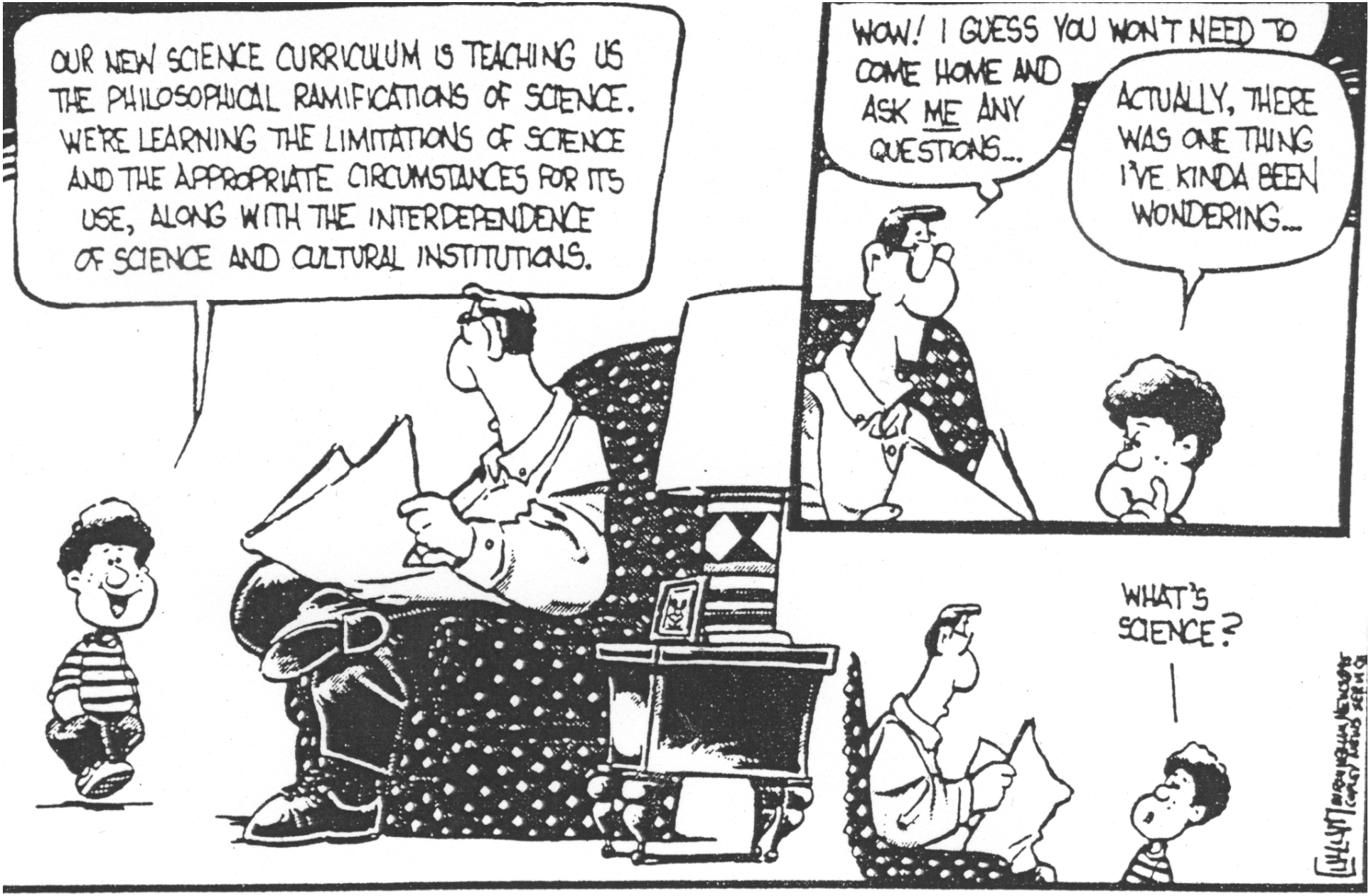
Circle sizes are very likely to be different with various sub-populations: Kansans, Europeans, those under 30 years of age, college graduates, …



http://www.merchantsofdoubt.org/

"[A] fascinating and important study ... *Merchants of Doubt* deserves a wide readership. It is tempting to require that all those engaged in the business of conveying scientific information to the general public should read it."***—Science***

Climate Science (models of the future) and the scholars who study the system suggest **we should be very concerned** for the future, but the "Merchants of Doubt" have had an impact


OUR NEW SCIENCE CURRICULUM IS TEACHING US THE PHILOSOPHICAL RAMIFICATIONS OF SCIENCE. WE'RE LEARNING THE LIMITATIONS OF SCIENCE AND THE APPROPRIATE CIRCUMSTANCES FOR ITS USE, ALONG WITH THE INTERDEPENDENCE OF SCIENCE AND CULTURAL INSTITUTIONS.
WOW! I GUESS YOU WON'T NEED TO COME HOME AND ASK ME ANY QUESTIONS...
ACTUALLY, THERE WAS ONE THING I'VE KINDA BEEN WONDERING...
WHAT'S SCIENCE?

Science and Ways of Knowing

- Human have a desire to order (make sense out of) our experiences
  - Knowledge = an understanding of the ways that experiences can be ordered
- Science is one of two major kinds of knowledge
  - **Rational** (science)
    - Answers tend to be **relative** and can change
  - **Intuitive** (theology, aesthetics, mysticism, common sense)
    - Answers tend to be fixed - **absolute**

What is science?

- A way of knowing
- A system of ordering experiences to provide explanation
  Where order = the absence of unanswered questions
- Characteristics of science
  - Highly formalized – systems exist for producing change
    - Checking the existence of relationships
      - Hypothesis testing, laws, theory building, models
      - Deterministic laws
      - Probabilistic laws
  - Communication network – build on each others work
  - Verification weeds out mistakes
  - Scientific answers are replicable (no varieties of science)

Theory and Science

"theory" has multiple meanings

Common use = a hypothesis (a guess)

In the **social sciences** = a mental construct about how things might work (a perspective)

rational choice theory is a framework for understanding

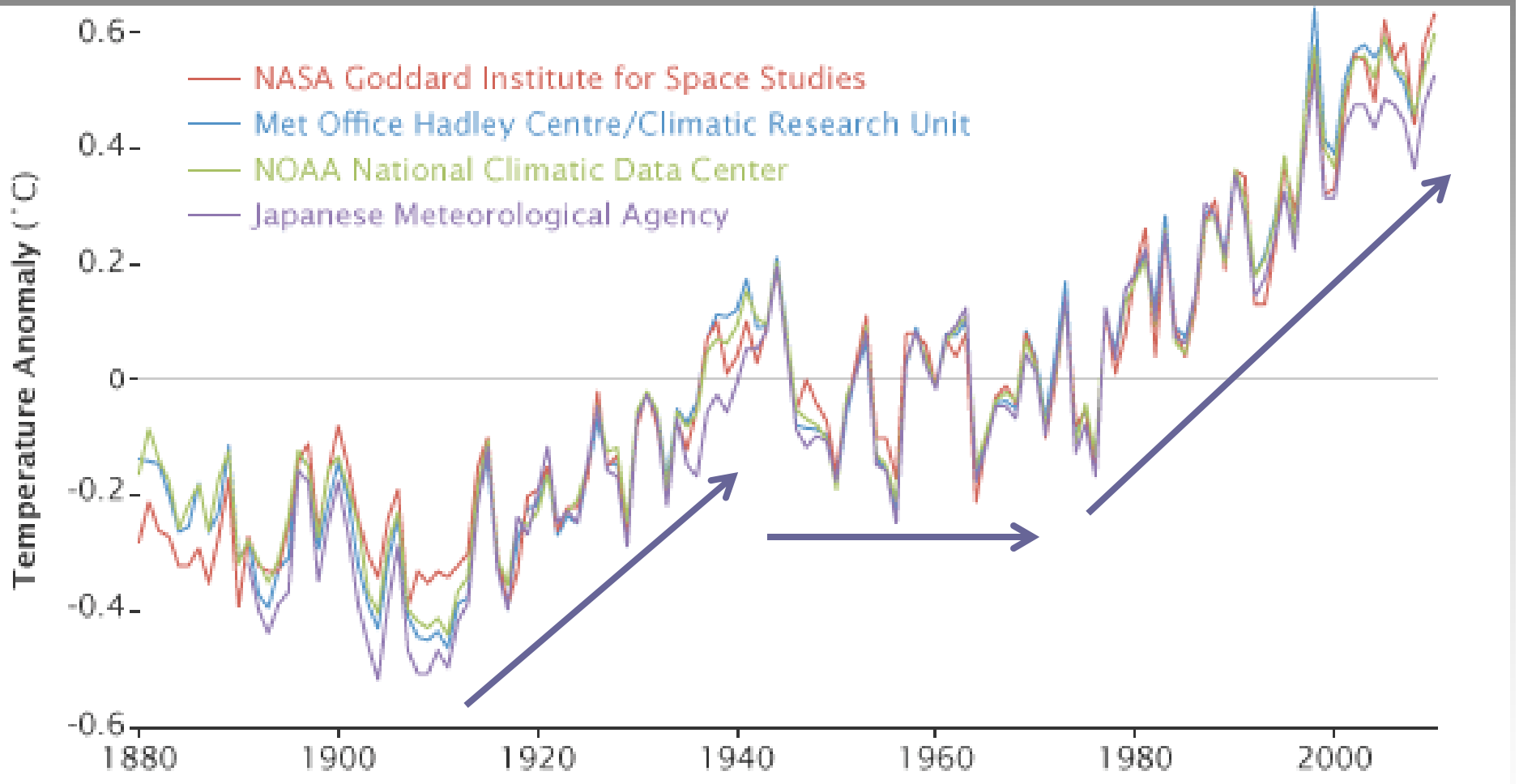
e.g., optimal/rational economic behavior - "economic man"

In the **lab sciences** = a complex concept built on scientific laws to explain how things work

e.g., plate tectonics, the Big Bang, and atomic theory

"**Global warming**" is **not a theory** – it is **a scientific observation** regarding what has been happening on our planet

"Global warming" is **not** a theory – it is a finding based on scientific observation regarding what has been happening on our planet



http://e360.yale.edu/feature/the_ethical_dimension_of_tackling_climate_change/2456/

The Ethical Dimension of Tackling Climate Change
BY STEPHEN GARDINER

"the biggest issue facing humanity at the moment is the looming global environmental crisis"

"Those least responsible for past emissions are likely to suffer the most serious impacts (at least in the short- to medium-term)."

"Climate change brings together many areas in which our best theories are far from robust, such as intergenerational ethics, global justice, scientific uncertainty, and humanity's relationship to nature."

"by failing to take action to rein in carbon emissions, the current generation is spreading the costs of its behavior far into the future"

IRB Approval? What is it?

Is it OK to not treat syphilis in a study of African American males?

Is it OK to release genetically modified organisms into the environment?

Is it OK to change to concentration of carbon dioxide in the atmosphere?

Geoengineering

2011

GAO
Accountability • Integrity • Reliability

GAO REPORT RELEASE

Climate Engineering: Technical Status, Future Directions, and Potential Responses

Geoengineering refers to "the deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming"

Is it OK to change to concentration of carbon dioxide in the atmosphere?

Or, put stuff in the stratosphere to mimic a volcanic eruption?

When does "inadvertent weather modification" become a recognized "side-effect" (or externality) of economic system?

Two geoengineering categories, as described by the UK Royal Society:

Carbon dioxide removal

Sequestration or CCS (carbon capture & storage)

Solar radiation management

most are against stratospheric injections

http://www.ted.com/talks/lang/en/david_keith_s_surprising_ideas_on_climate_change.html

David Keith: Moral hazard

Three questions:

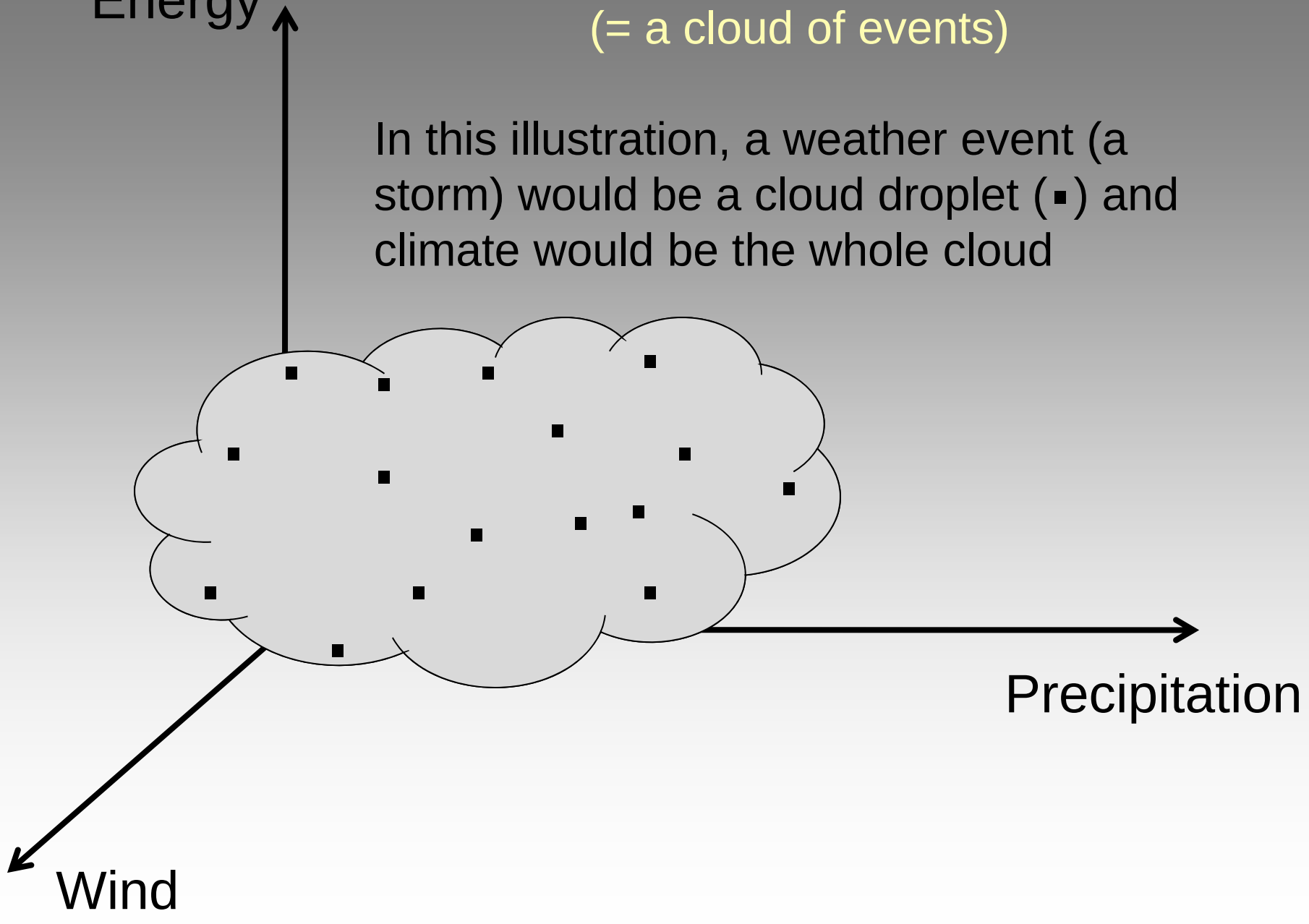
Should we do serious research? – risks/downsides

Do we need a treaty? – who gets to do this?

Do we need to think about climate and weather control?

Climate = the synthesis of weather
(= a cloud of events)

In this illustration, a weather event (a storm) would be a cloud droplet (▪) and climate would be the whole cloud



Climate

from the AMS Glossary

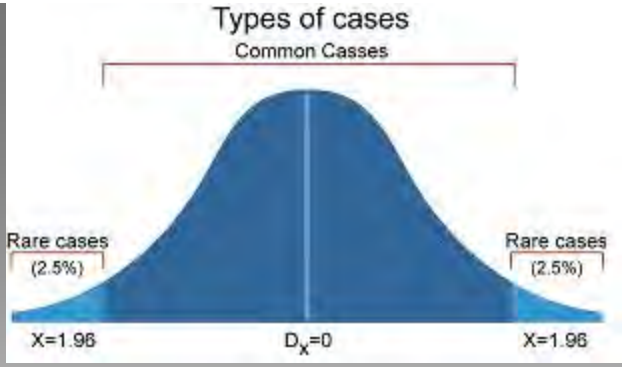
http://glossary.ametsoc.org/wiki/Climate

The **slowly varying** aspects of the atmosphere–hydrosphere–land surface system.

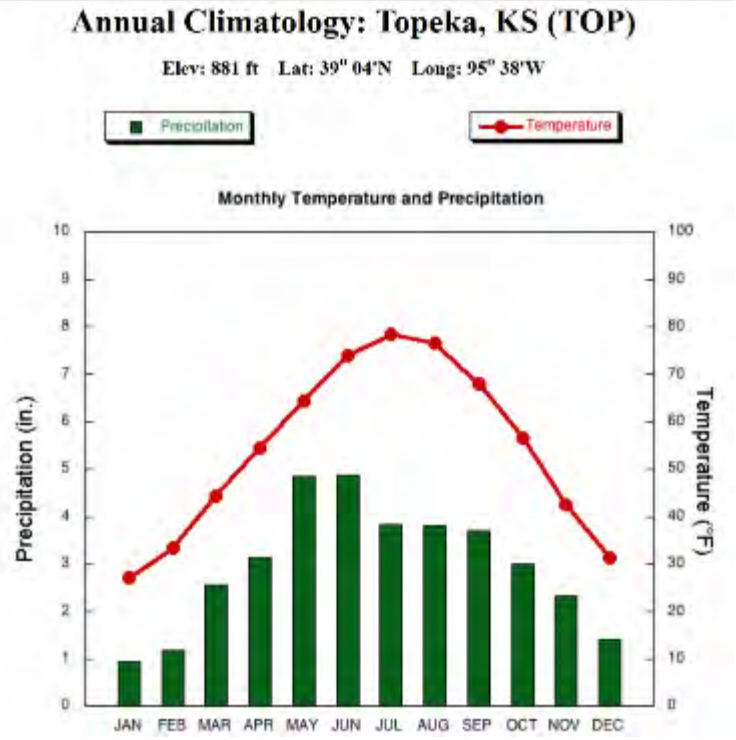
It is typically characterized in terms of suitable **averages** of the climate system over periods of a month or more, **taking into consideration the variability in time** of these averaged quantities. Climatic classifications include the spatial variation of these time-averaged variables. Beginning with the view of local climate as little more than the annual course of long-term averages of surface temperature and precipitation, **the concept of climate has broadened** and evolved in recent decades in response to the increased understanding of the **underlying processes that determine climate and its variability**.

See also climate system, climatology, climate change, climatic classification.

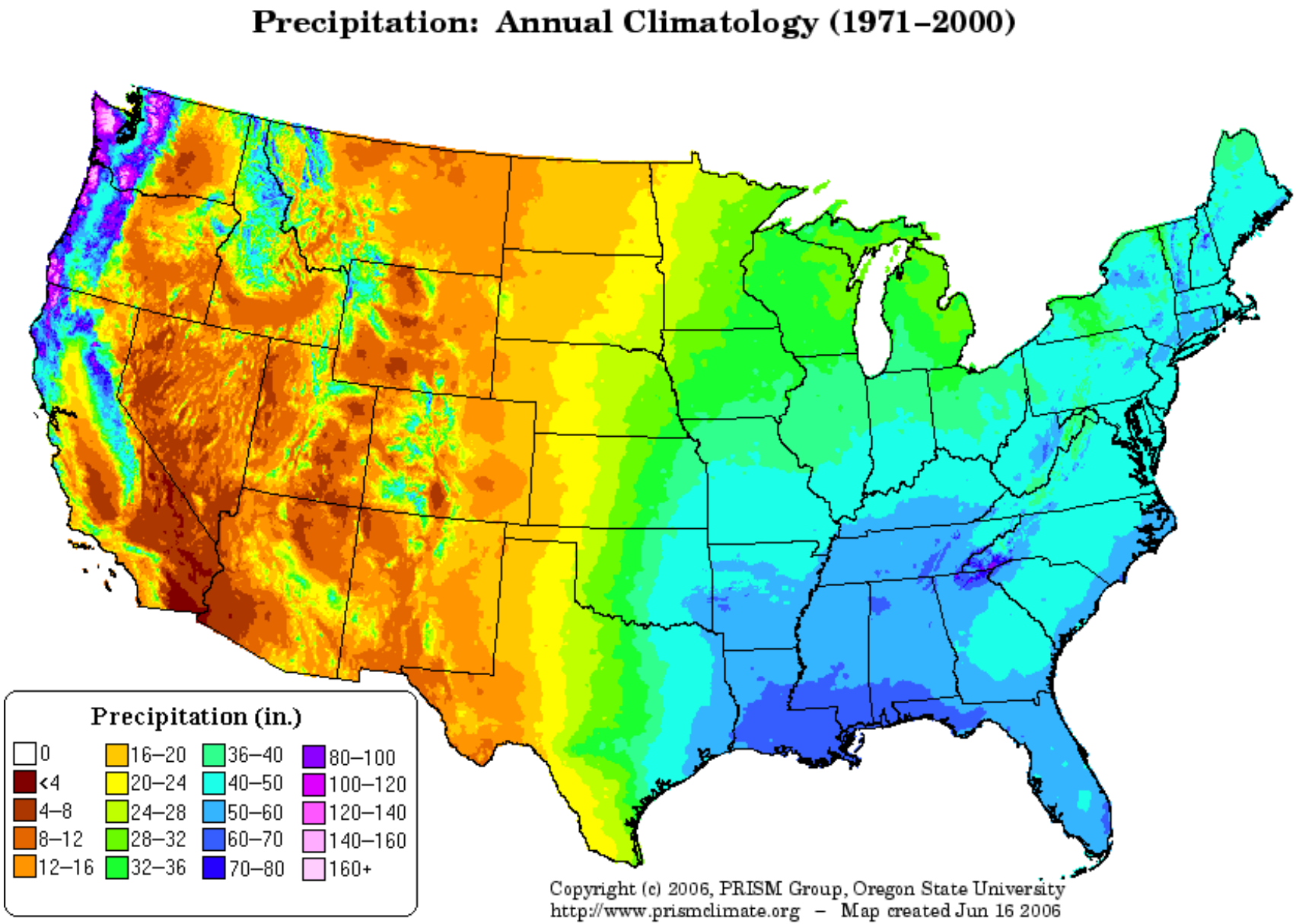
30 year “normals”



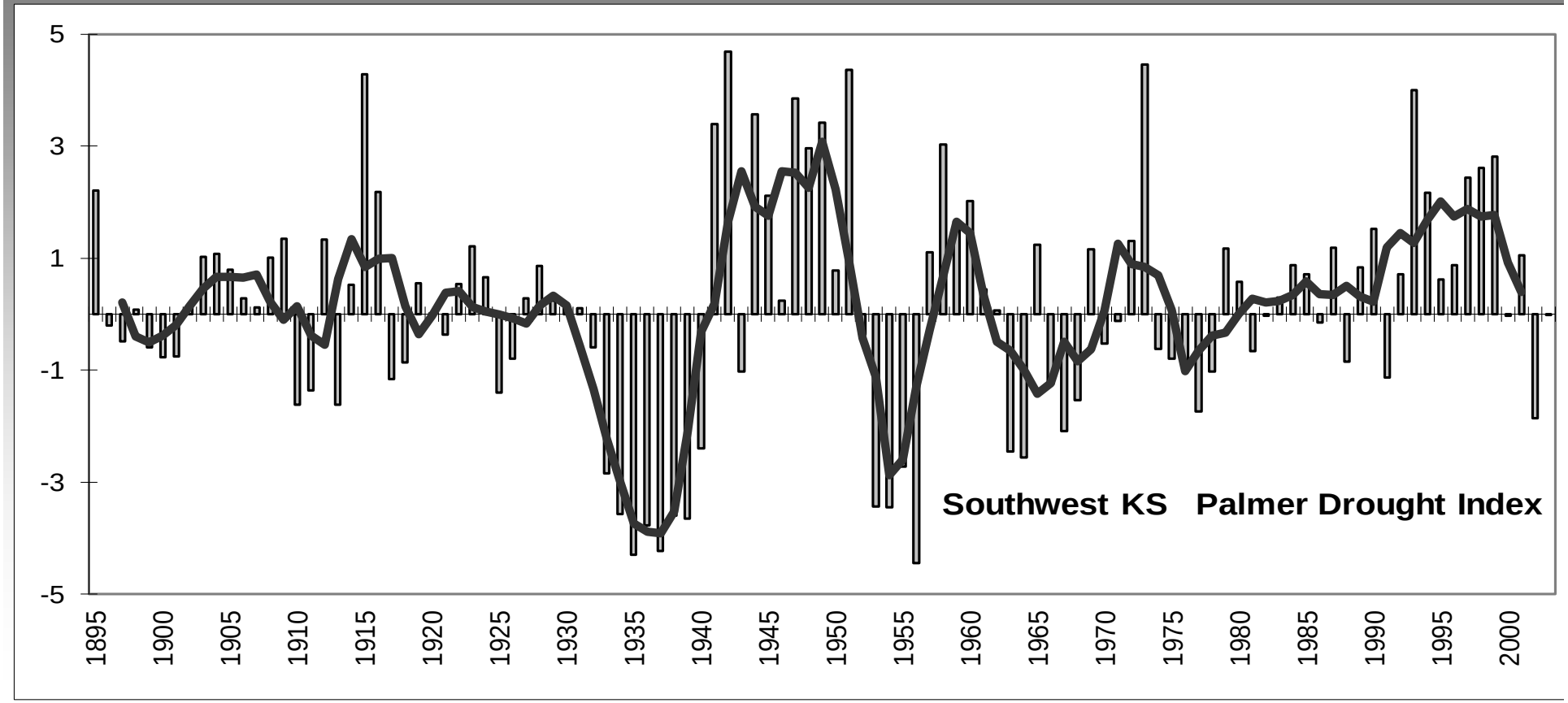
- Sampling from a bell-shaped curve
  - Only need 30 observations
- Want to be a climatologist?
  - Can you add 30 numbers
    and divide by 30?
  - Then describe the result
    Continental
    Early warm season precip max



It gets drier as you go west in KS and eastern CO because it is rare that Gulf moisture moves upslope against the prevailing winds



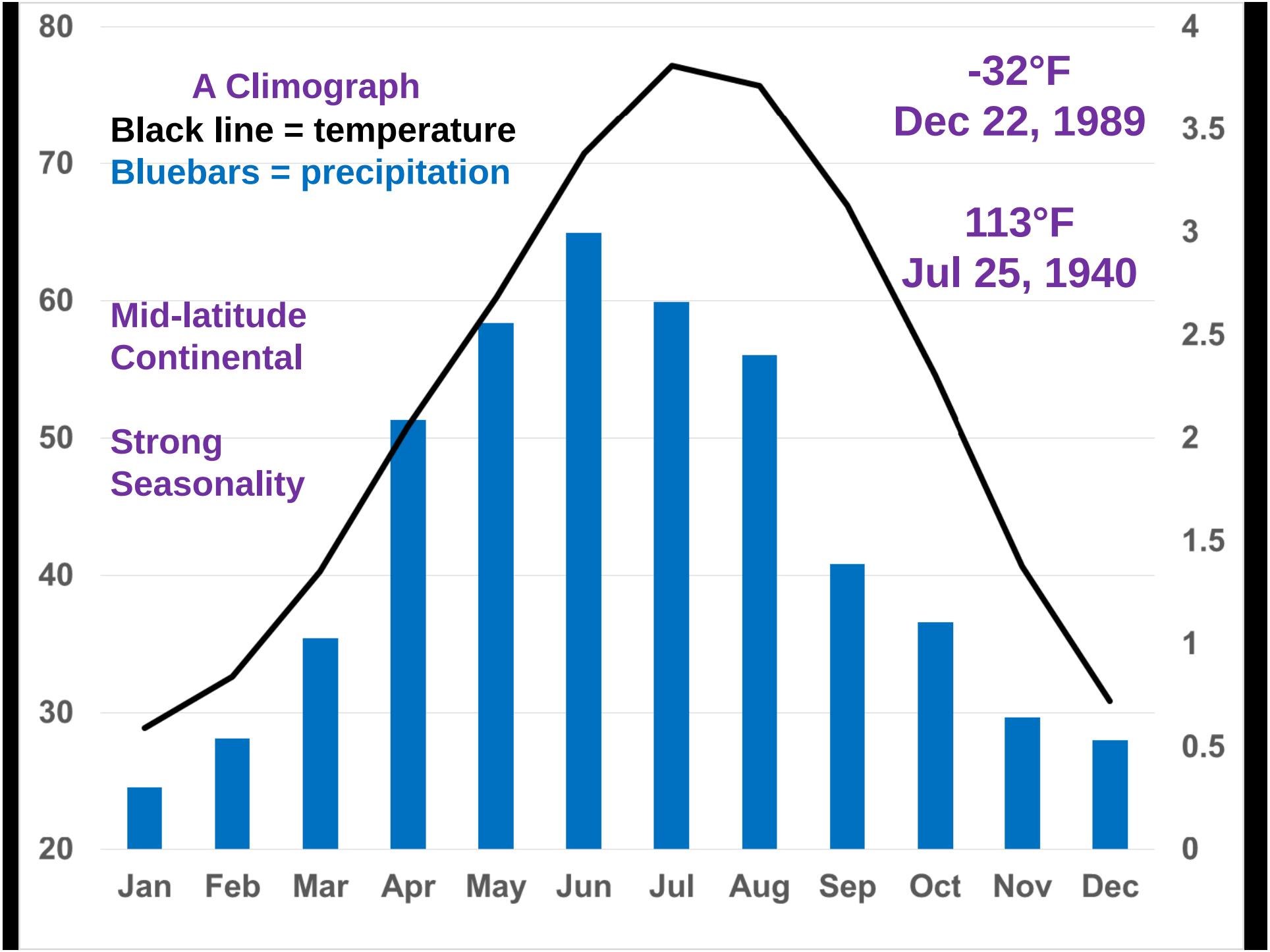
“taking into consideration the variability in time”

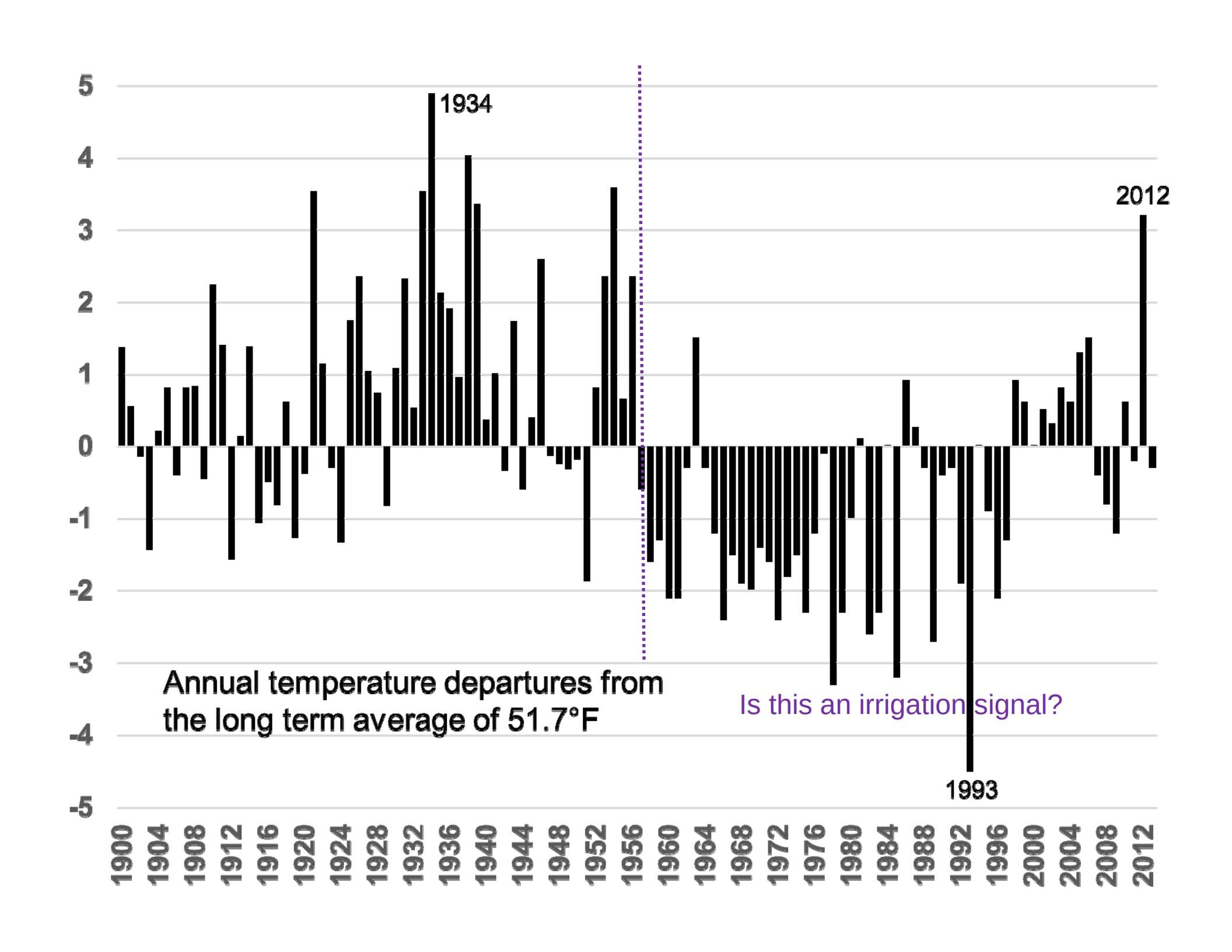


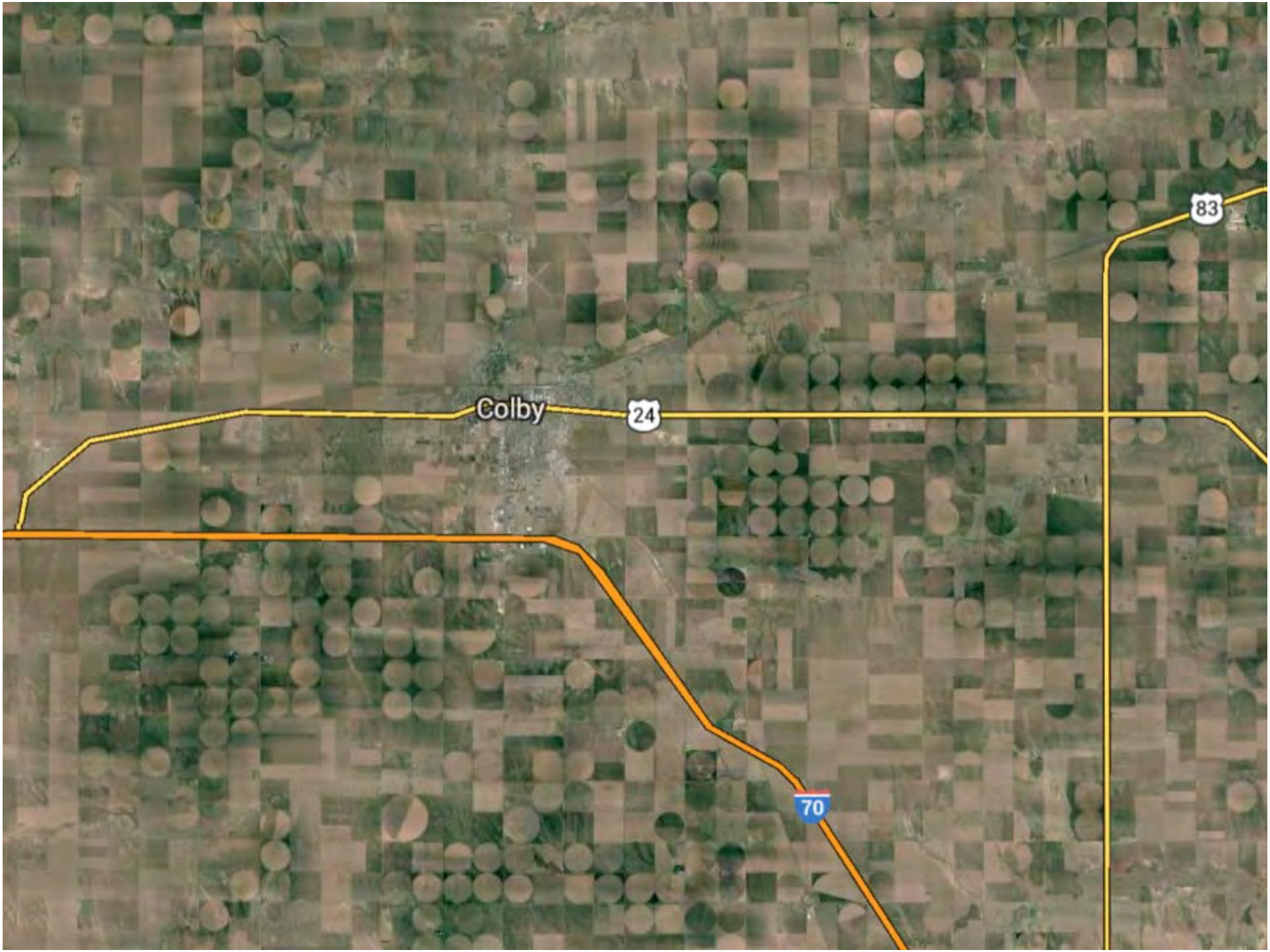
Dick Skaggs (1978) – same average but more variability in the 1930s thru the 1950s – possibly linked to oceans/SSTs

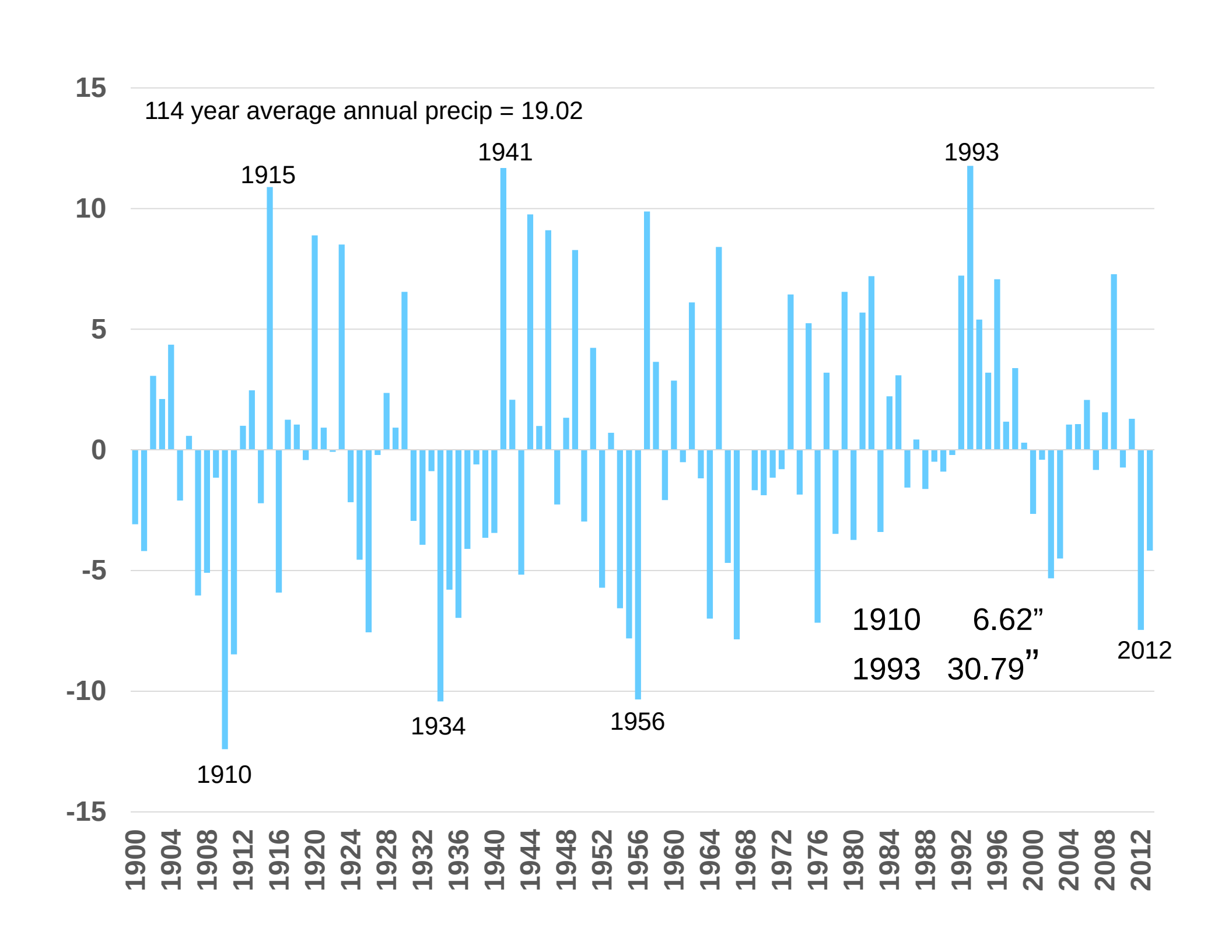
A Century of Climate Variability in Northwest Kansas

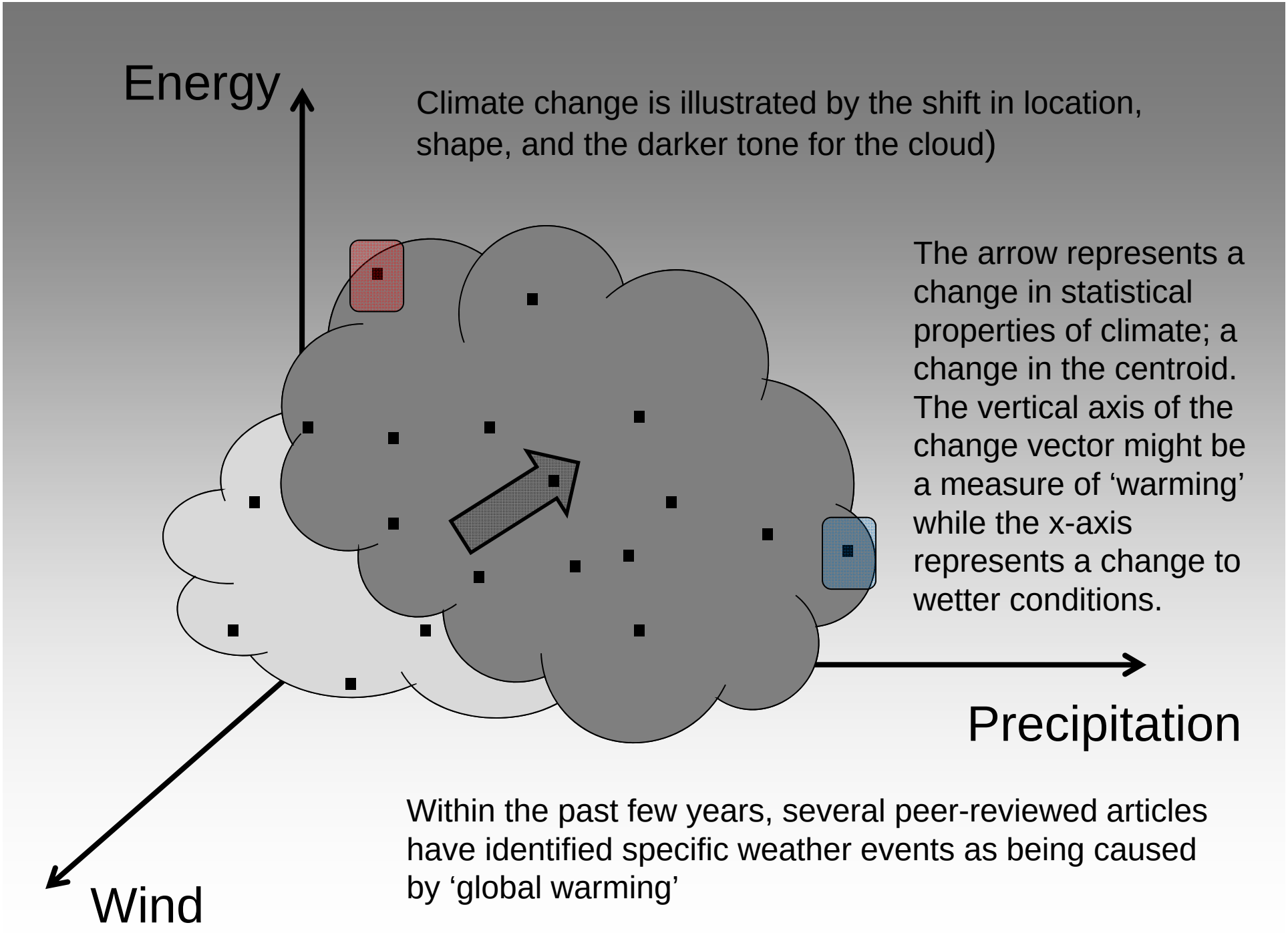
John Harrington Jr. jharrin@ksu.edu

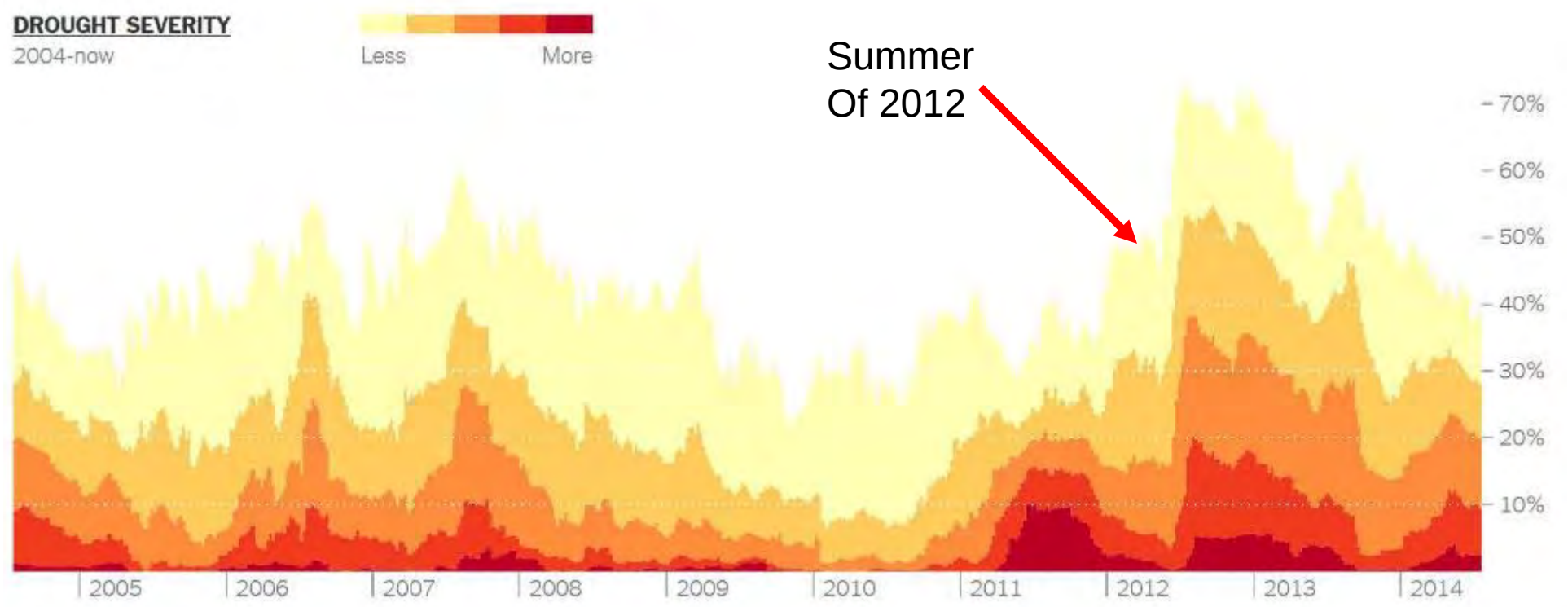

A Climograph
Black line = temperature
Bluebars = precipitation
Mid-latitude
Continental
Strong
Seasonality
-32°F
Dec 22, 1989
113°F
Jul 25, 1940
80
70
60
50
40
30
20
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


5
4
3
2
1
0
-1
-2
-3
-4
-5
1934
2012
1993
Annual temperature departures from
the long term average of 51.7°F
Is this an irrigation signal?
1900
1904
1908
1912
1916
1920
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
2004
2008
2012

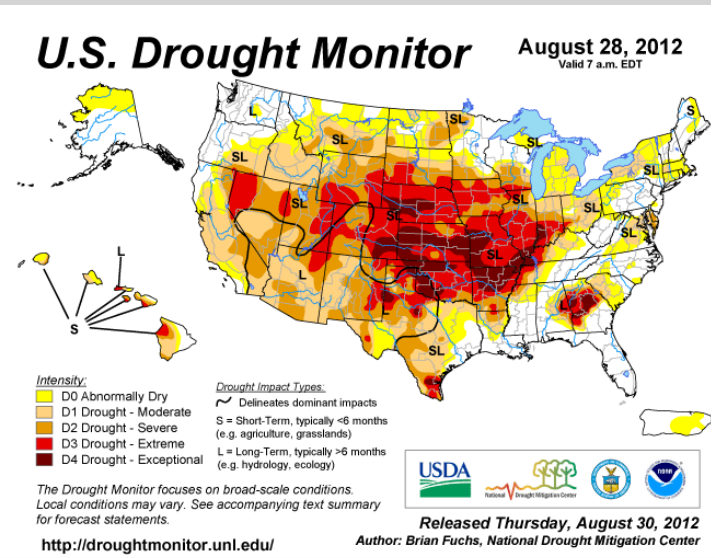

Colby
24
83
70

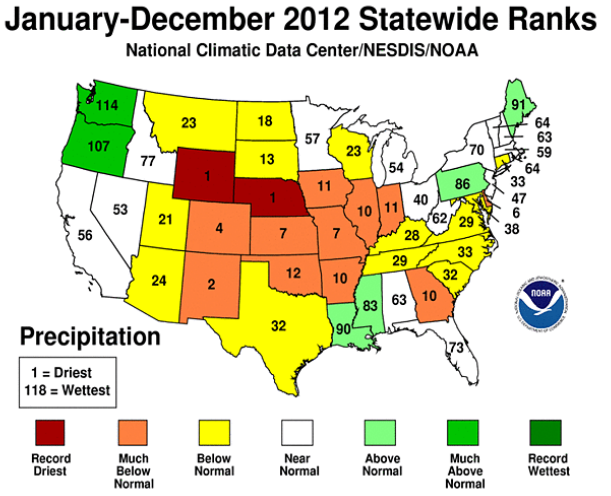

114 year average annual precip = 19.02
1915
1941
1993
1910
1934
1956
2012
1910 6.62”
1993 30.79”
15
10
5
0
-5
-10
-15
1900
1904
1908
1912
1916
1920
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
2004
2008
2012


Energy
Climate change is illustrated by the shift in location, shape, and the darker tone for the cloud)
The arrow represents a change in statistical properties of climate; a change in the centroid. The vertical axis of the change vector might be a measure of ‘warming’ while the x-axis represents a change to wetter conditions.
Precipitation
Within the past few years, several peer-reviewed articles have identified specific weather events as being caused by ‘global warming’
Wind

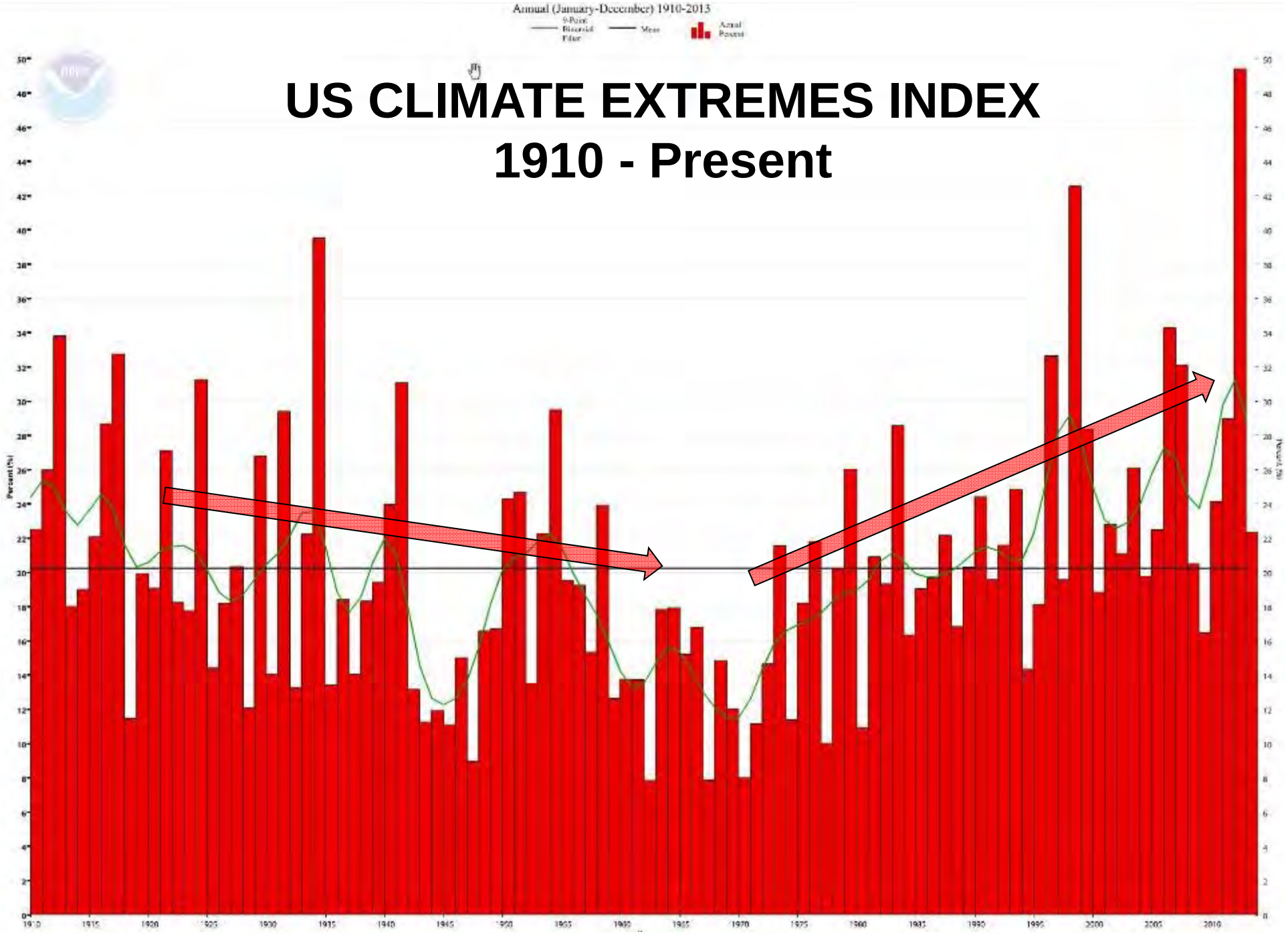


The 2012 drought is the most extensive drought to affect the U.S. since the 1930s. Losses are estimated at $30 billion. Moderate to extreme drought conditions affected more than half the country for a majority of the country.





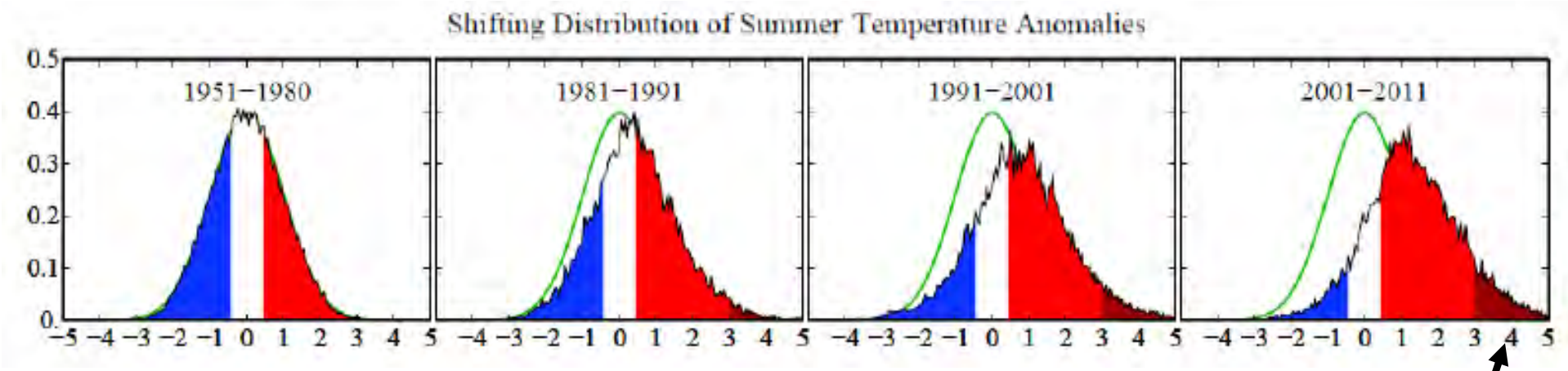
US CLIMATE EXTREMES INDEX
1910 - Present

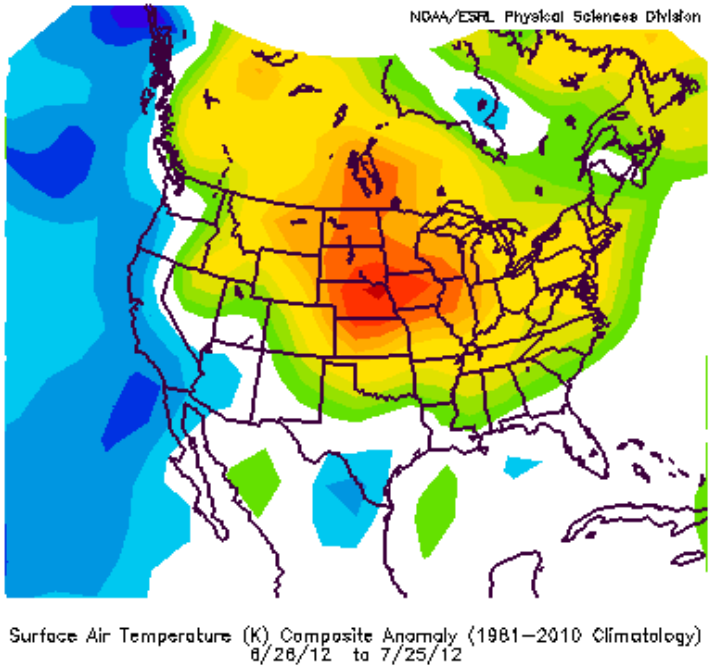


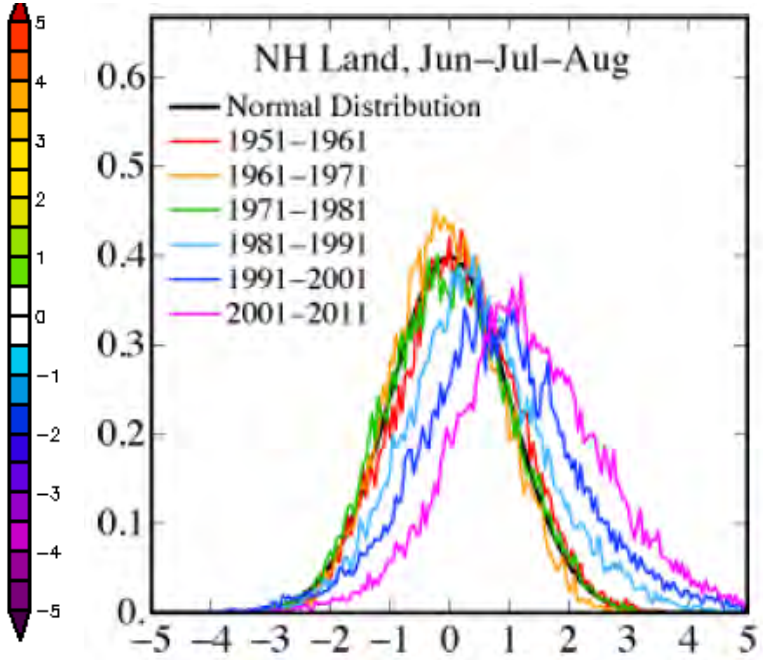
The 2012 drought and heat wave

Was it related to climate change?

Influenced by it – J. Hansen & loaded ‘climate dice’







Greater likelihood of an extreme event

Some argue the numbers are changing

Nomenclature and time scale of climatic variations (Landsberg 1976)

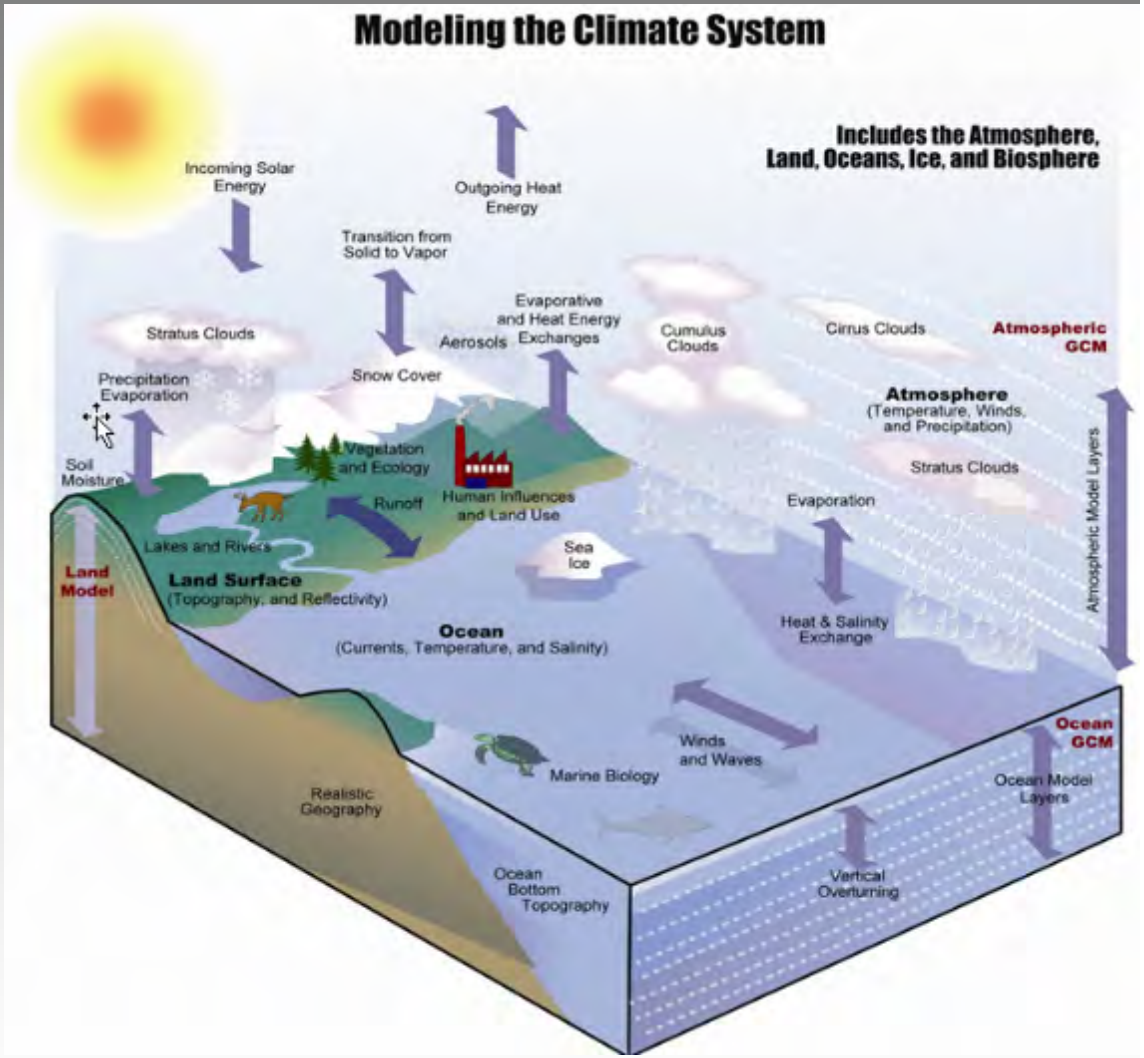
Designation	Known/Potential Origin	Duration
Revolution	Orogeny, Plate tectonics (solar)	$> 10^6$ years
Change	**Solar emissions, orbital changes of Earth**	**$10^4 – 10^6$ years**
Fluctuations	Quasi-periodic solar emissions, slow deep ocean circulations	$10 – 10^3$ years
Iterations	Terrestrial – possibly atmospheric Oceanic Interaction	< 10 years
Alterations	**Anthropogenic Causes**	**10 - ? Years**

External (solar + meteorites) v. Internal forcing (volcanoes)

Climate Science

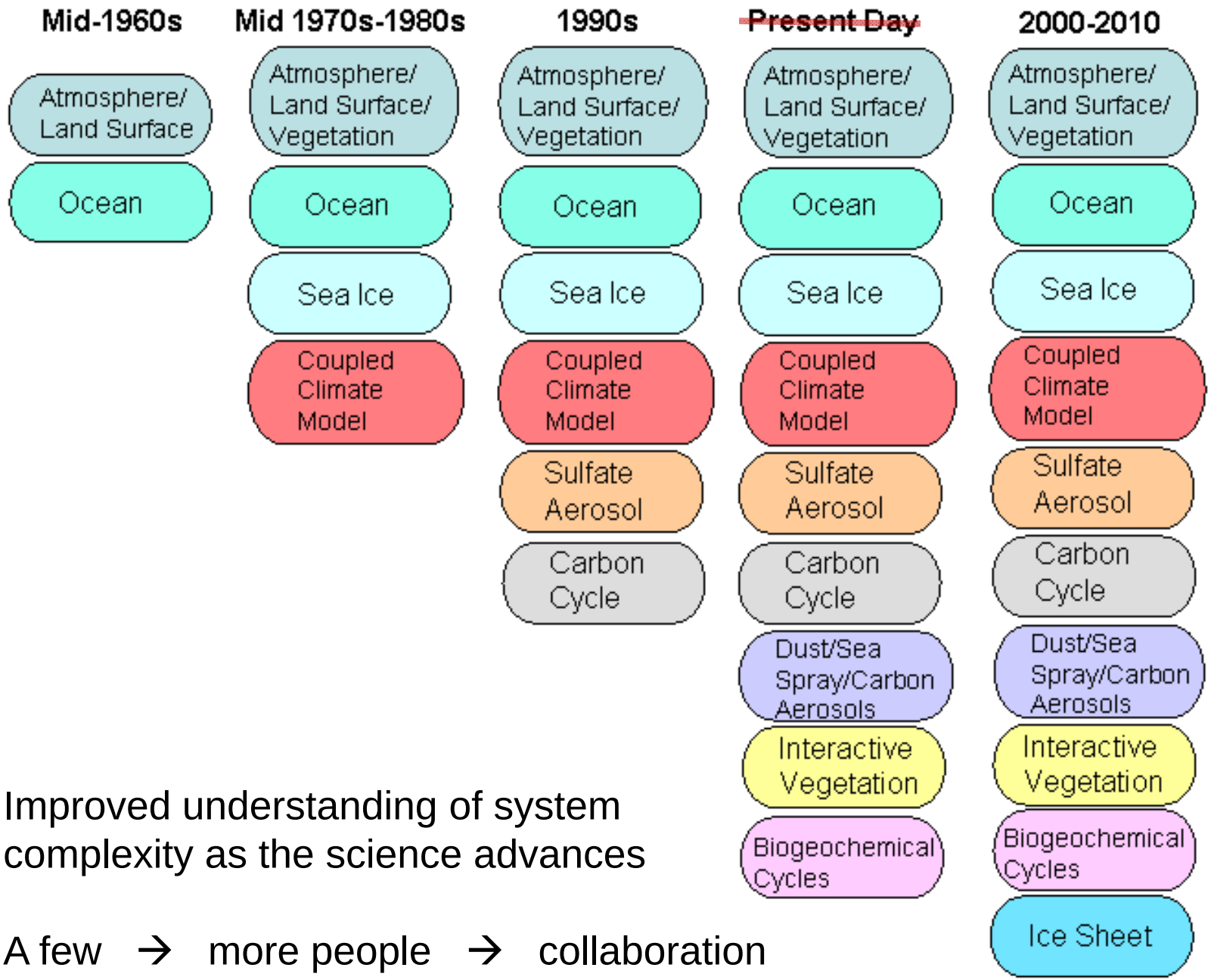
Some in the science community **collect and analyze data** = “old style climatology”

Others build **physically-based models** to increase our understanding of how things work = **modern climate science**



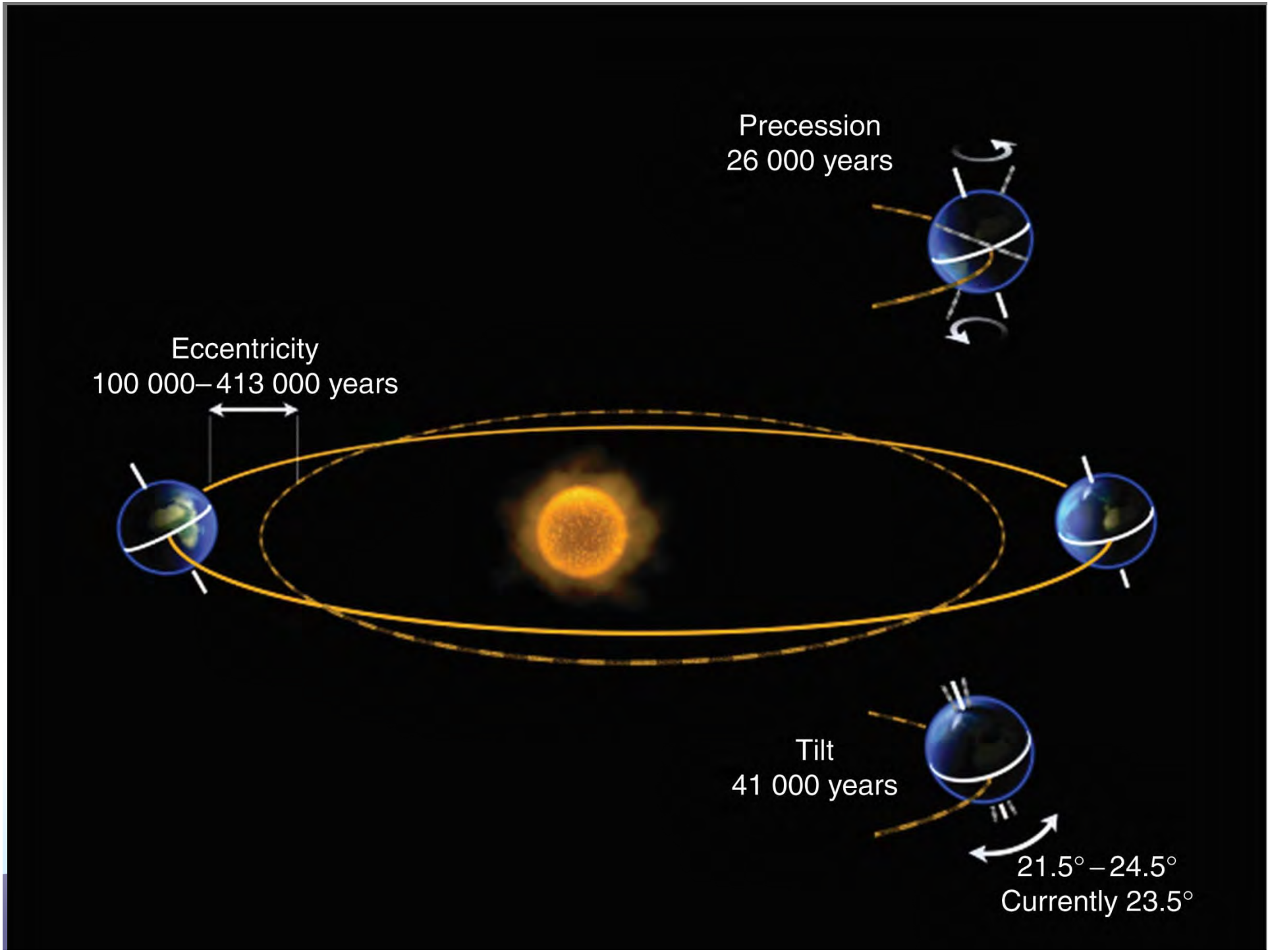
What happens when we change the initial conditions in the model?

Timeline of Climate Model Development – Climate Science is advancing

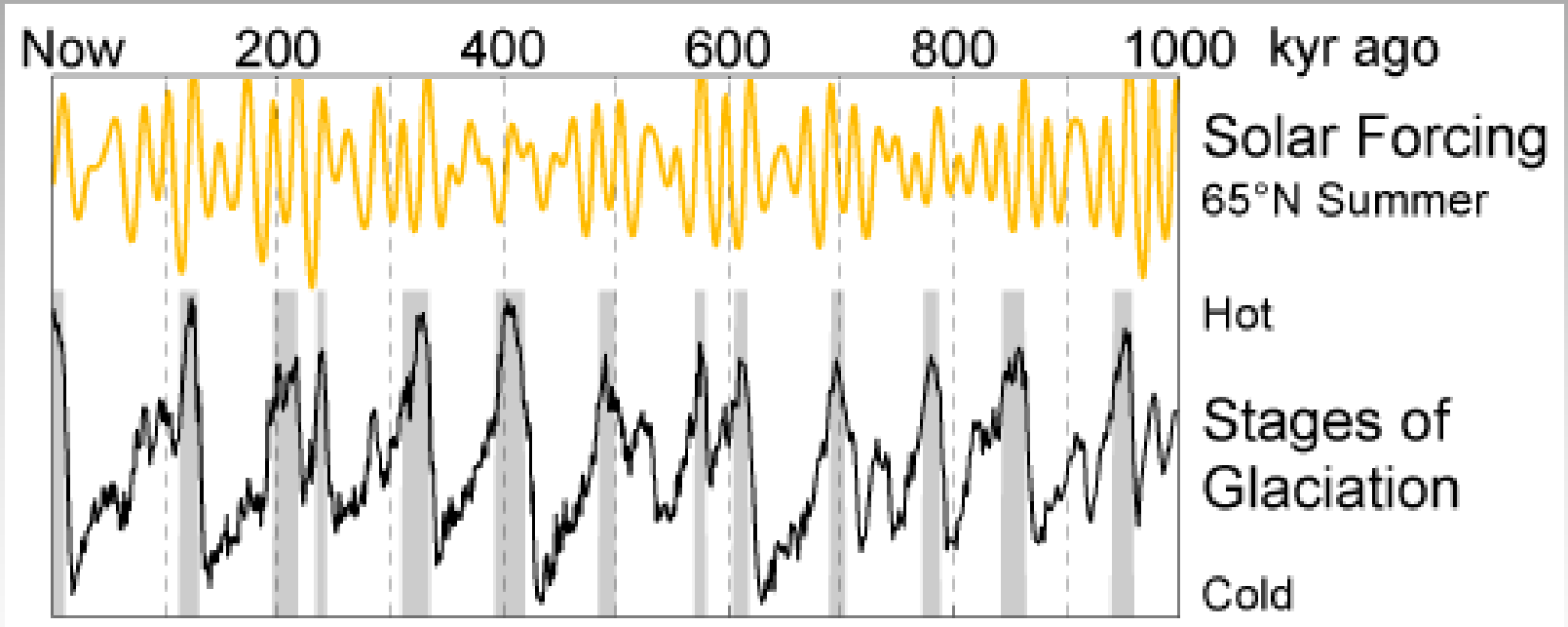


Improved understanding of system complexity as the science advances

A few → more people → collaboration

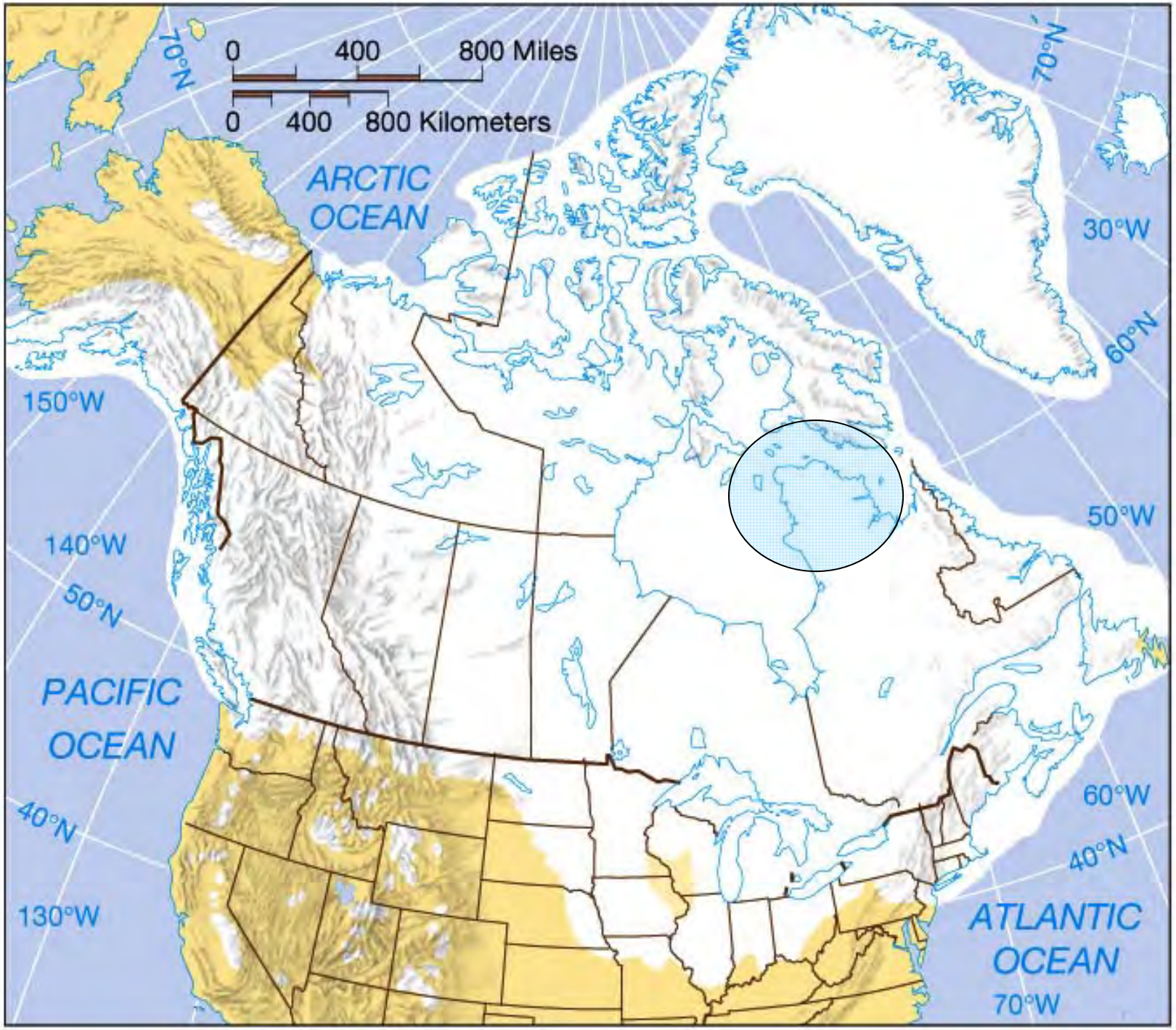

Precession
26 000 years
Eccentricity
100 000–413 000 years
Tilt
41 000 years
21.5° – 24.5°
Currently 23.5°

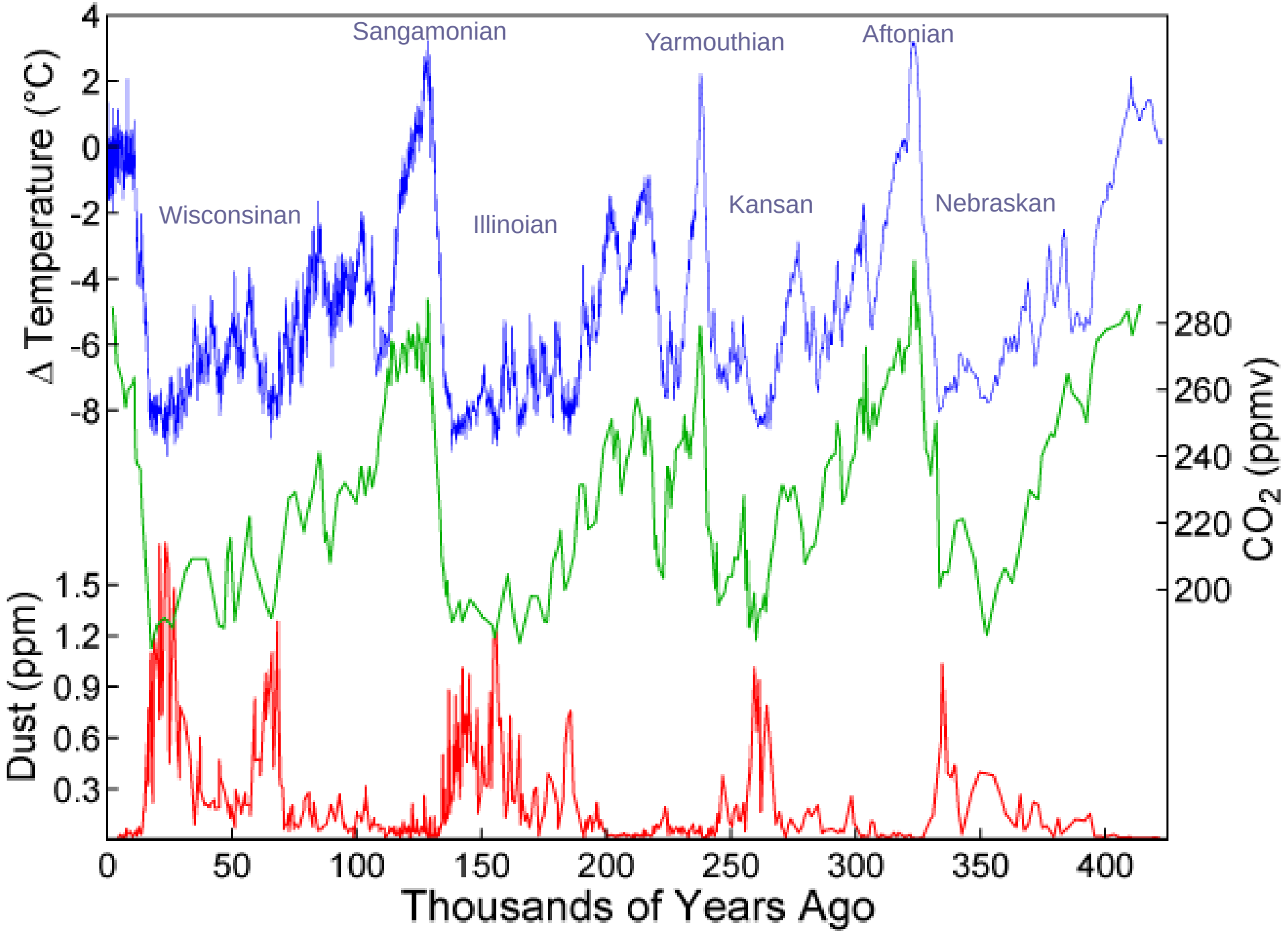
Milankovich ideas suggest that ice ages are started by a minima in summer insolation at 65°N
(so the snow does not melt in the summer)
then, internal postive feedbacks involving ice cover, vegetation, and GHG amounts ‘take over’



We do not need a change in solar irradiance, just a change in the pattern of how it is distributed on Earth


Nunavut
Northwestern Passages
Greenland
Hudson Bay
Canada
Manitoba
Newfoundland and Labrador
Ontario
Quebec
Winnipeg
Gulf of St Lawrence
North Dakota
Minnesota
New Brunswick
Prince Edward Island
Montreal
Ottawa
Maine
Nova Scotia
South Dakota
Wisconsin
Toronto
Michigan
Vermont


0 400 800 Miles
0 400 800 Kilometers
ARCTIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
70°N
70°N
30°W
60°N
150°W
50°W
140°W
50°N
60°W
40°N
40°N
130°W
70°W

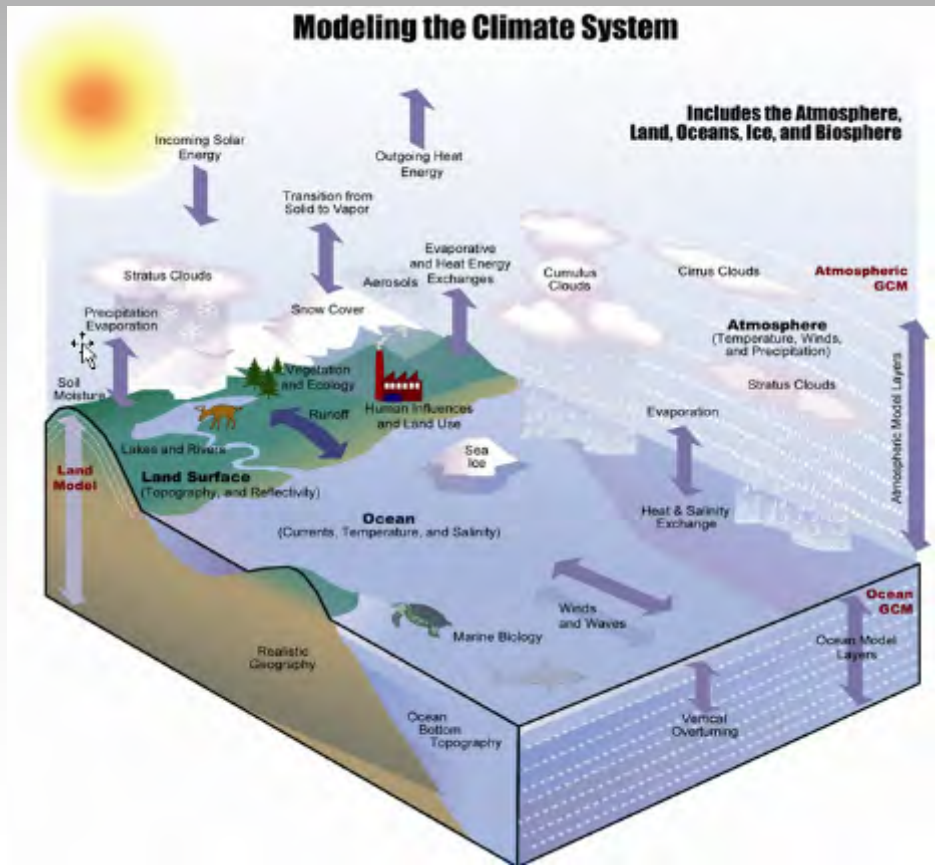

Sangamonian
Yarmouthian
Aftonian
Wisconsinan
Illinoian
Kansan
Nebraskan
Δ Temperature (°C)
4
2
0
-2
-4
-6
-8
Dust (ppm)
1.5
1.2
0.9
0.6
0.3
CO_2 (ppmv)
280
260
240
220
200
0
50
100
150
200
250
300
350
400
Thousands of Years Ago

What is climatic change from a climate science perspective?

- Has the system changed enough so that the system output is different?

- Pleistocene glaciers

- Ice-albedo feedback
  - More snow/ice
  - Higher albedo
  - Less absorption
  - Colder
  - More snow/ice



Ice Age Forcings Imply Global Climate Sensitivity of ¾°C per W/m².

Internal feedbacks influence the process, including the ice-albedo positive feedback:

cooler → more snow/ice → greater reflection → cooler →

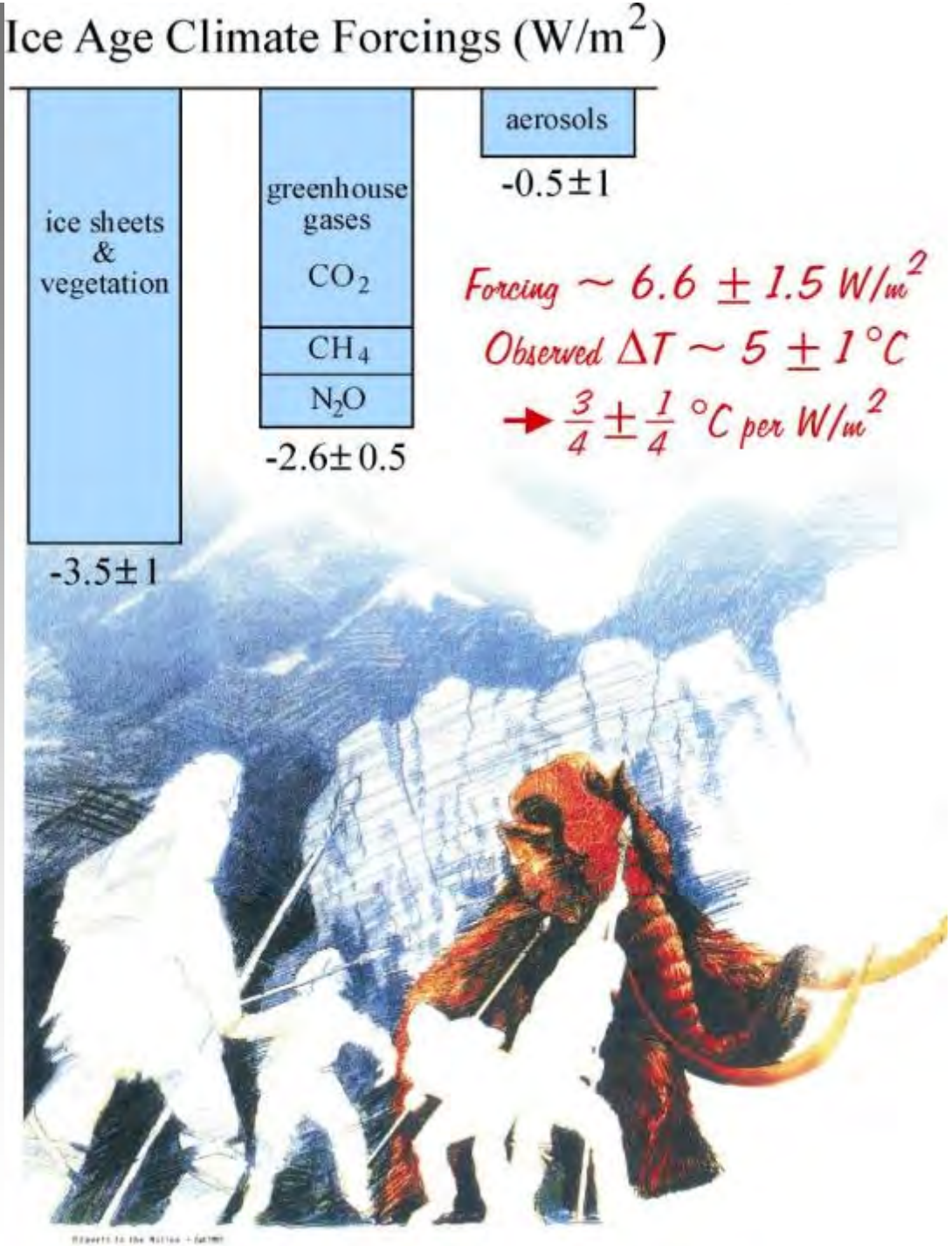
During a glacial period:

- More ice (more reflective)
- Less vegetation (less CO_2)
- More dust

Forcing down 6.6 Wm^{-2}

Temperature down 5°C

Source: Hansen *et al.*, *National Geographic Research & Exploration,* 1993, Vol. 9: 141.



How was the climate system different during the 1930s?

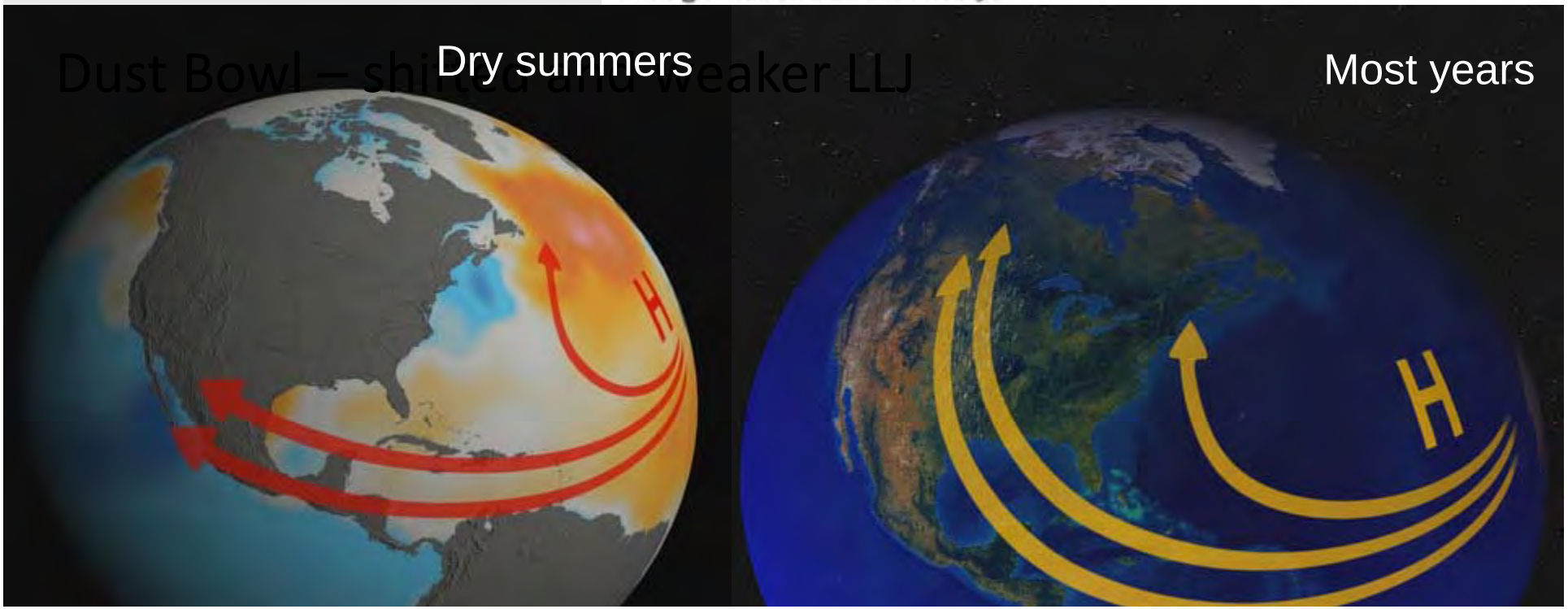
Schubert *et al.* 2004
SCIENCE 303: 1855-59

On the Cause of the 1930s Dust Bowl

Siegfried D. Schubert,[1]* Max J. Suarez,[1] Philip J. Pegion,[1,2]
Randal D. Koster,[1] Julio T. Bacmeister[1,3]

During the 1930s, the United States experienced one of the most devastating droughts of the past century. The drought affected almost two-thirds of the country and parts of Mexico and Canada and was infamous for the numerous dust storms that occurred in the southern Great Plains. In this study, we present model results that indicate that the drought was caused by anomalous tropical sea surface temperatures during that decade and that interactions between the atmosphere and the land surface increased its severity. We also contrast the 1930s drought with other North American droughts of the 20th century.

Dust Bowl – shifted and weaker LLJ



Unusual SSTs during the Dust Bowl -- warm Atlantic, cool Pacific

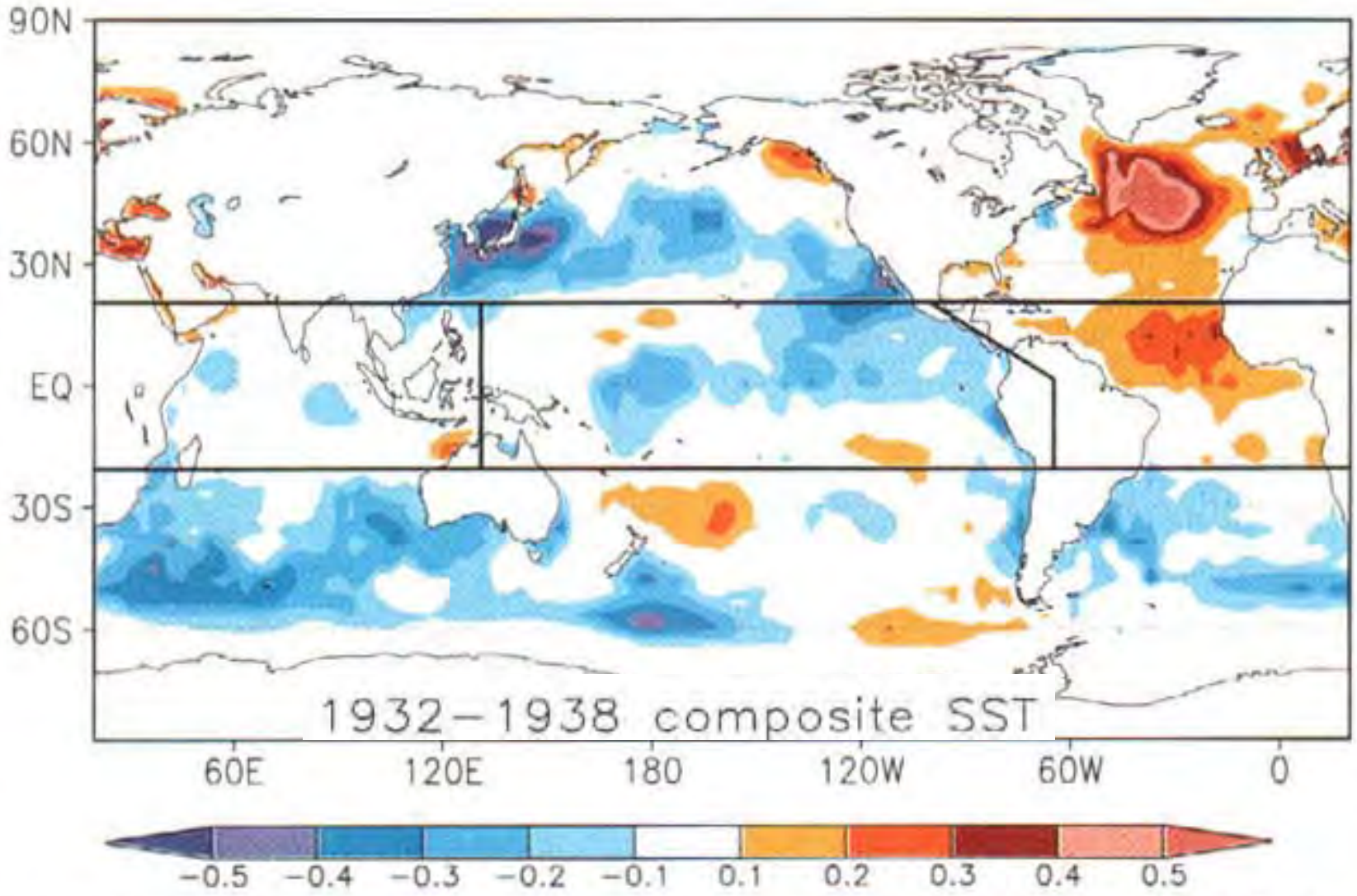
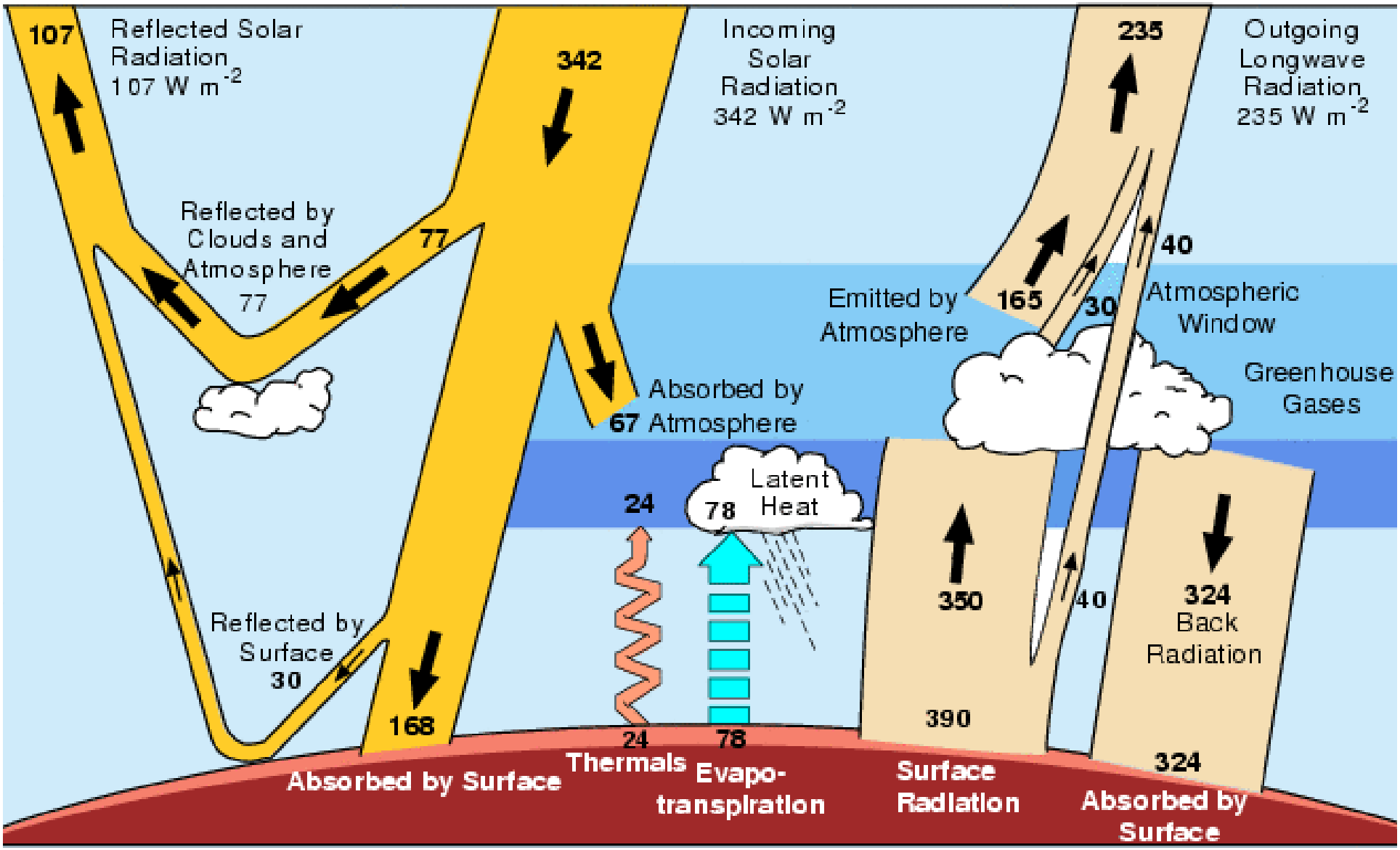


Fig. 2. The global SST anomalies averaged for the Dust Bowl period (1932 to 1938). The boxes delineate the various subregions (tropical oceans, Indian Ocean, Pacific Ocean, Atlantic Ocean) used in designing the idealized SST forcing experiments. The anomalies are the differences from the 1902 to 1999 SST climatology (*15*). Units, °C.



Kiehl, J. T. and Trenberth, K. E. (1997). "Earth's Annual Global Mean Energy Budget". *Bulletin of the American Meteorological Association* 78: 197-208.

How the greenhouse effect works:

- Earth emitted radiation (some call this heat) moves out from the surface
- The Earth emitted radiation is absorbed by clouds and greenhouse gases (water vapor, carbon dioxide, methane, …), so the energy moves from the surface to the atmosphere
- With more clouds or water vapor, more of the energy is not lost to space
- This greenhouse effect is a common human experience

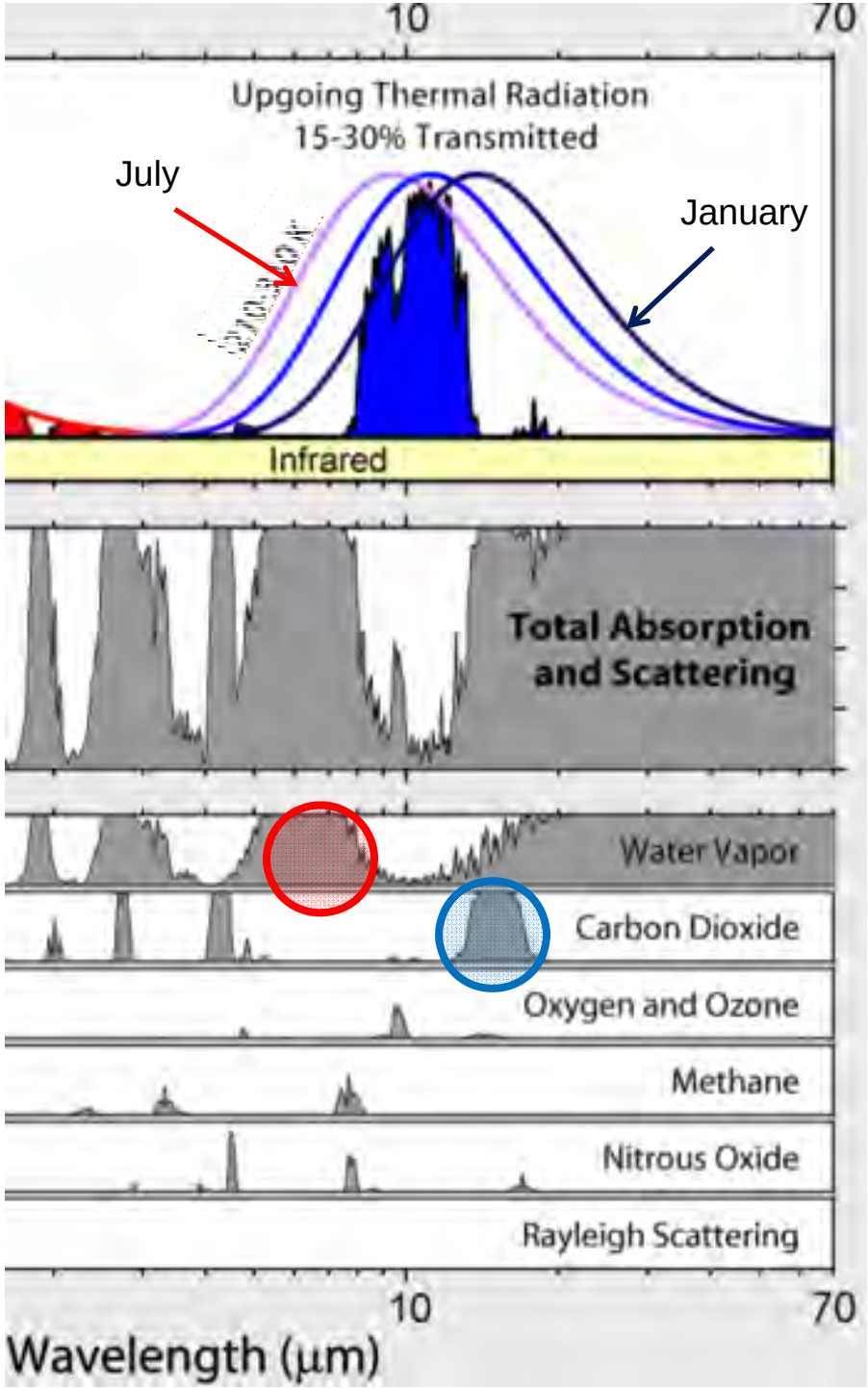
Earth-emitted or thermal radiation

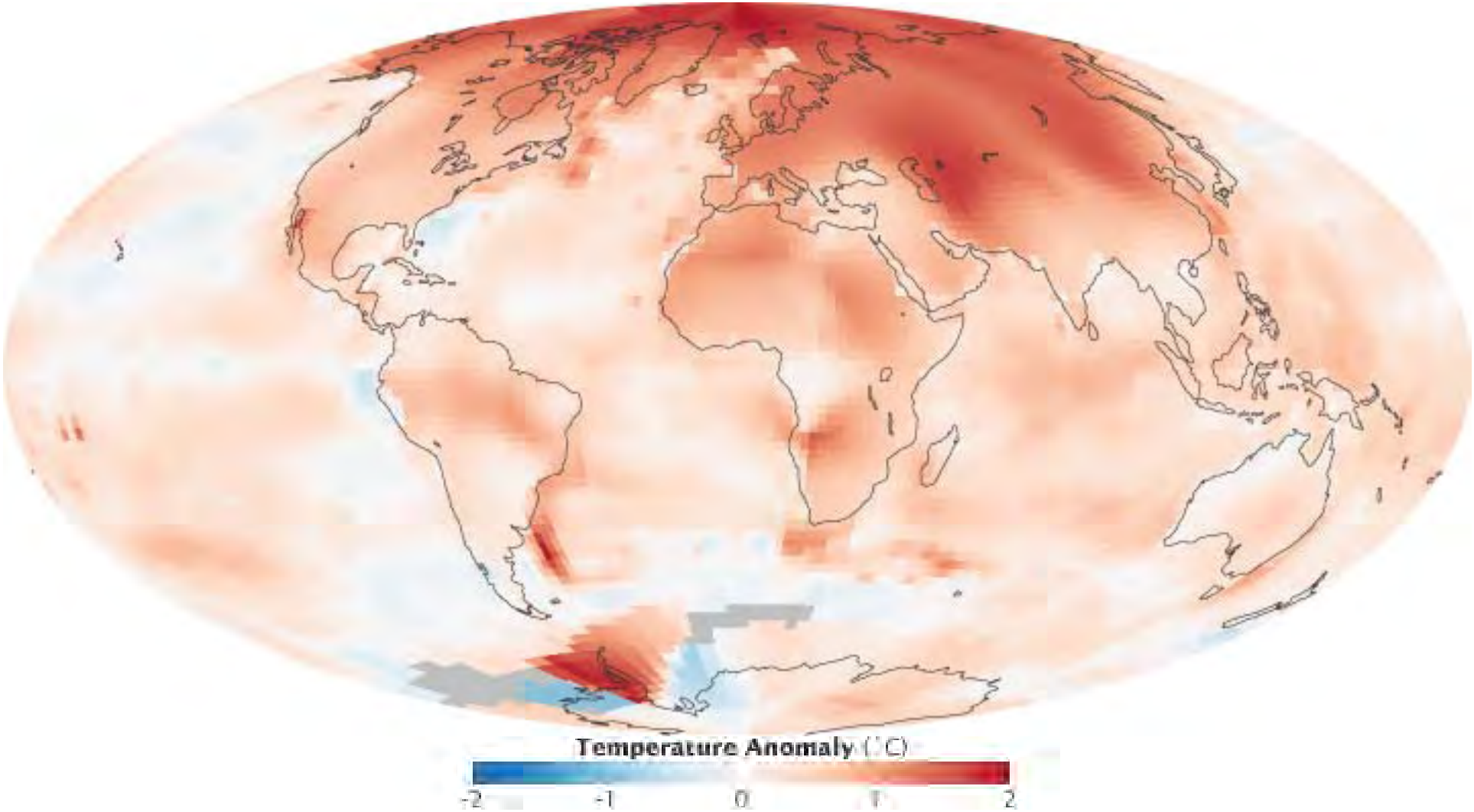
Topeka average temperature in:

July = 79 F (26.1)

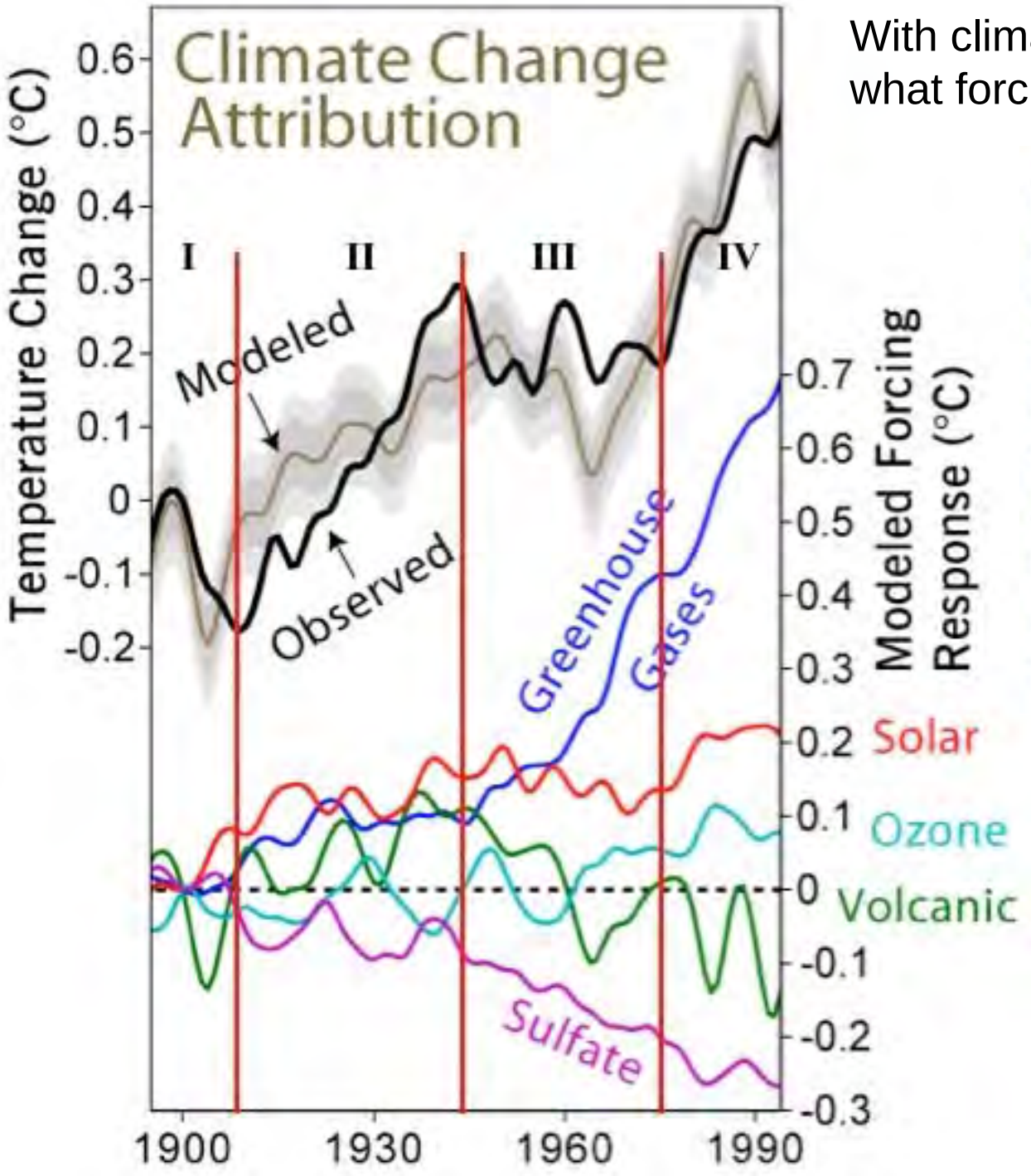
January = 26 F (-3.3)

	Peak wavelength
14.0°C	10.1 µm
26.1	9.7
-3.3	10.7





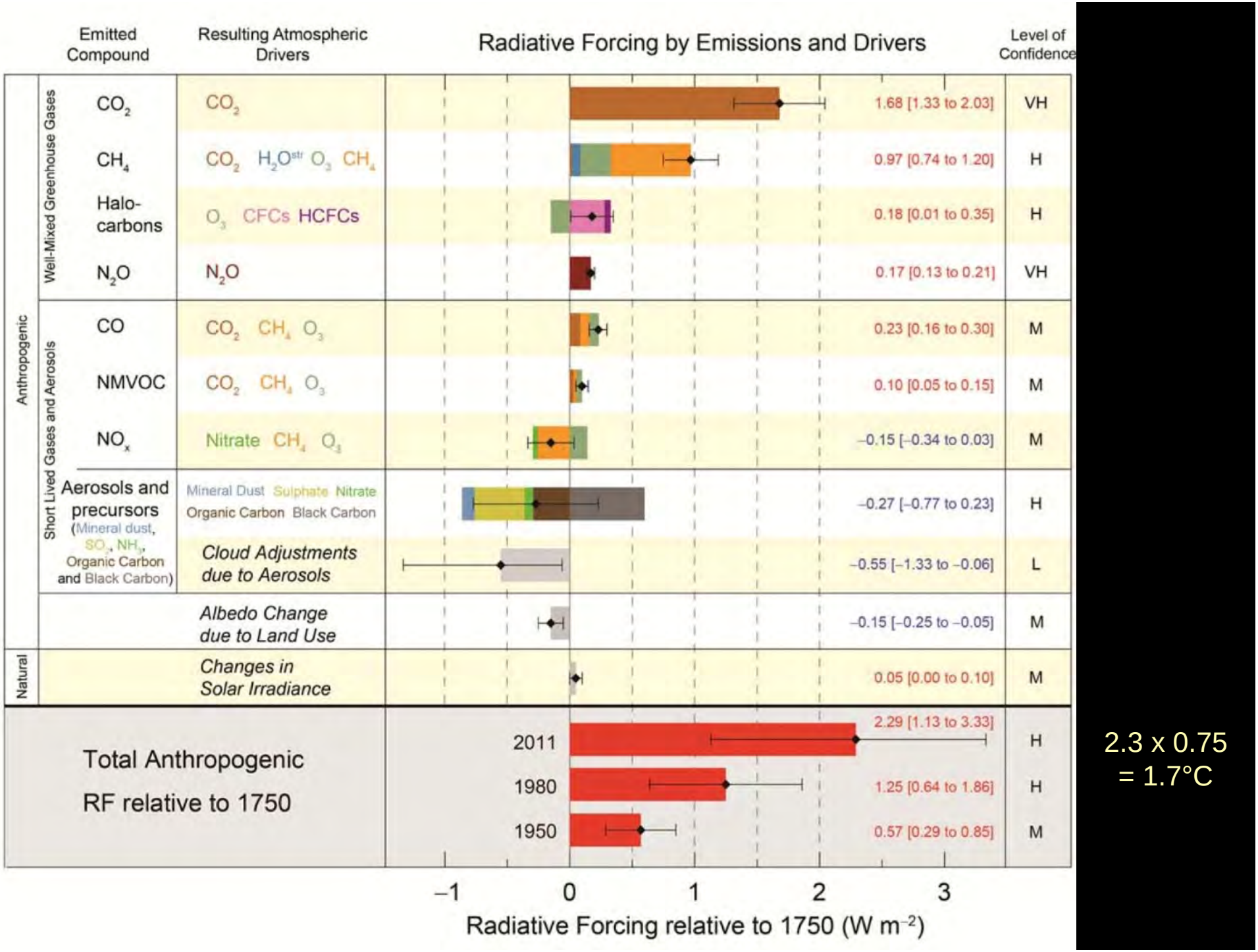
Global pattern of temperature anomalies for 2000-2009 compared with the 1950-1980 base period.
More CO_2 and cold places warm up.



With climate models, we can learn what forcings are more important

Natural and anthropogenic contributions to global temperature change (Meehl et al., 2004). Observed values from Jones and Moberg 2001. Grey bands indicate 68% and 95% range derived from multiple simulations.

Model runs suggest that since about 1975, the increase in GHGs has become the dominant reason for increasing planetary temperature


Emitted Compound
Resulting Atmospheric Drivers
Radiative Forcing by Emissions and Drivers
Level of Confidence
Anthropogenic
Natural
Well-Mixed Greenhouse Gases
Short Lived Gases and Aerosols
CO2
CH4
Halo-carbons
N2O
CO
NMVOC
NOx
Aerosols and precursors (Mineral dust, SO2, NH3, Organic Carbon and Black Carbon)
CO2
CO2 H2Ostr O3 CH4
O3 CFCs HCFCs
N2O
CO2 CH4 O3
CO2 CH4 O3
Nitrate CH4 O3
Mineral Dust Sulphate Nitrate Organic Carbon Black Carbon
Cloud Adjustments due to Aerosols
Albedo Change due to Land Use
Changes in Solar Irradiance
1.68 [1.33 to 2.03]
0.97 [0.74 to 1.20]
0.18 [0.01 to 0.35]
0.17 [0.13 to 0.21]
0.23 [0.16 to 0.30]
0.10 [0.05 to 0.15]
–0.15 [–0.34 to 0.03]
–0.27 [–0.77 to 0.23]
–0.55 [–1.33 to –0.06]
–0.15 [–0.25 to –0.05]
0.05 [0.00 to 0.10]
VH
H
H
VH
M
M
M
H
L
M
M
Total Anthropogenic RF relative to 1750
2011
1980
1950
2.29 [1.13 to 3.33]
1.25 [0.64 to 1.86]
0.57 [0.29 to 0.85]
H
H
M
–1
0
1
2
3
Radiative Forcing relative to 1750 (W m–2)

2.3 x 0.75
= 1.7°C

What about water vapor ?

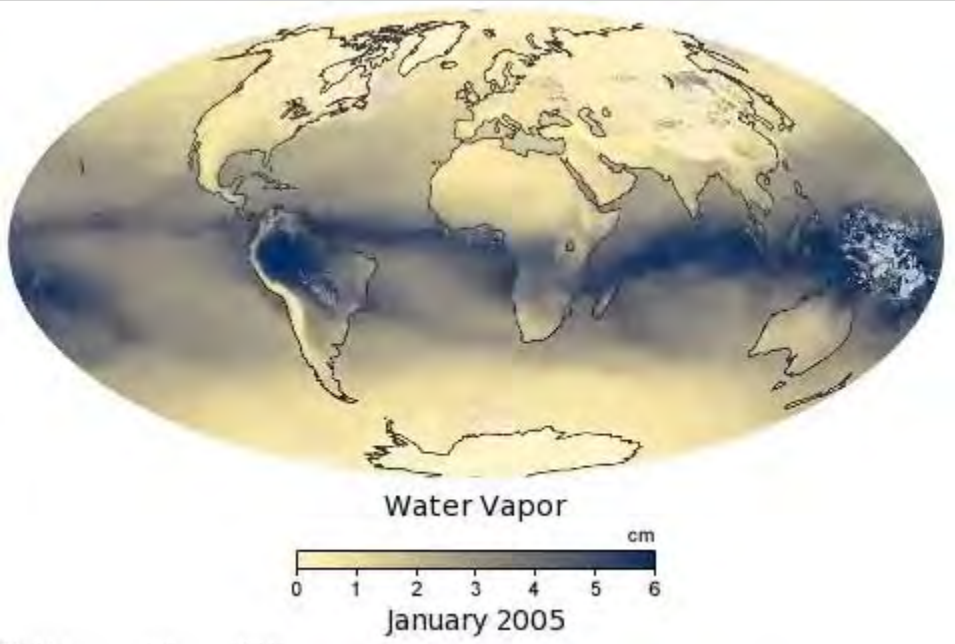
The most important greenhouse gas naturally

Accounts for over 50% of natural blanketing/warming

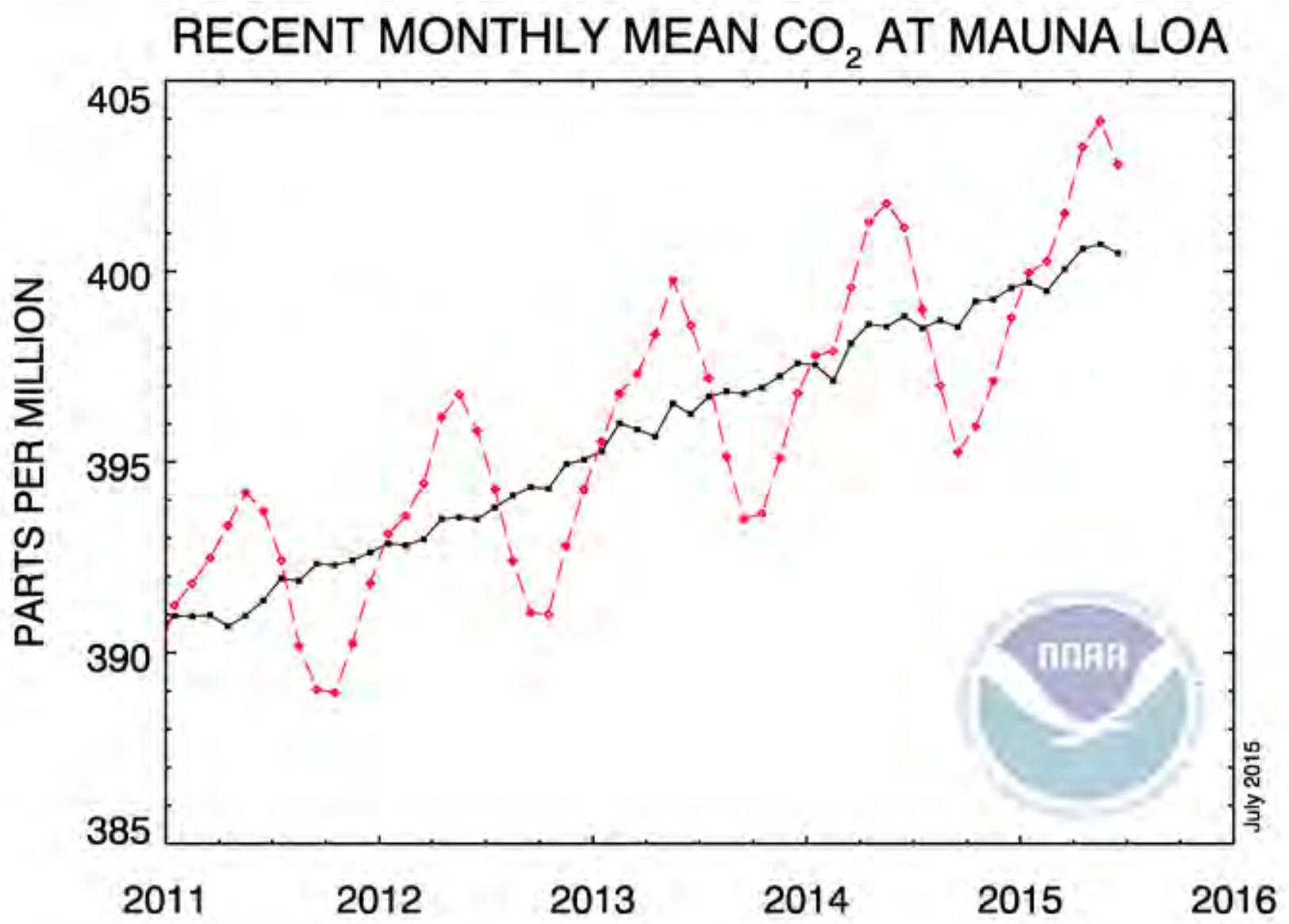
With more energy absorbed by the oceans, the rate of evaporation is higher

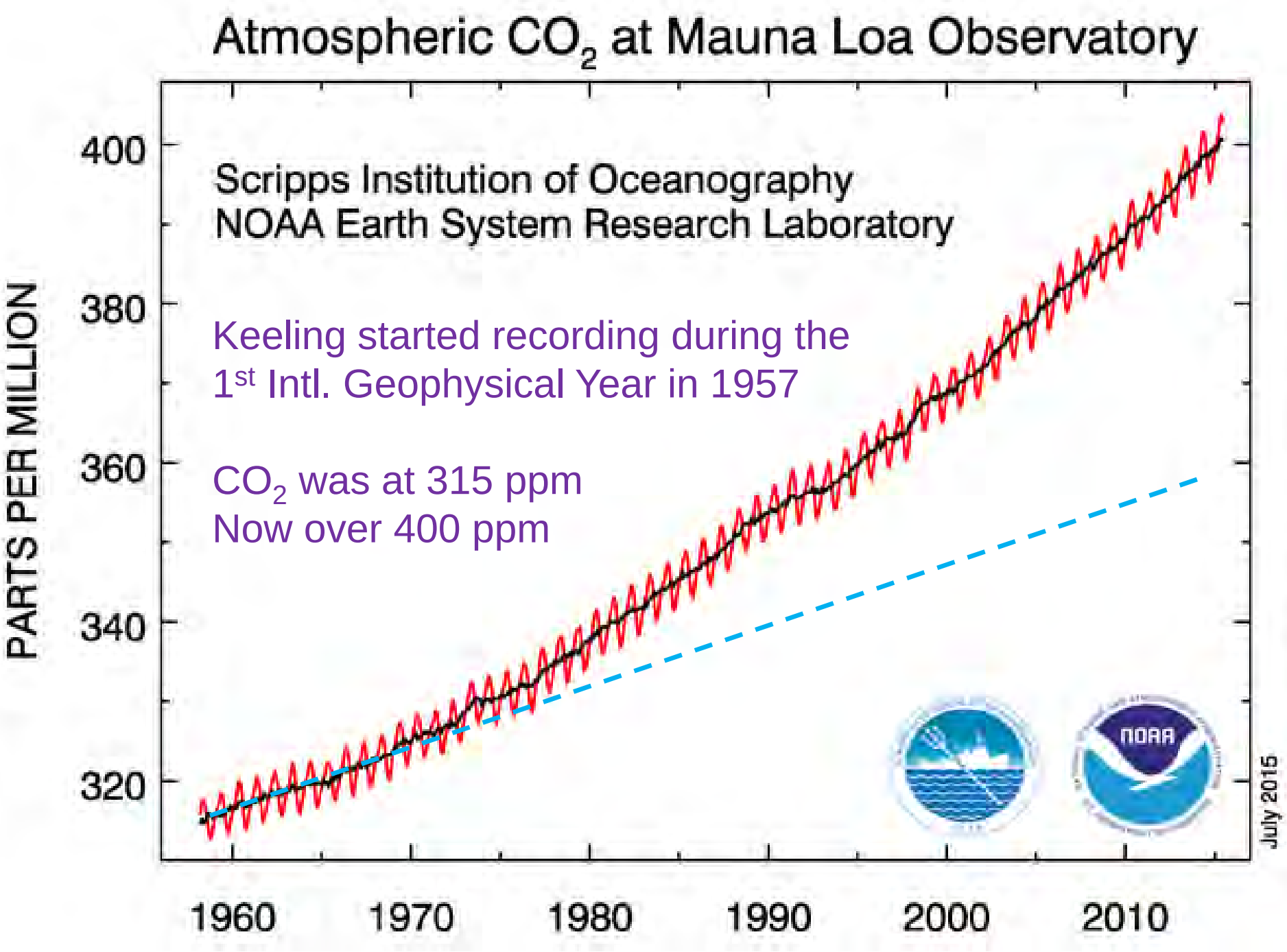
We have not monitored it

Clausius–Clapeyron relation
the water-holding capacity of the atmosphere increases by about 7% for every 1 °C rise in temperature

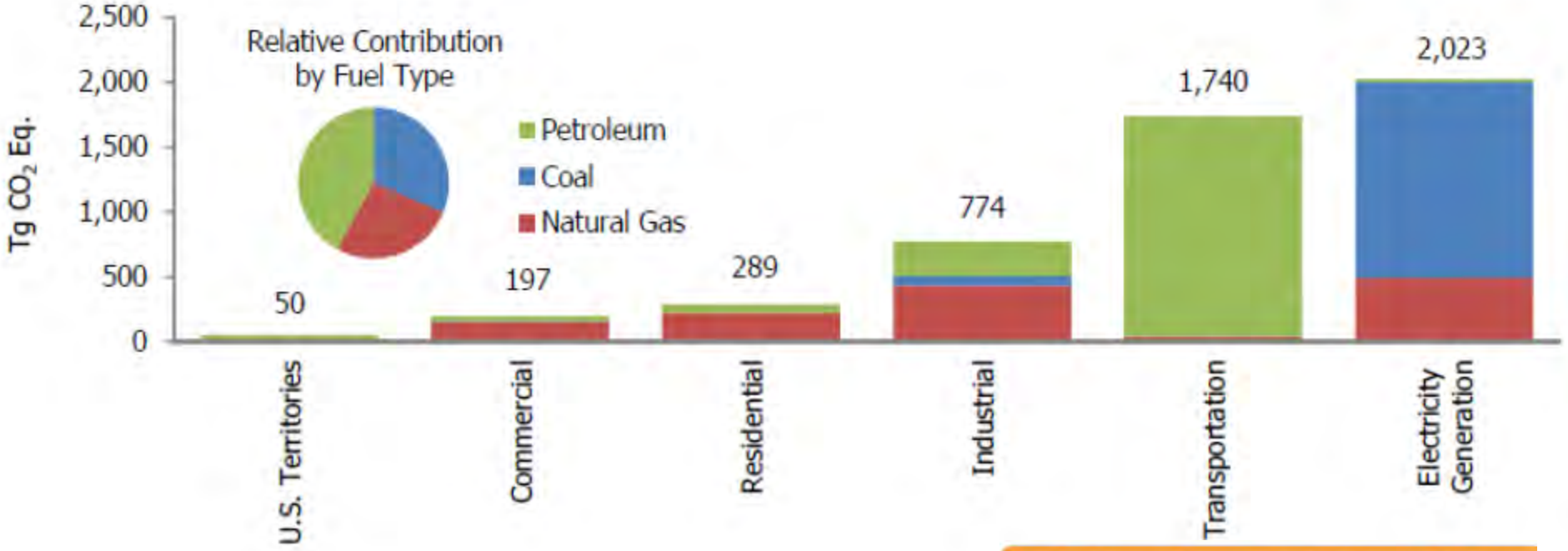


The Keeling Curve – carbon dioxide data recorded at an observatory in Hawaii – the annual cycle is linked to green up of vegetation in the No Hemisphere (CO_2 sequestration)

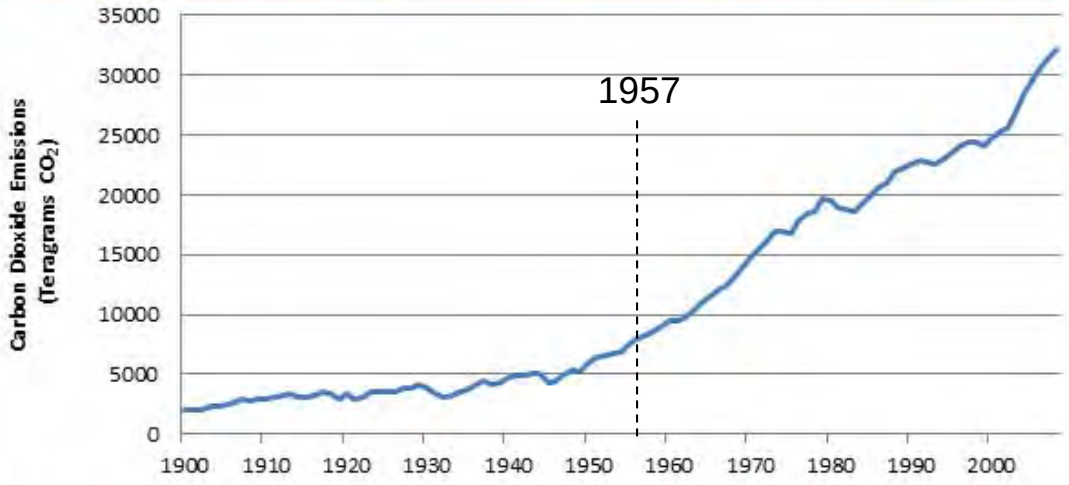



Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
Keeling started recording during the
1st Intl. Geophysical Year in 1957
CO_2 was at 315 ppm
Now over 400 ppm
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
NOAA
July 2015

2012 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

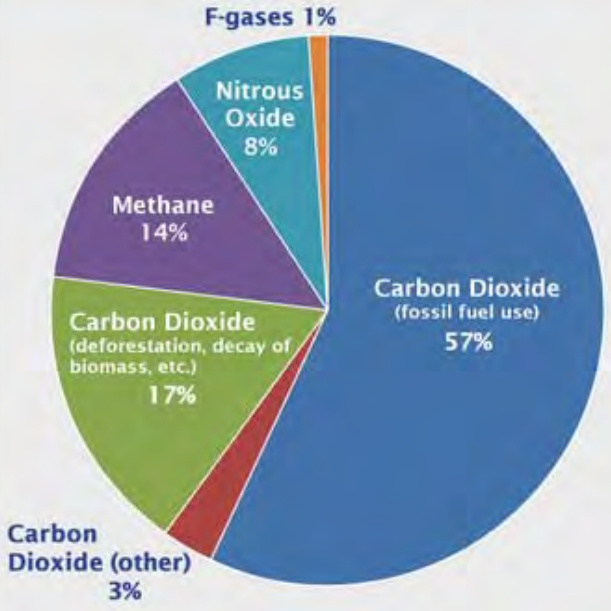


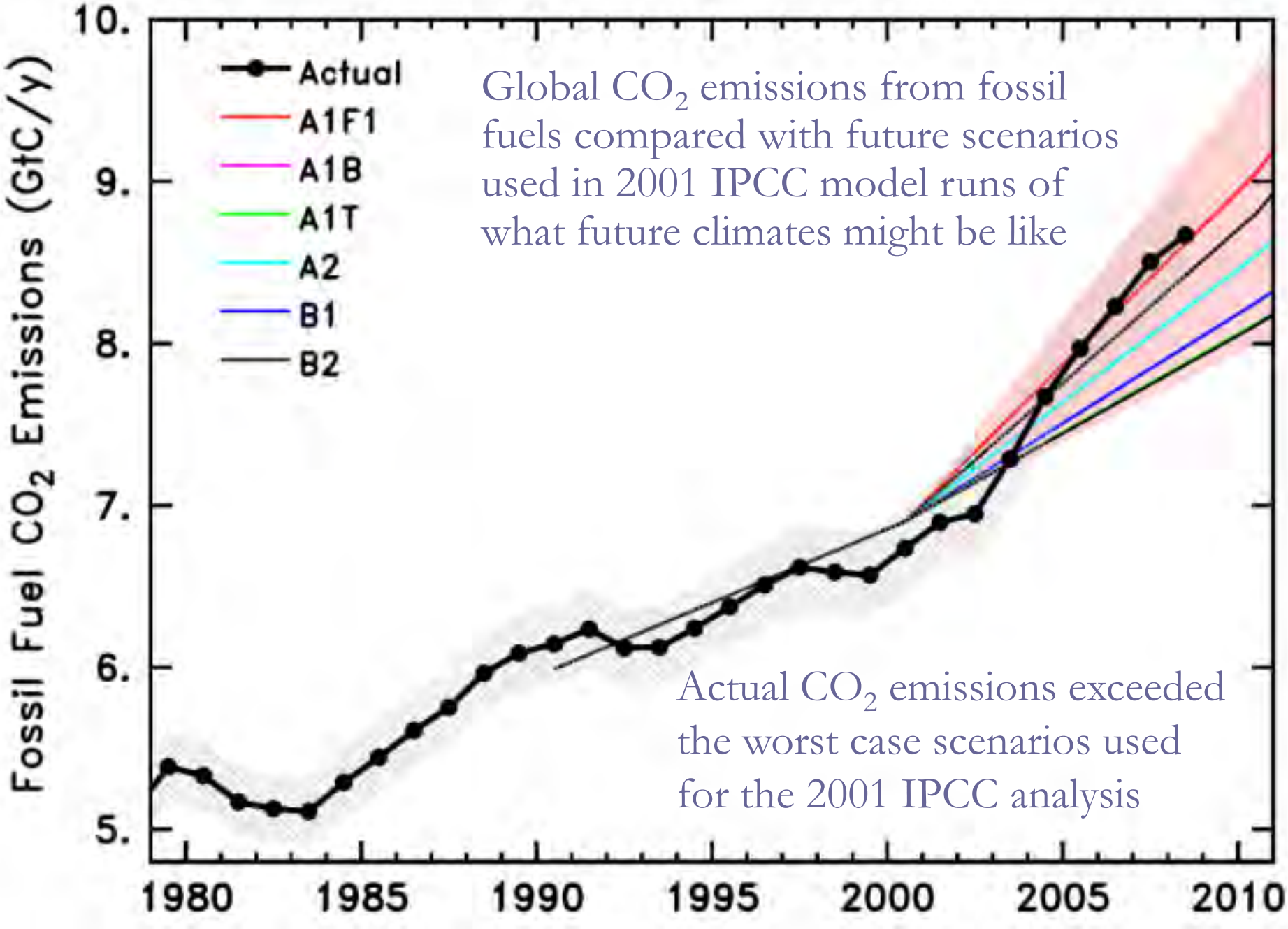
Global Carbon Dioxide (CO_2) emissions from fossil-fuels 1900–2008



Source of data: Boden, T.A., G. Marland, and R.J. Andres (2010). Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2010.

Global Greenhouse Gas Emissions by Gas




Fossil Fuel CO_2 Emissions (GtC/y)
10.
9.
8.
7.
6.
5.
1980
1985
1990
1995
2000
2005
2010
Actual
A1F1
A1B
A1T
A2
B1
B2
Global CO_2 emissions from fossil fuels compared with future scenarios used in 2001 IPCC model runs of what future climates might be like
Actual CO_2 emissions exceeded the worst case scenarios used for the 2001 IPCC analysis

8 September 2014 Last updated at 22:09 ET

Share

Greenhouse gas levels rising at fastest rate since 1984

COMMENTS (138)

By Matt McGrath
Environment correspondent, BBC News

New WMO Bulletin

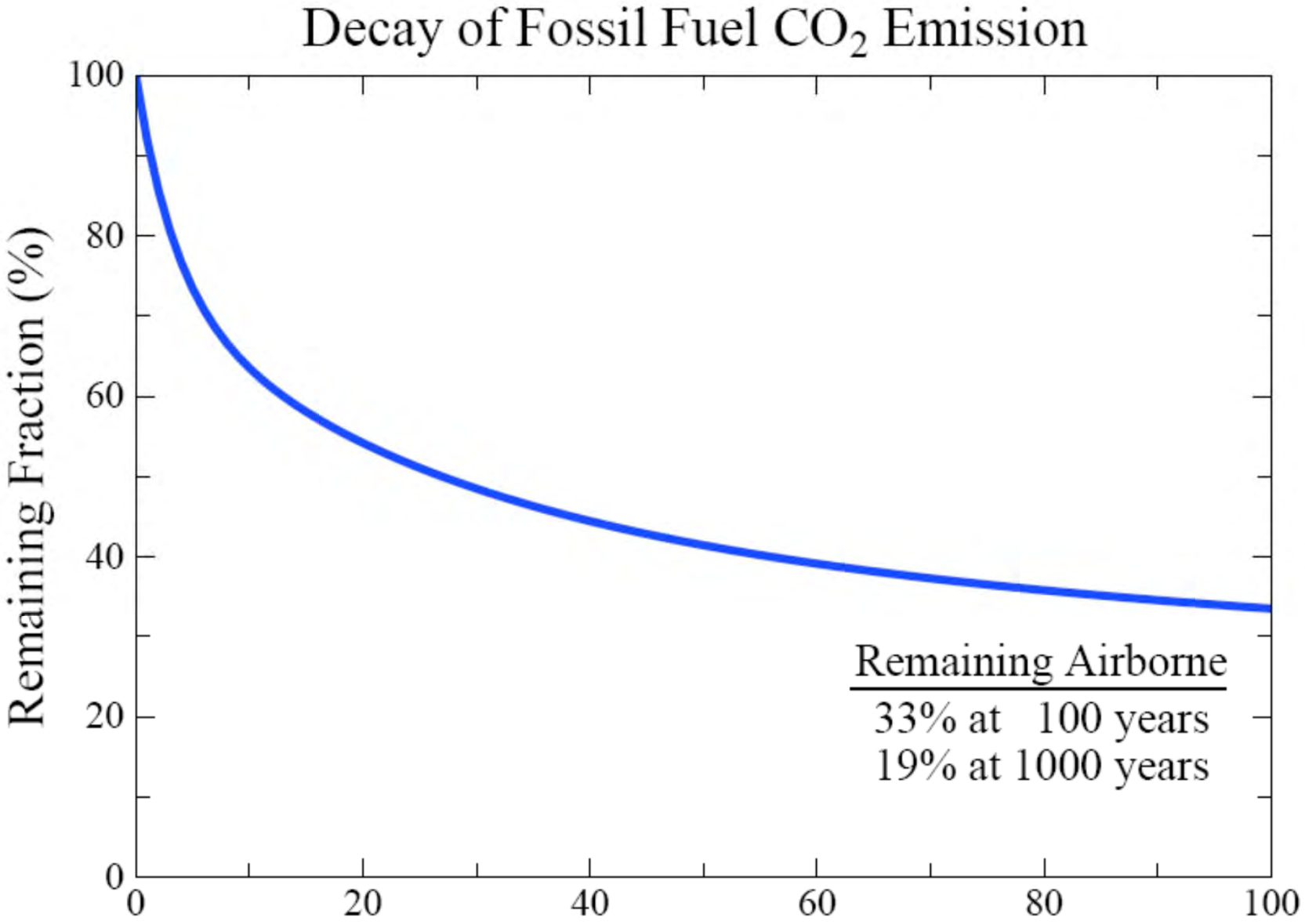
According to the bulletin, the globally averaged amount of carbon dioxide in the atmosphere reached 396 parts per million (ppm) in 2013, an increase of almost 3ppm over the previous year.

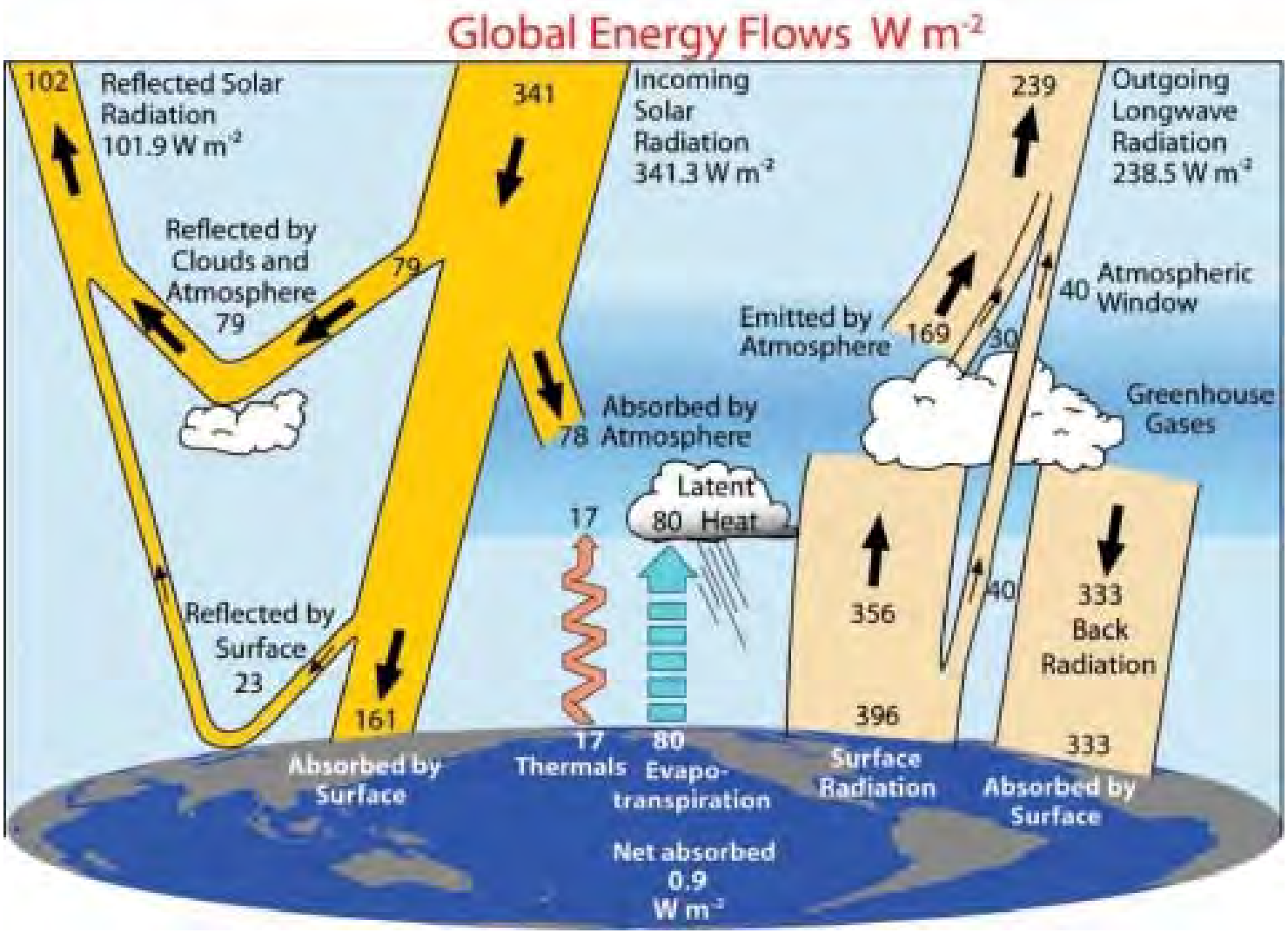
Concentrations of CO2 in the atmosphere rose rapidly in 2013

A surge in atmospheric CO2 saw levels of greenhouse gases reach record levels in 2013, according to new figures.

Related Stories

The fraction of CO_2 remaining in the air, after emission by fossil fuel burning, declines rapidly at first, but 1/3 remains in the air after a century and almost 1/5 after a millennium (*Atmos. Chem. Phys.* **7**, 2287-2312, 2007).





341.3 Wm^{-2}

-101.9

<u>- 238.5</u>

+ 0.9 Wm^{-2}

Trenberth, K.E., Fasullo, J.T., and Kiehl, J. (2009) Earth's Global Energy Budget, in *Bulletin of the AMS*, Vol 90, pp 311-323.

Latest data suggest the system is temporarily out of balance with most of the absorbed E going into the oceans

Box 1 | Updated energy balance

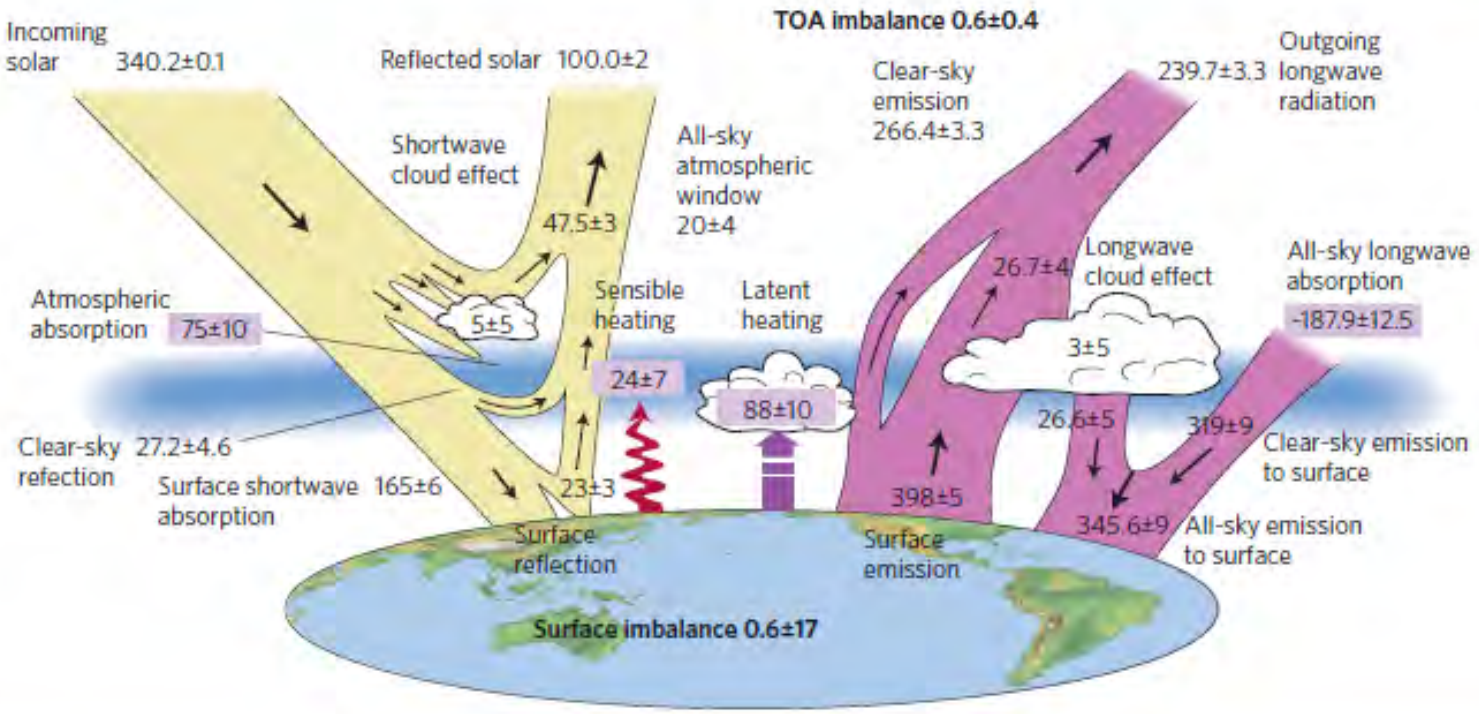
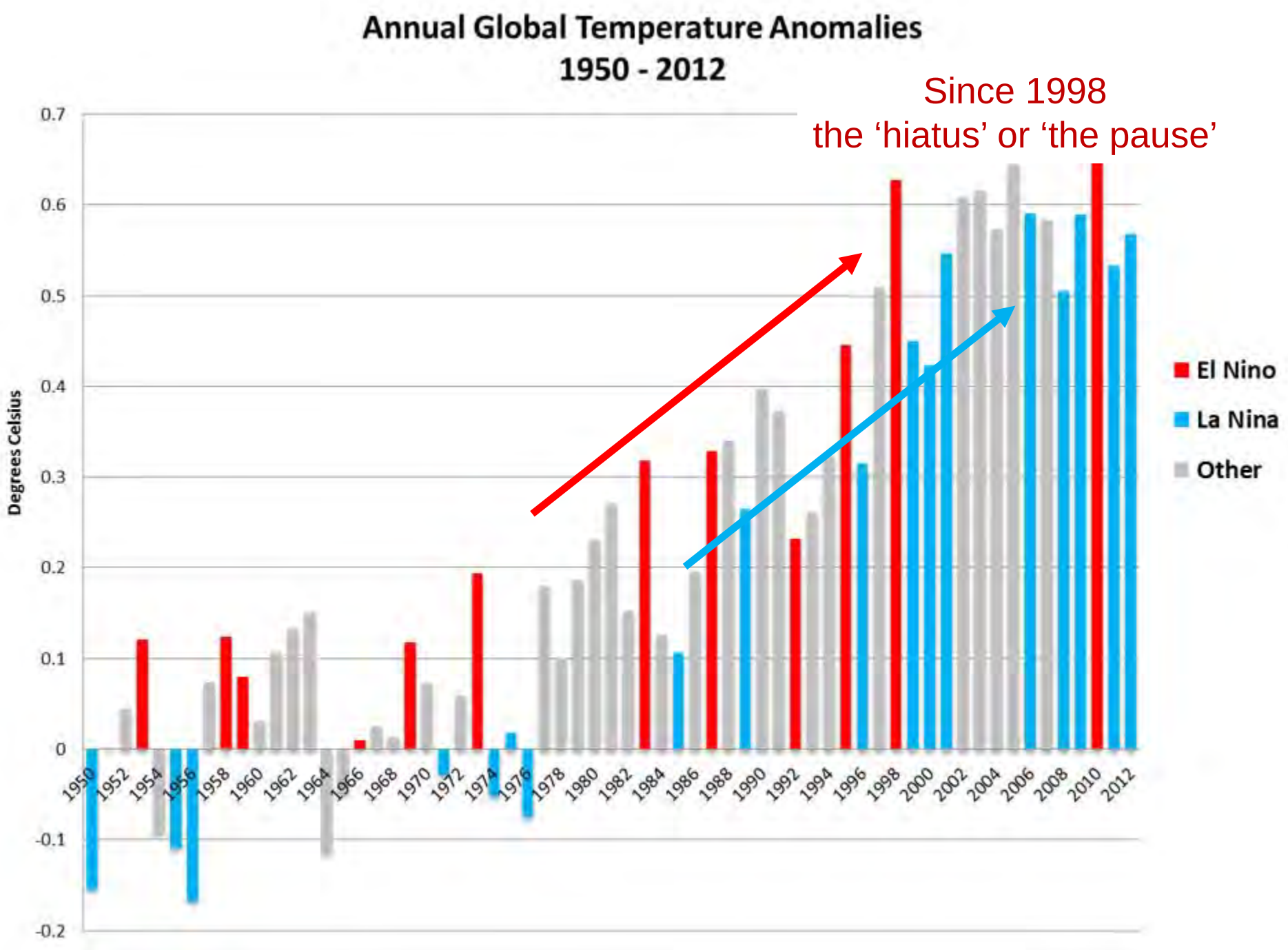


Figure B1 | The global annual mean energy budget of Earth for the approximate period 2000–2010. All fluxes are in Wm^{-2}. Solar fluxes are in yellow and infrared fluxes in pink. The four flux quantities in purple-shaded boxes represent the principal components of the atmospheric energy balance.

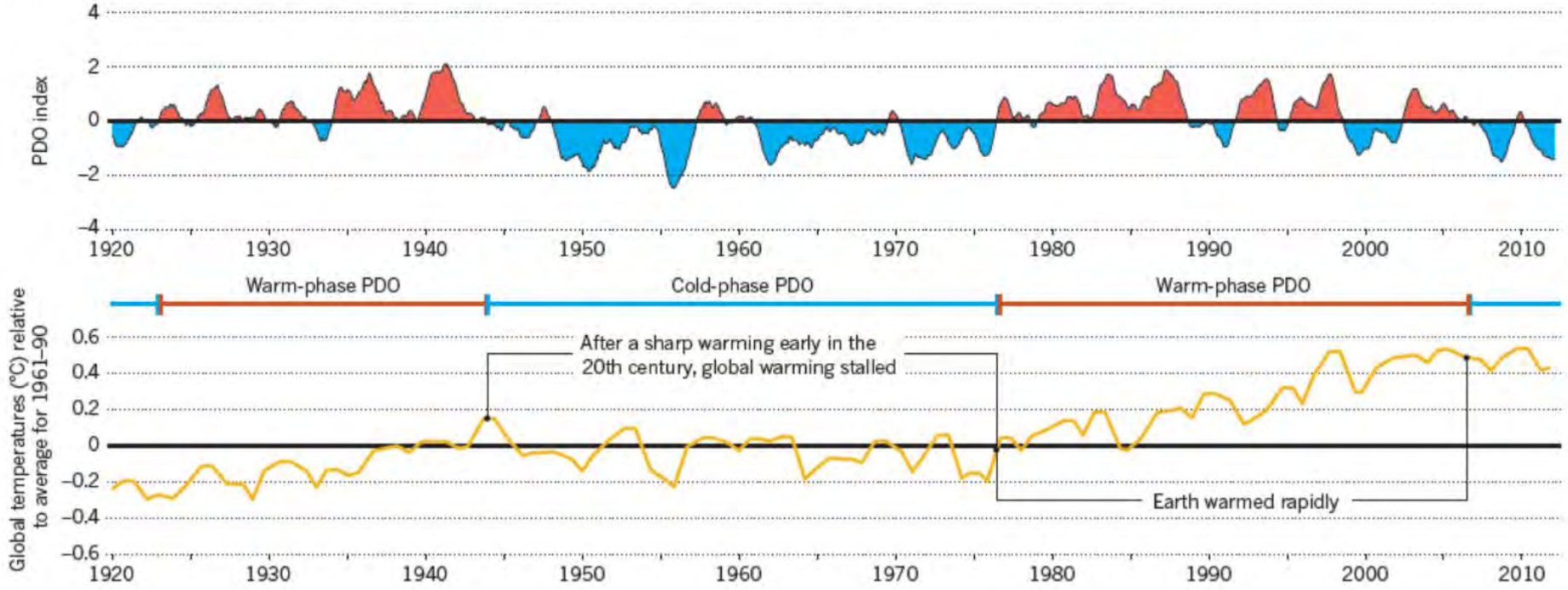
An update in 2013

Improved numbers – same conclusion (an imbalance)


Annual Global Temperature Anomalies
1950 - 2012
Since 1998
the 'hiatus' or 'the pause'
Degrees Celsius
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
El Nino
La Nina
Other

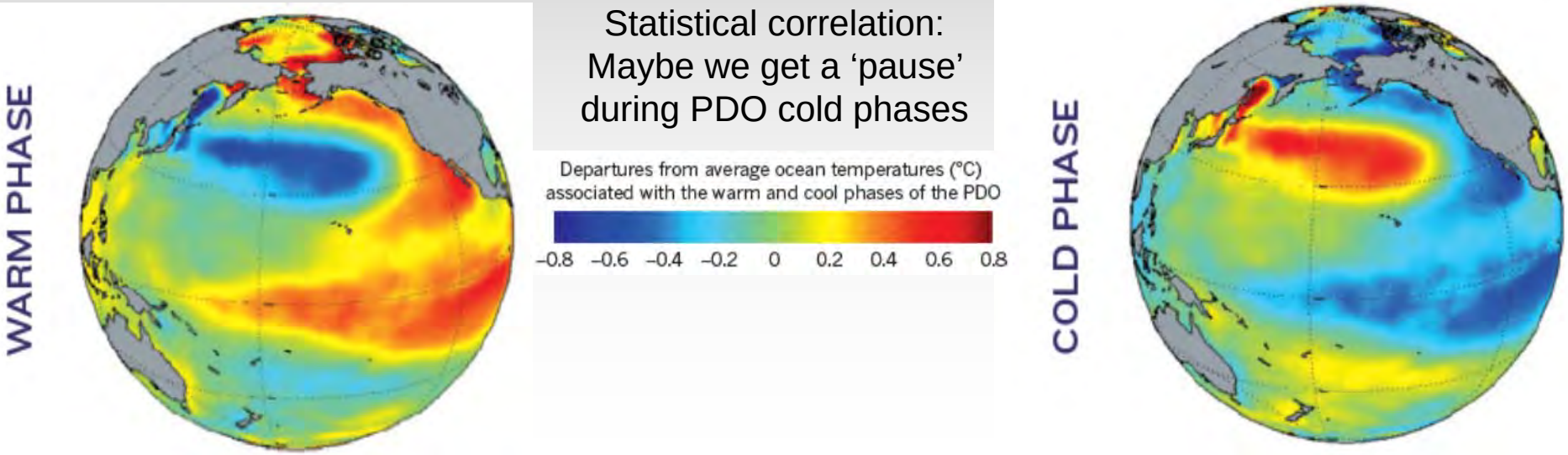
THE PACIFIC'S GLOBAL REACH

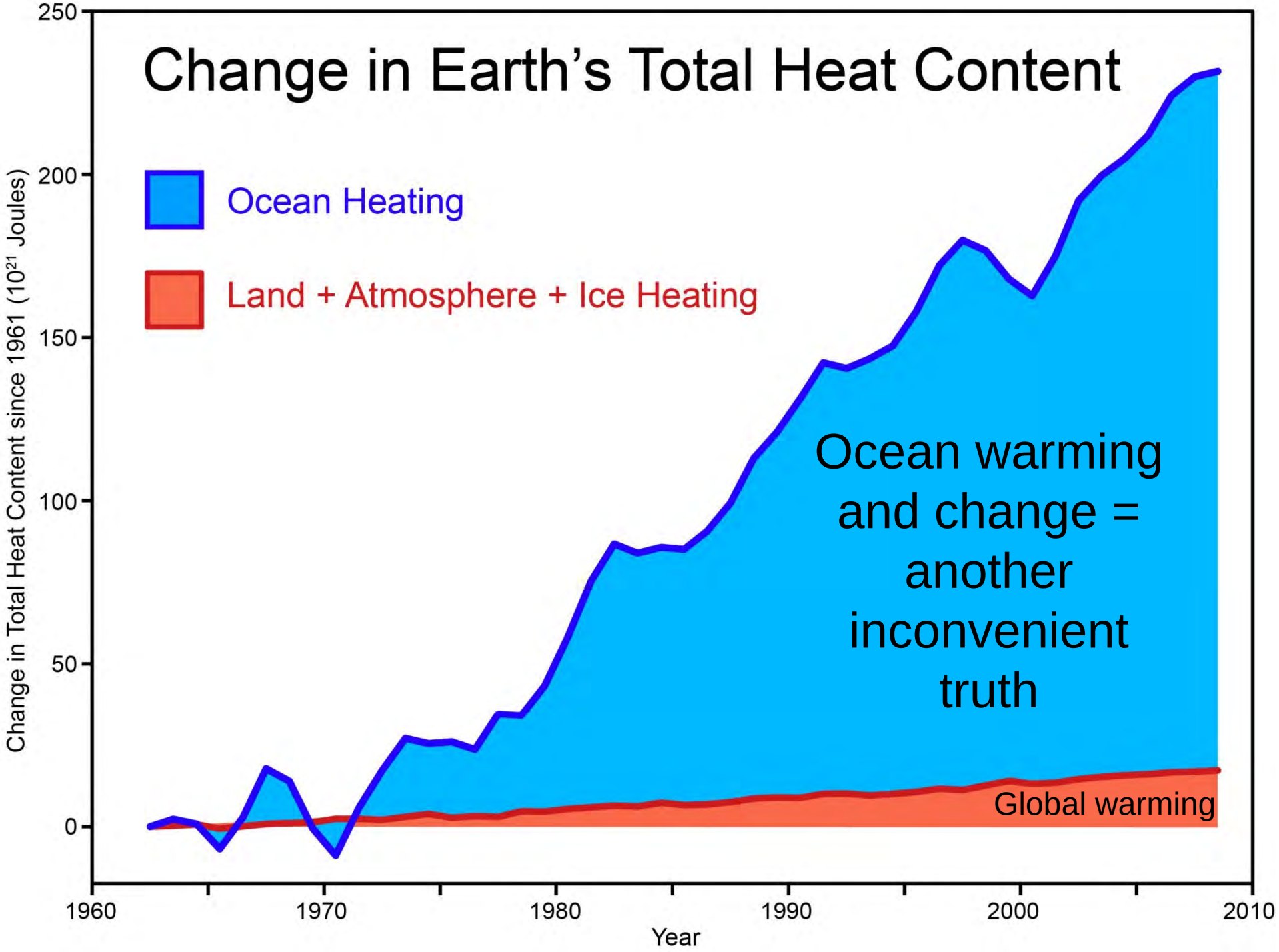
As researchers have investigated why global temperatures have not risen much since 1998, many have focused on an ocean cycle known as the Pacific Decadal Oscillation (PDO). During periods when the PDO index is positive and the eastern Pacific is warm, global temperatures have risen quickly. During spells when the PDO index is negative, the warming has stagnated.



UNIV. WASHINGTON/IPCC

Statistical correlation: Maybe we get a 'pause' during PDO cold phases




Change in Earth's Total Heat Content
Ocean Heating
Land + Atmosphere + Ice Heating
Ocean warming and change = another inconvenient truth
Global warming
Change in Total Heat Content since 1961 (10^{21} Joules)
250
200
150
100
50
0
1960
1970
1980
1990
2000
2010
Year

From NASA Scientist Jim Hansen's talk on Dec 6th 2005 at the American Geophysical Union Meetings

Implications of Paleo Forcings and Response

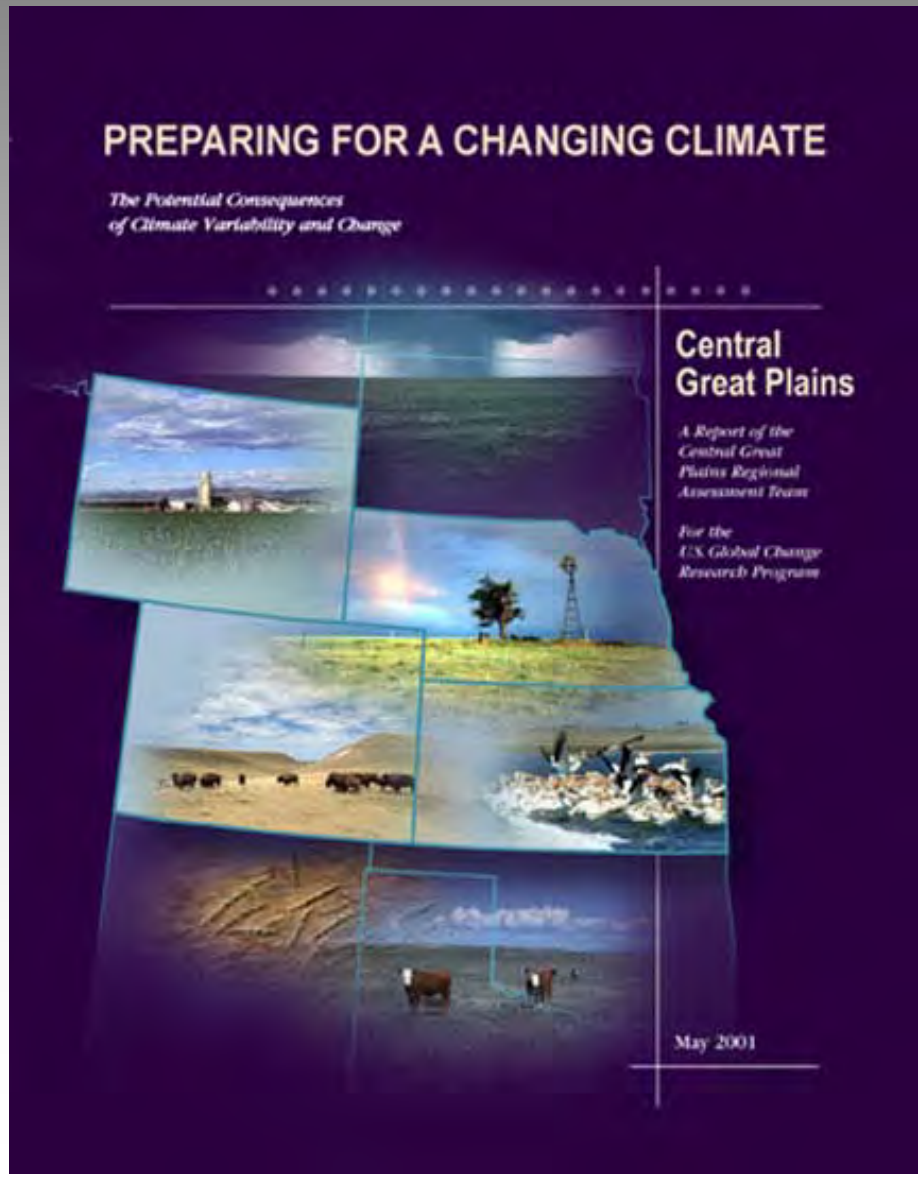
1. "Feedbacks" (or indirect forcings) cause almost all paleo temperature change.
2. Climate on these time scales is very sensitive to even small forcings.
3. Instigators of climate change must include: orbital variations, other small forcings, noise.
4. Another "ice age" cannot occur unless humans become extinct. Even then, it would require thousands of years. Humans now control global climate, for better or worse.

Implication = we are doing geoengineering whether we want to or not

Climate Change and Kansas

What might we expect to see?

- Warmer temperatures in both winter and summer
- More frequent and longer lasting heat waves
- Less soil moisture during the growing season
- More extreme events
- Declines in available water resources
- There is the potential for more and longer lasting drought
- The changes might not be gradual; we may have to deal with ‘non-linear’ system responses and rapid transitions to new states



Kansas Climate and Global Warming: Agricultural and Other Economic Impacts

Wayne M Wendland 1993 Trans. Kansas Academy of Science 96:161-166

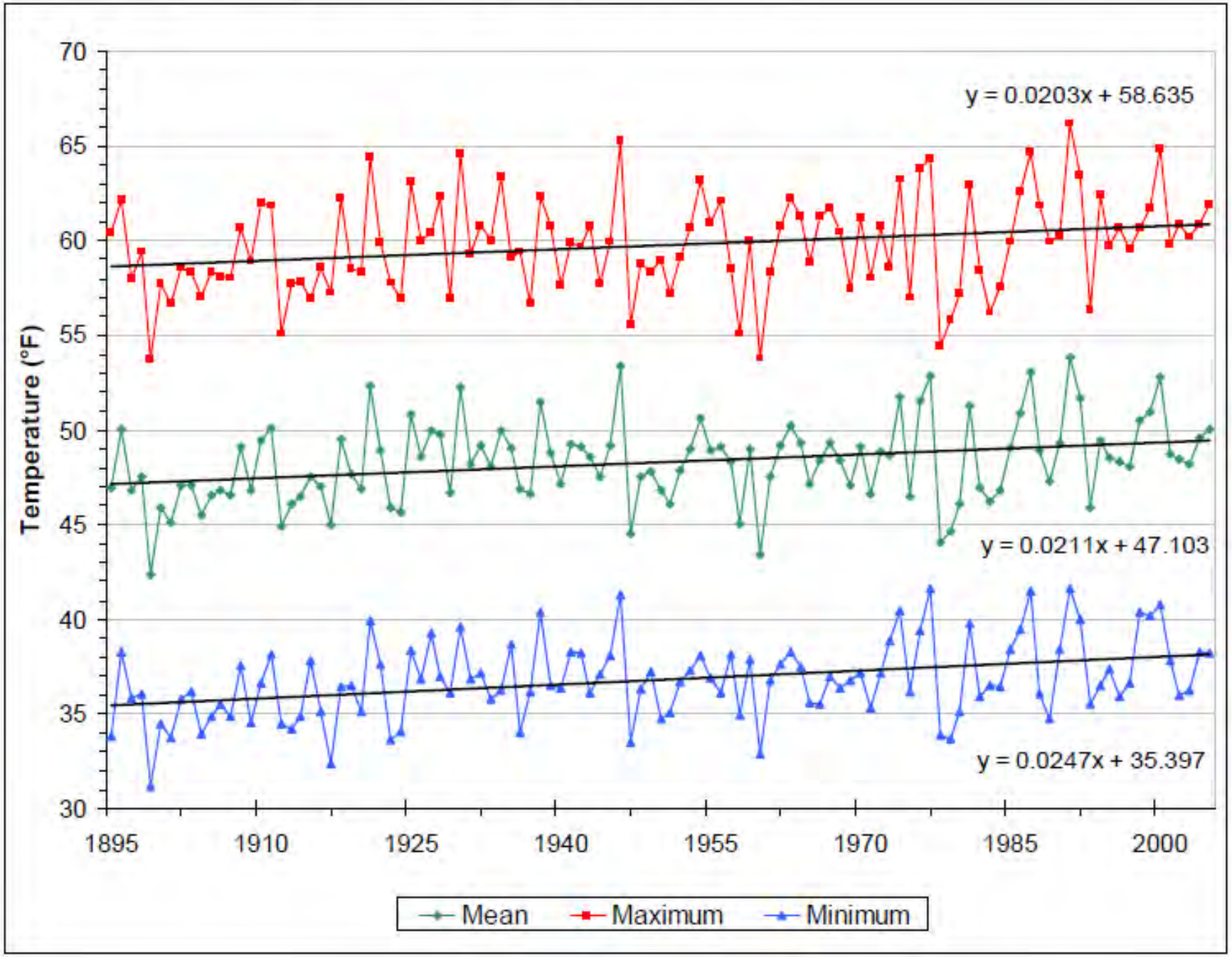
- By mid-21st Century (double CO_2)
  - Warming by approx 9ºF
    - Heating degree days cut by 40%
    - Cooling degree days up by 170%
  - Precip about the same
  - Ag implications (dramatic!)
    - Increase in growing degree days
    - Increased moisture stress
    - Corn yields down 19% in northeast KS

Table 1. Temperature (°F) and precipitation (%) differences from present over Kansas with twice present carbon dioxide concentrations.

	GFDL[1]		GISS[2]		OSU[3]		UKMO[4]		Mean change to	
	Temp	Precip	Temp	Precip	Temp	Precip	Temp	Precip	Temp	Precip
January	+7.2	+20%	+9.4	−10%	+7.2	−10%	+12.6	+20%	+9.2	+5%
April	+7.6	−10%	+8.8	−10%	+5.6	+20%	+10.8	+30%	+8.1	+8%
July	+8.1	0%	+7.2	−20%	+6.7	+10%	+9.0	+20%	+7.7	+2%
October	+8.6	+50%	+8.8	0%	+5.6	0%	+10.8	0%	+8.5	+13%
Mean changes	+7.9	+15%	+8.6	0%	+5.4	+5%	+10.8	+18%	+8.5	+6%

[1] Geophysical Fluid Dynamics Laboratory.
[2] Goddard Institute for Space Science.
[3] Oregon State University.
[4] United Kingdom Meteorological Office.

Figure 4.4 – Northeast Kansas Spring Temperatures Trends



M. Schwartz 1995 *Annals of the AAG* Vol 85: 553-568
Detecting Structural Climate Change: An Air Mass Based Approach in the North Central United States, 1958-1992

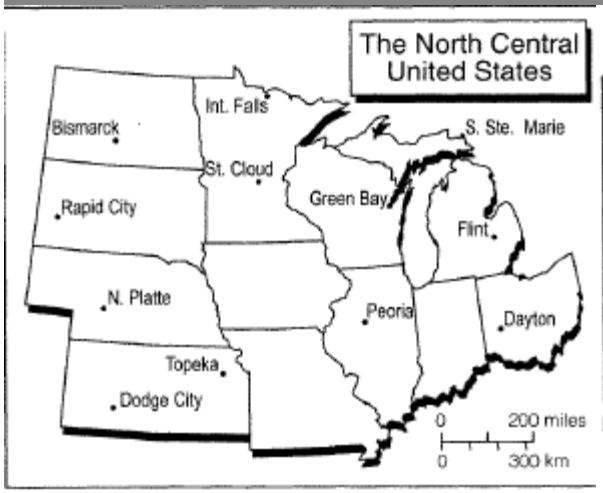


Figure 1. The North Central United States: Study area and station locations.

C = Continental

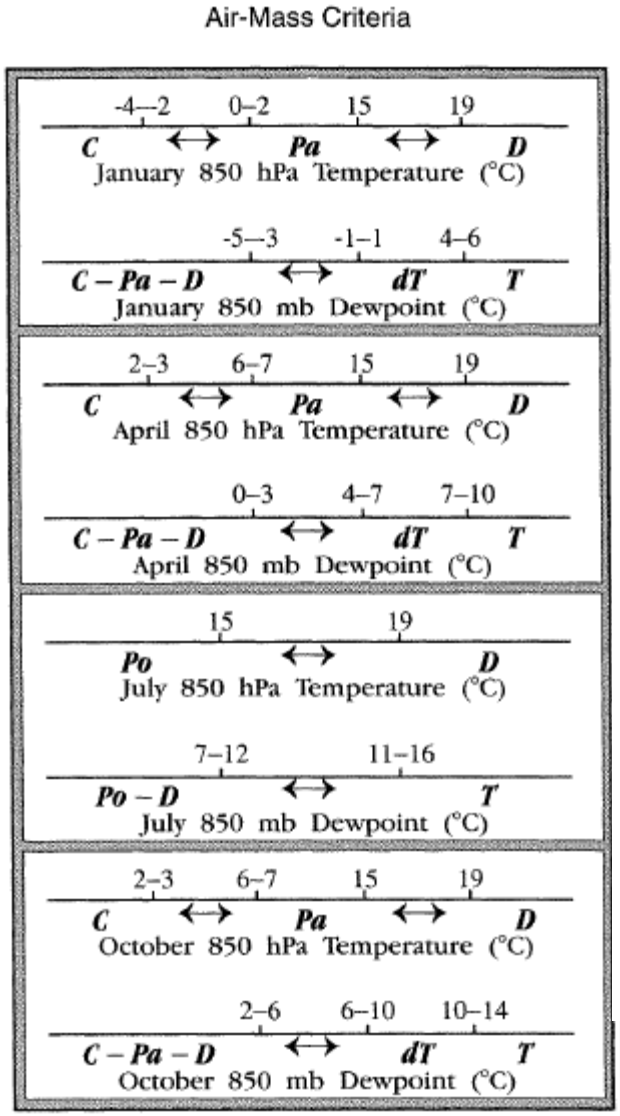
Pa = Pacific

Po = Polar

D = Dry Tropical

dT = dilute Tropical

T = Tropical



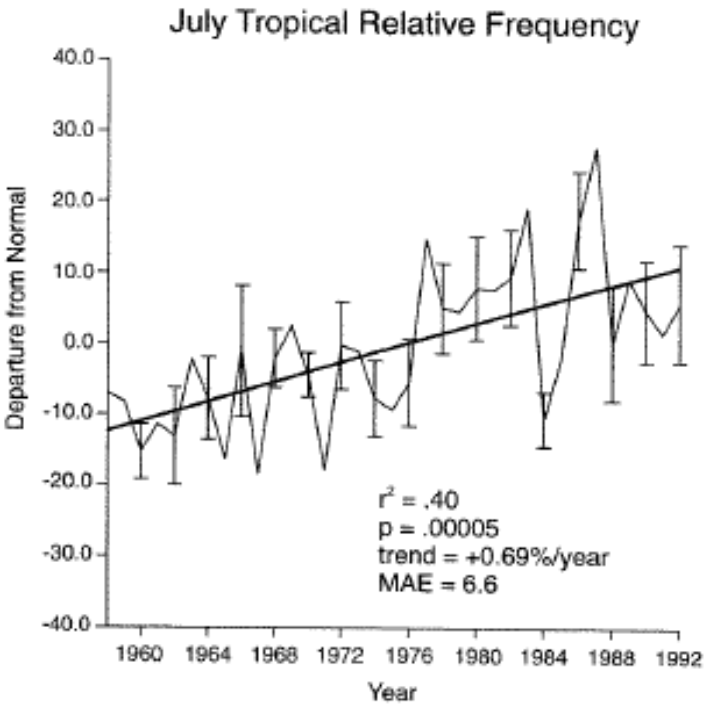


Figure 4. Six-station mean July Tropical (*T*) air-mass relative frequency departures from 1961–1990 normals (average of all data over the period), with ±1 s.e. bars at regular intervals and a regression trend line including r-squared, probability, trend, and mean absolute error terms. The six stations with significant individual trends include Dayton, Flint, Green Bay, Peoria, Sault Ste. Marie, and Topeka.

I do not want more frequent humid air in July

Climatic Change (2009) 97:529–541
DOI 10.1007/s10584-009-9615-1

Potential climate change effects on warm-season livestock production in the Great Plains

Terry L. Mader · Katrina L. Frank · John A. Harrington Jr. · G. Leroy Hahn · John A. Nienaber

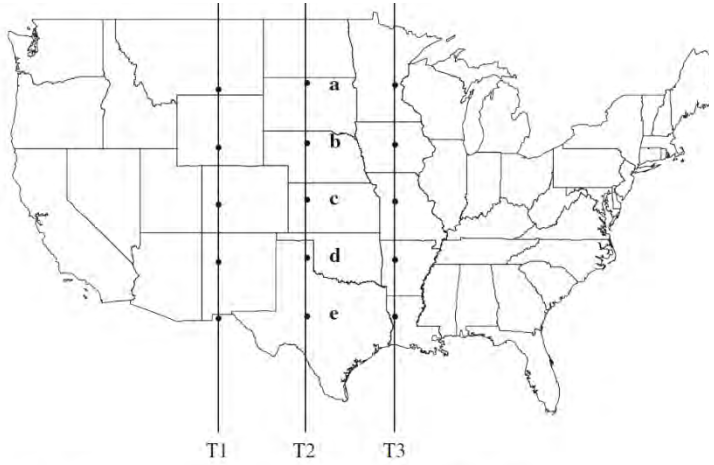


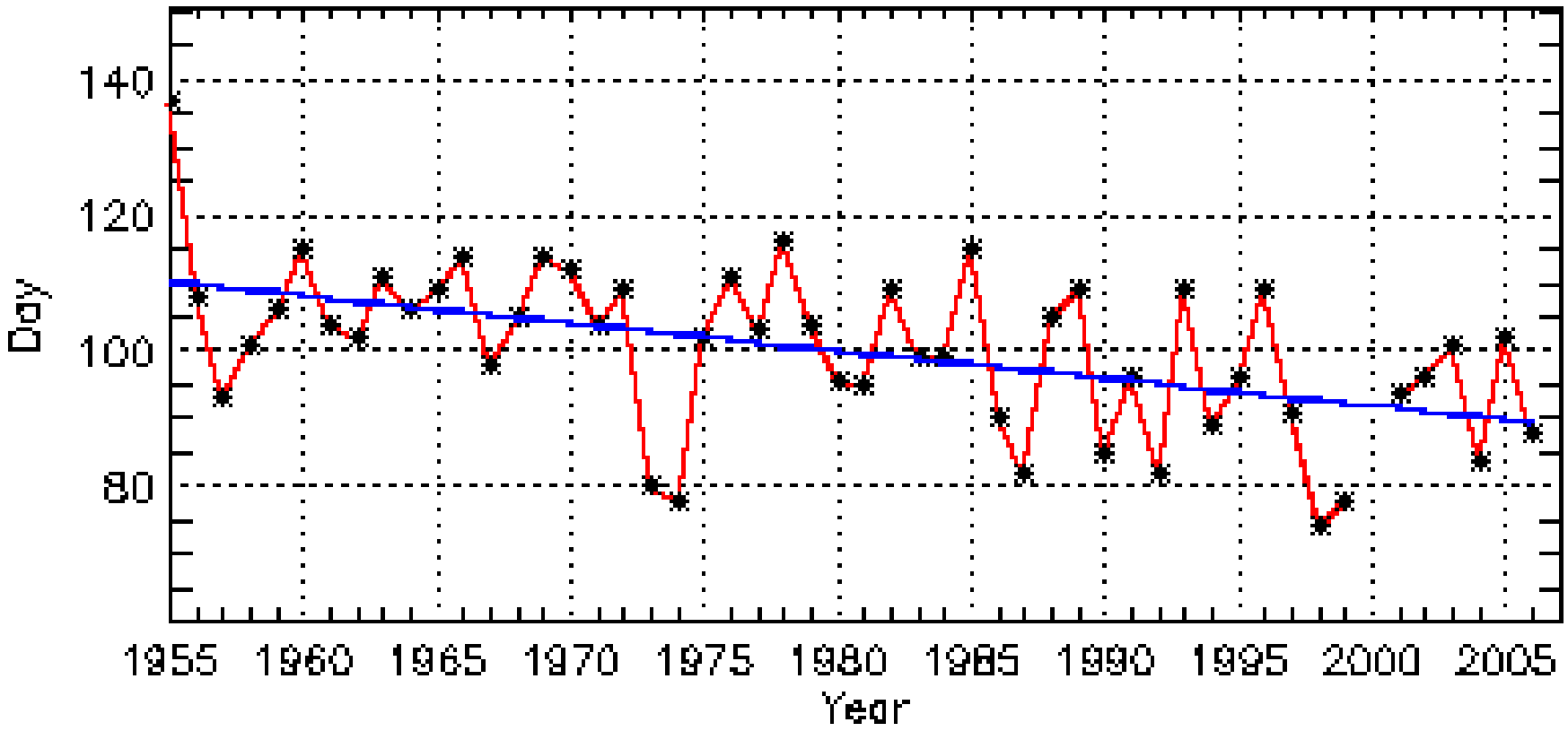
Fig. 3 Points analyzed along three transects in the central United States

data suggest that the greater negative impacts of climate change occur in eastern and/or southern regions of the central United States

Table 2 Projected percent change in days for beef cattle to grow from 350 to 550 kg beginning June 1 for the central United States for CGCMI and Hadley general circulation models and CO_2 doubling and CO_2 tripling scenarios

Region	T1			T2			T3		
	Change in days, %			Change in days, %			Change in days, %		
	Baseline	2x CO_2	3x CO_2	Baseline	2x CO_2	3x CO_2	Baseline	2x CO_2	3x CO_2
CGCMI									
A	125	−0.8	−2.4	123	−0.8	0.0	122	0.8	3.3
B	125	−1.6	−2.4	122	0.8	3.3	126	3.2	9.5
C	123	−0.8	−0.8	122	1.6	10.7	138	8.0	10.1
D	121	0.8	4.1	126	4.0	15.9	144	6.3	6.3
E	124	0.8	9.7	128	0.8	12.5	143	5.6	6.9
Hadley									
A	125	2.4	4.0	123	2.4	4.1	122	2.5	3.3
B	125	2.4	4.0	122	2.5	4.1	126	2.4	4.0
C	123	1.6	4.1	122	1.6	4.1	138	2.2	4.3
D	121	1.7	3.3	126	0.8	3.2	144	1.4	3.5
E	124	1.6	3.2	128	0.8	3.1	143	1.4	3.5

T1, T2, and T3 represent west, central and east transects, respectively, running north and south within the central United States Regions represent locations along transects in which production output was determined (Fig. 3)



OTTAWA

Lat=38.62 Lon=-95.28 Elev=274 m

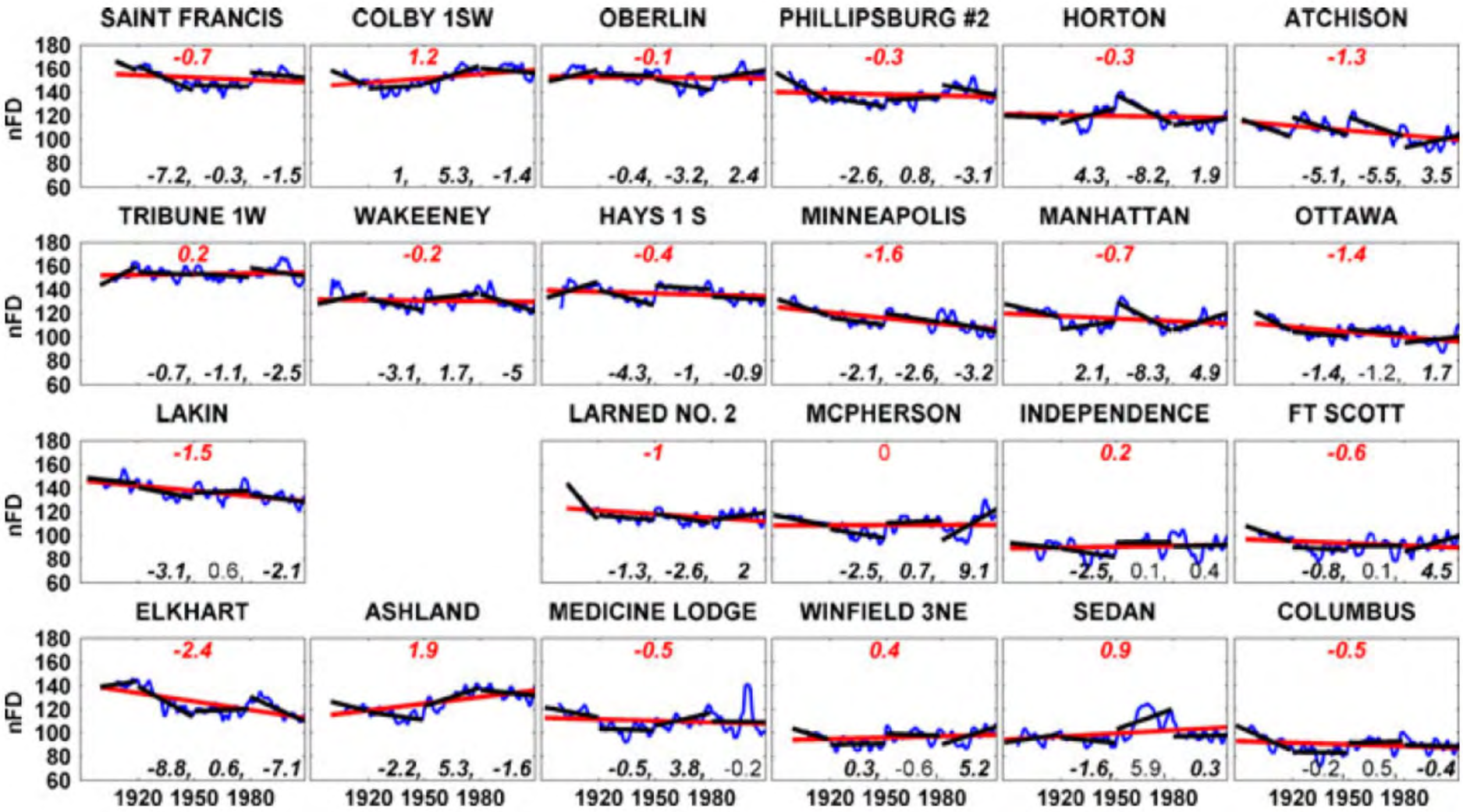
Number of frost days Tmin < 0 °C Annual, 1955-2006

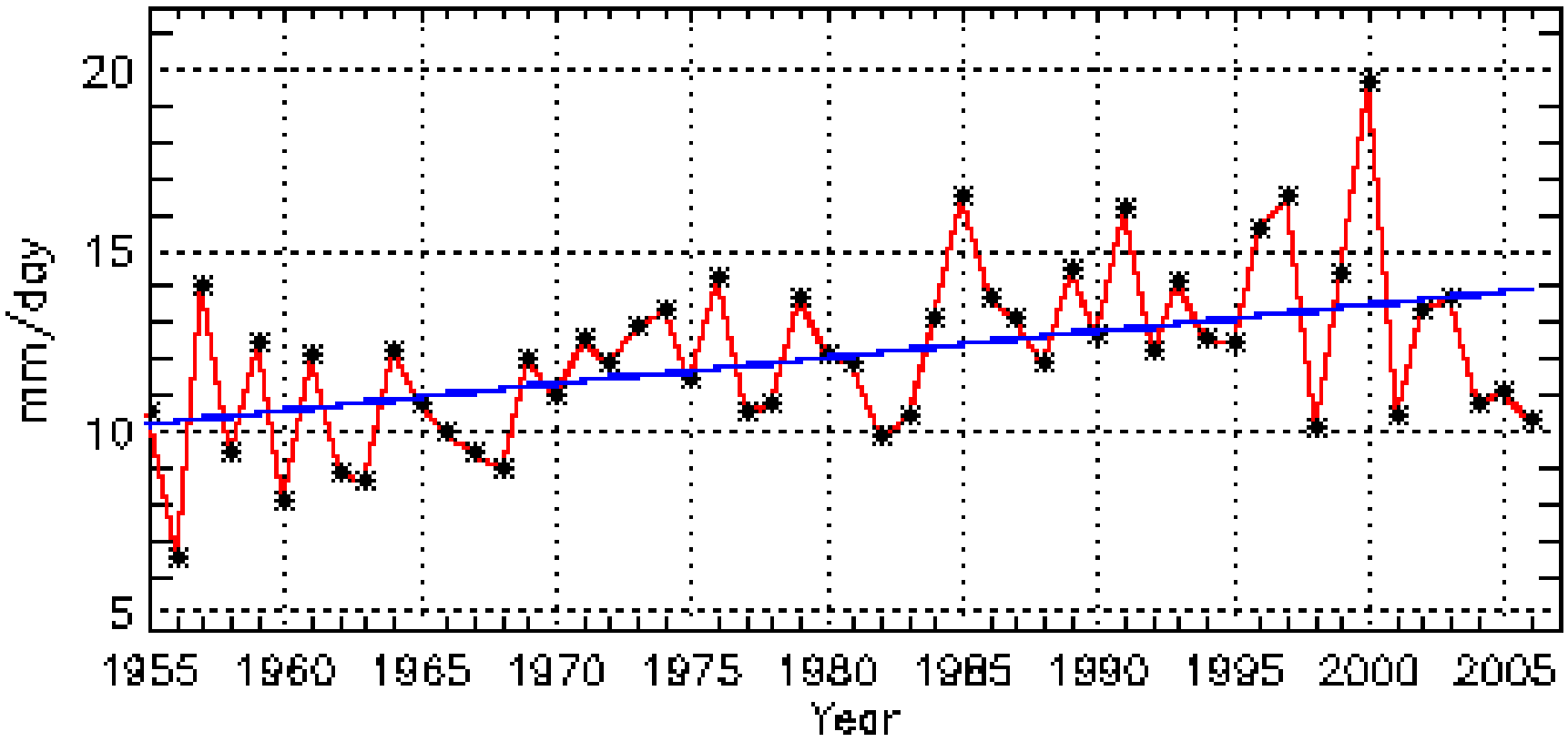
Trend= -4.0 day/decade Significance= 99.9% %

Long-term spatial and temporal trends in frost indices in Kansas, USA

Aavudai Anandhi · Sriram Perumal · Prasanna H. Gowda · Mary Knapp · Stacy Hutchinson · John Harrington Jr. · Leigh Murray · Mary B. Kirkham · Charles W. Rice

Climatic Change (2013) 120:169–181
DOI 10.1007/s10584-013-0794-4





PRATT 4 W

Lat=37.68 Lon=-98.8 Elev=591 m

Simple Precipitation Intensity Index Annual, 1955-2006

Trend= 0.7 mm/day per decade Significance= 99.9%

North America Climate Extremes Monitoring

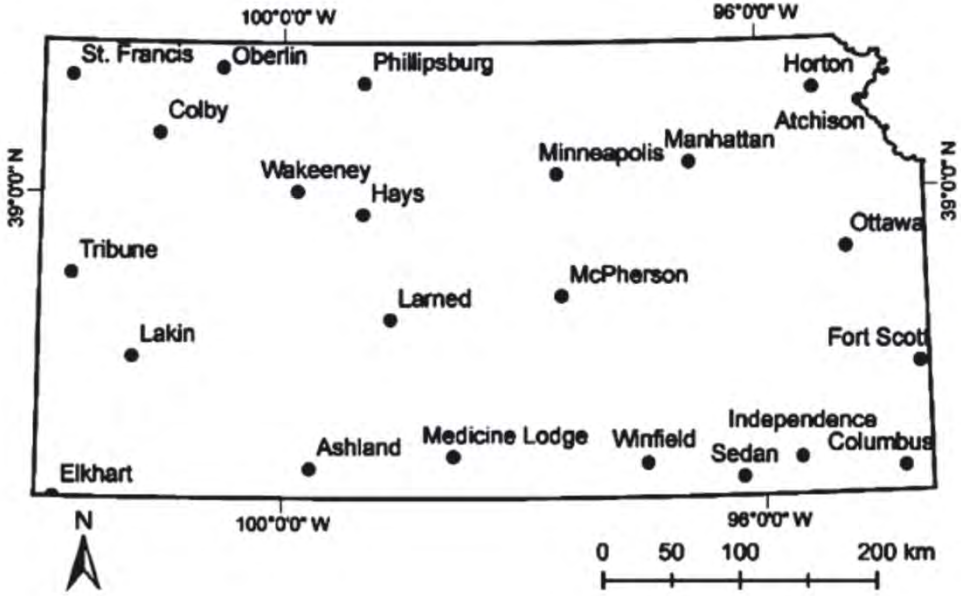
http://www.ncdc.noaa.gov/nacem/

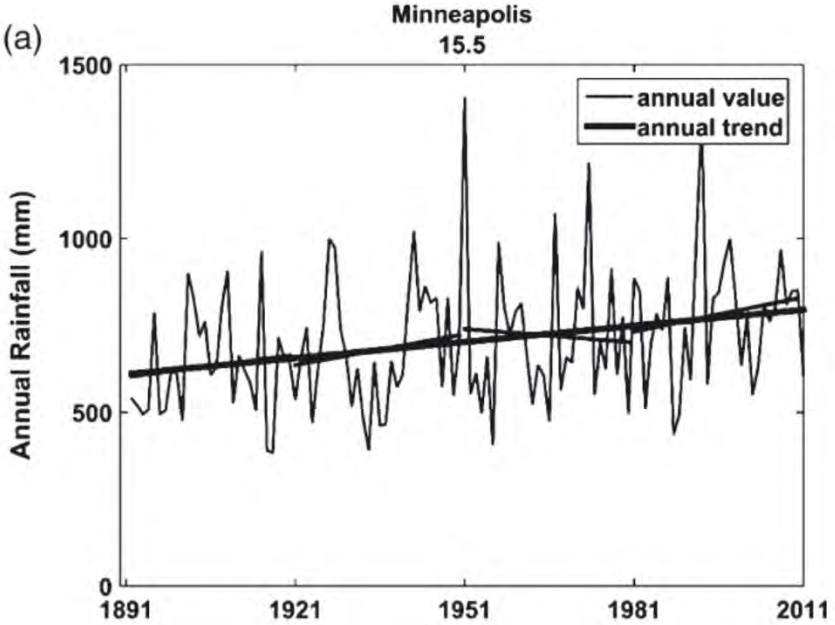
Analysis of temporal and spatial distribution and change-points for annual precipitation in Kansas, USA

Vahid Rahmani,[a]* Stacy L. Hutchinson,[a] John A. Harrington Jr,[b] J. M. Shawn Hutchinson[b] and Aavudai Anandhi[c]

[a] *Department of Biological and Agricultural Engineering, Kansas State University, Manhattan, USA*
[b] *Department of Geography, Kansas State University, Manhattan, USA*
[c] *Department of Agronomy, Kansas State University, Manhattan, USA*

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2015)





Long-term trend analysis on the total annual rainfall in Kansas showed an upward trend for 1890 to 2011. The positive slopes tended to increase across the state from west to east, with the steepest slopes (greatest increase) in eastern Kansas.

Seasonal trends in air temperature and precipitation in IPCC AR4 GCM output for Kansas, USA: evaluation and implications

N. A. Brunsell,* A. R. Jones, T. L. Jackson and J. J. Feddema
Department of Geography, University of Kansas, Lawrence KS 66044, USA

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **30**: 1178–1193 (2010)

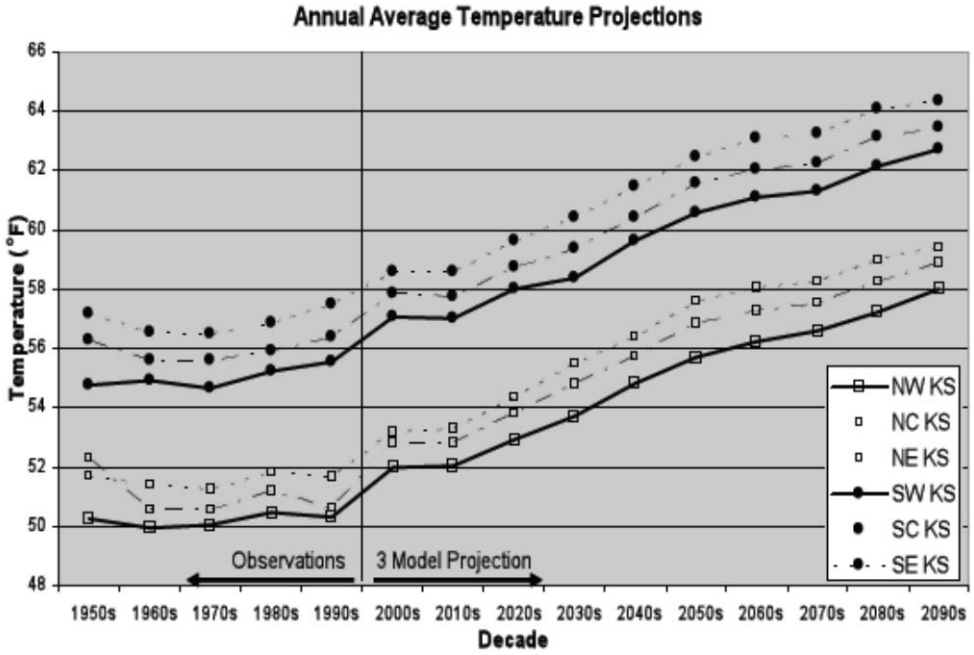


Figure 8. Historical observations (left of the vertical line) and projected temperature changes based on future climate simulations from three global climate models that best simulated the Kansas Climate conditions over the 20th Century. Projections are based on middle of the road (IPCC A1B) greenhouse gas emissions scenarios, and are given for 6 regions in the state.

Results indicate that temperatures are likely to warm in all seasons, with the largest trends being on the order of 0.04 °C/year in summer and fall. Precipitation is likely to increase slightly in winter and decrease in summer and fall. These changes have profound implications for both natural ecosystems and agricultural land uses in the region.

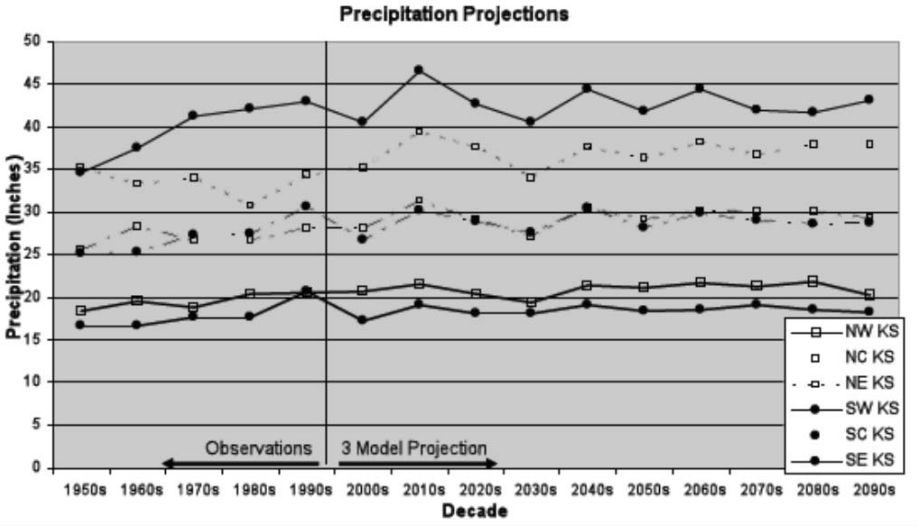


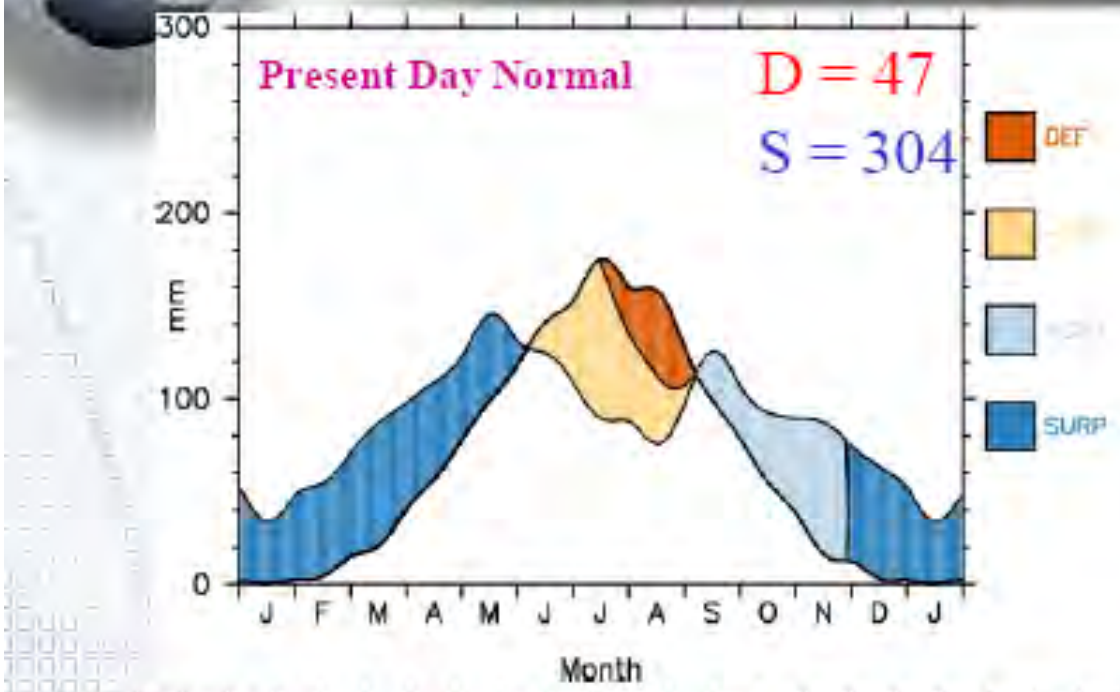
Figure 11. Past and projected future precipitation changes for the six regions in Kansas. Unlike the increase in water demand (Figure 9), the water supply from precipitation is unlikely to change much in the future.

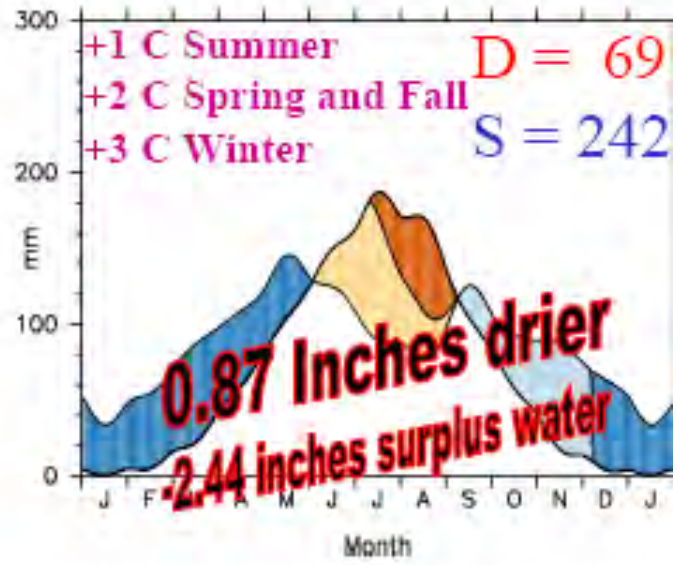
Climate projections

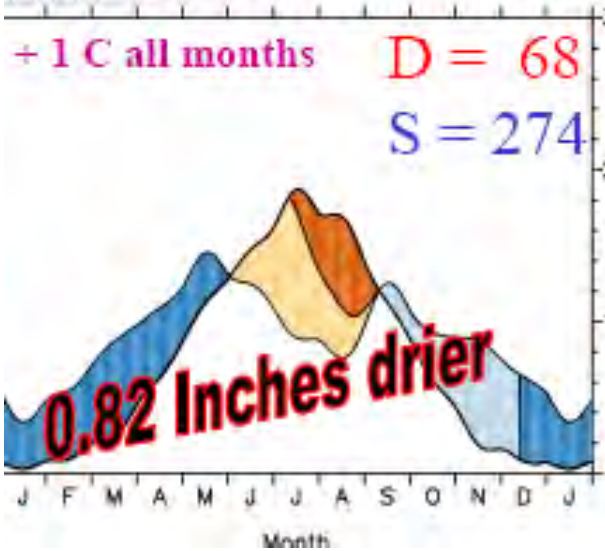
Eastern Kansas (37N, 95W)

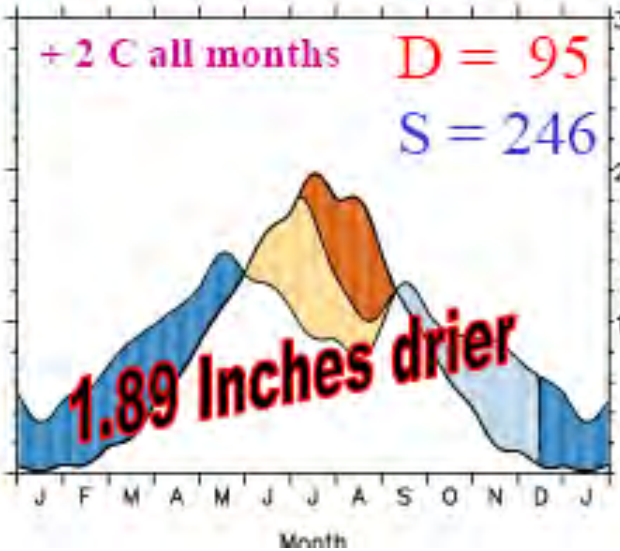
D = Annual Deficit (mm)

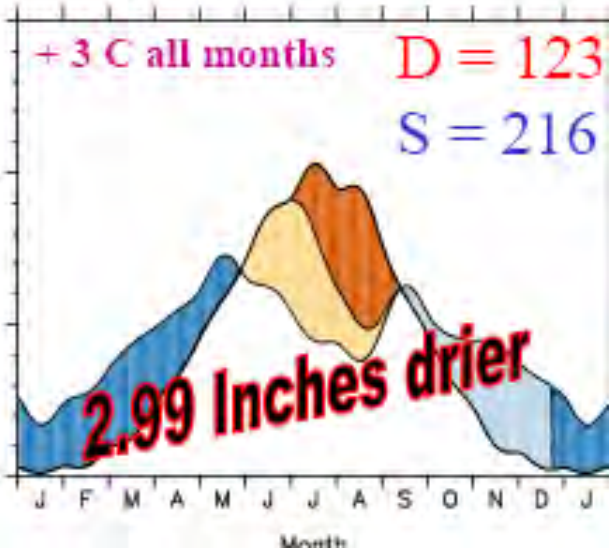
S = Annual Surplus (mm)









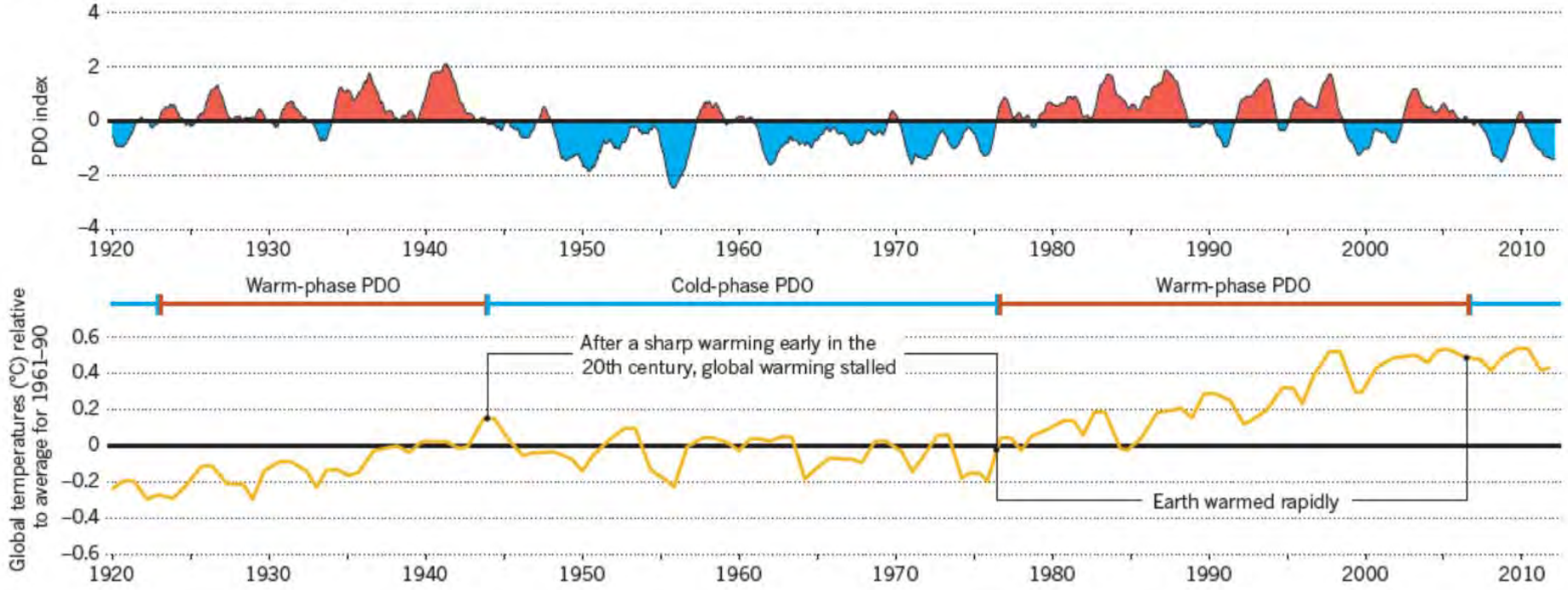


Cycles and a noisy system

- The weather will change; it’s just a cycle
- 11 year sun spot cycle
- 50 + years ago, there was a hypothesis that changes in sunspots drove a 22 year drought cycle
- The chaotic system produces a lot of year-to-year variation (noise)
- Electrical engineering – can we separate the signal from the noise?

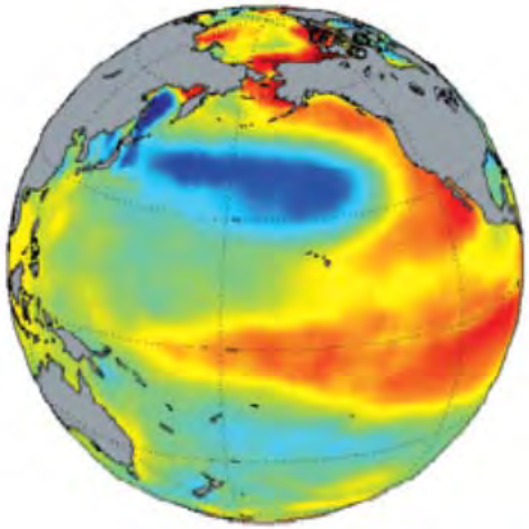
THE PACIFIC'S GLOBAL REACH

As researchers have investigated why global temperatures have not risen much since 1998, many have focused on an ocean cycle known as the Pacific Decadal Oscillation (PDO). During periods when the PDO index is positive and the eastern Pacific is warm, global temperatures have risen quickly. During spells when the PDO index is negative, the warming has stagnated.



UNIV. WASHINGTON/IPCC

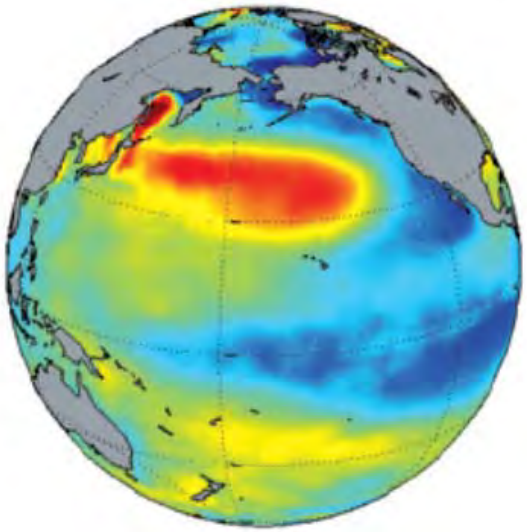
WARM PHASE



Departures from average ocean temperatures (°C) associated with the warm and cool phases of the PDO

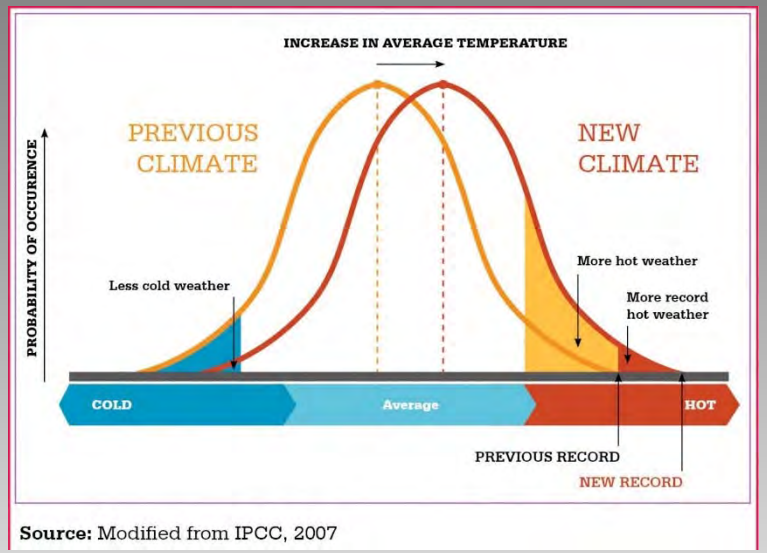
−0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8

COLD PHASE



Different approaches to climatology

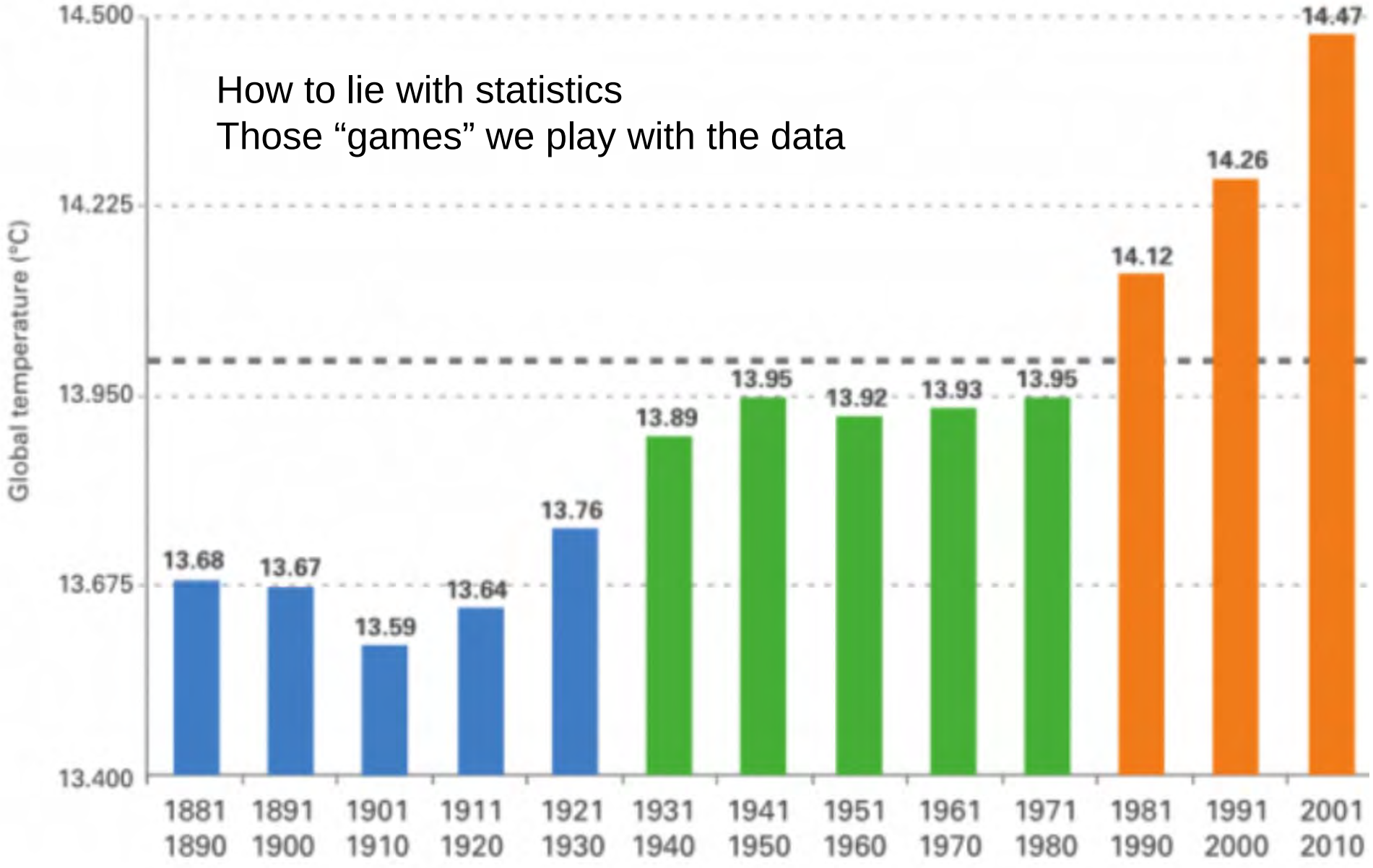
- Statistical



Source: Modified from IPCC, 2007

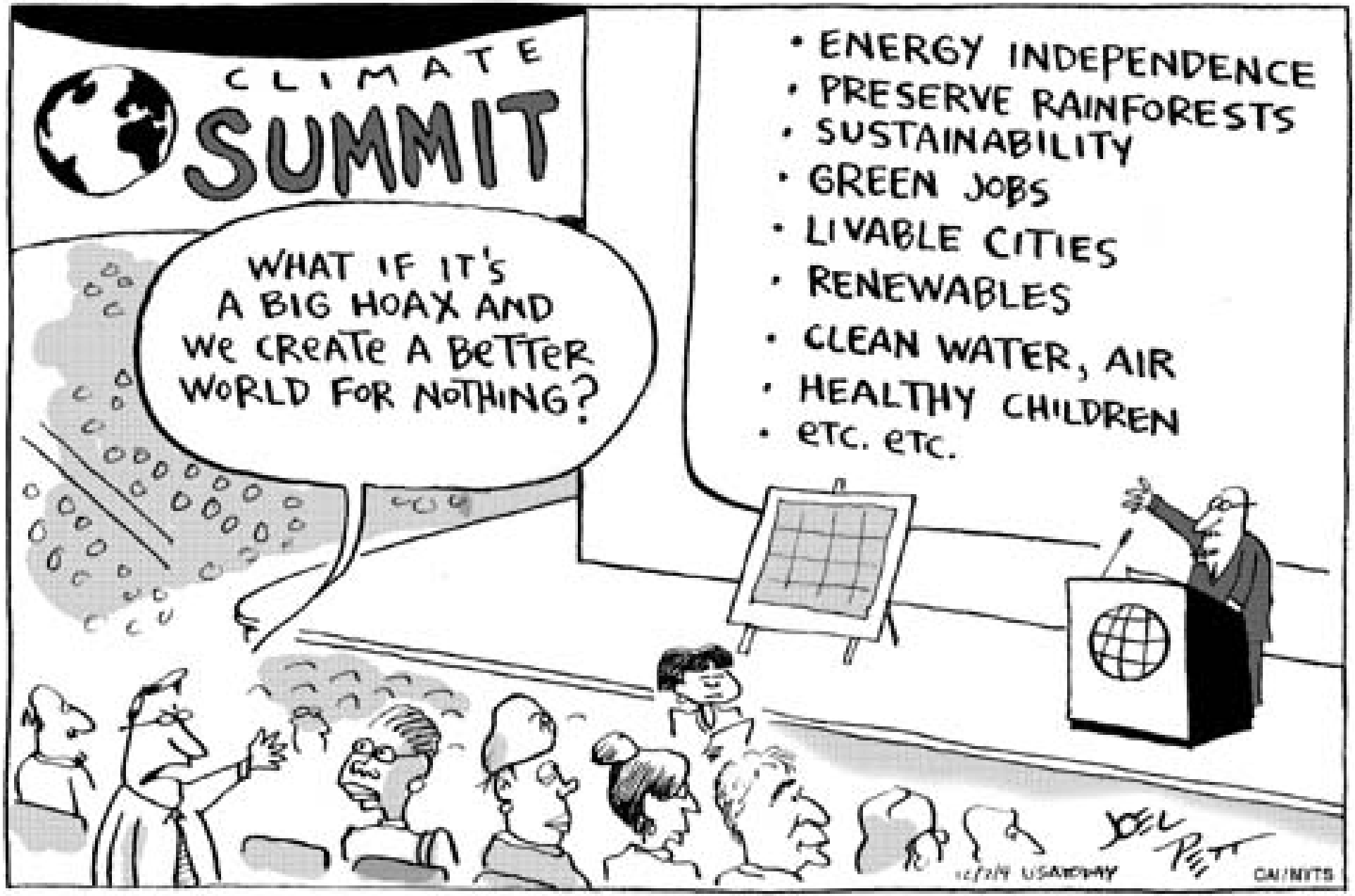
- Climate science
  - Climate science 1st used in journal articles in 1996
  - Modeling the system
  - Can we trust those scientists

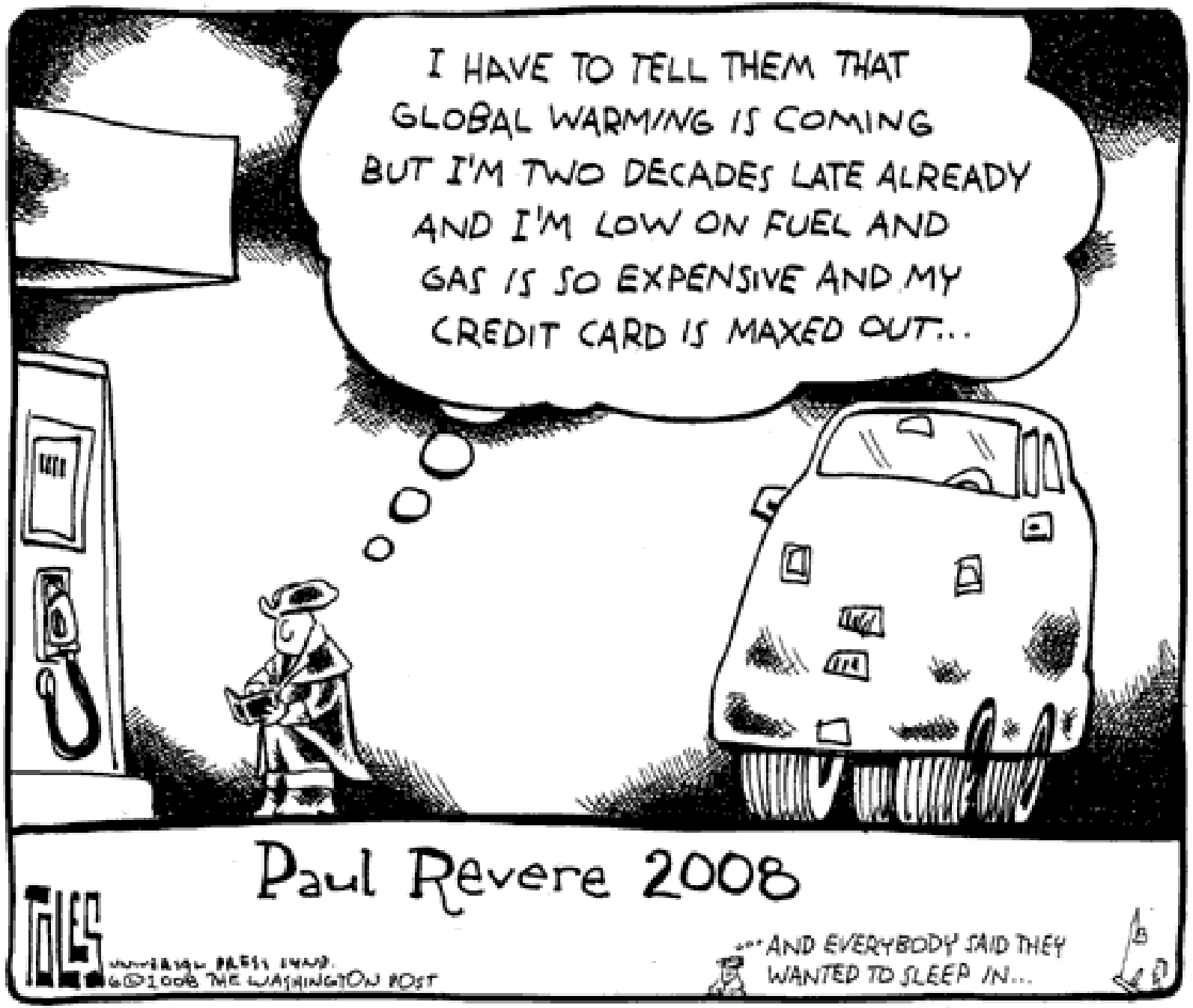
How to lie with statistics
Those “games” we play with the data



World Meteorological Organization: The Global Climate 2001 to 2010

USA Today cartoon from just before the UN Copenhagen climate summit




I HAVE TO TELL THEM THAT GLOBAL WARMING IS COMING BUT I'M TWO DECADES LATE ALREADY AND I'M LOW ON FUEL AND GAS IS SO EXPENSIVE AND MY CREDIT CARD IS MAXED OUT...
Paul Revere 2008
TOLES
©2008 THE WASHINGTON POST
...AND EVERYBODY SAID THEY WANTED TO SLEEP IN...

6-25-08

COMMENTARY

We Need To Do More When It Comes To Having Brief, Panicked Thoughts About Climate Change

BY RHETT STEVENSON
SEPTEMBER 6, 2011 | ISSUE 47•36

The 20 hottest years on record have all taken place in the past quarter century. The resulting floods, wildfires, and heat waves have all had deadly consequences, and if we don't reduce carbon emissions immediately, humanity faces bleak prospects. We can no longer ignore this issue. Beginning today, we must all do more when it comes to our brief and panicked thoughts about climate change.

Indeed, if there was ever a time when a desperate call to take action against global warming should race through our heads as we lie in bed and stare at the ceiling, that time is now.

Many well-intentioned people will take 20 seconds out of their week to consider the consequences of the lifestyle they've chosen, perhaps contemplating how their reliance

ARTICLE TOOLS
Tweet 821
Like 5K
+1 73
Email
Print
Share

Many well-intentioned people will take 20 seconds out of their week to consider the consequences of the lifestyle they've chosen, perhaps contemplating how their reliance on fossil fuels has contributed to the rapid melting of the Arctic ice cap. But if progress is what we truly want, **20 seconds is simply not enough**. Not by a long shot. **An issue this critical demands at least 45 seconds to a solid minute of real, concentrated panic.**

http://www.theonion.com/articles/we-need-to-do-more-when-it-comes-to-having-brief-p,21295/

A Parrot Head Looks at the IPCC

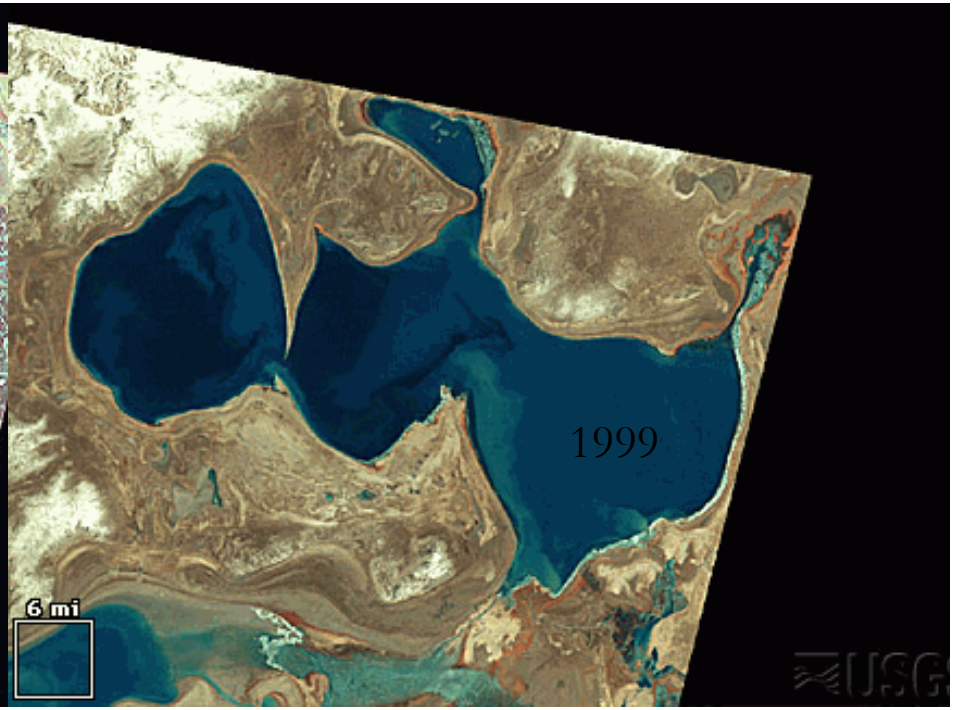
"wasted away in Margaritaville"

- FAR = First Assessment Report 1990
  - **'Its nobody's fault' [Jimmy Buffett – Margaritaville]**
  - **"Thus the observed increase could be largely due to this natural variability: alternatively this variability and other human factors could have offset a still larger human-induced greenhouse warming."**
- SAR = Second Assessment Report 1995
  - **'It could be my fault'**
  - **"The balance of evidence suggests that there is a discernible human influence on global climate. "**
- TAR = Third Assessment Report 2001
  - **'It's my own damn fault'**
  - **"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."**

Climate change is part of something bigger

Symptoms of human induced global change:

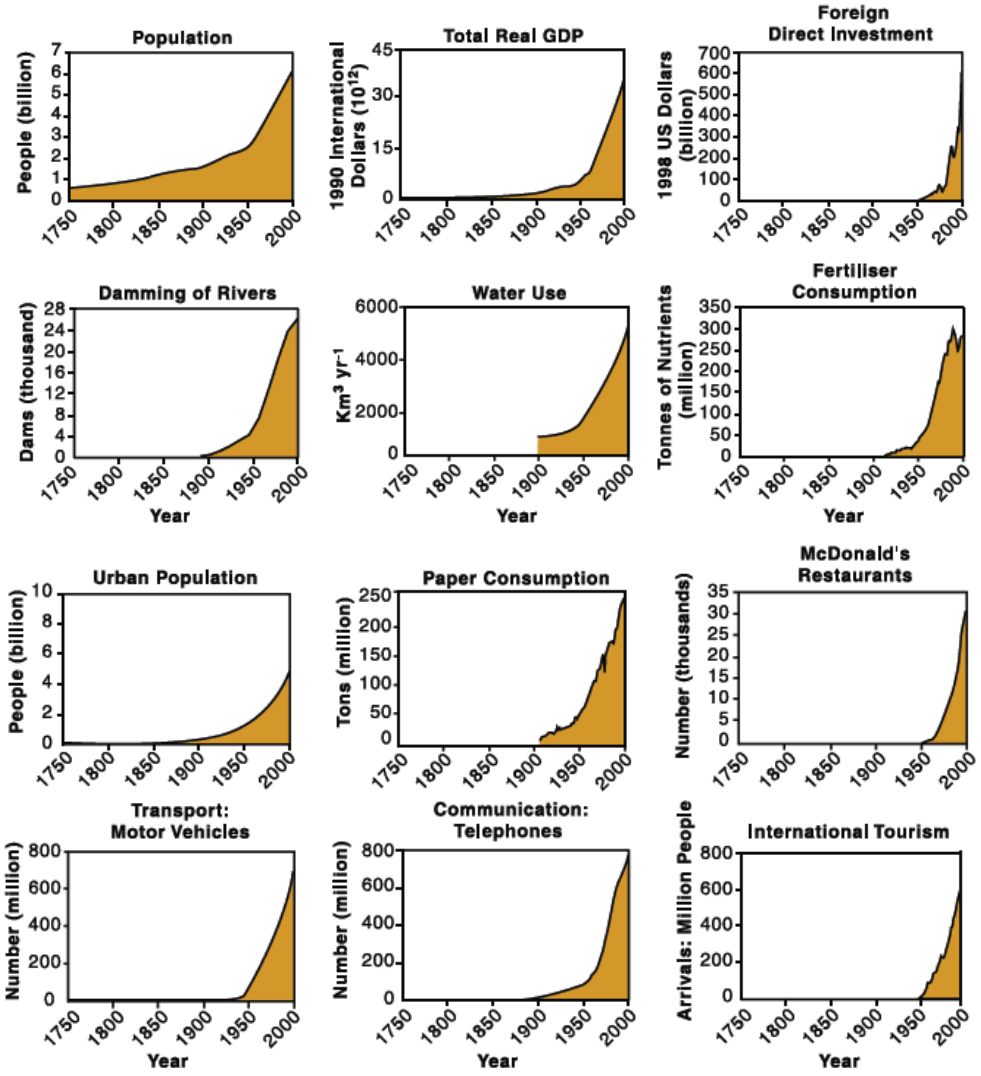
- warming
- rapid change in surface appearance (LUCC)
- changes in chemical indicators (nitrogen)
- change in gaseous composition (atmos)
- loss of key biotic components
- new organisms have been introduced
- rapid depletion of stored reserves (water)
- rapid depletion of stored reserves (energy)
- the rate of change is increasing

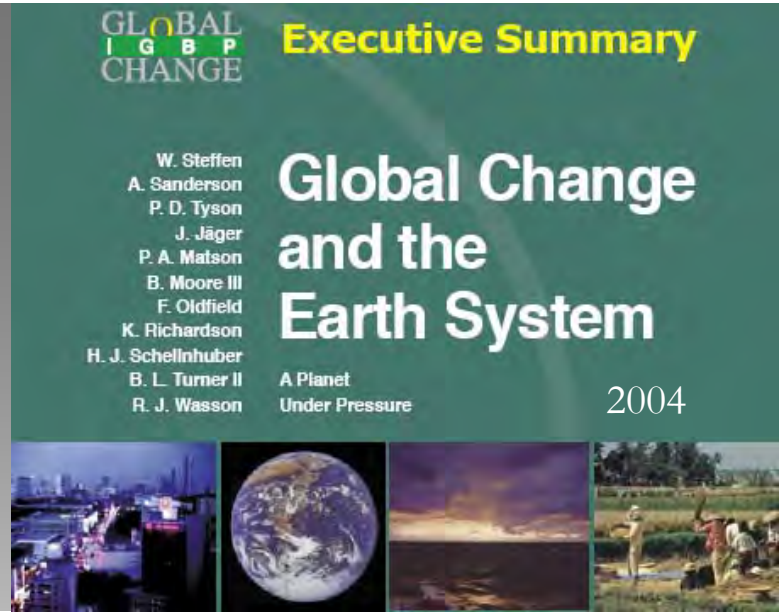


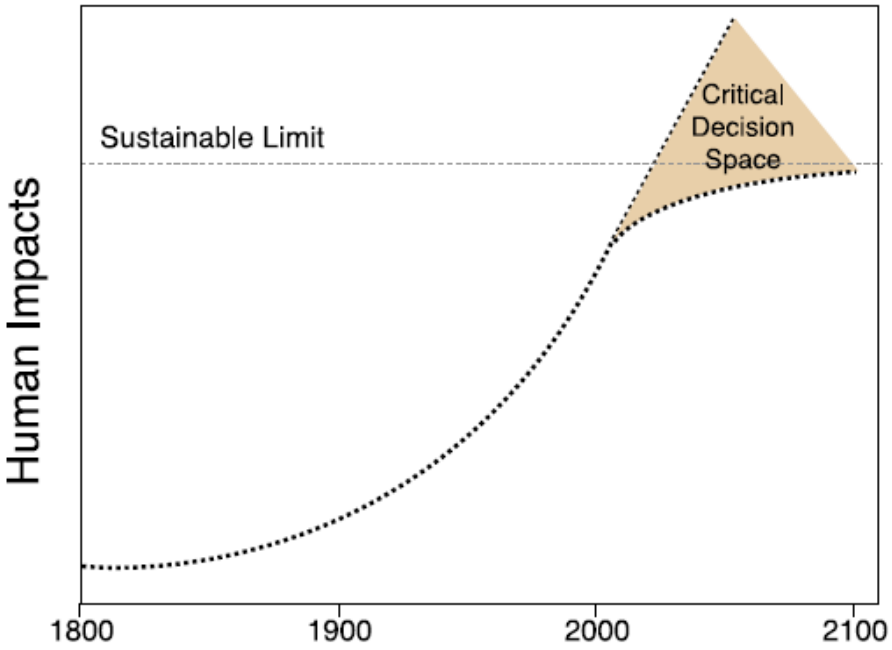
Unprecedented Types, Rates, Scales, Combinations, and the Magnitude of Change

The Great Acceleration

Planetary Destabilization





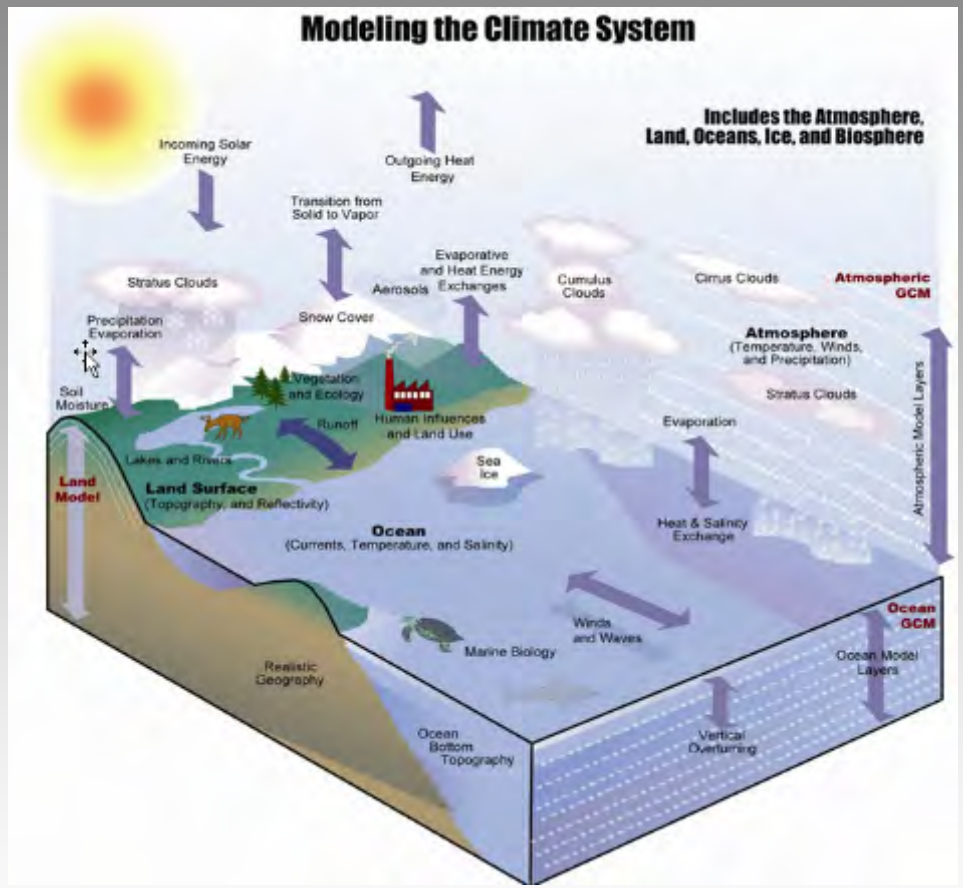


"… the Earth system is now operating in a 'no-analogue state'."

Climate science:
We've messed with the atmosphere

The Anthropocene
Planetary Boundaries

An ozone hole
The 6th great extinction
The nitrogen cycle
Land surface cover change
The hydrologic cycle
The carbon cycle



All organisms change their immediate environment.

We have changed things –
what should we do?
who should provide the leadership?
when should we change?

“To change something, build a new model that makes the existing model obsolete.”

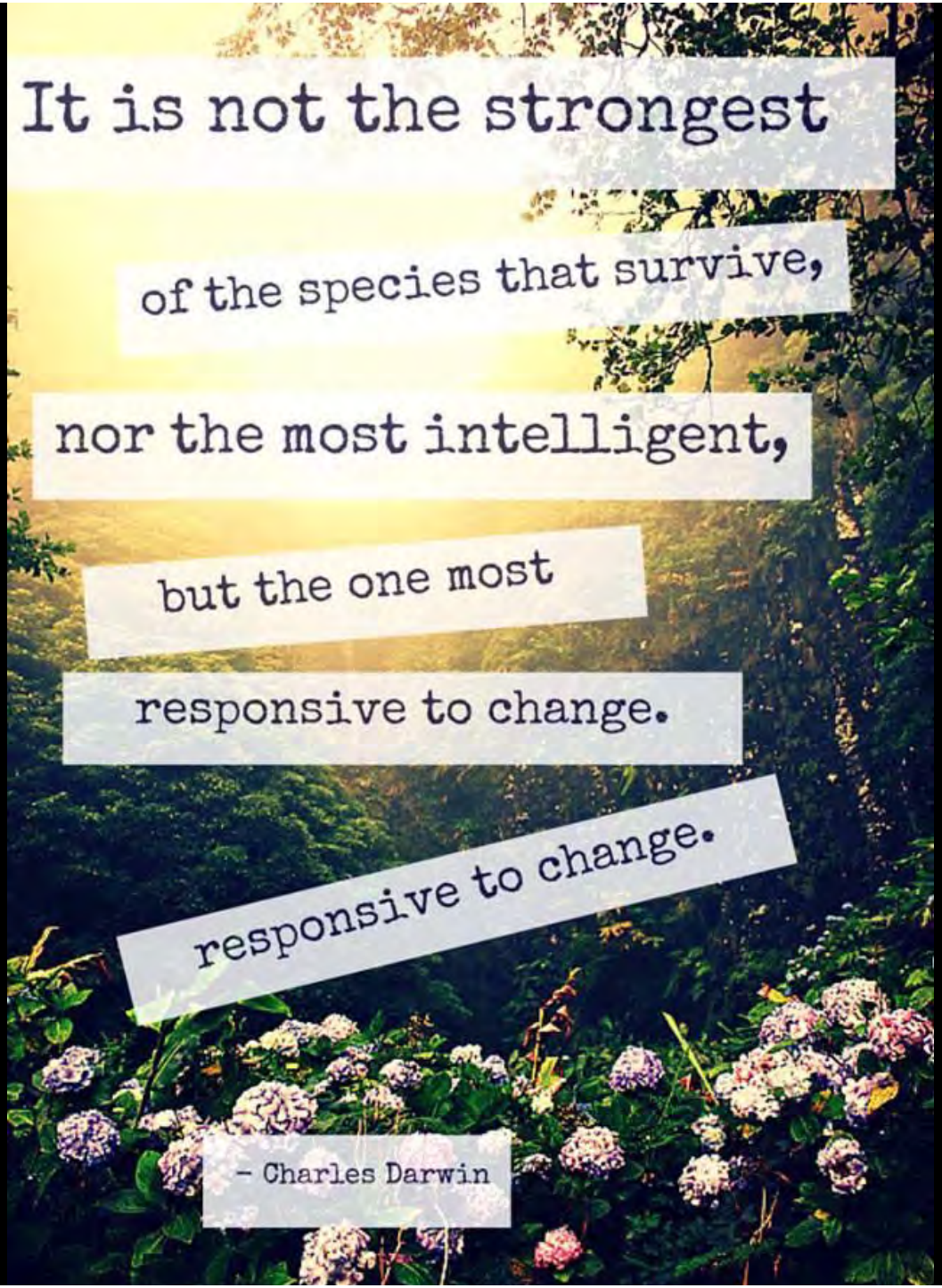
Buckminster Fuller

“If at first the idea is not absurd, then there is no hope for it.”

Albert Einstein

“Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it's the only thing that ever has.”

Margaret Mead


It is not the strongest
of the species that survive,
nor the most intelligent,
but the one most
responsive to change.
responsive to change.
- Charles Darwin

Thank you!

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Malcolm Gladwell's excellent book on social epidemics, "The Tipping Point"

the book is about how change in behavior can spread like a virus

there are 3 distinguishing characteristics:
1 - contagiousness of the idea
2 - little causes having big effects
3 - not incremental or gradual change, but a dramatic moment

there are 3 agents of change:
1 - the Law of the Few - a very small number of people play critical roles
2 - the Stickiness Factor - ideas need to connect
3 - the Power of Context - the environment - and it could be the smallest of details that needs to be right

Change is hard

- Roosevelt and the ‘new deal’
  - Business men don’t care for the social change
  - Bring religion back in: “one nation, under God”
- There is a major concern that those wind machines will result in a loss of personal freedom
  - Profit ?? or People ??
- Two important books:
  - Something New Under The Sun
  - This Changes Everything

Sustainable capitalism = an oxymoron ??