Observed and Projected Changes in Climate

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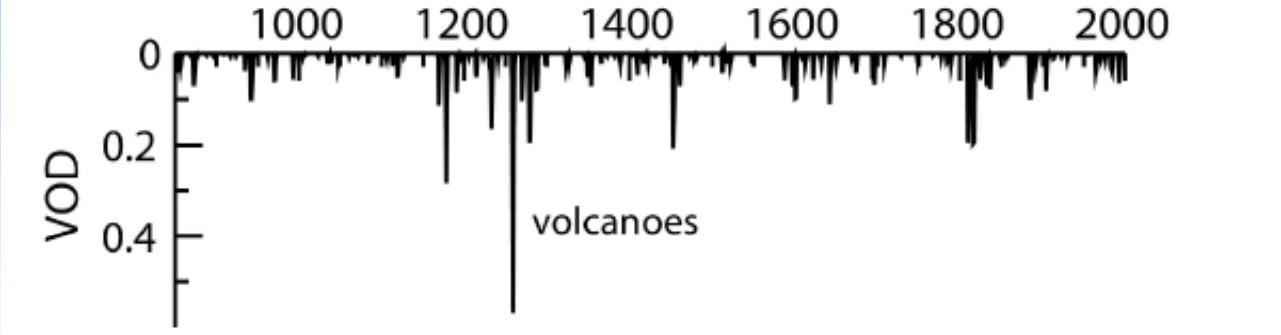
Overview

- What causes climate to change?
  - Climate Forcing Mechanisms
- Evidence for observed climate change.
  - Has it warmed?
  - Has precipitation changed?
  - Have extreme events changed?
- What do the models say about future climate?
  - Temperature
  - Precipitation
  - Extremes

What Causes the Climate to Change?

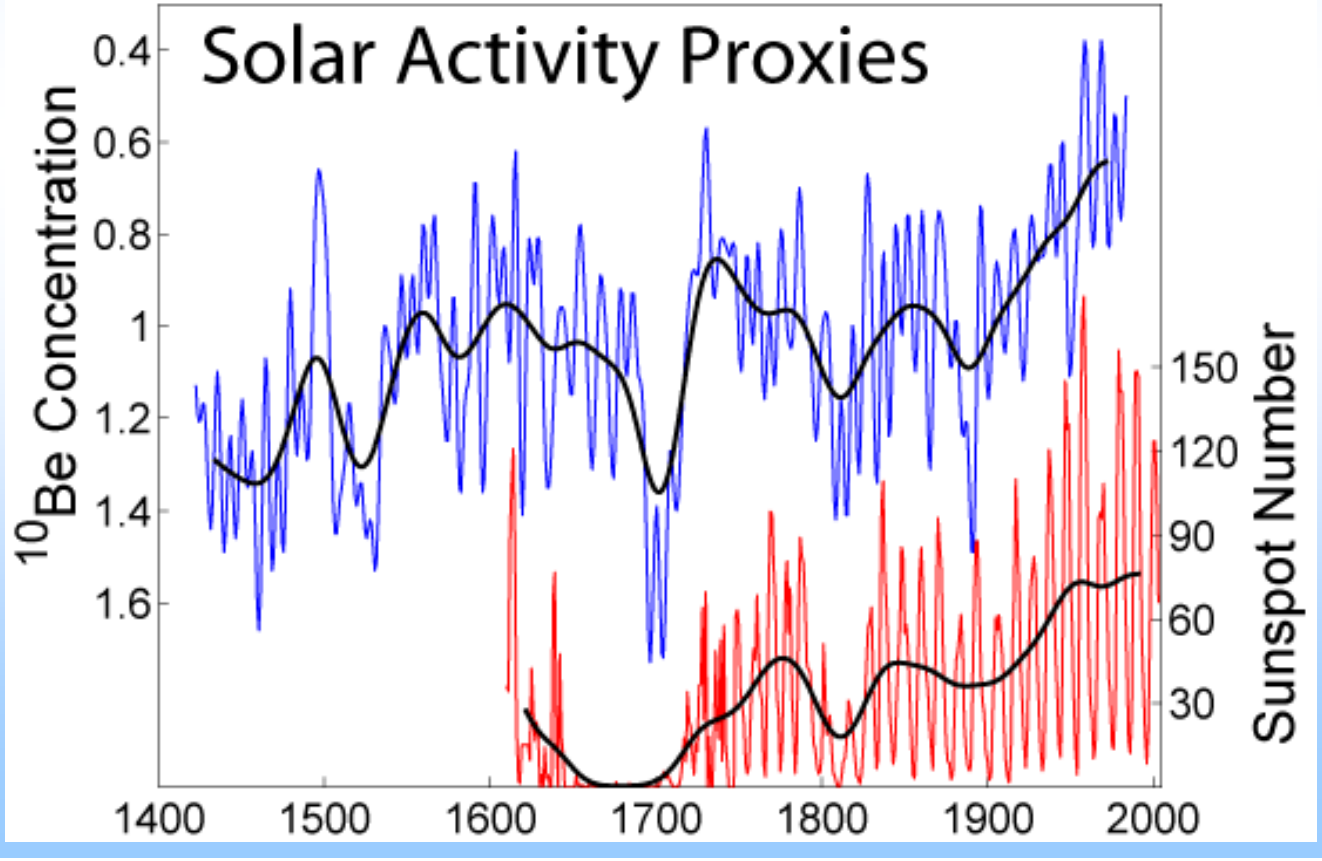
Climate Forcings

Natural Climate Forcings

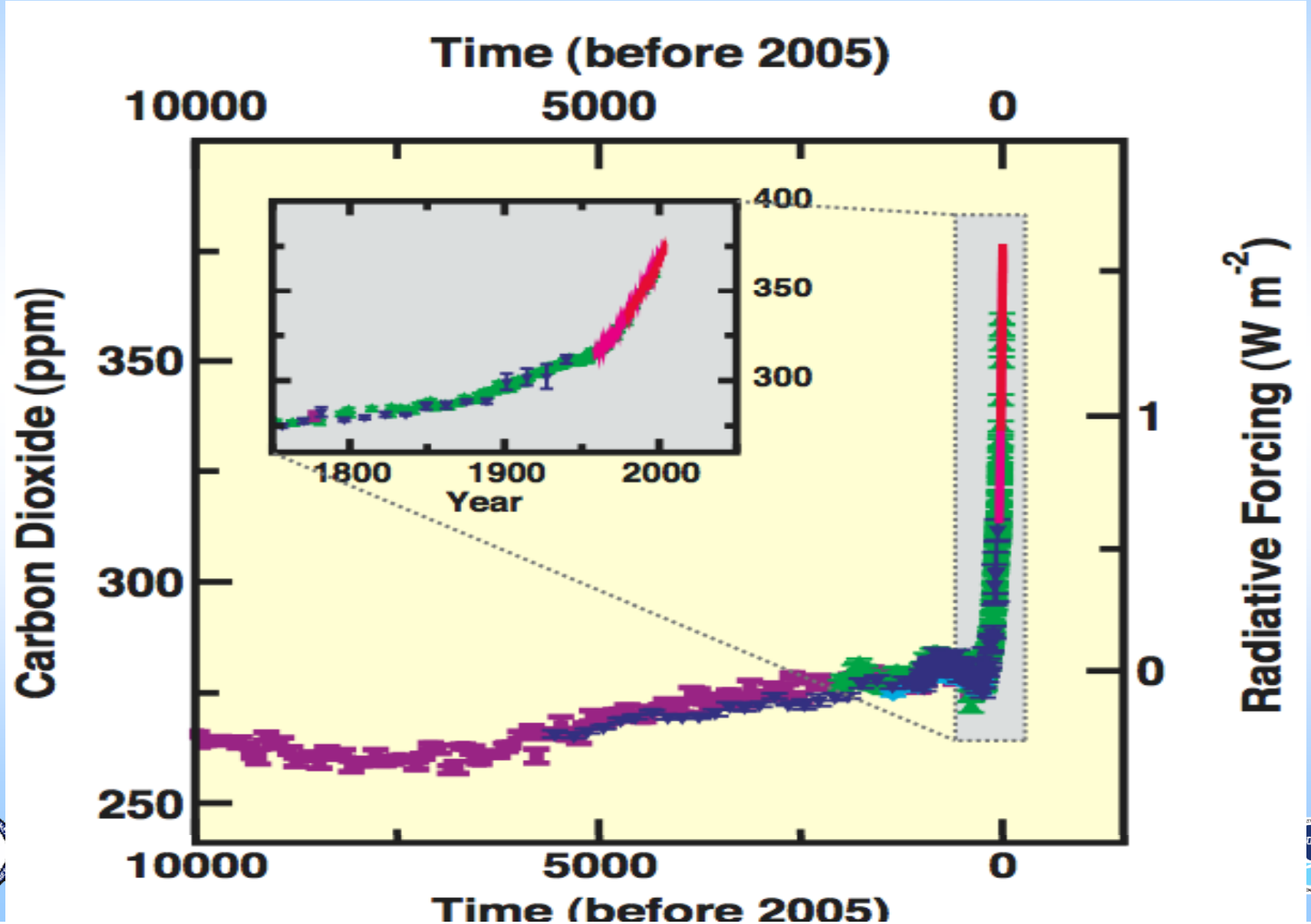


Volcanic Eruptions

Solar Variability

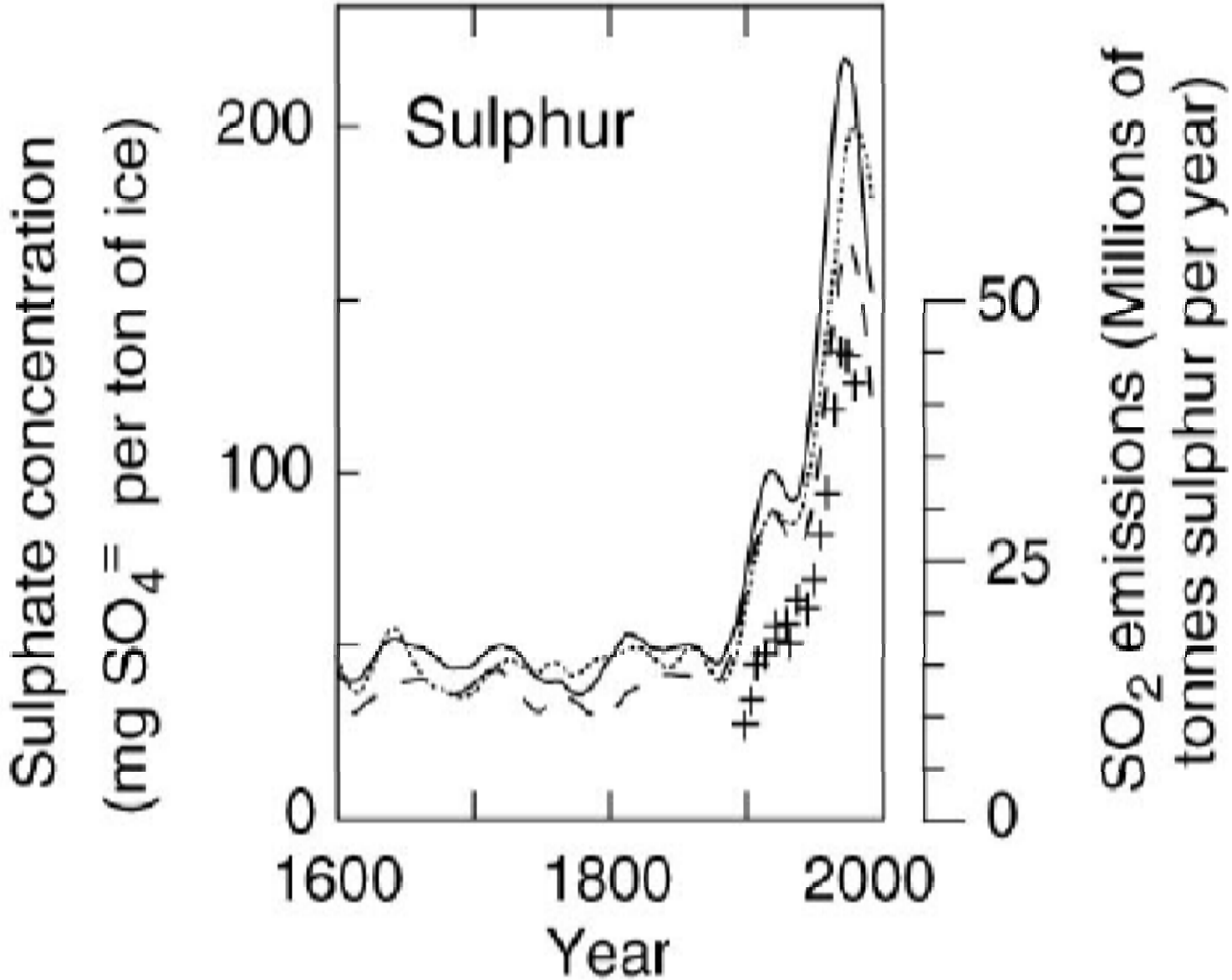


Climate Forcings:Anthropogenic (Human Induced)



Climate Forcings:Anthropogenic (Human Induced)

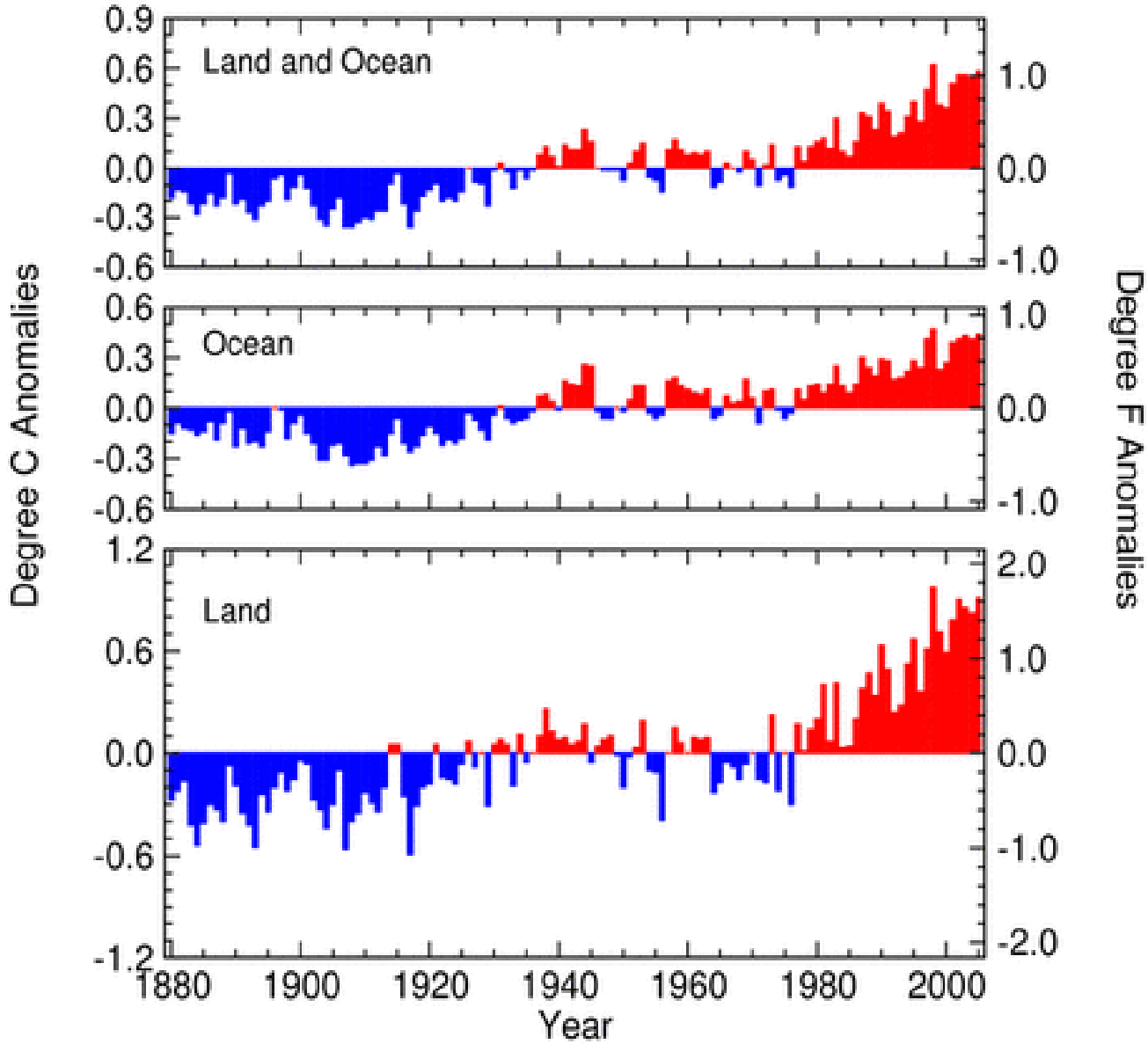
Sulphate Particulates



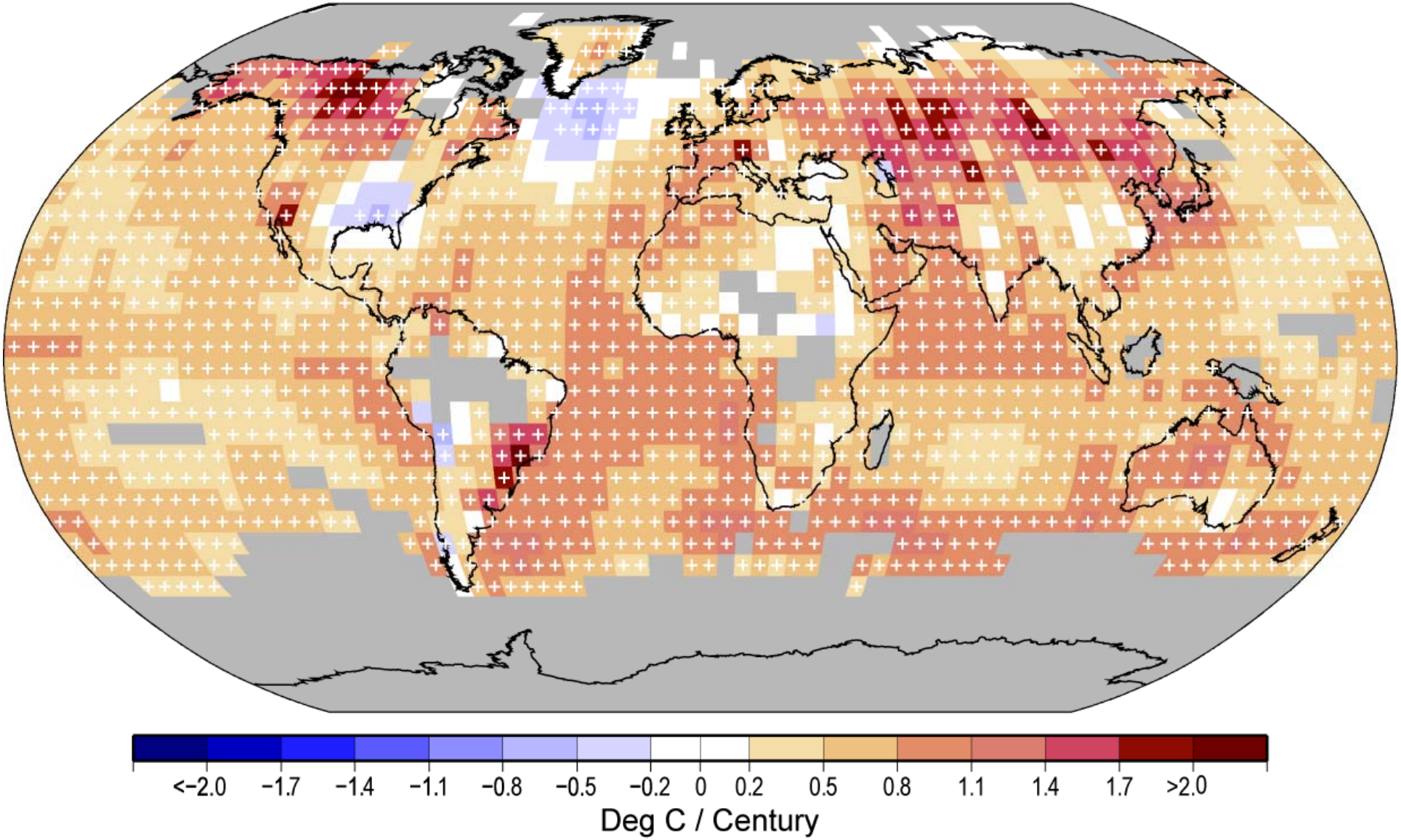
What Do Observations of Past Climate Show?

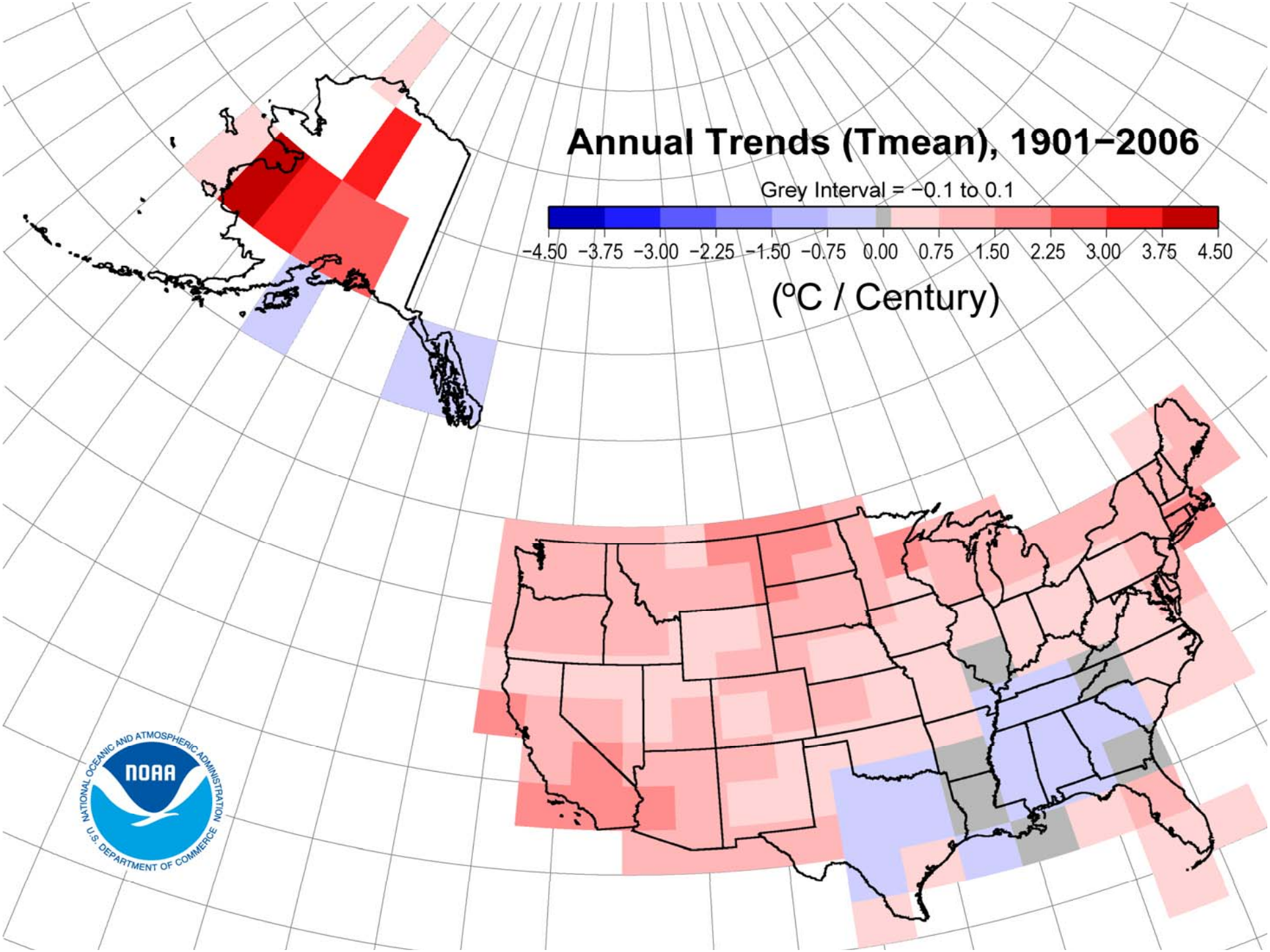
Jan - Dec Global Surface Mean Temp Anomalies

National Climatic Data Center/NESDIS/NOAA



Change in Annual Average Temperature: 1901-2005




Annual Trends (Tmean), 1901−2006
Grey Interval = −0.1 to 0.1
−4.50 −3.75 −3.00 −2.25 −1.50 −0.75 0.00 0.75 1.50 2.25 3.00 3.75 4.50
(ºC / Century)
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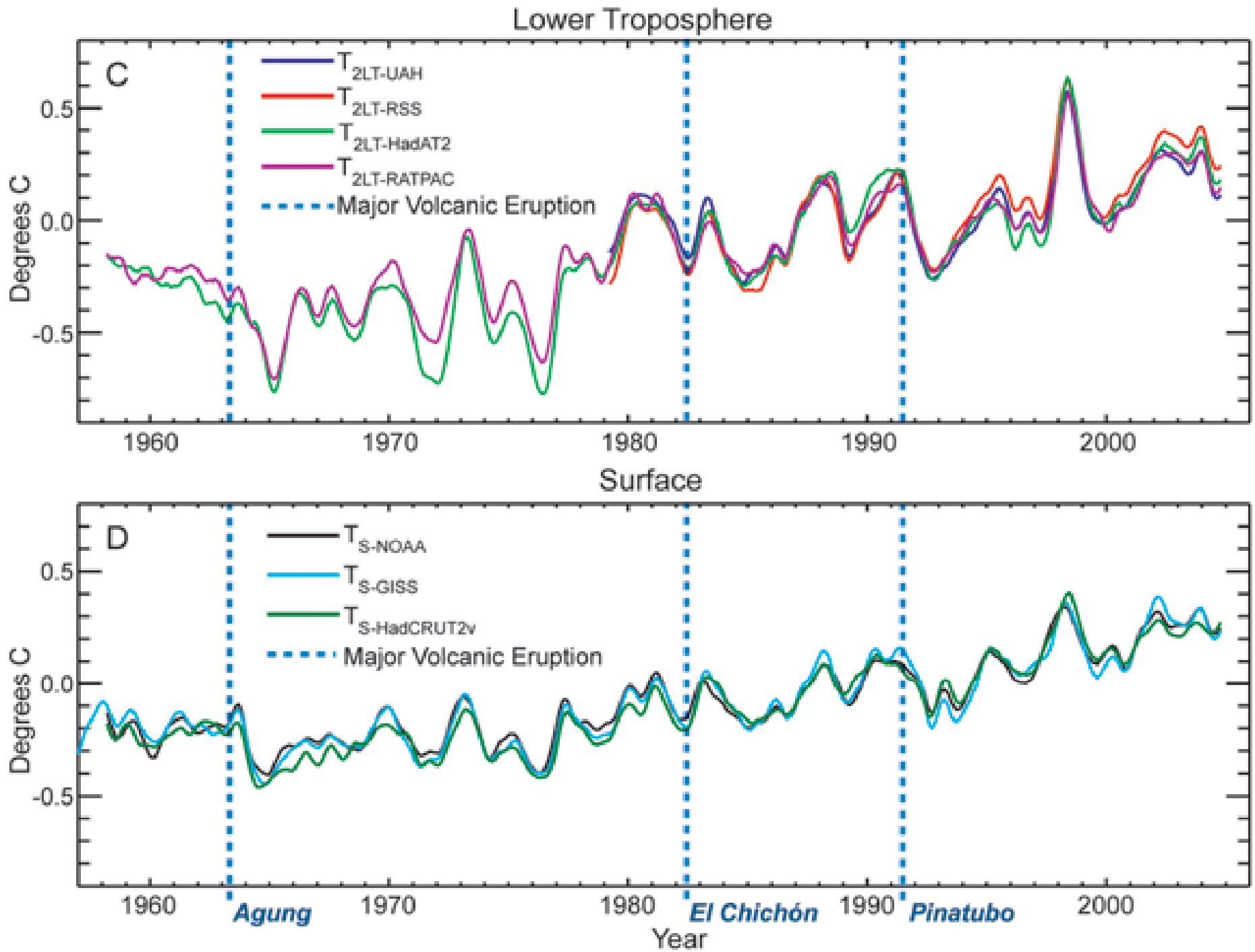
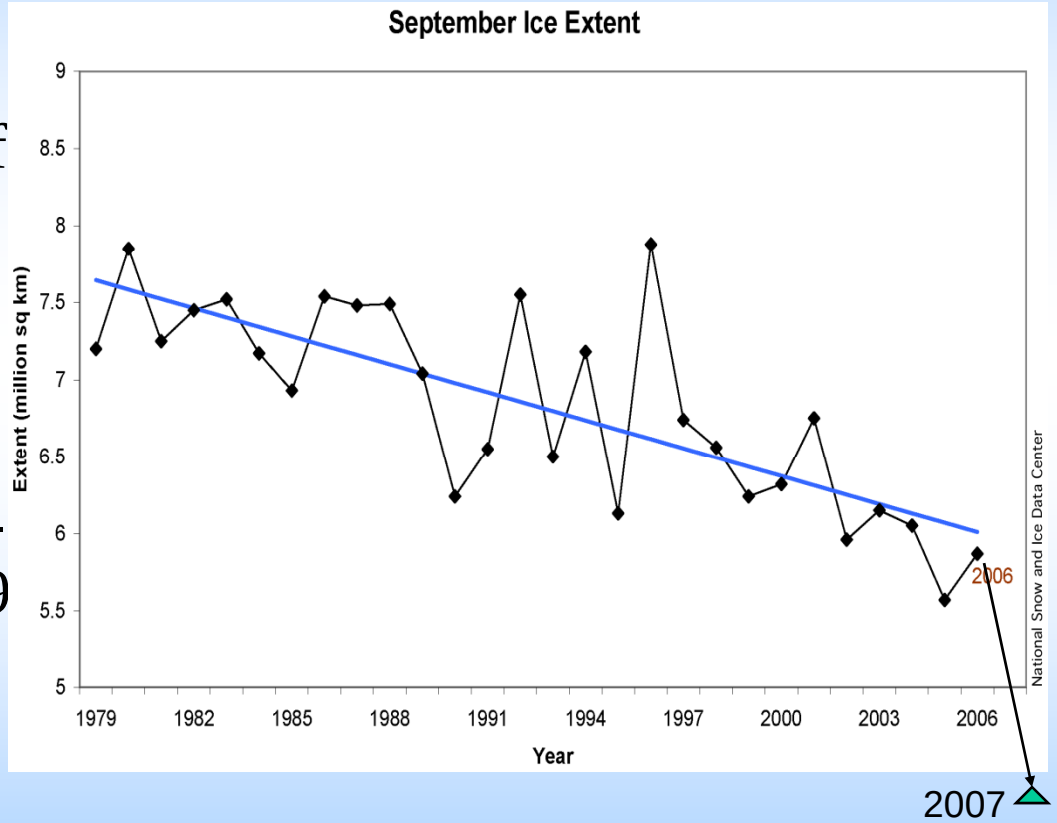

Lower Troposphere
C
$T_{2LT\text{-}UAH}$
$T_{2LT\text{-}RSS}$
$T_{2LT\text{-}HadAT2}$
$T_{2LT\text{-}RATPAC}$
Major Volcanic Eruption
Degrees C
0.5
0.0
-0.5
1960
1970
1980
1990
2000
Surface
D
$T_{S\text{-}NOAA}$
$T_{S\text{-}GISS}$
$T_{S\text{-}HadCRUT2v}$
Major Volcanic Eruption
Degrees C
0.5
0.0
-0.5
1960
Agung
1970
1980
El Chichón
1990
Pinatubo
2000
Year

What other evidence is there for warming?

Record Low Arctic Sea Ice Extent

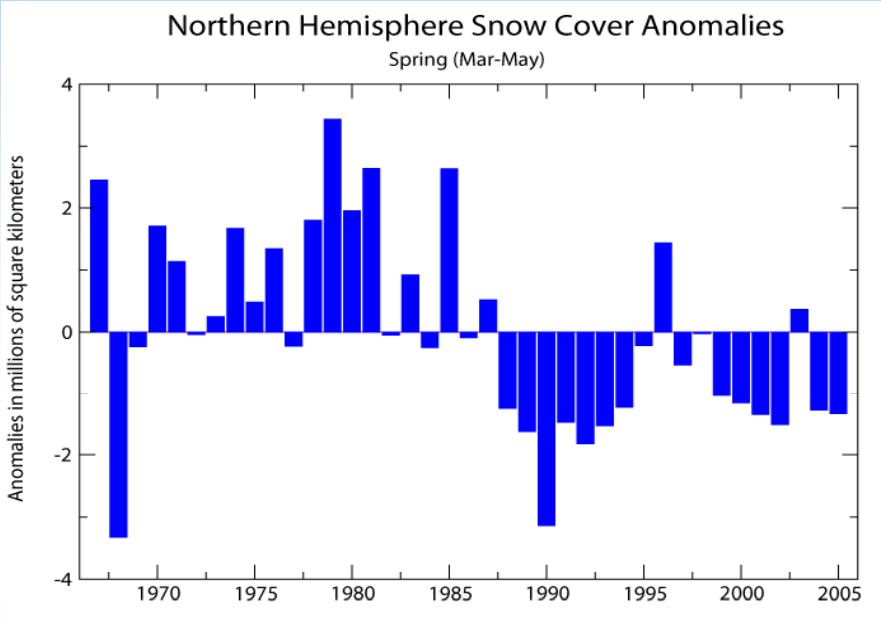
- Largest temperature anomalies in high latitudes of Northern Hemisphere
- Reflecting this warmth was a record low arctic sea ice extent in September
- 10% / Decade decline in end-of-summer sea ice since 1979
- 2007 record low of 4.28M sq. kms.
- 2008 potentially even lower.

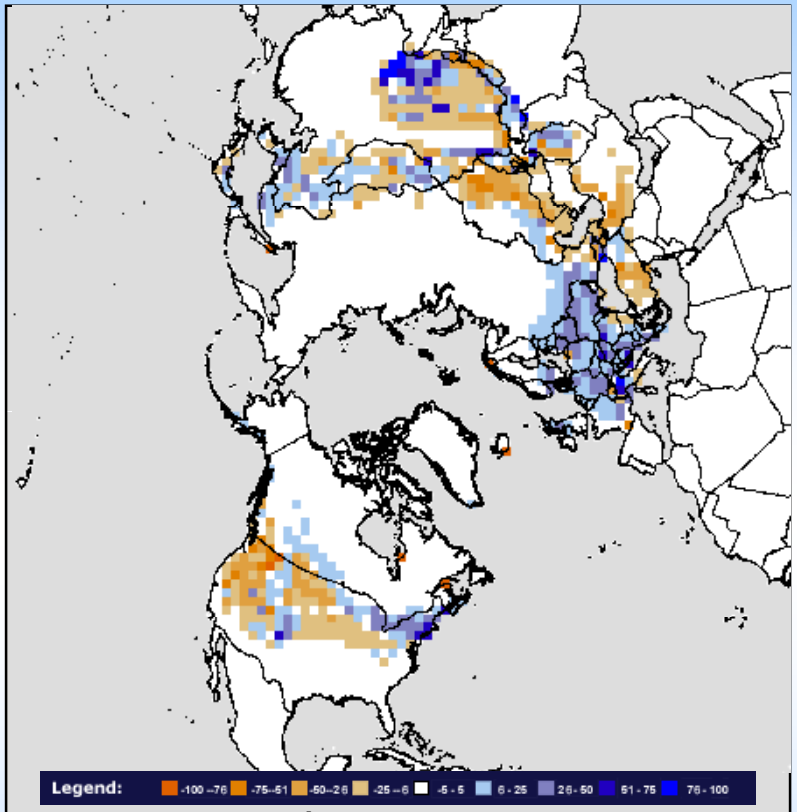


September Arctic Sea Ice Extent

Provided by NSIDC

N. Hem. Spring Snow Cover Extent





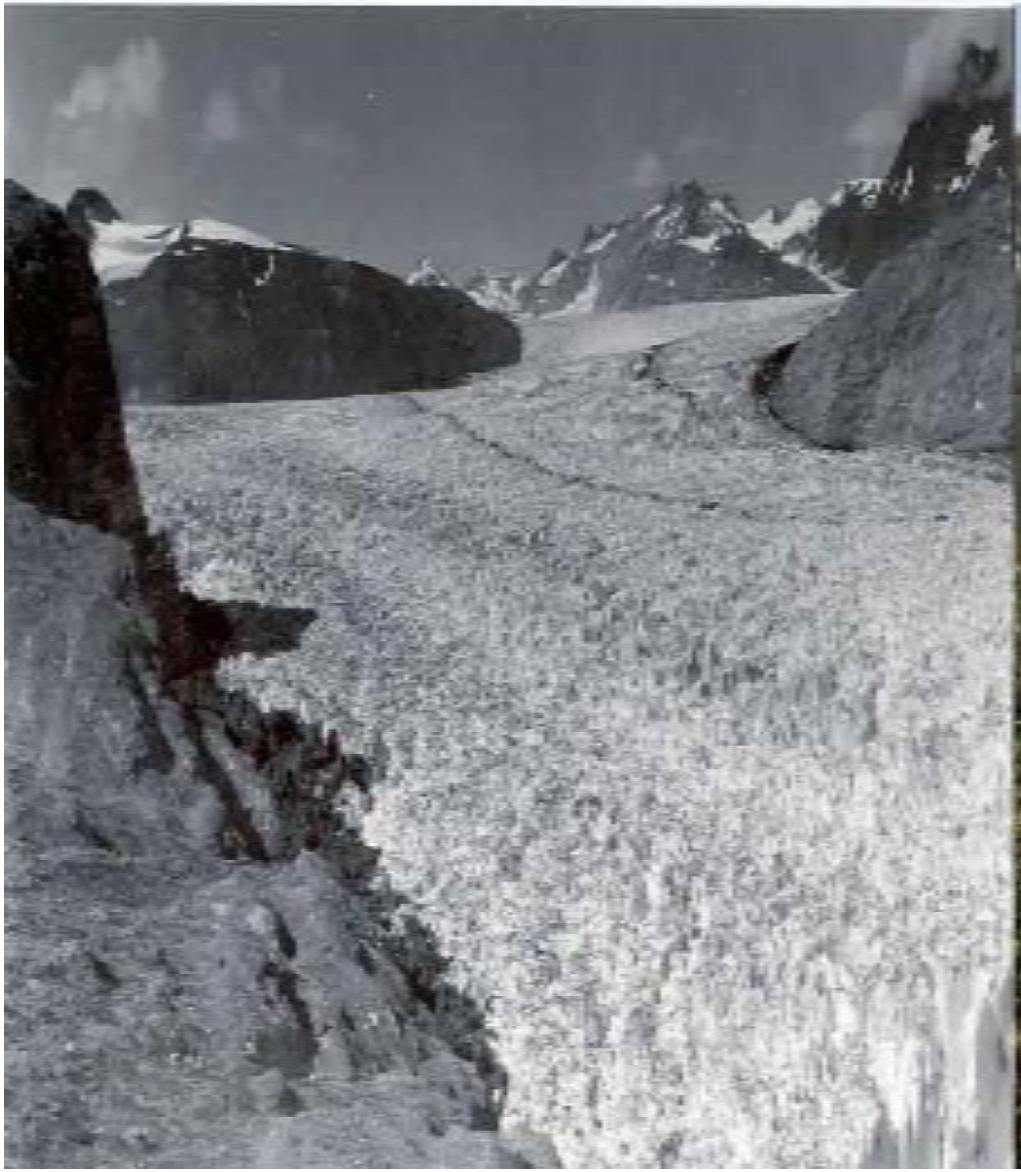
March 2005 Extent
Departure from Average

Provided by Rutgers Univ. Snow Lab

- 2-decade pattern in below average boreal spring snow cover extent continued
- Snow extent below average in 17 of past 20 springs

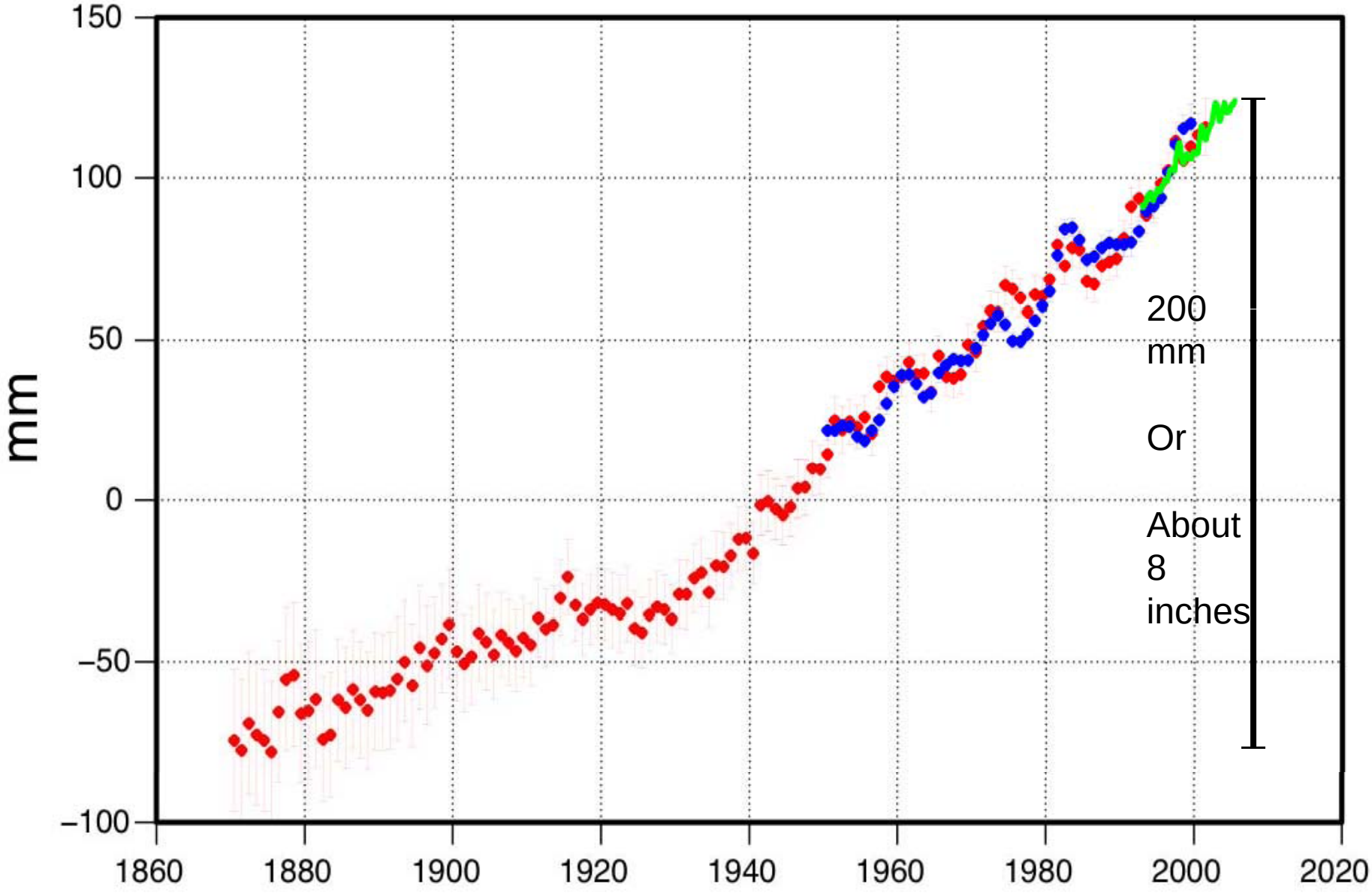
Muir Glacier, SE Alaska

August, 1941



August, 2003

Globally Averaged Sea-level Rise: 1860 - Present



Skeptics: “Its All Urban Warming and Land Use Change”

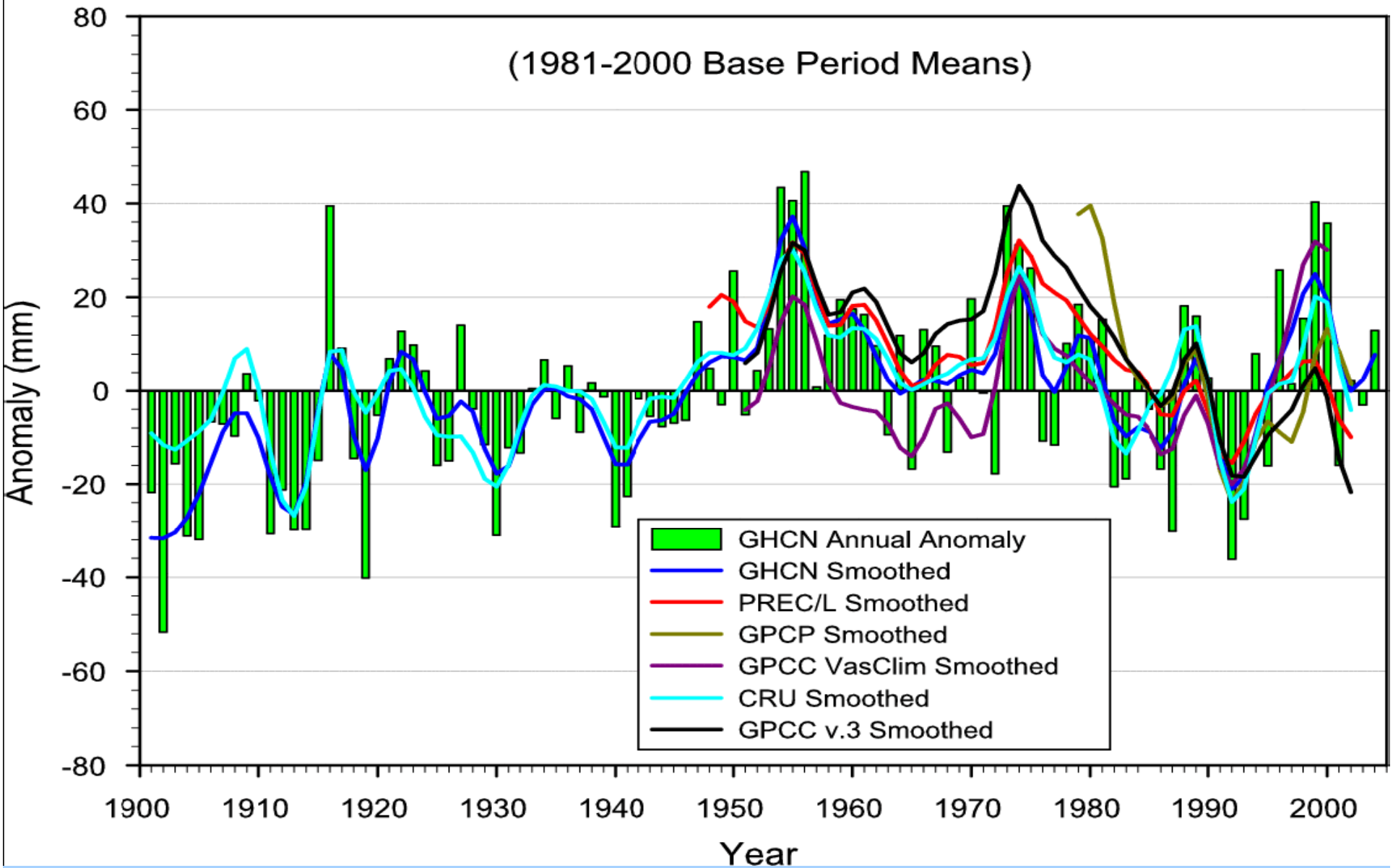
- Work done to exclude city stations shows little difference between global temperatures with and without these stations.
- Oceans are warming at a similar rate
- Troposphere warming at a similar rate.
- Cryosphere (snow, sea ice, glaciers etc.) shows large changes consistent with warming.
- Sea Level rise consistent with ocean warming.

- Bottom Line: Warming is “unequivocal” says IPCC AR4.

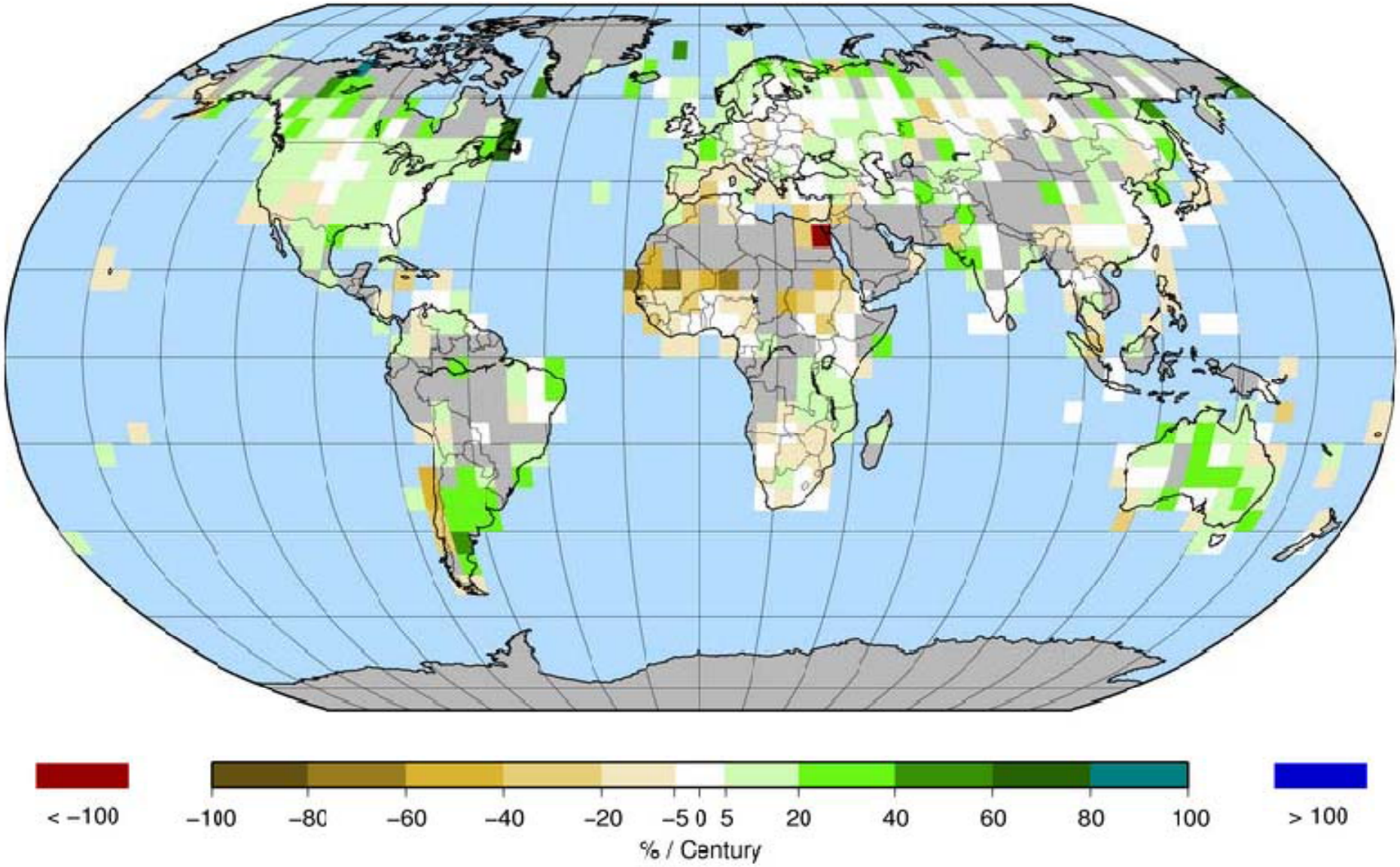
What About Precipitation?

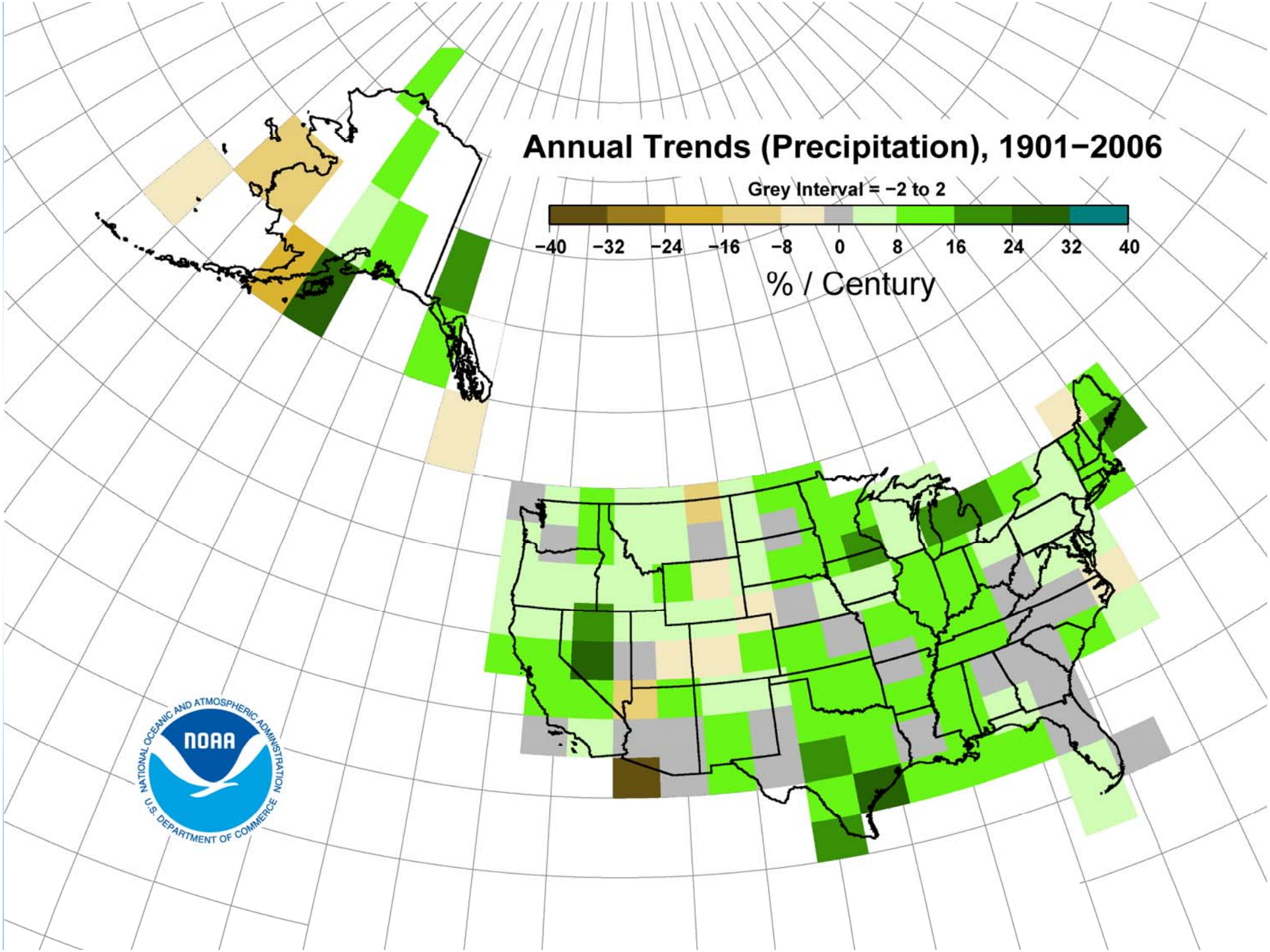
- Much harder to measure precipitation than temperature.
- Leads to less confidence in large-scale changes in observed precipitation.
- Precipitation much more variable both geographically and through time.

Global Annual Land Precipitation Anomalies



Trend in Annual PRCP, 1901 to 2004

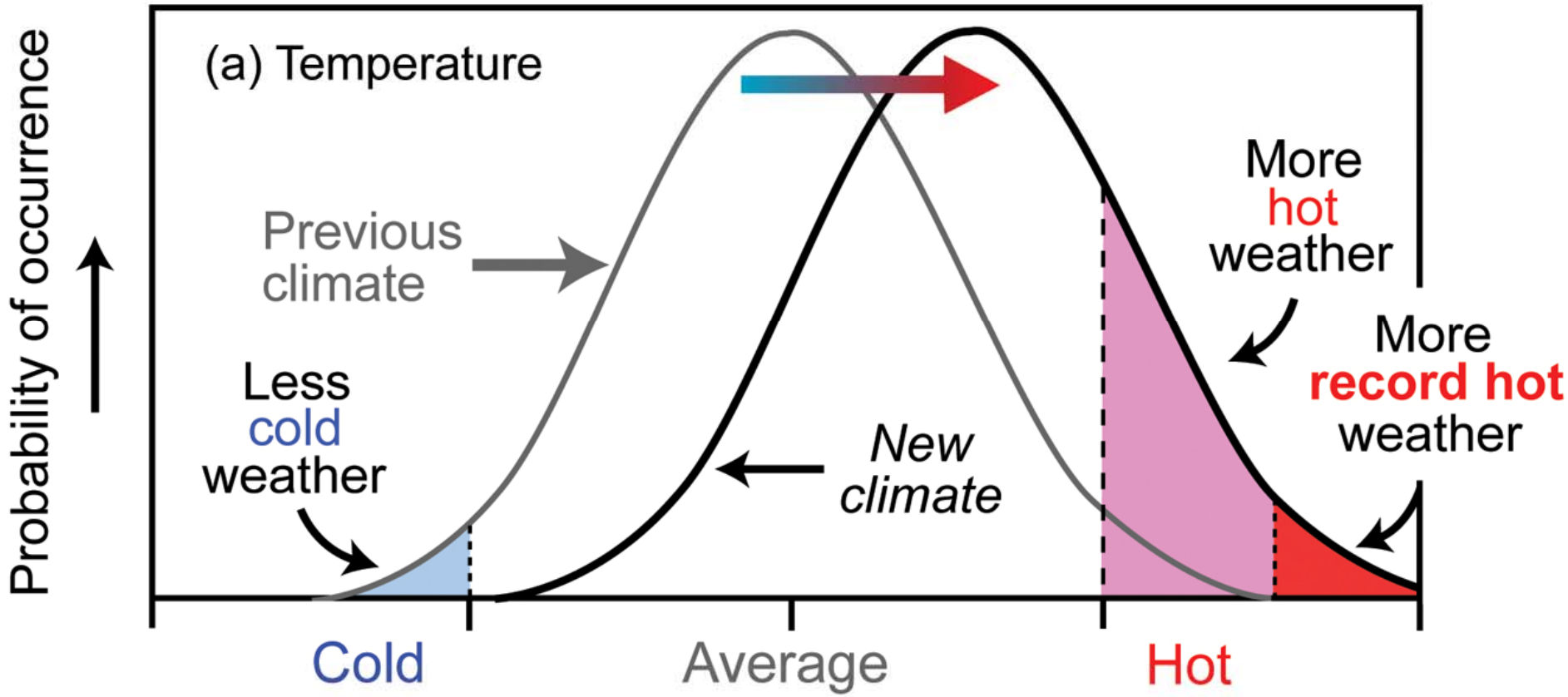


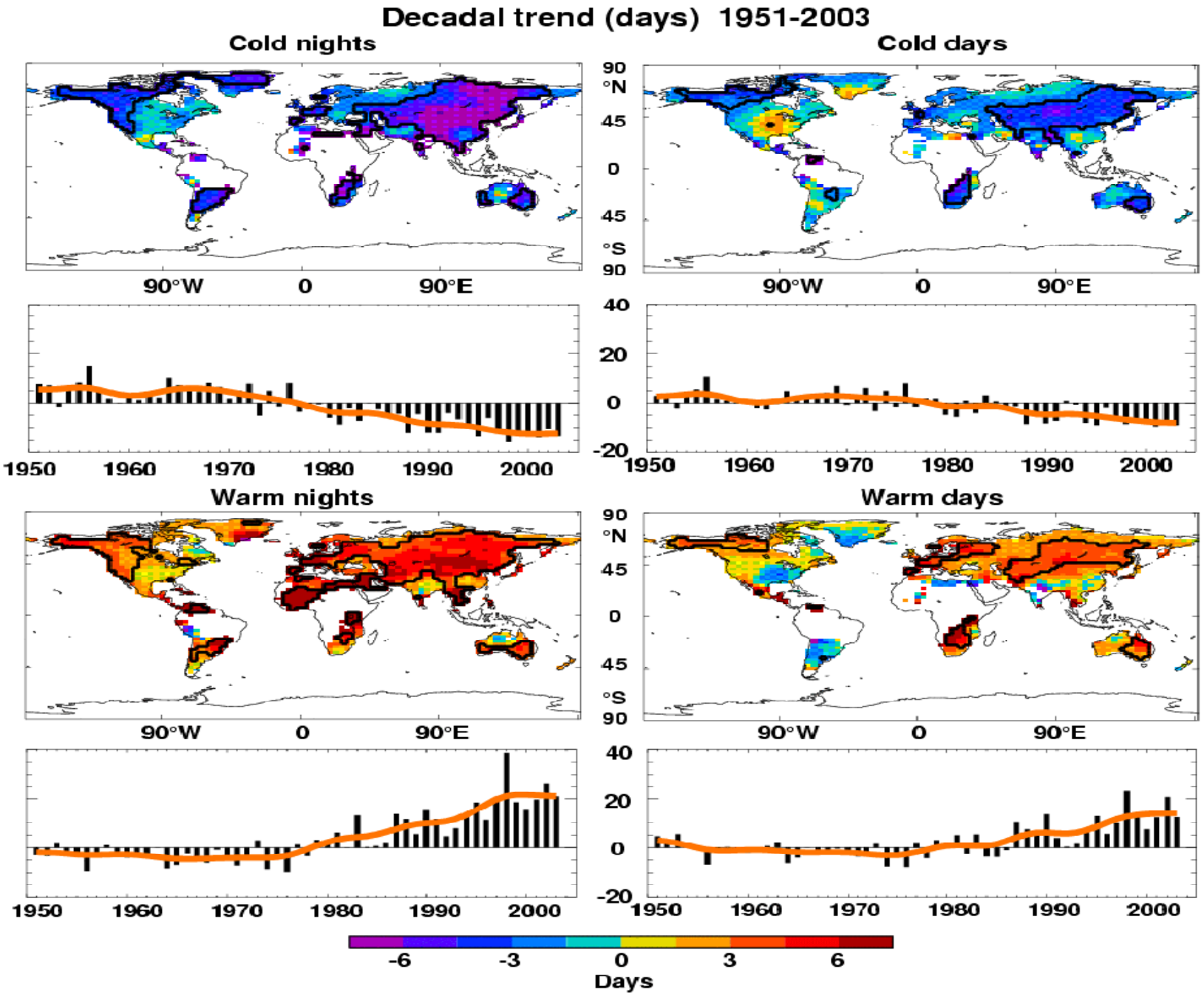

Annual Trends (Precipitation), 1901−2006
Grey Interval = −2 to 2
−40 −32 −24 −16 −8 0 8 16 24 32 40
% / Century
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Extreme Events

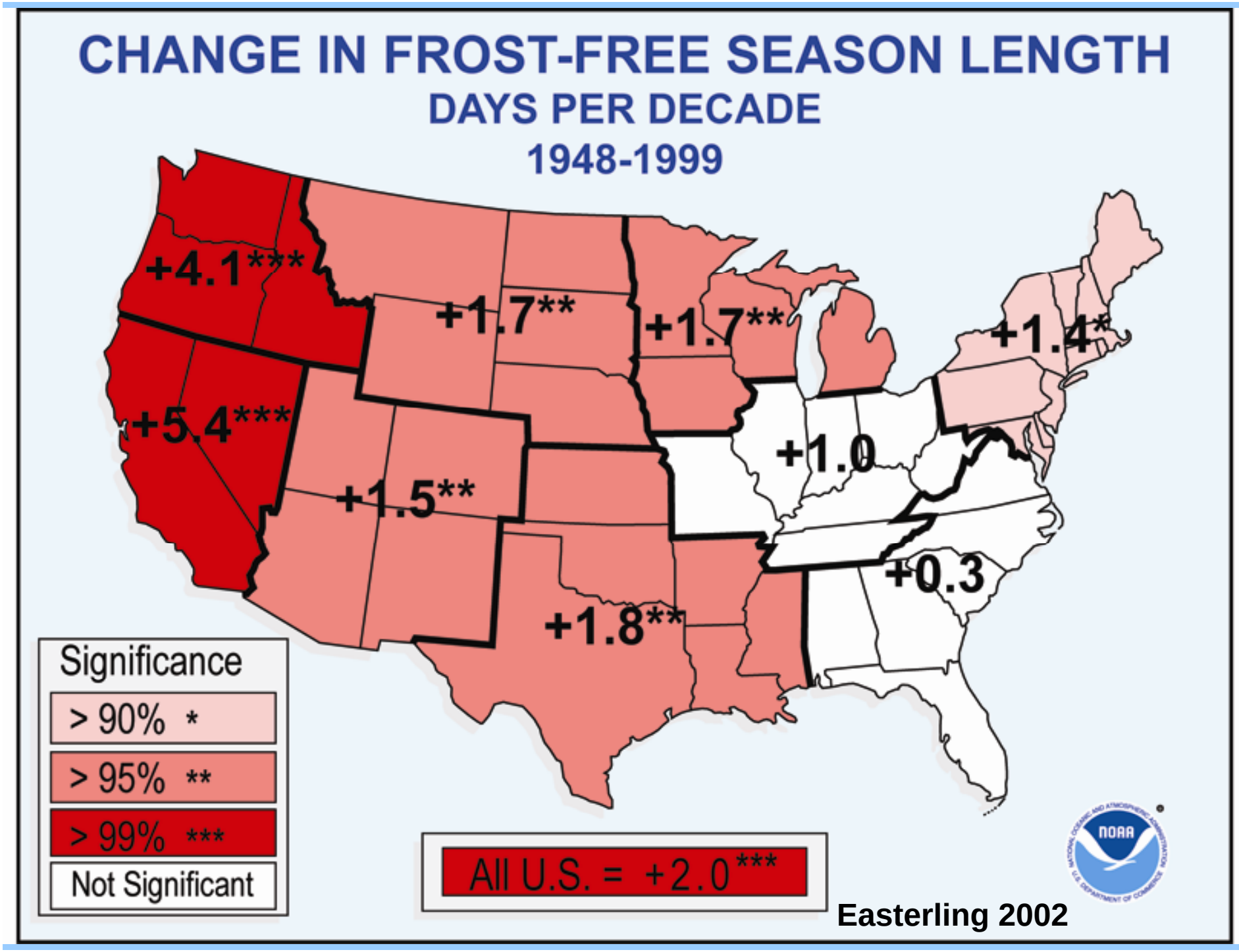
- Temperature
- Precipitation
- Drought

Increase in Probability of Extremes in a Warmer Climate





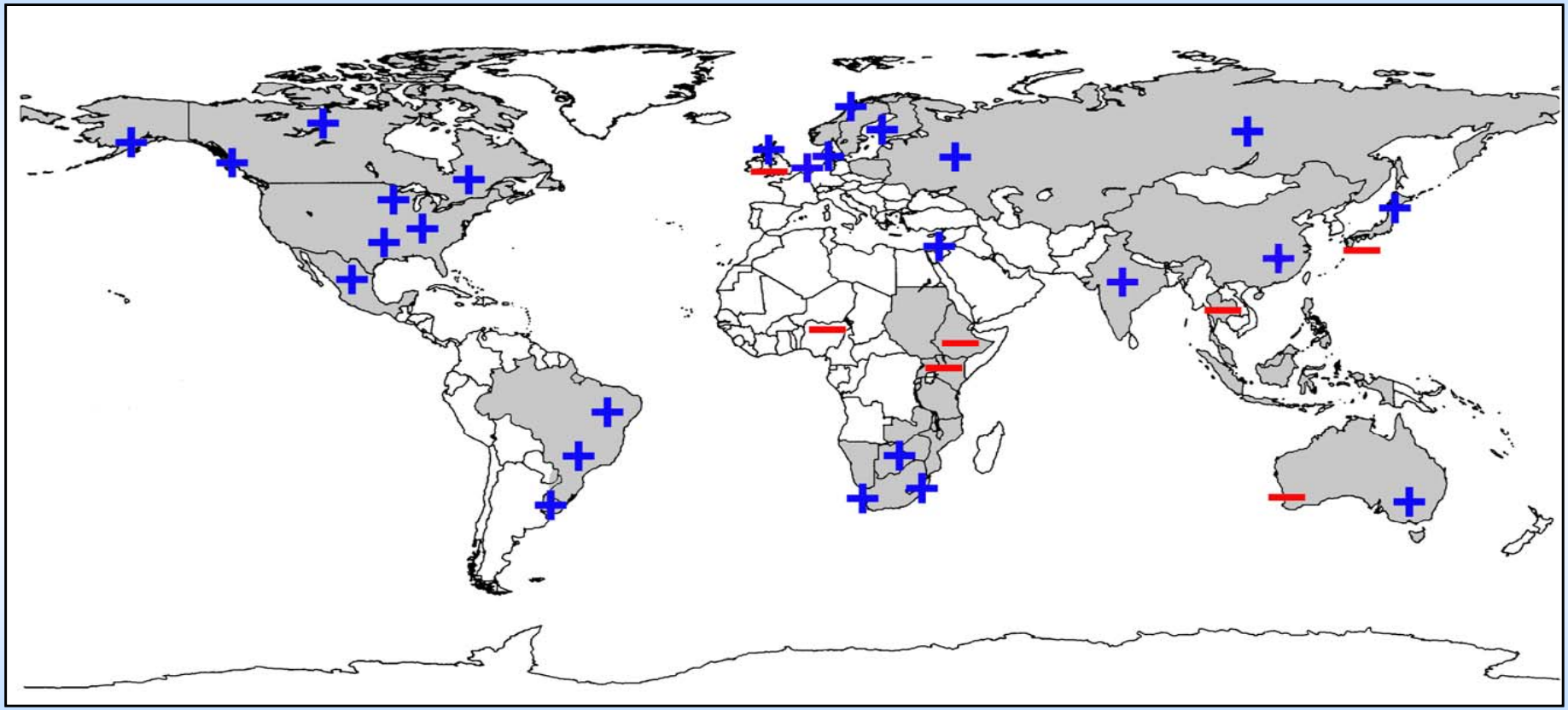
From Alexander et al. 2005



Easterling 2002

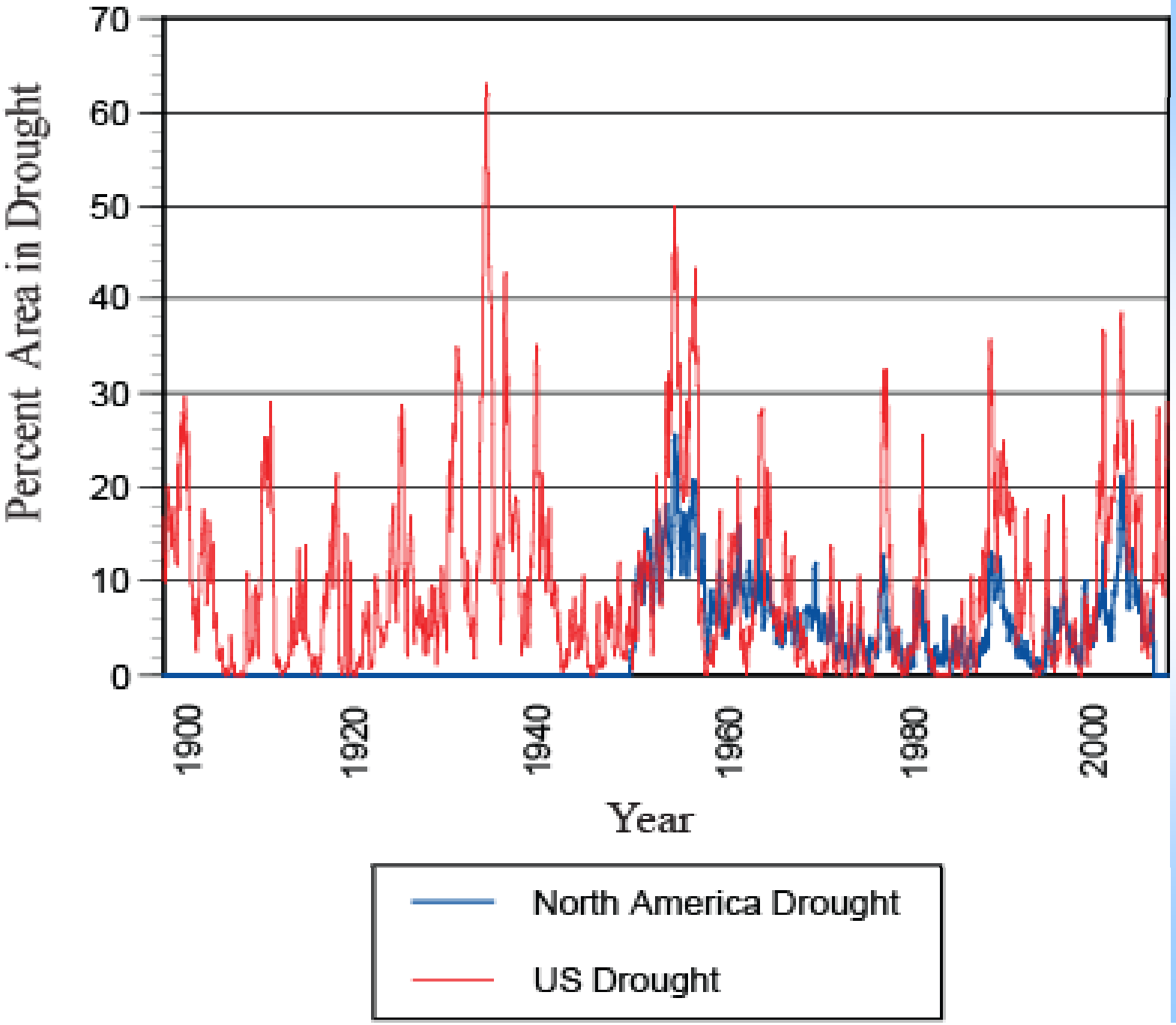
Regions Where Heavy Precipitation Events Have Increased (+) or Decreased (-)

(first half of 20th century to present)



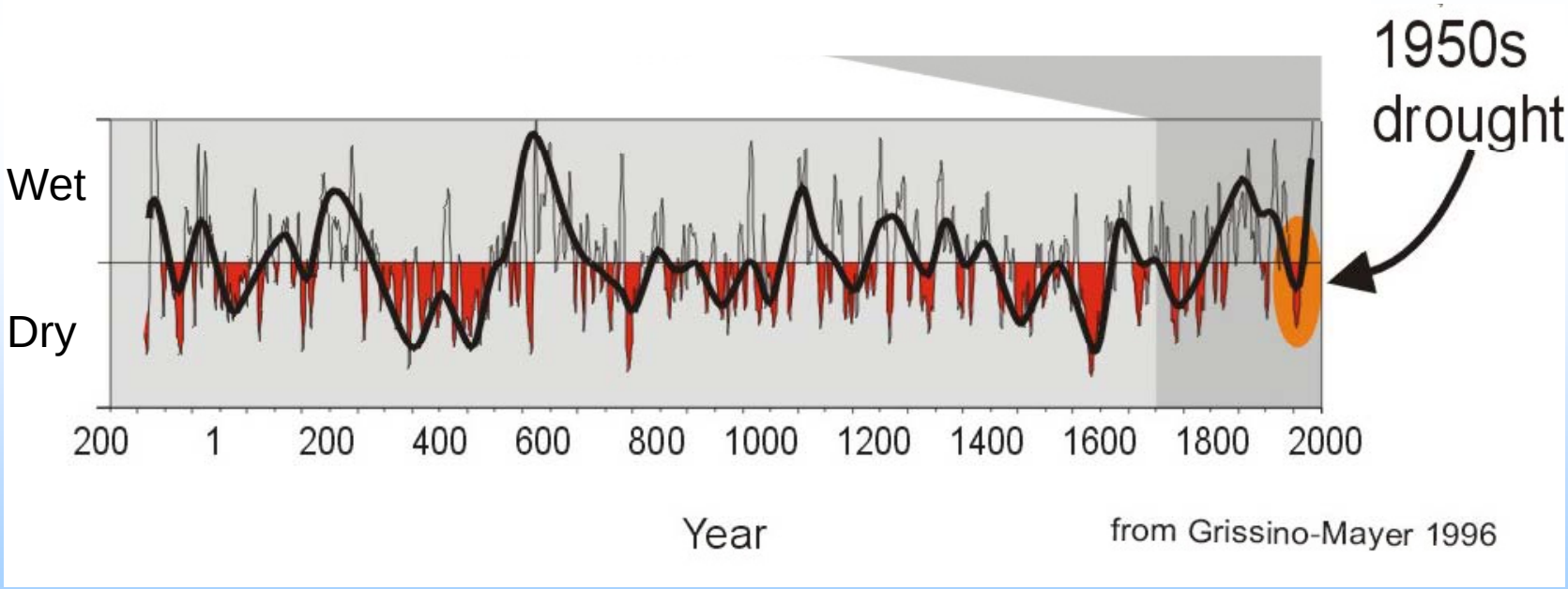
Updated from Easterling et al. 2000

US and North American Drought Comparison



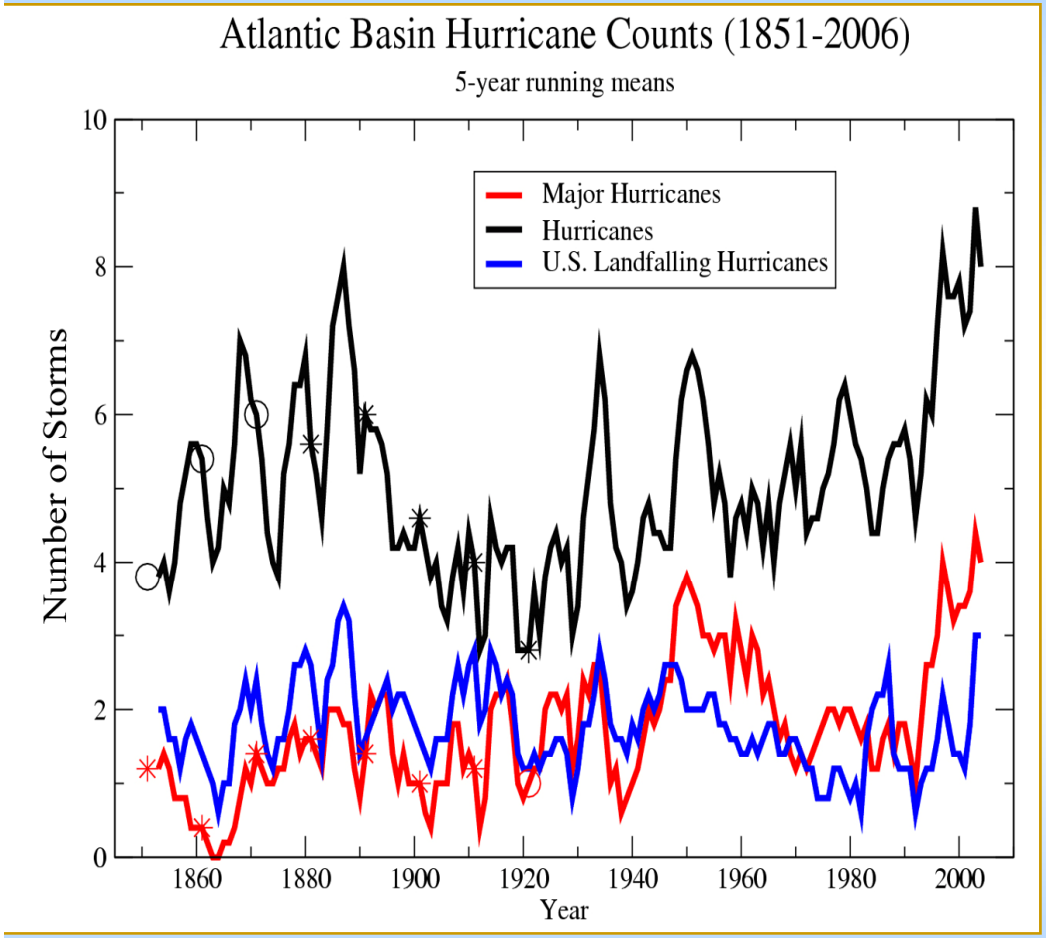
Reconstructions of Western Drought

Droughts over the past two millennia dwarf anything in the modern instrumental record.

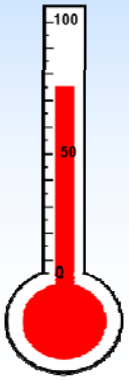


- Drought and wet periods are a persistent feature of the climate system.
- Droughts and wet periods in the past 1000 years dwarf anything in the instrumental record (since late 1800s).

Hurricanes - Observed



- The frequency of Atlantic tropical storms, hurricanes and major hurricanes has increased.



This increase is:

- substantial since 1970
- likely substantial since 1950
- there is less confidence in data prior to 1900

- There is no evidence for a trend in North American landfalling hurricanes

"Most of the observed increase in global average temperatures since the mid-20th century is ***very likely*** due to the observed increase in anthropogenic greenhouse gas concentrations"

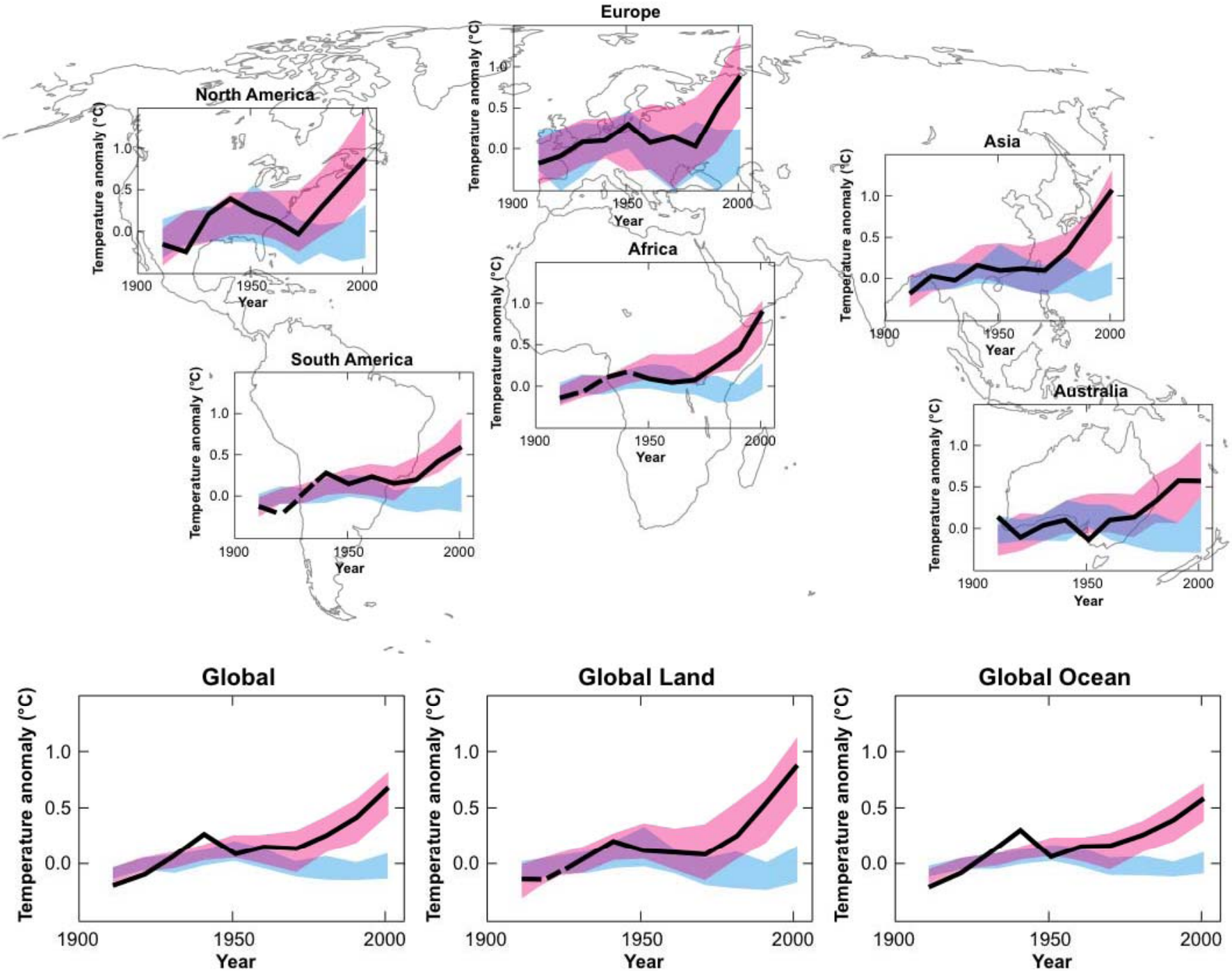
IPCC AR4, 2007

Very Likely* = > *90% probability

Why the confidence that observed warming is human-induced?

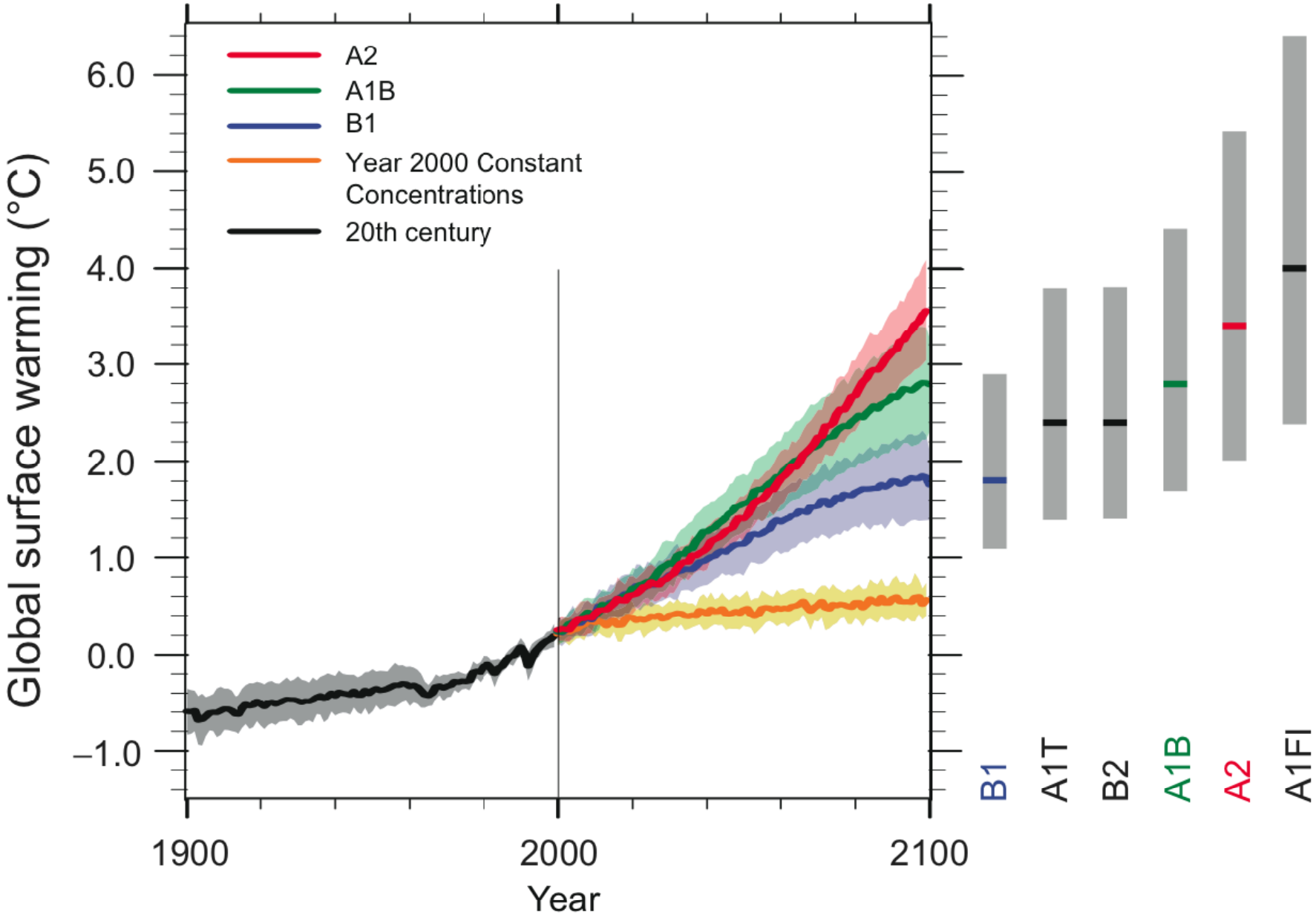
What might the future hold?

To answer these questions requires the use of climate models.


Europe
North America
Asia
Africa
South America
Australia
Global
Global Land
Global Ocean
Temperature anomaly (°C)
Year
1900
1950
2000
0.0
0.5
1.0

What Might the Future Hold?

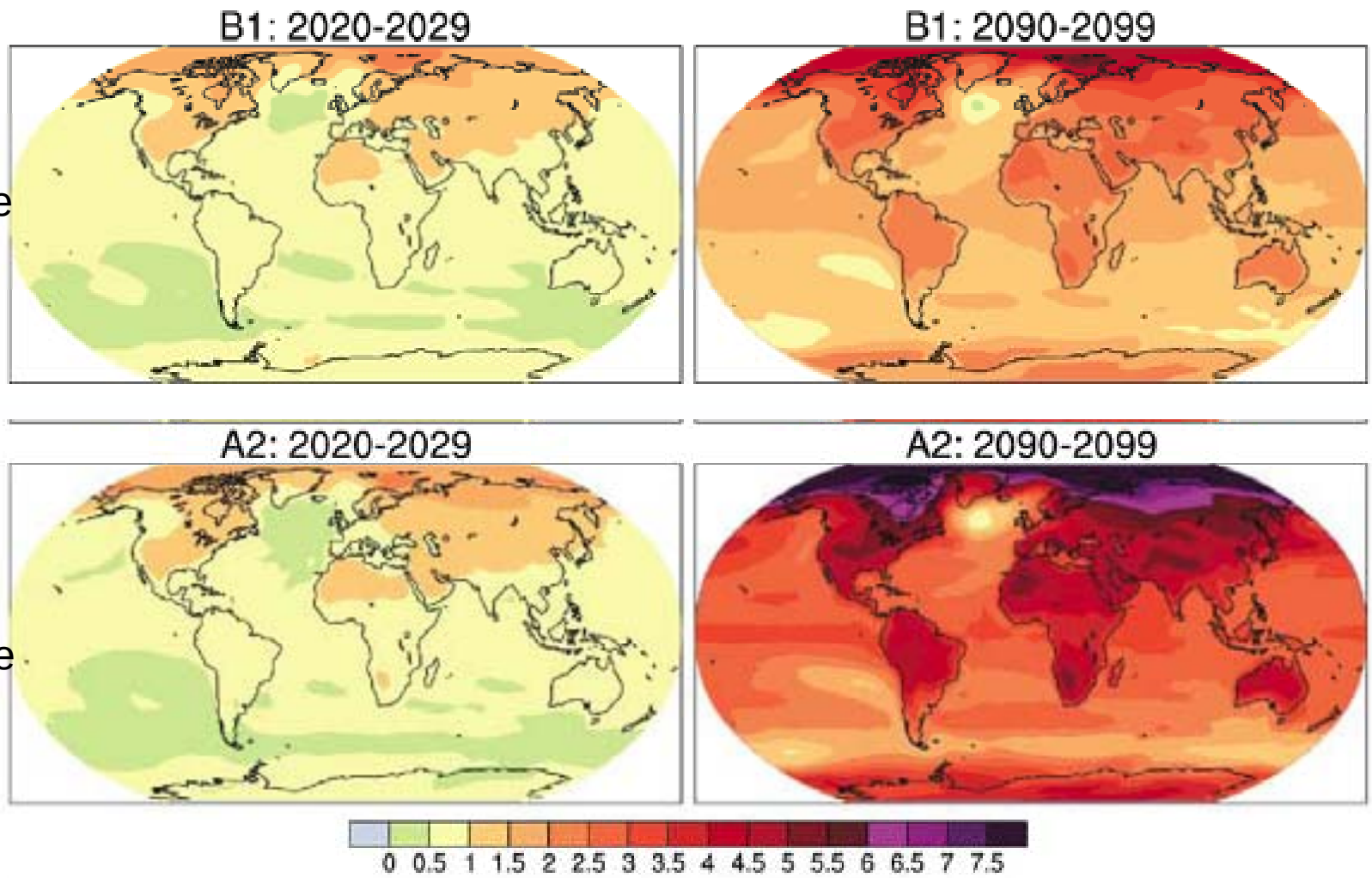
Multi-model Averages and Assessed Ranges for Surface Warming



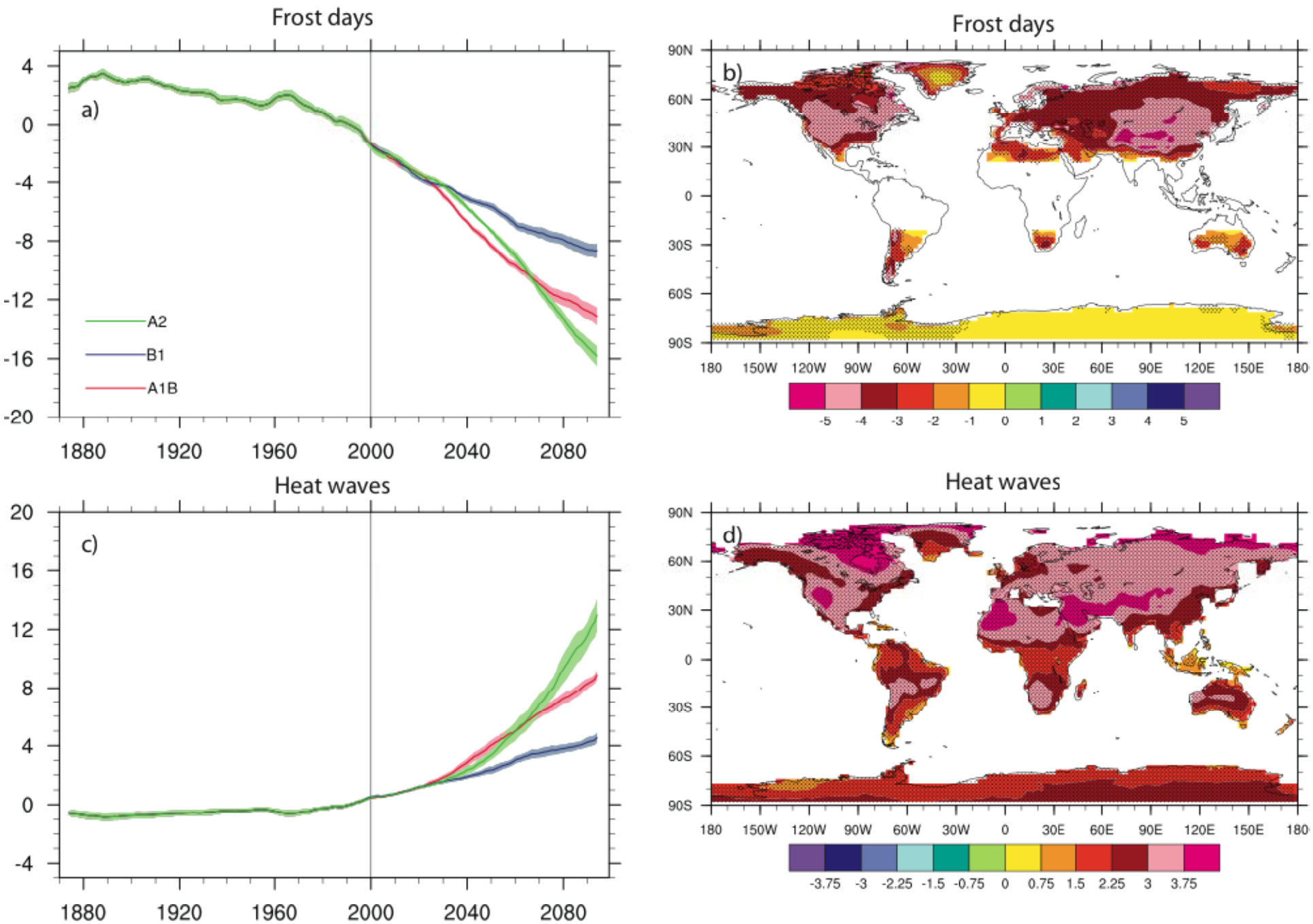
Projected Temperature Change

Moderate Greenhouse Gas Increase

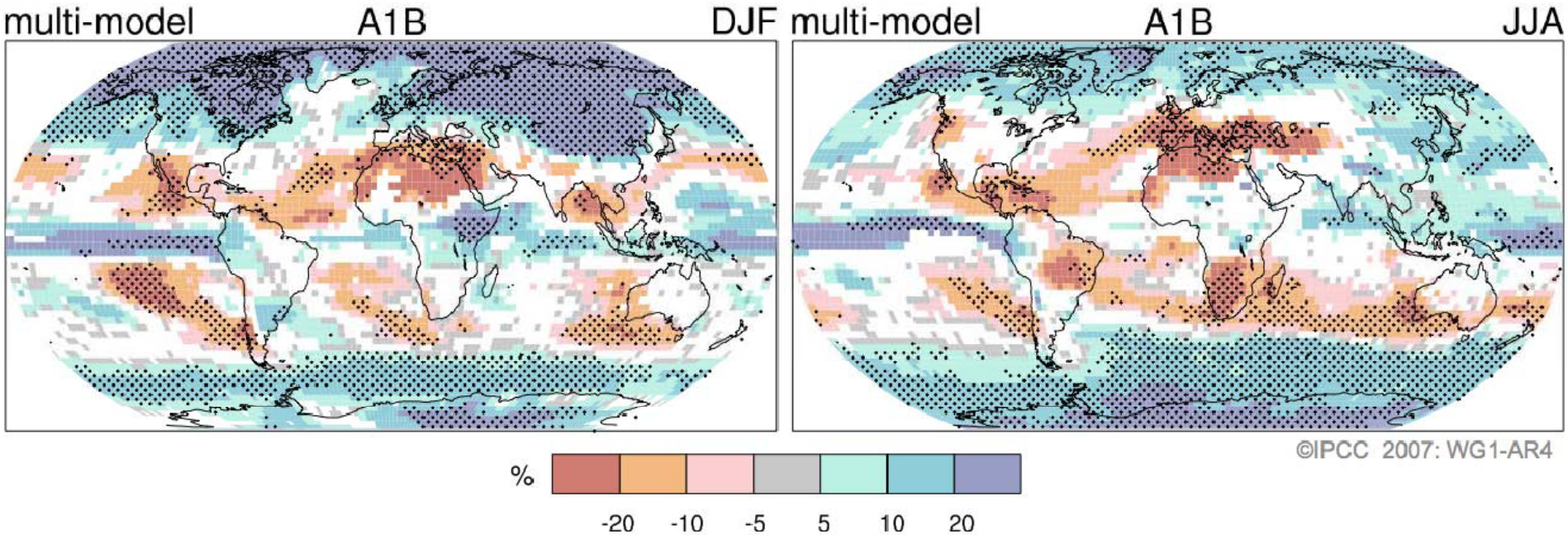
Large Greenhouse Gas Increase



©IPCC 2007: WG1-AR4

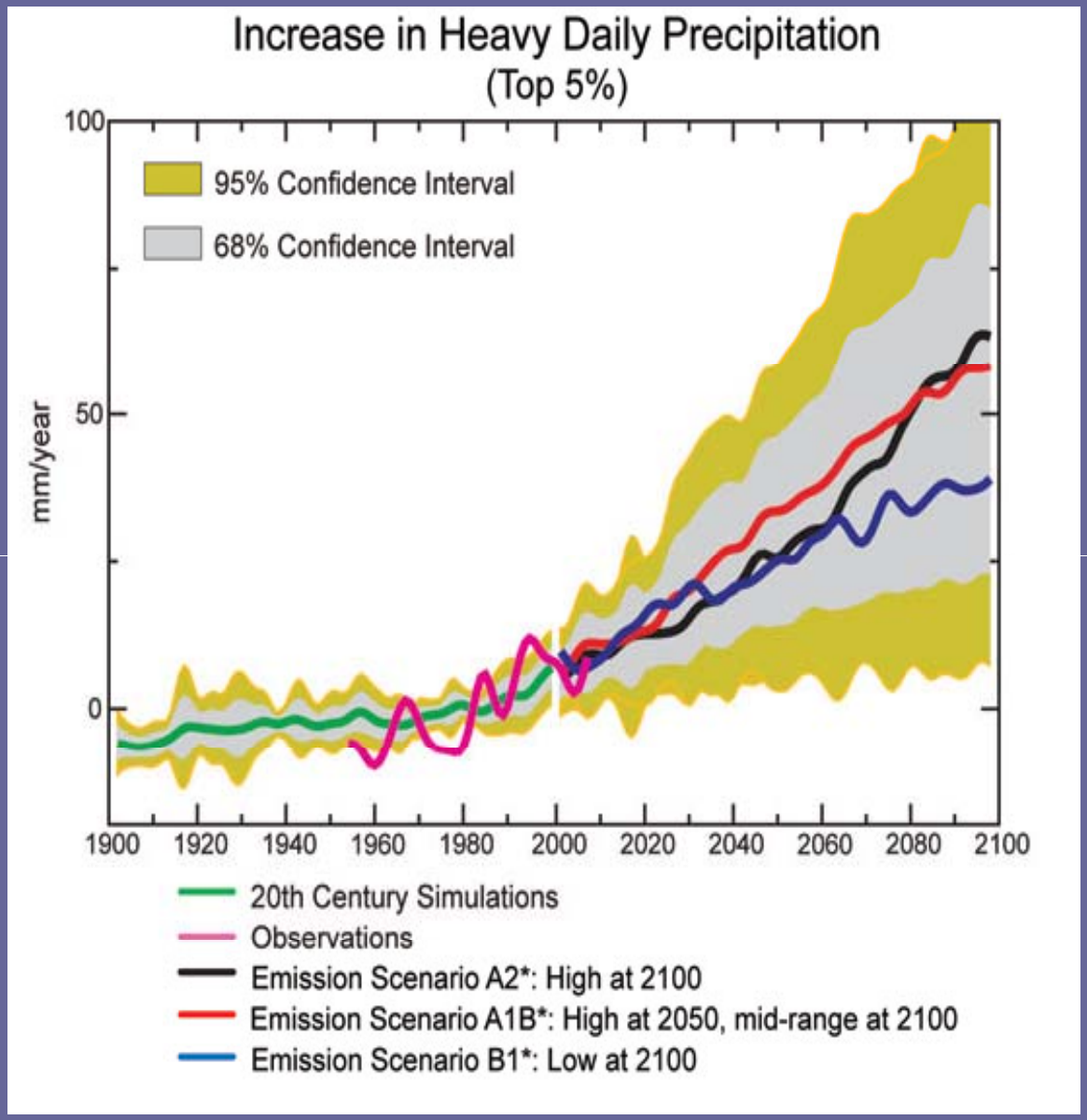

Frost days
a)
A2
B1
A1B
4
0
-4
-8
-12
-16
-20
1880
1920
1960
2000
2040
2080
Frost days
b)
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
-5
-4
-3
-2
-1
0
1
2
3
4
5
Heat waves
c)
20
16
12
8
4
0
-4
1880
1920
1960
2000
2040
2080
Heat waves
d)
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
-3.75
-3
-2.25
-1.5
-0.75
0
0.75
1.5
2.25
3
3.75

Projected Patterns of Precipitation Changes



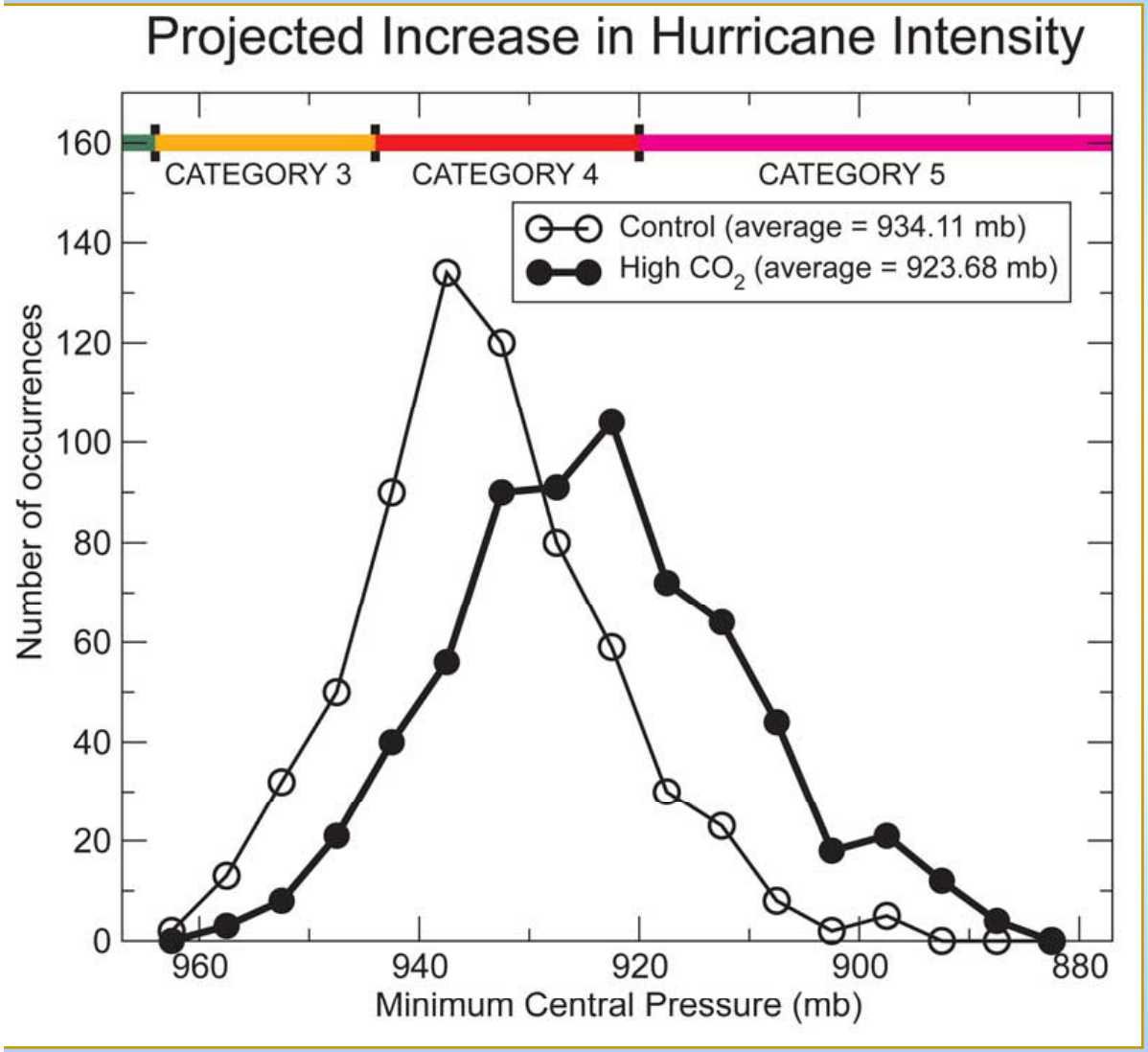
©IPCC 2007: WG1-AR4

- Increases in heavy rainfall events over North America.



Increase in the amount of daily precipitation over North America that falls in heavy events.

Storms: Hurricanes - Projections



- For North Atlantic and North Pacific hurricanes:

For every degree Celsius of tropical SST increase, the surface wind speeds of the strongest hurricanes will increase 2-10%

What Does This Mean for the USA?

- Amount of warming is uncertain, but will very likely warm some amount.
- Precipitation changes are less certain but likely increase.
- Climate Models show mid-continental summer drying of soil by end of 21st century, possibly more drought.
- Likely more heavy rainfall events.

Summary

- Has it warmed?
  - Global temperatures have warmed about 0.7^{o}C since the late 1800s.
  - Tropospheric temperatures since 1979 now show warming consistent with surface.
  - Warming since 1970s 0.2^{o}C per decade.
  - Other evidence
    - Sea Ice decrease
    - Snow cover decrease
    - Glacier/ice sheet decreases
    - Changes in frost days and days exceeding other thresholds

Summary

- Has precipitation changed?
  - Global precipitation appears to have increased since the late 1800s.
  - Other evidence
    - Heavy daily precipitation shows signs of increase.
- Hurricanes
  - More and more powerful since 1970s but long-term trend is uncertain.
- Confidence?
  - Greatest in temperature changes
  - Less in global precipitation changes, but confident regional changes in heavy precipitation.

Summary

- Future Climate
  - Possible large changes in temperature
  - Precipitation changes less certain
  - Possible changes in extremes
  - Possible changes in sea-level
  - Possible increase in drought conditions, esp. in mid-continental regions.
  - Hurricanes, likely stronger, but unknown about numbers.

Thank You!