Observed Climate Variability and Change

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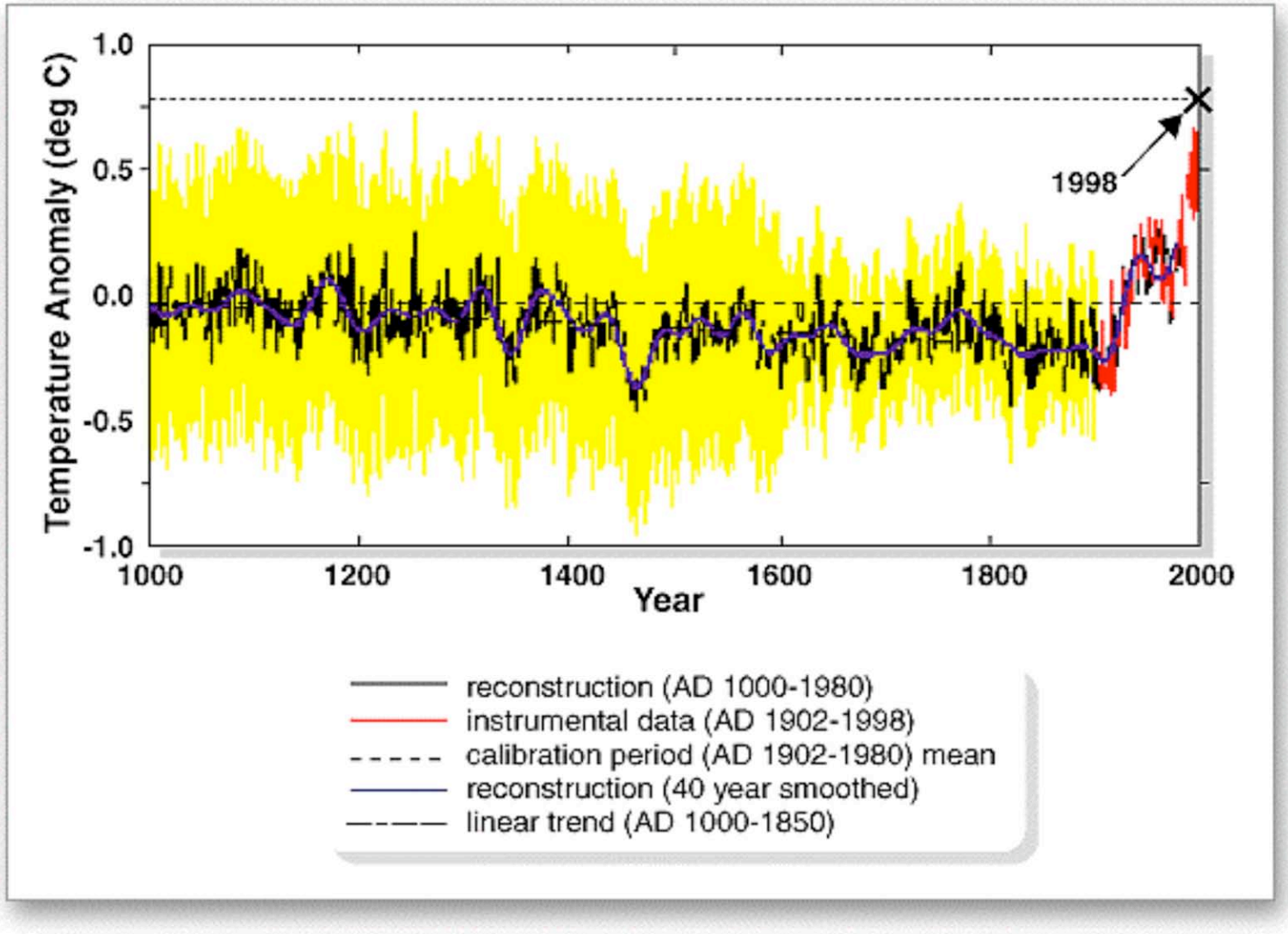
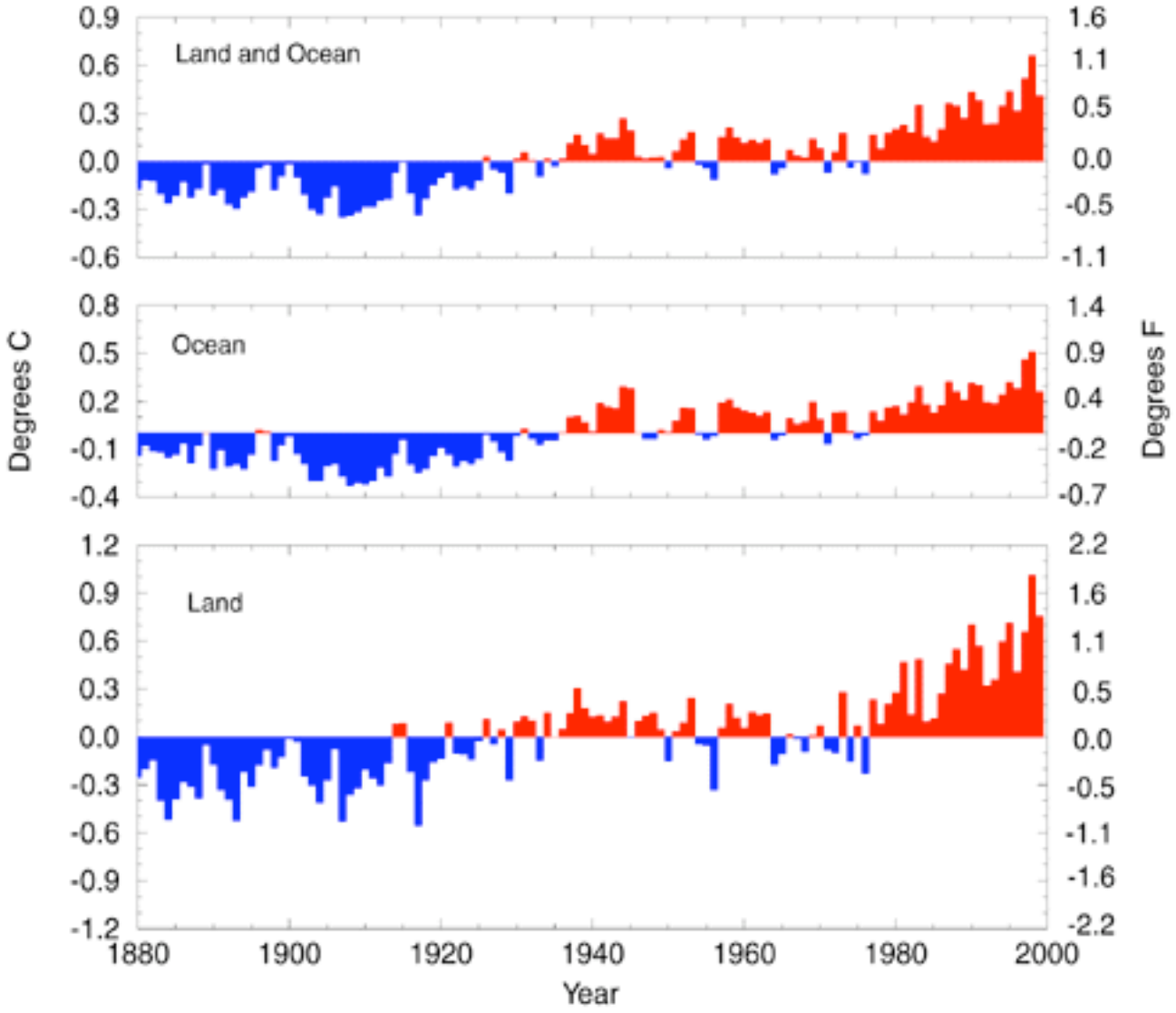
Overview

- The evidence for observed climate change.
  - Temperature
  - Precipitation
  - Extremes
  - Abrupt Climate Change

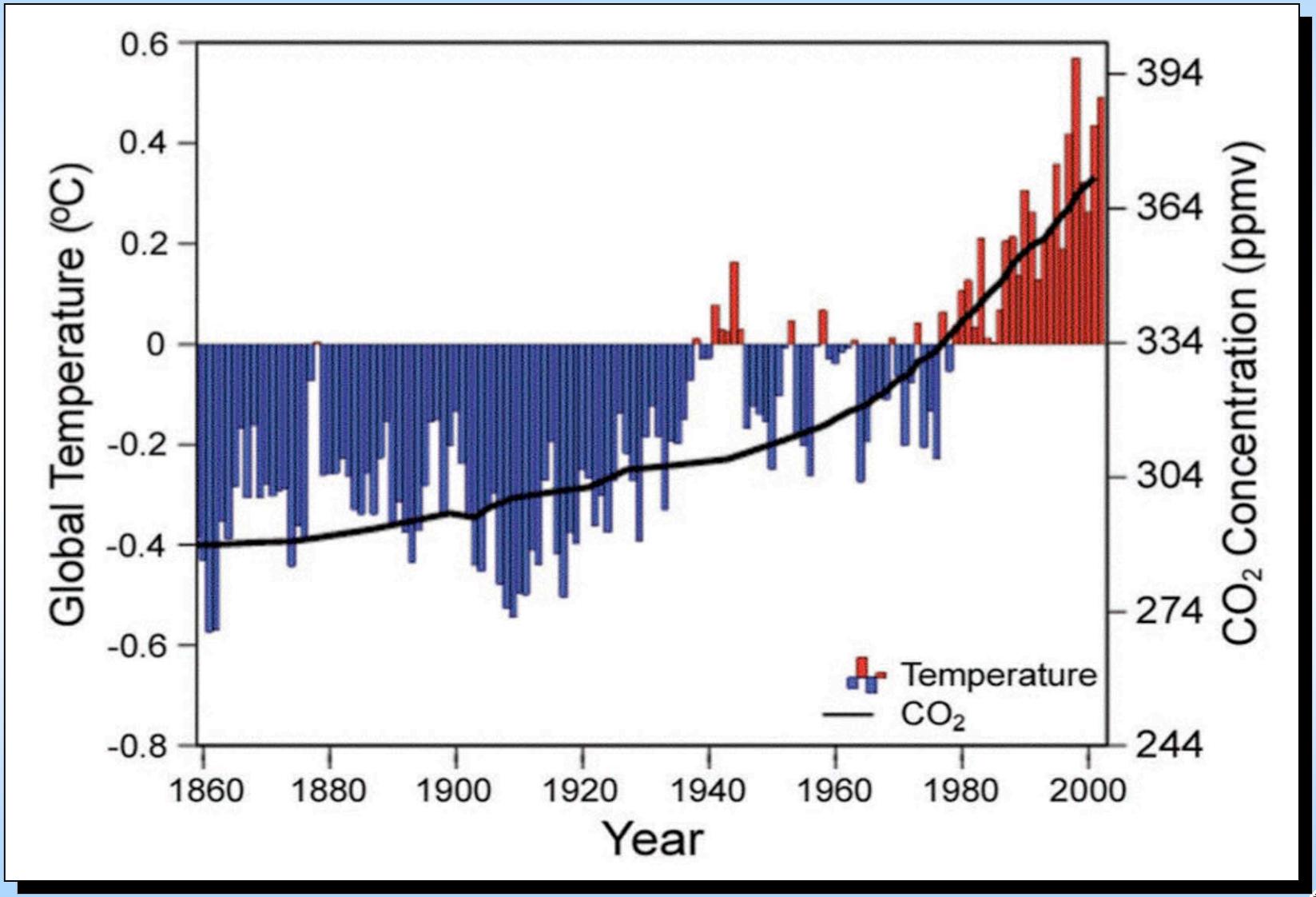
- How confident are we in these results?
  - Data and Observational Issues that can lead to uncertainties

Northern Hemisphere 1000 Year Temperature Reconstruction



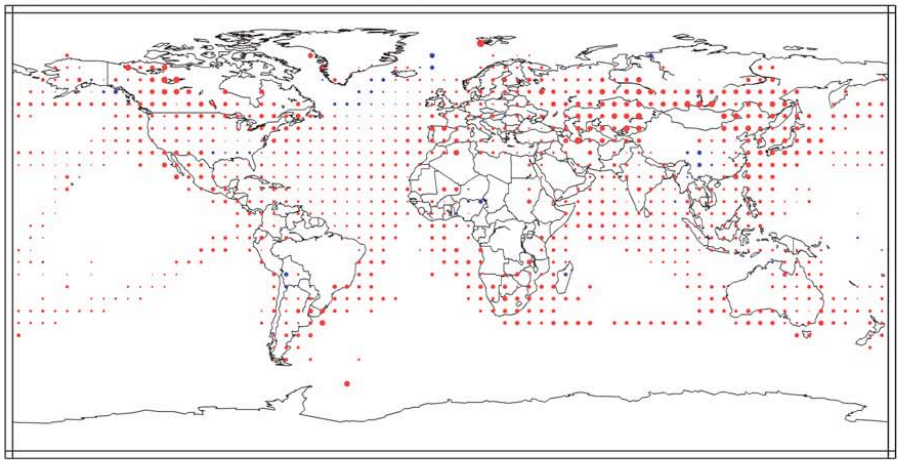

Annual Global Surface Mean Temperature Anomalies
National Climatic Data Center/NESDIS/NOAA
Land and Ocean
Ocean
Land
Degrees C
Degrees F
Year
0.9
0.6
0.3
0.0
-0.3
-0.6
1.6
1.1
0.5
0.0
-0.5
-1.1
0.8
0.5
0.2
-0.1
-0.4
1.4
0.9
0.4
-0.2
-0.7
1.2
0.9
0.6
0.3
0.0
-0.3
-0.6
-0.9
-1.2
2.2
1.6
1.1
0.5
0.0
-0.5
-1.1
-1.6
-2.2
1880
1900
1920
1940
1960
1980
2000

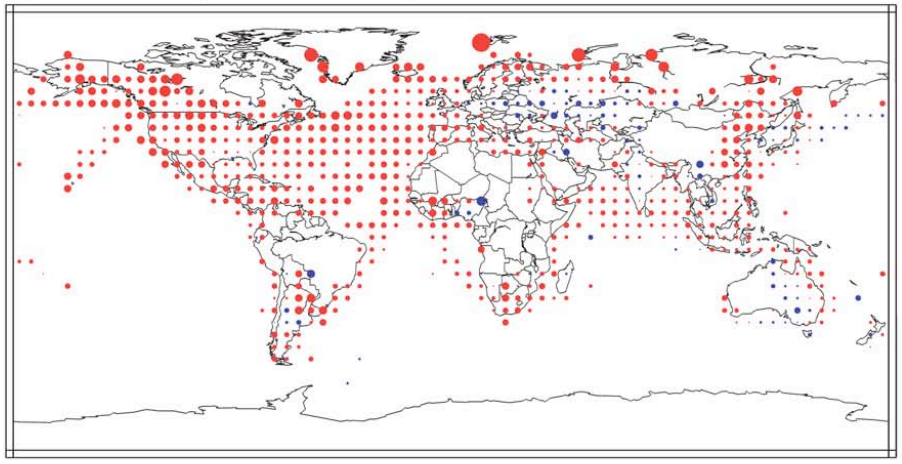
Global Temperature Change vs CO_2 Change



(a) Annual temperature trends, 1901 to 2000

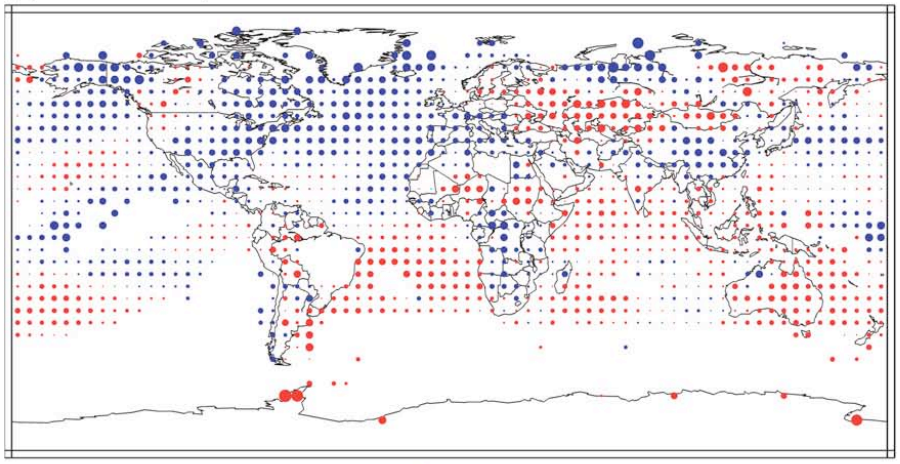
(b) Annual temperature trends, 1910 to 1945

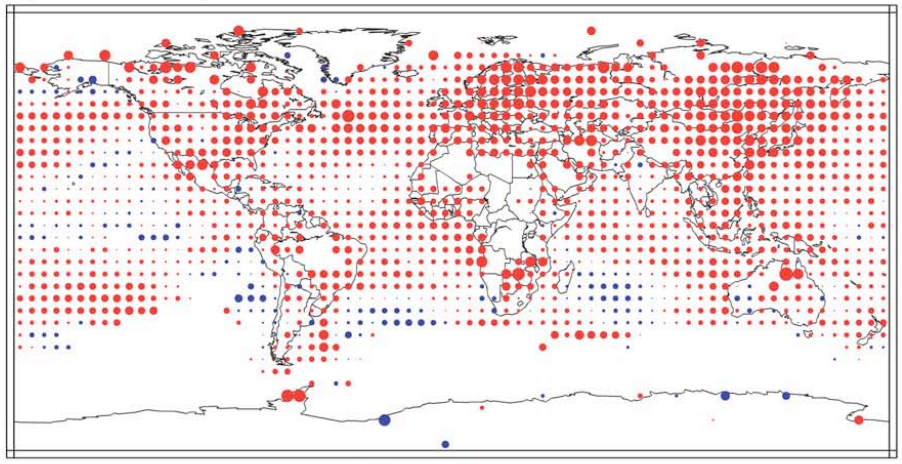


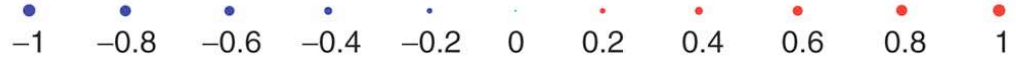


(c) Annual temperature trends, 1946 to 1975

(d) Annual temperature trends, 1976 to 2000

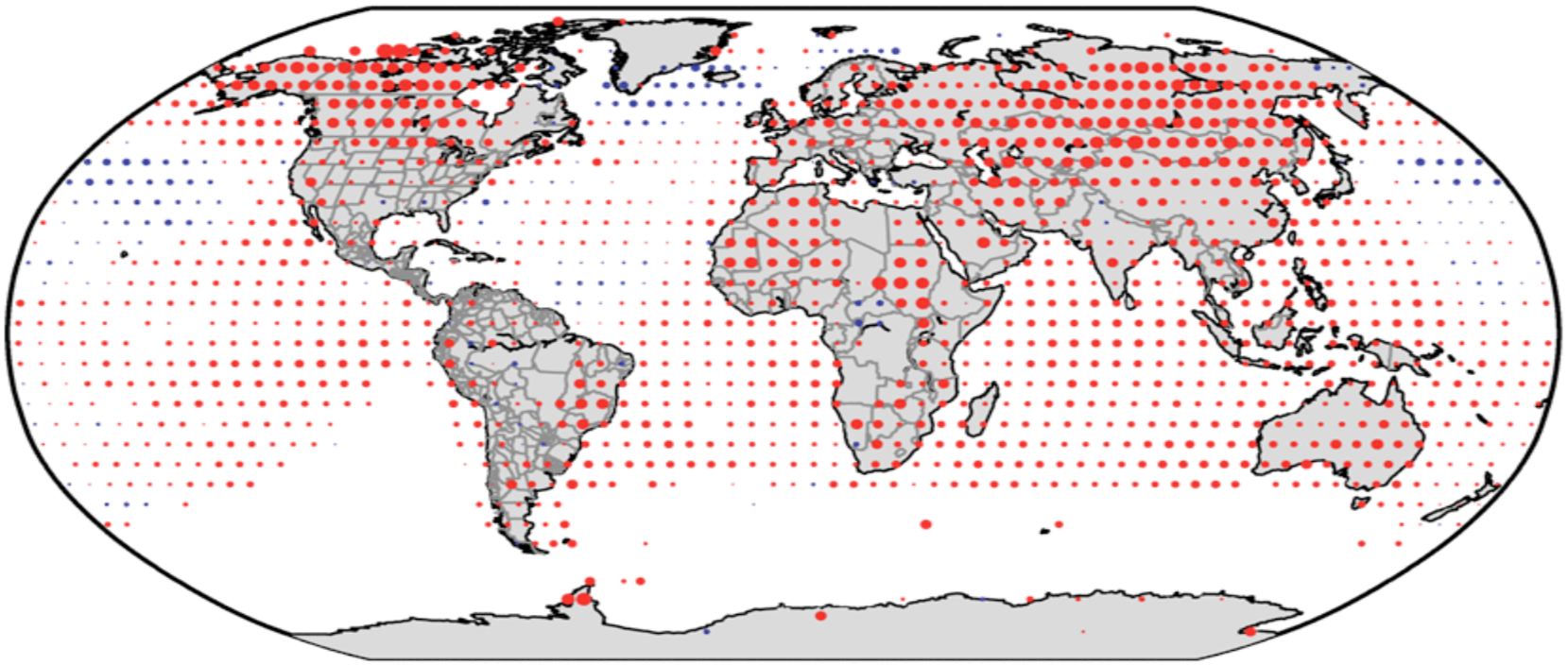






Trend (°C/decade)

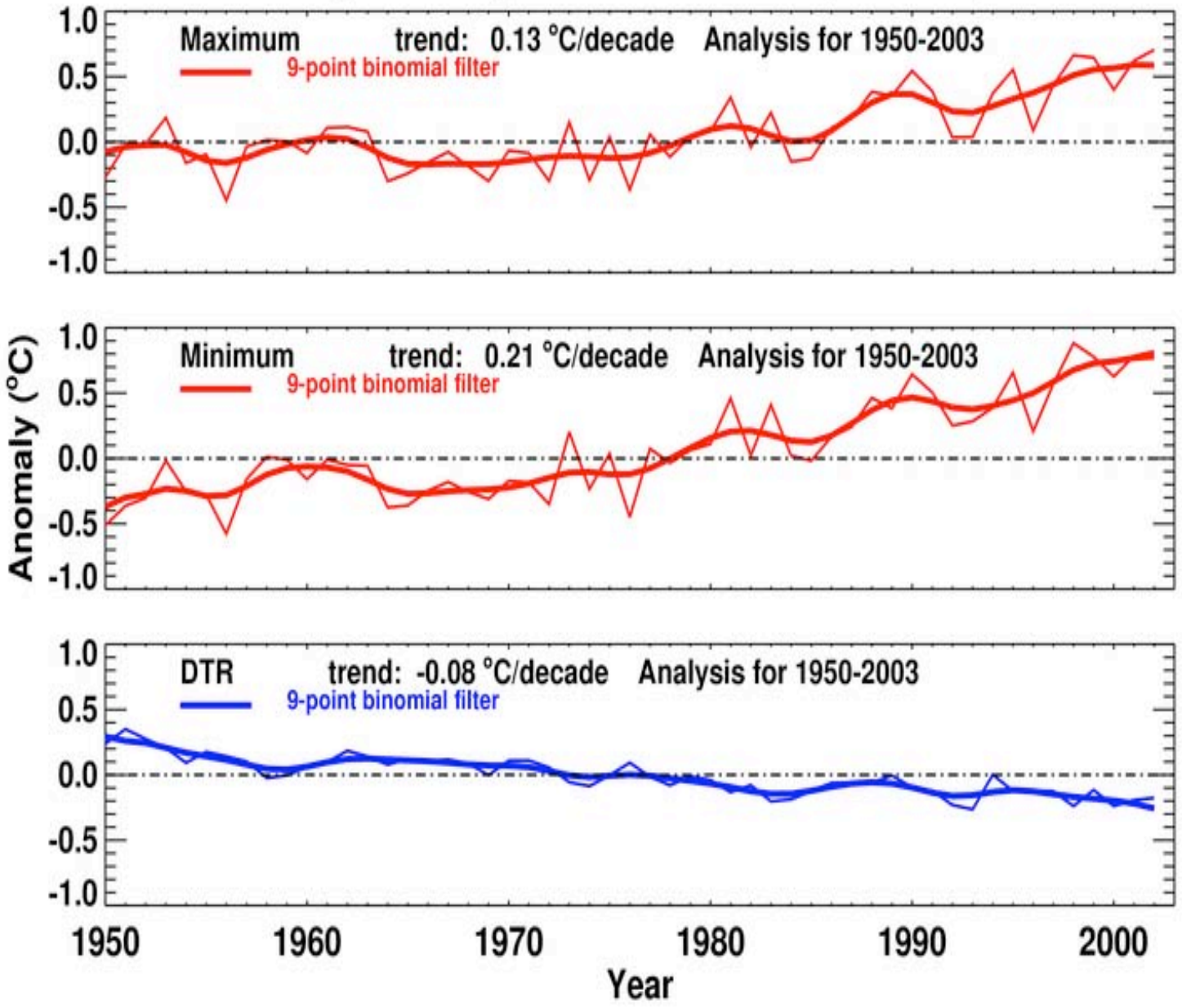
Annual Trends in Mean Temperature (1950-2002)



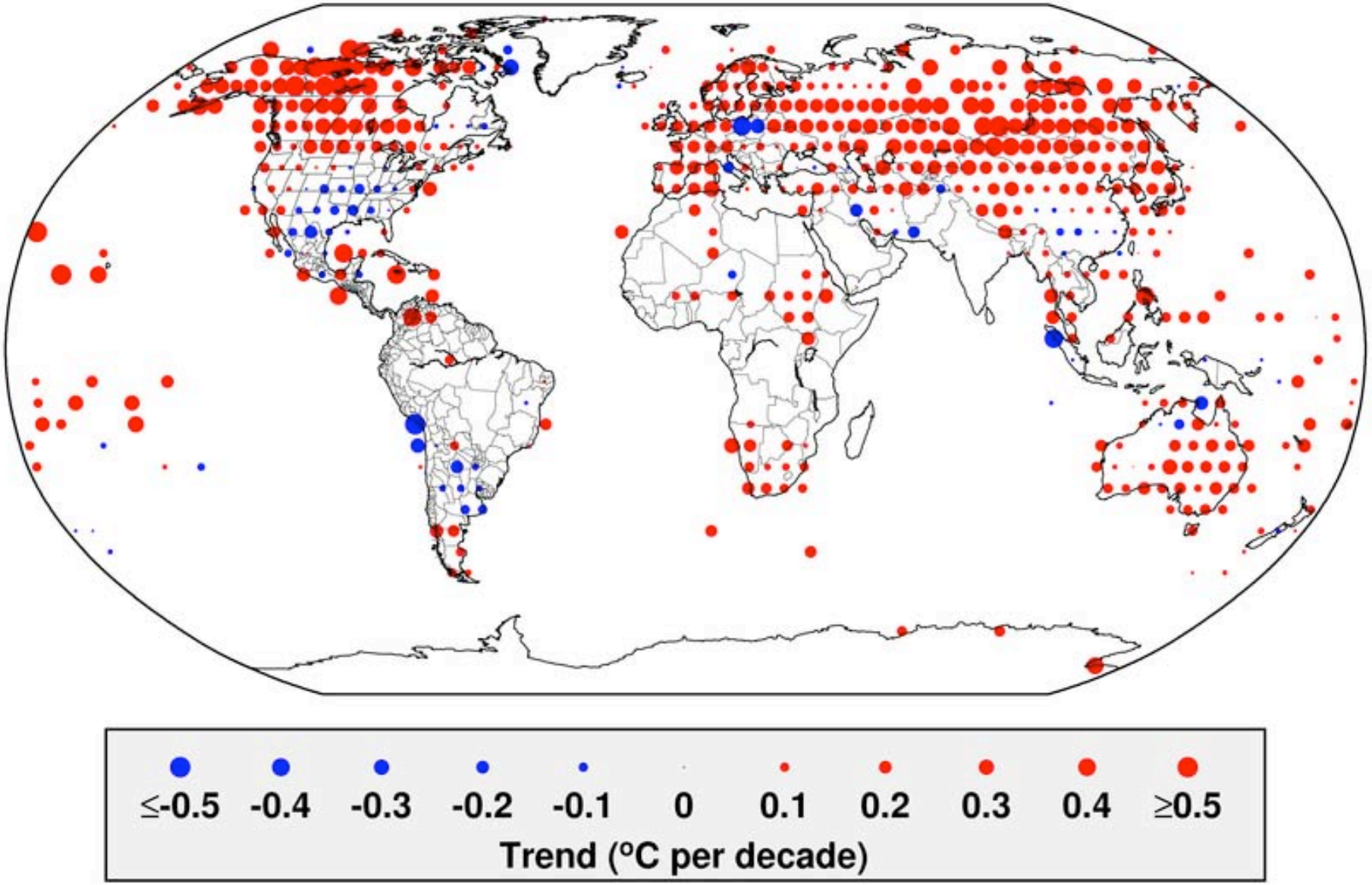
-0.10 -0.08 -0.06 -0.04 -0.02 0 0.02 0.04 0.06 0.08 0.10

Trend (°C/decade)

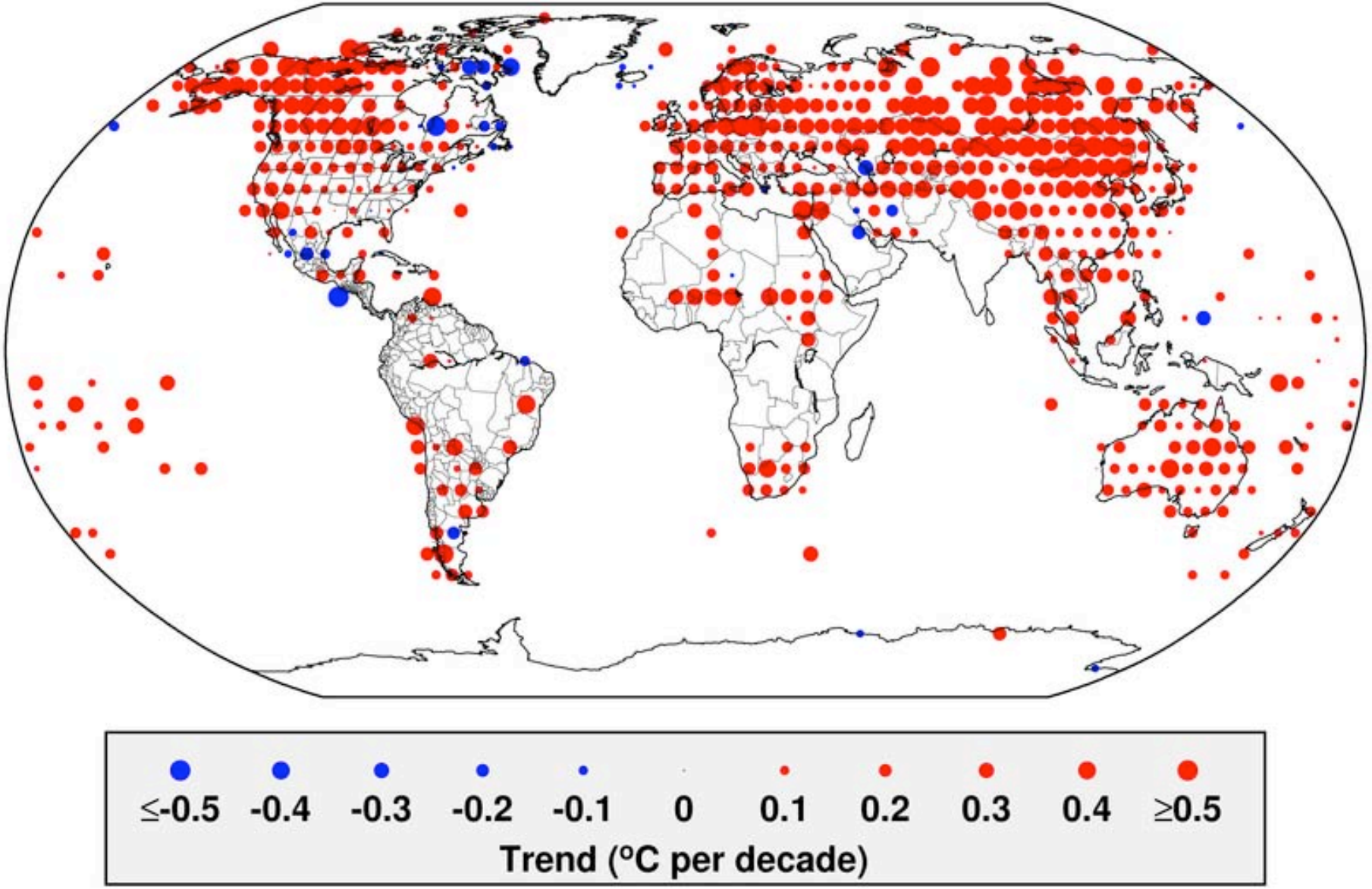
Globally Averaged Time Series (Annual)



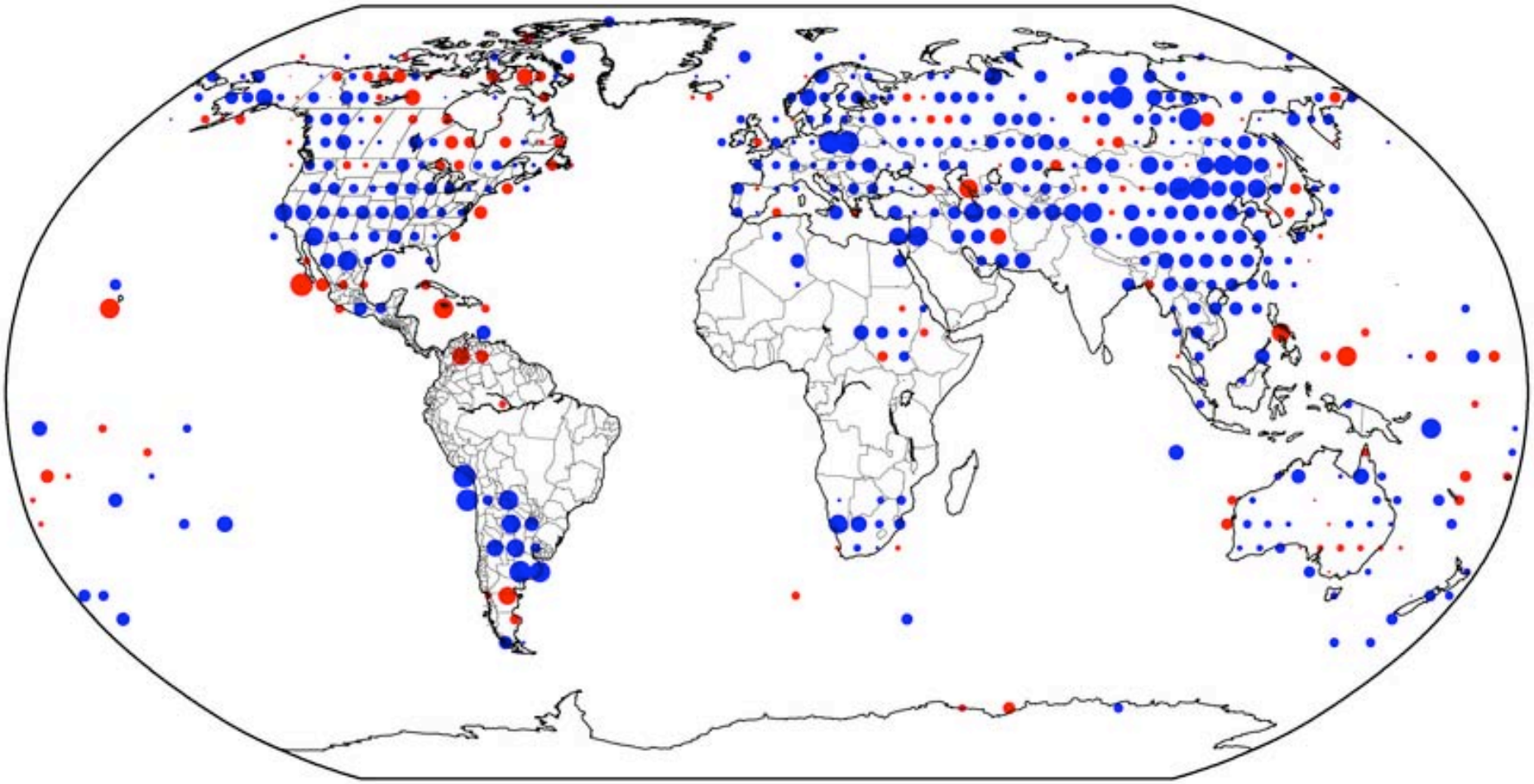
Annual Trends in Maximum Temperature Anomalies (1950-2003)



Annual Trends in Minimum Temperature Anomalies (1950-2003)



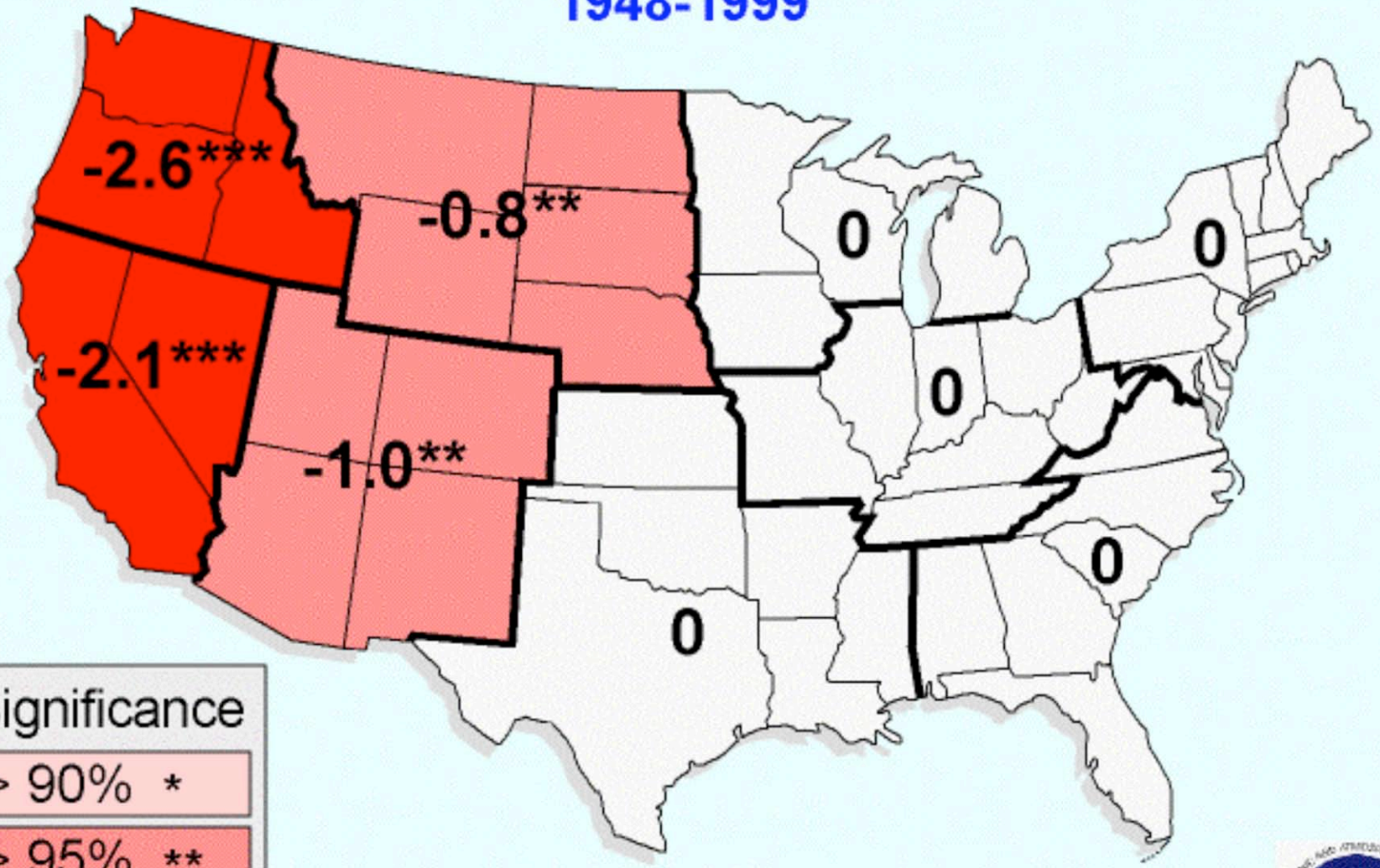
Annual Trends in DTR Anomalies (1950-2003)



≤-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 ≥0.5

Trend (°C per decade)

ANNUAL NUMBER OF FROST DAYS
TRENDS IN DAYS PER DECADE
1948-1999



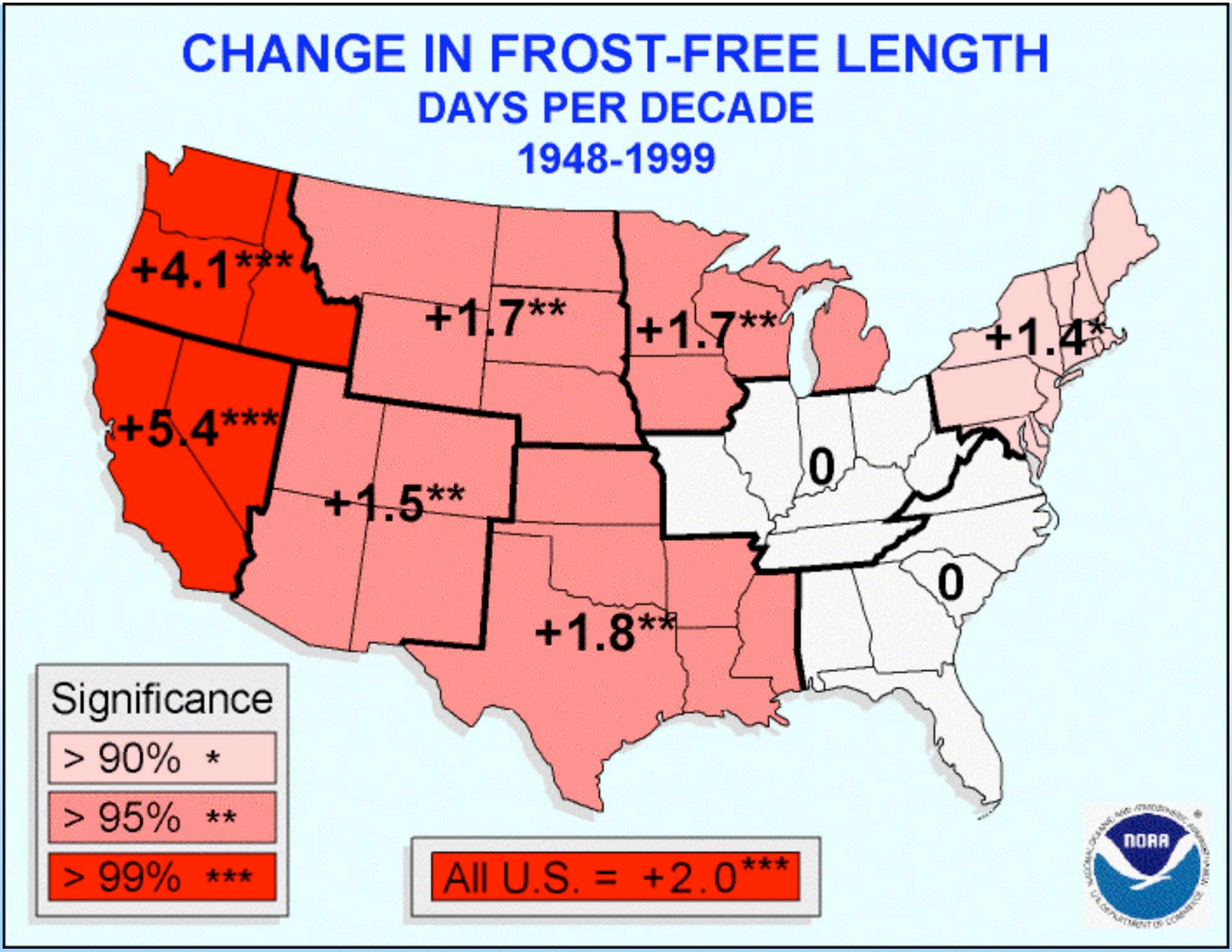
Significance

> 90% *

> 95% **

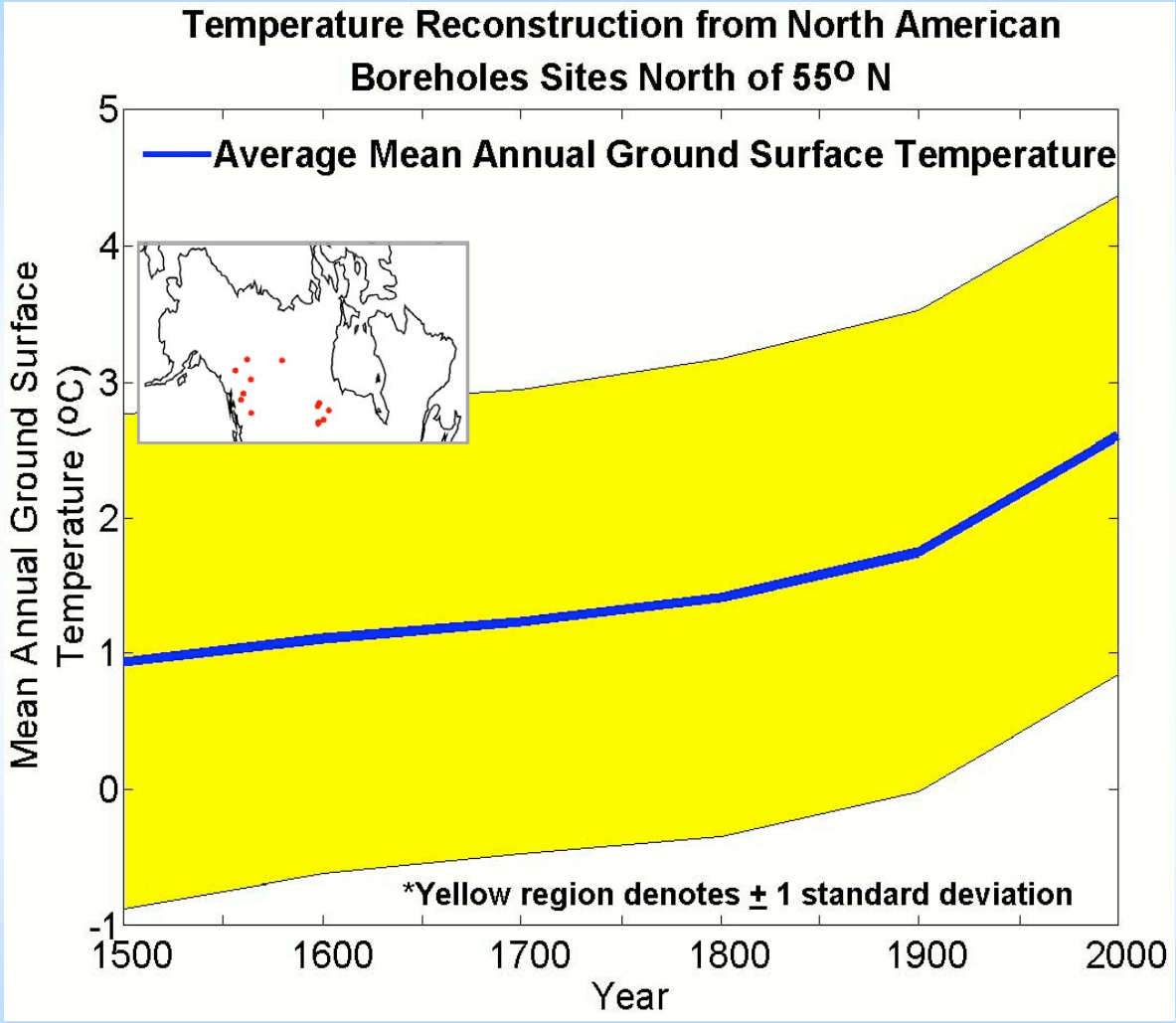
> 99% ***

All U.S. = -0.8**


CHANGE IN FROST-FREE LENGTH
DAYS PER DECADE
1948-1999
+4.1***
+1.7**
+1.7**
+1.4*
+5.4***
0
+1.5**
0
+1.8**
Significance
> 90% *
> 95% **
> 99% ***
All U.S. = +2.0***
NOAA

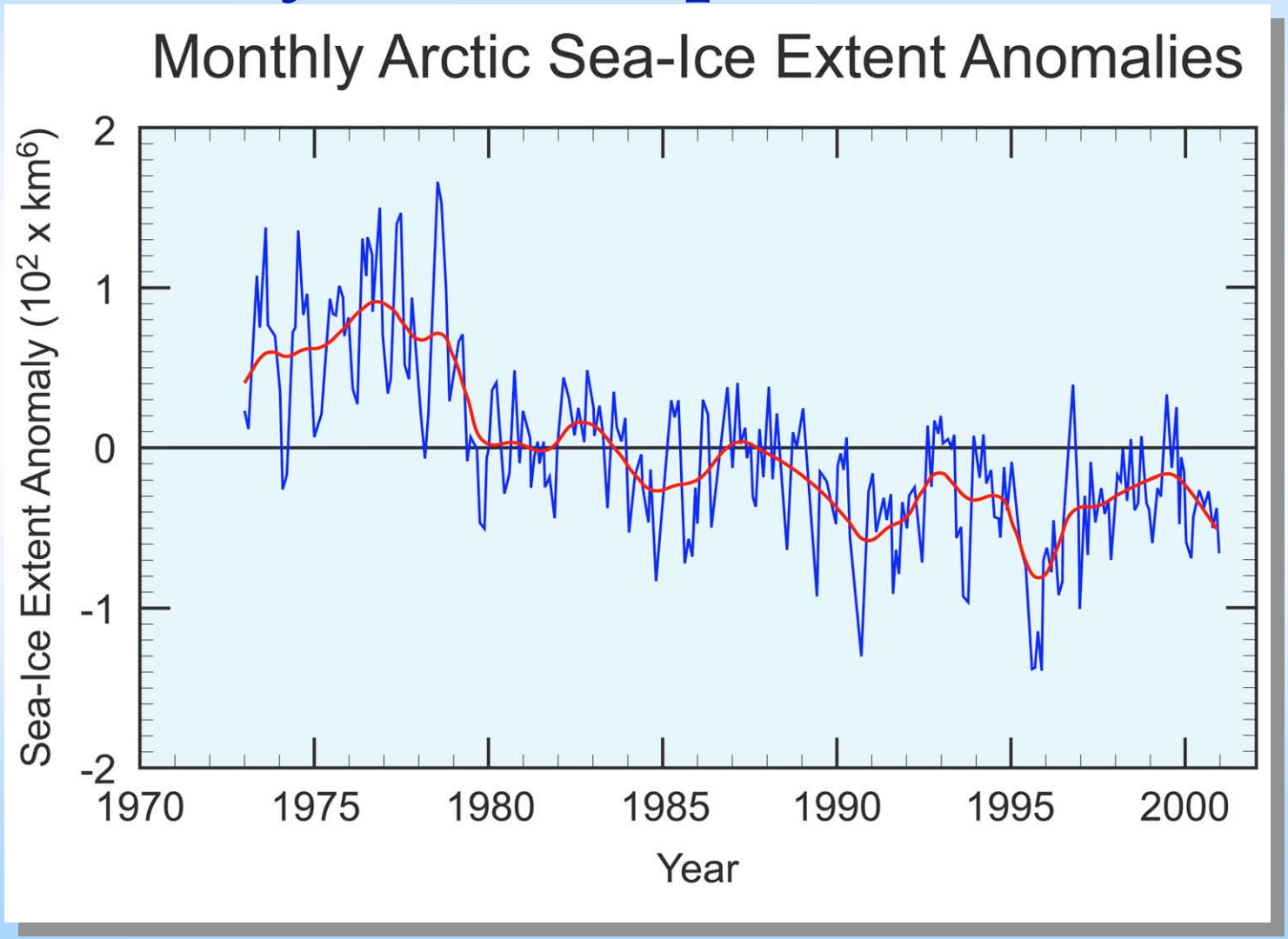
Past Climate From Borehole Records

- 16 borehole temperature records were averaged to create a temperature reconstruction for High Latitude North America
- 20th century temperatures show a major upturn relative to prior 4 centuries
- Temperatures rose at a rate of 1.5°F in the 20th Century

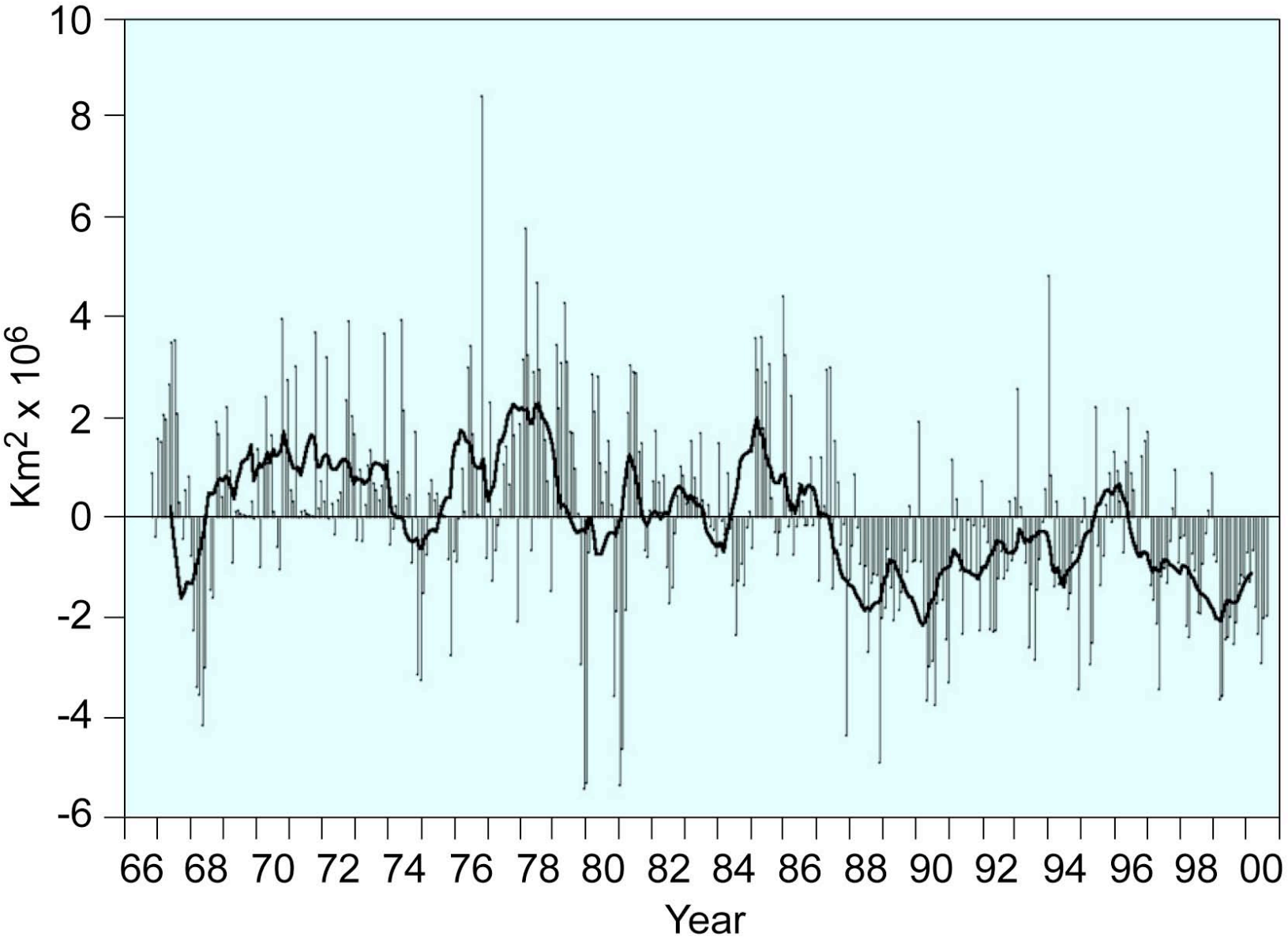


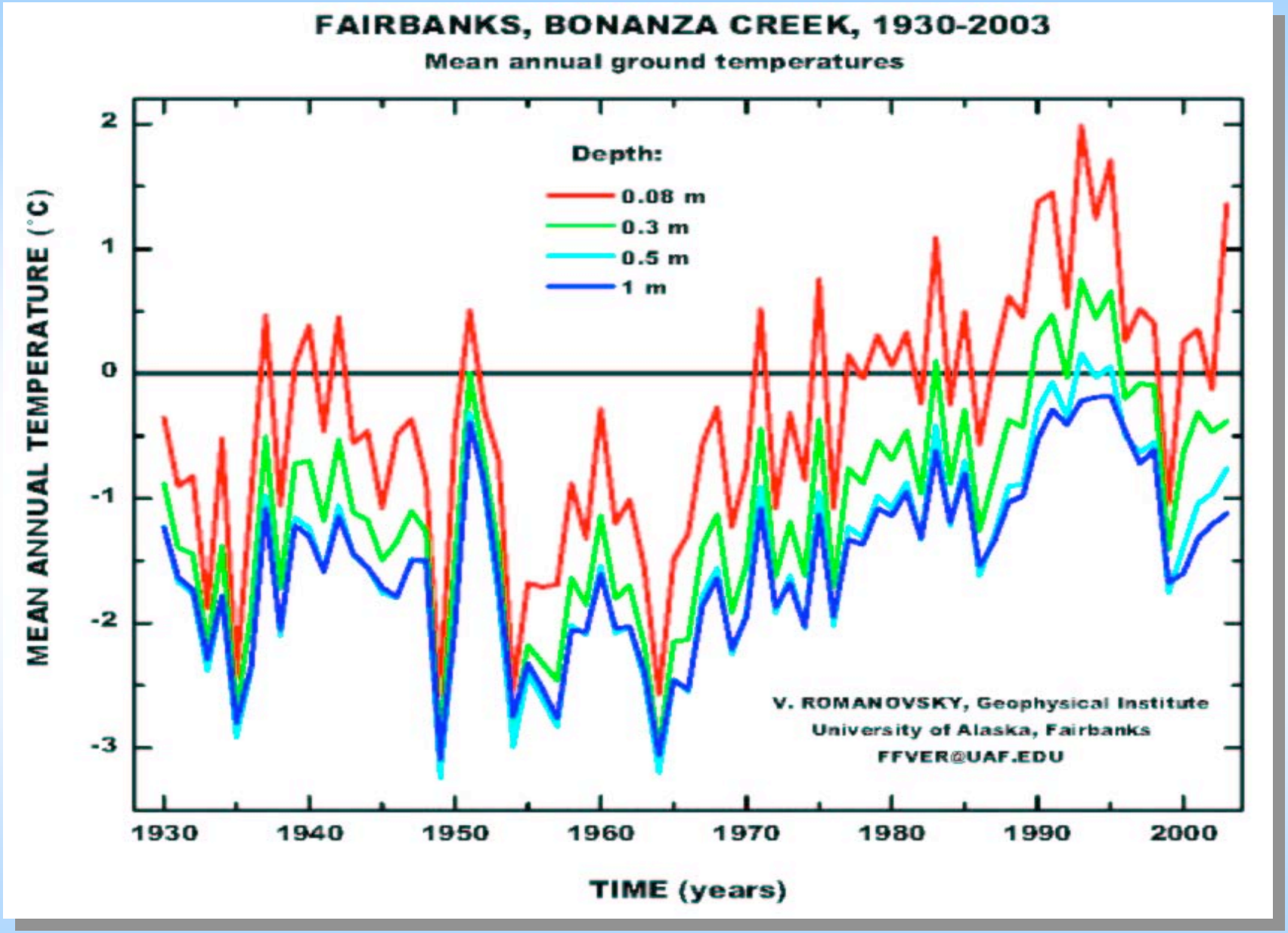
www.ngdc.noaa.gov/paleo

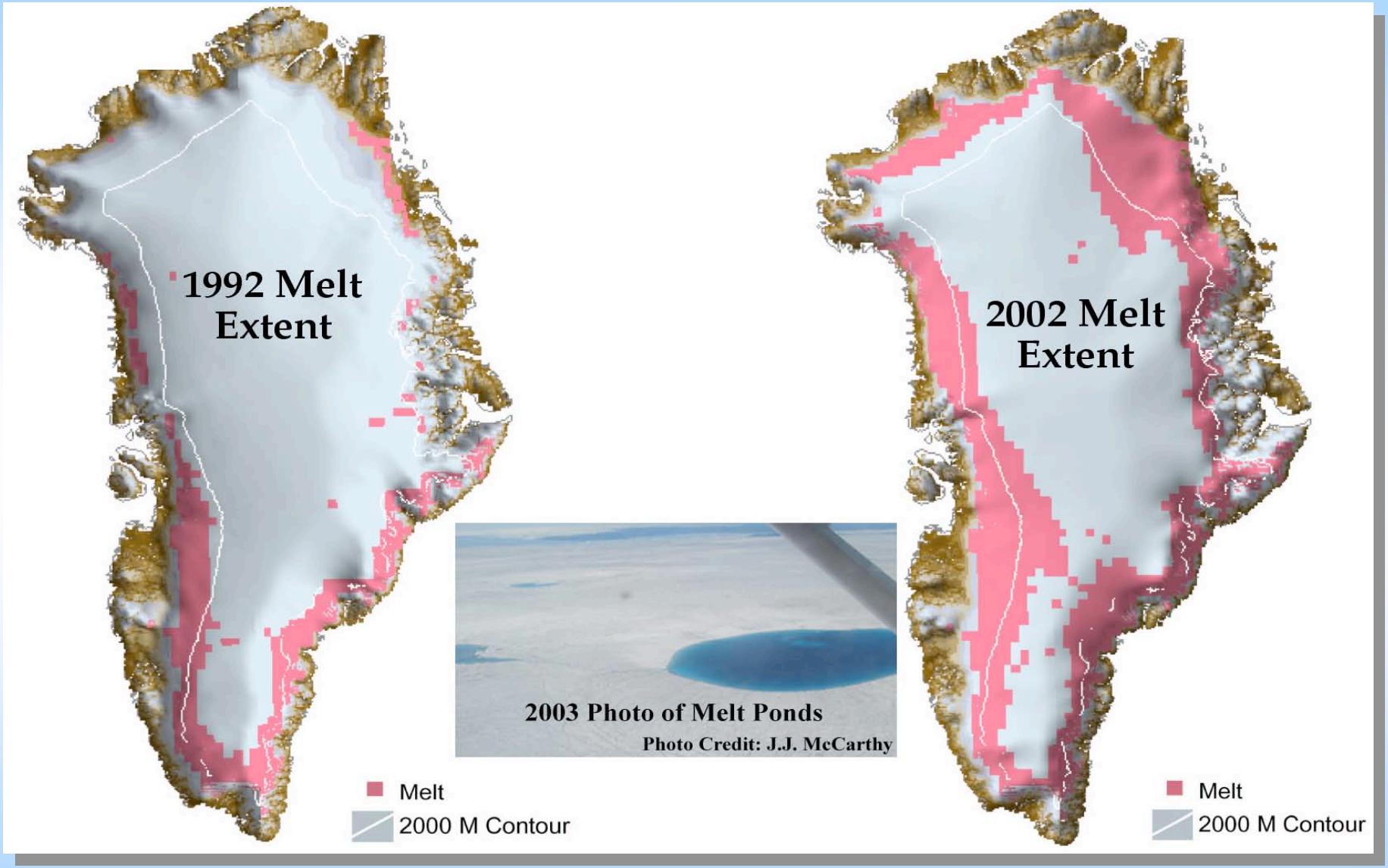
10-15% Decrease in Arctic sea ice revealed by NOAA operational satellites



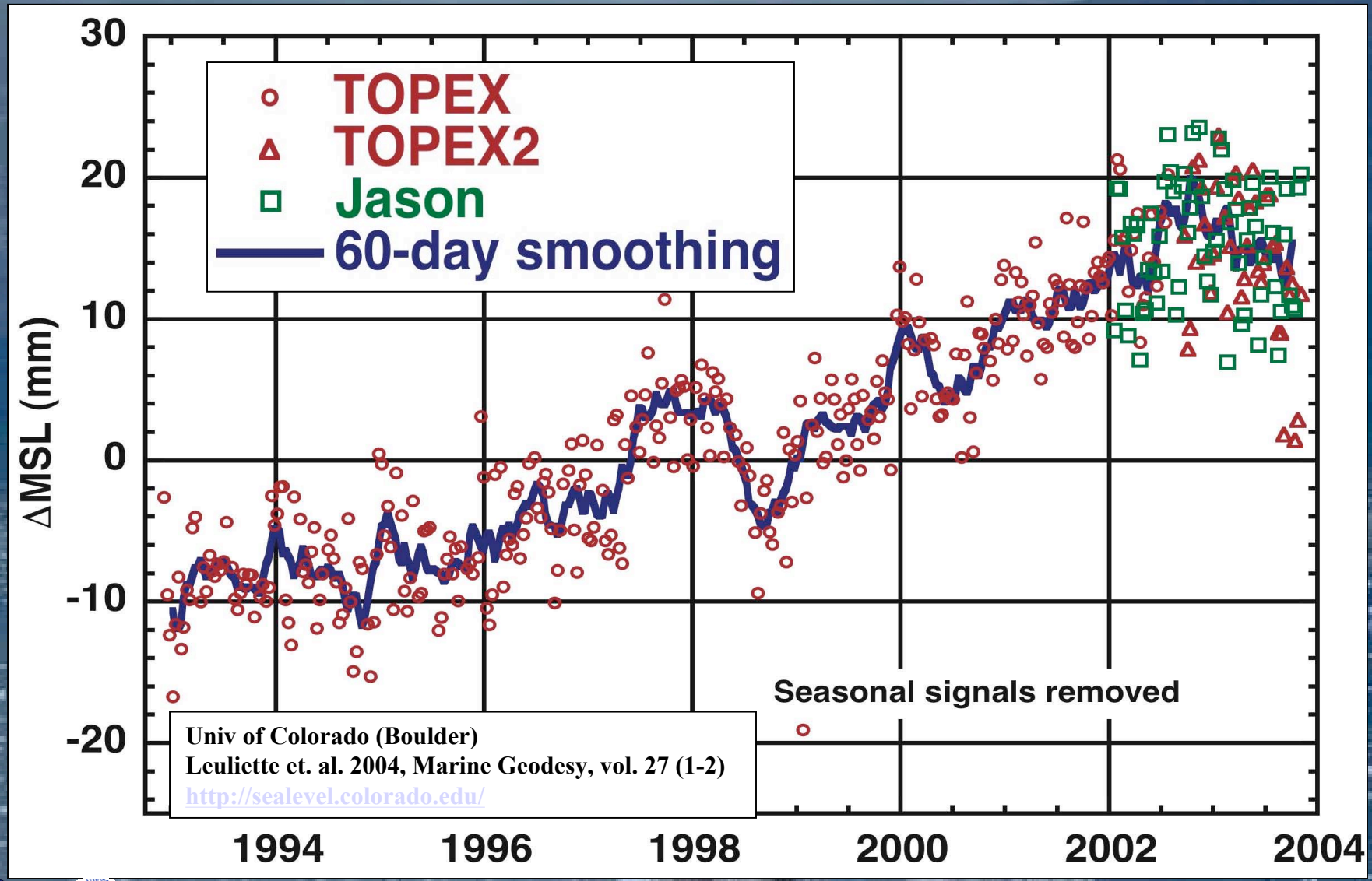
NH Snow Cover from NOAA Satellites

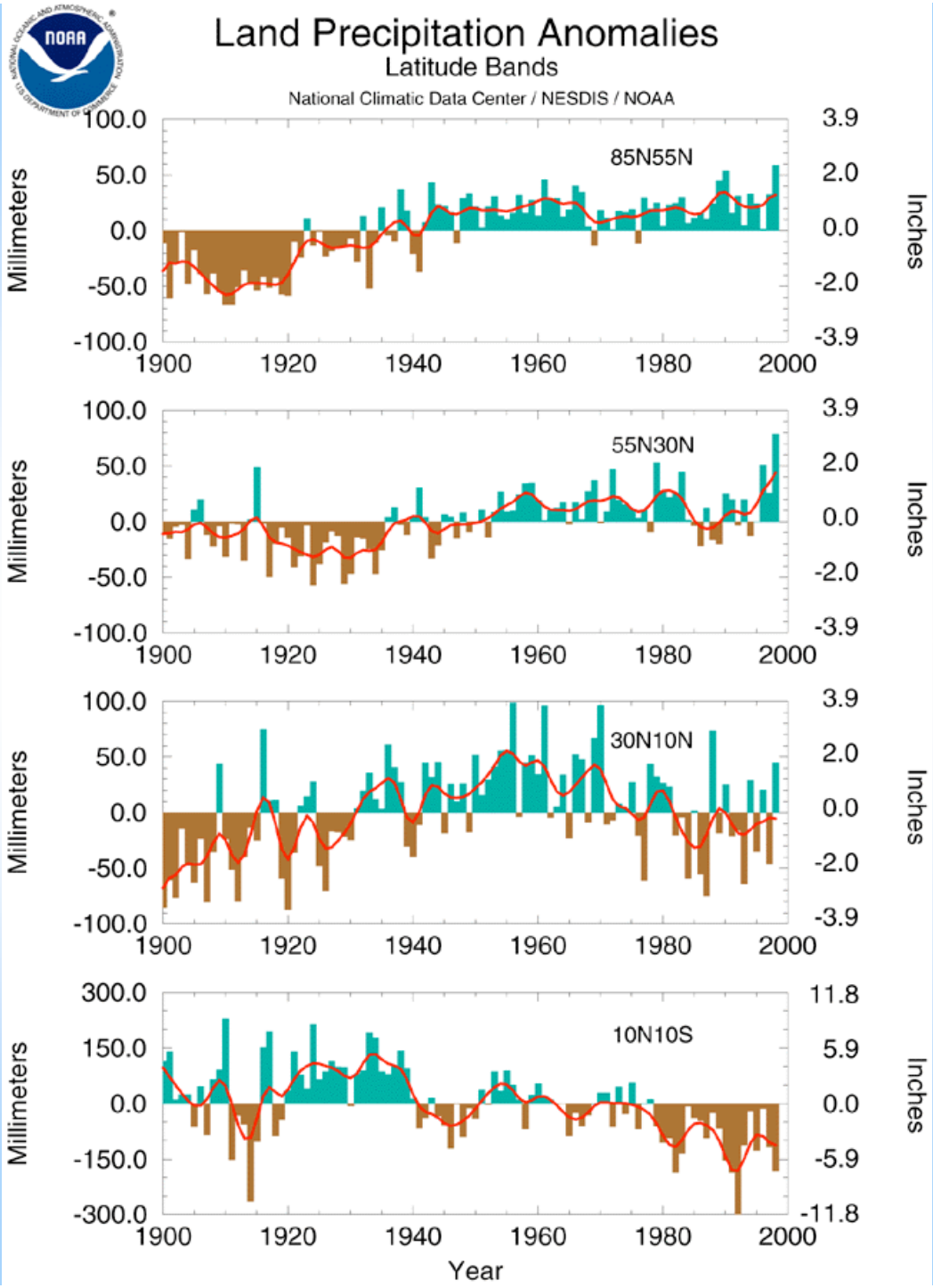



FAIRBANKS, BONANZA CREEK, 1930-2003
Mean annual ground temperatures
MEAN ANNUAL TEMPERATURE (°C)
2
1
0
-1
-2
-3
Depth:
0.08 m
0.3 m
0.5 m
1 m
V. ROMANOVSKY, Geophysical Institute
University of Alaska, Fairbanks
FFVER@UAF.EDU
1930
1940
1950
1960
1970
1980
1990
2000
TIME (years)


1992 Melt Extent
2002 Melt Extent
2003 Photo of Melt Ponds
Photo Credit: J.J. McCarthy
Melt
2000 M Contour
Melt
2000 M Contour

Global Sea Level Changes

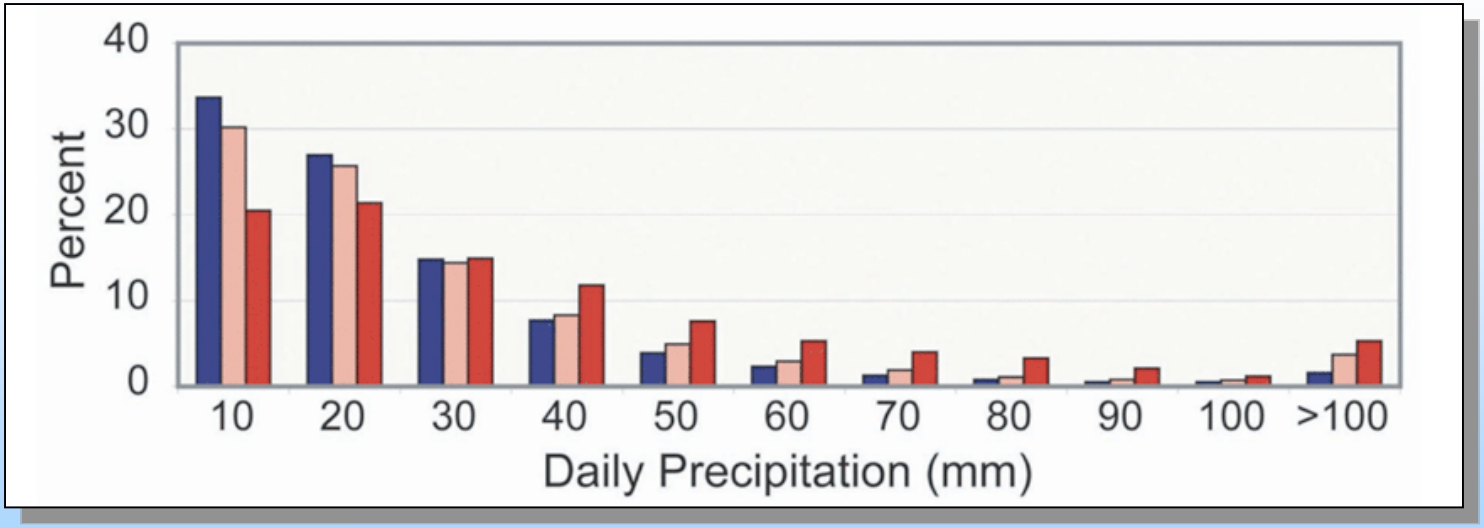



Land Precipitation Anomalies
Latitude Bands
National Climatic Data Center / NESDIS / NOAA
85N55N
55N30N
30N10N
10N10S
Millimeters
Inches
100.0
50.0
0.0
-50.0
-100.0
3.9
2.0
0.0
-2.0
-3.9
300.0
150.0
0.0
-150.0
-300.0
11.8
5.9
0.0
-5.9
-11.8
1900
1920
1940
1960
1980
2000
Year

Changes in the Hydrologic Cycle

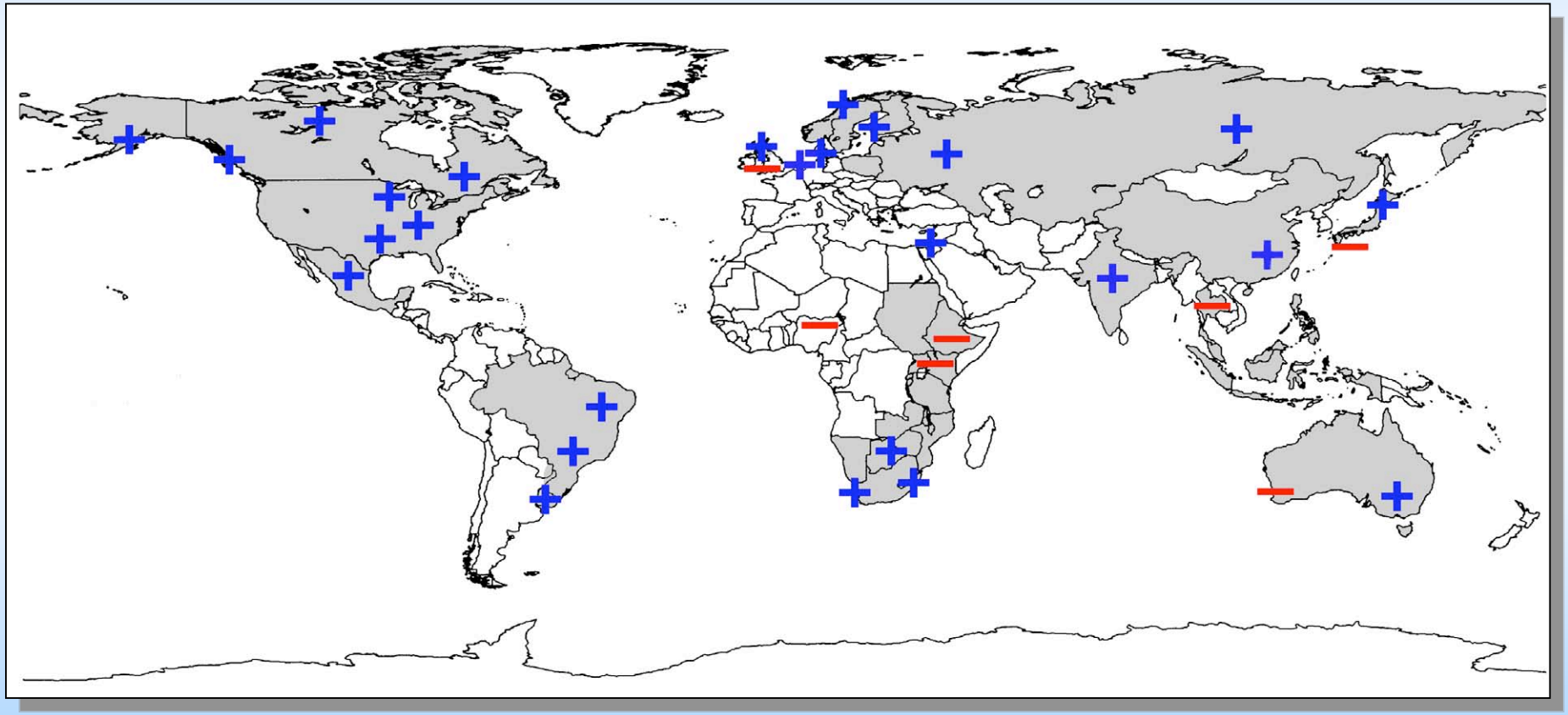
- **Global heating - - - accelerated land surface drying and more water in the atmosphere**
  - Increased severity of droughts
  - Increased risk of heavy and extreme precipitation events
    - Even with no change in total precipitation
    - Even stronger when precipitation increases

Observed climatology of daily precipitation Intensity (as a percentage of seasonal totals) as a function of observed mean temperature based on 100 worldwide stations



Regions where disproportionate changes in heavy and very heavy precipitation occurred compared to the mean

(first half of 20th century to present)



Abrupt Climate Change

- What is it?

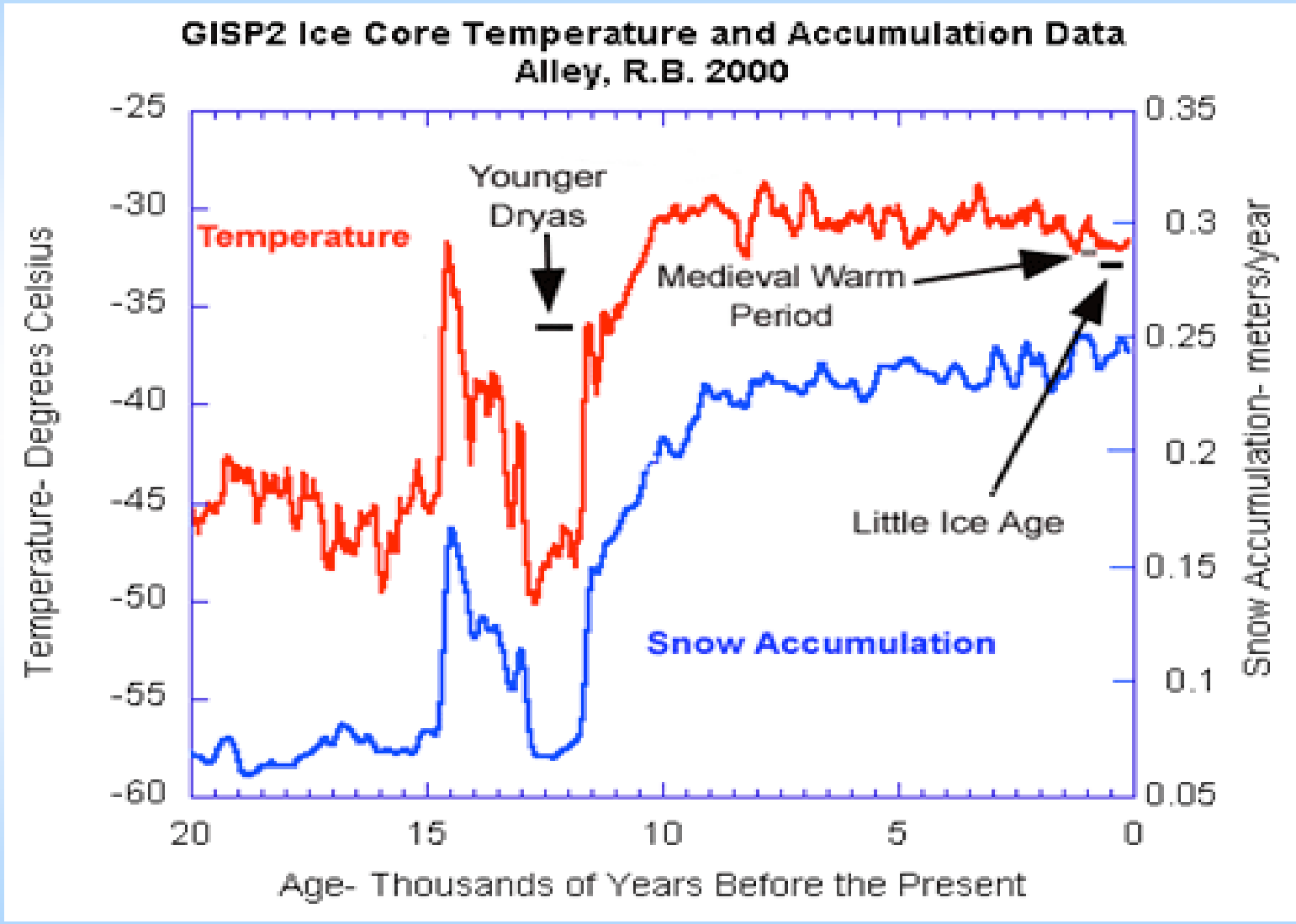
Mechanistic definition

– Transition of the climate system into a different state (of temperature, rainfall, and other aspects) on a time scale that is faster than the responsible forcing.

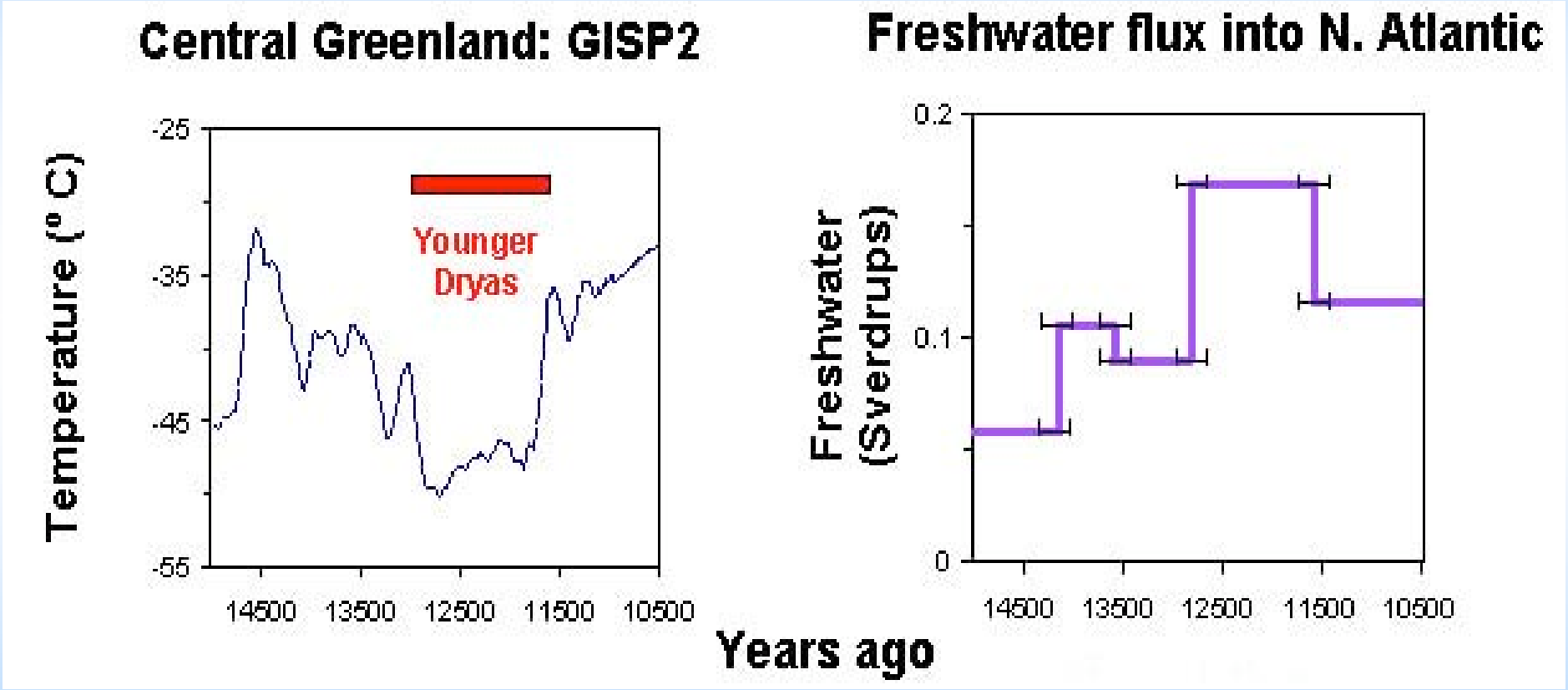
Impacts based definition

– Change of the climate system that is faster than the adaptation time of social and/or ecosystems.

Abrupt Climate Change



Abrupt Climate Change



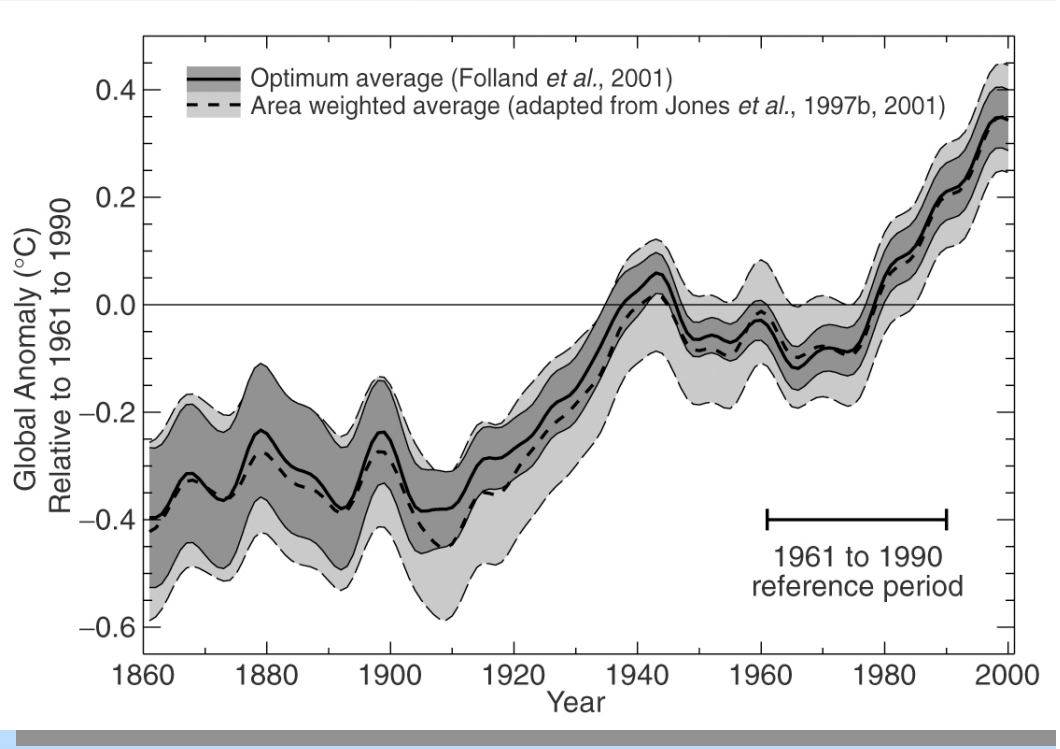
How significant are the uncertainties?

✓ State and Forcings Variables

- Few have quantitative confidence intervals (CIs) (including time-dependent biases) e.g., global surface temperature, CO_2
- Most CIs do not include time-dependent biases
- For many, CIs are uncertain or unknown

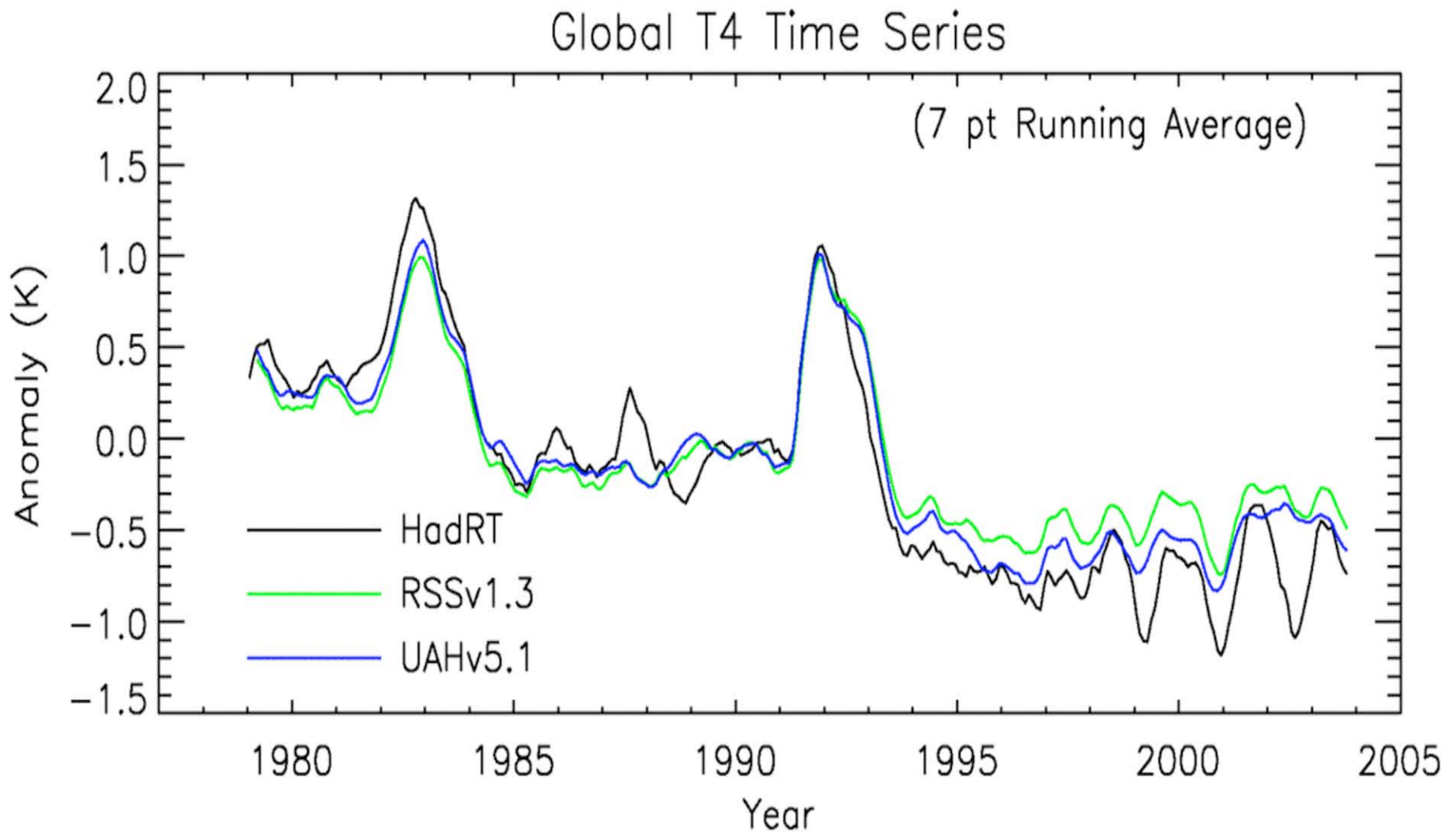
✓ Why?

- Examples provide numerous insights into observing and data system deficiencies

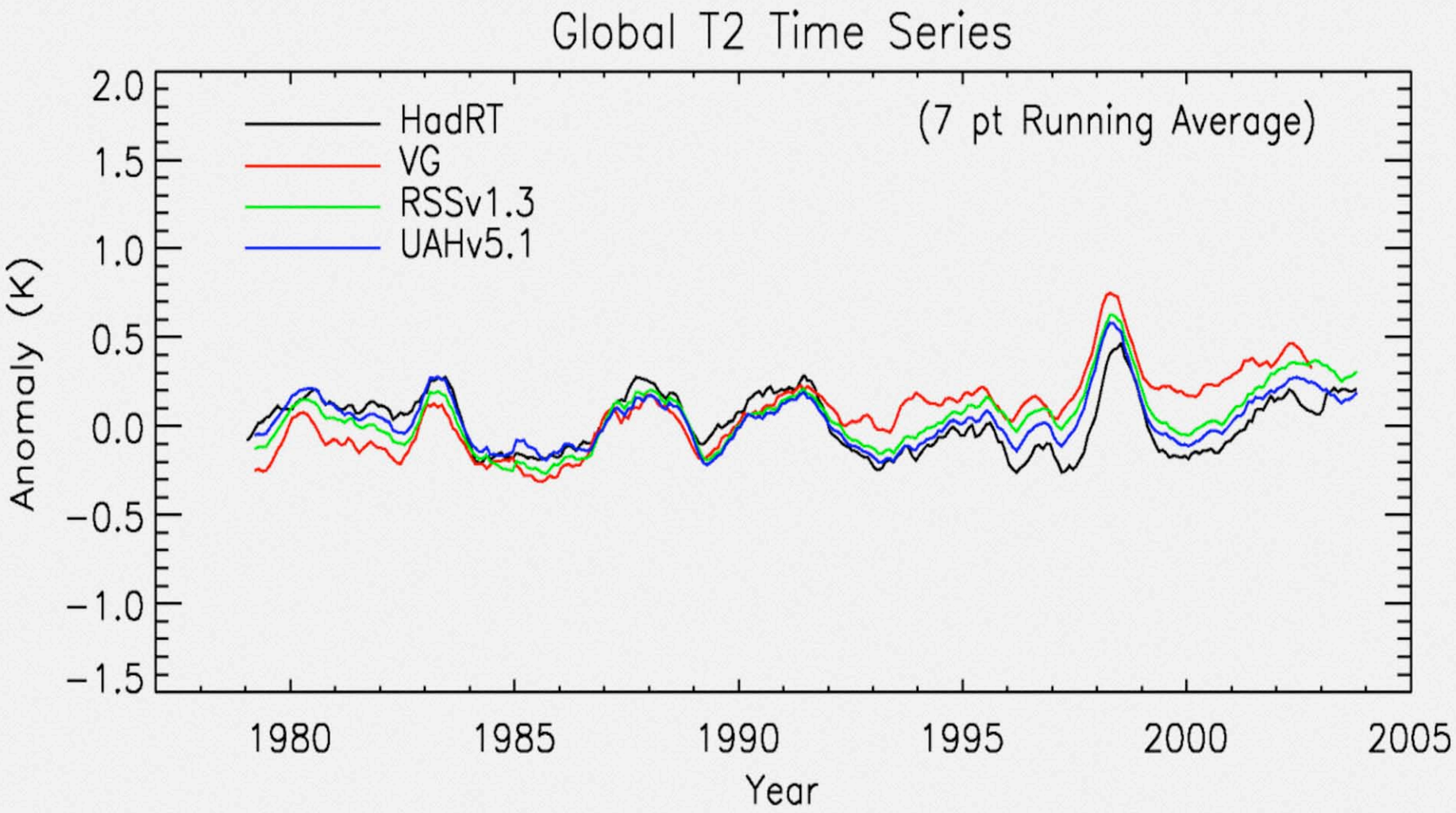


Smoothed annual anomalies of global combined land-surface air and sea surface temperatures (°C).

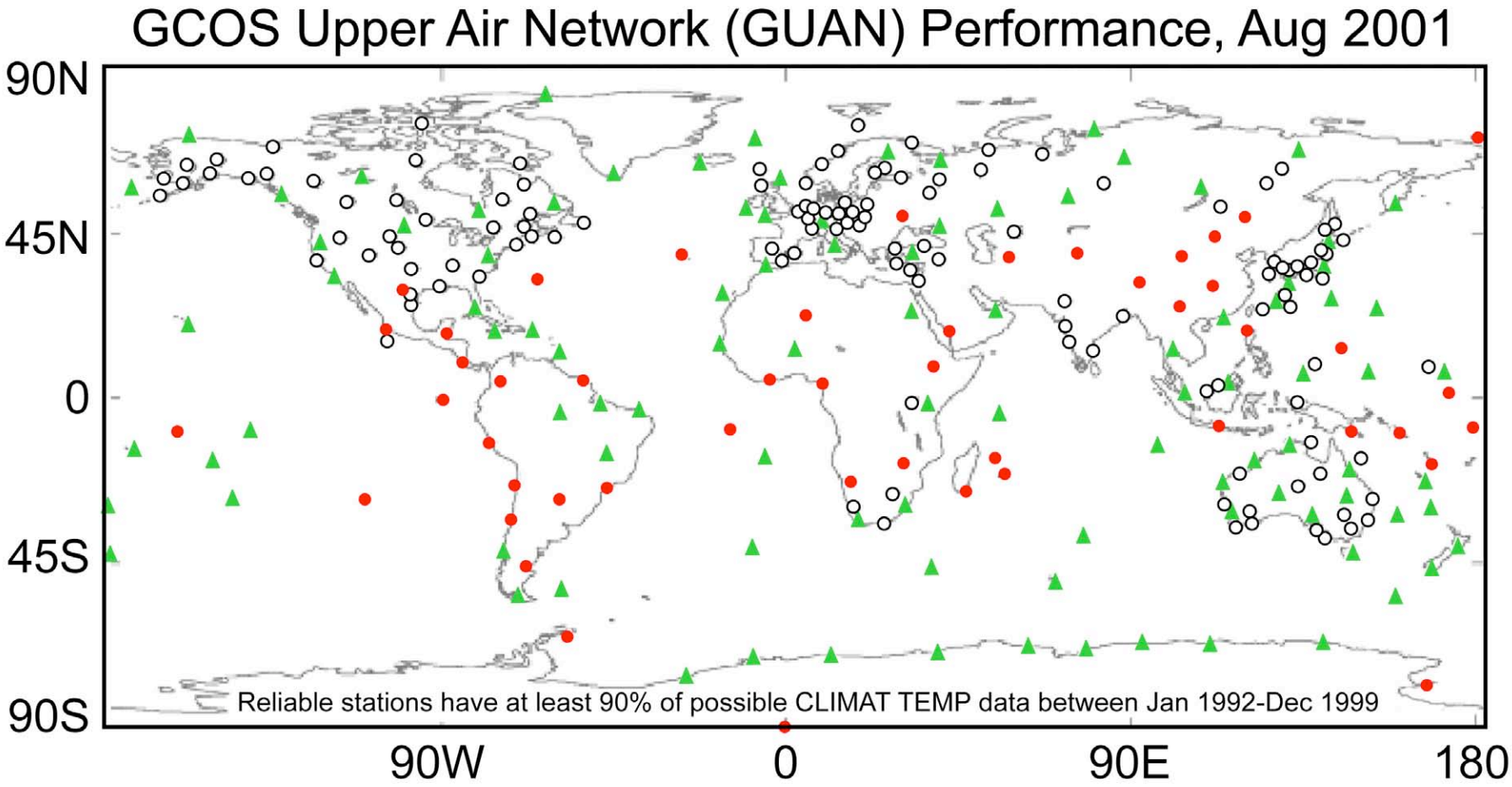
Current Stratospheric Temperatures: from satellites and weather balloons.



Current Tropospheric Temperatures: from satellites and weather balloons.



Observing and Data System Deficiencies



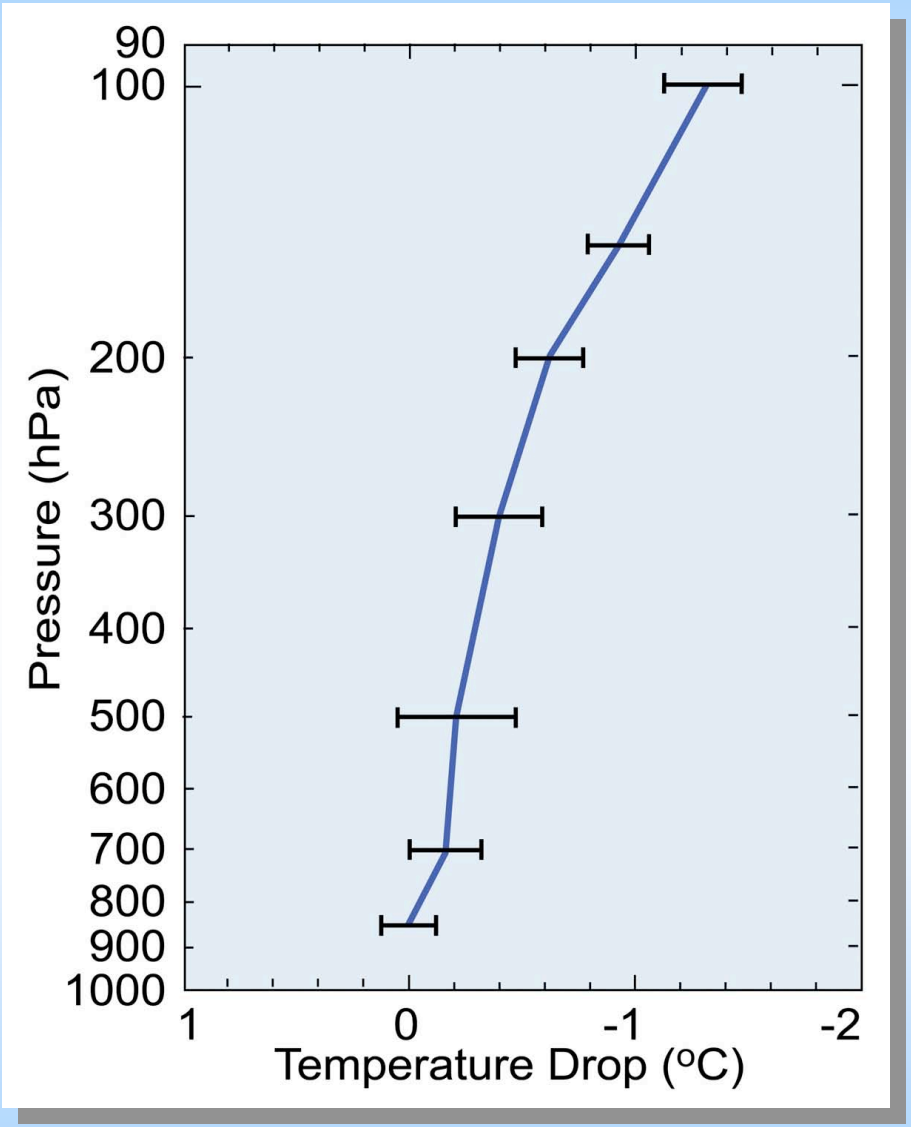
GREEN ▲ GUAN station, CLIMAT TEMP report received (98)

RED • Unreliable GUAN station, no report received (49)

BLACK ○ Reliable non-GUAN station, CLIMAT TEMP report received (144)

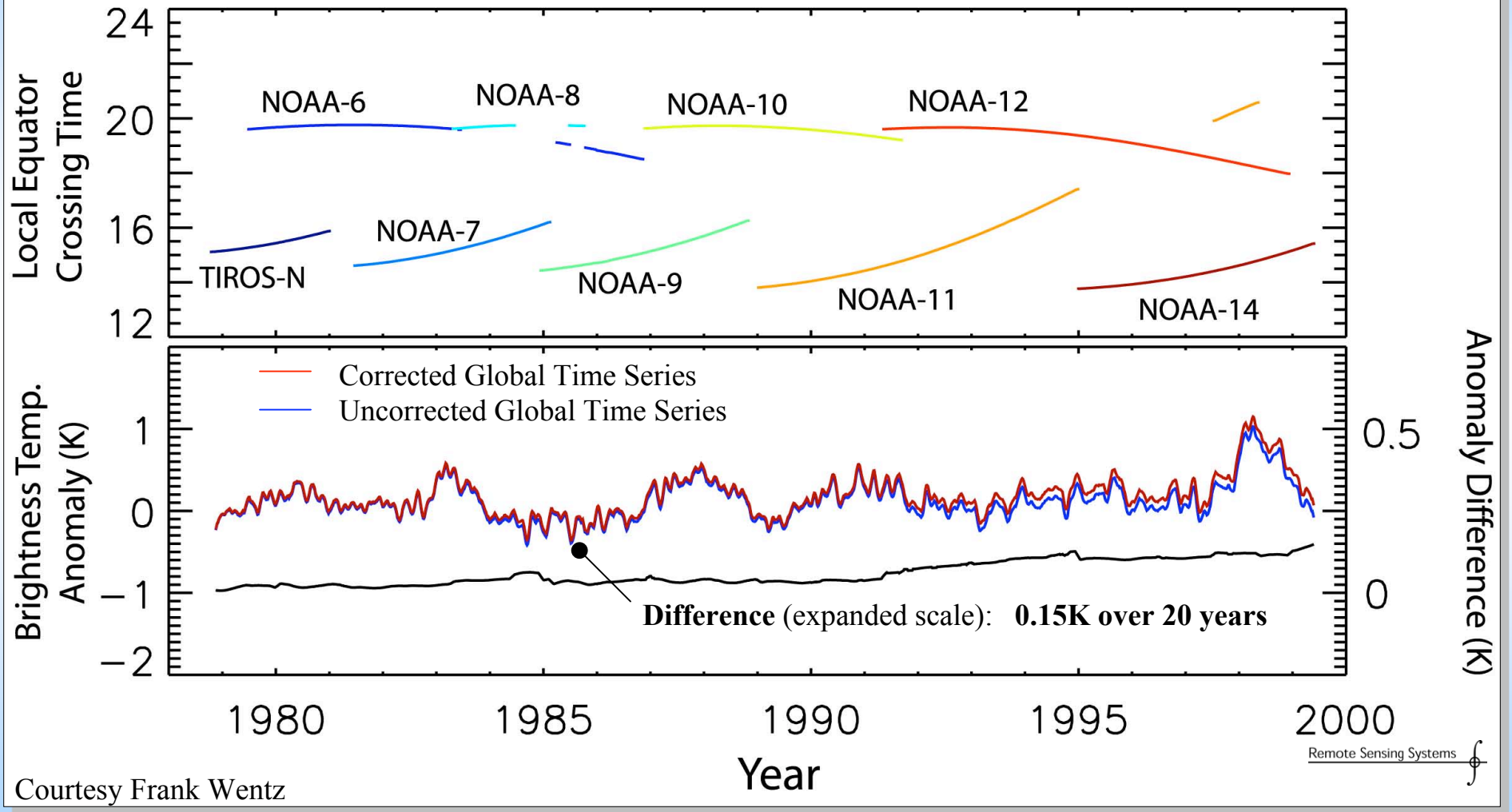
Observing and Data System Deficiencies

✓ Effect of lengthening radiosonde cords at 13 Japanese stations in 1968
Source: (Gaffen, JGR, 1994)



Observing and Data System Deficiencies

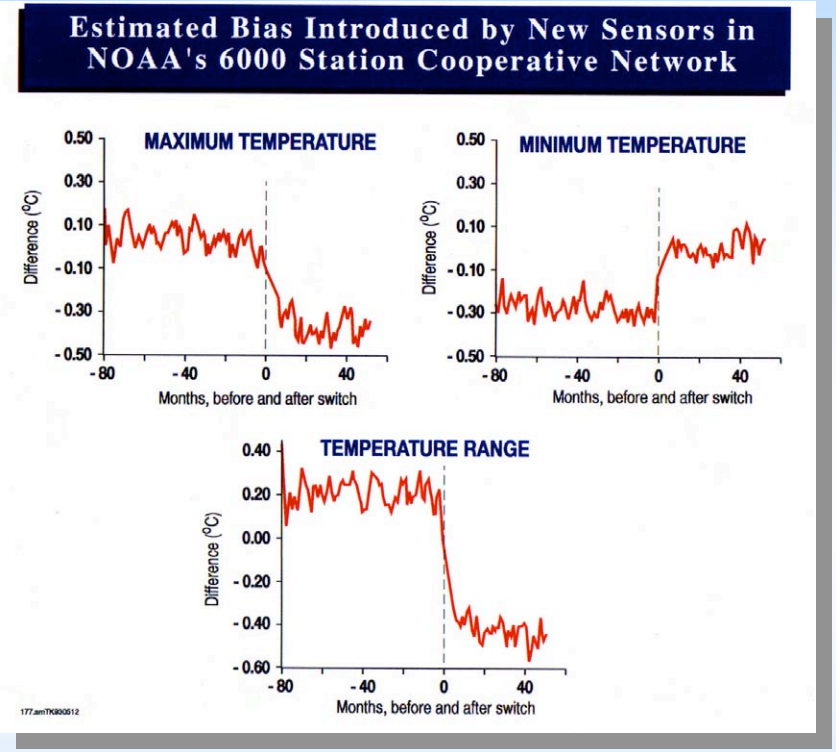
Changing local observation time leads to aliasing of diurnal signal into long term trends

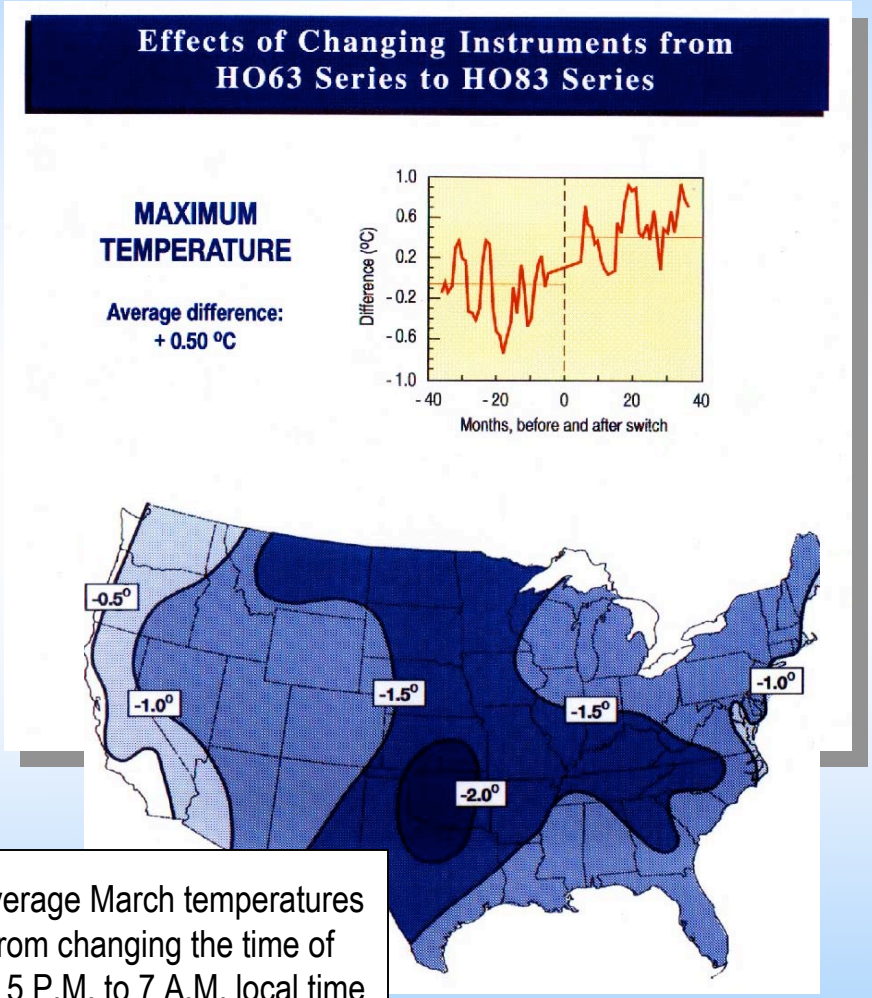


Courtesy Frank Wentz

Observing and Data System Deficiencies

✓ Issues with Surface-based observations



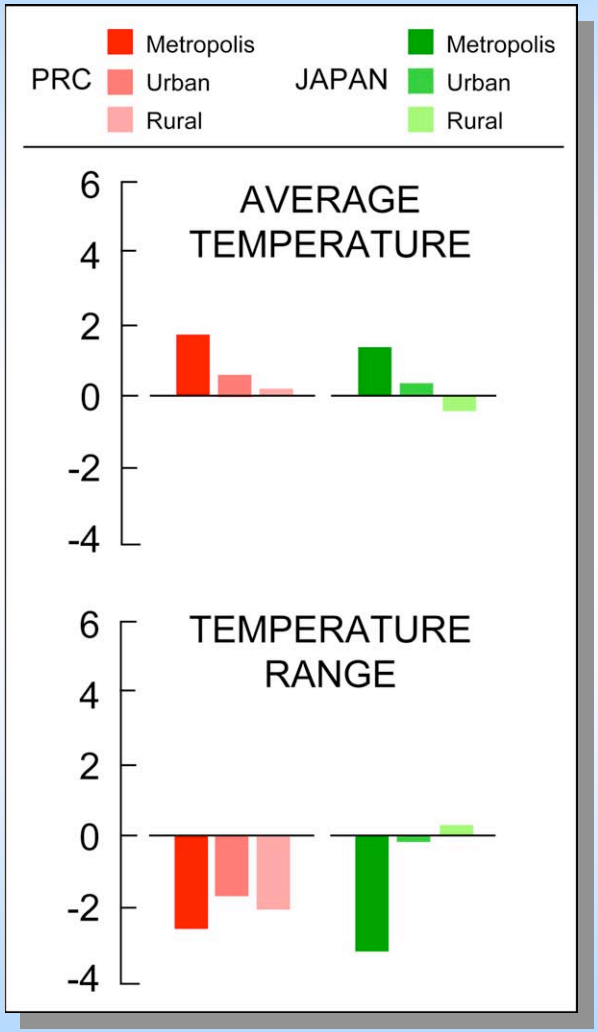


✓ Most observations taken for other purposes, e.g., weather forecasting

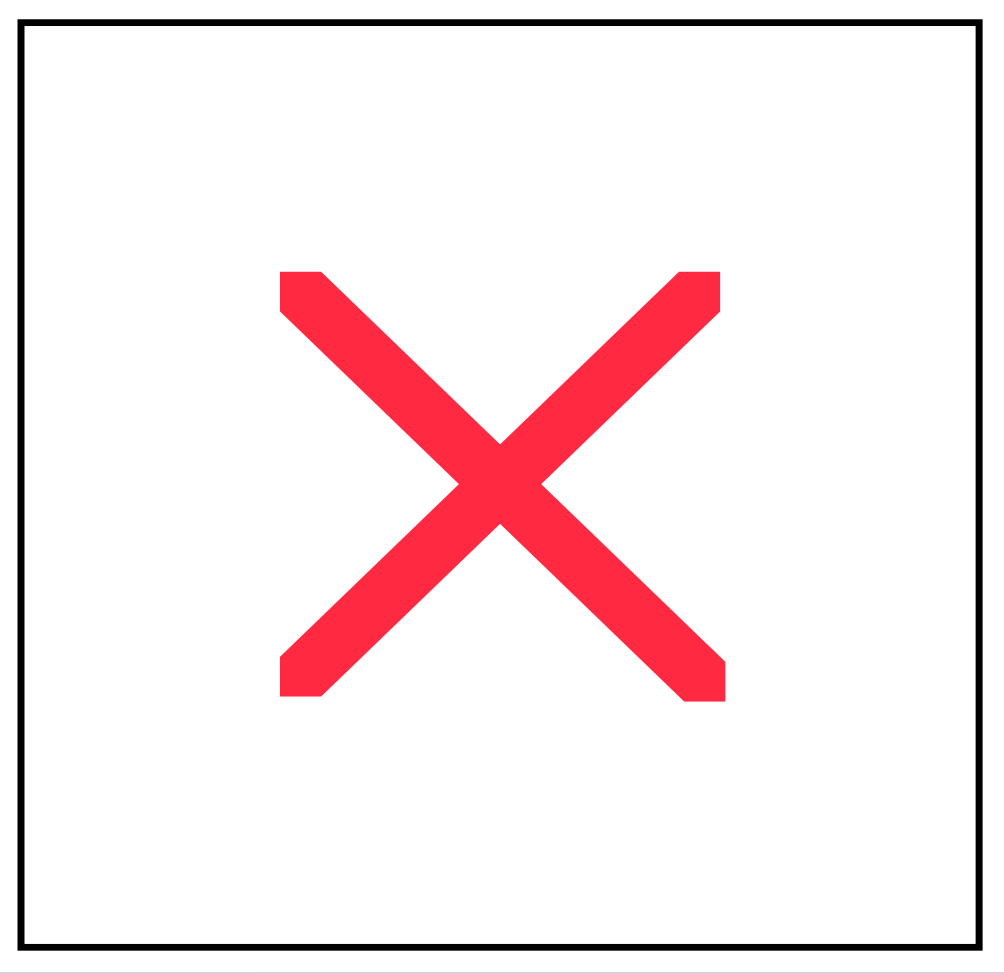
Change in the average March temperatures (°C) resulting from changing the time of observation from 5 P.M. to 7 A.M. local time

Observing and Data System Deficiencies

✓ Urban Heat Island Effects

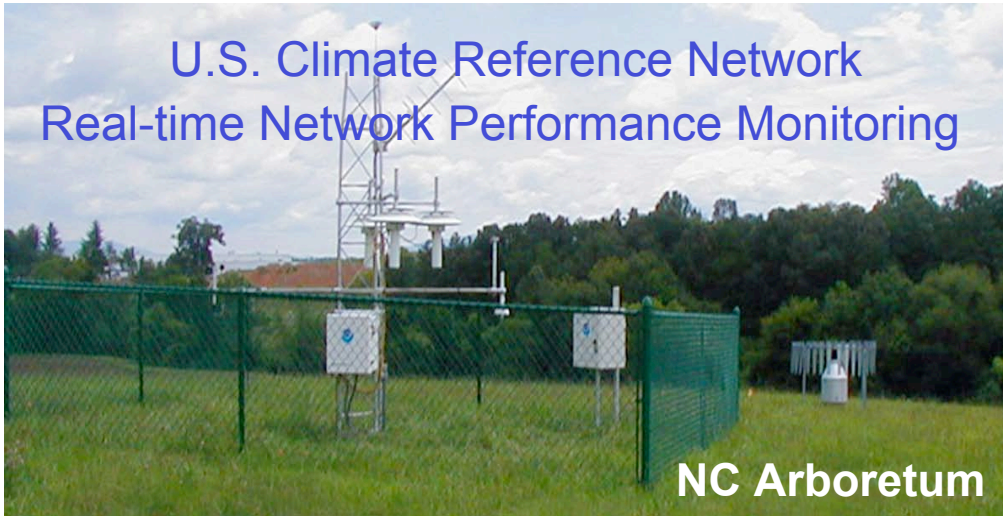


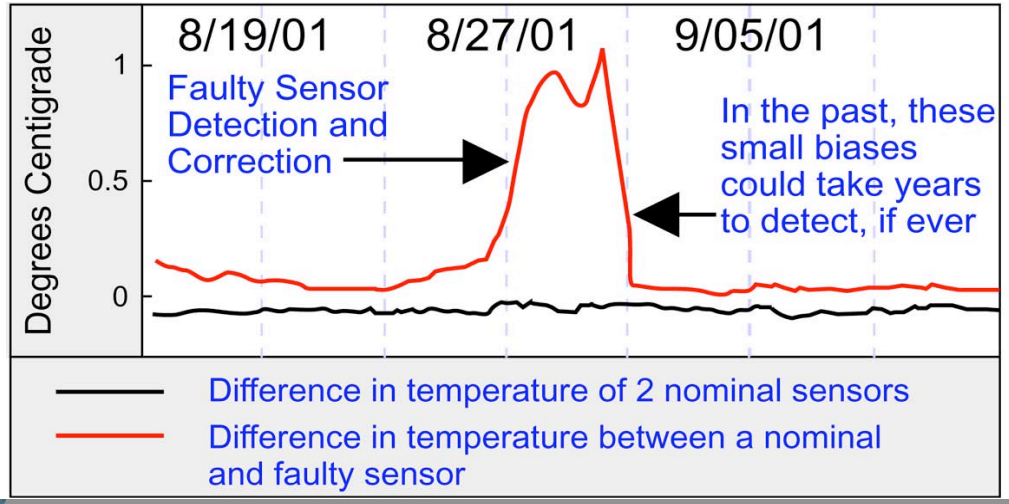
✓ Land use vs temperature



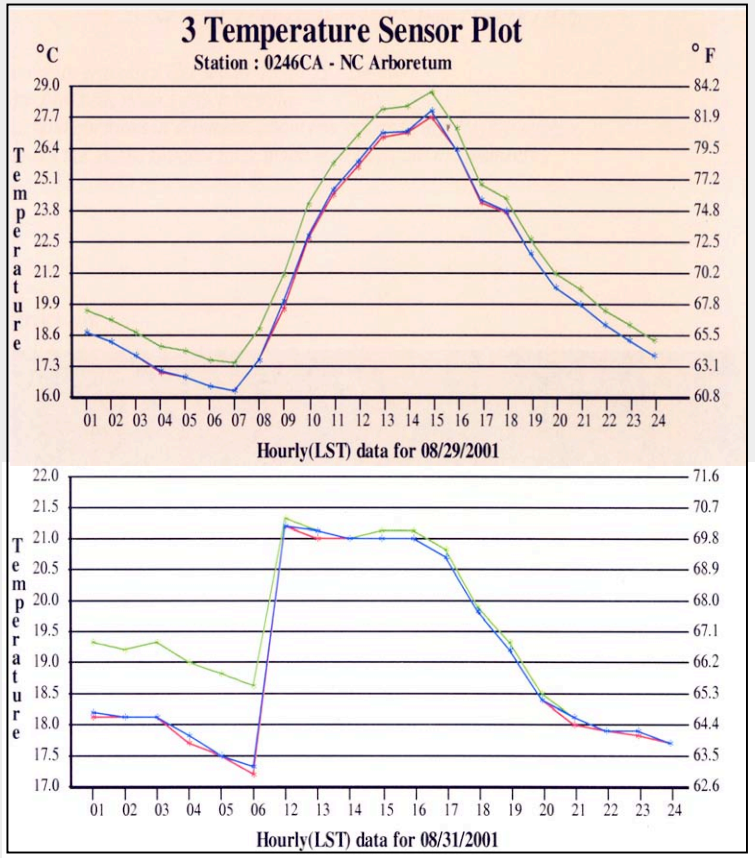
The Climate Observing System: *What is needed?*

U.S. Climate Reference Network
Real-time Network Performance Monitoring





High Quality Temperature Measurements

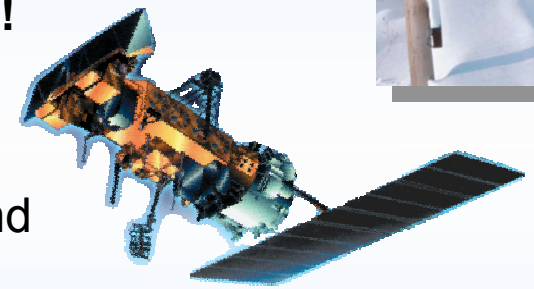


National Climatic Data Center

Common Misperceptions

- **Last winter was cold and snowy - - - so much for global warming!**
  - Actually - - - last winter was warmer than average across the USA
  - Cold weather struck during the coldest weeks of the year!
  - Probability of cold winters are decreasing (9 of last 10 above average)

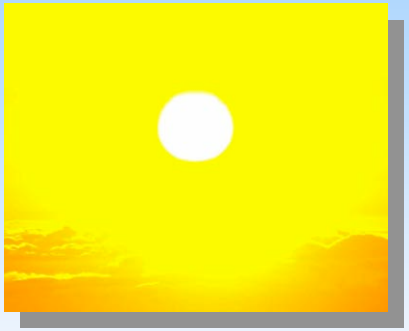
- **Satellites show global cooling not warming!**
  - True in the mid 1990s
  - Now - - - more data and improved analyses reveal significant warming at the surface and in the troposphere



- **Heat islands lead to over-exaggerated claims of observed warming!**
  - Strong warming over oceans (unaffected by heat islands), snow and ice extent decreasing
  - Heat island effect examined and addressed in the temperature records
  - Lake and river ice extent decreasing
  - Paleo data reveal warming (bore holes, tree rings, ice cores, etc.)

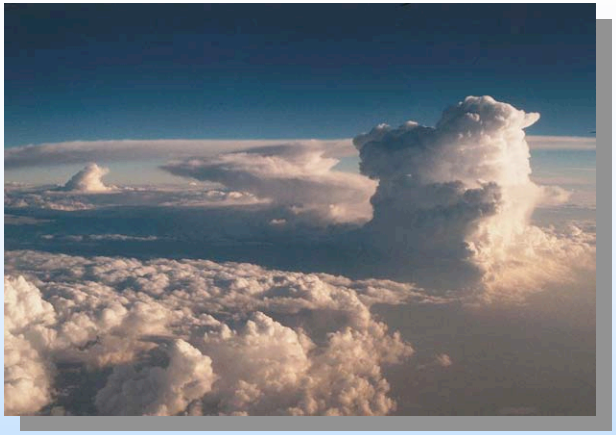
Common Misperceptions (cont'd.)

- **Solar variations are responsible for any global warming!**



  - Best evidence today suggests warming in first part of the 20th century influenced by solar radiation
  - Since satellite measurements (late 1970s) no significant changes in solar output - - - at time of rapid global temperature increases

- **Global warming will be negligible due to the planet's self regulating thermostat (the "iris effect")!**



  - Tropical clouds are supposed to allow more heat to escape into space as globe gets warmer
  - BUT - - - Observational data (in-situ and satellite) show the opposite
  - Earth's history (Ice sheets/Atmospheric Composition - - - including volcanic eruptions) demonstrates the climate is indeed sensitive to changes in forcings (about 0.75°C for 1 w/m^2 of forcing).

Conclusions

- ✓ Temperatures over past 100 years have warmed
  - ✓Greatest warming in high latitudes.
  - ✓Decrease in Arctic Sea Ice.
  - ✓Decrease in NH snow cover
  - ✓More warming in minimum (nighttime) temperature.
  - ✓Tropospheric warming, Stratospheric cooling.
  - ✓Observed Sea level rise.

- ✓ Large-scale precipitation over land has increased.
  - ✓Increase in high latitudes, decrease in Tropics.
  - ✓Evidence for increases in heavy precipitation events.

✓Uncertainties due to observing system issues, etc. but taken together balance of evidence points to discernable human influence on the climate.