A Review of Research and Data Set Development at NCDC: 1985-2003

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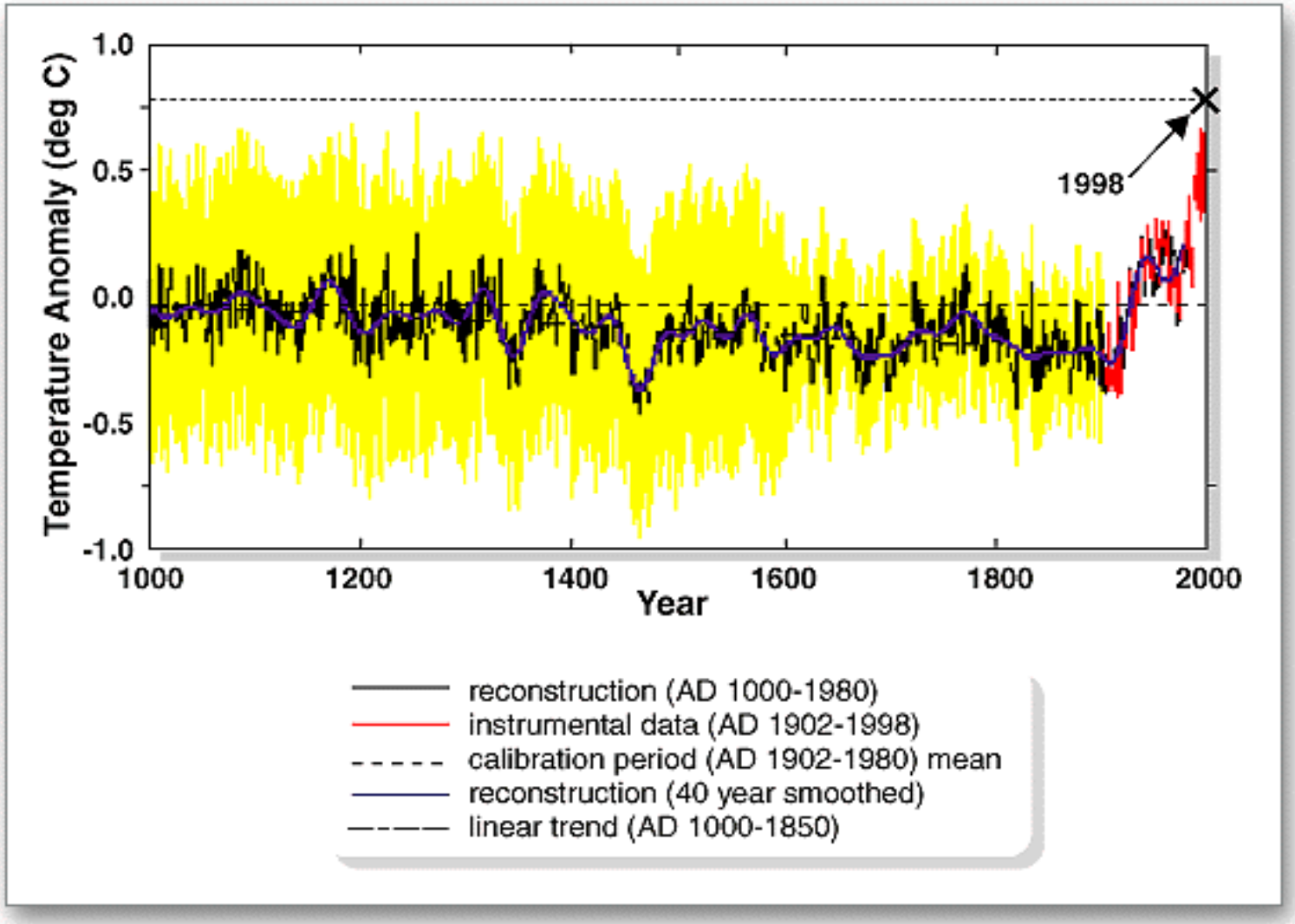
Outline

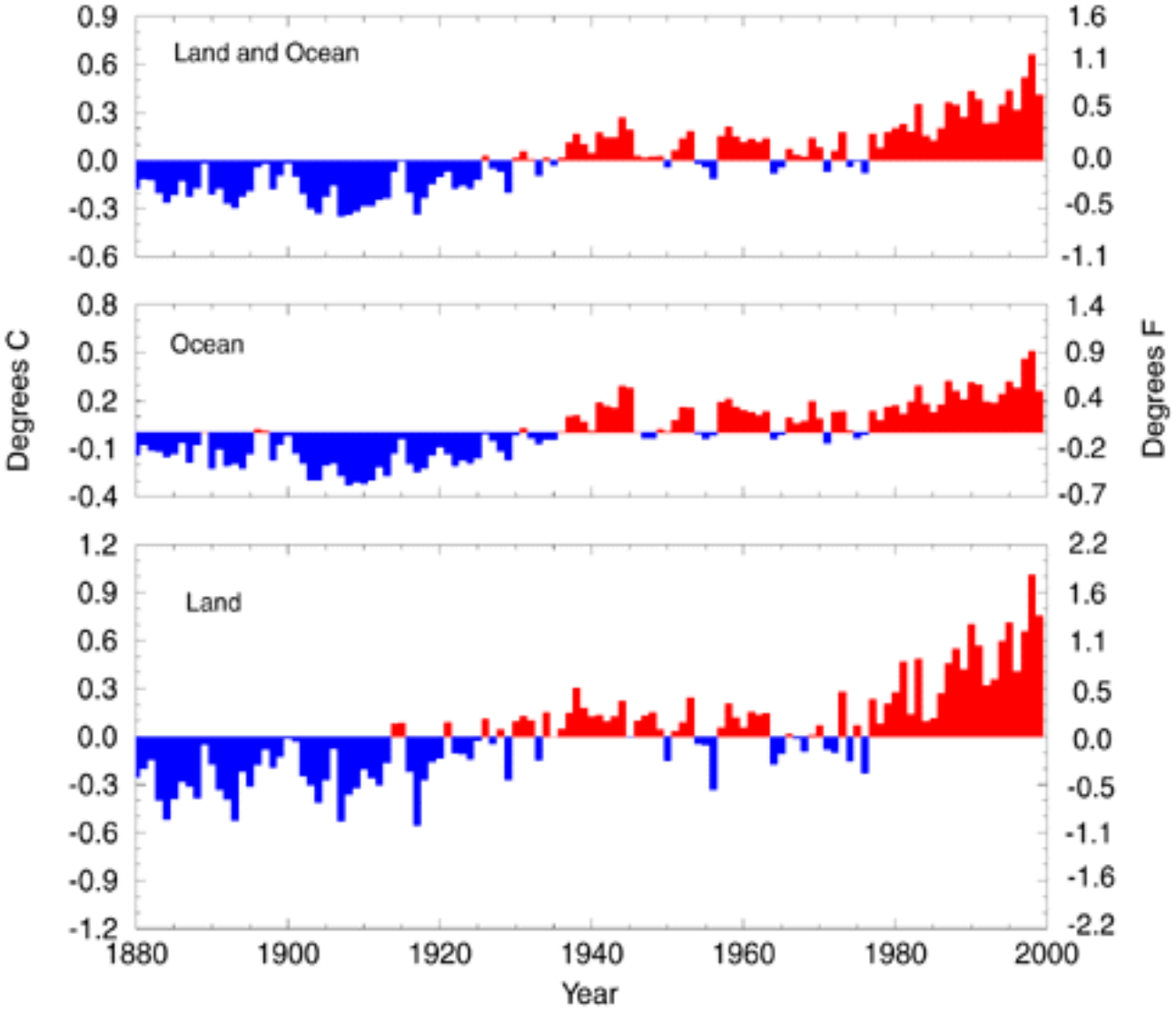
- Evidence of observed warming: is it real?
- Supplemental evidence
- Updated Max/Min/DTR trends for the globe.
- What kinds of days are changing the most, coldest, warmest?
- What kind of confidence can we place in these and other results?

Northern Hemisphere 1000 Year Temperature Reconstruction

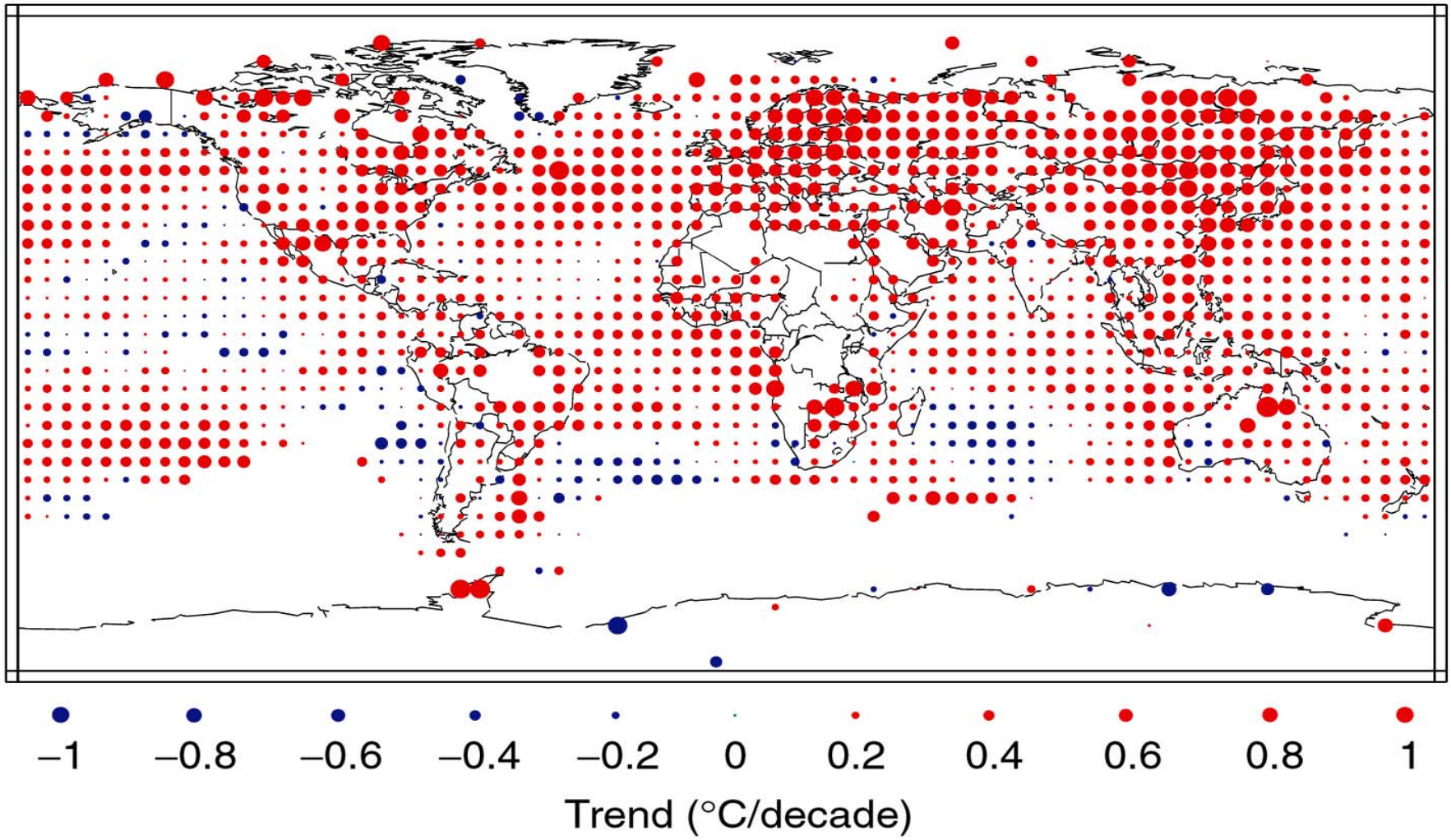


Annual Global Surface Mean Temperature Anomalies

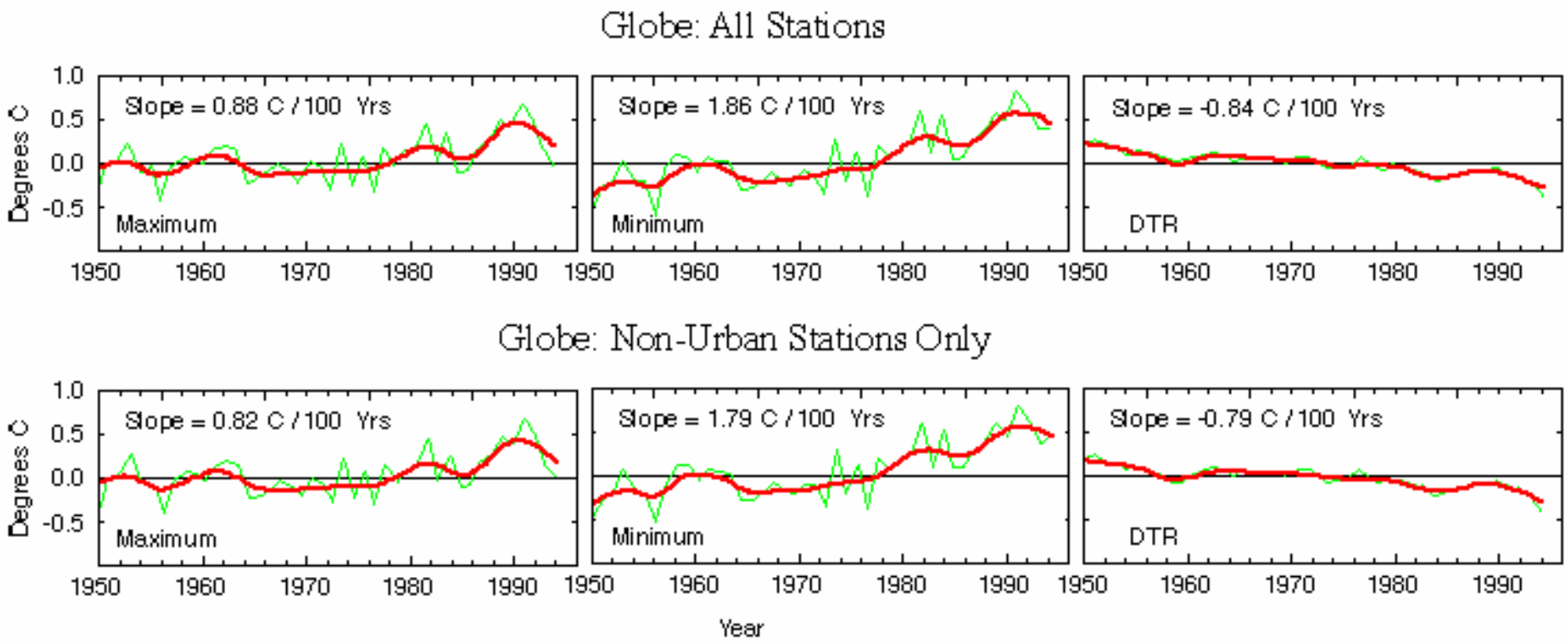
National Climatic Data Center/NESDIS/NOAA



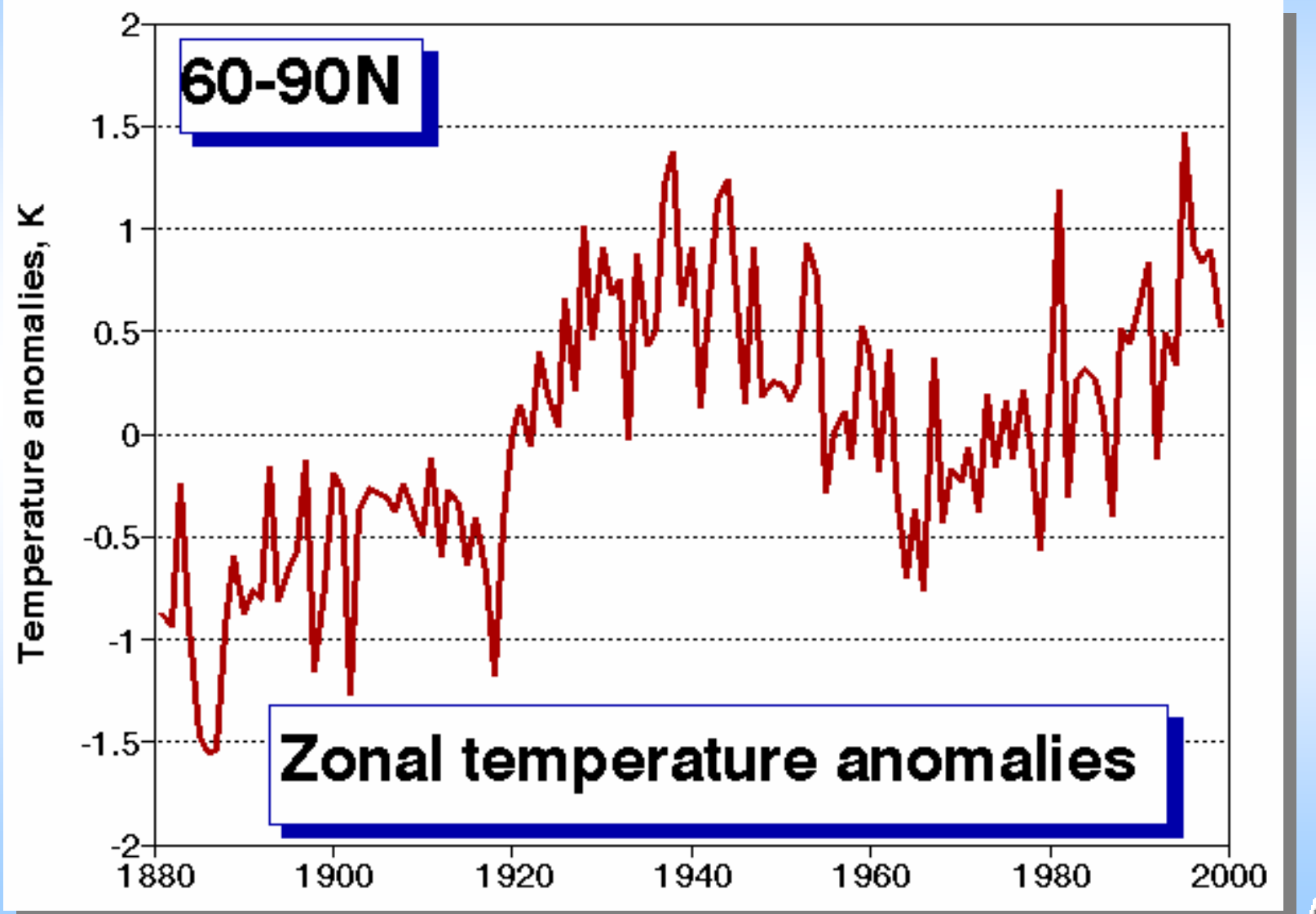
Annual temperature trends, 1976 to 2000



Maximum and Minimum Temperature and Diurnal Temperature Range Trends (Easterling et al., 1997)



Arctic Annual Temperature Variations



Temperature Indicators

KEY METRIC

OCEAN	LAND	OCEAN

LOWER STRATOSPHERE

** lower stratosphere: 0.5 to 2.5°C decrease since 1979

TROPOSPHERE

Upper

* little or no change since 1979

Low- to Mid-

** 0.0 to 0.2°C increase since 1979 - satellites & balloons

* 0.2 to 0.4°C increase since about 1960

NEAR-SURFACE

** N.H. Spring snow cover extent: since 1987, 10% below 1966 to 1986 mean

* 1990s warmest decade of the millennium and 1998 warmest year for at least the N. Hemisphere

** marine air temperature: 0.4 to 0.7°C increase since late 19th century

*** sea surface temperature: 0.4 to 0.8°C increase since the late 19th century.

* global ocean (to 300m depth) heat content increase since 1950s equal to 0.04°C / decade

*** widespread retreat of mountain glaciers during 20th century

** land night time air temperature increasing at twice the rate of daytime temperatures since 1950

* lake and river ice retreat since the late 19th century (2 week decrease in ice duration)

*** land air temperatures: 0.4 to 0.8°C increase since late 19th century

*** increase in freeze-free season over much of the mid- to high-latitude region

* Arctic sea ice: summer thickness decrease of 40% and 10 to 15% decrease in extent during spring and summer since 1950s

? Antarctic sea ice: no significant change since 1978

Likelihood:

*** Virtually certain (probability > 99%)

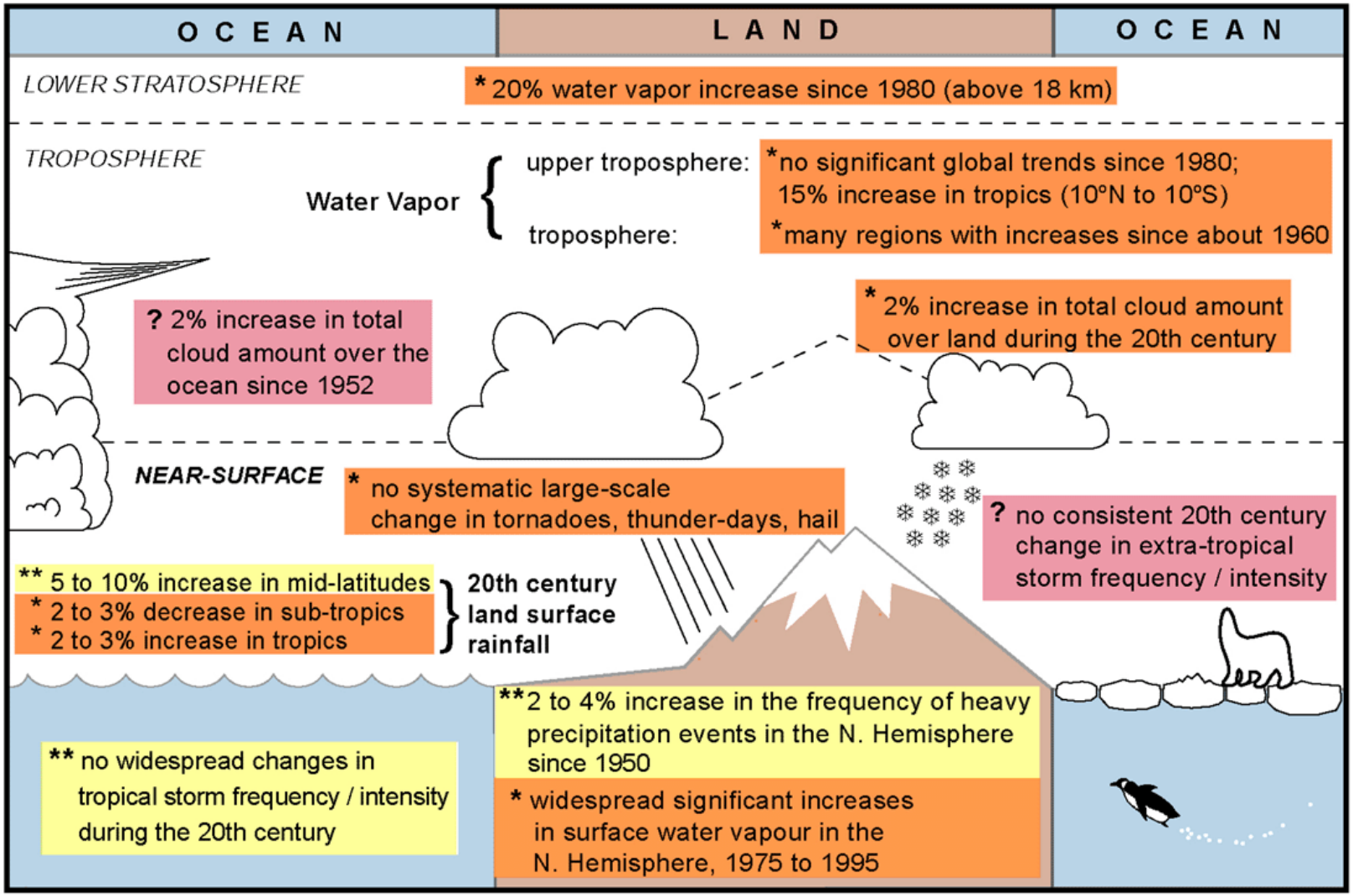
** Very likely (probability ≥ 90% but ≤99%)

* Likely (probability > 66% but < 90%)

? Medium likelihood (probability > 33% but ≤ 66%)

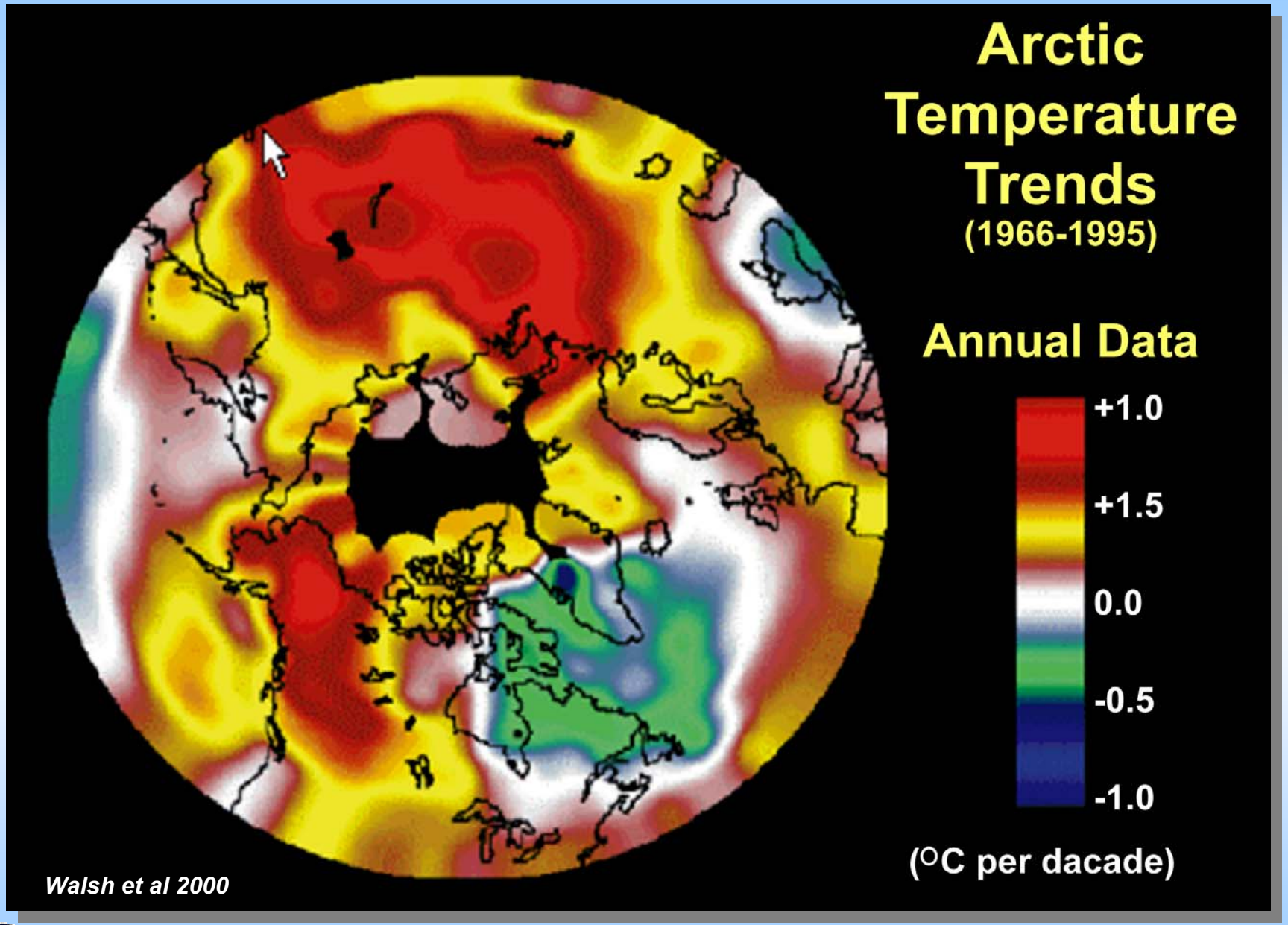
Hydrological and Storm-Related Indicators

KEY METRIC



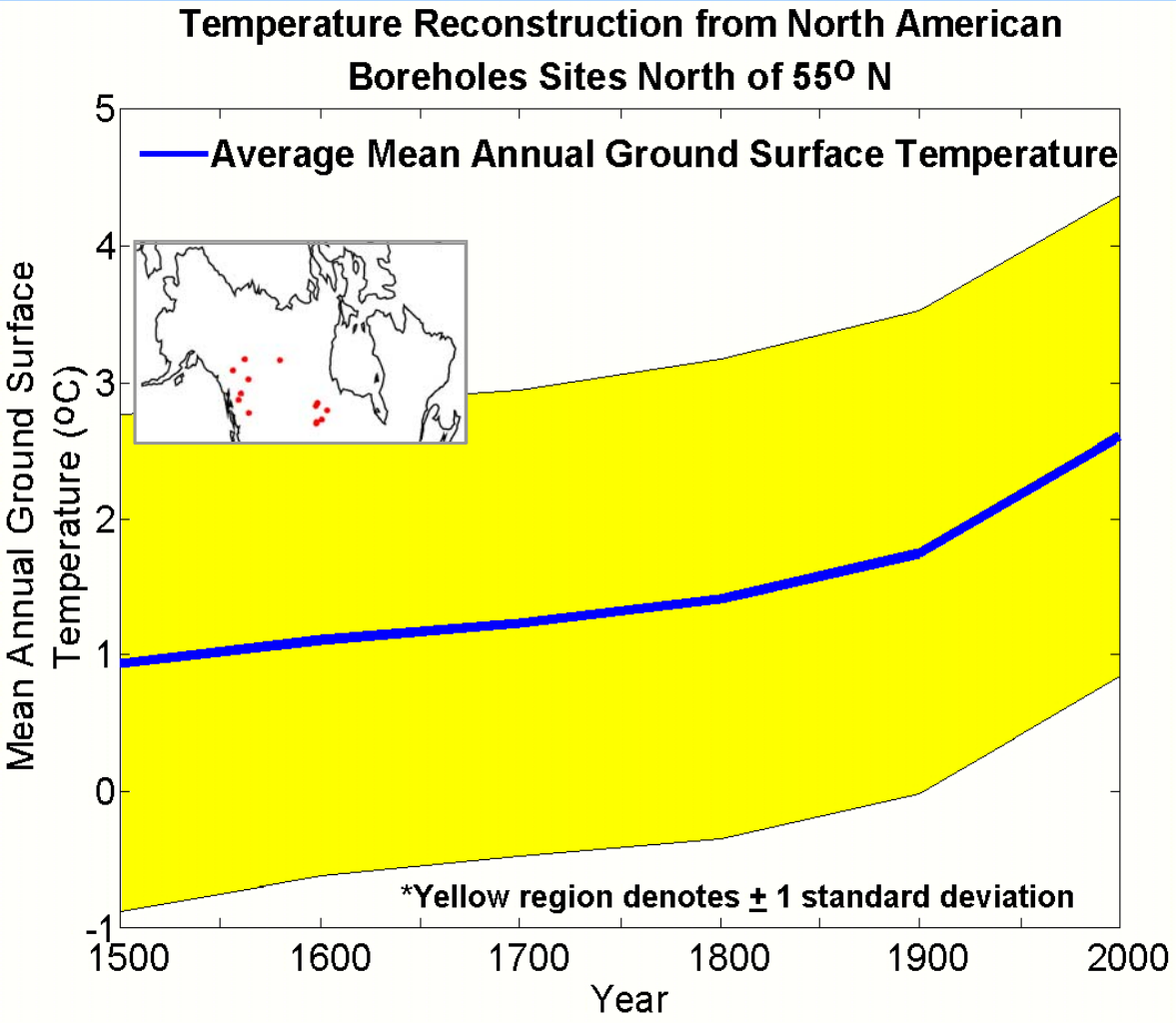
Likelihood:

- *** Virtually certain (probability > 99%)
- ** Very likely (probability ≥ 90% but ≤ 99%)
- * Likely (probability > 66% but < 90%)
- ? Medium likelihood (probability > 33% but ≤ 66%)

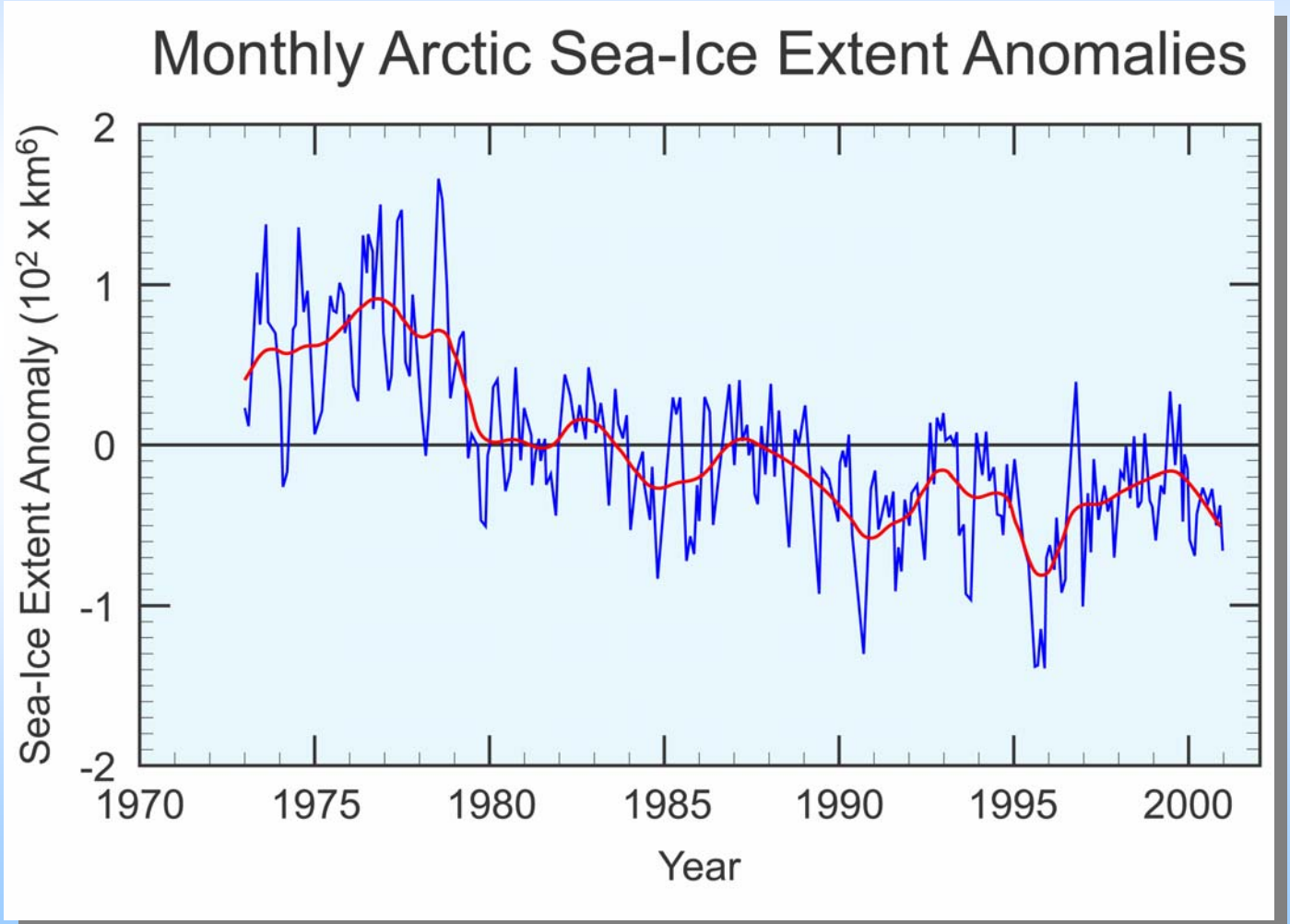

Arctic
Temperature
Trends
(1966-1995)
Annual Data
+1.0
+1.5
0.0
-0.5
-1.0
(°C per dacade)
Walsh et al 2000

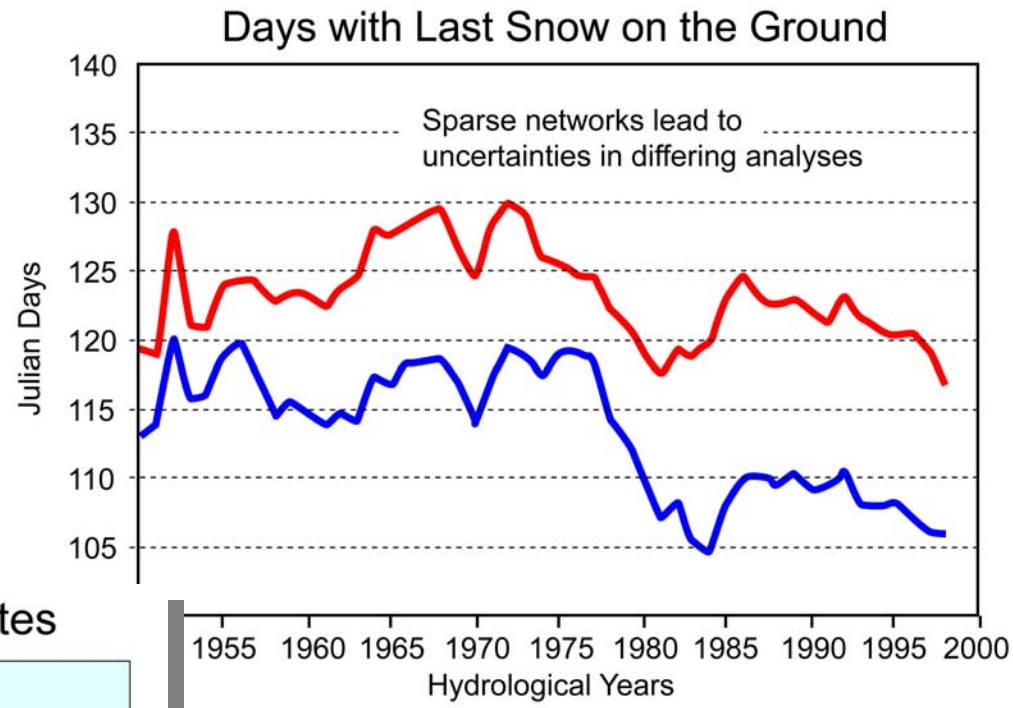
Past Climate From Borehole Records

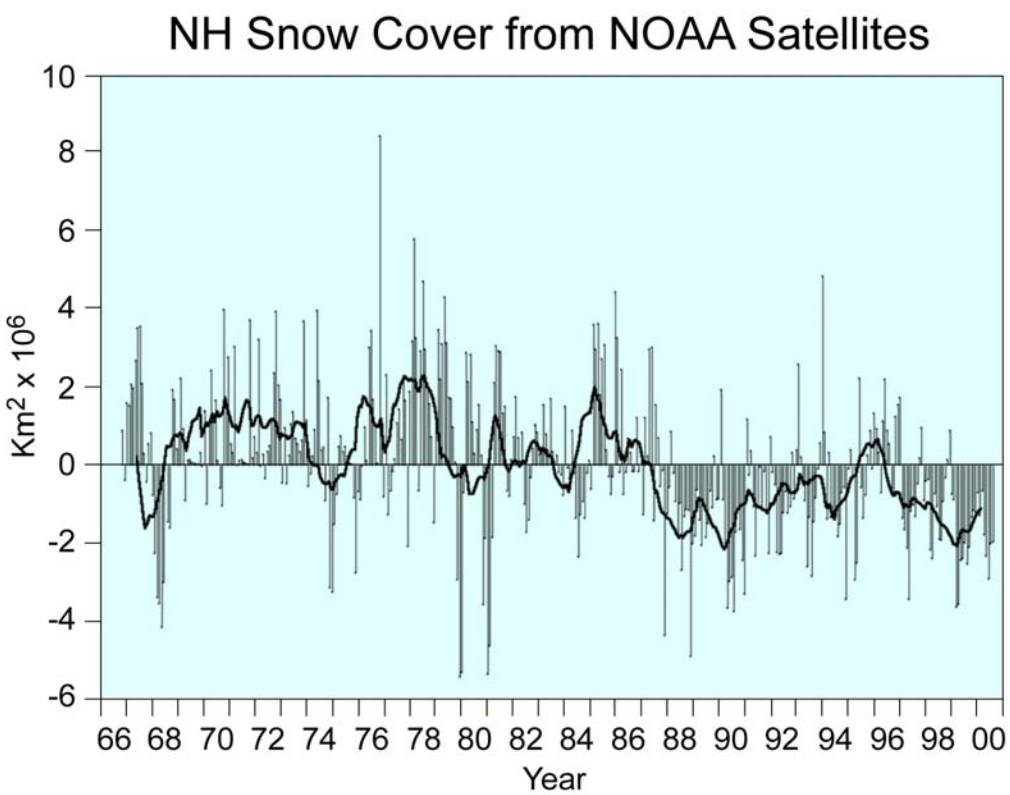
- 16 borehole temperature records were averaged to create a temperature reconstruction for High Latitude North America
- 20th century temperatures show a major upturn relative to prior 4 centuries
- Temperatures rose at a rate of 1.5°F in the 20th Century



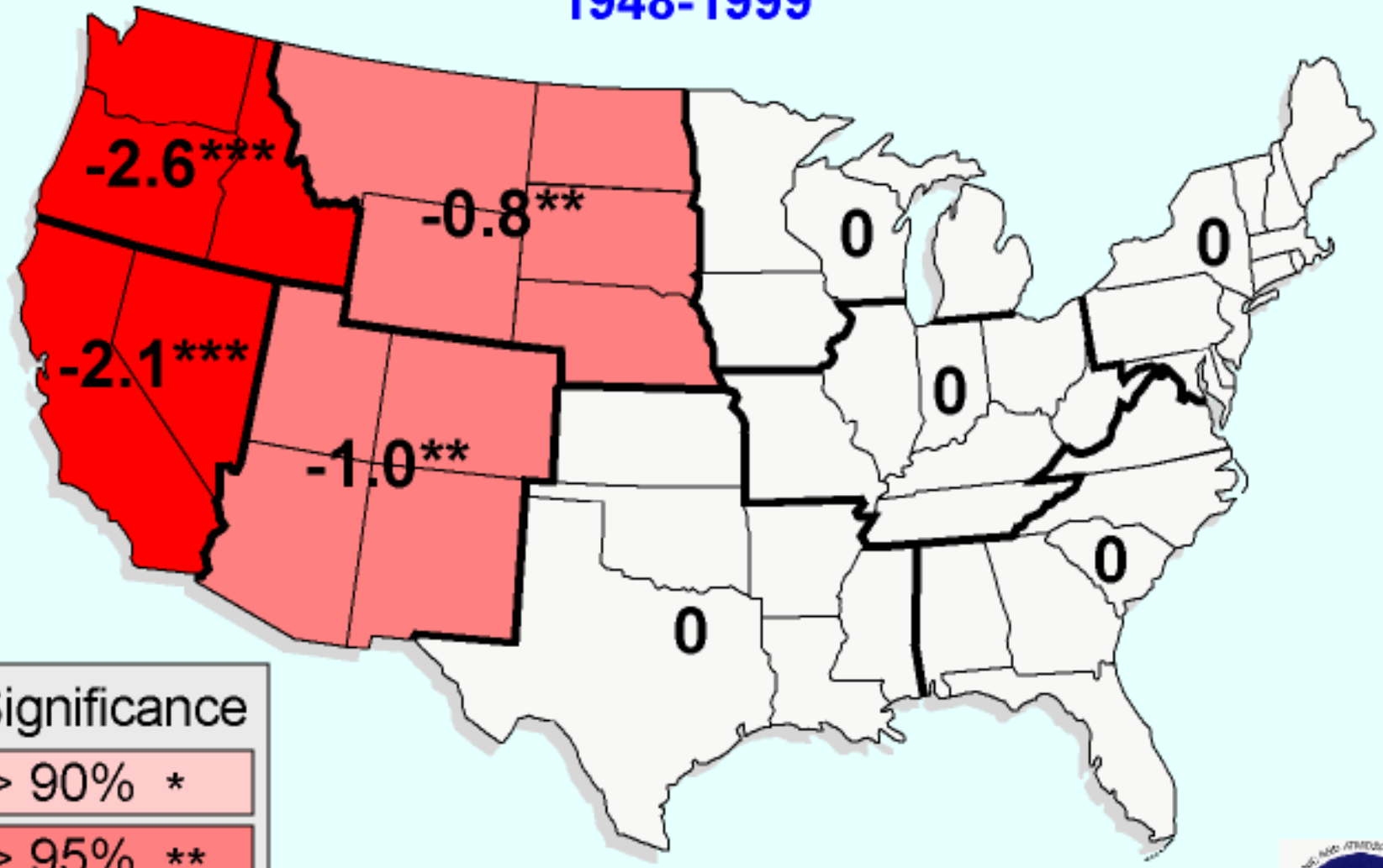
10-15% Decrease in arctic sea ice revealed by NOAA operational satellites




Days with Last Snow on the Ground
Sparse networks lead to
uncertainties in differing analyses
Julian Days
140
135
130
125
120
115
110
105
1955 1960 1965 1970 1975 1980 1985 1990 1995 2000
Hydrological Years


NH Snow Cover from NOAA Satellites
Km2 x 10^6
10
8
6
4
2
0
-2
-4
-6
66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 00
Year

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



Significance

> 90% *

> 95% **

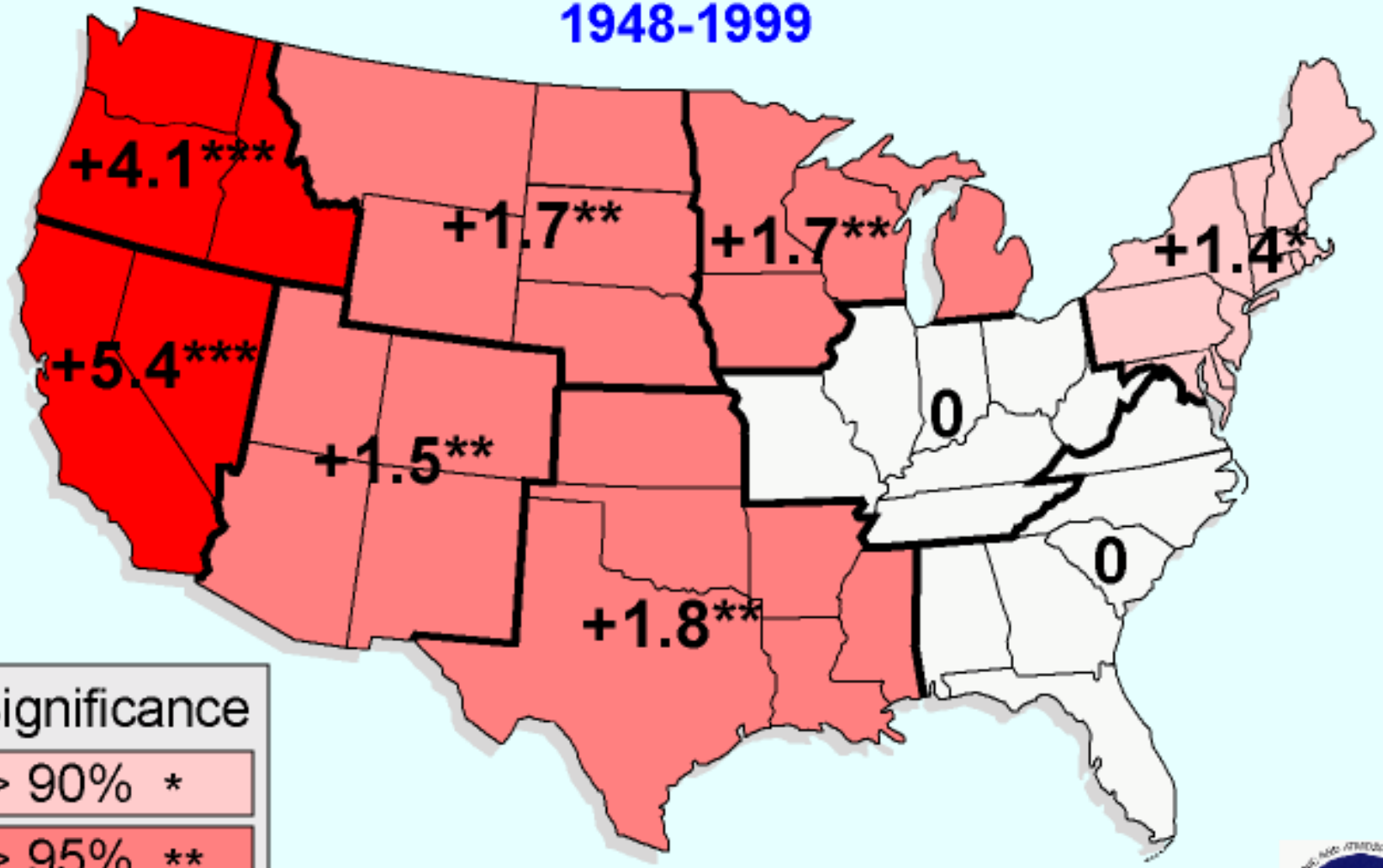
> 99% ***

All U.S. = -0.8**

CHANGE IN FROST-FREE LENGTH

DAYS PER DECADE

1948-1999



Significance

> 90% *

> 95% **

> 99% ***

All U.S. = +2.0***

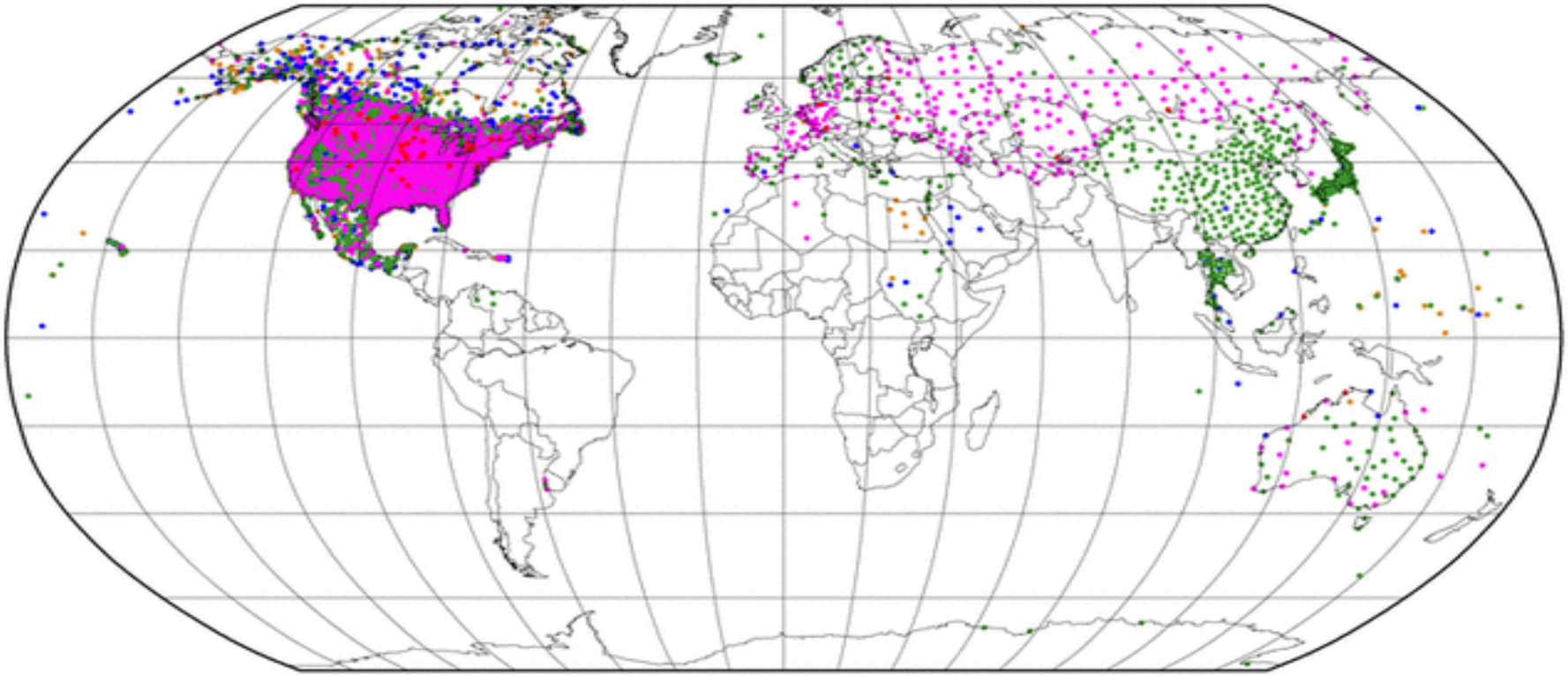
The Global Daily Climatology Network

- Daily observations of max/min temperature and precipitation from approx. 30,000 stations
- Highly variable period of record.
- Available on CD-ROM, soon by FTP.

www.ncdc.noaa.gov/oa/climate/research/gdcn/gdcn.html

Maximum Temperature, Period of Record (POR)

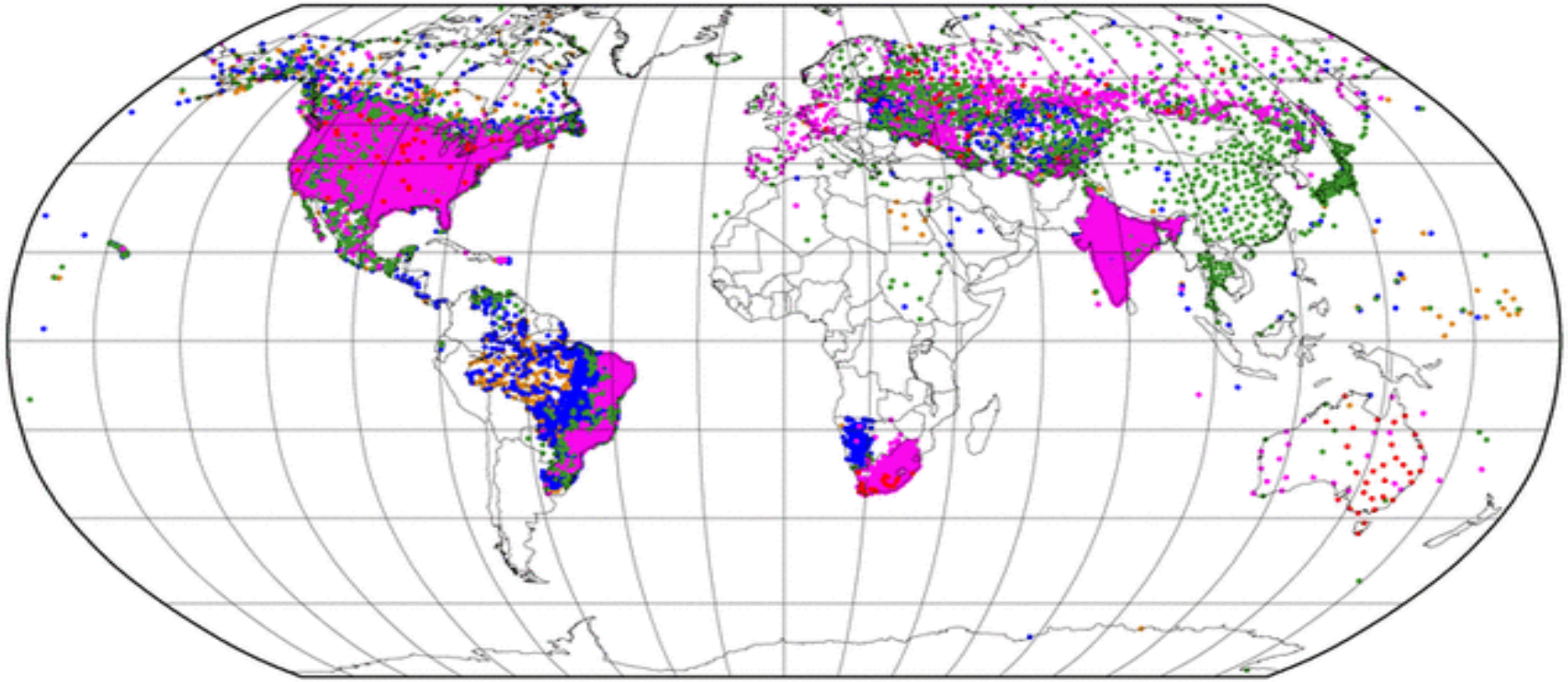
GDCN V1.0



- 00 yrs < POR <= 10 yrs
- 10 yrs < POR <= 25 yrs
- 25 yrs < POR <= 50 yrs
- 50 yrs < POR <= 100 yrs
- 100yrs < POR

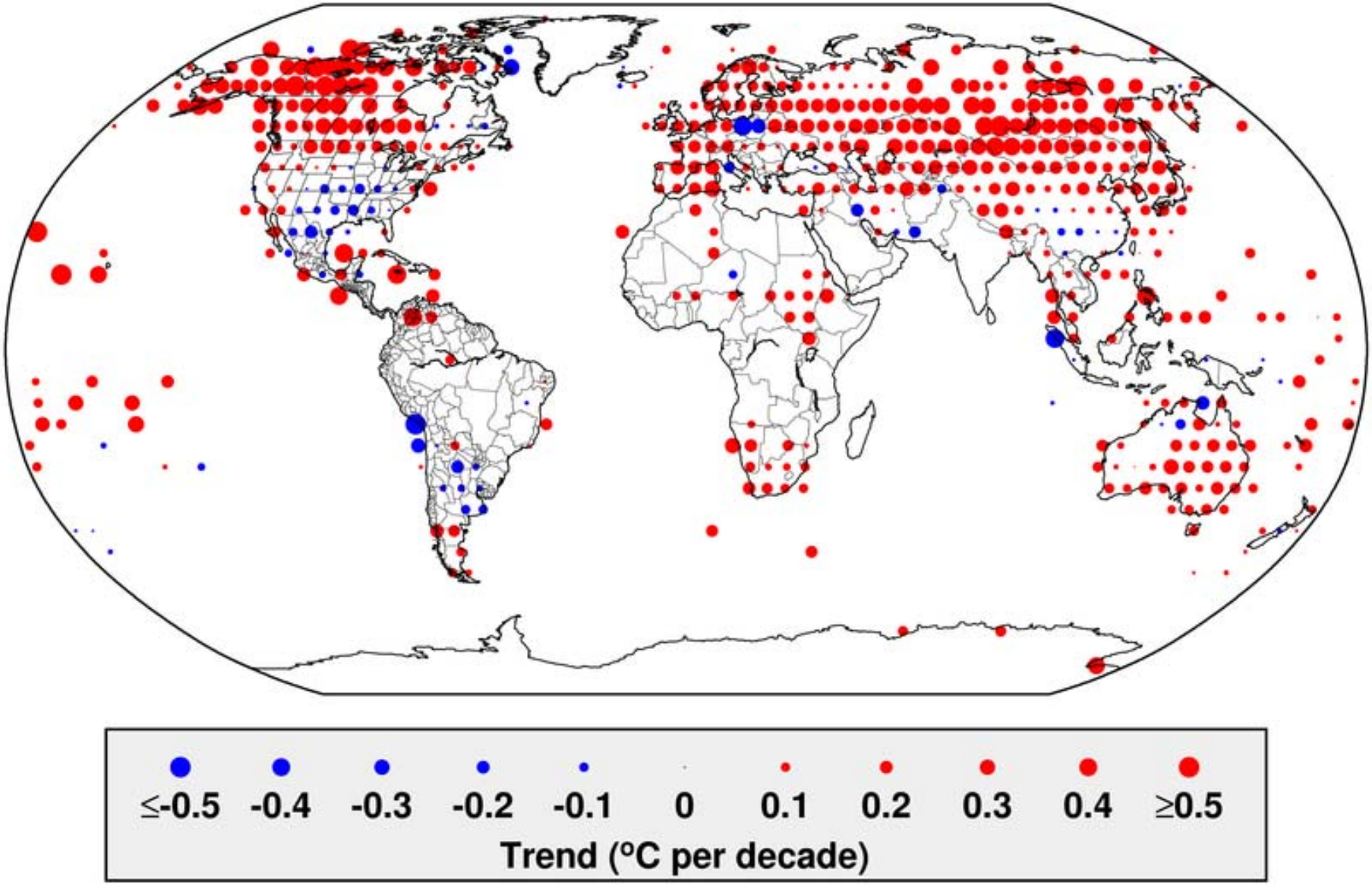
Precipitation, Period of Record (POR)

GDCN V1.0

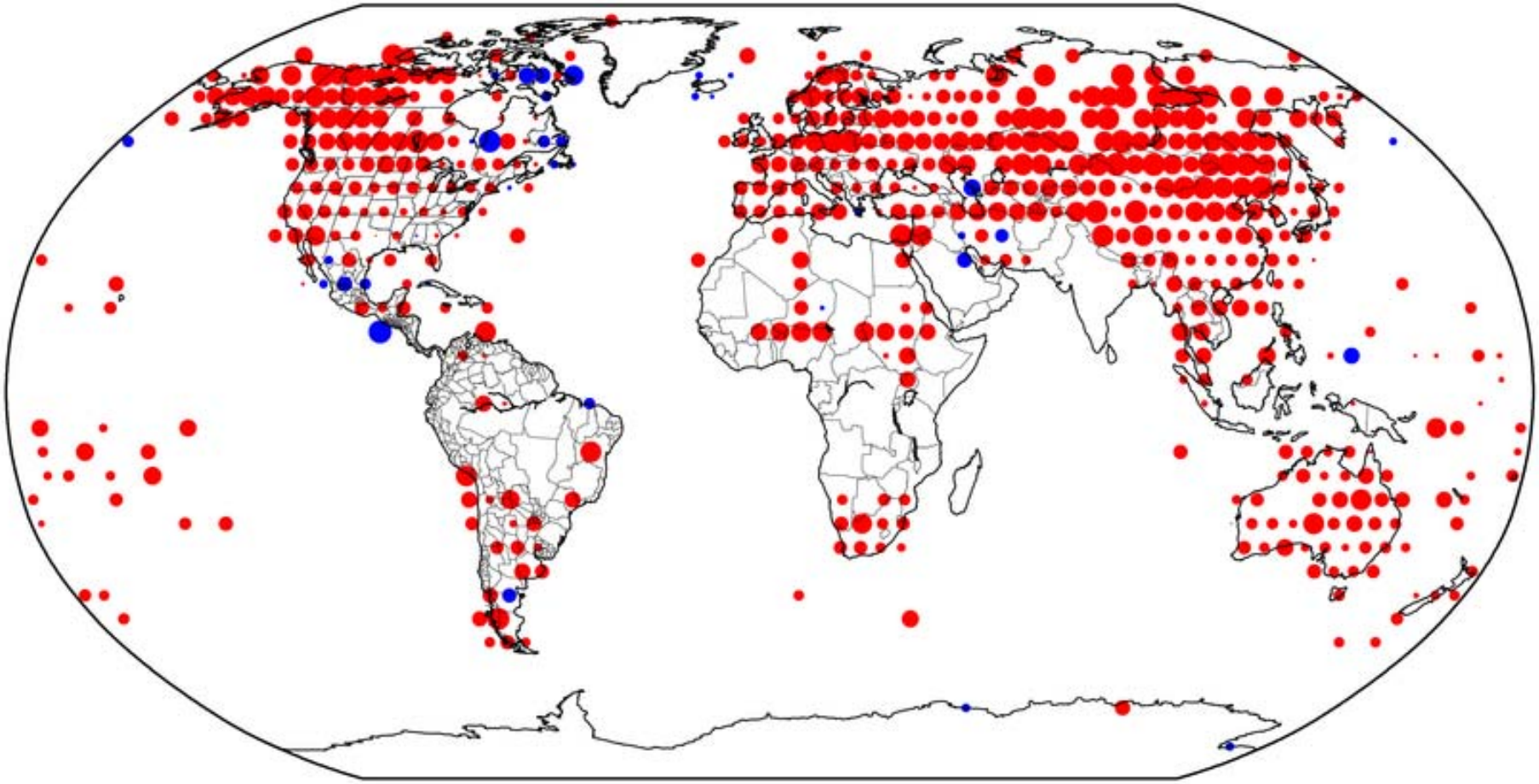


- 00 yrs < POR <= 10 yrs
- 10 yrs < POR <= 25 yrs
- 25 yrs < POR <= 50 yrs
- 50 yrs < POR <= 100 yrs
- 100yrs < POR

Annual Trends in Maximum Temperature Anomalies (1950-2003)



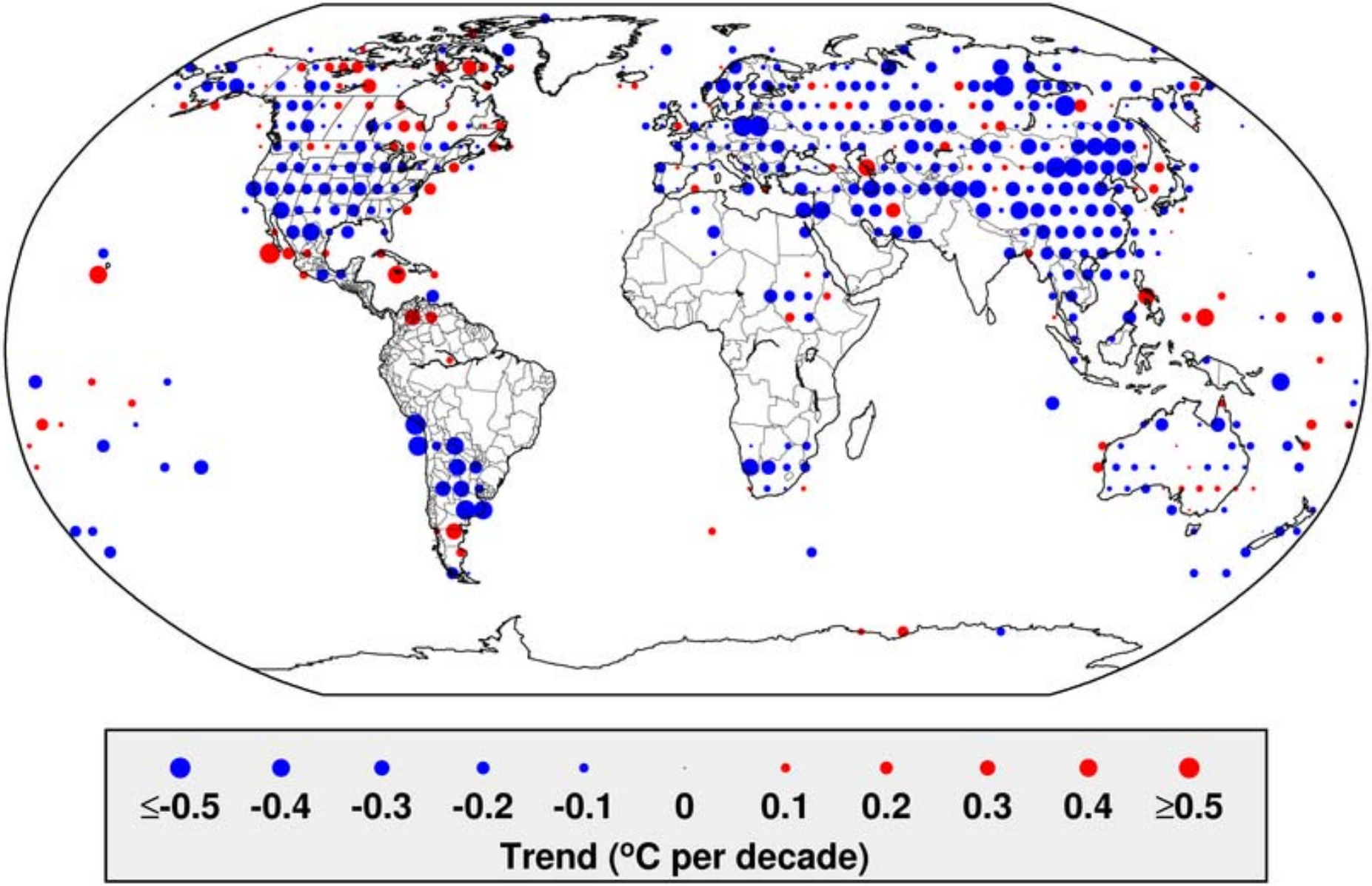
Annual Trends in Minimum Temperature Anomalies (1950-2003)



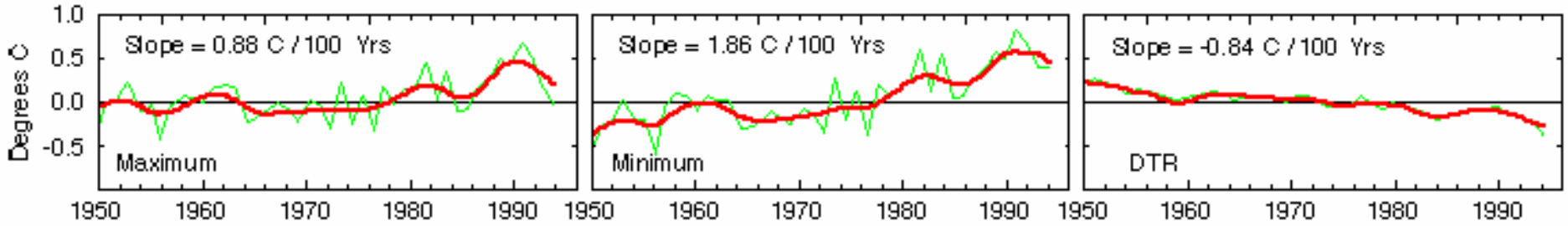
≤-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 ≥0.5

Trend (°C per decade)

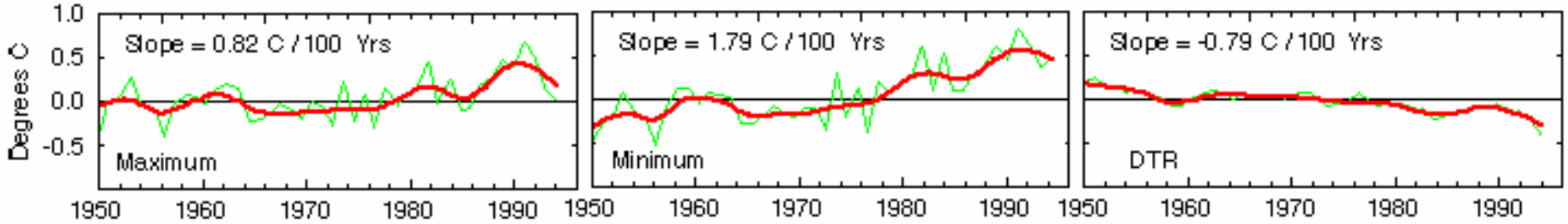
Annual Trends in DTR Anomalies (1950-2003)



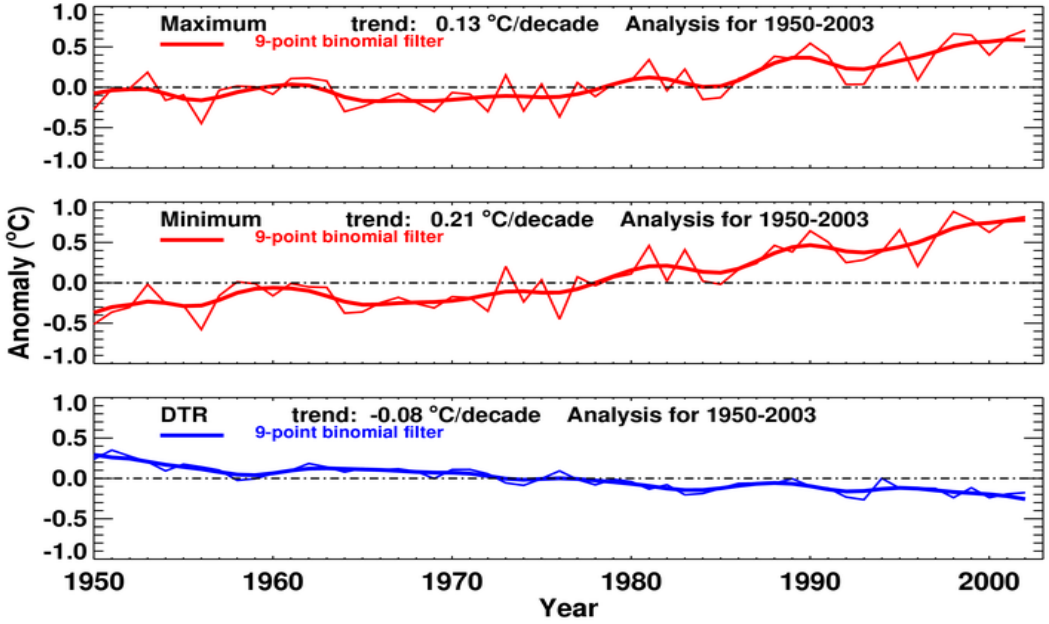
Globe: All Stations

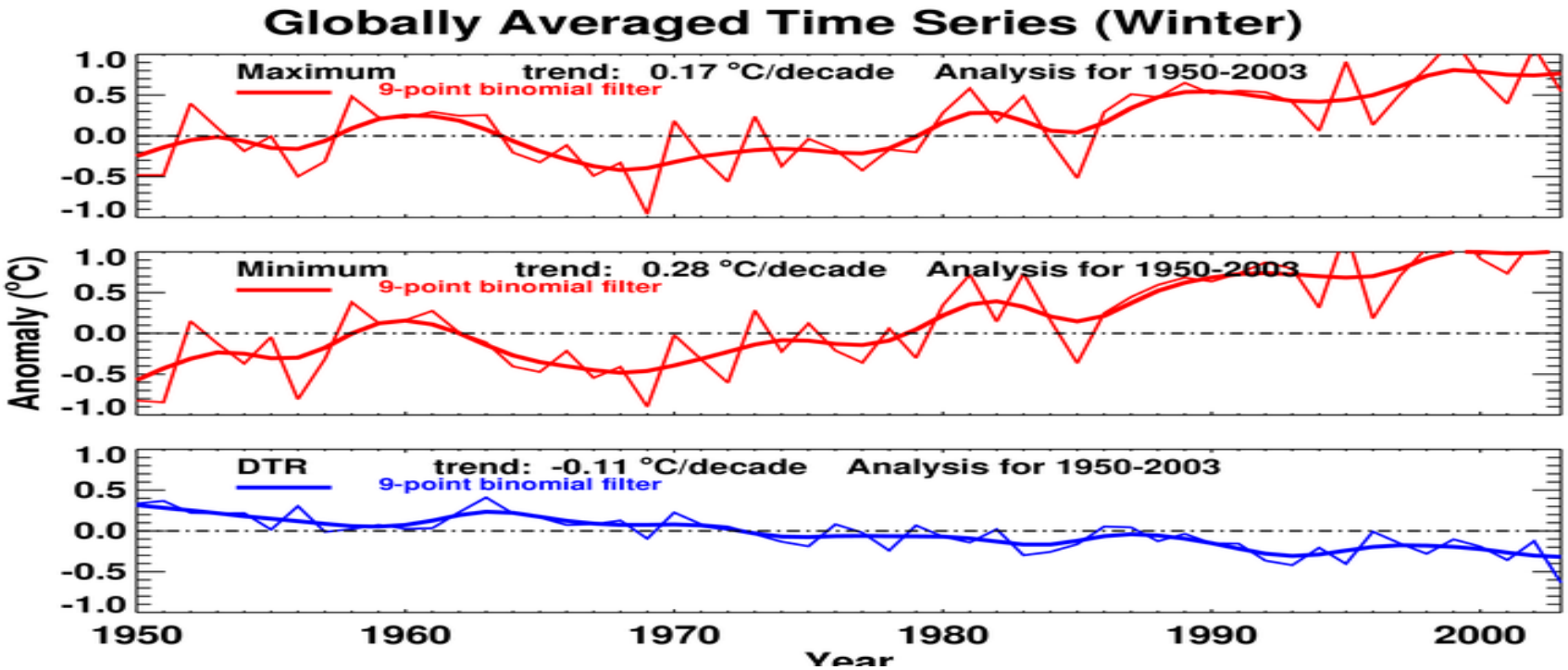


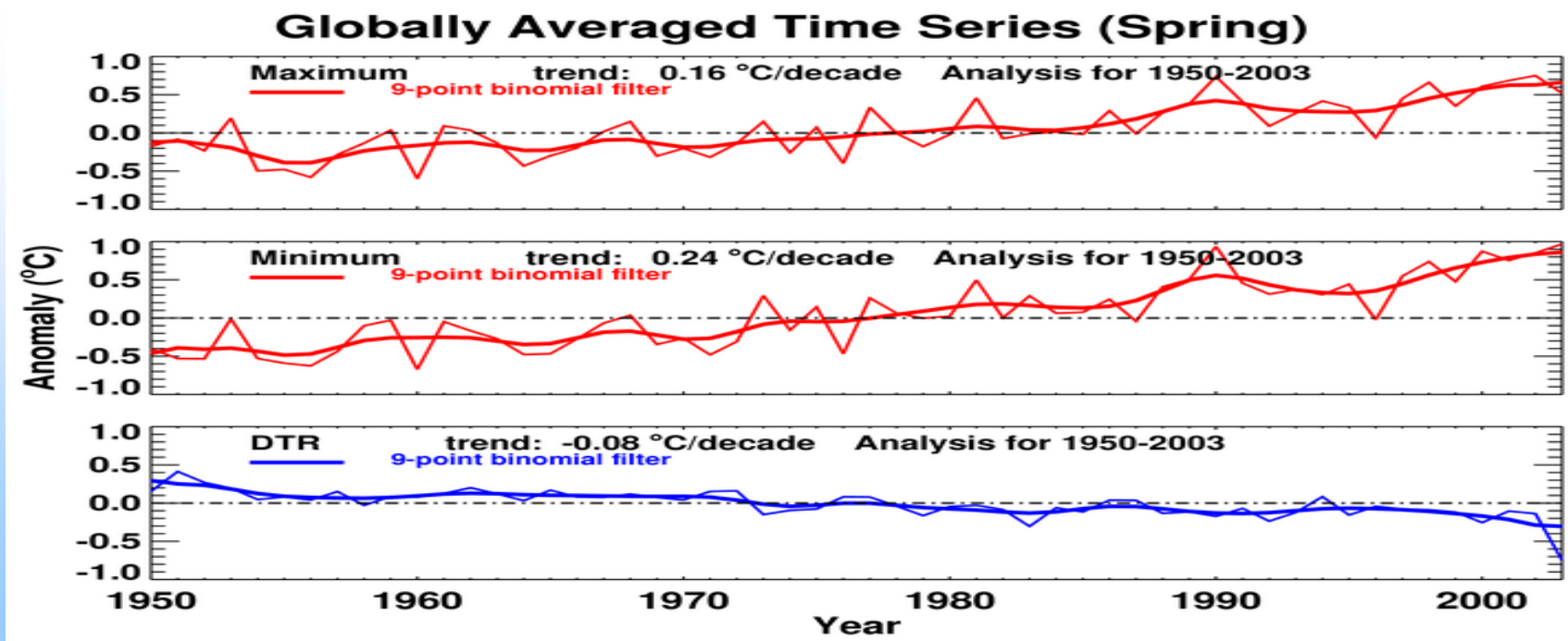
Globe: Non-Urban Stations Only

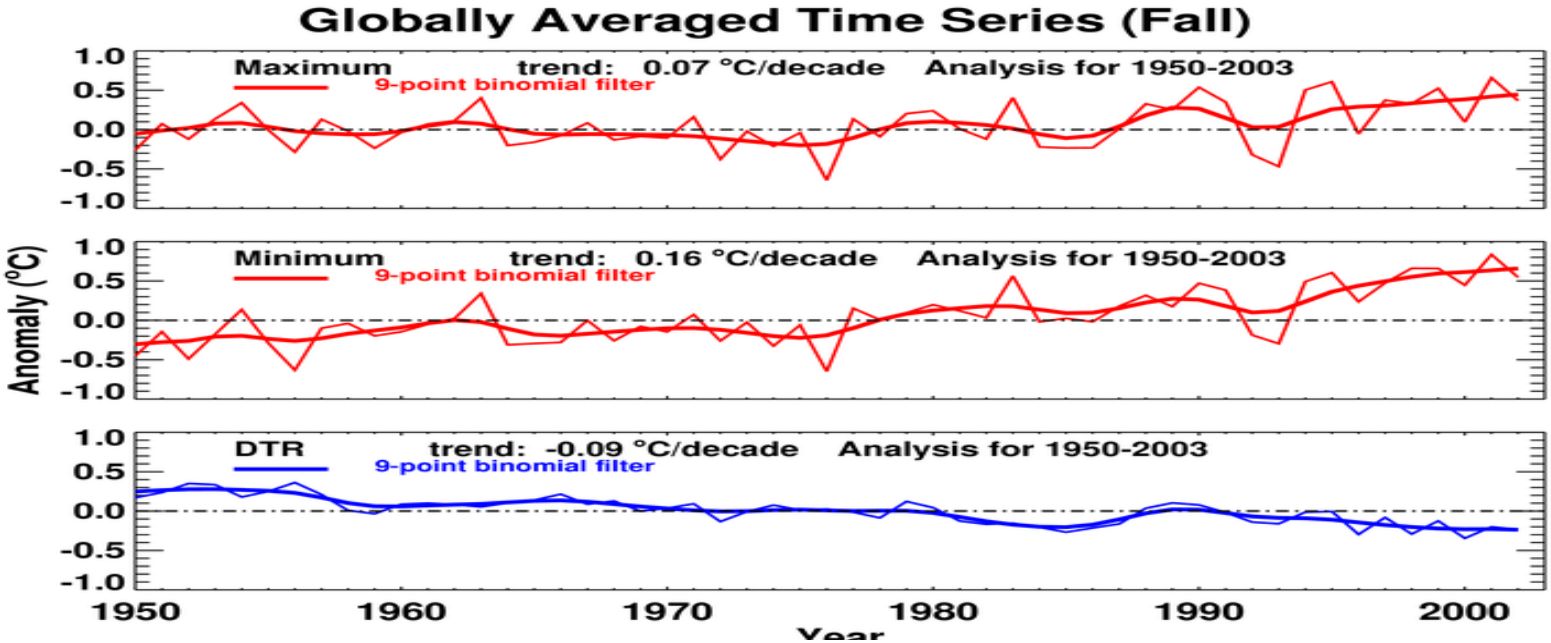


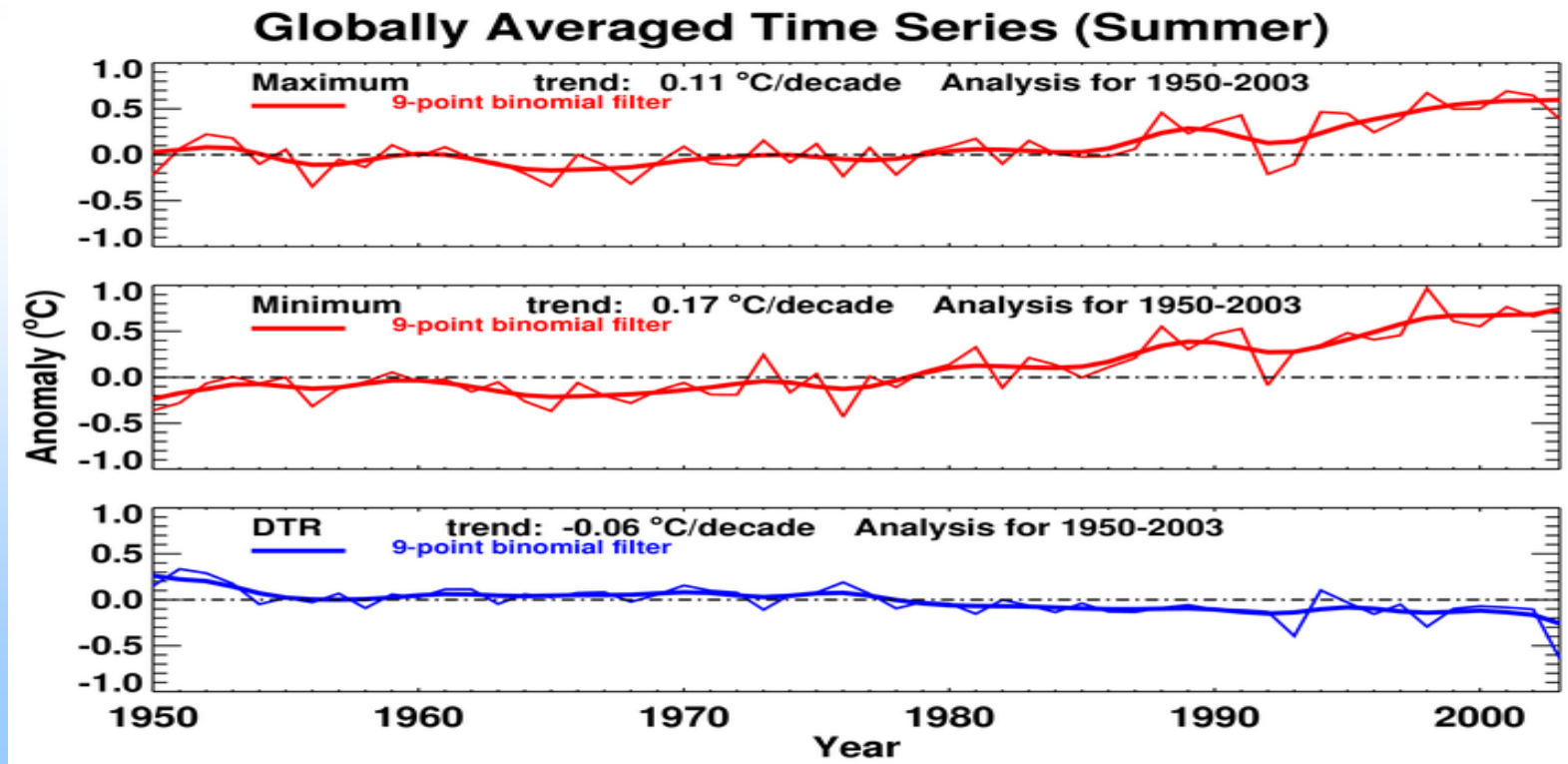
Globally Averaged Time Series (Annual)




Globally Averaged Time Series (Winter)
Maximum trend: 0.17 °C/decade Analysis for 1950-2003
9-point binomial filter
Minimum trend: 0.28 °C/decade Analysis for 1950-2003
9-point binomial filter
DTR trend: -0.11 °C/decade Analysis for 1950-2003
9-point binomial filter
Anomaly (°C)
1.0
0.5
0.0
-0.5
-1.0
1950
1960
1970
1980
1990
2000
Year


Globally Averaged Time Series (Spring)
Maximum trend: 0.16 °C/decade Analysis for 1950-2003
9-point binomial filter
Minimum trend: 0.24 °C/decade Analysis for 1950-2003
9-point binomial filter
DTR trend: -0.08 °C/decade Analysis for 1950-2003
9-point binomial filter
Anomaly (°C)
1.0
0.5
0.0
-0.5
-1.0
1950
1960
1970
1980
1990
2000
Year


Globally Averaged Time Series (Fall)
Maximum trend: 0.07 °C/decade Analysis for 1950-2003
9-point binomial filter
Minimum trend: 0.16 °C/decade Analysis for 1950-2003
9-point binomial filter
DTR trend: -0.09 °C/decade Analysis for 1950-2003
9-point binomial filter
Anomaly (°C)
1.0
0.5
0.0
-0.5
-1.0
1950
1960
1970
1980
1990
2000
Year


Globally Averaged Time Series (Summer)
Maximum trend: 0.11 °C/decade Analysis for 1950-2003
9-point binomial filter
Minimum trend: 0.17 °C/decade Analysis for 1950-2003
9-point binomial filter
DTR trend: -0.06 °C/decade Analysis for 1950-2003
9-point binomial filter
Anomaly (°C)
1.0
0.5
0.0
-0.5
-1.0
1950
1960
1970
1980
1990
2000
Year

Given that the strongest warming has occurred in the higher latitudes: is the warming occurring in the coldest or warmest days in a given season?

- Kalkstein et al. (1990) found that the coldest airmasses in Alaska and the Yukon appear to show signs of warming
- Others (e.g. Knappenberger et al. 2001) found that the warming in the U.S. appears to be strongest in the coldest days.

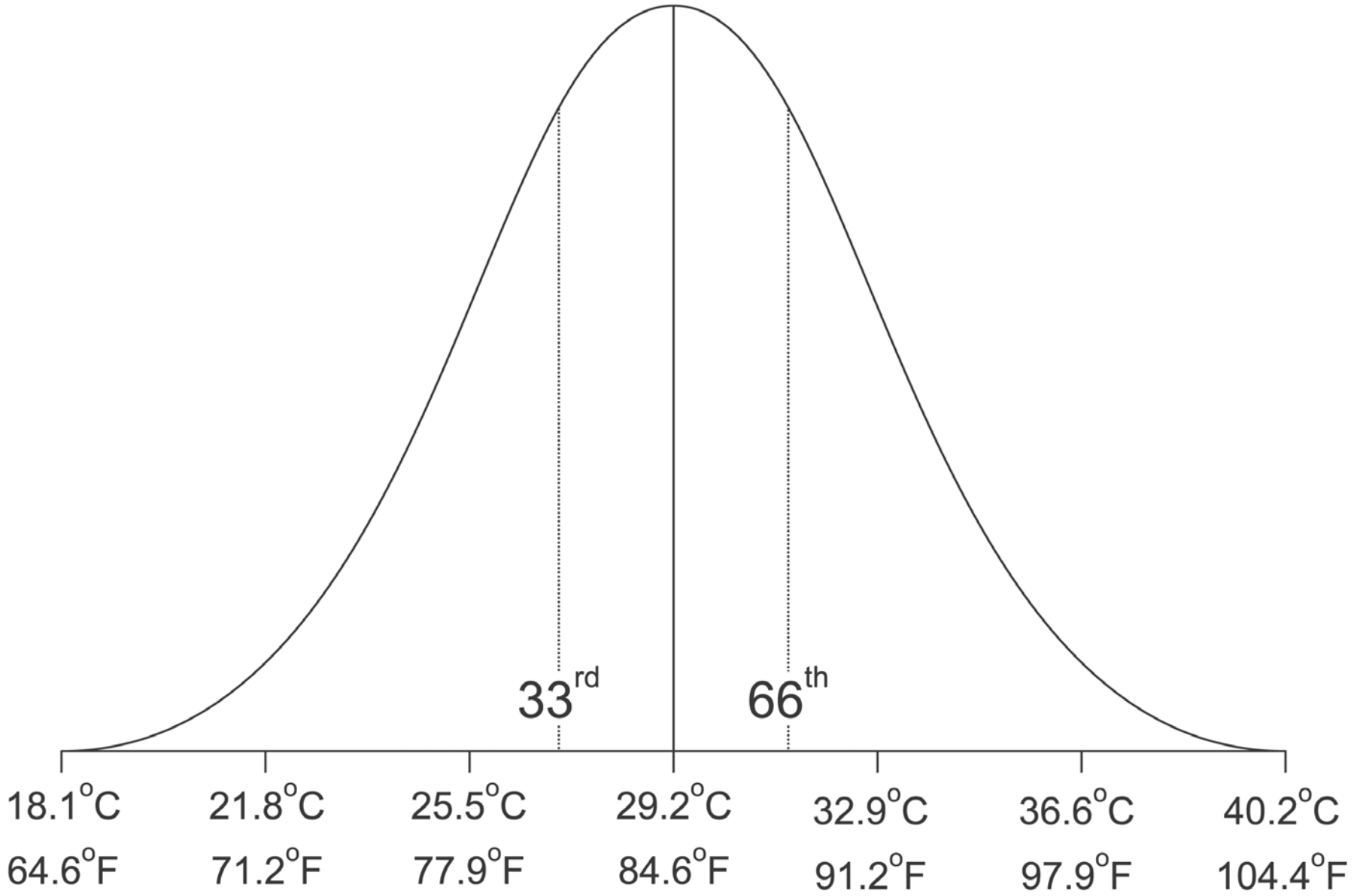
Methods

- Take max or min temperature time series at a station for a given month, for the period 1948-2001.
- Determine the 33rd and 66th percentile temperatures to define three bins, 0-33rd, 33rd-66th, 66th-100.
- Place each day into appropriate bin and average the values for a given year-month.
- This defines three temperature time series, one for each bin: coldest, middle, and warmest days for each month.

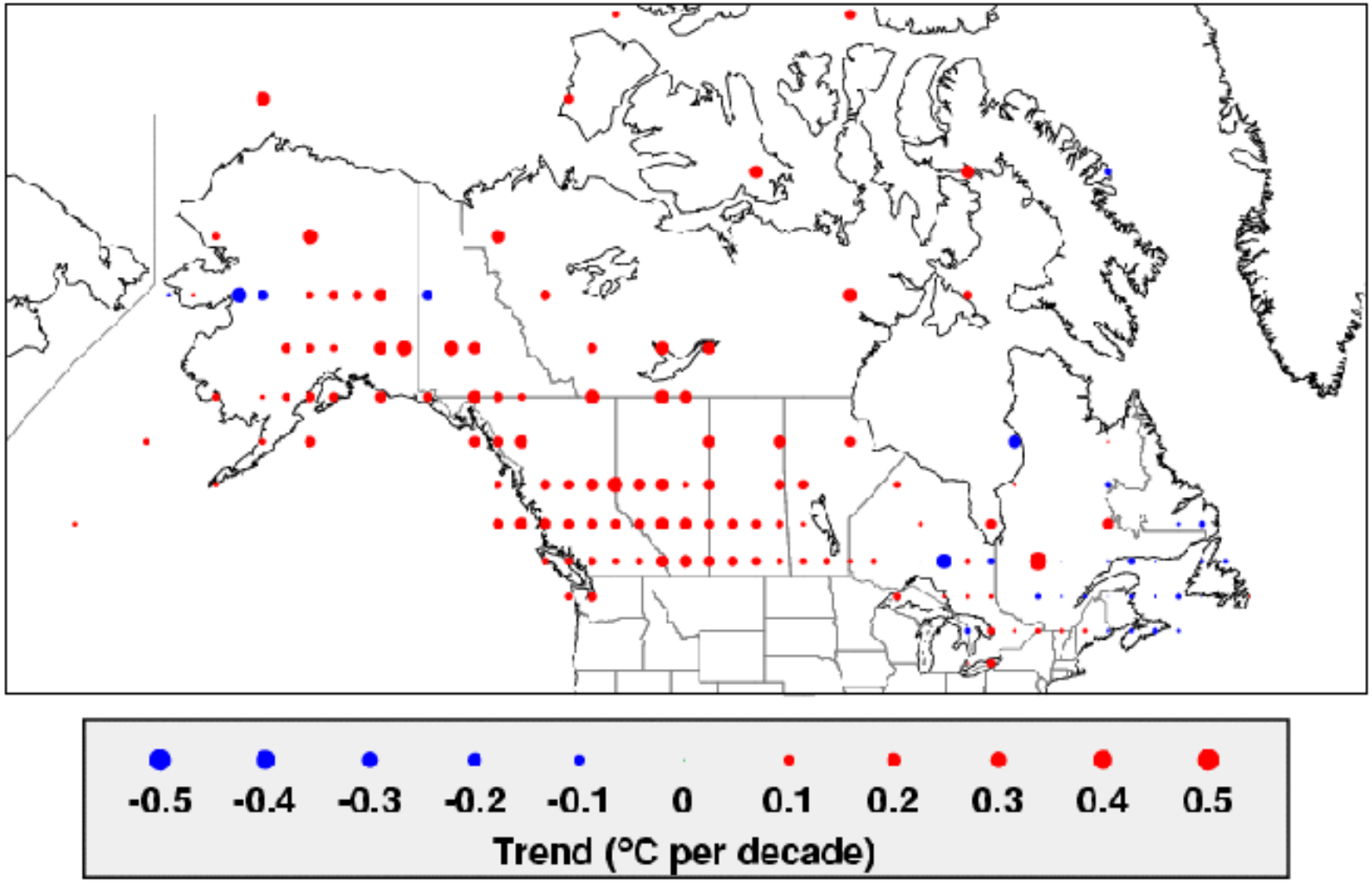
Methods, cont.

- Create an anomaly series and aggregate up to seasons (DJF, MAM, JJA, SON) and annual.
- Grid anomaly time series into 2.5 by 2.5 Lat/Lon grid.
- Trend analysis of each gridpoint time series.

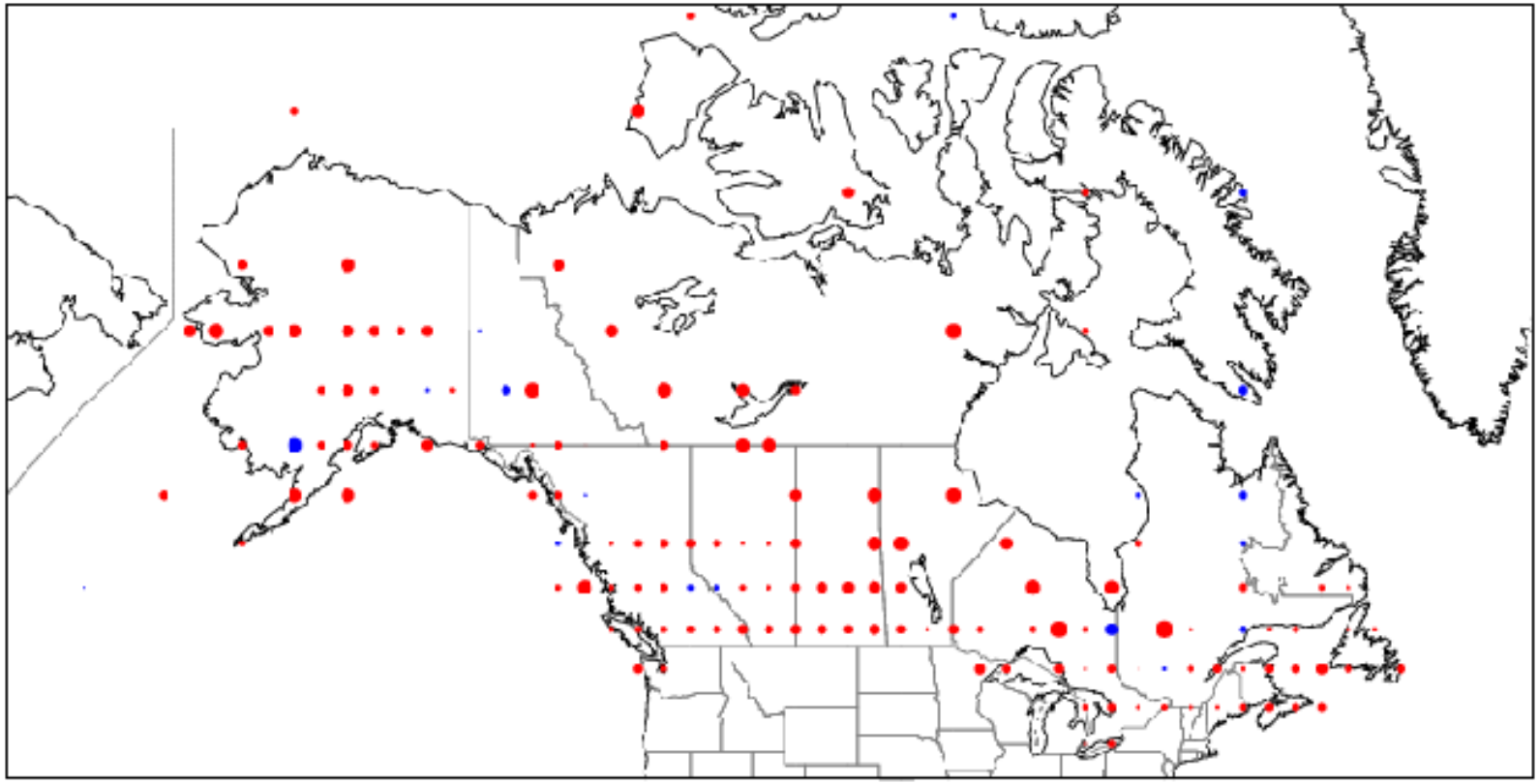
July Daily Maximum



Maximum Temperature Trends - Annual - Coldest Bin



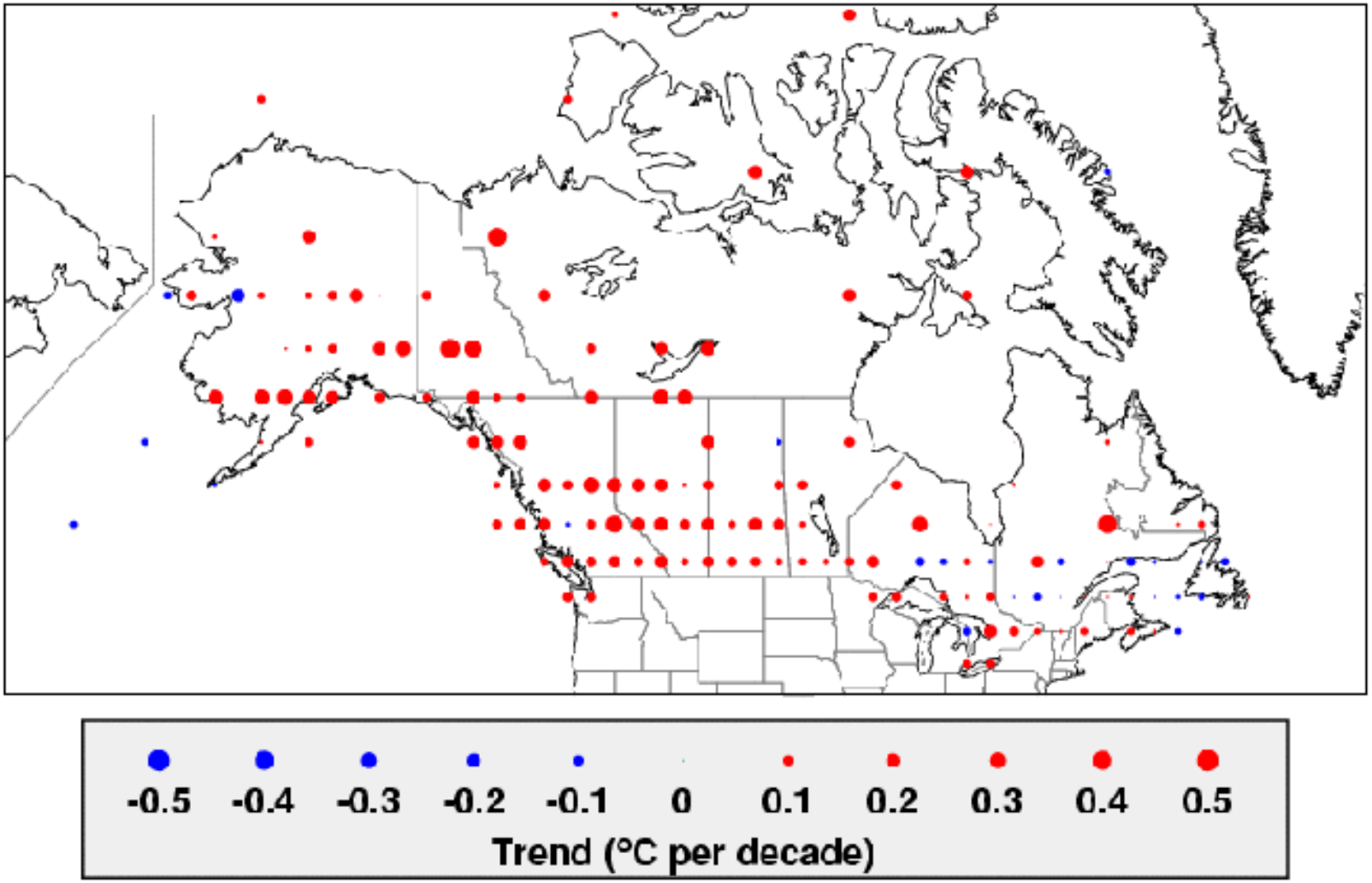
Maximum Temperature Trends - Annual - Warmest Bin



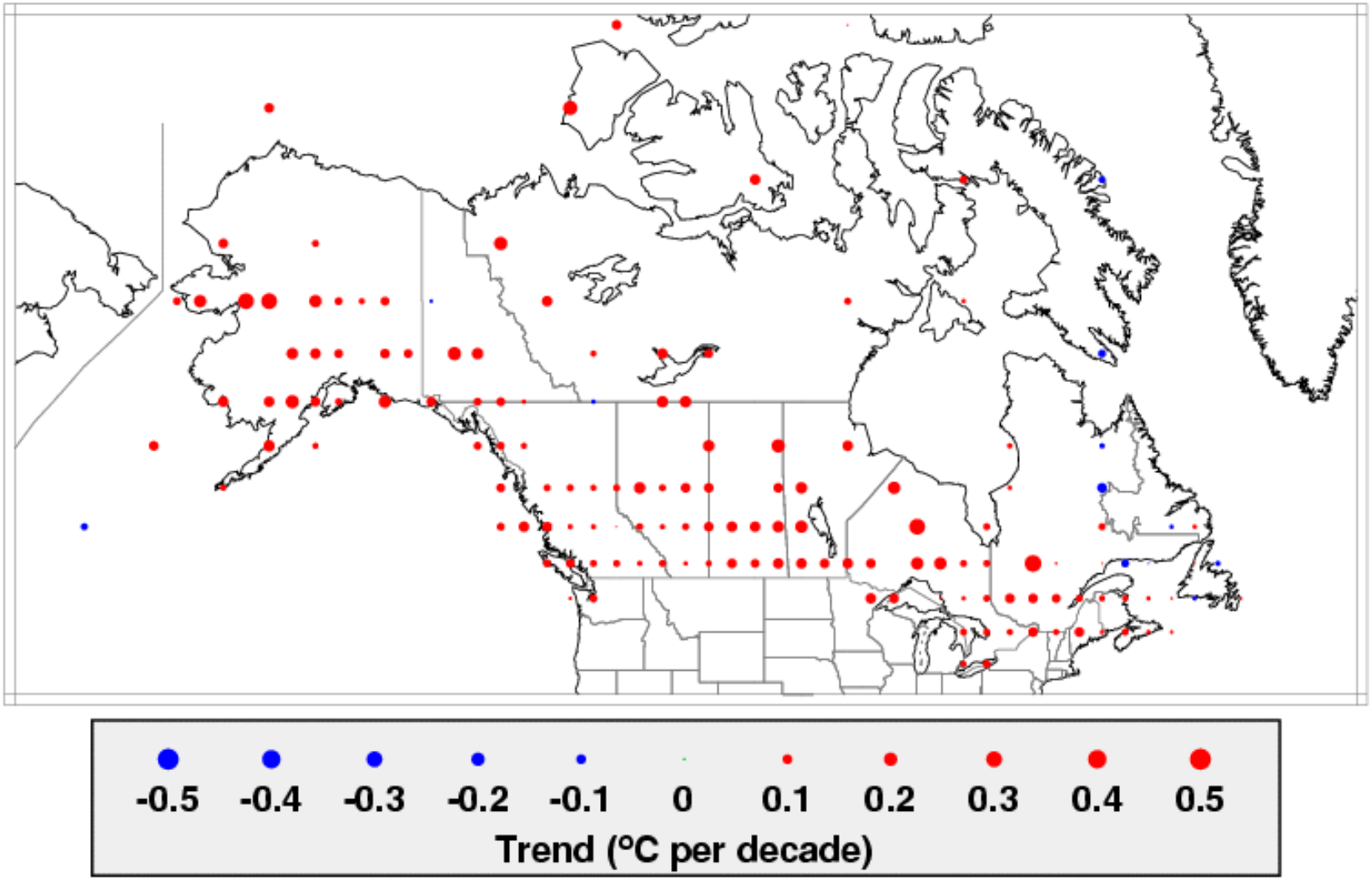
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

Trend (°C per decade)

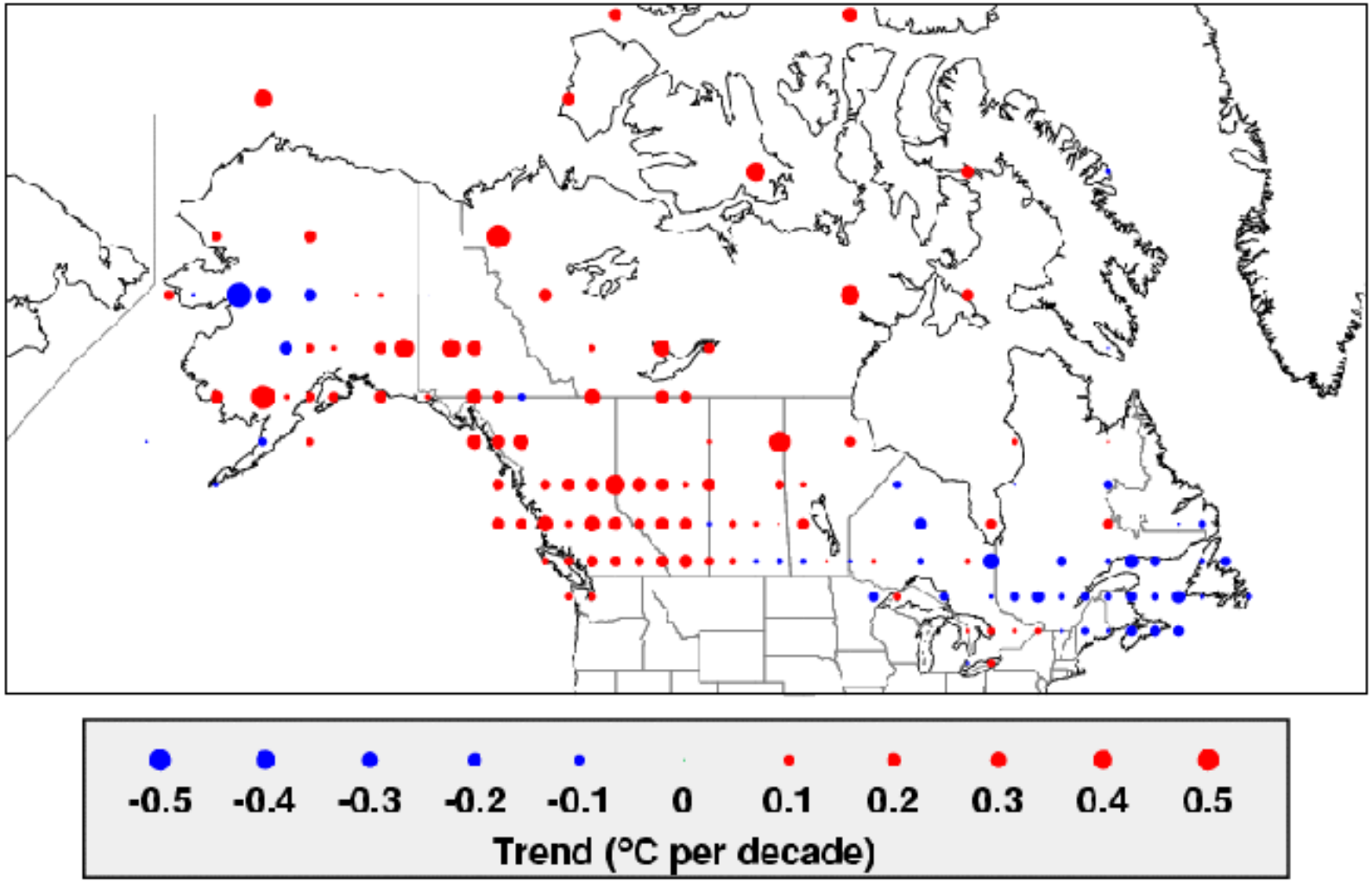
Minimum Temperature Trends - Annual - Coldest Bin



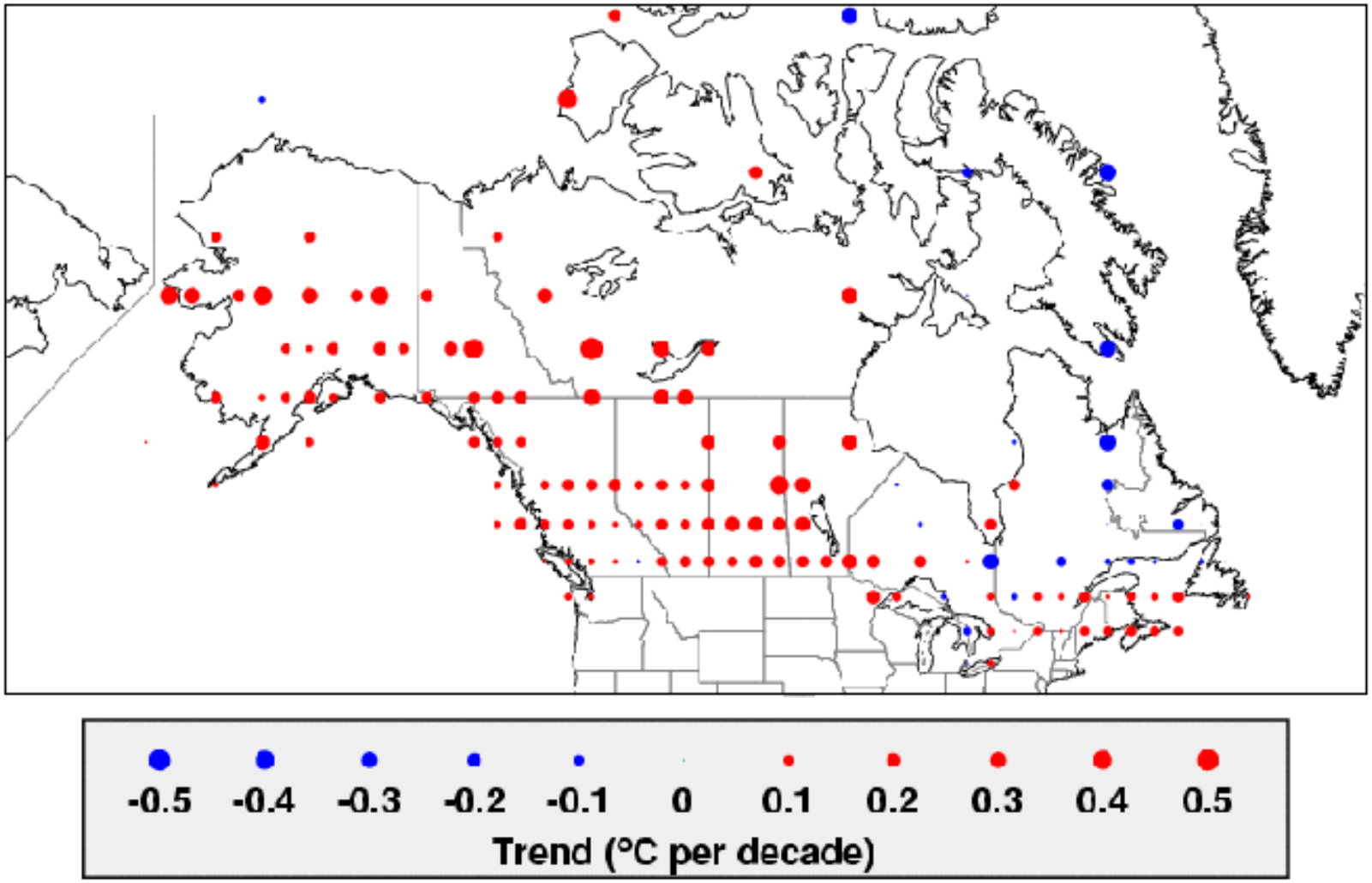
Minimum Temperature Trends - Annual - Warmest Bin



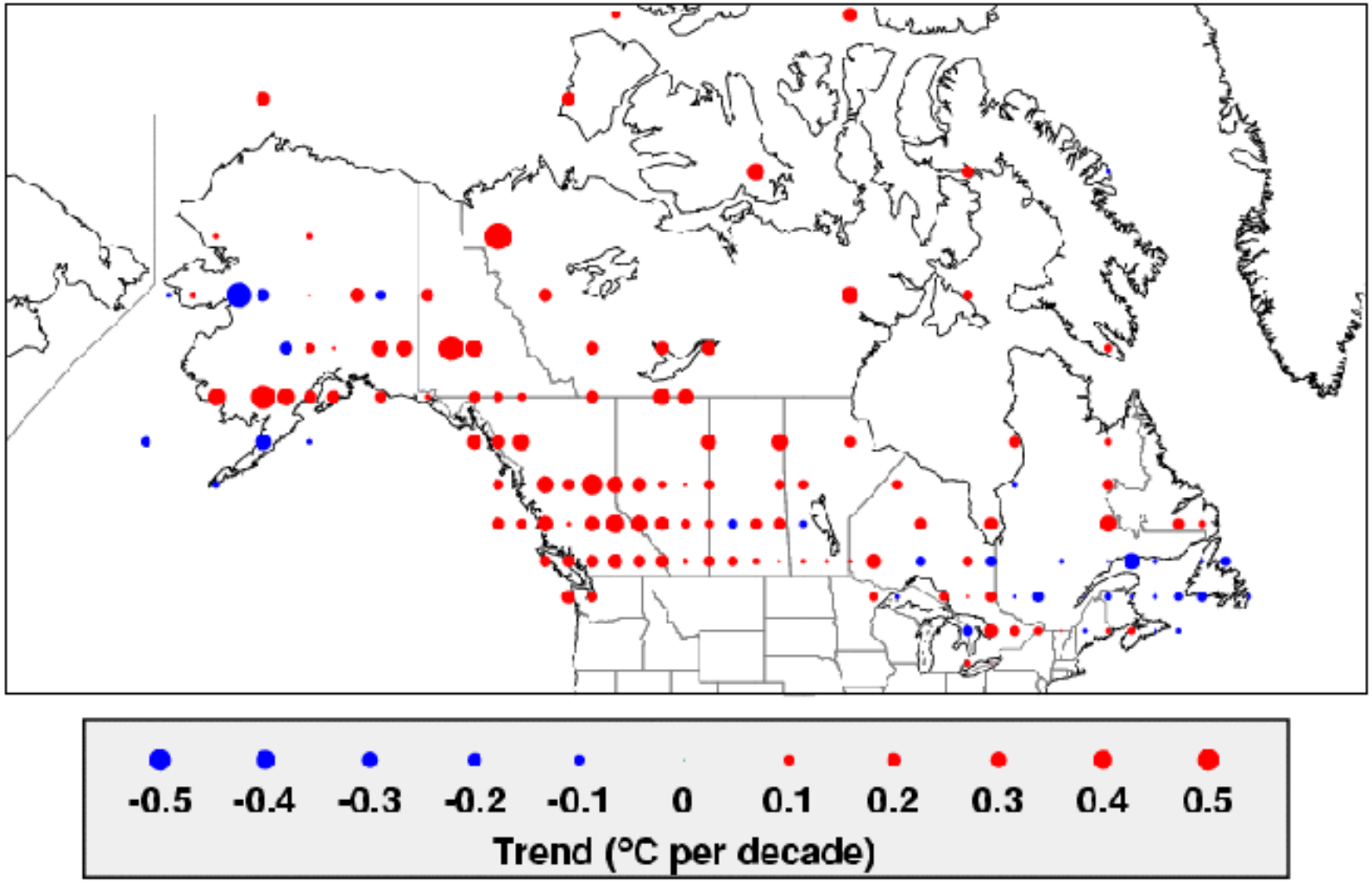
Maximum Temperature Trends - Winter - Coldest Bin



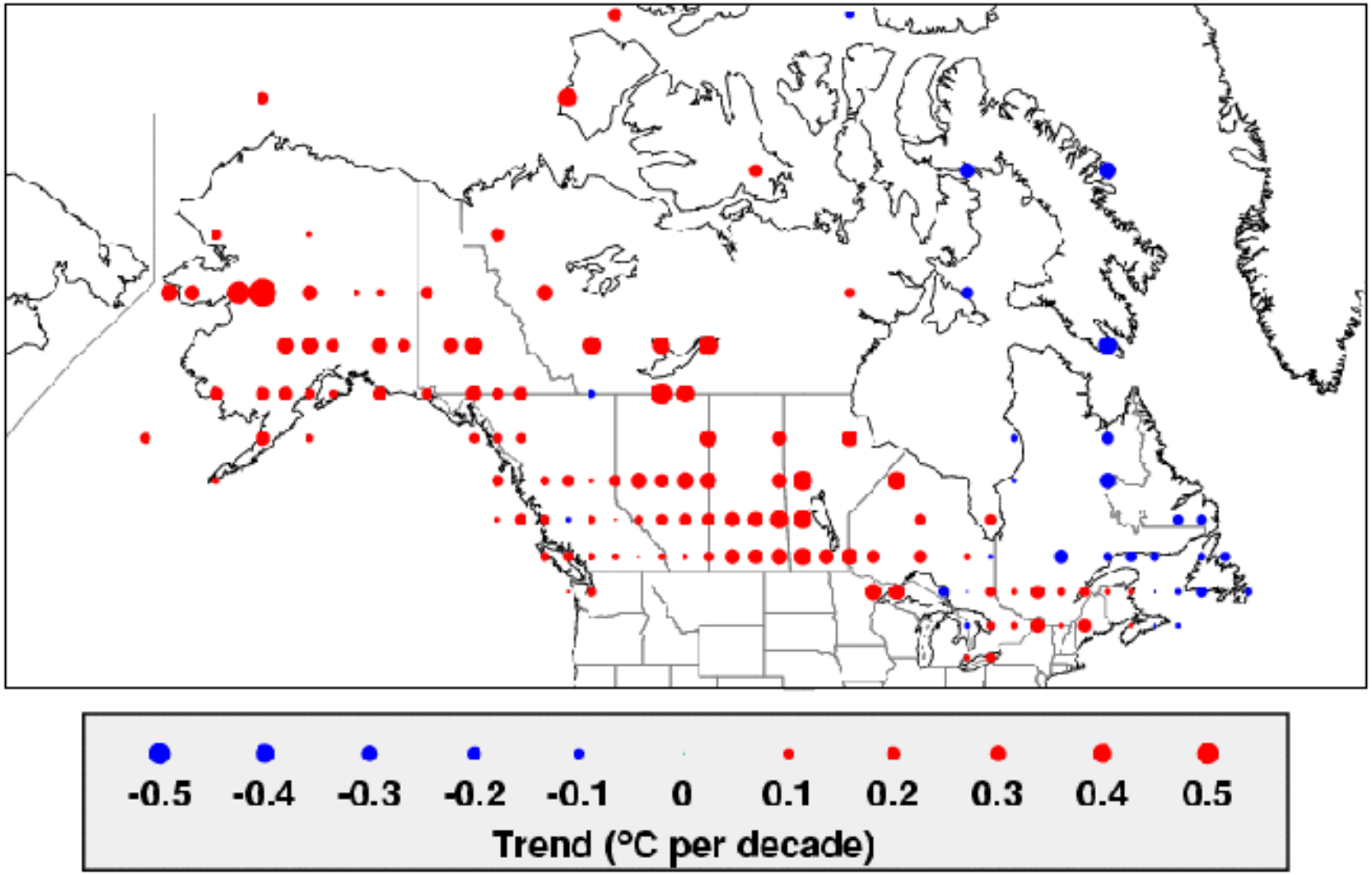
Maximum Temperature Trends - Winter - Warmest Bin



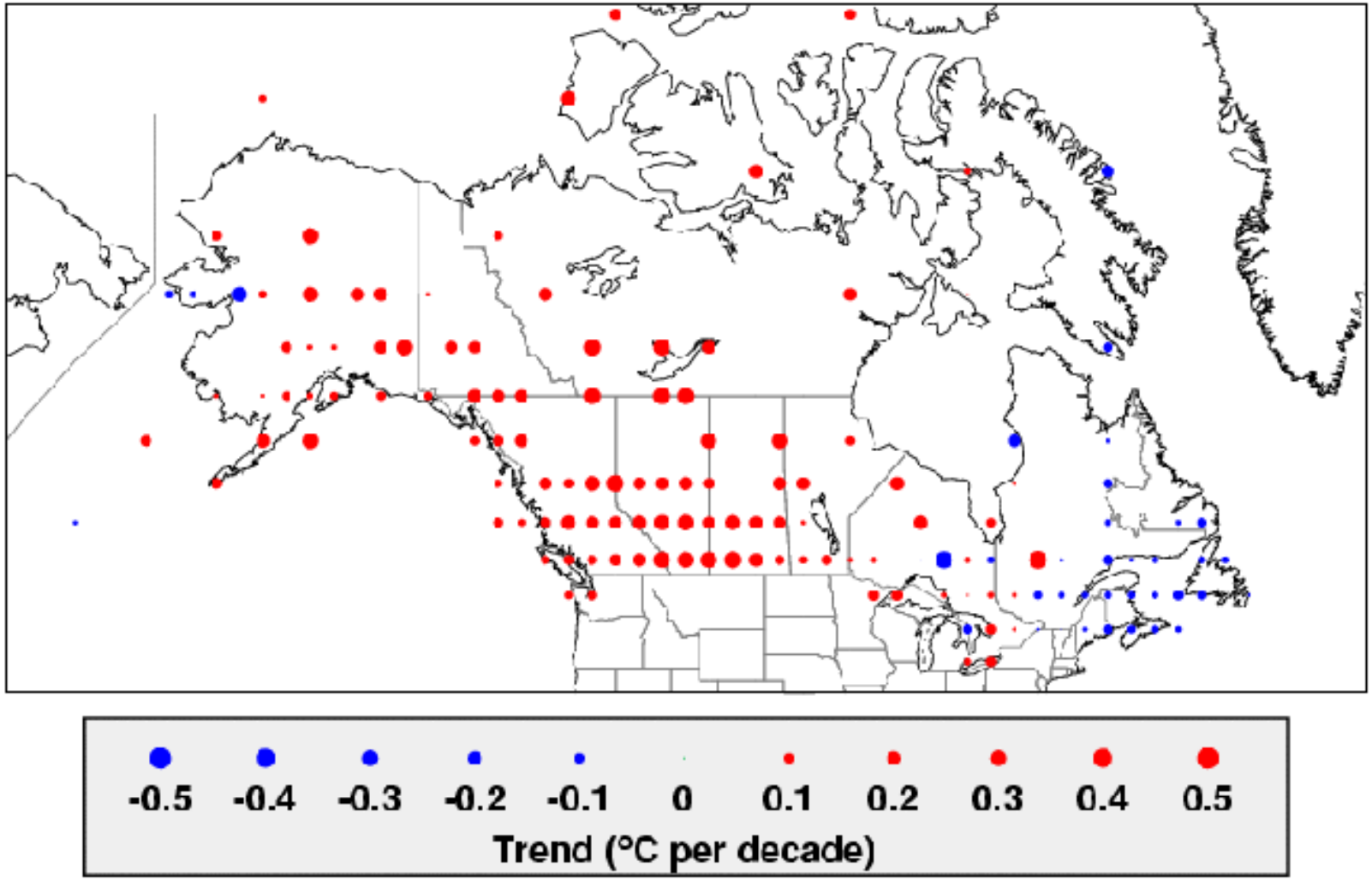
Minimum Temperature Trends - Winter - Coldest Bin



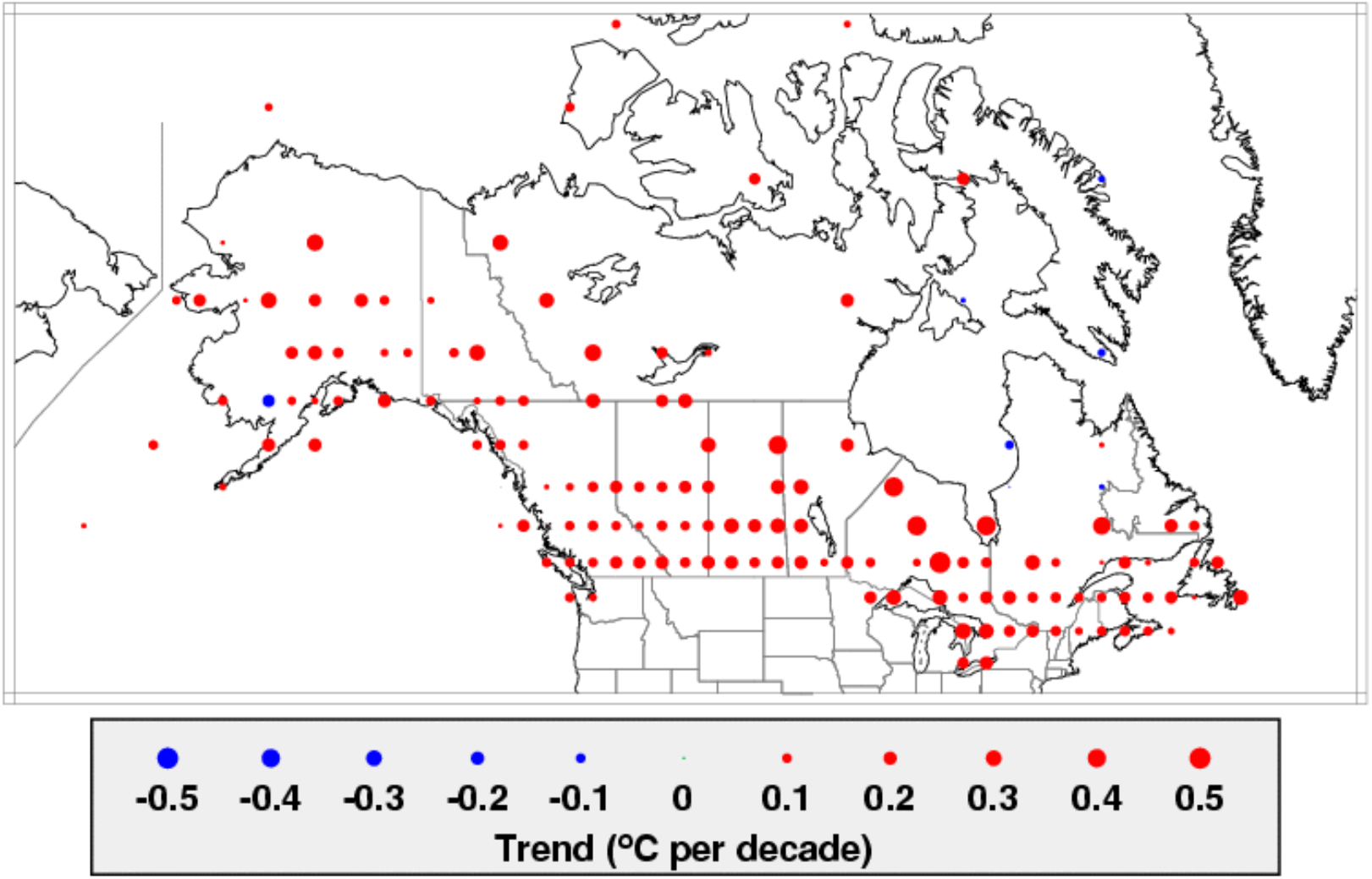
Minimum Temperature Trends - Winter - Warmest Bin



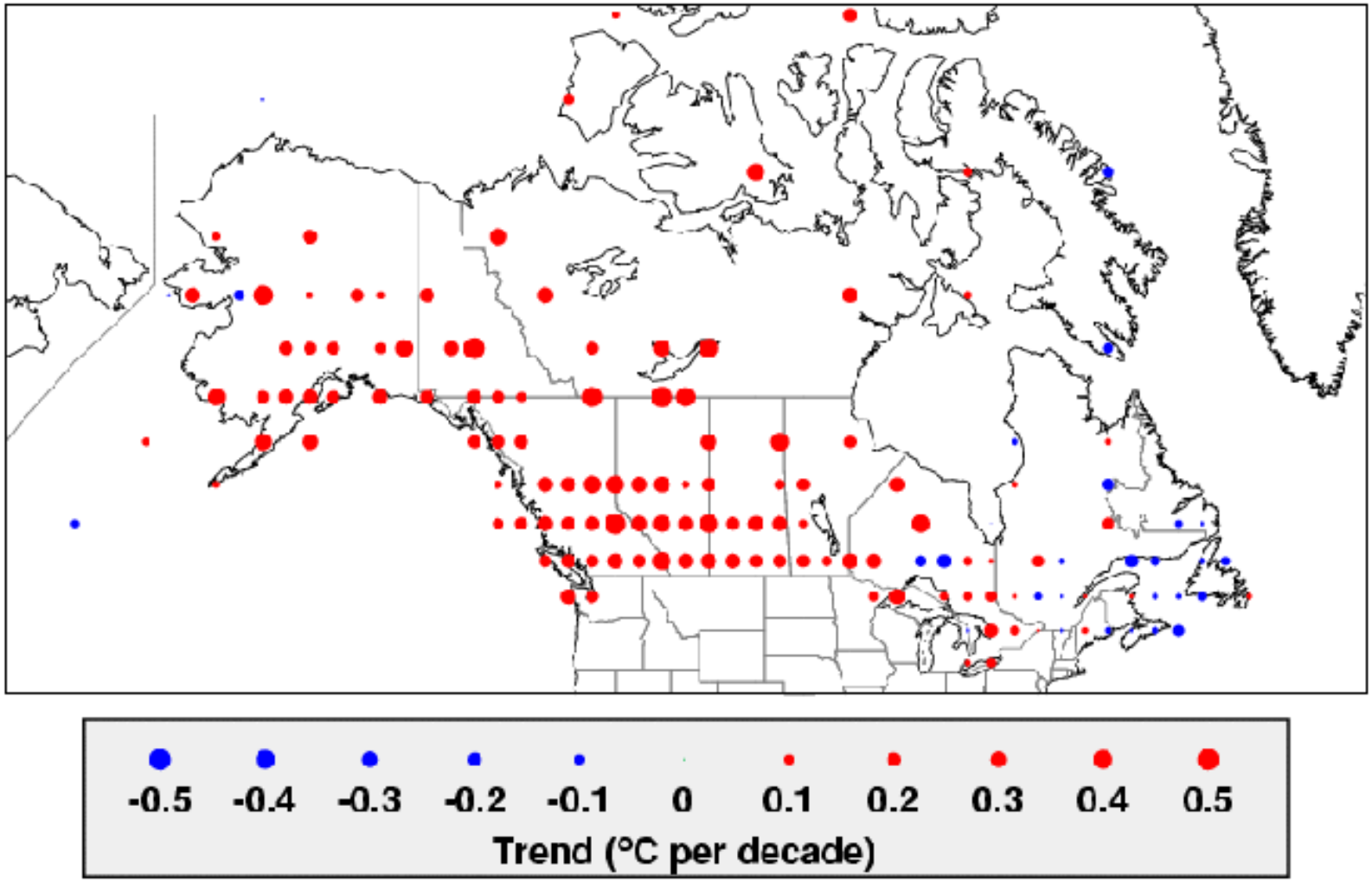
Maximum Temperature Trends - Spring - Coldest Bin



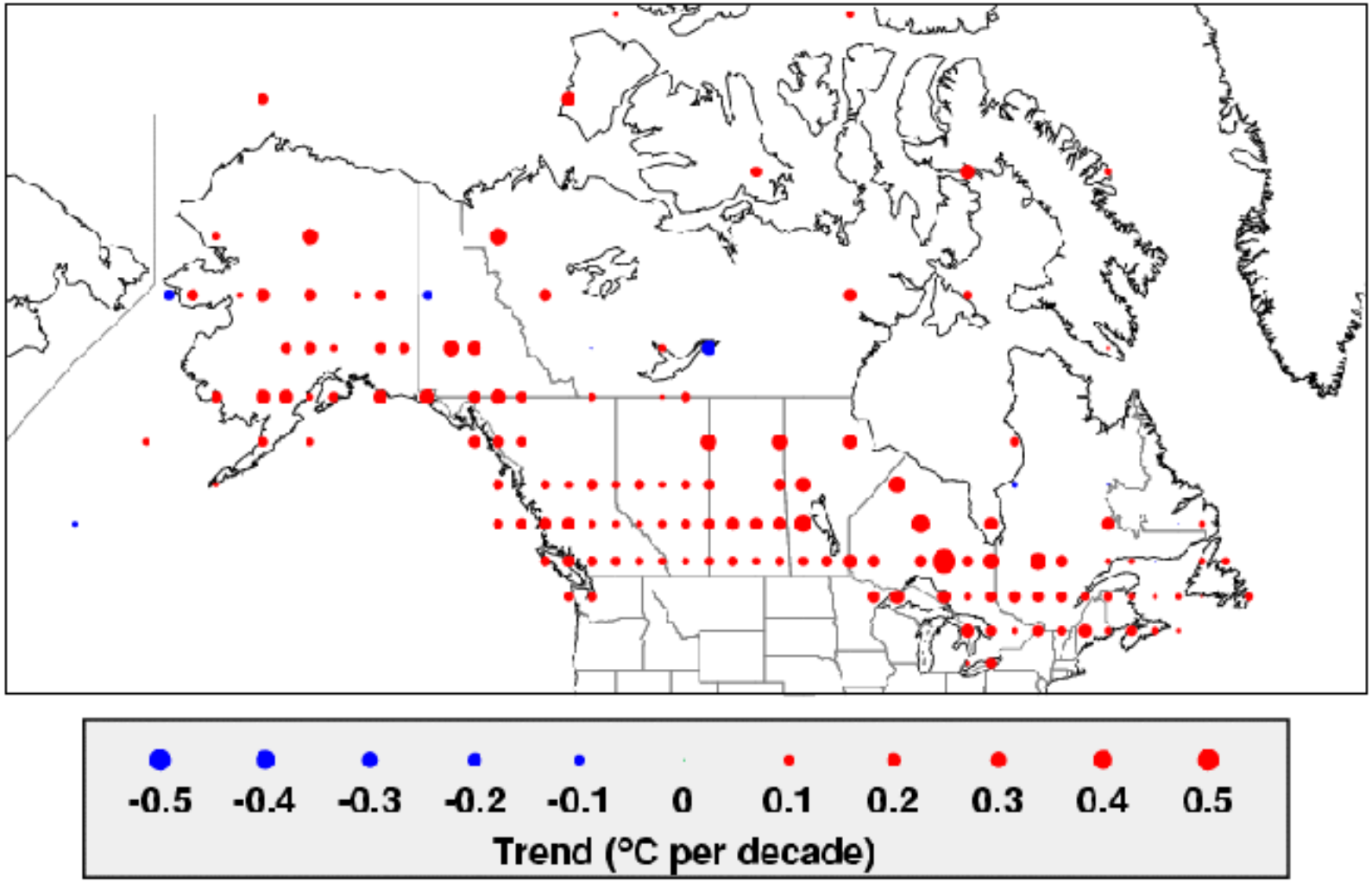
Maximum Temperature Trends - Spring - Warmest Bin



Minimum Temperature Trends - Spring - Coldest Bin

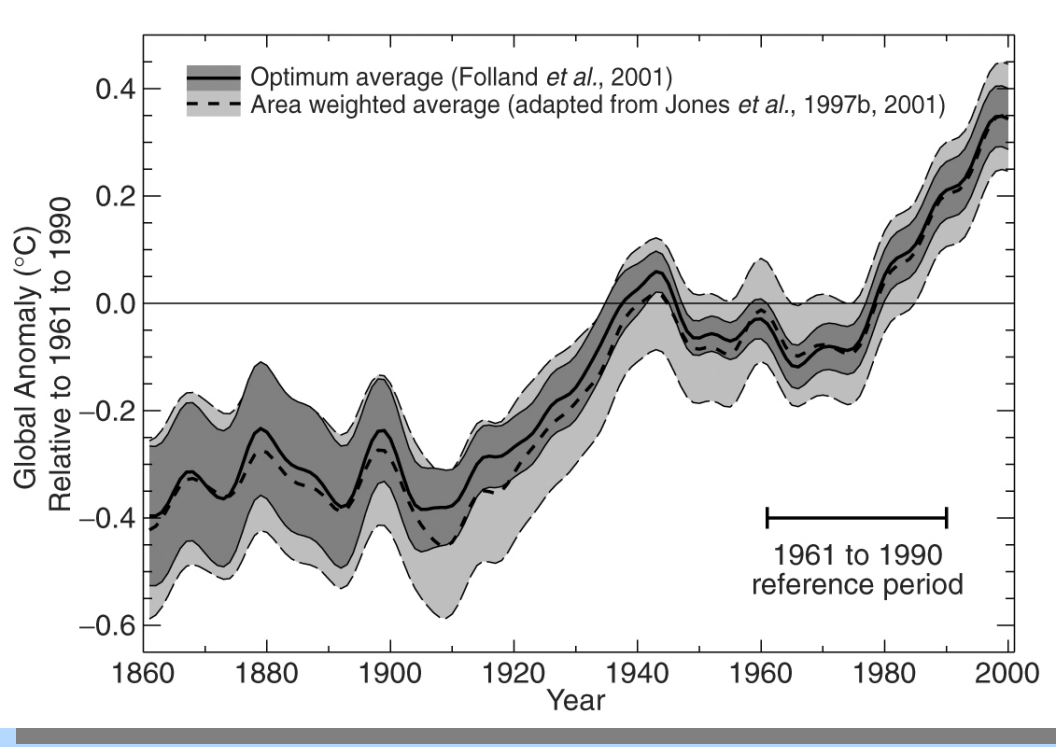


Minimum Temperature Trends - Spring - Warmest Bin



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

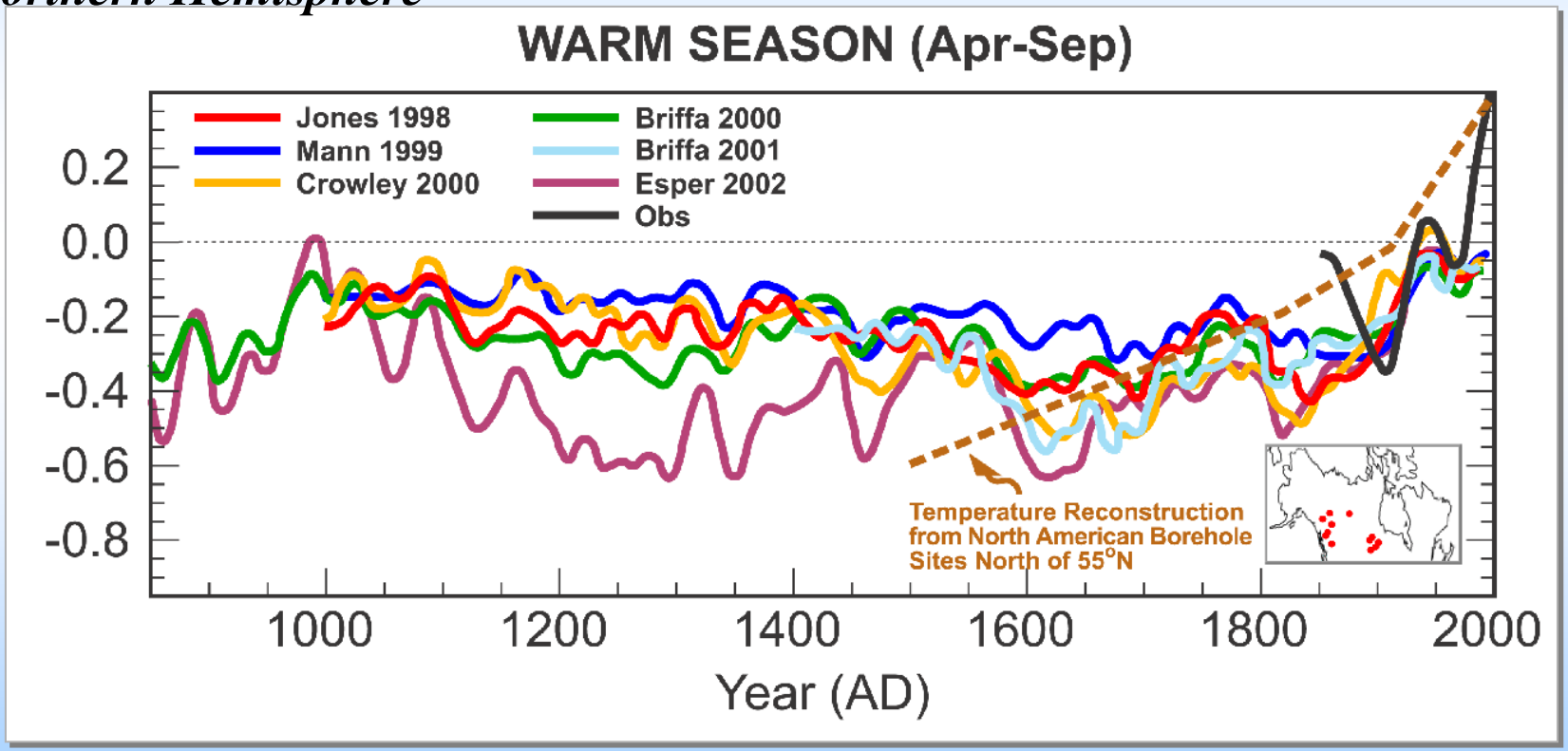


Smoothed annual anomalies of global combined land-surface air and sea surface temperatures (°C).

Differences Among Data Sets / Analyses

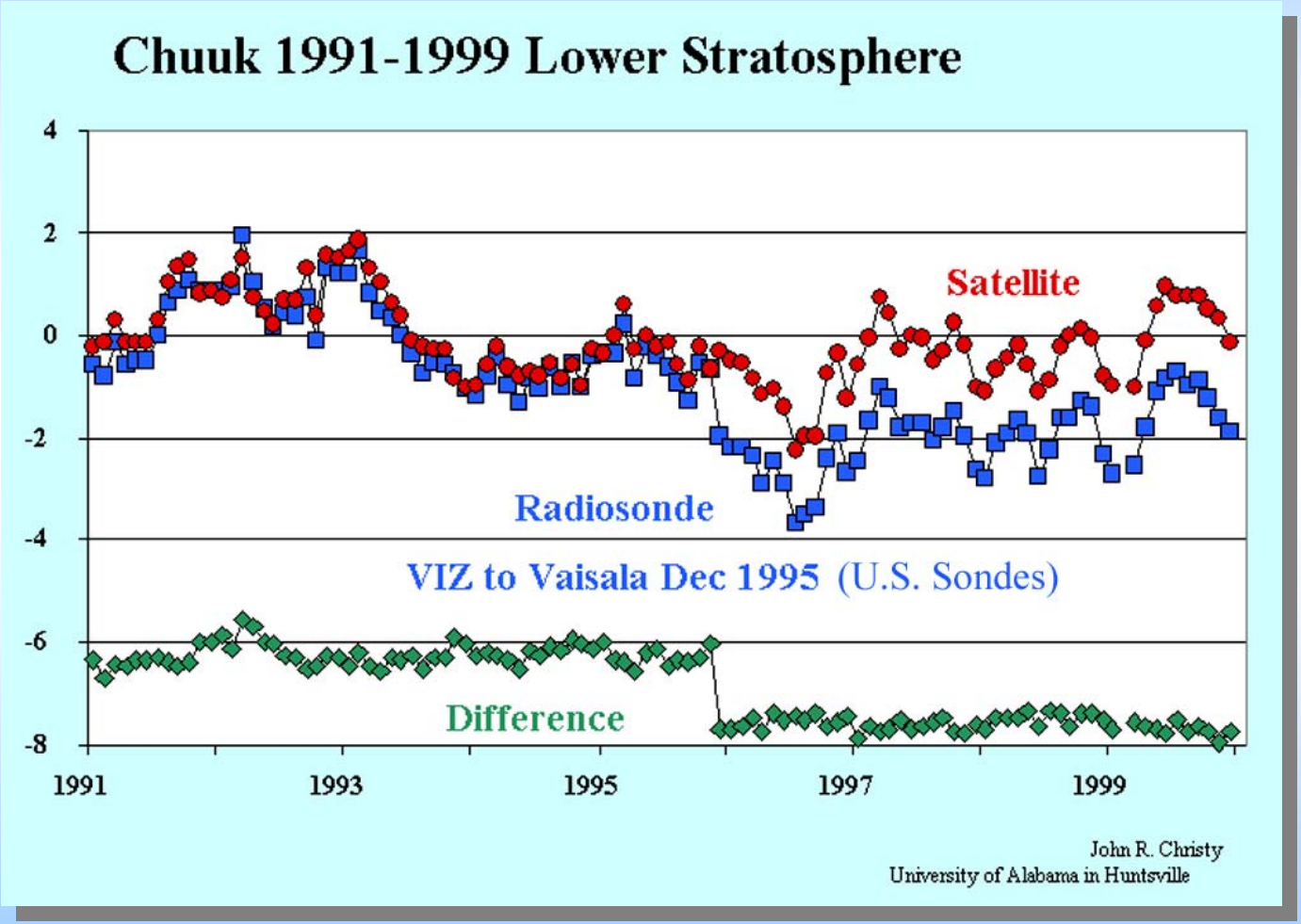
- ✓ **Considerable difference in variability of Paleo data**

Northern Hemisphere



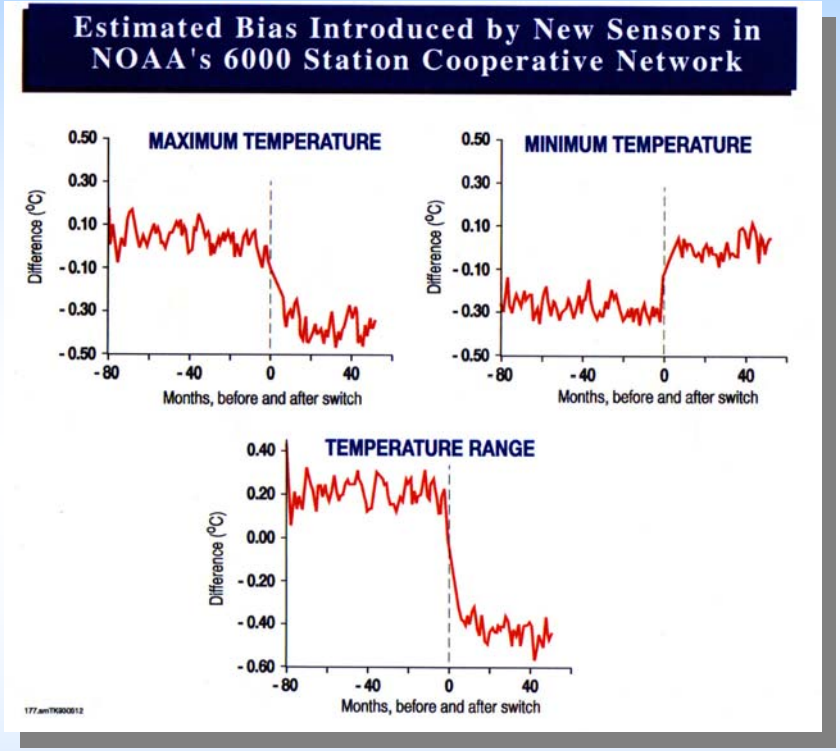
Observing and Data System Deficiencies

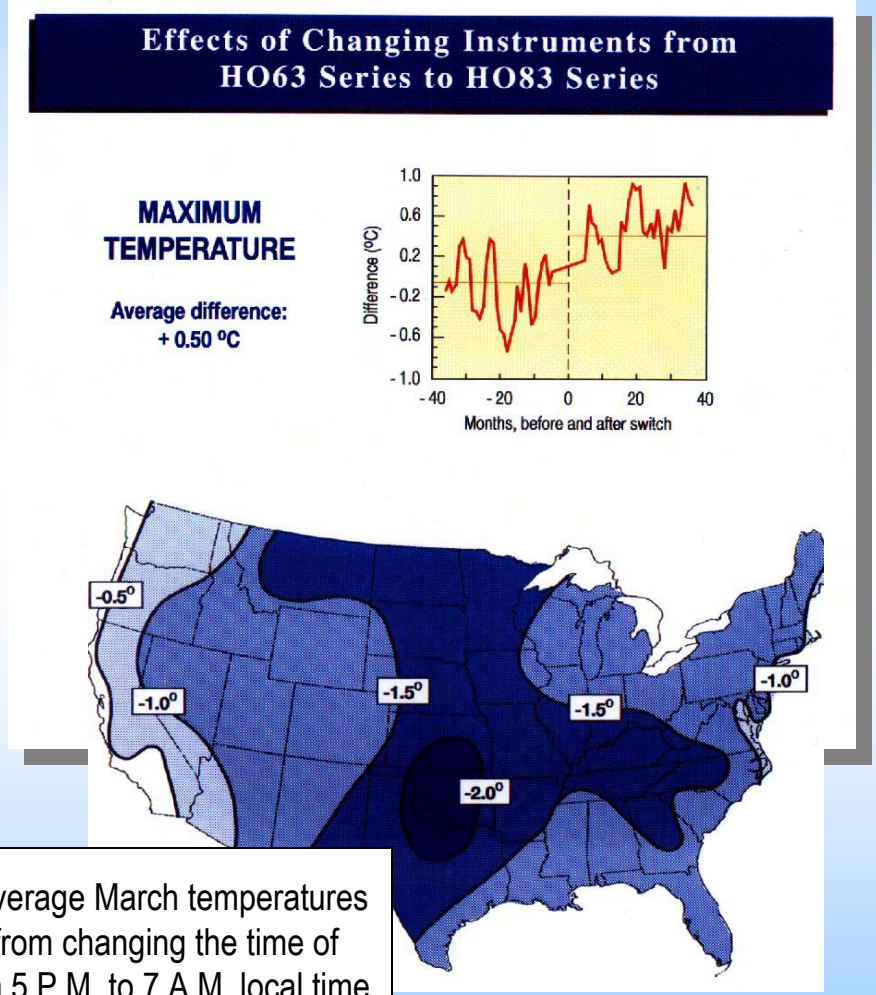
- ✓ Biases in radiosondes detected by satellite data



Observing and Data System Deficiencies

✓ We do not have an adequate Climate Observing System



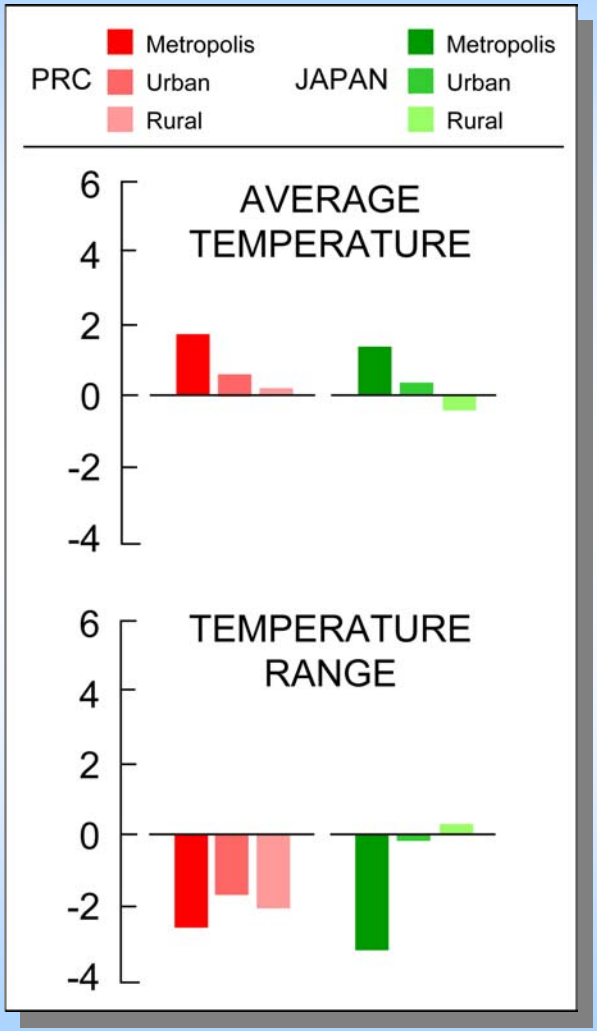


✓ Most observations taken for other purposes, e.g., weather forecasting

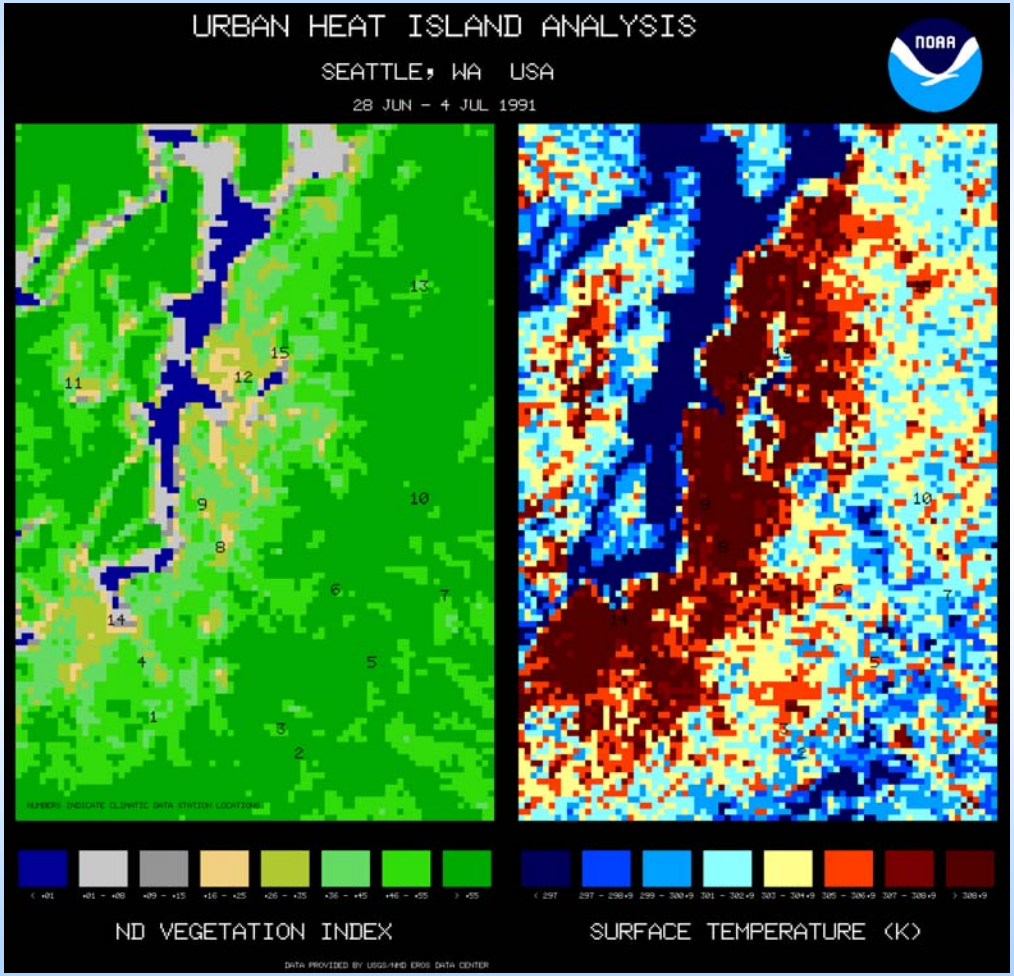
Change in the average March temperatures (°C) resulting from changing the time of observation from 5 P.M. to 7 A.M. local time

Observing and Data System Deficiencies

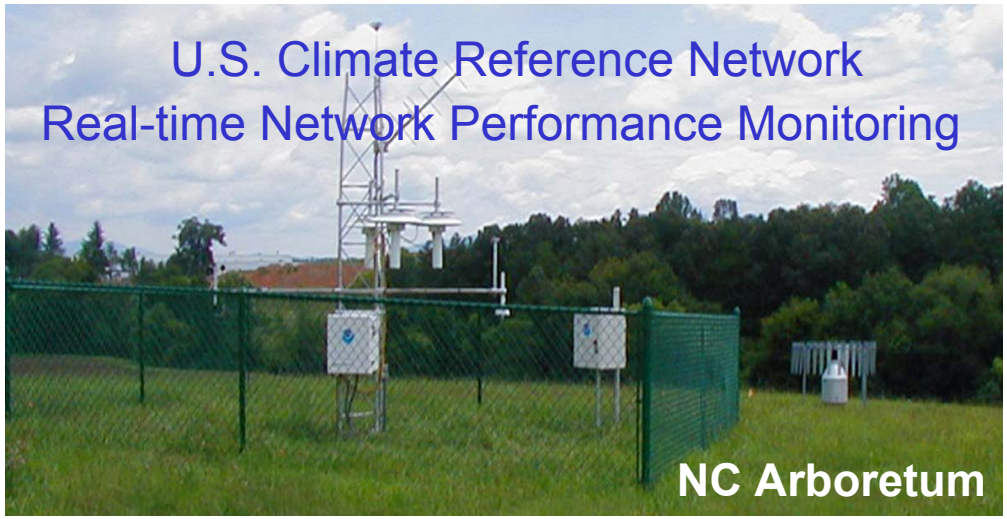
✓ Urban Heat Island Effects

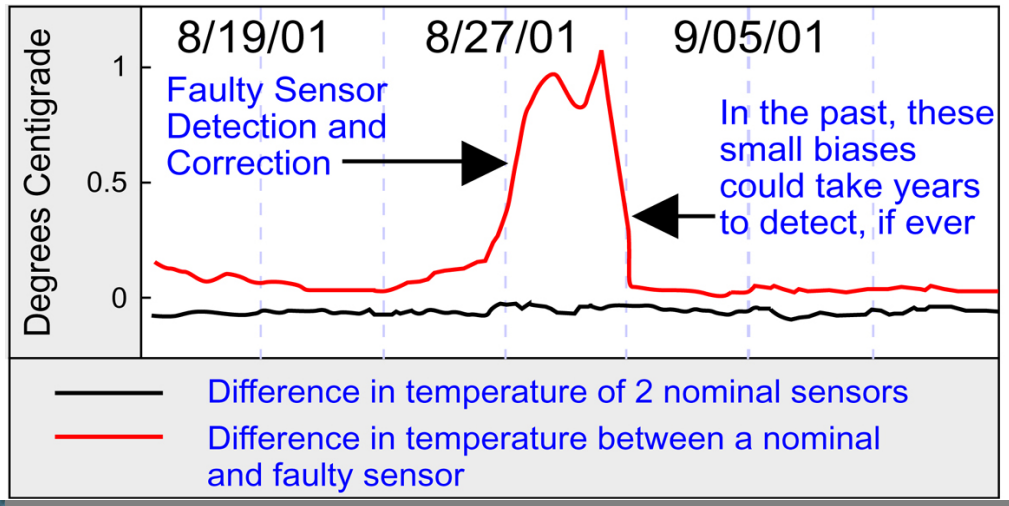


✓ Land use vs temperature

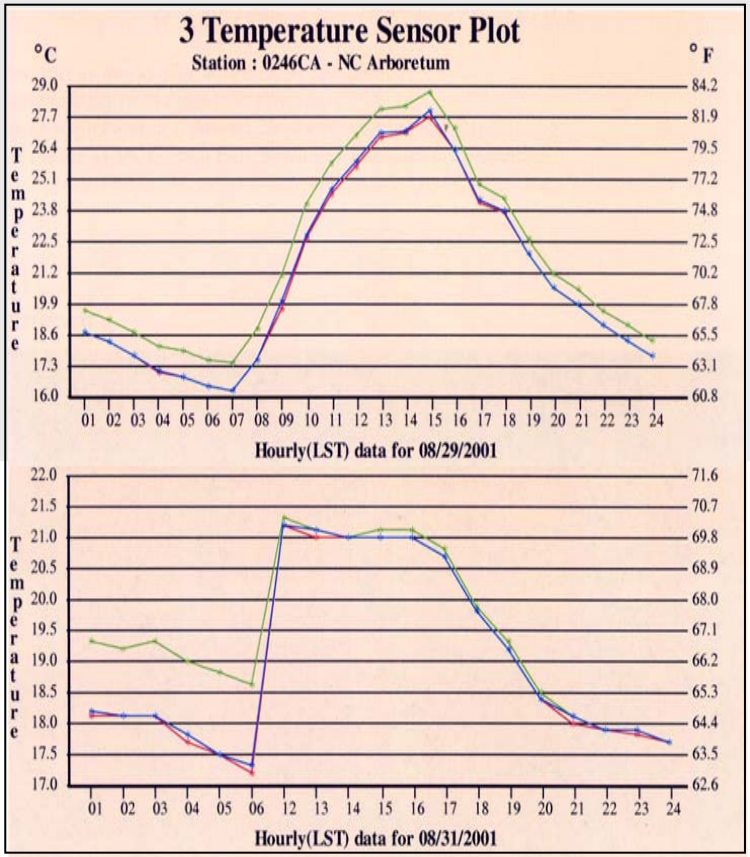


The Climate Observing System: *What is needed?*





High Quality Temperature Measurements



Summary/Conclusions

- Both maximum and minimum temperatures continue to rise for most of globe now at a faster rate than earlier work. Minimums rising at a faster rate than maximums. A few exceptions (e.g.eastern Canada).
- Strongest warming is in minimum temperatures in Winter and Spring.

Summary/Conclusions

- For most of higher latitude NA, strongest warming is occurring in the coldest days, minimum temperature.
- However, some areas show opposite (e.g. eastern Canada).
- Biggest effect appears to be in Winter, then Spring.
- Some interesting patterns emerge such as the flip-flop in western Alaska, and eastern Canada.
- Why? Is it related to AO, GHGs, some combination?

Summary/Conclusions

- Significant uncertainties remain due to numerous problems with time dependent biases.
- More work is needed to address issues and to develop high quality climate observing systems.