Observed Climate Variability and Change: Evidence and Issues Related to Uncertainty

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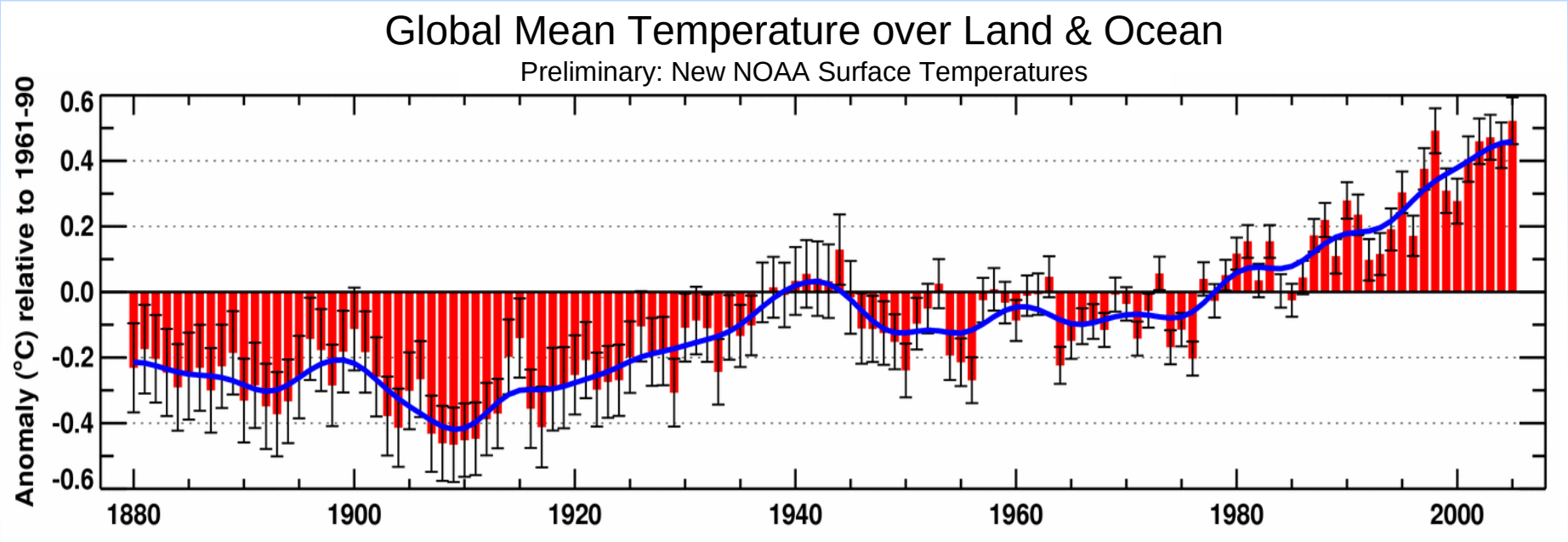
Overview

- Some examples of observed climate change.
  - Has it warmed?
    - Observations and models.
  - Has precipitation changed?
  - Have extreme events changed?

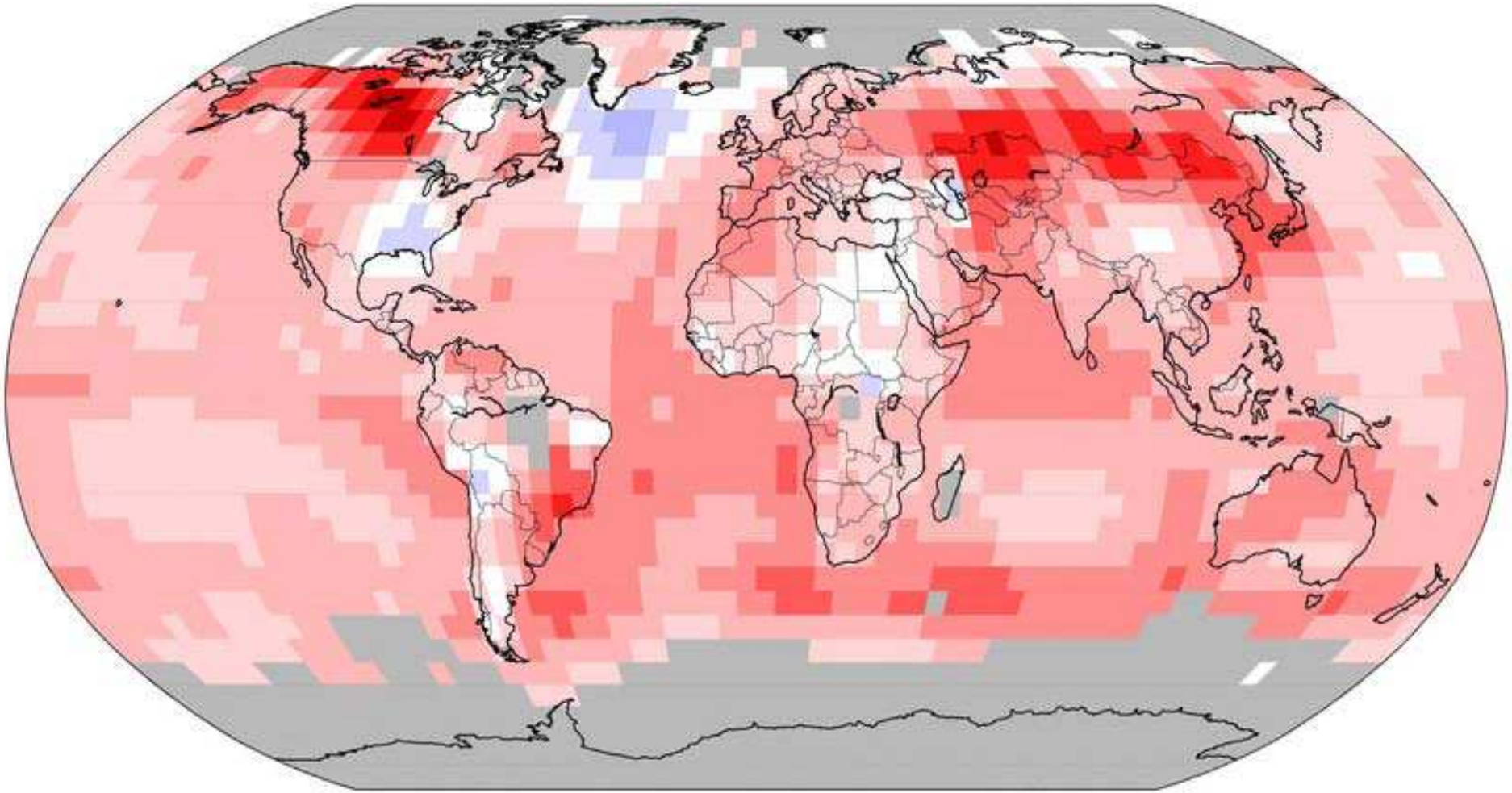
- How confident are we in these results?
  - Data and Observational Issues that can lead to uncertainties

Experimental Land & Ocean Blend



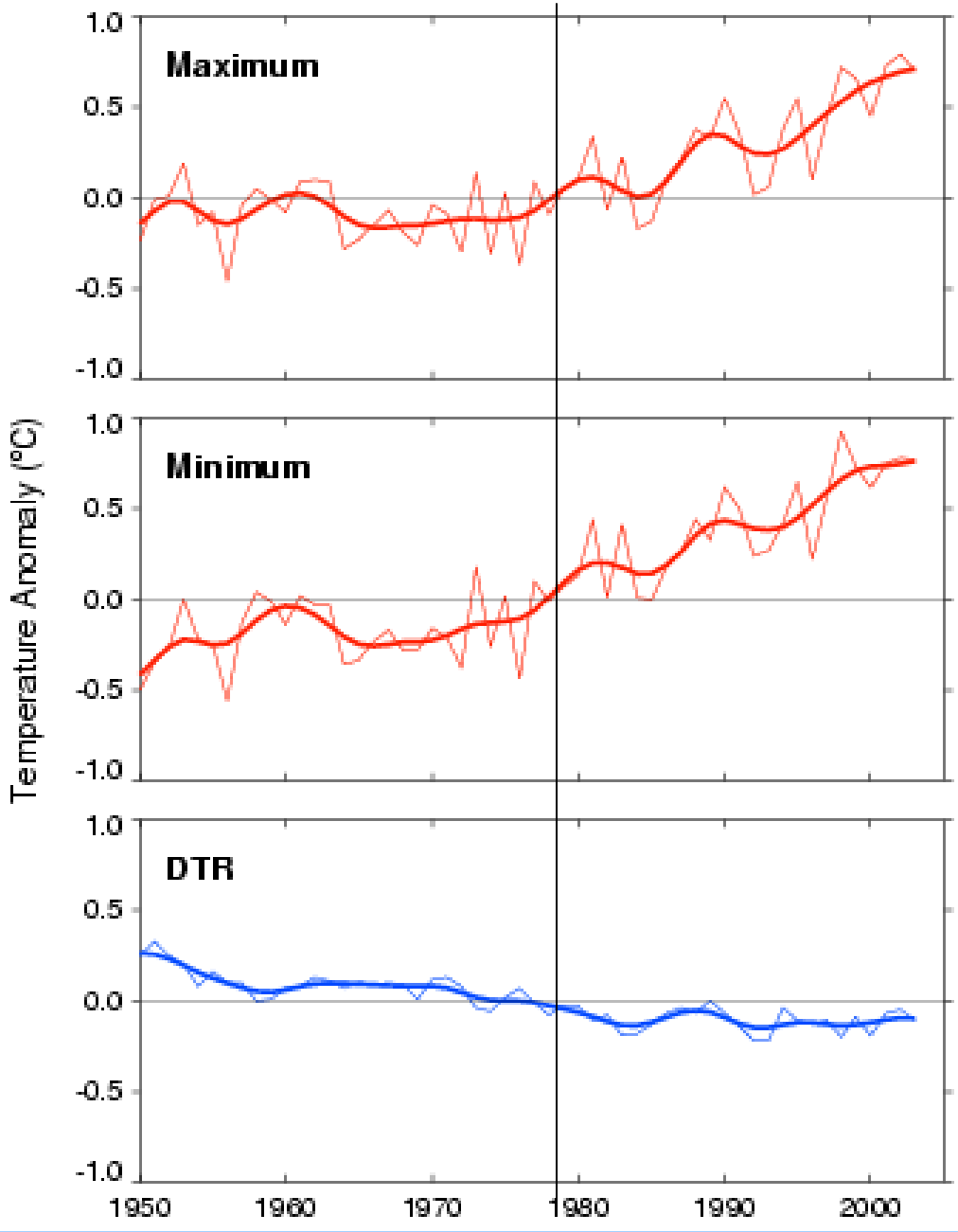
- No one year definitively warmest on record
- Sampling, Random and Bias Errors analyzed to estimate uncertainty in annual anomalies
  - Sampling and Random Errors decrease with time due to improved coverage and better instruments and measurement techniques

Trend in Annual TMEAN, 1901 to 2004



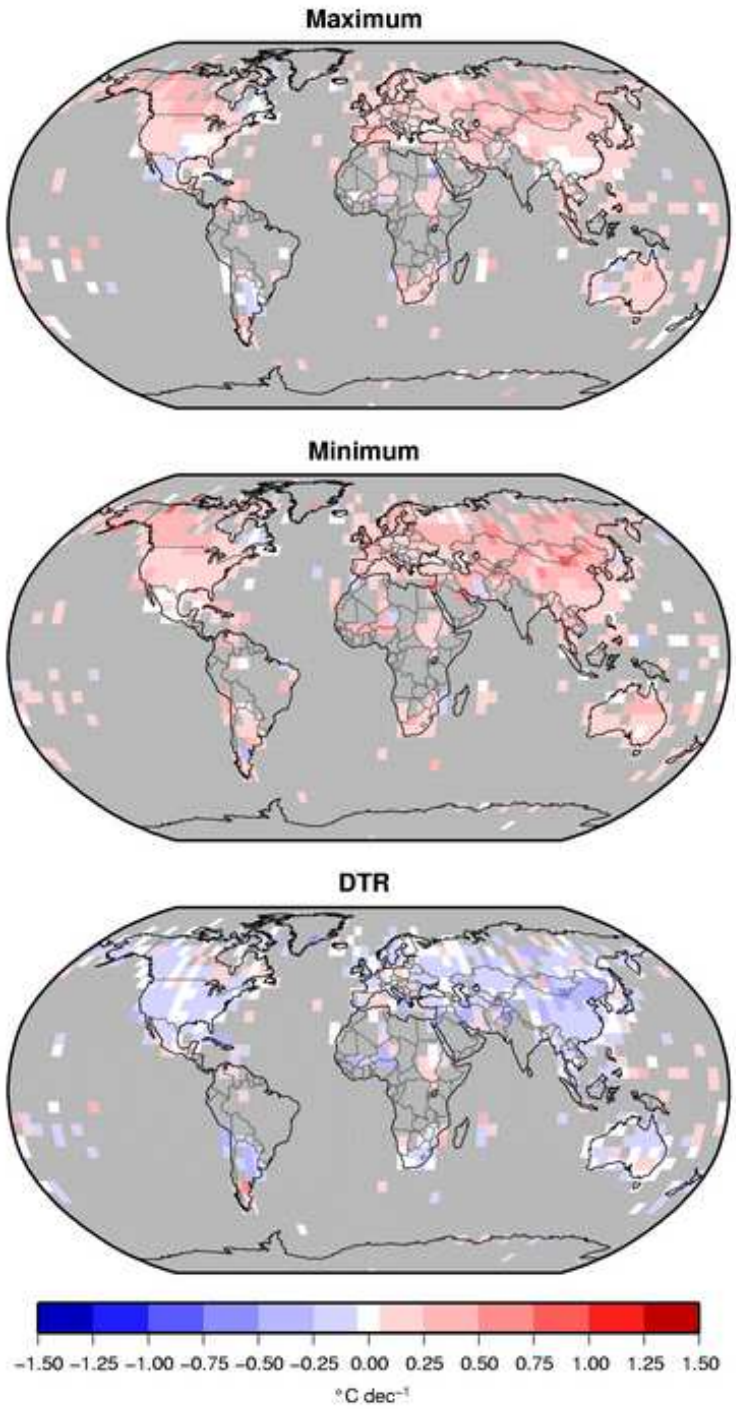
-2.0 -1.7 -1.4 -1.1 -0.8 -0.5 -0.2 0.0 0.2 0.5 0.8 1.1 1.4 1.7 2.0

Deg C / Century



Globally Averaged Maximum, Minimum and Diurnal Temperature Range 1950-2004.

From Vose et al. 2005

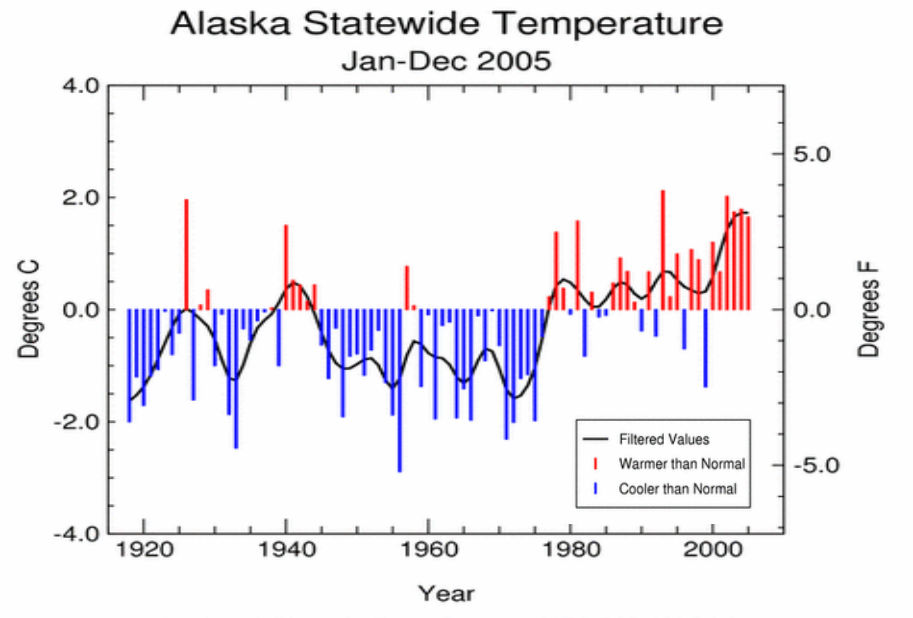


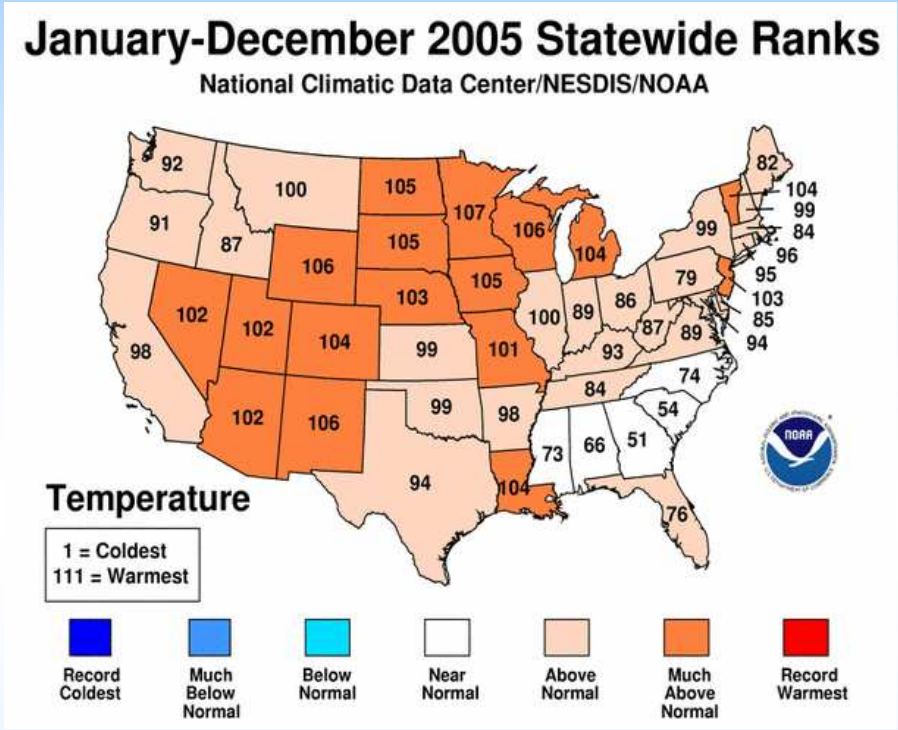
Maximum, Minimum and Diurnal Temperature Range Trends. 1950-2004

From Vose et al. 2005

US Temperatures

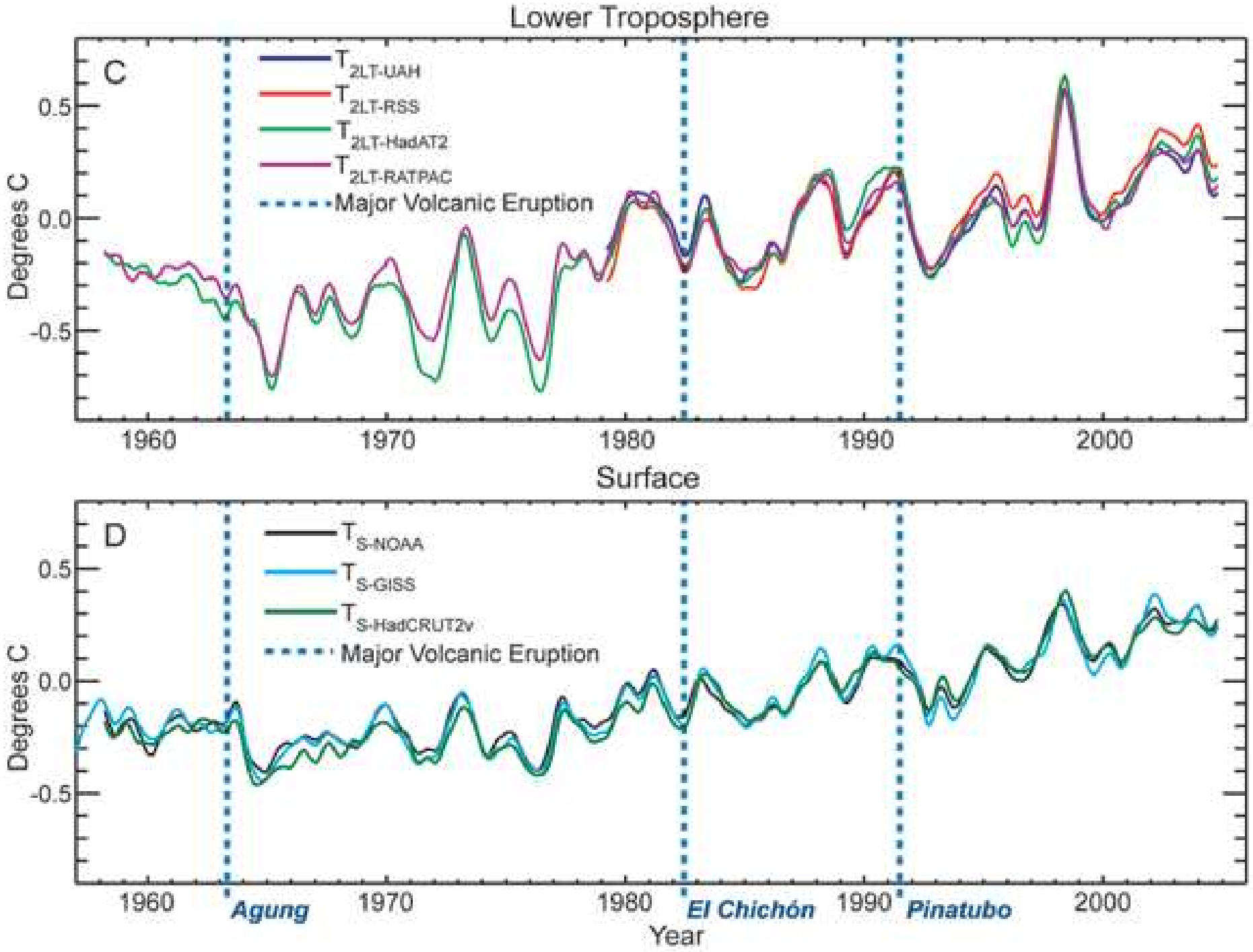
- **2005 Annual Temperature 13th warmest on record**
- **17 of past 20 years warmer than average**





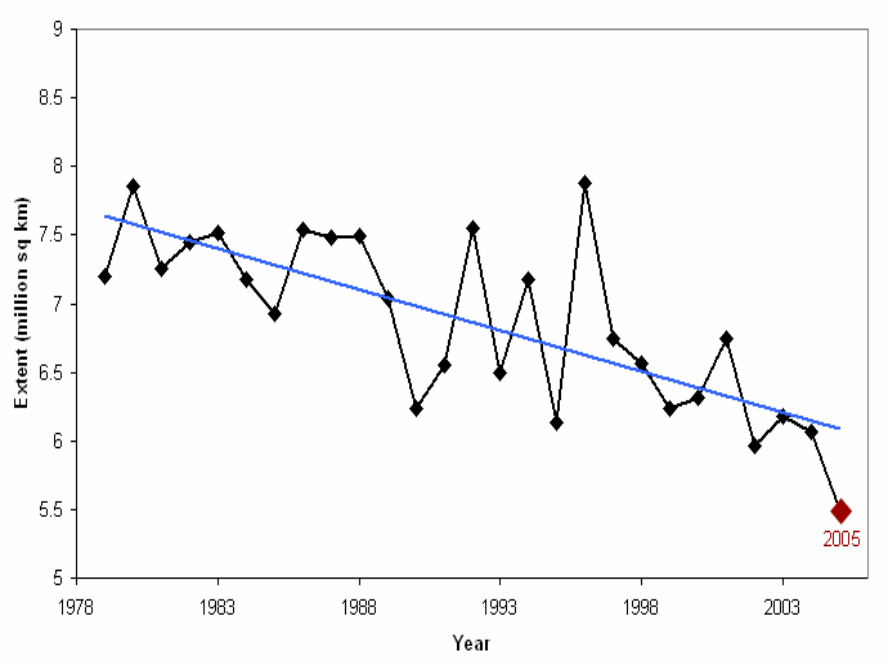
- **No state colder than average**
- **Alaska: 6th warmest year since 1918**

- What about the difference between surface and tropospheric warming?
  - Old: satellites show little or no warming of the lower troposphere, while surface warms.
  - New: satellites and weather balloon observations of troposphere and surface temperatures now much closer, both show warming.


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

Record Low Arctic Sea Ice Extent

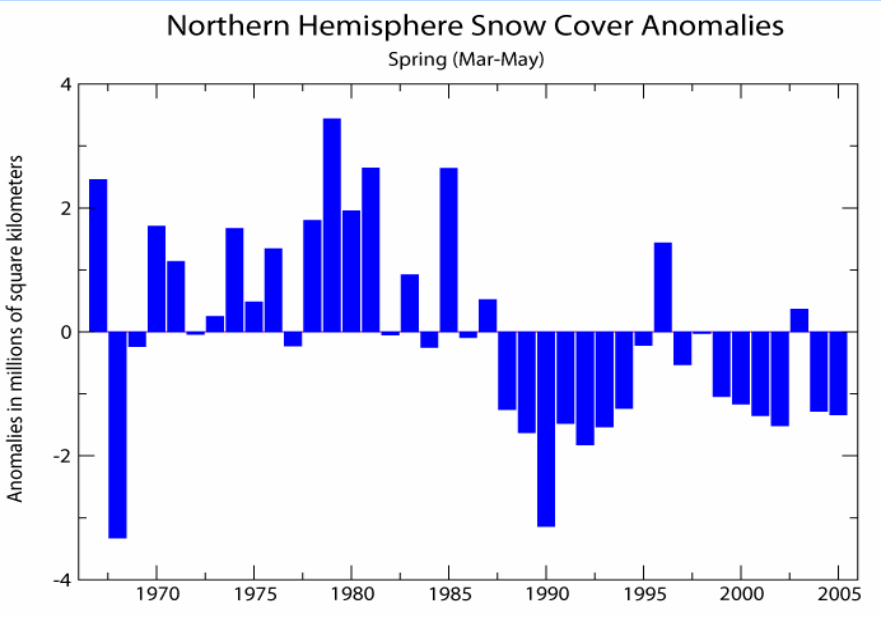
- Largest temperature anomalies in high latitudes of Northern Hemisphere
- Reflecting this warmth was a record low arctic sea ice extent in September
- 8% / Decade decline in end-of-summer sea ice since 1979

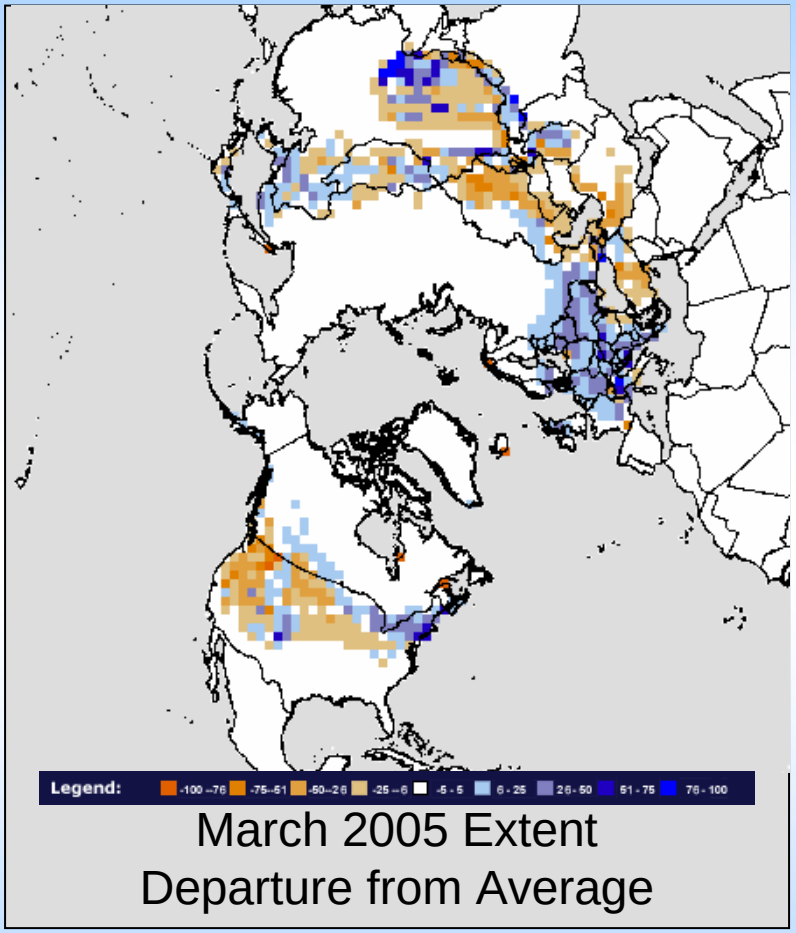


September Arctic Sea Ice Extent

Provided by NSIDC

N. Hem. Spring Snow Cover Extent



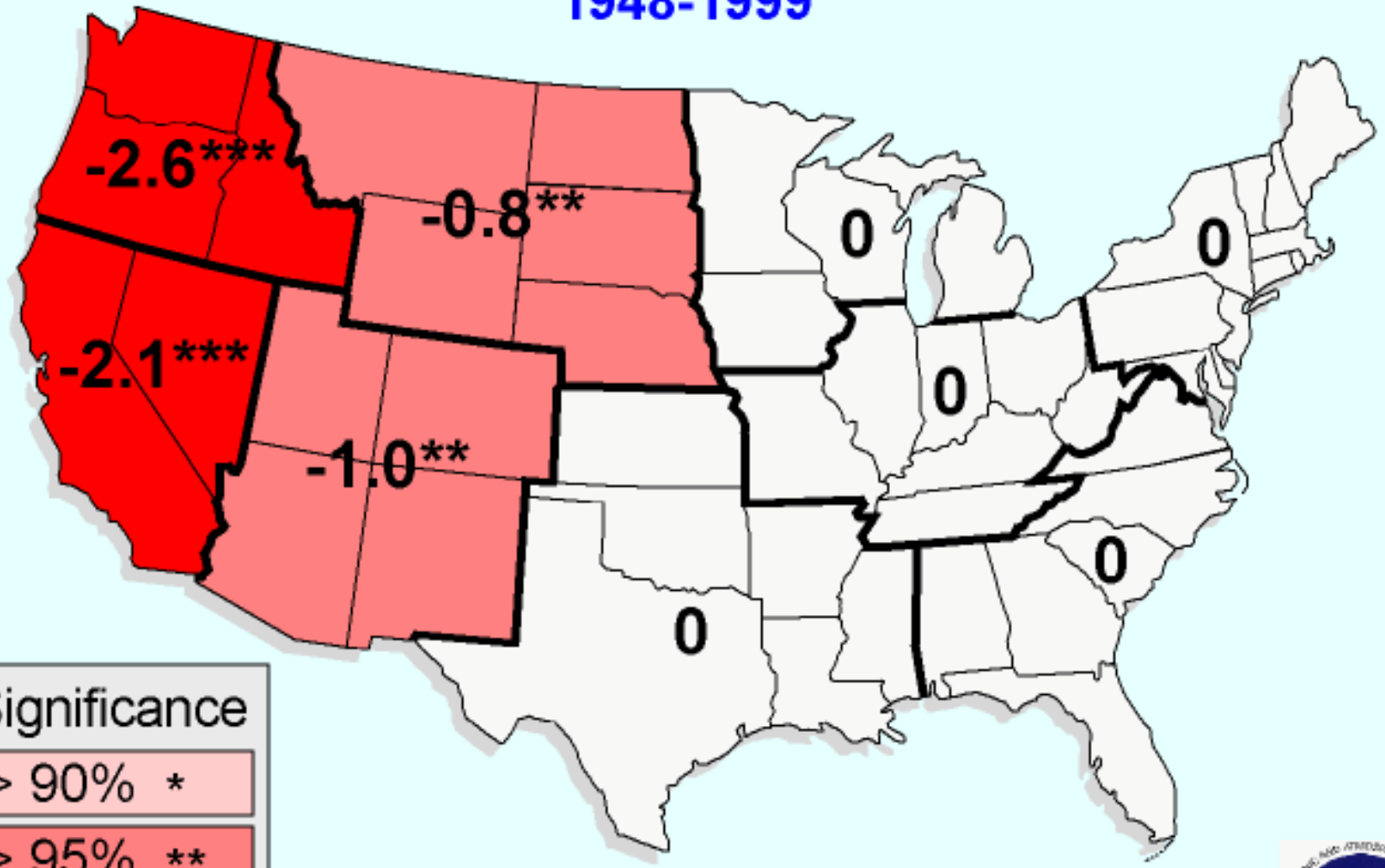


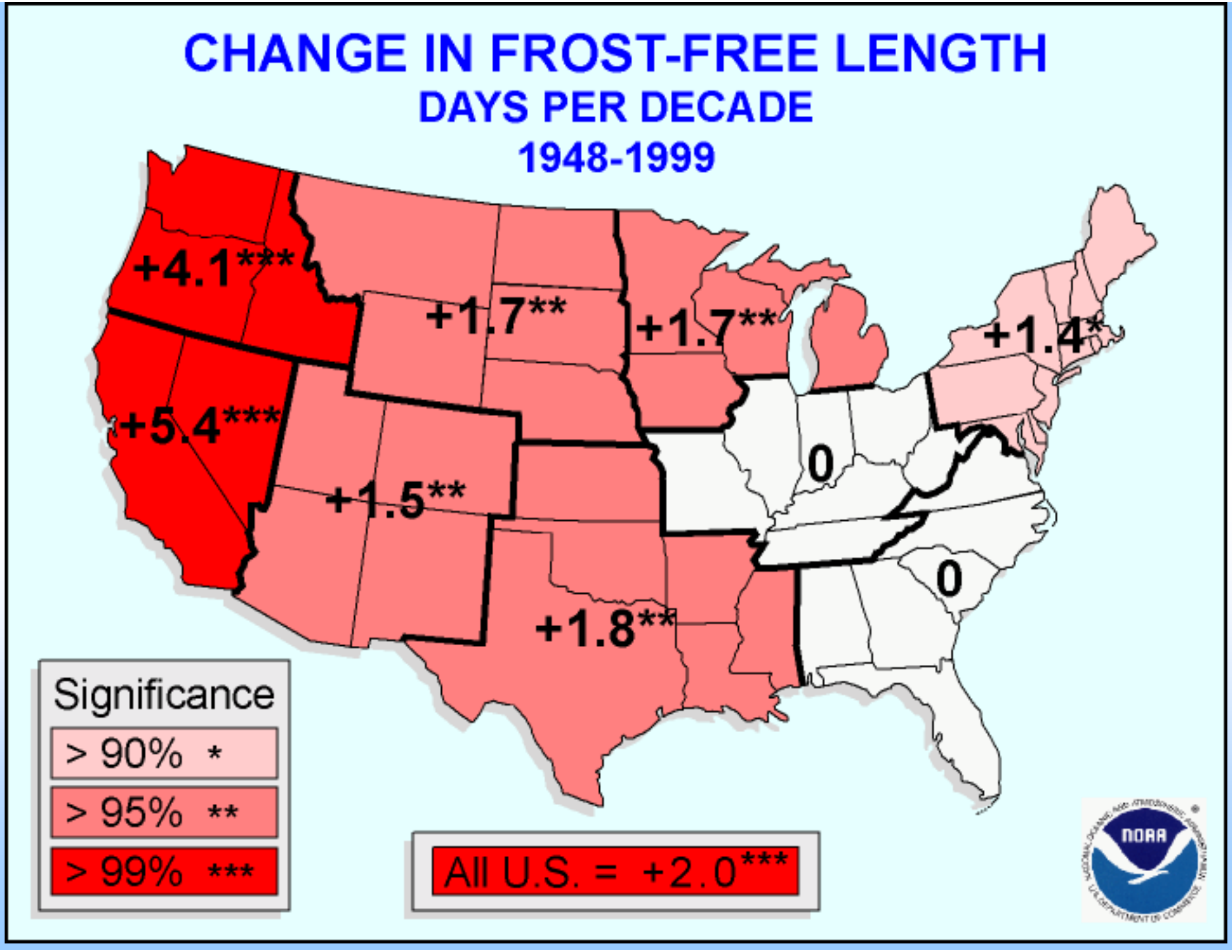
March 2005 Extent
Departure from Average

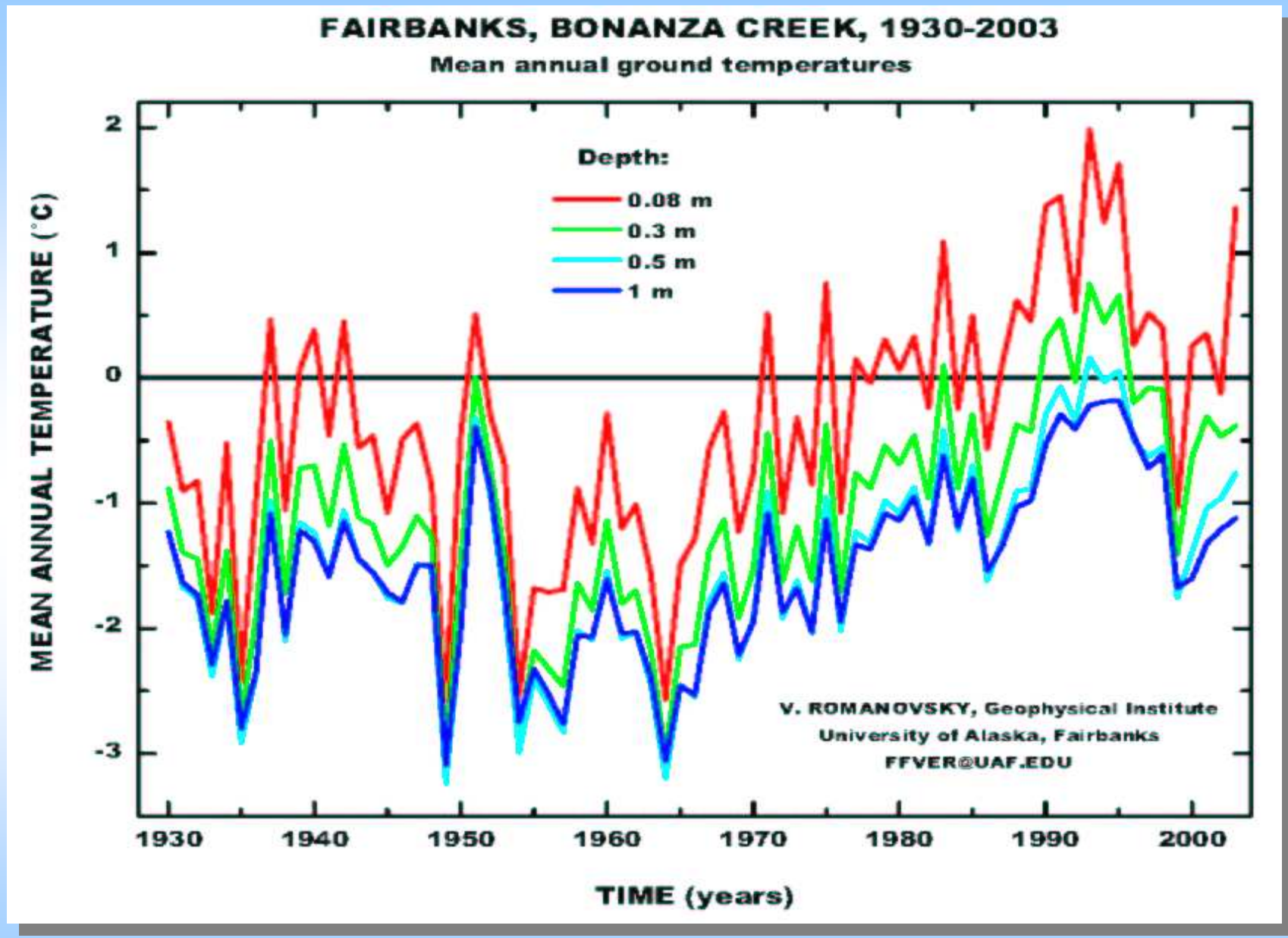
Provided by Rutgers Univ. Snow Lab

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

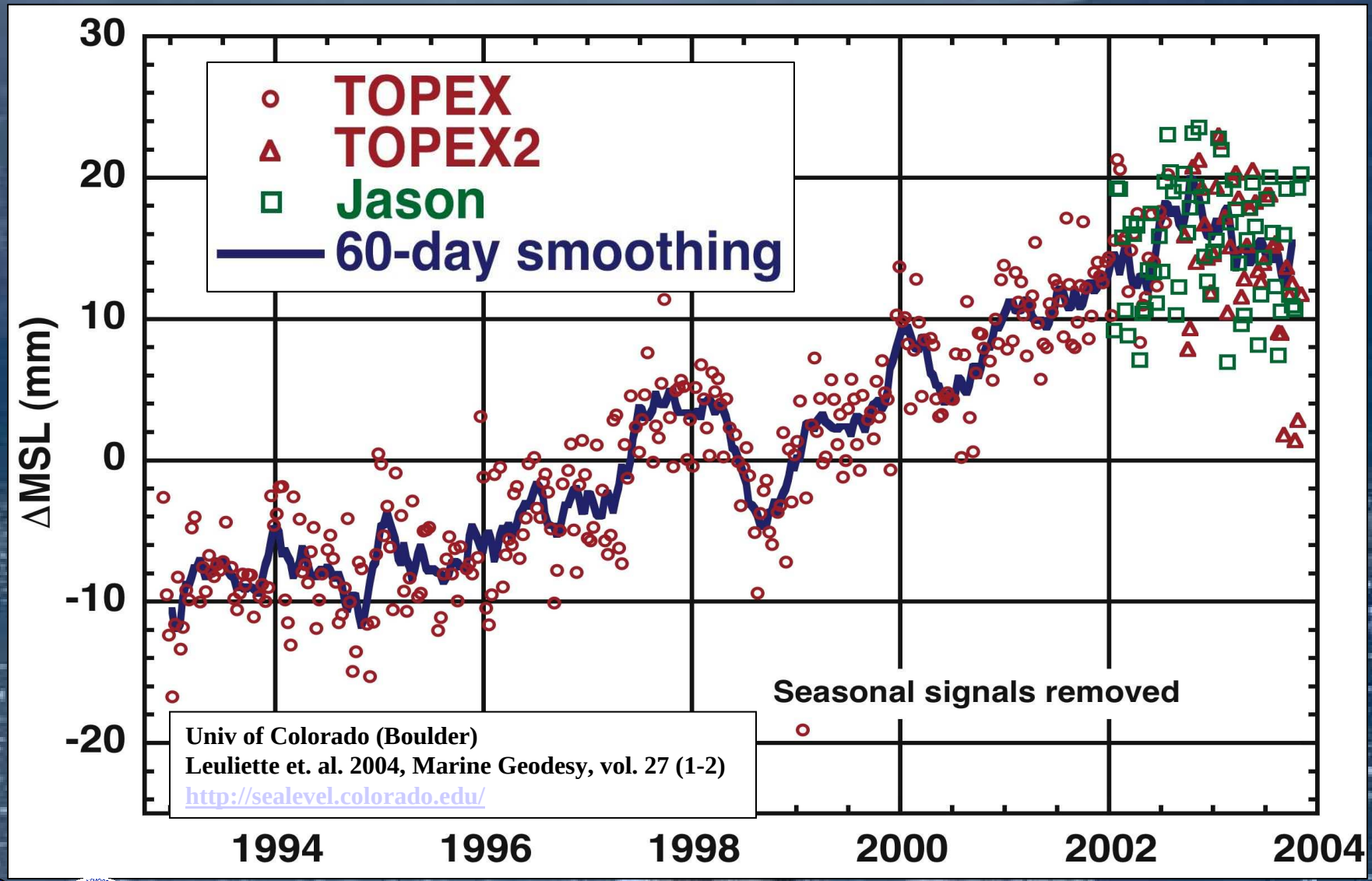
ANNUAL NUMBER OF FROST DAYS
TRENDS IN DAYS PER DECADE
1948-1999



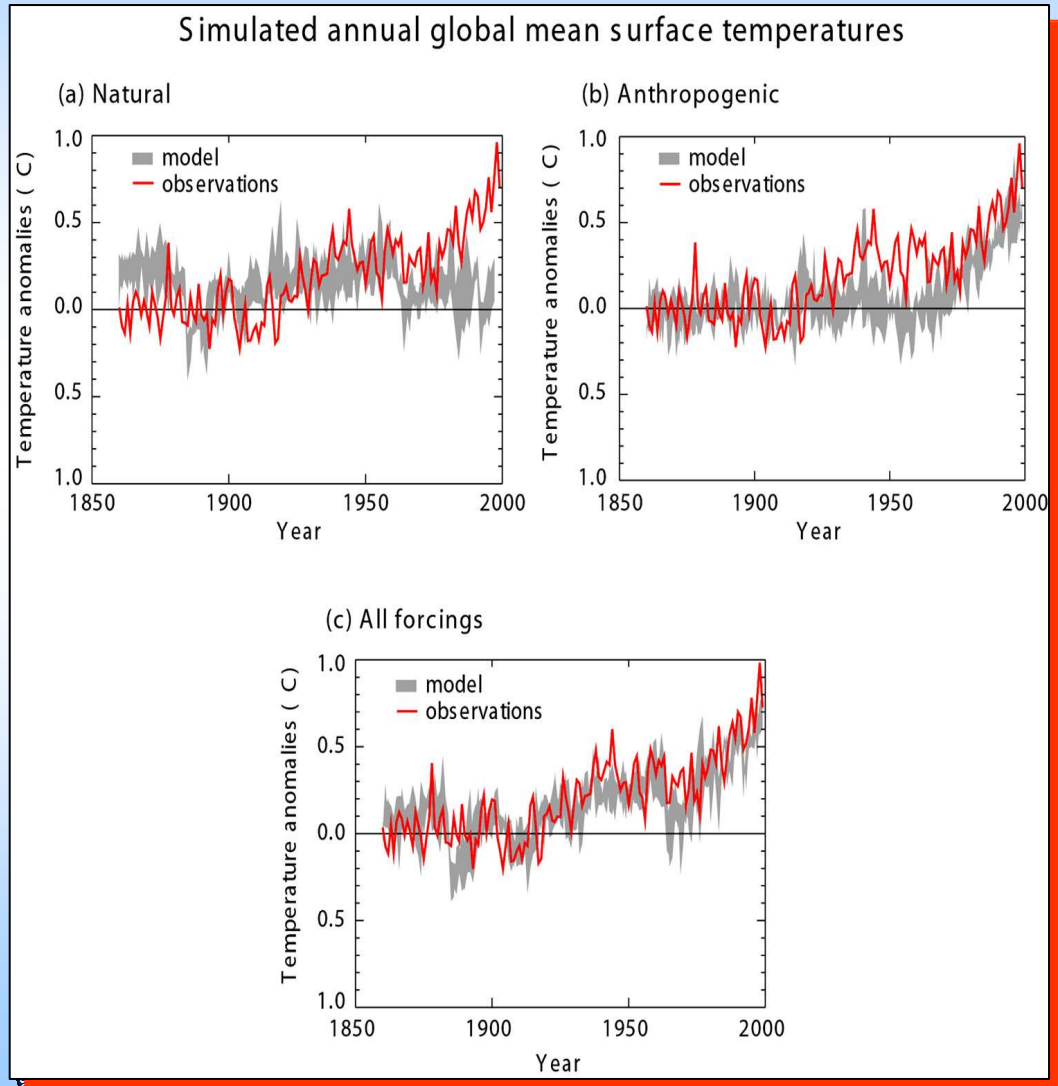

CHANGE IN FROST-FREE LENGTH
DAYS PER DECADE
1948-1999
+4.1***
+1.7**
+1.7**
+1.4*
+5.4***
0
+1.5**
0
+1.8**
Significance
> 90% *
> 95% **
> 99% ***
All U.S. = +2.0***
NOAA


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)

Global Sea Level Changes

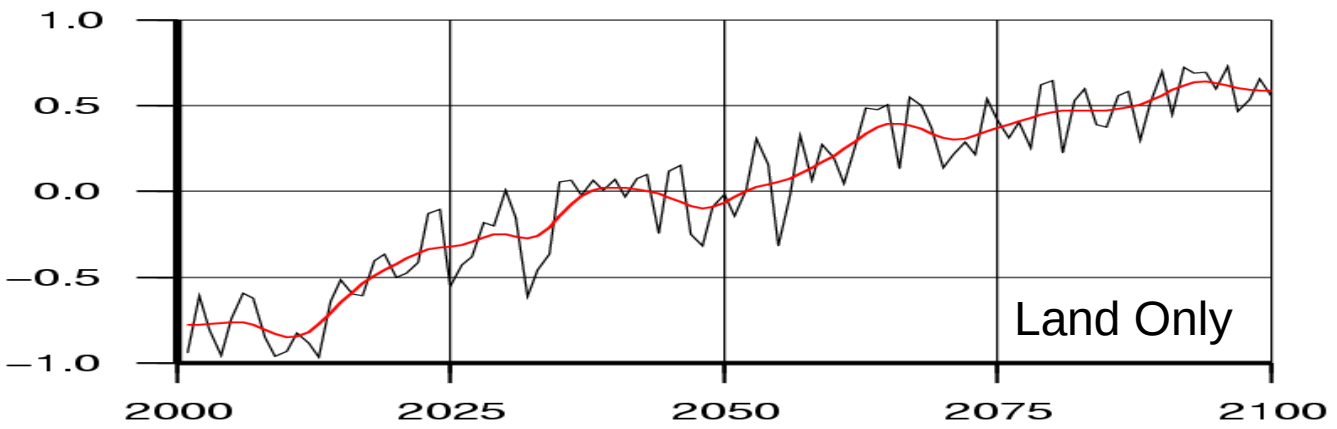


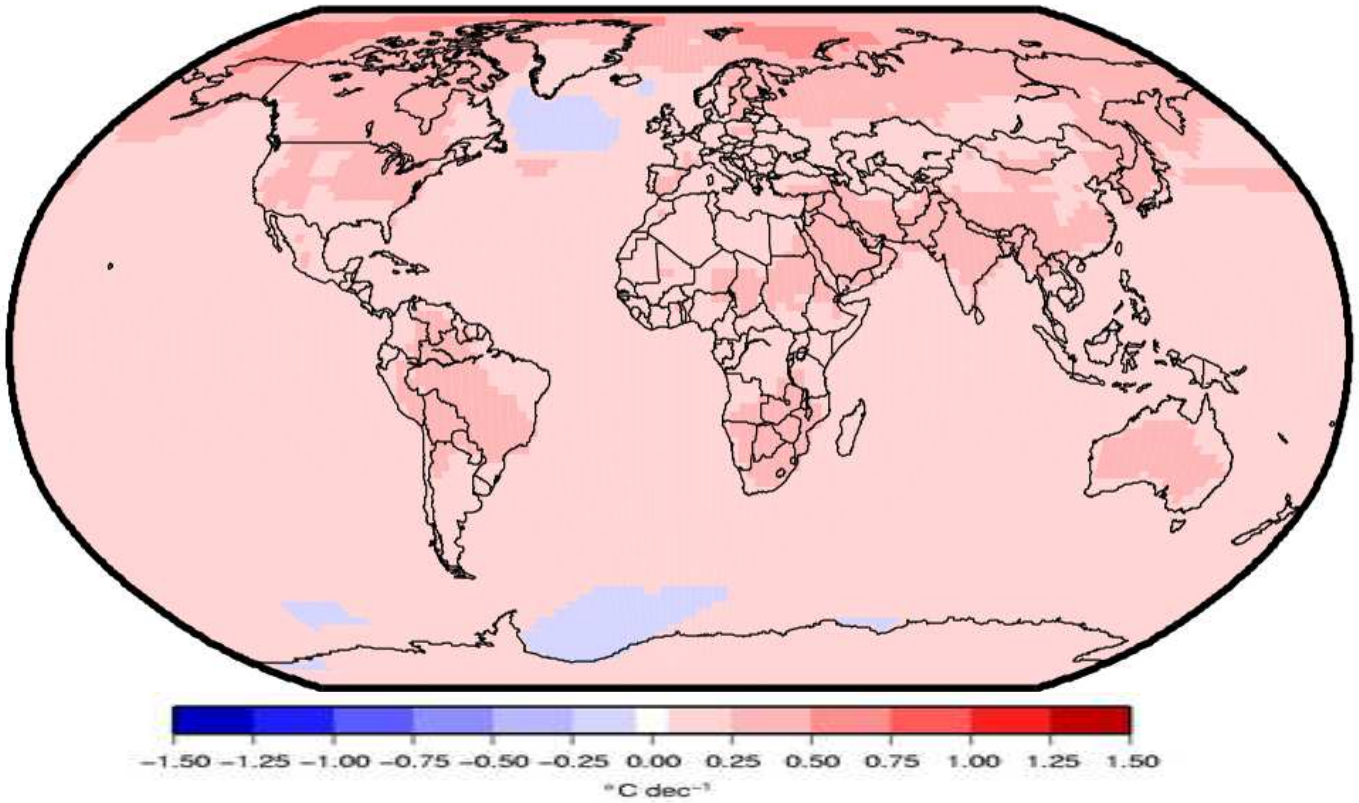
MOST OF THE WARMING OVER THE PAST 50 YEARS IS LIKELY TO BE DUE TO GREENHOUSE GAS INCREASES.



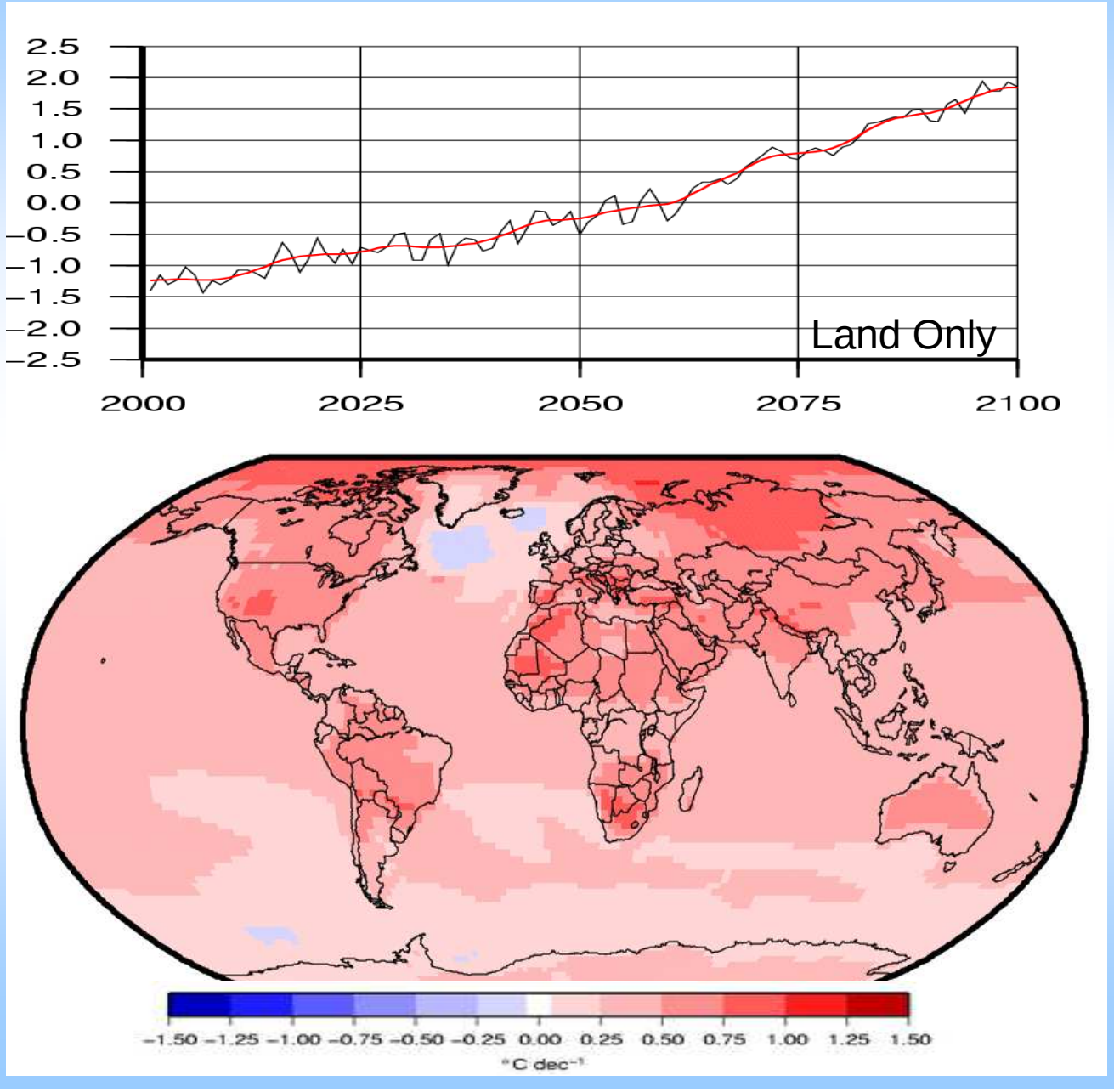
- **Simulations with natural and human factors match observations best**
- **Correspondences increase with time**
- **Probability is low that a "natural only" Earth would have such correspondences.**

Maximum Temperature, B1 (low GHG) Scenario

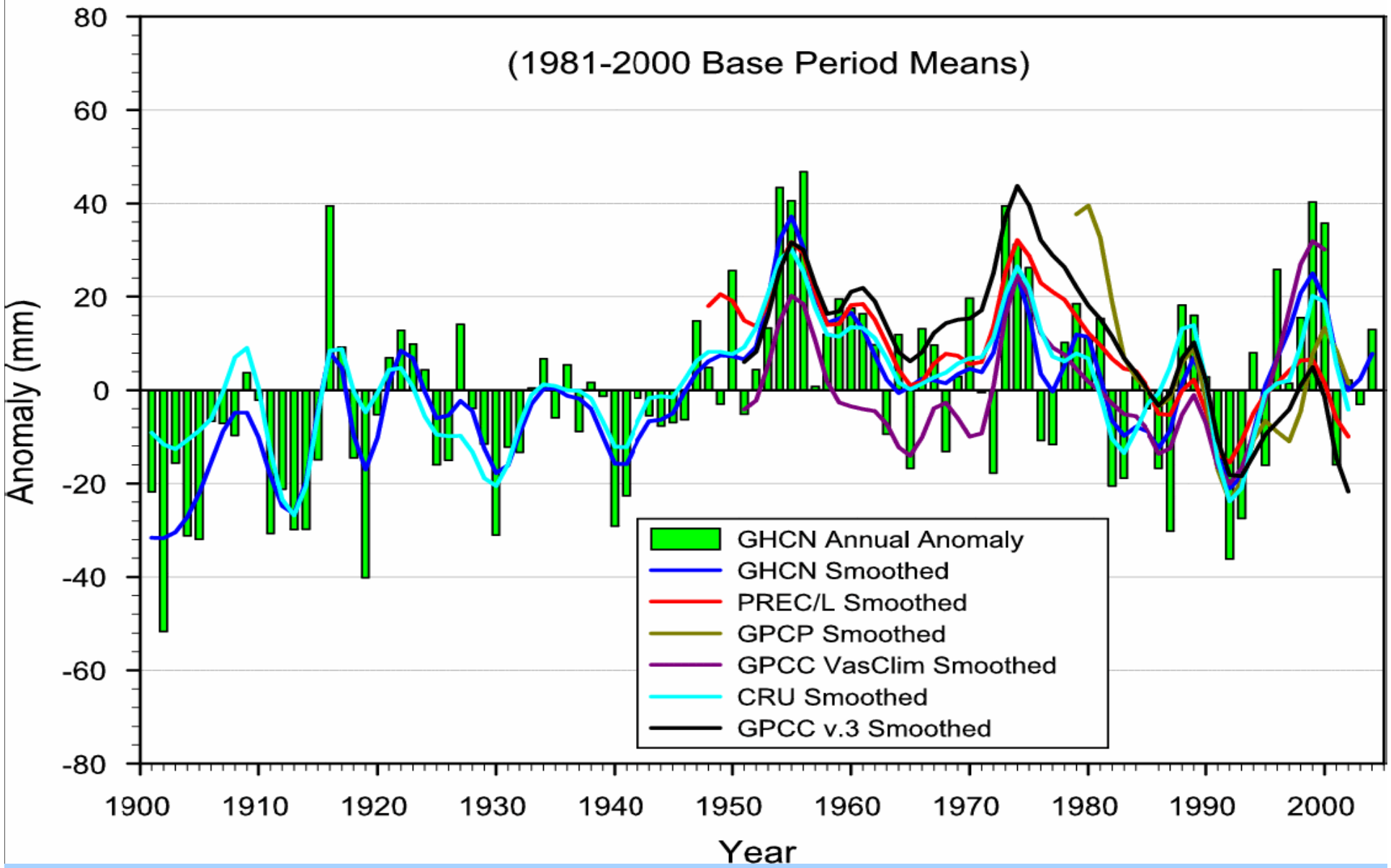




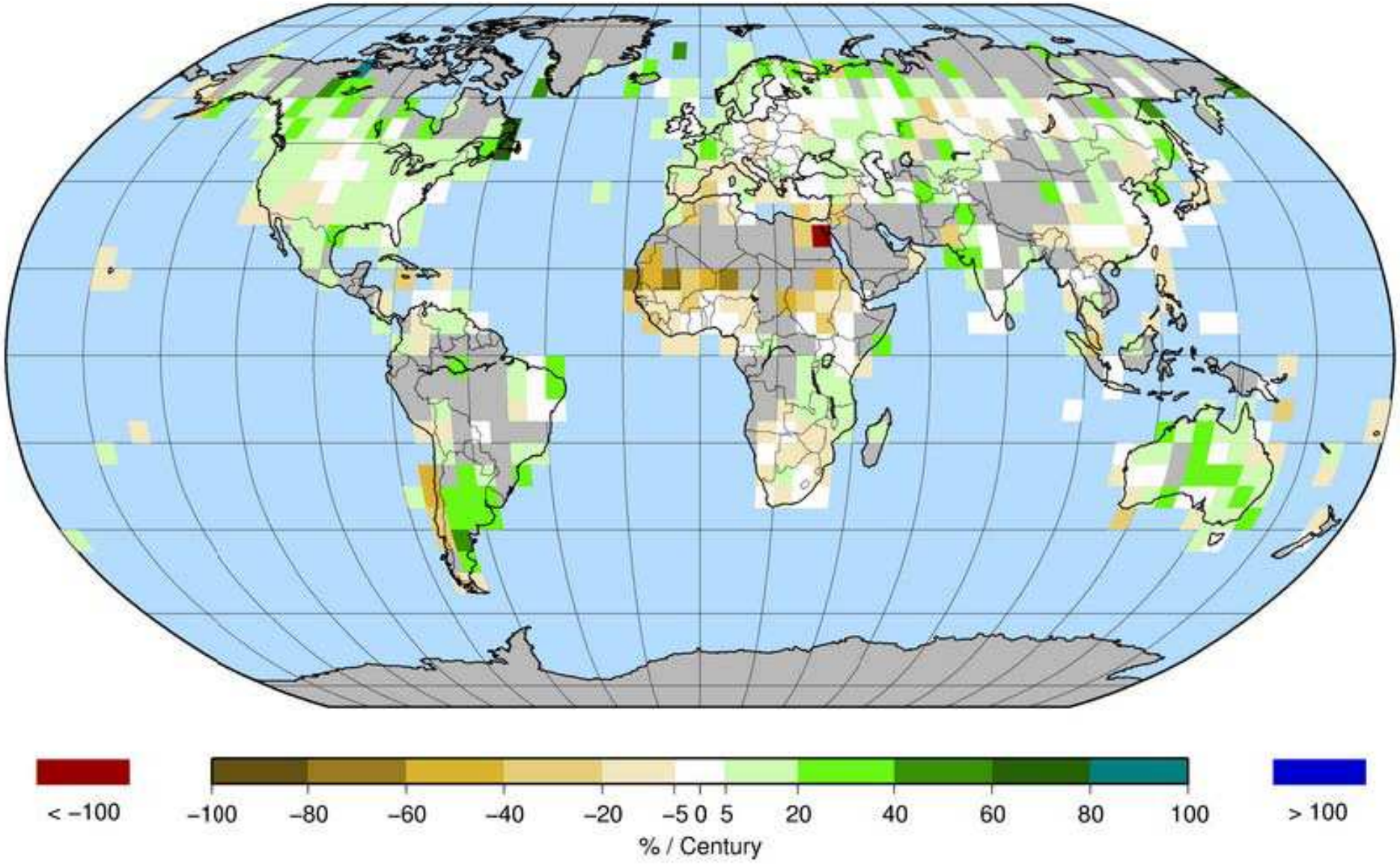
Maximum Temperature, A2 (High GHG) Scenario



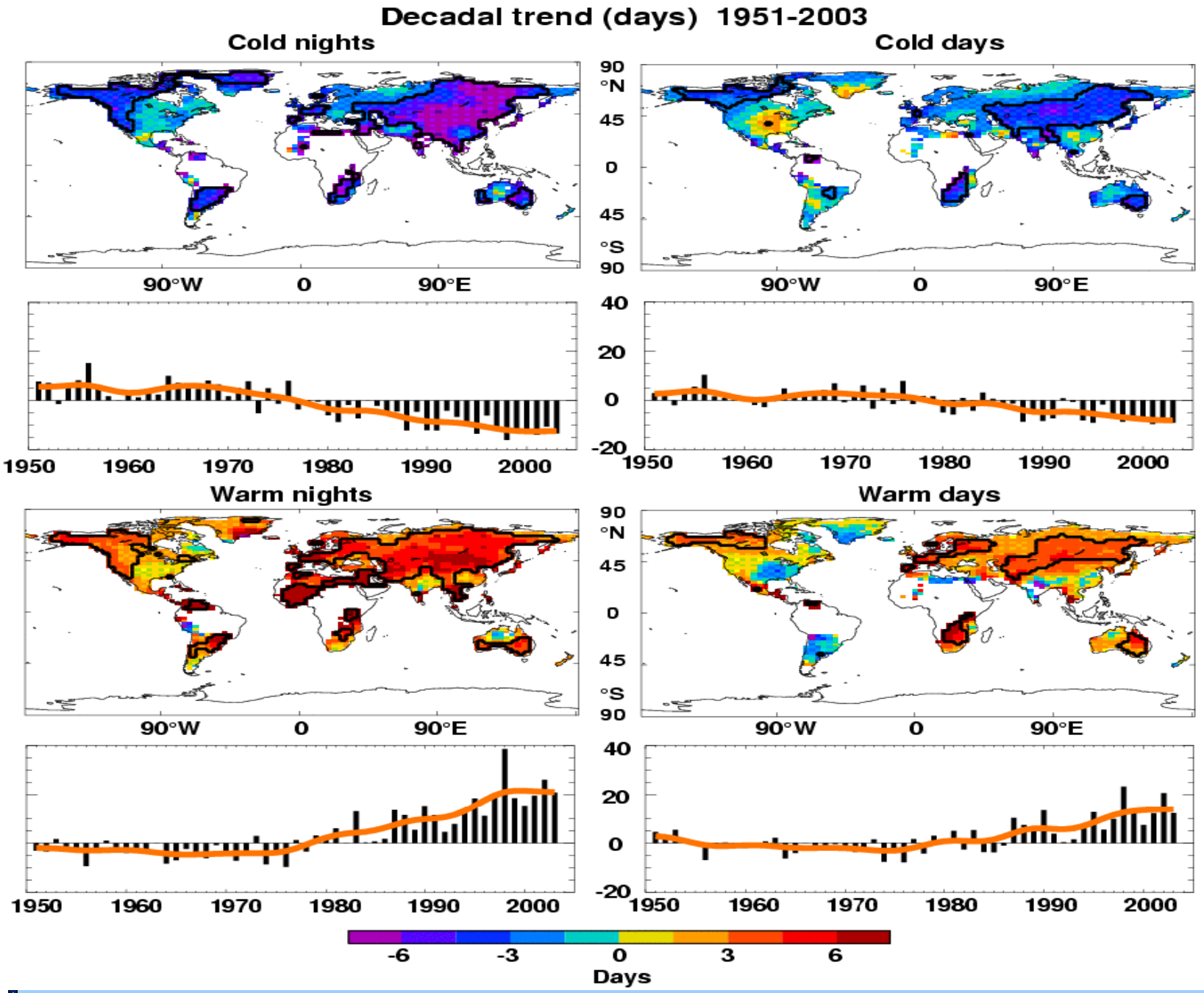
Global Annual Land Precipitation Anomalies



Trend in Annual PRCP, 1901 to 2004



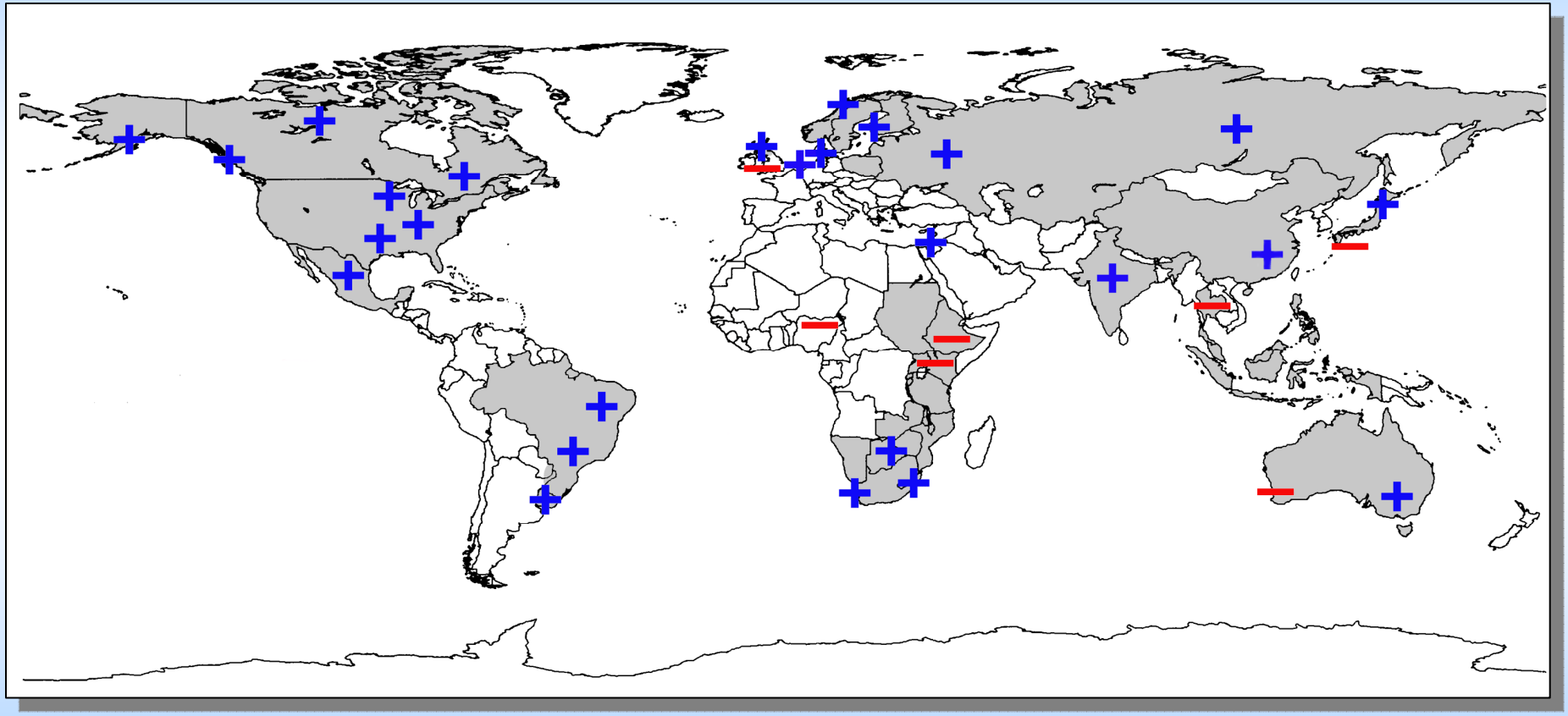
Extreme Events



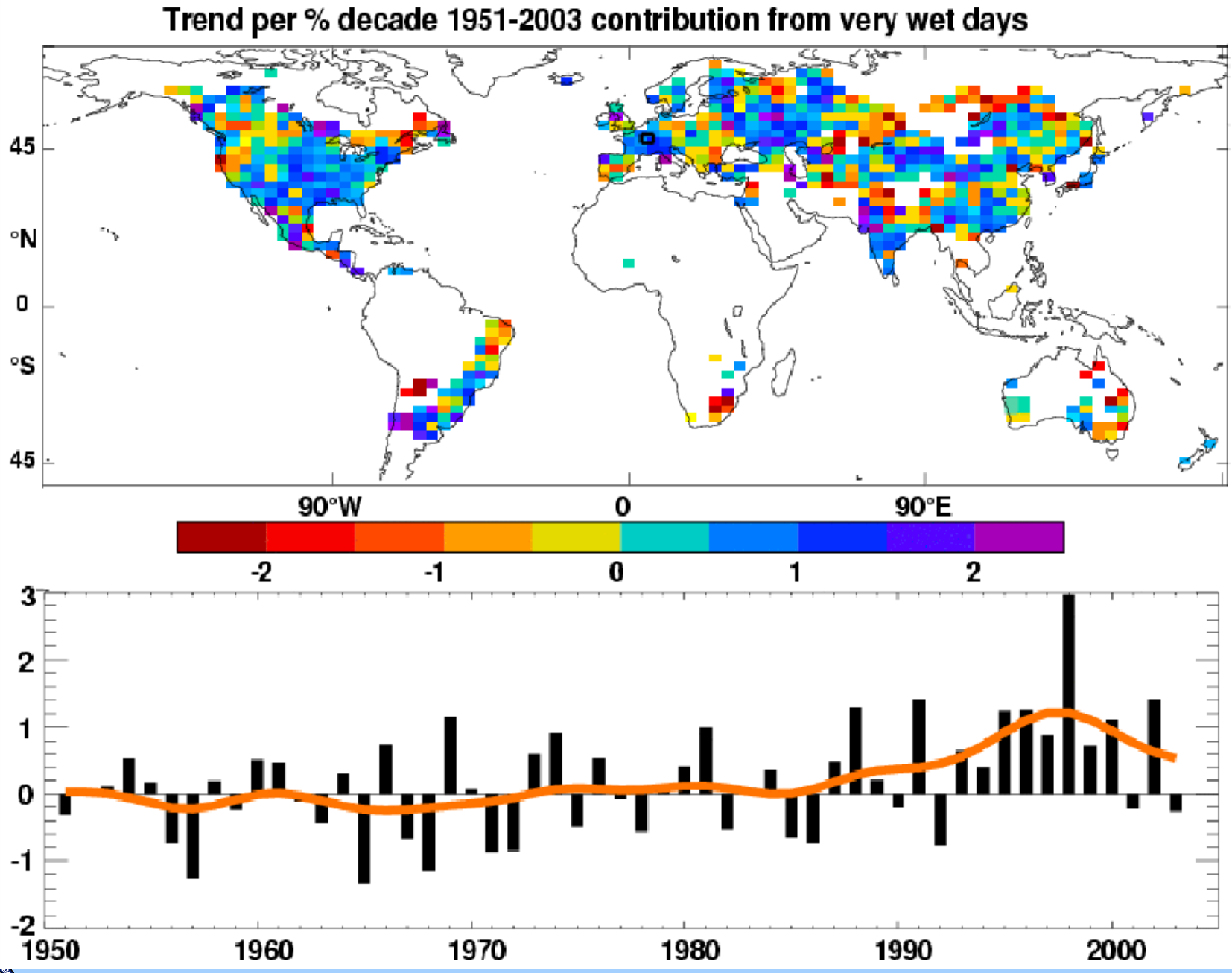
From Alexander 2005

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

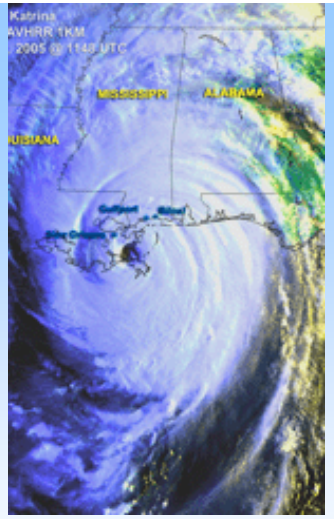
(first half of 20th century to present)



from Easterling et al. 2000



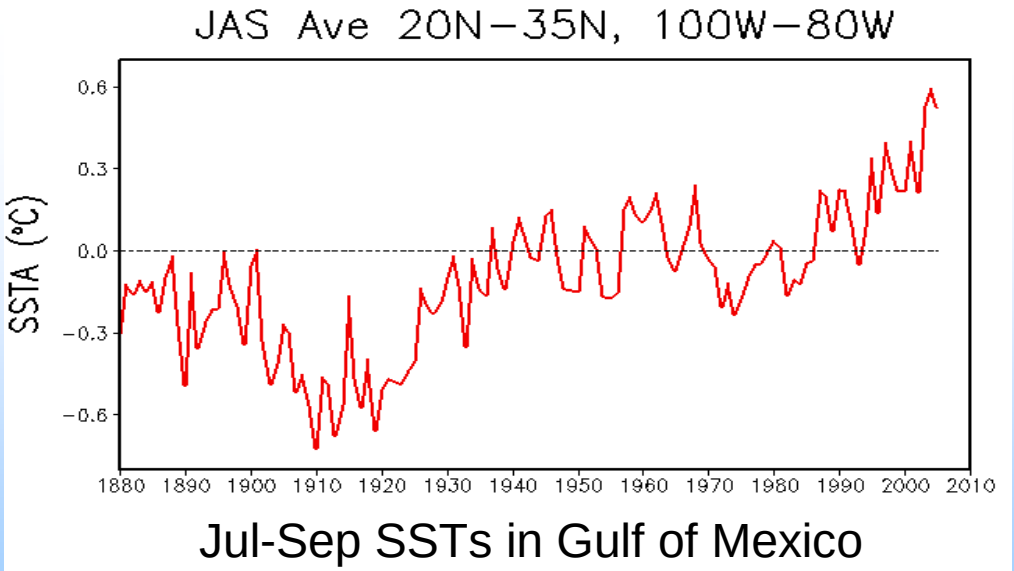
From Alexander 2005



Atlantic Tropical Cyclones

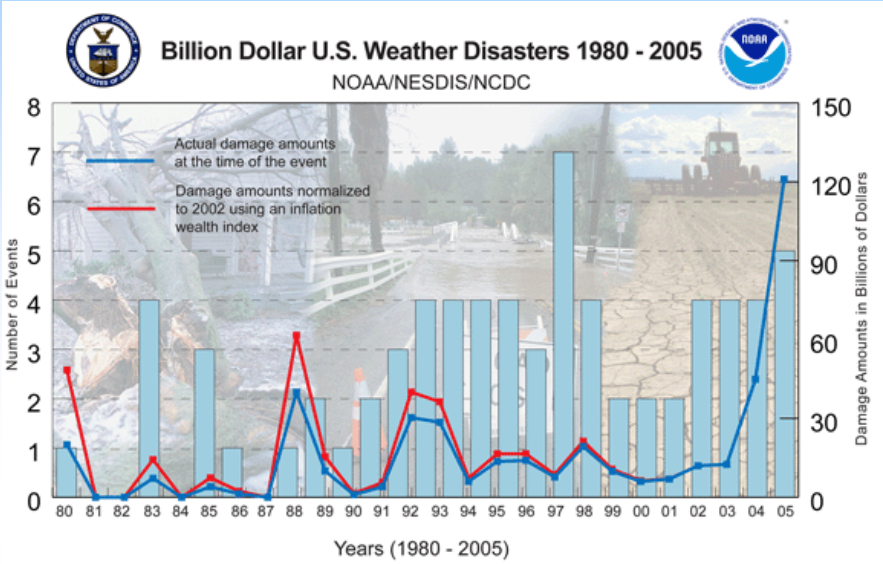
- Active season has been attributed to:
  - Century scale trend in sea surface temperatures contributing to anomalous warmth in Atlantic and Gulf of Mexico
  - Active phase of multi-decadal oscillation

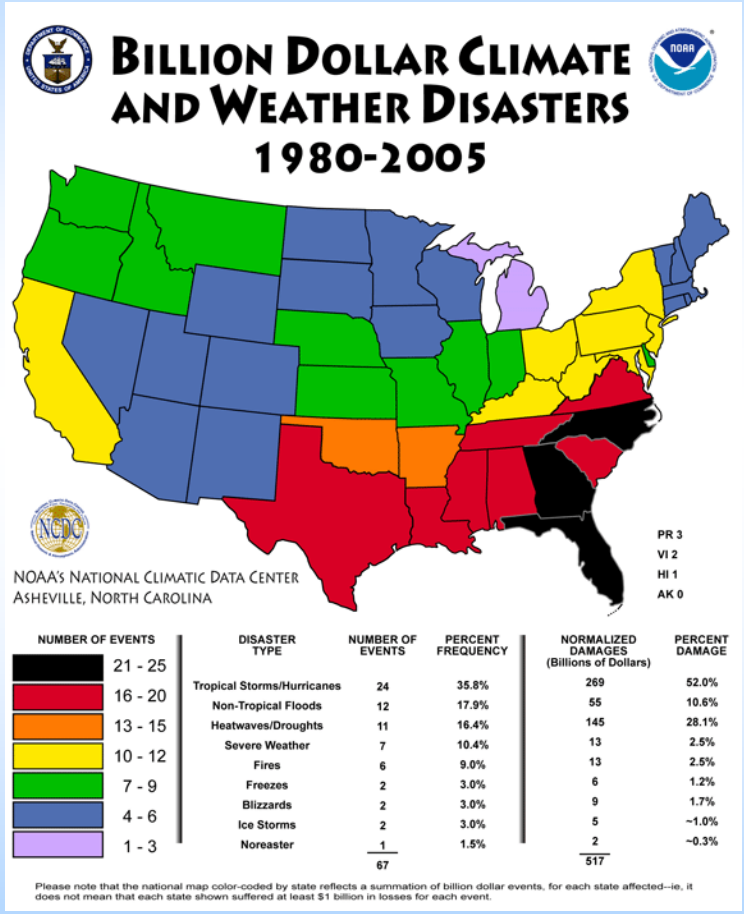
- Recent research points to link between warming ocean temperatures and frequency of strongest tropical cyclones --- BUT



Jul-Sep SSTs in Gulf of Mexico

Billion Dollar Disasters





DISASTER TYPE	NUMBER OF EVENTS	PERCENT FREQUENCY	NORMALIZED DAMAGES (Billions of Dollars)	PERCENT DAMAGE
Tropical Storms/Hurricanes	24	35.8%	269	52.0%
Non-Tropical Floods	12	17.9%	55	10.6%
Heatwaves/Droughts	11	16.4%	145	28.1%
Severe Weather	7	10.4%	13	2.5%
Fires	6	9.0%	13	2.5%
Freezes	2	3.0%	6	1.2%
Blizzards	2	3.0%	9	1.7%
Ice Storms	2	3.0%	5	~1.0%
Noreaster	1	1.5%	2	~0.3%
	67		517	

- Inflation adjusted costs of weather-related extremes continue to rise
  - Record losses in 2005
- Greatest number of billion-dollar disasters in the southern and southeastern U.S. since 1980

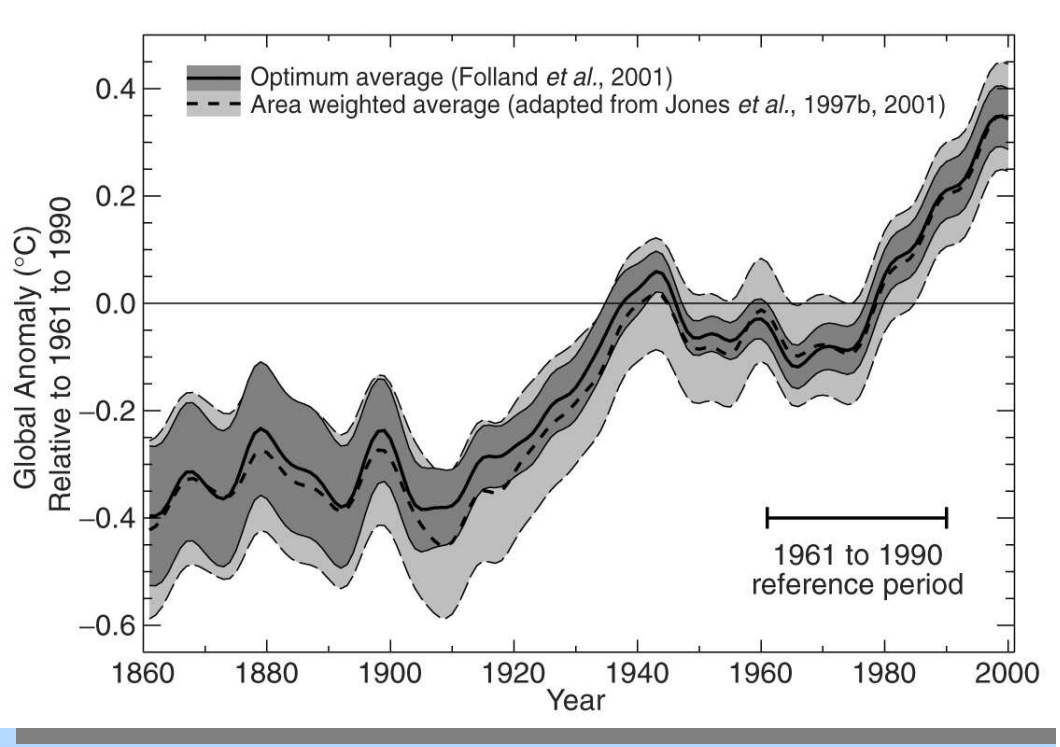
How significant are the uncertainties?

✓ 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?

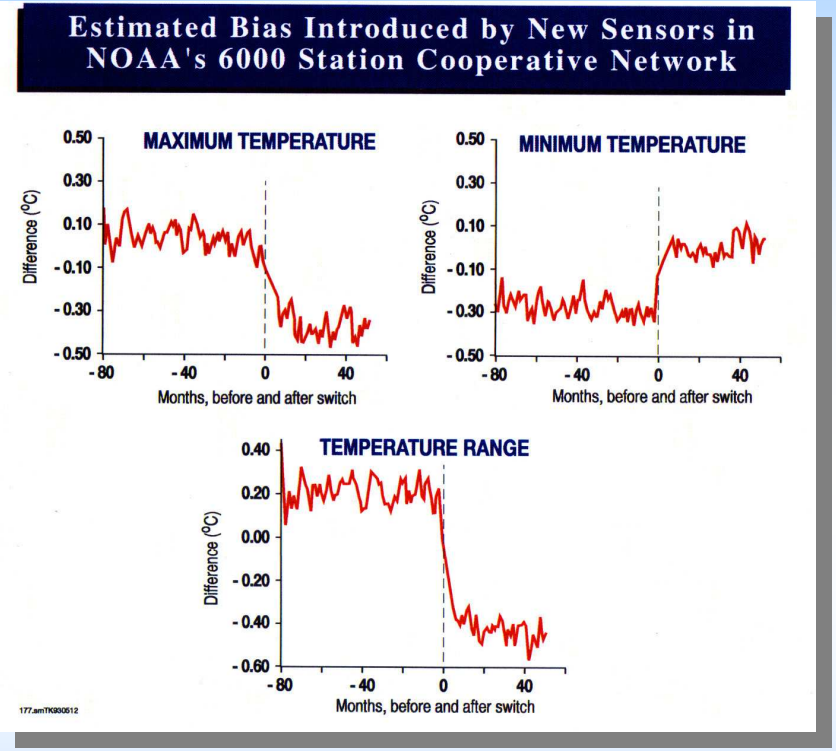
- Examples provide numerous insights into observing and data system deficiencies

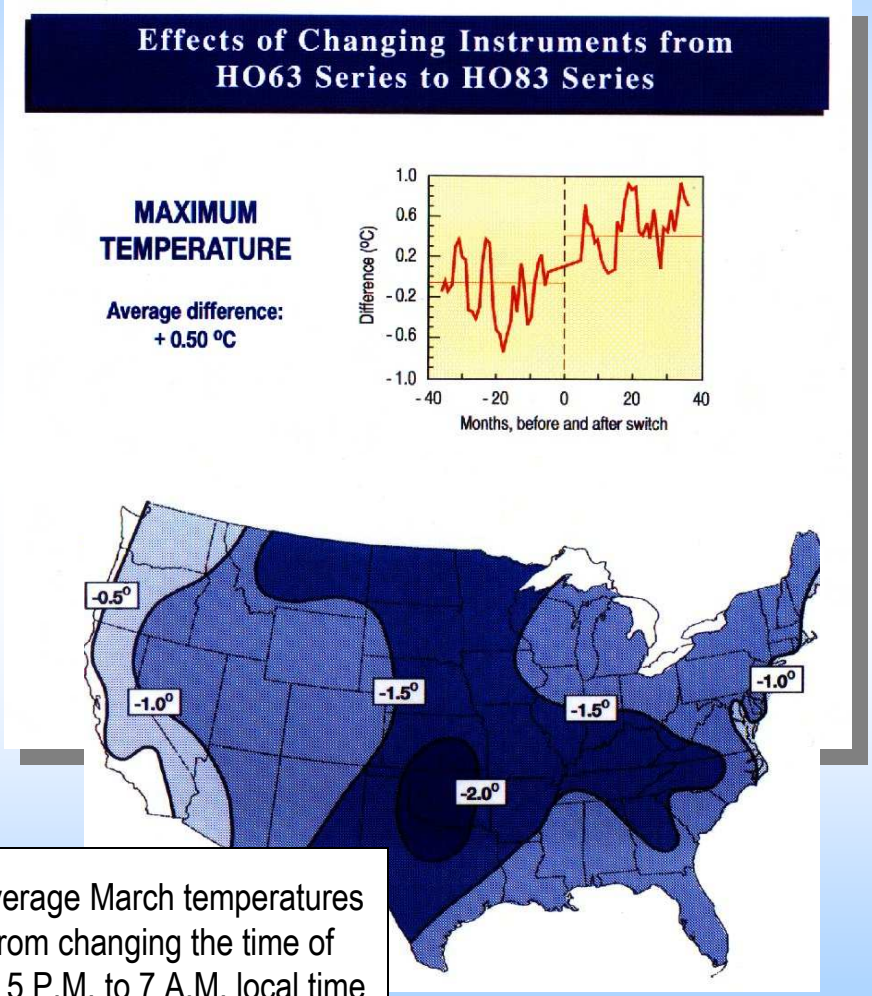


Smoothed annual anomalies of global combined land-surface air and sea surface temperatures (°C).

Observing and Data System Deficiencies

- ✓ Issues with Surface-based observations



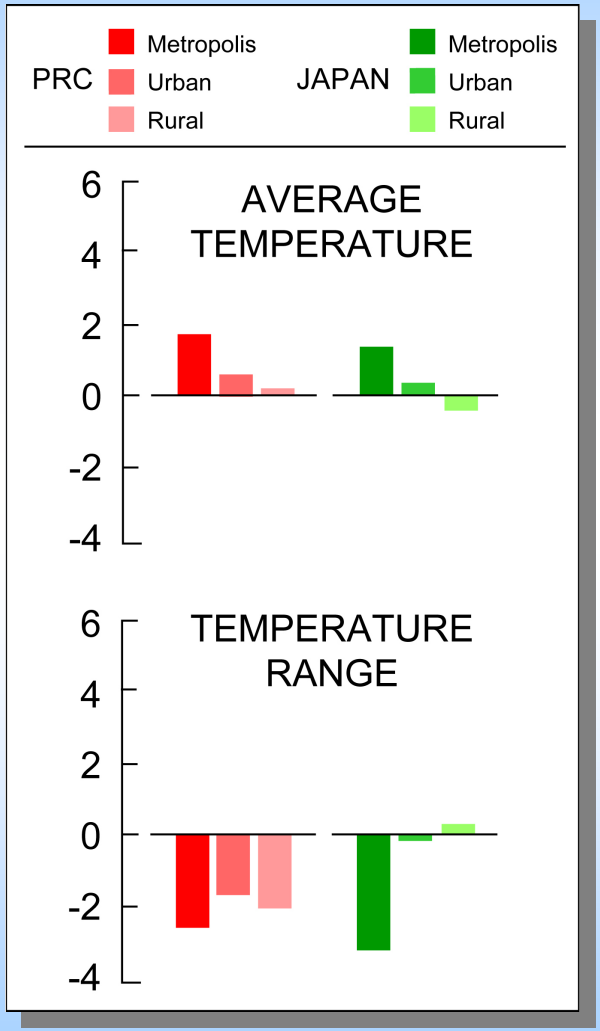


- ✓ Most observations taken for other purposes, e.g., weather forecasting

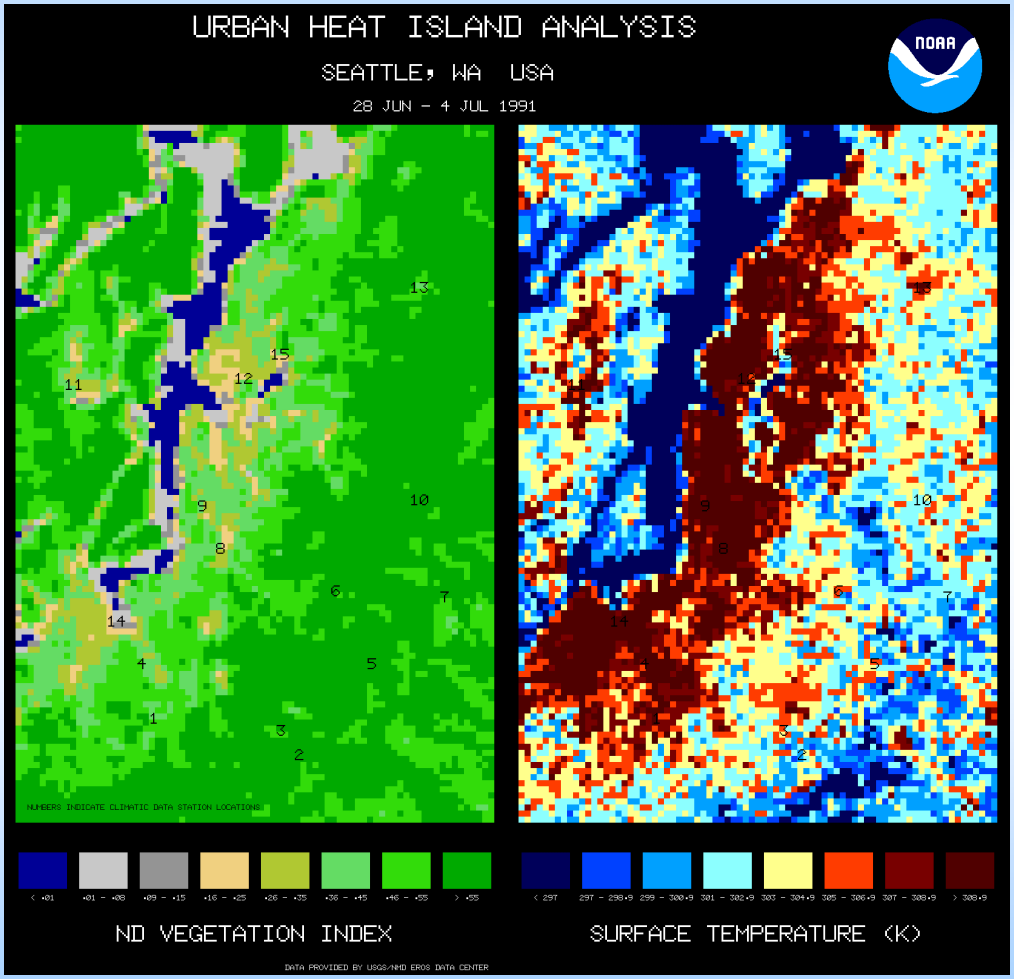
Change in the average March temperatures (°C) resulting from changing the time of observation from 5 P.M. to 7 A.M. local time

Observing and Data System Deficiencies

✓ Urban Heat Island Effects



✓ Land use vs temperature



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
    - 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.

- Confidence?
- Greatest in temperature changes
- Less in precipitation changes.

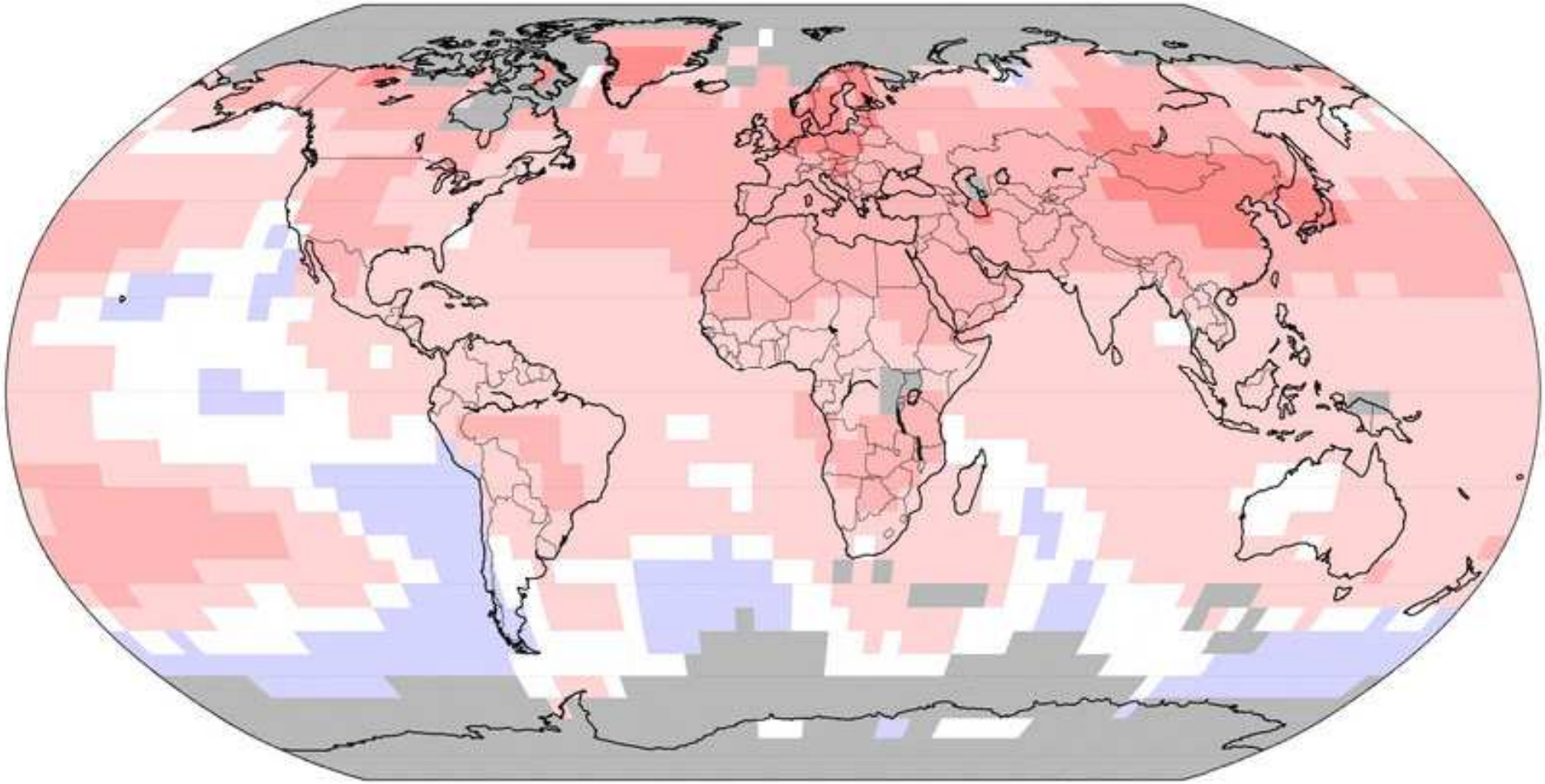
Summary

- Hurricanes?
  - We have entered a more active phase
  - Atlantic Multi-decadal Oscillation
  - Is there some Global Warming contribution?

The End

Backup Slides

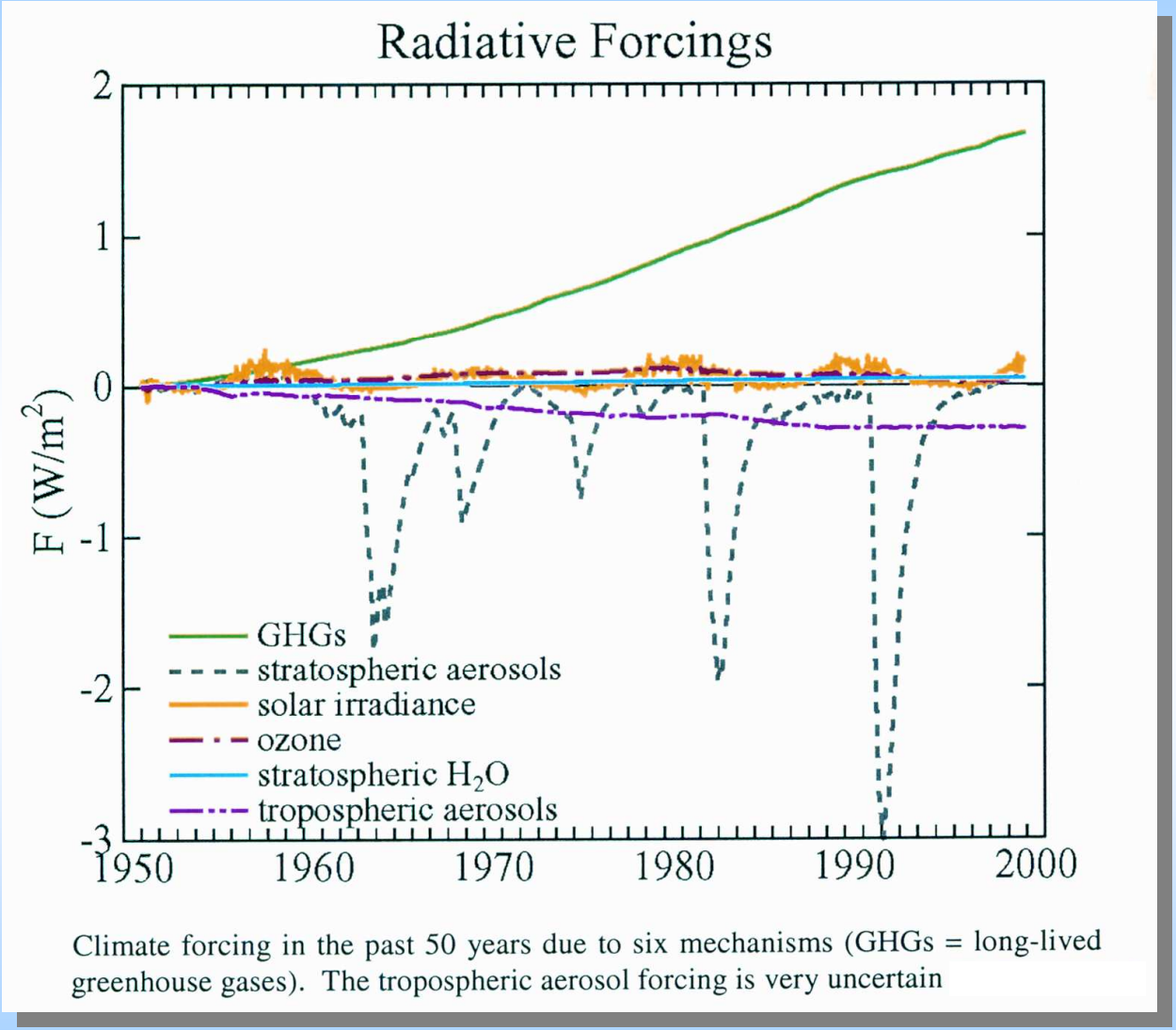
Trend in Annual TMEAN, 1979 to 2004



White Interval = -0.05 to 0.05

-1.50 -1.25 -1.00 -0.75 -0.50 -0.25 0.00 0.25 0.50 0.75 1.00 1.25 1.50

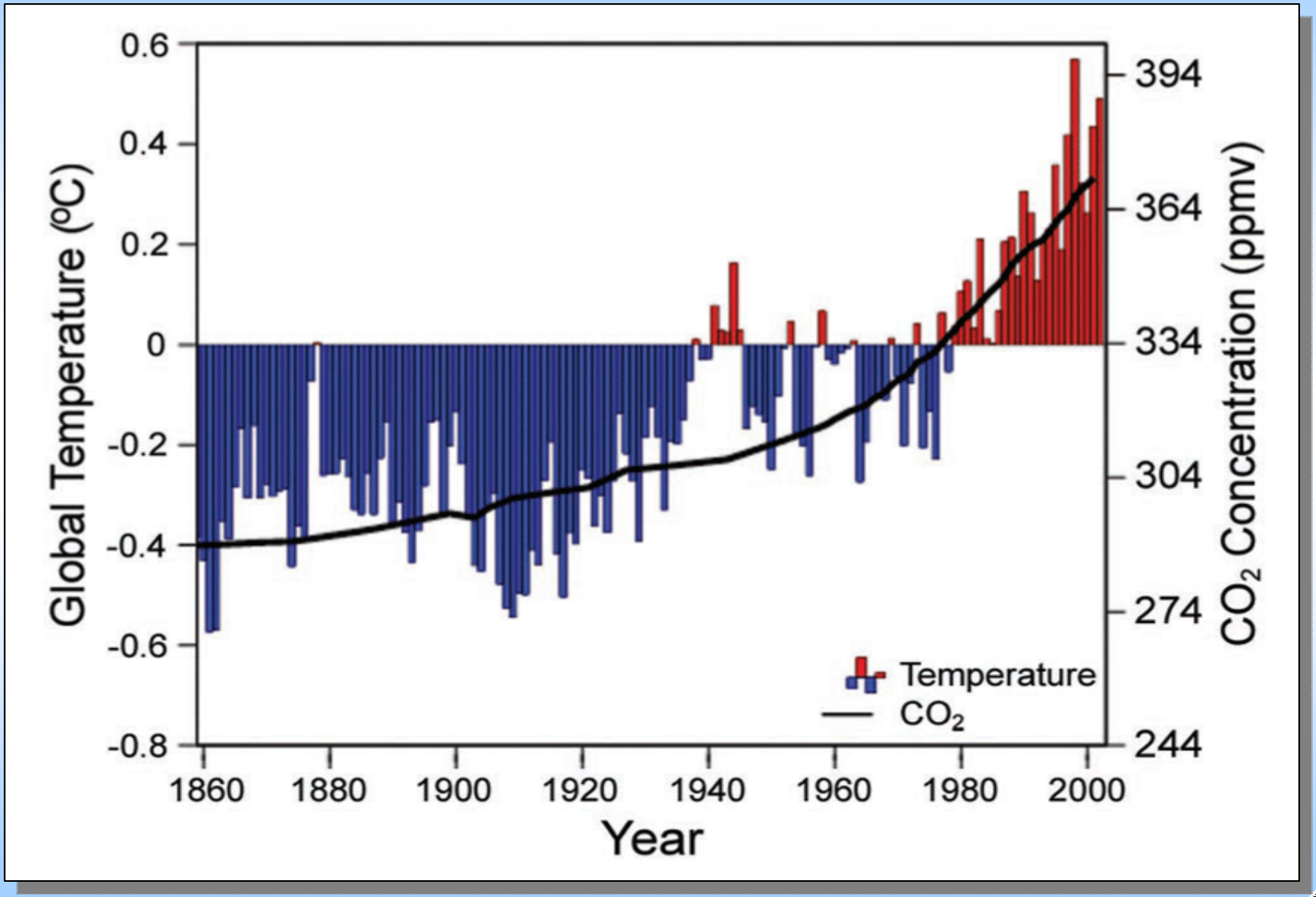
Deg C / Decade



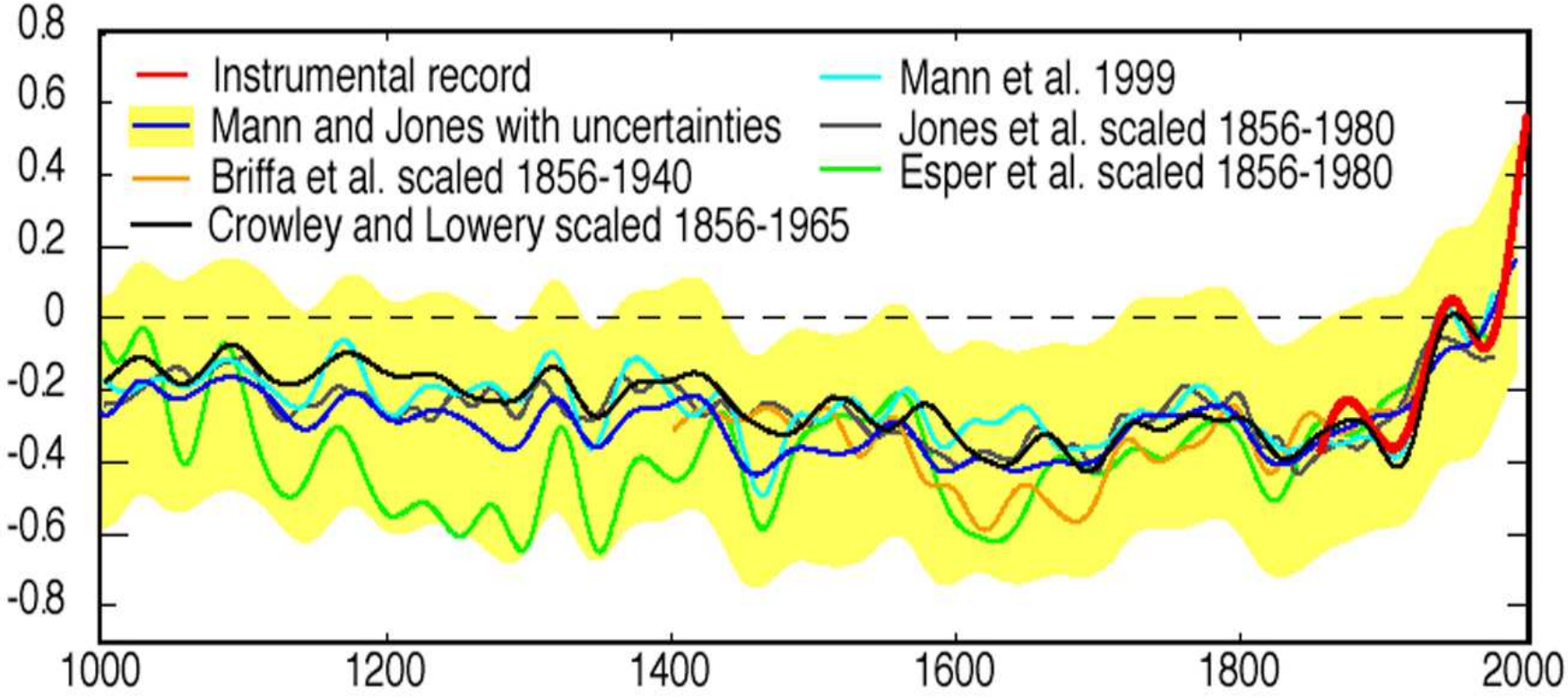
Climate forcing in the past 50 years due to six mechanisms (GHGs = long-lived greenhouse gases). The tropospheric aerosol forcing is very uncertain

From Hansen et al. (2003)

Global Temperature Change vs CO_2 Change



1000-Year NH Temperature Record

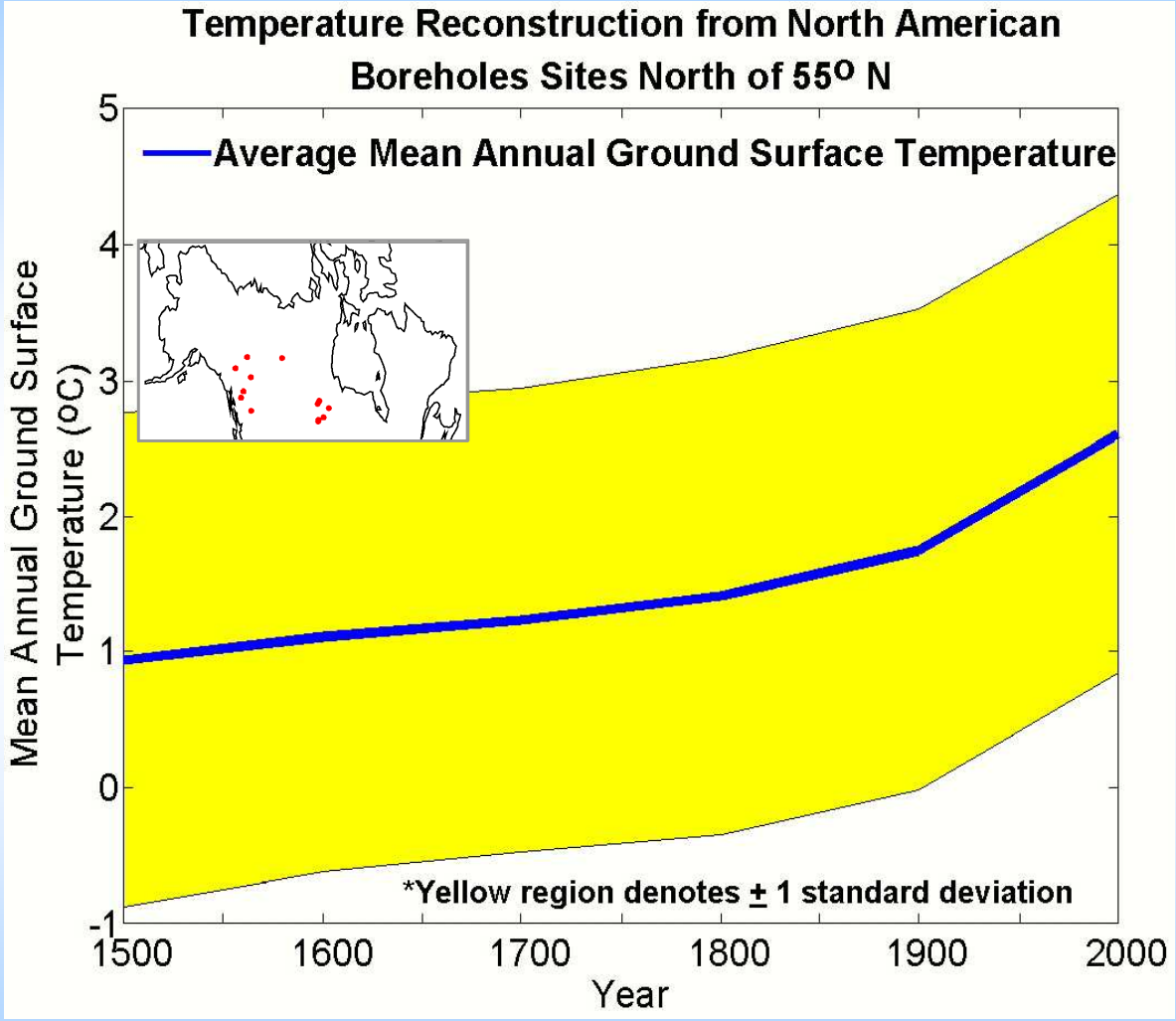


Jones, PD & ME Mann, 2004. Climate Over Past Millenia. *Reviews Of Geophysics* 42 (2): Art. No. RG2002

Temperature reconstruction created from tree rings, ice cores, ice melt, corals, lengthy instrumental records.

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℉ in the 20th Century



www.ngdc.noaa.gov/paleo

Abrupt Climate Change

- What is it?

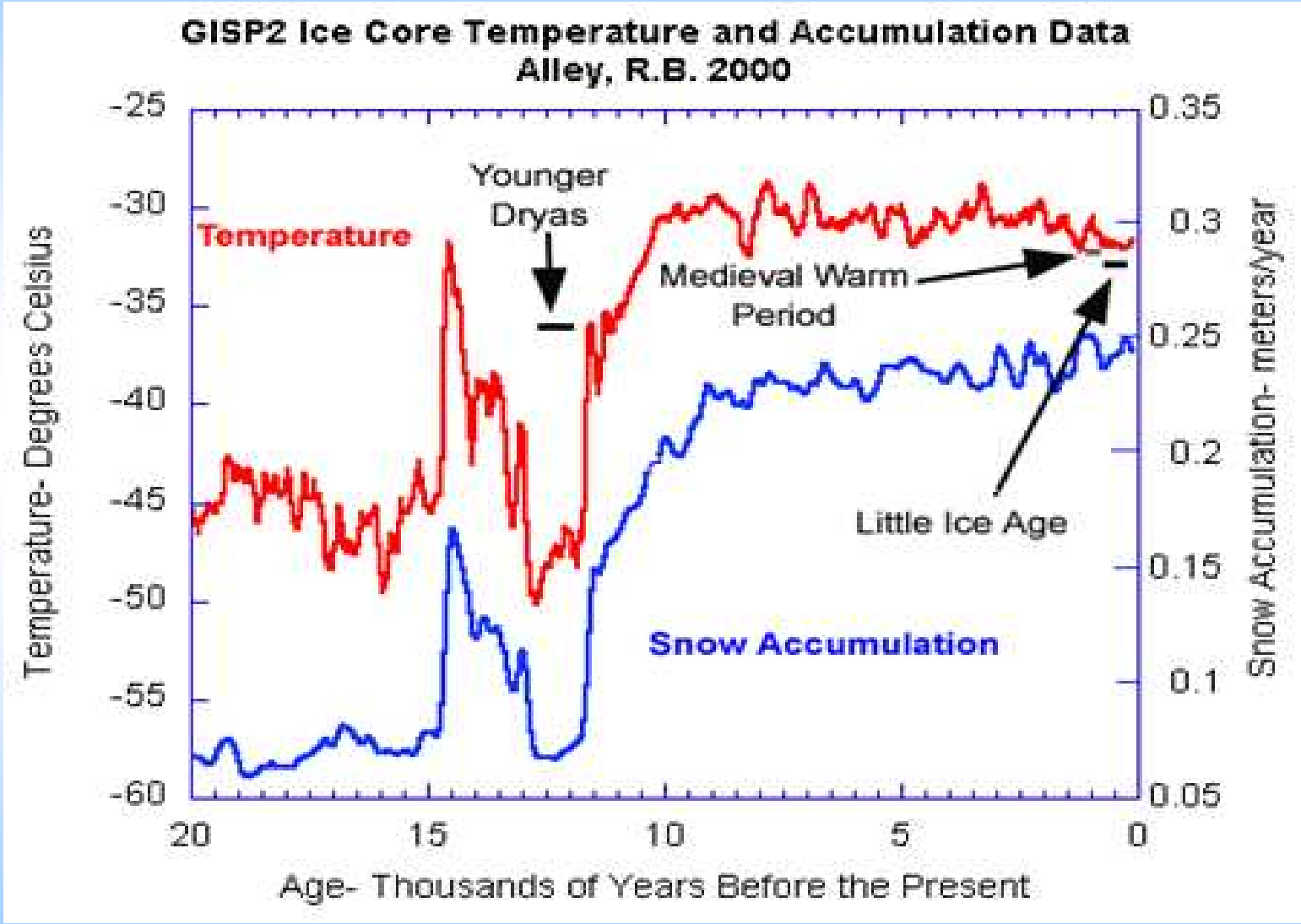
  Mechanistic definition

  – 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.

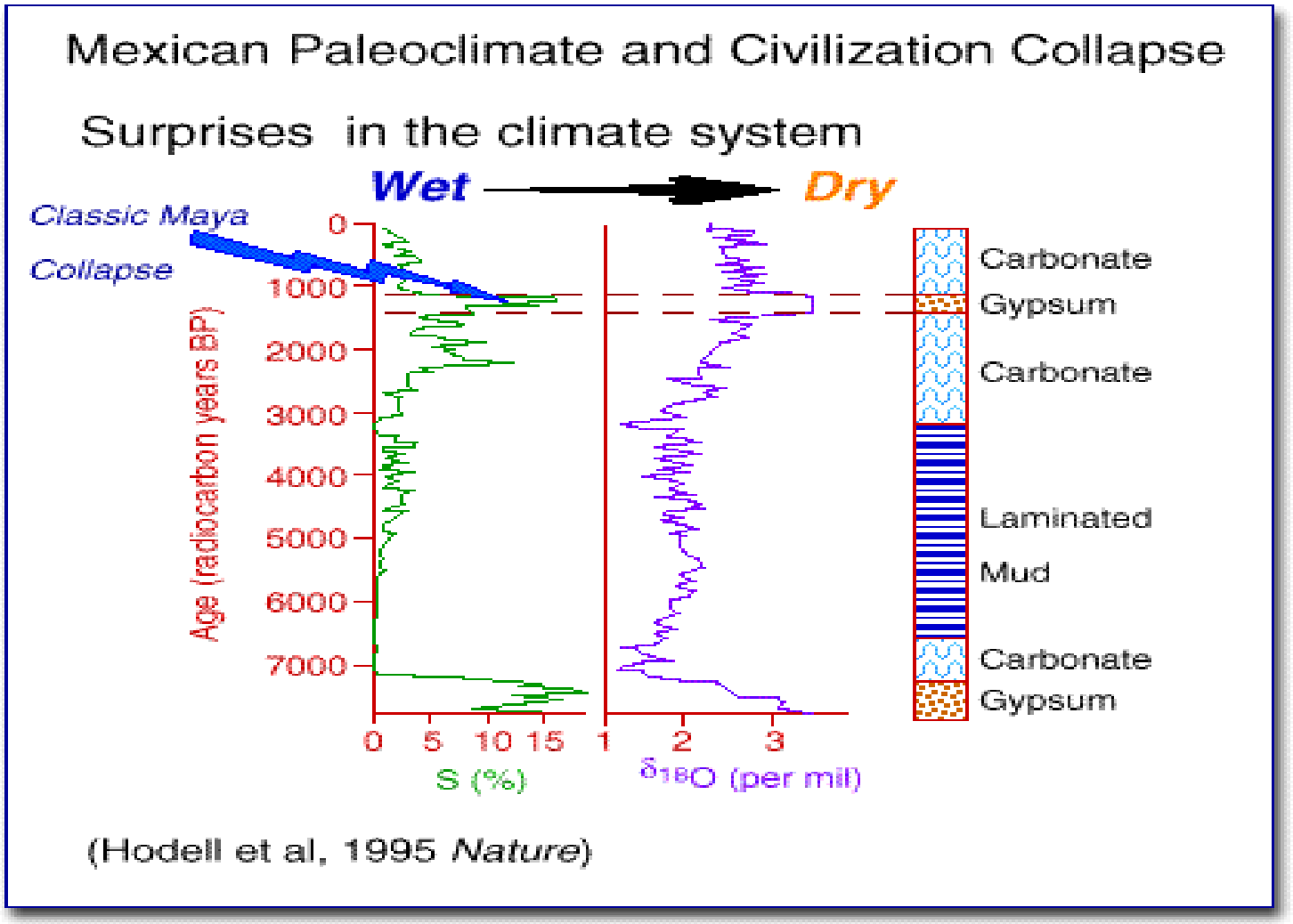
  Impacts based definition

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

Abrupt Climate Change



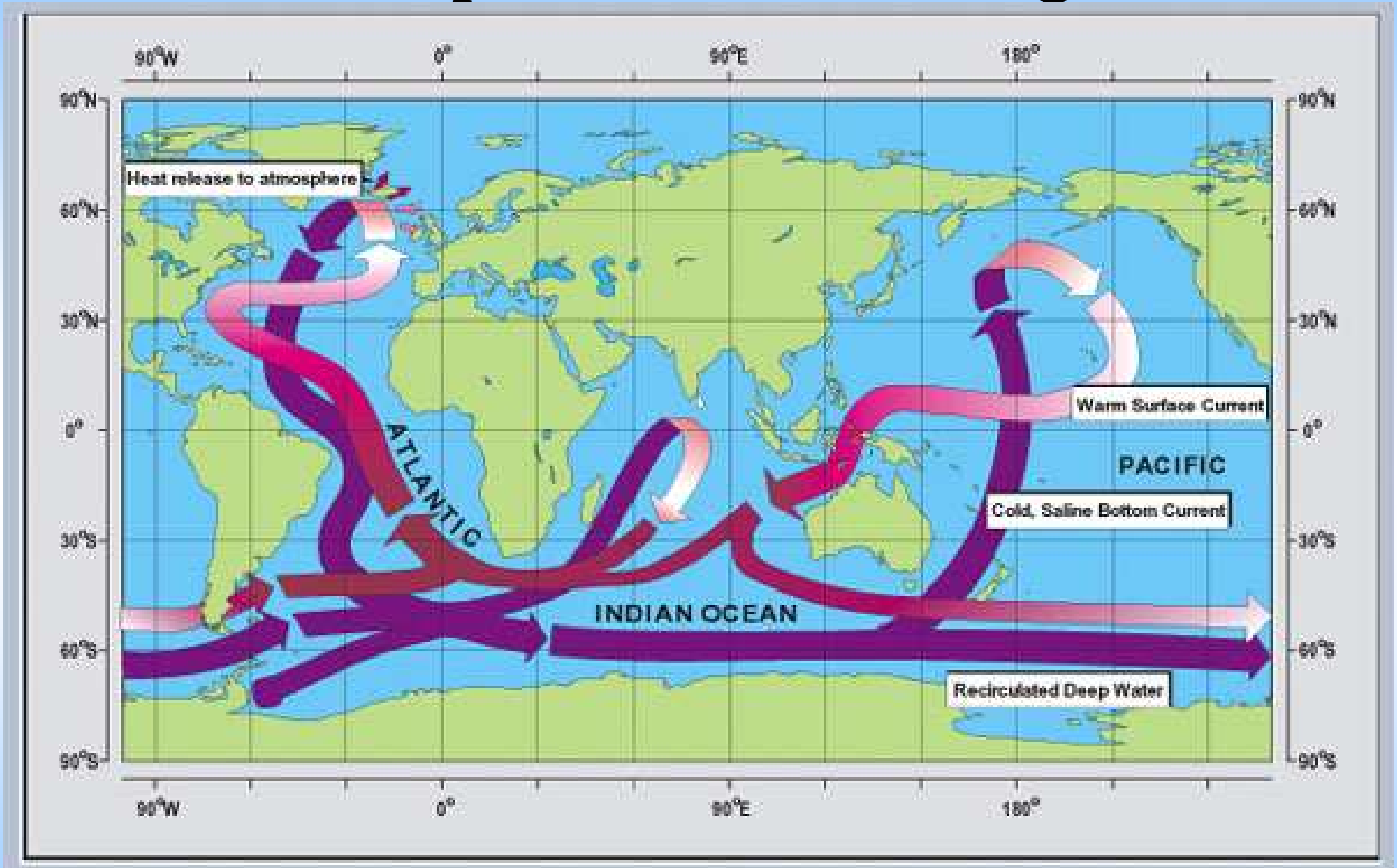
Abrupt Climate Change



Abrupt Climate Change

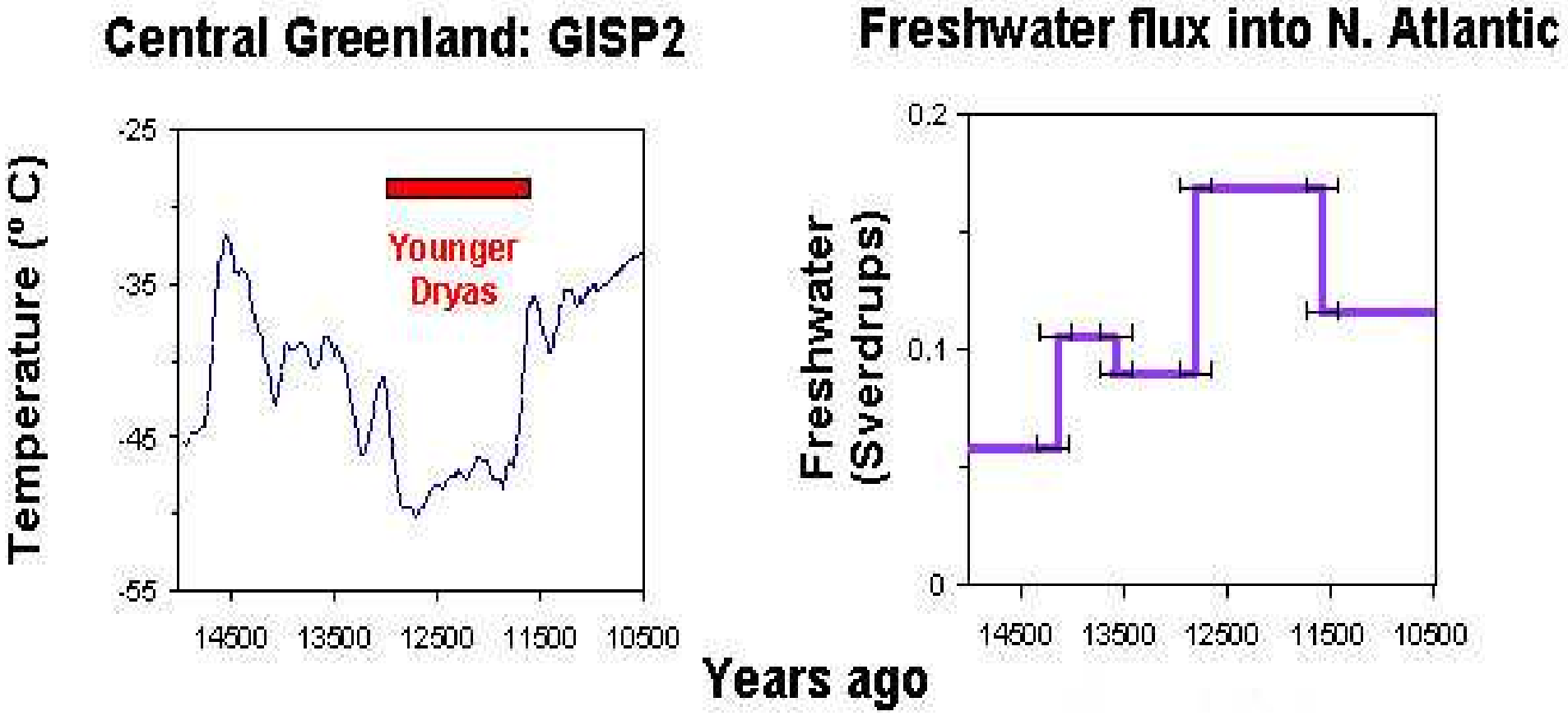
- What about future abrupt change?
  - One scenario, shutdown of the North Atlantic Thermohaline Circulation.

Abrupt Climate Change

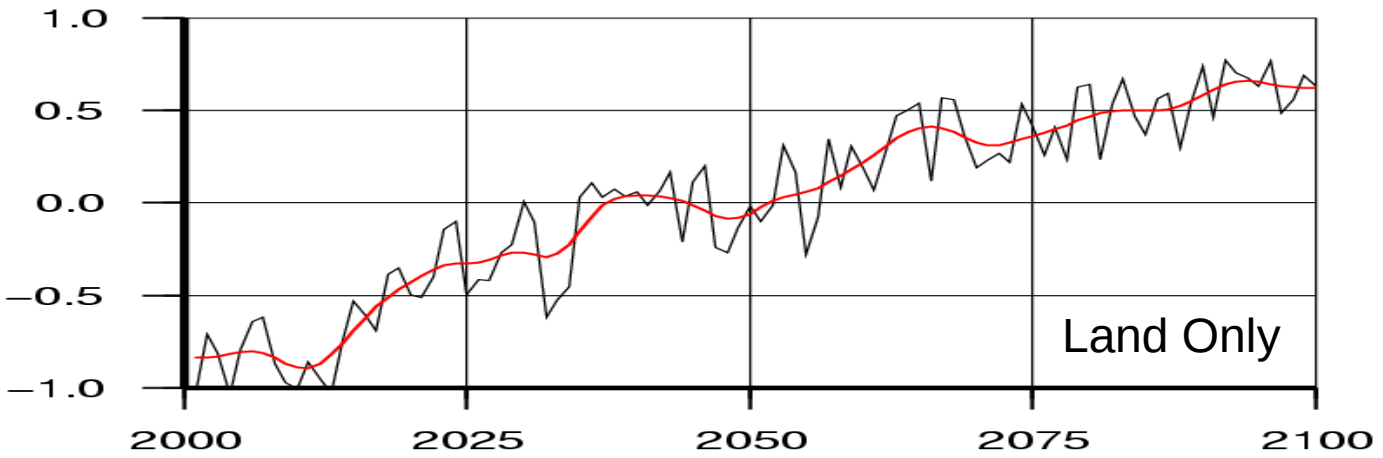


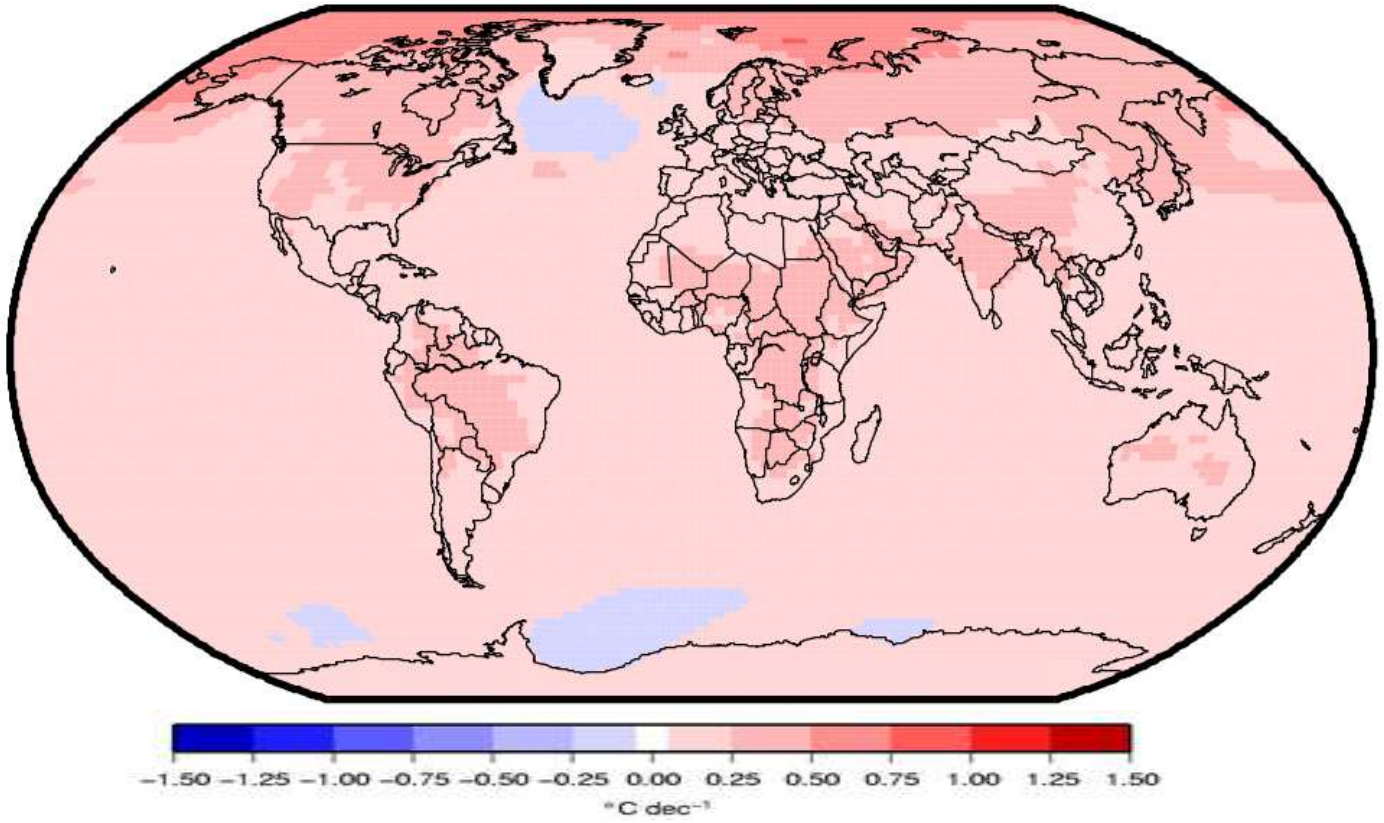
Schematic diagram of the global ocean circulation pathways, the 'conveyer' belt (after W. Broecker, modified by E. Maier-Reimer).

Abrupt Climate Change

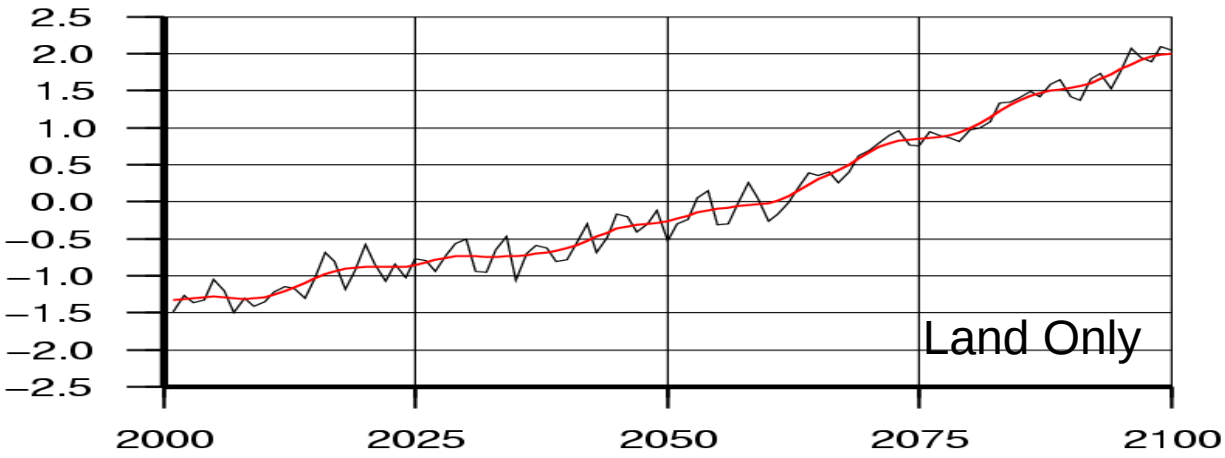


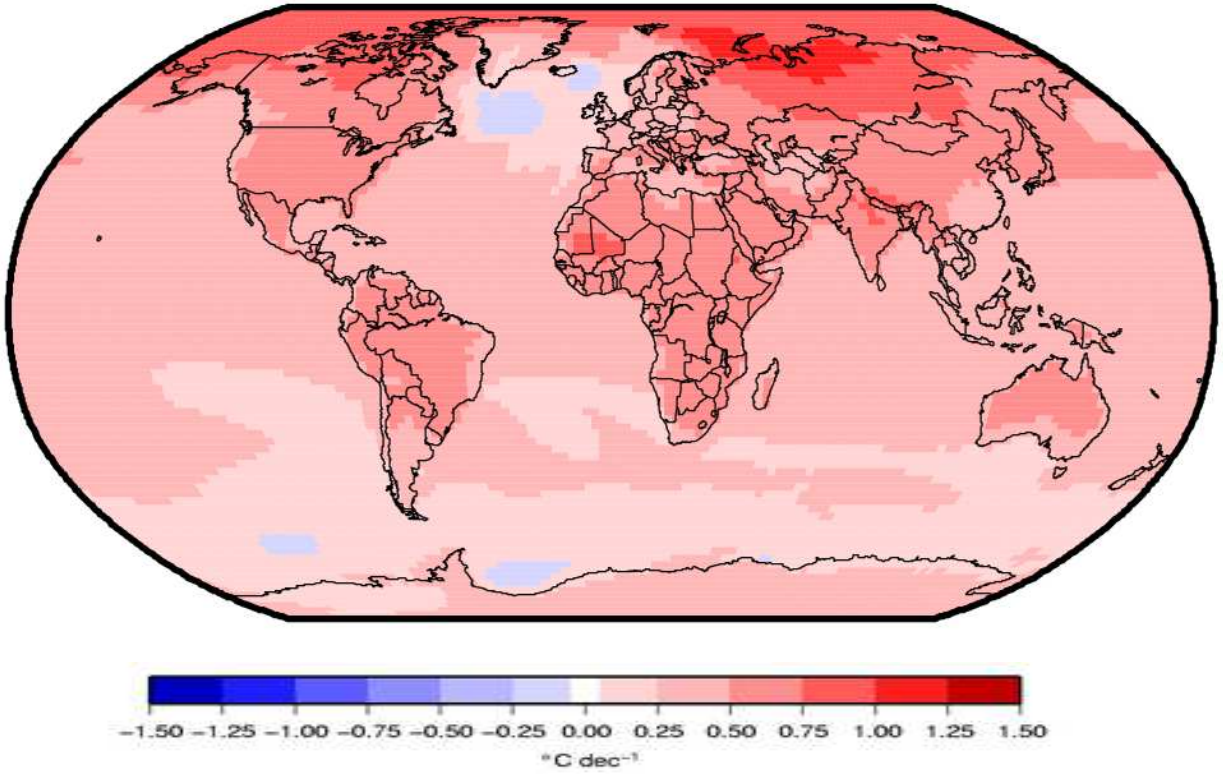
Minimum Temperature, B1 (low GHG) Scenario





Minimum Temperature, A2 (High GHG) Scenario

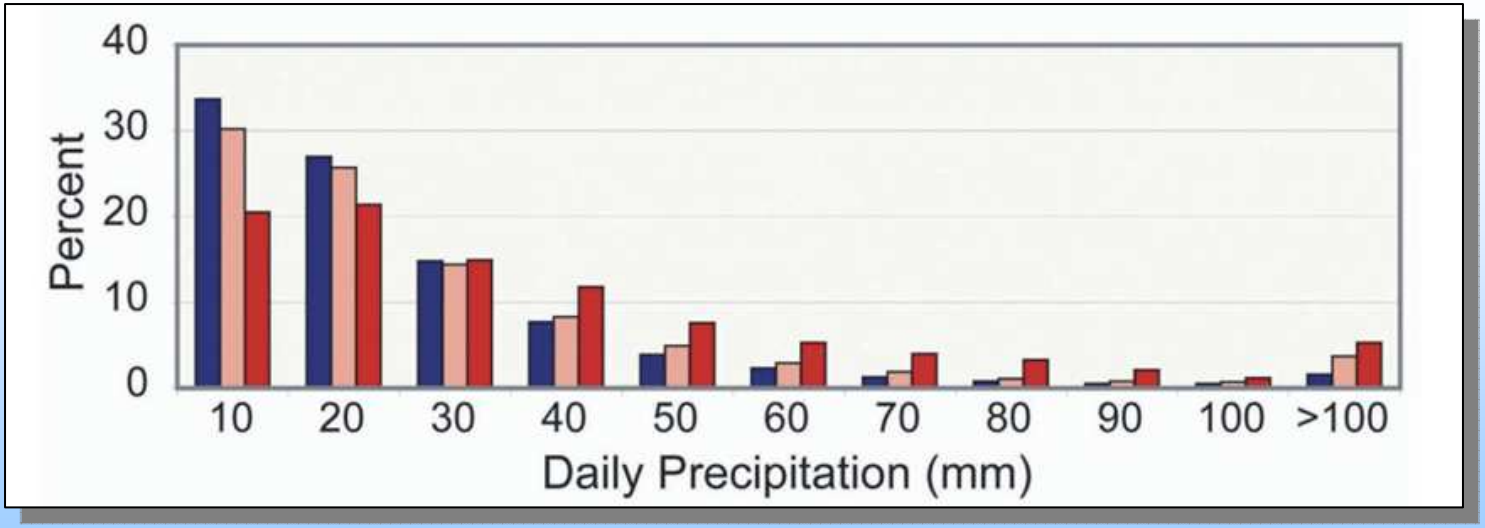


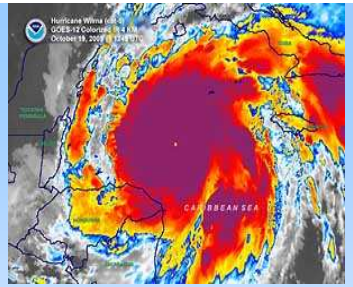


Changes in the Hydrologic Cycle

- **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





Atlantic Tropical Cyclones

- Numerous records established
  - Most named storms and hurricanes: 27 & 14
    - Previous record 21 (1933) & 12 (1969)
  - Three cat 5 storms (Katrina, Rita, Wilma)
    - Previous record of 2 in 1960 and 1961
  - 7 named U.S. landfalling storms (Tied 2nd) with 8th (Ophelia) brushing N.C. coast
    - Record 8 landfalling in 1916 and 2004
  - Lowest central pressure for Atlantic Hurricane
    - Wilma (882 mb) in October. Previous 888 mb (Gilbert, 1988)