

# Observed Climate Extremes

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**Observed  
(20th century)**

Modeling  
(end of 21st century)

***Simple extremes based on climate statistics***

Higher maximum temperatures

**Very likely**

Very likely

More hot summer days

**Likely**

Very likely

Increase in heat Index

**Likely**

Very likely

Higher minimum temperatures

**Virtually certain**

Very likely

Fewer frost days (higher  
minimum temperatures)

**Virtually certain**

Likely\*

More heavy 1-day precipitation  
Events (increased intensity of  
precipitation events)

**Likely**

Very likely

More heavy multiday  
precipitation events  
(increased intensity of  
precipitation events)

**Likely**

Very likely

## ***Complex event-driven climate extremes***

**Observed  
(20th century)**

Modeling  
(end of 21st century)

More heat waves

**Possible**

Very likely\* (higher  
maximum temperatures)

Fewer cold waves

**Very likely**

Very likely\* (higher  
minimum temperatures)

More drought

**Unlikely**

Very likely (reduced mid-  
latitude summer soil moisture)

More wet spells

**Likely**

Likely (increased  
precipitation at mid-and high  
latitudes in winter)

More tropical storms

**Unlikely**

Possible

More intense tropical storms

**Unlikely**

Possible

More intense mid-latitude  
storms

**Possible**

Possible

More intense El Nino events

**Possible**

Possible

More common El Nino like  
conditions

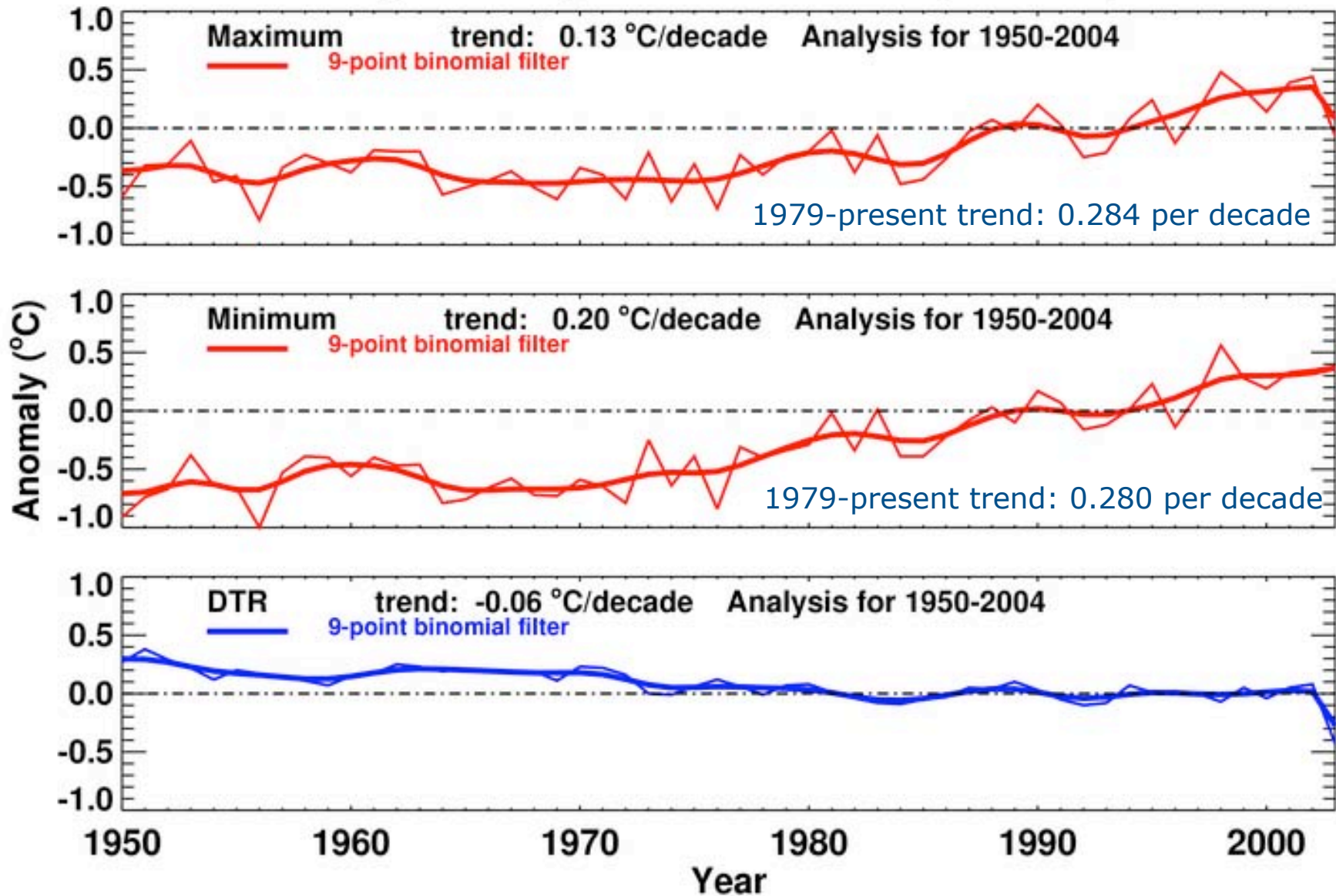
**Likely**

Likely\*

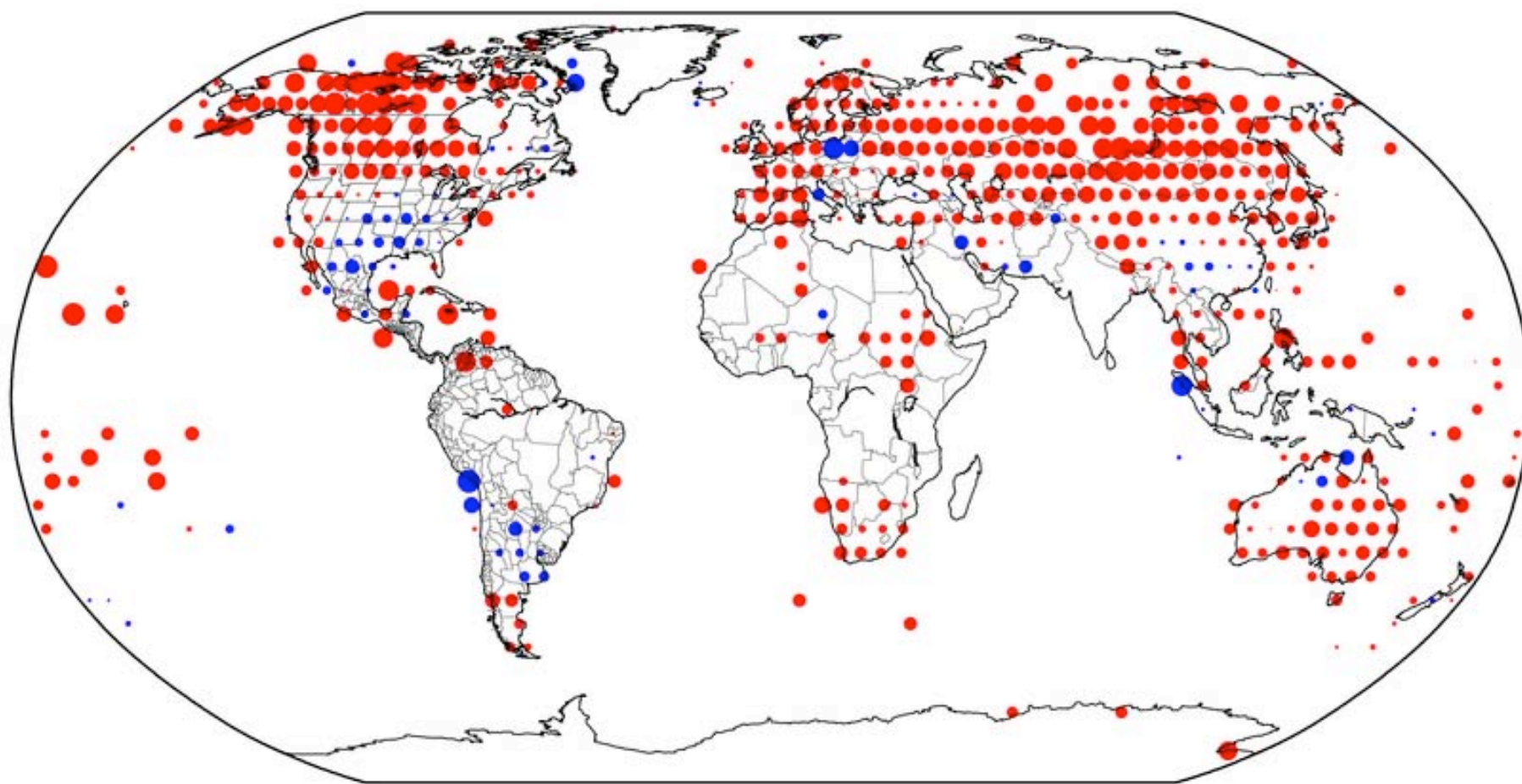
\*No direct model analyses, but these changes are physically plausible on the basis of other simulated model changes; comparable changes simulated by the models are noted in parentheses.

- Maximum daily temperature increase:  
very likely
- Minimum temperature increase:  
virtually certain

## Globally Averaged Time Series (Annual)



## Annual Trends in Maximum Temperature Anomalies (1950-2003)

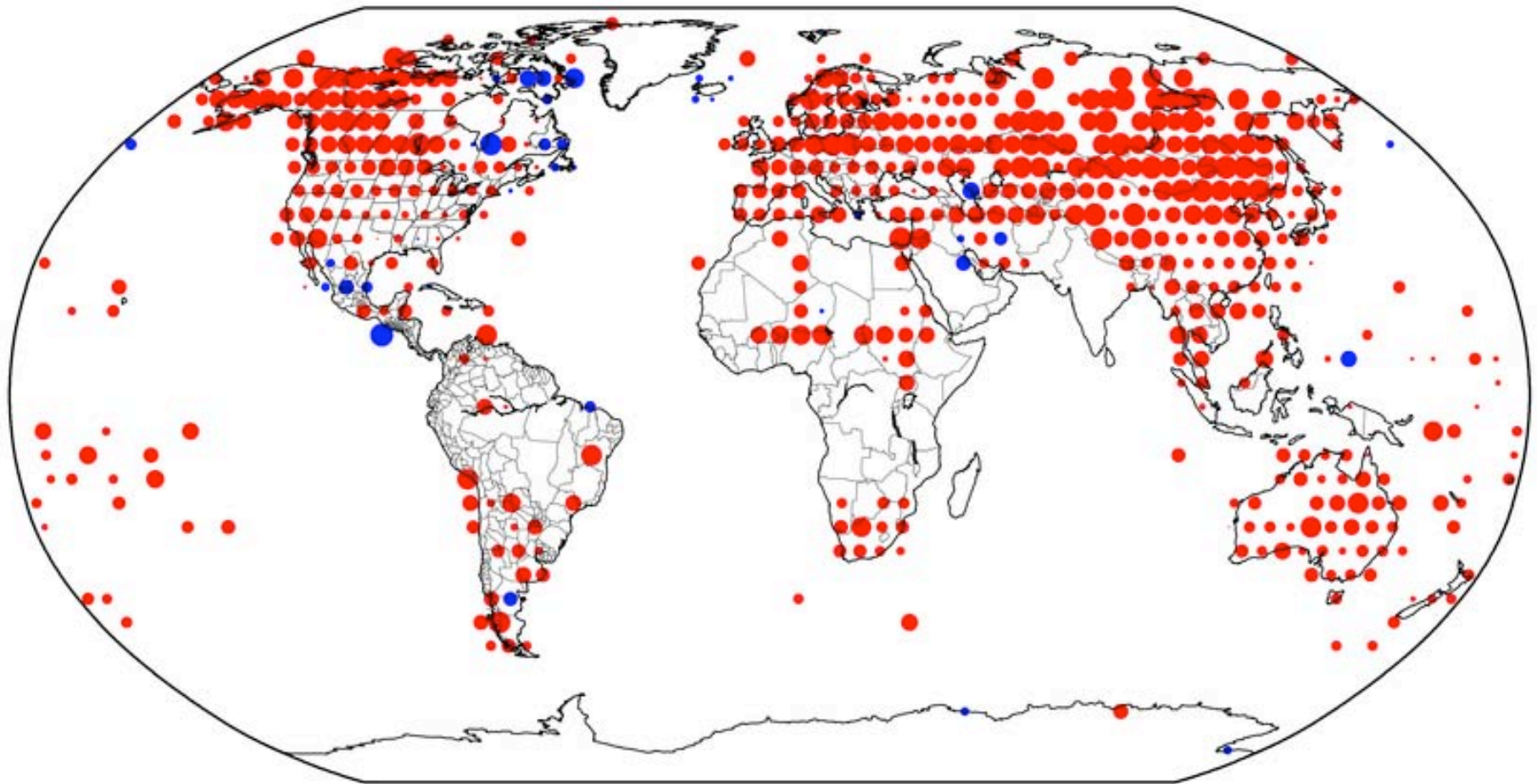


● ≤-0.5    ● -0.4    ● -0.3    ● -0.2    ● -0.1    0    ● 0.1    ● 0.2    ● 0.3    ● 0.4    ● ≥0.5

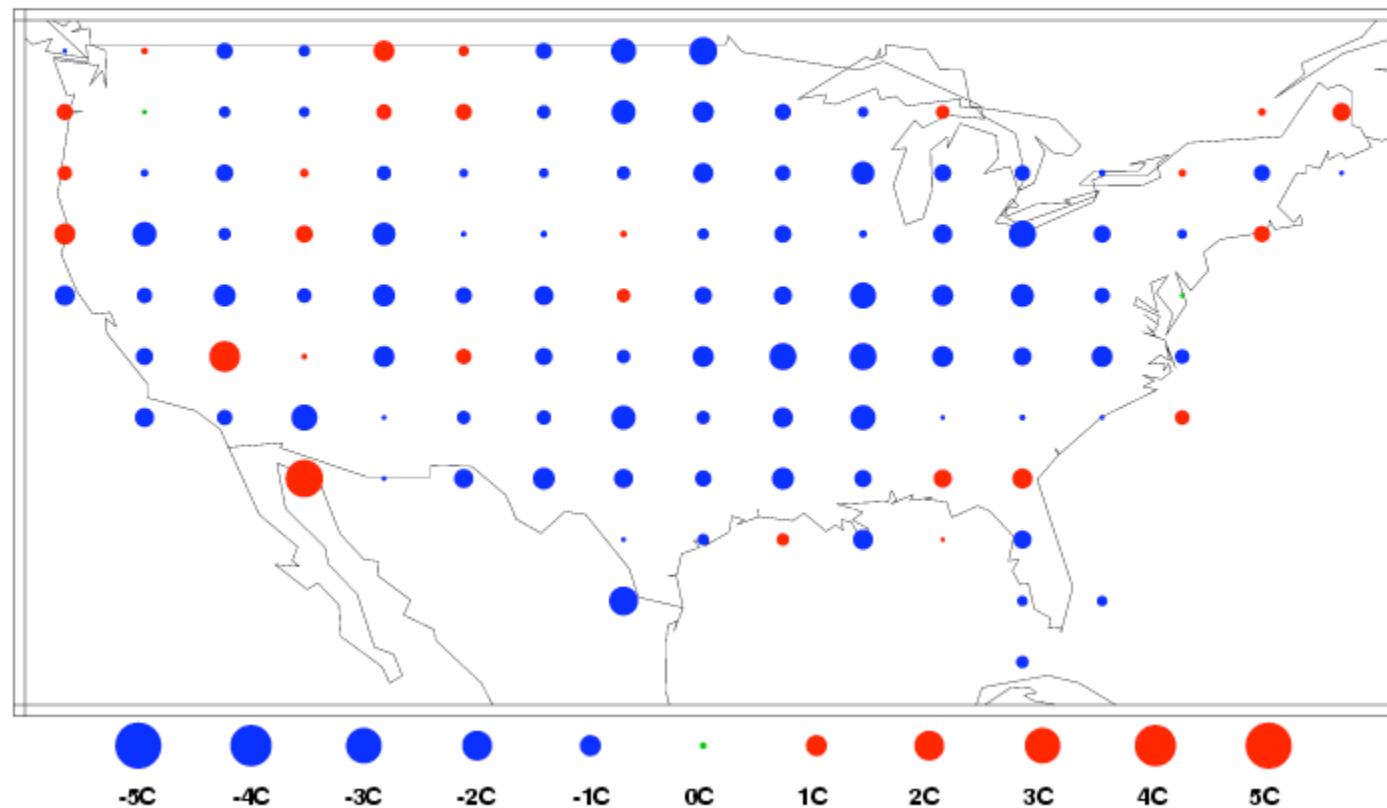
Trend (°C per decade)



## Annual Trends in Minimum Temperature Anomalies (1950-2003)

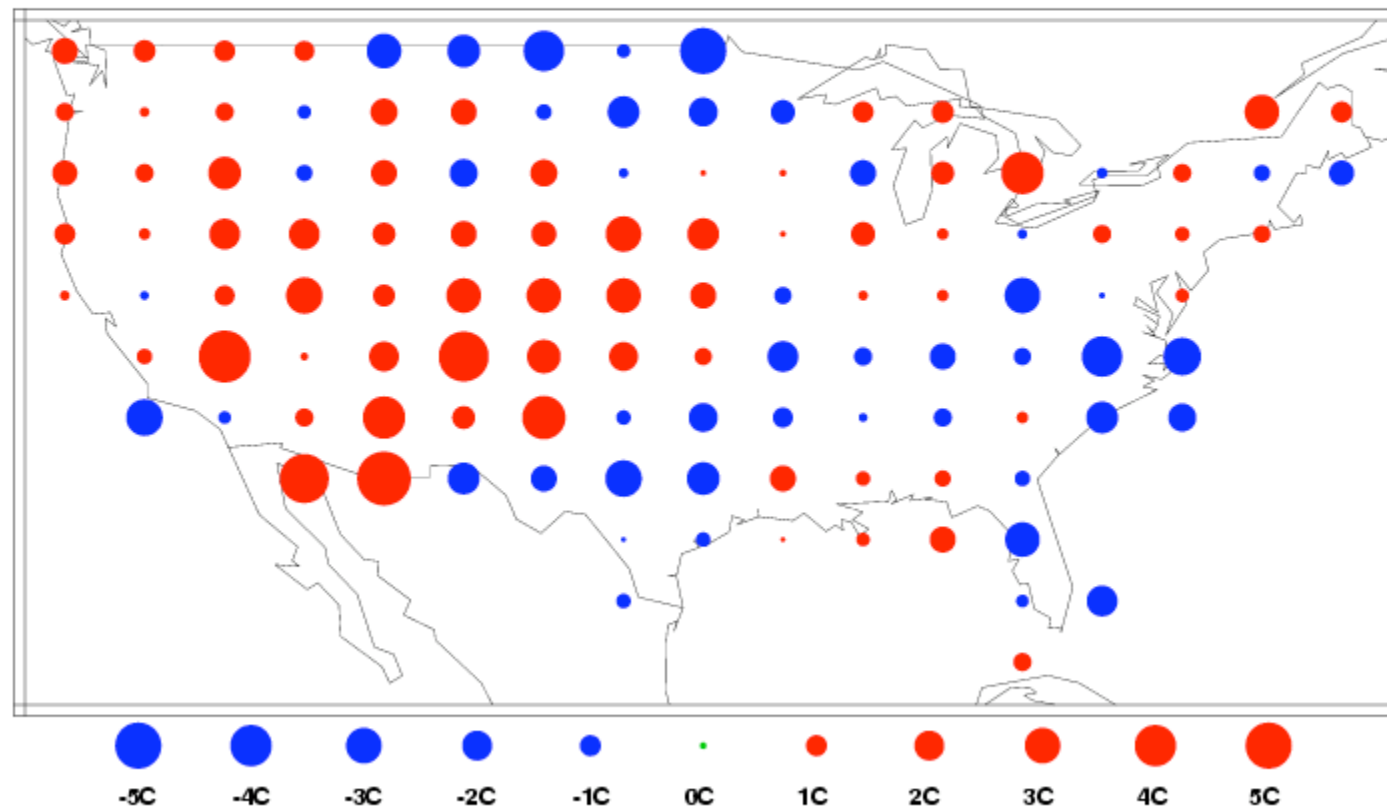


## Annual DTR Trends 1950-2004



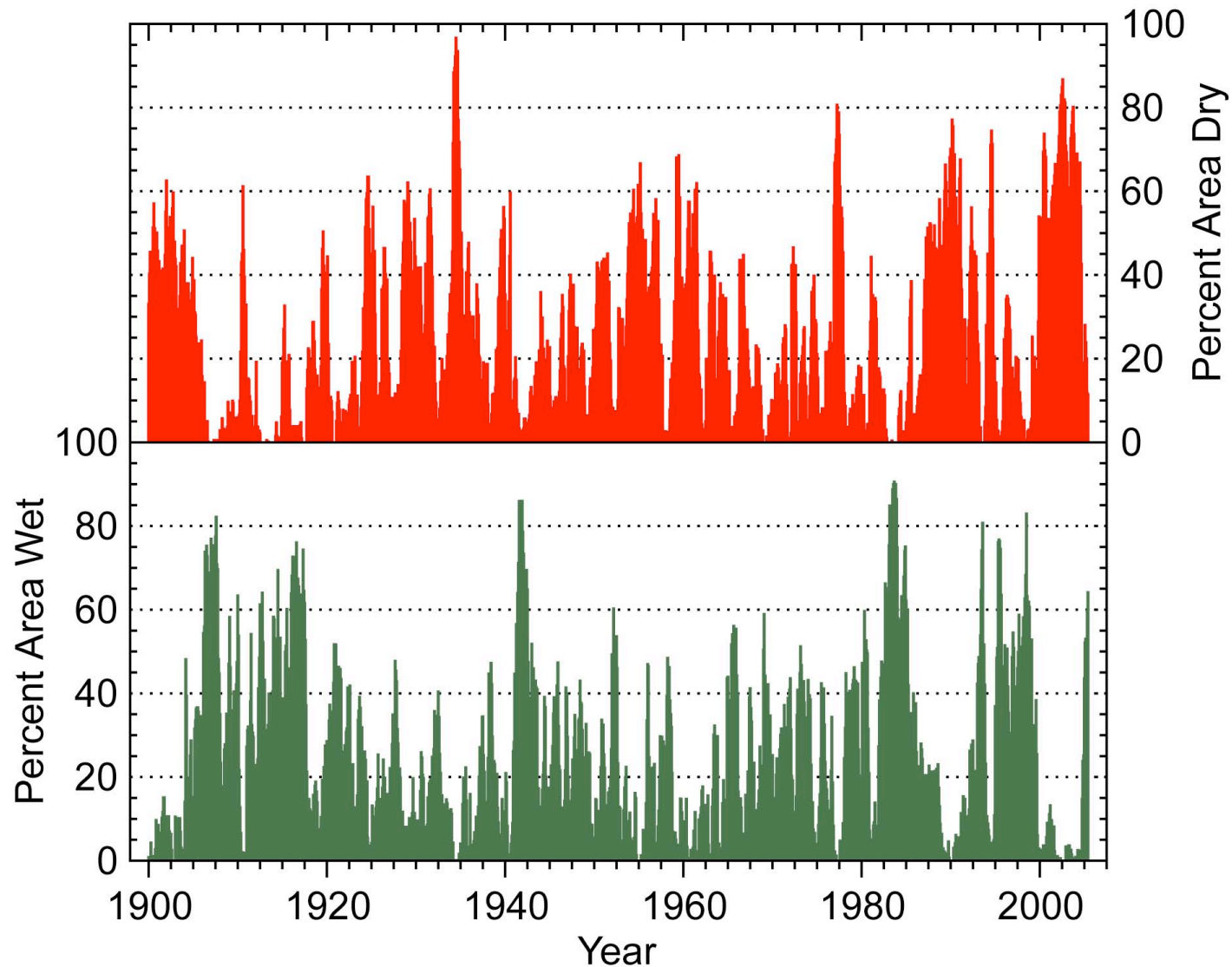


## Annual DTR Trends 1979-2004



- Increasing Drought: Unlikely
- Increaseing Wetness: Likely

# Western U.S. Percentage Area Wet or Dry January 1900 - June 2005



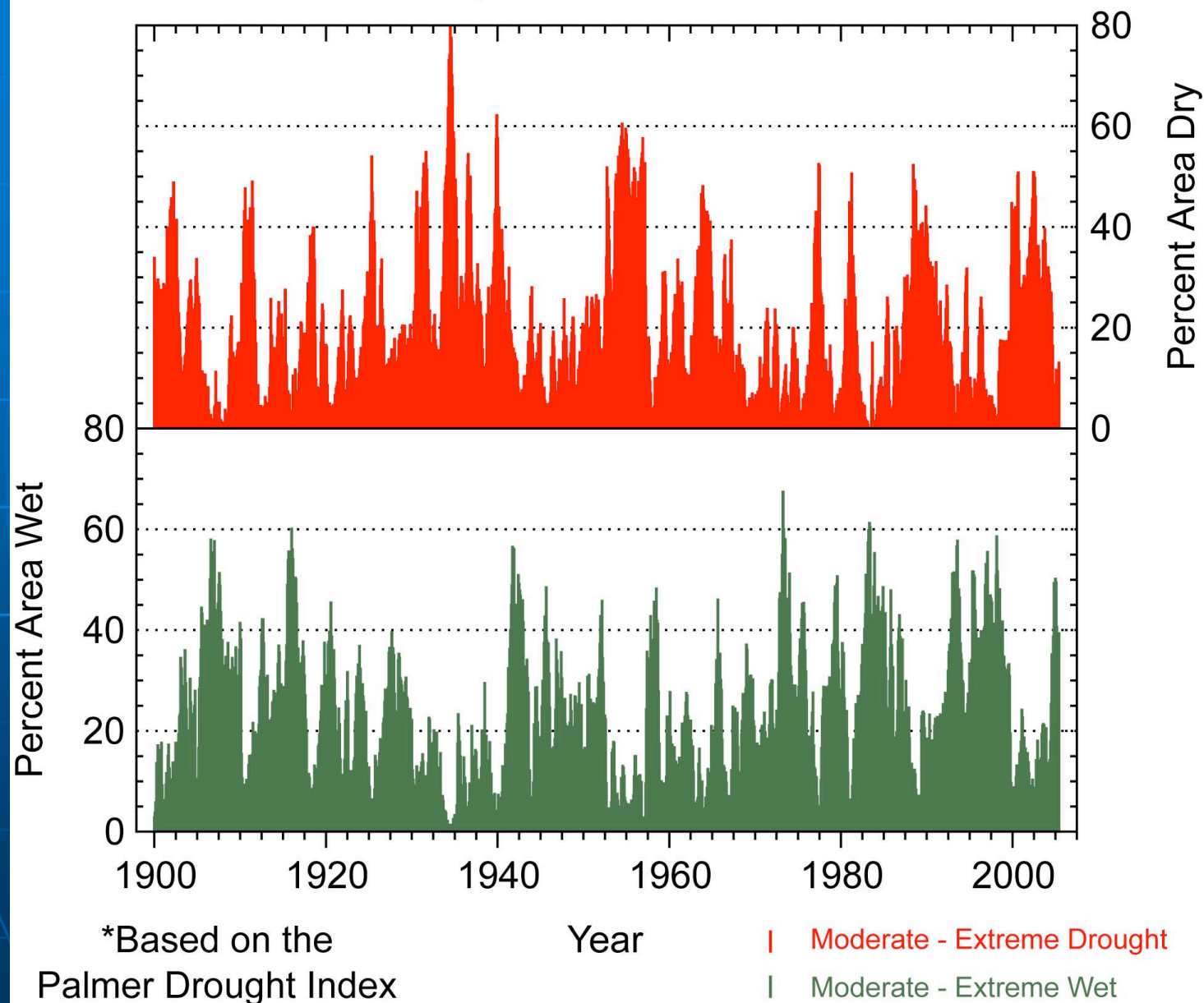
\*Based on the  
Palmer Drought Index

| Moderate - Extreme Drought

| Moderate - Extreme Wet

# U.S. Percentage Area Wet or Dry

January 1900 - June 2005



- Fewer Frost Days: Virtually Certain



1948-1999

State	Change (1948-1999)	Significance
Washington	-2.6	***
Oregon	-2.1	***
California	-1.0	**
Idaho	-0.8	**
Montana	-0.6	
Wyoming	-0.1	
Utah	-0.4	
Colorado	-0.08	
Nebraska	-0.1	
Kansas	-0.1	
Oklahoma	-0.1	
Missouri	-0.1	
Illinois	-0.1	
Indiana	-0.1	
Ohio	-0.1	
Michigan	-0.1	
Wisconsin	-0.1	
Minnesota	-0.1	
Iowa	-0.1	
Arkansas	-0.1	
Louisiana	-0.1	
Alabama	-0.1	
Georgia	-0.1	
Florida	-0.1	
South Carolina	-0.1	
North Carolina	-0.1	
Virginia	-0.1	
West Virginia	-0.1	
Maryland	-0.1	
Delaware	-0.1	
Pennsylvania	-0.1	
New Jersey	-0.1	
New York	-0.1	
Connecticut	-0.1	
Massachusetts	-0.1	
Rhode Island	-0.1	
Massachusetts	-0.1	
New Hampshire	-0.1	
Vermont	-0.1	
New Mexico	-0.1	
Arizona	-0.1	
Nevada	-0.1	
Alaska	-0.1	
Hawaii	-0.1	

Significance

90%	*
95%	**

> 90% \*

**> 95% \*\***

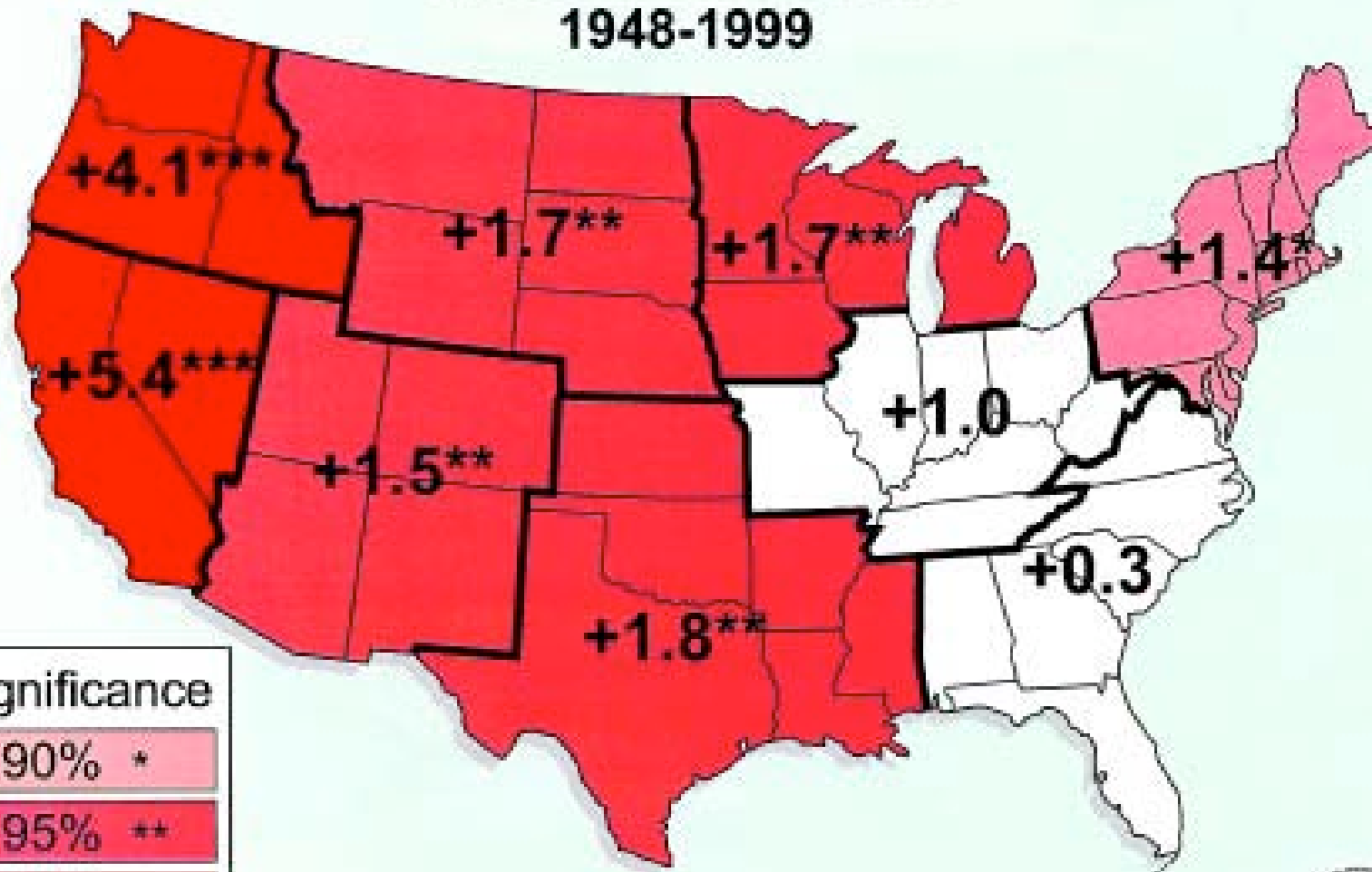
> 99% \*\*\*

Not Significant

All U.S. = -0.8\*\*



# CHANGE IN FROST-FREE LENGTH DAYS PER DECADE 1948-1999



## Significance

> 90% \*

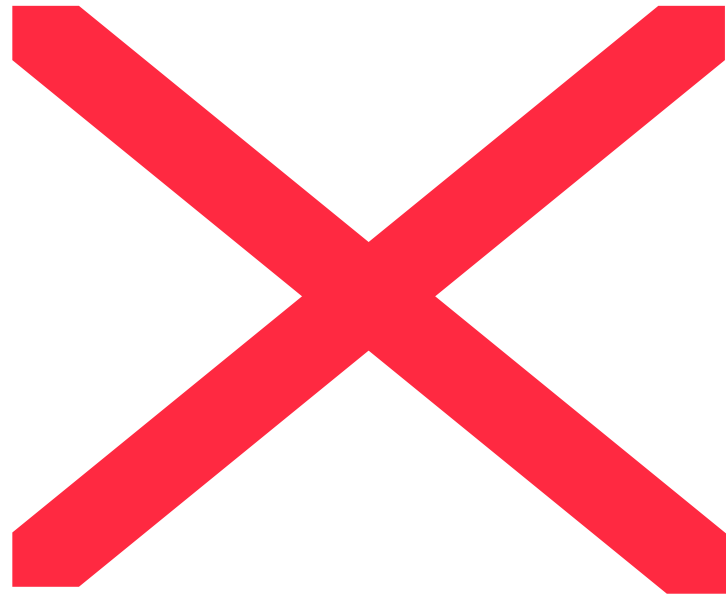
> 95% \*\*

> 99% \*\*\*

Not Significant

All U.S. = +2.0 \*\*\*





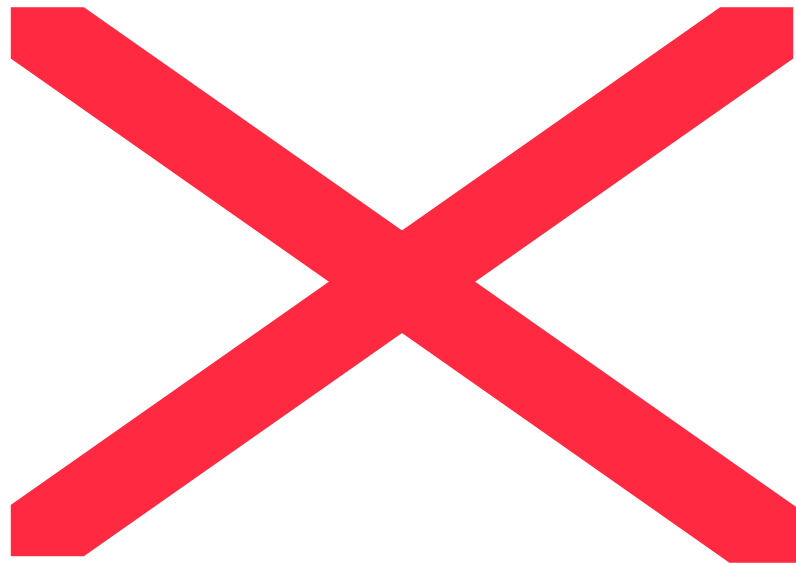
**Kunkel et al. 2003**

- More Heat Waves: Possible
- Fewer Cold Waves: Very Likely



**Kunkel *et al.* 1999**

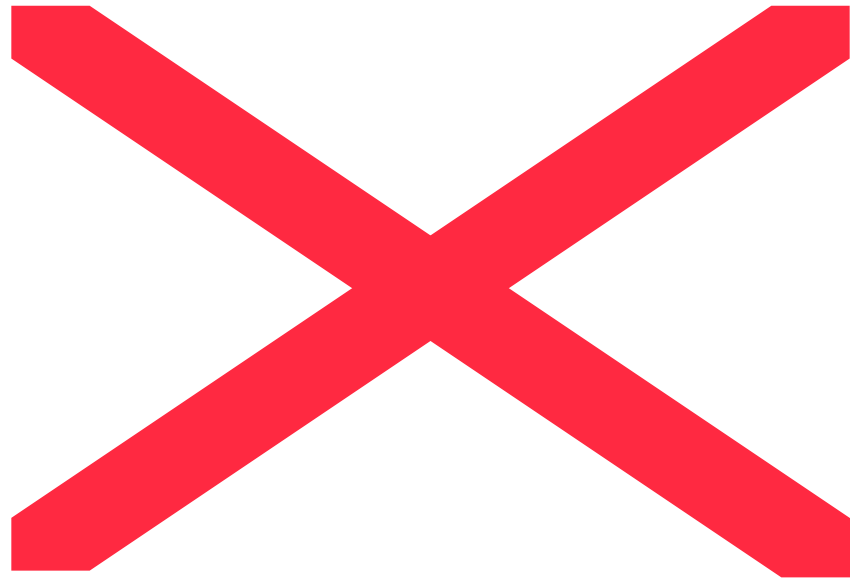


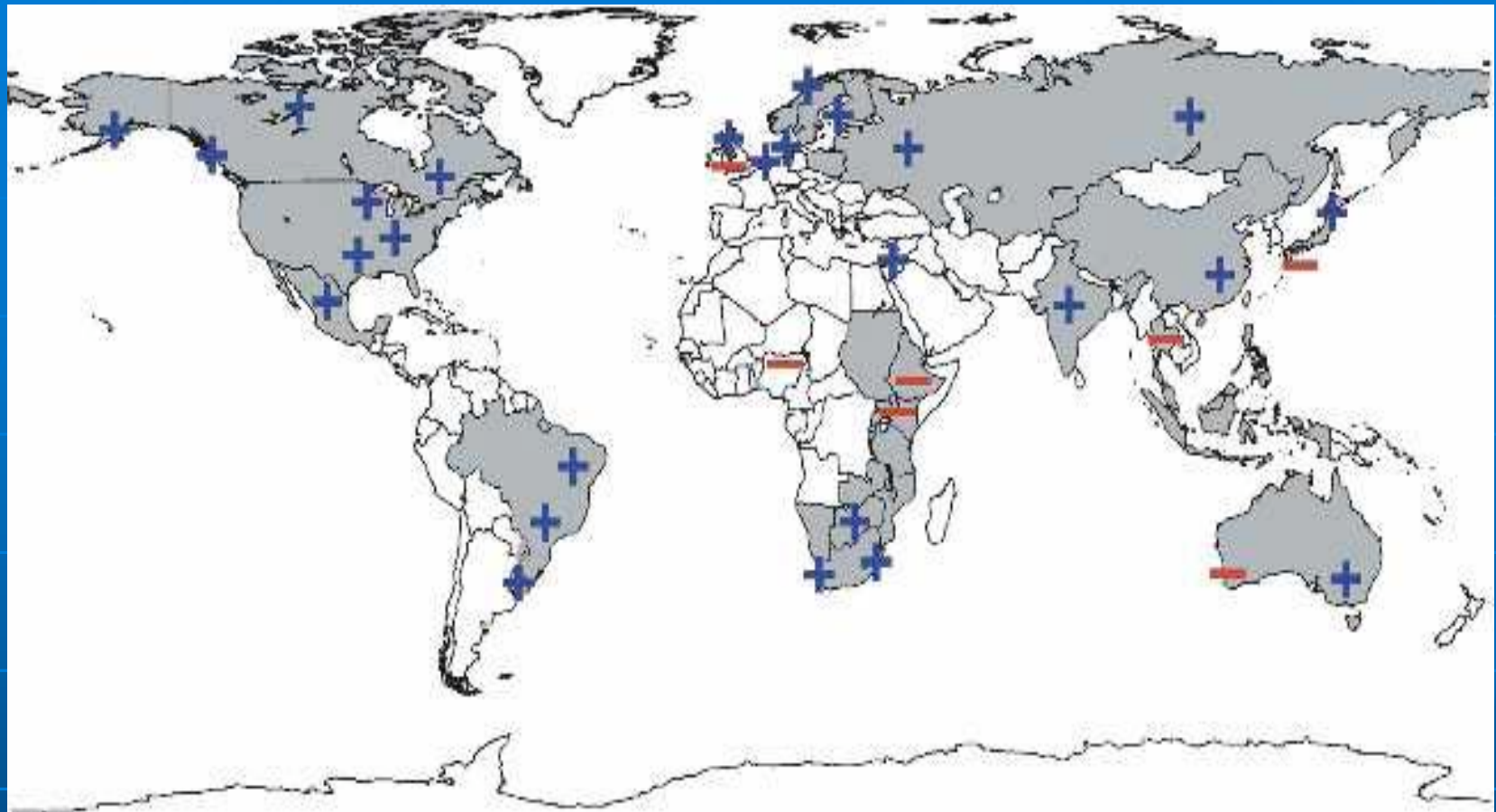


**Kunkel et al. 1999**

- More Heavy Precipitation Events:  
Likely

## Heavy Precipitation Indices, USA





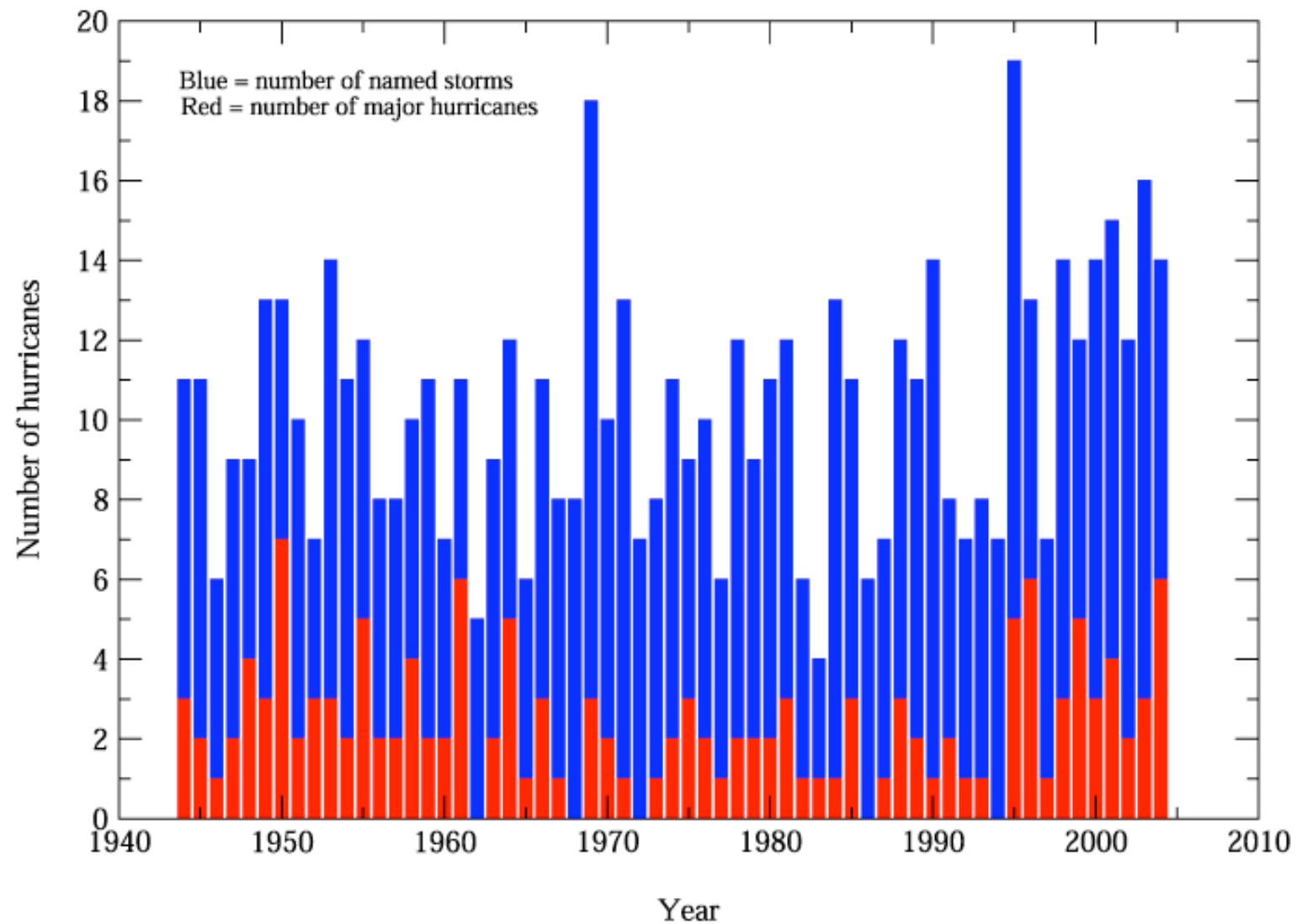
Regions where disproportionate changes in heavy and very heavy precipitation during the past decades were documented compared to the change in the annual and/or seasonal precipitation (Easterling et al. 2000c, substantially updated). Groisman et al. 2005

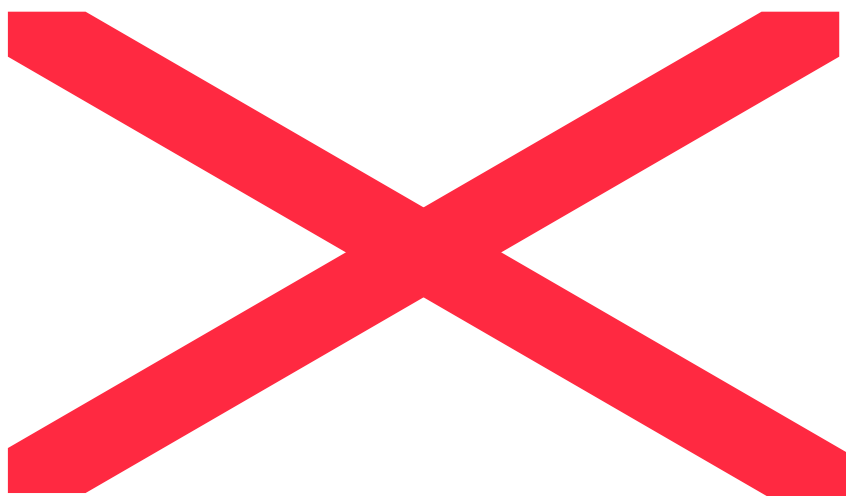
- More Tropical Cyclones: Unlikely
- More Intense Tropical Cyclones:  
Unlikely



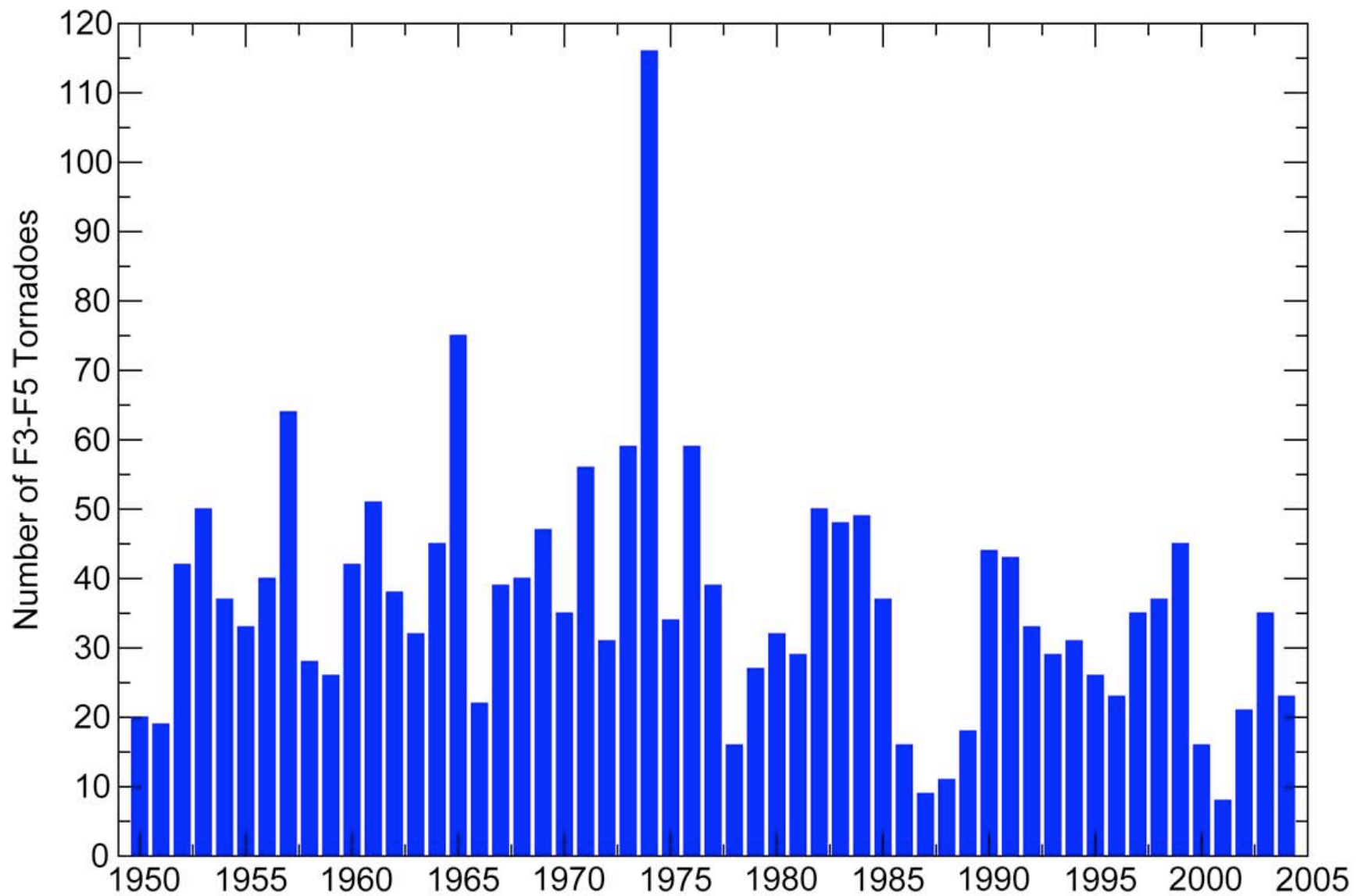
# Annual Number of Atlantic Tropical Storms and Hurricanes

1944-2004 (preliminary value for 2004)





# U.S. Tornadoes, F3-F5



# U.S. Tornadoes: Data Issues

- NWS training on estimating Fujita Scale in the 1980s
- Prior to 1970s Fujita Scale values estimated from news accounts, etc.
- All tornadoes (not shown) shows increase likely due to increase in population density and thus reporting.

# Data Issues: North America

- Daily data available for most of North America.
- Sub-daily (hourly) is available mainly for U.S.
- Spatial Distribution issues (e.g. Western US)
- Homogeneity issues: daily and hourly adjustments?
- Urbanization/land use effects?



# U.S. Climate Extremes Index (CEI)

Calculated by NCDC Climate  
Monitoring Branch

The U.S. CEI is the arithmetic average of the following six indicators of the percentage of the conterminous U.S. area:

- 1) The sum of (a) percentage of the United States with maximum temperatures much below normal and (b) percentage of the United States with maximum temperatures much above normal.
- 2) The sum of (a) percentage of the United States with minimum temperatures much below normal and (b) percentage of the United States with minimum temperatures much above normal.
- 3) The sum of (a) percentage of the United States in severe drought (equivalent to the lowest tenth percentile) based on the PDSI and (b) percentage of the United States with severe moisture surplus (equivalent to the highest tenth percentile) based on the PDSI.

- 4) Twice the value of the percentage of the United States with a much greater than normal proportion of precipitation derived from extreme (equivalent to the highest tenth percentile) 1-day precipitation events.
- 5) The sum of (a) percentage of the United States with a much greater than normal number of days with precipitation and (b) percentage of the United States with a much greater than normal number of days without precipitation.
- \*6) The sum of squares of U.S. landfalling tropical storm and hurricane wind velocities scaled to the mean of the first five indicators.

*# The original CEI utilized only the first five indicators.*

*\* The sixth indicator is only utilized when the period of interest includes months with significant tropical activity.*

# U.S. Climate Extremes Index

Annual (Jan-Dec)

1910-2004

