Extreme Precipitation Events: Data Issues and Meteorological Causes

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U.S. Climate Data

- U.S. Cooperative Observer Network in operation since late 1880s is the core network for examining long-term changes
- Daily Observations – Max and Min Temp, Precip, Snowfall, Snow Depth

Measurement Features/Issues

- Instrumentation – 8 inch gage
- Frozen precipitation catch
- Wind affected catch
- Exposure
- Volunteer observer adherence to procedures and accuracy in recording observations

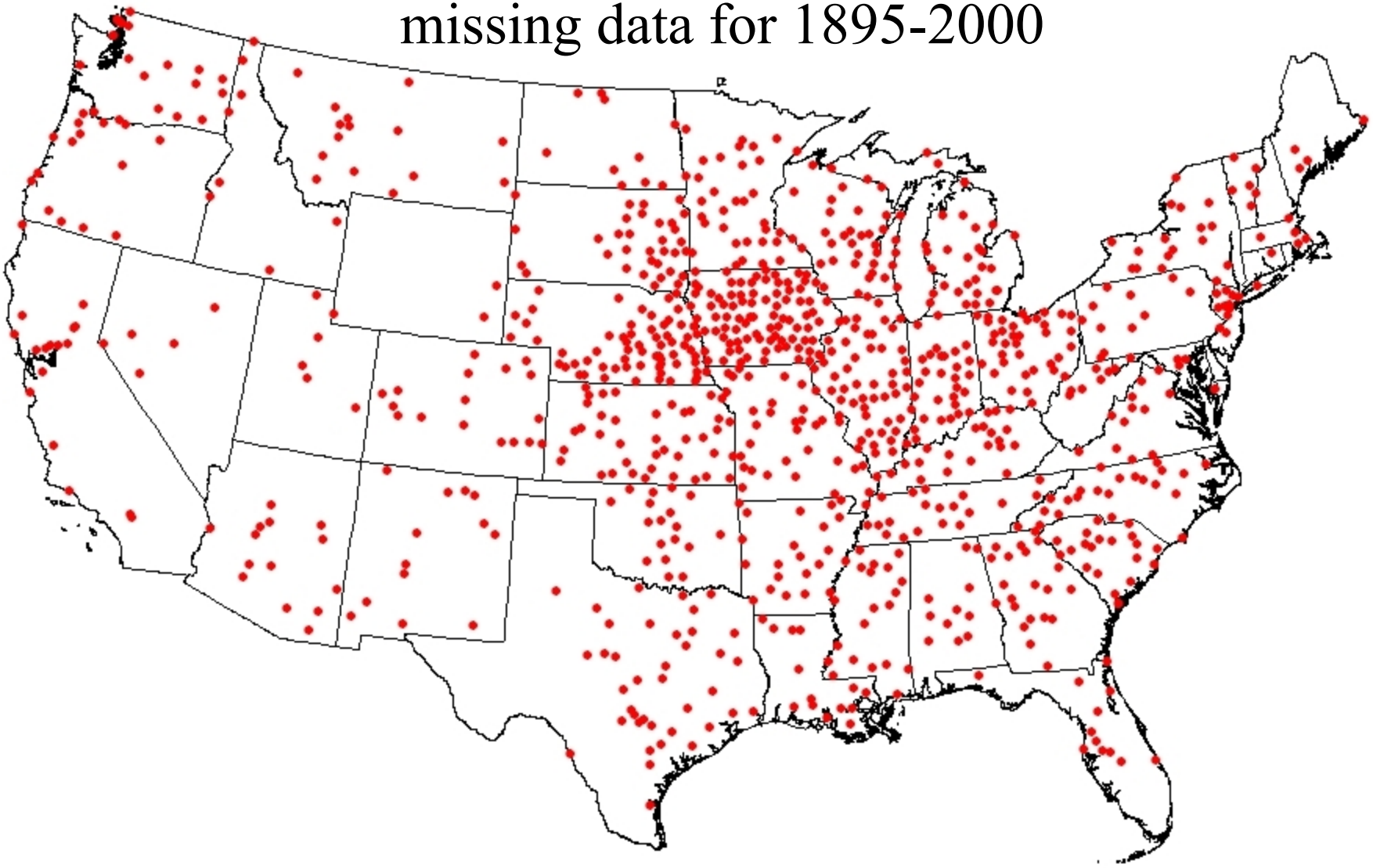
Data Issues

- Network changes
- Station density
- Missing data
- Erroneous values

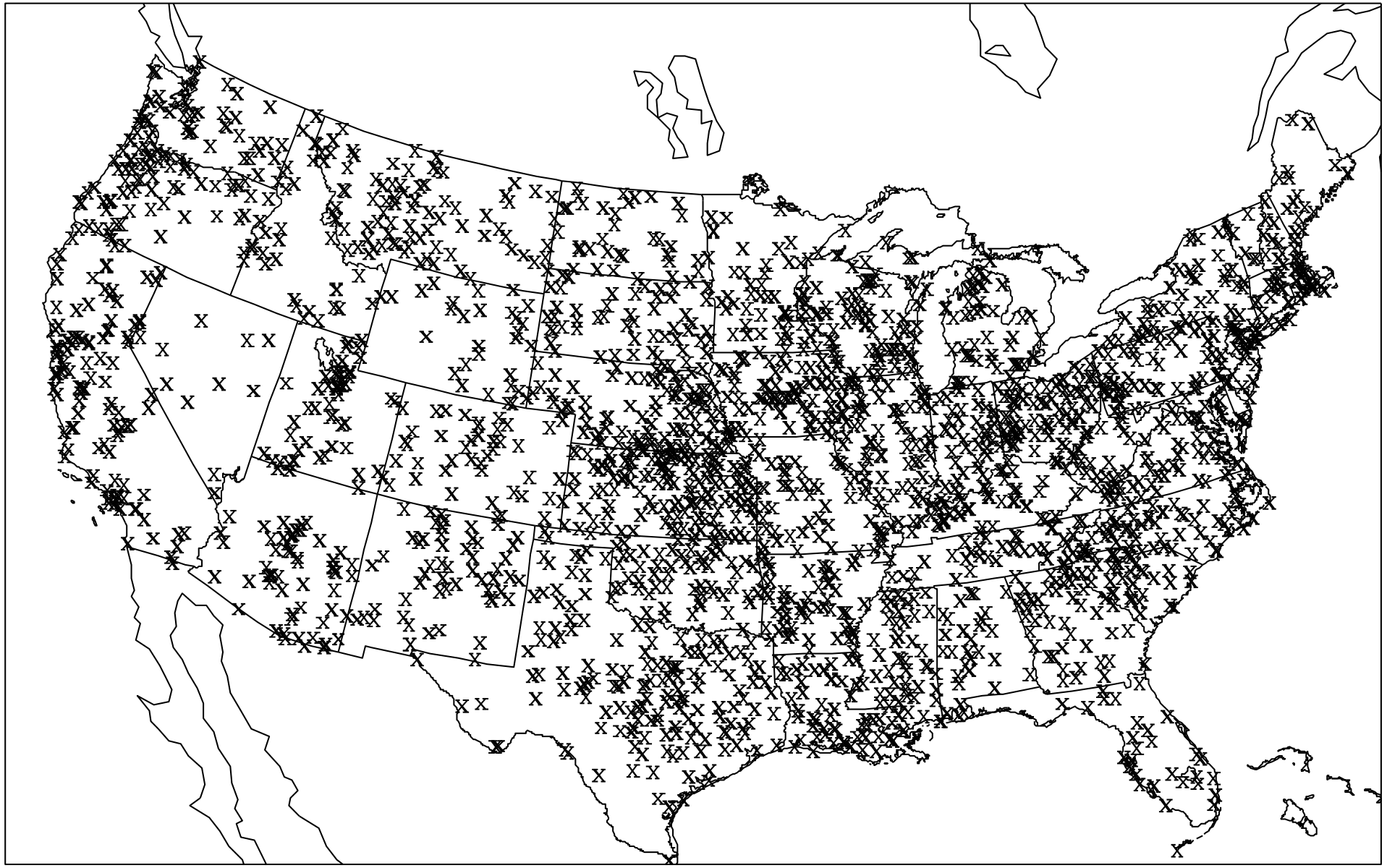
Data Issues

- (My) Principle for time series analysis: minimize missing data for period of analysis; choose only stations with minimal missing data such that the network remains largely constant over period of analysis
- This avoids issues of introducing artificial trends due to stations coming into and out of network

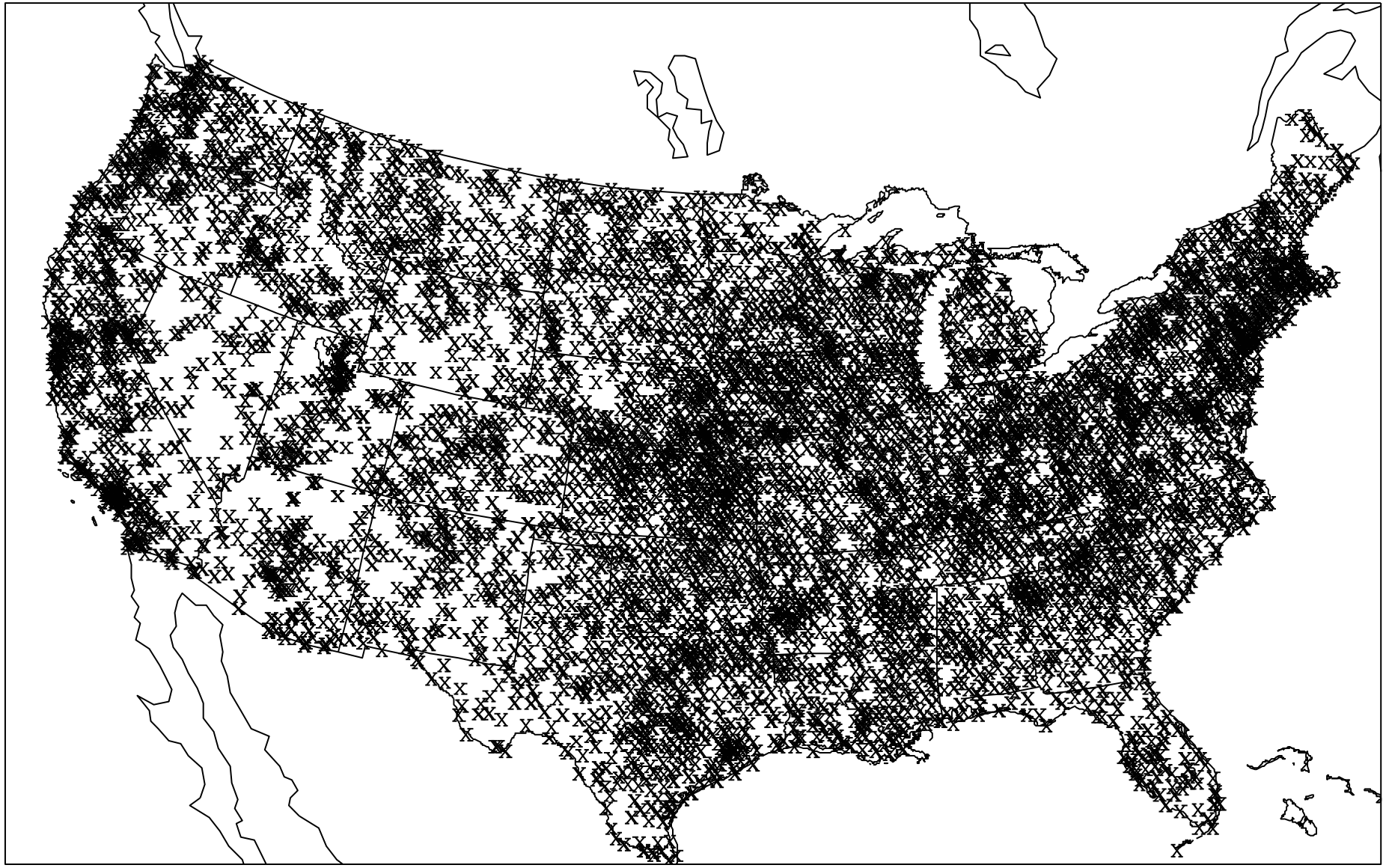
Long-term Precipitation Stations: <10% missing data for 1895-2000



High quality station network (2338 stations with < 1% missing data for 1971-2000



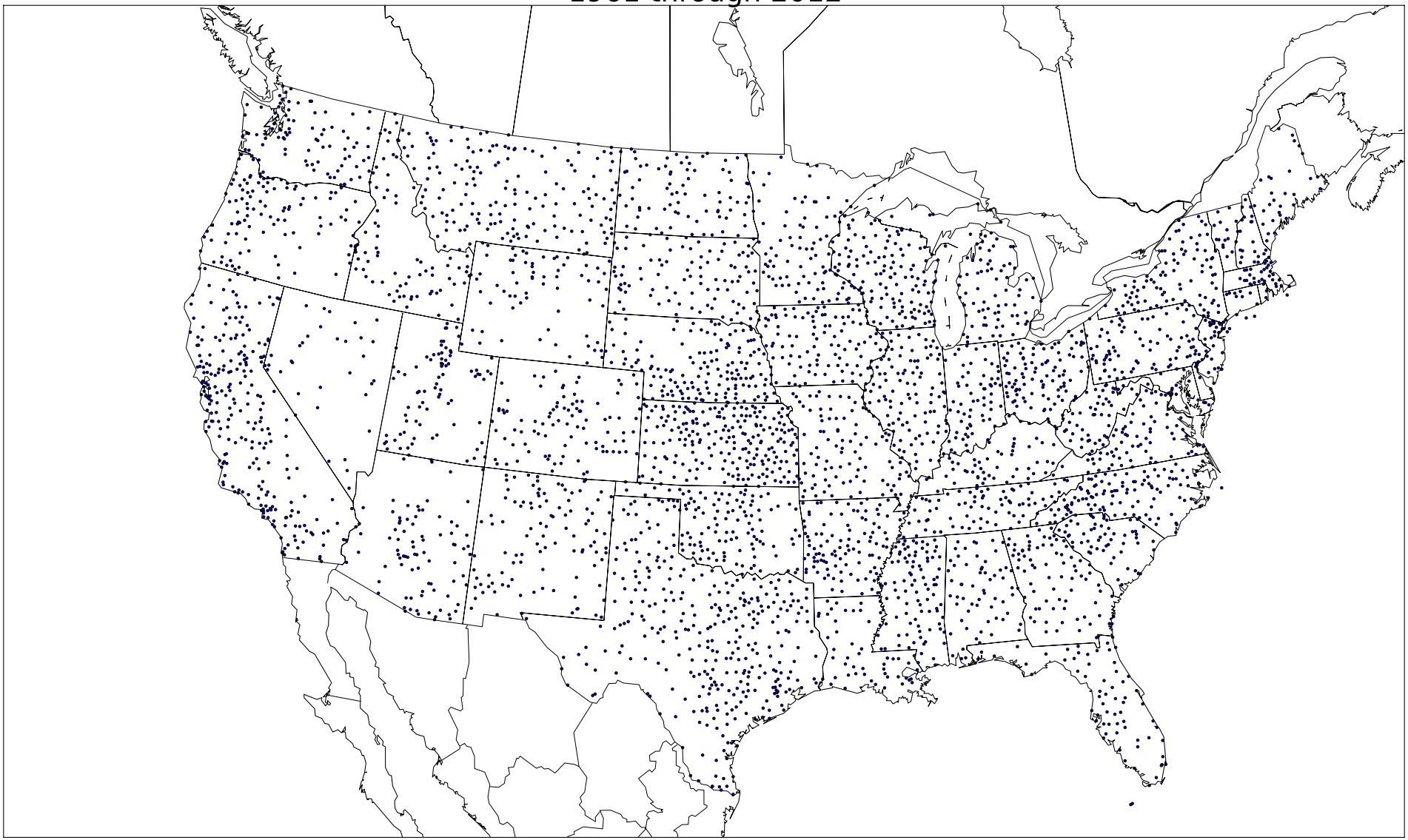
High density station network (stations with < 20% missing data for 1971-2000



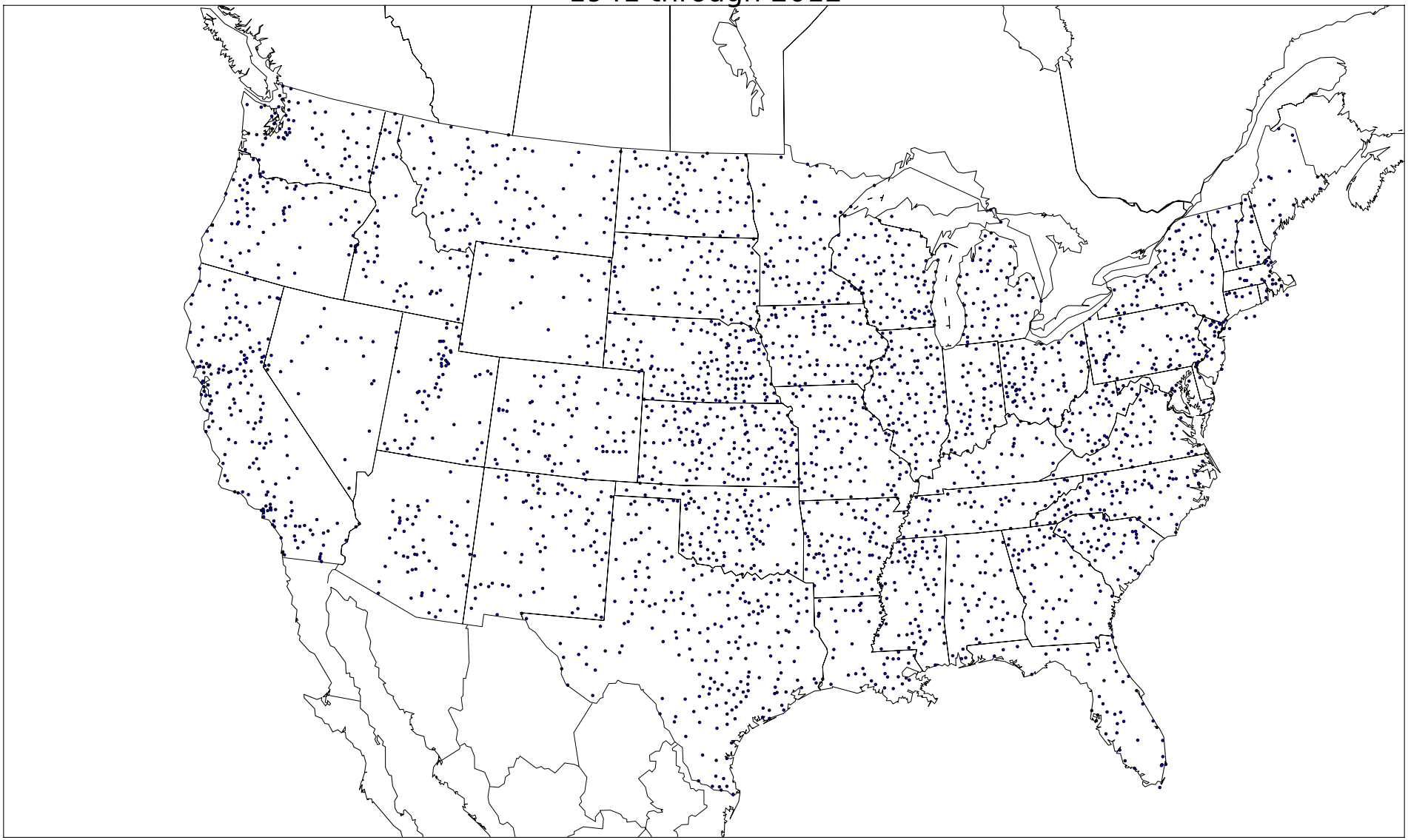
Station Density

- Following maps show locations of stations with less than 10% missing data for various periods ending in 2012
- 1961-2012, 1941-2012, 1921-2012,1901-2012, 1895-2012

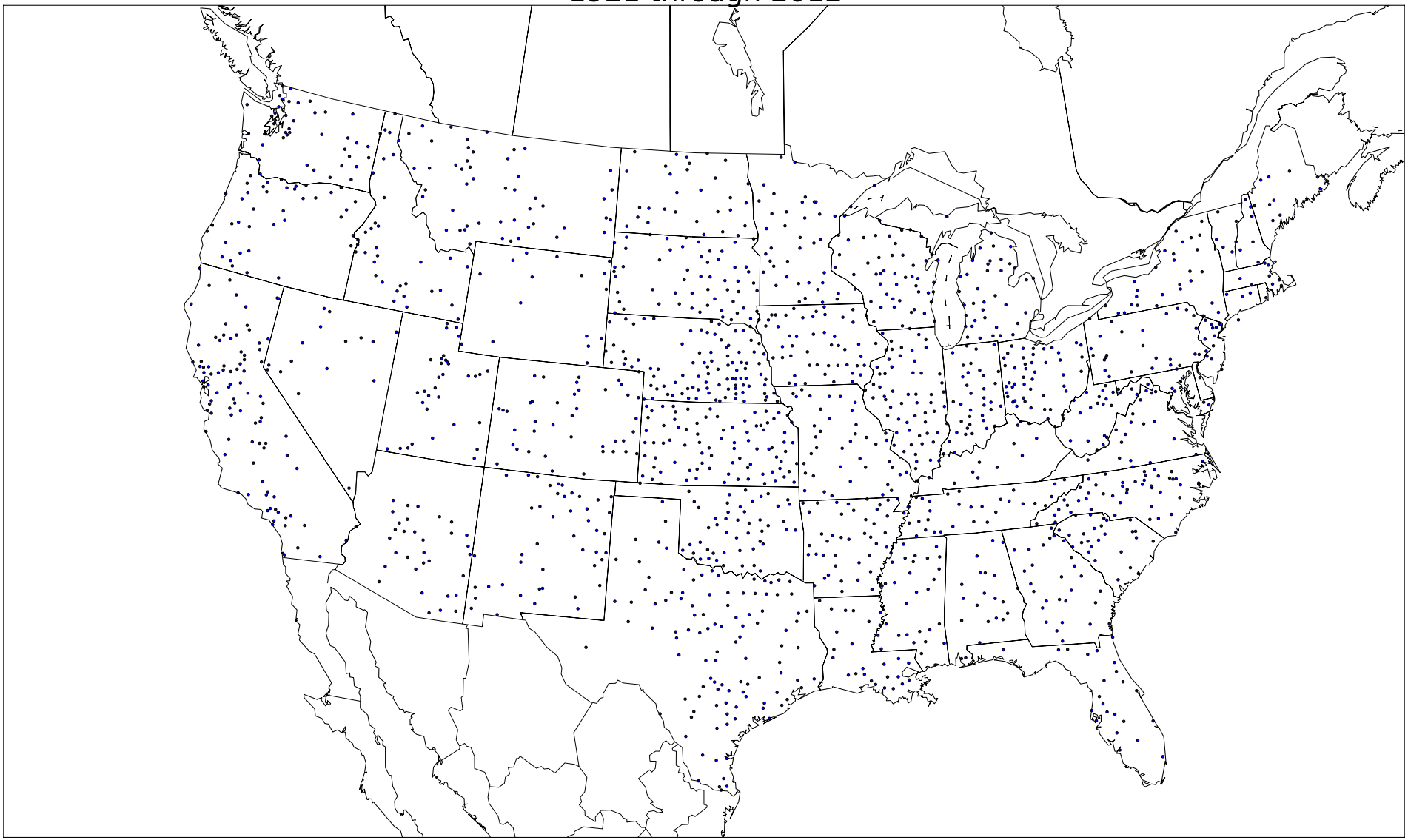
1961 through 2012



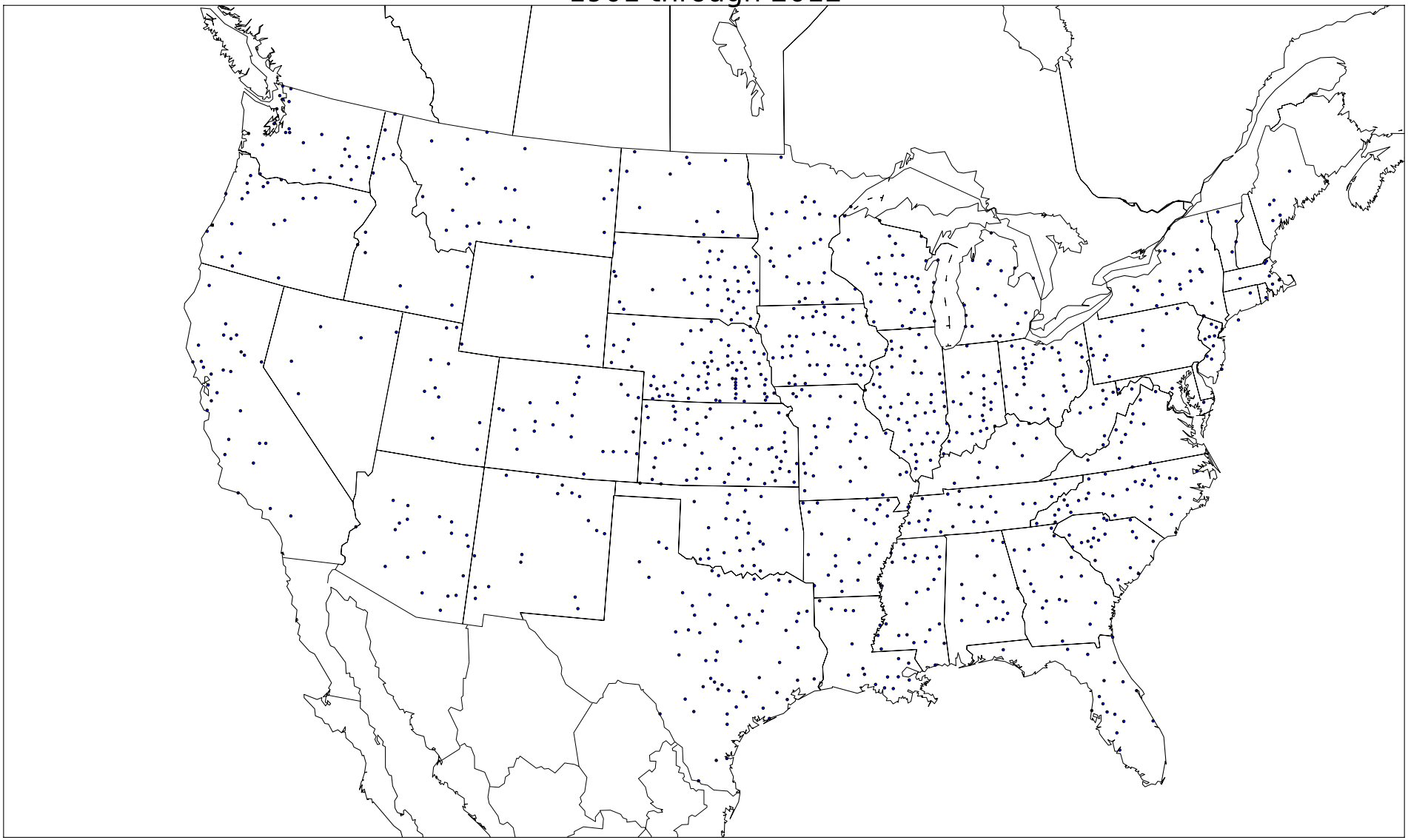
1941 through 2012



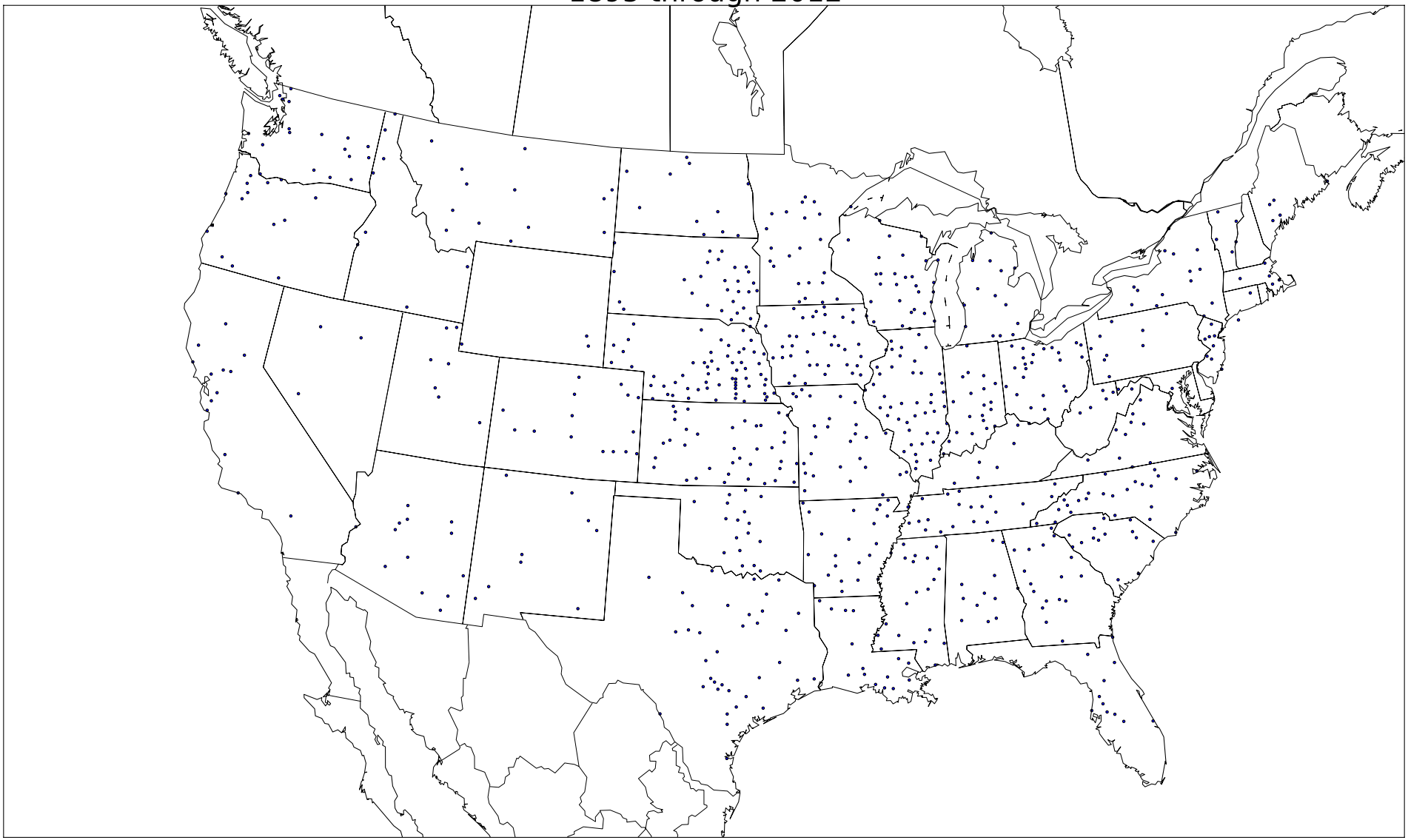
1921 through 2012



1901 through 2012



1895 through 2012



Observing and recording errors

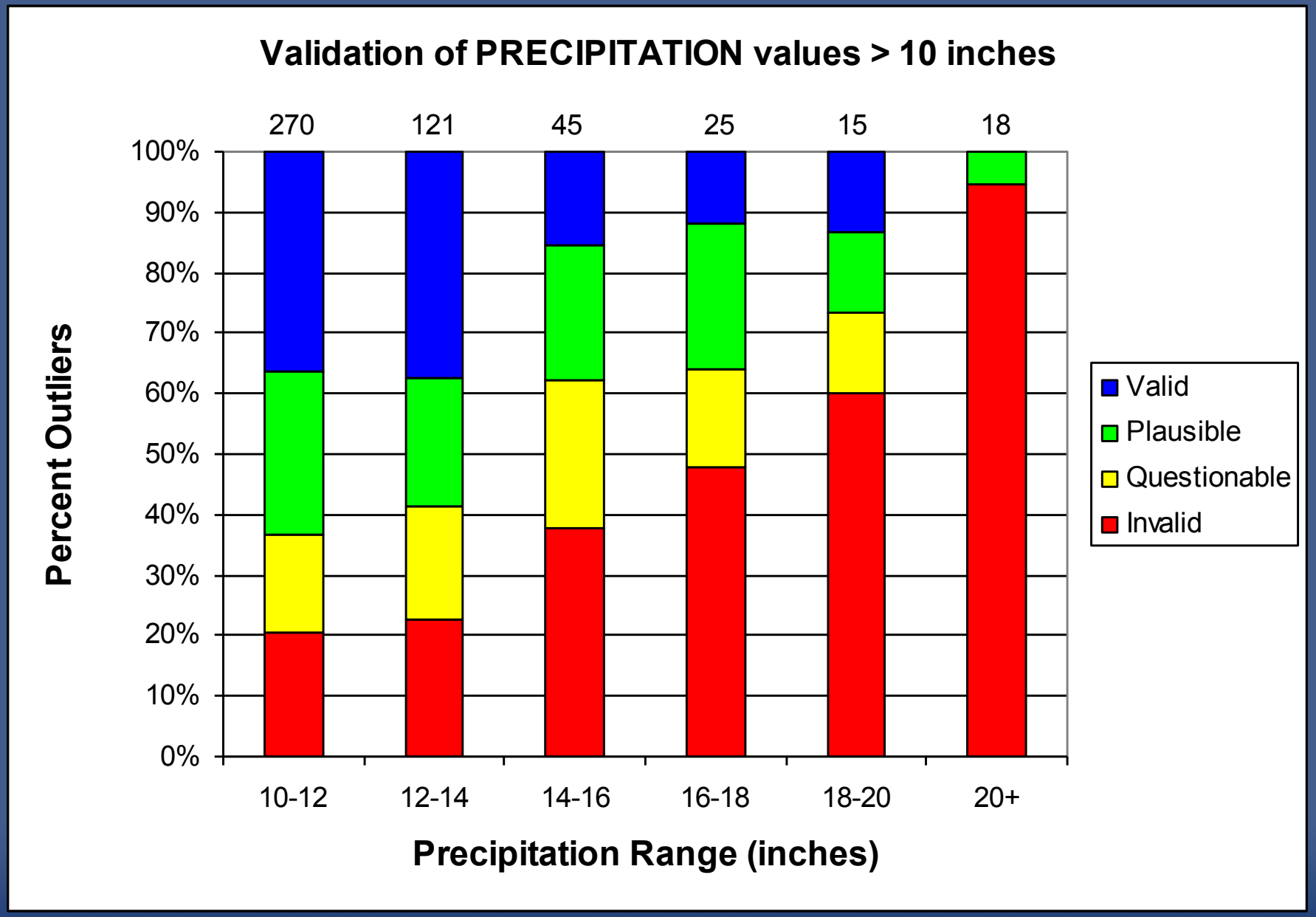
- In the early 2000s, COOP data that had not been previously digitized were keyed (primarily for the period prior to 1948)
- We performed QC on these data

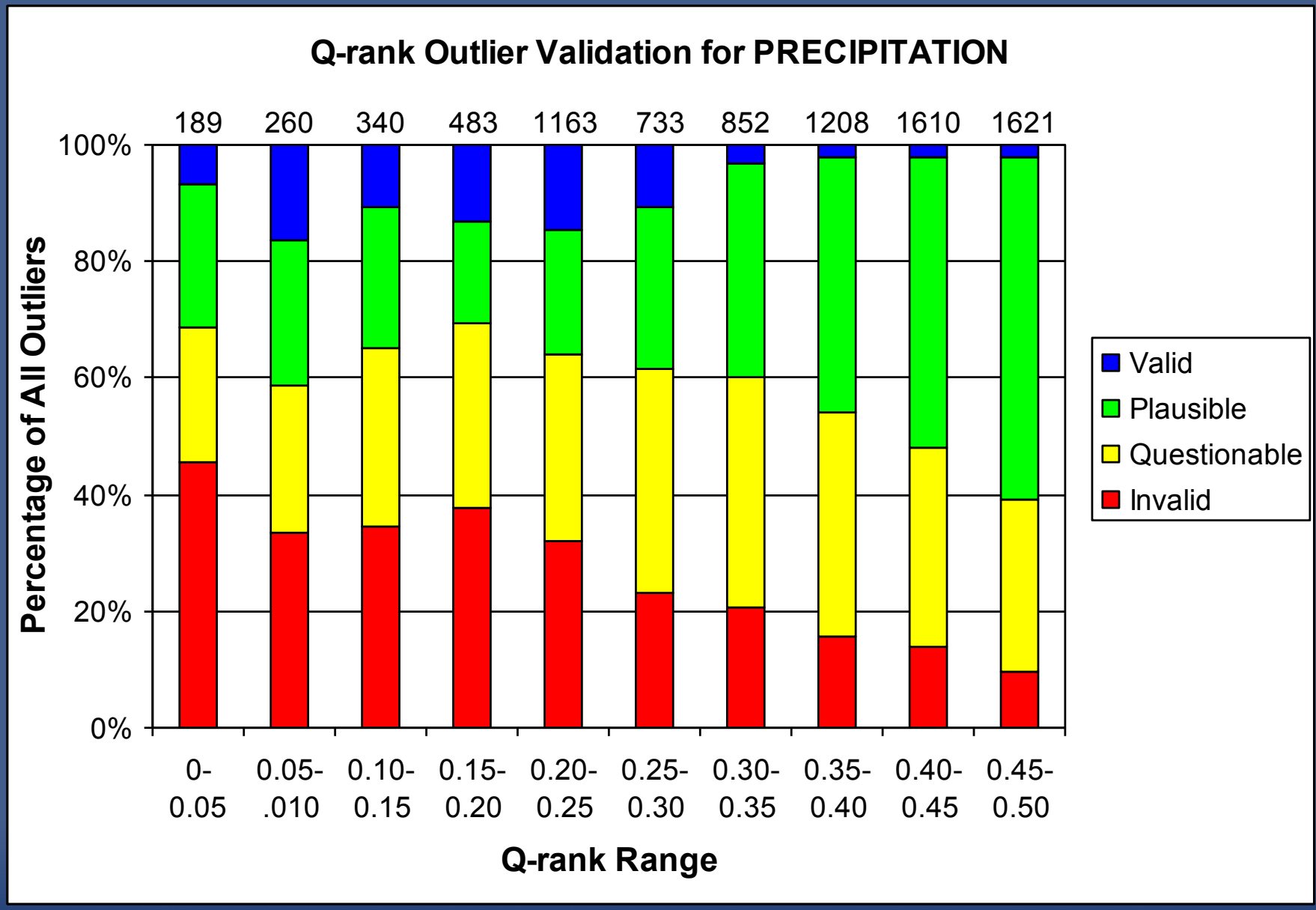
Identification of Precipitation Outliers

- Daily precipitation > 10 inches
- Spatial coherence test

  - ratio of precipitation amounts (nearby station/ tested station)

  - ratio of precipitation percentiles (nearby station/ tested station)


Validation of PRECIPITATION values > 10 inches
270
121
45
25
15
18
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent Outliers
10-12
12-14
14-16
16-18
18-20
20+
Precipitation Range (inches)
Valid
Plausible
Questionable
Invalid

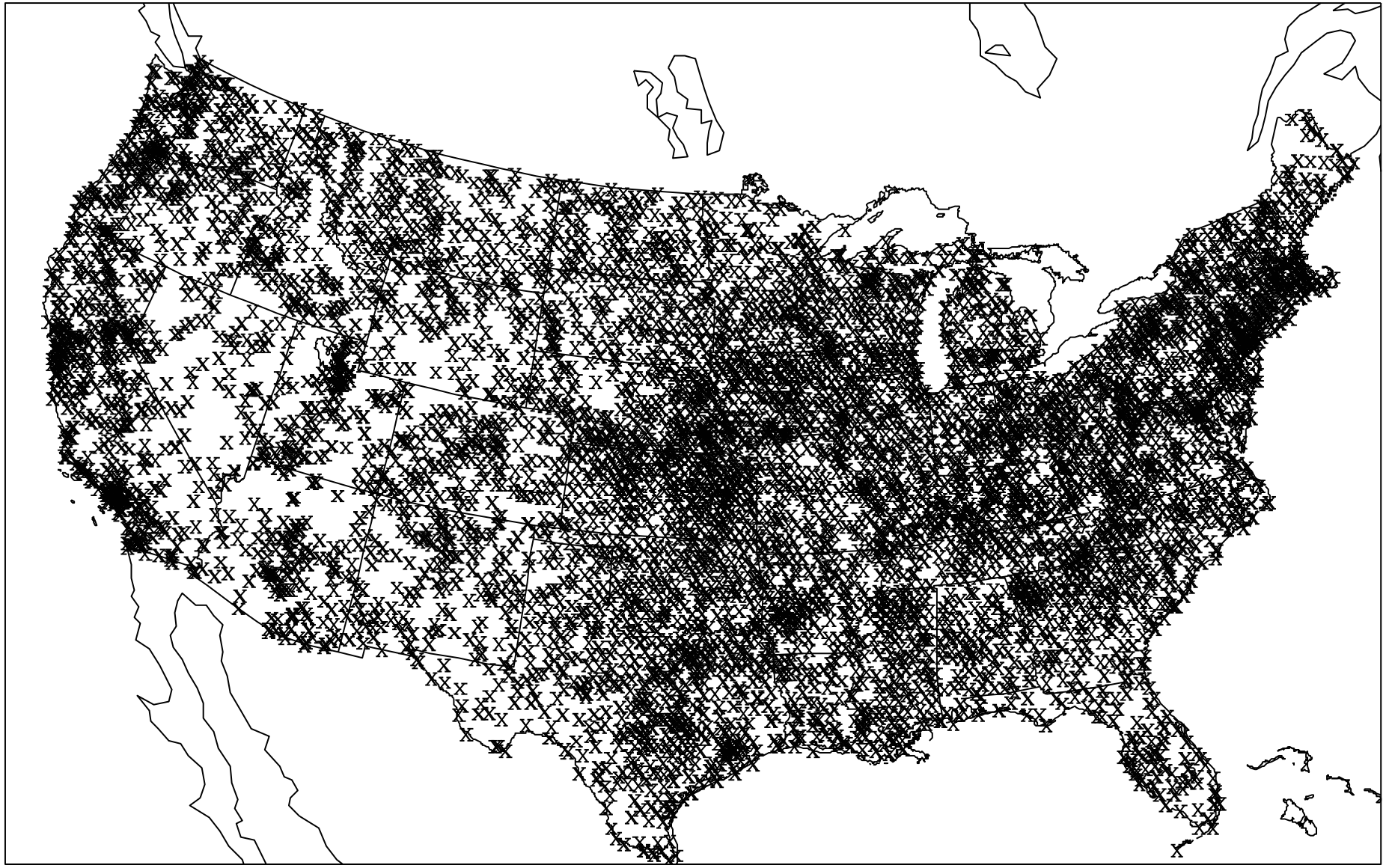

Q-rank Outlier Validation for PRECIPITATION
189
260
340
483
1163
733
852
1208
1610
1621
100%
80%
60%
40%
20%
0%
Percentage of All Outliers
0-0.05
0.05-.010
0.10-0.15
0.15-0.20
0.20-0.25
0.25-0.30
0.30-0.35
0.35-0.40
0.40-0.45
0.45-0.50
Q-rank Range
Valid
Plausible
Questionable
Invalid

Effects of limited spatial density on trends

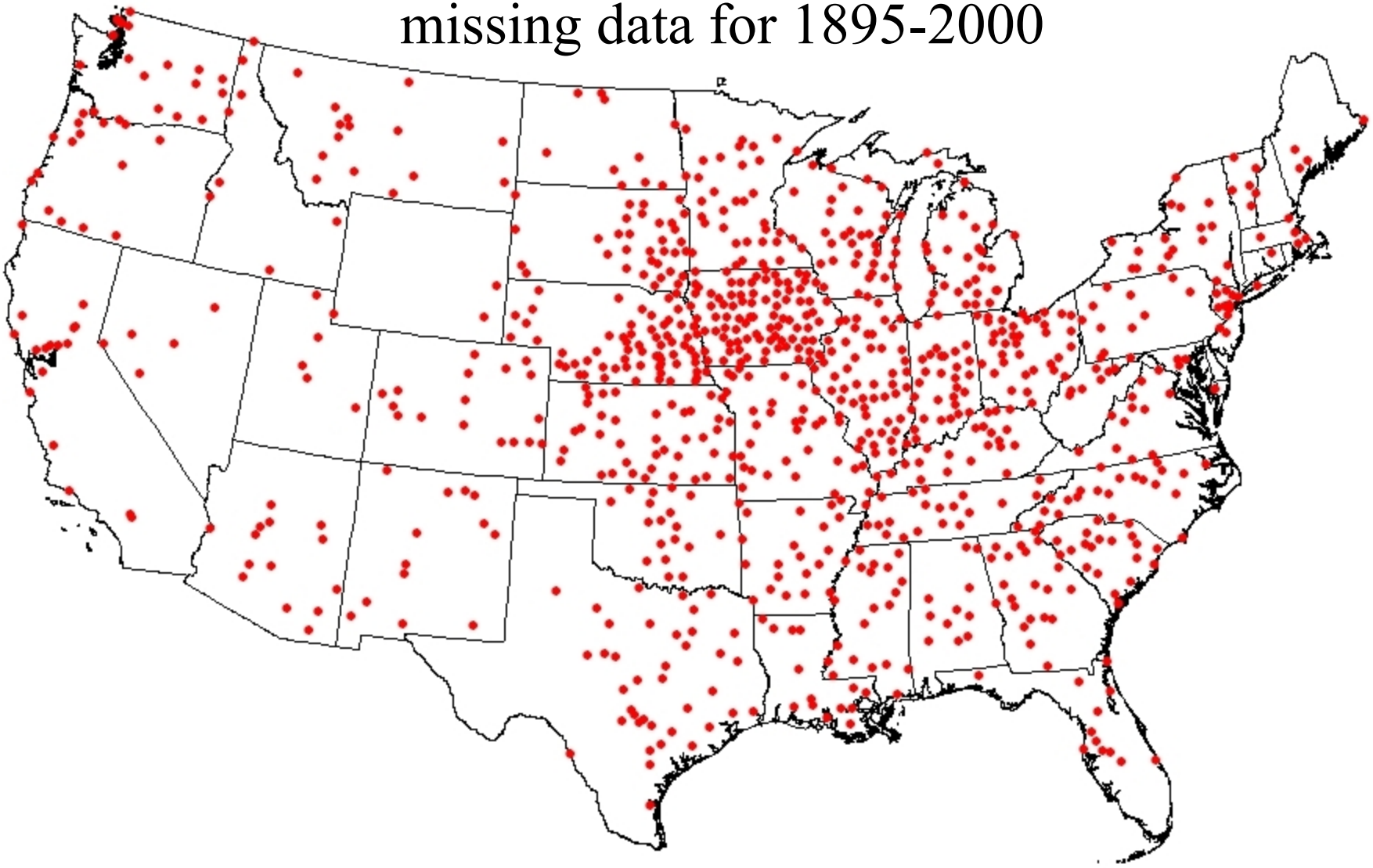
Monte Carlo Analysis

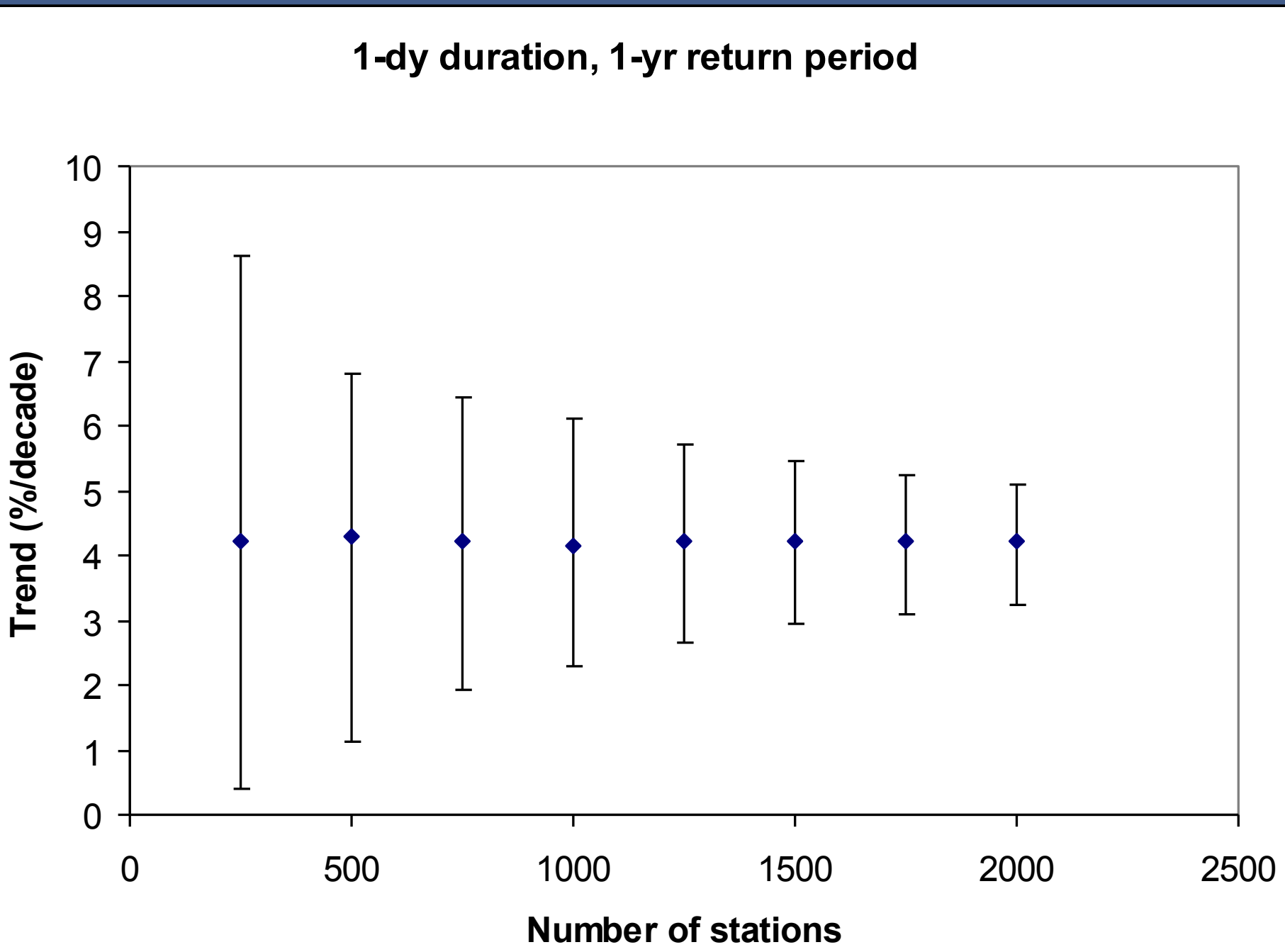
- Use data for the period 1971-2000 when station density is high; we assume that statistical properties of this period will be representative of entire instrumental period of record
- A random set of stations was selected with varying density and also for a density approximately similar to long-term stations (1985-2004). Extreme precipitation time series were calculated. This was repeated 500 times to establish confidence limits

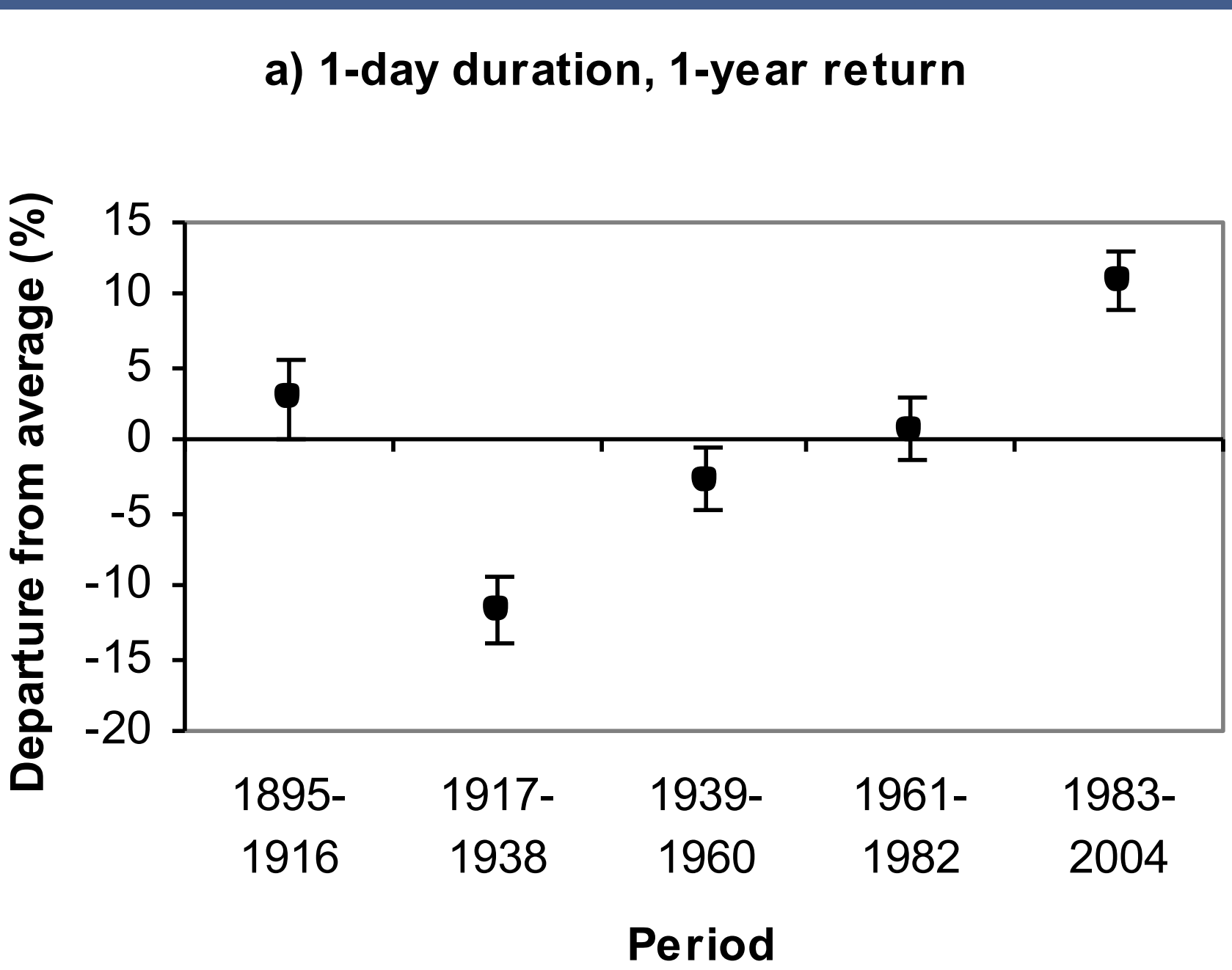
High density station network (stations with < 20% missing data for 1971-2000



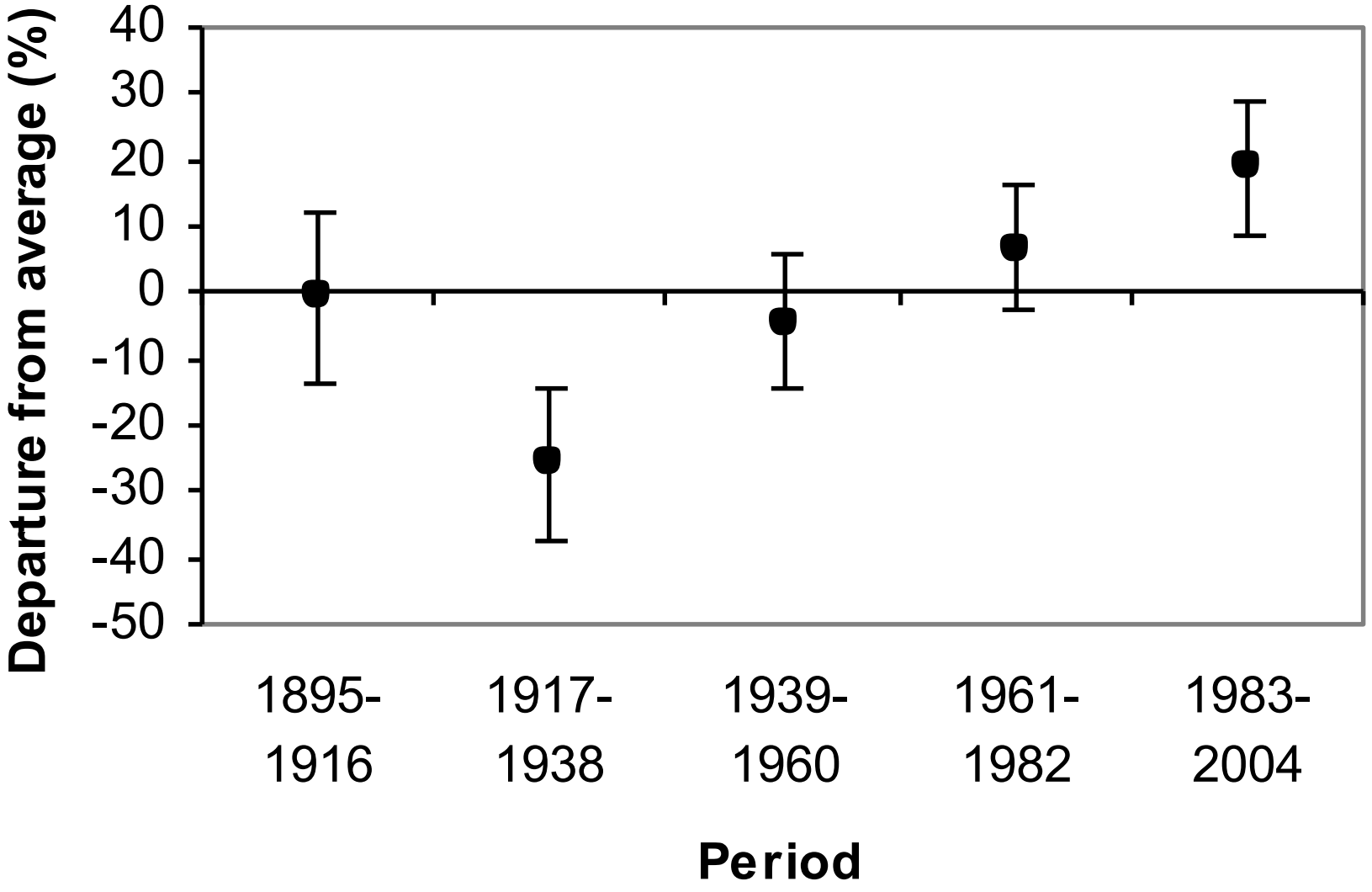
Long-term Precipitation Stations: <10% missing data for 1895-2000




1-dy duration, 1-yr return period
Trend (%/decade)
10
9
8
7
6
5
4
3
2
1
0
0
500
1000
1500
2000
2500
Number of stations

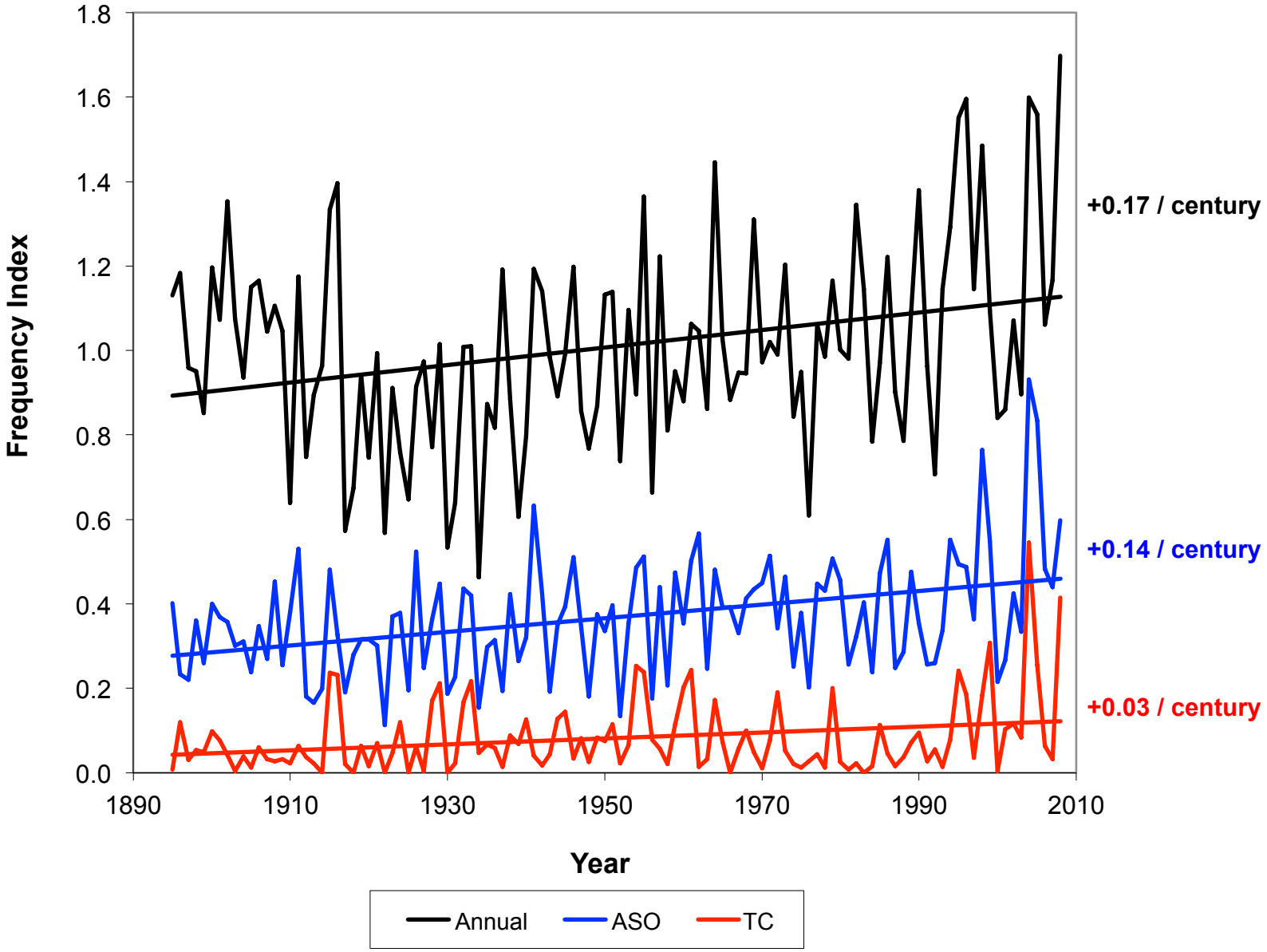

a) 1-day duration, 1-year return
Departure from average (%)
15
10
5
0
-5
-10
-15
-20
1895-1916
1917-1938
1939-1960
1961-1982
1983-2004
Period

c) 1-day duration, 20-year return



Meteorological Causes

- Many studies have found an upward trend in various measures of heavy precipitation events in the U.S.



Updated from Kunkel, K. E., D.R. Easterling, K. Redmond, and K. Hubbard, 2003: Temporal variations of extreme precipitation events in the United States: 1895–2000, *Geophys. Res. Lett.*, **30**, 1900, 10.1029/2003GL018052

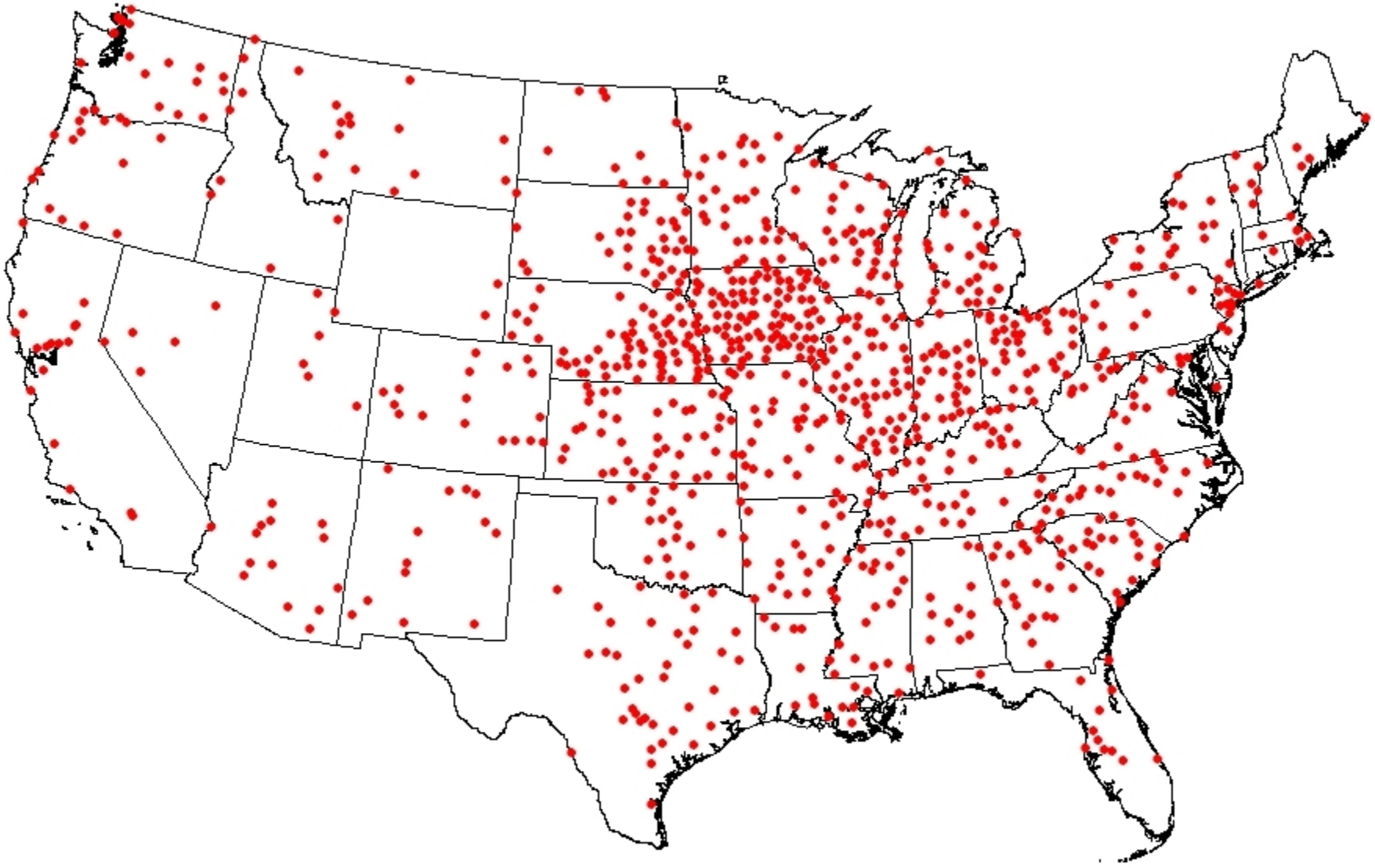
Causes

- Have there been secular changes in the frequency, intensity, and other characteristics of the meteorological phenomena producing heavy precipitation?
- Are the recent increases primarily a result of increases in atmospheric water vapor concentrations?

Extremes Definition

- 1-dy duration, 5-yr recurrence

Long-term Precipitation Stations



Meteorological Types

- Extratropical Cyclones
  - Frontal (at least ~300 km away from center of surface or upper low)
  - ETC (near surface or upper low center)
- Tropical Cyclones
- Mesoscale Convective Systems
- Air Mass Convection
- North American Monsoon
- Upslope

Data Sources

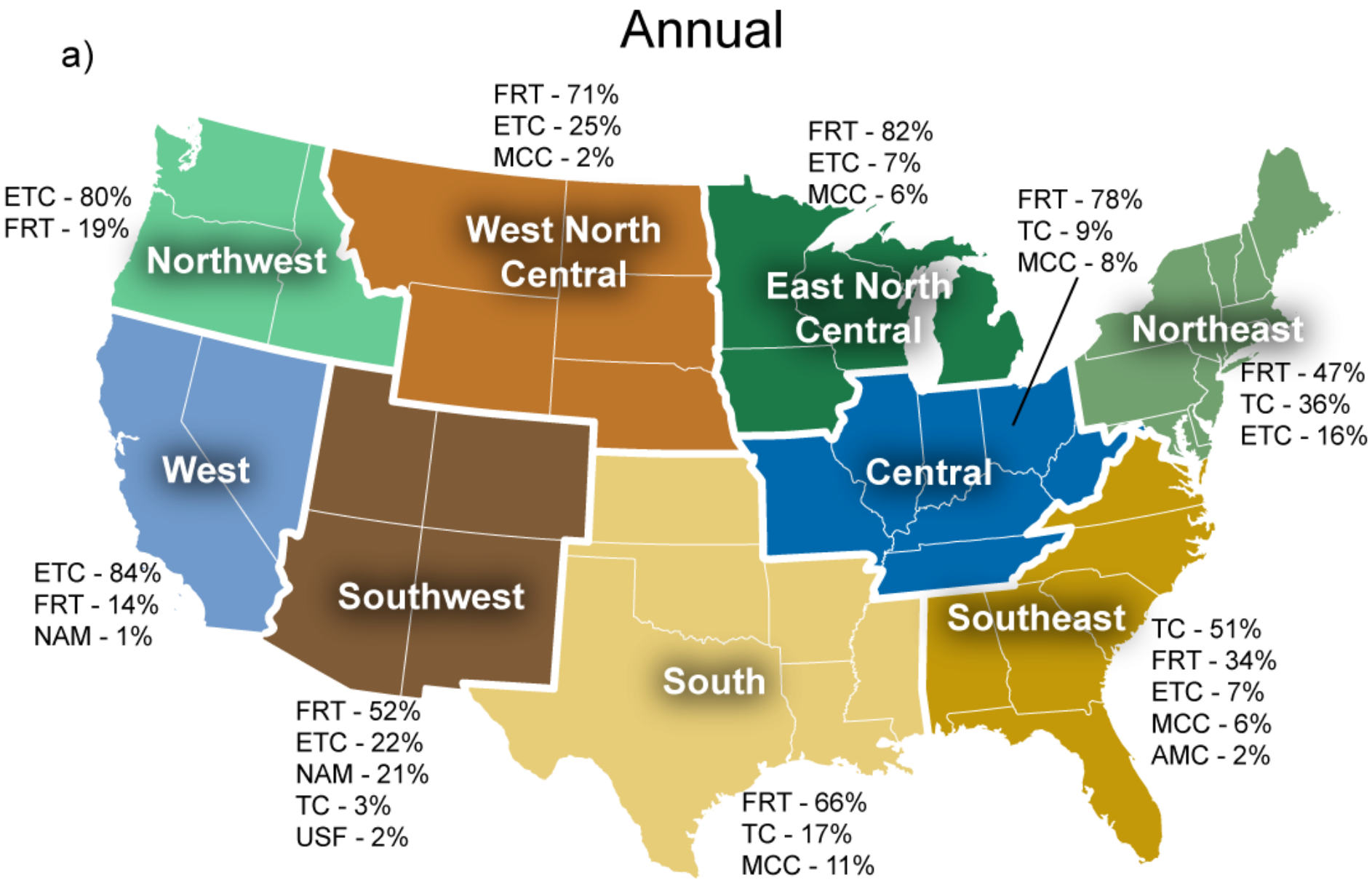
- Reanalysis
- Tropical Cyclone tracks
- Surface fields of temperature and precipitation
- Daily weather maps

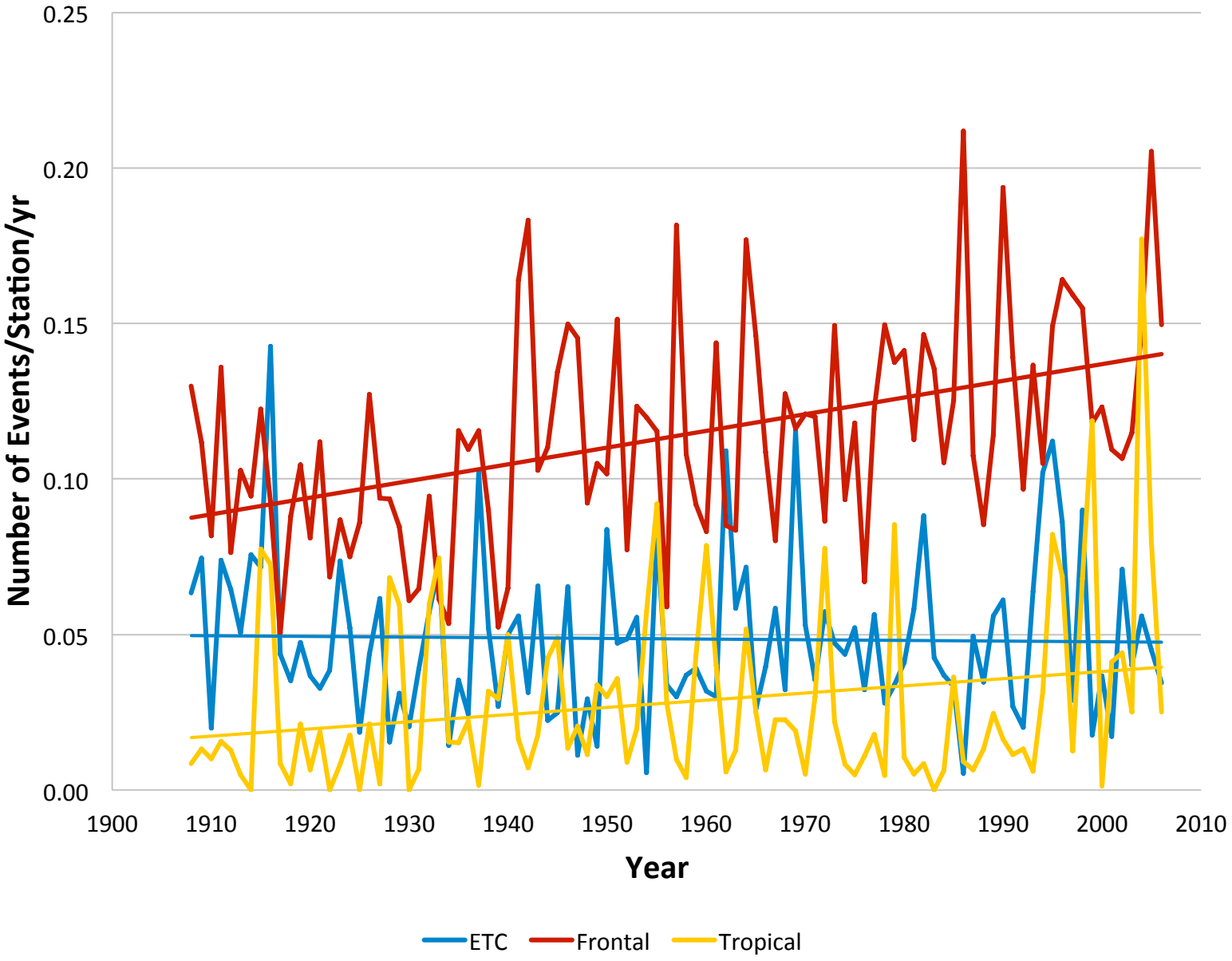
Identification of Type

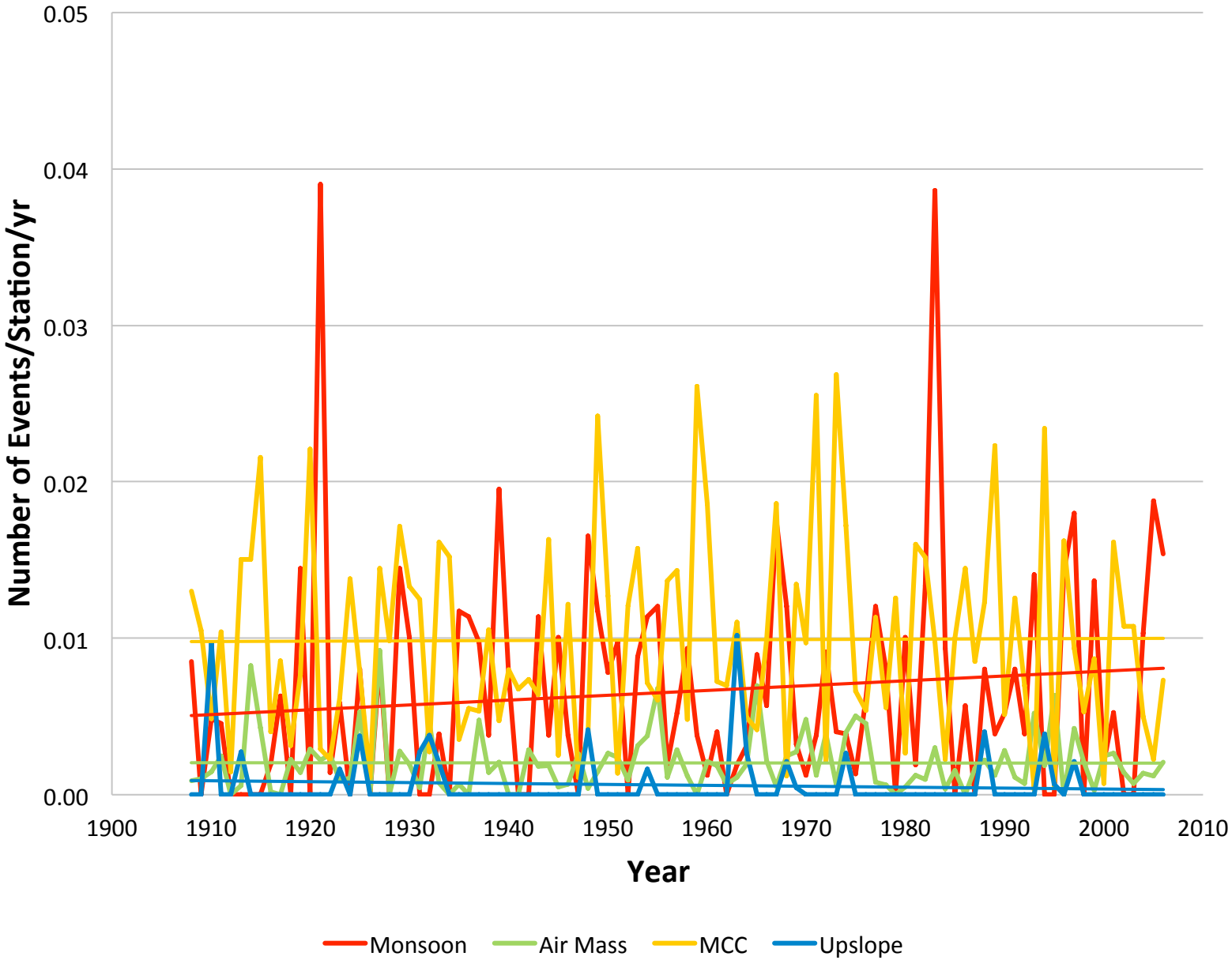
- Mostly based on judgment of authors
- Automated detection of tropical cyclone events based on HURDAT tracks
- We have completed analysis for the period of 1908-2009
- A total of 20,298 events were assigned causes

Contributions of Each Type

- 54% for Fronts-Extratropical Cyclones
- 24% for Nonfrontal-Extratropical Cyclone
- 13% for Tropical Cyclones
- 5% for Mesoscale Convective Systems
- 3% for North American Monsoon
- 1% for Air Mass Convection
- 0.1% for Upslope Flow


Annual
a)
ETC - 80%
FRT - 19%
Northwest
FRT - 71%
ETC - 25%
MCC - 2%
West North Central
FRT - 82%
ETC - 7%
MCC - 6%
East North Central
FRT - 78%
TC - 9%
MCC - 8%
Northeast
FRT - 47%
TC - 36%
ETC - 16%
West
Central
ETC - 84%
FRT - 14%
NAM - 1%
Southwest
FRT - 52%
ETC - 22%
NAM - 21%
TC - 3%
USF - 2%
South
FRT - 66%
TC - 17%
MCC - 11%
Southeast
TC - 51%
FRT - 34%
ETC - 7%
MCC - 6%
AMC - 2%

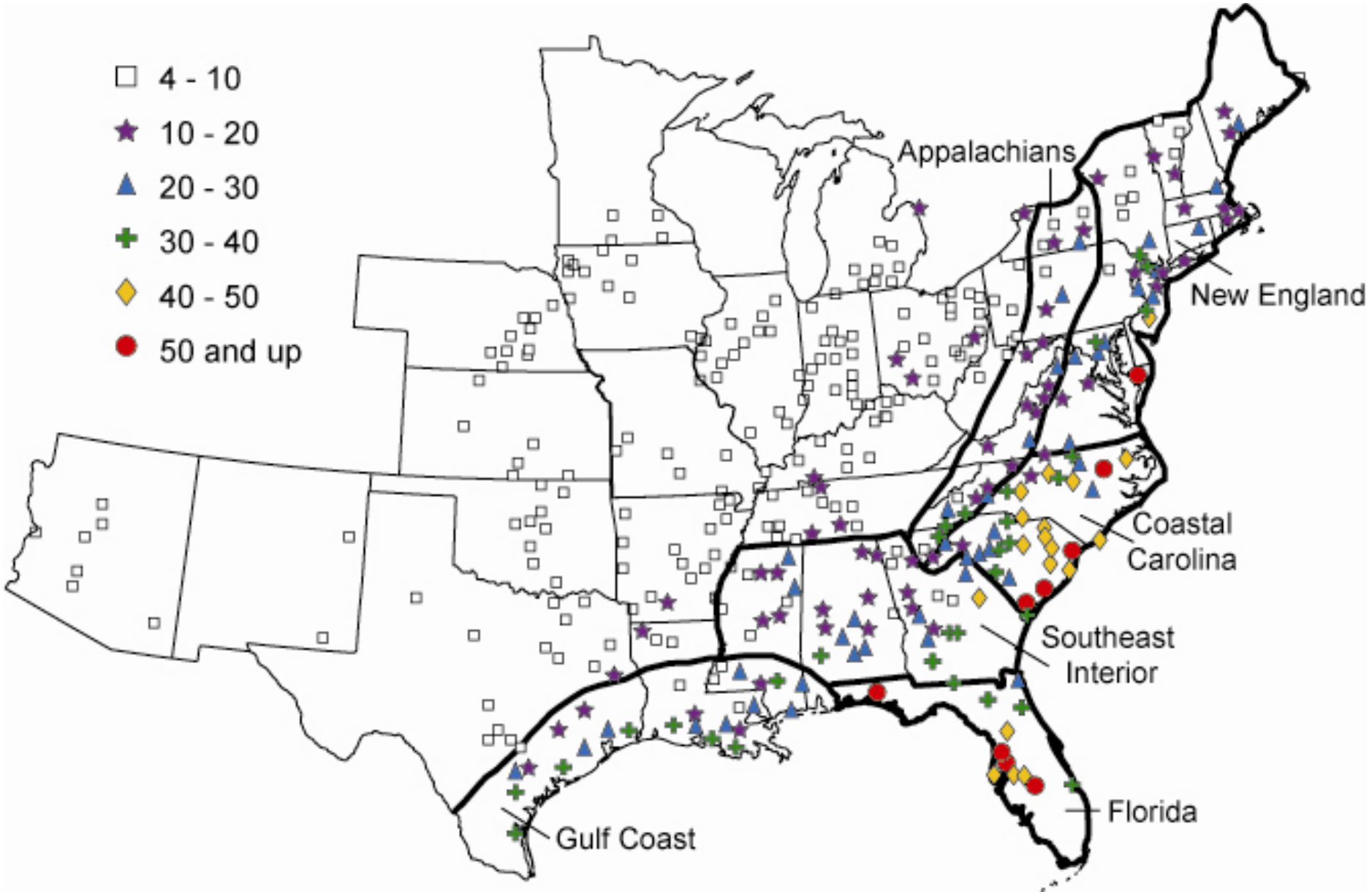

0.25
0.20
0.15
0.10
0.05
0.00
Number of Events/Station/yr
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
ETC
Frontal
Tropical


0.05
0.04
0.03
0.02
0.01
0.00
Number of Events/Station/yr
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Monsoon
Air Mass
MCC
Upslope

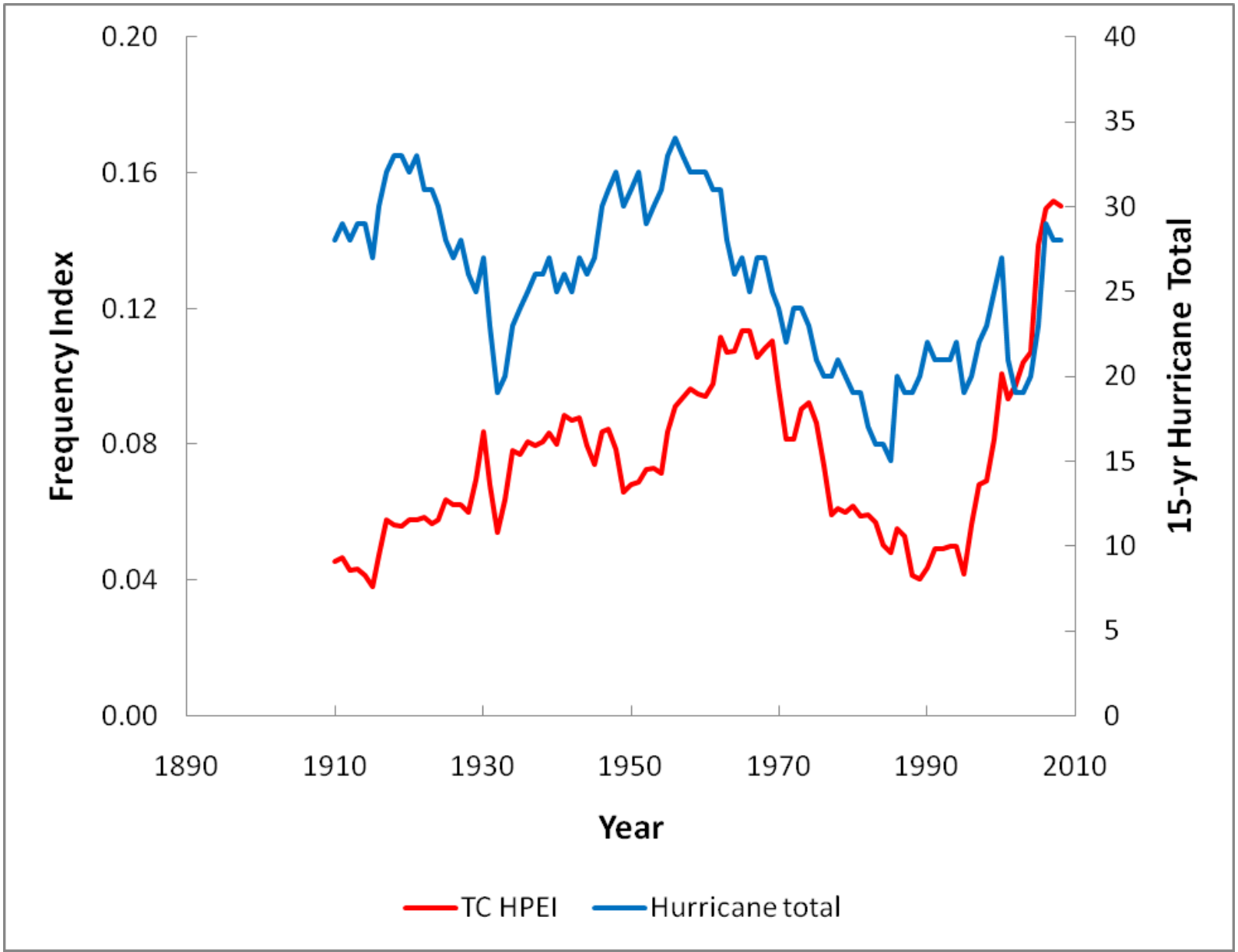
Contribution of Tropical Cyclones

- HURDAT tropical cyclone tracks dataset
- Heavy precipitation event considered to be caused by tropical cyclone if it occurred within 5 degrees of track

Percent of extreme events caused by Tropical Cyclones



Heavy Event Frequency vs. Landfalling Hurricane Number



Acknowledgements

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