Flood Frequency Analysis in a Changing Climate: Living with Uncertainty

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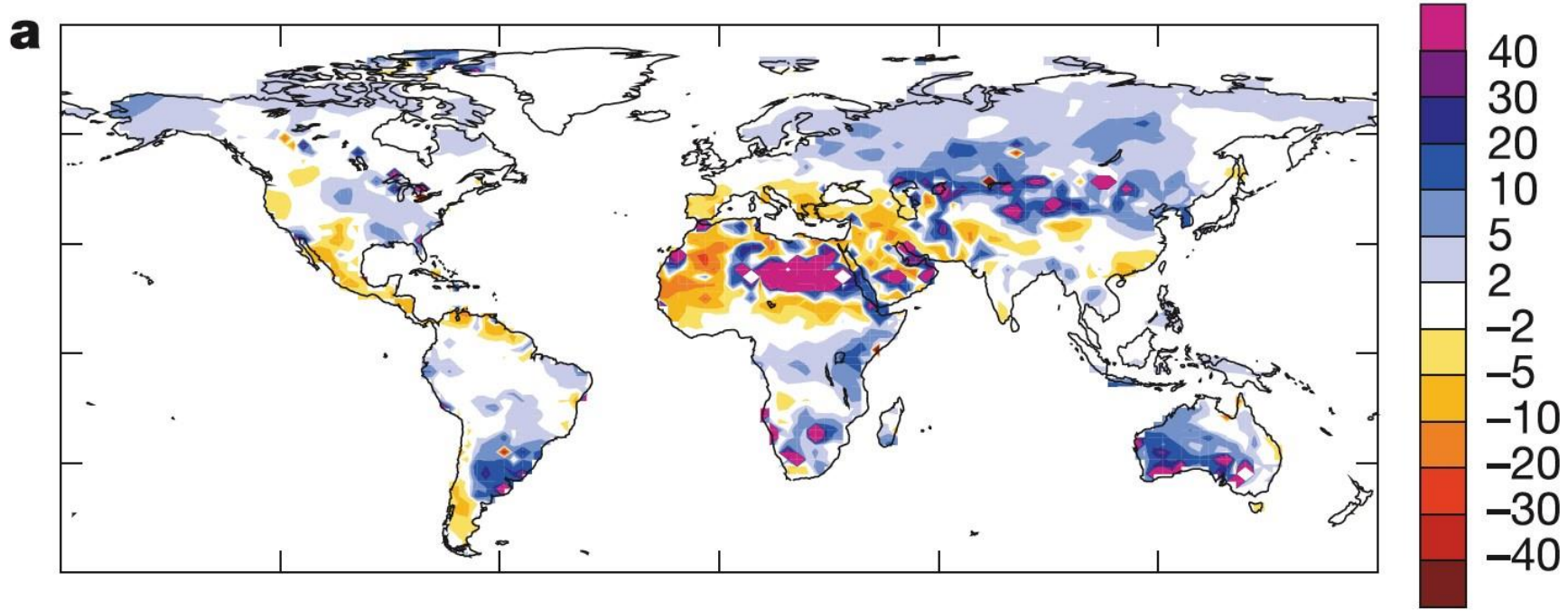
Changes in 20th Century Runoff

100*(mean[1971-1998]-mean[1900-1970])/mean[1900-1970]



Milly et al., 2005

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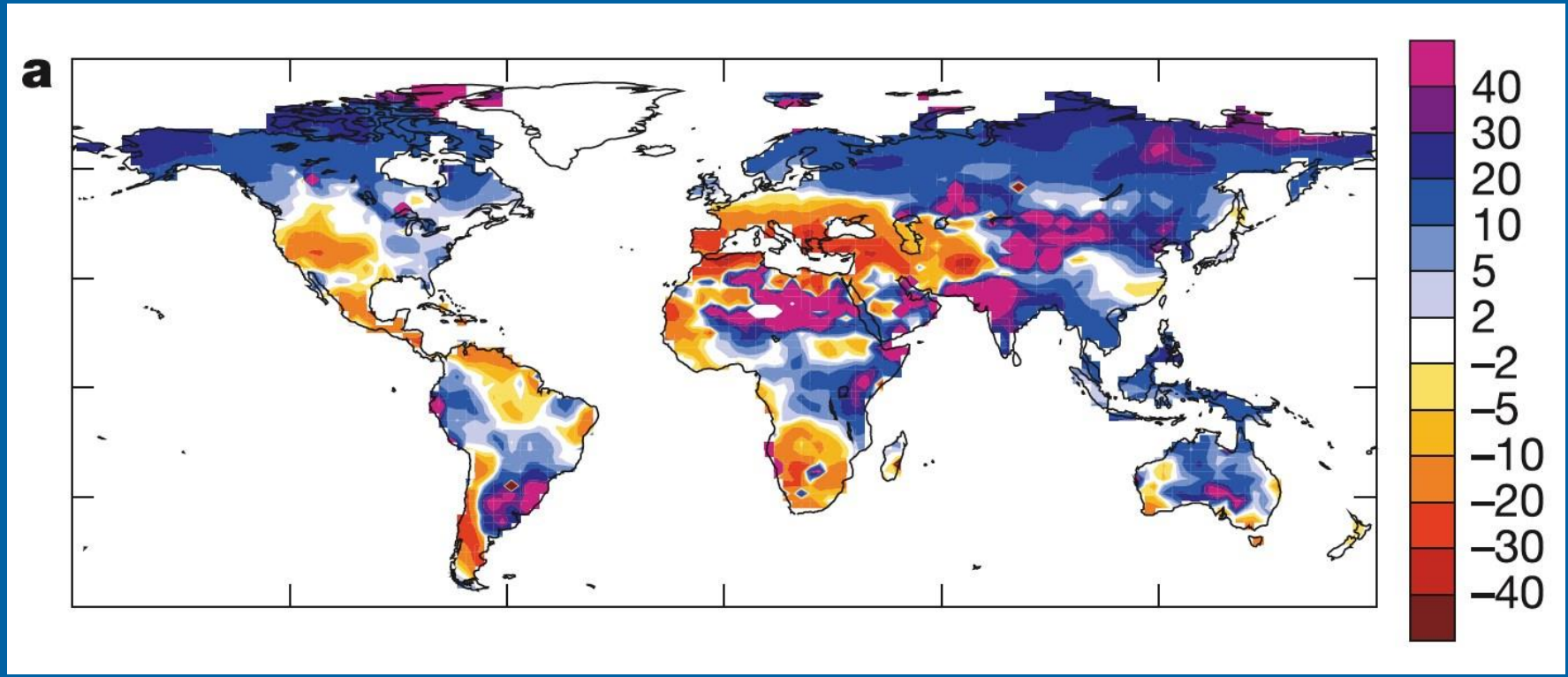
Projected Changes in 21st Century Runoff

100*(projected[2041-2060]-mean[1900-1970])/mean[1900-1970]



Milly et al., 2005

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Concern: What About Floods?

- Intuition (?):
  - Warmer climate => increased evaporation => increased precipitation => bigger floods (?)
- Physics:
  - Clausius-Clapeyron: Air can hold 7 percent more moisture for each 1 degree C increase in temperature; however, …
  - Extreme floods result from complicated interactions of timing, duration and magnitude of multiple meteorological factors, watershed and channel factors, among others
- Literature:
  - [Lins and Slack, 1999; Douglas et al., 2000; Milly, 2002; Lins and Cohn, 2002; Mudelsee et al., 2003; Kundzewicz et al., 2005; Small et al., 2006; Hannaford and Marsh, 2008; Milly et al., 2008; Villarini et al., 2009, 2010; Dettinger, 2011; Hirsch and Ryberg, 2012; …]

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IPCC AR5 (Draft 2, 2013):

"While the most evident flood trends appear to be in northern high latitudes, where observed warming trends have been largest, in some regions no evidence of a trend in extreme flooding has been found, e.g., over Russia based on daily river discharge (e.g., Shiklomanov et al., 2007). Other studies for Europe (Hannaford and Marsh, 2008; Petrow and Merz, 2009; Renard et al., 2008) and Asia (e.g., Delgado et al., 2010; Jiang et al., 2008) show evidence for upward, downward or no trend in the magnitude and frequency of floods, so that *there is currently no clear and widespread evidence for observed changes in flooding* (except for the earlier spring flow in snow-dominated regions(Seneviratne et al., 2012a))."

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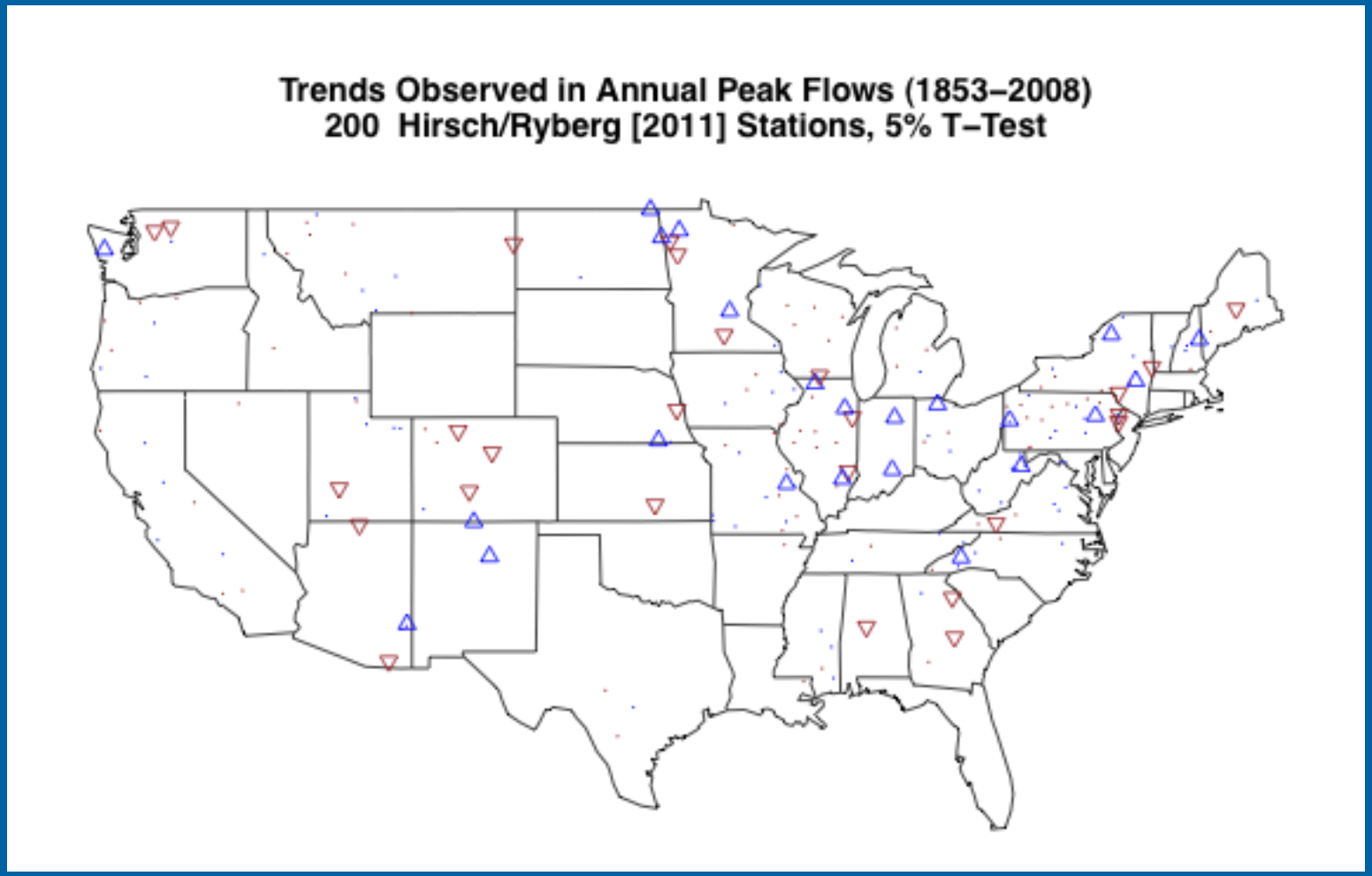
What U.S. Data Show



[Data from Table S2, Hirsch and Ryberg, 2011]

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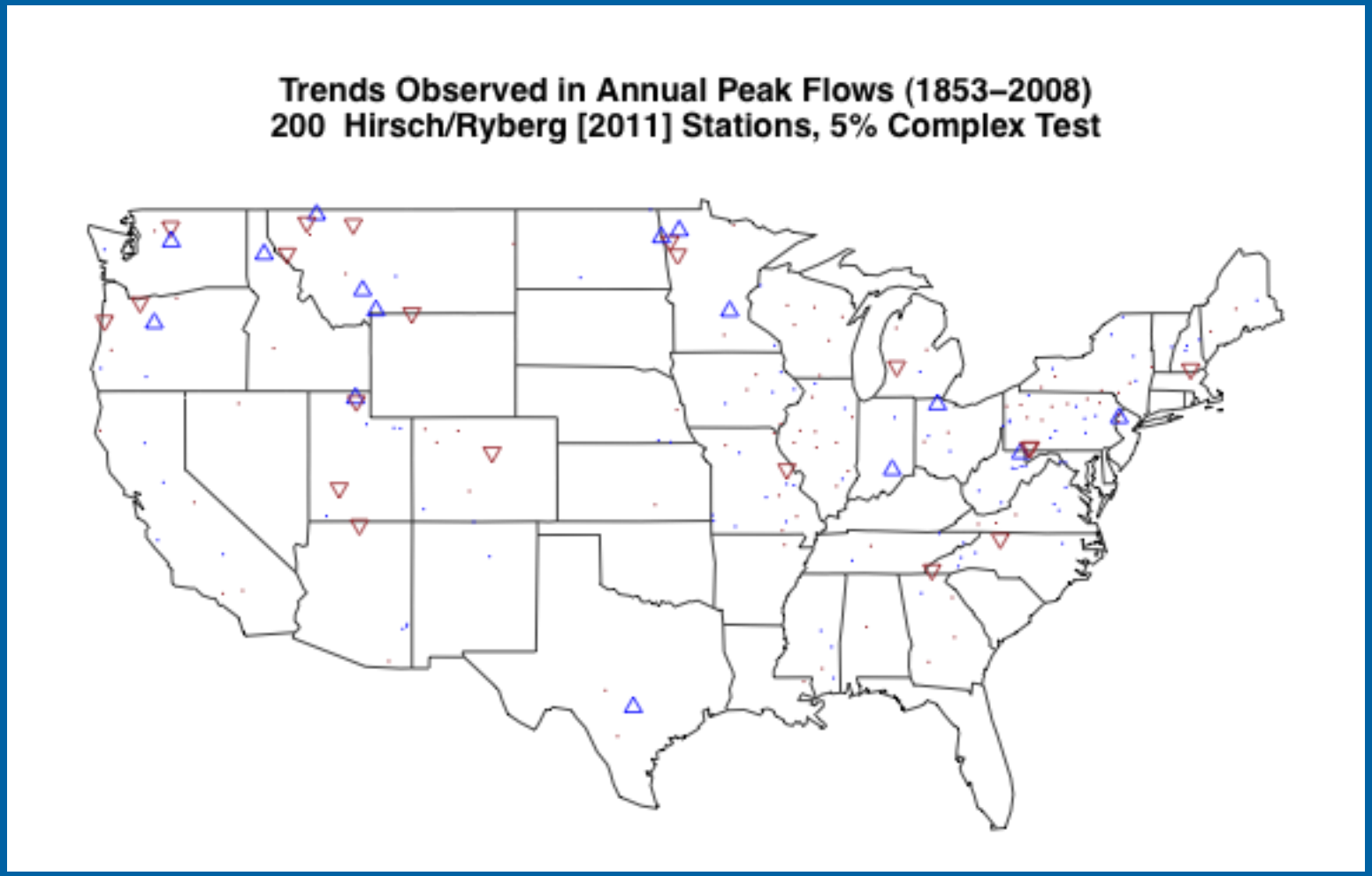

[Data from Table S2, Hirsch and Ryberg, 2011]

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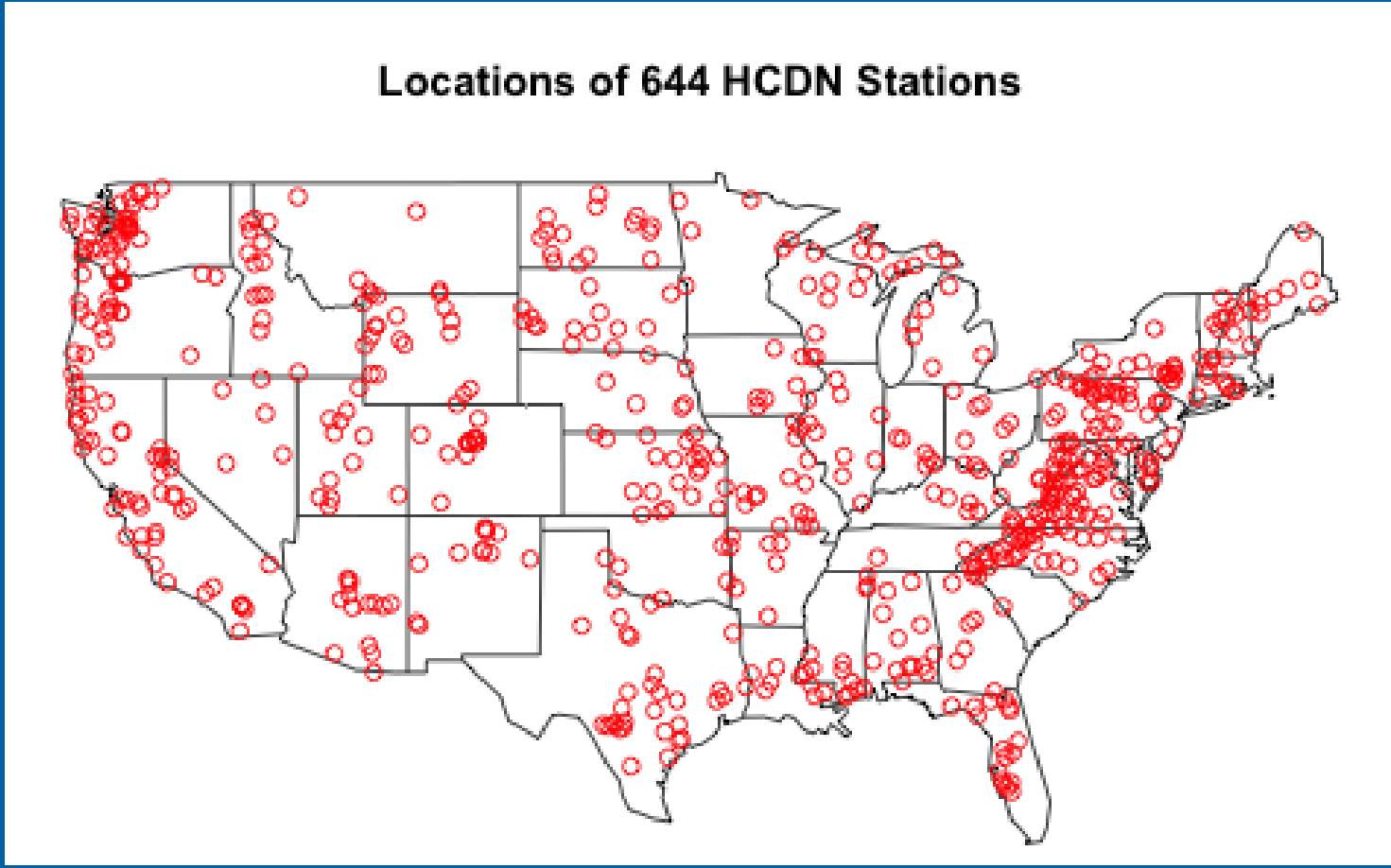
Gages-II HCDN Network

(Sites with at least 35 observations (1953-2012)



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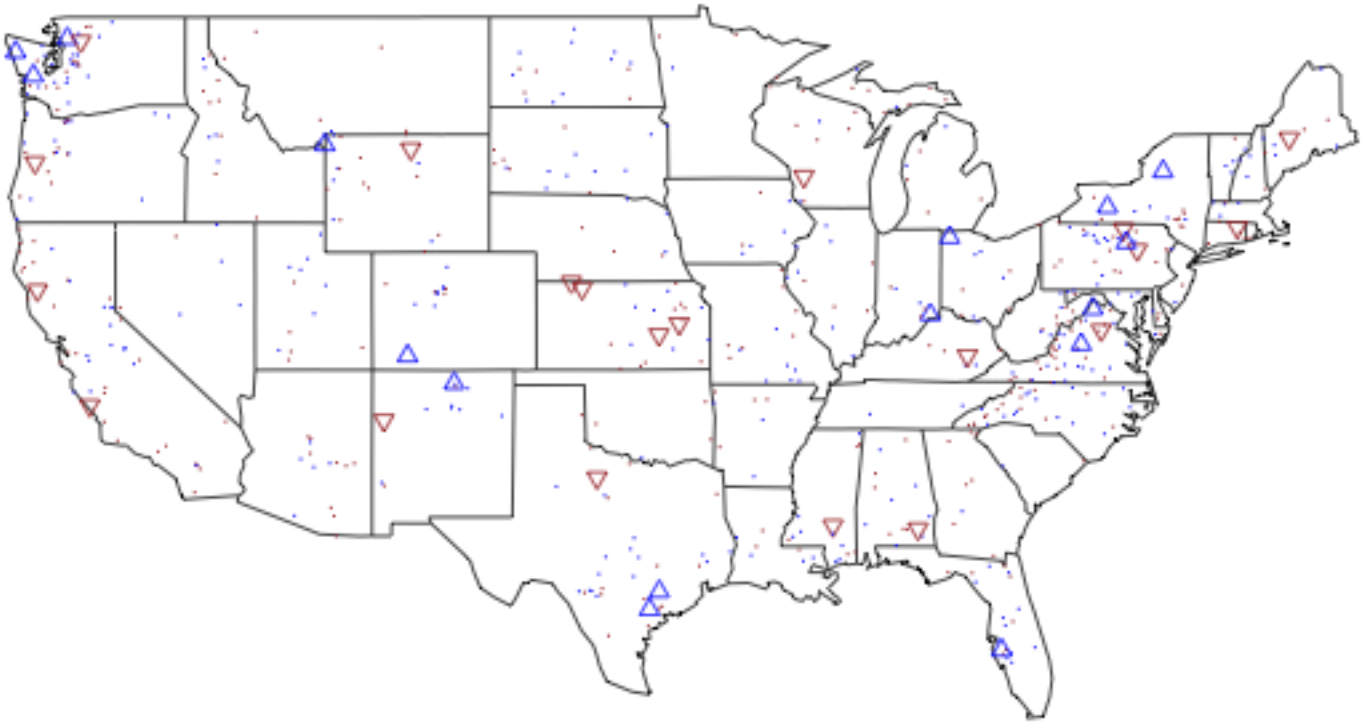
Trends Observed in Annual Peak Flows (1953–2012)
649 HCDN 2009 (GagesII) Stations, 5% ALRT Test



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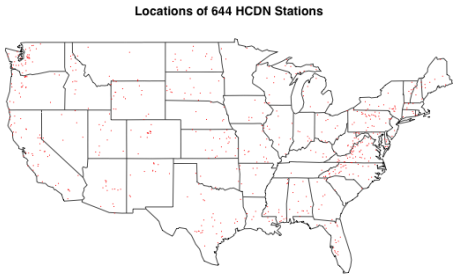
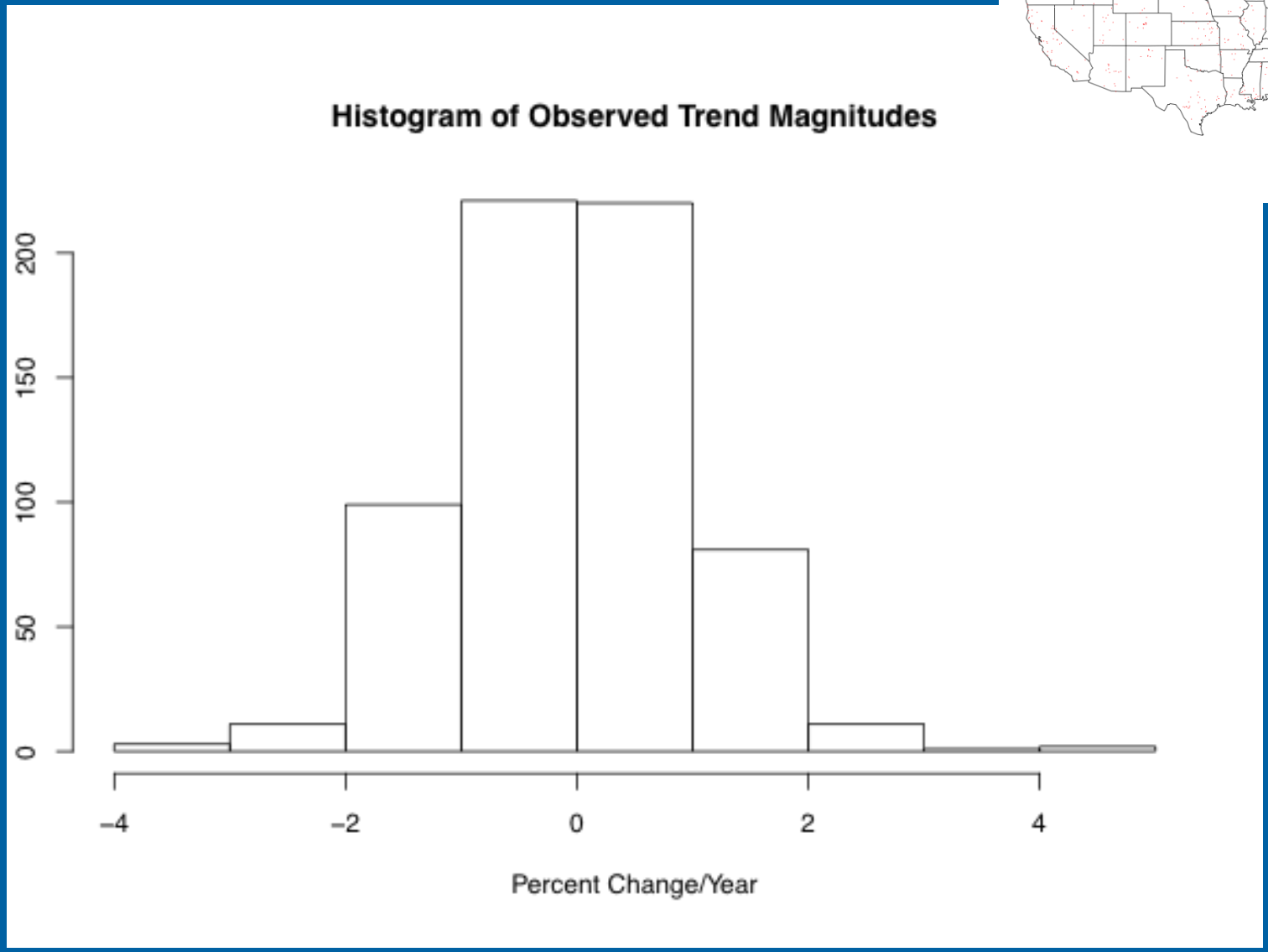

Locations of 644 HCDN Stations


Histogram of Observed Trend Magnitudes
0
50
100
150
200
−4
−2
0
2
4
Percent Change/Year

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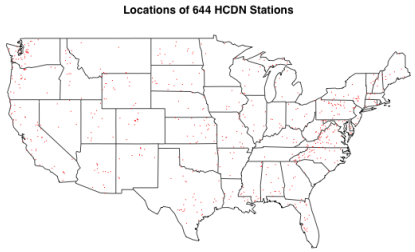
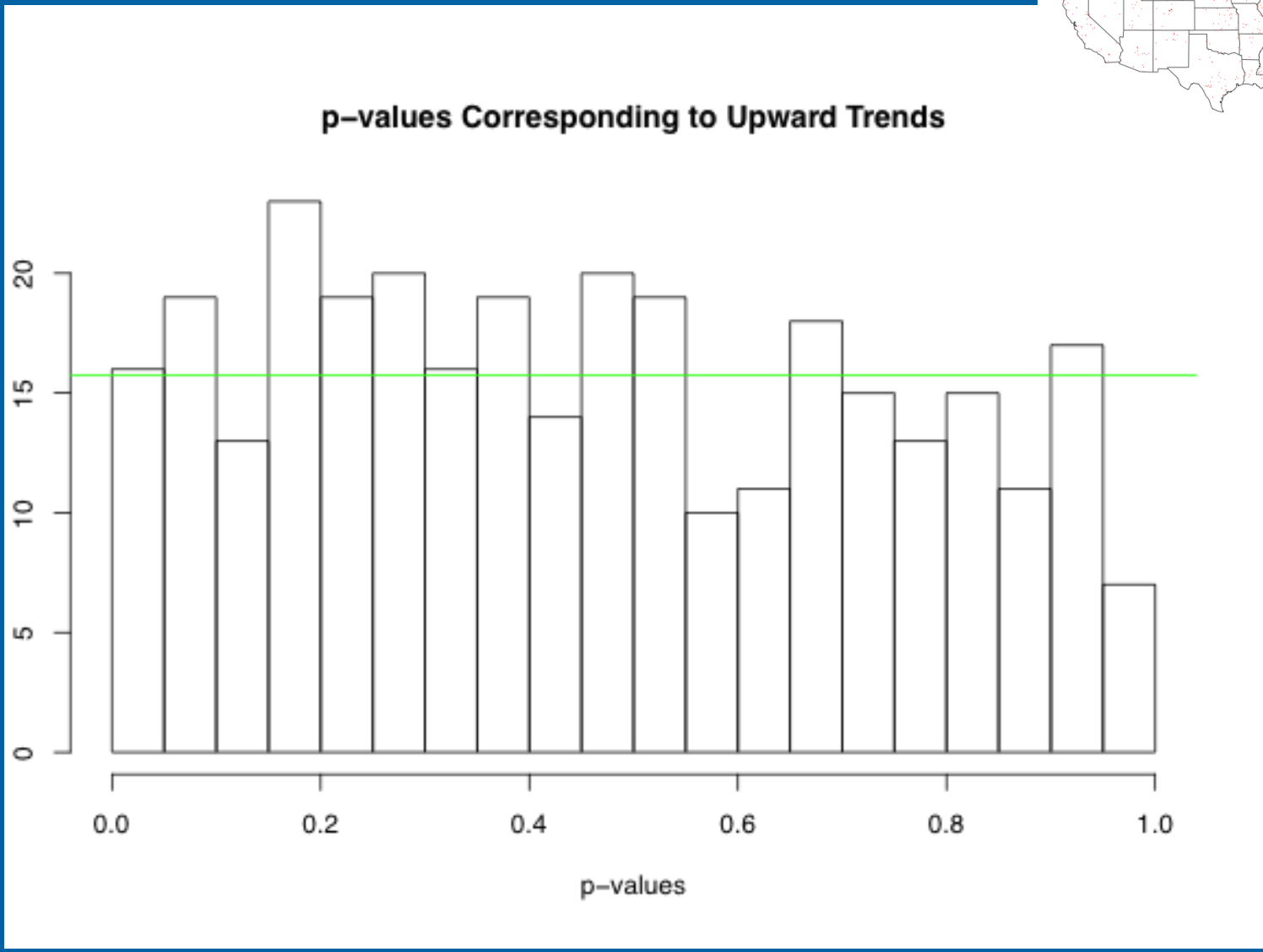

Locations of 644 HCDN Stations


p–values Corresponding to Upward Trends
0
5
10
15
20
0.0
0.2
0.4
0.6
0.8
1.0
p–values

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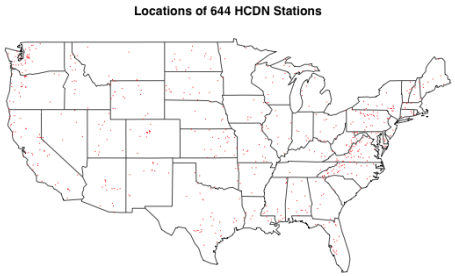
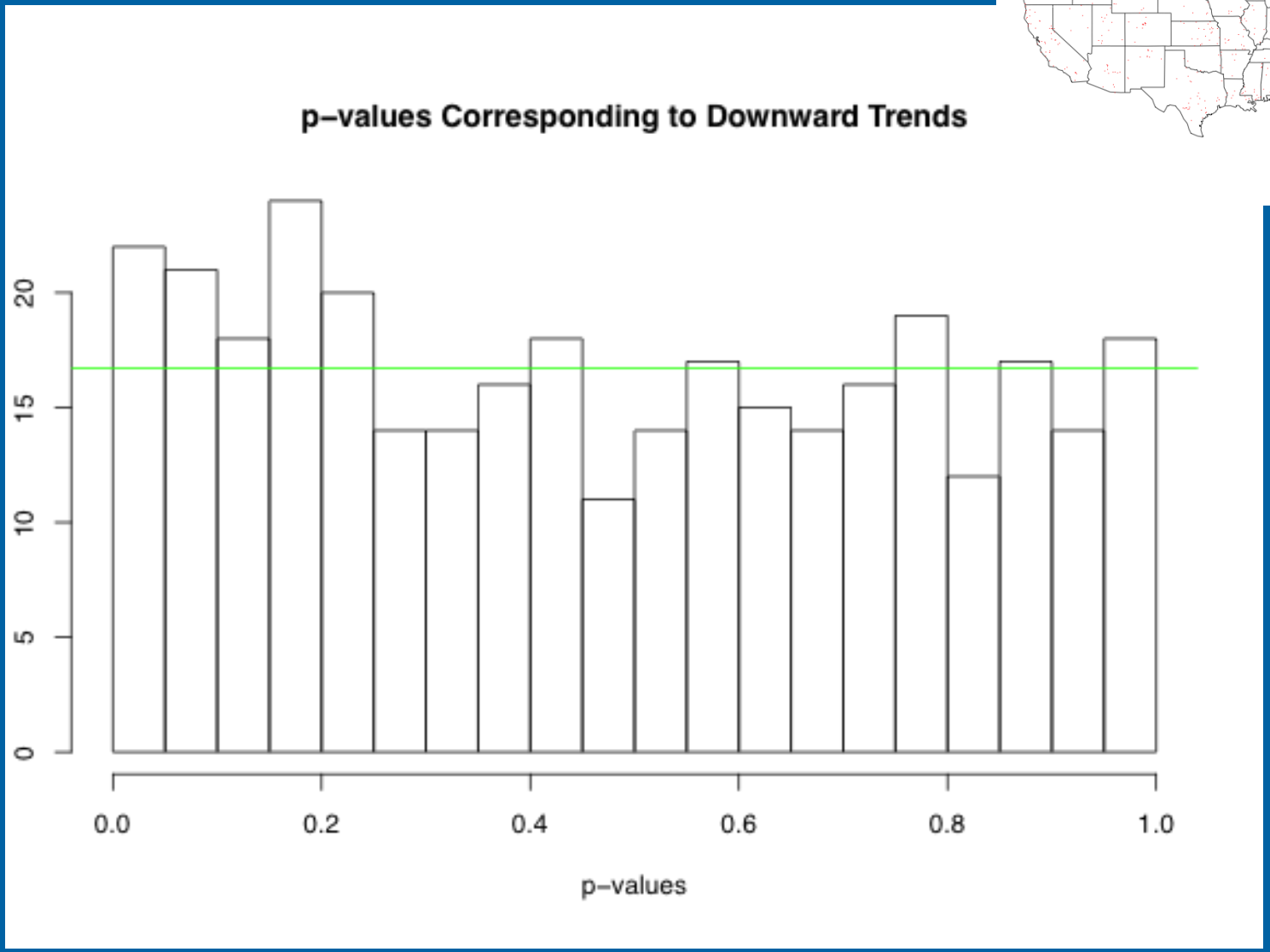

Locations of 644 HCDN Stations


p–values Corresponding to Downward Trends
0
5
10
15
20
0.0
0.2
0.4
0.6
0.8
1.0
p–values

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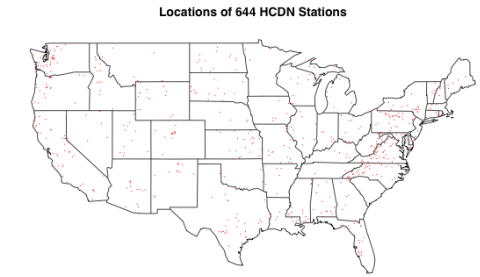
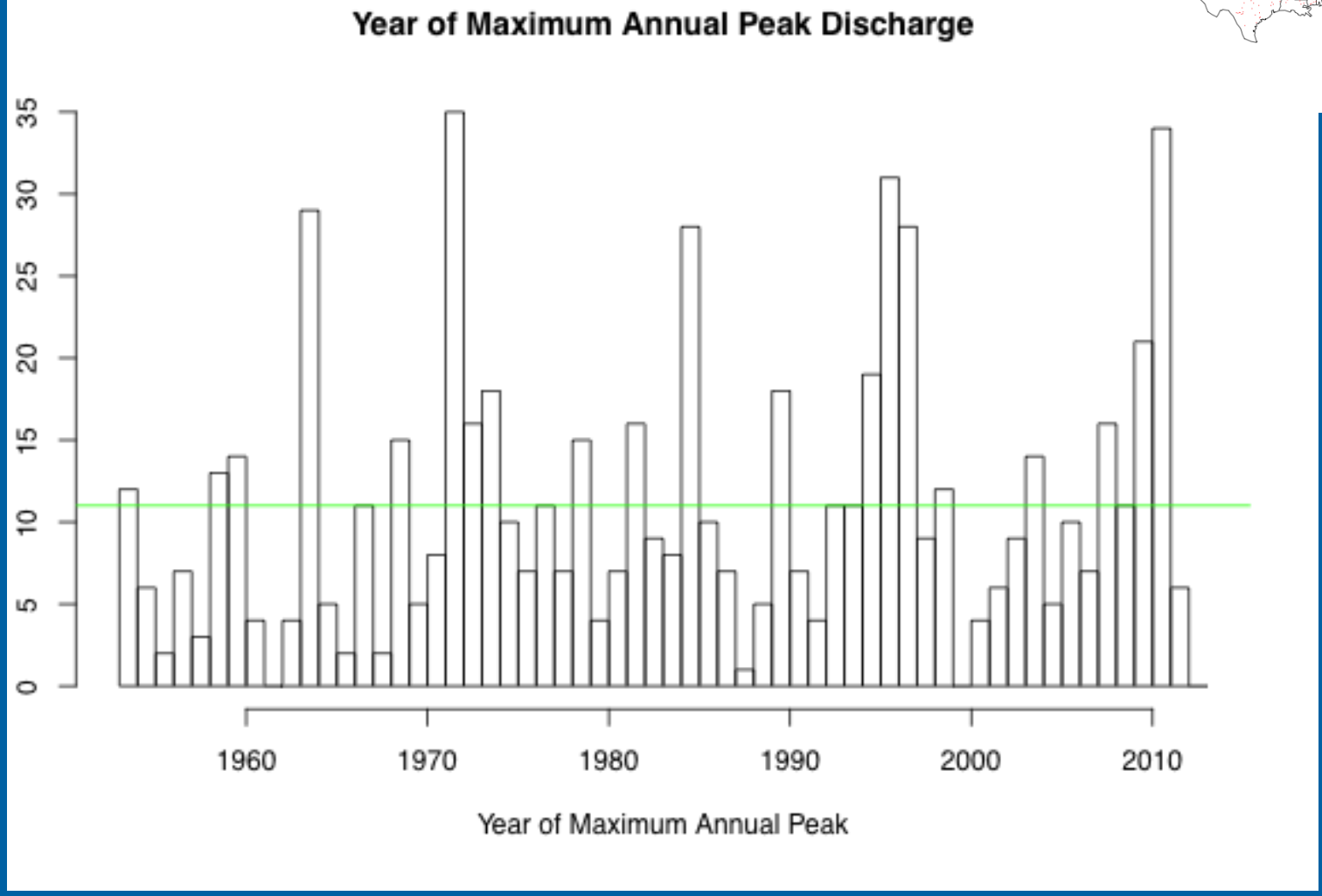

Locations of 644 HCDN Stations


Year of Maximum Annual Peak Discharge
0
5
10
15
20
25
30
35
1960
1970
1980
1990
2000
2010
Year of Maximum Annual Peak

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IPCC AR5 (Draft 2, 2013):

"There continues to be a lack of evidence and thus low confidence regarding the *sign* of trend in the magnitude and/or frequency of floods…"

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Hmmm…why are there so few significant trends in floods?

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Low Sensitivity (?)

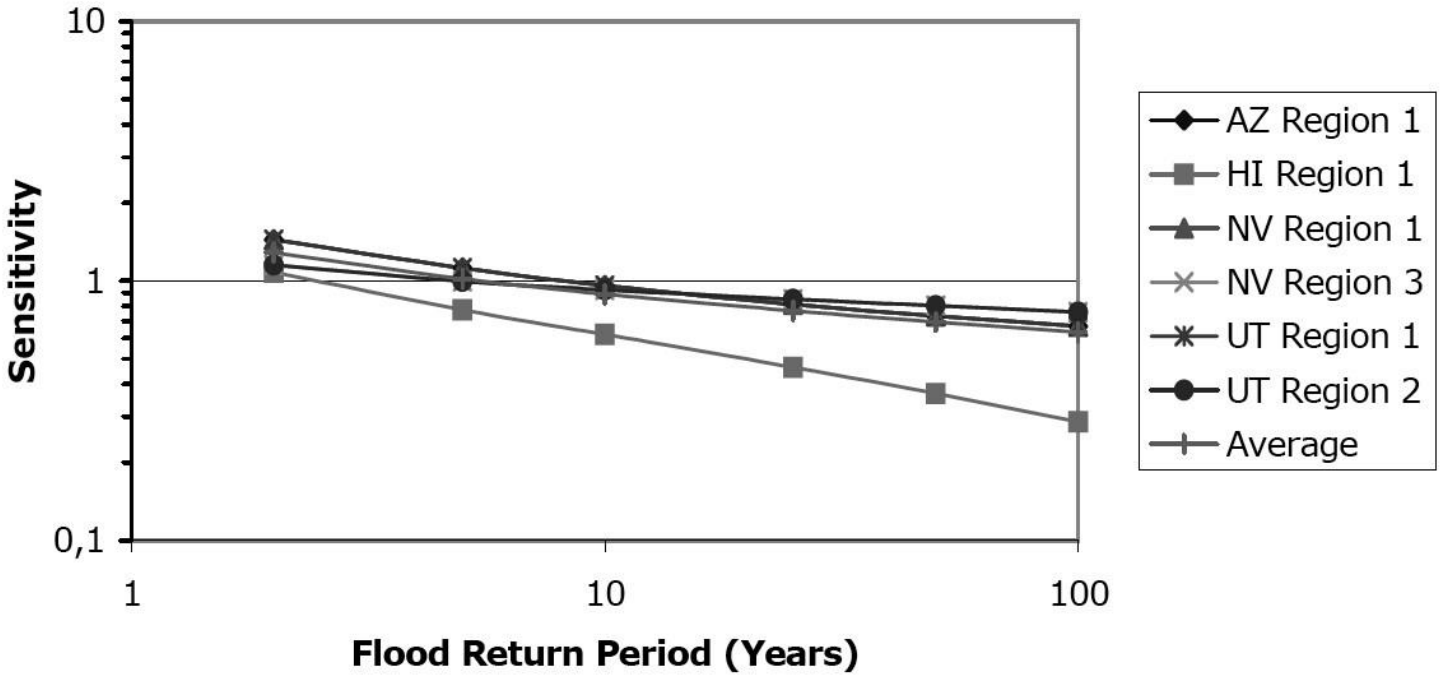

Figure 1. Sensitivity (elasticity) of flood flows at various return periods to mean annual precipitation.

[Lins and Cohn, 2002]

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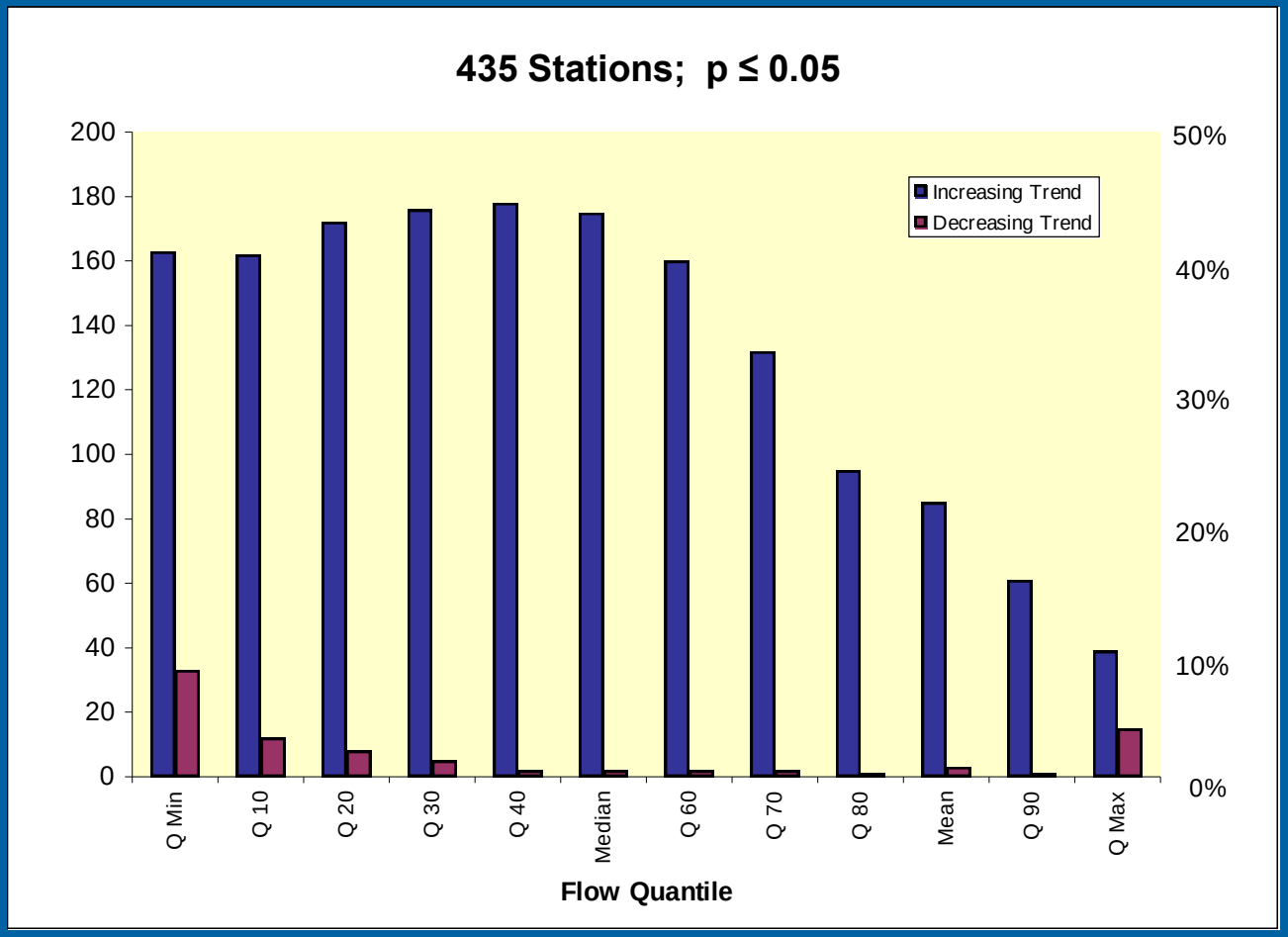
Trends in U.S. Streamflow, 1940-1999



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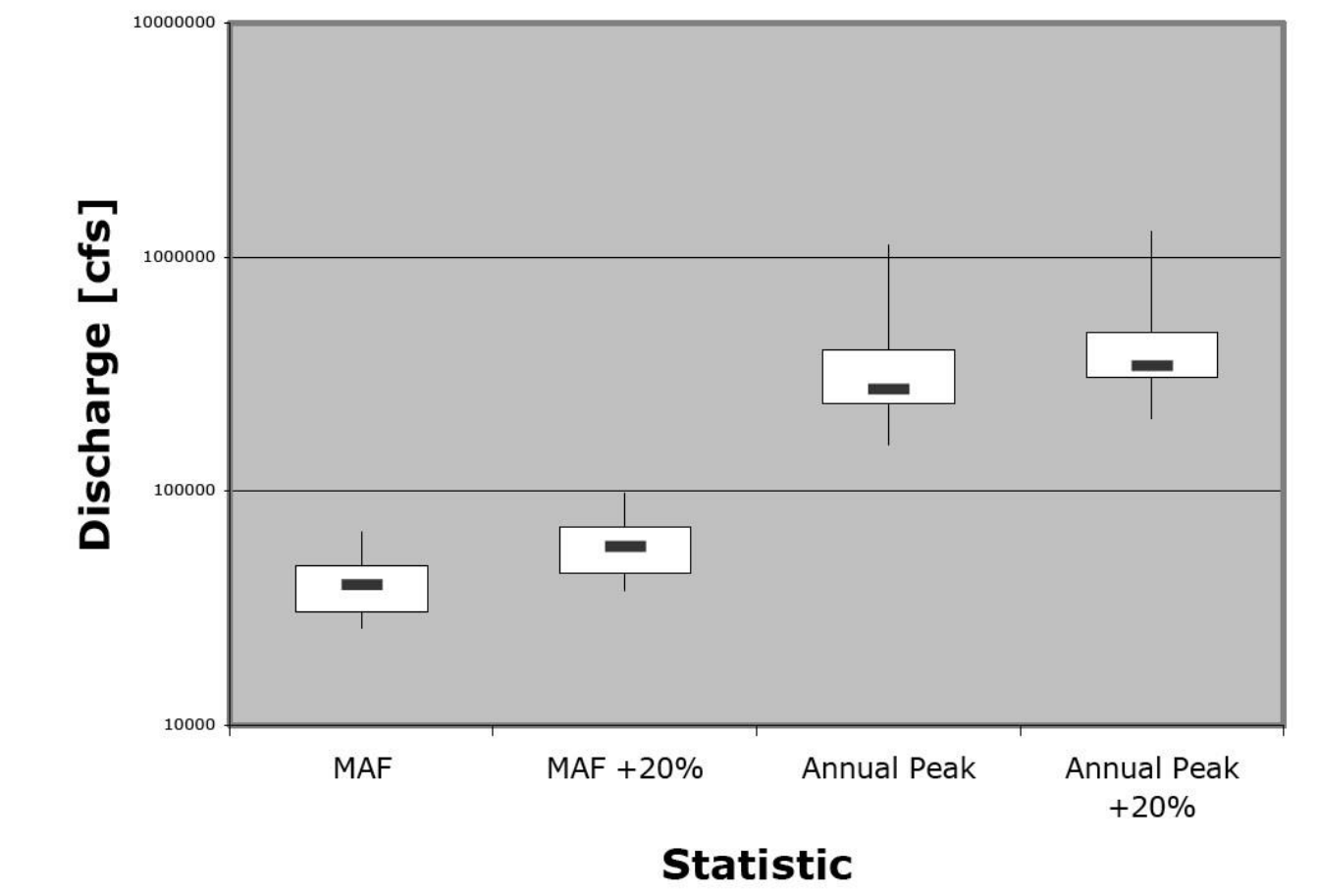
Source: Updated from Lins and Slack, Geophys. Res. Lett., 26, p. 227

Detectability: Natural Variability (?)



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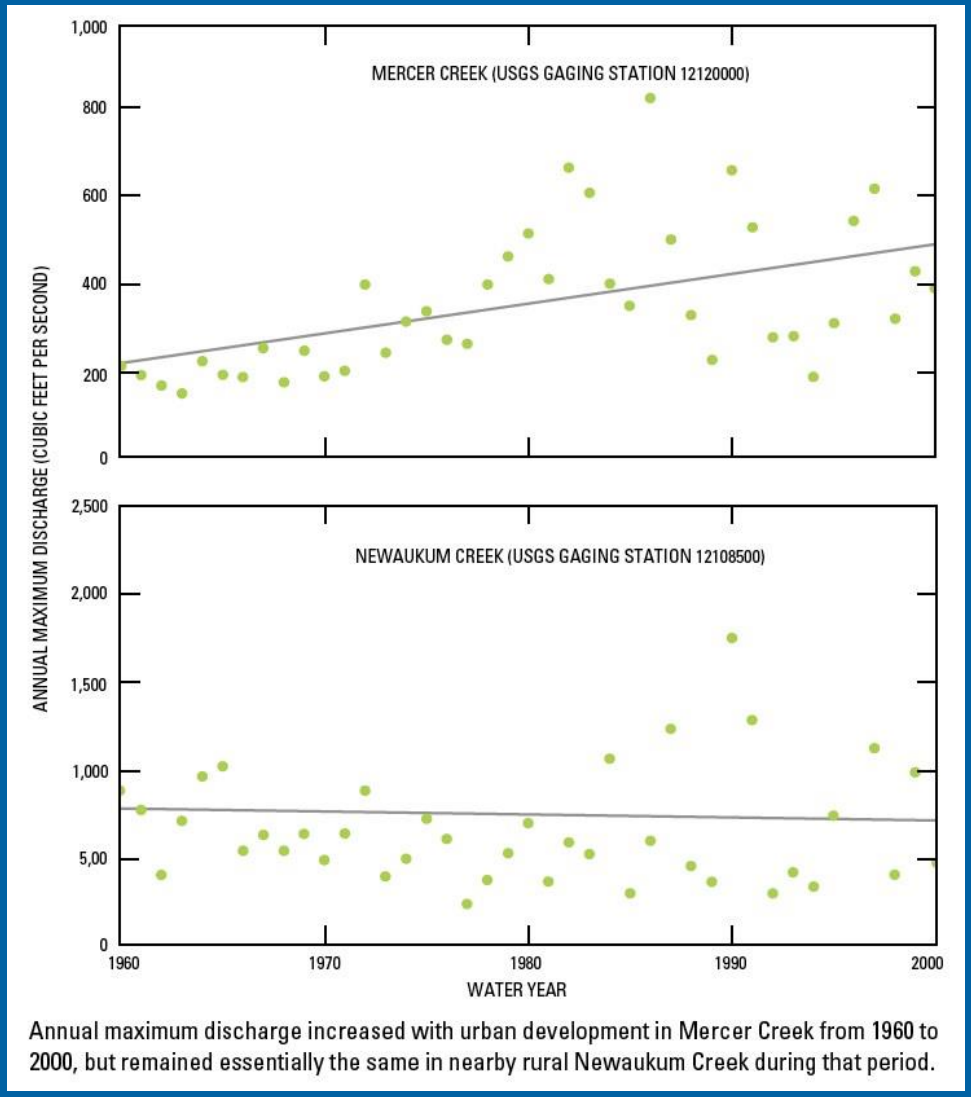
[Lins and Cohn, 2002]

Detectability: Extraneous Noise (?)



Annual maximum discharge increased with urban development in Mercer Creek from 1960 to 2000, but remained essentially the same in nearby rural Newaukum Creek during that period.

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[Konrad,2003]

Language on "Climatic Trends?"

1981: Bulletin 17B

There is much speculation about climatic changes. Available evidence indicates that major changes occur on time scales involving thousands of year. In hydrologic analysis it is conventional to ***assume that flood flows are not affected by climatic trends or cycles***.

2013: Proposed Update

There is much concern about changes in flood risk associated with climate variability and long-term climate change. Time invariance was assumed in the development of this guide. In those situations ***where there is sufficient scientific evidence to facilitate quantification of the impact of climate variability or change on flood risk, this knowledge should be incorporated in flood frequency analysis*** by employing time-varying parameters or other appropriate techniques. All such methods need to be thoroughly documented and justified.

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Questions?

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Example: Has the magnitude of floods across the USA changed with global CO2 levels?

The conterminous US is divided into four large regions and stationary bootstrapping is used to evaluate if the patterns of these statistical associations are significantly different from what would be expected under the null hypothesis that flood magnitudes are independent of GMCO2. In none of the four regions defined in this study is there strong statistical evidence for flood magnitudes increasing with increasing GMCO2.

[Hirsch and Ryberg, 2012]

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