Potential Impacts of Climate Change on Flood Frequency and Other Surface Water Phenomena

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Outline of Presentation

- Flood frequency analysis
  - Current procedures
  - Potential nonstationarity
- Influence of patterns of large scale variability
  - El Niño-Southern Oscillation
  - Pacific Decadal Oscillation
- Potential impacts of climate change

Flooding in the U.S.

- Large portion of U.S. population, industry, and infrastructure in flood prone areas
  - True for Great Lakes Region
- Floods cause an average of ~140 deaths and cost ~$6 billion annually
  - Excludes flooding caused by Hurricane Katrina which cost $200 billion alone
  - 1993 flooding along the Mississippi and Missouri Rivers caused $20 billion in damages
- Neglects real costs $\Rightarrow$ emotional costs, environmental costs

Flood Frequency Analysis

- Engineers cannot stop floods from happening, but should seek structural and nonstructural strategies to reduce flood risk
- Need to estimate flows for use in:
  - floodplain management
  - design of dams, culverts, bridges and roads
  - water management (dam / reservoir operation)
- Need to reduce risk of economic loss, environmental damage, and loss of life

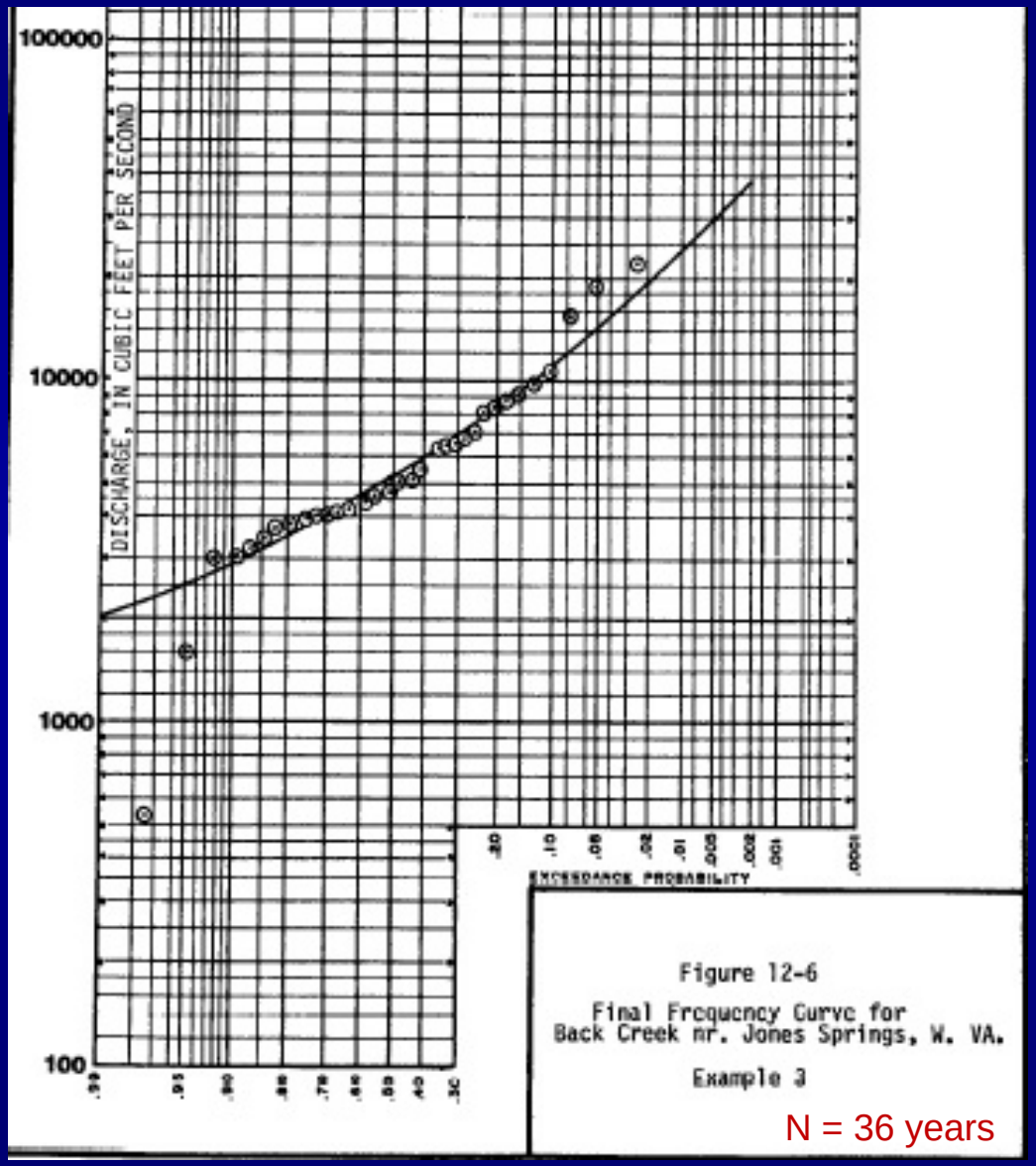
Flood Frequency Analysis

Flood frequency analysis is used to estimate large events such as the 100-year flood

- Flood flow expected to occur once every 100 years; equivalent to the 99th percentile
- Design flow used in floodplain management and by FEMA to define the regulated floodplain

Frequency Curve

- For annual maximum flood series, create frequency curve by fitting probability distribution to data to reflect likelihood these data values would have been observed
- Use fitted distribution to estimate design events (100 year flow)
- Requires extrapolation beyond data -- additional procedures to improve estimate



Guidelines For Determining

Flood Flow Frequency

Bulletin # 17B
of the
Hydrology Subcommittee

Revised September 1981
Editorial Corrections March 1982

INTERAGENCY ADVISORY COMMITTEE
ON WATER DATA

U.S. Department of the Interior
Geological Survey
Office of Water Data Coordination
Reston, Virginia 22092

Current set of flood frequency techniques for U.S. Federal agencies described by Bulletin 17B

- Last updated in 1982
- Currently discussions among agencies to update procedures
- Considering impacts of nonstationarity and climate variability

Problem

- Bulletin 17B procedures assume annual maximum flood series are stationary
  - Distribution is not significantly affected by climatic trends or longer-term cycles
  - Historical flood behavior is representative of future events
- Is assumption of stationarity valid?
  - Impacts of climate variability?
  - Impacts of climate change?

Problem

Climatic changes are evident in streamflow

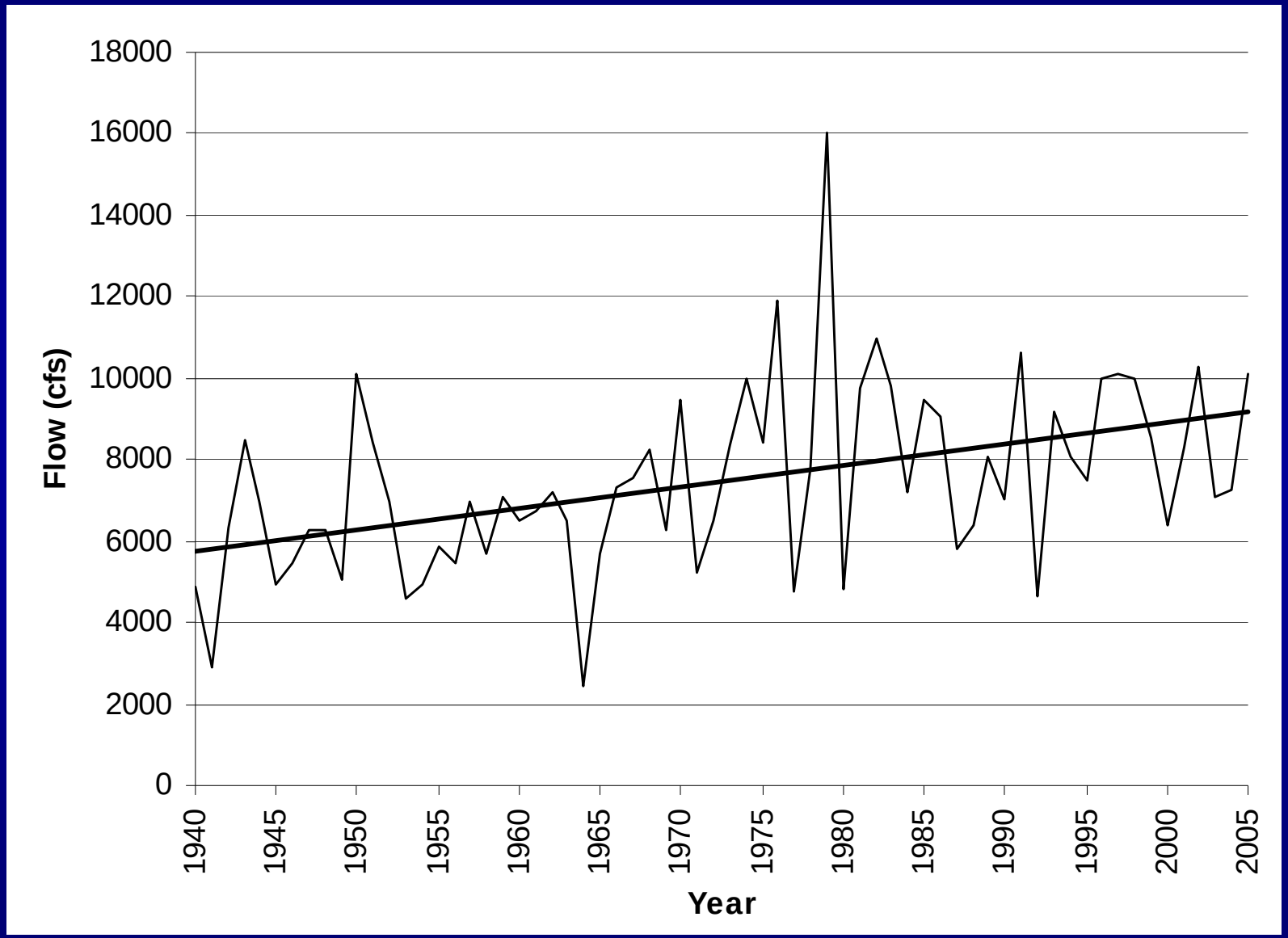
- Several studies have identified trends in U.S. streamflow records
- Links have been identified between streamflow and climate patterns such as

  Pacific Decadal Oscillation (PDO)

  North Atlantic Oscillation (NAO)

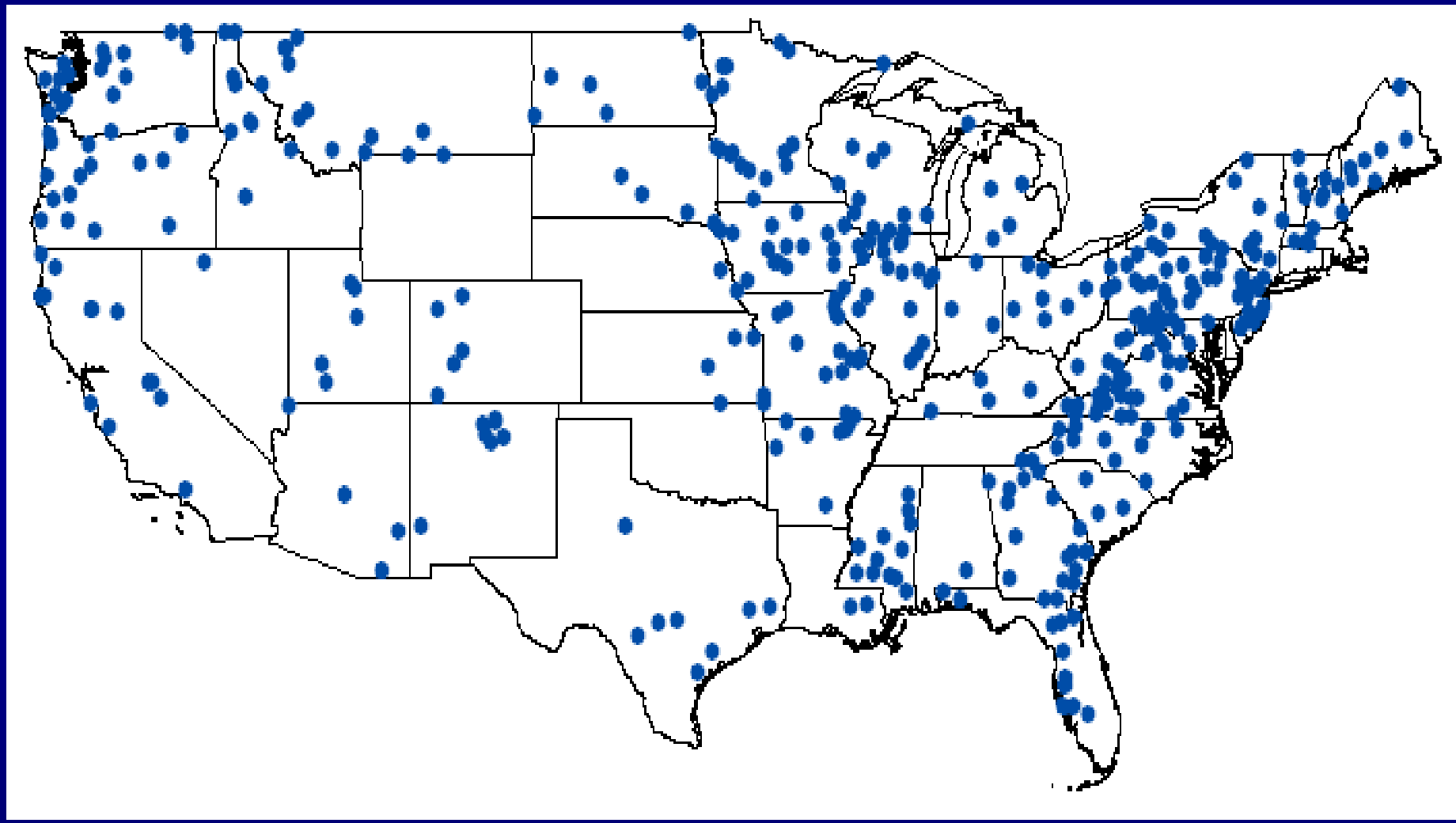
  El Niño-Southern Oscillation (ENSO)

Trend in Flood Flows at Momence (<0.1% Significance Level)



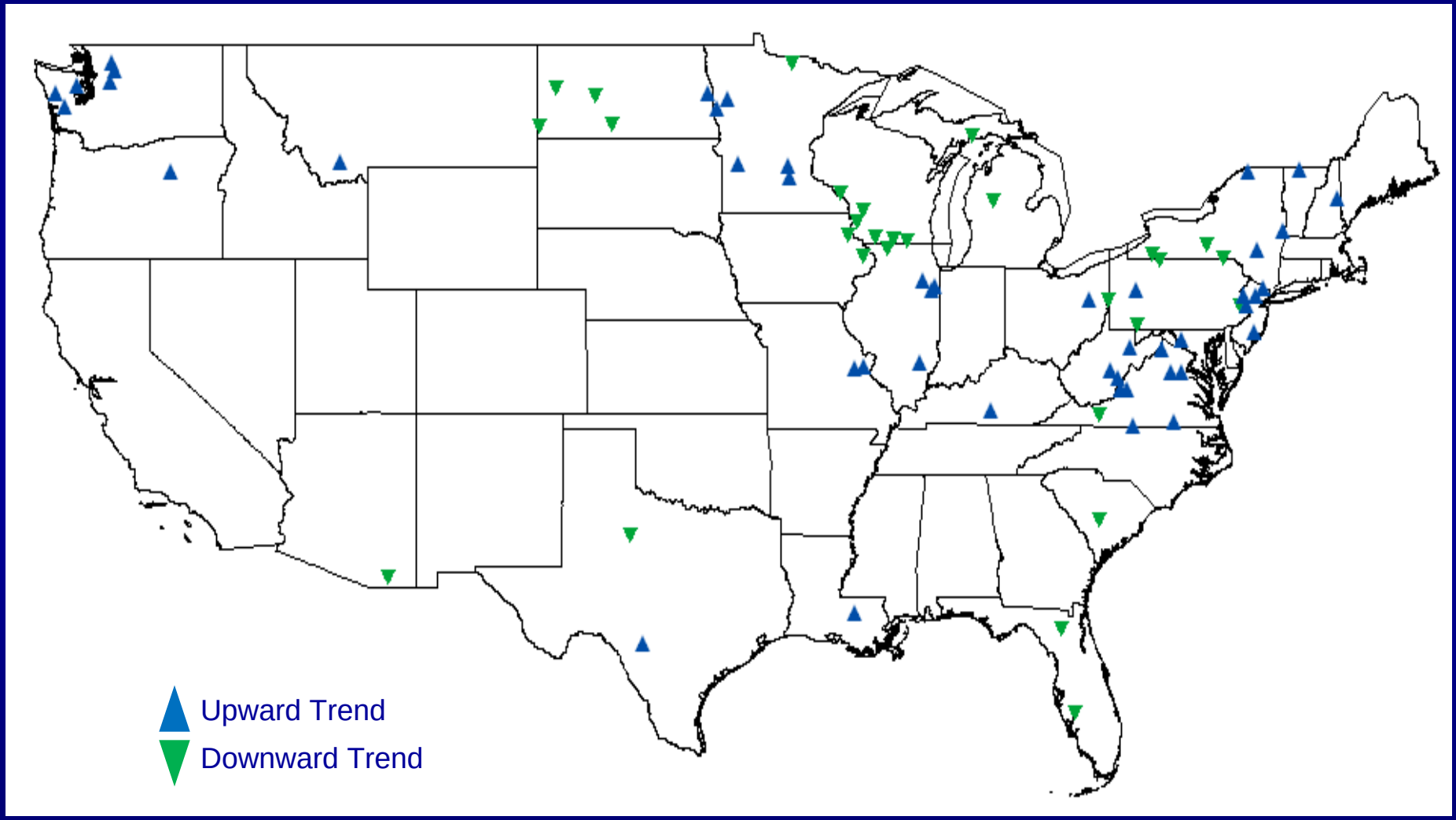
Source: Kashelikar & Griffis (2008) EWRI Proceedings

396 Unimpaired Gauging Stations with period of record: 1941 - 2005



Source: Kashelikar & Griffis (2008) EWRI Proceedings

Trends in Annual Maximum Flood Series (5% significance level)



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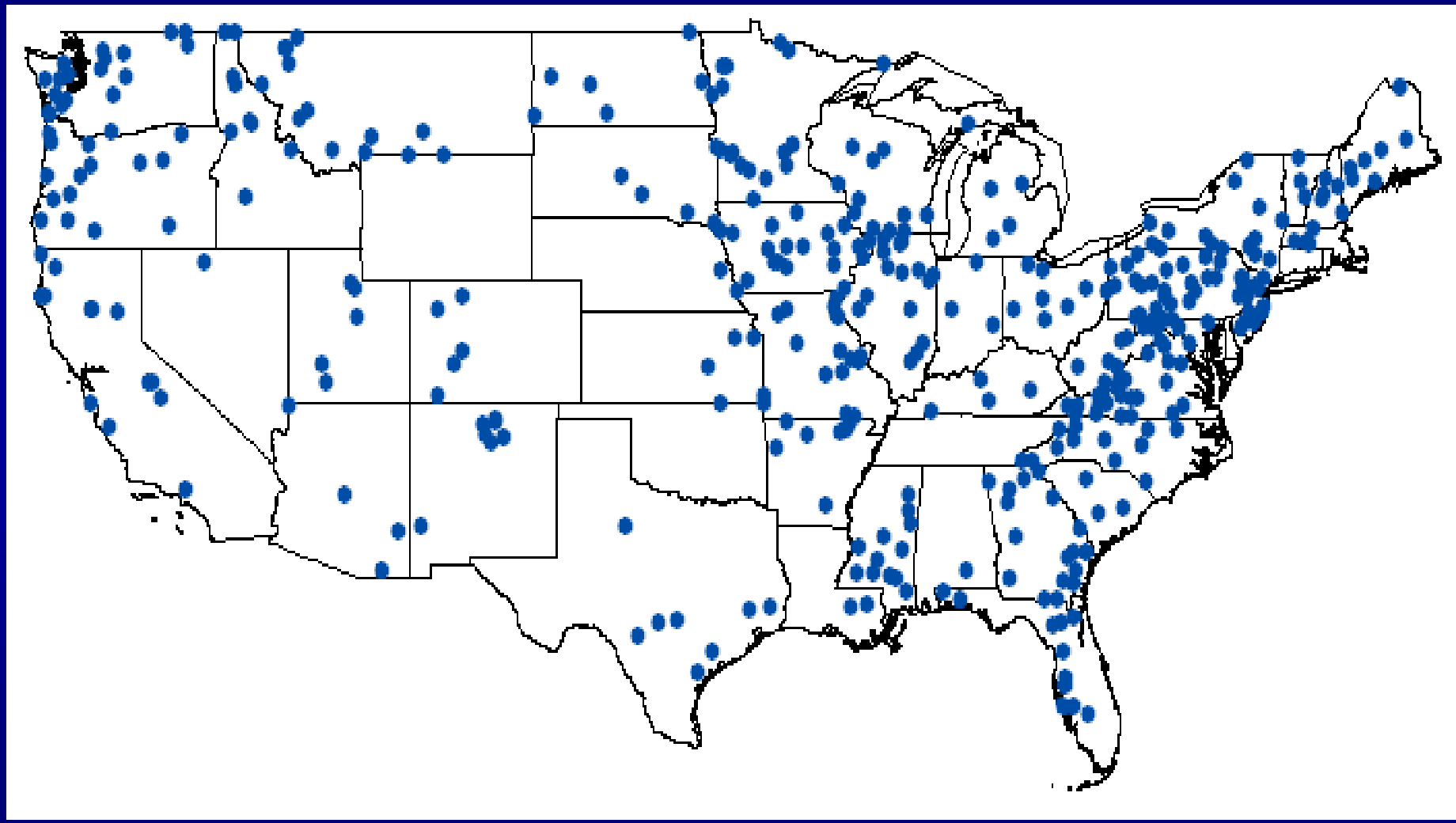

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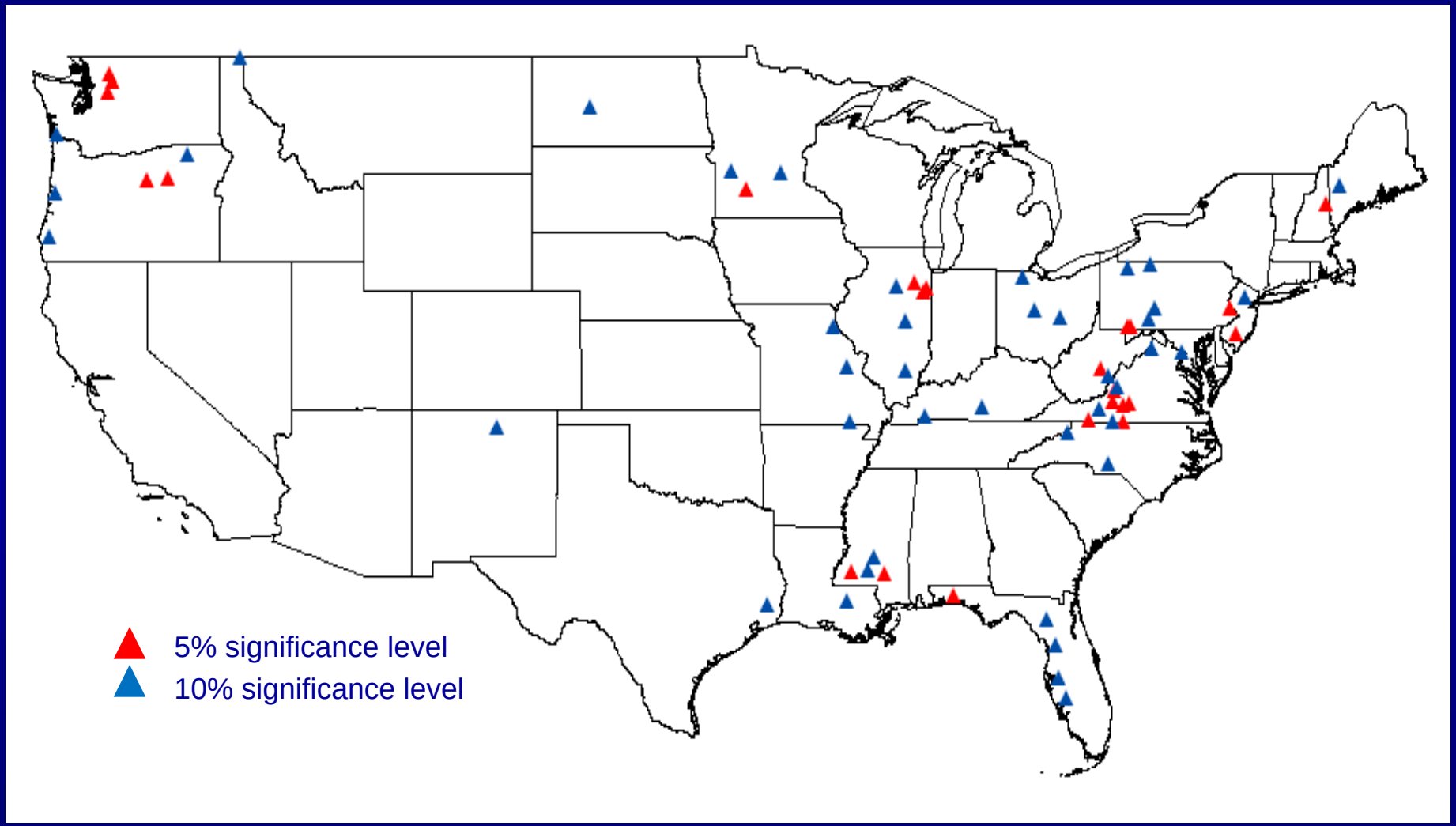
Significant Relationships Between ENSO Indices and Annual Maximum Flood Series



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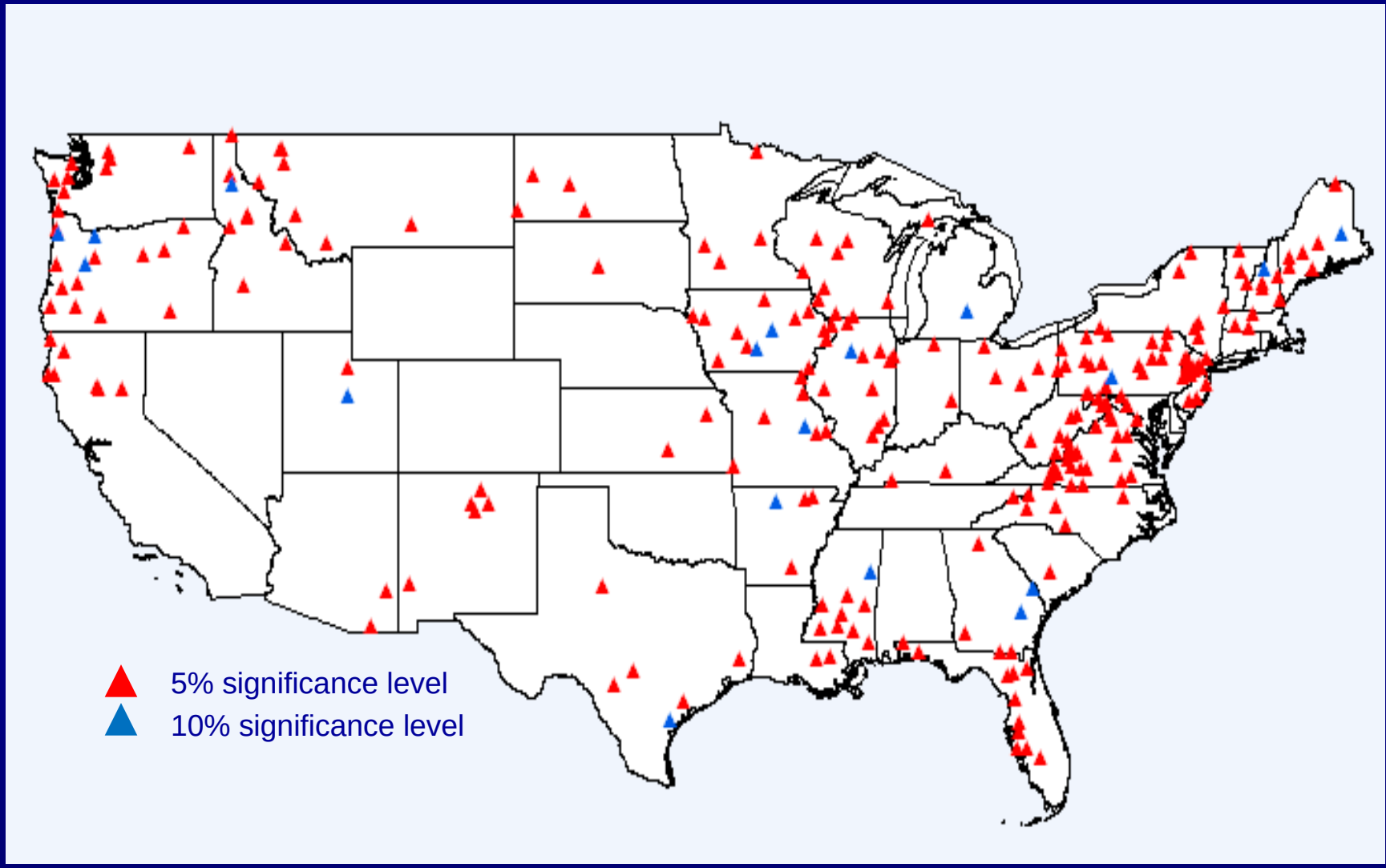
Significant Relationships Between PDO Indices and Annual Maximum Flood Series



Source: Kashelikar & Griffis (2008) EWRI Proceedings

Modification of Bulletin 17B

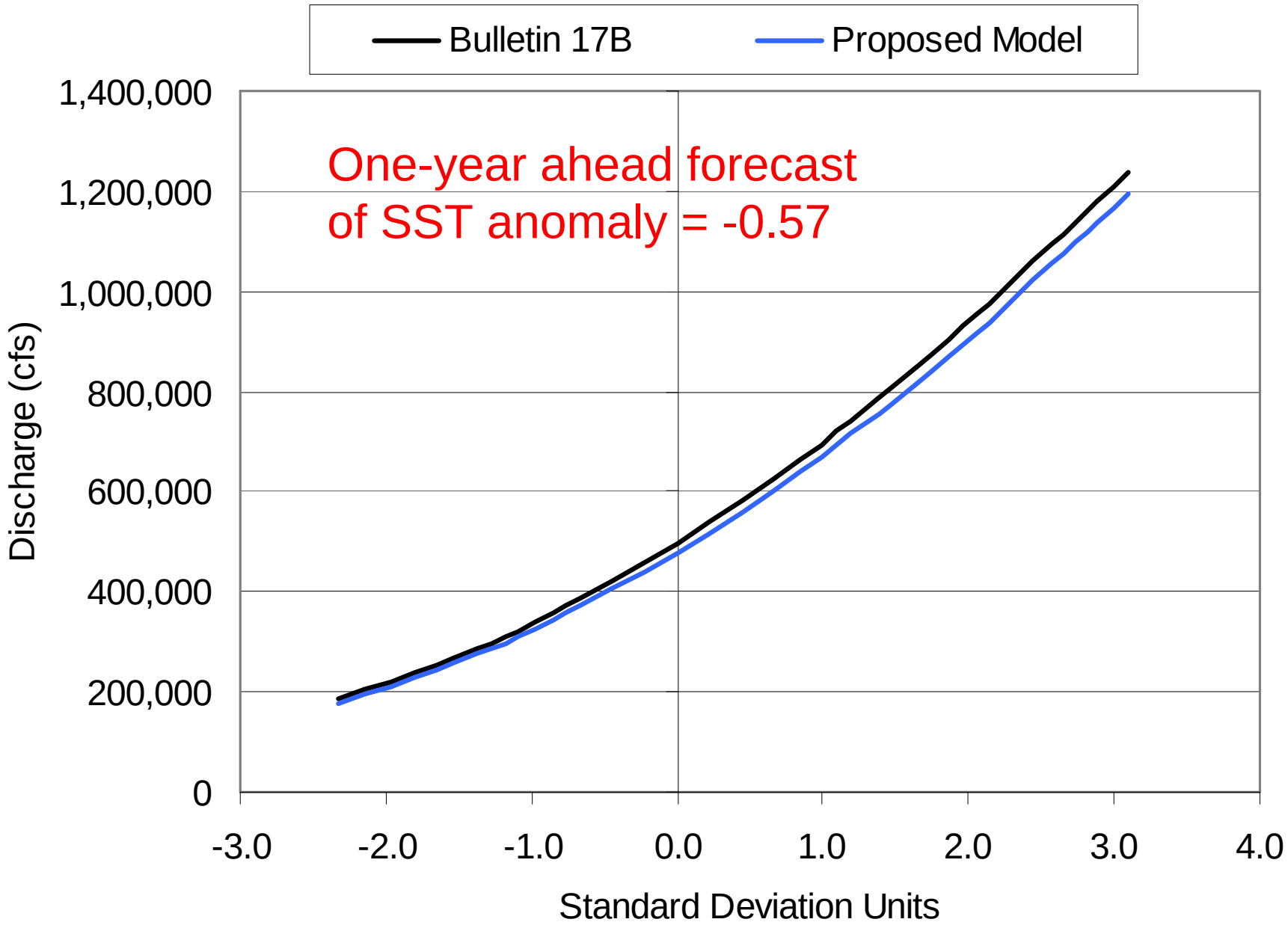
Proposal: Relate nonstationarity in flood series to climate indices representing patterns such as PDO, NAO, or ENSO

Method: Forecast flood risk as function of forecasted climate index (i.e. SST anomaly)

Goals:

- Produce forecasts of flood risk which reflect intensity/phase of ENSO, PDO, etc.
- Improve one-year ahead (or short-term) forecasts of flood risk

Flood Risk for Mississippi River at St. Louis, MO



One-Year Ahead Forecast of Flood Risk

- Proposed method estimates smaller flood risk than Bulletin 17B model
  - Smaller flows expected with negative SST
  - Conversely, expect larger flows / increased risk with positive SST
- Proposed model relates flood risk estimate to intensity and phase of ENSO event (or PDO, etc.)
- Longer planning horizons?
- Impacts of climate change?

Impacts of Climate Change

Similar model could be used to forecast flood risk over a longer planning horizon

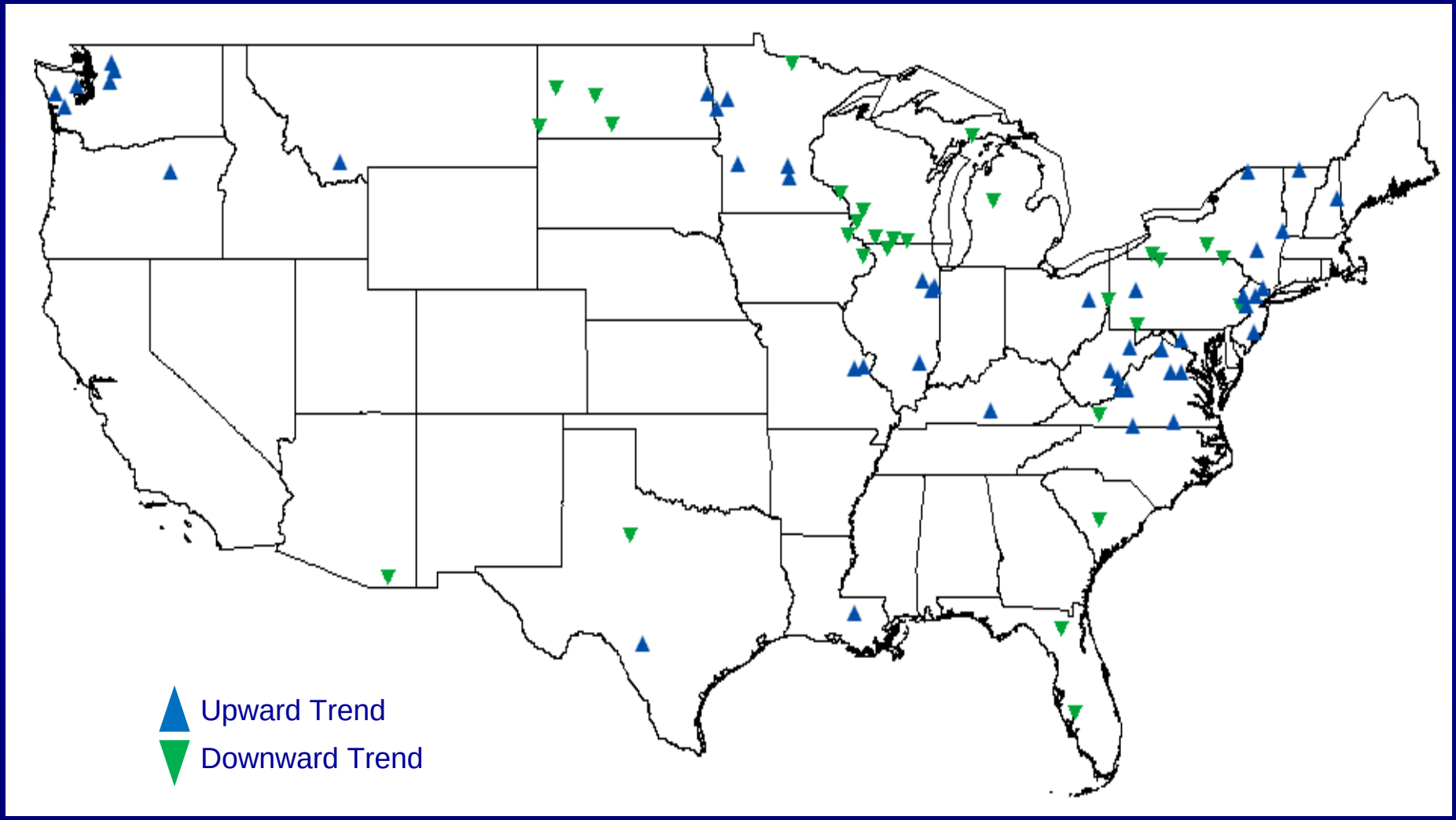
- Problem: Forecasts of needed climate indices are not available with adequate precision
- Will climate patterns change in future?
- Are historical flood series representative of future flood events?

Impacts of Climate Change

Could use time-dependent parameters to reflect observed trends in flood series

- Will observed trends continue into future?
- Are historical flood series representative of future flood events?
- Influence of time span of flood series on computed trend

Trends in Annual Maximum Peak Flows (5% significance level)

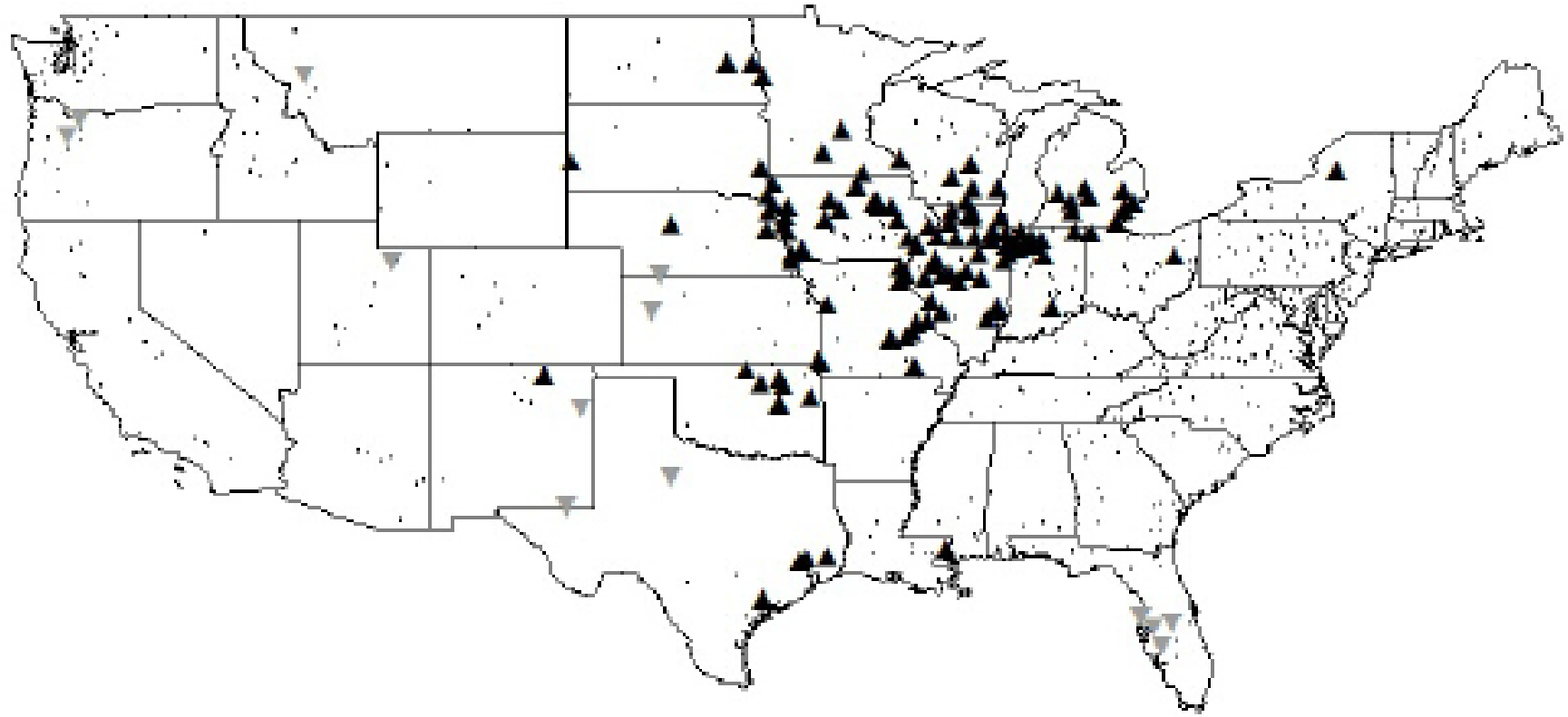


Source: Kashelikar & Griffis (2008) EWRI Proceedings

Impacts of Climate Change

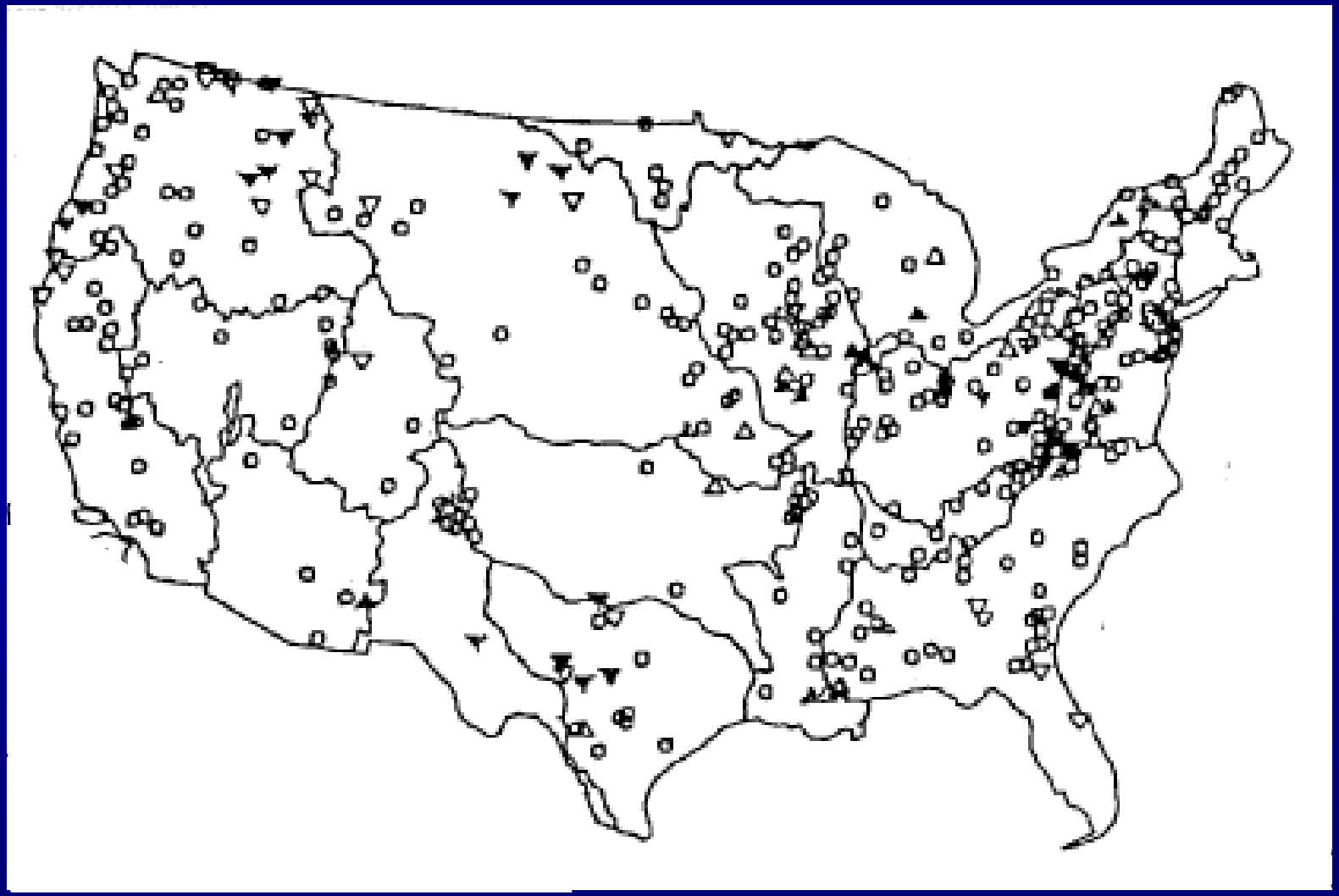
- Global warming expected to result in increased precipitation in Great Lakes region (IPCC, 2007)
  - Expect higher frequency of heavy precipitation events
- What impact will this have on flood flows?
- What impact will this have on runoff and streamflow in general?

Trends in Average Annual Streamflow (5% significance level)



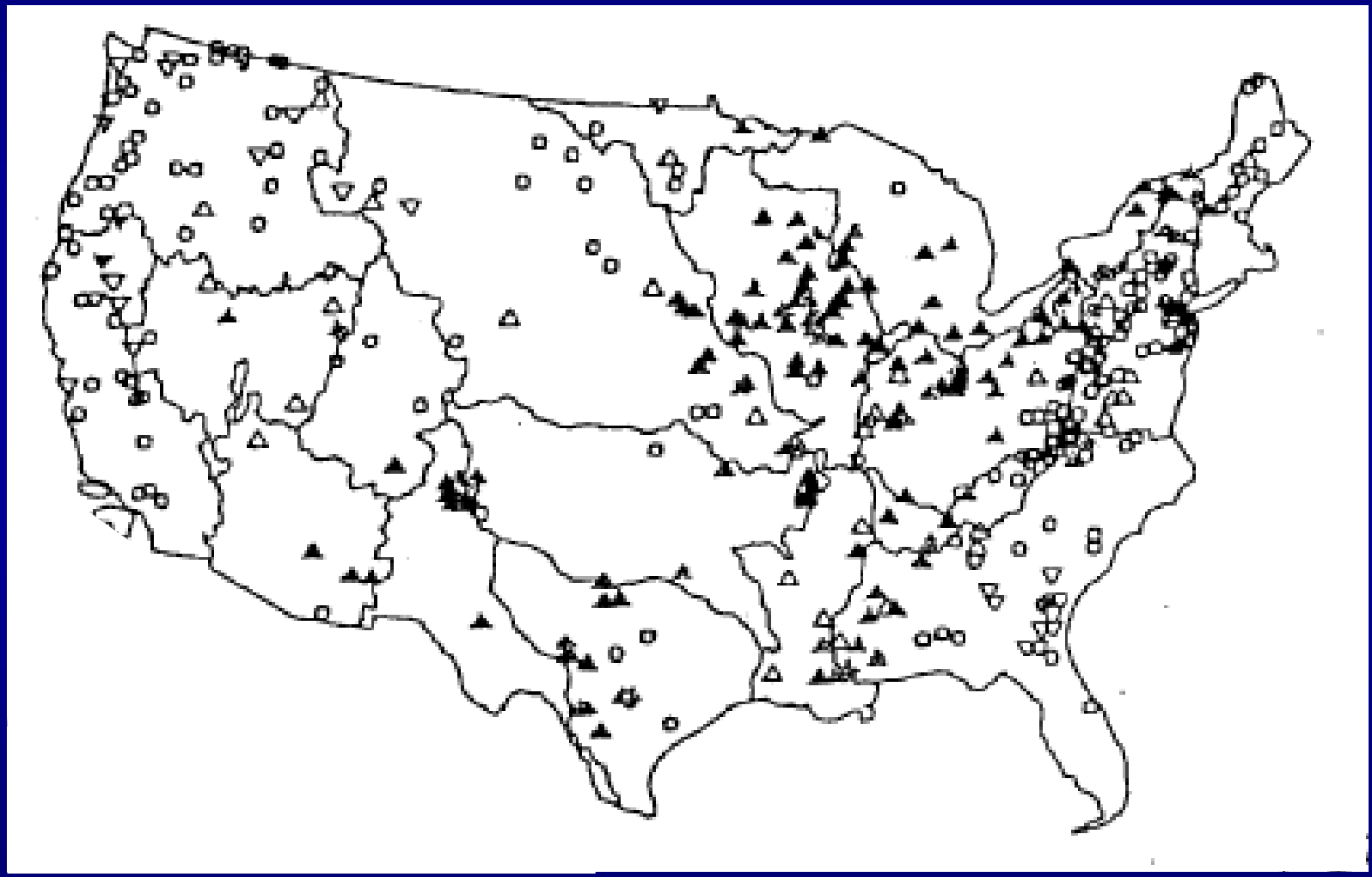
Source: Kalra et al. (2006) EWRI Proceedings

Trends in Maximum Daily (Annual Mean) Flow (5% significance level)



Source: Lins & Slack (1999) Geophysical Research Letters

Trends in Median Daily (Annual Mean) Flow (5% significance level)



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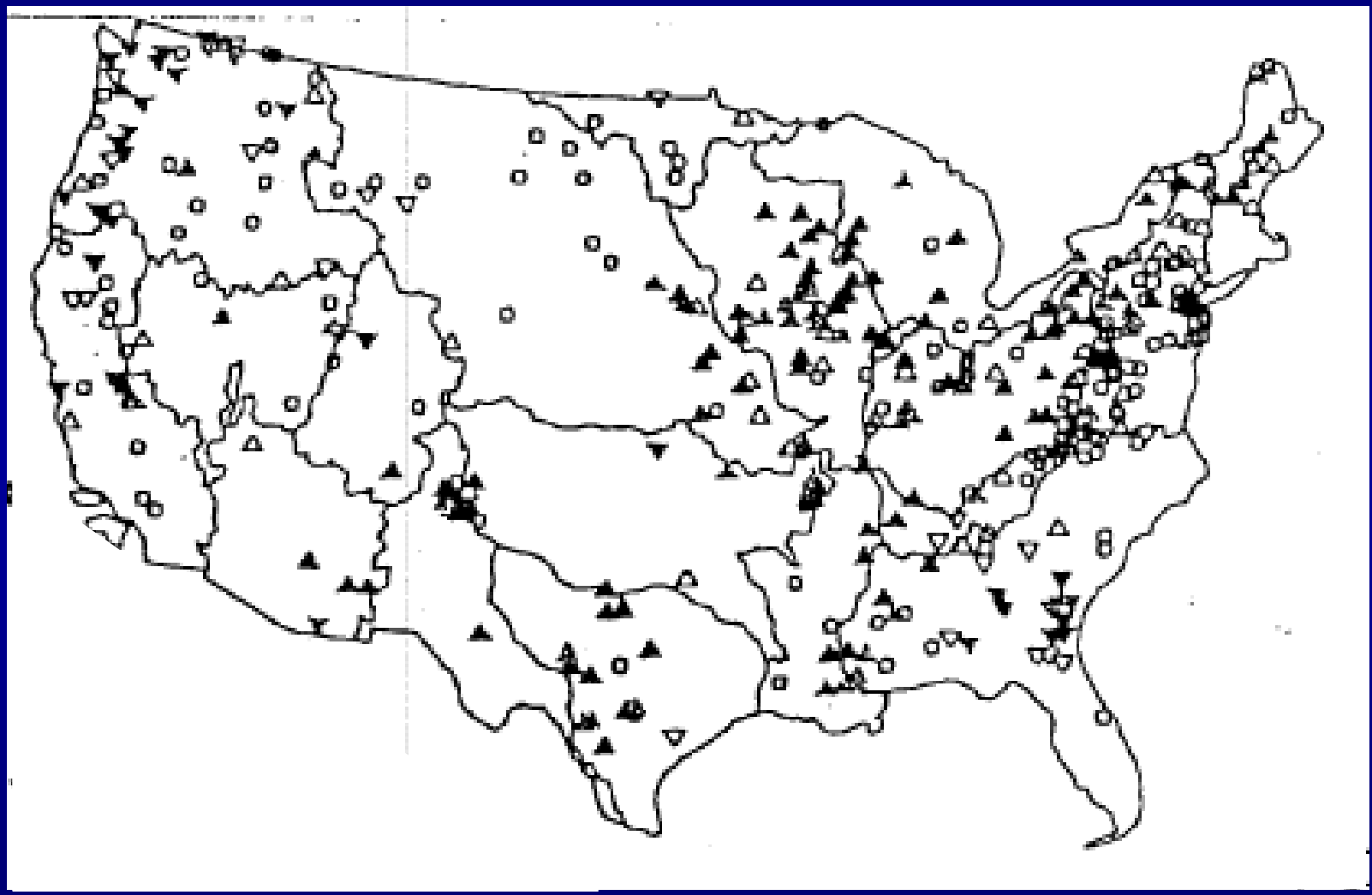
Trends in Minimum Daily (Annual Mean) Flow (5% significance level)



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Impacts of Climate Change

- Overall, Great Lakes region seems to be getting wetter, but not necessarily more extreme
  - Upward trends identified in minimum and median streamflow quantities, not in maximum quantities
  - Increased precipitation expected as a result of global warming
- Not clear that magnitude of flood events is increasing, BUT flood events could become more frequent

Impacts of Climate Change

- Timing of flood events could change
  - Possible ecosystem impacts if earlier in season
  - Coupling with increased sediment loads, changes in stream temperature, etc.?
- How will flood risk be affected by land use and land cover changes?
  - Impacts when coupled with climate change?
- How will changes in temperature, humidity, soil moisture, and groundwater levels affect the risk of large floods?