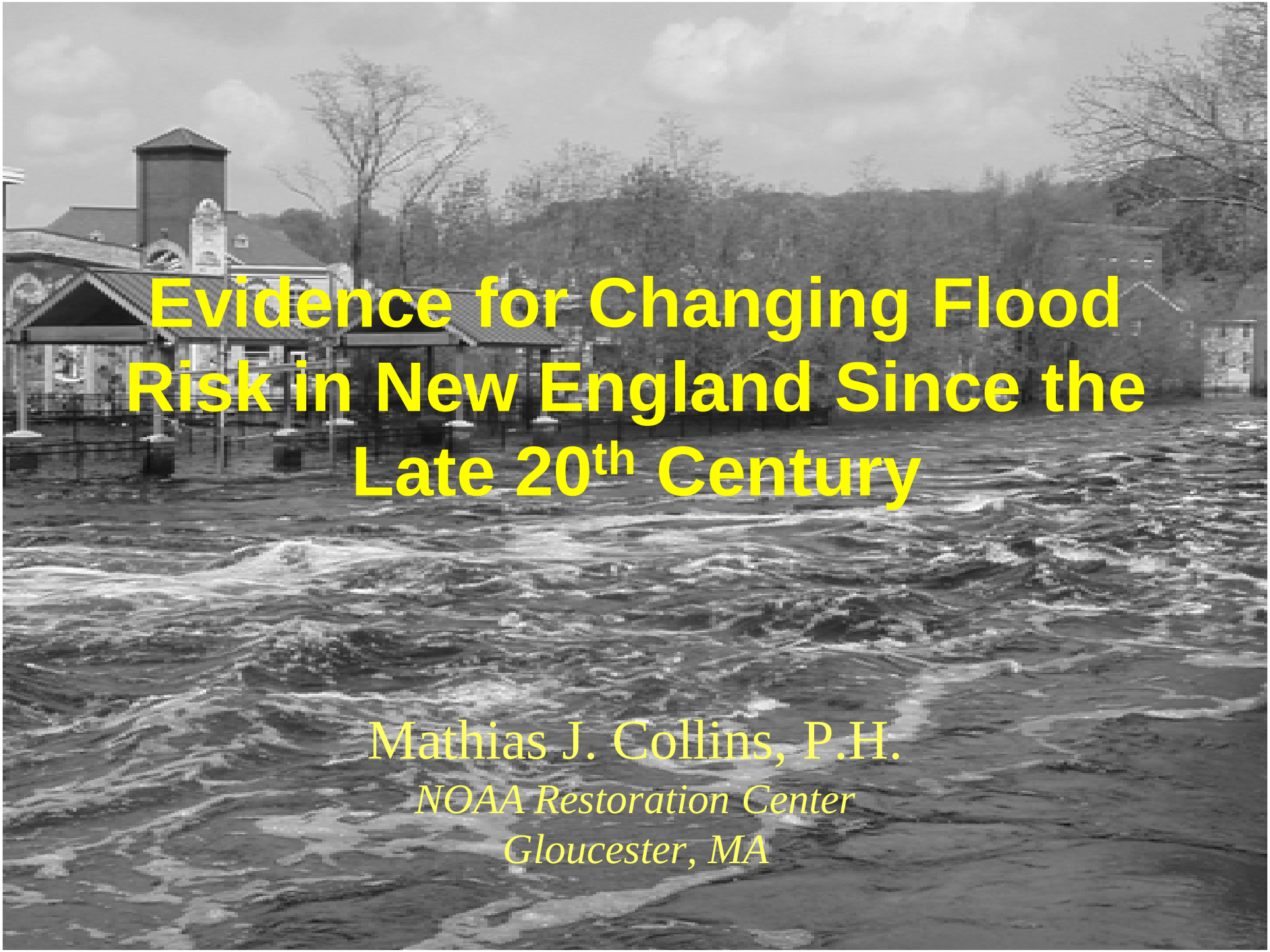
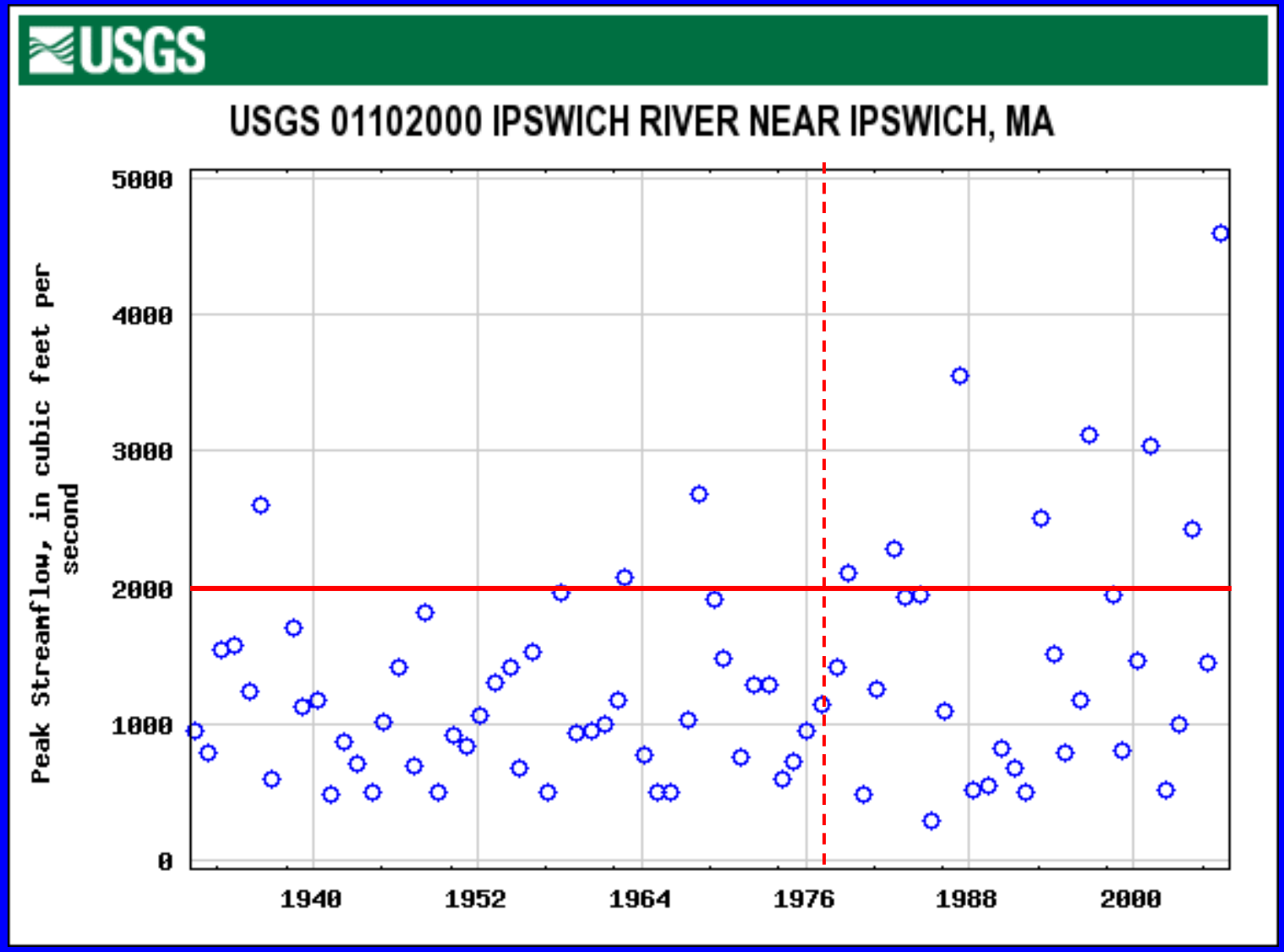
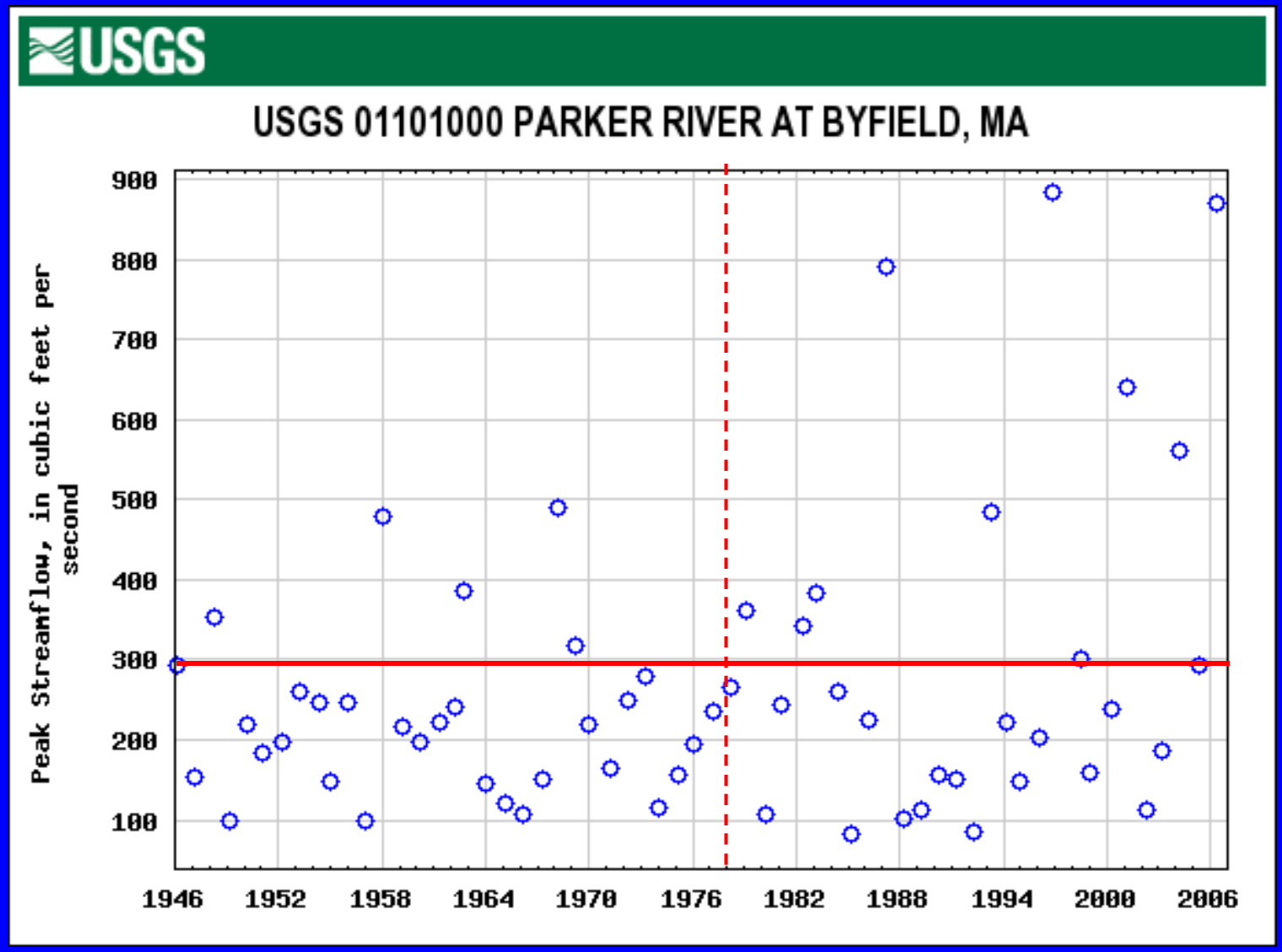
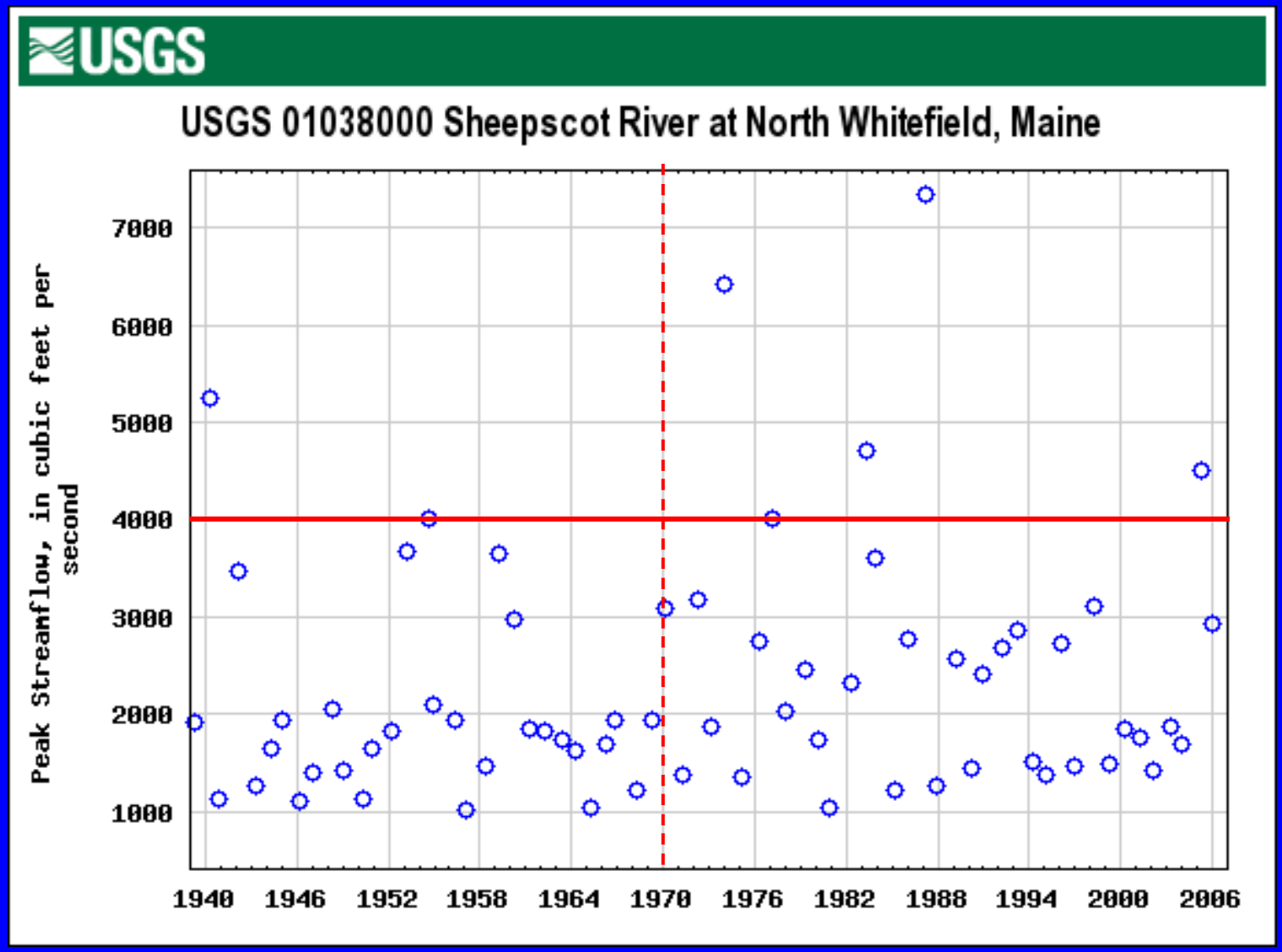


Evidence for Changing Flood Risk in New England Since the Late 20th Century

Mathias J. Collins, P.H.
NOAA Restoration Center
Gloucester, MA


USGS
USGS 01102000 IPSWICH RIVER NEAR IPSWICH, MA
Peak Streamflow, in cubic feet per second
5000
4000
3000
2000
1000
0
1940
1952
1964
1976
1988
2000


USGS
USGS 01101000 PARKER RIVER AT BYFIELD, MA
Peak Streamflow, in cubic feet per second
900
800
700
600
500
400
300
200
100
1946
1952
1958
1964
1970
1976
1982
1988
1994
2000
2006


USGS
USGS 01038000 Sheepscot River at North Whitefield, Maine
Peak Streamflow, in cubic feet per second
7000
6000
5000
4000
3000
2000
1000
1940
1946
1952
1958
1964
1970
1976
1982
1988
1994
2000
2006

Broad Scale Question

- Could climate also be influencing the magnitude and/or frequency of NE floods?

Existing Research

- Climate influencing streamflow: increased low and moderate flows annually
  - Documented nationally (e.g., Lins and Slack, 1999, 2005; McCabe and Wolok, 2002; Douglas et al., 2000)
  - Documented in New England: (e.g., Hodgkins and Dudley, 2005; Lins and Slack, 2005)
- Evidence for step increase in low to moderate flows nationally around 1970 (McCabe and Wolok, 2002; Mauget, 2003)

Existing Research

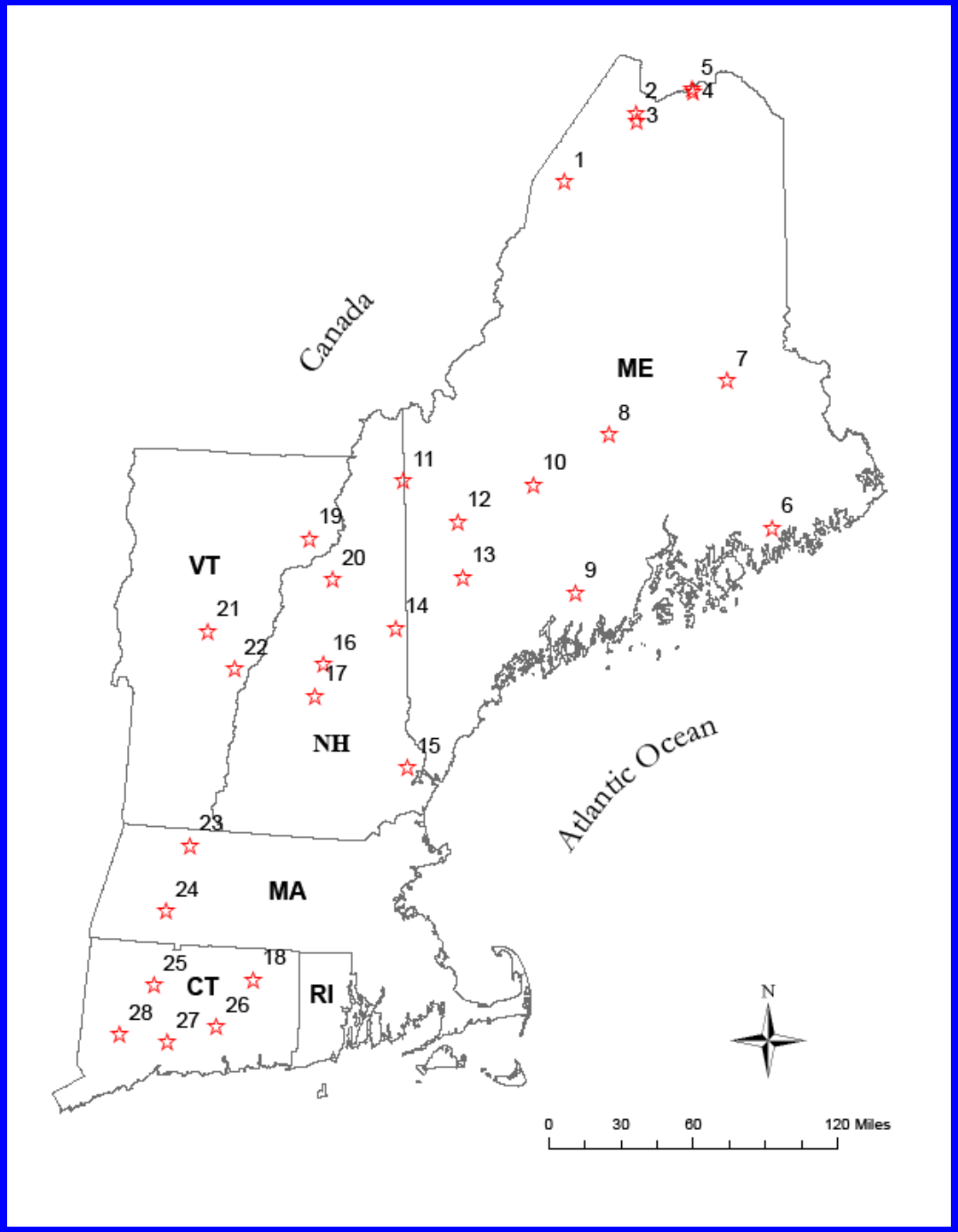
- Picture less clear nationally for high flows
- Trends in annual floods in New England not researched
- Karl and Knight (1998) and Madsen and Figdor (2007) document increased precipitation nationally over last 100 years
  - Primarily through heavy and extreme events
  - Pronounced in Northeast U.S.

Research Questions:

- Are trends detectable in long-term annual flood records for New England watersheds with minimal human impact?
- If so, is there evidence for step changes in these flood series around 1970?
- What are the potential mechanisms for any observed trends?
- What are the implications for flood risk analyses?

Methods

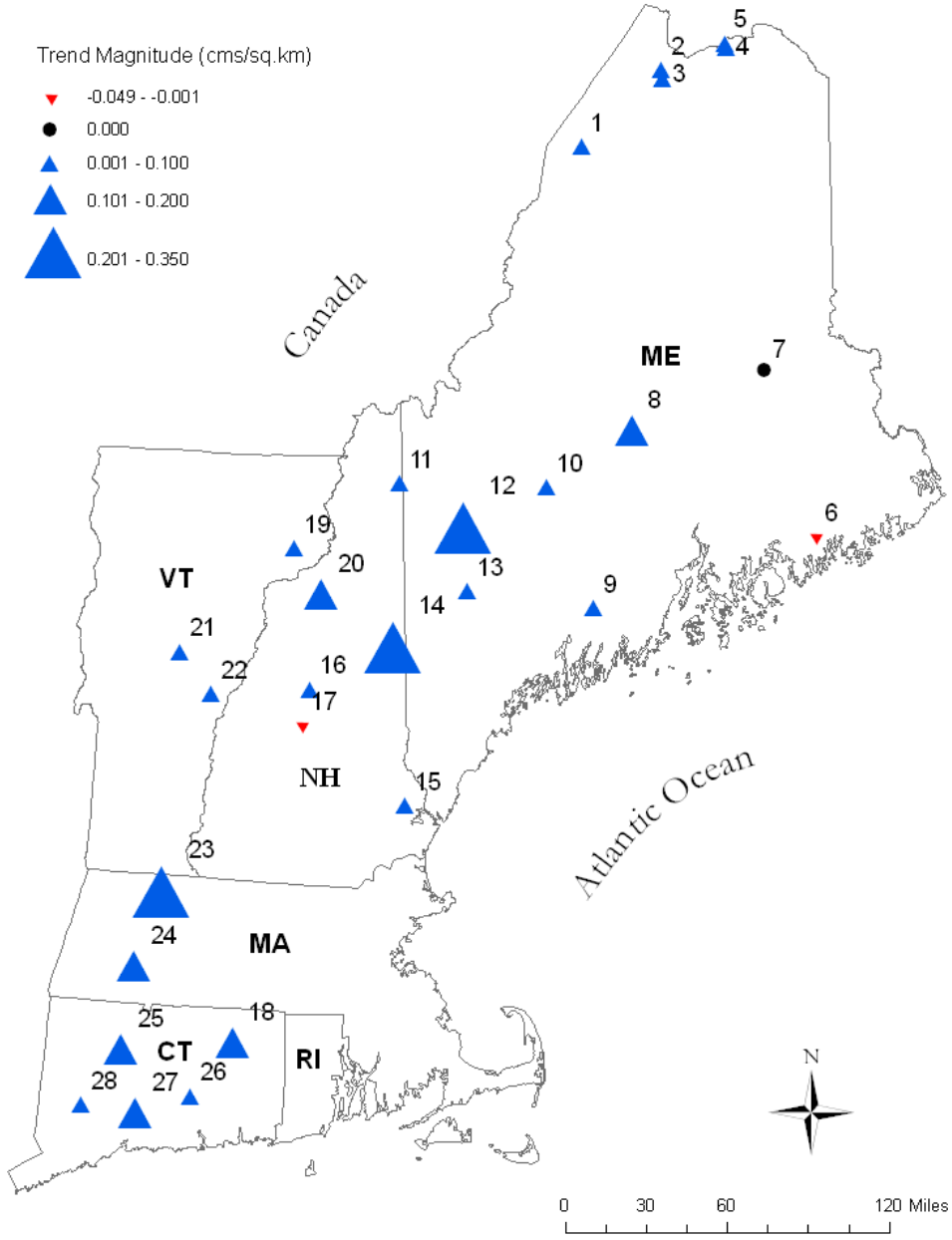
- USGS Hydro-Climatic Data Network (HCDN) (Slack and Landwehr, 1992)
  - relatively free of human influence
  - more than 1,500 gaging stations across U.S.
  - over 70 in New England
- Study Criteria:
  - records beginning by at least 1951
  - continuous through 2006
  - no evidence of flow regulation impacting flood flows



1.	St. John, Maine	1951-2006
2.	St. John, Maine	1947-2006
3.	Allagash, Maine	1932-2006
4.	Fish, Maine	1930-2006
5.	St. John, Maine	1927-2006
6.	Narraguagus, Maine	1948-2006
7.	Mattawamkeag, Maine	1903-2006
8.	Piscataquis, Maine	1903-2006
9	Sheepscot, Maine	1939-2006
10.	Carrabassett, Maine	1926-2006
11.	Diamond, New Hampshire	1942-2006
12.	Swift, Maine	1930-2006
13.	Little Androscoggin, Maine	1932-2006
14.	Saco, New Hampshire	1930-2006
15.	Oyster, New Hampshire	1935-2006
16.	Pemigewasset, New Hampshire	1904-2006
17.	Smith, New Hampshire	1919-2006
18.	Mount Hope, Connecticut	1941-2006
19.	Moose, Vermont	1947-2006
20.	Ammonoosuc, New Hampshire	1940-2006
21.	Ayers Brook, Vermont	1940-2006
22.	White, Vermont	1916-2006
23.	North, Massachusetts	1940-2006
24.	W. Br. Westfield, Massachusetts	1936-2006
25.	Burlington, Connecticut	1932-2006
26.	Salmon, Connecticut	1929-2006
27.	Quinnipiac, Connecticut	1931-2006
28.	Pomperaug, Connecticut	1933-2006

Methods

- Mann-Kendall non-parametric test for monotonic trends (simply ↑ or ↓ with time)
- Wilcoxon rank-sum test to investigate step changes in observed trends
- Correlation analyses to investigate New England climate-flood relationships
- Flood risk analysis implications demonstrated using federal interagency guidelines (“Bulletin 17B”) (IACWD, 1981)



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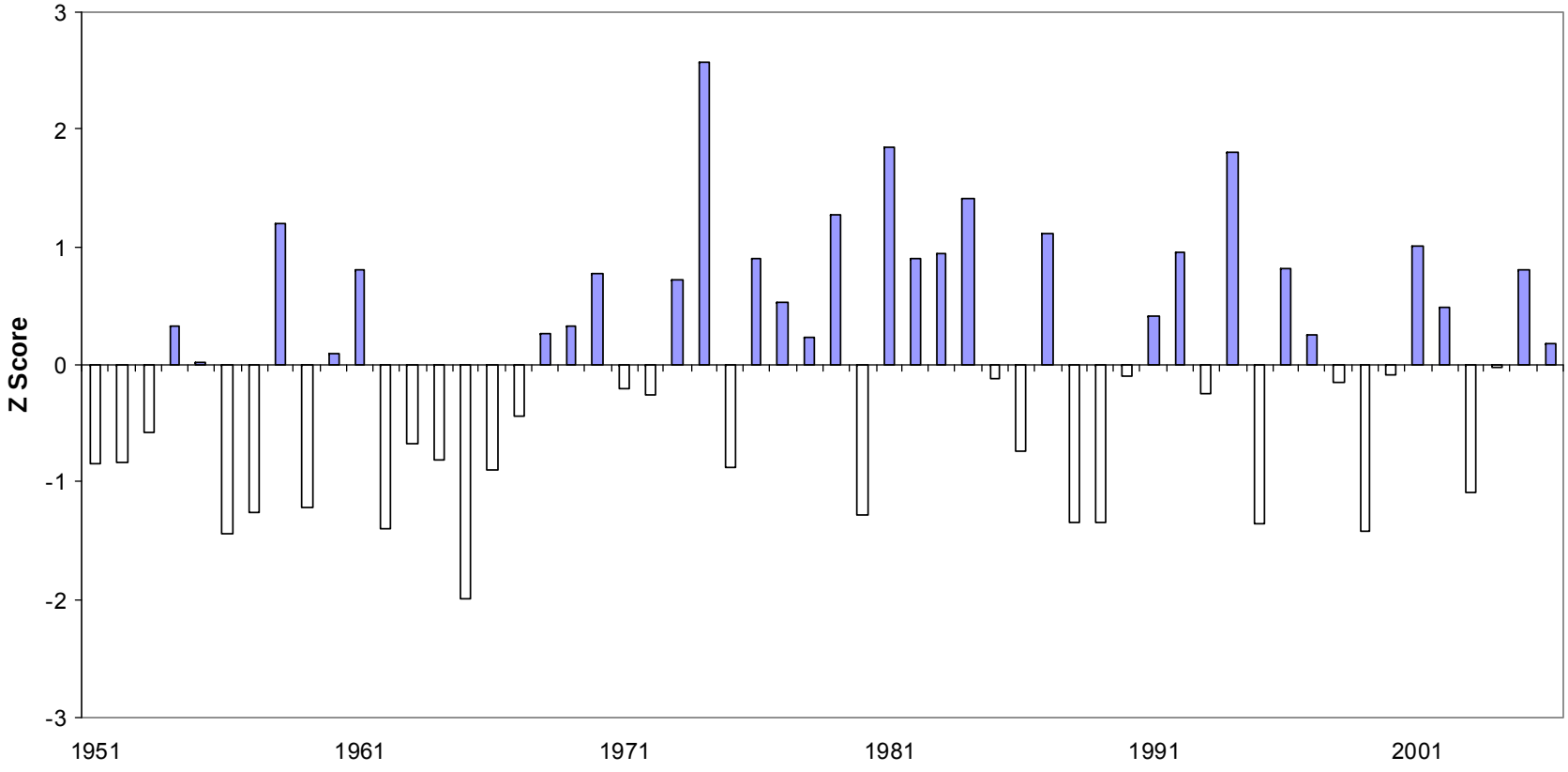
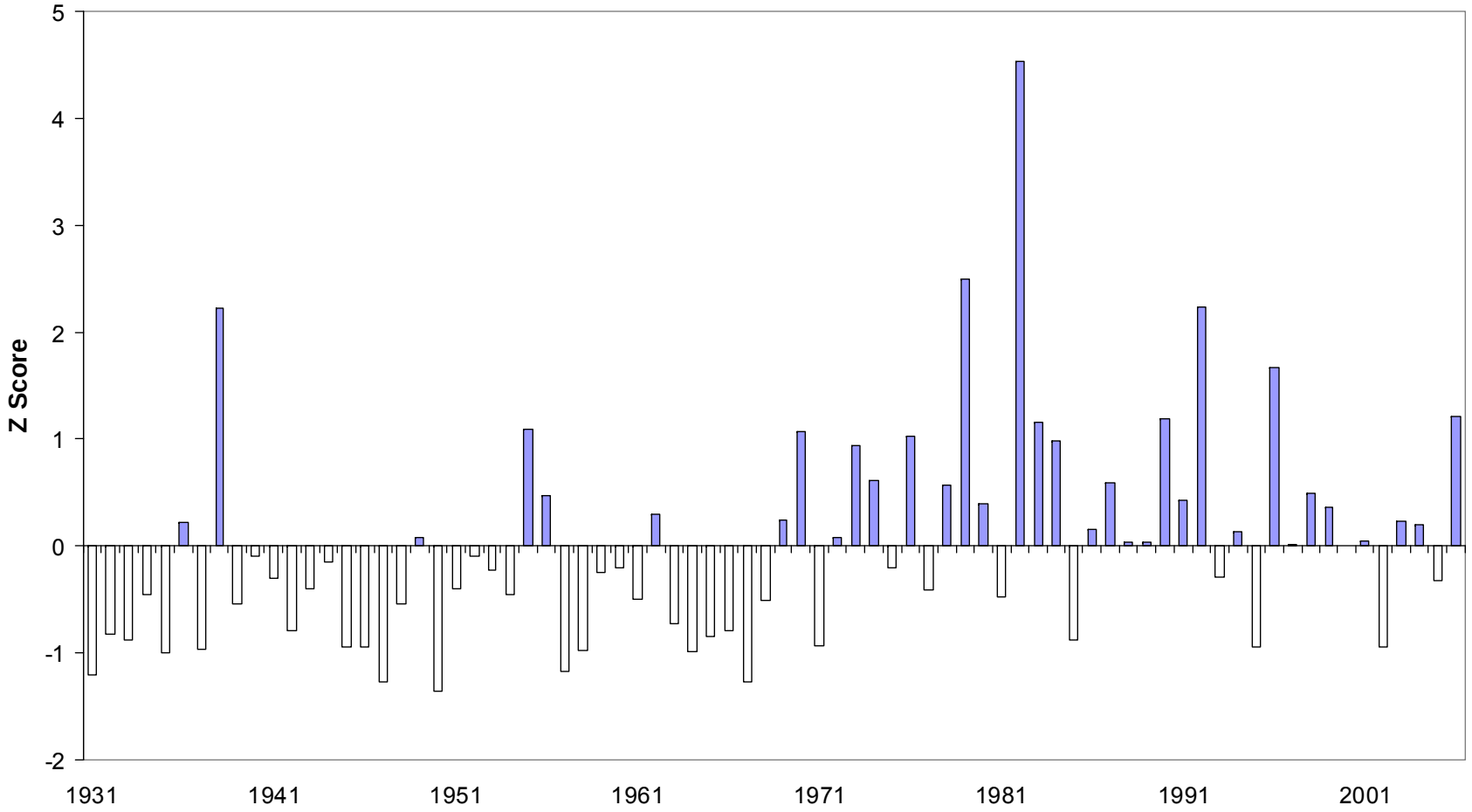
Trend Results

- Are the observed increasing trends gradual over time or step changes?

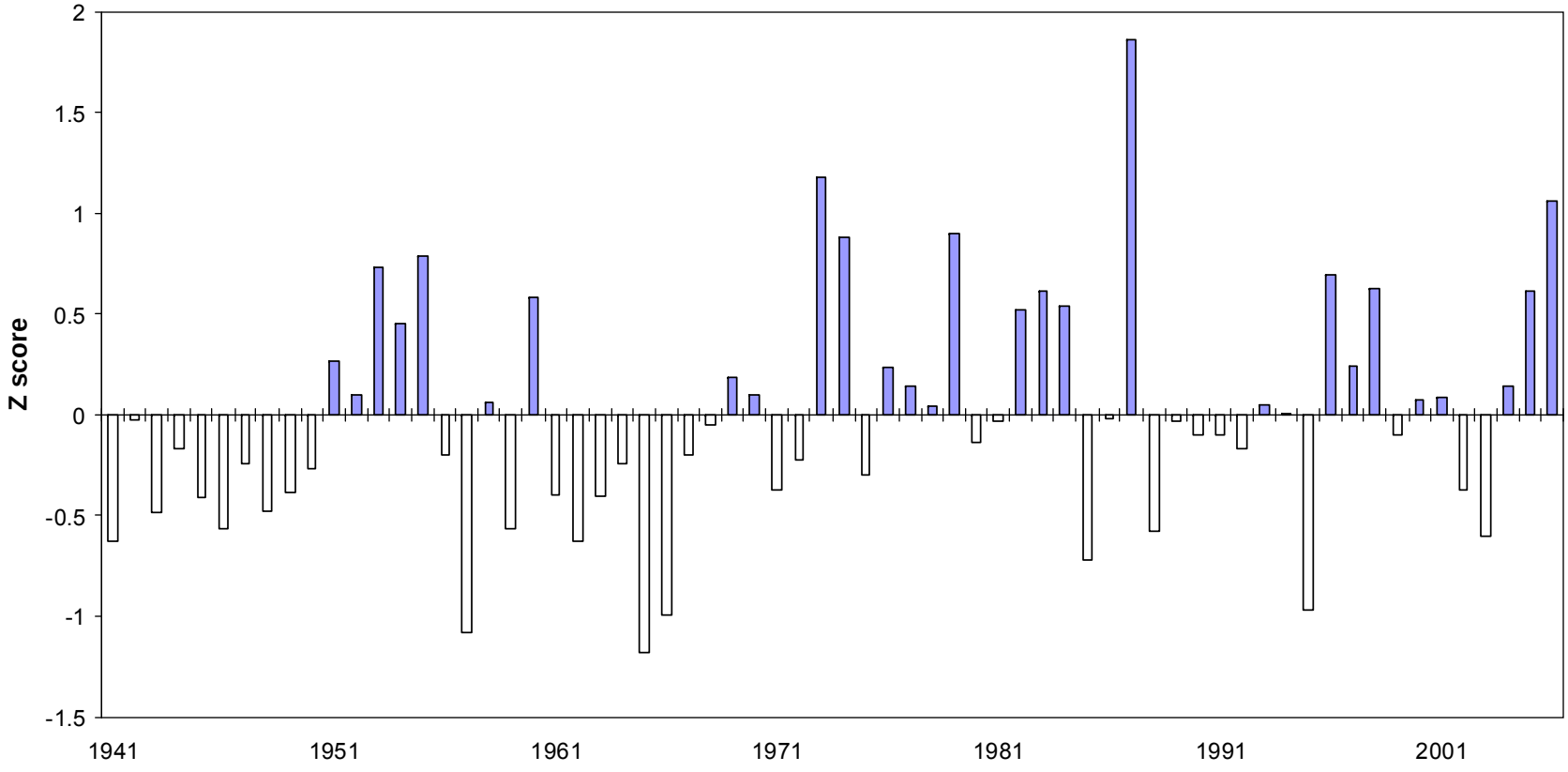
St. John River at Ninemile Bridge, Maine (USGS Gage No. 01010000)



Quinnipiac River at Wallingford, CT (USGS Gage No. 01196500)



Average Standardized Departures for 23 New England Flood Series



Step Change Evidence

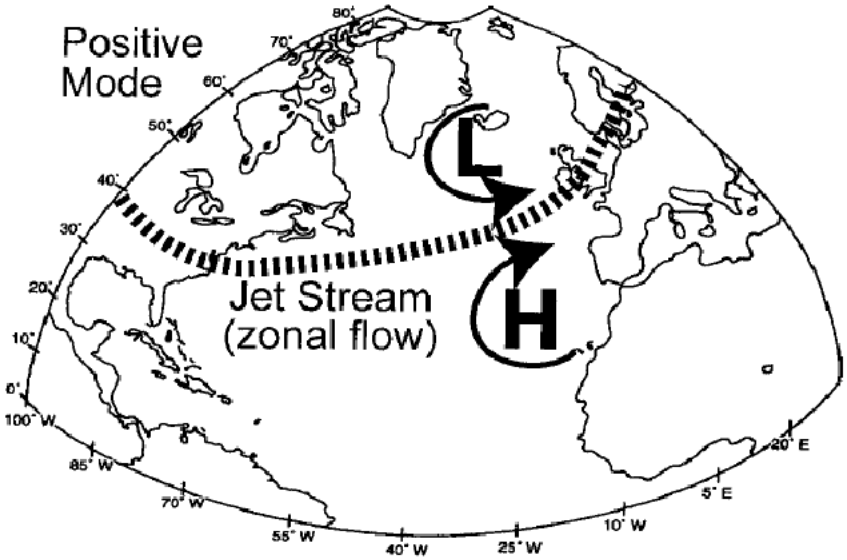
- Wilcoxon rank sum test:
  - Tests for the difference between two groups
  - Non-parametric version of Student's t-test
- The comparison groups:
  - Pre-1970 Z-scores
  - Post-1970 Z-scores
- Question: Is post-1970 group larger?

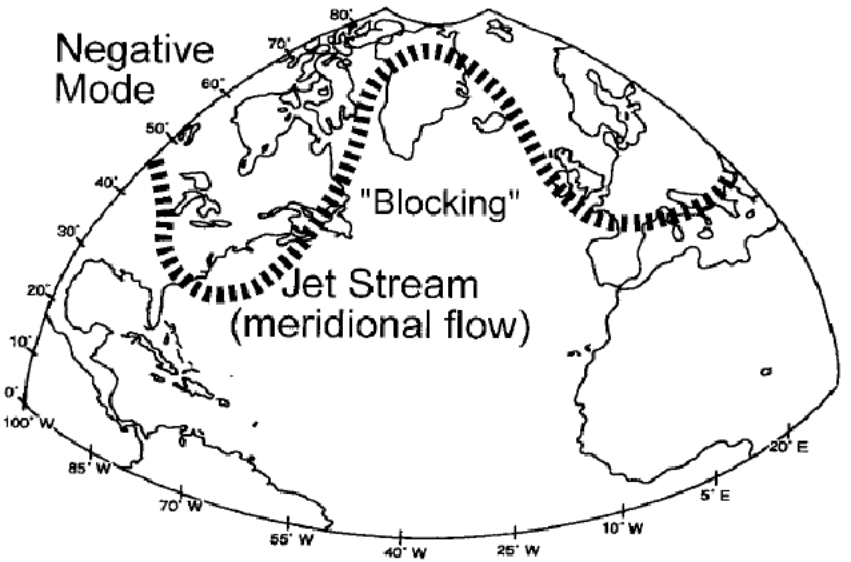
Step Change Evidence

- Post-1970 > pre-1970 for the averaged series (23 gages; $p<0.01$)
- Individual gage sites:
  - Post-1970 > pre-1970 at 27 gages
  - Results for 12 gages are significant at $p<0.1$

Investigating Potential Climate Links

- Bradbury et al. (2002a, b; 2003) show evidence for an North Atlantic Oscillation-New England streamflow link
- NAO: One of the oldest known, prominent, and recurrent upper atmospheric circulation patterns
- Alternate modes strongly influence climate variability along the U.S. east coast, especially in winter
- Modes are identified by the “NAO index”



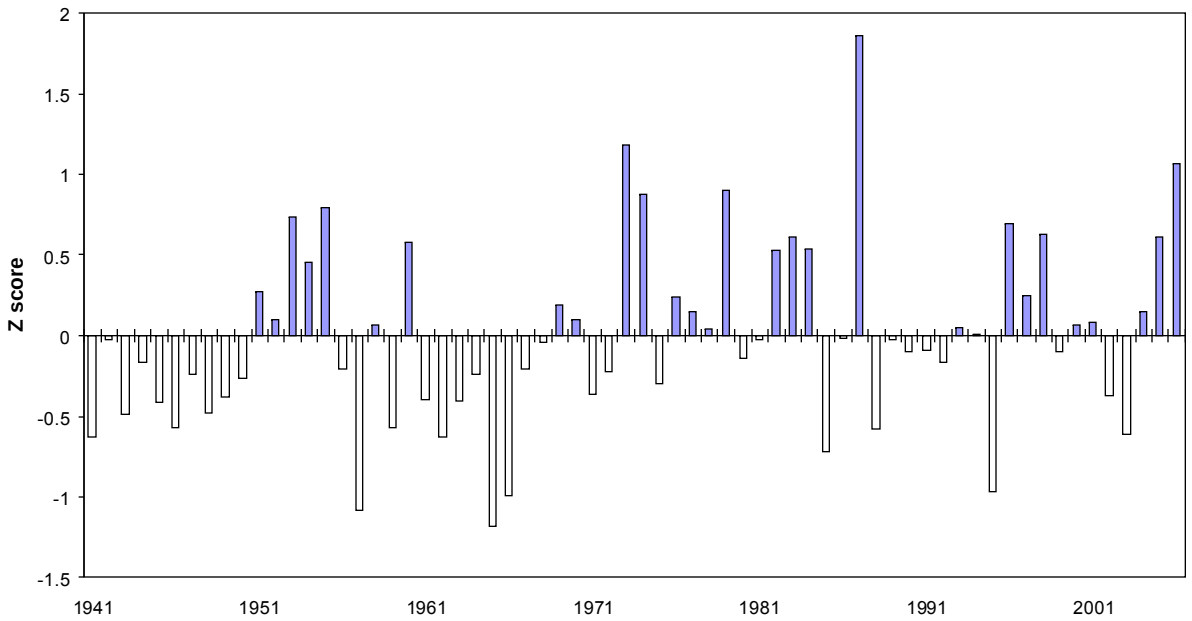


Bradbury et al. (2002)

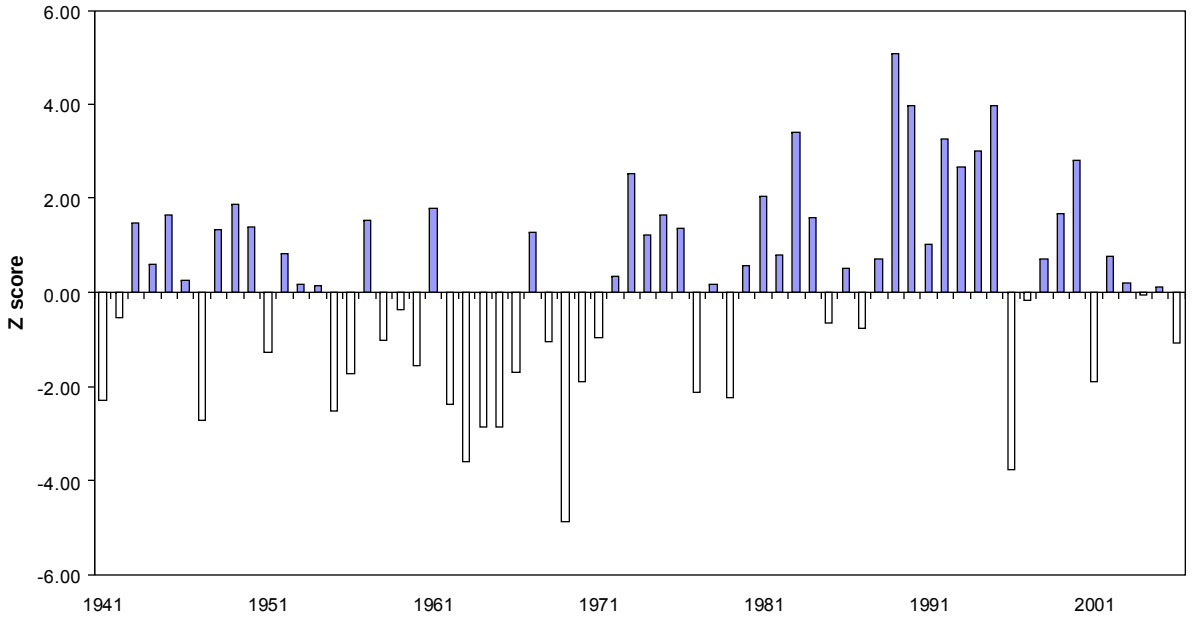
NAO

- Positive NAO – warmer, wetter NE winters
- Negative NAO – colder, drier NE winters

Average Standardized Departures for 23 New England Flood Series



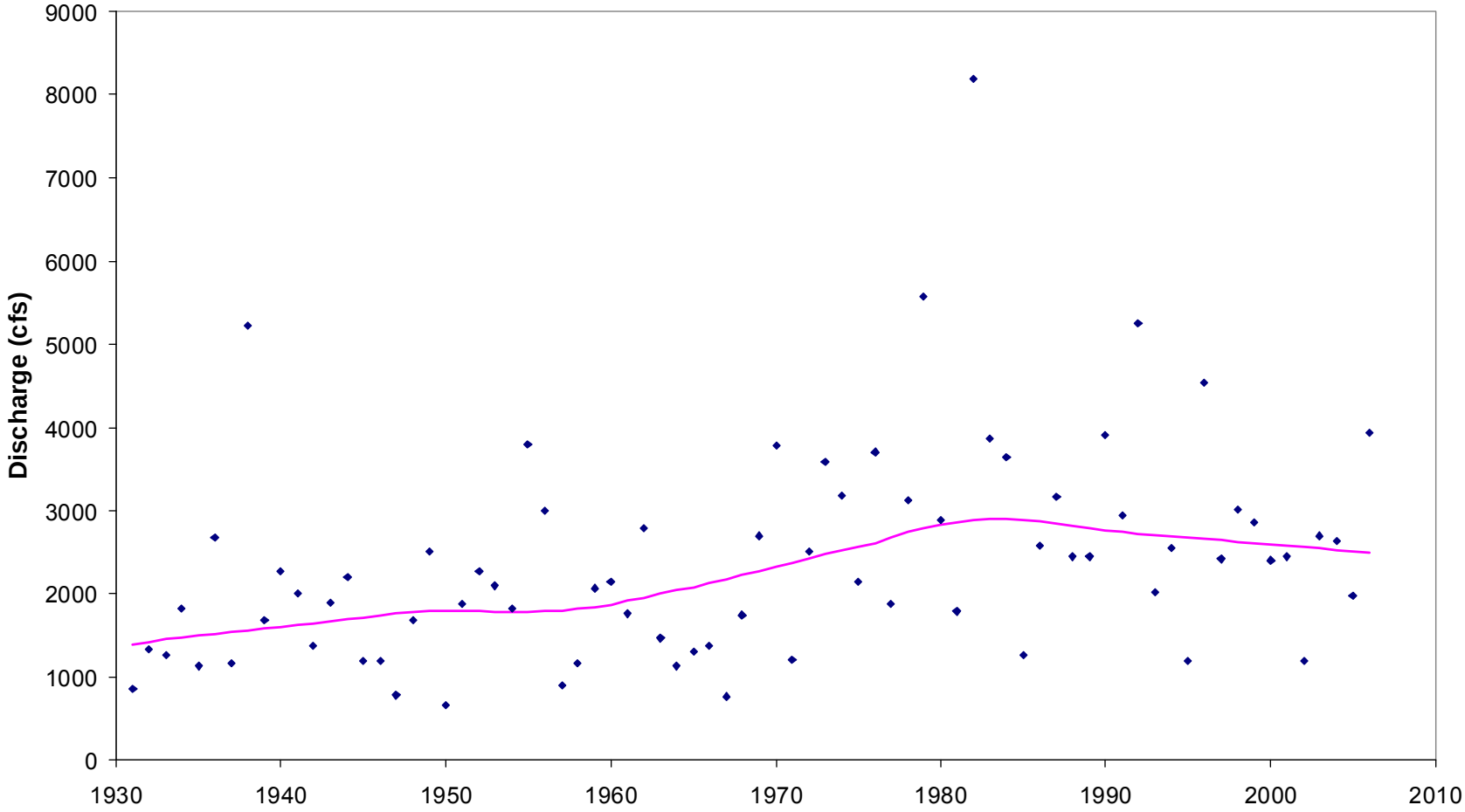
Station-based NAO Index (Dec-Mar)



Implications for Flood Frequency Analyses

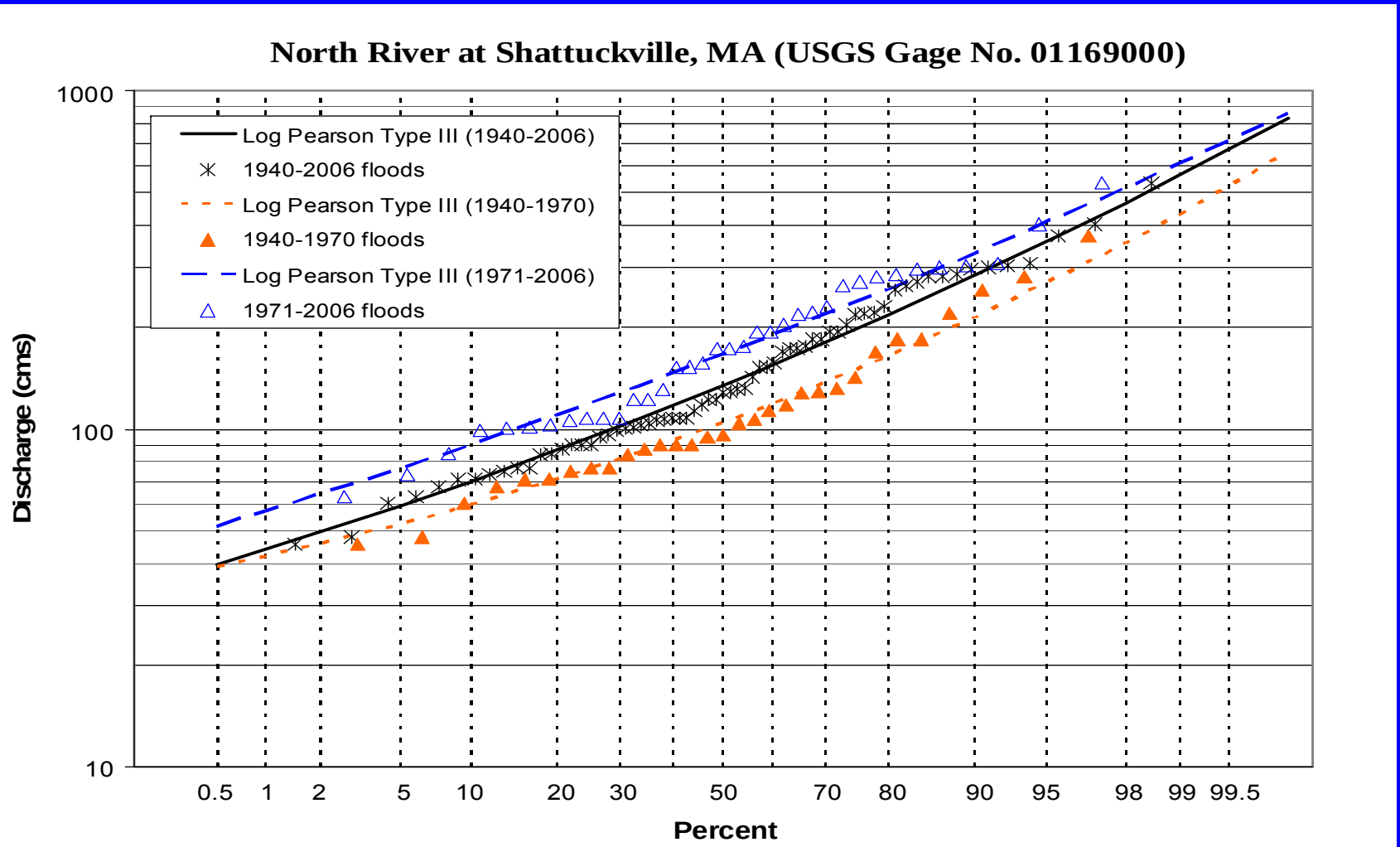
- Flood frequency statistics are valid under the assumption of non-varying climate

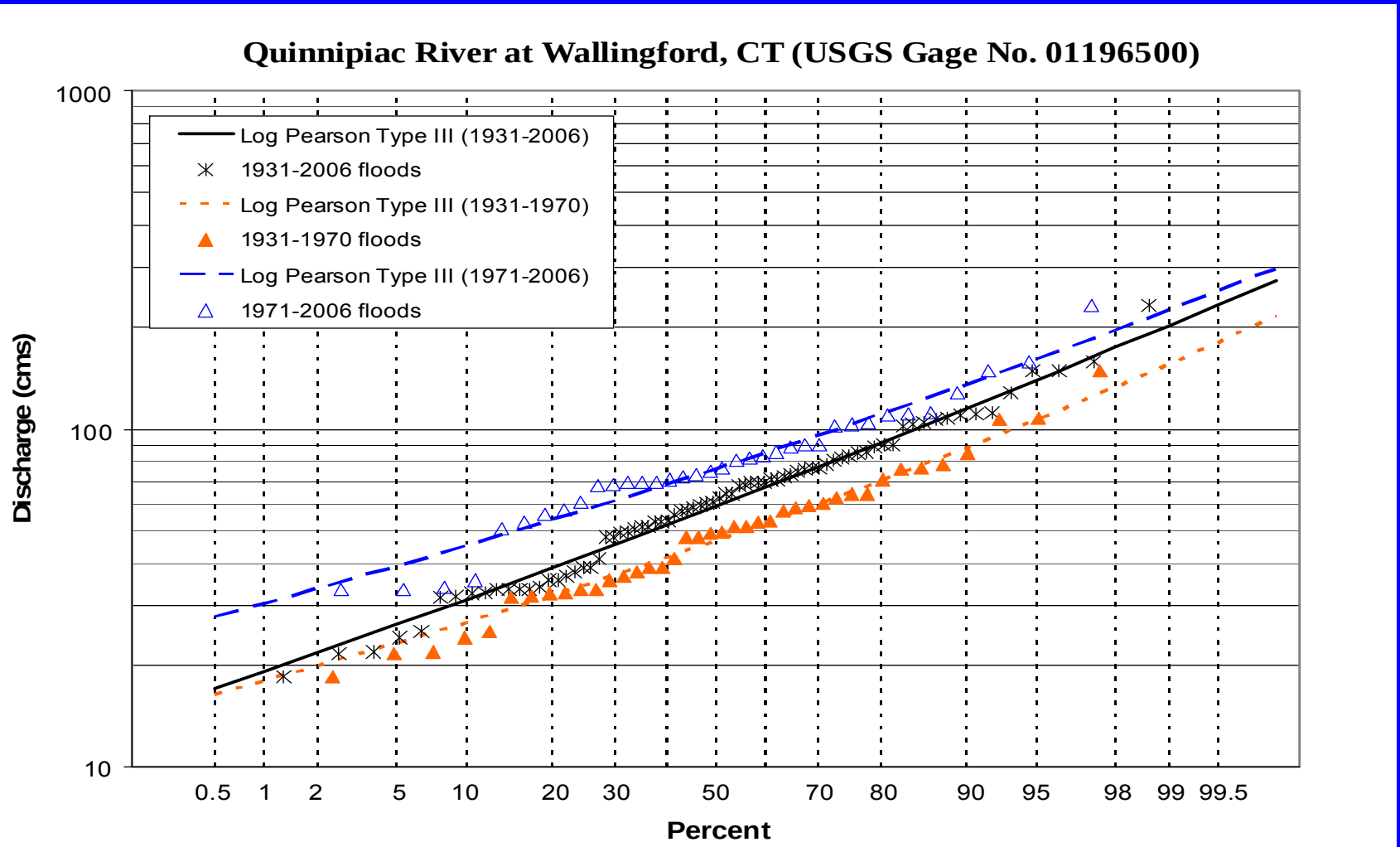
Quinnipiac River at Wallingford, CT (USGS Gage No. 01196500)

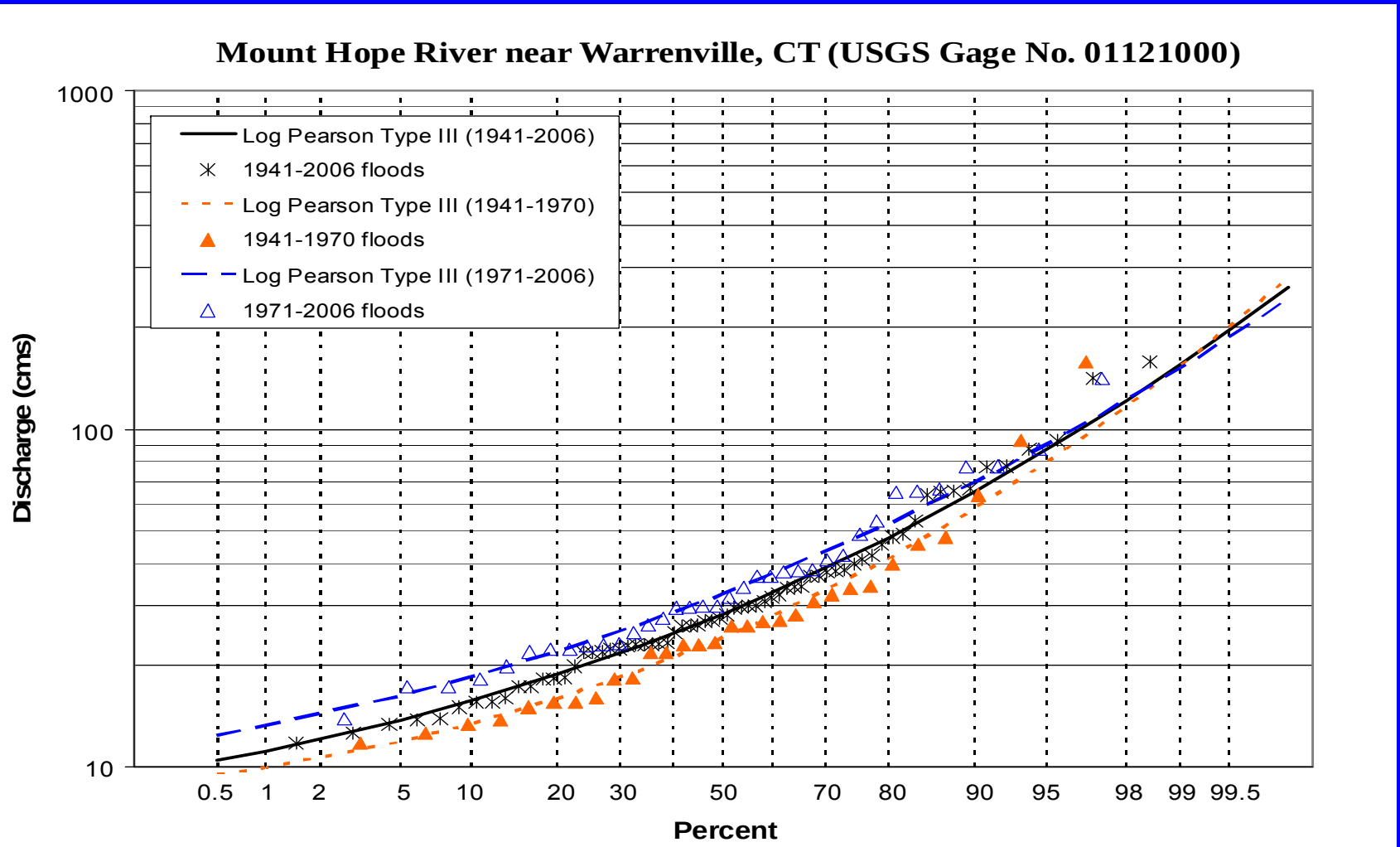


Implications for Flood Frequency Analyses

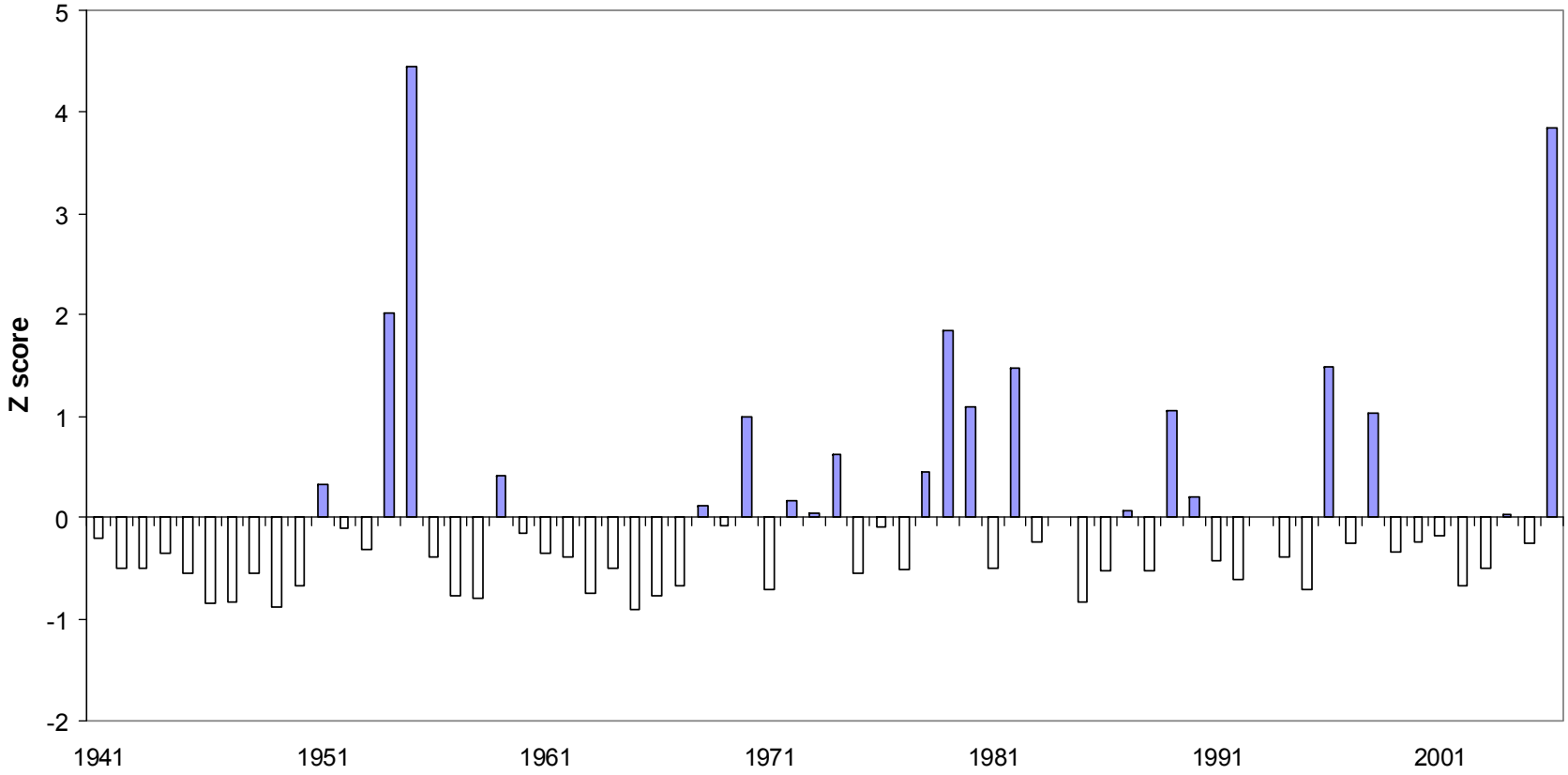
- Flood frequency statistics are valid under the assumption of non-varying climate
- If climatically distinct time periods can be identified, federal interagency guidelines (Bulletin 17B) recommend analyzing them separately


North River at Shattuckville, MA (USGS Gage No. 01169000)
Log Pearson Type III (1940-2006)
1940-2006 floods
Log Pearson Type III (1940-1970)
1940-1970 floods
Log Pearson Type III (1971-2006)
1971-2006 floods
Discharge (cms)
1000
100
10
0.5
1
2
5
10
20
30
50
70
80
90
95
98
99
99.5
Percent


Quinnipiac River at Wallingford, CT (USGS Gage No. 01196500)
Log Pearson Type III (1931-2006)
1931-2006 floods
Log Pearson Type III (1931-1970)
1931-1970 floods
Log Pearson Type III (1971-2006)
1971-2006 floods
Discharge (cms)
1000
100
10
0.5
1
2
5
10
20
30
50
70
80
90
95
98
99
99.5
Percent


Mount Hope River near Warrenville, CT (USGS Gage No. 01121000)
Log Pearson Type III (1941-2006)
1941-2006 floods
Log Pearson Type III (1941-1970)
1941-1970 floods
Log Pearson Type III (1971-2006)
1971-2006 floods
Discharge (cms)
1000
100
10
0.5
1
2
5
10
20
30
50
70
80
90
95
98
99
99.5
Percent

Mount Hope River Near Warrenville, CT (USGS Gage No. 01121000)



Summary

- Upward trends evident in many long-term NE flood records for HCDN watersheds
- Step increases around 1970
- Trends especially compelling given rural NE land cover trends over last 100 years
- NAO phase is broadly synchronous with step change in flood series, merits further research
- Step changes in flood series should be considered when calculating flood frequency estimates for NE watersheds
- High frequency events (e.g. 1.5-, 2-, 5-year) appear most sensitive to post-1970 NE hydroclimate