Quantifying Hydrologic "Flashiness"

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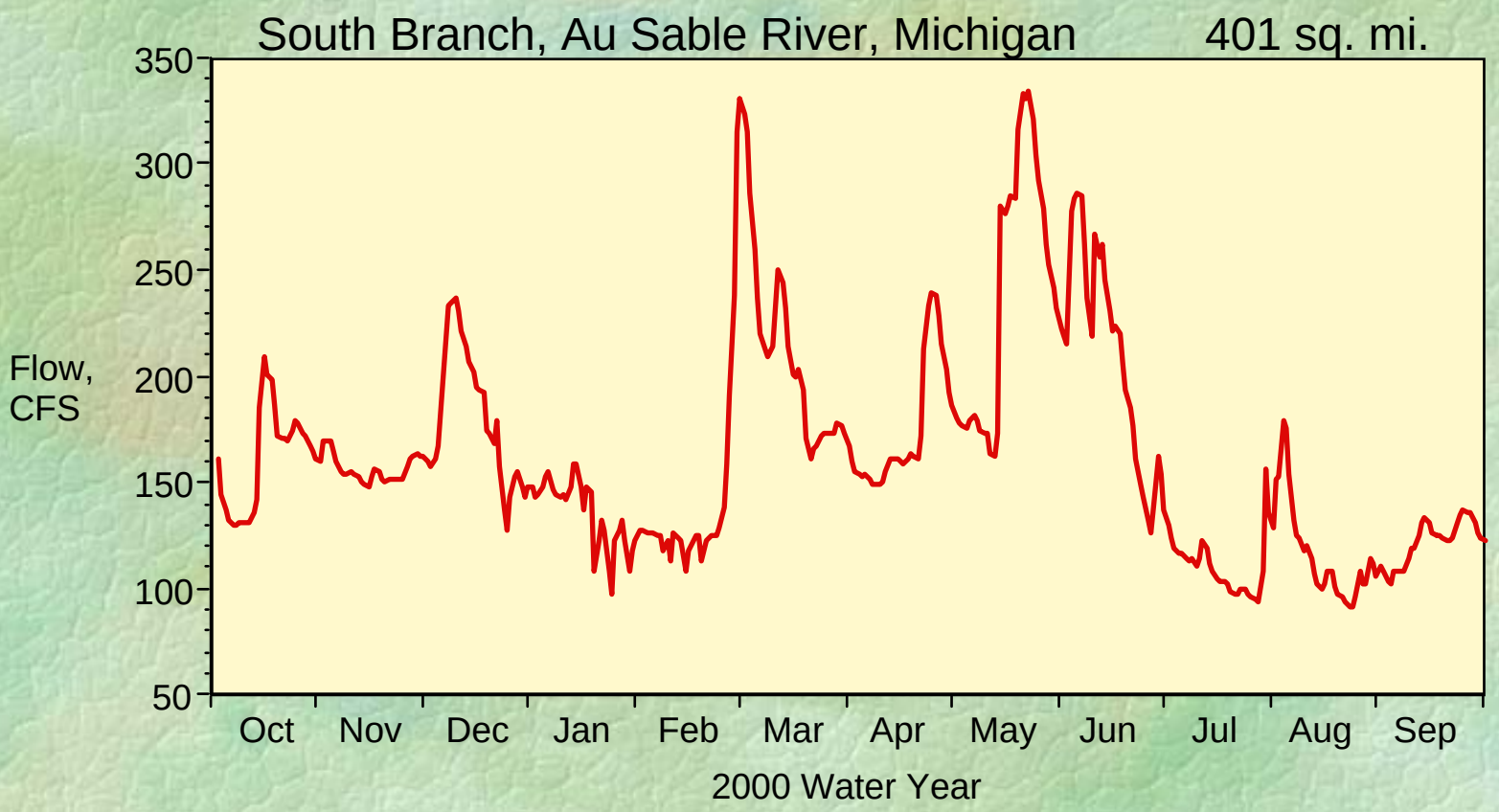
Outline

- Concepts of flow regime and flashiness, and a new flashiness index
- Regional levels and trends in flashiness in Upper Midwest, 1975-2001
- Selected applications
- Conclusions

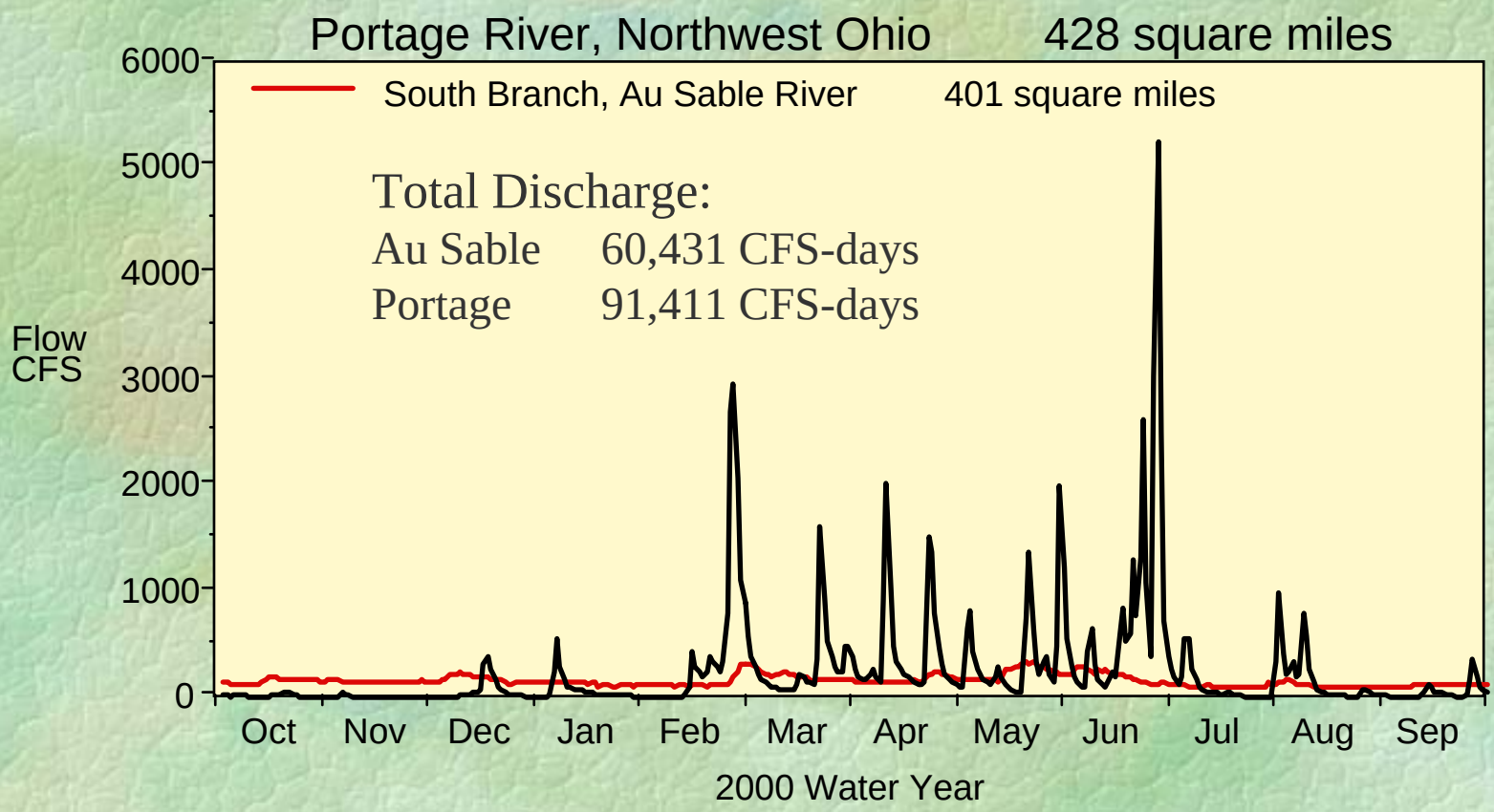
The Flow Regime and Flashiness

- The flow regime encompasses all aspects of the hydrology of a river or stream, particularly:
  - magnitude and duration and seasonal distribution of high and low flows
  - rapidity and magnitude of change in flow from hour to hour or day to day - "Flashiness"
- Departures from natural flow regime are typically detrimental to resident ecosystem
  - these typically include increased peak flows, reduced base flows, and more rapid changes in rate of flow (development)
  - or just the opposite (dams)

Flashiness Visualized



Flashiness Visualized



How does one measure flashiness?

- Most often with measures drawn from the distribution of flows:
  - Ratios of high to low flows, e.g. 20th/80th
  - Spread measures (e.g. 75th-25th)
  - Variance measures: CVLF5, CV of flows or stages
  - Skewness measures: T_{Qmean} (fraction of days with flows that exceed mean flow)

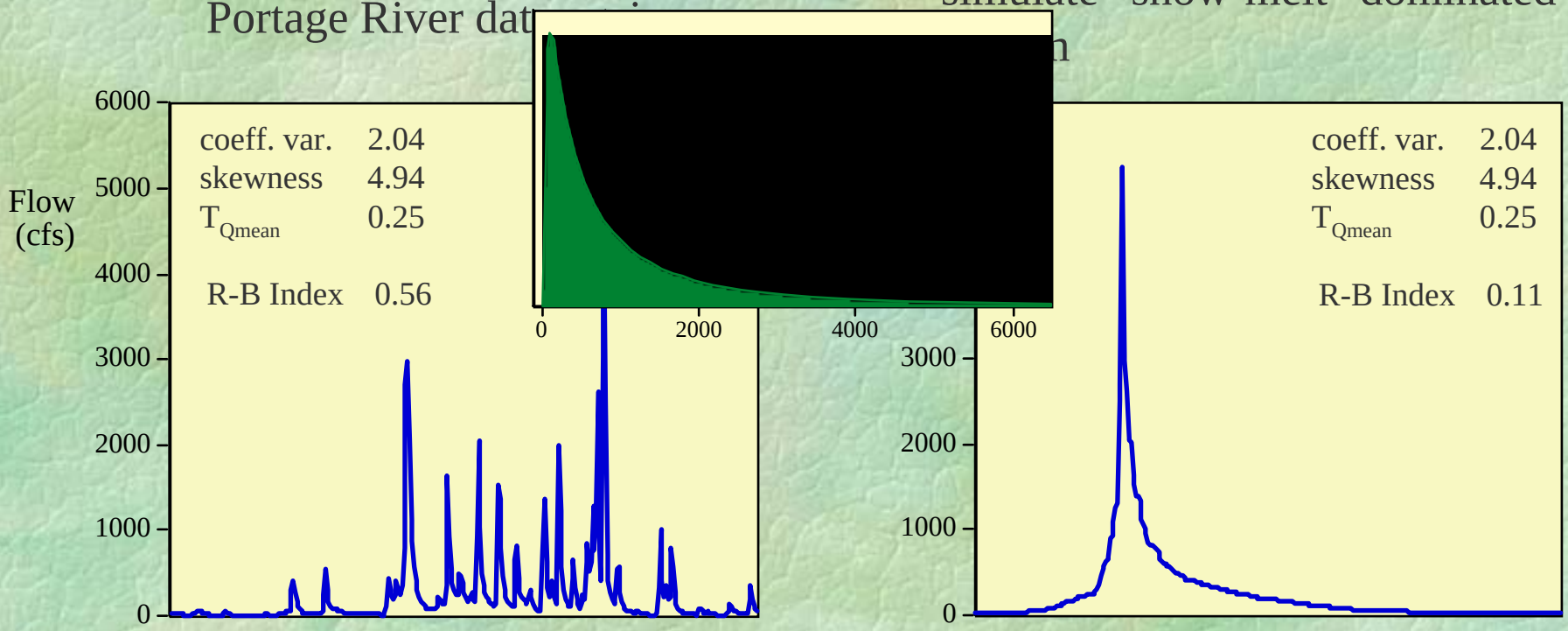
Shortcomings...

- Some of these measures may not be sensitive enough to the tails of the distribution
- They are based on the *distribution* of flows without regard for their *temporal sequence*
- They may be useful, but ultimately they're not measuring the right thing
- Flashiness is clearly tied up with *temporal sequence* of flows

Shortcomings...

Same daily flow data re-arranged to simulate “snow-melt” dominated

Portage River dat



Other measures that reflect flashiness

- Richter's 33 Indicators of Hydrologic Alteration
  - *n*-day minimum or maximum flow
  - base flow, number of pulses of high or low flow
  - rise rate, fall rate, number of reversals in flow
- Not directly designed to measure flashiness
- Because most use only part of the annual flow data, values are rather variable from year to year, and thus less sensitive to subtle change over time or space than a measure that uses all the data

Flashiness measured by pathlength

- Richards-Baker Pathlength (aka R-B Index)

$$R-B\ \ Index = \frac{\sum_{t=1}^{n} |q_{t-1} - q_t|}{\sum_{t=1}^{n} q_t}$$

  - Sum of the absolute values of the day-to-day changes in mean daily flows.
  - Normalize for flow by dividing by the total flow

Some Properties:

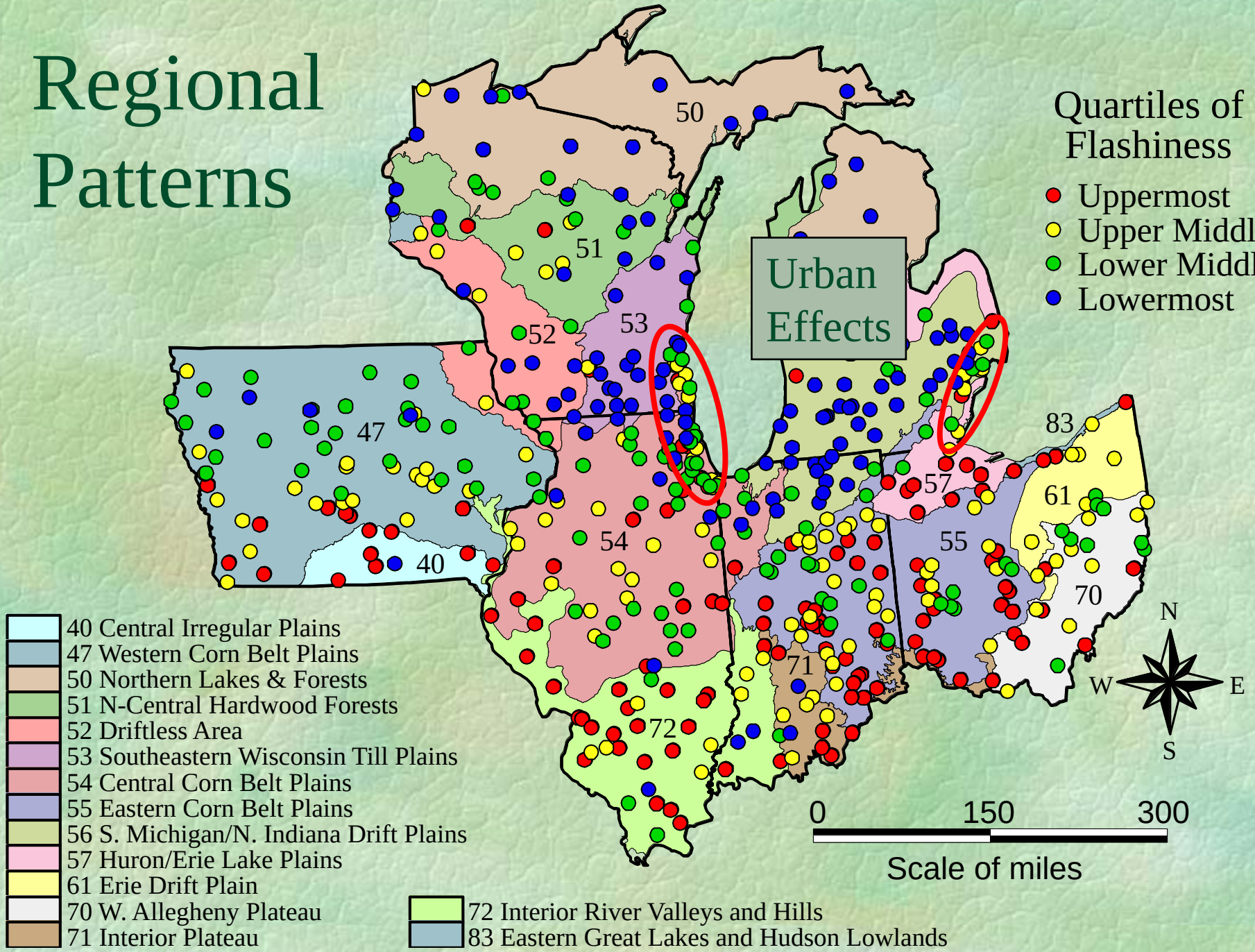
- Low year-to-year variability, therefore sensitive to sustained trends
- Integrates entire range of hydrological response, but primarily affected by high flow

Regional patterns and trends

Regional patterns and trends

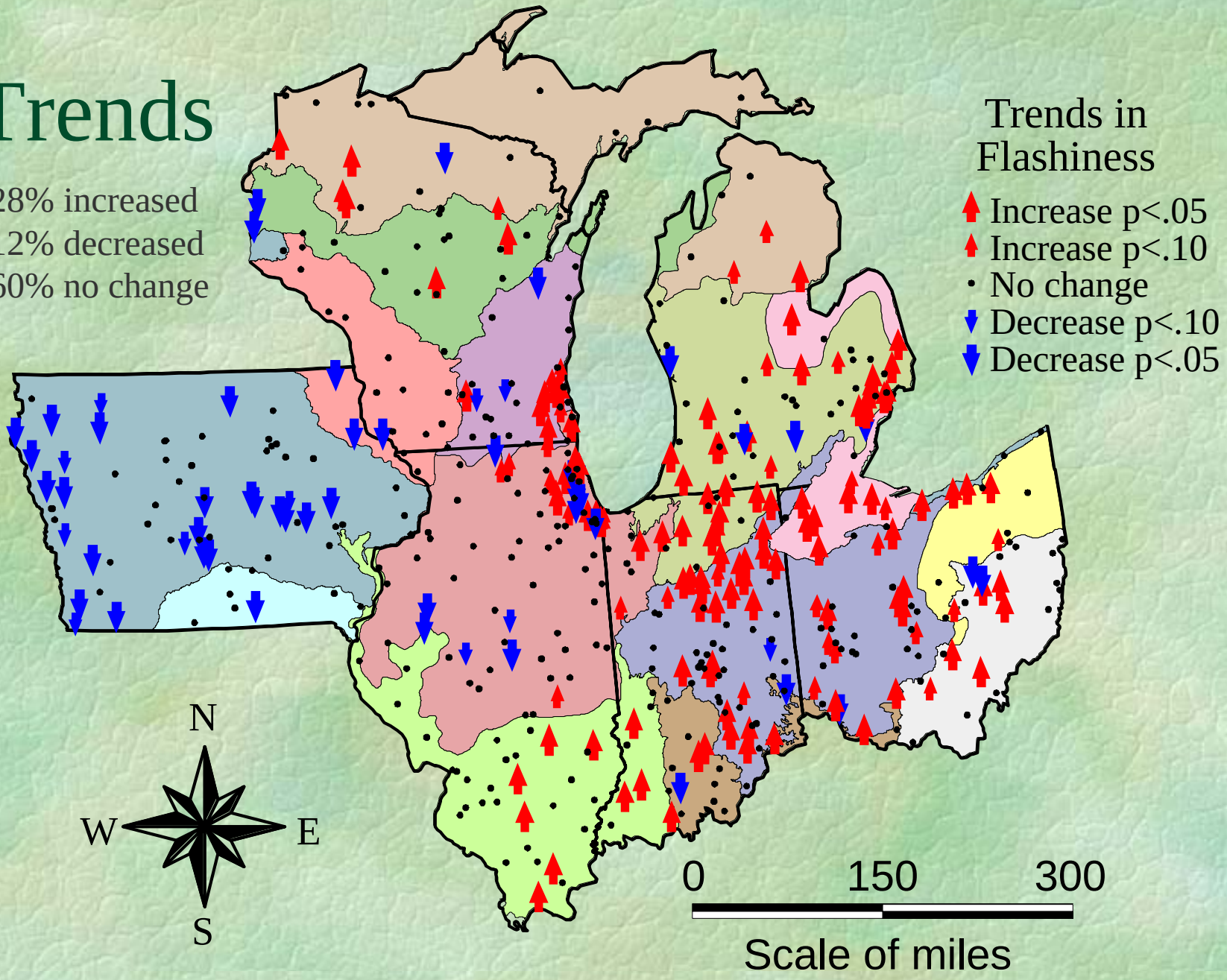
- Based on USGS mean daily flow data for 510 gages in upper Midwest: OH, IN, IL, IA, WI, MI.
- All had data that spanned 1975-2001
- We calculated annual R-B Indices for each year and gage (~14,000 index values)
- We visualized trends using LOWESS curves and assesed trend significance using linear regression analysis.

Regional Patterns



Trends

- 28% increased
- 12% decreased
- 60% no change



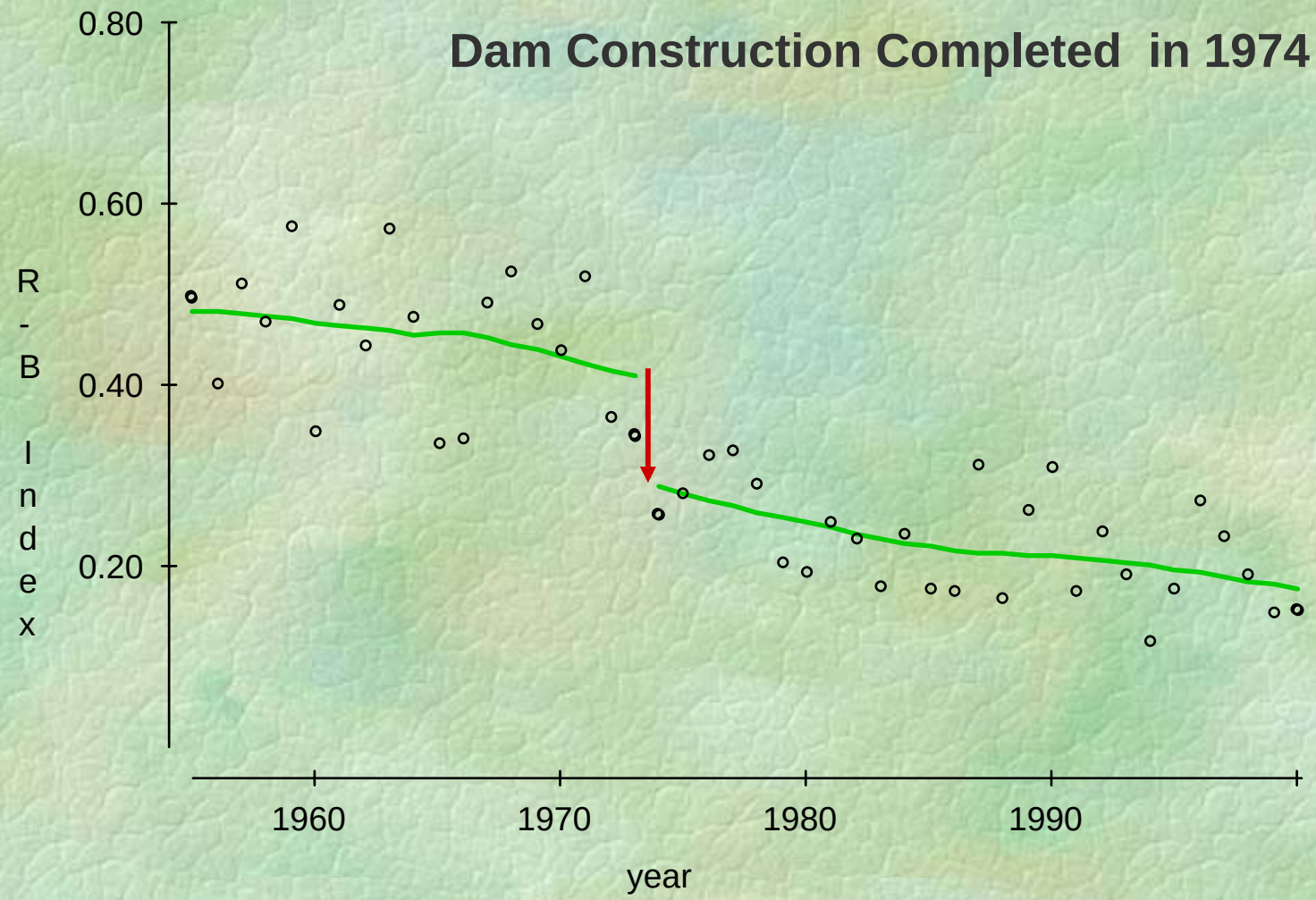
Hypotheses to explain trends:

- Urbanization leads to increased flashiness
  - Anybody surprised?!
- Rural trends in flashiness refect complex interactions between changing climate (especially storm intensity), soil types, and agricultural management practices (conservation tillage, especially soybeans)

Some Specific Applications

Dam Construction:

East Fork Whitewater River, IN USGS 03276000



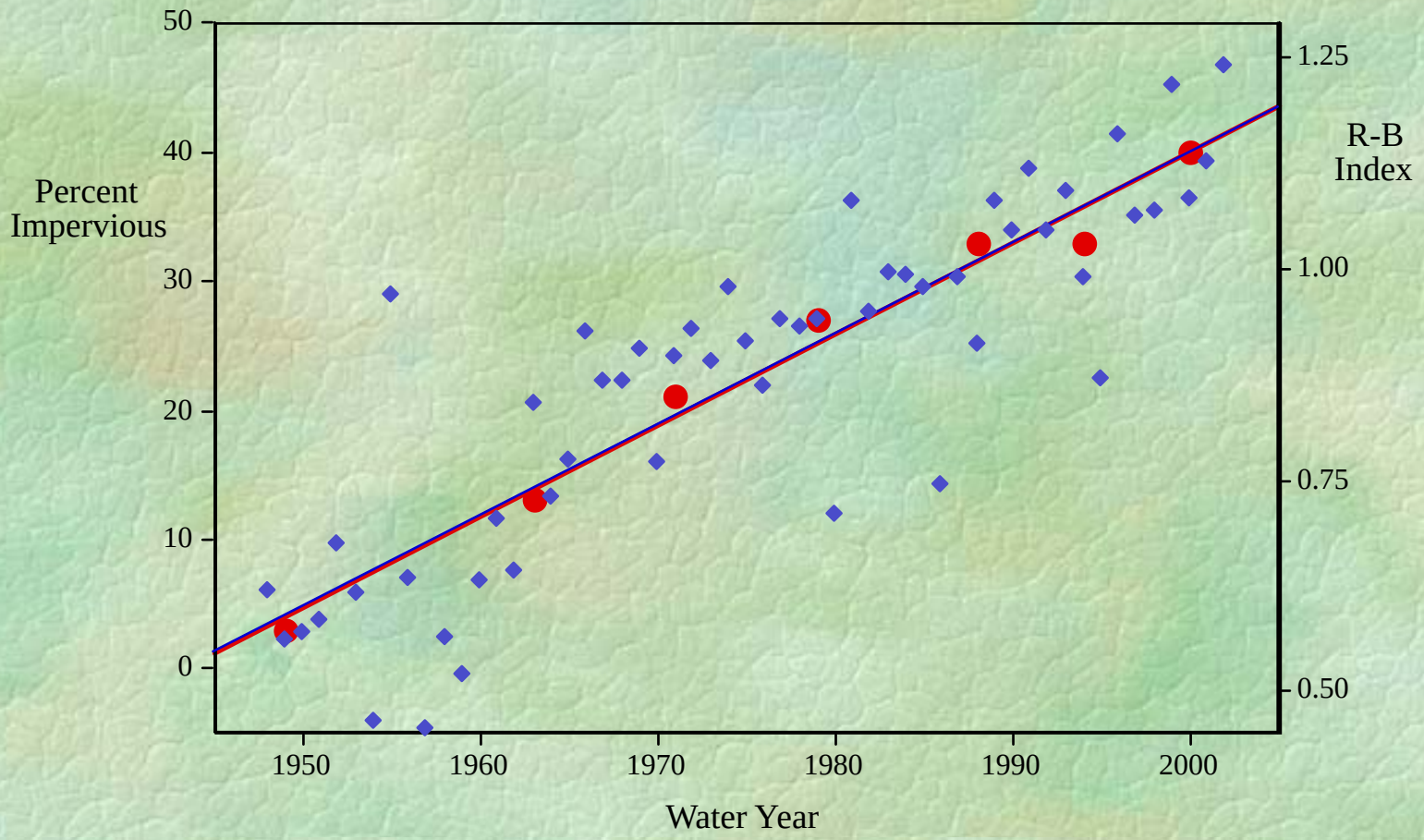
Dam Removal:

- Would expect flashiness to increase
- Not apparent in several examples we've studied
- Usually fairly recent; post-removal history too short
- Usually run-of-river dams, silted up, so hydrology is not too different from undammed condition.

Urbanization:

Accotink Creek, Fairfax Co, Virginia, USGS 01654000

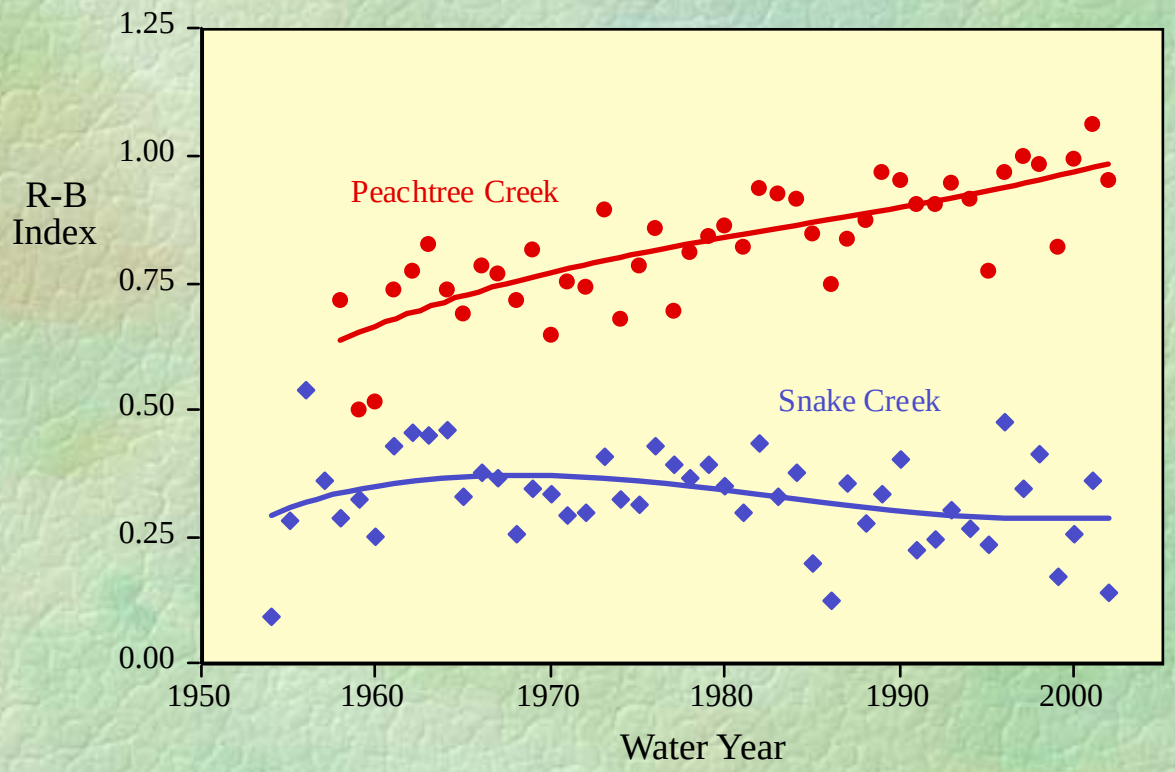
(Thanks to Taylor Jarnagin, EPA-ORD, for % impervious cover data)



Urbanization:

Peachtree Creek, Atlanta, GA USGS 02336300
Snake Creek, GA piedmont USGS 02337500 (Control)

(Thanks to Betsy Frick, USGS Atlanta for suggesting this dataset)

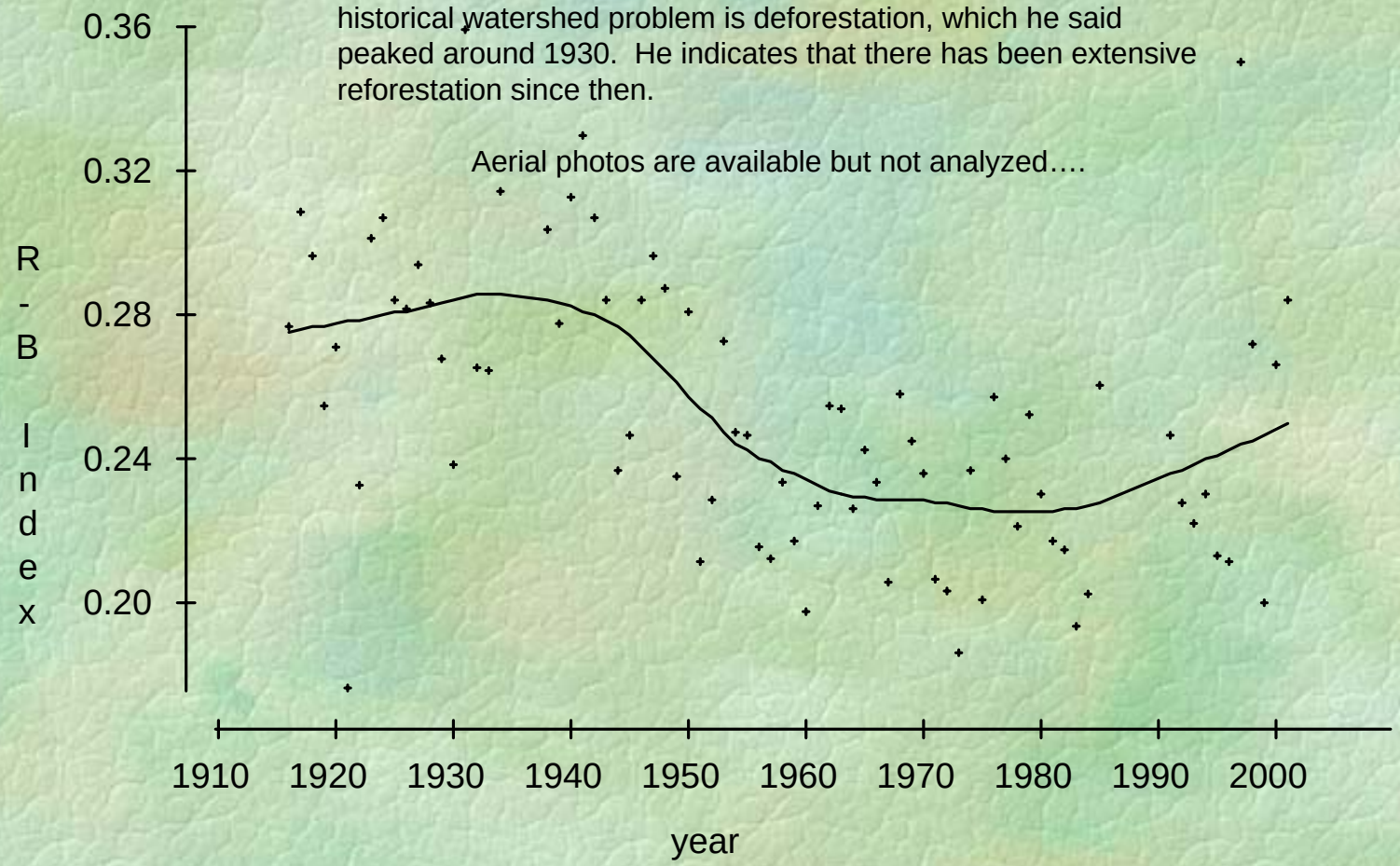


Reforestation:

Raccoon Creek, Southeast OH USGS 3202000

Brett Laverty, watershed coordinator, indicates that the major historical watershed problem is deforestation, which he said peaked around 1930. He indicates that there has been extensive reforestation since then.

Aerial photos are available but not analyzed….



Conclusions

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- The R-B Index is a sensitive measure of spatial and temporal variation in flashiness
- Flashiness shows non-random patterns of spatial variation regionally in the Upper Midwest
- Trends in flashiness in the Upper Midwest show spatially coherent patterns, but are not easily explained
- Quantified land use history is rare
- When land use history is available, the R-B Index often documents the expected changes in flashiness
- There are surprises as well…we can learn from them