Effects of land use and precipitation patterns on streamflow flashiness trends in the northeast USA

Wayne Ndlovu[1], Christa Kelleher[2], Jeff Wade[3], JP Gannon[4], Margaret Zimmer[5]

[1]Department of Geosciences, Smith College, Northampton, MA 01063
[2]Department of Earth Sciences and Civil Engineering, Syracuse University, Syracuse, NY, 13244
[3]Department of Earth Sciences, Syracuse University, Syracuse, NY, 13244
[4]Department of Forest Resources and Environmental Conservation, Virginia Tech, Blacksburg, VA, 24141
[5]Department of Earth and Planetary Science, University of California, Santa Cruz, CA, 95064

Motivation

Examining long term trends in streamflow signatures is useful for understanding how changes in land use and precipitation patterns impact streamflow regimes. One particular metric of streamflow regimes that encapsulates flow variations is the Richards-Baker flashiness index. High flashiness is commonly associated with imperviousness, agricultural land management, water management and dam removal, and other human activities. Therefore, examining trends in this signature may provide a lens to examine how streamflow regimes in both flashy and stable watersheds are responding to human activity. In this study, we evaluate the effects of human activities and precipitation pattern changes on streamflow flashiness for 304 watersheds across the northeastern US.

What is stream flashiness?

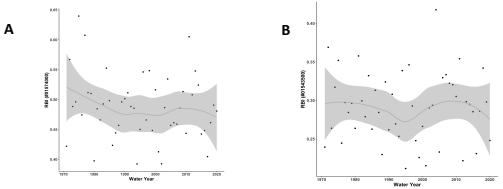
Stream flashiness is the rapidity and frequency of short term changes in the streamflow especially during runoff events.

We quantified flashiness using the Richards-Baker Flashiness Index (RBI) (Baker et al., 2004), calculated as the ratio between the sum of daily changes in discharge and sum of da

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

Detecting trends in stream flashiness

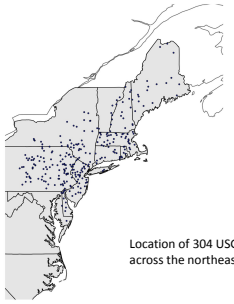
We computed trends using (method) for the period of 1970 to 2020. Below are two examples showing how RBI varies through time. RBI tends to decrease at **A** but is almost constant at **B** with some drops between 1985 and 2005.



Time series of RBI for the period of 1970 – 2020 for sites **A** West Conewago Creek near Manchester, PA and **B** Sinnemahoning Creek at Sinnemahoning, PA

Study Area

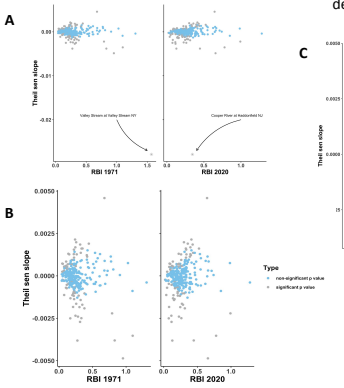
We quantified trends in annual Richards-Baker Flashiness Indices for the period of 1970 - 2020 using publicly available streamflow estimates from the USGS



Location of 304 USGS watersheds across the northeastern USA

Do we observe trends in flashiness across the Northeastern US?

Flashiness both increases and decreases across all sites

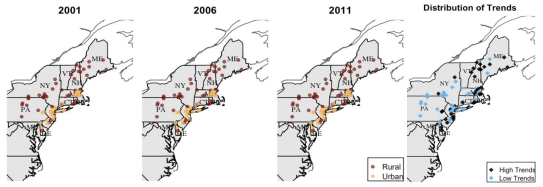


A: There are slight increases in RBI values between 1971 and 2020, with two strong negative outliers.

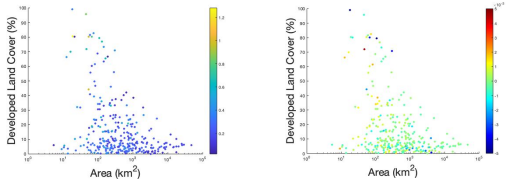
B: Shows the same relationship as **A** after removing an outlier.)

C: For sites with significant p.values, flashiness is both increasing and decreasing. Most negative trends are associated with larger watersheds whilst positive trends are associated with small to moderately sized watersheds.

Effects of changes in imperviousness on watershed flashiness

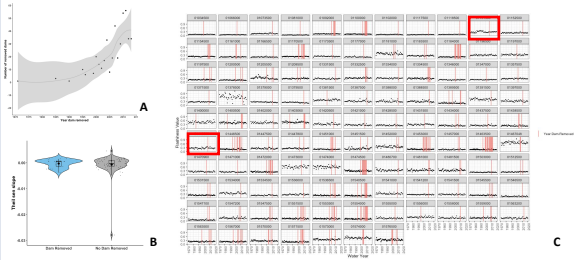


The number of urban and rural watersheds has remained constant from 2001 to 2011. Watersheds located in urban areas and high snowfall states (Maine and Vermont) have high flashiness indices.



Most watersheds with high developed land cover percentages tend to have higher RBI values (**left**) and larger positive and negative trend values (**right**)

Effects of dam removals on watershed flashiness



A: There is an increase in dam removals between 1985 and 2015
B: Overall, there are no differences in trends between sites with dam removals and those without dam removals
C: Only two watersheds (red boxes) had major changes in flashiness after a dam was removed. We failed to observe any changes at the remaining sites and this could be due to (1) some dams being much further from the gaging station, (2) dam size being unaccounted for (3) the presence of a larger dam close to the gaging station which could conceal any changes after dam removal.