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Flood trends in the Northeast—it's not just about event rainfall

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Overview

- Summary of national peak-flow trends and change points
- Attribution of historical peak-flow trends in the Northeast
- Why are trends in historical heavy precipitation different than trends in flood flows?
- What will the future bring?

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Historical flood trends

- Most flood-trend studies are based on annual peak flows or peaks over a threshold
  - Tend to be mostly minor floods, with some moderate floods, and a few major floods

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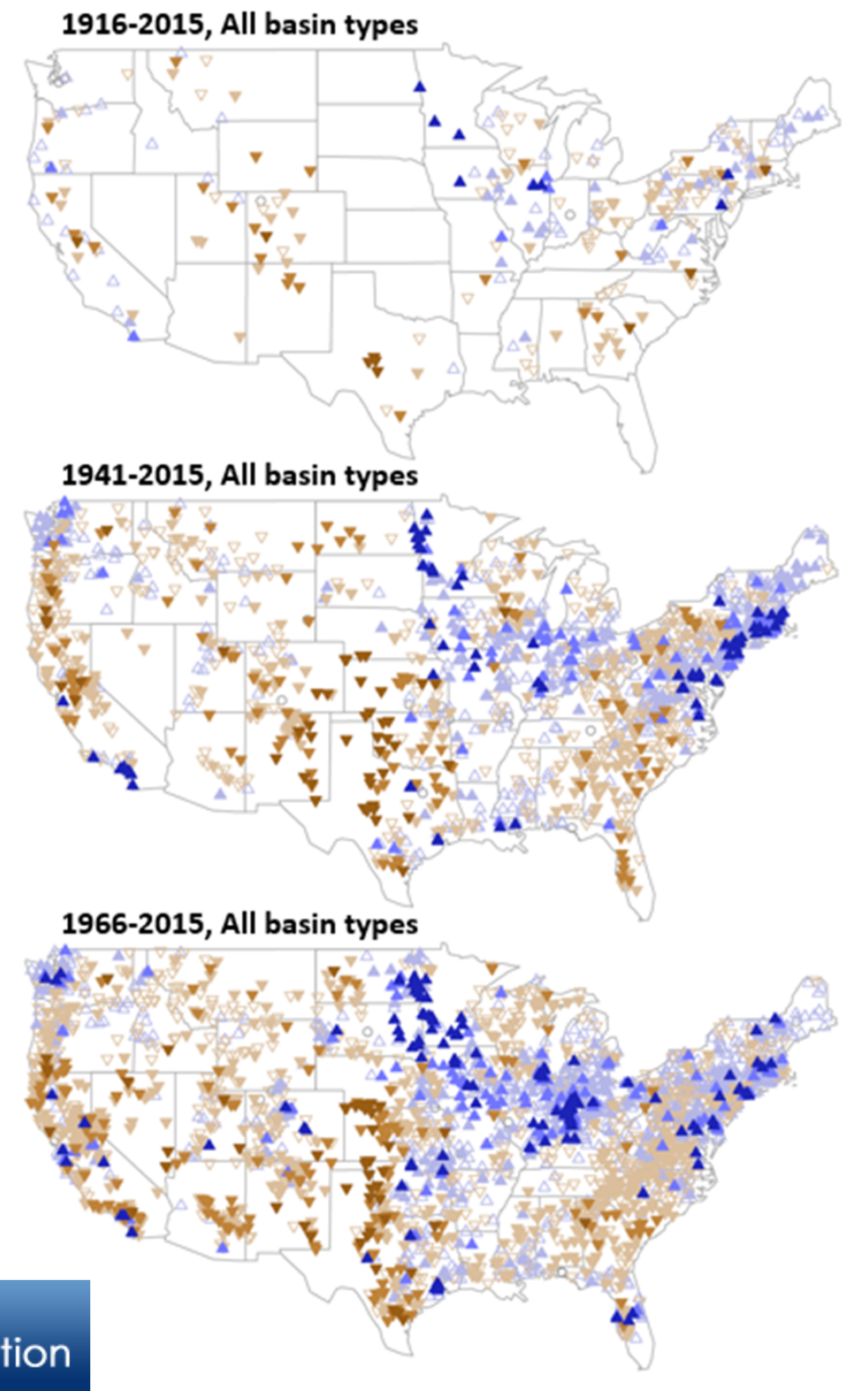
Annual peak-flow trends

- Magnitude of trends for 3 different time periods
- All basin types
- Regions with increases and decreases



Blue triangles, increases
Brown triangles, decreases

Open symbols, < 25%
Light solid, increases 25-50%
Medium solid, 50-75%
Dark solid, > 75%

Hodgkins et al., 2019

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U.S. Department of Transportation Federal Highway Administration

Annual peak-flow trends

- Magnitude of 50-year trends
- 3 different basin types
- Basin type important for trends
  - Relatively natural sites: not a lot of consistent trends
  - Regulated sites (high reservoir storage, minimal urban): many decreases
  - Urban sites (minimal regulation): mostly large increases

Hodgkins et al., 2019

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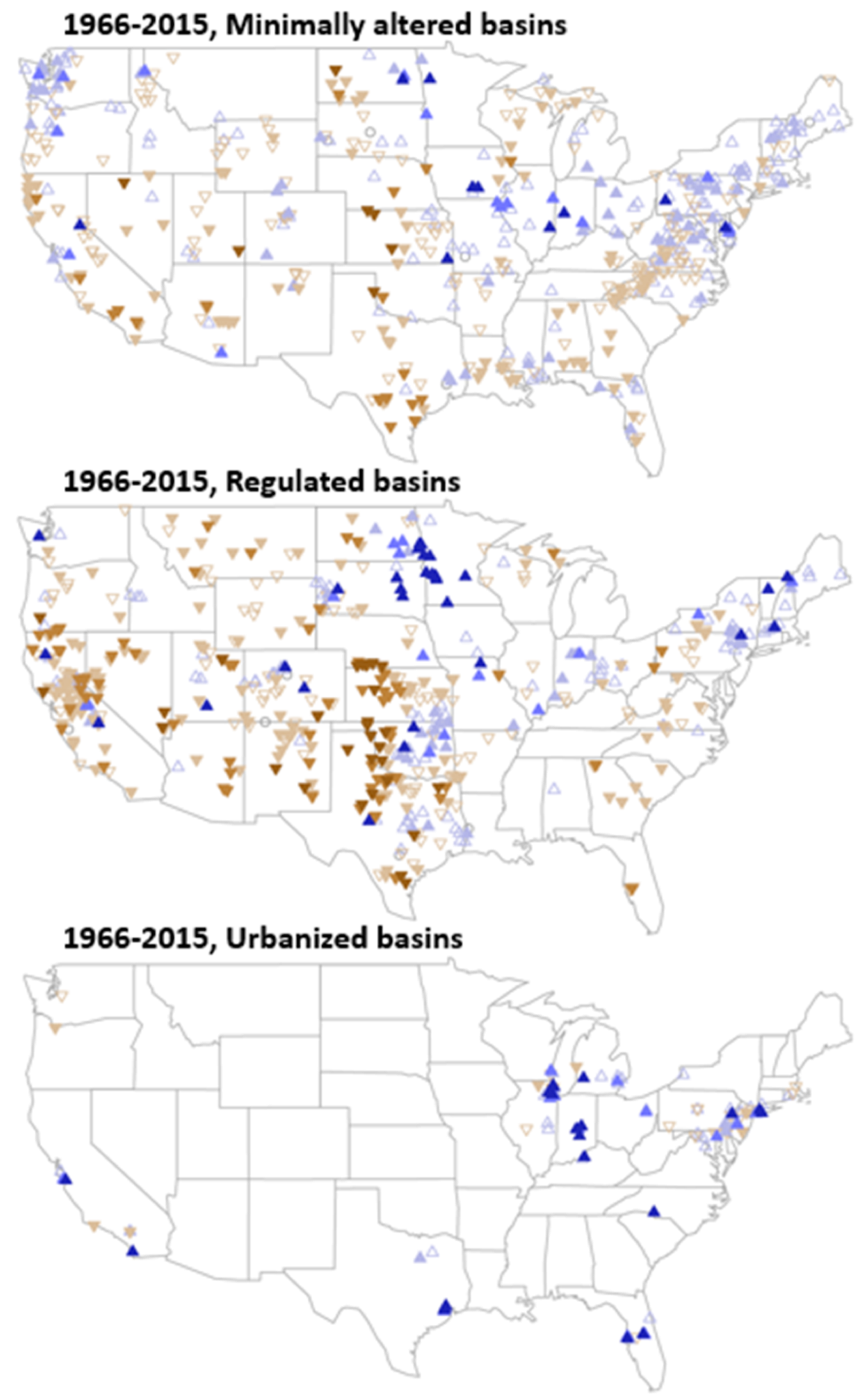

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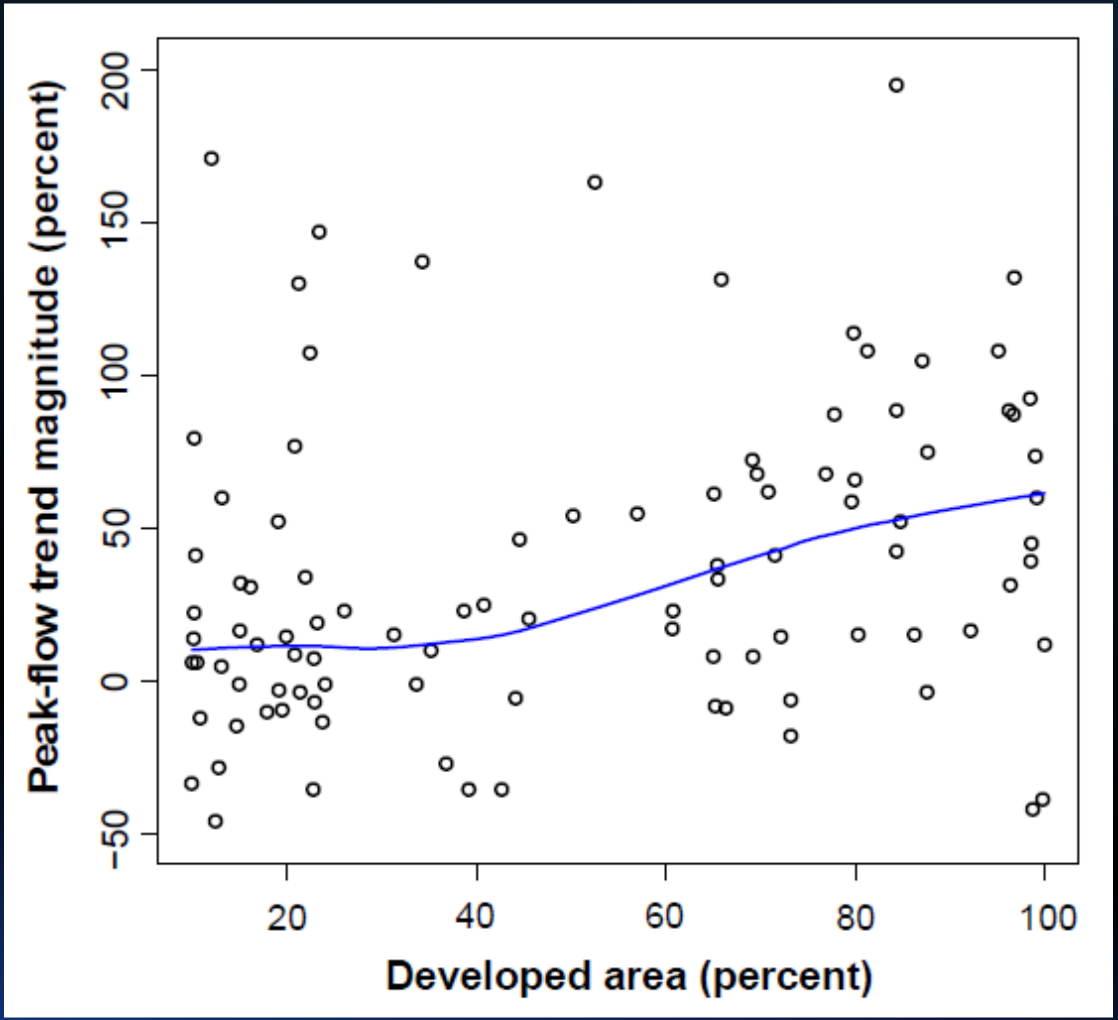
Impacts of urbanization

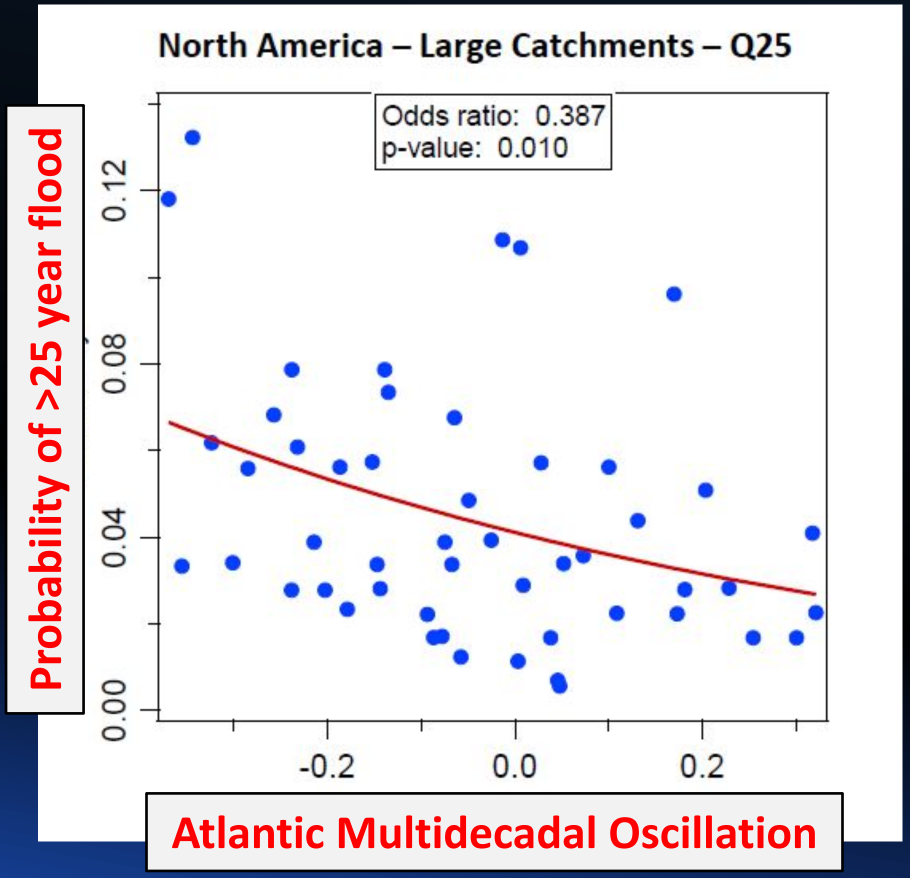
- Magnitude of trends vs. developed area
  - 1966-2015
- Basins with high amounts of developed area have larger increases, on average

Hodgkins et al., 2019



Historical changes in the annual number of major floods in North America and Europe

- 1204 minimally disturbed basins in N. America and Europe
- Grouped basins for analysis
- No compelling evidence for consistent changes over time in major-flood occurrence (25-100 year floods) during the last 80 years
- Found multiple significant relations with the Atlantic Multidecadal Oscillation



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Hodgkins et al., 2017

Attribution of trends and change points in the Northeast

- Statistical attribution of all significant annual peak-flow trends and change points for 50 and 75 year periods
- Focus
  - Short-term precipitation
    - Storm-event precipitation related to all annual peak flows
  - Long-term precipitation
    - Using a measure of antecedent basin moisture (Palmer Drought Severity Index (PDSI))
  - Presence of urban land cover and/or regulation (large impoundments)

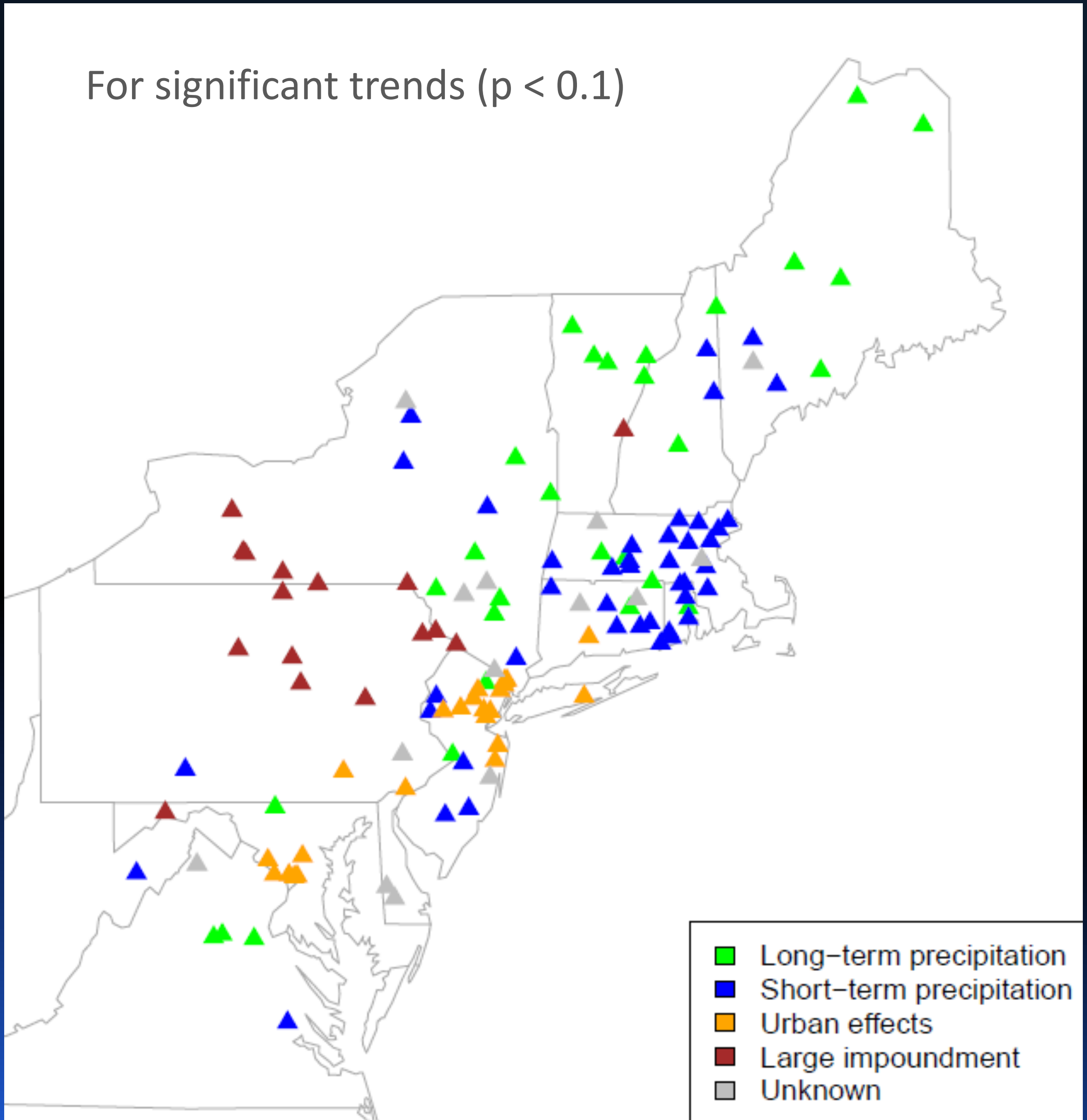
Attribution data

- Daily precipitation data from sites near each gage (Global Historical Climatology Network)
  - Precipitation from day of storm and 3 days prior
- Monthly Palmer Drought Severity Index (PDSI) values for climate division containing gages
- Basin-specific land-use and reservoir information

Attribution methods

- Significant year-to-year correlation
  - Peak magnitude vs. precipitation or PDSI magnitude
- Significant changes in same direction as peak changes
- Urban effects:
  - Basins > 25% developed
  - Peak changes increased substantially more than storm-event precipitation
- Large impoundments:
  - Basins contain large impoundments
  - Peak flow trends much smaller than precipitation changes (including peak decreases with precipitation increases)

Primary attributions
75-year peak-flow trends



Provisional: subject to revision

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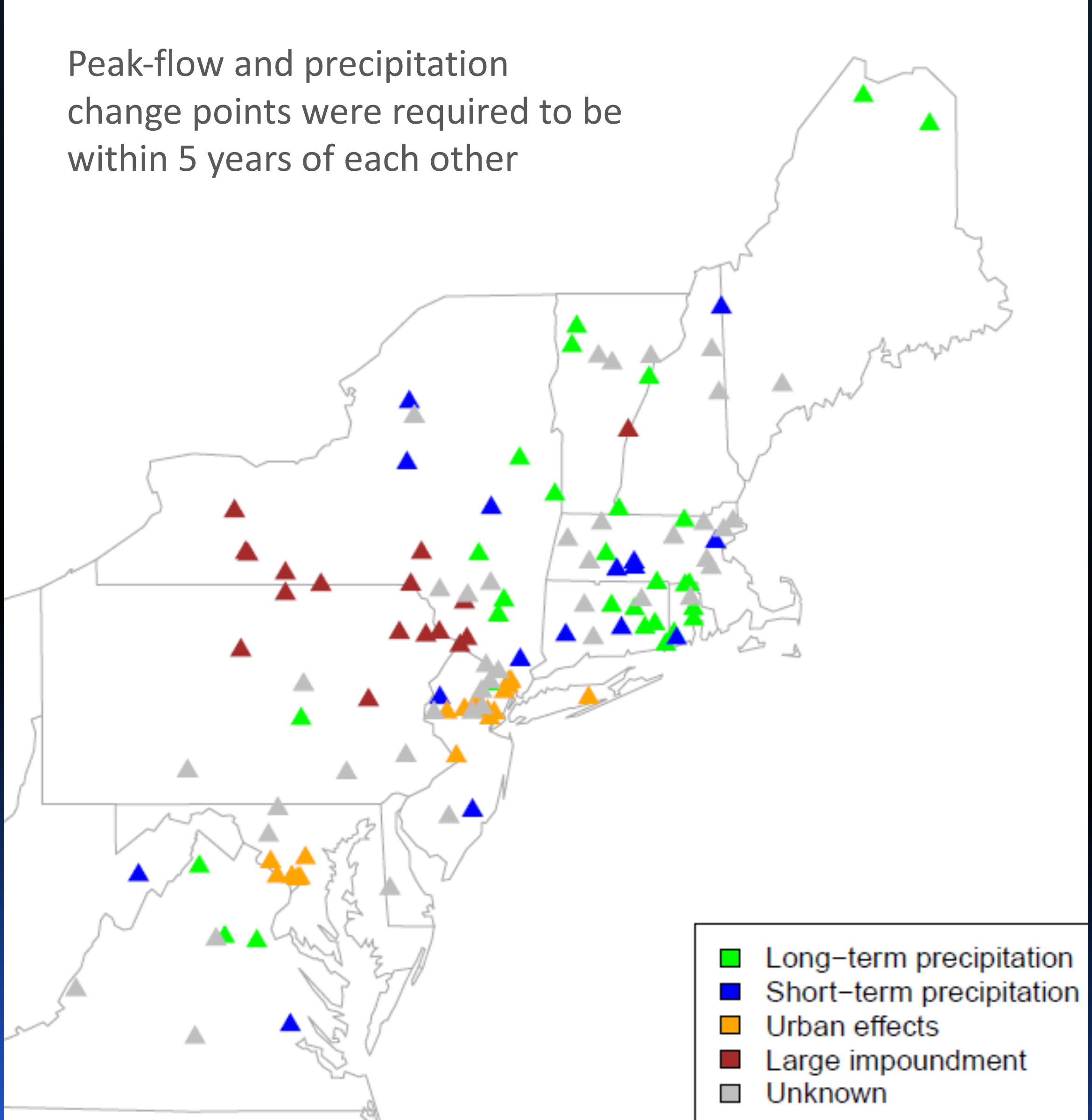
Primary attributions
75-year peak-flow change points



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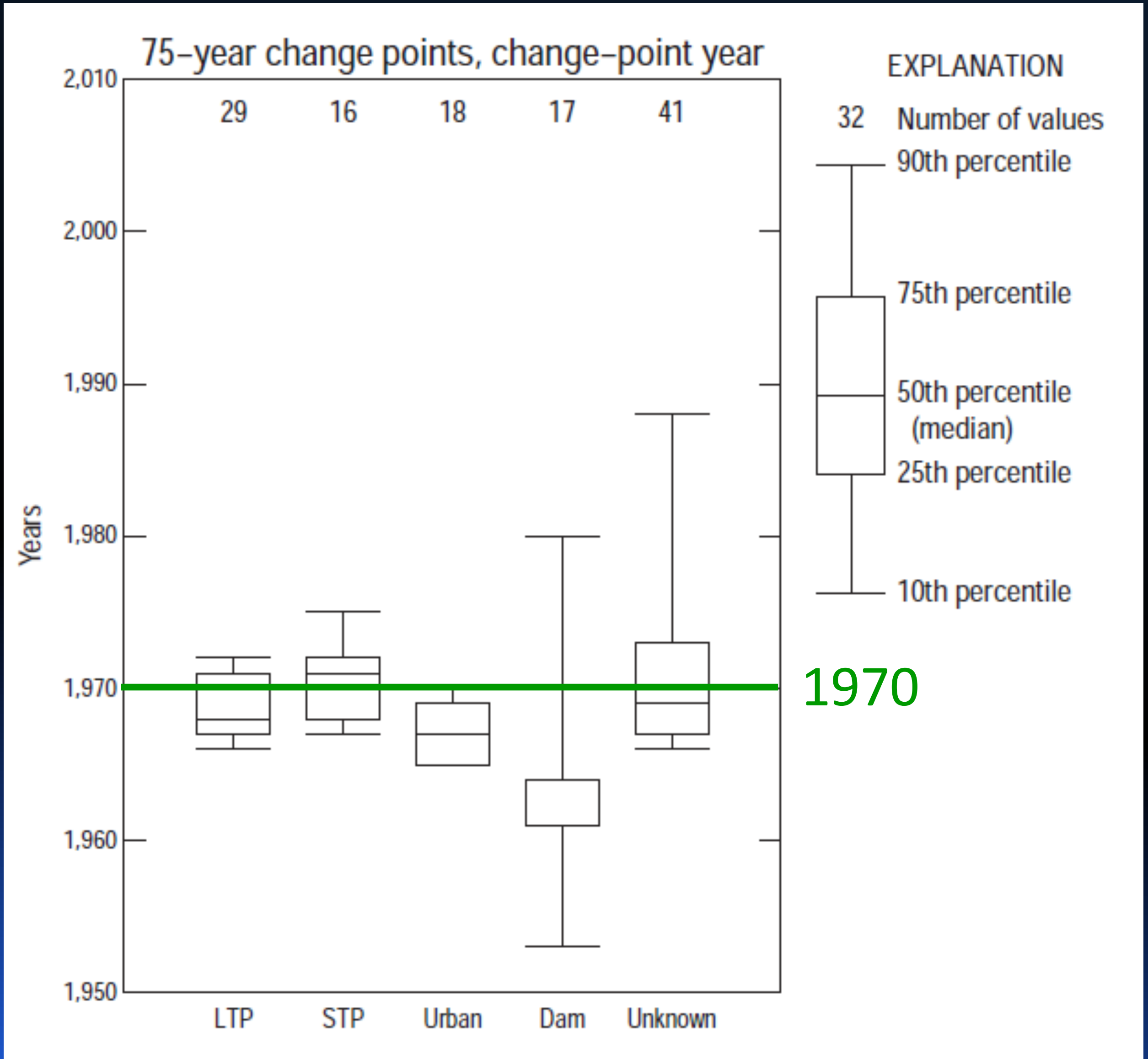
Primary attributions, *year* of 75-year change points



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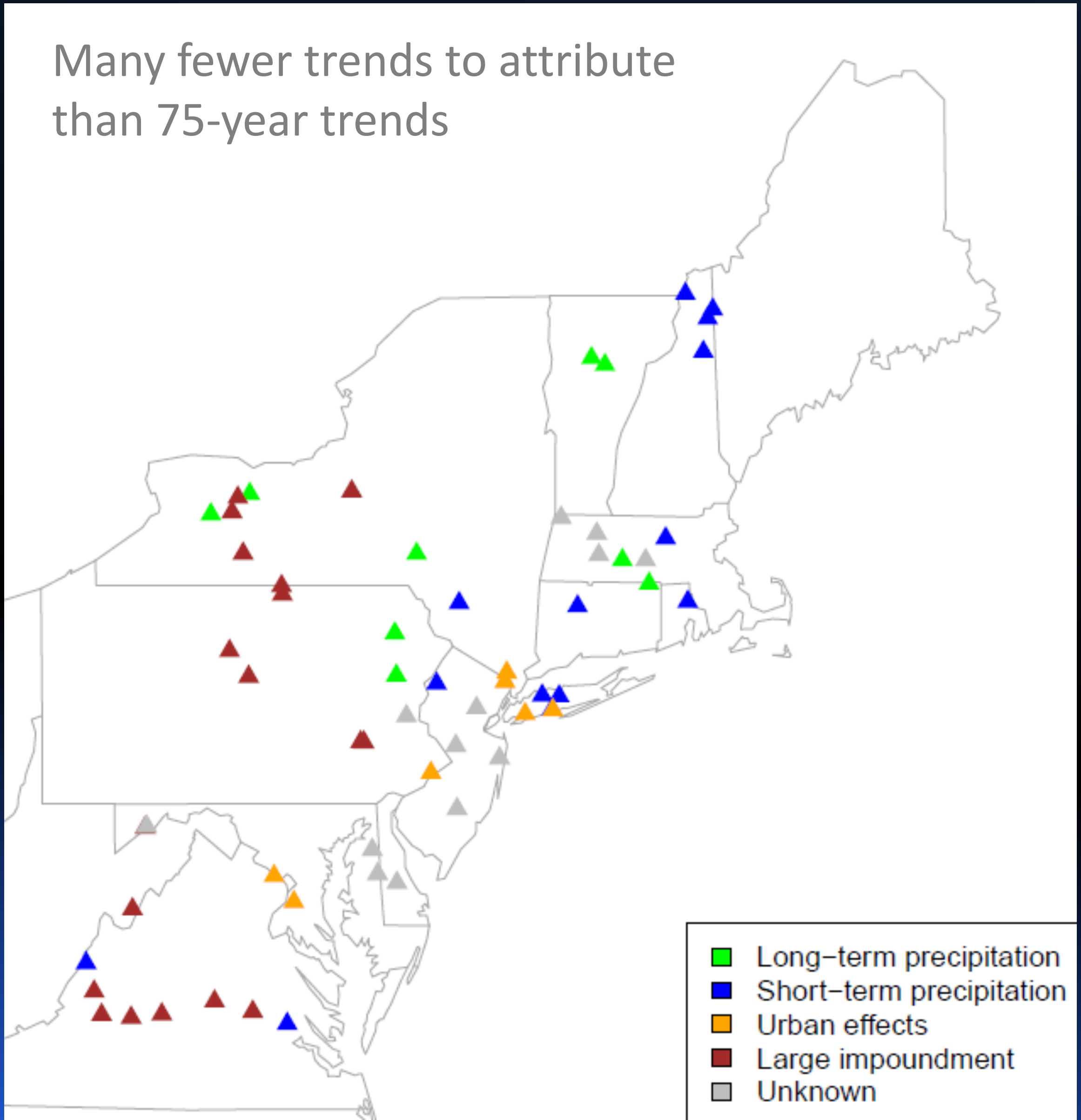
Historical peak-flow change points

- Change points near 1970 consistent with previous studies for the Northeast (Collins, 2009; Armstrong et al., 2014)
  - Relation with North Atlantic Oscillation
- Peak-flow change points different than 1996 extreme-precipitation change point from Jonathan Winter's 9/10/19 presentation

Primary attributions
50-year peak-flow trends



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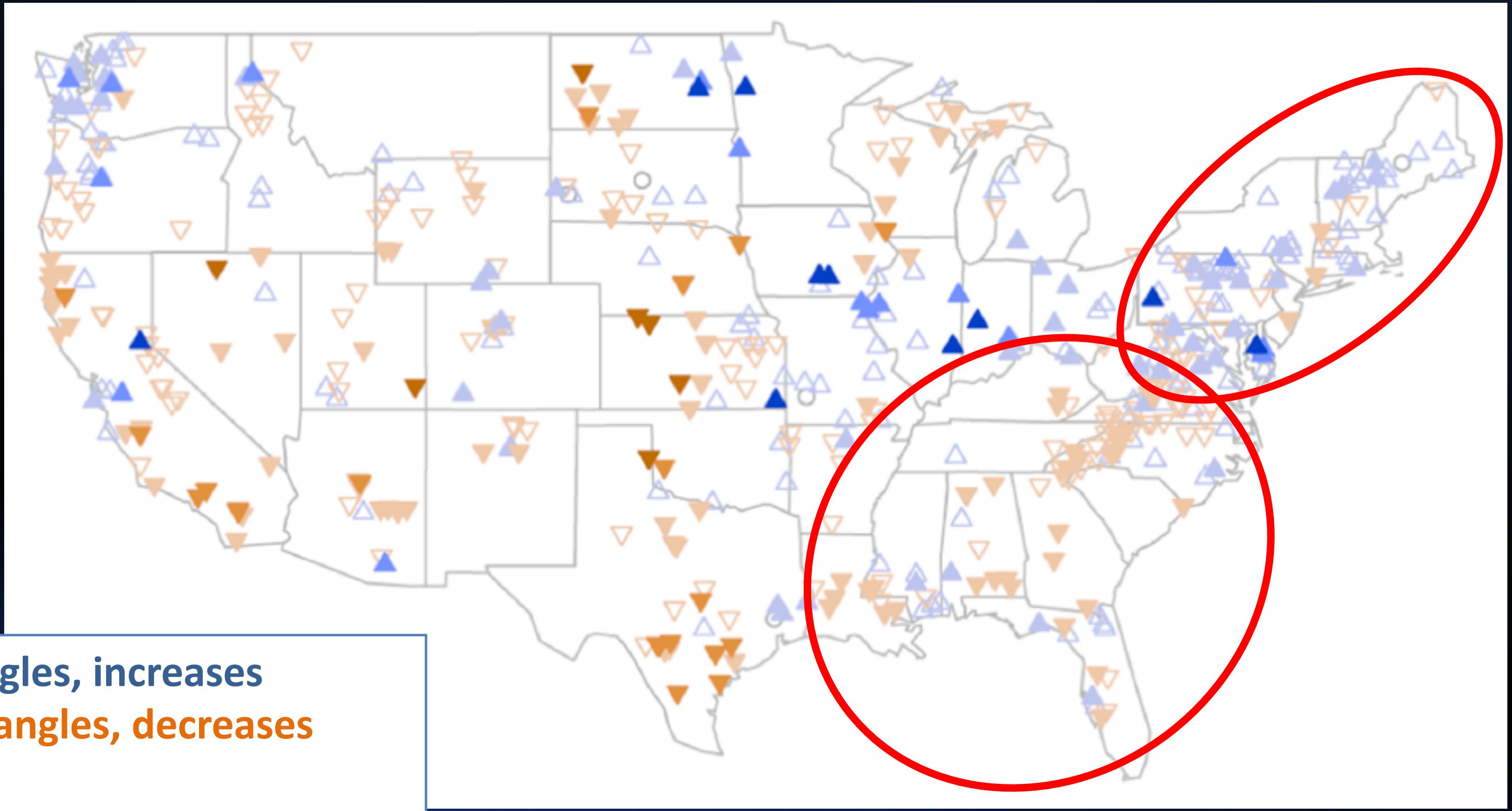
Peak flow trends vs. heavy precipitation trends

Magnitude of peak-flow trends
1966-2015, minimally altered basins



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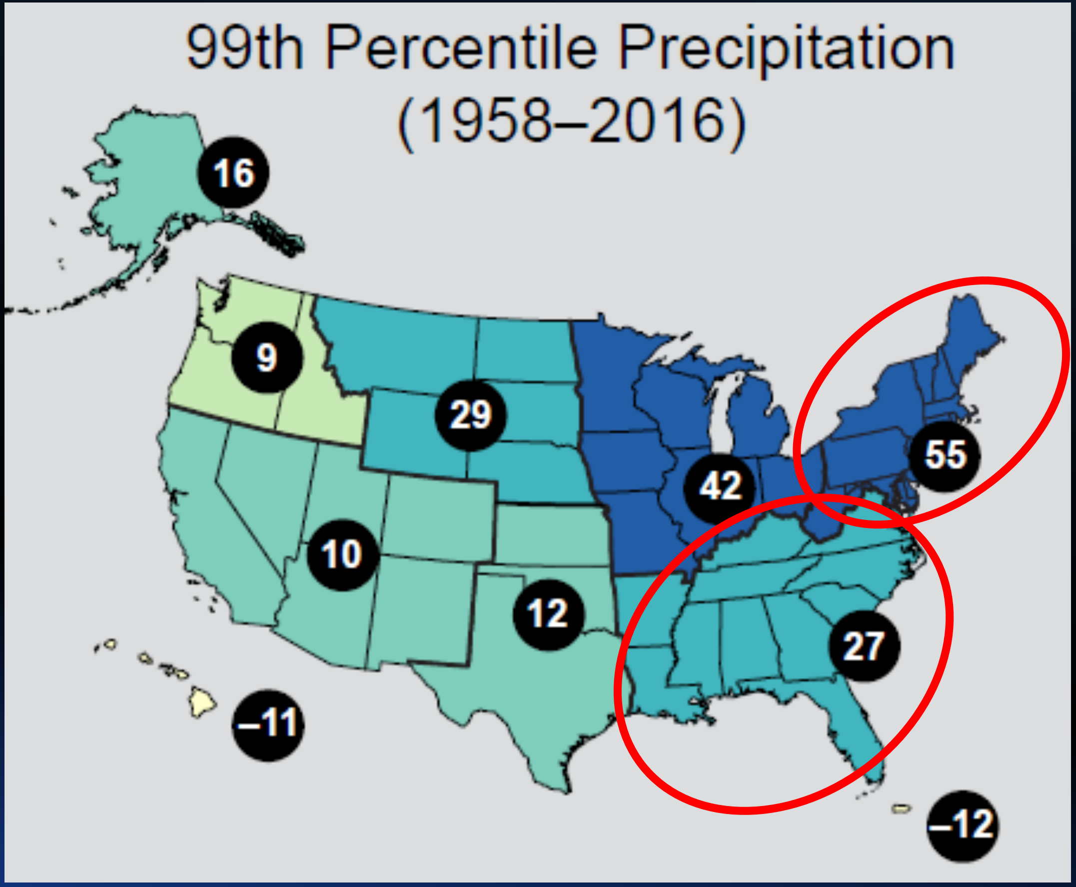
Hodgkins et al., 2019

Peak flow trends vs. heavy precipitation trends

Historical heavy precipitation trends



Easterling et al., 2017

- Large increases (55%) in daily heavy precipitation in Northeast
- Why haven't flood flows increased this much?

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Why aren't flood increases as big as heavy-precipitation increases?

- It's not just about heavy rainfall
  - Snowpack and antecedent conditions can be important to floods in the Northeast
- Precipitation increases can be in seasons that don't typically produce a lot of floods (Small et al., 2006; Frei et al., 2015)
- 99th percentile precipitation results in 99th percentile flow 36% of time in U.S. (Ivancic and Shaw, 2015)
  - 62% of time during wet periods
  - 13% of time during dry periods
- Different durations of heavy rainfalls are important for peak flows in different sized basins

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Sensitivity of 100-year peak flows to changes in precipitation and temperature

- Example output from detailed rainfall-runoff model
  - Change in 100-year peak flows for Narraguagus River (Eastern Maine) based on selected temperature and precipitation changes compared to modeled peak flows with no changes

Temperature change

Precip Change	0° F	+3.6° F	+7.2° F	+10.8° F
0 %	0 %	-12 %	-21 %	-20 %
+15 %	+26 %	+11 %	0 %	+4 %
+30 %	+55 %	+39 %	+28 %	+32 %

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MaineDOT

Hodgkins and Dudley, 2013

Sensitivity of 100-year peak flows to changes in precipitation and temperature

- Why do flood flows decrease with increasing temperature?
- Modeled maximum annual snowpack water-equivalent changes in Narraguagus River watershed

Temperature change

Precip Change	0° F	+3.6° F	+7.2° F	+10.8° F
0 %	0 %	-42 %	-72 %	-89 %
+15 %	+17 %	-33 %	-67 %	-87 %
+30 %	+33 %	-22 %	-62 %	-86 %

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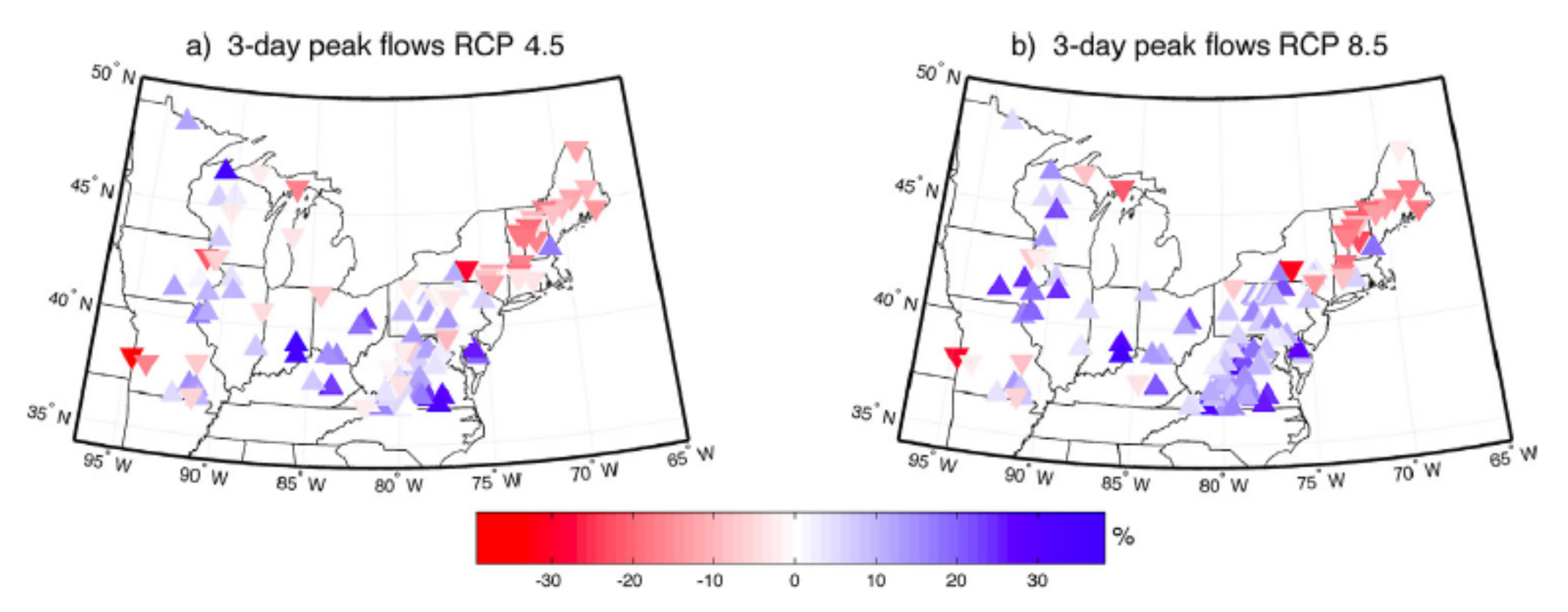
MaineDOT

Hodgkins and Dudley, 2013

Projected 100-year, 3-day peak flows

Trends in magnitude by mid-century for different climate scenarios



Demaria et al., 2016

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Summary

- Peak-flow increases in the last 50 years in the Northeast, from minimally impacted basins, are generally less than heavy precipitation increases
- Peak-flow changes over time can be influenced by climatic oscillations such as the Atlantic Multidecadal Oscillation and the North Atlantic Oscillation
- Basin urbanization and reservoir regulation strongly affect peak-flow trends and change points
- Peak flows are influenced by storm-event precipitation, antecedent basin moisture, snowpack, and other factors
- Future flood changes will depend on multiple factors in addition to future storm-event precipitation changes