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Synoptic-scale atmospheric patterns associated with flash flooding in watersheds of the New York City water supply

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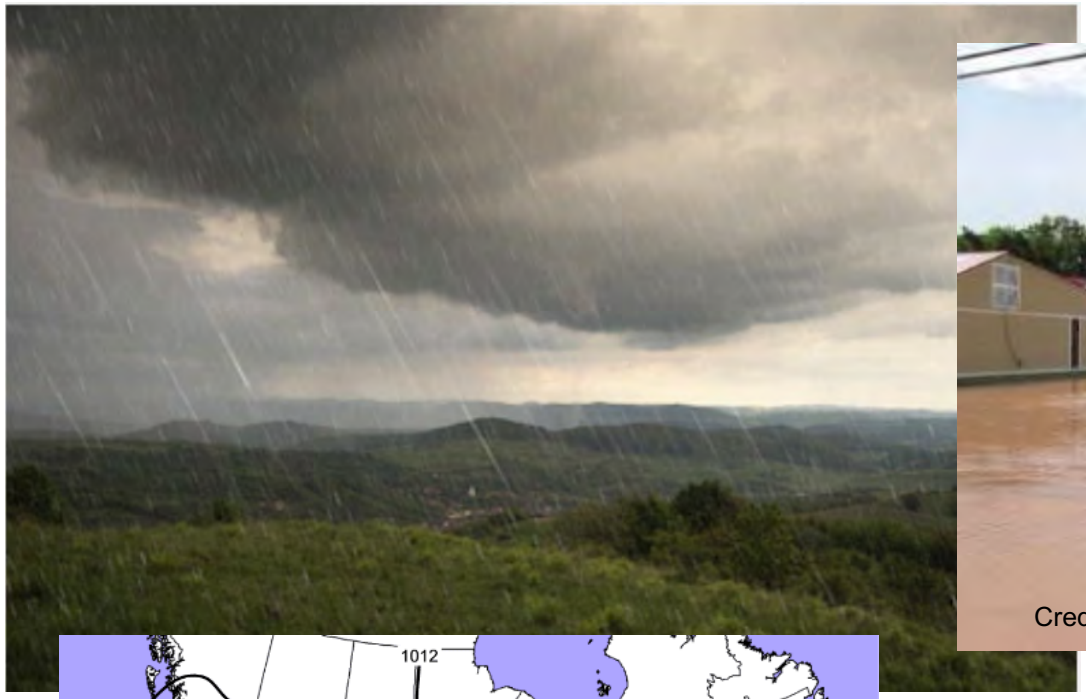
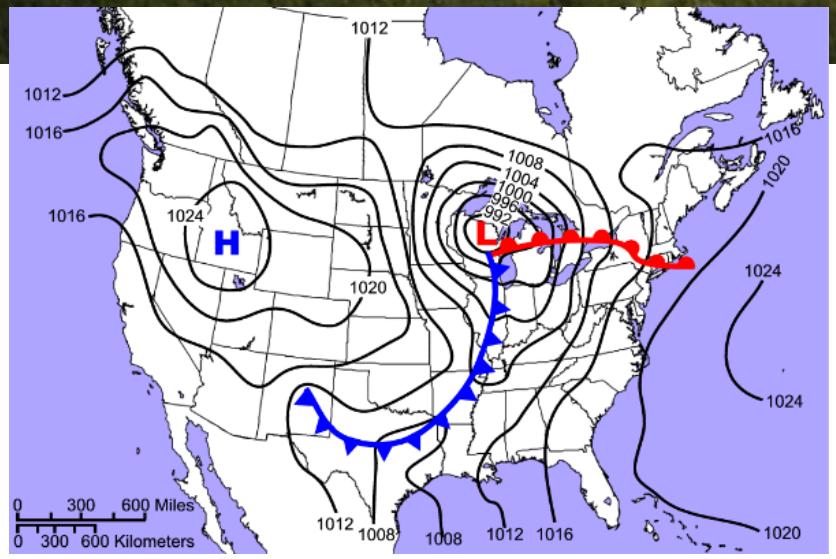
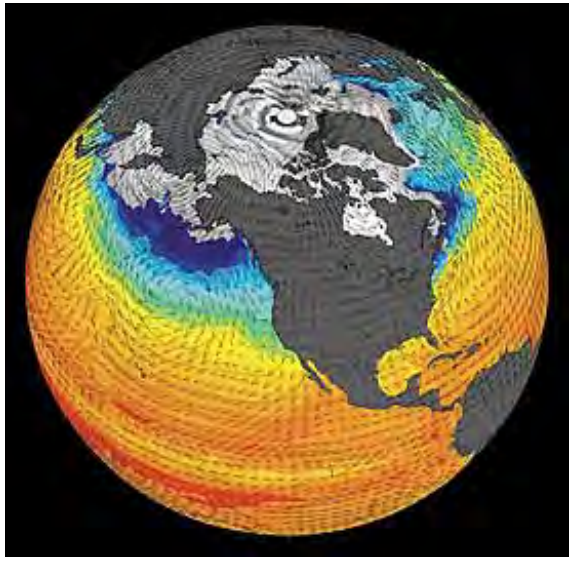
Motivation



Credit: Ashokan Watershed Stream Management Program



Credit: South Carolina Climate Office



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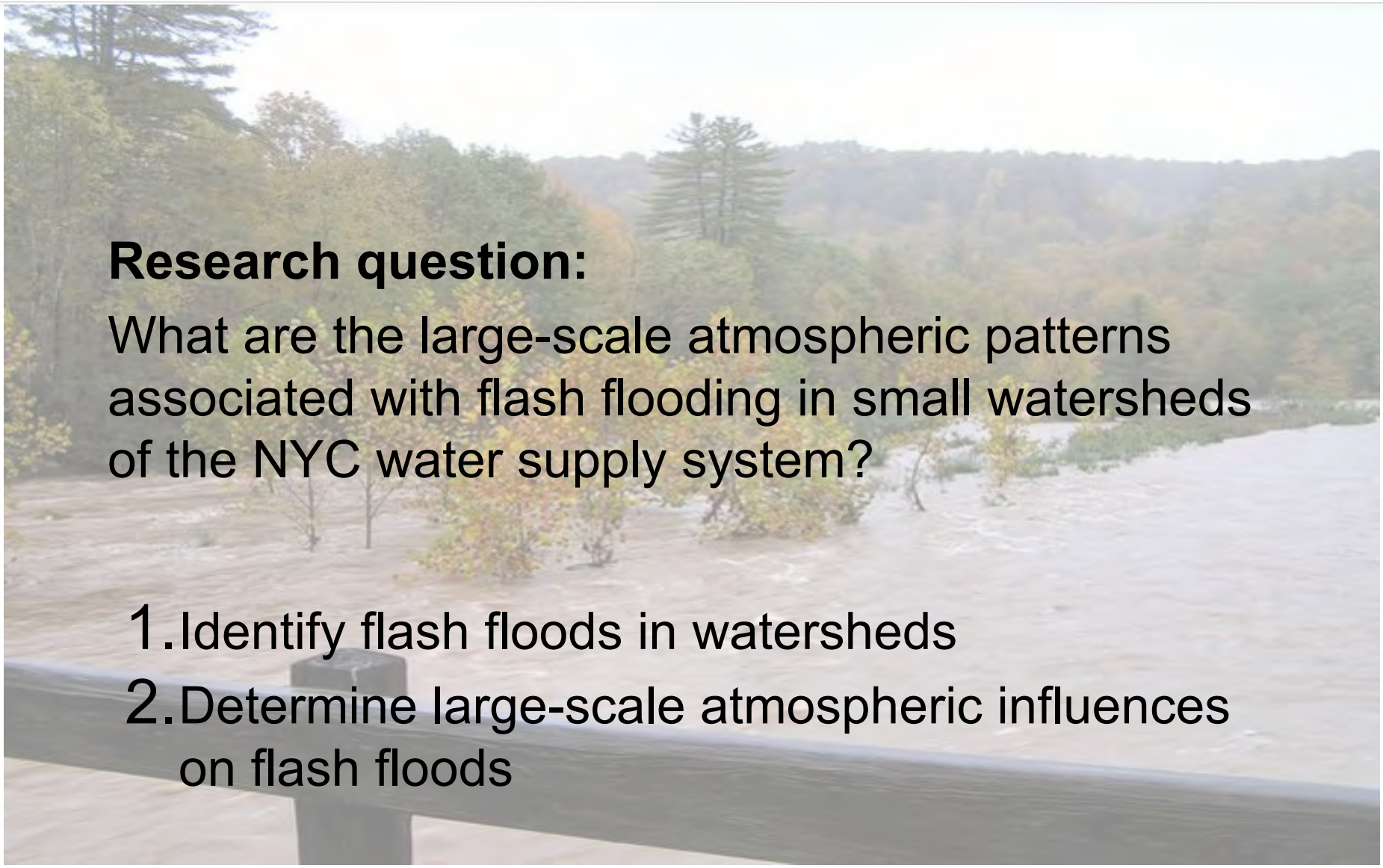
Research Objectives



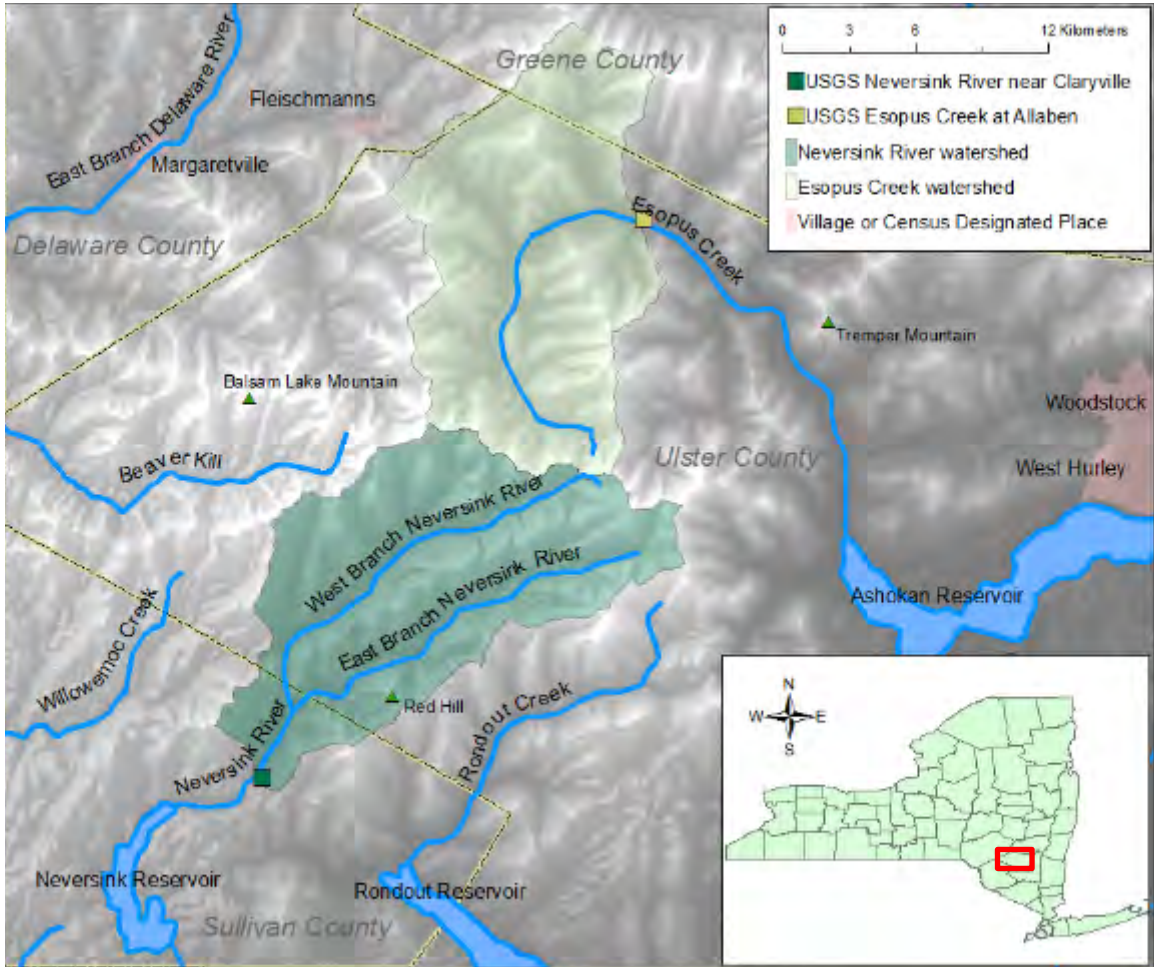
Research question:

What are the large-scale atmospheric patterns associated with flash flooding in small watersheds of the NYC water supply system?

1. Identify flash floods in watersheds
2. Determine large-scale atmospheric influences on flash floods

Data & Methods: Flash Flood Detection

- Data:
  - USGS 15-minute discharge
  - January 1987- December 2013
- Study watersheds:
  - Neversink River near Claryville, NY
  - Esopus Creek at Allaben, NY



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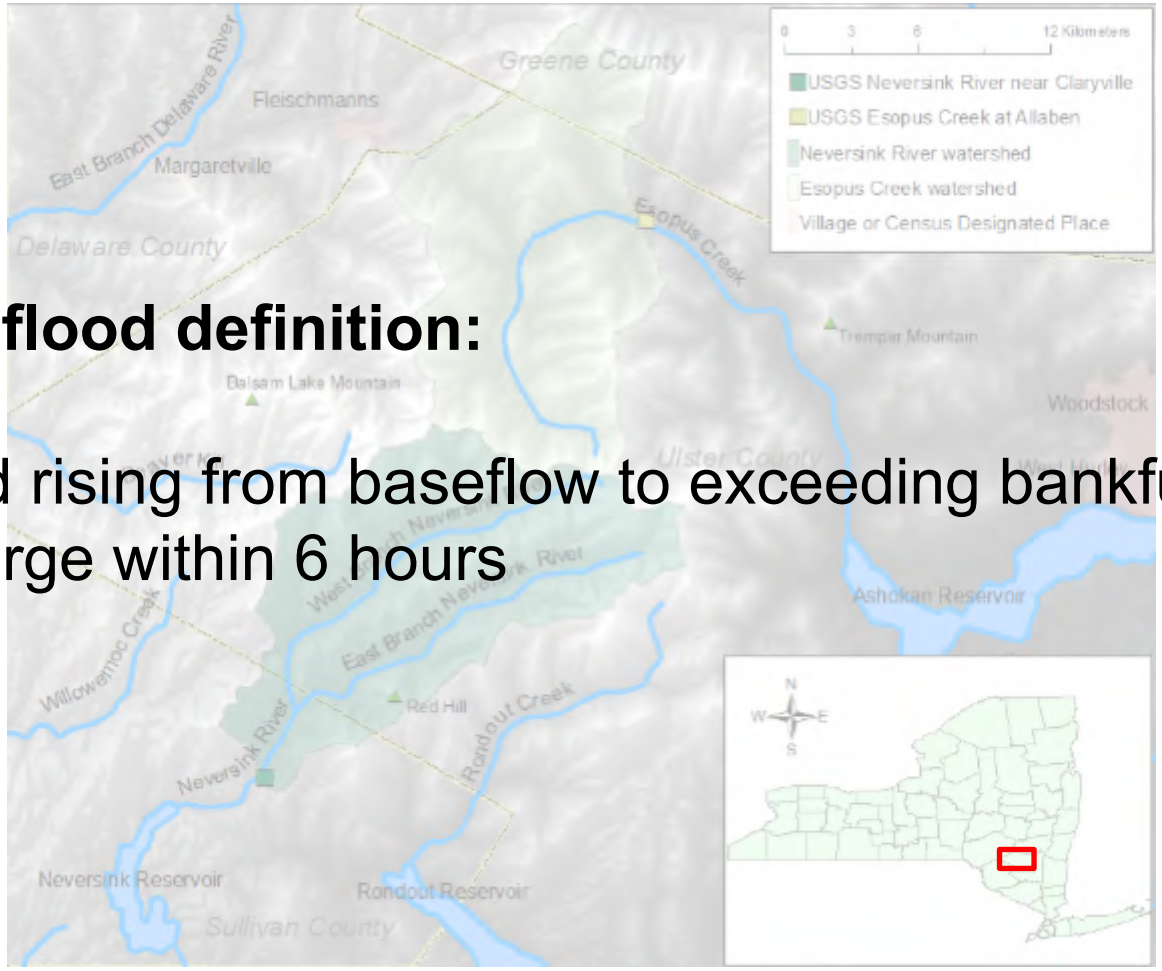

Flash flood definition:

A flood rising from baseflow to exceeding bankfull discharge within 6 hours

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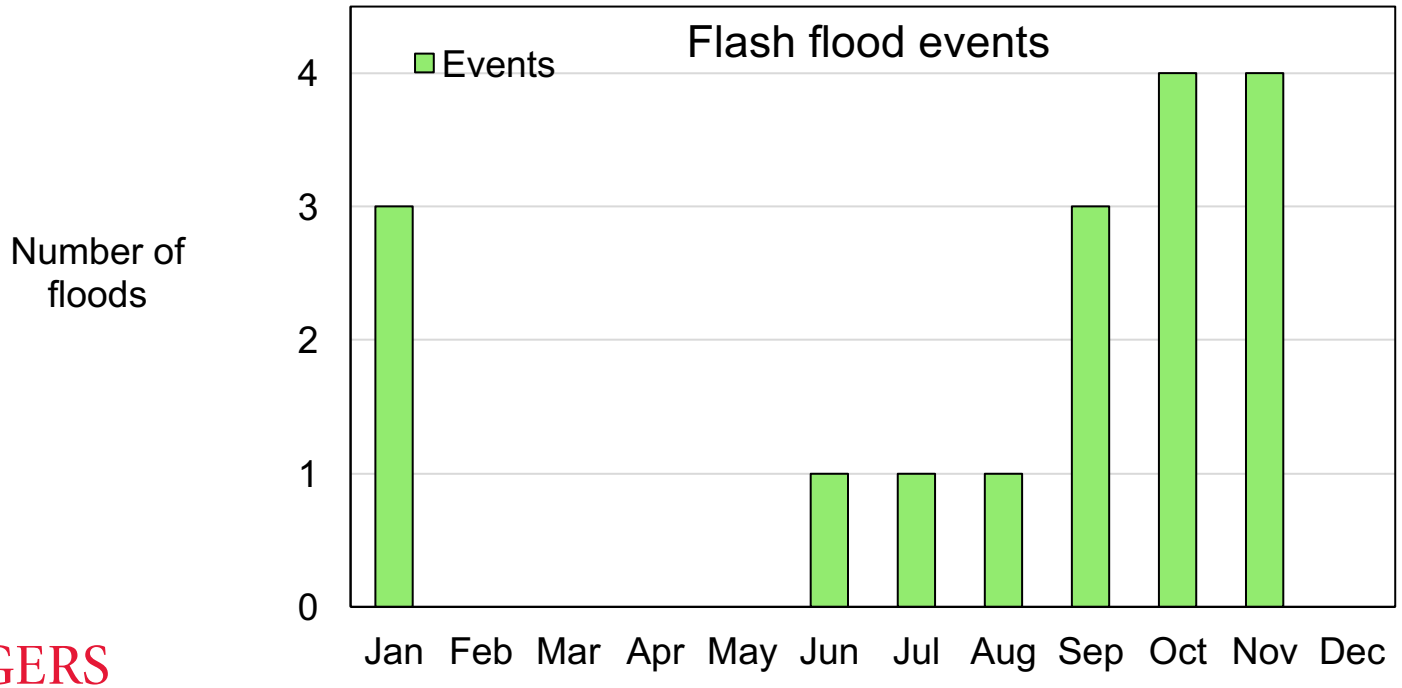
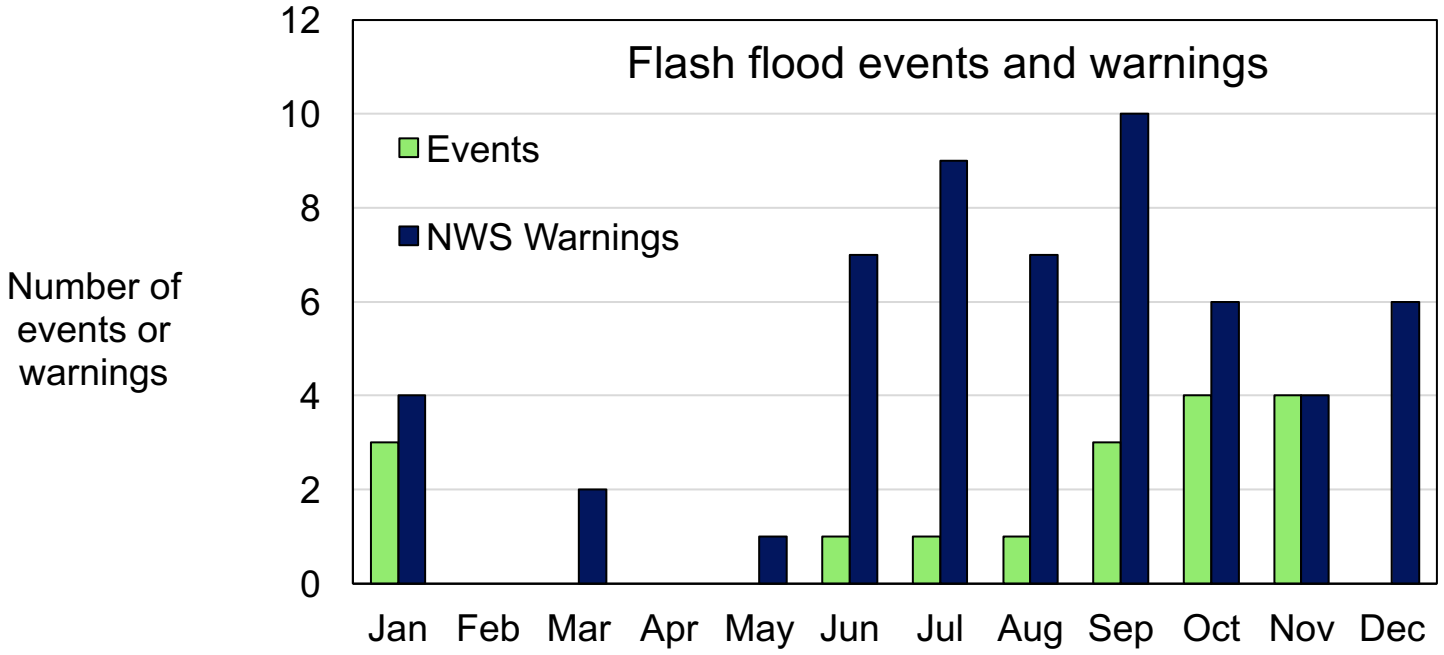
Results: Flash Floods Detected

- 25 flash floods detected (17 flash flood days)
  - 15 in Neversink River
  - 10 in Esopus Creek
  - Predominantly in fall and winter
- Snowpack present in only 3 of the flash flood days
  - Rain-on-snow events not the main cause of flash flooding



Results: Flash Floods Detected

- NWS flash flood warnings (Ulster County)
  - Warnings issued for 7 of the 17 flash flood days in study watersheds
  - 90% warnings issued did not result in a flash flood in these watersheds
  - Seasonality of warnings is slightly earlier than the seasonality of flash floods
  - **Importance of scale**



Data & Methods: Synoptic Typing

- Identify the large-scale atmospheric patterns associated with flash flooding in these watersheds
  - Synoptic typing: Identify the typical synoptic weather patterns

1. Identify the main climate patterns (“groups”)
2. Examine climate data from each day (1987-2013)
3. Sort each day into the most similar group

- Data reduction
  - Types/groups provide identifiable patterns while overlooking the day-to-day noise

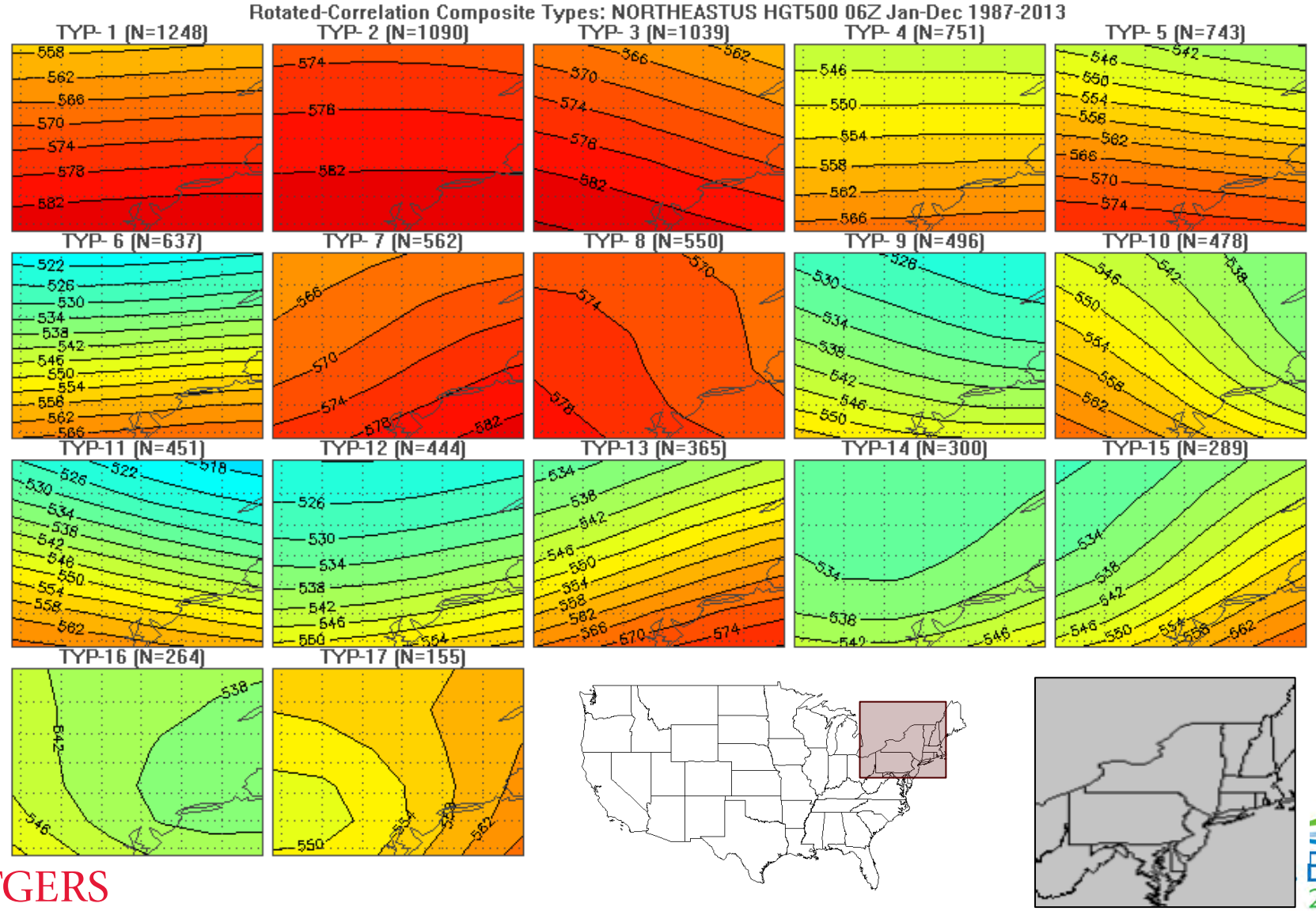
Data & Methods: Synoptic Typing

- Identify the large-scale atmospheric patterns associated with flash flooding in these watersheds
  - Develop typical patterns through principal component analysis (PCA) and k-means clustering
  - NCEP/NCAR 500 mb geopotential height reananlysis
    - Geopotential height: the height at which the atmospheric pressure is a certain value
      - Atmospheric “thickness”
    - Important for steering weather systems

  - 17 meaningful, unique synoptic types were identified
    - Daily weather patterns of the northeastern US can be grouped into 17 different types

Results: Synoptic Types

500 mb geopotential height composites



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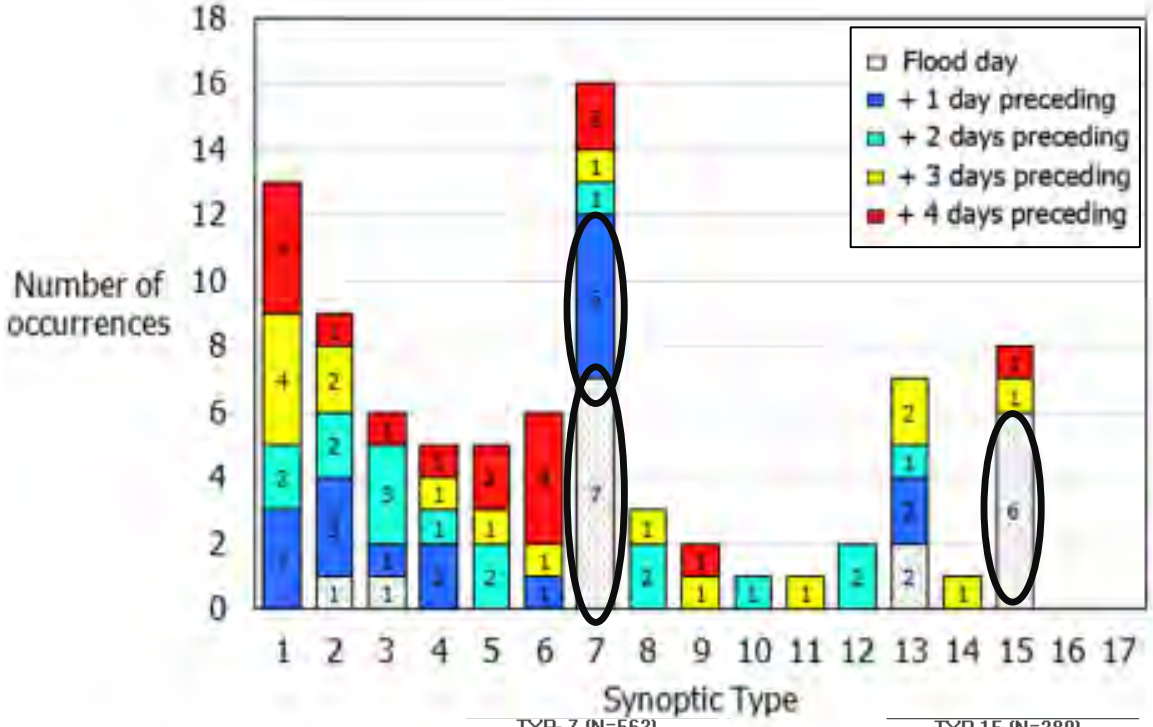
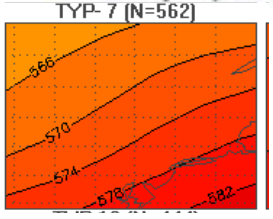
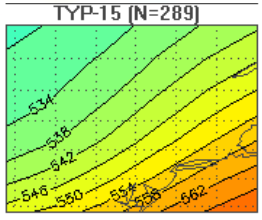
Results: Associating flash floods with synoptic types

- The synoptic type of each flash flood day and the 4 days preceding each flash flood were recorded
  - Weather pattern on the day of the flash flood, and the patterns on the days leading up to the flash flood







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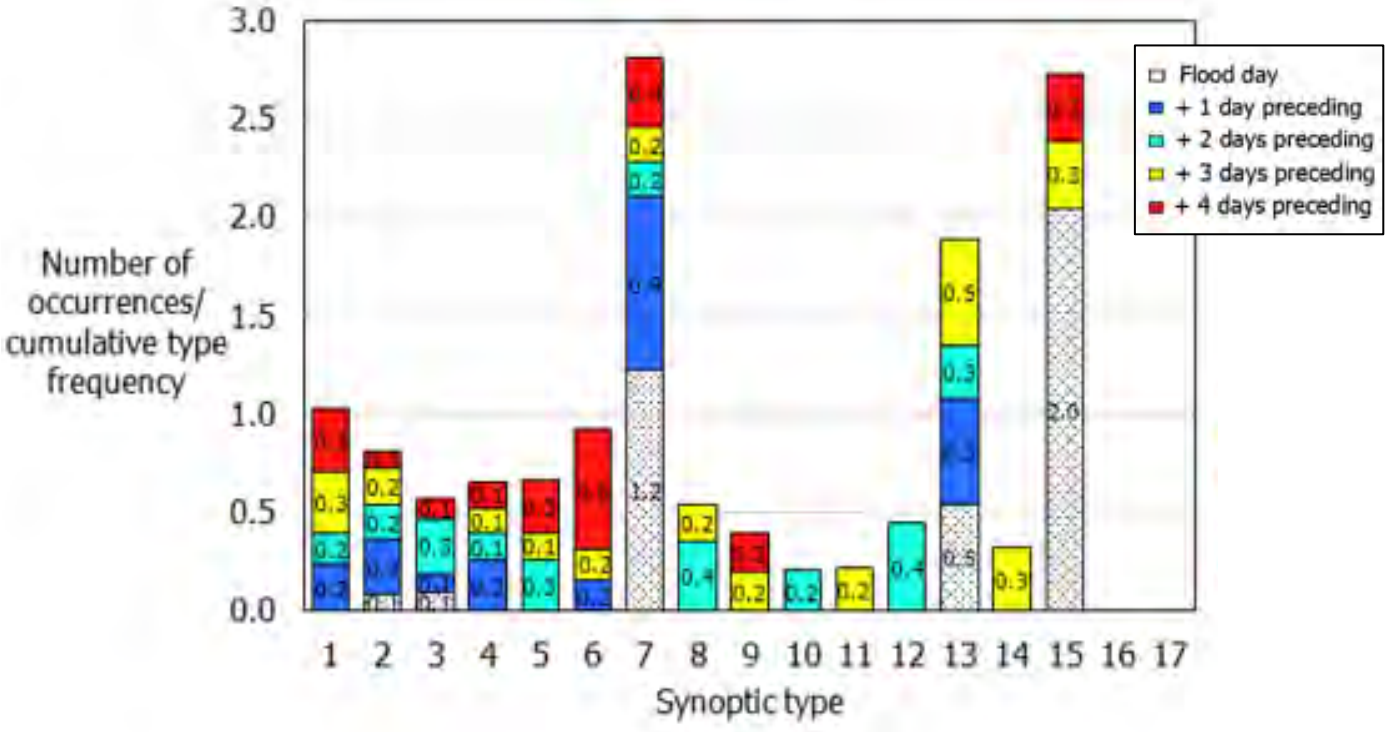
Results: Associating flash floods with synoptic types

- When normalized by the overall type frequency, higher than normal flood rates occur with Types 7, 13, and 15.



The number of types each type appears on a flood or pre-flood day normalized by the total type frequency

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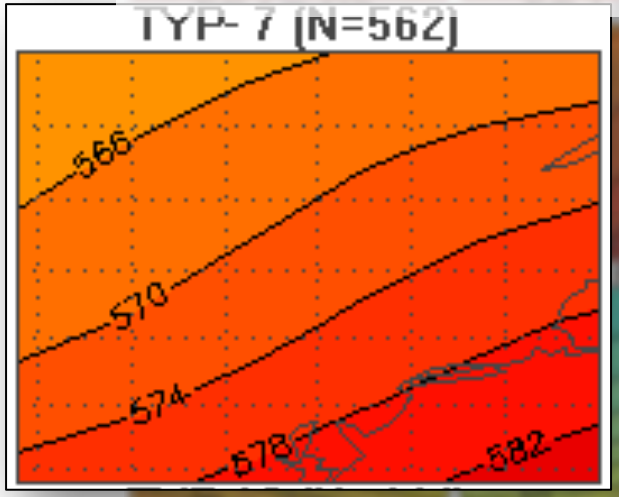
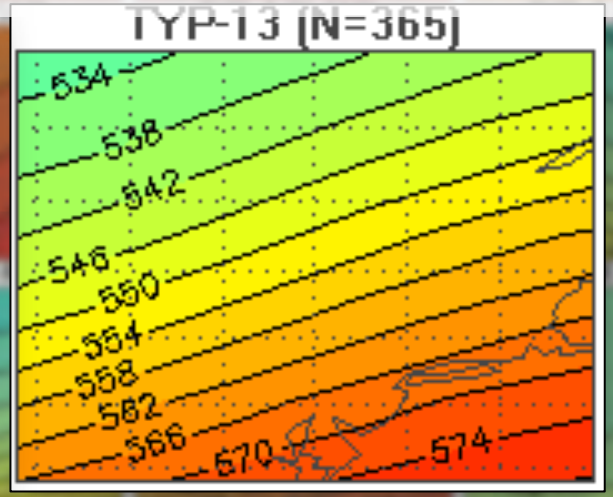
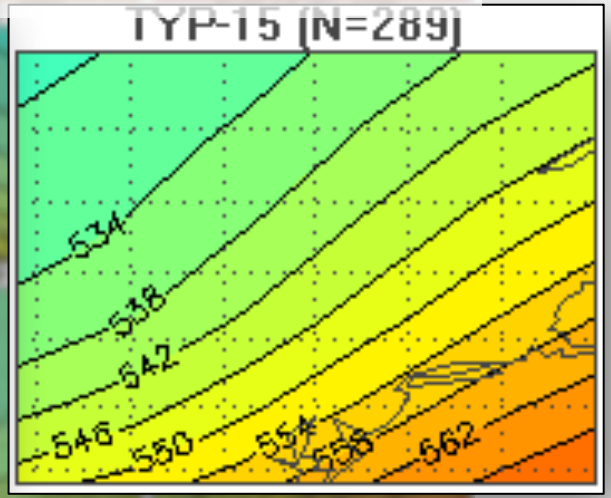
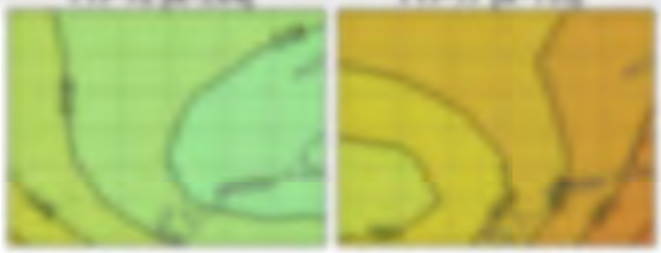
Results: Synoptic Types 7, 13, and 15

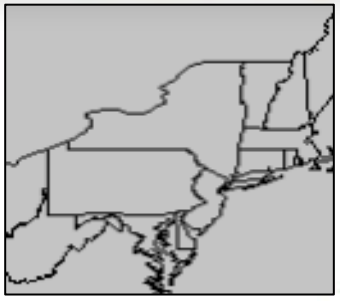
Bootstrap random sampling methodology showed that Types 7, 13, and 15 occurred significantly more frequently with flash floods than would be expected under normal conditions











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Conclusions

- 25 flash floods in the Neversink River and Esopus Creek watersheds were detected over 17 days (1987-2013)
  - Scale is extremely important
- Nearly all of the flash flood were associated with Types 7, 13, or 15.
  - The patterns for these types suggest advection of warm moist air along the Atlantic coast.
  - The only flash flood not associated with Types 7, 13, or 15 air masses occurred during the passage of Tropical Storm Irene remnants (August 28, 2011)
- Next steps: Almost all flash floods occur with Types 7, 13, and 15, but not all days of those types produce flash floods. What is different about those specific days?
- **Dissertation:** Identify pathways of moisture transport into the northeastern US and determine their influence in extreme precipitation at multiple scales

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Thank you

Questions?

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Association of synoptic-scale atmospheric patterns with flash flooding in watersheds of the New York City water supply system

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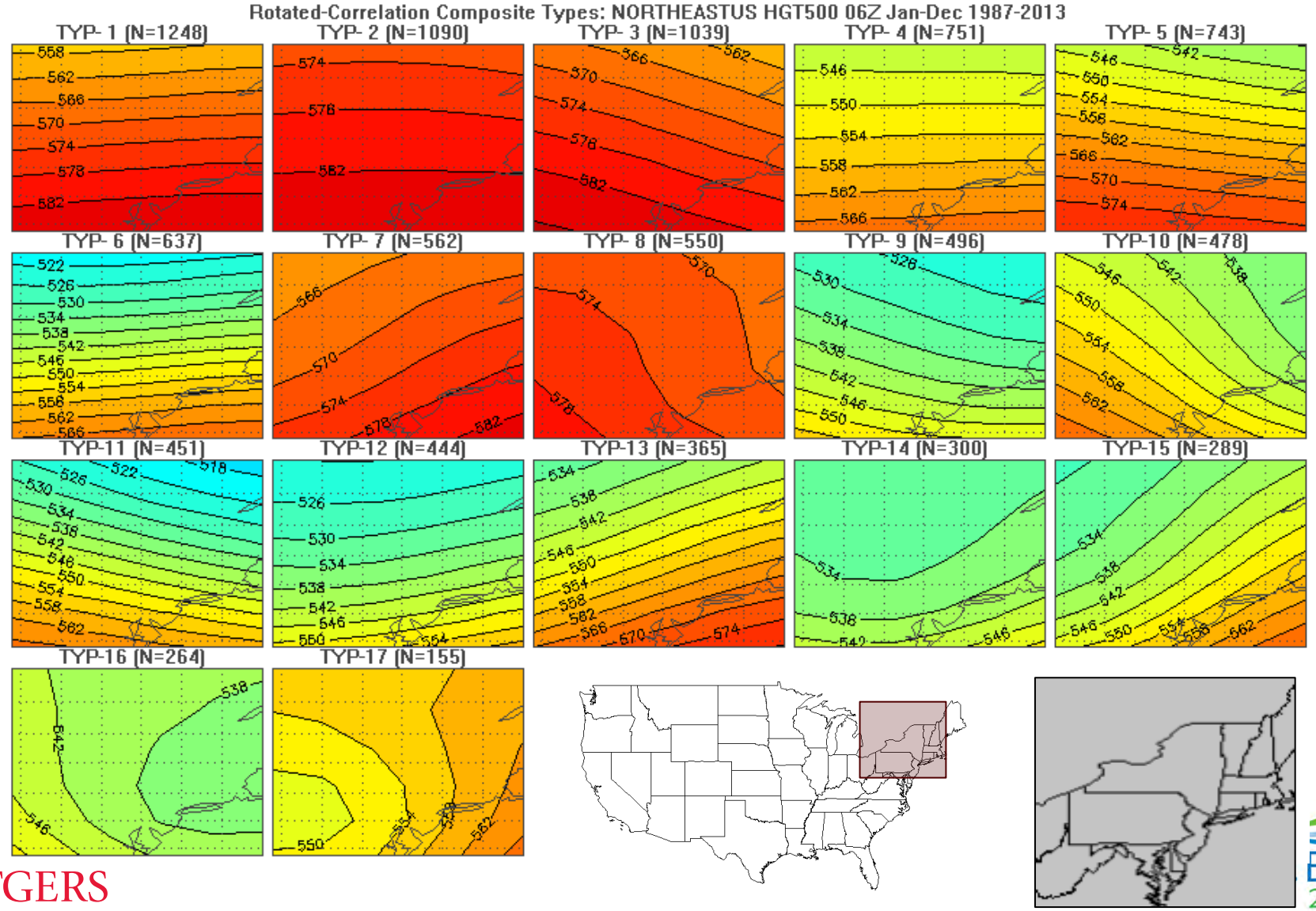
[b] *Department of Geography, Texas A&M University, College Station, TX, USA*
[c] *Department of Geography and Environmental Resources, Southern Illinois University, Carbondale, IL, USA*

Results: Synoptic Types

500 mb geopotential height composites



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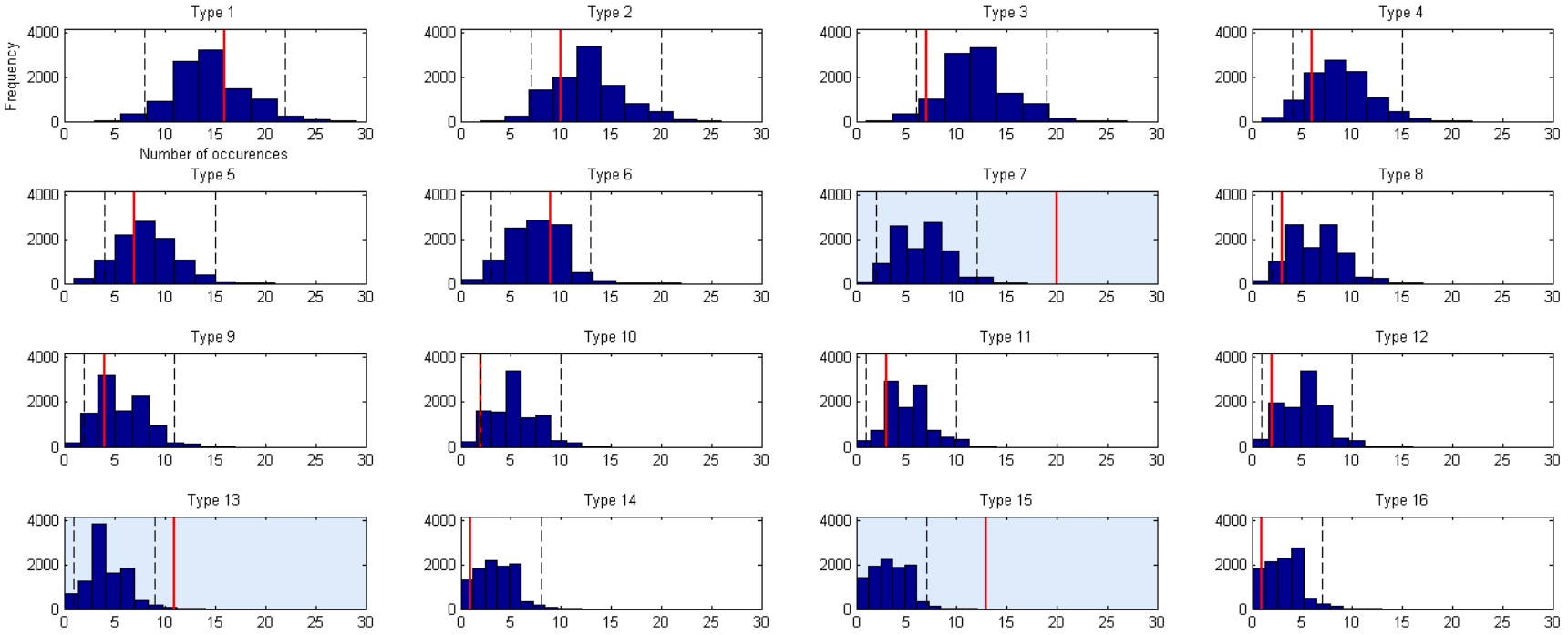
Results: Random Sampling

- Random sampling to determine if Types 7, 13, and 15 occur more frequently normal in preflood days
  - Randomly-sampled subsets (10000 iterations of subsetting 85 days)
    - Frequency of the number of times that each type appears in a random subset is shown below (blue bars)
    - 2.5th, 97.5th percentiles of random sampling (dashed lines)
    - Number of times each type appeared in preflood subset (red line)
    - Significant departure from normal conditions if preflood type frequency exceeds 2.5th-97.5th percentiles of random subset.



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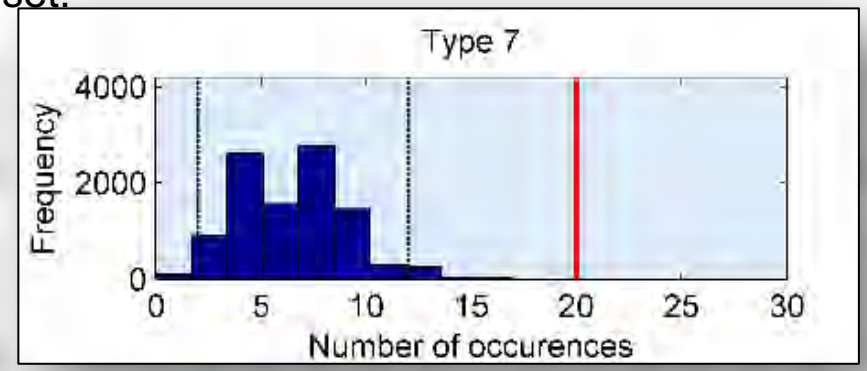

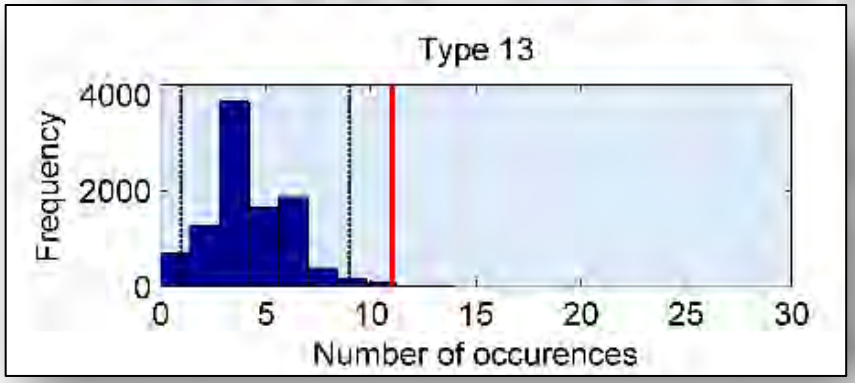

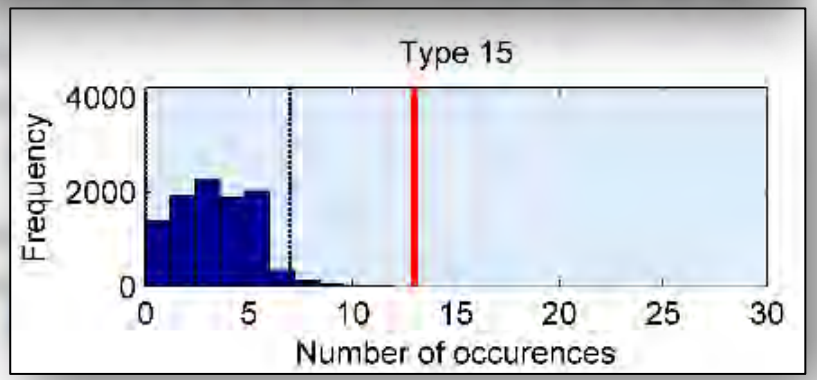

Data & Methods: Sensitivity Analysis

- The number of flash floods detected is sensitive to the definition employed
- 2 subjective components to the algorithm:
  1. Number of hours used for the flood to rise from baseflow to peak to be considered a flash flood (how "flashy" does it have to be)
  2. Percent of bankfull added to the calculated 2-day average discharge to estimate baseflow

Number of flash floods detected

Bankfull added (%)	Hours of flash flood rising limb				
	4	5	6	7	8
16	16	29	37	49	52
14	14	26	32	45	50
12	12	23	30	39	49
10	11	21	25	37	47
8	9	19	24	34	42
6	7	15	22	26	38

- Multiple linear regression showed that the number of flash floods detected is *most sensitive* to the length of the rising limb
- Most studies that quantitatively define the quickness of the rise use 6 hours as the window for rising limb
- Bankfull added:
  - Small increases in the number of flash floods below the optimal % of baseflow added indicate the same streamflow processes
  - Large increases above the optimal % added: indicates other hydrological processes are influencing discharge

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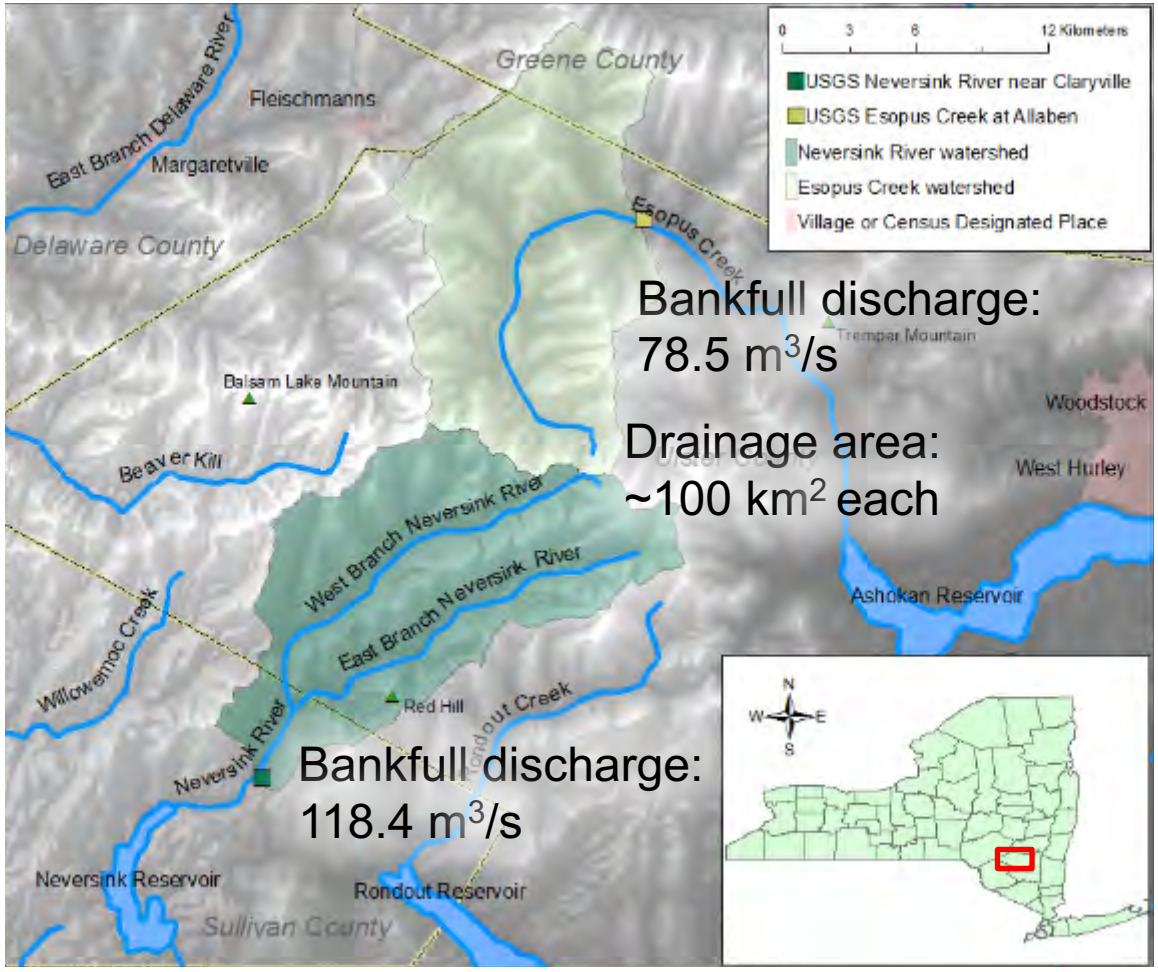
Determine if flash flood peak discharge can be predicted using local hydrometeorological variables

Predictor variable	Data Source
Antecedent percent bankfull	USGS gauge stations
Antecedent soil moisture	North American Land Data Assimilation (NLDAS)-2 Noah Model
24-hour precipitation total	National Climate Data Center (NCDC) cooperative stations
Precipitation duration	
24-hour precipitation intensity	
Maximum hourly precipitation intensity	

24-hour precipitation intensity and antecedent soil moisture explain 42% of variance in peak discharge

Data & Methods: Study Area

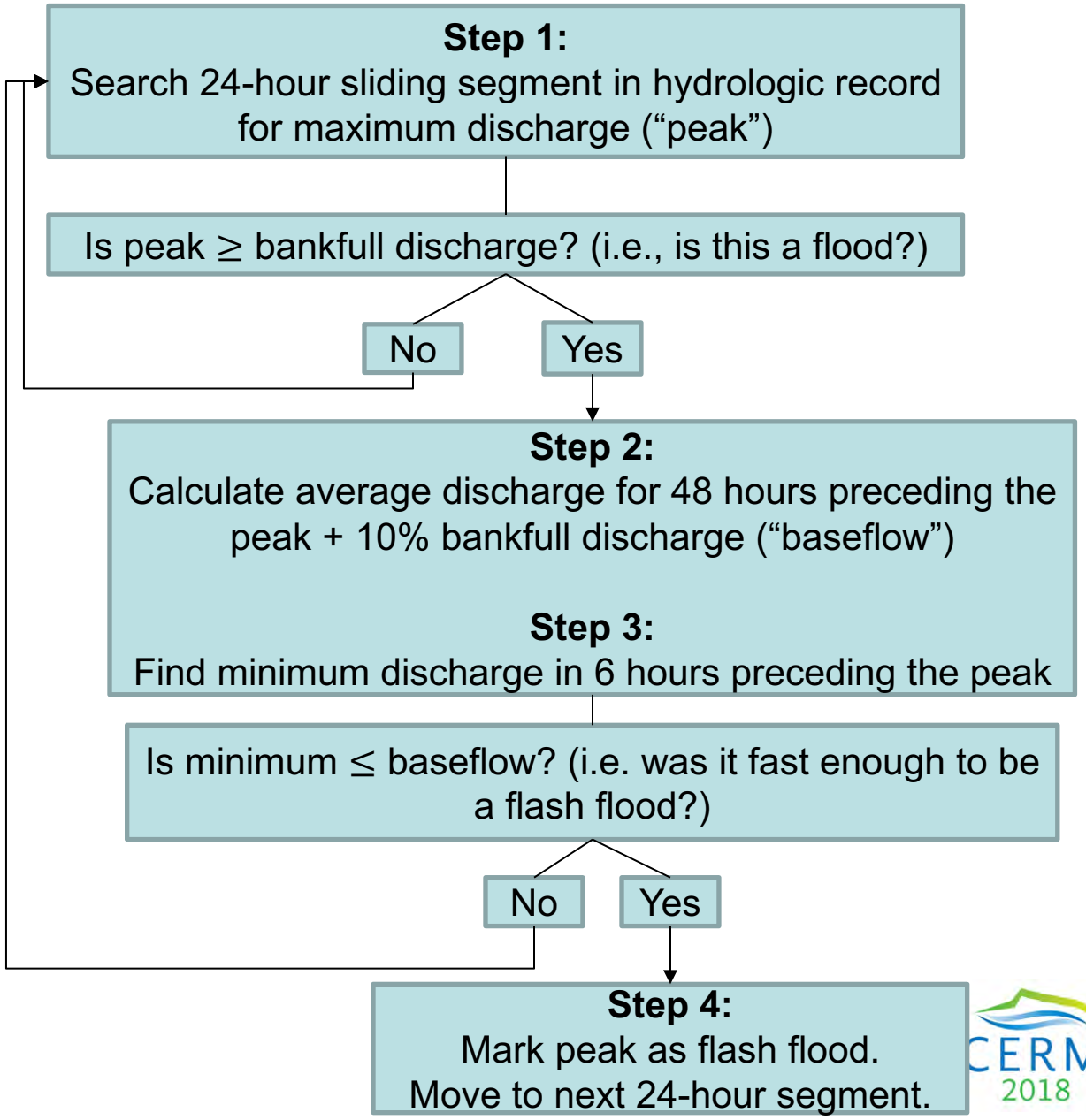
- Data:
  - USGS 15-minute discharge
  - January 1987- December 2013
- Study watersheds:
  - Neversink River near Claryville, NY
  - Esopus Creek at Allaben, NY



Basin data from Miller and Davis (2003)

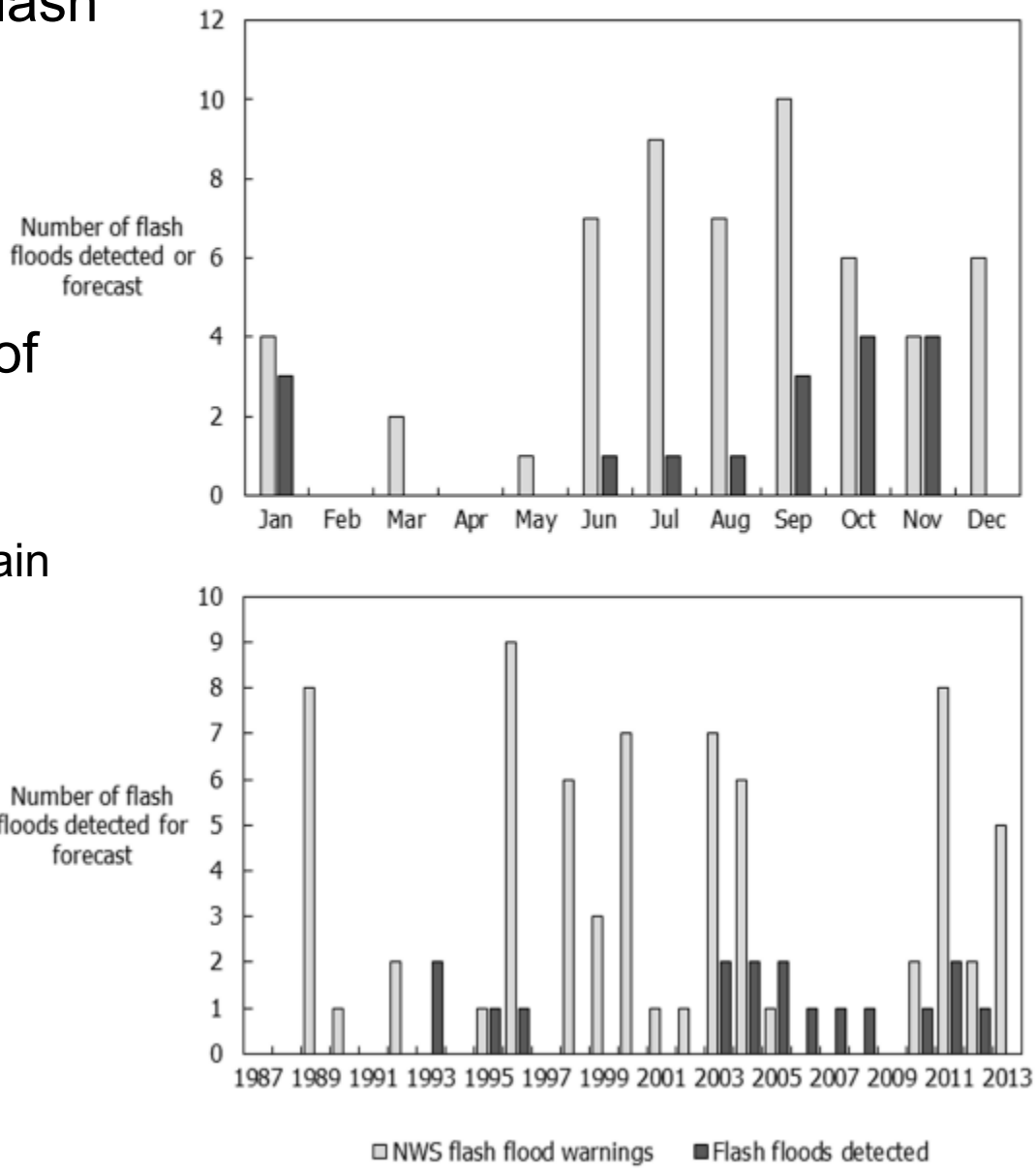
Data & Methods: Flash Flood Detection

- Flash flood definition:
  - *Increase from baseflow to exceeding bankfull in less than 6 hours*
- Flash flood detection
  - 24-hour sliding window
  - Basic criteria

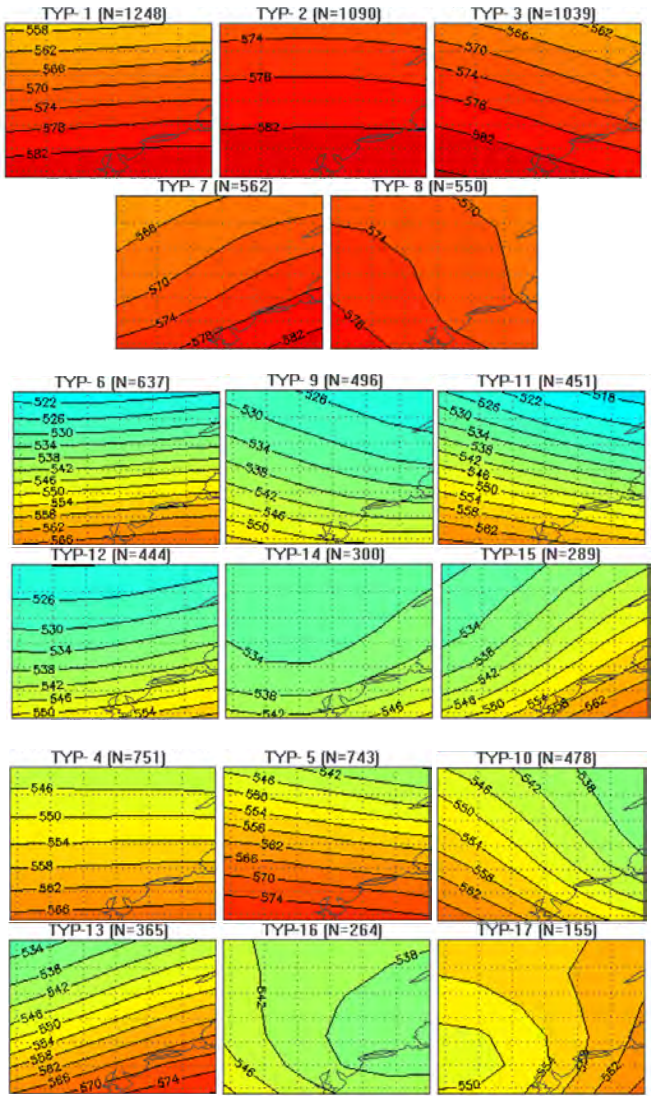


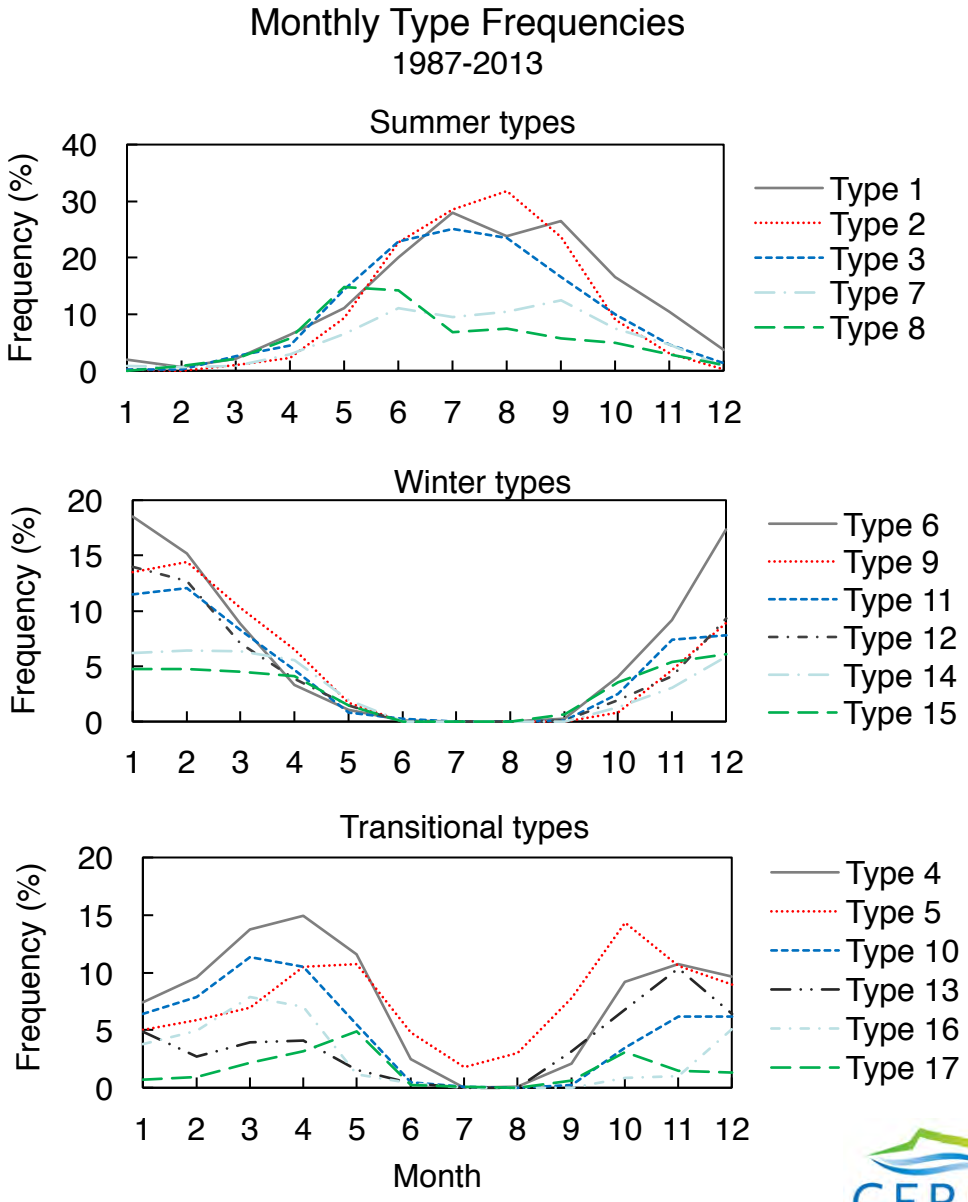
Results: Flash Floods Detected

- 25 flash floods detected (17 flash flood days)
  - 15 in Neversink River
  - 10 in Esopus Creek
  - Predominantly in fall and winter
- Snowpack present in only 3 of the flash flood days
  - Slide Mountain, NY GHCND
  - Rain-on-snow events not the main cause of flash flooding



Results: Synoptic Types (Seasonality)





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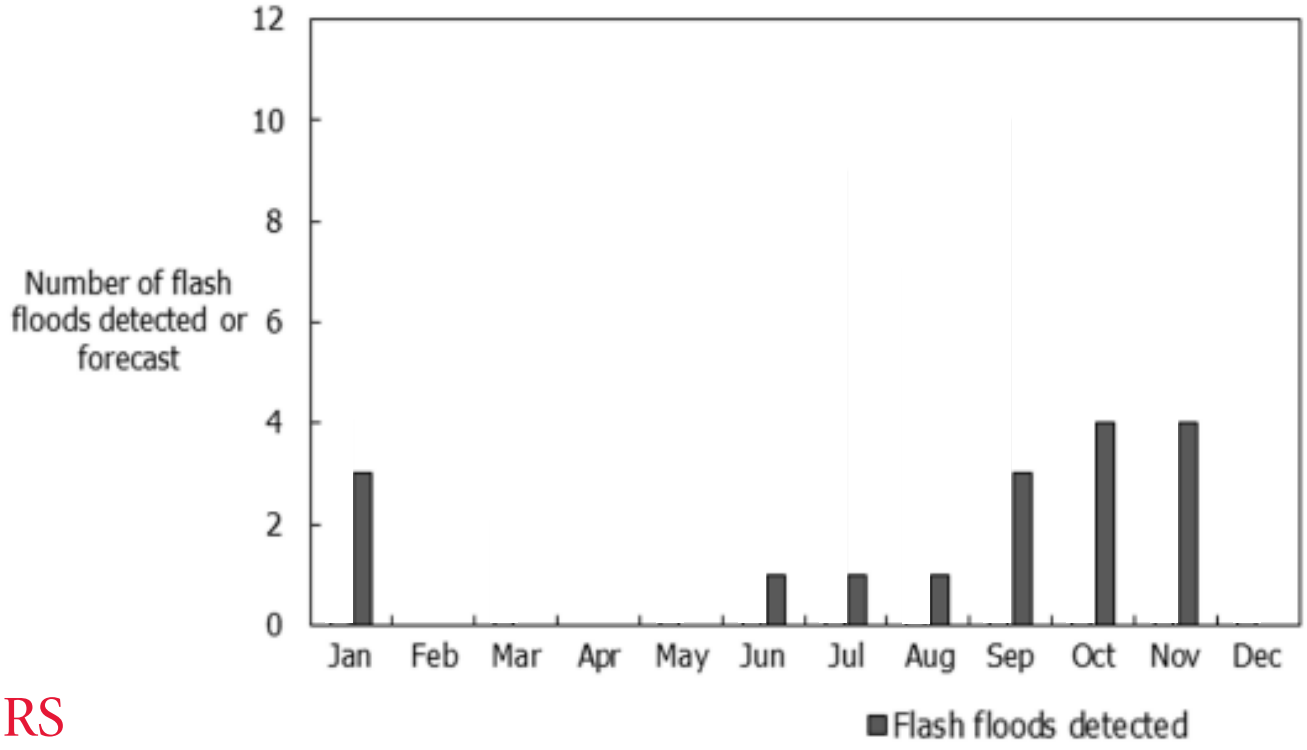

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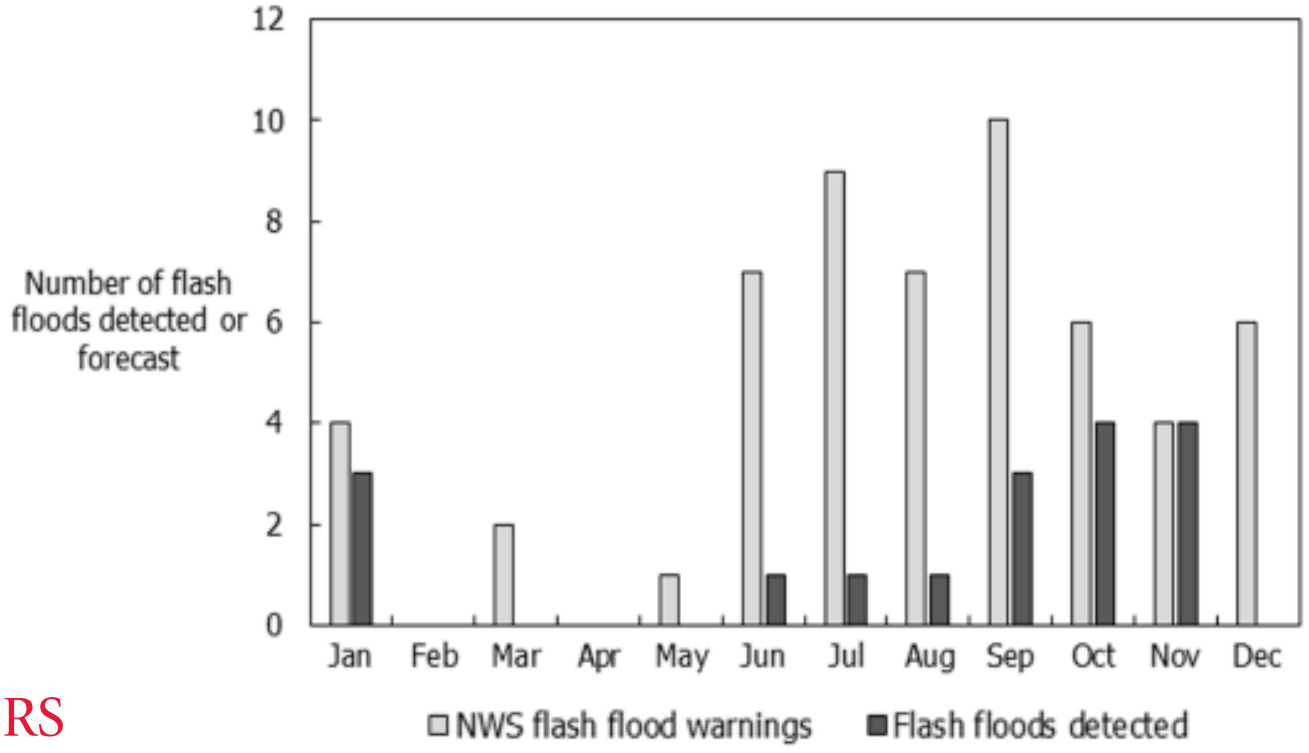
Results: Flash Floods Detected

- NWS flash flood warnings (Ulster County)
  - Warnings issued for 28% of flash floods in study watersheds
  - 90% of warnings did not result in a flash flood in these watersheds
  - Seasonality of warnings does not match seasonality of flash floods
  - **Importance of scale**



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Results: Associating flash floods with synoptic types

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