Synoptic-scale atmospheric patterns associated with flash flooding in watersheds in the Catskill Mountains, NY

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Motivation

As the magnitude and frequency of extreme precipitation in the northeastern United States increases, the impact of changing climate on the water supply systems becomes critical[1,2]. While regional trends in precipitation and streamflow have been studied, changes in rapid flooding in the region lack understanding. This matter is of critical importance in the New York City water supply system, serving over nine million residents in the New York City metropolitan area[3]. This system is especially sensitive to flash flooding events, as the turbidity associated with flooding[4] in the Catskill Mountains headwaters threatens the quality of the unfiltered water supply. The uncertainties associated with the changing hydroclimatology of the area coupled with the high impact of this water supply system make a study of this kind essential.

Research Question

What are the regional atmospheric circulation patterns associated with flash flooding in the Catskill Mountains?

Study area

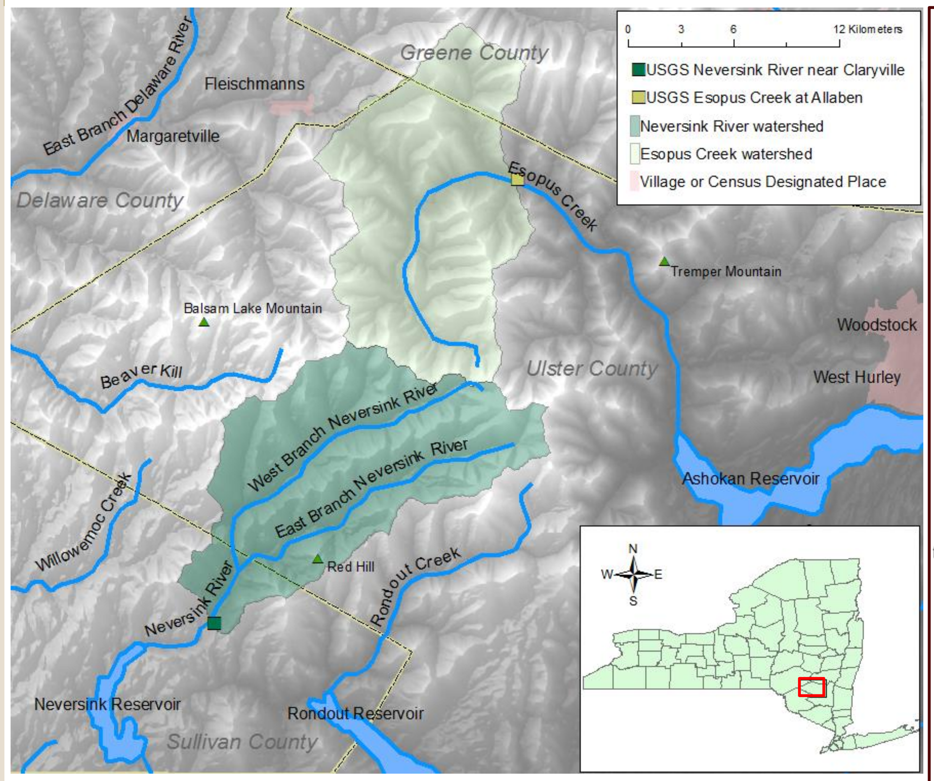

Figure 1. Study basins with regional features and USGS gauges marked

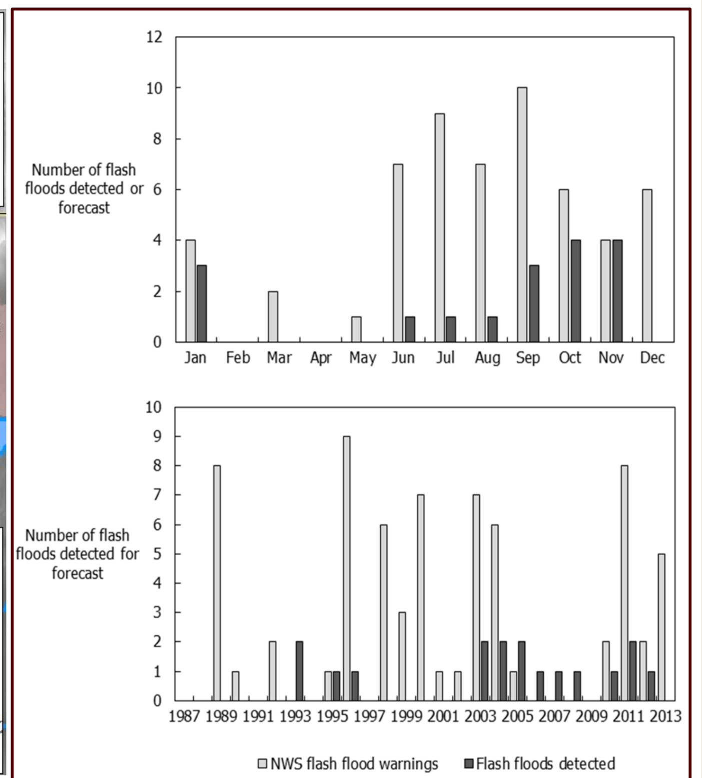

Figure 2. Frequency of detected and forecast flash floods by month and year

- 25 flash floods were detected over 17 days from 1987-2014 in the study basins.
- The majority of flash floods occurred in **fall** and **winter** months.
- The seasonality of flash floods does not correspond well with the NWS flash flood warnings issued for the county

Data & Methods

- January 1987 – December 2013
- Identifying flash flooding events:
  - USGS 15-minute discharge data from 2 comparable gauges
  - Flash flood: rising from baseflow to flood peak in < 6 hours
- Synoptic typing
  - NCEP/NCAR 500 mb geopotential height reanalysis
  - Spatial Synoptic Typer Tools (STT): rotated PCA and k-means clustering

Results

PCA and clustering:

- 3 principal components retained
  - Maximize between-type variance, minimize within-type variance

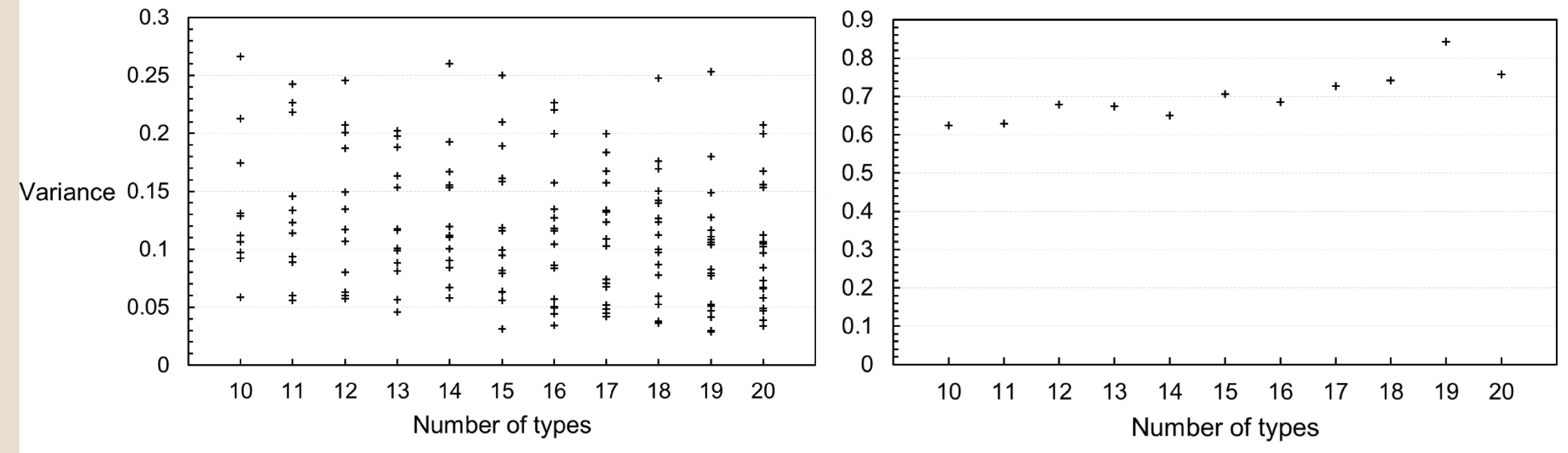

Figure 3. (left) Within-type variance; (right) Between-type variance

- 17 typical synoptic patterns represent climatology of study area

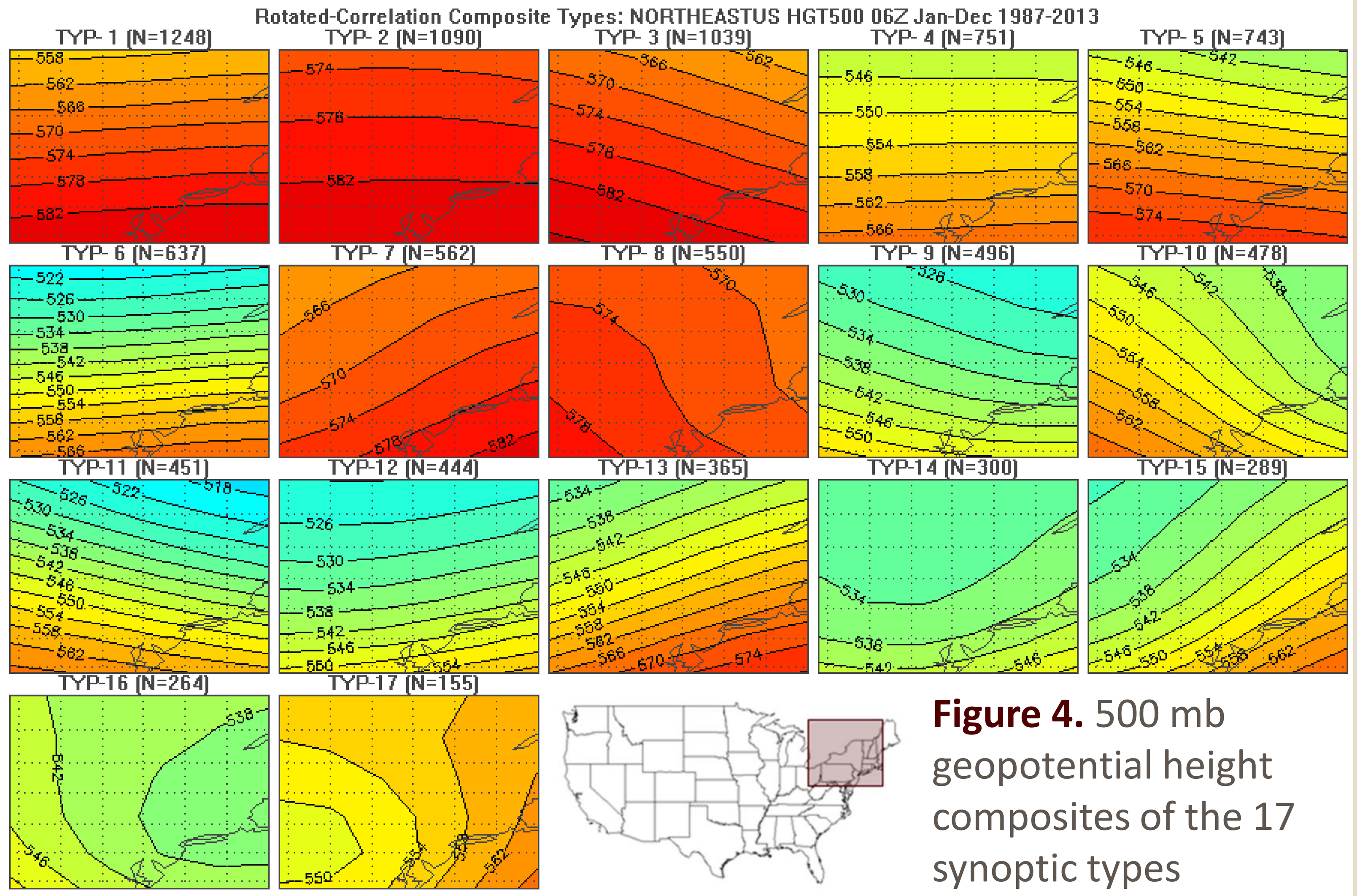

Figure 4. 500 mb geopotential height composites of the 17 synoptic types

- These types were associated with the flash flood days and the days preceding the flash floods
- Flash floods were generally associated with more frequent types
- ***When normalized by the frequency of each type, the presence of Types 7, 13, 15 patterns on and before flash flood days is apparent***
- Set of 85 preflood days extracted (5 days × 17 flash flood events)

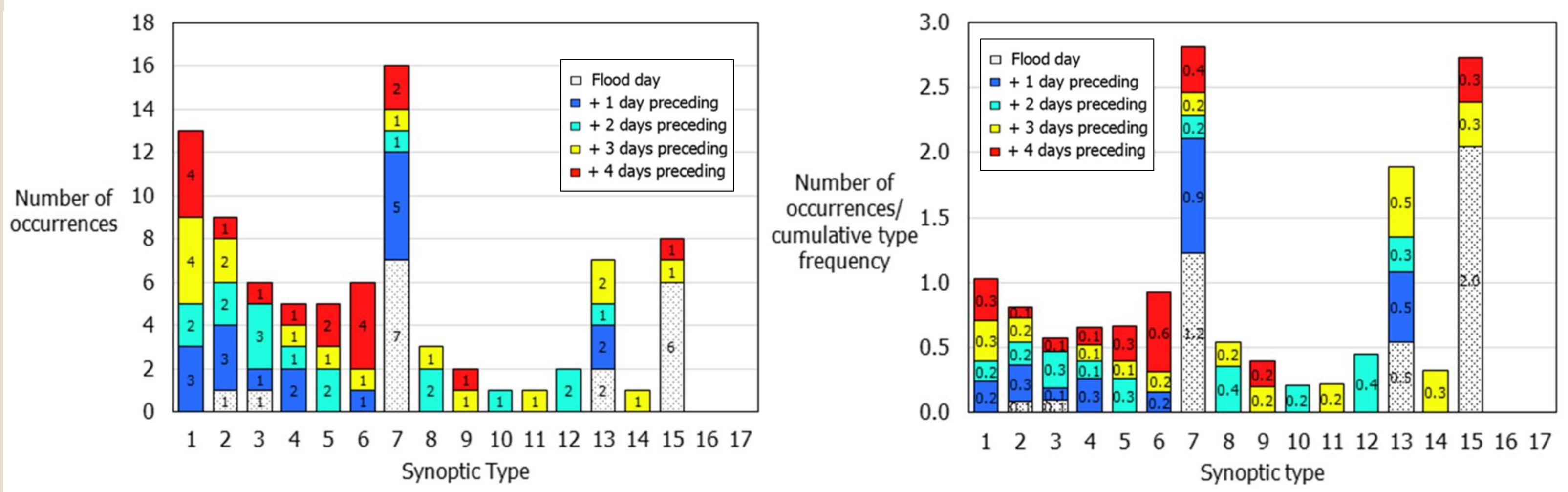

Figure 5. (left) Number of times each type appears on a flood or pre-flood day; (right) Number of types each type appears on a flood or pre-flood day normalized by the cumulative type frequency

Results

Random sampling to determine if Types 7, 13, and 15 are more frequent than normal in preflood subset

- Randomly-sampled subsets (85 days, 10000 iterations)
  - Frequency of number of times that each type appears in a 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.
- ***Types 7, 13, and 15 occurred more frequently than random in days including and preceding flash floods***

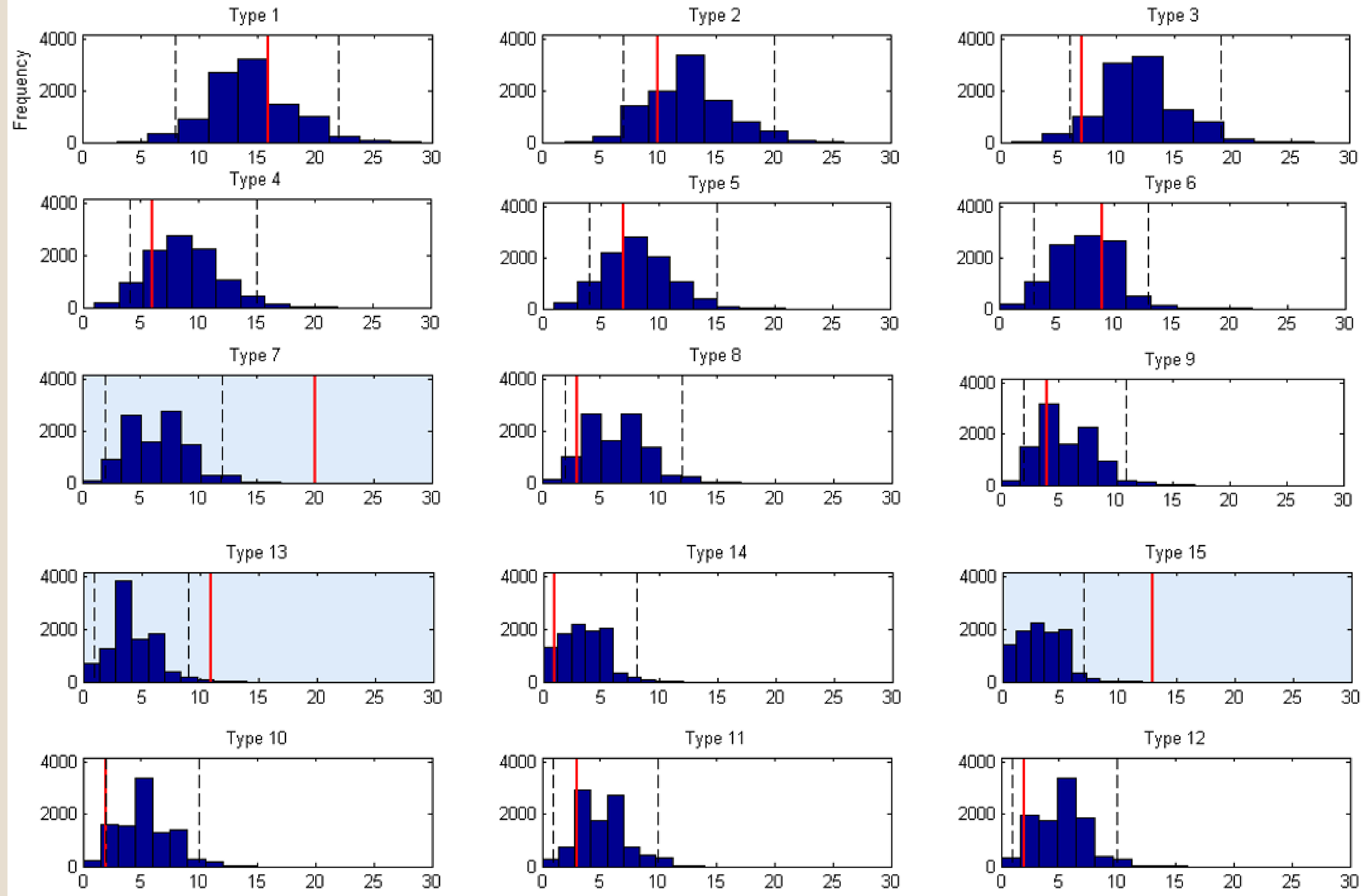

Figure 6. Bootstrapping methodology to test for significant departure from normal patterns. Distributions for Types 16 and 17 were omitted; results were insignificant.

Conclusions

- Flash floods in these basins exhibit a different seasonality than that of the flash flood warnings for Ulster County, NY
- 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)
- Future work will analyze these events on case-study level to identify features averaged out in composites such as atmospheric rivers.

Acknowledgements / References

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