Climatology of Extreme Precipitation for the Northeast US

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Webinar prepared for
NOAA/ICNet Extreme Precipitation In the Northeast Workshop
October 15, 2019

This climatology will set the stage for better understanding the relationship between flooding and extreme precipitation:

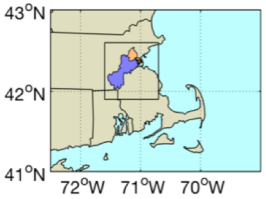
- **What** is the basic relationship between extreme precipitation and flooding?
- **Where** does extreme precipitation occur?
- **When** does extreme precipitation occur?
- **How much** extreme precipitation occurs?
- **What are the causes** for extreme precipitation?

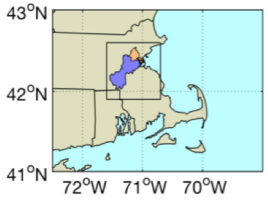
Merrimac, May 2006

Hurricane Irene, 2011

Extreme precipitation is intricately linked to episodes of flooding.

Example: **Mystic Watershed**





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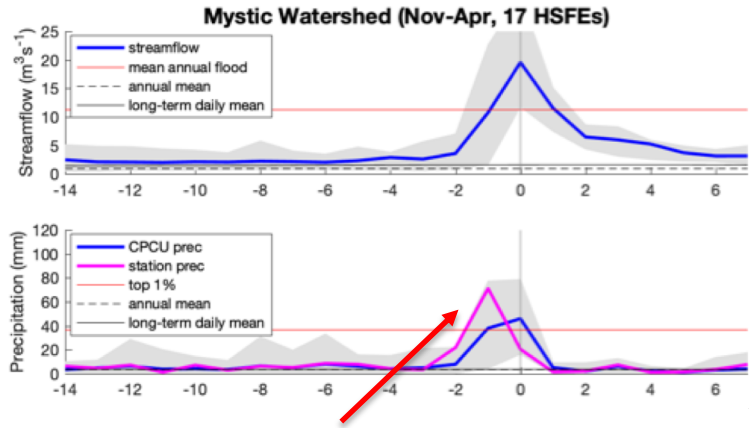
Winters, 1950-2014, 17 “flood events”



Extreme precipitation often precedes “flood event”

Agel et al. 2019

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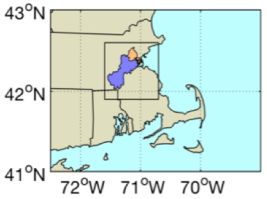

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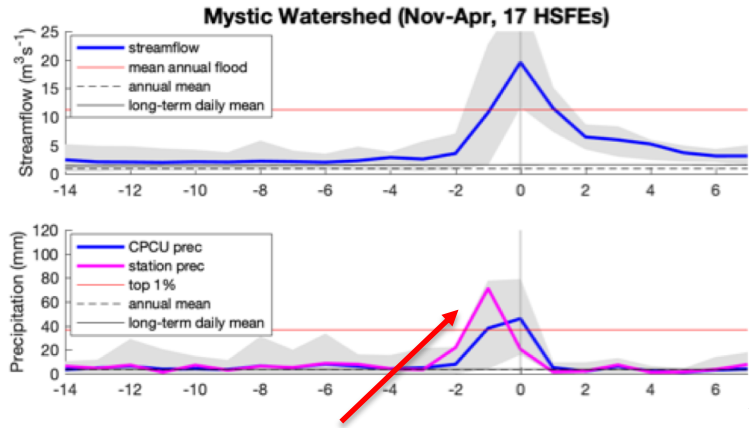

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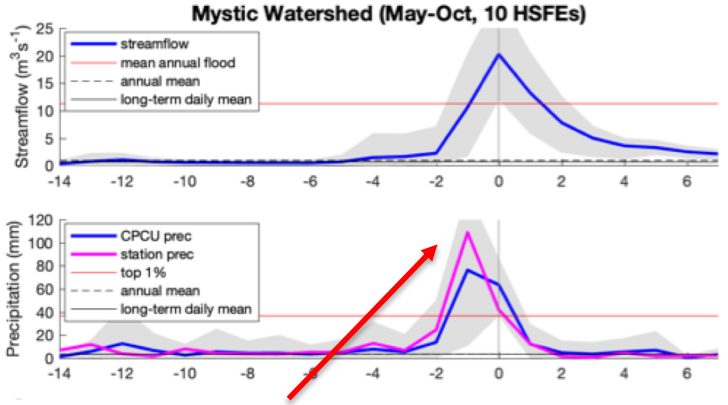

Even more pronounced relationship in summer

Agel et al. 2019

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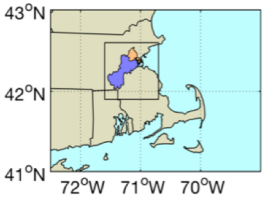

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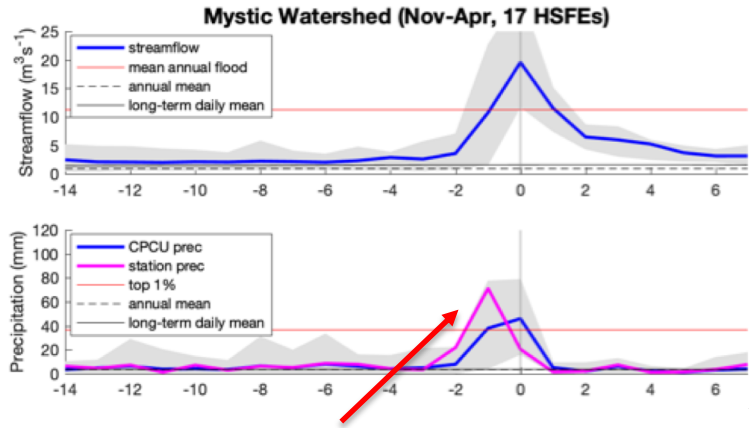

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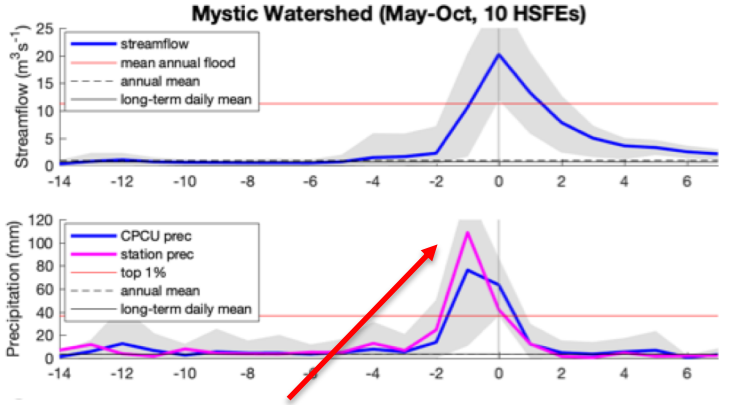
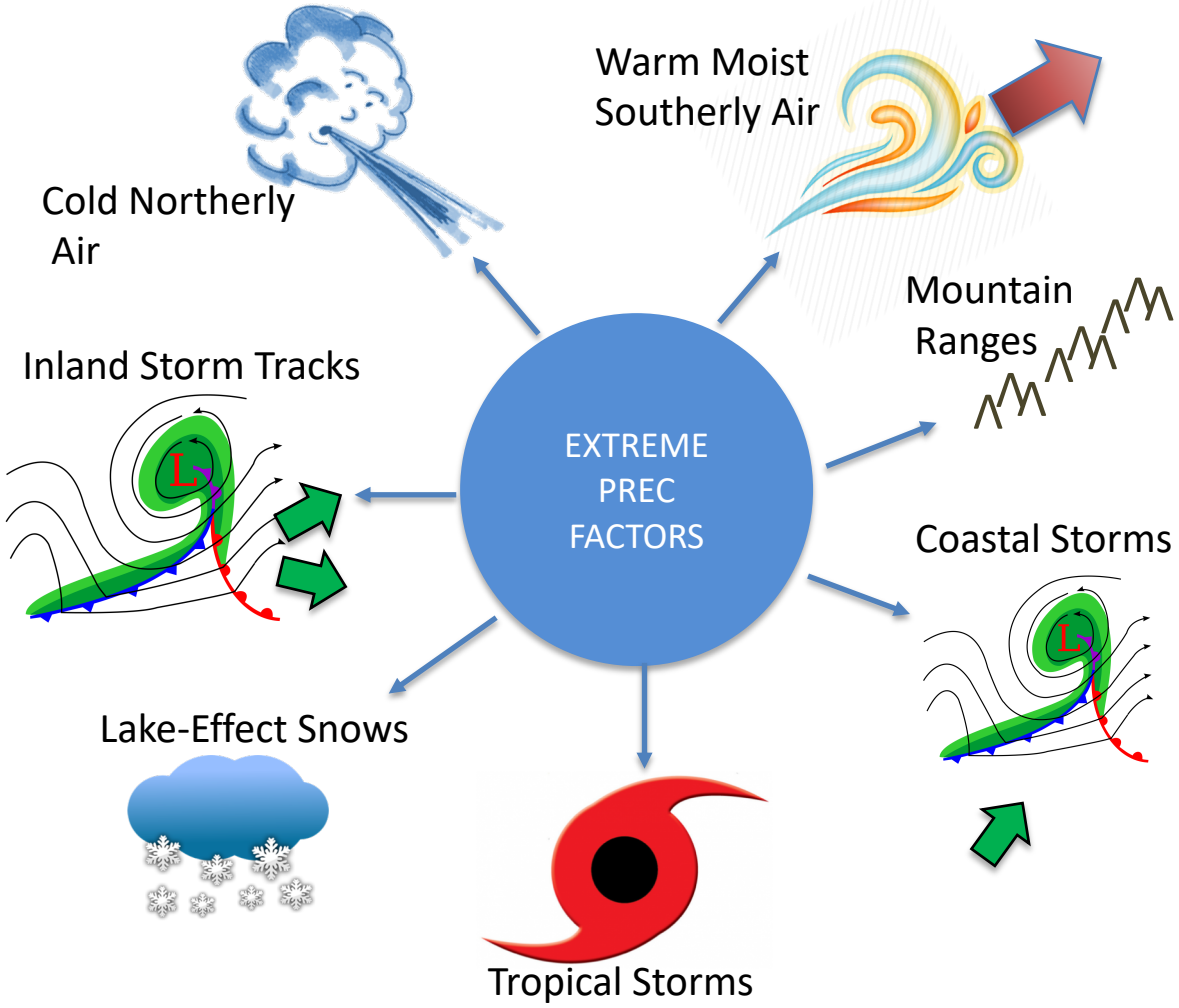


Even more pronounced relationship in summer

- For this particular watershed, ~90% of high streamflow events are associated with extreme precipitation!
- Each watershed is different: ~45% of Charles River high streamflow events are associated with extreme precipitation

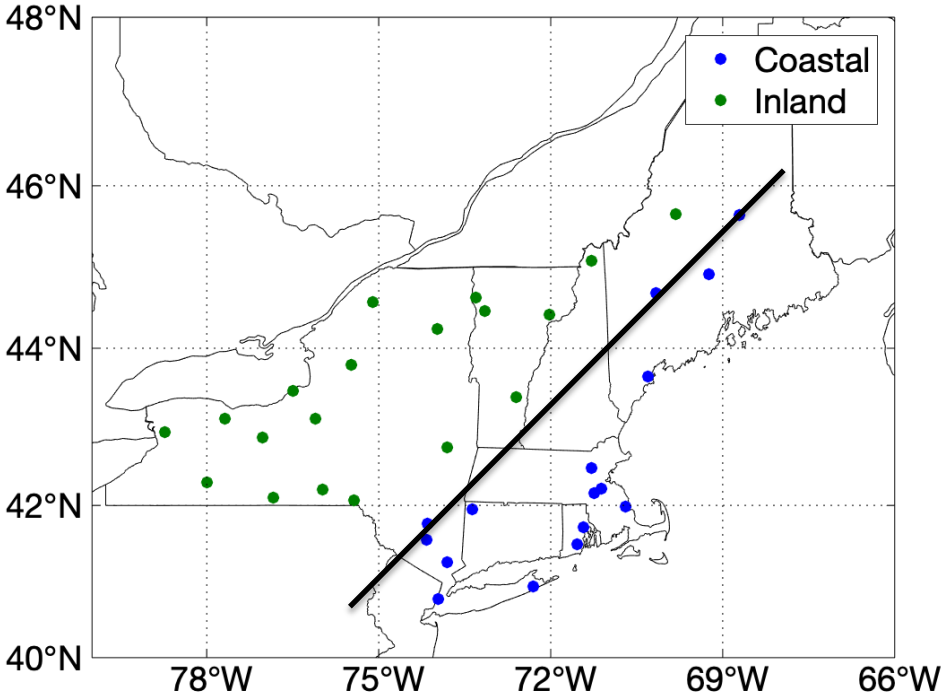
Agel et al. 2019

There are multiple mechanisms in the Northeast for creating precipitation, from tropical storms and mountains to lake-effect snows.



- Each of these factors is associated with extreme precipitation!
- However, the amount of extreme precipitation will vary depending on the location and the underlying cause

To the first order, we can separate the Northeast into two regions to better understand the overall and extreme precipitation climatology.

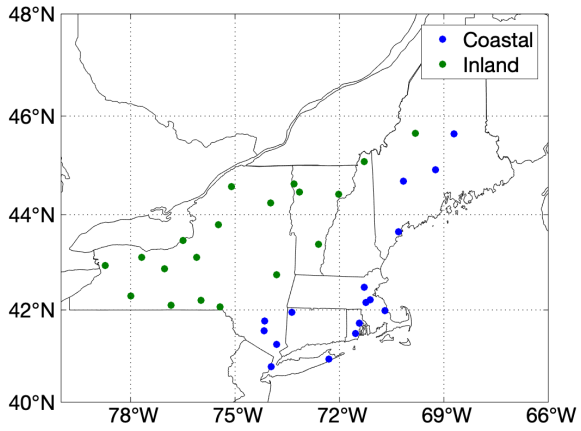


- NW to SE increase in precipitation amts
- Mean annual prec. ranges from ~35” (~900 mm) inland to ~52+” (~1325 mm) at coast
- Threshold for top 1% daily precipitation varies from 1-2” inland (~45 mm) to ~3+” (~75 mm) at coast

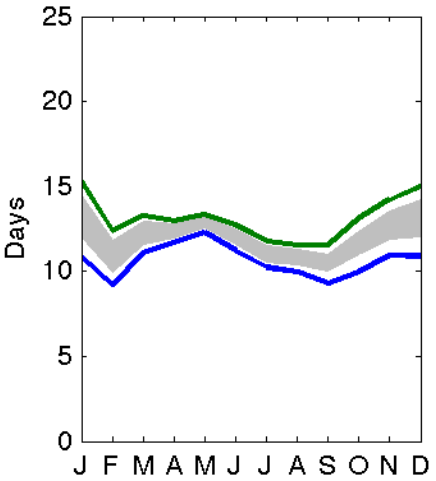
KEY POINT

- Helpful to separate coastal and inland climatology
- Strong NW to SE gradient for precipitation

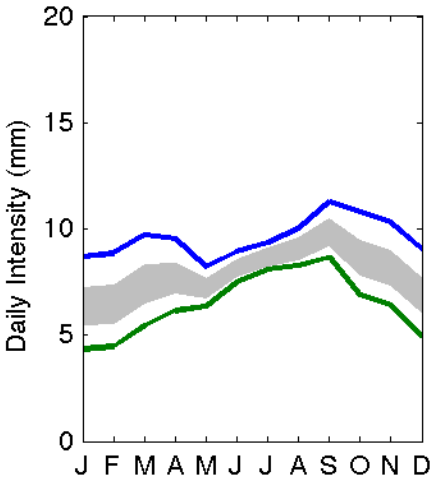
Agel et al. 2015



Monthly frequency



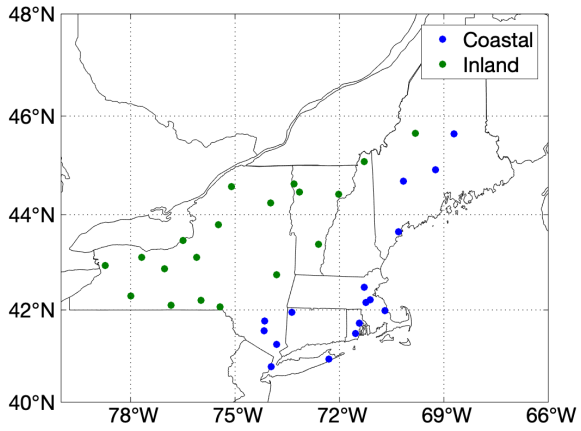
Monthly daily intensity



KEY POINT

- More frequent precipitation at inland locations, higher intensity at coastal locations

Agel et al. 2015



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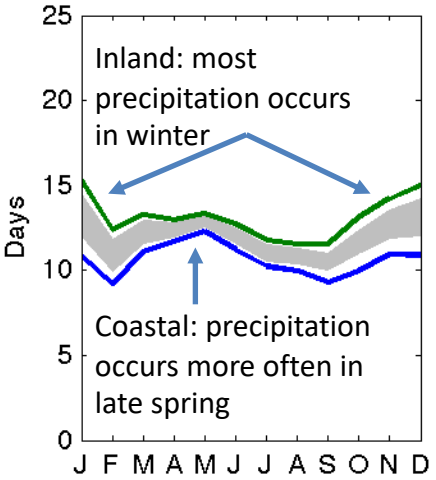

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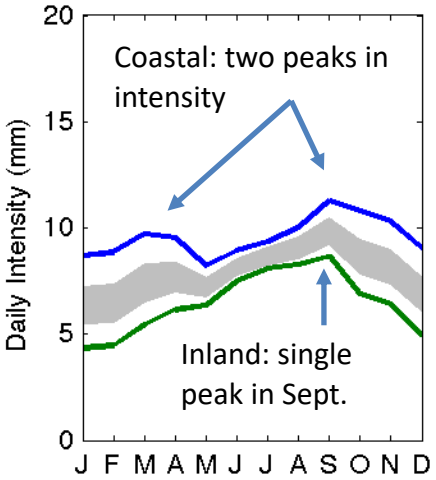
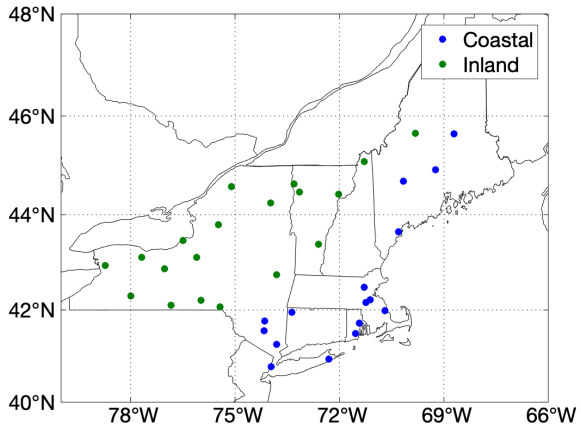


KEY POINT

- At inland locations, highest frequency in winter, but highest intensity in summer
- At coastal locations, highest frequency in spring, and highest intensity in spring and fall

Agel et al. 2015

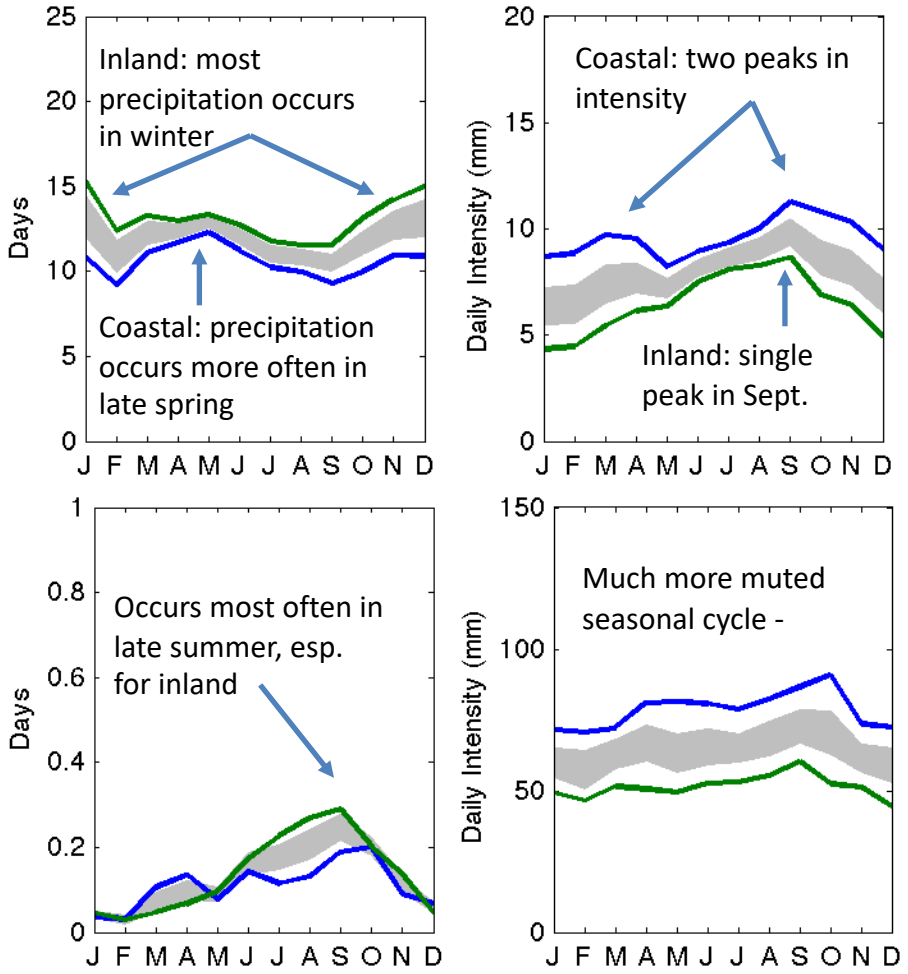


KEY POINT

- Extremes are more likely to happen at any time for coastal locations
- The intensity of extreme precipitation does not have a strong seasonal cycle: when it pours, it pours!

Monthly frequency

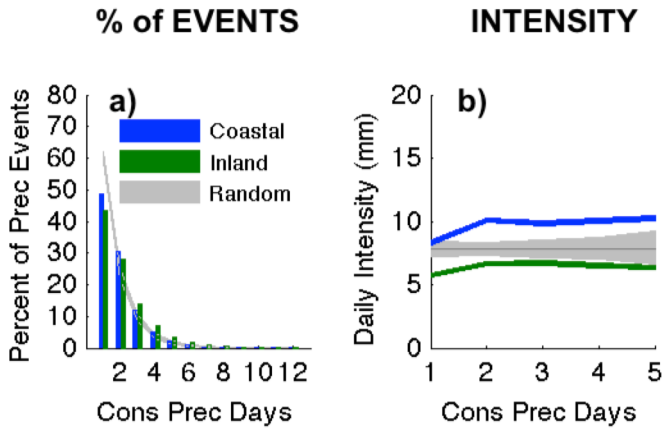
Monthly daily intensity



Extreme Precipitation

Agel et al. 2015

Duration

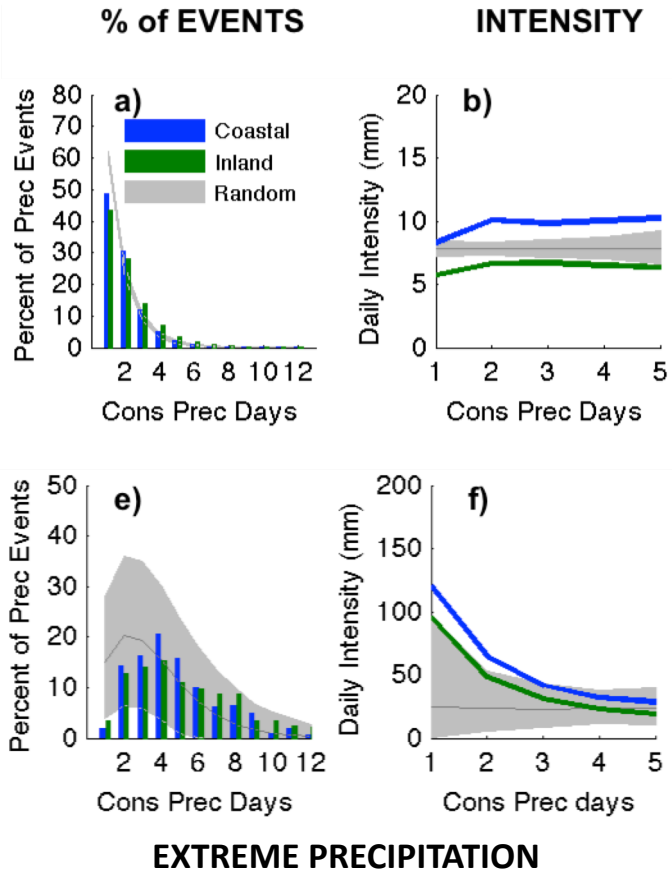


Overall Precipitation:

- Nearly 50% of precipitation occurs on a single day, another 45% or so over 2-4 days
- Consistent intensity for multiple-day precipitation

Agel et al. 2015

Duration



EXTREME PRECIPITATION

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KEY POINT

Extreme Precipitation:

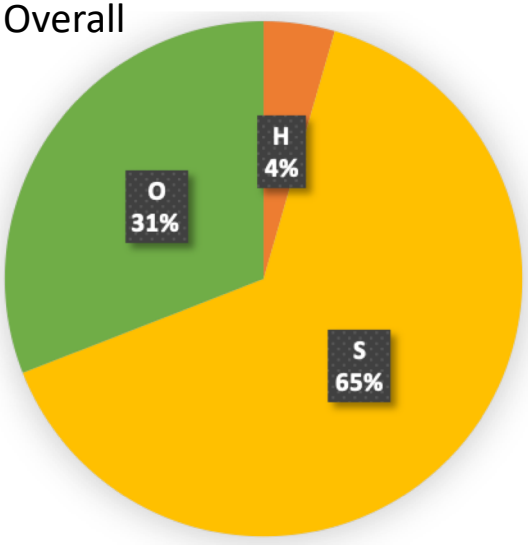
- Most extreme precipitation occurs within a 2-5 day precipitation event
- In a multi-day event, usually just one day is extreme
- Hourly data shows that most extreme precipitation falls within a 1–3 hour window

Agel et al. 2015

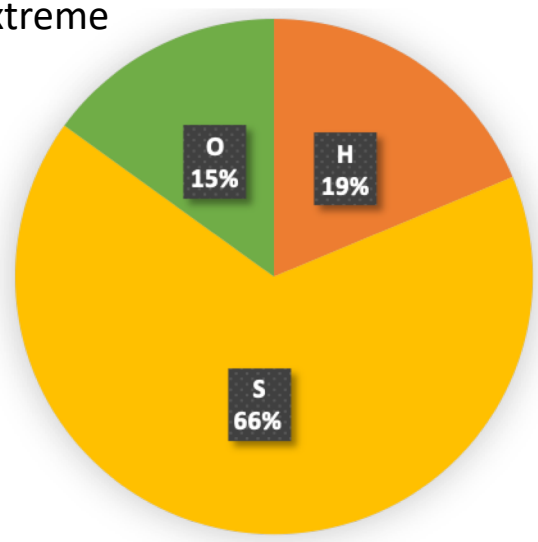
Three main categories for the Northeast:

- tropical storms (H)
- extratropical storms (S)
- other – detached fronts, convection, … (O)

Overall



Extreme



KEY POINT

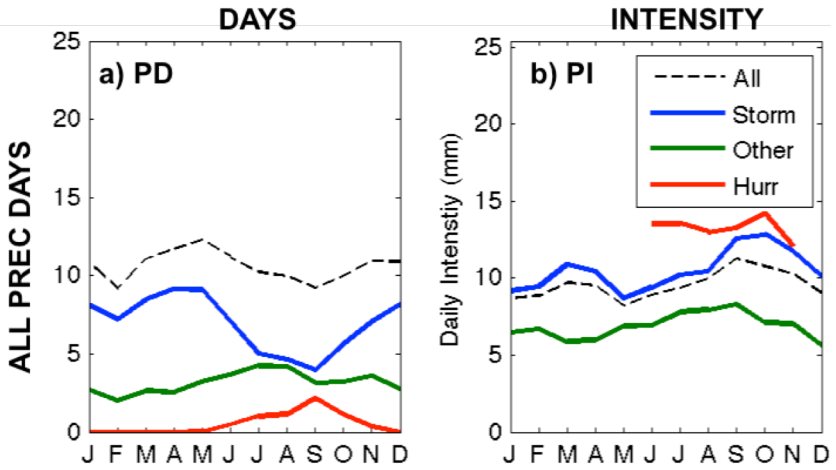
Both extratropical and tropical storms are the largest players for extremes

Agel et al. 2015

Coastal locations:

- Overall seasonal cycle of intensity driven by storms (blue line, with two peaks)
- Bump in prec days in spring due to storms
- In late summer, frequency of storms drop off, but tropical cyclone-related precipitation (red line) picks up

Coastal



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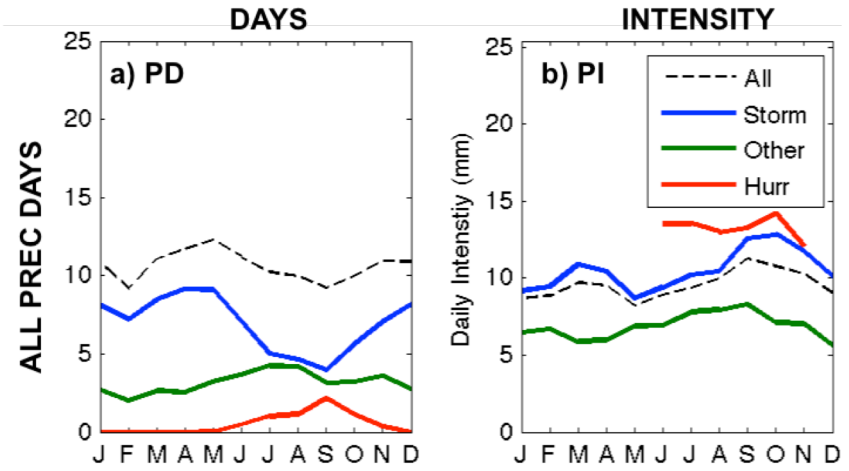
Inland locations:

- Same story

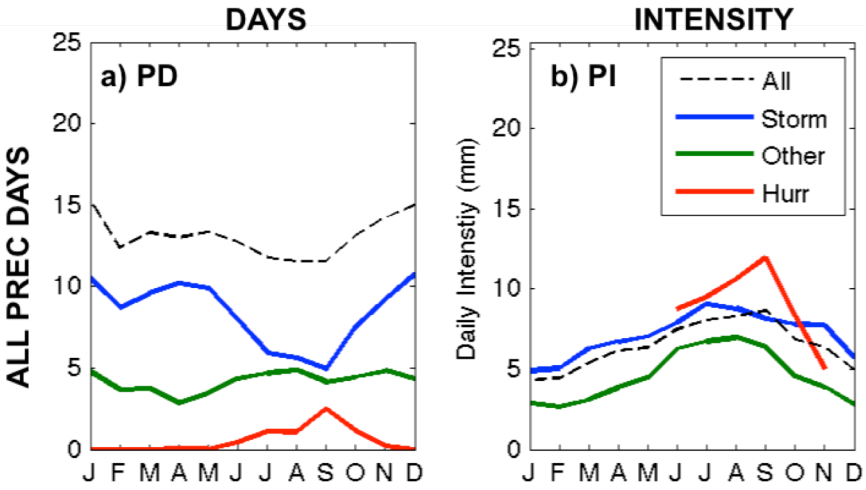
KEY POINT

Extratropical storms drive the seasonal intensity and spring frequency!

Coastal



Inland



Agel et al. 2015

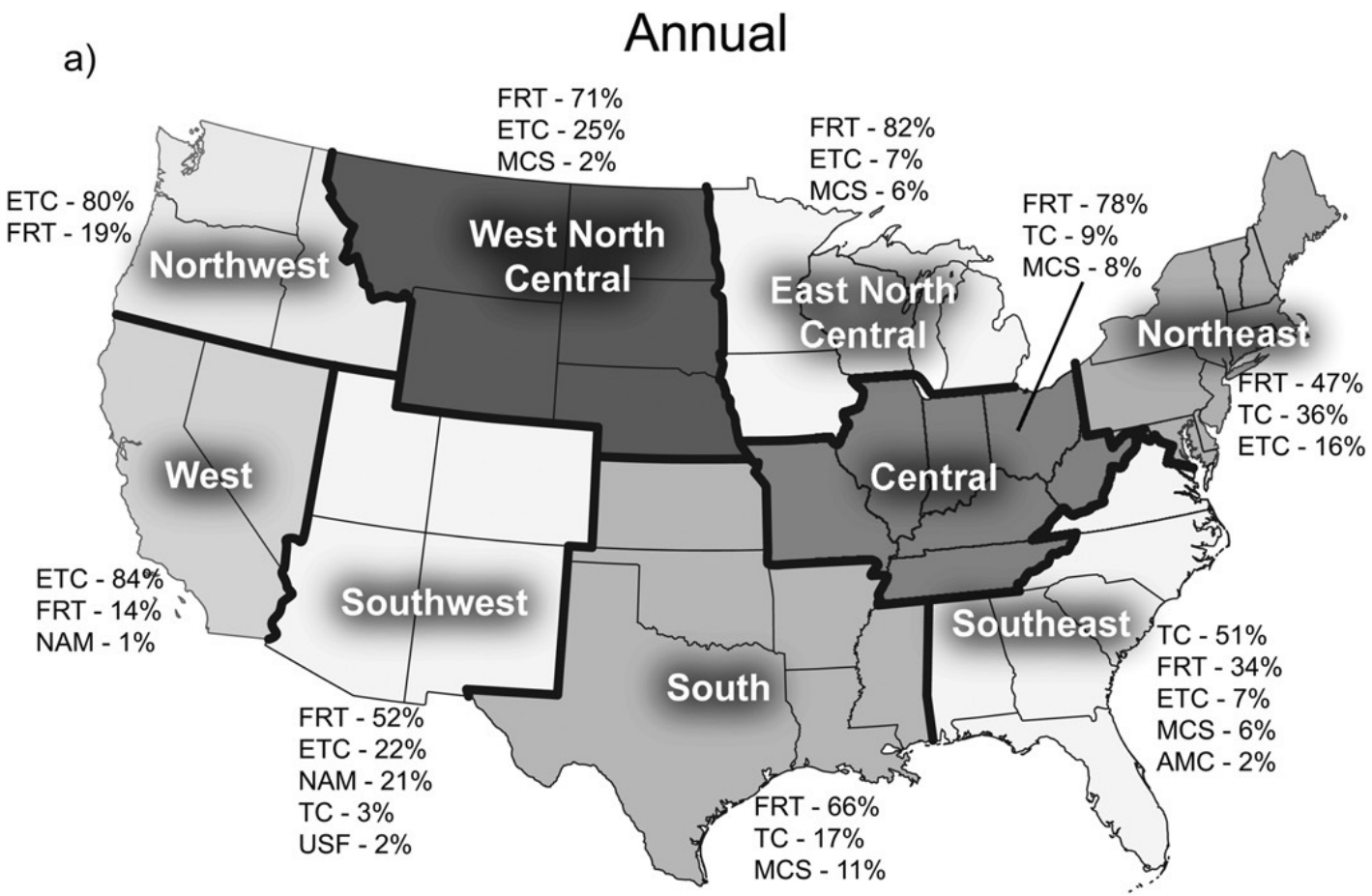
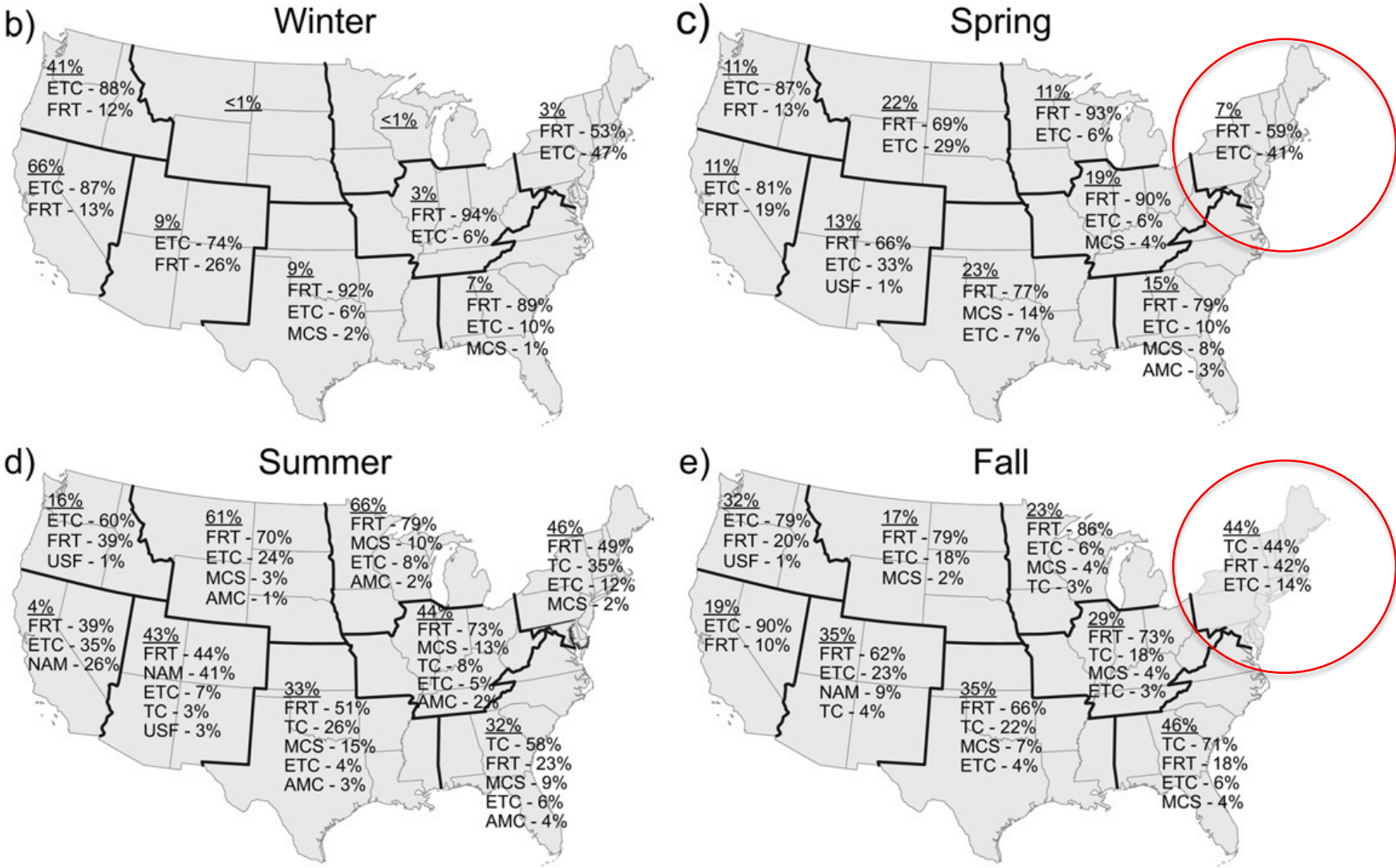


FIG. 5. Maps of regional and seasonal contributions of major extreme event causes for (a) annual, (b) winter [December–February (DJF)], (c) spring [March–May (MAM)], (d) summer [June–August (JJA)], and (e) autumn [September–November (SON)]. In the seasonal maps, the underlined values are the percentages of total events occurring in that season; the values next to the causes are the percentages of total seasonal number of events.

Kunkel et al. 2012



Kunkel et al. 2012

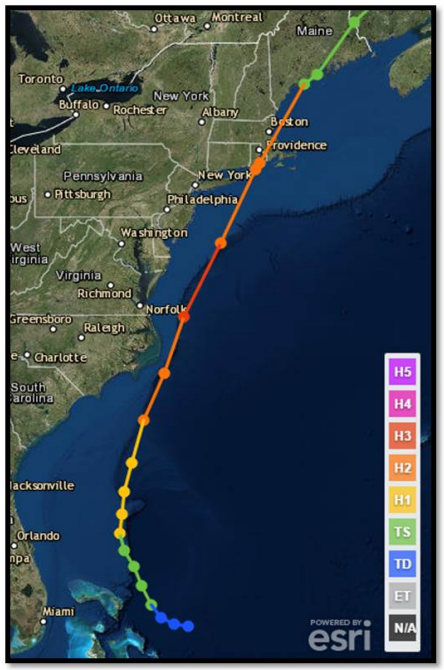
Tropical cyclones occur infrequently compared to extratropical cyclones, and are only relevant during late summer and early fall

- ~20% of top 1% precipitation is related to TCs (Agel et al. 2015)
- ~10% of top 5% precipitation is related to TCs (Collow et al. 2016)

Tropical cyclones generate the most extreme precipitation

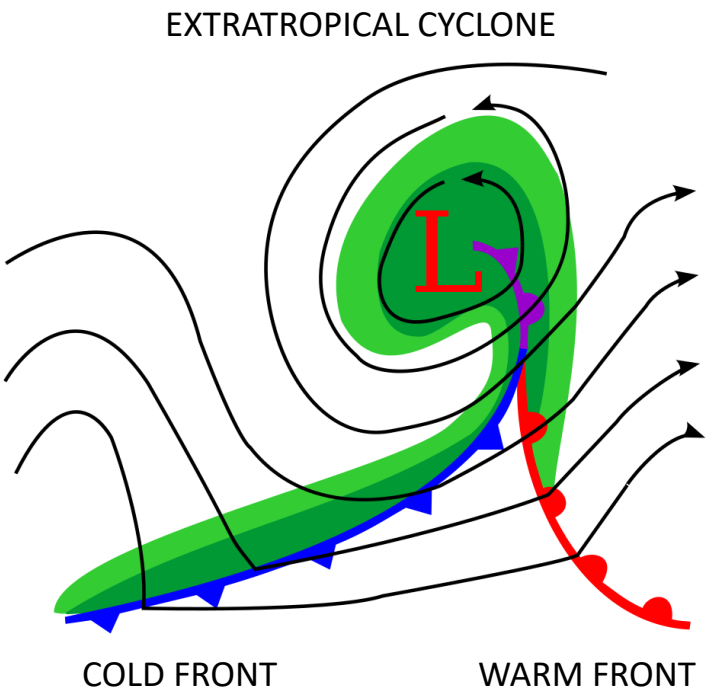
- Over 67% of 4+" days related to TCs, 1975-1999 (Barlow 2011)
- 10 out of 24 6+" days due to TCs, Jun-Oct 1979-2014 (Howarth et al. 2019)

Hurricane Bob, 1991



KEY POINT

Tropical cyclones are responsible for many of the largest extremes, but not the most extremes



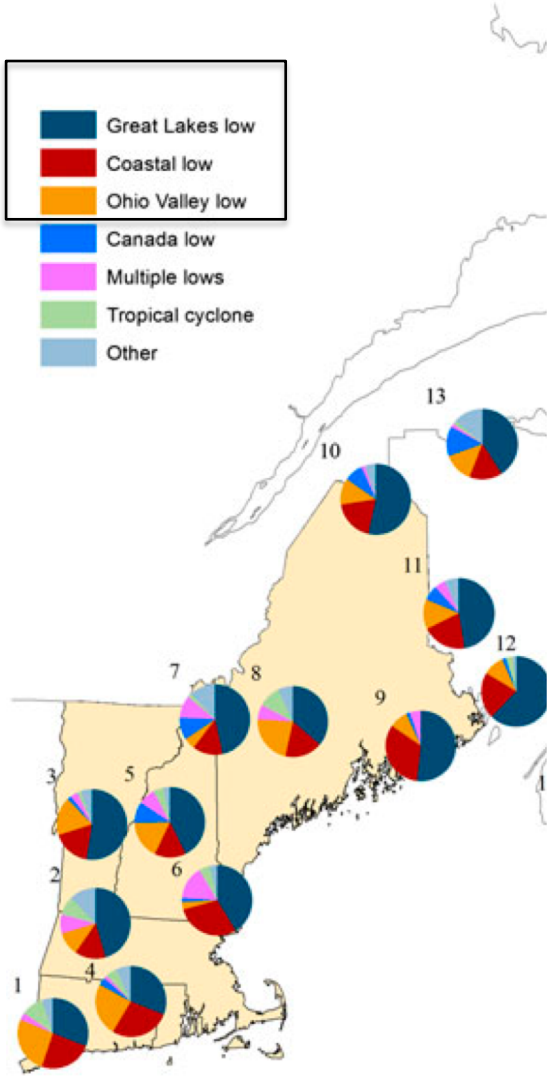
Extratropical storms are associated with the majority of extreme precipitation days

Within **extratropical storms,** the main producers of extreme precipitation are **cold** and **warm fronts**

- Globally, 75% of mid-latitude extreme precipitation is associated with fronts (Catto and Pfahl 2013)
- Warm fronts are especially important: ~40–50% of extreme precipitation occurs with nearby warm fronts in the Northeast (Catto and Pfahl 2013)
- Combination of a cyclone and a front is the most common cause of extreme precipitation in the Northeast (Dowdy and Catto 2017)

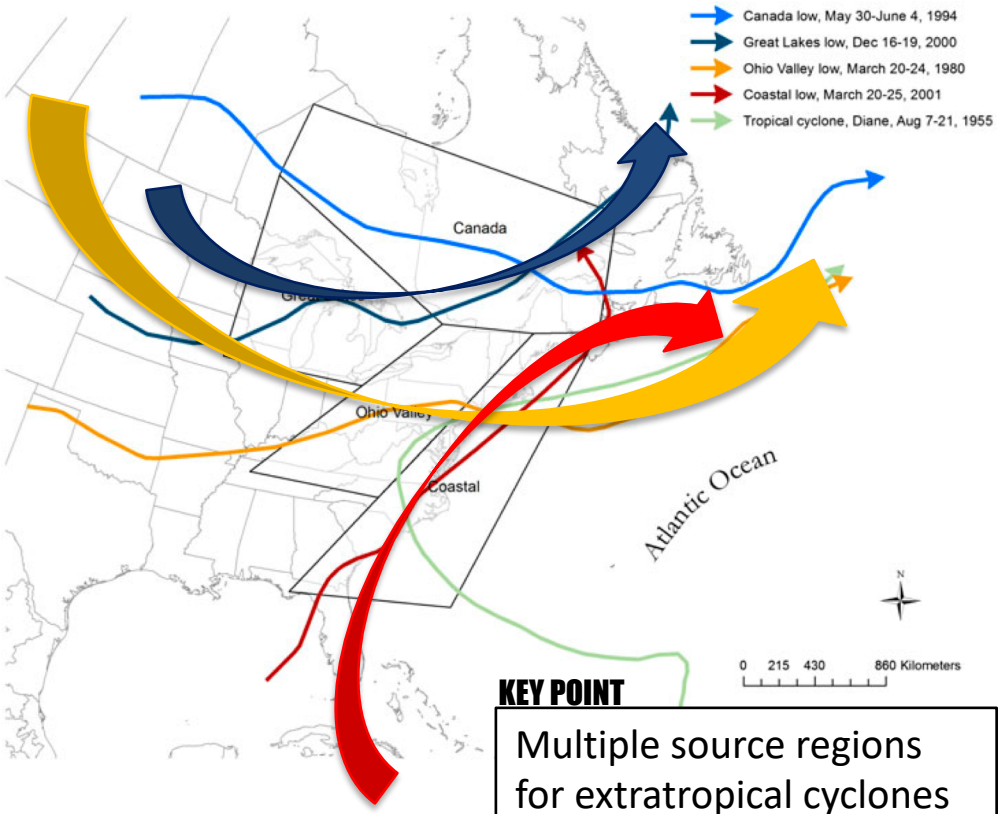
KEY POINT

Fronts associated with extratropical cyclones are the leading cause of extreme precipitation



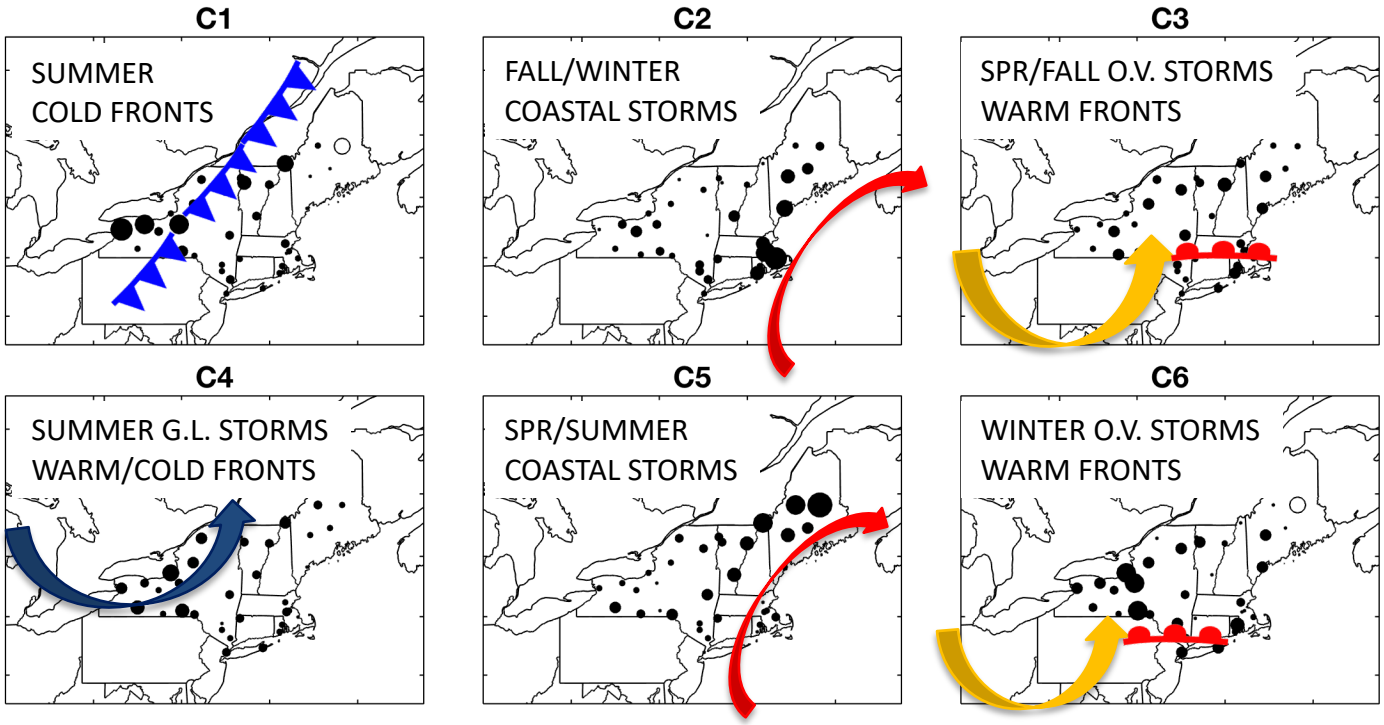
Collins et al. 2014

Extratropical storms associated with annual floods in the easternmost regions of the Northeast come from three main source regions.



KEY POINT

Multiple source regions for extratropical cyclones that produce extreme precipitation



- Separate non-tropical extreme precipitation days into 6 dynamical categories based on upper-level circulation
- Specific mechanisms associated with extremes in certain locations

KEY POINT

Given a particular location and season, certain dynamical processes may be more likely to be associated with Northeast extreme precipitation

Agel et al. 2017, 2018

Most important take-aways:

- Large northwest-to-southeast gradient in extreme precipitation intensity (separate coastal and inland climatology)
- Extreme precipitation can occur at any time of the year, esp. at coast
- At inland locations, most extreme precipitation occurs in the late summer, due to extratropical storms and tropical cyclones
- At coastal locations, most extreme precipitation occurs in the spring (extratropical storms) and in late summer (due to both extratropical and tropical cyclones)
- Although tropical systems typically produce the most extreme precipitation, they account for relatively few of the number of extreme events
- Extreme precipitation tends to occur embedded in multiple-day precipitation events, as a several-hour event on a single day
- There are three main storm track patterns associated with extreme precipitation
- Frontal processes within extratropical systems are linked to the majority of extreme precipitation events (esp. warm fronts), but vary by location

Agel, L., M. Barlow, J.-H. Qian, F. Colby, E. Douglas, and T. Eichler, 2015: Climatology of Daily Precipitation and Extreme Precipitation Events in the Northeast United States. *Journal of Hydrometeorology*, **16,** 2537-2557.

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