Subseasonal to Seasonal Extreme Precipitation Events in the Contiguous United States: Generation of a Database, Climatology, and Characteristics

Ty A. Dickinson[1], Jason C. Furtado[1], and Michael B. Richman[1]
[1]School of Meteorology, University of Oklahoma, Norman, OK

Introduction

Extreme precipitation poses a substantial risk on life and property globally. Most current literature focuses on precipitation on lasting up to 3 days despite desire from stakeholders from a myriad of backgrounds (e.g., water resources, agriculture, energy) for tools at S2S timescales (14 to 90 days).

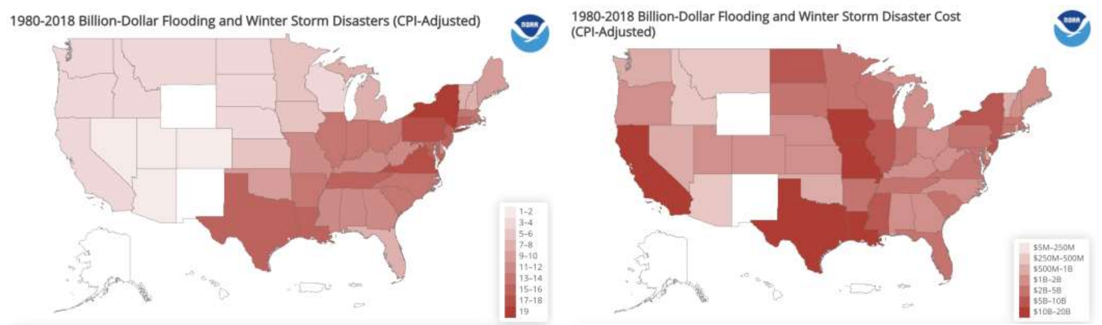

Figure 1: 1980-2018 CPI-Adjusted billion-dollar flooding and winter storm disaster (left) counts and (right) cost. Figures from NCEI.

Objective: Create a robust and adaptive methodology to identify S2S extreme precipitation events over the CONUS.

- ➢ **How does one define extreme over 14 days or longer?**
- ➢ **Are there preferred patterns for extreme rainfall on S2S timescales?**

Data

Precipitation:

- 1915 – 2011: Livneh (Livneh et al. 2013)
- 2012 – present : PRISM (Daly et al. 1994)
  - ➢ PRISM data bilinearly interpolated to Livneh grid
  - ➢ MAE $\mathcal{O}(10^{-2})$ for daily precipitation in all months

Atmospheric variables: ERA-20C (Compo et al. 2011)

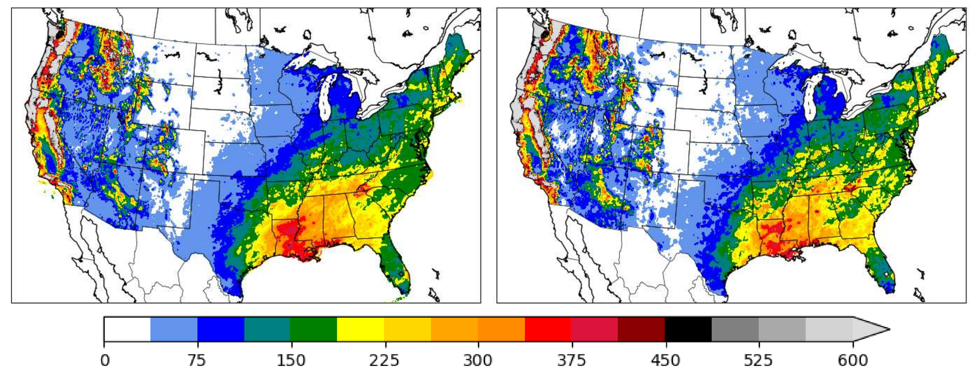

Figure 2: Comparison of the 95th percentile of January precipitation between PRISM (left) and Livneh (right). Amount is given in mm and is calculated for 2010 using a quantile regression model.

Defining an S2S Extreme Event

A given grid point is extreme if:

1. Observed 14-day precipitation exceeds 95th percentile.
   - ➢ Use quantile regression (Koenker and Bassett Jr. 1978) to model 95th percentile as a function of year.
2. Half of event duration (i.e., 7 days) receives above normal daily precipitation.
   - ➢ Normal = long term mean for all days in considered window.

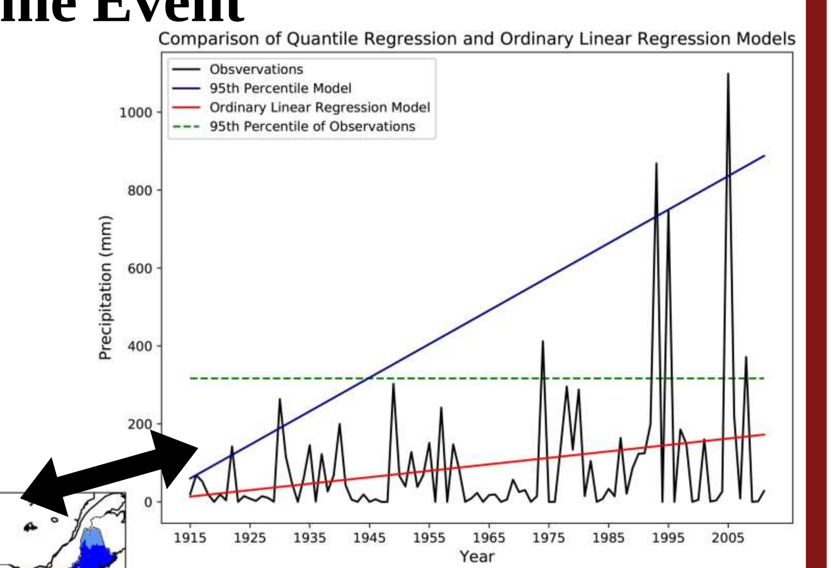

Figure 3 (above): Ordinary linear regression line (red) and quantile regression line (blue) fit on Livneh precipitation (mm; black). The QR line is fit on the 95th percentile; the green line depicts the time series' 95th percentile.

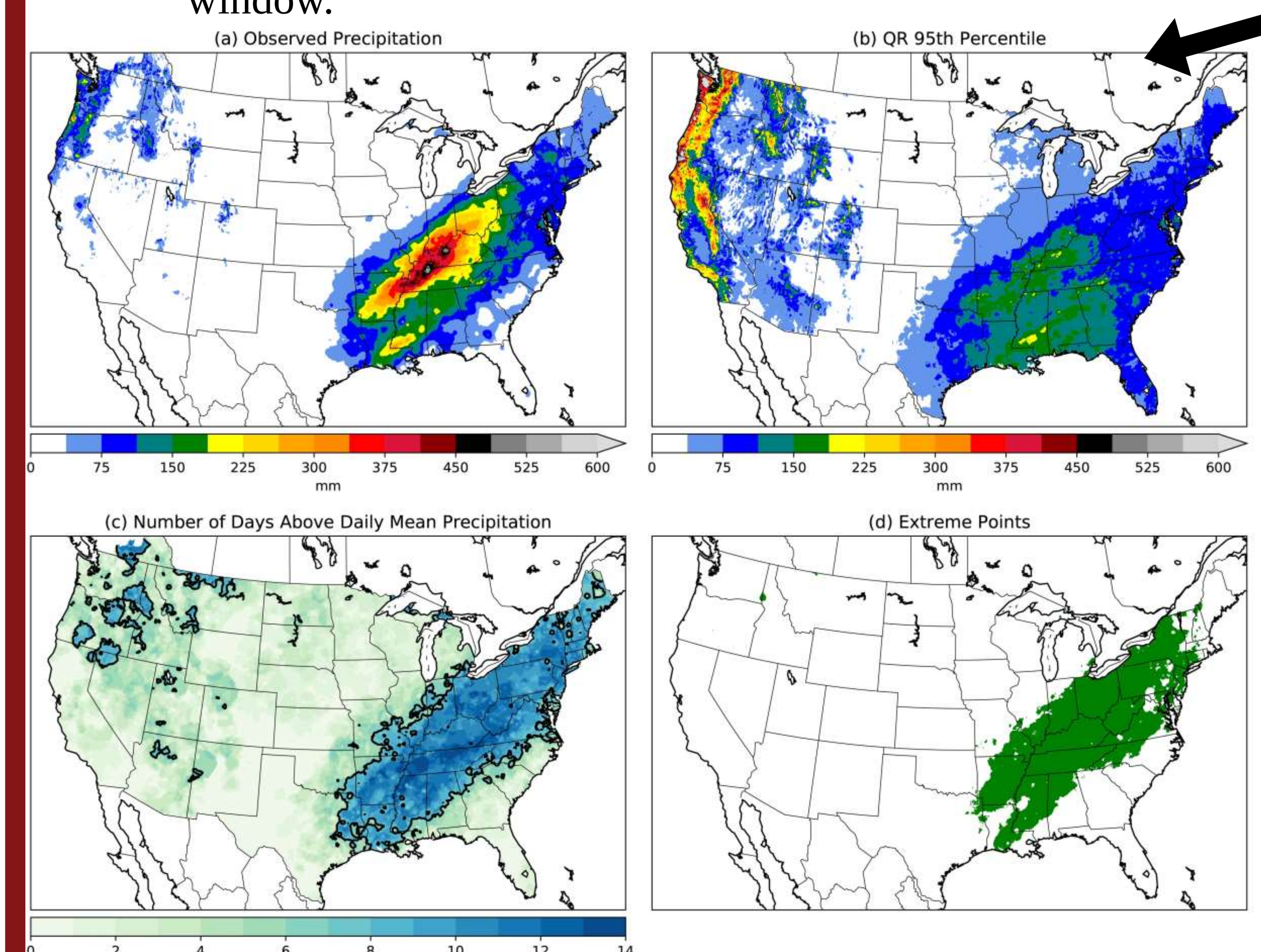

Figure 4 (left): Example 14-day event. Shading depicts (a) the recorded total precipitation (mm) between Jan. 12 and Jan. 25, 1937, (b) the 95th percentile calculating using quantile regression, (c) the number of days above mean daily precipitation, and (d) the points flagged as extreme. The black contour in (c) outlines the 7-day threshold.

Extreme points are gathered into a region using kernel density estimation (Rosenblatt 1956). The resulting density field is normalized by the maximum value, so each map has values in [0,1]. A polygon is developed using the larger of:

- ➢ 0.0865 (95th percentile of every possible density field).
- ➢ 90th percentile of local density field

Labeled as an extreme event if the area inside is ≥ 200,000 km².

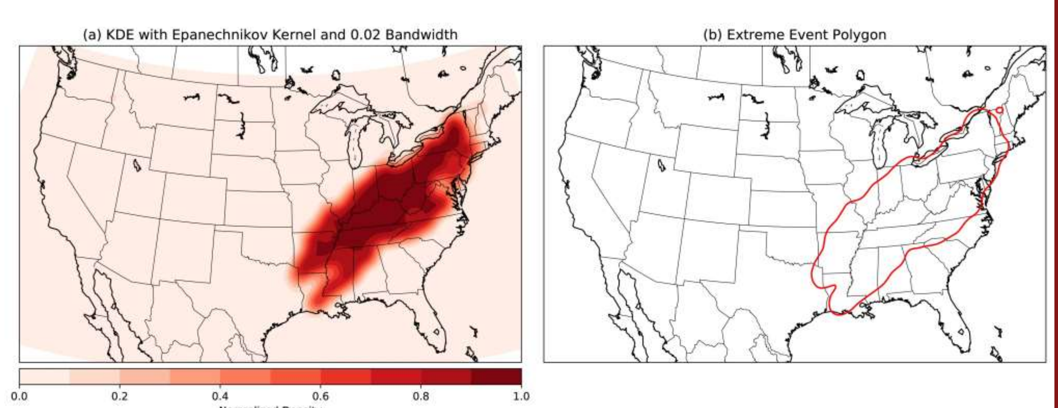

Figure 5: (a) Full normalized KDE density field fit using green points in Fig. 4d using the Epanechnikov kernel and the bandwidth set to 0.02. (b) Extreme event polygon developed using the 0.0865 contour.

Generating a Database

Every 14-day sliding window beginning 1/1/1915 through 12/31/2018 tested with all polygons meeting areal threshold written to text file. Need to postprocess the file to filter events such that remaining events are independent.

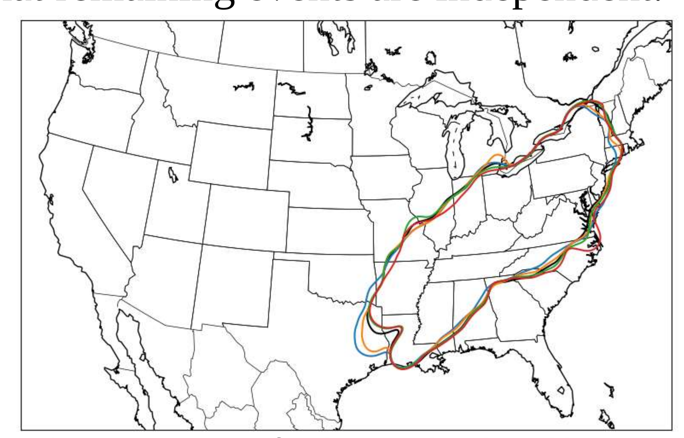

Figure 6: Series of polygons developed by changing start date of window by ± 2 days.

Groups of "similar events" are created by considering time and spatial correlation. **Two events are considered "similar" if their spatial correlation $r \geq 0.5$.** Then, we aim to choose the "most extreme" event of those in a group for the database. Define the total over extreme (TOE) as:

$$\mathrm{TOE} = \sum_{i=1}^{n} P_{total}^{i} - P_{q95}^{i}$$

14-day database: 5127 events

- ➢ Python program employed in analysis of windows is available on GitHub.
- ➢ Both preprocessed and postprocessed files available to stakeholders in .csv format; postprocessed database also available as .shp.

Spatial and Temporal Characteristics

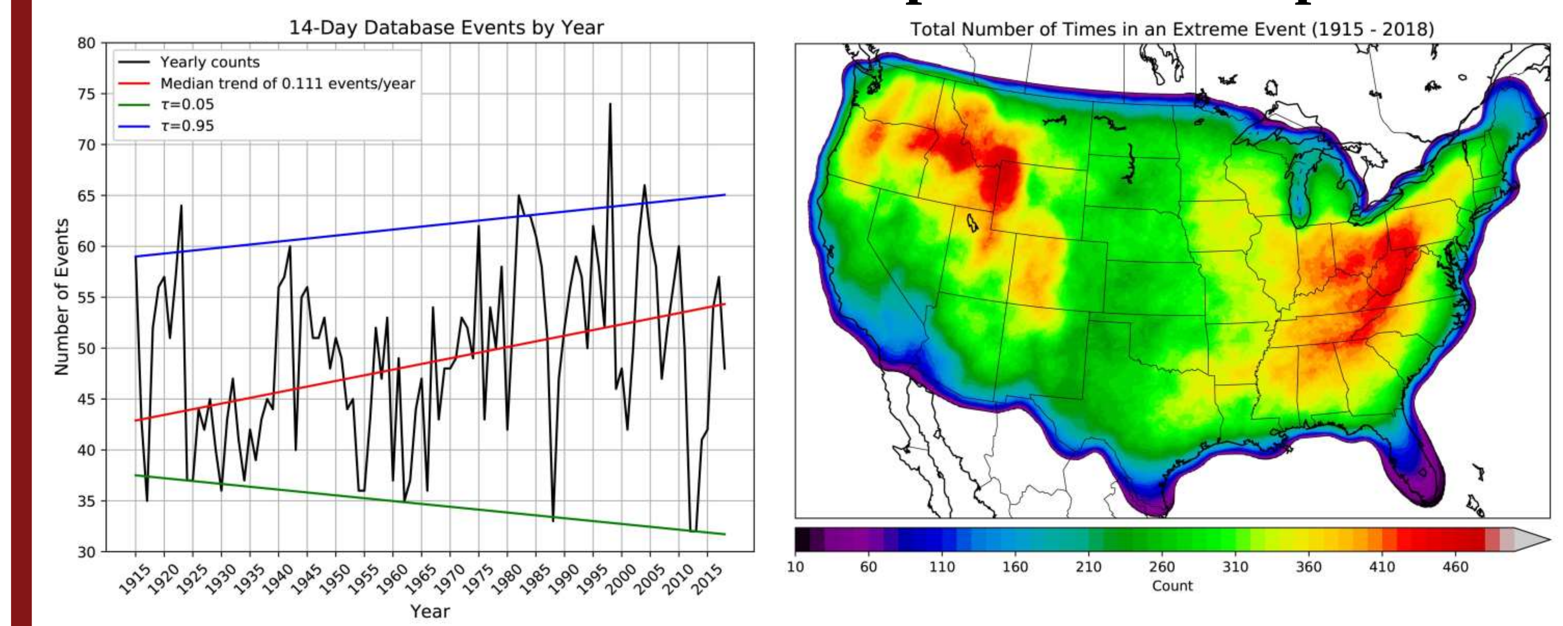

Figure 7: (left; black) Total number of recorded events throughout the CONUS. Quantile regression lines are fit on the (green) 5th percentile, (red) median, and (blue) 95th percentile. P-values for the 5th, 50th, and 95th percentiles are 0.052, 0.0028, and 0.089, respectively, calculated by bootstrapping the counts with 10,000 iterations. (right) Total number of times each grid point was inside an extreme event polygon between 1915 and 2018.

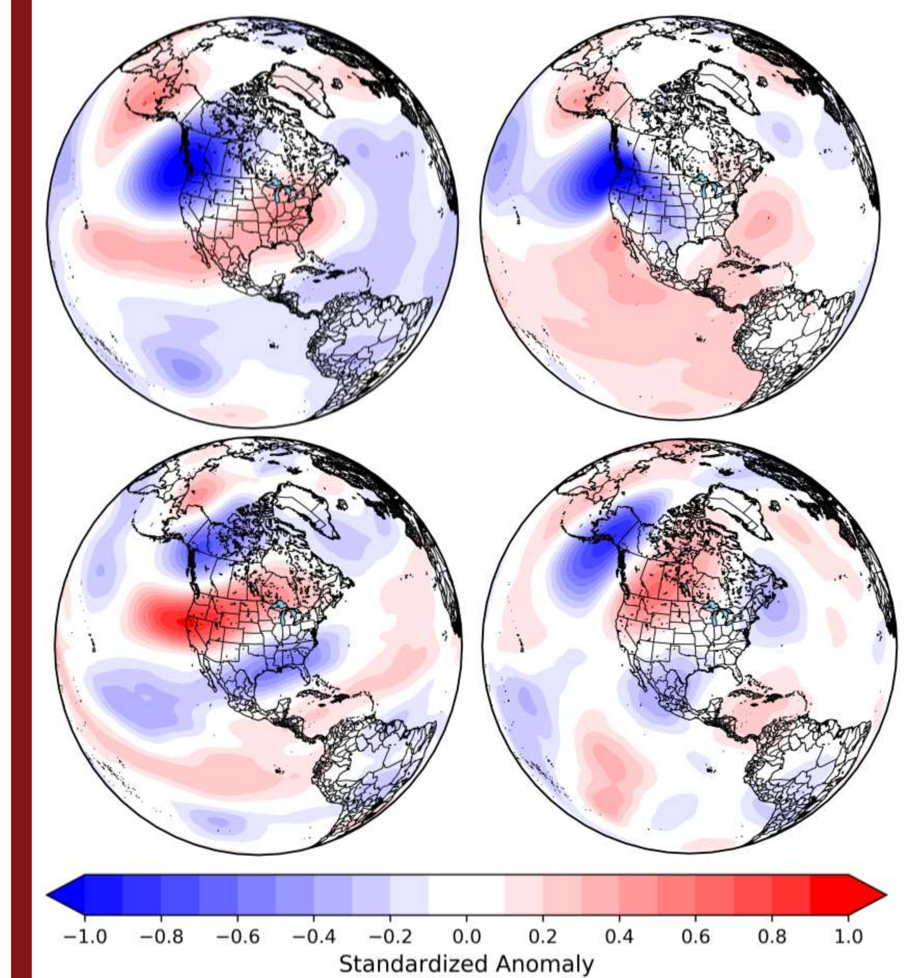

Figure 10: Composites for the top 25 events in large cluster 1 sorted by TOE. Variables are daily (top left) 500 hPa geopotential height, (top right) mean sea-level pressure, (bottom left) 200 hPa u-wind, and (bottom right) 200 hPa v-wind. All variables were detrended (1900 – 2010) and standardized by dividing by the detrended standard deviation.

KEY POINTS

- ➢ Quantile regression shows median number of events CONUS-wide increasing; interannual variability also increasing
- ➢ Although spatial counts are continuous within CONUS, the border is one boundary we cannot remove when using Livneh, PRISM
- ➢ Despite 21/25 events occurring pre-1981, composite patterns closely resemble those shown by Jennrich et al. (2020) for Pacific NW.

Small Events

- Small events = events with areas ≤ 375,000 km² (roughly the median).
- Events clustered into 22 regions using k-means.
  - ➢ 2263/2617 events grouped.
  - ➢ Average silhouette score = 0.1647.

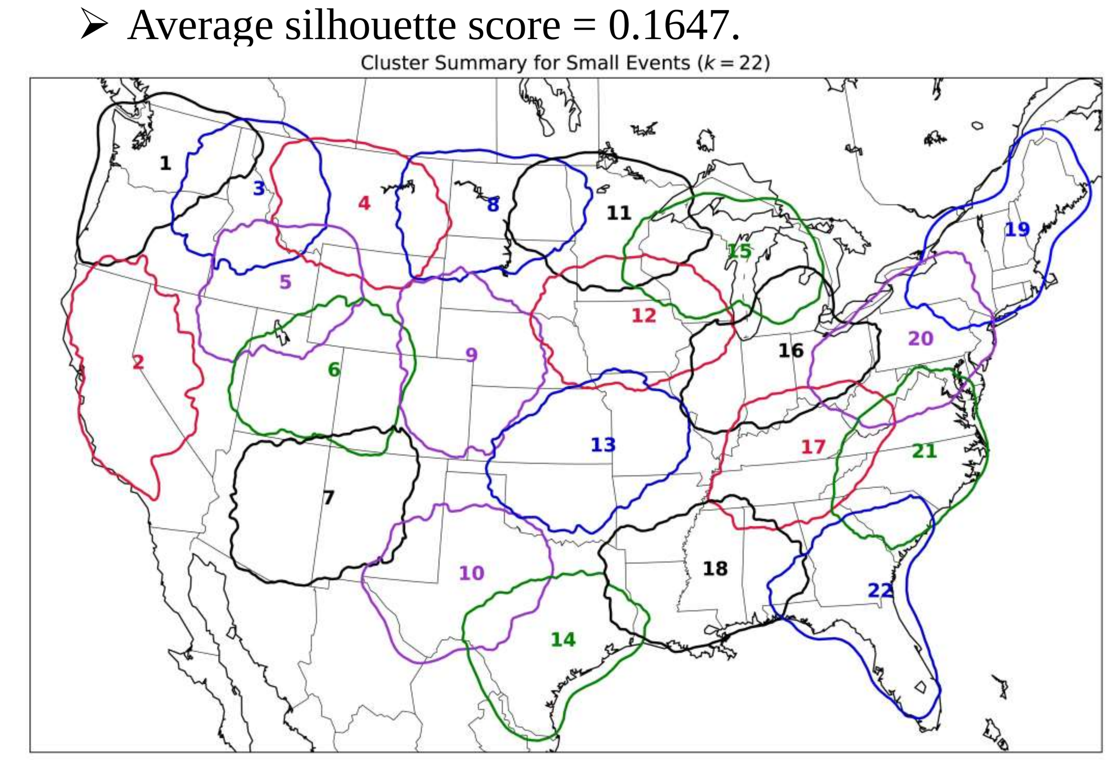

Figure 8: Composite cluster polygon for each cluster for small events.

Large Events

- Large events = events with areas > 375,000 km².
- Events clustered into 10 regions using k-means.
  - ➢ 2259/2510 events grouped.
  - ➢ Average silhouette score = 0.1456.

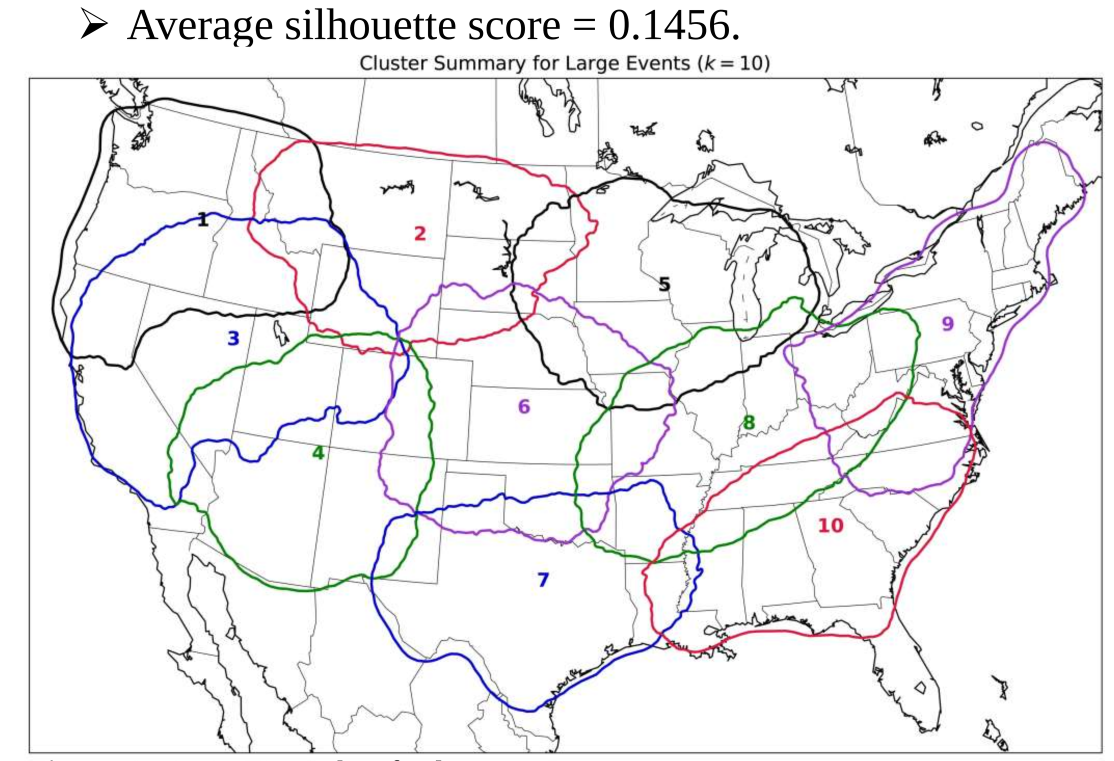

Figure 9: As in Fig. 8, but for large events.

Conclusions and Next Steps

- We define a 14-day extreme precipitation event as one that:
  - ➢ Exceeds the 95th percentile for the window,
  - ➢ Experiences above normal daily precipitation over at least 7 days, and
  - ➢ Exceeds 200,000 km².
- Identify a total of 5127 14-day events over the CONUS between 1915 and 2018.
  - ➢ Event ≠ societal impacts; total threshold relative to climatology
- Statistically significant trend in number of events per year suggests upper-tail of precipitation changing nonlinearly.
- Integrate synoptic precursors and characteristics (e.g., Jennrich et al. 2020) and stratiform vs. convective research (Bunker et al. 2020) to build statistical model, determine upper limits of predictability of S2S extreme precipitation.

References

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Contact: ty.dickinson@ou.edu