Classification of Meteorological Influences Surrounding Extreme Precipitation Events in the United States using the MERRA-2 Reanalysis

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Background

• Extreme precipitation = Day with > 95\textsuperscript{th} percentile of precipitation according to CPC gridded gauge observations

• Can lead to flooding, infrastructure damage, spread of vector borne disease, crop loss, economic damage, fatalities...

(https://www.ncdc.noaa.gov/billions/)
What is behind the interannual variability and trend?

Based on CPC 0.25° Gridded Gauge Observations

Manual analysis of event attribution by Kunkel et al. (2012) – Subjective, tedious, and time consuming
Modern Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2)

- Spatially and temporally consistent view of the weather with the help of over 62 billion observations and a single version of an atmospheric model
- Hourly information dating back to January 1, 1980 through 2 weeks behind near real time
- Main goal: Connect the analyzed large-scale weather association with historical extreme events to better forecast and prepare for future extremes
TempestExtremes

- Feature tracking algorithm developed under PI Paul Ullrich (UC Davis)
- Searches for minima/maxima and merges hits together in time and space
- Used here for closed lows but can also detect tropical cyclones, blocking, and atmospheric rivers

A closed low must have...
- Closed contour in SLP below 1008 hPa
- Negative anomaly in 500 hPa height
- Persisted for at least 24 hours
- Spent at least 24 hours at points with topography below 5,000 m
- Travelled a distance of 5 degrees
Summertime Extreme Precipitation Events Caused by a Closed Low in the Northeast U.S.

- TempestExtremes and a manual analysis give similar, but different results.
- Both are correct!
- Manual analysis allowed a closed low to also be defined as a closed contour in 500 hPa height.
- Manual analysis also filtered for tropical cyclones and frontal systems.
Years with more closed low events in TempestExtremes

- Manual analysis shows event is due to a warm conveyor belt/warm front
- TempestExtremes detects a closed contour in SLP within a cold front
Self Organizing Maps (SOMs)

- Unsupervised neural network approach that organizes a dataset into a grid of characteristic nodes
- Arbitrarily distributes nodes into the data space, iteratively adjusting the nodes to fit the distribution of the data space
- Treats the data as a continuum – event classifications are not always black and white

We tested various combinations of:
  - Input variables
  - Areal coverage
  - Iterations
  - Learning rates
  - Map Dimensions

But were happiest with the results using:
  - Anomalies of sea level pressure, 500 hPa height, and 250 hPa meridional wind
  - An area surrounding the region by 10 to 15°
  - 2 stage iteration process (rough, then fine)
  - Tens of thousands of iterations
  - 1x4 map
Cold Fronts
• Tropical cyclones appear in all four nodes
• Variables selected cannot distinguish between tropical and extratropical systems

Closed low pressure systems

Weak ETCs, warm fronts
• Is there a predictive capability if we include the day before an event occurs?

Mix of event types with strong onshore flow
Cold Fronts

• What if we remove tropical cyclones?

Closed low pressure systems

• Results are very similar -> most events are not tropical

Weak ETCs, warm fronts

• SLP anomaly weakens in node 1

Mix of event types with strong on shore flow

• Upper level anomalies change in node 3 north of the region
Take Home Messages:
• Two objective classification techniques were used to define attributions to observed extreme precipitation events in the northeastern U.S.
• Results from TempestExtremes were slightly different than a manual analysis, however encouraging
• SOMs had some skill with separating events by dynamical features

Moving Forward:
• Apply both techniques to other regions within the US
• Expand work with TempestExtremes to include blocking and atmospheric rivers
• Investigate predictability of events using SOMs