Regional and Seasonal Variations in Synoptic Scale Weather Patterns Associated with Extreme Precipitation across the Contiguous United States

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Introduction

- Synoptic scale weather patterns associated with extreme precipitation have regional and seasonal variations.
- This variation makes studies covering large geographical areas challenging.
- Here we present an approach to characterize variations in preferred patterns associated with extreme precipitation across the continental United States (CONUS).

Data

Modern Era Retrospective analysis for Research and Applications Version 2 (MERRA-2)[3] is used for precipitation (daily accumulation) and meteorological variables (daily average) for the period of 1980 - 2023.

Methodology

- Composites are created at each grid cell for days with precipitation >95th percentile of the daily non-zero precipitation distribution.
- All data within 3500 km of each grid cell are remapped to a radial composite to facilitate composite comparisons across the CONUS.



Fig. 1. Example: (left) composite sea level pressure anomalies for days above grid cell 95th percentile for the grid cell representing Portland, Oregon - marked by x. (right) Same data reprojected onto polar coordinate grid with a radius of 3200 km.

- Each grid cell's pattern are compared to a "grand composite" consisting of all composites (left column of **Fig. 3** panels) using pattern correlation and root mean square difference (right two columns).
- Multivariate k-means clustering is used to spatially group grid cells with similar composite patterns together (**Fig. 4** and **5**). Anomalies are standardized prior to clustering.

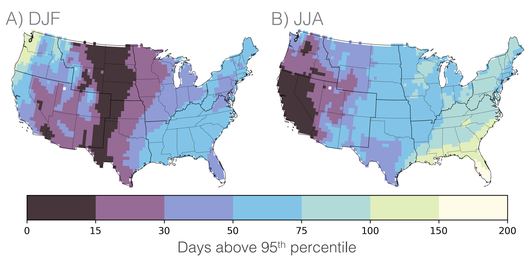


Fig 2. Number of days above grid cell 95th percentile for each meteorological season for the period 1980-2023, after the exclusion of days with total precipitation < 2mm.

3. Gelaro, R., McCarty, W., Suárez, M. J., Todling, R., Molod, A., Takacs, L., Randles, C. A., Darmenov, A., Bosilovich, M. G., Reichle, R., Wargan, K., Coy, L., Cullather, R., Draper, C., Akella, S., Buchard, V., Conaty, A., Silva, A. M. da, Gu, W., … Zhao, B. (2017). The Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2). *Journal of Climate*, *30*(14), 5419–5454. https://doi.org/10.1175/JCLI-D-16-0758.1

Measures of preferred pattern variation and strength

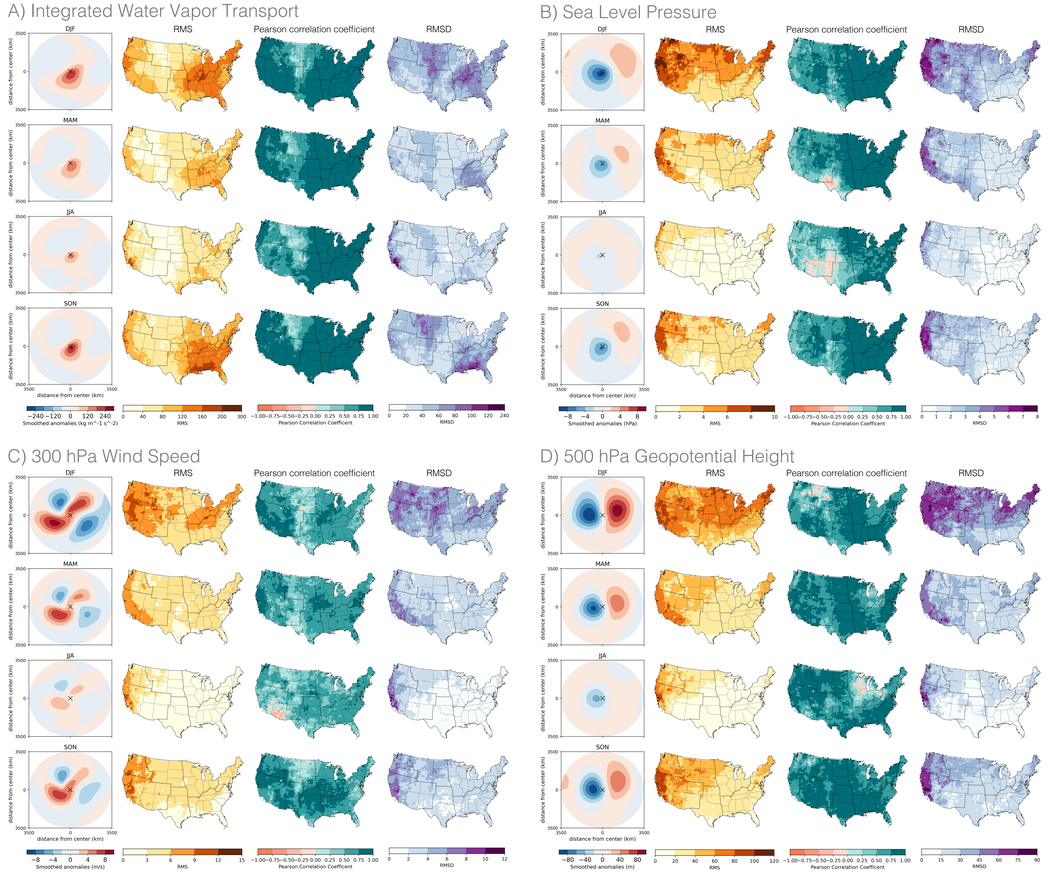


Fig. 3. Comparison statistics for all seasons for (a) IVT, (b) SLP, (c) H300 wind speed, and (d) Z500. Columns show (left) the grand composite, (second from left) the RMS of each grid cell's composite, (second from right) the pattern correlation between each grid cell's composite and the corresponding grand composite, and (right) the RMSD between each grid cell's composite and the corresponding grand composite. Seasons are standard 3-month meteorological seasons.

Key findings

- Results systematically identify regional variations in the atmospheric patterns associated with extreme precipitation across the CONUS.
- Distinct spatially coherent clusters of regions with similar atmospheric patterns are physically interpretable.
- Winter patterns are generally stronger than summer patterns when defined with the variables used here.

Multivariate clustering for identification of regions

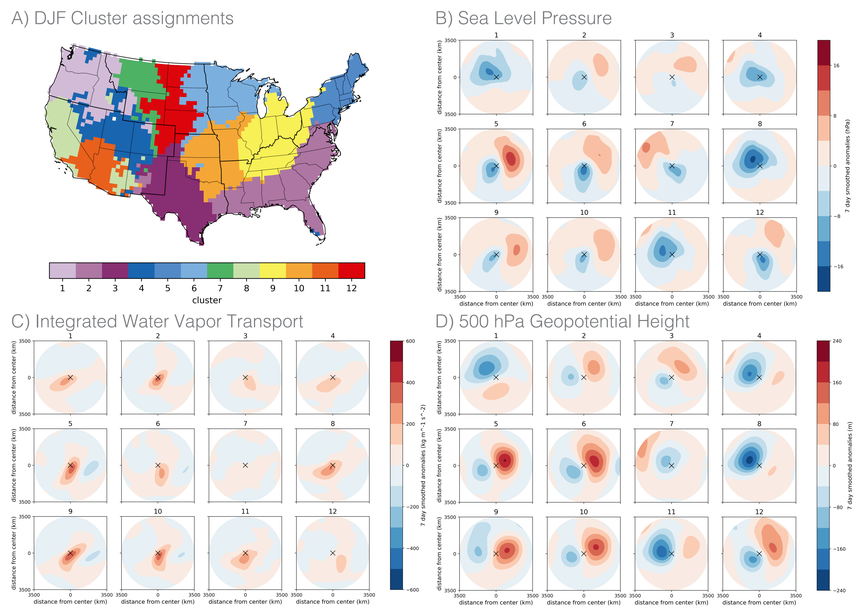


Fig. 4. (a) shows clusters generated using sea level pressure (SLP), integrated water vapor transport (IVT), and 500 hPa Geopotential Height (Z500) standardized anomaly composites. Panels (b) SLP, (c) IVT, and (d) Z500 show composites for clusters in (a). Grid cell radial composites are averaged to generate that cluster's composite, an x marks the center.

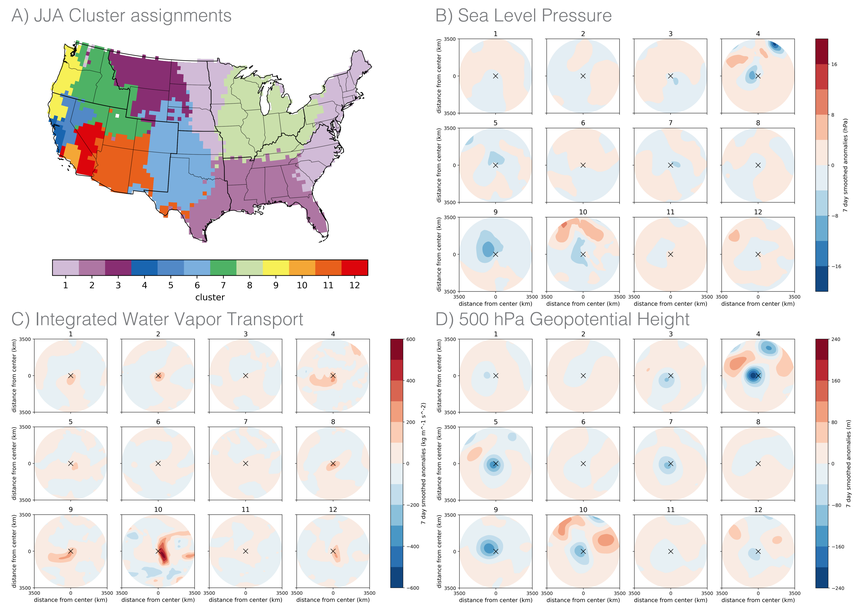


Fig. 5. Same as **Fig. 4** but for summer. Cluster 10 shows highly anomalous values in a region that has dry summers.

Future Directions

- Results provide an observational foundation for climate model evaluation.
- Methodology developed will be used to investigate projected changes in pattern characteristics and distributions under warming.

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