Statistical Modeling of Extreme Precipitation with TRMM Data

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9 January, 2018

Understanding the nature of extreme precipitation

- Scientifically important
- Significant real-world applications

Changes in precipitation extremes can produce dangerous socioeconomic conditions, particularly in vulnerable regions

- Syrian Drought, 2006 - 2011
- Hurricane Matthew, 2016
- Atlantic hurricanes, 2017

Key motivation for our work:

Effective modeling of extreme precipitation is integral for understanding the (changing) nature of extreme events

Presentation roadmap

1. Methodology
   - Data
   - Regional clustering
   - Point process characterization of extremes
2. Results
   - Return level estimates
   - Case study
   - Trends
3. Conclusion and future work

Data description and existing methodology

TRMM Multi-satellite Precipitation Analysis (TMPA)

Combines precipitation estimates from a variety of satellite systems

- Provides estimates at fine scales (3 hourly, $0.25^\circ \times 0.25^\circ$)
- Quasi-global coverage ($50^\circ S - 50^\circ N$)
- Estimates available in real time (3B42-RT) and post real-time (3B42) data products

Statistical framework of Zhou et al (2015)

1. Single-site framework
2. Fits GEV distribution to annual precipitation maxima
3. Cannot accommodate multiple extreme events per year

Regional analysis - combining data from similar sites

Pool data from regions where the underlying data generating processes are assumed to be the same

- Increases available data for subsequent model fitting

Recursive k-means clustering scheme to partition map

- Location, topography, 90^{th} percentile of precipitation values can be used as clustering inputs

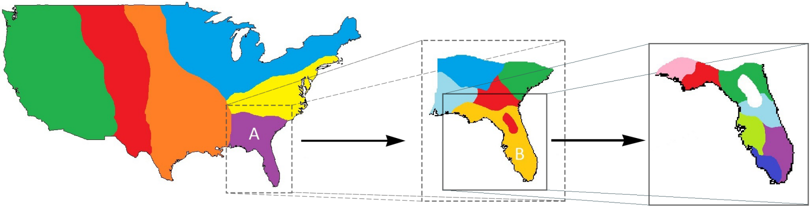


Figure 1: Illustration of clustering scheme

Statistical model of extreme precipitation intensity

- Define extreme events as those exceeding a pre-specified threshold; *peak-over-threshold (POT) approach*

Utilize the framework of **point processes (PP)** to model threshold exceedances:

1. More data than the annual maxima GEV approach
2. Can incorporate covariates into the analysis
3. Can model long-term trends, annual cycles
4. Likelihood function is parameterized in terms of the equivalent GEV parameters (easy to interpret)

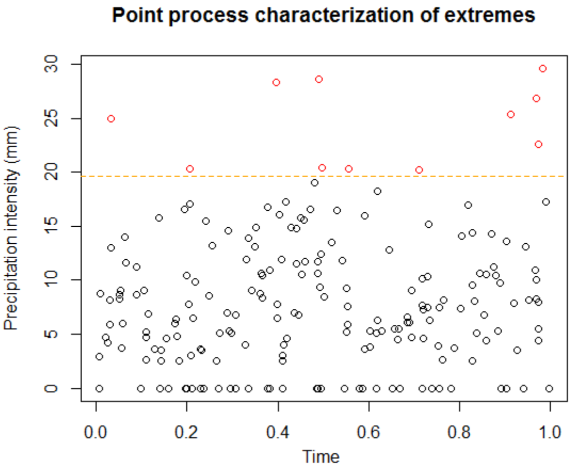


Figure 2: For large enough thresholds, the set of red points will approximately follow a Poisson point process

PP return levels resemble 64 year CPC-based levels

25 year return levels

1. Single-site GEV, TRMM data (**left**)
2. Pooled PP, TRMM data (**middle**)
3. Single-site GEV, CPC data (**right**)

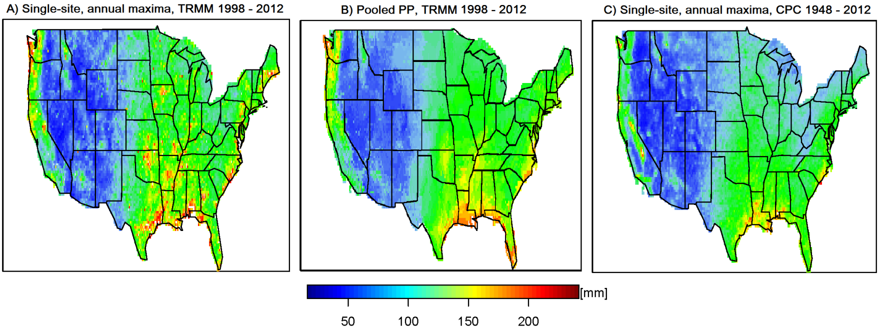


Figure 3: The PP return level map is smoother than the single-site GEV framework, capturing the general pattern in the CPC results.

We can model annual cycles in precipitation extremes

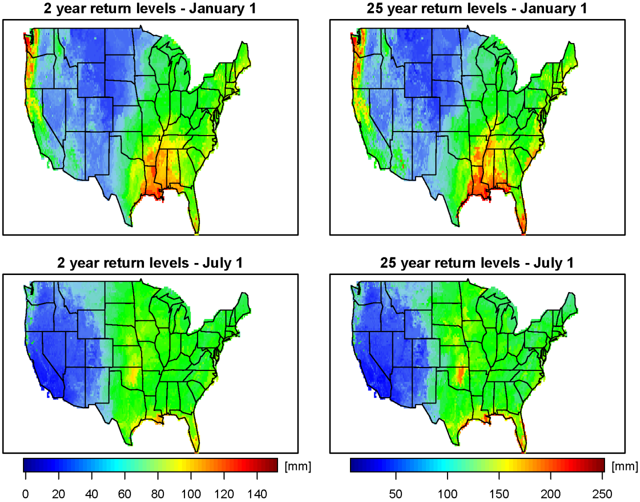


Figure 4: The west coast has higher return levels in January than in July; the return levels are relatively stable in the east coast.

Case study: Typhoon Fitow

- Strongest typhoon in mainland China in more than 60 years

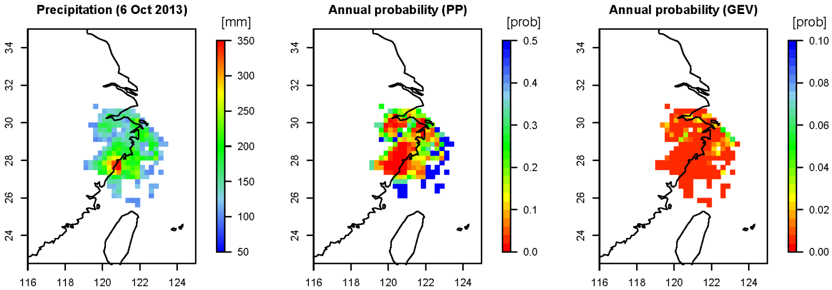


Figure 5: The pooled PP framework identifies 3 distinct regions of particularly rare precipitation intensity

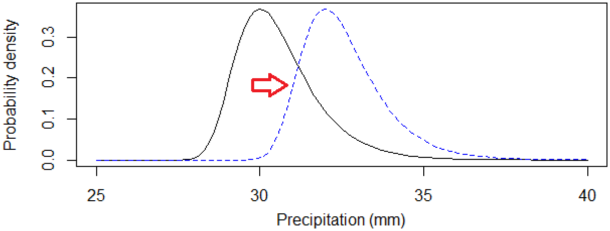
PP model allows for the analysis of trends

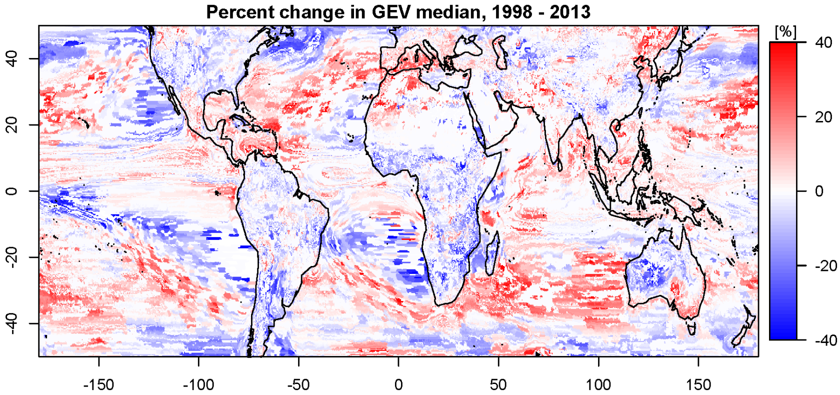
Simple starting point: model GEV location parameter μ as

$$\mu(time) = \mu_0 + \mu_1 \cdot time$$

How to visualize changes in extreme precipitation behavior?

- Measure the “shift” in the distribution of extreme precipitation intensities from 1998 to 2013
- Positive shifts indicate higher overall precipitation intensities





- **Increasing intensities**: tropical ITCZ, tropical Indian Ocean, Maritime continent, West Pacific warm pool, Caribbean and Gulf regions
- **Decreasing intensities**: tropical and subtropical land regions, i.e. South America, tropical and south Africa, north and west Australia
- Negative trends are also observed over most of CONUS, especially in the southwest US, contributing to the drying trend in the region

Summary

- Regional clustering algorithm with POT approach allows us to leverage more data than single-site block maxima method
- Return level maps based on PP model more closely resemble 64 year CPC gauge-based measurements
- Modeling annual cycles reveals significant variability in extremes throughout the year
- Significant spatial variability in changes in extreme precipitation intensity from 1998 – 2013

Future work

- Model multi-day cumulative precipitation intensity. Empirical data reveal significant multi-modality (mixture models)
- Model the spatial dependence in each cluster

Acknowledgments

- Yaping Zhou
- George J. Huffman
- Ying Nian Wu
- NASA Goddard Space Flight Center internship program
- Burroughs Wellcome Fund

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