Drivers of Extreme Rainfall:

Atmospheric Circulation Patterns and Regional Intense Rainfall in the Ohio River Basin

James Doss-Gollin
Columbia Water Center

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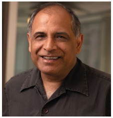
Oxford School of Geography and the Environment

Collaborators

Columbia Water Center (`water.columbia.edu`)

- David Farnham, co-author
- Upmanu Lall, supervisor & co-author



Beyond: Casey Brown, Caitlin Spence, Katherine Lownsbery of UMass Amherst – collaborators on project

Outline

1. Introduction
2. Intense ORB Rainfall
3. Active and Inactive Seasons in ORB
4. Wrap-Up
5. Future Work

Introduction

Motivation

1. Extreme flooding (at different scales, seasons, etc)
2. Dominant climate driver: future precipitation patterns

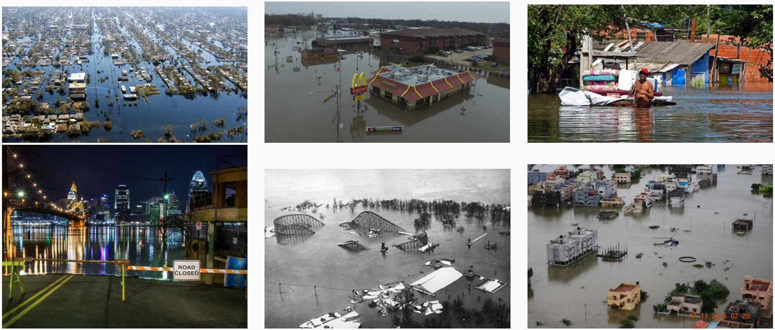


Figure 1: Source: Google Images

Statistical-Physical Modeling

Existing approaches:

GCM Downscaling currently precip may not be credibly simulated in GCMs – esp. local scales & extremes; downscaling struggles with spatial bias

Purely Statistical GEV stats: mechanism neglected – true distribution may be multi-modal, hard to understand

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Statistical-Physical Modeling:

1. *Identify driving mechanisms*
2. Model: $p(\text{precip}) \sim$ mechanisms
3. GCM, theory $\rightarrow$ project mechanisms into future
4. Using same model, (potentially) more credible $p(\text{precip})$

This Paper: Case Study

Ohio River Basin (ORB):

- high frequency of flooding, severe impacts
- extremes related to large-scale features, TME/ARs (i.e. Nakamura et al., 2012; Steinschneider et al., 2016; Lavers et al., 2013; Dirmeyer et al., 2009)

Cross-seasonal diagnostics → understand dominant mechanisms of intense precip in ORB

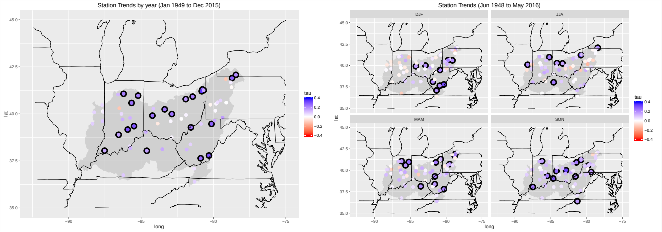

Figure 2: Trends in extremes by station

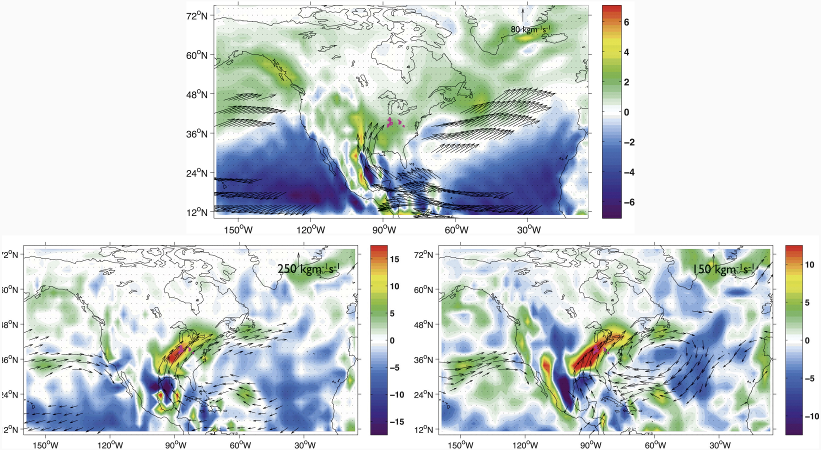

Figure 3: Nakamura et al. (2012) Figs. 1&3: Surface 600 hPa moisture flux (strongest 20% as arrows) and moisture convergence (mm d^{-1}) (colors). (Top): Climatology. (Bottom) (L/R) Full Field / Anomaly, April 18-27 2011

Intense ORB Rainfall

Data & Regional Extremes

GHCNv3 station precipitation data (Menne et al., 2012). Intense rainfall defined as:

- station scale: $>$ 99% of rainfall time series (all days)
- regional scale: $>$ 10% stations in ‘intense’

Climate fields from NCEP-NCAR reanalysis (Kalnay et al., 1996)

Hidden Markov Model (HMM) → transition matrix w/ latent states

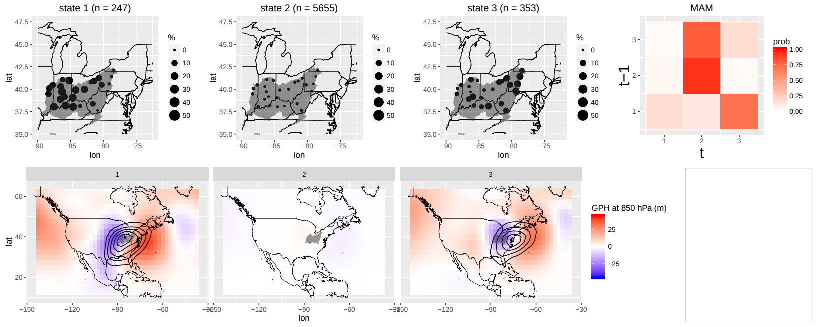

Figure 4: Spring (MAM) three state Hidden Markov model solution & composite PW, Z_{850}

Spatial Organization and Temporal Persistence II

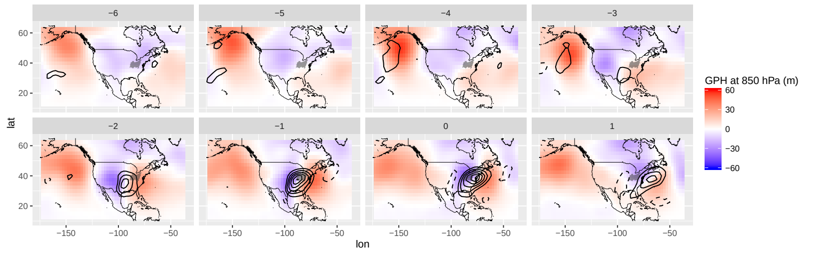

Figure 5: Z_{850}, PW evolution composite from -6 to +1 days of REP

Defining a Dipole Index

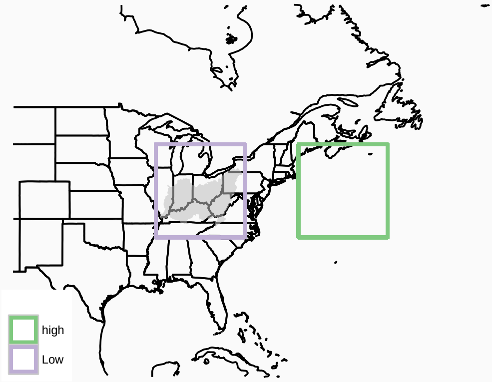

Figure 6: Dipole index: mean Z_{850} of “high” box minus mean of “low” box

Criteria: composite, “consistency” across seasons

Dipole Ramp-Up

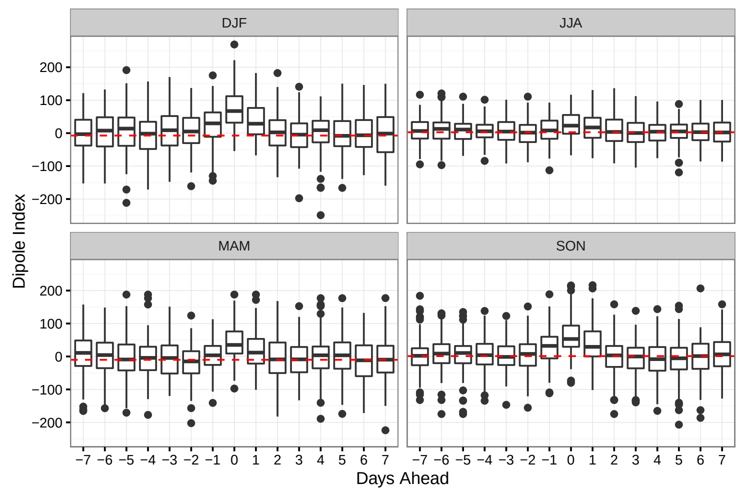

Figure 7: Ramping up of dipole index

Dipole "Inverse Probability"

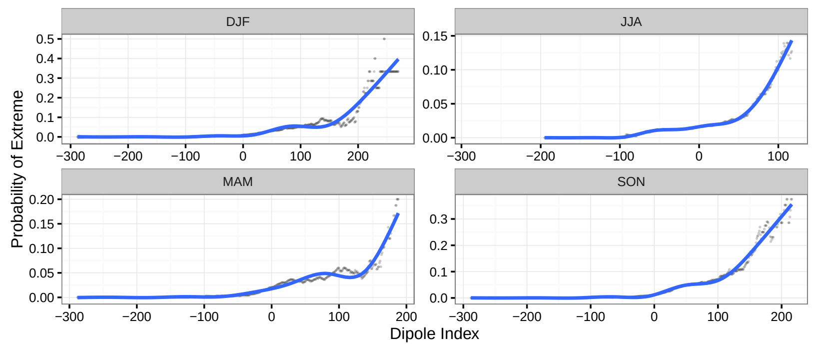

Figure 8: Conditional probability of extreme given dipole index

Limits to Predictability

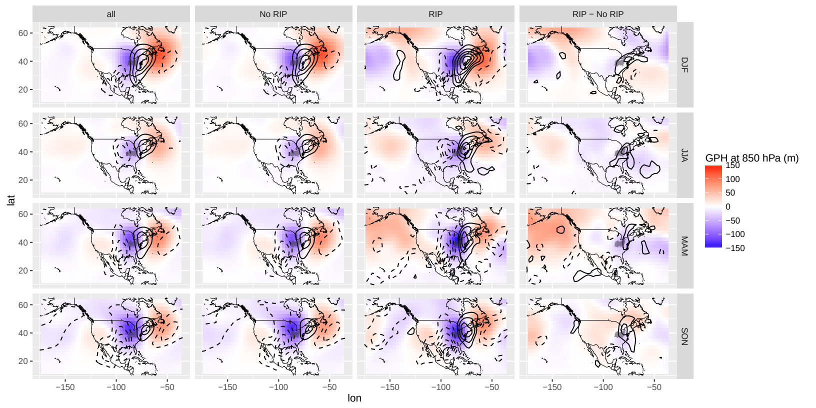

Figure 9: Composite $Z'850$ and Precipitable Water for dates with dipole $> 97.5\%$. (L-R): all, extreme, no extreme, difference

Active and Inactive Seasons in ORB

Changes in the Dipole

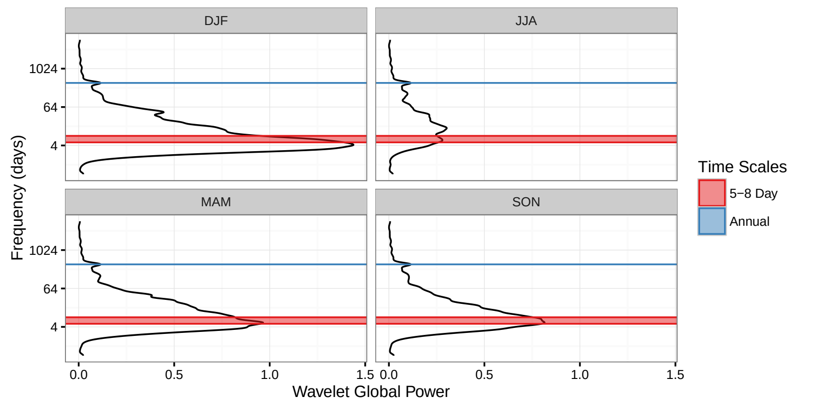

Figure 10: Global (average) wavelet spectrum of dipole by season

Active Seasons

Define season as active if exceeds 85th percentile (by season) of regional extreme days

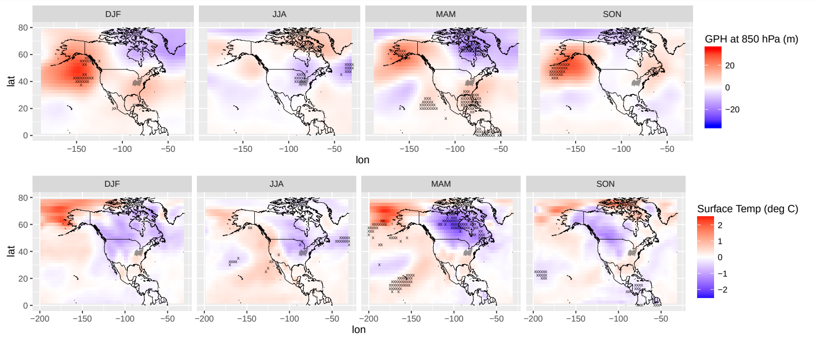

Figure 11: Mean $Z850$ (top), surface temperature (bottom), for active season; 'x' indicates 90% sign agreement

Wrap-Up

Summary

1. Atmospheric signatures of non-summer events similar at event scale, marked by dipole
2. Dipole describes a dominant mechanism of extreme precipitation, consistent with TMEs/ARs
3. Summer different from other seasons (waves less active)
4. Dipole index most active at periods of 5-8 days, is informative of probability of regional extreme
5. Coherent seasonal climate features of active seasons

Implications

GCM If a particular GCM isn't simulating the dipole accurately, can we trust its simulations of extremes?

Models Diagnostic of ORB mechanisms $\rightarrow$ build predictive model

Future Work

Future Work

Statistical-Physical Modeling – definitely using cross-timescale effects (Muñoz et al., 2015)

1. precip $\sim f(\text{dipole}, \ldots)$
2. dipole $\sim f(\text{Active Season Features}, \ldots)$

Precipitable water as intermediate step (more predictable?):
precip $\sim f(PW, \omega)$

Global-Local Interactions

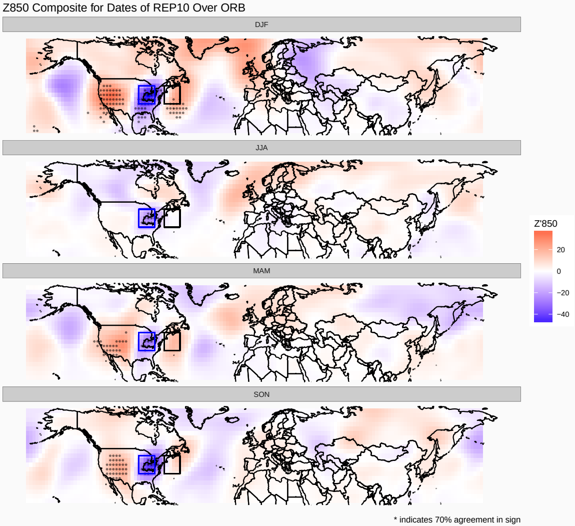

Figure 12: $Z'850$ composited globally for dates of intense ORB rainfall

“Dipole‘‘ as Waves → Integrate Dynamics Theory

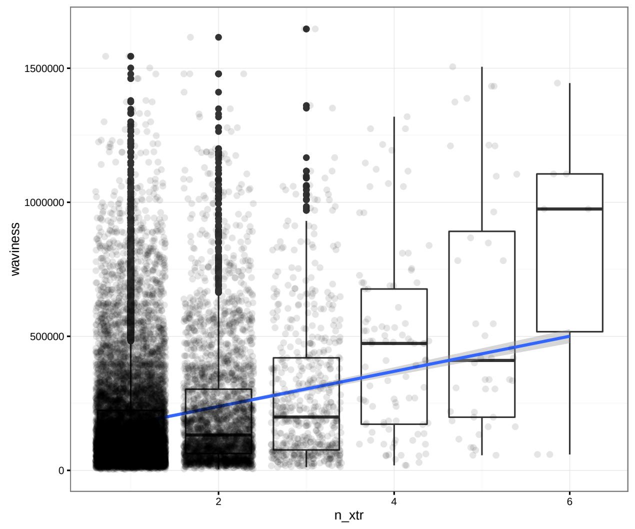

Figure 13: NH Mid-Lat 3-year return events: # extreme events (aggregated by longitude) & “local waviness”

Questions?

james.doss-gollin@columbia.edu

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