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3B.3: Climate Controls on the Extreme Rainstorms in the Contiguous US: 1979-2015

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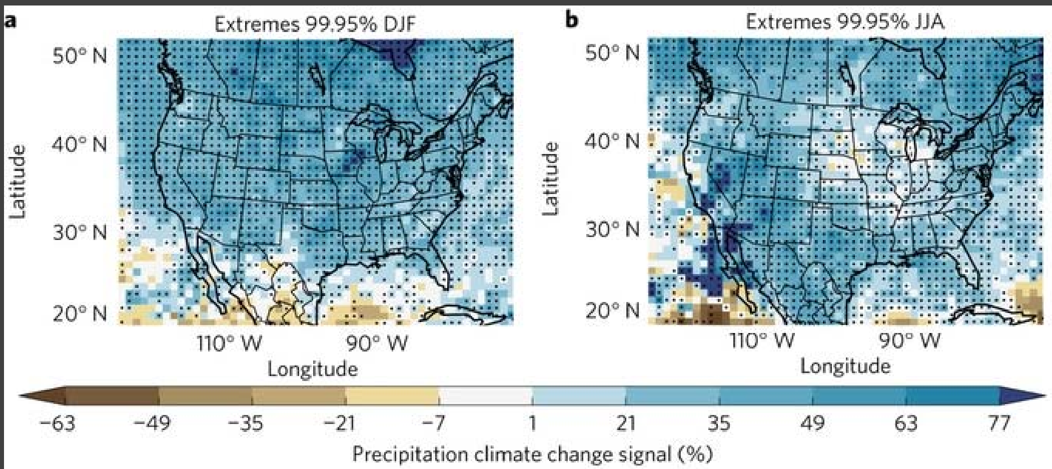
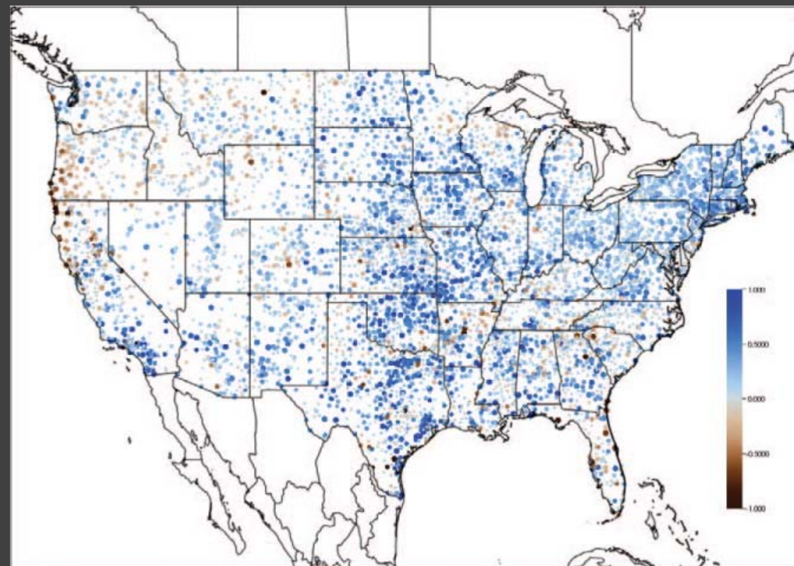
Motivation: extreme precipitation

Towards better understanding of how extreme precipitation responds to present and future climate change



Changes in <u>hourly</u> extreme precipitation (2001-2013)[a]



Changes in <u>daily</u> extreme precipitation (1948-2010)[b]

- Spatial heterogeneity increases from hourly to daily timescale
- 72 hour is also an important period, but no studies have been done

a Prein, A. F., R. M. Rasmussen, K. Ikeda, C. Liu, M. P. Clark, and G. J. Holland, 2017: The future intensification of hourly precipitation extremes. Nat. Clim. Chang., 7, 48–52.

b Kunkel, K. E., and Coauthors, 2013: Monitoring and understanding trends in extreme storms: State of knowledge. Bull. Am. Meteorol. Soc., 94, 499–514.

Motivation: PMP estimation

Towards more reliable model-based PMP estimation

- Probable Maximum Precipitation (PMP): upper bound of precipitation
- Design criteria of large water infrastructures posing high hazard to society
- Various methods have been proposed to make model-based PMP

WRF simulation of Jan 1-5, 1997 central California storm[a]

Method	Max. 72-hr rainfall (mm)	Modification to the simulation
Historical reconstruction	330	-
Moisture maximization (MM)	458	RH=100% in the boundary condition
Equilibrium condition (EC)	530	Maintaining most favorable atmospheric boundary condition
MM+EC	549	MM+EC
Boundary condition shifting	541	Shifting boundary condition in latitude

- No rational and consistent physics-based check has been done to understand which way is “correct”
- Suitability of these approaches based on climatology, location and season information

a Ohara et al., 2011: Physically based estimation of maximum precipitation over American River watershed, California. J. Hydrol. Eng., 16(4): 351-361.

Key questions

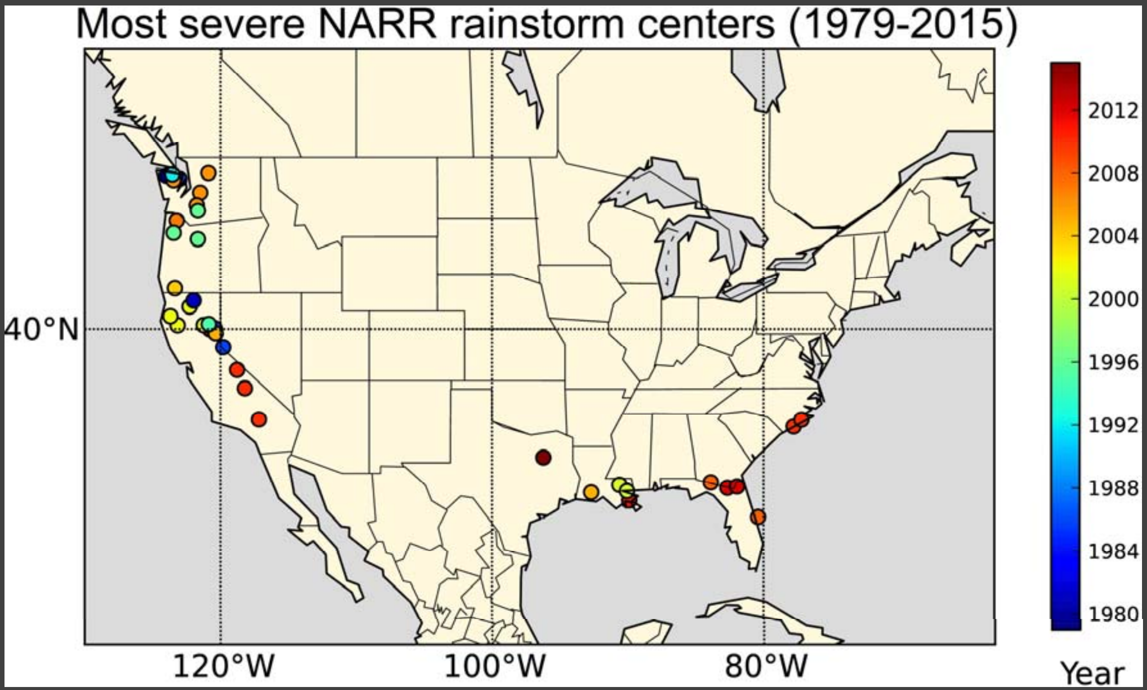
- What are the primary physical controls on the magnitudes of most severe rainstorms in the Contiguous US (CONUS), as revealed by the reanalysis products?

  This will tell us which meteorological factors we should play with in the model-based PMP estimation.

- How can the physical controls inform PMP estimation using numerical models and ensure some consistency?

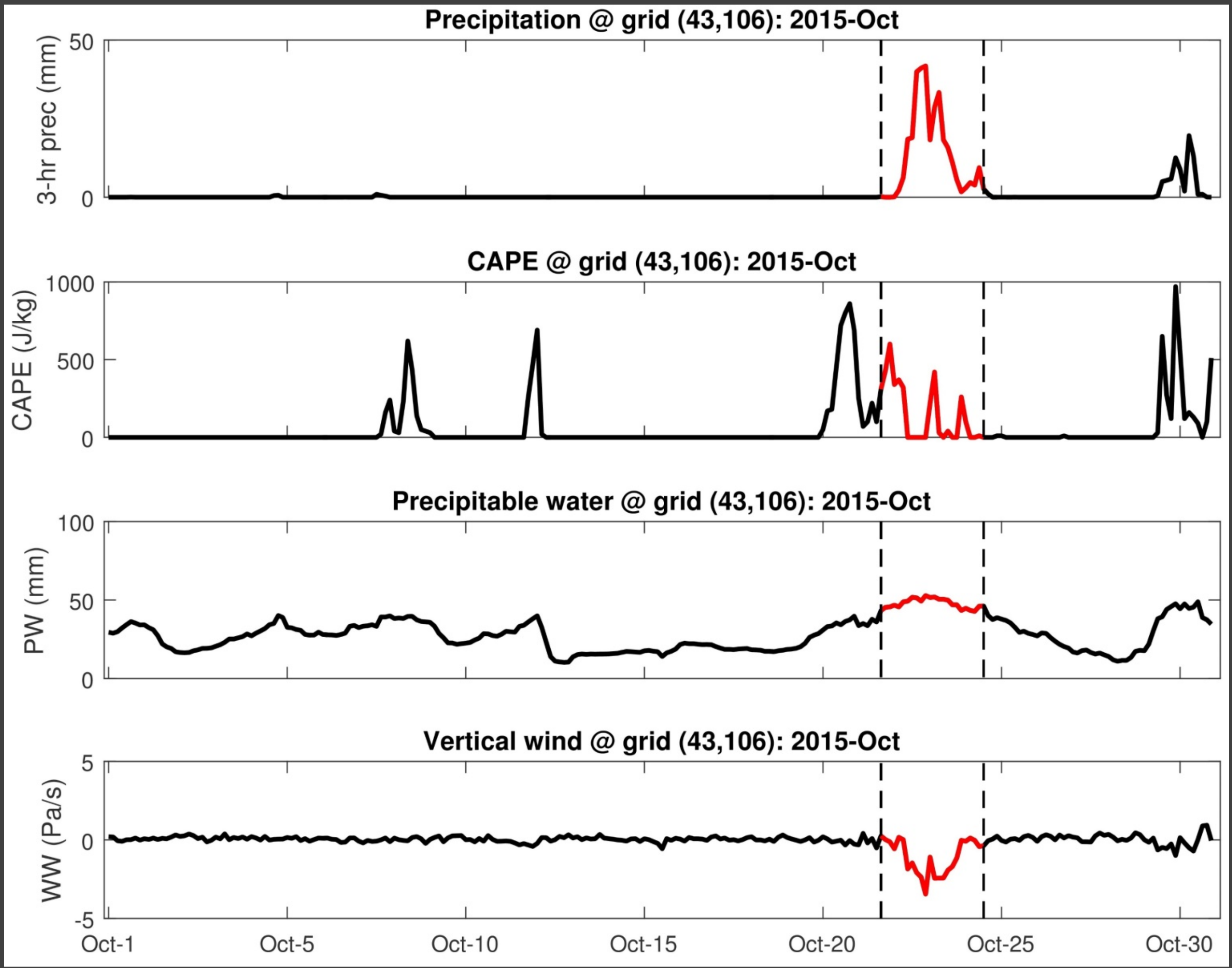
Data and methods

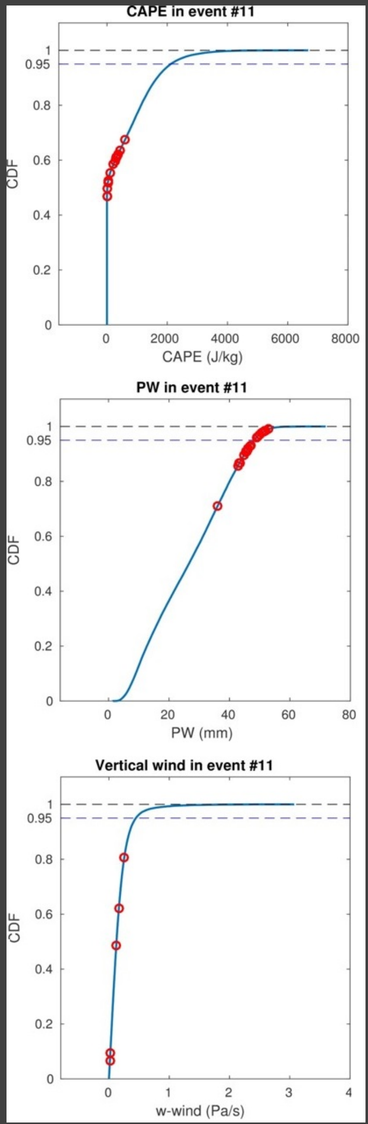
- North American Regional Reanalysis (NARR), CONUS, 1979-2015, 3hr/32km
- Focus on the top 50 most severe events (across CONUS; in each grid)
- Considering:
  CAPE (Convective Available Potential Energy)
  PW (Precipitable Water)
  WW (upward vertical wind velocity @700mb)



Data and methods

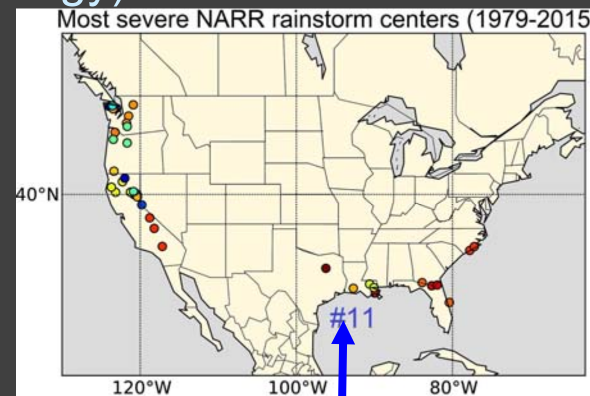
- Frequency-based view of physical controls
  - Hard to identify representative atmospheric state at event timescale
  - Different statistical distributions of prec, CAPE, PW and WW

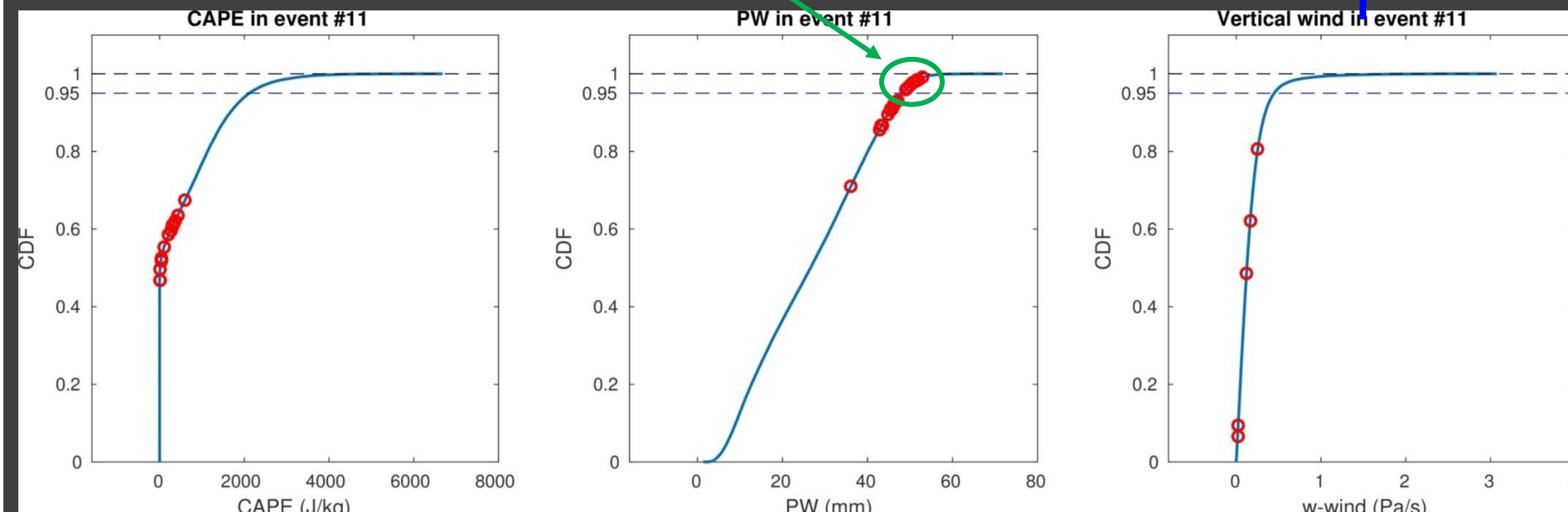




Data and methods

- Locate the peak storm center (1 NARR grid)
- Obtain the CDF of CAPE, PW and WW at this grid (climatology)
- Overlay the CAPE, PW and WW in the storm duration
- Persisting CDF>95% condition suggests dominant control

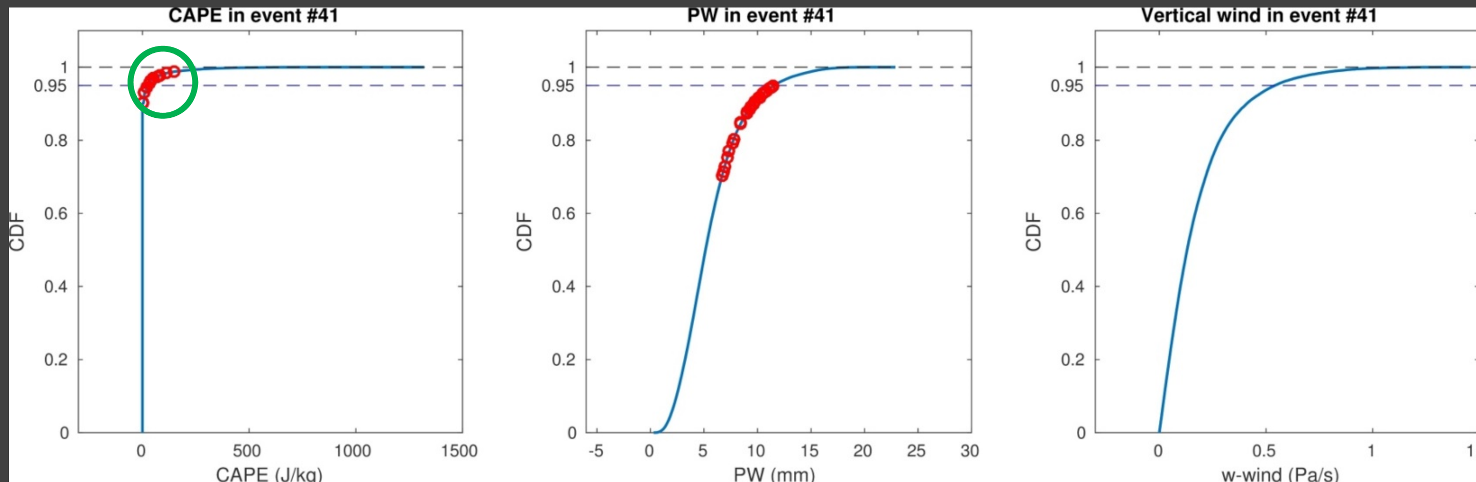




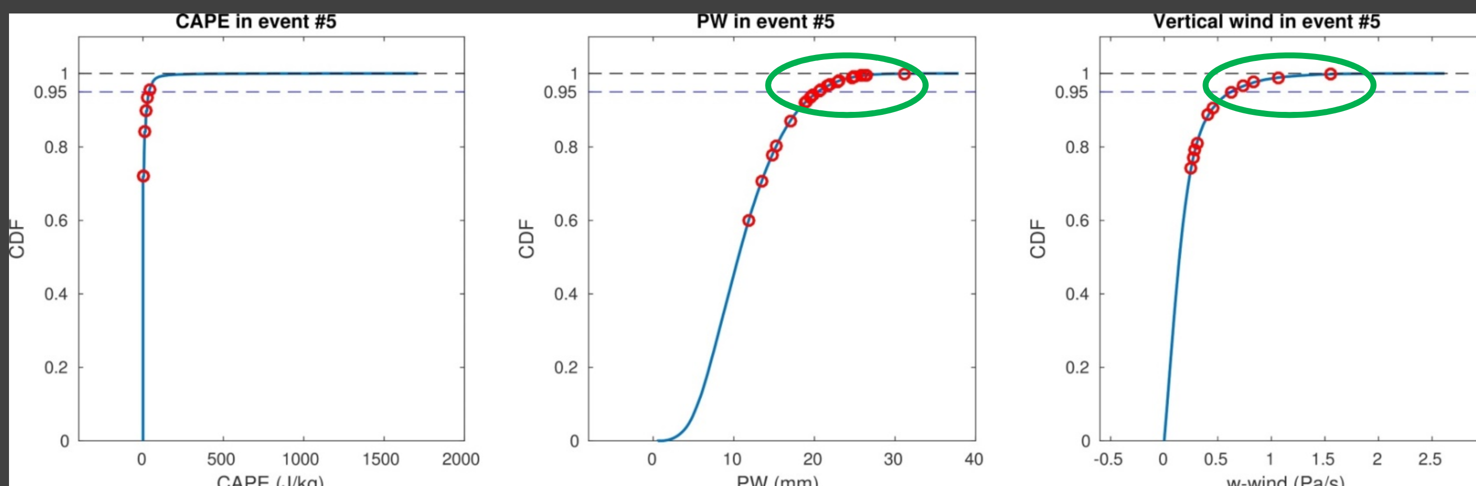
Results

1. Different physical controls on the extreme storms

CAPE control

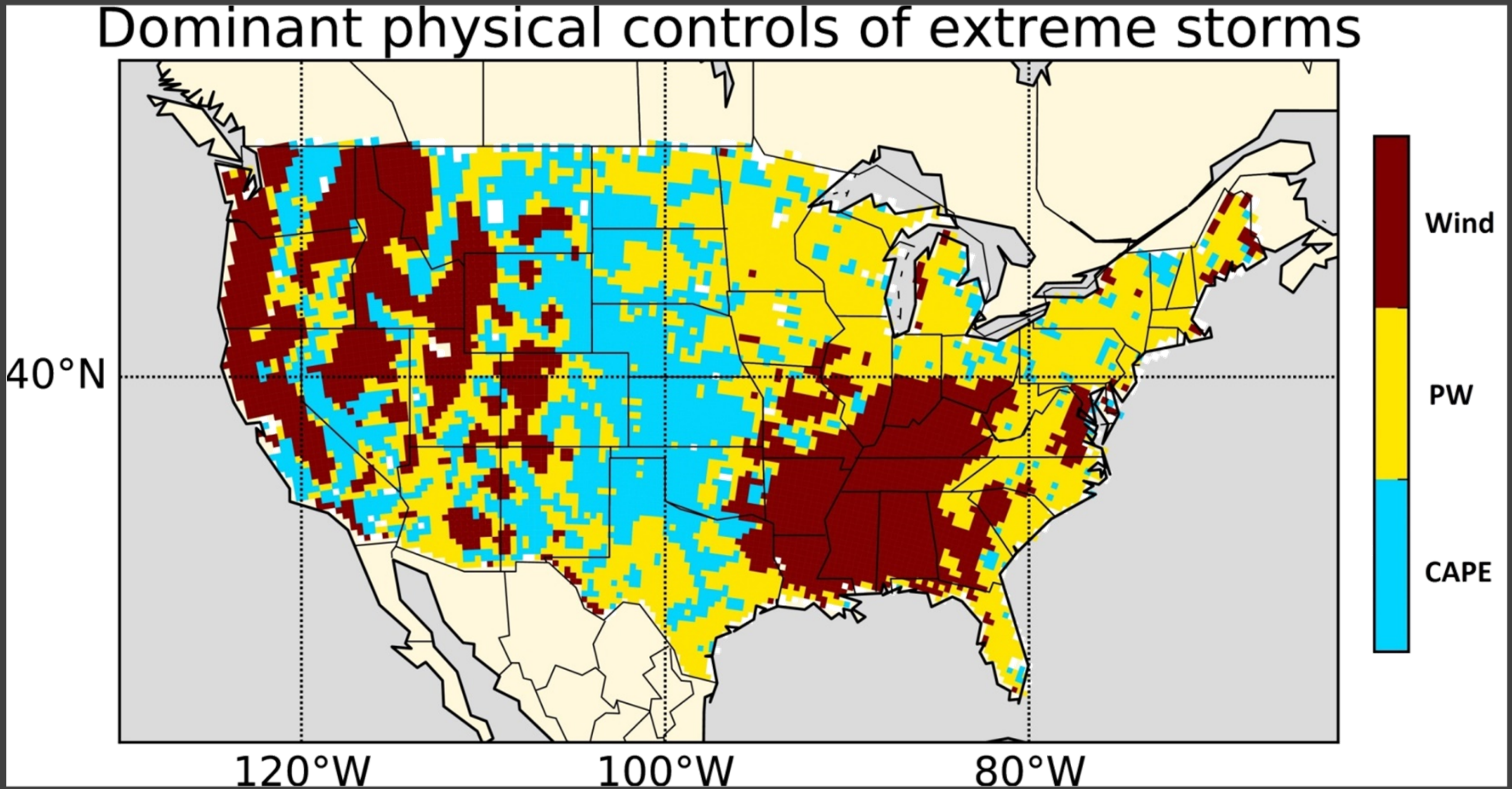


PW and Wind control



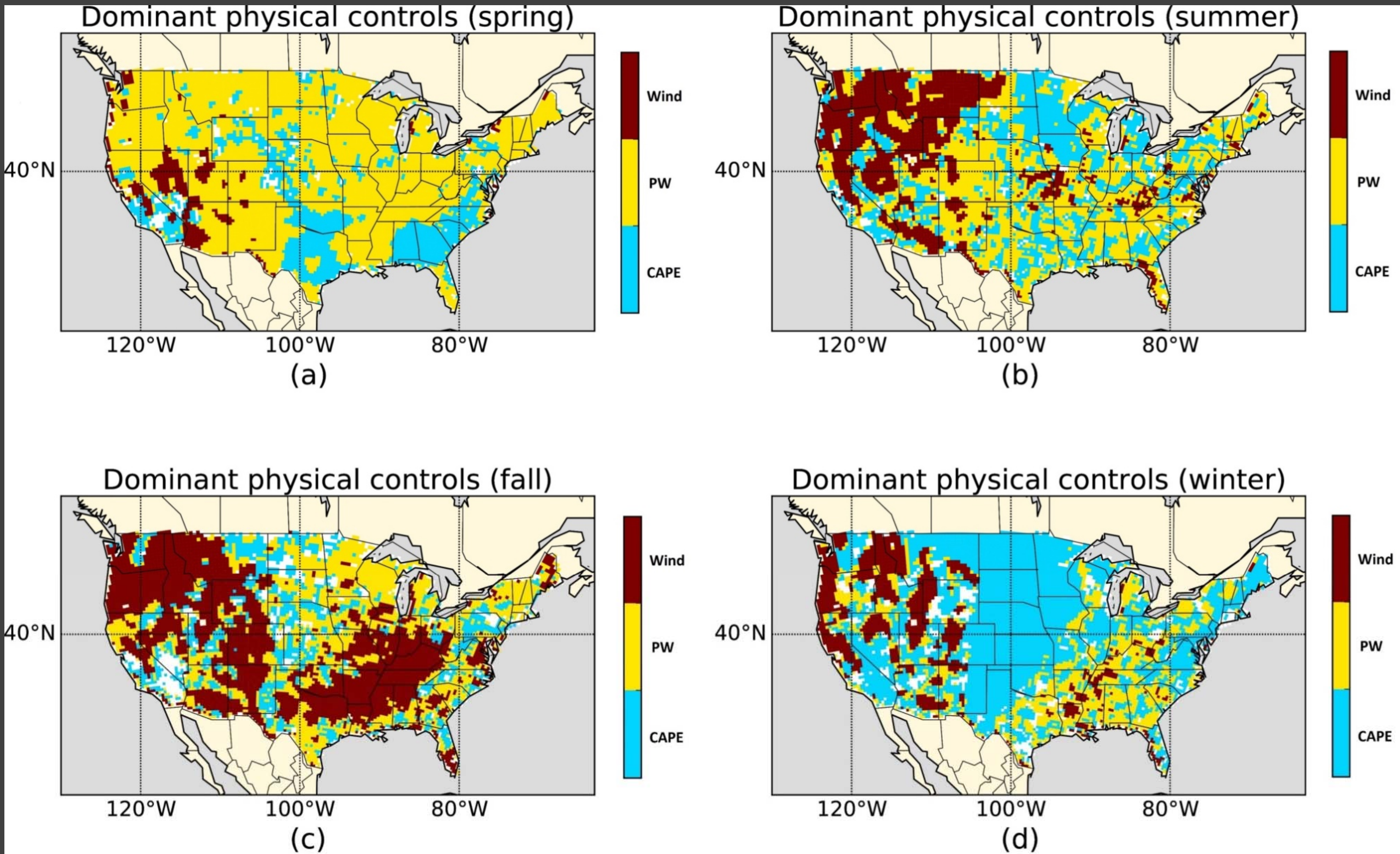
Results

2. Spatial distribution of physical controls on the extreme storms
   - Studied top 50 events at every grid
   - CAPE controlled western US
   - PW controlled eastern US
   - WW controlled west coast and southeast US
   - Ready-to-use guidelines to engineers



Results

3. Seasonality of physical controls on the extreme storms



Discussion

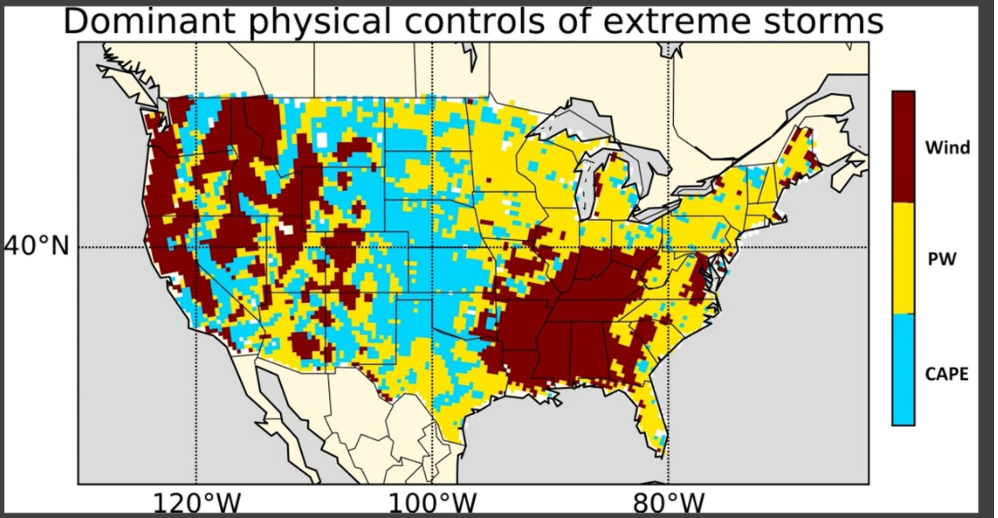
1. Guidelines on model-based PMP estimation for engineers

- Whatever is limiting the storm, we maximize it for PMP estimation
- Shift from ensemble to several prioritized approaches

CAPE control: Modifying air T and lapse rate	PW control: Modifying air T and relative humidity	WW control: Modifying wind fields

2. Heterogeneous response of extreme precipitation to global warming

- Regions with CAPE/PW controls are more susceptible to direct changes in T
- Regions with WW control are more susceptible to change in convection from warmer atmosphere



Summary

1. Understanding the climate controls on the storm magnitudes is important

2. Frequency-based analysis applied to the extreme storms in CONUS

3. Extreme storms in different regions of CONUS are controlled by various meteorological factors (instability, moisture, wind)

4. For model-based PMP estimation, different methods should be prioritized based on location and season

5. Extreme precipitation in different regions may have heterogeneous responses to global warming

Thank you!