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Observed U.S. Trends in Extreme Precipitation

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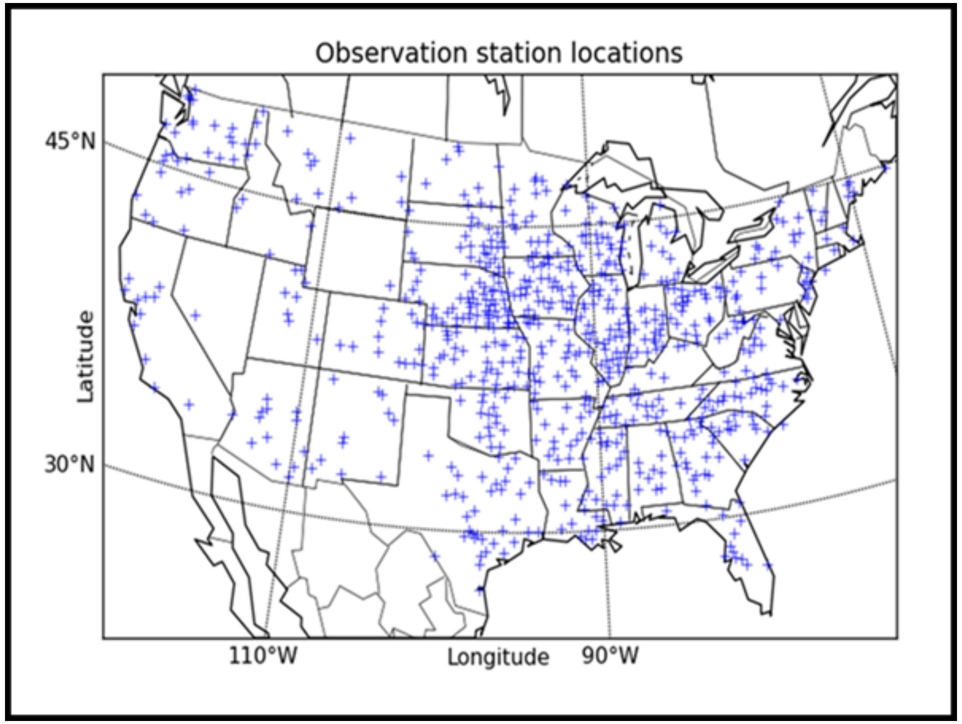
Key Questions:

- How is the frequency of extreme precipitation events changing over the contiguous United States?
- What are the regional changes in the frequency?
- How is extreme precipitation event frequency projected to change in the future?
- How is the frequency changing seasonally?
- What are the meteorological causes of extreme precipitation events and are there any trends?

Observational Data

- U.S. Cooperative Observer Network, Global Historical Climate Network-Daily data set from NCDC
  - 726 stations (1901-2012), 766 stations (1901-2014)
  - No known bias in precipitation data
  - 90% of daily data required for usable station
  - 300+ days of data required for any given year
  - 75 days of data required for any given season



Janssen et al., 2014

Simulation and Projection Data

- Historical Simulations: Fifth installment of the Coupled Model Intercomparison Project (CMIP5)
  - 1901-2005
  - 27 models, 94 simulations
- Projections: Representative Concentration Pathways (RCP)
  - RCP 4.5 (med-low mitigation) and RCP 8.5 (BAU) scenarios
  - 2006-2100
  - 21 models, 51 simulations

Extreme Precipitation Index

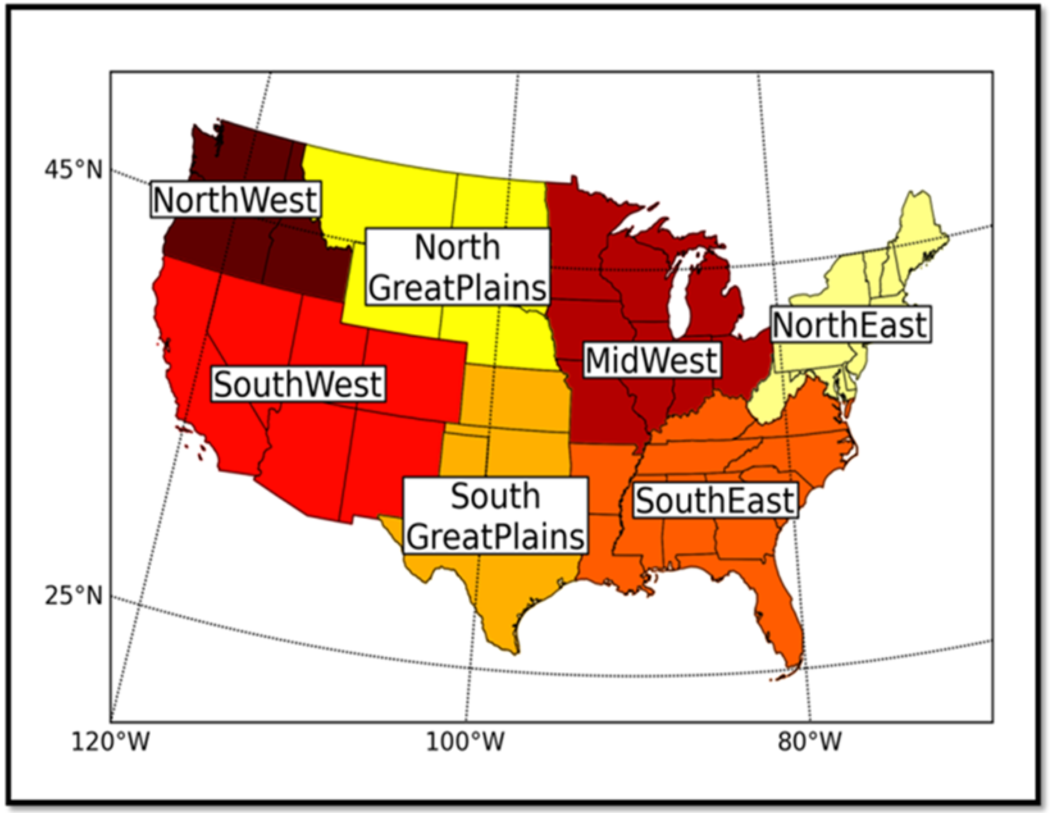
What is the EPI? A measure of the frequency of extreme precipitation events for a given duration and return interval

- Duration: Number of days over which precipitation is accumulated
- Return: Average or expected number of years between extreme precipitation event
  - 5-year storm, 20-year storm 100-year storm etc…

EPI calculation

Calculate number of extreme events (N) for return

- N = Time series length (yrs)/average return period (yrs)
- 100 yrs/20yrs = 5 events
- Largest magnitude (N) events are flagged for each station
  - Year and season of occurrence are recorded
- Stations assigned grid location and state identifiers
  - 1° by 1° grid
- Averages by region and entire CONUS



Janssen et al., 2014

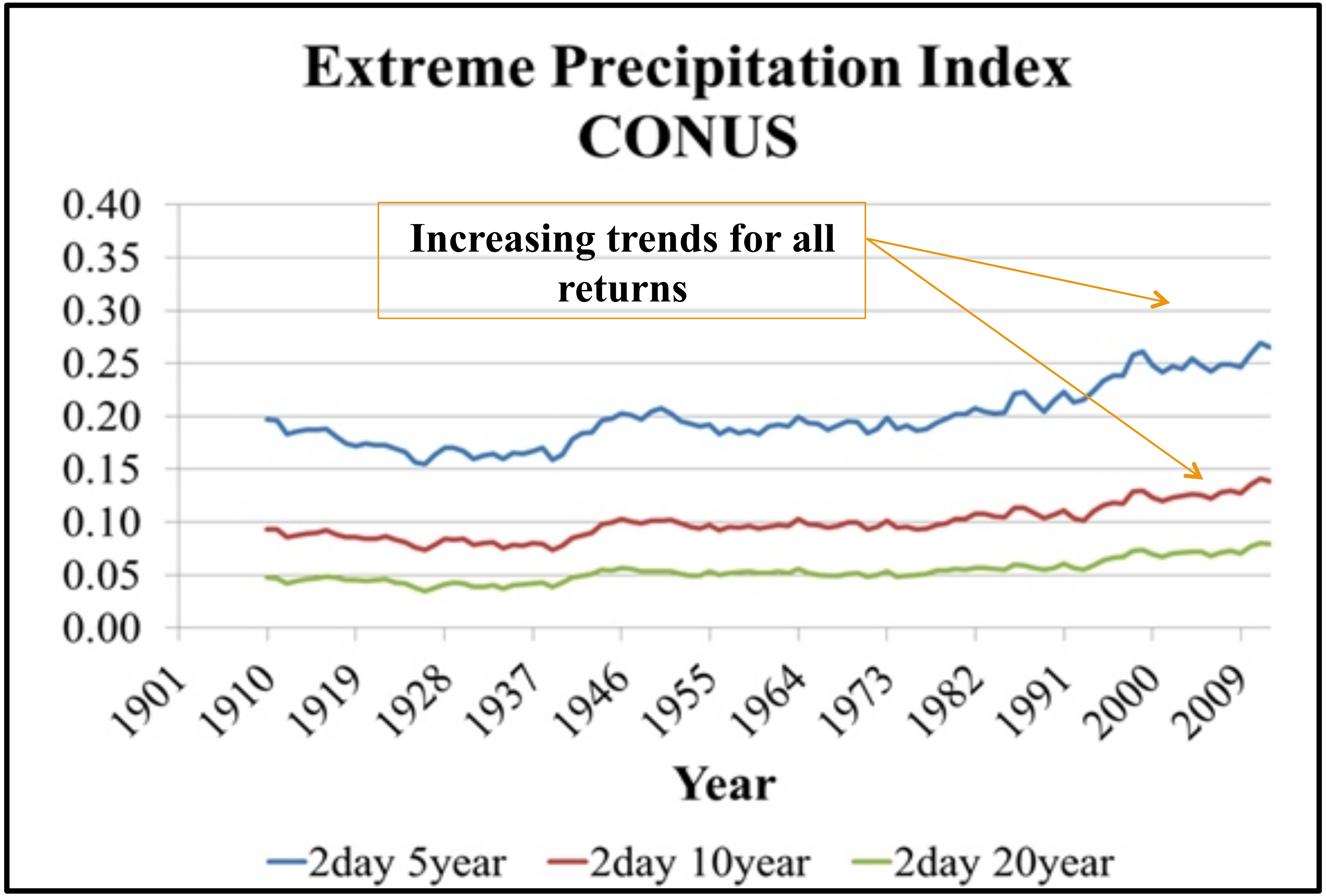
Extreme Precipitation Index (EPI)

Interpretation:

- EPI is a measure of the frequency of extreme precipitation events
- For 1, 5, and 20 year returns, average EPI values are 1, 0.2 and 0.05 respectively
  - If the EPI is as expected, averages would fall around these values
  - If values diverge upwards, frequency is increasing; if downwards, frequency is decreasing

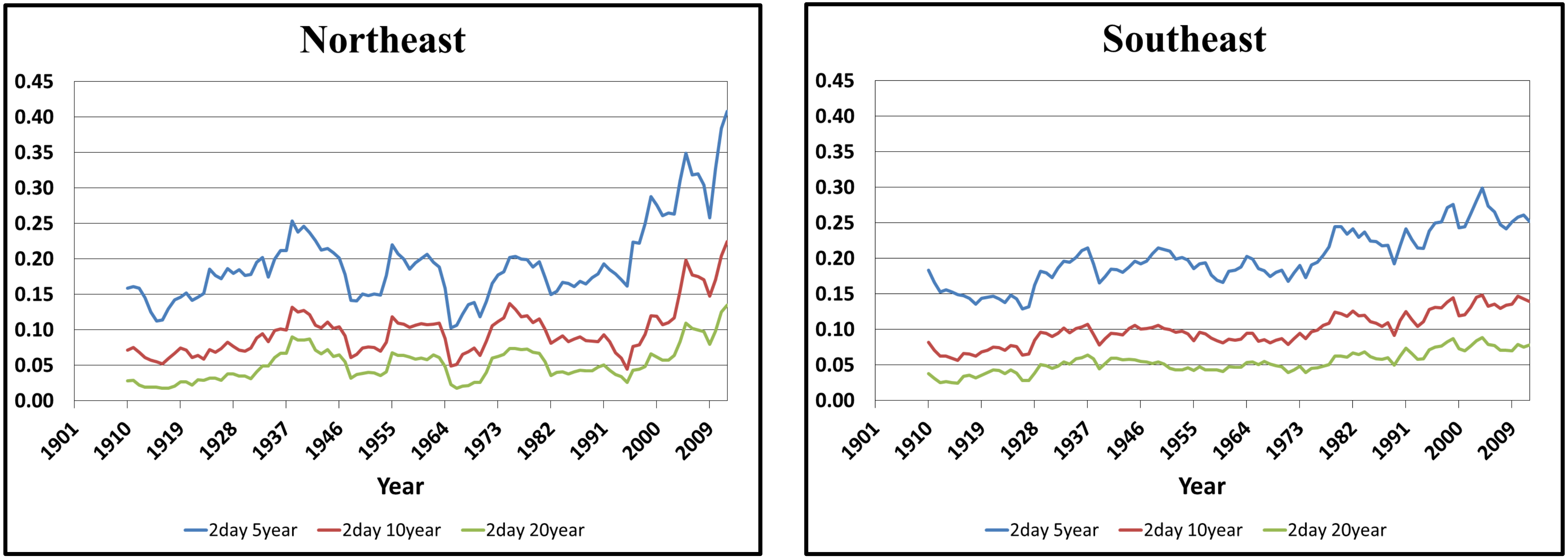
Advantages:

- Provides station-specific thresholds
- Restricts events to most extreme levels of precipitation



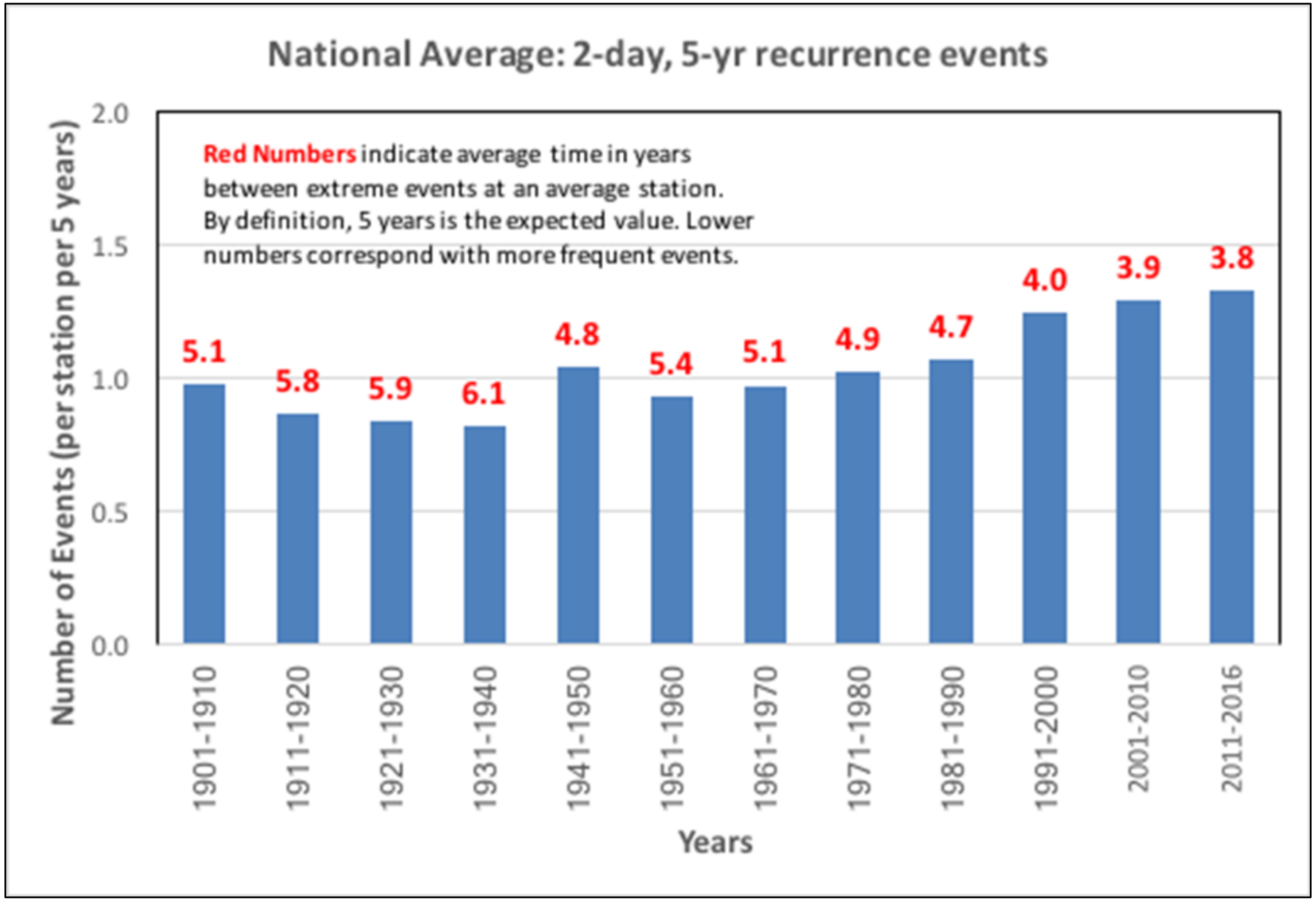
- 10-year running average of the EPI, 1901-2012

Extreme Precipitation Index – 10 year running averages



Janssen et al., 2014

Update through 2016 – National average frequency

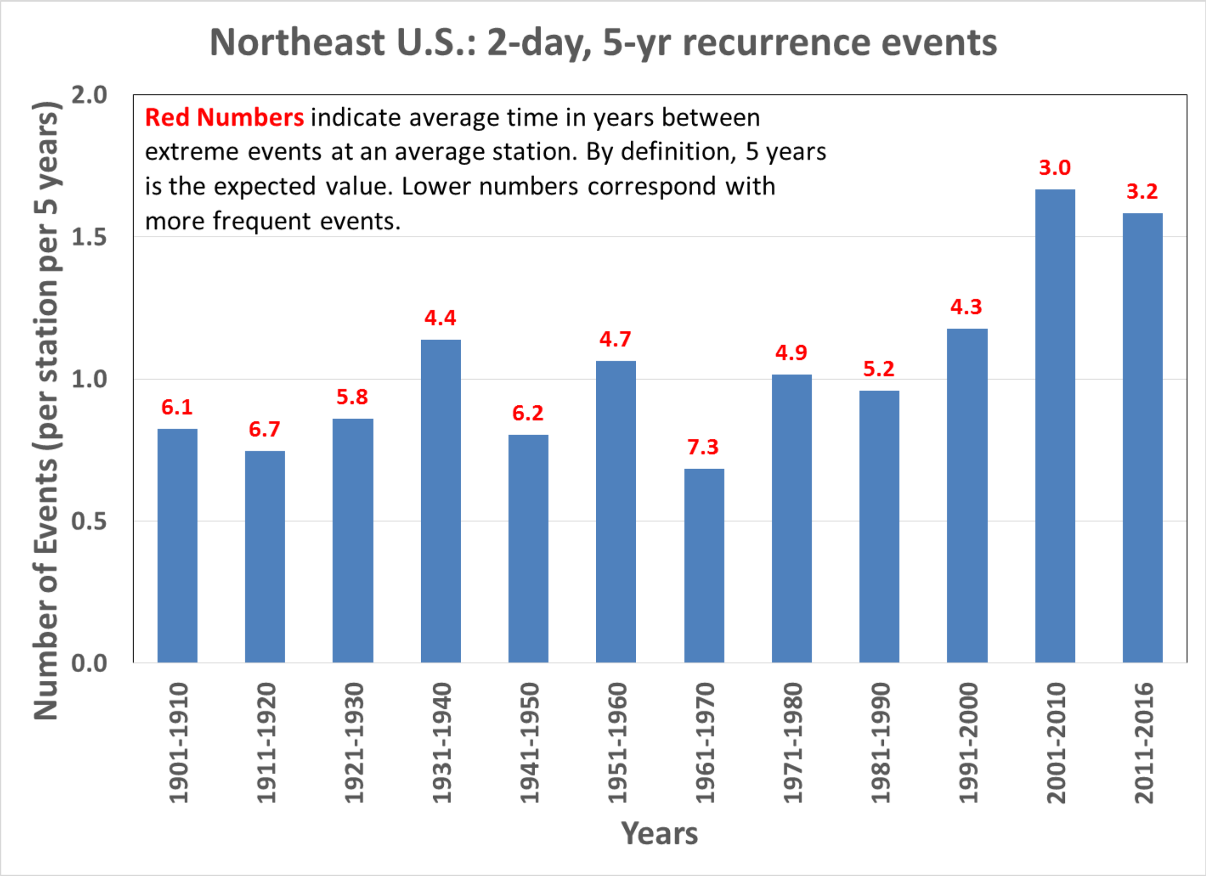


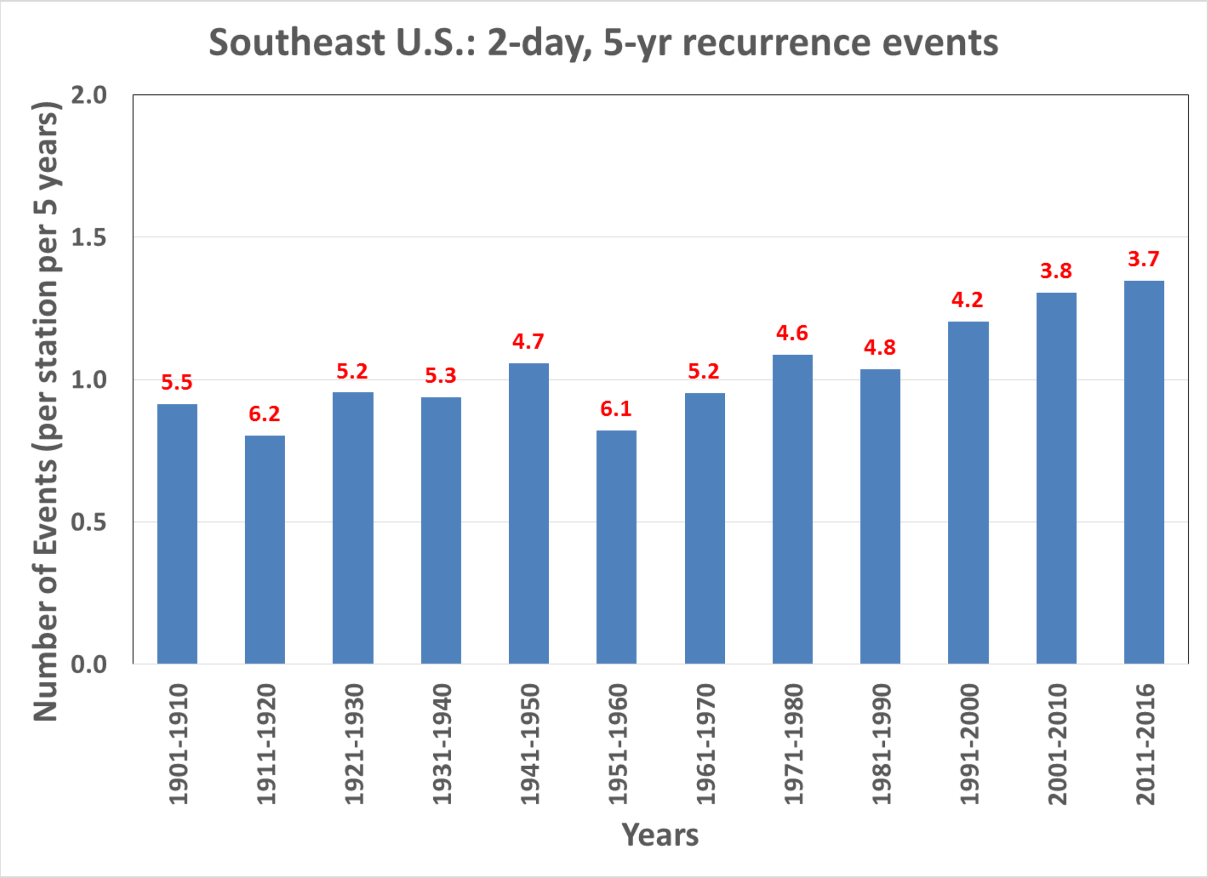
Blue Bars:
Decadal EPI

Red Numbers:
Average time between events

Squires, M.F., K.E. Kunkel, X. Yin, S. Stegall, and D.R. Easterling, 2017: Regional empirical precipitation intensity, duration, and frequency statistics for the contiguous United States. J. Geophys. Res., to be submitted shortly.

Eastern regions show recent increases





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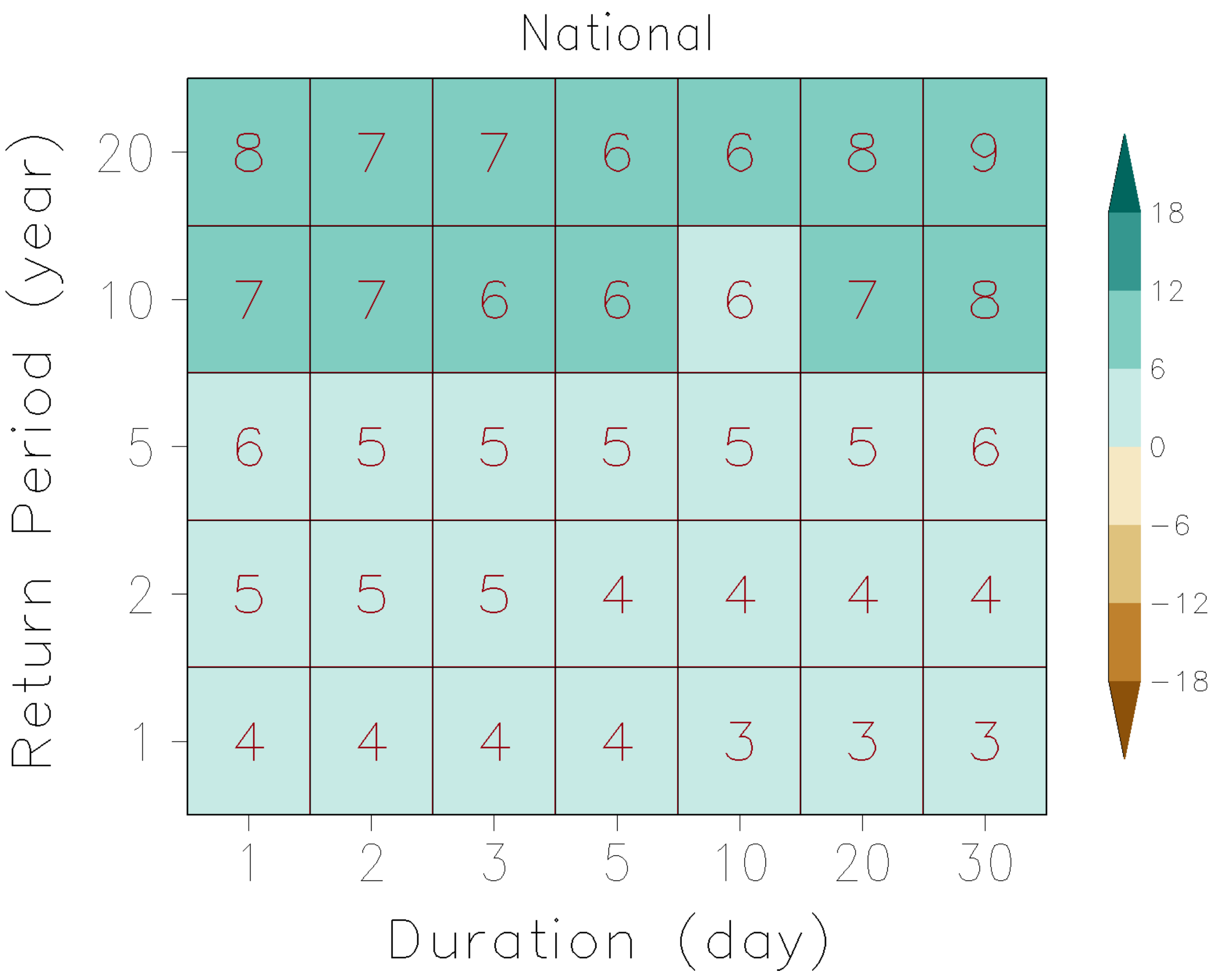
Trends by Duration and Recurrence



- Numbers represent average % change in trend per decade
  - 1949-2015
- All durations and returns show increasing trends in frequency
  - Largest returns have largest increases

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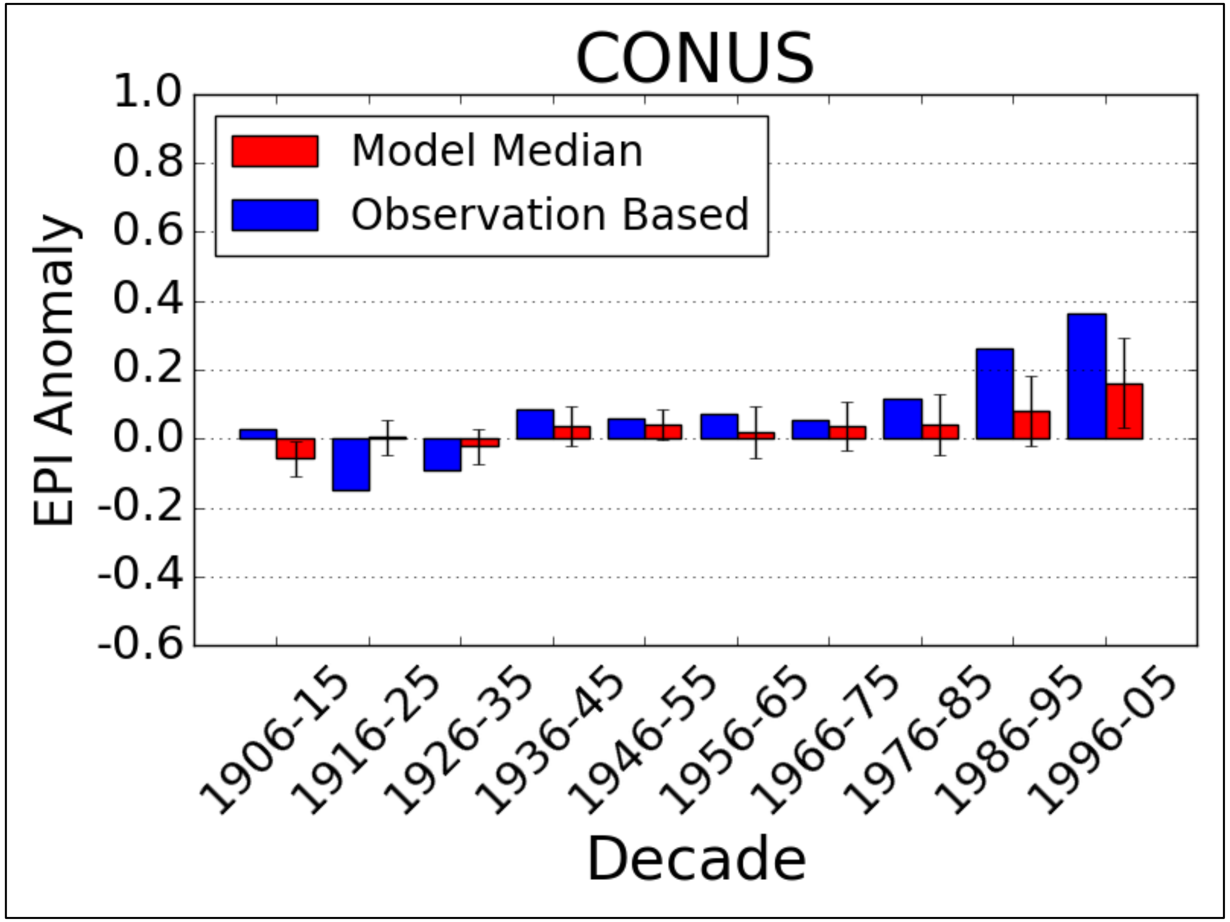
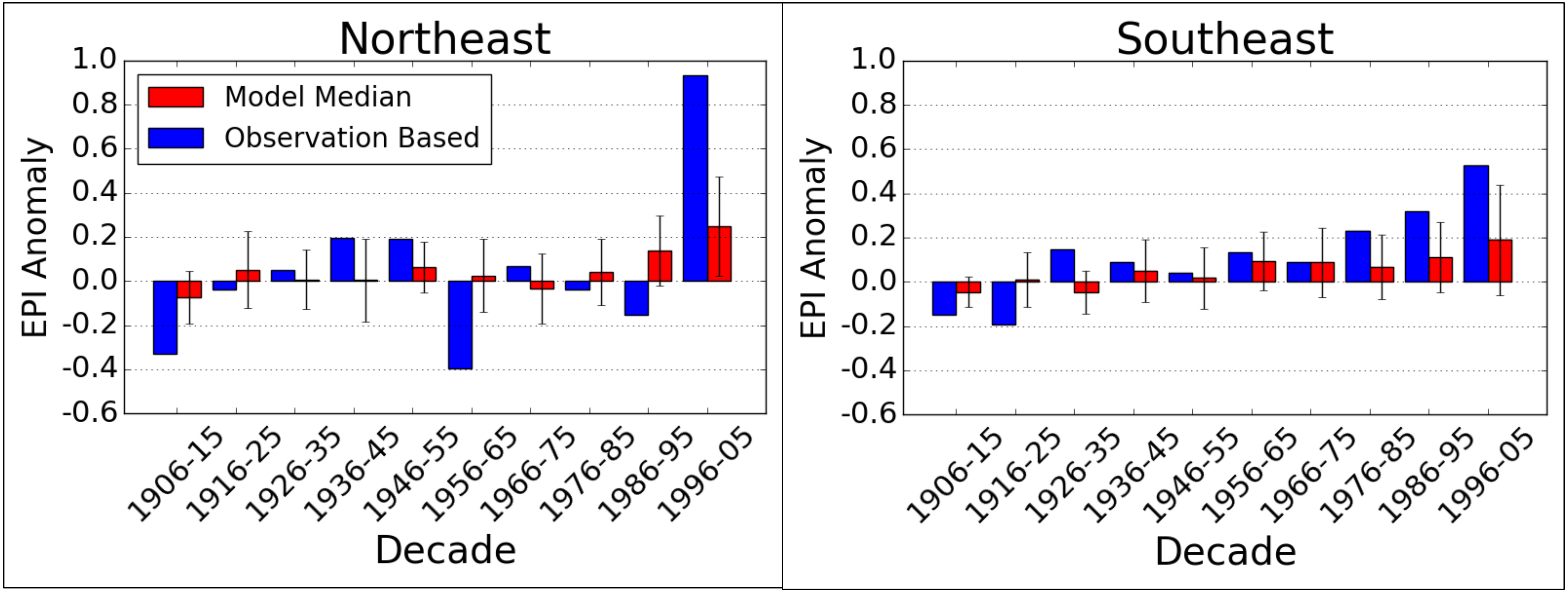
Historical Simulation based EPI

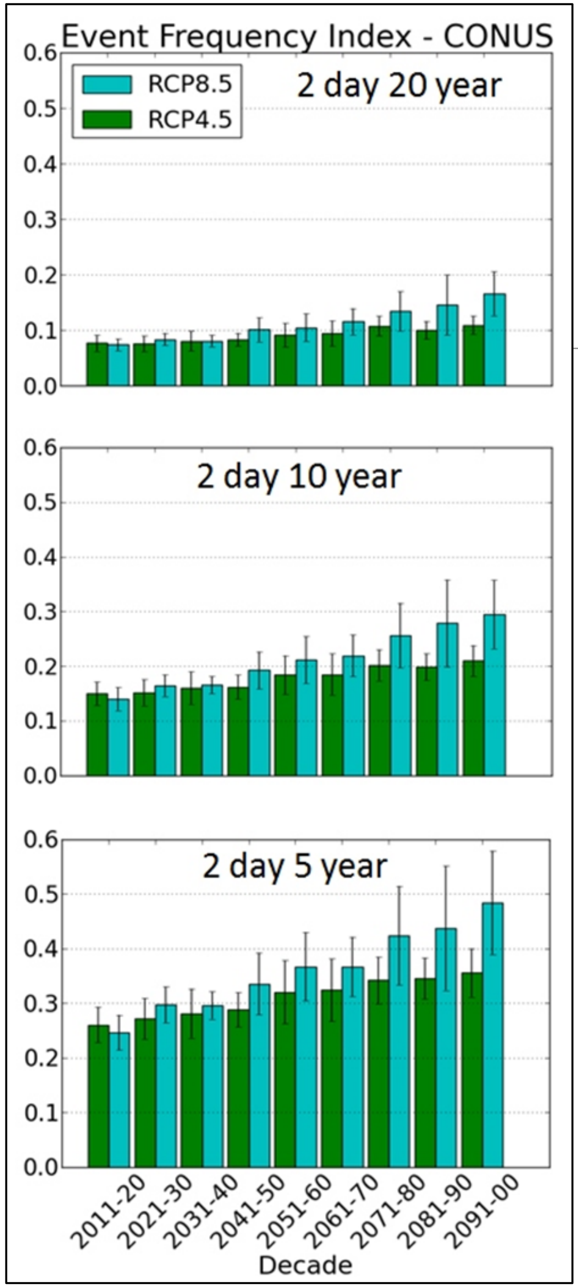


Lines: +/- 1 standard deviation

- 2-day duration 5-year return
  - EPI calculated annually for 1901-2005
  - Decadal averages calculated for 1906-2005
- Anomalies are fractional deviations from the long term mean (1901-1961)
- Models underestimate observations but capture trends

Historical Simulation based EPI



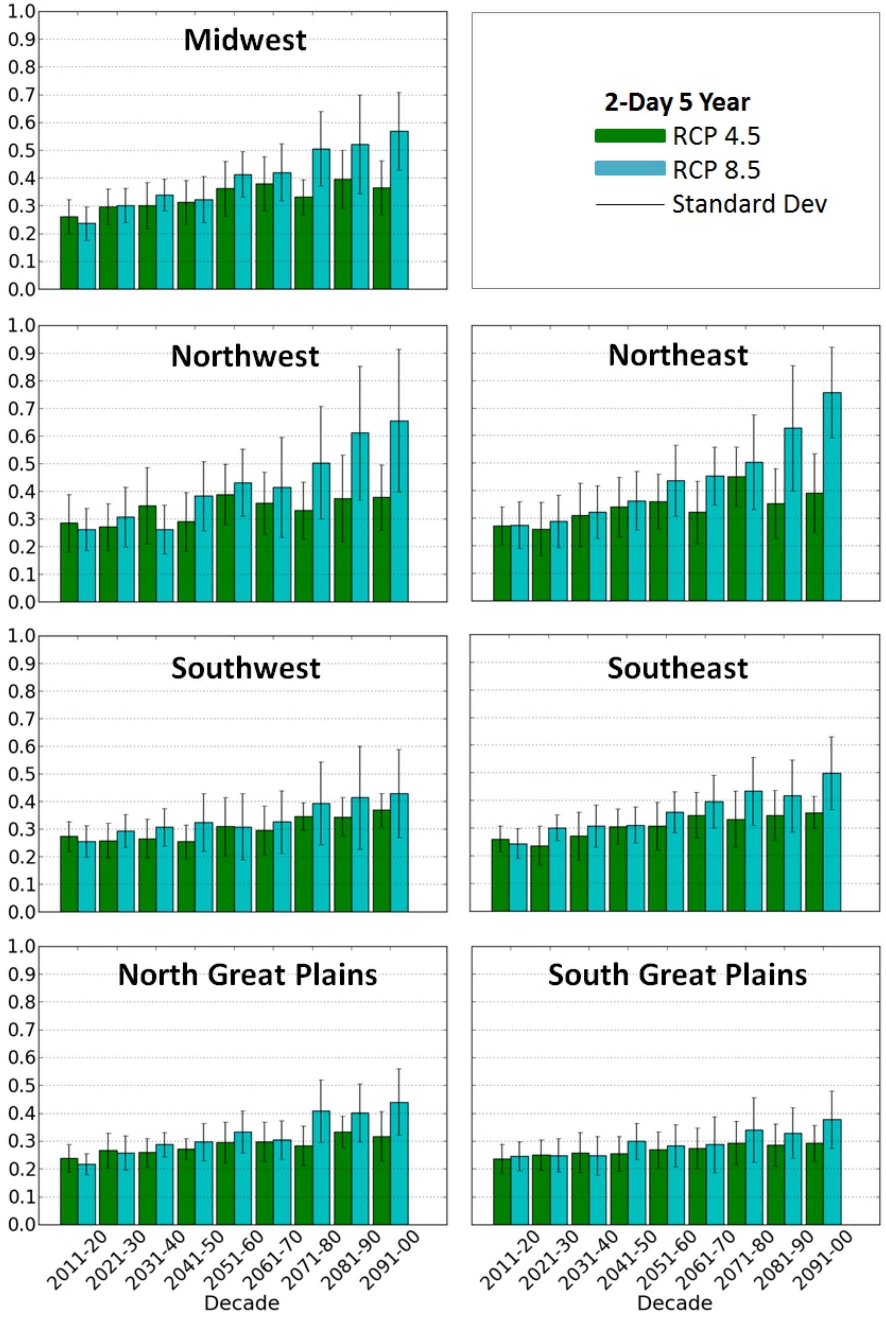


Projections of the Extreme Precipitation Index

- Model median EPI by decade
  - 2006-2100
  - Reference thresholds derived from smallest magnitude extreme event from historical model data
    - Ensemble average for each model
    - Otherwise same EPI methodology

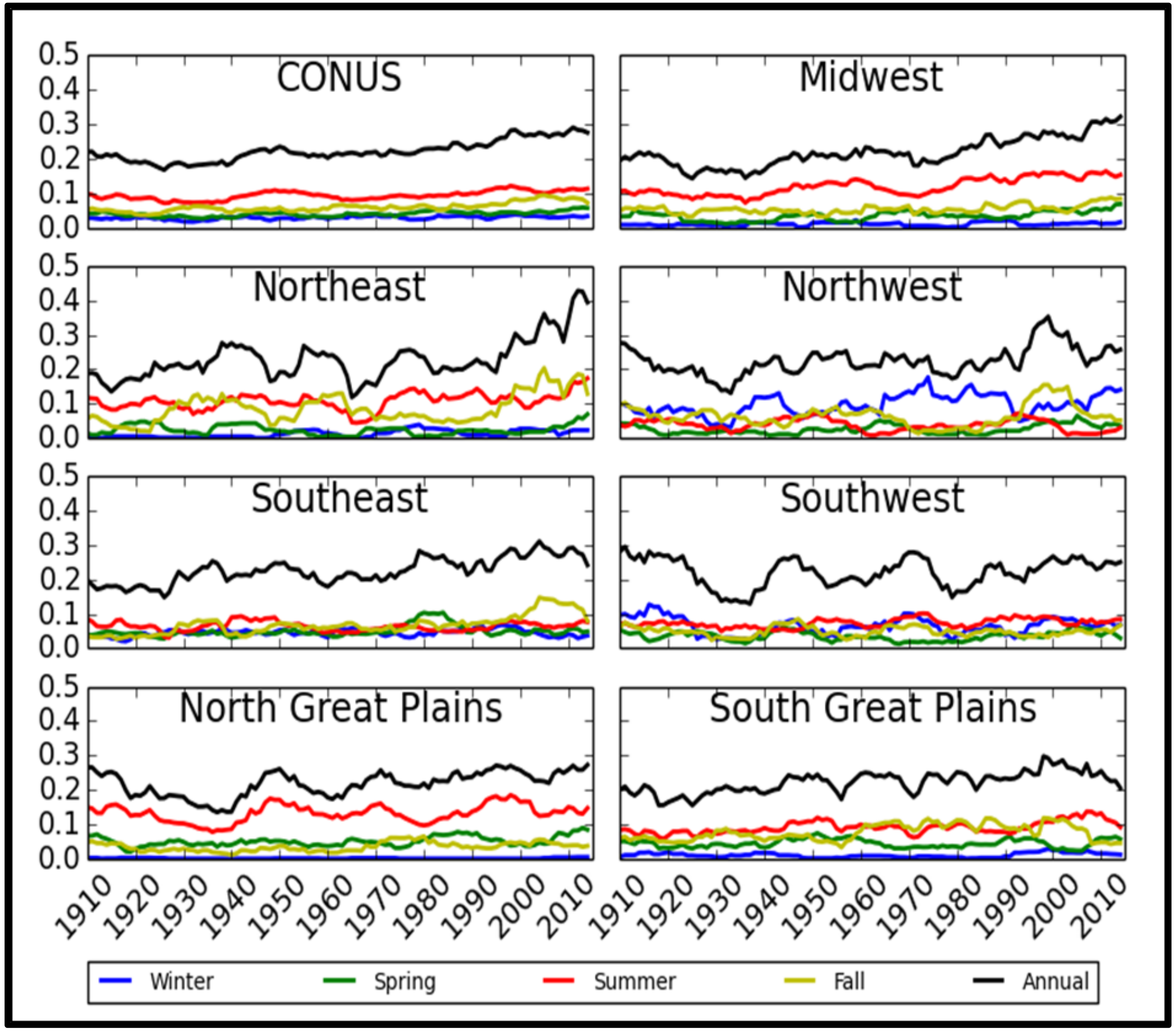
Regional EPI projections

- All regions show positive trends for RCP 8.5
- RCP 4.5 much more variable
- Largest increases in Northeast for RCP 8.5



What is the seasonality of the EPI and how is it changing?

- Colored lines are seasonal contribution to annual EPI
- 10-year running averages of the seasonal EPI
- 1901-2014
- Winter: DJF, Spring: MAM, Summer: JJA, Fall: SON



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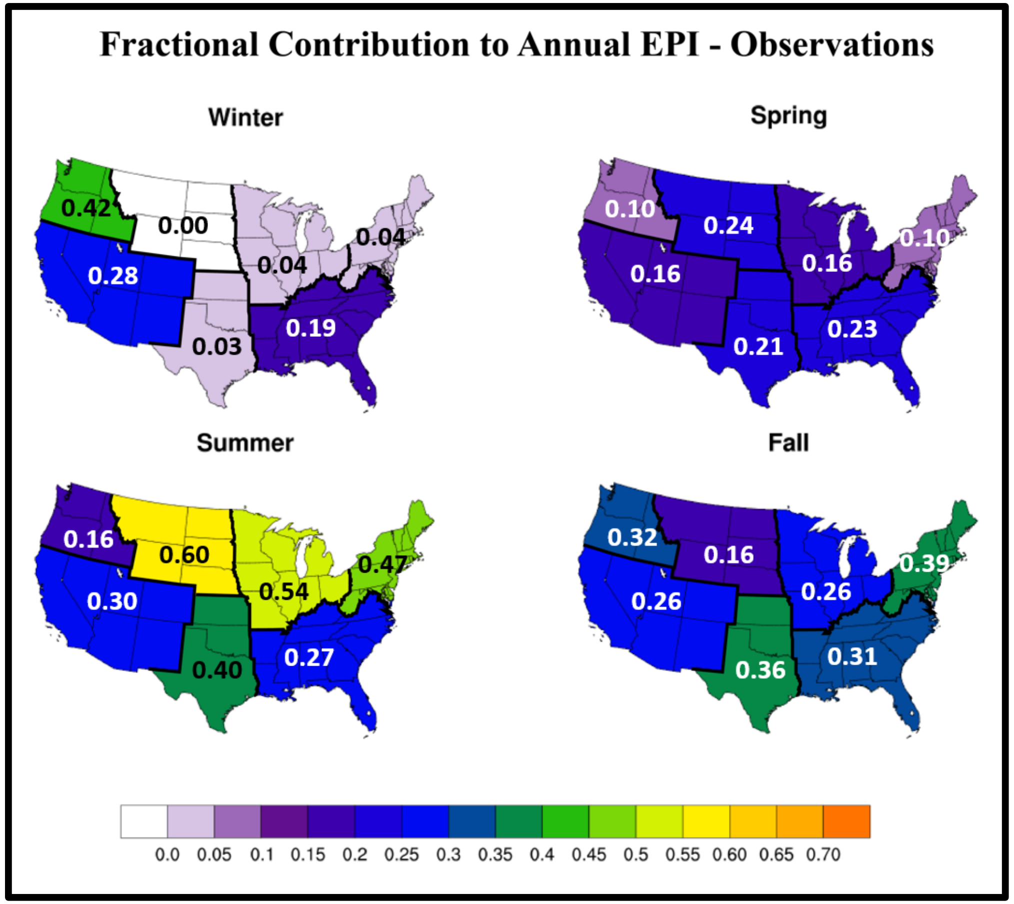
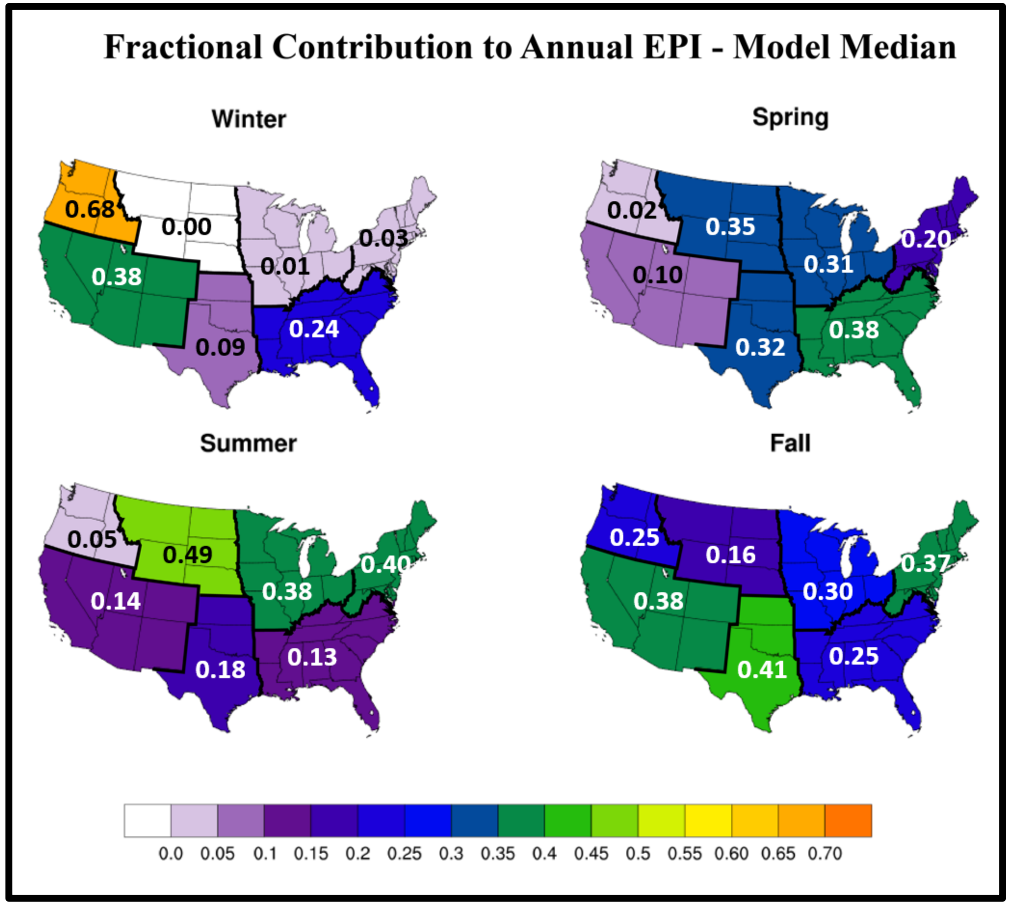




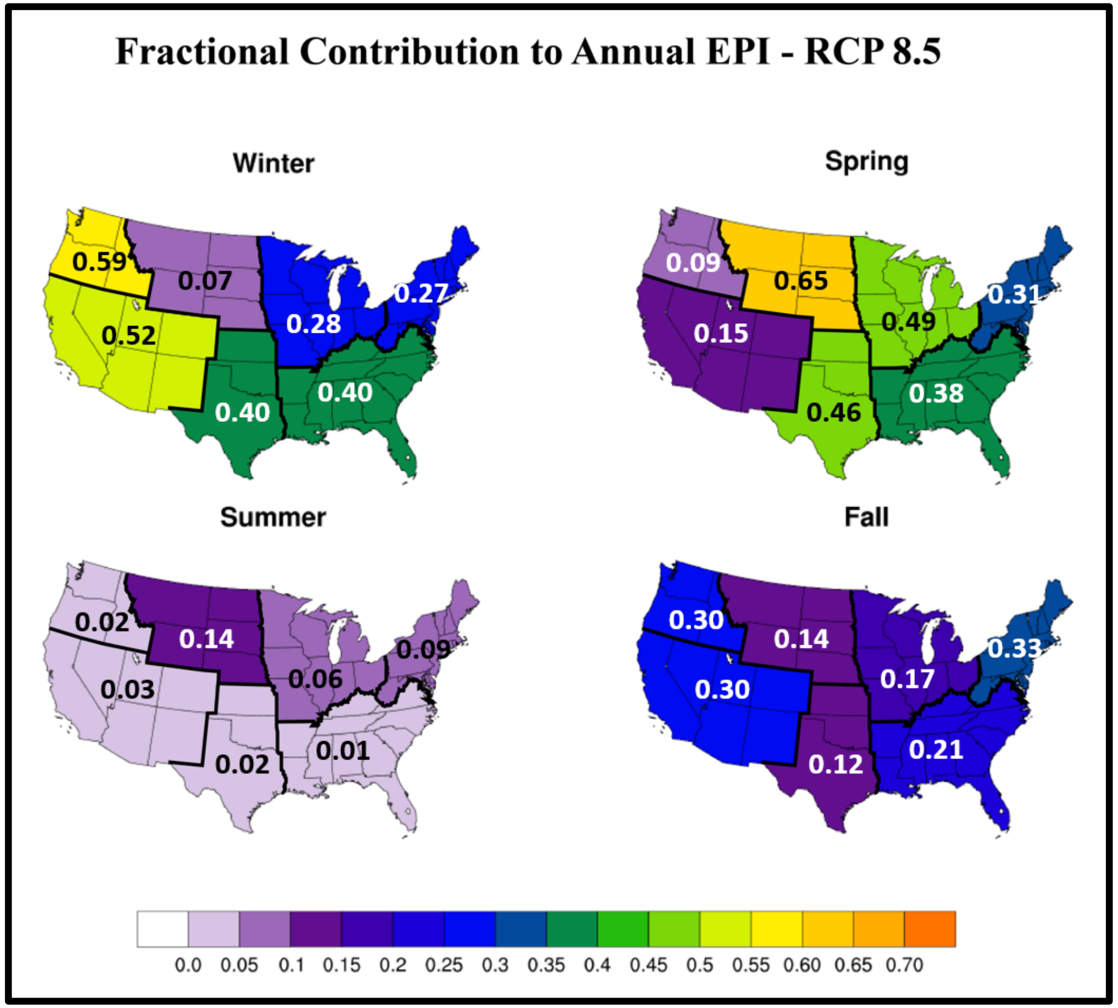
Numbers are average fractional contribution to annual

2-day 5-year
1901-2005

Historical CMIP5 simulations shift events from summer to spring for most regions

Janssen et al., 2016

How is the seasonality of the EPI projected to change?

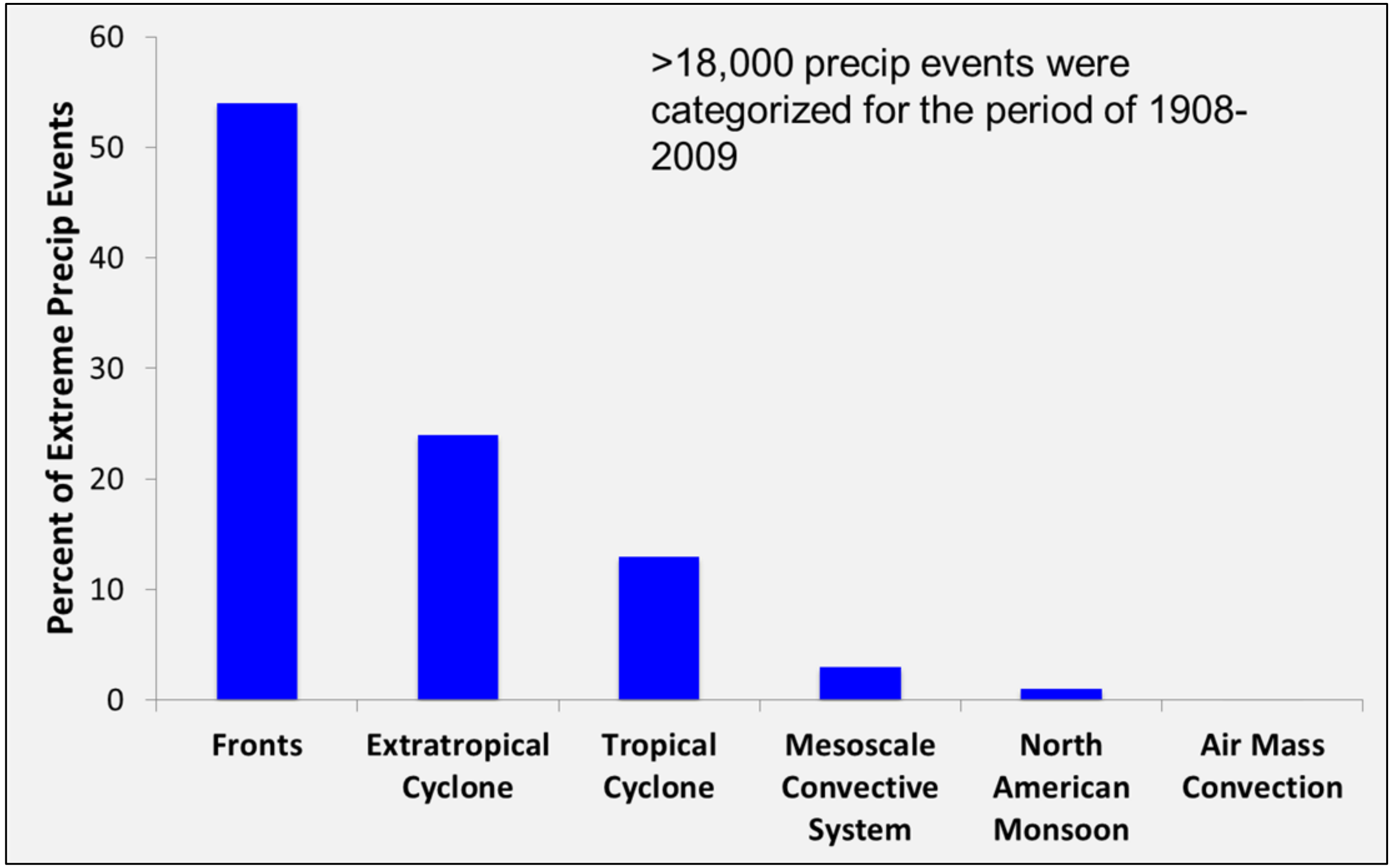


2006-2100, 2-day duration 5-year return

- A future increase in winter seasonal contribution projected for most regions
- The summer to spring shift is projected to increase for most regions through 2100
- Recall: Compared to observations, historical simulations put more events in spring and less in summer
  - This amplified shift could be a product of the models and not due to the underlying physics

Janssen et al., 2016

Meteorological causes of recent and projected increases?



Contribution by type:

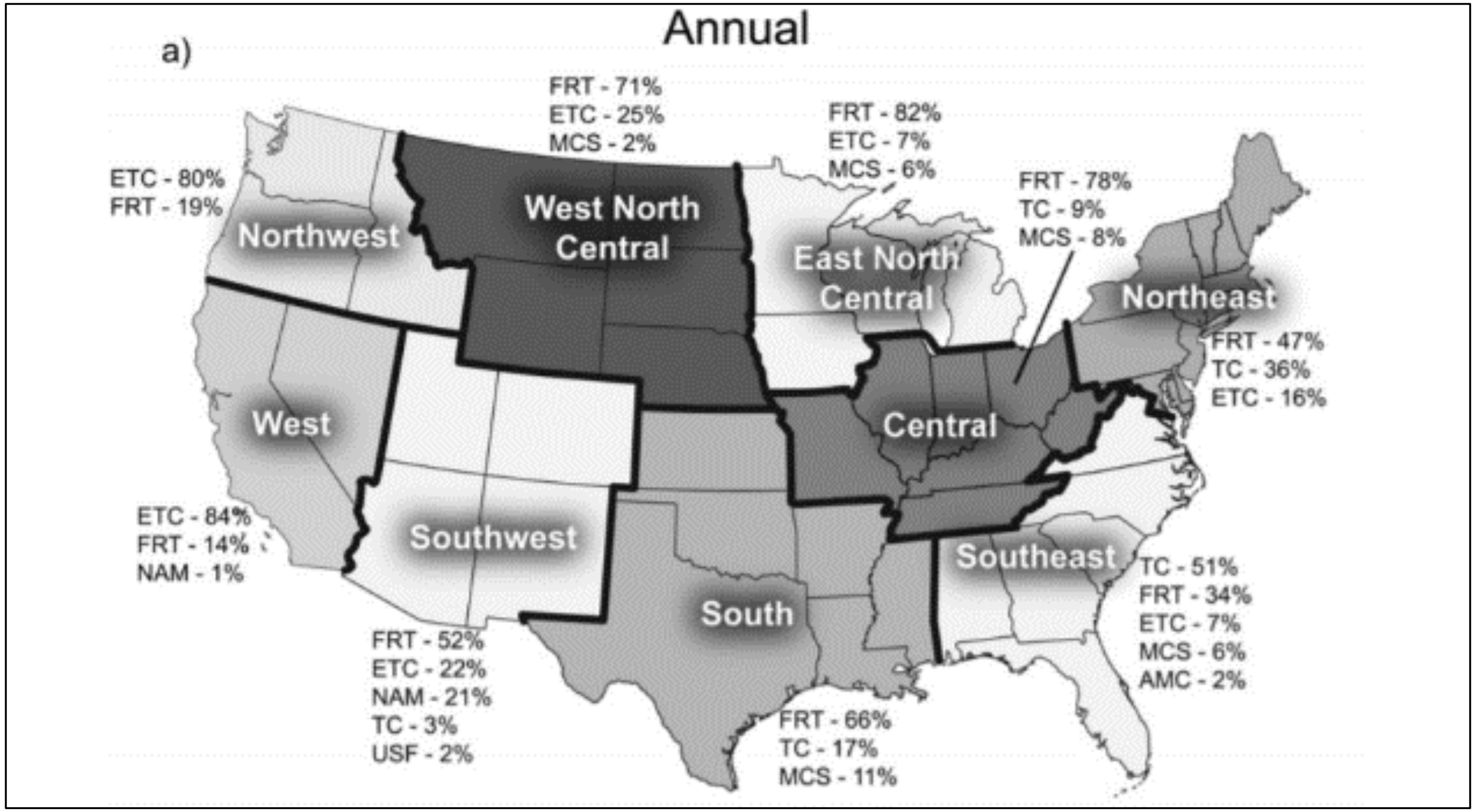
- 7 different types of event
  - 0.3% caused by upslope flow

Data:

- 1-in-5 year recurrence interval
- 1^o by 1^o grid

Kunkel, K.E., D.R. Easterling, D.A.R. Kristovich, B. Gleason, L. Stoecker, and R. Smith, 2012: Meteorological causes of the secular variations in observed extreme precipitation events for the conterminous United States. J. Hydromet., ***13****, 1131-1141.*

Regional contribution by type

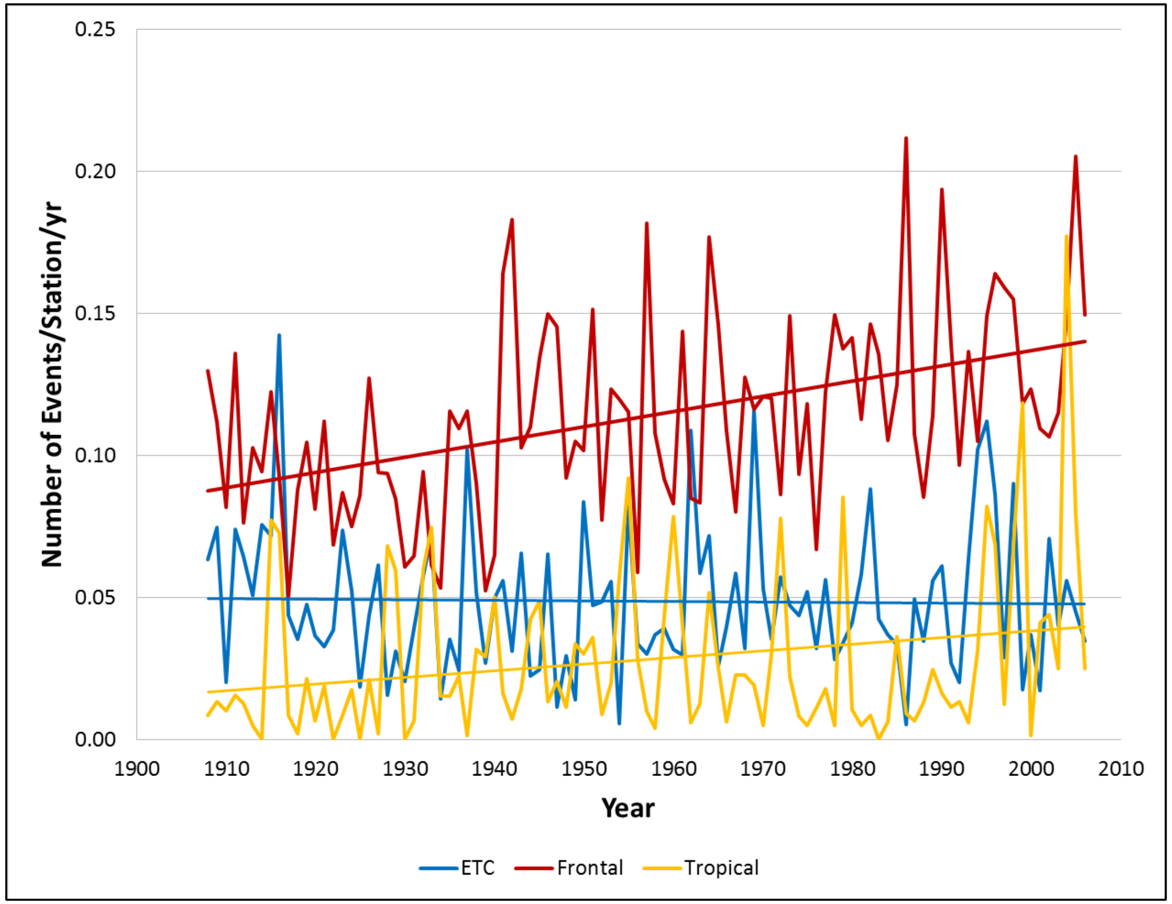


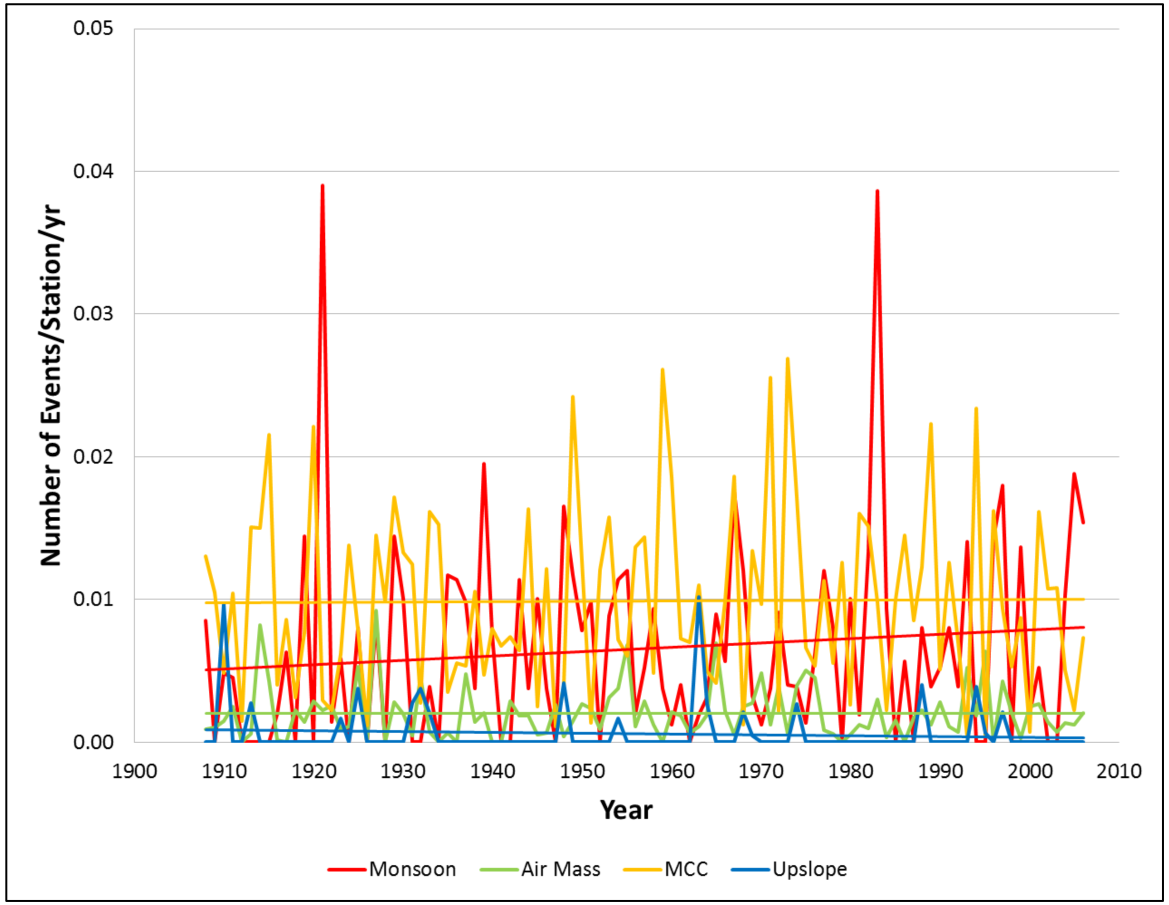
Eastern Regions

- Northeast – Mostly Frontal
- Southeast – Mostly Tropical Cyclone

Kunkel, K.E., D.R. Easterling, D.A.R. Kristovich, B. Gleason, L. Stoecker, and R. Smith, 2012: Meteorological causes of the secular variations in observed extreme precipitation events for the conterminous United States. J. Hydromet., ***13****, 1131-1141.*

Trends by Type





*Kunkel, K.E., D.R. Easterling, D.A.R. Kristovich, B. Gleason, L. Stoecker, and R. Smith, 2012: Meteorological causes of the secular variations in observed extreme precipitation events for the conterminous United States. J. Hydromet., **13**, 1131-1141.*

Meteorological Causes

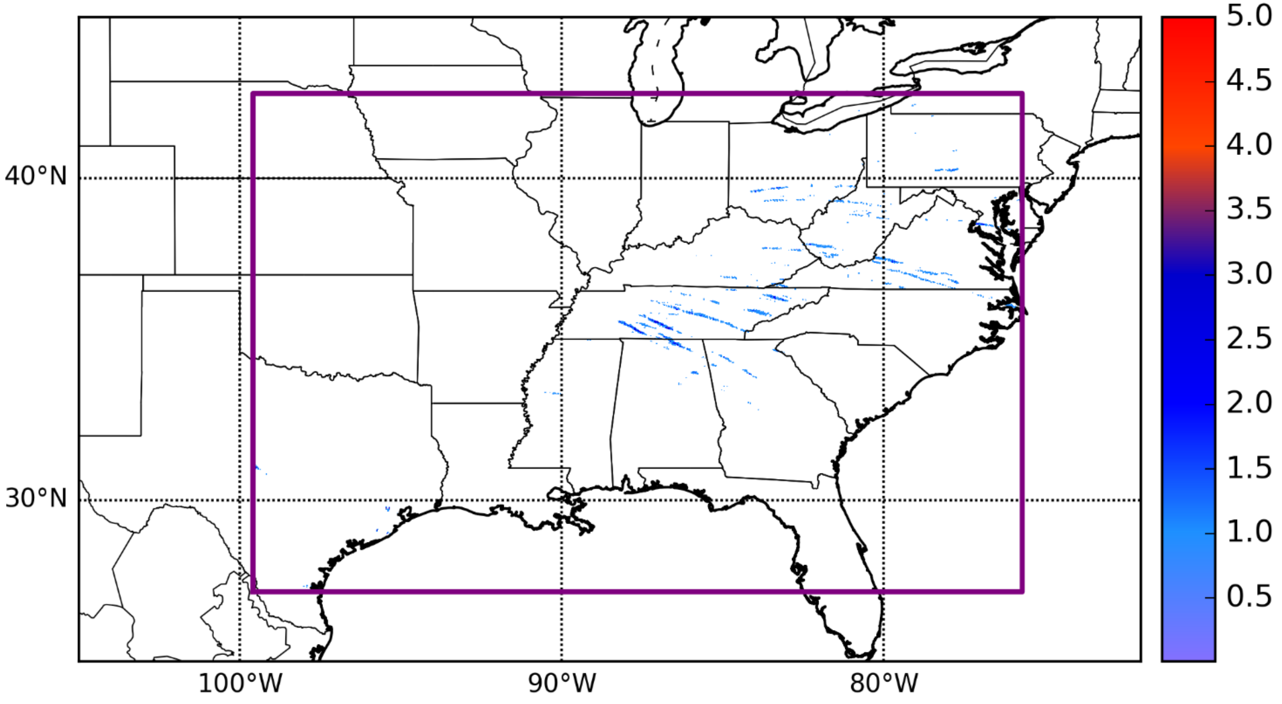
- Increase in extreme precipitation events linked to increase in number of events associated primarily with **fronts** and **tropical cyclones**.
- No long term change in number of landfalling tropical cyclones
  - TC's are producing more extreme precipitation events
- To be investigated:
  - Are more fronts occurring or are frontal characteristics becoming more favorable to extreme precipitation?
  - Attribution to increases in atmospheric water vapor concentrations?

Summary

- Increasing trends in observational EPI for all return periods over CONUS
  - Most drastic increase in Northeast
- Models underestimate observations but capture trends for CONUS
  - True for Eastern regions as well
- Increases in future EPI across all regions for RCP 8.5 (2006-2100)
  - RCP 4.5 is much more variable
- For Eastern regions most extreme events occur in Summer and Fall
- Historical simulations shift events from Summer to Spring for most regions
- A future increase in seasonal contribution of the EPI during winter is projected for most regions
- The summer to spring shift in the EPI is projected to increase for most regions through 2100
- Upward trends in extreme precipitation events mainly due to increases in storms associated with fronts and tropical cyclones

Future work – Severe hail outbreaks over the CONUS

April 28th 2002



Use 12 years of radar based severe hail proxy Maximum Expected Size of Hail (MESH) to investigate severe hail outbreaks over the CONUS

- Define a severe hail outbreak
- Short term trends in outbreaks
- Hailswath characteristics of outbreaks

- April 28th 2002
  - 8850 total severe MESH counts
  - 290 official hail reports

Current work funded by the Cooperative Institute for Climate and Satellites
Data provided by NCEI, CICS and NSSL

Questions?

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or
emilyjanssen12@gmail.com

References:

Janssen, E., D. J.Wuebbles, K. E. Kunkel, S. C. Olsen, and A. Goodman (2014), Observational- and model-based trends and projections of extreme precipitation over the contiguous United States, Earth's Future, 2, 99–113, doi:10.1002/2013EF000185.

Janssen, E., R. L. Sriver, D. J. Wuebbles, and K. E. Kunkel (2016), Seasonal and regional variations in extreme precipitation event frequency using CMIP5, Geophys. Res. Lett., 42, doi: 10.1002/2016GL069151.

Kunkel, K.E., D.R. Easterling, D.A.R. Kristovich, B. Gleason, L. Stoecker, and R. Smith, 2012: Meteorological causes of the secular variations in observed extreme precipitation events for the conterminous United States. J. Hydromet., 13, 1131-1141.

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