Hydroclimatic Extremes Trends and Projections: A View from the Fourth National Climate Assessment

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Outline

- Key findings from the Fourth National Climate Assessment
- Supplementary material from my research

Overarching Question

- How will global warming due to increasing greenhouse gas concentrations change the risk of extreme precipitation events?

The Challenge

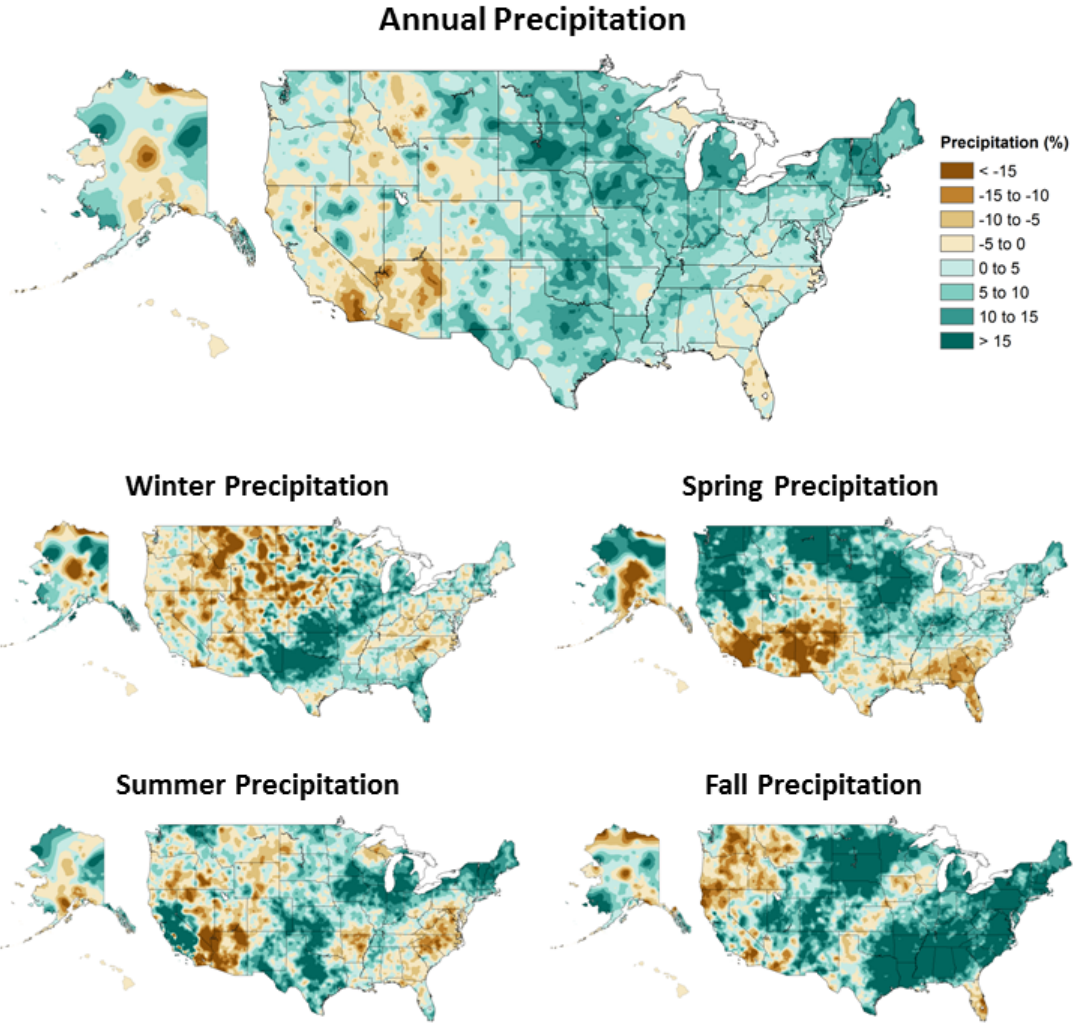
- Complex temporal and spatial coherence and variability of extreme precipitation events –
  - Individual thunderstorm cells – hour, a few km
  - Thunderstorm complexes – a few hours, tens-100+ km
  - Spiral rain bands in hurricanes – a few hours, tens-100+ km
  - Low pressure wave – day, 100s of km
  - Hurricanes – day, 100s of km
  - Synoptic low pressure system – days, 1000+ km
  - Hemispheric jet stream wave patterns – weeks, 1000s of km

NCA4

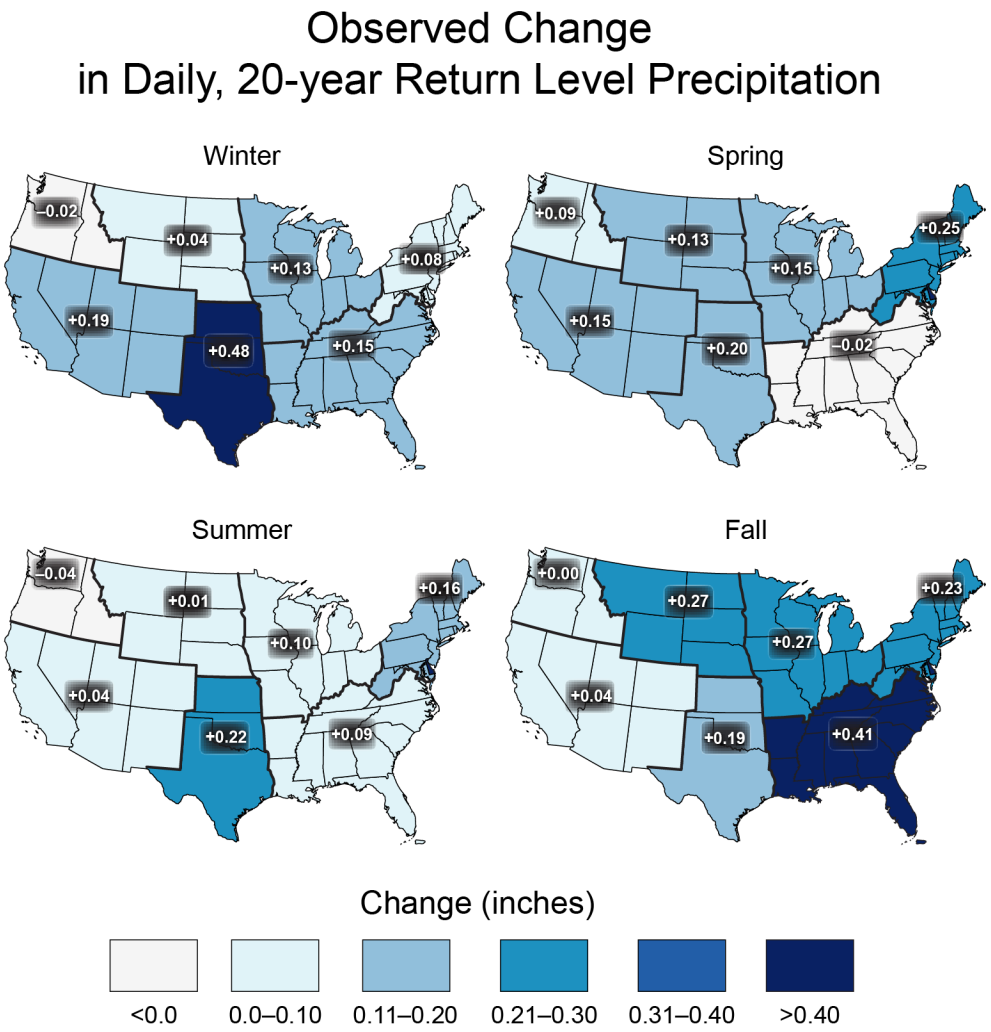
Historical Trends

- Global Historical Climatology Network-Daily (GHCND)
- Long-term stations

U.S. Mean Precipitation Trends



U.S. Extreme Precipitation Trends



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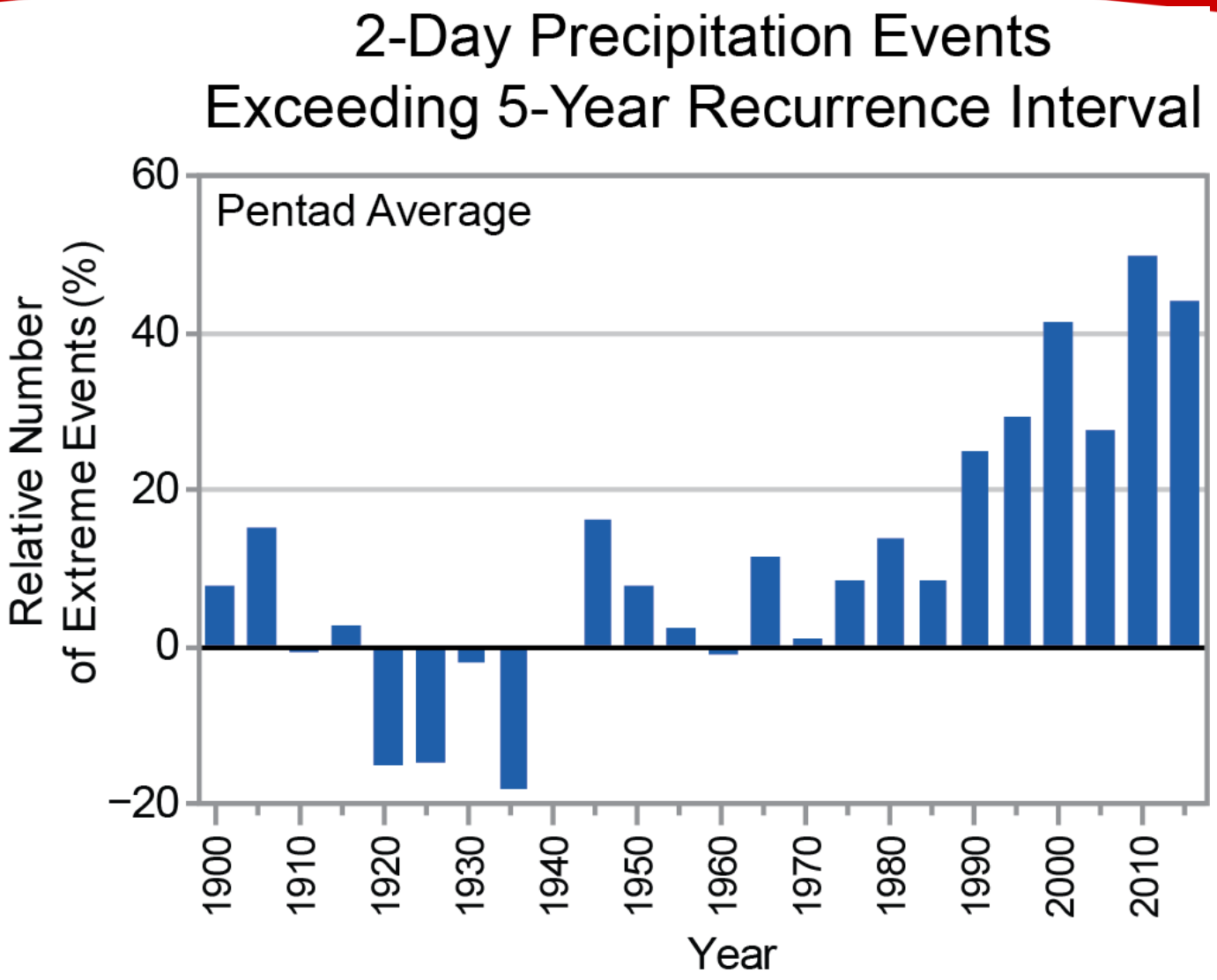

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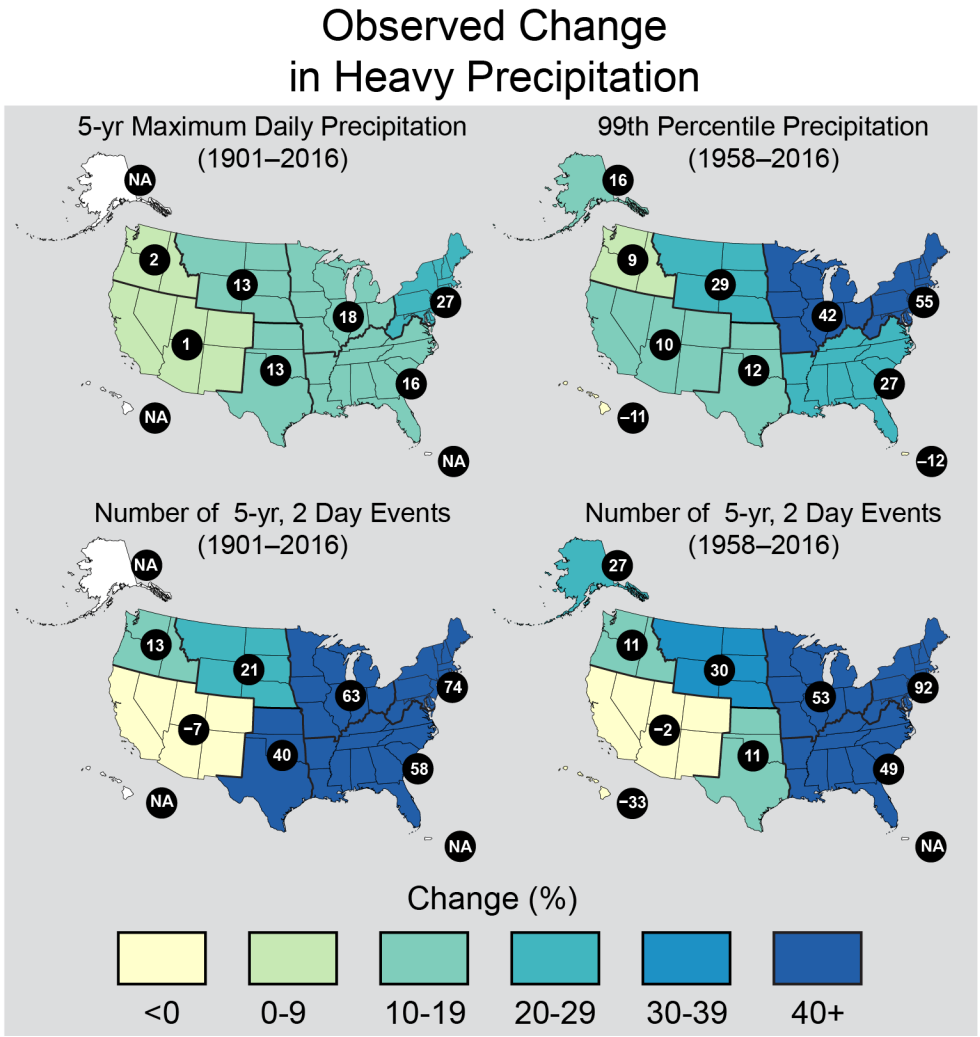
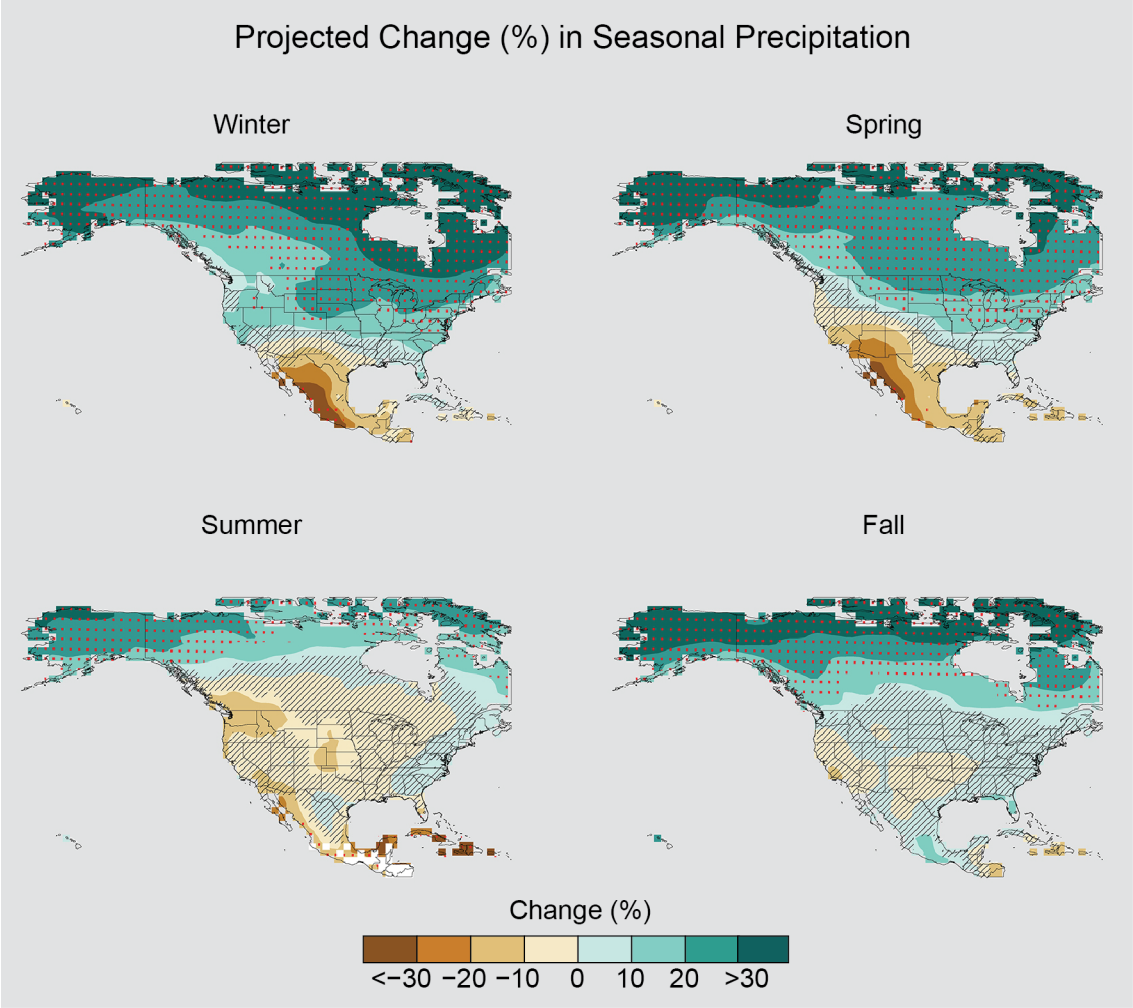


Future Projections

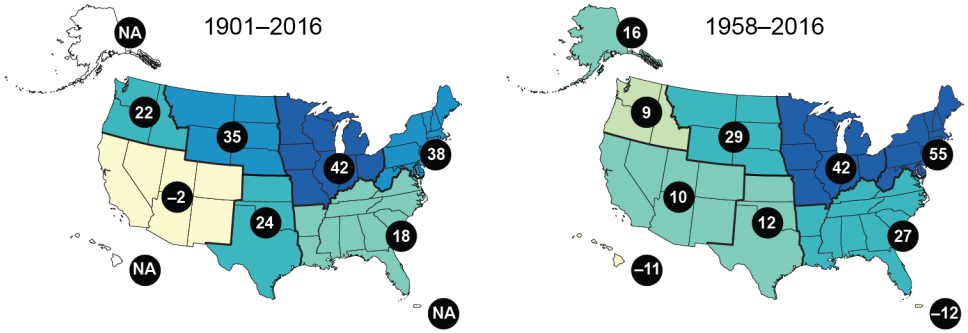
- NCA4 primarily used two future scenarios, RCP4.5 and RCP8.5, to frame the treatment
- Direct output of CMIP5 models
- Statistically downscaled data
  - Localized Constructed Analogs (LOCA)

Mean Precipitation Projections

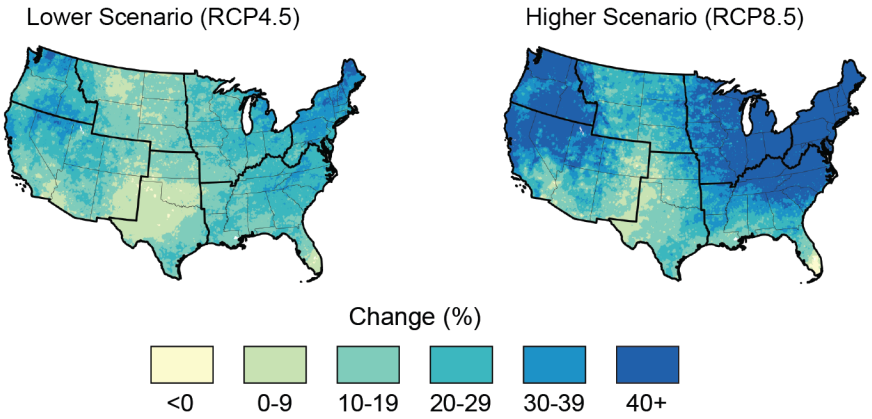


U.S. Extreme Precipitation Trends and Projections

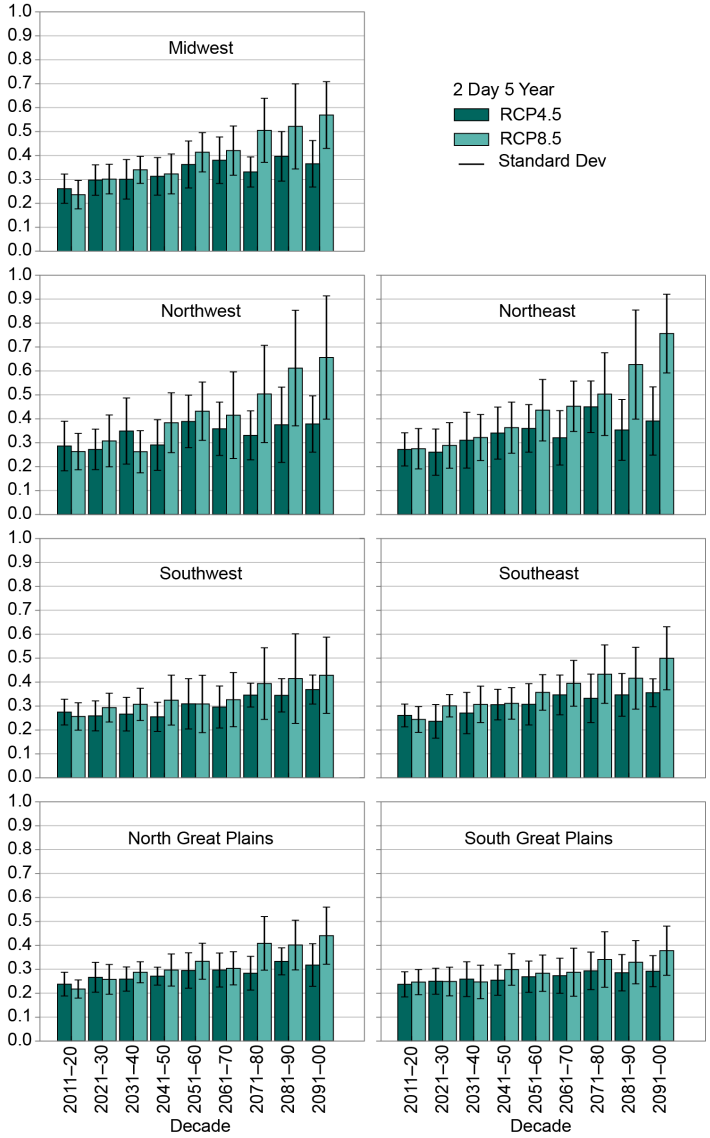
Observed Change in Total Annual Precipitation
Falling in the Heaviest 1% of Events



Projected Change in Total Annual Precipitation
Falling in the Heaviest 1% of Events by Late 21st Century



U.S. Extreme Precipitation Projections



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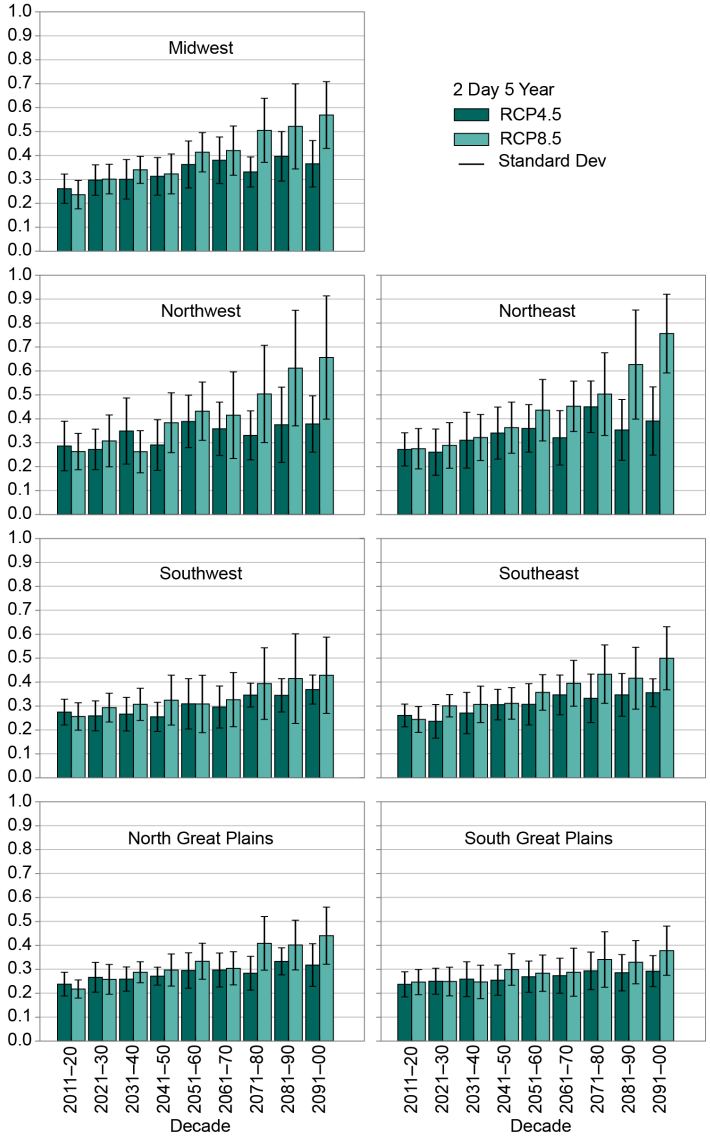
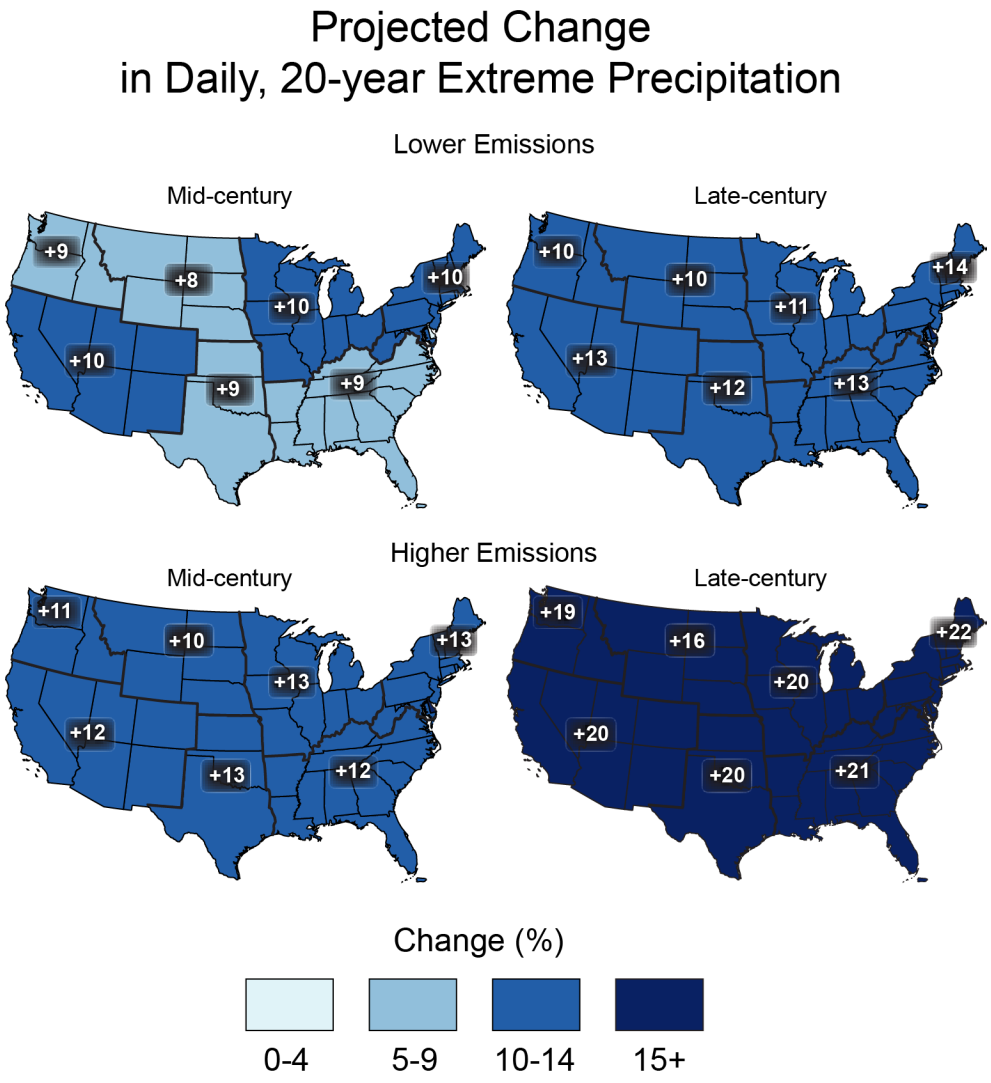


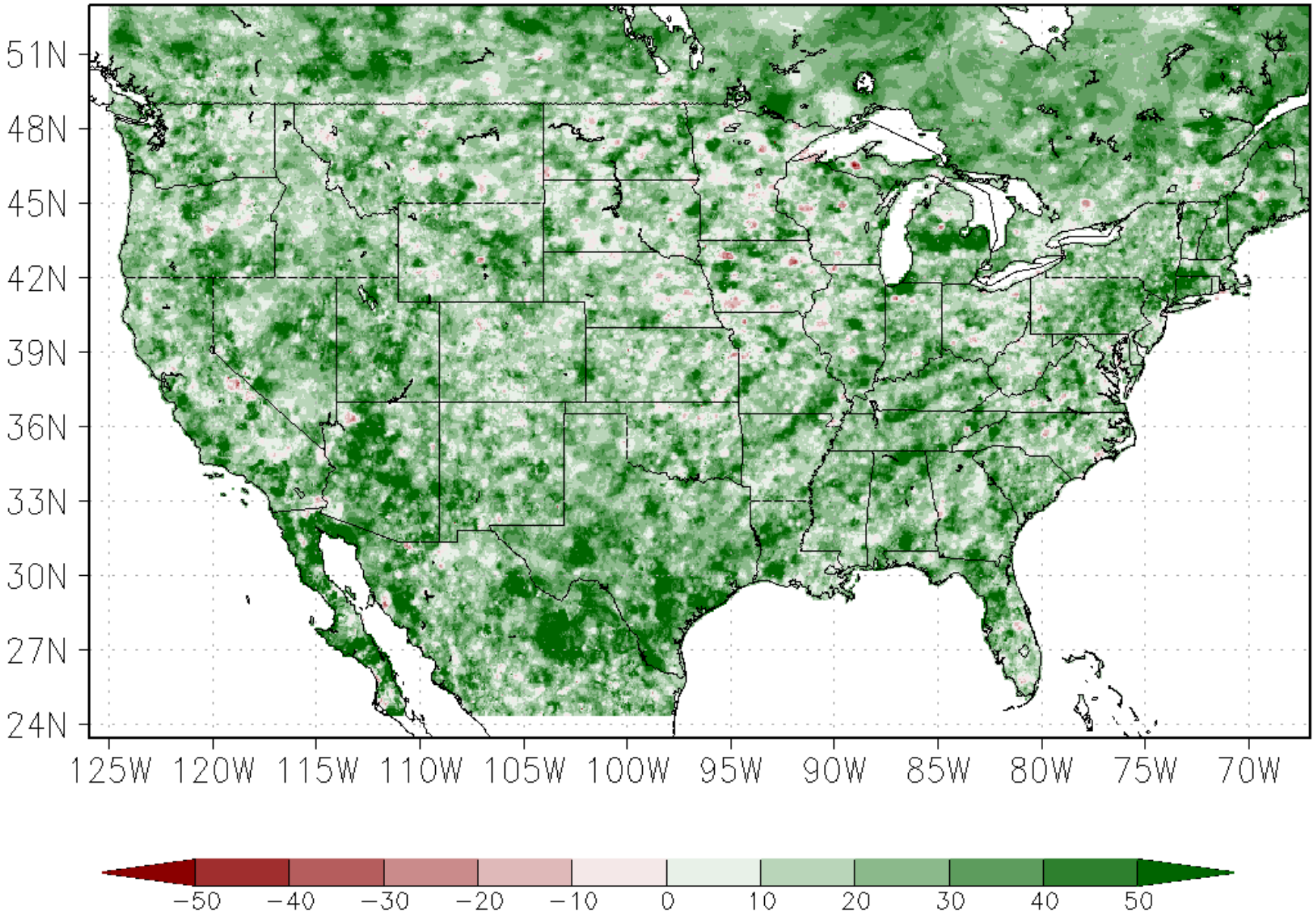
Janssen, E., R.L. Shriver, D.J. Wuebbles, and K.E. Kunkel, 2016: Seasonal and regional variations in extreme precipitation event frequency using CMIP5. *Geophys. Res. Lett.*, 43, 5385-5393, doi: 10.1002/2016GL069151

U.S. Extreme Precipitation Projections

- GEV analysis of daily precipitation
  - Annual Maximum Series of daily precipitation
  - 30-yr time blocks: 1976-2005, 2036-2065, 2070-2099
  - LOCA data

U.S. Extreme Precipitation Trends




51N
48N
45N
42N
39N
36N
33N
30N
27N
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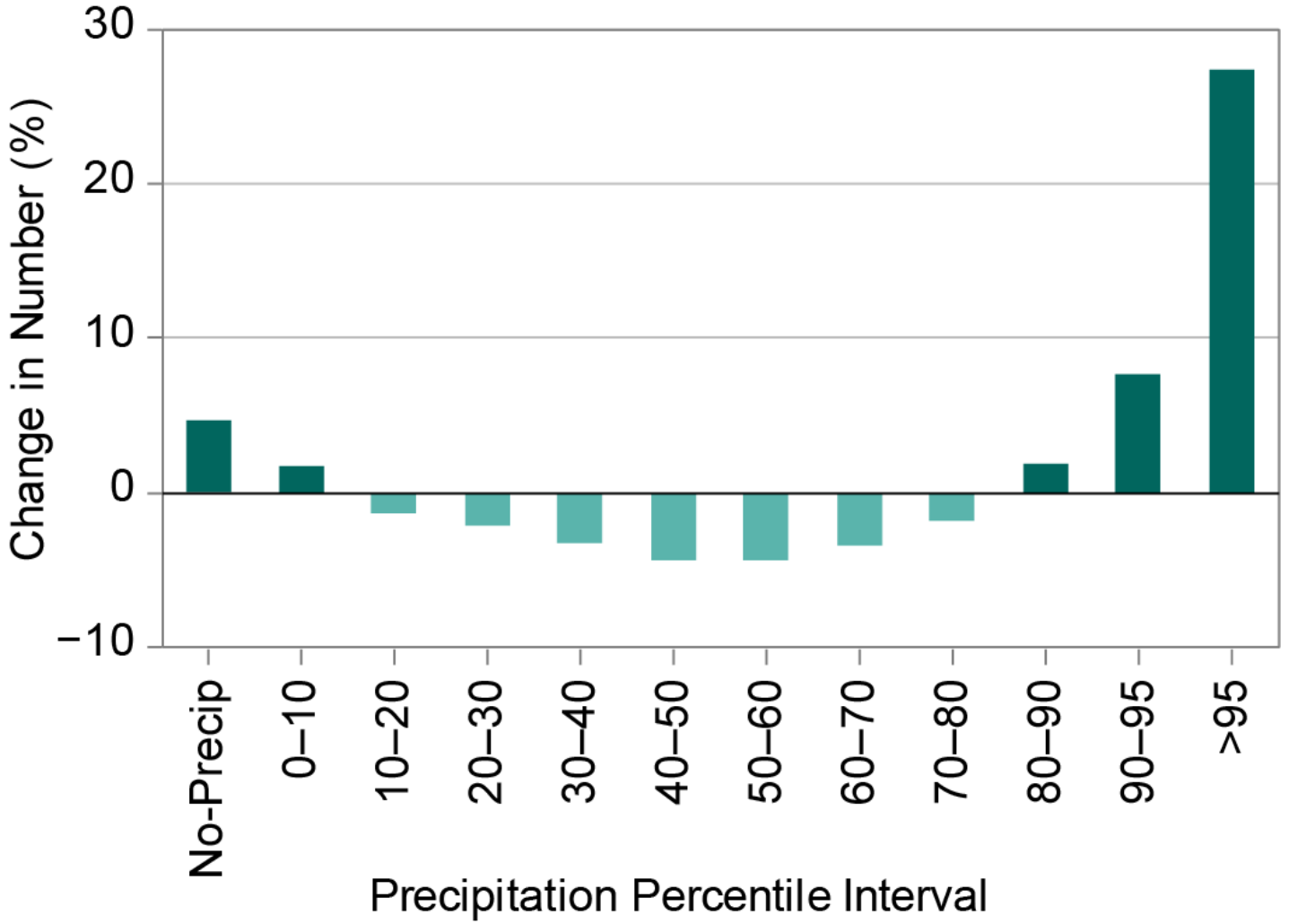
125W 120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W
−50 −40 −30 −20 −10 0 10 20 30 40 50

U.S. Precipitation Projections

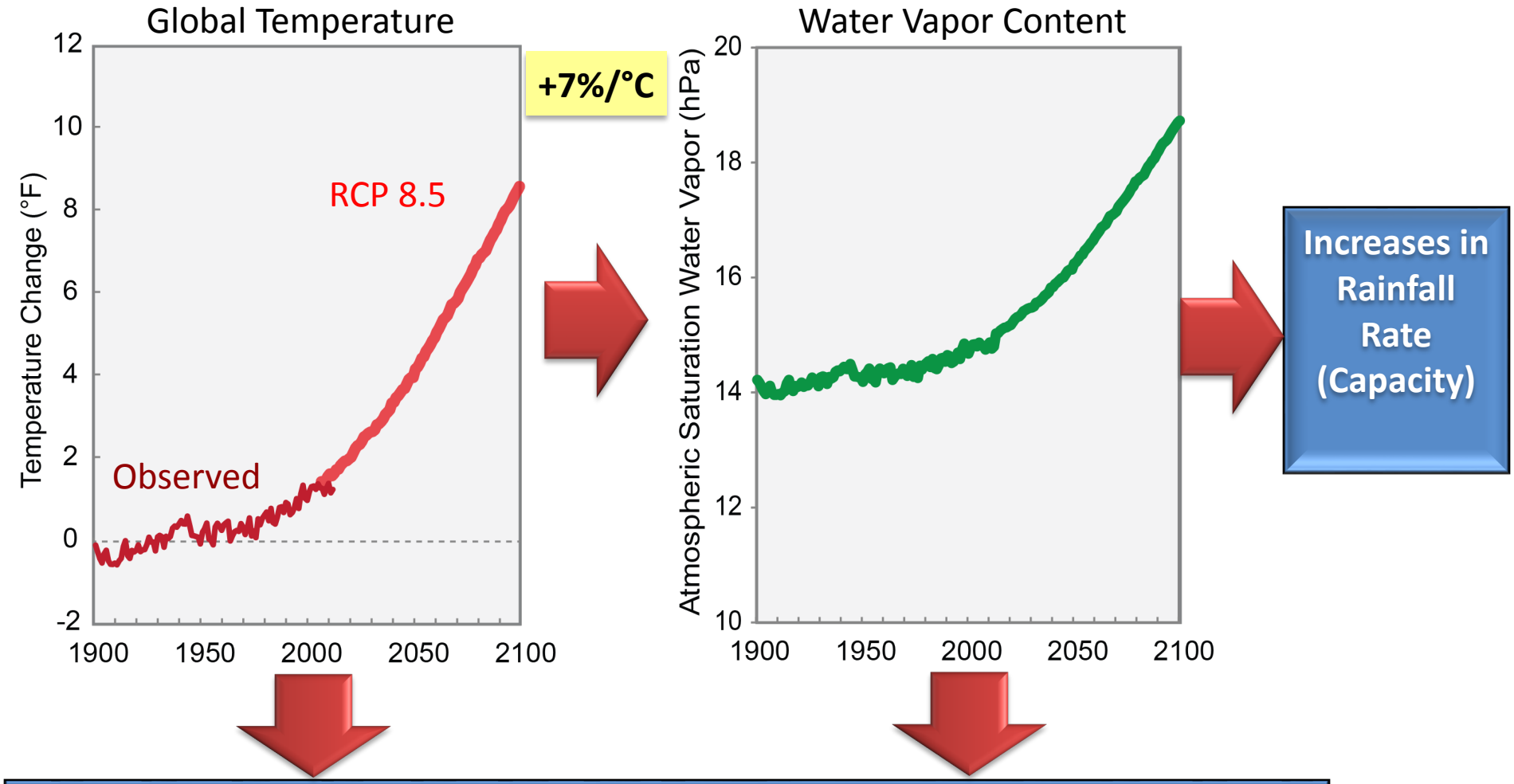


Personal Research Results

Extreme Precipitation Ingredients

- High atmospheric water vapor content
- Upward vertical motion caused by weather systems
  - Extratropical Cyclones
    - Mostly near the fronts of ETCs
  - Tropical Cyclones
  - Intense local convection

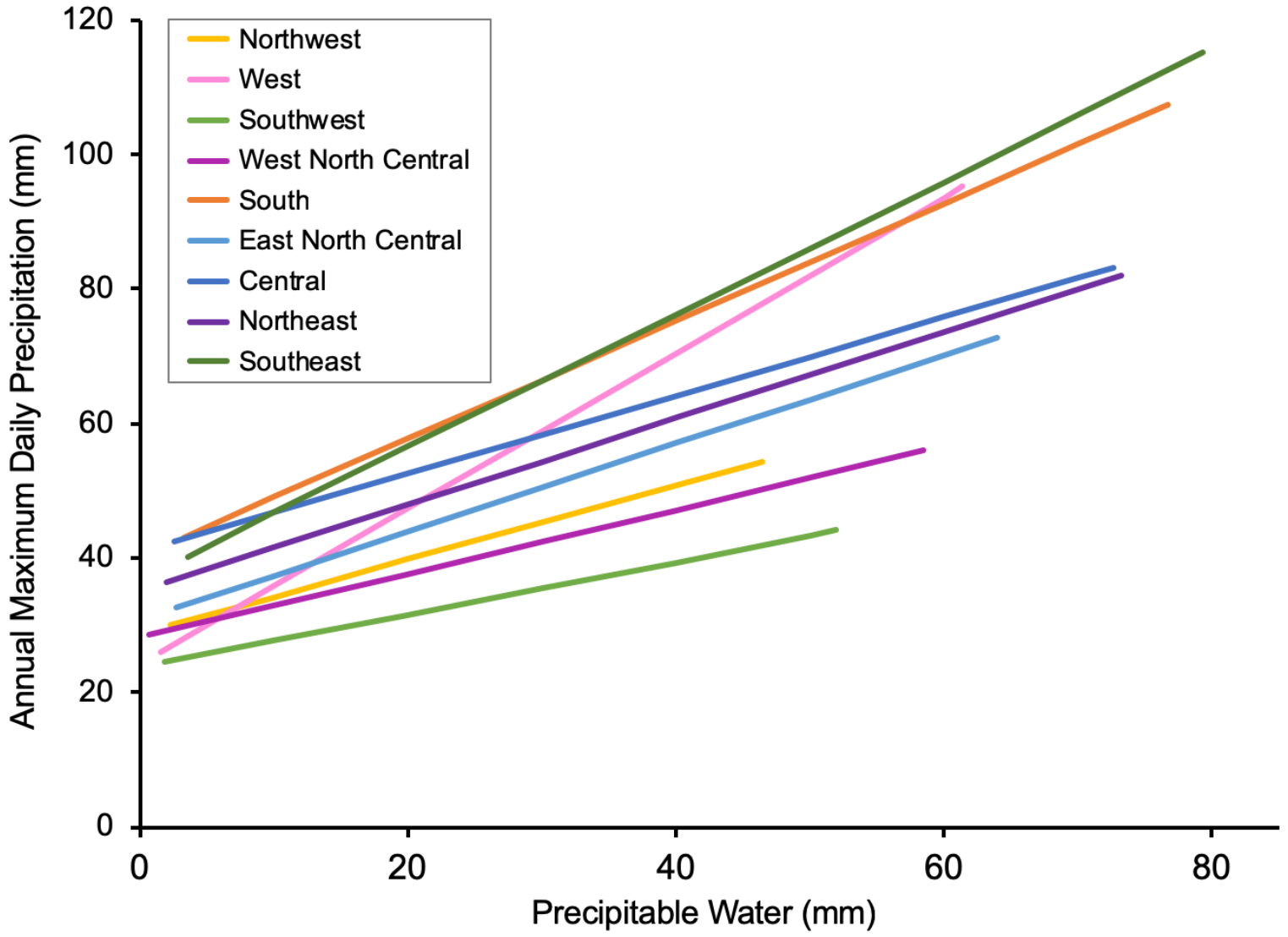
Global Warming->Saturation Water Vapor Increases



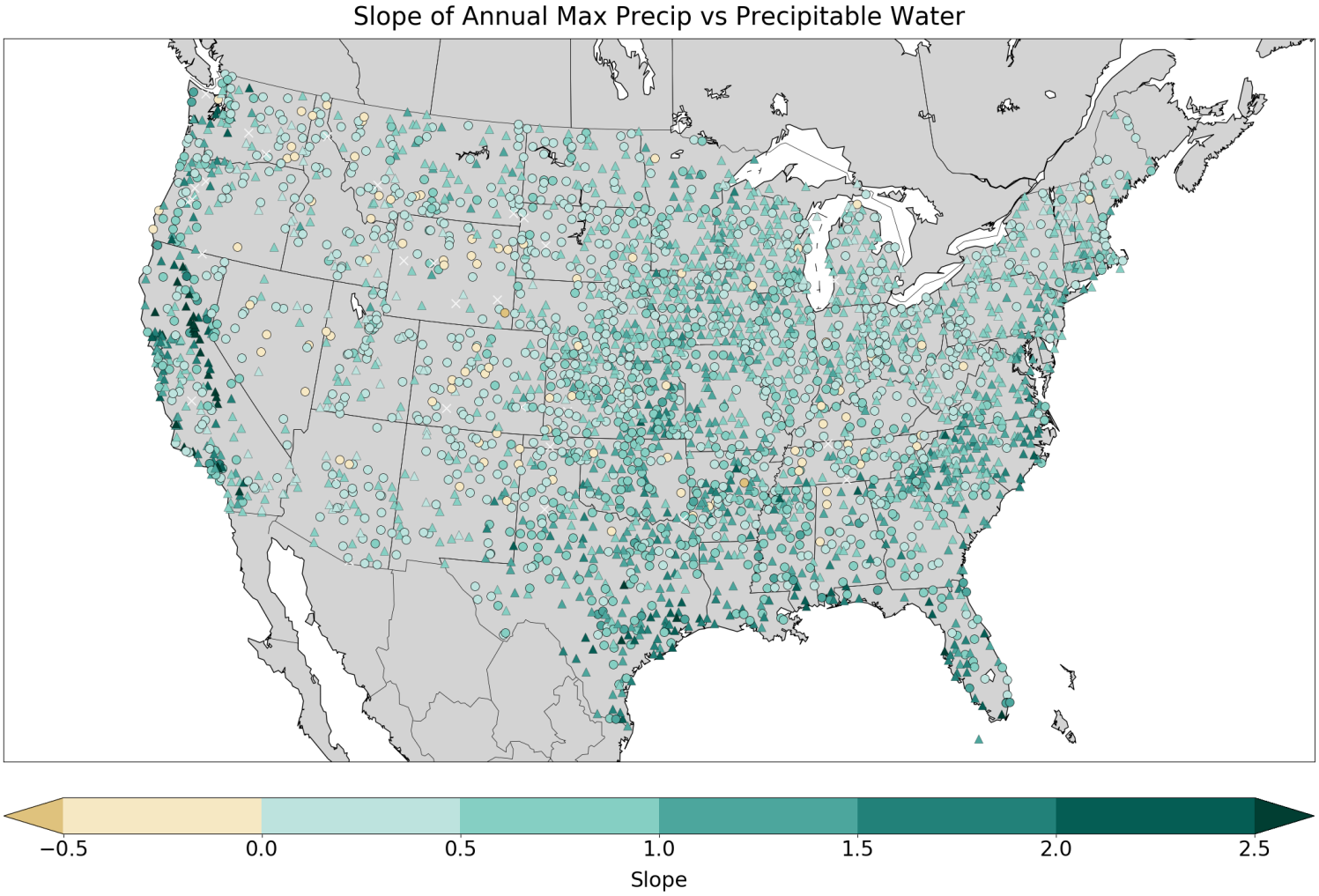
Water Vapor-Extreme Precipitation

- Annual maximum daily precipitation (AMS) at 3104 stations
- Relationship of precipitation magnitude with water vapor (precipitable water)
- Relationship of number of extreme precipitation events (1-yr, 1-dy) vs water vapor
- Probability of >25 mm events vs water vapor

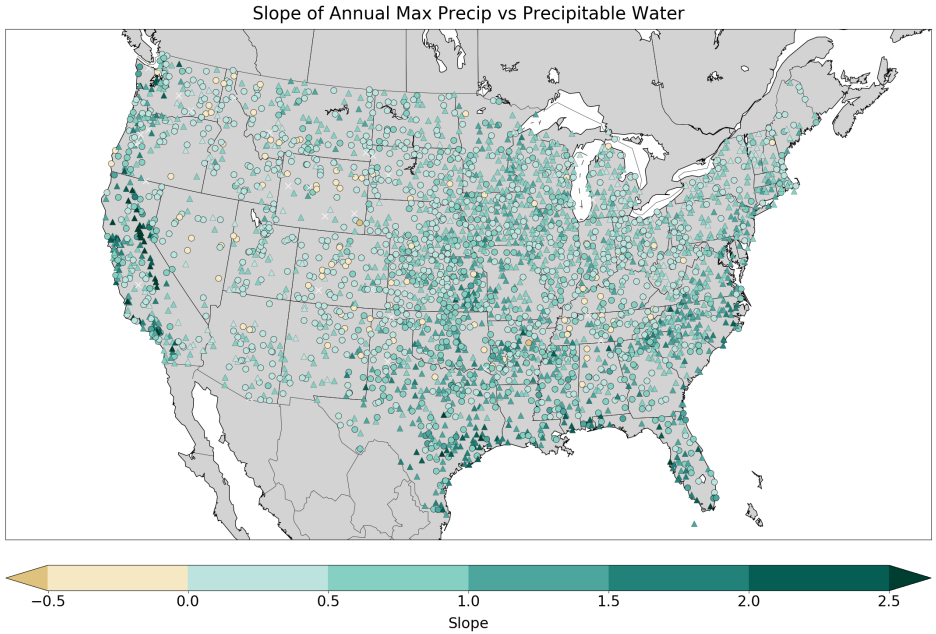
Water Vapor and Extreme Precipitation



Water Vapor and Extreme Precipitation



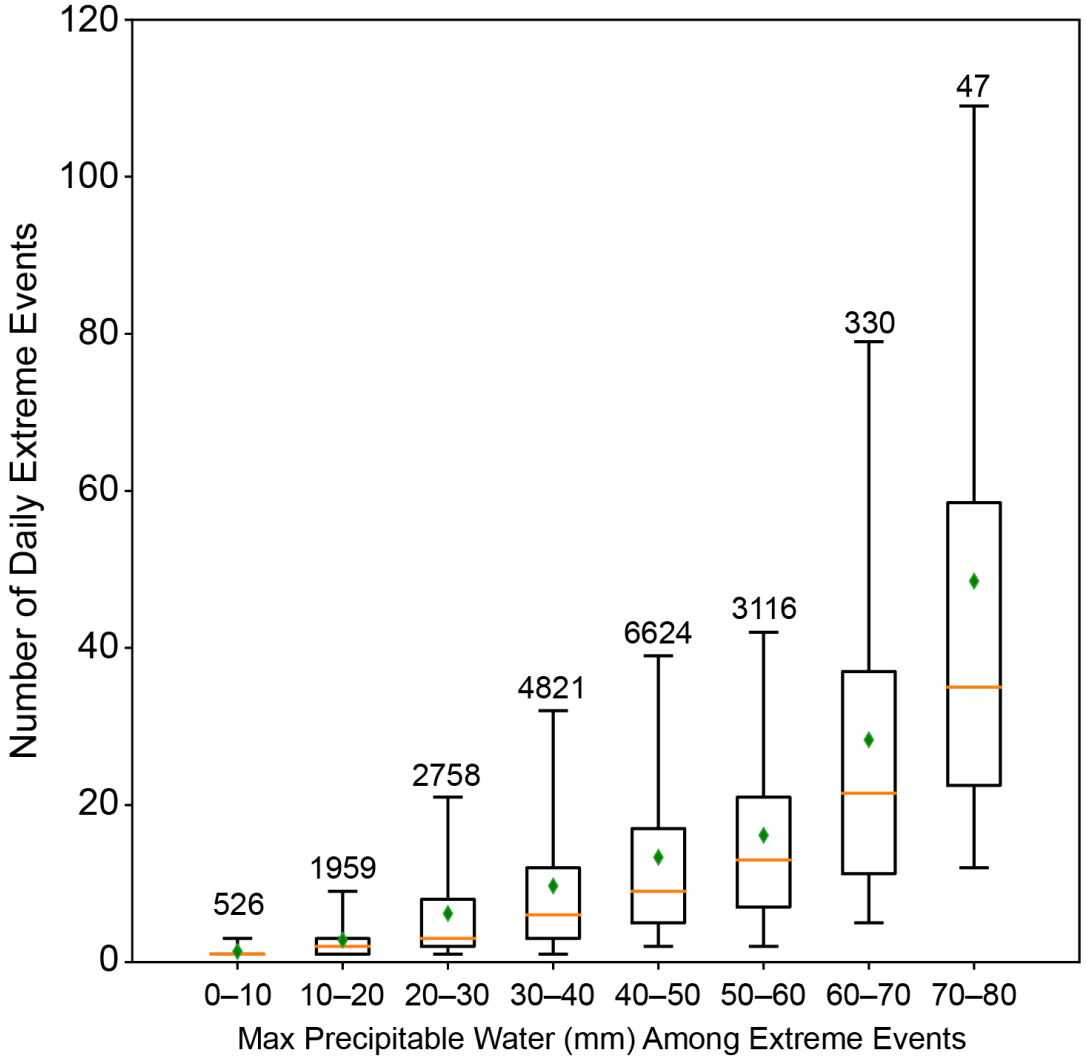
Water Vapor and Extreme Precipitation



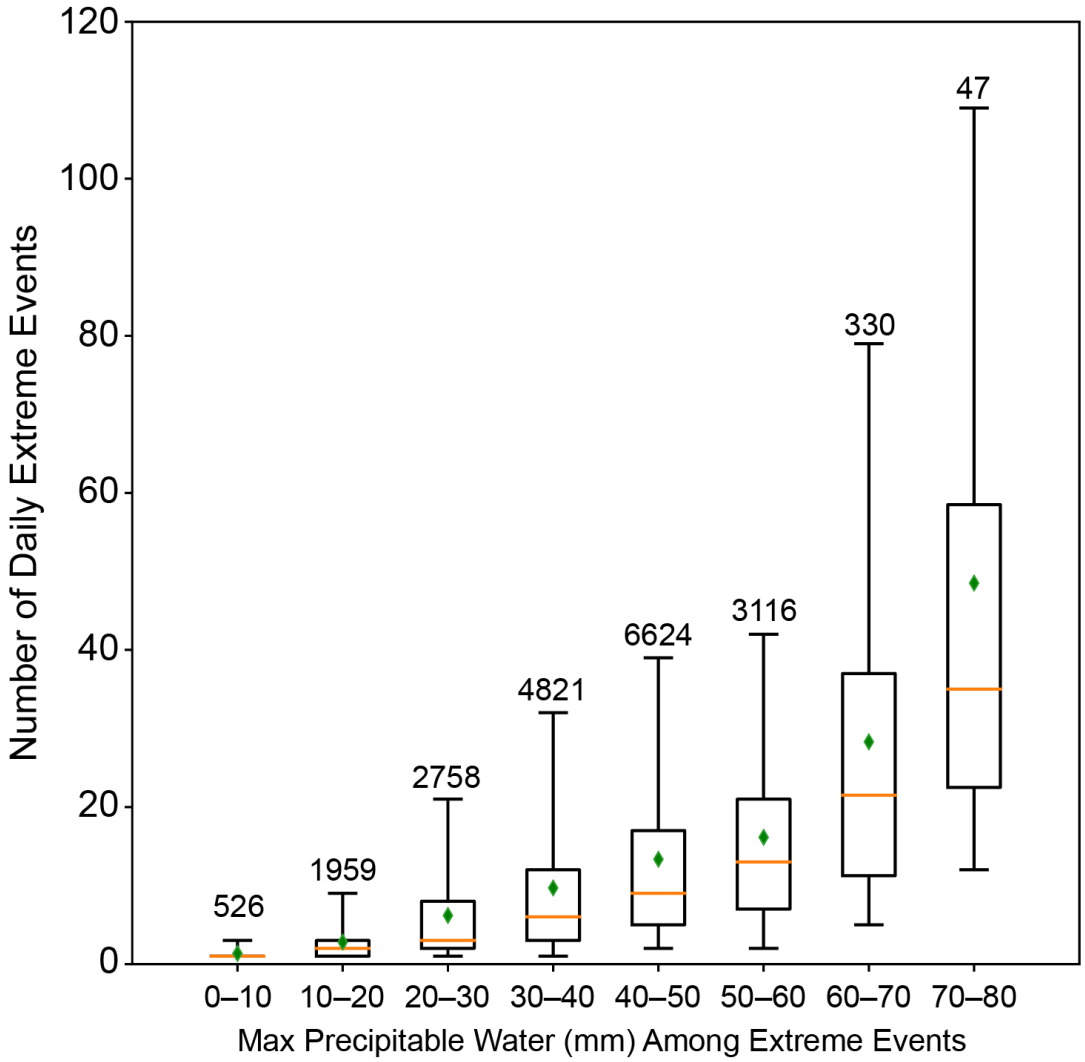
1617 of the 3104 stations have a **statistically significant positive** relationship

0 of the 3104 stations have a **statistically significant negative** relationship

Water Vapor and Extreme Precipitation

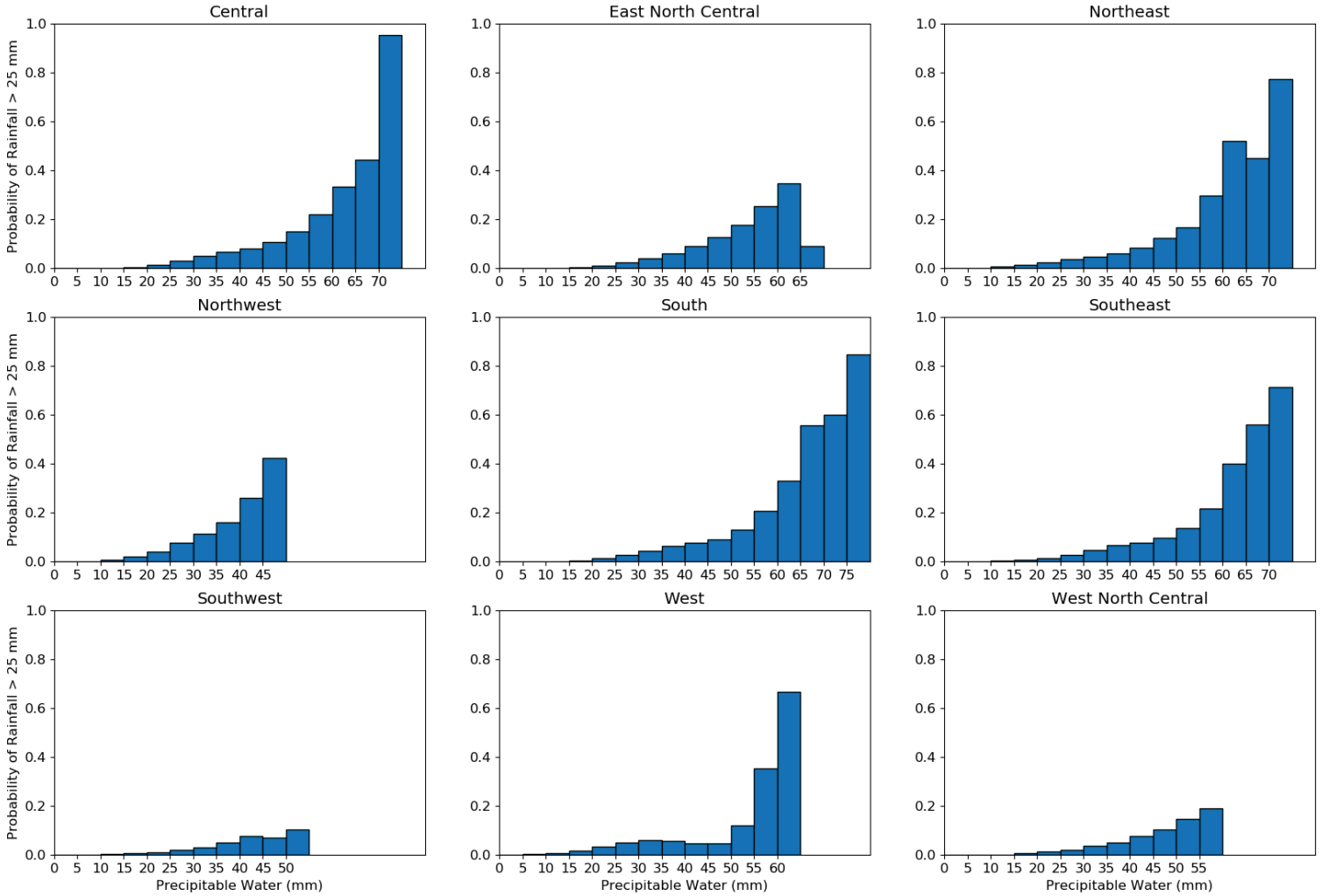


Water Vapor and Extreme Precipitation



Widespread occurrences of extreme precipitation events occur only with high water vapor content

Water Vapor and Extreme Precipitation

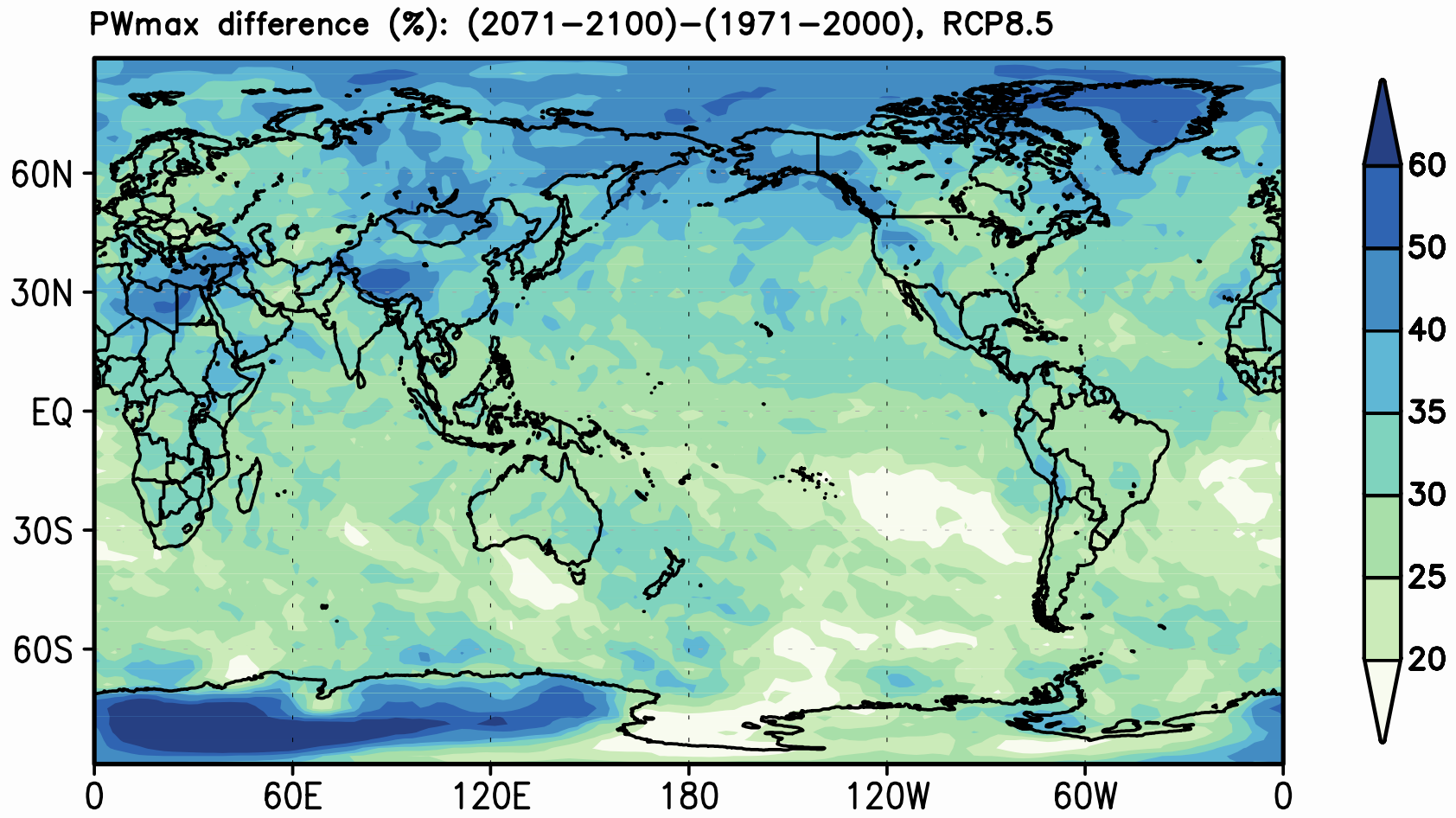


Future Projections

- 13 CMIP5 models
- Daily Precipitation
- Highest values of daily precipitation and precipitable water in 30-yr blocks

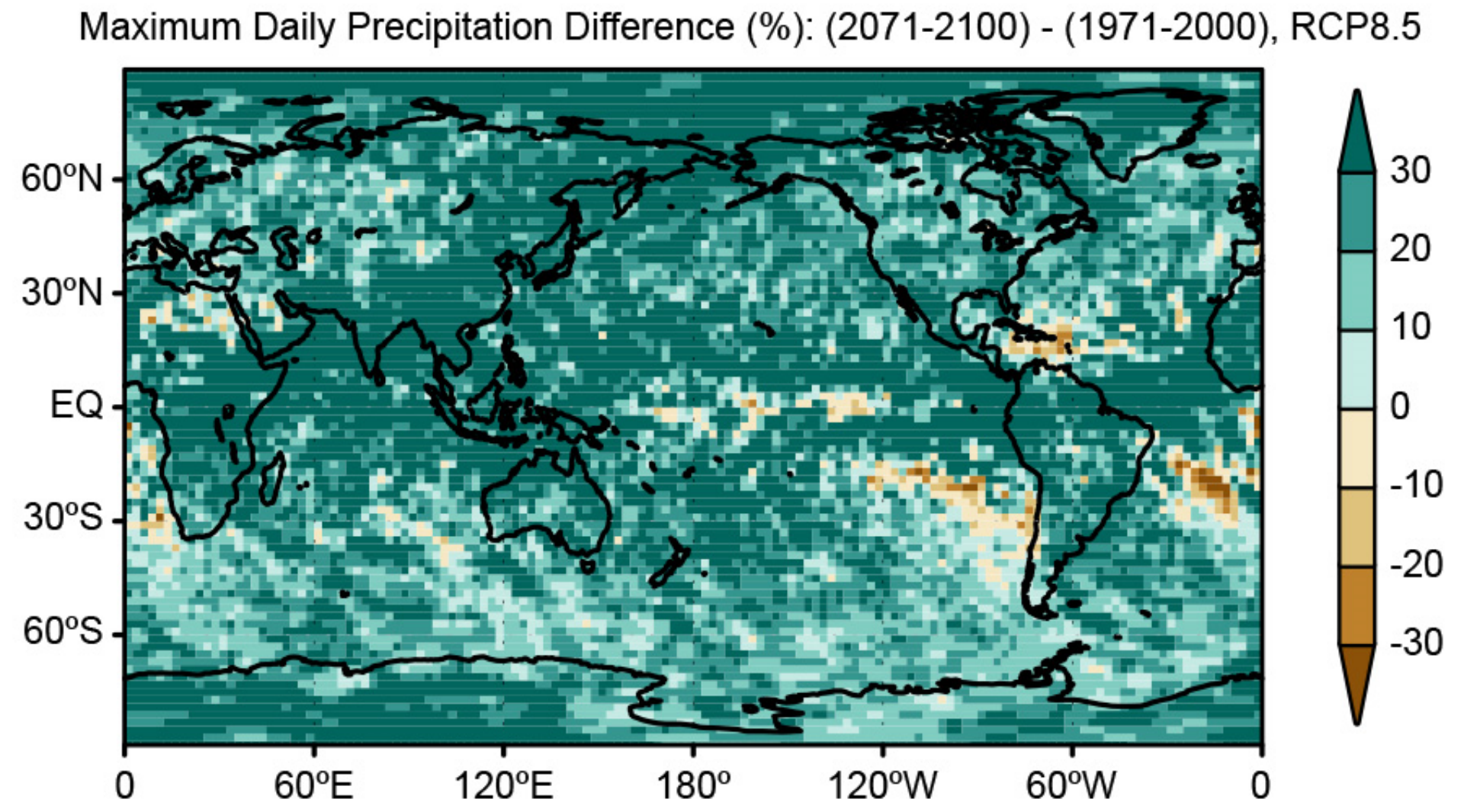
30-yr maximum precipitable water

Projected 100-yr trends



30-yr Maximum Daily Precipitation

Projected 100-yr trends

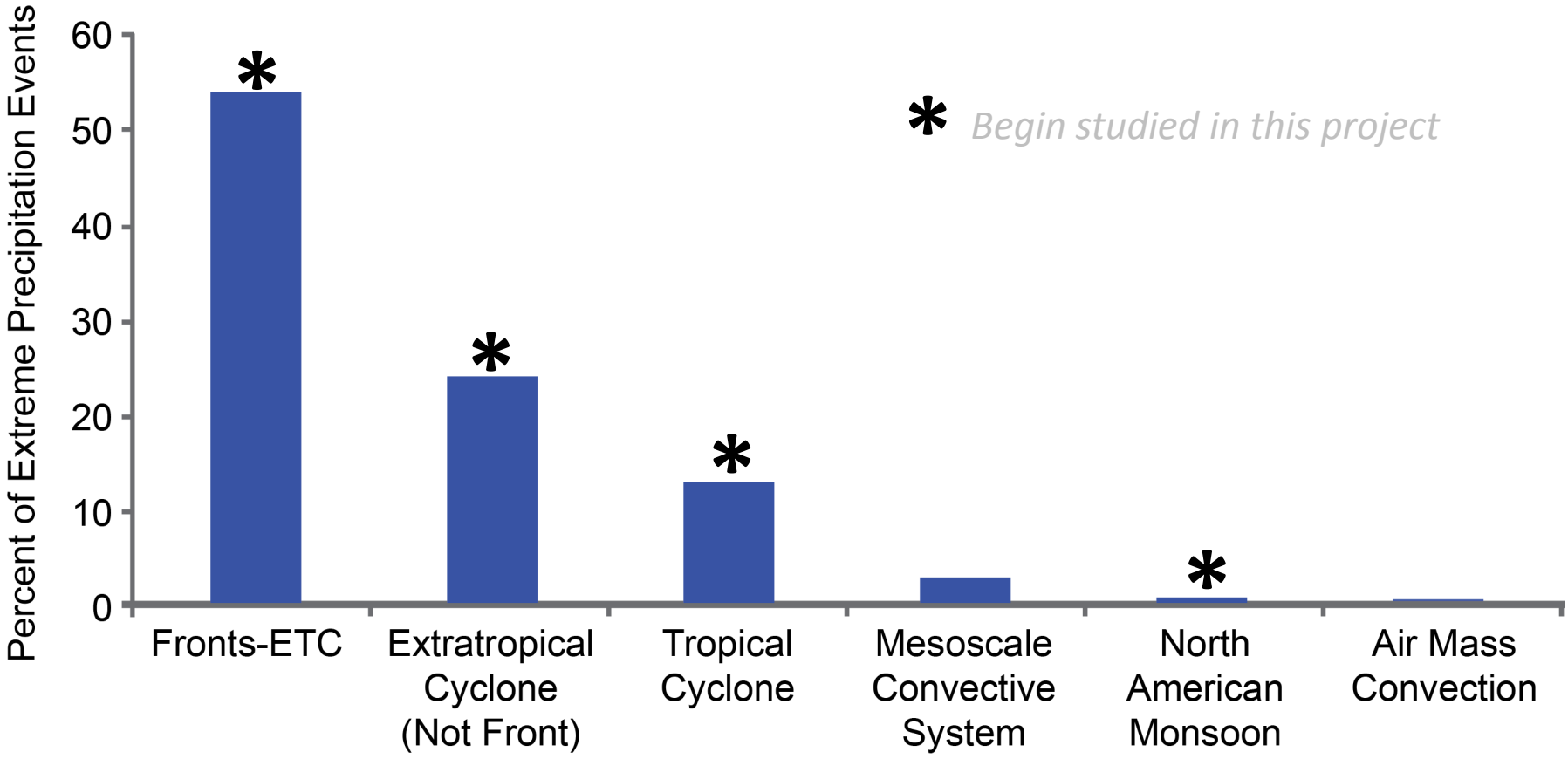


Phenomenological Analysis of Weather

- Major **meteorological phenomena** associated with extremes
  - 1-day duration events exceeding threshold for a 1-in-5yr average recurrence interval
  - 1908-2013
  - ~900 stations, > **18,000 events**
  - **Manual analysis**

Meteorology Causing Extreme Events

Dominated by Large Systems



Future Changes in Weather Systems

- Summer fronts may decrease in number
- Extratropical cyclones may also decrease in number but the number of strong ETCs may increase and they may slow down
- Strongest tropical cyclones are projected to increase in number

Conclusions

- Extreme precipitation events have increased
- We have High Confidence that global warming will lead to future increases in extreme precipitation
  - Basic physics of the saturation water vapor-temperature relationship
- Future weather system changes are less certain, but likely to be a second order effect