Update: IDF Design Value Improvement

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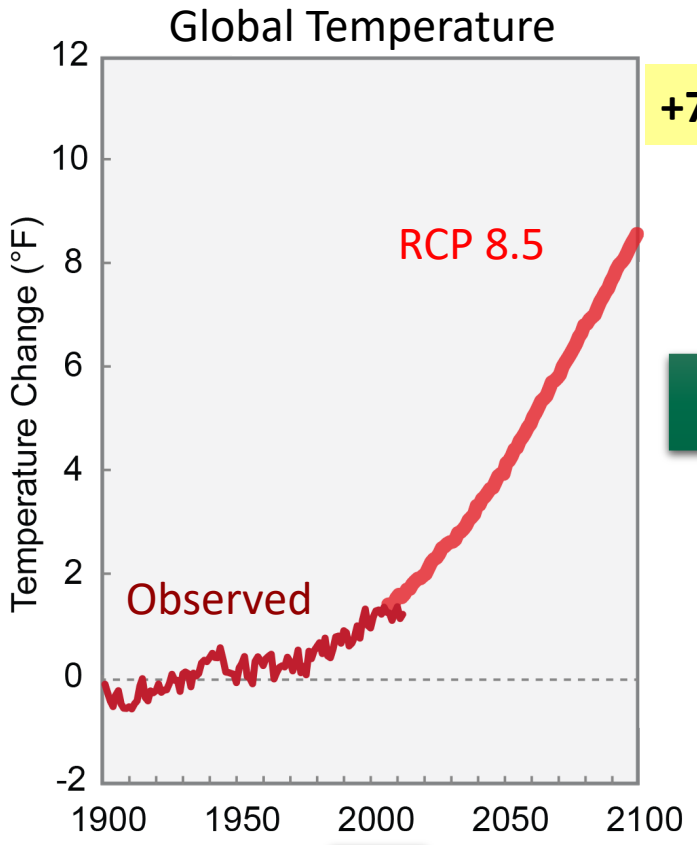
25 YEARS OF ESTCP
2019 | Enhancing DoD's Mission Effectiveness

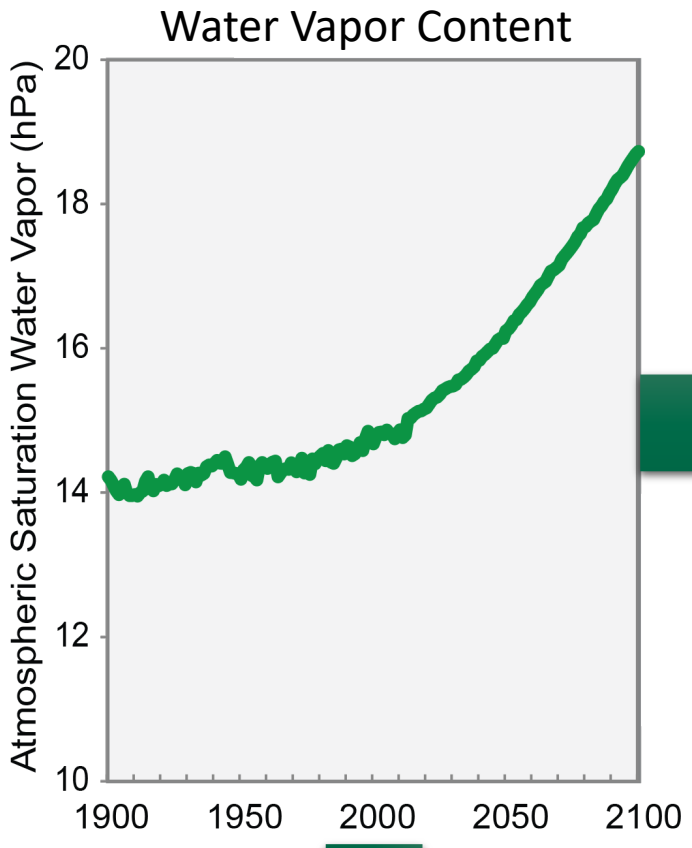
Global Warming and Extreme Precipitation

- How will global warming due to increasing greenhouse gas concentrations change the risk of extreme precipitation events?
- Primary Effect: A warmer world has more atmospheric water vapor

Global Warming->Saturation Water Vapor Increases



+7%/°C



Increases in Rainfall Rate (Capacity)

Changes in Meteorological Systems (Opportunity)

Historical Trends

Has Extreme Precipitation Increased?

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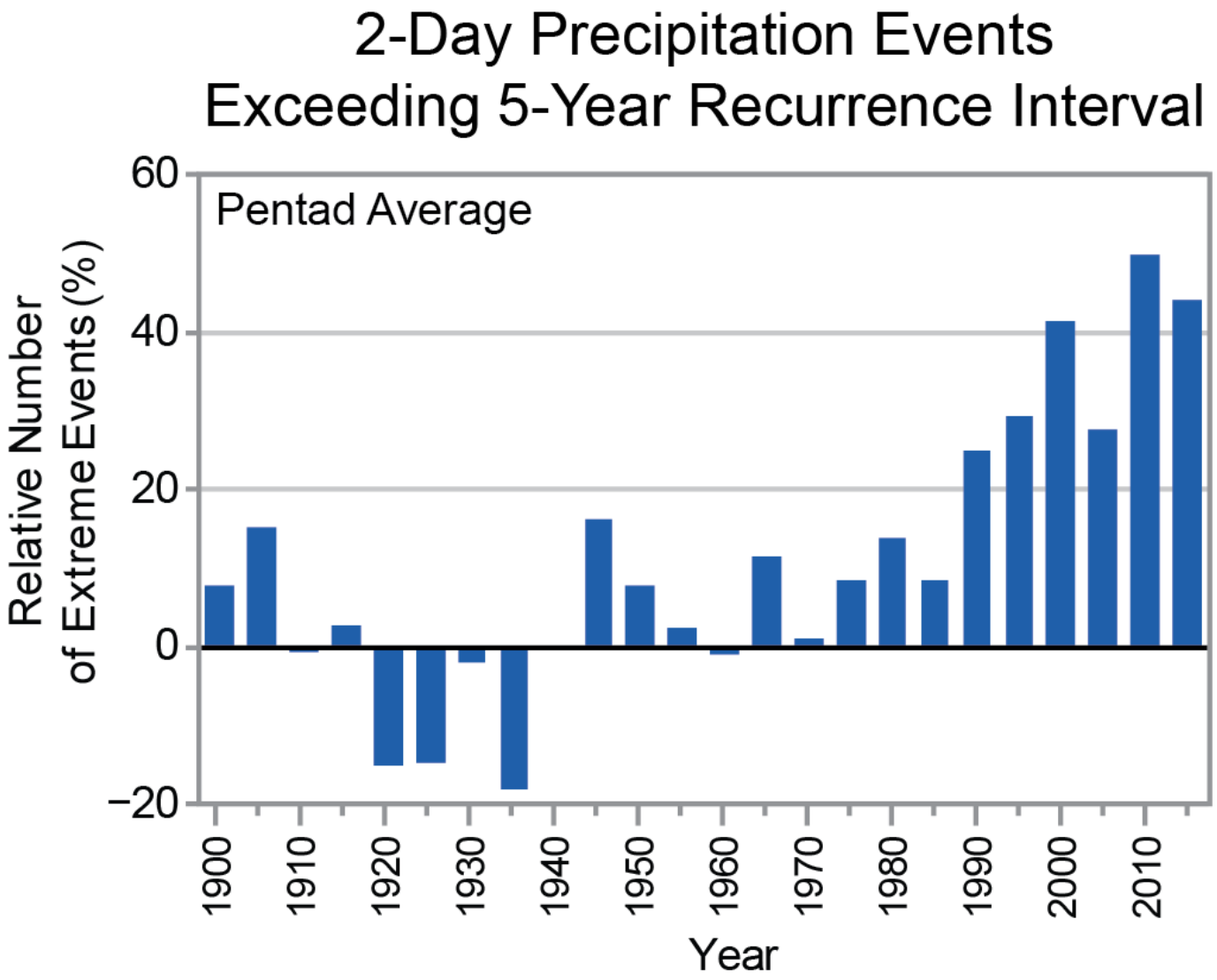
Historical Trends

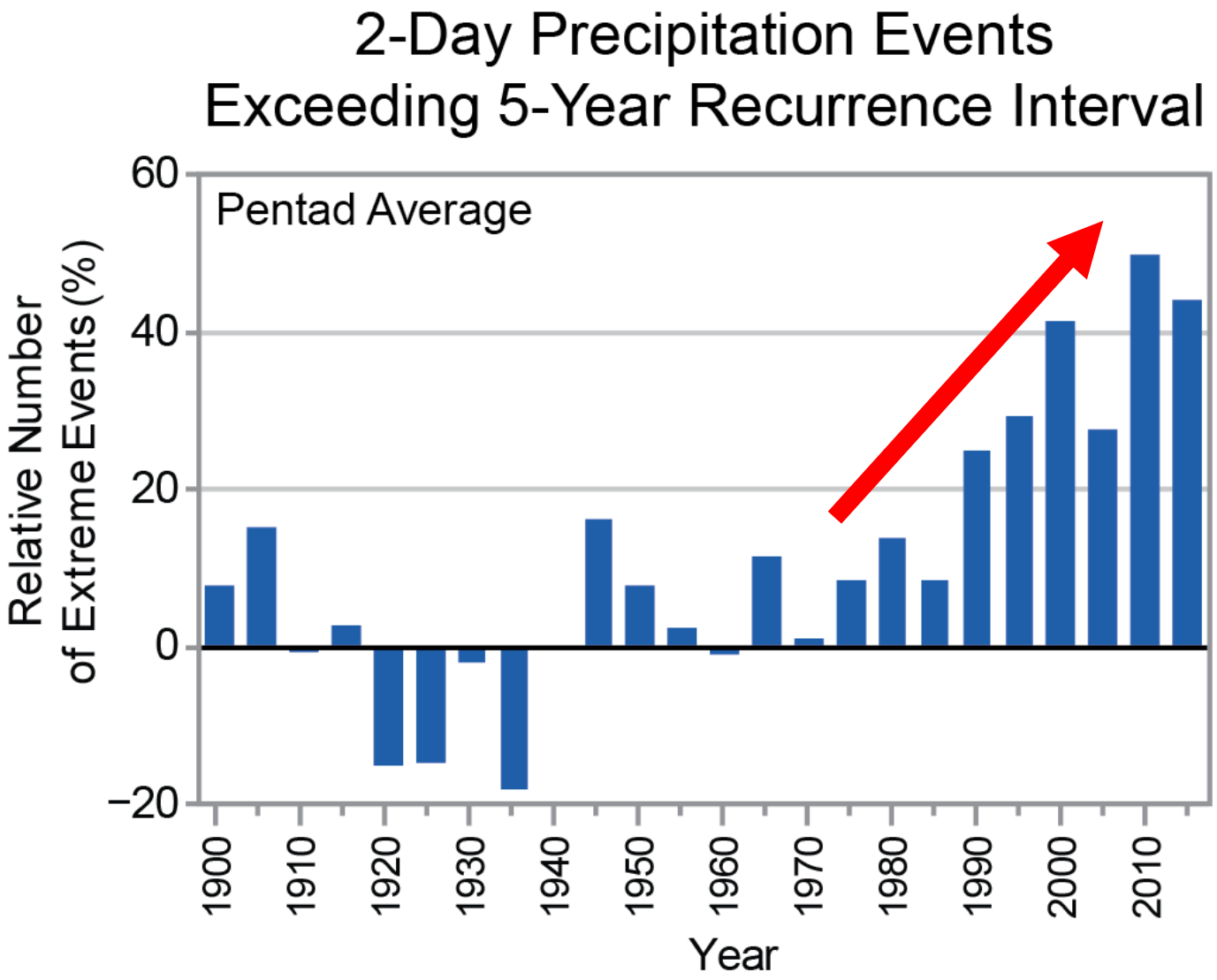
- Extensive analysis of data from long-term observing stations; multiple metrics
  - Durations: 1, 2, 3, 5, 10, 20, and 30 days
  - Return Intervals; 1, 2, 5, 10, and 20 years
  - 35 combinations
  - ~3000 stations, 1949-2016
- Selected results produced for the 4th National Climate Assessment (released in November 2018)

Historical Trends



Easterling, D.R., J.R. Arnold, T. Knutson, K.E. Kunkel, A.N. LeGrande, L.R. Leung, R.S. Vose, D.E. Waliser, and M.F. Wehner, 2017: Precipitation change in the United States. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 302- 335.

Historical Trends



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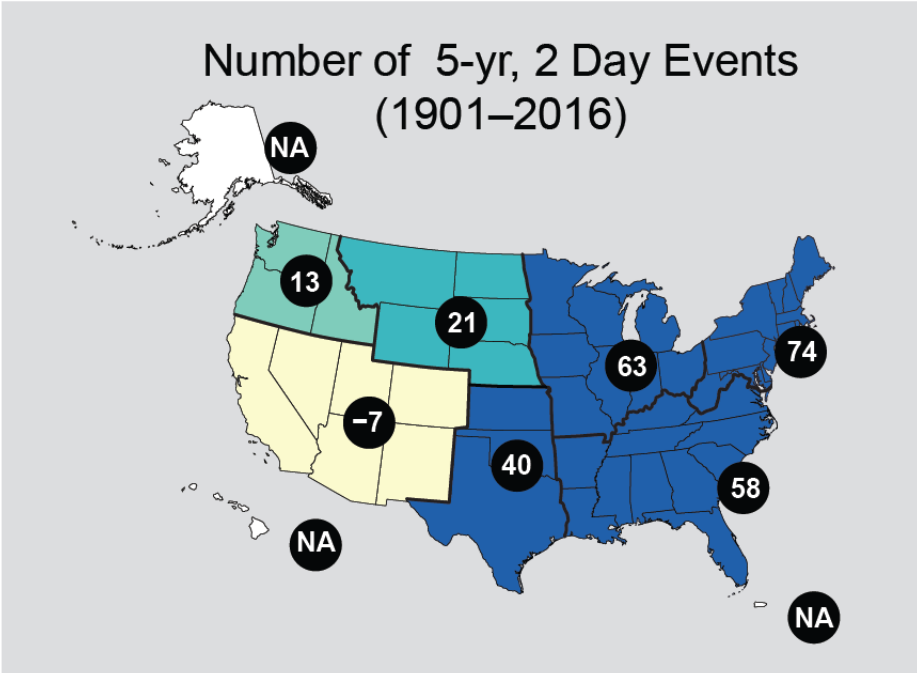
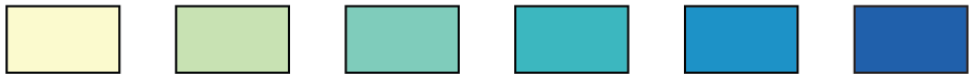
Historical Trends

Observed Change
in Heavy Precipitation



Change (%)



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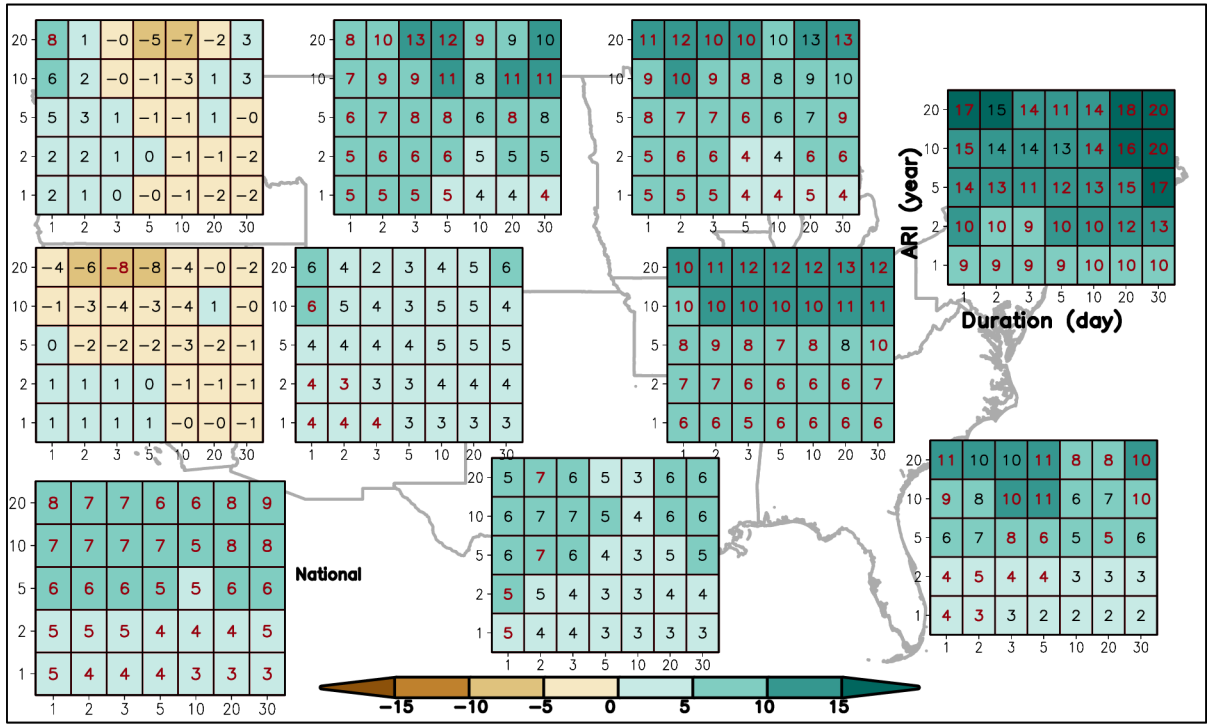
Historical Trends

(a) Annual Trend (% per decade), 1949–2016



All combinations of return period and duration

Teal: Increasing Trends

Brown: Decreasing Trends

Upward trends almost everywhere

Kunkel, K.E., T.R. Karl, M.F. Squires, X. Yin, S. Stegall, and D.R. Easterling, 2017: Precipitation extremes: Trends and relationships with average precipitation and precipitable water in the contiguous United States. *J. Appl. Meteor. Climatol., accep*ted.

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Hurricane Harvey/Florence Analysis

- 4- and 5-day rainfall totals averaged over ~20,000 square miles
- Compared with historical events for the period of 1949-2018 for the whole U.S.
- Top 100 events were analyzed

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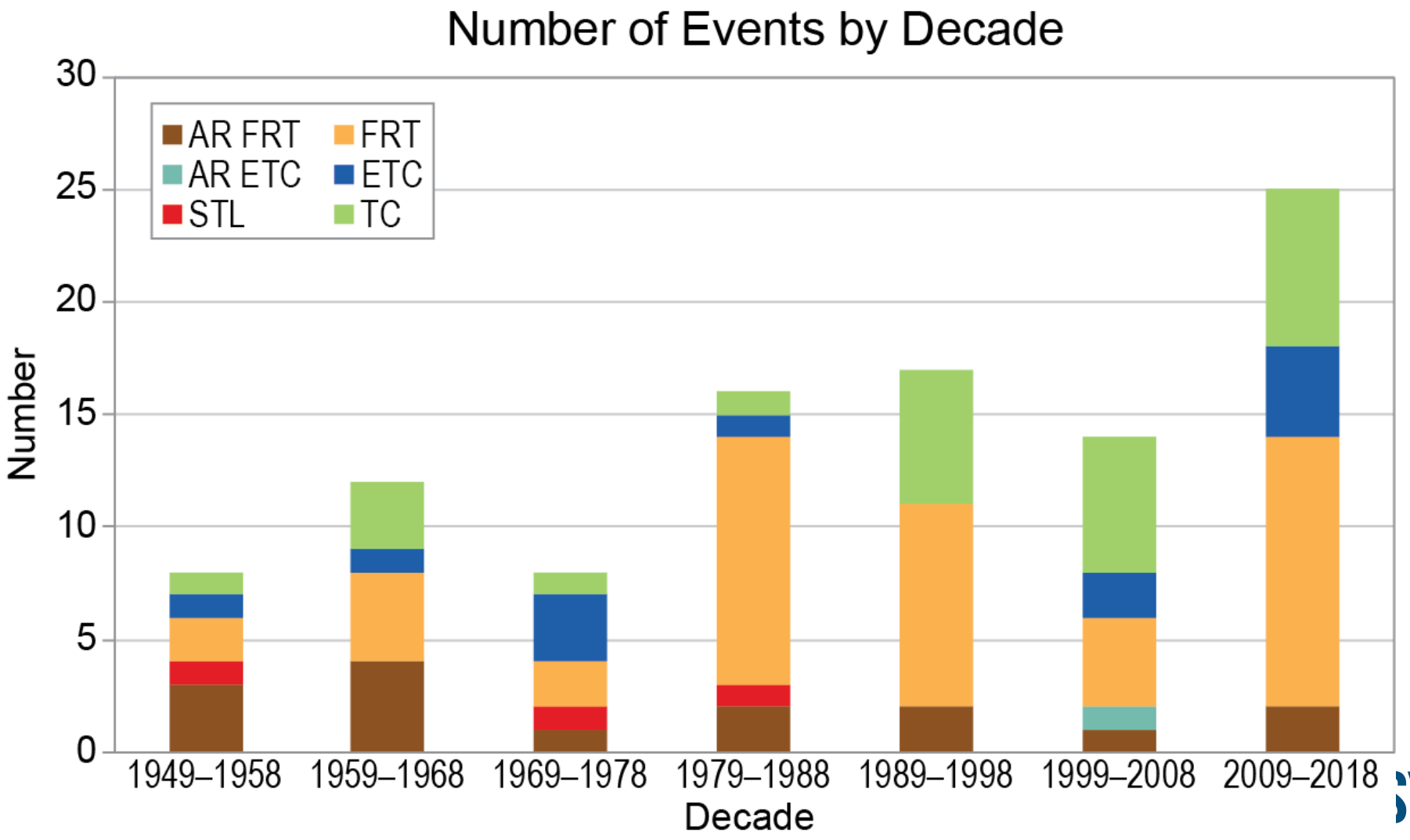
Trend in Top 100 4-day extreme events



Kunkel, K.E. and S.M. Champion, 2019: An assessment of rainfall from Hurricanes Harvey and Florence relative to other extremely wet storms in the United States. Geophys. Res. Lett., 46. https://doi.org/10.1029/2019GL085034

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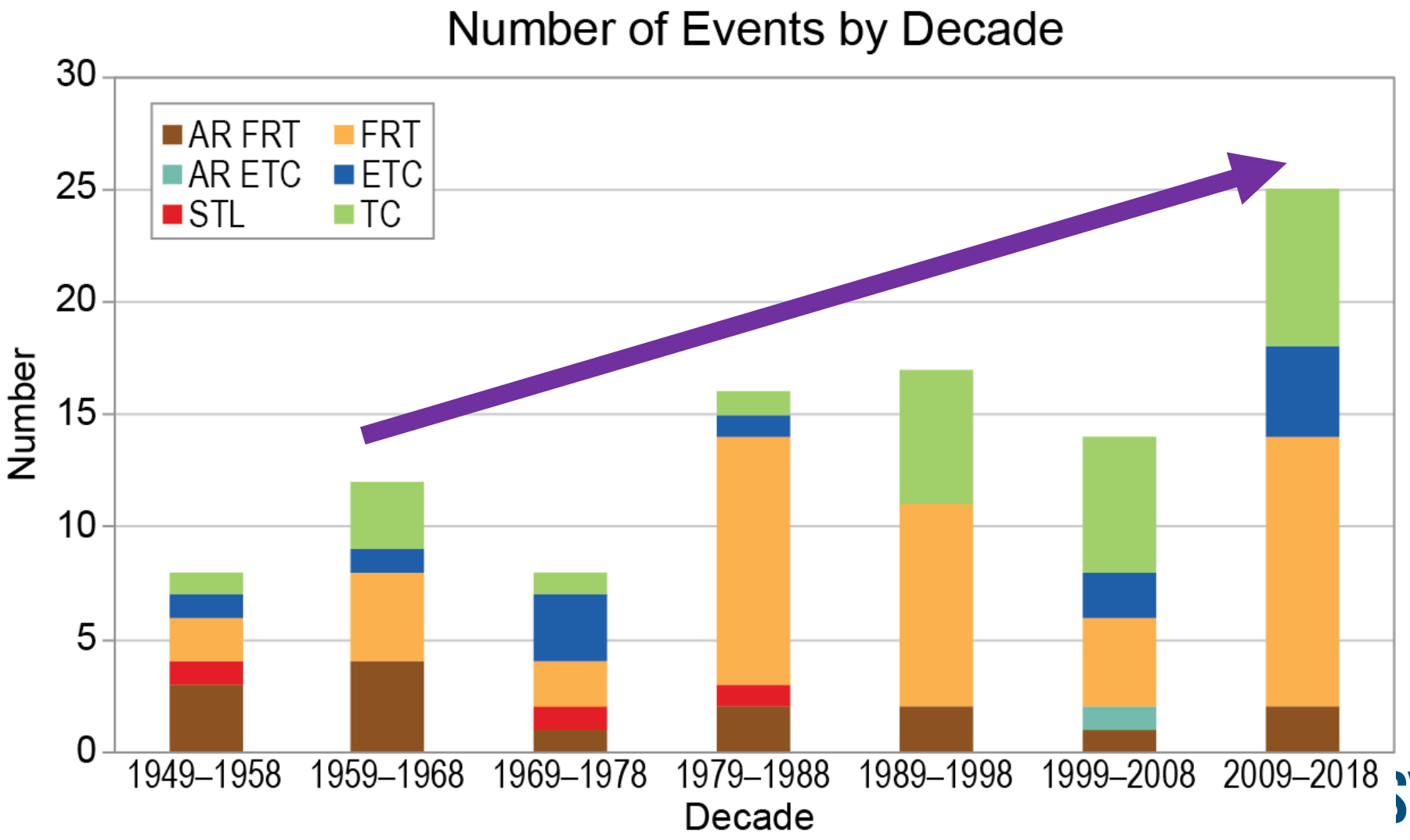

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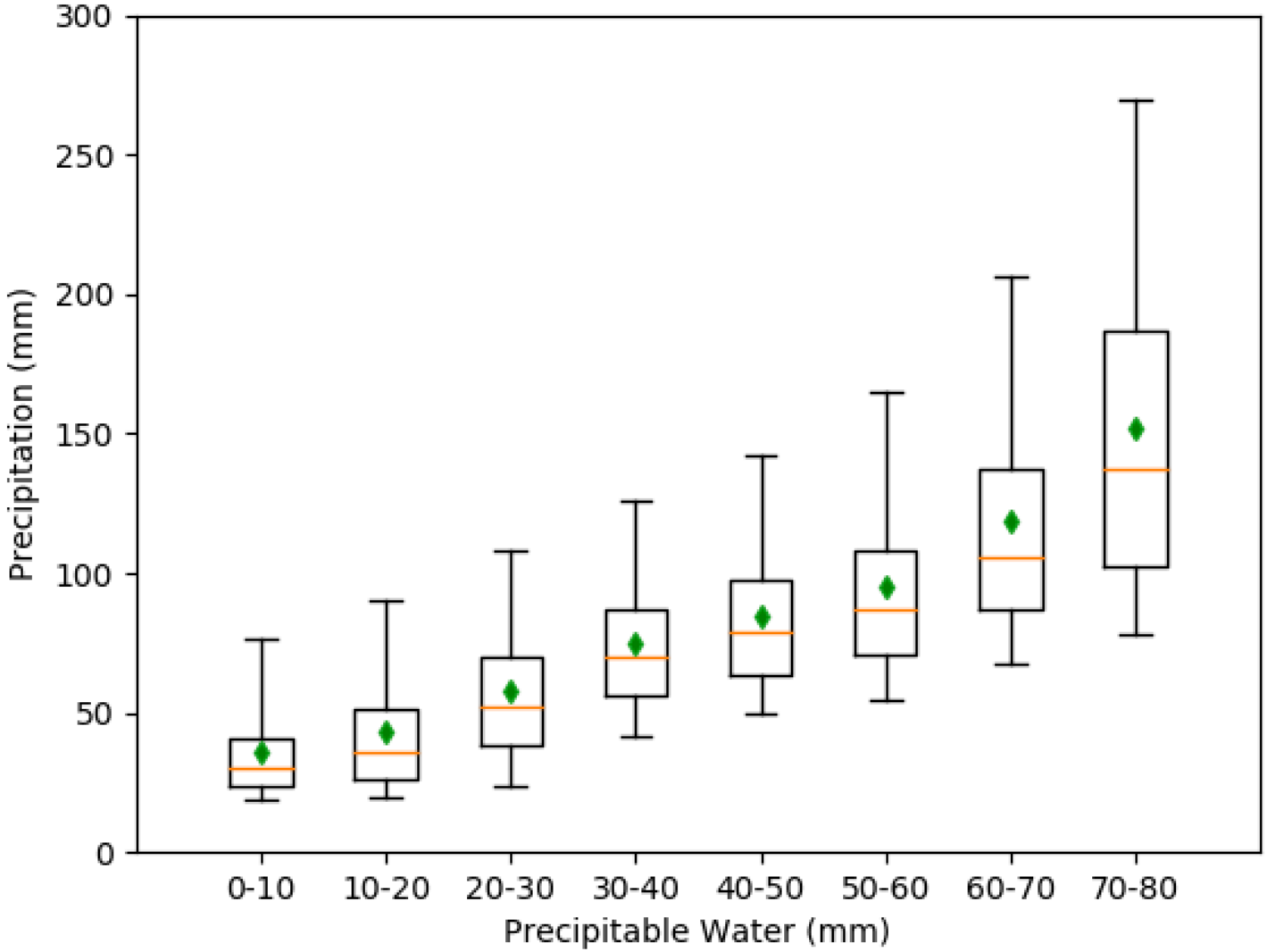
Extreme Precipitation Amounts vs Water Vapor

- Examined the Annual Maximum Series and the 1-yr, 1-dy Partial Duration Series
- ~3000 stations
- Precipitable Water obtained from NCEP/NCAR reanalysis

Extreme Precipitation Amounts vs Water Vapor



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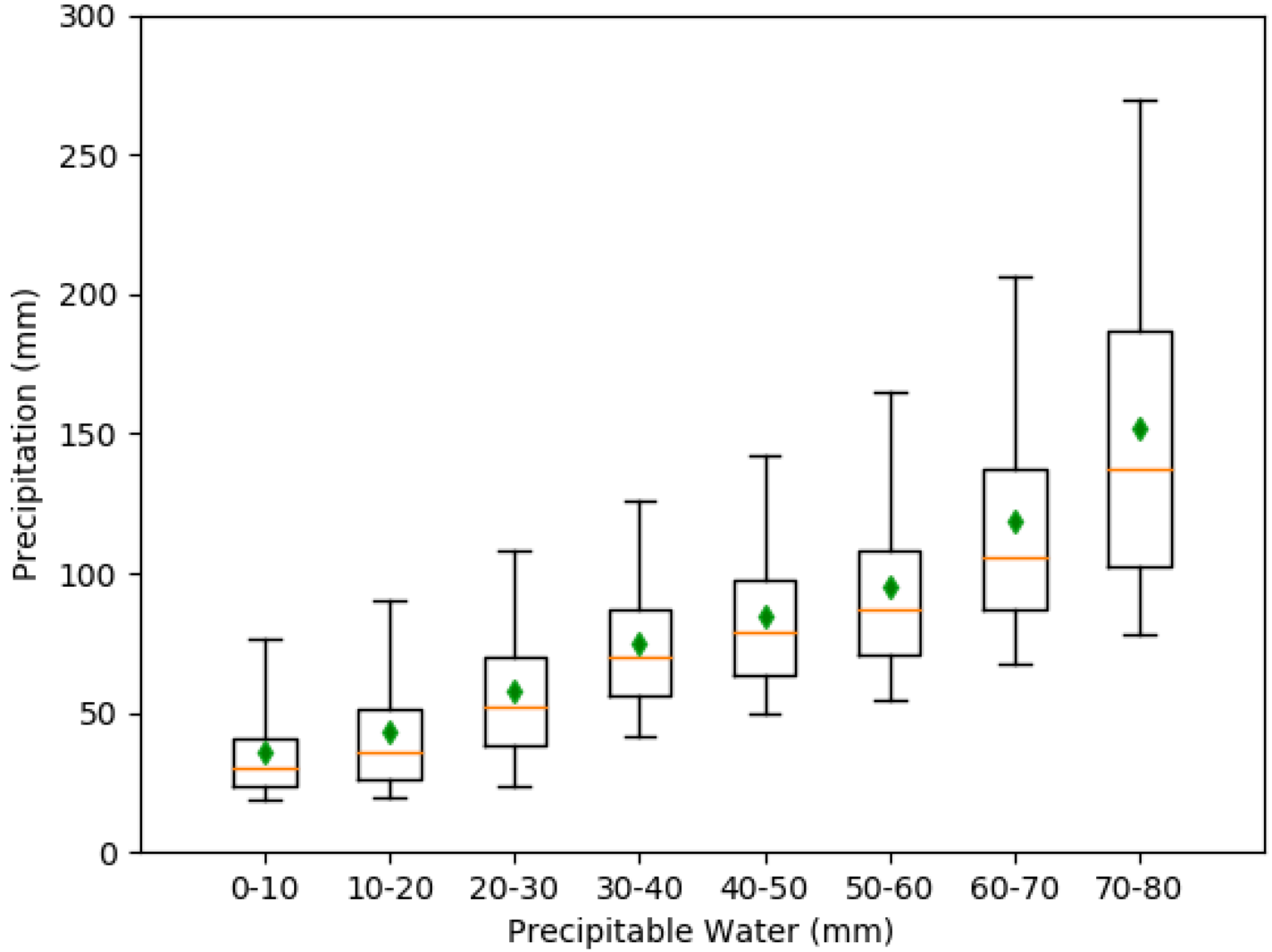

The amount of precipitation in historical extreme precipitation events increases (on average) with the amount of atmospheric water vapor

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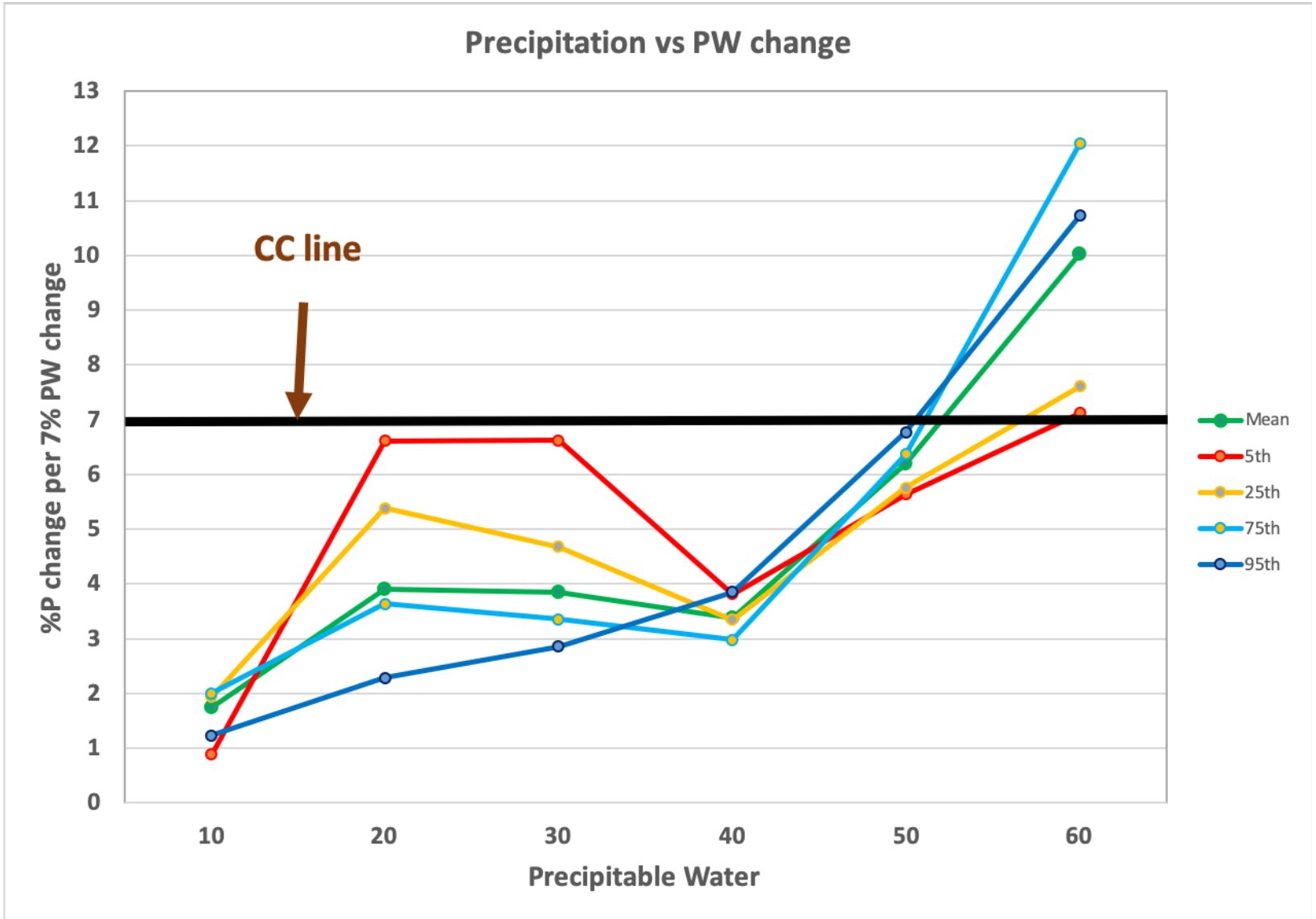
Extreme Precipitation Amounts vs Water Vapor

- Hypothesis: Atmospheric water vapor will increase approximately with the Clausius-Clapeyron relationship and extreme precipitation amounts will increase at the same rate
- Alternative hypothesis: Extreme precipitation amounts will increase at greater than the CC rate because of more vigorous convection in storms from enhanced latent heat release

Change in Precip Amounts vs Water Vapor



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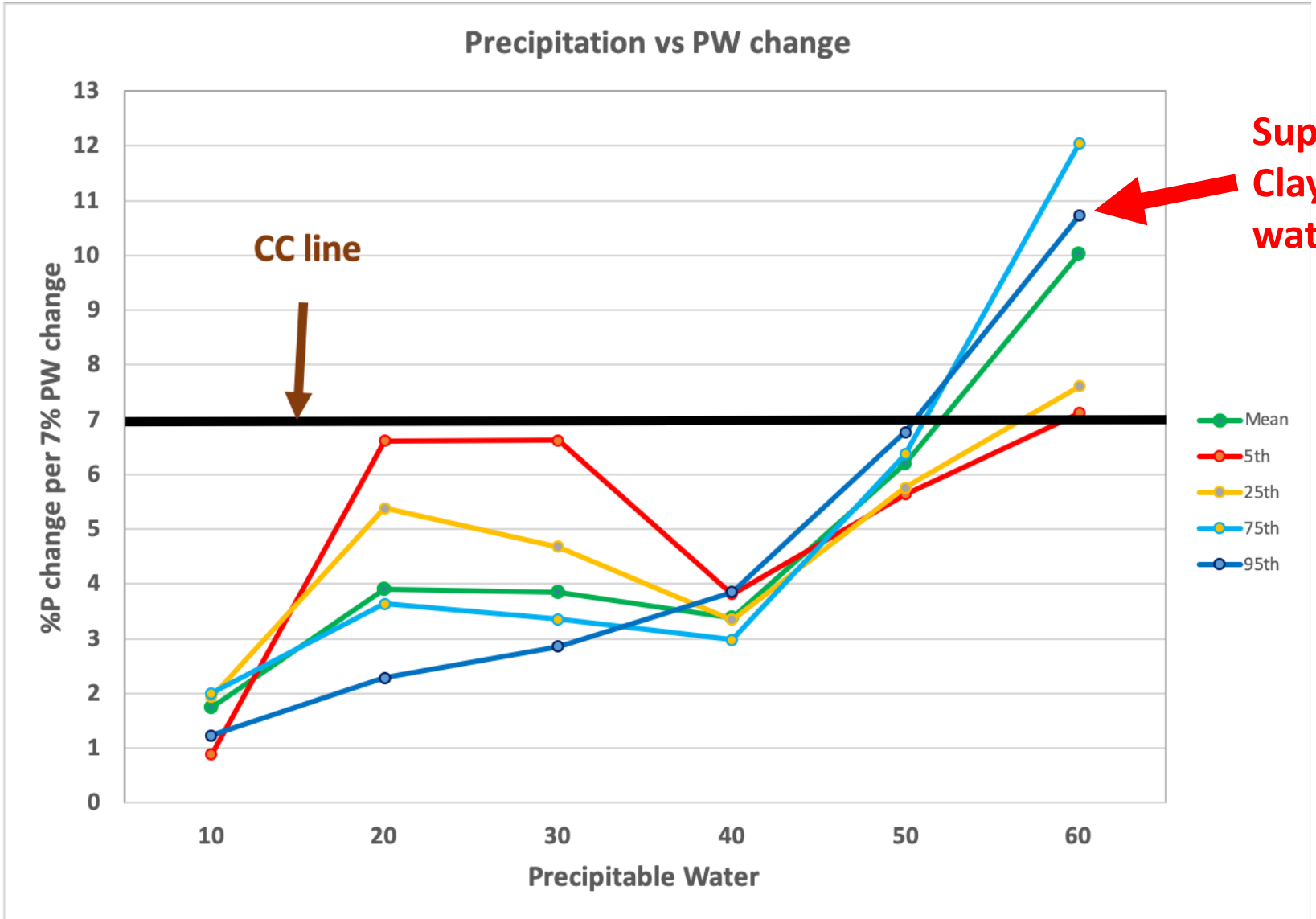
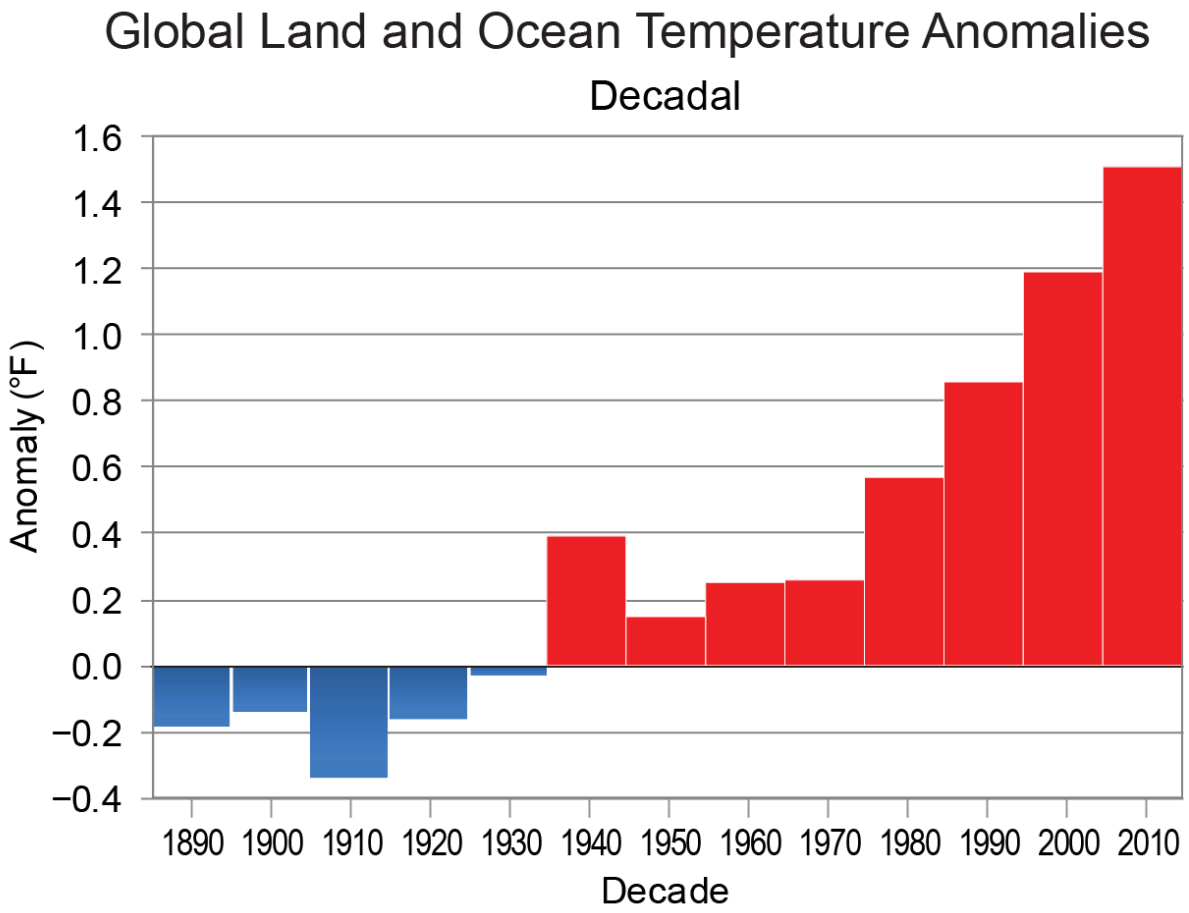


Super Clausius-Clayperon at high water vapor levels

Global Temperature Change by Decade



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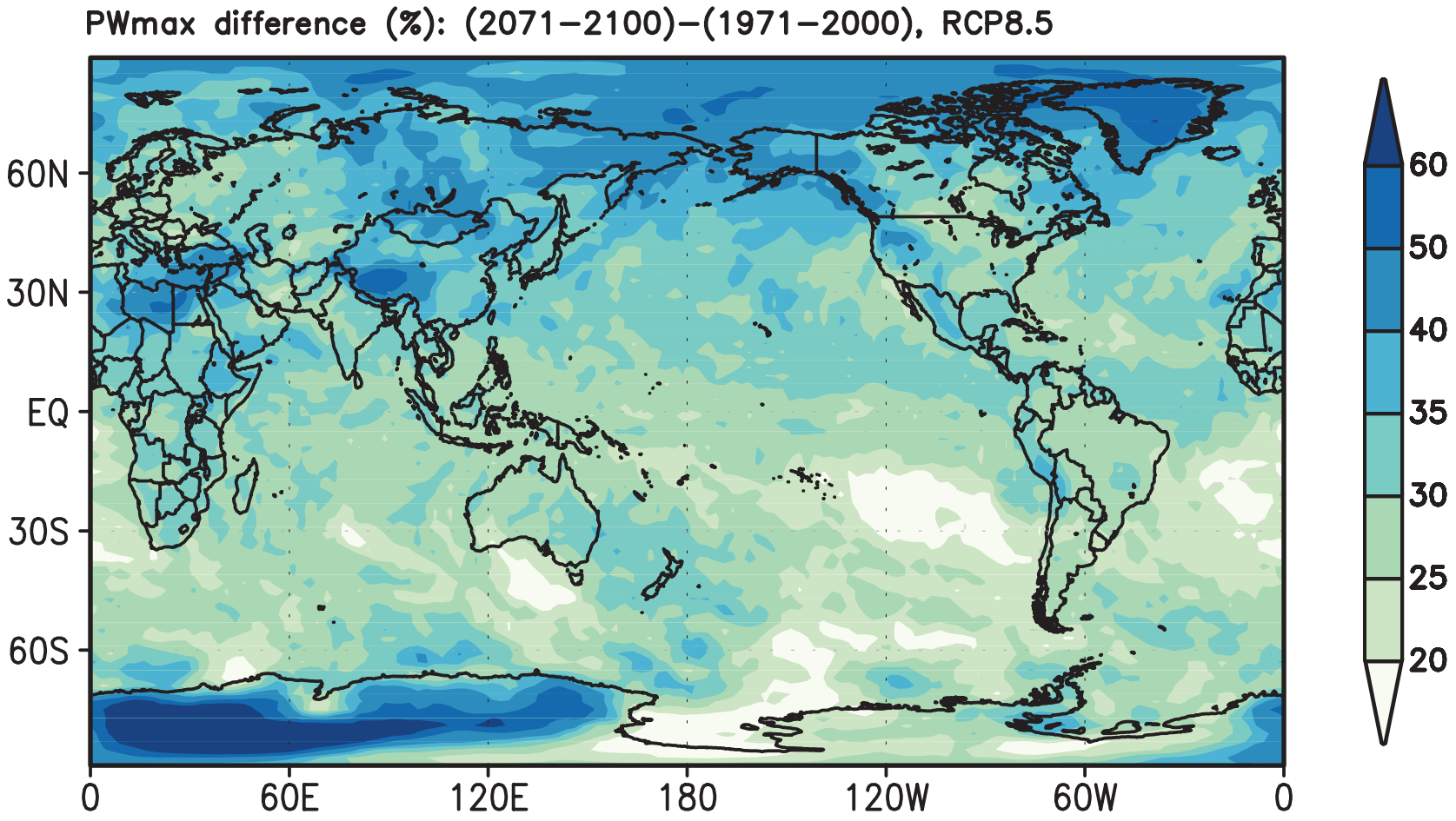
Future Changes in Water Vapor

- Basic physics tells us that water vapor over oceanic water vapor source regions will continue to increase as the oceans warm
- Global climate models are a tool that can be used to estimate how much

30-yr Maximum Precipitable Water: 100-yr trends



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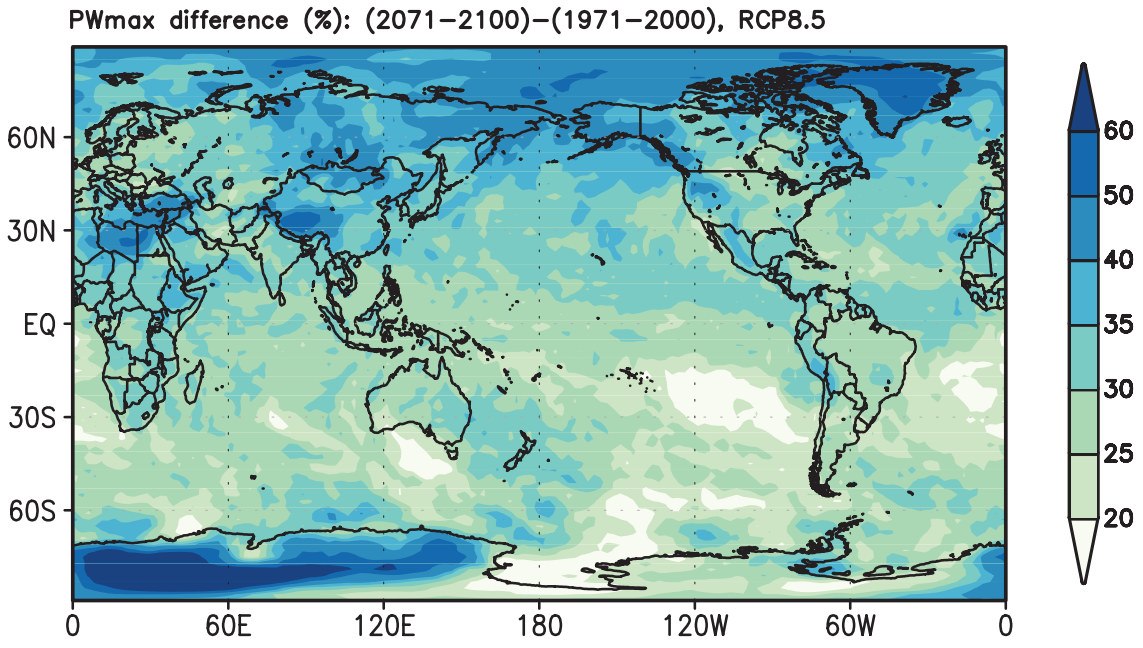

Increases of 25-40% over the U.S. by end of 21st Century under a high emissions scenario

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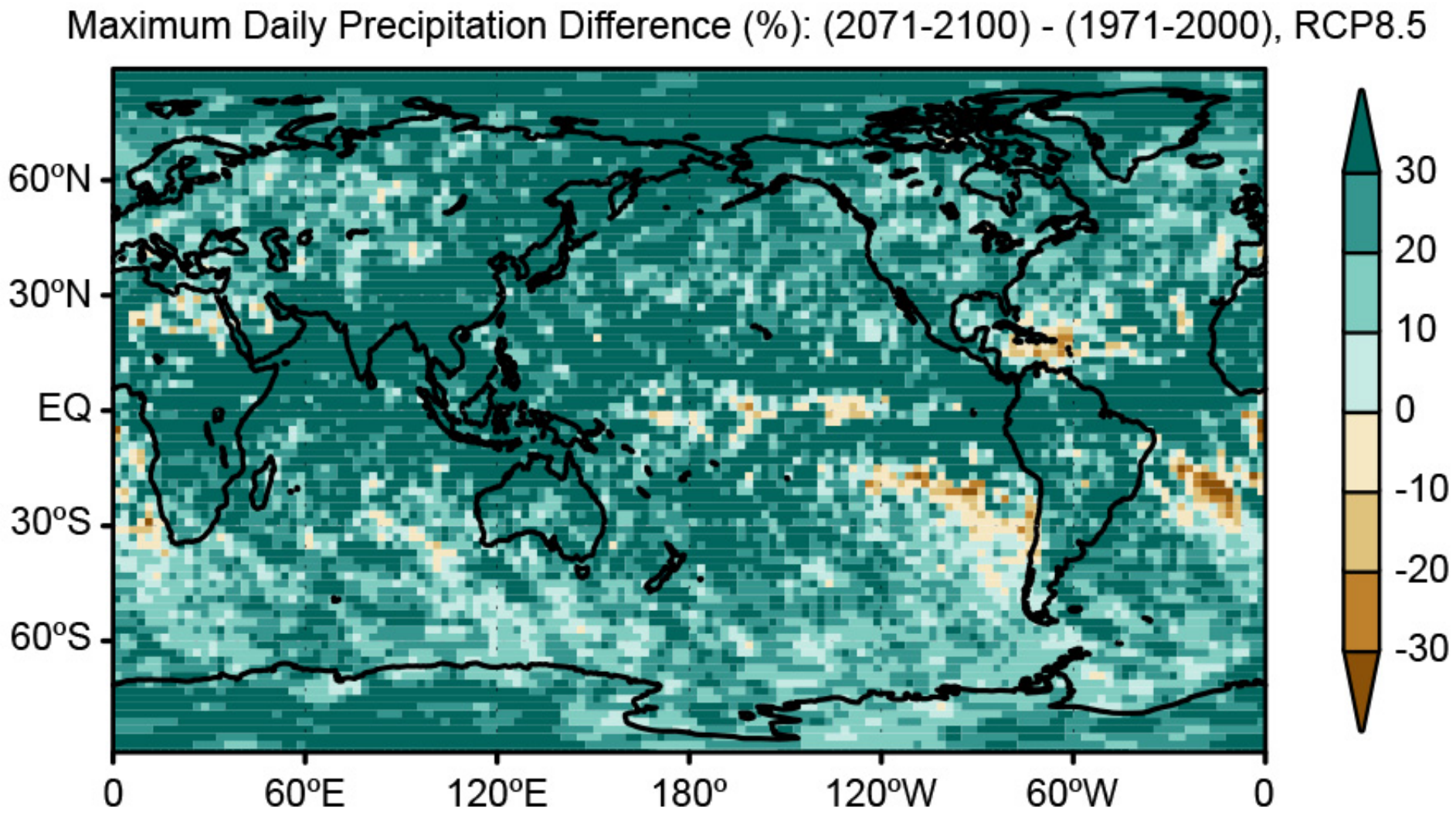
30-yr Maximum Precipitation: 100-yr trends



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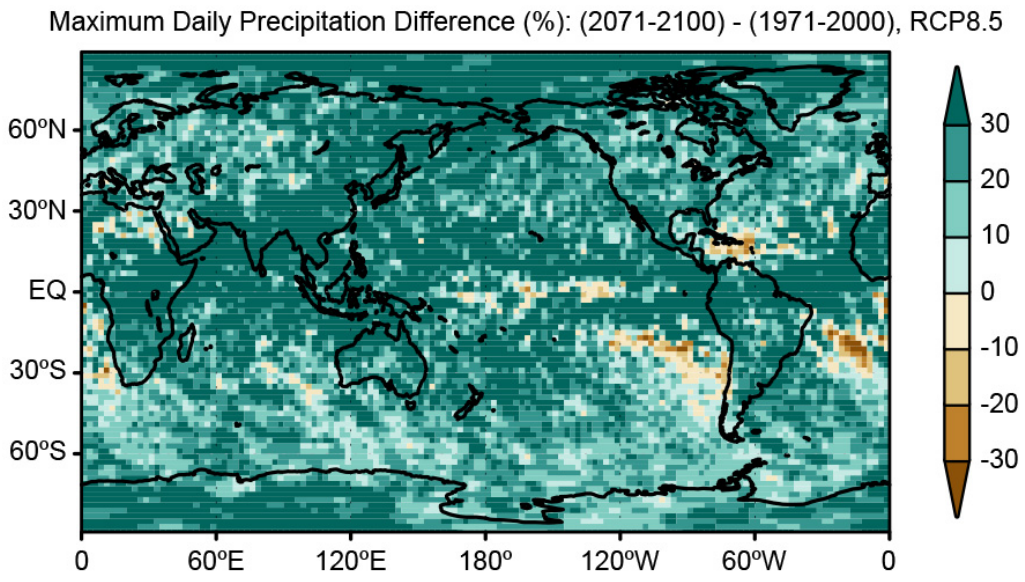

Model extreme precipitation increases by 10-30+% by end of 21st Century under a high emissions scenario

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Global Warming and Weather System Changes

- Potential **decreases in summer fronts** may dampen water vapor increases in some areas

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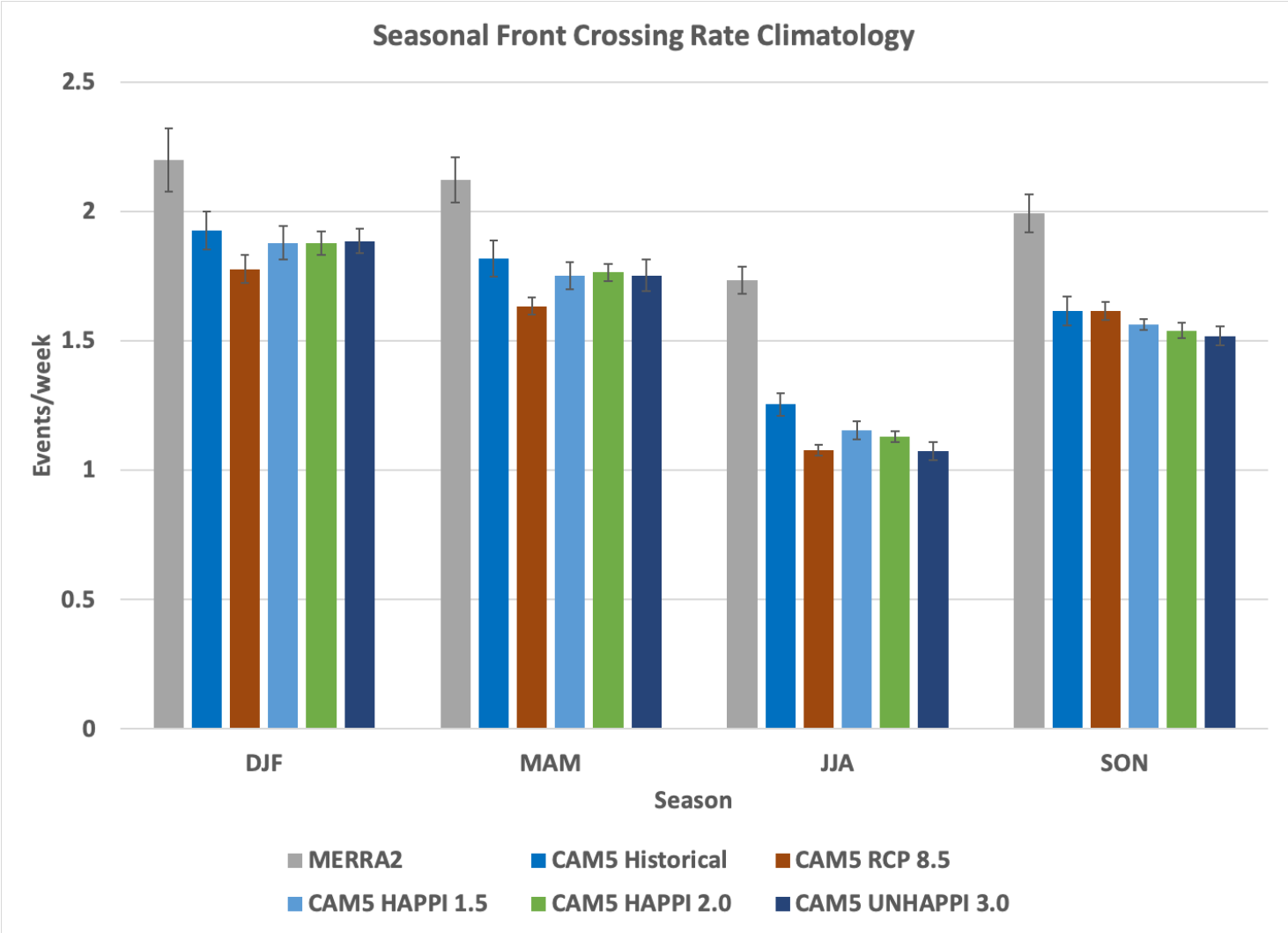
Global Warming and Weather System Changes



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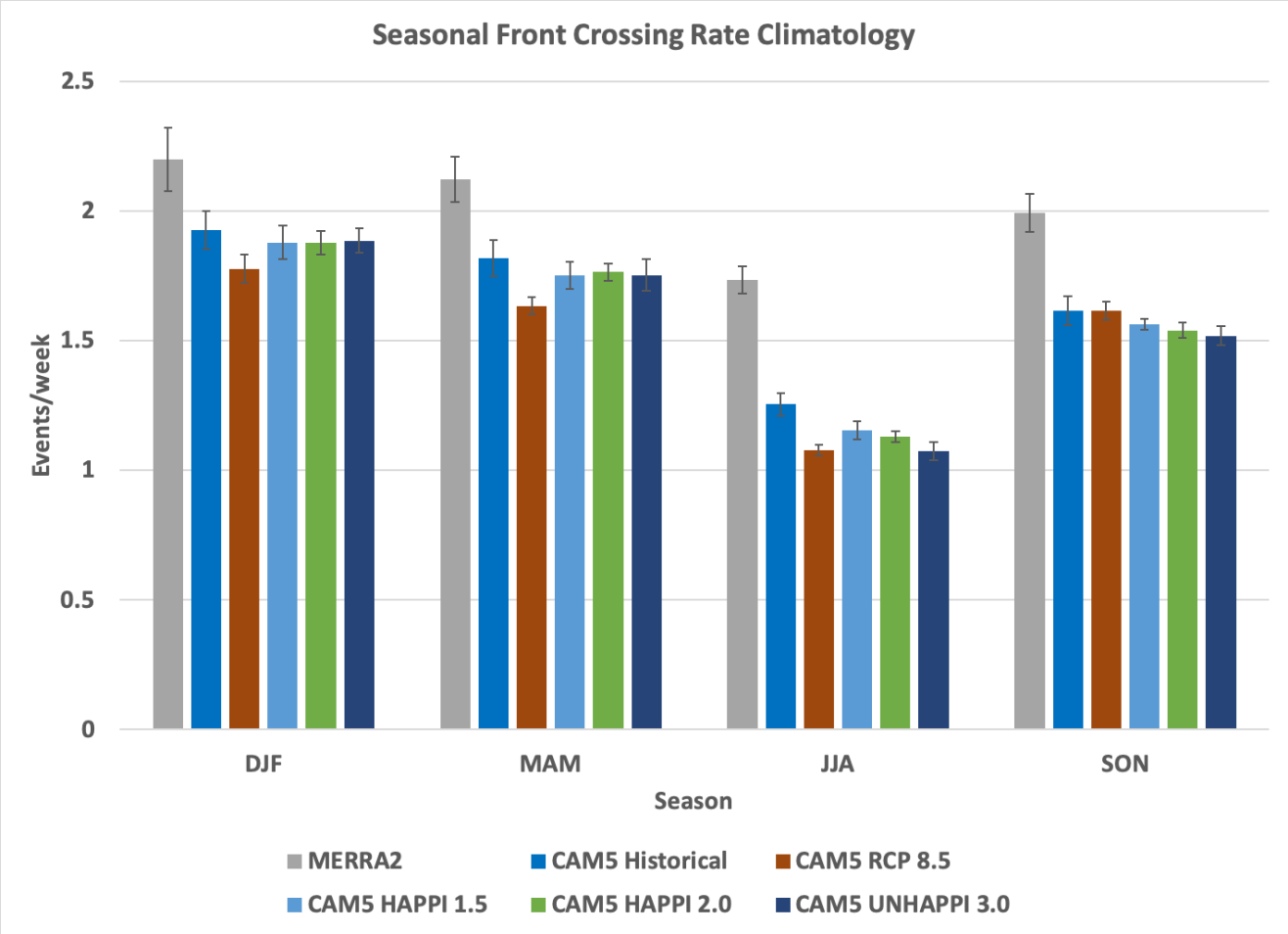
Global Warming and Weather System Changes

End of 21st Century

Small decreases in Spring and Summer: Important because many spring and summer extreme precipitation events are caused by fronts



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Science Conclusions

- Direct relationship between **water vapor** and magnitude of **extreme precipitation**
- Potentially **very large future increases** in atmospheric water vapor concentration (increased potential for extreme rainfall) due to global warming.
- **Weather system changes are likely to be lesser effect**

Infrastructure Resilience

- Three aspects support action to introduce future increases into rainfall design values
  - Historical relationship between **water vapor** and magnitude of **extreme precipitation**
  - Direction of change is not in question because of **future global warming and Clausius-Clapeyron** relationship
  - **Climate models** (for all their limitations) fully support increases in water vapor and extreme precip

Infrastructure Resilience

- Is there any scientific support for inaction?
  - Short answer is **NO**
  - But, lack of full understanding of magnitude of potential **variable regional changes**

- Other barriers
  - Lack of **accepted approaches**
  - Incorporation of **uncertainties**

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Acknowledgments

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