Historical Trends and Projections of Concurrent Extremes

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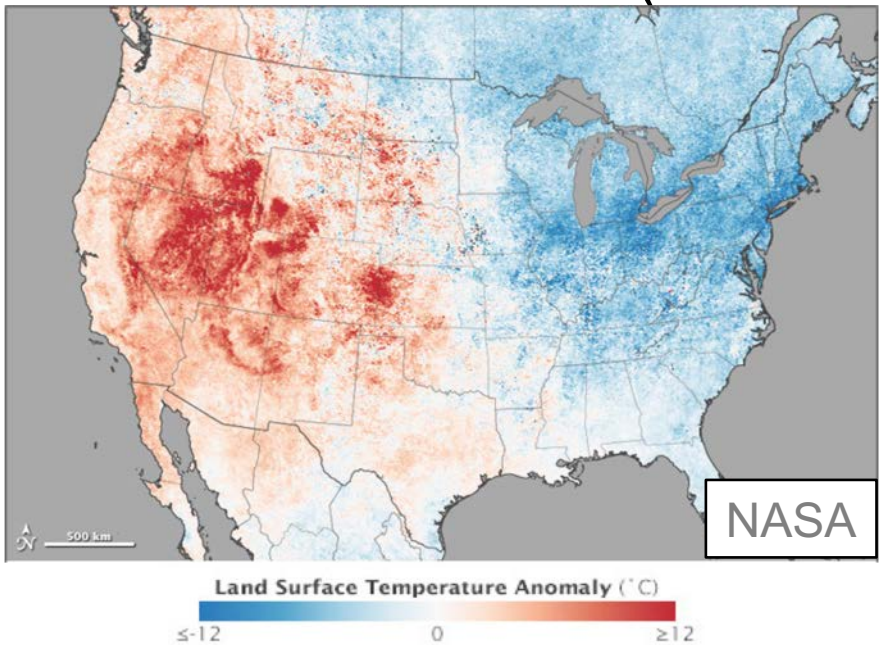
Concurrent extremes: events occurring in remote regions at the same time that are connected by some underlying physical processes

Impacts of Concurrent Extremes

- Severe economic and societal impacts (~2.4 billions USD in insured losses in 2013-14 & 2014-15 winters)
- Strain disaster relief and management resources

North American Winter Temperature Dipole (NAWTD)

Warm-West/Cool East (Feb 2015)



Unprecedented warm and dry conditions in the West

Anomalously cold conditions with frequent snowstorms in the East

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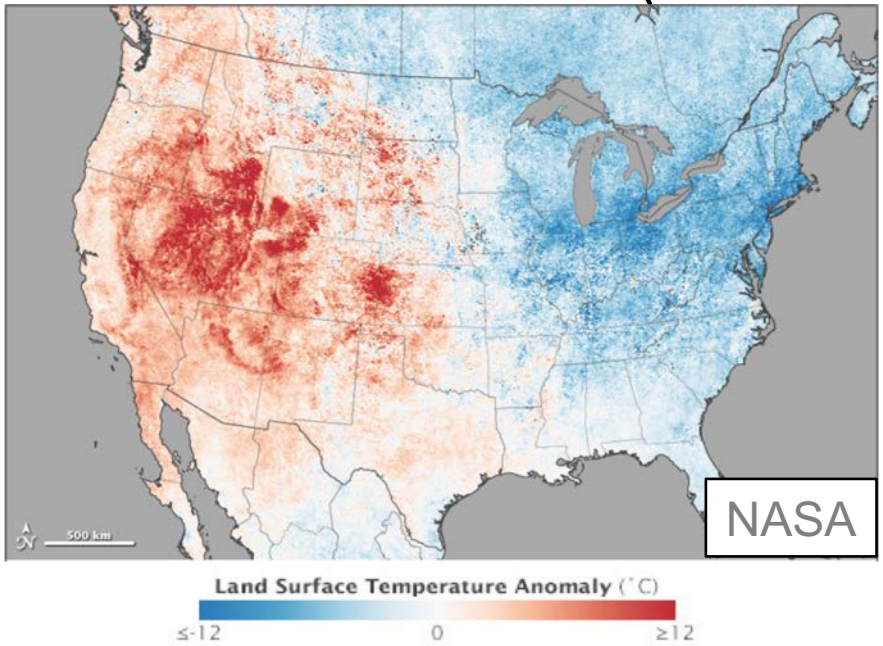

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Main Questions

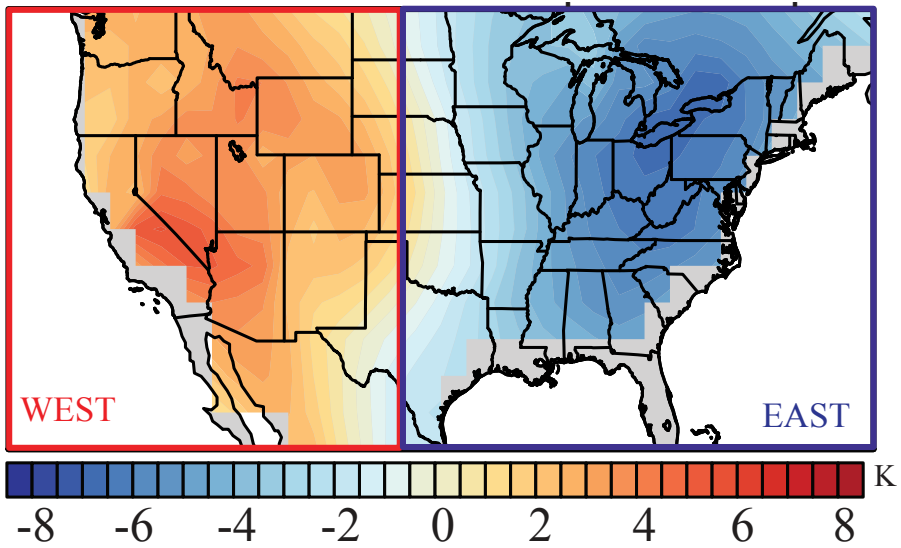
- **Have the characteristics of dipole extremes changed in the observed record?**
- **Have anthropogenic activities influenced their characteristics?**
- **Are historical trends likely to continue?**

*Singh et al., 2016: Recent amplification of the North American winter temperature dipole. J. Geophys. Res. Atmos., **121**, no. 17, 9911-9928, doi:10.1002/2016JD025116.*

A metric for NAWTD events

Co-occurrence of warm extremes in the west ($T_{max,West}$ > 84%) and cool extremes in the east ($T_{min,east}$ < 16%) over some minimum areas (X%)

NAWTD event composite (1980-2015)



NCEP-NCAR Reanalysis Data

NAWTD Intensity:

$(T_{max,\ Aw} - T_{min,\ AE})$

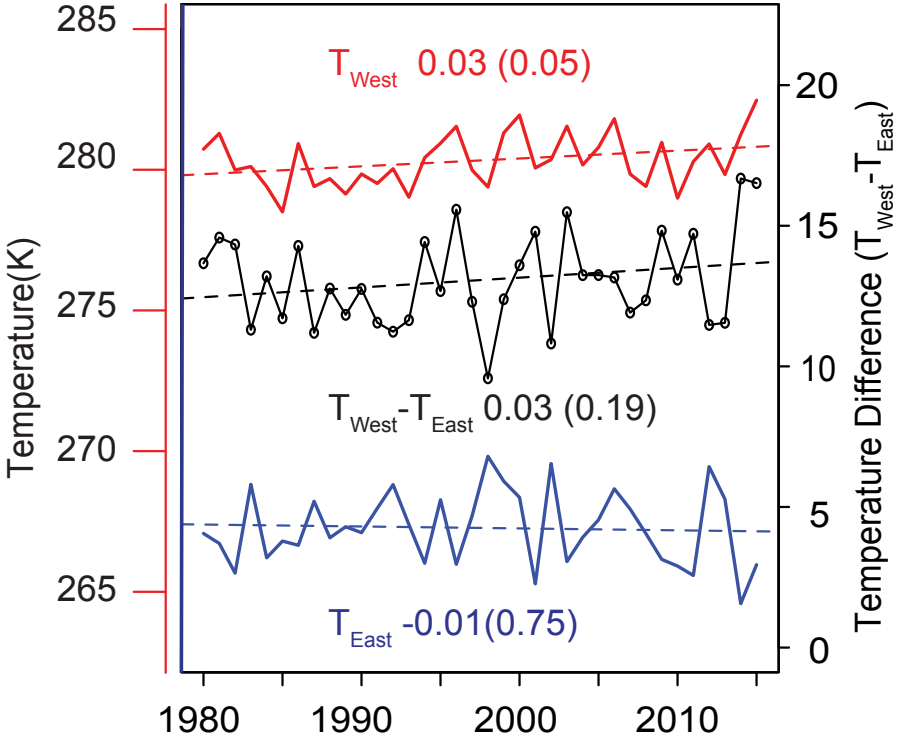
A_w & A_E > X%

A_W: area experiencing warm extremes

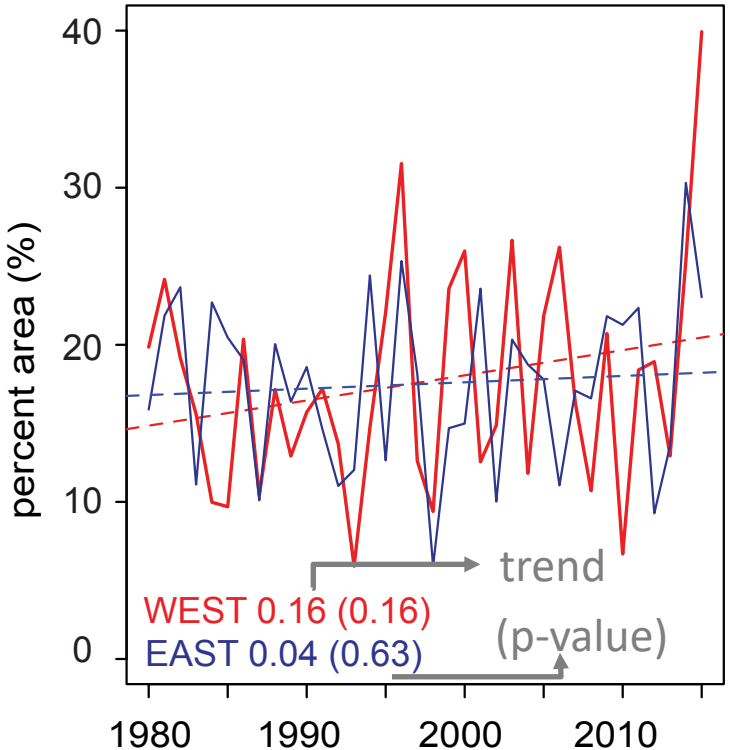
A_E: area experiencing cold extremes

Increases in seasonal temperatures and area experiencing extremes

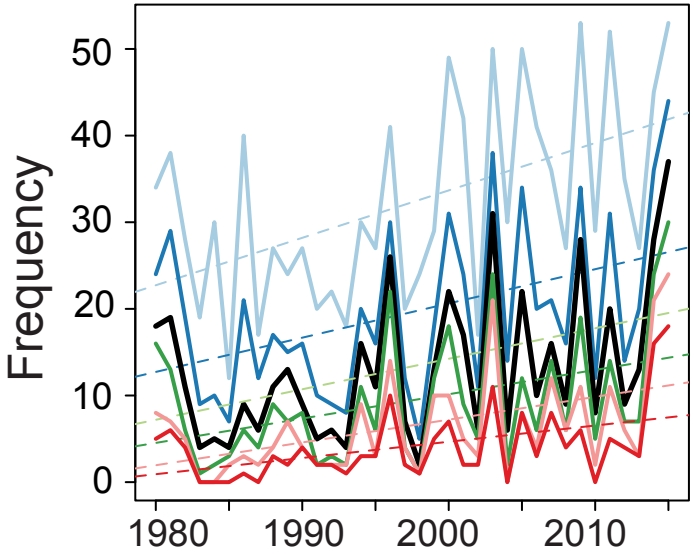
Average Temperature



% Area Experiencing Extremes

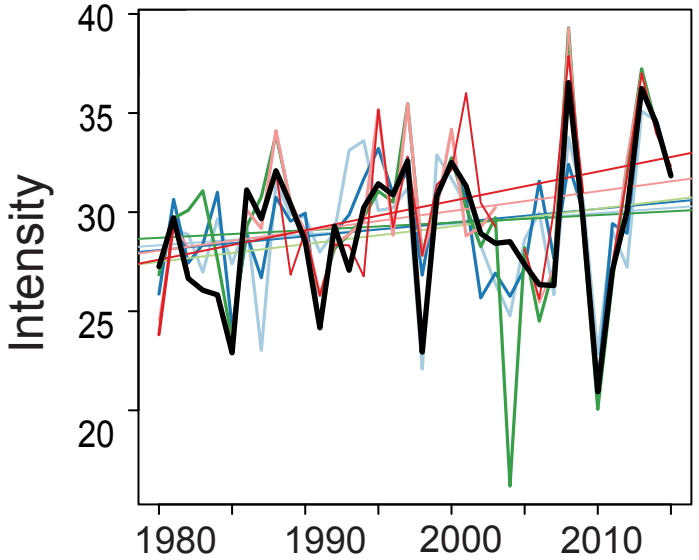


Robust increases in NAWTD frequency and Severity



Trend (pvalue)

15%: 0.35 (0.007)



Trend (pvalue)

15%: 0.09 (0.12)

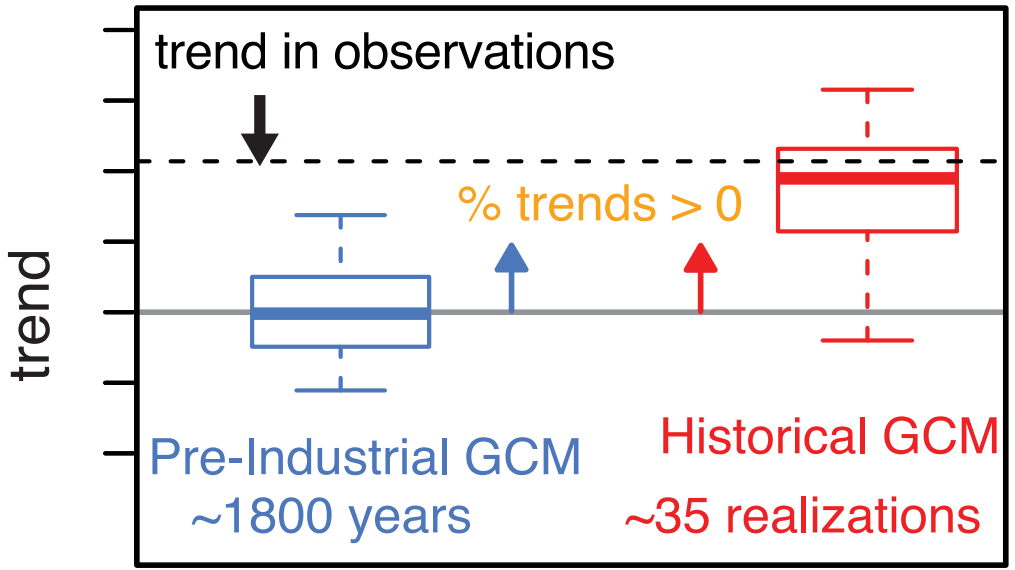
15% area fraction events: Increase in frequency of ~ 12 and severity of ~3K over 36 years

Assessing influence of anthropogenic forcings using the Large Ensemble

- NCAR fully coupled CESM1 Large Ensemble
- ~1800 year pre-industrial simulation *(natural variability without human influence)*
- 35 historical forcing simulations *(natural variability with human influence)*

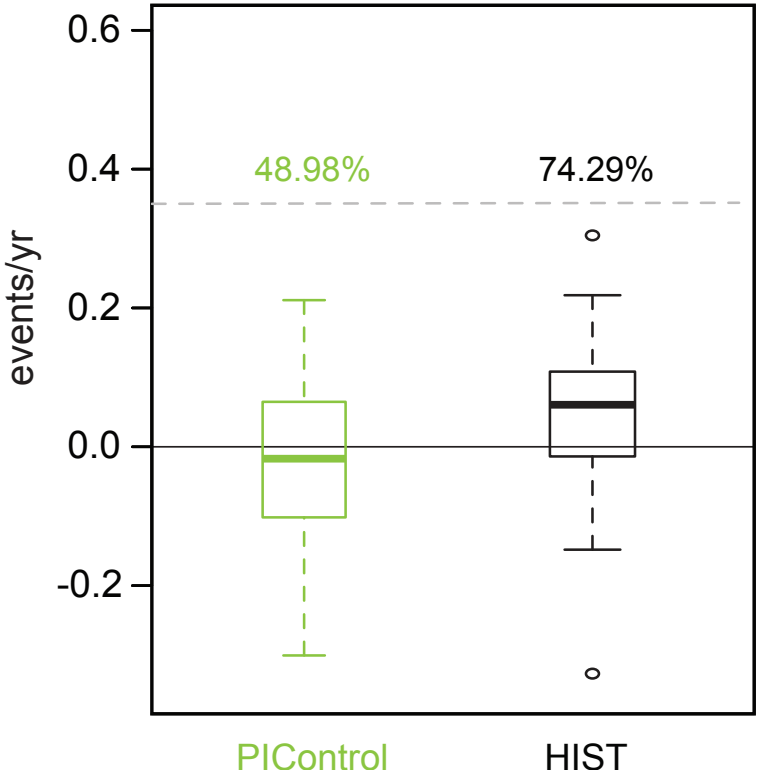
Method

- Estimate **36-year trends** in preindustrial and historical LENS ensemble
- Calculate **likelihood of observed trend** in simulated distributions
- Apply **binomial test** to assess **significance of change in likelihoods**



Diffenbaugh et al., 2017

Positive dipole occurrence trends more likely with historical forcings



15% dipole event frequency trends

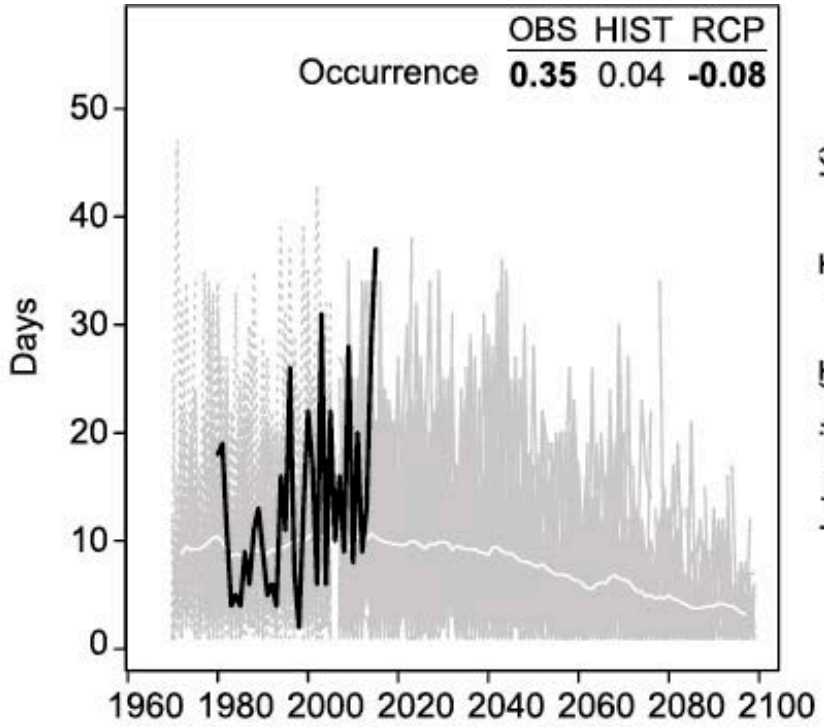
Likelihood: historical climate (~74%) & preindustrial climate (~49%)

P-value of binomial test: <0.001

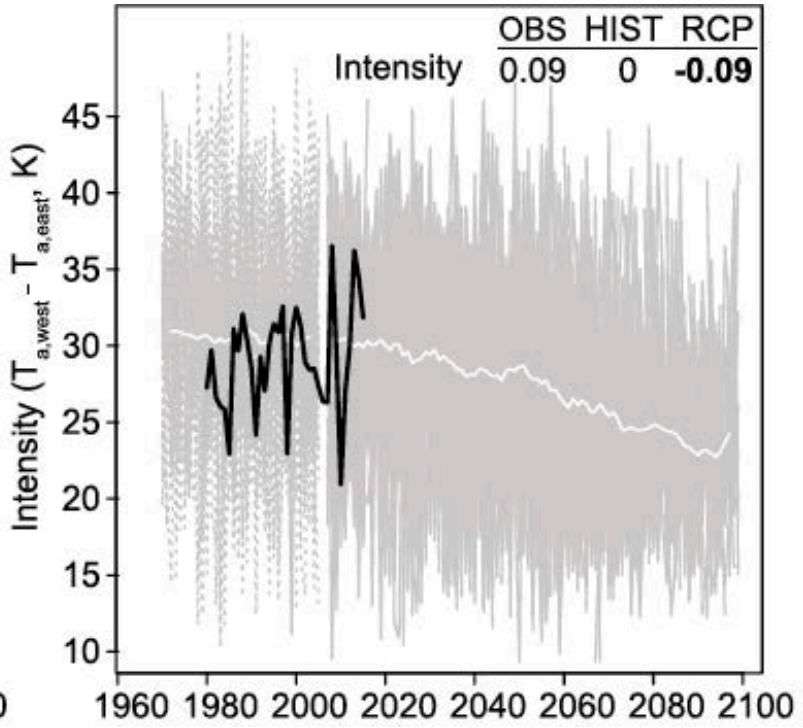
Trends in frequency of all types dipole events, seasonal temperatures and fraction of region experiencing extremes are significantly more likely in HIST than PI

Future decline in frequency and intensity of winter dipole events

Dipole Frequency



Dipole Intensity



Summary

- **Have the characteristics of dipole extremes changed in the observed record?** There have been significant increases in warm-west/cool-east events
- **Have anthropogenic activities influenced their characteristics?** Historical forcings have increased the likelihood of winter dipole events
- **Are historical trends likely to continue?** Trends reverse with projected changes in external forcings

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