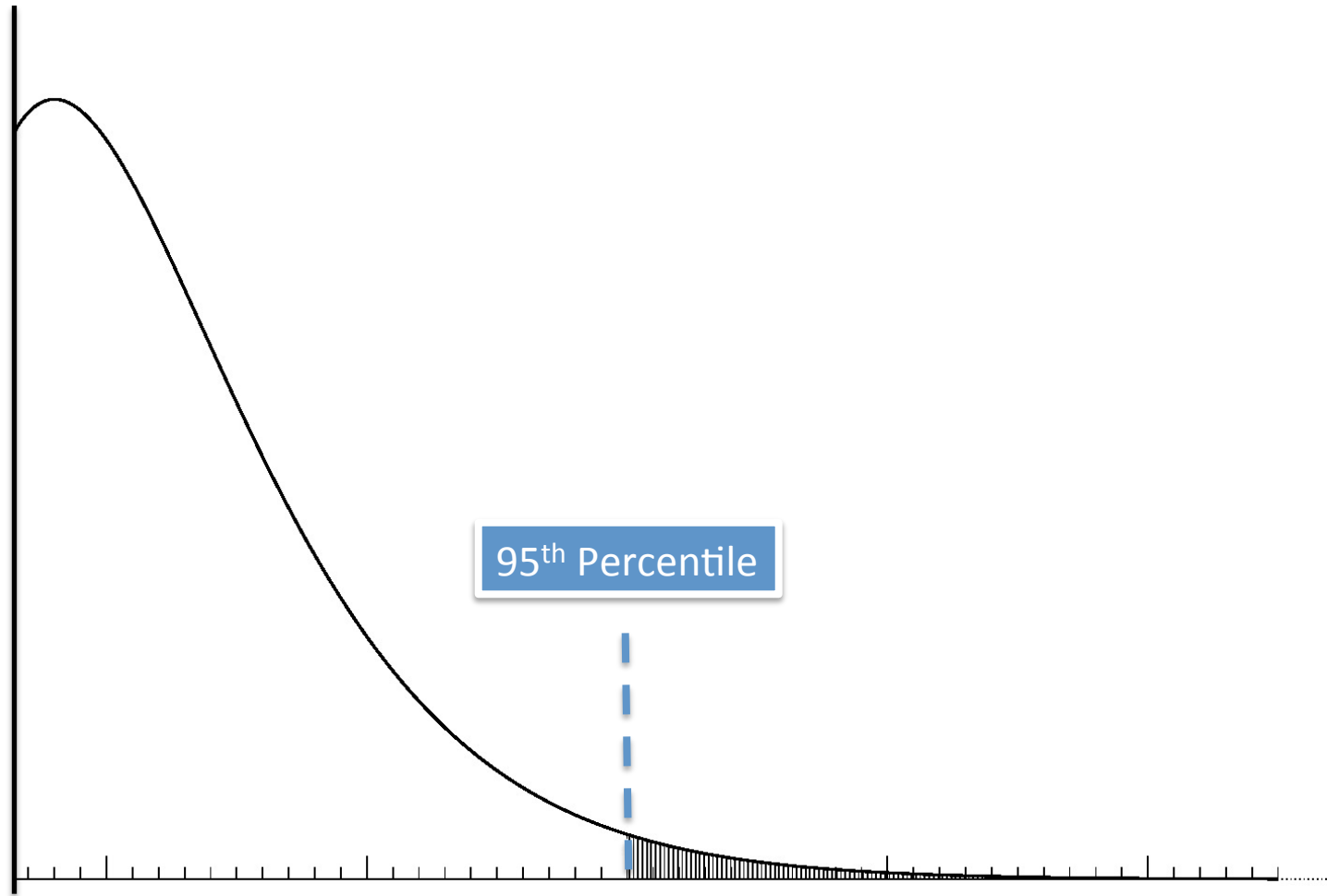


**On Trends in Very Wet Days
Over the United States:**

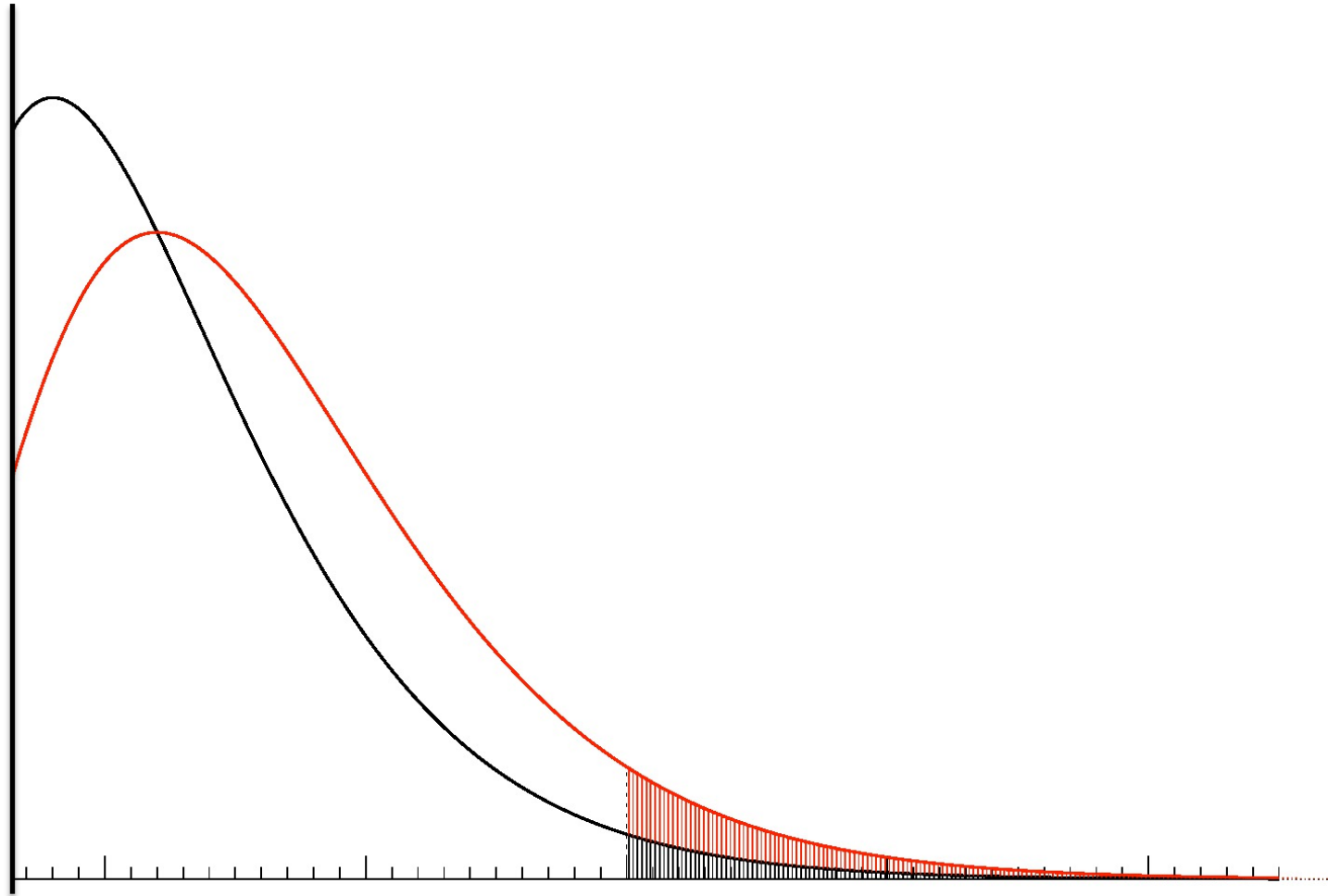
Coupled and Uncoupled Modeling Perspectives

Martin Hoerling, Jon Eischeid, Xiao-Wei Quan

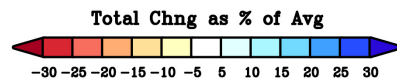
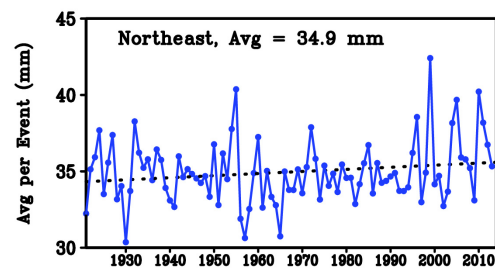
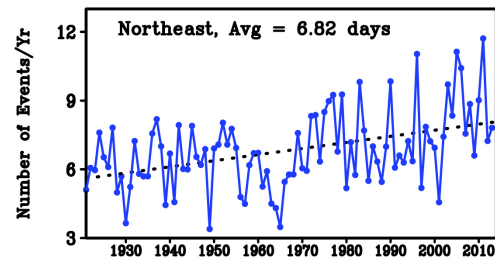
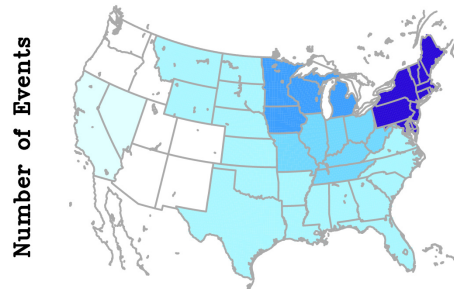
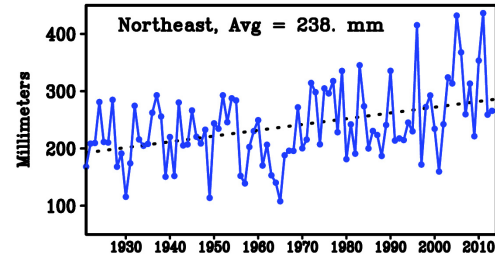
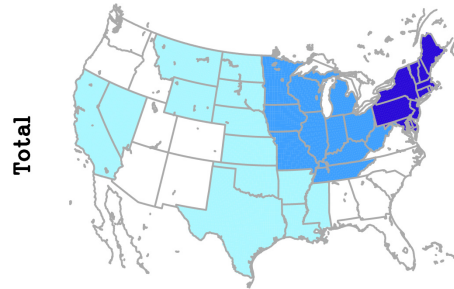
Schematic of Daily Rainfall Distribution and Possible Change in Extremes



Schematic of Daily Rainfall Distribution and Possible Change in Extremes

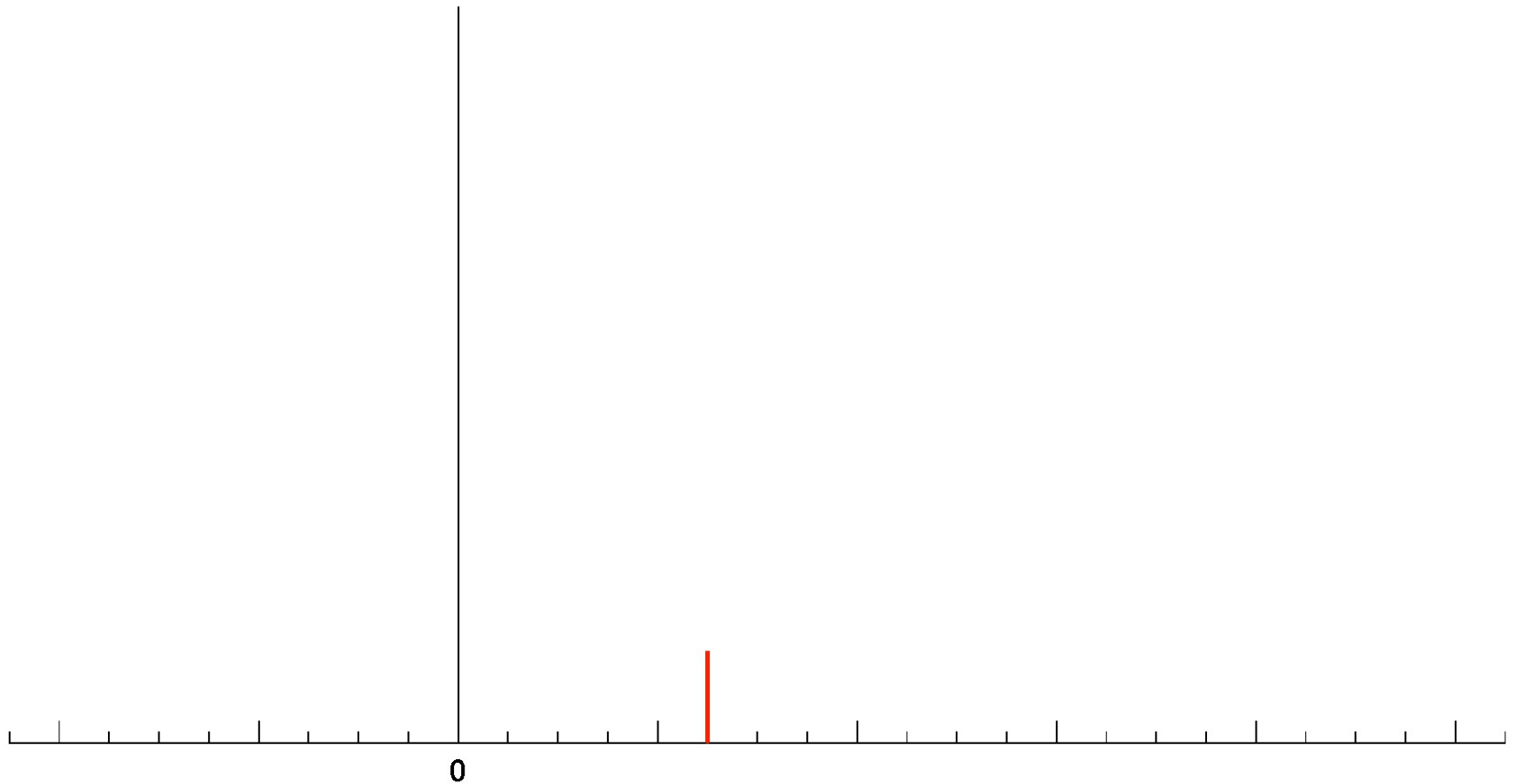


Changes in Very Wet Days*

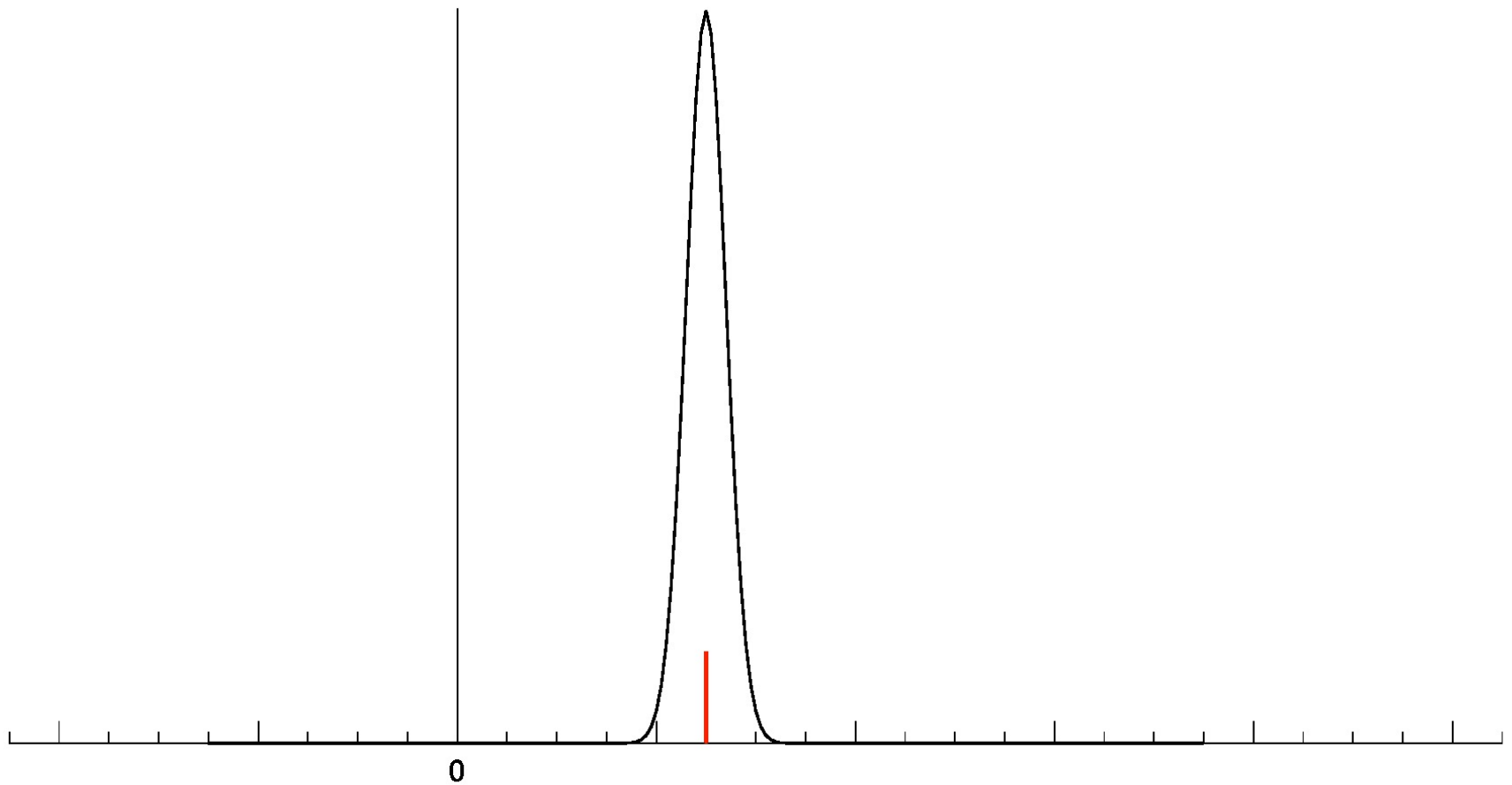


* 95th Percentile Derived from 1921-1980 GHCN-Daily (Menne et al. 2012)

How to Characterize the Upward Trend in Extreme Precipitation?



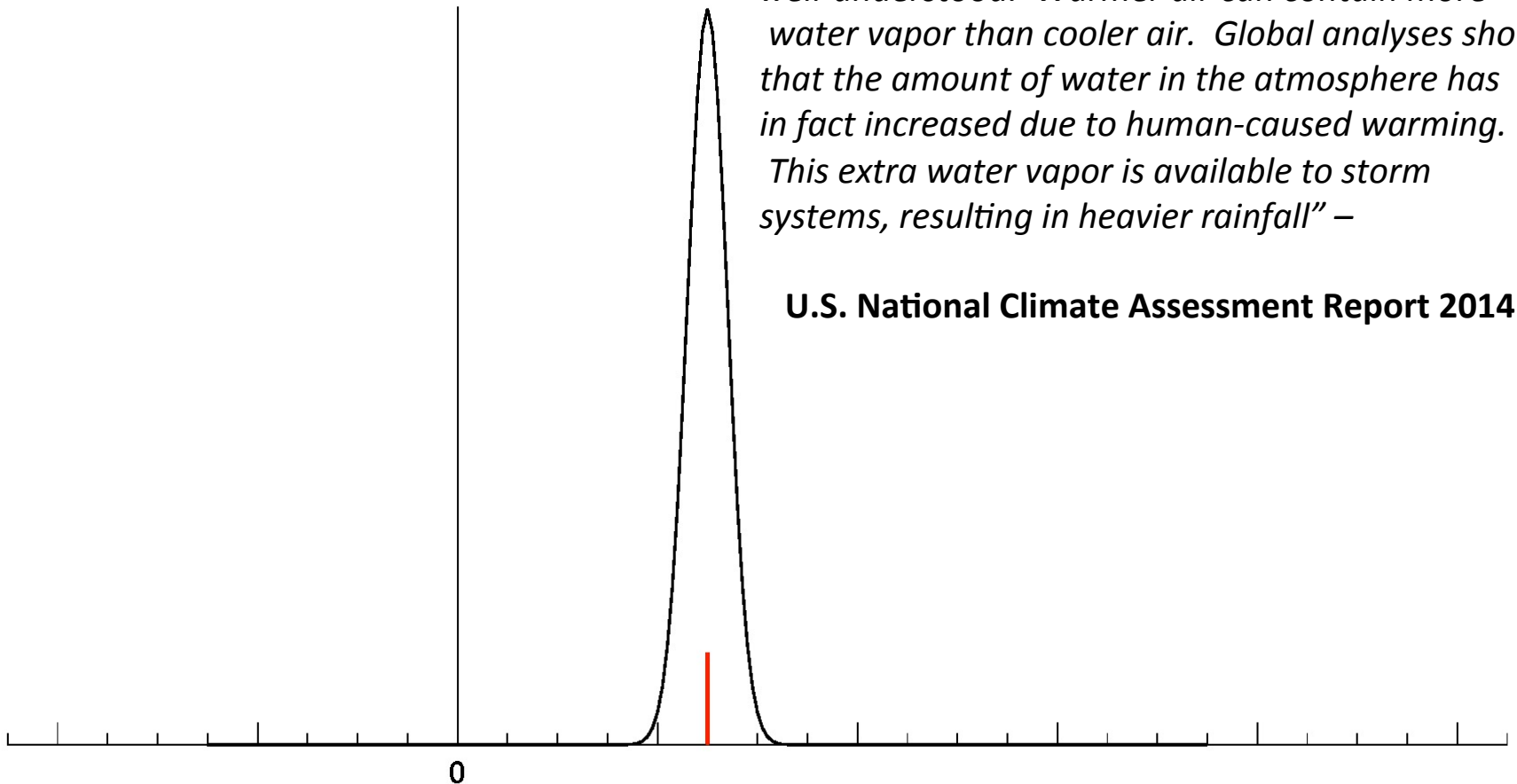
A Largely Deterministic Response to Forcing?



A Largely Deterministic Response to Forcing?

“The mechanism driving these changes is well-understood. Warmer air can contain more water vapor than cooler air. Global analyses show that the amount of water in the atmosphere has in fact increased due to human-caused warming. This extra water vapor is available to storm systems, resulting in heavier rainfall” –

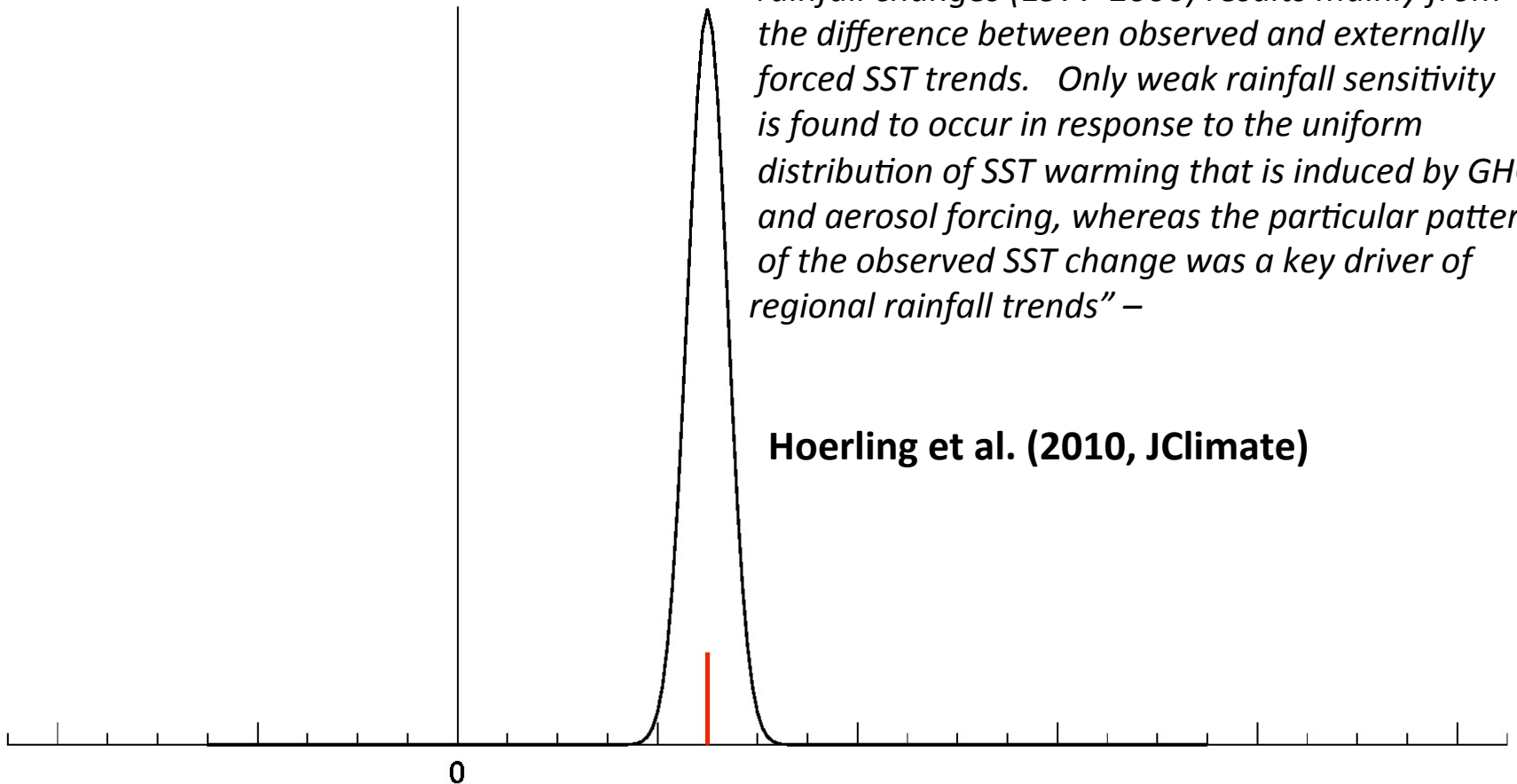
U.S. National Climate Assessment Report 2014



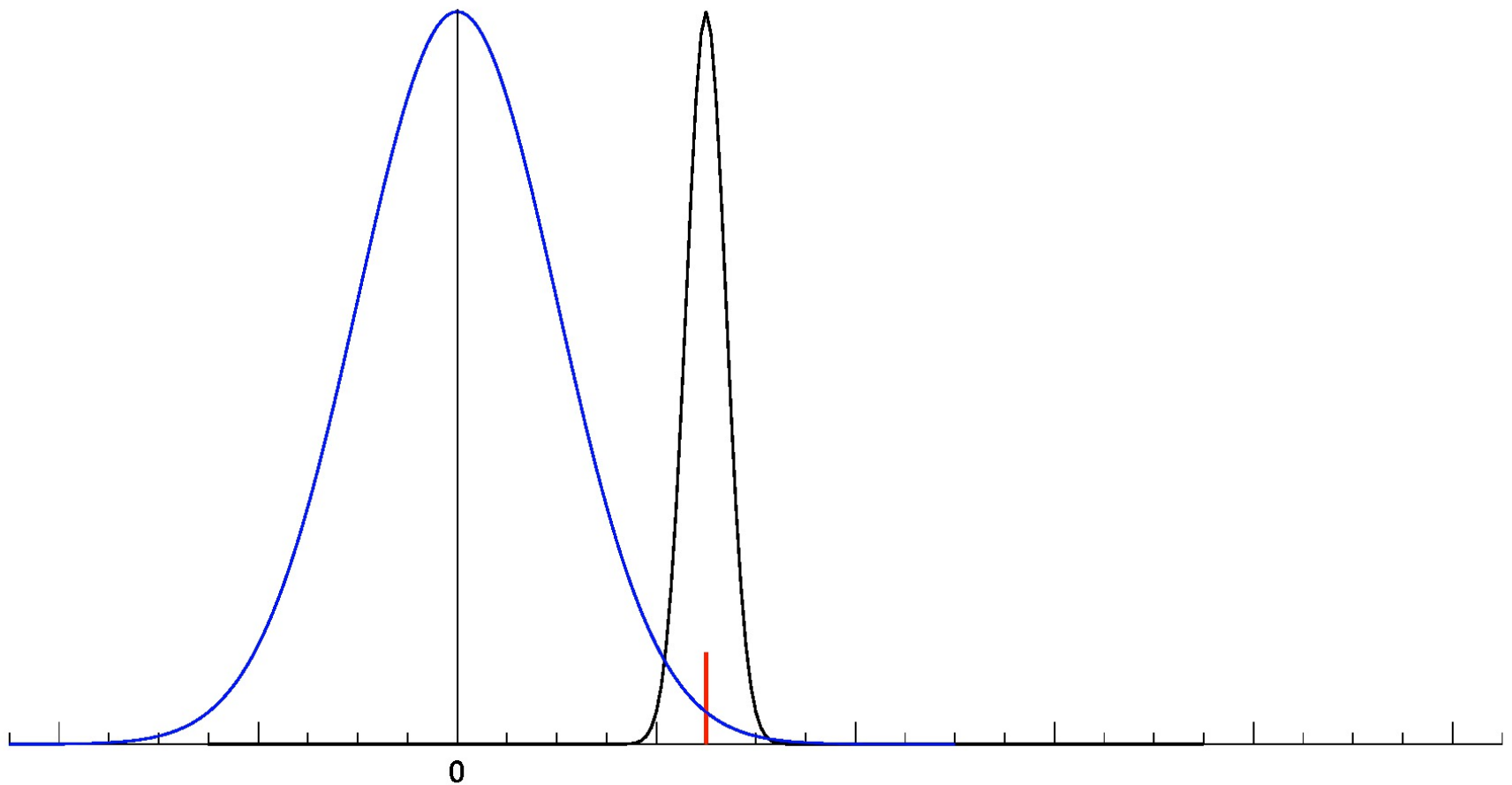
A Largely Deterministic Response to Forcing?

“The discrepancy between observed and GHG-forced rainfall changes (1977-2006) results mainly from the difference between observed and externally forced SST trends. Only weak rainfall sensitivity is found to occur in response to the uniform distribution of SST warming that is induced by GHG and aerosol forcing, whereas the particular pattern of the observed SST change was a key driver of regional rainfall trends” –

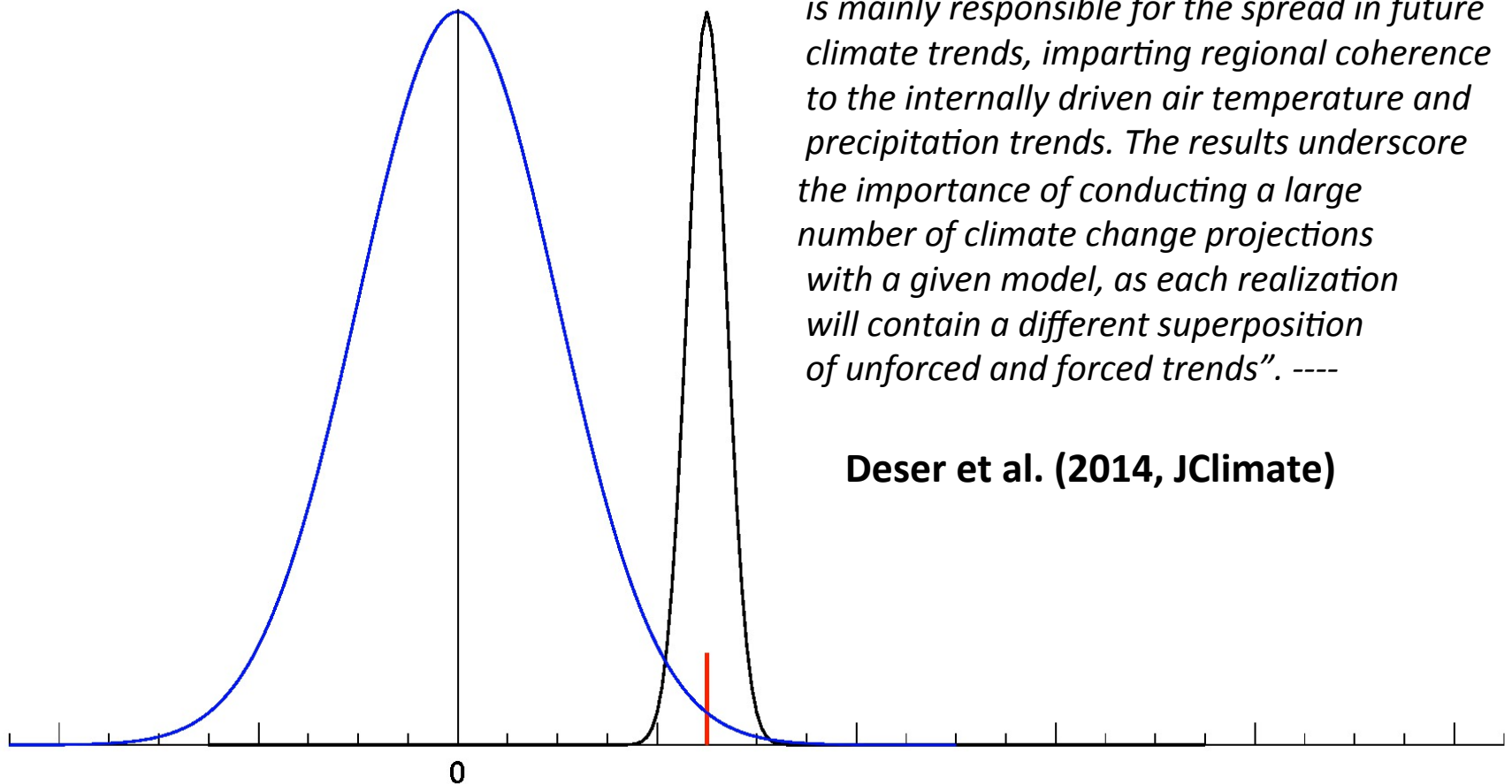
Hoerling et al. (2010, JClimate)



An “Extreme” Manifestation of Internal Coupled Variability?



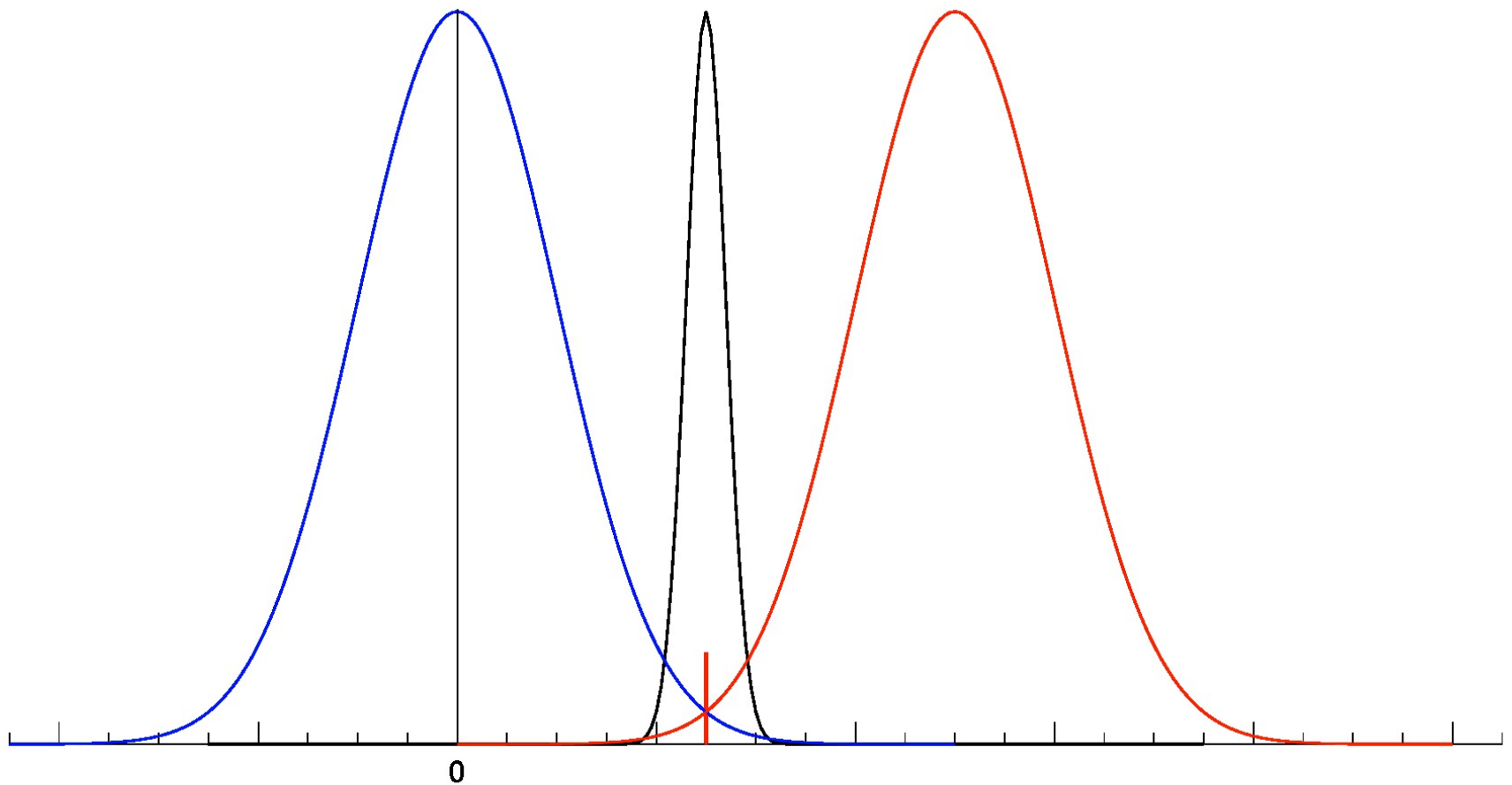
An “Extreme” Manifestation of Internal Variability?



“Intrinsic atmospheric circulation variability is mainly responsible for the spread in future climate trends, imparting regional coherence to the internally driven air temperature and precipitation trends. The results underscore the importance of conducting a large number of climate change projections with a given model, as each realization will contain a different superposition of unforced and forced trends”. ----

Deser et al. (2014, JClimate)

An “Extreme” Manifestation of Internal Variability---
Superposed Upon a Strong Forced Signal?



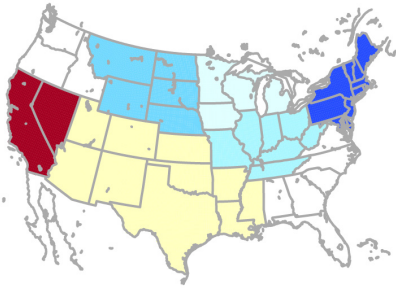
Coupled and Uncoupled Climate Model Simulations 1979-2013

- ° CCSM4 (Coupled)..... 20 member
- ° CAM4 (C-AMIP) 20 member
Specify varying SST/sea ice/radiative forcing from each CCSM4 trace
- ° CAM4 (O-AMIP)..... 20-member
- ° CAM4 (CCSM4 Trace 10)..... 20 member
- ° CAM4 (CCSM4 Trace 14)..... 20 member

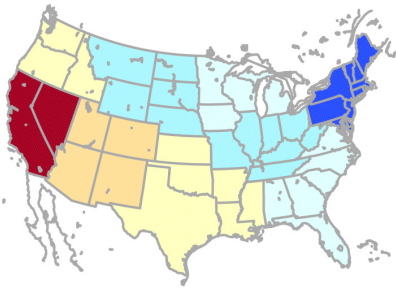
Change in Very Wet Days (95%) 1979–2013

Observed

Total



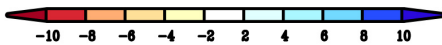
Number of Events



Avg/Event



% Chng per Decade

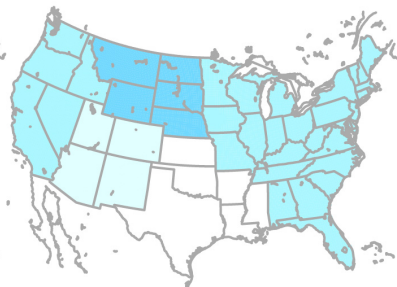
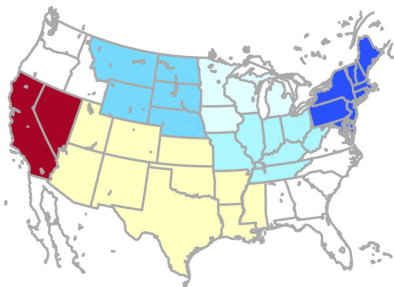


Change in Very Wet Days (95%) 1979–2013

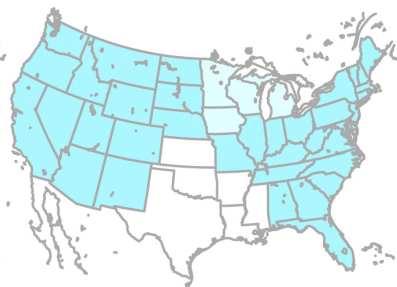
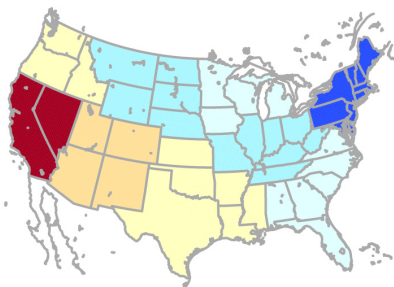
Observed

CCSM4

Total



Number of Events

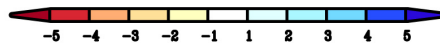
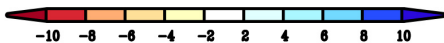


Avg/Event

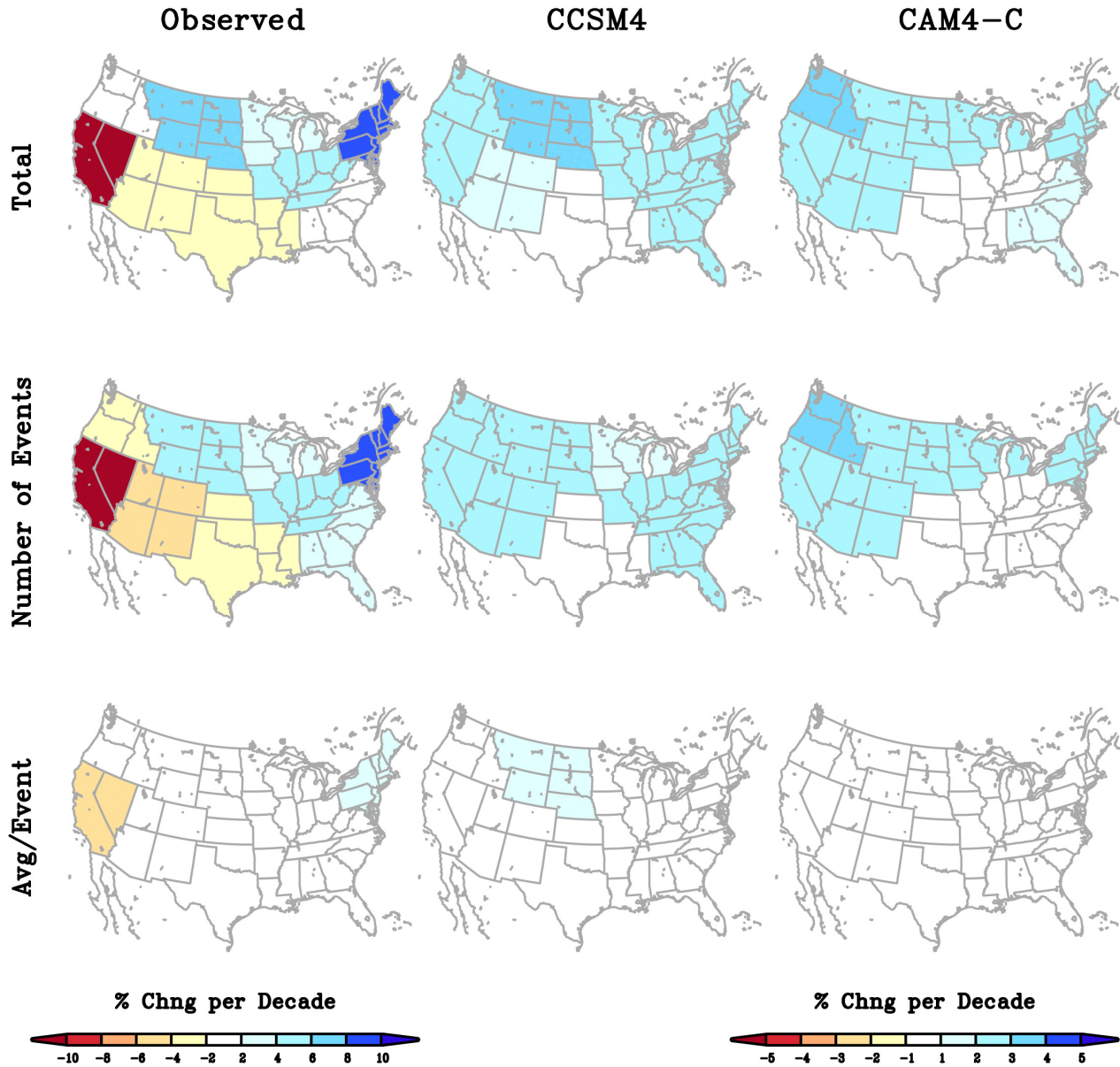


% Chng per Decade

% Chng per Decade



Change in Very Wet Days (95%) 1979–2013



Change in Very Wet Days (95%) 1979–2013

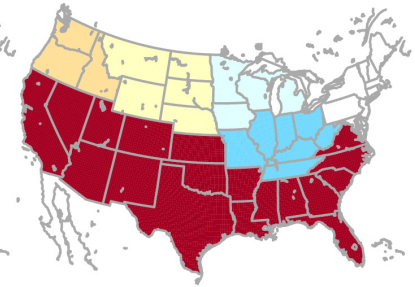
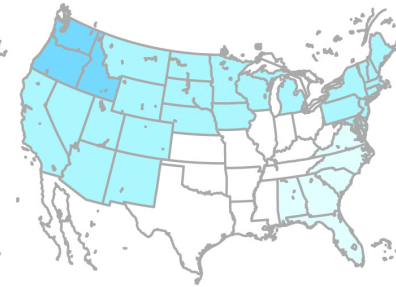
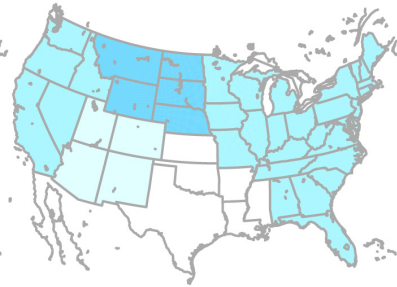
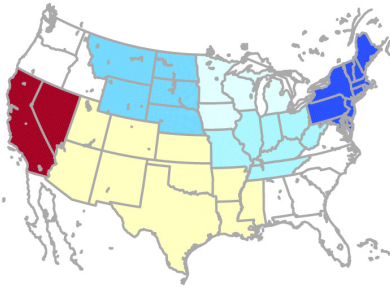
Observed

CCSM4

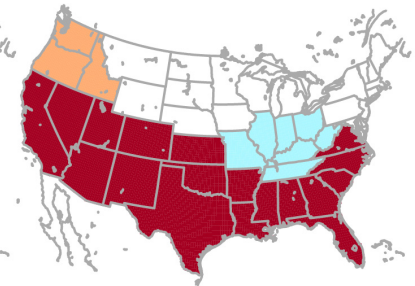
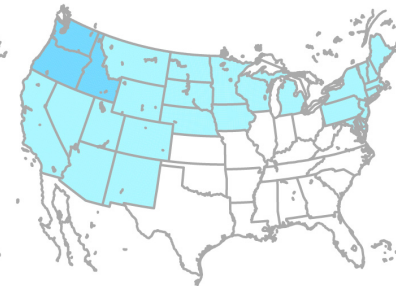
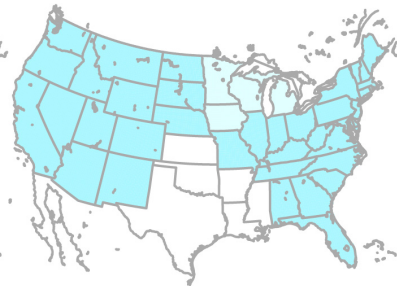
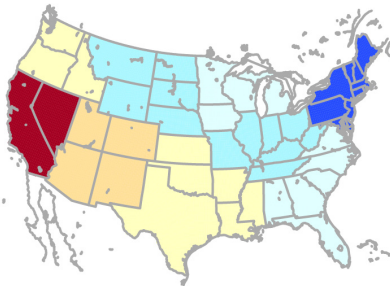
CAM4-C

CAM4-O

Total



Number of Events

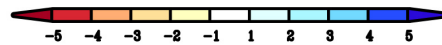
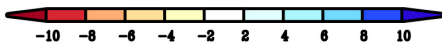


Avg/Event

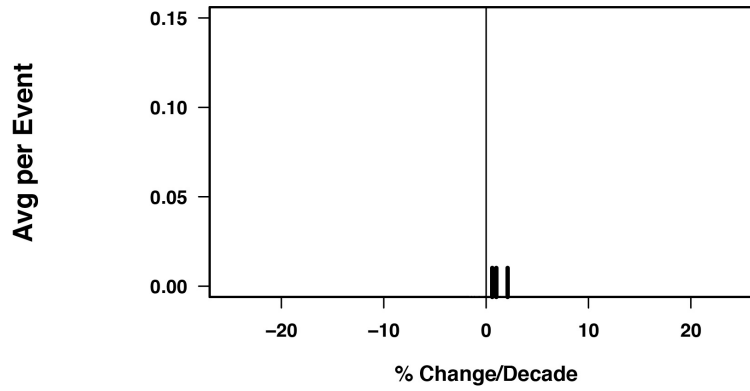
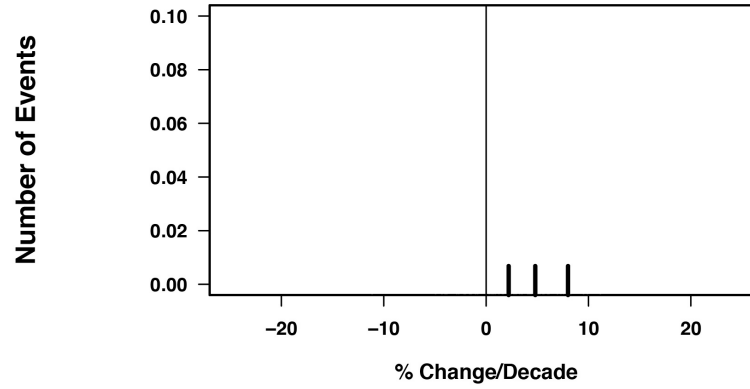
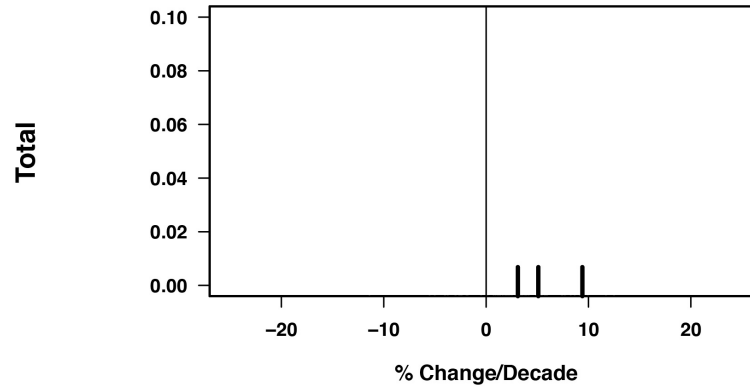


% Chng per Decade

% Chng per Decade

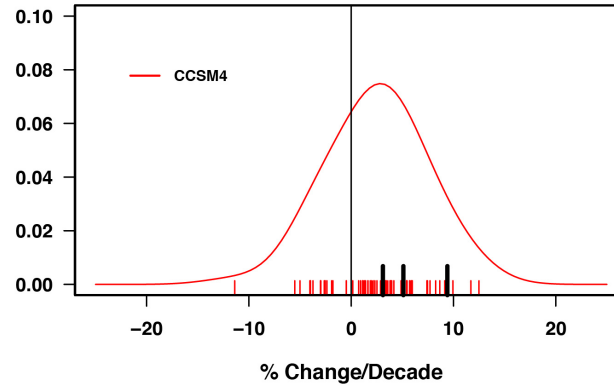


Change in PPT at the 95% Level North Central/Northeast Region

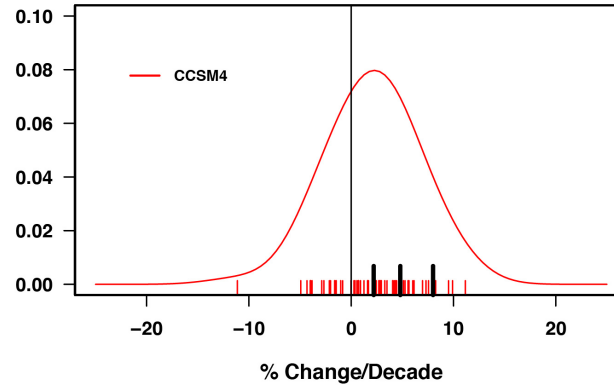


Change in PPT at the 95% Level North Central/Northeast Region

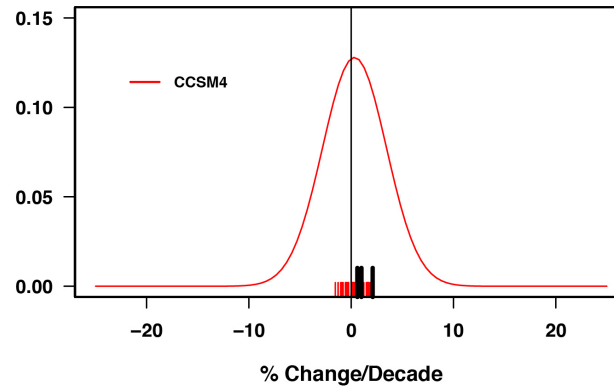
Total



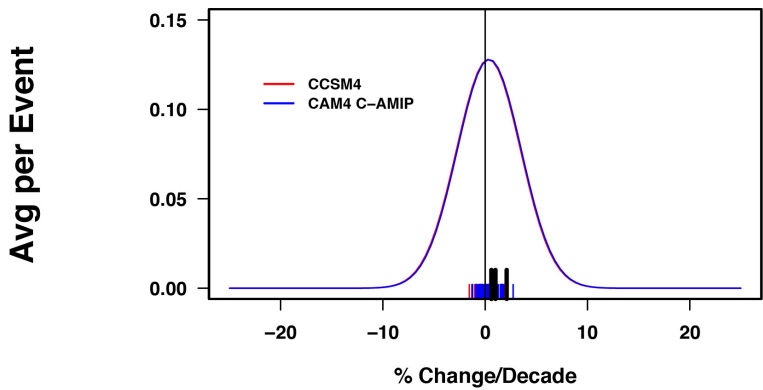
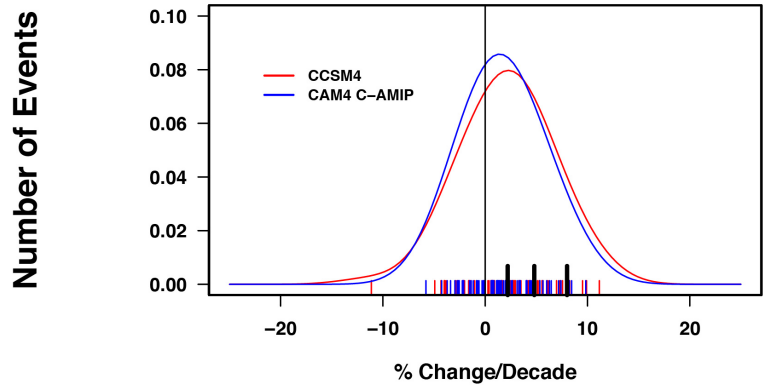
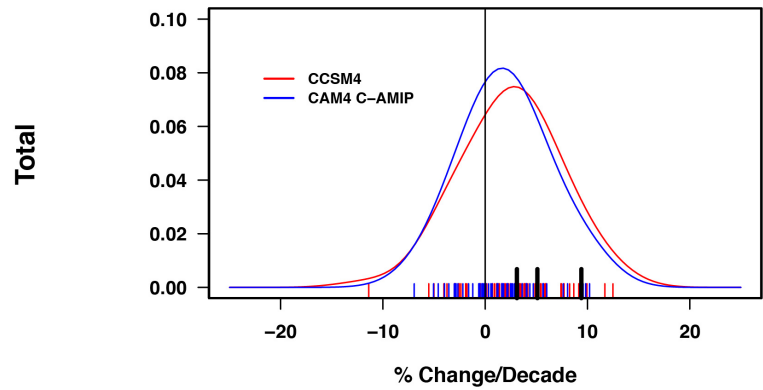
Number of Events



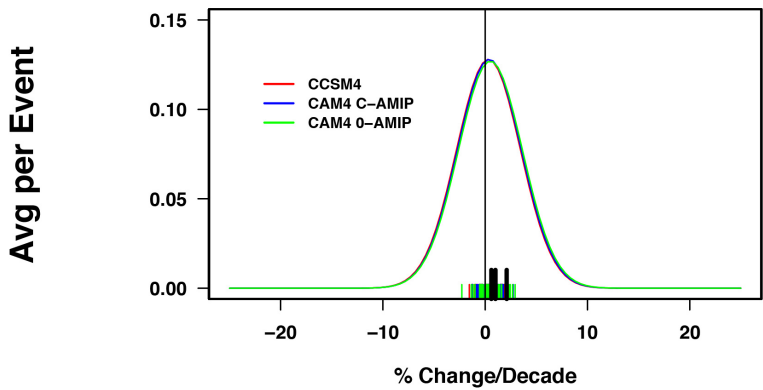
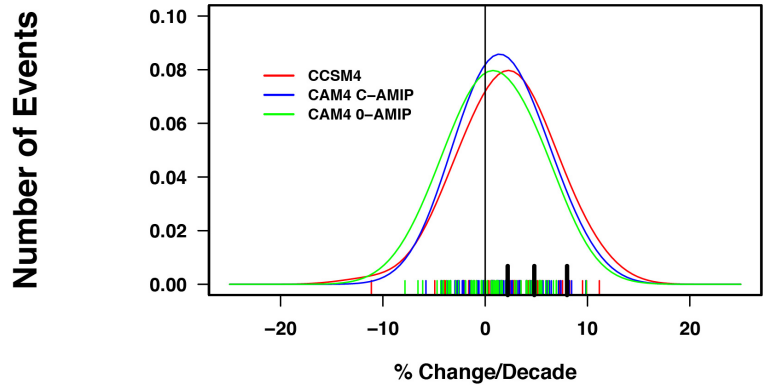
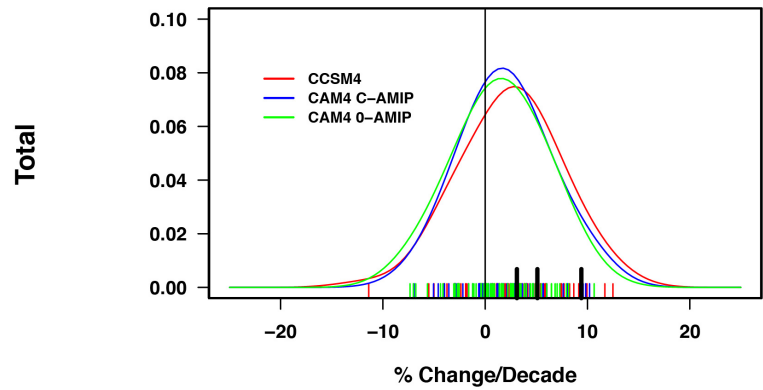
Avg per Event



Change in PPT at the 95% Level North Central/Northeast Region



Change in PPT at the 95% Level North Central/Northeast Region



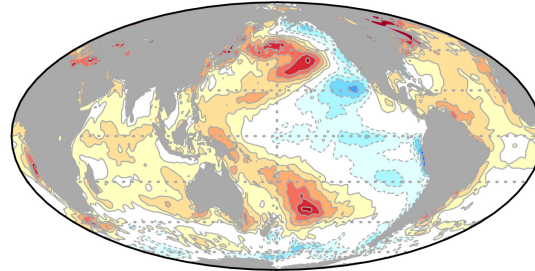
Interpretation of Simulations

vis-à-vis the Observed Upward Trend in Very Wet Days Over the Northern US (1979-2013)

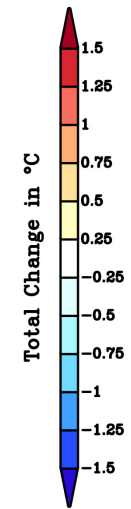
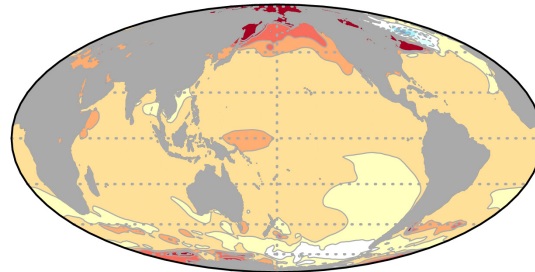
- ° **There exists a forced signal toward increased pcpn falling in the upper 95th percentile**
Forced signal of extreme wetness mostly via increase # of events, a characteristic of observed changes.
- ° **Coupled system noise ~ double the forced signal magnitude in very wet day trends**
Owing to large internal variability, observed changes are unlikely to have been strongly forced.
- ° **Coupled system (CCSM4) statistics largely reproduced in uncoupled system (CAM4) runs**
AMIP approach to understanding the observed (coupled system) changes has merit.
- ° **Statistics of change in extreme wet days for O-AMIP and C-AMIP are indistinguishable.**
Equally plausible that observed upward trend is a sample drawn from an externally-forced population as it is a sample drawn from a population forced by the particular trace of obs SST variation.

Annual SST Change: 1979–2013

Observed

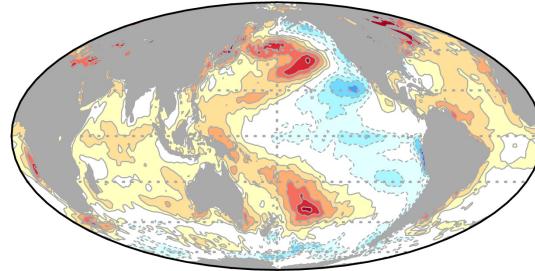


CCSM4

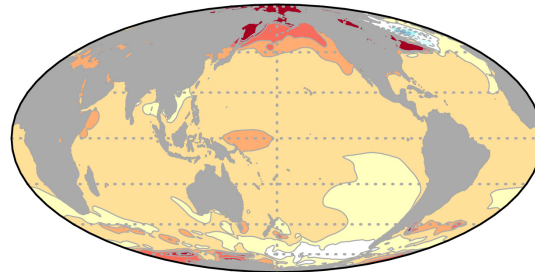


Annual SST Change: 1979–2013

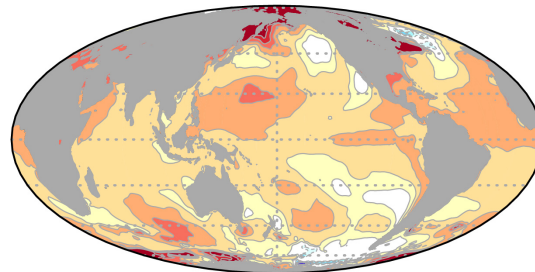
Observed



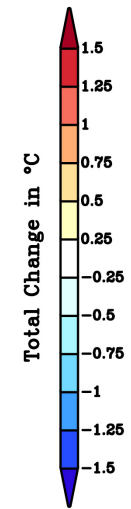
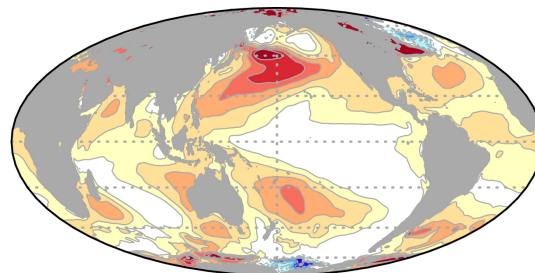
CCSM4



CAM4 Trace 10

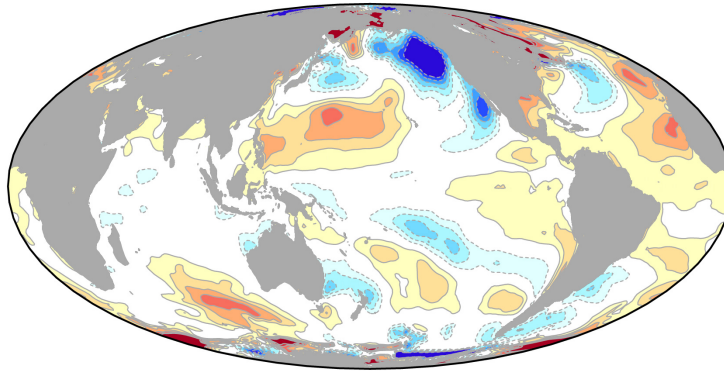


CAM4 Trace 14

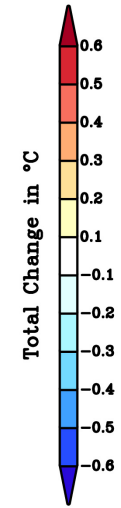
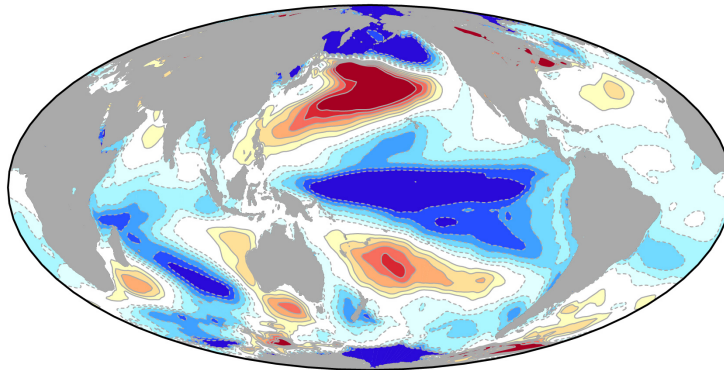


CCSM4 Internal SST Change: 1979–2013

Trace 10



Trace 14

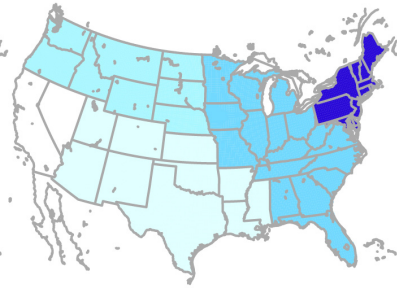
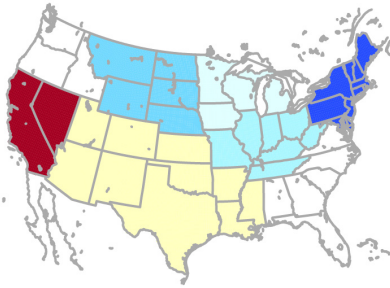


Change in Very Wet Days (95%) 1979–2013

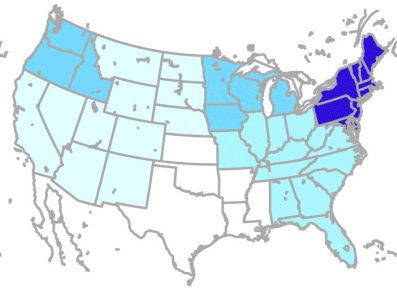
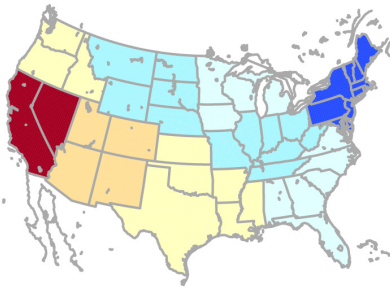
Observed

CAM4 Trace 10

Total



Number of Events

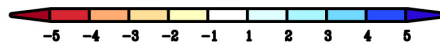
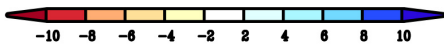


Avg/Event

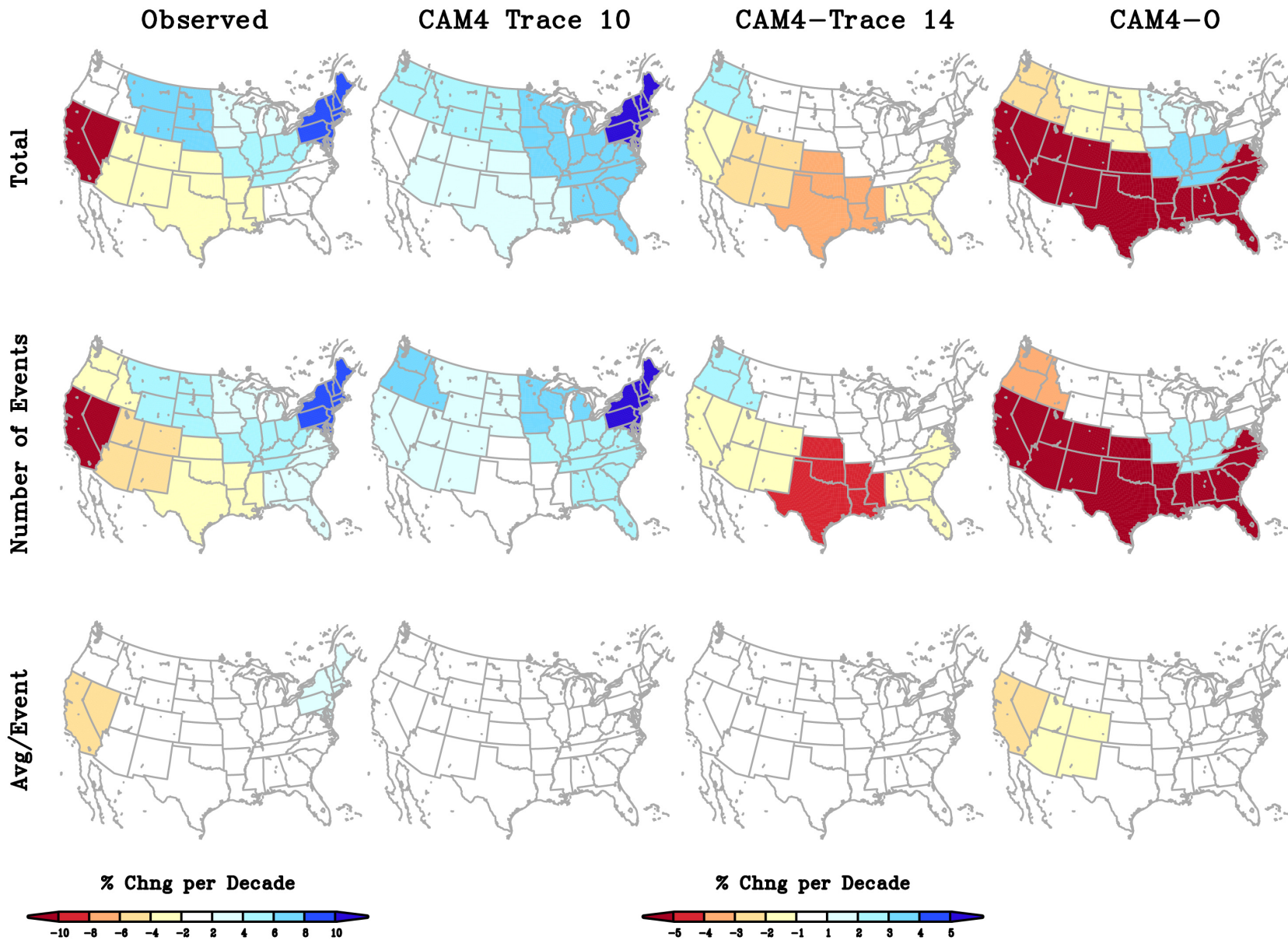


% Chng per Decade

% Chng per Decade

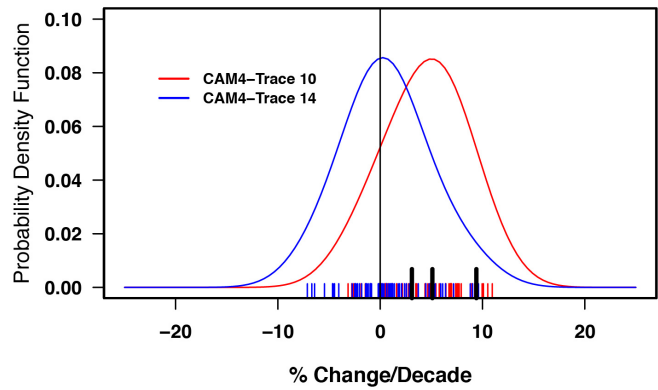


Change in Very Wet Days (95%) 1979–2013

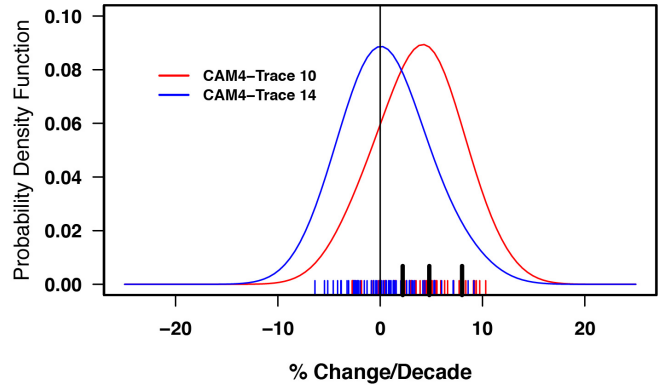


Change in PPT at the 95% Level North Central/Northeast Region

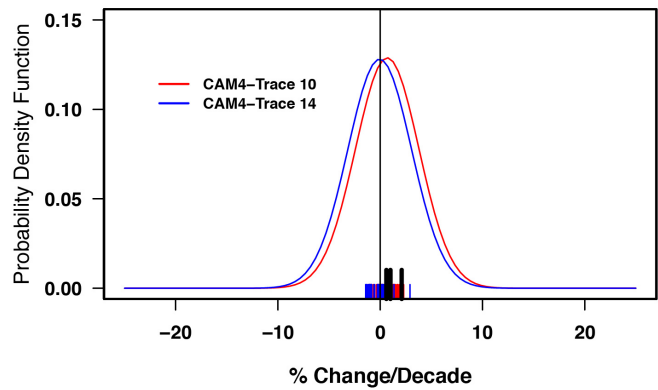
Total



Number of Events



Avg per Event

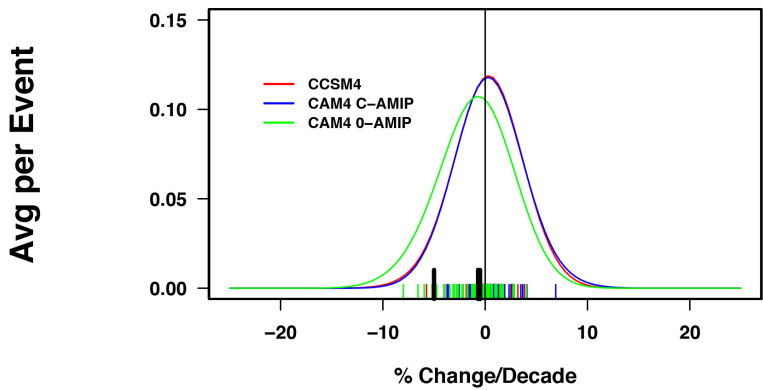
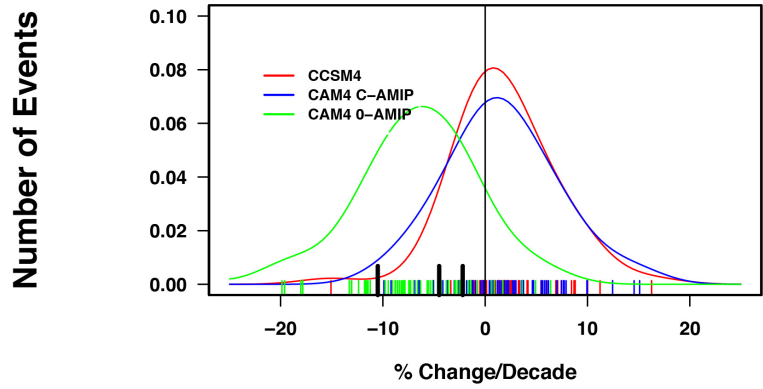
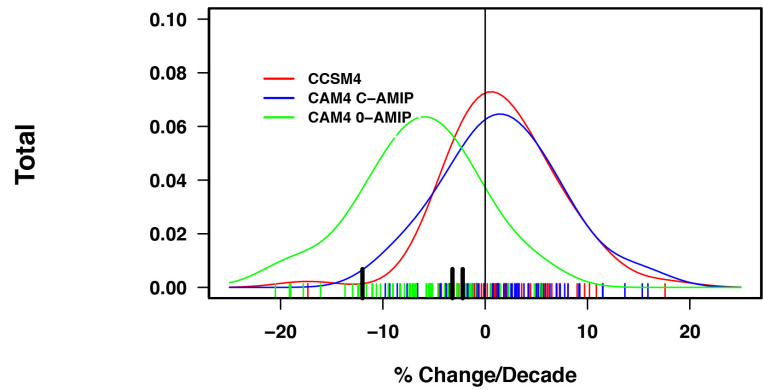


Some Closing Thoughts

On Trends in Very Wet Days Over the US (1979-2013)

- ° **Different factors** may be responsible for OBS regional differences in trends of very wet days.
Contrast between the northern and southern US unlikely reconcilable with GHG forcing alone
- ° **The particular SST trace may have been more relevant than the particular GHG trace.**
Contiguous US pattern of very wet day trends appears most congruent with CAM4 (O-AMIP) footprint.

Change in PPT at the 95% Level South/Southwest Region



Some Closing Thoughts

On Trends in Very Wet Days Over the US (1979-2013)

- **Concerning the particular SST trace: An extreme “event” of internal variability?**
No CMIP5 model (37) yields OBS strong increase in Indo-Pacific SST gradient during 1979-2013.
- **Seasonality of trends in very wet days may provide important clues on contributing factors.**
NE US upward trend may be warm season--- linked to land falling tropical disturbances.
Far West US downward trend may be cold season---linked to reduced extratropical storms.