Understanding the U.S. east-west differential of heat extremes in terms of record temperatures and the warming hole

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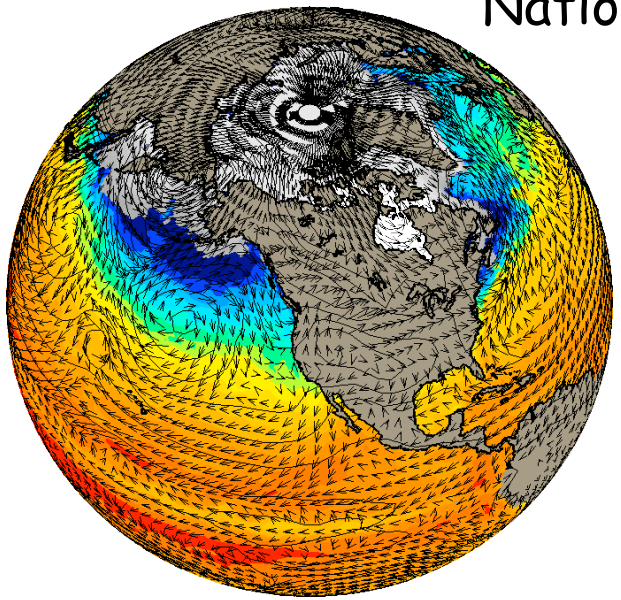
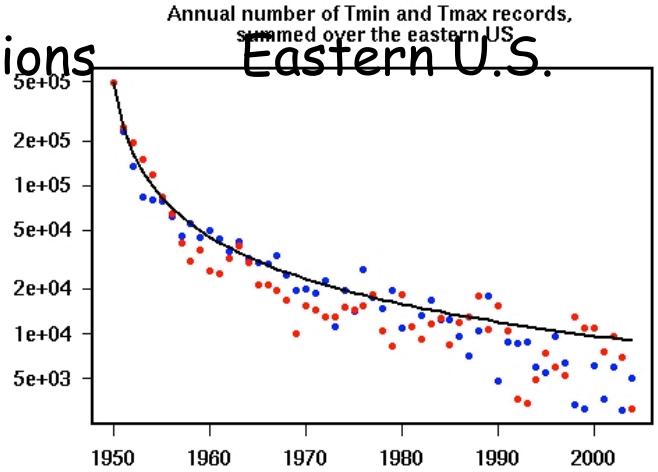


NCAR

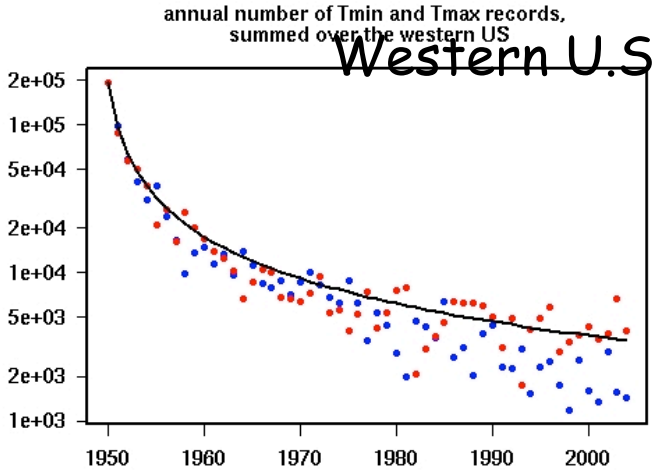
There has been relatively greater observed warming over the western U.S. than over the eastern U.S., and that has contributed to a larger ratio of record highs to lows in the west compared to the east (U.S. average ratio of record highs to record lows currently about 2 : 1)

Observations

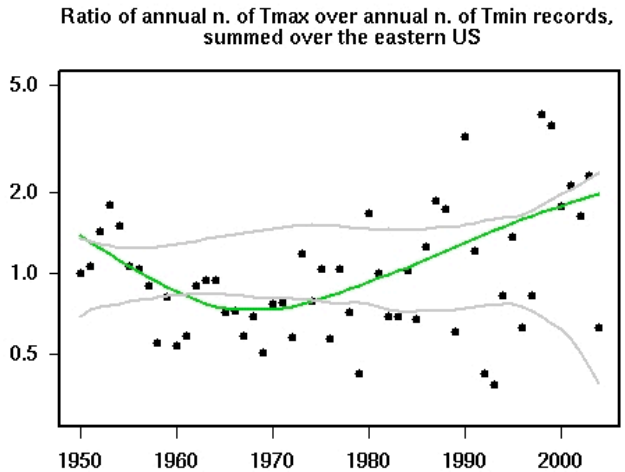
Eastern U.S.

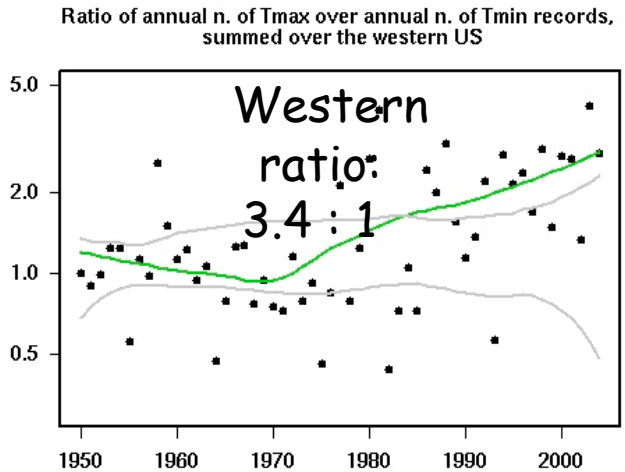


Western U.S.



Eastern U.S. ratio: 1.8 : 1



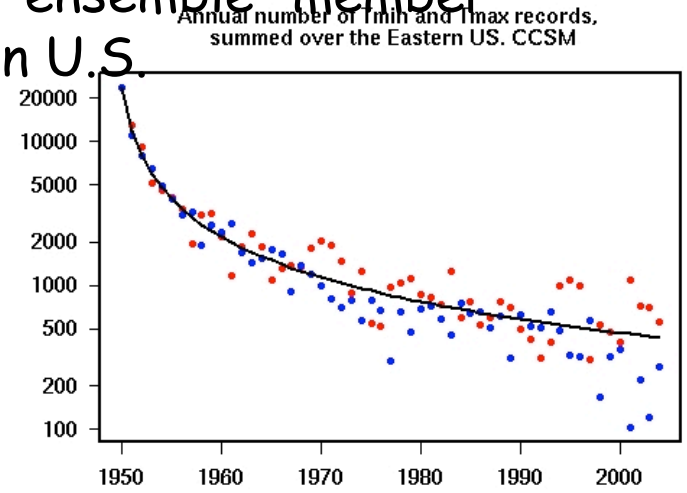


Meehl, G.A., C. Tebaldi, G. Walton, D. Easterling, and L. McDaniel, 2009: The relative increase of record high maximum temperatures compared to record low minimum temperatures in the U.S. *Geophys. Res. Lett.*, **36**, L23701, doi:10.1029/2009GL040736.

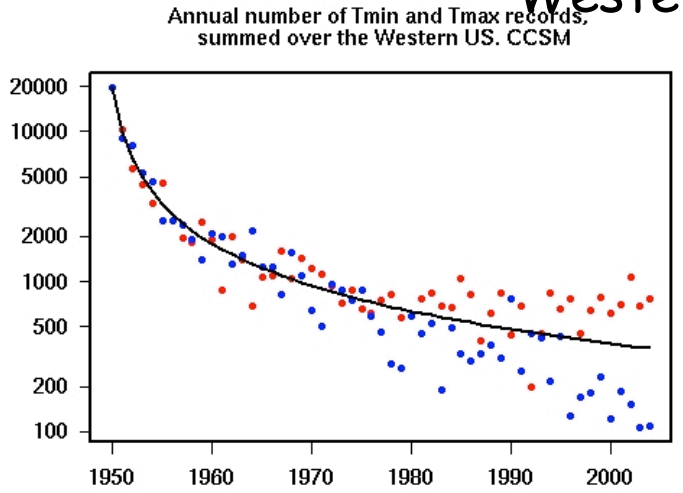
The model also shows greater warming in the west compared to the east, but greater overall warming contributes to larger ratios of record highs to record lows compared to the observations

Single ensemble member

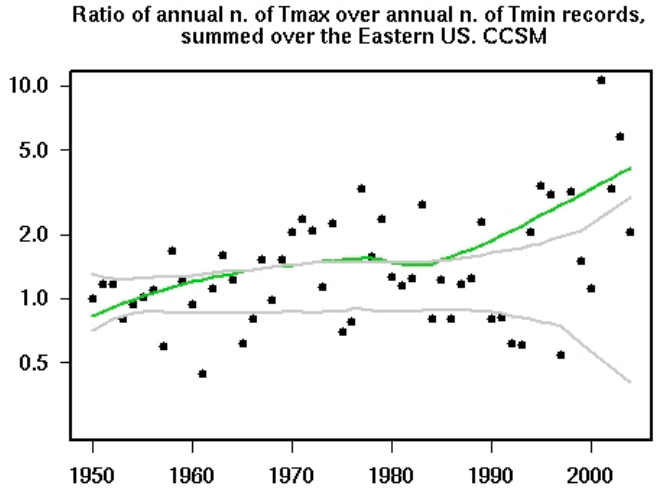
Eastern U.S.

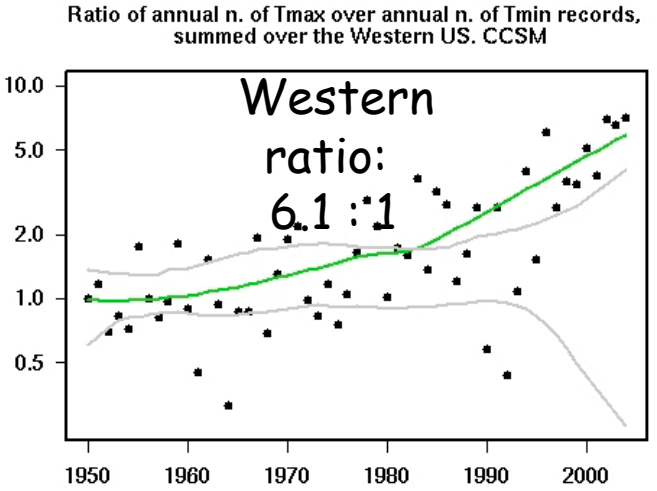


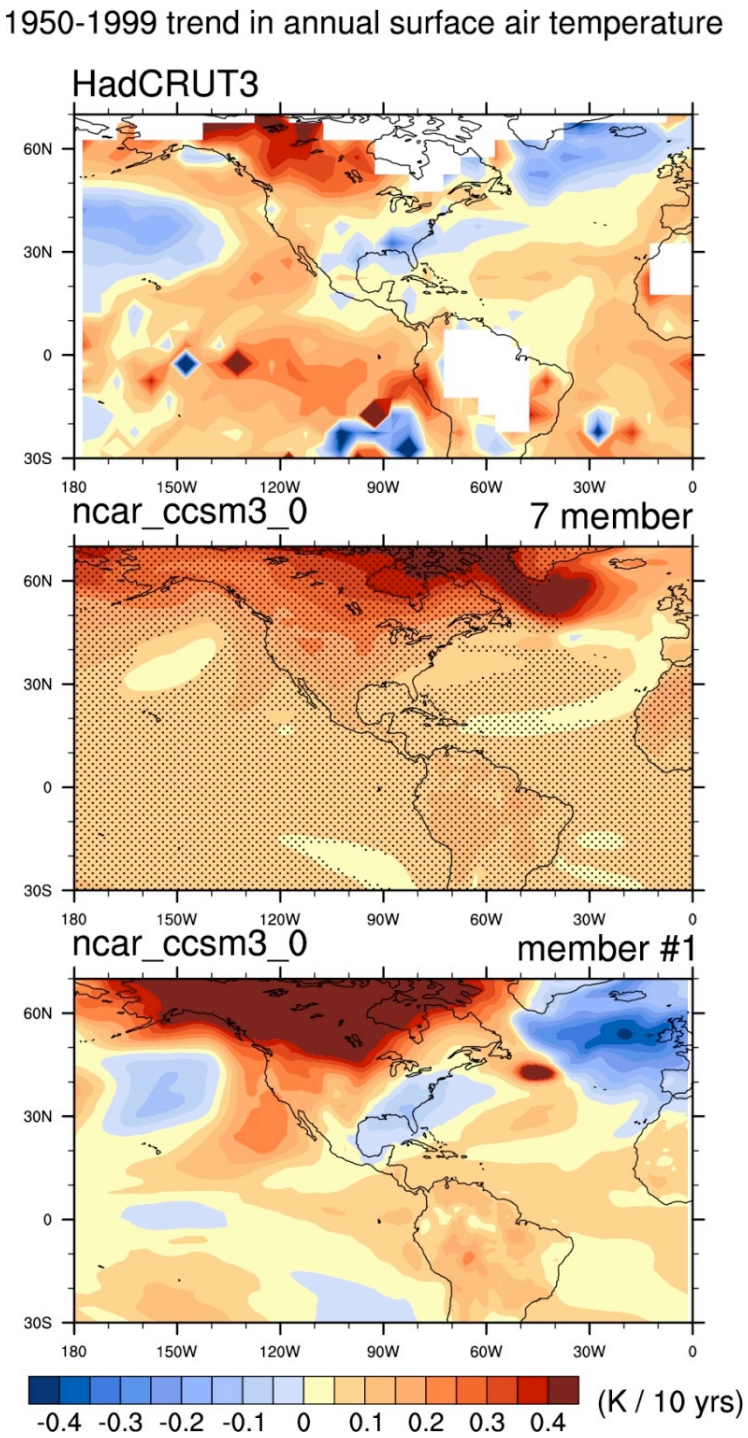
Western U.S.



Eastern U.S. ratio: 4.2 : 1







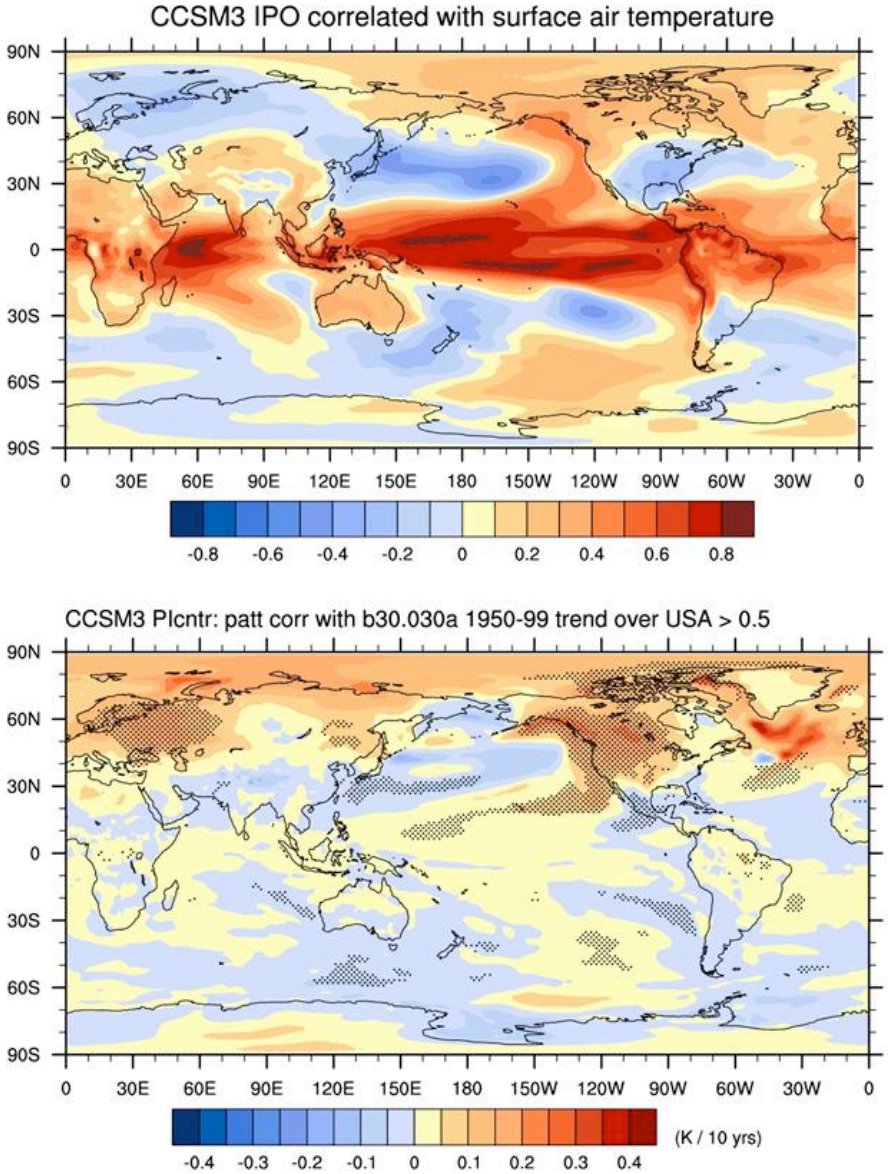
From 1950s to 1990s, observed warming in western U.S. outpaced eastern U.S. warming by about a factor of two, as did ratio of record highs to record lows

The CCSM3 model ensemble member used in the records study has only about 35% greater warming in western U.S. compared to eastern U.S. (using 100W as dividing line), and a comparable differential in the ratio of record highs to record lows

One ensemble member has some resemblance to observed temperature trends from the 1950s to 1990s, with over a factor of three greater warming in western U.S. compared to eastern U.S.; ensemble average doesn't

Comparable increase of the east-west differential of record highs to record lows (Anderson and Kostinski, 2010)

Connection to tropical SSTs (Kunkel et al, 2006; Wang et al, 2009; Shin and Sardeshmukh, 2010)

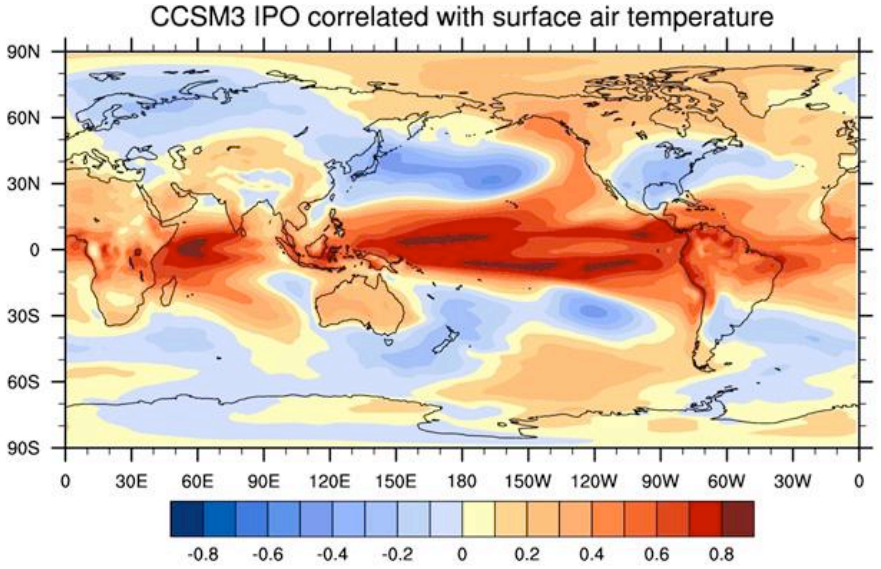


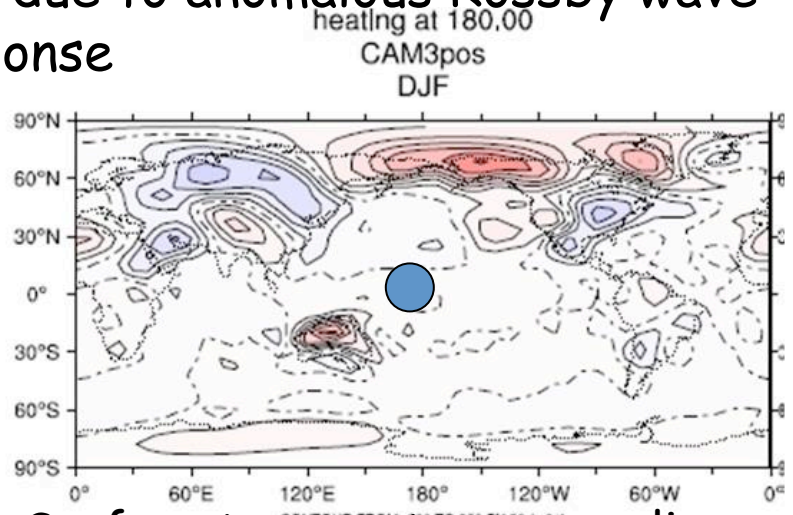
IPO index correlated with surface air temperature produces a warming hole in positive IPO phase;

Connection to equatorial western Pacific SST for warming hole periods in control run

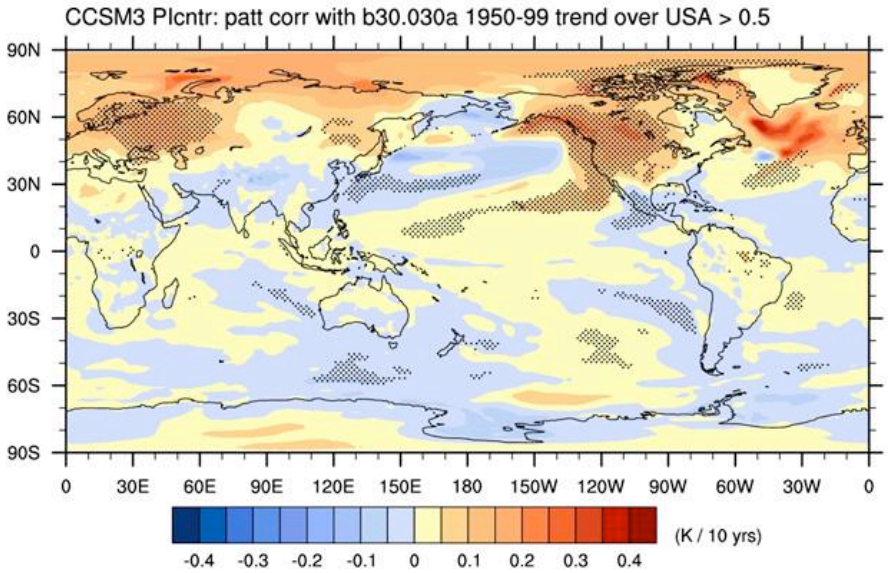
(451 50-yr trends from 500 yr control run, 42 member composite of trends based on pattern correlation of US warming hole pattern in the ensemble member greater than 0.5)

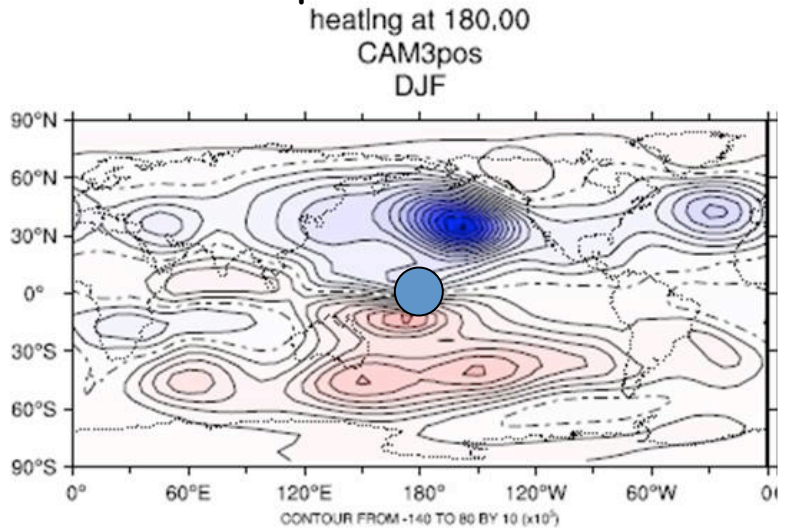
Convective heating anomaly at equator, Dateline, produces warming hole due to anomalous Rossby wave response





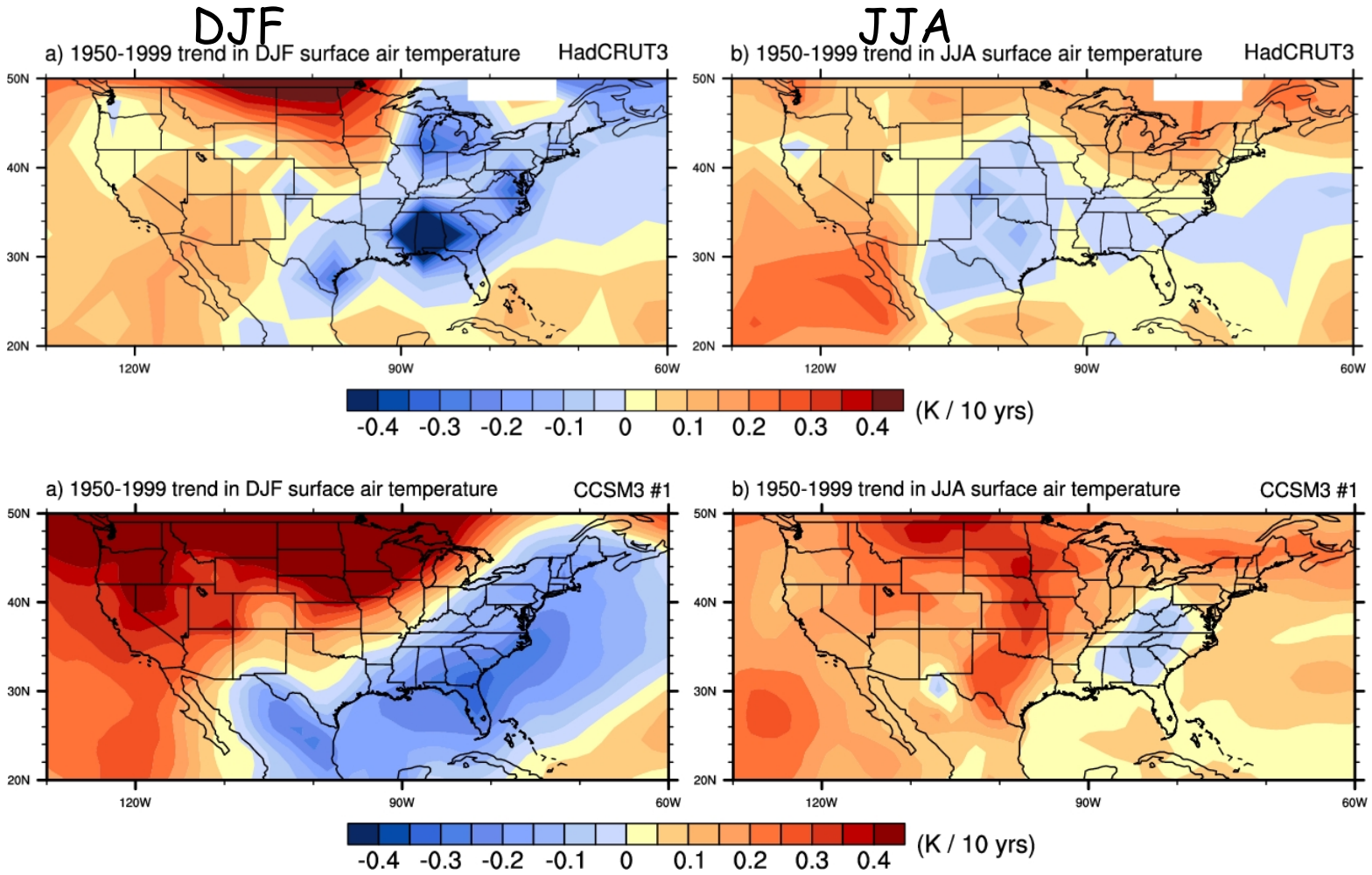
Surface temperature anomalies





850 hPa streamfunction

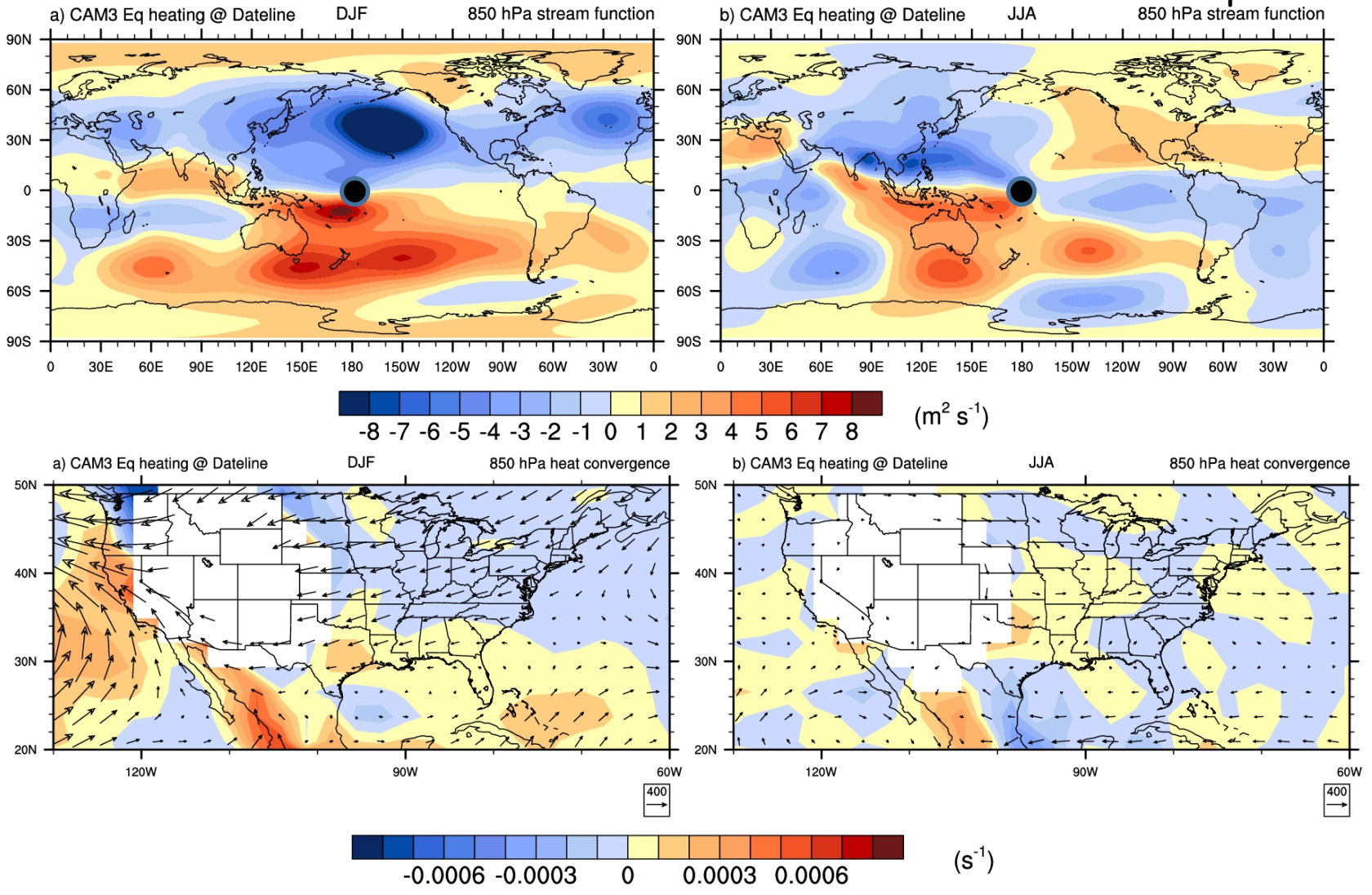
There is a seasonal signature to the warming hole in terms of magnitude and location in observations and the model ensemble member

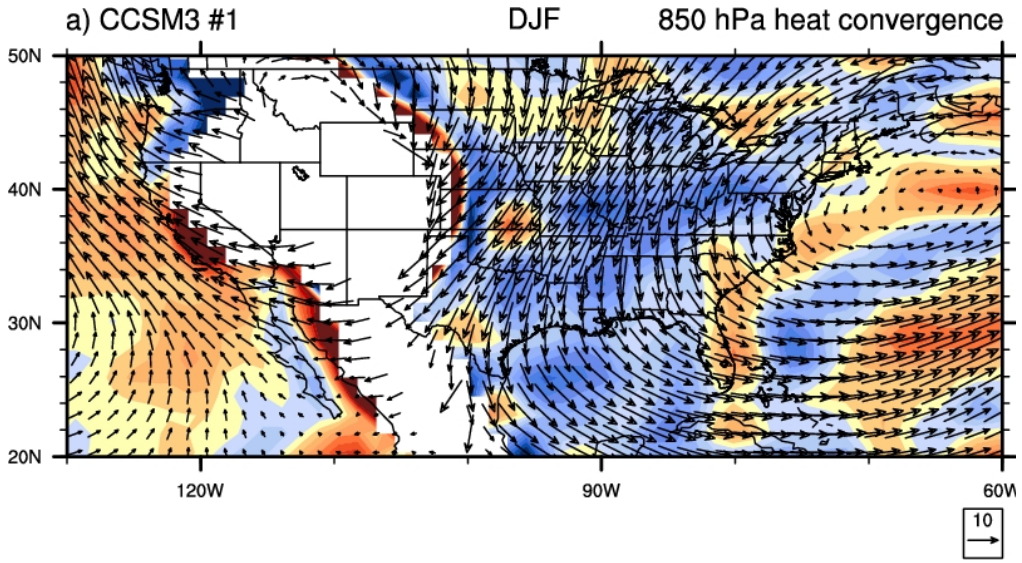


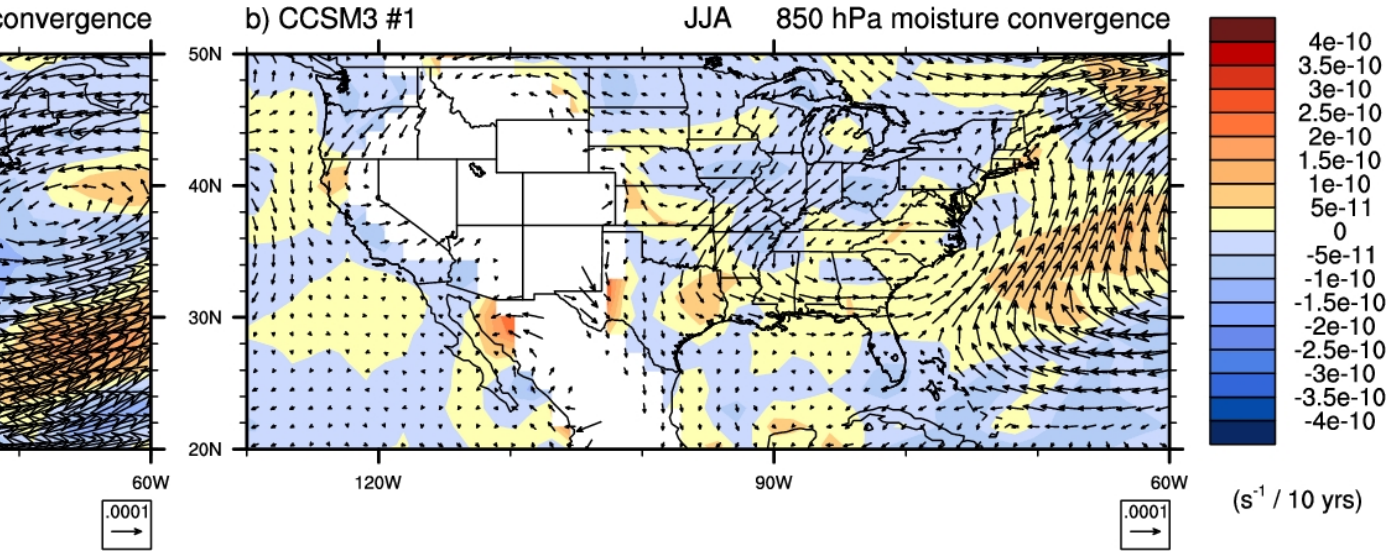
Specified convective heating anomaly experiment shows seasonal difference in North American teleconnection

DJF: anomalous Rossby wave response produces low level heat divergence and cooling

JJA: anomalous Gill-type response produces low level moisture convergence, increased precip, clouds, soil moisture and cooler temperatures



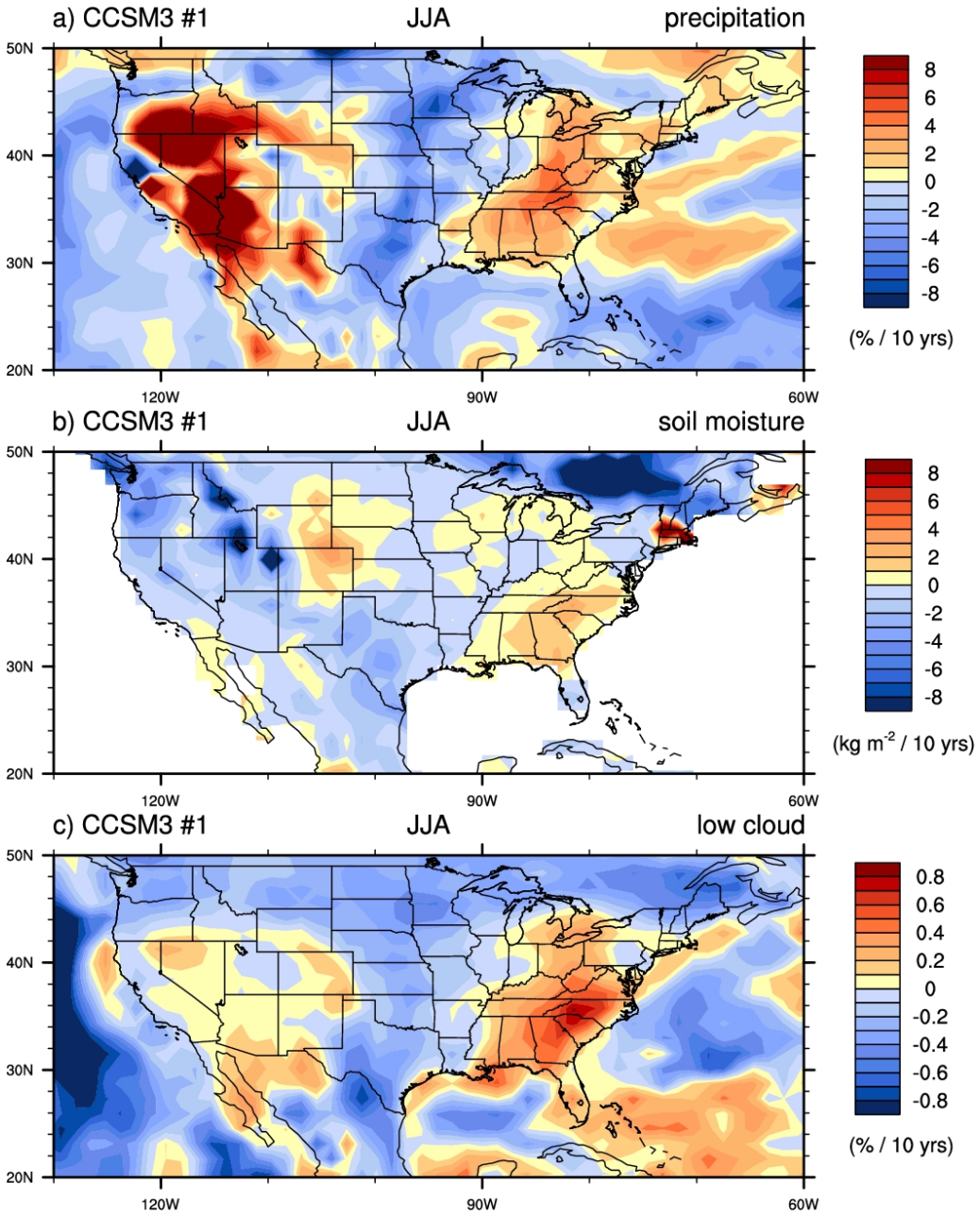




Similar seasonal teleconnection processes in CCSM3 warming hole ensemble member

DJF: anomalous Rossby wave response produces low level heat divergence and cooling (-2.0 Ks^{-1} for SE U.S. area average)

JJA: anomalous Gill-type response produces low level moisture convergence, increased precip, clouds, soil moisture and cooler temperatures (+0.2 s^{-1} for SE U.S. area average)

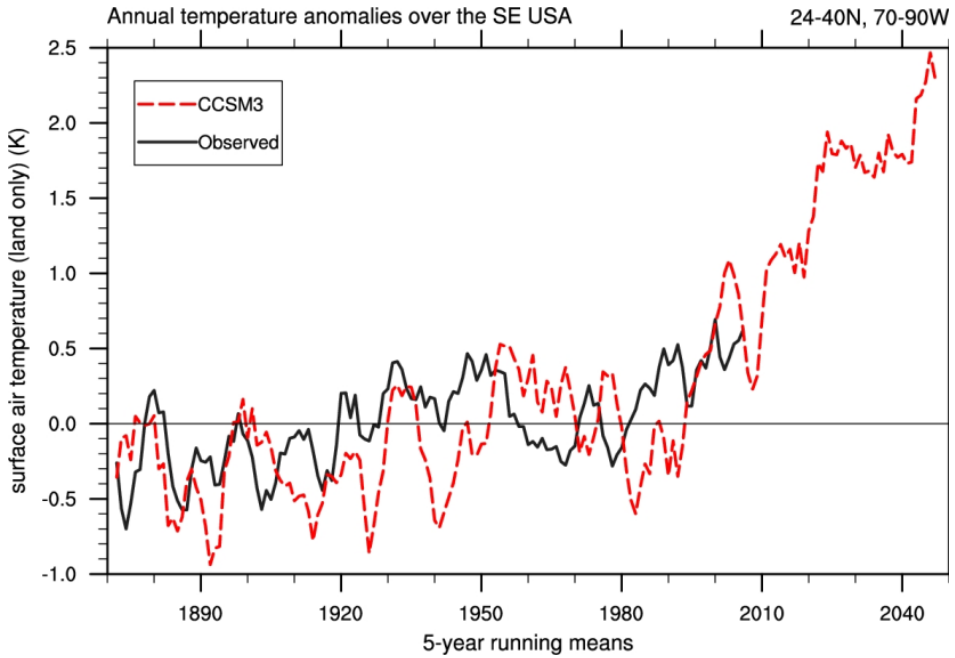


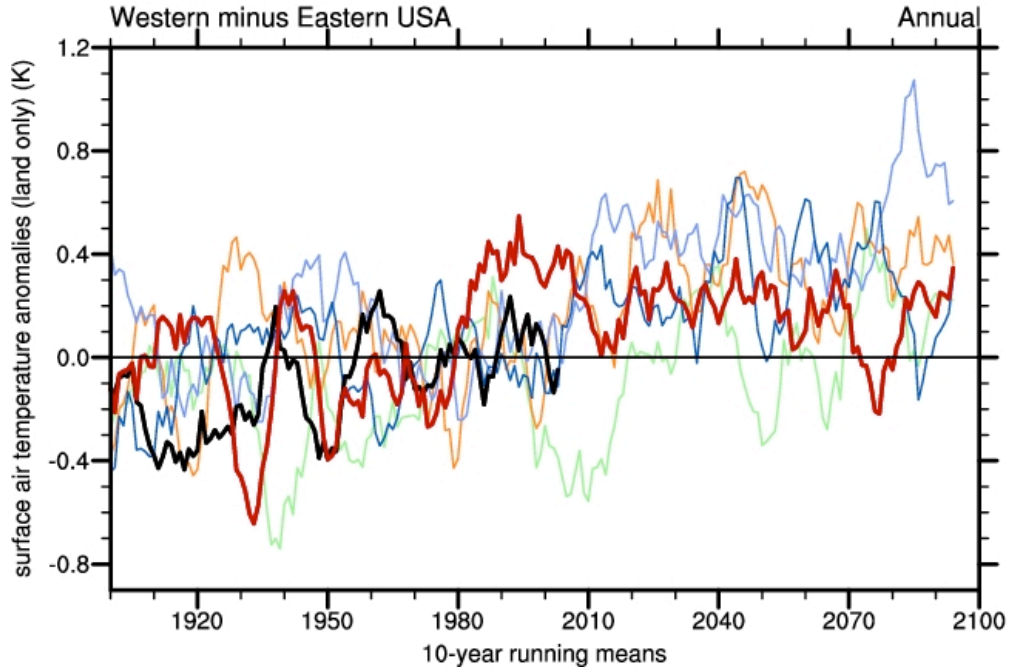
JJA processes in CCSM3 warming hole member for S.E. U.S.:

Increased precipitation

Increased soil moisture

Increased low cloud





The future: CCSM3 projects disappearance of warming hole, but ongoing decadal timescale variability

Other CCSM3 ensemble members show warming greater in the western U.S. compared to the eastern U.S. on average, with comparable larger ratio of record highs to record lows in the west compared to the east in the future

Summary

The east-west differential of the ratio of record daily high maximum temperatures to record daily low minimum temperatures (1950-1999) is greater in the observations where there was a warming trend in the west and cooling in the southeast (the "warming hole") compared to a typical model ensemble member with more uniform warming

However, one ensemble member produces a warming hole with greater east-west differential of record temperatures;

Changes in circulation, driven by anomalous convective heating anomalies in the equatorial western Pacific near the Dateline associated with Pacific SST pattern (positive IPO), produce the warming hole:

Cold season: ridge-trough teleconnection pattern over the U.S. with more cold air advection to the southeastern U.S.

Warm season: teleconnection pattern produces low level moisture convergence produces increased precipitation, cloudiness, and soil moisture

Projections show fluctuations of this pattern superimposed over warming from increasing greenhouse gases, implying a disappearance of the warming hole, with ongoing future larger increases in the ratio of daily record high maximum temperatures to record low minimum temperatures in the western U.S. compared to the eastern U.S.