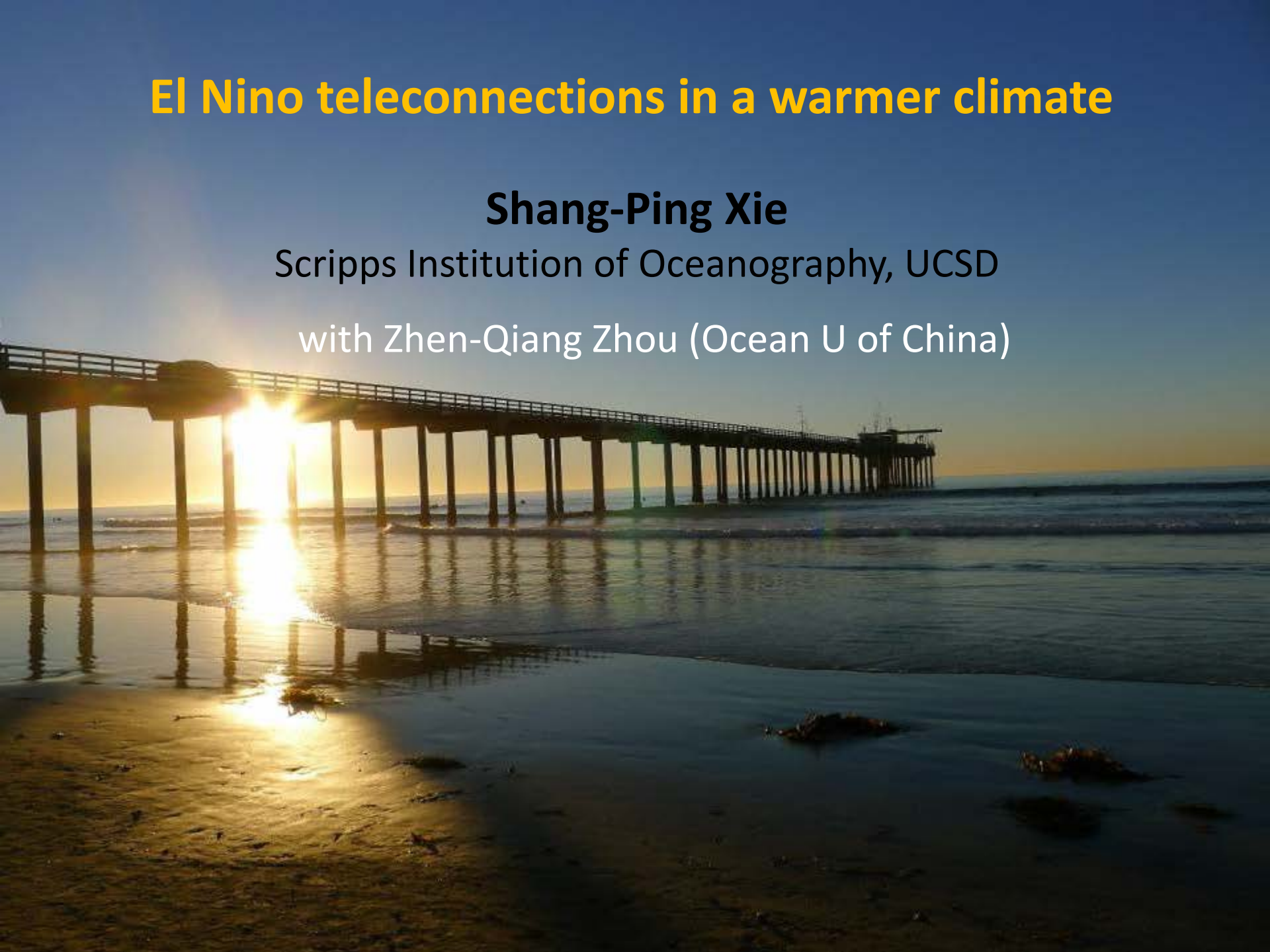
El Nino teleconnections in a warmer climate

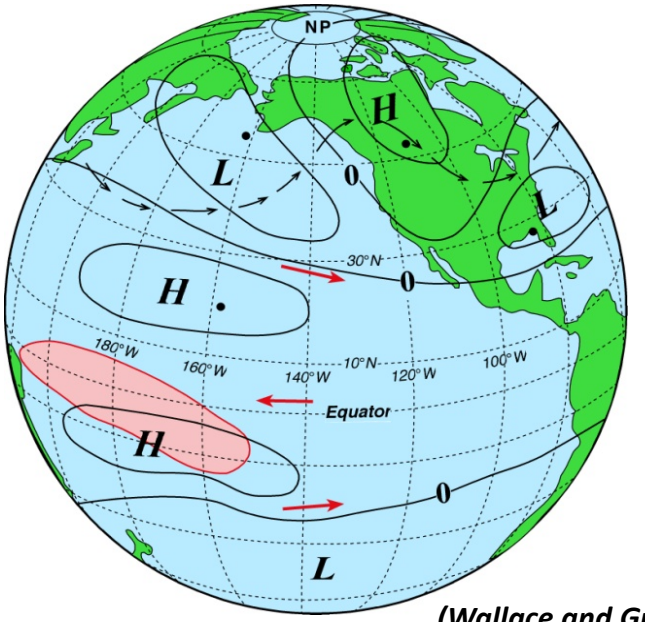


Shang-Ping Xie

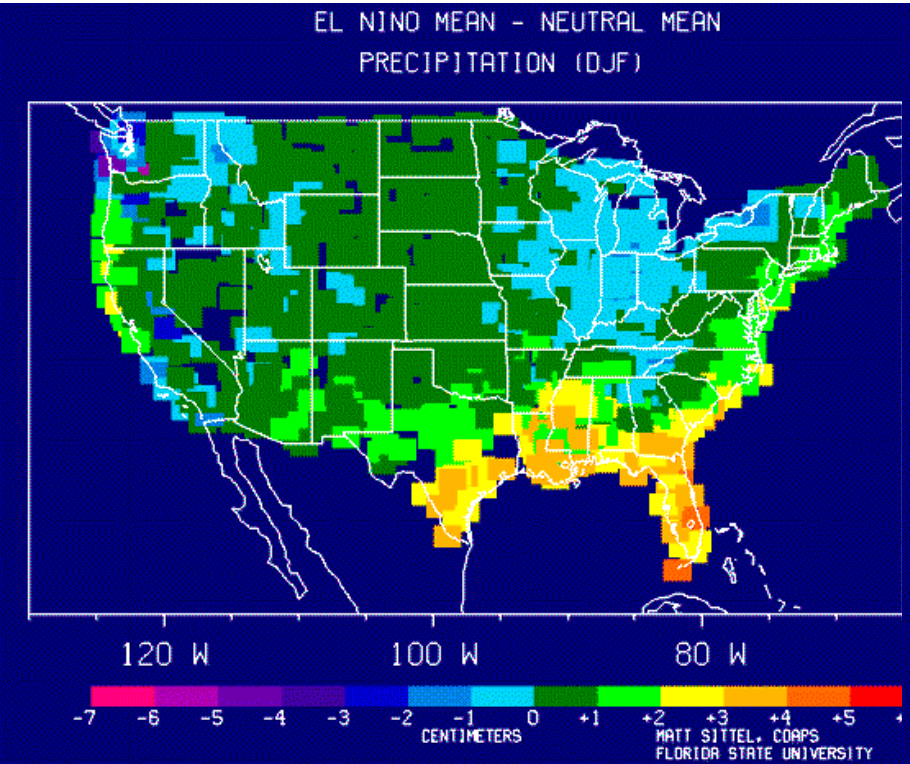
Scripps Institution of Oceanography, UCSD

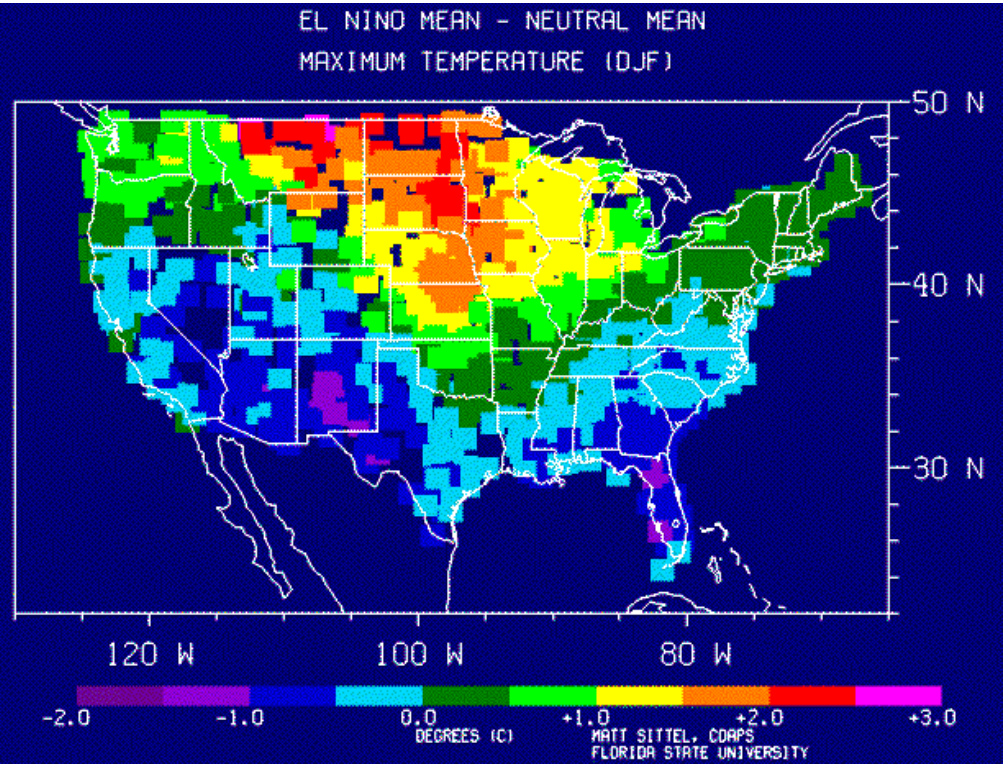
with Zhen-Qiang Zhou (Ocean U of China)

El Nino's influence on US winter climate

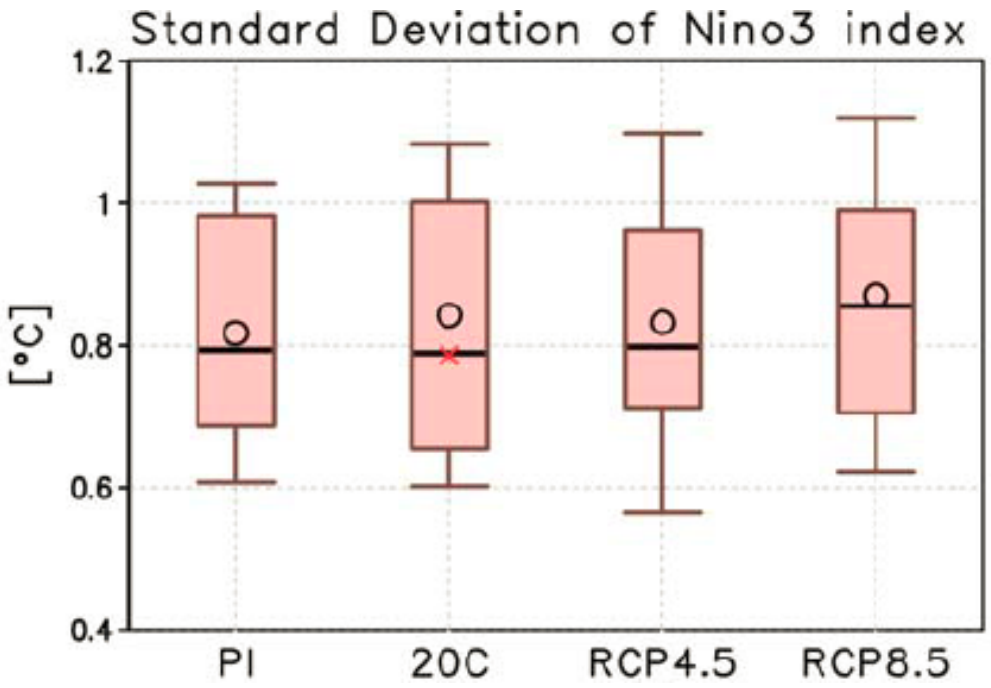


(Wallace and Gutzler,1981)





Change in ENSO SST variance is uncertain.

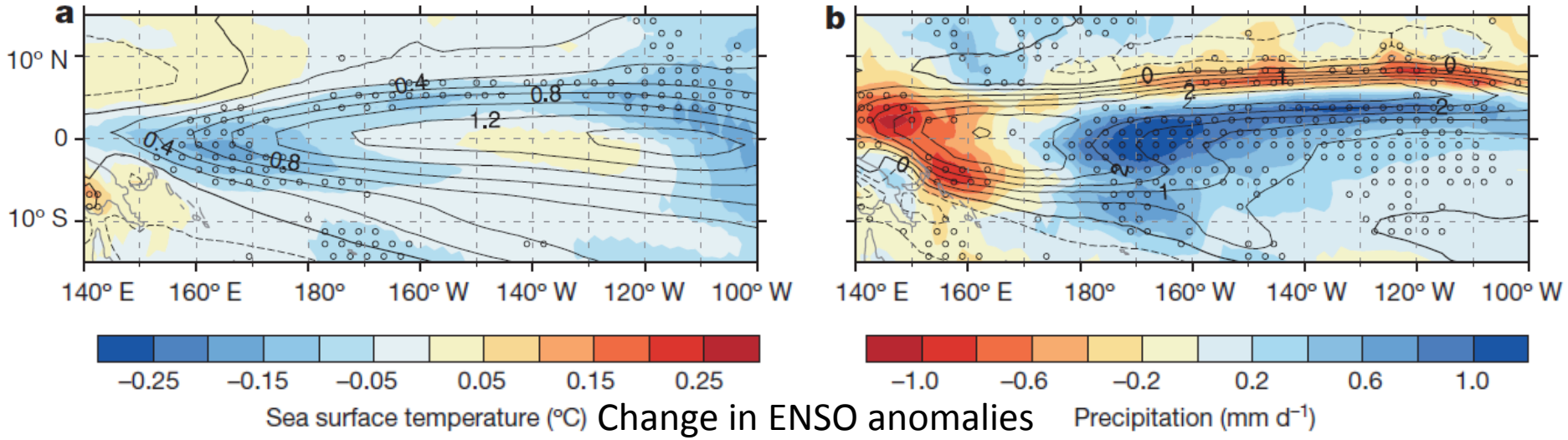


IPCC AR5 Ch 14

Figure 14.14: Standard deviation of Niño3 SST anomalies from CMIP5 model experiments. PI, 20C, RCP4.5, RCP8.5 indicate pre-industrial control experiments, 20th century experiments, and 21st century experiment from the RCP4.5 and RCP8.5. Open dot and solid black line indicate multi-model ensemble mean and median, respectively, and the cross mark is 20th observation, respectively. Thick bar and thin outer bar indicate 50% and 75% percentile ranges, respectively.

21st-20th century difference in El Nino anomalies

Power et al. (2013, Nature); Cai et al. (2014, NCC)



- Increased frequency of deep convection during El Nino, although ENSO itself does not change in SST pattern/amplitude.
- Eq. peak in mean warming reduces the barrier for atmospheric convection.

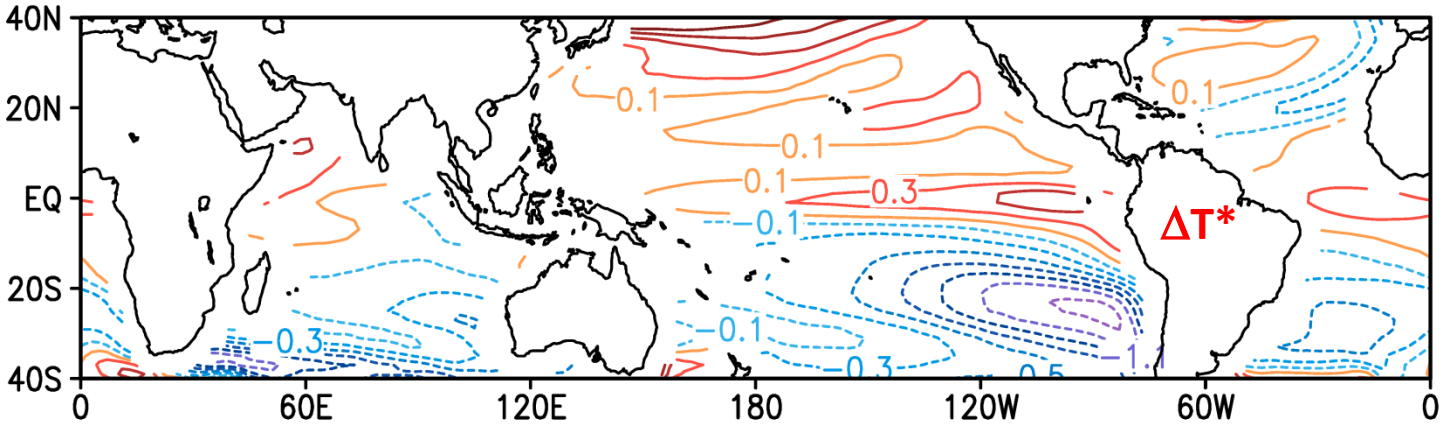


Fig. 14.8. Relative warming to tropical mean →change in SST threshold.

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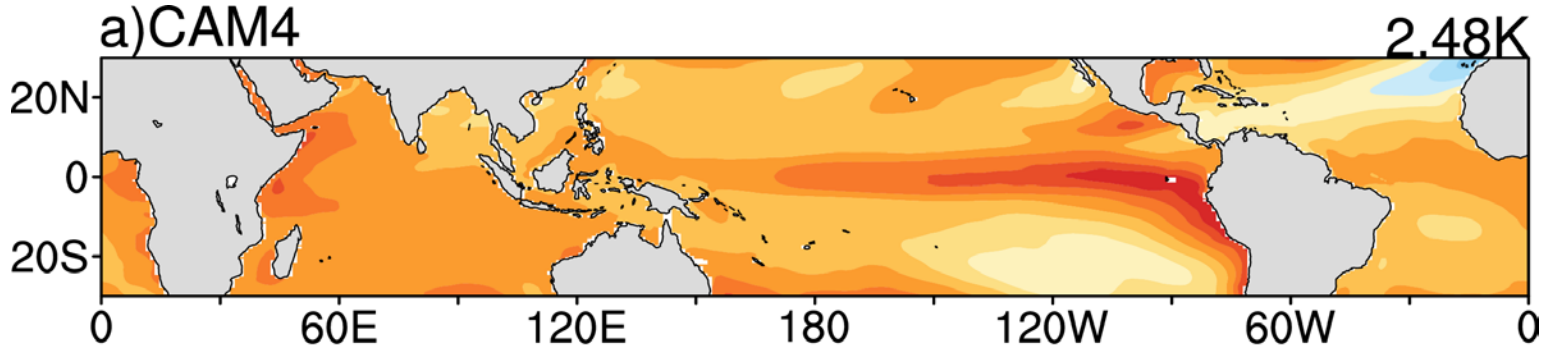
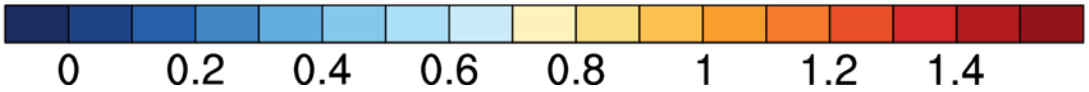
How does ENSO teleconnetion change in global warming?

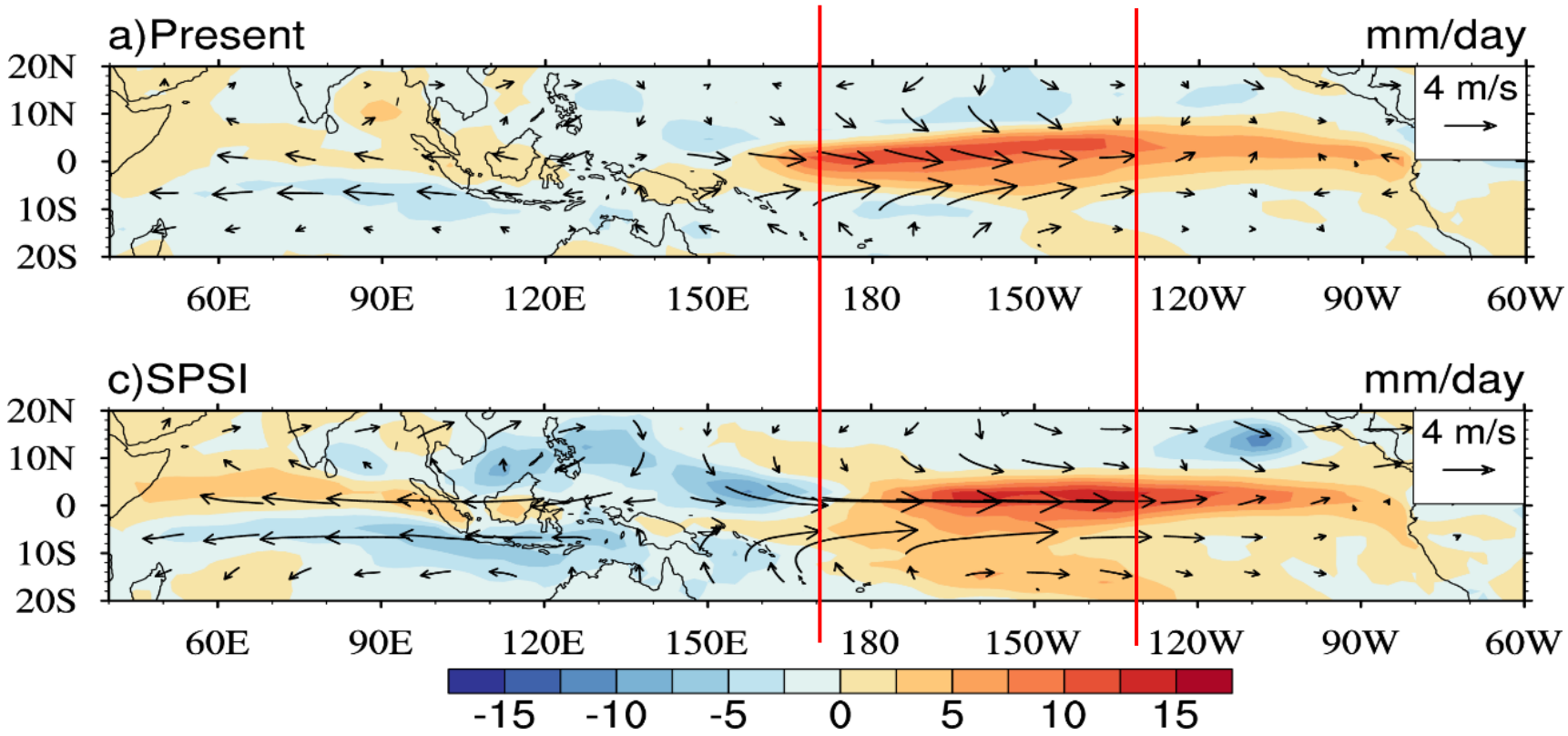
- Change in El Nino SST pattern;
- Atmospheric response to the same El Nino SST pattern under present and future climates. → sidestep the problem of El Nino change.



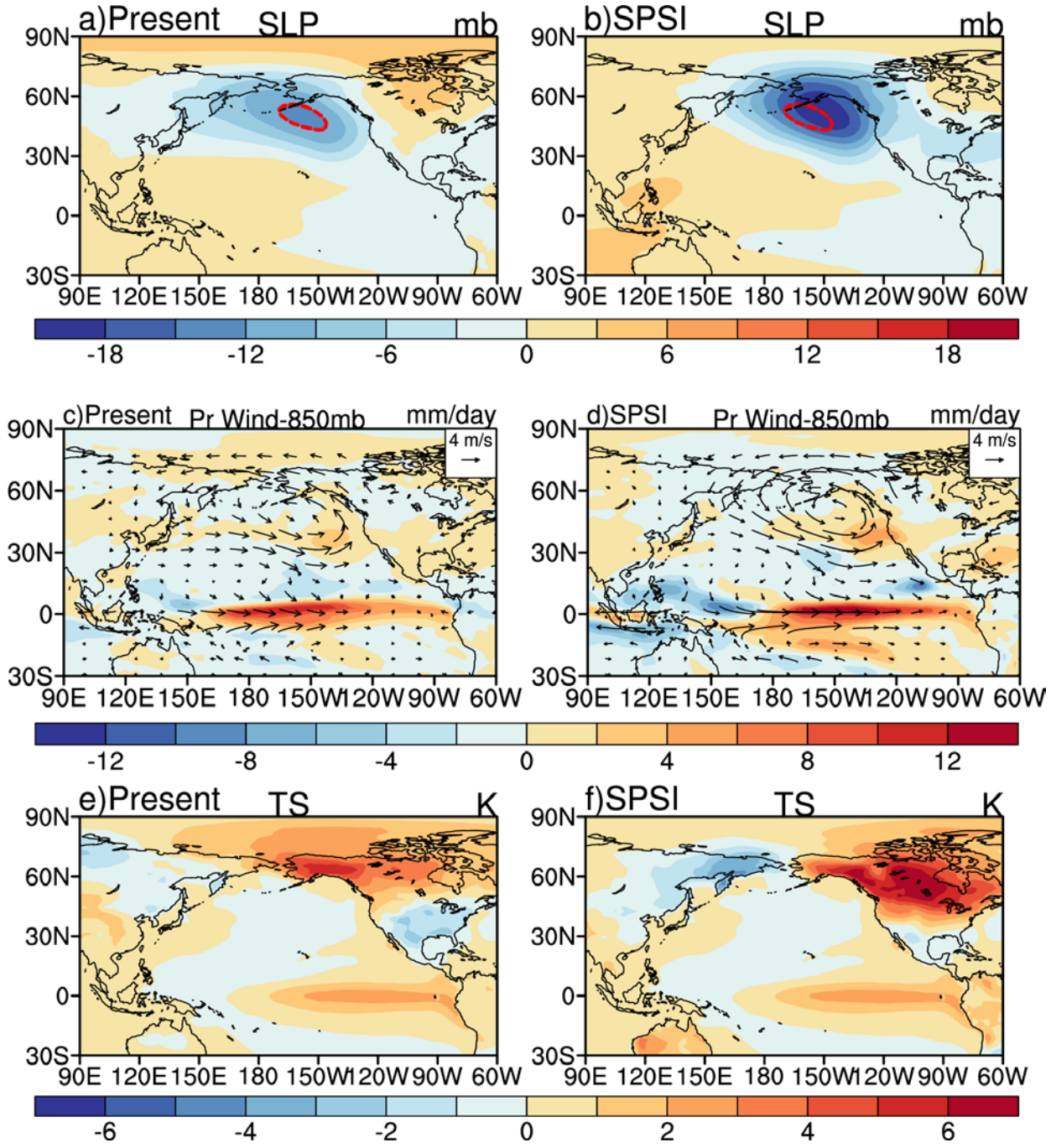
SST warming (K) pattern derived from years 2081–2100 (RCP 8.5 projection) mean minus years 1986–2005 (historical run) mean in CCSM4, normalized by the tropical-mean value (25N–25S).



El Nino anomalies of 850 hPa wind & precip



In a warmer climate, precipitation anomalies intensify and move eastward over the equatorial Pacific during El Niño.



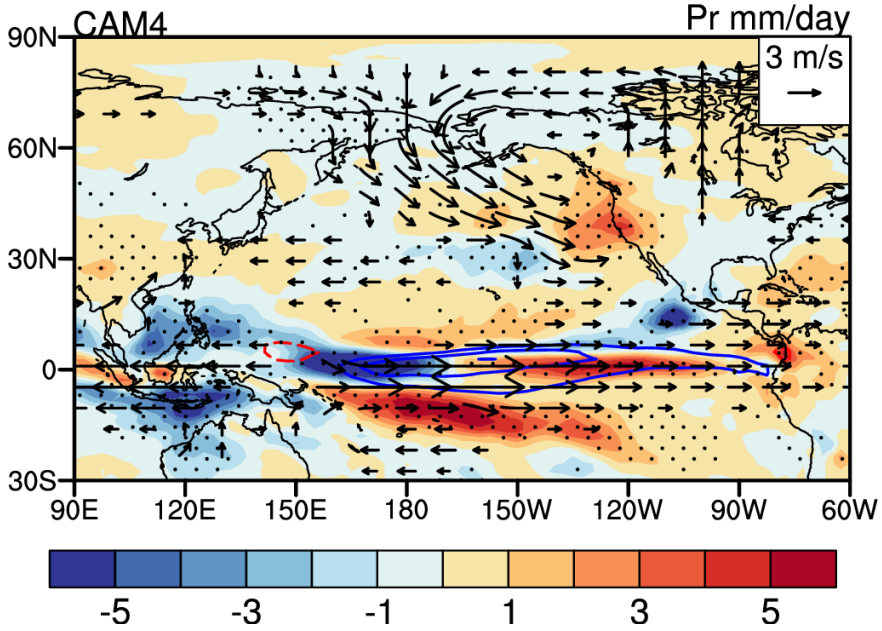
ENSO teleconnection change

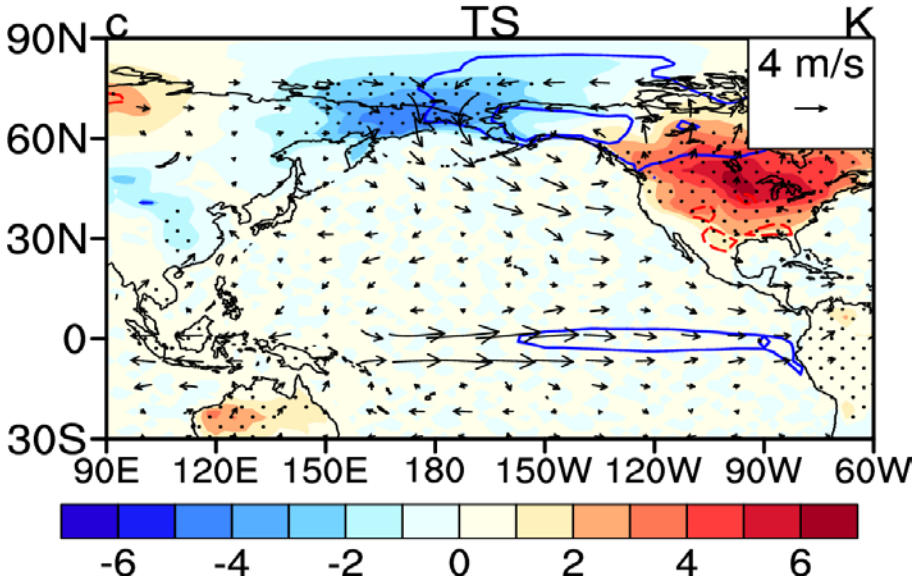
AGCM runs with identical ENSO SST (SPSI: spatial-patterned SST warming)

- Tropical convective anomalies shift eastward;
- **The Pacific-North American (PNA) pattern shifts eastward**.

Z. Zhou et al. (2014, JC)

Climate effects: warming – present in CAM4



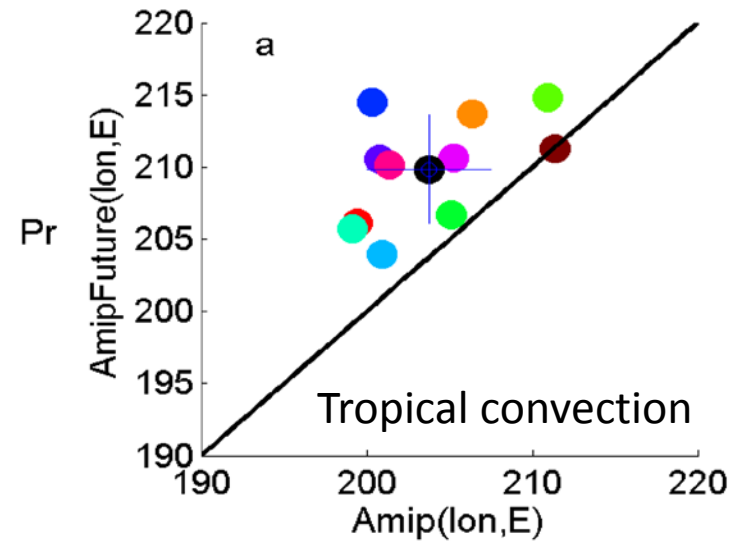


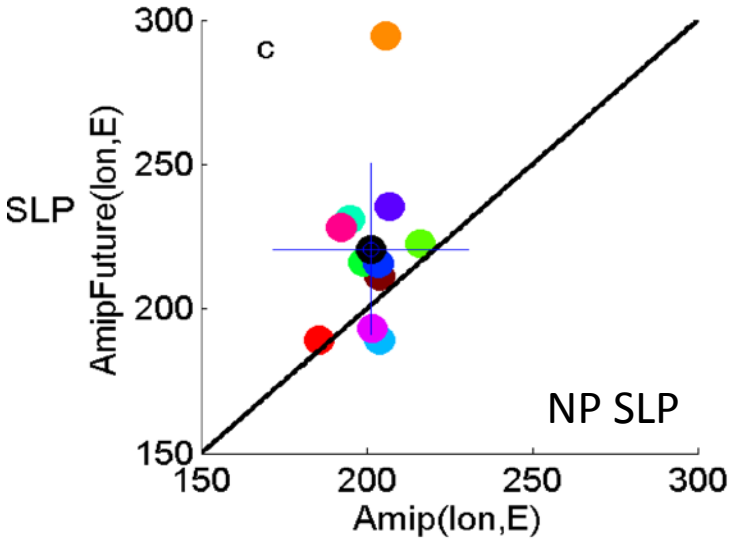
In El Nino winter over North America, rainfall anomalies intensify on the west coast, and the El Niño–induced surface warming expands eastward.

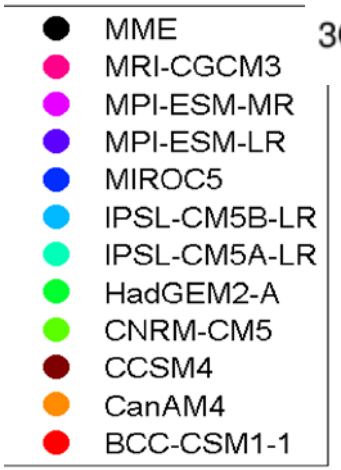
Changes in El Nino anomalies of precip, SAT and 850 hPa wind.

El Niño teleconnection changes under global warming: AMIP

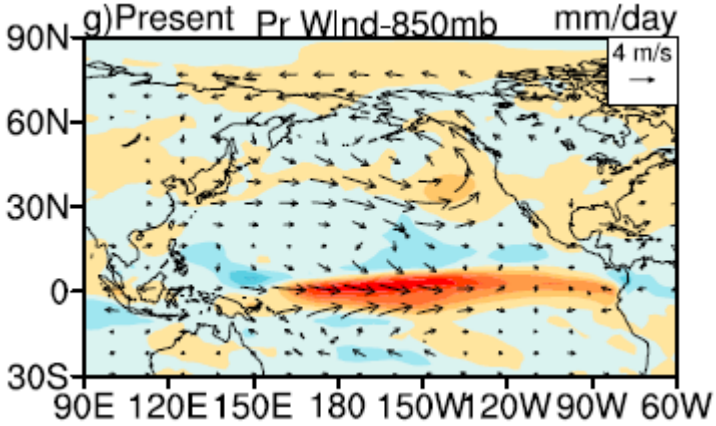
Center longitudes of tropical convective and NP SLP anomalies (DJF)

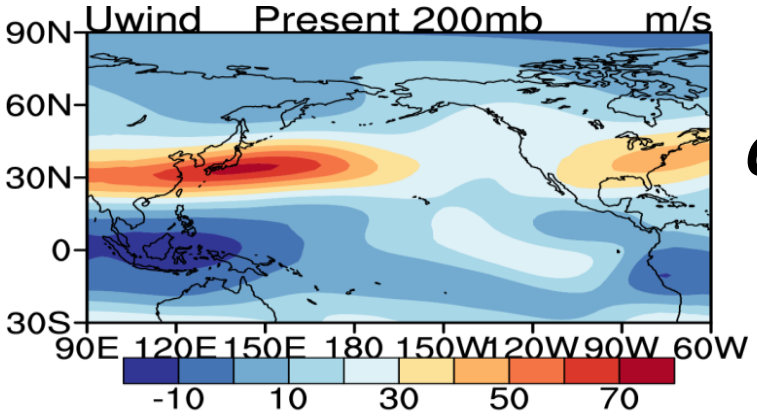


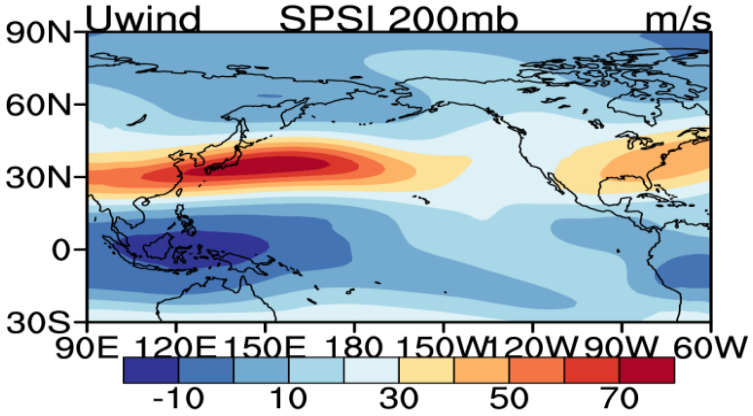


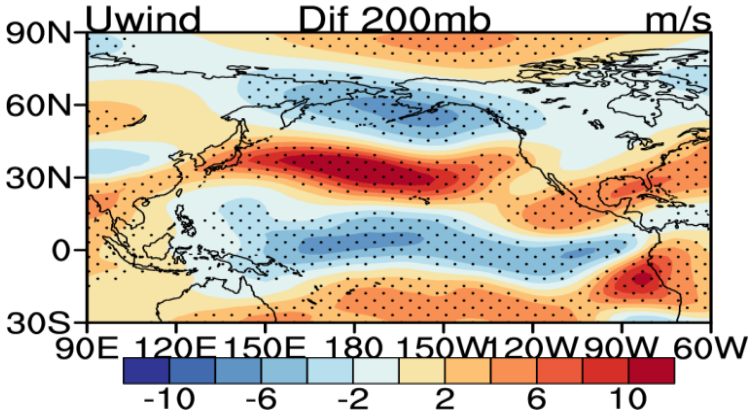


Anomaly centers consistently shift eastward in AMIP multi-model ensemble





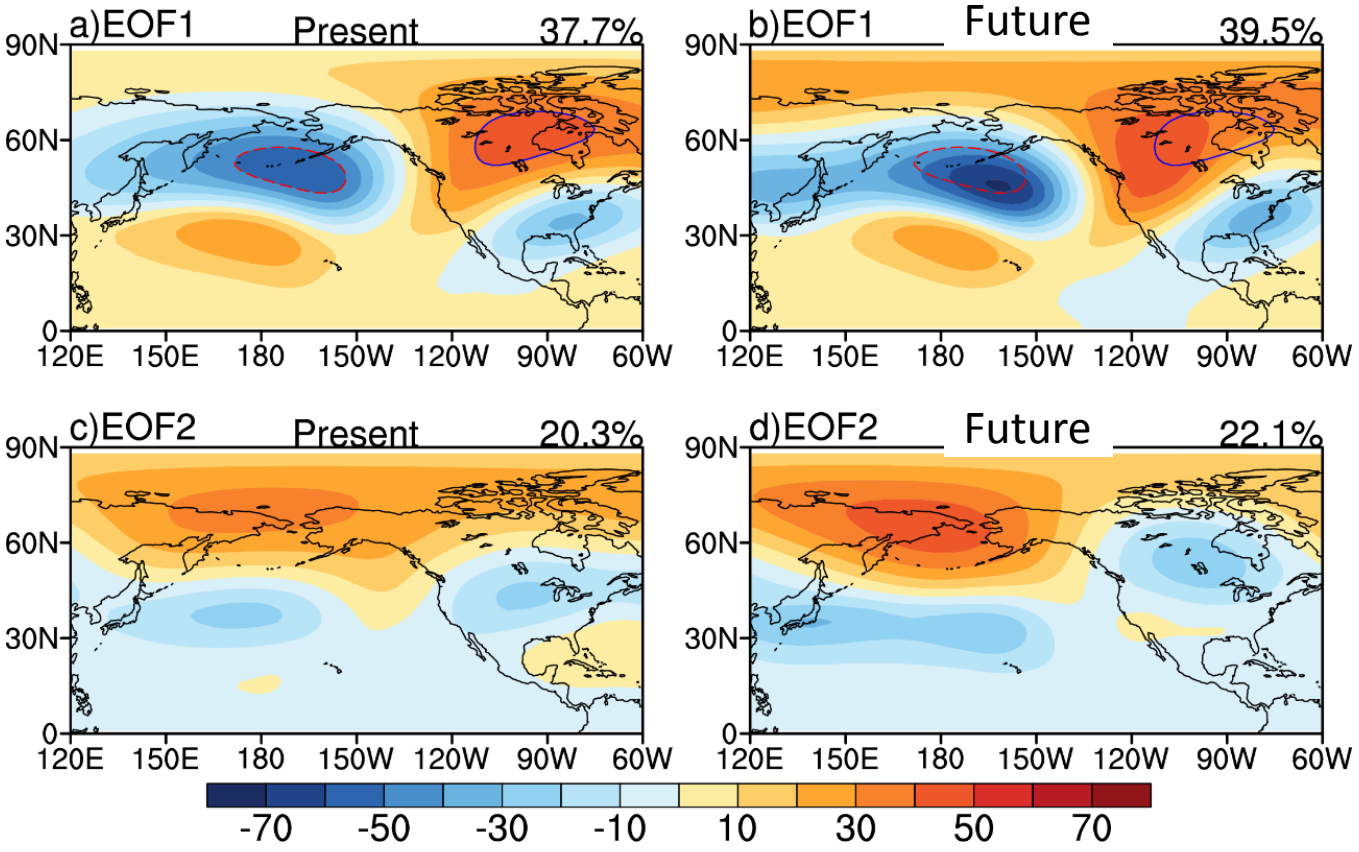




Changes in mid-latitude mean flow

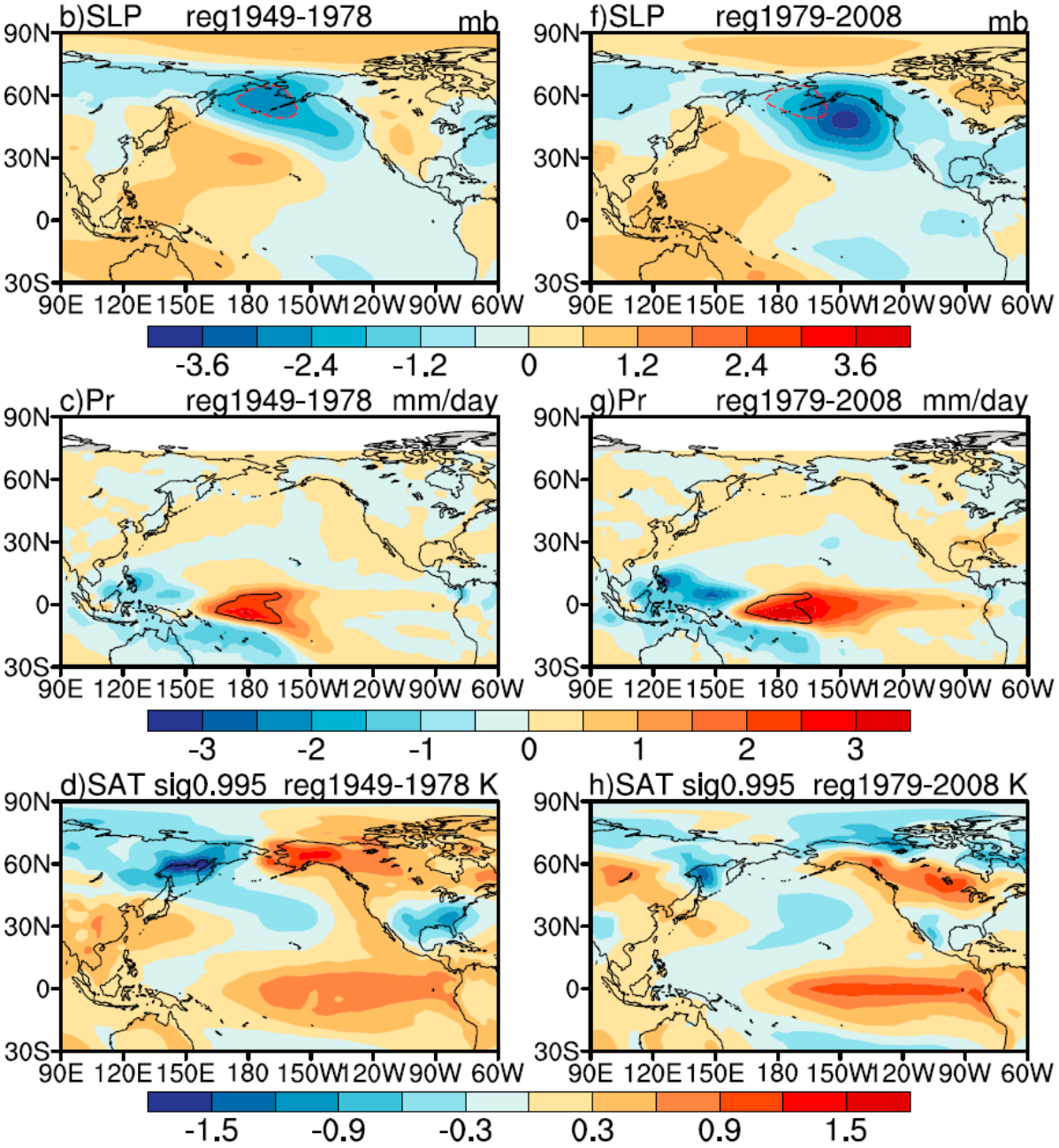
In warmer climate, the westerly jet accelerates.

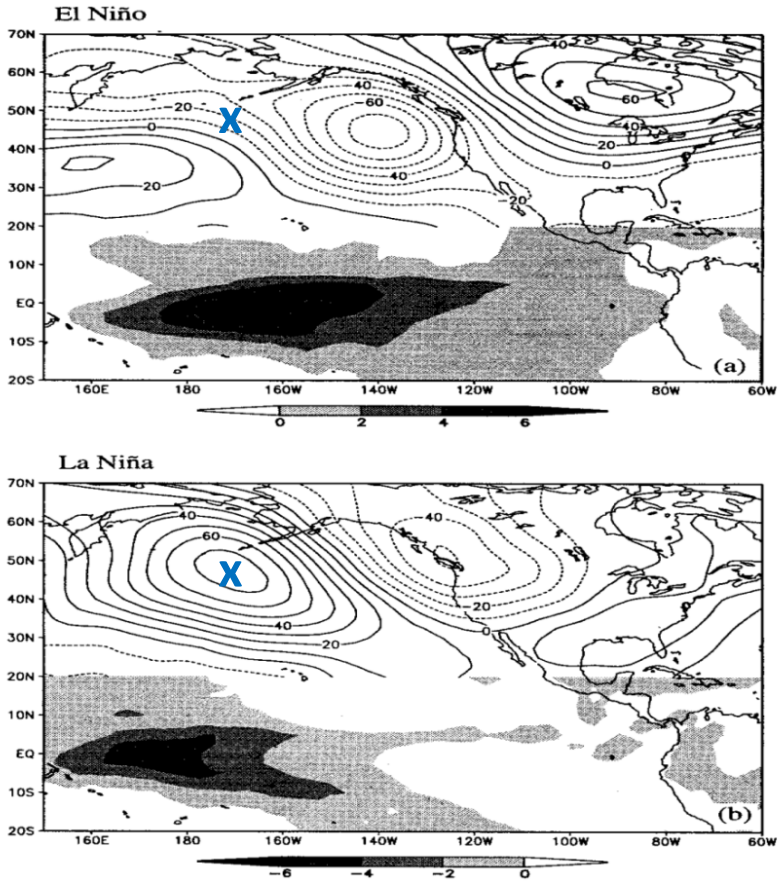
The PNA mode of internal variability remains largely unchanged, suggesting the importance of tropical convection in shifting ENSO-forced teleconnections



EOF modes of internal variability in 200-mb geopotential height

At PDO positive phase, convective and SLP anomalies intensify and shift eastward.

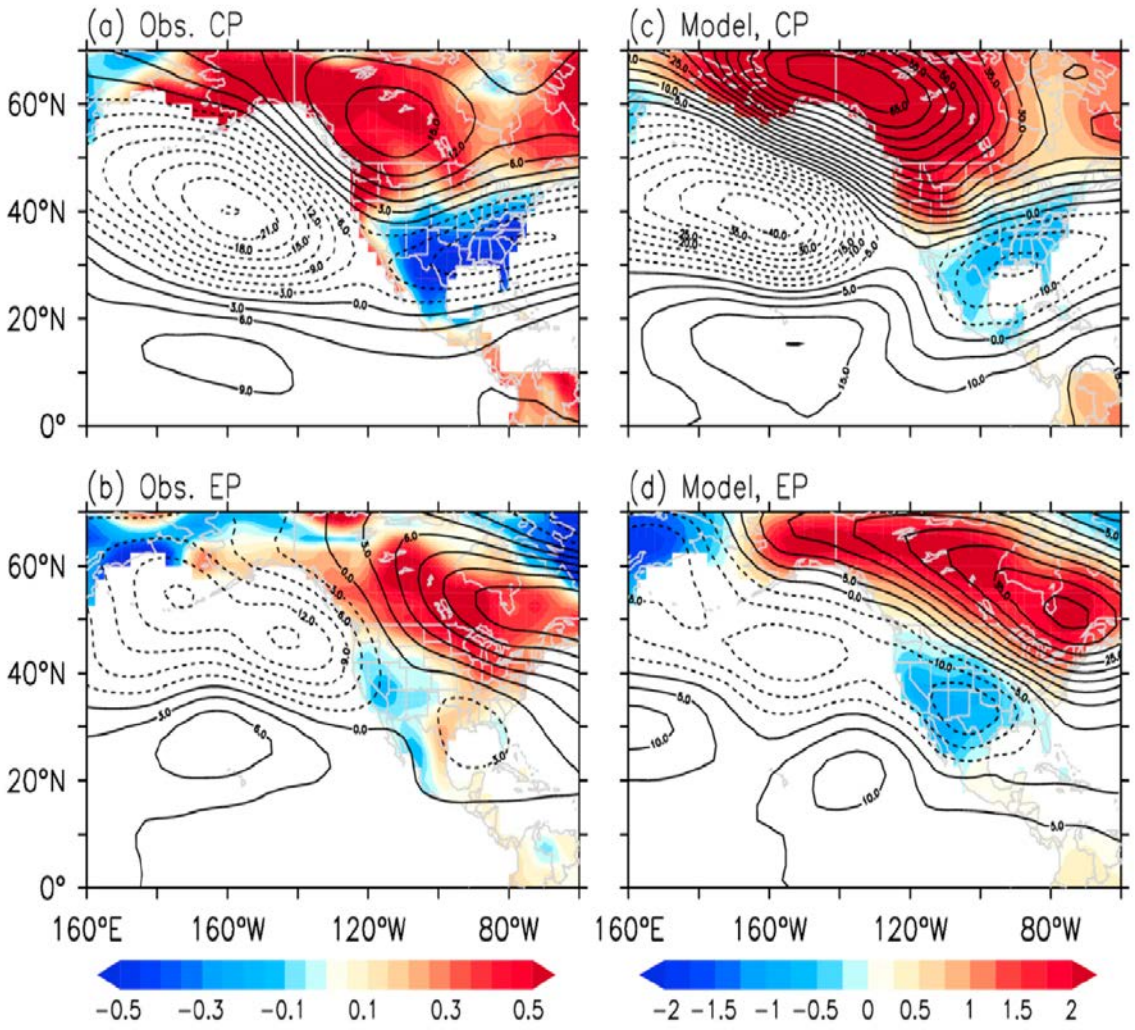




A systematic eastward migration of centers of tropical convection and NP SLP anomalies in El Nino compared to La Nina.

(Hoerling et al 1997)

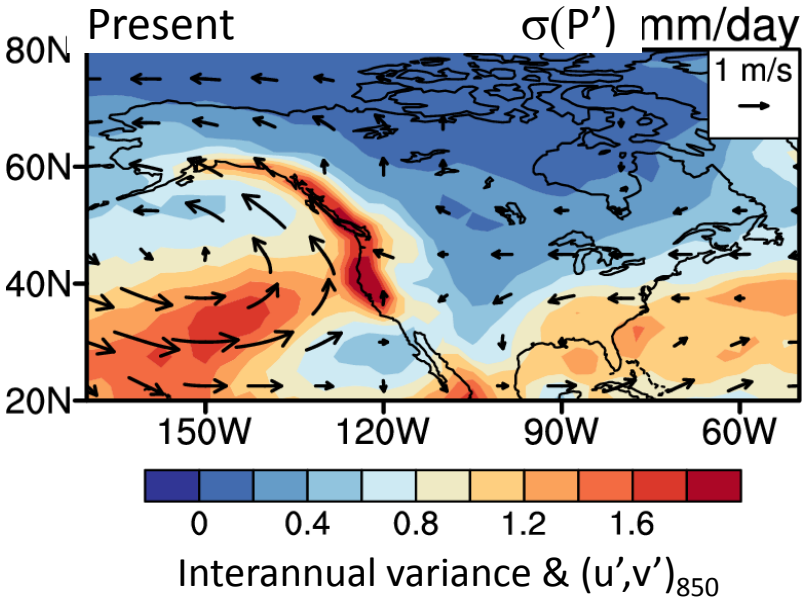
EP/CP El Niño's different impacts on US winter climate

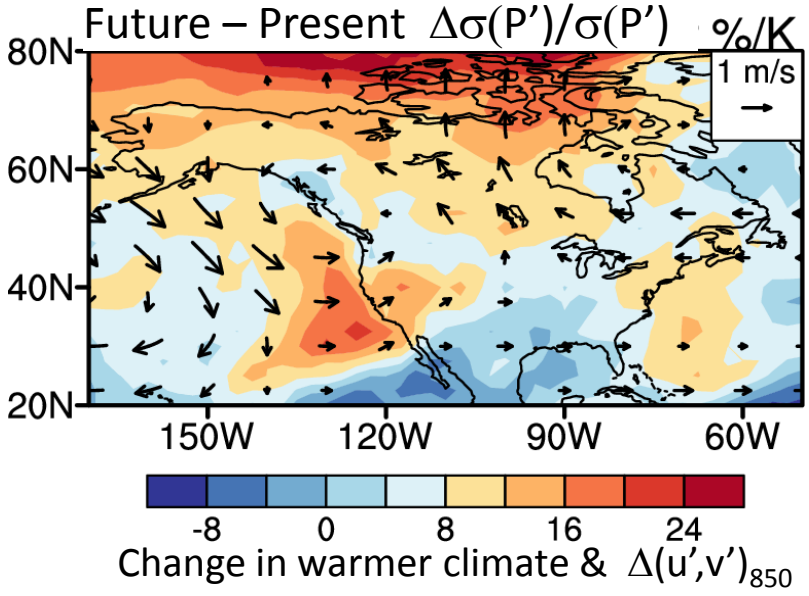


Yu et al. 2012

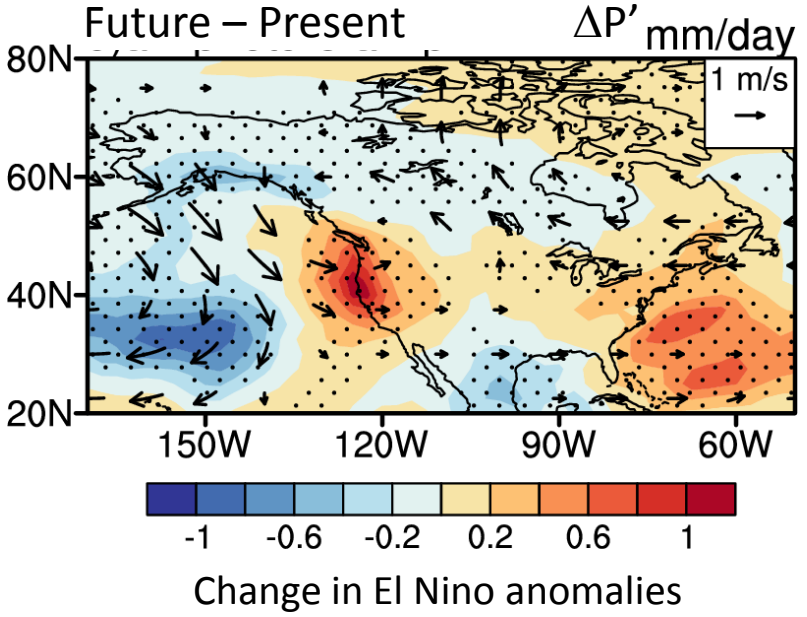
Observed and model simulated anomalies of 500 mb geopotential heights (contours) and surface air temperatures (color shade) regressed with the CP and EP indices.

Both of CP and EP El Niño teleconnections show an consistent change in our study.





Interannual variability of precipitation increases by >16% on the U.S. west coast, compared to the global mean rate of 8.1%.



Summary: Changes in warmer climate

- In the tropics, convective anomalies of El Nino intensify and shift eastward. ← the enhanced equatorial warming in the mean reduces barrier to convection.

- The El Nino-forced PNA pattern **strengthens** and shifts **eastward**.

- Precipitation variability intensifies on the U.S. west coast.

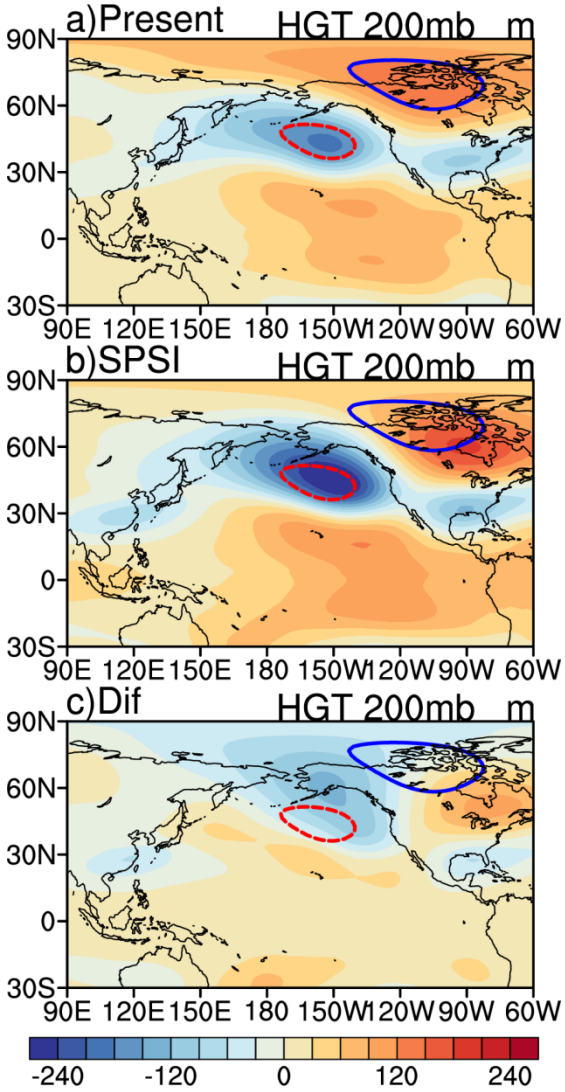
Zhou, Z.-Q., S.-P. Xie, X.-T. Zheng, Q. Liu, and H. Wang, 2014: Global warming-induced changes in El Nino teleconnections over the North Pacific and North America. *J. Climate*, 27, 9050-9064.

Contents

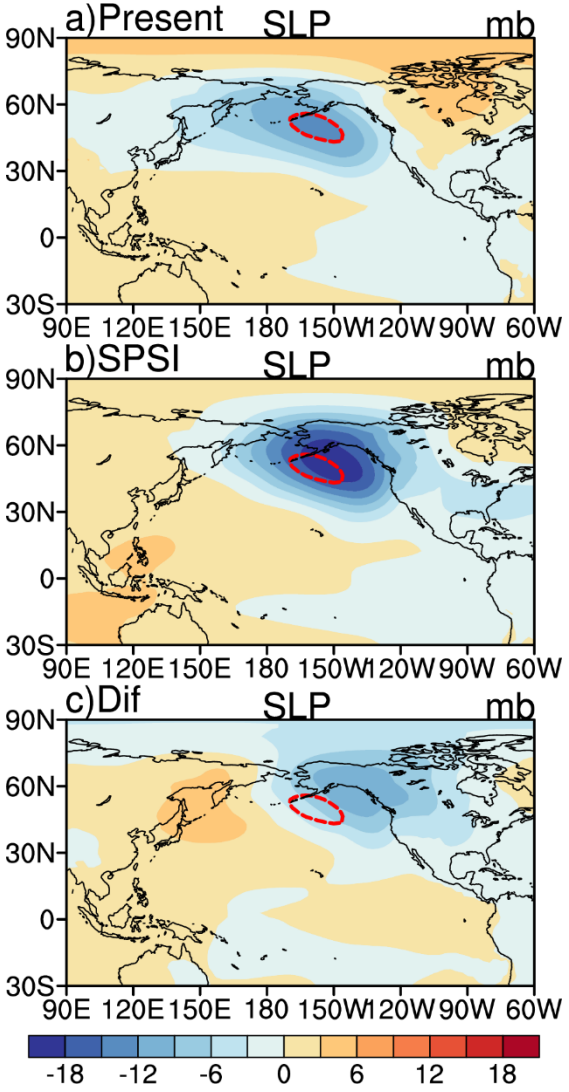
- Motivation
- Data and Methods
- El Niño teleconnection changes due to global warming
- Roles of tropical convection and mid-latitude mean flow
- Summary and conclusion

El Niño teleconnection changes due to global warming: CAM4

Geopotential height and SLP (DJF)



In a warmer climate, PNA intensify and shift eastward



In a warmer climate, the anomalous Aleutian low intensify and shift eastward

Scientific issue

How does the ENSO teleconnetions change under global warming?

Assumption

El Niño teleconnections will intensify and shift eastward under global warming

- a systematic eastward migration of convection center;
- the mid-latitude base state circulation strengthens.

This report only focus on changes in the North Hemisphere.

Data and Methods

1. Community Atmosphere Model(CAM4)

Name	Prescribed SST	Ensemble	Length (yr)
$Present_{ctrl}$	SST_{clim}	1	50
$Present_{EN}$	$SST_{clim} + SST_{EN}$	20	2
$SPSI_{ctrl}$	$SST_{clim} + SST_{SPSI}$	1	50
$SPSI_{EN}$	$SST_{clim} + SST_{EN} + SST_{SPSI}$	20	2

The same SST pattern of ENSO (4 events mean) is prescribed before and after the climate warming to sidestep the uncertainties in ENSO amplitude and pattern, this enables us to isolate atmospheric processes for teleconnection changes.

Data and Methods

2. AMIP experiment (197901-200812)

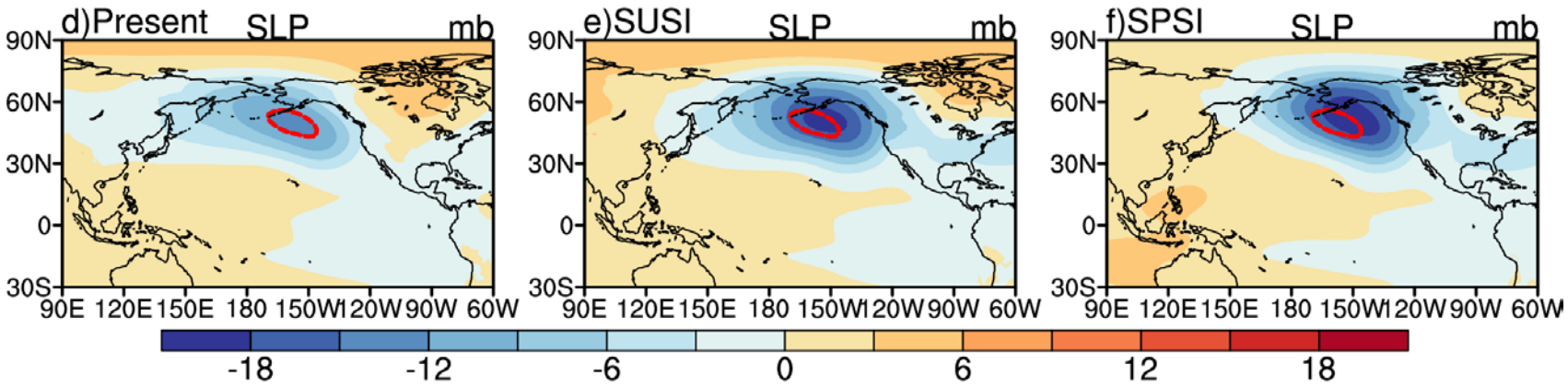
- 11 models
- BCC-CSM1-1, CanAM4, **CCSM4**, CNRM-CM5, HadGEM2-A, IPSL-CM5A-LR, IPSL-CM5B-LR, *MIROC5*, *MPI-ESM-LR*, MPI-ESM-MR, MRI-CGCM3
- Experiments: Amip, AmipFuture, Amip4K

3. Observations(194801-201310)

- ERSST (2^o x 2^o)
- SLP: NCEP (2.5^o x 2.5^o)
- NOAA's Precipitation Reconstruction (PREC 2.5^o x 2.5^o)
- Geopotential height(NCEP/NCAR Reanalysis 2.5^o x 2.5^o)

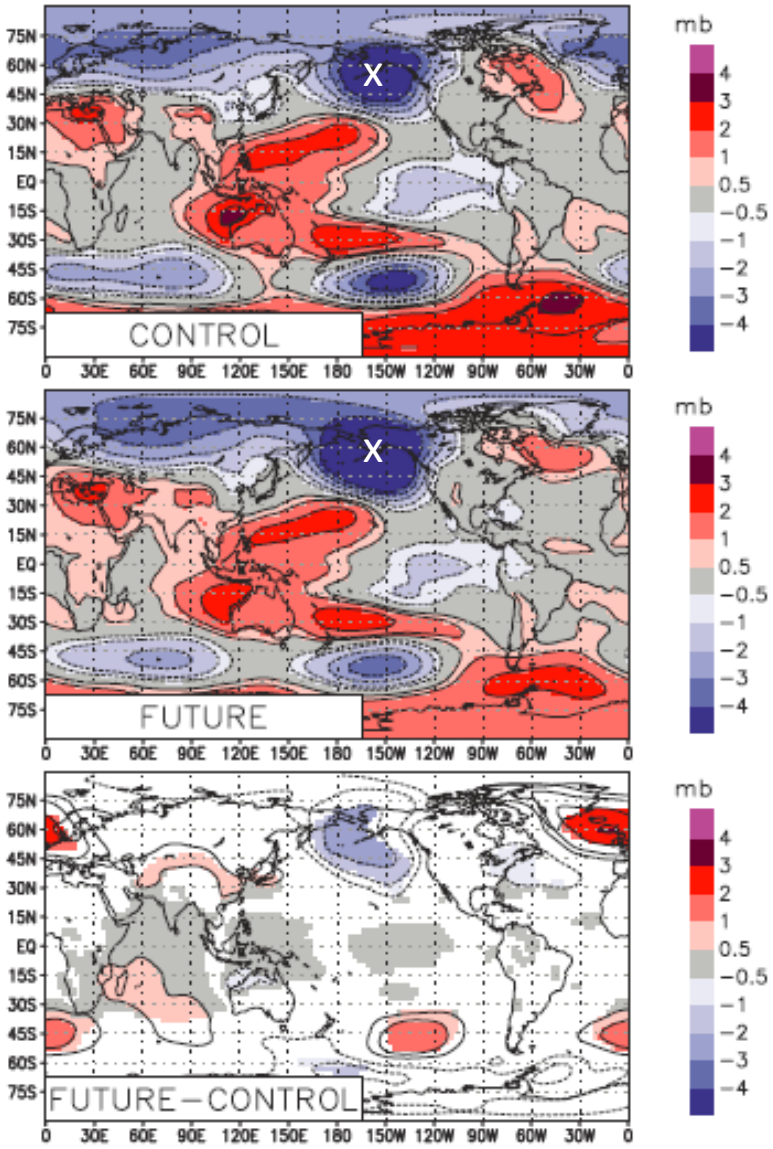
El Niño teleconnection changes due to global warming: CAM4

SLP (DJF)

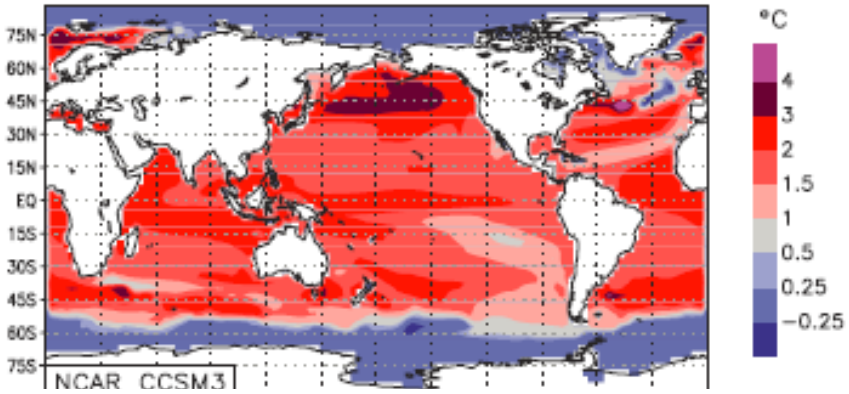


The teleconnection changes are larger with **patterned mean warming** than in an idealized case where the **spatially uniform warming** is prescribed in the mean state

Winter ENSO Teleconnections in a Future Climate: CCSM3 (2065–75 & 1965–75)



SLP



La Niña–like warming pattern

The ENSO teleconnections **strengthen** but without obvious displacement**.**

Schneider et al. 2009