ENSO diversity in CESM2

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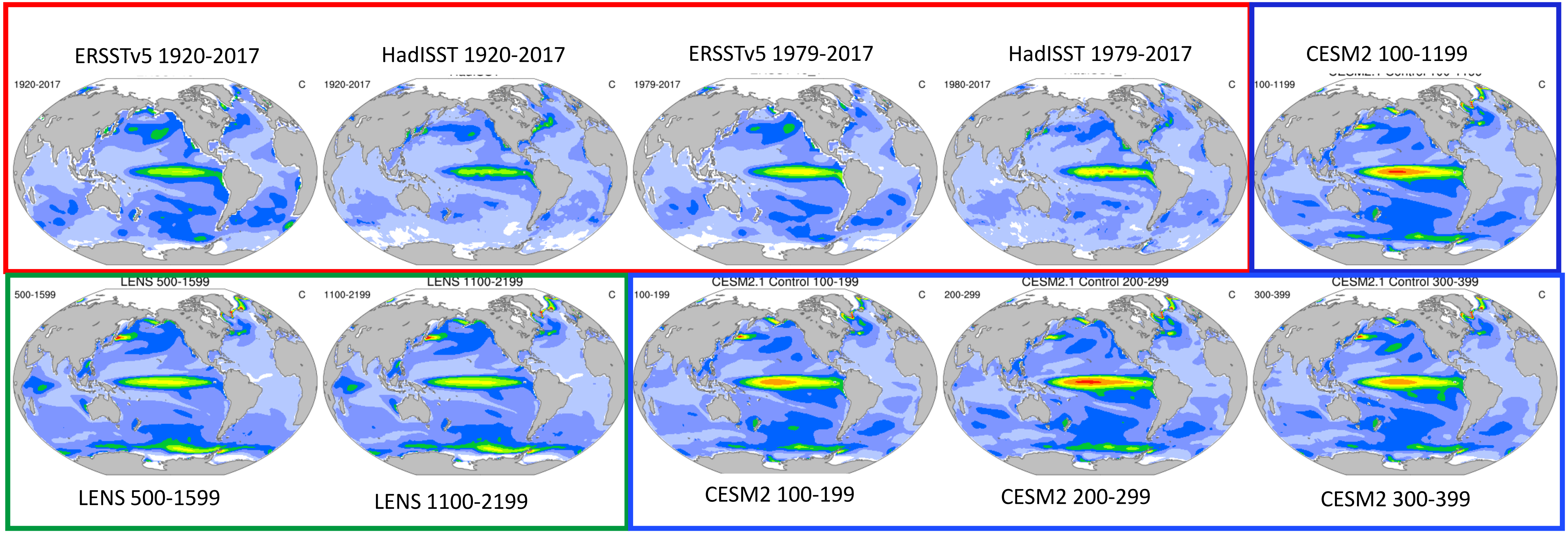
ENSO is a fundamental mode of climate variability. It is very important for climate models to represent it realistically.

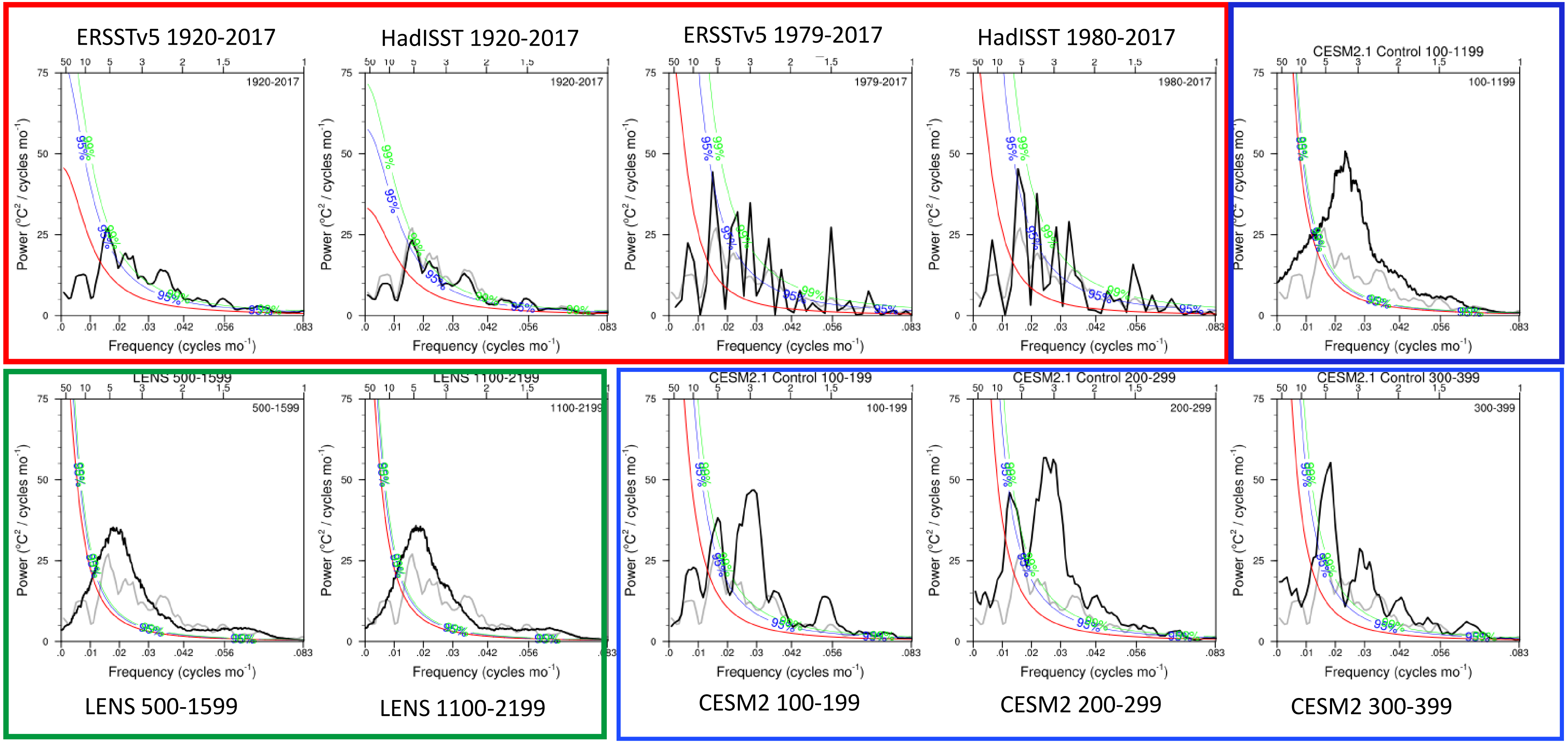
1. Basic ENSO characteristics in CESM2
2. Why do we care about ENSO diversity?
3. Examine basic characteristics of ENSO diversity using different indices

SST standard deviation (DJF)



The westward displacement of the interannual SST anomalies is still pronounced in CESM2. CESM2 variance larger than LENS.

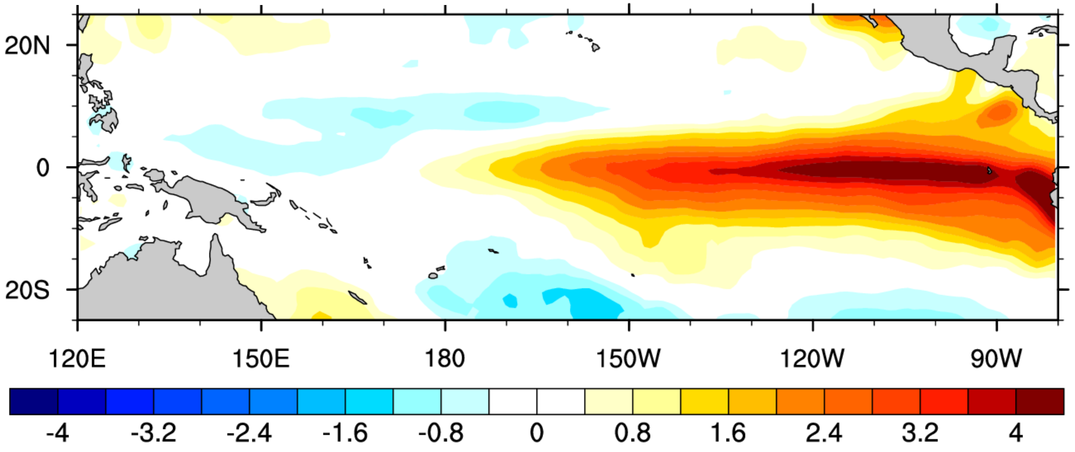
Spectra of Nino3.4 (Monthly, detrended)



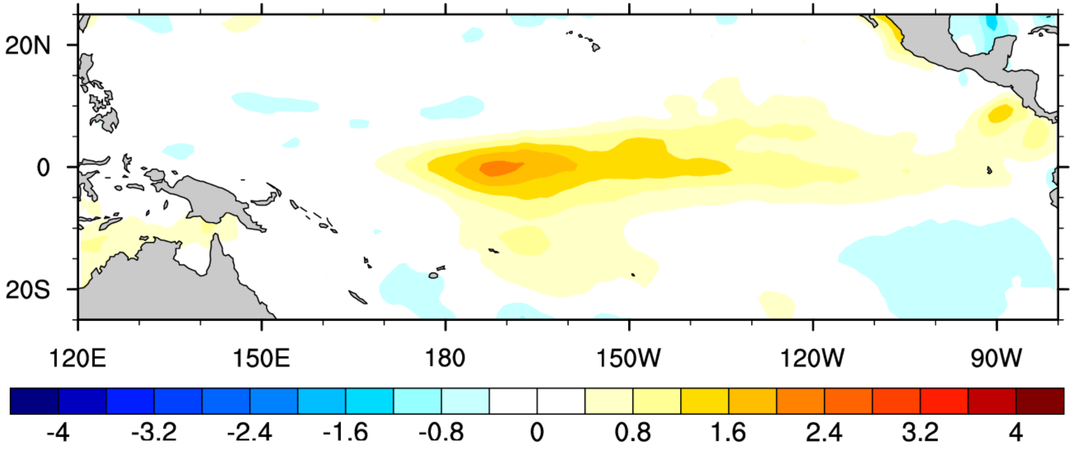
El Nino events differ in amplitude, spatial pattern and evolution

Examples of differences spatial pattern

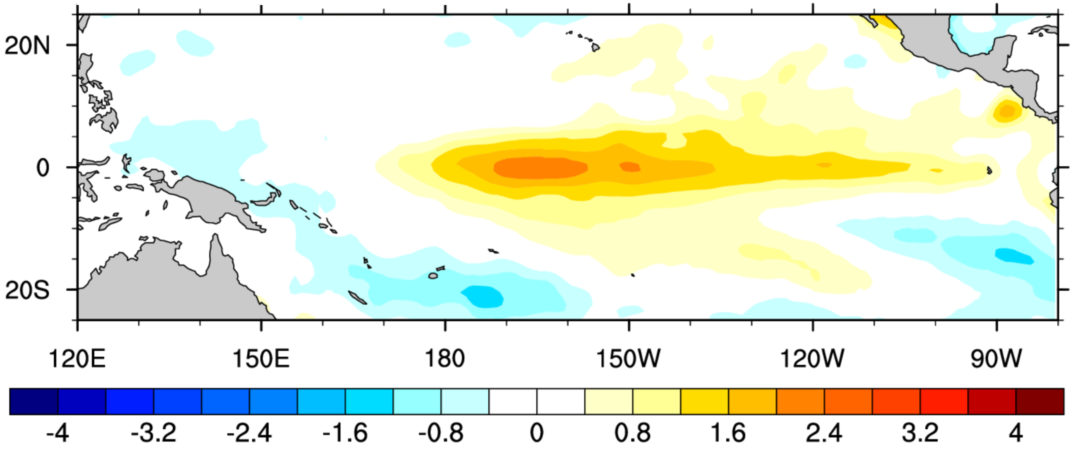
OISST DJF 1997/98



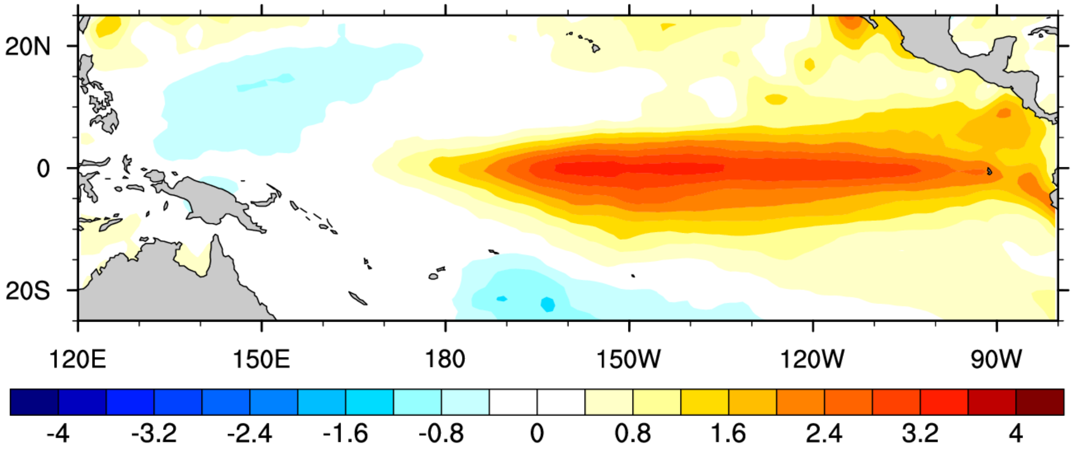
OISST DJF 2002/03



OISST DJF 2009/10

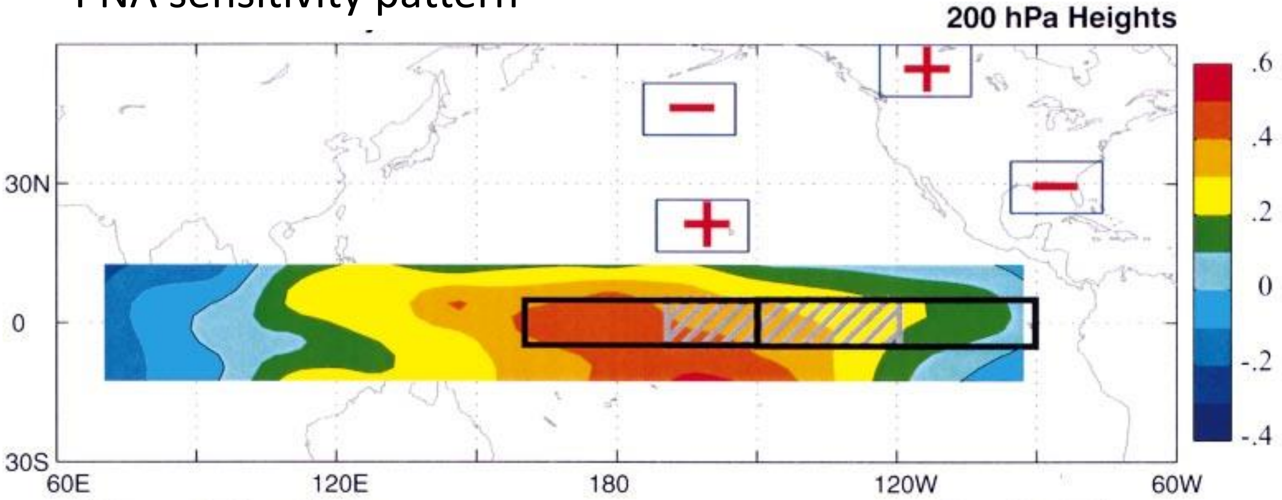


OISST DJF 2015/16



Dependency of atmospheric teleconnections on the location of equatorial SST anomalies

PNA sensitivity pattern



Barsugli and Sardeshmukh 2002

PNA is most sensitive to SST anomalies in the central-western Pacific.

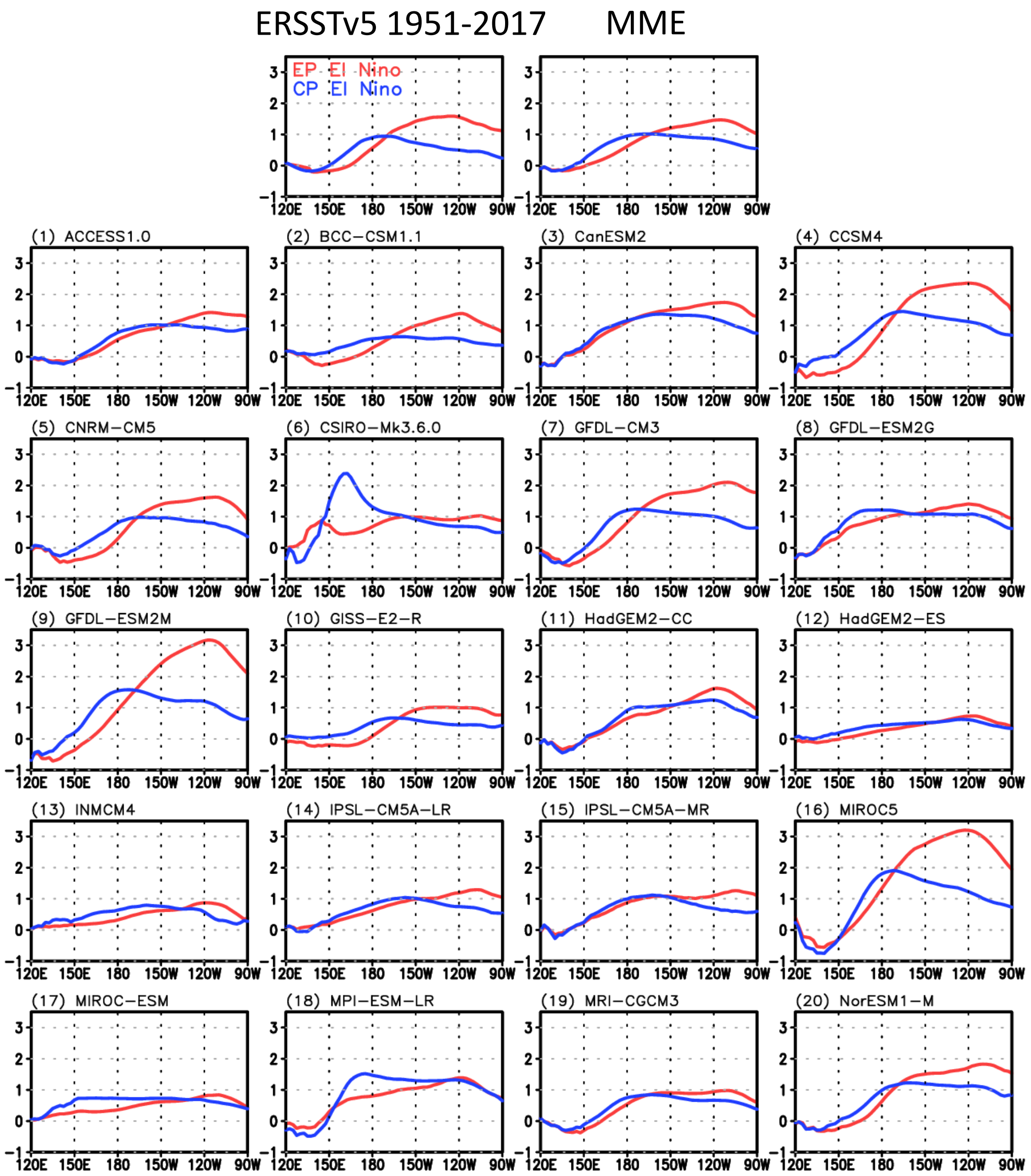
The most effective ENSO events to "excite" the PNA are those with a large projection on the sensitivity pattern

Relatively weak CP events may be as influential as strong EP events

Metrics used for ENSO diversity classification

- El Niño Modoki index (Ashok et al. 2007)
- Niño3/Niño4 approach (Kug et al. 2009; Yeh et al., 2009)
- Niño3.4/Trans-Niño-Index (TNI, Trenberth & Stepaniak, 2001)
- EP/CP approach (Kao and Yu, 2009)
- EP/CP subsurface index method (Yu et al., 2011)
- N_{CT}/N_{WP} indices (Ren and Jin, 2011)
- EP_{new}/CP_{new} indices (Sullivan et al., 2016)
- E/C indices (Takahashi et al., 2011)
- Sea Surface Salinity indices (Singh et al., 2011; Qu and Yu, 2014)
- OLR-based indices (Chiodi and Harrison, 2010; Johnson and Kosaka, 2016; Williams and Patricola, 2018)
- Spatio-temporal indices (Lee et al. 2014)

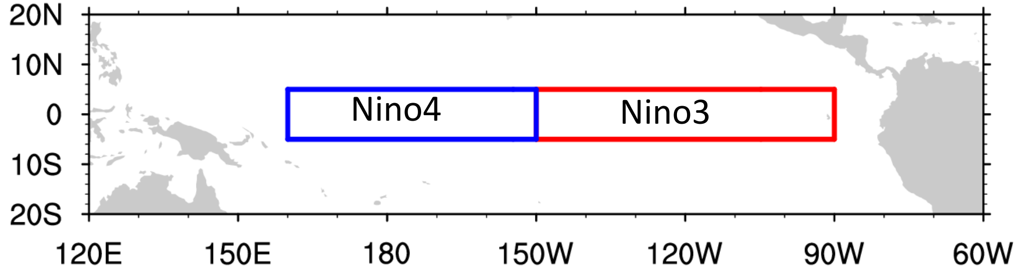
ENSO diversity in the CMIP5 models



EP and CP events have been identified using the Nino3 and Nino4 indices.

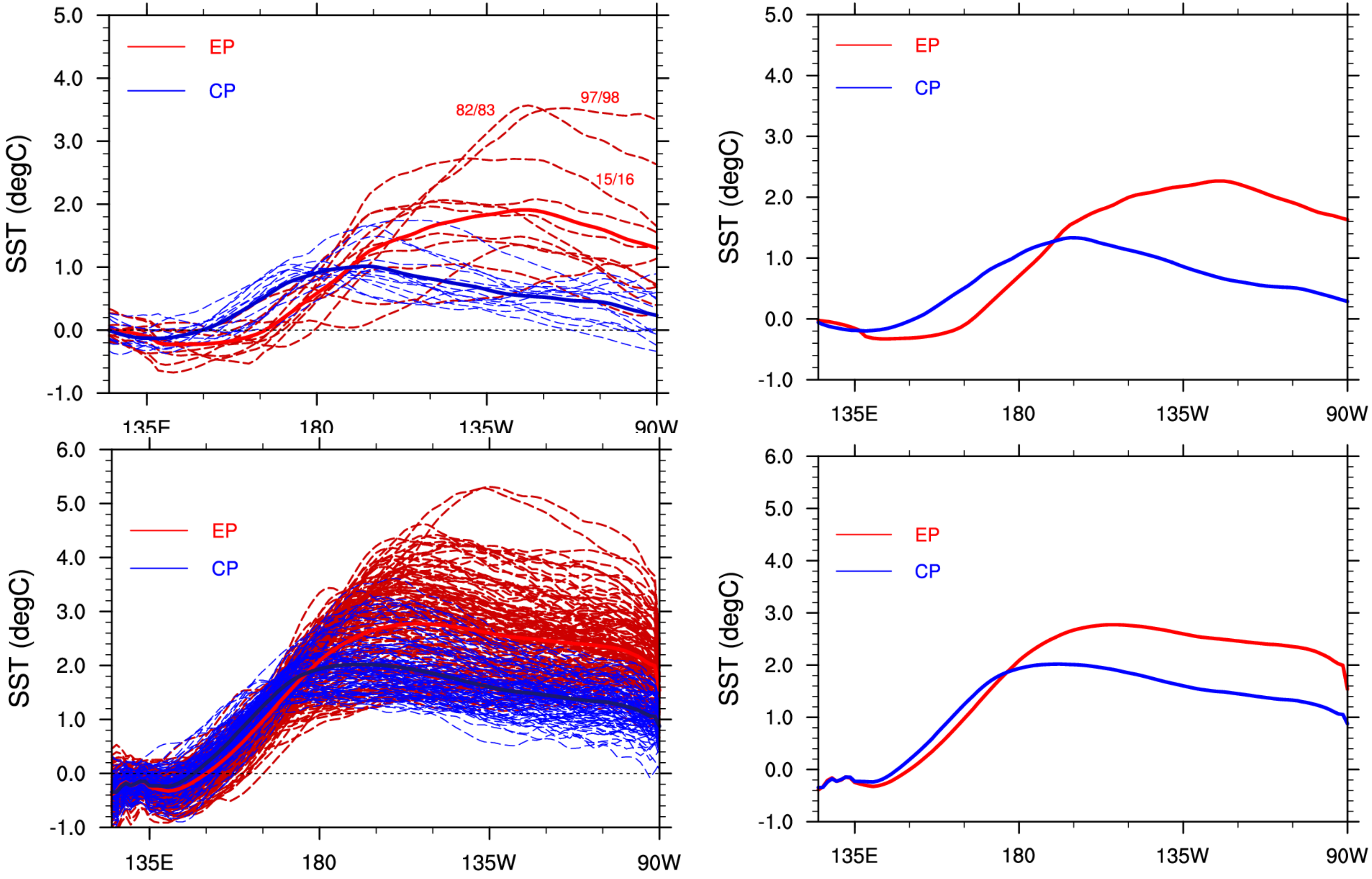
EP = Nno3 > 0.5°C and > Nino4

CP = Nino4 > 0.5°C and > Nino3



Only few models capture the diversity in the longitudinal profile of tropical SST anomalies.

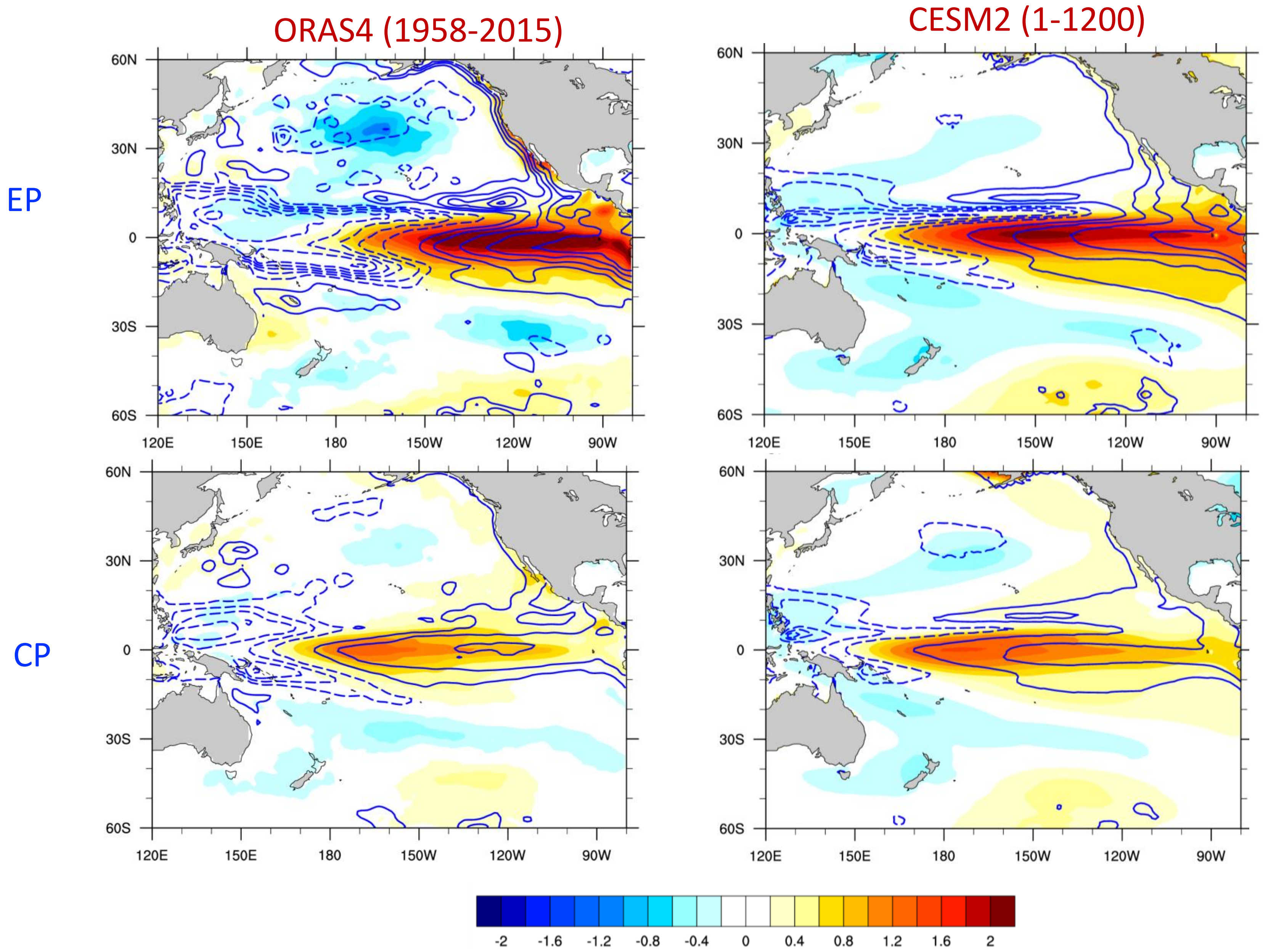
What about CESM2?



ERSSTv5
1951-2017

CESM2
1-1200

SST and SSH composites for EP and CP events (Niño3/Niño4 approach)

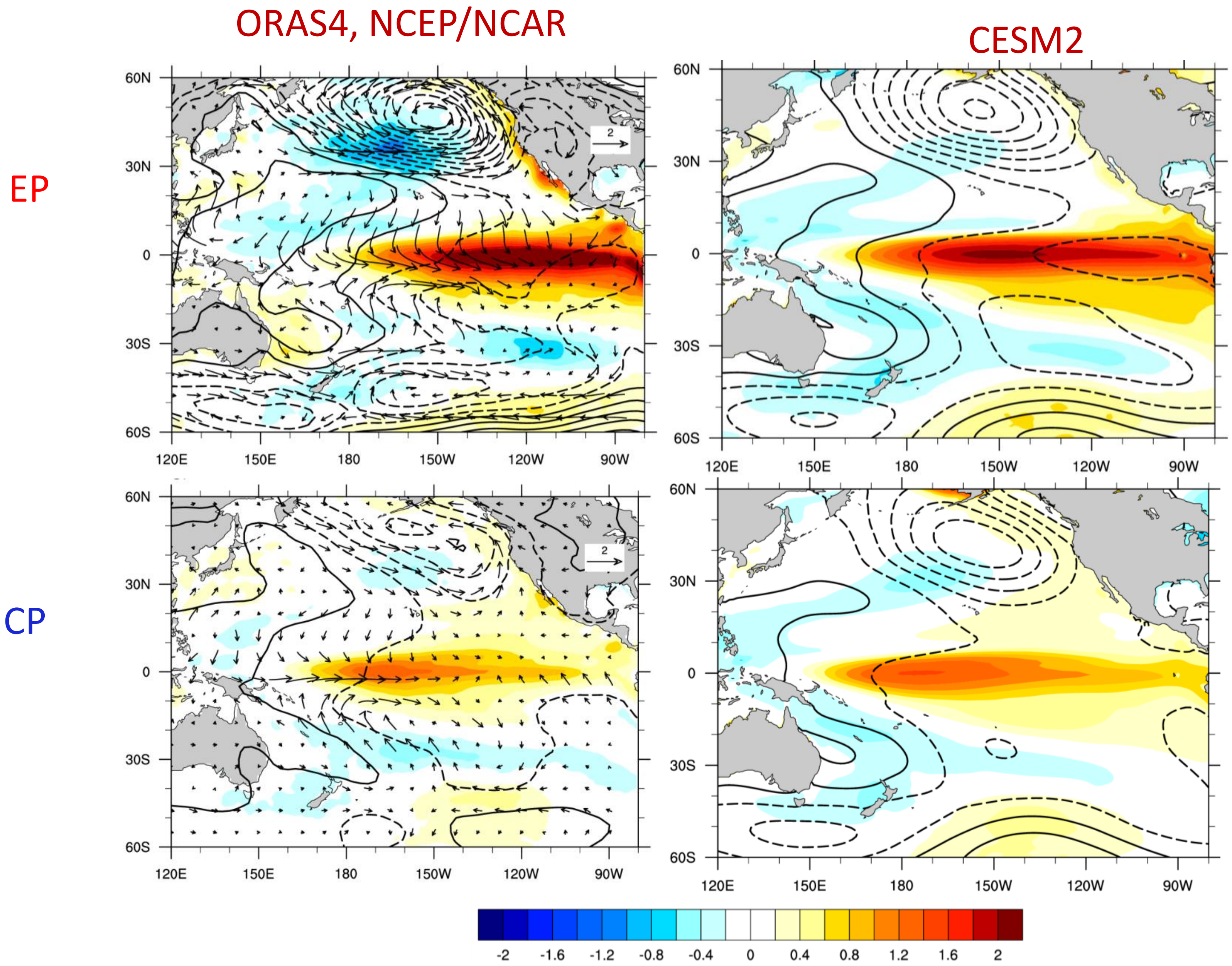


SSH (thermocline depth) anomalies larger during EP events

SSH anomalies more intense along the US West Coast during EP events

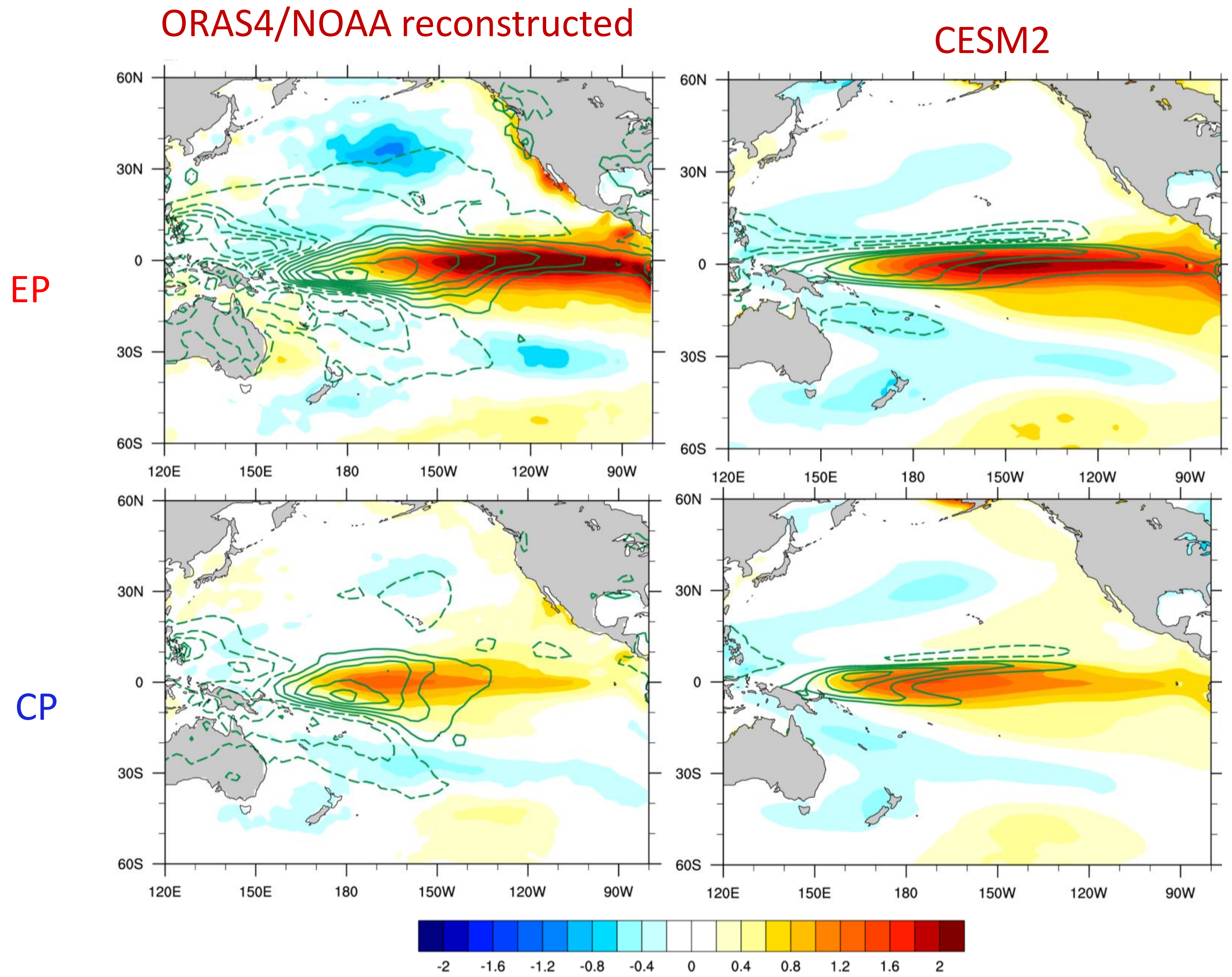
In CESM2 main difference between EP and CP is in the eastern equatorial Pacific

SST and SLP composites for EP and CP events (Niño3/Niño4 approach)



Zonal gradient of SLP (and surface winds) along the equator is confined further to the west during CP events than during EP events.
SLP zonal gradients are displaced to the west relative to obs for both EP and CP

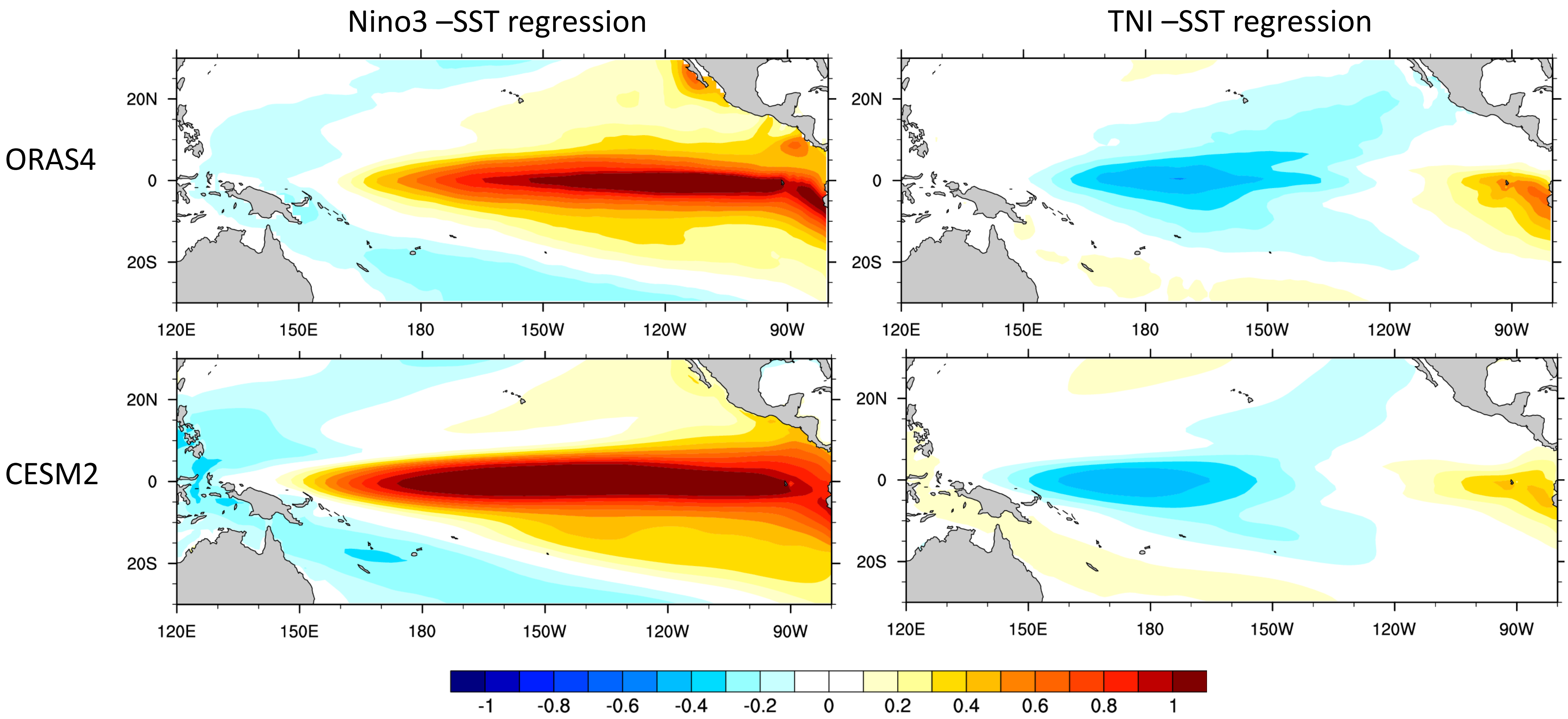
SST and Precip composites for EP and CP events (Niño3/Niño4 approach)



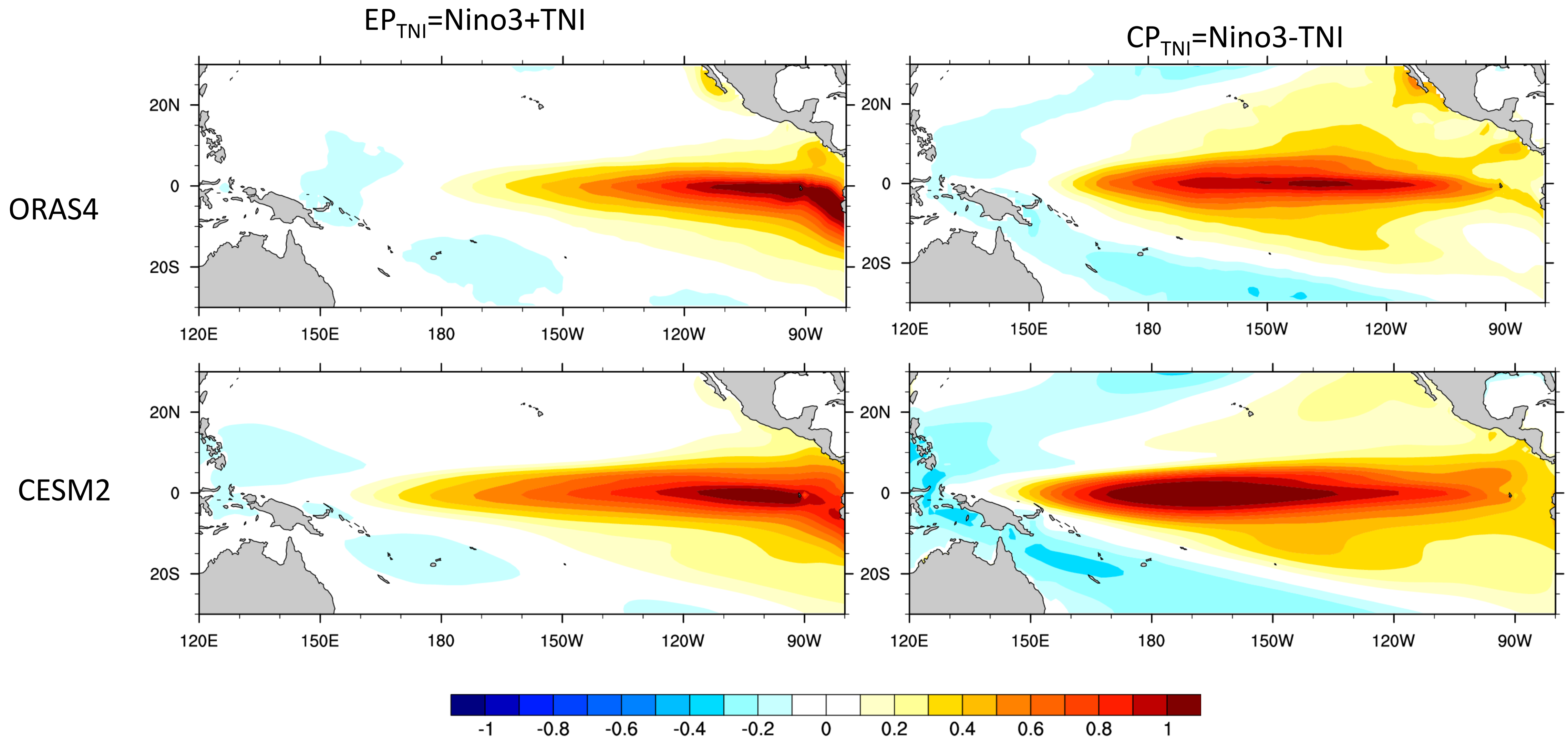
Precip anomalies along the equator are confined further to the west during CP events than during EP events.
SLP zonal gradients are displaced to the west relative to obs for both EP and CP

Two degrees of freedom are needed to capture the evolution of interannual SST anomalies along the equator (Trenberth and Stepaniak, 2001)

TNI = Nino1+2$_N$ –Nino4$_N$

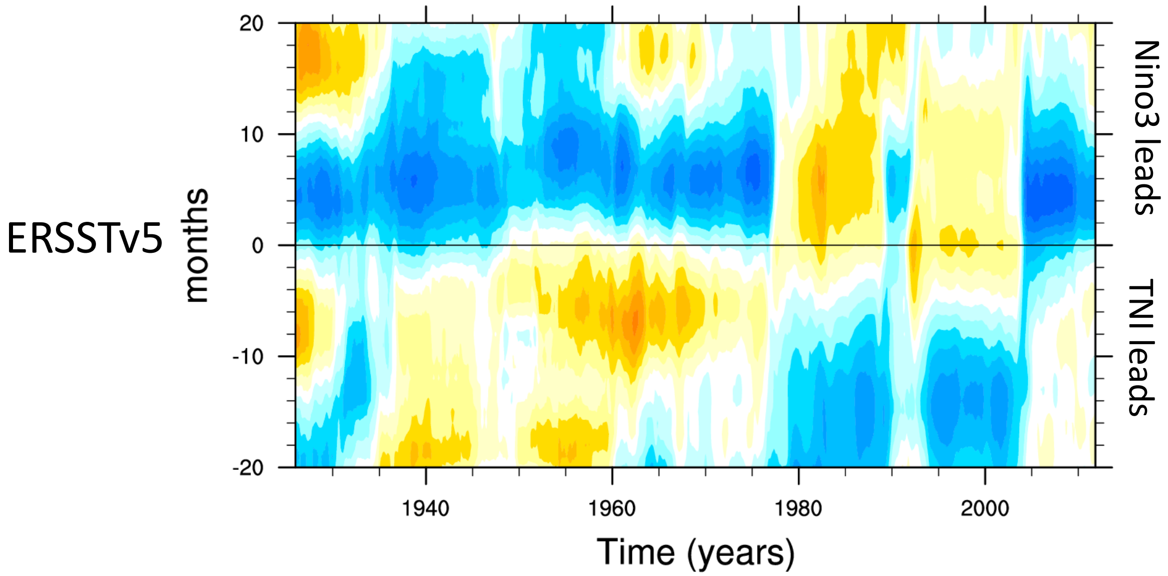


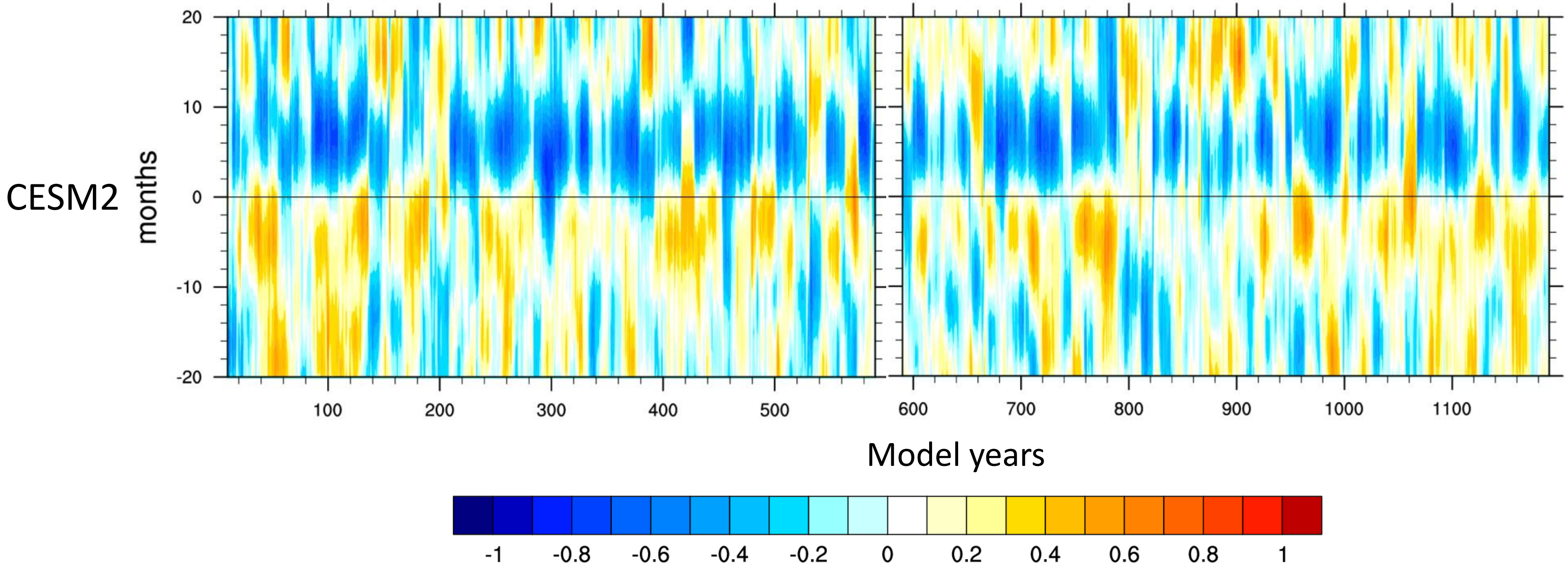
Linear combination of Nino3 and TNI can produce EP and CP spatial patterns



12-year sliding lag-correlation between Nino3 and TNI show anomaly propagation

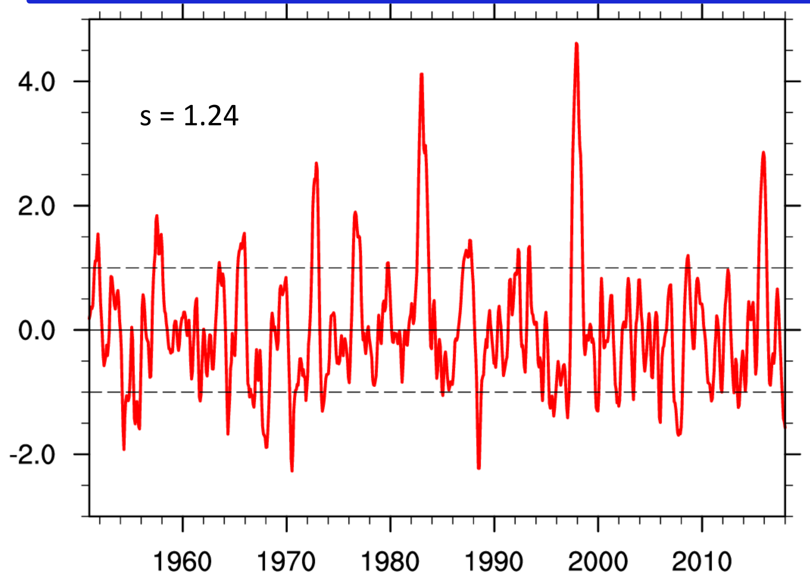
Negative Corr. = Westward propagation
Positive Corr. = Eastward propagation

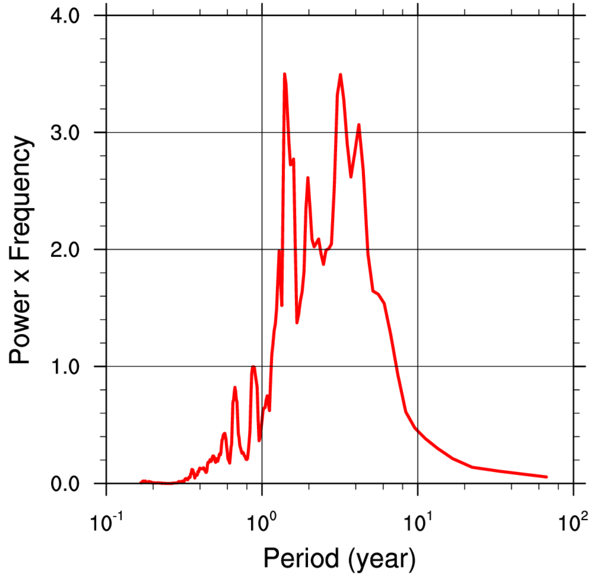




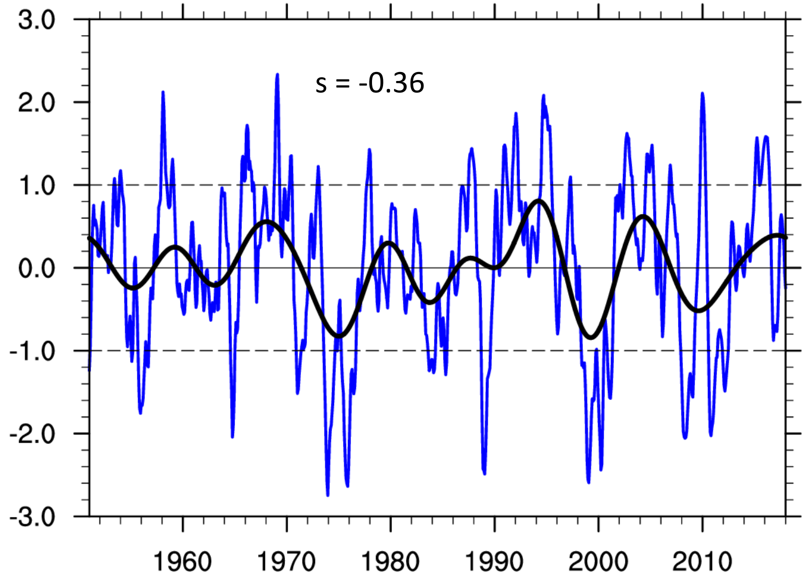
Propagation is predominantly westward in the model, similar to observations

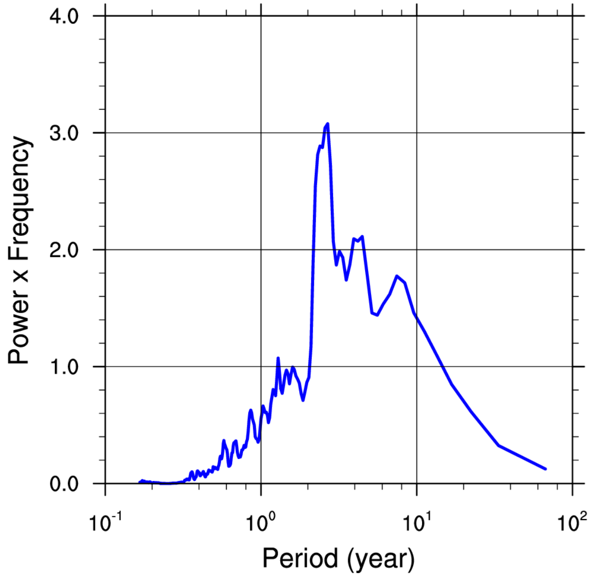
EP_{new} and CP_{new} show different spectral characteristics (Sullivan et al., 2016) ERSSTv5





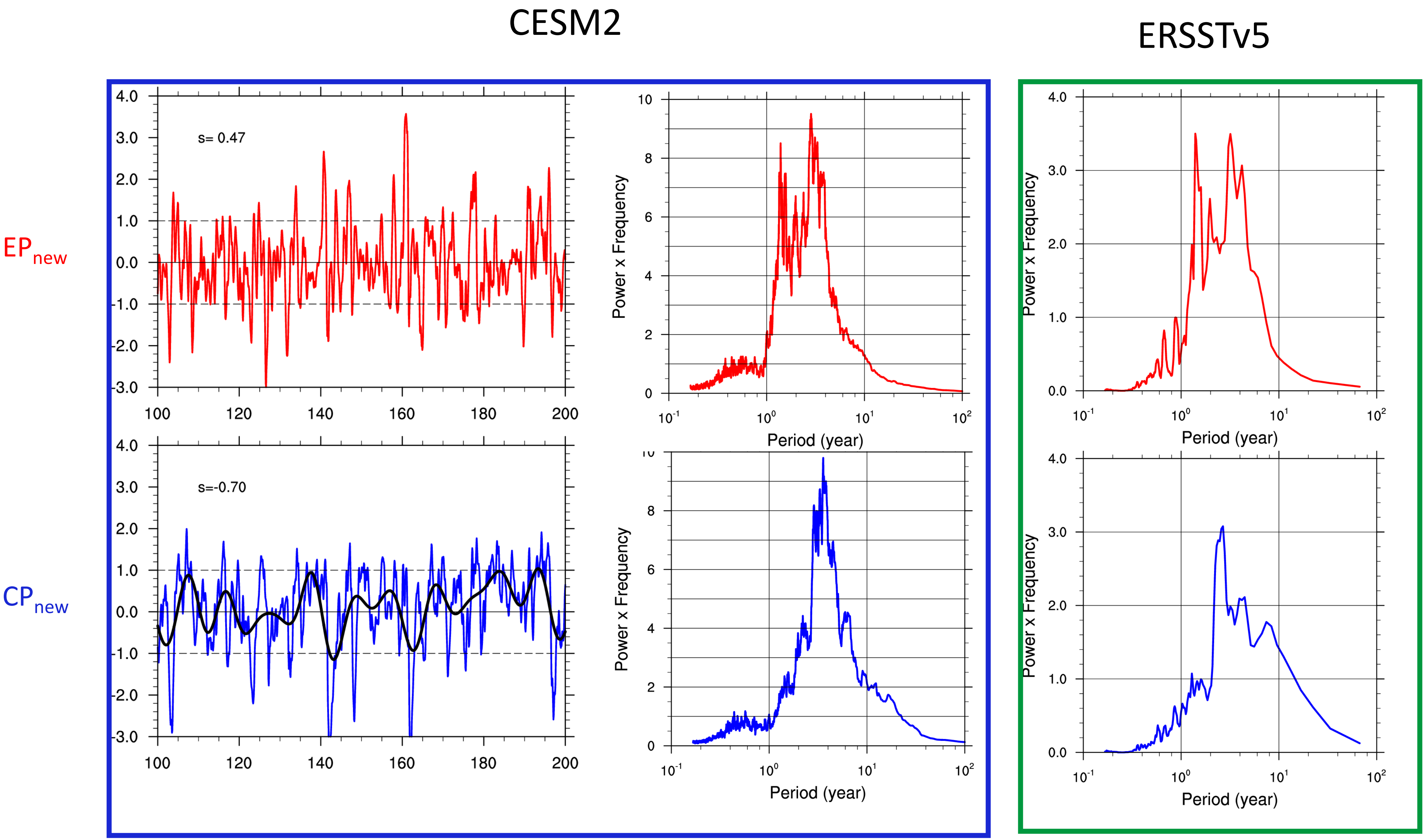
EP_{new}=Niño3 - 0.5 Niño4





CP_{new}=Niño4 - 0.5 Niño3

Niño3 and Niño4 normalized
ERSSTv5, 1951-2017



CESM2
ERSSTv5
EPnew
CPnew
s= 0.47
s=-0.70
Power x Frequency
Period (year)

Conclusions

- CESM2 exhibits more overlap between EP and CP events – less diversity? This is associated with the excessive westward extension of El Nino SST anomalies

- Composite SSH, SLP, and Precipitation have qualitative similar patterns to the observed

- SST anomalies zonal propagation is consistent with observations

- El Nino/La Nina asymmetry, as indicated by the skewness, is different than observed