ENSO 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, but it is also very challenging.

1. Comments on ENSO modeling
2. ENSO in CESM2 (focus on diversity)
3. Discussion about ways to approach model biases (Cold Tongue)

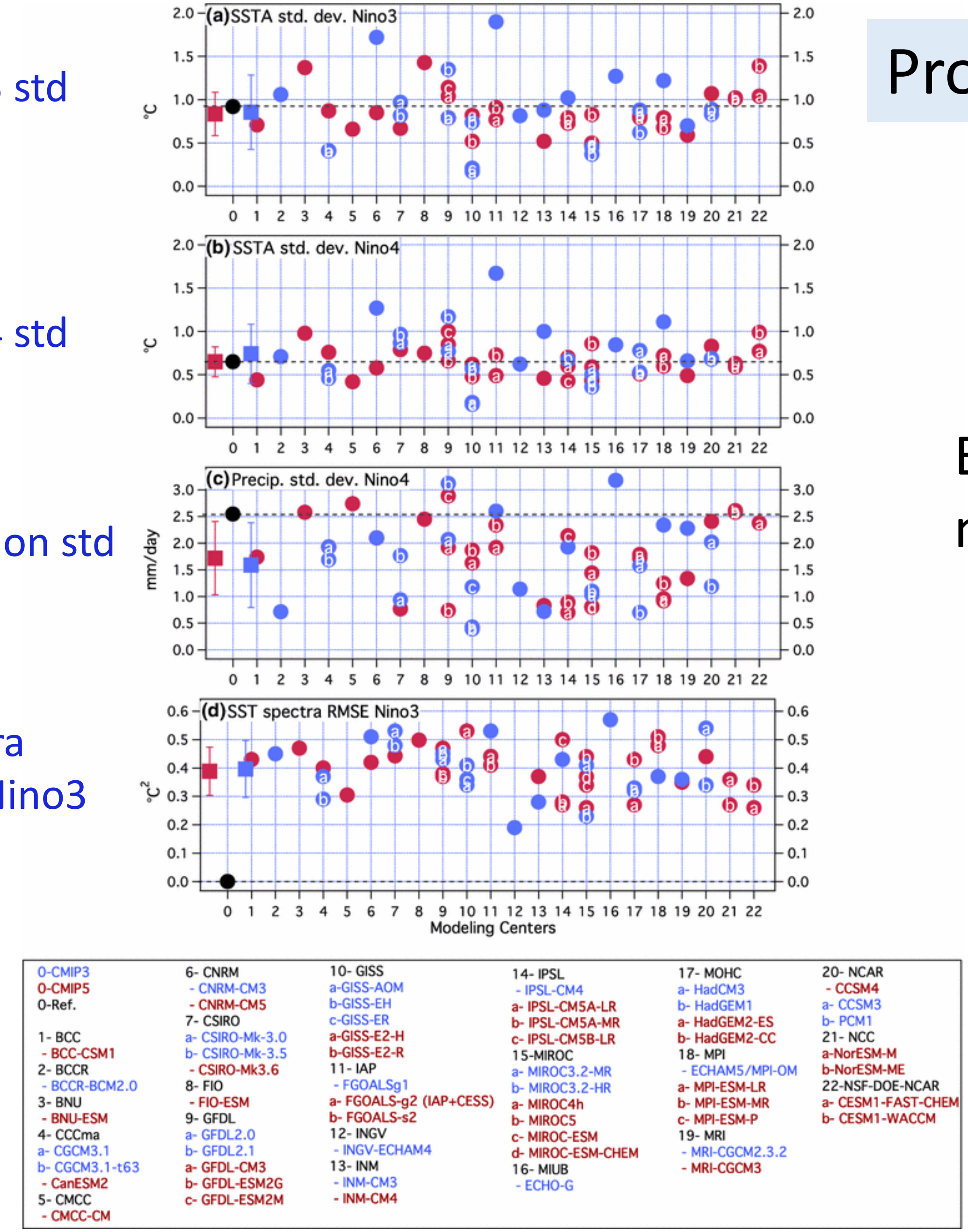
Progress in ENSO modeling is incremental

Nino3 std

Nino4 std

Precipitation std in Nino4

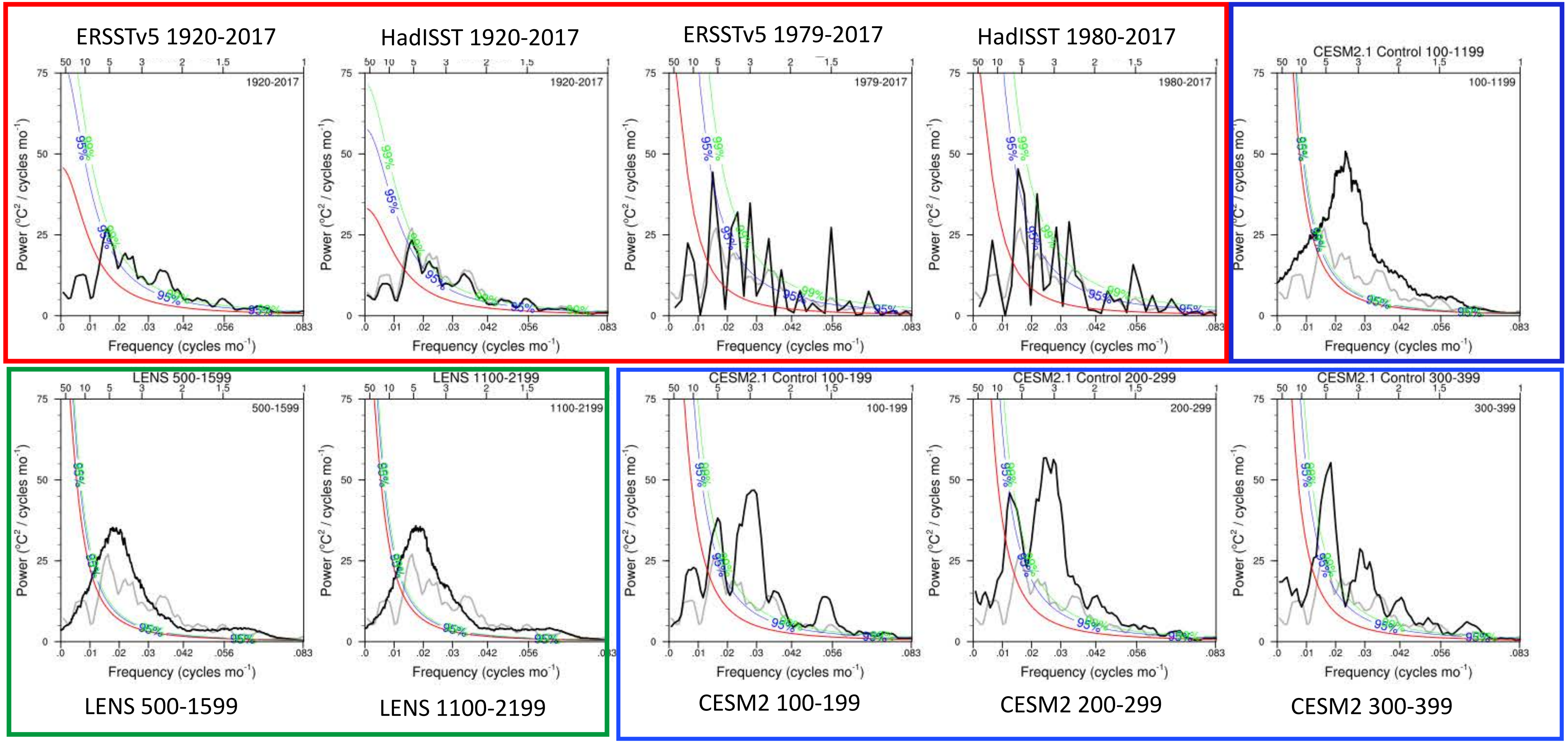
SST spectra RMSE in Nino3



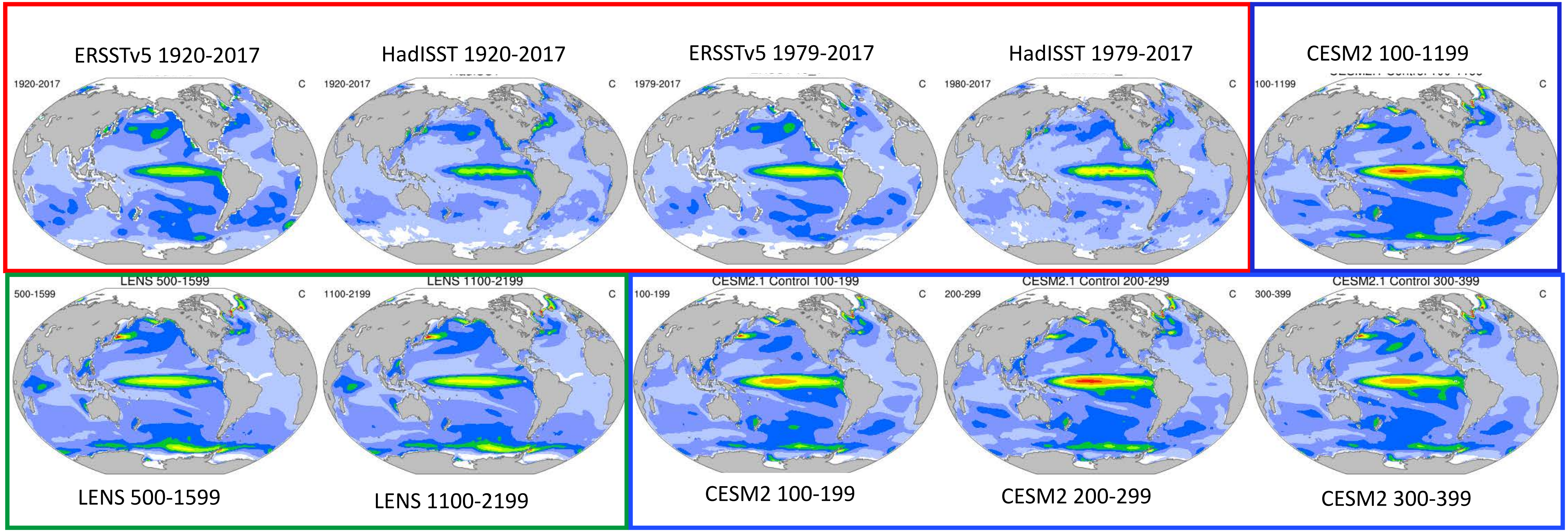
ENSO metrics in CMIP3 and CMIP5 multi-model ensembles

Bellenger et al. 2014

Spectra of Nino3.4 (Monthly, detrended)



SST standard deviation (DJF)

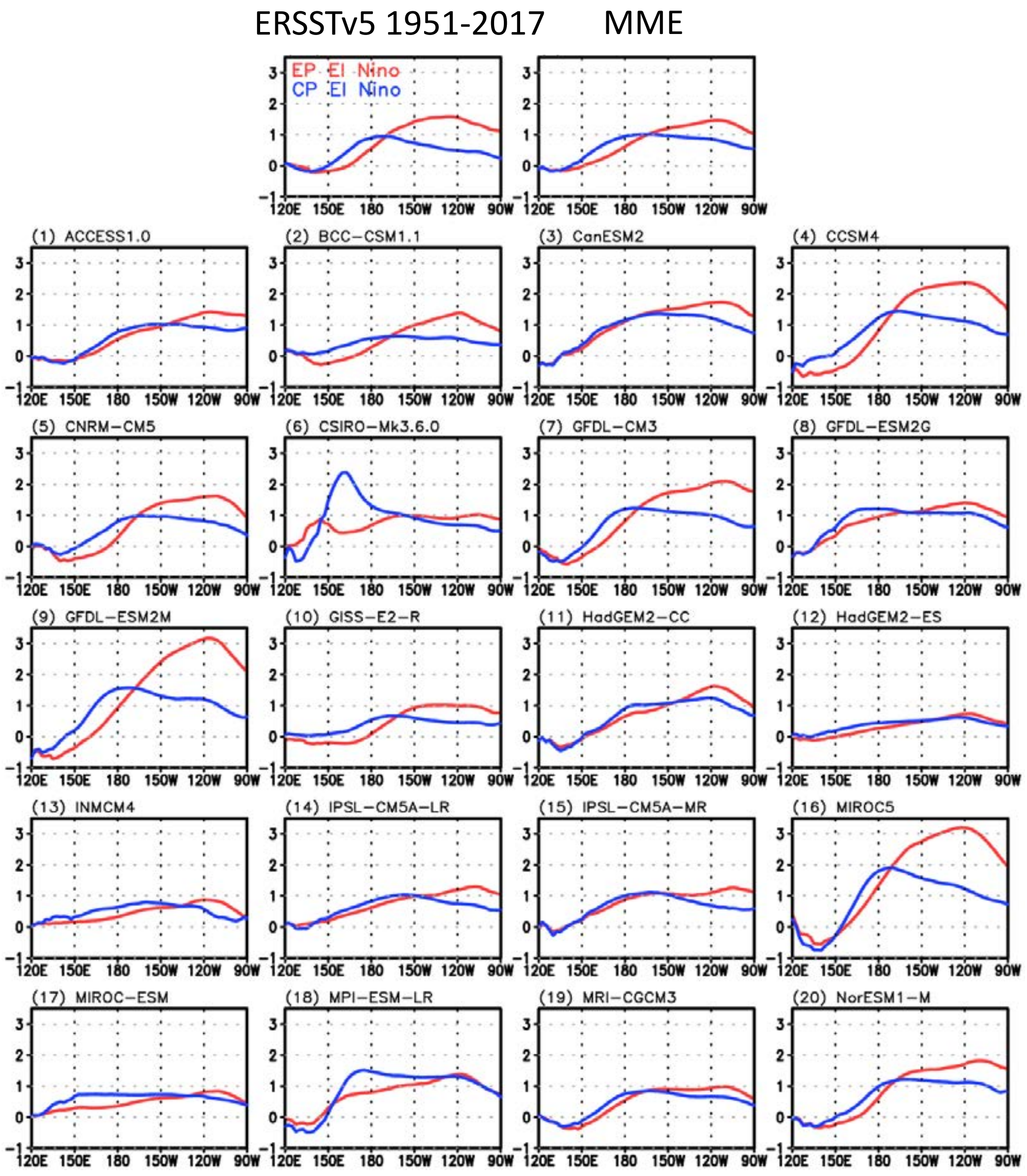


The westward displacement of the interannual SST anomalies is still pronounced in CESM2. CESM2 variance larger than LENS.

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/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)

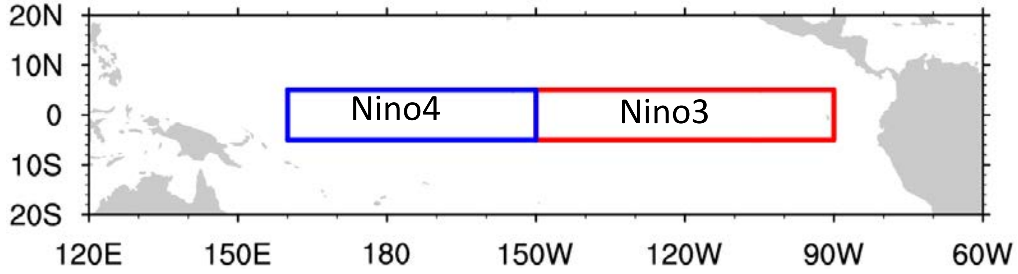
ENSO diversity in the CMIP5 models



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

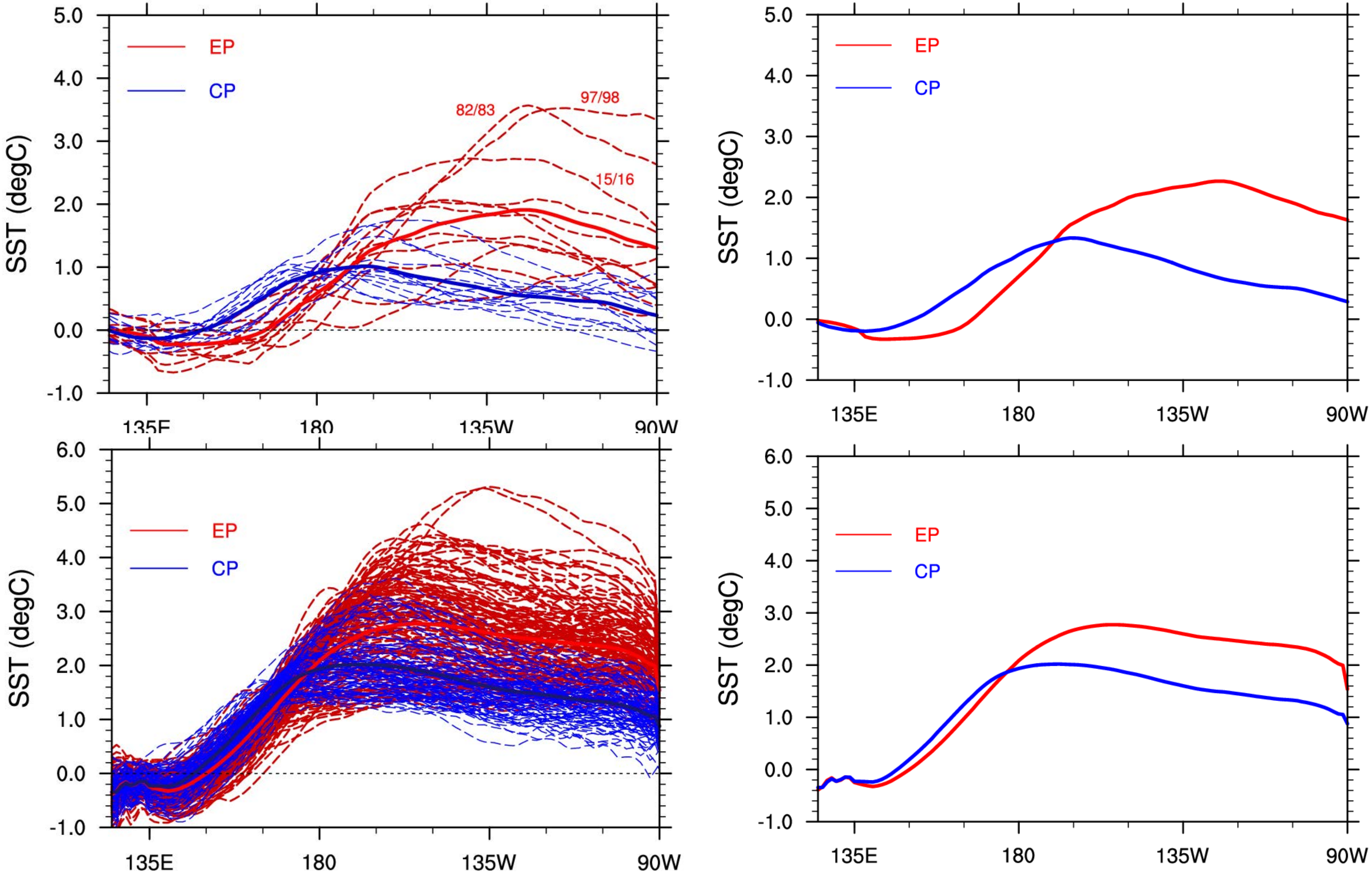
EP = Nno3 > $0.5^{o}C$ and > Nino4

CP = Nino4 > $0.5^{o}C$ and > Nino3



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

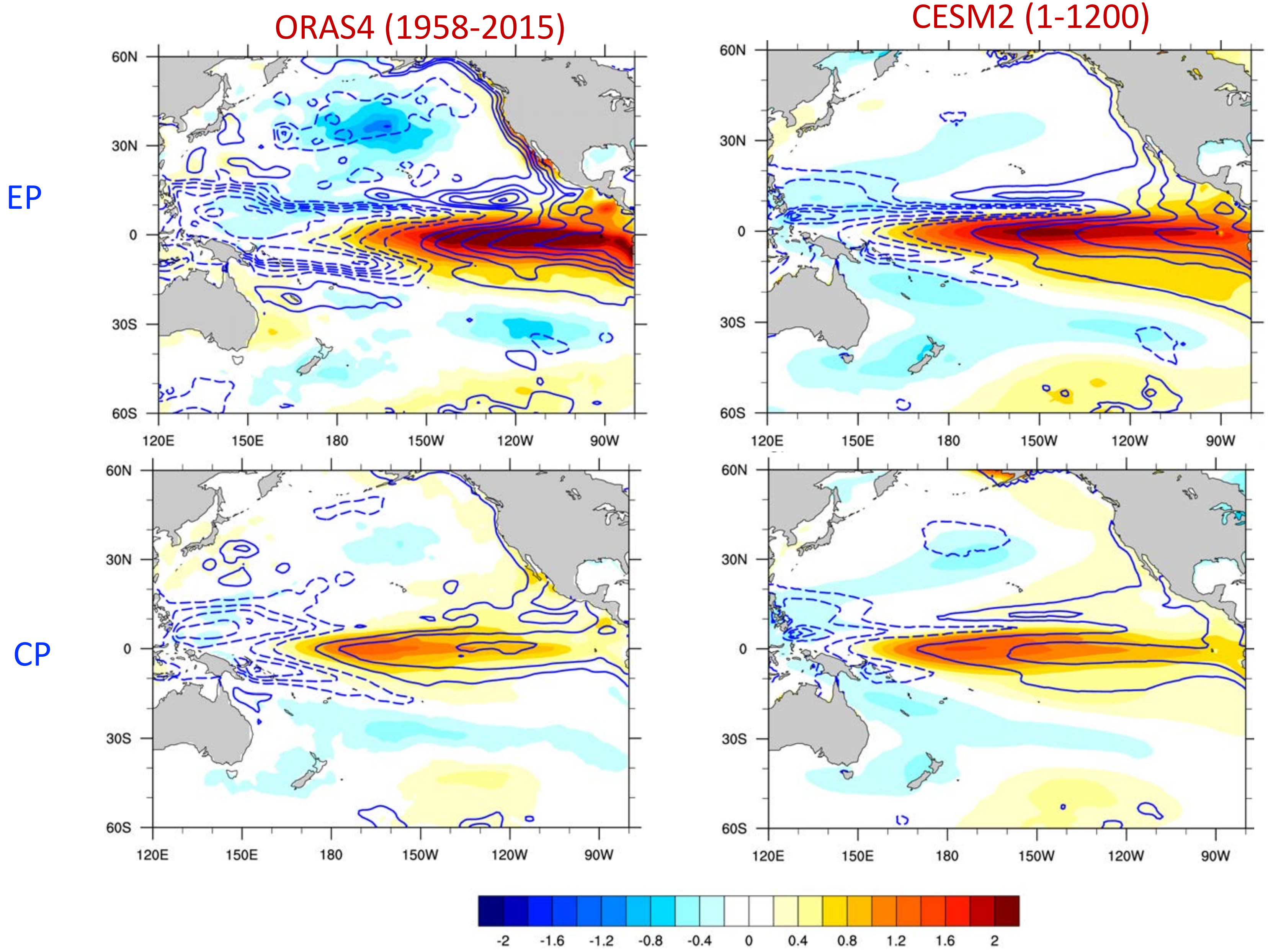
What about CESM2?



ERSSTv5
1951-2017

CESM2
1-1200

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

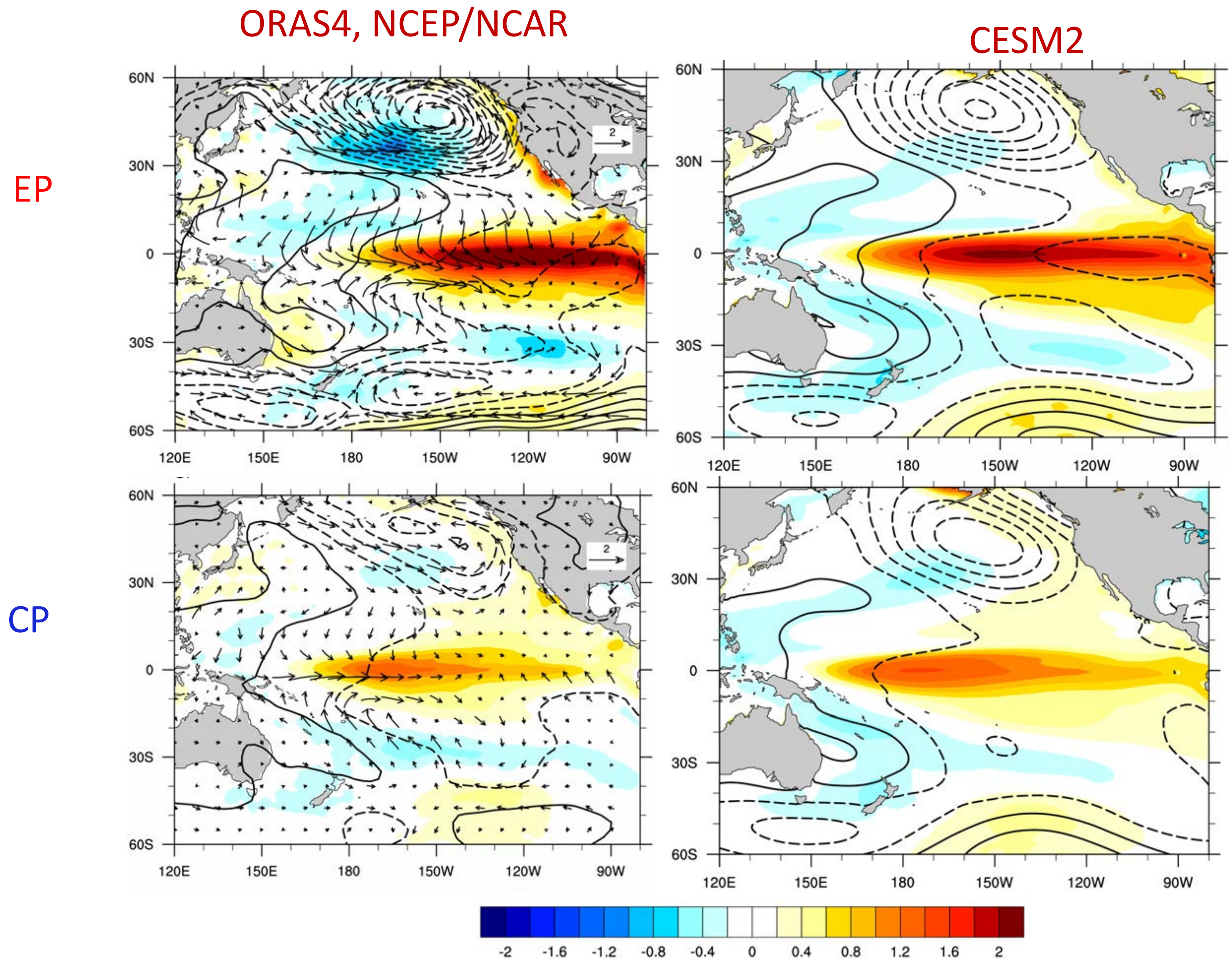


SSH (thermocline depth) anomalies larger during EP events

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

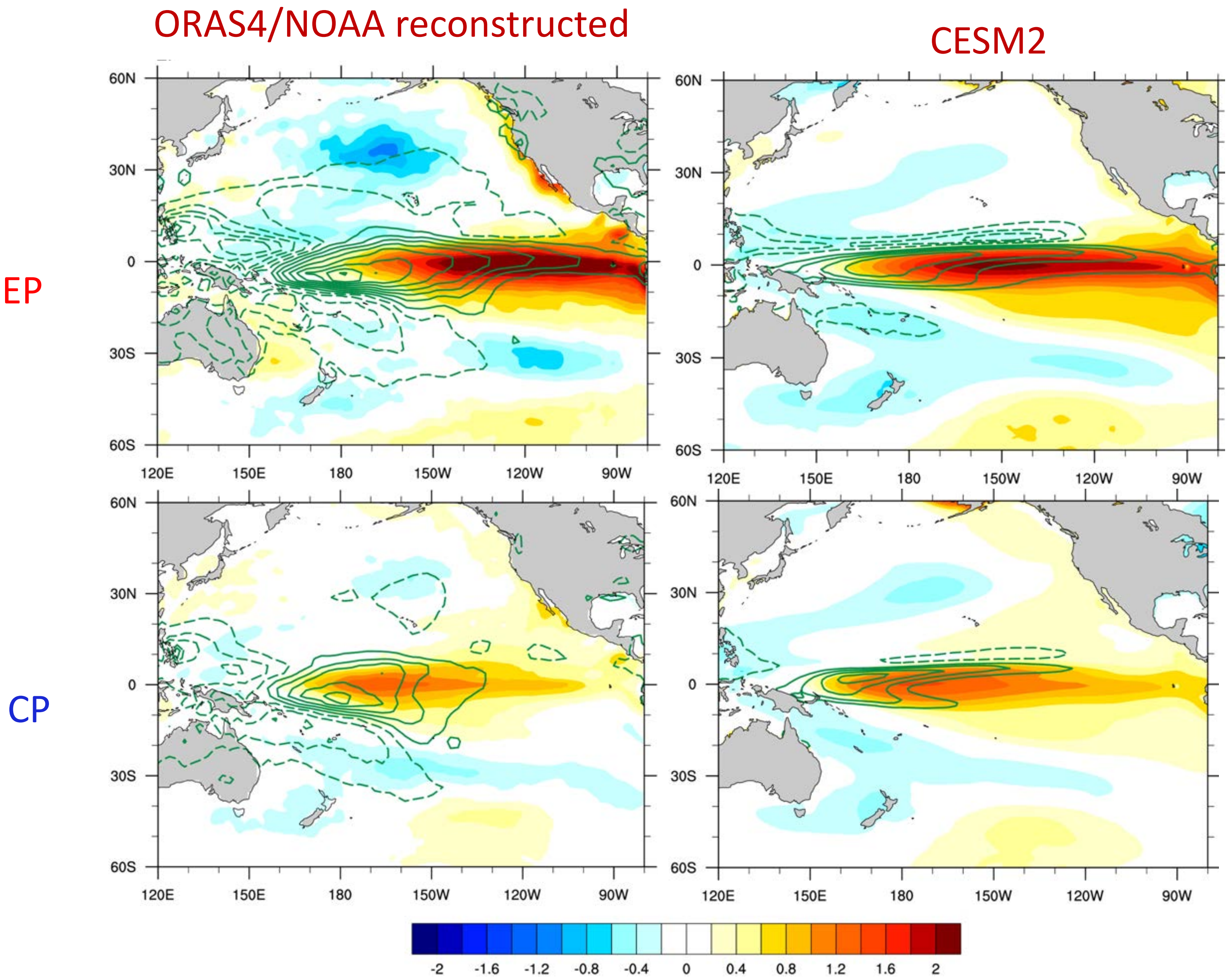
In CESM2 main difference between EP and CP is in the eastern equatorial Pacific

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)

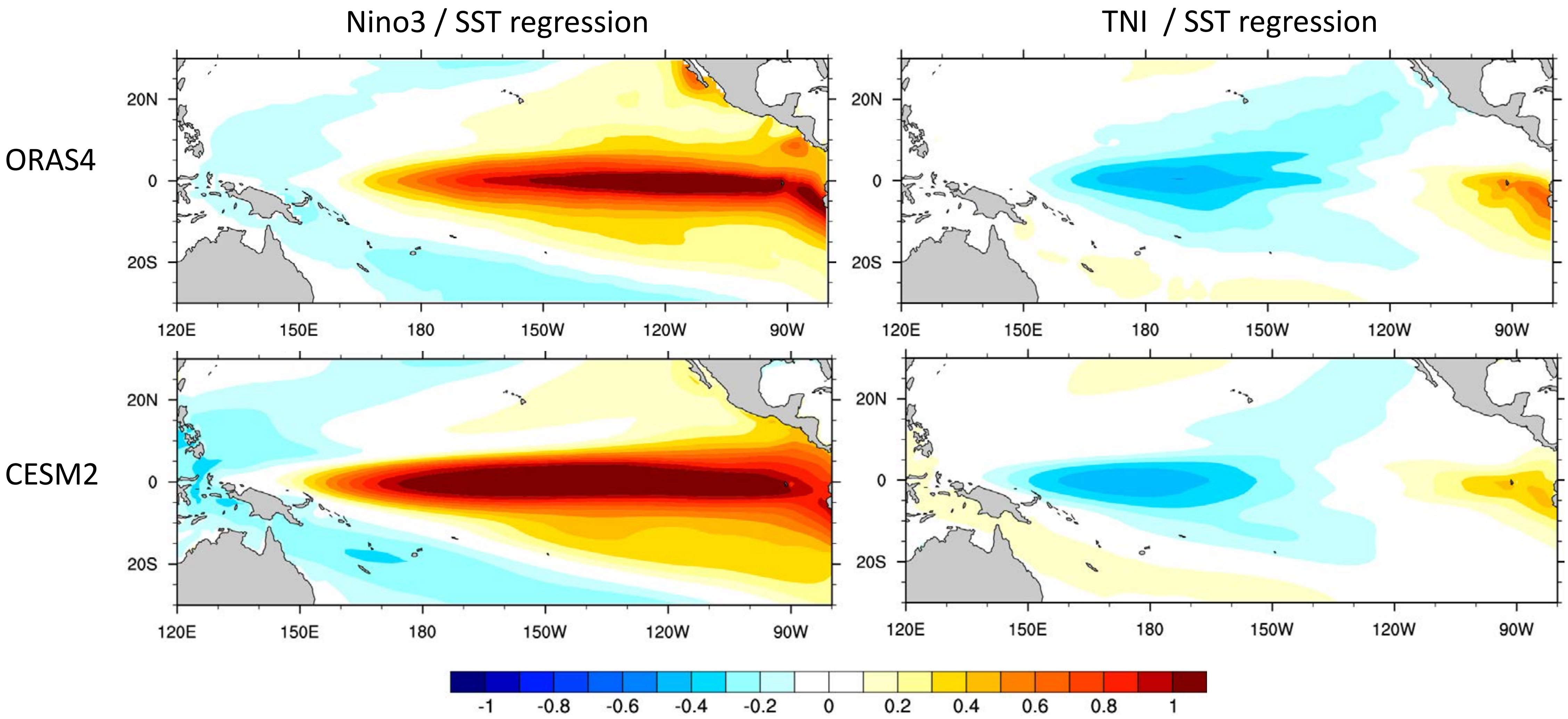


Precip anomalies along the equator are confined further to the west during CP events than during EP events.

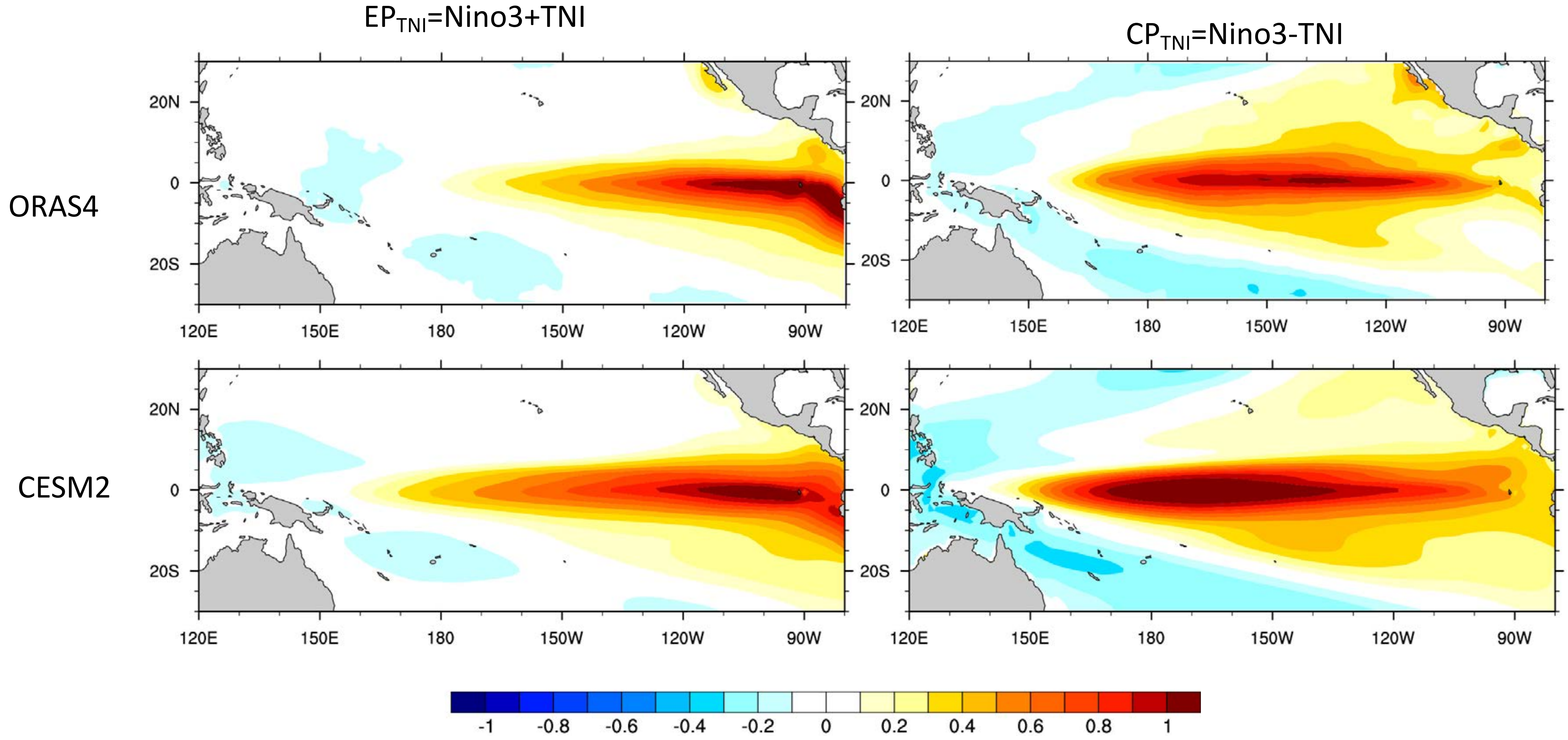
SLP zonal gradients are displaced to the west relative to obs for both EP and CP

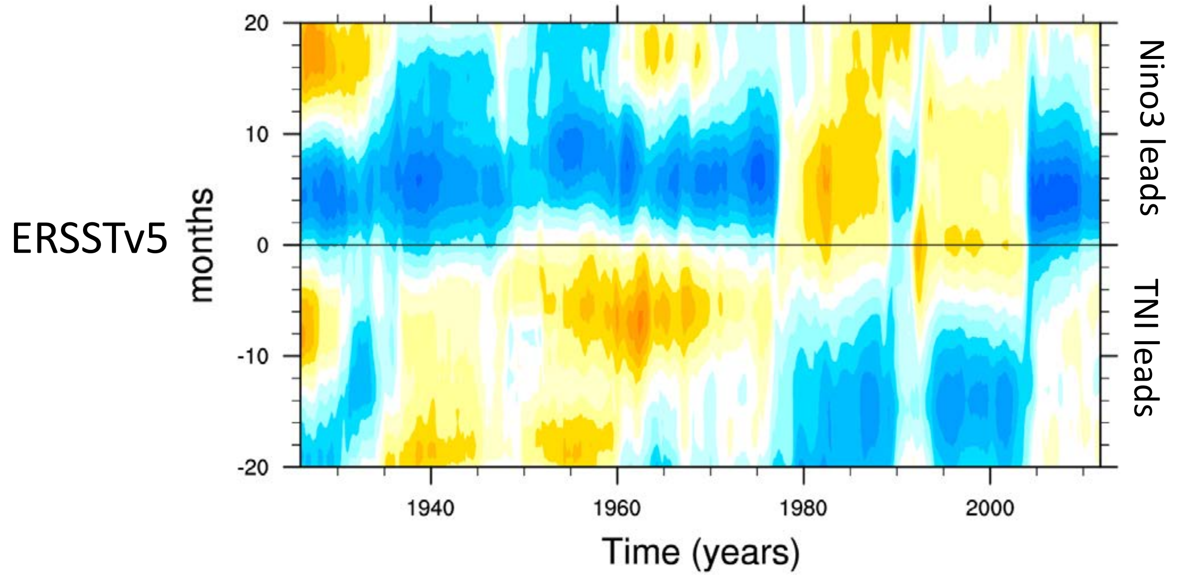
Two degrees of freedom are needed to capture the evolution of interannual SST anomalies along the equator (Trenberth and Stepaniak, 2001)

TNI = $Nino1{+}2_N - Nino4_N$



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

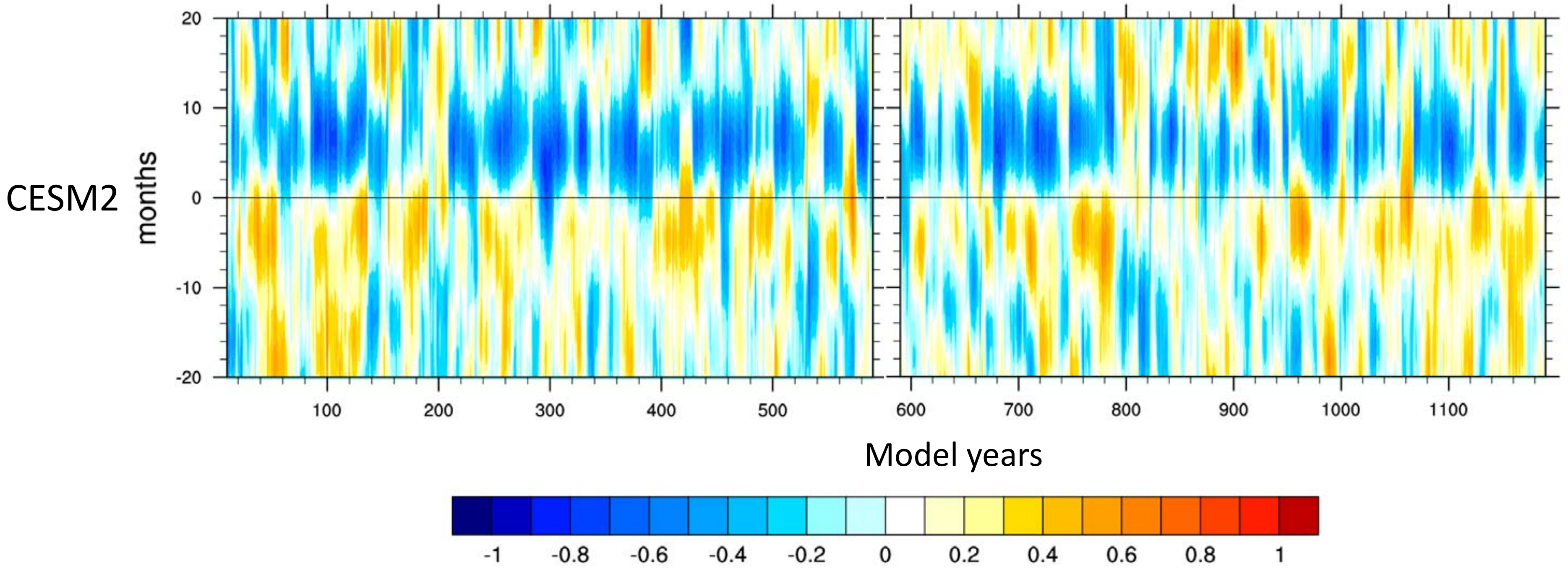




12-year sliding lag-correlation between Nino3 and TNI show anomaly propagation

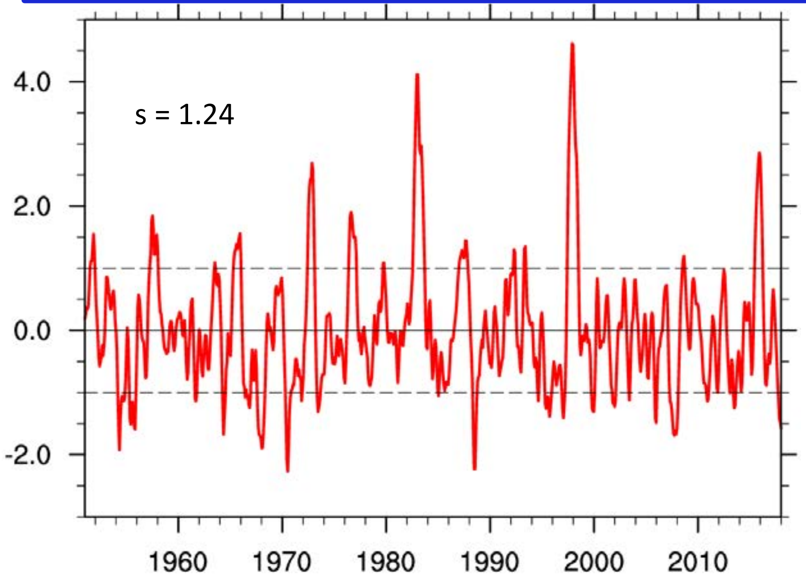
Negative Corr. = Westward propagation

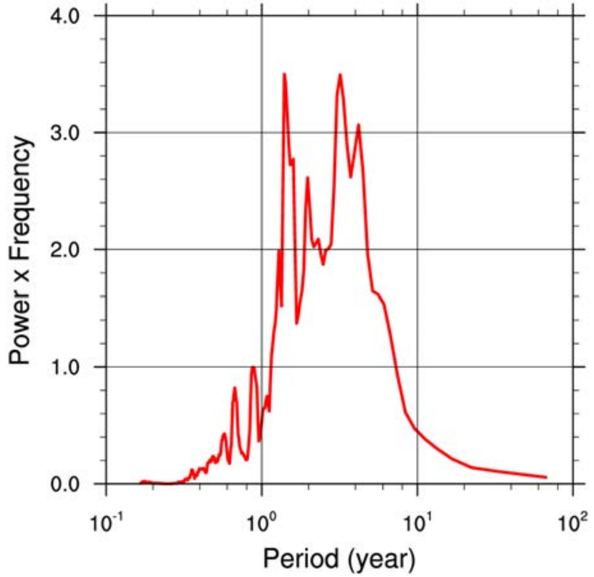
Positive Corr. = Eastward propagation



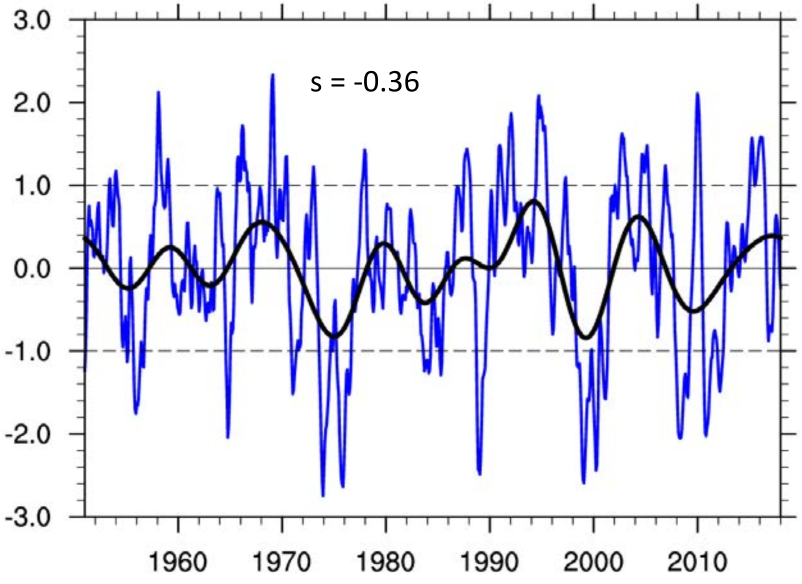
Propagation is predominantly westward in the model, similar to observations

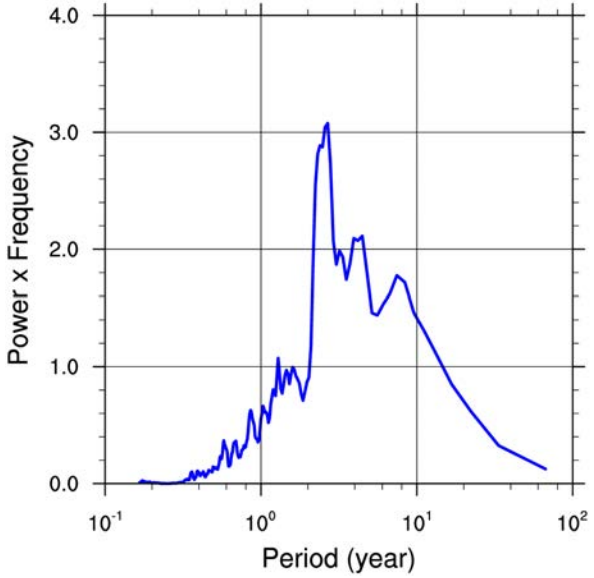
EP_{new} and CP_{new} show different spectral characteristics (Sullivan et al., 2016) ERSSTv5





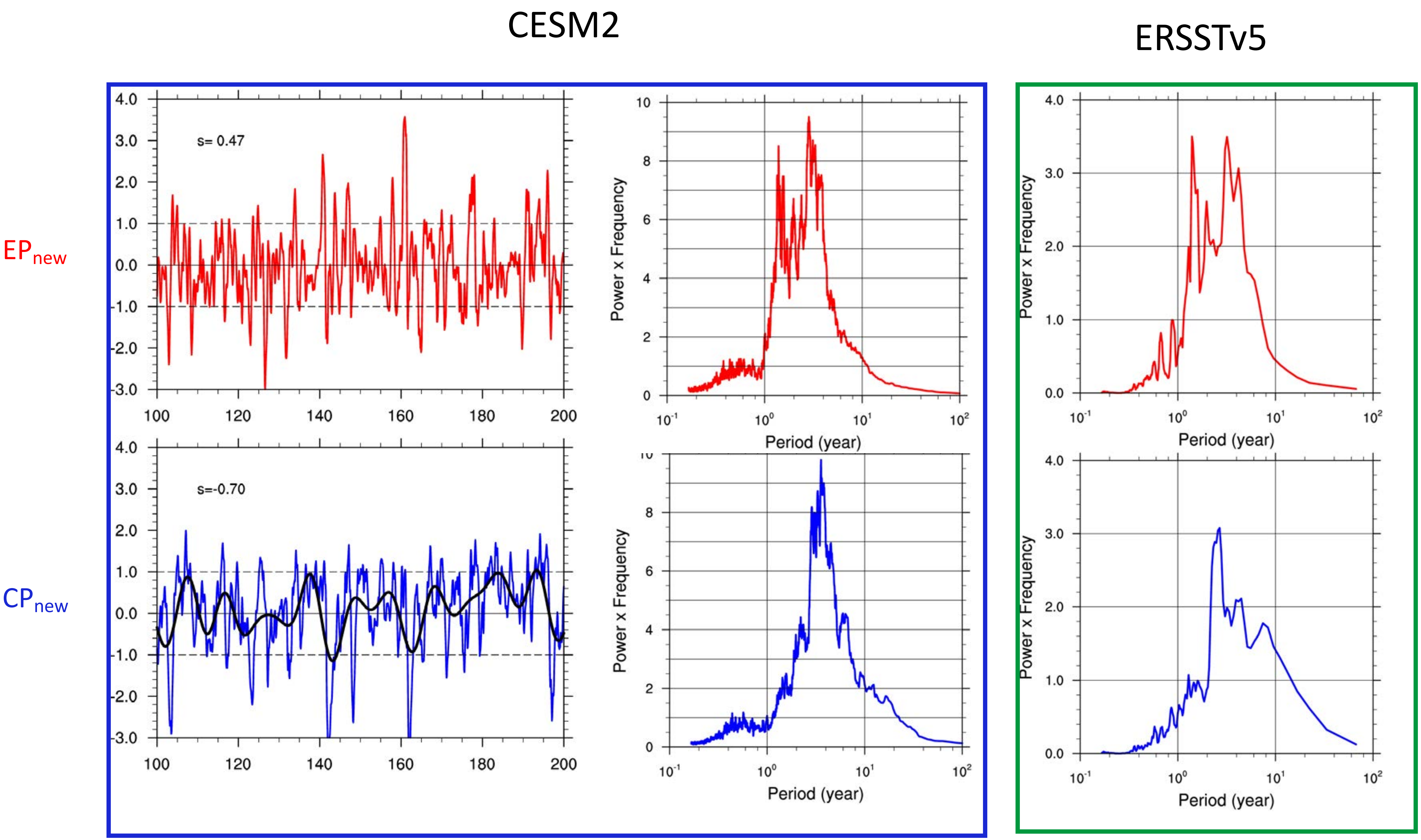
EP_{new}=Niño3 - 0.5 Niño4



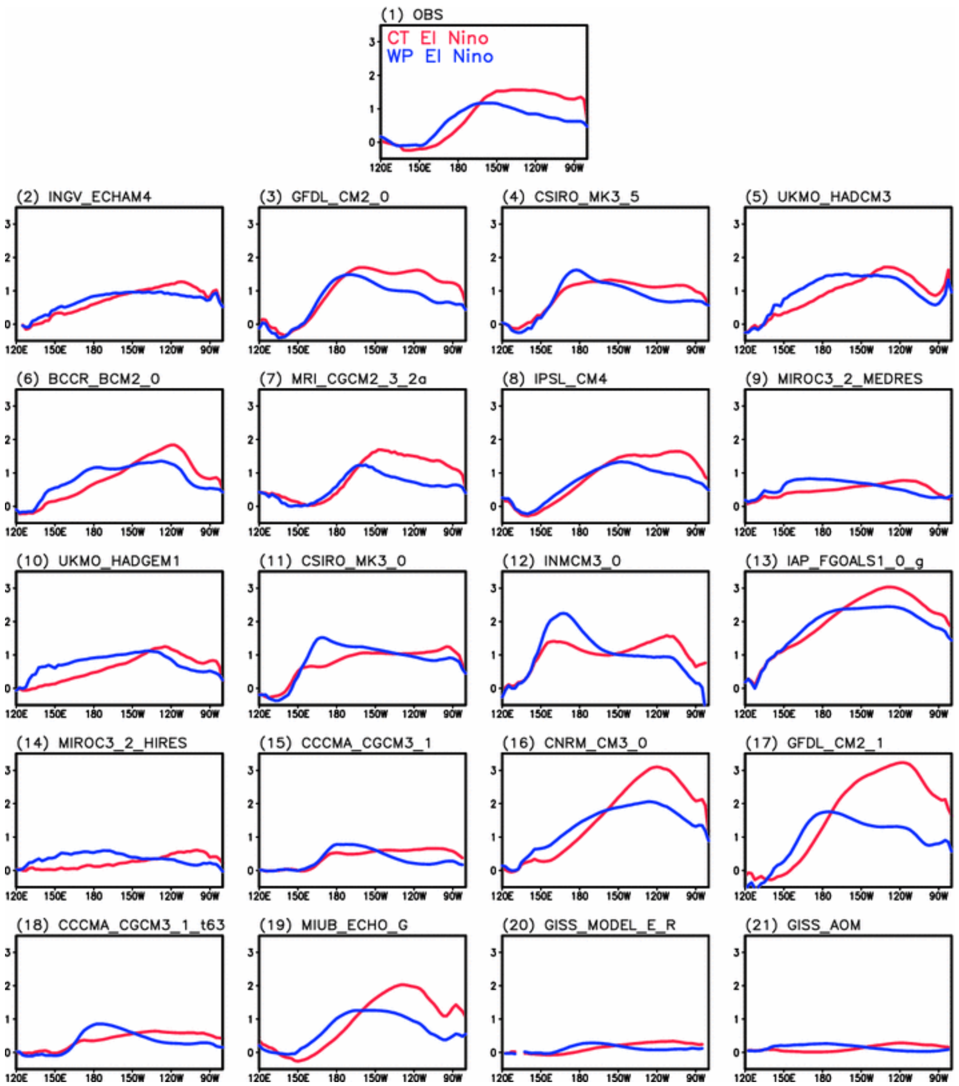


CP_{new}=Niño4 - 0.5 Niño3

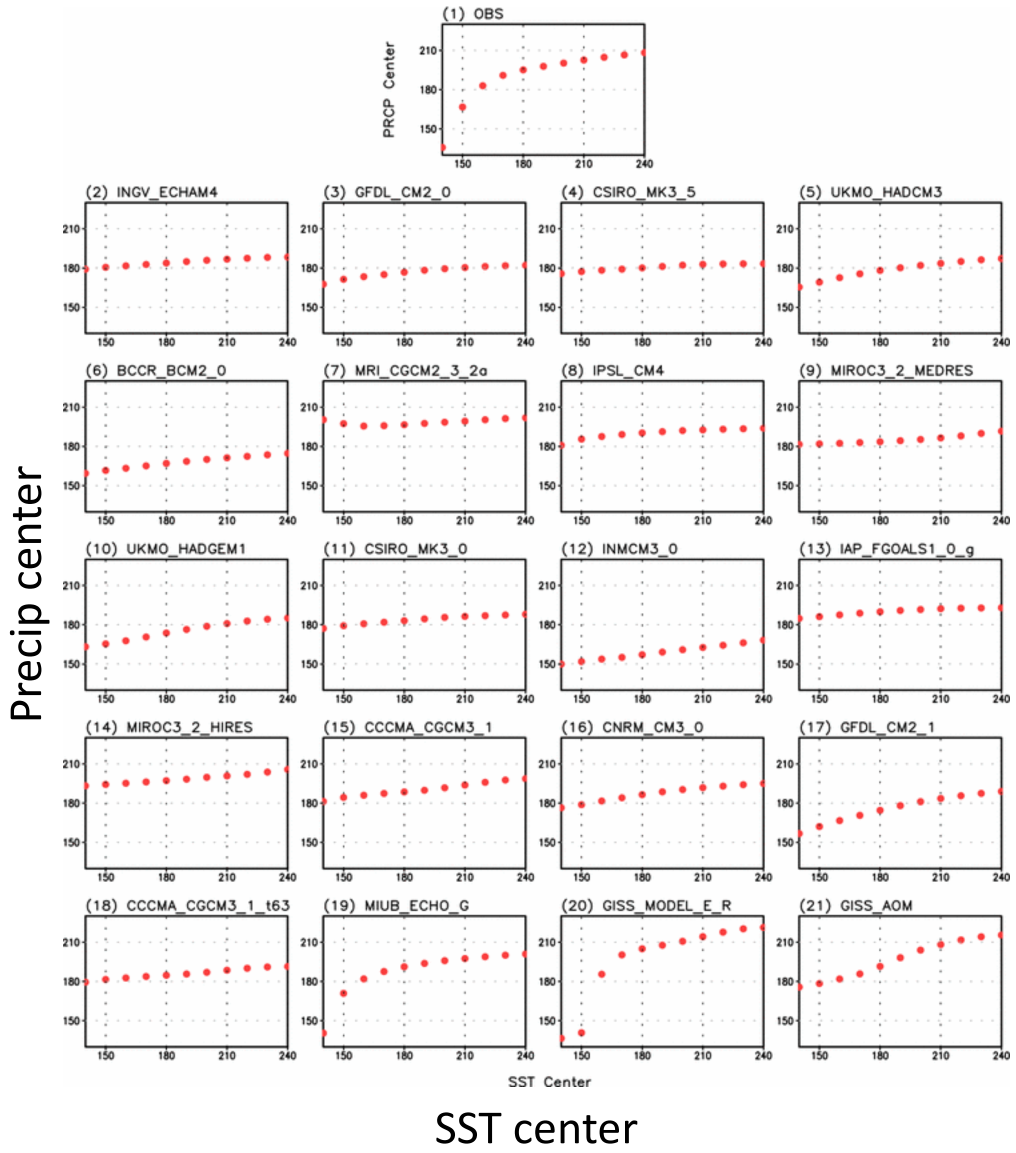
Niño3 and Niño4 normalized
ERSSTv5, 1951-2017


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

“Cold Tongue bias” responsible for models difficulty in simulating Diversity



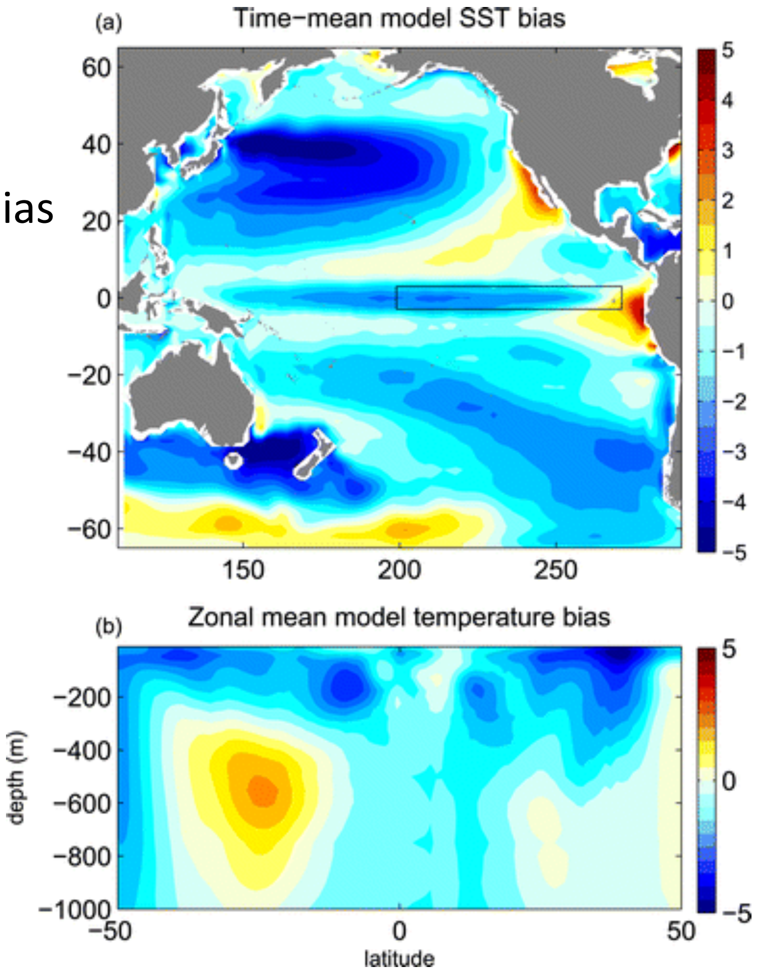
Ham and Kug, 2012



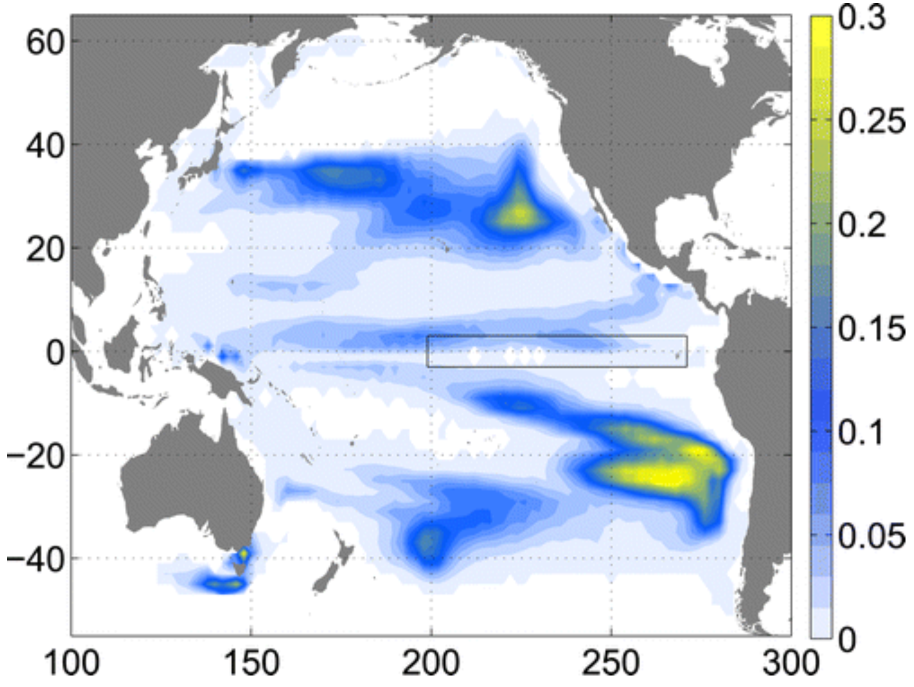
“Cold Tongue bias” may have remote origin

SST bias

T bias



Probability density function showing the origin of the upwelled water in the EEP region. Particles are initialized at the base of the ML in the EEP region and run backward in time until they cross the ML.



Thomas and Fedorov, 2017

Conclusions

- CESM2 simulation of ENSO does not show much improvement relative to previous model version.
- In particular, more overlap between EP and CP events than observed. This is associated with the excessive westward extension of El Nino SST anomalies
- SST anomalies zonal propagation is consistent with observations
- Very difficult to remove Cold Tongue bias likely due to its non-local origin.