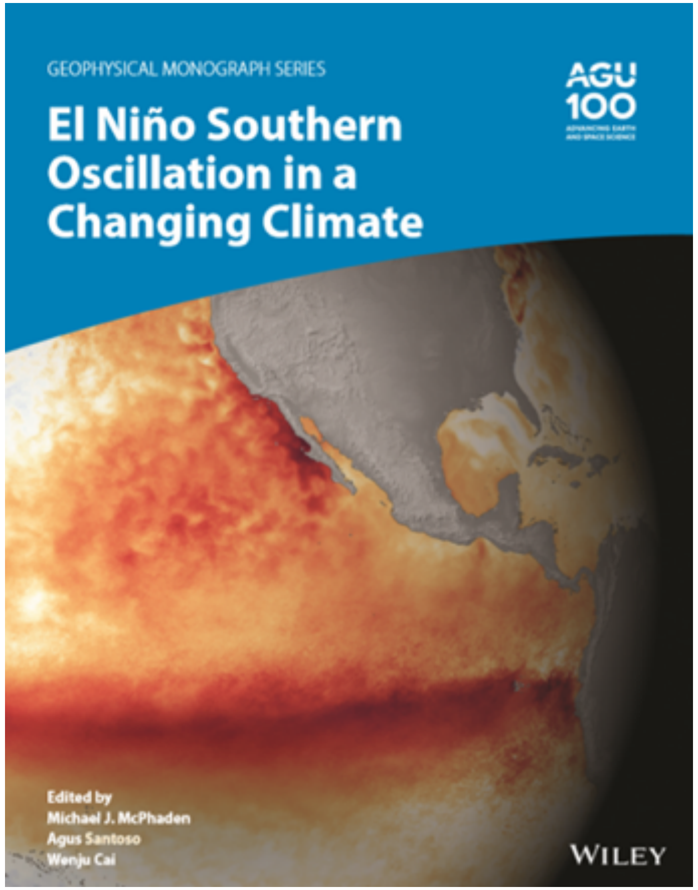
El Nino Southern Oscillation (ENSO) in the Community Earth System Model Version 2

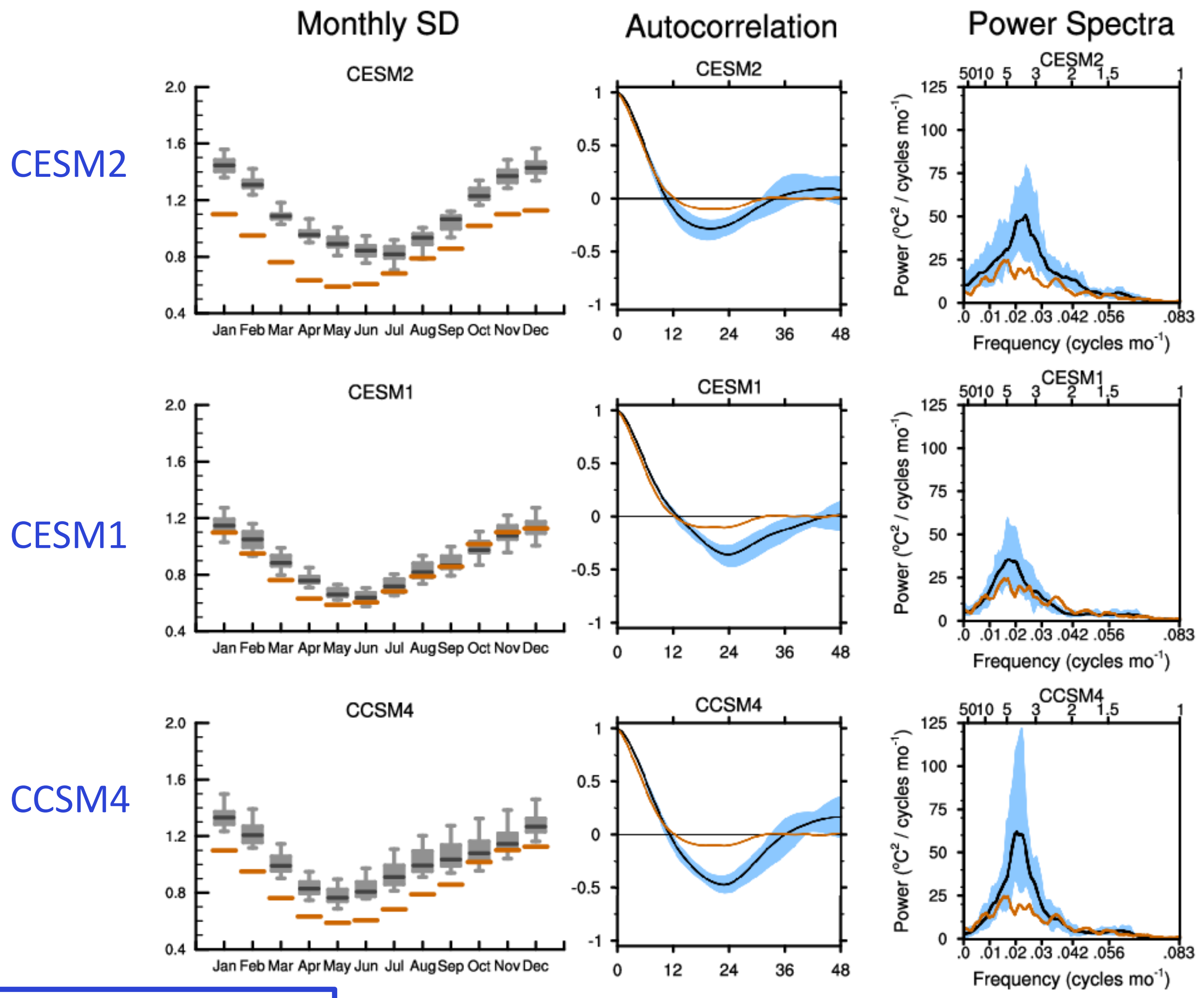
Antonietta.Capotondi@noaa.gov
University of Colorado, CIRES
NOAA Physical Sciences Laboratory



Capotondi, A., C. Deser, A. Phillips, Y. Okumura and S. Larson, 2020, *JAMES*, in press.

- ENSO temporal/spectral characteristics in CESM2
- ENSO diversity
- Precursors of different types of ENSO events

Spectral characteristics of Nino-3.4 in piControl



Nino-3.4 region: 5°S-5°N, 170°-120°W

Observations (ERSSTv5, 1900-2018)

Light blue shading is the range of spectral estimates in 18 119-yr overlapping segments of the CESM2 piControl simulation (model years 201-1200)

Boxplots and whiskers show the minimum values, first and third quartile, median and max. value

The model has a seasonal phase locking and dominant timescale in good agreement with observations, but amplitude is ~30% larger than observed.

Capotondi et al., 2020

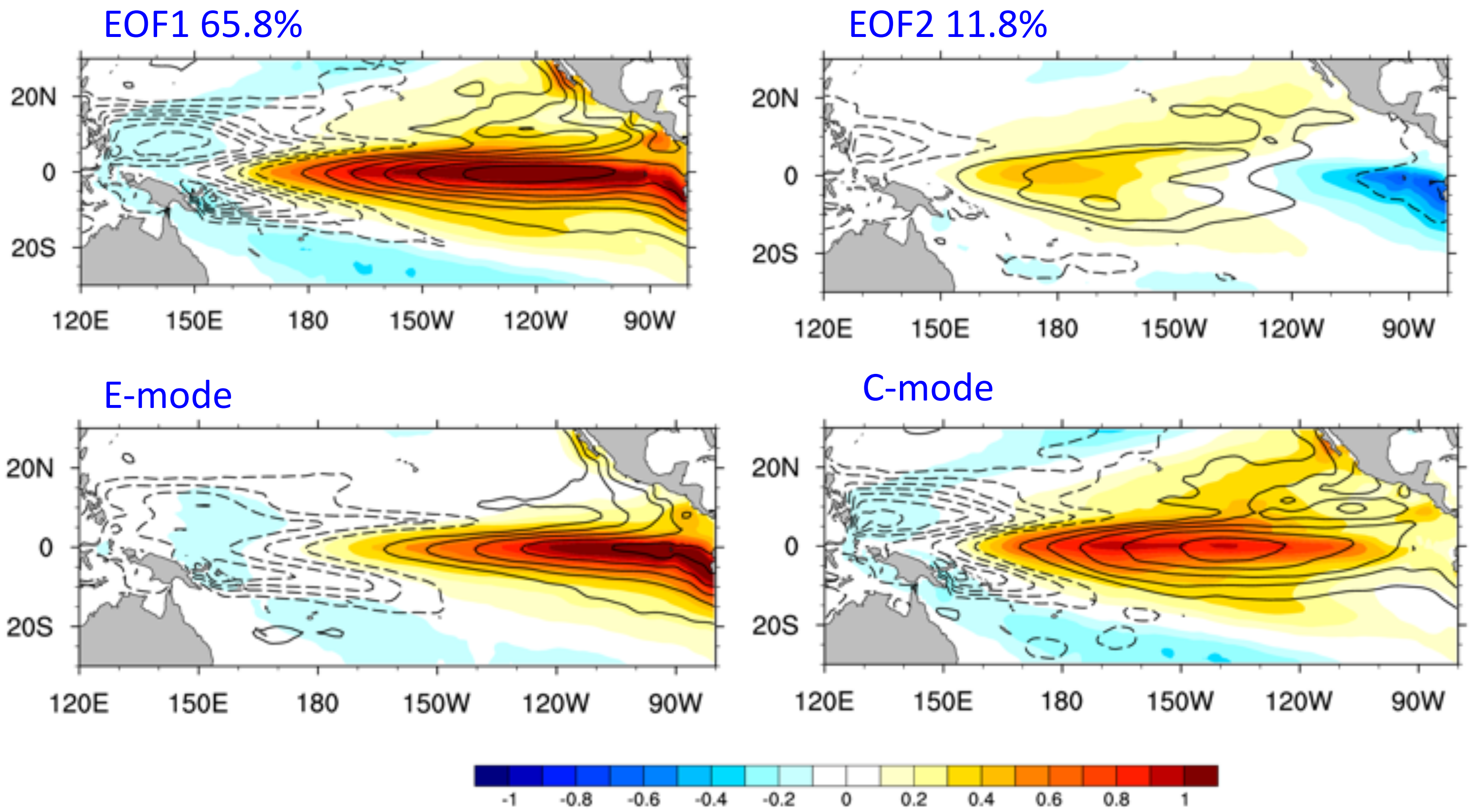
ENSO Diversity

<u>Definition</u> (Takahashi et al., 2011): Based on EOF analysis in the 10^{o}S-10^{o}N region

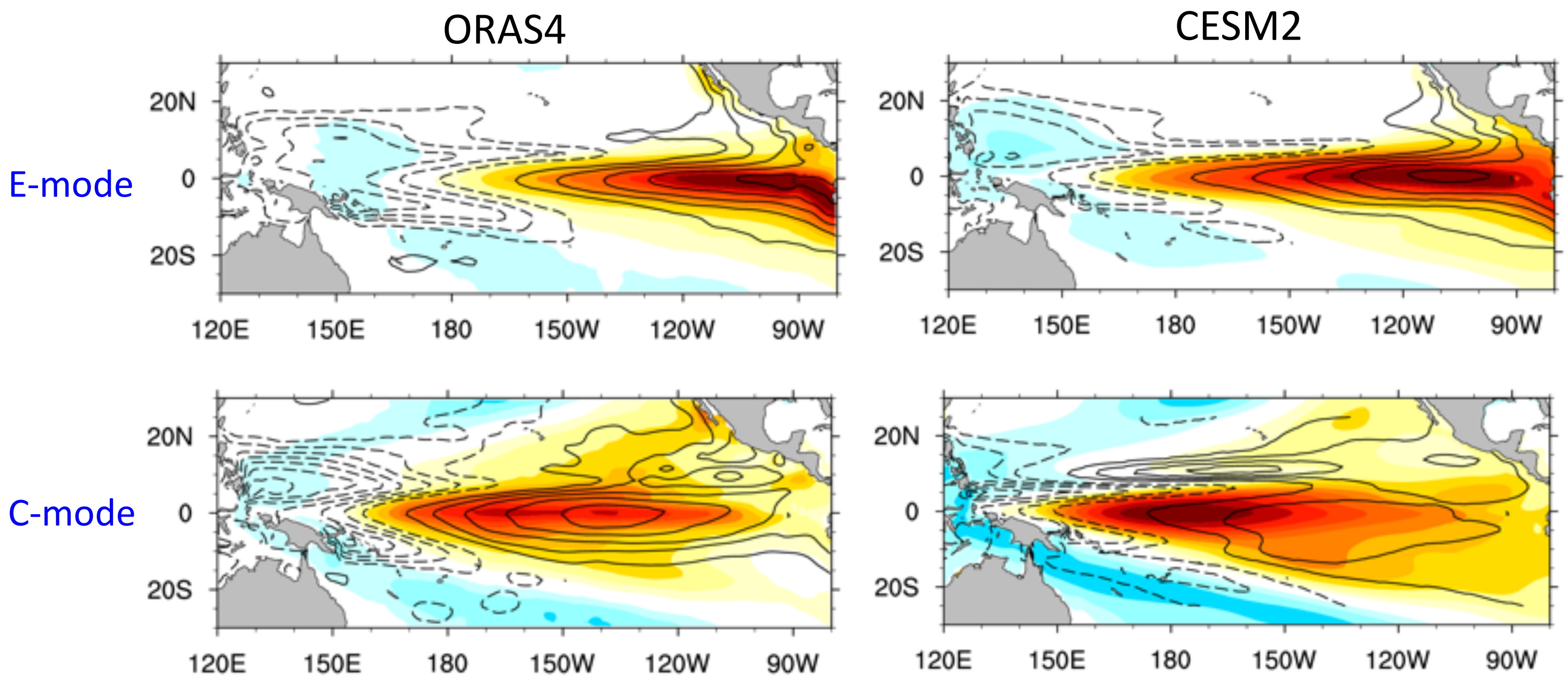
E-mode index: $(PC1-PC2)/\sqrt{2}$

C-mode index: $(PC1+PC2)/\sqrt{2}$

ORAS4 (1958-2015)



How do E and C modes in CESM2 compare with ORAS4?



E and C modes in CESM2 are qualitatively similar to those in ORAS4. Model's anomalies are displaced too far west.

ENSO **precursors** are determined using Linear Inverse Modeling (LIM)

The tropical Pacific (25°S-25°N) is described by the state vector ***x*** which includes SST and SSH. The evolution of ***x*** is well described by a multivariate, linear and stochastically forced system:

$$d\boldsymbol{x} = \mathbf{L}\,\boldsymbol{x}\,dt + \mathbf{S}\,\mathbf{r}\,(dt)^{1/2}$$

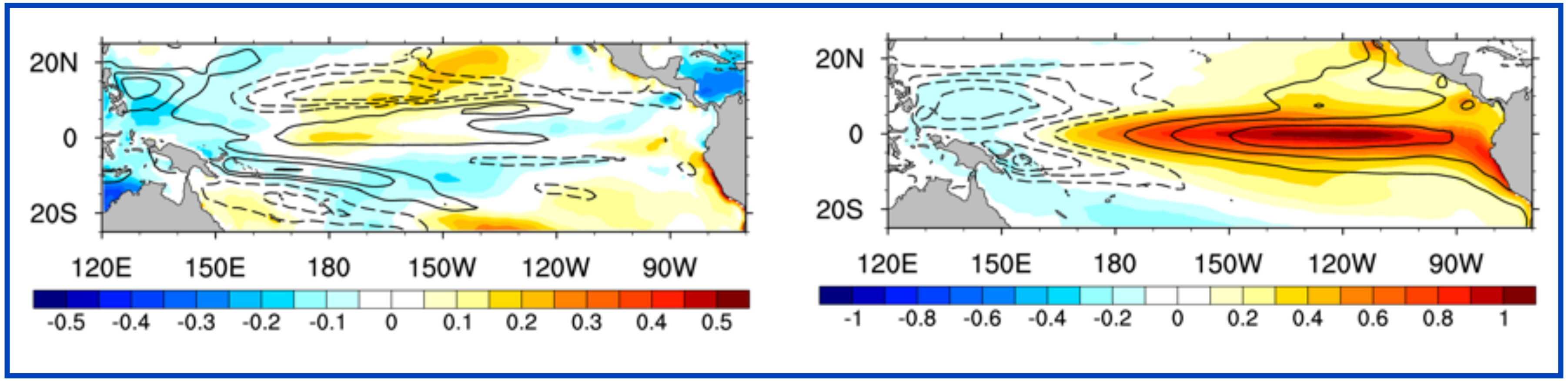
L = matrix encapsulating predictable dynamics
S = stochastic forcing amplitude covariance matrix
r = random noise vector from N(0,1)

Most likely solution at time t+τ : $\boldsymbol{x}(t+\tau) = \exp(\mathbf{L}\tau)\,\boldsymbol{x}(t) + \varepsilon$

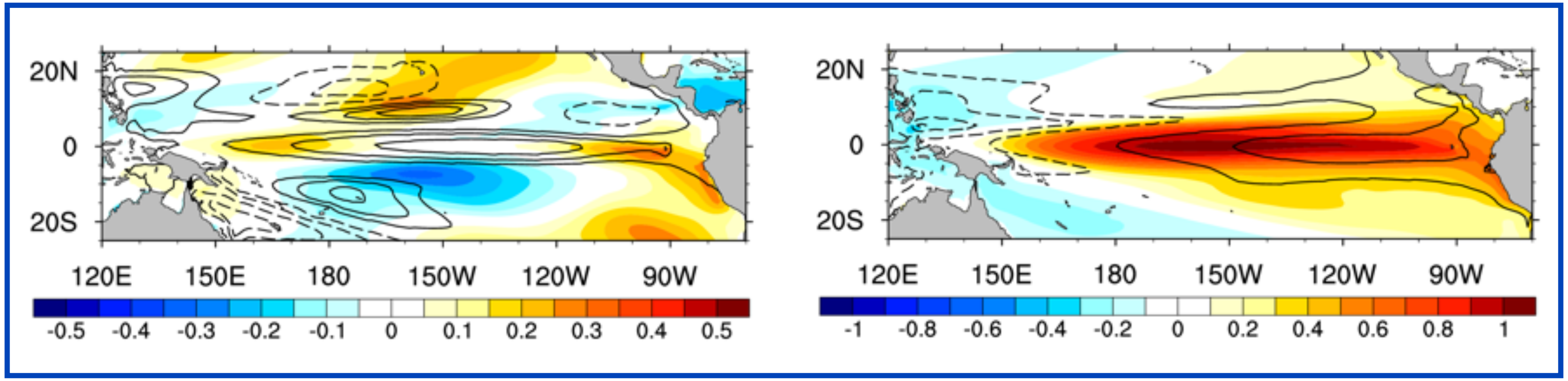
Penland and Sardeshmukh 1995; Newman and Sardeshmukh, 2017

Optimal Structures (τ = 8 months)

Initial (τ =0) ORAS4 Final (τ =8 months)

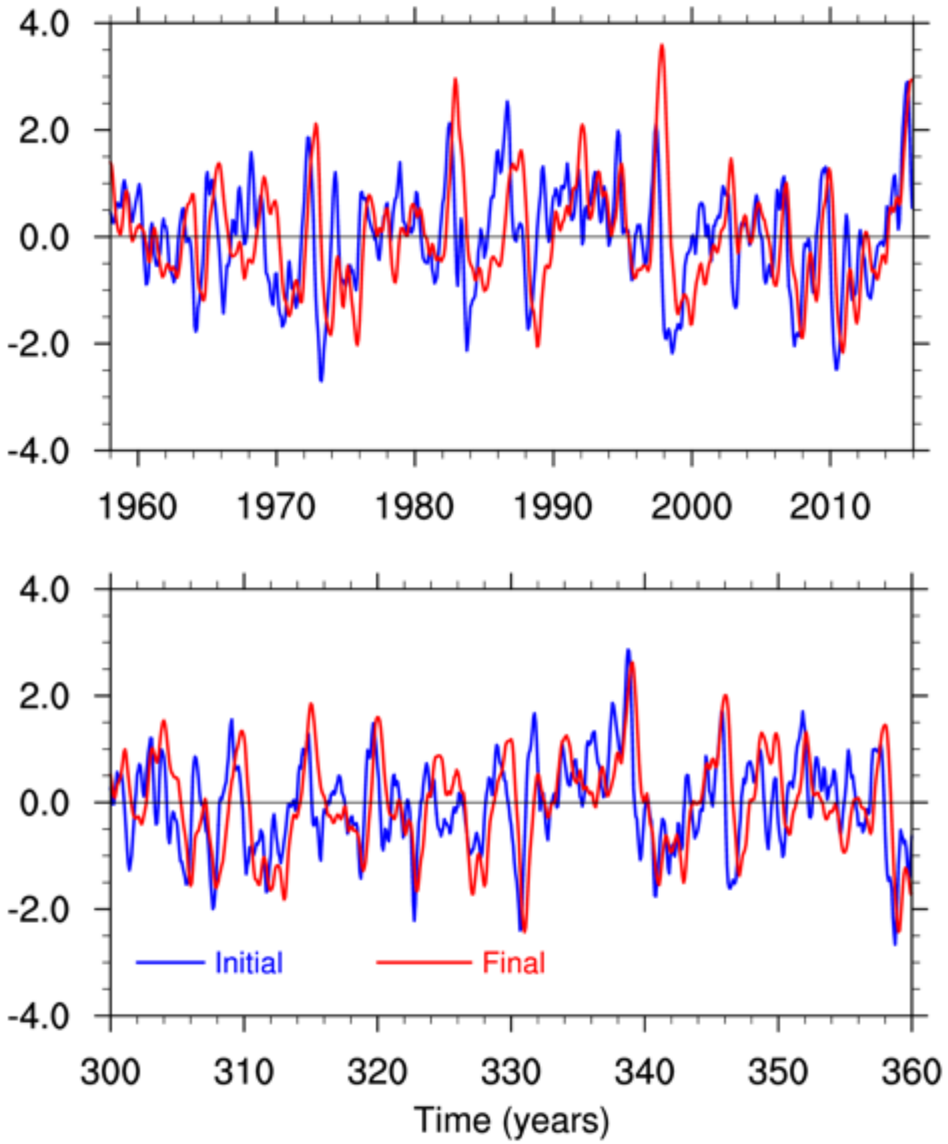


CESM2



Shading: SST, contours: SSH

The optimal initial structures have large correlations with the final structures



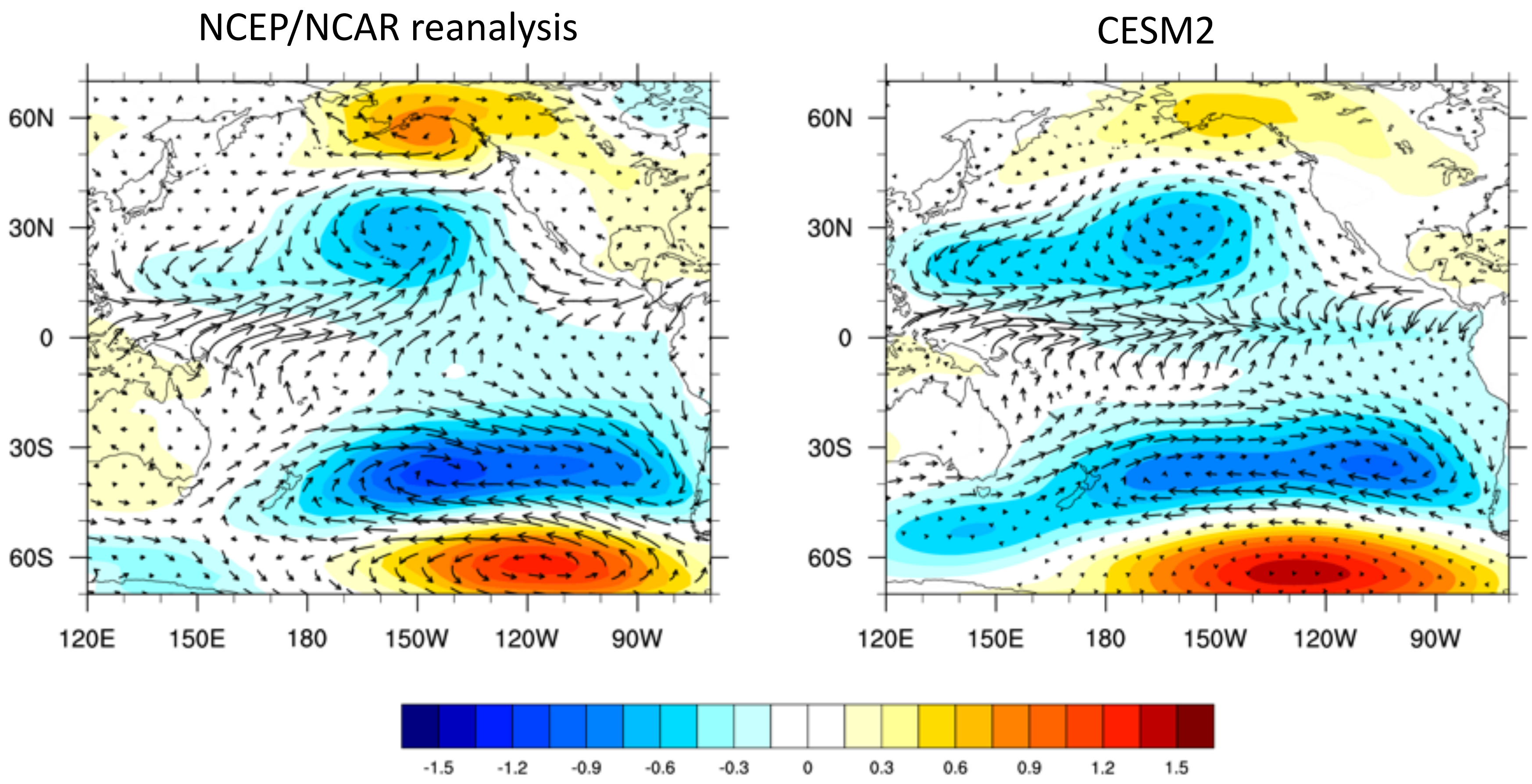
ORAS4

Corr = 0.71, lead 5 months

CESM2

Corr = 0.73, lead 5 months

Large scale SLP anomalies show structures similar to the NPO in the North Pacific and to the SPO in the South Pacific



Shading: SLP (hPa)

E and C modes are not the maximum growing structures in the LIM framework. Use multiple linear regression to determine the optimal initial conditions for E and C modes

$$\boldsymbol{E\_index}\,(\tau) = \boldsymbol{H_E(\tau)}\ \boldsymbol{x_E}(0) + \varepsilon$$

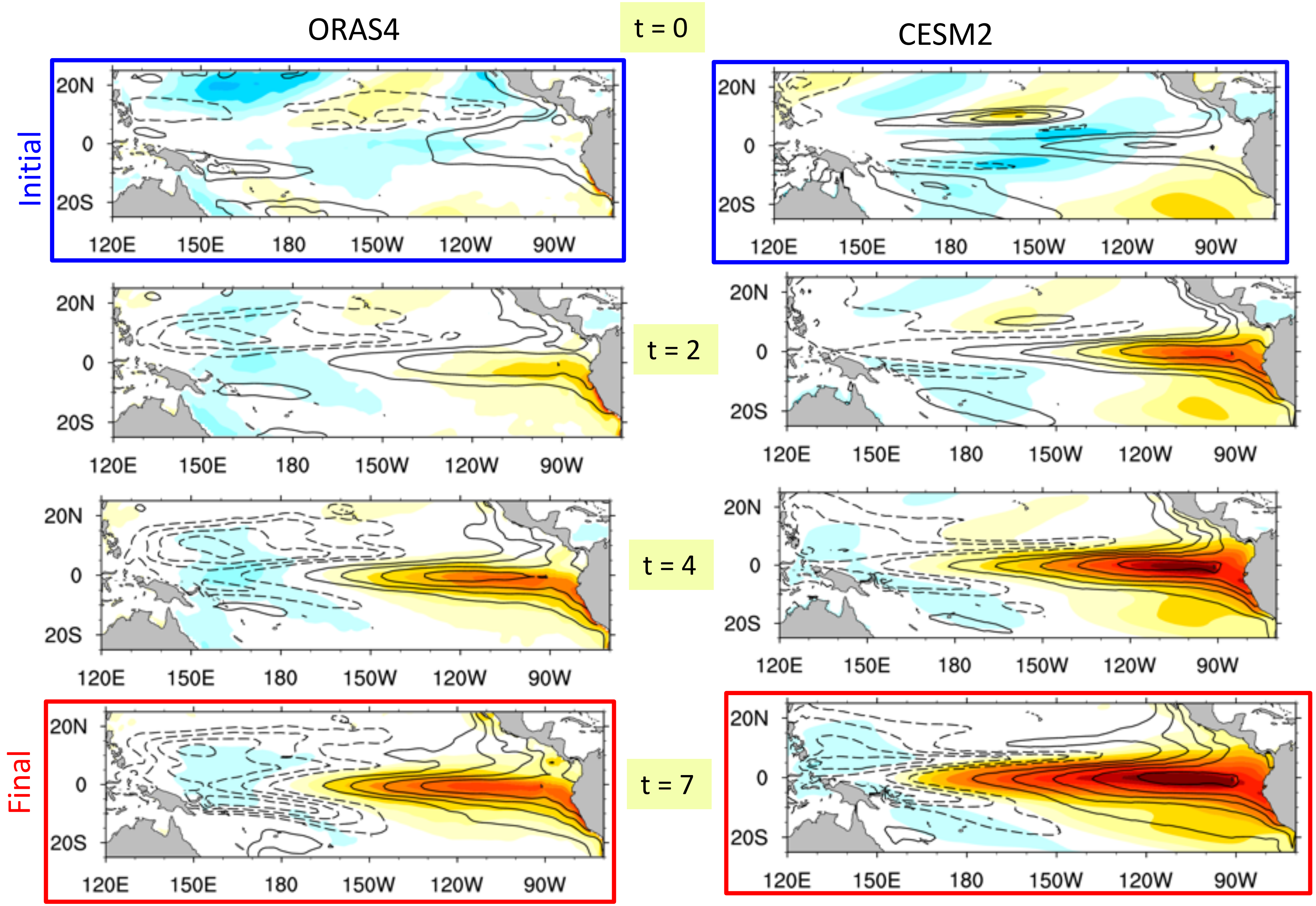
$$\boldsymbol{C\_index}\,(\tau) = \boldsymbol{H_C(\tau)}\ \boldsymbol{x_C}(0) + \varepsilon$$

x (0) Tropical Pacific state vector at time 0

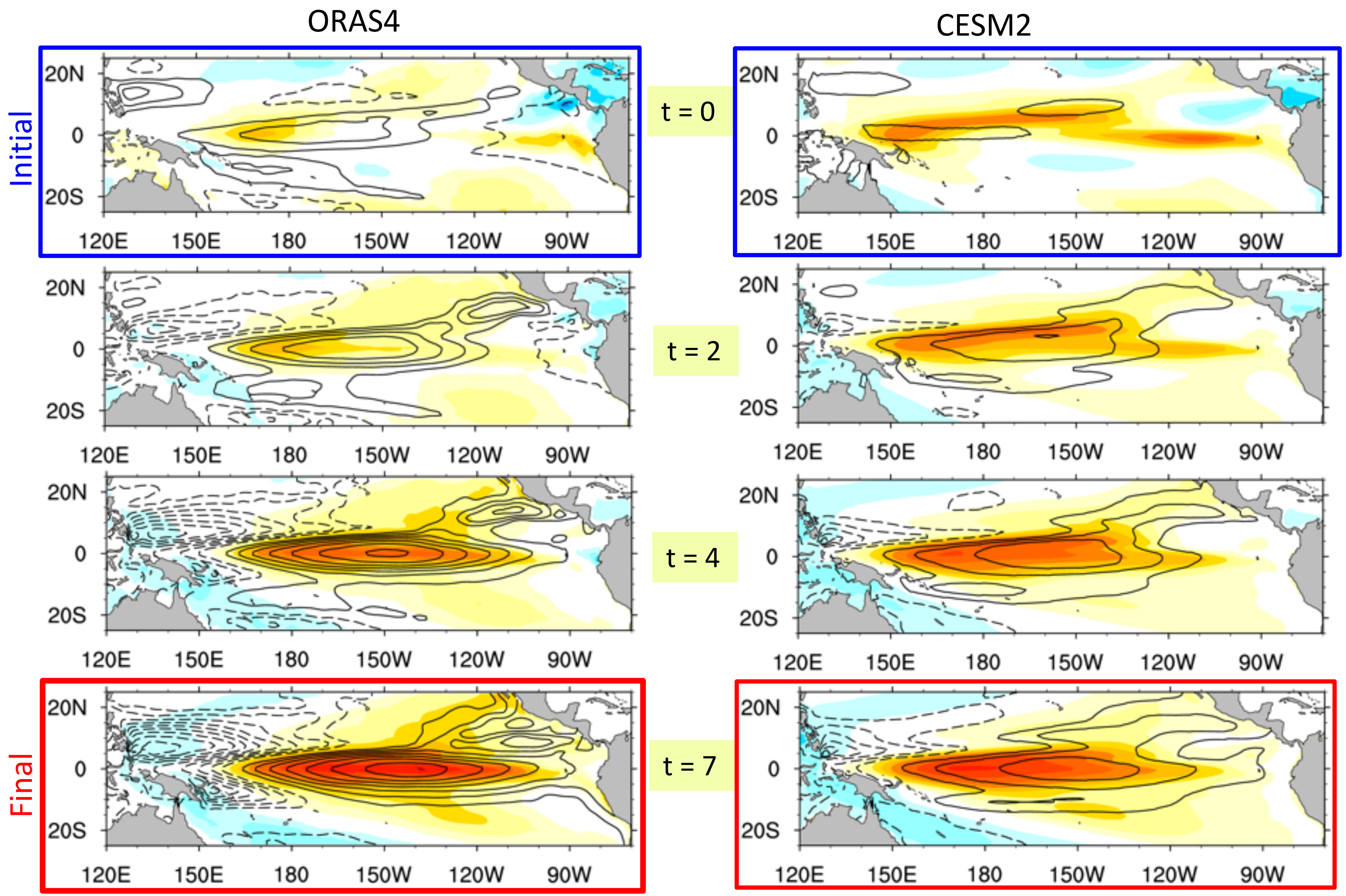
x (0) =[**SST** (0), **SSH**(0)]

Capotondi and Sardeshmukh, 2015

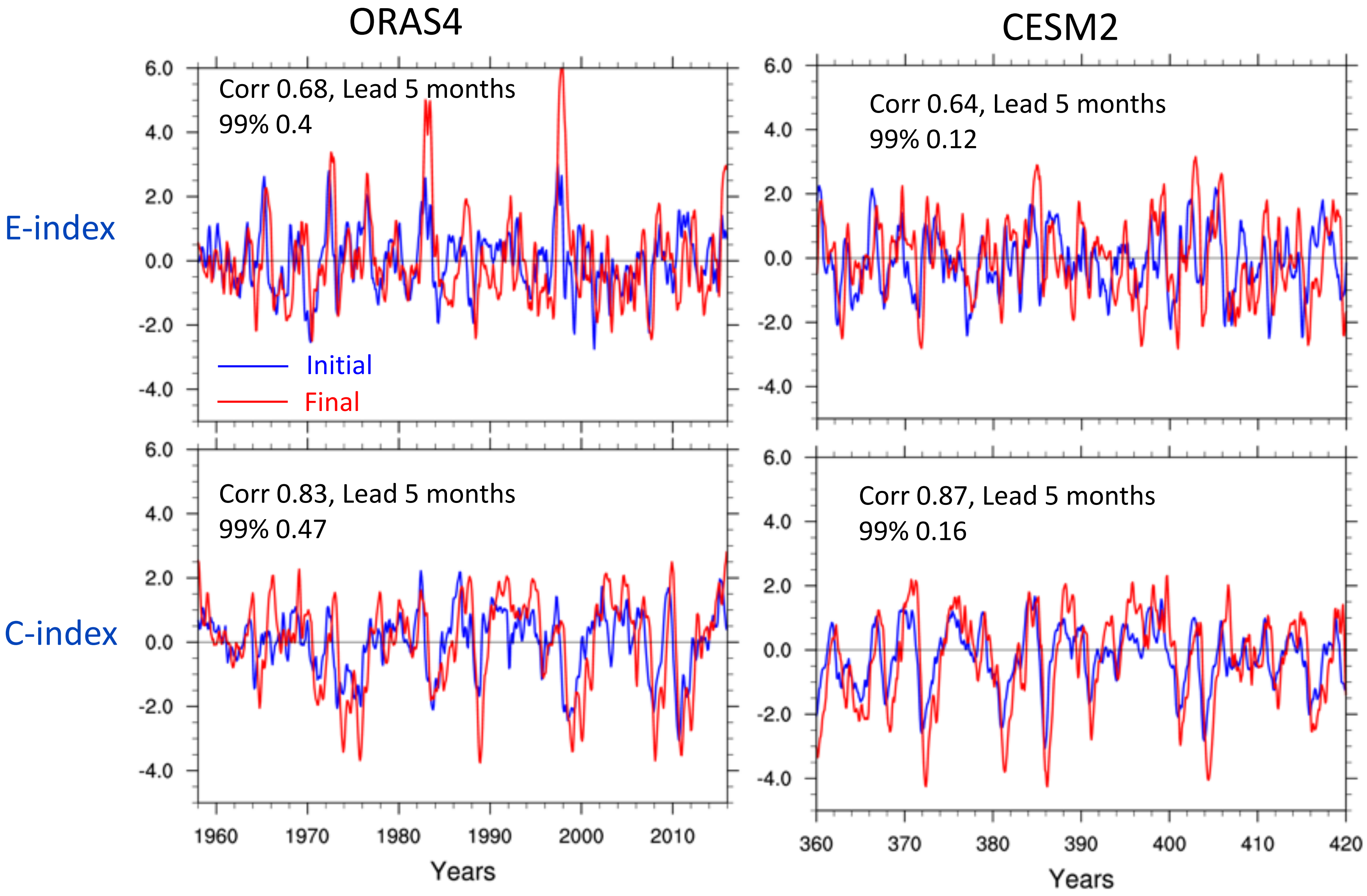
Optimal Structures for E Modes (τ = 7 months)



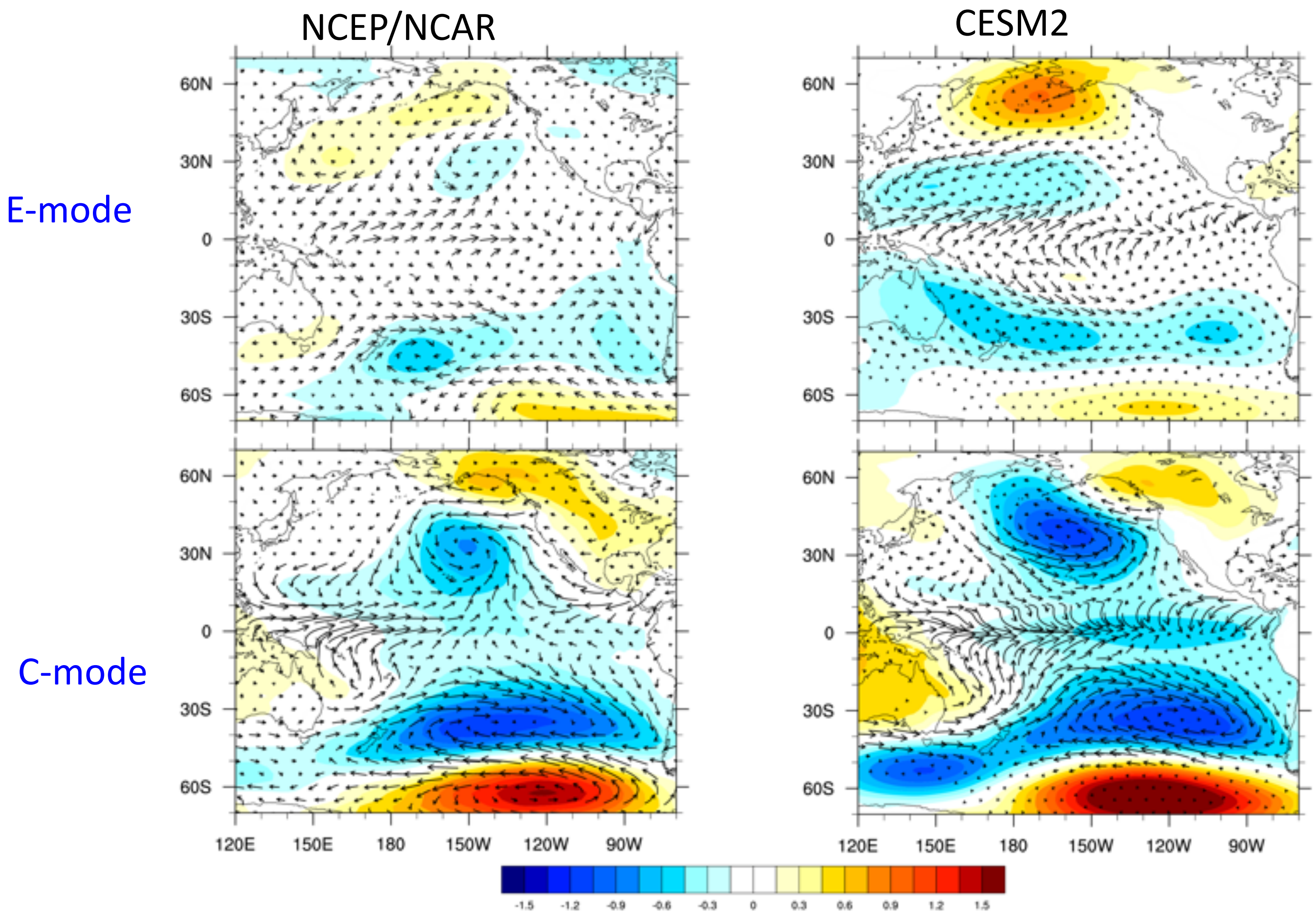
Evolution of Optimal Structures for **C Modes**



Time Series of initial optimals are significantly correlated with E and C indices



Large-scale SLP and wind anomaly fields



Atmospheric fields are weaker for E than C modes. In both cases we see expressions of the NPO and SPO. Easterly in the eastern equatorial Pacific are present in C precursors

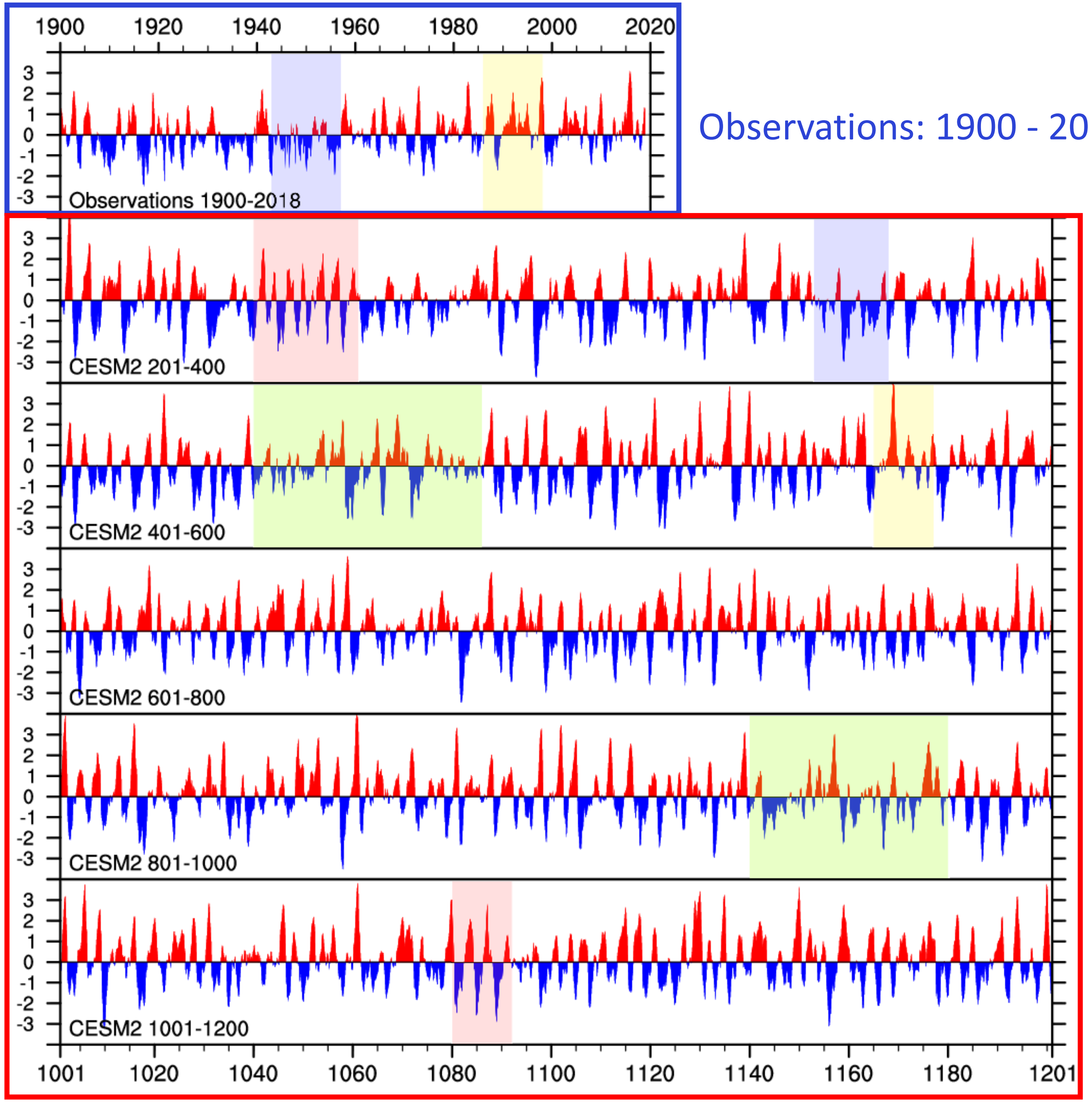
Conclusions

Several aspects of ENSO compare well with observations, but ENSO amplitude is too large and anomalies are displaced too lar west in the model relative to observations limiting the model's ability to represent the full range of ENSO diversity.

Precursors of ENSO diversity are very similar in the model (1000 years) and in the ocean reanalysis (58 years), and evolution of E and C events from the initial to the final conditions are also similar in the model and in ORAS4.

Both CESM2 and ORAS4 show that the leading SST precursors are somewhat similar for E and C modes, but there are differences in SSH precursors, highlighting a possible discriminating role for the ocean subsurface conditions.

Central Pacific El Nino events appear to be more "predictable" of Eastern Pacific events.



Observations: 1900 - 2018

CESM2: 201 -1200

The **Nino-3.4 index** (Area averaged SST in 5^{o}S-5^{o}N, 170^o-120^{o}W) shows irregular behavior similar to the observed, and decadal modulation of its evolution.