Natural variation in ENSO flavors

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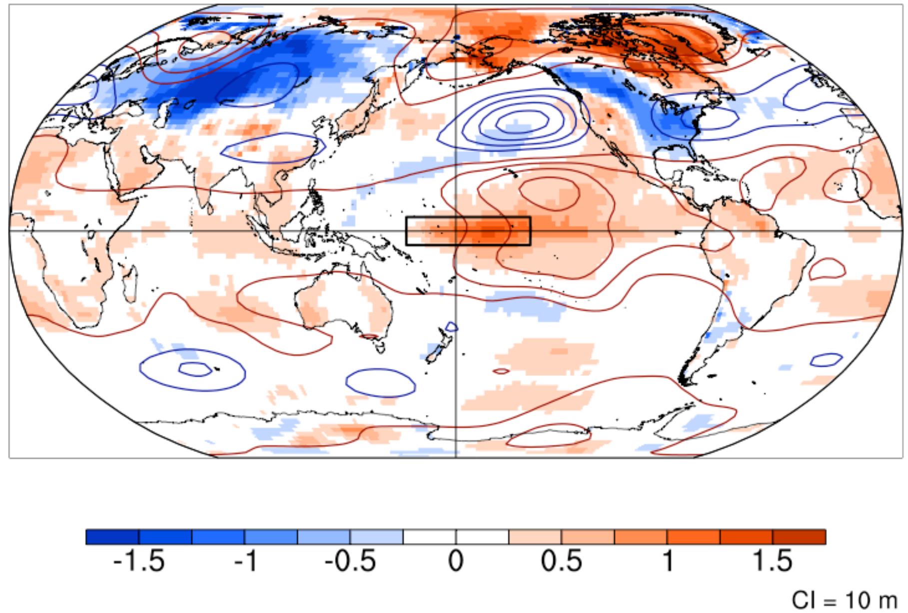
“Central Pacific” (CP) and “Eastern Pacific” (EP) ENSO composites

Surface temperature / 500 mb geopotential height

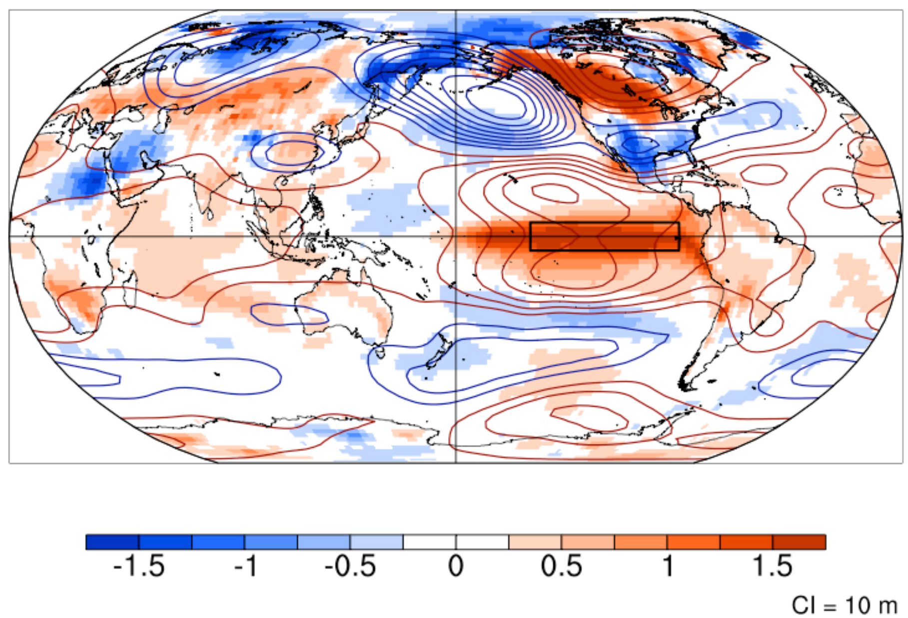
Define:

CP ENSO = Nino4 ≥ 0.5 and Nino4 > Nino3 (aka “New ENSO”)

EP ENSO = Nino3 ≥ 0.5 and Nino3 > Nino4 (aka “ENSO Classic”)



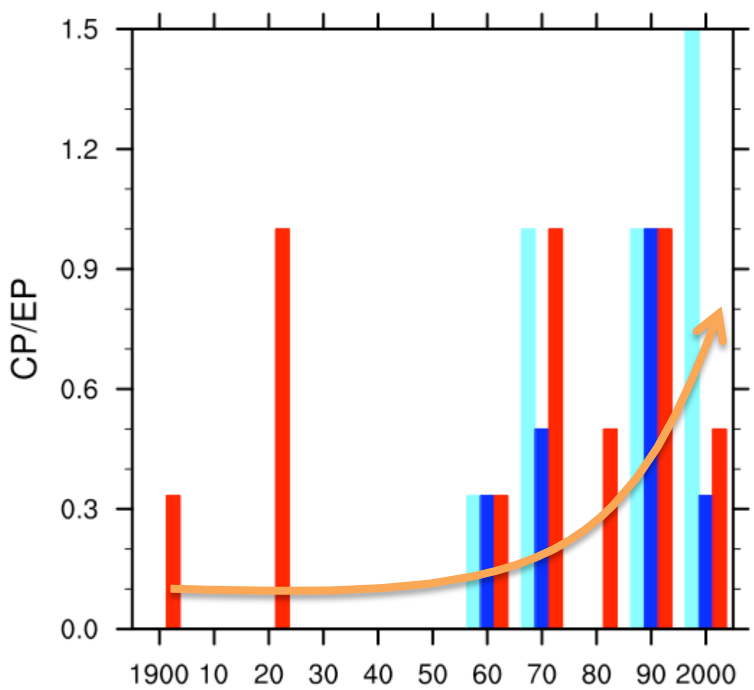
CP



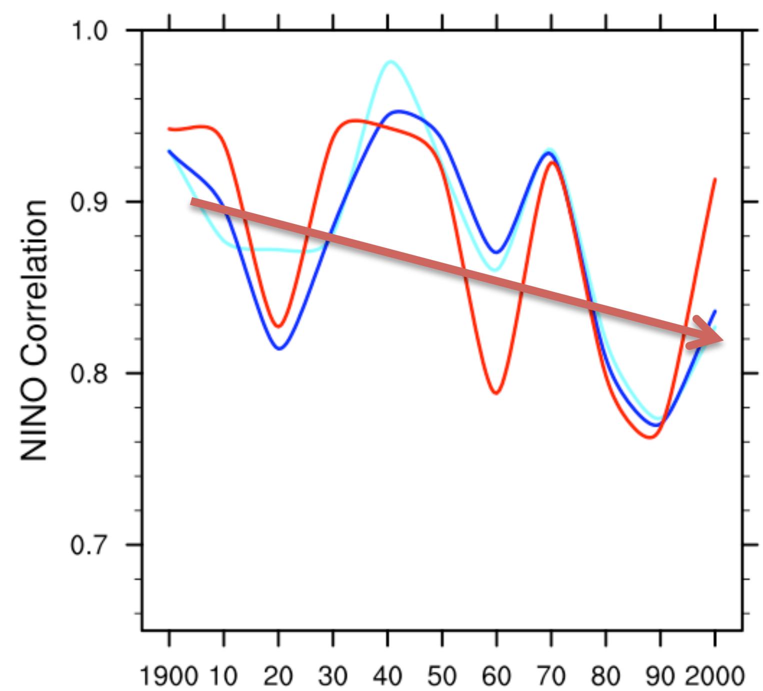
EP

Increasing occurrence of CP ENSOs?

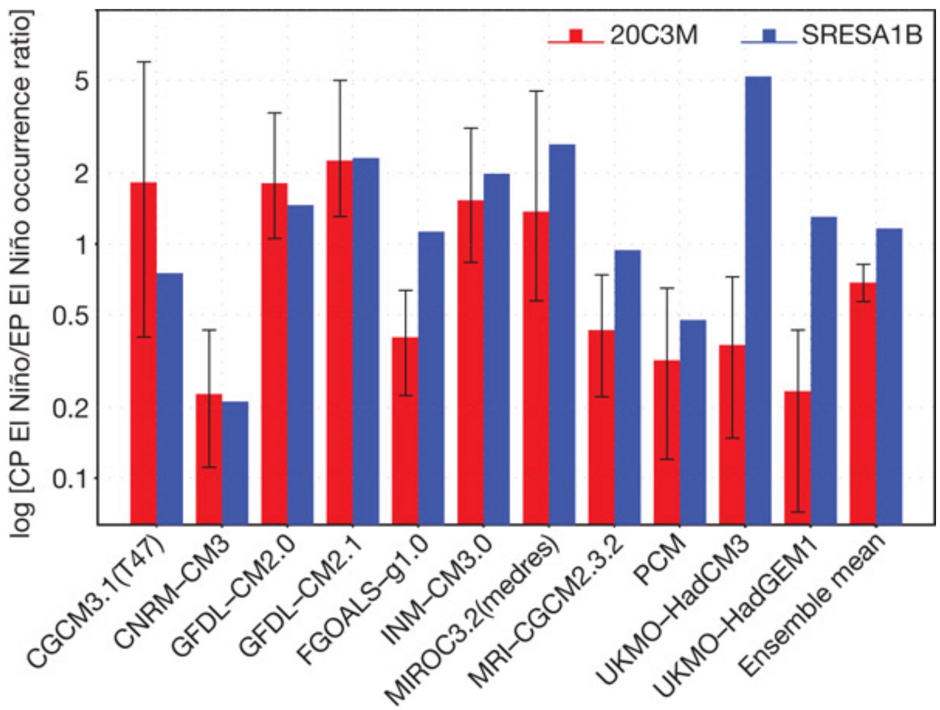
10-year averages of "CP/EP" occurrence ratio
[red:HadISST, blue: NOAA ERSST v.2 (dark) v.3 (light)]



11-year running mean of Nino3-Nino4 correlations determined in a 10-year sliding window
[red:HadISST, blue: NOAA ERSSTv2]



The CP-El Niño/EP-El Niño occurrence ratio increases in “8 out of 11 A1B scenarios”.



S-W Yeh *et al. Nature* (2009)

- Does the apparent recent increase in CP ENSOs reflect decadal "base state" change?

- Does this reflect anthropogenic change?

- To answer these questions, we need to first construct a suitable *null hypothesis*:

Observed changes in ENSO characteristics are consistent with natural seasonal variability with stationary statistics

"Multivariate Red Noise" null hypothesis

- Noise/response is local (or an index)
  - For example, air temperature anomalies force SST
  - use univariate ("local") red noise:

    $dx/dt = bx + f_s$ where $x(t)$ is a scalar time series, b<0, and f_s is white noise

- Noise/response is non-local: patterns matter
  - For example, SST sensitive to atmospheric gradient
  - use multivariate ("patterns-based") red noise:

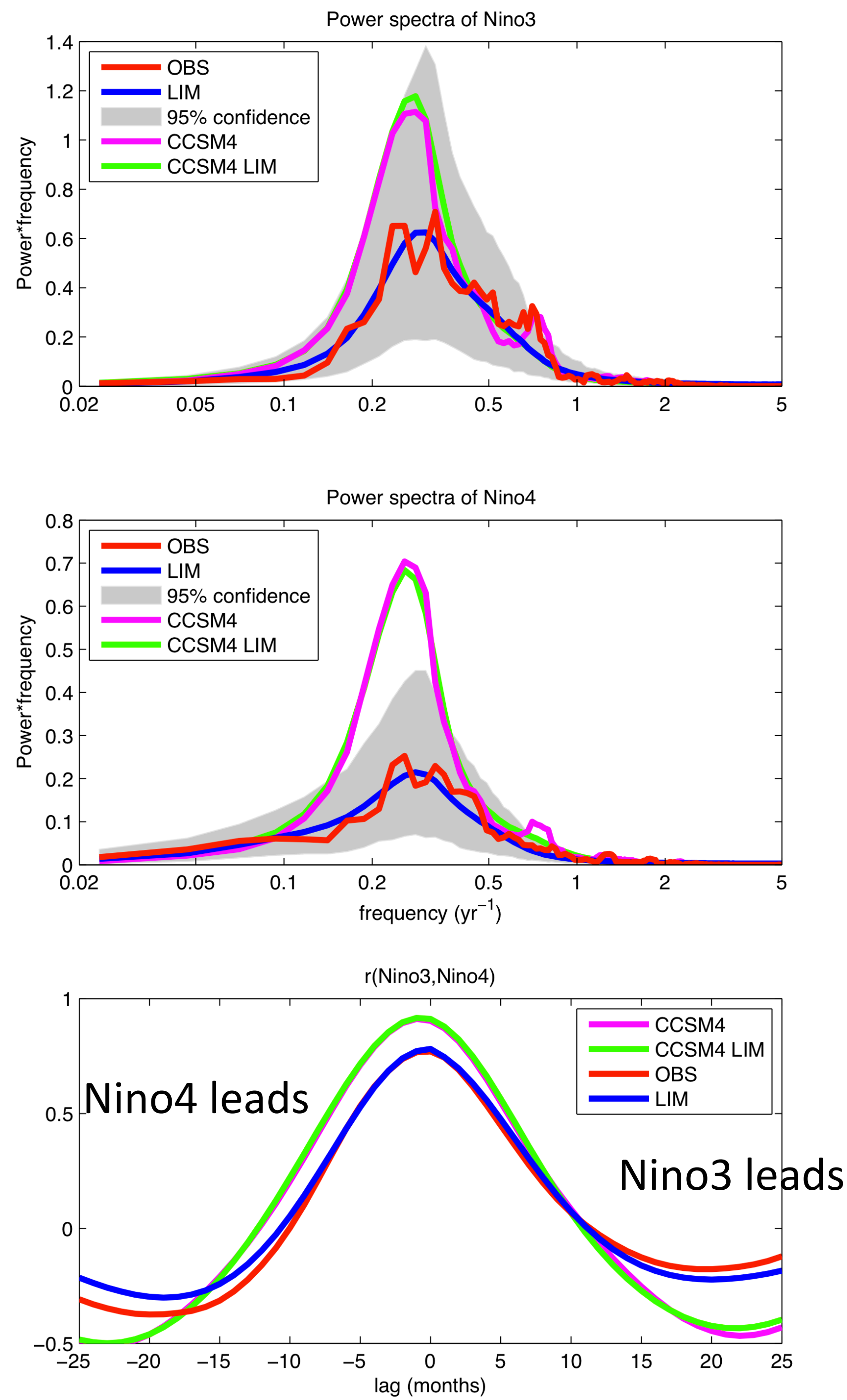
    $d\mathbf{x}/dt = \mathbf{Bx} + \mathbf{F}_s$ where $\mathbf{x}(t)$ is a series of maps, **B** is stable, and $\mathbf{F}_s$ is white noise (maps)

- Determine **B** and $\mathbf{F}_s$ using "Linear Inverse Model" (LIM)
  - ***x*** is ***SST/20 C depth/surface zonal wind stress*** seasonal anomalies in Tropics, 1959-2000 (Newman et al. 2011, *Climate Dynamics*)
  - LIM determined from specified lag (3 months) as in AR1 model

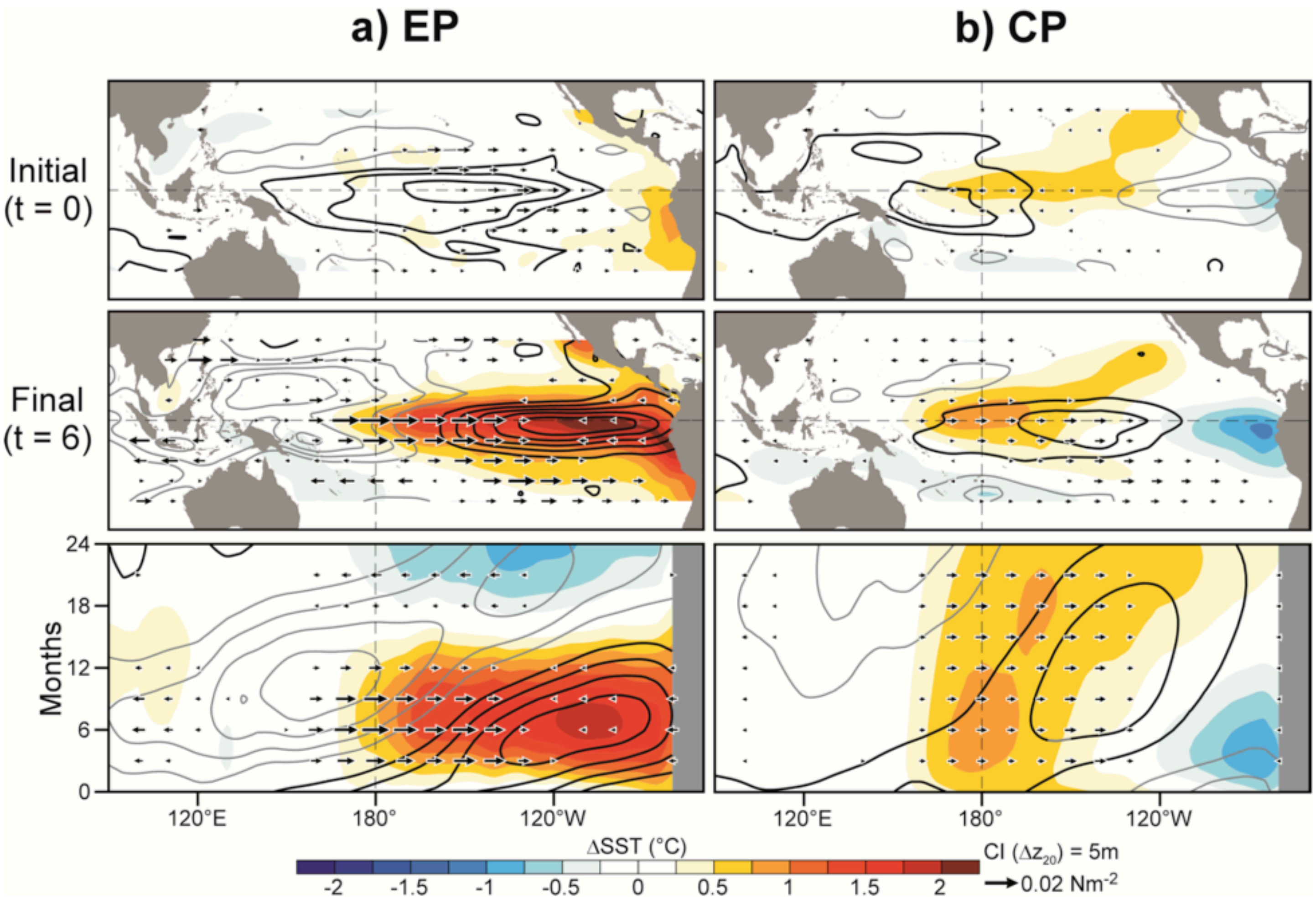
Verifying multivariate red noise: LIM spectra

OBS: HadISST 1959-2007

CCSM4: From 500-yr control run



Multivariate red noise captures "optimal" evolution of both ENSO types

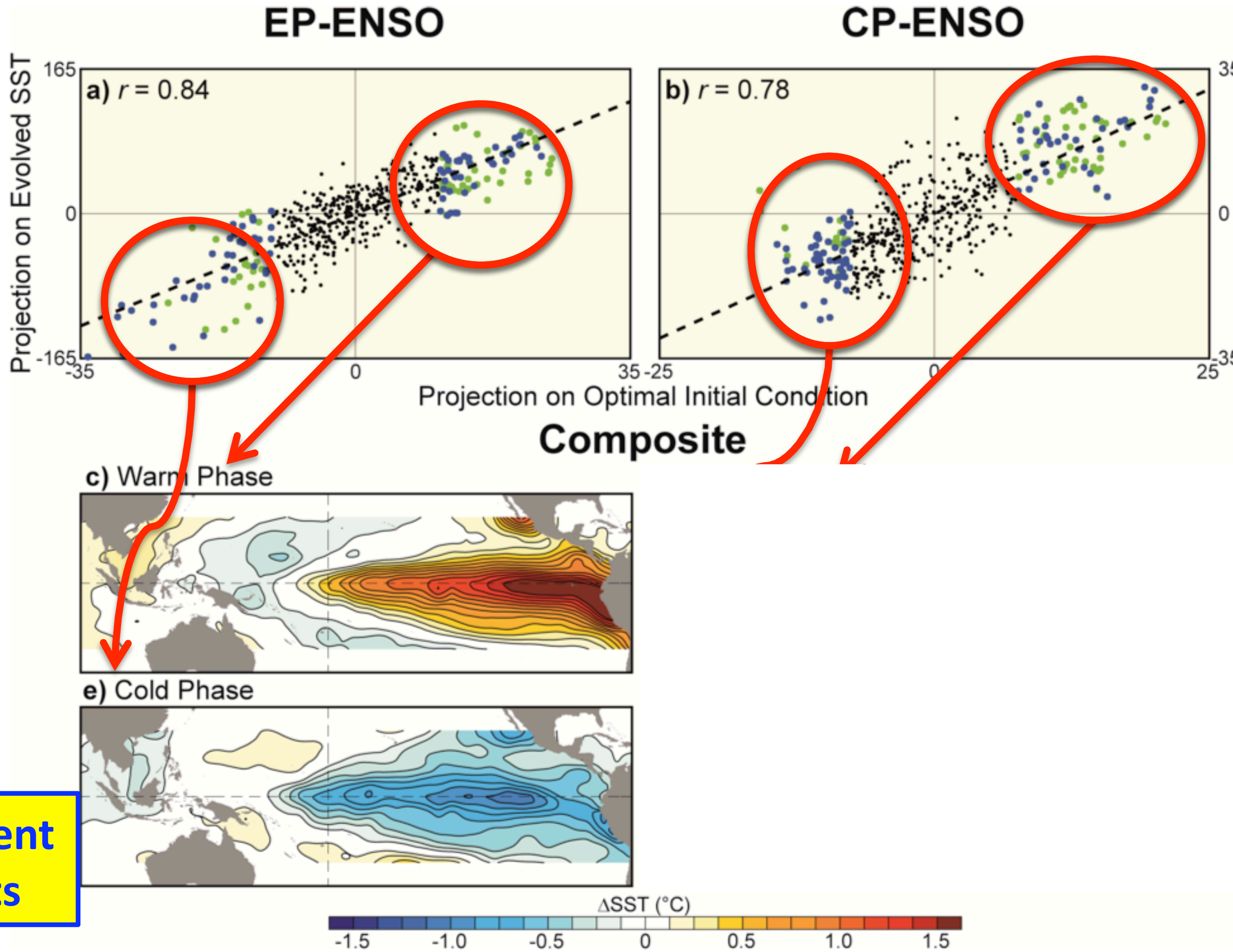


Along equator

SST: shading
Thermocline depth: contours
Zonal wind stress: vectors

Optimal structures are relevant to observed EP and CP ENSO events

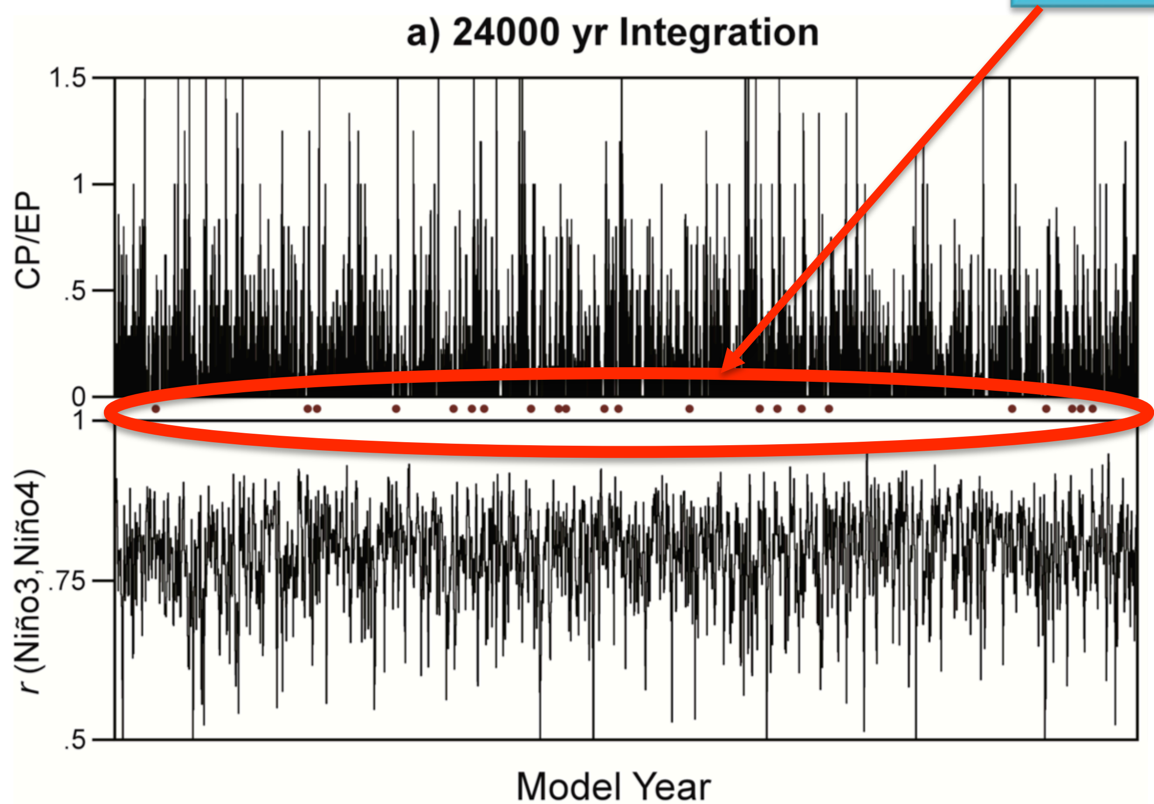
Composite:
Six months ***after*** a > ± 1 sigma projection (blue dots) on ***either*** the first or second optimal initial condition, constructed separately for warm and cold events



Green dots represent mixed EP-CP events

Variations of CP/EP ENSOs driven by noise

"Increasing CP/EP Cases":
Two adjacent 60-yr segments where
1) CP/EP ratio increases
2) *r*(Nino3,Nino4) decreases



24000 yr LIM "model run": $dx/dt = \mathbf{Bx} + \mathbf{F}_s$
Values determined over 30-yr intervals spaced 10 years apart

Conclusion

- **Multivariate ("patterns-based") red noise is a useful null hypothesis for testing changes in the nature of ENSO**
  - Different spatial patterns of "noise" can lead to central vs. eastern Pacific ENSO events or various combinations thereof
  - Natural random variations are large enough to account for observed and A1B projected variations of Nino3-Nino4 correlation and CP-EP ratio including apparent multidecadal "trends" during which these values increase or decrease
- **Climate indices are univariate measures of a multivariate system.**

  Changes in climate variability should at least be tested against multivariate red noise