Natural variation in ENSO flavors

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

Define:

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

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

GI = 10 m
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]

• 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:
    \[ \frac{dx}{dt} = bx + f_s \]
    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:
    \[ \frac{dx}{dt} = Bx + F_s \]
    where \( x(t) \) is a series of maps, \( B \) is stable, and \( F_s \) is white noise (maps)
- Determine \( B \) and \( F_s \) 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
Multivariate red noise captures “optimal” evolution of both ENSO types

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.
“Optimals” time series
Variations of CP/EP ENSOs driven by noise

“Increasing CP/EP Cases”: Two adjacent 60-yr segments where
1) CP/EP ratio increases
2) $r(\text{Nino3}, \text{Nino4})$ decreases

24000 yr LIM “model run”: $dx/dt = Bx + F_s$
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**
  – Constrained merely by average simultaneous and 3-month lagged relationships between different locations and variables

• **Natural random variations are large enough to account for**
  – all observed variations of Nino3-Nino4 correlation
  – all observed variations of the CP-EP occurrence ratio
  – all projected differences found in the SRESA1B runs of all AR4 climate models

• **Apparent multidecadal “trends” during which these values increase or decrease are also consistent with red noise**

• **Different spatial patterns of “noise” can lead to the development of central vs. eastern Pacific ENSO events or various combinations thereof**
Repeat analysis in the CCSM4
(500 years of PI Control Run)
CCSM4 and observed spectra with multivariate red noise “background”

- Nino3 strong, too peaked
- Nino4 way too strong, too peaked
- Nino3 and Nino4 too strongly related
- Multivariate red noise fit is very good
Variations of CP/EP ENSOs driven by noise

21000 yr LIM (from CCSM4) “model run”:  \( \frac{dx}{dt} = Bx + F_s \)

Values determined over 30-yr intervals spaced 10 years apart
EP cold composite

OBS

EP composite (cold phase), six months lead  

EP composite (cold phase)  

CCSM4

EP composite (cold phase), six months lead  

EP composite (cold phase)  

t=-6 months  
t=0  

t=-6 months  
t=0
Multivariate red noise captures “optimal” evolution of both ENSO types

Optimal EP

Optimal CP

SST: shading
Thermocline depth: contours
Zonal wind stress: vectors
Optimal structures are relevant to observed EP ENSO events in the CCSM4 (but not CP?)

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