Contrasting El Niño Southern Oscillation events in the tropical Pacific using Sea Surface Salinity observations

Awnesh Singh*, Thierry Delcroix, Sophie Cravatte

IRD/LEGOS-OMP, UMR 5566, 14 Avenue Edouard Belin, 31400 Toulouse, France

***Email: awnesh.singh@legos.obs-mip.fr**

EGU2011-7802

Introduction

The El-Niño Southern Oscillation (ENSO) phenomenon is the **strongest climatic signal** on an interannual timescale and greatly affects the world population[1].

- **New type** of El Niño (La Niña)[2]
- Added a new dimension to the **ENSO climatic puzzle**
- Different ENSO episodes have **different impacts** on weather and climate at both global and regional scales[3]

During this **new type/flavor** of El Niño (La Niña), the maximum (minimum) sea surface temperature anomalies are confined in the equatorial central Pacific (CP), in contrast to the conventional El Niño (La Niña), when they occur in the eastern Pacific (EP; see ***Figure 1***).

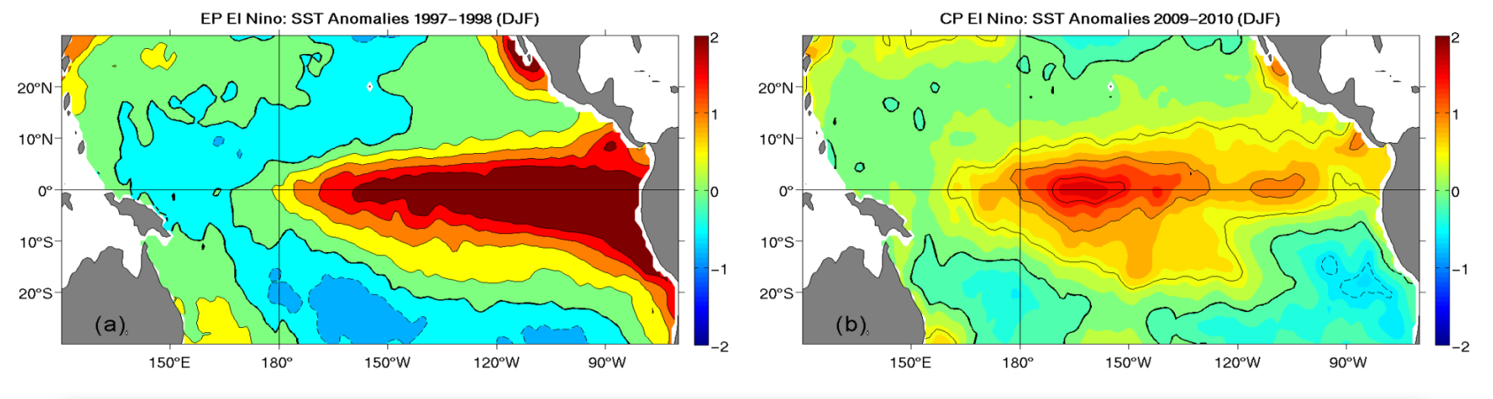


Figure 1. Sea surface temperature anomalies for the (a) 1997-98 EP El Niño, and (b) 2009-10 CP El Niño.

Being an **essential variable** of the global climate observing system[4], sea surface salinity is also affected by the ENSO cycle.

Objective: *To contrast the different flavors of ENSO using sea surface salinity observations.*

Data and Methodology

Datasets used:

- sea surface salinity[5] (SSS)
- sea surface temperature[6] (SST)
- precipitation[7] (P)
- surface zonal currents[8] (U)
- new ENSO indices[9] (N_{CT} and N_{WP})

Data treatment:

- detrending (except for trends calculation)
- removal of mean monthly climatology
- smoothing using a 13-months Hanning filter

Data analysis procedures used to characterize the different ENSO signatures:

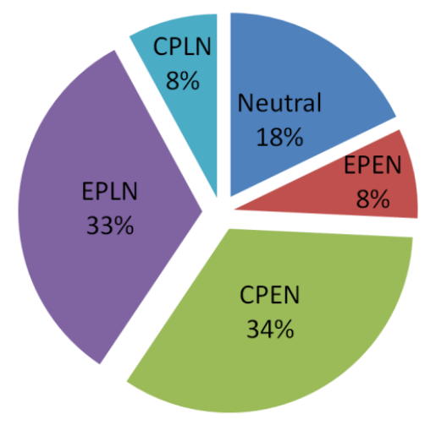
- empirical orthogonal function (EOF)
- agglomerative hierarchical clustering (AHC)
- linear and multivariate regression
- combined regression-EOF
- neural networks

Observations

The AHC technique was found to be **rather sensitive** to the selected SSS data coverage, error field and data processing. Hence, we show only the **robust** clusters. Five clusters (see ***Figure 2***) were identified in the region 20°S-10°N and 120°E-70°W.

The five clusters **characterize**:

- Neutral
- EP El Niño (EPEN)
- CP El Niño (CPEN)
- EP La Niña (EPLN)
- CP La Niña (CPLN)



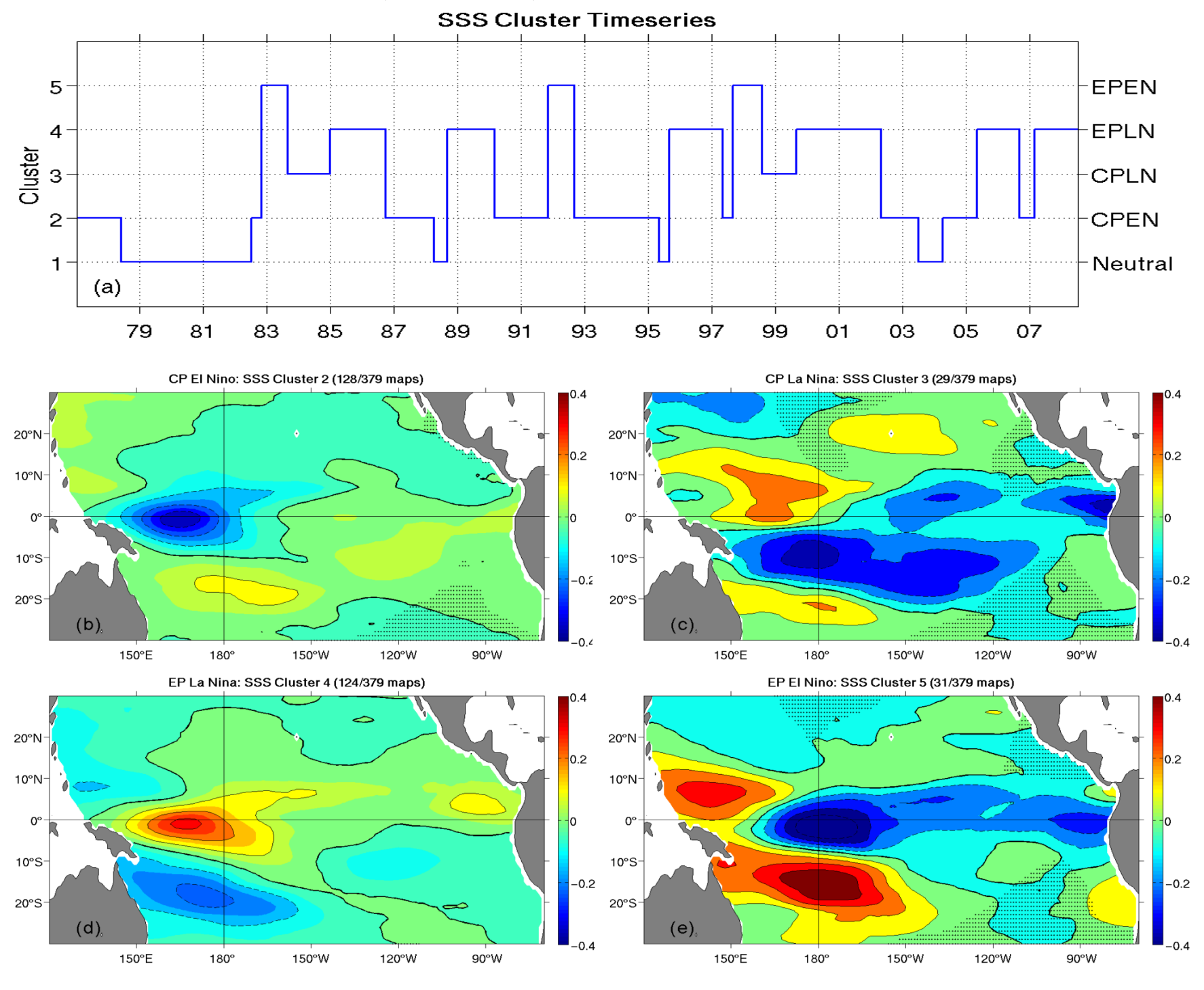


Figure 2. (a) The cluster timeseries and spatial structures from the AHC technique on SSS anomalies with (b) cluster 2 showing CPEN, (c) cluster 3 showing CPLN, (d) cluster 4 showing EPLN, and (e) cluster 5 showing EPEN conditions.

ENSO years as determined from the AHC procedure

EPEN	CPEN	EPLN	CPLN
1982-83	1977-78	1985-86	1983-84
1991-92	1986-88	1988-89	1998-99
1997-98	1990-91	1996-97	
	1992-95	1999-01	
	2002-03	2005-06	
	2004-05	2007-08	
	2006-07		

Explanations

Figure 3 illustrates the tight relationships between the 2°S-2°N averaged SSS, P and U over their respective measurement periods.

The **zonal displacements** of the **eastern edge of the western Pacific warm pool (WPWP)**:

- Characterized by the 34.8 isohaline positions
- Agree well with both the zonal currents direction and heavy precipitation location
- Corroborates with earlier results[10]

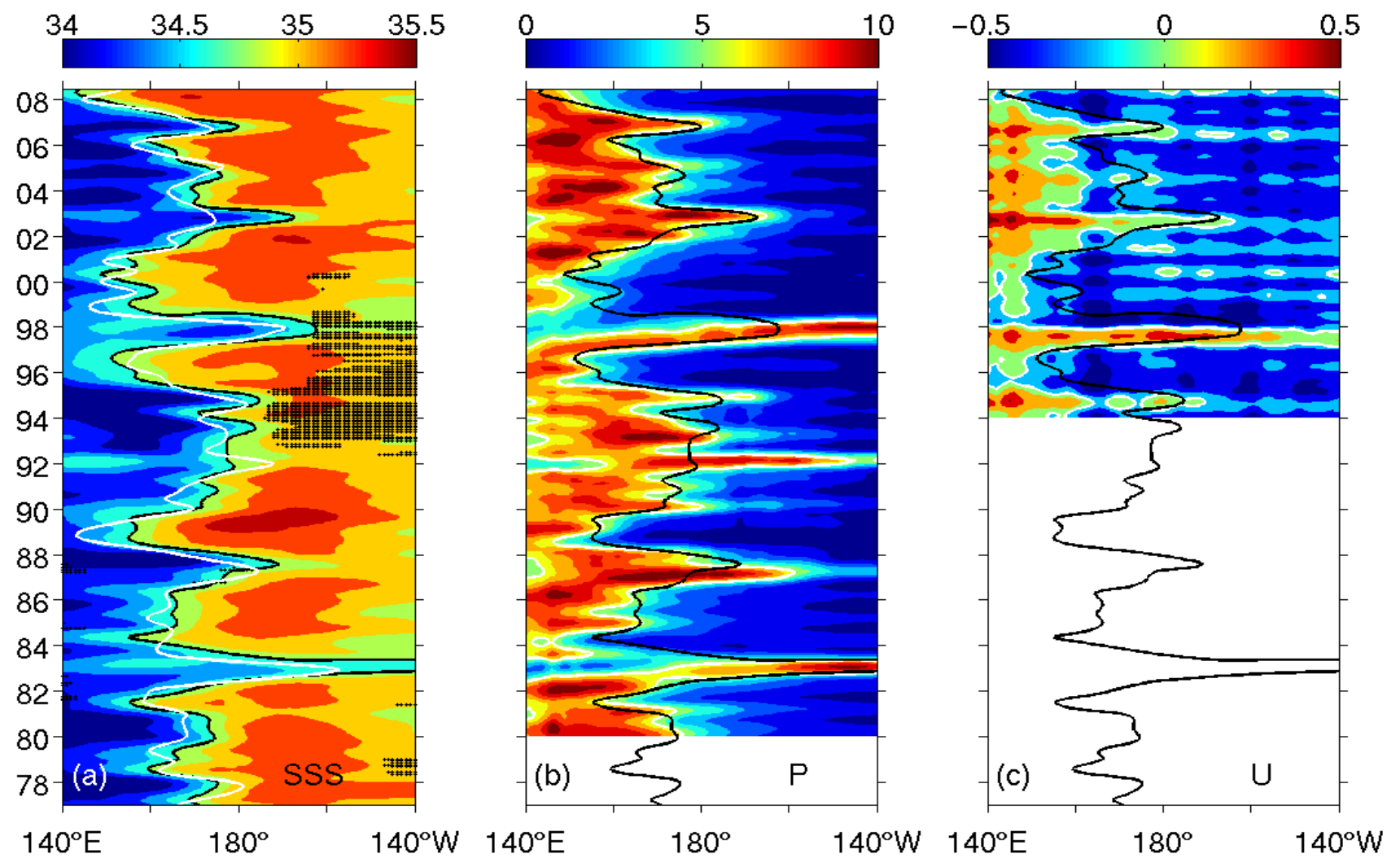


Figure 3. Time-longitude distribution of the 2°S-2°N averaged (a) SSS, (b) P, and (c) U showing the 34.8 isohaline positions in black, and in white, the SOI in (a), 6 mm day^{-1} isohyet in (b) and 0 m s^{-1} isotack in (c).

The **South Pacific Convergence Zone (SPCZ)** region has been shown to portray large interannual variability in terms of SST, SSS, P and U. Consequently, the P signal was extracted from the **SSS cluster timeseries** using a lag of 3 months for each cluster from 1980-2008 (see ***Figure 4***).

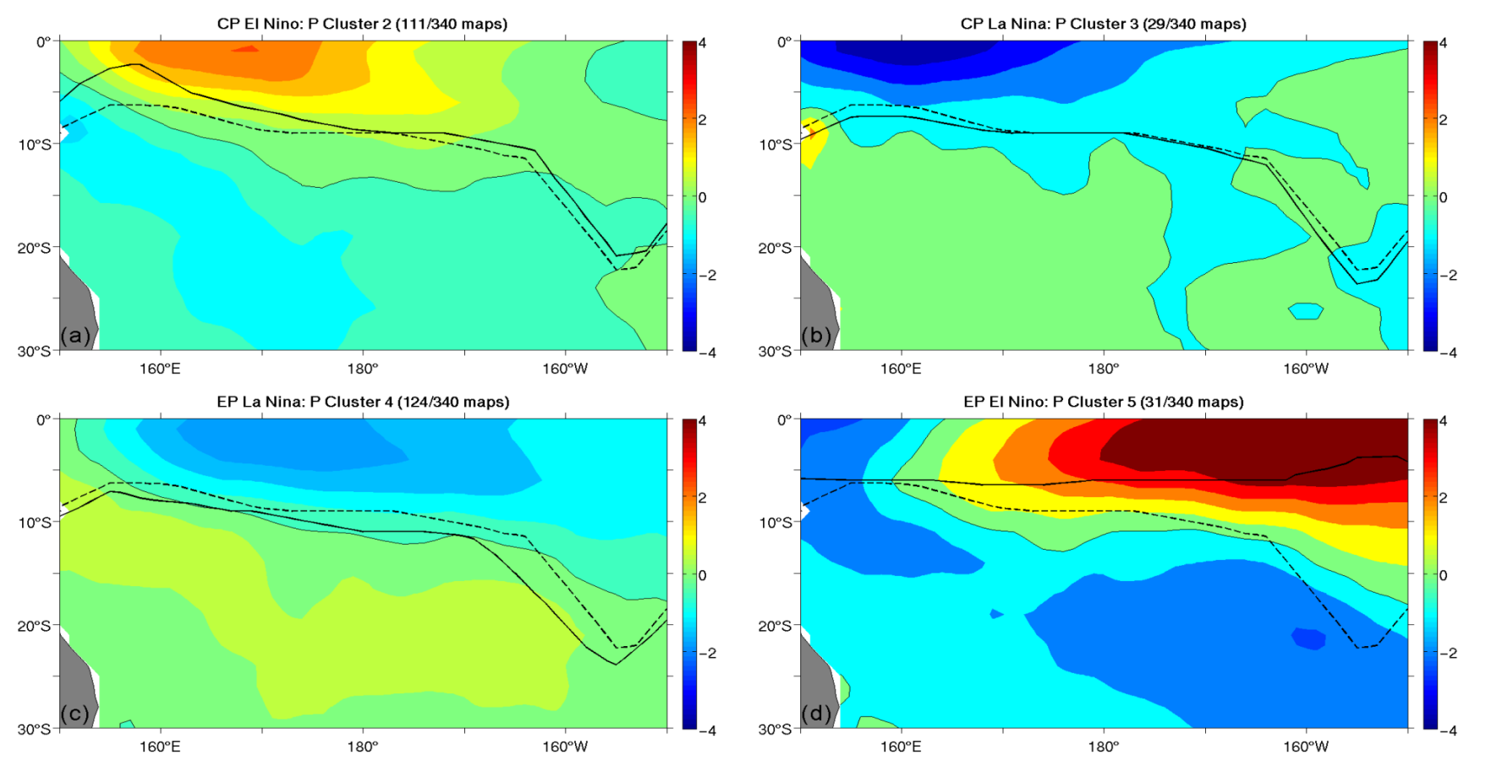


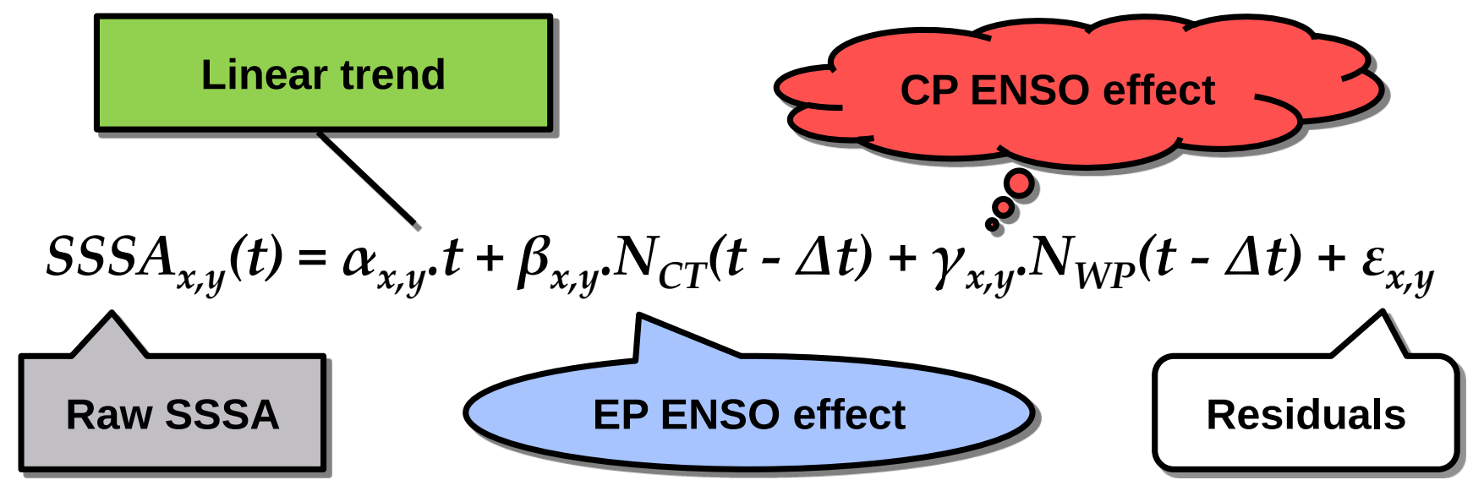
Figure 4. P anomalies and SPCZ position as calculated from the SSS cluster timeseries during (a) CPEN, (b) CPLN, (c) EPLN, and (d) EPEN. The mean SPCZ position is in dashed black.

(Non-) ENSO Trends in SSS

It is important to isolate the low frequency natural variability (for example, ENSO) from the anthropogenic induced climate variability. This will enable us to determine the actual **effects of ENSO on long term trends**.

Multivariate regression on 1955-2008 SSSA:

- 1971-2000 monthly climatology removed
- EP and CP ENSO events characterized by uncorrelated ENSO indices, N_{CT} and N_{WP}[9]
- SSS error field taken into account (error < 0.8)
- Gradients obtained were used to reconstruct the SSS anomalies according to the equation:



$$SSSA_{x,y}(t) = \alpha_{x,y}.t + \beta_{x,y}.N_{CT}(t - \Delta t) + \gamma_{x,y}.N_{WP}(t - \Delta t) + \varepsilon_{x,y}$$

SSS trends per 50 years were then calculated for the raw SSSA and the first three terms on the right in the equation above. These represent the **long term trends** and **trends due to EP ENSO, CP ENSO and non-ENSO**, respectively (see ***Figure 5***).

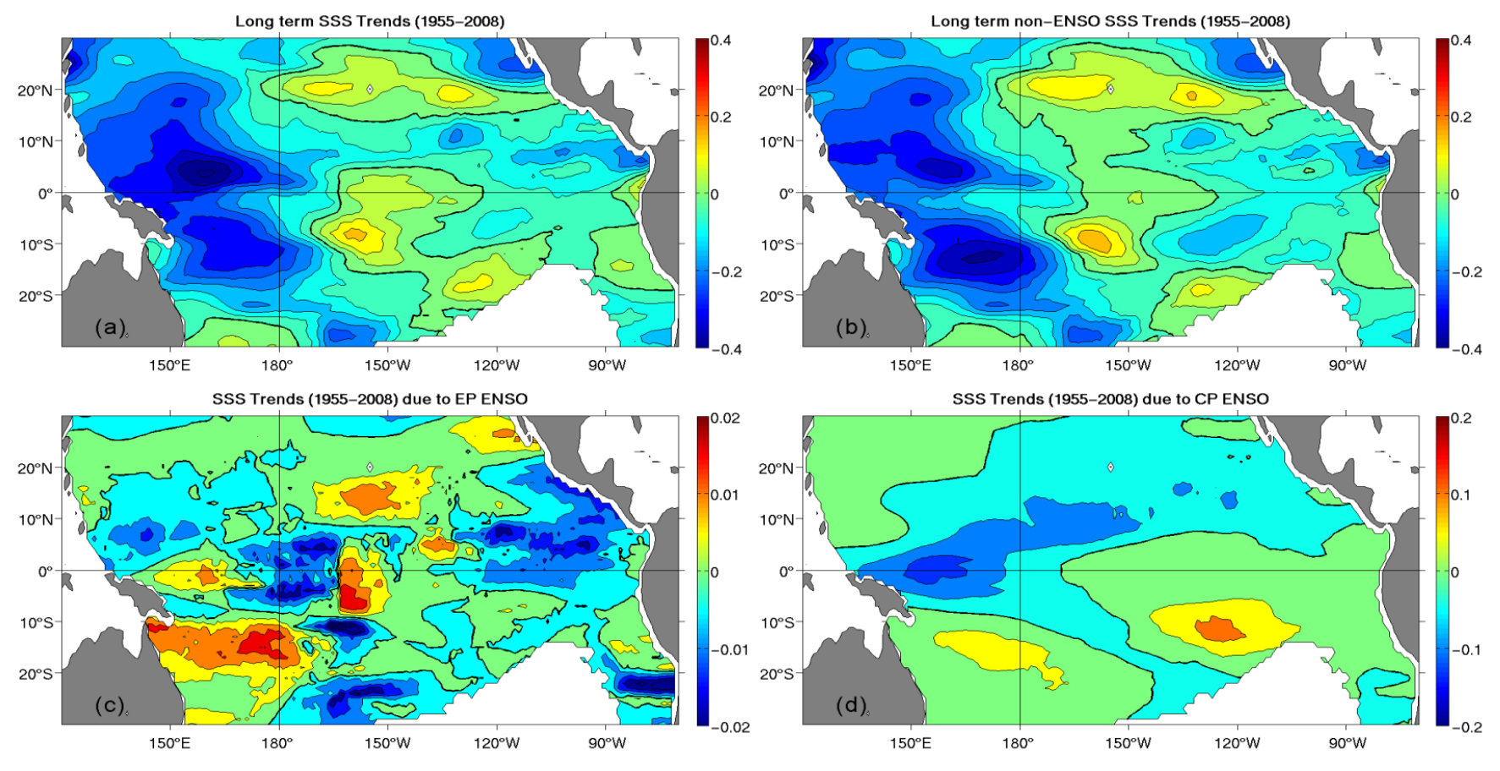


Figure 5. SSS trends over 1955-2008 due to (a) long term SSS variability, (b) long term non-ENSO variability, (c) EP ENSO, and (d) CP ENSO. Note the different scales in the plots. Units are in pss/50 years.

Trends contribution:

- Long term trends are consistent with earlier studies but for different analysis periods[11,12]
- CP (EP) ENSO accounts for ~23% (<1%) of the freshening trends in the WPWP region
- Reduced (increased) freshening in the SPCZ (ITCZ and far western Pacific) regions is due to CP ENSO

Conclusions

"… no two El Niño events are quite alike."
(Wyrtki, 1975)

In general, EP and CP El Niño (La Niña) events result in a **SSS freshening (saltening)** in the western half of the equatorial Pacific and a SSS increase (decrease) in the SPCZ mean area.

The EP and CP El Niño events, however, have distinct quantitative SSS signatures. In the **equatorial Pacific**, EP El Niño events are characterized by a maximum SSS freshening (~ -1) near the dateline and a strong (~30° longitude) eastward displacement of the 34.8 isohaline, materializing the eastern edge of the low-salinity warm pool waters. During CP El Niño events, the maximum SSS freshening is shifted westward by about 15° longitude and the eastward displacements of the 34.8 isohaline are only about half the EP El Niño amplitude.

In the **SPCZ mean area**, EP El Niño events are characterized by a well-marked increase (~ +1) in SSS, which is about 2-3 times less during CP El Niño events.

A qualitative analysis of the two main terms of the SSS balance strongly suggest that zonal advection by surface currents (U) and precipitation (P) changes are the **main mechanisms** responsible for the ENSO signatures in SSS.

SSS trends calculated over 1955-2008 show that the overall effect of CP ENSO is **~5 times more** than EP ENSO on the long term freshening trends. In comparison, **~75%** of the trends are accounted for by the **non-ENSO influence**. CP ENSO is responsible for the reduced (increased) freshening in the SPCZ (ITCZ and far western equatorial) regions.

References

1. McPhaden, M.J., Zebiak, S.E. & Glantz, M.H. **Science** (2006).
2. Ashok, K. *et al*. **Journal of Geophysical Research** (2007).
3. Larkin, N.K. & Harrison, D.E. **Geophysical Research Letters** (2005).
4. GCOS. **World Meteorological Organization** (2004).
5. Delcroix, T. *et al*. **Deep Sea Research I** (2011).
6. Rayner, N.A. *et al*. **Journal of Geophysical Research** (2003).
7. Huffman, G.J. *et al*. **Geophysical Research Letters** (2009).
8. Bonjean, F. & Lagerloef, G.S.E. **Journal of Physical Oceanography** (2002).
9. Ren, H.-L. & Jin, F.-F. **Geophysical Research Letters** (2011).
10. Picaut, J. *et al*. **Journal of Geophysical Research** (2001).
11. Cravatte, S. *et al*. **Climate Dynamics** (2009).
12. Durack, P.J. & Wijffels, S.E. **Journal of Climate** (2010).

* Singh, A., Delcroix, T. & Cravatte, S. **Journal of Geophysical Research** in press(2011).