ENSO Diversity Working Group (2012-2015)

Antonietta Capotondi and Ben Kirtman

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Motivation

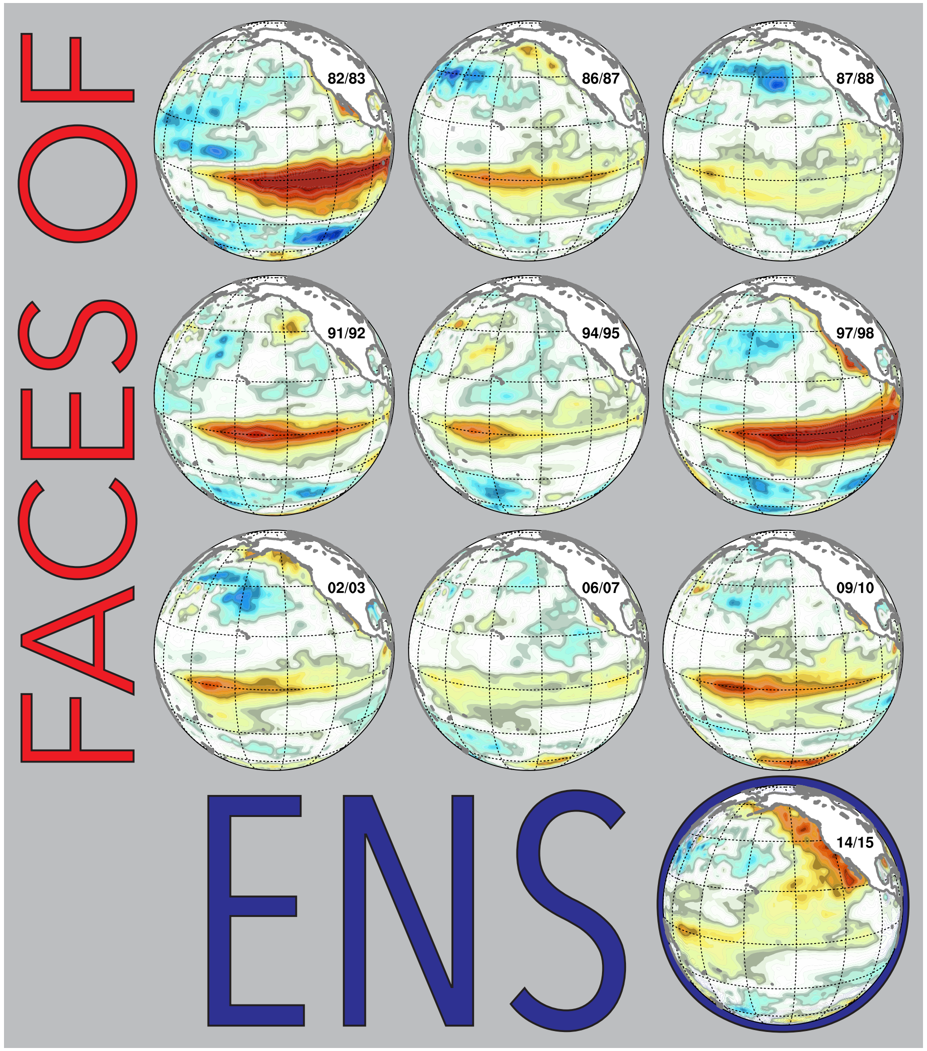


Figure prepared by Matt Newman with input from the Working Group for BAMS cover

- Details of the spatial pattern matter for atmospheric teleconnections and impacts
- Increased frequency of CP events in the 21st century → connection with global warming (e.g. Yeh et al. 2009)?
- CP events have a different Warm Water Volume (WWV)/SST relationship → Implications for predictability (i.e. McPhaden 2012)
- Need to synthesize the large literature on the subject, and clarify the nature of ENSO Diversity (bimodality or continuum?)

Scientific Objectives

1. Examine the range of ENSO "flavors" with focus upon longitudinal variations of warming, identify basic surface and subsurface characteristics that are robust among different datasets, assess the existence of possible, and distinct precursors to the different flavors, and improve our understanding of how the interplay of different oceanic, atmospheric, and coupled processes drive different ENSO flavors and impact their predictability.

2. Examine the performance of the CMIP5 archive in reproducing the best observational estimate of ENSO diversity, and assess its projected changes.

Accomplishments

1. AGU Fall 2012 Meeting session: **OS040: The El Niño – Southern Oscillation Continuum.** Conveners: Di Nezio, Capotondi, Kirtman, Newman

2. ENSO Diversity workshop (6-8 February 2013, Boulder CO)

3. Workshop Report

4. Special issue of *Variations* (Summer 2013)

5. BAMS article (June 2015)

6. Special collection of Climate Dynamics (in preparation)

ENSO Diversity Workshop
6-8 February 2013, Boulder CO

The workshop included ~50 participants

Themes:

1. Statistical characterization of ENSO diversity in models and observations
2. Dynamical processes associated with different ENSO types
3. Predictability and Prediction
4. Teleconnections and impacts
5. Insights from paleoclimate

The workshop was intended to provide a venue for discussion and synthesis of the above aspects, and identify key directions for future research.

ENSO Diversity Workshop
6-8 February 2013, Boulder CO

Example: Dynamical processes associated with different ENSO types

Questions to guide discussion:

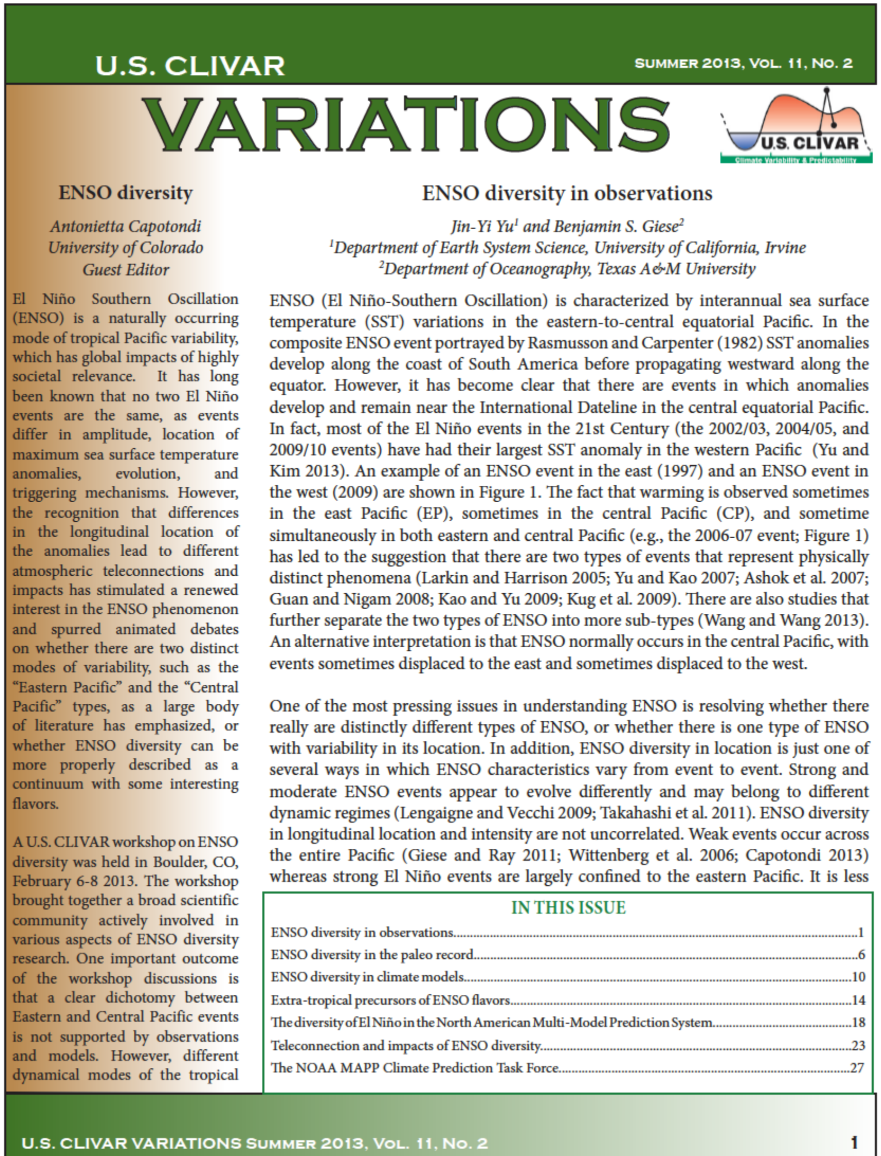
Are different ENSO flavors/extremes characterized by different leading dynamical processes?

Do climate models (CMIP3/CMIP5) capture the differences in dynamics suggested by the observations, and do they agree among themselves?

Are simple models (either statistical or dynamical) able to capture the full diversity of obs and GCMs? If so, how can they be used to improve the more complex models? Can they help us understand whether ENSO characteristics vary as a continuum or be characterized by "discrete modes"?

How does understanding of the dynamics of ENSO diversity inform the assessments of the influence of climate change on ENSO?

Special Issue of *Variations*


U.S. CLIVAR

SUMMER 2013, VOL. 11, NO. 2

VARIATIONS

U.S. CLIVAR Climate Variability & Predictability

ENSO diversity

Antonietta Capotondi
University of Colorado
Guest Editor

El Niño Southern Oscillation (ENSO) is a naturally occurring mode of tropical Pacific variability, which has global impacts of highly societal relevance. It has long been known that no two El Niño events are the same, as events differ in amplitude, location of maximum sea surface temperature anomalies, evolution, and triggering mechanisms. However, the recognition that differences in the longitudinal location of the anomalies lead to different atmospheric teleconnections and impacts has stimulated a renewed interest in the ENSO phenomenon and spurred animated debates on whether there are two distinct modes of variability, such as the "Eastern Pacific" and the "Central Pacific" types, as a large body of literature has emphasized, or whether ENSO diversity can be more properly described as a continuum with some interesting flavors.

A U.S. CLIVAR workshop on ENSO diversity was held in Boulder, CO, February 6-8 2013. The workshop brought together a broad scientific community actively involved in various aspects of ENSO diversity research. One important outcome of the workshop discussions is that a clear dichotomy between Eastern and Central Pacific events is not supported by observations and models. However, different dynamical modes of the tropical

ENSO diversity in observations

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ENSO (El Niño-Southern Oscillation) is characterized by interannual sea surface temperature (SST) variations in the eastern-to-central equatorial Pacific. In the composite ENSO event portrayed by Rasmusson and Carpenter (1982) SST anomalies develop along the coast of South America before propagating westward along the equator. However, it has become clear that there are events in which anomalies develop and remain near the International Dateline in the central equatorial Pacific. In fact, most of the El Niño events in the 21st Century (the 2002/03, 2004/05, and 2009/10 events) have had their largest SST anomaly in the western Pacific (Yu and Kim 2013). An example of an ENSO event in the east (1997) and an ENSO event in the west (2009) are shown in Figure 1. The fact that warming is observed sometimes in the east Pacific (EP), sometimes in the central Pacific (CP), and sometime simultaneously in both eastern and central Pacific (e.g., the 2006-07 event; Figure 1) has led to the suggestion that there are two types of events that represent physically distinct phenomena (Larkin and Harrison 2005; Yu and Kao 2007; Ashok et al. 2007; Guan and Nigam 2008; Kao and Yu 2009; Kug et al. 2009). There are also studies that further separate the two types of ENSO into more sub-types (Wang and Wang 2013). An alternative interpretation is that ENSO normally occurs in the central Pacific, with events sometimes displaced to the east and sometimes displaced to the west.

One of the most pressing issues in understanding ENSO is resolving whether there really are distinctly different types of ENSO, or whether there is one type of ENSO with variability in its location. In addition, ENSO diversity in location is just one of several ways in which ENSO characteristics vary from event to event. Strong and moderate ENSO events appear to evolve differently and may belong to different dynamic regimes (Lengaigne and Vecchi 2009; Takahashi et al. 2011). ENSO diversity in longitudinal location and intensity are not uncorrelated. Weak events occur across the entire Pacific (Giese and Ray 2011; Wittenberg et al. 2006; Capotondi 2013) whereas strong El Niño events are largely confined to the eastern Pacific. It is less

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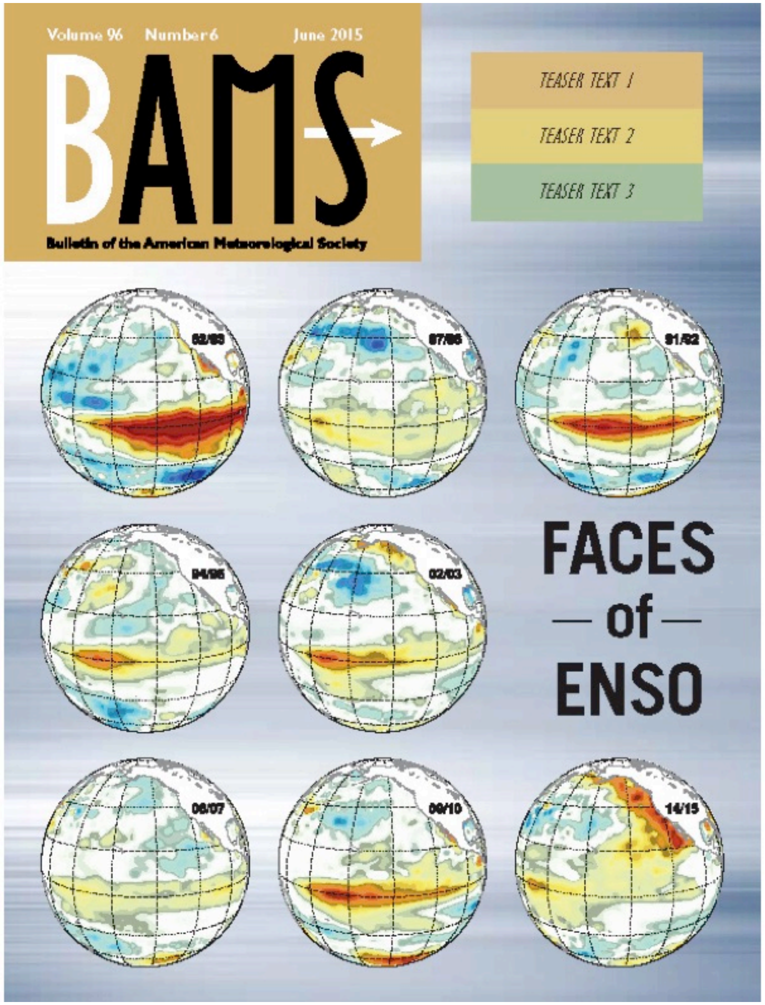
BAMS article (June 2015 issue)
"Understanding ENSO Diversity"

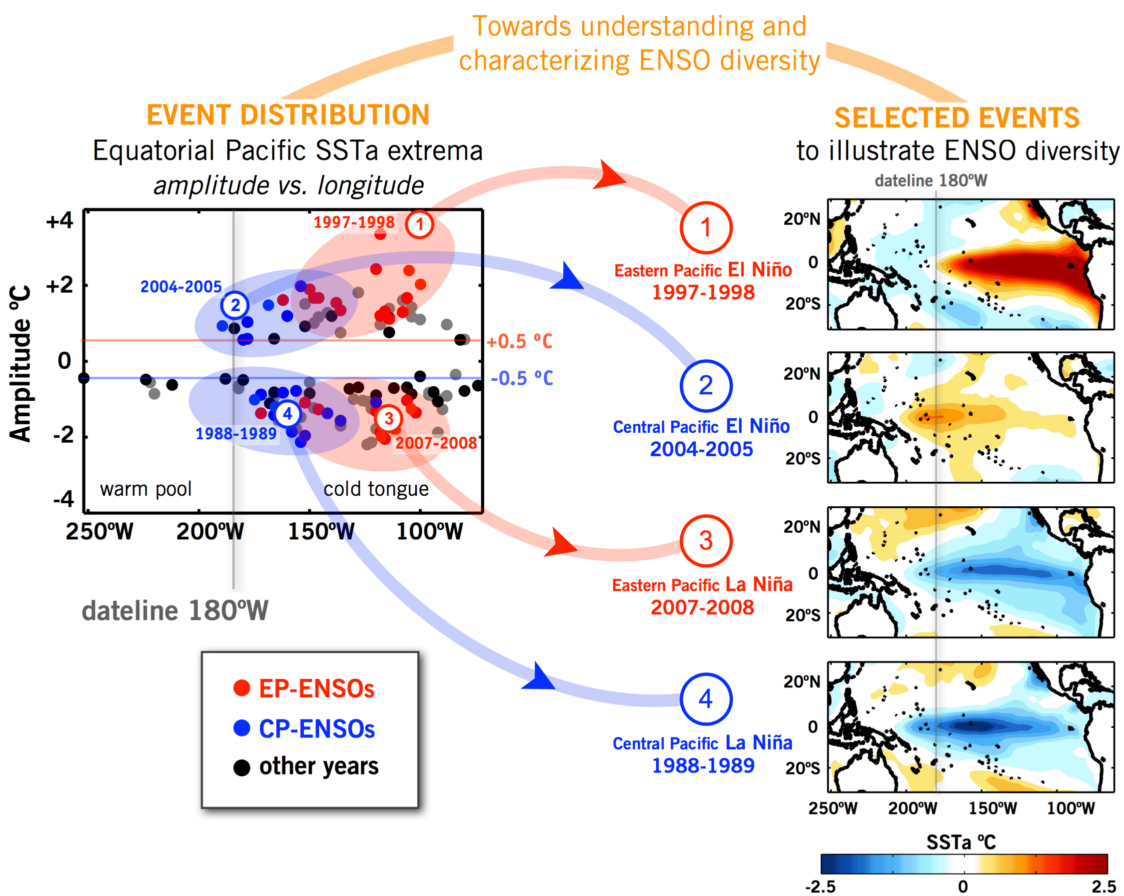


Preliminary cover of BAMS June issue, featuring ENSO diversity article

The article provides a synthesis of our understanding of ENSO diversity for the broader scientific community.

It provides a view of ENSO diversity that is broader than what emphasized by previous literature

Is there a bimodality in the longitudinal distribution of events? Or a continuum?



NDJ extreme equatorial (2°S-2°N, 110°E-90°W) SST values over 1900-2013 relative to the 1945-2013 climatology

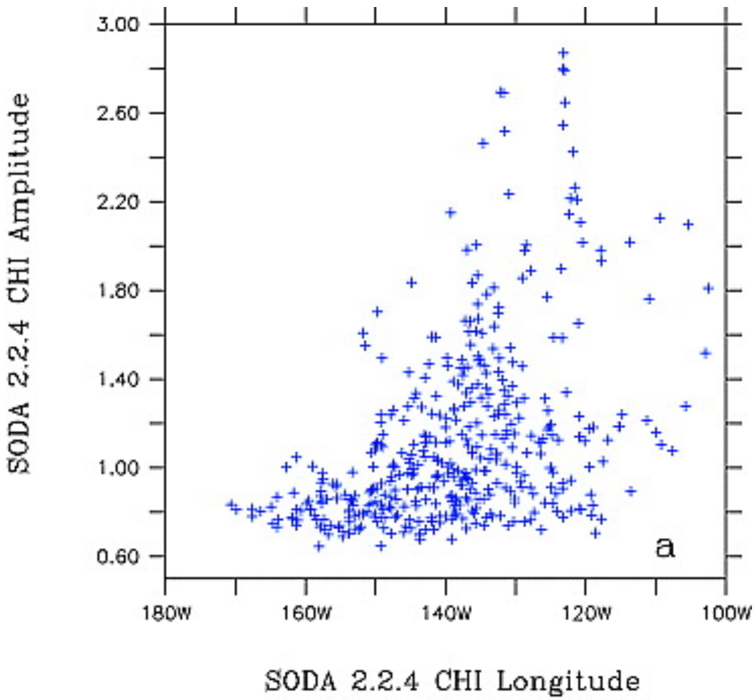
EP : Niño3 > 1 std

CP : PC of leading SST EOF > 1 std

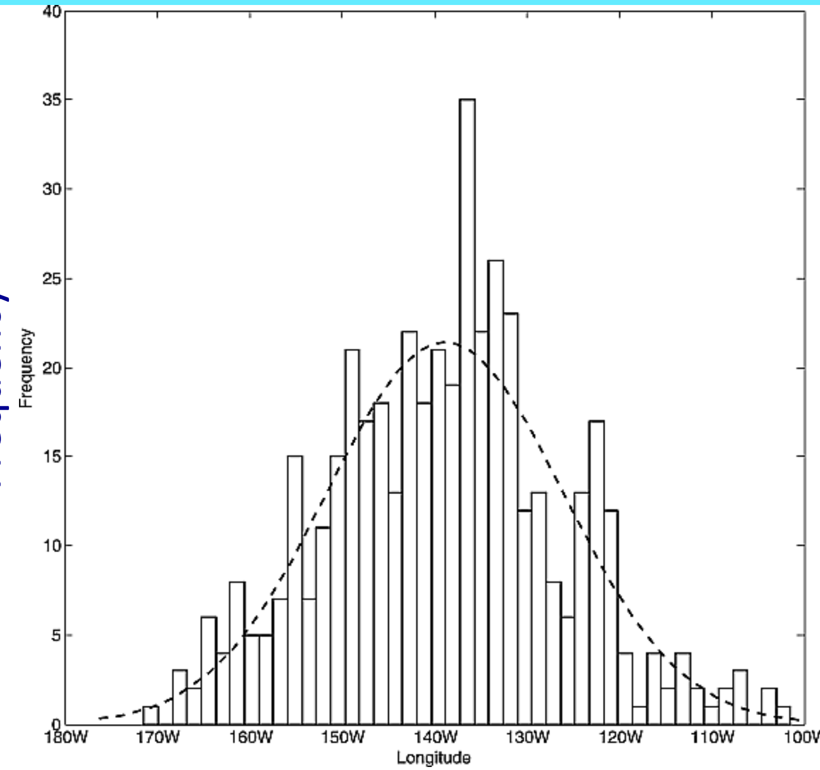
Capotondi et al. BAMS 2015 (Figure by E. Di Lorenzo)

CHI statistics applied to 20th century SODA ocean reanalysis (1871-2008) shows “smooth” event distribution

CHI amplitude



Frequency



CHI longitude

Longitude

Giese and Ray 2011

This analysis does not support the idea of two preferred peak longitudes

Event distribution in the GFDL CM2.1 model
From 4000 years of PI control simulation

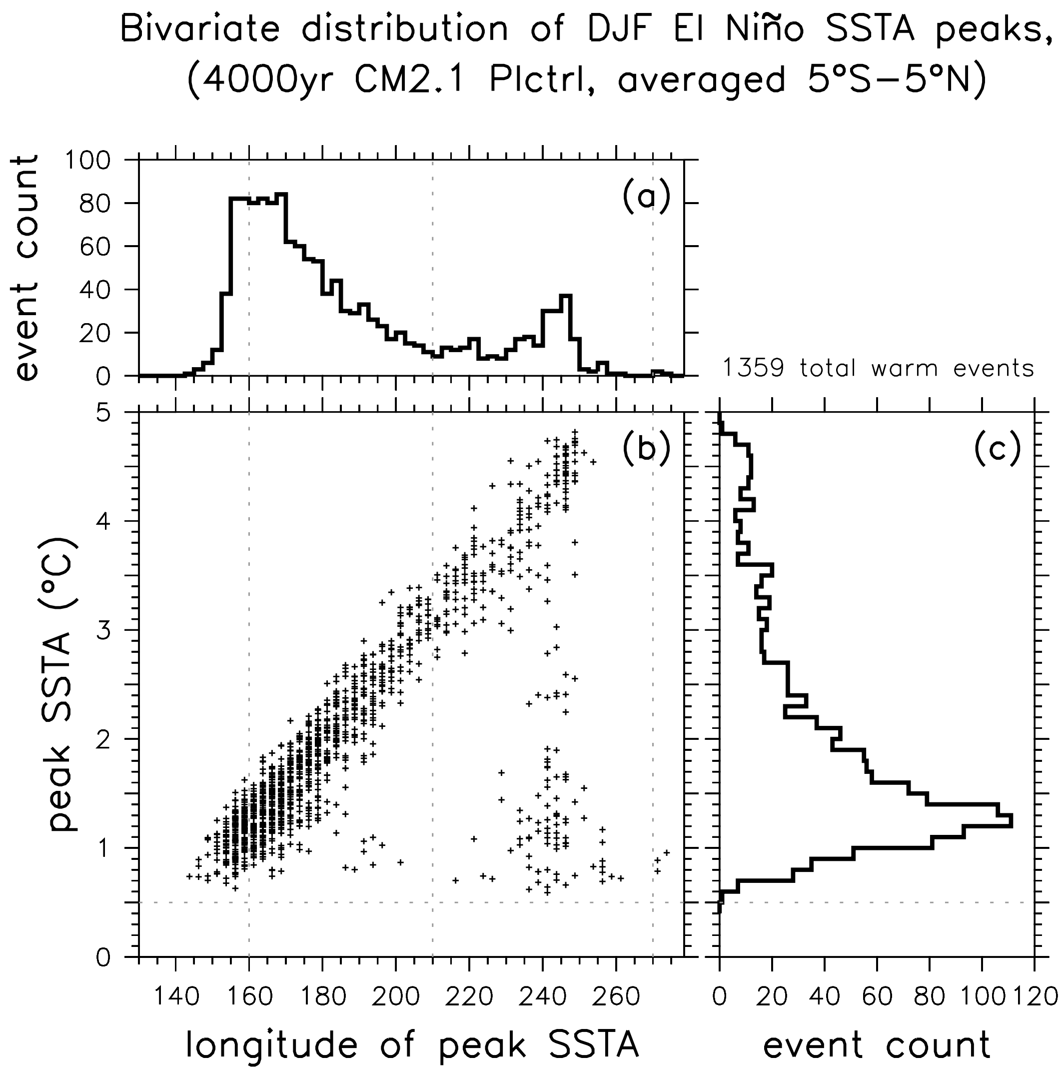
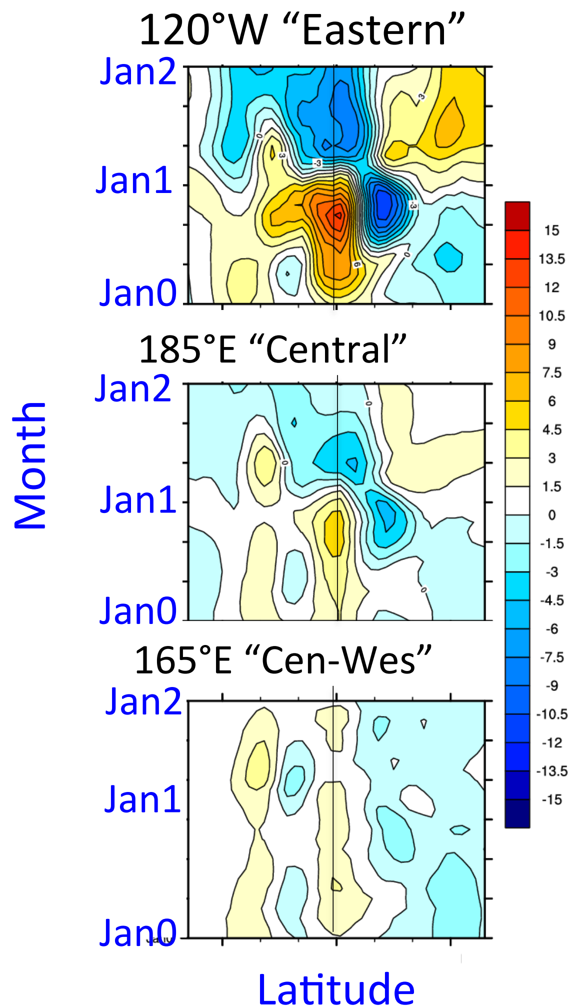


Figure by A. Wittenberg

Are dynamical processes different for events peaking at different longitudes? It has been suggested that Central Pacific events are not associated with recharge-discharge processes (Kug et al. 2009)

Thermocline depth evolution at different peak longitudes



NCAR-CCSM4 pre-industrial Control
500 years

Recharge-discharge processes become progressively weaker for events peaking further west

Basic processes are the same. Their relative influence is geographically dependent

Capotondi 2013

Bimodality or Continuum?

"ENSO can be described as a coupled atmosphere-ocean phenomenon that exhibits substantial variations with regionally different feedbacks, leading to a diverse continuum of realized ENSO events."

Open Questions

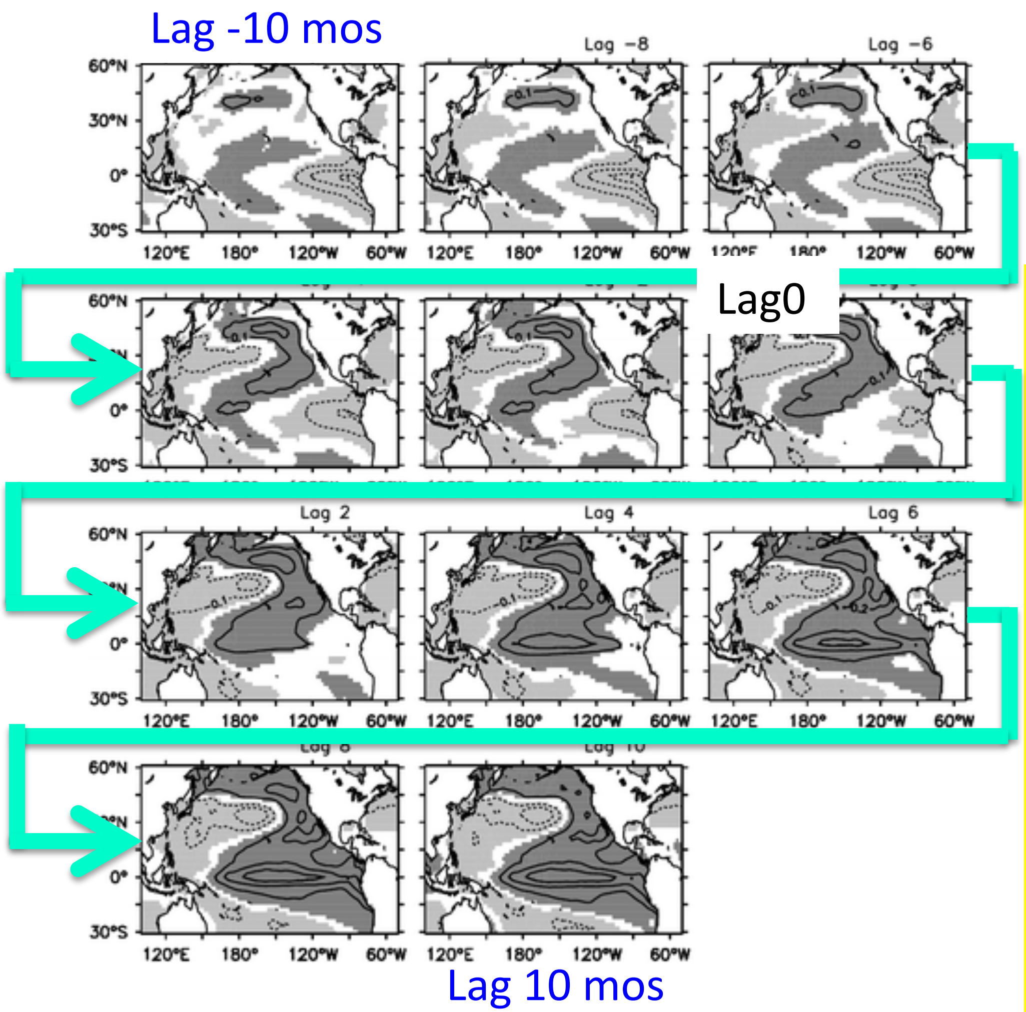
Origin of the different event types and their predictability
“Precursors” need to be better understood

Predictions of different ENSO types (model, data for initialization/assimilation)

Teleconnections and impacts

Influence of global warming

Are there specific precursors for different types of ENSO events? Can extra-tropical influences trigger Central Pacific events?



Yu and Kim 2011

Lag-regression of SST upon the North Pacific Oscillation (NPO) index, second EOF of winter SLP over the North Pacific

Is this mechanism a precursors only for Central Pacific events?

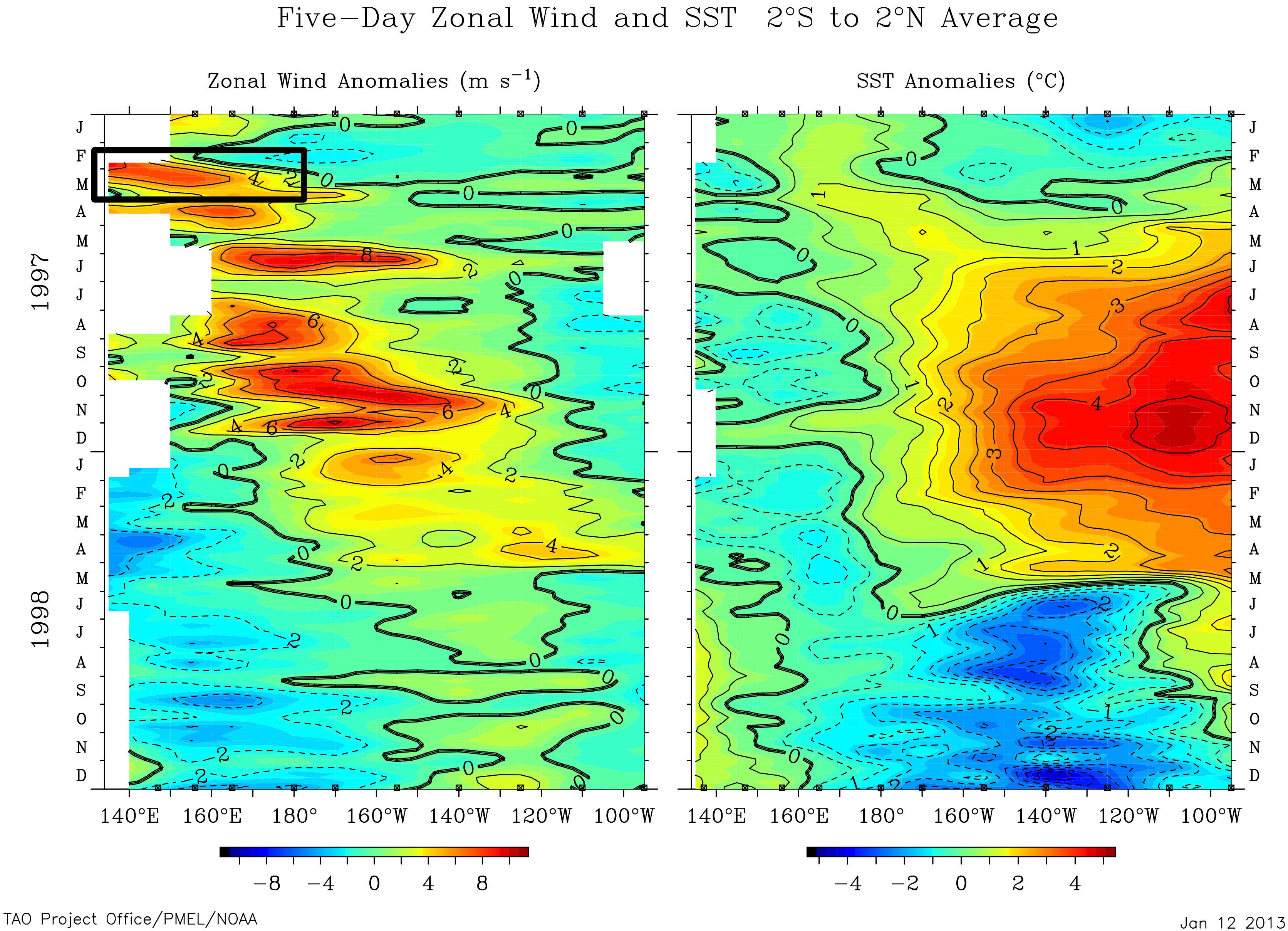
What is its efficiency?

What is the interplay with Southern Hemisphere influences?

What is the role of the oceanic background state? (Anderson 2007)

What is the role of equatorial atmospheric noise (WWBs)?

Westerly Wind Burst (WWB) in Feb-Mar 1997, preceding El Niño



Special Collection of Climate Dynamics (in preparation)

The special collection is envisioned to include papers on any aspect of ENSO diversity, with emphasis on contributions examining ENSO diversity in climate models that can inform the definition of metrics

The special collection has been approved by Climate Dynamics, and the link for submission will be available in a few weeks. We envision a 4 months timescale

We are finalizing the list of papers

Conclusions

1. The Working Group has provided a venue for constructive and useful discussions among the members and in the broader scientific community

2. Through our various publications, especially the BAMS article, we have established a broader and more realistic view of ENSO diversity

3. Our last endeavor (Climate Dynamics special collection) will provide insights in some of the remaining open questions, and hopefully guide the identification of critical aspects of ENSO diversity, and the definition of metrics for those aspects