Revisiting Equatorial Pacific Zonal Wind Stress Anomalies and ENSO Development:

What role do subseasonal wind events play in recent (partial) development of El Niño events?

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Motivation

•Knowledge of ENSO state can provide useful seasonal weather anomaly forecasts in many regions around the world *(where influence is strong and consistent enough)* but predicting ENSO development remains challenging.

• Both 2012 and 2014 (so far) basically fizzled-out after showing signs of El Nino-like development in spring/summer. Why?

We ask how well can we understand the recent (non) development of El Niño in terms of subseasonal wind events,

Outline

Background 1. Revisit composite Westerly Wind Events (WWEs) and their affect on ENSO-region sea surface temperature anomaly (SSTA).

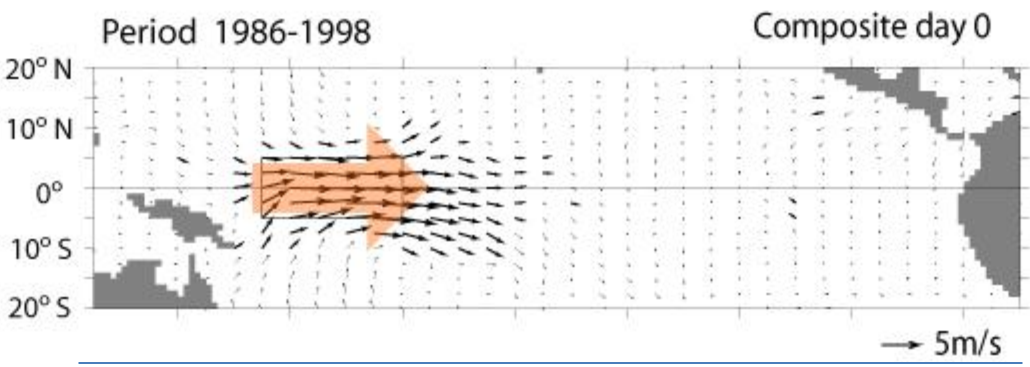
Background 2. Explore further, the role of Easterly Wind Surges (EWSs)

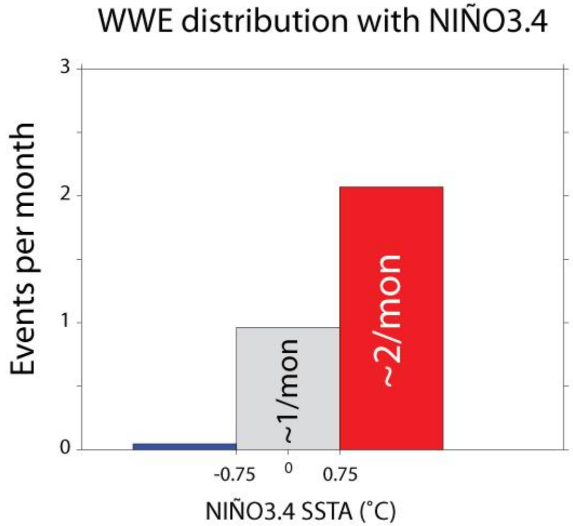
Integrals of Eq. Pacific Wind Stress and end of year Nino3.4 SSTA: *How well does wind stress forcing, and specifically the wind event component alone, account for recent behavior?*

Ocean Model Hindcast experiments: *How well can the detailed development of El Nino SSTAs be understood from a wind event-forced perspective?*

Background 1. WWEs and El Nino Onset

WWE composite wind anomaly





WWEs are rare in cool-ENSO, and increase in frequency as the system transitions through neutral to warm-ENSO conditions.

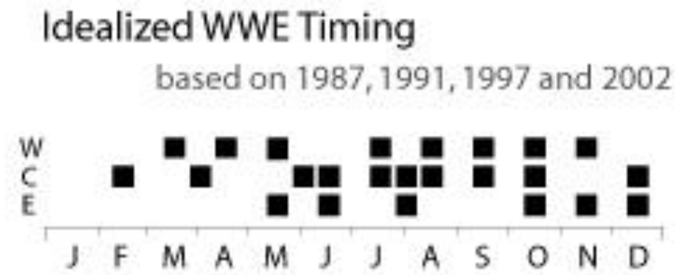
•WWE = 3 or more consecutive days in which WWE-region average zonal wind anomaly > 2 m/s. Harrison and Vecchi (1997) define 3 equatorial WWE-regions: W, C and E.

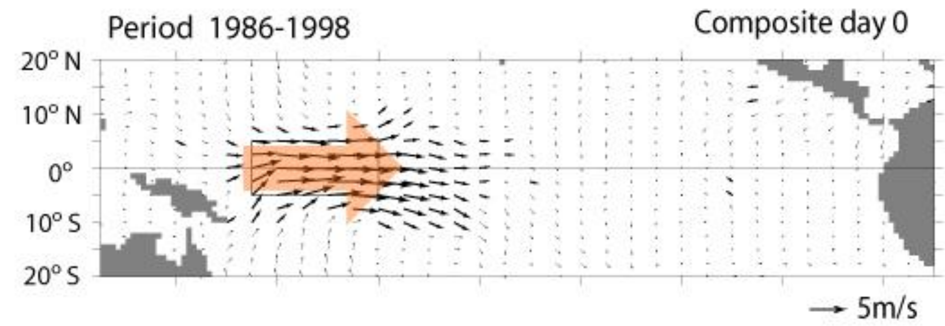
• "Day 0" is the event-day with maximum zonal wind anomaly (~7m/s average)

•Statistically significant anomalies are seen ~7 days before/after Day 0 in composite

•Cold-tongue SSTA warming of a few tenths °C follows a single WWE in ENSO-neutral conditions. This warming persists 2-3 months after wind event subsides.

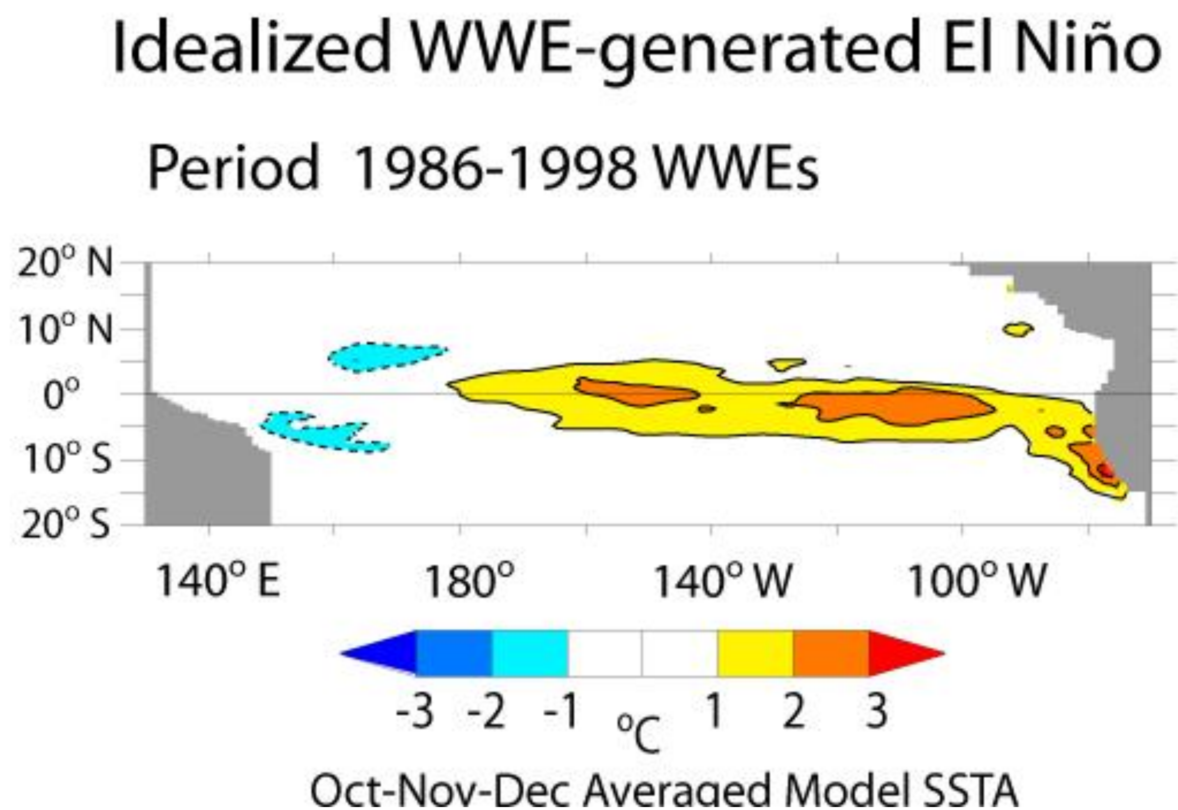
A series of WWEs typically occur in an El Nino year,



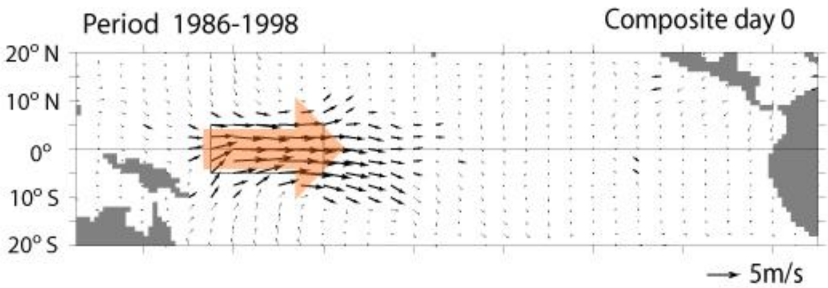


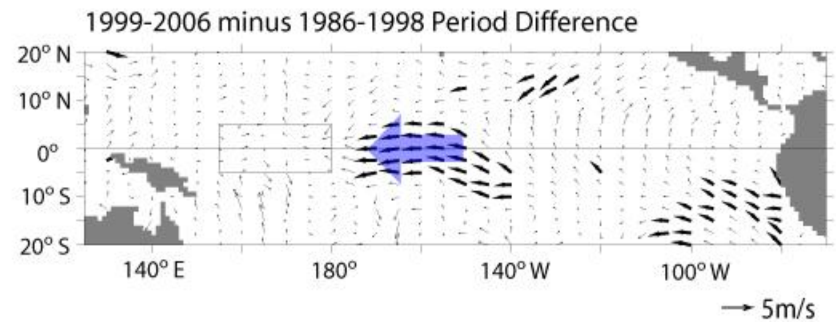
when the WWE-region contains most all of the statistically significant wind anomaly…

…a series of WWEs drives El Nino-like SSTAs in the model (an EP event) →



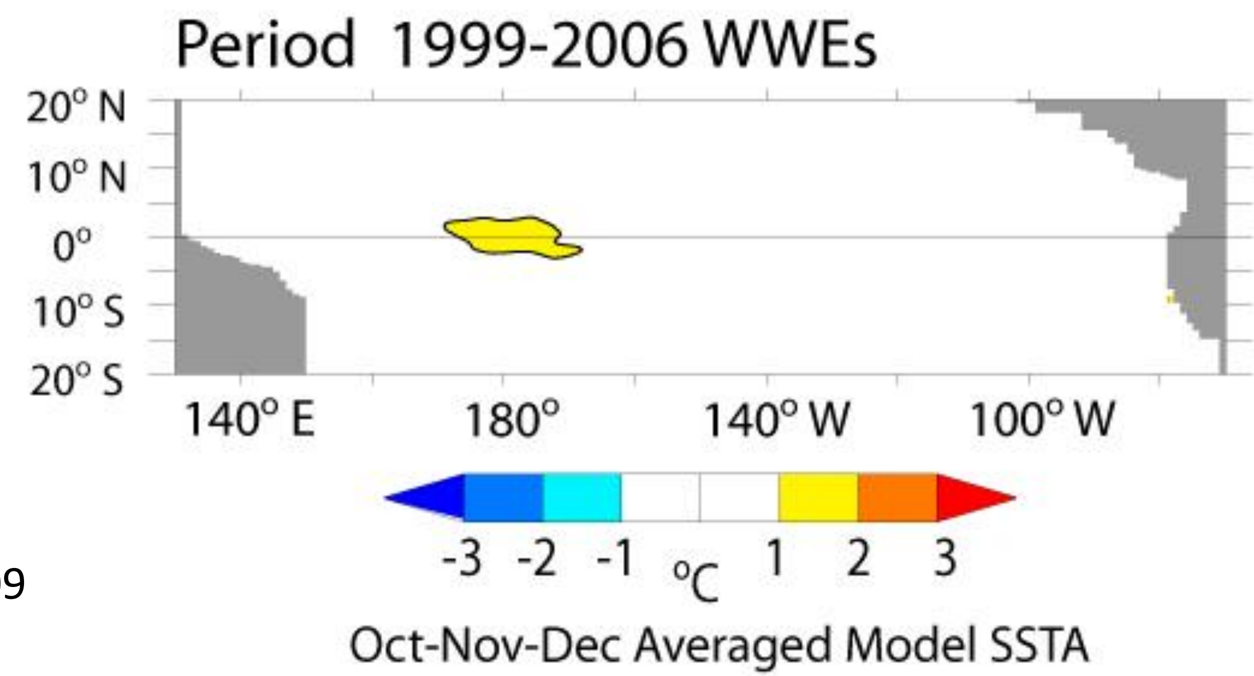
Post 1997-98 WWEs have a cold-tongue easterly element





Idealized WWE-generated El Niño

When WWEs that include the easterly pulse (like the 1999-2006 average) are applied to the model, a **Central Pacific El Nino** ***occurs***

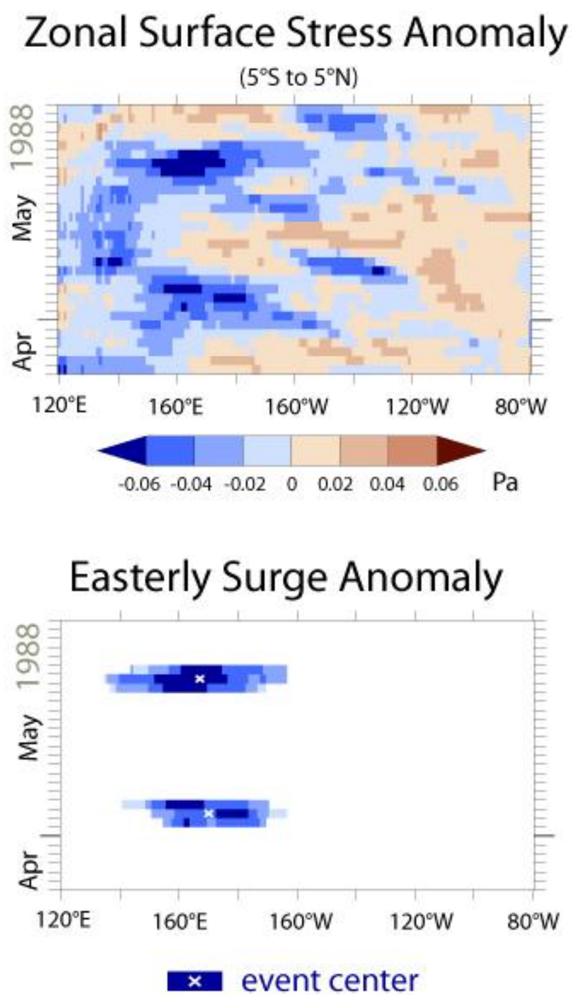


See Chiodi and Harrison, 2009

Model forced with WWE composites from TAO-buoy-based wind stress estimates

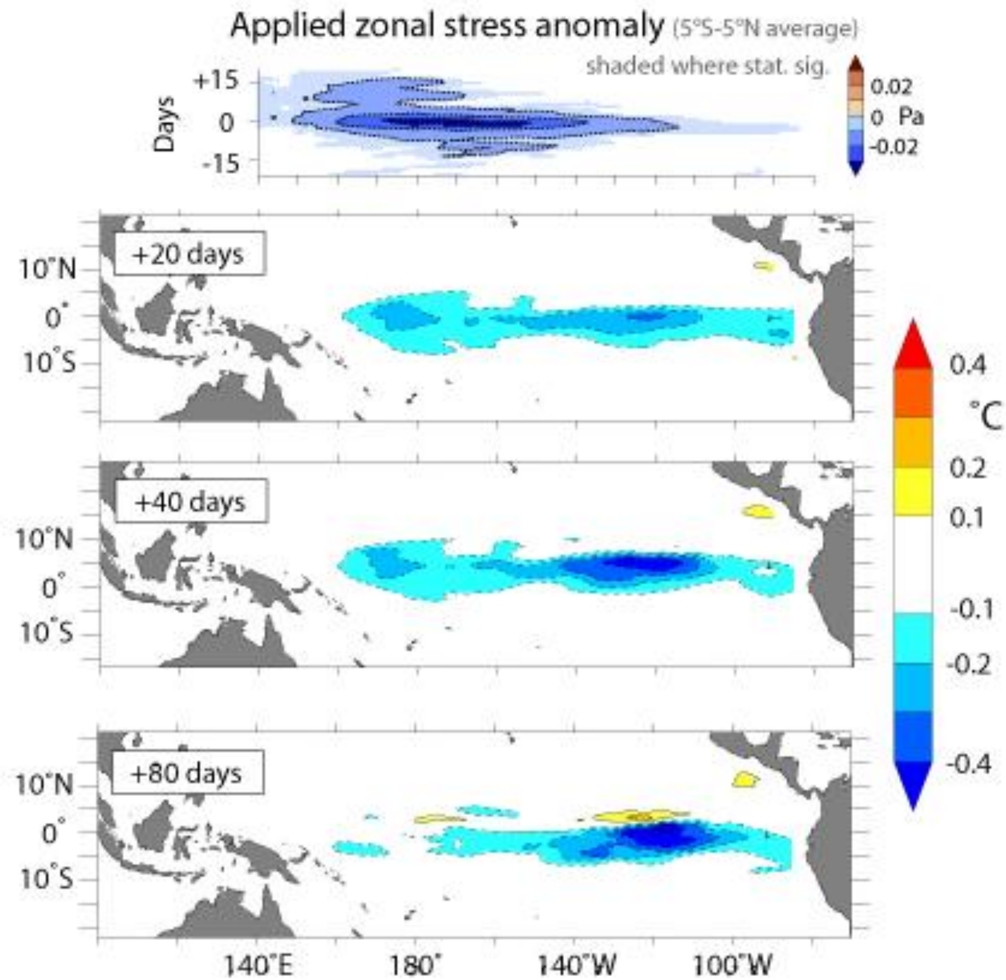
Background 2. Easterly Wind Surges (EWSs) and waveguide cooling

Easterly surges are also found in other (non-WWE) conditions



See Chiodi and Harrison, 2014, to appear in J. Climate

Model SSTA following Easterly Surge



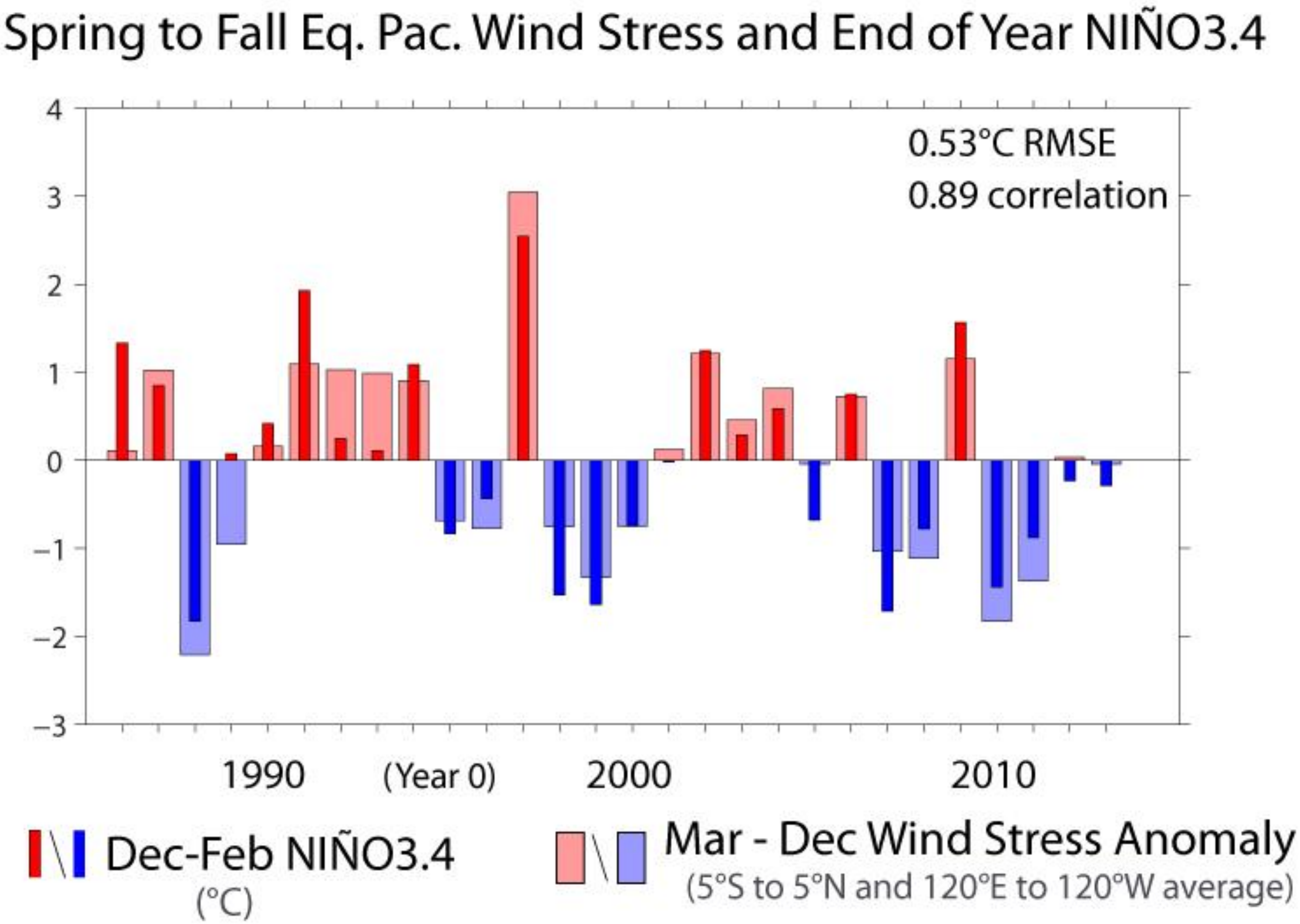
Solo EWSs drive a few tenths cooling, just as solo WWEs drive a few tenths ℃ warming

Wind Stress Integrals and end of year ENSO SSTA

End of year (ENSO peak) SSTA conditions may be controlled by many factors (e.g. initial oceanic conditions, wind stresses, heat fluxes)

How much of the story is controlled by the equatorial winds, and specifically the wind event component?

Integrated Eq. Pac. wind stress anomalies have close connection to end of year ENSO SSTA conditions



A reminder that Eq. Pac. wind stress anomalies across the ocean waveguide exert a dominant control on NINO3.4 SSTA

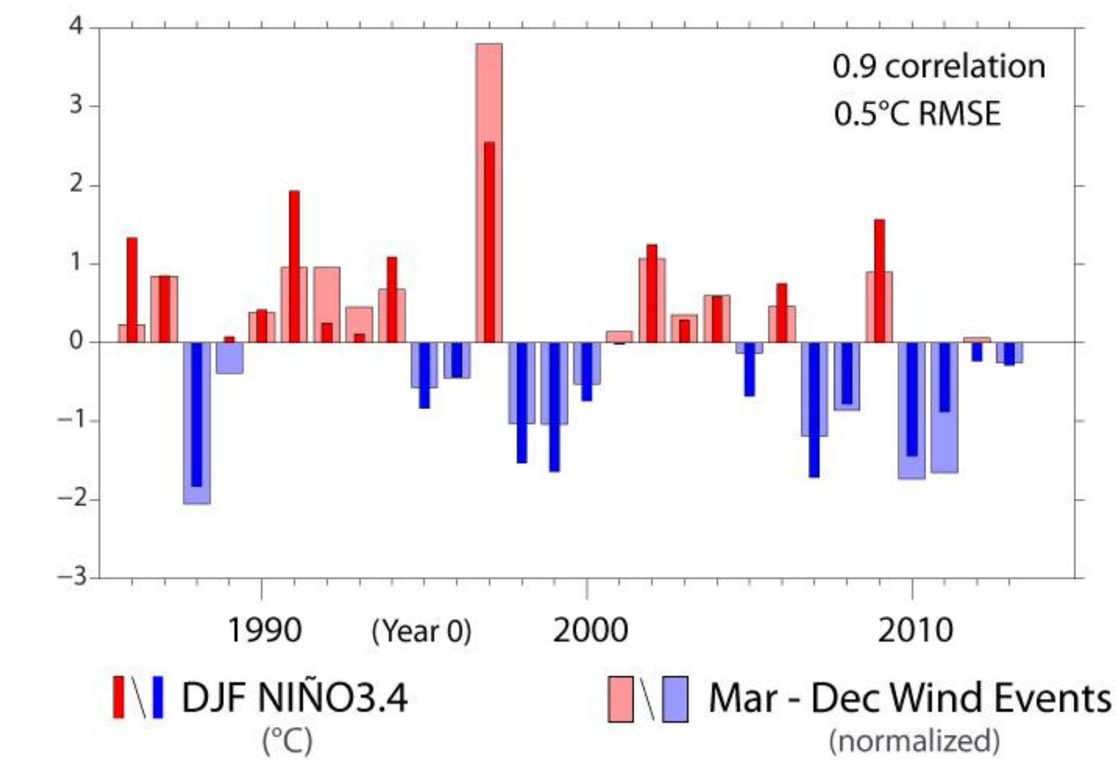
Based on NOAA OISST and Wind Stress from ERA Int. Reanalysis with 1986-2014 trend matched to TAO

Counting up the time and zonal extent of each year's wind events is able to reproduce the full integral result.

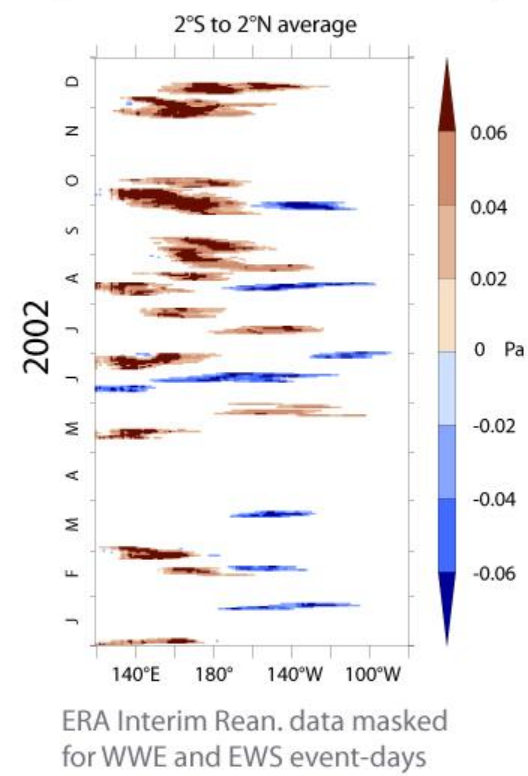
The wind event distribution plays a key role in shaping the ENSO associated wind stress variations

Example year: to get the integral value we count up red (westerly) minus blue (easterly) shaded regions

End of year NINO3.4 and Onset/Growth Season Zonal Wind Event Integral



Eq. Pac. Wind Stress Anomaly



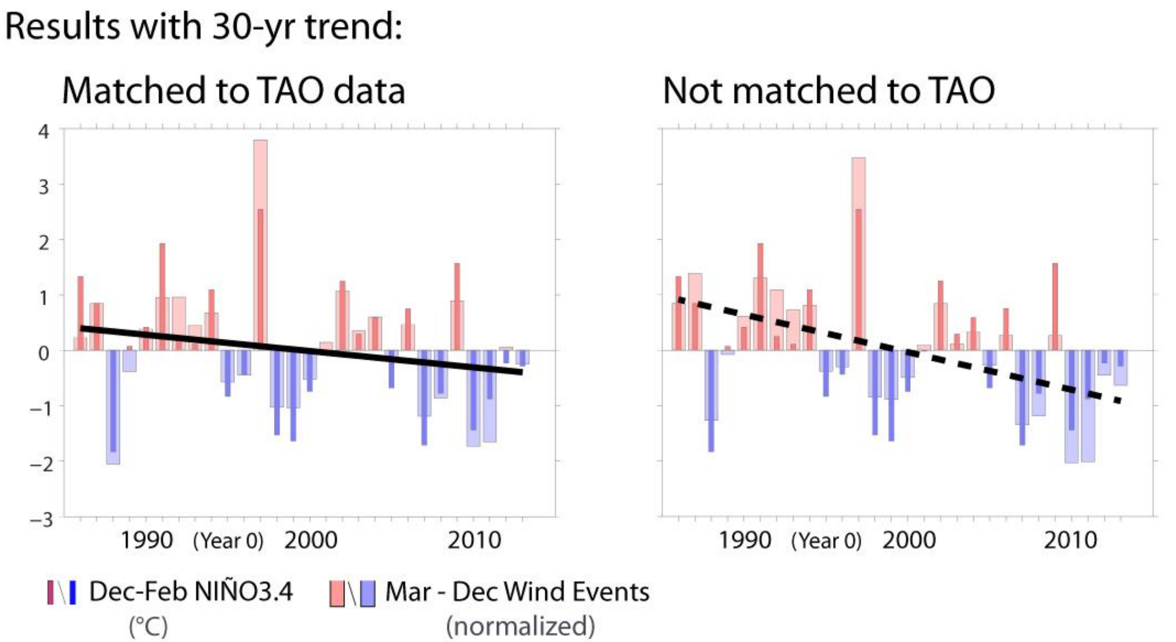
ERA Reanalysis wind stress, matched to TAO, is used for WWE/EWS identification

Issue

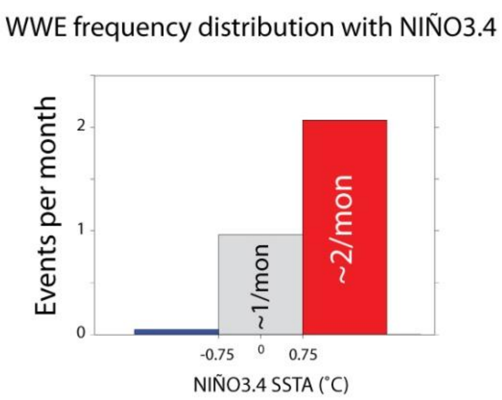
The ERA Interim Reanalysis has a 30-yr trend that is twice as large in amplitude as that seen in the TAO/Triton buoy data.

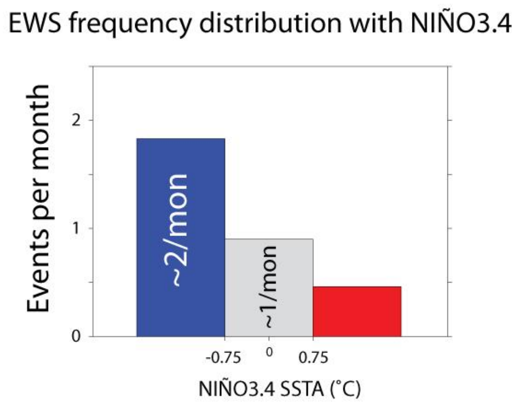
We adjusted the ERA trend to match TAO to produce the previous result. If this is not done, this (spurious) trend biases the comparison of recent and earlier study period zonal wind activity.

Bottom line: even with TAO data available, it is important to check reanalysis data for inconsistencies to understand observed relationships



Integrals of Springtime wind stress - implications?

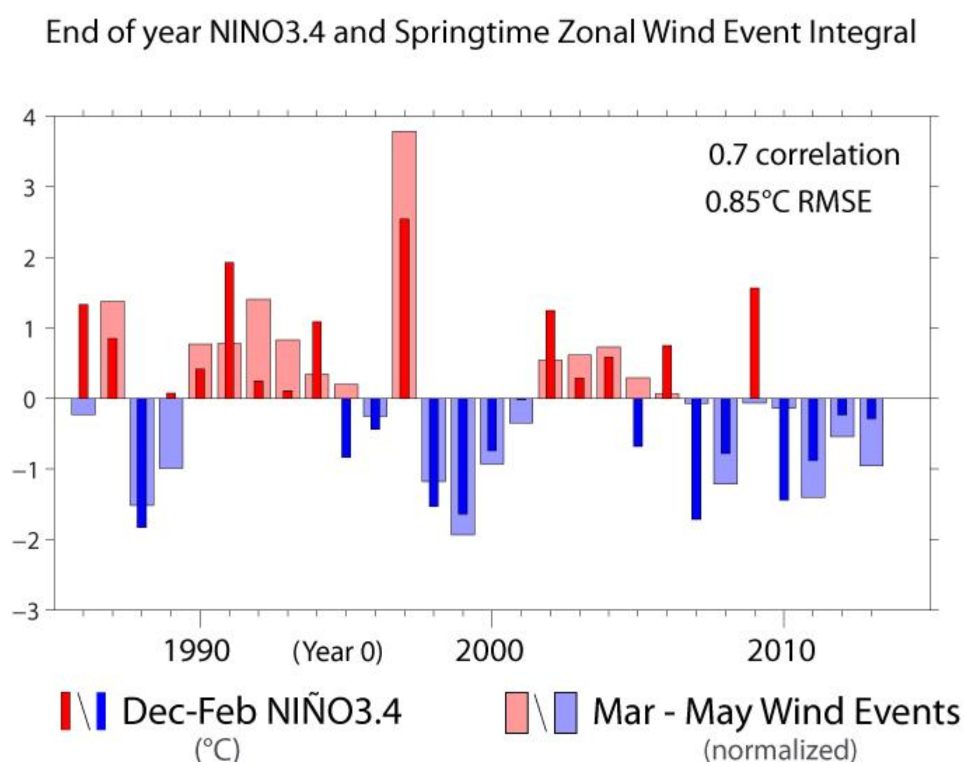




The distributions of wind events with ENSO SSTA show evidence of a positive feedback. Hypothesis: Gill-type mechanism but on a subseasonal scale

Thus, an early stage excess of one or the other type of wind event can help steer the ENSO trajectory

Some forecasting skill here (similar to many more sophisticated models) But a RMSE (0.85°C), close to the standard deviation of NINO3.4 itself, still leaves much of the story untold.



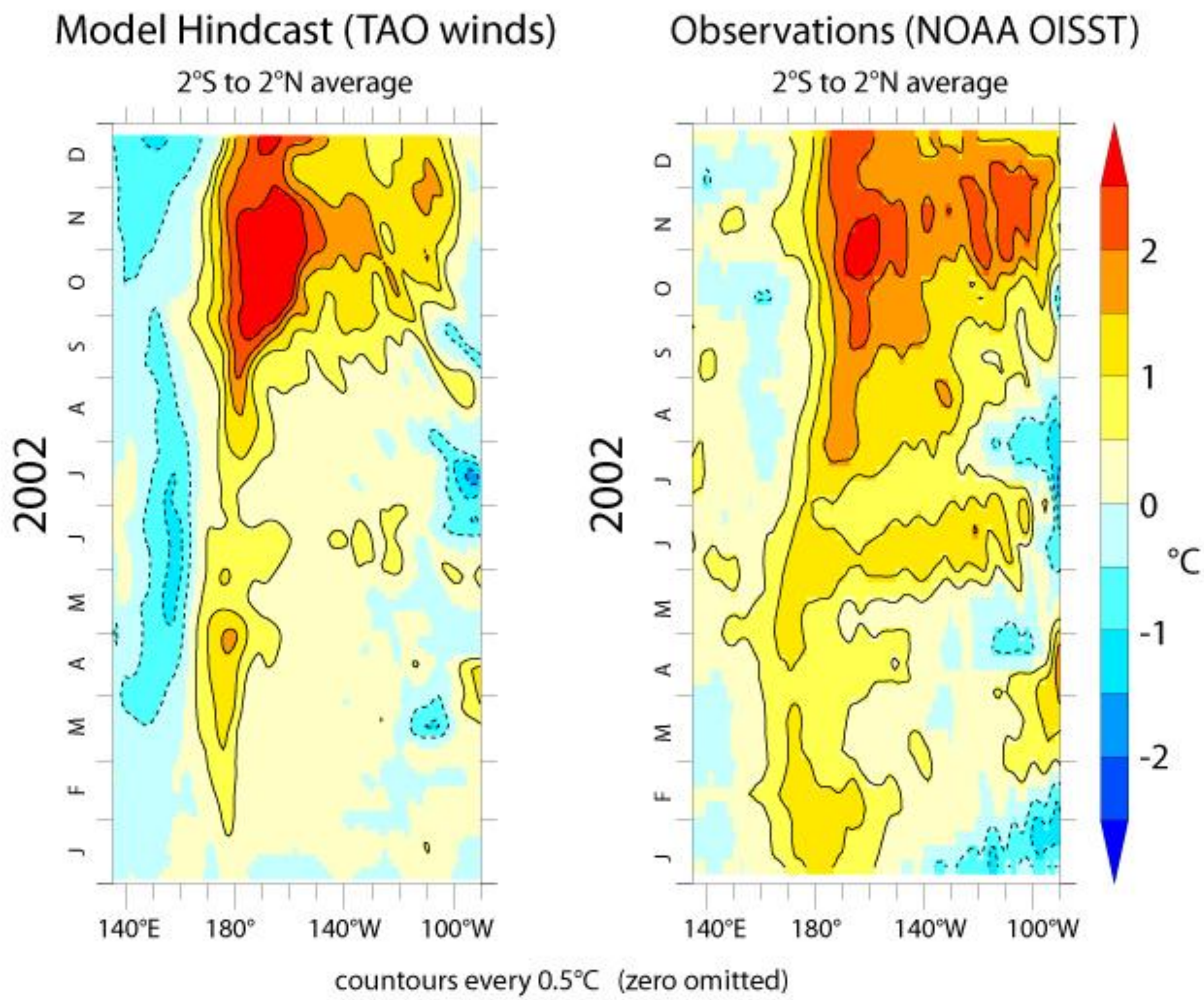
How much does the detailed development of ENSO SSTA depend upon frequency/distribution of wind events?

ISSUE: Lack of TAO data reduces ability to diagnose obs SSTAs

We start with the 2002-03 El Nino, a good example with (nearly) full TAO data

2002 Hindcasts

Forcing the model with just TAO wind stress anomaly TAO is able to produce qual. correct SSTA development



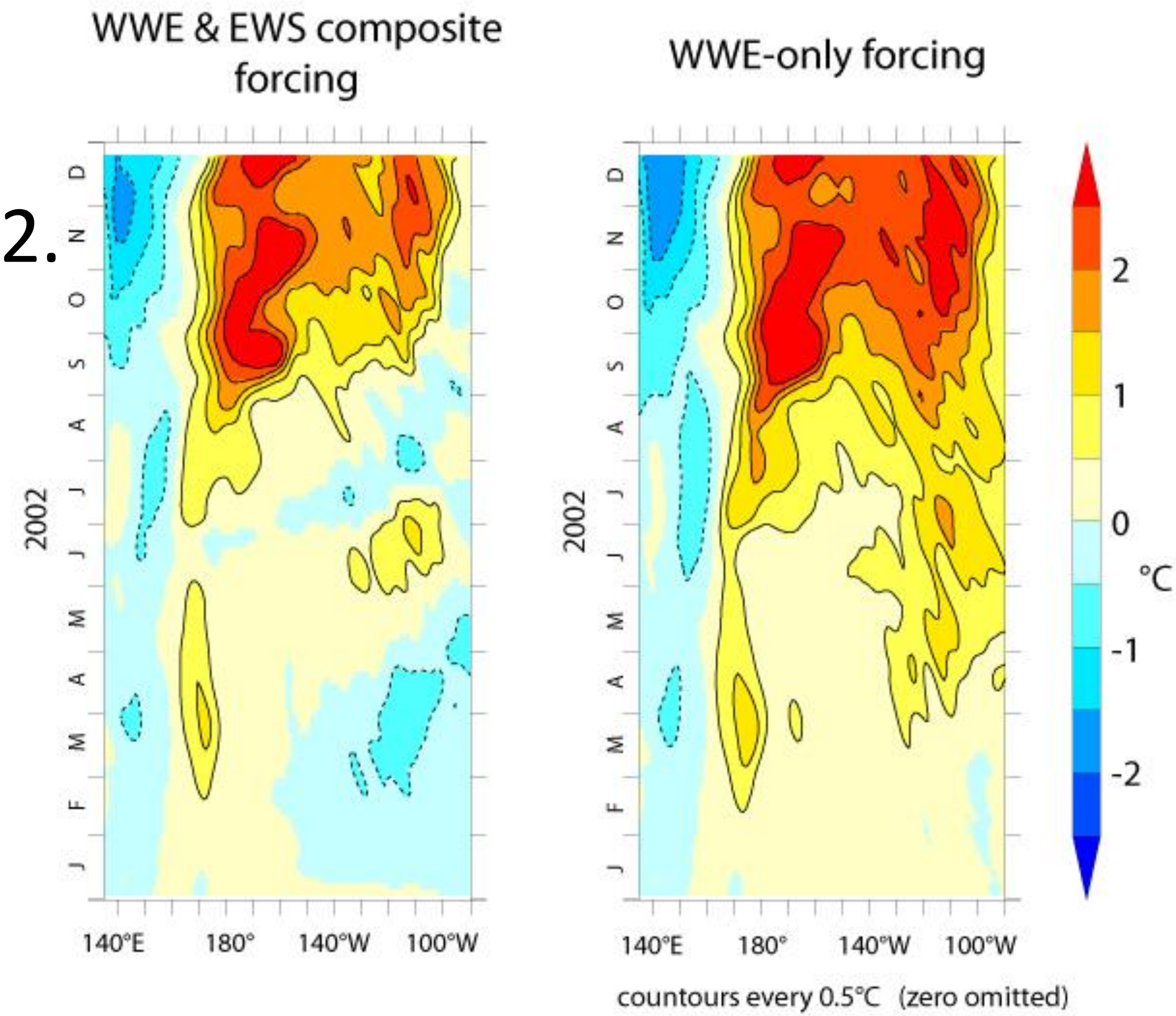
Buoy winds from 2°S to 2°N averaged and converted to pseudo-stress.
Good (84%) data return rate along Equator, in this case.

WWE/EWS construction hindcasts

We find 16 WWEs and 8 EWSs in 2002.

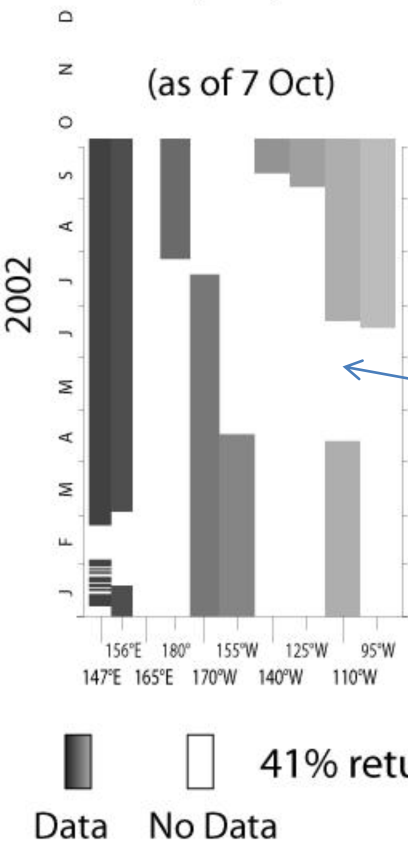
Applying WWE/EWS composites at the observed timing drives a qualitatively correct CP-type SSTA pattern (left)

Omitting the EWSs results in much stronger warming in East (an EP event).



2014 Hindcasts

TAO Wind Data Return (0°N)

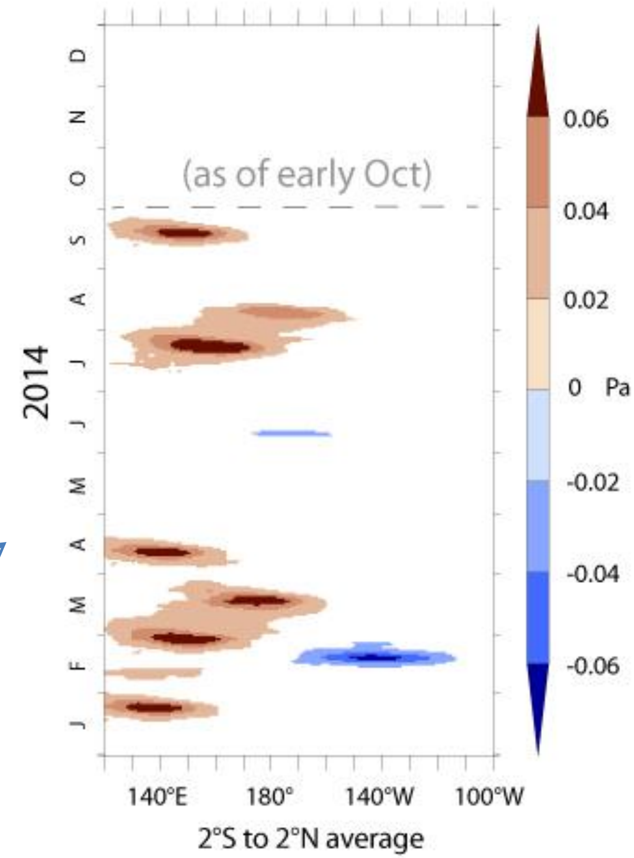


We've been unable to successfully hindcast 2012 and 2014 based on TAO (or ERA Reanalysis) wind stress data.

Recent data dropouts make it difficult to know what is going on

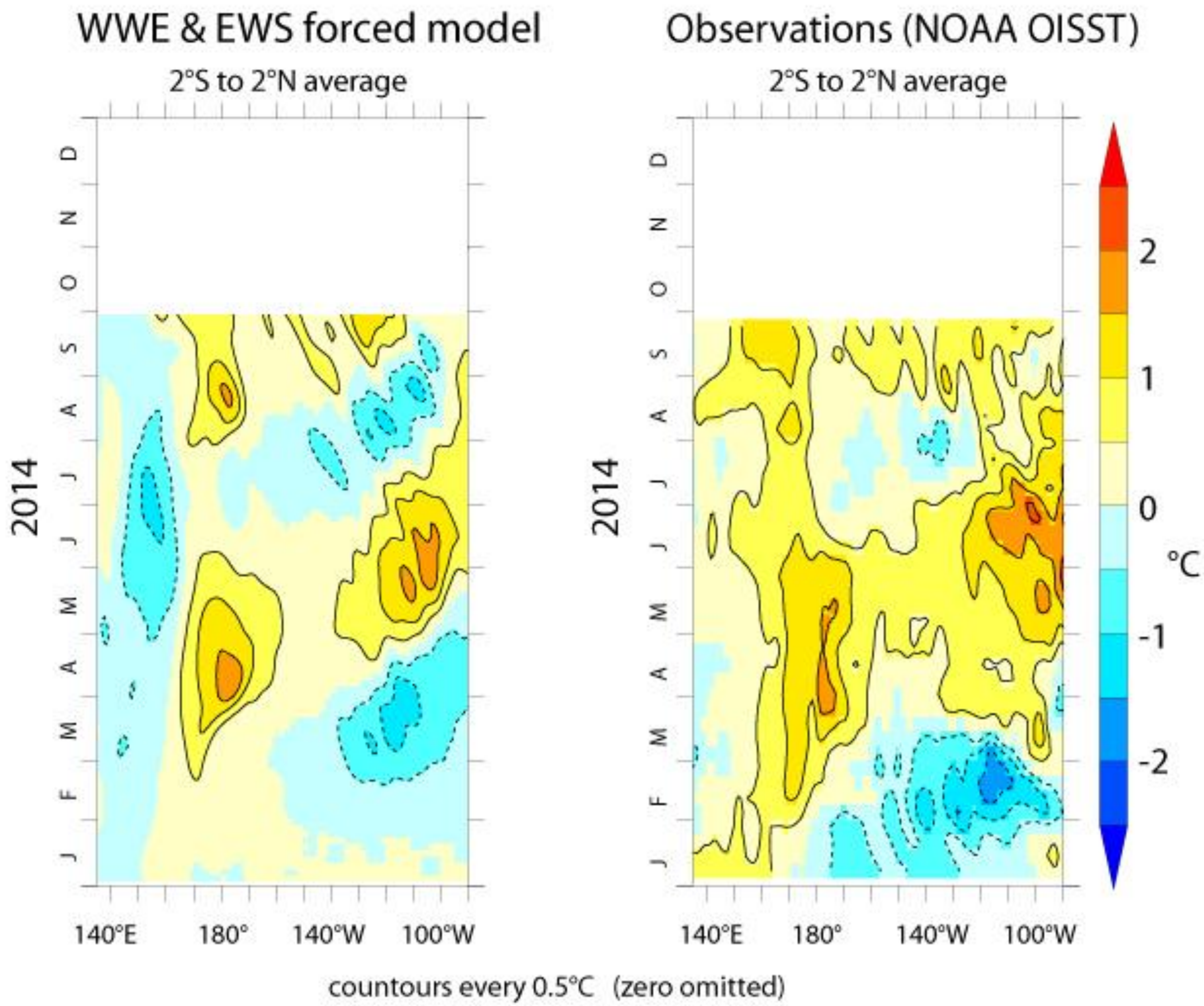
This is one possibility

2014 Wind Stress Anomaly (WWE & EWS scenario)



2014 Hindcast

In this scenario: early WWE activity drives mid-year warming, then warmth dissipates during lull. Recent WWEs keep us interested…



Conclusions

Diagnosis of ENSO SSTA development is feasible with accurate knowledge of winds across the Pacific waveguide *(TAO/Triton data needed to do this successfully)*

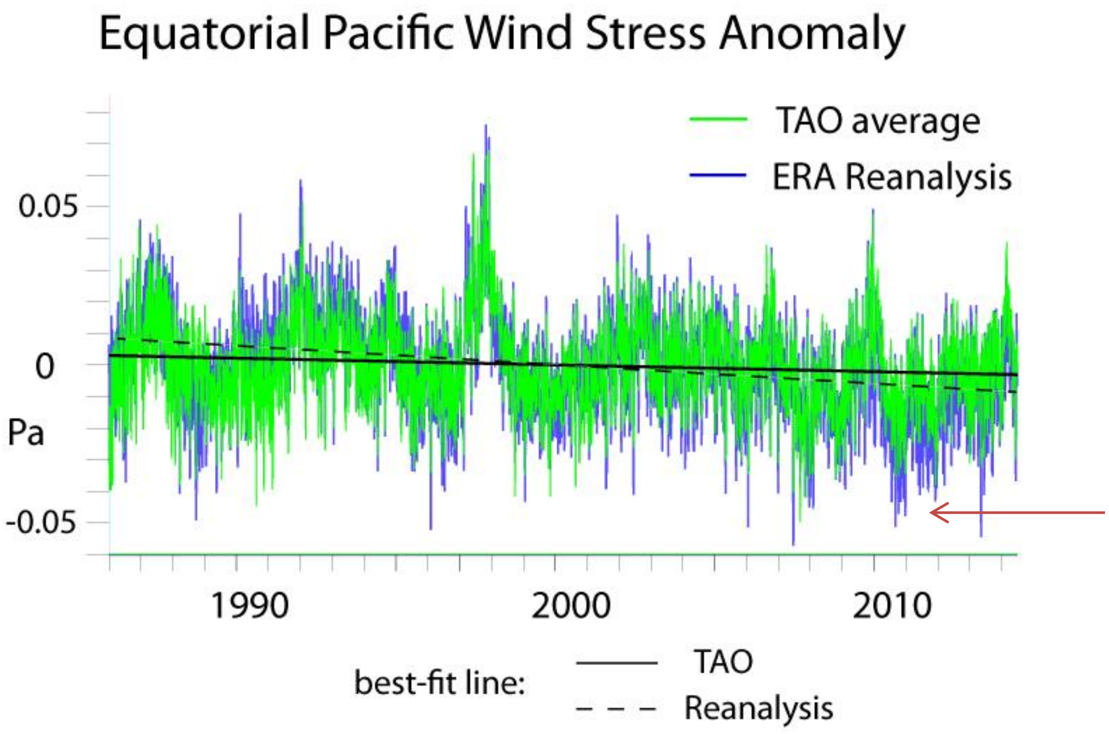
Westerly Wind Events, and their easterly counterparts (EWSs) are a dominant driver of ENSO SSTA (r~0.9, RMSE~0.5°C)

Wind event likelihood depends on SSTA. This plus their warming (WWE) and cooling (EWS) effects create positive feedback for El Nino and La Nina, respectively.

Statistics confirm some springtime skill (r~0.7 for end of year NINO3.4 from MAM winds), but the RMS error is almost 1°C, leaving plenty of room for surprises like 2012 and 2014.

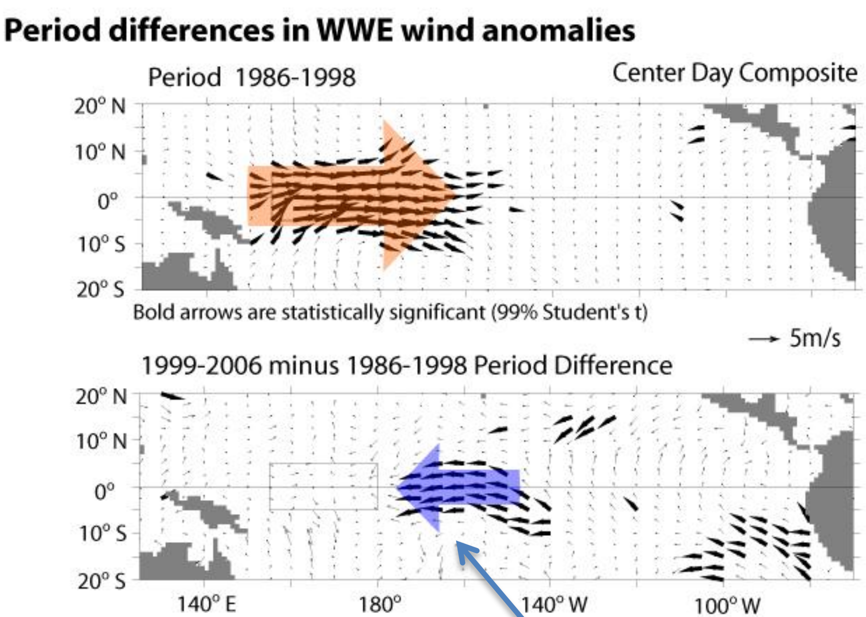
This leaves us currently waiting to see if another series of westerly wind events occur and we'll have a weak-moderate El Nino.

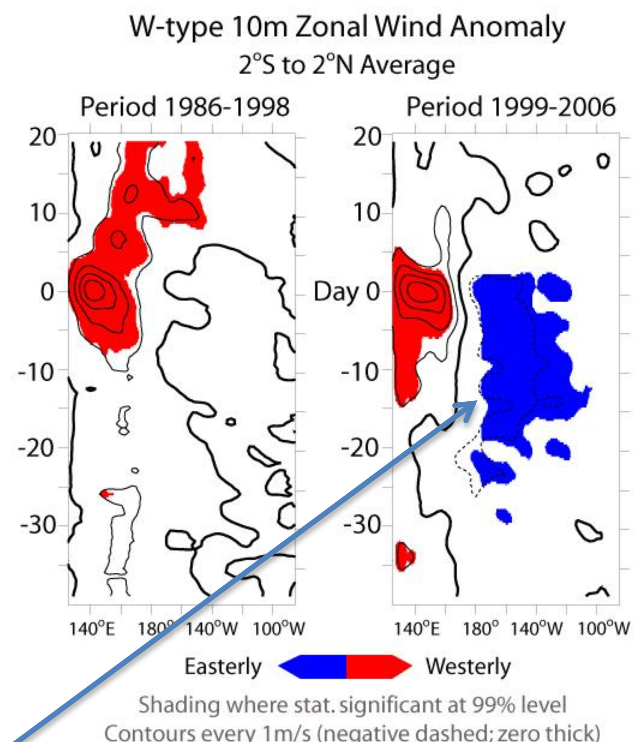
Plot of TAO averaged (2S to 2N) and ERA Interim averaged (@ TAO locations, accounting for data dropouts) Zonal Wind Stress Anomaly, period 1986-2014



In this case, the Reanalysis data has over-abundance of EWS activity in recent years, making wind stress comparisons with earlier periods difficult

Post 1997-98 WWEs have a cold-tongue easterly element

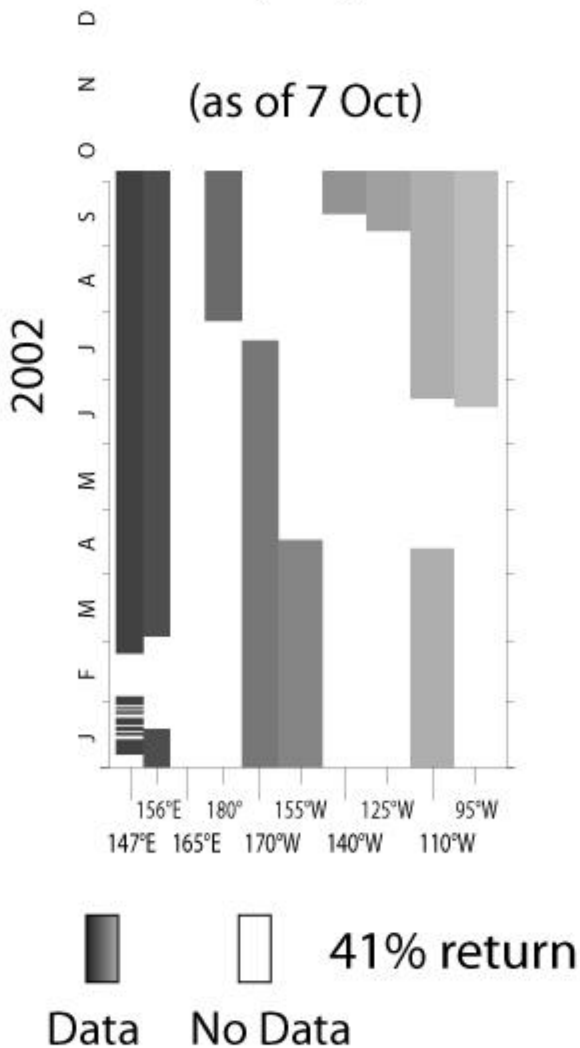




There has been a significant increase in trade wind easterlies, at the times of WWEs, after the 97/98 event

(Chiodi and Harrison, J. Climate, 2009)

TAO Wind Data Return
(0°N)



TAO Wind Data Return
(0°N)