Reconstructing recent ENSO SSTA variability:

A subseasonal wind event perspective

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Motivation

Both 2012 and 2014 basically fizzled-out after showing signs of El Niño-like development in spring/summer. Why?

We have been studying Westerly Wind Events (WWEs) and El Niño for many years (e.g. Harrison and Vecchi, ‘97; Vecchi and Harrison, 2000; Harrison et al. ‘09; Chiodi et al. ‘14). More recently we’ve learned about easterly wind events and La Niña (Chiodi and Harrison, ’15).

We ask how well can we can understand the recent (non) development of El Niño in terms of what we have learned about westerly and easterly wind events.

Outline

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

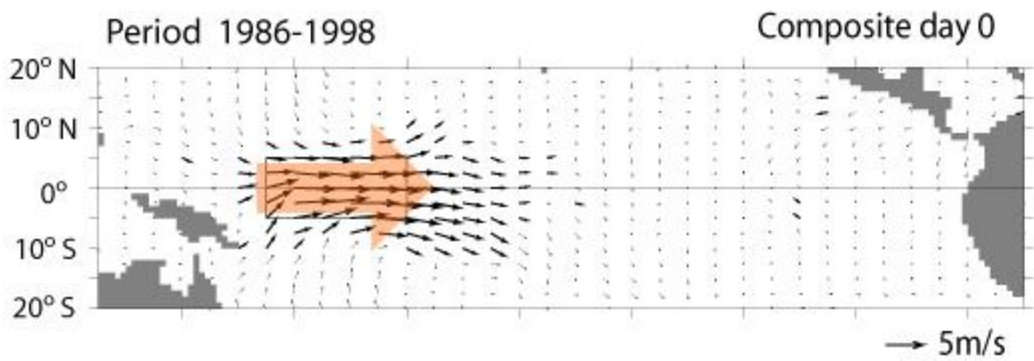
Background 2. Explore further the role of Easterly Wind Surges (EWSs)

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

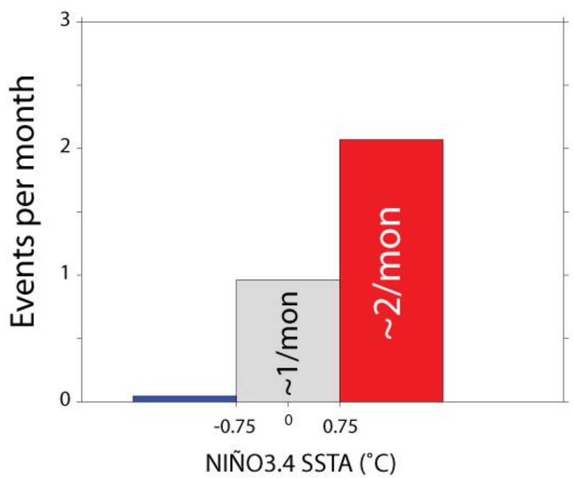
Ocean Model Hindcast experiments: *How well can the detailed development of El Nino SSTAs be understood from a wind event-forced perspective?*

Background 1. WWEs and El Nino Onset

WWE composite wind anomaly



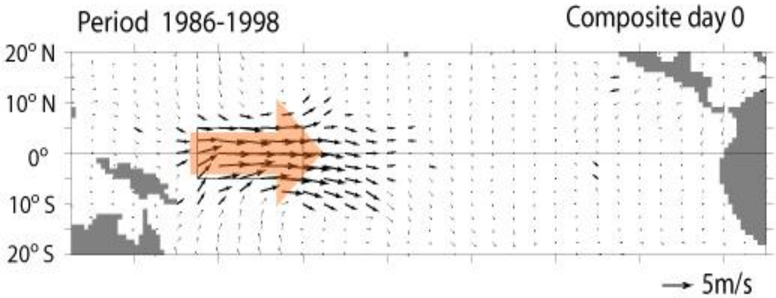
WWE distribution with NIÑO3.4



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

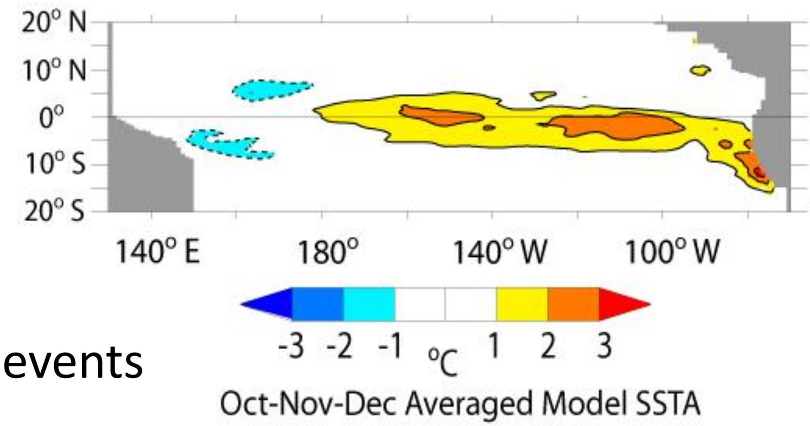
- WWE = 3 or more consecutive days in which WWE-region average zonal wind anomaly > 2 m/s. Harrison and Vecchi (1997) define 3 equatorial WWE-regions: W, C and E.
- "Day 0" is the event-day with maximum zonal wind anomaly (~7m/s average)
- Statistically significant anomalies are seen ~7 days before/after 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 Niño year,

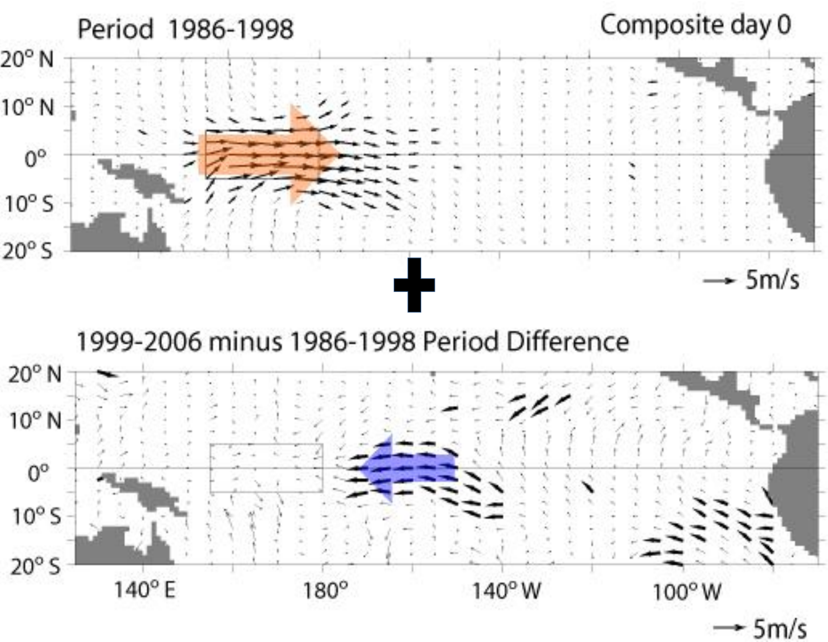


Idealized WWE-generated El Niño

Period 1986-1998 WWEs

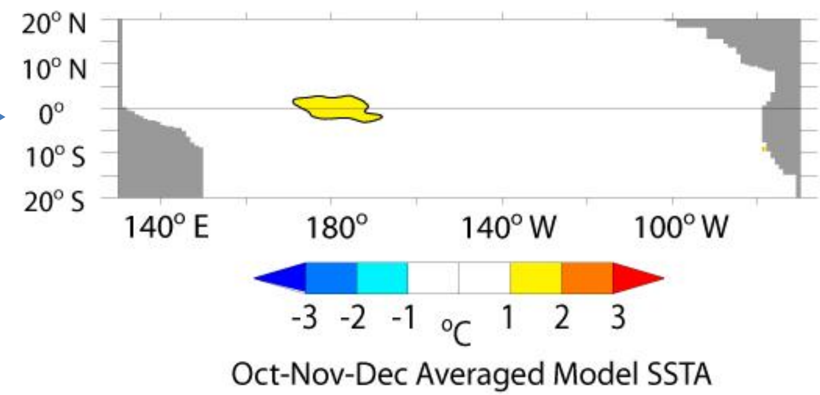


Traditional WWE-composites drive EP-type events



Idealized WWE-generated El Niño

Period 1999-2006 WWEs

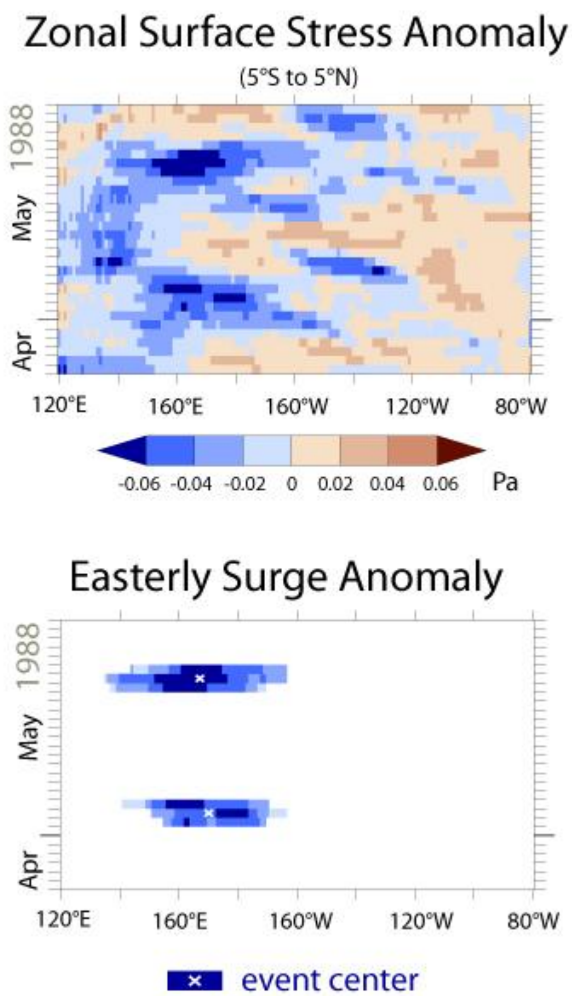


Harrison and Chiodi, 2009, JCLI

WWEs with cold-tongue easterlies drive CP-type events

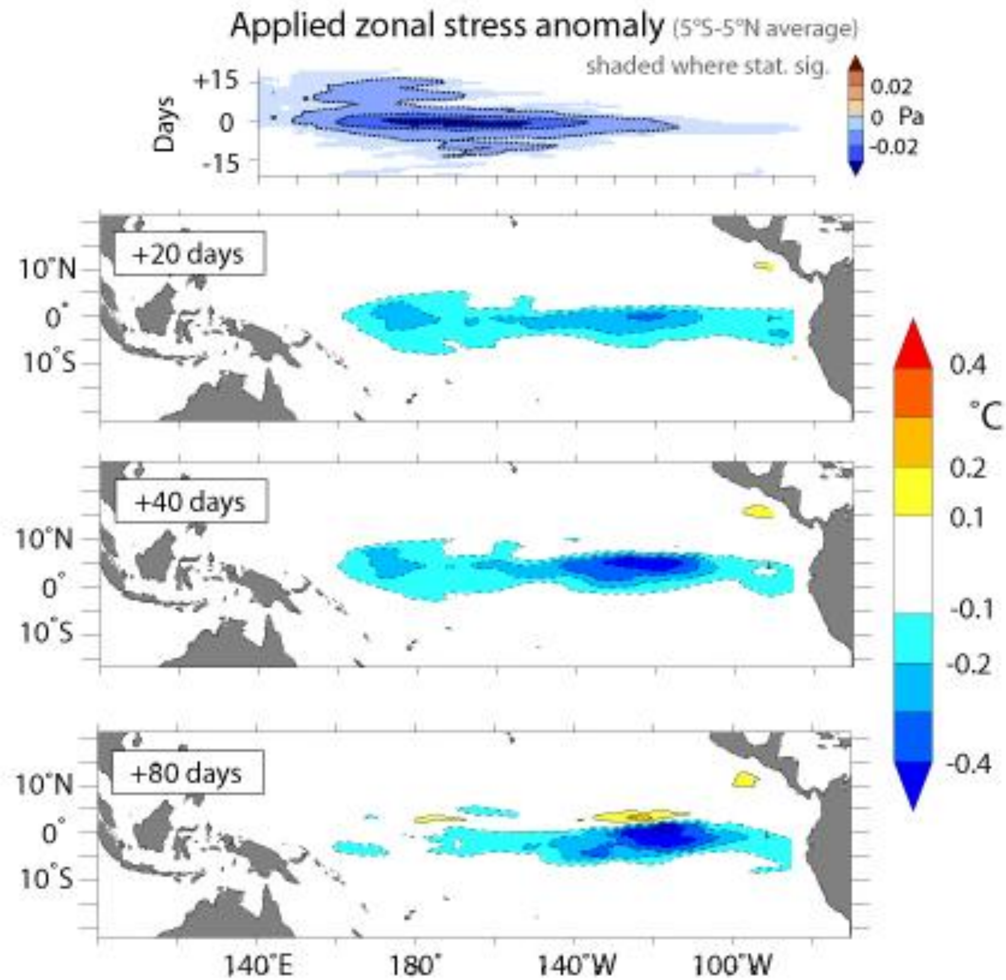
Background 2. Easterly Wind Surges (EWSs) and waveguide cooling

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



Chiodi and Harrison, 2015, JCLI

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 zonal wind event component?

Issue

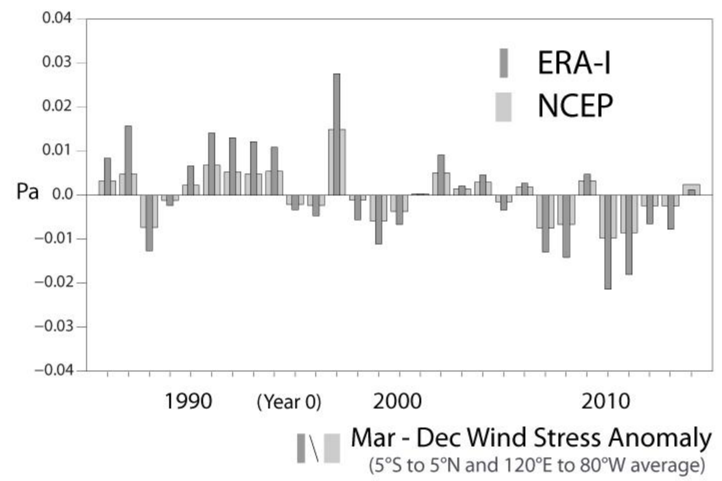
Which wind stress product to use?

Several possibilities (e.g. NCEP1, NCEP2, ERA-I, TROPFLUX)

We find they agree in some respects (good correlation), but disagree on others (large RMSD).

E.g., year-to-year Eq. Pac. Variability based on NCEP1 is only about half of ERA-I.

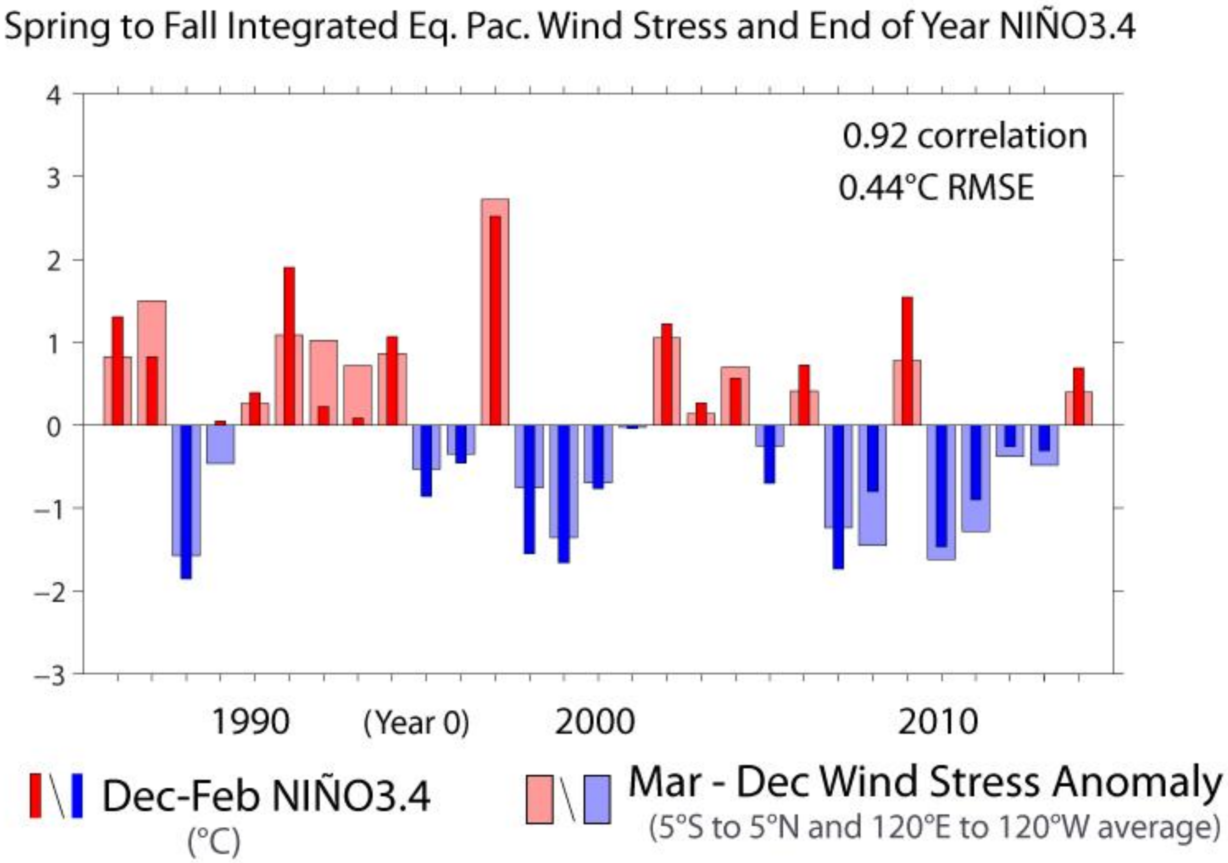
Spring to Fall Integrated Eq. Pac. Wind Stress



We find ERA-I to be closer to available wind obs. (TAO/TRITON buoy), but still has offsets w.r.t TAO that vary in time.

Best results (next) from using ERA-I adjusted to TAO

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



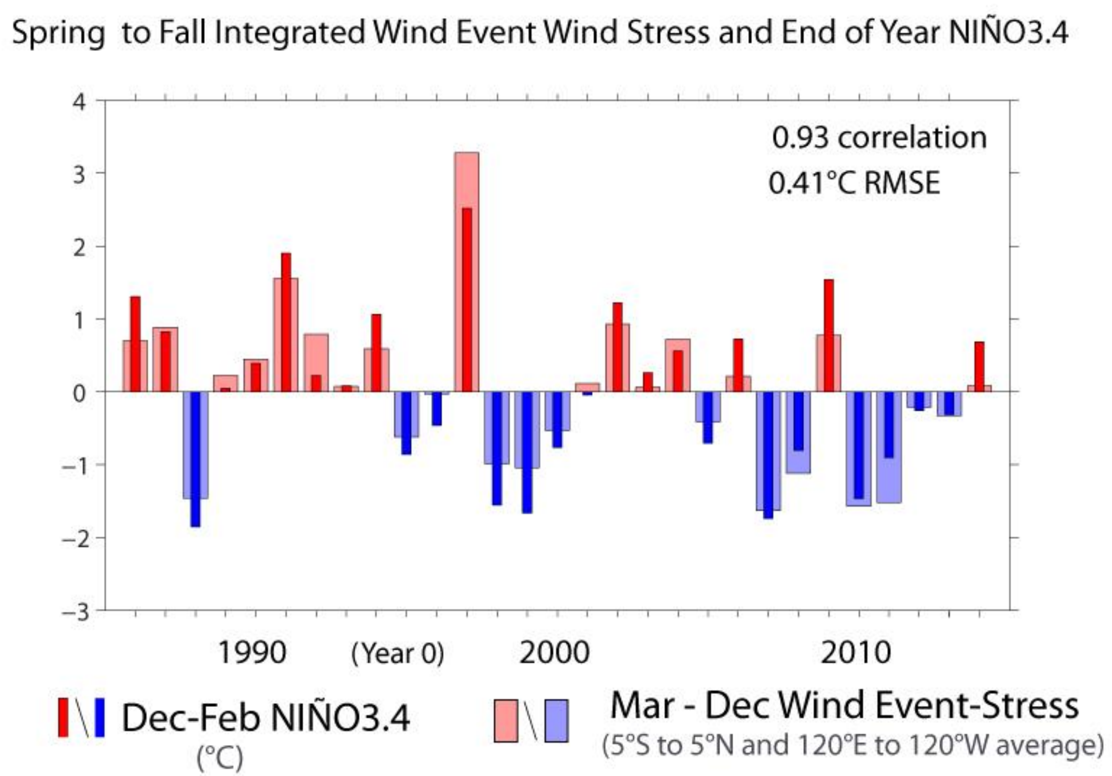
A reminder that Eq. Pac. wind stress anomalies across the ocean waveguide exert a dominant control on NINO3.4 SSTA

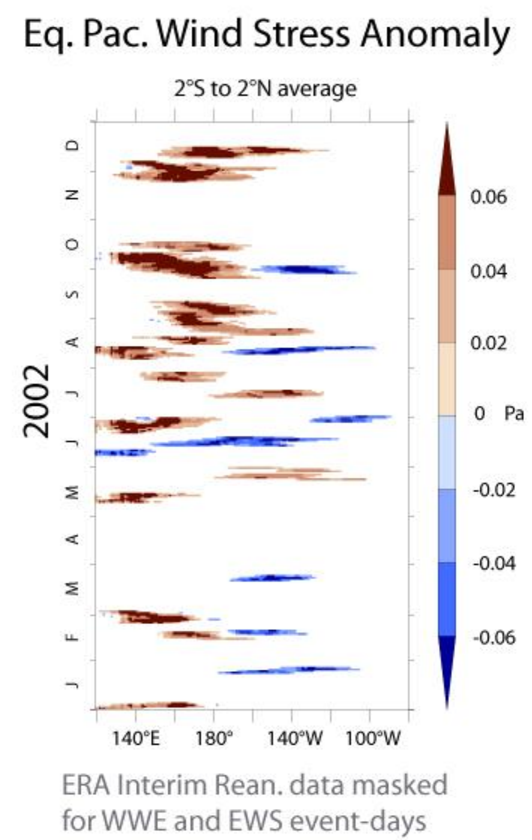
Based on NOAA OISST and Wind Stress from ERA Int. Reanalysis with 1986-2014 matched annually to TAO

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

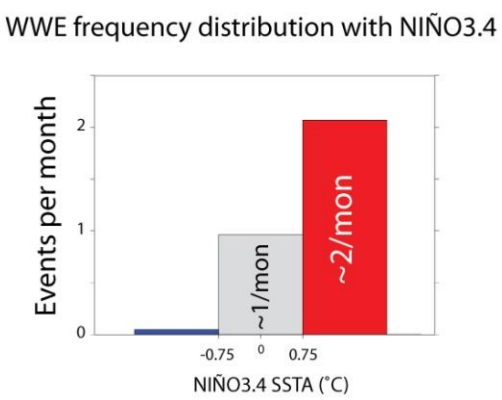
Example year: to get the integral value we integrate red (westerly) minus blue (easterly) shaded regions

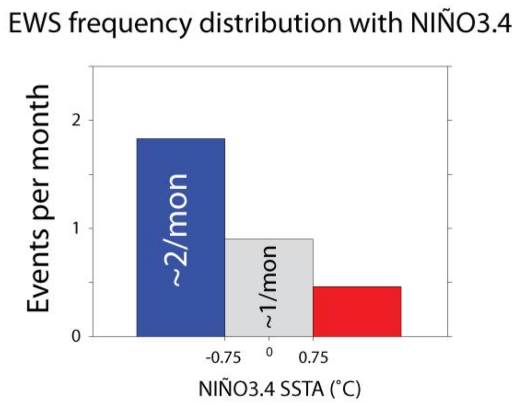




ERA Reanalysis wind stress, matched to TAO, is used for WWE/EWS identification

Integrals of Springtime wind stress - implications?

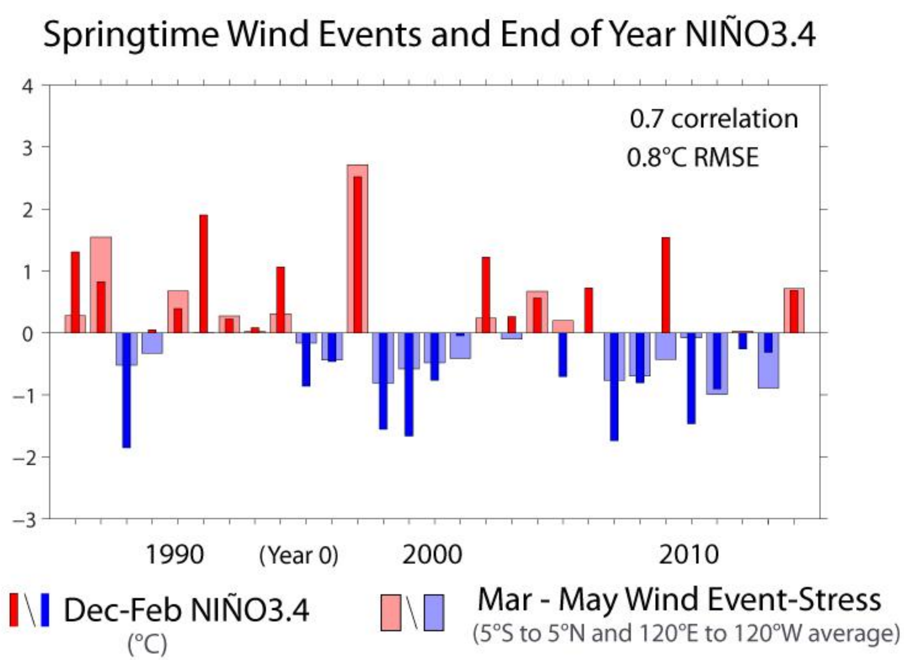




The distributions of wind events with ENSO SSTA show evidence of a positive feedback. Hypothesis: Gill-type mechanism but on a subseasonal scale

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

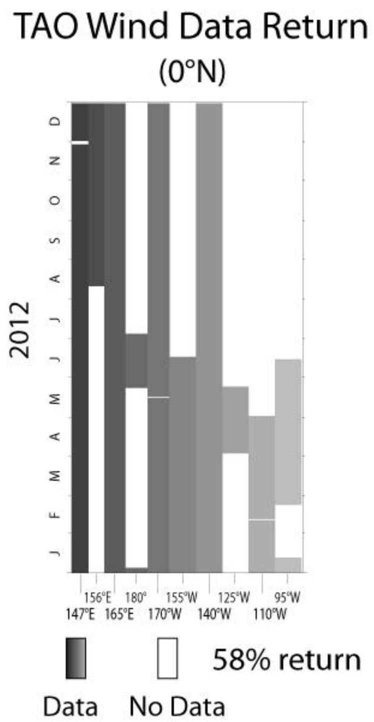
Some forecasting skill here (similar to many more sophisticated models) But a RMSE (0.82°C), close to the standard deviation of NINO3.4 itself, still leaves much of the story untold.

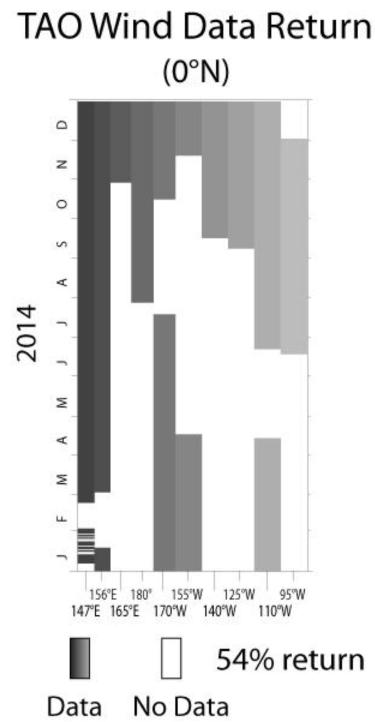


On to hindcasts of 2012 & 2014, and some other recent El Niño years,

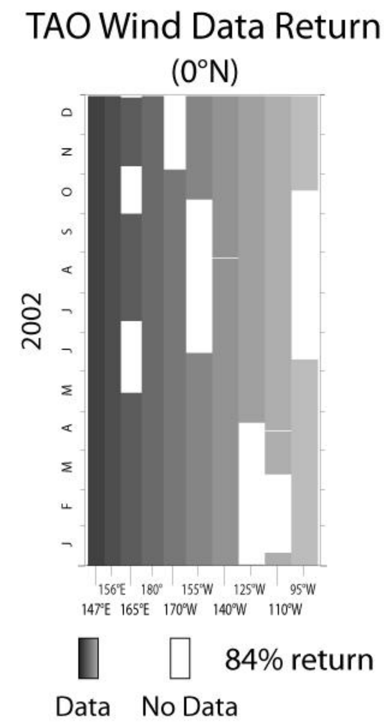
ISSUE: Lack of TAO data reduces ability to diagnose obs SSTAs

‘12 & ‘14 Not So Good





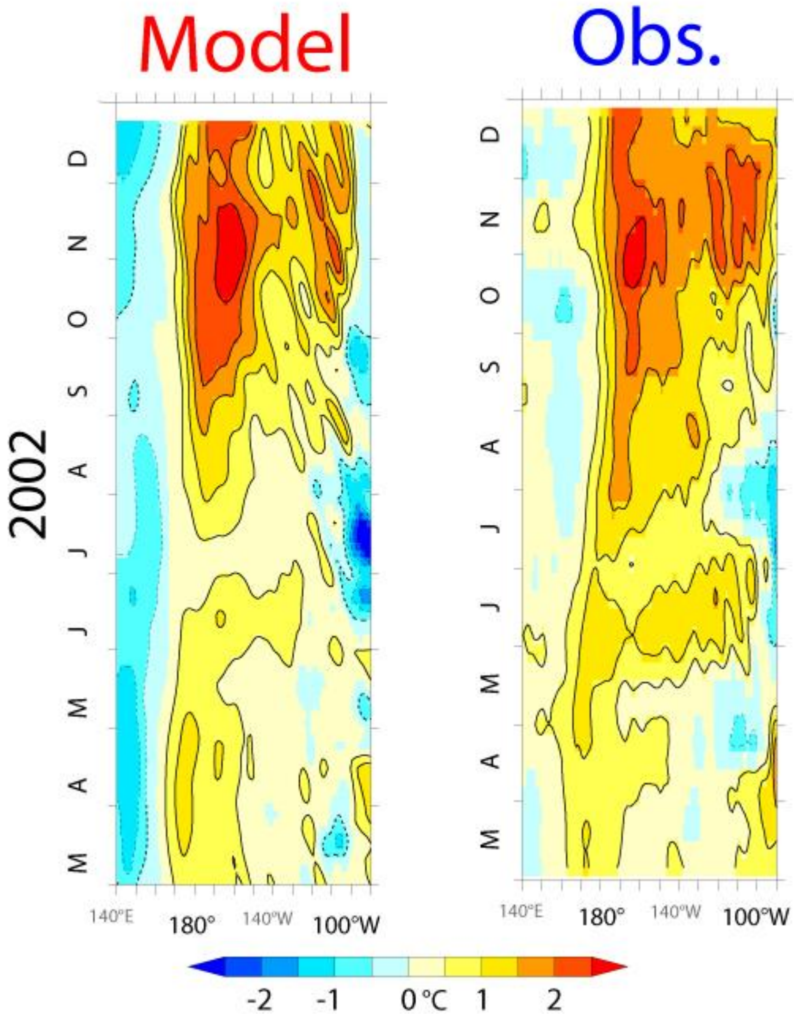
‘02 Good



2002 Hindcast

Forcing with just TAO wind stress anomaly produces qual. correct SSTA development in '02

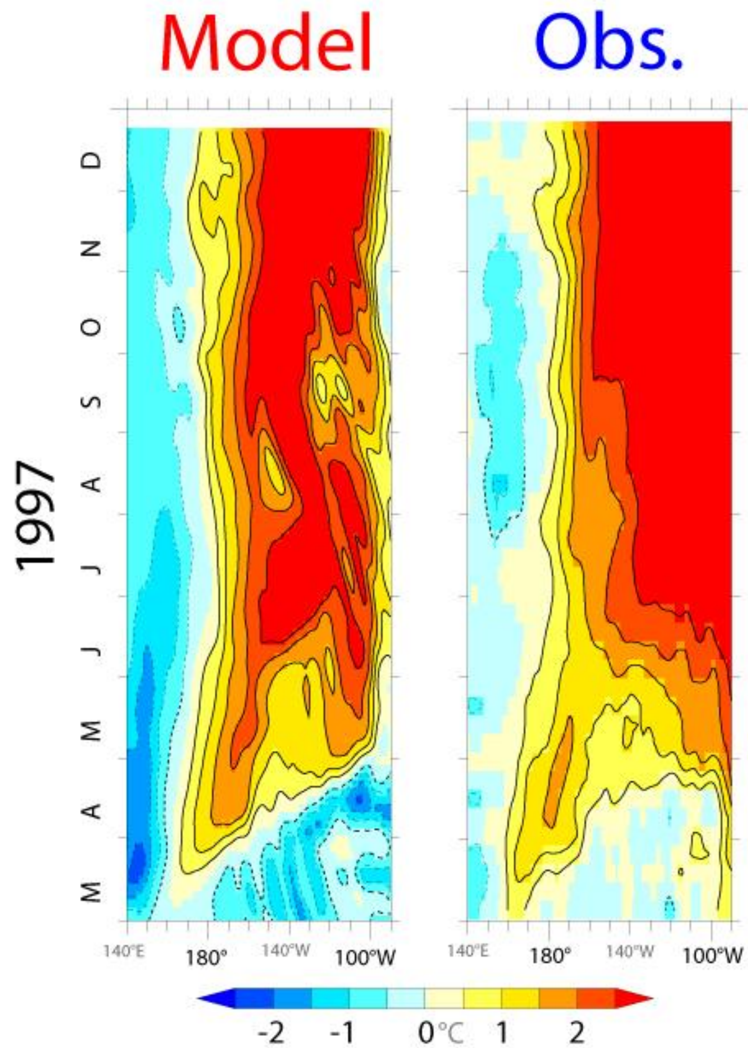
Model: an old one (Pacanowski & Philander, 1986), tweaked in the 1990s (e.g. Harrison, 1991) that (still) works well when we have high quality wind forcing.



Buoy winds from 2°S to 2°N averaged, converted to pseudo-stress & interpolated zonally. Good (84%) TAO/Triton data return rate along Equator, in the 2002 case.

1997 Hindcast

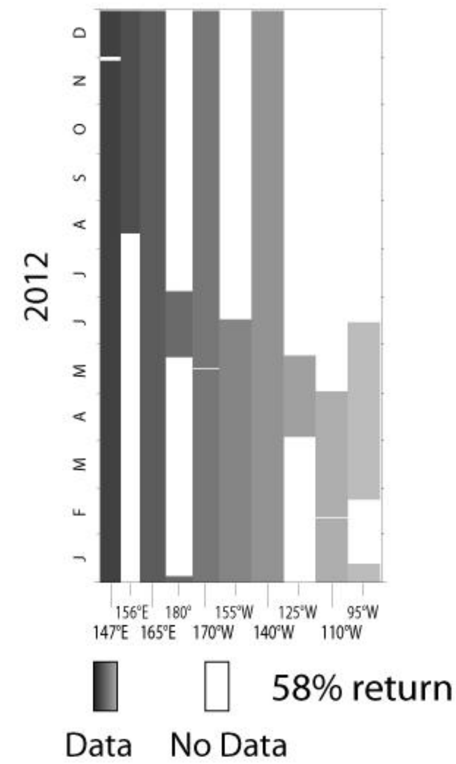
This works for '97 as well



75% TAO/TRITON data return, along equator, in '97

Now the 2012 case:

TAO Wind Data Return
(0°N)



- Forcing with the available TAO winds leads to poor model results.

- Using $\tau x'$ from the reanalyses (e.g. NCEP, ERA-I) also produces unsatisfactory model results.

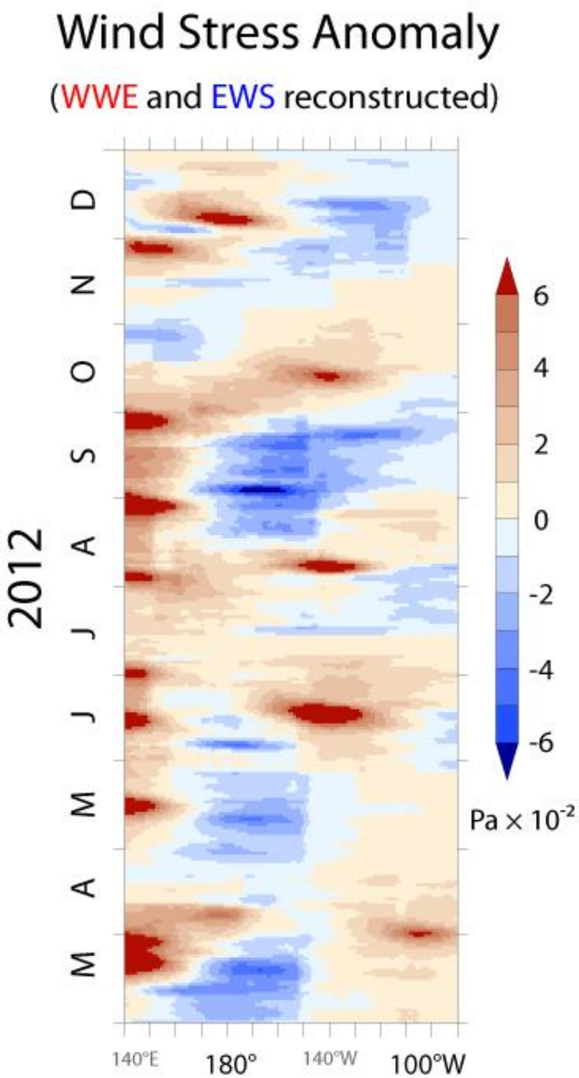
- NCEP vs ERA-I predictions differ (End of year Nino 3.4 SSTAs differ by 0.7°C)

- NCEP/ERA-I uncertainty remains high, even in years with better TAO coverage

Bottom line: uncertainty between Reanalysis wind stresses is a serious issue for diagnosing ENSO SSTA.

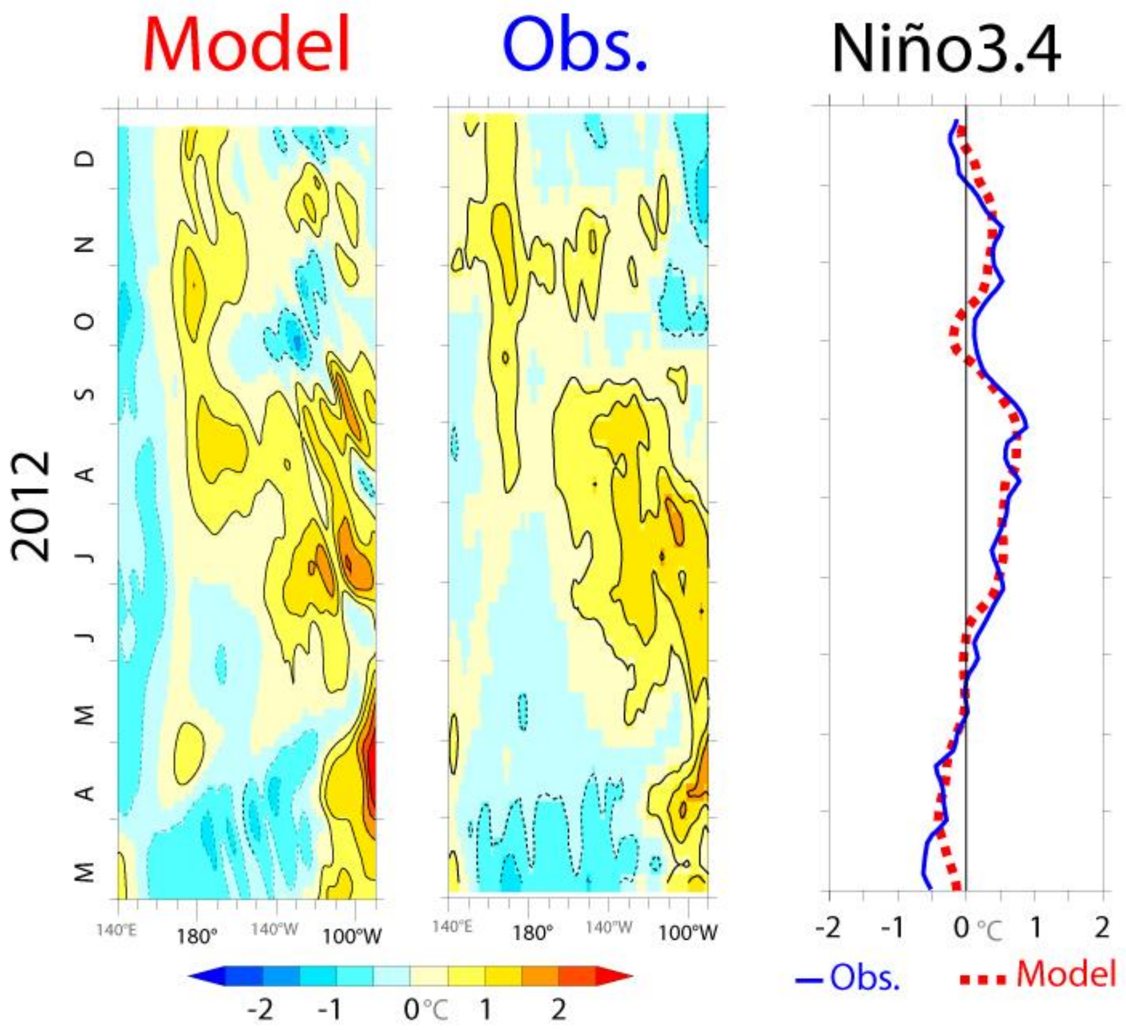
A plausible 2012 wind-event scenario.

Composite WWEs & EWSs applied here based on ERA-I data, and adjusted within the available uncertainty bounds



16 WWEs & **14 EWSs** in this case

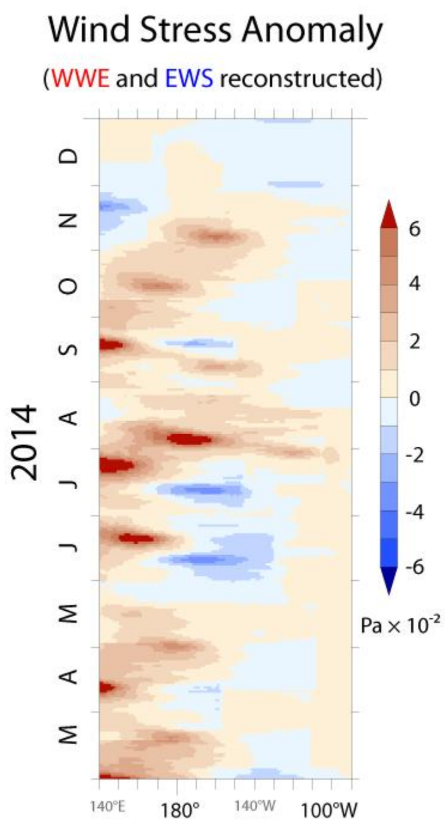
Qualitatively correct SSTA development is now produced in the model:

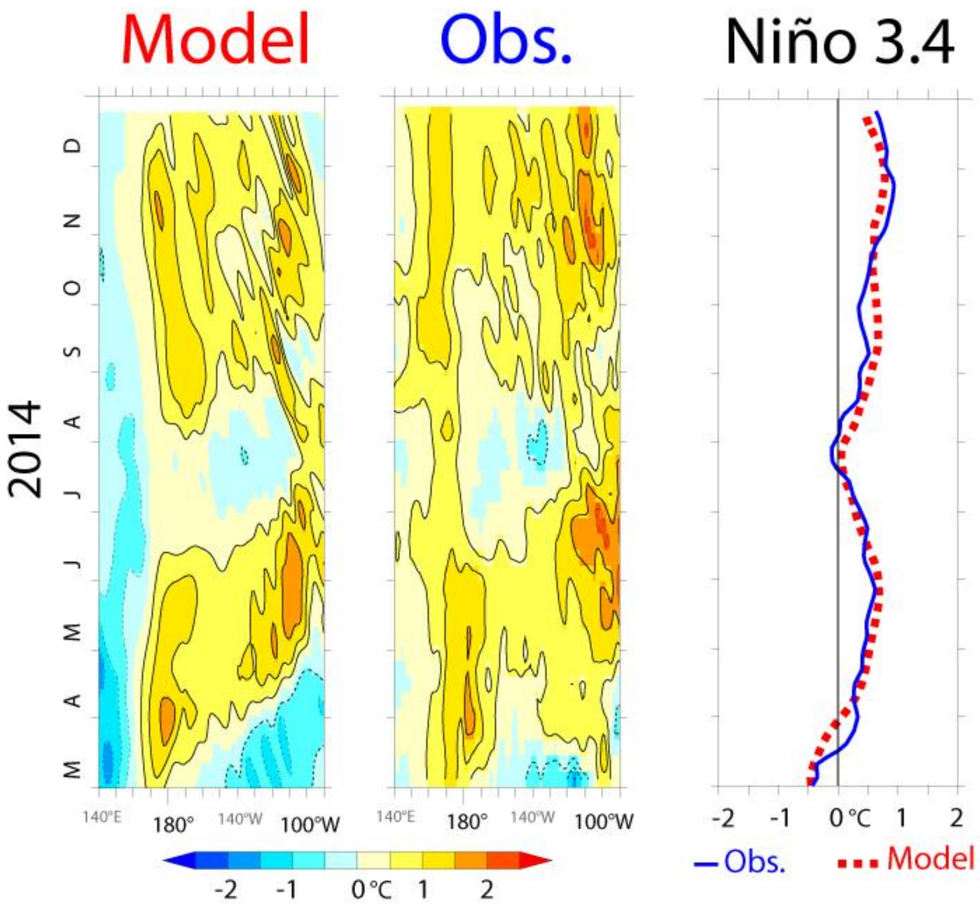


We can hypothesize that wind events forced 2012 ENSO SSA, but can't say for sure due to τ_x uncertainty

A similar story holds in 2014:

A series of WWEs & EWSs again reproduces obs. ENSO SSTAs



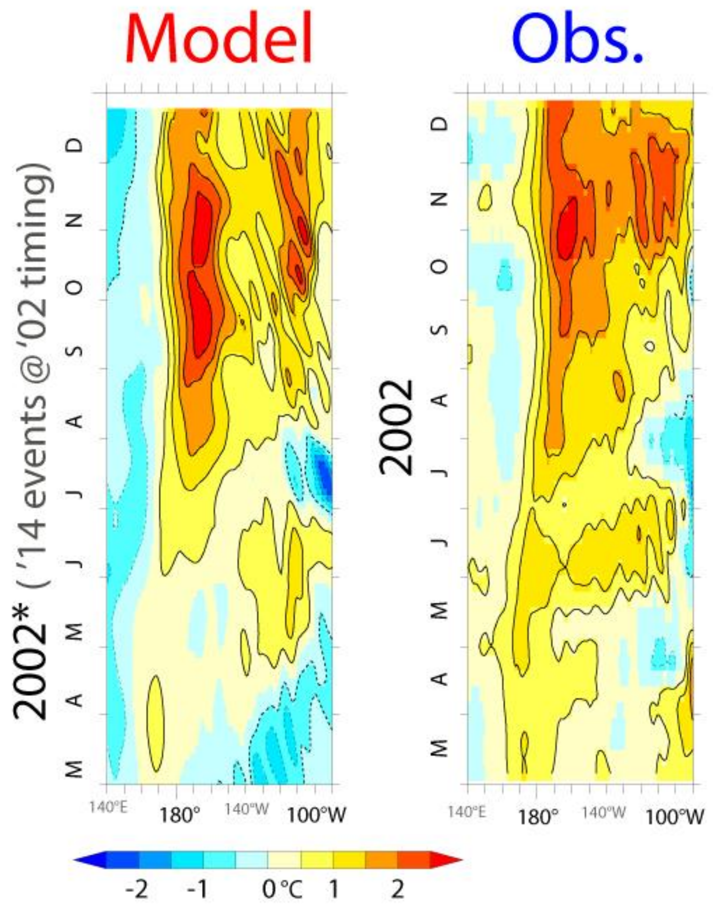


16 WWEs & 7 EWSs in this 2014 scenario

A wind event re-ordering experiment:

Using the same 2014-case wind events, applied instead at the timing/location observed in 2002, we basically recover a 2002-type SSTA development

The same 16 WWEs & 7 EWSs applied instead at 2002 timing/location drives 2002-like SSTA development



SSTA development patterns depend greatly on the wind event distribution

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~0.4°C), and SSTA pattern characteristics (CP vs EP) depend on distribution of westerly/easterly wind events

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.

Conclusions cont.

Wind events are dominant drivers of ENSO SSTA development:

Implications:

1. Accurate knowledge of wind stress across entire Eq. Pac. is necessary to diagnose obs. SSTA development (easterly events are harder to do than westerly)

2. Improving ENSO SSTA forecasts may require learning how to predict Easterly and Westerly Wind Events.