El Niño from onset to impact

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Outline

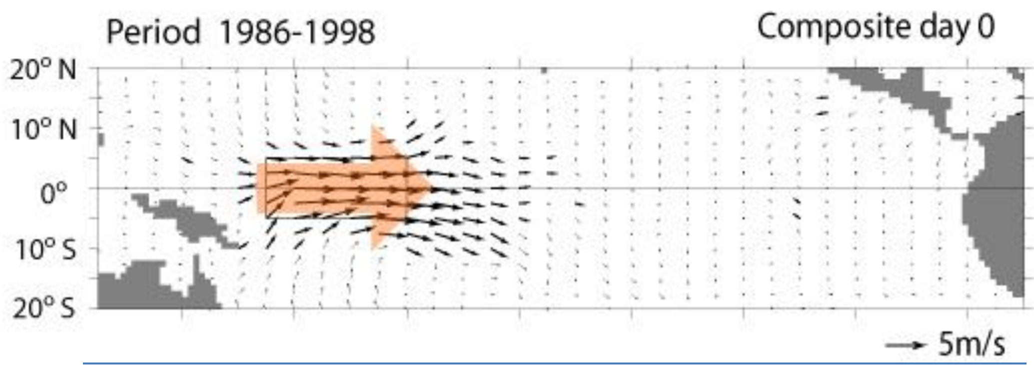
Part 1. Getting El Niño going: sub-seasonal wind events

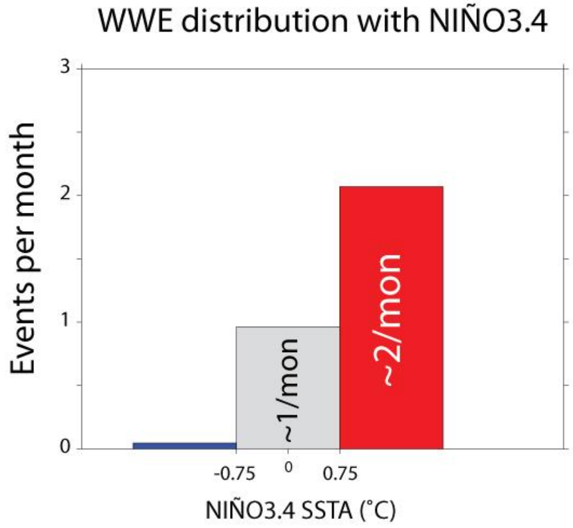
- -Westerly Wind Events (WWEs) and oceanic waveguide warming
- -Getting EP and CP El Niño events from WWEs – effects of cold tongue easterlies
- -Zonal Wind Stress Anomaly Integrals and ENSO SSTA
- -Ocean General Circulation Model Hindcasts

Part 2. Indices of the ENSO anomaly state and seasonal weather associations – how outgoing-longwave radiation can identify events with consistent impacts.

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.

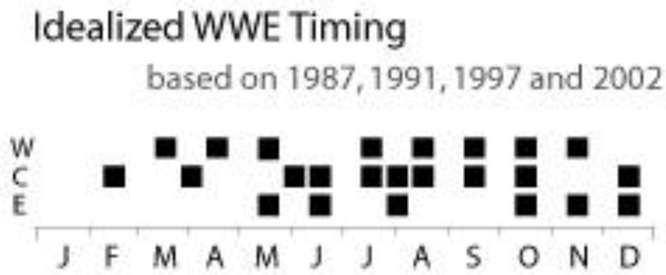
- WWE = 3 or more consecutive days in which WWE-region average zonal wind anomaly > 2 m/s. Harrison and Vecchi (1997) define 3 equatorial WWE-regions: W, C and E.

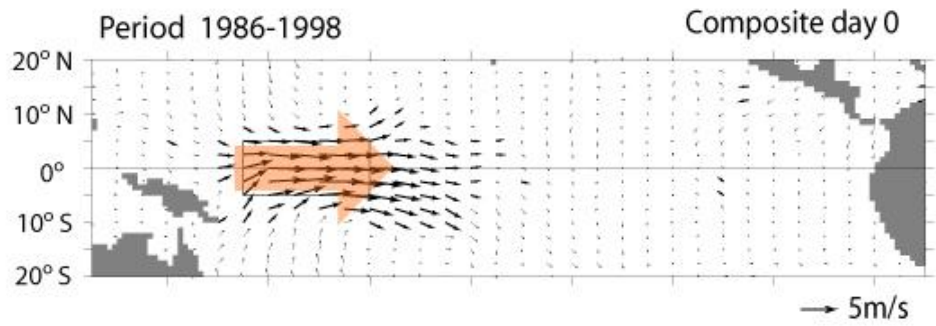
- "Day 0" is the event-day with maximum zonal wind anomaly (~7m/s average)

- 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 Niño year,

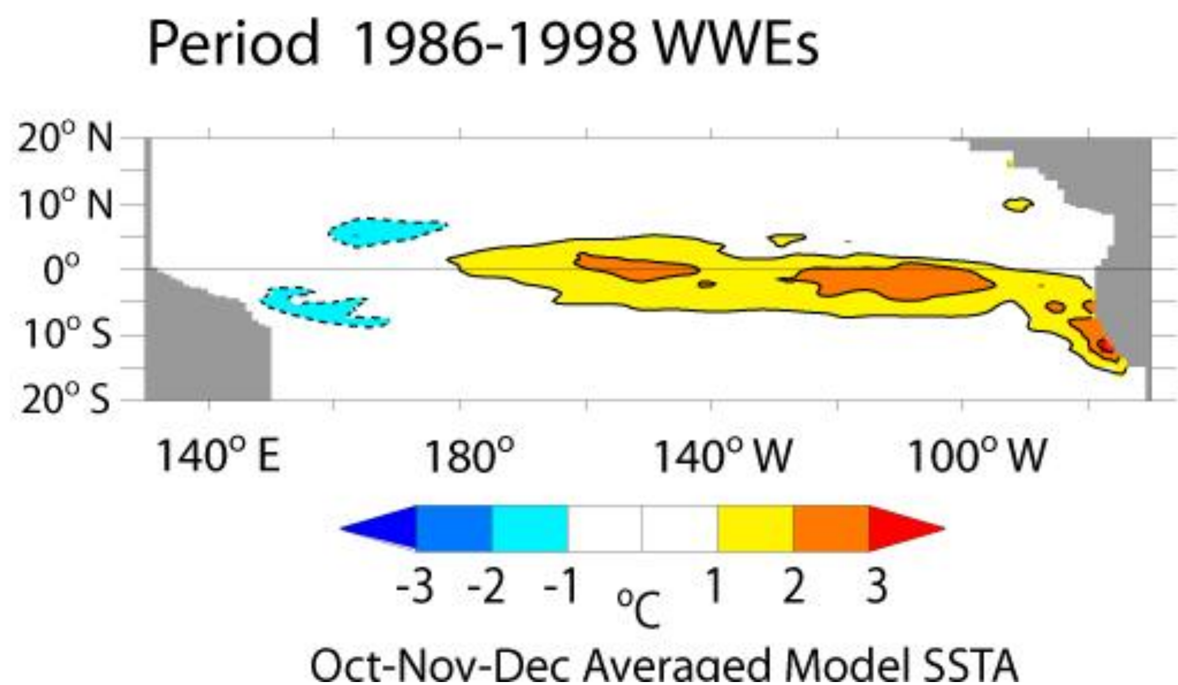




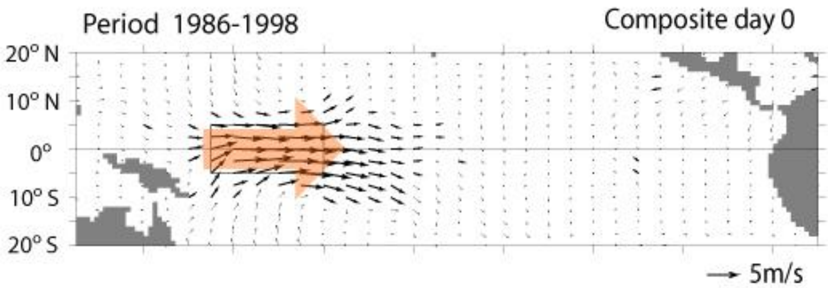
when the WWE-region contains most all of the statistically significant wind anomaly...

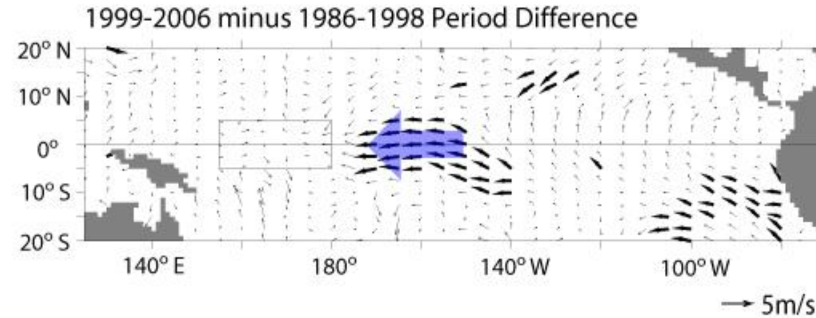
Idealized WWE-generated El Niño

...a series of WWEs drives El Niño-like SSTAs in the model (an EP event)



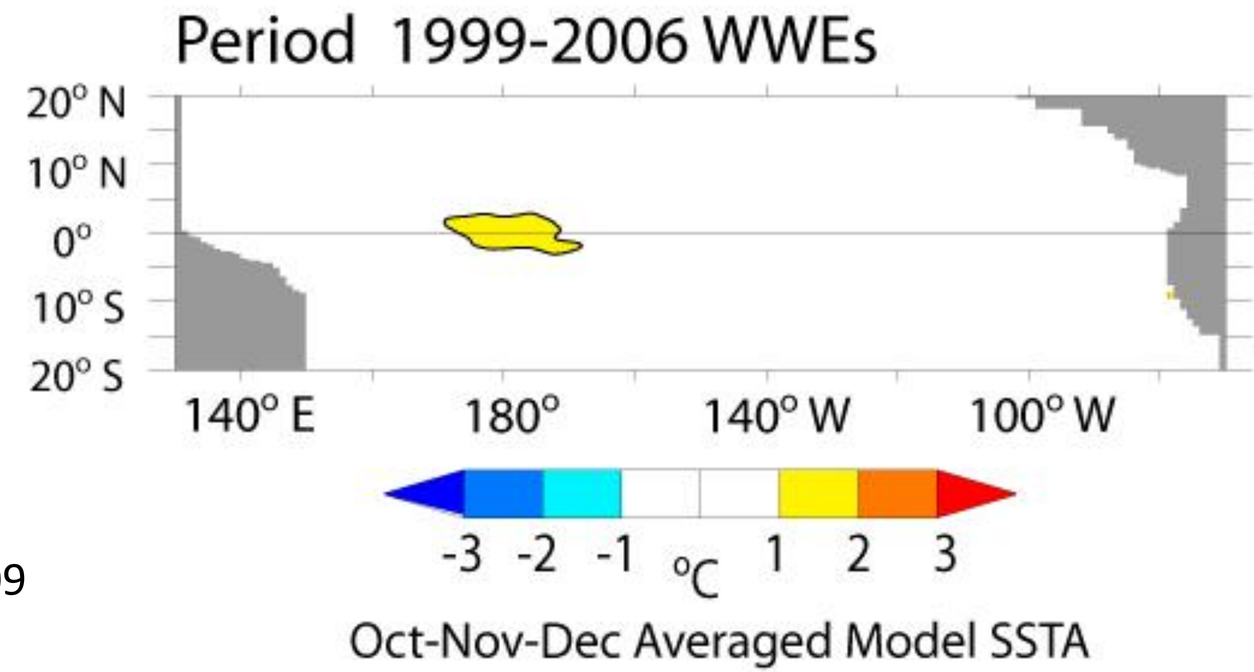
Post 1997-98 WWEs have a cold-tongue easterly element





Idealized WWE-generated El Niño

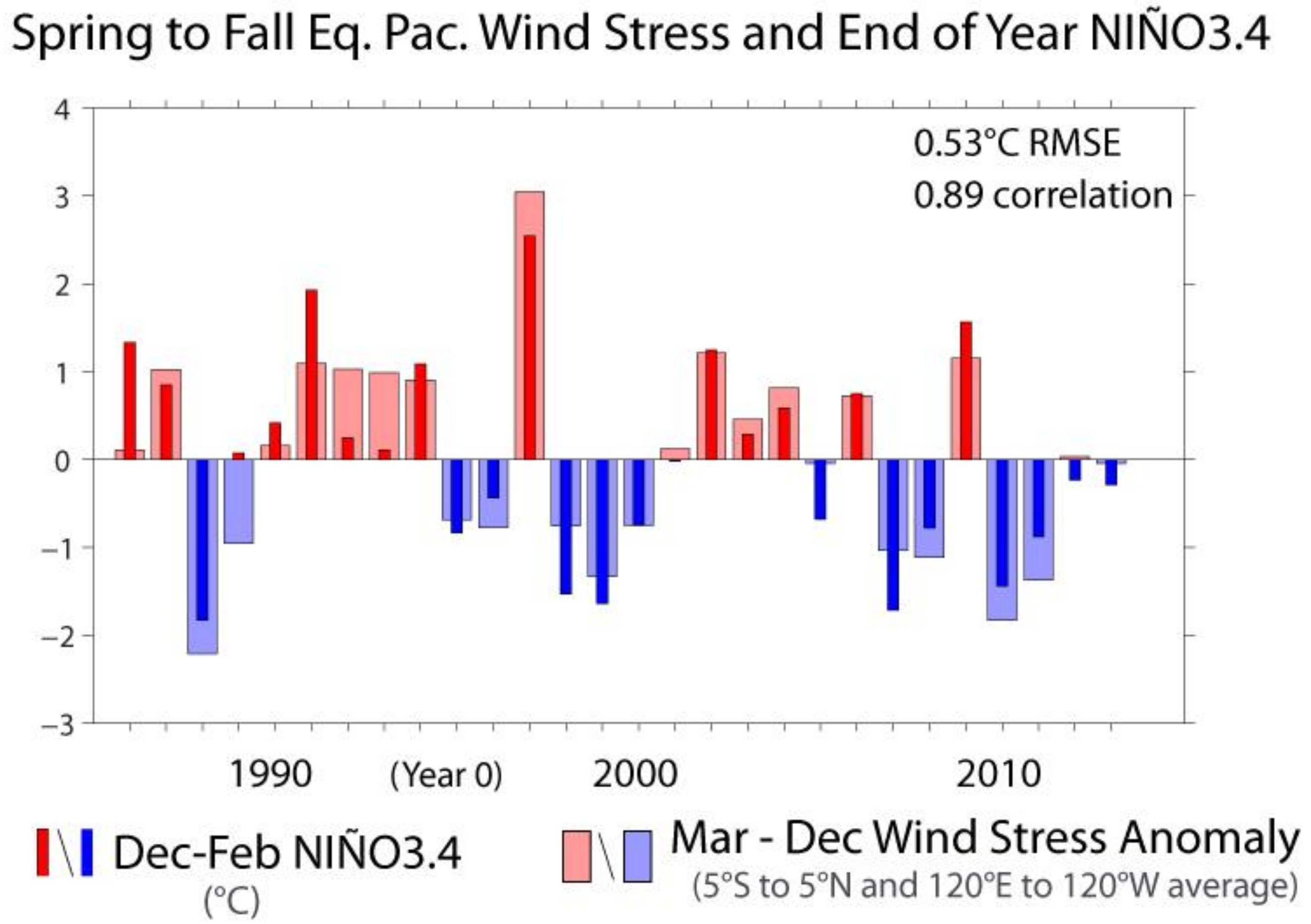
When WWEs that include the easterly pulse (like the 1999-2006 average) are applied to the model, a* Central Pacific El Niño *occurs



See Harrison and Chiodi, 2009

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

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



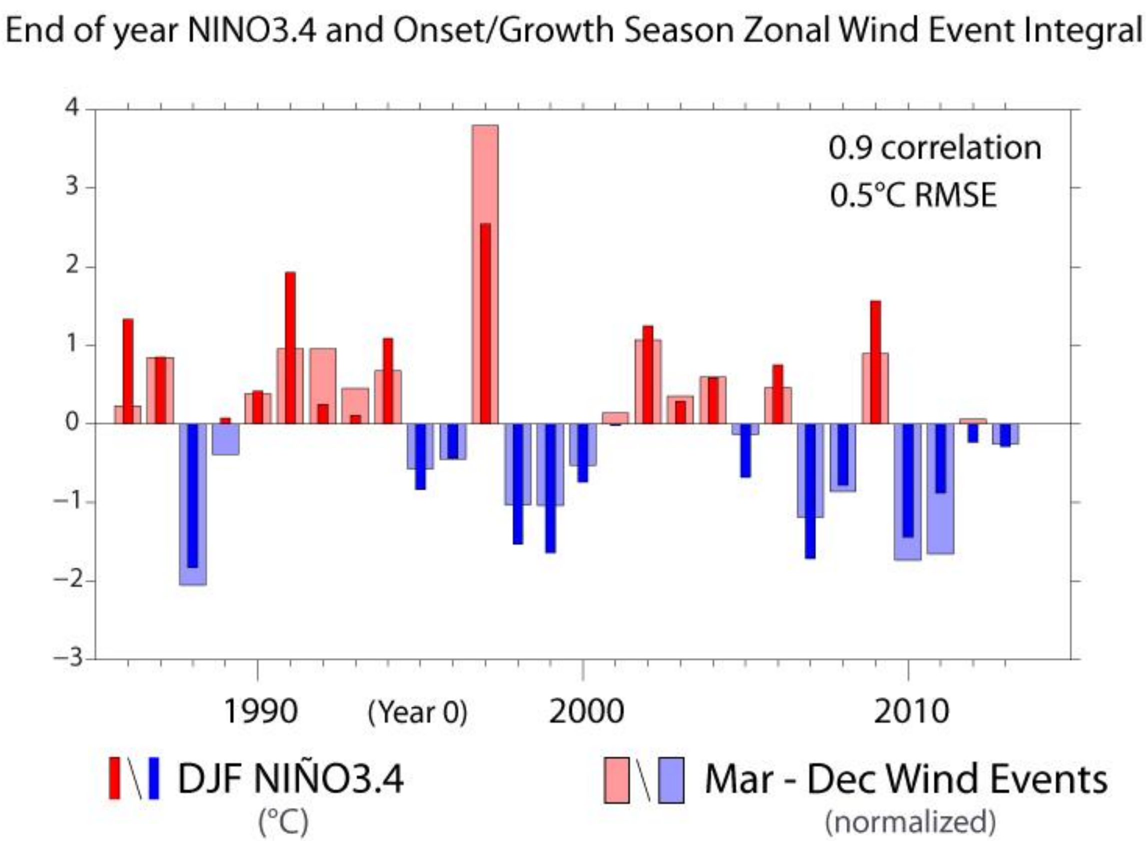
A reminder that Eq. Pac. wind stress anomalies across the ocean waveguide exert a dominant control on NIÑO3.4 SSTA

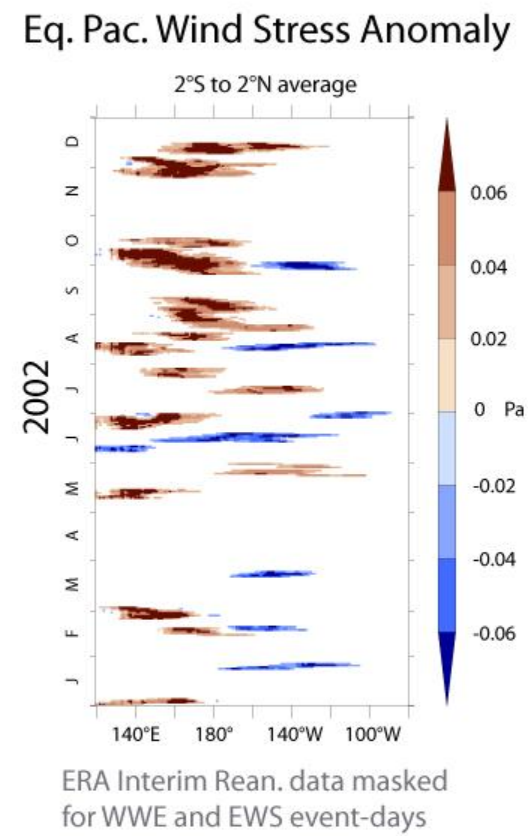
Based on NOAA OISST and Wind Stress from ERA Int. Reanalysis with 1986-2014 trend matched to TAO

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

The wind events are fundamental to the forced response.

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

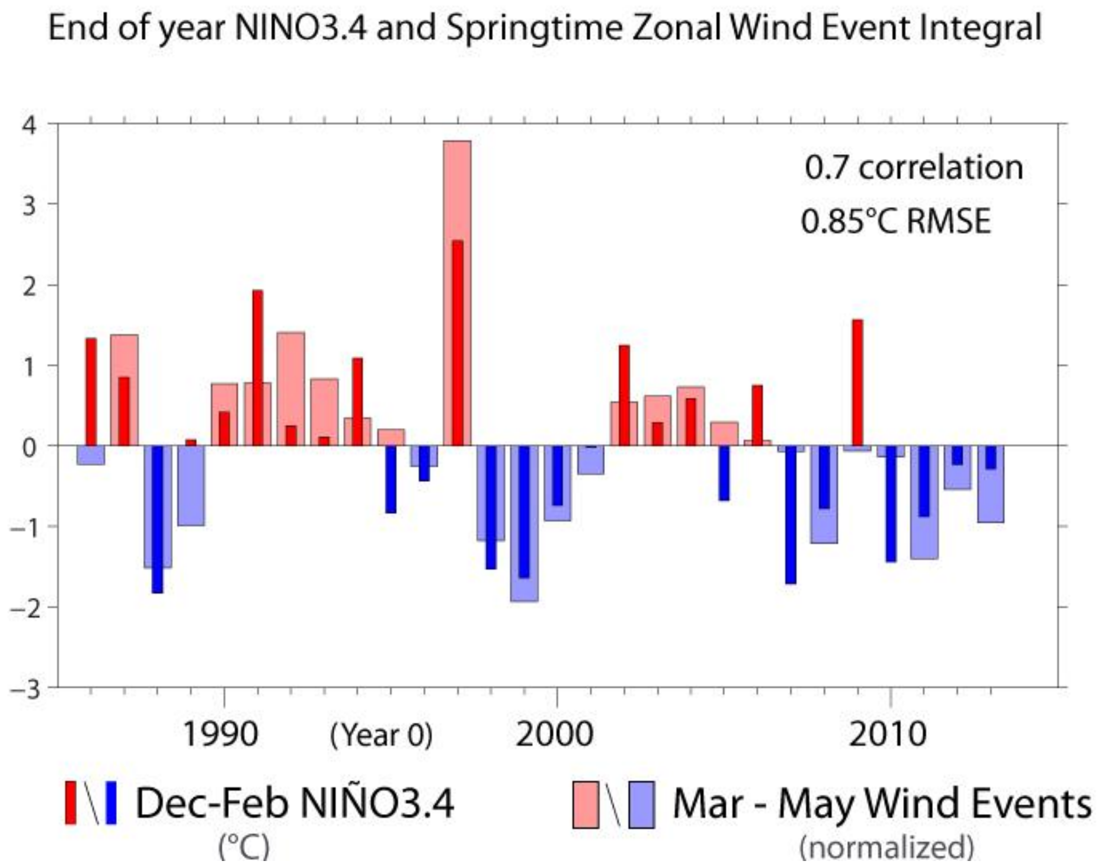




ERA Reanalysis wind stress, matched to TAO, is used for WWE/EWS identification

Integrals of wind stress – forecast implications?

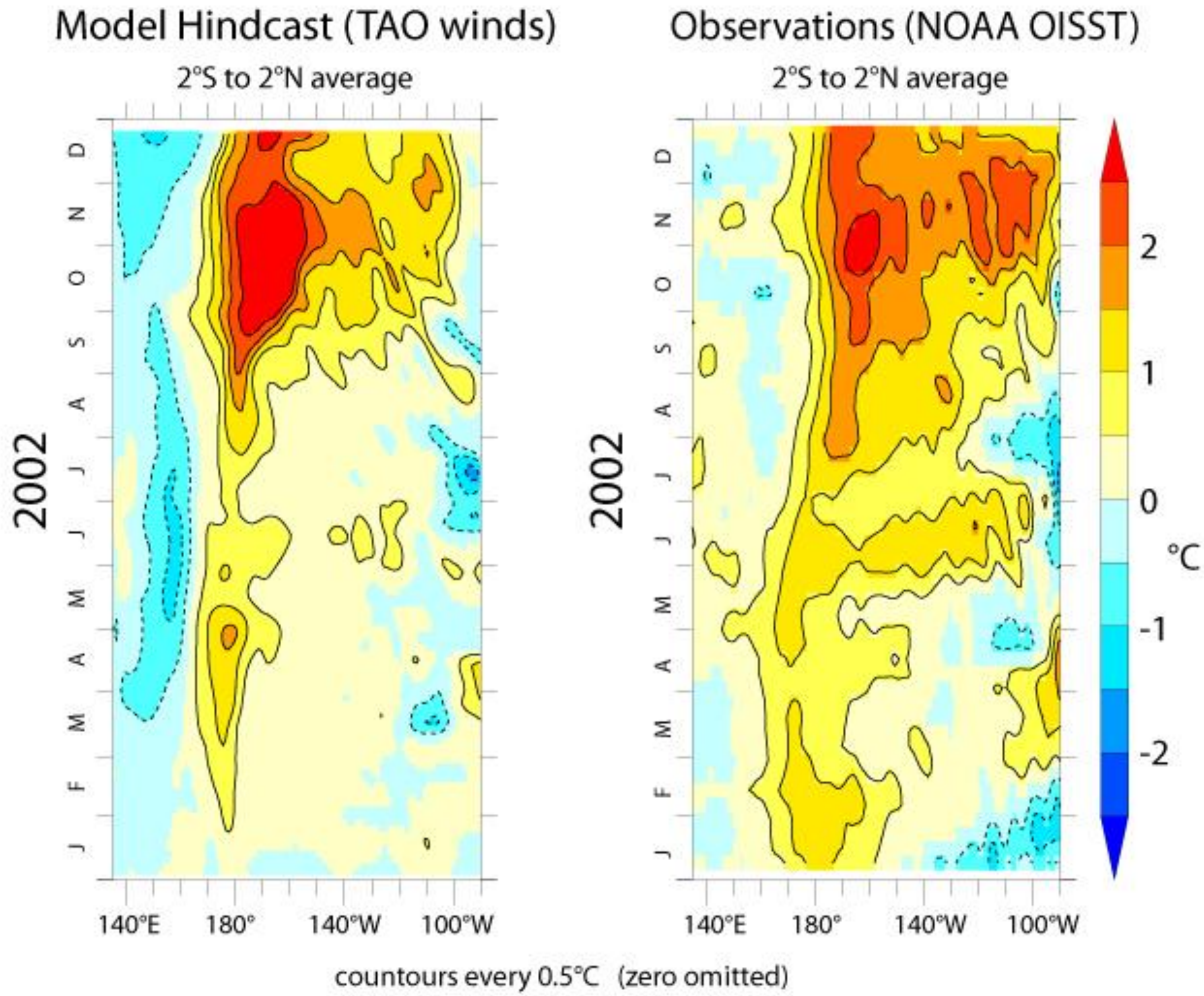
An early stage (e.g. Mar-Arp-May) excess of one or the other type of wind event can help steer the ENSO trajectory



The forecasting skill here is 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.

2002 SSTA Hindcasts

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



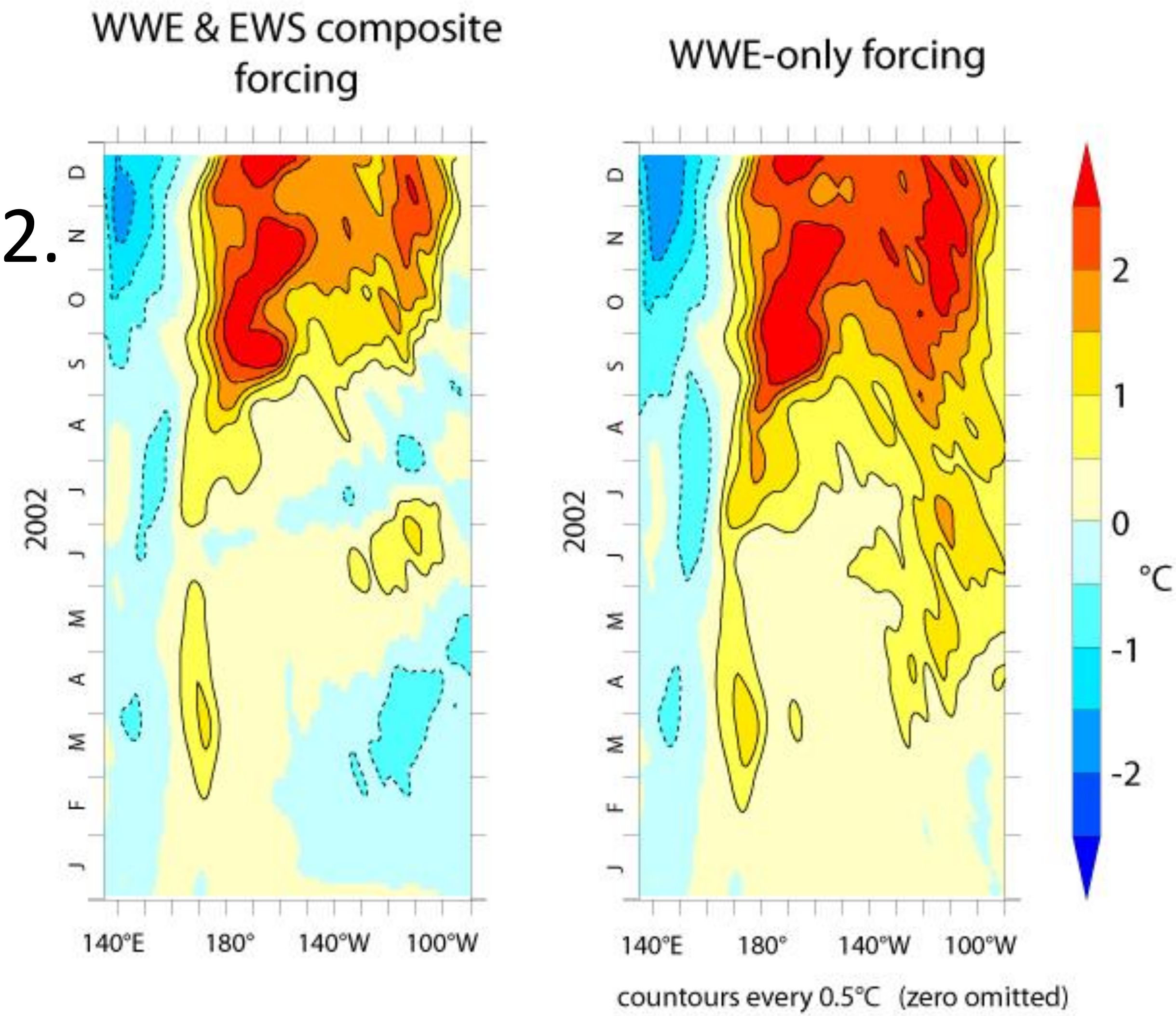
Buoy winds from 2°S to 2°N averaged and converted to pseudo-stress.
Good (84%) data return rate along Equator, in this case.

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).



Part 2: El Niño impacts on seasonal weather anomalies

•Many of ways have been used - SSTA, SLP, OLR and Multivariate indices - to characterize the anomaly state of the tropical Pacific

•Niño 3.4 SSTA indices are most widely used, but there is large event-to-event variation in associated seasonal weather anomalies.

•We show that an OLR index identifies a subset of years with consistent seasonal weather anomalies.

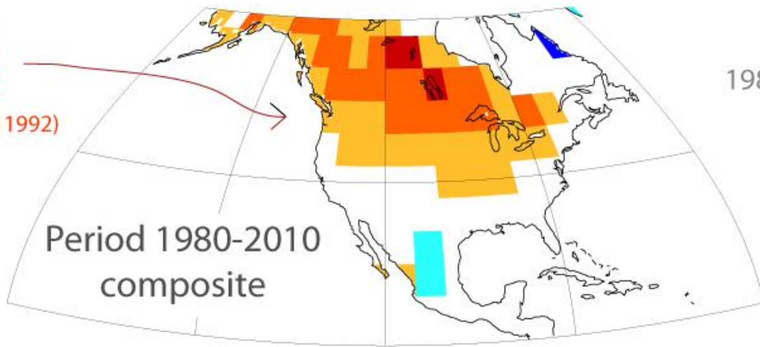
•Interestingly, there is little consistent seasonal weather behavior in the remaining, non-OLR, events.

ENSO composites are useful to forecasting efforts, but also frustrating.

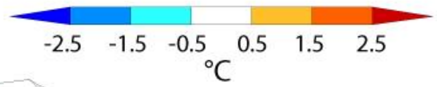
Wintertime (DJF) Temperature Anomaly

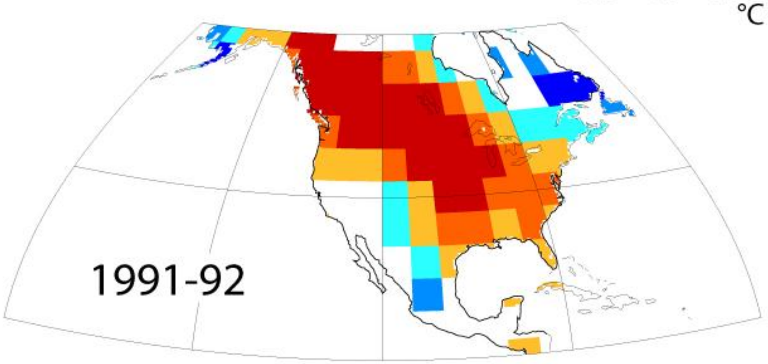
El Niño Average

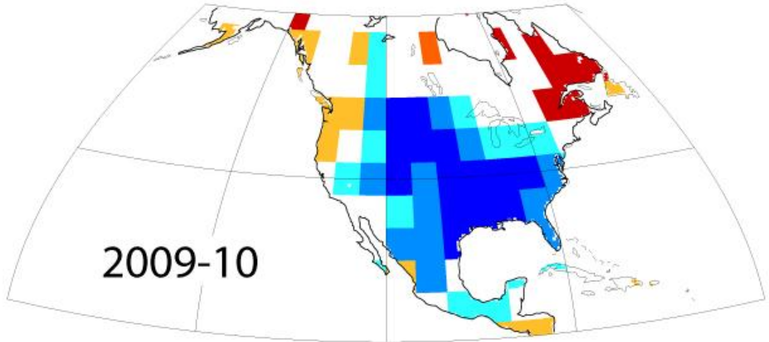
Warm anomaly as expected from classic previous-period composites (Halpert & Ropelewski 1992)



NIÑO3.4 SSTA-based El Nino year list:
1982-83, 1986-87, 1987-88, **1991-92**, 1994-95, 1997-98, 2002-03, 2004-05, 2006-07, **2009-10**







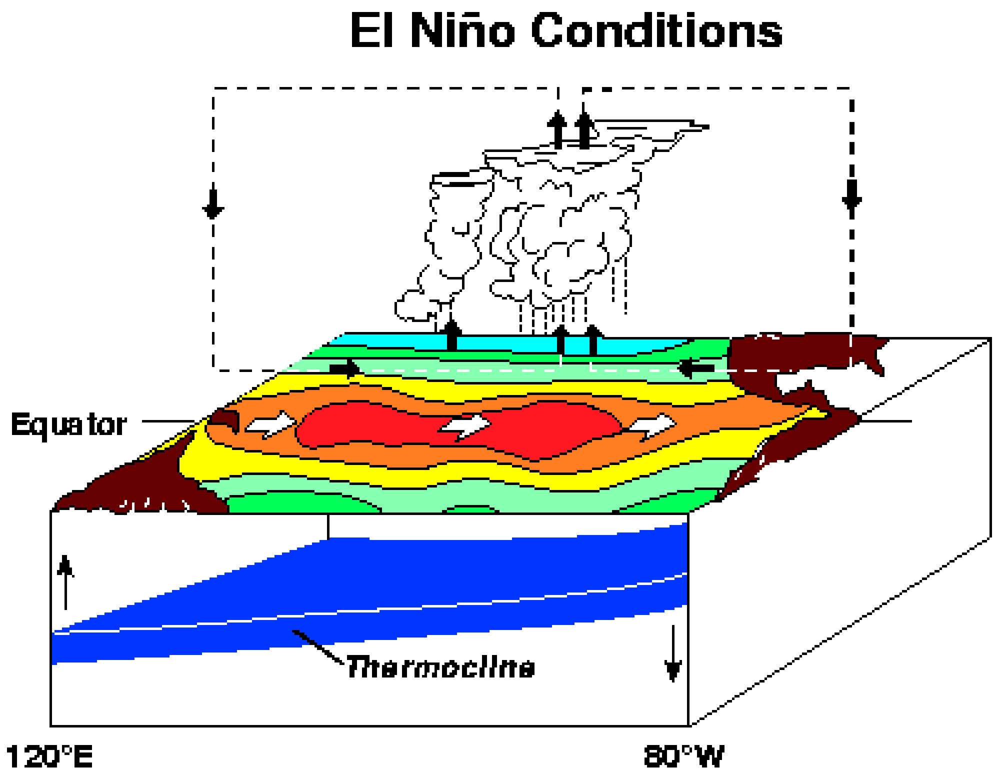
Some of the individual years have anomaly patterns that match the composites...

...and, frustratingly, others do not.

data: CRUTEM3

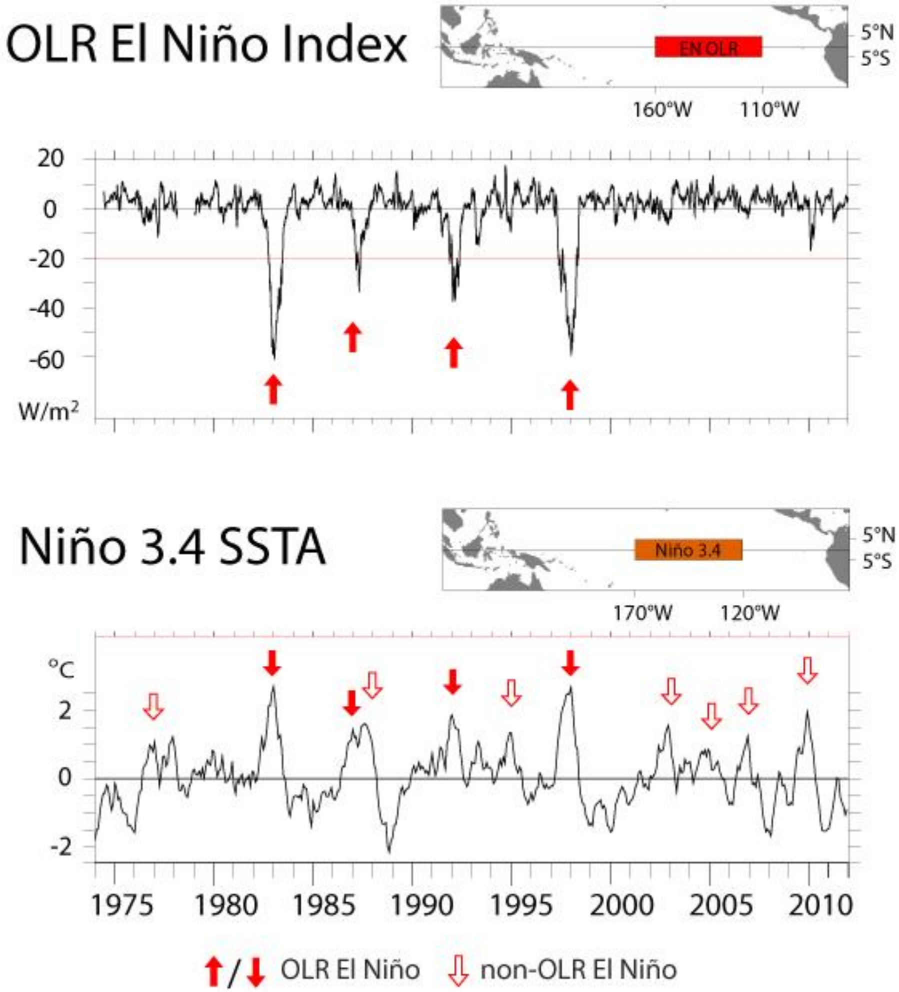
Our initial approach was motivated by the now familiar ENSO cartoons

In the tropics, the arrival of deep atmos. convection conditions is associated with large decreases in OLR.



SLP, SST and OLR all provide measures of coupled-system anomalies during ENSO, but **OLR** provides the best look at **atmospheric heating anomalies** which drive atmos. circulation, temp. and precipitation anomalies elsewhere

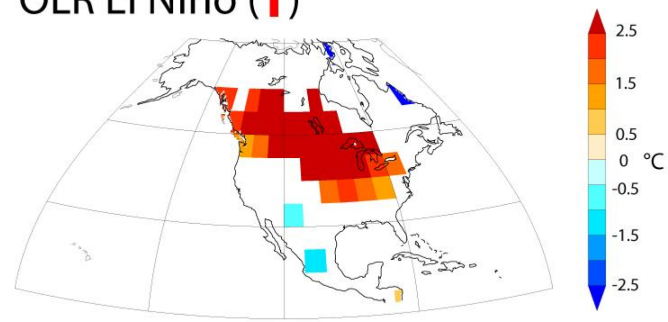
Deep atmospheric convection reaches the Eastern Central Pacific in a handful of El Niño years



DJF Temperature Anomaly Composites

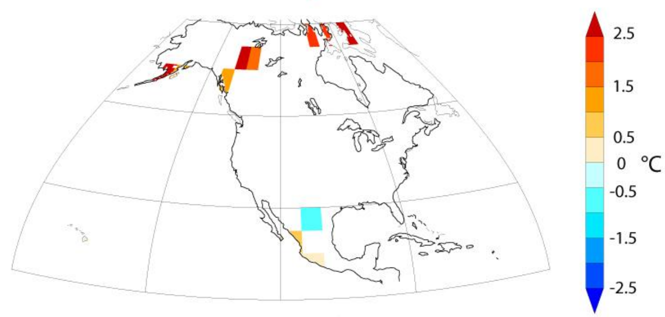
Shaded at 95% stat. sig.

OLR El Niño (↑)



1982-83, 1986-87, 1991-91, 1997-98

Non-OLR El Niño (⇩)



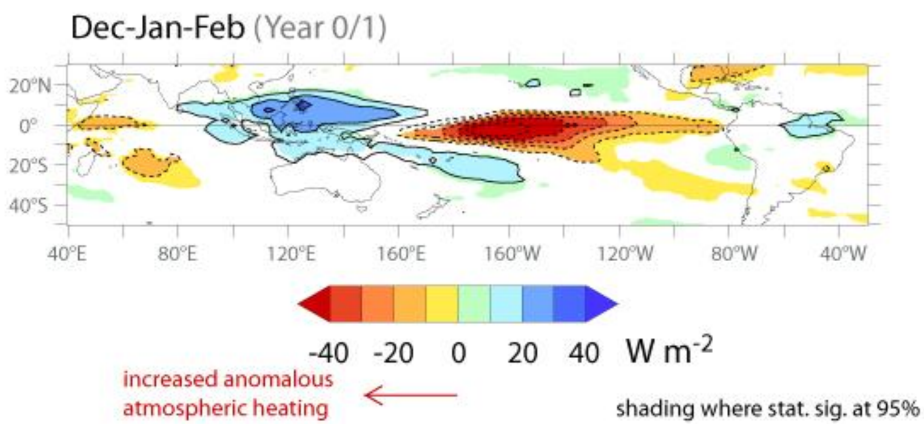
1976-77, 1987-88, 1994-95, 2002-03, 2004-05, 2006-07, 2009-10

The OLR-events have the expected DJF temperature anomalies, the others do not.

Data: CRU temp

A closer look at OLR El Niño events

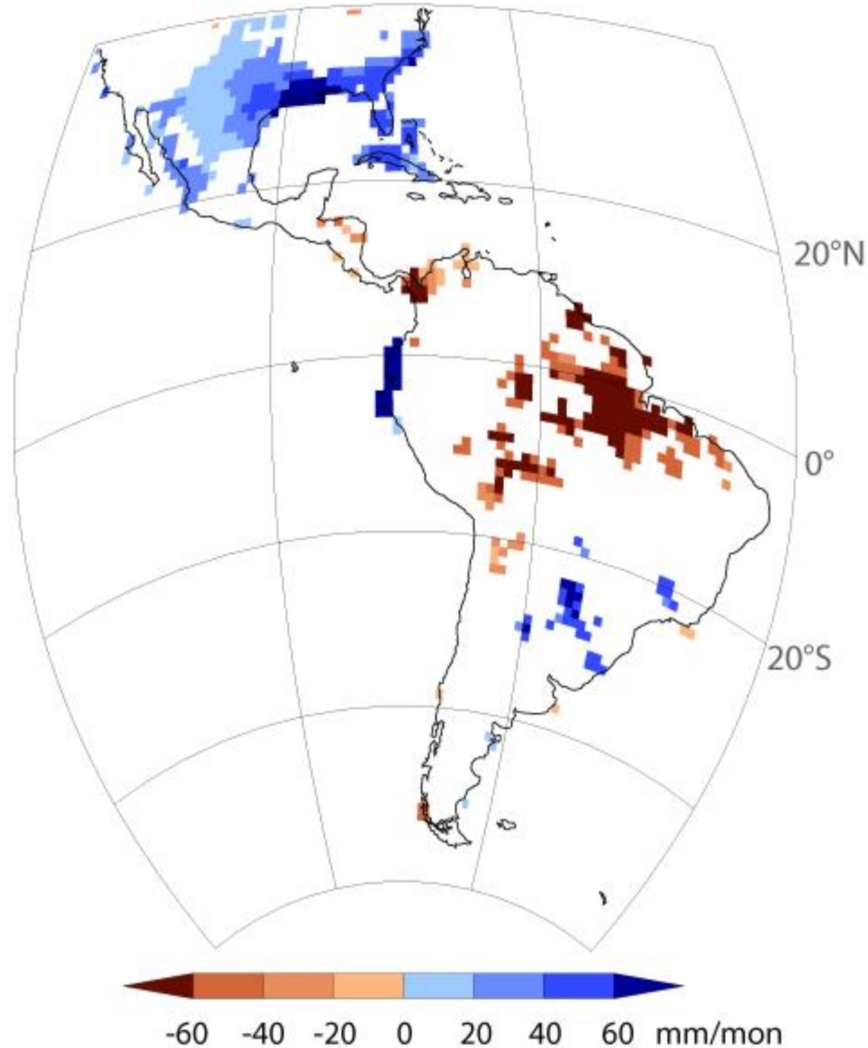
OLR composite



In this case we see ***statistically significant OLR anomalies*** across entire basin (above), as well as coherent ***precipitation anomalies*** over N. and S. America (right)

DJF Precip. Anomaly

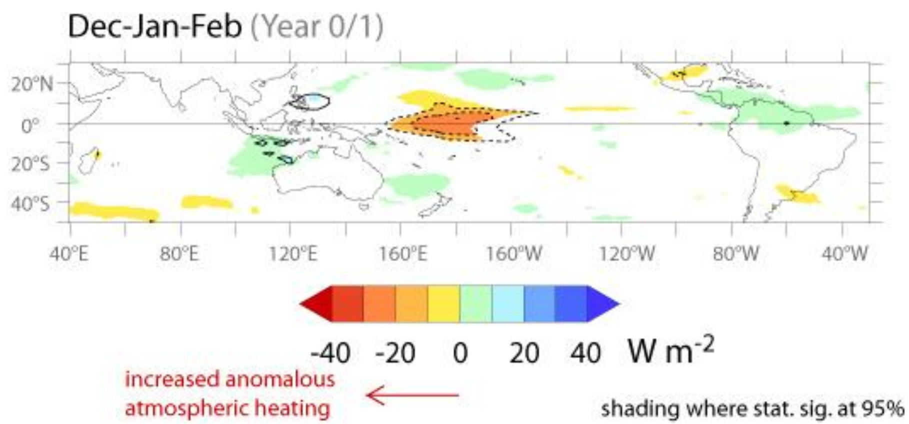
Shaded at 95% stat. sig.



GPCC precip. data

And now the non-OLR El Niño events

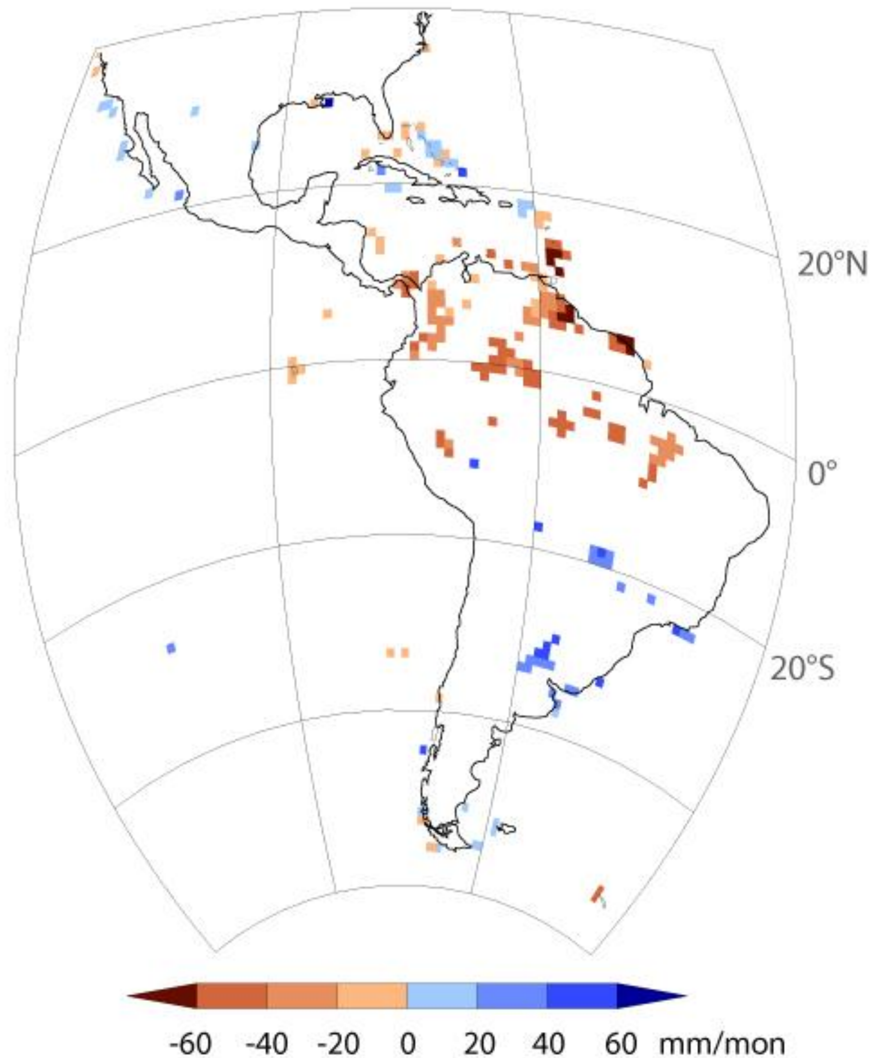
OLR composite



Wet anomalies over N. America and Ecuador/Northern Peru are not seen in this case

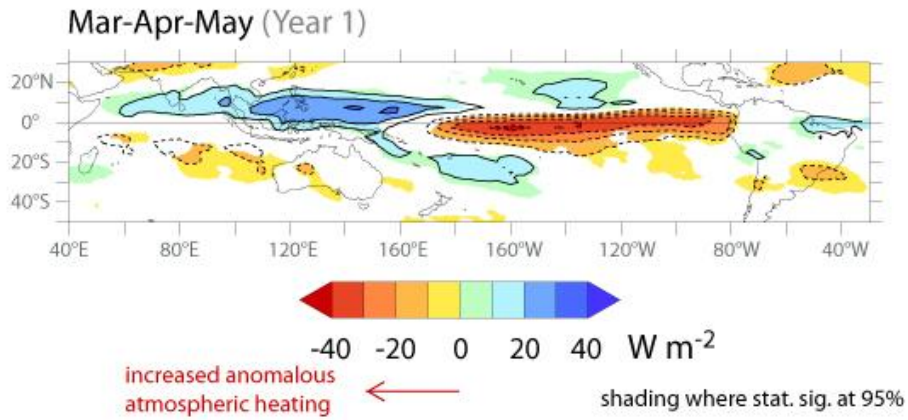
DJF Precip. Anomaly

Shaded at 95% stat. sig.



The OLR events, Mar-Apr-May (+1)

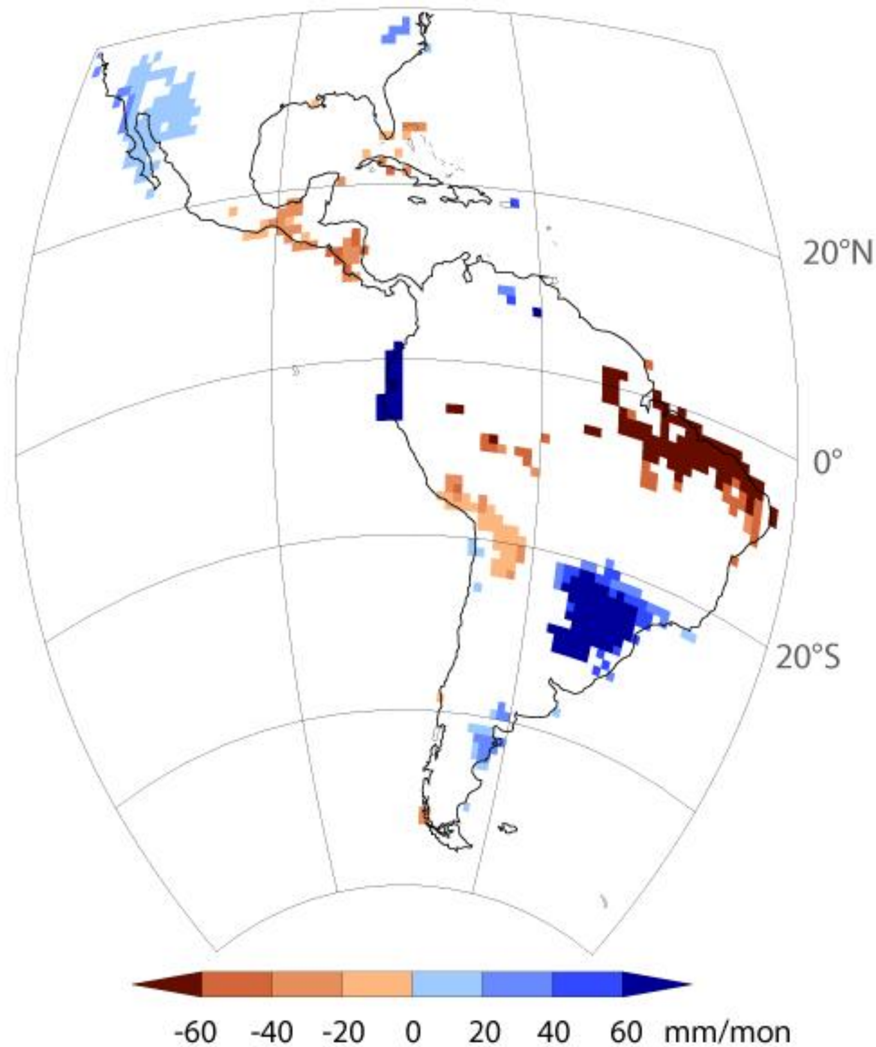
OLR composite



Coherent wet and dry anomalies over S. America

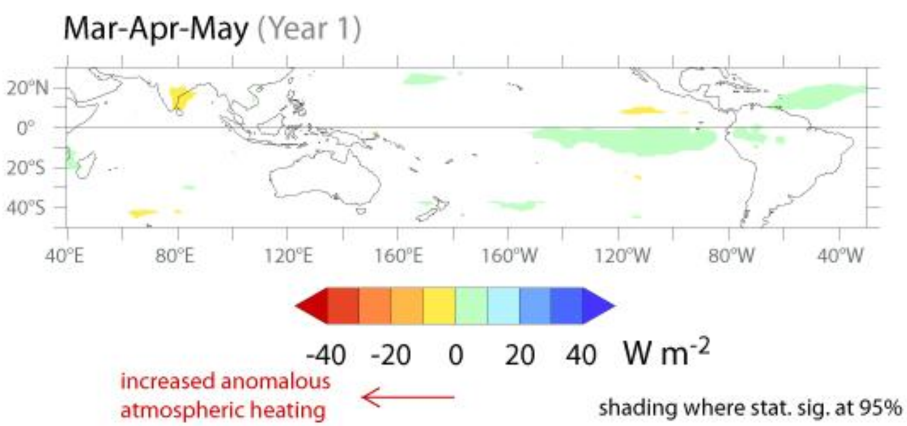
MAM Precip. Anomaly

Shaded at 95% stat. sig.



But the non-OLR events in Mar-Apr-May

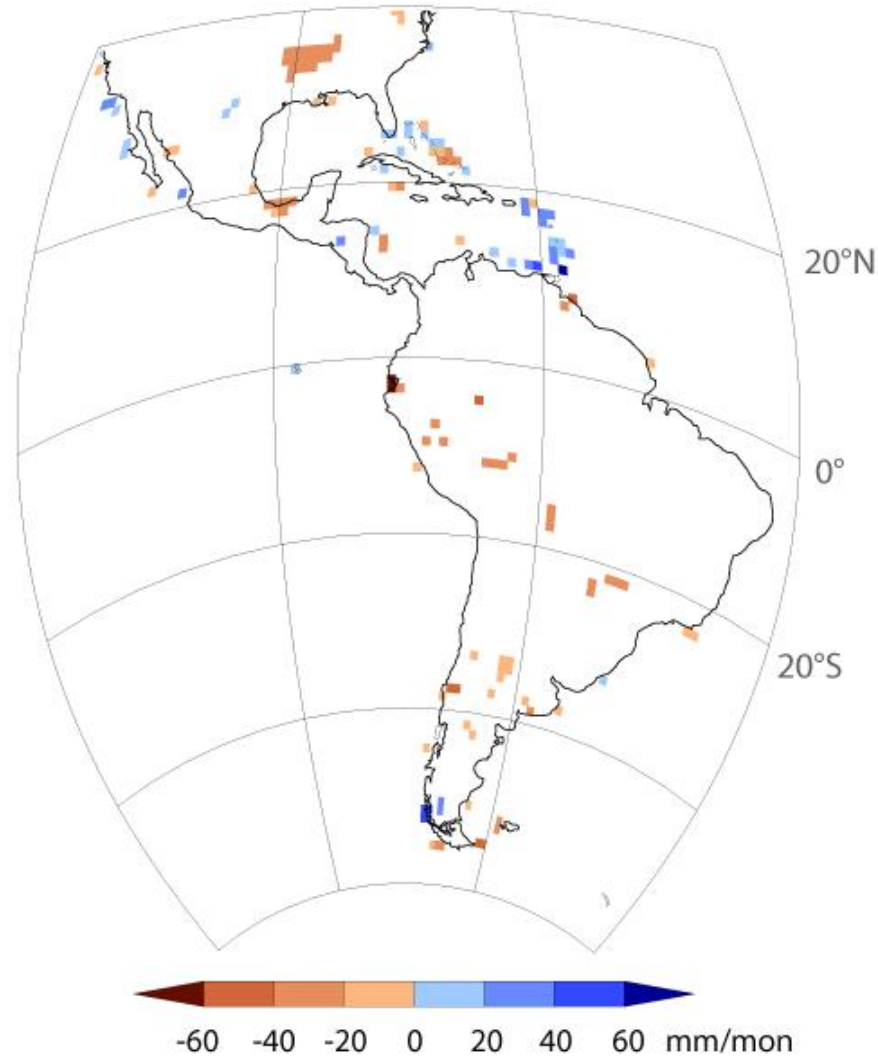
OLR composite



Coherent wet/dry anomalies not seen in this case

MAM Precip. Anomaly

Shaded at 95% stat. sig.



Conclusions

Westerly Wind Events appear to be fundamental to the onset of El Niño events.
Easterly wind surges, when they are associated with WWEs, can alter the character of the event from type-EP to type-CP
Just accounting for WWEs and EWSs is sufficient to give a wind field that gives satisfactory SSTA hindcasts for many El Nino events.
Springtime alone events give useful estimate of end-of-year Nino 3.4 SSTA, but not with sufficient accuracy to avoid surprises, e.g., years like 2012 and 2014.

Seasonal weather anomalies are not as closely linked to NIÑO 3.4 SSTA as is desired for skillful seasonal weather forecasts.
However an OLR index is able to identify a subset of events with pretty consistent seasonal weather anomalies, and give improved forecast skill.
There remains much to be understood about why similar NIÑO 3.4 SSTA years can have very different OLR behavior.

Interannual OLR and SSTA Peaks