The effect of the South Pacific Convergence Zone on the termination of El Niño events and the meridional asymmetry of ENSO

Shayne McGregor[1,2], Axel Timmermann[1], Niklas Schneider[1], Malte Stuecker[3] and Matthew England[2]

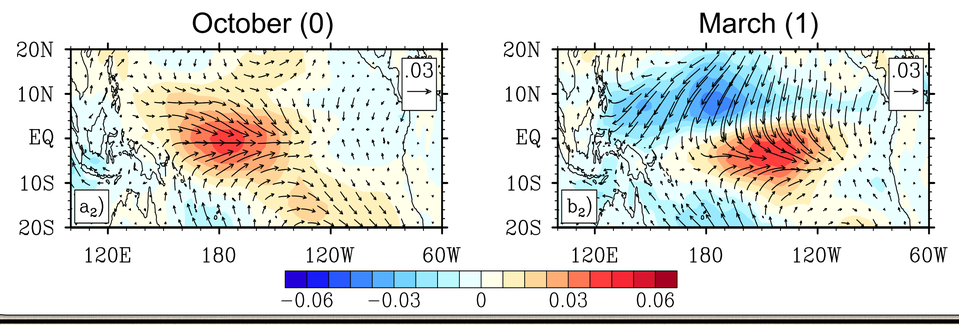
[1]IPRC, SOEST, University of Hawaii, Honolulu, USA
[2]CCRC, University of New South Wales, Sydney, Australia
[3]Department of Meteorology, SOEST, University of Hawaii, Honolulu, USA

1. Motivation

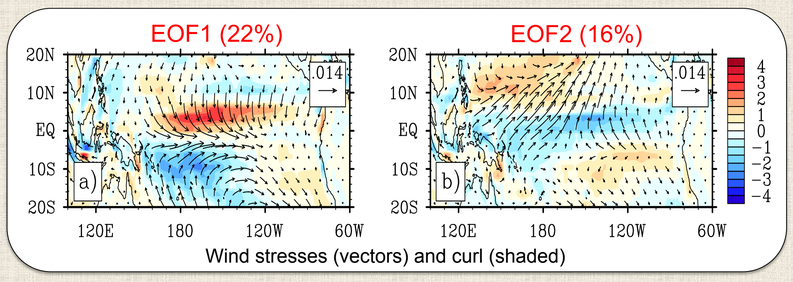
Here we focus on the identifying the dynamics and oceanic response of an observed feature of El Niño events that is often ignored by conceptual models; namely the southward shift of ENSO-related equatorial zonal wind anomalies (e.g., Harrison 1987). **Near the end of the calendar year, when ENSO events typically reach their peak amplitude, the associated zonal wind anomalies abruptly shift southward so that the maximum anomalous zonal wind is located around 5-7ºS.** Prior to this meridional shift, these zonal wind anomalies are responsible for maintaining the deep eastern equatorial Pacific thermocline. As such, the southward wind shift ultimately allows the eastern equatorial Pacific thermocline depth to return to near normal values (e.g., Vecchi and Harrison 2003).

This mechanism has been proposed to explain the termination of El Nino events and hence play a key role in the synchronisation of ENSO to the seasonal cycle.

CT El Niño composited wind stresses (vectors) and zonal wind speed (shaded)
(including 1972/73, 1976/77, 1982/83 and 1997/98)

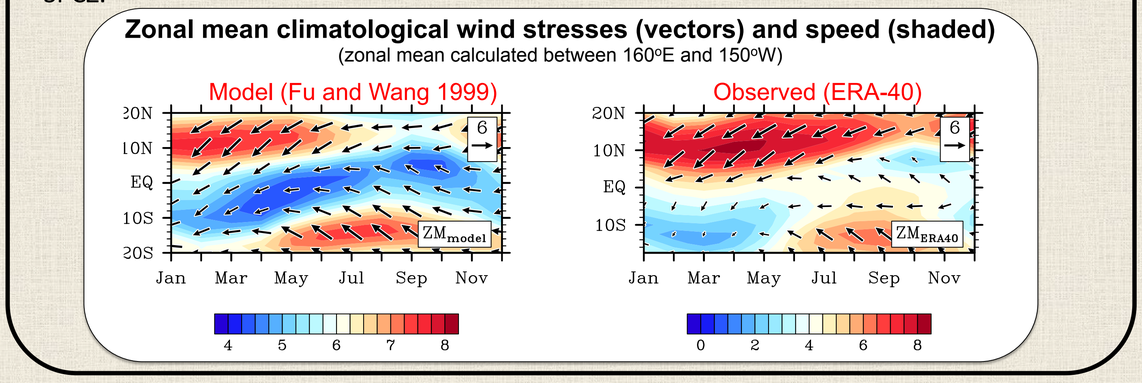


2. Wind stress EOFs



Despite principle component time series of EOF2 (PC2) having no significant correlation with ENSO (PC1 has a correlation coefficient of 0.84), looking the EOF1 & 2 reconstructed winds the composited around El Niño events reveals that **EOF2 works in quadrature with EOF1 to allow zonal wind anomalies shift southward during DJF**.

Cool tongue El Niño composited
(including 1972/73, 1976/77, 1982/83 and 1997/98)



3. Southward wind shift dynamics

Using the intermediate complexity atmospheric model of Fu and Wang (1999), which couples a LN-type (Lindzen and Nigam 1987) model of the atmospheric boundary layer (BL) with a Gill-type (Gill 1980) model of the lower troposphere (LT), we find:

- **the model reproduces the observed southward zonal wind anomaly shift quite well**.
- **interactions between the BL and LT are integral to the generation of this southward shift** (i.e.,BL or LT model component alone can reproduce thi shift).
- the total **anomalous surface wind response is amplified in the South Pacific during DJF/MAM**, compared to the North Pacific, **due to the reduced climatological wind speeds** and hence the related momentum damping, frictional divergence/ convergence and Ekman pumping of the region.

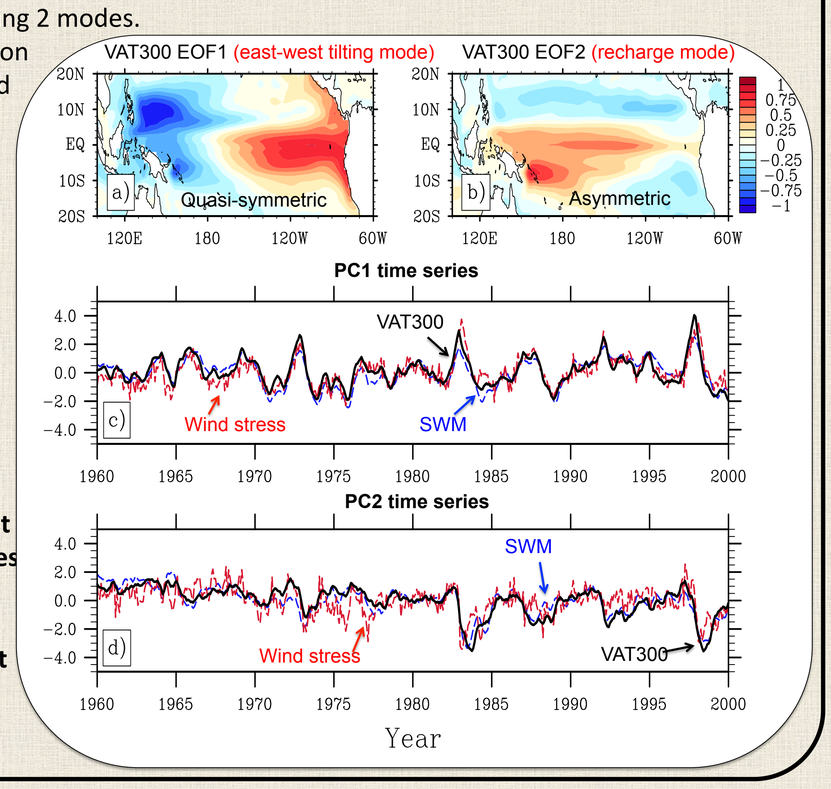
We note that the South Pacific region of low climatological wind speed and reduced momentum dissipation is also the region of largest climatological wind-convergence -- the SPCZ.

Zonal mean climatological wind stresses (vectors) and speed (shaded)
(zonal mean calculated between 160ºE and 150ºW)

4. Dynamics of ENSOs meridional asymmetry

Comparing the PC time series of the Vertically Averaged Temperature of the upper 300m (VAT300) from ORA-S3 with those of the observed wind stresses reveals a strong correlation for the leading 2 modes.
The respective correlation coefficients are 0.83 and 0.62.

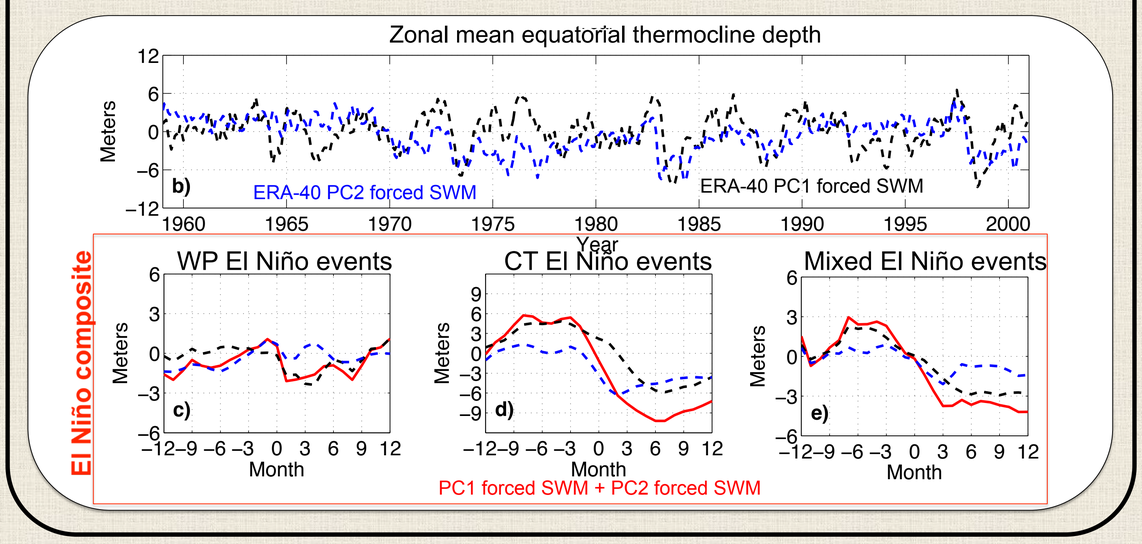
The direct correlation between the ORA-S3 simulated recharge mode (EOF2) and PC2 of the ERA-40 wind stresses implies that ocean dynamics, specifically due to the western boundary reflection of the gravest equatorial Rossby waves are not essential in the recharge/discharge of equatorial heat content during El Niño events.



5. Oceanic response to the southward wind shift

Using a linear shallow water model it can be shown that **the southward shift of ENSO-related surface wind anomalies near the end of the calendar year plays a key role in setting up the asymmetric structure of this second (recharge) mode.**

Furthermore, these results also show that the second wind-stress EOF mode plays an essential role in the zonal mean thermocline depth changes (a measure for recharge/ discharge dynamics) of the full ERA-40 forced (control) simulation and that the phase locked discharge of equatorial heat content in the 5-months after CT El Niño events peak is prominently due to EOF2 of the ERA-40 wind stress anomalies.



6. Conclusions

- **the development of a strong climatological SPCZ in DJF/MAM is one of the key factors in this southward wind shift and the seasonal termination of El Niño events.**
- **The Pacific Ocean's recharge mode incorporates the effects of two processes:**
  - **the southward shift of ENSO related wind stresses**
  - **an ocean dynamically induced component consistent with analytical theory (Jin 1997).**
- **Further to this, we find that the southward shift of the ENSO-related wind stress anomalies is responsible for:**
  - **the spatial asymmetry in the Pacific Ocean's recharge mode**
  - **A large amount of the zonal mean equatorial thermocline depth changes**
  - **the earlier, seasonal cycle synchronized, termination of CT and mixed type El Niño events.**

Thus, we confirm the earlier work of Vecchi and Harrison (2003) etc..and link it with the recharge/discharge oscillator paradigm of Jin (1997).

References

Fu, X. and B. Wang, 1999: The role of longwave radiation and boundary layer thermody- namics in forcing tropical surface winds. *Journal of Climat*e, 12, 1049–1069.

Gill, A. E., 1980: Some simple solutions for heat-induced tropical circulation. *Quarterly Journal of the Royal Meteorological Society*, 106, 447–462.

Harrison, D. E., 1987: Monthly mean island surface winds in the central tropical Pacific and El Nin˜o events. *Monthly Weather Review*, 115, 3133–3145.

Lindzen, R. and S. Nigam, 1987: On the role of sea surface temperature gradients in forcing low-level winds and convergence in the tropics. *Journal of the Atmospheric Sciences*, 44, 2418–2436.

Meinen, C. S. and M. J. McPhaden, 2000: Observations of Warm Water Volume changes in the equatorial Pacific and their relationship to El Niño and La Niña. *Journal of Climate*, 13, 3551–3559.

Vecchi, G. and D. E. Harrison, 2003: On the termination of the 2002-03 El Niño event. *Geophysical Research Letters*, 30 (18), 1964, doi:10.1029/2003GL017564