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THE SOUTH PACIFIC TROUGH: A CRUCIAL COMPONENT OF LOW FREQUENCY PRESSURE VARIATIONS THAT DETERMINE ENSO DEVELOPMENT AND STRENGTH

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1. INTRODUCTION

Much ENSO research and modelling has recently focussed on air-sea interactions along the equator and high-frequency wind and pressure changes. At a larger scale, van Loon (1984) proposed that the weakening of the Pacific trades between April-July prior to El Niño occurred as an enhanced surface trough in the westerlies developed in the South Pacific. This enhancement of the annual cycle (with a stronger high pressure over Australia) was proposed to: 1) direct southerly wind anomalies up into the western equatorial Pacific to the east of Australia, thereby contributing to westerly equatorial anomalies, and 2) direct south-westerly winds against the South Pacific high, thus weakening the ridge and the southeast trades moving back towards the western Pacific, i.e. a "combined effect" on the trades.

In the year leading into El Niño, van Loon and Shea (1985, 1987) have shown that a large see-saw in pressure, related to the 'Southern Oscillation', turns over at 30°S between Australia and the central South Pacific. At the end of the see-saw turnover (April-July year (0)), the quasi-stationary trough in the South Pacific is stronger and the subtropical high is stronger in the Australian region.

Here, we explore temporal and spatial aspects of El Niño development by comparing composite anomaly sequences of sea-level pressure (SLP) and surface winds leading into strong and weak El Niño events. We use the classification of El Niño strength used by Harrison and Larkin (1998), who defined 1957, 1965, 1972, 1982, 1991 and 1997 as the six strongest warm events. We grouped 1951, 1953, 1976, 1994 and 2002 into a weak category and discarded the other weak events 1986/87 and 1986/87 due to a much later development sequence. We confirm the traditional view that the Southern Oscillation is, to first order, a standing oscillation with geographically fixed nodes and antinodes. The South Pacific trough east of New Zealand appears to play a critical role in ENSO development and transitions.

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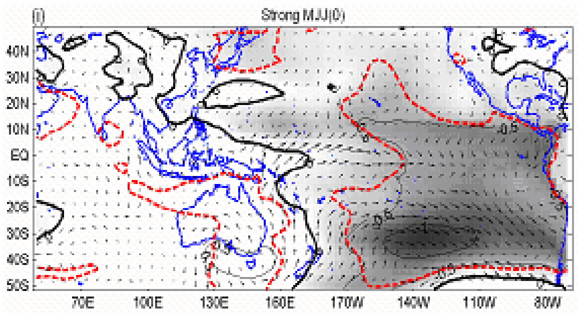
2. RESULTS

We find that the oscillation of low pressure between south-eastern Australia and the central South Pacific is more pronounced leading into stronger El Niño events. Figure 1 shows the end of the pressure reversal between Australia and the South Pacific at the critical time when El Nino events develop. The most notable difference between strong and weak events is the spatial extent and magnitude of the pressure and wind anomalies. A much stronger pressure gradient is found between Australia and the South Pacific. We confirm the van Loon hypothesis that an enhanced pressure gradient between these two regions, forces strong southerly wind anomalies up to the equator which supports westerly anomalies in the western equatorial Pacific. As the South Pacific trough expands north in May-July it takes on a more permanent feature. This directs more air away from the equator and is related to a gradual weakening of the South Pacific high and associated trades.

a)



b)

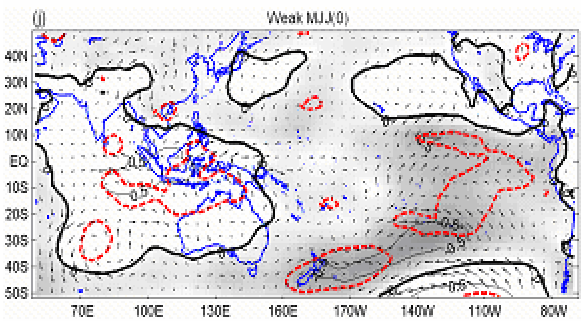


Figure 1. Composite mean anomalies of pressure and surface winds for a) strong and b) weak El Nino events between May-July (year 0). Regions of significantly different pressure anomalies at the 90% level based on the normal z statistic and a students t-test are highlighted with thick dashed lines.

On average the largest amount of warming in Nino 3 in El Niño years occurs between April-July when the South Pacific trough is most influential. An El Niño will not develop unless the broadscale pressure pattern shown in Figure 1 is in place, i.e. a high pressure anomaly over Indo-Australia and a low pressure anomaly extending from the South Pacific trough up to the eastern equatorial Pacific (van Loon et al. 2003; Stephens et al. 2005).

In weaker El Niño events the long-wave Rossby waves are centred further to the east in the South Pacific and further to the west in the central Indian Ocean. This suggests that the magnitude of the equatorial Pacific warming is related to the wavelength and amplitude of the Rossby waves, i.e. higher amplitude, shorter wavelength for strong events; lower amplitude, longer wavelength for weaker events.

Barnett (1985) found a self sustaining propagation of low pressure and associated westerly wind anomalies moved from the Australian region in year (-1) into the Pacific in year (0) prior to El Niño. Our composite analysis found that this was particularly the case for stronger El Niño events (Stephens et al. 2005). This propagation in pressure appears to be linked to an eastward progression of warm SST anomalies along the equator that bi-furcates into the South Pacific Convergence Zone and northern Pacific subtropics early in year (0). Significant low pressure anomalies in the North and South Pacific mid-latitudes appear critical in MJJ (0) to provide the large scale forcing required for significant Pacific warming. The larger spatial extent of warm SST and negative MSLP anomalies in strong events suggest that the planetary waves in the northern subtropics also become involved and compliment the southern hemisphere. In contrast, weaker El Niño events had a weaker and less distinct eastward progression of low pressure and SST anomalies and much less support from the northern mid-latitudes between May-October (0).

3. Conclusions

An enhanced South Pacific trough is critical for El Niño for the following reasons. Firstly, the increased equatorward flow on the south-west (rear) side of the trough adds to the westerly momentum change occurring further north along the equator. Secondly, the westerly wind anomalies to the north of the trough are associated with a change in momentum associated with a weakening of the South Pacific high and pressure gradient across the equatorial Pacific. Fundamentally this reduced pressure gradient is associated with a reduction in the transfer of air (trades) from the south-eastern Pacific to the Indonesian low. This change in momentum in the Western Pacific and weakened South Pacific High combine to: (a) assist westerly wind bursts and Kelvin wave activity to extend further east, (b) weaken equatorial undercurrent transport in the Pacific subsurface; and (c) weaken upwelling all the way along the equator from South America to the mid-Pacific. These all add to deepen the thermocline and increase SSTs in the eastern and central Pacific.

Therefore, ENSO modelling and monitoring must look beyond the equator and take into account important interactions between the equator and the mid-latitudes highlighted by van Loon and Shea (1985, 1987). A favourable broadscale pressure pattern is required for El Niño development and must involve the South Pacific trough. Atmospheric and oceanic processes along the equator and the mid-latitudes must interact and work together, especially in stronger events.

4. References

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