briefing note
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Implications of changes to El Niño Southern Oscillation for coastal vulnerability in NSW

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El Niño Southern Oscillation (ENSO) has a strong impact on weather patterns over Southeast Australia, but also influences ocean wave climate and the fluctuations of erosion and accretion along our coast. Now, both climate models and observations suggest that ENSO behaviour in the Pacific is changing, which could have significant consequences for coastal stability in NSW.

New research published in the journal Continental Shelf Research by Macquarie University and Risk Frontiers researchers has shown that changes to the 'flavour' of ENSO can significantly affect the amount of ocean wave energy reaching the coast and, as a consequence, the level of coastal vulnerability (Mortlock and Goodwin, 2016). The research, funded by the Australian Research Council, suggests that sustained periods of 'central Pacific' rather than the traditional 'eastern Pacific' type of ENSO can lead to more intense episodes of shoreline recession and longer recovery times for beaches on the central NSW coast.

The changing behaviour of ENSO

The traditional concept of El Niño is one of anomalous sea surface warming in the eastern Pacific (Figure 1 a) which acts to weaken or reverse the atmospheric circulation pattern across the entire equatorial Pacific.

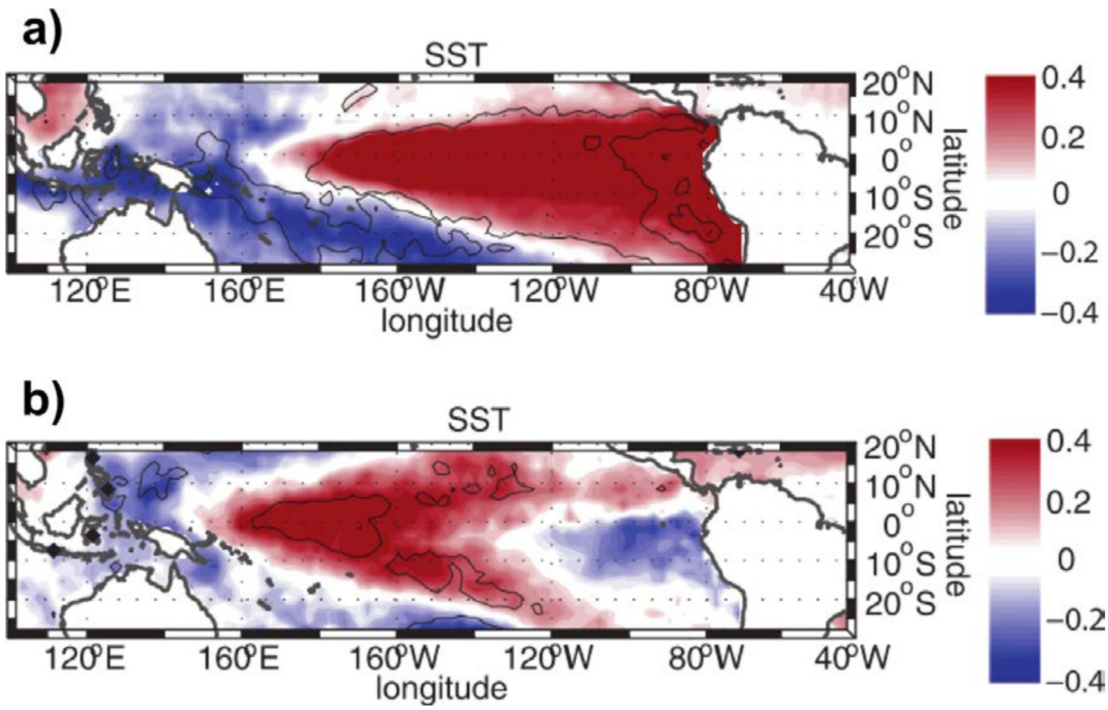

Figure 1. Sea Surface Temperature (SST, °C) anomalies during a) eastern Pacific and b) central Pacific types of ENSO. During central Pacific ENSO, the centre of the anomalous ocean temperatures shifts west with potential implications for weather patterns, wave climate and coastal response in Southeast Australia. (Figure modified from Taschetto and England (2009).)

For Southeast Australia, traditional El Niño events are associated with reduced storminess, weaker easterly trade winds and an overall more southerly wave climate. La Niña episodes are the reverse – ocean cooling in the eastern Pacific, and increased storminess, strengthened trade winds and a more easterly wave climate for Southeast Australia.

Since the 1970s, however, there have been an increasing number of ENSO events associated with anomalous warming or cooling in the *central*, rather than eastern, Pacific Ocean (Lee and McPhaden, 2010) (Figure 1 b). Some climate models indicate this is set to continue with greenhouse warming (Yeh *et al*., 2009), although the prediction of future ENSO behaviour by global climate models remains highly uncertain.

Present understanding of coastal response to ENSO

Coastlines in Southeast Australia are known to respond to fluctuations in ENSO, and the prediction of this response remains a key part of coastal zone management. For example, Collaroy-Narrabeen Beach and Palm Beach on Sydney's Northern Beaches have been observed to rotate clockwise during El Niño and anti-clockwise during La Niña (Short *et al*., 2000; Ranasinghe *et al*., 2004). This is attributed to a predominant southerly wave climate during El Niño (a dominant southerly 'Mode 3' with sub-dominant easterly 'Mode 1', Figure 2), and a predominant south-east to east wave climate during La Niña (enhanced Modes 1 and 2).

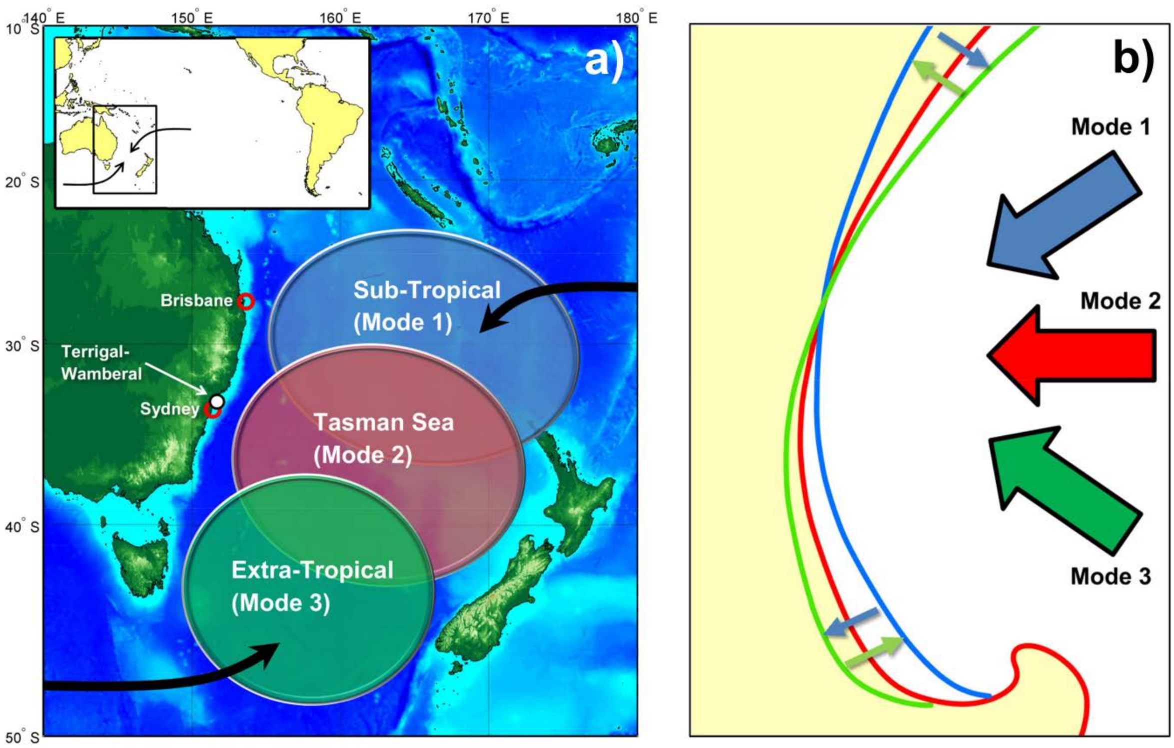

Figure 2. a) The three primary 'modes' of wave climate in the Tasman Sea, and b) the shoreline response of embayed beaches. Traditional El Niño events are associated with more Mode 3, causing a clockwise rotation of the shoreline. Traditional La Niña periods promote more Mode 1 and 2 wave conditions, leading to an overall anti-clockwise rotation of the beach. (Figure from Mortlock and Goodwin (2016).)

El Niño events usually only last the length of one summer, while La Niñas can be longer, impacting successive winter and summer wave and beach conditions. The sustained narrowing or widening of beaches associated with 'beach rotation' can be significant in economic terms where property along the NSW coast is built close to (or within) the active beach zone (Figure 3).

Figure 3. Beach and dune erosion at the south end of Collaroy-Narrabeen beach in Sydney, caused by a clockwise rotation of the shoreline under southerly wave conditions (photographs taken by Andy Short, 2015). Beach width (foot of dune to water line) can vary on the order of 15 - 20 m during rotation episodes.

Coastal response to enhanced central Pacific ENSO

While the coastal response to traditional ENSO is well established, coastal hazard assessments have not yet accounted for any change in the behaviour of ENSO – in particular, the potential for enhanced central Pacific-type ENSO with global warming.

The present study showed that central Pacific El Niño events in fact produce significantly more southerly wave conditions during summer than traditional El Niño (Figure 4 a). The research also found that central Pacific La Niña periods led to more southerly wave conditions during winter, and more north-easterly wave conditions during summer, compared to the traditional La Niña counterparts (Figure 4 b and c). In this study, only non-storm wave conditions (95% of record) were analysed.

The authors attribute these differences to changes in the strength of the Pacific trade winds that are manifest during the different 'flavours' of ENSO. But what do these wave climate changes mean for coastal stability in NSW?

Coastal response modelling at Terrigal-Wamberal beach, on the central NSW coast, indicated that the increase in southerly wave energy during central Pacific El Niño leads to a stronger clockwise rotation of the surf zone and shoreline than during traditional El Niño events (Figure 4 a). This means greater erosion potential at the southern end of embayed beaches, as all the sand is moved north.

However, the biggest changes were seen during La Niña. A traditional La Niña event is associated with enhanced south-east to east wave energy in both winter and the following summer. Since La Niñas usually follow El Niños, this can lead to a re-distribution of sand back towards the southern end of the embayment and erosion at the north, as observed with beach monitoring. The beach fluctuations are thus relatively balanced through the ENSO cycle.

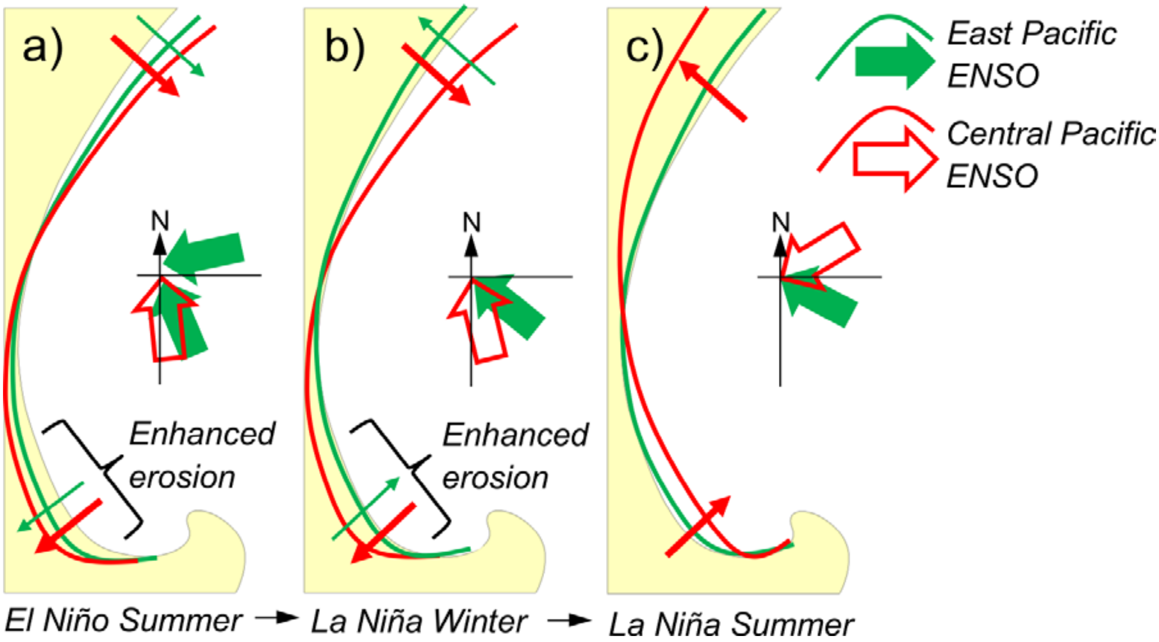

Figure 4. Wave direction and shoreline rotation patterns through a typical ENSO cycle for east and central Pacific ENSO. Central Pacific ENSO enhances beach erosion potential at the southern end. Shoreline movements are not to scale.

During a central Pacific La Niña winter however, a large clockwise, rather than anti-clockwise, shoreline rotation occurs with southerly wave conditions, followed by a clockwise rotation with north-easterly waves the following summer (Figure 4 b and c).

This means that through an El Niño summer / La Niña winter / La Niña summer cycle, there is a sustained clockwise rotation of the beach during the first summer and winter, with greater storm erosion potential at the southern end with central Pacific ENSO. Only during the last La Niña summer does beach recovery and anti-clockwise rotation begin, although modelling indicated that recovery is slower than during a traditional ENSO cycle.

Implications for coastal management

This research highlights the importance of considering variability in ENSO climate for coastal risk management in NSW. It shows that the present understanding of beach rotation with ENSO can lead to a significant underestimation of the level of coastal vulnerability, particularly for southern sections of embayed beaches. The present round of NSW coastal reforms and the associated re-assessment of coastal risk provide a good opportunity to incorporate these findings into management plans for the coming decades.

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