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INTERANNUAL VARIABILITY OF STORM SURGE

INTRODUCTION AND RESEARCH SIGNIFICANCE:

Flooding causes widespread damage to the Australian Coastal zone, which is an area of significant economic, social and environmental importance (DCC 2009). Coastal flooding can result from both heavy rainfall, and or 'storm surge', which is a rise in ocean levels due to low atmospheric pressure and persistent winds (BOM 2011).

Currently, most coastal planners rely on exceedance statistics such as the 100 year Average Reoccurrence Interval (ARI) storm surge estimate as an acceptable level of risk. This risk estimate informs planning controls such as floor heights and is also a base for calculating future sea level rise hazard areas. Exceedance statistics such as the ARI are calculated based on the assumption of a 'stationarity' climate – that is, the assumed chance of an extreme event occurring is the same from one time period (season, year, decade) to another. However, recent research has shown that the ARI of extreme climatic events (e.g. heavy rainfall, floods, droughts etc) may be significantly under or over estimated depending on the climate state (e.g. Franks and Kuczera 2002, Kiem et al 2003) and that non-stationarity exists within historical Australian rainfall and streamflow records (e.g. Verdon et al 2004; Verdon and Kiem 2010).

This research aims to extend this previous work by (a) investigating whether non-stationarity exists in historical storm surge (or sea level anomaly) records; (b) determining how (if at all) variability in storm surge is related to large-scale climate drivers emanating from the Pacific, Indian and Southern Oceans; and (c) determining what this means for flood risk assessments in the Australian coastal zone.

This research will help improve our understanding of flood and inundation risk in the coastal zone and will be valuable for anyone dealing with urban and coastal management. The better we understand our historical and current sea level fluctuations, and what drives them, the better our coastal planning and management will be into the future.

MAJOR FINDINGS AND OUTCOMES:

Research to date (1st 12 months of research) has found that three of Australia's dominate climate drivers, the El Niño / Southern Oscillation (ENSO), the Southern Annual Mode (SAM) and the Indian Ocean Diapole (IOD) have a significant influence on tidal residual, which has been used in this study as a proxy for storm surge around Australia. This significance is highly dependent on location (see Figures 1-3). For example, ENSO influences on storm surge are seen on almost the entire Australian coastline, IOD impacts occur mostly in the southern to mid latitudes with almost no influence in the north east, while SAM shows significant relationships with storm surge along the southern coast but not in the north.

Figure 1 illustrates the significance of difference in tidal heights between the negative and positive phase of the ENSO. There is a difference in tidal heights between the two extreme phases of ENSO right across Australia. When looking at the means and quantiles, it was found that tidal heights were higher during a La Niña than during an El Niño for every tidal gauge across Australia. In fact, for the 90% quantile for La Niña the tidal height is 38% higher than it is for El Niño at Fort Denison and 55% higher at Fremantle.

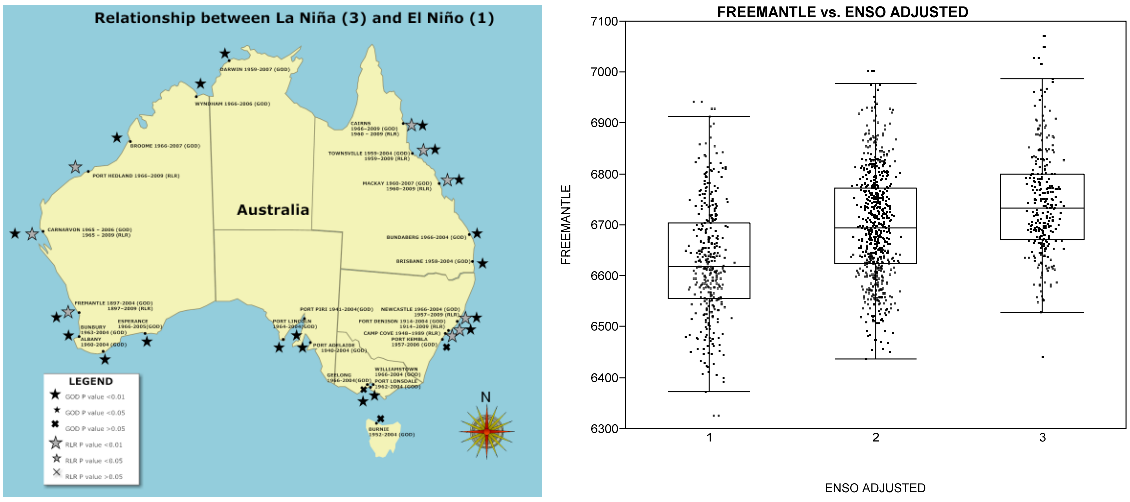

Figure 1: Relationship between storm surge (as represented by tidal residuals) and ENSO (a) around Australia represented by the significance (large star 99%, small star 95%) of the difference between storm surge associated with El Niño and storm surge associated with La Niña and (b) at Freemantle as represented by the comparison of box plots showing storm surge during En Niño, La Niña and Neutral.

Figure 2 illustrates the significance of difference in tidal heights between the negative and positive phase of the IOD. Generally, tidal heights are different between the extreme phases of the IOD across the southern to mid latitude regions. However this significance is less so in the tropical north regions. When looking at the means and quantiles, it was found that there is no difference between phases of the IOD in the north-eastern regions of Australia. However for Freemantle and Fort Denison, the median and the 90% quantile were both found to be higher during an IOD positive phase than during an IOD negative.

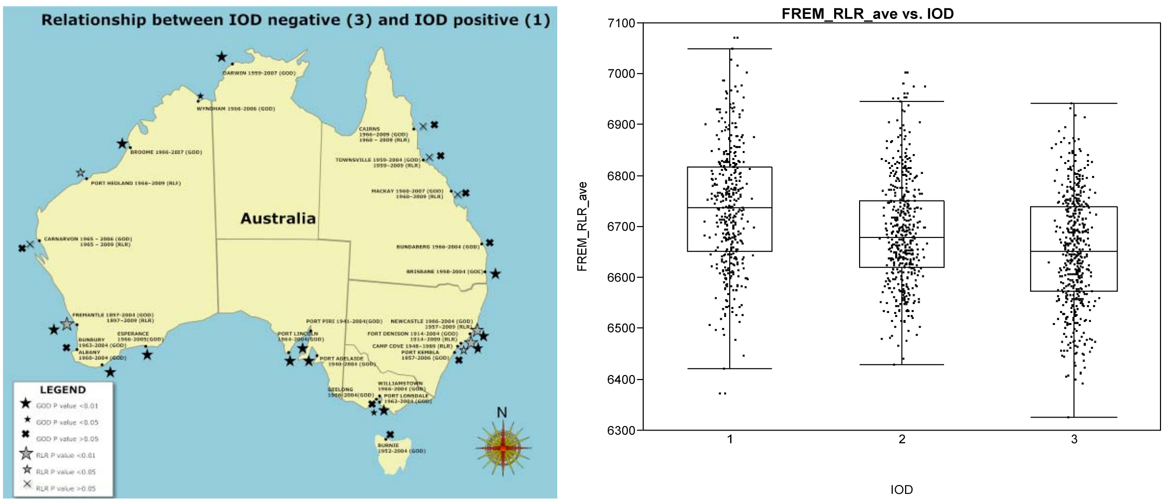

Figure 2: Relationship between storm surge (as represented by tidal residuals) and IOD (a) around Australia represented by the significance (large star 99%, small star 95%) of the difference between storm surge associated with IOD negative and storm surge associated with IOD positive and (b) at Freemantle as represented by the comparison of box plots showing storm surge during En Niño, La Niña and Neutral.

Figure 3 illustrates the significance of difference in tidal heights between the negative and positive phase of the SAM. For the southern regions of Australia, there is a significant difference in tidal heights between the two extreme phases of SAM. There is very little to no significance in the Northern regions of Australia.

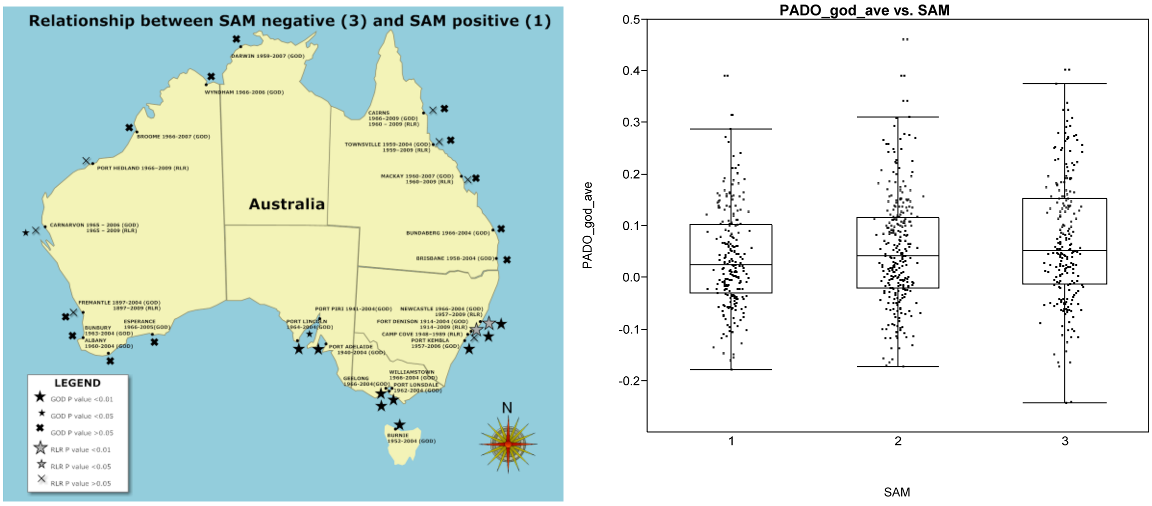

Figure 3: Relationship between storm surge (as represented by tidal residuals) and SAM (a) around Australia represented by the significance (large star 99%, small star 95%) of the difference between storm surge associated with SAM negative and storm surge associated with SAM positive and (b) at Port Adelaide as represented by the comparison of box plots showing storm surge during En Niño, La Niña and Neutral.

When looking at the means and quantiles of these tidal gauges for each phase of the SAM, it was found that the negative phases of SAM have higher tidal readings than during the positive – for example in Freemantle, the monthly mean is 17% larger during the negative phase than during the positive.

FURTHER RESEARCH SUGGESTIONS:

This research is a 'first pass' assessment into the relationship between climate cycles and tidal residuals. Further research suggestions include:

- *Seasonal assessment:* In this study, the monthly averages were compared with monthly climate indices. As many climate cycles vary depending on the season, we are now working on an investigation to determine whether the relationships obtained above vary from season to season. Given previous studies which show the that the major climate modes are not influential all year round we expect that this analysis will refine the existing results and provide further insights into the relationship between natural variability and storm surge.

- *interaction between climate modes*: In this study each climate mode was assessed independently of others, however there are known links between climate modes. Therefore, we are also reevaluating the above findings in light of the fact that the various climate modes do not act in isolation.

- *Site by site assessment:* Each site has specific factors that may alter the results (i.e land subsidence, estuary vs ocean, local wind and wave conditions). We will look at any abnormalities at the location sites to ensure consistent results.

- *Tidal residual as a proxy for storm surge:* this study used two methods for removing the astronomical tides and used those 'residuals' as a proxy for storm surge. Further research will identify how much of this tidal residual is storm surge.

CONCLUSION:

These preliminary findings highlight the flaws in assuming that the risk of storm surge does not change from one period to another. Exceedance probability such as the 1:100 year storm surge event may be inaccurate representation of the likelihood of a storm event. A storm surge may be more frequent and have higher flood levels during certain phases of a climate cycle than another. These results can help coastal flood forecasting and also provide an opportunity to increase effectiveness of emergency management and response.

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