Indian Ocean Climate Initiative
Informed Adaptation

How our regional sea level has changed

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Climate Note 9/05 (August) in a series outlining observed climate changes or variations over recent decades in south-west Western Australia.

Summary

Fremantle tide data have shown that the mean sea level has increased almost 20 cm at a rate of 1.54 mm per annum since 1897. This represents 20% of the maximum tidal range at Fremantle. The rise in sea level has been attributed to thermal expansion of the oceans due to increased warming. Superimposed on this increasing trend, the rate of sea level rise has changed due to inter-annual variability resulting from the El Nino-Southern Oscillation (ENSO) phenomenon. As a result, the mean sea level remained almost constant between 1952 and 1991 and has increased at almost three times the global rate since 1991. The rise in sea level is expected to continue throughout the 21st century resulting in sandy beaches eroding up to 30 m by 2040.

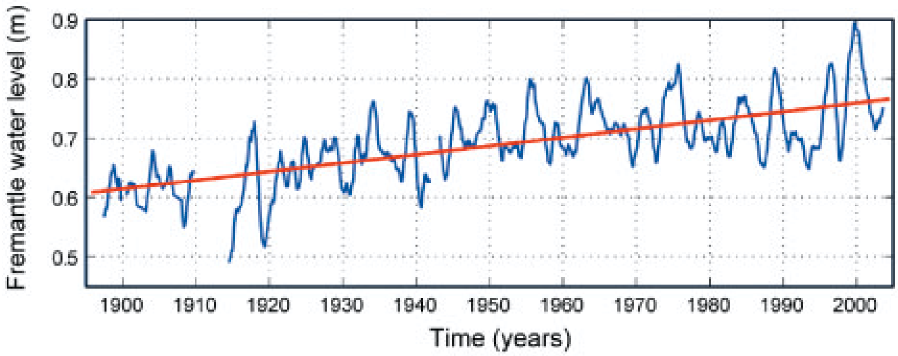

Figure 1: Time series of Fremantle sea level (one year running mean) with the linear trend of 1.54 mm per annum superimposed in red.

Table 1: Major processes influencing sea level variability along the south-west WA coastline.

Processes	Time scale	Maximum amplitude
Astronomical tide	12–24 hours	0.80 m
Storm surge	1–10 days	0.80 m
Leeuwin Current	Seasonal	0.30 m
ENSO	Inter-annual	0.30 m
Global warming	Decadal	0.015 m per decade

Sea level variability

Sea level variability along the WA coastline is the result of a number of different processes acting on different time scales ranging from days to decades with amplitudes of the order of 0.2 to 0.5 m (Table 1).

Sea level, recorded at Fremantle since 1897, indicates that there has been a mean rate of sea level rise of 1.54 mm per annum (Figure 1). This rate of increase is similar to that observed globally, which has been estimated to range between 1.1 to 1.8 mm per annum.

Although there has been an increasing trend over the last 100 years, there have been periods, which are revealed when the linear trend is removed (Figure 2), where the rate of mean sea level change varied with time. These variations were dominated by the inter-annual variability of sea level linked to the ENSO phenomenon.

From 1900 to 1952 there were cyclic periods of sea level increase and decrease ranging between 10 to 14 years. Between 1952 and 1991, there was a decreasing trend, but in combination with the mean sea level rise the ENSO conditions resulted in almost constant mean sea level. A reversal of this trend occurred between 1991 and 2004, producing an apparent rapid mean sea level rise at a rate of 5 mm per annum - a rate more than three times the trend over the previous 100 years. This resulted in Fremantle recording maximum sea levels in 2003 and 2004 (Table 2).

What caused the decadal trends?

The increase in mean sea level since 1897 is most likely related to the concurrent rise in global temperature over the past 100 years. On this time scale, warming and the consequent thermal expansion of the oceans account for about 0.02–0.07 m of the observed sea level rise, while the observed retreat of glaciers and ice caps may account for about 0.02–0.05 m. The rate of increase over the last 100 years has been much greater than the rate over the last 1000 years.

What caused the inter-annual variability?

The cyclic changes (Figure 2) in the rate of mean sea level rise, attributed to the inter-annual variability, can be directly related to the El Nino Southern Oscillation phenomenon. For example, the decrease in the mean water levels between 1952 and 1991 can be attributed to the increased frequency of El Nino events over this period.

Table 2: Highest water levels recorded at Fremantle 1897–2004.

Date	Level
16 May 2003	1.98 m
09 May 2004	1.90 m
18 May 1909	1.87 m
10 Jun 1956	1.86 m
20 Sep 1988	1.85 m

Impacts on WA

The main impact of sea level rise in WA is on beach stability and potential inundation of low-lying coastal regions under storm conditions. Quantifying the relationship between sea level rise and beach erosion isn't easy. The short-term movement of sand in the cross-shore direction under storm action is much larger than any change associated with the mean sea level rise. Also, the longshore transport of sand is commonly higher than that in the cross-shore direction. Under the action of storms, sand is eroded from the beach and deposited offshore under the combined action of the storm waves and the higher water levels caused by the storm surge. An increase in mean sea level results in higher erosion of the beach. This is due to the fact that under an increased water level, storm waves will act on a section of a beach that was not reached under a lower mean sea level. It is generally accepted that a 1 cm rise in mean sea level will be accompanied by a loss of about 1 m of beach. These effects have been confirmed through widespread erosion observed on south-west WA beaches in 2003 and 2004.

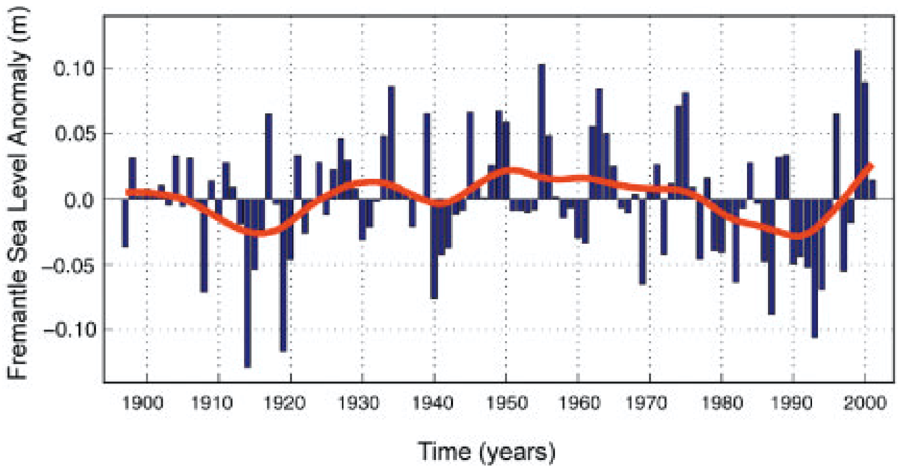

Figure 2: Time series of Fremantle sea level anomaly (variations of annual mean levels from the trend line of Figure 1) shown in blue. The red line shows the inter-annual variability (El Nino driven) in the record after removing the long-term tidal effects.

What can we say about the future?

It is generally expected that, due mainly to the continuing warming of the oceans and the resulting thermal expansion, the global mean sea level will continue to rise throughout the 21st century. The predicted increase is up to 0.30 m and 0.88 m by 2040 and 2100, respectively. For sandy beaches this could result in beach recession of 30 m by 2040.

Acknowledgements

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