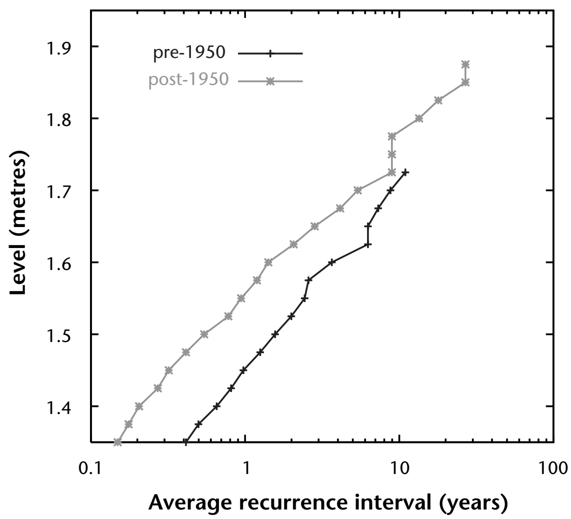

Figure 5: Changes in the average recurrence intervals for Fremantle for the period 1897–2004 (Source: Church *et al.* 2006).

change in the mean value dominates over changes in the height of surges about this mean value.

Future changes in the frequency of extreme events

The severity and frequency of extreme sea-level events in the future will increase with rising sea levels and may also change as a result of changes in the frequency and intensity of the meteorological drivers of storm surge. It may be seen from either curve in Figure 5 that the sea level varies approximately logarithmically with the average recurrence interval, indicating that the extremes approximately follow a Gumbel distribution. The increase in the frequency of extreme high levels, caused by a future increase in mean sea level, may be estimated from the slope of such curves. If a sea-level rise of h increases the frequency of occurrence by a factor r, then, a sea-level rise of H increases the frequency of occurrence by a factor $r^{H/h}$ (this is a consequence of the form of Gumbel distribution), which can become very large, even for modest increases in sea level. Figure 6 shows the estimated increase in the frequency of occurrence of extreme high levels, caused by a sea-level rise of 0.1 m, for the 29 Australian tidal records that are longer than 30 years. This multiplying factor has a range of 1.8 – 5.8 and a mean of 3.1, which is broadly consistent with the 20th century observations for Fremantle and Fort Denison, Sydney (Church *et al.* 2006). For a mid-range 21st century rise of mean sea level of 0.5 m (see above), the mean multiplying factor for Australia would therefore be $3.1^{0.5/0.1}$ or 286, indicating that events which now happen every 10 years would happen more than once a month in 2100. Figure 6 shows that even larger increases in the frequency of extremes would occur around Sydney, Brisbane and in Bass Strait, with smaller increases off the north-west and north-east coasts, and off South Australia.

The meteorological drivers of sea-level extremes in Australia include cyclones in the tropics north of 30°S, westerly winds associated with cold fronts along the south coast and a combination of cyclones of tropical and mid-latitude origin on the east and west coasts south of 30°S. Storm surges occur more commonly during the warmer months in the north and during the colder months in the south. The effect of climate change on these systems has been summarised recently in a report by the CSIRO and the Bureau of Meteorology (2007). Studies of tropical cyclones in the Australian region indicate a likely increase in the number of tropical cyclones in the more intense categories, but a possible decrease in the total number of cyclones. They also indicate a poleward extension of tropical cyclone

Figure 6: Estimated multiplying factor for the increase in the frequency of occurrence of high sea-level events (indicated by the diameters of the discs), caused by a sea-level rise of 0.1 m.