Spatial variability of sea level change

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Globally averaged sea level has risen by just under 10 cm during the last 50 years as a consequence of global warming. The rise, however, is not uniform, neither in time nor in space. Natural climate fluctuations and associated changes in the ocean currents have contributed to the inhomogeneity and is an important factor which will determine the pattern of future sea level rise. While research in the past years has focused on the global-mean trend and its attribution to the melting of glaciers and the thermal expansion of sea water under global warming, attention is shifting to the geographical pattern of sea level change. This is essential for coastal impact assessments, but has not been practical yet because ocean projections from current climate models widely diverge. The improvement of regional sea level prediction requires a better understanding of the underlying dynamical causes.

Coastal sea level records together with modern satellite measurements reveal a mean increase of about 1.6 mm/year during the last 50 years, with some indication of acceleration during the recent years featuring a rate of about 3 mm/year. Local rates of change, however, significantly differ from the global average in many places and also experienced a strong temporal variability. During El Niño, an inter-annually occurring warming of the tropical Central and East Pacific, for instance, sea level typically rises by about 20 cm in the eastern Equatorial Pacific for several months, while it drops more or less simultaneously by a similar amount in the west. Strong swings in local sea level due to such natural climate oscillations are also seen over time spans of many years: in the western tropical Pacific sea level rose by about 10 cm since the second half of the 1990s (Fig. 1), much more than the global average, thereby amplifying concerns about the future fate of low-lying tropical islands. The eastern Pacific, however, featured a drop of sea level during this time.

Although much of this variability averages out when considering longer periods, recent studies found indications of considerable geographical deviations from a globally-uniform trend to persist even over several decades. A prominent example is the eastern tropical Indian Ocean, with multi-decadal changes of ±2-3 mm/year on top of the global-mean rise (Fig. 2).

Regional sea level swings on the short interannual time scales are largely wind-driven: changing ocean currents lead to a redistribution of the upper-ocean (thermocline) layer of warm water. Forced ocean model simulations suggest that in the tropical oceans wind-driven changes appear also important on the longer, multi-decadal time scales

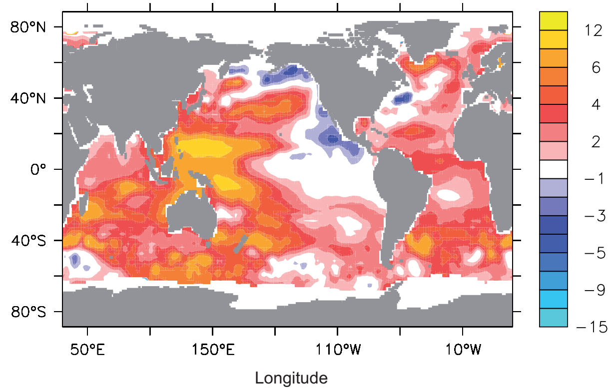

Figure 1: Rate of sea level change (mm/year) during 1993-2010 as derived from satellite altimetry. Source H. Ding, IFM-GEOMAR.

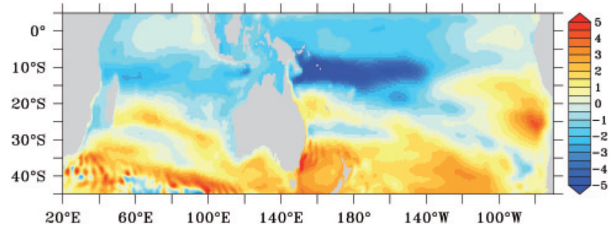

Figure 2: Sea level trend over the last five decades in the Indo-Pacific (relative to the global-mean rise) as simulated by an ocean model forced by the fluctuating atmospheric conditions at the sea surface: while sea level in the eastern and south Pacific rose at a higher rate than the global mean trend, the model reconstruction suggests a falling trend in the western tropical Pacific and parts of the Indian Ocean. (From Schwarzkopf and Böning, 2011).

(Schwarzkopf and Böning, 2011). The sea level drop off Western Australia (Fig. 3) during the 1960s-1990s, for instance, appears to be related to a decrease in upper-ocean heat content related to changes in tropical ocean currents due to a weakening of the Trade Winds over the Pacific. Heat content

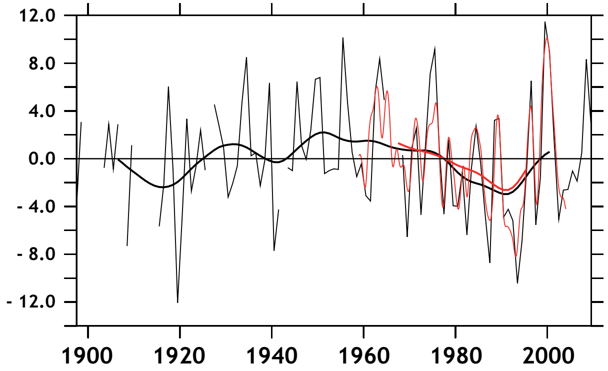

Figure 3: Interannual variability and multi-decadal changes of sea level (in cm) off the west coast of Australia as given by a tide gauge record at Fremantle (black) and the corresponding model simulation (red). The global-mean trend was removed from both time series. (From Schwarzkopf and Böning, 2011).

anomalies in the West Pacific then propagate through the Indonesian Passages to the west coast of Australia. The subsequent radiation of the signal by planetary waves to the west eventually produces an elongated band of falling sea level along most of the South Tropical Indian Ocean. Whether or not the changes in the Pacific trade winds contain an anthropogenic signal is being controversially discussed (e.g. Meng et al., 2011).

Another area of interest regarding regional sea level change is the North Atlantic. In addition to strong inter-annual sea level variability associated with wind-driven changes in ocean circulation, significant longer-term trends may be expected here, if the Gulf Stream/North Atlantic Current system would slow down in a warming 21st century as projected by the majority of climate models.

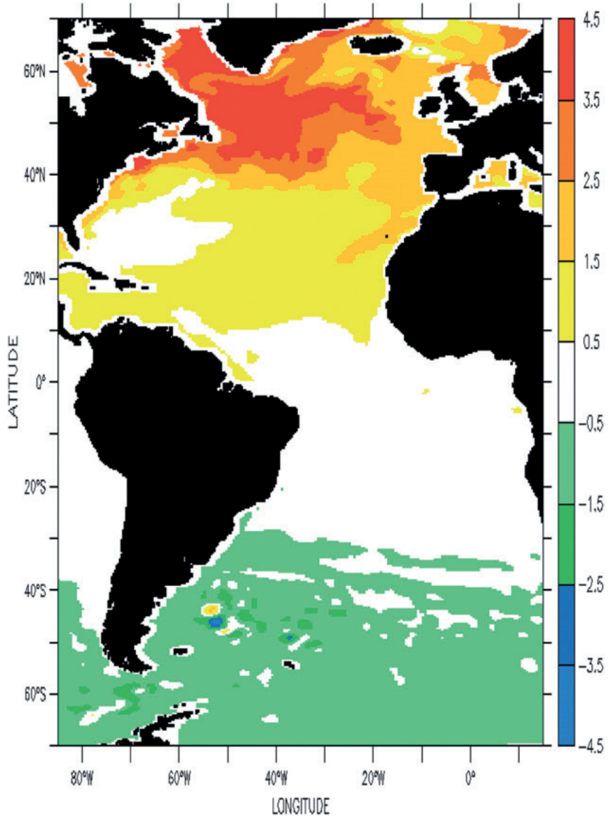

Figure 4: Future sea level change (in mm/year) in the Atlantic Ocean (relative to the global mean rise): model projection for the case of a gradual weakening of the Gulf Stream/North Atlantic current system. (From Lorbacher et al., 2010).

Ocean circulation models suggest that even a gradual decline by only about 30% over 50 years of this current system would lead to a significant geographical redistribution of sea level (Fig. 4). While it would fall in the South Atlantic relative to the global mean, the North Atlantic would see an additional rise, of 2-4 mm/year along the North American, and about 2 mm/year along the European coasts (Lorbacher et al., 2010).

References

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