Derivation of the NSW Government's sea level rise planning benchmarks

Technical Note

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Introduction

The NSW Government has prepared this Technical Note to support the *Sea Level Rise Policy Statement*. The Policy Statement includes sea level rise planning benchmarks for use in coastal hazard and flood risk assessments. These assessments are used in land-use planning and development assessment decisions in coastal areas and for sea level rise adaptation.

The Policy Statement's sea level rise planning benchmarks are an increase in sea levels above 1990 mean sea level of 40 cm by 2050 and 90 cm by 2100. This Technical Note outlines the derivation of these benchmarks, including how relevant scientific information was used.

The components of these sea level rise planning benchmarks are noted in Table 1, with details of these components provided in the following sections. These benchmarks were based on the sea level rise projections developed by Australian and international experts and considered most appropriate for planning purposes in NSW, while acknowledging the uncertainty associated with these projections. The benchmarks will be reviewed based on updated information, with the next review likely to coincide with the release of the fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2014.

Table 1 Components of the sea level rise planning benchmarks

Component	Year 2050	Year 2100
Sea level rise	30 cm	59 cm
Accelerated ice melt	(included in above value)	20 cm
Regional sea level rise variation	10 cm	14 cm
Rounding*	–	–3 cm
Total	40 cm	90 cm

* Rounding was adopted as the projections have a degree of uncertainty, and adopting values to the nearest centimetre would imply unrealistic precision.

Global greenhouse gas emissions projections and observations

Global greenhouse gas emissions projections

The IPCC 2007 Assessment Report provides projections for carbon dioxide emissions (CO_2 equivalent or CO_2-e*) associated with six different future development and mitigation scenarios (IPCC 2007). These emission scenarios influence projections for atmospheric CO_2 concentrations. While three of these scenarios are associated with reduced emissions over the twenty-first century, none of the scenarios are projected to result in decreased atmospheric CO_2 concentrations by the year 2100 (see Figure 1).

Due to the projected increase in CO_2 concentrations, global temperatures are also expected to increase under all of the IPCC's scenarios. This is also illustrated in Figure 1, which notes the range of temperature predictions for each emissions scenario (a range is provided due to uncertainties in the temperature projections from the computer models based on defined concentration data).

* CO_2-e concentration includes the contribution from other greenhouse gases such as methane, nitrous oxide and perflourcarbons, in addition to carbon dioxide.

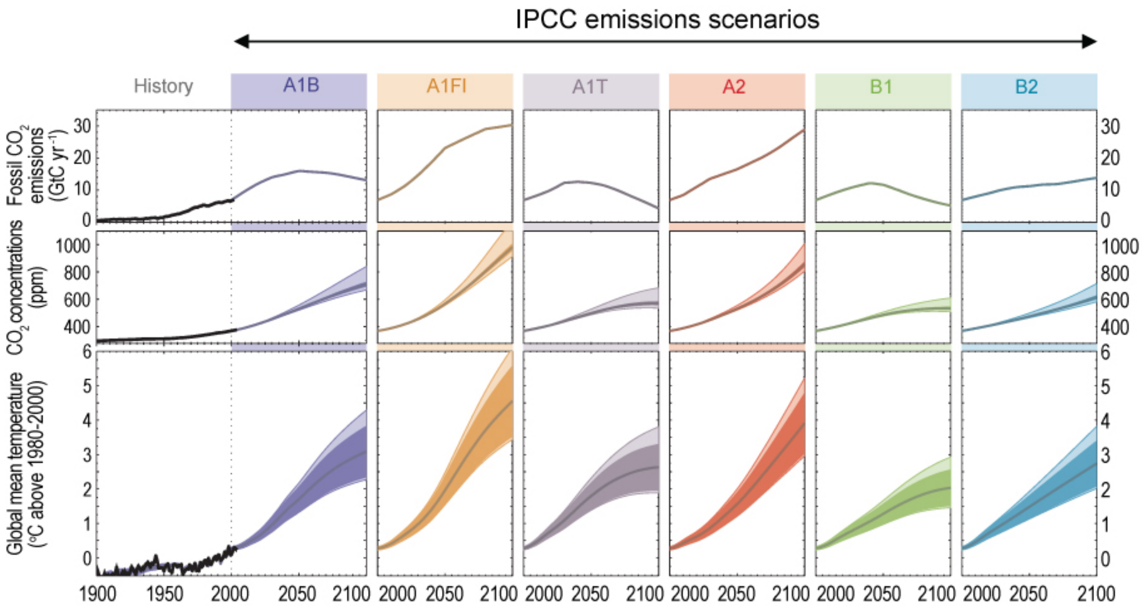

Figure 1 Projected CO_2 emissions and associated projected CO_2 concentrations and global mean temperatures (*Source*: IPCC 2007)

Comparison of projected versus observed greenhouse gas emissions

The IPCC has projected greenhouse gas emissions since its first report in 1990. Figure 2 presents actual CO_2 emissions since 1990 against projected emissions (Steffen 2009). This comparison of the IPCC projected CO_2 emissions and actual observed CO_2 emissions indicates CO_2 emissions have been higher than the highest projected IPCC emissions scenario (scenario A1FI) since 2005. Preliminary estimates of 2008 emissions by the Netherlands Environmental Assessment Agency (2009) indicate emissions grew by 1.7% from 2007 levels, despite the global financial crisis.

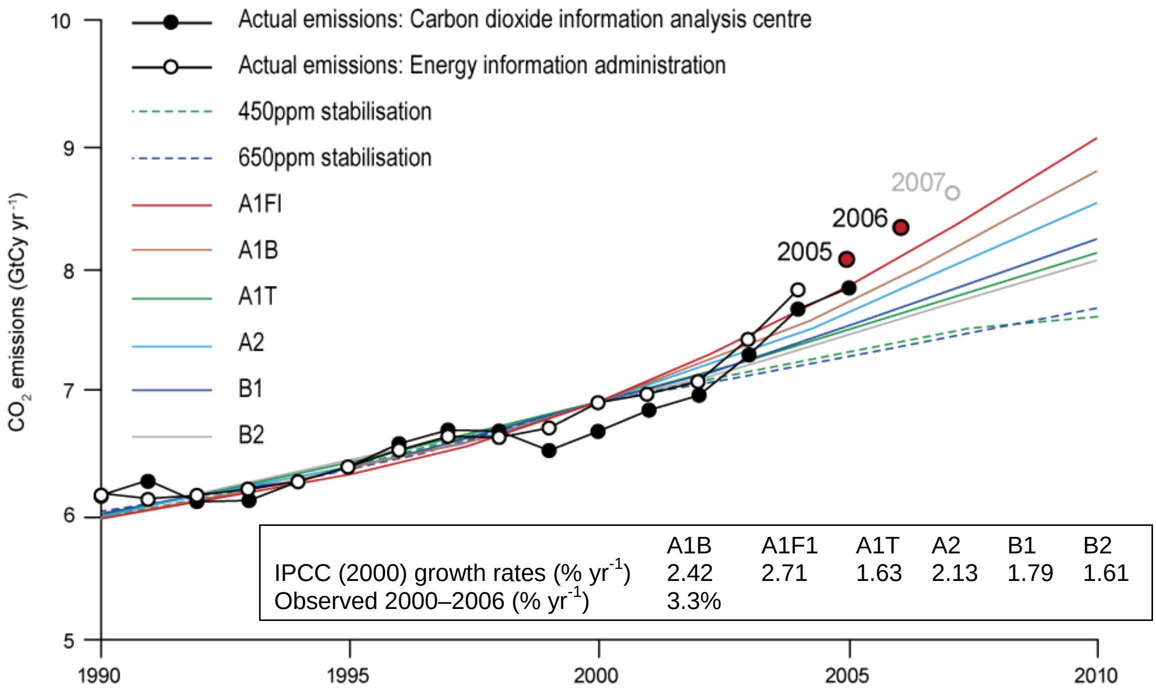

Figure 2 Projected and observed CO_2 emissions. The envelope of IPCC projections are shown for comparison (*Source*: Steffen 2009, Raupach et al. 2007; with additional data points from Canadell et al. 2007 and Global Carbon Project annual carbon budgets; © National Academy of Sciences, USA)

Influence of emission reductions on projected sea level rise

Various initiatives in Australia and internationally are underway or proposed to reduce greenhouse gas emissions. While there is some uncertainty about future emissions, the following points are relevant to future sea level rise projections.

- In order to have a 50% chance of limiting global temperature change to a maximum of 2°C, global CO_2-e concentrations must stabilise at or below 450ppm (European Commission 2008). This will require ambitious global cuts in CO_2-e emissions to approximately 50% of 1990 levels by 2050 (IPCC 2007).
- While stabilisation of CO_2-e concentrations in the short term may halt temperature increases, other processes such as sea level rise will take centuries to reach their maximum potential and stabilise (IPCC 2007).
- At CO_2-e concentrations of 450ppm, thermal expansion alone is expected to contribute 0.4–1.4 m of total sea level rise above 1990 levels (IPCC 2007), with an additional contribution expected from melting ice sheets.

Global sea level rise projections and observations

Sea level rise associated with global warming

Increasing global temperature has a direct impact on sea level. As atmospheric temperature increases so too does ocean temperature through heat transfer. As oceans warm, they expand and take up more space; therefore, any increase in global temperature will result in sea level rise. Increased atmospheric temperatures can also increase the melting of land-based ice into water, which then flows into the ocean elevating sea levels.

Ice sheets on land can also break up and slide into the ocean. This process is referred to as the ‘dynamic response of ice sheets’ and can contribute to increasing sea levels in three important ways: surface meltwater increasing the speed at which glaciers flow, the break up and removal of sea ice that would otherwise slow the flow of large land-based glaciers, and the floating of grounded ice sheets.

Global warming may also lead to changes in land-based water storage and snowfall over Antarctica, with both processes having the potential to slightly offset the rise in sea level (IPCC 2007).

Projections of future sea level rise

The IPCC reports base their projections of sea level rise on various future greenhouse gas emissions scenarios and provide a range of sea level rise projections for each emissions scenario. In the latest report, released in 2007, the IPCC projections ranged 0.18 to 0.59 m across all the emissions scenarios by 2090–2099 – these projections have been applied to 2100 (Table 2).

When making these projections the IPCC did not include projections for how much the dynamic response of ice sheets would contribute to future sea levels because they could not be made with confidence owing to limited understanding of the relevant processes in 2007. So the IPCC noted that if this contribution was to grow in line with global average temperature change, the upper ranges of sea level rise for the emissions scenarios shown in Table 2 would increase by 0.1 to 0.2 m.

Table 2 IPCC projected global average sea level rise by 2050 and by 2100

Emissions scenario	Sea level rise by 2050 (m) *	Sea level rise by 2100 (m) †
B1 scenario	0.05–0.26	0.18–0.38
A1T scenario	0.07–0.29	0.20–0.45
B2 scenario	0.06–0.28	0.20–0.43
A1B scenario	0.06–0.28	0.21–0.48
A2 scenario	0.06–0.27	0.23–0.51
A1FI scenario	0.06–0.30	0.26–0.59

All values are the relative increase to 2090–2099 from average levels at 1980–1999. The projections for 2100 exclude contributions from future rapid dynamical changes in ice flow.
* IPCC 2001
† IPCC 2007

The IPCC also noted that larger values were not excluded. Overall the understanding of the likely dynamic response of the ice sheets was considered too limited to assess their likelihood but important enough for the IPCC to not provide a best estimate or an upper bound for sea level rise.

Observations of sea level rise

An analysis of tide gauge records from around the world has found that during the twentieth century (1870–2001), global sea level rose by 19.5 cm at a rate of 1.7±0.3 mm per year, with the rate of sea level rise accelerating towards the end of the twentieth century (Church & White 2006). This information is summarised in Figure 3, which includes global average tide gauge data between 1870 and 2001 and global average satellite altimeter data from 1993 to 2006. A recent analysis of satellite data (1993–2007) shows the current global average annual sea level rise to be 3.4 ± 0.4 mm per year (Beckley et al. 2007).

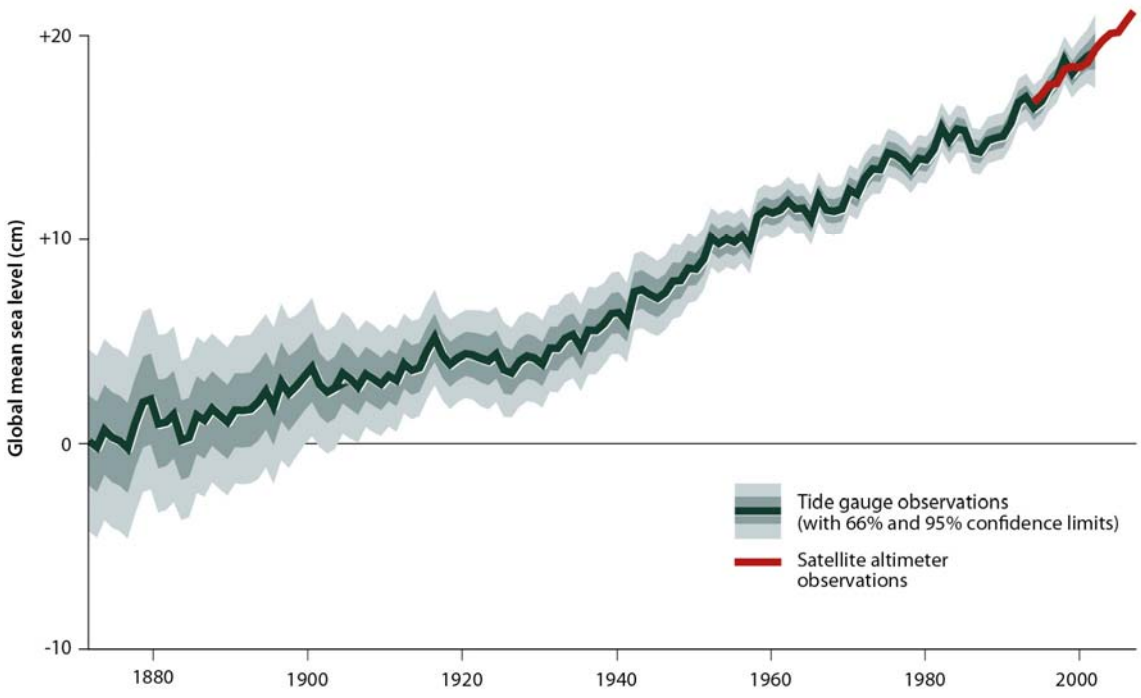

Figure 3 Annual averages of the global mean sea level (cm)
(*Source*: UNEP/GRID-Arendal 2007a)

The relative contributions of thermal expansion and melting of land-based ice to observed sea level rise were identified by the IPCC in 2007 (Table 3). These contributions show that, in the decade 1993–2003, thermal expansion and land based ice melting had increased substantially when compared to the past 40–50 years. Since the release of the latest IPCC report, the contributions from land based ice have continued to grow (Cazenave et al. 2009; Rignot et al. 2008) and suggest the dynamic response of the major ice sheets will make an important contribution to sea level rise during the twenty-first century. These observations support the inclusion of the additional 0.1–0.2 m allowance discussed by the IPCC when considering projections for sea level rise by the year 2100.

Table 3 Contributions to sea level rise over the past 50 years

Source	**Contribution to sea level rise (mm per year)**		
	1961–2003 *	**1993–2003 ***	**2003-2008 †**
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5	0.37± 0.1
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22	1.1± 0.24
Greenland ice sheet	0.05 ± 0.12	0.21 ± 0.07	0.38± 0.05
Antarctic ice sheets	0.14 ± 0.41	0.21 ± 0.35	0.56 ± 0.06

* IPCC 2007
† Cazenave et al. 2009

Comparison of projected versus observed sea level rise

In 2007, the IPCC only provided projections for sea level rise for the decade 2090–2099 (IPCC 2007), which does not enable a direct comparison with observations since 1990. Recent research has been able to make the comparison by using the IPCC's 2001 projections (Church et al. 2008; Rahmstorf et al. 2007). This research indicates observed global mean sea levels are rising at the top of the IPCC's sea level rise projections for the highest emissions scenario (scenario A1FI) but only when including the additional 0.1–0.2 m for the dynamic response of ice sheets (Figure 4). It is acknowledged that this data represent observations for around 15% of the period to 2100, when comparison can validly be made with the IPCC's 2007 projections.

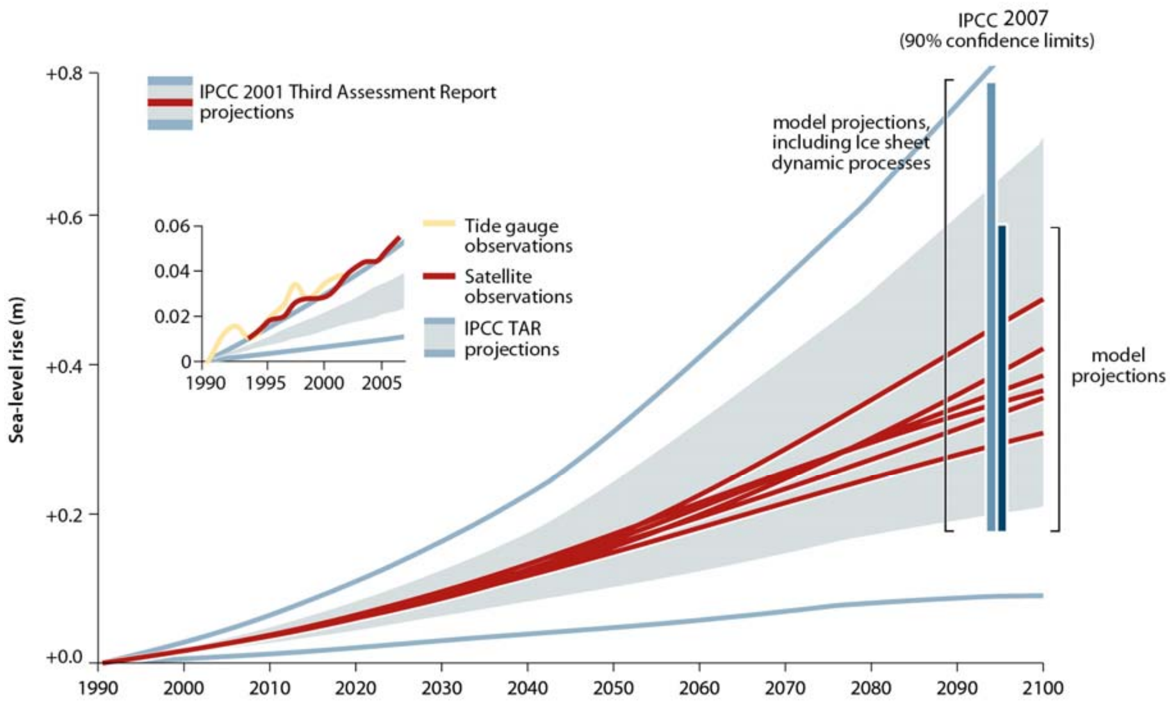

Figure 4 Projected global sea level rise for the twenty-first century (*Source*: UNEP/GRID-Arendal 2007b)

Regional variation in sea level rise

Current and projected sea level rise is not uniform across the globe due to the influence of currents, water temperature, local land movements and other more complex factors (Peltier 2009).

CSIRO have modelled the regional sea level rise variation around Australia, with the highest projected increases occurring along the NSW coastline. This is illustrated in Figure 5, which presents 2070 sea level rise projections for a mid-range greenhouse gas emissions scenario. Higher regional variations are therefore projected for the NSW coastline in 2100. The Queensland and Victorian coastlines are projected to have either minor increases or decreases relative to the global average.

CSIRO undertook detailed modelling to derive sea level rise projections for the NSW coastline. The modelling results projected a NSW regional variation above global levels of up to 8 cm by 2030 and 12 cm by 2070 (McInnes et al. 2007). This regional variation is associated with a projected strong warming of the sea surface temperatures in the region and a strengthening of the East Australian Current. Linear interpolation and extrapolation of these upper limit projections were used to arrive at a value of 0.1 m for 2050 and 0.14 m for 2100. This in part explains the differences in the NSW benchmark figures from those adopted for Victoria (Victorian Coastal Council 2008) and proposed for Queensland (Queensland Department of Environment and Resource Management 2009).

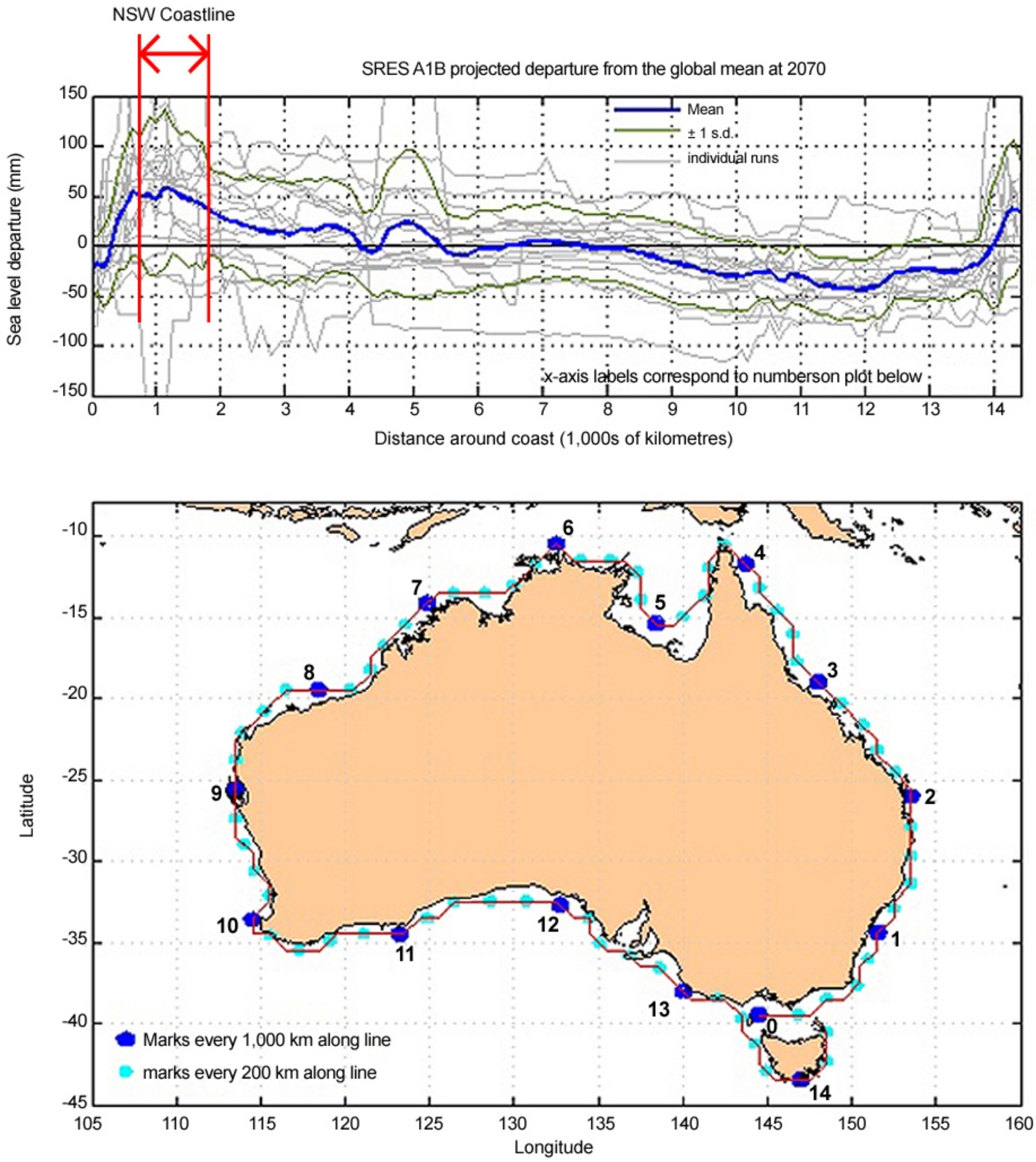

Figure 5 Regional variations in projected sea level rise along the Australian coastline (*Source*: CSIRO 2009, reproduced with permission from www.cmar.csiro.au/sealevel)

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