Derivation of Revised Victorian Sea-Level Planning Allowances Using the Projections of the Fifth Assessment Report of the IPCC

Research conducted for

The Victorian Coastal Council

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Executive Summary

Sea-level planning allowances for the Victorian coastline are here derived, based on the method of Hunter (2012). These allowances ensure that the average number of inundation events in a given period is preserved. In other words, any asset raised by this allowance would experience the same frequency of inundation events under sea-level rise as it would without the allowance and without sea-level rise.

These allowances are based on the latest projections of regional sea-level rise from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), and on the present statistics of storm tides (the combination of tides and storm surges). The latter have been derived from both tide-gauge observations (at Point Lonsdale and Williamstown) and the results of a storm-tide model of the Australian region. In deriving the allowance, it has been assumed that the statistics of storm tides will not change significantly during the 21st century.

This is a continuation of earlier estimates of planning allowances for the Victorian coastline Hunter (2013), which were based on regional sea-level rise projections from the Fourth Assessment Report (AR4) of the IPCC.

For the periods 2010-2040, 2010-2070 and 2010-2099, the suggested allowances are 0.2, 0.4 and 0.8 (0.9) metres, respectively (where the figure in brackets indicates a more protective option).

NOTE that, in order to enable skimming of this report for its most salient features, the most important text is highlighted in red.

1 Introduction

The work described in this document was commissioned by the Victorian Coastal Council in December 2013, in order to provide advice concerning appropriate vertical allowances[1] for sea-level rise for Victoria for this century. The methodology is similar to that used for the recent derivation of the Tasmanian Sea Level Rise Planning Allowances (Tasmanian Climate Change Office, 2012). Planning allowances were recently derived for Victoria (Hunter, 2013), based on regional sea-level rise projections from the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). This report describes an update of this work using regional sea-level rise projections from the Fifth Assessment Report (AR5) of the IPCC.

For a general discussion of climate change, sea-level rise, other Australian sea-level planning allowances and a description of the background behind the allowances developed here, the reader is referred to Hunter (2013).

2 Caveats

The allowances presented here are subject to a number of caveats:

a. These allowances only relate to the effect of sea-level rise on *inundation* and *not* on the recession of soft (e.g. sandy) shorelines or on other impacts.

b. While these allowances include the effects of vertical land motion due to changes in the Earth's loading and gravitational field, caused by past and ongoing changes in land ice (glacial isostatic adjustment (GIA) and the 'gravitational fingerprint' contribution, respectively), they do not include effects due to local land subsidence produced, for example, by groundwater withdrawal; *separate allowances should be applied to account for these latter effects.*

c. These allowances are based on the assumption that the statistics of the storm tides will not change in time. This is supported by the fact that present evidence (Bindoff et al, 2007, Lowe et al, 2012, Menéndez and Woodworth, 2010, Woodworth and Blackman, 2004) suggests that the rise in mean sea level is generally the dominant cause of any observed increase in the frequency of inundation events. In addition, using model projections of storm tides in southeast Australia to 2070, McInnes et al (2009) showed that the increase in the frequency of inundation events was dominated by sea-level rise.

d. These allowances include no contribution due to possible changes in wave setup or runup.

e. These allowances include no contribution due to the change in tides caused by sea-level rise, which are generally small and confined to quite specific locations in shelf seas.

f. These allowances depend on an assumed probability distribution for the uncertainty of the sea-level rise projections. Here, a normal or Gaussian distribution has been used,

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[1] In this context, an 'allowance' is the vertical distance that a coastal entity needs to be raised in order to cope with the projected sea-level rise.

which represents a pragmatic compromise between a tightly confined distribution, and one with a fat upper tail (i.e. one in which there is a low probability of having a very high sea-level rise relative to the best estimate of that rise). The allowances represent a practical solution to planning for sea-level rise while preserving an acceptable level of inundation likelihood, in cases where 'getting the allowance wrong' is manageable. However, in cases where the consequence of inundation would be 'dire' (in the sense that the consequence of inundation would be unbearable, no matter how low the likelihood, as in case of the Netherlands), a precautionary approach would be *not* to use the allowances presented here, but to base an allowance on the best estimate of the maximum possible rise.

3 Summary of the Method of Deriving the Sea-Level Planning Allowance

The method used to derive the sea-level planning allowances was described by Hunter (2012) and Hunter (2013). This allowance ensures that the expected, or average, number of extreme (inundation) events in a given period is preserved. In other words, any asset raised by this allowance would experience the same frequency of inundation events under sea-level rise as it would without the allowance and without sea-level rise. It is important to note that this allowance only relates to the effect of sea-level rise on *inundation* and not on the recession of soft (e.g. sandy) shorelines or on other impacts.

In the terminology of risk assessment (e.g. ISO, 2009), the expected number of inundation events in a given period is known as the *likelihood*. If a specific cost may be attributed to one inundation event, then this cost is termed the *consequence*, and the combined effect (generally the product) of the likelihood and the consequence is the *risk* (i.e. the total effective cost of damage from inundation over the given period). The allowance is therefore the height that an asset needs to be raised under sea-level rise in order to keep the inundation risk the same.

An important property of the allowance is that it is *independent of the required level of precaution*. In the case of coastal infrastructure, an appropriate height should first be selected, based on *present* conditions and an acceptable degree of precaution (e.g. an average of one inundation event in 100 years). If this height is then raised by the allowance calculated for a specific period, the required level of precaution will be sustained until the end of this period.

The method assumes that there is no change in the variability of the extremes (specifically, the value of the *scale parameter of the Gumbel distribution*[2] which describes this variability). In other words, the statistics of storm tides relative to mean sea level are assumed to be unchanged. It is also assumed that there is no change in wave climate (and therefore in wave setup and runup). The allowance derived from this method depends also on the probability distribution of the uncertainty in the rise in mean sea level at some future time. However, once this distribution and the Gumbel scale parameter has been chosen, the remaining derivation of the allowance is entirely objective.

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[2] The statistics of extreme value distributions and the detailed derivation of the allowances will not be further explained here; they have been fully described by Hunter (2012).

The allowances derived here are based on the following information:

1. the regional projections of sea-level rise for the RCP8.5 Representative Concentration Pathway, which is roughly equivalent to the A1FI emission scenario (Wayne, 2013), which the world is broadly following at present (Le Quéré et al, 2009),
2. the statistics of storm tide extremes (i.e. the Gumbel scale parameter) from tide-gauge observations at Point Lonsdale and Williamstown (from the *GESLA* (Global Extremes Sea-Level Analysis) database (see Menéndez and Woodworth, 2010)), and
3. the statistics of storm tide extremes (i.e. the Gumbel scale parameter) from the results of a storm-tide model of the Australian region (Haigh et al, 2012) (two versions of this model exist: one for simulating the effects of mid-latitude storms and the other for simulating the effects of tropical cyclones; due to Victoria's southerly location, only the results from the first version have been used here).

A normal or Gaussian distribution has been used to describe the uncertainty distribution of the sea-level rise projections. This represents a pragmatic compromise between a tightly confined distribution, and one with a fat upper tail (i.e. one in which there is a low probability of having a very high sea-level rise relative to the best estimate of that rise). Following Hunter (2012), the allowance A is given by:

$$A = \Delta z + \frac{\sigma^2}{2\lambda} \tag{1}$$

where Δz is the central value of the sea-level rise projection, σ is the standard deviation of the uncertainty of the sea-level rise projection, and λ is the Gumbel scale parameter (derived either from tide-gauge records or the storm-tide model). The standard deviation, σ, is derived from 5- and 95-percentile limits of the projections assuming that the uncertainty is normally distributed.

4 The Input Data

The recent report on Victorian sea-level planning allowances (Hunter, 2013) used the regional projections of the IPCC AR4, with enhancements to include the effects of past and future changes of ice on land (which cause vertical motions of the Earth's crust and changes in the Earth's gravitational field). The processing of the projections was fully described by Hunter et al (2013), and was summarised by Hunter (2013). At the time of the AR4, the climate models were forced by a range of plausible emission scenarios[3]. The allowances described by Hunter (2013) were based on the A1FI emission scenario, which the world is broadly following at present (Le Quéré et al, 2009).

The models described in the AR5 are forced by *atmospheric concentrations* of greenhouse gases and aerosols, rather than by the *emission scenarios* used by the AR4. The

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[3] The main emission scenarios used for the IPCC Third Assessment Report (TAR) and AR4 modelling are described in the Special Report on Emission Scenarios (SRES; Nakicenovic et al, 2000).

atmospheric concentrations are characterised by *Representative Concentration Pathways* or *RCPs*. The allowances presented here are based on the RCP8.5 Representative Concentration Pathway, which is roughly equivalent to the A1FI emission scenario (Wayne, 2013) and is the highest-emission RCP presented in the AR5.

The AR5 presented regional projections including the effects of past and future changes of ice on land (glacial isostatic adjustment (GIA) and the 'gravitational fingerprint' contribution, respectively). These were calculated in a similar (but not exactly the same) technique as that described by Hunter et al (2013) and summarised by Hunter (2013). As an example, Figure 1 shows regional projections of sea-level rise between 1986-2005 and 2081-2100 from the AR5, based on the RCP4.5 Representative Concentration Pathway (IPCC, 2013, and draft report at `http://www.ipcc.ch/report/ar5/wg1`). (NOTE that this is *not* RCP8.5, which was used to derive the allowances)

The allowances were based on annual time series of the AR5 sea-level projections for the RCP8.5 Representative Concentration Pathway, which are defined on a 1° longitude × 1° latitude grid. Figure 2 shows the coastline of Victoria with the locations of the sea-level projections shown as black dots. Also shown are the coastal locations (red and brown dots) at which the earlier planning allowances were computed (Hunter, 2013). Geelong is here shown as a brown dot as it is outside the 'range' of the locations of the sea-level projections (in the sense that it was more than 1° in both longitude or latitude from any 'projection' point). Allowances were therefore computed for the nine locations shown by red dots in Figure 2, but not for Geelong.

The AR5 sea-level rise projections were interpolated to the nine coastal locations using variants of linear interpolation, depending on the number of 'model' points surrounding each coastal point. One component of the total sea-level rise, the *glacial isostatic adjustment* or *GIA*, was treated in a slightly different way, because it is available over the whole Earth (i.e. at the black dots shown in Figure 2 *plus* the remaining locations that would complete the 'checker-board' pattern). GIA can therefore be interpolated at the coastal locations using all four nearest neighbours and bilinear interpolation. Two sets of coastal sea-level projections have therefore been computed:

1. projections based on linear interpolation of the regional sea-level projections, *using ocean points only*, and
2. projections based of linear interpolation of the regional sea-level projections *without GIA*, *using ocean points only*, plus bilinear interpolation of GIA projections, *using ocean and land points*.

The coastal projections (2), referred to here as the *corrected* projections, are generally better than (1), referred to here as the *uncorrected* projections, because the interpolation uses more data (the GIA points over the land). However, the difference in the resulting allowances is small (i.e. at the centimetre level; compare Figures 8 and 9, and Table 6 and 7). For the final allowances presented here, the *corrected* projections (2) have been used.

As in the earlier report (Hunter, 2013), the Gumbel scale parameter was provided by the storm-tide model of Haigh et al (2012) (red dots) in Figure 2, and from tide-gauge observations (black rings in Figure 2).

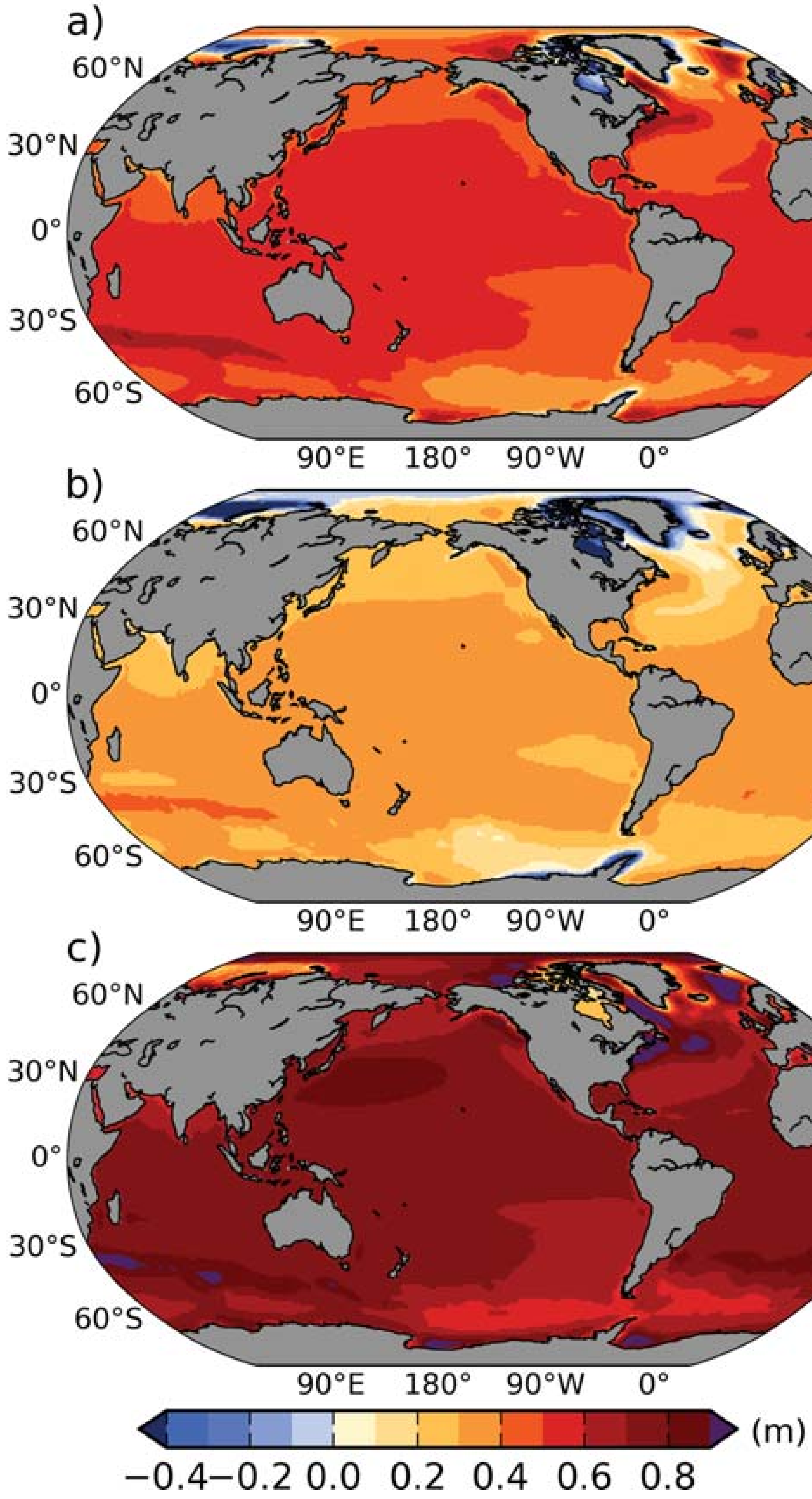

Figure 1: Regional projections of sea-level rise between 1986-2005 and 2081-2100 from the AR5, based on the RCP4.5 Representative Concentration Pathway. (a) is the global mean, (b) the 5-percentile lower bound and (c) the 95-percentile upper bound. From `http://www.ipcc.ch/report/ar5/wg1` (Figure 13.19).

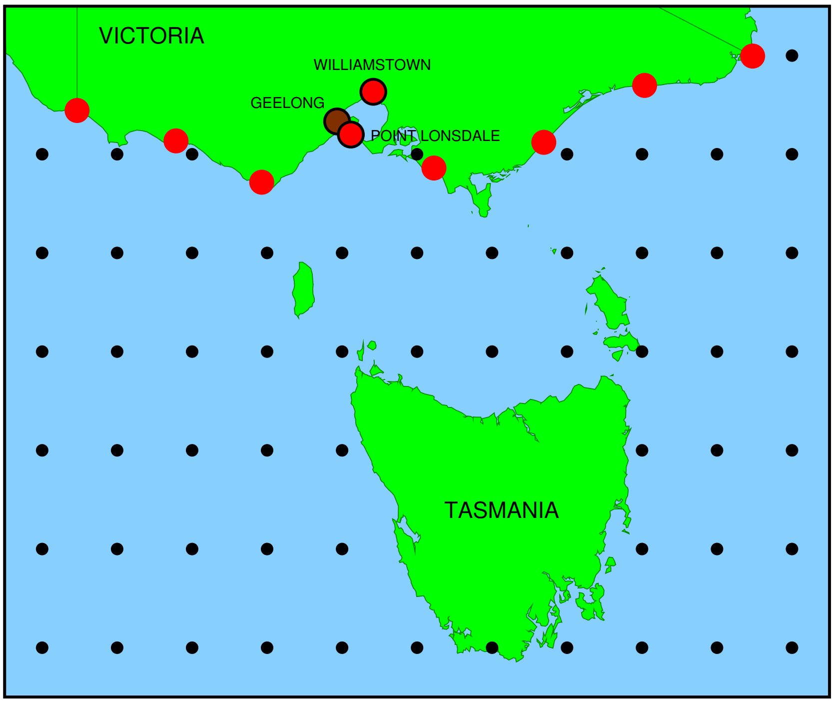

Figure 2: Locations of sites where sea-level planning allowance has been estimated. Red and brown dots indicate locations where modelled storm-tide statistics (specifically, the Gumbel scale parameter) have been evaluated. Black rings indicates locations of tide gauges. Black dots indicate locations of AR5 sea-level rise projections; the tide-gauge station at Geelong is coloured brown to indicate that it falls outside the range of these projections and was not therefore used in the present analysis.

5 Sea-Level Planning Allowances for Victoria

5.1 Introduction

Ten potential locations used for the evaluation of the Victorian sea-level planning allowances are shown in Figure 2. Regionally-varying sea-level rise projections are available at only nine of these locations, because the tide-gauge station at Geelong falls outside the range of the AR5 sea-level projections (see Section 4). The RCP8.5 Representative Concentration Pathway, which is roughly equivalent to the A1FI emission scenario (Wayne, 2013), which the world is broadly following at present (Le Quéré et al, 2009), has been used throughout.

The statistics of present storm tides (specifically, the Gumbel scale parameter) have been estimated at all these sites using the storm-tide model of Haigh et al (2012), and from tide-gauge data at Point Lonsdale and Williamstown (shown as red dots with black rings in Figure 2). There are therefore two groups of allowances:

1. allowances for two locations, derived using the regionally-varying sea-level rise projections, combined with the Gumbel scale parameter from the tide gauges at Point Lonsdale and Williamstown, and
2. allowances for nine locations, derived using the regionally-varying sea-level rise projections, combined with the Gumbel scale parameter from the storm-tide model of Haigh et al (2012).

It may be seen, from inspection of Tables 5 and 7, that the Gumbel scale parameters estimated from the tide gauges are about 0.015 metres greater than those estimated from the storm-tide model, and that the corresponding allowances estimated from the tide gauges are slightly *smaller* than those estimated from the storm-tide model (by about 0.02 metres for the period 2010-2099). *It is therefore recommended that sea-level planning allowances should be based on the allowances derived using the storm-tide model, because they are slightly larger (and therefore more conservative) and because they cover all nine locations along the coast.* However, the allowances derived using the tide-gauge data have been included here for completeness.

All allowances have been derived using Equation 1. The following Sections describe the results for planning periods of 2010-2040, 2010-2070 and 2010-2099 (the last of these relates to 2010-2099, rather than to 2010-2100, because the AR5 regional projections end in the middle of 2099).

Figures 4, 6 and 9, and Tables 2, 4 and 7 show a slight increase in the allowance from west to east, particularly for the period 2010-2099. This suggests that it may be appropriate to prescribe different allowances in different regions, for any give period. However, this would represent a deviation from the current (or abandoned) policies in all Australian States; the suggestions given in Sections 5.2 to 5.4 are therefore based on the assumption that a single Victorian sea-level planning allowance will be prescribed for each period.

5.2 2010-2040

The results derived using the present storm-tide statistics from tide-gauges for the period 2010-2040 are shown in Figure 3 and Table 1.

The results derived using the present storm-tide statistics from the storm-tide model for the period 2010-2040 are shown in Figure 4 and Table 2. As noted in Section 5.1, the following discussion is confined to these results, rather than to those that were derived using the tide-gauge data.

Figure 4 and Table 2 suggest a suitable allowance of 0.2 metres, on the assumption than the allowances will be rounded to the nearest 0.1 metres.

5.3 2010-2070

The results derived using the present storm-tide statistics from tide-gauges for the period 2010-2070 are shown in Figure 5 and Table 3.

The results derived using the present storm-tide statistics from the storm-tide model for the period 2010-2070 are shown in Figure 6 and Table 4. As noted in Section 5.1, the following discussion is confined to these results, rather than to those that were derived using the tide-gauge data.

Figure 6 and Table 4 suggest a suitable allowance of 0.4 metres, on the assumption than the allowances will be rounded to the nearest 0.1 metres.

5.4 2010-2099

The results derived using the present storm-tide statistics from tide-gauges for the period 2010-2099 are shown in Figure 7 and Table 5.

The results derived using the present storm-tide statistics from the storm-tide model for the period 2010-2099 are shown in Figures 8 and 9, and Tables 6 and 7. Figure 8 and Table 6 (based on *uncorrected* projections) have been included here to indicate that they differ little from Figure 9 and Table 7 (based on *corrected* projections). As noted in Section 5.1, the following discussion is confined to results derived using the storm-tide model, rather than to those that were derived using the tide-gauge data.

Figure 9 and Table 7 suggest a suitable allowance of 0.8 metres, or possibly 0.9 metres (which would be more conservative), on the assumption than the allowances will be rounded to the nearest 0.1 metres.

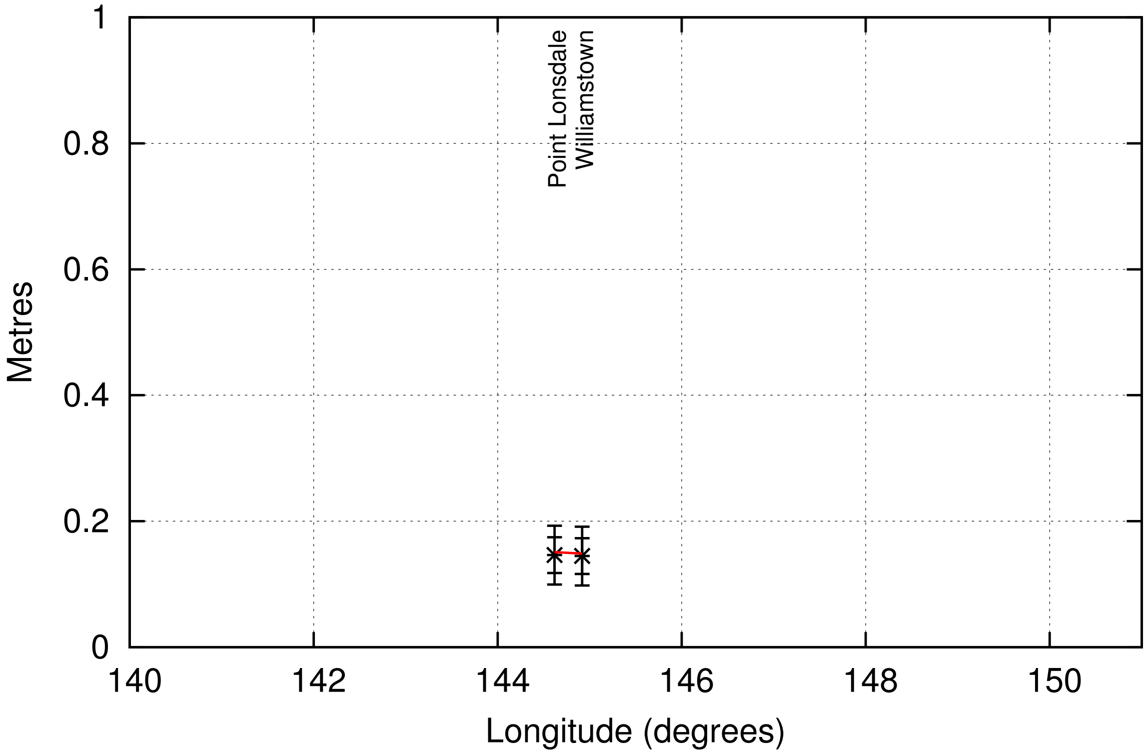

Figure 3: Sea-level projections (black bars; crosses indicating central value, inner range indicating ± one standard deviation, and outer range indicating 5- to 95-percentile limits) and sea-level planning allowance (red curve), for RCP8.5 and years 2010-2040, plotted against longitude for tide-gauge locations only. The allowances were derived using tide-gauge data and corrected sea-level rise projections.

Name	Longitude, Latitude (°)	Gumbel scale parameter, λ (metres)	Projection Δz, σ (metres)	Projection 5,95% (metres)	Allowance (metres)
Point Lonsdale	144.617, -38.300	0.085	0.15, 0.03	0.10, 0.19	0.15
Williamstown	144.917, -37.867	0.102	0.14, 0.03	0.10, 0.19	0.15

Table 1: Summary of locations, Gumbel scale parameter (from tide-gauge data), mean and standard deviation of sea-level projections, 5- 95-percentile range of sea-level projections, and sea-level planning allowances, for RCP8.5, years 2010-2040 and tide-gauge stations only. Sea-level rise projections are corrected.

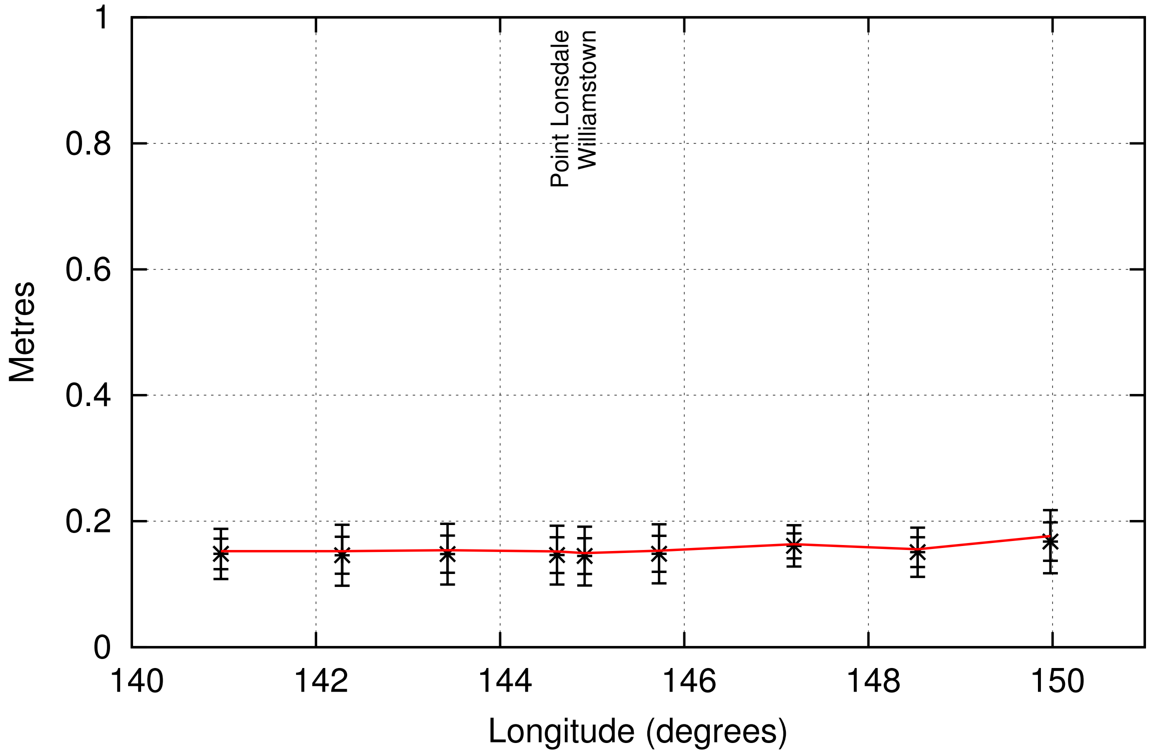

Figure 4: Sea-level projections (black bars; crosses indicating central value, inner range indicating ± one standard deviation, and outer range indicating 5- to 95-percentile limits) and sea-level planning allowance (red curve), for RCP8.5 and years 2010-2040, plotted against longitude for all locations. The allowances were derived using the storm-tide model and corrected sea-level rise projections.

Name	Longitude, Latitude (°)	Gumbel scale parameter, λ (metres)	Projection Δz, σ (metres)	Projection 5,95% (metres)	Allowance (metres)
Western coastal border	140.966, -38.056	0.067	0.15, 0.02	0.11, 0.19	0.15
East of Port Fairy	142.285, -38.364	0.066	0.15, 0.03	0.10, 0.19	0.15
West of Cape Otway	143.428, -38.783	0.067	0.15, 0.03	0.10, 0.20	0.15
Point Lonsdale	144.617, -38.300	0.069	0.15, 0.03	0.10, 0.19	0.15
Williamstown	144.917, -37.867	0.090	0.14, 0.03	0.10, 0.19	0.15
Inverloch	145.725, -38.639	0.082	0.15, 0.03	0.10, 0.20	0.15
Seaspray	147.190, -38.379	0.076	0.16, 0.02	0.13, 0.19	0.16
Marlo	148.534, -37.802	0.062	0.15, 0.02	0.11, 0.19	0.16
Eastern coastal border	149.975, -37.505	0.052	0.17, 0.03	0.12, 0.22	0.18

Table 2: Summary of locations, Gumbel scale parameter (from storm-tide model), mean and standard deviation of sea-level projections, 5- 95-percentile range of sea-level projections, and sea-level planning allowances, for RCP8.5, years 2010-2040, and all locations. Sea-level rise projections are corrected.

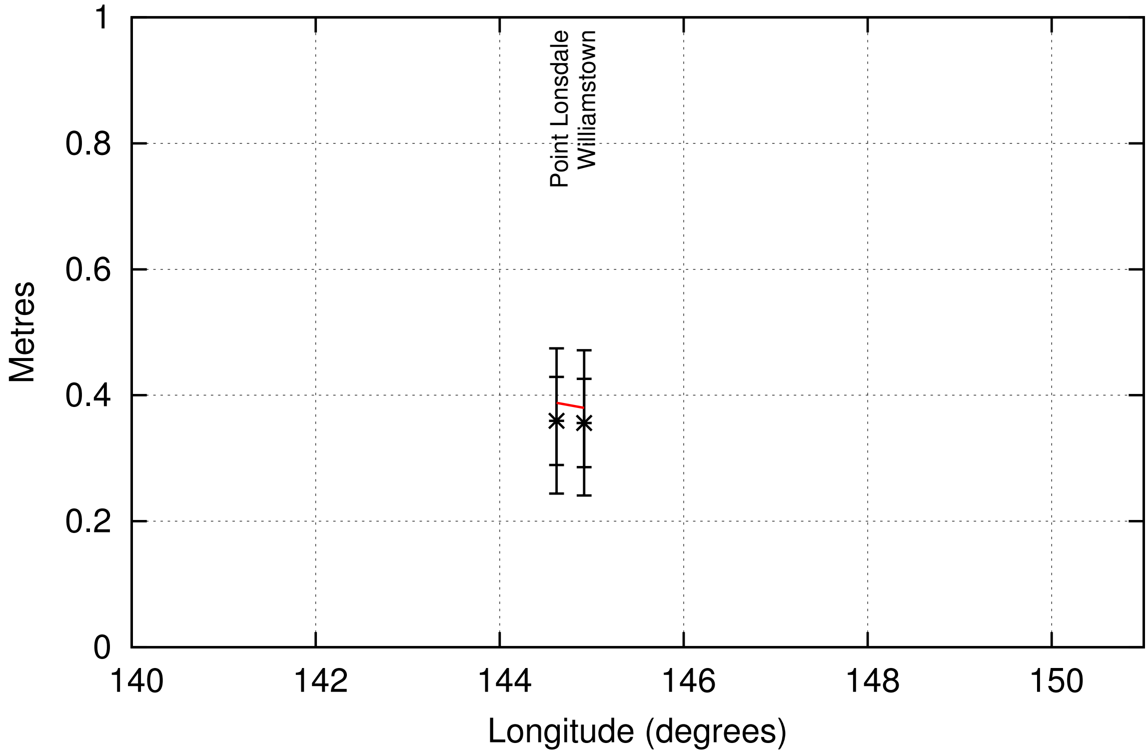

Figure 5: Sea-level projections (black bars; crosses indicating central value, inner range indicating ± one standard deviation, and outer range indicating 5- to 95-percentile limits) and sea-level planning allowance (red curve), for RCP8.5 and years 2010-2070, plotted against longitude for tide-gauge locations only. The allowances were derived using tide-gauge data and corrected sea-level rise projections.

Name	Longitude, Latitude (°)	Gumbel scale parameter, λ (metres)	Projection Δz, σ (metres)	Projection 5,95% (metres)	Allowance (metres)
Point Lonsdale	144.617, -38.300	0.085	0.36, 0.07	0.24, 0.47	0.39
Williamstown	144.917, -37.867	0.102	0.36, 0.07	0.24, 0.47	0.38

Table 3: Summary of locations, Gumbel scale parameter (from tide-gauge data), mean and standard deviation of sea-level projections, 5- 95-percentile range of sea-level projections, and sea-level planning allowances, for RCP8.5, years 2010-2070 and tide-gauge stations only. Sea-level rise projections are corrected.

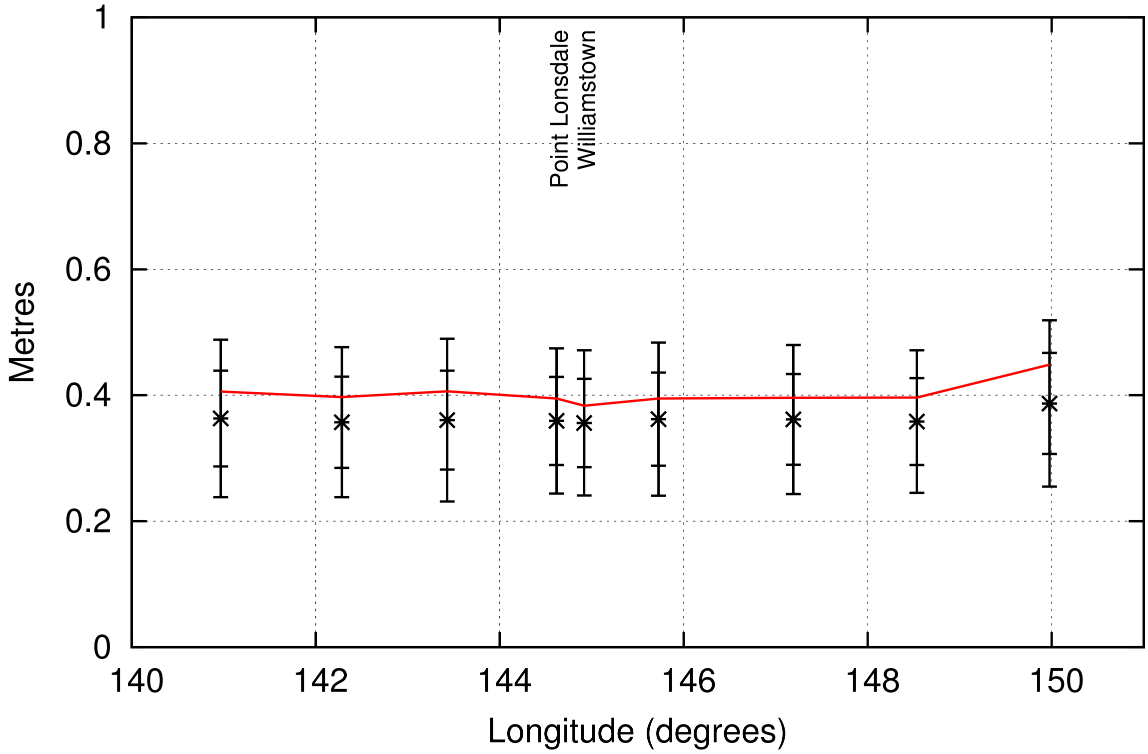

Figure 6: Sea-level projections (black bars; crosses indicating central value, inner range indicating ± one standard deviation, and outer range indicating 5- to 95-percentile limits) and sea-level planning allowance (red curve), for RCP8.5 and years 2010-2070, plotted against longitude for all locations. The allowances were derived using the storm-tide model and corrected sea-level rise projections.

Name	Longitude, Latitude (°)	Gumbel scale parameter, λ (metres)	Projection Δz, σ (metres)	Projection 5,95% (metres)	Allowance (metres)
Western coastal border	140.966, -38.056	0.067	0.36, 0.08	0.24, 0.49	0.41
East of Port Fairy	142.285, -38.364	0.066	0.36, 0.07	0.24, 0.48	0.40
West of Cape Otway	143.428, -38.783	0.067	0.36, 0.08	0.23, 0.49	0.41
Point Lonsdale	144.617, -38.300	0.069	0.36, 0.07	0.24, 0.47	0.39
Williamstown	144.917, -37.867	0.090	0.36, 0.07	0.24, 0.47	0.38
Inverloch	145.725, -38.639	0.082	0.36, 0.07	0.24, 0.48	0.40
Seaspray	147.190, -38.379	0.076	0.36, 0.07	0.24, 0.48	0.40
Marlo	148.534, -37.802	0.062	0.36, 0.07	0.24, 0.47	0.40
Eastern coastal border	149.975, -37.505	0.052	0.39, 0.08	0.26, 0.52	0.45

Table 4: Summary of locations, Gumbel scale parameter (from storm-tide model), mean and standard deviation of sea-level projections, 5- 95-percentile range of sea-level projections, and sea-level planning allowances, for RCP8.5, years 2010-2070, and all locations. Sea-level rise projections are corrected.

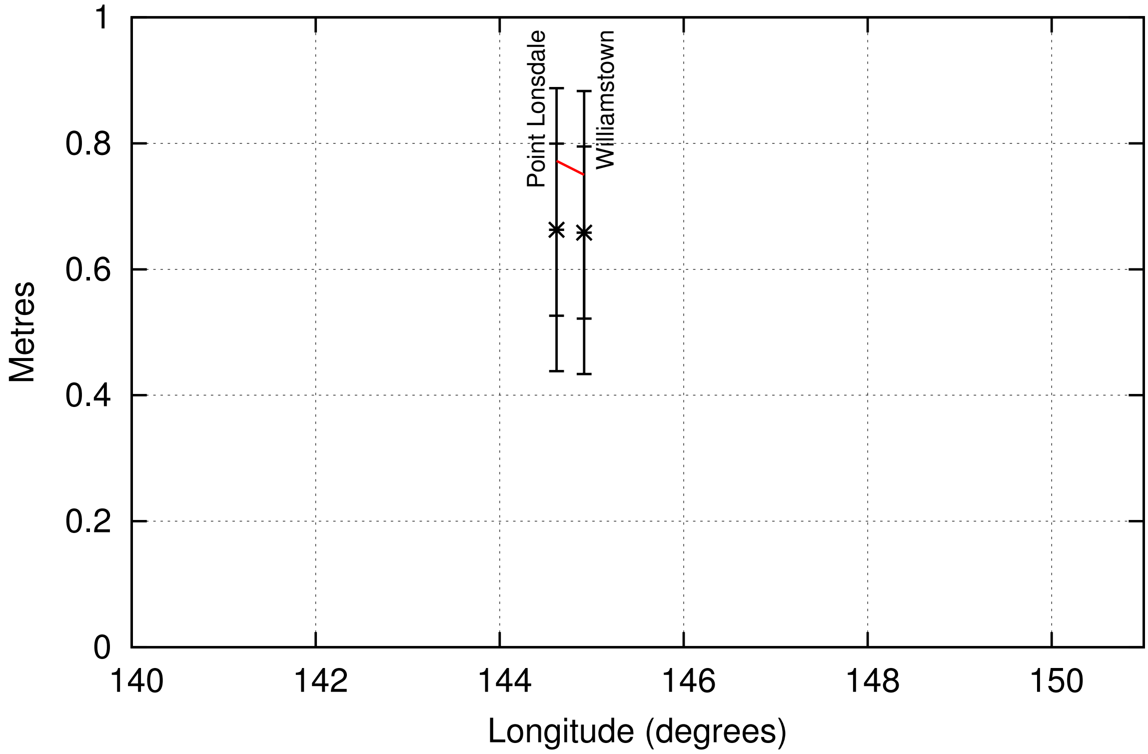

Figure 7: Sea-level projections (black bars; crosses indicating central value, inner range indicating ± one standard deviation, and outer range indicating 5- to 95-percentile limits) and sea-level planning allowance (red curve), for RCP8.5 and years 2010-2099, plotted against longitude for tide-gauge locations only. The allowances were derived using tide-gauge data and corrected sea-level rise projections.

Name	Longitude, Latitude (°)	Gumbel scale parameter, λ (metres)	Projection Δz, σ (metres)	Projection 5,95% (metres)	Allowance (metres)
Point Lonsdale	144.617, -38.300	0.085	0.66, 0.14	0.44, 0.89	0.77
Williamstown	144.917, -37.867	0.102	0.66, 0.14	0.43, 0.88	0.75

Table 5: Summary of locations, Gumbel scale parameter (from tide-gauge data), mean and standard deviation of sea-level projections, 5- 95-percentile range of sea-level projections, and sea-level planning allowances, for RCP8.5, years 2010-2099 and tide-gauge stations only. Sea-level rise projections are corrected.

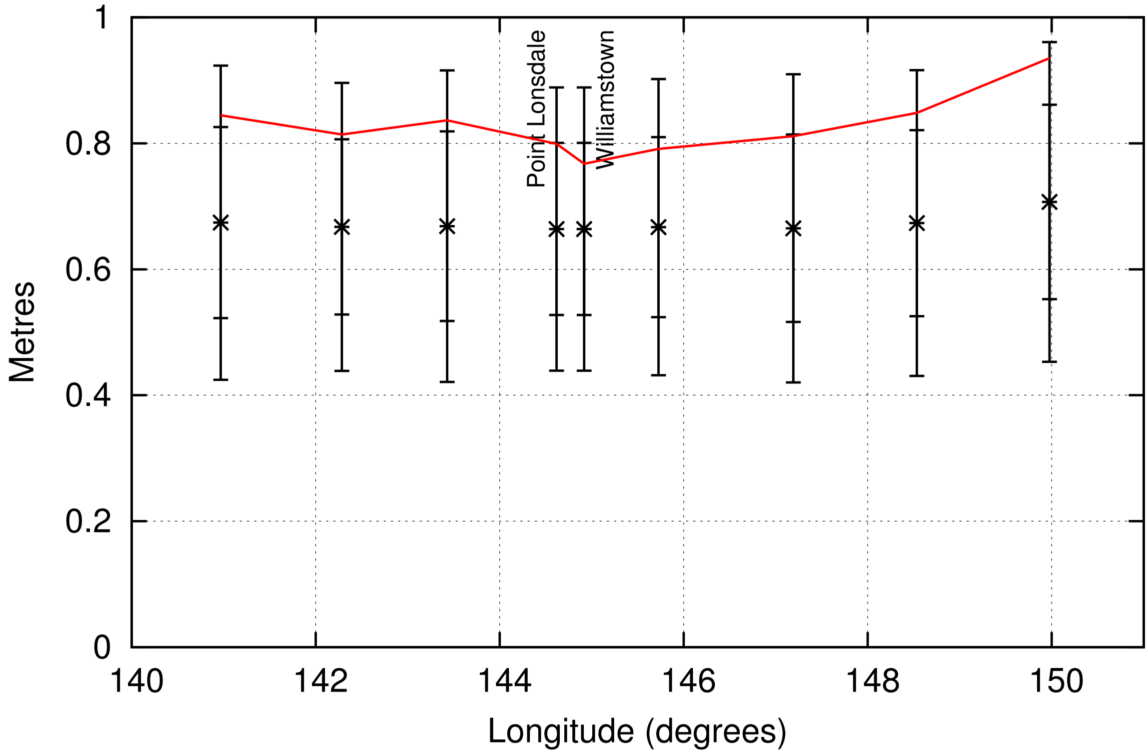

Figure 8: Sea-level projections (black bars; crosses indicating central value, inner range indicating ± one standard deviation, and outer range indicating 5- to 95-percentile limits) and sea-level planning allowance (red curve), for RCP8.5 and years 2010-2099, plotted against longitude for all locations. The allowances were derived using the storm-tide model and uncorrected sea-level rise projections.

Name	Longitude, Latitude (°)	Gumbel scale parameter, λ (metres)	Projection Δz, σ (metres)	Projection 5,95% (metres)	Allowance (metres)
Western coastal border	140.966, -38.056	0.067	0.67, 0.15	0.42, 0.92	0.84
East of Port Fairy	142.285, -38.364	0.066	0.67, 0.14	0.44, 0.90	0.81
West of Cape Otway	143.428, -38.783	0.067	0.67, 0.15	0.42, 0.92	0.84
Point Lonsdale	144.617, -38.300	0.069	0.66, 0.14	0.44, 0.89	0.80
Williamstown	144.917, -37.867	0.090	0.66, 0.14	0.44, 0.89	0.77
Inverloch	145.725, -38.639	0.082	0.67, 0.14	0.43, 0.90	0.79
Seaspray	147.190, -38.379	0.076	0.67, 0.15	0.42, 0.91	0.81
Marlo	148.534, -37.802	0.062	0.67, 0.15	0.43, 0.92	0.85
Eastern coastal border	149.975, -37.505	0.052	0.71, 0.15	0.45, 0.96	0.94

Table 6: Summary of locations, Gumbel scale parameter (from storm-tide model), mean and standard deviation of sea-level projections, 5- 95-percentile range of sea-level projections, and sea-level planning allowances, for RCP8.5, years 2010-2099, and all locations. Sea-level rise projections are uncorrected.

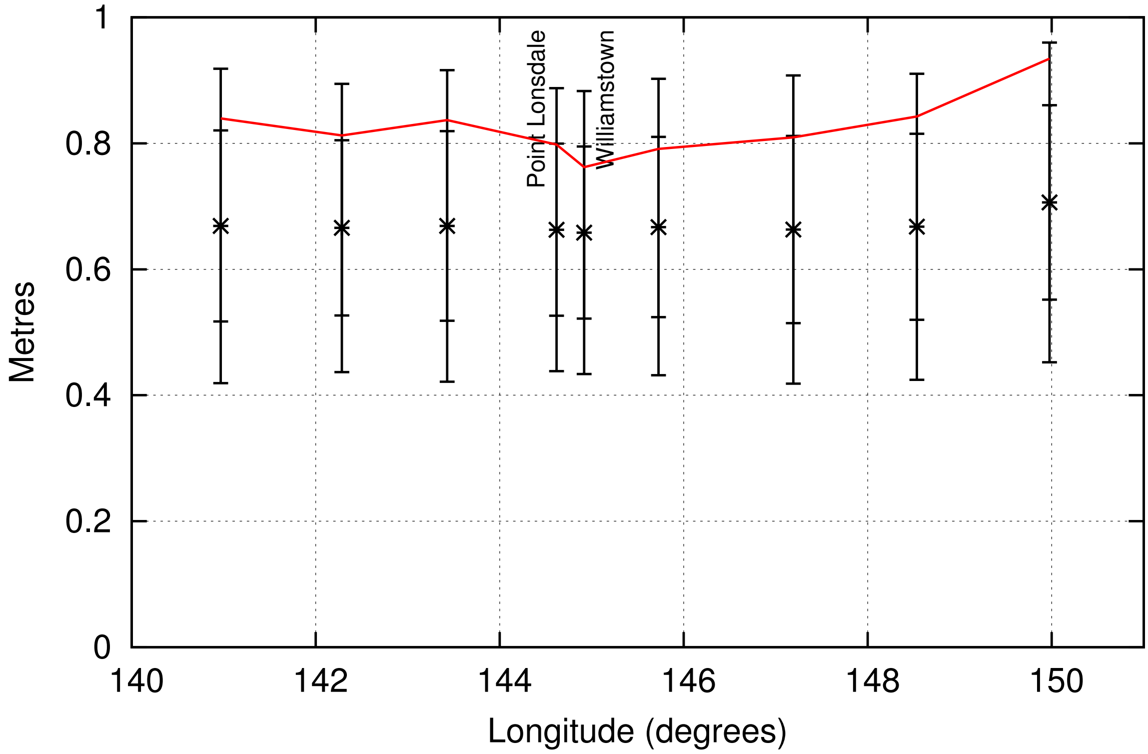

Figure 9: Sea-level projections (black bars; crosses indicating central value, inner range indicating ± one standard deviation, and outer range indicating 5- to 95-percentile limits) and sea-level planning allowance (red curve), for RCP8.5 and years 2010-2099, plotted against longitude for all locations. The allowances were derived using the storm-tide model and corrected sea-level rise projections.

Name	Longitude, Latitude (°)	Gumbel scale parameter, λ (metres)	Projection Δz, σ (metres)	Projection 5,95% (metres)	Allowance (metres)
Western coastal border	140.966, -38.056	0.067	0.67, 0.15	0.42, 0.92	0.84
East of Port Fairy	142.285, -38.364	0.066	0.67, 0.14	0.44, 0.89	0.81
West of Cape Otway	143.428, -38.783	0.067	0.67, 0.15	0.42, 0.92	0.84
Point Lonsdale	144.617, -38.300	0.069	0.66, 0.14	0.44, 0.89	0.80
Williamstown	144.917, -37.867	0.090	0.66, 0.14	0.43, 0.88	0.76
Inverloch	145.725, -38.639	0.082	0.67, 0.14	0.43, 0.90	0.79
Seaspray	147.190, -38.379	0.076	0.66, 0.15	0.42, 0.91	0.81
Marlo	148.534, -37.802	0.062	0.67, 0.15	0.42, 0.91	0.84
Eastern coastal border	149.975, -37.505	0.052	0.71, 0.15	0.45, 0.96	0.93

Table 7: Summary of locations, Gumbel scale parameter (from storm-tide model), mean and standard deviation of sea-level projections, 5- 95-percentile range of sea-level projections, and sea-level planning allowances, for RCP8.5, years 2010-2099, and all locations. Sea-level rise projections are corrected.

6 Glossary of Terms

AR4 Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

AR5 Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

GESLA Global Extremes Sea-Level Analysis database.

GIA Glacial isostatic adjustment (the continuing response of the ocean surface and Earth's crust to the end of the last glaciation).

IPCC Intergovernmental Panel on Climate Change.

RCP Representative Concentration Pathway (prescribed concentrations of greenhouse gases and aerosols that are used to force the climate models described by the IPCC AR5).

Sea-level planning allowance The vertical distance that a coastal entity needs to be raised in order to cope with the projected sea-level rise.

SRES Special Report on Emission Scenarios (Nakicenovic et al, 2000).

Storm tide The combination of tide and storm surge.

TAR Third Assessment Report of the Intergovernmental Panel on Climate Change.

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