Sea-Level Rise Allowances in the PCCSAP Region of the Pacific Ocean

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J. R. Hunter

Antarctic Climate & Ecosystems
Cooperative Research Centre

Private Bag 80, Hobart, Tasmania 7001

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Executive Summary

Allowances have been developed for future sea-level rise in the western Pacific, based on the projections of regional sea-level rise, its uncertainty, and the statistics of tides and storm surges ('storm tides'). An 'allowance' is, in this case, the vertical distance that an asset needs to be raised under a rising sea level, so that the present likelihood of flooding does not increase. This continues the work of Hunter (2012), which presented allowances based on global-average sea level and local storm tides, and Hunter et al (2013) which included regional variations of sea-level rise. This report focuses on the region of interest of the Pacific Climate Change Science and Adaptation Program (PCCSAP) and uses tide-gauge data from the western Pacific locations included in Hunter et al (2013) and additional tide-gauge data for the monitoring locations of the South Pacific Sea Level and Climate Monitoring Project (SPSLCMP, see `http://www.bom.gov.au/pacificsealevel`). The study also employs regional projections of sea-level rise as described by Church et al (2011) and Hunter et al (2013).

Allowances are provided both for 1990-2100 (the conventional period used for the projections of the Intergovernmental Panel on Climate Change (IPCC)), and for 2010-2100, which is a more appropriate period for planning from now for the 21st century. For the period 1990 to 2100 and the A1FI emission scenario, these allowances cover the range 0.63 m to 0.93 m. For comparison, the range of the 95-percentile upper limit of projected sea-level rise for the same period and emission scenario is 0.76 m to 0.87 m.

1 Introduction

A major effect of climate change is a present and continuing increase in sea level, caused mainly by thermal expansion of seawater and the addition of water to the oceans from melted land ice (e.g. Meehl et al, 2007, as reported in the Fourth Assessment Report (AR4) of the IPCC). Over the last two decades, the rate of global-average sea-level rise was about 3.2 mm yr^{-1} (Church and White, 2011). At the time of AR4 in 2007, sea level was projected to rise at a maximum rate of about 10 mm yr^{-1} and to a maximum level of about 0.8 m (relative to 1990) by the last decade of the 21st century, in the absence of significant mitigation of greenhouse-gas emissions (Meehl et al, 2007: Table 10.7, including 'scaled-up ice sheet discharge').

Sea-level rise, like the change of many other climate variables, will be expressed mainly as an increase in the frequency or likelihood (probability) of extreme events, rather than simply as a steady increase in an otherwise constant state. One of the most obvious adaptations to sea-level rise is to raise an asset (or its protection) by an amount that is sufficient to achieve a required level of precaution. The selection of such an allowance has often, unfortunately, been quite subjective and qualitative, involving concepts such as 'plausible' or 'high-end' projections. Hunter (2012) described a simple technique for estimating an allowance for sea-level rise using extreme-value theory. This allowance ensures that the expected, or average, number of extreme (flooding) events in a given period is preserved. In other words, any asset raised by this allowance would experience the same frequency of flooding 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.

Under conditions of uncertain sea-level rise, the 'expected number of flooding events in a given period' is here defined in the following way. It is supposed that there are n possible futures, each with a probability, P_i, of being realised. For each of these futures, the expected number of flooding events in a given period is given by N_i. The effective, or overall, expected number of flooding events (considering all possible futures) is then considered to be $\sum_{i=1}^{n} P_i N_i$.

In the terminology of risk assessment (e.g. ISO, 2009), the expected number of flooding events in a given period is known as the *likelihood*. If a specific cost may be attributed to one flooding 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 flooding 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 flooding 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 flooding 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 scale parameter of the Gumbel distribution; see Section 2). In other words, the statistics of tides and storm surges ('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 distribution function 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.

Hunter (2012) combined the Gumbel scale parameters derived from 198 tide-gauge records in the *GESLA* (Global Extremes Sea-Level Analysis) database (see Menéndez and Woodworth, 2010) with projections of global-average sea-level rise, in order to derive estimates of the allowance around much of the world's coastlines. The spatial variation of this allowance therefore depended only on variations of the Gumbel scale parameter. Hunter et al (2013) derived improved estimates of the allowance using the same *GESLA* tide-gauge records, but spatially-varying projections of sea level from the IPCC AR4 (Meehl et al, 2007) with enhancements to account for glacial isostatic adjustment (GIA), and ongoing changes in the Earth's loading and gravitational field (Church et al, 2011).

This work focuses on the western Pacific and includes the GESLA data used by Hunter (2012) and additional tide-gauge data (from both GESLA and the Australian National Centre (NTC)) for the monitoring locations of the South Pacific Sea Level and Climate Monitoring Project (SPSLCMP, see `http://www.bom.gov.au/pacificsealevel`).

Both Hunter et al (2013) and the work described here used projections for the A1FI emission scenario (which the world is broadly following at present; Le Quéré et al, 2009).

2 Theory

Extremes are generally described by *exceedance events* which are events which occur when some variable exceeds a given level. Two statistics are conventionally used to describe the likelihood of extreme events such as flooding from the ocean. These are the *average recurrence interval* (or *ARI*), R, and the *exceedance probability*, E, for a given period, T. The ARI is the average period between extreme events (observed over a long period with many events), while the exceedance probability is the probability of at least one exceedance event happening during the period T. Exceedance distributions are often expressed in terms of the *cumulative distribution function*, F, where $F = 1 - E$. F is just the probability that there will be *no* exceedances during the prescribed period, T. These statistics are related by (e.g. Pugh, 1996):

$$F = 1 - E = \exp\left(-\frac{T}{R}\right) = \exp(-N) \tag{1}$$

where N is the expected, or average, number of exceedances during the period T.

Eq. 1 involves the assumption (made throughout this paper) that exceedance events are independent; their occurrence therefore follows a Poisson distribution. This requires a further assumption about the relevant time scale of an event. If multiple closely-spaced events have a single cause (e.g. flooding events caused by one particular storm), they are generally combined into a single event using a declustering algorithm.

The occurrence of sea-level extremes, and therefore the ARI and the exceedance probability, will be modified by sea-level rise, the future of which has considerable uncertainty. For example, the projected sea-level rise for 2090-2099 relative to 1980-1999, for the A1FI emission scenario (which the world is broadly following at present; Le Quéré et al, 2009), is 0.50±0.26 m (5%-95% range, including scaled-up ice sheet discharge; Meehl et al, 2007), the range being larger than the central value.

The expected number of exceedances above a given level and over a given period may, in general, be described by:

$$N = \mathcal{N}\left(\frac{\mu - z_P}{\lambda}\right) \tag{2}$$

where $\mathcal{N}$ is some general dimensionless function, z_P is the physical height (e.g. the height of a critical part of the asset), μ is a 'location parameter' and λ is a 'scale parameter'. As noted in Section 1, it is assumed that there is no change in the variability of the extremes, which implies that the scale parameter, λ, does not change with a rise in sea level.

Mean sea level is now raised by an amount $\Delta z + z'$, where Δz is the central value of the estimated rise and z' is a random variable with zero mean and a distribution function, $P(z')$, to be chosen below. On average, this effectively increases the location parameter, μ, by $\Delta z + z'$. At the same time, the asset is raised by an allowance, a, so that it is now located at a height $z_P + a$. Under these conditions of (uncertain) sea-level rise and raising of the asset, the overall (or effective) expected number, N_{ov}, of exceedances ($> z_P + a$) during the period T, becomes:

$$N_{ov} = \int_{-\infty}^{\infty} P(z')\mathcal{N}\left(\frac{\mu - z_P + \Delta z + z' - a}{\lambda}\right) dz' \tag{3}$$

The function, $\mathcal{N}$, is often well-fitted by a *generalised extreme-value distribution (GEV)*. The simplest of these, the *Gumbel* distribution, fits most sea-level extremes quite well (e.g. van den Brink and Können, 2011). The Gumbel distribution may be expressed as (e.g. Coles, 2001, p. 47):

$$F = \exp\left(-\exp\left(\frac{\mu - z_P}{\lambda}\right)\right) \tag{4}$$

where F is the probability that there will be no exceedances $> z_P$ during the prescribed period, T.

From Eqs. 1, 2 and 4:

$$N = \mathcal{N}\left(\frac{\mu - z_P}{\lambda}\right) = \exp\left(\frac{\mu - z_P}{\lambda}\right) \tag{5}$$

μ is therefore the value of z_P for which $N = 1$ during the period T, and λ, the 'scale parameter', is an e-folding distance in the vertical. Globally, the scale parameter has a quite narrow range; for the global GESLA sea-level records (Section 4), the 5-percentile, median and 95-percentile values of the scale parameter are 0.05 m, 0.12 m and 0.19 m, respectively (Hunter et al, 2013).

Again, as noted in Section 1, it is assumed that the scale parameter, λ, does not change with a rise in sea level. Also, as noted by Hunter et al (2013), Equation 5 is only valid over the restricted range of z_P that encompasses the high extreme values.

Equation 3 therefore becomes (Hunter, 2012):

$$\begin{aligned} N_{ov} &= \int_{-\infty}^{\infty} P(z') \exp\left(\frac{\mu - z_P + \Delta z + z' - a}{\lambda}\right) dz' \\ &= N \exp\left(\left(\Delta z + \lambda \ln\left(\int_{-\infty}^{\infty} P(z') \exp\left(\frac{z'}{\lambda}\right) dz'\right) - a\right) \Big/ \lambda\right) \end{aligned} \tag{6}$$

In order to preserve the expected number of exceedances (or flooding events), we require that $N_{ov} = N$. Therefore, the allowance, a, is equal to the term $\Delta z + \lambda \ln(\cdots)$ in the last part of Eq. 6. This allowance is composed of two parts: the mean sea-level rise, Δz, and the term $\lambda \ln(\cdots)$, which arises from the uncertainty in future sea-level rise. Hunter (2012) evaluated the allowance for three types of uncertainty distribution for future sea-level rise: a normal distribution, a boxcar (uniform) distribution and a raised cosine distribution. The resulting allowances may all be expressed as simple analytical expressions, involving the Gumbel scale parameter, λ, the central value of the estimated rise, Δz, and its standard deviation, σ. Hunter et al (2013) estimated the allowances using normal and raised cosine distributions, the former having fatter tails and therefore yielding higher allowances (the raised-cosine distribution falls to zero at a finite distance from the central value, the total range of the distribution being about 1.7 times the 5- to 95-percentile range). However, the differences between the allowances derived from these two different distributions were small (typically, less than 0.05 m). Therefore, only the normal distribution is used here, giving a slightly larger, and therefore more conservative, allowance. The normal distribution was fitted to the 5- and 95-percentile range of the IPCC AR4 projections of sea-level rise, with the central value, Δz, being the mean of the 5- and 95-percentile values.

3 Projections of Regional Sea-Level Rise

Projections of the future climate are based on models driven by plausible scenarios for the emissions of greenhouse gases. In the case of the IPCC AR4 and the projections to be described in this Section, emissions were based on the Special Report on Emission Scenarios (SRES; Nakicenovic et al, 2000).

The derivation of the projections of regional sea-level rise followed Church et al (2011) and Slangen et al (2012), and was described in detail by Hunter et al (2013, Appendix A). The resultant projections are composed of terms due to:

1. the global-average sea-level rise (including 'scaled-up ice sheet discharge' (Meehl et al, 2007),
2. spatially-varying 'fingerprints' to account for changes in the loading of the Earth and in the gravitational field, in response to ongoing changes in land ice (Mitrovica et al, 2001, 2011),
3. spatially-varying sea-level change due to change in ocean density and dynamics (e.g. Meehl et al, 2007, Section 10.6.2 and Figure 10.32), and
4. glacial isostatic adjustment (GIA; Kendall et al, 2005). GIA is the result of changes in the Earth's loading and gravitational field caused by past changes in land ice (predominantly, the most recent deglaciation from about 20,000 years ago).

Figure 1 shows an example of the regional projections of sea-level change from 1990 to 2090, for the A1B emission scenario (after Church et al 2011).

The spatially-varying sea-level rise related to change in ocean density and dynamics (term (3), above) is provided by atmosphere-ocean general circulation models (AOGCMs). While global-average sea-level rise has been reported for six emission scenarios (B1, B2, A1B, A1T, A2, A1FI; Meehl et al, 2007), results from AOGCMs are only available for scenarios B1, A1B and A2. For estimating spatially-varying projections for A1FI, the central values and uncertainties derived from combining terms (1) to (4), above, were scaled using ratios of the global-average projections for A1FI and A2.

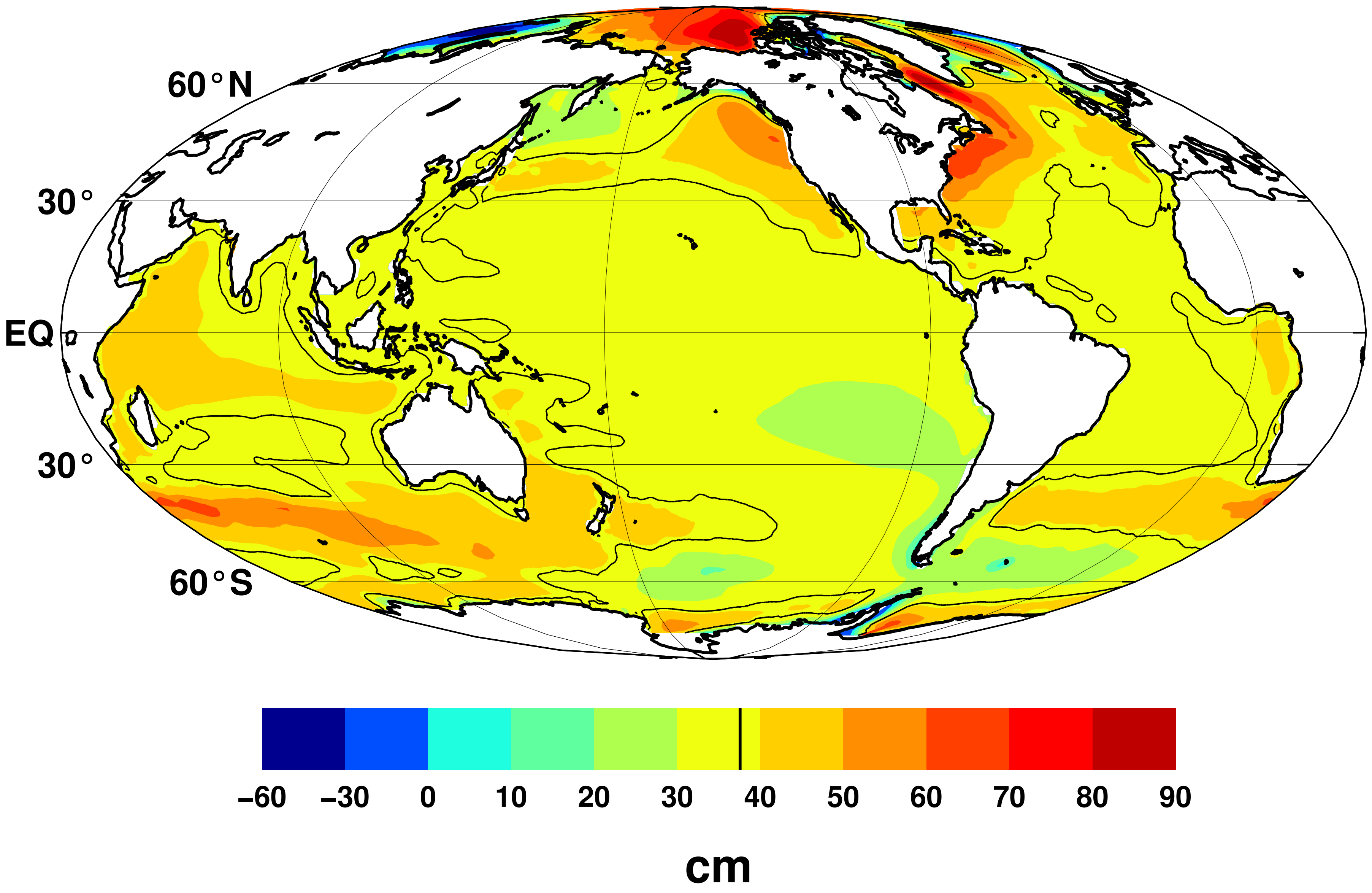

Figure 1: **The regional distribution of the projections of sea-level change from 1990 to 2090, for the A1B emission scenario.** This was obtained by combining global average sea-level rise, a spatially-varying component due to changes in ocean density and dynamics, and regional components associated with the changing distribution of land ice. The black contour and the black bar on the key indicate the global-average change (0.38 m), dividing those regions with above- and below-average sea-level rise. After Church et al 2011.

4 Statistics of Storm Tides

The scale parameter, λ, was estimated from three groups of sea-level data:

1. **A subset from the *GESLA* (Global Extreme Sea-Level Analysis) sea-level database:** This data has been collected through a collaborative activity of the Antarctic Climate & Ecosystems Cooperative Research Centre, Australia, and the National Oceanography Centre Liverpool (NOCL), UK. The data covers a large portion of the world and is sampled at least hourly (except where there are data gaps). The database was downloaded from NOCL on 26 October 2010 and contains 675 files. However, many of these files are near-duplicates provided by different agencies. Many are also as short as one or two years and are therefore not suitable for the analysis of extremes. Hunter (2012) performed initial data processing, resulting in 198 tidal records, each of which was at least 30 years long. For further information on the GESLA database, see Menéndez and Woodworth (2010).
2. **A further subset of shorter records from the*GESLA* sea-level database:** Additional records were extracted from the GESLA database for the sites of the tide gauges of the South Pacific Sea Level and Climate Monitoring Project (SPSLCMP). These records were between 15 and 30 years long (any shorter records being deemed inappropriate for the estimation of storm-tide statistics).
3. **Data collected by SPSLCMP:** Hourly sea-level data were downloaded from `www.bom.gov.au/oceanography/projects/spslcmp/data` on 4 June 2012.

Only data within the region of interest of the Pacific Climate Change Science and Adaptation Program (PCCSAP; 120° East to 150° West, and 25° South to 20° North) were included.

Table 1 shows the sources of tide-gauge data used in this study. For locations where there were data from both GESLA and SPSLCMP, the records were not combined but treated separately, each yielding one estimate of the Gumble scale parameter and of the allowance. This obviated the need to address (unknown) differences in the vertical datums between records at the same location. In the final step in the analysis, the average allowance at each location was calculated (Section 5).

Prior to extremes analysis, the data were ‘binned’, so as to produce files with a minimum sampling interval of one hour, and detrended. Annual maxima were estimated using a declustering algorithm such that any extreme events closer than 3 days were counted as a single event, and any gaps in time were removed from the record. These annual maxima were then fitted to a Gumbel distribution using the *ismev* package (Coles 2001, p. 48) implemented in the statistical language *R* (R Development Core Team 2008). This yielded the scale parameter, λ, for each record. It is assumed that λ does not change in time.

5 Regional Allowances

An alternative ‘allowance’ for sea-level rise is often based simply on the 95-percentile upper limit of one of the projections. Figure 2 shows the regional variation in the 95-percentile

Site name	Longitude, Latitude (°)	Source	Time span
Apia	188.24,-13.83	GESLA	1954-1971
		SPSLCMP	1993-2012
Broome	122.22,-18.00	GESLA	1966-2005
Bundaberg	152.38,-24.77	GESLA	1966-2004
Darwin	130.85,-12.47	GESLA	1959-2004
Guam	144.65,13.43	GESLA	1948-2005
Hilo	204.93,19.73	GESLA	1927-2005
Honiara	159.96,-9.43	GESLA	1974-1995
		SPSLCMP	1994-2012
Johnston	190.47,16.74	GESLA	1947-2003
Kiribati	172.93,1.37	SPSLCMP	1993-2012
Kwajalein	167.73,8.73	GESLA	1946-2005
Lautoka	177.44,-17.60	SPSLCMP	1992-2012
Majuro	171.37,7.11	GESLA	1968-2006
		SPSLCMP	1993-2012
Malakal	134.48,7.33	GESLA	1926-2003
Manus	147.37,-2.04	SPSLCMP	1994-2012
Nauru	166.91,-0.53	GESLA	1974-1995
		SPSLCMP	1993-2012
Noumea	166.44,-22.29	GESLA	1967-2003
Pago Pago	189.32,-14.28	GESLA	1948-2005
Pohnpei	158.24,6.99	GESLA	1974-2004
Rarotonga	200.22,-21.20	GESLA	1977-2001
		SPSLCMP	1993-2012
Suva	178.43,-18.13	GESLA	1972-1997
		SPSLCMP	1997-2012
Tonga	184.82,-21.14	SPSLCMP	1993-2012
Townsville	146.83,-19.25	GESLA	1959-2004
Truk	151.85,7.45	GESLA	1963-1995
Tuvalu	179.20,-8.50	GESLA	1977-1999
		SPSLCMP	1993-2012
Vanuatu	168.31,-17.76	SPSLCMP	1993-2012
Wake	166.62,19.28	GESLA	1950-2004
Wyndham	128.10,-15.45	GESLA	1966-2004
Yap	138.13,9.51	GESLA	1969-2004

Table 1: Sources of tide-gauge data used in this study.

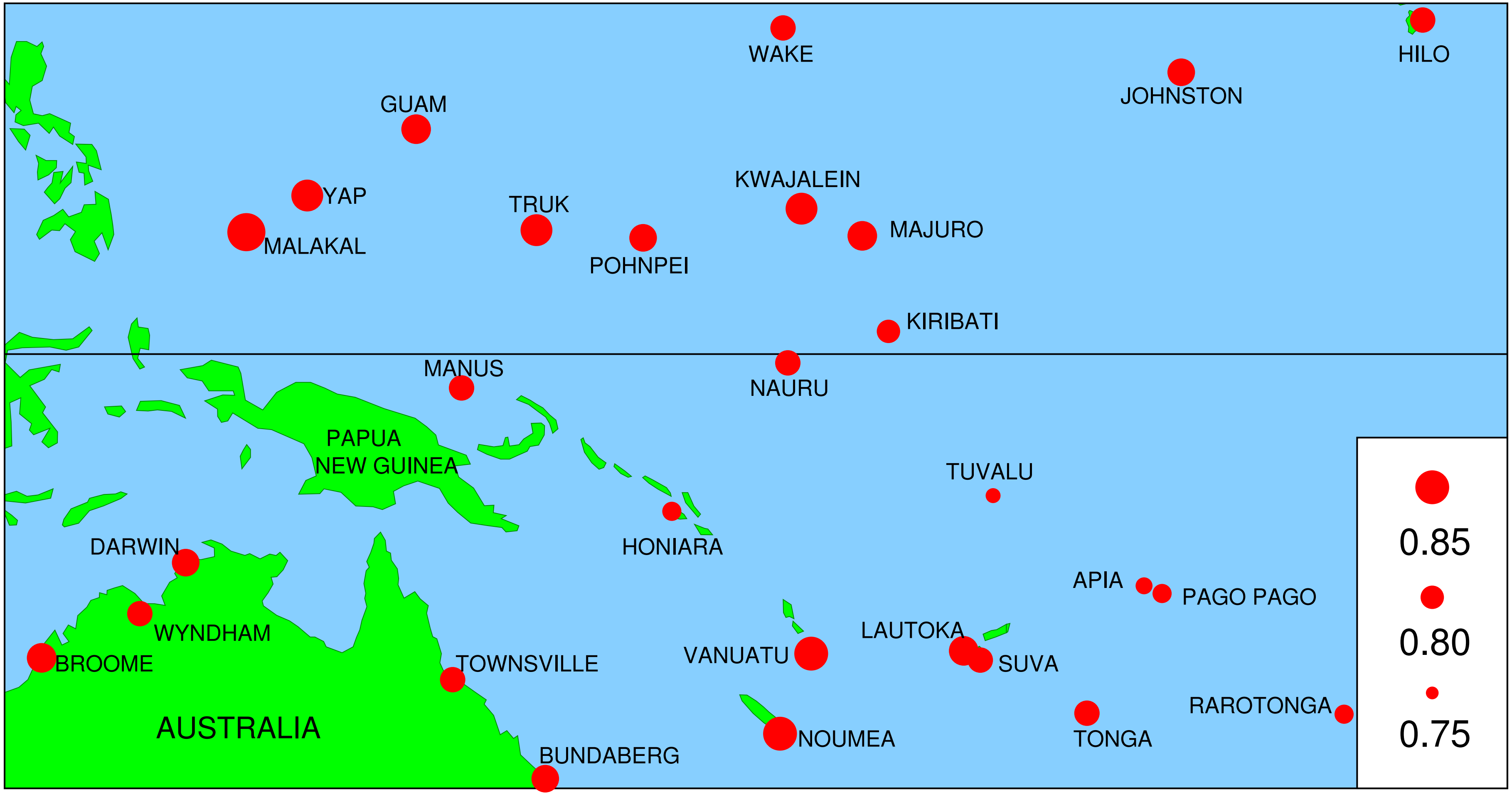

Figure 2: **Upper limit of projected sea-level rise.** The 95-percentile upper limit for the projected sea-level rise from 1990 to 2100 (m, indicated by dot diameter), based on the A1FI emission scenario.

upper limit for the projected sea-level rise from 1990 to 2100, based on the A1FI emission scenario and derived in the way described in Section 3. This shows relatively small regional variations which are broadly in line with Figure 1 (although for a different emission scenario, A1B); for example, a weak overall decrease towards the east.

Figure 3 shows the cumulative distribution function for 95-percentile upper and 5-percentile lower limits for the projected sea-level rise from 1990 to 2100, based on the A1FI emission scenario, for the locations shown in Figure 2. As indicated by Figure 1, the regional projections in this area are similar to the global-average projections (also shown in Figure 3). The range of the regional projections is slightly larger than the range of the global-average projections because of additional uncertainty inherent in modelling the regional variations.

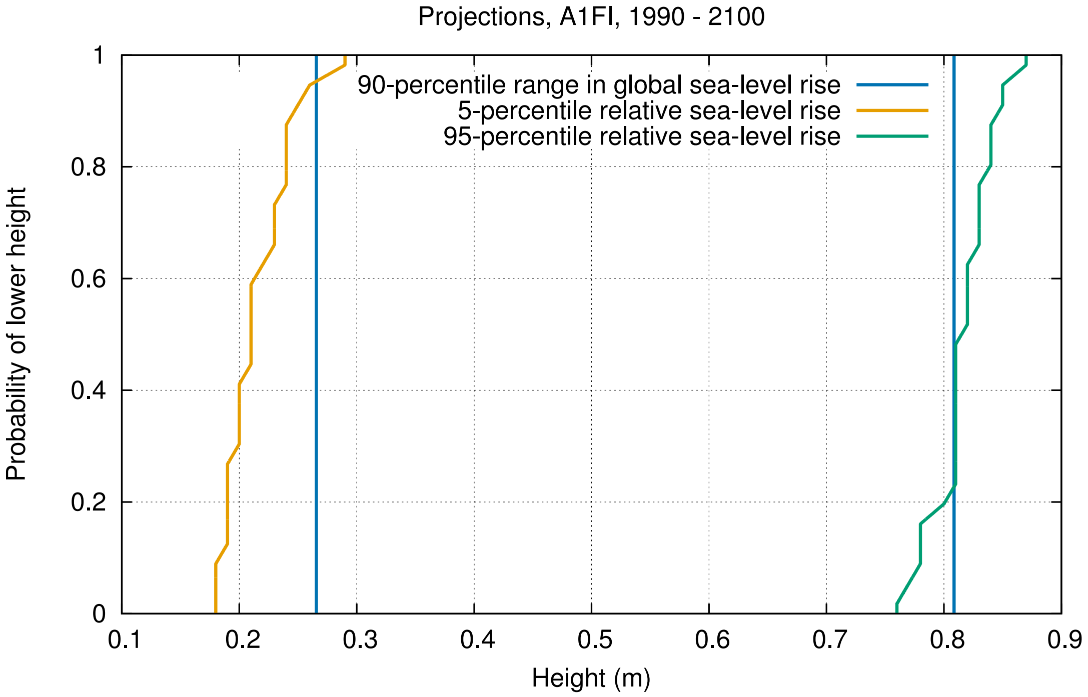

Figure 3: **Upper and lower limits of projected sea-level rise.** Cumulative distribution function for 95-percentile upper and 5-percentile lower limits for the projected sea-level rise from 1990 to 2100, based on the A1FI emission scenario, for locations shown in Figure 2. Also shown (vertical blue lines) are the 95-percentile upper and 5-percentile lower limits of global-average sea-level rise for the same period and emission scenario.

Figure 4 shows the sea-level rise allowance (calculated according to Section 2) for the period 1990 to 2100, based on the A1FI emission scenario and determined as described in Sections 2 to 4. Where there was more than one tide-gauge record at a given location, the average allowance at that location was calculated (see Section 4). Figure 5 shows the cumulative distribution function of this allowance and of the 95-percentile upper limit of the sea-level rise projections for the same period, emission scenario and locations (also shown in Figure 2). The allowances cover a wider range than the 95-percentile upper limit of sea-level rise, in part because of the additional variability introduced by the regional variation in storm tides (through the term $\lambda \ln(\cdots)$ in Equation 6).

The results for each location are summarised in Table 2, which shows the 5-and 95-percentile ranges of projections of mean sea-level rise, and allowances, for the periods

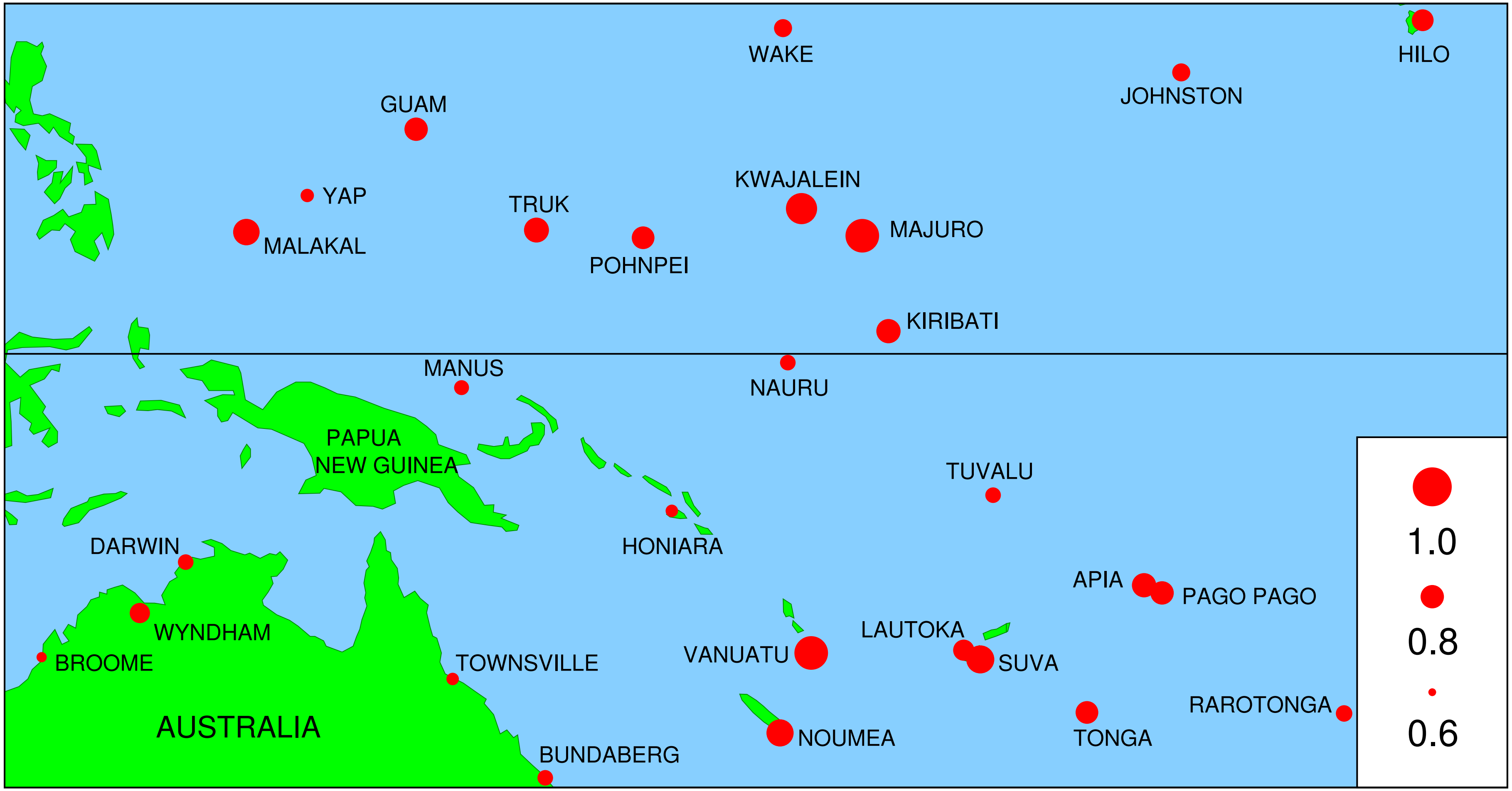

Figure 4: **Allowance for sea-level rise.** Vertical allowance (m) for sea-level rise from 1990 to 2100 for the A1FI emission scenario, indicated by the dot diameter.

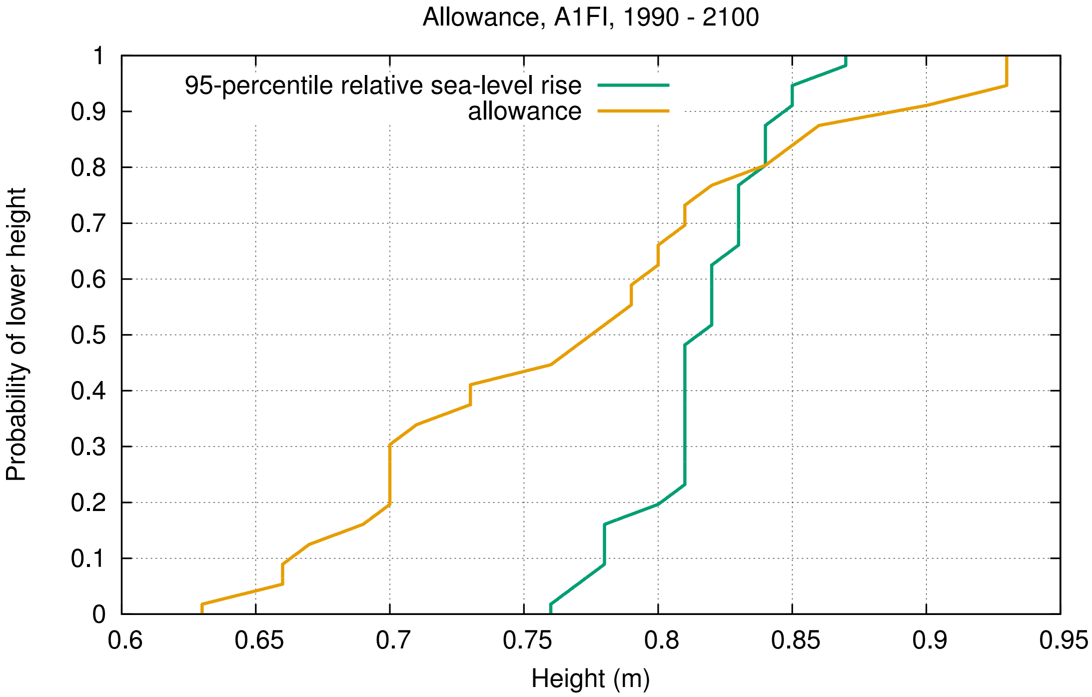

Figure 5: **Allowance for sea-level rise.** Cumulative distribution function for vertical allowance (m) for sea-level rise from 1990 to 2100 for the A1FI emission scenario, for locations shown in Figure 4. Also shown is the 95-percentile upper limit of sea-level rise for the same period, emission scenario and locations.

1990-2100 and 2010-2100, for the A1FI emission scenario. The results for 2010-2100 are more appropriate for present-day planning and policy decisions.

6 Conclusion

Vertical allowances for future sea-level rise have been derived for the 'PCCSAP region' in the western Pacific (120° East to 150° West, and 25° South to 20° North). These allowances are based on regional-varying sea-level rise and its uncertainty, and on the regionally-varying statistics of storm tides (specifically, the scale parameter of the Gumbel distribution). For the period 1990 to 2100 and the A1FI emission scenario, these allowances cover the range 0.63 m to 0.93 m. For comparison, the range of the 95-percentile upper limit of projected sea-level rise for the same period and emission scenario is 0.76 m to 0.87 m.

The following caveats to these results should be recognised:

1. The determination of allowances given in this paper are based on the assumption that the Gumbel scale parameter (and hence the variability of the storm tides) will not change in time. This is supported by the fact that present evidence (Bindoff et al 2007, 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 extreme 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 flooding events was dominated by sea-level rise.

2. The allowance includes no contribution due to possible changes in wave setup or runup.

3. The allowance depends on the shape of the distribution of the uncertainty of the projections of mean sea-level rise. For the present work, a normal distribution of uncertainty has been assumed, although Hunter et al (2013) considered the possibility of the uncertainty distribution having fatter tails than a normal distribution. Unfortunately the IPCC AR4 gives no guidance as to the choice of an appropriate uncertainty distribution, nor any indication of an 'upper bound for sea-level rise' (IPCC, 2007). These allowances therefore represents a practical solution to planning for sea-level rise while preserving an acceptable level of risk, in cases where 'getting the allowance wrong' is manageable. However, in cases where the consequence of flooding would be dire, a precautionary approach is to choose an allowance based on the best estimate of the maximum possible rise.

4. The projections of the IPCC AR4 apparently relate to the *spread* of model projections (akin to the *standard deviation*) rather than to the uncertainty (akin to the *standard error*) of the best estimate of the projections. The metric of uncertainty, σ (see Section 2), strictly relates to the *standard error*. However, for reasons discussed by Hunter (2012), σ is here associated with the *standard deviation* (rather than the *standard error*) of the projections.

Site name	Longitude, Latitude (°)	Projection 1990-2100 5,95% (m)	Projection 2010-2100 5,95% (m)	Allowance 1990-2100 (m)	Allowance 2010-2100 (m)
Apia	188.24,-13.83	0.20,0.77	0.19,0.71	0.81	0.72
Broome	122.22,-18.00	0.18,0.83	0.19,0.74	0.63	0.56
Bundaberg	152.38,-24.77	0.26,0.82	0.25,0.75	0.70	0.63
Darwin	130.85,-12.47	0.21,0.82	0.19,0.75	0.70	0.63
Guam	144.65,13.43	0.25,0.83	0.28,0.72	0.80	0.65
Hilo	204.93,19.73	0.21,0.81	0.24,0.72	0.78	0.65
Honiara	159.96,-9.43	0.21,0.78	0.20,0.72	0.66	0.60
Johnston	190.47,16.74	0.24,0.82	0.27,0.71	0.73	0.61
Kiribati	172.93,1.37	0.23,0.80	0.23,0.73	0.81	0.70
Kwajalein	167.73,8.73	0.19,0.84	0.21,0.74	0.90	0.73
Lautoka	177.44,-17.60	0.21,0.83	0.21,0.76	0.77	0.68
Majuro	171.37,7.11	0.19,0.83	0.22,0.73	0.93	0.74
Malakal	134.48,7.33	0.19,0.87	0.22,0.76	0.84	0.68
Manus	147.37,-2.04	0.24,0.81	0.22,0.75	0.69	0.63
Nauru	166.91,-0.53	0.24,0.81	0.23,0.74	0.70	0.63
Noumea	166.44,-22.29	0.29,0.85	0.31,0.75	0.85	0.71
Pago Pago	189.32,-14.28	0.20,0.78	0.19,0.70	0.80	0.70
Pohnpei	158.24,6.99	0.21,0.82	0.23,0.73	0.79	0.66
Rarotonga	200.22,-21.20	0.19,0.78	0.22,0.69	0.71	0.59
Suva	178.43,-18.13	0.20,0.81	0.24,0.72	0.86	0.71
Tonga	184.82,-21.14	0.22,0.81	0.27,0.70	0.79	0.63
Townsville	146.83,-19.25	0.24,0.81	0.24,0.74	0.66	0.59
Truk	151.85,7.45	0.20,0.84	0.23,0.74	0.82	0.67
Tuvalu	179.20,-8.50	0.18,0.76	0.19,0.68	0.70	0.61
Vanuatu	168.31,-17.76	0.23,0.85	0.27,0.76	0.93	0.77
Wake	166.62,19.28	0.19,0.81	0.24,0.70	0.73	0.60
Wyndham	128.10,-15.45	0.18,0.81	0.16,0.74	0.76	0.68
Yap	138.13,9.51	0.23,0.84	0.24,0.75	0.67	0.59

Table 2: Summary of locations, 5- to 95-percentile ranges of projections of mean sea-level rise, and allowances, for the periods 1990-2100 and 2010-2100, and for the A1FI emission scenario.

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