
Chatham Islands Climate Change



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Brett Mullan
Jim Salinger
Craig Thompson
Doug Ramsay
Michelle Wild

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National Institute of Water & Atmospheric Research Ltd

301 Evans Bay Parade, Greta Point, Wellington
Private Bag 14901, Kilbirnie, Wellington, New Zealand
Phone +64-4-386 0300, Fax +64-4-386 0574
www.niwa.co.nz

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Reviewed by:

Approved for release by:

Dr David Wratt

Dr Murray Poulter

Executive Summary

Purpose of this report

This brief report provides guidance on climate change specific to the Chatham Islands, to complement the information recently produced for local government by the Ministry for the Environment in “Climate Change Effects and Impacts Assessment: A guidance manual for Local Government in New Zealand” (MfE, 2004a) and “Coastal Hazards and Climate Change: A guidance manual for Local Government in New Zealand” (MfE, 2004b). These previous reports contain a lot of generic information on climate change, and how to assess associated risks, that is relevant to the Chatham Islands Council.

The future is uncertain: how do we plan for it?

- There is convincing evidence that the global climate is changing. However, there are many uncertainties in predicting the size and effect of future climate changes. This is especially the case when it comes to pinpointing what might happen in a specific place, such as the Chatham Islands.
- Faced with the need to plan for climate change, the most pragmatic approach is to look for a plausible range of what might happen. Councils might look at a best case (where global warming is at the low end of what could happen), a worst case (where global warming is at the high end), and a mid-range scenario.

Key findings

- The Chatham Islands is already experiencing climate change. Annual mean temperature has increased by about 1.0°C at the Chatham Islands over the past 100 years, and annual rainfall has increased by about 10%. 1998 was the warmest year on record.
- The mid-range scenario for temperature change at the Chatham Islands suggests a warming rate of about 0.2°C/decade through the 21st century. This is double the average rate of warming observed during the 20th century.
- The full range of warming at 2100 for the Chathams is from about +0.5 to +3.9°C, relative to the 1990 baseline (approximately the 1971-2000 normal) adopted by the Intergovernmental Panel on Climate Change (IPCC).
- The Chatham Islands is likely to experience stronger westerly winds and increased annual rainfall by the end of the 21st century.

- There is likely to be an increase in extreme rainfalls at the Chathams through the 21st century as the temperature increases. What is an extreme rainfall in the current climate is likely to occur about twice as often by the end of the 21st century under a mid-range temperature change scenario, and 3 to 4 times as often under a high temperature change scenario.
- There is no clear evidence to indicate whether there will be either an increase or decrease in the size of storm surges in the next 50 years. The highest storm surge experienced in the past 25 years appears to be about 0.55m. (A storm surge is the extra height of sea level above the predicted tide due to storm-generated low pressure, strong winds and breaking waves.)
- It is expected that storm tide elevations will rise at the same rate as mean sea level rise. (A storm tide is the level of the predicted tide plus storm surge.) For planning purposes, it is recommended to use a sea-level rise of 0.2m by 2050 and 0.5m by 2100.
- The Chatham Islands' climate is affected by year to year variations in the state of the El Niño-Southern Oscillation. El Niño periods tend to be cooler and drier than normal, and La Niña periods warmer and wetter. This variability will be superimposed on top of the climate change trends. It is not yet possible to say how El Niño events might change in their frequency or severity under global warming.

1. Introduction

1.1 Background to Chatham Islands Study

Human activity is increasing the concentration of greenhouse gases in the atmosphere, and leading to global climate changes (IPCC, 2001). As well as rising temperatures and sea levels, changes in rainfall and atmospheric circulation patterns are to be expected. Scenarios of future climate in New Zealand suggest that there are likely to be increased westerly winds, along with increased rainfall in the west and decreased rainfall in the east of the North and South Islands.

In 2004, the Ministry for the Environment released a guidance manual on New Zealand climate change aimed at helping local government identify and quantify hazards posed by future climate change. This guidance manual came in two parts: a general overview document (MfE, 2004a, hereafter the “Climate Change Guidance Manual”) that covered a wide spectrum of climate change issues and laid out a risk analysis framework, and a second document (MfE, 2004b, hereafter the “Coastal Guidance Manual”) that focussed on coastal and sea level hazards.

Much of the information in these guidance manuals was generic and, being focussed on the New Zealand region, is just as applicable to the Chatham Islands as to the rest of New Zealand. However, there were also scenarios for each regional council area, which showed geographic differences over the country. No location-specific information was provided for the Chatham Islands in these guidance manuals.

This report aims to provide climate change scenario guidance specific to the Chatham Islands. To put the guidance in context, some of the generic comments from MfE (2004a, 2004b) are included as well, although these primary sources should be consulted for further detail. We also take the opportunity to present analyses of long-term rainfall and temperature trends at the Chathams, and recent variability in extreme storm surges, which have not been published previously.

1.2 Climate Change

There are many uncertainties in predicting future climate changes and their effects. The best way to approach this uncertainty, in a pragmatic way, is to present a range of future possibilities. Individual users may choose to focus on a best or worst case, or a mid-range scenario.

There are two main causes for the uncertainties in predicting climate change impacts. The first is that the level of future greenhouse gas emissions depends very much on social and economic development and on political decisions. The second is that, even

for the same greenhouse gas concentration, different global climate models will predict different climate changes at both the global and regional scale. The IPCC addressed these problems by considering a range of scenarios, which span plausible future emissions and incorporate model uncertainty ranges. This approach was followed in the Climate Change Guidance Manual for New Zealand: the IPCC extreme range of global changes was used to scale what changes the models predicted locally for New Zealand.

In the global setting, climate projections developed by the IPCC based on scenario analysis include:

- an increase in globally-averaged surface temperature of 1.4°C to 5.8°C over the period 1990 to 2100. This rate of warming is probably without precedent during at least the last 10,000 years
- both increases and decreases in annual rainfall (depending on location) of typically 5–20% at regional scales during the 21st century
- continued widespread retreat of glaciers throughout the 21st century
- a rise in global mean sea level of 0.09 to 0.88 m between 1990 and 2100
- a range of beneficial and adverse effects on both environmental and socio-economic systems.

1.2.1 Consequences of Climate Change for New Zealand

Local government already addresses many effects of extreme weather events and climate variations in planning and providing services. The Climate Change and Coastal Guidance Manuals are intended to assist people to identify effects of climate change for their area, and to take account of these effects in their planning and decision-making processes. The intent is to help councils get ahead and plan in a proactive way for climate change where necessary, rather than to wait for changes and then react to them. A reactive mode is likely to be more costly and disruptive to communities affected by climate change.

Addressing climate change effects may seem forbiddingly complex for a small council, but the Guidance Manual does not advocate a separate set of processes for dealing with climate change effects and impacts. The issues can be broken down into manageable pieces, and dealt with as part of normal council planning and management activities. The approach for considering climate change effects on a particular council function or asset (e.g. storm water drainage systems) includes the following common-sense steps.

- Consider whether the particular function or service is important to your council and influenced by climate. Don't waste effort on low priority issues.
- Start with an initial "screening" analysis, using simple initial estimates of how climate factors relevant to this function may change, and expert judgement or simple calculations of likely impacts of these changes.
- Only if the screening analysis indicates problems are likely is it necessary to embark on a more detailed study of likely climate change effects on the function or activity, utilising more staff or consultant time.

Despite uncertainties about the magnitude of regional climate changes, certainty is growing as to the direction of expected changes over the coming century. These directions include increasing temperatures over the whole country; annual average rainfall increases in the west of the country and decreases in many eastern areas; reductions in frosts; increasing risk of dry periods or droughts in some eastern areas; increased frequency of heavy rainfall events, and long-term increases in sea level.

Indeed, New Zealand is already experiencing climate changes. These include a trend of increasing temperatures (about 0.7°C during the 20th century), a reduction in frost frequency over much of the country, retreat of South Island glaciers and snowlines and reduction of alpine snow mass, and a trend to rising sea level (estimated at 14–17 cm during the 20th century). Natural fluctuations in climate are also experienced from year to year and decade to decade, such as the changes in rainfall, droughts, sea level and coastal erosion associated with El Niño / La Niña conditions.

In this report, the key science information is contained in section 2 (on historical trends of temperature and rainfall), section 3 (future scenarios for temperature and rainfall), section 4 (storm surge variability and sea level rise), and section 5 (heavy rainfall). Remaining sections provide summaries and discussion of the implications for the Chatham Islands of the potential climate changes.

2. Historical Trends and Patterns in Chatham Islands Climate

Key points:

- During the 20th century, annual mean temperature increased by about 1.0°C at the Chatham Islands, and annual rainfall by about 10%. 1998 was the warmest year on record, as it also was for mainland New Zealand.
- El Niño periods tend to be cooler and drier than normal at the Chatham Islands, and La Niña periods warmer and wetter.

2.1 Trends in Temperature and Rainfall

Climate in the New Zealand region is varying all the time, and that of the Chatham Islands is no exception. This is one of the few parts of New Zealand where climate observations commenced in the 19th century. Temperature and rainfall records began in 1878, with a break during 1915-1938 for temperature and 1915-1917 for rainfall. The records analysed in this report have been adjusted to the current NZ MetService site, 1 km southwest of Waitangi, which opened in 1956. Earlier sites (overlapping in time) were at: Waitangi township 1878-1915, Whangamarino 1912-1929, and Chatham Island radio 1917-1986.

All temperature records show an increase since the 19th century (Fig. 2.1). Mean temperatures have increased by 1.0°C, maximum temperatures by 1.2°C and minimum temperatures by 0.8°C. The coolest runs of years occurred around 1890 and 1900, with the warmest runs of years in the 1980s and around 2000. 1998 was the warmest individual year. The bottom panel of Figure 2.1 shows that the diurnal temperature range (difference between daily minimum and maximum) has also increased.

Despite temperature increases in the latter part of the 20th century, year-to-year variability is quite large. All seasons show increases in mean temperature (Fig. 2.2). The largest rise occurs in summer (+1.3°C) and the least in spring (0.6°C). However, winter shows the most consistent increasing trend (+1.2°C), with a group of very warm years around 2000.

The rainfall record is virtually complete from 1878 (Fig 2.3). From 1878 to about 1940 the climate of the Chatham Islands was drier, with rainfall only 90% of the 1971-2000 normal. Rainfall was then near this normal for the period 1940 to 1990, but has increased by about 10% since 1990 to make this latest period the wettest on record. Summer and autumn rainfall show more variability than other seasons. Summer rainfall (Fig 2.4) increases to a peak of 120% of normal around 1940 before decreasing, then increasing again by the end of the record (2004). Autumn rainfall was only about 80% of the 1971-2000 normal prior to 1950, then increased to 120% of

normal by 1960 and has since decreased slightly to 110% of normal. Winter rainfall (Fig. 2.5) decreased to a minimum of 80% of normal by 1900, and then fluctuated subsequently around normal with a slight increase by the end of the record. Springs were drier prior to 1960, averaging only 90% of normal. Since the 1990s spring rainfall in the Chatham Islands has been 110% of normal.

2.2 Natural Variability

There are two key natural cycles that operate over timescales of years (El Niño-Southern Oscillation, ENSO) and decades (Interdecadal Pacific Oscillation, IPO). Both these natural phenomena are confined largely to the Pacific Ocean, but there is evidence that sea temperature conditions elsewhere, such as in the Indian Ocean, can also affect New Zealand climate at some times of year. ENSO is a tropical Pacific-wide oscillation that affects pressure, winds, sea-surface temperature and precipitation. The El Niño phase produces more southwesterly winds over the New Zealand/Chatham Island area, whilst the La Niña phase results in more northeasterlies.

The status of the ENSO phenomenon is commonly measured by the Southern Oscillation Index (SOI), a measure of how unusual the west-east pressure difference is across the tropical Pacific Ocean. Table 2.1 shows correlations between the SOI and anomalies of temperature and rainfall at the Chatham Islands. Significant positive relationships occur with spring and annual temperature, indicating that La Niña years and springs are warmer than in El Niño. Although there was little association between seasonal values of the SOI and rainfall, higher correlations occurred with annual rainfall. Thus, for the Chatham Islands, La Niña years are wetter and El Niño years drier than average.

The Interdecadal Pacific Oscillation is an “ENSO-like” feature of the climate system that operates on time scales of several decades, and appears to modulate the impacts of interannual ENSO climate variability over New Zealand and the southwest Pacific (Salinger *et al.*, 2001). Three phases of the IPO have identified during the 20th century: a positive phase (1922-1944), a negative phase (1947-1977) and the most recent positive phase (1978-1998). Since 1998, the index used to measure the IPO status has been near zero but otherwise shown little change. Changes between the two phases of the IPO did not give any consistent pattern of change for the Chatham Islands (Table 2.2). Between the first early period (1922-1944) and the second (1947-1977) annual rainfall, and particularly autumn rainfall, increased. The next change to the positive phase in 1978 saw a slight increase in annual rainfall, increases in spring rainfall, but decreases in summer rainfall.

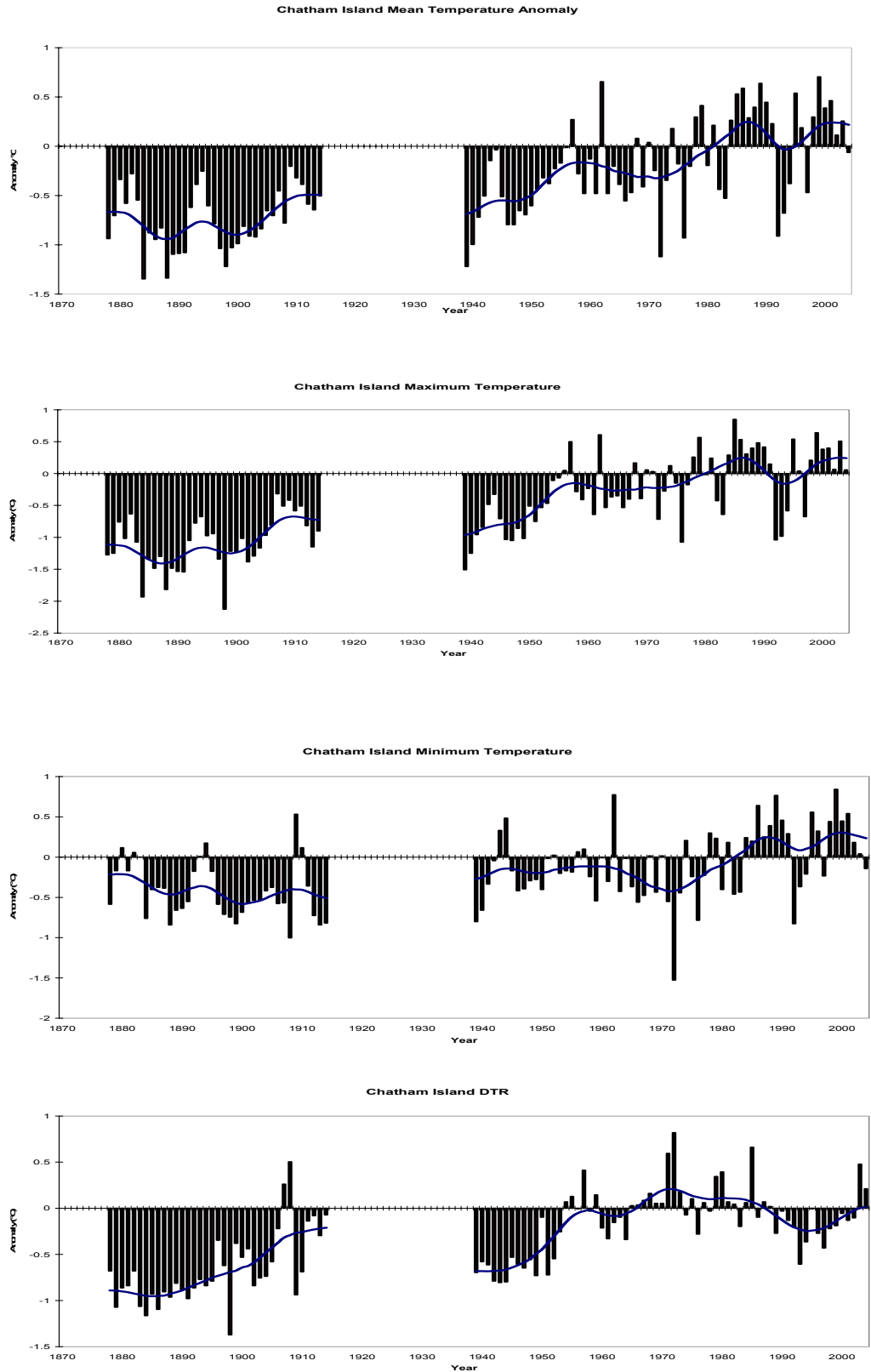


Figure 2.1 Chatham Islands annual mean, maximum and minimum temperature and diurnal temperature range anomalies for the period 1878-2004, shown as deviations in °C from the 1971-2000 normal. The long-term trend (solid line) indicates warming through the period.

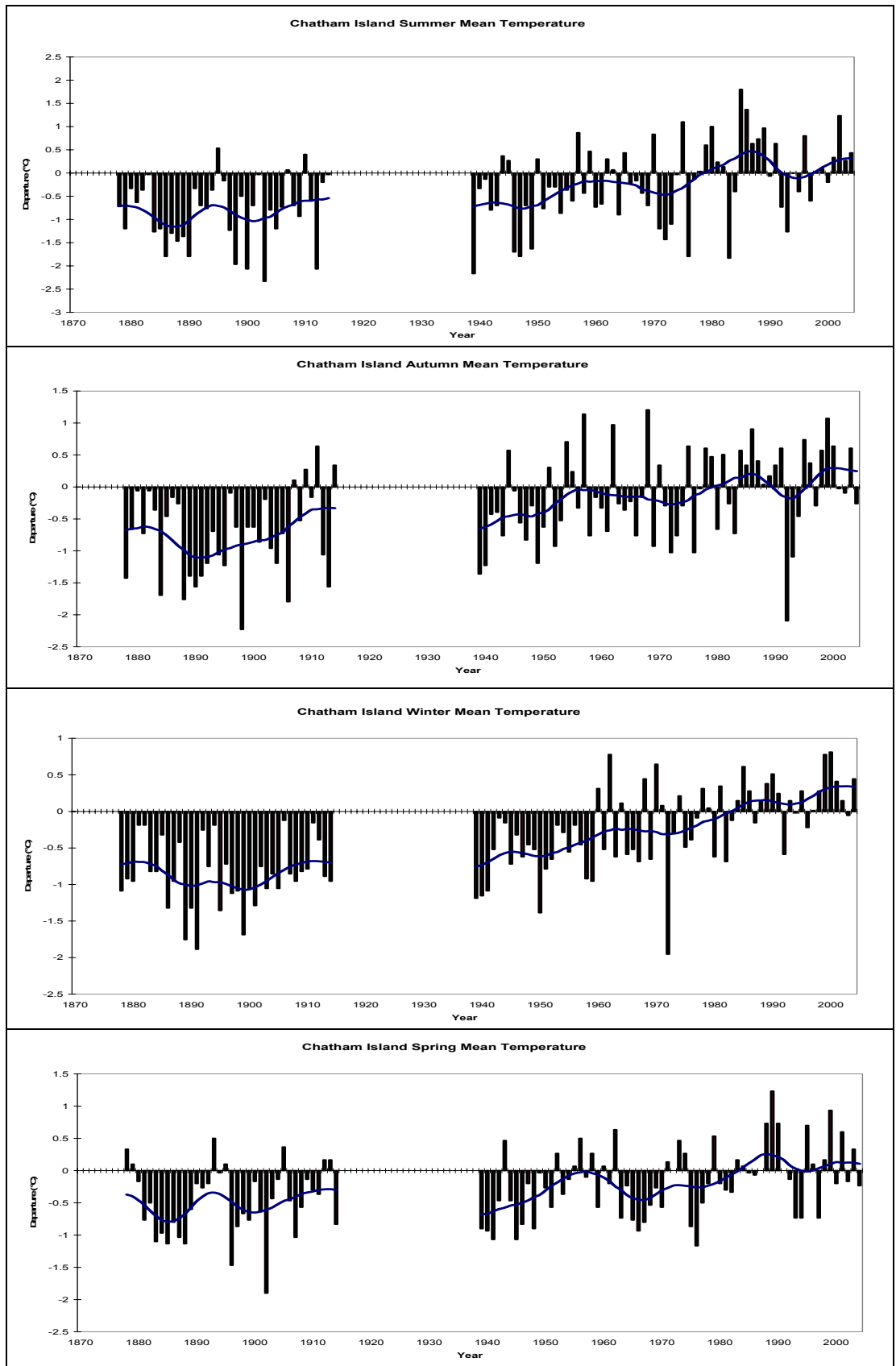


Figure 2.2

Chatham Islands summer, autumn, winter and spring mean temperature anomalies for the period 1878-2004, shown as deviations in °C from the 1971-2000 normal. The long-term trend (solid line) shows all seasons warming.

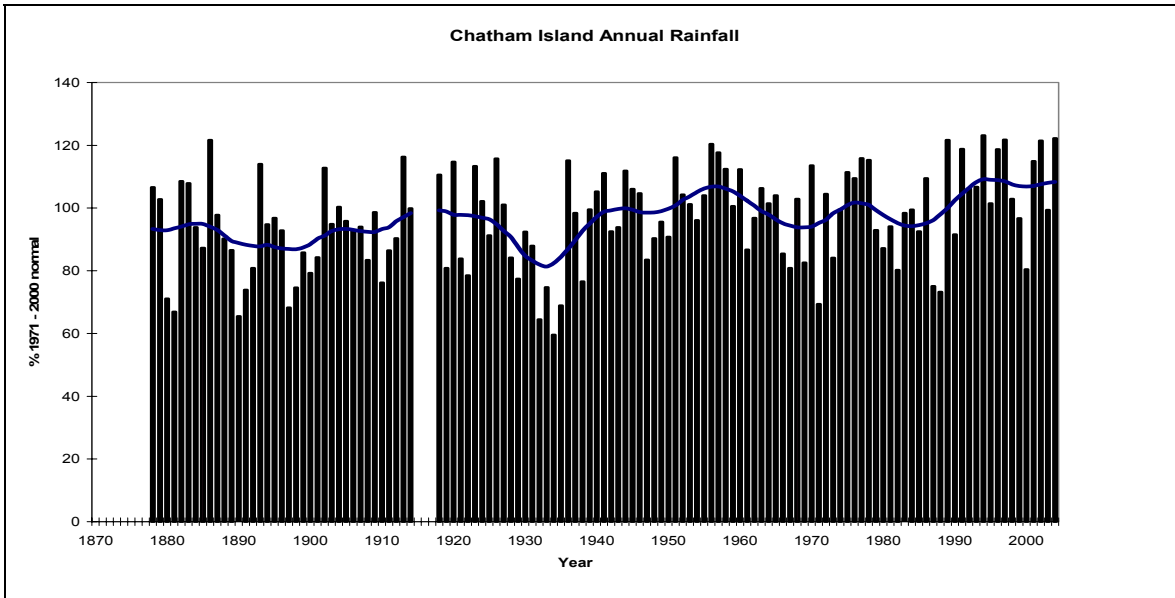


Figure 2.3 Chatham Islands annual rainfall anomalies for the period 1878 – 2004, shown as the percentage of the 1971-2000 normal. The smoothed curve indicates the long-term trend. There is a tendency for rainfall to increase slightly over the period, but with lots of year-to-year variability.

Table 2.1 Correlations between the Southern Oscillation Index (SOI) and either temperature or rainfall over 1878 - 2004. Correlations are shown for each season, and for the year as a whole.

	Summer	Autumn	Winter	Spring	Annual
Temperature	0.12	0.09	0.00	0.33	0.28
Rainfall	0.00	-0.12	0.14	-0.02	0.41

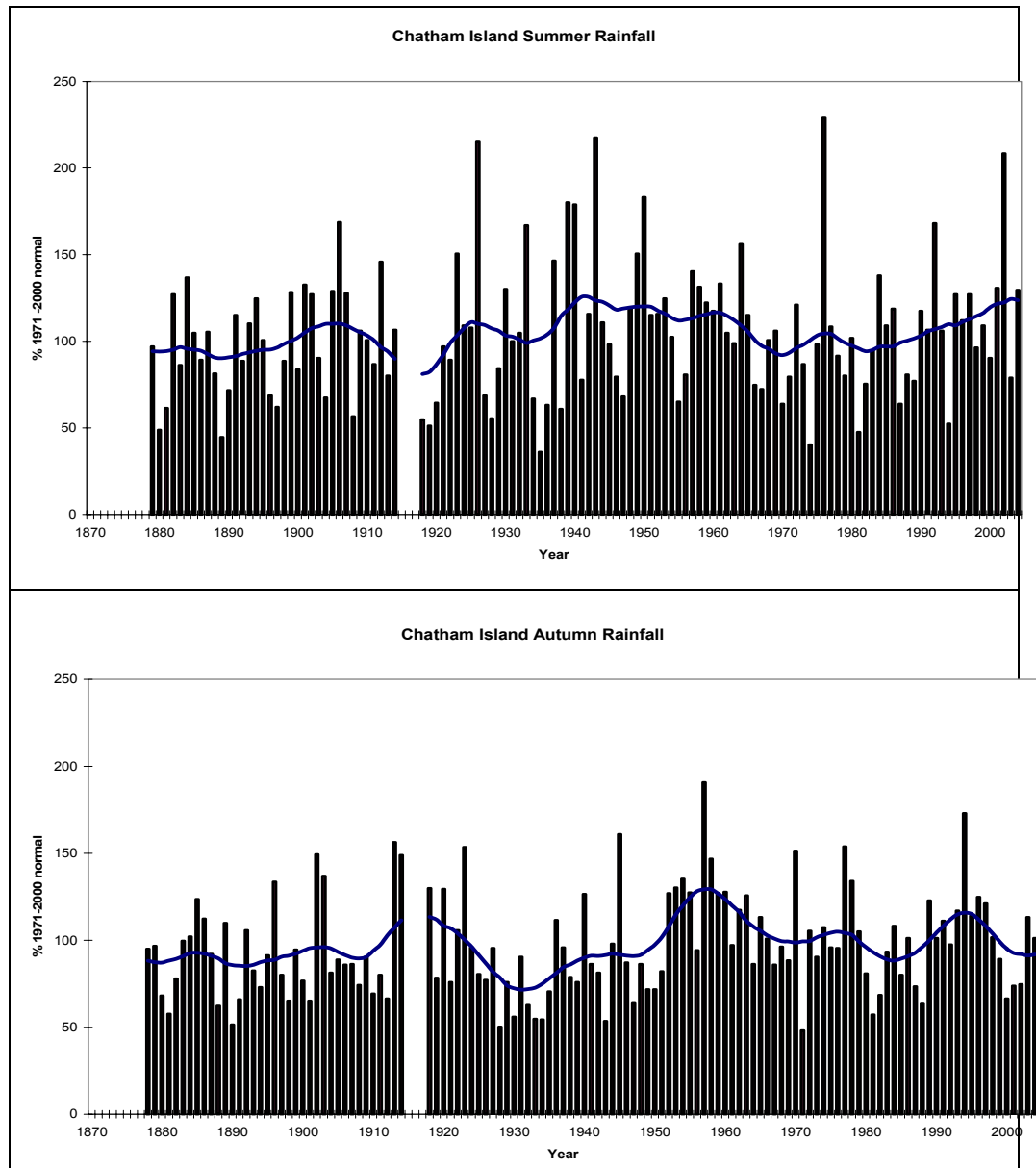


Figure 2.4 Chatham Islands summer and autumn rainfall anomalies for the period 1878 – 2004, shown as the percentage of the 1971-2000 normal. The smoothed curve indicates the long-term trend.

Table 2.2 Percentage change in rainfall between the various phases of the Interdecadal Pacific Oscillation (i) 1922-1944 to 1947-1977 and (ii) 1947-1977 to 1978-1998.

Phase	Annual	Summer	Autumn	Winter	Spring
(i) Pos to Neg	6.4	-3.0	19.1	1.1	5.2
(ii) Neg to Pos	2.7	-15.6	-1.5	6.6	12.7

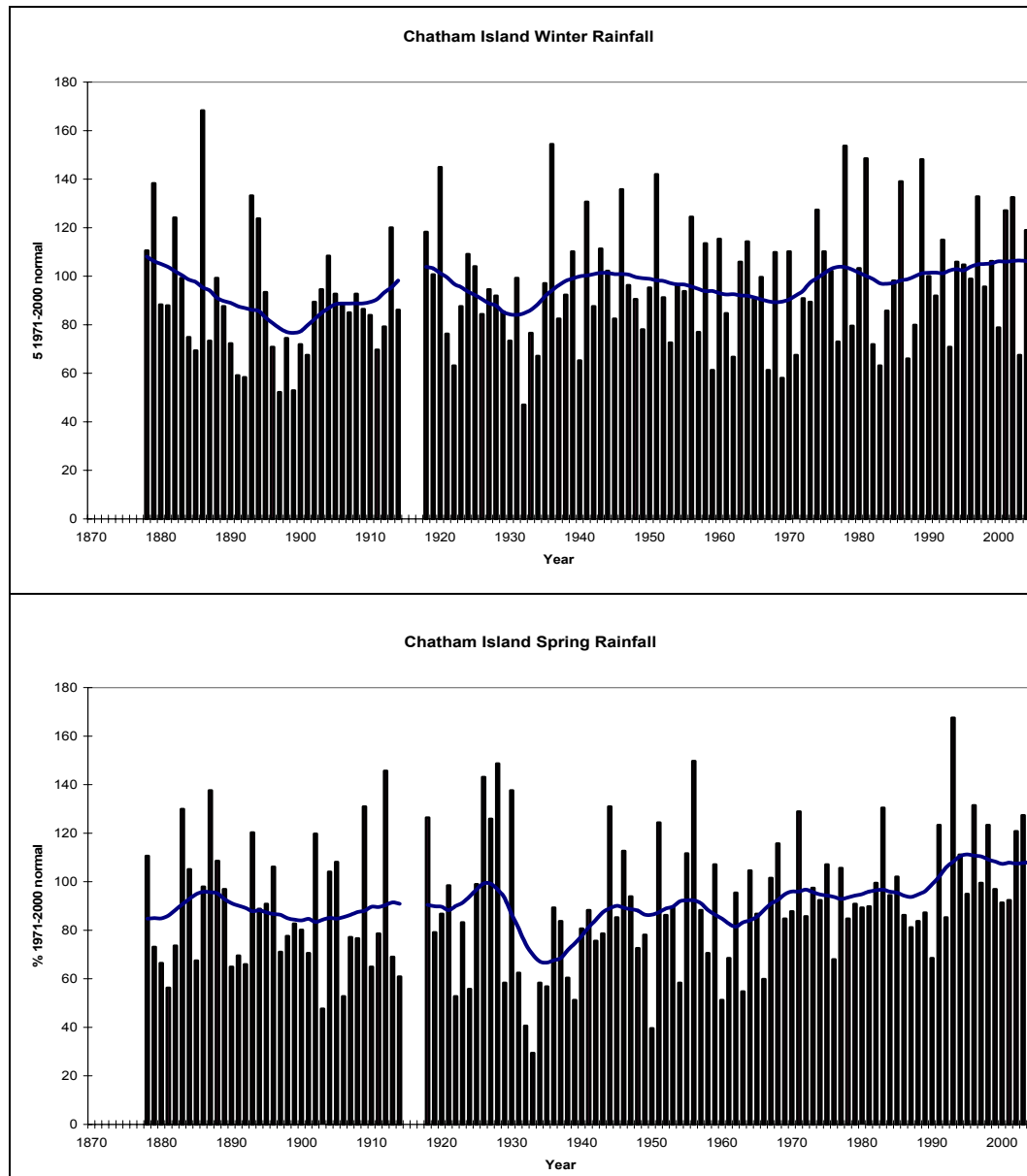


Figure 2.5 Chatham Islands winter and spring rainfall anomalies for the period 1878 – 2004, shown as the percentage of the 1971-2000 normal. The smoothed curve indicates the long-term trend.

3. Expected Temperature and Rainfall Changes

Key points:

- A mid-range scenario for temperature change at the Chatham Islands suggests a warming rate of about 0.2°C per decade through the 21st century. The full range of warming at 2100 for the Chathams is from about +0.5 to +3.9°C, relative to the 1990 baseline used by the IPCC.
- It also seems likely that the Chathams will experience stronger westerly winds and increased annual rainfall by the end of the 21st century.

The Climate Change Guidance Manual summarised the current knowledge of human-induced climate change expected for New Zealand through this century. It highlighted projected changes from 1990 (the standard IPCC ‘starting point’) out to 2020-2049 and to 2070-2099. These future periods were called the “2030s” and “2080s” for short.

The standard approach to assessing future impacts of climate change is to develop ‘scenarios’ that take account of the range of estimated future emissions of greenhouse gases, and also the variation between models in the projected patterns for the New Zealand region. The New Zealand changes were derived from climate model simulations, and were scaled to the full range of the IPCC Third Assessment Report, which suggested a global temperature increase between 1.4 and 5.8°C by 2100.

The broad pattern of expected New Zealand changes included:

- increased temperatures (with greater increases in the winter season, and in the north of New Zealand)
- decreased frost risk but increased risk of very high temperatures
- stronger west-east rainfall gradient (wetter in the west and drier in the east)
- increased frequency of extreme daily rainfalls
- increased sea level
- increased westerly winds

With the exception of rainfall, this pattern of changes is expected to be valid for the Chatham Islands also.

3.1 Temperature

The global climate models predict trends in broad climate patterns across the Pacific, but do not take account of the effect of New Zealand’s topography on the local climate. The local changes are inferred from the coarser-scale information of the global climate models by a statistical technique known as ‘downscaling’. This

technique was necessary for mainland New Zealand, for example, in determining how local rainfall might change with future trends in wind strength and direction. However, the situation is rather simpler for the Chatham Islands, which are low-lying and situated well east of the main islands of New Zealand.

For the Chatham Islands, it was decided to use the climate model changes directly, without further statistical adjustment. A 5 degree longitude by 3 degree latitude box centred on the Chathams was taken (178.5-173.5°W, 42.5-45.5°S) and model climate data averaged over this region. (This is a typical size for a grid box in a global climate model). Table 3.1 shows the seasonal and annual changes for temperature, after adjusting to a 1990 start-point and scaling to match the full IPCC range. This Table is the equivalent of Tables 2.2 and 2.3 in the Climate Change Guidance Manual.

Table 3.1 Projected changes for Chatham Islands in seasonal and annual mean temperature (in °C), from 1990 to the 2030s, and from 1990 to the 2080s.

	Summer	Autumn	Winter	Spring	Annual
2030s	0.0 to 1.3	0.0 to 1.3	0.2 to 1.7	0.1 to 1.5	0.1 to 1.4
2080s	0.2 to 3.2	0.3 to 3.6	0.7 to 3.6	0.4 to 3.2	0.4 to 3.4

The temperature changes (Table 3.1) are very similar to mainland New Zealand, as would be expected. At the extreme low end (a combination of the smallest increase in greenhouse gas emissions and the model with the smallest local warming), the projected changes are substantially smaller than have been observed in the historical record (section 2). A mid-range change would correspond to a warming rate of about 0.2°C per decade.

Figure 3.1 puts the projected temperature changes in the historical context. Most of the warming at the Chathams since 1880 has occurred since 1940 (the time series in Figure 3.1 begins at this date because of missing data for the period 1915-1938). The annual mean temperature projections from Table 3.1 were readjusted relative to the 1971-2000 baseline and extrapolated out to the year 2100 (red vertical bar in Figure 3.1). Relative to the IPCC start date of 1990, the full range of warming at 2100 for the Chathams turns out to be +0.5 to +3.9°C (the local equivalent of the IPCC global range of +1.4 to +5.8°C). Figure 3.1 also suggests that the lowest warming scenario is too conservative; an extrapolation of past warming puts the temperature more than 1°C above the extreme low scenario by 2100.

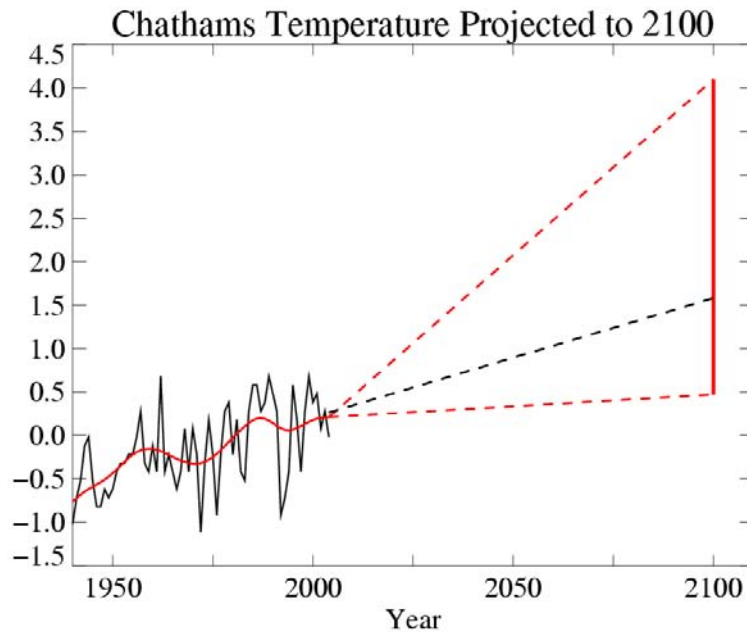


Figure 3.1 Annual temperatures at Chatham Islands, for historical period 1940-2004, and extrapolation to 2100: observed annual temperatures (black solid line), smoothed trend (red line), extrapolation of line 1939-2004 trend from 2004 to 2100 (black dotted line), total IPCC range by 2100 (red vertical bar). All temperatures are shown as deviation in °C from the 1971-2000 normal.

3.2 Rainfall

Table 3.2 shows the projected changes in seasonal and annual precipitation at the Chathams (the equivalent of Tables 2.4 and 2.5 in the Climate Change Guidance Manual). There is a very wide range in the rainfall projections, encompassing possible decreases or increases in all seasons. However, for the annual rainfall by the 2080s, the range is almost all on the side of an increase, similar to a number of other western regional council regions (Table 2.5 in Climate Change Guidance Manual). This probably reflects the exposure of the Chatham Islands to low pressure systems and cold fronts moving along in the westerly wind belt, which is expected to intensify during this century.

Table 3.2 Projected changes for Chatham Islands in seasonal and annual mean rainfall (as a percentage of current rainfall), from 1990 to the 2030s, and from 1990 to the 2080s.

	Summer	Autumn	Winter	Spring	Annual
2030s	-10 to +9	-2 to +6	-13 to +9	-8 to +11	-6 to +7
2080s	-8 to +26	-1 to +8	-19 to +27	-11 to +28	-1 to +18

4. Tides, storm surge and the effects of sea level rise

Key points:

- There is no clear evidence to indicate whether there will be either an increase or decrease in storm surge magnitudes in the next 50 years. The highest storm surge experienced in the past 25 years appears to be about 0.55 m.
- It is expected that storm tide elevations will rise at the same rate as mean sea level rise. It is recommended to use a sea-level rise of 0.2 m by 2050 and 0.5 m by 2100 for planning purposes.

4.1 Introduction

Coastal hazards, such as inundation and coastal erosion, tend to be caused by a range of inter-relating factors or “drivers” which can be both natural and caused or exacerbated by human actions. Besides earthquakes and underwater landslides (which can cause a tsunami or coastal subsidence) and ocean tides, the main natural causes of coastal hazards arise from extremes in weather such as storms and cycles in ocean-atmosphere response (sea level and currents). It is these weather and climate-related causes that will be altered most by climate change arising from global warming, mostly exacerbating the potential problems for the coast e.g., heightened storm tides, stronger winds and waves, sea-level rise.

This section reviews existing information on tides and sea-level in the Chatham Islands and discusses how climate variability and change may impact on sea levels. It does not consider the wave climate (which is an important factor influencing both coastal inundation and erosion), nor does it provide any significant information on the consequences of inundation or erosion, or how this may change in the future, within the Chatham Islands.

4.2 Tides

Tides are an important factor in determining the potential impact of coastal hazards on the coastline of the Chatham Islands. It is the tide height that governs the likelihood of coastal inundation from storm surge (see next section), with the effect of wave conditions experienced at the coastline highly dependent on water level.

Sea level data for the Chatham Islands is limited. Despite there being three sea level recorders currently installed (2 at Waitangi and the NIWA gauge at Kaingaroa) the length of the data record is relatively short. Tide information for the Chatham Islands can be located at:

- Forecast tides: <http://www.niwa.co.nz/services/tides>
- Near real time sea level data:
<http://www.niwa.co.nz/services/sealevels/sites/kaingaroa/>

The tide range in the Chatham Island is modest, being microtidal with a Spring tide range of around 0.7 m and a Neap tide range of approximately 0.6 m. Based on the tidal constituent data, derived from the NIWA gauge at Kaingaroa, Figure 4.1 shows the probability of exceedence of predicted high water above mean level of the sea. This suggests that the “pragmatical” mean high spring tide (the tide height that is exceeded by about 10-12% of all high tides) is around 0.61 m relative to MLOS¹ and the Highest Astronomical Tide (HAT)² is 0.74 m relative to MLOS. Figure 4.2 shows the probability of exceedence of high tide levels above MLOS (metres) for the Kaingaroa tide gauge predicted for the 100 year period (2000 to 2099) assuming no sea-level rise. Table 4.1 summarises the high tide levels at key probability values from the analysis of Figure 4.2.

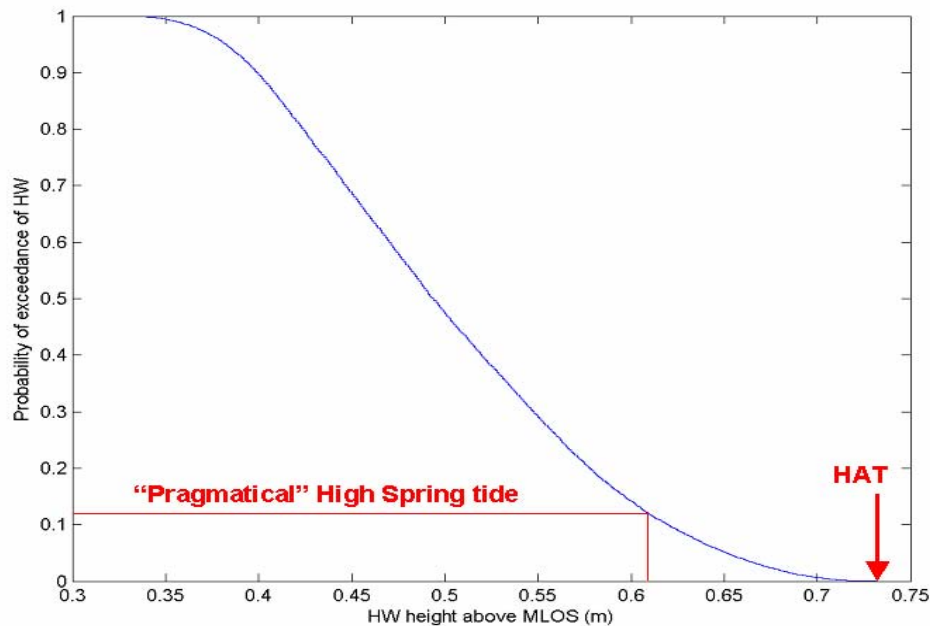


Figure 4.1 Probability of exceedence of predictable high tides based on tide data from the Kaingaroa tide gauge.

¹ Mean Level Of the Sea, for this period of record. Note that *Mean Sea Level* (MSL) is a surveyed height datum point, generally measured sometime between about 1930 and 1950 (depending on location). Because sea levels have been rising, it differs from present day mean level of the sea by a few cm. See Glossary of Coastal Guidance Manual for further definitions.
² HAT is the highest possible tide that can occur (excluding meteorological effects).

Table 4.1 Frequency or probability of exceedance of high tide levels at Kaingaroa over the 100 years from 2000 to 2099, focusing on the higher tidal elevations. Note: Levels are not tied in to any MSL or survey datum.

% of high tides that will be above the specified level	High tide elevation (m above MLOS)
10%	0.62
1%	0.69
0.1%	0.72
Maximum	0.73

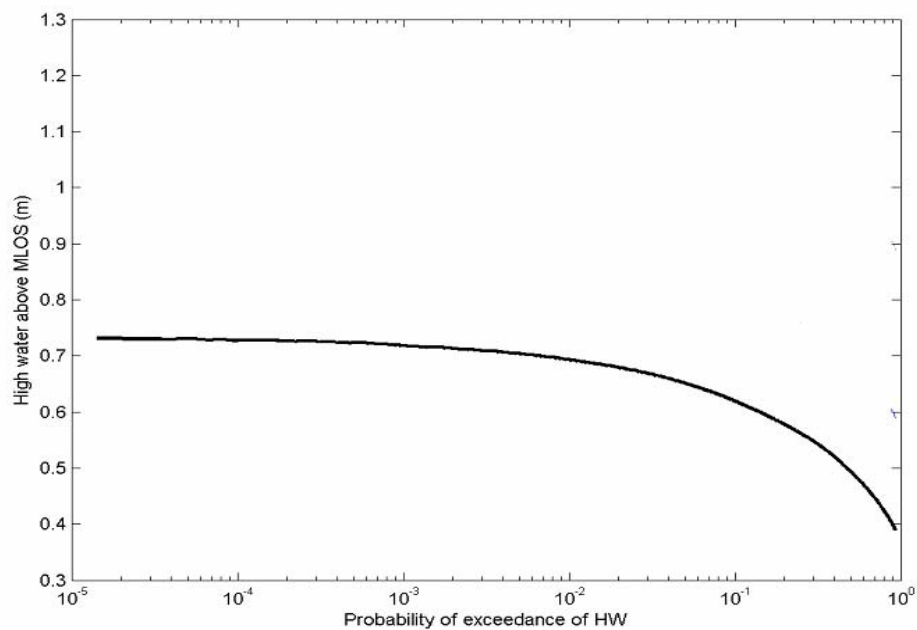


Figure 4.2 Probability of exceedance of predictable high tides over the next 100 years (2000-2099), excluding the effects of sea-level rise, based on tide data from the Kaingaroa tide-gauge.

4.3 Storm surge and storm tide

Storm surge is the temporary elevation in sea level at the shoreline above the predicted tide height caused by a combination of both low atmospheric pressure (inverted barometer) and set-up by adverse winds, and breaking surf waves during a storm, Figure 4.3. An additional component that needs to be considered for each site is wave run-up, which varies locally with the topography of the coastal margin.

Storm tide is the level of the predicted tide plus storm surge. This demonstrates the important point that high tides play a critical role in determining the elevation of coastal sea levels during a storm.

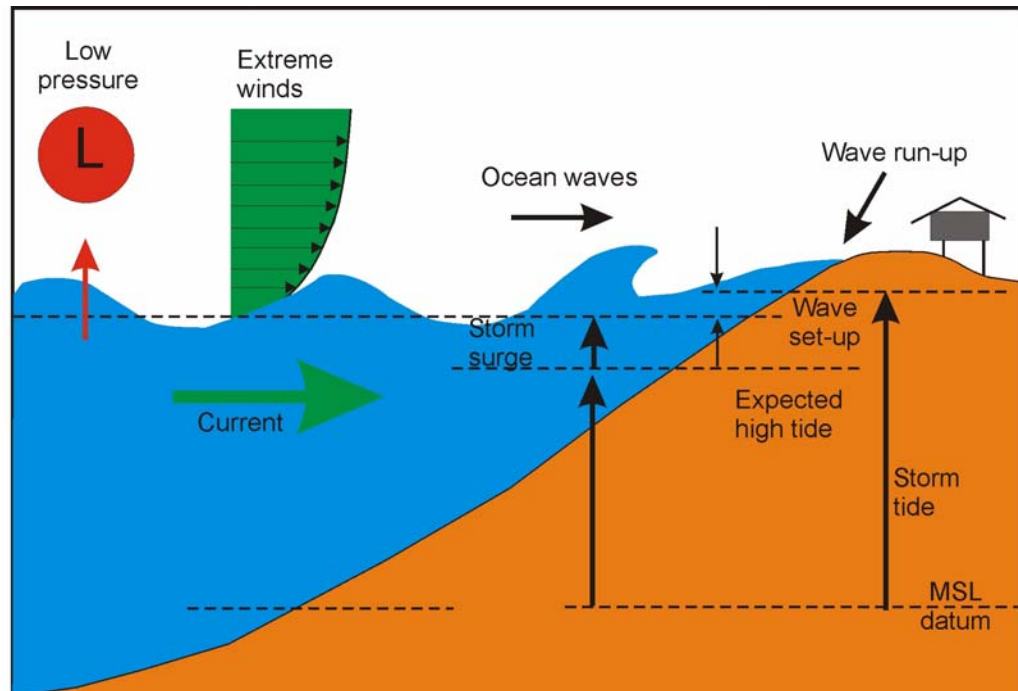


Figure 4.3 Schematic showing components of a storm tide.

Data from the Kaingaroa tide-gauge were analysed and the storm surge component separated from the predictable part of the tide. Figure 4.4 shows a summary of the storm surge over the three year period that data have been collected at the gauge. Over this period the largest storm surge has been about 0.25 m, with a storm surge of over 0.20 m occurring 15 times over this period.

Estimates of annual exceedance probability (AEP) for storm surge magnitude were derived from the 3 years of storm surge data for Kaingaroa (Figure 4.4) using the r-Largest method. The r-Largest method is based on the idea of using a fixed number, r , of independent extreme values from each year to provide an estimate of the parameters of the extreme value distribution. Practically, the method involves 2 steps: firstly, identification of extreme events; and secondly the selection of a suitable number of independent events from each year of data. The number of events has to be large enough to ensure sufficient data are available to obtain reasonable parameter estimates, but also small enough that the lowest level used still belongs to the extreme tail of the distribution. We used 5 events per year and a Gumbel (EV1) fit to the empirical storm surge distribution. Using this approach, the following storm surge levels were derived:

5 year return period = 0.37 m, and 10 year return period = 0.39 m.

The sea level records for the Chatham Islands are too short to estimate longer return periods of storm surge on the open coast. However, there are longer records (up to 25 years) available of atmospheric pressure and to a lesser extent, winds, which can be used as surrogates for estimating storm surge. Of interest are minimum atmospheric pressures as most storm-surge events have common elements to varying degrees —

low atmospheric pressure, high tides, adverse winds and high seas. Typically a 1 hectopascal drop in atmospheric pressure results in about a 1 cm rise in sea level. However, Stanton (1997) observed that in the Chatham Islands, this relationship was less, being around 0.75 cm per hectopascal.

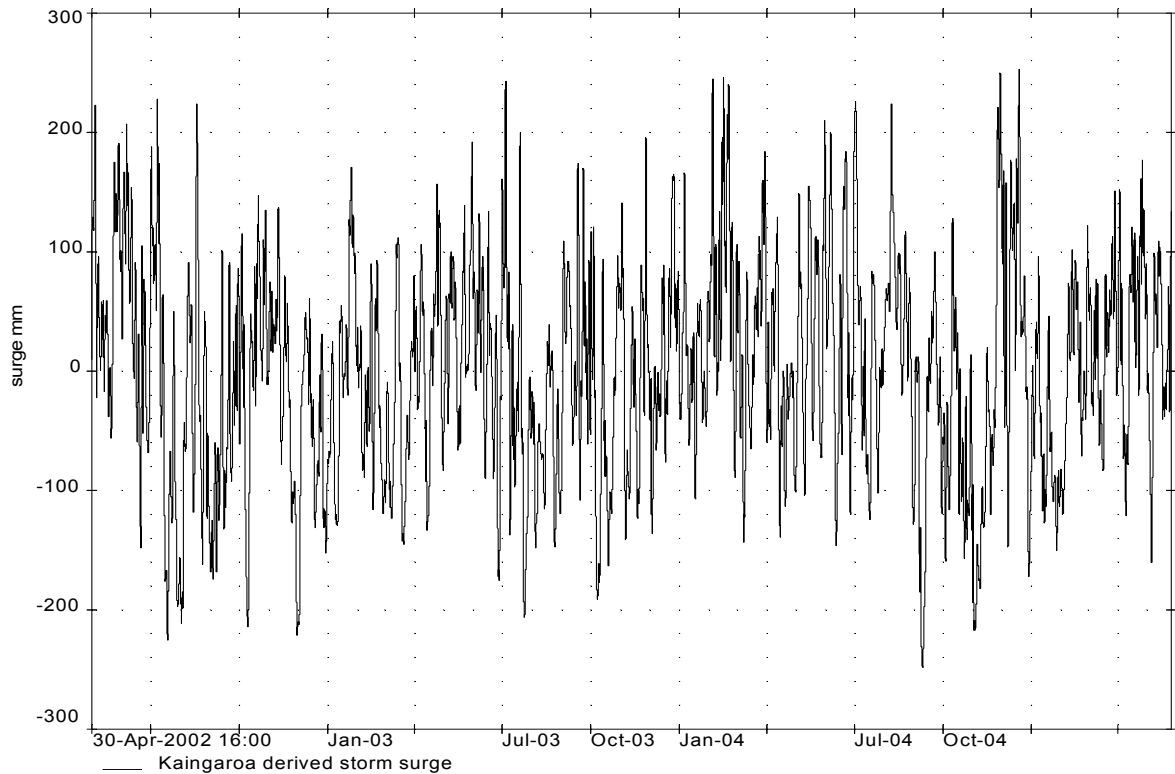


Figure 4.4 Storm surge magnitude over the three year period of sea level recordings from the Kaingaroa tide gauge.

Figure 4.5 shows minimum daily barometric pressure (hPa) and maximum daily storm surge from the Kaingaroa tide gauge from May 2002 to May 2005. This shows an approximate relationship of a 0.60 cm increase in storm surge for every 1 hectopascal reduction in barometric pressure although, as would be expected, there is considerable scatter in the data (i.e. the residual after allowing for inverted barometer, IB, appears to be approximately ± 100 mm) since the relationship does not consider wave setup. The r^2 of the relationship is 0.67, which indicates that inverted barometer explains 67% of the variance in the maximum daily storm surge. Therefore, an equation to estimate storm surge for the Chatham Islands at Kaingaroa (using barometric pressure) is:

$$\text{Maximum daily storm surge} = -6.04 \times \text{Barometric pressure} + 6110 \quad (1)$$

where maximum daily storm surge is in mm, and barometric pressure is in hPa.

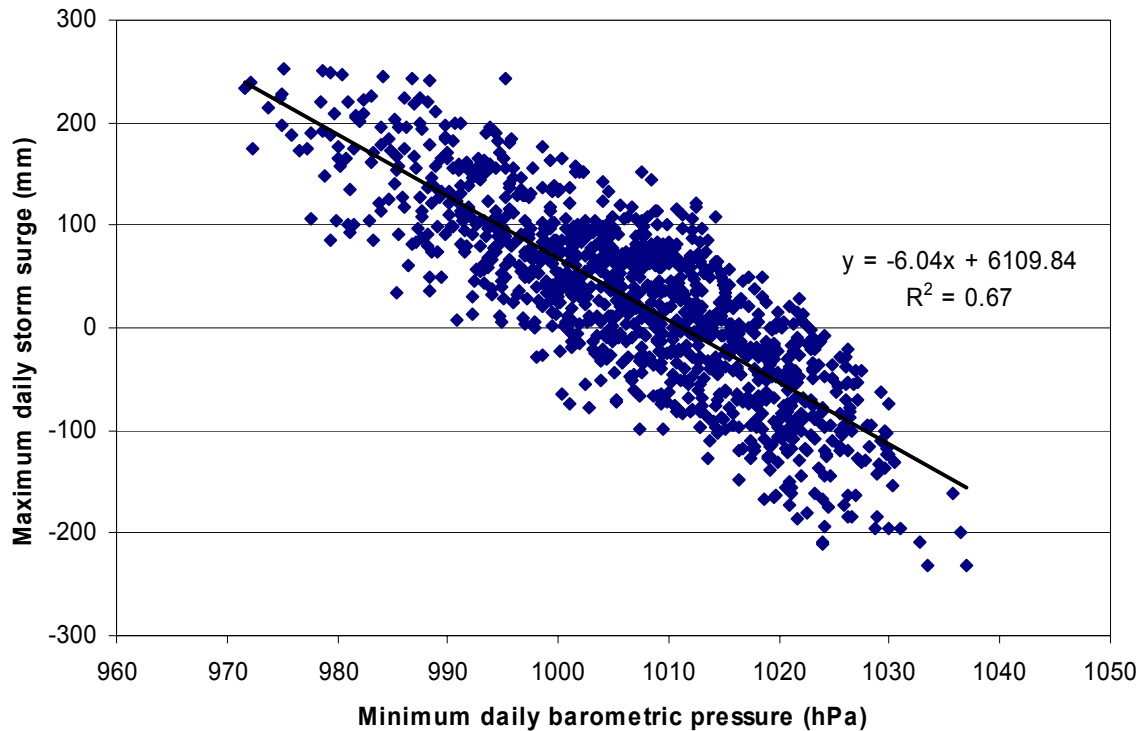


Figure 4.5 Minimum daily barometric pressure (hPa) versus maximum daily storm surge (mm) for the Kaingaroa tide-gauge from May 2002 to May 2005.

Barometric pressure has also been recorded on the Chatham Islands at the other sites summarised in Table 4.2. For the period of overlap (for all 4 barometric pressure sites), the minimum recorded barometric pressure occurred on 21/22 February 2004 (Figure 4.6, top). From Figure 4.6 (top) it can be seen that the Waitangi and Chatham Island EWS sites do not record as low values for minimum pressure over the February 2004 period. In February 2004 the Waitangi record is no longer recording hourly data for *every* hour of the day. In the case of the Chatham Island EWS record, however, a 6 hPa systematic bias is apparent over the February 2004 period, which may reflect a calibration problem with the pressure transducer.

Table 4.2: Available barometric pressure records for the Chatham Island.

Site	Site Number	Start of record	Data interval	Minimum bar. pressure (hPa)
Waitangi	6176	1 January 1970	various	968.3 (28/11/71)
Chatham Island AWS	6191	27 October 1991	3 hourly/hourly	969.0 (17/7/95)
Chatham Island EWS	17840	13 October 1999	hourly	977.3 (22/2/04)
Kaingaroa tide gauge	34397	30 April 2002	5 minute	971.6 (22/2/04)

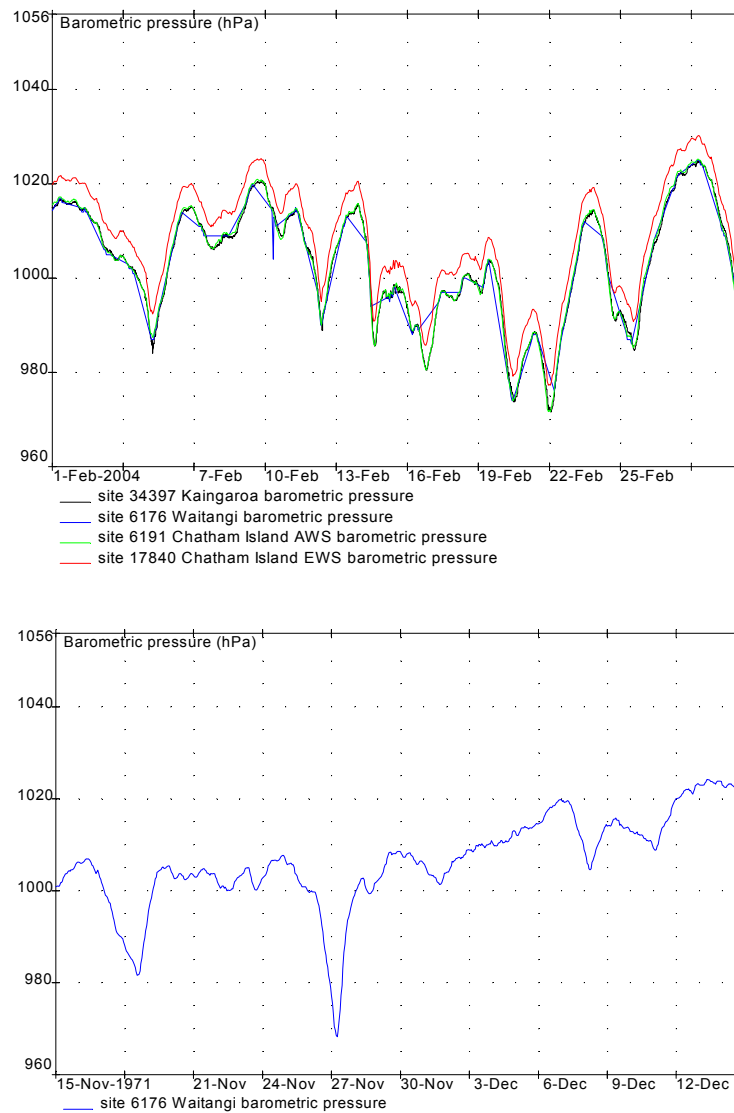


Figure 4.6 Minimum daily barometric pressure (hPa) for February 2004 (top), and mid November to mid December 1971 (bottom).

Overall, the lowest recorded barometric pressure is 968.3 hPa (Figure 4.6, bottom), recorded on 28 November 1971 at the Waitangi site (Site 6176). Using Equation 1, this gives a storm surge of approximately 0.26 m due to inverted barometer.

An approximate rule of thumb is that inverted barometer contributes half the set-up in ocean storm surge (above the predicted tide), while the other half comes from wind set-up and other coastal trapped-waves that propagate out from the storm centre (Bell *et al.*, 2000). This rule is only approximate, as the two contributory processes can vary considerably. However, based on the above analysis this suggests that the maximum storm surge experienced over the last 25 years, has been in the order of 0.55 m.

At present there is an insufficient data record to assess the full likelihood of occurrence for a given storm-surge height. Experience from elsewhere in New

Zealand suggests that, during the last century the highest storm surge (excluding wave effects) is generally around 1 m above the predicted tide, (Bell *et al.*, 2000), and is limited by the depth of depressions experienced.

4.4 Sea level fluctuations

“Sea-level fluctuations” refers to the fluctuations in the mean level of the sea, after taking out the influence of tides and without the influence of long-term sea-level rise. The main long-term fluctuations (excluding storm-driven fluctuations which are discussed above) are:

- Annual seasonal heating and cooling cycle by the sun on the ocean surface);
- interannual (2 to 4 year El Niño-Southern Oscillation³ cycles); and
- interdecadal (20 to 30 year Interdecadal Pacific Oscillation⁴ or IPO cycles).

There is little information on sea level fluctuations in the vicinity of the Chatham Islands but in areas of the North Island seasonal fluctuations are relatively small, averaging around a range of 0.08 m over a year (but can range up to 0.16 m in some years). The highest sea level tends to occur in late summer or early autumn (January to April), when the thermal expansion due to warmer seawater is greatest. Sea level and sea surface temperature variability was assessed by Stanton (1997) but could not verify the hypothesis that there is a direct link between sea surface temperature and sea level associated with the movement of the Subtropical Convergence to the south and north of the Chatham Islands.

The El Niño–Southern Oscillation (ENSO) is a quasi-periodic climate system on cycles of 2 to 4 years. During El Niño episodes (negative SOI), the mean level of the sea is depressed below normal levels typically by up to 0.12 m around New Zealand. The converse is true for strong La Niña episodes, where sea levels are higher than normal by a similar amount. The second climatic feature known to affect long-period sea-level fluctuation is the Interdecadal Pacific Oscillation (IPO) which operates on a 20 to 30 year cycle. The IPO tends to modulate interannual ENSO climate variability over the region, with increased frequency of El Niño events occurring during positive phases of the cycle.

The 20 to 30 year positive phase of IPO cycle probably ended around 1998. An extended period of negative phase IPO would bring more balance between El Niño and La Niña episodes, and has exhibited a quicker rate of sea-level rise than that

³ Cycle of alternate El Niño and La Niña episodes that govern climate and sea-level variations around the Pacific and Indian Oceans—commonly called the El Niño–Southern Oscillation or ENSO system.

⁴ Longer “El-Niño-like” 20–30 year cycles of alternate positive and negative phases that effect the wider Pacific Ocean region, abbreviated as IPO. Since 1998 the IPO has been negative.

experienced over the previous positive phase of IPO from 1976 to 1998. This pattern of a quicker sea-level rise during negative phases of the IPO has been demonstrated from the Port of Auckland tide-gauge record. It is possible that a similar trend is occurring regionally, in which case the next 20 to 30 years could see a faster rise in sea level than the mean long-term trend of 1.6 mm/yr.

Based on sea level fluctuation information for the North Island, Figure 4.7 combines all three long-term sea-level fluctuations (annual, ENSO, IPO), implying that the mean level of the sea could vary by up to ± 0.25 m above the average mean level of the sea.

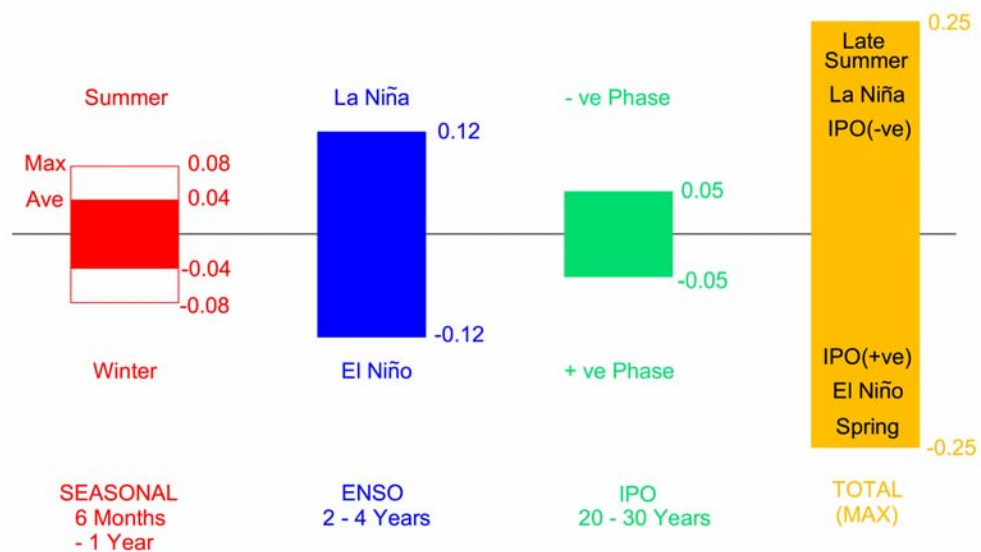


Figure 4.7 Summary of the relative magnitudes of long period sea level fluctuations (excluding storm-driven fluctuations and global warming effects).

4.5 Sea level rise

Sea level is rising around New Zealand, starting around the early to mid part of the 1800's. For New Zealand, the historic rate of rise has been around 1.6 mm/yr or approximately 0.16 m over the past 100 years up to 2000 based on Hannah's (2004) analysis of tide-gauge data from the four main ports. This value also lies mid-way in the range of estimated global sea-level rise of between 1 and 2.5 mm/yr since the early 1800's.

There is no sign yet of any definitive acceleration in the rise of sea level from any New Zealand sea-level gauges. However, the Third Assessment Report of the IPCC (2001) is predicting a slowly increasing acceleration over the next 50 years and beyond (Figure 4.8). The most likely mid-range rates of global mean sea-level rise are between 0.14 and 0.18 m by 2050 and between 0.3 and 0.5 m by 2100, with an upper-

limit projection of 0.88 m by 2100. It should also be noted from Figure 4.8 that the acceleration of sea level rise will not be discernable for another 20 to 30 years.

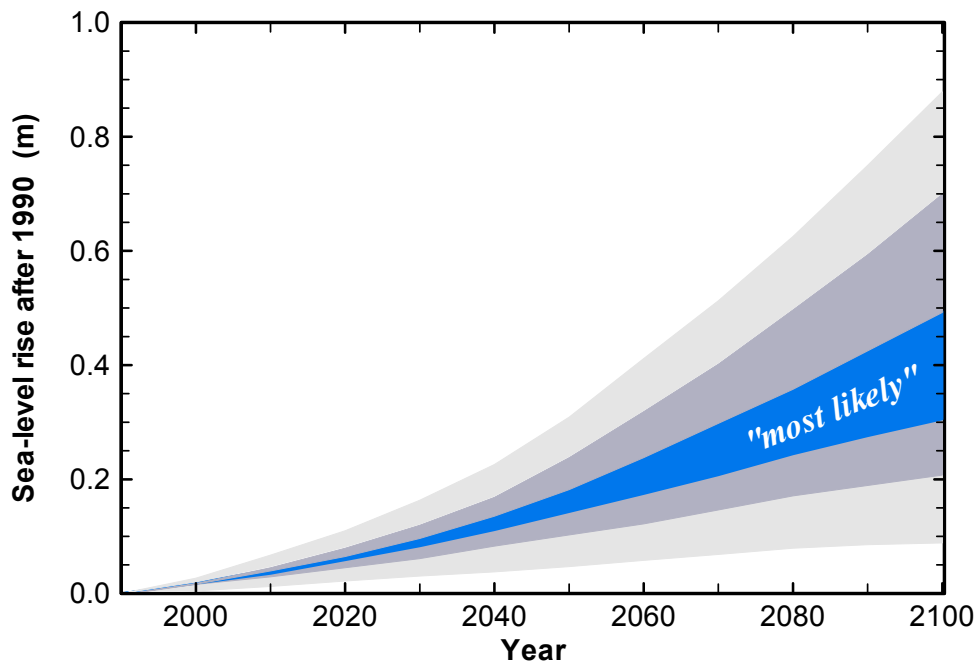


Figure 4.8 IPCC (2001) global mean sea level rise projections (tied back to 1990). Note the blue band corresponds to the most likely range of sea level rise, the dark grey to the intermediate zone, and light grey to the upper and lower extreme zones.

When it comes to the risks associated with sea-level rise, the quantity of primary interest is the sea-level rise relative to the landmass that the tide gauge sits on. In particular, if the landmass is subsiding, then the relative sea-level rise is higher than the absolute sea-level rise. There is little information on how tectonically stable the Chatham Island land mass is. Also, little is known yet about the regional differences in the rise in ocean levels around the SW Pacific, compared to the global average rates given in IPCC (2001). Taken together, this means that relative sea-level rise within the Chatham Islands can be treated to be similar to the global average rate of rise. So until such time as further information to the contrary becomes available, the projected IPCC (2001) sea-level rise should be used for coastal hazard planning as recommended by the recent Coastal Guidance Manual (MfE, 2004b):

- 0.2 m by 2050 (relative to 1990)
- 0.5 m by 2100 (relative to 1990)

Figure 4.9 shows the probability of exceedance (same as Figure 4.2 above) of high tide levels above MLOS (metres) predicted for the 100 year period (2000 to 2099) assuming (1) no sea-level rise (heavy black line); 0.2 m rise in mean sea level by 2050 (solid blue line), and a 0.5 m rise in sea level by 2100 (dashed line).

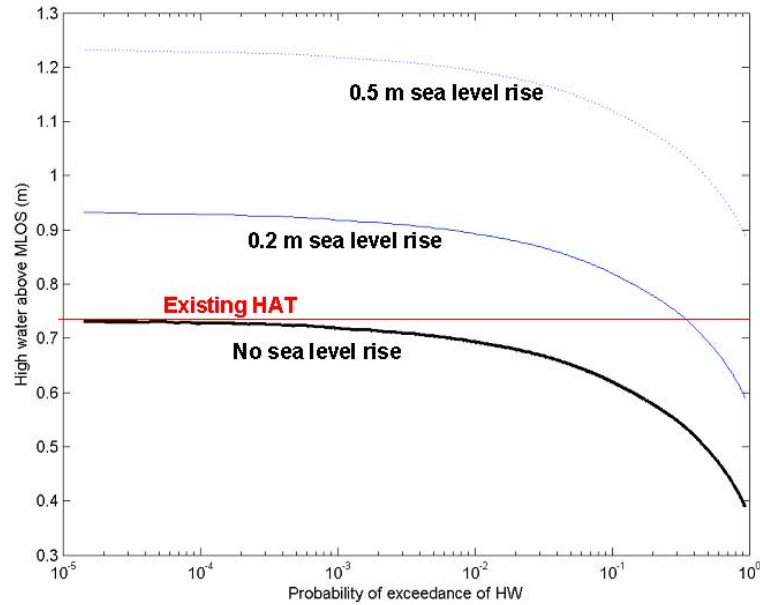


Figure 4.9 Probability of exceedance of high tide levels above MLOS (metres) at Kaingaroa predicted for the 100 year period (2000 to 2099) assuming (1) no sea-level rise (heavy black line), 0.2 m rise in mean sea level by 2050 (solid blue line), and a 0.5 m rise in sea level by 2100 (light dashed line). This suggests that the existing HAT (red line) would be exceeded by about 35% of tides assuming a 0.2 m sea-level rise spread over the 100 year period (solid blue line), and would be exceeded by all high tides assuming a 0.5 m rise in sea level (dashed line).

It is important to note that IPCC expects sea level will continue to rise for several centuries after 2100, even if greenhouse gas emissions are stabilised. This is due to the long lag times needed for the deep oceans to respond to ocean surface heating and the potential contribution from polar ice sheets, particularly from the Greenland ice sheet after 2100.

Ocean tides will not be directly affected by climate change but tidal ranges in shallow harbours and estuaries could be altered by deeper channels (following sea-level rise). Of perhaps greater concern than mean sea level rise, from the viewpoint of flooding, overtopping and in the design and assessment of coast protection works is any increase in the magnitude or frequency of storm-tide water levels. As discussed above, storm-tide levels depend mainly on the magnitude and frequency of storm surges as well as the timing with spring or neap tides. If deeper atmospheric low-pressure systems and stronger winds occur, then surge levels may increase in magnitude. There is no evidence (yet) that low atmospheric pressure systems will become more frequent or more intense with global warming. Furthermore, changes in the pattern of tracking of low-pressure systems and ex-tropical cyclones may also have an effect on extreme water levels due to the complex way that they interact with the continental shelf and coastline.

In summary there is no clear evidence as yet to indicate whether there will be either an increase or decrease in storm surge magnitudes in the next 50 years, and hence how storm tide levels will change. Due to the lack of such information, it is normally assumed that storm tide elevations will rise at the same rate as mean sea level rise.

Coastal hazards are not only dependent on the ‘hazard drivers’ but also on the geomorphology of the coast. How coastal hazards affect different coastal types, and how these different coastal types will respond to the impacts on climate change, is described in the guidance manual, *Coastal Hazards & Climate Change: A Guidance Manual for Local Government in New Zealand*, published by the Ministry for the Environment (MfE, 2004b).

5. Analysis of Heavy Rainfall – Past and Future

Key points:

- What is an extreme rainfall in the current climate is likely to occur about twice as often by the end of the 21st century under a mid-range temperature change scenario.
- For the high temperature change scenario, an extreme rainfall in the current climate is likely to occur 3 to 4 times as often by the end of the 21st century.
- For the high temperature change scenario, an extreme rainfall in the current climate is likely to fall within about half the duration (e.g., 12 hours instead of 24 hours) by the end of the 21st century.

5.1 Historical high intensity rainfall

High intensity rainfall statistics have a wide variety of uses. These extend from a range of engineering construction work, where allowance has to be made for the disposal of rainfall from storm, to the influence of heavy rainfall on soil erosion and vegetation damage. For many purposes it is necessary to express, in probabilistic terms, the likelihood of various amounts of rainfall for a range of storm durations. To do this the concept of annual recurrence interval (ARI), or return period, is used.

5.1.1 Method

The ARI of a given storm event is the average number of years within which the event magnitude is expected to be at least equalled. This definition assumes that the storm events being considered are the maximum values of all such similar events in a year. For example the series of annual maximum one-hour rainfalls, sampled of several years, meets this criterion. Estimates of high intensity rainfall are often presented in tables that provide the rainfall amounts for various ARI and for a range of storm durations.

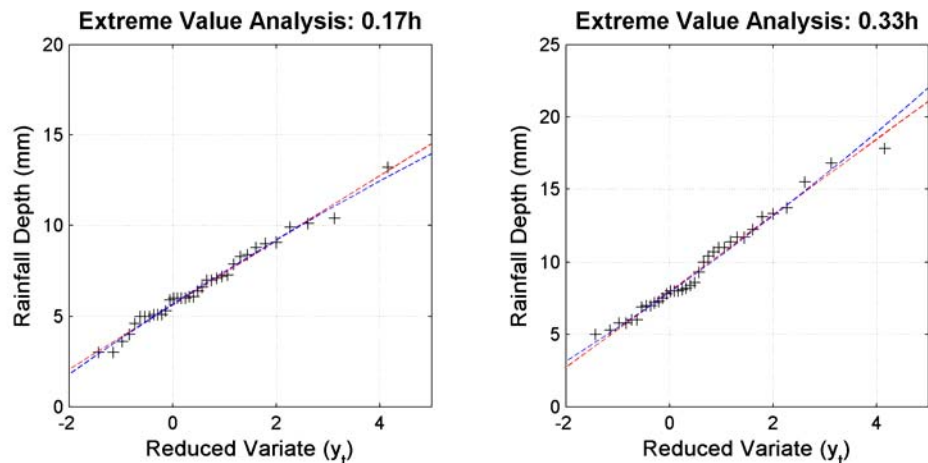
Annual maximum rainfalls from Waitangi, Chatham Islands, for 10 standard storm durations (10, 20, 30, 60-minutes, 2, 6, 12, 24, 48, 72-hours) are available for the period 1957 – 1992. To obtain the probabilistic estimates or average recurrence intervals from these data, it is necessary to fit a frequency distribution, such as a three-parameter generalised extreme-value (GEV) distribution (Jenkinson, 1955). This distribution has three characteristic types, known as EV1 or Gumbel, and EV2 and EV3. Once the distribution parameters have been estimated, by a method such as probability-weighted moments (Hosking *et al.*, 1985), the average recurrence interval can be obtained from standard formulae. For each of the 10 durations, the Waitangi

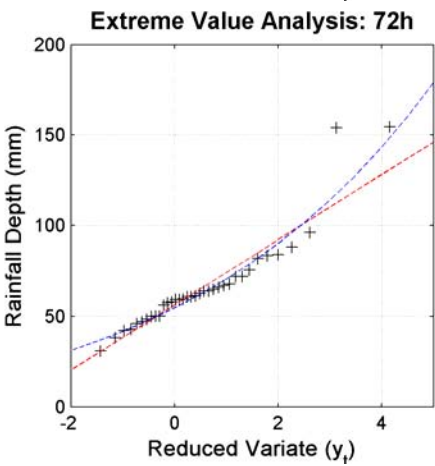
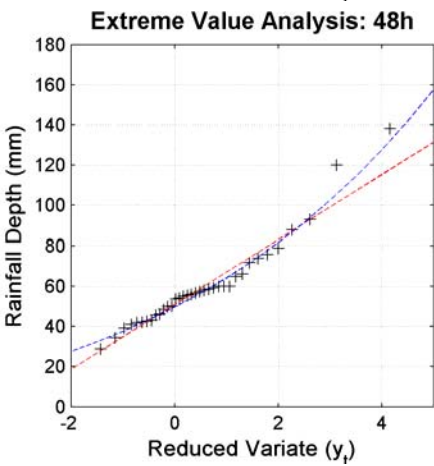
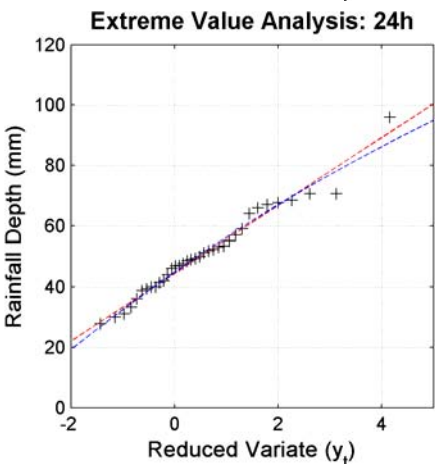
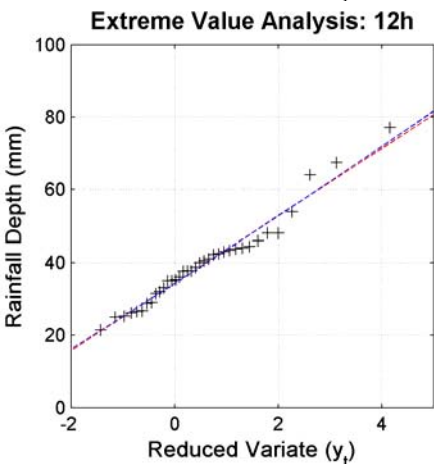
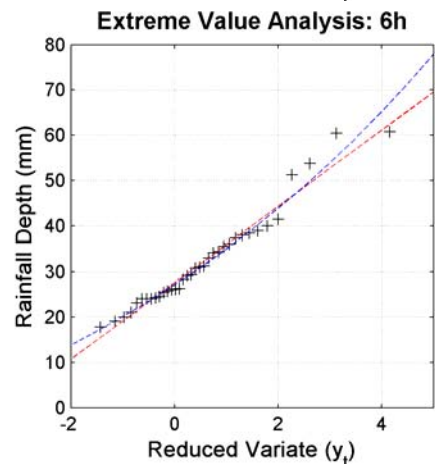
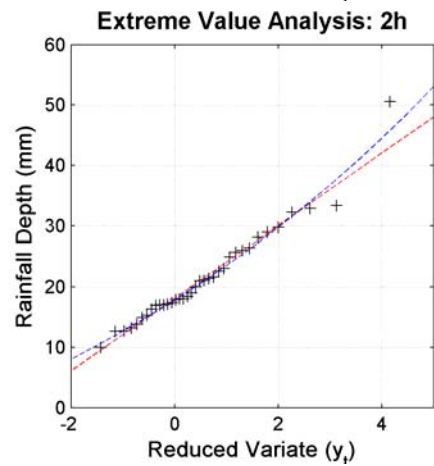
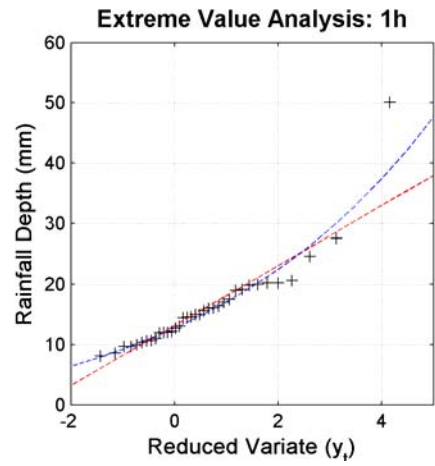
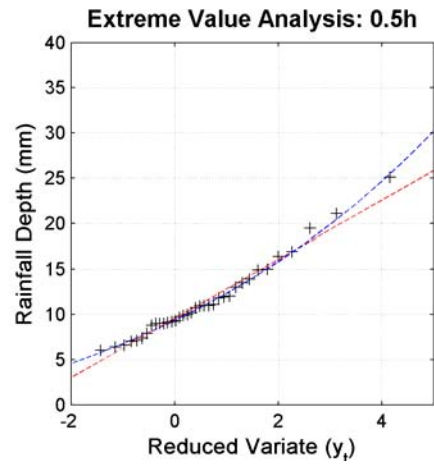
rainfall series were fitted to both a Gumbel and full generalised extreme-value distributions, and average recurrence intervals computed.

Figure 5.1 gives plots of rainfall depth for each duration against a plotting variable, known as a “reduced variate”. The reduced variate, y_T , on the x-axis has the effect of “straightening” the lines on the plots, and can be used to graphically compare how well different distributions fit the data series. There is also a direct relationship between ARI and the reduced variate. For example, when y_T is 4.6, this corresponds to an ARI of approximately 100-years. In each diagram the rainfall maxima are also plotted. These data are ranked, and an estimate of the reduced variate is made from the ranking position of the rainfall maxima.

All the diagrams in this figure show that the difference between the two extreme value distributions is small, and statistically insignificant, based on a test to see whether the EV1 distribution is an acceptable alternative to the EV2 or EV3 distributions (Hosking *et al.*, 1985). Thus, all these distributions are effectively equivalent when estimating design rainfalls. In this report the EV1 distribution is used to provide table of high intensity rainfall for Waitangi.

Figure 5.1 Plots of extreme value distributions for EV1 distribution (red line) and GEV distribution (blue line) for Waitangi, Chatham Island annual maxima for 1957-1992, for 10 standard durations. The annual maxima have been plotted on the diagrams. (Figure continues on next page).





5.1.2 Results

Table 5.1 gives a table of rainfall depths for various durations and average recurrence intervals for Waitangi, Chatham Islands. To interpret this table, for example, a 12-hour storm rainfall of 71 mm could be expected to recur on average once every 50 years. Further, as to be expected, the high intensity rainfalls in the table increases monotonically with duration and with average recurrence interval.

Table 5.1 Depth (mm) – Duration (minutes or hours) – Frequency (years) analysis from an EV1 distribution for Waitangi, Chatham Islands using annual maximum rainfalls for the period 1957 – 1992.

ARI (years)	Durations									
	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	6.3	8.9	10.7	15.0	20.3	30.6	37.7	48.5	56.8	62.8
5	8.3	11.9	14.4	20.6	27.1	40.1	48.2	61.2	75.0	83.2
10	9.6	13.9	16.9	24.3	31.6	46.4	55.2	69.6	87.1	96.7
20	10.9	15.8	19.2	27.9	35.9	52.5	61.8	77.7	98.7	109.6
30	11.6	16.8	20.6	29.9	38.4	55.9	65.7	82.3	105.4	117.0
50	12.6	18.2	22.3	32.5	41.5	60.3	70.5	88.1	113.7	126.3
80	13.4	19.4	23.8	34.8	44.3	64.3	74.9	93.4	121.4	134.8
100	13.8	20.0	24.5	35.9	45.6	66.2	67.9	95.9	125.0	138.9

5.2 Climate Change Scenarios

The Climate Change Guidance Manual provided a method showing how to adjust high intensity rainfalls for preliminary scenario studies (Section 5.2 and Appendix 4, MfE, 2004a). It was advocated that at least two sets of calculations be undertaken for low and high temperature change scenarios. Table 5.2 shows (for screening assessment scenario purposes) the recommended percentage adjustments per degree Celsius of warming to apply to high intensity rainfalls for various durations and average recurrence intervals. Note that the percentage changes in the table are mid-range estimates per degree Celsius and should be used in only preliminary scenario studies.

For the Chatham Islands, the projected temperature changes for 2030s and 2080s for a low, mid-range and high temperature change are given in Table 5.3 (from Table 3.1 in this report). Tables 5.4 and 5.5 provide the high intensity rainfall estimates for the projected temperature scenarios for the 2030s (Table 5.4) and 2080s (Table 5.5).

Table 5.2 Factors (percentages/degree Celsius of warming) for use in deriving high intensity rainfall information in preliminary scenario studies. (Adapted from MfE, 2004a).

ARI (years)	Durations									
	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	8.0	7.7	7.4	7.1	6.7	6.3	5.8	5.4	4.6	4.3
5	8.0	7.8	7.5	7.2	7.0	6.6	6.2	5.9	4.9	4.6
10	8.0	7.9	7.6	7.4	7.1	6.8	6.5	6.2	5.1	4.8
20	8.0	7.9	7.6	7.4	7.2	7.0	6.6	6.4	5.2	5.0
30	8.0	8.0	7.7	7.5	7.3	7.0	6.7	6.5	5.3	5.1
50	8.0	8.0	7.7	7.5	7.3	7.1	6.8	6.6	5.4	5.2
80	8.0	8.0	7.7	7.5	7.4	7.1	6.9	6.7	5.4	5.3
100	8.0	8.0	7.7	7.5	7.4	7.1	6.9	6.7	5.5	5.3

Table 5.3 Projected temperature changes (degrees Celsius) for Chatham Islands for 2030's and 2080's for lowest, mid-range and highest temperature changes.

	2030s	2080s
Lowest	0.1	0.4
Mid-Range	0.7	1.9
Highest	1.4	3.4

Table 5.4a Low Temperature Scenario for 2030's: Depth (mm) – Duration (minutes or hours) – Frequency (years) for Chatham Island.

ARI (years)	Durations									
	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	6	9	11	15	20	31	38	49	57	63
5	8	12	15	21	27	40	48	62	75	84
10	10	14	17	24	32	47	56	70	88	97
20	11	16	19	28	36	53	62	78	99	110
30	12	17	21	30	39	56	66	83	106	118
50	13	18	22	33	42	61	71	89	114	127
80	14	20	24	35	45	65	75	94	122	135
100	14	20	25	36	46	67	77	97	126	140

Table 5.4b Mid-Range Temperature Scenario for 2030's: Depth (mm) – Duration (minutes or hours) – Frequency (years) for Chatham Island.

ARI (years)	Durations									
	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	7	9	11	16	21	32	39	50	59	65
5	9	13	15	22	28	42	50	64	78	86
10	10	15	18	26	33	49	58	73	90	100
20	12	17	20	29	38	55	65	81	102	113
30	12	18	22	31	40	59	69	86	109	121
50	13	19	24	34	44	63	74	92	118	131
80	14	20	25	37	47	68	78	98	126	140
100	15	21	26	38	48	70	81	100	130	144

Table 5.4c High Temperature Scenario for 2030's: Depth (mm) – Duration (minutes or hours) – Frequency (years) for Chatham Island.

ARI (years)	Durations									
	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	7	10	12	16	22	33	41	52	60	67
5	9	13	16	23	30	44	52	66	80	89
10	11	15	19	27	35	51	60	76	93	103
20	12	18	21	31	40	58	67	85	106	117
30	13	19	23	33	42	61	72	90	113	125
50	14	20	25	36	46	66	77	96	122	136
80	15	22	26	38	49	71	82	102	131	145
100	15	24	27	40	50	73	84	105	135	149

Table 5.5a Low Temperature Scenario for 2080's: Depth (mm) – Duration (minutes or hours) – Frequency (years) for Chatham Island.

ARI (years)	Durations									
	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	7	9	11	15	21	31	39	50	58	64
5	9	12	15	21	28	41	49	63	77	85
10	10	14	17	25	32	48	57	71	89	99
20	11	16	20	29	37	54	63	80	101	112
30	12	17	21	31	40	57	67	84	108	119
50	13	19	23	33	43	62	72	90	116	129
80	14	20	25	36	46	66	77	96	124	138
100	14	21	25	37	47	68	79	98	128	142

Table 5.5b Mid-Range Temperature Scenario for 2080's: Depth (mm) – Duration (minutes or hours) – Frequency (years) for Chatham Island.

ARI (years)	Durations									
	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	7	10	12	17	23	34	42	53	62	68
5	10	14	16	23	31	45	54	68	82	90
10	11	16	19	28	36	52	62	78	96	105
20	13	18	22	32	41	59	70	87	108	120
30	13	19	24	34	44	63	74	92	116	128
50	15	21	26	37	47	68	80	99	125	139
80	15	22	27	40	51	73	85	105	134	148
100	16	23	28	41	52	75	87	108	138	153

Table 5.5c High Temperature Scenario for 2080's: Depth (mm) – Duration (minutes or hours) – Frequency (years) for Chatham Island.

ARI (years)	Durations									
	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	8	11	13	19	25	37	45	57	66	72
5	11	15	18	26	34	49	58	74	88	96
10	12	18	21	30	39	57	67	84	102	112
20	14	20	24	35	45	65	76	95	116	128
30	15	21	26	38	48	69	81	100	124	137
50	16	23	28	41	52	75	87	108	135	149
80	17	25	30	44	55	80	93	115	144	159
100	18	25	31	45	57	82	95	118	148	164

5.2.1 How to use the tables

As an example of how to use the above table to compute changes in high intensity rainfall, consider the 50-year 24-hour rainfall. From Table 5.1 the rainfall depth is 88mm, and the projected adjustment for global warming (Table 5.2) is 6.6 percent per degree Celsius warming. For a mid-range temperature adjustment for the 2030s of 0.7 °C, the increase in high intensity rainfall is 4.6 percent (i.e. 0.7°C times 6.6%). This gives an estimate rainfall of 92mm for the 2030s scenario, (i.e. 1.046 times 88mm).

5.2.2 Implications

So what does this mean? The changes in rainfall extremes look relatively modest, but in all cases there is an increase with time and with temperature. The best way to interpret the results is to ask how extreme rainfall events might change in the future. For the example above, the current Waitangi estimate in Table 5.1 of 88 mm for a 50-year 24-hour rainfall suggests that for the mid-range scenario this amount of rainfall is expected to have a recurrence interval of about 35 years by the 2030s (Table 5.4b) and

about 20 years by the 2080s (Table 5.5b). In other words, what is an extreme rainfall in the current climate is likely to occur at least twice as often by the end of the century. This can be taken as a useful ‘rule of thumb’ for other combinations in the tables too.

For the high temperature scenario at the 2080s (the ‘worst case’), current extreme rainfalls are projected to occur 3 to 4 times more often. Alternatively, what is currently a 50-year 24-hour rainfall (Table 5.1) becomes a 50-year 12-hour rainfall (Table 5.5c). Obviously, this is likely to have implications for drainage and flooding.

6. Discussion and Recommendations

6.1 Natural Variability

The climate of the Chatham Islands varies naturally from year to year and from decade to decade. Such natural variations will continue through the 21st century, and will be superimposed on the human-induced climate change trends. Section 2 described the effects of natural variations on the annual timescale (ENSO) and decadal timescale (IPO). It is not yet possible to say how El Niño events might change in their frequency or severity, for example, under global warming.

Section 3 provided scenarios of anthropogenic climate change for the Chatham Islands, and indicated a wide range in possible temperature and rainfall changes. The observed 20th century increase in annual rainfall at the Chathams is consistent with a trend towards generally the wetter conditions expected under the climate change scenarios, but with decadal trends above the long-term average trend during prolonged La Niña-like periods (negative IPO phase), and trends below the long-term during prolonged El Niño-like periods (positive IPO phase).

We would expect such decadal fluctuations in rainfall to continue. Given that the recent 1978-1998 positive IPO phase appears to have ended (although there is not yet strong evidence of a distinct negative phase starting), it is possible that the Chathams will experience higher annual rainfall, on average, for the next 20 years or so compared to the recent past. An increase in mean rainfall has been found (elsewhere in New Zealand) to increase the occurrence of extreme rainfall also, although such an analysis has not been carried out for the Chathams.

6.2 Influence of Climate Change on Natural Hazards

Climate hazards result from extremes in the distribution of climate events. The hazards include such issues as: heavy rain or flooding, drought, coastal erosion, inundation from sea level rise or storm surge, severe winds, extreme temperatures, occurrence of lightning and hail, occurrence of severe storms, wildfire risk, and impacts on biodiversity and ecosystems.

Very little information is available directly from the global models on these issues because there is not sufficient local detail to provide reliable spot value estimates of extremes. However, some general comments can be made, on the basis of physical reasoning and analyses carried out elsewhere. The Climate Change and Coastal Guidance Manuals discussed briefly how some of these hazards could change in a new climate. The report has specifically addressed heavy rainfall and storm surge.

A warmer atmosphere can hold more moisture (about 8% more for every 1°C rise in temperature), so there is the potential for heavier extreme rainfall than at present, with a consequent increased risk of flooding. Section 5 has quantified the rainfall changes for several scenarios of temperature rise. For the high temperature change scenario in the 2080s (the most extreme case analysed), the time to accumulate high rainfall amounts was halved – that is, a 24-hour extreme total in the present climate accumulated in only 12 hours in the 2080s, or a 2-hour total became a 1-hour accumulation.

An alternative way of viewing these systematic increases in heavy rainfall is to say that a reduction in return period of heavy rainfall events is expected. For the high temperature change scenario in the 2080s, the return periods for extreme rainfall decreased by a factor of 3 to 4: e.g., a 24-hour extreme that currently occurs only once every 50 years in the present climate would occur in every 10-20 years by the 2080s. Obviously, for scenarios with smaller temperature increases, the extreme rainfall changes are not as marked. There could be little or no change in extreme rainfall and flood return period at the low end scenario. It is hoped that new NIWA research using regional models will lead to improved guidance on heavy rainfall in a few years.

Sea level is rising around New Zealand, with a historic rate of rise of about 1.8mm/year, or approximately 0.2 m over the last 100 years. The rise of relative sea level around New Zealand is likely to be similar to global changes given the historic similarity between New Zealand and global sea level rise. The IPCC global projections are therefore a useful guide. The Climate Change and Coastal Guidance Manuals suggested a sea-level rise of 0.2 m by 2050 and 0.5 m by 2100 should be used routinely for planning and design purposes until updated projections become available.

Storm surge will add on top of any sea-level rise. From analysis of the limited records available, the maximum storm surge experienced over the last 25 years has been about 0.55 m. There is no clear guidance of whether storm surge magnitudes will increase or decrease in the next 50 years, and hence how storm tide levels will change.

7. References

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