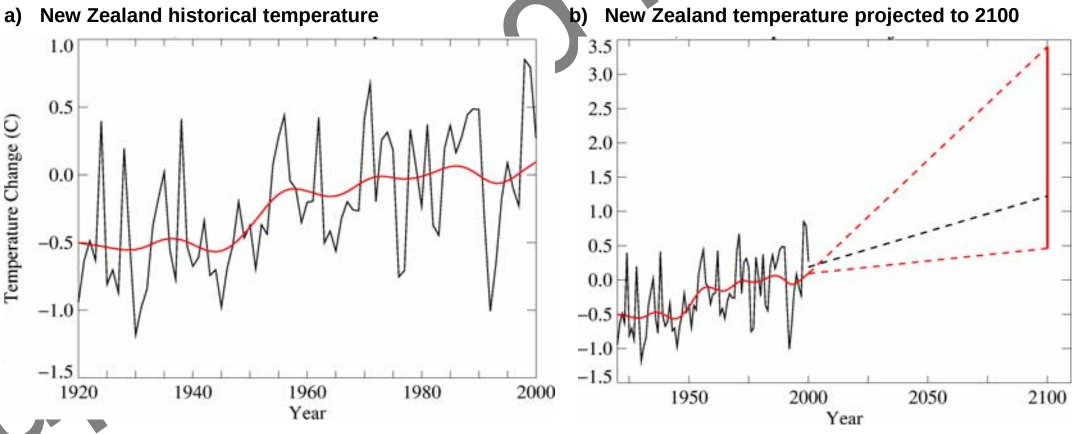
Chapter 3: Relationship to Current Climate Variability and Change

3.1 Introduction

Chapter 2 outlined projected changes in New Zealand's climate as a result of global human-induced emissions of greenhouse gases and aerosols. These projections of human-induced (or anthropogenic) climate changes should be viewed within the context of natural yearly and decadal variability in circulation and climate. Chapter 3 provides this context by briefly summarising variations in current climate, comparing the projected climate changes with current variability, and commenting on records used to describe climate.

New Zealand's climate is varying all the time, and future climate variability will be superimposed on the future long-term trends described in Chapter 2. Much of the variation in New Zealand climate is random and short-lived, but some of the variations are quasi-cyclic[30] in nature and some are long-lasting from seasons to years to decades. Figure 3.1 shows the national-average temperature for New Zealand, both historical and projected, and sets the scene for discussing past and future changes and variability. New Zealand temperatures have increased by about 0.6°C between 1920 and 2000 (Figure 3.1a), although much of this warming occurred rapidly between 1945 and 1955 (see section 3.2). Year-to-year temperature changes that are substantially larger than the trend are also evident.

Figure 3.1: New Zealand national-average temperature, historical and projected


a) New Zealand historical temperature

b) New Zealand temperature projected to 2100

Note: Shown as deviation in °C from 1961–90 climatology: (a) annual mean temperatures (black line) and a smoothed curve (red line) indicating the long-term trend; (b) reproduction of (a) but time and temperature scales expanded to encompass projected long-term trend at 2100 (range shown by vertical red bar) and extrapolated trend line (black dashed line) of 1920-2000 data.

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[30] There are very few true cycles in climate records, apart from the daily (diurnal) and annual cycle, in the sense of having a clearly defined period and being predictable for many cycles into the future. For this reason, the term "oscillation" is often used in preference to "cycle".

Figure 3.1b reproduces 3.1a with an expanded time and temperature scale, and adds two additional components. The first (black dashed line on Figure 3.1b), is the extension of a linear trend fitted to the 1920 to 2000 observations of Figure 3.1a. The second (vertical red bar), represents the projected range in New Zealand-average temperature, scaled to the full IPCC global range (following the methodology of Appendix 2, except that here the extrapolation is carried out to the year 2100 and is relative to 1961–1990). The red dashed lines join the smoothed historical trend at 2000 to the lower and upper bounds of the 2100 projection. Figure 3.1b shows that extrapolating the warming trend of the 20th century out to 2100 would lead to a temperature well above the projected lower bound at 2100. Thus, the projected lower bound (and all the "lowest" projected changes in Chapter 2 and Appendix 2) is a very conservative estimate of the change at 2100.

Further, the actual temperature in any future year will have the natural variability added to whatever the trend line is to that point. For example, the smoothed temperature of the linear trend line extrapolated to 2100 is already higher than temperatures experienced in any individual year in the historical record. Natural variability could add a further 1°C to that value for any individual year around 2100. Of course, natural variability could also produce a year cooler than the long-term mean. This emphasises that there will always be individual years that are up to 1°C or so warmer than the average over the surrounding period. It is this extreme that communities of the future will have to adapt to. The same reasoning applies to trends in precipitation and other climate elements.

3.2 Variability of current climate, extremes and natural oscillations

3.2.1 Climate variability and natural oscillations

New Zealand's climate varies naturally with fluctuations in the prevailing westerlies and in the strength of the subtropical high-pressure belt. Local climate changes often have a strong spatial pattern imposed on them by interactions between the circulation and the southwest/northeast alpine ranges. Many of the circulation fluctuations that affect New Zealand are short-lived or random, but other changes are associated with large-scale patterns over the Southern Hemisphere or Pacific Ocean. A number of key natural oscillations operate over timescales of seasons to decades. This section focuses particularly on the El Niño-Southern Oscillation (operating at the interannual timeframe) and the Interdecadal Pacific Oscillation (which persists in one phase for two or three decades).

Other factors that affect New Zealand's climate are large volcanic eruptions in the tropics (leading to cooling for a year or more), and possibly solar variations over a range of timescales. On the extremely long timescale of thousands of years, there are the well-documented ice age cycles caused by systematic and predictable variations in the earth's orbit, but these do not concern us here.[31] On timescales shorter than one year, the only significant oscillation affecting New Zealand is the Antarctic Oscillation (also known as the High Latitude Mode).[32] This oscillation appears to change sign with very little predictability. Recent work has identified a

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[31] The issue is sometimes raised that scientists in the 1970s were predicting an "impending" ice age. Hays et al (1976) predicted a cooling trend over the next several thousand years and glacial conditions in 20,000 years time. However, this log-term cooling was predicted specifically in the absence of human perturbation of the climate system.

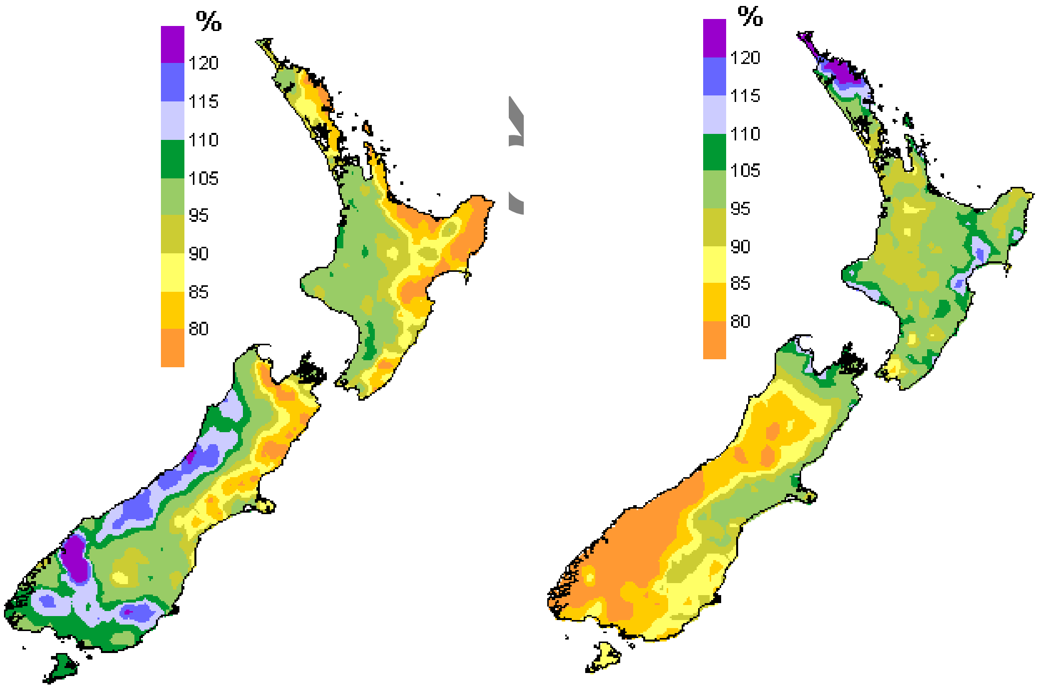
[32] First described by Kidson (1988).

long-term trend towards a stronger positive phase in the Antarctic Oscillation, meaning stronger westerlies at 50° south), which has been tentatively related to stratospheric ozone depletion.[33] This trend also appears to be reproduced in climate model studies.[34]

The Southern Oscillation, or more generally the El Niño-Southern Oscillation (ENSO), is a tropical Pacific-wide oscillation that affects pressure, winds, sea-surface temperature (SST) and rainfall. In the El Niño phase, the easterly trade winds weaken and SSTs in the eastern tropical Pacific can become several degrees warmer than normal. There is a systematic eastward shift of convection out into the Pacific. Australia then experiences higher pressures and droughts, whereas New Zealand experiences stronger than normal southwesterly airflow. This generally results in lower seasonal temperatures for New Zealand, and drier conditions in the northeast of the country. The La Niña phase is essentially the opposite in the tropical Pacific, and New Zealand experiences more northeasterly flows, higher temperatures, and wetter conditions in the north and east of the North Island. Pressures tend to be higher than normal over the South Island, and this can lead to drought conditions in the south. Thus, drought can occur in New Zealand in both El Niño and La Niña phases. Figure 3.2 shows typical rainfall anomalies in New Zealand associated with El Niño and La Niña summers.

Figure 3.2: Rainfall anomalies (in %) averaged over summer (December–February) seasons

El Niño (nine summers 1957/58 to 1997/98) **La Niña (nine summers 1949/50 to 1999/2000)**



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[33] Thompson and Solomon (2002).

[34] Cai et al (2003).

Figure 3.3: Time series of Southern Oscillation Index (upper panel) and Interdecadal Pacific Oscillation (lower panel) from 1920 to 2000

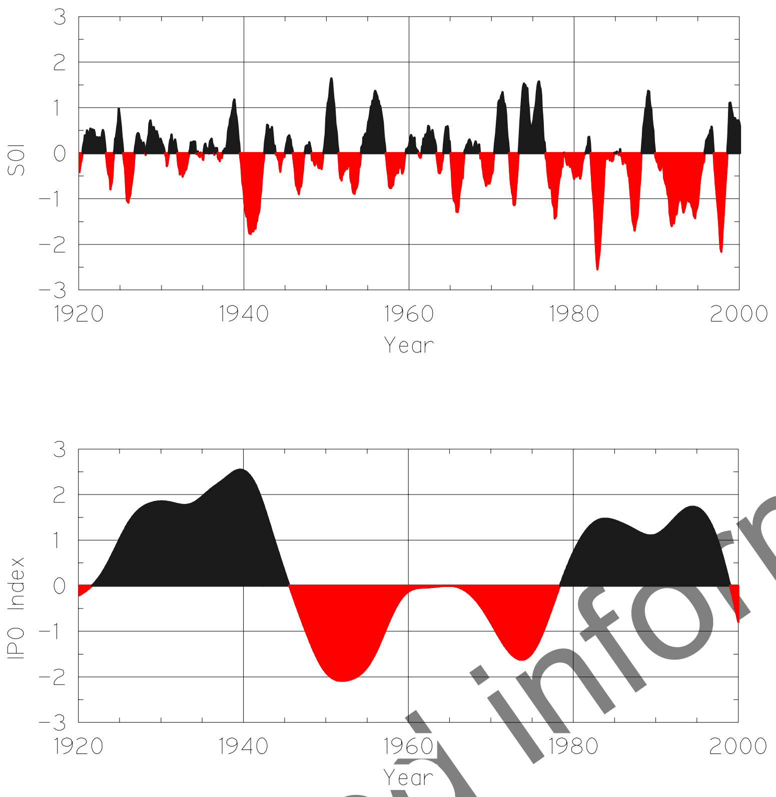

Figure 3.3 (upper panel) shows a time series of the Southern Oscillation Index (SOI), a common measure of the intensity and state of ENSO events derived from the pressure difference between Tahiti and Darwin. Persistence of the SOI below about –1 coincides with El Niño events, and periods above +1 with La Niña events. Because the tropical Pacific SST anomalies persist for up to a year, there is substantial predictability in how ENSO events affect New Zealand's climate, and there has been considerable research to identify local impacts.[35] NIWA's seasonal climate outlooks routinely make use of the results of such research.[36] The ENSO cycle varies between about three and seven years and there is large variability in the intensity of individual events. An increase in the frequency of El Niño events occurred between 1978 and 1998, and there has been much debate about whether or not this is a consequence of global warming.[37]

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[35] For example, Gordon (1986), Mullan (1995).

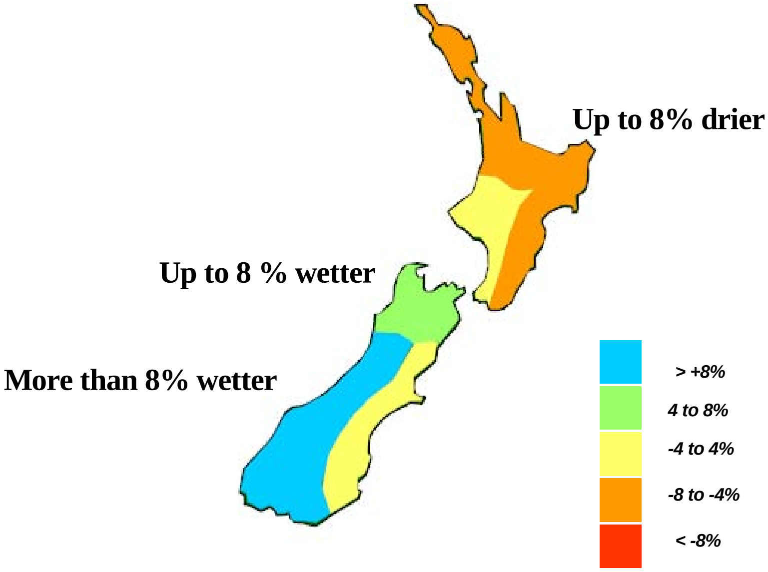
[36] See http://www.niwa.co.nz/ncc/

[37] Trenberth and Hoar (1996).

Another possible explanation for increased El Niño activity in the last two decades is low frequency natural variability in climate. The Interdecadal Pacific Oscillation (IPO) has been shown to be associated with decadal climate variability over parts of the Pacific Basin,[38] and to modulate interannual ENSO climate variability over Australia[39] and New Zealand.[40] A time series of the IPO, derived from a UK MetOffice analysis of global SST patterns is shown in Figure 3.3 (lower panel). Three phases of the IPO have been identified during the 20th century: a positive phase (1922–44), a negative phase (1946–77) and another positive phase (1978–98). The pattern associated with the positive phase is higher SSTs in the tropical Pacific (more El Niño-like) and colder conditions in the North Pacific. Around New Zealand the SSTs tend to be lower, and westerly winds stronger.

We therefore see long-lived fluctuations in New Zealand climate, both rainfall and temperature, that coincide with IPO variations. The increase in New Zealand temperatures around 1950 seen in Figure 3.1a coincides with the change from positive to negative phase IPO in Figure 3.3. The switch from negative to positive IPO in the late 1970s coincides with significant rainfall changes. Figure 3.4 maps annual rainfall changes between negative and positive IPO periods centred on 1978, and Figure 3.5 shows the corresponding time series for the southwest part of New Zealand. In the later (positive IPO) period, rainfall increased in the southwest of the South Island, but decreased in the north and east of the North Island, relative to the earlier (negative IPO) period.

Figure 3.4: Percentage change in average annual rainfall for 1978 to 1998 compared to the previous 21 years



Note: In 1978–98 the IPO was in its positive phase, compared to preceding 21 years, when the IPO was negative. Any local rainfall response due to global warming would also be contained within this pattern of trend, which applies to about 40 years at the end of the 20th century.

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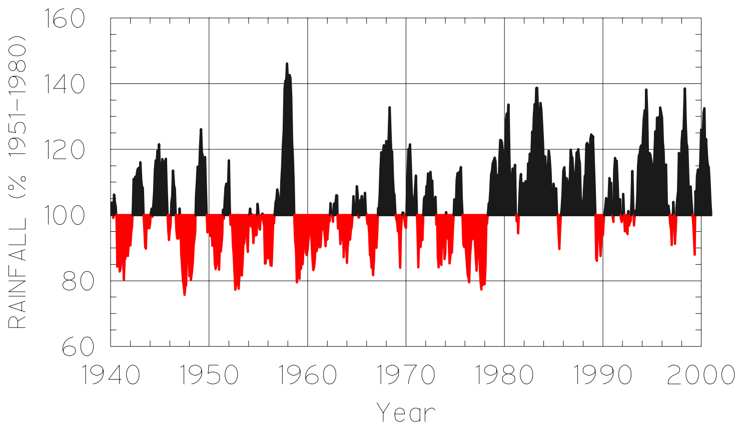
[38] Mantua et al (1997).

[39] Power et al (1999).

[40] Salinger et al (2001).

Figure 3.5: Annual rainfall (as a percentage of that between 1951 and 1980) for the southwest part of the South Island



Note: This time series applies to the area shaded blue in Figure 3.4.

Two main circulation changes affecting New Zealand in the period 1930–94 have been identified as occurring around 1950 and 1975.[41] The period 1930–50 was one of more south to southwest flow. Temperatures in all regions were lower in this period. Wetter conditions occurred in North Canterbury, particularly in summer, and drier conditions in the north and west of the South Island. In the period 1951–75 (corresponding approximately with the negative IPO phase), there was increased airflow from the east and northeast, and temperatures in all regions increased. Conditions became wetter in the north of the North Island, particularly in autumn, and drier in the southeast of the South Island, particularly in summer. From 1976 onwards, west to southwest flow was more frequent, with little additional warming relative to the 1951–75 period. There were significant rainfall trends, with summers becoming drier in the east of the North Island and wetter in the southeast of the South Island, and winters becoming wetter in the north of the South Island.[42]

What are the implications for future climate of a shift in the IPO phase? Analysis of the latest sea temperature data suggests that another negative IPO phase is under way, although some scientists consider it still premature to make such a claim. If the IPO has returned to the negative phase, then more La Niña (and less El Niño) activity could be expected compared to the 1978–98 period, together with a period of higher temperatures for New Zealand. Weaker westerlies are also likely, along with an implied weakening in the west-east rainfall gradient across the country. This would act to weaken the otherwise-projected anthropogenic trend of increasing westerlies for perhaps the next 20 to 30 years or so. Subsequently, after a switch back to a positive IPO again, the westerly influence would be accentuated.

At this stage, it is uncertain to what extent the IPO index represents a predictable interdecadal signal. Higher frequency natural climate variations, such as ENSO, are also not predictable very far in advance. For this reason, it is not feasible to extrapolate natural variations out to 2100.

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[41] Salinger and Mullan (1999).

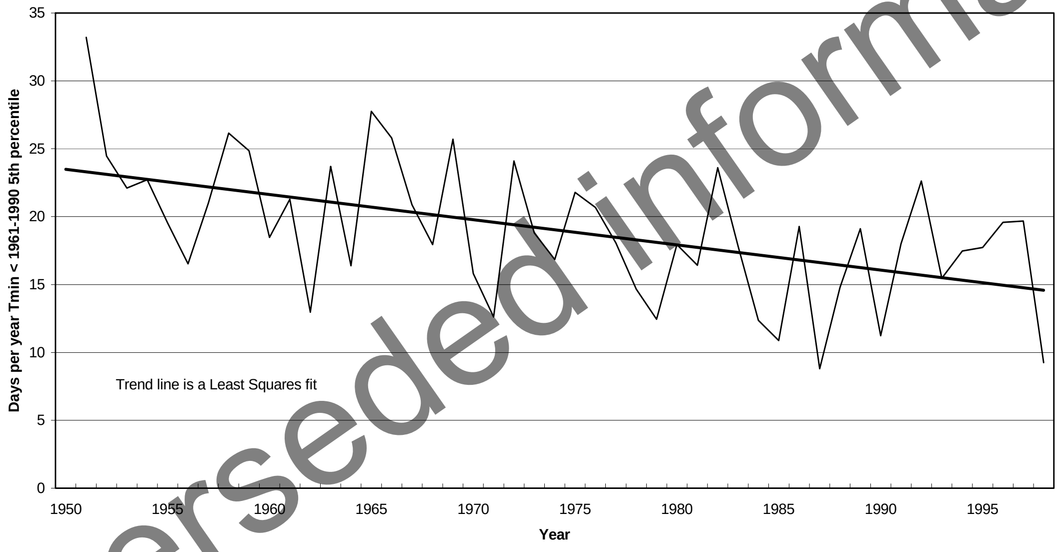
[42] Mullan et al (2001b).

3.2.2 Variability of extremes

Trends in New Zealand's daily temperature and rainfall extremes over the period 1951–98 have been calculated.[43] Some of the computed changes (such as a decrease in frequency of frosts) are in agreement with global climate model projections, but most of the observed past changes had marked temporal variations and could be related qualitatively to regional decadal circulation changes as outlined in 3.2.1 above.

Higher mean temperatures obviously increase the probability of extreme warm days and decrease the probability of extreme cold days. The IPCC also notes that climate models forecast a decrease in diurnal temperature range at many locations;[44] that is, the night-time minimum increases faster than the day-time maximum. There is clear evidence of a decreasing number of frost days in the past record at many New Zealand sites, as can be seen in Figure 3.6. The evidence for increasing numbers of very warm days is less clear, with regionally varying patterns that can be related instead to circulation fluctuations.

Figure 3.6: New Zealand nationally-averaged frequency of days per year with daily minimum temperature below the 1961–1990 5th percentile



Note: This calculation has been undertaken over the period 1951–98 separately over 21 sites, including outlying islands, and then aggregated to produce this figure. The straight trend line is a least squares fit to the annual values. The 5th percentile of daily minimum temperature at any location is that minimum temperature for which only 5% of days are colder over the reference period (in this case 1961–1990). Figure taken from Salinger and Griffiths (2001).

Historical changes in New Zealand's extreme rainfall have also been documented.[45] The variations in extremes were quantified by measures such as the annual 95-percentile rainfall amount, or number of days per year with rain exceeding the long-term mean 95-percentile. In some places (notably the West Coast and central Otago), the pattern of variations seems to coincide with the IPO shift around 1978, but elsewhere there is no obvious relationship.

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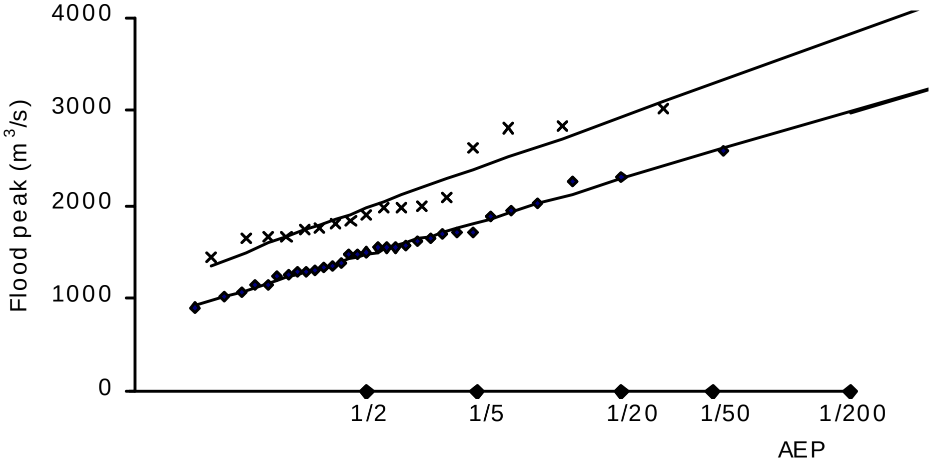
[43] Salinger and Griffiths (2001).

[44] Cubasch et al (2001).

[45] Salinger and Griffiths, ibid.

Historical changes in extreme river flows, both very low flows and floods,[46] have shown very marked changes in the frequency of extreme flows with the phase of the IPO in some parts of New Zealand. A decrease in flood size has occurred since 1978 in the Bay of Plenty, and increases in flood size have occurred in the South Island for most rivers with headwaters draining from the main divide of the Southern Alps and in Southland. An example is given in Figure 3.7, which shows an analysis of flood return periods for Lake Te Anau. A high flow with an estimated return period of 50 years during 1947–77 (a period of negative phase IPO, the lower line in the figure) has a return period of approximately seven years during 1978–94 (a period of positive phase IPO, upper line).

Figure 3.7: Flood frequency analysis for the Lake Te Anau three-day annual maxima for 1947–77 (lower line) and 1978–94 (upper line)



Note: AEP is annual exceedance probability. The fitted lines are Gumbel, Extreme Value Type 1, distributions fitted using Probability Weighted Moments. Figure from McKerchar and Henderson (2003).

3.2.3 Variability of sea level

Observations dating back to the early to mid-19th century show that sea level is rising around New Zealand. In Wellington, the historic rate of rise has been around 1.7 mm/year, or approximately 0.2 metres over the past 100 years up to 1988.[47] The average of 1.7 mm/year across New Zealand is based on analysis of tide-gauge data from the four main ports (Auckland, Wellington, Lyttelton, and Dunedin). This value also lies midway in the range of estimated global sea-level rise of between 1 and 2.5 mm/year since the early 1800s.

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 is predicting a slowly increasing acceleration over the next 50 years and beyond.

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[46] McKerchar and Henderson (2003).

[47] Hannah (1990).

The IPO variation, which spends 20 to 30 years in each phase, appears to have changed around 1998 or 1999 to a negative phase. This is likely to bring more balance between El Niño and La Niña episodes and show a quicker rate of sea-level rise than that experienced over the previous positive phase of IPO from 1976 to 1998. This pattern of more rapid sea-level rise during negative phases of the IPO has been demonstrated from the Port of Auckland tide-gauge record.[48] Other records show that a similar trend is occurring around the southern North Island, in which case the next 20 to 30 years should see a faster rise in sea level than the mean long-term trend of 1.7 mm/yr. This local acceleration of sea-level rise is irrespective of any changes in the rate of sea-level rise attributable to global warming.

3.3 Comparison of projected climate changes with current variability

Figures 3.1, and 3.3 to 3.5, give some feel for the magnitude of current climate variability of New Zealand's temperature and rainfall. The national-average temperature can vary by up to about 1°C from year to year, and more than this on a seasonal timescale. The long-term temperature trend, much of which is very likely to be anthropogenic during the second half of the 20th century, is about 0.6°C over the 80-year period shown in Figure 3.1. This long-term trend is mid-way between the ranges of warming projected for the 2030s (as can be seen from Table 2.1 and Figure 3.1b). The warmest individual years in the current climate have temperatures lying near the upper end of the projected mean (climatological) warming for the 2030s. Projected temperatures for the mid to high range of the 2080s are well outside the values experienced by New Zealand in the 20th century.

The current seasonal rainfall anomalies in Figure 3.3 are at least 20% wetter or drier than the long-term average. Figure 3.3 is a composite over nine El Niño summers, and therefore localised extremes for individual events will be larger. These seasonal anomalies seem to be comparable to the projected ranges for the 2030s of Table 2.3. So areas that currently have problems with water resources in extreme years could see this become 'the norm' by the 2030s, depending on the direction of projected rainfall change for their region, and which emissions scenario and model simulation turns out to be closest to reality.

Tables 3.1 and 3.2 have been prepared as a further guide to the context to the projected changes in Figures 2.1 to 2.6 and Tables 2.1 to 2.4. Tables 3.1 and 3.2 show the observed range in temperature and precipitation, respectively, over the period 1930 to 2002, for one key climate station within each region. To be consistent with the approach for the projections (that is, for future 30-year periods), the observed data were averaged over moving 30-year periods (that is, for 1930–59, 1931–60, 1973–2002). The extreme anomalies relative to the 1971–2000 base climate were extracted for each site and season, and are listed in Table 3.1 and 3.2.

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[48] Tait et al (2002). See also the Coastal Guidance Manual.

Table 3.1: Historical observed ranges in seasonal and annual mean temperature (in °C), for a key station within each regional council area

Station start	Summer/Tr	Autumn/Tr	Winter/Tr	Spring/Tr	Annual/Tr
Kaitaia (1943)	-0.3 to 0.0	-0.1 to 0.0	-0.2 to 0.0	-0.1 to 0.0	-0.1 to 0.0
Mangere	-0.8 to 0.0 +	-0.4 to 0.0	-0.6 to 0.0 +	-0.6 to 0.0 +	-0.6 to 0.0 +
Ruakura	-0.7 to 0.0 +	-0.6 to 0.0 +	-0.6 to 0.0 +	-0.6 to 0.0 +	-0.6 to 0.0 +
Rotorua	-0.5 to 0.0 +	-0.6 to 0.1 +	-0.7 to 0.0 +	-0.4 to 0.1	-0.5 to 0.0 +
New Plymouth	-0.0 to 0.0 +	-0.6 to 0.0 +	-0.6 to 0.0 +	-0.7 to 0.0 +	-0.7 to 0.0 +
Palmerston North	-0.7 to 0.0 +	-0.6 to 0.0 +	-0.7 to 0.0 +	-0.5 to 0.0	-0.6 to 0.0 +
Napier	-1.1 to 0.1 ++	-0.9 to 0.1 +	-1.1 to 0.1 +	-1.1 to 0.1 +	-1.0 to 0.1 +
Gisborne (1938)	-0.5 to 0.0 +	-0.3 to 0.0	-0.2 to 0.0	-0.3 to 0.0	-0.3 to 0.0
Kelburn	-0.5 to 0.0 +	-0.5 to 0.0	-0.7 to 0.0 +	-0.3 to 0.0	-0.5 to 0.0
Appleby	-0.4 to 0.0	-0.3 to 0.0	-0.4 to 0.0	-0.3 to 0.0	-0.3 to 0.0
Blenheim (1933)	-0.3 to 0.0	-0.3 to 0.0	-0.5 to 0.0 +	-0.3 to 0.0	-0.3 to 0.0
Hokitika	-0.6 to 0.0 +	-0.4 to 0.0	-0.5 to 0.0	-0.4 to 0.0	-0.4 to 0.0
Lincoln	-0.4 to 0.2	-0.5 to 0.0 +	-0.6 to 0.0 +	-0.2 to 0.1	-0.4 to 0.0
Queenstown	-1.0 to 0.0 ++	-0.8 to 0.0 +	-0.5 to 0.1 +	-0.6 to 0.0 +	-0.7 to 0.0 +
Invercargill	-0.6 to 0.0 +	-0.6 to 0.0 +	-0.6 to 0.1 +	-0.4 to 0.0	-0.6 to 0.0 +

Note: The period covered is 1930–2002 unless otherwise noted. Ranges are relative to the 1971–2000 climatology. The symbol under column 'Tr' shows the sign of the linear trend (positive or negative, as appropriate) if the trend is at least 0.5°C; a double symbol is used if at least 1.0°C.

A linear trend over the period was also calculated, and large trends indicated alongside the observed range (+ for increasing trend, – for decreasing). The largest warming trends in Table 3.1 occur for North Island sites, especially in summer and winter. For precipitation in Table 3.2, there is a tendency for a decreasing trend in summer, but an increasing trend in spring for the majority of sites listed. For most sites, the observed range is again comparable to the projected range in the 2030s of Table 2.3.

Table 3.2: Historical observed ranges in seasonal and annual mean precipitation (in %, relative to 1971–2000 climatology) for a key station within each regional council area

Station start	Summer/Tr	Autumn/Tr	Winter/Tr	Spring/Tr	Annual/Tr
Kaitaia	-2 to 11 –	-2 to 17 –	-5 to 1	-4 to 2	-1 to 4
Mangere	-2 to 15 –	-3 to 12	-3 to 4	-10 to 0 +	-1 to 4
Ruakura	-2 to 14 +	-4 to 9	-3 to 5	-4 to 3	-3 to 5
Rotorua	-1 to 19 –	-3 to 18 –	-7 to 2	-8 to 5 +	-2 to 8
New Plymouth	-2 to 19 ––	-9 to 0 +	-1 to 9 –	-9 to 1	-3 to 4
Palmerston North	-2 to 25 ––	-6 to 1	-1 to 8 –	-9 to 1	-1 to 5 –
Napier	-5 to 10 –	-8 to 3	-6 to 5	-15 to 0 +	-5 to 2
Gisborne (1938)	-2 to 16	-11 to 4	-2 to 18 ––	-2 to 9	-1 to 8 –
Kelburn	-1 to 25 ––	-4 to 10	-10 to 3 +	-8 to 1 +	-2 to 5
Appleby	-12 to 3	-6 to 15 –	-8 to 1	-19 to 2 ++	-5 to 0
Blenheim	-10 to 6	-4 to 18	-14 to 2 +	-13 to 2 +	-7 to 1
Hokitika	-11 to 5	-5 to 4	-7 to 1	-12 to 2 ++	-5 to 1
Lincoln	-1 to 34 ––	0 to 41 –	-1 to 3	-1 to 14 ––	-0 to 20 ––
Queenstown	-16 to 2	-10 to 0 +	-17 to 2 ++	-12 to 2 +	-10 to 0 +
Invercargill	-15 to 3 ++	-9 to 1 +	-10 to 0	-8 to 1 +	-8 to 0 +

Note: The period covered is 1930–2002 unless otherwise noted. The symbol under column 'Tr' shows the sign of the linear trend (positive or negative, as appropriate), if the trend at least 5%; a double symbol is used if at least 10%.

3.4 Reliability of records for describing current climate

Considerable efforts have been made to homogenise temperature and rainfall records for 21 key locations around New Zealand to produce equivalent 'single-site' series of both temperature and rainfall.[49] These 21 sites are considered to have particularly high reliability, and accurately describe the current climate and past variations. Seven of these sites with the longest temperature records have been used to develop the "New Zealand" (i.e. national-average) temperature series in Figure 3.1a. For data from sites other than the 21 key locations (such as those included in Appendix Figure A3.1 and used in preparing the maps in Chapter 2), records have been carefully checked for errors, and stations with low quality records have been eliminated.

The New Zealand temperature series (Figure 3.1a) has been prepared using seven long-term sites that together have good spatial coverage of New Zealand. The sites are located at Mangere (Auckland), Masterton, Kelburn (Wellington), Appleby (Nelson), Hokitika, Lincoln (Canterbury) and Musselburgh (Dunedin).[50] These seven key locations have been used to produce the New Zealand temperature series. The linking together of records from several neighbouring sites is necessary to produce a long continuous time series, either because observation stations are closed, new instrumentation and technology introduced, or to avoid contamination by "urban warming". The early sites for these seven locations were little urbanised. Later sites were generally in rural settings or on town fringes, or else were well-exposed.

Figure 3.8 is an example of how urban warming could affect a temperature record if it was not explicitly excluded. The rural Lincoln site, the black line, shows a relatively constant warming trend through the 20th century. The blue line shows the difference between the city record in Christchurch Botanical Gardens and Lincoln (that is, Gardens minus Lincoln temperatures). There is little trend in the blue line between 1920 and about 1955, but after that as Christchurch city grew in size there is a steady increasing trend. That is, since 1955 Christchurch city has warmed by about 0.1°C per decade faster than the outlying rural environment, which demonstrates an urban heat island effect. By using the Lincoln record, any such bias is avoided in the New Zealand temperature series.

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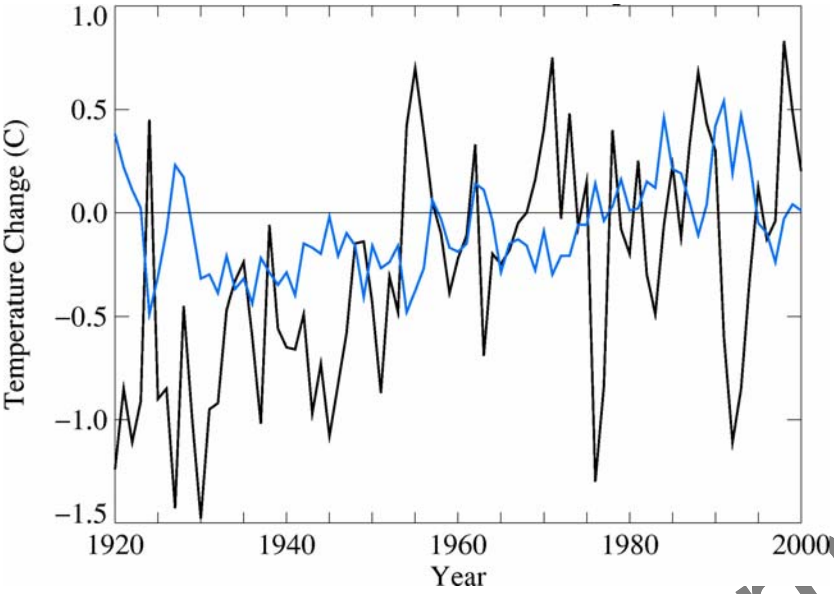
[49] The records were carefully screened for possible inhomogeneities by examining station histories (Fouhy et al 1992) to identify site changes or other possible environmental changes near the climate station site. Statistical procedures (Rhoades and Salinger 1993) were then used to homogenise the data. Neighbouring station methods, as well as other techniques, were used to evaluate the significance of, and make adjustments for, suspected inhomogeneities.

[50] For Auckland, Albert Park records until 1958 have been used along with subsequent records from the Mangere Wastewater Treatment site on the shores of the Manukau Harbour. Essex Street in Masterton was used until 1942, when the site was relocated to Waingawa, then East Taratahi in 1991 – both outside the Masterton township. Wellington records were taken in Thorndon until 1928, and after that from the well-exposed Kelburn site. Nelson area records from 1920 are from the Cawthron Institute, and since 1932 from Appleby on the Waimea Plains. The Hokitika record is from the township to 1965, and the Airport from 1966. The Canterbury long-term record is from Lincoln College until 1971, then Broadfield near Lincoln from 1972, both of which are rural sites The long Dunedin record is from the Botanical Gardens until 1942, from Beta Street in the period 1943 to 1947, and from the Musselburgh Pumping Station from 1948.

Figure 3.8: Lincoln versus Christchurch temperature



Note: Lincoln annual mean temperature anomaly (black line), and the difference Christchurch Gardens minus Lincoln (blue line). All anomalies are relative to respective 1961–1990 climatologies.

The consistency of climate records from different sites is continually checked. For example, advanced statistical techniques have been used to identify patterns of change. If such an analysis shows up a particular station as an “outlier”, then its observational record becomes suspect and may need to be adjusted or omitted from further analyses. From these records and by these methods, broad-scale long-term climate trends and variations in New Zealand climate from the 1860s have been able to be described. From 1930 onwards a regional breakdown into spatially coherent regions from the 1930s has been used to analyse trends.[51]

The longest records[52] show a clear rise in New Zealand temperatures since the 19th century, of the order of 0.7°C since 1871. Figure 3.9 shows distinctly how minimum temperatures are increasing faster than maximum temperatures over the last 50 years. The New Zealand long-term records of land temperature also agree well with independent measurements of surrounding sea surface temperature trends. Underneath this warming trend, the more detailed analysis from 1930 shows the marked influence of the IPO circulation changes on New Zealand’s climate outlined above.

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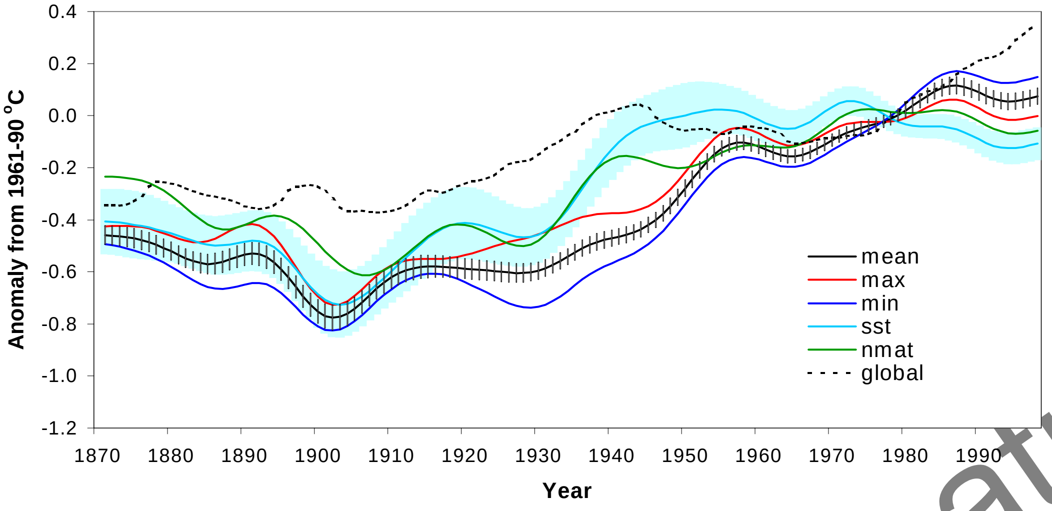
[51] Salinger and Mullan (1999).

[52] Folland et al (2003).

Figure 3.9: New Zealand smoothed temperatures 1871–1998



Note: This figure shows annual filtered composite marine and surface air temperatures for the New Zealand region, 1871–1998, compared with the 1961–90 average, using a mathematical smoothing routine with a half-amplitude of 25 years. Uncertainty bands about SST (blue shading) and the mean air temperatures (black hatching) indicate plus and minus one standard error. Trends are shown for annual maximum, mean and minimum air temperatures, sea surface temperatures and night marine air temperatures. The global surface temperature trend is indicated by a dashed line. Figure taken from Folland et al (2003).

3.5 Summary

New Zealand's climate varies substantially from year to year and from decade to decade. The long-term records are sufficiently robust to identify consistent regional patterns of change. In individual years, annual New Zealand-wide temperatures can deviate from the long-term average by up to 1°C (plus or minus), and regional precipitation can deviate by about 20% (plus or minus). The size of the deviation will depend on whether it is a La Niña or El Niño year, and also for precipitation, on geographic location (details can also vary considerably from event to event). These ENSO perturbations of the climate in individual years have amplitudes comparable to the mid-range projected changes expected over 30 to 50 years.

New Zealand also has decadal circulation and climate variations that appear to be related to the IPO. The predictability of the IPO, and how consistently it is reflected in local climate, is still an active research topic, but some cautious extrapolations can be made.

In the coming negative IPO phase (which has probably already started and could last for the next 20 to 30 years), there are likely to be reduced westerly and southwesterly winds, reduced rainfall in the southwest of the country but increased in the northeast, and an increased rate of rise in air temperature and sea-level.

These natural variations will continue to impact New Zealand climate through this century, and will be superimposed on the human-induced long-term trends. It is this combination of underlying mean climate, appropriate global warming adjustments, and natural variations, that will provide the extremes that future New Zealand society faces.