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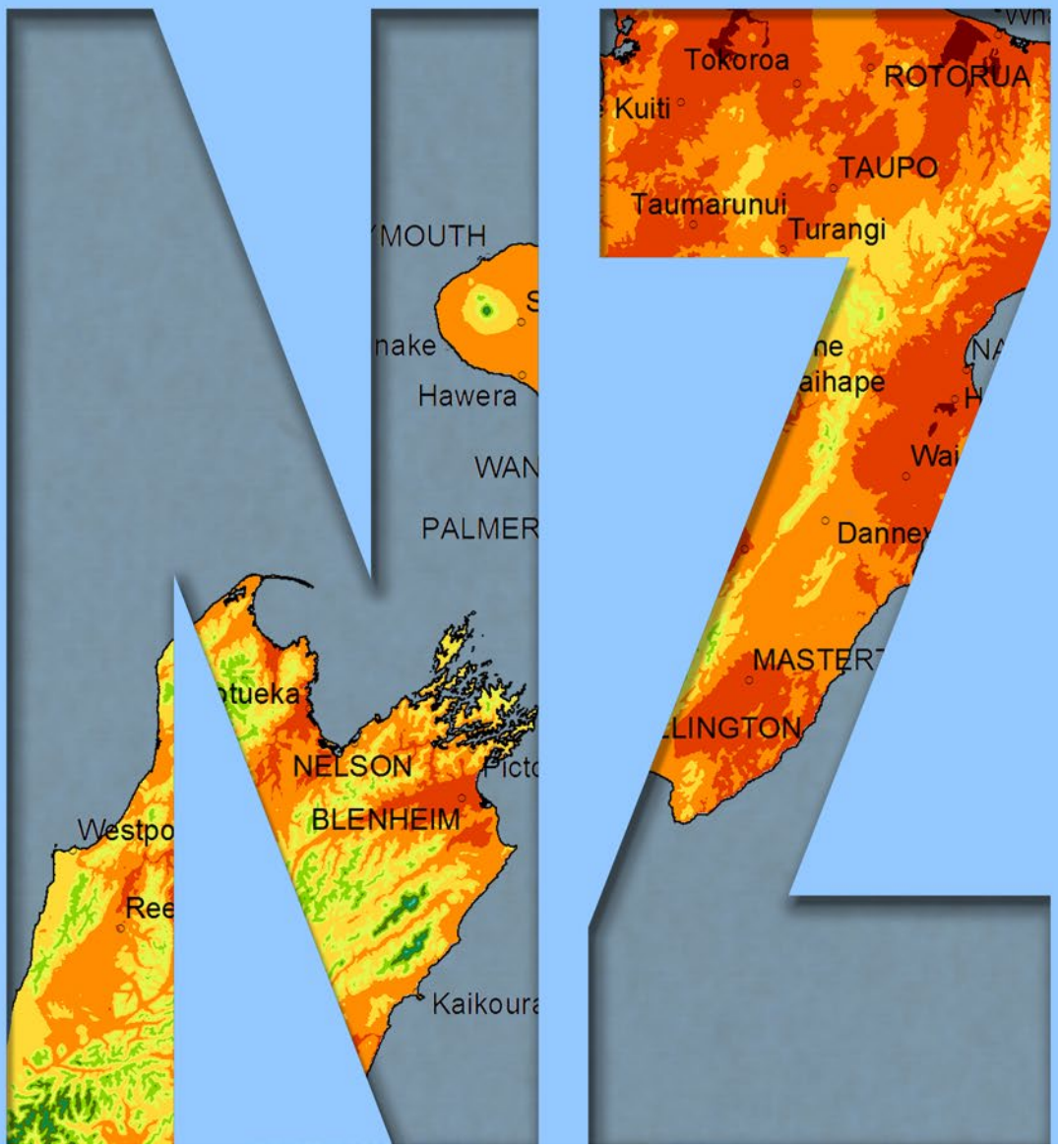
THE CLIMATE AND WEATHER OF NEW ZEALAND

1st edition

G. R. Macara



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SUMMARY

New Zealand is situated in the latitudes of prevailing westerlies and exposed coastal locations often experience strong winds, with generally lighter winds elsewhere. Rainfall is evenly distributed across the year, although late-summer and early-autumn is typically the driest time of the year, whereas the wettest months are typically observed in winter. Parts of the Southern Alps receive more than 10,000 mm of annual rainfall. Central Otago is the driest region of the country, and is sheltered from rain-bearing systems arriving from the west and north. Here, annual rainfall totals of approximately 350 mm are recorded. Dry spells of more than two weeks are quite common, particularly in eastern and inland locations. Temperatures are relatively mild throughout New Zealand, with the moderating influence of the surrounding sea resulting in a relative lack of extreme high and extreme low temperatures. Temperatures exceeding 30°C aren't especially common for most locations around the country, although they do occur reasonably frequently during summer at low elevation inland areas and in eastern parts of the country. Frosts are common in the cooler months for most of the country, however they occur rarely north of Waikato. Nelson and Marlborough are typically New Zealand's sunniest regions, while parts of the Bay of Plenty receive similarly high sunshine hours.

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INTRODUCTION

New Zealand spans latitudes 34 to 47 degrees south, and so lies within the Southern Hemisphere temperate zone. In this zone, westerly winds at all levels of the atmosphere move weather systems, which may also be either decaying or developing, eastwards over New Zealand giving great variability to its weather. These prevailing westerlies sometimes abate, and air from either tropical or polar regions may reach New Zealand with heavy rainfalls or cold showery conditions, respectively. New Zealand is oriented roughly southwest to northeast (Figure 1), with most weather in the country arising from its exposure to the prevailing westerly airflows.

The main divide of the Southern Alps acts as a barrier to these prevailing westerlies and has a profound effect on the climate of the South Island, separating New Zealand's wettest region (the West Coast) from New Zealand's driest region (Central Otago). No area of New Zealand, other than Central Otago, has a climate where the hot dry summers and cold dry winters approximate a semi-arid 'continental' climate. Other eastern regions sheltered from these westerly airflows are also relatively dry, such as Canterbury, Marlborough, and Hawke's Bay. In coastal areas of New Zealand, conditions are tempered by relatively mild sea surface temperatures nearby. As a result, both diurnal and seasonal temperature variations are lower at coastal locations compared with inland locations.

Note that all numbers given in the following tables are calculated from the 1981–2010 normal period (a normal is an average or estimated average over a standard 30-year period), unless otherwise stated. For this publication, the locations selected are associated with metropolitan areas and/or to provide good coverage

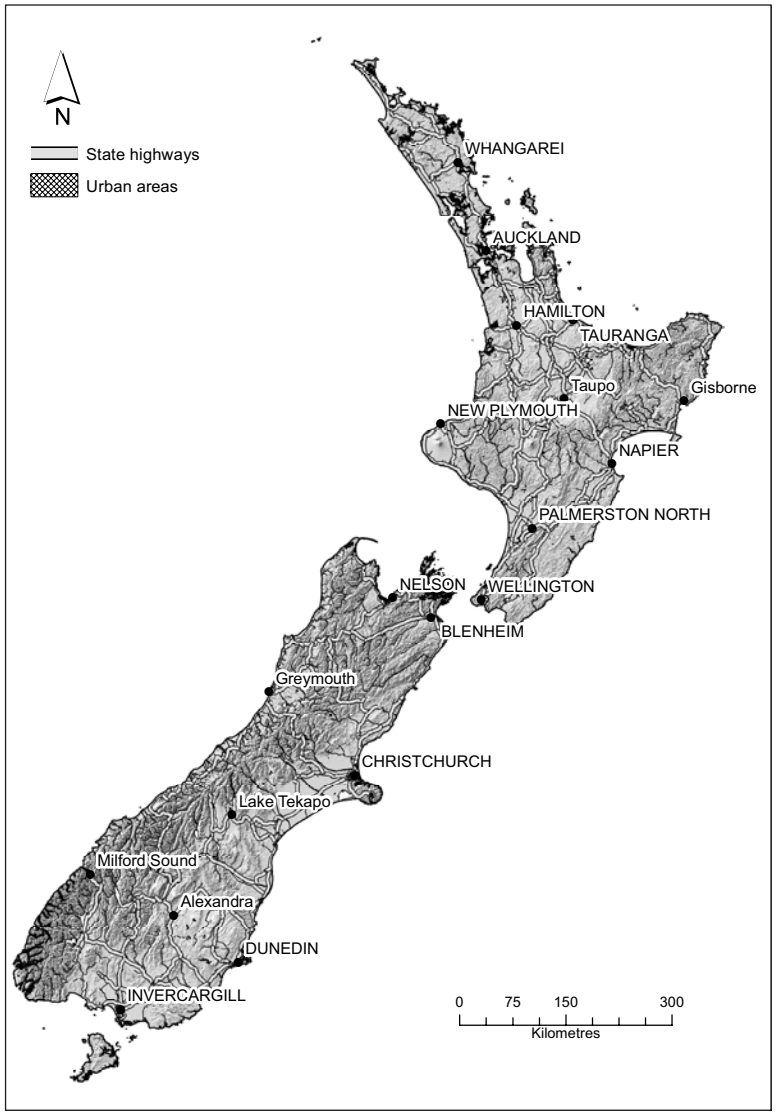

Figure 1. Map of New Zealand, showing the places mentioned in this publication.

across the country. There are many more sites with long records of climate data available, much of which has been summarised in the regional weather and climate publications.

TYPICAL WEATHER SITUATIONS IN NEW ZEALAND

New Zealand lies in the zone of mid-latitude westerlies where a succession of depressions (lows) and subtropical anticyclones (highs) generally progress eastwards over the country. Often, a trough of low pressure separates two highs, and it usually contains a frontal system, which extends into one or more lows on the southern side of the highs. As the highs move east, New Zealand experiences a regular weather sequence, which has a period of about a week. The path followed by the centre of an anticyclone may be to the north of New Zealand, across the country, or occasionally to the south. The first type of track is more likely in winter and spring and the other types are more likely in summer and autumn.

It is unusual for an anticyclone to move from Australia across the Tasman Sea and out to the east without a change in its intensity, speed and direction of movement. These changes are closely related to developments in the low-pressure trough which is an unstable region where vigorous storms sometimes form. The storms are depressions which typically form in the north-west Tasman Sea. From there they tend to move in a south-east direction, growing in intensity as they move, and frequently cross or pass near the North Island. Another less frequent type of storm which affects New Zealand is the ex-tropical cyclone which forms in the south-west Tropical Pacific, usually in the months from December to April. The air in an ex-tropical cyclone is still warm and moist by the time the storm reaches New Zealand due to its long passage over tropical waters, and the resulting rainfall may be especially heavy.

The irregular topography of New Zealand, with its many mountain ranges, has a considerable influence on the weather experienced across the country. Although many different weather situations are possible in New Zealand, they tend to fall into only a few characteristic categories: (a) fine weather spells, (b) heavy rain, and (c) showery weather.

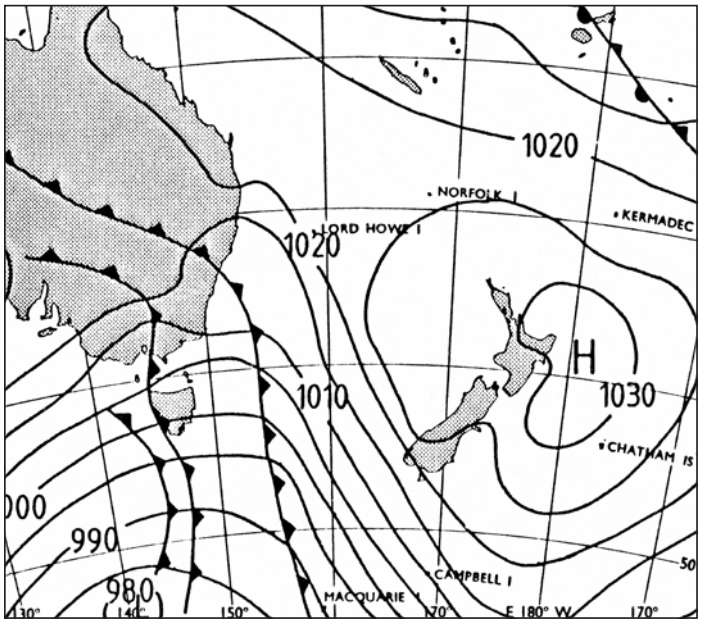

Figure 2. Mean sea level pressure analysis for 0000 hours NZST on 18 September 1982.

Fine weather spells

Prolonged spells of fine weather are usually associated with a large anticyclone moving slowly eastwards over New Zealand (Figure 2). Fine, sunny weather and light winds typically prevail over the country during such periods, although there are some exceptions. For example, fresh sea breezes can occur along coastal areas, especially during summer. Additionally, anticyclones support the development of low cloud or fog in inland parts of the country, chiefly at morning and nighttime during May to September. This low cloud usually 'burns off' during the day due to heating from the sun, but may persist throughout the day in inland valleys and basins of the South Island during the winter months. The air pressure set up shown in Figure 2 would typically result in relatively warm daytime temperatures throughout New Zealand during summer, whereas during winter temperatures would be relatively mild, with widespread morning frosts.

Heavy rain

Prolonged periods of heavy rain occur commonly when there is a large, slow-moving anticyclone east of New Zealand and a deep depression in the eastern Tasman Sea. This results in a strong northerly flow of air over New Zealand, which may be warm and moist if the air is of tropical origin. The period of 17 to 19 May 1965 (Figure 3) was typical of this type of situation. Under such circumstances, heaviest rainfall is typically recorded in western and northern parts of the North and South Islands. Heavy rain events can also occur when there is an anticyclone to the south of New Zealand, and a depression approaching to the north of the North Island (Figure 4). Easterly-northeasterly winds strengthen as the depression approaches the North Island, and areas exposed to this airflow (e.g. northern and eastern parts of the North Island) experience periods of heavy rainfall. If the low is an ex-tropical cyclone, rainfalls can be particularly heavy and often result in flooding, slips and road closures. As the depression moves farther south, northeastern parts of the South Island begin to experience heavy rain, while conditions over the North Island gradually ease. Under such circumstances, the West Coast of the South Island typically experiences dry weather, and temperatures there may be relatively warm due to the Foehn effect associated with the easterly airflow over the Southern Alps.

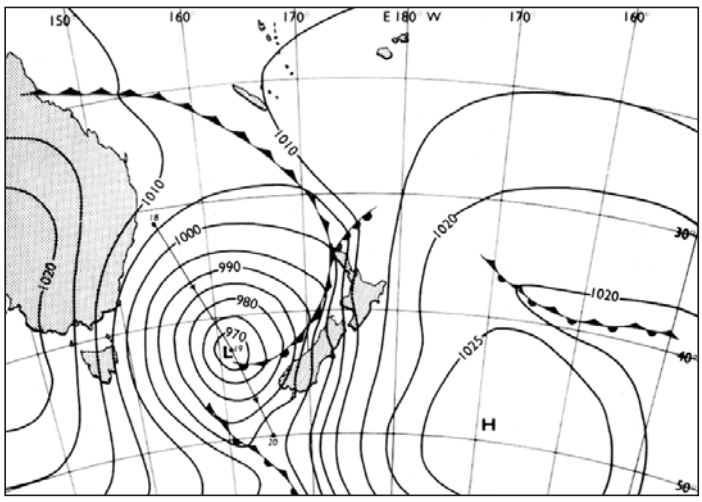

Figure 3. Mean sea level pressure analysis for 0600 hrs NZST on 19 May 1965.

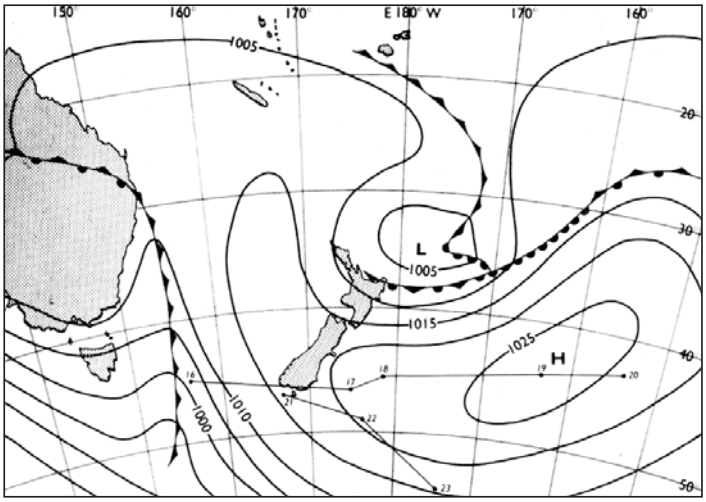

Figure 4. Mean sea level pressure analysis for 1200 hrs NZST on 19 November 1960.

Showery weather

Brief periods of showery weather in New Zealand are typically associated with the northward passage of a cold front over the country (Figure 5). Convective clouds and showers develop as the relatively cool air passes northward over relatively warm sea water. If the atmosphere is particularly unstable, thundery showers may develop, especially in southernmost parts of the South Island and western and northern parts of the North Island. In areas sheltered from the southwest airflow (e.g. Bay of Plenty and Marlborough), rainfall totals will be relatively low, and some of these areas may receive little or no rainfall. During such southwesterly airflows, temperatures will be relatively cool or cold throughout the country. In winter, snow will fall to relatively low elevations, particularly in Southland, Otago and Canterbury.

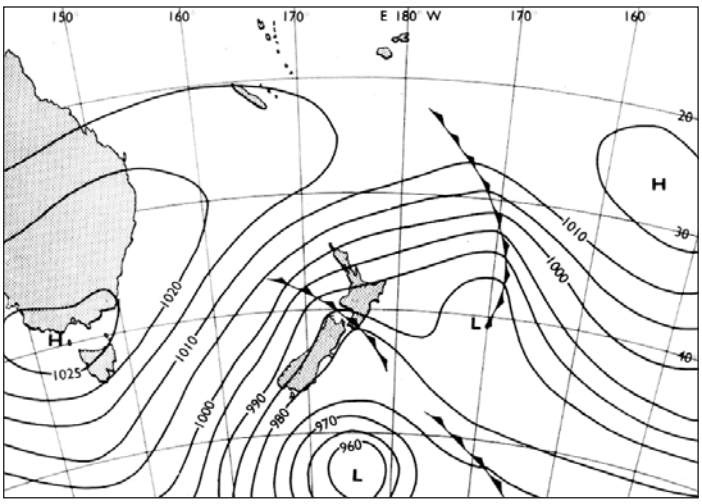

Figure 5. Mean sea level pressure analysis for 1800 hrs NZST on 26 April 1965.

CLIMATIC ELEMENTS

Wind

Wind direction over New Zealand in the zone directly above the Earth's surface may be interpreted from a mean sea level pressure (MSLP) map, following the general principle that in the Southern Hemisphere air flows in a clockwise direction around a depression (or a 'low'), and in an anticlockwise direction around an anticyclone (or a 'high'). As such, MSLP maps can be used to indicate the general wind direction at the Earth's surface. However, actual wind direction and speed at a locality is modified by the influence of friction and topography. Sea breezes develop along coastal parts of New Zealand when synoptic-scale pressure gradients are weak, and are generated by air temperatures over land becoming higher than air temperatures over the sea. These sea breezes may develop throughout the year, but are most common in summer and least common in winter. Figure 6 shows mean annual wind frequencies of surface wind based on hourly observations from selected New Zealand locations. In Wellington, winds are channelled by nearby Cook Strait, such that wind directions recorded are almost exclusively from the north-northwest and south-southeast. Invercargill is similarly influenced by nearby Foveaux Strait, with westerly winds there strengthened as they are channelled through the strait, such that most of Invercargill's strongest winds are recorded from the westerly direction. Christchurch residents will be familiar with the northeast sea breeze that develops on fine weather days, and this is the dominant wind direction recorded in the city.

Mean wind speed data (average wind speeds are taken over the 10-minute period preceding each hour) illustrate the several different wind regimes of the country (Table 1). Mean wind speeds are highest at exposed coastal locations

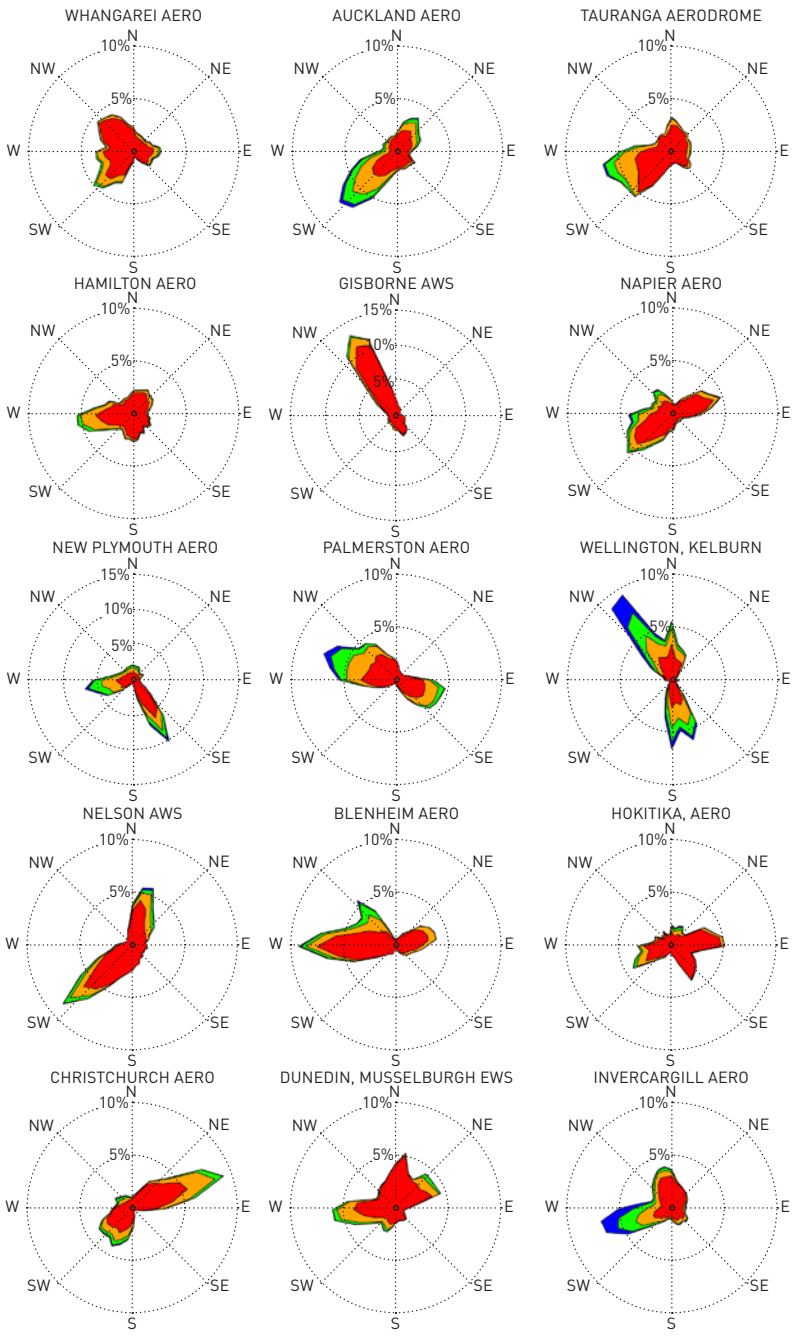

Figure 6. Mean annual wind frequencies (%) of surface wind directions from hourly observations at selected New Zealand stations. The plot shows the directions from which the wind blows, e.g. the dominant wind direction at Gisborne is from the northwest.

such as Wellington, New Plymouth and Invercargill, and lowest at inland and sheltered locations. There is notable variability in mean monthly wind speeds over the course of a year in New Zealand, where wind speeds are typically highest from around mid-spring (October) to mid-summer (January), and lowest from mid-autumn to the end of winter (April to August). Figure 7 shows the median annual average wind speed for New Zealand.

Table 1. Mean monthly and annual wind speed (km/hr).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Aero Aws	12.3	11.7	11.1	9.8	10.0	10.2	11.3	11.3	11.5	13.1	13.4	12.3	11.5
Auckland Aero	17.9	17.0	16.6	15.1	15.6	15.5	15.9	17.4	18.9	20.9	20.5	19.0	17.5
Tauranga Aero Aws	15.1	14.1	13.8	13.0	13.1	13.0	13.5	13.9	15.7	17.1	16.7	15.8	14.4
Hamilton Aws	11.0	10.3	9.8	8.8	9.3	9.7	10.3	10.8	12.1	13.4	12.7	11.9	10.7
Taupo Aws	13.4	12.5	12.5	11.5	12.3	12.6	11.6	12.5	12.8	15.1	15.2	14.3	13.0
Gisborne Aws	13.1	11.7	11.8	11.1	11.5	11.9	11.8	12.1	13.1	14.4	14.3	13.7	12.6
Napier Aero Aws	15.2	14.4	14.2	12.9	13.0	13.0	13.6	13.9	14.8	16.6	16.4	16.0	14.5
New Plymouth Aws	17.8	17.2	18.0	17.0	18.5	19.1	18.8	19.1	19.8	21.3	20.2	18.6	18.8
Palmerston North Aws	16.2	15.6	15.5	12.9	13.7	13.7	13.9	14.2	15.6	17.0	17.8	16.1	15.1
Wellington, Kelburn Aws	21.6	18.9	19.8	18.4	20.0	19.0	19.7	18.9	20.7	22.8	21.8	21.7	20.4
Nelson Aws	14.4	12.6	12.2	10.3	9.1	8.2	7.8	9.4	11.7	14.0	14.9	15.1	11.6
Blenheim Aero Aws	15.1	14.2	14.1	11.6	11.3	11.3	11.2	11.9	14.5	15.6	16.2	16.6	13.7
Greymouth Aero Ews	13.1	11.1	12.2	13.0	13.4	14.3	14.5	12.8	14.0	14.4	13.8	12.8	13.2
Christchurch Aero	17.7	16.9	15.4	13.1	12.3	11.2	11.3	13.2	14.4	16.2	17.0	17.6	14.7
Lake Tekapo Ews	16.2	13.4	12.8	11.5	11.8	11.0	11.7	11.4	14.6	16.3	16.9	14.9	13.5
Alexandra Aws	13.1	11.0	8.1	7.2	7.0	6.3	7.1	6.1	7.7	11.3	11.3	11.9	9.0
Dunedin, Musselburgh Ews	14.9	14.6	13.8	13.2	13.3	13.5	12.1	13.3	14.2	15.3	15.7	15.2	14.1
Milford Sound Aws	8.8	8.2	7.7	7.5	7.9	8.3	8.6	8.1	8.4	9.1	9.0	9.0	8.4
Invercargill Aero	19.2	17.6	17.1	16.2	15.5	14.2	12.5	13.5	17.2	19.6	20.4	18.8	16.8

Table 2. Seasonal distribution (%) of strong winds (daily mean wind speed > 30 km/hr).

	Summer	Autumn	Winter	Spring
Whangarei Aero Aws	19	15	36	30
Auckland Aero	21	19	23	36
Tauranga Aero Aws	21	16	27	37
Hamilton Aws	17	10	29	44
Taupo Aws	17	26	27	30
Gisborne Aws	16	18	16	50
Napier Aero Aws	23	17	26	34
New Plymouth Aws	21	23	24	31
Palmerston North Aws	26	18	19	37
Wellington, Kelburn Aws	18	23	30	29
Nelson Aws	30	21	13	36
Blenheim Aero Aws	36	17	10	37
Greymouth Aero Ews	18	26	30	26
Christchurch Aero	28	21	16	35
Lake Tekapo Ews	28	15	18	39
Alexandra Aws	22	11	35	32
Dunedin, Musselburgh Ews	26	24	21	29
Milford Sound Aws	10	25	35	30
Invercargill Aero	28	24	16	32

Table 2 gives the seasonal distribution of strong winds (defined as having a daily mean wind speed of greater than 30 km/hr). For example, of all strong winds recorded at Hamilton, 44% occur in spring. Note that although a similar seasonal distribution of strong winds may be observed between different locations, the actual number of strong wind days per season at those locations may be considerably different. For example, Dunedin and Invercargill both observe 24% of their annual strong wind days during autumn. However, the total number of strong wind days recorded during autumn are 3 in Dunedin, and 12 in Invercargill. Spring is typically the windiest season throughout the country.

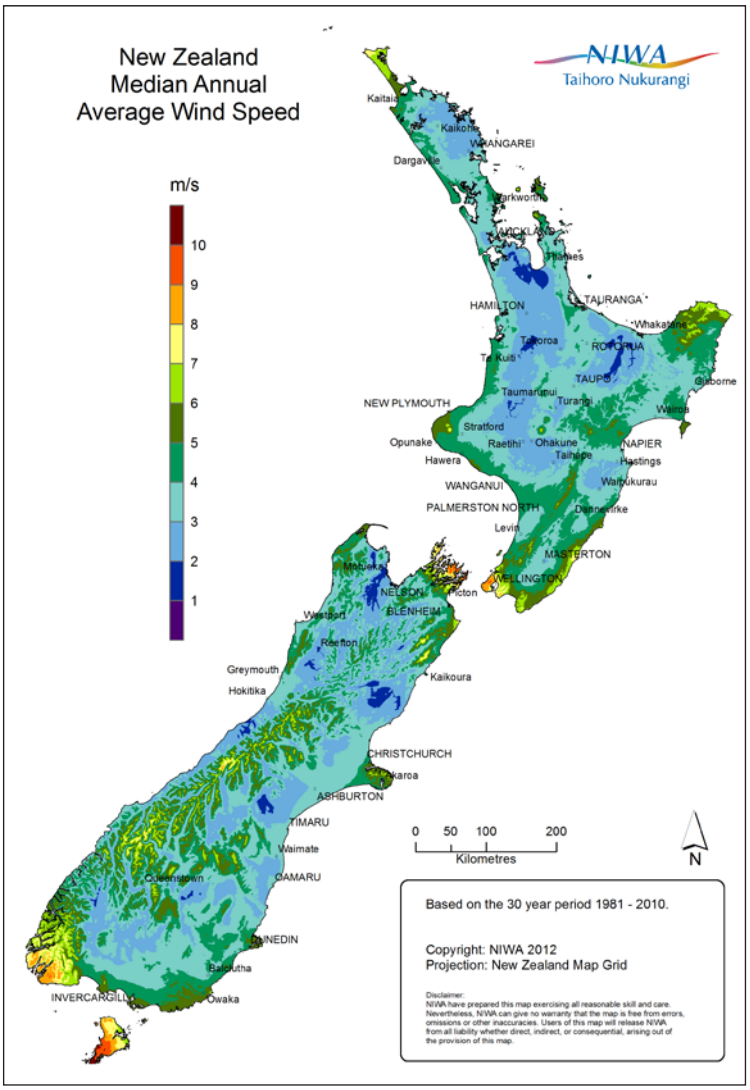

Figure 7. New Zealand median annual average wind speed, 1981–2010.

Diurnal variation in wind speed is well-marked, with highest wind speeds occurring mid-afternoon before decreasing overnight. This is because heating of the land surface is most intense during the day, and stronger winds aloft are brought down to ground level by turbulent mixing. Cooling at night generally restores a lighter wind regime. Table 3 gives average wind speeds at three-hourly intervals for selected locations.

Table 3. Mean wind speed (km/hr) at three-hourly intervals of the day.

	0000	0300	0600	0900	1200	1500	1800	2100
Whangarei Aero Aws	8	8	8	10	16	18	15	10
Auckland Aero	15	14	14	16	20	23	22	17
Tauranga Aero Aws	12	11	11	13	17	19	17	13
Hamilton Aws	8	7	7	9	14	16	14	9
Taupo Aws	12	10	10	11	15	16	15	14
Gisborne Aws	9	9	9	12	15	16	13	9
Napier Aero Aws	11	11	11	13	18	19	15	12
New Plymouth Aws	17	17	17	18	21	22	20	17
Palmerston North Aws	12	12	12	15	20	21	17	13
Wellington, Kelburn Aws	18	17	17	18	21	22	21	19
Nelson Aws	8	8	7	9	16	20	16	10
Blenheim Aero Aws	11	10	10	12	17	20	16	12
Greymouth Aero Ews	13	13	13	13	14	15	14	13
Christchurch Aero	12	11	10	13	18	21	19	14
Lake Tekapo Ews	12	12	11	11	13	17	16	14
Alexandra Aws	8	7	6	6	9	12	13	10
Dunedin, Musselburgh Ews	12	12	12	13	16	18	16	14
Milford Sound Aws	8	8	8	8	8	11	10	8
Invercargill Aero	14	14	14	15	20	23	21	17

Gusty winds occur most frequently in the mountain ranges and exposed coastal locations of New Zealand. Wellington is undoubtedly the windiest city in the country, and experiences an average of 198 days per year with wind gusts exceeding 61 km/hr (33 knots). This is considerably more than Invercargill, itself considered a windy location, where on average 109 such days per year are recorded (Table 4). Maximum gusts recorded at New Zealand locations are listed in Table 5. Wellington's highest wind gust on record was 198 km/hr on 10 April 1968, and was associated with a weather system now known colloquially as The Wahine Storm. New Zealand's highest recorded wind gust is 250 km/hr, observed at Mt John (Canterbury) on 18 April 1970.

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Table 4. Mean number of days per year with gusts exceeding 61 km/hr (33 knots) and 94 km/hr (50 knots). Note 34-40 knot winds are defined as gale force on the Beaufort Scale, and 48-55 knot winds are defined as storm force.

	Days with gusts >61 km/hr	Days with gusts >94 km/hr
Whangarei Aero Aws	27	0.9
Auckland Aero	55	3
Tauranga Aero Aws	30	0.4
Hamilton Aws	21	0.4
Taupo Aws	30	0.3
Gisborne Aws	32	0.8
Napier Aero Aws	52	2
New Plymouth Aws	74	3
Palmerston North Aws	62	2
Wellington, Kelburn Aws	198	52
Nelson Aws	40	0.4
Blenheim Aero Aws	42	0.5
Greymouth Aero Ews	44	0.9
Christchurch Aero	51	1
Lake Tekapo Ews	72	5
Alexandra Aws	52	1
Dunedin, Musselburgh Ews	94	4
Milford Sound Aws	47	7
Invercargill Aero Aws	109	14

Table 5. Highest recorded wind gusts from all available data.

	Gust (km/hr)	Direction	Date
Whangarei Airport	126.0	SE	8/03/1988
Auckland Aero	146.4	S	6/09/1981
Tauranga Airport	111.2	W	24/10/1977
Hamilton Airport	111.2	W	2/08/1982
Taupo Airport	113.0	SE	9/04/1982
Gisborne Airport	137.1	W	12/09/1976
Napier Airport	129.7	W	17/05/1977
New Plymouth Airport	157.5	SE	9/04/1982
Palmerston North Airport	122.3	W	18/02/1940
Wellington, Kelburn Aws	198.2	SW	10/04/1968
Nelson Airport	139.0	SE	12/03/1975
Blenheim Airport	118.6	W	6/02/1975
Greymouth Aero Ews	140.8	E	17/04/2014
Christchurch Aero	172.3	W	1/08/1975
Lake Tekapo Ews	126.0	NW	4/10/2015
Alexandra Aws	114.9	NW	8/10/2014
Dunedin, Musselburgh Ews	140.8	W	18/11/1984
Milford Sound	157.5	NW	20/04/1994
Invercargill Airport	142.7	W	16/05/1994

Rainfall

Rainfall distribution

New Zealand's median annual rainfall is shown in Figure 8, which clearly illustrates how rainfall is affected by topography and exposure to the main rain-bearing airflows from the west. Rainfall is highest in the Southern Alps of the South Island which have both high elevation and western exposure. This is the result of orographic enhancement. Specifically, moisture-laden air masses passing over the Tasman Sea are forced to rise over the mountain range. As these air masses rise, they cool rapidly, causing the stored water vapour to condense, resulting in rainfall. The air masses continue eastwards, but they hold significantly less moisture once beyond the western ranges. Thus, there is a marked decrease eastwards in median annual rainfall in the South Island. Many areas of the North Island receive greater than 1000 mm of annual rainfall. The exception is parts of Hawke's Bay, Whanganui, Manawatu and Wairarapa which typically receive between 750 mm and 1000 mm of annual rainfall. Central Otago is New Zealand's driest region, and average annual rainfall in parts of this region are as low as 350 mm. In contrast, the western flanks of the Southern Alps frequently receive more than 10,000 mm annually. For example, Cropp River (West Coast) has recorded an annual average rainfall of 11,373 mm between 1982 and 2016.

Table 6 lists monthly rainfall normals and the percentage of the annual total for selected locations. Rainfall is evenly distributed throughout the year at all locations, although most places receive a higher proportion of their annual rainfall during winter. The variation of monthly rainfall is shown in Figure 9. The 10th percentile, 90th percentile, and mean rainfall values for each month are shown along with maximum and minimum recorded values for New Zealand's main centres.

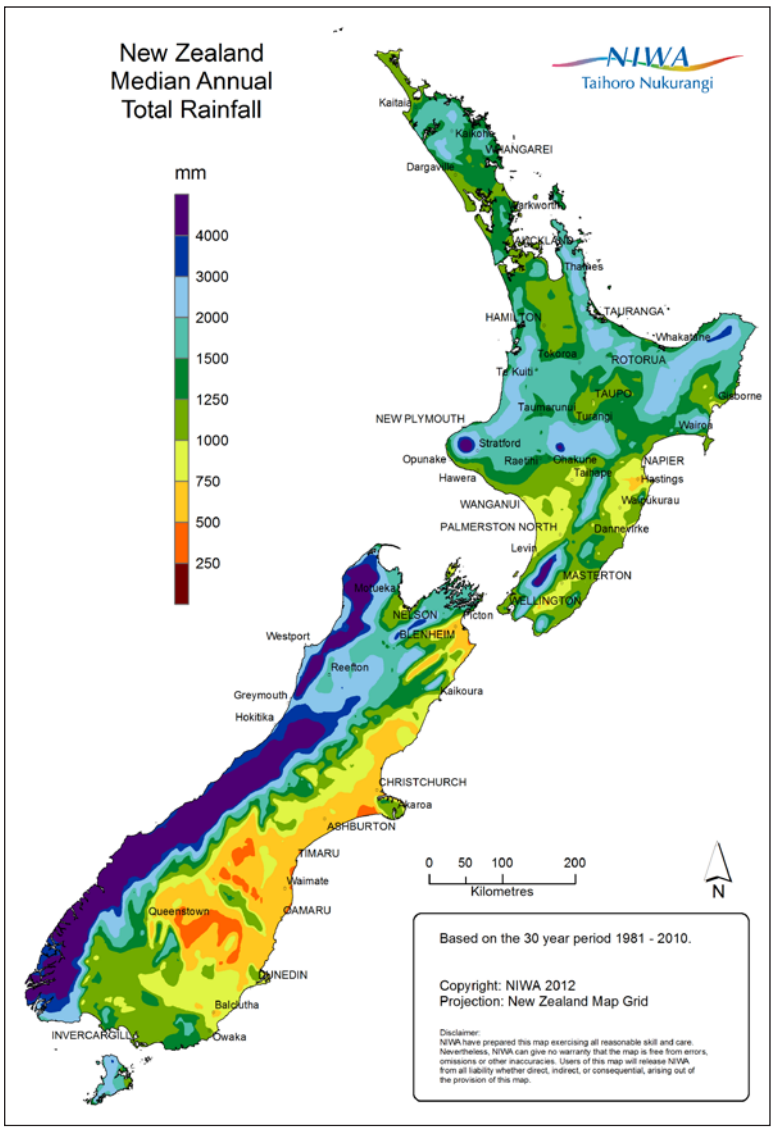


Figure 8. New Zealand median annual total rainfall, 1981–2010.

Table 6. Monthly and annual rainfall normal (a; mm), and monthly distribution of annual rainfall (b; %).

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Aero Aws	a	78	98	117	103	110	132	169	127	110	84	76	97	1300
	b	6	8	9	8	8	10	13	10	8	6	6	7	
Auckland Aero	a	66	71	75	85	110	108	133	111	91	94	72	87	1101
	b	6	6	7	8	10	10	12	10	8	9	7	8	
Tauranga Aero Aws	a	78	86	97	121	110	115	129	110	85	89	74	95	1189
	b	7	7	8	10	9	10	11	9	7	7	6	8	
Hamilton Aws	a	82	74	84	88	107	126	129	120	101	98	89	105	1202
	b	7	6	7	7	9	10	11	10	8	8	7	9	
Taupo Aws	a	78	69	65	68	75	93	96	87	82	86	68	94	960
	b	8	7	7	7	8	10	10	9	8	9	7	10	
Gisborne Aws	a	59	68	93	97	96	105	131	78	72	70	63	57	987
	b	6	7	9	10	10	11	13	8	7	7	6	6	
Napier, Nelson Pk	a	47	54	67	68	75	82	109	61	58	60	52	54	786
	b	6	7	8	9	10	10	14	8	7	8	7	7	
New Plymouth Aws	a	93	96	98	116	126	148	136	127	120	125	104	121	1409
	b	7	7	7	8	9	11	10	9	9	9	7	9	
Palmerston North Aws	a	55	71	55	60	74	92	85	69	85	84	75	96	900
	b	6	8	6	7	8	10	9	8	9	9	8	11	
Wellington, Kelburn Aws	a	75	71	85	85	111	138	137	116	98	118	98	83	1215
	b	6	6	7	7	9	11	11	10	8	10	8	7	
Nelson Aero	a	77	64	71	81	82	92	78	82	85	87	78	84	959
	b	8	7	7	8	9	10	8	9	9	9	8	9	
Blenheim Aero Aws	a	49	49	46	53	60	72	75	61	66	66	55	58	711
	b	7	7	6	7	8	10	11	9	9	9	8	8	
Greymouth Aero	a	209	161	177	195	197	238	198	192	209	225	197	252	2452
	b	9	7	7	8	8	10	8	8	9	9	8	10	
Christchurch Aero	a	36	43	46	44	58	58	65	62	41	49	46	47	594
	b	6	7	8	7	10	10	11	10	7	8	8	8	
Lake Tekapo	a	44	36	49	45	57	60	50	58	50	50	41	52	591
	b	7	6	8	8	10	10	8	10	9	8	7	9	
Alexandra, Bridge Hill	a	48	36	29	24	28	31	19	23	19	31	31	47	363
	b	13	10	8	6	8	9	5	6	5	8	8	13	
Dunedin, Musselburgh Ews	a	73	68	64	51	65	58	57	56	48	62	56	80	738
	b	10	9	9	7	9	8	8	8	7	8	8	11	
Milford Sound	a	722	455	595	533	597	487	424	464	551	640	548	700	6716
	b	11	7	9	8	9	7	6	7	8	10	8	10	
Invercargill Aero	a	115	87	97	96	114	104	85	76	84	95	90	105	1149
	b	10	8	8	8	10	9	7	7	7	8	8	9	

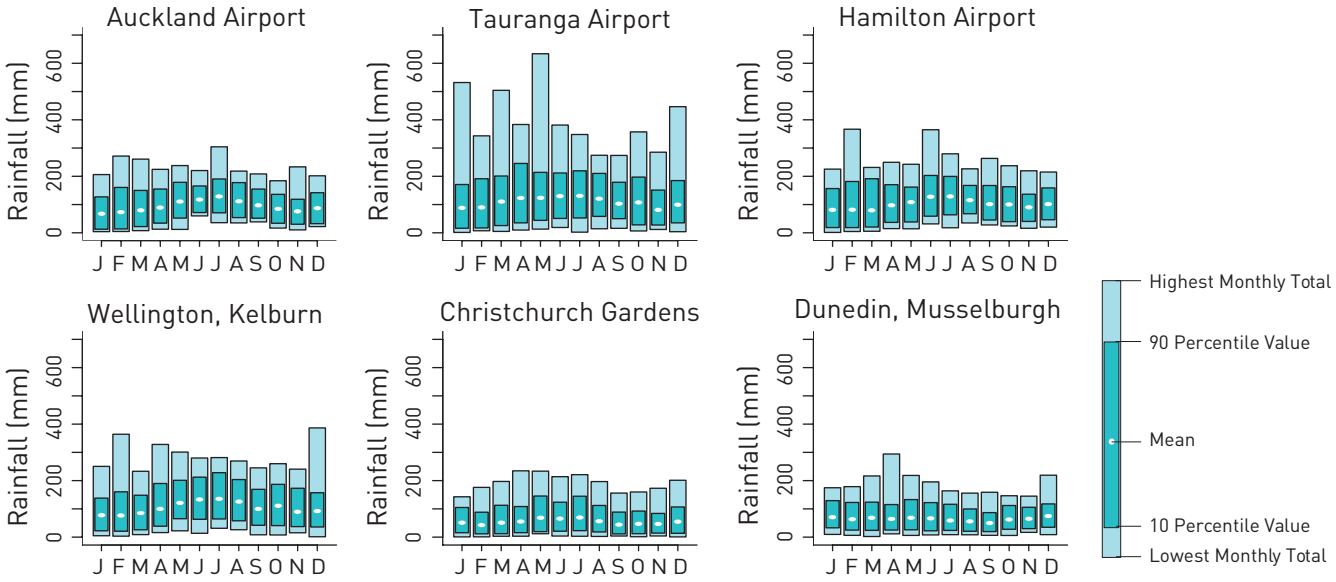


Figure 9. Monthly variation of rainfall for New Zealand main centres from all available data.

Rainfall variability is further indicated by annual rainfall deciles, as given in Table 7. The 10th percentile values show the accumulated rainfalls that will normally be exceeded in nine out of ten years, whilst the 90th percentile values indicate the annual totals that will normally be exceeded in only one year in ten. The 25th percentile and 75th percentile values show the accumulated rainfalls that will normally be exceeded in three out of every four years and one out of every four years, respectively. For example, using the table for Christchurch, an annual rainfall total of 462 mm or more of rainfall can be expected in nine years in ten, while a total of 735 mm or more should occur, on average, in only one year in four.

Table 7. Annual rainfall deciles from all available data.

	10th-percentile	25th-percentile	75th-percentile	90th-percentile
Whangarei Airport	1062	1237	1565	1839
Auckland Aero	907	987	1232	1347
Tauranga Airport	1011	1125	1467	1653
Hamilton Airport	987	1086	1316	1483
Taupo Airport	746	827	1040	1213
Gisborne Airport	762	879	1180	1332
Napier, Nelson Pk	597	695	938	1062
New Plymouth Airport	1194	1353	1578	1748
Palmerston North Airport	737	828	1002	1053
Wellington, Kelburn	992	1066	1373	1519
Nelson Aero	762	860	1087	1267
Blenheim Airport	545	598	815	902
Greymouth Aero	2045	2229	2618	2839
Christchurch Gardens	462	549	735	836
Lake Tekapo	429	489	695	766
Alexandra	270	298	392	433
Dunedin, Musselburgh	601	672	848	940
Milford Sound	5192	5730	7049	7802
Invercargill Aero	931	1012	1160	1283

Rainfall frequency and intensity

Table 8 lists the average number of days per month with at least 0.1 mm (a 'rain day') and at least 1 mm (a 'wet day') of rain for selected locations. The number of rain days and wet days recorded at a given station is highest in western parts of the South Island, and lowest in Central Otago, Mackenzie Country and Marlborough. The average number of wet days each year varies from 189 days at Milford Sound to 68 days at Alexandra. A seasonal variation of rain days and wet days is present in most locations, with a maximum occurring in winter or spring. Spring maximums may be attributed to the seasonal changes in the general circulation of the Southern Hemisphere. Specifically, westerly air flows over New Zealand may be intensified by development and southward movement of the belt of subtropical anticyclones which in turn are associated with changes in the principal upper-air hemispheric jet stream. The seasonal changes in the general circulation of the Southern Hemisphere result in a maximum frequency of disturbed westerly situations in spring (Reid, 1980).

Table 8. Average monthly rain days (a; days where at least 0.1 mm rainfall is measured) and wet days (b; days where at least 1 mm rainfall is measured).

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Whangarei Airport	a	10	12	14	15	19	20	21	21	17	15	13	13	189
	b	8	8	9	10	13	14	15	15	13	10	9	9	132
Auckland Aero	a	11	10	12	14	18	19	20	20	17	16	14	13	183
	b	7	7	8	9	13	14	15	14	12	12	9	9	129
Tauranga Airport	a	10	10	11	11	12	14	15	16	14	14	12	12	151
	b	6	7	8	8	9	11	11	12	10	10	9	8	110
Hamilton Airport	a	11	9	11	12	17	19	18	19	17	16	14	13	175
	b	8	7	8	8	11	13	13	14	13	12	11	10	127
Taupo Airport	a	10	9	10	10	13	16	16	16	14	15	12	13	153
	b	8	7	7	7	9	11	11	11	11	11	8	9	110
Gisborne Airport	a	10	10	13	13	14	15	16	15	13	12	11	11	152
	b	6	7	9	9	10	11	12	11	9	8	8	7	107
Napier, Nelson Pk	a	8	8	10	10	11	12	13	12	11	11	9	9	124
	b	6	6	7	7	8	9	9	8	7	8	6	7	88
New Plymouth Airport	a	12	11	12	13	17	19	18	19	18	18	14	15	186
	b	9	8	9	10	13	14	14	15	13	13	11	11	140
Palmerston North	a	11	10	11	11	15	17	17	17	16	16	13	15	171
	b	7	7	8	8	11	12	12	13	12	12	10	10	122
Wellington, Kelburn	a	10	9	12	13	15	18	17	17	15	16	13	13	169
	b	7	7	9	9	11	14	13	13	11	12	9	9	122
Nelson Aero	a	10	9	9	9	11	11	11	13	13	14	12	13	135
	b	7	6	7	6	7	8	8	9	10	9	8	9	93
Blenheim Airport	a	7	7	8	7	10	11	11	11	11	11	9	9	112
	b	5	5	5	5	7	8	8	8	9	8	7	7	81
Greymouth Aero	a	15	14	15	16	17	18	16	18	20	21	18	19	207
	b	13	11	13	13	15	15	14	16	17	18	15	16	176
Christchurch Gardens	a	9	8	9	9	10	12	11	12	9	10	9	10	117
	b	6	6	6	7	8	9	8	8	6	7	7	7	84
Lake Tekapo	a	8	8	8	9	10	10	9	10	10	11	9	10	111
	b	6	5	6	6	7	7	7	7	7	8	6	7	79
Alexandra	a	10	8	9	9	11	11	10	10	9	10	8	11	116
	b	7	6	5	5	6	6	5	5	5	6	5	8	68
Dunedin, Musselburgh	a	14	12	13	13	15	14	14	14	14	16	15	17	171
	b	10	9	9	8	10	9	9	10	9	10	10	12	114
Milford Sound	a	18	15	17	16	18	18	17	18	20	21	17	20	213
	b	16	13	15	15	16	16	14	16	17	19	15	18	189
Invercargill Aero	a	17	15	18	18	21	20	20	18	18	19	19	19	222
	b	13	10	12	12	15	16	14	13	13	14	13	14	160

Heaviest short period rainfalls in New Zealand are typically recorded at relatively high elevations and often occur when persistent northerly/northwesterly airflows are established as a trough approaches the country. For remaining areas of New Zealand, heavy short period rainfalls occur with the passage of a depression over or close to the country (e.g. Figure 3), or in association with slow moving fronts, especially when the air has originated from tropical regions. Very intense rainfalls often result in flooding, as described in the next section.

In Table 9, maximum short period rainfalls for periods of 10 minutes to 72 hours with calculated return periods are given for Auckland, Christchurch and Milford Sound. Also listed in this table are the maximum rainfalls expected in 2, 5, 10, 20, and 50 years. Depth-duration frequency tables for New Zealand locations are available from NIWA's High Intensity Rainfall Design System (HIRDS). HIRDS uses the index-frequency method to calculate rainfall return periods. For more information on methods and to use the tool, see https://hirds.niwa.co.nz/.

Table 9. Maximum recorded short period rainfalls and calculated return periods (or average recurrence intervals, ARI) from HIRDS.

Location		**10min**	**20min**	**30min**	**1hr**	**2hrs**	**6hrs**	**12hrs**	**24hrs**	**48hrs**	**72hrs**
Auckland Aero	a	14	27	38	53	61	127	153	168	181	181
	b	9	47	95	90	43	100+	100+	48	40	29
	c	7.5	11.3	14.2	21.3	28.2	43.9	58.1	76.8	88.9	96.9
	d	9.8	14.6	18.5	27.8	36.4	56.1	73.6	96.6	111.9	121.9
	e	11.6	17.4	22.1	33.1	43.2	65.9	86.1	112.5	130.2	141.9
	f	13.8	20.6	26.1	39.1	50.8	77	100.1	130.2	150.7	164.2
	g	17.1	25.6	32.4	48.6	62.8	94.2	121.7	157.2	182	198.3
Christchurch Aero	a	16	20	22	27	51	81	108	118	121	138
	b	100+	71	37	23	75	83	89	40	18	18
	c	4.7	6.9	8.6	12.7	17.6	29.4	40.6	56.1	69.0	77.9
	d	6.4	9.5	11.9	17.5	23.8	39.0	53.1	72.4	89.1	100.6
	e	7.9	11.7	14.7	21.6	29.2	47.0	63.5	85.8	105.6	119.2
	f	9.7	14.3	17.9	26.4	35.4	56.2	75.3	101.0	124.2	140.2
	g	12.6	18.6	23.3	34.3	45.4	71.0	94.0	124.6	153.3	173.0
Milford Sound	a	30.8	33.3	43.9	53	89.9	234.9	368.1	537.5	651.4	741.4
	b	97	22	21	8	10	37	44	37	24	21
	c	10.5	16.8	22.1	35.2	57.2	123.6	200.9	326.5	421.5	489.4
	d	14.1	22.4	29.5	47.1	74.6	155	245.7	389.6	502.9	583.9
	e	17	27.2	35.8	57.1	89	180	280.8	437.9	565.3	656.3
	f	20.5	32.7	43	68.6	105.3	207.8	319.1	489.9	632.4	734.2
	g	26	41.5	54.6	87.1	131	250.3	376.5	566.4	731.1	848.9

a: highest fall recorded (mm)
b: calculated return period of a (years)
c: max fall calculated with ARI 2 years (mm)
d: max fall calculated with ARI 5 years (mm)
e: max fall calculated with ARI 10 years (mm)
f: max fall calculated with ARI 20 years (mm)
g: max fall calculated with ARI 50 years (mm)

Recent extreme events in New Zealand

New Zealand experiences numerous extreme weather events, with significant damage and disruption caused by heavy rain and flooding. The events listed below are among the most severe rainfall and flooding events to have affected the country in recent times.

4 – 5 April 2017: The remnants of ex-Tropical Cyclone Debbie delivered very heavy rainfall to northern and eastern parts of the North Island, resulting in widespread flooding and slips. Flooding was particularly severe in Edgecumbe after the Rangitaiki River burst its floodbanks, and all residents of the town (approximately 1600 people) were forced to evacuate. Several towns in the Whakatane District were cut off by floodwaters and slips, including Ruatahuna, Minginui, Waimana and Ruatoki. Whangaparaoa (north of Auckland) recorded 172 mm of rain in the 24-hours to 9 a.m. on 5 April, which is 240% of its normal total April rainfall. In the 14-hours to 6 a.m. on 5 April, Auckland (Mangere) recorded 84.6 mm of rain, equal to the normal total April rainfall at that location.

March - April 2014: March and April 2014 were remarkably wet months for eastern parts of Canterbury. Christchurch (Riccarton) endured its wettest March on record at the time (records began in 1863). Additionally, of the 200 mm (437% of the March normal) that fell during the month at Christchurch, 123 mm accumulated on one day (4 March), which was the greatest one-day March rainfall on record for the city at the time. The highest one-day rainfall total in New Zealand for the month of March 2014 was 153 mm, recorded at Lyttelton on the 4th. These records were largely caused by heavy rain that fell on 4 and 5 March, which caused considerable flooding throughout Christchurch and surrounding areas. At least 100 homes in Woolston, Richmond, St Albans and Mairehau were inundated with water, and residents of Akaroa and Sumner were temporarily isolated by flooding. Further significant rainfall was recorded during April 2014. Winchmore experienced its wettest April on record at the time, with 301 mm recorded there (599% of the April normal). In Christchurch, 224 mm of rain was recorded (499% of the April normal): the second-wettest April observed there on record at the time. Farther north, Kaikoura recorded 264 mm of rain in April (475% of the April normal). Christchurch received a total of 424 mm of rain for the March-April 2014 period. This is more than four-times greater than the normal March-April rainfall, with the city receiving 71% of its average annual rainfall over the two-month period.

December 2011: An active front associated with a low pressure system was preceded by a strong and very humid northeasterly flow, which transported air directly from the sub-tropics to New Zealand. The front moved very slowly eastwards across New Zealand, resulting in very heavy rainfall across Nelson and Tasman. Some exceptionally large rainfall totals were recorded across the region. In Takaka, nearly 400 mm was recorded in just 24 hours and 607 mm in 48 hours, greatly exceeding any previous record at this site. The event was also the largest 48-hour accumulation ever recorded in an urban area in New Zealand, with an estimated return period of 500 years. A state of emergency was declared on 14 December, and the National Crisis Management Centre at Parliament was activated. More than 200 landslides occurred across the region, with Collingwood, Cable Bay, Totaranui and Ligar Bay isolated due to landslides cutting off access roads to those areas. In Nelson and Pohara, 160 and 30 houses were evacuated due to flooding or landslides, respectively. Insurance claims from the event totalled $16.8 million. This event was the primary contributor to record-breaking December rainfall totals throughout the region. Nelson received more than six times and Takaka received more than eight times their normal December rainfall (the highest December totals there since records began in 1941 and 1976, respectively).

February 2004: A significant storm brought high winds, heavy rain, flooding and slips to much of the North Island and upper South Island. Widespread 24-hour rainfall totals of 65–150 mm occurred in population centres throughout the southwestern North Island. 2300 people were evacuated due to flooding, and 20,000 ha of farmland was under water. Local authorities described the floods as the most devastating in over 100 years. The flooding caused a major vegetable shortage in the lower North Island, and 10 million litres of milk was dumped as flooding and closed roads meant it couldn't be collected. Damage from the event was estimated at $300 million 2004 dollars.

Periods of low rainfall

Periods of fifteen days or longer with less than 1 mm of rain on any day are referred to as 'dry spells'. Dry spells are relatively common in inland and eastern areas of New Zealand, however they occur relatively infrequently in the western- and southern-most parts of the country. Dry spells throughout New Zealand typically occur when a persistent (blocking) anticyclone becomes established over the country. Table 10 outlines the average annual maximum dry spell length (consecutive dry days, CDD) for selected locations. On average, Alexandra's longest annual dry spell is 27 days, compared to 13 days at Greymouth, Invercargill and Milford Sound. Average annual maximum consecutive wet days (CWD) is also provided in Table 10, where a wet day is defined as one where at least 1 mm of rainfall is recorded. Locations that observe the longest dry spells typically observe the shortest periods of consecutive wet days.

Table 10. Average annual maximum dry spell length (consecutive dry days, CDD), and average annual maximum consecutive wet days (CWD).

	CDD	CWD
Whangarei	19	9
Auckland	19	9
Tauranga	20	7
Hamilton	19	9
Taupo	20	7
Gisborne	22	7
Napier	25	6
New Plymouth	18	10
Palmerston North	20	8
Wellington	19	8
Nelson	24	6
Blenheim	26	5
Greymouth	13	12
Christchurch	26	5
Lake Tekapo	26	5
Alexandra	27	4
Dunedin	18	7
Milford Sound	13	13
Invercargill	13	10

Temperature

Sea surface temperature

Monthly mean sea surface temperatures (SST) off the coast of Northland and Southland are compared with mean air temperature for New Zealand in Figure 10. Here, New Zealand's mean temperature is represented by NIWA's seven station temperature series, which begins in 1909 and is constructed from seven low-elevation stations. There is a lag in the increase of sea surface temperatures when compared to air temperatures from July to September. This is at least in part attributed to the greater heat capacity of the sea compared to land, which results in the sea surface temperatures taking longer to increase and decrease in response to changing seasons compared to land-based areas. Figure 11 shows the mean sea surface temperatures for the New Zealand region for February and August, which are typically the warmest and coolest months with respect to sea surface temperatures.

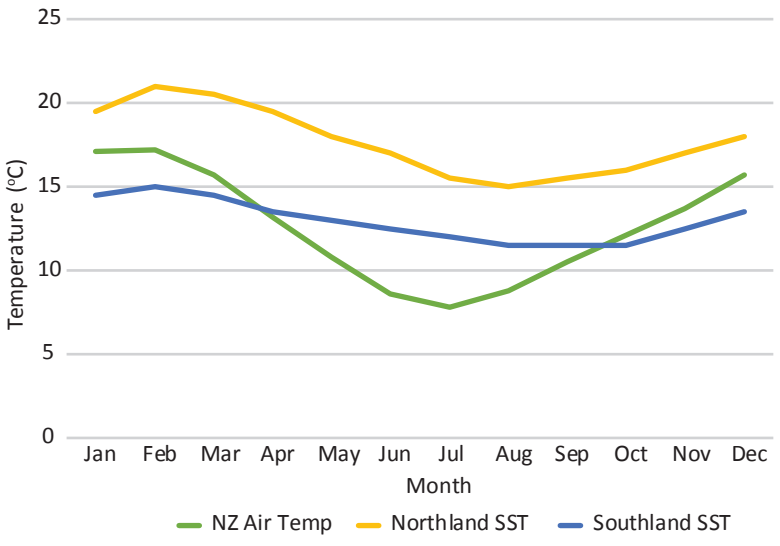


Figure 10. Mean monthly air temperature (New Zealand) and estimated sea surface temperatures (off the coast of Northland and Southland).

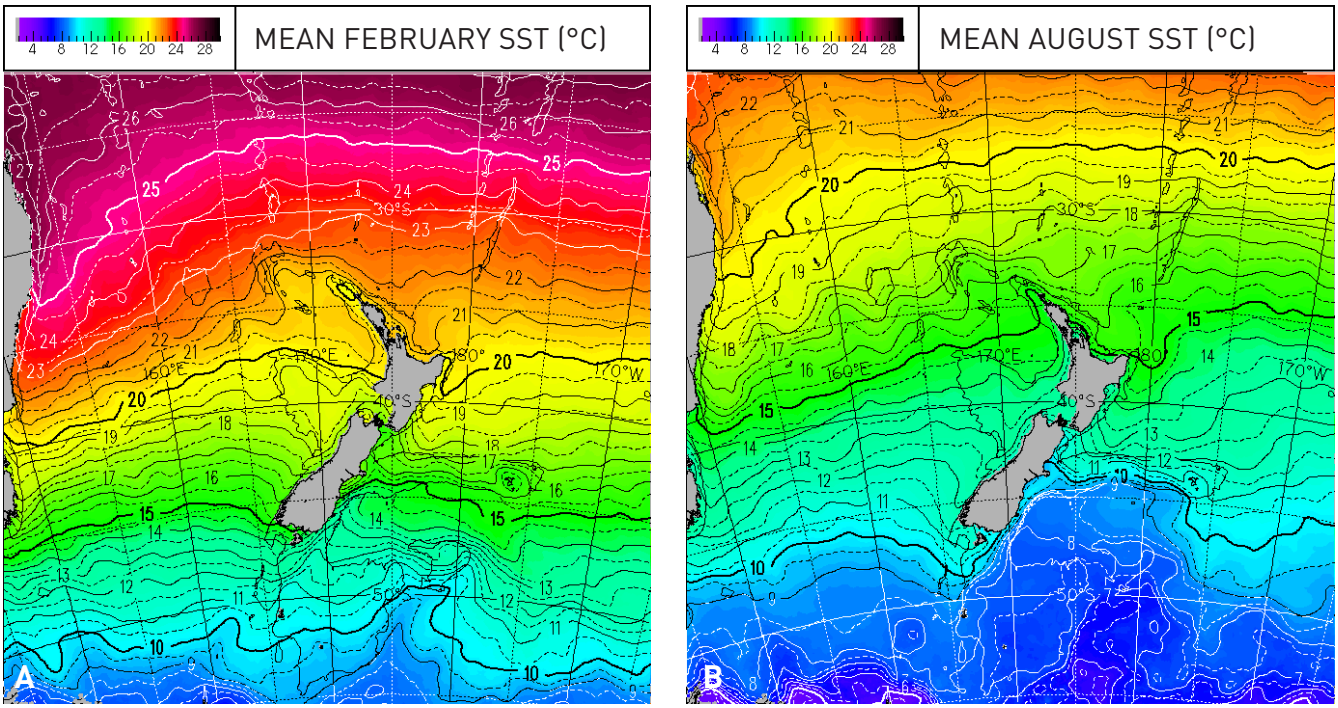
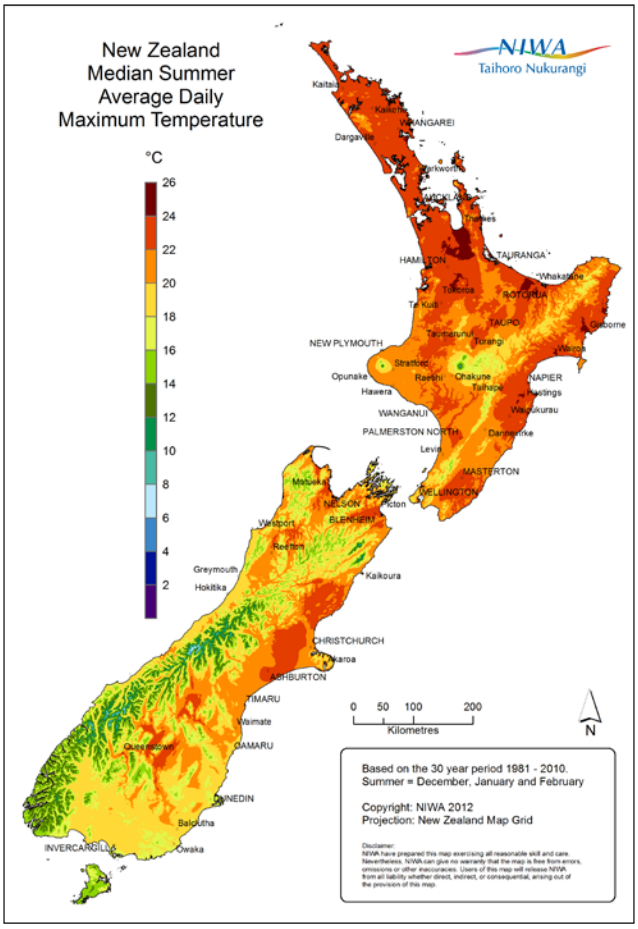


Figure 11. Monthly mean sea surface temperatures (°C) for: a) February; b) August. Source: NIWA SST Archive, Uddstrom and Oien (1999).

Air temperature

For most of the country, afternoon temperatures typically reach between 18°C and 24°C in summer, and overnight temperatures fall to between -2°C and 8°C in winter (Figure 12). The notable exception is high elevation areas where temperatures become increasingly lower as elevation increases. In winter, daily minimum temperatures become lower as distance from the coast and elevation increases. Figure 13 shows the median annual average temperature in New Zealand, and clearly demonstrates that lower temperatures are recorded at higher elevation locations and southernmost locations, whereas higher temperatures are recorded at lower elevations and northernmost locations. Highest median annual temperatures of between 16°C and 18°C are observed north of Kaitaia, while lowest median annual temperatures of 2°C or lower are observed along the Southern Alps near Mt Cook, which contributes to the perennial snow and glaciers at high elevations in those areas. Figure 14 gives the monthly temperature regime (highest recorded, mean monthly maximum, mean daily maximum, mean, mean daily minimum, mean monthly minimum, and lowest recorded) for New Zealand's main centres.



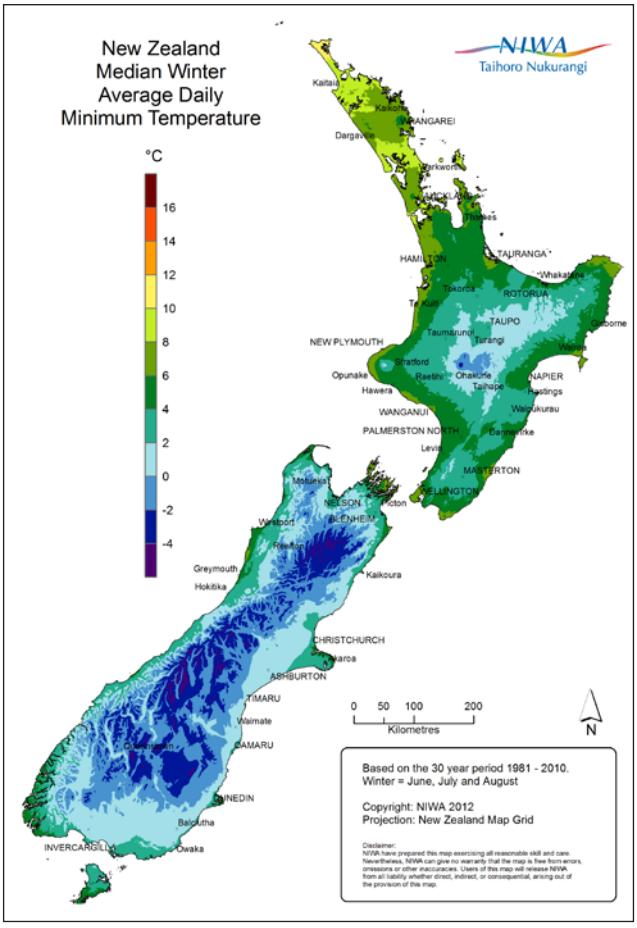


Figure 12. Left: New Zealand median summer (December, January and February) average daily maximum temperature; Right: New Zealand median winter (June, July and August) average daily minimum temperature, 1981 - 2010.

Photo: ©mychillybin.co.nz/Julie Fitz-Gerald

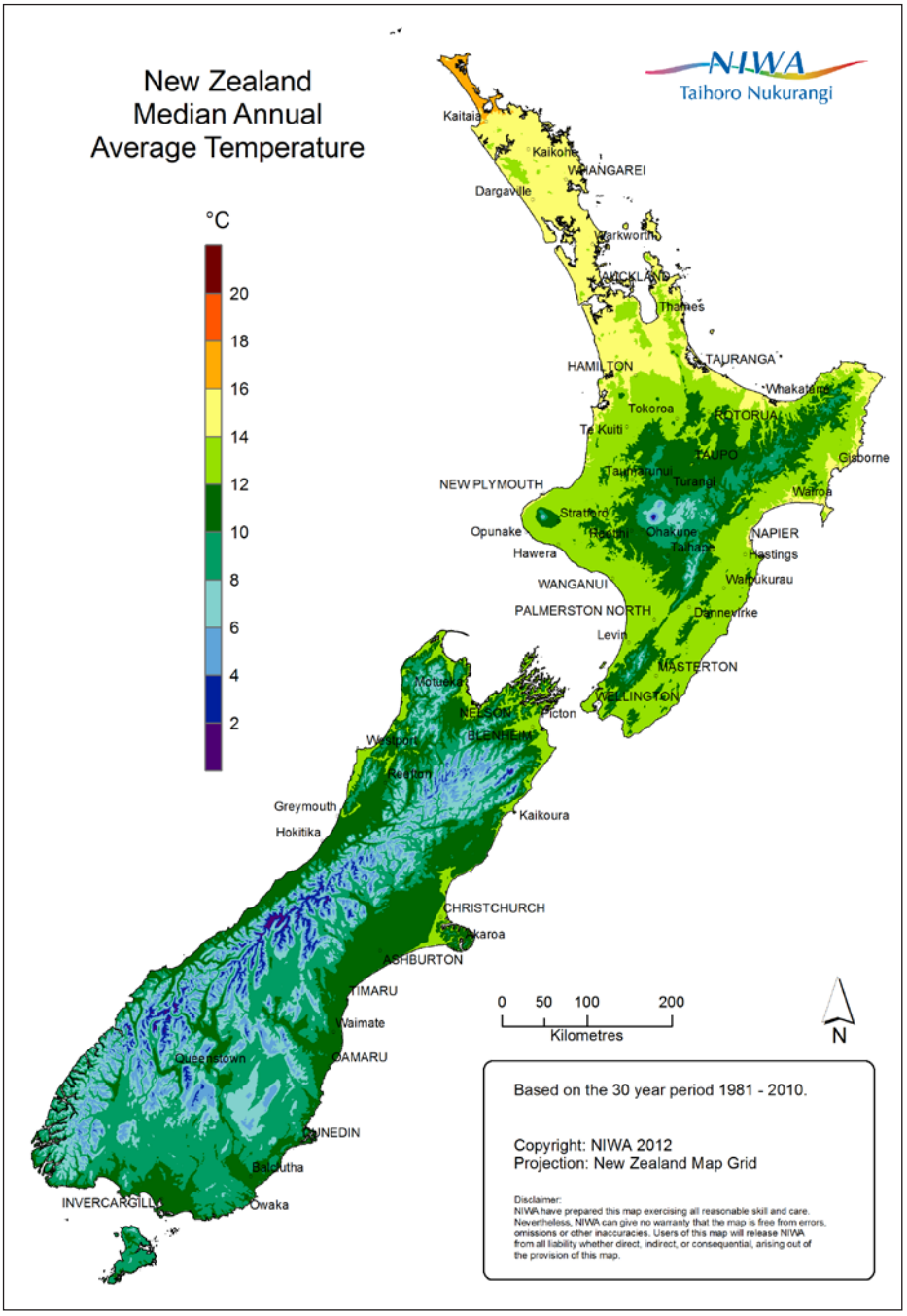


Figure 13. New Zealand median annual average temperature, 1981–2010.

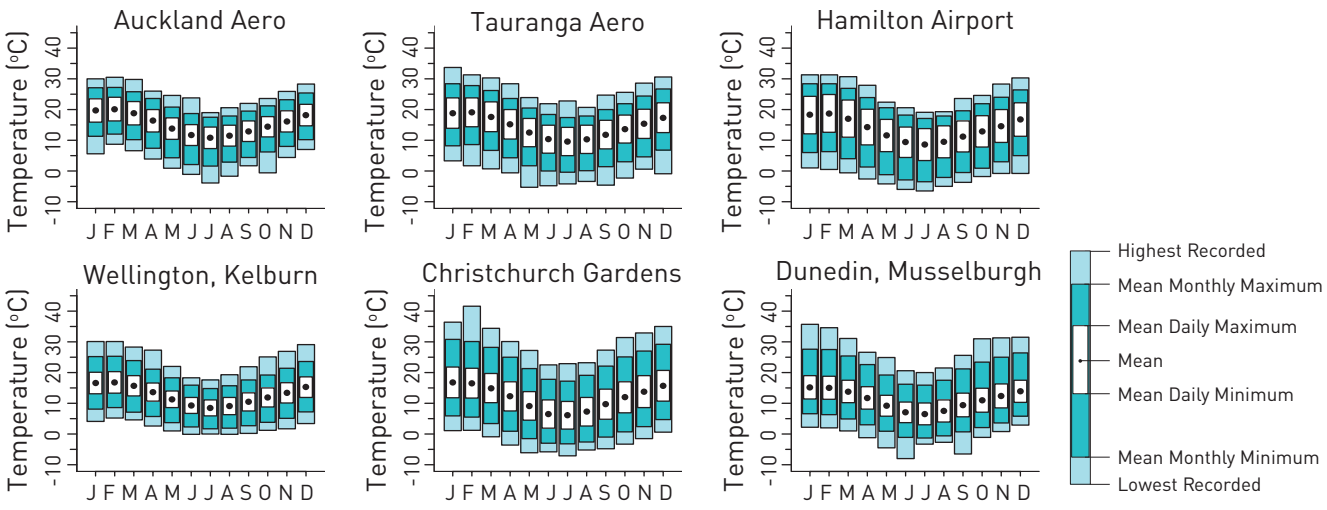


Figure 14. Monthly variation in air temperatures for New Zealand's main centres from all available data.

Table 11 shows that the average daily temperature range, i.e. the difference between the daily maximum and minimum temperature, varies minimally over the course of the year at locations near the coast. In contrast, inland locations observe considerable variation in average daily temperature range over the course of the year: the range is highest in summer and lowest in winter.

Table 11. Average daily temperature range (Tmax – Tmin, °C).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Airport	8.8	8.3	8.1	7.8	7.6	7.4	7.6	7.6	7.9	8.1	8.4	8.6	8.0
Auckland Aero	7.6	7.7	7.7	7.3	7.0	6.8	7.0	6.8	6.7	6.6	6.9	7.1	7.1
Tauranga Airport	9.9	9.5	9.7	9.6	9.2	9.1	9.2	9.2	9.2	9.2	9.5	9.6	9.4
Hamilton Airport	12.2	12.2	12.1	11.6	10.6	9.9	10.4	10.4	10.1	10.2	10.7	10.9	10.9
Taupo Airport	11.4	11.1	10.9	10.3	9.3	8.6	8.8	9.2	9.4	9.5	10.5	10.3	9.9
Gisborne Airport	11.2	10.7	10.4	10.2	9.8	9.6	9.2	9.5	10.0	10.5	10.8	10.9	10.2
Napier, Nelson Pk	9.8	9.4	9.6	9.6	9.3	9.3	9.0	9.1	9.5	9.8	9.8	9.5	9.5
New Plymouth Airport	8.3	8.6	8.5	8.1	7.6	7.3	7.5	7.4	7.2	7.1	7.5	7.6	7.7
Palmerston North Airport	10.3	10.6	10.4	9.8	9.0	8.5	8.4	8.5	8.5	8.8	9.3	9.6	9.3
Wellington, Kelburn	7.0	7.0	6.6	5.9	5.4	5.2	5.3	5.5	5.9	6.2	6.6	6.7	6.1
Nelson Aero	9.3	9.4	9.5	9.9	10.2	10.6	10.7	10.0	9.6	9.2	9.2	8.9	9.7
Blenheim Airport	11.9	12.0	11.6	11.4	11.1	11.0	11.0	10.8	10.9	11.2	11.5	11.3	11.3
Greymouth Aero	7.2	7.2	7.4	7.4	7.3	7.2	7.6	7.6	7.3	6.8	6.8	6.9	7.2
Christchurch Gardens	10.0	9.7	9.5	9.5	9.3	9.2	9.0	9.3	9.8	10.2	10.4	10.0	9.6
Lake Tekapo	12.9	13.2	12.6	11.3	9.8	8.9	8.8	9.7	10.9	11.6	12.0	12.5	11.2
Alexandra	13.2	13.4	13.3	12.9	11.3	9.6	9.9	12.1	13.0	13.0	13.1	12.9	12.3
Dunedin, Musselburgh	7.6	7.6	7.3	7.3	6.9	6.8	7.0	7.2	7.7	7.8	7.8	7.2	7.4
Milford Sound	8.3	8.6	8.6	8.6	7.9	7.5	7.9	8.8	8.8	8.4	8.2	8.0	8.3
Invercargill Aero	9.3	9.6	9.5	9.2	8.7	8.1	8.6	9.4	9.4	9.1	9.1	9.1	9.1

Table 12 and Figure 15 further highlight the diurnal temperature range, showing the median hourly mean air temperature for January and July at Alexandra, Auckland and Christchurch. Overnight air temperatures at Alexandra are lower than Auckland and Christchurch in January and July, which may be attributed to its location farther south and from the sea. Note that hourly mean air temperature at a given time is calculated as the mean of many air temperature observations recorded over the previous hour. As such, both the daily maximum and minimum air temperatures calculated from hourly values are damped, resulting in a reduced diurnal temperature range (Table 12) compared to the absolute daily temperature range recorded (Table 11).

Table 12. Mean hourly air temperatures for January and July at Alexandra, Auckland and Christchurch.

Alexandra Cws		**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
	Jan	15.0	14.2	13.5	13.0	12.5	12.1	11.8	12.5	14.2	16.0	17.5	18.8
	Jul	1.0	0.7	0.4	0.1	-0.1	-0.2	-0.2	-0.4	-0.6	-0.5	0.4	1.9
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
	Jan	20.0	20.9	21.7	22.2	22.5	22.3	21.7	20.7	19.4	17.8	16.7	15.8
	Jul	3.5	5.0	6.3	7.0	7.3	6.7	5.5	4.2	3.4	2.7	2.2	1.7
Auckland Aero		**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
	Jan	17.9	17.7	17.4	17.2	17.1	16.9	17.0	18.1	19.2	20.2	21.0	21.6
	Jul	9.8	9.7	9.6	9.4	9.3	9.2	9.1	9.1	9.3	10.1	11.3	12.2
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
	Jan	22.1	22.4	22.5	22.5	22.2	21.5	21.0	20.2	19.2	18.8	18.6	18.2
	Jul	12.8	13.3	13.5	13.4	13.2	12.5	11.6	11.3	10.9	10.5	10.3	10.0
Christchurch Aero		**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
	Jan	14.7	14.4	14.1	13.9	13.6	13.4	13.4	14.4	15.9	17.3	18.4	19.3
	Jul	5.0	4.7	4.4	4.1	3.9	3.8	3.7	3.5	3.4	3.8	5.5	7.4
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
	Jan	20.1	20.5	20.6	20.5	20.1	19.4	18.8	17.9	16.9	16.1	15.6	15.2
	Jul	9.1	9.9	10.3	10.4	10.1	9.2	8.0	7.1	6.5	6.1	5.8	5.5

Maximum air temperatures exceeding 25°C occur relatively frequently at low elevation inland locations, and parts of Hawke's Bay, Gisborne, Bay of Plenty and Northland (Table 13). Minimum temperatures below 0°C occur very frequently at Lake Tekapo and Alexandra, but are rare in Auckland, Wellington and Northland. The highest air temperature recorded in New Zealand to date is 42.4°C at Rangiora on 7 February 1973. This temperature occurred on the last day of an extremely hot spell in Rangiora between 31 January 1973 and 7 February 1973. During these eight days, the average daily maximum temperature was 32.1°C, with the temperature reaching at least 32.5°C on five out of the eight days. Ranfurly has recorded the lowest air temperature in New Zealand on record; -25.6°C on 17 July 1903.

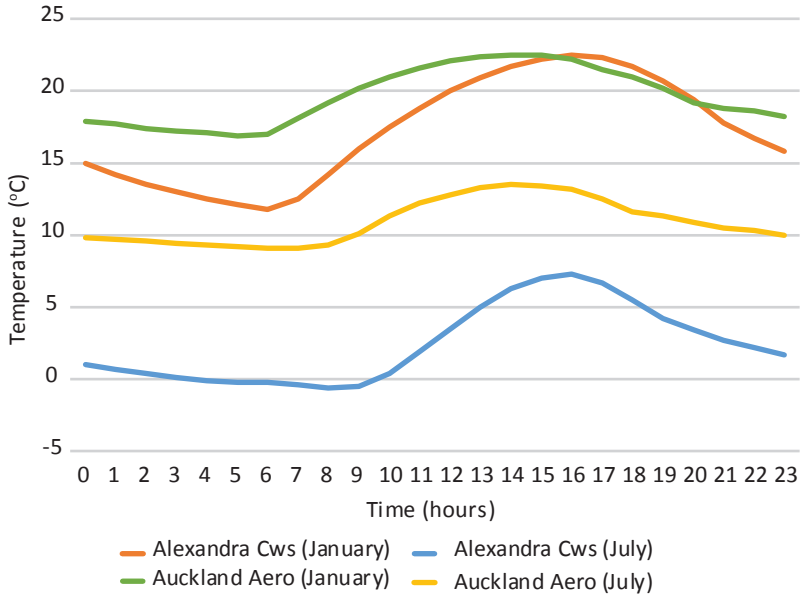


Figure 15. Mean hourly air temperatures at Alexandra and Auckland in January and July.

Table 13. Highest and lowest recorded air temperatures, average number of days per year where maximum air temperature exceeds 25°C, and average number of days per year where the minimum air temperature falls below 0°C, from all available data.

	Highest recorded (°C)	Annual days max temp > 25°C	Lowest recorded (°C)	Annual days min temp < 0°C
Whangarei Airport	31.5	33	-0.1	0
Auckland Aero	30.5	22	-1.2	0.3
Tauranga Airport	33.7	21	-4.8	3
Hamilton Airport	31.3	37	-6.5	22
Taupo Airport	32.0	15	-7.1	45
Gisborne Airport	38.1	48	-5.3	5
Napier, Nelson Pk	36.0	39	-3.9	8
New Plymouth Airport	30.6	5	-2.6	2
Palmerston North Airport	32.8	23	-6.9	18
Wellington, Kelburn	30.1	3	-0.1	0
Nelson	36.3	8	-6.6	31
Blenheim Airport	37.8	39	-6.2	37
Greymouth Aero	29.7	1	-2.5	2
Christchurch Gardens	41.6	26	-7.1	33
Lake Tekapo	33.5	17	-16.7	99
Alexandra	38.7	46	-11.7	88
Dunedin, Musselburgh	35.7	8	-8.0	8
Milford Sound	28.5	0.9	-9.8	29
Invercargill Airport	32.1	5	-9.1	40

Earth temperatures

Earth (soil) temperatures are measured once daily at 9 a.m. at many New Zealand locations. Earth temperatures are measured at varying depths and are important for determining the growth and development of plants. Different plants have different rooting depths and as such, earth temperatures are routinely monitored at 10, 20, 30, and 100 cm depths. Table 14 lists mean monthly 10 cm earth temperatures for a selection of New Zealand locations, and shows that earth temperatures are typically warmer at locations that are farther north and/or closer to the coast compared with southern and inland locations. Table 15 list the monthly earth temperatures for a number of standard depths at Auckland and Christchurch.

Figure 16 shows how earth temperatures change throughout the year at Christchurch, compared with mean air temperature. The 10 cm earth temperatures are lower than the mean air temperature except during summer. The annual earth temperature cycle at 100 cm depth is more damped and lagged than at shallower depths. Thus, earth temperatures at 100 cm remain above mean air temperature in June and July, but fall slightly below mean air temperatures during spring, before returning to higher temperatures than the mean air temperature in summer. Diurnal variation of earth temperatures (not shown) decreases with increasing depth, such that earth temperatures may show little-to-no diurnal variation at 100 cm depth.

Table 14. Mean 9 a.m. 10 cm earth temperature (°C) from all available data. Note: Milford Sound is not included in this table due to insufficient data. Records at Whangarei Ews began in September 2015.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Ews	21.8	22.2	20.5	18.1	15.2	12.4	11.6	11.0	12.9	15.1	17.7	20.3	16.5
Auckland Aero	20.4	20.3	18.6	15.8	12.9	10.7	9.4	10.2	12.1	14.1	16.5	18.8	15.0
Tauranga Aero	19.5	19.5	18.1	15.2	12.0	9.7	8.4	9.4	11.2	13.5	16.0	18.1	14.1
Hamilton Aws	19.1	19.2	17.1	14.2	11.2	8.7	7.3	8.3	10.6	12.5	15.1	18.0	13.5
Taupo N.Z.E.D.	18.1	17.8	15.5	11.9	8.5	6.2	5.0	6.0	8.1	11.4	14.3	16.7	11.6
Gisborne Aero	20.2	19.6	17.2	13.6	10.2	7.8	6.9	8.0	10.3	13.6	16.7	19.2	13.6
Napier, Nelson Pk	20.4	20.1	17.5	14.1	10.9	8.2	7.6	8.1	10.3	13.3	16.1	18.9	13.8
New Plymouth Aero	18.4	18.6	16.9	13.8	11.0	8.8	7.8	8.6	10.4	12.6	14.9	17.0	13.2
Palmerston North	18.4	18.1	16.3	13.2	10.3	7.9	6.8	7.7	9.9	12.5	14.9	17.2	12.8
Wellington, Kelburn	17.4	17.1	15.2	12.5	9.9	7.6	6.7	7.4	9.2	11.4	13.8	16.1	12.0
Nelson Aero	18.4	18.0	15.8	12.2	8.5	5.6	4.5	5.9	8.7	11.9	14.7	17.1	11.8
Blenheim Research Ews	18.9	18.2	15.5	11.9	8.6	5.8	5.0	6.4	9.1	11.8	14.8	17.6	12.0
Greymouth Aero Ews	18.4	18.9	16.7	14.0	10.6	8.3	7.0	8.4	10.3	12.4	14.9	17.5	13.2
Christchurch Aero	17.4	16.8	14.3	10.9	7.4	4.5	3.8	4.8	7.3	10.5	13.7	16.2	10.7
Lake Tekapo Ews	15.1	14.6	11.4	8.0	4.0	1.3	0.2	1.4	4.2	6.7	10.8	13.8	7.7
Alexandra 1	16.4	15.4	13.2	9.0	4.8	1.9	1.2	2.5	5.8	9.7	13.0	15.5	9.0
Dunedin, Musselburgh	15.7	15.3	13.5	10.7	7.9	5.5	4.4	5.3	7.7	10.0	12.5	14.5	10.3
Invercargill Aero	14.0	13.7	12.0	9.7	7.1	5.0	3.8	4.6	6.7	9.0	11.1	13.2	9.1

Table 15. Mean 9 a.m. earth temperatures (°C) at varying depths from the ground surface for Auckland and Christchurch.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Auckland Aero													
10 cm	20.4	20.4	18.5	15.8	13.0	10.7	9.5	10.2	12.2	14.1	16.6	18.9	15.0
20 cm	21.1	21.2	19.5	16.6	13.8	11.7	10.4	11.1	12.6	14.7	17.2	19.5	15.8
30 cm	21.5	21.5	20.0	17.2	14.5	12.3	11.1	11.7	13.1	15.1	17.6	19.8	16.3
100 cm	20.1	20.7	20.3	18.6	16.5	14.4	13.1	12.9	13.6	14.9	16.7	18.5	16.7
Christchurch Aero													
10 cm	17.4	16.8	14.3	10.9	7.4	4.5	3.8	4.8	7.3	10.5	13.7	16.2	10.7
20 cm	18.5	18.1	15.6	12.2	8.4	5.4	4.6	5.7	8.1	11.2	14.5	16.9	11.6
30 cm	19.2	18.9	16.6	13.3	9.5	6.3	5.4	6.5	8.9	12.0	15.1	17.6	12.5
100 cm	18.1	18.4	17.2	14.8	11.6	8.6	7.0	7.4	9.0	11.4	14.2	16.4	12.9

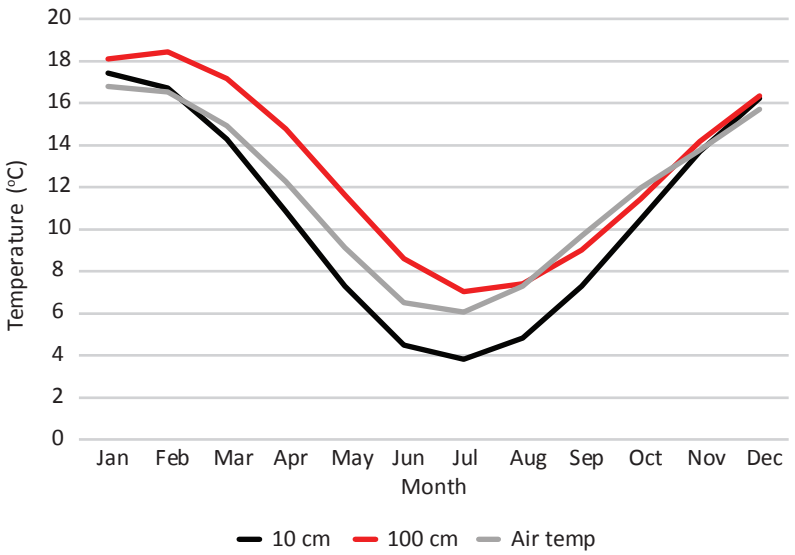


Figure 16. Monthly mean 9 a.m. earth temperature at different depths from the ground surface, and monthly mean air temperature, from all available data at Christchurch Aero.

Frosts

Frost is a local phenomenon and both its frequency of occurrence and intensity can vary widely over small areas. Frosts occur most frequently in winter during periods of anticyclonic conditions, primarily for two reasons. Firstly, clear skies associated with anticyclones enhance the rate of radiative cooling during the night. Secondly, anticyclones are associated with light winds, which reduces the amount of turbulent mixing of air. Cold air is relatively dense, so when there is a lack of turbulent mixing it tends to sink towards the Earth's surface. Therefore, areas most likely to experience frost are flat areas, where relatively cold air is not able to drain away on calm nights, and in valleys and basins, where relatively cold air pools after descending from higher elevation areas nearby. Under such conditions, temperature inversions (where the air temperature increases with elevation) are common.

There are two types of frost recorded. Air frosts occur when air temperature measured by a thermometer in a screen 1.3 m above the ground falls below 0°C. Ground frosts are recorded when the air temperature 2.5 cm above a closely cut grass surface falls to -1.0°C or lower. Both types of frost are quite common for many New Zealand locations in the cooler months, but they occur less frequently in coastal and northernmost areas. Table 16 lists for selected locations the mean daily grass minimum and extreme grass minimum temperatures, and the average number of days each month with ground and air frosts. Ground frosts occur more frequently than air frosts, and both types occur most frequently at inland South Island locations such as Alexandra.

Photo: ©mychillybin.co.nz/Mark Meredith

Table 16. Frost occurrence and grass minimum temperatures.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whangarei Aero	a	12.4	13.0	12.3	9.4	6.6	5.1	3.8	4.5	5.6	6.8	8.8	10.7
	b	3.4	4.1	2.0	0.6	-4.6	-4.2	-6.1	-4.6	-3.6	-2.1	-0.6	1.3
	c	0.0	0.0	0.0	0.0	0.6	2.6	4.2	1.9	0.8	0.4	0.0	0.0
	d	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Auckland Aero	a	13.8	14.2	12.4	9.6	7.6	5.7	4.9	5.6	7.1	9.0	10.7	12.8
	b	3.1	4.2	2.2	-0.8	-2.7	-4.4	-6.0	-4.2	-3.0	-1.8	1.5	2.5
	c	0.0	0.0	0.0	0.0	0.7	2.5	3.7	1.2	0.6	0.1	0.0	0.0
	d	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Tauranga Aero	a	10.5	11.0	9.4	6.3	3.9	1.9	0.8	2.0	3.4	5.0	7.1	9.3
	b	0.3	-2.0	-1.8	-2.6	-5.7	-7.0	-9.4	-8.1	-5.0	-5.7	-3.2	-1.7
	c	0.1	0.1	0.3	1.4	6.4	10.9	13.4	10.5	6.4	3.6	1.3	0.3
	d	0.0	0.0	0.0	0.0	0.1	1.2	1.9	0.5	0.2	0.0	0.0	0.0
Hamilton, Ruakura	a	8.9	9.3	7.7	5.3	2.9	1.1	-0.1	1.0	2.5	4.5	6.3	8.0
	b	-2.9	-1.8	-5.2	-8.3	-8.7	-10.0	-9.4	-8.7	-7.6	-6.7	-5.4	-3.4
	c	0.1	0.1	1.0	3.1	7.7	11.4	15.0	11.8	7.9	3.4	1.0	0.4
	d	0.0	0.0	0.0	0.2	2.2	5.8	7.2	4.1	1.3	0.1	0.0	0.0
Taupo N.Z.E.D.	a	8.4	8.7	7.3	4.4	2.4	0.7	-0.4	0.2	1.7	3.4	5.3	7.4
	b	-5.6	-5.7	-5.2	-5.6	-9.6	-9.1	-9.6	-10.2	-9.1	-8.2	-6.8	-6.4
	c	0.4	0.3	1.0	2.9	7.0	11.5	15.3	13.1	8.6	5.7	2.1	0.8
	d	0.0	0.0	0.1	0.5	3.2	8.2	10.6	7.2	3.7	1.2	0.4	0.0
Gisborne Aero	a	10.5	10.8	9.1	6.7	4.2	2.3	1.6	2.2	3.3	5.1	7.1	9.2
	b	1.5	1.0	-1.4	-2.2	-7.0	-6.9	-8.9	-6.4	-4.6	-2.7	-2.5	-0.9
	c	0.0	0.0	0.1	0.9	3.7	8.1	9.6	8.4	5.1	2.2	0.7	0.1
	d	0.0	0.0	0.0	0.0	0.3	2.0	2.3	1.2	0.2	0.1	0.0	0.0
Napier, Nelson Pk	a	12.5	12.7	10.7	7.9	5.2	2.8	2.4	2.8	4.7	6.9	8.9	11.6
	b	2.3	0.2	-1.2	-2.5	-3.6	-7.2	-6.4	-6.4	-6.1	-3.5	-4.2	1.0
	c	0.0	0.0	0.0	0.0	2.0	6.0	7.0	6.0	2.0	1.0	0.0	0.0
	d	0.0	0.0	0.0	0.0	0.0	2.0	3.0	2.0	1.0	0.0	0.0	0.0
New Plymouth Aws	a	11.7	12.1	10.5	8.6	7.1	5.2	4.2	4.4	6.1	7.5	8.3	11.0
	b	0.6	1.5	0.2	-0.8	-2.6	-4.2	-5.9	-5.0	-4.3	-2.7	-1.8	-0.3
	c	0.0	0.0	0.0	0.0	0.6	1.4	3.2	1.8	0.8	0.6	0.2	0.0
	d	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.3	0.1	0.0	0.0	0.0
Palmerston North	a	10.8	11.0	9.2	6.5	4.6	2.8	1.8	2.2	4.1	6.1	7.8	9.7
	b	-1.2	-1.1	-1.1	-4.9	-5.7	-7.0	-7.3	-6.2	-6.1	-6.0	-3.7	-1.7
	c	0.1	0.0	0.2	1.5	4.8	8.0	10.3	9.2	4.1	2.3	0.7	0.2
	d	0.0	0.0	0.0	0.0	0.5	2.4	3.8	2.5	0.8	0.2	0.0	0.0
Wellington, Kelburn	a	11.4	11.5	10.2	7.7	6.3	4.6	3.6	3.8	5.3	7.0	8.1	10.3
	b	2.5	2.5	0.4	-2.4	-3.1	-3.0	-4.4	-4.6	-3.5	-2.0	0.4	0.2
	c	0.0	0.0	0.0	0.1	0.6	1.6	3.4	3.2	1.2	0.4	0.0	0.0
	d	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nelson Aero	a	9.1	9.1	7.4	4.2	1.4	-1.2	-2.0	-0.5	1.5	3.9	5.6	8.0
	b	-1.7	-2.8	-5.0	-10.2	-10.2	-13.0	-9.7	-9.4	-8.1	-6.1	-5.8	-3.2
	c	0.0	0.1	0.7	3.7	11.2	17.6	20.8	16.8	10.2	4.3	1.3	0.3
	d	0.0	0.0	0.0	0.1	2.5	9.1	11.4	5.8	1.5	0.2	0.0	0.0
Blenheim Research Ews	a	10.3	9.9	7.8	5.1	3.0	0.5	-0.1	1.0	2.8	4.9	6.6	9.1
	b	0.1	-1.3	-2.5	-4.6	-6.8	-8.2	-8.3	-7.6	-7.8	-3.2	-2.7	-1.3
	c	0.0	0.1	0.4	1.5	7.8	12.8	17.2	11.9	4.8	2.1	0.2	0.3
	d	0.0	0.0	0.0	0.3	1.8	5.4	9.3	4.2	0.6	0.1	0.0	0.0

Greymouth Aero	a	10.9	11.0	9.5	7.3	5.1	2.9	2.0	2.9	4.6	6.5	8.0	9.9
	b	0.1	-3.4	-3.2	-3.8	-6.7	-7.2	-8.6	-7.3	-6.0	-5.7	-2.3	-0.4
	c	0.0	0.0	0.1	0.3	2.0	4.2	6.4	3.9	1.8	0.3	0.0	0.0
	d	0.0	0.0	0.0	0.0	0.2	0.6	1.0	0.3	0.0	0.0	0.0	0.0
Christchurch Gardens	a	9.1	9.0	7.1	4.1	1.2	-1.2	-1.5	-0.8	1.1	3.2	5.2	7.8
	b	-4.9	-3.0	-6.2	-11.3	-11.5	-14.9	-12.1	-12.9	-11.7	-9.0	-6.9	-6.3
	c	0.1	0.2	1.0	4.0	10.8	17.6	18.7	16.5	10.1	5.2	2.2	0.4
	d	0.0	0.0	0.0	0.5	3.1	9.5	10.7	7.1	2.0	0.3	0.1	0.0
Lake Tekapo	a	5.0	4.7	2.7	-0.1	-2.7	-5.1	-6.0	-4.5	-2.0	0.1	2.0	4.0
	b	-10.7	-9.5	-11.7	-12.5	-14.4	-21.1	-20.6	-21.6	-14.9	-15.3	-11.1	-8.8
	c	3.2	3.3	6.9	13.3	20.7	25.3	27.4	25.5	18.4	12.3	7.7	3.9
	d	0.2	0.2	0.9	3.5	12.3	20.5	24.0	20.2	10.0	4.6	1.9	0.5
Alexandra	a	7.5	7.2	4.9	1.3	-1.9	-3.9	-4.6	-3.5	-1.2	1.2	3.7	6.6
	b	-4.3	-7.5	-7.8	-11.9	-13.9	-13.9	-14.4	-15.0	-11.9	-10.6	-7.8	-5.2
	c	0.6	1.1	3.6	10.6	19.2	24.5	27.0	24.3	17.2	11.1	4.9	1.2
	d	0.0	0.0	0.3	3.5	12.4	20.0	24.2	18.5	7.1	2.1	0.5	0.0
Dunedin, Musselburgh	a	8.7	8.5	7.2	4.5	2.1	-0.1	-0.9	0.1	1.7	3.6	5.4	7.8
	b	-2.7	-2.6	-3.5	-5.5	-8.9	-10.1	-11.1	-9.0	-9.4	-6.5	-5.5	-2.8
	c	0.1	0.1	0.4	2.1	6.7	12.8	16.2	13.0	7.8	3.7	1.1	0.2
	d	0.0	0.0	0.0	0.0	0.4	2.3	3.5	1.5	0.3	0.1	0.0	0.0
Milford Sound	a	8.6	8.6	7.2	5.0	2.5	0.1	-0.4	0.6	2.2	3.9	5.4	7.7
	b	-1.0	-1.0	-4.6	-2.7	-7.5	-8.8	-11.0	-8.0	-5.3	-6.9	-2.4	-1.5
	c	0.0	0.0	0.3	1.2	5.8	14.1	15.6	11.4	5.4	2.3	0.9	0.1
	d	0.0	0.0	0.0	0.0	2.0	8.1	11.4	6.4	1.3	0.1	0.0	0.0
Invercargill Aero	a	6.7	6.3	5.1	3.0	0.9	-1.1	-2.1	-1.5	0.5	2.5	4.0	5.7
	b	-6.2	-6.0	-8.1	-9.5	-12.3	-11.7	-14.2	-11.6	-9.2	-8.5	-7.2	-7.8
	c	1.7	2.1	3.9	6.6	10.9	15.8	19.3	17.6	11.5	7.0	4.5	2.2
	d	0.0	0.0	0.3	1.6	4.6	8.8	11.7	8.8	3.2	1.1	0.4	0.0

a: Mean daily grass minimum (°C)

b: Lowest grass minimum recorded (°C)

c: Mean number of ground frosts per month

d: Mean number of air frosts per month

Sunshine and solar radiation

Sunshine

Sunshine hours are highest in Nelson and Marlborough, where annual sunshine totals exceeding 2,300 hours are typical (Figure 17). Nelson and Blenheim are frequently among the top-four sunniest locations in New Zealand on an annual basis. Annual sunshine hours tend to decrease towards the south of the country, especially at high elevation mountainous areas where increased cloudiness reduces the annual sunshine totals experienced. Figure 18 shows the monthly mean, maximum, and minimum recorded bright sunshine hours for New Zealand's main centres. Note that the lower sunshine hours recorded in the winter months tends to reflect the northerly declination of the sun, as opposed to signalling an increase in cloudiness during those times.

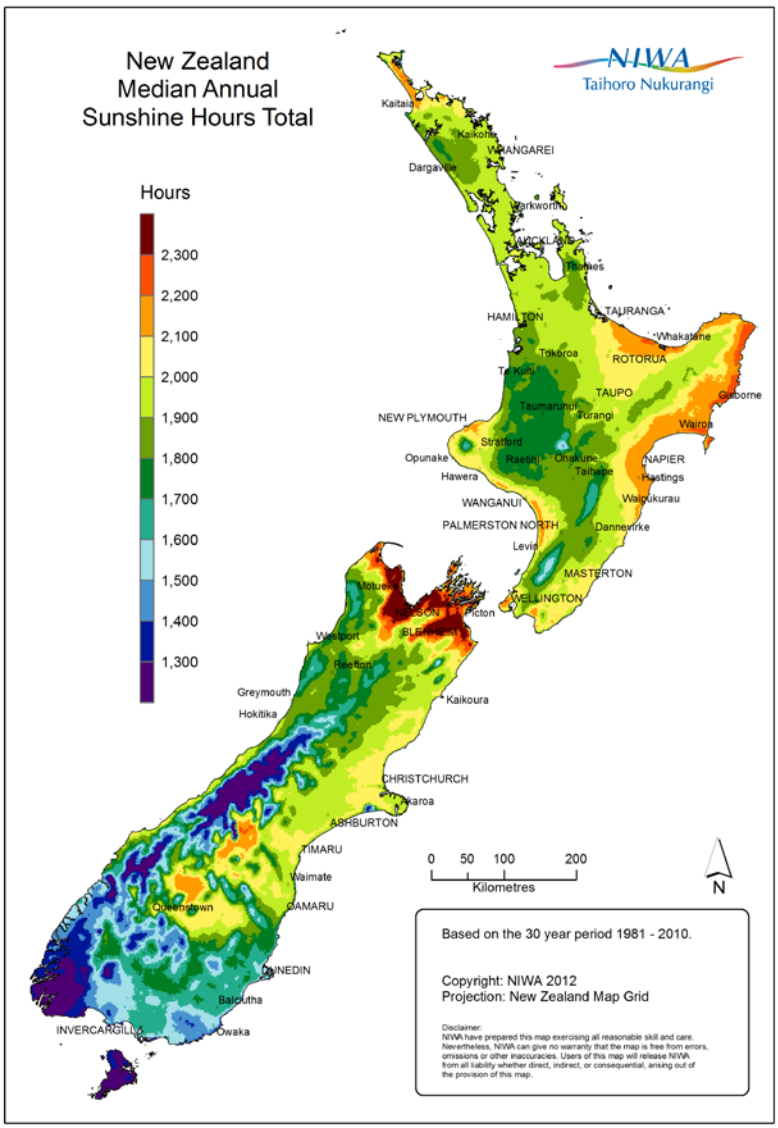


Figure 17. Median annual sunshine hours for New Zealand, 1981–2010.

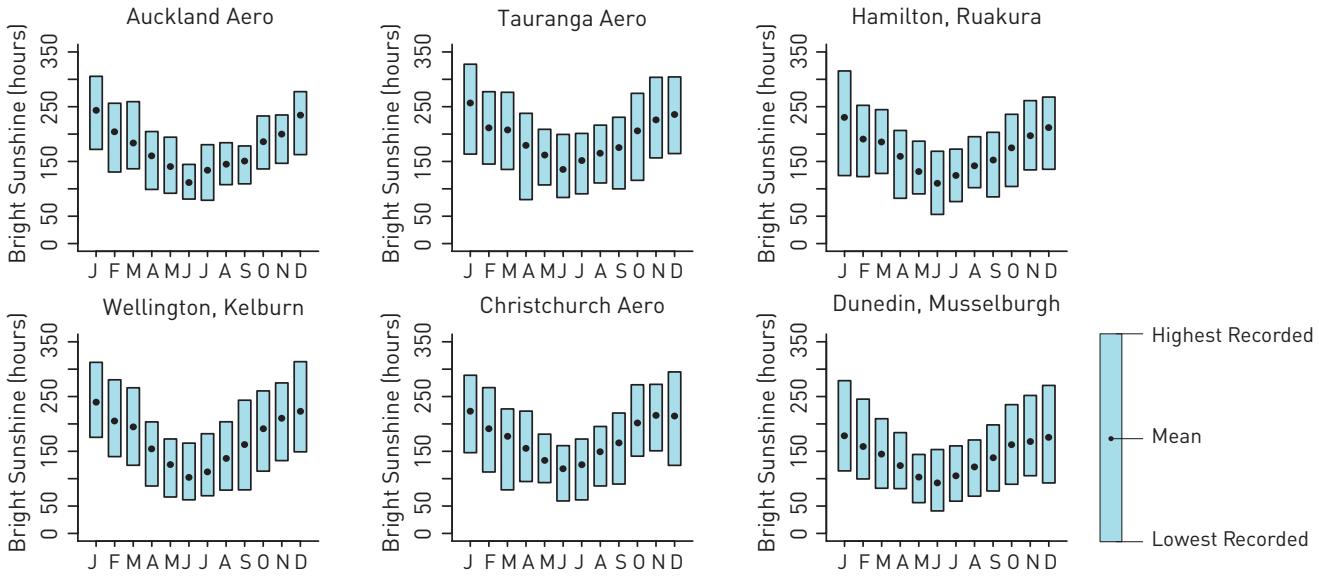


Figure 18. Mean, highest and lowest recorded monthly bright sunshine hours for New Zealand's main centres from all available data.

Solar radiation

Table 17 presents the mean daily global (i.e. direct and diffuse) solar radiation for selected New Zealand locations. Insolation is highest in January and lowest in June at all locations, and is higher at northern locations compared to southern locations throughout the year.

UV (ultra-violet) radiation

Figure 19 shows an example of a UV forecast for Auckland, Wellington and Dunedin, indicating the UV levels and times of the day where sun protection is required. UV levels in Wellington are higher than Dunedin, but lower than those experienced in Auckland. All locations observe significantly higher UV levels in summer than in winter.

Table 17. Mean daily global solar radiation (MJ/m^2/day) from all available data. The following locations are not included in this table due to insufficient data: Taupo, Milford Sound.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Aero Aws	21.6	18.4	15.4	11.1	8.3	6.9	7.4	10.0	13.5	17.1	19.9	20.4	14.1
Auckland Aero	23.3	20.2	16.1	11.8	8.2	6.6	7.5	10.1	13.8	17.7	21.3	22.8	14.9
Tauranga Aero Aws	23.8	20.4	16.8	11.8	8.5	6.9	7.4	10.1	13.8	17.9	21.5	22.5	15.1
Hamilton, Ruakura	22.5	19.4	16.1	11.4	7.8	6.3	7.0	9.6	13.0	16.8	20.3	21.3	14.3
Gisborne Airport	23.4	19.6	15.5	11.0	7.8	6.2	6.7	9.7	14.0	18.5	21.9	23.3	14.7
Napier Aero Aws	23.5	19.8	15.9	11.2	8.1	6.4	6.9	10.0	14.0	18.7	22.0	23.1	15.0
New Plymouth Aws	24.0	21.2	16.9	11.6	7.8	6.1	7.0	9.9	13.5	17.7	22.0	22.6	15.0
Palmerston North Aws	22.6	20.1	15.4	10.6	7.0	5.3	6.2	8.7	12.3	15.8	19.8	21.4	13.8
Wellington, Kelburn	23.4	19.9	15.0	10.3	6.5	5.1	5.6	8.1	12.5	17.1	20.9	22.5	13.9
Nelson Aws	24.4	21.7	17.2	11.5	8.0	6.0	6.8	9.7	13.6	18.3	22.5	23.5	15.2
Blenheim Aero Aws	24.1	20.8	16.9	11.4	7.8	5.8	6.7	9.8	13.9	18.9	22.7	23.3	15.0
Greymouth Aero Ews	20.8	19.3	14.7	9.4	6.3	4.7	5.7	8.1	11.9	15.5	18.9	20.8	13.1
Christchurch Aero	21.8	18.9	14.1	9.7	6.2	4.7	5.4	8.0	12.3	17.3	21.2	22.3	13.5
Lake Tekapo Ews	24.7	21.8	16.4	11.0	6.9	5.6	6.3	9.4	13.9	18.8	23.8	24.8	15.4
Alexandra 1	21.4	19.1	14.1	9.2	5.5	4.1	4.8	7.7	12.0	16.7	20.9	21.7	13.2
Dunedin, Musselburgh	19.3	17.1	12.6	8.1	4.9	3.7	4.5	6.7	10.8	15.3	18.3	19.9	11.8
Invercargill Aero Aws	20.2	17.4	12.4	8.1	4.8	3.6	4.4	6.9	10.9	15.5	19.1	21.2	12.1

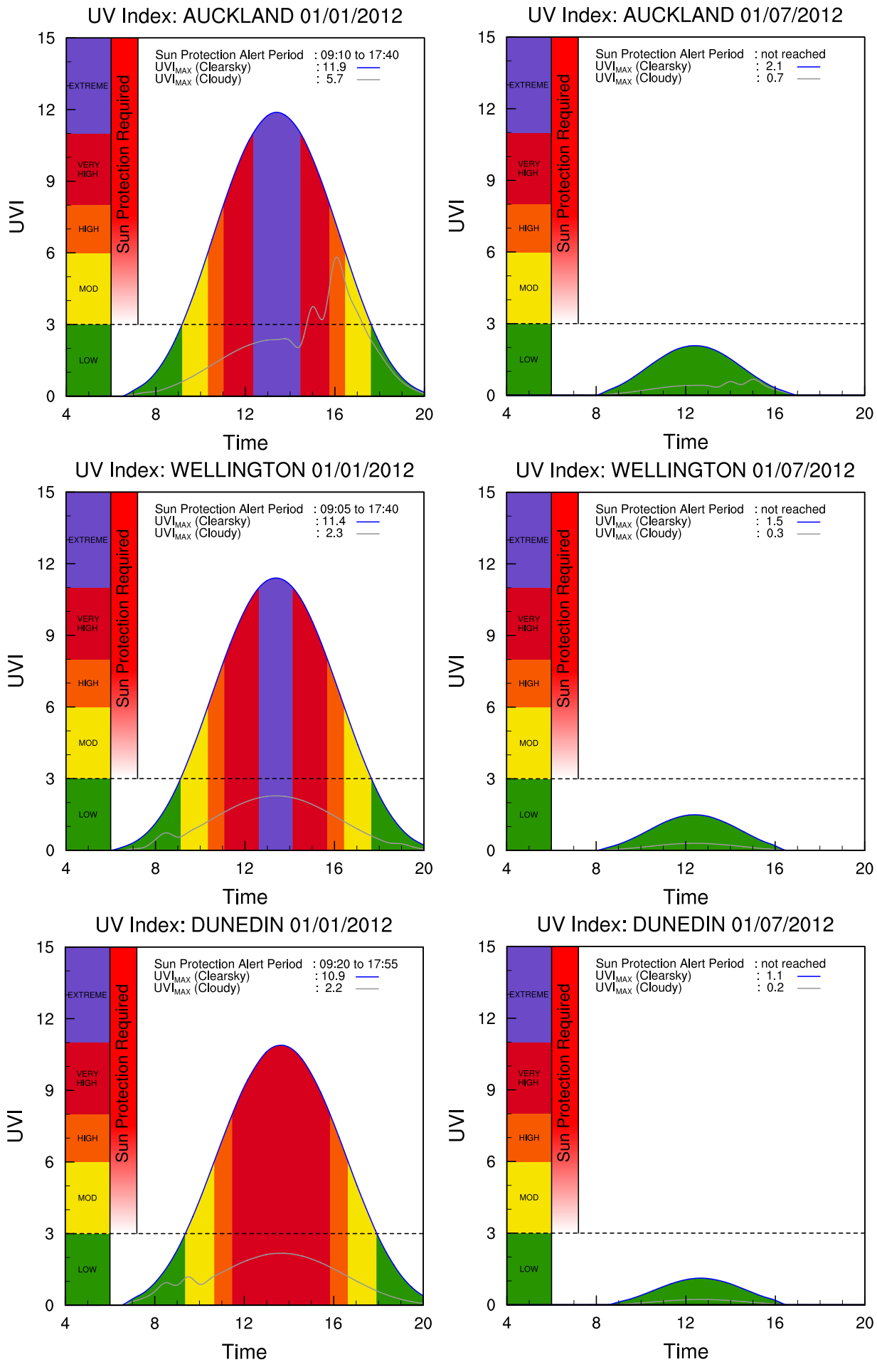


Figure 19. January (left) and July (right) UV Index forecast for Auckland, Wellington and Dunedin.

Other elements

Note the thunder, fog, hail and snow data (Table 18) were calculated from all available data at each location, which typically extends before the most recent climate normal period (1981-2010), and therefore may not be a reliable estimate of the contemporary frequency of occurrence.

Thunderstorms and hail

Thunderstorms are a relatively infrequent occurrence in most parts of the country, with most towns and cities observing fewer than 12 thunderstorms per year (Table 18). Thunderstorms are associated with bouts of high intensity rainfall, lightning, hail, and wind squalls which sometimes cause considerable localised flooding and damage to vegetation and crops. Hail is also relatively uncommon, with most locations observing less than seven days of occurrence per year. Severe hailstorms may be classified as those which cause damage and/or have hailstones of at least 0.5 cm in diameter. One such severe hailstorm occurred in Ashburton late in the afternoon on 17 November 2008. The hail stones were larger than 2.5 cm in diameter, with some reportedly as large as golf balls. The hail smashed glasshouses, skylights and windows, ruined gardens, damaged street lights and shop signs and created hazardous driving conditions. Hundreds of cars were damaged, and local orchardists had their crops decimated. Ashburton Airport recorded 13.6 mm of rainfall in the hour between 4 p.m. and 5 p.m.

Table 18. Average number of days each year with thunder, fog, hail and snow from all available data. The elevation of each station above mean sea level is also shown.

	Thunder	Fog	Hail	Snow
Whangarei Aero (37 m)	2	11	0.3	0
Auckland Aero (7 m)	12	17	4	0
Tauranga Aero (0 m)	5	16	1	0
Hamilton, Ruakura (40 m)	10	38	2	0
Taupo (376 m)	4	50	1	0.3
Gisborne Aero (4 m)	8	36	3	0.2
Napier, Nelson Pk (7 m)	4	4	0.9	0
New Plymouth Aero (27 m)	15	16	7	0.1
Palmerston North (34 m)	5	1	3	0.1
Wellington, Kelburn (125 m)	5	9	9	0.9
Nelson Aero (2)	7	17	2	0.1
Blenheim Aero (40 m)	2	5	0.5	0.2
Greymouth Aero (4 m)	14	5	5	0
Christchurch Aero (37 m)	3	49	6	3
Lake Tekapo (762 m)	2	9	0.3	13
Alexandra (141 m)	2	25	1	4
Dunedin, Musselburgh (2 m)	5	6	5	4
Milford Sound (3 m)	22	2	6	5
Invercargill Aero (1 m)	11	40	30	5

Fog

The most common type of fog in inland parts of New Zealand is radiation fog, formed when the air cools to its dew-point on clear nights, allowing the water vapour in the air to condense. Near the coast, advection fog can occur, where sea fog spreads onto the land as evening cooling proceeds. The average number of days per year with fog for selected locations is listed in Table 18. Although fog can occur at any time of the year, it is recorded most frequently during autumn and winter. For example, of the annual average of 17 days with fog at Nelson Airport, 10 days (60%) are recorded between May and August. In Invercargill, of the annual average of 41 days with fog, 15 days (36%) are recorded in autumn.

Snow

Snowfalls occur frequently in the mountains and high elevation inland locations of New Zealand, but are uncommon at low elevations. Seasonal snowfields typically begin to accumulate in the mountains in late autumn, and persist through to late-spring. Snowfalls to sea level are exceptionally rare in regions north of Canterbury. Table 18 shows the average number of days each year that snowfall occurs at selected locations. Note a frequency of 0.1 days/year equates to 1 day/10 years. Snow doesn't usually settle for long periods of time at coastal locations, however settled snow may last longer than a day or two at a time at higher elevation inland locations after a heavy snowfall event.

Exceptionally heavy snowfall events followed by prolonged spells of cool and dry weather can result in rare instances of snow lying for weeks at a time, as occurred on the Canterbury Plains from mid-June to early-July 2006. The snowstorm was a result of a rapidly deepening depression moving south-eastward from the Tasman Sea across New Zealand, with a strong moist north-westerly flow preceding it and a very cold southerly airflow behind. Snow fell in Canterbury overnight on 11 June and lay for about two weeks across the plains. The weight of snow and ice destroyed more than 500 power poles around the region, cutting power to 35,000 homes and businesses. Between 30 cm and 60 cm of snow accumulated over much of the plains, with approximately 40 cm recorded in Ashburton, 30 cm in Timaru and 15 cm in Christchurch.

Photo: ©mychillybin.co.nz/Murray Handley

DERIVED CLIMATOLOGICAL PARAMETERS

Apart from elements such as temperature and rainfall which can be measured directly, it has been found that parameters calculated from several elements have some important uses, especially in industry. Parameters which define the overall suitability of the climate for agriculture, horticulture, architectural and structural designs, and contracting, etc., are vapour pressure, relative humidity, evapotranspiration (leading to soil water balance), degree-days (thermal time), and rainfall extremes. Some of these and their uses are discussed in the following paragraphs.

Vapour pressure and relative humidity

Vapour pressure and relative humidity are the two parameters most frequently used to indicate moisture levels in the atmosphere. Both are calculated from simultaneous dry and wet bulb thermometer readings, although a hygrograph may be used to obtain continuous humidity readings.

Vapour pressure is the part of the total atmospheric pressure that results from the presence of water vapour in the atmosphere. It varies greatly with air masses from different sources, being greatest in warm air masses that have tropical origins and lowest in cold, polar-derived air masses. Vapour pressure can be important in determining the physiological response of organisms to the environment (very dry air, especially if there is a pre-existing soil moisture deficit, can cause or increase wilting in plants). Mean monthly 9 a.m. vapour pressures for selected New Zealand locations are given in Table 19, which shows that vapour pressures are lowest in the winter months.

Table 19. Mean monthly and annual vapour pressure (hPa).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Aero Aws	17.7	18.6	17.4	16.2	14.2	12.3	11.6	11.7	12.6	13.2	14.1	16.3	14.7
Auckland Aero	17.4	17.9	16.7	15.2	13.4	11.8	11.0	11.4	12.4	13.0	14.0	16.0	14.2
Tauranga Airport	16.5	16.9	15.7	14.1	12.3	10.8	10.0	10.4	11.5	12.2	13.2	15.5	13.3
Hamilton Aero	16.6	16.8	15.5	13.8	11.8	10.2	9.4	10.2	11.7	12.5	13.5	15.7	13.1
Taupo Aero	14.0	14.4	13.4	12.0	10.3	8.9	8.2	8.6	9.5	10.3	11.2	13.0	11.2
Gisborne Aero	15.6	16.3	15.4	13.6	11.5	9.8	9.4	9.9	10.8	11.7	12.7	14.4	12.6
Napier Aero Aws	14.6	15.6	14.2	13.0	11.0	9.2	9.0	9.2	10.1	10.7	11.4	13.6	11.8
New Plymouth Aero	16.3	16.6	15.6	13.8	12.0	10.5	9.7	10.3	11.5	12.5	13.5	15.1	13.1
Palmerston North Aws	14.9	15.4	14.2	13.0	11.5	9.9	9.4	9.8	10.7	11.7	12.3	14.1	12.2
Wellington, Kelburn	14.8	15.2	14.2	12.6	11.4	10.0	9.4	9.7	10.3	11.1	12.0	13.7	12.0
Nelson Aws	14.5	14.7	13.5	11.9	10.1	8.5	7.8	8.7	10.0	10.8	11.7	13.6	11.5
Blenheim Aero Aws	13.6	14.0	12.6	11.3	9.6	7.9	7.4	8.2	9.3	10.2	10.8	12.7	10.6
Greymouth Aero Ews	14.4	15.1	13.5	12.4	10.3	9.2	8.2	9.1	10.1	10.9	12.0	13.9	11.7
Christchurch Gardens	15.0	14.9	13.6	11.9	9.8	8.1	7.7	8.5	9.6	10.7	12.0	13.8	11.2
Lake Tekapo Ews	9.2	10.0	9.0	7.9	6.6	5.3	4.9	5.6	6.2	6.5	7.4	8.9	7.3
Alexandra 1	11.7	11.9	11.0	8.9	6.9	5.8	5.6	6.1	7.3	8.4	9.4	10.9	8.6
Dunedin, Musselburgh	12.3	12.4	11.5	10.1	8.7	7.6	7.2	7.6	8.3	9.1	9.9	11.3	9.7
Milford Sound	13.4	13.4	12.4	10.8	9.1	7.7	7.3	7.7	8.8	9.8	10.9	12.6	10.3
Invercargill Aero Aws	12.5	12.7	11.5	10.4	9.1	7.8	7.1	7.8	8.8	9.5	10.3	11.7	9.9

Relative humidity relates the amount of water present in the atmosphere to the amount of water necessary to saturate the atmosphere. Unlike vapour pressure, relative humidity is dependent on the air temperature. This is because as air temperature increases, the capacity of the atmosphere to hold water also increases. Therefore, relative humidity often displays large diurnal variation. Table 20 shows the 9 a.m. relative humidity at centres throughout New Zealand. Highest relative humidity is typically experienced in the winter months due to lower air temperatures.

Evapotranspiration and soil water balance

Evapotranspiration is the process where water held in the soil is gradually released to the atmosphere through a combination of direct evaporation and transpiration from plants. A water balance can be calculated by using daily rainfalls and by assuming that the soil can hold a fixed amount of water with actual evapotranspiration continuing at the potential rate until total moisture depletion of the soil occurs. The calculation of water balance begins after a long dry spell when it is known that all available soil moisture is depleted or after a period of very heavy rainfall when the soil is at field capacity. Daily calculations are then made of moisture lost through evapotranspiration or replaced through precipitation. If the available soil water becomes insufficient to maintain evapotranspiration, then a soil moisture deficit occurs and irrigation becomes necessary to maintain plant growth. Runoff occurs when the rainfall exceeds the field capacity (assumed to be 150 mm for most New Zealand soils).

Mean monthly and annual water balance values for selected New Zealand locations are given in Table 21. Soil moisture deficit peaks in summer, with highest soil moisture deficit of the main centres observed in Christchurch, whereas runoff peaks in the winter months. Figure 20 shows nationwide variability in days of soil moisture deficit per year, which illustrates the dryness of Central Otago, Canterbury, Marlborough and Hawke's Bay compared to other regions of the country.

Table 20. Mean monthly and annual 9 a.m. relative humidity (%).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Aero Aws	79	84	86	86	88	89	89	86	81	81	77	78	84
Auckland Aero	77	80	81	83	86	88	88	85	81	79	77	77	82
Tauranga Airport	74	78	78	80	83	85	84	82	77	75	73	75	79
Hamilton Aero	82	85	86	89	92	92	91	90	85	83	80	82	86
Taupo Aero	76	78	80	82	86	87	87	85	80	79	76	77	81
Gisborne Aero	70	76	78	80	82	83	83	81	74	71	68	69	76
Napier Aero Aws	66	73	75	77	78	79	80	76	70	67	63	66	73
New Plymouth Aero	80	81	82	83	86	86	86	85	82	82	80	80	83
Palmerston North Aws	75	78	80	82	86	87	87	85	80	81	77	76	81
Wellington, Kelburn	81	83	83	83	85	86	86	85	81	81	80	81	83
Nelson Aws	72	76	78	80	83	85	85	84	79	76	71	72	79
Blenheim Aero Aws	69	75	77	79	82	83	83	81	74	73	67	67	76
Greymouth Aero Ews	83	85	85	84	83	84	82	82	82	84	82	83	83
Christchurch Gardens	81	86	86	89	91	92	92	88	80	79	78	79	85
Lake Tekapo Ews	58	67	71	71	77	81	78	77	66	63	58	61	69
Alexandra 1	70	76	76	85	86	89	91	87	76	68	68	68	78
Dunedin, Musselburgh	74	78	77	77	80	80	80	78	72	72	71	73	76
Milford Sound	87	90	91	92	92	92	91	91	90	88	86	85	90
Invercargill Aero Aws	81	85	87	86	88	88	88	88	82	82	79	79	85

Table 21. Mean monthly and annual water balance summary for a soil moisture capacity of 150 mm. The following locations are not included in this table due to insufficient data: Lake Tekapo, Milford Sound.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Airport	DE	72	46	25	11	0	0	0	0	0	3	38	52	239
	ND	15	11	8	5	0	0	0	0	0	1	9	12	59
	RO	5	4	33	27	47	83	139	81	54	15	11	9	525
	NR	0	0	1	2	4	9	12	9	5	2	1	1	47
Auckland Aero	DE	98	73	43	16	2	0	0	0	0	3	47	74	357
	ND	19	16	12	7	2	0	0	0	0	1	10	15	81
	RO	3	3	1	2	29	66	98	66	30	15	0	3	315
	NR	0	0	0	0	3	9	12	9	4	2	0	0	40
Tauranga Airport	DE	83	57	25	12	1	0	0	0	0	6	46	57	288
	ND	16	13	8	6	1	0	0	0	0	2	10	12	67
	RO	6	5	6	35	50	73	101	72	34	22	4	8	416
	NR	0	0	0	2	3	7	9	7	3	2	0	1	36
Hamilton Airport	DE	51	49	22	9	1	0	0	0	0	0	8	24	164
	ND	12	13	8	5	1	0	0	0	0	0	2	6	46
	RO	6	9	2	14	42	103	108	90	47	34	6	10	470
	NR	1	1	0	1	5	12	12	12	6	4	1	1	55
Taupo Airport	DE	61	49	29	10	2	0	0	0	0	2	23	43	223
	ND	13	12	11	7	2	0	0	0	0	1	6	10	62
	RO	3	3	1	7	14	52	76	58	34	24	2	2	269
	NR	0	0	0	1	2	7	9	8	5	3	0	0	36
Gisborne Airport	DE	103	59	35	13	4	1	0	0	2	29	67	98	418
	ND	20	14	10	6	3	1	0	0	1	8	15	19	97
	RO	0	4	11	18	39	59	94	38	28	12	2	0	306
	NR	0	0	0	1	3	6	9	5	2	1	0	0	28
Napier Aero Aws	DE	104	67	57	13	5	2	0	0	3	48	85	101	491
	ND	20	15	16	7	3	2	0	0	1	12	18	19	114
	RO	2	1	0	1	16	40	64	21	6	11	0	1	169
	NR	0	0	0	0	1	3	5	2	1	1	0	0	14
New Plymouth Airport	DE	52	45	27	6	2	0	0	0	0	0	9	23	175
	ND	11	10	8	3	1	0	0	0	0	0	2	5	44
	RO	4	11	11	29	55	115	107	82	62	46	17	14	560
	NR	0	1	1	2	6	11	12	10	7	4	1	1	57
Palmerston North Aws	DE	86	73	47	10	1	0	0	0	0	0	18	45	291
	ND	18	16	14	6	1	0	0	0	0	0	4	10	72
	RO	0	5	1	0	5	44	58	43	33	28	6	4	225
	NR	0	0	0	0	1	6	9	8	5	3	1	1	35
Wellington, Kelburn	DE	69	51	25	7	0	0	0	0	0	0	12	41	206
	ND	15	13	9	4	0	0	0	0	0	0	3	9	53
	RO	3	9	1	13	51	110	117	84	47	44	21	6	505
	NR	0	1	0	1	5	12	12	10	5	4	1	0	51
Nelson Aero	DE	90	69	34	10	1	0	0	0	0	6	41	64	317
	ND	18	16	11	6	1	0	0	0	0	2	9	13	77
	RO	3	0	3	14	41	62	61	58	31	20	7	6	306
	NR	0	0	0	1	3	6	6	6	3	2	1	0	28
Blenheim Aero Aws	DE	118	84	57	24	6	1	1	0	3	19	71	101	477
	ND	22	19	16	12	5	2	1	0	1	5	15	19	116
	RO	0	0	0	2	7	22	33	29	15	7	2	0	117
	NR	0	0	0	0	1	2	3	3	2	1	0	0	12

Greymouth Aero	DE	4	3	1	0	0	0	0	0	0	0	1	1	9
	ND	1	1	0	0	0	0	0	0	0	0	0	0	3
	RO	92	65	101	163	194	198	173	159	147	151	118	111	1671
	NR	5	4	7	11	14	14	13	13	12	12	8	7	119
Christchurch Gardens	DE	113	74	48	16	2	0	0	0	4	24	76	100	458
	ND	22	18	16	10	2	0	0	0	2	7	18	20	117
	RO	0	0	0	0	3	18	38	32	6	4	0	0	102
	NR	0	0	0	0	1	3	4	4	1	0	0	0	13
Alexandra	DE	98	75	46	18	2	1	0	3	20	54	88	100	505
	ND	21	19	18	14	4	2	1	3	11	19	22	22	157
	RO	0	0	0	0	0	0.1	0.5	0.6	0.1	0	0	0	1.3
	NR	0	0	0	0	0	0	0.2	0.2	0	0	0	0.0	0.4
Dunedin, Musselburgh	DE	50	41	26	8	2	0	0	0	1	11	38	45	223
	ND	12	12	10	5	2	0	0	0	1	4	10	11	68
	RO	1	1	6	2	15	20	28	24	8	3	2	0	110
	NR	0	0	1	0	2	4	5	4	1	1	0	0	19
Invercargill Aero	DE	33	21	9	1	0	0	0	0	0	0	8	23	96
	ND	8	6	4	1	0	0	0	0	0	0	2	6	27
	RO	7	3	8	29	71	92	66	43	35	23	9	2	389
	NR	1	0	1	4	11	16	13	9	6	3	1	0	66

DE: average amount of soil moisture deficit (mm)
ND: average number of days on which a soil moisture deficit occurs
RO: average amount of runoff (mm)
NR: average number of days on which runoff occurs

Potential evapotranspiration (PET) has been calculated for selected New Zealand locations using the Penman method (Penman, 1948). The monthly mean, minimum, and maximum PET values for these locations are listed in Table 22.

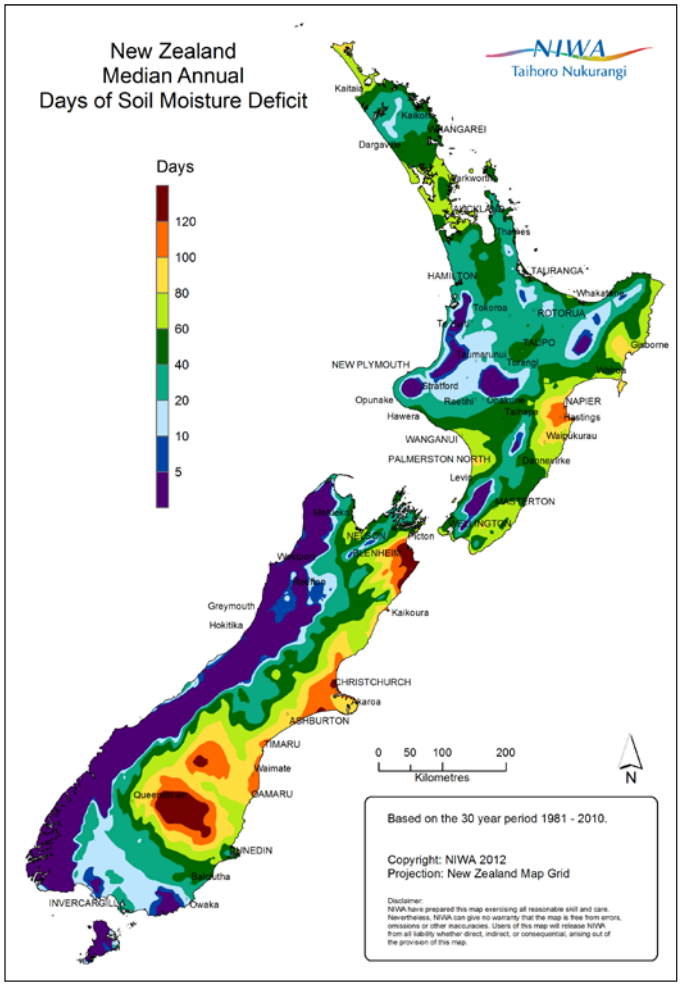


Figure 20. Median annual days of soil moisture deficit for New Zealand, 1981–2010.

Table 22. Penman calculated maximum, mean, and minimum monthly potential evapotranspiration (mm), and mean annual total potential evapotranspiration. The following locations are not included in this table due to insufficient data: Greymouth, Lake Tekapo, Alexandra, Milford Sound.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Aero Aws	Max	175	127	121	68	42	31	40	52	76	119	129	167	
	Mean	143	114	97	58	38	27	31	46	67	99	121	135	980
	Min	124	94	83	53	35	23	27	40	60	81	109	111	
Auckland Aero	Max	187	146	124	79	51	36	45	60	81	126	150	176	
	Mean	161	129	109	65	40	27	31	48	72	107	133	153	1075
	Min	137	113	91	52	33	18	23	35	61	87	116	139	
Tauranga Airport	Max	186	150	117	73	47	33	44	50	81	124	148	186	
	Mean	161	125	104	63	40	26	31	45	68	105	130	148	1045
	Min	136	109	86	46	34	19	26	36	58	80	104	123	
Hamilton, Ruakura	Max	163	122	98	56	32	21	35	40	59	104	131	139	
	Mean	133	105	86	49	26	15	20	33	54	83	106	124	835
	Min	117	89	71	38	22	11	16	27	45	65	96	111	
Taupo N.Z.E.D.	Max	144	119	91	51	31	19	24	33	60	92	112	147	
	Mean	130	107	79	45	26	15	18	31	50	80	104	121	807
	Min	107	96	69	38	22	11	14	29	42	62	91	103	
Gisborne Airport	Max	184	149	130	75	51	35	36	61	88	152	166	184	
	Mean	158	117	96	57	37	26	28	44	70	109	133	156	1030
	Min	131	85	78	46	25	17	22	34	54	82	102	119	
Napier, Nelson Pk	Max	175	135	118	72	50	32	39	55	88	151	159	191	
	Mean	152	117	97	57	35	23	27	42	69	107	125	150	1008
	Min	121	95	75	39	25	17	18	29	53	78	96	118	
New Plymouth Airport	Max	174	139	114	75	50	34	45	59	76	109	136	152	
	Mean	144	119	99	60	38	27	31	44	61	90	116	132	963
	Min	125	103	84	49	27	19	25	28	48	73	97	116	
Palmerston North Ews	Max	163	138	118	60	35	20	26	41	67	94	129	148	
	Mean	137	112	88	49	26	15	18	32	54	80	106	125	847
	Min	113	94	73	35	19	10	14	25	44	68	88	98	
Wellington, Kelburn	Max	168	131	115	65	41	26	30	53	76	121	137	148	
	Mean	143	111	89	51	30	18	22	36	59	90	111	133	891
	Min	123	90	72	40	22	13	16	28	43	70	93	101	
Nelson Aero	Max	188	138	112	66	35	25	25	39	72	114	147	180	
	Mean	152	115	89	49	25	15	17	30	57	92	120	141	901
	Min	124	86	75	37	19	10	11	25	47	55	99	115	
Blenheim Aero Aws	Max	192	148	127	81	47	36	33	52	82	124	196	195	
	Mean	164	123	107	57	33	23	26	41	67	106	135	158	1056
	Min	131	98	84	38	24	16	19	31	48	83	107	111	
Christchurch Aero	Max	194	139	124	61	40	26	26	49	82	146	175	191	
	Mean	152	114	86	47	26	16	19	33	57	95	126	148	919
	Min	113	91	59	33	16	10	12	25	44	70	98	111	
Dunedin, Musselburgh	Max	155	115	91	59	44	32	36	51	78	107	133	149	
	Mean	126	98	79	47	29	20	22	35	61	91	112	124	856
	Min	95	79	69	38	21	14	11	25	44	76	91	107	
Invercargill Airport	Max	148	113	85	55	34	19	25	41	62	98	122	145	
	Mean	121	94	71	39	22	13	15	29	53	84	109	125	775
	Min	99	80	53	31	13	5	8	22	45	68	91	101	

Degree-day totals

The departure of mean daily temperature above a base temperature which has been found to be critical to the growth or development of a plant is a measure of the plant's development on that day. The sum of these departures then relates to the maturity or harvestable state of the crop. Thus, as the plant grows, updated estimates of harvest time can be made. These estimates have been found to be very valuable for a variety of crops with different base temperatures.

Degree-day totals indicate the overall effects of temperature for a specified period, and can be applied to agricultural and horticultural production. Growing degree-days express the sum of daily temperatures above a selected base temperature that represent a threshold of plant growth. Table 23 lists the mean monthly growing degree-day totals above base temperatures of 5°C and 10°C for New Zealand's main centres. Figure 21 illustrates the national variability of annual growing degree-day totals (base 10°C).

Table 23. Average growing degree-day totals above base 5°C and 10°C.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Airport	5°C	462	429	428	349	293	221	204	216	248	300	343	419	3921
	10°C	307	288	273	199	138	76	57	65	99	145	193	264	2114
Auckland Aero	5°C	459	432	428	340	277	204	184	205	243	293	337	415	3817
	10°C	304	290	273	190	123	64	45	56	94	138	187	260	2025
Tauranga Airport	5°C	446	413	403	314	253	176	161	176	218	277	323	402	3562
	10°C	291	272	248	164	100	44	31	37	72	123	173	247	1802
Hamilton Airport	5°C	414	388	368	274	206	133	117	139	187	245	290	368	3131
	10°C	259	247	213	126	65	26	18	20	50	94	140	213	1472
Taupo Airport	5°C	373	341	309	209	138	82	63	77	125	189	241	328	2472
	10°C	219	200	155	72	28	9	3	4	18	53	96	174	1028
Gisborne Airport	5°C	442	398	388	295	232	160	147	165	209	276	323	405	3444
	10°C	287	257	233	146	80	34	24	34	67	123	173	250	1711
Napier, Nelson Pk	5°C	451	406	394	300	229	150	137	163	219	288	332	417	3497
	10°C	296	264	239	151	80	32	23	35	77	135	182	262	1785
New Plymouth Airport	5°C	390	369	362	286	234	169	146	162	196	239	274	346	3186
	10°C	235	228	207	137	84	39	24	29	55	87	124	191	1449
Palmerston North	5°C	397	372	358	266	203	131	115	137	181	233	275	352	3017
	10°C	242	231	203	119	62	23	14	20	47	85	126	197	1366
Wellington, Kelburn	5°C	370	343	335	260	207	141	120	137	175	216	253	323	2881
	10°C	215	202	181	112	62	23	11	17	39	68	104	168	1201
Nelson	5°C	388	354	341	241	160	81	64	95	152	220	271	344	2711
	10°C	233	213	186	95	35	8	3	7	28	72	122	189	1190
Blenheim Airport	5°C	400	356	339	239	163	86	70	103	159	225	275	357	2794
	10°C	245	215	185	94	38	11	5	11	36	81	128	203	1267
Greymouth	5°C	343	321	313	246	182	115	100	125	164	205	241	305	2658
	10°C	188	180	158	97	42	12	6	11	29	56	92	150	1021
Christchurch Gardens	5°C	365	326	308	218	129	55	47	77	142	216	264	333	2480
	10°C	211	185	154	78	23	4	3	7	28	74	117	178	1062
Lake Tekapo	5°C	307	276	241	136	53	13	7	18	63	132	188	259	1693
	10°C	155	138	96	29	4	0	0	0	5	26	61	113	628
Alexandra	5°C	381	340	301	178	72	18	12	42	119	205	267	346	2279
	10°C	226	199	148	52	8	1	0	2	19	66	121	191	1023
Dunedin, Musselburgh	5°C	315	283	274	202	131	67	55	82	133	186	223	277	2228
	10°C	160	142	120	61	18	3	2	5	21	49	80	123	785
Milford Sound	5°C	295	275	263	186	107	42	33	61	106	157	197	264	1986
	10°C	140	135	110	49	12	2	1	2	7	27	56	111	651
Invercargill Aero	5°C	277	248	232	159	91	40	30	54	103	153	189	247	1822
	10°C	123	108	83	34	7	1	0	2	10	29	53	96	545

Cooling and heating degree days are measurements that reflect the amount of energy that is required to cool or heat buildings to a comfortable base temperature, which in this case is 18°C. Table 24 shows that the number of cooling degree days reaches a peak in mid-late summer throughout New Zealand, when energy required to cool building interiors to 18°C is highest. Conversely, heating degree days reach a peak in winter, when the energy required to heat buildings to 18°C is highest. Figure 22 shows nationwide variability in the number of heating degree days per year. The number of heating degree days tends to be lower in low elevation coastal areas and towards the north of the country, compared with inland high elevation areas and southern locations.

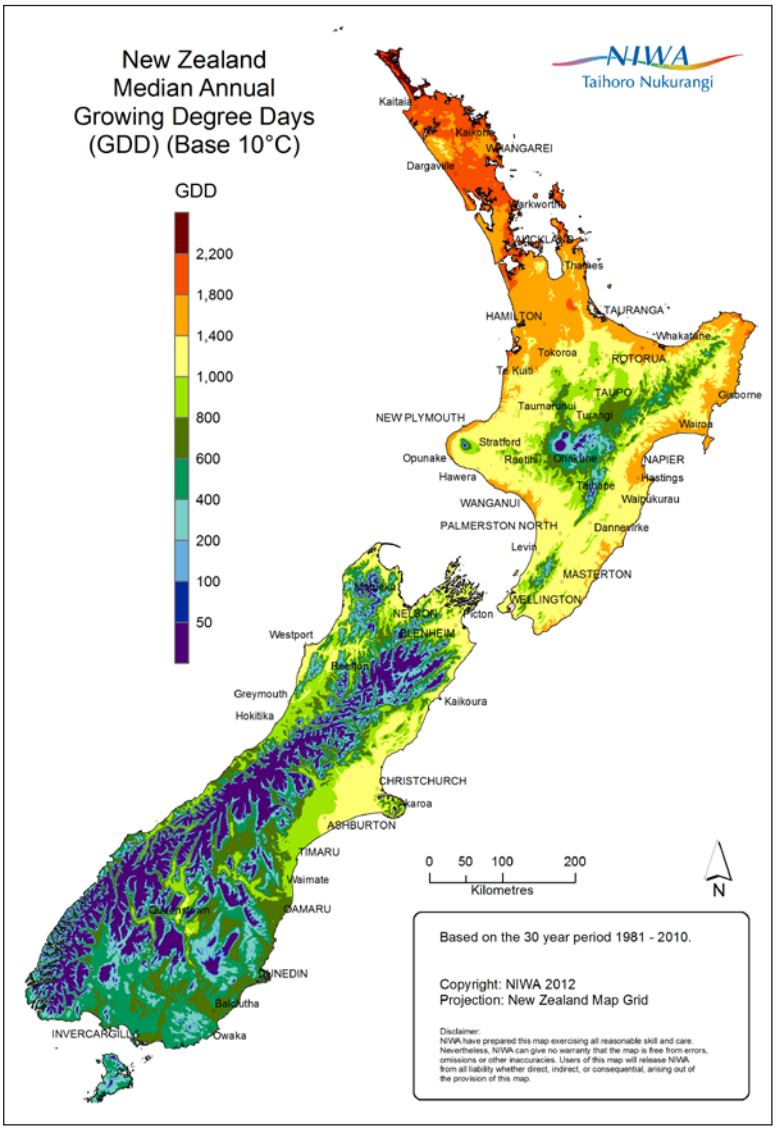


Figure 21. Median annual growing degree days (base 10°C) for New Zealand, 1981 – 2010.

Table 24. Average cooling (CDD) and heating (HDD) degree-day totals with base 18°C.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Airport	CDD	63	64	36	10	1	0	0	0	0	1	7	34	220
	HDD	4	2	12	51	111	169	200	187	142	104	55	18	1046
Auckland Aero	CDD	61	67	38	7	1	0	0	0	0	0	4	30	209
	HDD	5	3	13	57	126	186	219	198	147	110	57	18	1140
Tauranga Airport	CDD	53	52	26	4	1	0	0	0	0	0	4	25	165
	HDD	10	6	27	81	151	214	242	227	172	126	71	26	1352
Hamilton Airport	CDD	37	37	17	2	0	0	0	0	0	0	2	16	111
	HDD	25	17	52	118	197	259	288	265	203	158	102	51	1734
Taupo Airport	CDD	17	16	4	0	0	0	0	0	0	0	1	6	45
	HDD	47	42	98	181	266	319	356	333	267	214	149	81	2358
Gisborne Airport	CDD	60	47	25	5	1	0	0	0	0	2	11	40	190
	HDD	21	16	40	100	172	230	256	238	181	129	77	38	1495
Napier, Nelson Pk	CDD	64	52	29	7	1	0	0	0	1	5	14	44	220
	HDD	17	14	38	97	175	240	266	240	171	120	72	31	1471
New Plymouth Airport	CDD	22	24	12	1	0	0	0	0	0	0	1	7	69
	HDD	35	22	53	105	169	222	257	241	194	164	117	64	1631
Palmerston North	CDD	28	29	14	1	0	0	0	0	0	0	1	11	86
	HDD	34	24	59	125	201	260	289	266	209	170	117	62	1820
Wellington, Kelburn	CDD	13	15	6	0	0	0	0	0	0	0	0	3	38
	HDD	47	38	74	130	196	249	283	266	215	188	138	83	1905
Nelson	CDD	21	19	7	0	0	0	0	0	0	0	1	7	56
	HDD	36	32	70	149	243	313	346	310	238	183	120	67	2108
Blenheim Airport	CDD	36	28	14	1	0	0	0	0	0	1	5	21	108
	HDD	38	39	77	153	241	309	340	303	232	179	119	66	2077
Greymouth	CDD	6	6	2	0	0	0	0	0	0	0	0	2	17
	HDD	66	53	93	145	221	276	304	279	226	198	149	100	2109
Christchurch Gardens	CDD	23	18	8	1	0	0	0	0	0	1	4	14	68
	HDD	60	59	103	173	275	345	370	332	249	188	130	84	2370
Lake Tekapo	CDD	10	7	1	0	0	0	0	0	0	0	1	2	21
	HDD	106	99	164	256	379	459	509	447	342	275	204	146	3385
Alexandra	CDD	33	25	7	0	0	0	0	0	0	0	4	18	87
	HDD	55	53	109	212	350	438	471	386	273	199	127	75	2749
Dunedin, Musselburgh	CDD	7	7	3	0	0	0	0	0	0	0	1	3	22
	HDD	96	91	131	189	273	328	355	323	258	218	168	129	2559
Milford Sound	CDD	2	2	0	0	0	0	0	0	0	0	0	0	4
	HDD	110	94	141	204	299	366	393	348	285	246	193	140	2817
Invercargill Aero	CDD	3	3	1	0	0	0	0	0	0	0	0	1	8
	HDD	129	122	172	231	316	370	398	359	289	250	201	158	2994

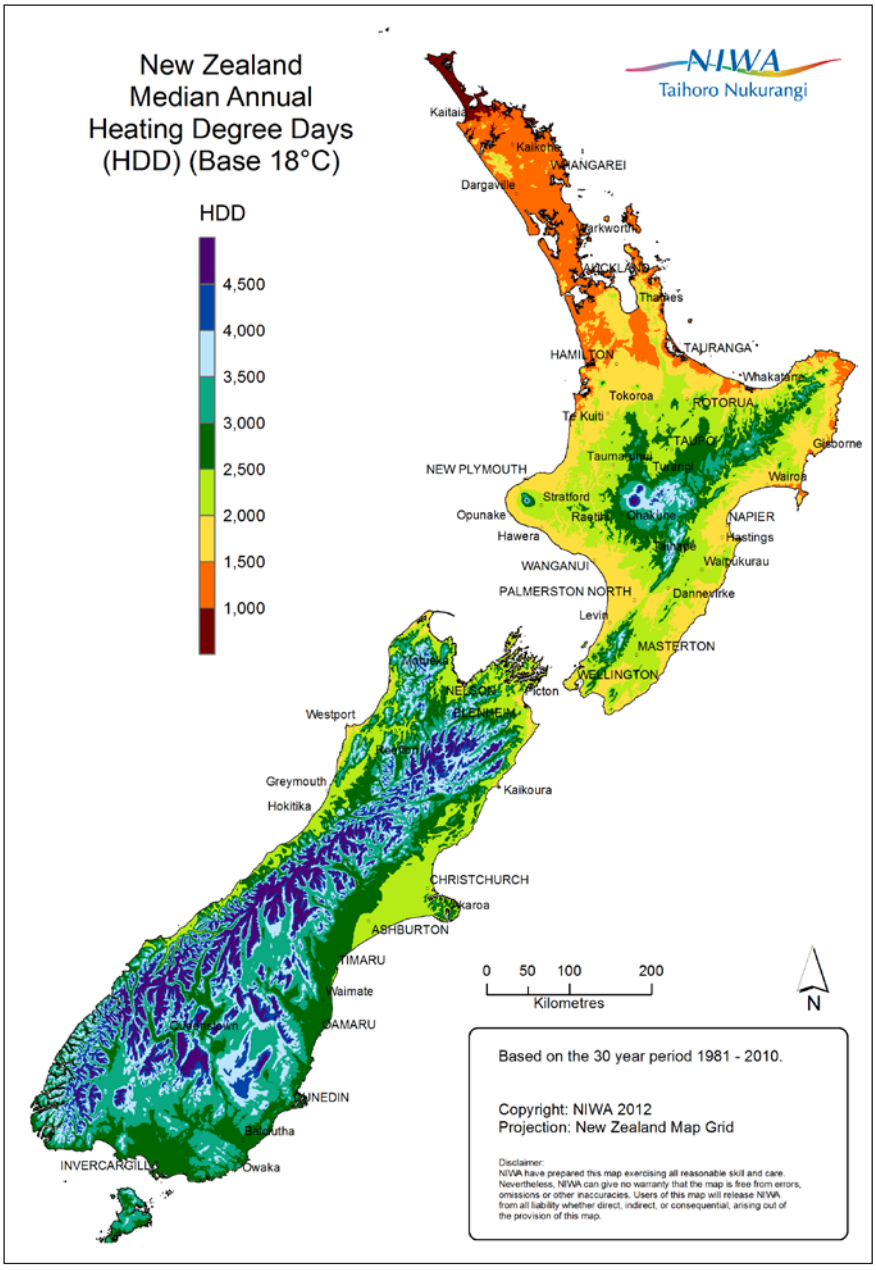


Figure 22. Median annual heating degree days for New Zealand, 1981–2010.

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