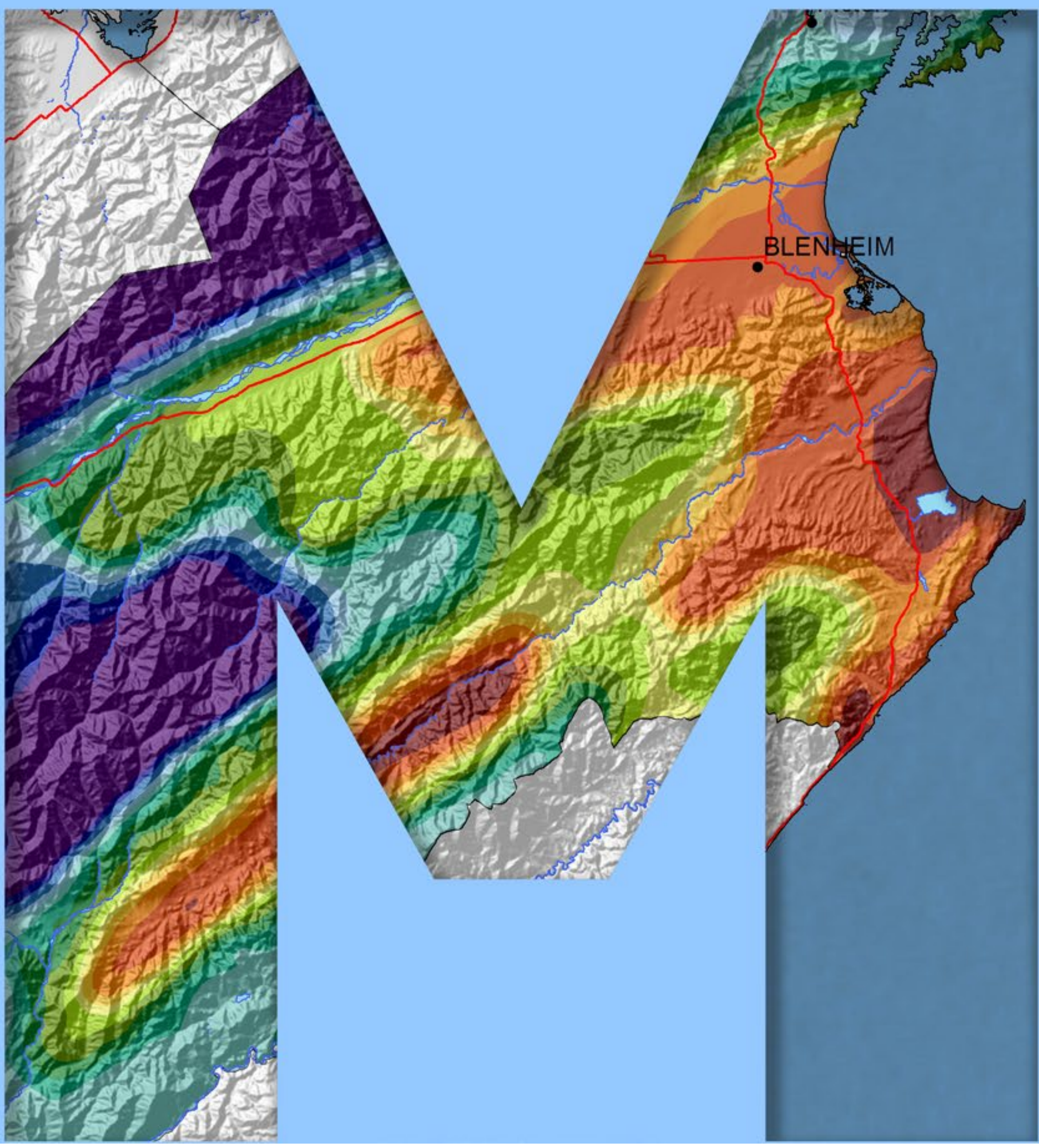
NIWA
Taihoro Nukurangi

THE CLIMATE AND WEATHER OF
MARLBOROUGH

2nd edition

P.R. CHAPPELL



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Note to Second Edition

This publication replaces the first edition of the New Zealand Meteorological Service Miscellaneous Publication 115 (12) 'The climate and weather of Marlborough', written in 1983 by R.M. Pascoe. This edition incorporates more recent data and updated methods of climatological variable calculation.

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P.R. Chappell

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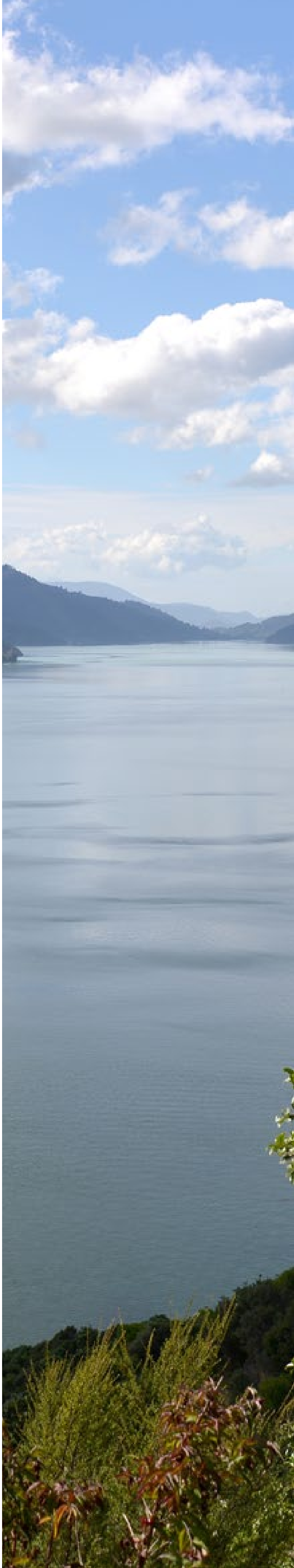
CONTENTS



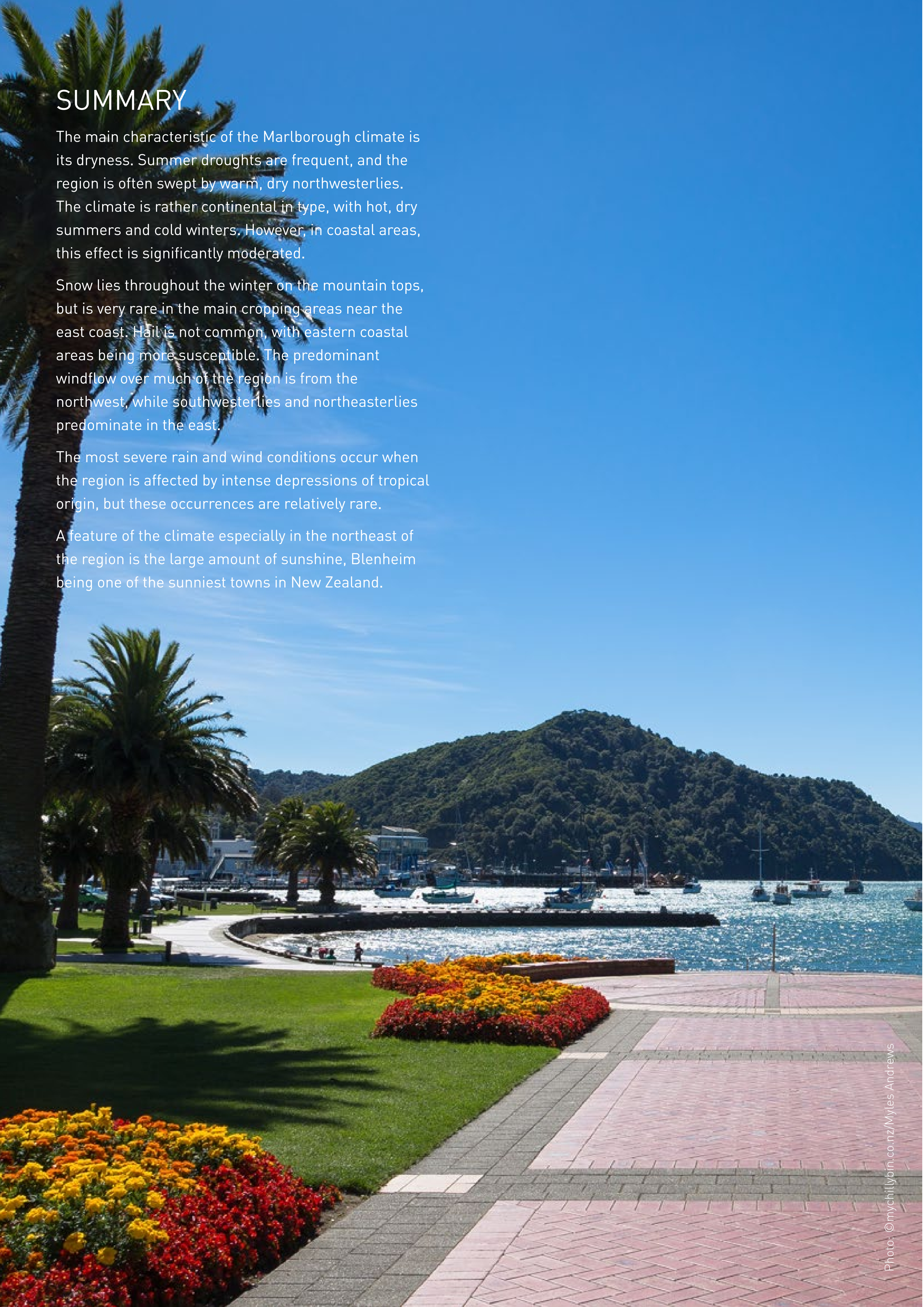
SUMMARY

The main characteristic of the Marlborough climate is its dryness. Summer droughts are frequent, and the region is often swept by warm, dry northwesterlies. The climate is rather continental in type, with hot, dry summers and cold winters. However, in coastal areas, this effect is significantly moderated.

Snow lies throughout the winter on the mountain tops, but is very rare in the main cropping areas near the east coast. Hail is not common, with eastern coastal areas being more susceptible. The predominant windflow over much of the region is from the northwest, while southwesterlies and northeasterlies predominate in the east.

The most severe rain and wind conditions occur when the region is affected by intense depressions of tropical origin, but these occurrences are relatively rare.

A feature of the climate especially in the northeast of the region is the large amount of sunshine, Blenheim being one of the sunniest towns in New Zealand.



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INTRODUCTION

New Zealand is a narrow, mountainous country situated in the vast oceans of the Southern Hemisphere. The nearest land mass is the continent of Australia, some 1600 km to the northwest. The day-to-day weather of New Zealand is affected by a succession of anticyclones and depressions moving eastward. The weather characteristics of these systems determine the broad climatic features of the New Zealand region. The predominant wind flow over the country is westerly, and this together with the mountain ranges exerts a major influence on New Zealand's climate. Winds are often deflected by the ranges, and speed is increased through gaps, such as Cook and Foveaux Straits. As the main ranges lie in a northeast to southwest direction, regions in their lee are significantly drier and sunnier than those exposed to the predominant westerlies. Occasionally the country is affected by airmasses which originate in the Antarctic region or in the tropics. These airmasses are modified as they move over the seas bringing to New Zealand periods of intense showery weather associated with the cold air, or heavy rainfalls from a warm humid airmass.

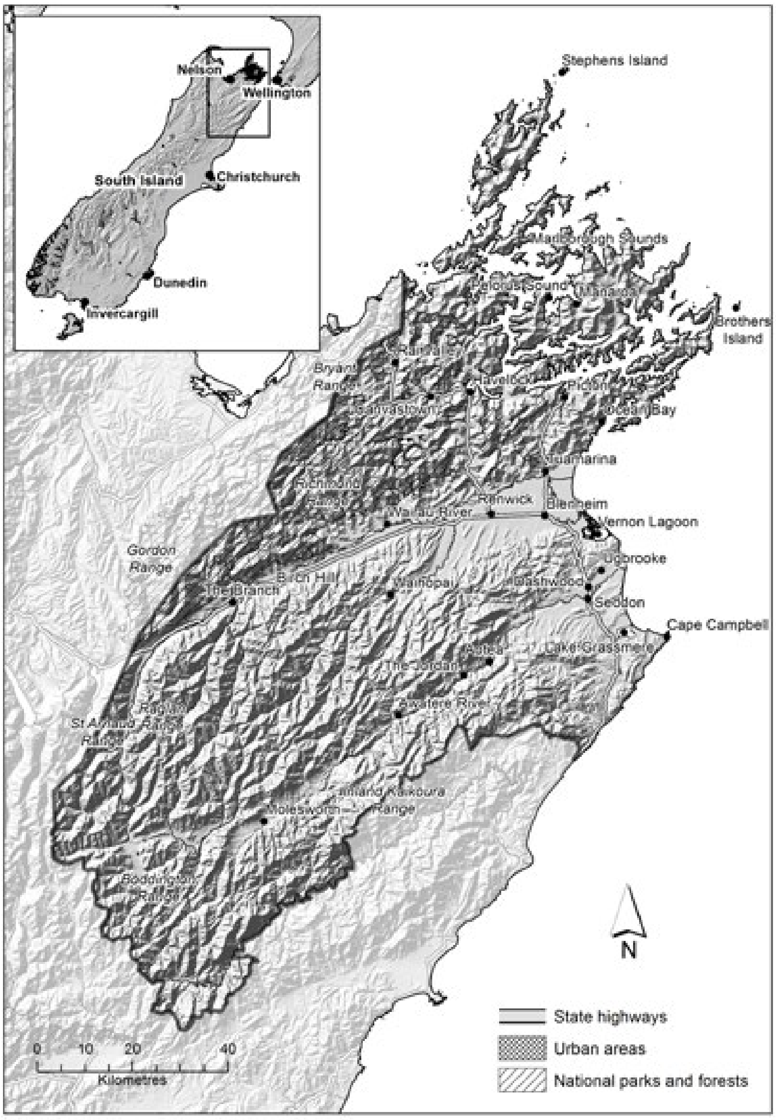

Figure 1. Map of Marlborough region, with locations of places mentioned in the text, tables, and figures.

In this publication, the Marlborough region considered is that administered by the Marlborough District Council (Figure 1). This region covers the northeast part of the South Island, and borders Nelson and Tasman regions to the west, and Canterbury to the south. The region encompasses two major catchments, those of the Wairau and Awatere Rivers. These rivers flow northeastwards into the Pacific Ocean. The region is bounded in the southeast by the Inland Kaikoura Range, in the south by the Boddington Range, in the southwest by the St Arnaud Range, and in the west by the Gordon and Bryant Ranges. The highest point in Marlborough is Mt Tapuaenuku (2885 m), which forms part of the Inland Kaikouras and is on the border between Marlborough and Canterbury regions. In the north lie the Marlborough Sounds, a network of sunken valleys.

Blenheim, the major town in the region, is situated in the northeast. There are other small towns which follow State Highway 1 along the east coast from Picton (in the Marlborough Sounds), but the remainder of the region is predominantly rural. As such, the main economic activity of the region is agriculture. This is mostly extensive sheep and beef farming in the uplands and viticulture on the plains, but there is also some cropping, orcharding, and market gardening (chiefly around Blenheim), forestry and some dairying. The Marlborough region is renowned for its production of the Sauvignon Blanc wine variety.

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.

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TYPICAL WEATHER SITUATIONS IN MARLBOROUGH

As in other parts of the country, Marlborough's weather is dominated by eastward-moving anticyclones with intervening troughs of low pressure. The anticyclones are generally accompanied by fine weather but it may be cloudy particularly if the wind is blowing onshore. The troughs often contain only a narrow band of cloud but the more active troughs are associated with a belt of rain. If a trough or frontal zone becomes slow-moving over the region, significant rainfalls may ensue. However, in some circumstances troughs that produce significant rainfalls in some other parts of New Zealand yield little rain in most of Marlborough because of the sheltering of the ranges.

New Zealand lies within the Southern Hemispheric temperate zone, and the predominant wind flow over the country is from a little south of west. As Marlborough lies over and east of the Main Divide, most of the region experiences a significant rain shadow. It is one of the three eastern South Island regions which are the driest regions in the country.

A less common weather system which may affect Marlborough is the cyclonic storm of tropical origin which may still be very vigorous. This injects into the region large amounts of moist air because of its origin in warm tropical oceans.

Westerly situations

In a southwesterly flow behind a cold front or trough, rainfall in Marlborough is negligible, being confined mainly to the high country in the southwest. As the flow turns to the northwest ahead of the next front, more significant rain falls in the northwest of the region. Characteristically, a westerly airstream is dry and often very warm. An extreme example is the situation on 7 February 1973 (Figure 2) when the temperature at The Jordan in the Awatere Valley reached 42.2°C. This temperature is one of the highest ever recorded in New Zealand. Low cloud and drizzle affected the west coast, but skies were almost completely clear over Marlborough, with relative humidities falling below 20%.

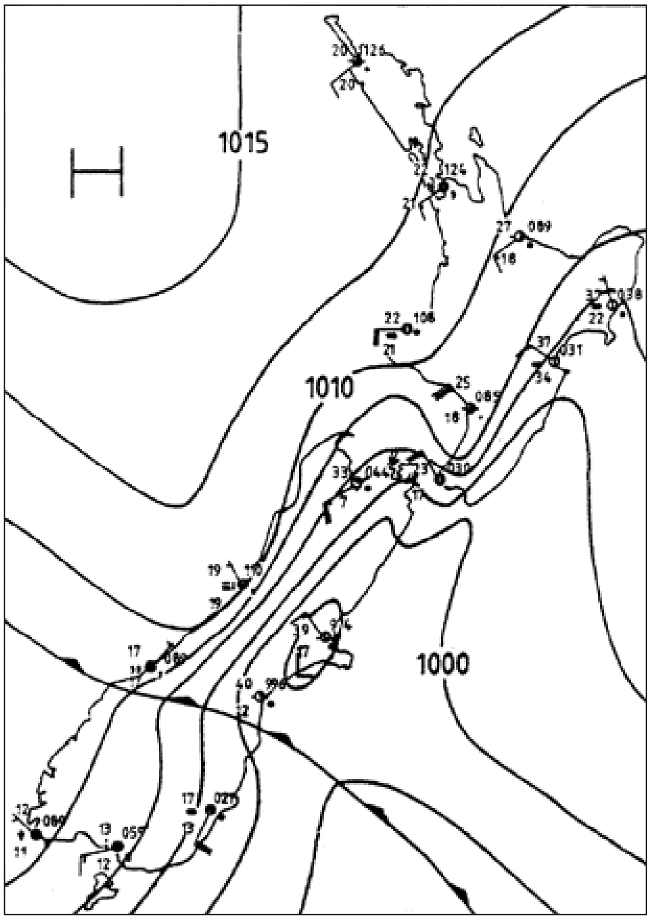

Figure 2. Mean sea level analysis for 1200 NZST 7 February 1973.

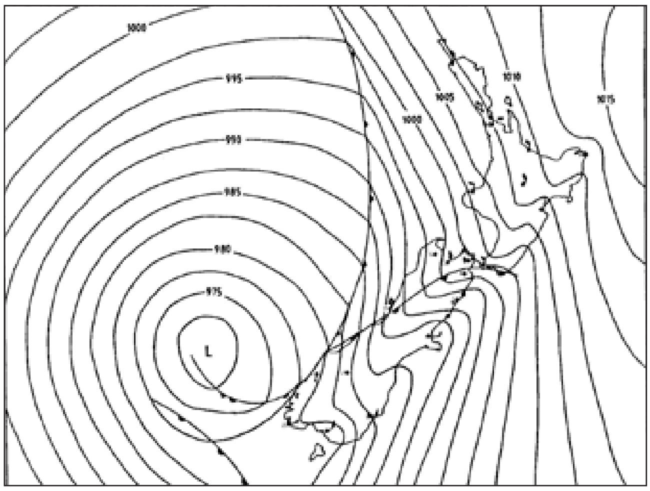

Figure 3. Mean sea level analysis for 1500 NZST 1 April 1975.

Northerly airstreams

As well as being sheltered from the west by the central high country, the region is also significantly sheltered from the northeast by the North Island. However, in a flow from between north and northwest, significant amounts of rain can fall in the Marlborough Sounds and in an area over and immediately adjacent to the Richmond Range. An example is the situation of 1 April 1975 (Figure 3). On this day over 150 mm of rain was recorded on the Richmond Range in a 15-hour period from 9am to midnight. The rain was accompanied by strong north to northwest surface winds. At Wairau Valley township the rainfall was 137 mm, and the wind during the evening was strong enough to cause substantial damage to trees.

Northeasterly airstreams

Under northeasterly conditions, the region is sheltered from heavy rainfalls by the North Island. However, there is often a depression lying west of the country and the region is then covered by a sheet of high cloud. An example is 27-28 June 1977 (Figure 4). Dry conditions prevailed during most of the 27th but in the evening light rain began in the north of the region, where the actual surface windflow was from between east and southeast. By 9 am on the 28th there had been 26 mm at Manaroa in the Marlborough Sounds, 15 mm at Blenheim, and 18 mm at The Branch in the upper Wairau Valley. After 9 am the airflow over Marlborough turned more to the north as the depression drifted southwards.

Easterly airstreams

Easterly airstreams in Marlborough are occasionally very wet, especially in the eastern part of the region, the uplift caused by the mountains serving to enhance the rainfall.

An extreme example is the airstream caused by ex-Tropical Cyclone Alison in March 1975 (Figure 5), which caused torrential rain on Marlborough's east coast and in the Marlborough Sounds. Many rivers, including the Awatere, flooded, and bridges and approaches were washed out. Many slips occurred and State Highway 1 and the main trunk railway line was blocked in several places. Picton was flooded, causing some evacuations. High winds caused power cuts to some parts of the region.

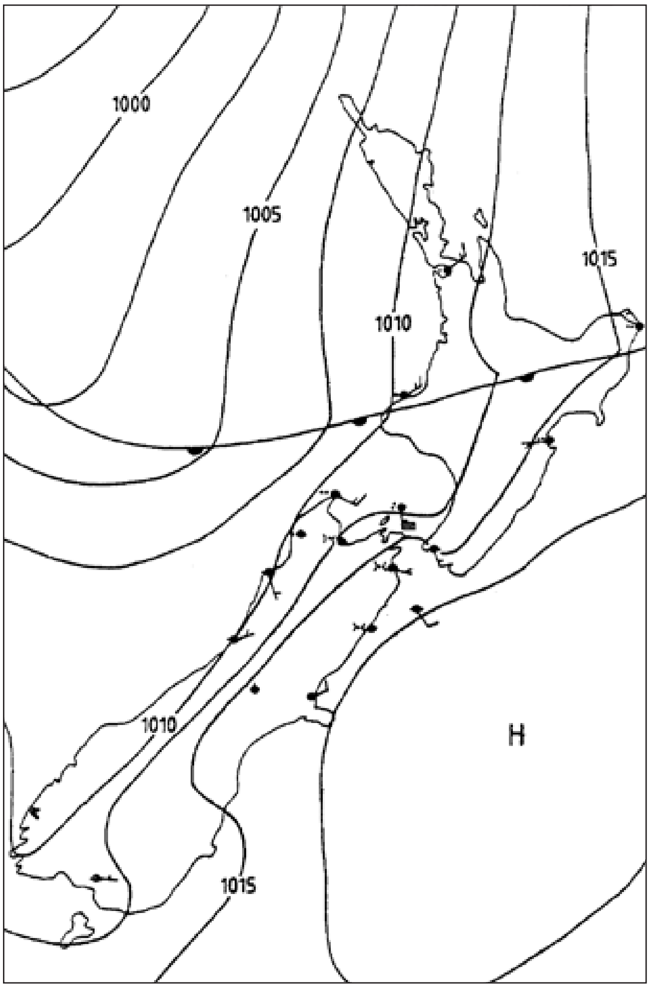

Figure 4. Mean sea level analysis for 1800 NZST 27 June 1977.

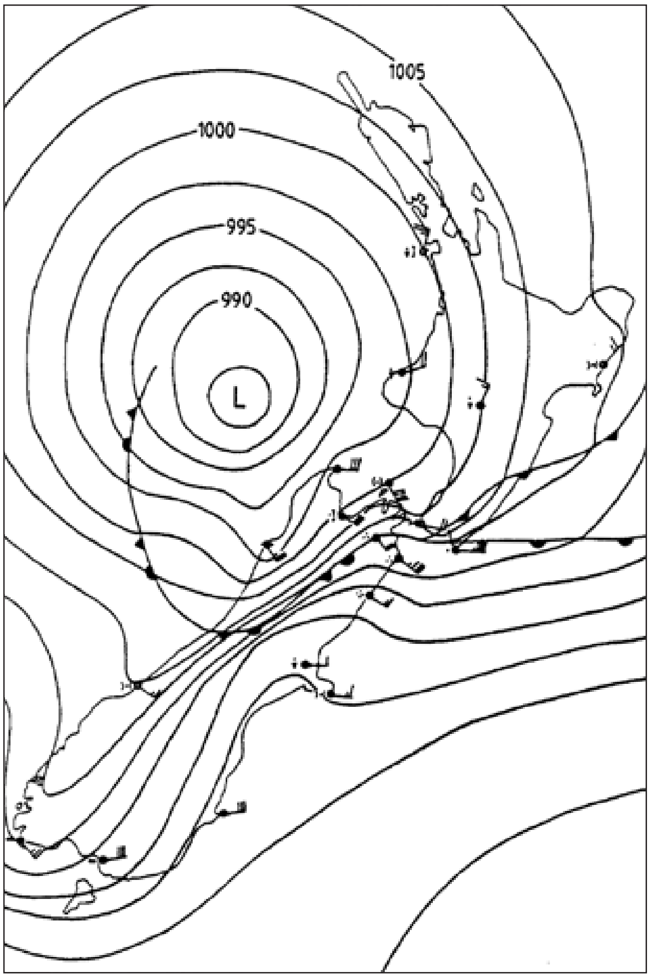

Figure 5. Mean sea level analysis for 1800 NZST 12 March 1975.

Southerly airstreams

As a trough of low pressure moves to the east of the country, a change to southerly winds often spreads northwards along the South Island east coast. As the cold air flows over warmer seas it is warmed from below, and precipitation in southerly flows is usually in the form of showers. Rainfall amounts are therefore not likely to be great, and the rainfall is confined mainly to the coast. A typical example occurred on 6 May 1977 (Figure 6). Rainfall on that day was a trace at Cape Campbell lighthouse and nil at Blenheim.

Orographic influences

The orography of the mountainous country comprising Marlborough, and of Cook Strait, ensures that the surface wind flows in Marlborough are not always as one might expect from a synoptic chart.

For example, in a northeasterly airstream, the isobars lie along the main mountain chain of the country with low pressure to the northwest, and one might therefore expect no wind at all in Cook Strait. However, in this situation the Cook Strait wind is usually a southeasterly (i.e. blowing from higher pressure to lower) and is often quite strong in western parts of the Strait. An eddy forms off the Kaikoura coast and along the coast the wind is a light southerly or southwesterly. In the west of the province the wind will usually follow the line of the isobars (Figure 7).

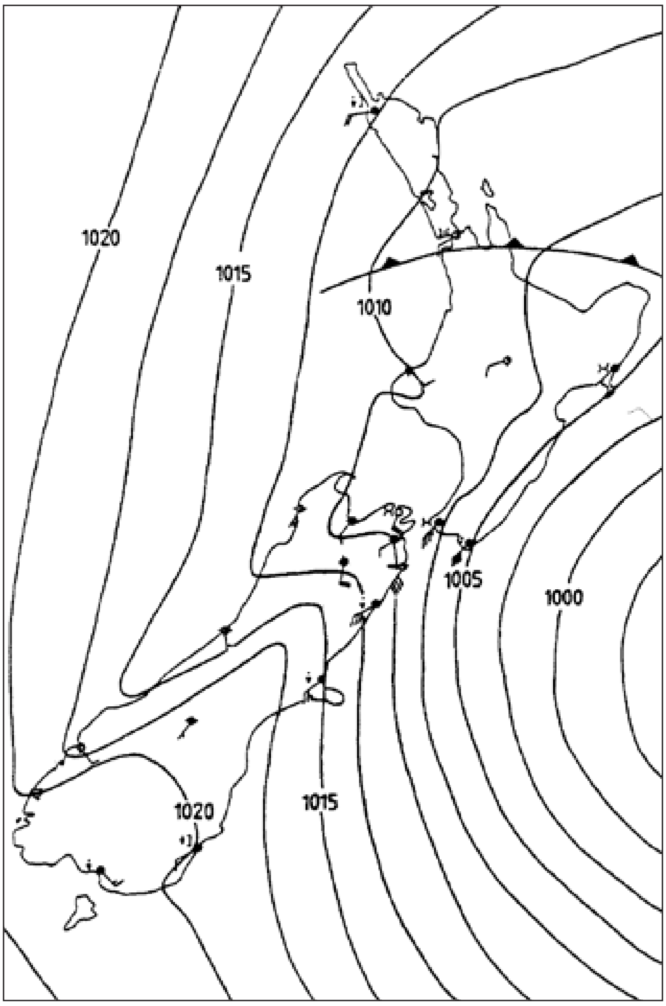

Figure 6. Mean sea level analysis for 1200 NZST 6 May 1977.

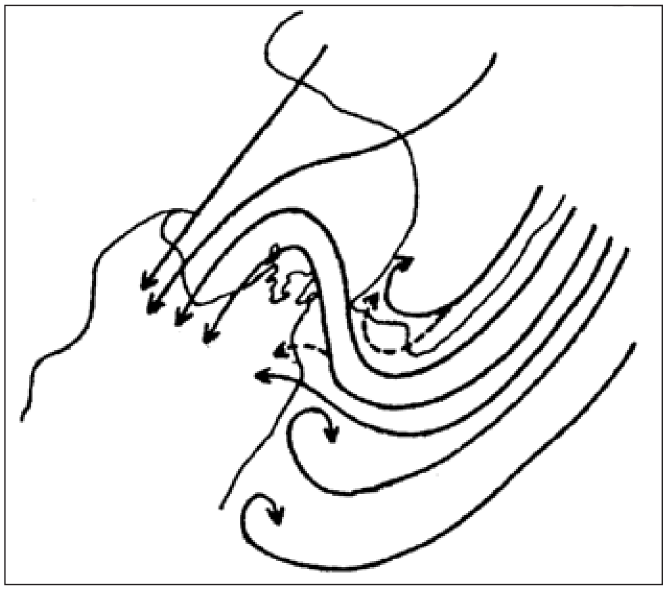

Figure 7. Streamlines of the local winds associated with broadscale northeast flows.


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CLIMATIC ELEMENTS

Wind

The predominant airflow over Marlborough at mountain-top level is from near to due west throughout the year, but at the surface directions are greatly influenced by local topography. The effect of friction at the surface causes some cross-isobar flow with the result that northwesterlies are as common as westerlies. In eastern parts of the region, such as at Cape Campbell, a secondary maximum of southerly winds is manifested. Apart from the mountain tops, the windiest parts of the region are about the coast. The outer Marlborough Sounds often come under the influence of the frequent gales that buffet nearby Cook Strait (e.g. Brothers Island, Figure 8). In this area the winds are strongly channelled into northerly and southerly directions.

Figure 9 shows mean annual wind frequencies of surface wind based on hourly observations from selected stations. Due to its exposed location, Brothers Island has a higher percentage of strong winds than the other selected stations. Blenheim has the lowest mean wind speeds, due to its sheltered location in the Wairau Valley.

An easterly sea breeze is often observed at Blenheim during the day, while a light westerly wind is very common at night. The sea breeze incidence is concentrated in the warmer months of the year (as might be expected), while the night time katabatic drainage of cold air down the Wairau Valley makes the westerly the most common wind in the winter months. Blenheim is completely sheltered from the south by nearby hill country and the Kaikoura Ranges. In fact, a southerly wind may be of storm force in Cook Strait while at Blenheim, only 30 km away, conditions will often be calm.

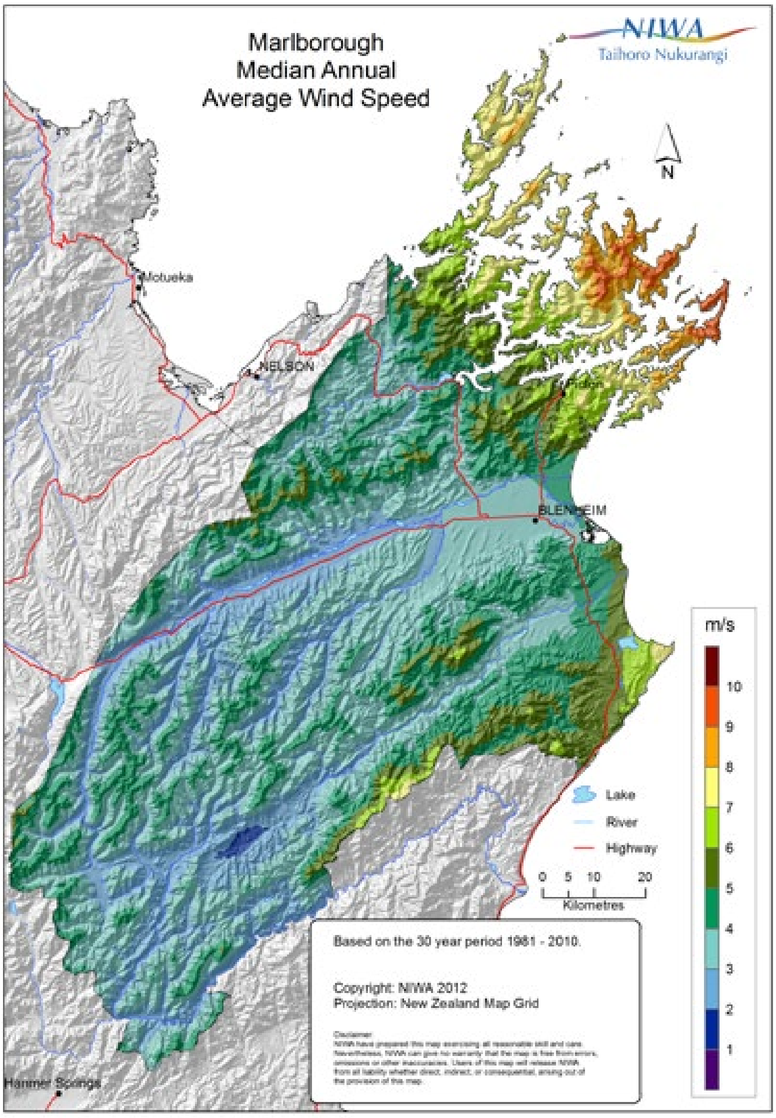


Figure 8. Mean sea level analysis for 1200 NZST 7 February 1973.

Mean wind speed data (average wind speeds are taken over the 10 minute period preceding each hour) are only available for a few sites in the Marlborough region but these illustrate the several different wind regimes of the region (Table 1). Inland areas such as around Blenheim, which are protected from Cook Strait, generally have lower mean wind speeds than locations that are more exposed, such as Brothers Island and Cape Campbell.

Spring is generally the windiest season throughout the region, whereas winter records the lowest percentage of strong winds. Table 2 gives the seasonal proportion of strong or light winds as a percentage of the annual total. For example, of all strong winds recorded at Blenheim, 36% occurred in summer, 17% in autumn, 10% in winter and 37% in spring. In compiling this table a strong wind was defined as having a mean wind speed of at least 31 km/hr.

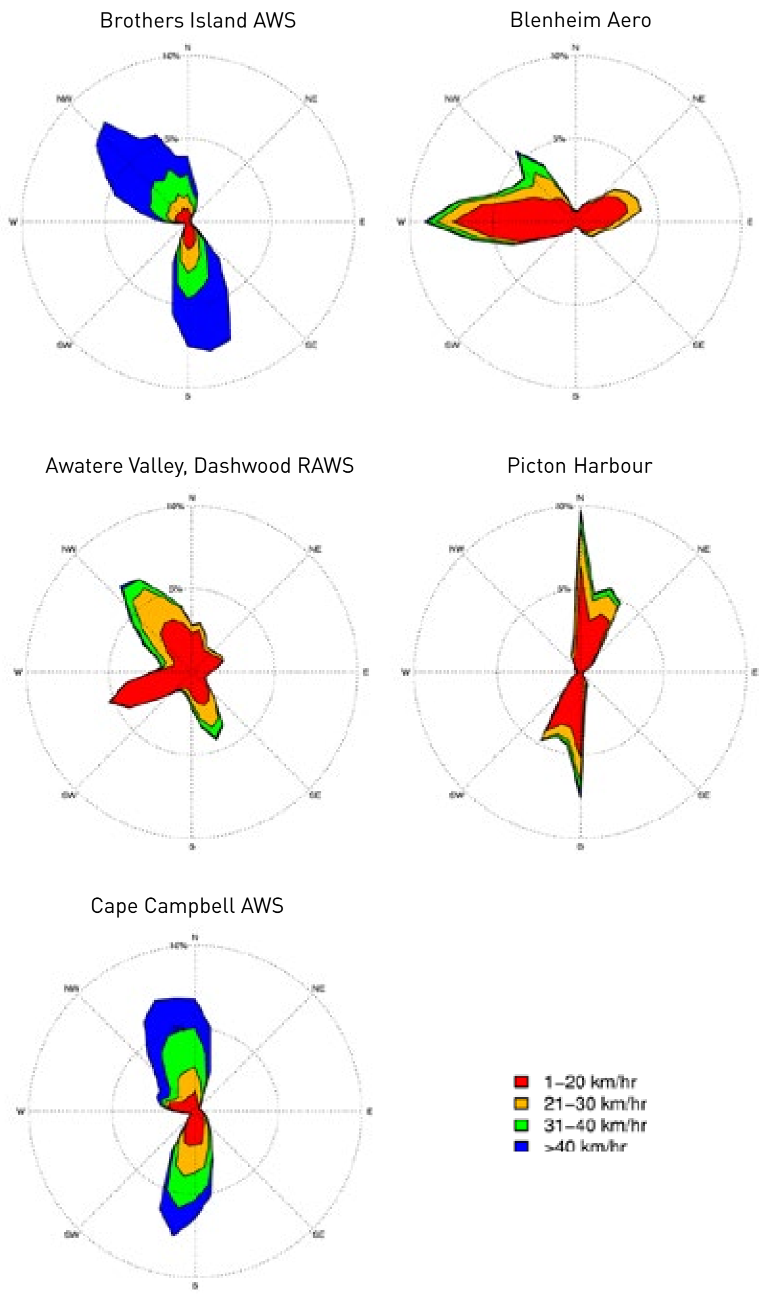


Figure 9. Mean annual wind frequencies (%) of surface wind directions from hourly observations at selected Marlborough stations. The plots show the directions from which the wind blows, e.g. the dominant wind direction at Blenheim airport is from the west.

Table 1. Mean monthly/annual wind speeds (km/hr) for Marlborough sites.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blenheim Aero AWS	15.2	14.0	13.9	11.6	11.1	11.0	11.3	11.7	14.5	15.5	16.0	16.4	13.5
Brothers Island AWS	39.1	37.0	38.1	35.8	35.6	35.8	37.2	35.0	38.2	39.4	39.8	39.7	37.6
Cape Campbell AWS	28.6	26.5	27.7	25.4	25.9	26.0	25.7	25.4	28.9	30.0	30.1	29.4	27.5

Table 2. Seasonal percentages of strong or light winds (%) for Marlborough sites.

Location		Summer	Autumn	Winter	Spring
Blenheim Aero AWS	Strong	36	17	10	37
	Light	24	26	26	24
Brothers Island AWS	Strong	26	24	23	26
	Light	21	27	29	22
Cape Campbell AWS	Strong	25	23	23	29
	Light	24	26	28	22

Diurnal variation in wind speed is well-marked, with greatest wind speeds occurring in the middle of the afternoon. This is because at that time of day heating of the land surface is most intense and stronger winds aloft are brought down to ground level by turbulent mixing, and sea breezes are also important in the summer months. Cooling at night generally restores a lighter wind regime. During clear, cold nights, especially in winter under anticyclonic conditions, the hill country may give rise to a light but weak katabatic breeze. Calm conditions are most frequent during the early hours of the morning just before sunrise, especially on cold winter mornings. Table 3 gives average wind speeds at three-hourly intervals for selected stations.

Table 3. Average wind speed (km/hr) for selected hours, for selected Marlborough stations.

Location	0000	0300	0600	0900	1200	1500	1800	2100
Blenheim Aero Aws	10.7	10.4	10.1	12.4	16.5	20.2	16.1	11.6
Brothers Island Aws	36.4	36.1	36.2	36.8	38.7	40.2	39.6	37.5
Cape Campbell Aws	25.8	25.9	25.4	26.3	29.2	30.8	29.2	26.4

Strong gusts are frequent at exposed sites in Marlborough (Table 4). Gusts of at least 63 km/hr are recorded at Brothers Island on an average of 243 days each year, and gusts over 96 km/hr occur on average 51 days each year. In comparison, Blenheim is more sheltered, with 39 days per year with gusts over 63 km/hr, and about one day every two years with gusts over 96 km/hr.

Table 4. Average number of days per year with gusts exceeding 63 km/hr and 96 km/hr for selected stations.

Location	Days with gusts >63 km/hr	Days with gusts >96 km/hr
Blenheim Aero Aws	39	0.4
Brothers Island Aws	243	51
Grassmere Salt Works	152	10

Although gale force winds can occur in any month, they are most frequent in winter. The highest gust recorded in the region was 171 km/hr at Brothers Island, on 14 July 2013. See http://www.niwa.co.nz/education-and-training/schools/resources/climate/extreme for New Zealand climate extremes. Maximum gusts recorded at different stations in the region are listed in Table 5.

Table 5. Highest recorded gusts at selected Marlborough stations, from all available data.

Location	Gust (km/hr)	Direction	Date
Awatere Valley, Dashwood RAWS	134	NW	5/10/2000
Blenheim Aero	118	W	6/02/1975
Brothers Island AWS	171	S	14/07/2013
Grassmere Salt Works	131	W	19/11/1982
Vernon Lagoon	115	SSE	20/05/1981

Rainfall

Rainfall distribution

Average annual rainfall is variable across the Marlborough region, as shown in Figure 10 and Table 6. This is due to the topography of the region, which influences airflows and thus the patterns of precipitation. The Wairau and Awatere valleys are sheltered from the predominant westerly rain-bearing weather systems, and so many areas around and inland from Blenheim and Seddon receive less than 800 mm of rainfall per year (less than 600 mm in some locations within Awatere Valley, around Lake Grassmere, and along the coast south of Cape Campbell). In contrast, parts of the Richmond and Raglan Ranges receive over 2000 mm of rainfall per year. The Marlborough Sounds receives around 1600-1800 mm per year.

Table 6 lists monthly rainfall normals and percentage of annual total for selected stations. There is a slight winter rainfall maximum at some places, ranging from 26% at Molesworth to 34% at Picton and Grassmere Salt Works. The wintertime maximum is associated with the increased frequency of depressions which cross the North Island during this period. Summer generally records the lowest proportion of annual rainfall throughout the region, ranging from 17% at Picton to 23% at Aotea, Molesworth, and Pelorus Sound. However, there is no clear overall season of maximum rainfall.

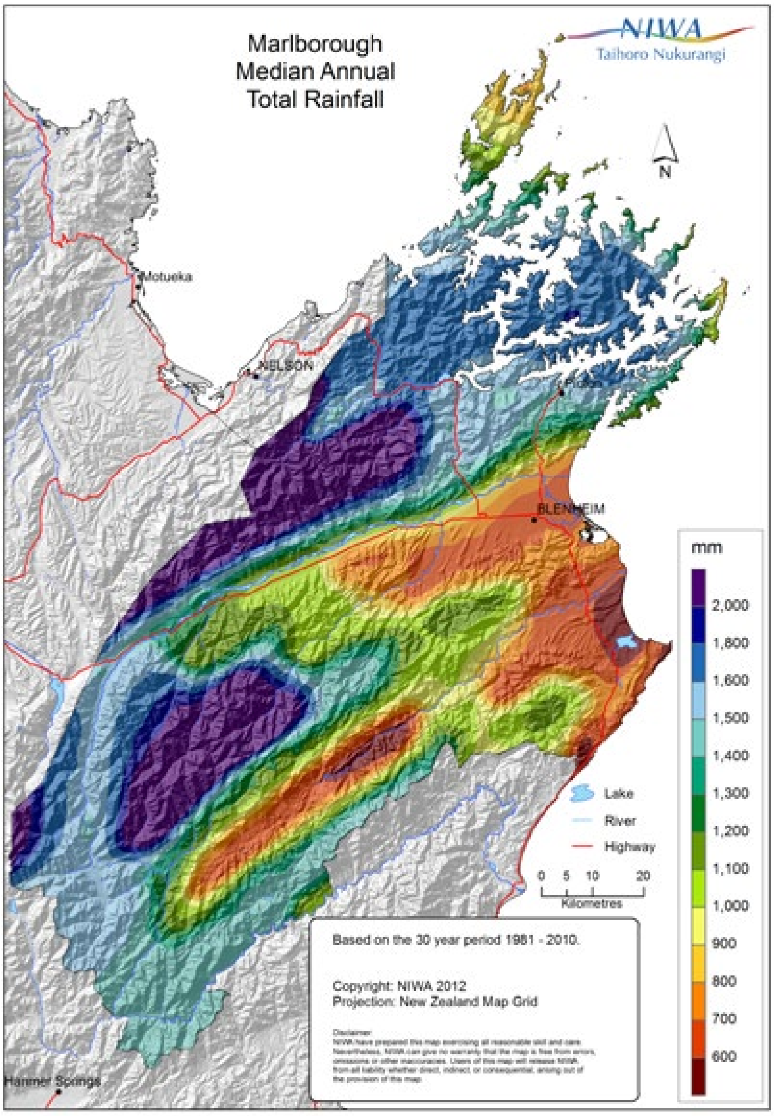


Figure 10. Marlborough region median annual total rainfall.

Table 6. Monthly/annual rainfall normals (a; mm) and percentage of annual total for each month (b; %).

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Aotea	a	55	61	56	59	68	81	82	83	68	85	70	74	840
	b	7	7	7	7	8	10	10	10	8	10	8	9	
Birch Hill	a	80	69	71	88	88	110	85	91	106	113	104	93	1098
	b	7	6	6	8	8	10	8	8	10	10	9	8	
Blenheim Research EWS	a	45	46	42	45	56	63	70	60	55	63	51	55	650
	b	7	7	6	7	9	10	11	9	9	10	8	8	
Grassmere Salt Works	a	32	37	38	32	51	61	69	54	42	42	49	43	550
	b	6	7	7	6	9	11	13	10	8	8	9	8	
Havelock 2	a	127	89	114	114	113	174	156	161	174	215	169	128	1733
	b	7	5	7	7	6	10	9	9	10	12	10	7	
Molesworth	a	43	46	49	48	54	59	54	48	53	69	50	58	630
	b	7	7	8	8	9	9	9	8	8	11	8	9	

Table 6 continued.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Ocean Bay	a	86	99	96	107	125	126	146	125	115	140	114	118	1396
	b	6	7	7	8	9	9	10	9	8	10	8	8	
Pelorus Sound, Crail Bay	a	136	102	115	128	131	152	172	151	158	192	151	159	1747
	b	8	6	7	7	7	9	10	9	9	11	9	9	
Picton 4	a	87	65	101	104	112	145	207	151	121	140	133	98	1463
	b	6	4	7	7	8	10	14	10	8	10	9	7	
The Brothers Lighthouse	a	35	44	69	45	75	65	90	48	54	61	53	58	697
	b	5	6	10	6	11	9	13	7	8	9	8	8	
Ugbrooke	a	43	62	59	48	63	64	75	69	72	49	65	55	724
	b	6	9	8	7	9	9	10	10	10	7	9	8	

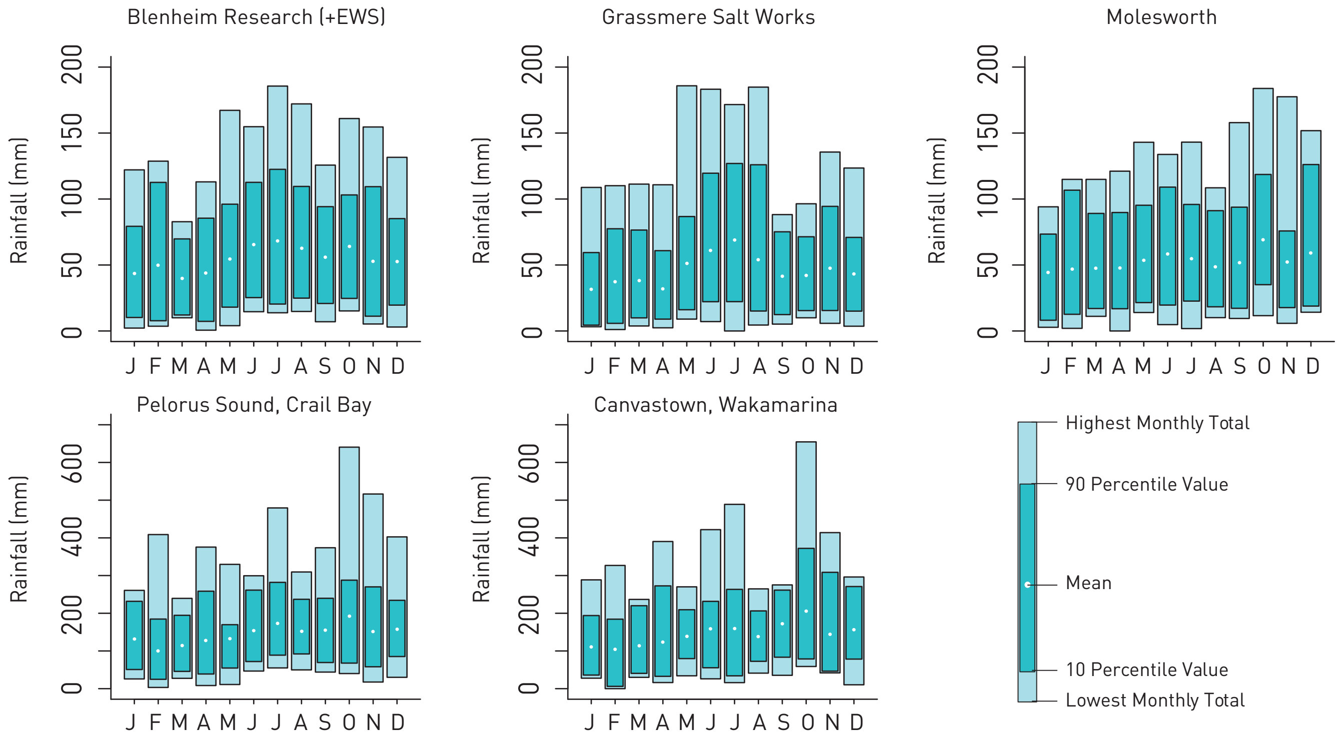


Figure 11. Monthly variation in rainfall for selected Marlborough stations (note the difference in scale in top and bottom graphs).

The distribution of monthly rainfall is shown in Figure 11. The 10th percentile, 90th percentile, and mean rainfall values for each month are shown along with maximum and minimum recorded values for several stations in the Marlborough region.

Rainfall variability over longer periods is indicated by 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, while the 90th percentile values indicate the accumulated falls that will normally be exceeded in only one year in ten. The table includes periods from one month to twelve months; each period over one month begins with the month stated. For example, using the table for Pelorus Sound, Crail Bay, for three months it can be seen that in the three month period beginning in April, less than 257 mm can be expected in one year in ten, between 257 and 570 mm in eight years in ten, and more than 570 mm in one year in ten.

Table 7. Rainfall deciles for consecutive months for selected Marlborough stations.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelorus Sound, Crail Bay												
1 month												
10th	51	25	46	39	55	72	89	92	69	68	58	85
90th	232	185	195	259	170	261	282	237	240	288	270	234
3 months												
10th	177	173	245	257	332	375	340	343	334	332	263	244
90th	491	541	568	570	569	600	637	663	715	700	612	573
6 months												
10th	608	652	708	737	726	742	760	708	610	505	547	569
90th	1008	1032	1088	1163	1133	1174	1274	1176	1151	1068	1008	968
12 months												
10th	1466	1508	1489	1438	1355	1448	1487	1528	1564	1542	1482	1416
90th	2020	2026	2038	2112	2084	2056	2073	2077	2067	2148	2049	2018

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Blenheim Research EWS												
1 month												
10th	10	8	12	7	18	25	20	25	21	25	11	20
90th	79	113	70	85	96	113	123	110	94	103	109	85
3 months												
10th	73	61	73	120	126	124	101	104	111	110	81	80
90th	183	204	223	260	267	295	280	248	233	235	242	205
6 months												
10th	195	222	249	254	288	269	234	218	211	198	172	198
90th	419	426	459	498	499	489	472	418	405	400	386	390
12 months												
10th	511	491	498	472	471	463	459	482	524	521	534	528
90th	798	813	819	813	778	790	808	759	765	778	763	779

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Molesworth												
1 month												
10th	8	13	17	17	22	20	23	18	17	35	18	19
90th	73	107	89	90	95	109	96	91	94	119	76	126
3 months												
10th	69	73	101	96	102	88	75	106	116	110	86	84
90th	202	198	196	239	249	221	235	245	232	248	252	247
6 months												
10th	224	236	234	194	245	242	230	230	234	231	201	229
90th	396	383	389	425	465	442	424	402	466	430	429	394
12 months												
10th	512	465	507	517	528	523	528	519	511	476	500	476
90th	202	198	196	239	249	221	235	245	232	248	252	247

Table 7 continued.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Birch Hill												
1 month												
10th	27	11	29	20	42	54	23	47	39	44	30	41
90th	151	142	126	182	135	178	169	139	181	238	186	171
3 months												
10th	137	125	162	165	177	203	151	180	198	195	173	147
90th	293	328	330	403	402	427	431	432	437	394	412	333
6 months												
10th	384	315	410	380	455	465	370	427	389	361	365	359
90th	650	651	695	768	798	771	806	756	777	702	725	649
12 months												
10th	874	862	884	889	891	882	868	882	859	831	858	852
90th	293	328	330	403	402	427	431	432	437	394	412	333

Rainfall frequency and intensity

Rain day frequency (where at least 0.1 mm of rain falls) varies over the Marlborough region, and is highest in the Marlborough Sounds at Pelorus Sound, Crail Bay (highest out of the stations in Table 8). Rain day frequency is assumed to be higher in the Richmond and Raglan Ranges, but there is no available data for those areas. The least rain days occur in the Awatere Valley around Molesworth. Rain days are less frequent from January to March (coinciding with the driest time of the year), and occur most often between June and September. In most places there are only a few more rain days in winter than in spring. The annual number of wet days (where at least 1 mm of rain falls) exhibits the same geographic variability as rain days. Table 8 lists the average number of days per month with 0.1 mm and 1 mm of rain for selected stations.

Table 8. Average monthly rain days and wet days for Marlborough stations; a: 0.1 mm rain day, b: 1 mm wet day.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Birch Hill	a	8	7	8	8	9	10	9	10	11	12	10	10	112
	b	7	7	7	7	8	9	8	9	9	10	9	9	100
Blenheim Research EWS	a	7	7	8	7	9	11	10	12	11	12	10	9	113
	b	5	5	5	5	6	8	8	8	8	8	7	6	79
Grassmere Salt Works	a	6	6	7	7	8	10	10	10	9	9	8	8	97
	b	4	4	5	5	5	7	7	7	7	7	6	6	69
Molesworth	a	6	6	6	6	7	7	7	7	8	9	8	8	84
	b	5	5	6	5	6	6	6	6	7	8	7	7	74
Pelorus Sound, Crail Bay	a	10	9	11	11	13	15	14	15	17	15	13	13	157
	b	8	7	8	8	9	11	10	11	13	12	10	10	117

Most heavy rainfalls in the eastern Marlborough region occur during periods of easterly wind flow, and also when ex-tropical depressions affect the region (see Section 2). Heavy rainfall may occur in the Marlborough Sounds and the Richmond Range in northwesterly flows.

In Table 9, maximum short period rainfalls for periods of 10 minutes to 72 hours with calculated return periods are given for several stations. Also listed in this table are the maximum rainfalls expected in 2, 5, 10, 20, and 50 years. Depth-duration frequency tables for Marlborough region 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 www.hirds.niwa.co.nz.

Table 9. Maximum recorded short period rainfalls and calculated return periods from HIRDS.

Location		10min	20min	30min	1hr	2hrs	6hrs	12hrs	24hrs	48hrs	72hrs
Blenheim	a	10	11	13	20	27	53	75	90	101	104
	b	24	25	13	19	15	27	27	11	8	5
	c	5	7	8	11	16	30	43	63	76	85
	d	7	9	11	15	21	37	53	77	93	104
	e	8	11	13	17	25	43	62	88	107	120
	f	9	12	15	20	29	50	71	100	121	136
	g	11	15	18	25	35	60	84	118	144	161
Grassmere Salt Works	a	8	12	17	25	34	68	85	129	177	180
	b	23	24	39	40	29	40	80	24	53	100+
	c	5	7	9	13	19	33	48	69	79	85
	d	6	9	11	16	23	42	61	89	101	109
	e	7	10	13	19	27	50	72	106	120	130
	f	8	12	15	22	32	58	85	124	141	152
	g	10	14	18	26	38	71	104	153	174	188
Waihopai Power Station	a	10	15	21	27	39	67	80	109	131	137
	b	17	24	34	29	37	47	23	22	21	25
	c	5	7	8	11	17	31	46	68	82	92
	d	7	10	11	16	23	40	58	83	100	112
	e	9	12	14	20	28	48	67	95	114	127
	f	11	15	18	24	33	56	77	107	129	144
	g	14	19	23	32	43	69	93	126	152	170

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 Marlborough region

The Marlborough region has experienced numerous extreme weather events, with significant damage and disruption caused by flooding and high winds. The events listed below are some of the most severe events to have affected the region between 1980 and 2015.

8–12 July 1983: A complex, slow-moving depression covered the whole Tasman Sea, with an anticyclone east of the country also slow-moving (Figure 12). Heavy rain associated with a northerly airstream resulted in severe and extensive flooding in the Marlborough region. The Wairau catchment was the worst affected. There was rapid depletion of the extensive high country snow cover during the period of heavy rain, and significant runoff occurred due to the already saturated ground from the snow melt. The melt water probably contributed significantly to the flooding. A Civil Defence Emergency (CDE) was declared from the 10th to the 12th. Five hundred people were evacuated from Tuamarina, Spring Creek, and Renwick due to flooding of the Wairau River, and about 5600 stock were lost in the flood. Damage to dams, bridges, river banks, and stop banks was extensive in Marlborough. The rail link between Blenheim and Picton was cut, and parts of State Highway (SH) 1, SH 6, and SH 63 were closed due to flooding and washouts. In Tuamarina, the worst affected town, one house was washed away and the village was almost submerged. The Awatere River also flooded, isolating some properties and washing out bridges.

21–23 October 1983: Heavy rainfall caused severe flooding in parts of the Marlborough region, including Northbank, Canvastown, Rai Valley, Spring Creek, and Tuamarina. A CDE was declared for 21-22 October. Floodwaters cut the main highway between Blenheim and Nelson, and numerous roads in the Marlborough Sounds were closed by flooding and slips. Stock losses from flooding were estimated at about 800.

14–19 February 2004: A deep low moved over the North Island and caused severe flooding in the Picton area. Flooding was caused by an intense short period of rain in the Burns Range behind Picton, causing streams and rivers to rise rapidly. A CDE was declared for the Picton area from 17-18 February, due to fears of a break in Burns Dam due to high inflow capacities and landslides into the reservoir. 800 people (one-fifth of Picton's population) were evacuated because of fears that the dam would burst. 200 more people were evacuated from other parts of Picton, and many properties were flooded. Some were deemed unsafe after the event due to sewage contamination.

24–27 August 2008: A deepening low combined and a stationary front combined with a moist east to southeast flow brought rain to Marlborough. SH 1 was closed between Seddon and Cheviot (Cheviot is in north Canterbury) due to flooding, and the main railway line between Christchurch and Picton was closed due to slips and flooding around Kaikoura (also in north Canterbury). Damage to roads in the Marlborough region was estimated to cost around $2.5 million. Campgrounds, low-lying vineyards, and houses around Blenheim were affected by flooding. Parts of Picton also experienced flooding, and numerous roads in Marlborough Sounds were closed due to slips.

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'. There is an average of 4.4 such periods each year in

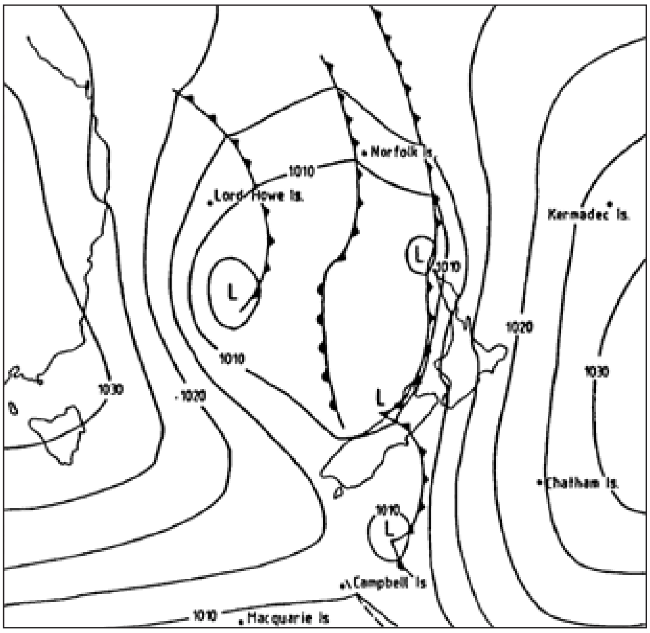


Figure 12. Mean sea level analysis for 1800 NZST 9 July 1983.

Blenheim, 4.1 per year in Molesworth, and 1.6 per year in Pelorus Sound (Crail Bay). Most dry spells occur in the summer months when anticyclonic conditions are prevalent, and also during westerly flows as rainfall is generally negligible in much of Marlborough (see Section 2). The average duration of a dry spell in the region is about 20 days. The longest recent dry spell between three key Marlborough sites (Blenheim Research EWS, Molesworth, and Pelorus Sound Crail Bay) was 56 days recorded at Molesworth from 18 March to 12 May 2010, where no days observed any rain. The longest recent dry spell at Blenheim was 47 days between 22 March and 7 May 1992 (36 consecutive days with no rain), and at Pelorus Sound the longest recent dry spell was 40 days between 6 February and 17 March 2013, with 31 consecutive days with no rain.

Some long dry spells are interspersed with only a few days where more than 1 mm of rain fell on each day. For example, from 13 February 2001 at Molesworth there was a 44-day dry spell, followed by six days with 30.9 mm of rain, followed by a 28-day dry spell. This 78-day period recorded only 31.7 mm of rainfall.

See later for further information on soil moisture and past droughts in Marlborough region.

Temperature

Sea surface temperature

Monthly mean sea surface temperatures off the coast of Marlborough are compared with mean air temperature for Blenheim Research EWS in Figure 13. Between March and September, mean air temperatures are lower than mean sea surface temperatures. However in the warmer months, mean air temperatures are higher than mean sea surface temperatures. Figure 14 shows the mean sea surface temperatures for the New Zealand region for February and August, which are the warmest and coolest months with respect to sea surface temperatures.

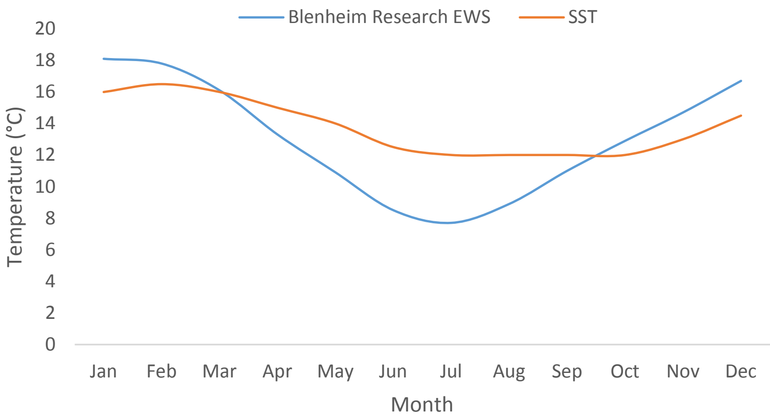


Figure 13. Mean monthly land (Blenheim Research EWS) and sea surface temperatures (off the coast of Blenheim).

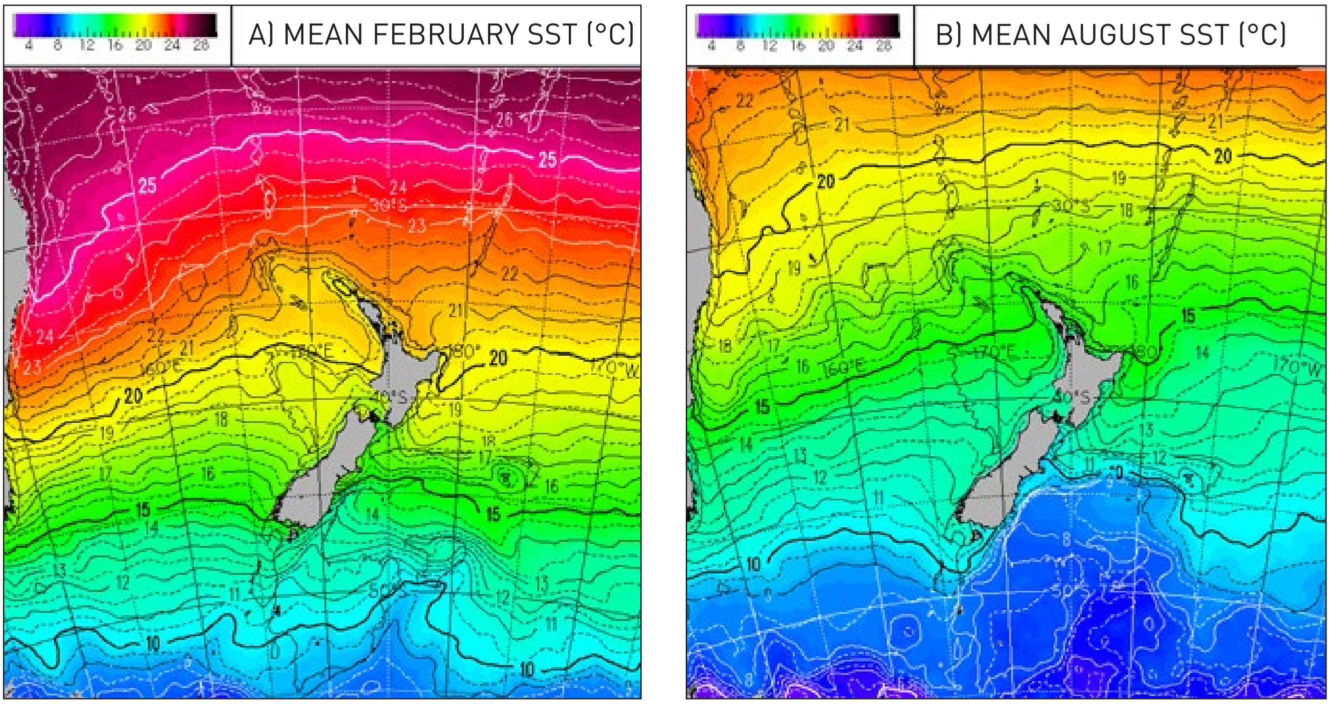
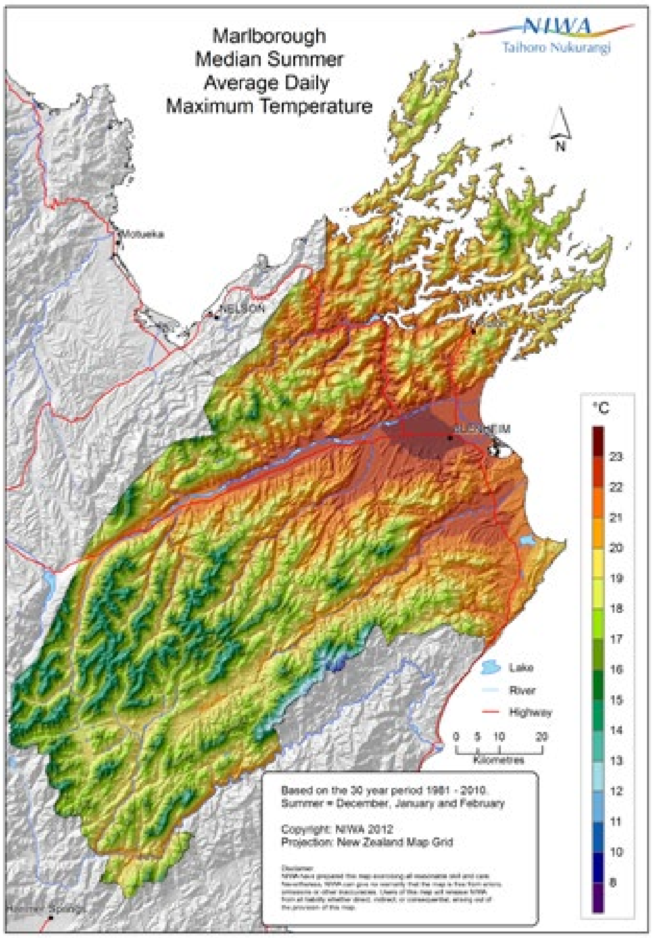


Figure 14. Monthly mean sea surface temperatures (°C) for: a) February; b) August. Source: NIWA SST Archive, Uddstrom and Oien (1999).

Air temperature

The lowlands around Blenheim, up the Wairau Valley, the lower Awatere Valley, and lower elevation valleys in the Richmond Ranges experience warm summer afternoon temperatures of more than 22°C (Figure 15a). Summer afternoon temperatures are cooler (between 16 and 21°C) in the Marlborough Sounds and in higher elevations of the Richmond Ranges. Summer afternoon temperatures may not reach higher than 15°C in high elevation areas in the southwest of the region.

During winter nights, the outer Marlborough Sounds and the eastern coastal strip is warmer than further inland and at higher elevations, in part due to the modifying effect of the sea on air temperature and partly because air temperature decreases with height above sea level by about 0.6°C for each 100 m increase in elevation (6-8°C average minimum daily winter temperature at the coast, 1-4°C across the lowland area in the Wairau and Awatere Valleys, and in the Richmond Ranges closer to the coast, and less than 0°C in much of the high country in the western half of the region; Figure 15b).



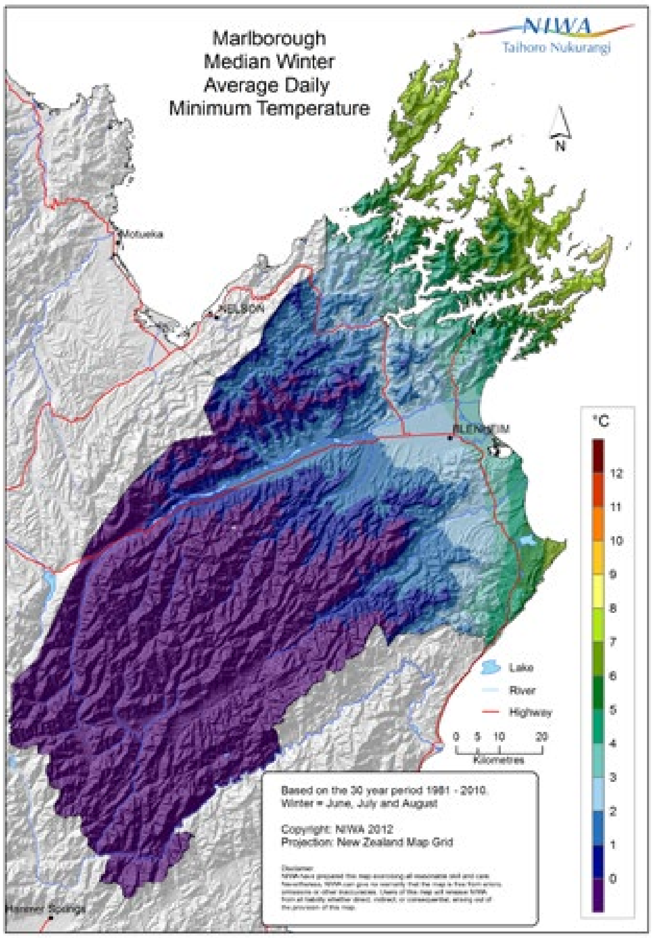


Figure 15. a) Left: Marlborough median summer average daily maximum temperature; b) Right: Marlborough median winter average daily minimum temperature.

Figure 16 shows that median annual average temperature in the Marlborough region varies with elevation. Low-lying areas around the coast and the Wairau and lower Awatere Valleys have a median annual temperature of around 12.5°C, whereas higher elevation areas further inland experience median annual temperatures of about 8-11°C. Median annual air temperatures are significantly cooler higher in the alpine areas in the southwest of the region (less than 6°C). In elevated areas, the cooler conditions mean that temperatures are often below freezing, especially during the winter. Further, the daily variation in temperature decreases as the altitude increases. Figure 17 gives the monthly temperature regime (highest recorded, mean monthly maximum, mean daily maximum, mean, mean daily minimum, mean monthly minimum, and lowest recorded) for selected sites in the Marlborough region. The effect of the foehn northwesterly winds can be seen in the relatively high mean monthly maxima at most of the stations.

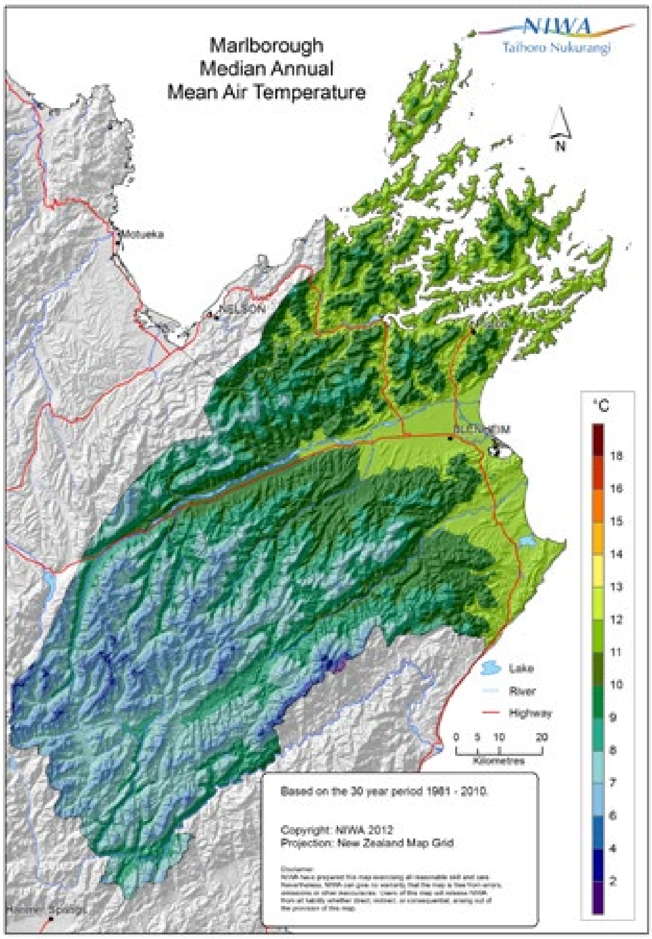


Figure 16. Marlborough median annual average temperature.

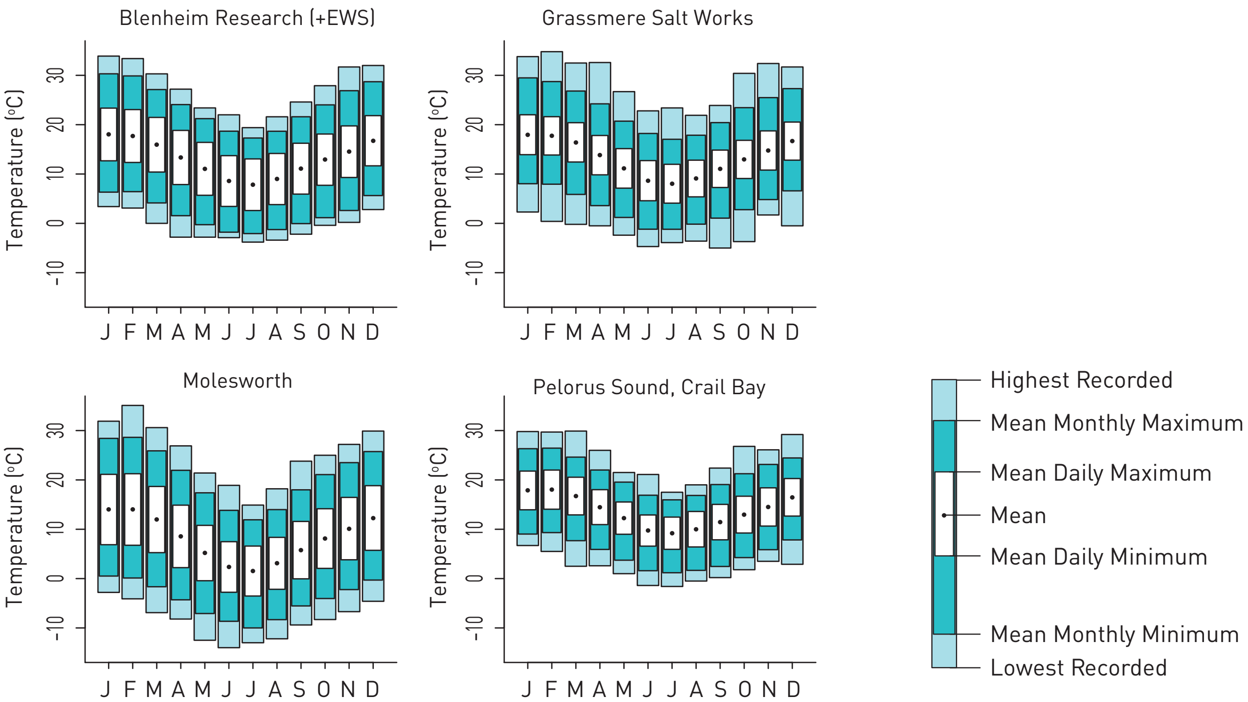


Figure 17. Monthly variation in air temperatures for selected Marlborough region stations, from all available data.

Daily temperature ranges in Marlborough vary across the region (Table 10). The daily range of temperature, i.e. the difference between the maximum and the minimum, is smaller at the coast (e.g. Grassmere Salt Works, Pelorus Sound) than inland areas (e.g. Blenheim, Molesworth). In the mountain ranges the daily variation is also influenced by cloudiness and elevation; the higher the elevation and cloudier the conditions, the smaller the temperature range.

Table 10. Average daily temperature range (Tmax – Tmin, °C) for Marlborough sites.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blenheim Research EWS	10.9	10.9	11.1	11.1	10.8	10.4	10.5	10.5	10.4	10.5	10.5	10.3	10.7
Grassmere Salt Works	7.9	7.6	8.1	8.1	8.2	8	7.9	7.6	7.7	7.8	7.6	7.7	7.9
Molesworth	14.7	14.5	14	13.7	12.1	10.8	10.2	10.6	11.7	12.1	12.8	13	12.5
Pelorus Sound, Crail Bay	7.9	8	7.7	7.1	6.6	6.5	6.6	7.2	7.1	7.4	7.7	7.7	7.3

The diurnal temperature range for Cape Campbell is moderate, due to its coastal location. Blenheim, which is inland and further away from the modifying effect of the sea, has a larger diurnal temperature range than Cape Campbell. Table 11 and Figure 18 show mean hourly temperatures for Blenheim and Cape Campbell for January and July.

Table 11. Mean hourly temperatures at Blenheim Research EWS and Cape Campbell AWS for January and July.

		00	01	02	03	04	05	06	07	08	09	10	11
Blenheim	**January**	15.2	14.8	14.5	14.1	13.9	13.6	13.5	14.7	16.4	18.1	19.5	20.4
	July	5.8	5.5	5.3	5.1	4.9	4.7	4.5	4.4	4.3	4.8	6.5	8.4
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
	January	21.2	21.6	21.9	21.9	21.6	21.0	20.2	19.2	17.9	16.8	16.1	15.6
	July	10.2	11.6	12.3	12.4	12.0	10.8	9.2	8.2	7.5	7.0	6.6	6.2
		00	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
Cape Campbell	**January**	15.2	15.1	15.0	15.0	14.9	14.8	15.0	15.4	16.0	16.4	16.9	17.3
	July	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.5	8.4	8.9	9.4	9.9
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
	January	17.3	17.5	17.6	17.4	17.1	16.9	16.5	16.1	15.8	15.6	15.5	15.4
	July	10.4	10.5	10.6	10.5	10.2	9.8	9.6	9.5	9.4	9.2	9.0	9.0

Pelorus Sound has the least extreme temperatures out of the sites in Table 12, with 6 days per year on average where the maximum air temperature exceeds 25°C and one day in three years when minimum temperatures fall below 0°C. In contrast, Molesworth records 16 days where temperatures rise above 25°C, and 129 days when temperatures fall below freezing. In general, coastal sites have fewer extremes than inland sites.

Marlborough sometimes experiences extremely warm temperatures as a result of northwesterly foehn winds (see Section 2). The highest temperature on record in Marlborough is 42.2°C at The Jordan, Awatere Valley, recorded on 7 February 1973 under northwesterly foehn conditions. This is one of the highest temperatures ever recorded in New Zealand (the highest temperature recorded in New Zealand is 42.4°C, recorded at Rangiora, Canterbury on the same day). The lowest temperature on record in Marlborough is -14.0°C, observed at Molesworth on 28 June 1975. The lowest temperature ever recorded in New Zealand is -25.6°C.

More information on New Zealand climate extremes can be found at https://www.niwa.co.nz/education-and-training/schools/resources/climate/extreme.

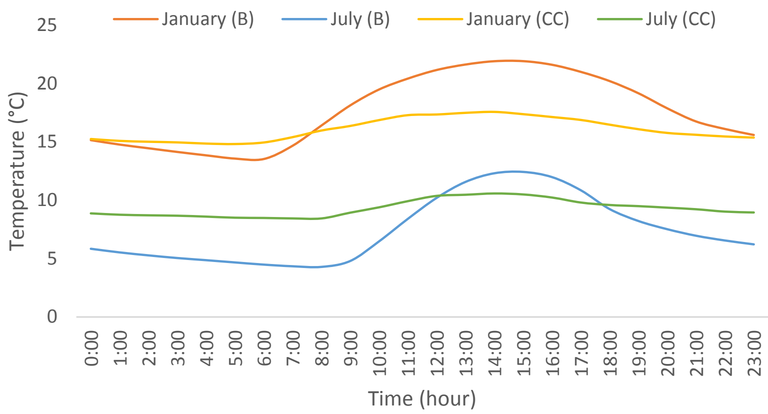


Figure 18. Mean hourly temperatures at Blenheim Research EWS (B) and Cape Campbell AWS (CC) for January and July.

Table 12. Number of days where maximum temperature exceeds 25°C and minimum temperature falls below 0°C for Marlborough sites.

Location	**Days with Tmax >25°C**	**Days with Tmin <0°C**
Blenheim Research (+ EWS)	34	20
Grassmere Salt Works	21	7
Molesworth	16	129
Pelorus Sound, Crail Bay	6	0.3

Earth temperatures

Earth (soil) temperatures are measured once daily at 9 am at Blenheim and Molesworth. Earth temperatures are measured at varying depths and are important, amongst other things, 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 13 lists mean monthly earth temperatures for a number of standard depths.

In the Marlborough region, earth temperatures, like air temperatures, vary spatially. The inland and higher elevation site at Molesworth exhibits cooler 9 am earth temperatures than Blenheim, which is only 4 m above sea level and has a higher mean annual temperature. In July, the mean 9 am 10 cm temperature at Molesworth drops to freezing. Figure 19 shows how earth temperatures change throughout the year at Blenheim, compared with air temperature. The temperature cycle for 100 cm depth is more damped and lagged than at shallower depths.

Table 13. Mean 9 am earth temperatures at Blenheim and Molesworth, with station elevations

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blenheim Research (+ EWS) (4 m)													
10 cm	18.8	18.1	15.3	11.7	8.4	5.5	4.8	6.3	8.9	11.7	14.7	17.5	11.8
20 cm	20.3	19.9	17.2	13.3	9.9	6.9	6.1	7.6	10.0	13.0	16.0	18.7	13.2
30 cm	20.7	20.5	18.0	14.4	11.0	8.0	6.9	8.4	10.7	13.5	16.5	19.1	14.0
100 cm	18.4	19.0	18.1	16.2	13.9	11.4	9.7	9.9	11.1	12.9	15.0	16.9	14.4
Molesworth (890 m)													
10 cm	15.4	14.6	11.6	7.2	3.4	0.9	0.0	1.0	3.7	7.5	11.3	14.1	7.5
20 cm	16.0	15.8	13.3	9.2	5.0	2.0	0.8	1.6	4.6	8.1	11.6	14.3	8.5
30 cm	16.3	16.2	13.8	9.7	5.6	2.6	1.2	1.9	4.9	8.3	11.8	14.6	8.9

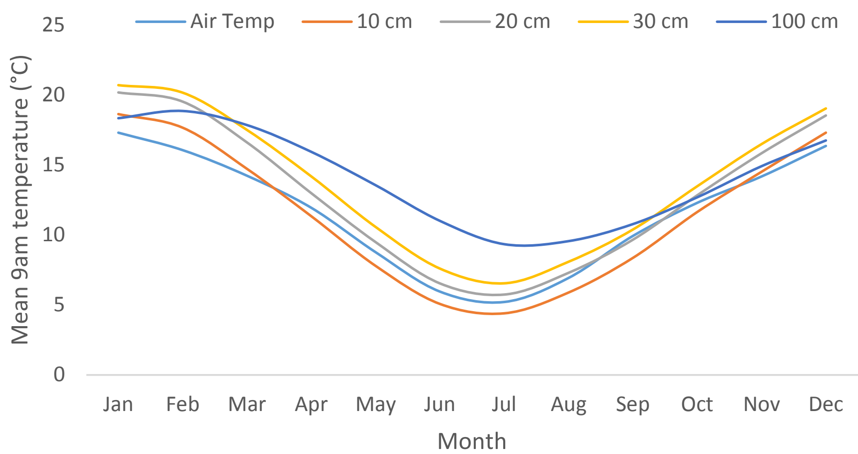


Figure 19. Average monthly 9 am earth temperatures for different depths and mean 9 am air temperature at Blenheim Research.

Frosts

Frost is a local phenomenon and its frequency of occurrence can vary widely over very small areas. Areas most likely to be subjected to frost are flat areas, where air is not able to drain away on calm nights, and valleys, where cold air is likely to drift from higher areas.

There are two types of frost recorded. Air frosts occur when air temperature measured in a screen by a thermometer 1.3 m above the ground falls below 0°C. Ground frosts are recorded when the air temperature 2.5 cm above a clipped grass surface falls to -1.0°C or lower. Both types of frost are common in the inland parts of the Marlborough region in the cooler months, especially at higher elevation sites. Land surrounding the Marlborough Sounds is not very susceptible to frosts due to the moderating effect of the surrounding water.

Table 14 lists for selected sites the mean daily grass minimum and extreme grass minimum temperatures and the average number of days each month with ground and air frosts. Data on air temperatures (mean daily, monthly minima, and extreme minima) can be obtained from Figure 17.

Table 14. Occurrences of frosts and grass minimum temperatures in Marlborough region, from all available data.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
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	5
	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	0.1	0.4	1.5	7.8	12.8	17.2	11.9	4.8	2.1	0.2	0.3	59
	d	0	0	0	0.3	1.8	5.4	9.3	4.2	0.6	0.1	0	0	22
Molesworth	a	2.0	1.7	0.6	-2.7	-4.9	-7.0	-7.5	-5.9	-4.2	-2.6	-0.8	1.3	-2.5
	b	-11.9	-12.0	-14.9	-14.0	-16.4	-19.1	-19.4	-16.2	-15.0	-16.2	-15.6	-12.5	
	c	7.4	8.9	12.9	19.6	24.8	27.3	28.3	27.0	23.4	19.5	16.5	9.2	225
	d	0.5	0.6	2.2	8.4	17.1	23.2	26.0	22.6	15.8	8.4	3.7	0.9	129
Pelorus Sound, Crail Bay	a	12.8	12.7	11.2	9.0	6.8	4.1	3.4	4.1	6.0	7.6	9.4	11.5	8
	b	3.0	3.4	2.2	-0.5	-3.2	-4.0	-4.4	-4.0	-1.5	-0.4	1.5	-0.7	
	c	0	0	0	0	0.2	1.3	1.0	0.9	0.1	0	0	0	4
	d	0	0	0	0	0	0.2	0	0.1	0	0	0	0	0.3

a: mean daily grass minimum (°C)
b: lowest grass minimum recorded (°C)
c: average number of ground frosts per month
d: average number of air frosts per month

Sunshine and solar radiation

Sunshine

Marlborough is one of the sunniest parts of New Zealand, with the average number of sunshine hours for Blenheim (2475) being the highest for any town or city in the country. Other sunshine totals from around New Zealand are Auckland (2003 hours), Gisborne (2217 hours), Hamilton (2020 hours), Wellington (2110 hours), Nelson (2472 hours), Westport (1799 hours), Christchurch (2142 hours), and Dunedin (1683 hours). Sunshine data (and other climate data) for towns and cities in New Zealand can be found at: http://www.niwa.co.nz/education-and-training/schools/resources/climate.

A feature of the climate of eastern Marlborough is the large amount of winter sunshine. Blenheim residents, in particular, receive a large number of fine, frosty days. The Wairau Valley receives the highest number of bright sunshine hours in the region (more than 2400 hours per year; Figure 20), followed by the inner Marlborough Sounds and further inland around Havelock and the Rai Valley. The lower Awatere Valley also has quite high sunshine hours, around 2275 hours per year. Bright sunshine declines appreciably towards the west of the region, corresponding with increase in elevation (and thus increase in cloudiness). Annual bright sunshine falls below 1800 hours in the far west of the region. Figure 21 shows the monthly mean, maximum, and minimum recorded bright sunshine hours for selected sites in Marlborough.

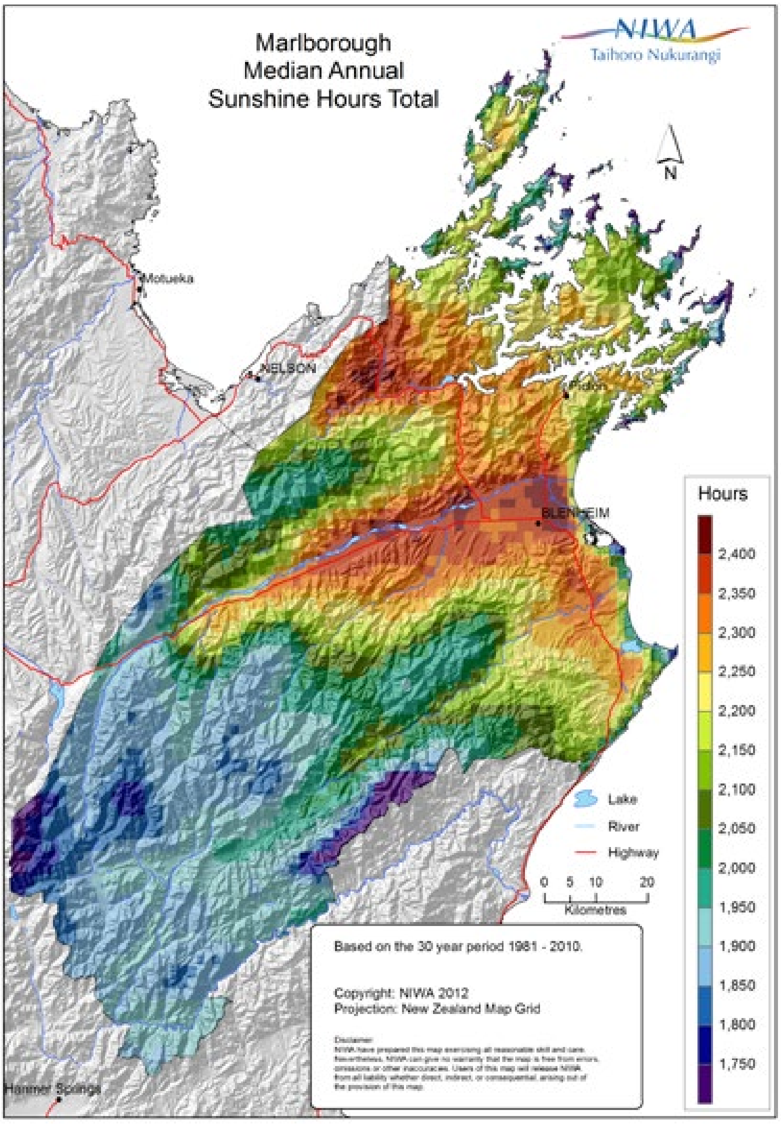
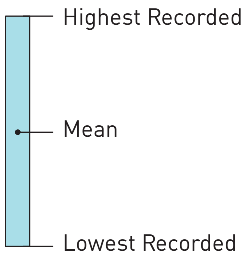


Figure 20. Median annual sunshine hours for Marlborough.



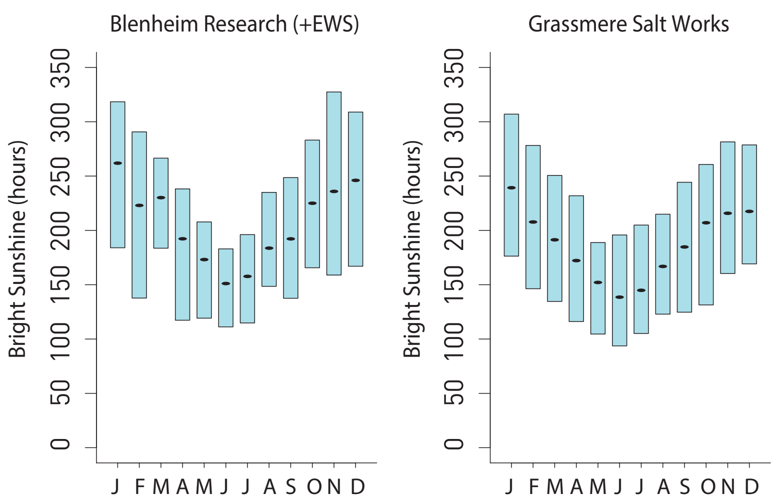


Figure 21. Mean, highest, and lowest recorded monthly bright sunshine hours for selected sites in Marlborough region, from all available data.

Solar radiation

Solar radiation records are only available for a small number of sites in the Marlborough region. Solar radiation (mean daily global solar radiation) is presented for Blenheim and Grassmere Salt Works in Table 15. Insolation is at a maximum in December and January and a minimum in June.

Table 15. Mean daily global solar radiation (MJ/m²/day) for Marlborough sites.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blenheim Research (+ EWS)	23.6	20.3	16.5	11.3	7.5	5.9	6.5	9.3	13.4	18.2	22.0	23.7	14.8
Grassmere Salt Works	23.8	20.9	17.0	11.4	7.7	6.1	6.8	9.9	14.0	18.9	22.8	24.4	15.3

UV (Ultra-violet) radiation

Ultra-violet radiation (UV) measurements are not available for any stations in the Marlborough region. However, Figure 22 shows an example of a modelled UV forecast for Blenheim, and indicates the levels of UV and times of the day where sun protection is required. In the summer (Figure 22a) UV radiation is high, prompting warnings for sun protection between 9:10 am and 5:45 pm. In the winter (Figure 22b), the amount of UV radiation does not reach the level at which sun protection is advised.

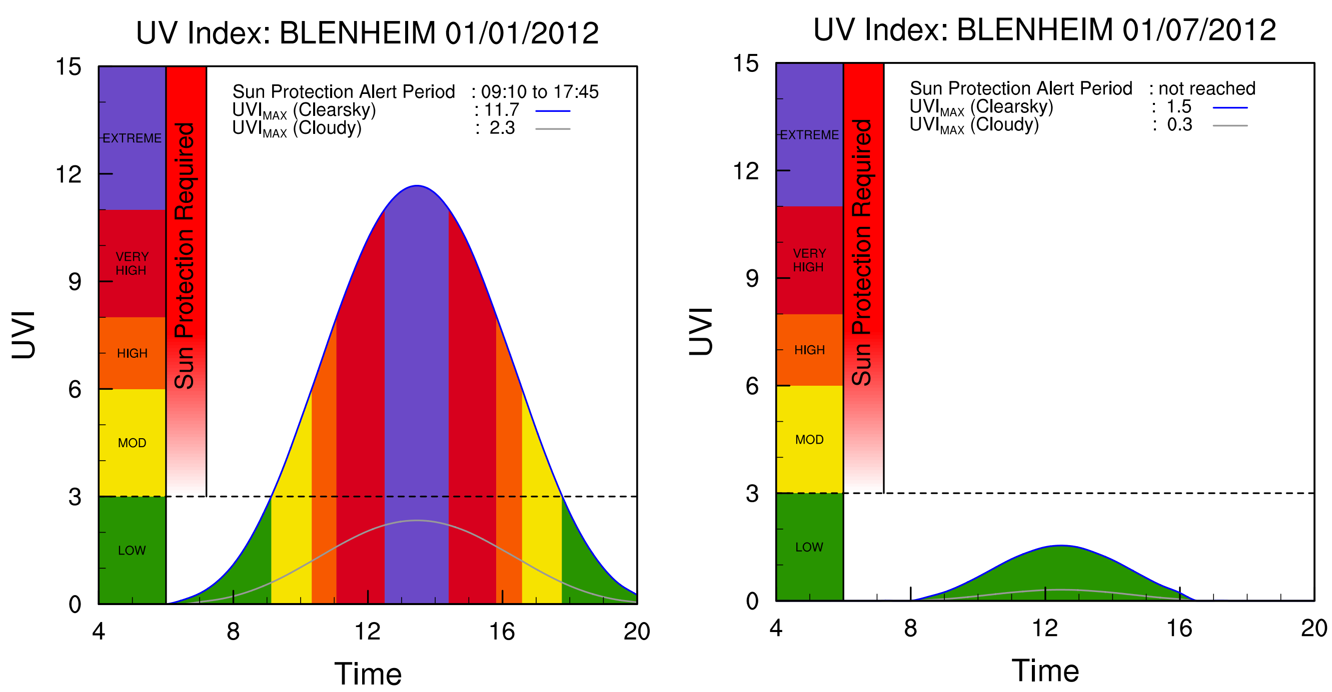


Figure 22. UV Index forecast for Blenheim, (a) January and (b) July. Source: https://www.niwa.co.nz/our-services/online-services/uv-and-ozone.

Fog

Fogs are uncommon over much of the Marlborough region, with only two fogs observed per year on average in Blenheim, three at Cape Campbell, and four at Waihopai Power Station (Table 16). The fogs that do form generally form at night under anticyclonic conditions with clear skies and very little air movement. Radiational cooling of the land also contact cools the air above and fogs will normally form if the air is cooled to its dew-point, allowing the water vapour in the air to condense. In contrast, 71 fogs per year are observed at Rai Valley (probably due to sheltered nature of the valley, and katabatic drainage of cold air to the base of the valley and warmer temperatures aloft), and 32 per year at Stephens Island (most likely sea fogs or low stratus cloud). Although fog can occur at any time of the year it is recorded most frequently during winter at Rai Valley, and during summer at Stephens Island (the other locations record similar averages year-round).

Table 16. Average number of days each year with thunder, fog, and hail, from all available data.

	Fog	Thunder	Hail
Blenheim	2	3	1.1
Cape Campbell	3	0.3	0.7
Molesworth	8	2	0.5
Rai Valley	71	1	0.1
Stephens Island	32	3	0.8
Waihopai Power Stn	4	2	1.4

Severe convective storms

Thunderstorms

Thunderstorms are fairly evenly distributed throughout the year, but there is a tendency for them to be more frequent during the summer months when strong afternoon surface heating leads to intense convection and cumuliform cloud development. Average annual frequencies for selected stations are given in Table 16, and range from one every three years at Cape Campbell to three per year at Blenheim and Stephens Island. At some of the stations, it is likely that not all thunderstorms are detected. The heavy rain, lightning, hail, wind squalls, and rare tornadoes which can occur with thunderstorms will sometimes cause severe local flooding, disruption of electrical and electronic equipment, and damage to trees, crops, and buildings.

Hail

Table 16 gives the average number of days per year on which hail is reported at selected stations. Hail is seldom experienced at the sites selected in Table 16. Hail occurs from once every ten years at Rai Valley to three days every two years at Waihopai Valley Power Station. As with thunderstorms, an unknown number of hail falls will escape detection at some of the stations. Hail can occur at any time, but winter and spring occurrences are more common than in summer or autumn.

A significant hail storm affected Marlborough on 8 December 1991. Approximately 40% of orchards in the region were affected, causing significant damage. The Royal Gala apple variety was particularly affected because it bruises easily.

Tornadoes

Tornadoes are rapidly rotating columns of air extending from the base of a cumulonimbus cloud, and have in New Zealand a damage path typically 10–20 m wide and 1–5 km long. The small size (compared to tornadoes in the USA), their short lifetimes, and the sparse population of much of New Zealand must result in an unknown number of tornadoes not being reported. Tornadoes are rare in the Marlborough region, with only one damage-causing tornado being reported in NIWA's Historical Weather Events Archive (1900-2012) and climate summaries (2000–2013). This tornado occurred on 26 April 2011, at Waikawa near Picton. The tornado tore the roof off at least one house, and left roofing iron lying metres up a nearby hillside.

Snow

Snow is frequent in the higher altitude areas of the Marlborough region, but rare in the lowlands. On the summit of Mt Tapuaenuku (2885 m, in the Inland Kaikoura Ranges, the highest mountain in the region), snow lies for most of the year. In 1977, snow lay in the glacial basin of Six Mile Creek, St Arnaud Range (altitude 800 to 1800 m) from August to October, with an average depth of 61.6 cm (the depth varying according to rock outcrops) and drifts up to 2.4 m. On passes above 1200 m in the Molesworth area, drifts of 3 m or more have been reported. About Molesworth Station (altitude 893 m), general snow cover to a depth of 7–15 cm can be expected at least once in an average year, and in exceptional years falls of 30–60 cm with deep drifts. On average, snow falling is recorded on 13 days per year at Molesworth, ranging from a minimum of one day in 1949 and 1954 to a maximum of 32 days with snow falling in 1918. Days where snow is lying on the ground is recorded on average 18 days per year at Molesworth, ranging from a minimum of one day in 1987 to a maximum of 53 days in 1975. Other sites with more than ten years of snow data in Marlborough (Blenheim, Rai Valley, Cape Campbell, and Stephens Island) have only recorded snow falling a couple of times in their records (generally 1960s to 1980s), so snowfall is rare in these low elevation and/or coastal sites.

Parts of Marlborough were affected by significant snowfall in August 2008. Ewes on Middlehurst Station in the Awatere Valley were trapped in deep snow for two weeks. Rainbow Ski Field and its access road were closed for 10 days from 12 August because of too much snow, and during one storm during the month the ski field received 100 cm of snow over a few days, making an average snow base of 3 m – a record at that ski field. Electricity was cut for nearly a week at Wairau Pass due to the snow.

Sea swell and waves

The ocean off the west coast of New Zealand is exposed to the prevailing west to southwest swells of its latitude zone. Consequently, swells off the west coast are much higher than those off the east coast.

Cook Strait is the only gap between the mountainous North and South Islands, and because it is located in the westerly wind belt known as the Roaring Forties, the strait acts as a giant wind tunnel. The swells on Cook Strait can increase rapidly with a southerly storm, sometimes reaching heights of 15 m or more. Because of the wind funnelling and strong tidal flows, Cook Strait is regarded as one of the most dangerous and unpredictable stretches of water in the world.

The closest wave buoys to Marlborough are off Baring Head on Wellington's south coast (across Cook Strait from Marlborough), and off Banks Peninsula in Canterbury. Off Baring Head, prevailing swells come from the south 45% of the time, and from the southwest 35% of the time (Gorman et al., 2003). Of all swells observed, the frequency of those from one to two metres is 40%, while for those greater than two metres is about 12%. About 1% of swells are over four metres. Off Banks Peninsula, south-southwest is the prevailing direction that swells come from (35% of the time). Of all swells observed, the frequency of those from one to two metres is 40%, while for those from two to four metres is about 35%, and about 2% of swells are greater than 4 m.

There is a known relationship between steady wind speed and wave heights over the open sea. The most probable wave heights for a given wind speed over a typical fetch length in New Zealand coastal waters of about 500 km are given in Table 17.

Table 17. Generated wave heights associated with specific wind speeds. Assumes a fetch length of 500 km with unlimited wind duration.

Wind speed (km/hr)	Associated wave height (m)
10	0.5
20	1
30	2
40	3
50	4
75	7
100	11
125	13+


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 computed 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 section. Short-term high intensity rainfalls have been covered previously in this report.

Vapour pressure and relative humidity

Vapour pressure and relative humidity are 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 total air 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). Average 9 am vapour pressures for several stations in Marlborough are given in Table 18.

Relative humidity relates the amount of water present in the air to the amount required to saturate it. This varies with temperature, and so a large diurnal variation is usually noticeable. Relative humidity is quite high in all seasons, but there is a peak in winter, as shown in Table 19. Inland areas (e.g. Molesworth and Blenheim) tend to have lower relative humidity than coastal sites (Pelorus Sound and Cape Campbell).

Table 18. Mean monthly/annual 9 am vapour pressure (hPa) for selected Marlborough sites.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blenheim Aero AWS	13.7	13.9	12.4	11.1	9.5	7.7	7.4	8.1	9.3	10.2	10.8	12.7	10.6
Cape Campbell AWS	14.6	14.9	13.5	12.1	10.8	9.1	8.8	9.0	9.9	10.6	11.4	13.3	11.5
Molesworth (+ AWS)	10.1	10.3	9.2	7.7	6.4	5.5	5.1	5.3	5.9	7.2	7.6	9.5	7.5
Pelorus Sound, Crail Bay	15.2	15.5	14.3	12.7	11.2	9.7	9.3	9.6	10.4	11.2	12.2	14.1	12.1

Table 19. Mean monthly/annual 9 am relative humidity (%) for selected Marlborough sites.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blenheim Aero AWS	69.6	75.0	74.4	77.7	81.7	82.2	83.1	80.2	73.7	73.6	67.0	67.4	75.5
Cape Campbell AWS	80.3	81.4	76.8	77.3	76.8	75.1	76.9	75.8	75.4	76.8	75.1	78.1	77.1
Molesworth (+ AWS)	61.2	72.2	72.4	71.9	75.6	79.1	79.5	74.2	66.1	64.2	65.3	66.2	70.7
Pelorus Sound, Crail Bay	74.7	77.4	75.8	76.8	78.9	81.4	81.8	79.3	74.7	73.6	73.0	74.8	76.8

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 maximum 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 completely saturated. 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 soil moisture capacity (assumed to be 150 mm for most New Zealand soils).

Mean monthly and annual soil water balance values are given in Table 20, for a number of sites in the Marlborough region. It can be seen from this table that eastern sites such as Blenheim and Awatere Valley have more days of soil moisture deficit (around 100 days between November and April at these sites) compared with Canvastown (42 days of soil moisture deficit during the same period). Canvastown and Pelorus Sound observe almost ten times the amount of runoff of Blenheim and Awatere Valley, highlighting the very different rainfall regimes of the region. There is adequate moisture available to maintain plant growth between June and October in the wetter sites of Pelorus Sound and Canvastown, but July is the only month without soil moisture deficit at Blenheim. Figure 23 shows region-wide variability in days of soil moisture deficit per year.

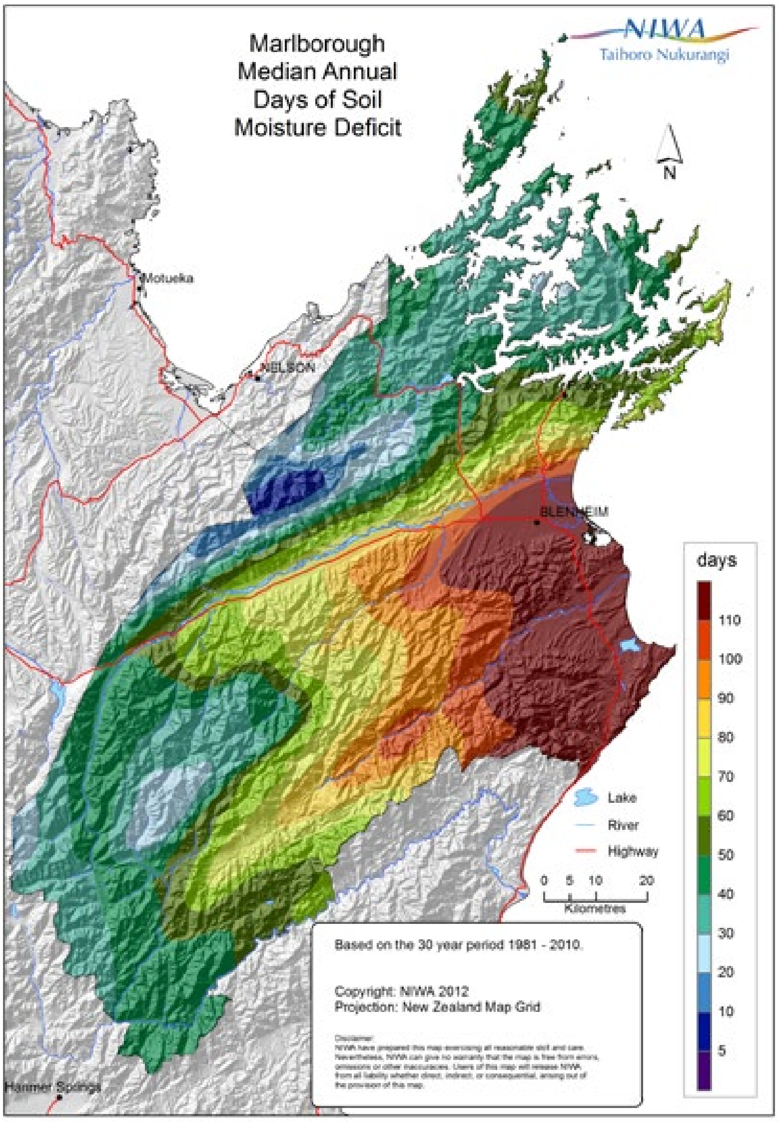


Figure 23. Marlborough median annual days of soil moisture deficit.

Evapotranspiration relates to the amount of water used by plants in transpiration. Penman (1948) developed an energy-based method of estimating this quantity, i.e. potential evapotranspiration (PET). PET has been calculated for Blenheim and Grassmere Salt Works using the Penman method. The monthly mean, minimum, and maximum PET values are listed in Table 21.

Table 20. Mean monthly/annual water balance summary for a soil moisture capacity of 150 mm.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Awatere Valley, Hillside (213 m)	NR	0	0	0	0	0	1	3	3	2	0	0	0	9
	RO	0	0	0	1	3	9	33	33	12	5	1	0	97
	ND	22	18	15	12	5	2	0	0	2	5	12	18	108
	DE	110	76	49	21	6	2	0	0	4	17	50	86	421
Blenheim Research (+ EWS) (4 m)	NR	0	0	0	0	0	2	2	3	1	1	0	0	9
	RO	0	0	0	1	4	15	21	25	10	4	1	0	81
	ND	23	18	16	14	6	2	0	0	1	6	16	20	122
	DE	116	78	54	26	6	2	0	1	3	20	70	100	475
Canvastown, Wakamarina (14 m)	NR	1	1	1	3	4	8	8	7	8	4	3	1	48
	RO	12	13	19	47	78	136	132	104	130	107	64	20	862
	ND	10	11	6	4	2	0	0	0	0	0	3	7	44
	DE	56	51	20	8	3	0	0	0	0	1	16	38	193
Pelorus Sound, Crail Bay (13 m)	NR	1	1	1	3	5	9	9	8	7	5	2	1	51
	RO	11	17	11	45	64	112	134	104	95	106	55	27	781
	ND	7	9	5	2	0	0	0	0	0	0	4	5	32
	DE	35	38	17	4	0	0	0	0	0	0	19	27	141

NR is the average number of days per month on which runoff occurs
RO is the average amount of runoff in mm
ND is the average number of days per month on which a soil moisture deficit occurs
DE is the average amount of soil moisture deficit in mm

Table 21. Penman calculated maximum, mean, and minimum monthly potential evapotranspiration (mm), as well as total mean annual PET.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blenheim Aero AWS	Max	192	148	127	81	47	36	33	52	82	124	196	195	
	Mean	165	123	106	57	33	22	27	40	67	105	135	157	1037
	Min	131	98	84	38	24	14	19	31	48	83	107	111	
Grassmere Salt Works	Max	220	165	147	92	64	42	46	68	113	143	193	213	
	Mean	173	136	111	73	46	31	33	50	79	116	146	162	1155
	Min	128	97	88	55	32	3	21	33	58	79	111	124	

Drought in Marlborough

The Marlborough region is accustomed to periods of low rainfall due to its position in a rain shadow. However, sometimes extended periods of very low rainfall occur, resulting in droughts, which have a significantly negative impact on the economy.

One particularly severe drought occurred during the summer of 2000-2001 which had a significant impact on the Marlborough region. In Blenheim, rainfall was less than half of normal for the months from December 2000 to May 2001. Rainfall was at a minimum in January, when Blenheim received only 2.2 mm of rain during the entire month, which was 5 % of normal January rainfall. In February, 5.6 mm of rain was recorded (13 % of normal for the month), and in March, 11.8 mm was recorded (28 % of normal for March). Soil moisture deficits approached 150 mm of deficit (wilting point) around Blenheim between January and March 2001 (Figure 24). Wildfires razed over 7000 hectares of Marlborough farmland, across 17 farms on Boxing Day 2000. More than 2000 sheep and cattle were killed in the fires. By March, there had still been not enough rain to re-sow the pastures that had been destroyed by the fires, and the economic impact was severe as stock had to be sold off early.

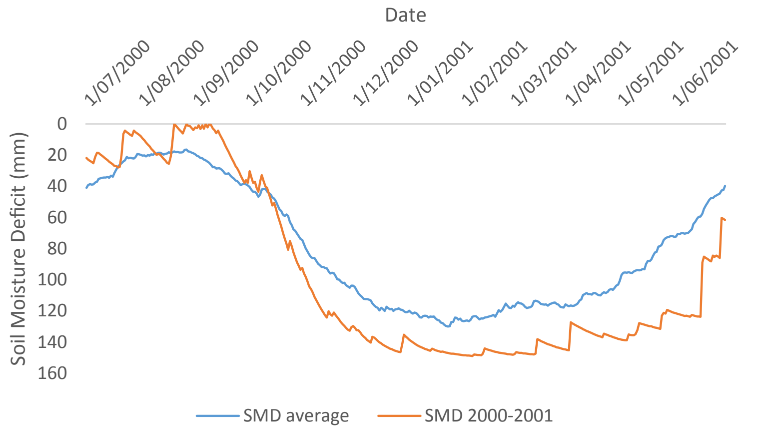


Figure 24. Soil moisture deficit at Blenheim during the 2000-2001 drought, compared with normal soil moisture deficit conditions for the same time of year at Blenheim (1985–2010).

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 particular 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 22 lists the monthly totals of growing degree-day totals above base temperatures of 5°C and 10°C for sites in the Marlborough region. Two of the most successful crops in Marlborough are wheat and grapes; their suitability is related to GDD with a base of 10°C or higher, while pasture growth is usually assessed from a base of 5°C.

Table 22. Average growing degree-day totals above base 5°C and 10°C for selected Marlborough sites.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blenheim Research (+ EWS)	5°C	405	358	336	249	185	107	87	122	179	244	285	364	2920
	10°C	250	217	181	103	49	16	8	16	49	95	136	209	1328
Grassmere Salt Works	5°C	408	362	359	271	196	119	107	135	193	254	297	371	3073
	10°C	253	221	204	124	60	22	14	23	59	104	148	216	1449
Molesworth	5°C	281	256	220	116	42	8	2	10	43	104	159	229	1471
	10°C	131	119	80	20	3	0	0	0	2	13	40	88	495
Rai Valley	5°C	364	323	324	236	140	76	65	88	149	209	254	324	2552
	10°C	209	182	169	91	23	8	4	7	26	63	106	169	1059

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 23 shows that the number of cooling degree days reach a peak in summer in the Marlborough region, where there is a higher demand for energy to cool building interiors to 18°C. Conversely, heating degree days reach a peak in winter, where the demand for energy to heat buildings to 18°C is highest. Figure 25 shows region-wide variability in the number of heating degree days per year. The number of heating degree days is lower in low elevation or coastal areas (e.g. Blenheim and Grassmere Salt Works), compared with areas further inland and at higher elevations (e.g. Rai Valley and Molesworth). The coastal sites experience more cooling degree days than the inland sites, also.

Table 23. Average cooling (CDD) and heating (HDD) degree-day totals with base 18°C for selected Marlborough sites.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Blenheim Research (+ EWS)	CDD	36	28	11	1	0	0	0	0	0	1	5	23	104
	HDD	35	37	79	142	218	284	319	282	211	159	110	62	1938
Grassmere Salt Works	CDD	38	31	21	4	0	0	0	0	0	2	7	26	130
	HDD	33	36	65	123	207	273	297	269	198	151	99	59	1810
Molesworth	CDD	3	3	0	0	0	0	0	0	0	0	0	0	7
	HDD	125	114	184	278	394	465	516	462	367	306	232	174	3619
Rai Valley	CDD	16	12	7	0	0	0	0	0	0	0	0	5	40
	HDD	55	57	86	155	264	324	349	317	241	194	136	84	2262

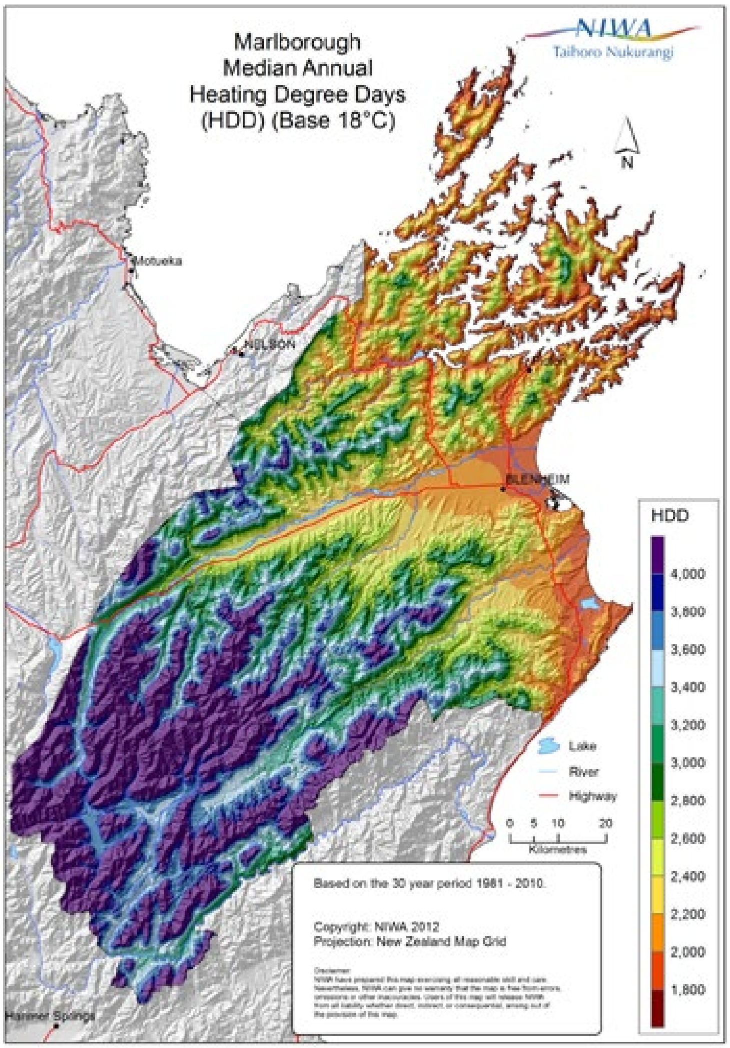


Figure 25. Median annual heating degree days for Marlborough, 1981-2010

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Photo credits:

Page 33, Dave Allen, NIWA

Pages 35, Gregor Macara, NIWA

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