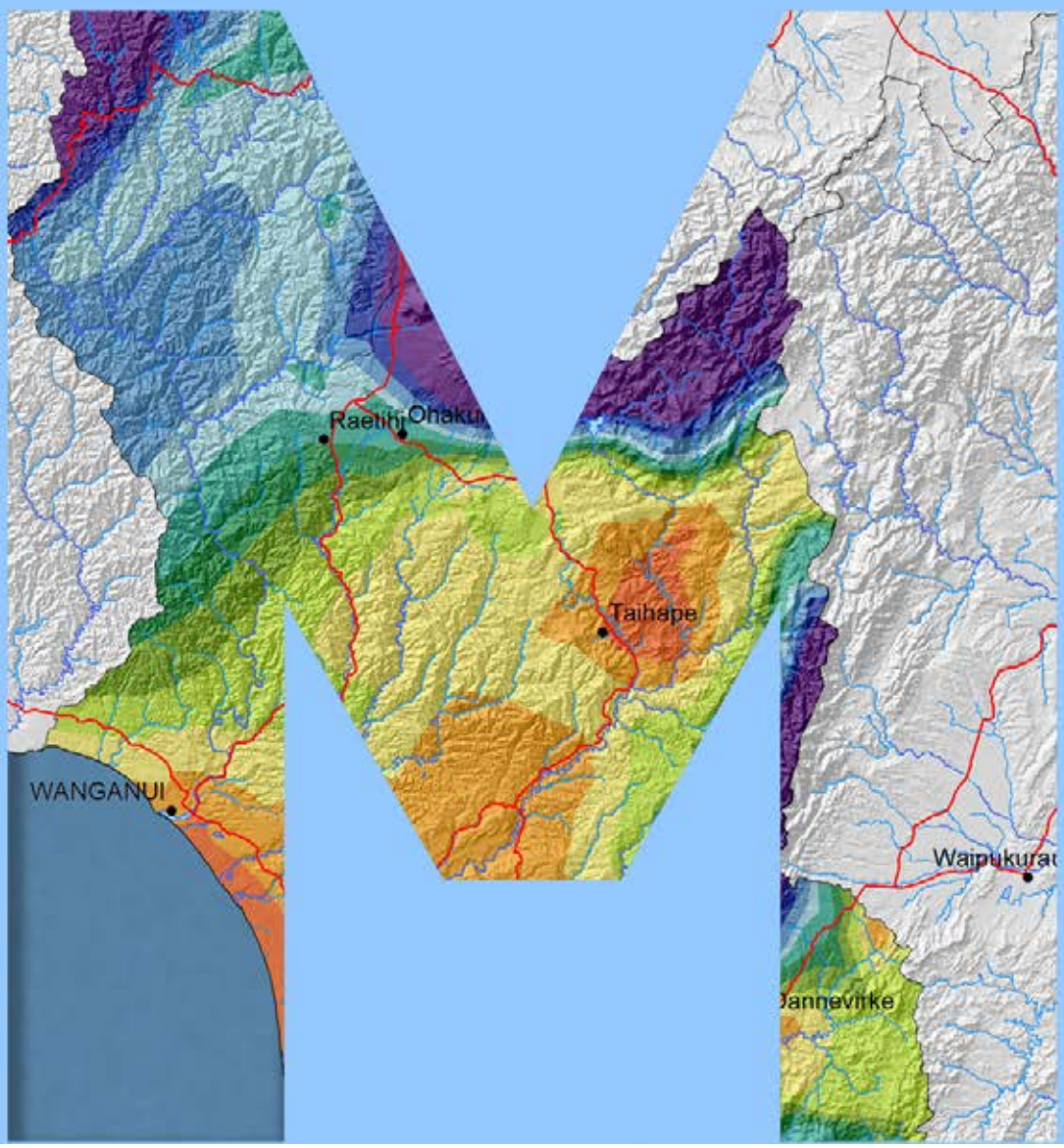
NIWA
Taihoro Nukurangi

THE CLIMATE AND WEATHER OF MANAWATU-WANGANUI

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 (18) 'The climate and weather of Manawatu and Horowhenua', written in 1982 by S.M. Burgess, and the first edition of the New Zealand Meteorological Service Miscellaneous Publication 115 (6) 'The climate and weather of the Wanganui region of New Zealand', written in 1972 by W.M. Maunder and M.L. Browne. This edition incorporates more recent data and updated methods of climatological variable calculation.

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CONTENTS

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SUMMARY

The climate of the Manawatu-Wanganui region is a reflection of the general disturbed westerly air flow with interspersed anticyclones, modified in specific places by the local topography. Much of the Manawatu-Wanganui region has relatively few climatic extremes, except in the higher elevation areas around the Central Plateau. The rainfall is usually adequate for pasture growth, except on occasions in the summer, and temperatures have a relatively small range. Summers are warm and frosts frequent in sheltered inland areas during winter. The weather is often cloudy about the hills, but sunshine hours increase toward the west coast where around 2025 hours are recorded each year. Except at higher elevations, snow and hail are rare occurrences, although fog occurs at times in coastal areas. The prevailing air flow is from the westerly quarter, and except during the passage of the occasional depression, or when a depression of tropical origin passes to the east of the North Island, the day-to-day weather conditions are not severe.

INTRODUCTION

New Zealand is a narrow mountainous country situated in the midst of the South Pacific Ocean. The nearest major landmass is Australia, located some 1600 km to the northwest. The day-to-day weather is produced by a regular series of anticyclones and troughs or depressions, which move eastwards over the Tasman Sea and onto New Zealand. The predominant wind flow over the country is westerly, and this together with the mountain ranges exerts a major influence on the climate of the country. Winds are often deflected by the ranges, and speed is increased through gaps, such as the Manawatu Gorge, Cook, and Foveaux Straits. As the main ranges lie in a north-east to south-west direction, regions in their lee are significantly drier and sunnier than those exposed to the predominant westerlies. New Zealand is occasionally affected by air masses which have originated in the tropics or the Antarctic, but have been modified with their passage across the sea. The warm air masses are often associated with humid weather and heavy rainfall, while the cold air masses are usually associated with unstable showery conditions.

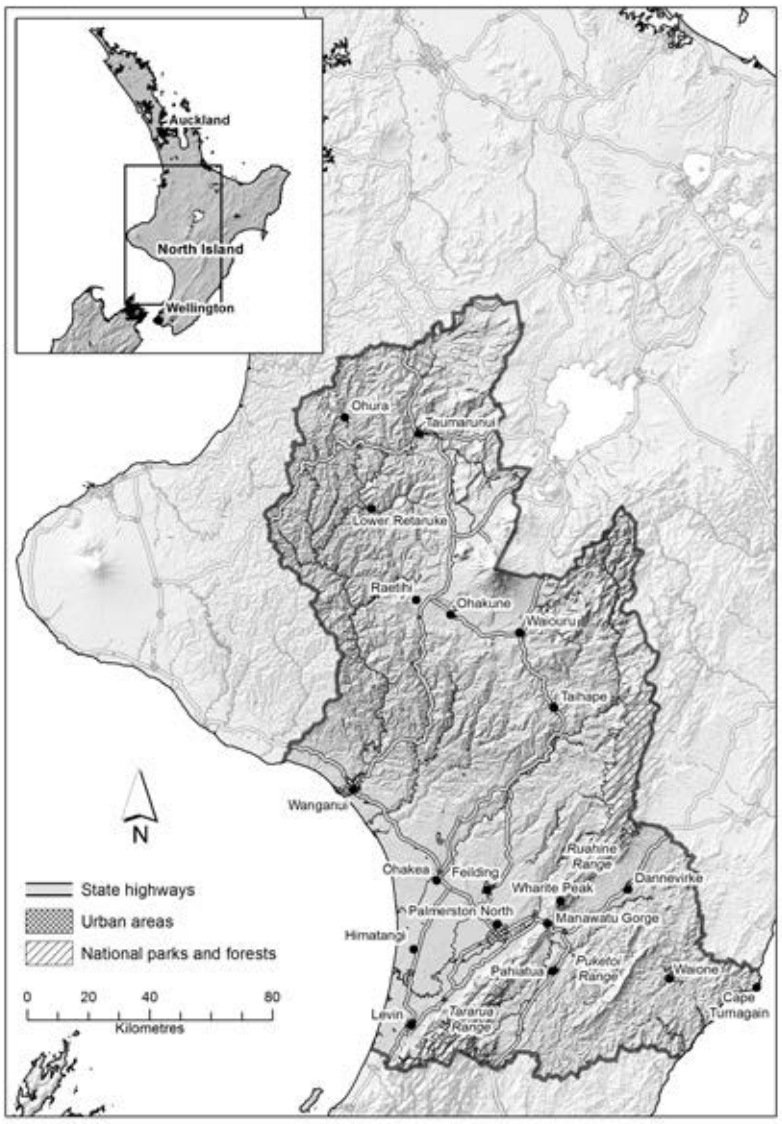

Figure 1. Map of Manawatu-Wanganui region, with locations of places mentioned in the text, tables, and figures.

In this publication, the Manawatu-Wanganui region is the region administered by Horizons Regional Council[1] (Figure 1). The Manawatu-Wanganui region borders the west coast of the North Island between Wanganui and Levin, and covers a 50 km stretch of the east coast south of Cape Turnagain. Taumarunui is the northernmost town.

Some important topographic features of the region are the Ruahine, Tararua, and Puketoi Ranges. The Ruahine Range extends in a line south-southwestwards to the Manawatu Gorge. The Tararua Range then extends southwestwards into the Wellington region. These ranges rise to over 1000 m in places, but are lower near the Manawatu Gorge, forming a ridge between 300 and 500 m above mean sea level. They effectively divide the southern part of the region in half. The Puketoi Range lies to the east of the Ruahine and Tararua Ranges. The Central Plateau (with Tongariro National Park and the volcanoes of Ruapehu, Ngauruhoe, and Tongariro at its centre) extends from near Taumarunui south to Taihape. Steep, dissected hill country is characteristic of the region to the south and west of the Central Plateau towards Wanganui. The southwest part of the region is flat lowland country, especially southwest of Feilding. Much of the lowland area is used for intensive dairy farming, while much of the hill country is used for semi-intensive sheep and beef farming and forestry.

The Manawatu-Wanganui region borders the Taranaki region to the west, the Waikato region to the north, the Hawke's Bay region to the east, and the Wellington region to the south.

[1]Although part of the Tongariro National Park is within the Manawatu-Wanganui region, this area has been covered in the Waikato climatology report (NIWA Science and Technology Series, number 61), and therefore statistics for this area will not be presented in this publication.

TYPICAL WEATHER SITUATIONS IN MANAWATU-WANGANUI

The weather of the Manawatu-Wanganui region is dominated by migratory anticyclones and intervening troughs of low pressure. The majority of anticyclones passing over the New Zealand area have their centres to the north of the region and the wind flow in the lower atmosphere over Manawatu-Wanganui is generally from the westerly quarter. The lifting of westerly air streams over the high ground in the north and northeast of the region, as well as the Ruahine and Tararua Ranges, often results in increased shower activity and also in heavier falls during a period of general rain. Cloud and rainfall can also spill over the ranges into the east of the region and through the Manawatu Gorge. When the prevailing airflow is east or southeast there is a sheltering effect in the areas to the west of the Ruahine and Tararua Ranges. The high country to the north also shelters the coastal area when the air flow is northerly and on these occasions showers may fall over the ranges, while fine warm weather predominates on both coasts. Anticyclones usually give settled dry weather in the Manawatu-Wanganui region, with moderate frosts in the winter, and pronounced sea breezes in the summer.

West to northwest airstreams

In most west to northwest airstreams, showers fall in the Ruahine and Tararua Ranges. Light or moderate rain usually occurs throughout the region with the passage of any frontal systems. The duration of the rain varies, depending on the speed of the frontal passage. In northwesterly conditions, showers may spread over to the eastern side of the region through the Manawatu Gorge.

Strong westerly flows occur at any time of the year, but are most frequent in the spring, and may persist for 4 to 5 days. These are usually associated with a deep depression situated far to the south of New Zealand. On some occasions lenticular clouds (associated with

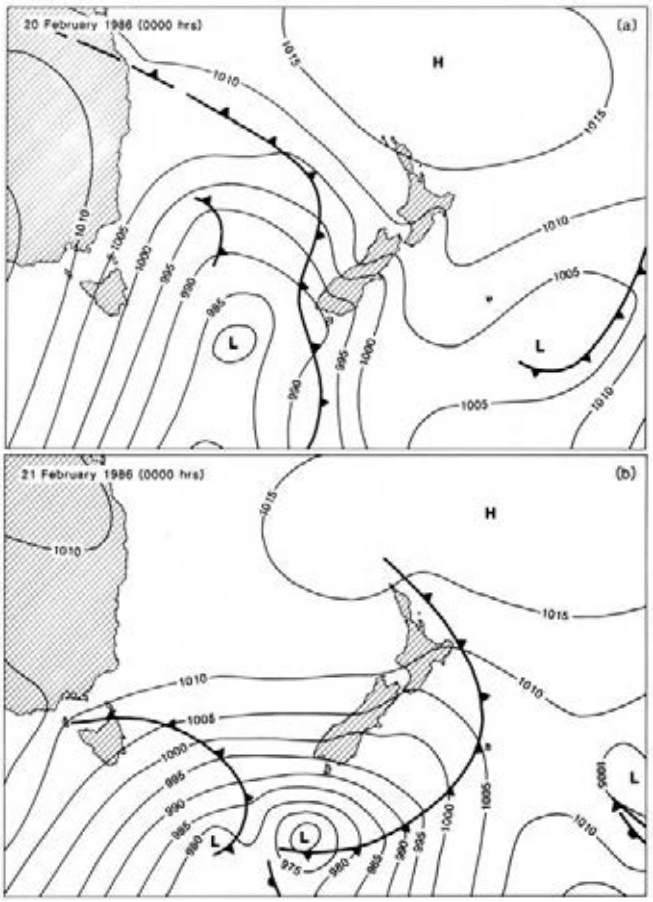

Figure 2. Mean sea level maps at 0000 NZST on (a) 20 and (b) 21 February 1986.

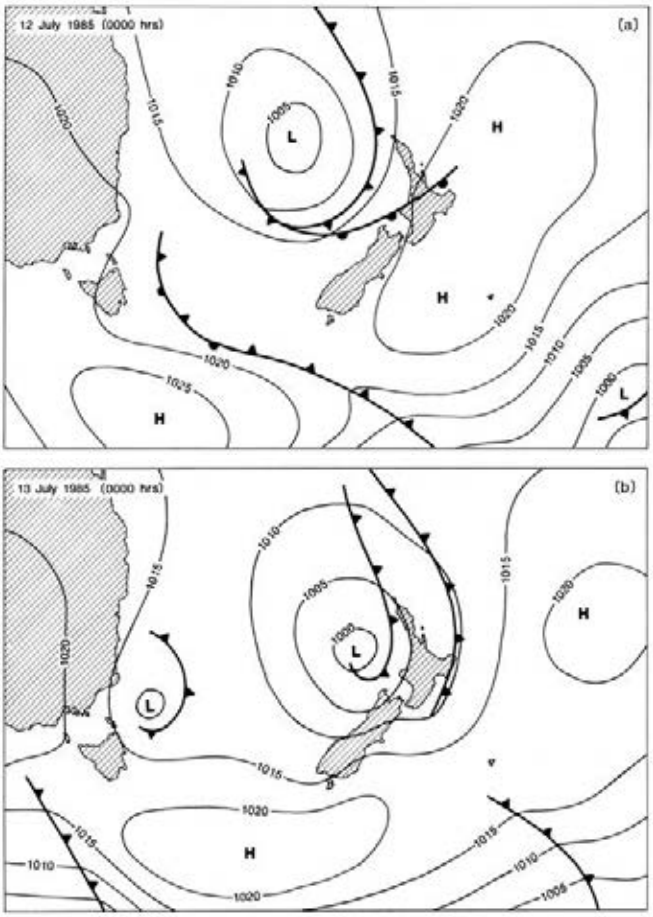

Figure 3. Mean sea level maps at 0000 NZST on (a) 12 and (b) 13 July 1985.

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stable conditions) form to the east of the ranges because of the ascent of strong westerlies, and dull conditions prevail. In unstable westerly airstreams the mountain ranges in the north of the South Island can exert a sheltering effect over the lower part of the North Island. The weather in the southeastern part of the Manawatu-Wanganui region is often fine and sunny during these conditions, while more cloudy weather prevails over the remainder of the region.

Figure 2a shows a trough of low pressure in the Tasman Sea moving eastwards toward New Zealand on 20 February 1986. This was preceded by a northwesterly airstream with wind speeds of 20-30 km/hr. The associated cold front which moved onto the country was preceded by a brief period of showers, which lasted for 4 to 5 hours. Light rain (1-5 mm) was recorded in Manawatu-Wanganui west of the ranges, but no rain fell east of the Manawatu Gorge. Maximum afternoon temperatures ranged from 24-26°C to the east of the Manawatu Gorge, and 22-23°C elsewhere. The cold front was followed by moderate to fresh westerlies (Figure 2b) on the following day with slightly cooler temperatures and dry, sunny weather.

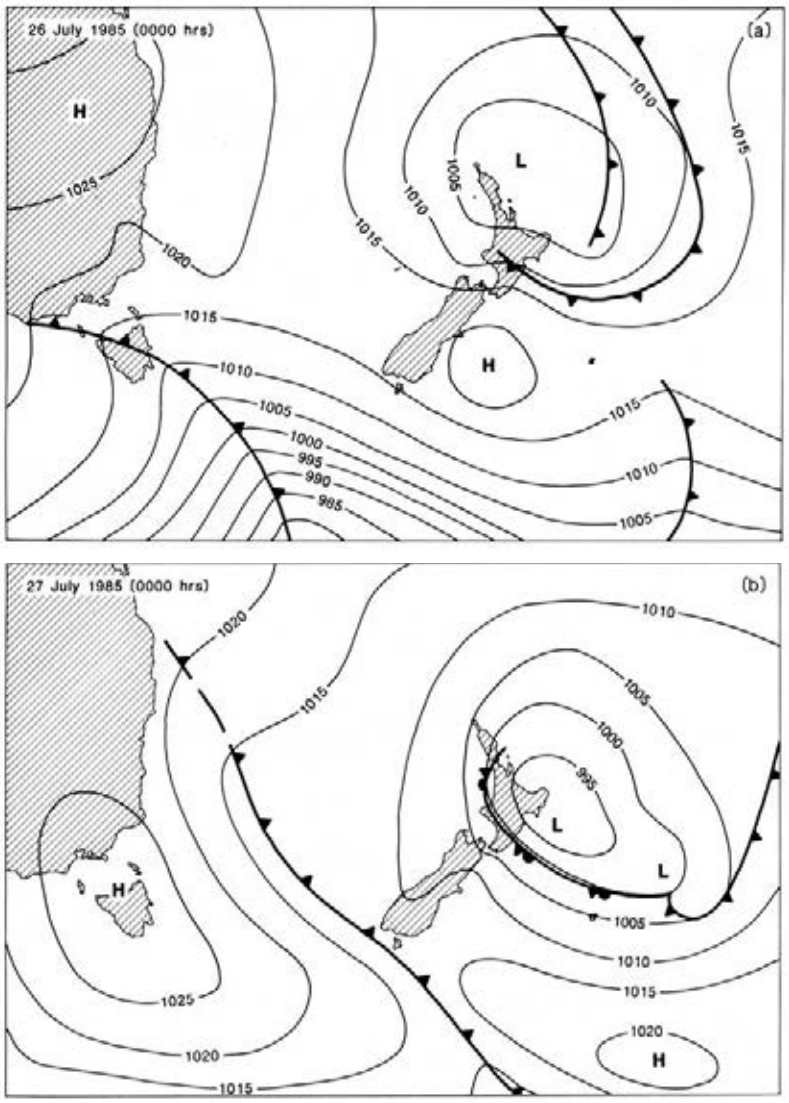

Figure 4. Mean sea level maps at 0000 NZST on (a) 26 and (b) 27 July 1985.

North to northeast airstreams

North to northeast airstreams cover New Zealand when a depression is situated to the west or northwest of the North Island. An anticyclone is usually located just to the east of the North Island and the airflow is almost parallel to the ranges. Dry, warm, and often cloudy weather prevails. Rain or drizzle normally occurs, with low stratus clouds and overcast skies preceding the passage of any frontal systems associated with the depression. If the flow is more northeasterly than northerly, light to moderate rain or drizzle may occur in the eastern Manawatu-Wanganui region preceding the passage of the front, while it can remain dry elsewhere. When the flow is northerly and rain occurs, totals are usually higher in the west than in areas east of the ranges. Northeasterly winds are often deflected through the Manawatu Gorge and occur as easterlies from Palmerston North northwards. Elsewhere over the region, winds are mostly light and variable.

Figure 3a shows a depression to the west and a northerly flow covering the North Island on 12 July 1985. Intermittent light to moderate rain was recorded throughout the day from the warm front. Moderate to fresh east to southeasterlies prevailed from Palmerston North northwards. Elsewhere winds were light and variable. On the following day (Figure 3b) the flow remained northerly as the depression moved southeastwards. Fog patches developed after the passage of the cold front in areas to the east of the Manawatu Gorge. Cloudy weather prevailed in the west, where above average temperatures of 18°C were recorded at Palmerston North. This was 5°C above the monthly average for July.

East to southeast airstreams

Figure 4a shows a shallow but deepening depression that moved slowly southeastwards over the North Island, with an east to southeast airflow in its southern sector on 26 July 1985. On this occasion fresh to strong east to southeast winds affected the area in the lee of the Manawatu Gorge. Strong to gale force southerlies affected the southwest of the region on the 27th (Figure 4b). Rainfalls of over 100 mm were recorded over the Puketoi Range in the 24 hours to 9 am on the 27th.

In this type of situation heavy rain often falls in and to the east of the ranges, while the area to the west is sheltered and receives less, and in some cases none. Southeast or easterly winds blow through the Manawatu Gorge affecting the region to the west, and southerly winds prevail elsewhere.

South to southwest airstreams

South to southwest conditions frequently follow the passage of a trough or a depression across New Zealand. When the flow is southerly, cold unstable showery weather is usual over and to the east of the ranges. Showers are more isolated elsewhere.

In a southwest flow, sheltering by the South Island generally gives fine weather to the southwest North Island. Figures 5a and 5b show an anticyclone situated in the Tasman Sea at latitude 42°S, with a trough of low pressure to the east of the country on 16 and 17 June 1986. There are often showers along the east coast, which may persist for 2 or 3 days. Showers also occur in the west in a southwest flow, with the passage of any frontal systems. This type of situation is often followed by the onset of an anticyclone or ridge bringing clear skies and cool nights.

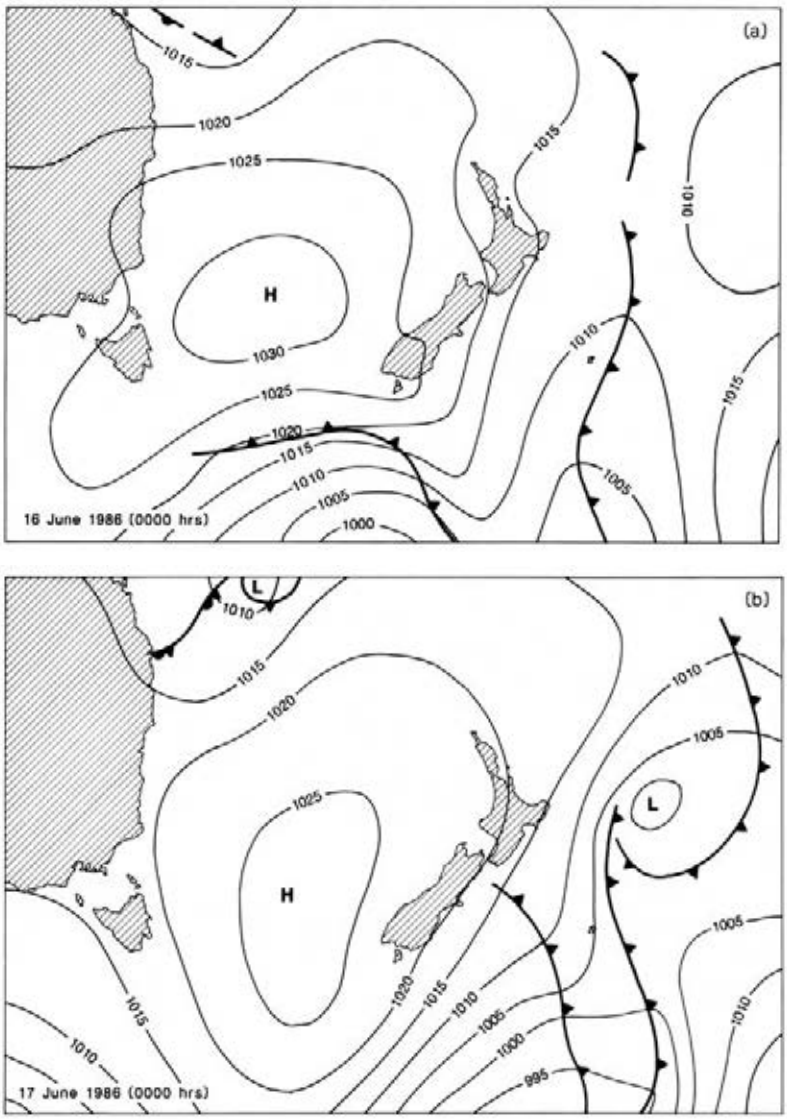

Figure 5. Mean sea level maps at 0000 NZST on (a) 16 and (b) 17 June 1986.

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CLIMATIC ELEMENTS

Wind

At the surface, wind direction and speed is strongly modified by topography. The Ruahine and Tararua Ranges, as well as the Manawatu Gorge, have a strong influence on wind in the southern part of the Manawatu-Wanganui region. In the hill country, winds tend to flow along the line of valleys. Throughout the region, the occurrence of light winds is more likely in the low-elevation inland areas than near the coast or at higher elevations.

Figure 6 shows mean annual wind frequencies of surface wind based on hourly observations from selected stations. Westerly-quarter winds prevail at all sites except for Taumarunui (no prevailing wind direction) and Wanganui Spriggens Park (north-northeast prevailing wind direction). Palmerston North has a higher proportion of stronger winds than the other sites selected.

Mean wind speed data (average wind speeds are taken over the 10 minute period preceding each hour) are available for several sites in Manawatu-Wanganui and these illustrate the several different wind regimes of the region (Table 1). Inland sites such as Waione and Waiouru, which are protected from the prevailing westerly winds, generally have lower mean wind speeds than locations that are more exposed to the west, such as Ohakea and Palmerston North.

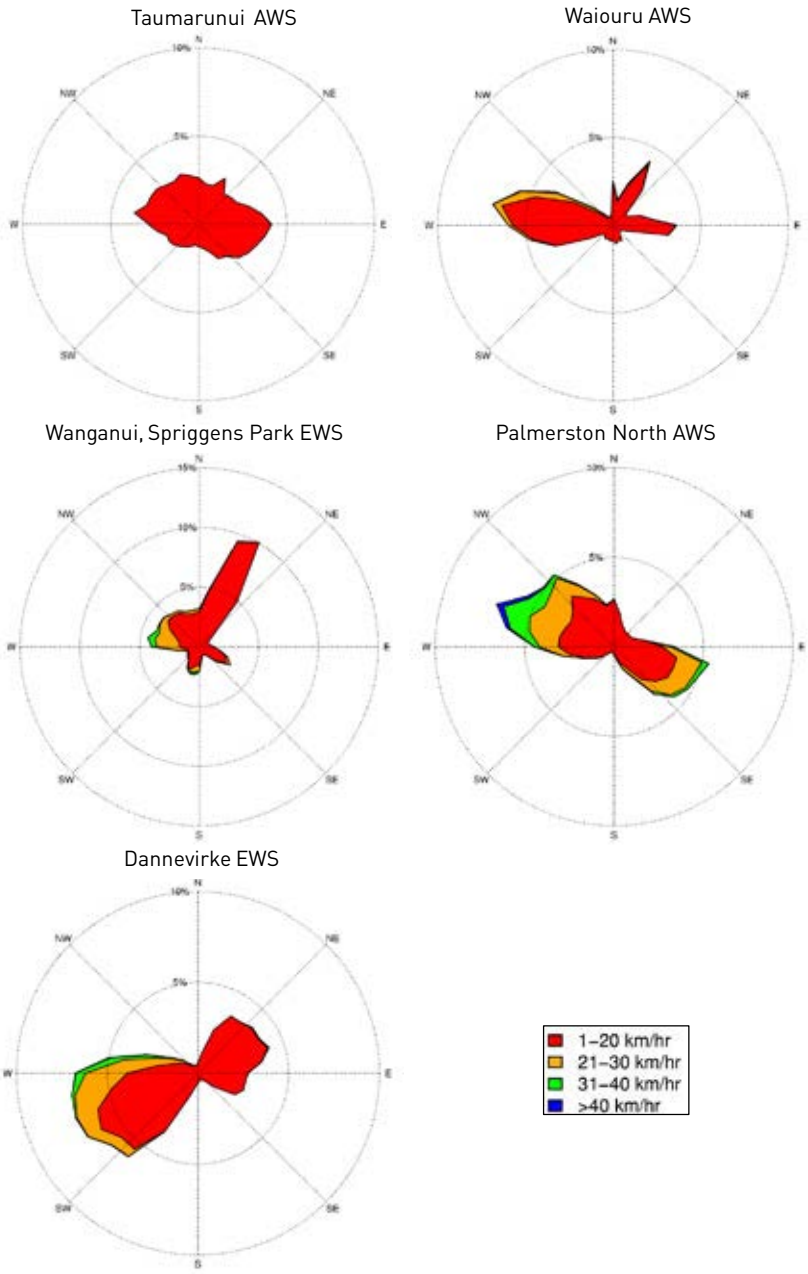


Figure 6. Mean annual wind frequencies (%) of surface wind directions from hourly observations at selected Manawatu-Wanganui stations. The plots show the directions from which the wind blows, e.g. the dominant wind direction at Palmerston North is from the west-northwest.

Table 1. Mean monthly/annual wind speeds (km/hr) for Manawatu-Wanganui sites.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Levin AWS	9.9	9.4	9.4	8.2	8.6	9.4	8.6	9.9	10.9	12.5	12.4	11.5	10.1
Ohakea Aero	19.0	17.6	17.4	16.4	16.7	15.5	16.0	16.1	18.1	20.1	20.7	19.5	17.8
Palmerston North AWS	15.8	15.6	15.3	12.9	13.7	13.7	13.9	14.2	15.6	17.0	17.8	16.1	15.1
Waione RAWS	9.0	8.3	7.9	6.8	7.0	7.6	6.9	7.6	8.0	9.8	10.1	9.6	8.2
Waiouru AWS	7.7	7.4	7.2	6.8	7.2	7.7	7.0	8.1	8.9	10.0	9.7	9.2	8.1
Wanganui, Spriggens Park EWS	13.4	12.4	12.2	10.8	11.2	11.9	11.2	12.0	12.5	14.7	15.0	13.8	12.6

Spring is generally the windiest season throughout the region, whereas autumn records the lowest percentage of strong winds. Table 2 gives the seasonal proportion of strong and light winds as a percentage of the annual total. For example, of all strong winds recorded at Waiouru, 20% occurred in summer, 12% in autumn, 24% in winter and 44% in spring. In compiling this table a strong wind was defined as having a mean wind speed of at least 31 km/hr.

Diurnal variation in wind speed is well-marked, with greatest wind speeds occurring in the middle of the afternoon.

Table 2. Seasonal percentages of strong or light winds (%) for Manawatu-Wanganui sites.

Location		Summer	Autumn	Winter	Spring
Palmerston North AWS	Strong	26	18	19	37
	Light	25	25	25	25
Waiouru Aws	Strong	20	12	24	44
	Light	25	26	25	25
Wanganui, Spriggens Park EWS	Strong	27	17	20	36
	Light	24	26	26	24

Table 3. Average wind speed (km/hr) for selected hours in Manawatu-Wanganui.

Location	00	03	06	09	12	15	18	21
Palmerston North AWS	12.3	11.8	11.8	15.4	19.6	20.6	16.6	13.2
Waiouru AWS	6.7	6.8	6.7	8.1	11.6	12.1	8.4	6.7
Wanganui, Spriggens Park EWS	9.8	9.9	10.3	11.9	16.2	18.0	13.9	10.0

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

Location	Gusts >63 km/hr	Gusts >96 km/hr
Levin AWS	22	0.2
Palmerston North AWS	50	0.6
Waione RAWS	39	1.3
Wanganui, Spriggens Park EWS	59	3.8

Table 5. Highest recorded gusts at selected Manawatu-Wanganui stations, from all available data.

Location	Gust (km/hr)	Direction	Date
Dannevirke EWS	126	WNW	23/10/2007
Levin MAF	128	E	19/07/1978
Ohakea Aero	135	WNW	17/05/1977
Palmerston North Aero	115	NW	15/06/1987
Taumarunui AWS	74	NW	3/03/2012
Wanganui Aero	118	W	17/05/1977
Wharite Peak	171	WNW	8/09/1980

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. Cooling at night generally restores a lighter wind regime. During clear, cold nights, especially in winter under anticyclonic conditions, the inland hills and high 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.

Strong gusts over 96 km/hr are relatively infrequent at the selected sites shown in Table 4. It is likely that in the high country, strong gusts are more common, but long records (> 10 years) are lacking for those locations and therefore are not included here. Gusts of at least 63 km/hr are recorded at Wanganui Spriggens Park on an average of 59 days each year, and gusts over 96 km/hr occur on average 3.8 days each year. In comparison, Levin is more sheltered, with 22 days per year with gusts over 63 km/hr, and only one day every five years with gusts over 96 km/hr, on average.

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 Wharite Peak on 8 September 1980. Maximum gusts recorded at different stations in the region are listed in Table 5.

Rainfall

Rainfall distribution

The coastal and lowland area of western Manawatu-Wanganui is one of the driest areas in the North Island. Even so, rainfall is usually adequate for agricultural needs, except during summer. Figure 7 shows the distribution of median annual rainfall over the region. A triangle including the area roughly from Wanganui to Palmerston North to Levin receives less than 900 mm of rainfall per year, as does the area around Taihape. In contrast, higher elevation areas around the Central Plateau, the Ruahine and Tararua Ranges, and to the west of Taumarunui, receive more than 2000 mm per year. The hill country north of Raetihi and around Taumarunui experiences more than 1400 mm of rain per year. The eastern Manawatu-Wanganui region generally receives less than 1200 mm per year, except for the Puketoi Range which experiences about 1500 mm per year.

The variability of seasonal and annual rainfall over Manawatu-Wanganui is generally quite low, and is markedly less than other NI east coast districts. Table 6 lists monthly rainfall normals and percentage of annual total for selected

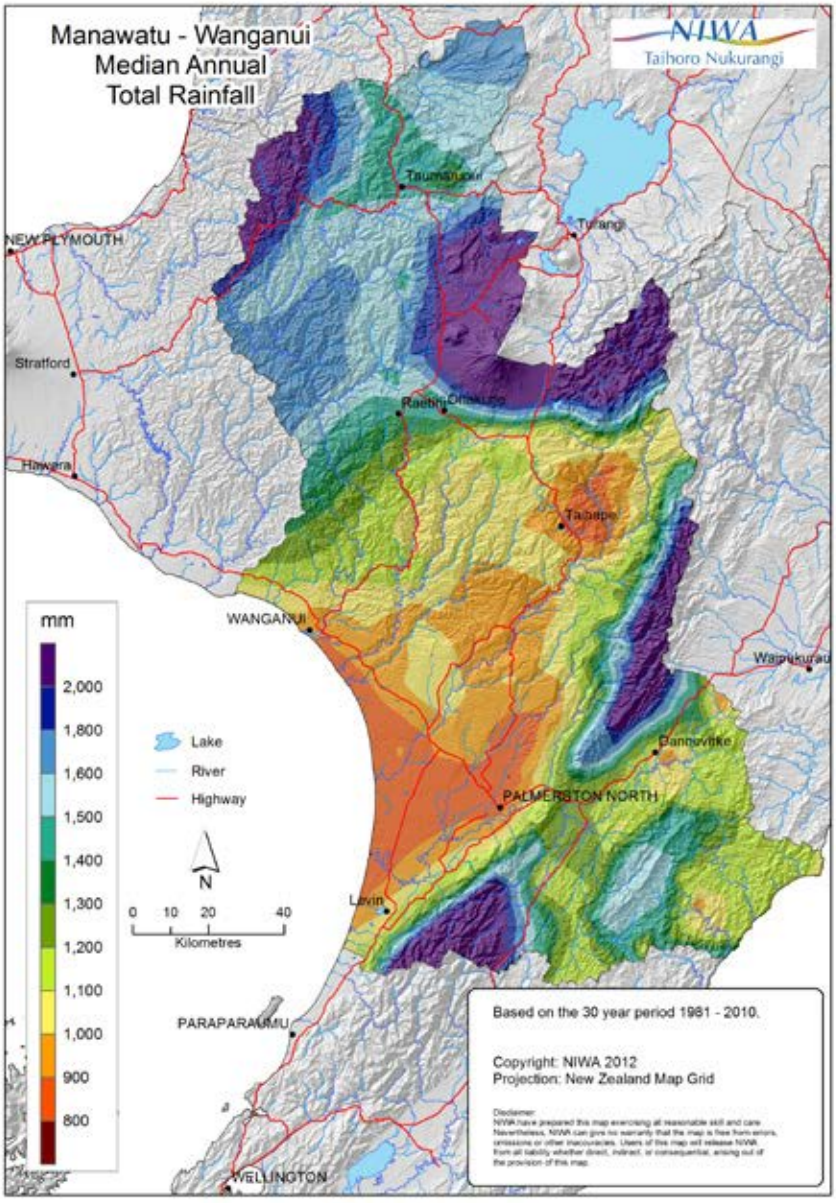


Figure 7. Manawatu-Wanganui median annual total rainfall, 1981-2010.

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

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Dannevirke	a	76	82	75	75	84	99	102	82	89	101	88	82	1034
	b	7	8	7	7	8	10	10	8	9	10	8	8	
Himatangi	a	75	79	73	56	70	87	77	64	56	64	64	77	842
	b	9	9	9	7	8	10	9	8	7	8	8	9	
Levin, Winchester St	a	69	85	114	83	90	114	106	91	99	111	99	104	1163
	b	6	7	10	7	8	10	9	8	8	10	9	9	
Lower Retaruke, Retaruke Station	a	117	108	101	121	139	160	161	165	170	171	146	163	1721
	b	7	6	6	7	8	9	9	10	10	10	8	9	
Ohakea Aero	a	64	75	77	62	69	78	82	67	64	74	62	90	864
	b	7	9	9	7	8	9	10	8	7	9	7	10	
Pahiatua	a	96	115	78	91	113	150	124	116	136	145	160	126	1450
	b	7	8	5	6	8	10	9	8	9	10	11	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	

Table 6 continued.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Raetihi No2	a	106	102	95	113	138	155	154	152	155	157	135	153	1615
	b	7	6	6	7	9	10	10	9	10	10	8	9	
Taihape Rec	a	70	60	64	73	79	87	79	75	77	84	70	86	904
	b	8	7	7	8	9	10	9	8	8	9	8	9	
Taumarunui	a	105	96	89	107	129	143	148	145	147	149	126	138	1522
	b	7	6	6	7	9	9	10	10	10	10	8	9	
Waiouru Treatment Plant	a	82	69	66	75	94	105	104	95	92	100	79	90	1050
	b	8	7	6	7	9	10	10	9	9	10	8	9	
Wanganui, Spriggens Park EWS	a	59	77	63	69	80	89	85	74	74	88	75	86	921
	b	6	8	7	8	9	10	9	8	8	10	8	9	

stations. The proportion of annual rainfall that is recorded in the winter months from June to August is fairly consistent across the Manawatu-Wanganui region at 27% (ranging from 26% to 29%), and the proportion of rain in summer months averages 24% (ranging from 22% to 27%).

The distribution of monthly rainfall is shown in Figure 8. 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 Manawatu-Wanganui 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 Dannevirke, it can be seen that during the three month period beginning in April, less than 182 mm can be expected one year in ten, between 182 and 344 mm eight years in ten, and over 344 mm one year in ten.

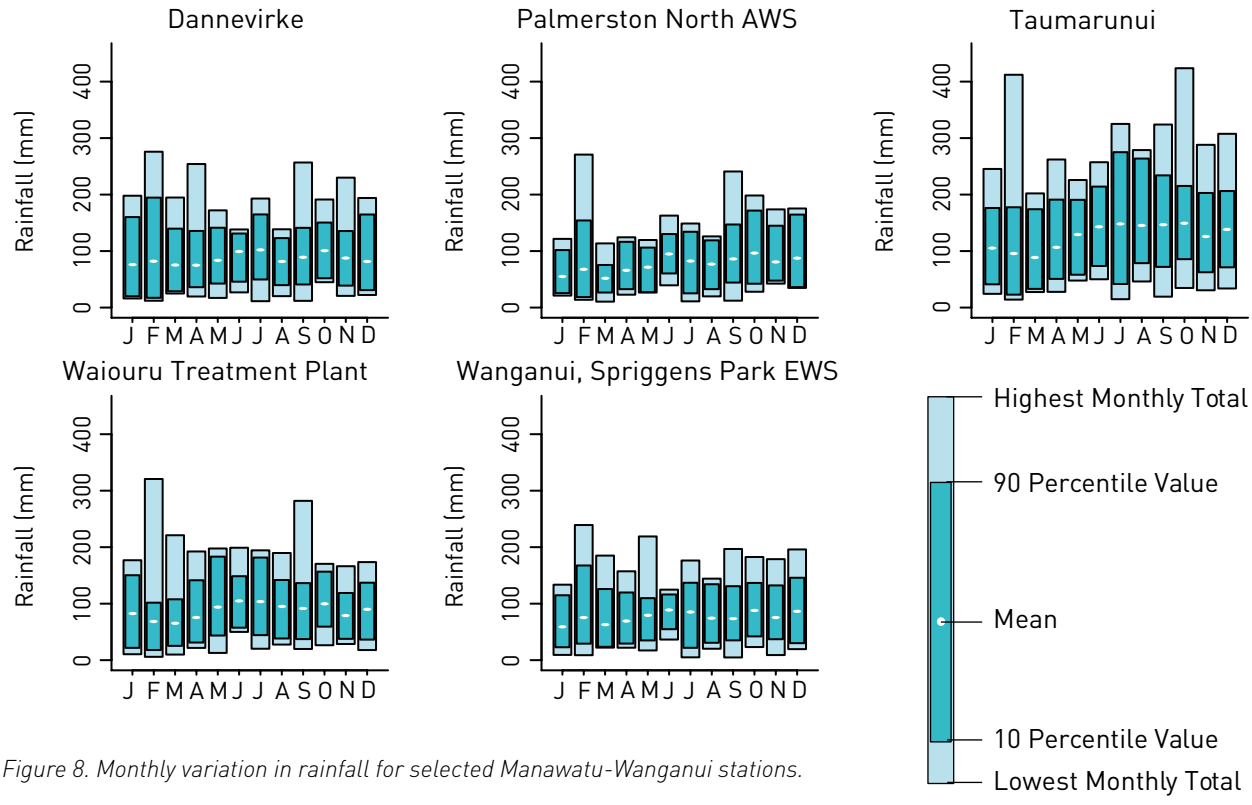


Figure 8. Monthly variation in rainfall for selected Manawatu-Wanganui stations.

Table 7. Rainfall deciles for consecutive months for selected Manawatu-Wanganui stations.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dannevirke												
1 month												
10th	20	17	29	36	43	46	50	40	41	52	39	31
90th	160	195	140	136	141	131	165	123	141	150	135	165
3 months												
10th	120	116	149	182	185	173	174	162	204	178	125	137
90th	358	391	322	344	355	353	387	359	374	379	412	378
6 months												
10th	346	391	401	363	344	401	409	468	366	338	317	340
90th	680	709	647	662	679	689	678	781	671	743	708	610
12 months												
10th	813	820	814	794	805	837	806	874	853	796	789	786
90th	1325	1316	1256	1281	1228	1225	1220	1273	1239	1320	1302	1284
Palmerston North												
1 month												
10th	20	18	29	33	28	61	33	36	27	42	34	45
90th	123	155	122	143	121	142	141	111	159	164	136	159
3 months												
10th	111	117	134	168	187	178	138	172	177	168	157	134
90th	303	322	338	317	369	362	359	336	360	376	317	342
6 months												
10th	338	350	373	370	378	367	384	425	352	367	323	310
90th	605	626	633	610	661	681	653	735	628	600	606	574
12 months												
10th	802	798	791	769	756	789	796	837	810	811	777	804
90th	1192	1197	1165	1191	1197	1180	1182	1229	1219	1219	1217	1144
Taumarunui												
1 month												
10th	41	23	33	51	58	74	42	79	72	86	63	71
90th	176	178	174	191	191	214	275	264	234	215	203	206
3 months												
10th	168	177	215	273	320	247	255	275	293	302	287	231
90th	419	478	482	470	539	609	630	581	619	562	493	510
6 months												
10th	502	542	584	603	634	628	666	717	590	560	491	509
90th	910	1009	968	1020	1095	1114	1057	1131	940	878	959	801
12 months												
10th	1249	1271	1245	1217	1253	1256	1282	1265	1220	1226	1216	1290
90th	1921	1880	1806	1897	1979	1926	1940	1996	2029	2001	1966	1877
Wanganui, Spriggens Park EWS												
1 month												
10th	23	29	24	29	35	55	22	31	35	42	37	30
90th	115	168	126	120	110	116	137	134	131	137	132	146
3 months												
10th	120	120	156	175	165	156	124	147	182	196	154	132
90th	299	298	312	288	342	355	341	308	312	327	306	367
6 months												
10th	318	321	334	345	344	366	333	416	359	331	328	332
90th	571	585	606	593	628	621	597	688	587	595	556	561
12 months												
10th	734	724	753	755	732	741	759	739	714	704	677	712
90th	1124	1077	1139	1113	1118	1110	1096	1102	1104	1139	1123	1085

Rainfall frequency and intensity

Rain day frequency (where at least 0.1 mm of rain falls) varies greatly over the Manawatu-Wanganui region. It is highest in the hill country around Taumarunui, and is assumed to be high in the Tararua and Ruahine Ranges (no data are available there). The least rain days occur over the Rangitikei Plains and north to Wanganui. The high frequency of rain days in the east of the region is because of the hilly terrain and the greater exposure to moist southerly and easterly airstreams. 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.

Most heavy rainfalls in Manawatu-Wanganui (west of the ranges) occur with the approach of an active frontal system and are preceded by a warm moist north to northwest flow. To the east of the ranges the heaviest rain is often accompanied by a strong south to easterly airflow. This is usually associated with a depression located just to the north-east of the region. Heavy rain and consequent flooding may occur when a warm moist northerly airstream, associated with a depression situated in mid-Tasman or just west of the North Island, affects the region. On other occasions, if an active cold front orientated in a northwest/southeast direction becomes slow moving over the southwest of the North Island, prolonged heavy rain may occur. High rainfall also occurs in eastern Manawatu when a moist south or southeast airstream is associated with a depression situated over, or just east of the region.

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 Manawatu-Wanganui 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 hirds.niwa.co.nz.

Table 8. Average monthly rain days and wet days for Manawatu-Wanganui 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
Dannevirke	a	12	11	13	13	16	18	19	18	17	17	15	14	182
	b	9	8	9	9	11	13	13	13	12	12	11	11	132
Levin AWS	a	11	10	11	12	14	18	18	18	17	16	15	16	176
	b	8	7	8	8	10	12	12	12	13	12	10	11	124
Lower Retaruke, Retaruke Station	a	12	11	11	13	16	18	16	19	17	18	15	16	181
	b	10	9	9	11	13	14	14	16	15	15	12	13	150
Palmerston North AWS	a	10	10	11	12	15	17	18	18	16	16	14	15	171
	b	7	7	8	8	10	12	12	13	12	12	10	11	122
Taihape Rec	a	13	11	13	14	19	20	20	18	19	18	15	16	195
	b	9	7	9	9	12	14	12	13	13	14	11	11	133
Taumarunui	a	14	13	14	15	19	21	19	21	20	20	17	18	209
	b	10	9	10	10	13	14	14	15	14	15	13	13	147
Waiouru Treatment Plant	a	12	11	12	13	17	19	19	19	18	17	15	14	187
	b	9	8	9	10	12	14	14	14	13	13	11	11	138
Wanganui, Spriggens Park EWS	a	10	9	11	11	14	16	15	16	14	15	12	13	155
	b	7	7	8	8	10	12	11	12	10	11	9	10	116

Table 9. Maximum recorded short period rainfalls and calculated return periods (or average recurrence intervals, ARI) from HIRDS (combined record 1981-2010 from Palmerston North and Palmerston North EWS (stations at same location)).*

Location		10min	20min	30min	1hr	2hrs	6hrs	12hrs	24hrs	48hrs	72hrs
Dannevirke	a	13	23	31	42	60	73	103	144	153	160
	b	11	26	37	39	58	26	38	57	36	31
	c	7	10	12	16	22	36	48	66	76	84
	d	10	14	17	22	30	47	63	84	98	107
	e	13	17	21	28	37	57	75	99	115	125
	f	16	21	26	34	45	68	88	115	134	146
	g	21	28	34	45	58	86	110	141	164	179
Palmerston North*	a	9	16	17	28	35	83	108	110	124	155
	b	5	13	7	12	11	100+	100+	45	32	69
	c	7	10	12	17	22	35	47	63	75	82
	d	9	13	16	22	29	44	58	76	90	99
	e	11	15	19	26	34	51	66	86	102	112
	f	13	18	22	32	40	59	76	97	115	127
	g	16	23	28	40	50	72	90	113	134	148
Taumarunui	a	15	24	32	39	43	70	92	111	152	168
	b	16	24	32	19	11	18	24	20	38	33
	c	8	12	15	21	28	43	56	73	90	102
	d	11	16	20	28	36	53	69	88	108	122
	e	13	19	24	34	43	62	78	99	122	138
	f	16	23	28	40	50	72	89	111	137	155
	g	20	29	36	51	63	86	106	130	160	180
Wanganui, Spriggens Park EWS	a	19	27	29	31	41	67	72	90	104	106
	b	69	75	49	18	21	39	20	19	11	7
	c	7	9	11	16	21	33	44	59	73	82
	d	9	13	15	21	28	42	55	72	88	100
	e	11	16	19	26	34	50	64	81	100	113
	f	14	19	23	32	40	58	73	92	114	128
	g	17	24	29	41	50	71	87	108	133	151

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 Manawatu-Wanganui

The Manawatu-Wanganui 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 2013.

23-27 July 1988: Flooding in the Manawatu-Wanganui region was caused by the passage of two low pressure systems. A number of state highways were flooded. Heavy rain caused streams to burst their banks and stormwater drains backed up, causing flooding in Palmerston North, inundating over 60 houses. A Civil Defence Emergency (CDE) was declared in Palmerston North on the 24th and lasted until the 27th, and about 1000 people were evacuated. Industry insurance payouts for the flood event totalled $4.25 million 2008 dollars for the region.

27-30 October 1998: An active trough and a small low moved across the Tasman Sea and caused flooding in Manawatu-Wanganui. A CDE was declared in Ohura in the Ruapehu District, from 30 October to 4 November. Silt-laden water flooded through the township, inundating properties to a height of up to 1.2m. 27 houses were deemed uninhabitable. The surrounding hill country was severely impacted by slips, loss of productive soil, damage to roads, bridges, tracks, culverts, and other infrastructure. Up to 60

rural families were isolated by damage to roads for up to three weeks. A CDE was declared in Wanganui for 36 hours as the Whanganui River flooded, and 150 people were evacuated from their homes alongside the river.

13-16 August 2001: A southerly storm brought snow and high winds to the Manawatu-Wanganui region. Every major travel route through the central North Island was closed due to snow, with the only open route through Taranaki. Central North Island train services were also cancelled, and there were extensive power cuts in the central North Island area (around 8000 homes between Taihape and Ohakune). It was said to be the heaviest snowfall in 30 years for the area. The Manawatu River burst its banks after heavy rain, causing widespread flooding.

14-19 February 2004: A deep low moved over the North Island, causing severe flooding, high winds, heavy rain, and slips in the Manawatu-Wanganui region. This storm was considered to be the largest widespread natural disaster to strike New Zealand in 20 years. A CDE was declared for the Manawatu-Wanganui region on the 17th and lasted until the 25th. 100-year floods were experienced in the region. Stock losses were estimated at 1300, and considerable areas of farmland were underwater. In the lower North Island, up to 40,000 homes, businesses, and schools were affected by power cuts. Over 1000 people were evacuated and 500 houses were damaged (160 deemed uninhabitable) throughout the Manawatu-Wanganui region. Roading was hit particularly hard, with state highways closed and 60-70% of backcountry roads blocked by slips. SH 3 through Manawatu Gorge was closed for two months. Moderate to severe slipping occurred across 120,000 ha of hill country. Feilding was isolated by flooding, with many bridges washed out. The short-term impact (cost of damage and economic impact) from the floods and wind damage in the lower North Island was estimated at $350 million 2008 dollars, the fourth most expensive disaster since 1968.

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 two such periods each year in Palmerston North and Wanganui, and one dry spell per year in Taumarunui and Dannevirke. The average duration of a dry spell in the region is about 19 days. The longest recent dry spell between these key Manawatu-Wanganui sites (Palmerston North and Palmerston North EWS, Wanganui Spriggens Park EWS, Taumarunui, and Dannevirke) was 40 days recorded in both Palmerston North (19 consecutive days with no rain) and Taumarunui (16 consecutive days with no rain) between 6 February and 17 March 2013. The longest recent dry spell at Wanganui was 39 days between 7 February and 17 March 2013 (38 consecutive days without any rain), and at Dannevirke the longest recent dry spell was 26 days between 7 February and 4 March 2013 (19 consecutive days with no rain).

Dry spells may only be separated by a few days with more than 1 mm of rainfall. The dry spells during early 2013 are a good example of this: Palmerston North experienced a 17-day dry spell between 19 January and 4 February, followed by one day with 34 mm of rain, which was then followed by 40 days with 0.6 mm total rainfall (6 February – 17 March), then two days with 36 mm total rainfall, followed by 15 days (20 March – 3 April) where only 1 mm of rain fell.

Temperature

Sea surface temperature (SST)

Monthly mean sea surface temperature off the coast of Manawatu-Wanganui is compared with mean air temperature for Wanganui in Figure 9. The minimum land temperature occurs about six weeks earlier than the sea surface temperature minimum. Throughout most of the year, mean air temperature is cooler than mean sea surface temperature. Figure 10 shows the mean sea surface temperature for the New Zealand region for February and August, which are the warmest and coolest months with respect to sea surface temperature.

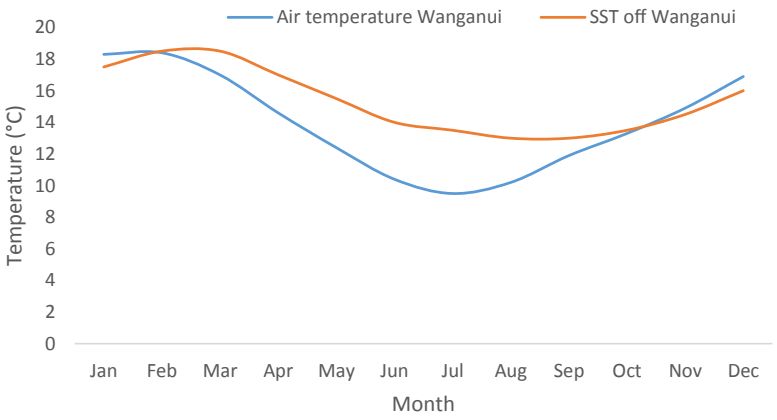


Figure 9. Mean monthly land (Wanganui Spriggens Park EWS) and sea surface temperatures (off the coast of Wanganui).

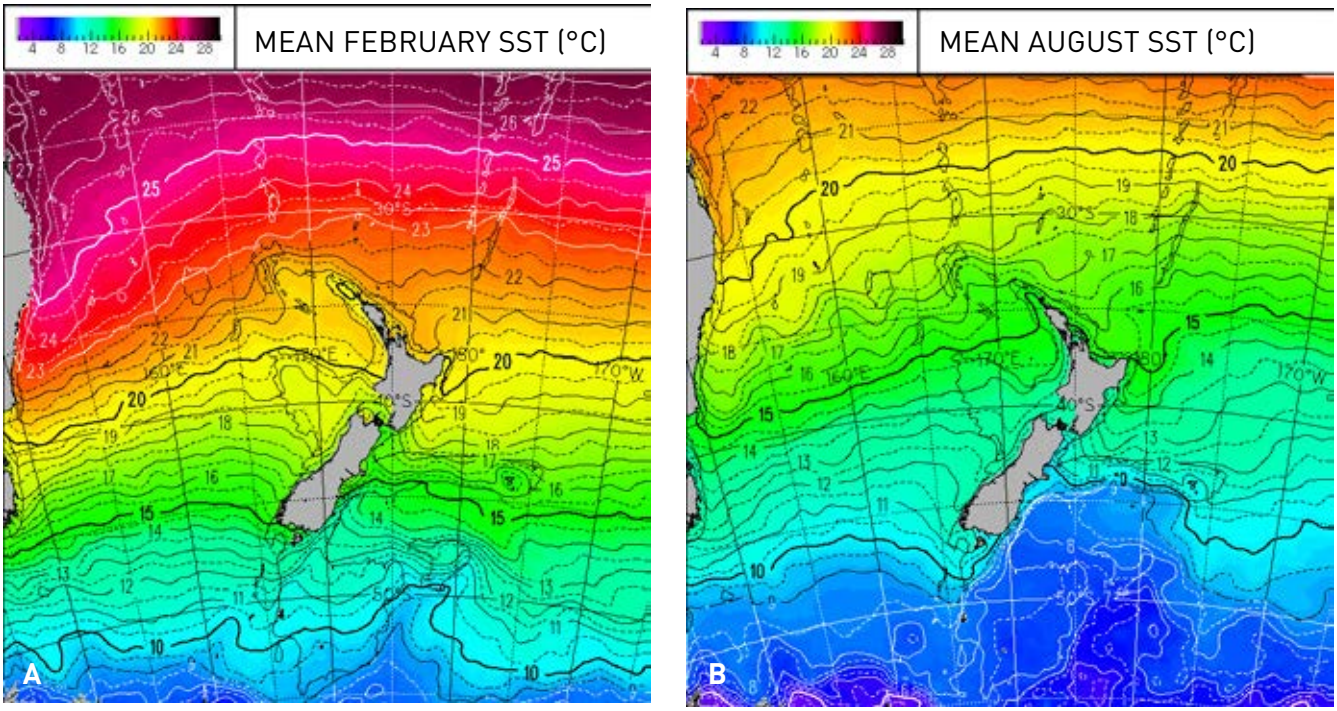
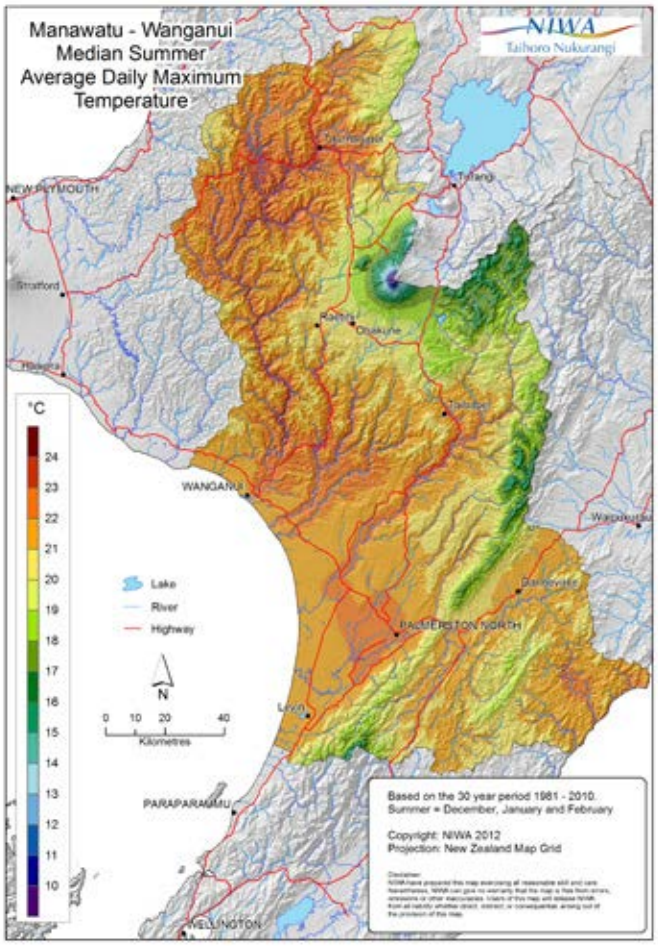


Figure 10. Monthly mean sea surface temperatures (°C) for: a) February; b) August. Source: NIWA SST Archive, Uddstrom and Oien (1999).

Air temperature

In general, air temperatures in much of the Manawatu-Wanganui region (excluding mountainous areas) are quite moderate with few extremes. Most of the Manawatu-Wanganui region experiences warm summer afternoon temperatures of 20-22°C, with temperatures appreciably cooler towards high elevation areas of the Central Plateau and the Ruahine and Tararua Ranges (Figure 11a). Areas along the coast may experience slightly lower afternoon temperatures than locations further inland at similar elevations due to the cooling effect of sea breezes. During winter nights, the 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 (6-7°C minimum winter temperature at the coast, 2-4°C further inland, and less than 2°C throughout the Central Plateau, Figure 11b).



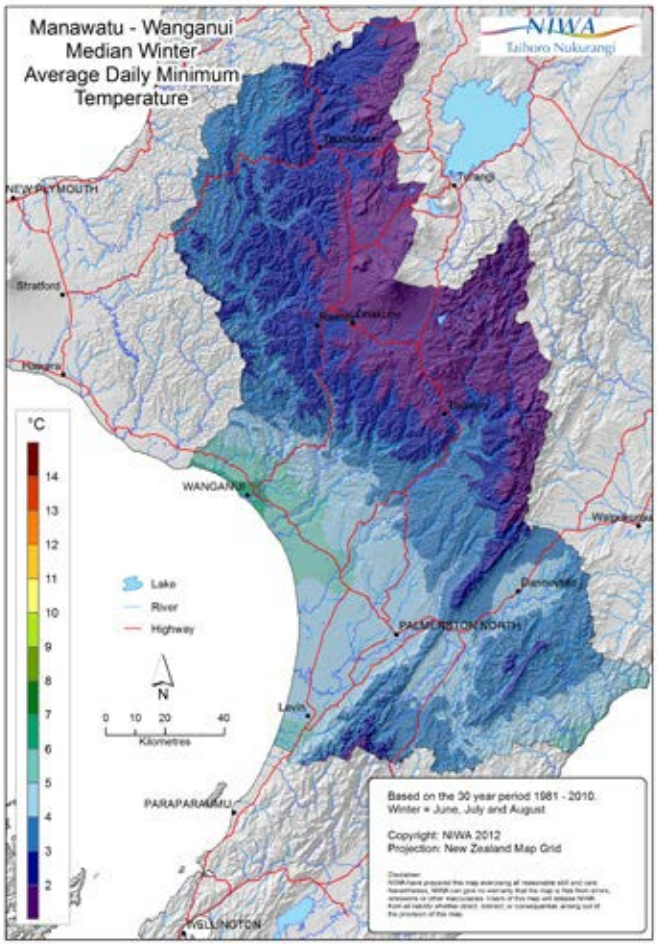


Figure 11. a) Left: Manawatu-Wanganui median summer average daily maximum temperature; b) Right: Manawatu-Wanganui median winter average daily minimum temperature, 1981–2010.

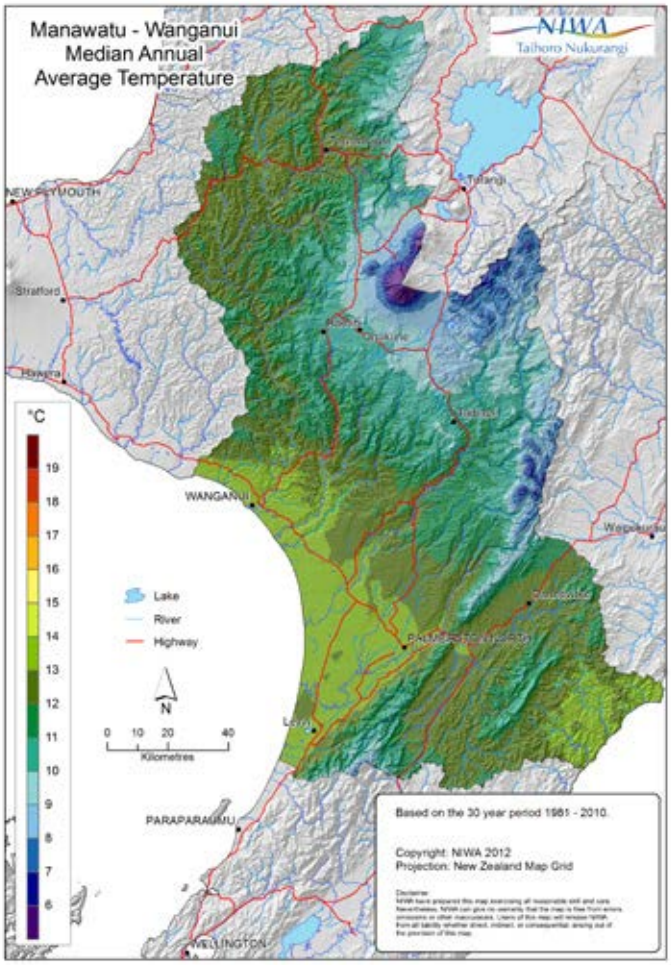


Figure 12. Manawatu-Wanganui median annual average temperature, 1981-2010.

Figure 12 shows that median annual average temperature in the Manawatu-Wanganui region varies markedly with elevation. Low-lying areas around the coast have a median annual temperature of around 13.5°C, whereas the inland hill country experiences median annual temperatures of about 11-13°C. Median annual air temperatures are significantly cooler on the Central Plateau and the mountain ranges in the region (less than 9°C). In elevated areas, the cooler conditions mean that temperatures will often fall below freezing, especially during the winter. Further, the daily variation in temperature decreases as the altitude increases. Figure 13 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 Manawatu-Wanganui.

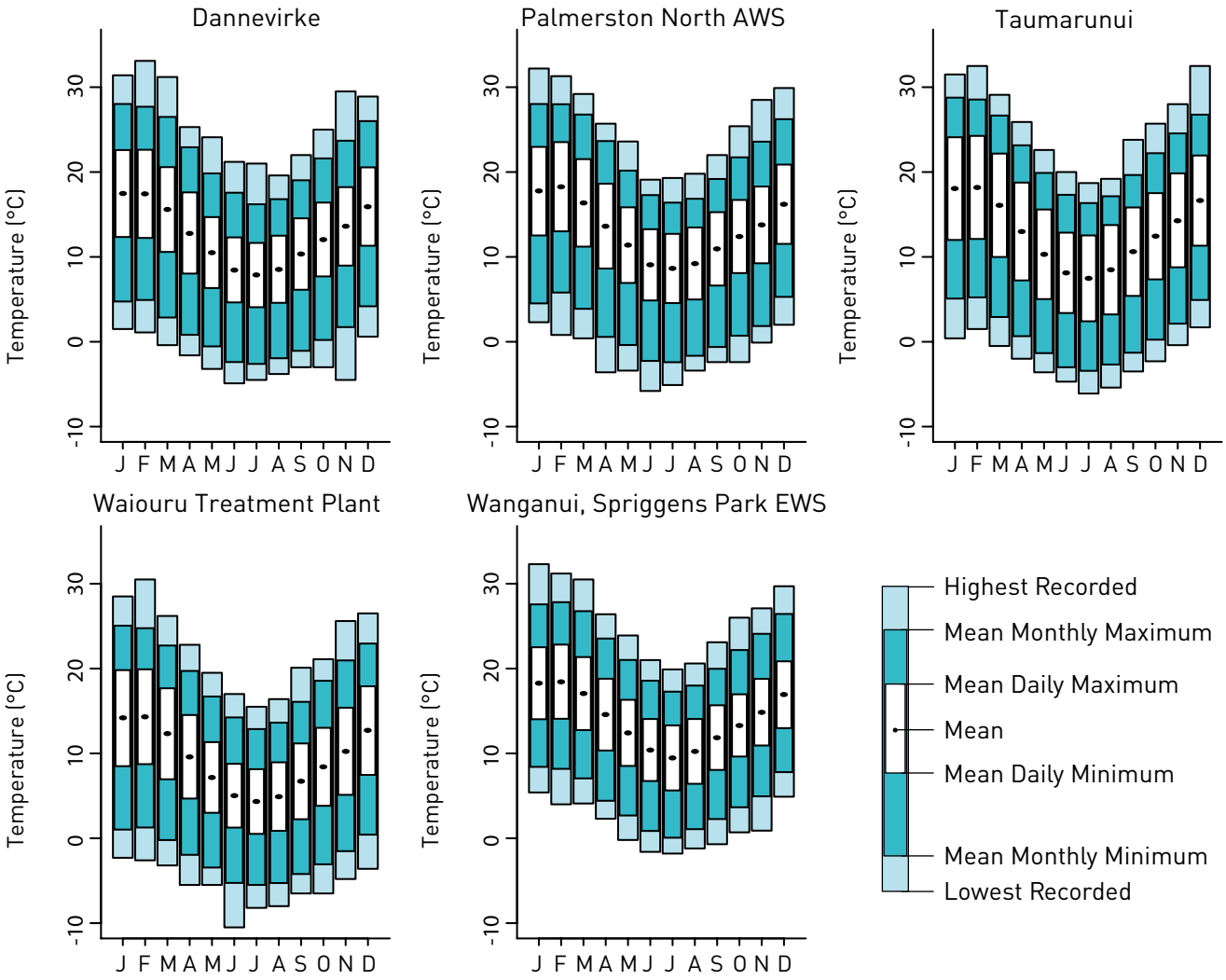


Figure 13. Monthly variation in air temperatures for selected Manawatu-Wanganui stations.

Daily temperature ranges in Manawatu-Wanganui 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. Wanganui) than inland areas (e.g. Taumarunui). However, in the ranges the daily variation is also influenced by cloudiness and elevation; the higher the elevation and cloudier the conditions, the smaller the temperature range (e.g. Waiouru).

The diurnal temperature range for Wanganui is moderate, and less than that of locations further inland (e.g. Palmerston North) due to the modifying effect of the sea. Table 11 and Figure 14 show mean hourly temperatures for Wanganui and Palmerston North for January and July.

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

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Dannevirke	10.3	10.4	10.0	9.6	8.3	7.7	7.6	7.9	8.4	8.7	9.2	9.2	8.9
Palmerston North AWS	10.3	10.3	10.2	9.9	8.9	8.2	8.3	8.5	8.5	8.6	9.1	9.4	9.1
Taumarunui	12.1	12.2	12.3	11.6	10.6	9.4	10.1	10.6	10.4	10.2	10.9	10.7	11.0
Waiouru AWS	11.0	10.7	10.2	9.5	8.2	7.2	7.2	7.9	8.5	9.0	10.1	10.1	9.1
Wanganui, Spriggens Park EWS	8.5	8.7	8.6	8.5	7.8	7.3	7.7	7.6	7.6	7.4	7.8	7.9	8.0

Table 11. Mean hourly temperatures at Wanganui Spriggens Park and Palmerston North AWS for January and July.

hrs	00	01	02	03	04	05	06	07	08	09	10	11
Wanganui, Jan	15.8	15.4	15.1	14.9	14.7	14.5	14.7	15.8	17.5	18.9	19.9	20.4
Wanganui, Jul	8.0	7.9	7.7	7.5	7.4	7.3	7.3	7.2	7.3	8.2	9.6	11.1
Palmerston N, Jan	14.6	14.3	14.0	13.9	13.7	13.5	14.1	15.6	17.2	18.5	19.5	20.4
Palmerston N, Jul	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.6	6.7	7.8	9.4	10.6
hrs	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Wanganui, Jan	20.8	21.0	20.9	20.7	20.4	19.8	19.3	18.5	17.5	17.0	16.6	16.2
Wanganui, Jul	12.1	12.6	12.7	12.5	12.1	11.2	10.1	9.6	9.1	8.8	8.5	8.2
Palmerston N, Jan	21.1	21.5	21.6	21.6	21.2	20.5	19.5	18.3	16.8	15.9	15.4	15.0
Palmerston N, Jul	11.3	11.7	11.9	11.7	11.3	10.3	9.1	8.5	8.0	7.7	7.5	7.3

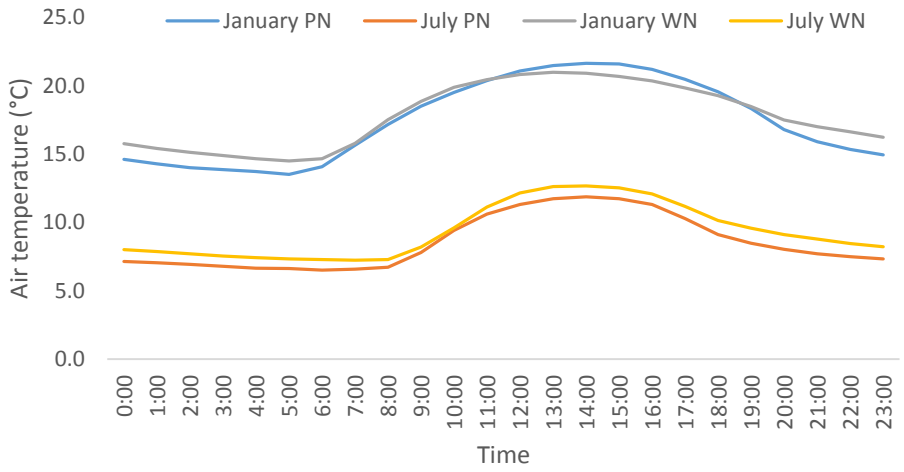


Figure 14. Mean hourly temperatures at Palmerston North AWS (PN) and Wanganui Spriggens Park EWS (WN) for January and July.

Wanganui has the least extreme temperatures out of the sites in Table 12, with 17 days per year where the maximum air temperature exceeds 25°C and only 2 days per year when temperatures fall below 0°C. In contrast, Taumarunui records 34 days where temperatures rise above 25°C, and 30 days when temperatures fall below freezing. Waiouru is significantly cooler, with only 2 days per year when the maximum temperature is above 25°C, and 62 days when minimum temperatures fall below 0°C.

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

Location	Days >25°C	Days <0°C
Dannevirke	16	17
Palmerston North AWS	25	16
Taumarunui	34	30
Waiouru Treatment Plant	2	62
Wanganui, Spriggens Park EWS	17	2

Extreme maximum temperatures in Manawatu-Wanganui are not as high as those recorded under foehn conditions in east coast districts. The highest maximum temperature measured in the region to date is 33.9°C, recorded at Taumarumui on 29 December 1948. The extreme minimum temperature of -11.1°C was recorded at Waiouru Airstrip AWS on 16 August 2011. These extreme temperatures compare to national extremes of 42.4°C and -25.6°C.

Earth temperatures

Earth (soil) temperatures are measured once daily at 9 am at several Manawatu-Wanganui locations. 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 Manawatu-Wanganui region, earth temperatures, like air temperatures, vary spatially. The sites at higher elevations, such as Ohakune, exhibit cooler 9 am earth temperatures than sites at lower elevations, such as Wanganui. Figure 15 shows how earth temperatures change throughout the year at Wanganui, compared with air temperature. The temperature cycle for 100 cm depth is more dampened and lagged than at shallower depths.

Table 13. Mean 9 am earth temperatures at different Manawatu-Wanganui locations, with station elevations.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Dannevirke (207m)	10cm	17.0	17.0	14.9	11.9	9.2	7.0	6.2	6.8	8.9	11.0	13.3	15.7	11.6
	20cm	18.4	18.5	16.3	13.3	10.4	7.9	7.0	7.6	9.6	11.9	14.5	16.9	12.7
Ohakune, Ruapehu College (610m)	10cm	16.7	16.8	14.4	11.2	8.7	6.2	5.1	5.6	7.8	10.3	12.2	14.9	10.8
	20cm	18.3	18.6	16.3	13.2	10.4	7.8	6.5	6.9	9.0	11.6	13.7	16.4	12.4
	30cm	18.0	18.5	16.5	13.6	10.9	8.2	6.8	7.2	9.3	11.7	13.7	16.1	12.5
	100cm	14.9	15.8	15.8	14.8	13.4	11.6	10.1	9.4	9.6	10.7	12.0	13.4	12.6
Palmerston N (34m)	10cm	18.2	18.1	16.1	13.2	10.6	8.4	7.1	7.8	10.0	12.5	14.7	16.9	12.8
	20cm	19.4	19.5	17.4	14.4	11.8	9.4	8.2	8.8	10.7	13.2	15.6	17.7	13.8
	30cm	20.0	20.2	18.3	15.4	12.7	10.3	9.0	9.5	11.3	13.7	16.2	18.3	14.6
	100cm	18.6	19.3	18.8	16.9	14.8	12.6	11.1	10.8	11.6	13.3	15.2	17.0	15.0
Taumarunui (171m)	10cm	19.1	19.5	17.0	14.0	11.2	8.5	7.3	8.3	10.7	13.2	15.4	17.6	13.5
	30cm	20.7	20.9	18.9	15.8	12.8	10.3	9.0	9.9	12.1	14.5	17.0	19.2	15.1
Wanganui, Spriggens Park EWS (15m)	10cm	19.5	19.2	16.9	13.4	10.8	8.6	7.4	8.3	10.6	12.9	15.6	17.9	13.4
	20cm	20.7	20.4	18.0	14.6	11.6	9.5	8.2	9.0	11.0	13.4	16.6	19.0	14.3
	30cm	21.1	21.0	18.6	15.5	12.5	10.3	8.9	9.6	11.4	13.9	16.9	19.3	14.9
	100cm	19.8	20.4	19.6	17.6	15.1	12.8	11.3	11.0	11.9	13.6	16.0	17.9	15.6

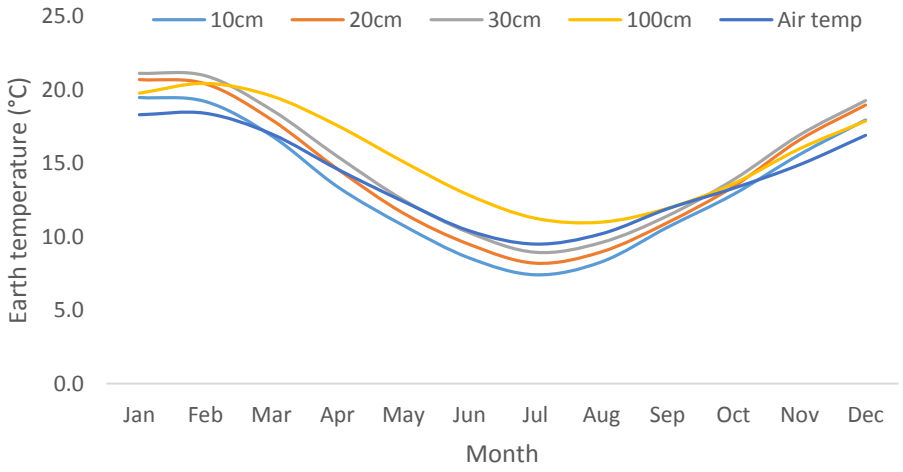


Figure 15. Average monthly 9 am earth temperatures for different depths and mean 9 am air temperature at Wanganui, Spriggens Park EWS.

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 Manawatu-Wanganui region in the cooler months, especially at inland, higher elevation sites. 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 13.

Table 14. Occurrences of frosts and grass minimum temperatures in Manawatu-Wanganui.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Dannevirke	a	9.9	9.9	8.1	5.2	3.4	1.6	1.0	1.4	3.2	5.2	6.4	9.2	5.4
	b	-3.6	-1.7	-4.5	-6.8	-8.4	-9.2	-9.6	-10.2	-8.9	-9.3	-7.0	-4.1	
	c	0.1	0.1	1.0	3.5	6.6	10.4	11.3	10.0	6.1	3.2	2.0	0.5	54.9
	d	0.0	0.0	0.0	0.4	1.4	4.3	4.9	3.6	1.4	0.7	0.1	0.0	16.9
Palmerston N	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	6.4
	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	41.4
	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	10.1
Taumarunui	a	10.6	10.7	8.4	5.8	3.4	1.5	0.5	1.2	3.3	5.5	7.3	9.8	5.7
	b	0.0	-1.5	-2.2	-3.8	-9.0	-9.5	-9.5	-9.5	-7.3	-7.1	-2.1	-1.5	
	c	0.0	0.0	0.2	1.8	4.9	9.0	12.3	9.2	5.0	2.4	0.4	0.1	45.4
	d	0.0	0.0	0.1	0.5	2.9	7.5	9.6	6.3	2.3	0.8	0.0	0.0	30.1
Wanganui, Spriggens Park EWS	a	12.4	12.5	11.0	8.6	6.6	4.9	3.8	4.5	6.0	7.6	9.1	11.4	8.2
	b	3.0	3.0	1.7	-0.2	-3.1	-4.8	-5.9	-4.8	-3.8	-2.8	-0.9	1.4	
	c	0.0	0.0	0.0	0.0	0.4	1.3	3.1	1.6	0.4	0.2	0.0	0.0	7.0
	d	0.0	0.0	0.0	0.0	0.0	0.4	1.0	0.2	0.0	0.0	0.0	0.0	1.6

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

The west coast is the sunniest area in the Manawatu-Wanganui region, with more than 2025 bright sunshine hours per year recorded there on average (Figure 16). Cloudiness increases towards the hill country in the northern part of the region to the north of Ohakune, as well as in the Ruahine and Tararua Ranges, so that bright sunshine hours typically total less than 1750 hours per annum. Figure 17 shows the monthly mean, maximum, and minimum recorded bright sunshine hours for selected sites in Manawatu-Wanganui.

Solar radiation

Solar radiation records are available for a number of sites in Manawatu-Wanganui, but only a small number of sites have a long record (>10 years). Hence, solar radiation data are only presented for Palmerston North and Wanganui. Insolation is at a maximum in December and January and a minimum in June. Table 15 shows mean daily solar radiation (global) for each month for these two sites.

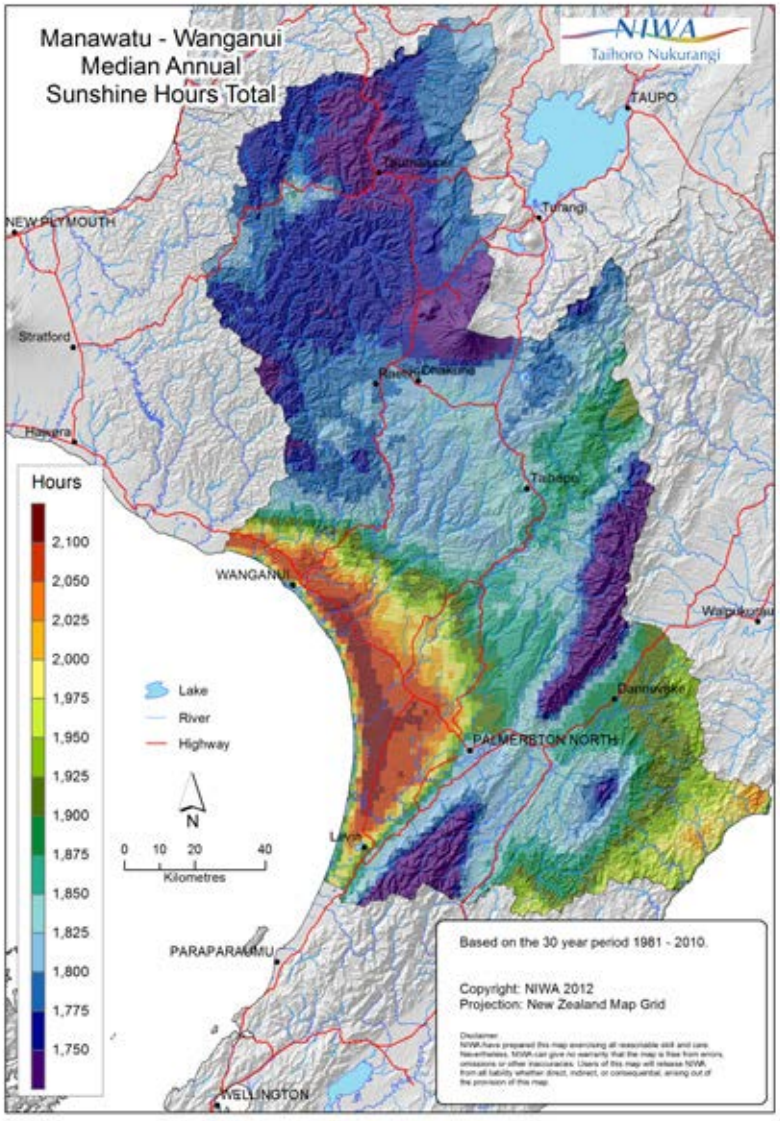


Figure 16. Median annual sunshine hours for Manawatu-Wanganui, 1981-2010.

Photo: ©mychillybin.co.nz/Brian Livingstone

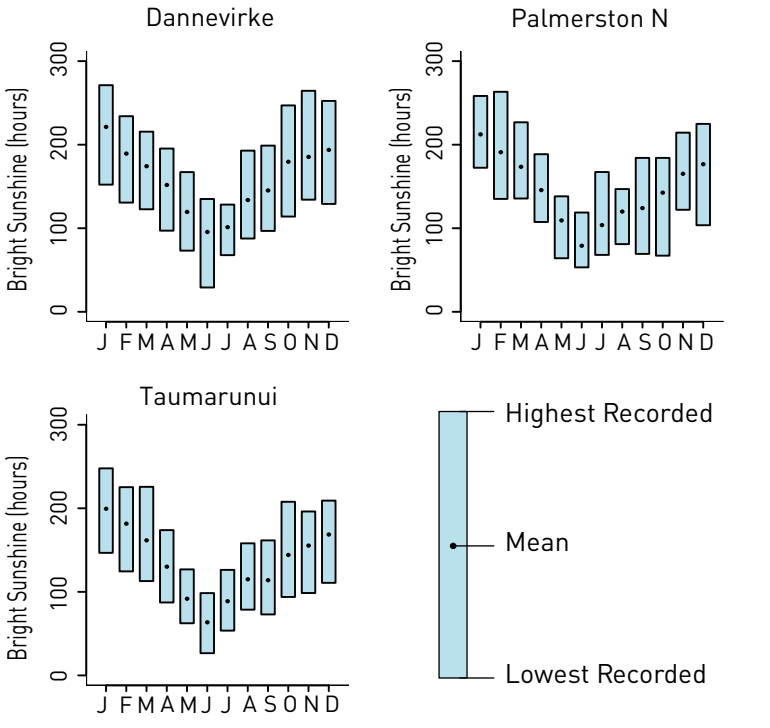


Figure 17. Mean, highest, and lowest recorded monthly bright sunshine hours for selected sites in Manawatu-Wanganui.

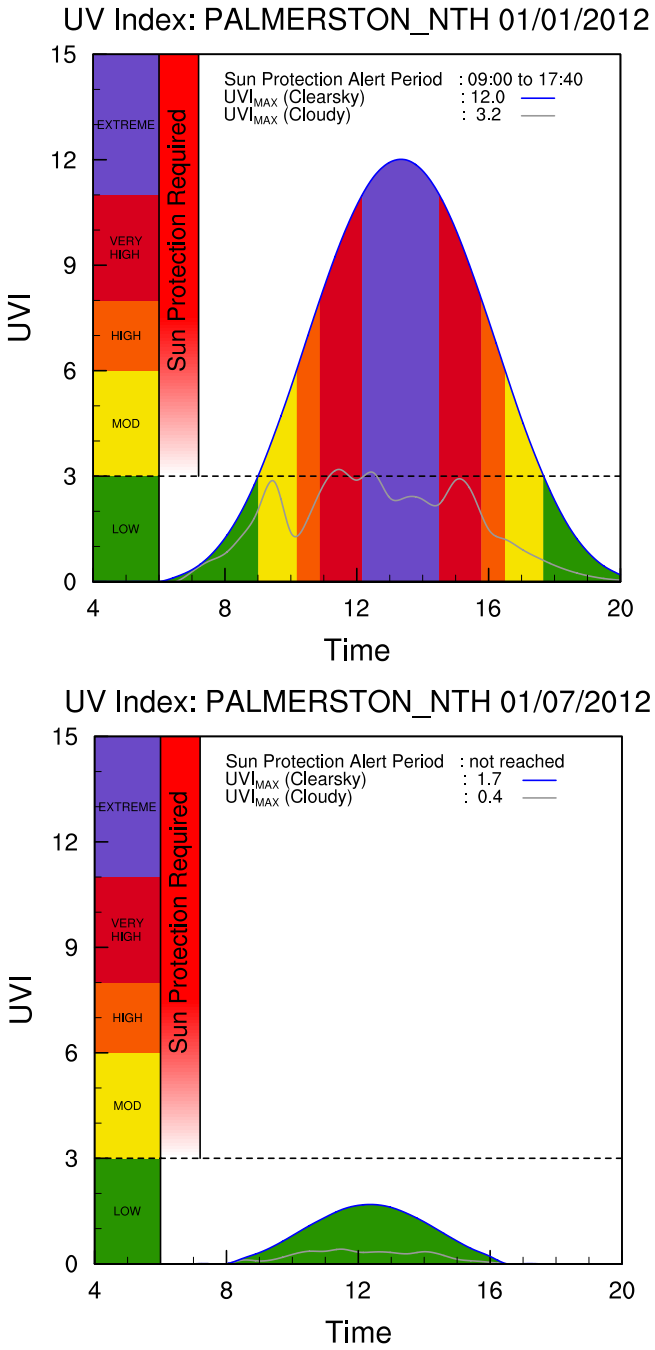
Table 15. Mean daily global solar radiation (MJ/m2/day) for Manawatu-Wanganui sites, from all available data

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Palmerston North AWS	22.4	19.9	15.4	10.6	7.0	5.3	6.1	8.7	12.3	15.7	19.8	21.1	13.7
Wanganui, Spriggens Park EWS	23.9	20.6	16.2	11.0	7.3	5.7	6.6	9.1	13.1	17.1	21.5	22.7	14.6

UV (Ultra-violet) radiation

Ultra-violet radiation (UV) measurements are not available for any stations in the Manawatu-Wanganui region. However, Figure 18 shows an example of a modelled UV forecast for Palmerston North, and indicates the levels of UV and times of the day where sun protection is required. In the summer (Figure 18a) UV radiation is high, prompting warnings for sun protection between 9 am and 5.30 pm. In the winter (Figure 18b), the amount of UV radiation does not reach the level at which sun protection is advised.

Figure 18. UV Index forecast for Palmerston North, January and July. Source: https://www.niwa.co.nz/our-services/online-services/uv-and-ozone.



Fog

Most fogs reported in Manawatu-Wanganui 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.

The frequency of fog varies widely over the Manawatu-Wanganui region, ranging from an average of 133 and 124 days with fog per year at Lower Retaruke and Taumarunui, respectively, to an average of only once per year at Palmerston North. Although fog can occur at any time of the year it is recorded most frequently between March and August. The average number of days per year with fog for selected stations in the Manawatu-Wanganui region is listed in Table 16.

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

Location	Thunder	Fog	Hail
Dannevirke	4	9	3
Lower Retaruke	15	133	3
Ohakea Aero	9	10	6
Ohakune	2	4	1
Palmerston N	5	1	3
Taumarunui	6	124	1
Wanganui, Spriggens Park EWS	3	9	3

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 winter when cold and unstable air masses cross the region. Thunderstorms are usually associated with cold south or southwest airstreams.

Average annual frequencies for selected stations are given in Table 16, and range from 15 per year at Lower Retaruke to two per year at Ohakune. 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. These range from one day per year at Ohakune and Taumarunui to six days per year at Ohakea. As with thunderstorms, an unknown number of hail falls will escape detection at some of the stations. Hail is most likely over the winter and spring months, and like thunderstorms (with which hail is normally associated), hail is more frequent when cold and unstable air masses cross the region.

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 infrequent in the Manawatu-Wanganui region, with only five being reported in the region between 1981 and 2013.

One tornado that caused damage in the region occurred on 4 August 2008 in Weraroa, an area of Levin. A garage and about 20 trees were totally destroyed, and a house suffered extensive structural damage and was left with warped floors. The water tank was ripped from the roof of the house. Nearby, a woolshed was destroyed and sections of corrugated roofing iron were scattered up to 1.5 km away.

Snow

Snowfall is relatively frequent during winter in the Ruahine and Tararua Ranges, as well as around the Central Plateau. At Waiouru Military Camp (823 m elevation), snow falls on average 18 days per year. At Wharite Peak (914 m) at the southern extent of the Ruahine Range, 11 days per year record snowfall, on average. Areas at lower elevations rarely observe snowfall – Palmerston North and Wanganui experience snow falls about once every seven years, and Taumarunui observes snow approximately once every three years. When a snowfall does occur in the lowland areas, it is usually associated with a deep depression just to the east of the region together with a very cold south to southwest airstream over much of New Zealand. Days with snow are averaged from all available data.

Sea swell and waves

The ocean off the west coast of Manawatu-Wanganui is exposed to the prevailing west to southwest swells of its latitude zone. Consequently, swells off the west coast of New Zealand are much higher than those off the east coast. At Maui A Platform (offshore from the Taranaki region, to the northwest of Manawatu-Wanganui), prevailing swells come from the southwest quarter (75% of the time). Of all swells observed, the frequency of those from one to two metres is 35%, while for those greater than two metres is 30% (Gorman et al., 2003). Swells greater than four metres account for about 2% of waves.

Offshore from the east coast of the region, waves from the southerly quarter are the most frequent (due to the coast's exposure to the south). The prevailing easterly flow over the Pacific Ocean to the north of New Zealand produces a persistent easterly swell in the latitude of northern New Zealand, especially during the summer and autumn when the belt of southeasterly trade winds tends to lie further south than in other seasons. The frequency of swells from one to two metres is 65%, while for swells greater than two metres is 20% (Gorman et al., 2003).

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+

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.

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 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. The sites inland (e.g. Taumarunui) tend to have higher relative humidity than coastal sites (e.g. Wanganui).

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

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Dannevirke	14.3	14.5	13.4	11.7	10.2	8.9	8.5	8.7	9.6	10.5	11.5	13.2	11.3
Palmerston North AWS	14.9	15.3	14.0	12.7	11.4	9.7	9.3	9.7	10.7	11.6	12.2	14.0	12.1
Taumarunui	15.7	15.6	14.0	12.0	10.3	9.1	8.4	9.0	10.3	11.5	12.6	14.7	11.9
Waiouru AWS	12.2	12.5	11.4	10.2	8.7	7.4	6.9	7.2	8.0	8.6	9.5	11.2	9.5
Wanganui, Spriggens Park EWS	15.1	15.4	14.3	12.6	11.3	10.0	9.3	9.6	10.6	11.4	12.3	14.3	12.2

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

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Dannevirke	79.1	82.2	83.8	83.9	84.5	85.1	85.4	82.9	78.1	78.2	77.7	76.5	81.5
Palmerston North AWS	75.3	77.7	79.4	81.2	85.8	86.8	86.8	84.6	79.7	80.5	76.7	76.0	80.9
Taumarunui	87.2	90.9	91.4	92.9	94.5	94.6	94.2	92.8	88.1	86.3	84.6	85.6	90.3
Waiouru AWS	77.8	82.3	83.0	84.9	87.6	88.3	86.7	85.6	81.4	80.2	77.4	77.5	82.7
Wanganui, Spriggens Park EWS	74.4	78.9	78.1	80.3	83.5	84.2	85.0	82.2	76.8	75.6	73.3	74.4	78.9

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 water balance values are given in Table 20, for a number of sites in Manawatu-Wanganui. It can be seen from this table that sites at lower elevations in the west, as well as Dannevirke, have more days of soil moisture deficit, e.g. Wanganui (73 days of soil moisture deficit between November and April) compared with Taumarunui (18 days of soil moisture deficit during the same period). There is usually adequate moisture available to maintain plant growth between June and October. Higher elevation sites exhibit more runoff than lower elevation sites. Figure 19 shows region-wide variability in days of soil moisture deficit per year.

Potential evapotranspiration (PET) has been calculated for Palmerston North, Taumarunui, and Wanganui using the Penman method (Penman, 1948). The monthly mean, minimum, and maximum PET values are listed in Table 21.

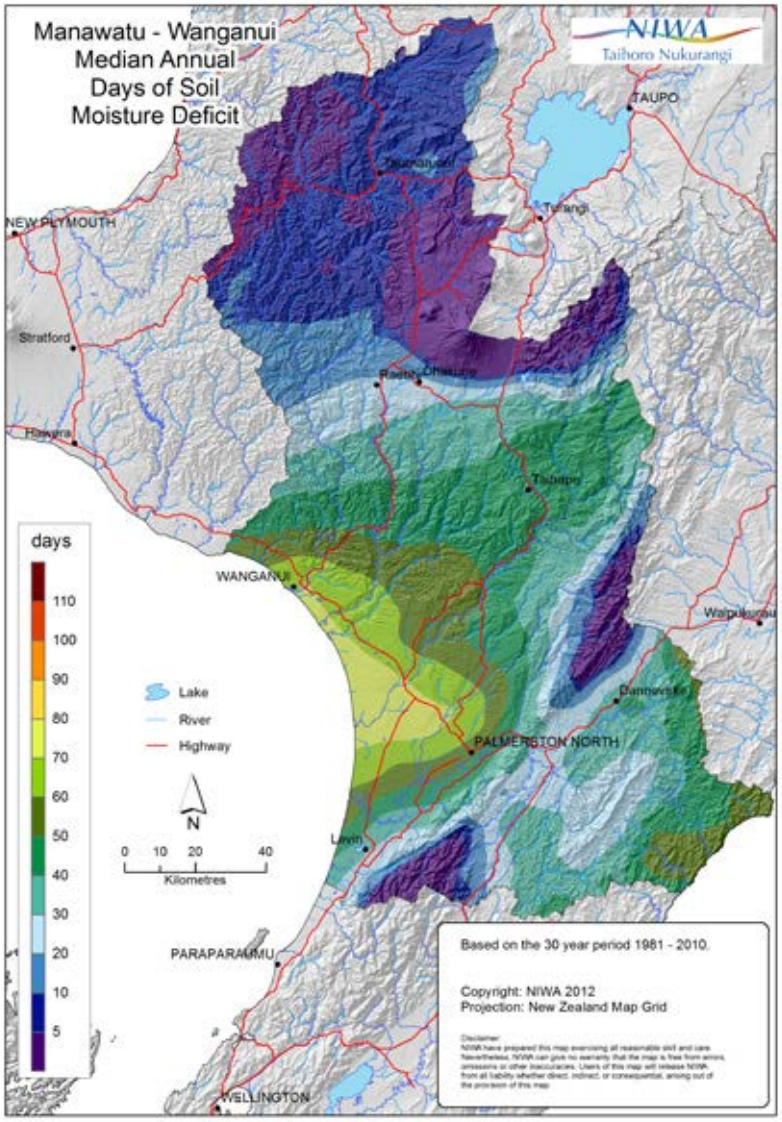


Figure 19. Manawatu-Wanganui median annual days of soil moisture deficit, 1981-2010.

Drought in Manawatu-Wanganui

The Manawatu-Wanganui region is generally not prone to drought, due to exposure to moisture-laden westerly winds. However, a significant drought occurred throughout the entire North Island during summer and early autumn of 2012-2013. The hardest hit areas within the region were eastern areas of Manawatu-Wanganui (south of the Hawke's Bay region), around Taumarunui, and the Rangitikei District (approximately between Taihape and Wanganui). Severe soil moisture deficits (more than 130 mm of deficit) were present in much of the Manawatu-Wanganui region (Figure 20). The dry conditions meant that farmers had to dry off cattle early and sell off stock. The stock feed situation remained low in drought-stricken areas, and the price of feed significantly increased. Numerous locations in the region experienced low rainfall during the drought, with Taihape recording only 12 mm of

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
Dannevirke (207m)	NR	0	0	0	1	3	10	12	8	5	4	1	0	43
	RO	2	9	1	9	17	66	81	48	38	31	8	4	313
	ND	15	13	9	5	1	0	0	0	0	0	3	10	55
	DE	68	54	27	9	1	0	0	0	0	0	12	45	216
Palmerston N (34m)	NR	0	0	0	1	3	11	12	9	5	3	1	0	43
	RO	0	0	1	8	20	68	70	46	31	25	6	2	279
	ND	14	13	10	5	0	0	0	0	0	0	3	10	55
	DE	63	50	27	8	0	0	0	0	0	1	11	42	202
Taumarunui (171m)	NR	1	1	1	3	10	15	13	13	9	7	4	3	81
	RO	17	16	10	37	90	130	133	118	101	85	41	36	814
	ND	4	6	4	2	0	0	0	0	0	0	1	1	18
	DE	17	23	10	2	0	0	0	0	0	0	2	5	59
Wanganui, Spriggens Park EWS (15m)	NR	0	0	0	0	1	6	8	7	3	2	0	0	27
	RO	0	1	1	0	8	37	57	37	18	14	2	1	177
	ND	18	14	13	6	1	0	0	0	0	1	8	13	75
	DE	93	62	43	12	1	0	0	0	0	3	36	59	308

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
Palmerston North AWS	Max	178.0	141.3	119.1	64.9	41.1	25.9	34.0	45.0	66.6	98.0	138.7	174.2	
	Mean	148.1	122.6	97.6	52.2	29.7	19.2	22.8	36.4	58.3	87.4	113.5	135.4	76.9
	Min	120.7	103.1	74.3	38.7	22.8	13.6	17.8	30.3	46.2	77.4	95.2	98.3	
Taumarunui	Max	136.8	110.4	83.9	45.9	26.2	14.1	21.6	31.3	52.6	81.5	101.0	125.4	
	Mean	119.3	97.8	73.1	39.8	20.6	11.0	14.7	27.4	45.4	71.9	92.2	110.2	60.3
	Min	104.5	88.4	61.7	33.5	16.4	8.1	10.7	22.3	39.4	64.2	75.0	91.1	
Wanganui, Spriggens Park EWS	Max	179.5	143.5	113.2	70.2	45.9	32.5	36.0	51.6	73.4	112.0	145.2	163.3	
	Mean	153.7	120.7	98.1	57.5	35.2	24.2	26.8	41.7	64.7	97.1	124.0	142.2	82.2
	Min	135.3	102.6	83.5	44.1	28.4	17.4	21.2	33.3	54.1	75.0	98.8	107.3	

rain in February 2013, 19% of normal February rainfall. During November 2012 to March 2013, Taumarunui recorded 56% of normal rainfall for the same period (374 mm). At the time of writing (September 2013), economic costs due to the 2012-13 drought across the North Island and Westland were estimated at a minimum of $2 billion. Figure 21 shows the soil moisture deficits reached at Taumarunui over the drought period, compared to normal soil moisture deficit conditions for the same time of year (soil moisture deficit from September to May averaged from 1981-2010).

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 Manawatu-Wanganui region.

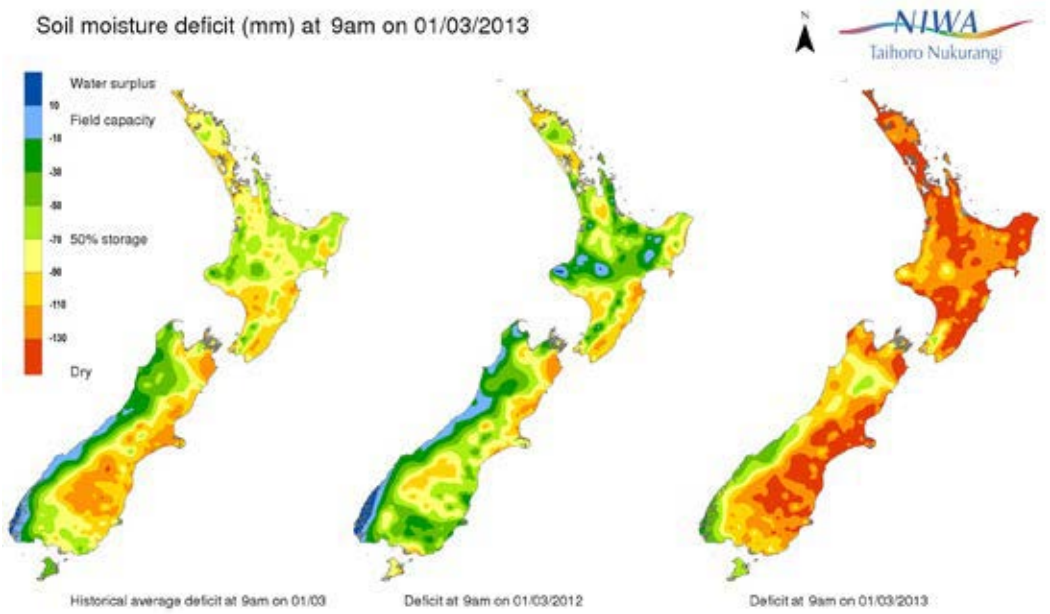


Figure 20. Soil moisture deficit as at 1 March 2013 (right hand map). Areas of extreme soil moisture deficit (more than 130 mm of soil moisture deficit) are shown in red, and areas of significant soil moisture deficit (more than 110 mm of soil moisture deficit) are shown in dark orange. Normal soil moisture deficit conditions for the time of year are given in the left hand figure, and the middle figure shows soil moisture deficit conditions as at 1 March 2012.

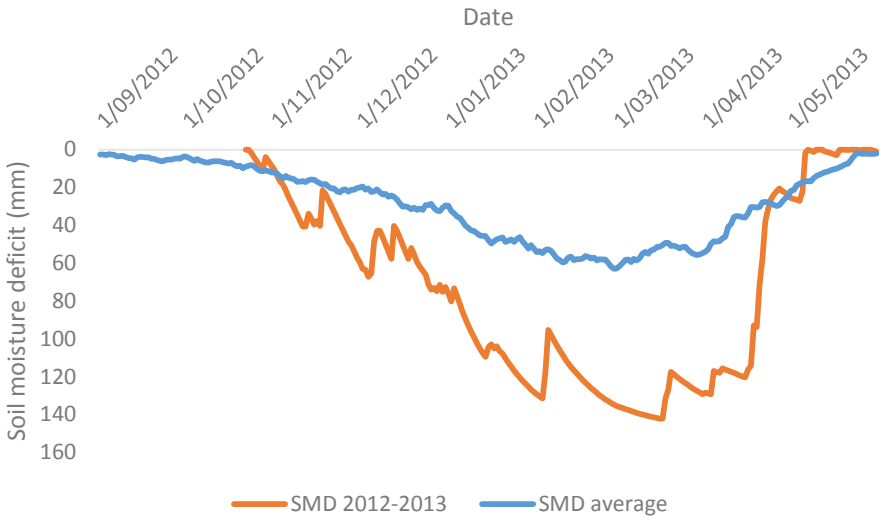


Figure 21. Soil moisture deficit (SMD) at Taumarunui during the summer and early autumn 2012-2013 drought, compared with normal soil moisture deficit conditions for the same time of year at Taumarunui (1981-2010).

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

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Dannevirke	5°C	386	351	328	234	171	107	93	111	160	219	258	339	2757
	10°C	231	210	174	90	42	17	10	13	37	75	111	185	1193
Ohakune, Ruapehu College	10°C	325	301	269	184	130	58	43	46	104	153	184	273	2070
	5°C	172	160	117	52	21	4	1	0	10	29	49	121	737
Palmerston North Aws	5°C	396	375	353	259	198	124	115	132	179	229	263	348	2969
	10°C	241	234	198	114	60	21	15	17	45	81	115	193	1331
Taumarunui	5°C	405	372	344	240	165	99	83	109	168	230	278	361	2856
	10°C	250	231	189	96	38	13	7	10	38	82	129	206	1290
Waiouru Treatment Plant	5°C	285	263	227	140	76	34	22	28	62	111	157	239	1643
	10°C	133	124	84	29	7	1	0	0	4	14	36	94	527
Wanganui, Spriggens Park EWS	5°C	411	379	374	287	230	162	139	163	206	257	294	370	3273
	10°C	256	238	219	138	81	36	22	31	64	105	144	215	1548

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

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Dannevirke	CDD	25	22	9	1	0	0	0	0	0	0	1	10	69
	HDD	42	39	84	157	232	286	314	294	230	185	133	74	2069
Ohakune, Ruapehu College	CDD	7	7	1	0	0	0	0	0	0	0	0	1	16
	HDD	85	72	135	207	275	345	379	370	289	251	206	131	2745
Palmerston North AWS	CDD	29	32	13	1	0	0	0	0	0	0	1	11	88
	HDD	36	24	63	132	205	268	290	272	211	174	128	67	1872
Taumarunui	CDD	32	30	11	1	0	0	0	0	0	0	2	15	90
	HDD	30	24	70	151	238	297	326	295	222	173	114	56	1996
Waiouru Treatment Plant	CDD	2	3	1	0	0	0	0	0	0	0	0	0	6
	HDD	121	107	177	252	337	390	424	406	339	297	233	164	3245
Wanganui, Spriggens Park EWS	CDD	35	33	18	3	0	0	0	0	0	0	3	18	110
	HDD	27	20	47	106	173	228	264	241	184	146	99	51	1585

Photo: ©mychillybin.co.nz/Andrea Howard

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 Manawatu-Wanganui, 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 22 shows region-wide variability in the number of heating degree days per year. The number of heating degree days is lower in low elevation coastal areas (e.g. Wanganui), compared with areas further inland and at higher elevations (e.g. Waiouru and Ohakune). These higher elevation sites have a very low number of cooling degree days, and a much higher number of heating degree days than other sites in the region.

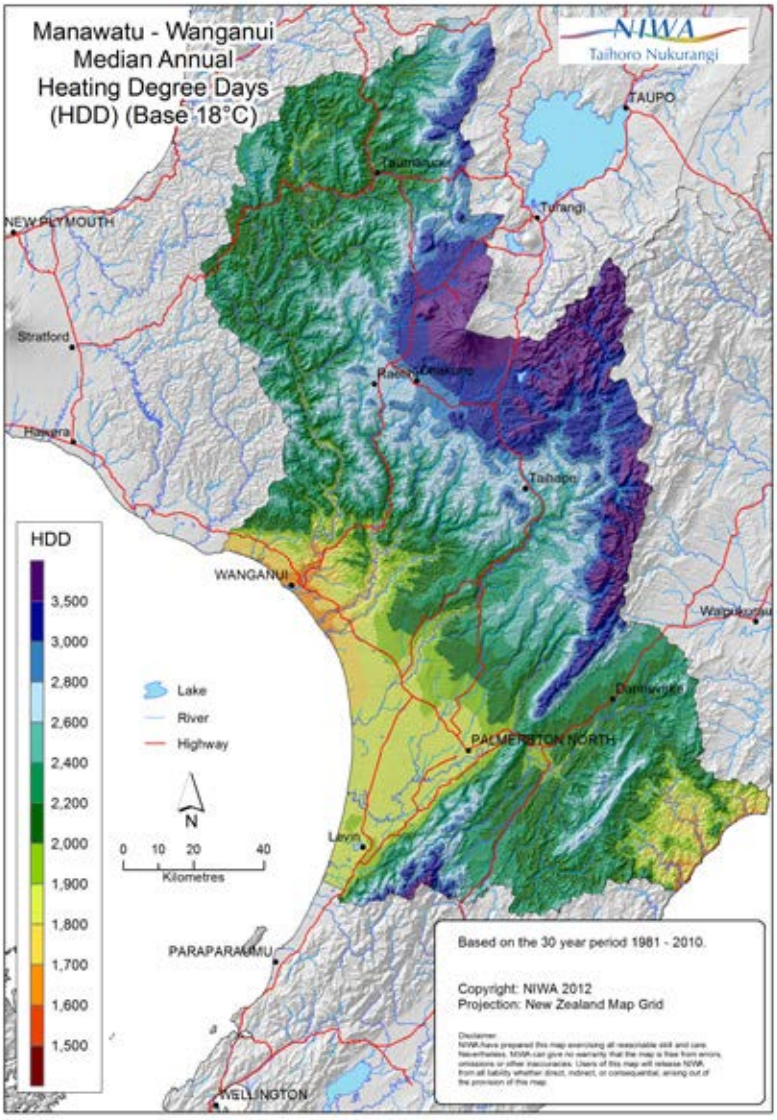


Figure 22. Median annual heating degree days for Manawatu-Wanganui, 1981-2010.

Photo: ©mychillybin.co.nz/Stephen Watson

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Photo credits:

Page 36, Gunilla Jensen, NIWA

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cliflo.niwa.co.nz

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hirds.niwa.co.nz

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