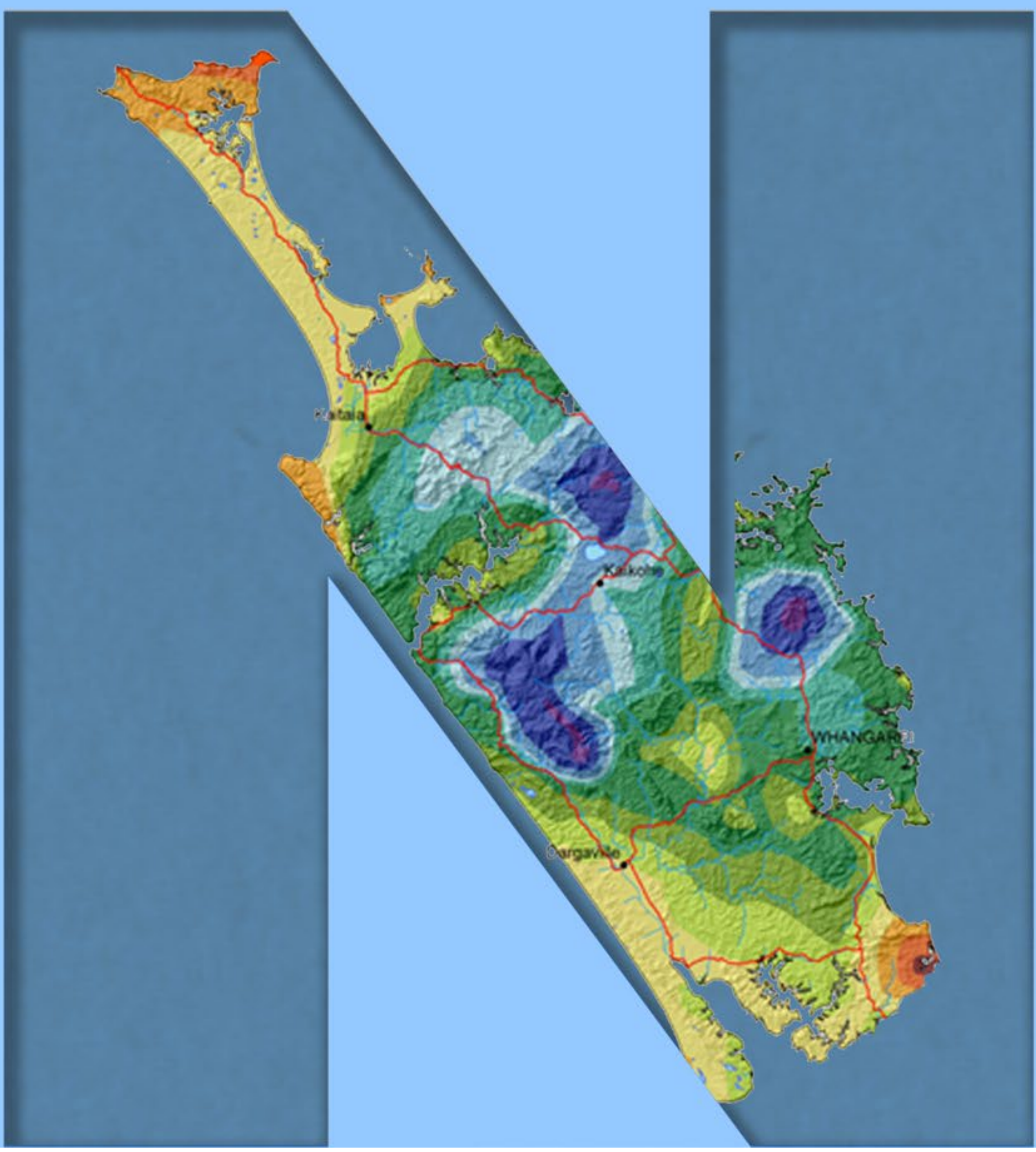
NIWA
Taihoro Nukurangi

THE CLIMATE AND WEATHER OF NORTHLAND

3rd edition

P.R. Chappell



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Note to Third Edition

This publication replaces the second edition of New Zealand Meteorological Service Miscellaneous Publication 115 (2), written in 1986 by R.W. Moir, B. Collen, and C.S. Thompson. It was considered necessary to update the second edition, incorporating more recent data and updated methods of climatological variable calculation.

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CONTENTS

SUMMARY

Northland, with its northern location, low elevation and close proximity to the sea is characterised by a mild, humid, and rather windy climate. Summers are warm and tend to be humid, while winters are mild, with many parts of the region having only a few light frosts each year. Rainfall is typically plentiful all year round with sporadic very heavy falls. However dry spells do occur, especially during summer and autumn. Most parts of Northland receive about 2000 hours of sunshine per year. It can be very windy in exposed areas and occasionally Northland experiences gales, sometimes in association with the passage of depressions of tropical origin.

INTRODUCTION

The North Auckland peninsula extends from Auckland City to North Cape for a length of about 300 km. Northland is defined here as the region administered by Northland Regional Council, encompassing the jurisdictions of Kaipara, Whangarei, and Far North Districts.

Most of Northland lies between the latitudes 34° S and 36° S. Despite its length, the peninsula is less than 100 km across at its widest point. The eastern coastline is indented by many inlets and bays, the most famous of which is the Bay of Islands. On the western side, the Kaipara and Hokianga Harbours penetrate far inland, but much of the exposed coastline is dominated by long surf beaches. Figure 1 provides geographic context for the Northland region, and shows all locations mentioned in the following text and tables.

Most of the region lies below 150 m elevation although some points in the central ranges are above 600 m. Together these factors give Northland a climate that is warm and humid in the summer and mild in the winter. Rainfall is highest in winter while dry spells tend to occur in summer and autumn. Cultivation of sub-tropical fruits is well suited to these climatic conditions, especially in eastern areas. However even with this diversification, Northland's economy still largely depends on forestry, intensive dairy farming, and tourism, which like horticulture are industries closely linked to the climate.

All numbers given in the following tables are calculated using data from the 1981-2010 normal period (a normal is an average or estimated average over a standard 30 year period), unless otherwise stated.

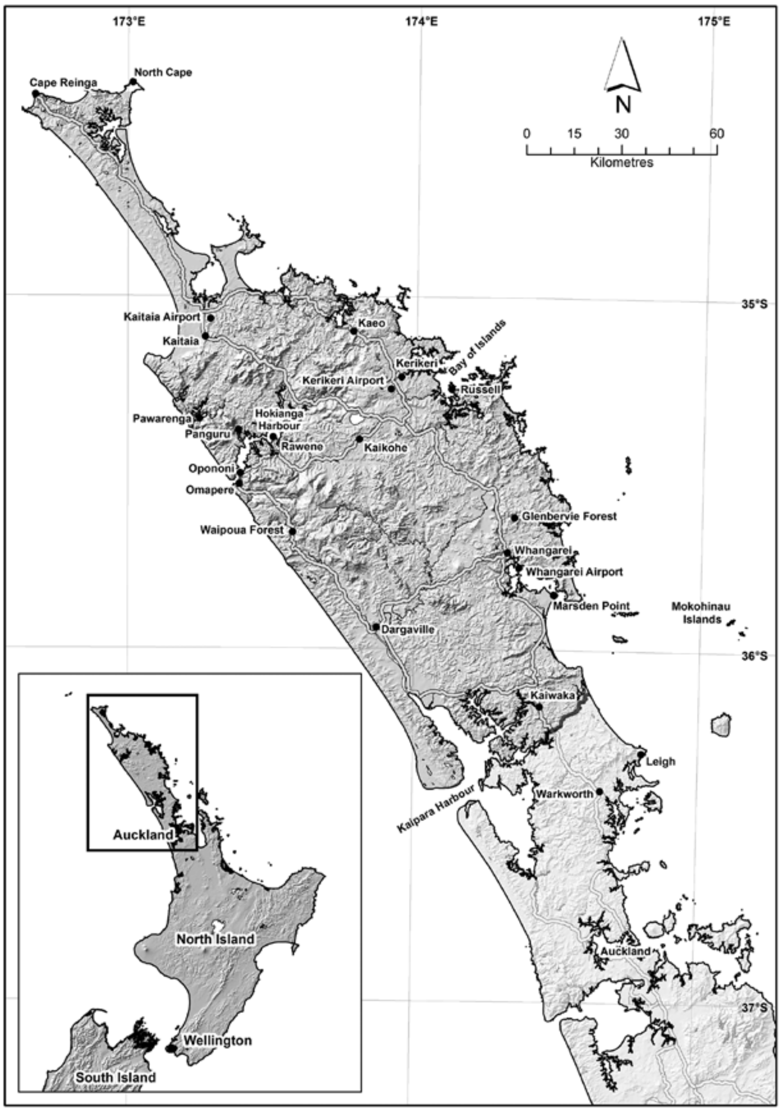


Figure 1. Map of Northland, with locations of places mentioned in the text, tables, and figures.

THE WEATHER IN NORTHLAND

Weather systems affecting Northland

Northland's latitude means that the tracks of anticyclone centres crossing New Zealand are often to the south of the region. As a result, winds tend to be southeasterly following the passage of a trough as the next anticyclone advances, and turn to the northeast once the anticyclone has moved off to the east and the next trough is approaching. The northeast winds have had a long passage over a warm water surface to the north of New Zealand. They are usually very moist and cloud may develop as the air turns southward and is cooled from below by the sea surface. Upward motion associated with the trough leads to rain. Sometimes subtropical depressions form in these troughs in the easterlies and move close to Northland, producing heavy rain. When anticyclones pass to the north of New Zealand the passage of the following trough is accompanied by a wind change from northwesterly to southwesterly. The cold fronts in such troughs of low pressure are likely to bring less rain to Northland than areas further south.

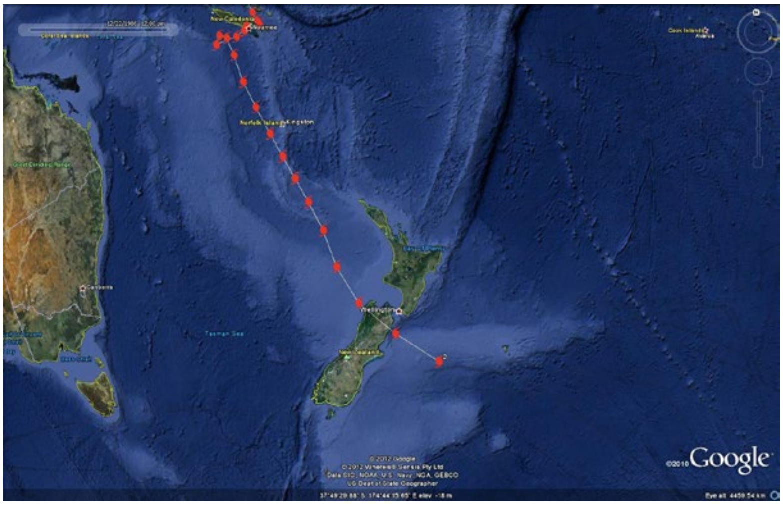


Figure 2a. Tropical cyclones which made landfall in New Zealand during December, 1970-2010. Source: Southwest Pacific Enhanced Archive of Tropical Cyclones (SPEArTC; Diamond et al., 2012).

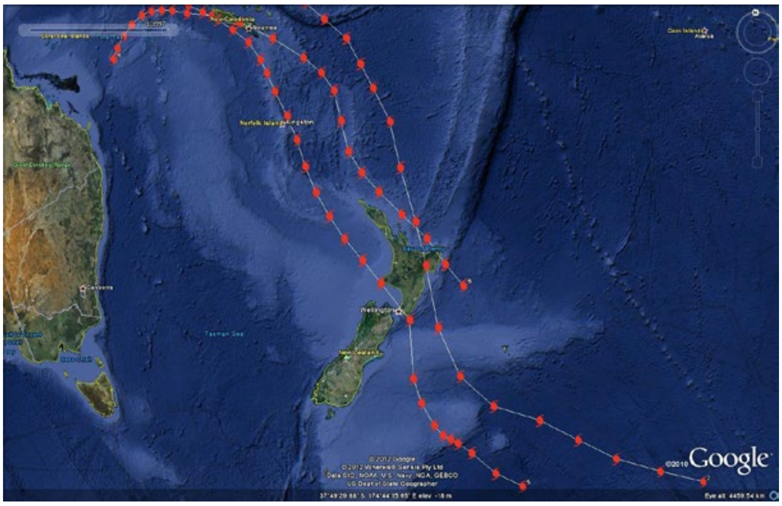


Figure 2b. Tropical cyclones which made landfall in New Zealand during January, 1970-2010. Source: SPEArTC (Diamond et al., 2012).

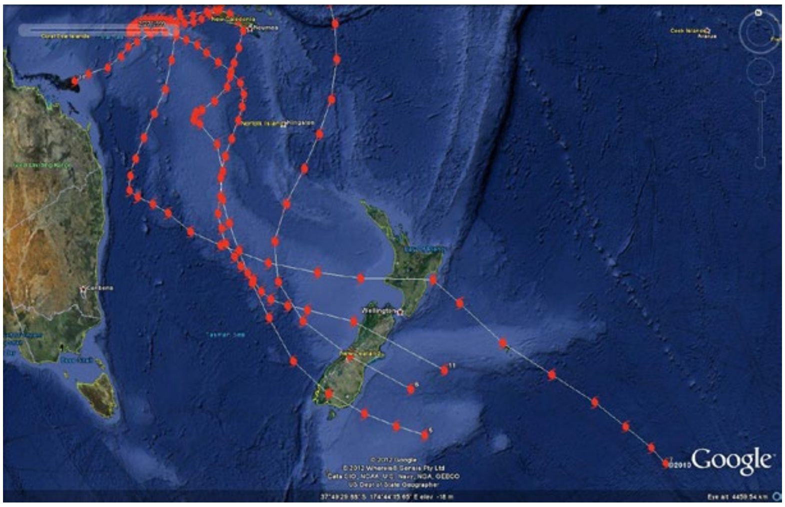


Figure 2c. Tropical cyclones which made landfall in New Zealand during February, 1970-2010. Source: SPEArTC (Diamond et al., 2012).

Tropical cyclones that reach Northland and still retain very low pressures and hurricane force winds are very rare. However, other storms of tropical origin (which may never have been fully developed tropical cyclones) affect Northland about once or twice each year, mainly between the months of December and April. They usually bring heavy rain and strong easterly winds. See 'Recent extreme events in Northland' section for a detailed description of the impact of Cyclone Bola in March 1988. Figure 2 shows, by months, the tracks of tropical cyclones which made landfall in New Zealand during the period between 1970 and 2010.

Characteristic weather sequences in Northland

Fine weather spells

The simplest situation, resulting in a long spell of fine weather (five days or more), occurs when a large anticyclone moves slowly over the Northland region. For example if the centre of an anticyclone moves slowly over the South Island with an eastward moving ridge of high pressure extending northward or northwestward from its centre, a period of fine weather will result in Northland.

In summer, Northland sometimes experiences two to three weeks of mostly fine weather due to a process known as anticyclone replacement. In this process, an anticyclone becomes stationary east of Australia and begins to lose intensity. A following cold front moves along the southern edge of the anticyclone and over New Zealand, bringing cloudy conditions and little or no rainfall. The original anticyclone, which has virtually disappeared, is replaced by the next in a series, and the whole process repeats itself, sometimes several times. Except for a short period with the passage of the weak fronts, the weather in Northland is fine and temperatures are normal or slightly above normal, often for quite prolonged periods. This type of situation is shown in Figure 3. No rain fell at Kaitaia during 9-26 April 1984, a total of 17 days without rain. Daytime temperatures were generally between 2°C and 3°C higher than usual, although night time temperatures were a little cooler than usual due to strong outgoing radiation associated with clear skies.

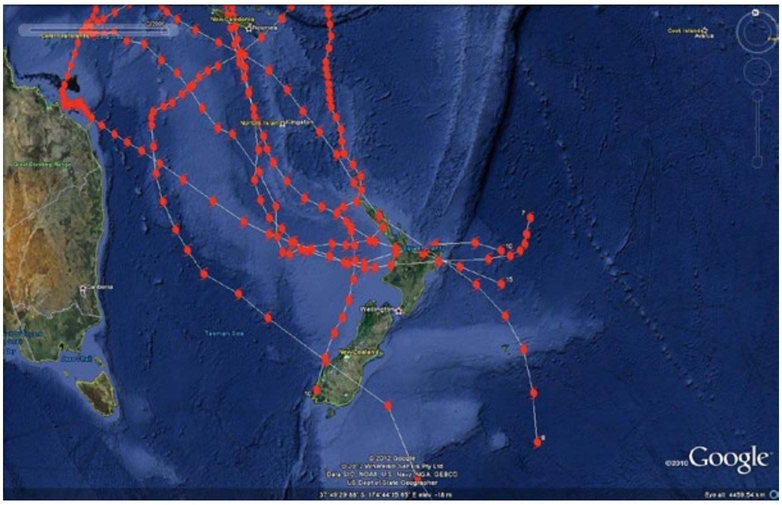


Figure 2d. Tropical cyclones which made landfall in New Zealand during March, 1970-2010. Source: SPEArTC (Diamond et al., 2012).

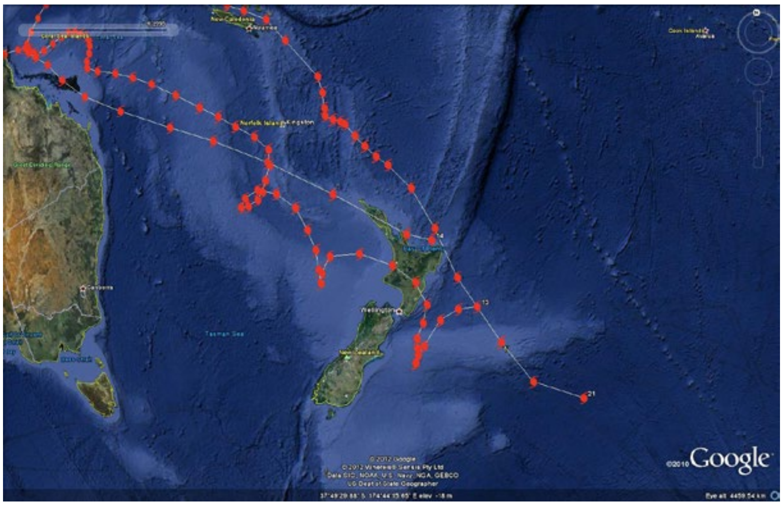


Figure 2e. Tropical cyclones which made landfall in New Zealand during April, 1970-2010. Source: SPEArTC (Diamond et al., 2012).

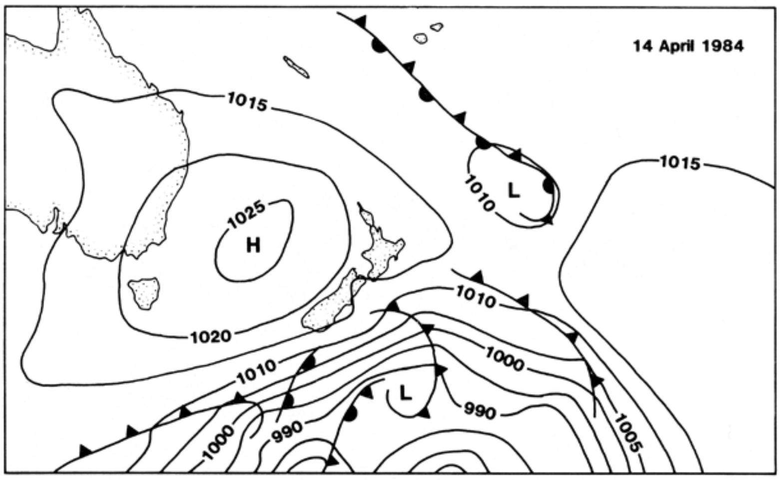


Figure 3. Prolonged period of fine weather.

Brief periods of rain

When a cold front oriented northwest to southeast crosses Northland, preceded by north to northwest winds and followed by southwesterlies, there is usually only a brief period of rain, often light. Figure 4 illustrates this situation. The passage of this front brought rain between midnight and 7 am on 22 September 1983 when 21.4 mm of rain fell at Kaitaia during this period.

When a depression develops in the trough between two anticyclones and subsequently moves over central and southern New Zealand, the rainfall in Northland is again brief but may be heavy. Figure 5 illustrates such a situation.

Showery weather

Prolonged changeable weather with frequent and sometimes heavy showers occurs with two main types of situation:

(i) Following the passage of a depression or cyclonic storm which has moved over Northland from the northwest or west, cold weather with moderate or fresh southwesterly to southerly winds and frequent showers may last two to three days. This type of situation is shown in Figure 6.

(ii) When the track of an anticyclone lies well to the south of Northland, the region experiences easterlies for long periods. A trough of low pressure between two anticyclones may develop to the north of the region. The wind east of the trough is north-east and to the west of the trough is southeasterly. Once established, such troughs usually move slowly and may cause several days of showery weather in Northland, with rainfalls typically higher in the east than in the west. This type of situation is shown in Figure 7.

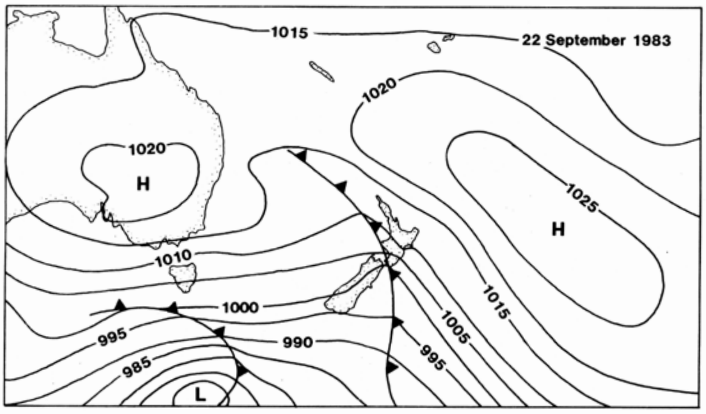


Figure 4. Brief period of rainfall.

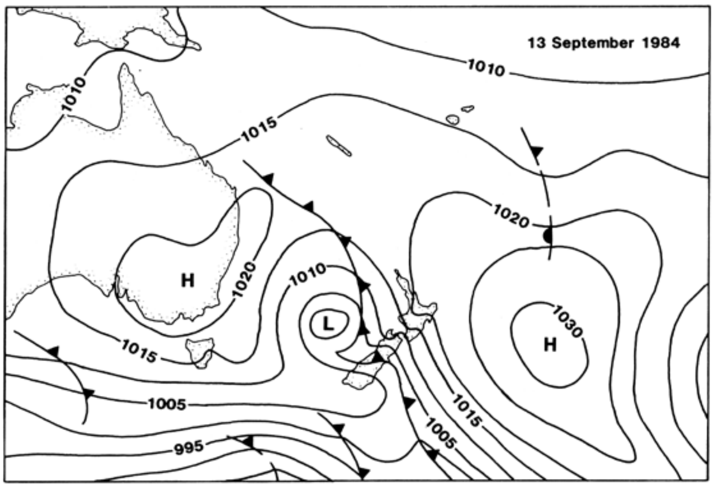


Figure 5. Brief period of heavy rainfall.

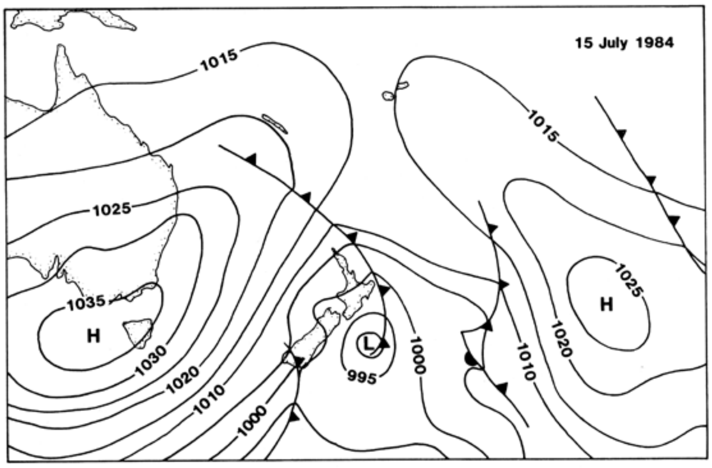


Figure 6. Showers associated with a depression or cyclonic storm.

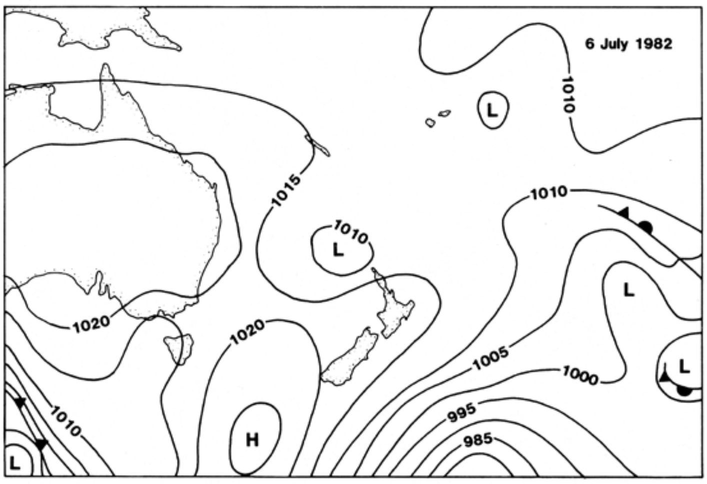


Figure 7. Showers associated with a trough of low pressure.

Prolonged rainfall

Most long periods of rain in Northland occur when there is an anticyclone to the east or southeast of New Zealand that has become stationary. The anticyclone is typically elliptic in shape with its major axis extending far to the north or northeast of New Zealand. Under such circumstances there is a flow of moist warm air from the low latitudes over Northland. Where this flow is lifted by vertical motion associated with a trough in the north Tasman Sea, rain may occur for several days and high rainfall totals can accumulate – often up to 100 mm, occasionally more. A situation of this type is shown in Figure 8.

Other situations that can lead to prolonged rainfalls are illustrated in Figures 9 and 10. In Figure 9 successive daily positions of a depression centre moving off Australia, across the Tasman Sea and South Island are shown. In advance of the frontal trough (which by 25 October had become stationary) persistent rain fell in Northland.

Figure 10 is representative of situations where a depression which originated as a tropical cyclone passes over or, in this case, close to, Northland. Successive daily positions of the centre are again shown. On this occasion Northland received between 70 and 130 mm of rain. Such situations (and those of the type illustrated in Figure 8) may also be accompanied with damaging winds.

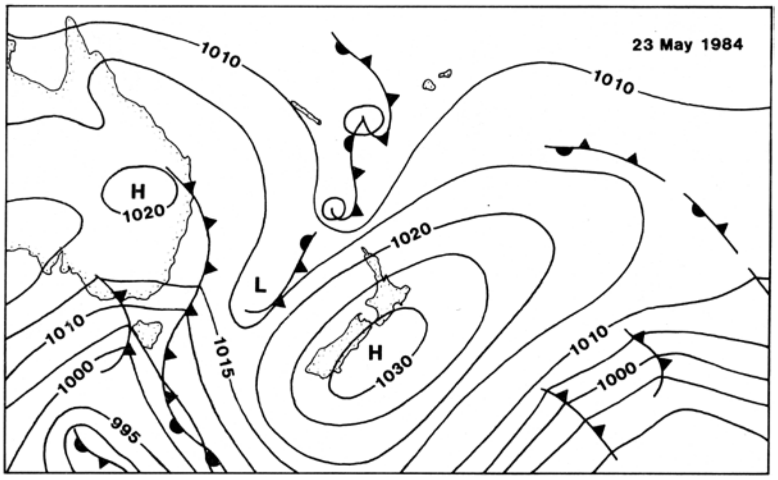


Figure 8. Prolonged heavy rainfall associated with a stationary anticyclone.

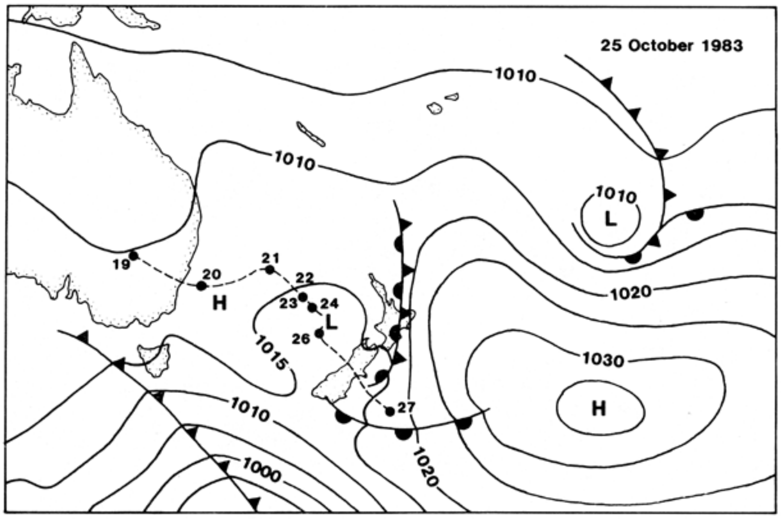


Figure 9. Prolonged heavy rainfall.

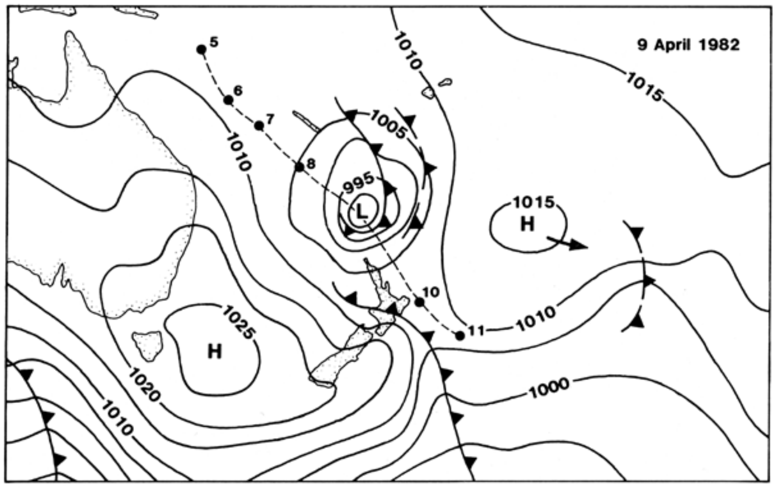


Figure 10. Prolonged heavy rainfall associated with a severe depression passing over Northland.

CLIMATIC ELEMENTS

Wind

The airflow over Northland is predominantly from the southwest (Tomlinson, 1975). This is particularly so in winter and spring, but in summer the proportion of winds from the easterly quarter, especially in eastern districts, about equals that from the southwest. This arises from the changing location of the high pressure belt, which is further to the south in summer and early autumn than it is in winter and spring. As well, sea breezes add to the proportion of easterlies in eastern areas in summer and early autumn. Figure 11 shows mean annual wind frequencies of surface wind based on hourly observations from selected stations.

Mean wind speed data (average wind speeds are taken over the 10 minute period preceding each hour), are available for several sites in Northland, and these illustrate the several very different wind regimes of the region. Exposed coastal areas tend to be very windy, with mean annual wind speeds among the highest in New Zealand. Such areas are typified by data from Cape Reinga and Mokohinau Islands, where mean annual wind speeds are around 30 km/hr. Areas that are exposed to most winds but receive some sheltering, such as Kaitaia Airport, characteristically have speeds of between 15 and 20 km/hr. Inland and sheltered areas of Northland are among the least windy in the country, with mean annual wind speeds at Kaikohe and Kerikeri about 10 km/hr. Table 1 gives mean monthly wind speeds for selected stations in Northland.

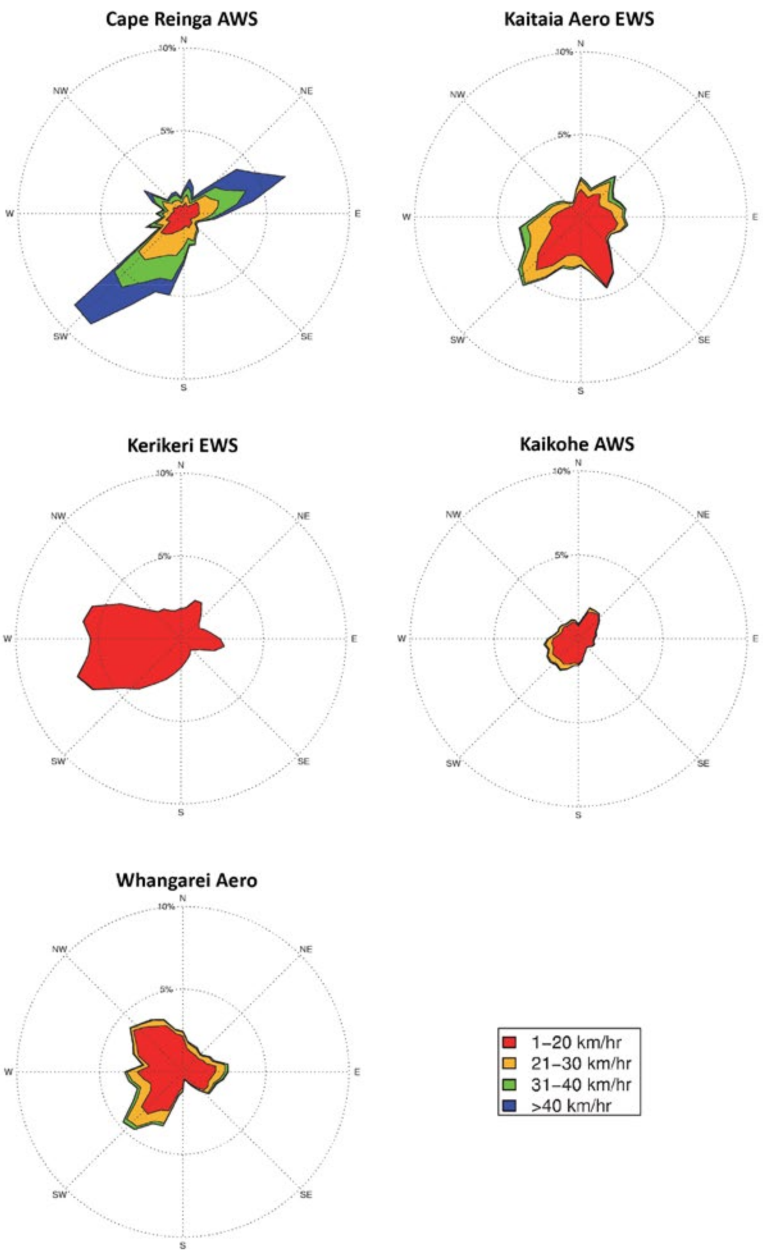


Figure 11. Mean annual wind frequencies (%) of surface wind directions, from hourly observations at selected Northland sites. The plots show the directions from which the wind blows, e.g. the dominant wind direction at Cape Reinga is from the southwest.

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

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cape Reinga	29	28	28	29	32	34	33	33	30	32	30	28	31
Kaitaia Airport	16	15	15	15	15	16	17	16	17	18	17	16	16
Kaikohe AWS	11	10	10	9	10	11	12	12	13	14	13	12	11
Kerikeri EWS	7	7	6	6	6	7	7	7	7	8	8	7	7
Whangarei Airport	12	12	11	10	10	10	11	11	12	13	13	12	11
Mokohinau Islands	24	24	24	25	28	30	31	29	27	28	28	25	27

Spring is generally the windiest season except in exposed places such as Cape Reinga and Mokohinau Islands where winter tends to be the windiest period. Summer and autumn are the seasons when the greatest numbers of light wind days are recorded. 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 Cape Reinga, 21 percent occurred in summer, 24 percent in autumn, 29 percent in winter, and 26 percent in spring. In compiling this table a strong wind was defined as having a mean speed of at least 31 km/hr.

Table 2. Seasonal proportions of strong winds or calms (%).

Location		Summer	Autumn	Winter	Spring
Cape Reinga	Strong	21	24	29	26
	Light	28	26	22	24
Kaitaia Observatory	Strong	13	17	32	38
	Light	26	25	25	24
Kaikohe AWS	Strong	11	10	36	43
	Light	25	25	25	25
Kerikeri EWS	Strong	24	17	23	37
	Light	25	25	25	24
Whangarei Airport	Strong	19	15	36	30
	Light	25	25	25	25
Mokohinau Islands	Strong	20	24	30	27
	Light	28	26	23	24

Diurnal variation in wind speed is, well-marked, with greatest wind speeds occurring in the early part of the afternoon (Table 3).

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

Location	00	03	06	09	12	15	18	21
Cape Reinga	30	29	29	29	31	32	32	30
Kaitaia EWS	11	12	12	13	18	20	17	12
Kaikohe AWS	9	8	8	10	16	17	15	10
Kerikeri EWS	5	5	5	9	10	10	8	6
Whangarei Airport	8	8	8	10	16	18	15	10

Table 4. Average number of days per year with gusts exceeding 63 km/hr and 96 km/hr, and gale force winds.

Location	Gusts >63 km/hr	Gusts >96 km/hr	Days of gale
Cape Reinga	167	34	42
Kaitaia Observatory	63	3	2
Whangarei Airport	22	0.3	1

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

Location	Gust (km/hr)	Direction (°)	Date
Cape Reinga	183	060	22/07/2002
Kaitaia Observatory	139	320	24/04/1991
Kerikeri Aerodrome	85	281	12/09/2011
Whangarei Airport	122	090	28/07/1982
Marsden Point	154	050	28/06/1977
Dargaville	117	084	10/07/2007
Mokohinau Islands	152	110	29/11/1998

Winds can be strong and gusty at times, especially in exposed coastal areas. As expected, the well exposed site at Cape Reinga records the greatest number of days each year on which gusts exceed 63km/hr and 96km/hr. Table 4 shows the average number of days each year with gusts exceeding 63km/hr and 96km/hr and also lists the average number of days each year on which gale force winds (10-minute average speeds in excess of 63 km/hr) are recorded.

Although gale force winds can occur in any month they are most frequent between May and August, and especially in July. The highest gust recorded in the region was 183 km/hr at Cape Reinga on 22 July 2002. Maximum gusts recorded at different stations in the region are listed in Table 5.

Sea breezes are common on both coasts during summer and autumn on days when there is no strong pressure gradient over the region. They may reach 20 to 30 km/hr when there is a marked difference between the sea temperature and the land temperature, especially in the afternoon. On occasions the opposing sea breezes from the west and east coasts converge inland in a zone marked by a line of cloud and showers. At Kaitaia both sea breezes can occur at different times of the day.

Rainfall

Rainfall distribution

Northland is a narrow peninsula with no part more than 50 kilometres from the sea. This causes winds to be very moist with abundant rainfall throughout the region. Distribution patterns are related to orography: rainfalls range from about 1000 mm in low-lying coastal areas, to approximately 2000 mm at higher elevations. Figure 12 shows the distribution of median annual rainfall based on the 1981-2010 period.

Seasonal influences on rainfall distribution are also quite well defined. Table 6 lists monthly rainfall normals and percentage of annual total for the period 1981-2010 for selected stations. This table shows a clearly defined winter rainfall maximum. The north and east of the region gets 35 to 40 percent of its annual rainfall in the period June to August while stations to the south and west receive about 30 to 35 percent during these three winter months. 18 to 20 percent of Northland annual rainfall is experienced during the summer months (December to February).

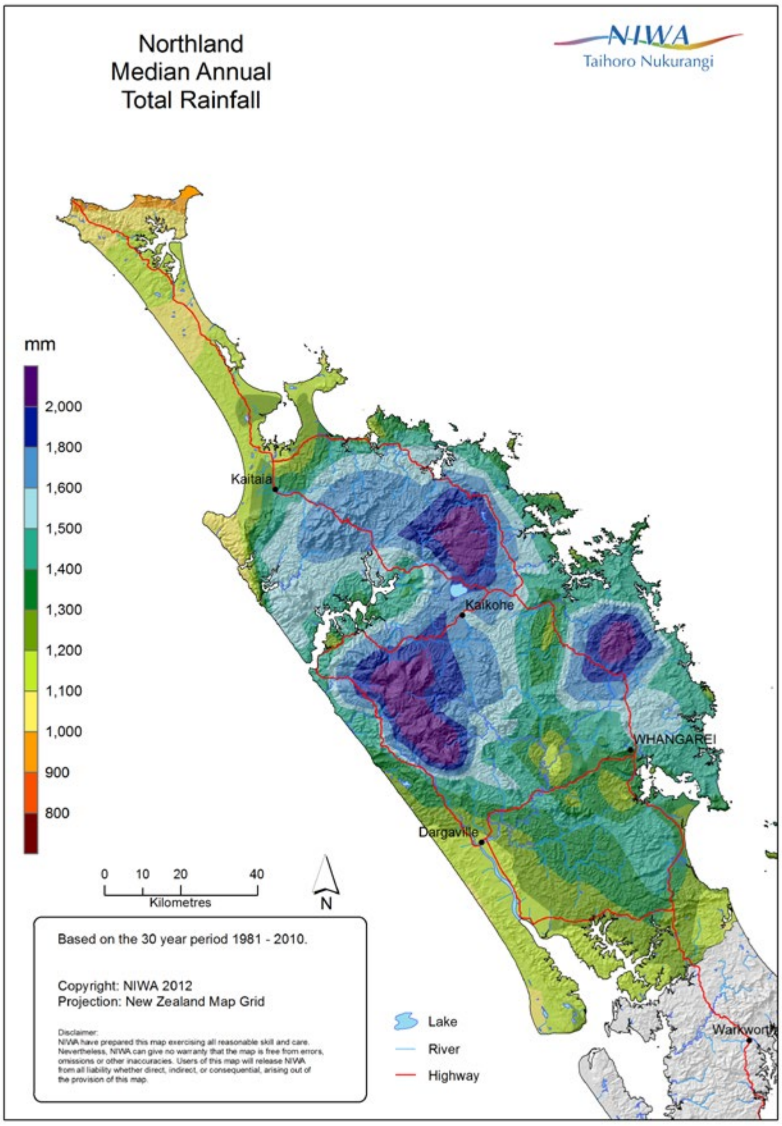


Figure 12. Northland median annual rainfall, 1981-2010.

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
Cape Reinga Aws	a	58	65	56	109	96	103	128	95	85	61	57	76	988
	b	6	7	6	11	10	10	13	10	9	6	6	8	
Kaitaia Observatory	a	85	93	81	96	135	151	169	144	128	99	87	100	1367
	b	6	7	6	7	10	11	12	11	9	7	6	7	
Kaitaia Aero Ews	a	69	121	86	119	138	125	136	104	93	93	73	99	1253
	b	5	10	7	9	11	10	11	8	7	7	6	8	
Kaeo Northland	a	88	102	120	140	144	169	200	170	148	113	102	100	1596
	b	6	6	8	9	9	11	12	11	9	7	6	6	
Rawene 2	a	78	72	89	98	128	145	164	142	118	91	83	91	1299
	b	6	6	7	8	10	11	13	11	9	7	6	7	
Opononi	a	86	65	93	94	124	144	133	116	105	93	92	88	1234
	b	7	5	8	8	10	12	11	9	8	8	7	7	
Kaikohe Aws	a	110	106	109	140	139	152	188	159	124	100	96	109	1532
	b	7	7	7	9	9	10	12	10	8	6	6	7	

Table 6 continued.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Kerikeri Airport	a	122	117	138	145	154	185	205	182	162	127	114	123	1775
	b	7	7	8	8	9	10	12	10	9	7	6	7	
Russell	a	91	87	116	117	130	144	172	146	121	97	89	90	1400
	b	7	6	8	8	9	10	12	10	9	7	6	6	
Waipoua Visitor Centre	a	89	82	103	97	146	177	166	153	132	110	93	94	1443
	b	6	6	7	7	10	12	11	11	9	8	6	7	
Whangarei Airport	a	78	98	117	103	110	132	169	127	110	84	76	97	1300
	b	6	8	9	8	8	10	13	10	8	6	6	7	
Dargaville 2	a	64	69	102	107	97	121	141	109	109	82	63	74	1137
	b	6	6	9	9	9	11	12	10	10	7	6	7	

The distribution of monthly rainfall is shown in Figure 13. The 10 percentile, 90 percentile and mean values for each month are shown along with maximum and minimum recorded values for several stations.

One of the most marked characteristics of the rainfall regime in Northland is its great variability from month to month and year to year. Rainfall variability can be described by the coefficient of variation (the ratio of the standard deviation to the mean, expressed as a percentage). Table 7 gives seasonal and annual variability for stations in Northland and for selected sites in other regions for comparative purposes.

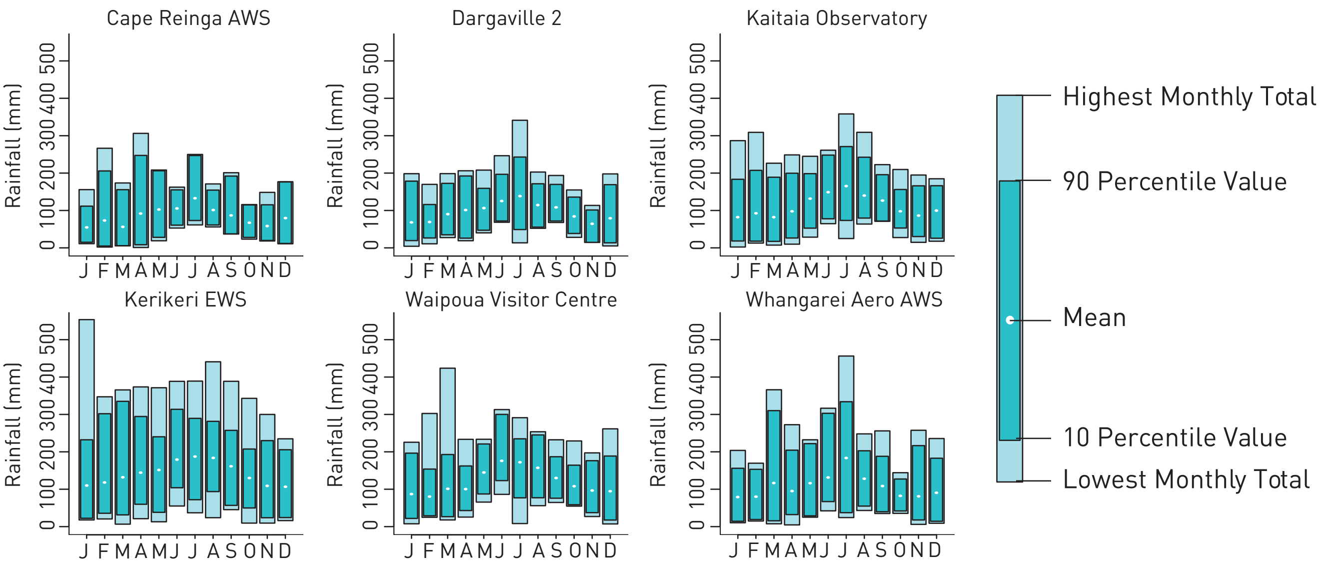


Figure 13. Monthly rainfall for selected Northland stations.

Table 7. Seasonal variability of rainfall (Coefficient of variation).

Location	Summer	Autumn	Winter	Spring
Cape Reinga	46	75	25	45
Kaitaia Observatory	41	34	24	19
Kaeo Northland	50	45	30	31
Rawene 2	42	32	29	25
Kaikohe AWS	47	45	38	33
Kerikeri EWS	46	39	28	32
Waipoua Visitor Centre	42	25	23	31
Whangarei Aero AWS	37	41	33	31
Dargaville 2	37	21	24	17
Auckland	47	24	27	25
Wellington	42	38	30	36
Christchurch	37	27	42	32
Westport	24	28	20	17

Rainfall variability over longer periods is indicated by rainfall deciles, as given in Table 8. 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 Kaitaia, for three months it can be seen that in the three month period beginning in April, 257 mm or more of rainfall can be expected for nine years in ten, while a total of 522 mm or more should occur in only one year in ten.

Table 8. Rainfall deciles for consecutive months.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaitaia Observatory												
1 month												
10th	18	18	17	26	53	78	73	80	72	53	30	26
90th	183	207	189	200	198	248	271	242	196	156	166	166
3 months												
10th	114	118	192	257	301	301	301	270	221	194	159	130
90th	431	423	472	522	550	603	606	479	407	426	423	481
6 months												
10th	412	528	563	631	672	611	556	513	405	302	274	364
90th	829	894	917	981	993	947	879	790	836	770	718	755
12 months												
10th	1086	1119	1093	1102	1046	1054	993	1131	1116	1074	1035	1105
90th	1584	1569	1619	1533	1625	1652	1643	1578	1637	1609	1593	1587
Kerikeri EWS												
1 month												
10th	22	33	3	60	38	104	72	94	57	50	24	24
90th	232	302	335	295	240	314	290	282	257	208	230	206
3 months												
10th	148	221	228	305	360	385	379	298	226	166	143	153
90th	617	629	731	645	663	748	727	626	545	550	554	624
6 months												
10th	534	639	699	779	781	736	594	548	507	357	433	462
90th	1148	1222	1229	1269	1290	1188	1157	1194	1025	1045	1078	1079
12 months												
10th	1303	1334	1258	1332	1283	1231	1267	1342	1327	1275	1349	1288
90th	2175	2358	2293	2186	2162	2129	2094	2130	2128	2181	2244	2202
Whangarei Aero												
1 month												
10th	14	19	16	32	29	67	37	55	40	42	18	14
90th	156	153	310	204	222	303	334	203	188	127	217	183
3 months												
10th	122	113	165	175	229	261	253	193	156	140	108	129
90th	578	504	630	742	768	784	805	648	480	459	499	417
6 months												
10th	359	469	517	586	557	518	439	384	374	296	299	349
90th	877	1003	988	961	927	1034	948	757	720	775	803	836
12 months												
10th	955	979	966	932	879	939	831	927	953	942	937	936
90th	1642	1636	1697	1606	1732	1843	1741	1595	1586	1641	1624	1609

Rainfall frequency and intensity

The average number of days each year on which 0.1 mm or more of rain is recorded varies from around 150 days in eastern coastal areas of the peninsula to over 200 days in some western and inland areas. Table 9 lists the average number of days per month with 0.1 mm and 1 mm of rain for selected stations. The 0.1 mm rain days and 1 mm wet days show the same geographic variability.

Table 9. Average monthly rain days and wet days for Northland region. 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
Kaitaia Observatory	a	11	10	12	15	18	19	22	21	18	16	14	13	191
	b	7	7	7	11	13	15	16	16	13	11	9	10	134
Kaeo Northland	a	9	10	11	12	15	16	17	18	15	12	11	10	167
	b	7	8	9	10	12	13	15	14	12	10	8	9	128
Kaikohe AWS	a	12	12	15	18	21	21	23	23	18	18	15	14	217
	b	9	8	9	12	14	14	16	16	13	12	10	10	147
Opononi	a	11	10	12	15	19	20	21	22	18	16	15	12	198
	b	8	7	8	10	14	16	16	16	13	12	10	9	142
Rawene 2	a	10	9	11	13	18	19	20	20	17	15	12	11	191
	b	7	7	9	10	14	16	17	17	14	12	10	9	154
Kerikeri EWS	a	13	13	15	17	20	20	22	22	19	17	14	14	206
	b	8	8	9	11	12	13	15	14	13	11	9	9	134
Russell	a	9	9	10	12	14	15	17	16	14	12	10	10	156
	b	7	7	7	10	11	11	14	13	11	9	8	8	120
Waipoua Visitor Centre	a	11	10	13	15	18	19	19	20	17	16	14	12	199
	b	9	8	10	11	16	16	17	16	15	14	11	10	163
Whangarei Aero AWS	a	11	12	13	15	20	21	22	21	17	15	13	13	192
	b	8	8	9	10	13	14	15	15	13	11	9	9	133
Dargaville 2	a	11	10	13	15	19	21	23	23	19	17	15	12	197
	b	8	7	9	11	14	16	17	17	15	11	9	8	142

As noted in Section 2, heavy rainfalls can occur with the passage of depressions of tropical origin over or close to Northland, and with northeasterly flows between ridges of high pressure to the east and troughs over the Tasman Sea. Intense rainfalls also occur with thunderstorms. In Table 10, 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 Northland 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 10. Maximum recorded short period rainfalls and calculated return periods

Location		10min	20min	30min	1hr	2hrs	6hrs	12hrs	24hrs	48hrs	72hrs
Kaitaia Observatory	a	15	26	30	47	66	146	158	159	166	169
	b	15	29	29	21	30	100+	60	18	9	8
	c	10	15	18	27	36	56	73	97	114	126
	d	12	18	23	34	45	70	93	122	145	160
	e	14	21	27	40	53	82	108	143	169	187
	f	17	25	31	46	61	95	125	166	196	217
	g	20	30	37	56	74	115	152	201	238	263
Kerikeri EWS	a	11	20	23	33	53	100	134	165	339	340
	b	4	7	6	5	9	13	9	4	64	43
	c	10	15	18	27	38	66	93	132	155	171
	d	13	18	23	33	47	83	117	166	195	215
	e	15	21	27	39	55	96	137	194	228	251
	f	17	24	31	45	64	111	158	225	264	291
	g	20	29	37	54	77	134	191	272	320	351
Whangarei Aero AWS	a	12	18	24	34	43	75	95	125	162	207
	b	4	4	4	4	3	4	3	3	3	6
	c	11	16	20	28	39	63	86	117	143	160
	d	14	20	25	36	49	80	108	148	180	202
	e	16	23	29	42	57	93	126	172	210	235
	f	18	27	33	48	66	108	146	199	243	272
	g	22	32	40	59	80	130	177	241	293	329
Dargaville 2	a	12	18	26	25	43	69	94	122	129	133
	b	7	10	23	3	13	17	20	20	11	8
	c	9	13	16	23	29	43	55	71	86	96
	d	11	16	19	28	36	54	70	90	109	121
	e	13	18	22	32	41	63	81	105	127	142
	f	14	21	26	36	47	72	94	122	148	165
	g	17	25	30	43	57	87	114	149	180	200

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 Northland

Northland has experienced numerous extreme weather events, with significant damage and disruption caused by flooding and high winds (e.g. Figure 14). The events listed below are some of the most severe events to have affected Northland in the past 30 years.

6-9 March 1988: Ex-tropical Cyclone Bola caused widespread flooding and wind damage throughout the North Island. In Northland, most of the region was without power and telephone. A total of $17 million 2008 dollars of damage was done to Northland's horticulture and farming industries, and wind gusts up to 130 km/hr damaged 1500 ha of plantation forest. Up to 500 mm of rain fell in the 6 day period, causing widespread slipping and flooding, which closed roads and isolated people.

21-22 January 1999: Extreme rainfall caused a Civil Defence Emergency (CDE) in the Far North. Roads and bridges were washed out, stranding vehicles and isolating houses. The CDE status lasted for 19 days, due to health and safety concerns. In the Far North, 270 people were evacuated, many to local maraes. The towns of Panguru, Pawarenga, and Omapere were severely affected. Numerous homes needed to be replaced or shifted as a result of the flooding. Panguru Area School was devastated, with an estimated rebuilding cost of $3.9 million 2008 dollars. Two children were sucked down a stormwater drain in Kaiwaka, and one subsequently died.

Figure 14. Flooding in Kaeo, March 2012.

28-30 March 2007: Extreme rainfall brought extensive flooding to parts of Northland. Some areas received 450 mm of rain in 36 hours. The event had an estimated return period of 150 years. About 260 people required emergency accommodation, power and telephone services were cut in some areas, numerous roads were blocked by slips and flooding, and a number of houses were deemed uninhabitable following the event. The total repair bill was estimated at $85 million 2008 dollars, and insurance claims totalled $13 million 2008 dollars.

26-27 July; 29 July – 1 August 2008: Two large storms hit Northland within a week. The first was a rapidly deepening low that brought heavy rainfall, high winds, and high seas to Northland. Gusts of >130 km/hr brought down trees and power lines, causing about 25,000 homes across Northland to be without power. Low-lying coastal areas were flooded, in part due to the very low air pressure that caused tides to rise over 0.5 m above normal levels in some places. Kaeo was submerged by floodwaters on the 26th. Whangarei's CBD was flooded, leaving streets knee-deep in water and causing shops to close early. The second storm was a large depression that caused heavy rain and high winds throughout the Northland region. On the morning of 30 July, Northland was cut off from the south due to a large slip on SH 1 near Warkworth and flooding on the SH 16 alternative route. Schools released pupils early for fear that floodwaters would trap students. Two people drowned trying to cross the Waikare River. $10 million 2008 dollars worth of damage was done to Northland's roads during these two storms.

Periods of low rainfall

Periods of fifteen days or longer with less than 1 mm of rain on any day are referred to as "dry spells". Dry spells are not uncommon in Northland during the summer and early autumn. There is usually at least one, and frequently two, such periods each year between December and March. The average duration of a dry spell is about 20 days. The longest recent dry spell between the three main centres in Northland (Kaitaia, Kerikeri, and Whangarei) was 42 days recorded in Whangarei, from 5 December 1990 to 15 January 1991. During this dry spell, 22 consecutive days were without any rain. Other long dry spells include 35 days in Kaitaia from 3 January to 6 February 1988, of which 12 consecutive days were without rain, 32 days at Whangarei from 26 February to 29 March 2010, of which 9 consecutive days were without rain, and 28 days in Kerikeri from 7 February to 6 March 2006, of which 24 consecutive days were without rain.

Temperature

Sea temperature

Northland enjoys a mild climate with very few extremes of temperature. Although this is partly due to the relatively low latitudes, the extensive surrounding ocean also has a modifying effect on temperature in the region. Monthly mean sea surface temperature for the vicinity of Northland is compared with mean monthly air temperature for Cape Reinga in Figure 15. There is a six to eight week lag between the minima of land and sea temperatures. Figure 16 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 temperatures.

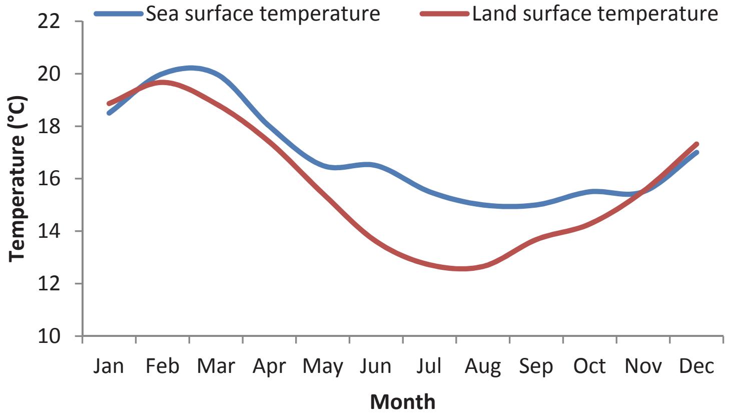


Figure 15. Mean monthly land and sea surface temperatures – Cape Reinga

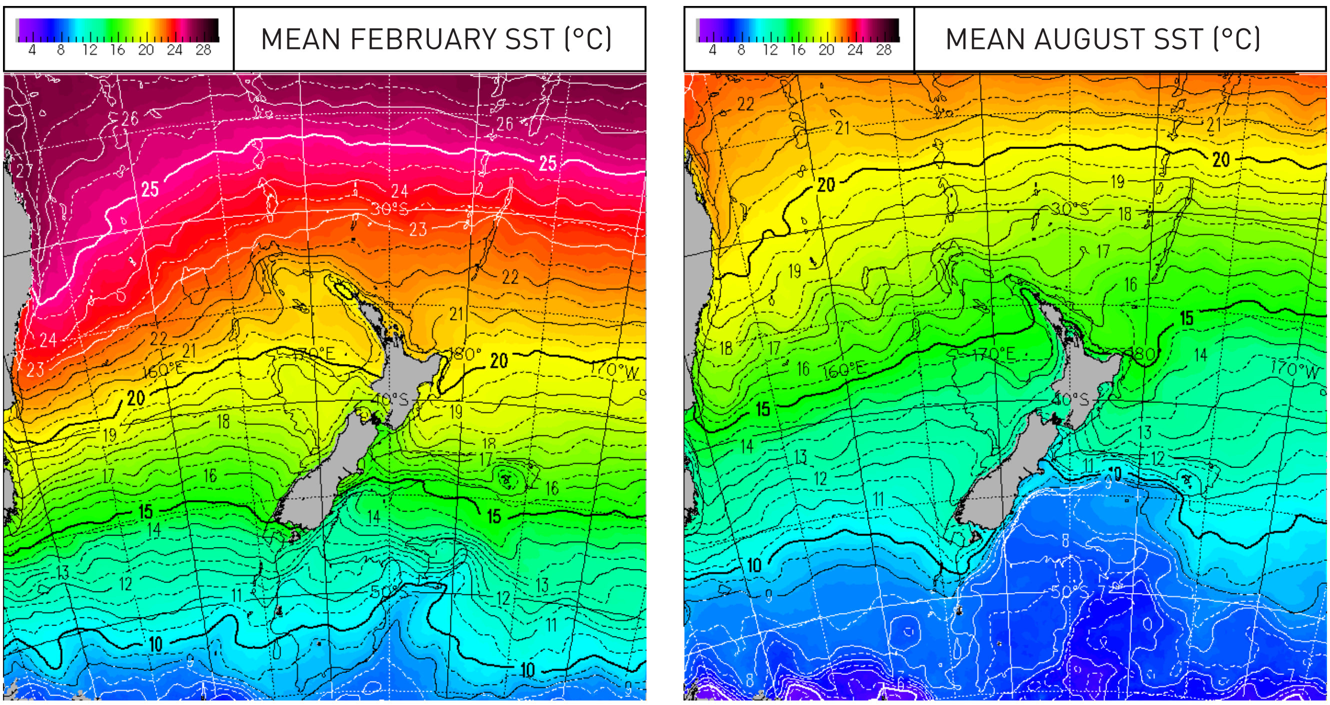
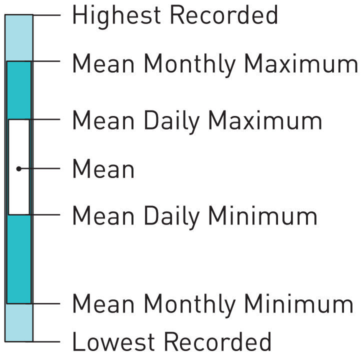


Figure 16. Monthly mean sea surface temperatures (°C) for: a) February; b) August, based on the years 1993-2002. Source: NIWA SST Archive. Uddstrom and Oien (1999).

Air temperature

Mean annual temperatures in Northland vary from about 15.5°C to 16.5°C on the Aupouri Peninsula (north of Kaitaia) to between 14°C and 16°C elsewhere. The mean annual temperature for the region north of Auckland City is the highest for any part of New Zealand. Although higher February temperatures are recorded in other parts of the country, no area south of Auckland City has higher mean July temperatures. Figure 17 shows the median annual average temperature for Northland, for the period 1981-2010. Figure 18 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 Northland.



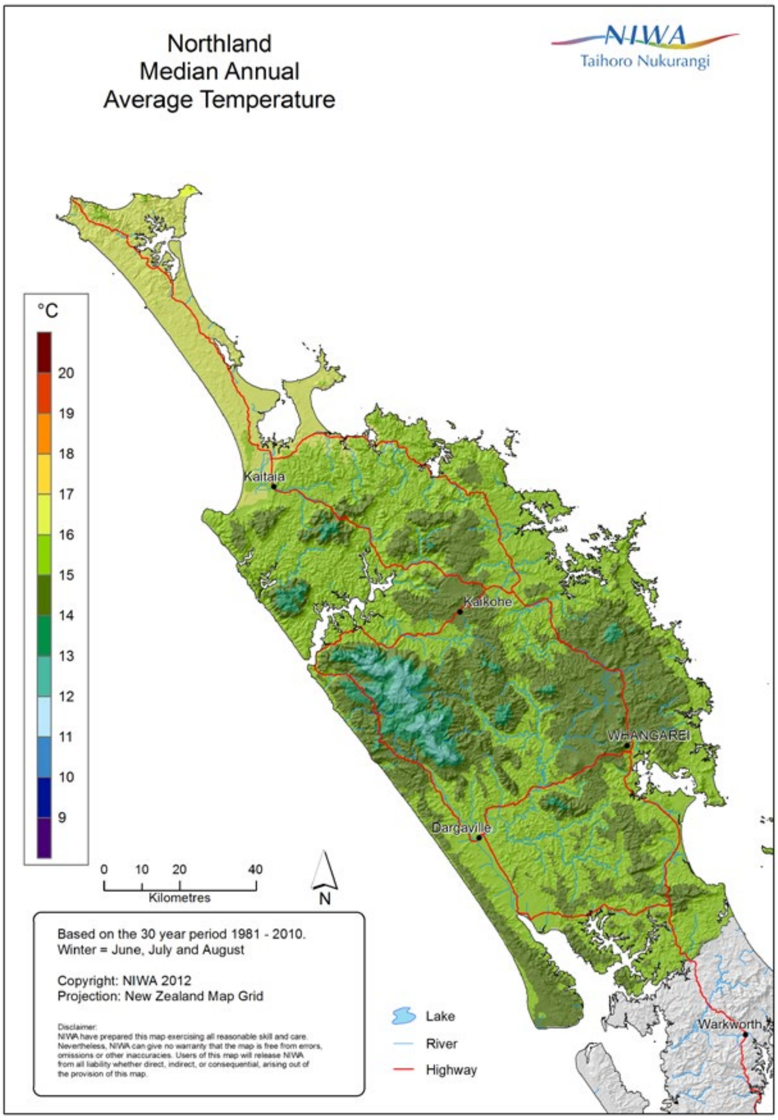


Figure 17. Northland median annual average temperature, 1981-2010.

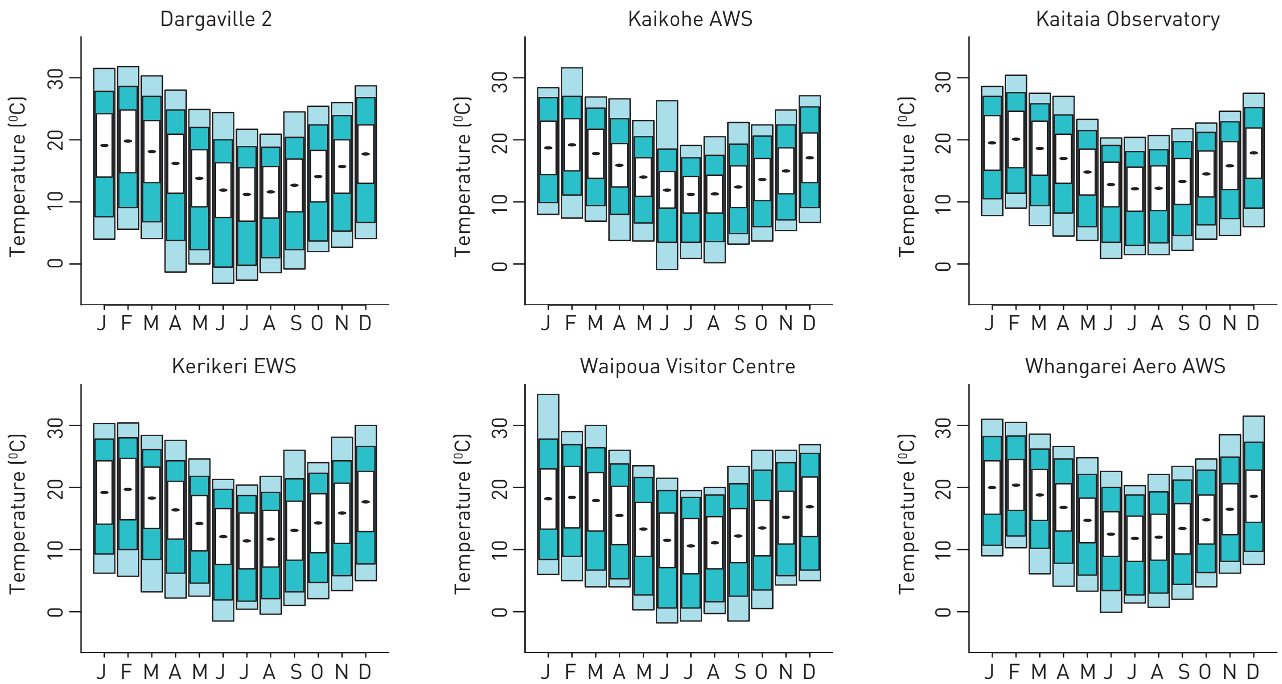


Figure 18. Mean, maximum, and minimum monthly temperature for Northland sites.

The mean annual temperature range for Northland is small, averaging 8.1°C. Table 11 shows the average daily temperature range for each month for a number of sites in Northland. Cape Reinga has the smallest temperature range for any station in the region and Kerikeri one of the greatest.

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

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cape Reinga	5.9	5.9	5.7	5.3	4.4	4.2	4.2	4.6	4.9	5.2	5.5	5.4
Kaitaia Observatory	8.8	9.1	8.8	8.0	7.4	7.2	7.1	7.2	7.4	7.4	7.8	8.2
Kerikeri EWS	10.2	9.9	10.0	9.3	8.8	9.1	9.0	9.1	9.4	9.5	9.7	9.8
Waipoua Visitor Centre	9.7	10.0	9.4	9.4	8.7	8.8	8.9	8.4	8.7	8.9	8.5	9.6
Whangarei Aero AWS	8.7	8.2	8.3	7.7	7.1	7.2	7.3	7.4	8.0	7.9	8.2	8.5
Dargaville 2	10.1	10.0	10.0	9.4	9.2	8.8	8.7	8.3	8.5	8.2	8.7	9.4

Diurnal temperature variations are also relatively minor. Table 12 and Figure 19 show mean hourly temperatures for Kaikohe for January and July.

Table 12. Mean hourly temperature at Kaikohe in January and July (°C).

hrs	00	01	02	03	04	05	06	07	08	09	10	11
January	15.7	15.5	15.3	15.2	15.1	15.0	15.1	16.2	17.9	18.8	19.7	20.6
July	9.5	9.5	9.4	9.3	9.2	9.2	9.1	9.1	9.2	10.2	11.3	12.1
hrs	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
January	21.2	21.6	21.8	21.6	21.3	20.5	19.7	18.6	17.3	16.7	16.3	16.0
July	12.6	12.8	12.9	12.8	12.4	11.6	10.7	10.3	10.0	9.9	9.8	9.7

Extreme temperatures are also moderate. The highest temperature recorded in Northland was 35.0°C at Waipoua Forest on 30 January 1991, and the lowest -5.6°C at Glenbervie Forest on 31 July 1957. These compare with national extremes of 42.4°C and -25.6°C.

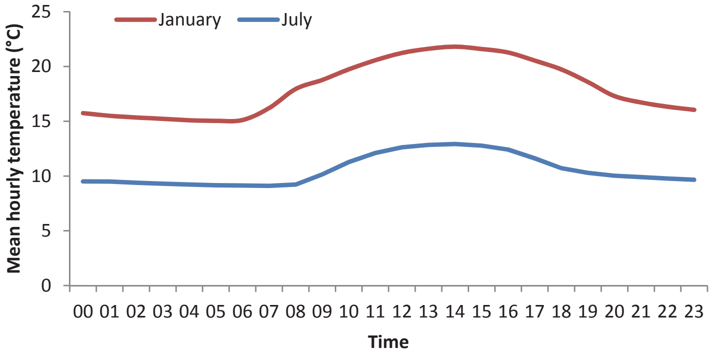


Figure 19. Mean hourly temperature at Kaikohe, January and July.

Earth Temperatures

Earth (soil) temperatures are measured once daily at 9 am at several Northland locations. Table 13 lists mean monthly earth temperatures covering the period 1981-2010 for a number of standard depths.

Although earth temperatures are particularly sensitive to specific site conditions (aspect, elevation, soil colour and type, etc.) no great spatial variations in earth temperatures are apparent in Northland. There is also some response to elevation at all depths. Earth temperatures at Kaikohe (204 m above sea level), the highest station, are approximately 2°C cooler at all depths than those at Kerikeri (79 m above sea level). Fluctuations in earth temperatures are less than air temperatures due to the slower heating and cooling rates of the soil. Highest temperatures are found in January or February and lowest in July or August. Figure 20 shows how earth temperatures change throughout the year for different depths at Kaitaia. The temperature cycle for 100 cm depth is more dampened than shallower depths.

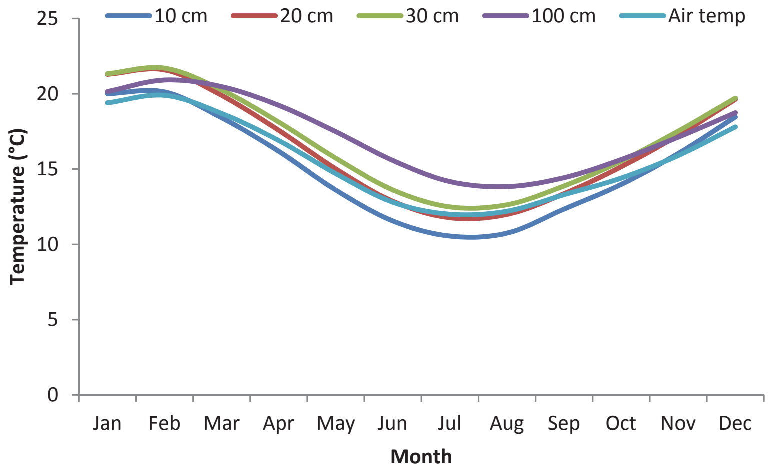


Figure 20. Average monthly 9 am earth temperatures for different depths at Kaitaia Observatory (air temperature for Kaitaia EWS, 140 m from Observatory site).

Table 13. Mean 9am earth temperatures at different Northland locations (°C).

Location		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ann**
Kaitaia Observatory (85m)	10cm	20.0	20.1	18.4	16.2	13.6	11.6	10.6	10.7	12.3	14.0	16.0	18.5	15.2
	20cm	21.3	21.6	19.9	17.6	15.0	12.9	11.8	12.0	13.4	15.2	17.2	19.6	16.5
	30cm	21.3	21.7	20.3	18.1	15.7	13.6	12.5	12.6	13.9	15.5	17.5	19.7	16.9
	100cm	20.1	20.9	20.5	19.2	17.5	15.6	14.2	13.8	14.4	15.6	17.1	18.7	17.4
Kaikohe AWS (204m)	10cm	18.1	18.4	16.9	15.3	13.4	11.1	9.9	10.0	11.5	12.9	14.8	17.1	14.1
	20cm	19.3	19.7	18.2	16.3	14.4	12.1	11.0	11.1	12.3	13.8	15.7	17.9	15.2
	50cm	19.5	20.1	19.1	17.5	15.5	13.4	12.0	12.2	13.1	14.3	16.1	18.1	16.0
	100cm	18.7	19.5	19.2	18.2	16.8	15.2	13.8	13.3	13.7	14.6	15.8	17.3	16.3
Kerikeri EWS (79m)	10cm	20.9	20.6	18.6	16.0	13.2	10.7	9.5	10.3	12.5	14.8	17.1	19.6	15.2
	20cm	22.4	22.4	20.4	17.7	14.8	12.4	11.1	11.8	13.7	16.0	18.5	20.9	16.8
	30cm	22.7	22.7	21.0	18.4	15.7	13.3	11.9	12.6	14.3	16.7	19.1	21.3	17.2
	100cm	20.0	20.9	20.5	19.4	17.7	15.7	14.1	13.7	14.2	15.5	17.0	18.4	17.1
Dargaville 2 (15m)	10cm	19.5	19.2	18.0	15.2	12.5	10.8	9.7	10.4	12.1	14.2	16.5	18.7	14.7
	20cm	20.1	19.9	18.4	15.7	13.1	11.5	10.3	10.9	12.3	14.2	17.0	19.2	15.2
	30cm	20.9	20.6	19.1	16.5	13.9	12.2	10.9	11.4	12.8	14.7	17.5	19.7	15.8

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, when air temperature measured in a screen by a thermometer 1.3 m above the ground falls below 0°C, are rare in most parts of Northland. Ground frosts are recorded when the air temperature 2.5 cm above a clipped grass surface falls to -1.0°C or lower. Ground frosts can be quite frequent in Northland, especially in sheltered inland areas. However many recorded ground frosts are restricted to a very shallow layer just above the surface and do not seriously affect plant life. 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, for the period 1981-2010. Data on air temperatures (mean daily, monthly minima and extreme minima) can be obtained from Figure 18.

Table 14. Occurrences of frosts and grass minimum temperatures in Northland.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Kaitaia Observatory	a	12.7	13.1	11.6	10.4	8.7	6.9	6.1	6.1	7.3	8.4	9.5	11.4	9.4
	b	2.2	4.4	2.5	1.3	0.6	-1.9	-3.4	-1.9	-1.0	0.0	0.3	2.1	-3.4
	c	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.5
	d	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kerikeri EWS	a	11.5	12.2	10.7	8.8	6.7	4.4	3.7	3.8	5.3	6.6	8.3	10.1	7.6
	b	0.6	1.8	-0.5	-1.5	-2.9	-6.8	-5.0	-3.5	-2.2	-2.1	-0.2	-1.1	-6.8
	c	0.0	0.0	0.0	0.0	0.2	3.0	3.8	2.7	0.9	0.3	0.0	0.0	10.7
	d	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.4
Waipoua Visitor Centre	a	11.5	11.2	10.9	8.6	6.6	4.9	3.9	4.2	5.1	6.4	8.6	9.7	7.7
	b	4.6	2.0	0.5	0.3	-1.0	-5.2	-4.5	-3.0	-3.0	0.0	1.4	1.0	-5.2
	c	0.0	0.0	0.0	0.0	0.1	1.8	3.9	1.6	1.0	0.0	0.0	0.0	11.6
	d	0.0	0.0	0.0	0.0	0.0	0.5	1.3	0.1	0.1	0.0	0.0	0.0	1.7
Dargaville 2	a	11.6	12.3	10.5	9.0	7.0	5.4	4.7	5.0	5.9	7.7	9.2	10.5	8.2
	b	1.0	1.6	0.1	-4.2	-5.3	-7.2	-6.0	-4.2	-5.0	-1.0	0.0	-1.0	-7.2
	c	0.0	0.0	0.0	0.3	0.7	2.3	3.9	1.6	1.8	0.1	0.0	0.1	14.6
	d	0.0	0.0	0.0	0.1	0.0	1.4	1.7	0.4	0.1	0.0	0.0	0.0	4.7

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

Most parts of Northland receive a total of about 2000 hours of bright sunshine each year (Figure 21). Parts of the Aupouri Peninsula and the east coast receive in excess of 2100 sunshine hours annually. The only area of Northland to receive appreciably less sunshine is the western flanks of the Tutamoe Ranges on the southwestern side of the peninsula. The highland areas of Northland receive approximately 1900 hours of bright sunshine per year. Figure 22 shows the monthly mean, maximum and minimum recorded sunshine for selected sites in Northland.

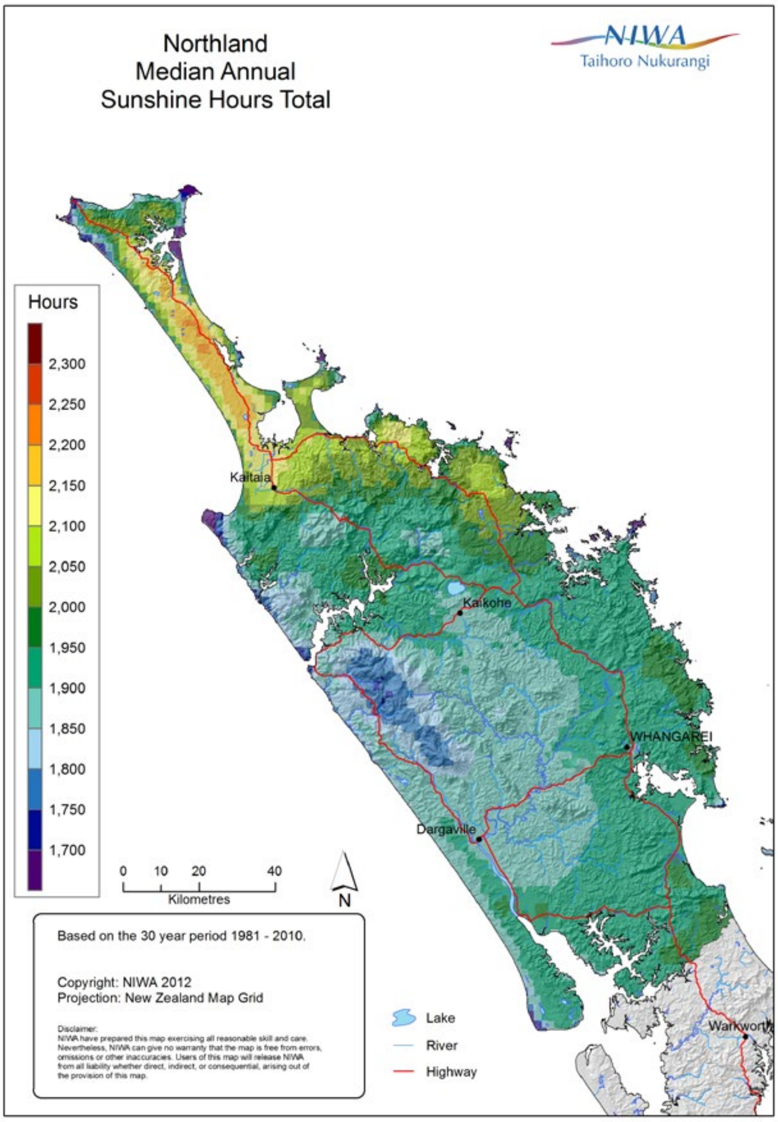


Figure 21. Median annual sunshine hours for Northland, 1981-2010.

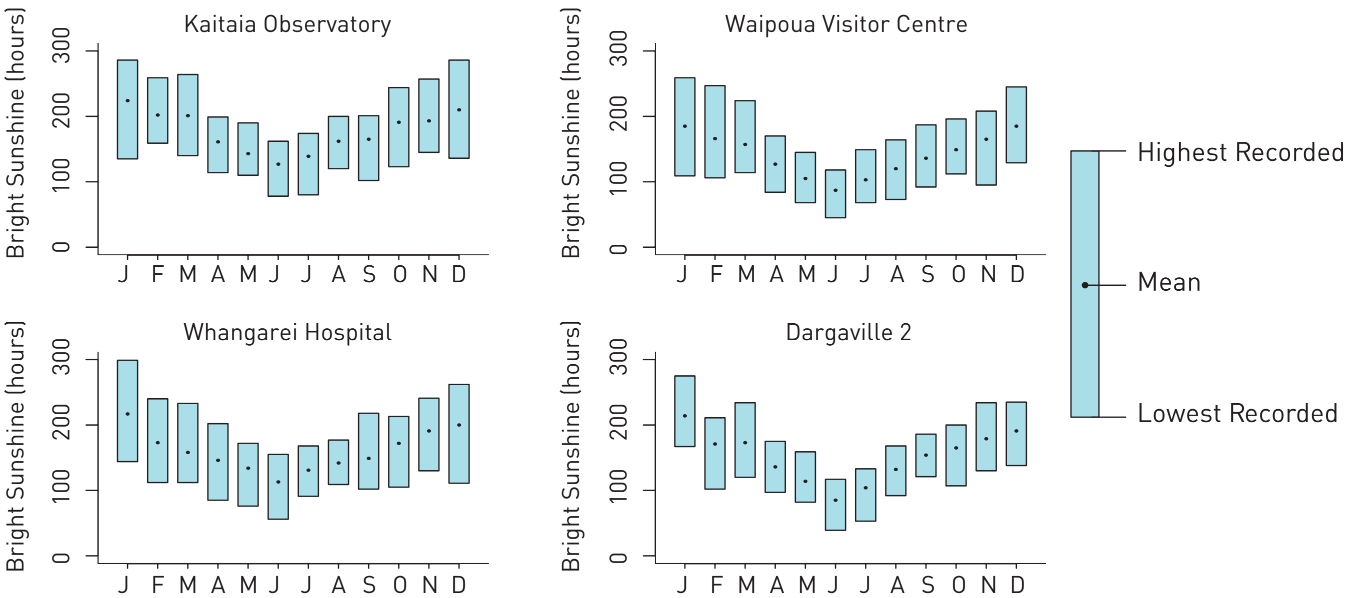


Figure 22. Mean, highest, and lowest recorded monthly sunshine for selected sites in Northland.

Solar radiation

Solar radiation records are available for a number of sites in Northland. Solar radiation is presented for Kaitaia, Kaikohe, and Whangarei for the 1981-2010 normal period. Insolation is at a maximum in December and January and a minimum in June. Table 15 shows mean daily solar radiation for each month for these three stations.

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

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Kaitaia Observatory	21.7	19.4	16.4	11.6	8.5	7.0	7.7	10.1	13.5	16.9	19.9	22.1	14.5
Kaikohe AWS	20.5	18.2	15.3	11.0	8.2	7.1	7.5	9.8	13.3	16.5	19.2	20.6	13.9
Whangarei Aero AWS	21.4	18.2	15.5	11.1	8.2	7.0	7.4	10.1	13.6	17.0	19.6	20.4	14.1

UV (Ultra-violet radiation)

Ultra-violet radiation (UV) is not recorded at any stations in the Northland region. Table 16 and Figure 23 show the mean monthly UV Index at Leigh, the closest site to the Northland region, compared with Lauder, a site in Central Otago in the South Island. Leigh records higher UV levels than Lauder throughout the year due to Leigh's more northerly location, although at both sites, summer months record significantly higher UV levels than winter months. Figure 24 shows an example of a UV forecast for Whangarei, and indicates the levels of UV and times of the day where sun protection is required.

Table 16. Mean daily maximum UV Index at Leigh and Lauder.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Leigh	12.2	10.7	8.4	5.1	2.8	1.8	1.9	3.0	4.8	7.2	9.8	11.5	6.6
Lauder	10.4	8.9	6.0	2.9	1.3	0.8	0.9	1.7	3.3	5.2	7.9	10.0	4.9

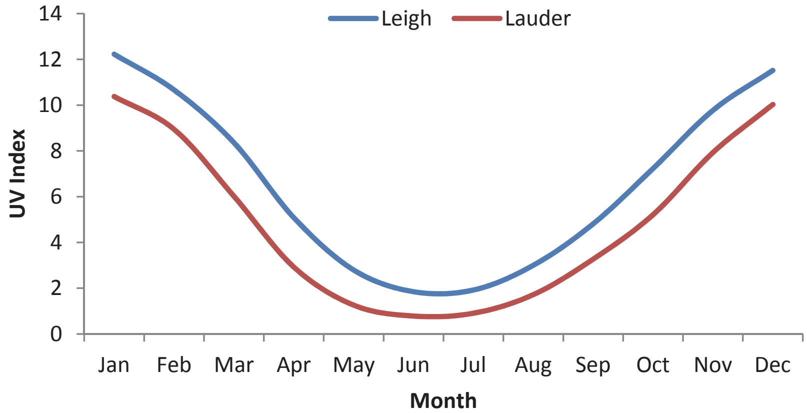


Figure 23. Mean monthly maximum UV Index at Leigh and Lauder.

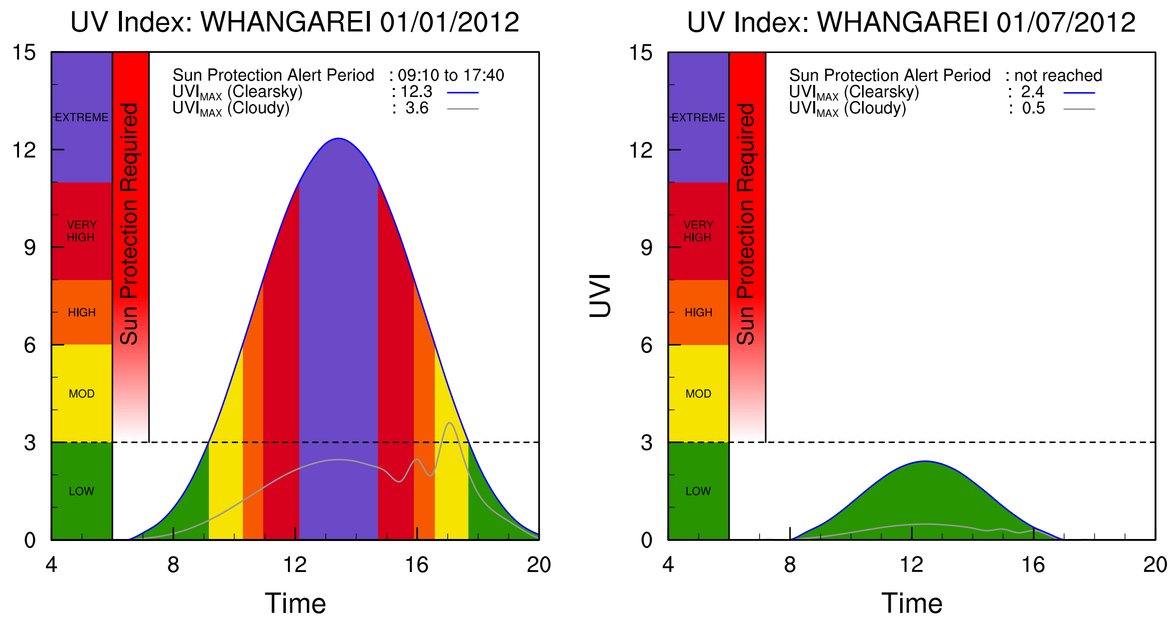


Figure 24. UV Index forecast for Whangarei, January and July.
Source: http://www.niwa.co.nz/our-services/online-services/uv-ozone

Fog

The frequency of fog in Northland is variable, ranging from an average of 47 days with fog per year at Cape Reinga and Dargaville to only twice per year at Glenbervie Forest. Although fog can occur at any time of the year it is recorded most frequently between March and August.

Radiation fogs are the most frequent and these tend to form under anticyclonic conditions when skies are clear and there is little wind. Such fogs usually clear by 9 am.

Widespread sea fog and low stratus is also recorded at times. These can be advected over land and occur particularly during humid northeast airstreams on the east coast, or humid northwestern airstreams on the western coast. This type of fog tends to be more persistent than radiation fog but even so seldom stays for longer than one day. The average number of days with fog for selected stations is listed in Table 17.

Table 17. Average number of days each year with thunder, fog, and hail, from all available data.

Location	Thunder	Fog	Hail
Cape Reinga	4	47	1
Kaitaia Observatory	15	24	4
Kerikeri EWS	6	5	0
Waipoua Visitor Centre	6	3	5
Glenbervie Forest	3	2	1
Whangarei aero	2	11	0
Dargaville 2	4	47	1

Severe convective storms

Thunderstorms

Thunderstorms occur throughout the year but days of thunder are most frequent between May and August when cold, unstable air masses cross the region. Western and central areas have more thunderstorm days than areas on the eastern side of the peninsula. Average occurrences vary from about 15 each year at Kaitaia to 2 thunderstorms per year at Whangarei. The average number of days with thunderstorms each year for selected stations is listed in Table 17. It is highly likely that not all thunderstorm episodes are detected.

Hourly weather observations from Kaitaia Airport show a diurnal variation in thunderstorm occurrence. In summer, there is a pronounced maximum in the afternoon, while in winter most thunderstorms occur during the night and morning (Revell, 1984). This type of diurnal variation pattern occurs over much of northern Northland. Over the rest of the region thunderstorms are most frequent during the afternoon in all four seasons.

Hail

Hailstorms occur on about two days each year in Northland, although this varies from an average of five days a year at Waipoua Forest to less than once in five years at Whangarei. As with thunderstorms, many hail storms could also pass unnoticed. Days with hail are most frequently recorded between May and October when ninety percent of hailstorms in the region occur, and are least likely to occur between January and April. The average number of hailstorms reported each year is listed in Table 17.

Tornadoes

Tornadoes in New Zealand are much smaller than those that occur in the USA, with paths typically in the order of ten to thirty metres wide and between one and five kilometres in length. They are reported infrequently in Northland, where only seven damage-causing tornadoes were noted during the twelve year period from 2001 to 2012. However, because of their local and highly transient nature, many probably pass unnoticed. Tornadoes occasionally cause damage when they travel through urban areas, such as in Kaitaia on 4 July 2009. On that occasion a small tornado approached Kaitaia from the west coast during a period of intense frontal activity. The tornado travelled rapidly through the southern part of the town, removing roof tiles and smashing windows of about 20 houses, as well as the hospital. Many trees were also uprooted, some crushing cars.

Sea swell and waves

In enclosed waters such as the Whangarei, Kaipara, and Hokianga Harbours it is unlikely that the wind generated waves ever exceed two metres. This is because the winds to generate such waves would need to be either a steady wind of 70 km/hr or more (a very rare event in Northland), or would require a much longer fetch than the enclosed harbours provide.

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 18.

Much of the swell that affects the west coast of New Zealand originates in the ocean to the south of Australia.

On the west coast of Northland, the most frequent swell direction is from the southwest, occurring nearly 40 percent of the time (Gorman et al., 2003). The frequency of swells of less than one metre is about 20 percent, while swells over two metres occur approximately 35 percent of the time. Heavy southwest swells are particularly noticeable in winter and spring.

Table 18. Generated wave heights associated with specific wind speeds. Assumes a fetch length of 500 km with unlimited 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+

On the east coast of Northland, swells from an easterly or northeasterly direction tend to predominate. These can originate from tropical cyclones well to the north of New Zealand or from anticyclones far to the east. Of all swells observed on the eastern coast the frequency of those less than one metre is about 40 percent, while for those greater than two metres is 8 percent (Gorman et al., 2003).

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 degree-days (thermal time), evapotranspiration (leading to soil moisture balance), rainfall extremes, and relative humidity. Some of these parameters and their uses are discussed in the following paragraphs.

Vapour pressure and relative humidity

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

Vapour pressure is the part of 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 19.

Relative humidity is high in all seasons throughout the region due to the influence of the surrounding sea and the lack of any large mountain masses. Stations on the western side of the peninsula and those very close to the sea (e.g. Cape Reinga) tend to have slightly higher humidity than those on the east or inland. Table 20 gives the average relative humidity at 9 am for selected stations in Northland.

Table 19. Mean monthly/annual 9 am vapour pressure (hPa) for selected Northland stations.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cape Reinga	17.5	18.2	16.9	15.9	14.0	12.4	11.9	11.6	12.7	12.6	13.9	16.3	14.5
Kaitaia Observatory	18.1	18.3	16.9	15.8	14.0	12.5	11.8	11.9	13.0	13.5	14.5	16.8	14.8
Kaikohe AWS	17.4	18.0	16.5	15.3	13.7	11.9	11.3	11.4	12.3	13.1	14.1	15.9	14.2
Kerikeri Airport	17.3	17.6	16.6	15.1	13.3	11.6	10.9	11.3	12.3	12.7	14.0	16.0	14.0
Whangarei Airport	17.8	18.4	17.1	15.9	14.1	12.1	11.5	11.5	12.6	13.1	14.1	16.2	14.5
Dargaville 2	18.5	19.0	17.6	15.8	13.4	12.0	11.5	11.6	12.7	13.8	15.0	17.0	14.8

Table 20. Mean monthly/annual 9 am relative humidity (%) for selected Northland stations.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cape Reinga	83	84	81	81	81	80	82	81	82	79	81	84	82
Kaitaia Observatory	87	88	87	87	89	90	90	88	87	86	84	85	87
Kaikohe AWS	86	88	87	88	89	89	89	88	85	86	84	83	87
Kerikeri Airport	86	89	88	88	90	91	91	89	86	83	83	83	87
Whangarei Airport	80	84	84	86	88	89	89	85	81	81	77	78	83
Dargaville 2	83	87	85	85	87	89	89	86	83	82	81	80	85

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 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

Table 21. 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
Kaitaia Observatory	DE	74	55	37	15	1	0	0	0	0	1	24	48	254
	ND	15	12	11	7	1	0	0	0	0	0	6	11	62
	RO	7	16	5	16	45	105	129	92	62	21	6	6	510
	NR	0	0	0	1	4	11	13	11	6	2	1	0	52
Kaeo Northland	DE	62	39	25	10	1	0	0	0	0	0	21	44	202
	ND	13	10	8	5	1	0	0	0	0	0	5	10	52
	RO	15	18	31	50	80	136	167	129	92	38	22	9	787
	NR	1	0	1	2	6	10	12	10	6	3	1	1	53
Rawene 2	DE	60	51	25	10	0	0	0	0	0	0	13	38	198
	ND	14	13	8	5	0	0	0	0	0	0	4	9	54
	RO	7	9	9	16	51	113	125	100	57	22	11	6	527
	NR	0	0	0	2	5	13	15	13	7	3	1	1	61
Kerikeri EWS	DE	50	31	15	7	0	0	0	0	0	0	14	34	151
	ND	11	8	5	4	0	0	0	0	0	0	4	8	40
	RO	27	25	44	62	97	153	161	145	105	55	32	19	925
	NR	1	1	1	3	6	11	13	10	7	4	2	1	60
Whangarei aero	DE	75	51	29	12	1	0	0	0	0	3	38	61	268
	ND	16	12	9	6	1	0	0	0	0	1	9	13	67
	RO	3	0	34	23	48	79	157	80	52	11	15	11	514
	NR	0	0	1	2	5	10	13	9	5	1	1	1	47

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

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 21, for a number of sites in Northland.

It can be seen from this table that Northland has on average about 55 days between November and April when there is insufficient soil moisture to maintain plant growth without irrigation. There is adequate moisture available to maintain plant growth between May and October. Figure 25 shows region-wide variability in days of soil moisture deficit per year.

Potential evapotranspiration (PET) has been calculated for Kaitaia, Kaikohe, and Whangarei, using the Penman method (Penman, 1948). The monthly mean, minimum, and maximum PET values are listed in Table 22.

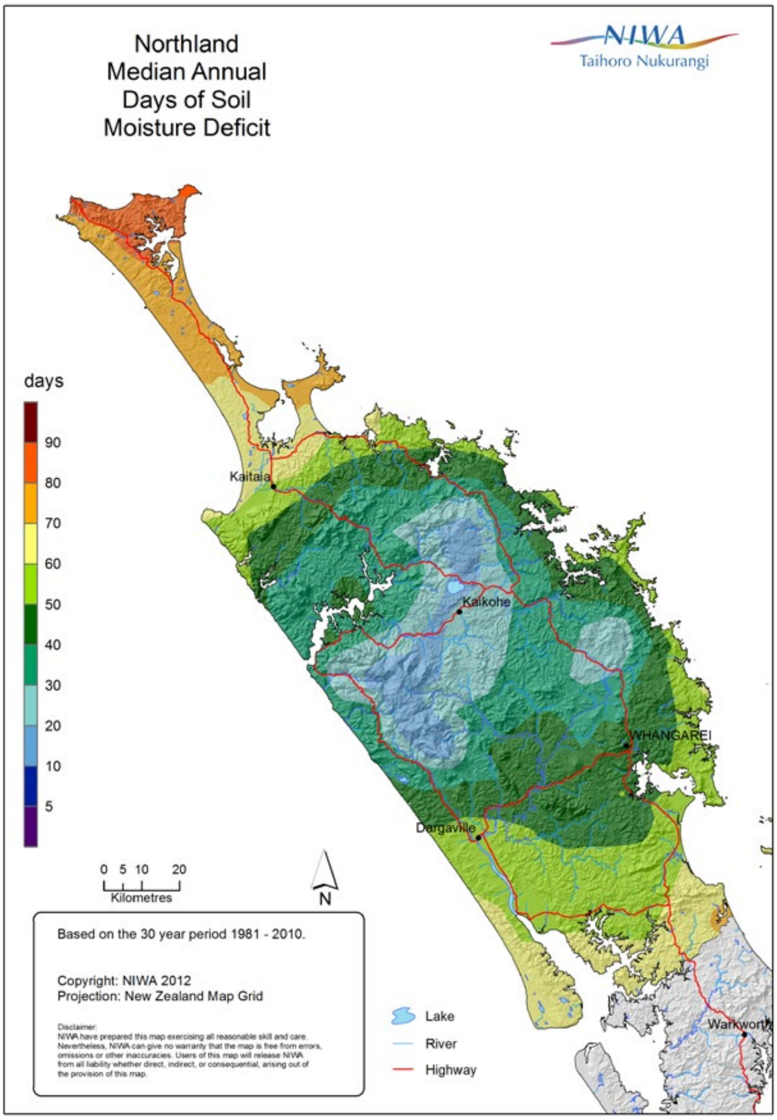


Figure 25. Northland median annual days of soil moisture deficit, 1981-2010.

Table 22. 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
Kaitaia Observatory	Max	174	134	122	81	53	38	44	59	77	107	127	156	
	Mean	145	120	105	67	46	32	38	52	70	98	116	136	1025
	Min	125	108	96	58	36	28	34	48	60	87	104	126	
Kaikohe AWS	Max	152	115	103	67	40	30	33	47	67	109	123	158	
	Mean	125	102	89	54	35	25	28	41	62	87	104	123	877
	Min	93	81	72	49	32	20	22	33	53	71	86	102	
Whangarei Aero AWS	Max	175	127	121	68	42	31	40	52	76	119	129	167	
	Mean	143	114	97	58	38	27	31	46	67	99	121	135	977
	Min	124	94	83	53	35	23	27	40	60	81	109	111	

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 23 lists the monthly totals of growing degree-day totals above base temperatures of five and ten degrees Celsius.

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.

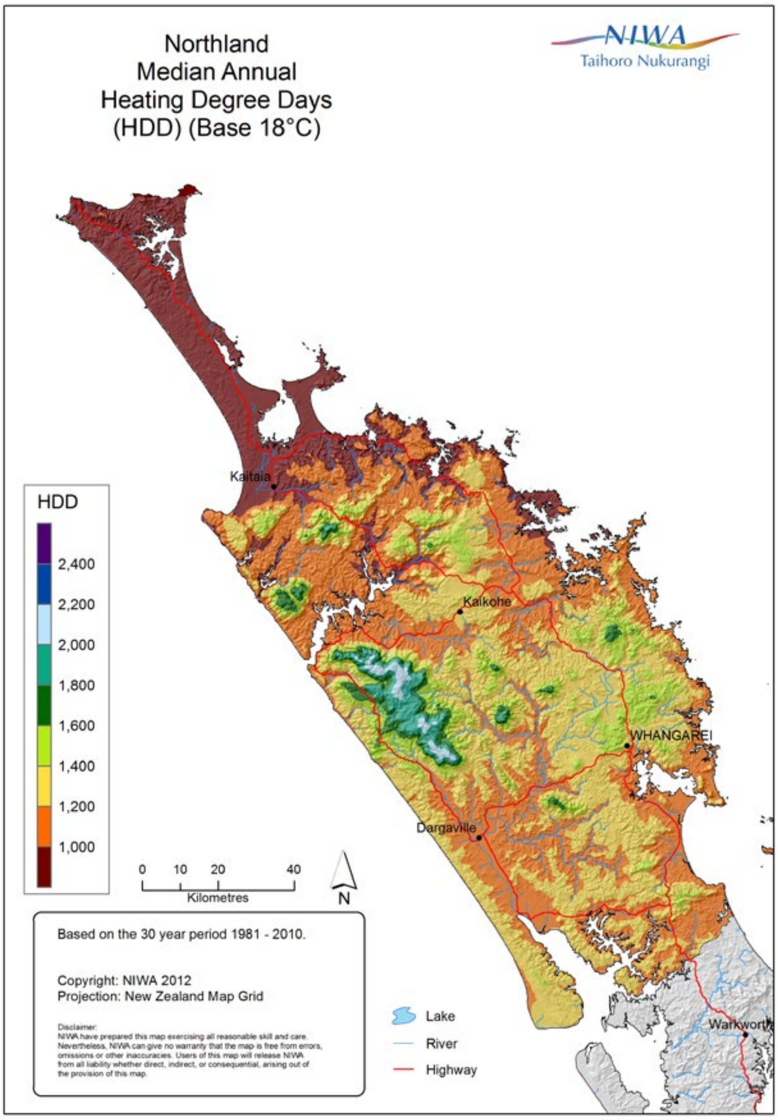


Figure 26. Median annual heating degree days for Northland, 1981-2010.

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

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Kaitaia Observatory	5°C	450	425	423	359	305	234	219	223	251	293	325	399	3904
	10°C	295	284	268	209	150	86	67	70	101	138	175	244	2086
Kaikohe AWS	5°C	420	398	393	325	276	205	189	194	224	266	298	374	3561
	10°C	265	256	238	175	121	61	44	47	76	111	148	219	1761
Kerikeri EWS	5°C	440	415	414	339	285	213	197	209	243	286	325	394	3762
	10°C	285	274	259	189	131	69	50	59	94	131	175	239	1956
Whangarei Airport	5°C	464	433	428	352	300	225	209	220	253	304	343	422	3953
	10°C	309	292	273	202	145	80	61	69	104	149	193	267	2143
Dargaville 2	5°C	337	362	348	336	273	209	195	204	229	284	321	395	3493
	10°C	289	278	251	186	120	69	54	56	82	129	171	240	1925

Conversely, heating degree days reach a peak in winter, where the demand for energy to heat buildings to 18°C is highest. Figure 26 shows region-wide variability in the number of heating degree days per year. The number of heating degree days tends to be lower in northern and coastal areas, compared with areas at higher elevations.

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

Location		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Ann**
Kaitaia Observatory	CDD	53	60	32	10	1	0	0	0	0	0	2	21	180
	HDD	5	2	12	41	100	156	184	180	139	110	67	25	1024
Kaikohe AWS	CDD	33	38	17	5	0	0	0	0	0	0	2	13	108
	HDD	15	8	27	70	128	185	214	209	167	137	93	42	1296
Kerikeri EWS	CDD	47	52	28	7	1	0	0	0	0	1	5	22	163
	HDD	9	4	18	59	119	177	206	194	148	117	69	31	1150
Whangarei Airport	CDD	65	68	36	12	2	0	0	0	0	1	7	36	228
	HDD	4	2	11	50	105	165	194	183	137	100	54	18	1023
Dargaville 2	CDD	51	57	28	10	0	0	0	0	0	1	3	24	175
	HDD	11	4	25	64	130	181	208	199	161	119	73	32	1208

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