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THE CLIMATE AND WEATHER OF NORTHLAND

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Note to Second Edition

This publication replaces the first edition of New Zealand Meteorological Service Miscellaneous Publication 115(2) written in 1964 by J. F. de Lisle and I. S. Kerr. It was considered necessary to update the original work as more data have since become available and also imperial units were used in the earlier edition. Kerr's description of the weather and typical weather sequences in Northland which was used extensively in the first edition has again been closely followed in this edition (Kerr, 1962).

The initial draft of this edition was prepared in the Auckland Weather Centre by R. W. Moir immediately before his retirement. Subsequently the work was completed in the Climatological Section, Wellington, by B. Collen and C. S. Thompson.

Previous issues in the N.Z. Met. Serv. Misc. Publ. 115 series were for the regions:

115(1)	Bay of Plenty (2nd edition)	(1984)
115(2)	Northland	(1964)
115(3)	Nelson	(1965)
115(4)	Otago	(1968)
115(5)	Hawkes Bay	(1971)
115(6)	Wanganui	(1972)
115(7)	Waikato-Coromandel-King Country	(1974)
115(8)	Gisborne	(1980)
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115(10)	Westland	(1982)
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115(15)	Southland	(1984)
115(16)	Wellington	(1984)

THE CLIMATE AND WEATHER OF NORTHLAND

Summary

Northland , with its northern location, low elevation and closeness 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 late summer and early 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.

1. 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 local government counties of: Otamatea, Hobson, Whangarei, Hokianga, Bay of Islands, Whangaroa and Mangonui.

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", while on the western side the Kaipara and Hokianga Harbours penetrate far inland (see Fig. 1 for all locations mentioned in the text and following tables). Most of the region lies below 150 metres, although some points in the central ranges are above 600 metres. 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 conditions and in recent years there has been rapid growth in specialized horticulture particularly in eastern districts (Ministry of Agriculture and Fisheries, 1980). 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.

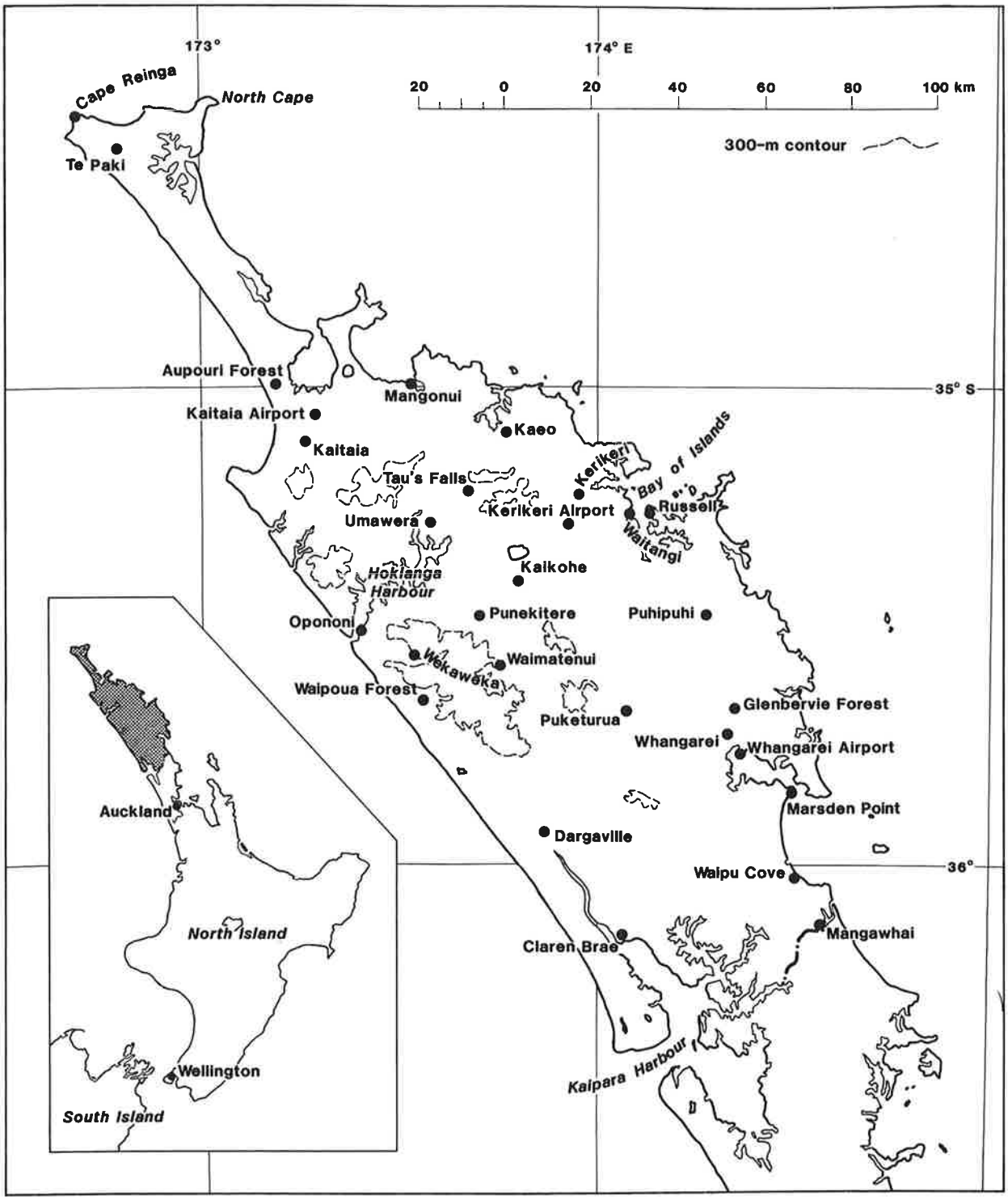

Fig. 1. Location of places mentioned in text

All climate data used in this publication were obtained from the archives of the New Zealand Meteorological Service.

2. THE WEATHER IN NORTHLAND

Weather systems affecting Northland

Northland is more often north of the tracks of anticyclone centres crossing New Zealand than are other districts. 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 the east and the next trough is approaching. The northeast winds have had a long passage over a warm water surface. 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. Also 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.

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 hurricanes) affect Northland about once or twice each year, between the months of December and April. They usually bring heavy rain and strong easterly winds.

Figure 2 shows, by months, the tracks of individual storms originating as tropical cyclones which affected the Northland area during the period between 1960 and 1980 inclusive.

The following list gives a brief description of the weather conditions associated with each cyclone recorded at Kaitaia.

Cyclone	Year	Dates	Significant weather at Kaitaia
January			
A	1967	30/1-3/2	Heavy rain. SW winds gusting to 87 km/hr.
B (Rose)	1971	3-4	Heavy rain on the 3rd. NW winds gusting to 102 km/hr.
February			
A	1963	19-21	Strong NE winds 20-21 gusting to 107 km/hr.
B	1969	4-7	Moderate to heavy rain on the 6th.
C	1967	6-10	Moderate rain on the 9th.

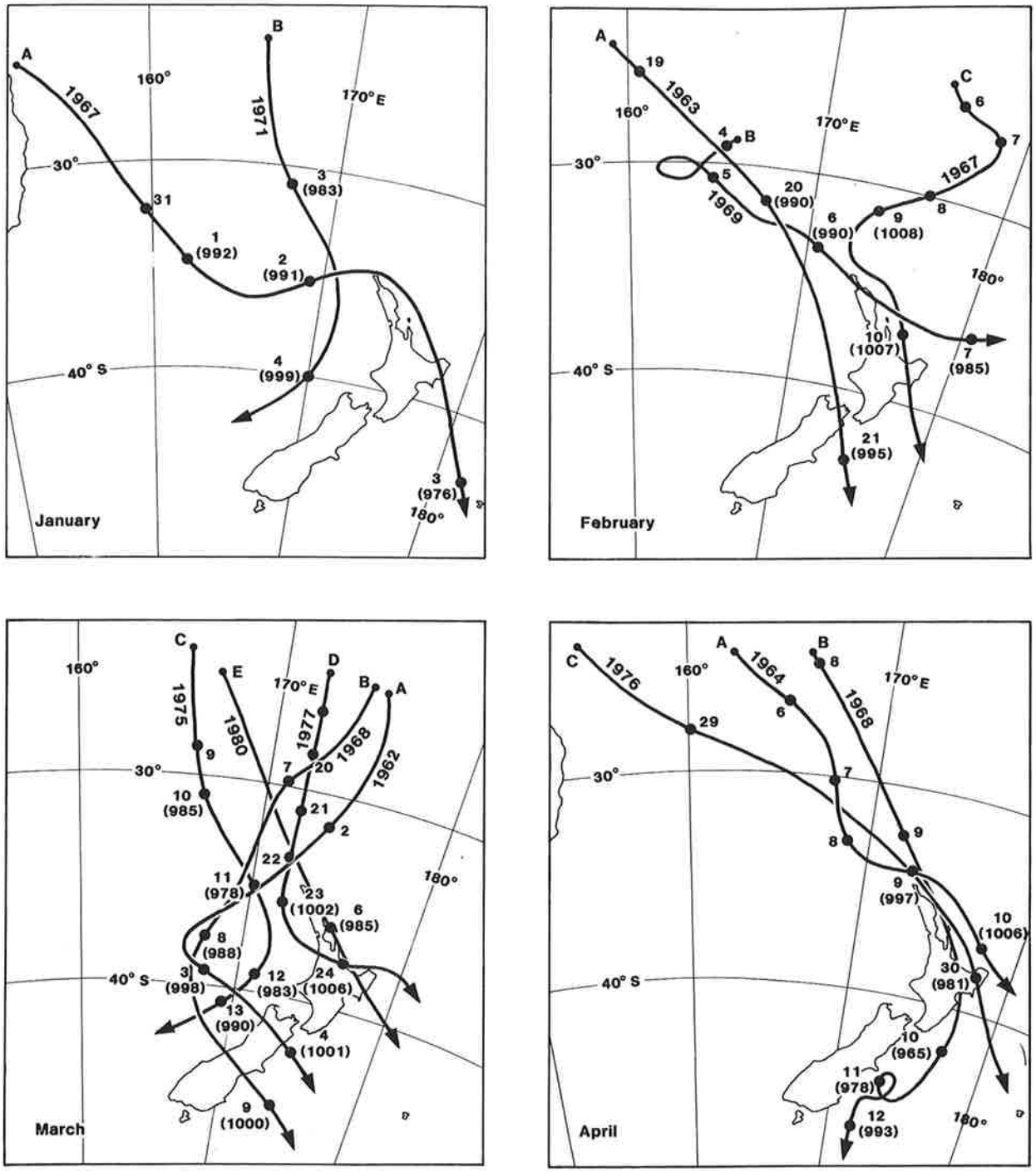

Fig. 2 The tracks of tropical cyclones in the New Zealand region during the period 1960-1980

Positions of the low pressure centres are shown for mid-day (NZ local time) with the date and, where possible, an estimate of the central pressure in millibars.

March

A	1962	2-4	Heavy rain and thunderstorms.
B	1968	6-9	Moderate rain. N winds gusting to 107 km/hr.
C (Alison)	1975	9-13	Moderate to heavy rain. N winds gusting to 102 km/hr, on the 11th.
D (Norman)	1977	19-24	Moderate rain. SE winds gusting to 81 km/hr.
E (Sina)	1980	6-10	Moderate rain on the 9th.

April

A	1964	5-10	Heavy rain on the 8th. E to NE winds gusting to 87 km/hr.
B	1968	8-12	Very heavy rain. SW winds to 98 km/hr on 10th.
C (Watorea)	1976	29-30	Heavy rain on the 29th. Gusts to 90 km/hr on the 30th.

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 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.

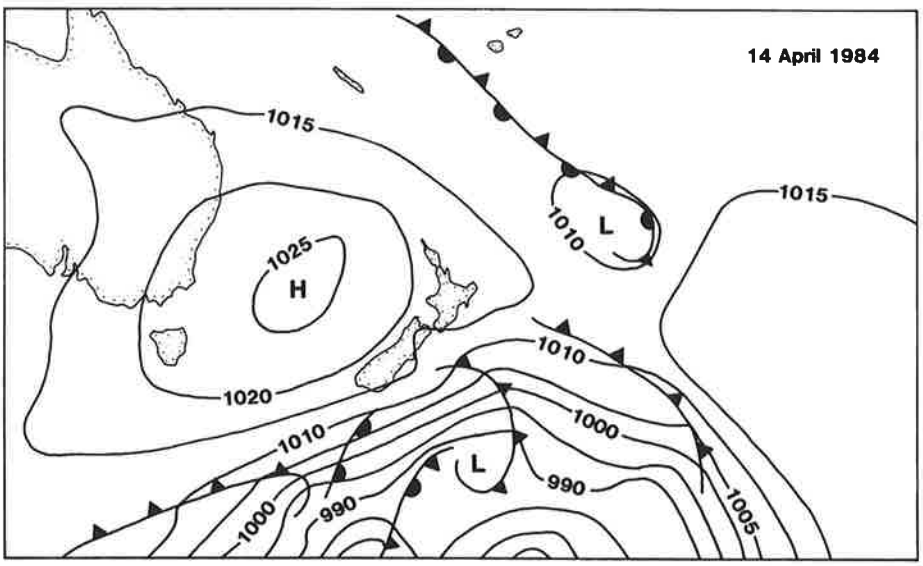

Fig. 3(a) Prolonged period of fine weather

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. Its following cold front moves along the southern edge of the anticyclone and over New Zealand, bringing only 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 Fig. (3a). No rain fell at Kaitaia from the 9th April 1984 until the 26th, a total of 17 days without rain. Daytime temperatures were generally between 2°and 3° higher than usual, although night time temperatures were a little cooler than usual due to strong outgoing radiation associated with clear skies.

Brief periods of rain. When a cold front orientated 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 3(b) illustrates this situation. The passage of this front brought rain between midnight and 7 a.m. on the 22nd September 1983 when 21.4 mm of rain fell at Kaitaia during this period.

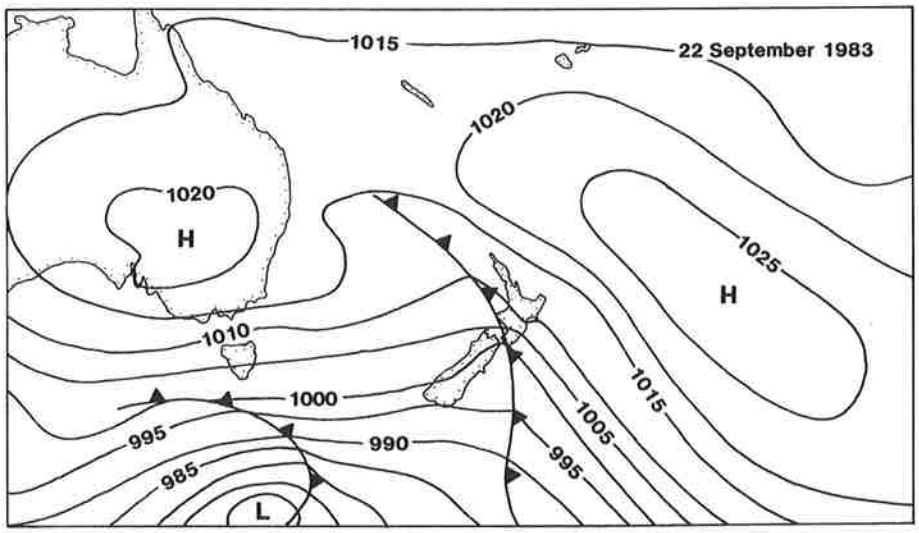

Fig. 3(b) Brief period of rainfall

When a depression develops in the trough between two anticyclones and subsequently moves over central and southern

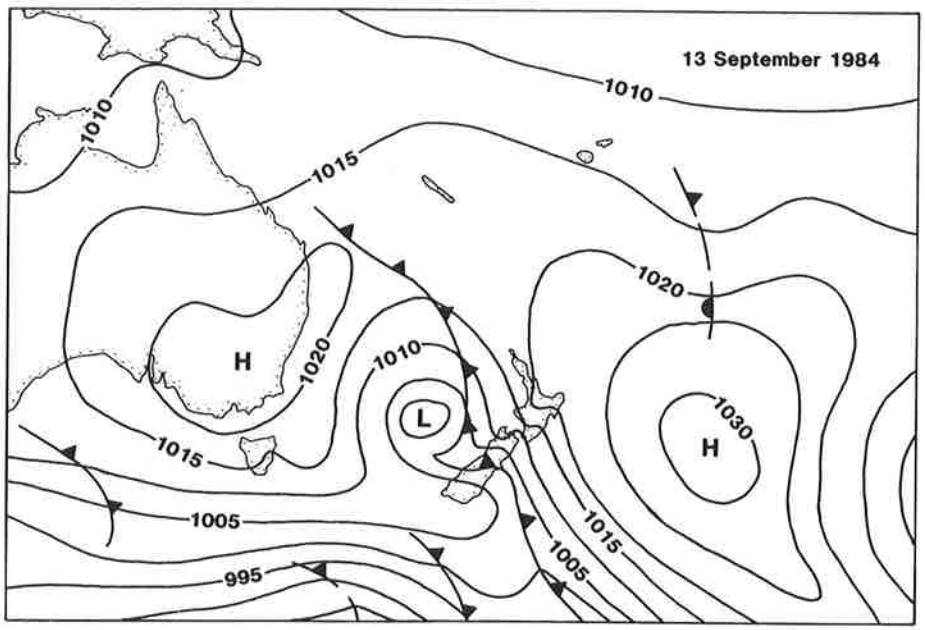

Fig. 3(c) Brief period of heavy rainfall

New Zealand, the rainfall in Northland is again brief but may be heavy. Figure 3(c) illustrates such a situation.

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

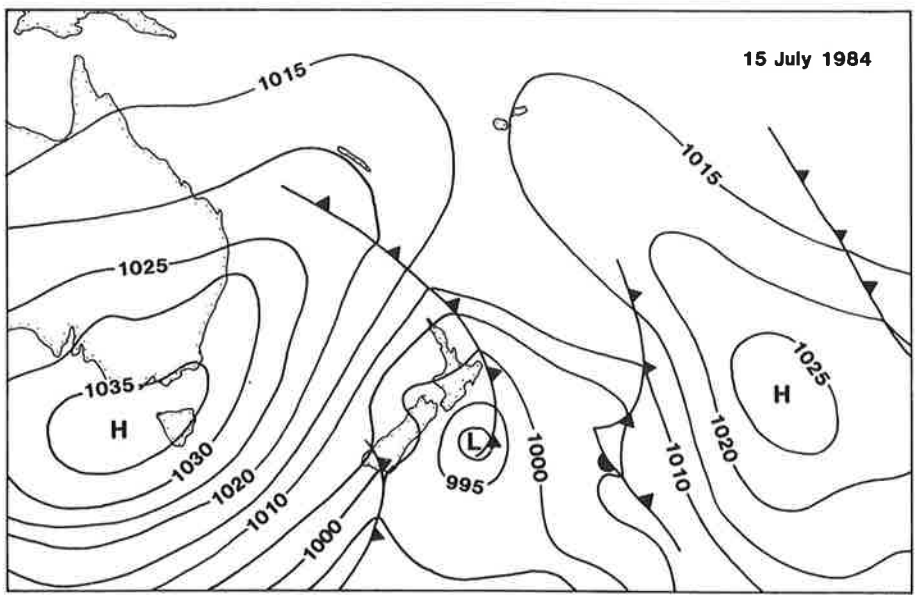

Fig. 3(d) Showers associated with a depression or cyclonic storm

(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 Fig. 3(d)

(ii) When the track of an anticyclone lies well to the south of Northland the district 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

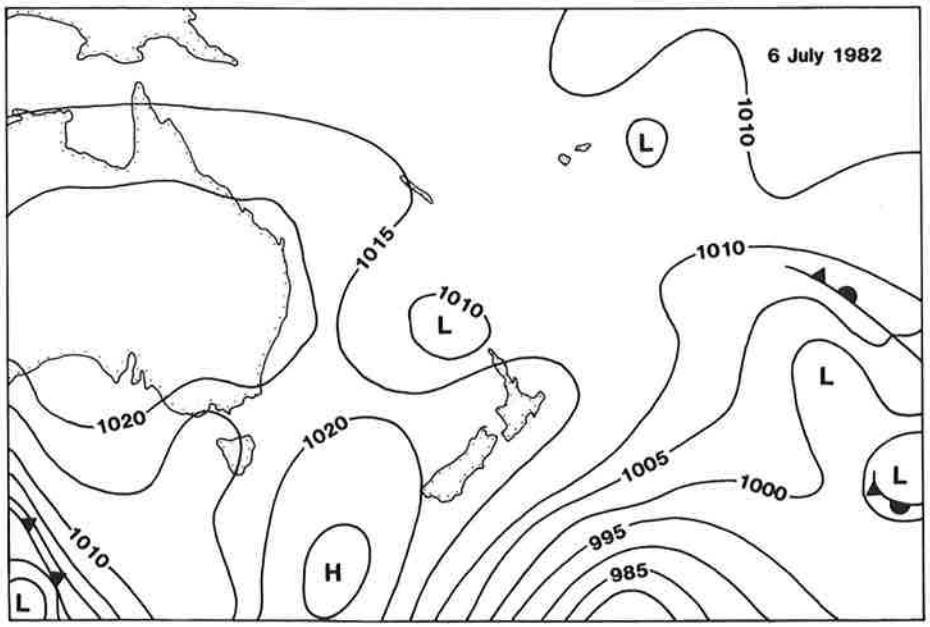

Fig. 3(e) Showers associated with a trough of low pressure

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 Fig. 3(e).

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 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 Fig. 3(f).

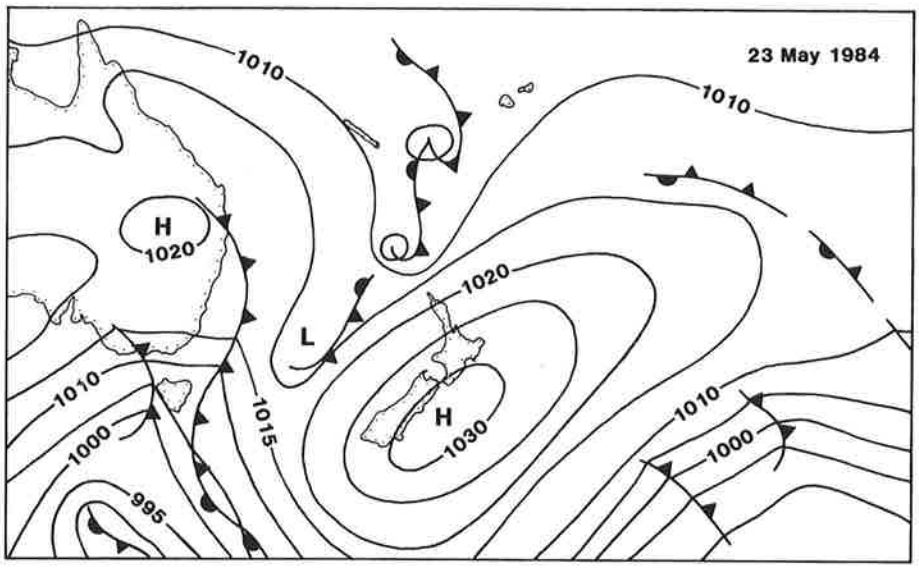

Fig. 3(f) Prolonged heavy rainfall associated with a stationary anticyclone

Other situations that can lead to prolonged rainfalls are illustrated in Figs. 3(g) and 3(h). In Fig. 3(g) 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 the 25th October had become stationary) persistent rain fell in Northland.

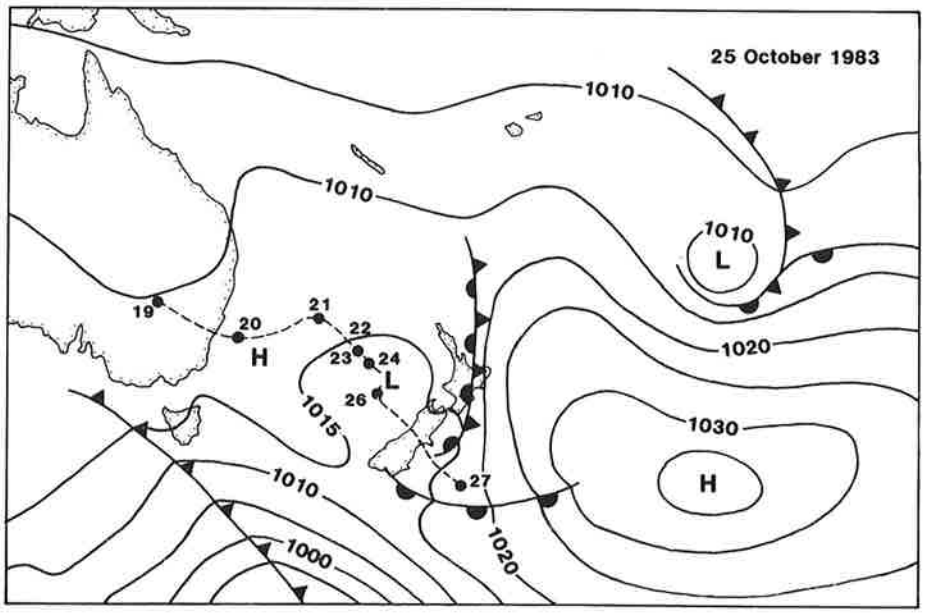

Fig. 3(g) Prolonged heavy rainfall

Figure 3(h) 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 Fig. 3(f) may also be accompanied with damaging winds.

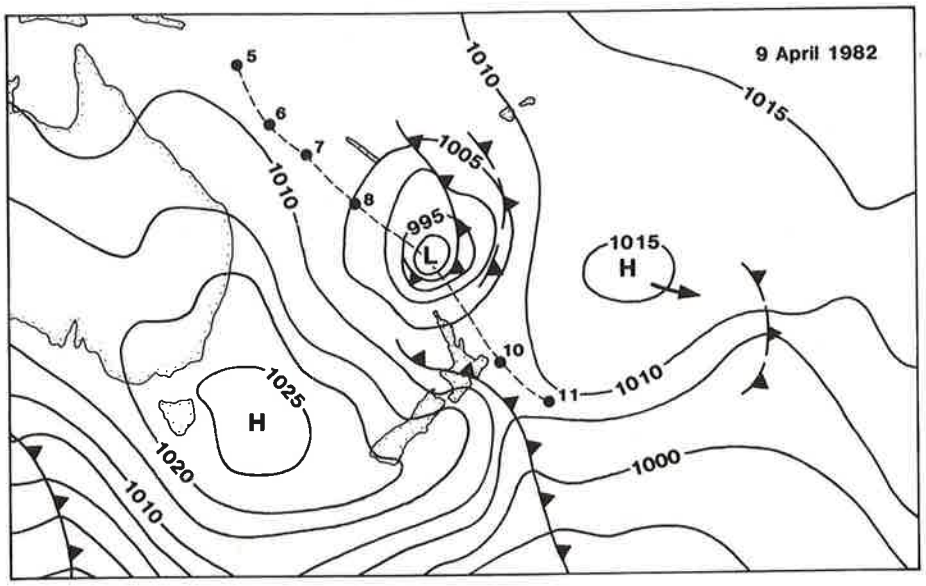

Fig. 3(h) Prolonged heavy rainfall associated with a severe depression passing over Northland

3. CLIMATIC ELEMENTS

Wind

The airflow over Northland is predominantly from the south-west (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 south-west. 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 districts in summer and early autumn. Figure 4 shows mean annual wind frequencies (percent) 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 area. 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

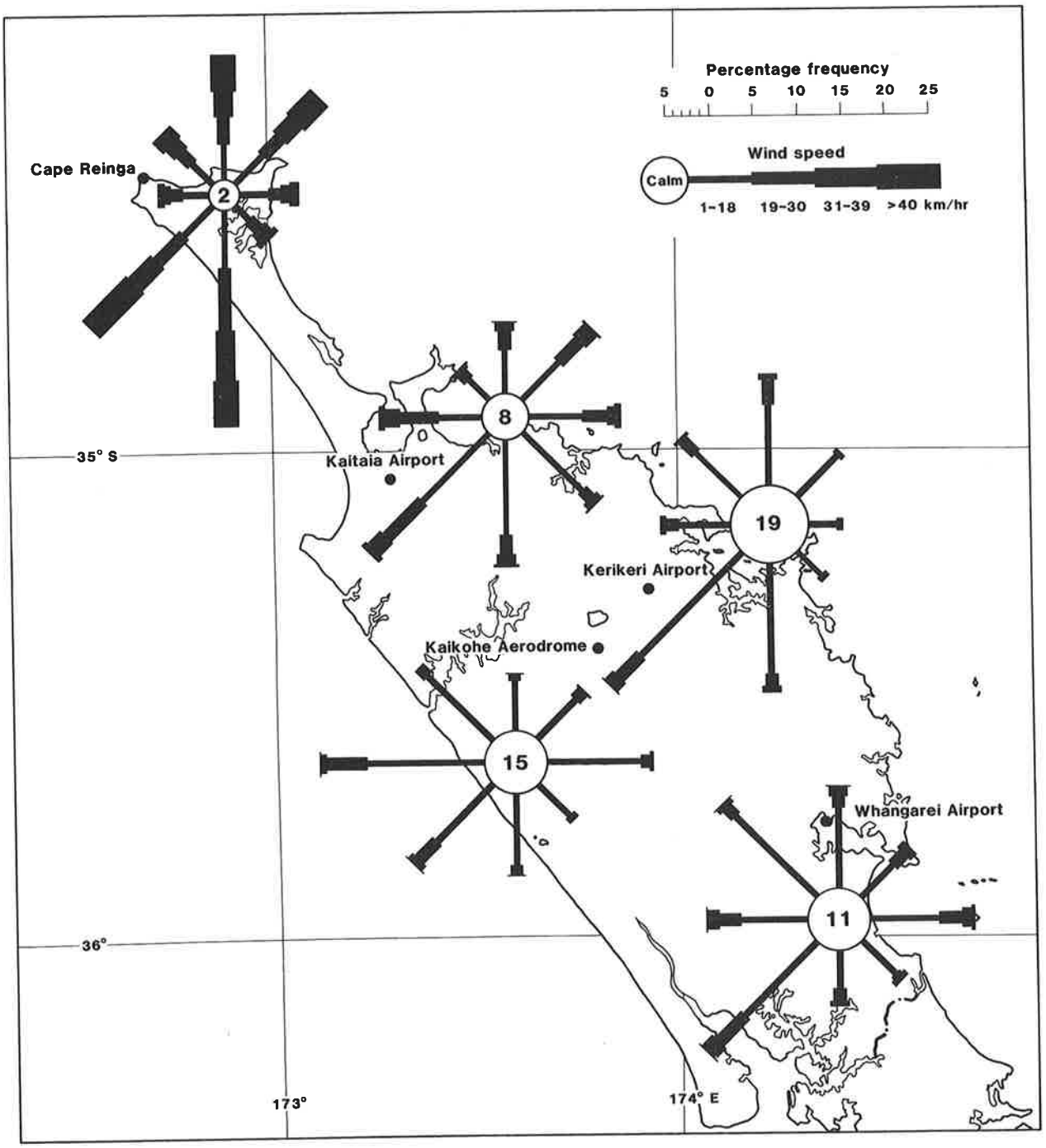

Fig. 4. Mean annual wind frequencies (percent) of surface wind directions found from hourly observations. (Locations shown are from north to south; Cape Reinga, Kaitaia Airport, Kerikeri, Kaikohe and Whangarei Airport.)

from Cape Reinga and Mokohinau Island, where speeds are around 30 km/hr*. Areas that are exposed to most winds but receive some sheltering, such as Marsden Point and 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 Airports about 10 km/hr. Table 1 gives mean monthly wind speeds for selected stations in Northland.

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

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cape Reinga (1961-1979)	26	27	28	30	31	33	35	34	32	30	29	28	30
Kaitaia Airport (1950-1980)	15	15	15	15	15	16	16	16	16	17	16	15	16
Kerikeri Airport (1964-1966)	8	6	7	7	10	11	12	13	11	13	11	8	10
Punakitere (1969-1975)	10	11	10	10	10	11	11	10	11	12	11	11	11
Kaikohe Aerodrome (1956-1961)	11	9	9	9	11	10	12	11	11	15	12	11	11
Whangarei Airport (1958-1963)	10	9	9	9	9	10	11	10	11	12	9	9	10
Marsden Point (1969-1978)	17	17	17	18	17	18	19	18	19	18	17	18	18
Mokohinau Lighthouse (1961-1979)	27	28	29	32	33	36	37	35	33	30	29	28	31

Spring is generally the windiest season except in exposed places such as Cape Reinga and Kaitaia Airport where winter tends to be the windiest period. Summer and autumn are the seasons when the greatest numbers of calm days are recorded. Table 2 gives the seasonal proportion of strong winds and of calm conditions as a percentage of the annual total. (For example of all strong winds recorded at Cape Reinga 18 percent occurred in summer, 25 percent in autumn, 31 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.

* 1 km/hr equals 0.54 knots or 0.278 m/sec.

Table 2. Seasonal proportions of strong winds or calms

Location		Summer	Autumn	Winter	Spring
Cape Reinga	a	18	25	31	26
(1961-1978)	b	27	28	23	22
Kerikeri	a	6	18	28	47
(1964-1966)	b	31	26	21	22
Kaitaia Airport	a	19	22	31	27
(1962-1978)	b	28	28	22	22
Kaikohe Aerodrome	a	11	3	40	44
(1956-1961)	b	24	32	27	17
Whangarei Airport	a	17	23	28	32
(1958-1974)	b	20	30	30	20

a = percent strong winds
b = percent calm

Diurnal variation in wind speed is, as expected, well marked, with greatest wind speeds occurring in the early part of the afternoon. Table 3 gives average wind speeds at three hourly intervals for selected stations.

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

Location	0600	0900	1200	1500	1800	2100	0000	0300
Kaitaia Airport	14	17	23	24	18	13	13	13
Kaikohe Aerodrome	7	12	17	17	11	8	7	7
Kerikeri Aerodrome	6	12	16	16	16	8	6	6
Whangarei Airport	8	11	14	14	10	8	8	8
Marsden Point	15	19	23	24	19	15	15	14

Winds can be strong and gusty at times, especially in exposed coastal areas. There are only six stations in Northland from which records of wind gusts are available. 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 (speeds in excess of 63 km/hr) are recorded.

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

Location	Gusts 63km/hr	Gusts 96km/hr	Days of gale
Cape Reinga (1974-1980)	179	52	45
Kaitaia Airport (1954-1980)	59	3	1
Kaikohe Aerodrome (1954-1961)	28	1	1
Dargaville (1952-1982)			1
Whangarei Airport (1965-1976)	42	2	1
Marsden Point (1961-1978)	61	9	-

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 200km/hr (108 knots) at Cape Reinga on 8th April 1976 during the passage of a tropical cyclone. Maximum gusts recorded in the region are listed in Table 5.

Table 5. Highest recorded gusts

Location	Gust (km/hr)	Direction (deg.true)	Date
Cape Reinga (1974-82)	200	060	08/04/76
Kaitaia Airport (1950-82)	178	080	14/03/59
Kaikohe (1954-61)	128	090	14/03/59
Whangarei Airport (1954-82)	159	330	15/09/69
Marsden Point (1961-82)	154	050	28/06/77

Maximum gusts have been estimated for average return periods of five, ten, twenty and fifty years (i.e. the highest gust of 3 seconds duration expected once in five years, once in ten years etc.) and these are listed in Table 6.

Table 6. Estimated maximum gusts (km/hr) for selected return periods (years)

Location	5 Yrs	10 Yrs	20 Yrs	50 Yrs
Kaitaia	130	142	157	174
Whangarei	115	127	140	155
Kaikohe	118	129	139	152

Sea breezes are common on both coasts during the summer and autumn on days when there is no strong pressure gradient over the region. They may reach 20 to 30 km per hour when there is a marked difference between the sea temperature and the land temperature, especially in the afternoon. The diurnal variability of the land-sea temperature difference and interactions with the airflows associated with pressure gradients leads to considerable variation in the daily wind regime. 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 1200 mm in low-lying coastal areas. Figure 5 shows the distribution of mean annual rainfall based on 1941-1970 rainfall normals (a normal is an average or estimated average over a standard 30 year period).

Seasonal influences on distribution are also quite well defined. Table 7 lists monthly rainfall normals and percentage of annual total for the period 1941-1970 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 percent to 35 percent during these three winter months. 18 to 20 percent of Northland annual rainfall during the three summer months (December to February).

The distribution of monthly rainfall is shown in Fig. 6. The 10 percentile, 90 percentile and mean values for each month are shown along with maximum and minimum recorded values for several stations.

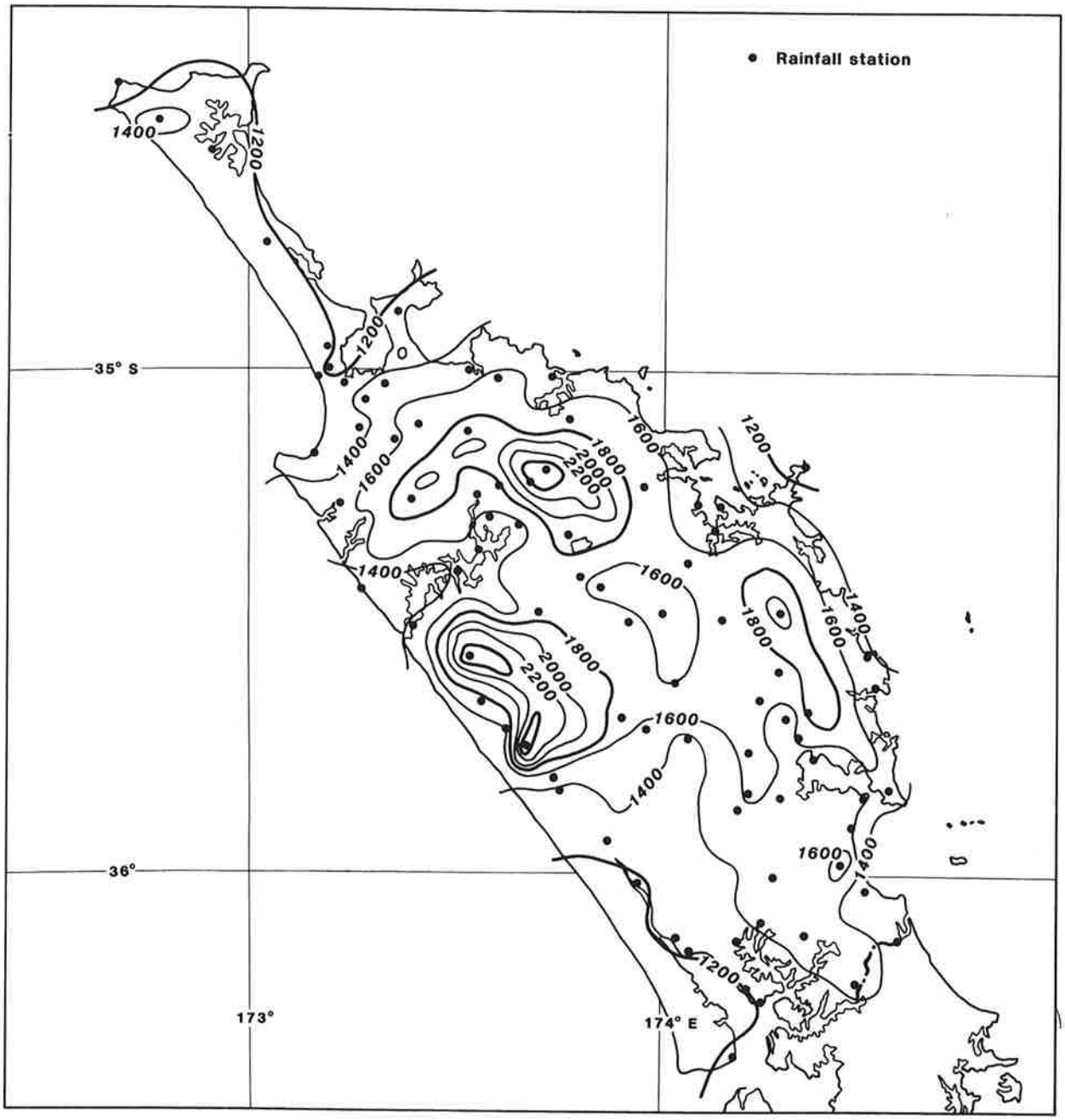

Fig. 5. Mean annual rainfall, 1941-1970

Table 7. Monthly/annual rainfall normals and percentage of annual total for each month

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cape Reinga	a	63	79	78	97	99	123	127	129	91	73	63	61	1083
	b	6	7	7	9	9	11	12	12	8	7	6	6	
Mangonui	a	76	108	91	119	149	173	152	173	123	107	84	92	1447
	b	5	8	6	8	10	12	11	12	9	7	6	6	
Kaitaia Airport	a	87	111	81	110	139	166	148	164	118	111	101	93	1429
	b	6	8	6	8	10	12	10	12	8	8	7	6	
Tau's Falls	a	115	207	180	202	228	278	237	267	207	194	132	150	2397
	b	5	9	7	8	10	12	10	11	9	8	5	6	
Opononi	a	70	97	94	128	142	178	149	172	126	115	100	96	1467
	b	5	7	6	9	10	12	10	12	9	8	7	6	
Kaikohe	a	91	143	133	133	209	191	156	205	145	125	105	130	1766
	b	5	8	7	7	12	11	9	12	8	7	6	7	
Waipoua Forest	a	72	111	108	137	166	203	176	180	140	149	111	104	1657
	b	4	7	6	8	10	12	11	11	8	9	7	6	
Waimatenui	a	90	155	125	167	211	257	226	231	165	163	130	129	2049
	b	4	8	6	8	10	13	11	11	8	8	6	6	
Dargaville	a	71	91	83	94	126	157	130	129	94	103	86	85	1249
	b	6	7	7	8	10	13	10	10	8	8	7	7	
Waitangi Forest	a	81	117	111	117	138	190	162	178	126	108	83	84	1495
	b	5	8	7	8	9	13	11	12	8	7	6	6	
Russell	a	73	123	106	123	145	170	159	172	121	100	81	86	1459
	b	5	8	7	8	10	12	9	12	8	7	6	6	
Glenbervie Forest	a	96	169	177	166	176	229	210	214	153	156	112	115	1973
	b	5	8	9	8	9	12	11	10	8	8	6	6	
Whangarei Airport	a	77	130	137	126	147	181	166	162	122	120	89	98	1555
	b	5	8	9	8	9	12	11	10	8	8	6	6	
Waipu Cove	a	81	97	107	115	123	168	148	141	100	101	95	92	1368
	b	6	7	8	8	9	12	11	10	7	7	7	6	
Claren Brae	a	90	75	90	94	121	146	136	119	99	101	90	78	1239
	b	7	6	7	7	10	12	11	10	8	8	7	6	

a = Rainfall normal in mm
b = Percentage of annual total/month

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 8 gives seasonal and annual variability for stations in Northland and for selected sites elsewhere for comparative purposes.

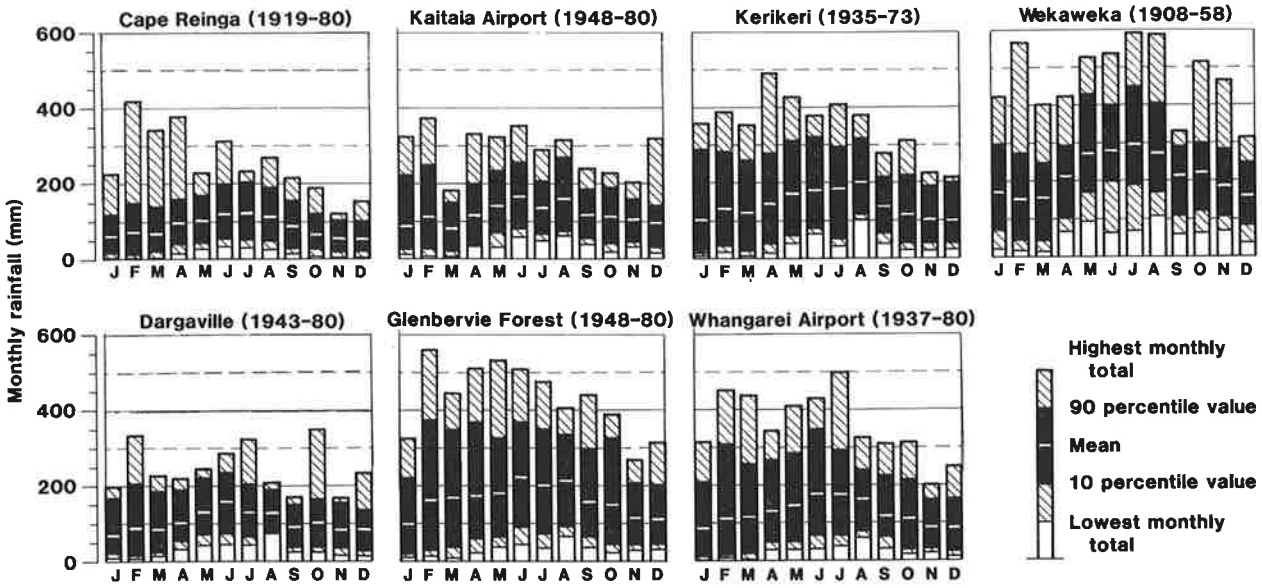

Fig. 6. Mean monthly rainfall

Table 8. Seasonal Variability of rainfall (Coefficient of variation)

Location	Summer	Autumn	Winter	Spring	Year
Cape Reinga	51	43	35	38	20
Kaitaia	50	35	23	26	18
Mangonui	48	42	31	27	19
Kerikeri	54	48	25	26	21
Kaeo	43	38	22	28	13
Waipoua Forest	43	35	18	23	13
Glenbervie	51	47	27	41	19
Whangarei	48	44	31	31	22
Auckland	46	37	27	28	19
Wellington	40	30	27	27	17
Christchurch	41	44	41	42	22
Westport	25	25	23	19	11

Rainfall variability over longer periods is indicated by rainfall deciles, as given in Table 9. The 10 percentile values show the accumulated rainfalls that will normally be exceeded in nine out of ten years, while the 90 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

Table 9. Rainfall deciles for consecutive months

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaitaia Airport												
1948-1979)												
One Month												
10 Percentile	22	25	19	38	74	81	66	74	53	42	49	31
90 Percentile	187	210	151	202	233	255	206	268	186	192	159	138
Three Months												
10 Percentile	148	198	203	270	294	337	292	269	237	202	163	117
90 Percentile	418	411	529	622	609	616	542	517	408	402	434	473
Six Months												
10 Percentile	513	564	605	634	641	645	555	485	379	384	415	425
90 Percentile	908	1035	1109	1067	1087	987	911	897	848	735	730	830
Twelve Months												
10 Percentile	1134	1131	1132	1078	1135	1169	1191	1158	1135	1143	1146	1141
90 Percentile	1719	1733	1689	1645	1654	1705	1672	1659	1717	1643	1699	1693
Dargaville												
(1943-1979)												
One Month												
10 Percentile	18	15	25	53	75	75	63	79	39	37	35	37
90 Percentile	169	204	189	190	221	237	204	191	153	164	155	138
Three Months												
10 Percentile	98	154	197	265	315	269	240	234	192	175	125	82
90 Percentile	390	396	432	553	566	575	486	467	401	384	347	410
Six Months												
10 Percentile	467	504	539	534	560	498	504	416	330	322	370	408
90 Percentile	816	904	1021	958	938	914	859	719	643	661	656	762
Twelve Months												
10 Percentile	1046	996	978	943	1012	1006	1001	1017	1029	1054	1018	1021
90 Percentile	1560	1595	1641	1589	1539	1595	1463	1424	1422	1448	1457	1495
Whangarei Airport												
(1937-1979)												
One Month												
10 Percentile	13	14	22	52	49	67	64	76	59	30	30	25
90 Percentile	210	268	264	269	286	352	296	243	225	215	161	166
Three Months												
10 Percentile	118	175	201	236	283	334	295	251	203	174	140	133
90 Percentile	506	566	652	716	760	730	632	519	517	420	399	483
Six Months												
10 Percentile	497	542	626	627	646	569	543	467	384	361	396	453
90 Percentile	1039	1217	1244	1250	1213	1071	972	937	869	855	875	984
Twelve Months												
10 Percentile	1225	1129	1106	1064	1088	1107	1128	1153	1139	1183	1213	1189
90 Percentile	1928	1968	1990	1899	1857	1899	1949	1933	1882	1922	1948	1945

Table 10. Average monthly raindays for Northland Region

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Cape Reinga	a	8	8	10	14	18	19	19	19	15	13	11	10	163
	b	6	6	7	10	13	14	15	14	10	9	7	7	118
	c	2	2	2	3	3	3	4	3	2	2	2	2	30
Mangonui	a	7	7	8	10	14	15	16	16	13	12	10	9	136
	b	7	6	7	9	12	13	14	14	12	11	8	8	121
	c	2	2	3	3	4	5	5	5	4	3	3	2	41
Kaitaia Airport	a	10	11	13	15	19	20	20	21	18	17	14	13	188
	b	7	8	8	11	13	15	16	15	13	12	11	9	138
	c	2	3	2	4	4	5	5	5	3	4	3	3	43
Tau's Falls	a	10	13	15	16	19	20	21	21	18	17	14	14	200
	b	8	11	12	12	14	16	17	16	14	13	10	11	154
	c	3	4	5	5	5	6	6	6	5	5	4	5	59
Opononi	a	10	9	11	15	18	22	21	21	19	16	14	13	189
	b	7	7	9	13	14	18	17	18	16	13	11	9	153
	c	2	2	3	4	4	5	4	5	4	4	4	3	44
Kaikohe	a	11	11	13	15	18	20	20	20	17	15	13	12	185
	b	8	8	10	11	11	16	16	14	15	13	10	10	142
	c	3	3	4	4	3	6	4	4	4	4	3	3	45
Waipoua Forest	a	12	10	12	16	19	21	21	21	18	17	15	13	196
	b	9	9	10	14	17	19	19	19	16	15	12	11	170
	c	3	3	3	5	5	7	6	6	5	4	4	3	54
Dargaville	a	10	10	11	15	18	20	20	20	17	16	13	11	184
	b	7	7	9	12	15	18	17	17	14	13	10	9	148
	c	2	2	2	3	4	5	4	4	3	3	3	3	38
Waitangi Forest	a	8	9	12	12	13	17	18	15	15	13	10	10	154
	b	6	8	9	10	10	13	13	12	12	10	8	8	119
	c	2	3	3	4	3	5	5	5	4	3	3	3	43
Puhipuhi	a	10	10	12	14	17	18	19	18	15	14	11	11	170
	b	8	9	10	12	14	15	16	16	13	12	10	9	144
	c	3	4	4	4	5	5	6	6	4	4	3	3	51
Whangarei Airport	a	9	10	13	15	18	19	19	19	17	15	12	11	177
	b	7	8	10	11	13	14	15	14	13	12	9	8	134
	c	2	3	3	3	4	4	4	4	3	3	3	3	39
Claren Brae	a	9	10	12	17	18	22	20	20	19	15	12	12	180
	b	6	8	9	13	14	17	17	15	15	12	9	9	144
	c	2	3	3	3	4	4	4	4	3	3	3	2	37

a = 0.1 mm or greater, b = 1 mm or greater, c = 10 mm or greater

stated. For example, using the table for Kaitaia Airport for three months it can be seen that in the three month period beginning in April, 270 mm or more of rainfall can be expected for nine years in ten, while a total of 622 mm or more should occur in only one year in ten.

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 140 in eastern coastal areas of the peninsula to over 200 in some western and inland areas. Table 10 lists the average number of days each month with 0.1 mm, 1.0 mm and 10 mm of rain for selected stations. The 1 mm and 10 mm raindays show the same geographic variability as the 0.1 mm rainday.

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 11 maximum short period rainfalls for periods of 10 minutes to 72 hours with calculated return periods are given for several stations

Table 11. Maximum short period rainfalls

Location		10min	20min	30min	60min	2hr	6hr	12hr	24hr	48hr	72hr
Kaitaia	a	23	36	44	77	88	127	160	163	186	229
(1939-1982)	b	40	16	30	100+	38	85	65	28	25	48
	c	18	29	35	50	65	91	117	132	158	175
	d	21	33	40	59	75	103	132	149	180	199
	e	24	39	47	69	88	119	152	171	208	230
Kerikeri	a	19	29	44	51	60	89	131	157	191	226
(1956-1973)	b	18	18	26	16	13	17	18	14	12	14
	c	18	27	36	46	58	84	120	150	186	214
	d	20	31	41	53	65	93	134	168	209	242
	e	23	36	49	62	75	105	151	191	239	277
Glenbervie Forest	a	23	33	44	75	85	134	180	228	309	358
(1949-1982)	b	40	20	35	65	34	39	40	18	34	23
	c	19	29	36	54	69	110	150	207	257	308
	d	21	33	40	61	78	123	166	230	287	349
	e	24	38	46	71	89	138	187	260	325	401

a = highest fall recorded, mm
b = calculated return period for a, in years
c = max. fall calculated to occur once in 10 years, mm
d = max. fall calculated to occur once in 20 years, mm
e = max. fall calculated to occur once in 50 years, mm

with autographic raingauges. Also listed in this table are the maximum rainfalls expected in 10, 20 and 50 years. These have been calculated from annual maxima recorded at each station, using the Gumbel method of calculation of extreme values (Coulter and Hessell, 1980).

Rainfall data are recorded on a daily basis (9am-9am) at stations throughout the region. Depth-duration frequency tables have also been calculated for some of those stations which have a suitably long record (N.Z. Met. Serv., 1980). A selection of these are given in Table 12. This table lists the maximum fall

Table 12. Frequency of heavy rainfalls, 24, 48 and 72 hour periods

Return Period (years)	2	5	10	20	50	Max
Cape Reinga (1919-1980)						
24 Hrs	74	113	138	163	194	239
48 Hrs	93	143	176	208	249	366
72 Hrs	99	152	188	222	267	389
Mangonui (1901-1980)						
24 Hrs	95	130	154	176	205	229
48 Hrs	112	153	181	207	241	330
72 Hrs	122	170	202	232	272	414
Opononi (1967-1980)						
24 Hrs	84	112	131	149	172	110
48 Hrs	109	143	165	186	214	153
72 Hrs	125	168	197	225	261	197
Dargaville (1905-1980)						
24 Hrs	76	105	124	142	165	216
48 Hrs	95	137	164	191	225	246
72 Hrs	102	144	172	199	233	246
Russell (1919-1980)						
24 Hrs	108	165	202	238	285	301
48 Hrs	137	198	239	278	329	343
72 Hrs	147	207	247	286	336	343
Whangarei Airport (1943-1980)						
24 Hrs	125	182	219	255	301	309
48 Hrs	154	212	250	286	334	369
72 Hrs	166	233	261	298	345	371
Puhipuhi (1905-1980)						
24 Hrs	141	193	228	261	304	350
48 Hrs	183	248	290	331	384	370
72 Hrs	202	270	316	359	415	400
Mangawhai (1917-1980)						
24 Hrs	91	136	166	194	231	236
48 Hrs	113	158	187	209	246	244
72 Hrs	121	169	202	217	255	249

expected in two, five, ten, twenty and fifty years for periods of 24, 48 and 72 hours. A correction factor has been applied during the calculations in order to convert the 9am-9am totals to apply to any 24, 48 or 72 hour period. The maximum rainfalls recorded at each station for each period are also listed.

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 are 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, although the longest on record lasted 71 days. This was recorded in Kerikeri from 12 December 1945 to 20 February 1946 and of the 71 days 63 consecutive days were without any rain (12 Dec. 1945 to 20 Feb. 1946). Other long dry spells include 58 days at Dargaville from 29 Dec. 1927, of which 37 consecutive days were without rain and 51 days at Mangonui from 7 Dec 1905, all of which were without rain.

Temperature

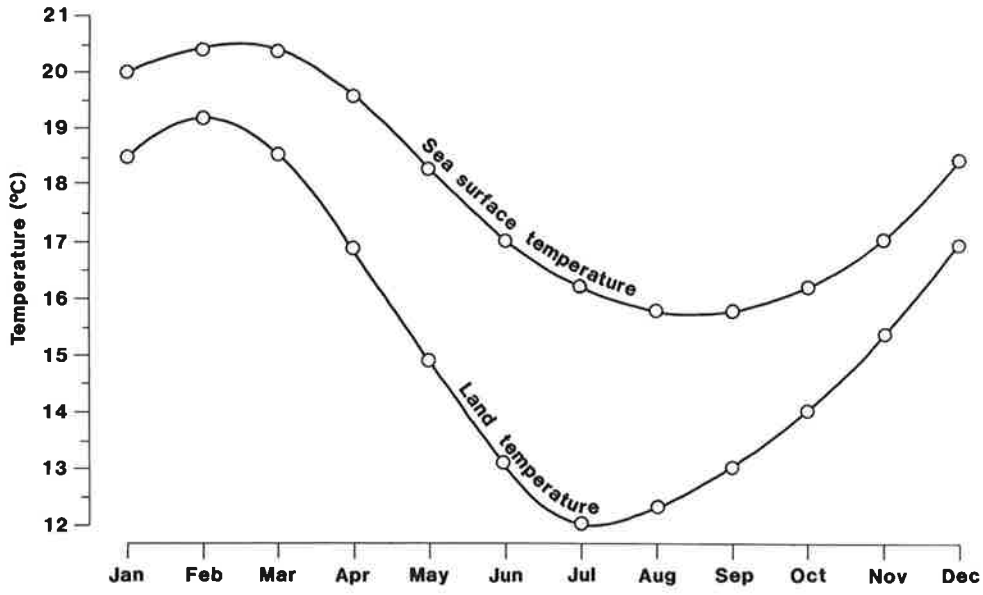

Fig. 7(a) Mean monthly land and sea surface temperatures Cape Reinga

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 means of sea surface temperature for the vicinity of Northland (Taylor and Thompson, 1980) are compared with mean monthly air temperature for Cape Reinga (Fig. 7a). There is a six to eight

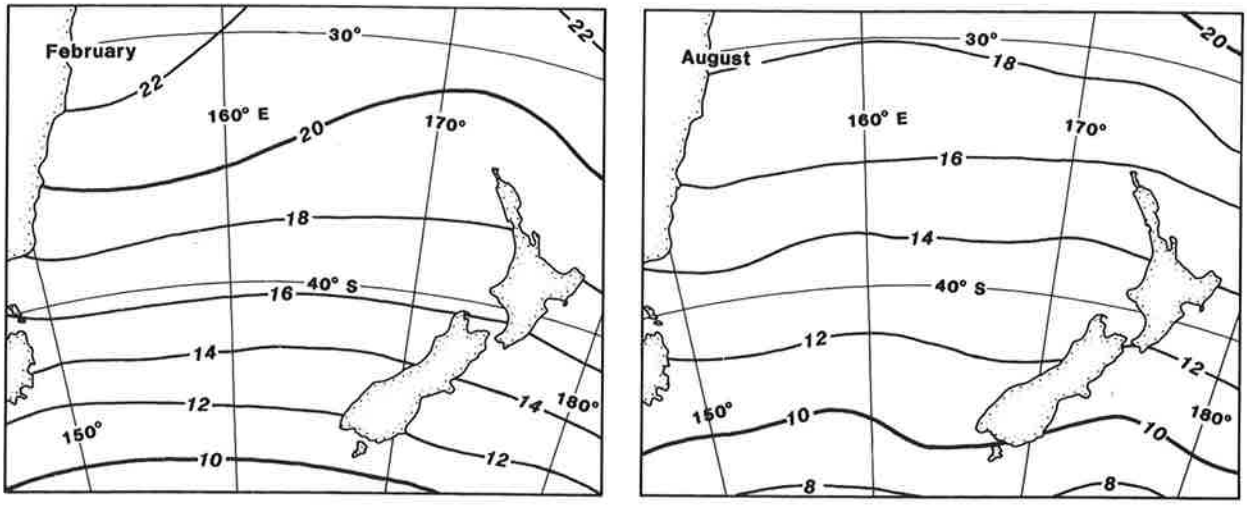

Fig. 7(b) Monthly mean sea surface temperatures (°C) for: a February; b August. (Derived from Taylor and Thompson, 1980)

week lag between the minima of land and sea temperatures. Figure 7(b) 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.

Air temperature. Mean annual temperatures in Northland vary from about 15.5°to 16.0°C in eastern areas and the Aupouri Peninsula to between 14° and 15.5°C in western and southern areas. The mean annual temperature for the region north of Auckland City is the highest for any part of New Zealand. Although higher than February temperatures are recorded in other parts of the country no area south of Auckland City has higher mean July temperatures. Figure 8 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.

Monthly values (selected) and annual values of air temperatures for New Zealand have been mapped and are available as N.Z. Met. Serv. Misc. Publ., no. 175.

In the Northland region, the temperature of the air decreases at an average rate of about 0.6°C for every 100 m elevation (Coulter, 1967). Thus, the mean annual temperature at a station close to sea level, such as Kaitaia (8 m above sea level) is 15.9°C, while at Kaikohe, which is 204 m above sea level the mean annual temperature is 14.7°C, 1.2°C below Kaitaia. Therefore in the ranges of Northland, at an altitude of about 500 m, the mean annual temperature should be close to 12°C, ranging from about 17°C during January to 10°C during July.

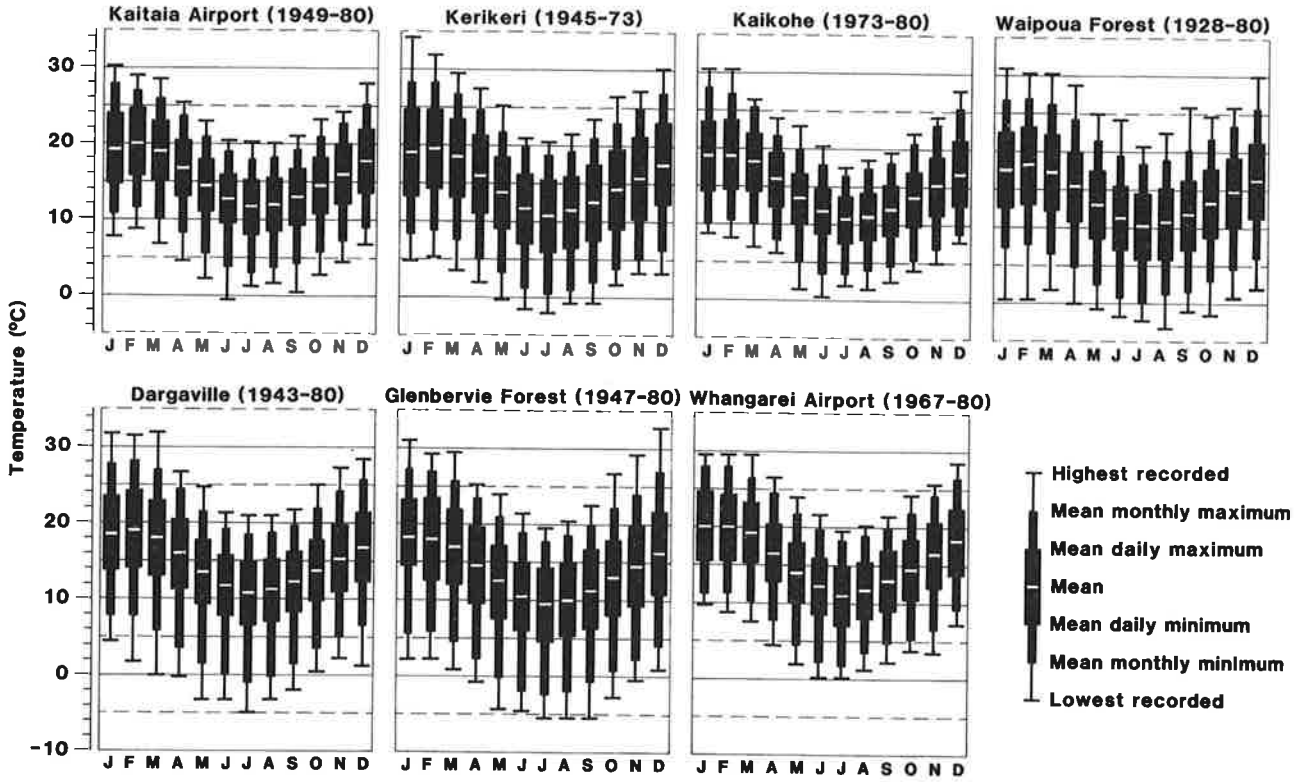

Fig. 8. Mean monthly temperature

The mean annual temperature range for Northland is small, averaging 8.5°C which is close to the variation in western districts of both islands. Table 13 shows the average daily temperature range for each month for Cape Reinga, Kaikohe, Dargaville and Glenbervie Forest. Cape Reinga has the smallest temperature range for any station in the region and Glenbervie Forest one of the greatest.

Table 13. Average daily temperature range (°C)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Cape Reinga	5.6	5.7	5.3	4.8	4.3	4.3	4.4	4.6	5.0	5.2	5.5	5.5	5.0
Kaikohe	9.3	9.2	7.8	7.1	6.7	6.0	6.2	6.3	6.7	7.1	7.9	8.9	7.4
Dargaville	9.7	10.3	9.9	9.1	8.5	7.9	8.4	8.2	8.1	8.0	8.7	9.1	8.9
Glenbervie Forest	11.2	10.8	10.2	10.1	9.7	9.2	9.7	9.6	9.9	10.0	10.8	10.9	10.1

Diurnal temperature variations are also relatively minor. Table 14 shows mean hourly temperatures for Kaitaia for January and July and from this it can be seen that the daily range for January is about 7 degrees and for July about 4 degrees.

Table 14. Mean hourly temperatures at Kaitaia Airport

hrs	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
a	17	16	16	16	16	16	16	17	19	20	21	22	22	23	23	23	22	22	21	20	19	18	17	17
b	10	10	10	10	10	10	10	10	10	11	13	14	14	14	14	14	14	13	12	11	11	11	11	11

a = mean hourly temperature in January
b = mean hourly temperature in July

Extreme temperatures are also moderate. The highest temperature recorded in Northland was 34.3°C at Kerikeri and the lowest -5.6°C at Glenbervie Forest. These compare with national extremes of 42.4°C and -18.6°C.

Earth Temperatures. Earth (soil) temperatures are measured once daily at 9 a.m. at several Northland locations. Table 15 lists earth temperature normals (a normal is an average value taken or calculated over a standard 30 year period) covering the period 1951-1980 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), the highest station, are 2°C cooler at all depths than those at Kerikeri (70 m). 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. Earth temperature normals have been mapped and are available as N.Z. Met. Serv. Misc. Publ., no. 175.

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

Table 15. Mean 9 a.m. earth temperatures (°C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Te Paki Station (64 m)													
30cm	22.2	22.2	21.0	18.5	16.0	13.7	12.6	13.1	14.5	16.8	19.0	20.9	17.5
Kaitaia Airport (80 m)													
10cm	18.9	19.1	17.7	15.3	12.6	10.8	9.6	10.0	11.4	13.6	15.6	17.3	14.3
20cm	19.8	20.3	19.0	16.7	14.2	12.3	11.1	11.4	12.6	14.4	16.4	18.1	15.5
30cm	20.2	20.6	19.6	17.4	15.0	13.0	11.8	12.0	13.2	14.9	17.0	18.7	16.1
Kerikeri (73 m)													
10cm	20.7	20.7	19.1	16.0	13.0	10.9	9.6	10.4	12.0	14.8	17.2	19.2	15.3
20cm	21.6	21.6	20.2	17.3	14.3	12.1	11.0	11.6	13.1	15.5	17.9	20.0	16.3
30cm	21.5	21.7	20.4	17.9	15.1	12.8	11.5	12.0	13.4	15.6	18.0	20.0	16.7
Punakitere (180 m)													
10cm	19.6	19.3	17.6	14.8	11.7	10.0	8.5	9.1	11.1	13.7	16.4	18.0	14.1
20cm	18.9	19.3	17.7	15.1	12.4	10.7	9.2	10.0	11.4	13.5	15.5	17.3	14.3
30cm	19.1	19.5	18.1	16.0	13.2	11.5	10.0	10.5	11.8	13.9	15.6	17.3	14.7
100cm	19.5	20.0	19.3	17.7	15.4	13.5	12.0	11.9	12.7	14.3	16.2	17.9	15.9
Kaikohe (204 m)													
10cm	18.0	17.8	16.8	14.4	11.9	10.4	9.0	9.4	10.5	12.8	14.8	16.7	13.5
20cm	18.6	19.0	17.8	15.5	13.2	11.5	10.0	10.4	11.5	13.5	15.5	17.3	14.3
30cm	19.0	19.2	18.1	15.9	13.7	12.0	10.5	10.8	11.8	13.8	15.7	17.3	14.8
100cm	18.5	19.1	18.9	17.7	16.0	14.5	13.1	12.7	13.0	14.2	15.6	17.1	15.9
Dargaville (20 m)													
10cm	20.8	20.5	18.6	15.6	12.8	10.8	9.6	10.3	12.2	14.9	17.4	19.5	15.3
20cm	20.9	20.8	19.1	16.2	13.4	11.4	10.2	10.9	12.4	14.8	17.2	19.2	15.5
30cm	21.3	21.4	19.8	16.9	14.1	12.1	10.8	11.4	12.9	15.1	17.5	19.7	16.1
Puketurua (101 m)													
10cm	19.9	19.9	18.3	15.3	12.2	10.5	9.1	9.7	11.2	13.8	16.3	18.1	14.5
20cm	20.3	20.6	19.2	16.5	13.7	11.7	10.4	10.9	12.1	14.2	16.4	18.3	15.4
30cm	20.2	20.5	19.3	17.0	14.3	12.6	11.2	11.4	12.6	14.5	16.6	18.5	15.7
100cm	18.9	19.9	19.6	18.1	16.1	14.3	12.9	12.6	13.1	14.3	15.9	17.5	16.1

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 16 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 Fig. 8.

Table 16. Occurrence of frosts and grass minimum temperatures

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Te Paki Stn., Te Hapua (1931-1973)													
a	12.4	13.0	12.2	10.6	8.6	6.8	5.8	6.1	6.8	8.5	10.1	11.6	9.4
b	1.9	2.2	1.3	-0.8	-2.4	-3.9	-7.2	-4.9	-3.9	-1.1	0.6	2.2	-7.2
c	0.0	0.0	0.0	0.0	0.1	1.2	1.9	1.3	0.6	0.2	0.0	0.0	5.3
d	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.1	0.0	0.0	0.0	0.0	1.0
Kaitaia Airport (1949-1980)													
a	12.0	13.4	12.4	10.4	8.5	7.1	5.7	6.1	6.7	8.2	9.5	10.9	9.2
b	1.9	1.4	1.4	-0.6	-1.7	-2.8	-3.3	-1.9	-1.6	-1.1	-1.2	0.3	-3.3
c	0.0	0.0	0.0	0.0	0.1	0.5	0.6	0.3	0.2	0.0	0.0	0.0	1.7
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 (1945-1973)													
a	10.1	11.3	9.8	7.5	5.3	3.2	2.2	2.9	3.7	5.6	7.0	9.1	6.5
b	1.1	-0.8	-1.7	-2.7	-6.4	-7.9	-7.2	-6.7	-6.1	-3.3	-1.1	-1.0	-7.9
c	0.0	0.0	0.0	0.1	1.8	4.5	8.4	6.4	2.8	0.7	0.2	0.0	24.9
d	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.2	0.1	0.0	0.0	0.0	1.0
Dargaville (1943-1980)													
a	10.9	11.1	10.7	8.5	6.4	4.9	3.6	4.3	5.1	6.9	8.3	9.6	7.5
b	1.0	-0.4	-2.3	-3.6	-6.0	-6.9	-7.7	-7.2	-4.5	-3.5	-2.9	-1.7	-7.7
c	0.0	0.0	0.1	0.4	1.2	3.3	5.4	4.0	1.7	0.6	0.1	0.0	16.8
d	0.0	0.0	0.0	0.0	0.3	1.0	2.3	1.2	0.2	0.0	0.0	0.0	5.0
Glenbervie Forest (1947-1980)													
a	9.7	10.5	9.7	7.1	4.5	2.9	1.6	2.3	3.3	5.2	6.6	8.4	6.0
b	-0.6	0.0	-1.7	-5.3	-9.0	-10.7	-11.0	-9.4	-10.1	-5.0	-3.8	-2.2	-11.0
c	0.0	0.0	0.2	0.9	4.3	7.7	10.5	8.9	6.1	2.4	0.9	0.2	42.1
d	0.0	0.0	0.0	0.1	1.4	3.5	4.9	4.1	1.9	0.4	0.0	0.0	16.3

a = mean daily grass mimimum, °C
b = lowest grass mimimum recorded, °C
c = average number of ground frosts/month
d = average number of air frosts/month

Sunshine and Solar Radiation

Sunshine. Most parts of Northland receive a total of about 2000 hours of bright sunshine each year. This is fairly uniform throughout the region and represents about 50 percent of the possible sunshine that could be recorded at each site. 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. At Waipoua, the only high level site in

Northland, about 1700 hours of sunshine is recorded. This is about 40 percent of the total possible. Other highland areas in Northland could expect similar sunshine totals. Figure 9 shows the monthly mean, maximum and minimum recorded sunshine for selected sites while illustrating the percentage of possible sunshine recorded each month at Kaitaia Airport and Waipoua Forest.

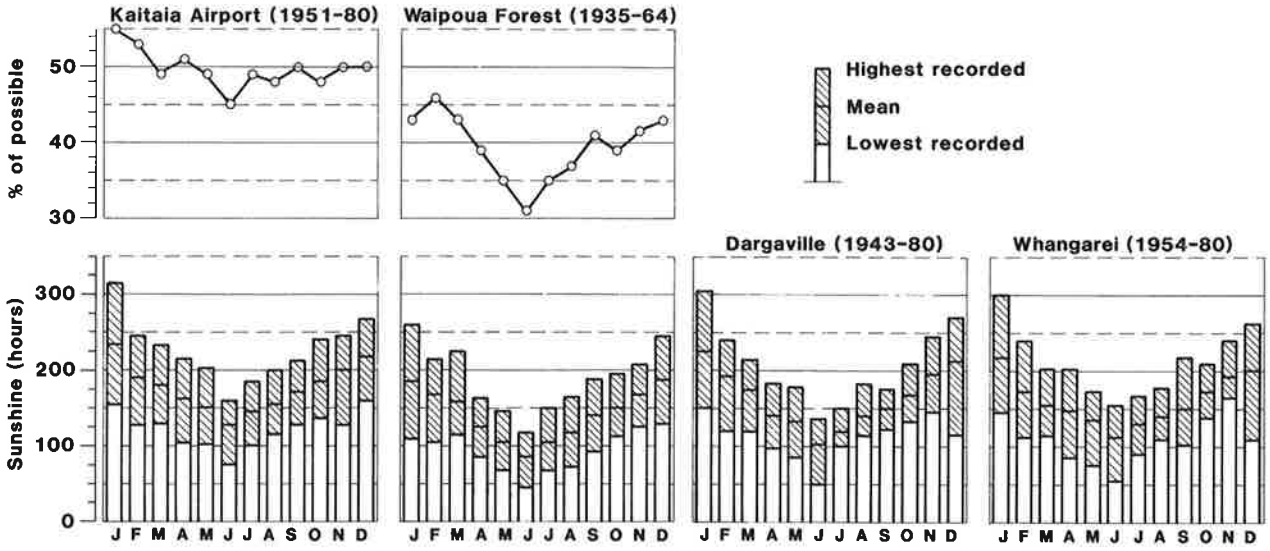

Fig. 9 Mean monthly sunshine for Northland
Percentage of possible sunshine at selected sites

Solar radiation. Solar radiation records are available for two sites in Northland, at Kaitaia Airport and Puketurua (22 km northwest of Whangarei). Insolation is at a maximum in December and January and a minimum in June. Table 17 shows mean daily solar radiation for each month for these two stations.

Table 17. Mean global solar radiation ($MJ/m^2/day$)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaitaia Airport 1969-1980	23.0	19.3	15.7	12.0	8.9	7.2	8.2	10.4	14.5	17.6	20.6	23.1
Puketurua 1966-1975	22.2	18.1	14.7	11.7	8.8	6.8	7.8	10.4	14.1	17.2	20.5	22.2

Evaporation

Records of raised pan evaporation are available for Punakitere, Kaikohe, Dargaville and Puketurua and these have been used to prepare an areal average of evaporation for Northland. A mean of the monthly averages, maximum and minimum values are listed in Table 18. This was achieved by simply averaging the total monthly evaporation recordings from all available stations.

Table 18. Average monthly evaporation (mm) from raised pan evaporimeters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	182	143	116	79	55	36	41	59	81	113	136	168	1213
Max	223	166	140	90	69	50	49	69	98	122	156	189	1293
Min	154	113	90	62	44	27	30	47	69	99	124	134	1134

Fog

The frequency of fog in Northland is very variable, ranging from an average of 75 days with fog each year at Umawera to only once or twice each year at Kerikeri. Although fog can occur at any time of the year it is recorded most frequently between March and August.

Table 19. Average number of days each year with fog, hail and thunder

Location	Fog	Hail	Thunder
Cape Reinga	47.5	0.9	4.4
Kaitaia Airport	21.1	3.5	15.8
Aupouri Forest	5.4	0.2	2.8
Kerikeri	1.1	0.7	4.6
Umawera	74.2	1.9	7.2
Punakitere	35.6	2.0	5.8
Waipoua Forest	2.1	6.4	6.3
Dargaville	53.7	1.2	4.7
Waitangi Forest	10.0	1.0	3.3
Puketurua	17.1	1.4	3.8
Glenbervie Forest	1.7	1.1	3.5
Whangarei Airport	12.7	0.4	1.9
Whangarei	5.5	1.0	3.2

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 a.m.

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 19.

Thunderstorms and related phenomena

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 16 each year at Kaitaia to 3 at Whangarei. The average number of days with thunderstorms each year for selected stations is listed in Table 19. It is highly likely that at some of the locations not all thunderstorm episodes are detected.

At Kaitaia airport, where hourly weather observations are made, the diurnal variation of thunderstorms indicates that in summer there is a pronounced maximum in the afternoon, while in winter most thunderstorms are noted 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 six days a year at Waipoua Forest to less than once in five years at Aupouri Forest. 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 are listed in Table 19 above.

Tornadoes. Tornadoes in New Zealand are very much smaller than those that occur in the U.S.A., 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 twelve were noted during the fifteen year period from 1961 to 1975 (Tomlinson and Nicol, 1976). 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 6 June 1979. On that occasion a small tornado developed in the Awanui area

during a period of intense frontal activity (thunderstorms and hail showers were reported in the area at the same time). The tornado travelled rapidly inland across farmlands, lifting several farmhouse roofs, damaging barns and outbuildings, felling many large trees and scattering hay crops. Several roofs were lifted in outlying areas of Kaitaia before the tornado died away.

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 20.

Table 20. 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 (metres)
10	0.5
20	1
30	2
40	3
50	4
75	7
100	11
125	13+

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 35 percent of the time (Reid and Collen, 1982). The frequency of swells of less than one metre is about 20 to 25 percent, while swell over three metres occur 30 percent of the time. Heavy southwest swells are particularly noticeable in winter and spring.

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 50 percent, while for those greater than three metres is 8 percent.

4. DERIVED CLIMATOLOGICAL PARAMETERS

Vapour pressure and relative humidity

Relative humidity and vapour pressure 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 that 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 air masses that have tropical origins and lowest in cold 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 21.

Table 21. Mean monthly/annual 9 a.m. vapour pressure (hPa*)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Cape Reinga	18.2	18.9	18.2	16.2	14.3	13.1	11.9	12.2	12.8	13.9	15.1	16.6	15.1
Kaitaia Airport	17.5	18.3	17.7	15.9	14.0	12.6	11.6	12.0	12.7	13.6	14.8	16.0	14.7
Kerikeri	17.3	18.3	17.5	15.8	14.0	12.3	11.4	11.9	12.5	13.5	14.6	16.0	14.6
Waipoua Forest	16.9	17.8	17.2	15.5	13.6	11.9	11.1	11.6	12.5	13.2	14.3	15.7	14.3
Dargaville	17.9	18.4	17.8	15.5	13.2	11.8	10.7	11.4	12.5	13.6	14.9	16.4	14.5
Glenbervie Forest	17.0	17.9	17.6	15.6	13.4	11.5	10.5	11.4	12.1	13.0	14.1	15.6	14.1

* one hectopascal (hPa) is equivalent to one millibar (mb)

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 22 gives the average relative humidity at 9 a.m. for selected stations in Northland.

Table 22. Average 9 a.m. relative humidity (percentage)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Cape Reinga	85	86	83	85	86	87	85	85	86	85	85	84	85
Kaitaia Airport	75	79	80	83	87	89	88	87	82	79	77	75	82
Kerikeri	72	76	78	82	88	90	89	86	80	76	74	71	80
Kaikohe	81	85	84	86	87	89	88	87	84	79	83	80	84
Waipoua Forest	77	79	83	88	91	91	91	88	83	78	76	76	83
Dargaville	77	81	83	85	82	85	83	83	83	80	77	77	81
Whangarei	76	79	81	84	87	89	88	87	81	75	78	77	82

Although still larger than the variation from month to month, diurnal variation in relative humidity in Northland tends to be smaller than in many other parts of New Zealand. Unlike vapour pressure relative humidity varies greatly with temperature and high humidity can be associated with high temperatures at times, thus making conditions rather oppressive. Table 23 lists the average relative humidity at three hourly intervals for February, July and the whole year at Kaitaia

Table 23. Diurnal variation of relative humidity (percentage) at Kaitaia Airport in February and July

	0000	0300	0600	0900	1200	1500	1800	2100	Day
February	89	90	75	64	64	71	85	88	78
July	89	90	88	76	75	84	88	89	85
Year	90	90	81	70	70	78	87	89	82

Airport. The early morning maximum and afternoon minimum show clearly in each instance.

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 for many stations by using daily rainfalls and by assuming that the soil can hold a fixed

Table 24. Daily water balance summary for a soil moisture capacity of 75 mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Aupouri Forest 1970-1980													
DE	75	73	41	6	0	0	0	0	0	0	8	59	262
ND	18	20	14	3	0	0	0	0	0	0	3	14	72
RO	19	12	6	13	28	114	88	96	39	42	5	1	463
NR	1	1	1	1	4	11	14	11	5	3	1	1	51
Kaitaia Airport 1949-1980													
DE	69	49	31	9	0	0	0	0	0	1	13	44	216
ND	16	13	10	4	0	0	0	0	0	0	4	12	59
RO	18	20	6	27	71	131	99	106	51	31	11	6	577
NR	1	1	0	2	7	15	14	11	7	3	1	0	62
Kerikeri 1946-1973													
DE	56	31	13	4	1	0	0	0	0	0	12	33	150
ND	15	10	6	3	1	0	0	0	0	0	4	9	48
RO	12	44	48	82	129	153	151	164	82	50	13	12	940
NR	1	2	2	4	9	13	13	12	6	3	1	1	67
Dargaville 1943-1979													
DE	62	48	23	4	0	0	0	0	0	0	9	39	185
ND	17	15	9	2	0	0	0	0	0	0	3	11	57
RO	5	13	14	21	79	130	105	88	48	36	7	6	552
NR	0	1	1	2	9	16	15	12	7	4	1	1	69
Whangarei 1967-1980													
DE	26	35	16	3	0	0	0	0	0	0	1	7	88
ND	9	12	7	2	0	0	0	0	0	0	0	1	33
RO	22	24	53	80	84	172	130	128	90	69	32	16	900
NR	1	1	2	4	5	12	13	11	8	4	2	1	64

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