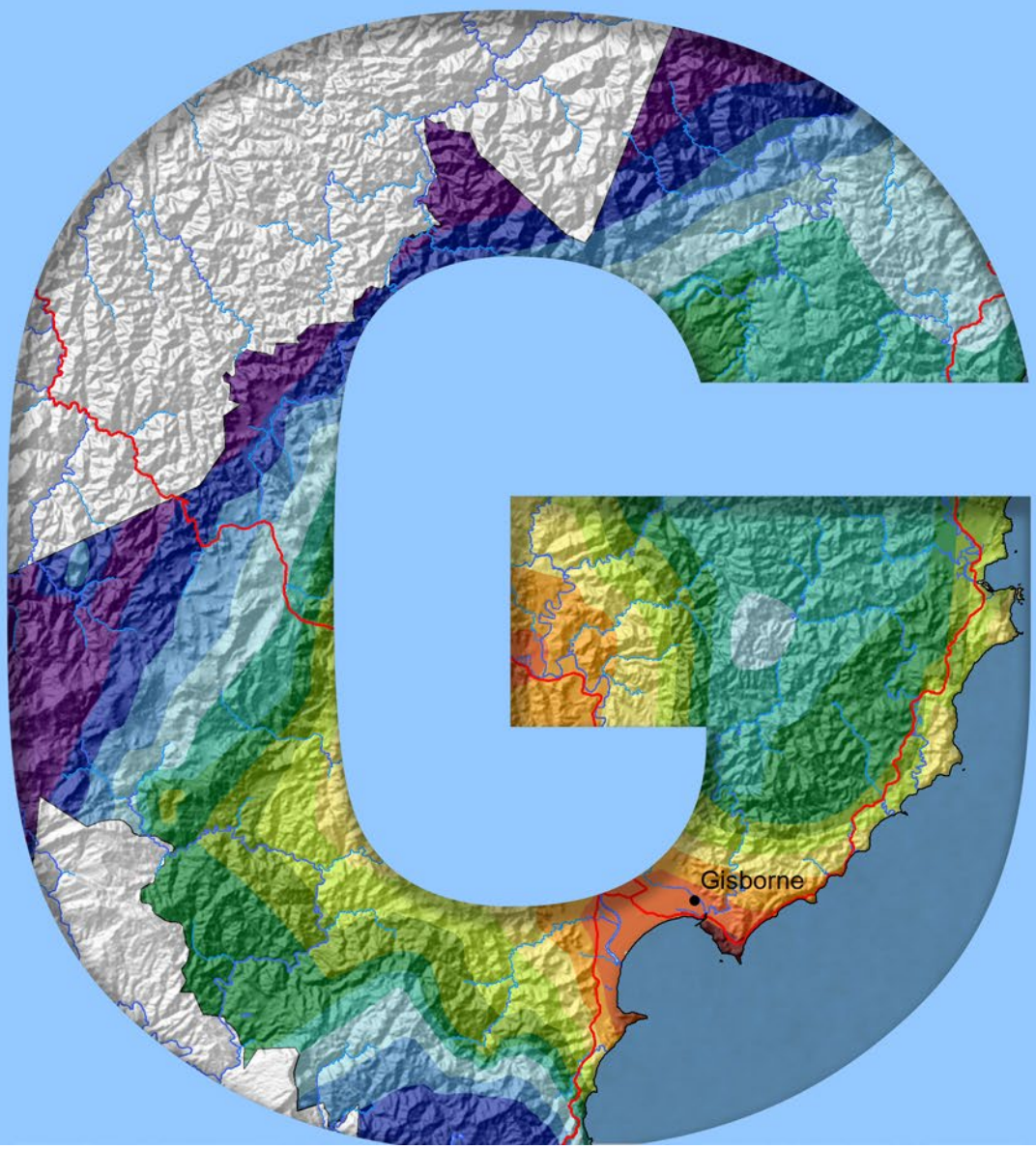
NIWA
Taihoro Nukurangi

THE CLIMATE AND WEATHER OF GISBORNE

2nd edition

P.R. CHAPPELL



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Note to Second Edition

This publication replaces the first edition of the New Zealand Meteorological Service Miscellaneous Publication 115 (8), written in 1980 by J. W. D. Hessell. It was considered necessary to update the second edition, incorporating more recent data and updated methods of climatological variable calculation.

THE CLIMATE AND WEATHER OF THE GISBORNE DISTRICT

2nd edition

P.R. Chappell

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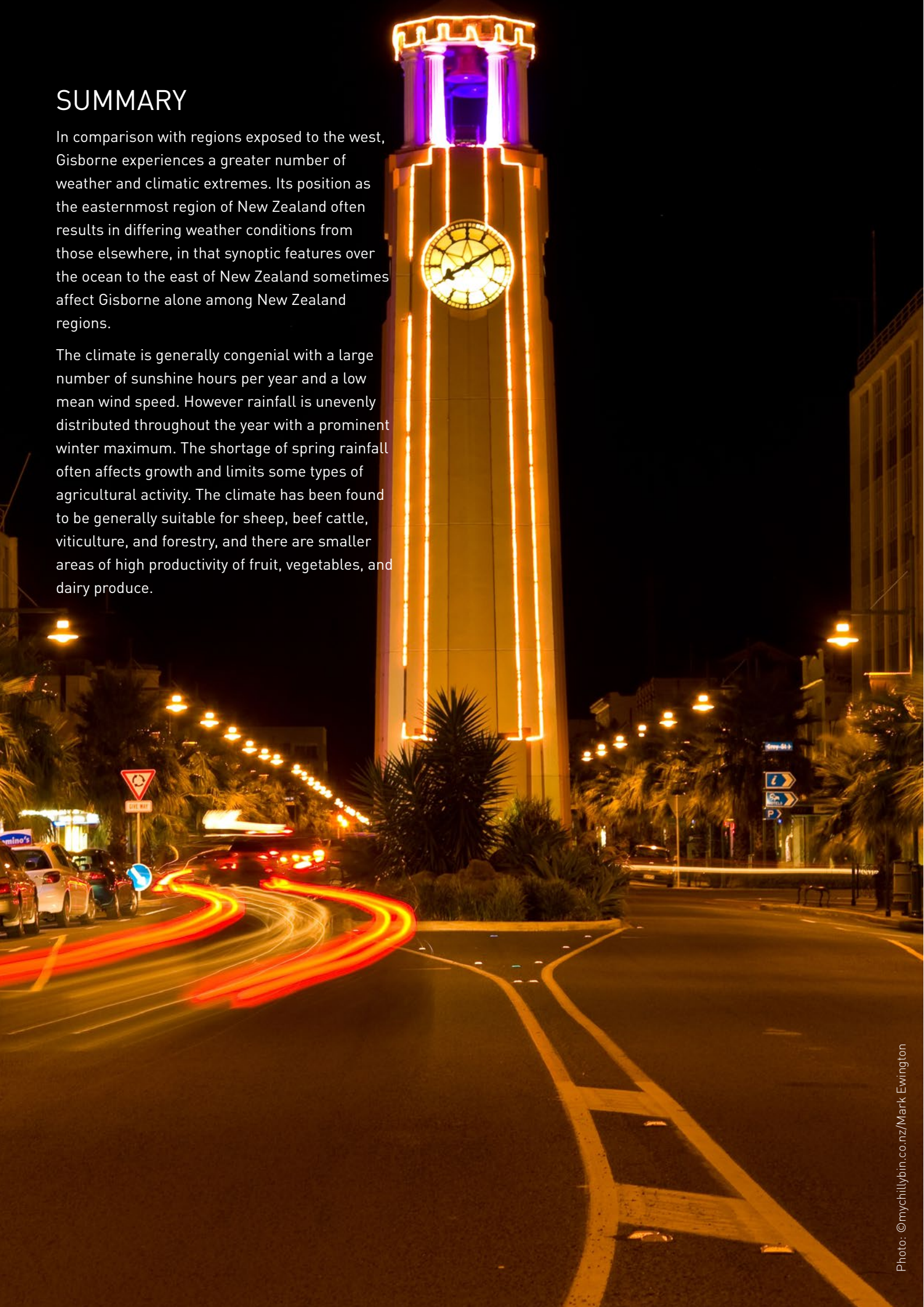
CONTENTS

SUMMARY

In comparison with regions exposed to the west, Gisborne experiences a greater number of weather and climatic extremes. Its position as the easternmost region of New Zealand often results in differing weather conditions from those elsewhere, in that synoptic features over the ocean to the east of New Zealand sometimes affect Gisborne alone among New Zealand regions.

The climate is generally congenial with a large number of sunshine hours per year and a low mean wind speed. However rainfall is unevenly distributed throughout the year with a prominent winter maximum. The shortage of spring rainfall often affects growth and limits some types of agricultural activity. The climate has been found to be generally suitable for sheep, beef cattle, viticulture, and forestry, and there are smaller areas of high productivity of fruit, vegetables, and dairy produce.



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INTRODUCTION

The Gisborne district is defined here as the area administered by Gisborne District Council. The district includes East Cape – the most easterly point of the main islands of New Zealand, and is bounded in the west by the main divide of the Raukumara Range, whose highest point is Mt Hikurangi (1753 m). The southwestern extent of the district primarily follows the boundary separating the Waipaoa and Wairoa River catchments. The principal population centre is Gisborne City, in and near which live most of the district's population.

The North and South Islands of New Zealand, spanning latitudes 34°S to 47°S, lie within the hemispheric temperate zone where weather systems usually migrate from west to east. The ever-changing synoptic patterns cause considerable variability in the weather. Prolonged extremes of heat or cold, flood or drought are rare. Broken only at Cook Strait, the country's main divide extends from near East Cape to Puysegur Point in the southwest of the South Island; Gisborne is thus the northernmost of the eastern districts that are protected by substantial mountains to the west. The mean wind flow over the country is from slightly south of west and areas east of the main divide have differing climatic characteristics from those in the west.

As New Zealand lies in the mid-latitudes it may experience outbreaks of air originating in the tropics or Antarctica, and the Gisborne district is occasionally affected by these. The effect of the oceans on air of tropical origin is to cool the lower layers creating broad sheets of stratiform cloud capable of producing large amounts of rain especially when they are entrained into cyclonic synoptic systems. Conversely in southerlies the ocean tends to destabilise the cold air by warming it at low levels which causes showery activity. The orography of the Gisborne district further controls airmass characteristics so that for example southwest winds are often associated with fine weather while southeasterlies (apart from sea breeze) are usually cloudy and wet (see next section).

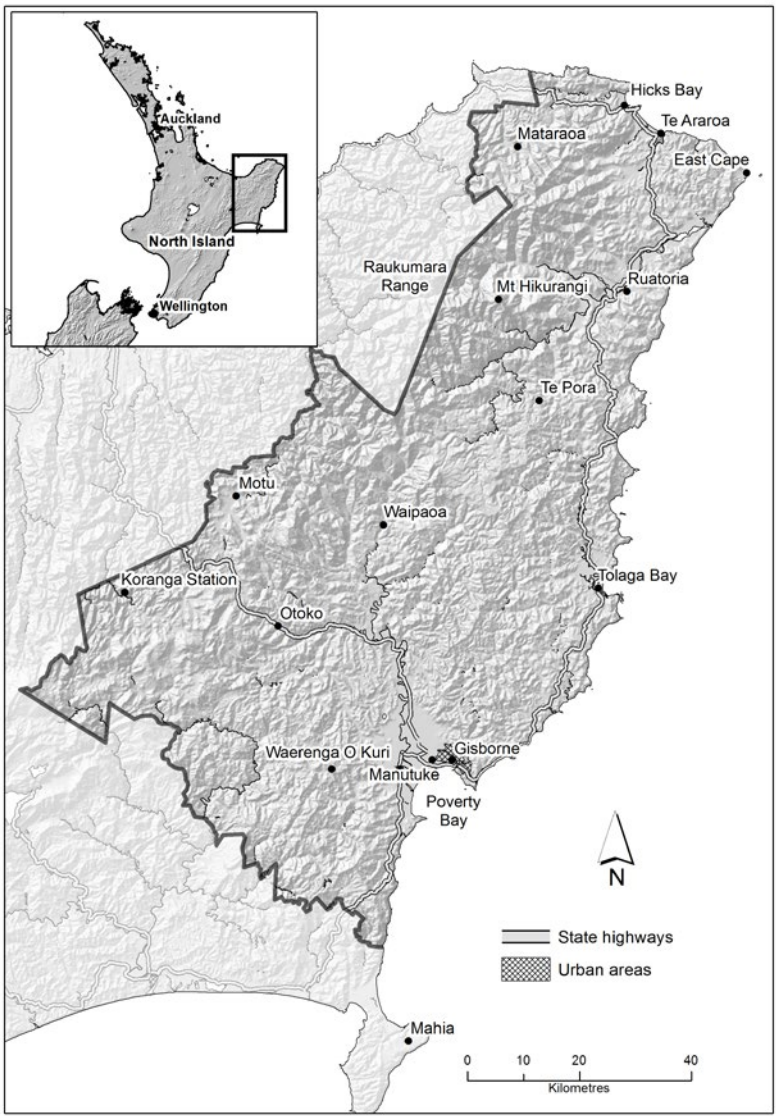

Figure 1. Map of Gisborne district, with locations of places mentioned in the text, tables, and figures.

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.

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THE WEATHER IN GISBORNE DISTRICT

Typical weather situations

The weather of the Gisborne district is greatly influenced by the orography of the area. When winds are from the westerly quarter, sheltering by the Raukumara Range causes high temperatures and limited rainfall in the district. Conversely in easterly situations, the uplift caused by the mountains serves to enhance the rainfall and high intensities are recorded at all altitudes. Katabatic (downhill) drainage of cold air on winter nights often results in very low temperatures, and altogether the district has a greater range of weather conditions than many other parts of New Zealand. In situations where the broad scale wind flow is slight, frequent sea breezes occur in summer penetrating considerable distances inland.

Cyclones of tropical origin

Tropical cyclones that reach Gisborne 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 New Zealand about once or twice each year, mainly between the months of December and April. They usually bring heavy rain and strong easterly winds. See the 'Recent extreme events in Gisborne District' section for a detailed description of the impact of ex-tropical cyclone Bola in March 1988. Figure 2a-e shows, by month, the tracks of tropical cyclones which made landfall in New Zealand during the period between 1970 and 2010.

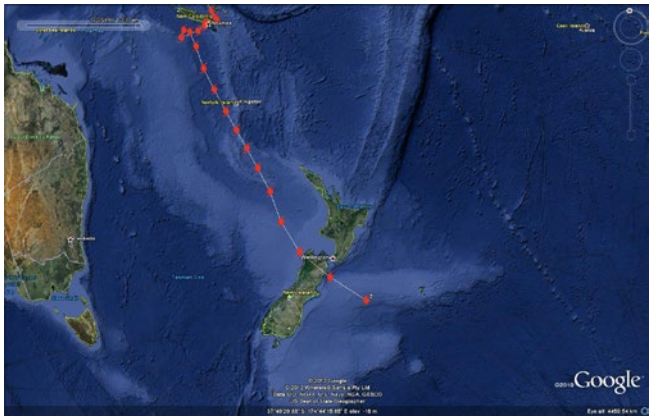

Figure 2a. Tropical cyclones which made landfall in New Zealand during December, 1970–2010. Source: Southwest Pacific Enhanced Archive of Tropical Cyclones (SPEArTC; Diamond et al., 2012).

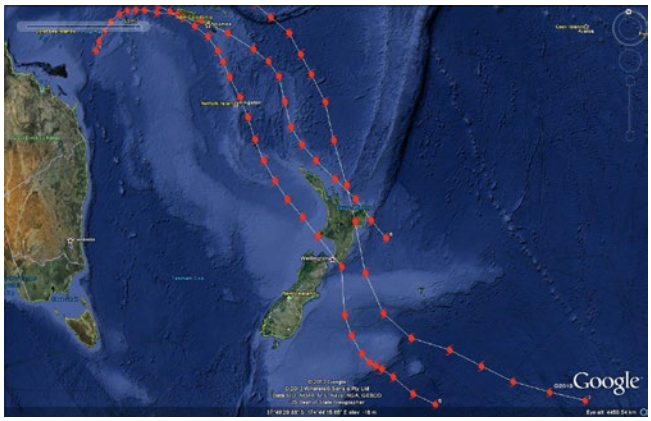

Figure 2b. Tropical cyclones which made landfall in New Zealand during January, 1970–2010. Source: SPEArTC (Diamond et al., 2012).

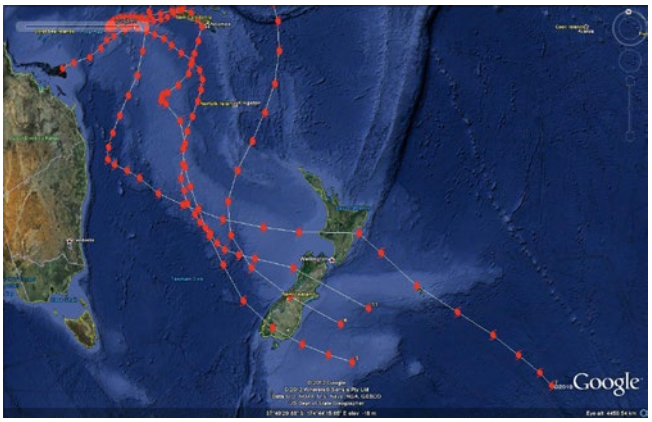

Figure 2c. Tropical cyclones which made landfall in New Zealand during February, 1970–2010. Source: SPEArTC (Diamond et al., 2012).

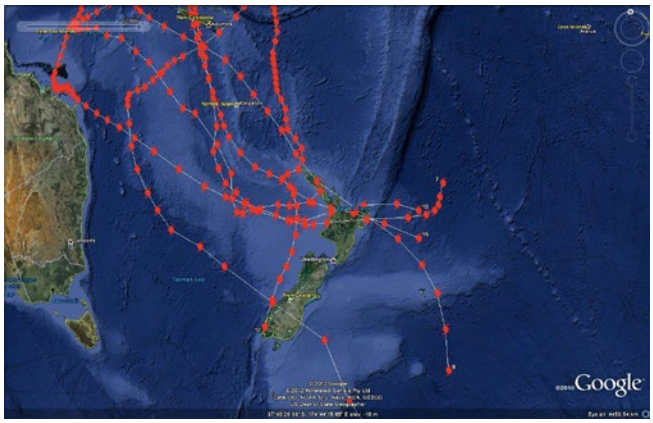

Figure 2d. Tropical cyclones which made landfall in New Zealand during March, 1970–2010. Source: SPEArTC (Diamond et al., 2012).

Westerly or northwesterly situations

The strongest northwesterly winds occur just ahead of cold fronts, moving east or northeast over New Zealand. In periods of prolonged westerlies over New Zealand a high pressure belt lies to the north and a series of eastward-moving depressions to the south of the country. Figure 3, showing the situation at midnight on 2–3 February 1977, is typical of westerly or northwesterly situations. At midday on 2 February 1977 the relative humidity at Gisborne aerodrome was 29% and had dropped to only 19% by 3 pm, reverting to 29% at 6 pm as the temperature fell. A dry day was also recorded on 3 February with a midday humidity of only 26%. During this period surface winds were northwesterly 30–40 km/hr, the passage of the front being detectable only by changes in the high cloud, there being no significant low cloud at any stage.

Northerly situations

A typical north to northeast airflow is caused by situations similar to those of 28 June 1977 (Figure 4). The wind flow was more parallel to the main divide than in the northwesterlies and there was not as marked a descent in the coastal areas. Heavy rain occurred in the ranges, and at Gisborne persistent light rain fell throughout the day. Surface winds were somewhat variable but with a negligible westerly component. Wind strengths at Gisborne varied from 30–50 km/hr from the northeast, the strongest winds being accompanied by the most intense rainfalls of the day. Days such as this with steady light rain and mild temperatures are favourable for plant growth though they may be followed by general heavy rain causing flooding if the depression moves on a track to the north of the district. On this occasion the depression moved southwards and there was no rain in the area on the next day.

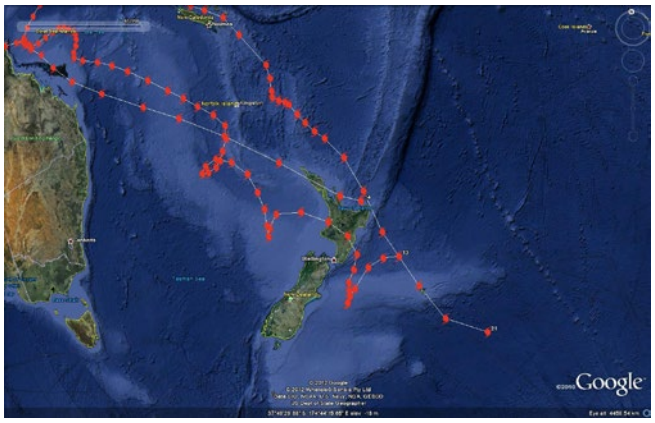

Figure 2e. Tropical cyclones which made landfall in New Zealand during April, 1970–2010. Source: SPEArTC (Diamond et al., 2012).

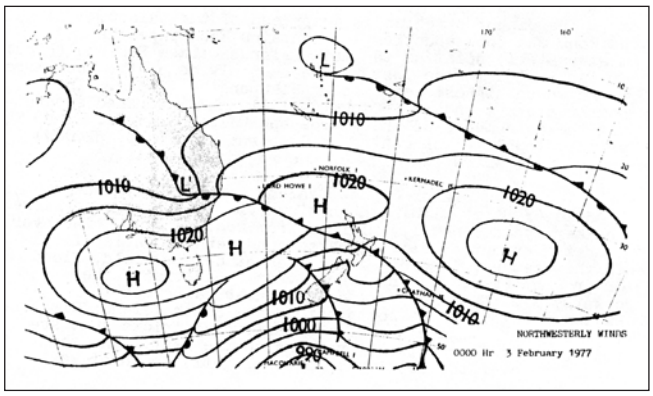

Figure 3. Sea level pressure analysis at 0000 NZST, 3 February 1977.

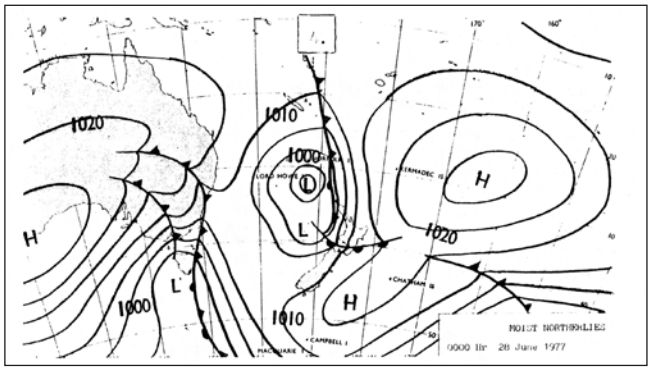

Figure 4. Sea level pressure analysis at 0000 NZST, 28 June 1977.

Southwesterly and southerly situations

When the general air flow over New Zealand is from the southwest or south, the Gisborne district may receive coastal showers while little rain occurs in the ranges (Figure 5). On 6 May 1977, 17 mm of rain was recorded in Gisborne while places further inland had no rain. Under the usual conditions of atmospheric stability the coastal regions will be cloudy with high relative humidity but the ranges will be clear of cloud. This situation is a complete reversal of northwest situations with respect to the distribution of cloud and precipitation.

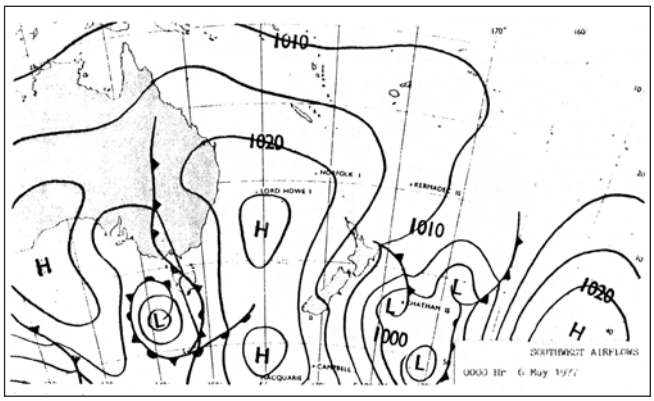

Figure 5. Sea level pressure analysis at 0000 NZST, 6 May 1977.

Southeasterly situations

With the main divide and the coastline lying directly across southeasterly airstreams, these flows usually produce heavy rains over the whole district. An extreme example occurred on 21 June 1977 when surface winds at Gisborne were southeast 45–55 km/hr with gusts to 87 km/hr (Figure 6). Rainfall there was 156 mm for 24 hours, 90 mm of this falling between 9 am and noon. Although the overall rain period in the ranges was longer than on the coast, the two-day rainfalls were comparable, the greatest 24 hour maximum occurring in the coastal zone. Flooding in the area was widespread as a result of this weather and a state of emergency was declared for part of Gisborne City where the river overflowed its banks, being some 2 m above its normal level. Gisborne is usually the last region in the country to clear when a moist southeast airstream progresses towards the east as a high latitude anticyclone advances.

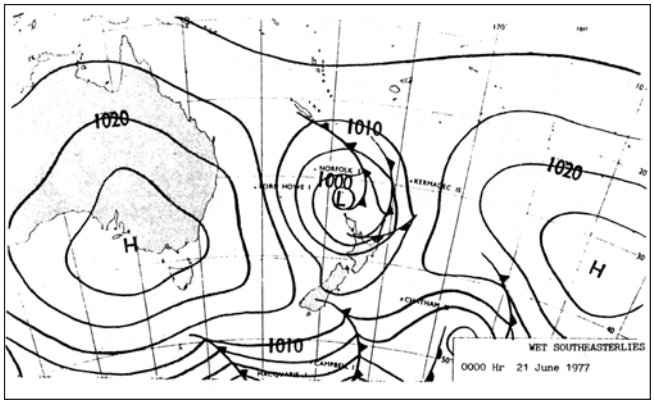

Figure 6. Sea level pressure analysis at 0000 NZST, 21 June 1977.

Sea breeze situations

Sea breezes are common in the Gisborne district in summer, penetrating considerable distances inland in the afternoons. Their development is favoured by clear skies and small pressure gradients and thus they are most frequent during anticyclonic conditions.

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CLIMATIC ELEMENTS

Wind

Apart from the East Cape area which is very exposed, wind flow over the Gisborne district is lighter than in many coastal areas of New Zealand. Wind roses (mean annual frequency of surface wind speed and direction based on hourly observations) for sites in the Gisborne district are shown in Figure 7. Winds from the west and southeast prevail at Hicks Bay, which also experiences the strongest winds of the selected stations. At Gisborne and Motu, northwest winds are the most frequent (with some winds from the southeast also). At Mahia[1], the prevailing wind is north-north-east, but winds from between south and west are also common.

Mean wind speed data (average wind speeds are taken over the 10 minute period preceding each hour), are available for several sites in the Gisborne district, and these illustrate the several very different wind regimes of the district. Hicks Bay is the most exposed station in the district, followed by Mahia. Gisborne is more sheltered due to its location within an embayment. Table 1 gives mean monthly wind speeds for selected stations in Gisborne district.

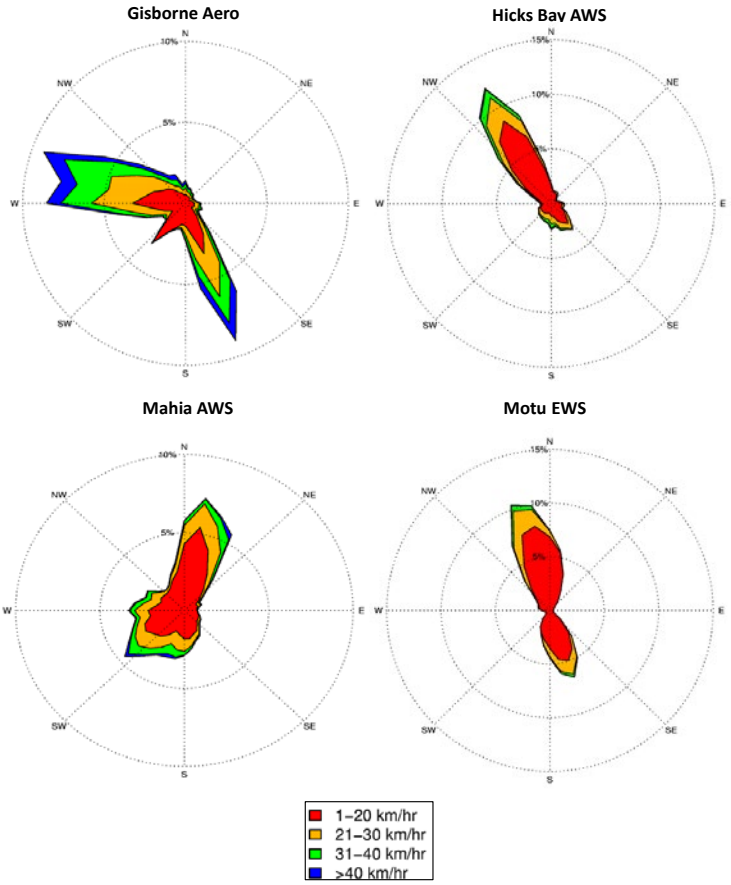

Figure 7. Mean annual wind frequencies (%) of surface wind directions from hourly observations at selected Gisborne district (and surrounding) stations. The plot shows the directions from which the wind blows, e.g. the dominant wind direction at Gisborne Aero is from the northwest.

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

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay AWS	23	23	23	22	23	25	25	24	26	26	26	24	24
Gisborne AWS	12	11	11	10	10	11	11	11	12	13	13	12	11
Motu EWS	13	13	12	11	12	13	13	12	14	15	15	14	13
Mahia AWS	17	17	17	16	17	19	18	18	18	19	18	18	18

Spring is generally the windiest season throughout the Gisborne district. Summer and autumn are the seasons when the greatest proportions of light wind days are recorded. Table 2 gives the seasonal proportion of strong or light winds as a percentage of the annual total. For example, of all strong winds recorded at Gisborne, 16% occurred in summer, 18% in autumn, 16% in winter and 50% in spring. In compiling this table a strong wind was defined as having a mean wind speed of at least 31 km/hr.

Table 2. Seasonal proportions of strong or light winds (%) for Gisborne sites.

Location		Summer	Autumn	Winter	Spring
Hicks Bay AWS	Strong	21	22	28	30
	Light	27	26	24	23
Gisborne AWS	Strong	16	18	16	50
	Light	25	25	25	25
Motu EWS	Strong	13	15	32	41
	Light	25	25	25	24
Mahia AWS	Strong	16	22	32	30
	Light	26	25	24	24

[1]Mahia Peninsula is just south of the boundary of the Gisborne District. It is included in this report due to limited available long-term climate data from within the Gisborne District.

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

Winds can be strong and gusty at times, especially in coastal areas. Hicks Bay has the highest number of gusts per year that are both greater than 63 km/hr and 96 km/hr (Table 4). In comparison, Motu and Gisborne are relatively sheltered.

Although gale force winds can occur in any month, they are most frequent in winter. The highest gust recorded from selected stations in the district was 134 km/hr at Hicks Bay on 23 November 2001. Maximum gusts recorded at different stations in the district are listed in Table 5.

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

Location	0000	0300	0600	0900	1200	1500	1800	2100
Hicks Bay AWS	23	23	22	24	27	27	25	23
Gisborne AWS	9	9	9	12	15	16	13	9
Motu EWS	11	11	11	13	16	17	15	12

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

Location	Gusts >63 km/hr	Gusts >96 km/hr
Hicks Bay AWS	139	12
Motu EWS	44	1
Gisborne Aero	56	2
Mahia AWS	72	3

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

Location	Gust (km/hr)	Direction	Date
Hicks Bay AWS	134	S	23/11/2001
Motu EWS	118	NNE	2/08/2008
Gisborne AWS	111	NW	8/11/1994

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Rainfall

Spatial variability of rainfall

The pattern of rainfall distribution over the Gisborne district is shown in Figure 8. Because of the mountainous terrain, orographic influences on rainfall are marked. Coastal rainfalls vary from around 1300–1800 mm north of Gisborne to East Cape, to less than 1000 mm near Gisborne and further inland. In some parts of the Raukumara Range, annual rainfall exceeds 2200 mm. These rainfalls reflect the effect of the topography on the principal rain producing winds, the northerlies and the southeasterlies.

Seasonal influences on rainfall distribution are also quite well defined. Table 6 lists monthly rainfall normals and percentage of annual total for selected stations. This table shows a clearly defined winter rainfall maximum. This is typical of most North Island regions. The depressions which frequently move southeast across the North Island in winter cause this rainfall maximum and often bring a period of heavy rain to the Gisborne area. Monthly percentages of the annual rainfall total are fairly consistent across the Gisborne district, with around 30% of annual rainfall expected in the winter months from June to August, and around 20% of rain in the summer months from December to February.

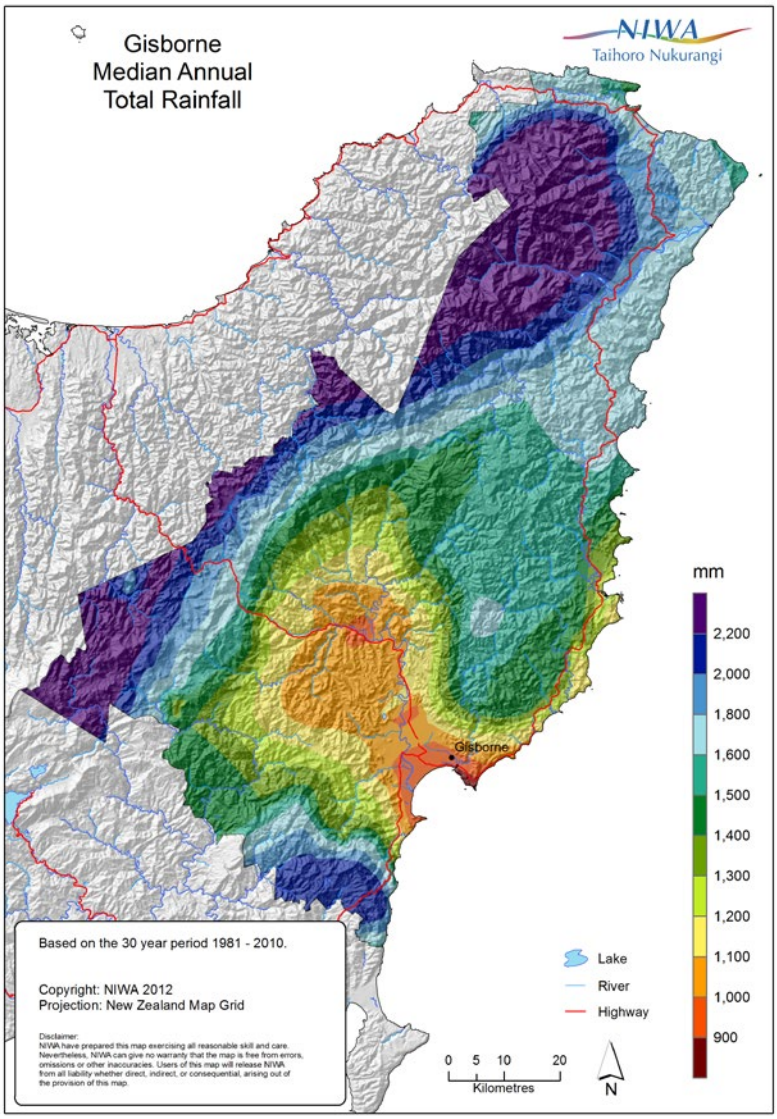

Figure 8. Median annual total rainfall for Gisborne district, 1981–2010.

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

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mataraoa	a	158	127	169	217	188	254	258	240	220	155	194	176	2355
	b	7	5	7	9	8	11	11	10	9	7	8	7	
Ruatoria 2	a	83	155	165	162	160	167	187	187	164	95	118	105	1748
	b	5	9	9	9	9	10	11	11	9	5	7	6	
Te Pora	a	114	128	159	137	154	176	226	160	124	114	95	90	1675
	b	7	8	9	8	9	10	14	10	7	7	6	5	
Motu Ews	a	131	127	128	145	192	246	216	208	199	207	174	185	2158
	b	6	6	6	7	9	11	10	10	9	10	8	9	
Waipaoa	a	98	116	130	130	127	156	186	123	98	93	66	73	1395
	b	7	8	9	9	9	11	13	9	7	7	5	5	
Tolaga Bay, Mangatuna	a	178	117	143	129	145	174	151	198	156	174	157	145	1868
	b	10	6	8	7	8	9	8	11	8	9	8	8	

Table 6 continued.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Otoko	a	90	86	106	100	105	128	142	111	99	113	87	93	1259
	b	7	7	8	8	8	10	11	9	8	9	7	7	
Gisborne Aws	a	59	68	93	97	96	105	131	78	72	70	63	57	987
	b	6	7	9	10	10	11	13	8	7	7	6	6	

The distribution of monthly rainfall is shown in Figure 9. The 10th percentile, 90th percentile, and mean rainfall values for each month are shown along with maximum and minimum recorded values for several stations.

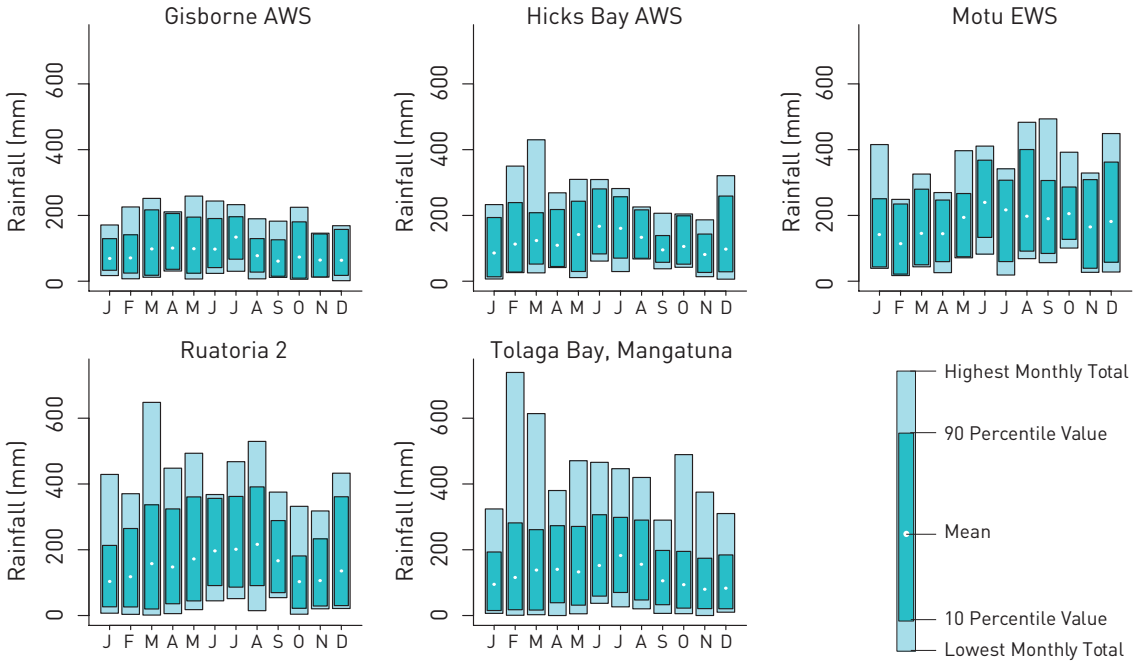

Figure 9. Monthly variation in rainfall for selected Gisborne district stations.

Rainfall variability over longer periods is indicated by rainfall deciles, as given in Table 7. The 10th percentile values show the accumulated rainfalls that will normally be exceeded in nine out of ten years, while the 90th percentile values indicate the accumulated falls that will normally be exceeded in only one year in ten. The table includes periods from one month to twelve months; each period over one month begins with the month stated. For example, using the table for Hicks Bay, it can be seen that in the three month period beginning in April, 268 mm or more of rainfall can be expected in nine years in ten, while a total of 616 mm or more should occur in only one year in ten.

Table 7. Rainfall deciles for consecutive months for sites in Gisborne district (mm).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hicks Bay AWS												
1 month												
10th	12	28	51	44	26	77	65	69	58	51	26	28
90th	197	243	191	219	223	291	259	218	147	200	144	274
3 months												
10th	204	157	193	268	294	287	233	217	179	213	147	166
90th	529	561	530	616	604	601	528	446	375	449	418	520
6 months												
10th	498	593	660	595	575	564	514	414	464	464	438	428
90th	1050	1122	1106	1036	1014	909	917	879	840	820	814	958
12 months												
10th	1170	1179	1168	1172	1232	1204	1203	1188	1201	1174	1189	1198
90th	1915	1807	1789	1709	1695	1715	1722	1697	1744	1798	1789	1774

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Motu EWS												
1 month												
10th	43	21	47	57	73	128	51	93	89	124	36	54
90th	225	236	289	247	247	373	315	417	327	297	315	372
3 months												
10th	260	251	311	389	449	444	378	426	368	369	304	308
90th	594	586	662	747	796	884	892	983	915	787	703	646
6 months												
10th	706	830	876	882	962	939	1007	764	684	657	549	638
90th	1158	1287	1384	1513	1704	1596	1431	1450	1441	1320	1169	1050
12 months												
10th	1698	1651	1689	1668	1681	1741	1808	1786	1790	1846	1840	1686
90th	2451	2546	2654	2671	2578	2510	2466	2629	2620	2488	2457	2496

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gisborne AWS												
1 month												
10th	33	24	18	36	22	39	63	25	16	8	13	17
90th	109	146	188	194	199	191	188	130	128	190	142	159
3 months												
10th	109	117	82	160	155	162	168	95	83	99	75	115
90th	349	418	421	435	488	472	412	339	372	358	296	317
6 months												
10th	269	408	431	418	317	323	287	241	234	228	257	238
90th	671	749	768	704	828	703	639	580	629	679	652	633
12 months												
10th	701	712	697	728	721	723	713	742	684	660	773	722
90th	1180	1179	1214	1262	1311	1243	1285	1319	1290	1223	1203	1200

Table 7 continued.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mahia AWS												
1 month												
10th	32	14	17	53	37	52	74	32	18	13	21	14
90th	108	164	170	231	205	219	192	165	117	196	155	142
3 months												
10th	110	121	117	198	221	221	172	99	80	76	93	104
90th	405	463	518	485	497	544	425	364	390	393	340	370
6 months												
10th	318	408	426	404	368	372	276	192	257	301	298	362
90th	810	891	903	799	877	815	807	652	695	710	766	744
12 months												
10th	723	716	716	768	756	804	881	891	963	917	800	691
90th	1525	1489	1507	1570	1616	1547	1473	1494	1492	1466	1518	1487

Rainfall frequency and intensity

The average number of days each year on which 0.1 mm or more of rain is recorded varies from 132 days at Tolaga Bay to 203 days at Motu. Most areas record around 155 days per year where at least 0.1 mm of rain is recorded. The 0.1 mm rain days and 1 mm wet days show the same geographic variability. Table 8 lists the average number of days per month with 0.1 mm and 1 mm of rain for selected stations.

Table 8. Average monthly rain days and wet days for Gisborne district; a: 0.1 mm rain day, b: 1 mm wet day, from all available data.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay AWS	a	10	10	13	13	14	16	17	17	14	13	12	12	162
	b	8	8	10	9	11	12	14	13	11	11	9	9	124
Mataraoa	a	10	9	11	12	13	13	14	15	14	13	12	11	148
	b	9	8	10	10	12	12	13	14	12	12	11	10	131
Ruatoria 2	a	10	10	12	13	13	15	16	17	15	13	11	12	156
	b	8	8	10	10	10	12	13	14	12	10	8	10	124
Te Pora	a	11	11	12	13	13	14	16	17	14	13	11	11	156
	b	8	8	10	10	11	11	13	13	11	10	9	8	123
Motu Ews	a	14	14	15	15	19	19	20	20	18	18	15	15	203
	b	10	10	11	10	12	14	14	14	14	14	11	12	146
Waipaoa	a	10	10	11	13	13	15	16	16	14	13	11	12	155
	b	9	8	9	10	11	12	13	14	12	11	9	10	130
Tolaga Bay Mangatuna	a	8	9	11	11	11	12	14	14	11	11	9	9	132
	b	7	7	9	10	9	11	12	12	9	9	7	7	108
Otoko	a	11	10	12	12	14	14	15	16	14	14	13	12	156
	b	9	8	9	9	11	11	12	13	11	11	10	10	126
Gisborne Aws	a	10	10	13	13	14	14	17	15	12	12	11	11	152
	b	7	8	9	9	10	10	13	11	8	8	8	7	108
Mahia AWS	a	11	11	14	15	17	17	19	17	13	13	12	11	169
	b	7	8	10	11	12	14	15	13	10	9	9	8	126

Gisborne is exposed to winds from the easterly quarter, so moisture-laden winds from this direction can induce heavy rainfalls. Intense rainfalls also occur with thunderstorms. In Table 9, maximum short period rainfalls for periods of 10 minutes to 72 hours with calculated return periods are given for Gisborne Airport, from all available data. Also listed in this table are the maximum rainfalls expected in 2, 5, 10, 20, and 50 years at those locations. Depth-duration frequency tables for locations in the Gisborne district are available from NIWA's High Intensity Rainfall Design System (HIRDS). HIRDS uses the index-frequency method to calculate rainfall return periods. For more information on methods and to use the tool, see www.hirds.niwa.co.nz.

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

Location		10min	20min	30min	1hr	2hrs	6hrs	12hrs	24hrs	48hrs	72hrs
Gisborne Aero	a	18	29	35	43	69	132	139	215	237	291
	b	55	87	75	39	88	100+	57	90	61	98
	c	7	11	13	19	27	45	63	87	104	115
	d	10	14	18	26	35	59	81	111	133	148
	e	12	17	21	31	42	70	96	131	157	174
	f	14	20	25	37	50	83	113	154	184	204
	g	17	25	32	46	63	103	139	189	226	251

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 Gisborne district

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

8–10 April 1982: Ex-tropical Cyclone Bernie brought high winds to the Gisborne district, causing significant damage to farms and buildings. The entire district suffered power cuts, and there were large-scale crop losses (up to 80% on some farms). At East Cape, winds reached hurricane-force. In Te Araroa, a man was killed when a falling tree crushed a car.

26–27 July 1985: Torrential rain and consequent flooding in the Gisborne district caused a Civil Defence Emergency (CDE) to be declared. People in rural areas were isolated by floodwaters, and in Gisborne raw sewage overflowed onto the land surface. Whole hillsides were lost in slips and there were high stock losses. Approximately 100 people were evacuated in the Poverty Bay area.

6–12 March 1988: Ex-tropical Cyclone Bola caused heavy rain, flooding, high winds, and heavy seas in the Gisborne district. Bola produced some of the largest rainfall totals for any single storm ever recorded in the North Island. In the Gisborne district, some stations in the high country recorded more than 800 mm of rain over the four-day storm (Sinclair, 1993). Significant landsliding occurred in the district, with some farmers losing 30% of their grazing area. A CDE was declared

for the district from 7–13 March, and was re-declared for parts of the district from the 22–25 March. By the third day of the storm, 17 helicopters were operating to rescue people throughout the district. In Gisborne city alone, 3000 people were evacuated. Three people drowned near Tolaga Bay, when they were trapped in a car that was swept away by floodwaters. Damage costs to the district totalled $189 million 2008 dollars (Figure 10). Assistance costs paid to farmers following the event were estimated at $35 million 2008 dollars, and the cost for repairing non-insurable on-farm storm damage (fences, farm tracks, etc.) was estimated at $29 million 2008 dollars. In the district, farm valuations reduced by an estimated $32.5 million 2008 dollars.

Photo. Noel Trustrum, GNS

Figure 10. Damage caused by ex-Tropical Cyclone Bola.

1–2 September 1988: High winds and heavy rain associated with a deep depression caused severe flooding and damage to the Gisborne district. More than 10% of some farmers' lambs died during the storm, and bridge/roading damage was estimated at $3.7 million 2009 dollars. During the storm, the Waimata and Waipaoa Rivers deposited 3–4 m of silt in some places, and numerous slips occurred.

20–22 October 2005: A deep low caused heavy rain and strong winds in the Gisborne district. Three main highways into the district, as well as many other local roads, were closed by slips, fallen trees, and flooding. Power was cut to hundreds of homes, and phone communications were lost in some rural areas. Hundreds of hectares of crops were lost after stopbanks were breached during a critical part of the growing season. A number of people were evacuated from rural areas where floodwaters threatened their homes. The event was expected to cost the district more than $55 million 2008 dollars.

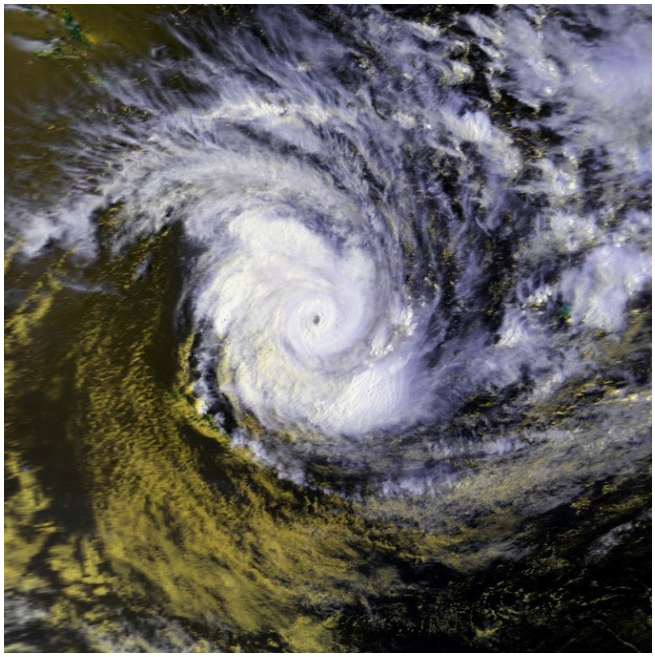

Photo. NOAA

20 September 2015: A stalling low to the east of the North Island began to direct heavy rainfall to the Gisborne region causing widespread surface flooding. Fallen trees and many slips were widely reported, and the town of Te Karaka was isolated by flooding. Gisborne recorded 104 mm of rain, which at the time of publication is its highest 1-day rainfall for September since records began in 1937.

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 common in the Gisborne district during the summer and early autumn. There is usually one, and frequently two, such periods each year between December and March. This frequency is similar to that recorded in other eastern parts of New Zealand. The average duration of a dry spell is about 18 days. The longest recent dry spell between three key sites in Gisborne district (Gisborne, Hicks Bay, and Motu) was 69 days recorded in Gisborne, from 3 November 1994 to 10 January 1995. During this dry spell, it did not rain for 27 consecutive days. Other long dry spells include 39 days at Hicks Bay from 11 January to 18 February 1998, of which 20 consecutive days were without any rain, and 28 days at Gisborne from 1–28 March 2007, of which 12 consecutive days were without any rain.

Temperature

Sea surface temperature

In the Gisborne district, average sea surface temperatures range from around 14°C in August up to 20°C during February (Figure 11, 12). Monthly mean sea surface temperatures off the coast of the Gisborne district are compared to mean air temperature for Gisborne AWS in Figure 11. There is a six to eight week lag between the minima of land and sea temperatures. Figure 12 shows the mean sea surface temperatures for the New Zealand region for February and August, which are the warmest and coolest months with respect to sea surface temperatures.

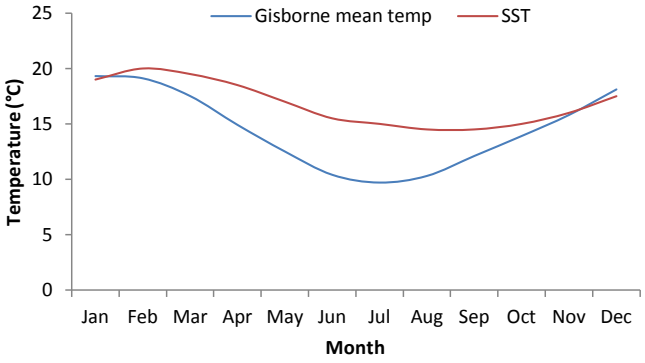

Figure 11. Mean monthly land (Gisborne AWS) and sea surface temperatures.

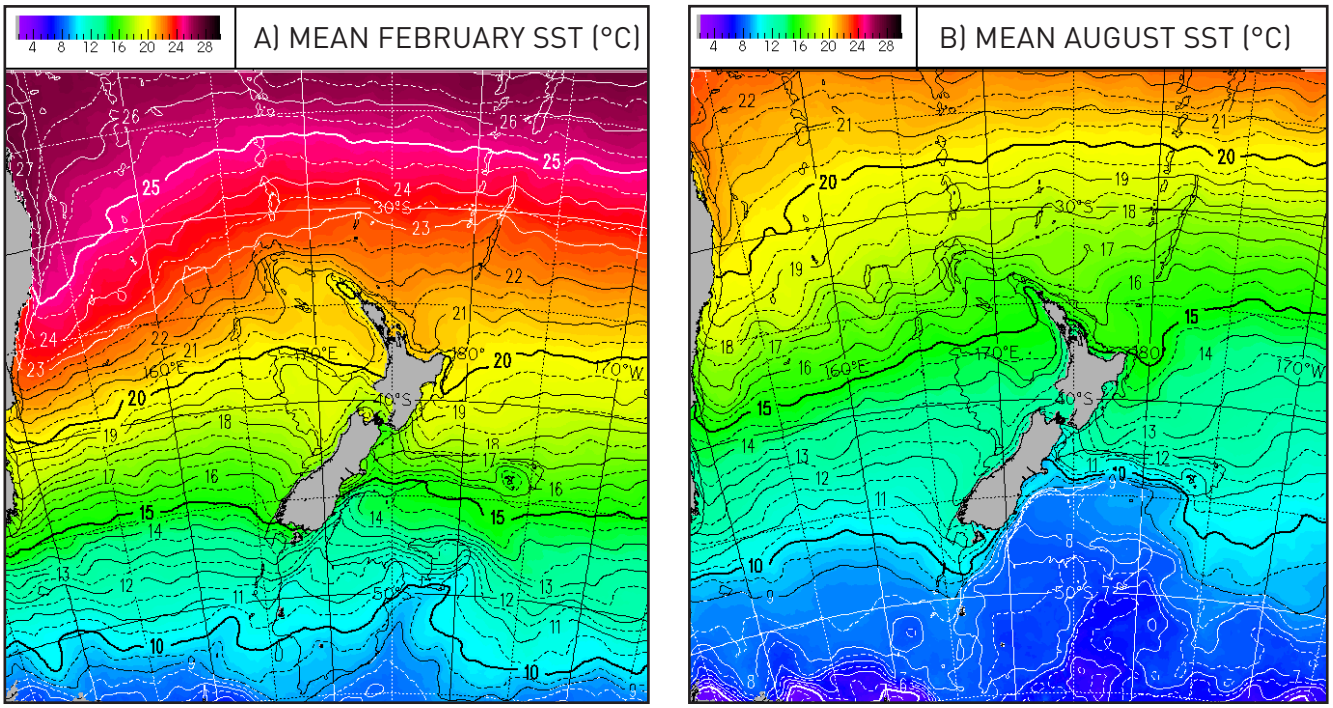

Figure 12. Monthly mean sea surface temperatures (°C) for: a) February; b) August. Source: NIWA SST Archive, Uddstrom and Oien (1999).

Air temperature

Because New Zealand has a relatively small land area and is surrounded by a vast area of ocean, seasonal and diurnal temperature variations are relatively small. This is especially apparent near the coast in the Gisborne district, where the sea exerts a modifying effect. Katabatic drainage of cold air contributes to lower minimum temperatures at Gisborne city, especially in winter. Variations in altitude are accompanied by variations in mean temperature, where mean temperature reduces with height. The eastern part of the district, under the influence of foehn winds, has recorded some of the highest North Island temperatures known. Average daily maximum temperatures over 20°C are recorded over most of the district during the months December to March (Figure 13a) and most places have recorded temperatures over 30°C on at least one occasion.

Inland areas in particular are subject to cold night-time temperatures during winter, especially when clear skies permit rapid radiational cooling. Air temperatures below 0°C are recorded in most parts of the district each winter, with mean daily minimum winter temperatures between 1°C and 5°C experienced for most inland parts of the district (Figure 13b). Figure 14 shows that median annual average temperature in the Gisborne district varies with elevation. Low-lying coastal areas have a mean annual temperature of around 14°C, whereas the higher-elevation Raukumara Range experiences a mean annual temperature of around 9°C. Figure 15 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 Gisborne district.

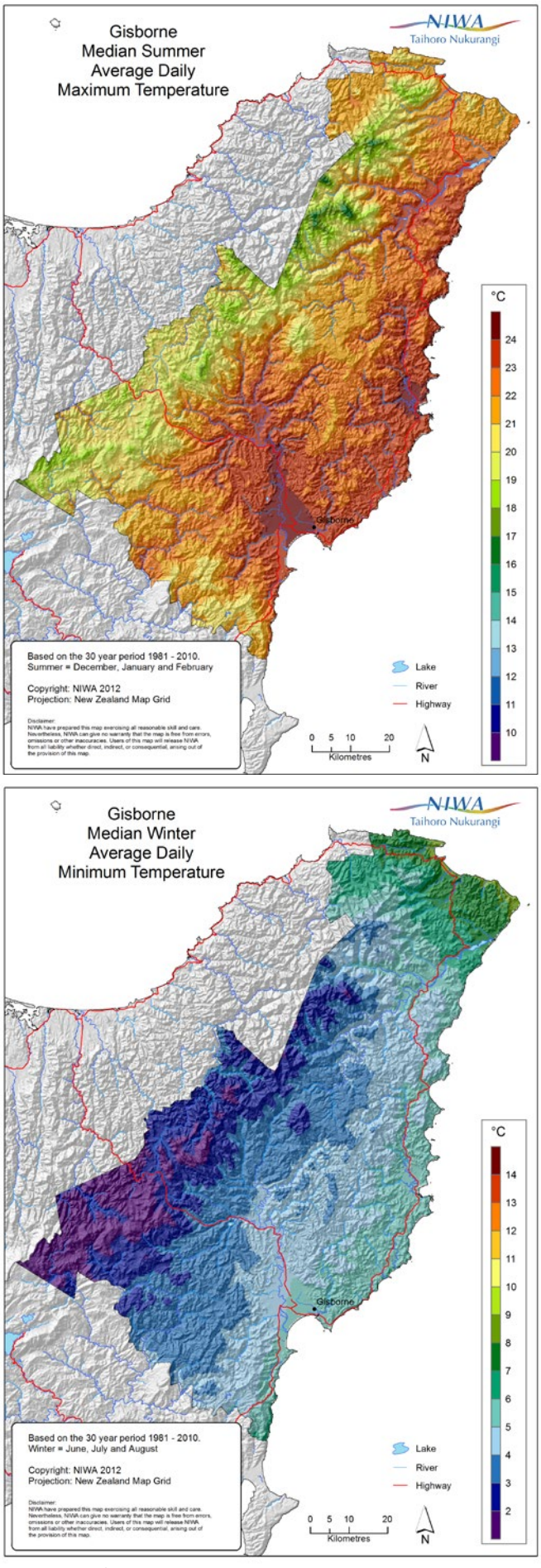

Figure 13. a) Gisborne district median summer average daily maximum temperature; b) Gisborne district median winter average daily minimum temperature.

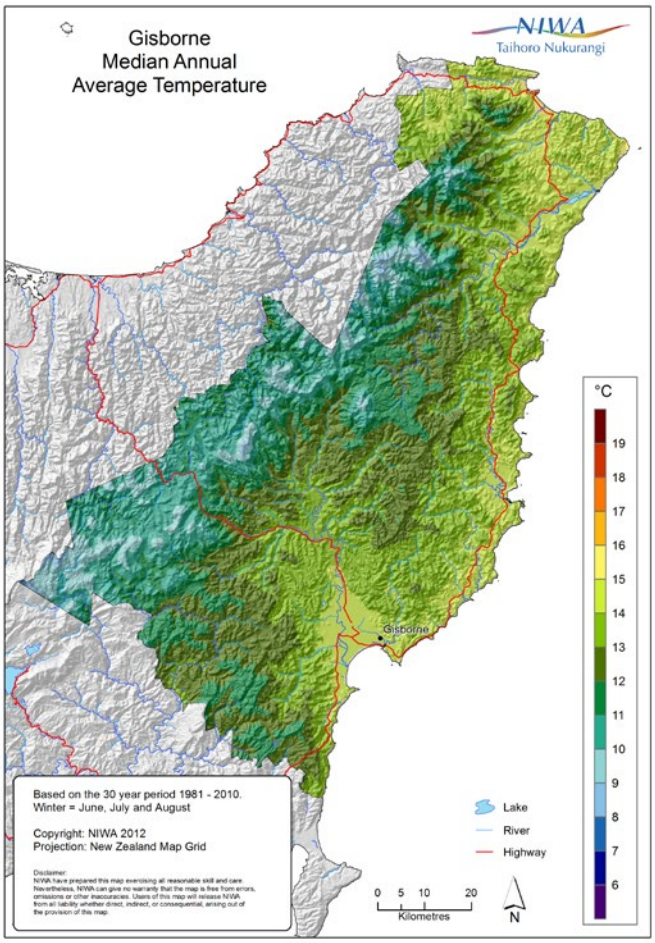

Figure 14. Gisborne district median annual average temperature, 1981–2010.

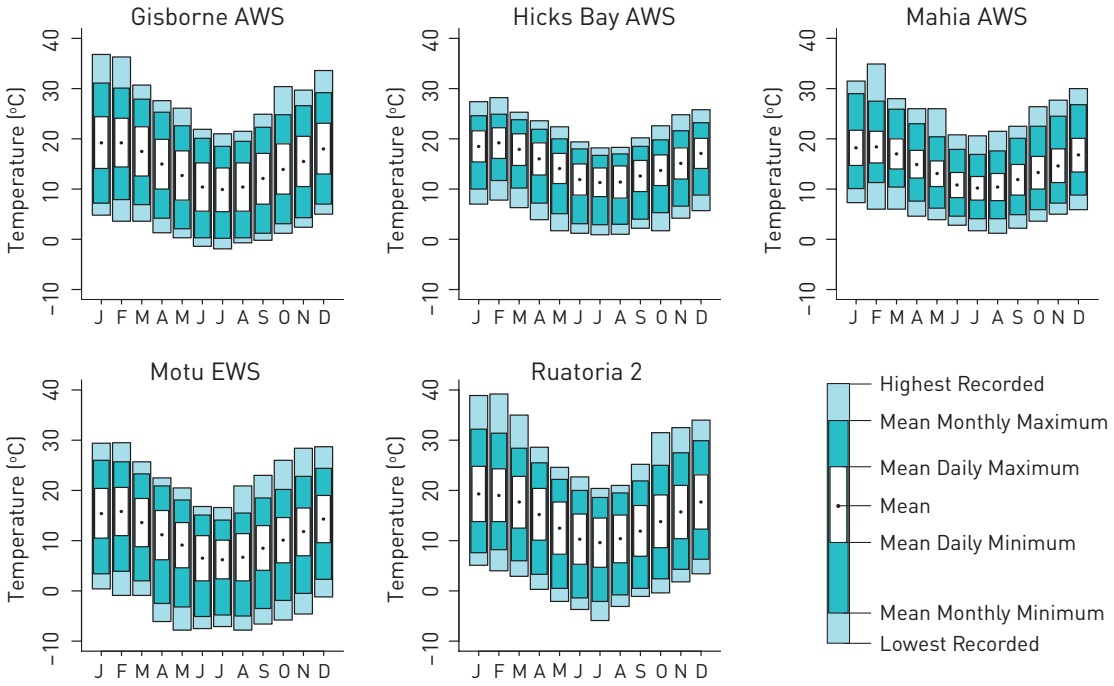

Figure 15. Monthly variation in air temperatures for selected Gisborne stations.

The annual mean daily temperature range for Gisborne district is 8.1°C. Table 10 shows the average daily temperature range for each month for a number of sites in Gisborne district. Hicks Bay has the smallest temperature range and Ruatoria has the largest.

Table 10. Average daily temperature range (°C) for Gisborne sites.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay Aws	6.4	6.2	6.2	6.5	6.1	6.2	5.9	6.3	6.0	6.1	6.1	6.1	6.2
Ruatoria 2	11.1	10.3	10.3	10.4	10.4	10.2	9.8	9.8	10.3	10.5	10.4	10.8	10.3
Gisborne Aws	10.8	10.2	10.1	10.1	9.9	9.5	9.0	9.6	9.9	10.1	10.3	10.3	10.0

The diurnal temperature range for Gisborne is moderate. Table 11 and Figure 16 show mean hourly temperatures for Gisborne AWS for January and July. From this, it can be seen that the average daily range for January is 7.9°C and for July it is 6.0°C.

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

		00	01	02	03	04	05	06	07	08	09	10	11
Gisborne	**January**	16.4	16.0	15.7	15.4	15.1	14.9	15.6	17.4	19.1	20.5	21.5	22.2
	July	8.1	8.1	8.0	7.8	7.7	7.6	7.4	7.5	7.7	9.1	10.7	11.9
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
	January	22.5	22.7	22.8	22.7	22.3	21.8	21.0	19.9	18.7	17.9	17.3	16.8
	July	12.6	13.2	13.4	13.1	12.7	11.6	10.3	9.6	9.2	8.8	8.6	8.4

The highest daily temperature recorded to date in the Gisborne district is 39.2°C, at Ruatoria on 7 February 1973. This is also the highest temperature recorded to date in the North Island. The lowest air temperature recorded in the Gisborne district to date is -7.8°C, at Motu on both 24th August 2000 and 22nd May 2009. These extreme temperatures compare to national extremes of 42.4°C and -25.6°C.

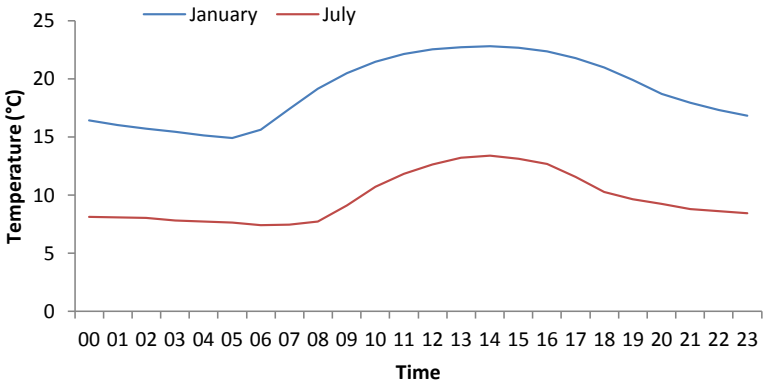

Figure 16. Mean hourly temperatures at Gisborne AWS for January and July.

Earth temperatures

Earth (soil) temperatures are measured once daily at 9 am at several locations in the Gisborne district. Earth temperatures are measured at varying depths and are important, amongst other things, for determining the growth and development of plants. Different plants have different rooting depths and as such, earth temperatures are routinely monitored at 10, 20, 30, 50, and 100 cm depths. Table 12 lists mean monthly earth temperatures for a number of standard depths.

In the Gisborne district, earth temperatures, like air temperatures, vary spatially. Waerenga O Kuri is at an elevation of 314 m, and therefore exhibits cooler 9 am earth temperatures than the sites at lower elevations. Figure 17 shows how earth temperatures change throughout the year at Gisborne Airport, compared with air temperature at Gisborne AWS (at the same location as Gisborne Airport station). The temperature cycle for 100 cm depth is more damped and lagged than at shallower depths.

Table 12. Mean 9 am earth temperatures at different Gisborne district locations, with station elevations, from all available data.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Ruatoria 2 (61m)													
10 cm	21	20	18	14	10	8	7	8	11	14	17	19	14
20 cm	22	21	19	16	12	10	9	9	11	14	17	20	15
30 cm	22	22	20	17	13	10	9	10	12	15	18	20	16
Gisborne Aero (4m)													
10 cm	20	20	17	14	10	8	7	8	10	14	17	19	14
20 cm	21	21	18	15	12	9	8	9	11	14	17	20	15
30 cm	21	21	19	16	12	10	9	10	12	14	17	20	15
100cm	19	20	19	17	15	12	11	11	12	14	16	18	15
Waerenga O Kuri 2 (314m)													
10cm	18	18	16	13	10	7	6	7	9	12	15	17	12
20cm	19	19	17	15	11	9	8	9	11	13	15	17	14
30cm	19	19	18	15	12	10	9	9	11	13	15	18	14
100cm	17	18	18	16	14	13	11	11	11	13	14	16	14

Frosts

Frost is a local phenomenon and its frequency of occurrence can vary widely over 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 inland valleys, where cold air is likely to drift from higher areas. In general, frosts are infrequent close to the moderating effects of the sea.

There are two types of frost recorded. Air frosts occur when air temperature measured in a screen by a thermometer 1.3 m above the ground falls below 0°C. Ground frosts are recorded when the air temperature 2.5 cm above a clipped grass surface falls to -1.0°C or lower. Both types of frost are common in the Gisborne district in the cooler months. Table 13 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. Manutuke is influenced by katabatic drainage resulting from its location at the base of the surrounding hills, and therefore records the greatest number of frosts in the district. Data on air temperatures (mean daily, monthly minima, and extreme minima) can be obtained from Figure 15.

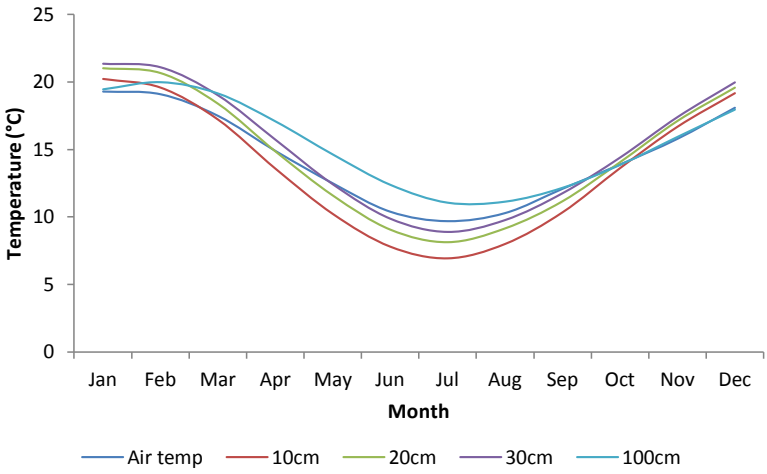

Figure 17. Average monthly 9 am earth temperatures for different depths at Gisborne Airport and mean 9 am air temperature at Gisborne AWS (same location as Gisborne Aero).

Table 13. Occurrences of frosts and grass minimum temperatures in Gisborne district. Insufficient (<10 years) daily temperature data to obtain a record grass minimum temperature for Waerenga O Kuri.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Ruatoria 2	a	11.0	11.2	9.9	7.3	4.3	2.3	1.6	2.6	3.6	5.6	7.6	9.8	6.4
	b	1.7	1.0	-0.6	-3.4	-5.9	-8.9	-8.6	-7.4	-5.7	-4.6	-1.8	-1.9	
	c	0.0	0.0	0.0	0.7	4.0	8.2	10.0	7.3	3.9	1.0	0.2	0.0	35.2
	d	0.0	0.0	0.0	0.0	0.5	3.0	3.4	1.8	0.4	0.0	0.0	0.0	9.2
Gisborne Aero	a	10.5	10.8	9.1	6.7	4.2	2.3	1.6	2.2	3.3	5.1	7.1	9.2	6.0
	b	1.5	1.0	-1.4	-2.2	-7.0	-6.9	-8.9	-6.4	-4.6	-2.7	-2.5	-0.9	
	c	0.0	0.0	0.1	0.9	3.7	8.1	9.6	8.4	5.1	2.2	0.7	0.1	39.0
	d	0.0	0.0	0.0	0.0	0.3	2.0	2.3	1.2	0.2	0.1	0.0	0.0	6.1
Gisborne Manutuke	a	10.2	10.4	9.0	6.2	3.4	1.4	0.8	1.8	3.1	4.9	6.8	9.0	5.6
	b	0.2	0.5	-2.1	-4.0	-8.2	-7.9	-7.1	-5.1	-5.1	-4.0	-2.2	-1.5	
	c	0.0	0.0	0.2	1.3	5.7	10.7	11.7	9.4	4.7	1.7	0.5	0.1	46.0
	d	0.0	0.0	0.0	0.1	0.8	3.7	4.1	1.8	0.5	0.1	0.0	0.0	11.2
Waerenga O Kuri 2	a	9.3	9.7	8.0	5.9	3.6	1.5	0.9	1.7	2.7	4.5	6.1	8.0	5.2
	b	-	-	-	-	-	-	-	-	-	-	-	-	
	c	0.1	0.0	0.3	1.0	3.9	8.3	9.8	8.1	4.8	1.9	0.9	0.3	39.3
	d	0.0	0.0	0.0	0.0	0.2	1.5	2.0	1.0	0.3	0.1	0.0	0.0	5.1

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

Gisborne district is among New Zealand's sunniest regions, with most parts of the district receiving at least 2200 bright sunshine hours per year. Gisborne city records an average of 2219 bright sunshine hours per year. There is a west to east gradient of sunshine hours in the district, with western areas receiving between 1800 and 2100 hours of bright sunshine per year, compared to eastern areas receiving at least 2200 hours (Figure 18). Figure 19 shows the monthly mean, maximum, and minimum recorded bright sunshine hours for selected sites in the Gisborne district.

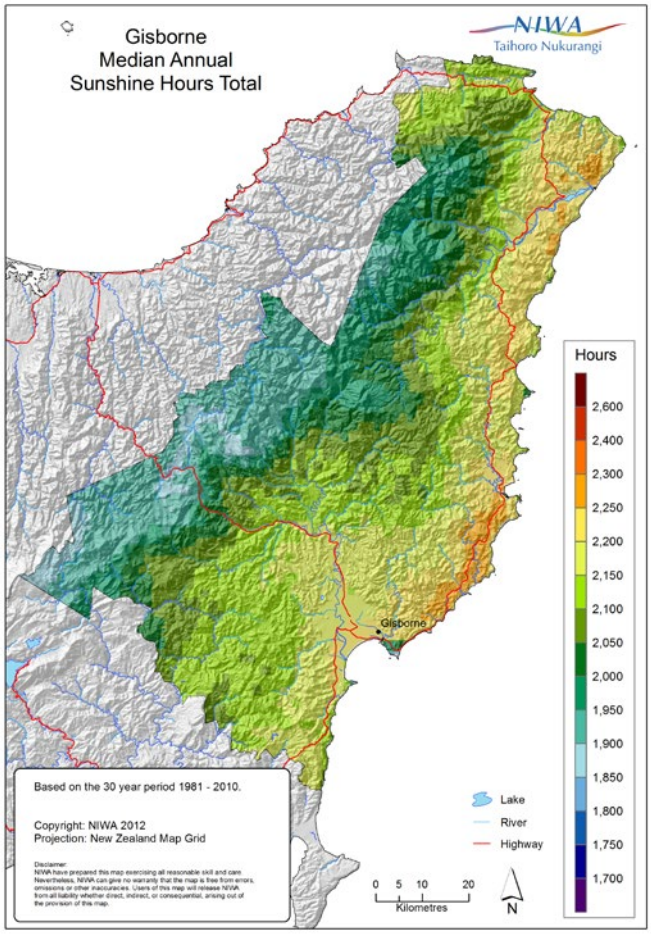

Figure 18. Median annual sunshine hours for Gisborne district, 1981–2010.

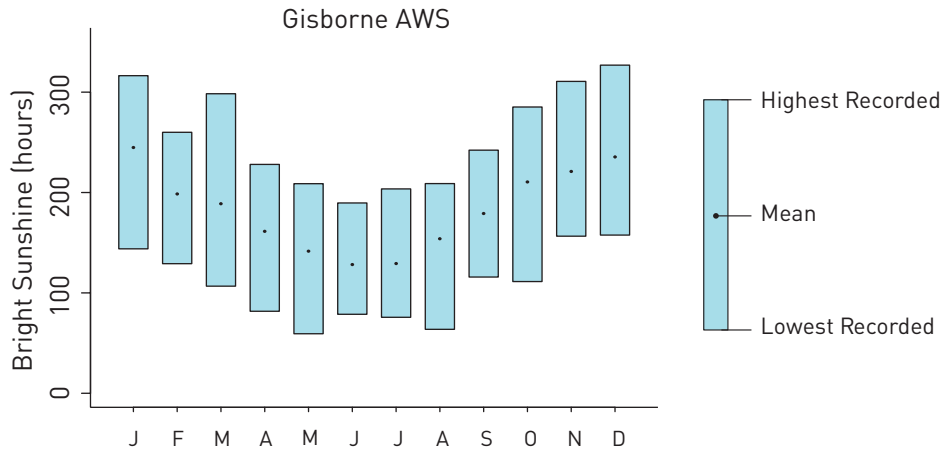

Figure 19. Mean, highest, and lowest recorded monthly bright sunshine hours for Gisborne Aero. Note that Gisborne Aero is the only site in the Gisborne district with sunshine records longer than 10 years.

Solar radiation

Solar radiation records are available for a number of sites in the Gisborne district. Solar radiation is presented for a selection of sites, using all available data. Insolation is at a maximum in December and January and a minimum in June. Table 14 shows mean daily solar radiation (global) for each month for these four sites.

Table 14. Mean daily global solar radiation (MJ/m2/day) for Gisborne sites, using all available data.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay AWS	23	19	16	12	9	7	8	11	15	18	21	22	15
Motu EWS	21	18	14	10	7	6	6	9	12	16	20	20	13
Gisborne AWS	23	19	15	11	8	6	7	10	14	19	22	23	15
Mahia AWS	22	19	15	11	8	6	6	10	14	18	21	22	14

UV (Ultra-violet) radiation

Ultra-violet radiation (UV) measurements are not available for the Gisborne district. Figure 20 shows an example of a UV forecast for Gisborne which is representative of most locations in the Gisborne district. In the summer (Figure 20a) UV radiation is high, prompting warnings for sun protection between 9 am and 5.30 pm. In the winter (Figure 20b), the amount of UV radiation does not reach the level at which sun protection is advised.

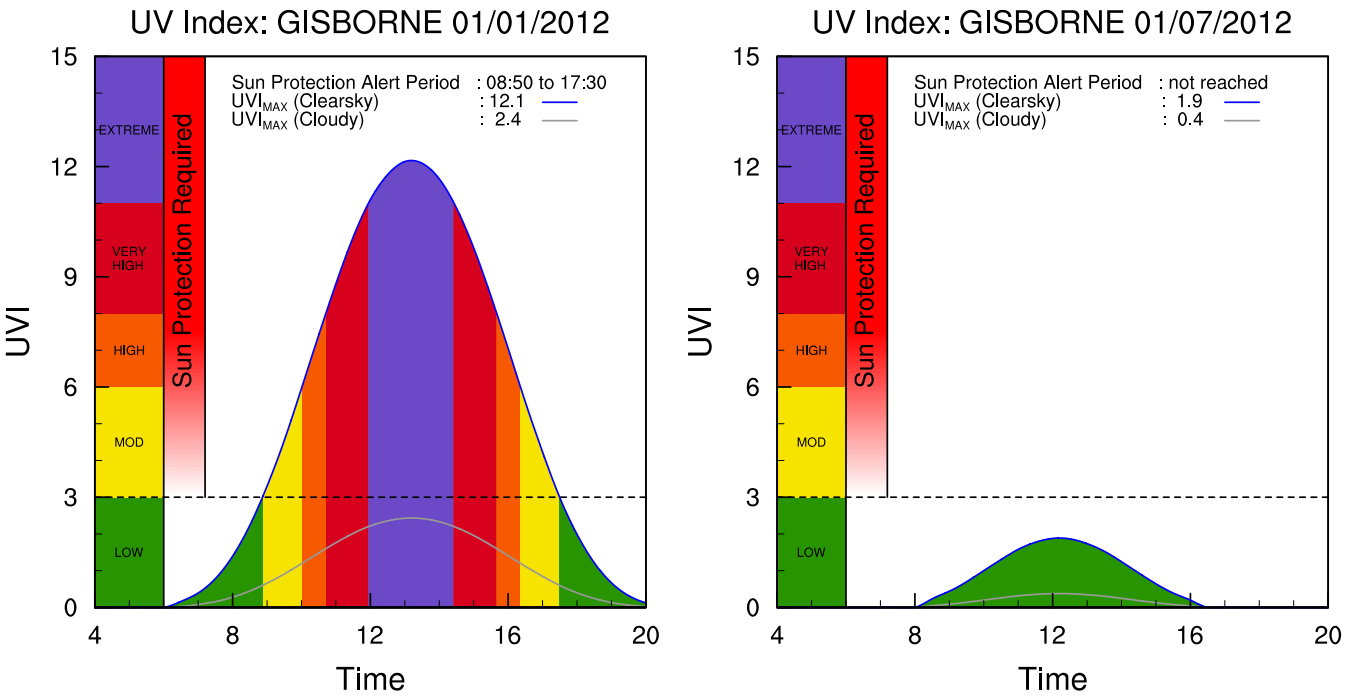

Figure 20. UV Index forecast for Gisborne, January (a) and July (b). Source: https://www.niwa.co.nz/our-services/online-services/uv-and-ozone.

Fog

The most common type of fog in the Gisborne district is radiation fog, formed when the air cools to its dew-point on clear nights, allowing the water vapour in the air to condense. Coastal areas occasionally experience sea fogs, and extensive low cloud, with very moist onshore flows. Another type of fog sometimes seen in the district is 'steaming fog'. This forms predominantly on cold nights when the water vapour evaporating off lakes and rivers condenses as it rises into the cool air, giving the impression of steam rising off the water surface. Fogs also sometimes form when the humidity of the air near the ground has been raised by falling rain.

The frequency of fog in the Gisborne district varies considerably (Table 15). Gisborne Airport experiences many more fogs than other areas (36 per year on average, compared with 2 per year for other locations in Table 15). Although fog can occur at any time of the year it is recorded most frequently between March and August.

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

	Fog	Thunder	Hail
East Cape	5	2	0.5
Ruatoria 2	4	2	0.5
Gisborne Aero	8	36	3
Gisborne Manutuke	6	2	0.5

Severe convective storms

Thunderstorms and hail

While thunderstorms and hail may occur in the Gisborne district in any month, thunderstorms are most frequent in the summer and hail is more likely in spring. Average annual frequencies of thunder and hail for selected stations are given in Table 15. Thunder is recorded most frequently in Gisborne (8 days per year) and least frequently in Ruatoria (4 days per year). Hail is also observed in Gisborne most often (3 days per year), whereas other sites record only one day every two years with hail, on average. At some of the stations, it is likely that not all thunderstorms and hail events are detected. The heavy rain, lightning, hail, wind squalls, and rare tornadoes which can occur with thunderstorms will sometimes cause severe local flooding, disruption of electrical and electronic equipment, and damage to trees, crops, and buildings.

Tornadoes

Tornadoes are rapidly rotating columns of air extending from the base of a cumulonimbus cloud, and have in New Zealand a damage path typically 10–20 m wide and 1–5 km long. The small size (compared to tornadoes in the USA), their short lifetimes, and the sparse population of much of New Zealand must result in an unknown number of tornadoes not being reported.

Tornadoes are rare in the Gisborne district, but the steep topography of the hill country can amplify air currents and localised tornadoes can occasionally form, but they are usually very short-lasting. Only one damage-causing tornado was reported in the Gisborne district between 1981 and 2012, on 13 September 2011. The tornado caused damage to a farm about 35 km inland from Gisborne, felling trees and ripping roofing iron off buildings.

Snow

Snow is rare in most parts of the Gisborne district and is unknown near the coast. Above an altitude of 600 m a few falls of snow may be expected in any winter and in some areas moderate or even heavy falls have occurred at times.

Sea swell and waves

The area of the Pacific Ocean which is bounded by the Gisborne district is sheltered from the prevailing west to southwest swells of its latitude zone by the land mass of the North Island. Consequently high waves are less frequent than in corresponding western areas. Similarly it is protected from the cool ocean currents induced by the prevailing westerly winds.

Sea and swell wave characteristics in the Gisborne district are determined by the area's exposure to the prevailing winds and by the sheltering provided by the North Island. Thus waves from the southerly quarter are the most frequent (due to the district's exposure to the south). The prevailing easterly flow over the Pacific Ocean to the north of New Zealand produces a persistent easterly swell in the latitude of northern New Zealand, especially during the summer and autumn when the belt of southeasterly trade winds tends to lie further south than in other seasons. Of all swells observed, the frequency of those from one to two metres is 65%, while for those greater than two metres is 20% (Gorman et al., 2003).

There is a known relationship between steady wind speed and wave heights over the open sea. The most probable wave heights for a given wind speed over a typical fetch length in New Zealand coastal waters of about 500 km are given in Table 16.

Table 16. Generated wave heights associated with specific wind speeds. Assumes a fetch length of 500 km with unlimited wind duration.

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


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DERIVED CLIMATOLOGICAL PARAMETERS

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

Vapour pressure and relative humidity

The water vapour content of air can be expressed in several ways - the most commonly used being vapour pressure and relative humidity. Vapour pressure is the part of the total air pressure which results from the presence of water vapour. Relative humidity expresses the actual vapour pressure as a percentage of the saturation vapour pressure at the ambient temperature. Relative humidity is therefore normally highest in the morning at the time of the minimum temperature and lowest during the afternoon when temperatures are at their warmest.

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 17.

Relative humidity is variable throughout the year, but there is a peak in winter and a low point in spring, as shown in Table 18. Gisborne and Ruatoria record the highest average relative humidities in the district, but also some of the lowest.

Evapotranspiration and soil water balance

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

Mean monthly and annual water balance values are given in Table 19, for a number of sites in the Gisborne district. It can be seen from this table that coastal parts

Table 17. Mean monthly/annual 9 am vapour pressure (hPa) for selected Gisborne district sites, from all available data.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay AWS	16.7	17.4	16.0	14.5	13.0	11.0	10.6	10.6	11.7	12.5	13.4	15.8	13.6
Ruatoria 2	16.5	16.9	15.8	14.1	11.5	10.3	9.6	10.3	11.1	12.3	13.3	15.0	13.1
Gisborne Aero	15.6	16.3	15.4	13.5	11.5	9.8	9.4	9.9	10.8	11.7	12.7	14.4	12.6
Mahia AWS	15.6	16.2	14.9	13.7	12.0	10.2	9.9	9.8	10.5	11.2	12.2	14.5	12.6

Table 18. Mean monthly/annual 9 am relative humidity (%) for selected Gisborne district sites, from all available data.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay AWS	76	78	77	76	78	77	78	75	75	77	76	79	77
Ruatoria 2	70	77	75	78	80	85	83	81	74	71	70	70	76
Gisborne Aero	70	76	78	80	82	83	84	81	74	71	68	69	76
Mahia AWS	75	79	79	80	80	79	81	78	74	74	74	76	77

of the district have about 46 days between November and February when there is insufficient soil moisture to maintain plant growth without irrigation, but this is only 13 days in inland areas (Motu). There is adequate moisture available to maintain plant growth between June and September, except for at Gisborne where only July and August have no days of soil moisture deficit, on average. Figure 21 shows district-wide variability in days of soil moisture deficit per year.

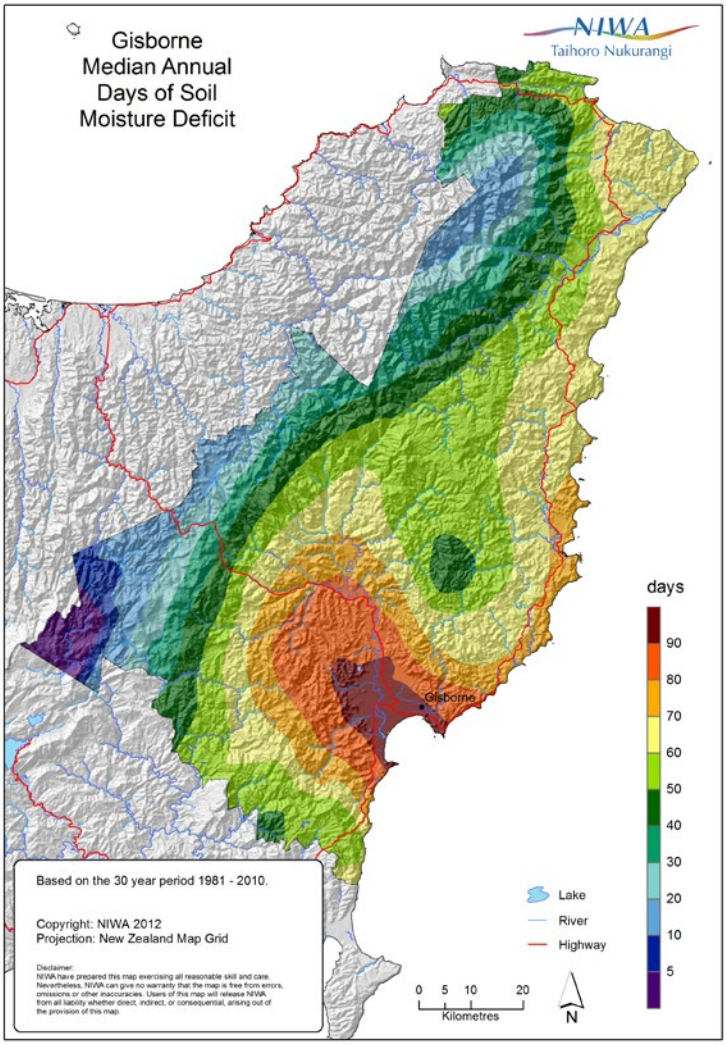

Figure 21. Gisborne district median annual days of soil moisture deficit, 1981–2010.

Table 19. Mean monthly/annual water balance summary for a soil moisture capacity of 150 mm, from all available data.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay AWS	DE	85	57	17	13	5	0	0	0	0	5	44	58	284
	ND	16	12	4	5	3	0	0	0	0	1	10	12	64
	RO	4	14	25	23	64	112	112	71	21	19	2	11	478
	NR	0	1	1	1	4	8	9	7	3	2	0	0	36
Tolaga Bay Mangatu	DE	81	50	24	7	1	0	0	0	1	14	60	78	317
	ND	16	12	7	3	1	0	0	0	0	4	13	15	71
	RO	8	18	43	62	78	106	143	122	55	29	15	8	688
	NR	0	1	2	3	5	7	9	8	4	2	1	0	42
Motu Waiwhero	DE	19	19	4	0	0	0	0	0	0	0	2	8	52
	ND	5	6	2	0	0	0	0	0	0	0	0	2	14
	RO	33	23	49	85	166	220	211	160	133	138	71	62	1352
	NR	1	1	2	5	11	13	14	12	8	8	4	3	83
Gisborne AWS	DE	92	57	35	8	3	1	0	0	2	34	70	93	393
	ND	18	13	10	4	2	1	0	0	1	9	15	18	92
	RO	0	3	12	25	39	56	101	39	17	14	1	0	306
	NR	0	0	1	2	4	6	9	5	1	1	0	0	29

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

Potential evapotranspiration (PET) has been calculated for Hicks Bay, Gisborne, and Mahia, using the Penman method (Penman, 1948). The monthly mean, minimum, and maximum PET values are listed in Table 20.

Table 20. Penman calculated maximum, mean, and minimum monthly potential evapotranspiration (mm), as well as total mean annual PET, from all available data.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay AWS	Max	190	149	126	91	75	52	61	74	101	137	155	166	
	Mean	159	129	114	78	56	44	50	64	85	115	133	143	1170
	Min	135	99	102	58	45	33	42	45	70	91	112	117	
Gisborne Aero	Max	189	147	130	80	54	36	40	61	92	152	164	184	
	Mean	154	119	94	58	36	26	29	42	68	103	133	151	1011
	Min	110	99	79	43	26	16	20	27	55	80	102	112	
Mahia AWS	Max	184	154	125	74	60	45	48	63	95	147	166	183	
	Mean	151	117	98	60	43	34	36	52	77	112	132	144	1056
	Min	91	87	61	47	31	24	23	40	63	96	85	101	

Gisborne experienced a severe drought in the summer and early autumn of 2012–2013. Between December 2012 and March 2013, only 35% of normal rainfall for that period was recorded in Gisborne (98 mm), and 50% of normal rainfall for December to March was recorded in Motu (287 mm). Motu experienced its driest summer on record (records began in 1990) of 245 mm of rain, which was 55% of normal summer rainfall. In Gisborne city, a sprinkler ban was in force, and there was a total fire ban throughout the district. Figure 22 shows the soil moisture deficits reached at Gisborne over the drought period, compared to normal soil moisture deficit conditions for the same time of year (soil moisture deficit from August to May averaged from 1981–2010). Much of the district was suffering from extreme soil moisture deficits (more than 130 mm of deficit), which meant that pasture growth had ceased (Figure 23). The dry conditions meant that farmers had to dry off cattle early and sell off stock. The stock feed situation remained very low in drought-stricken areas, and the price of feed significantly increased. At the time of writing (June 2013), economic costs due to the 2012–13 drought across the North Island and Westland were estimated at a minimum of $1.6 billion.

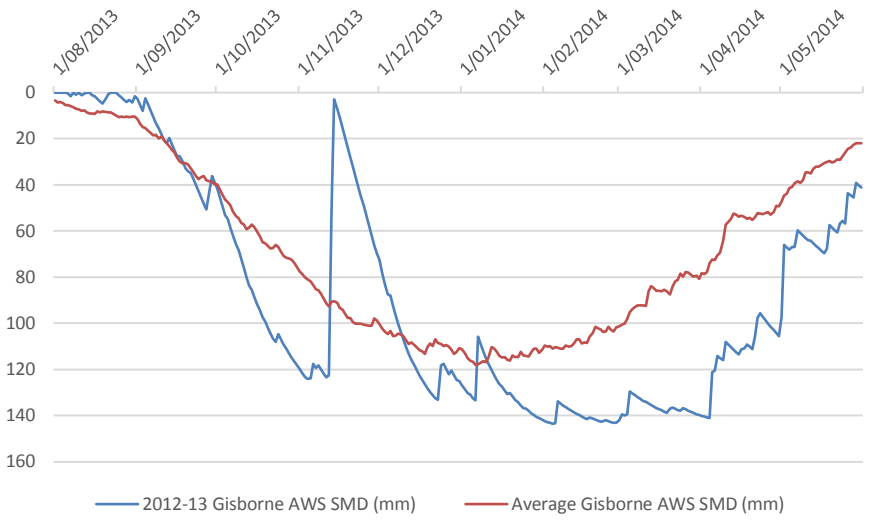

Figure 22. Soil moisture deficit at Gisborne AWS during the 2012–2013 drought, compared with normal soil moisture deficit conditions for the same time of year at Gisborne AWS (1981–2010).

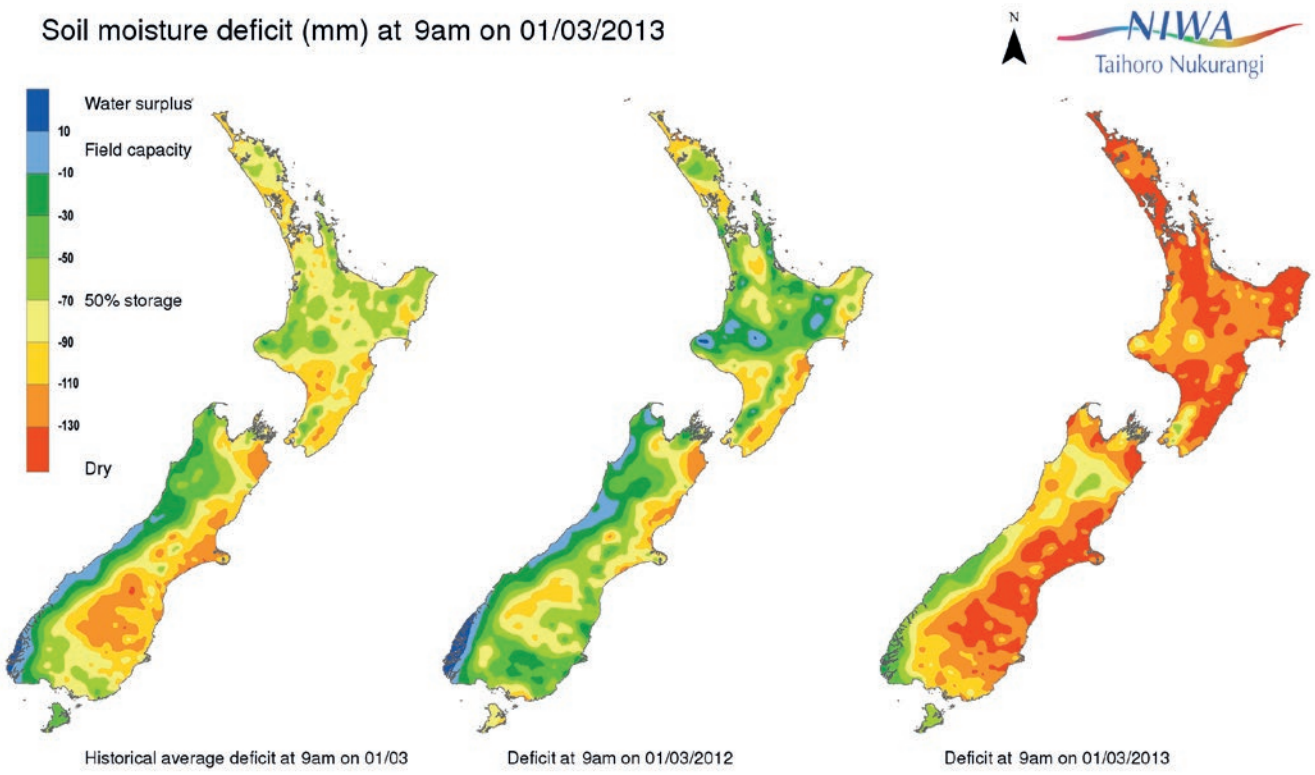

Figure 23. Soil moisture deficit as at 1 March 2013 (right hand map). Areas of extreme soil moisture deficit (more than 130 mm of soil moisture deficit) are shown in red, and areas of significant soil moisture deficit (more than 110 mm of soil moisture deficit) are shown in dark orange. Normal soil moisture deficit conditions for the time of year are given in the left hand figure, and the middle figure shows soil moisture deficit conditions as at 1 March 2012.

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 21 lists the monthly totals of growing degree-day totals above base temperatures of 5°C and 10°C for sites in the Gisborne district.

Table 21. Average growing degree-day totals above base 5°C and 10°C for selected Gisborne district sites.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay AWS	5°C	419	401	400	331	282	208	197	198	228	272	302	375	3612
	10°C	264	259	245	181	128	65	50	50	79	117	152	220	1811
Ruatoria 2	5°C	445	399	398	308	231	160	143	168	215	271	329	398	3464
	10°C	290	257	243	158	79	37	22	34	71	118	179	243	1731
Gisborne AWS	5°C	441	403	386	299	239	162	152	165	211	278	316	404	3455
	10°C	286	261	231	149	88	34	26	34	69	124	166	249	1717
Mahia AWS	5°C	408	379	371	298	250	174	160	167	205	256	289	365	3323
	10°C	253	238	216	148	97	38	25	30	61	103	139	210	1559

Cooling and heating degree days are measurements that reflect the amount of energy that is required to cool or heat buildings to a comfortable base temperature, which in this case is 18°C. Table 22 shows that the number of cooling degree days reach a peak in summer in Gisborne district, where there is a higher demand for energy to cool building interiors to 18°C. Conversely, heating degree days reach a peak in winter, where the demand for energy to heat buildings to 18°C is highest. Figure 24 shows district-wide variability in the number of heating degree days per year. The number of heating degree days tends to be lower in low elevation coastal areas, compared with areas further inland and at higher elevations.

Table 22. Average cooling (CDD) and heating (HDD) degree-day totals with base 18°C for selected Bay of Plenty sites.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Hicks Bay AWS	CDD	31	40	21	5	1	0	0	0	0	0	0	11	109
	HDD	15	7	24	64	121	182	206	205	162	131	88	39	1246
Ruatoria 2	CDD	57	44	27	5	1	0	0	0	0	1	10	29	175
	HDD	15	13	33	87	173	230	260	236	175	132	71	35	1460
Gisborne AWS	CDD	59	50	24	6	1	0	0	0	0	2	9	38	189
	HDD	21	15	40	97	165	228	252	238	179	128	83	37	1483
Mahia AWS	CDD	33	31	14	3	0	0	0	0	0	1	3	16	101
	HDD	28	19	45	95	154	216	243	236	185	148	105	54	1527

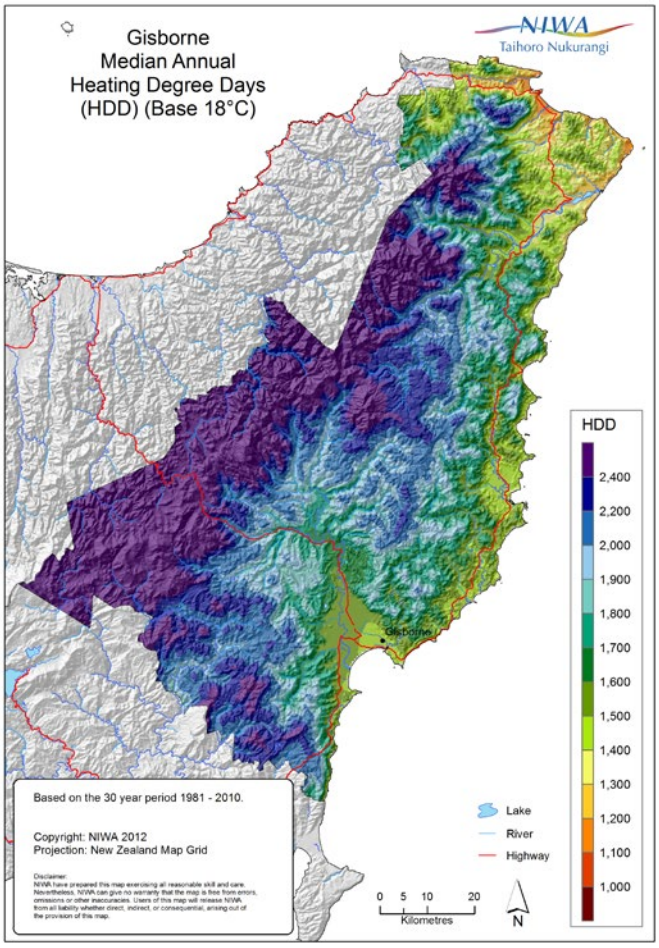

Figure 24. Median annual heating degree days for Gisborne district, 1981–2010.

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