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THE CLIMATE OF CHRISTCHURCH

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THE CLIMATE OF CHRISTCHURCH

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1. INTRODUCTION

Christchurch lies on the coast, on the northeastern part of the low-lying Canterbury Plains. Its climate is largely influenced by the presence of the Southern Alps (average height 2000 m some 65 km to the west), the Port Hills and Banks Peninsula (5 km and 30 km to the southeast respectively) and its proximity to the Pacific Ocean to the east. It is flat apart from some of its southern suburbs which lie on the Port Hills.

The Southern Alps act as a massive barrier to westerly airstreams, with the consequence that Christchurch has a relatively low mean annual rainfall. Moist easterly airstreams can give rise to significant rainfall in Christchurch at times. Surface winds in these airstreams can be considerably modified by the presence of Banks Peninsula.

Quite high temperatures with very low relative humidities can occur, mostly in summer (December, January, February). These conditions are associated with strong northwesterly winds, which give the highest temperatures in all seasons. In winter, there is a high frequency of calm conditions with frequent frosts (particularly in July) and associated air pollution problems. However, the close proximity of the ocean has a moderating effect on temperature extremes and contributes to a sea breeze effect, as well as being a source of sea fog.

2. WIND

The wind climate of Christchurch is influenced markedly by the Southern Alps some 65 km to the west and northwest, the Canterbury Plains, Banks Peninsula and the nearby ocean.

The prevailing wind directions are east-northeasterly and from the southwesterly quarter. Other wind directions are noticeably less frequent. About half of the winds lie in the 5 km/h - 19 km/h* speed range with another 20% in the 20 km/h - 30 km/h range. Stronger winds account for less than 10% of the winds experienced in Christchurch and calm conditions occur 17% of the time.

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* 1 km/h = 0.3 m/s = 0.5 knot

Figure 1(a) - (g) shows the percentage frequency of occurrence of the winds at Christchurch Airport, for the whole year, the four seasons, as well as daytime and night-time. The diagrams are similar to a topographical map, where the peaks indicate the most commonly occurring wind speeds and directions. The percentage frequency of occurrence of a given wind speed and direction is represented by the height of the contours above the plane formed by the speed and direction axes.

Figure 1(a) shows the main annual features of the wind at Christchurch:

(i) a marked predominance of east-northeast winds (070°);

(ii) a high proportion of winds between south and west (with peaks at 210° and 240°), but less marked than the east-northeasterlies;

(iii) a minor, yet very significant, occurrence of north-west winds (300°), especially in the higher speed range;

(iv) a very low frequency of winds from the southeast (140°), due to the sheltering effect of Banks Peninsula.

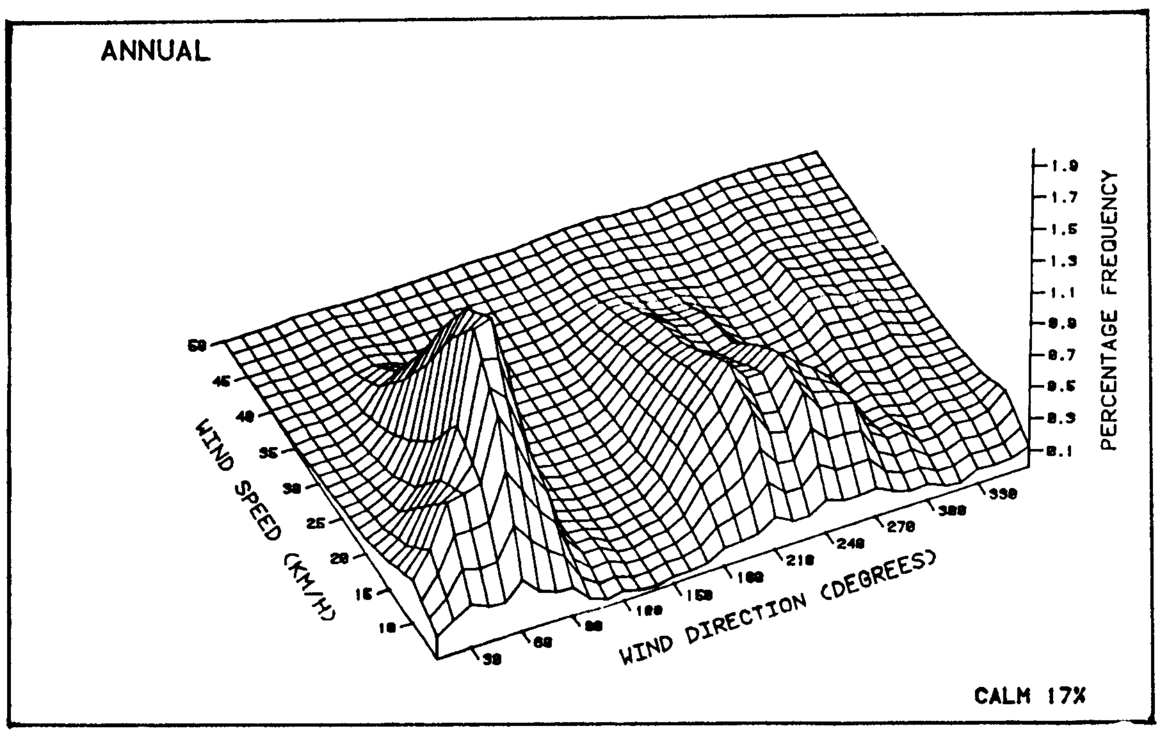

Fig. 1(a) Annual percentage frequency of occurrence of winds at Christchurch Airport.

In summer (Fig.1(b)), the east-northeasterlies (070°) are the most commonly occurring winds (reinforced at times by the sea breeze effect) and also attain their highest speeds for the year. Their most common speed is 15 - 20 km/h.

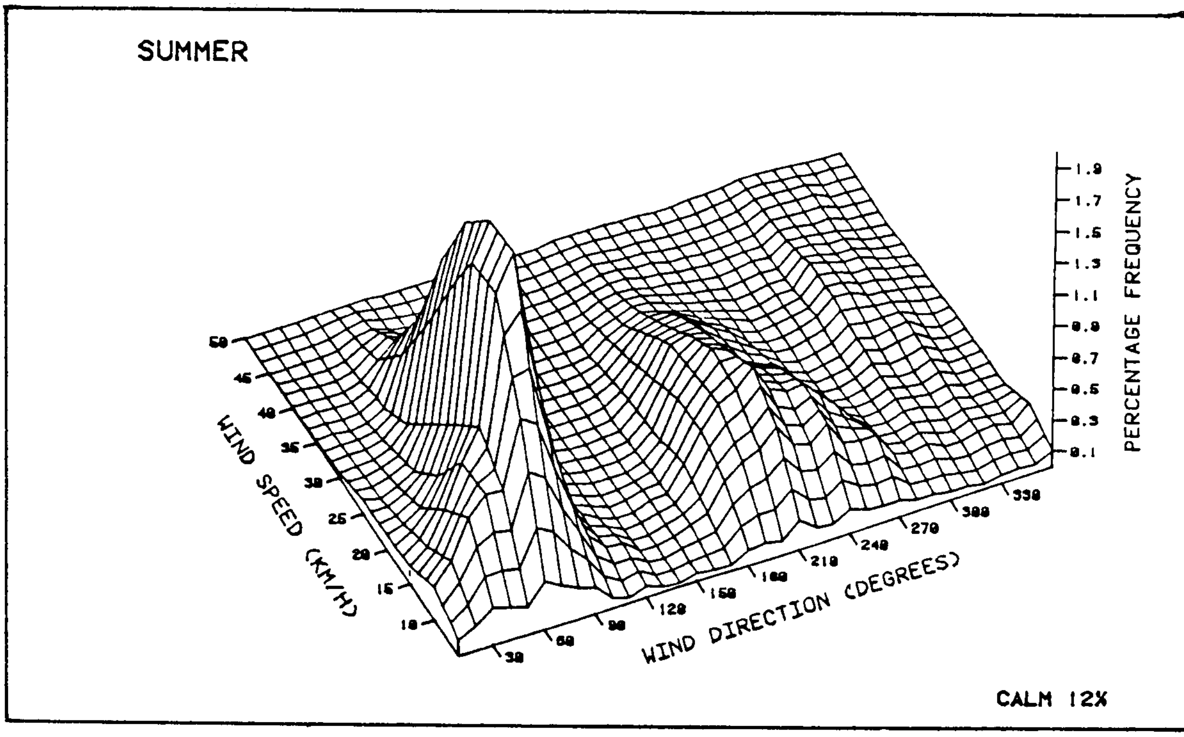

Fig. 1(b) Percentage frequency of occurrence of winds in summer at Christchurch Airport.

In autumn (Fig.1(c)), the east-northeast peak drops from a summer maximum of 1.9% to 1.6%, and the most common speed decreases to 15 km/h. There is a marked decrease in the occurrence of strong east-northeast winds. This is partially due to the fact that the sea breeze effect (which provides reinforcement of the synoptic east-northeast wind) is most evident in summer, when it attains its peak, both in terms of frequency of occurrence and strength. East-northeast winds are least common in winter (Fig.1(d)) and also have their lowest speeds for the year. The most common speed remains 15 km/h, but there is a slight shift in direction of the peak from 070° to 060° and a decrease in height of the peak from 1.6% to 1.1%.

In spring (Fig.1(e)), the east-northeasterlies increase again, both in speed and frequency of occurrence, the shape of their distribution being similar to that of summer. The maximum frequency of 1.5% (at 15-20 km/h), is well above that of winter, but less than that of summer.

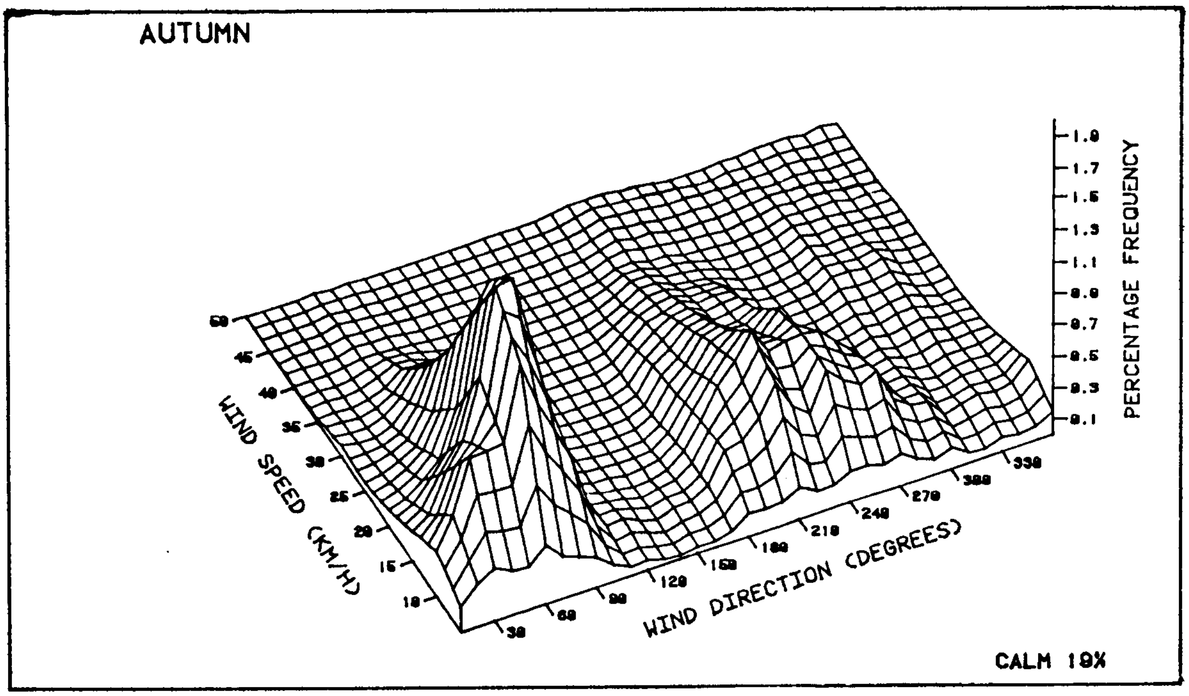

Fig. 1(c) Percentage frequency of occurrence of winds in autumn at Christchurch Airport.

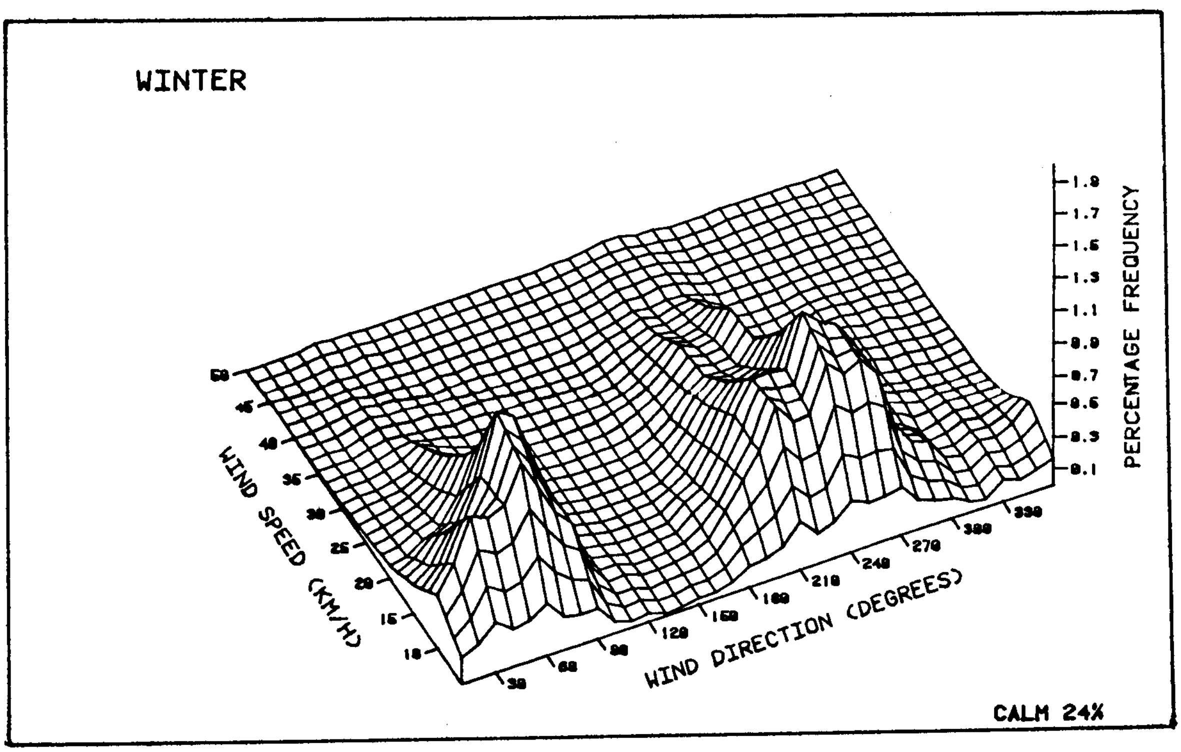

Fig. 1(d) Percentage frequency of occurrence of winds in winter at Christchurch Airport.

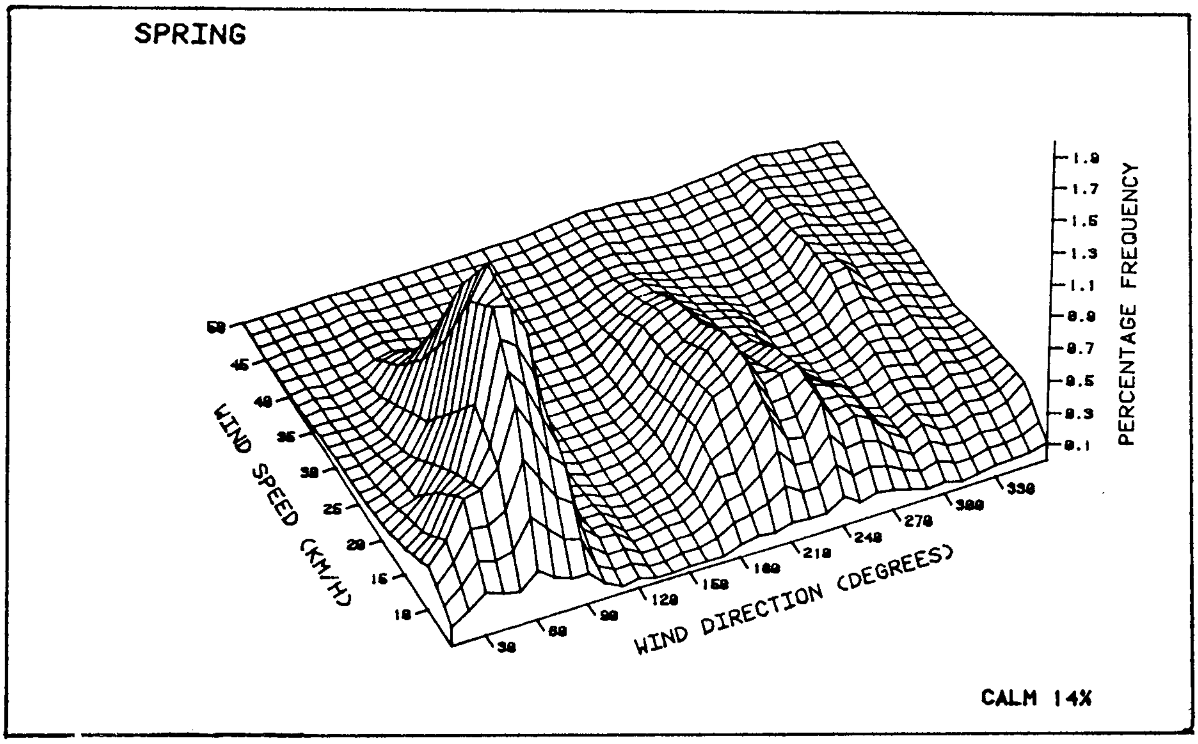

Fig. 1(e) Percentage frequency of occurrence of winds in spring at Christchurch Airport.

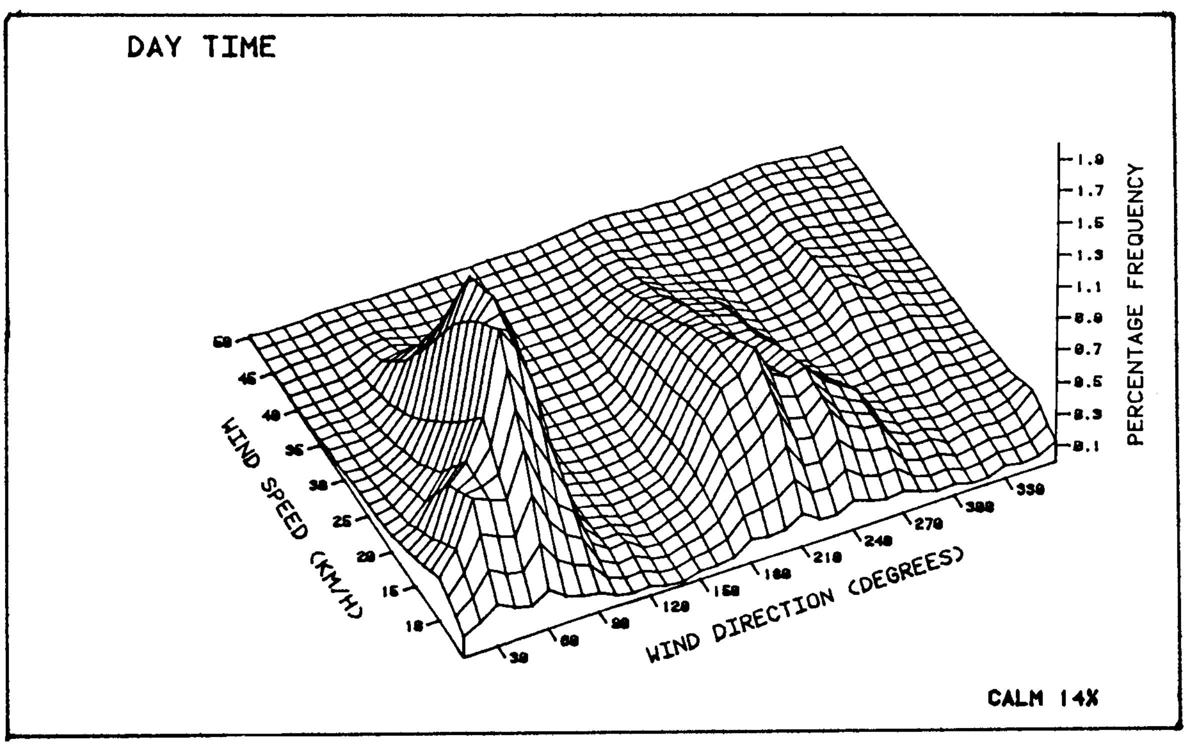

Fig. 1(f) Daytime percentage frequency of winds at Christchurch Airport.

Inset 1

Figures 1 (f) and (g) show the diurnal behaviour of the east-northeasterlies. During the day there are two peaks in the distribution, the first at 060° and 15 km/h (1.4%) and the other at 070° and 20 km/h (1.4%). On the other hand, at night, there is just a single peak (1.7%) at 070° and 15 km/h i.e. there are fewer strong east-north-east winds at night and lower speeds are more common.

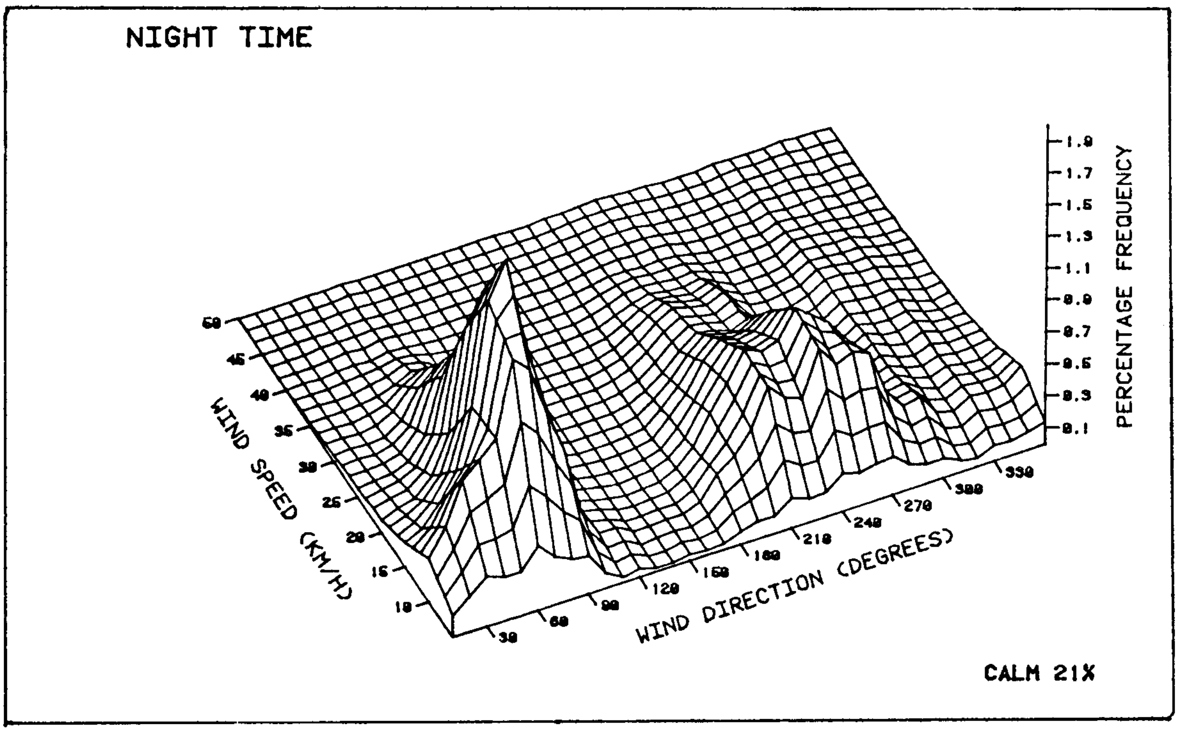

Fig. 1(g) Night-time percentage frequency of winds at Christchurch Airport.

The other main prevailing winds come from between south and west. In summer, the most frequent wind from this quarter is from 210° at 15 km/h (0.7%), with a minor peak at 240° at 15 km/h (0.5%). However the east-northeast winds are by far the most predominant winds in summer. In autumn with the decrease in frequency of the east-northeast winds, as discussed above, there is a corresponding overall increase in the winds from between south and west with the peak at 210° rising slightly to 0.8% from its 0.7% value in summer and the peak at 240° rising correspondingly to 0.6%.

There is a very marked change between autumn and winter. In winter, the east-northeasterlies and the southwesterlies have peaks of equal height (1.1%). In summer and autumn the most frequent direction is 210°, but in winter, winds from 240° are more frequent (1.1%) than winds from 210° (0.8%). So essentially there is an increase in frequency of winds from 240° with higher speeds appearing as well.

In spring, there is a marked decrease in the frequency of winds from 240°, especially at low speeds where the peak changes from 1.1% in winter to 0.7% in spring. Higher speeds are also less frequent in spring. On the other hand, the shape of the distribution for winds from 210° changes so that low speeds are less frequent in spring than in winter, and speeds above about 20 km/h become more frequent.

Winds from 240° are more common at night (0.8%) than during the day (0.6%), whereas winds from 210° are more common by day (0.8% compared with 0.6%). This reflects the tendency for westerly katabatic* winds to blow overnight across the foothills of the Canterbury Plains, towards Christchurch. As with the east-northeasterlies, wind speeds for winds between south and west are lower overnight than during the day.

Although not occurring very frequently compared with the prevailing winds discussed above, winds from the northwest (300°) play a very important role in the climate of Christchurch. These winds are most common in spring, followed by summer, much less common in autumn and least frequent in winter. The most significant winds from the northwest precede cold fronts and constitute the föhn** northwesterlies which are a well known characteristic of Christchurch. The speeds of these winds are greater in spring than in summer.

There are fewer strong northwest winds overnight and there is an increase in the frequency of lighter northwest winds at night compared with daytime. Some of these lighter winds will be due to katabatic drainage from the foothills of the Alps across the Plains.

There is a gradual increase in the frequency of calm conditions from summer (12%) to autumn (19%) to winter (24%). In spring, the frequency of calms decreases again to 14%. So although Christchurch is subject to strong south or southwest winds at times during the winter, there are appreciable periods when calm conditions prevail, especially in July, which has frequent frosty days (see frost section). The high occurrence of calms in winter is also an important factor in Christchurch's air pollution problems (see air pollution section).

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* These winds occur on clear nights with weak pressure gradients when sloping ground cools by radiation, thus cooling the air in contact with it. As the air cools, it becomes denser and a downslope gravitational airflow develops. This is called a "katabatic" or "drainage" wind. It is more pronounced over snow covered ground.

** A warm, dry wind which occurs to leeward of a ridge of mountains.

2.1 Persistence

The persistence of the wind is measured by the number of consecutive hours it blows in a particular speed and direction range.

The east-northeasterlies are noticeably more persistent than the southwesterlies, particularly in summer and also in autumn. Speeds are usually in the ranges 10 km/h - 19 km/h and 20 km/h - 40 km/h with the former being more common. The east-northeasterlies can blow for up to 6 or 12 hours at a time, but sometimes last up to 18 hours. Usually the most common occurrences of the east-northeasterlies last up to 4 - 6 hours. There are two exceptions to this, both for the 20 km/h - 40 km/h speed range. These occur in summer when 9 - 12 hours is a common persistence period and in spring, when 5 - 12 hours occurs more frequently than shorter persistence periods. The most persistent southwesterlies are in the range 10 km/h - 19 km/h and occur in winter, usually for up to 6 hours, sometimes up to 12 hours and rarely up to 18 hours. On very rare occasions they can last 25 - 36 hours.

Strong winds (greater than about 40 km/h) come from the westerly quarter, but strong easterlies are not unknown. Most of these strong winds, which are not very frequent anyway, only last up to 4 - 6 hours. Occasionally, southwesterlies in winter and northweasterlies in spring persist up to 12 hours.

Calms are more persistent in the cooler part of the year. In winter they can commonly last up to 18 hours and less frequently as long as 36 hours. On rare occasions winter calms can last more than 48 hours. The persistence of calm conditions in the winter is an important factor in Christchurch's air pollution problems. In the warmer part of the year calms can last up to 12 hours, but are usually shorter lived than that. On occasions, calms can persist up to 18 hours, but this is infrequent.

2.2 Physical causes of wind variations

The predominance of east-northeast winds is due to a combination of the differential heating of the Canterbury Plains and the ocean (giving rise to a sea breeze which is most pronounced in summer and can reach speeds of up to 30 km/h), the presence of Banks Peninsula and the distortion of westerly airstreams by the Southern Alps (which give rise to an orographic trough in the isobars over Canterbury).

While in some cases the east-northeast wind may well be a classical sea breeze, the tendency for it to often persist through the night suggests there is a complex interaction of thermal effects and topography as well as the synoptic pattern that led to its occurrence. Further analysis of the structure of east-northeast flows in Christchurch may be found in Sturman and Tyson (1981).

The complex nature of the windflow around the Christchurch area is confirmed by the work of Smyth (1982), who found that winds measured on the hills surrounding Lyttelton Harbour are more often from the northeasterly octant, than are the surface winds at Christchurch Airport or winds measured at 900 mb (~1000 m) by radar tracking of balloons from the Airport.

The east-northeasterlies blowing from the sea are sometimes unpleasantly cool, especially in contrast with the warm föhn northwesterlies. In strong northwest airstreams, the surface wind at Christchurch can remain east-northeast with temporary changes to gusty northwesterlies. In this type of situation, there is a northwest airstream aloft which overrides the surface east-northeasterlies, but is not strong enough to overcome them. Sometimes the northwesterlies are strong enough to reach the ground and the surface wind then becomes a gusty northwesterly for a time, before reverting to an east-northeasterly again. This process can then repeat itself when the northwesterlies increase sufficiently to overcome the surface east-northeasterlies.

In practice then, there can be northwesterlies blowing over the foothills and plains, but east-northeasterlies on the coast. This situation can persist and the northwesterlies may or may not reach the coast, or reach the coast, but not be able to establish themselves there and the east-northeasterlies take over again.

The "Canterbury Northwester", although blowing only about 3% of the time is an important factor in the climate of Christchurch. It is a warm, dry, gusty föhn wind which gives the city most of its highest temperatures. When a disturbed westerly airstream flows over the South Island, the duration of the northwesterlies may be up to a week or more as happened for example during 15-24 October 1947. Not all northwesterlies are of the föhn type however. After a cold front has passed over from the west, the winds may remain northwest, instead of changing to the west or southwest. In these conditions, the prevailing northwest winds are quite cool.

Sometimes associated with the northwesterlies a band of high cloud forms over the plains with clear sky visible between the tops of the mountains and the cloud sheet. This phenomenon is commonly called the "Northwest Arch".

There is also a katabatic westerly wind which blows on cold clear nights. It is more pronounced in winter and spring when the mountain slopes are snow-covered, but seldom exceeds 5 km/h.

Southeasterlies are uncommon in Christchurch because of the sheltering effect of Banks Peninsula. Consequently there is no southeast sea breeze. Strong southeast airstreams are deflected towards the southwest by the surrounding topography.

2.3 Strong winds

The strongest winds generally come from the northwest or the southwest, but occasionally strong winds from the easterly quarter are experienced. When active cold fronts move up from the south, there can be a rapid change in wind direction from northwest to south or southwest with accompanying squalls and a very marked temperature fall.

High wind gusts are infrequent in Christchurch. The highest gusts recorded at the airport are usually from the northwest. The average number of days per year that have wind gusts equal to or in excess of gale force (63 km/h) and storm force (96 km/h) respectively are given in Table 1 with the corresponding number of days for some other New Zealand cities. It can be seen from the table that Christchurch is comparable to Auckland and Dunedin in the frequency of gusty days, but is much less windy than Wellington.

TABLE 1: Average number of days per year on which wind gusts equal or exceed

	(a) 63 km/h	(b) 96 km/h
Christchurch	54	3
Auckland	46	2
Wellington	188	41
Dunedin	51	4

The strongest winds ever experienced in Christchurch were associated with two storms which battered the city, one on 11 April 1968 and the other on 1 August 1975. The first was the "Wahine Storm" with southerly wind gusts reaching 135 km/h. In the 1975 storm northwesterlies gusted up to 172 km/h. This is also the highest recorded wind gust to date.

The 1975 storm was the worst to hit Christchurch in recent years and caused widespread damage. On 31 July 1975 a very deep complex depression was passing over the seas south of the South Island. The cold front associated with this depression was just moving off Australia and had a very strong northwest airstream ahead of it, which covered the Tasman Sea and the South Island. As this system moved eastwards, very strong turbulent northerwesterlies affected most of the South Island and, in Christchurch itself, the wind caused some damage on the afternoon of 31 July. As the cold front moved on to the South Island in the early hours of the morning of 1 August, the pressure gradient strengthened over Canterbury and the northwest winds increased

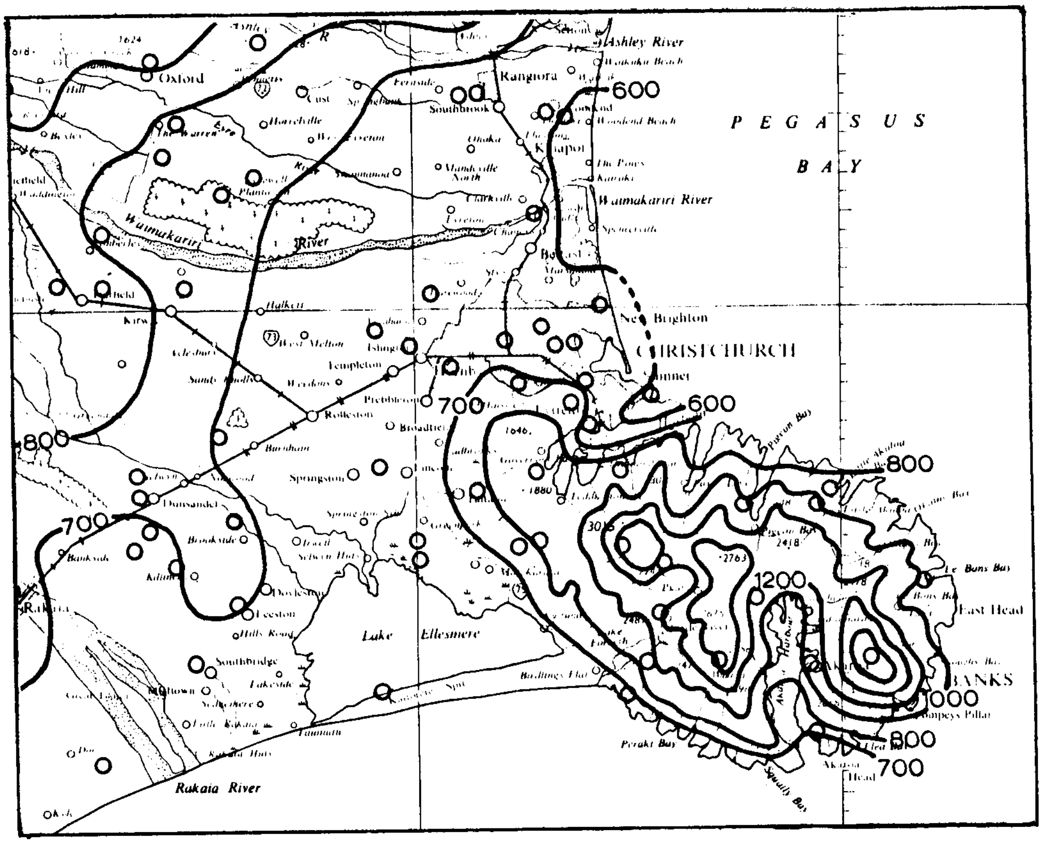

Fig. 2 Isohyets of mean annual rainfall (mm)
(1941-70)

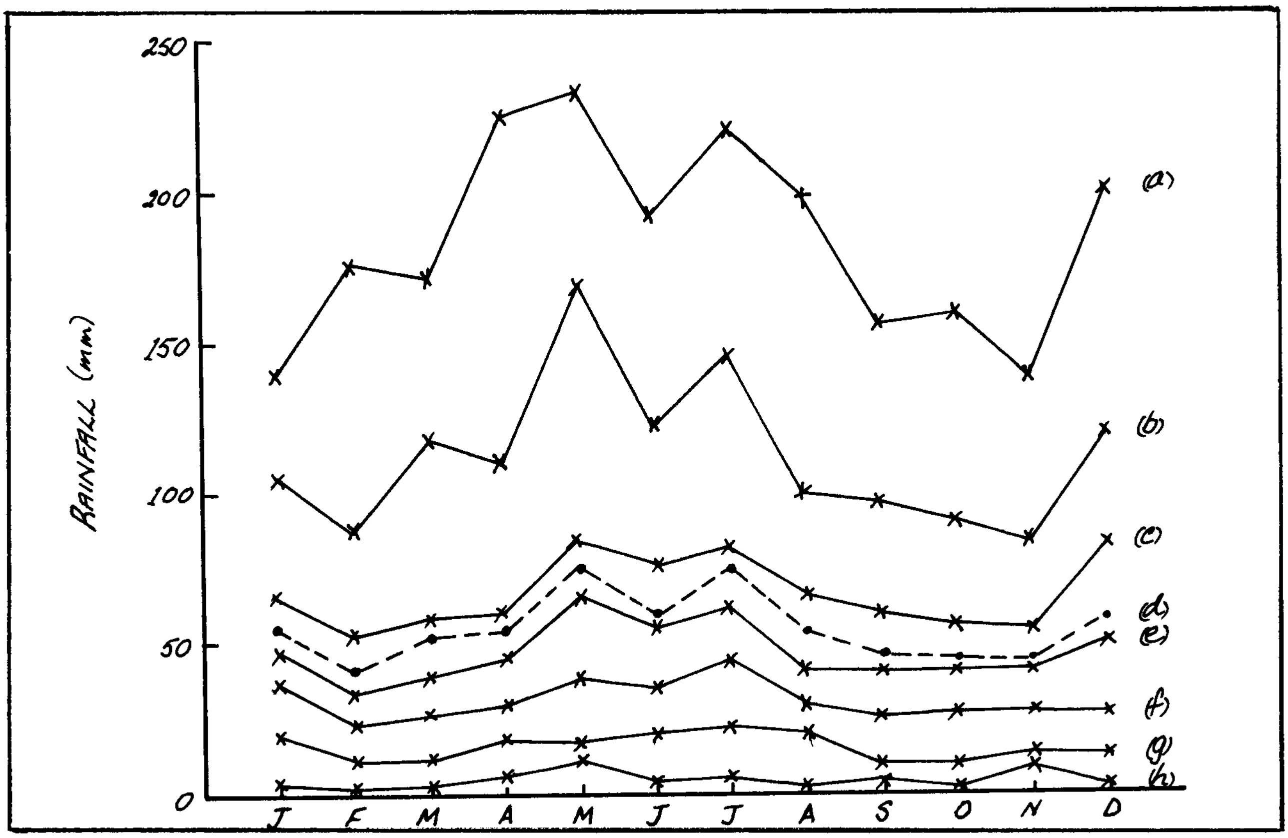

Fig. 3 Monthly rainfall at Christchurch (1894-1980).
(a) Highest recorded; (b) 90 percentile;
(c) 70 percentile; (d) Mean;
(e) 50 percentile; (f) 30 percentile;
(g) 20 percentile; (h) lowest recorded.

from about 4.30 a.m., reaching a maximum mean speed of 126 km/h about 7.30 a.m., then decreased again from about 9.30 a.m. It was in this period that the most destructive winds occurred and the major damage was done.

Other major northwesterly storms occurred on 22 March 1964 and 13 July 1945. There have also been some bad duststorms, caused by high winds, such as occurred in 1973. The worst on record was on 23 September 1898 (thereafter called "Black Friday").

3. RAINFALL

The rainfall at Christchurch is greatly influenced by the sheltering provided by the Southern Alps and to a much lesser extent by Banks Peninsula.

Average annual rainfall in the Christchurch area varies between 600 and 700 mm, with about 85 days per year on which 1 mm or more of rain is recorded. However, wide variations can occur from month to month and year to year. Rainfall is fairly evenly distributed throughout the year with a tendency for a winter maximum. Compared with other parts of the country, Christchurch rainfall is relatively low. Figure 2 shows the mean annual rainfall in the Christchurch region and Fig.3 the monthly percentiles. From Fig.2 it can be seen that the northern parts of Christchurch have a slightly lower mean annual rainfall than in the south. This is because most of Christchurch's rain comes from the southwest, with the Cashmere and Port Hills catching more rain than the northern suburbs, which are sheltered by the hills to the south.

3.1 Rain-bearing winds

The wind frequency distribution for rain-bearing winds is quite different from the overall wind distribution shown in Fig.1. Whereas the predominant wind directions are east-northeast and southwest, three-quarters of the mean annual rainfall occurs with winds between south and west and nearly half the annual rainfall is associated with southwest winds which blow less than 20% of the time.

East-northeast winds contribute very little to the annual total, even though they constitute one of the prevailing wind directions. Very little rain comes from the northwest and southeast, partly because of the sheltering effects of the Southern Alps and Banks Peninsula respectively and partly because these winds are not very common.

3.2 Diurnal variation

There is a slight minimum in the mean annual rainfall during the middle part of the day (9 a.m. - 3 p.m.) compared with other hours. This can be seen in Table 2.

TABLE 2: Christchurch Mean Annual Rainfall (mm) and Percentage of Total in 3 hour periods

3 hr period	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
Mean Annual Rainfall (mm)	86	89	91	74	74	81	91	89
% of Total Rainfall	12	13	14	11	11	12	14	13

There are slight variations from season to season, but overall the pattern in Table 2 applies.

3.3 Causes of rainfall variations

In westerly airstreams, the presence of the Alps causes enhancement of the rainfall on the windward side and a rain shadow on the leeward side. Consequently although the west coast can get very high rainfalls in westerlies, the rainfall in Christchurch is mostly light. The heaviest falls occur in southerly airstreams when a depression lies between Banks Peninsula and the Chatham Islands. Occasionally strong moist easterly airstreams give heavy rain. Heavy rain can occur in any season and past flooding resulting from heavy rain has been fairly evenly distributed over the seasons. High intensity, short duration rainfall is usually associated with thunderstorm activity and is not very common in Christchurch. However falls of up to 14 mm have occcurred in 10 minutes, 22 mm in 30 minutes and 30 mm in an hour.

Christchurch has a low incidence of days on which thunderstorms occur (average 3 days per year) and most of these occur in the warmer part of the year (particularly summer), when there is considerable ground heating. Winter is relatively free of thunderstorms. When thunderstorms do occur they are usually accompanied by heavy rain (some causing local flooding) and on very rare occasions by tornadoes.

Extremes of rainfall and dry spells are given in the climatological summary in Appendix A.

3.4 Dry spells

Christchurch sometimes experiences long periods of little or no rain. There have been three periods (1903, 1908 and 1916) of 30 consecutive days in which no rain fell and a maximum of 44 consecutive days in 1911 which had less than 1 mm of rain. Since records began in 1894, there have been 25 occasions when 30 or more consecutive days have had less than 1 mm of rain per day.

The period 1 November 1981 to 31 August 1982 was the driest for the ten-month period November-August since records began in 1894. A total of 306 mm of rain was recorded, which is only 54% of the average of 566 mm. The previous lowest rainfall for this ten month period was in 1896-97 when a total of 314 mm was recorded.

The very low rainfall total from 1 November 1981 to 31 August 1982 was accompanied during the summer and autumn by very high evaporation, which accentuated the drought conditions then prevailing in Canterbury.

3.5 Water balance

A simple method of measuring soil moisture, which is useful for horticultural purposes, is to assume that the soil is capable of retaining some maximum amount of water before run-off occurs. For Christchurch soils this maximum water holding capacity is typically 50 mm, although in some areas it is 75 mm. The amount of water stored in the soil at any given time depends on how much moisture has been lost to the atmosphere by the soil and vegetation and to what extent this loss has been made up by rainfall. A deficit occurs when the combination of rainfall and available soil moisture is less than the moisture loss to the atmosphere by soil and vegetation. On the other hand, if the rainfall is greater than the soil's storage capacity, then run-off occurs. Table 3 shows the average number of days per month for which deficits or run-offs occur, after allowance is made for the soil moisture storage capacity.

TABLE 3: Average number of days per month on which run-off or deficit occurs assuming a soil moisture capacity of 50 mm

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
RUN-OFF	0	0	1	1	3	6	7	4	1	0	0	0	23
DEFICIT	23	20	15	9	2	0	0	0	1	14	22	23	129

It can be seen from the table that from November to February there are, on average, at least 20 days per month on which there is insufficient soil moisture to maintain plant growth and irrigation is necessary. During the winter months, rainfall is adequate for growing purposes.

3.6 Snow

While Banks Peninsula can experience quite heavy snowfalls, Christchurch does not get much snow, partly because of sheltering by the Port Hills. Severe snowstorms are very rare in Christchurch, there having been only two this century (in July 1918 when 18 cm fell in the city and again in July 1945 when up to 45 cm fell in some suburbs). Snowfalls have been recorded in all months except January and February. Most snow falls in July followed by June, August, September and October, but is rare in other months.

The average number of days per year on which snow falls is 3, but in some years no snow at all has fallen.

3.7 Hail

Damaging hailstorms, with large hailstones are uncommon in Christchurch. The most active period for those that do occur is October to March (the warmer part of the year) and particularly during the afternoon. Otherwise hail showers can occur in any month of the year with the highest frequencies occurring in February, July, August and September. The average number of days with hail per year is six.

4. TEMPERATURE

Figure 4 shows the average daily temperatures by month with average daily maxima and minima. January is the warmest month with a mean daily maximum of 21.4°C, although the highest temperature ever recorded in Christchurch was 41.6°C in February 1973 in föhn conditions. Christchurch has warm summers and cold winters. In summer, 20% of days have maximum temperatures over 25°C and 4% have maxima greater than 30°C. July is the coldest month with a mean daily maximum temperature of 10.2°C. One effect of the prevailing east-northeast wind is to lower the maximum temperatures during the day by bringing in cooler air off the sea.

On the other hand hot, dry föhn northwesterlies blowing over the plains raise the maximum temperatures in Christchurch. By contrast cold fronts moving rapidly up the east coast of the South Island can bring outbreaks of very cold sub-Antarctic air with them, giving very low minimum temperatures. Thus the city can experience very large temperature changes when the hot northwesterlies are replaced by cold showery southerlies as a cold front passes through. Temperature changes of up to 20°C in about 30 minutes have been recorded on such occasions, whereas the mean annual daily temperature range is only 10°C.

The city itself behaves as a "heat island" with highest temperatures occurring near Cathedral Square and relative minima over Hagley Park and the southern suburbs. The "heat island" effect is greatest at night, especially if the winds are light. On suitable nights temperature differences of up to 7°C may develop between the warm and cool parts of the city (Kingham, 1969).

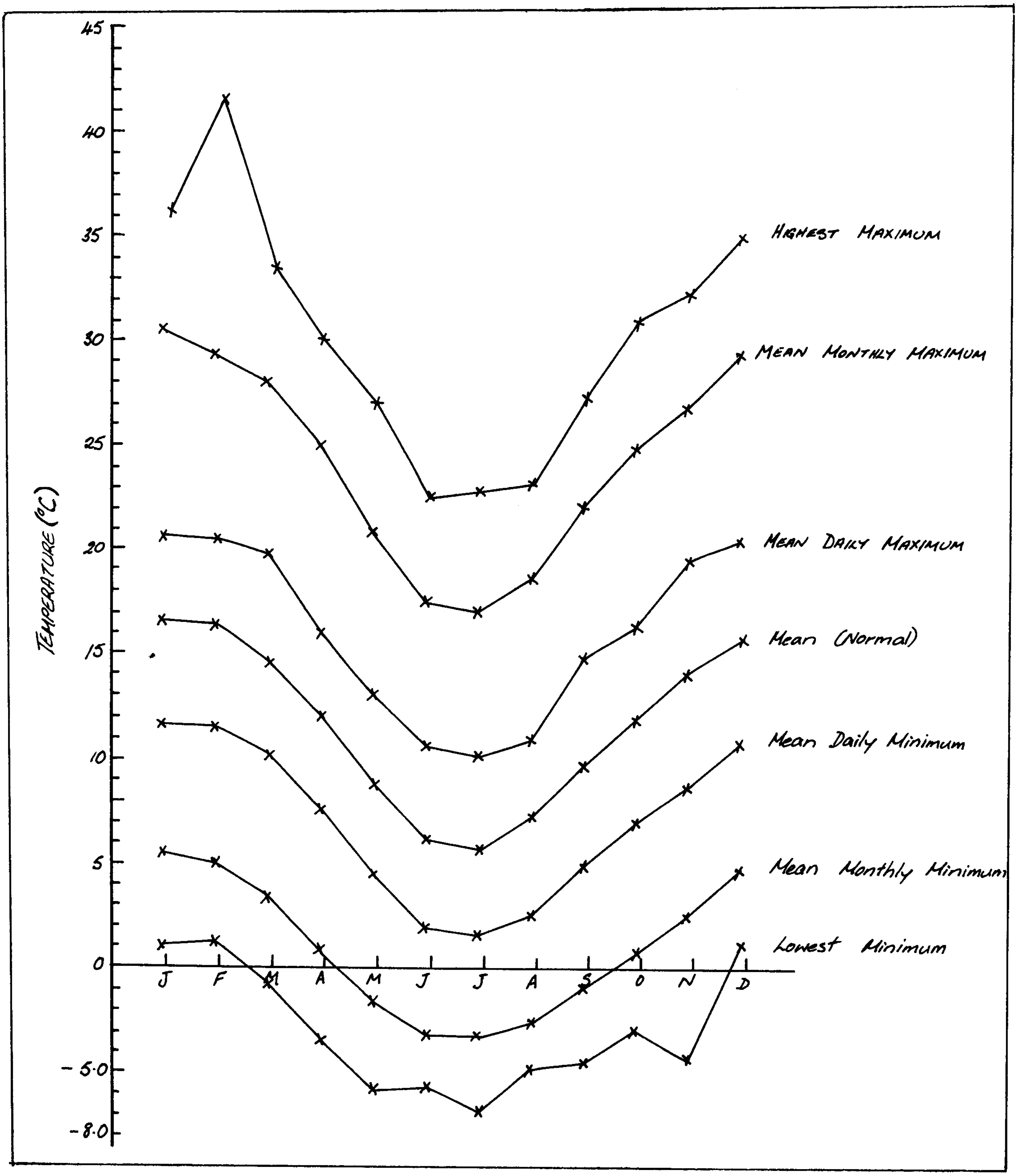

Fig. 4 Christchurch Temperatures (1864-1980)

4.1 Frosts

Frosts are common in the winter in Christchurch with June, July and August having average numbers of 18, 19 and 17 days with ground frosts respectively. Ground frosts can occur in any month, with an average of 89 per year. Of these, 37 will be air frosts as well.

The date of occurrence of the first air frost of the year varies quite markedly for different parts of Christchurch and typically may vary by two weeks. For the date of occurrence of the last air frost of the year, the variability is even larger, being typically about four weeks. However, there is not quite as much variation in the dates of occurrence of the first and last frost in any given suburb in Christchurch from year to year (Goulter, 1981). Usually the first ground frost of the year will occur before the first air frost and conversely, the last ground frost of the year will occur later than the last air frost.

Even with a relatively flat area like Christchurch, there is a large amount of scatter in the dates of first and last frosts from year to year, with the last frost dates having more scatter than the first frost dates (Goulter, 1981).

Frosts are less likely in the southern hill suburbs than in the more sheltered parts of the city, since katabatic drainage ensures that the coldest air finds its way into the low-lying suburbs.

The lowest air temperature recorded to date in Christchurch is -7.1°C on 18 July 1945.

5. RELATIVE HUMIDITY

The main feature of the relative humidity in Christchurch is the low value that is reached, when hot, dry, föhn northwesterlies blow. Sometimes the relative humidity, in föhn conditions, can drop as low as 20-40% and on rare occasions below 20%. A combination of hot, dry, blustery winds and very low humidity can be very uncomfortable. However, strong föhn northwesterlies blow only a few percent of the time, mostly in spring and summer.

The 9 a.m. relative humidity over the year is about 77%, varying from about 65-75% in the warmer part of the year to 85-90% in the cooler part of the year. Averaged over 24 hours, the relative humidity is about 70% in the warm part and in the low 80's in the cool part of the year respectively.

6. SUNSHINE

Christchurch averages 1985 hours of bright sunshine per year. This is of the same order as many other cities in New Zealand. The monthly maximum, average and minimum sunshine hours for Christchurch Airport are shown in Fig.5.

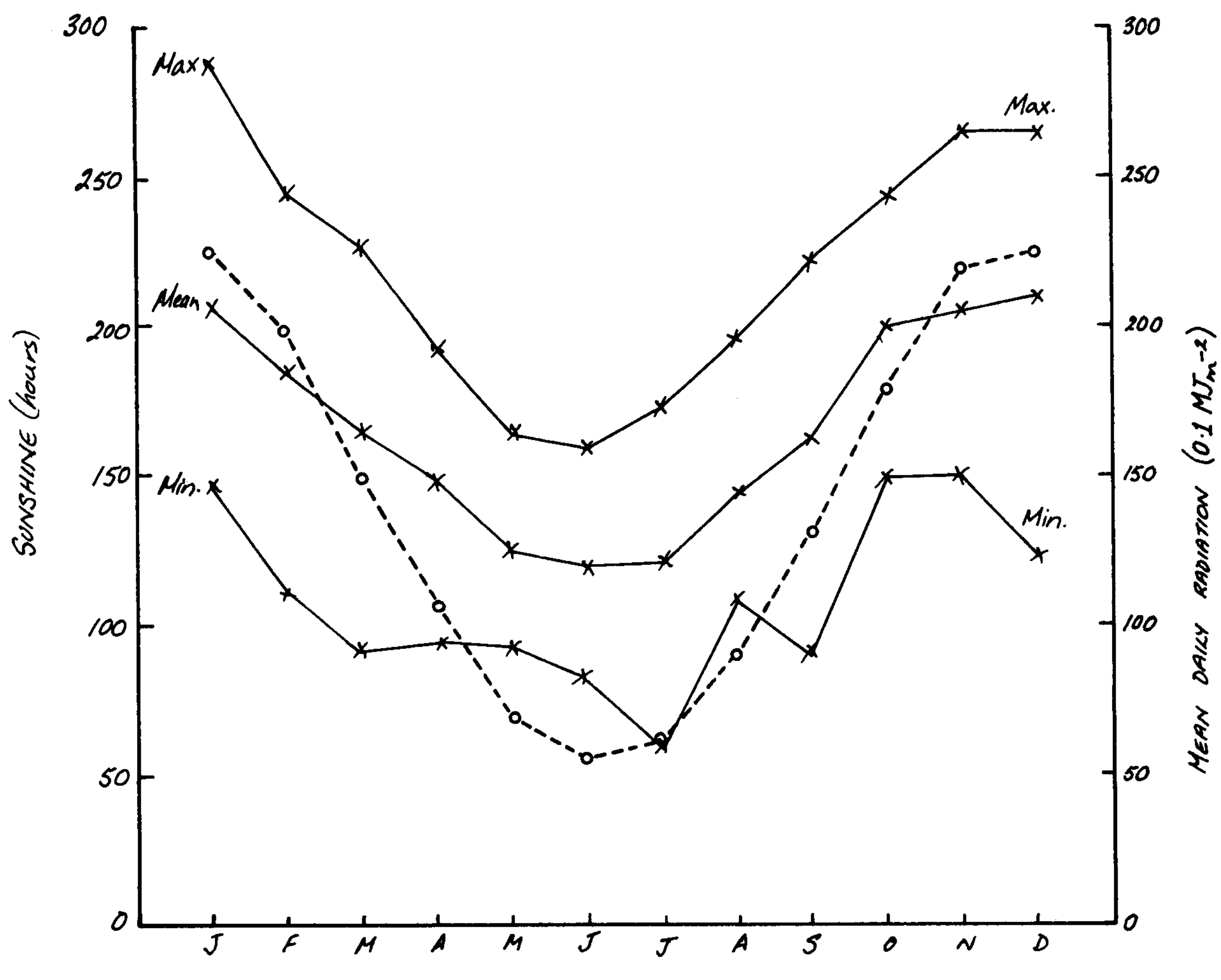

Fig. 5 Christchurch Airport mean monthly sunshine (1949-1980). Mean monthly sunshine with maximum and minimum values recorded (solid lines); mean daily radiation (dashed line).

Since the South Island lies in the path of the prevailing westerlies, it might be expected that Christchurch, being east of the massive Southern Alps, would have greater sunshine hours than places on the west coast of the South Island with more rain days. However Table 4 shows that places like Westport and Haast have similar sunshine hours to Christchurch. Although the Southern Alps cause enhanced rainfall on the west coast and a rain shadow in the east, when westerly airstreams flow, they do not prevent layers of middle and high cloud from extending considerable distances east of the Alps. One example of this effect is the "Northwest Arch" mentioned previously. This effect increases the cloudiness of Christchurch and thus reduces its sunshine hours. To a lesser extent, the prevailing east-northeasterlies at Christchurch bring in moist air and cloud from over the sea, again reducing the sunshine hours.

Table 4 also shows the average daily solar radiation in units of 0.1 megajoules per square metre.

TABLE 4: Comparative Sunshine and Solar Radiation Figures.

	Average Annual No. Hours of Sunshine	Average Daily Solar Radiation (0.1 MJm^{-2})
Christchurch	1985	142
Westport	1937	144
Hokitika	1883	139
Greymouth	1736	137
Haast	1918	139
Auckland	2140	161
Wellington	2014	150
Dunedin	1695	127

7. FOG

Fog occurs in Christchurch about 56 days per year. Fogs are more frequent in winter when they are denser and more persistent, but fog can occur at other times of the year as well. On rare occasions, fogs can be very persistent, as happened for example on 11-15 April 1939, when there was fog for 84 hours and also on 28 June-1 July 1949 when fog persisted for 81 hours (Wilkinson, 1959).

Some of the fogs are of the "radiation" type and occur on clear nights with little wind, when the ground radiates heat to the atmosphere. The other type of fog is the "advection" kind, which is formed elsewhere and is carried in by the wind. Pegasus Bay is a favoured location for extensive low cloud or sea fog and in east-northeasterly conditions this may spread very quickly over the city. Fog is less frequent over the hill suburbs than in the low-lying areas of the city and Hagley Park. It tends to form earlier around the rivers. Another source of advection fog is the shallow water of Lake Ellesmere to the south of the city. Light southerly winds can cause this fog to drift in over the city overnight.

8. AIR POLLUTION

Some meteorological factors which favour the formation or inhibit the dispersal of air pollutants are:

(i) a high frequency of dry, calm conditions, which may persist for some time, especially during the winter;

(ii) the occurrence of "temperature inversions" (a temperature inversion is a layer of warm air above a layer of air which has been cooled by contact with the ground. The inversion layer acts as a lid on the lower layer in which pollutants are trapped. Inversions are usually accompanied by stable atmospheric conditions);

(iii) sufficient sunlight to cause photochemical reactions to occur with pollutants already present in the atmosphere.

The above meteorological conditions can occur in Christchurch, thus making it susceptible to air pollution. At times, concentrations of pollutants approach or even exceed World Health Organisation recommended guidelines (see Health Department reports in References). Most of these occasions occur in the winter.

During the summer, air mixing is good in Christchurch and air pollution is not a serious problem. However, on an average of nine summer days, (Ryan, 1980), conditions are favourable for the formation of photochemical pollutants, which are usually prevented from building up to harmful levels by the early onset of a sea breeze.

In winter, anticyclones frequently occur either over Christchurch or east of Banks Peninsula. In Christchurch itself, wind speeds up to 5 km/h occur 10% of the time and calm conditions another 24% of the time, with clear skies, marked radiational cooling overnight and an average of at least 17 days with frost for each winter month. This results in the formation of temperature inversions, trapping the pollutants, which are usually emitted at low levels and drift over the city. The main pollutants are smoke (from domestic fires), sulphur dioxide, ozone and oxides of carbon and nitrogen. There is also considerable lead present from combustion of petrol in motor vehicles.

Health Department measurements show that the concentrations of all pollutants reach a maximum in the evening and again to a much lesser extent in the morning. These maxima correspond to the periods of greatest domestic open fire and motor vehicle usage. Over the last 20 years pollutant concentrations, according to the Health Department (see Health Department reports), have shown a downward trend. However, this downward trend slowed in the 1970's and since 1979 has been reversed. As similar types of weather conditions are likely to continue to affect Christchurch in the future, only a change in fuel usage patterns will reduce the incidence of air pollution there.

SUMMARY

The climate of Christchurch is greatly dependent on its proximity to the sea and the nearby topography of Banks Peninsula and the Port Hills, as well as the massive Southern Alps to the west.

Christchurch has mild summers, with its highest temperatures occurring when hot, dry föhn northwest winds blow over the Alps and Plains. Marked temperature changes can occur when the föhn northwesterlies are followed by cold southwesterlies as a cold front passes over the city. Winters are cold with frequent frosts. Mean annual rainfall is relatively low, and long dry spells can occur, especially in summer, resulting in insufficient soil moisture for plant growth. Sunshine hours are comparable to other main cities, but are affected by high cloud blown in by the upper westerly winds of these latitudes, and by low cloud brought in from Pegasus Bay by the prevailing east-northeast surface wind at Christchurch. The city is moderately windy in the warmer months, but strong winds are relatively rare and calms occur frequently in winter. Fogs, which occur mostly around the rivers and Hagley Park, are most common and persistent in winter. Because of the relatively high frequency in winter of frosty conditions, due to light winds and clear skies (with resulting temperature inversions), Christchurch is susceptible to air pollution problems and the concentration of pollutants at times approaches or even exceeds World Health Organisation recommended guidelines. At present, although there are a few days each summer when conditions are favourable for the formation of photochemical smog, the early onset of a sea breeze usually prevents this happening.

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APPENDIX A

CLIMATOLOGICAL SUMMARY - CHRISTCHURCH

The data given below refer to the Botanical Gardens unless otherwise indicated.

Wind

* Average Number of Days with Wind Gusts ⩾ 63 km/h = 54
  ⩾ 96 km/h = 3

* Maximum Gust Recorded: Northwest - 172 km/h (1 August 1975)

Rainfall (1894-1980)

Wettest Year: 1951	1008 mm
Driest Year: 1969	379 mm
Mean Annual Rainfall (1941-70):	658 mm
Wettest Month:	May 1945 (233 mm)
Driest Months:	February 1908, October 1929, December 1934 (1 mm)
Longest Period of No Rain:	30 days: 9 October 1903 - 7 November 1903 30 days: 2 February 1908 - 2 March 1908 30 days: 26 November 1916 - 25 December 1916
Highest Number of Days with Rainfall less than 1 mm per day:	44 days: 1 August 1911 - 13 September 1911
Wettest Day:	16 April 1974 (124.2 mm)
Maximum Rainfalls in:	30 minutes: 22 mm * 6 hours: 80 mm *12 hours: 108 mm *24 hours: 119 mm

Temperature (1864-1980)

Highest temperature recorded:	41.6°C (7 February 1973)
Lowest temperature recorded:	-7.1°C (18 July 1945)

Frosts (1864-1980)

Average number of days per year with

Ground frost:	(Grass minimum temperature ⩽-1°C)	89
Air frost:	(Air minimum temperature ⩽0°C)	37

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* Values at Christchurch Airport

Sunshine (1930-1980)

Highest Monthly Total:	*288 hours	(January 1957)
Lowest Monthly Total:	*61 hours	(July 1978)
Highest Annual Total:	*2199 hours	(1949)
Lowest Annual Total:	*1847 hours	(1970)

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* Values at Christchurch Airport.

APPENDIX B

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