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THE CLIMATE AND WEATHER OF SOUTHLAND

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PREFACE

This publication is the fifteenth in a series on the climate and weather of specific regions of New Zealand. The first seven were published as sections of the National Resources Survey produced by the Town and Country Planning Branch of the Ministry of Works and Development and were later reprinted as parts of N.Z. Meteorological Service Miscellaneous Publication 115. Although compilation of the resources survey has been discontinued, the Miscellaneous Publication 115 series is continuing and it is proposed to produce further parts for remaining areas of New Zealand.

Previous parts of this N.Z. Meteorological Service Miscellaneous Publication 115 are :-

115(1)	Bay of Plenty	(1963)
115(2)	Northland	(1964)
115(3)	Nelson	(1965)
115(4)	Otago	(1968)
115(5)	Hawkes Bay	(1971)
115(6)	Wanganui	(1972)
115(7)	Waikato-Coromandel-King Country	(1974)
115(8)	Gisborne	(1980)
115(9)	Taranaki	(1981)
115(10)	Westland	(1982)
115(11)	Wairarapa	(1982)
115(12)	Marlborough	(1983)
115(13)	The Chatham Islands	(1983)
115(14)	Tongariro	(1984)

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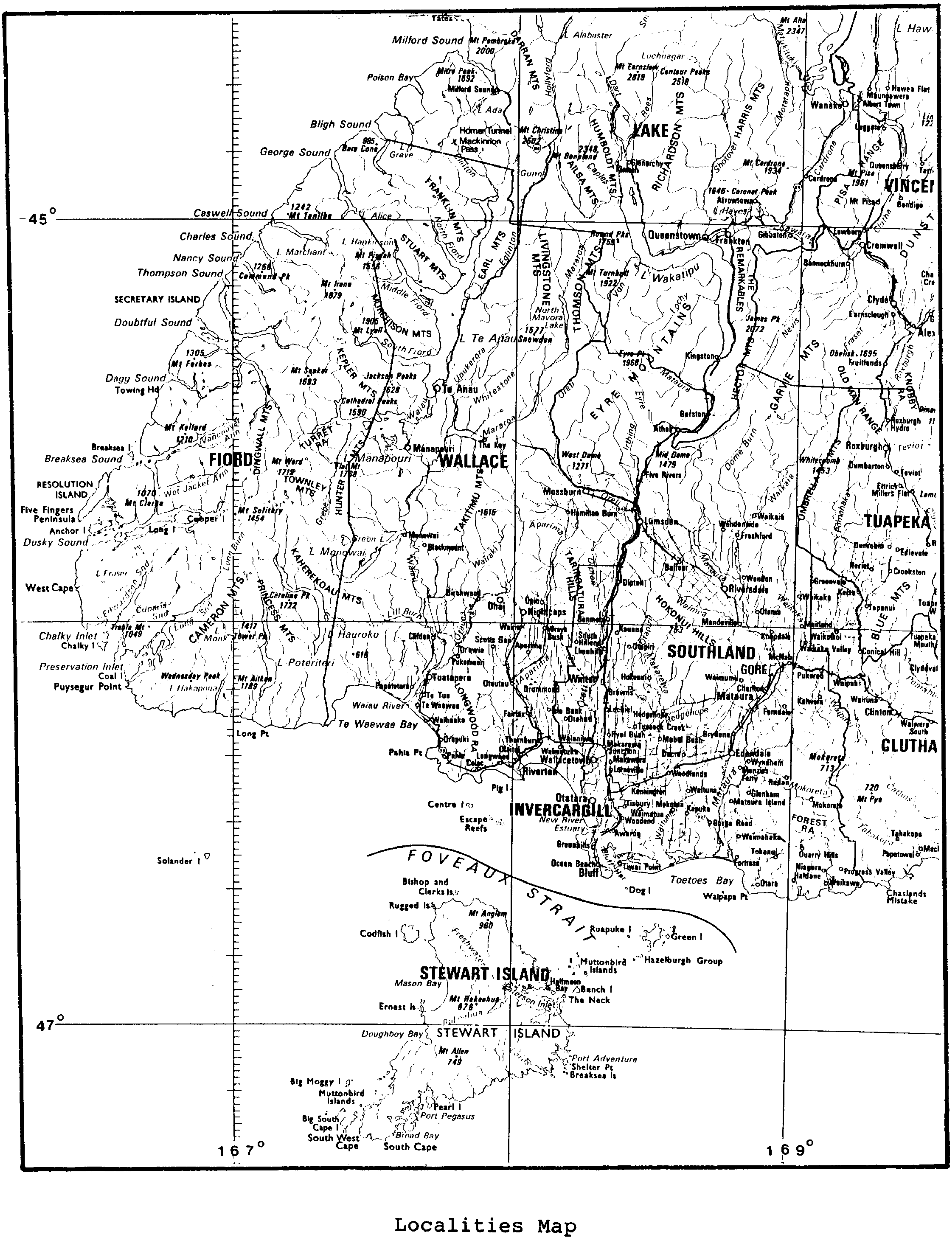
THE CLIMATE AND WEATHER OF SOUTHLAND

by J. Sansom

ABSTRACT

Southland, the most southerly part of New Zealand is cooler than the rest of the country with more frosts and less sunshine. The region is in the latitudes of prevailing westerlies, and areas around Foveaux Strait frequently experience strong winds, but the winds are lighter inland. The westerly winds bring a plentiful supply of moisture, the western ranges being one of the wettest places in the world whereas eastern areas have much less, but still adequate, rainfall.



Localities Map

THE CLIMATE AND WEATHER OF SOUTHLAND

By J. Sansom

1. INTRODUCTION

The Southland region as defined by the New Zealand Planning Tribunal (1980) consists of the Southland, Wallace, Fiord and Stewart Island Counties. These counties comprise all the land south of a line from the mouth of Bligh Sound to approximately the northern end of Lake Wakatipu, then from its southern end to the Old Man Range. The eastern boundary of the region consists of the Umbrella Mountains and a line extending southwards to meet the coast just west of Chaslands Mistake. However, the area considered in this publication also includes that part of Lake County between Bligh Sound and Milford Sound. This extra 20km is included so that use can be made of observations from Milford Sound which are typical of western parts of the Southland region where the only other existing station is Puysegur Point.

Southland is both the most southerly and most westerly area of New Zealand which spans latitudes 34 to 47 degrees south and so lies within the Southern Hemisphere temperate zone. In this zone, westerly winds at all levels of the atmosphere move weather systems, which may also be either decaying or developing, eastwards over New Zealand giving great variability to its weather. These prevailing westerlies sometimes abate and air from tropical or polar regions may reach New Zealand with heavy rainfalls or cold showery conditions respectively. The other major factor determining weather conditions in Southland is the elevation and orientation of the land itself. The high ranges in the west which lie in a southwest to northeast direction form a partial barrier to any airstreams crossing them, providing shelter on their lee side and enhanced rainfall on the windward side.

The data used in this publication, when not otherwise acknowledged, were obtained from the New Zealand Meteorological Service archives. For some places, records have been kept since about 1850 but most of the data used in this publication will be of the last 60 or 70 years. There are, or have been, in excess of 90 rainfall stations in the Southland area and there are currently 17 climate stations which make climatological observations as well as rainfall observations.

2. TYPICAL WEATHER SITUATIONS

The temperature, wind, rain, fog, frost etc are the elements comprising the weather at a particular moment while the climate is their integrated effect over a longer period. The types and sequence of weather elements affecting Southland are determined by large-scale synoptic situations consisting of the distribution of pressure and fronts over a large part of the Southern Hemisphere. Although many different situations are possible, they tend to fall into only a few important patterns, i.e.

1. Disturbed westerlies when a persistent westerly flow is interrupted for short periods by fast moving, and usually weak, fronts.

2. The passage of a major trough with perhaps several frontal zones. Its approach turns the flow over Southland northerly and behind the trough southerly airstreams prevail.

3. The low index pattern where the usual pressure distribution is reversed with depressions north of 40 degrees south and anticyclones to the south of New Zealand. In these situations, easterly airstreams flow over Southland.

The relative frequencies of these patterns can be assessed from Invercargill's wind data. For a third of the time wind directions at Invercargill are between southwest and northwest (i.e. 1. above); another third of the time is shared between northerly and southerly directions (i.e. 2. above). The remaining time is divided equally between easterly winds (i.e. 3. above) and calm conditions.

2.1 Disturbed Westerlies

The flow over Southland is westerly when pressures are high to the north and depressions lie to the south of New Zealand. The depressions are usually moved rapidly eastwards by strong westerly winds in the upper atmospheric flow and similar upper flows in sub-tropical latitudes (the subtropical jet streams) often intensify mid-latitude aniticyclones to give periods of strong westerlies over Southland. The annual cycle of changes in the upper flow is such that there is a minimum in the frequency of westerly winds over the South Island in winter (Reid, 1980) and a maximum in spring.

For strong westerlies, pressures in the 30 to 40 degrees south latitude belt of 1020hPa or more extending from about 130 degrees east to 170 degrees west are required, while pressures in the Macquaire/Campbell Island region should be about 980hPa. Such strong westerlies will persist over Southland while weak fronts pass with only minor wind changes (e.g. Fig. 1). However with more active fronts pressures to the north will not

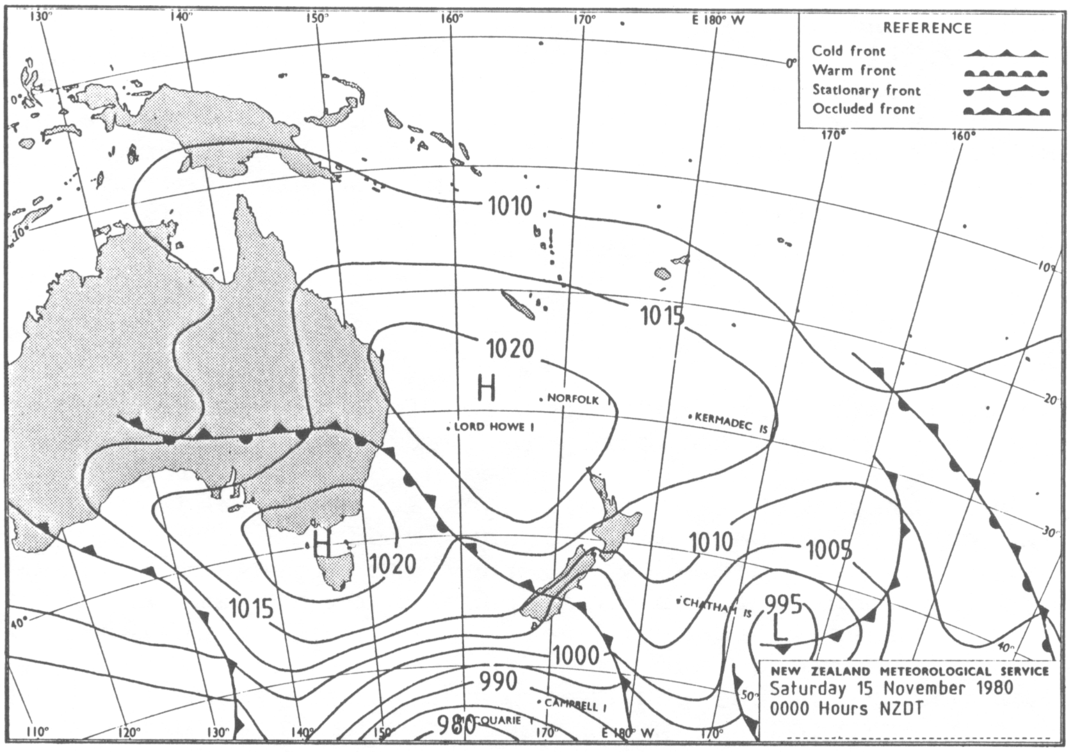


FIG. 1: Disturbed Westerlies - Strong Winds

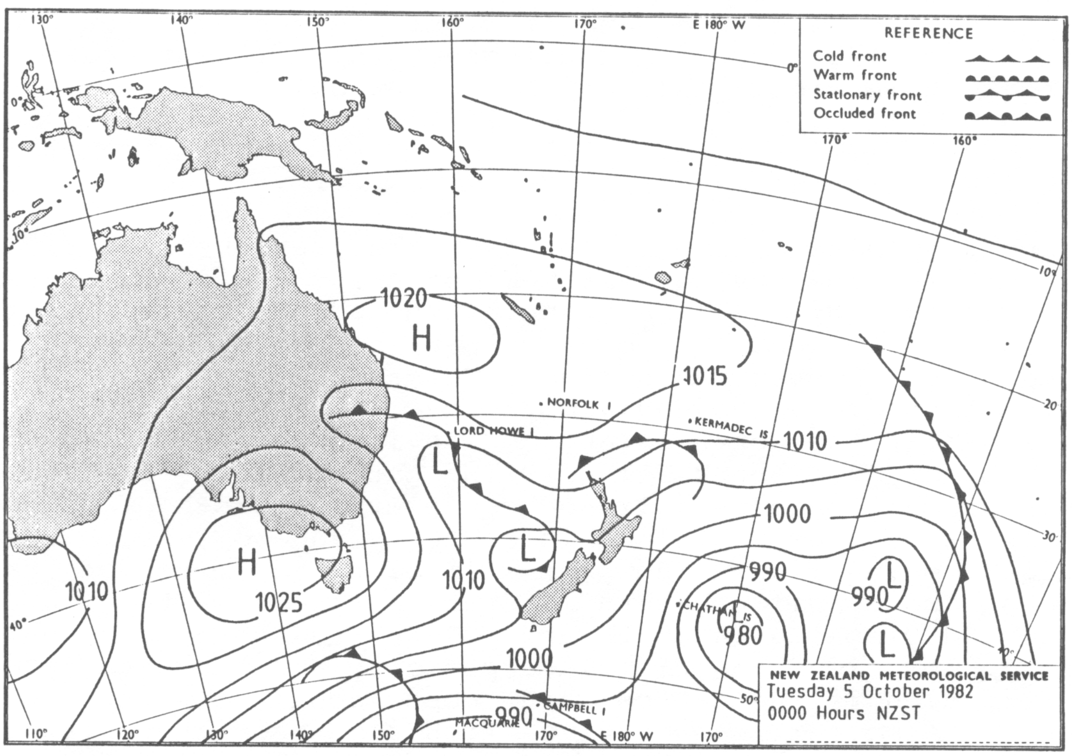


FIG. 2: Disturbed Westerlies - Moderate Winds

be so high and, therefore, the flow will decrease. Additionally, if the high pressure belt is much less extensive, then, only moderate winds will prevail (e.g. Fig. 2). These westerly flows are onshore and bring showers which are usually frequent and heavy about the western coast and ranges, but scattered about the south coast and isolated inland. As a front approaches, rain develops in the west and this spreads elsewhere with the frontal passage.

2.2 Passage of a Major Trough

As troughs of large amplitude approach from the west, the flow over Southland tends northerly (e.g. Fig. 3). Northerly wind directions are still onshore in western areas, bringing rain there, but areas east of the ranges are sheltered and remain fine, and can become warm with foehn winds. Although these major troughs are slow-moving, they are often accompanied by faster moving frontal zones which pass through them and bring periods of general rain to all parts of Southland. The amplitude of the trough and ridge to the west may be such that the flow turns to the southwest, but not any more southerly, before another trough approaches or the westerlies are re-established. In this case (e.g. Fig. 4), showery conditions prevail in most areas. However, with a larger amplitude system when the ridge extends well to the south (e.g. Fig. 5) a cold south to southeast flow covers Southland. In this case, western areas are sheltered and fine but the east and south are subject to periods of rain and drizzle. This latter case is more frequent in winter than any other season.

2.3 Low Index Situations

A low index situation can develop from the previous case if the trough becomes slow-moving over New Zealand; the southern part of it becoming very weak or disappearing as the ridge in the south intensifies and the northern part of the trough develops into a depression over the northern Tasman Sea or the North Island. Other processes can also result in this pattern with a depression near the North Island and an intense anticyclone to the south of the South Island. The pattern (e.g. Fig. 6) is slow-moving, and once established usually persists for some days. The flow over Southland is easterly and so western areas are sheltered and fine. The east will also be fine on many occasions, and as will be seen later this type of situation can cause long dry spells in Southland. However, the east can be subject to low cloud and drizzle especially about coastal areas in winter which is the season when these conditions are most frequent. Also, if an active front is associated with the depression in the north, and this moves sufficiently far south, then, periods of rain are likely.

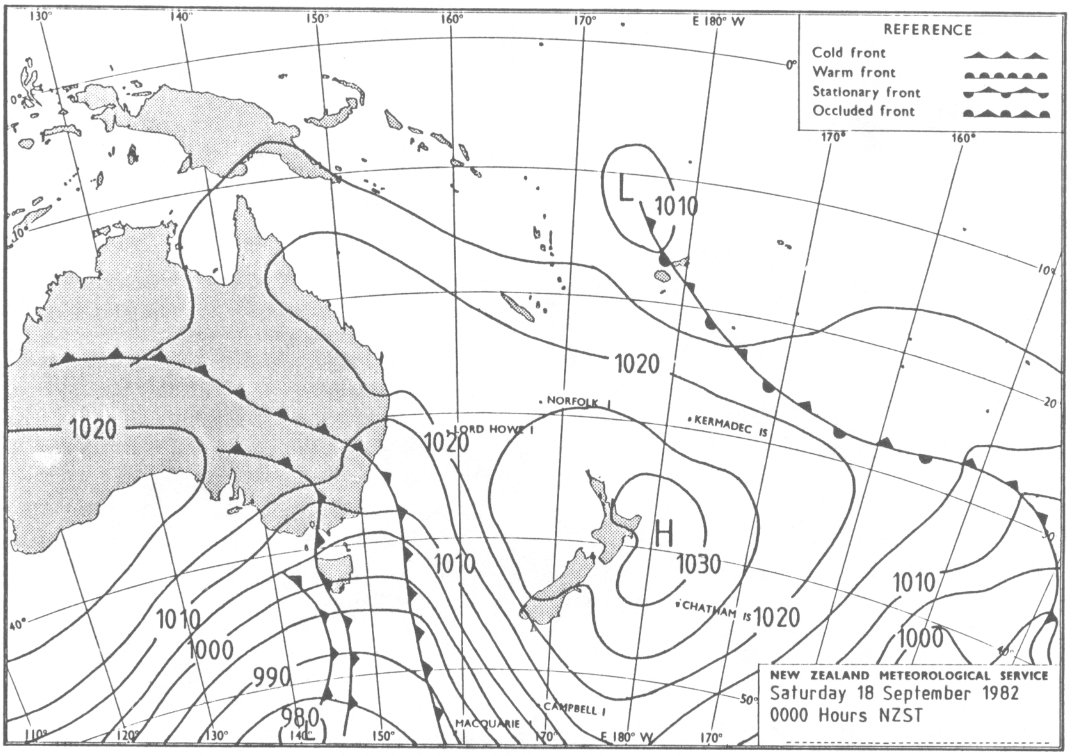


FIG. 3: Approach of a Major Trough

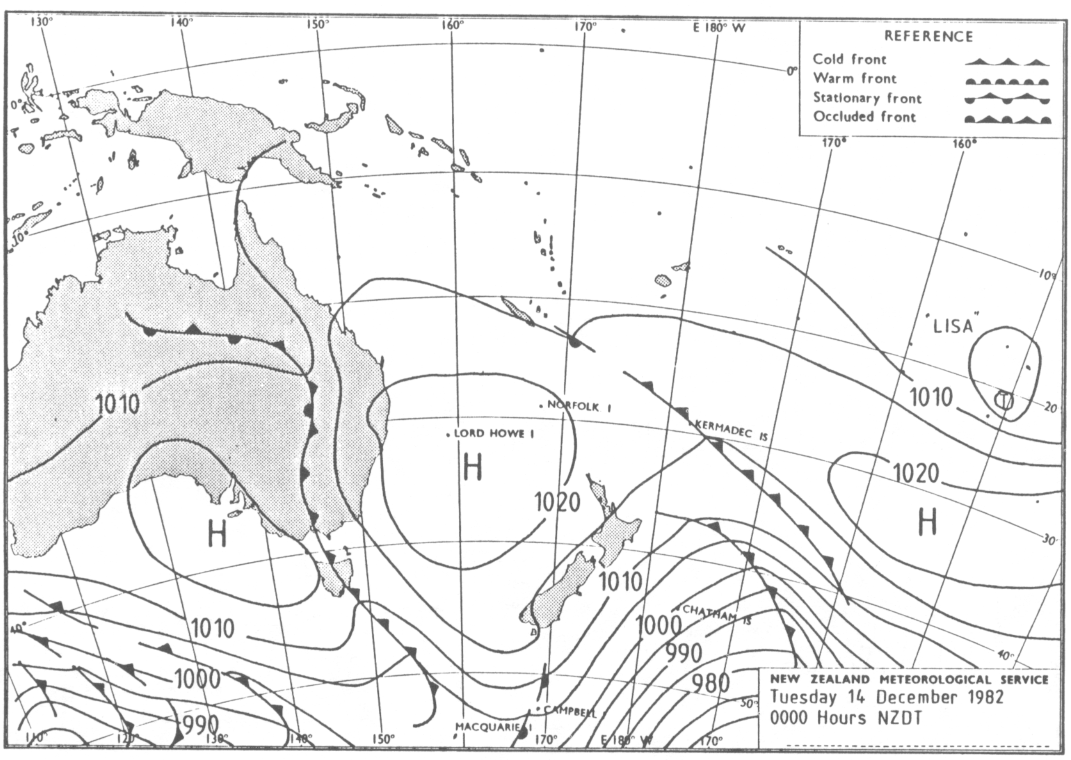


FIG. 4: After Passage of a Major Trough - Southwesterly Flow

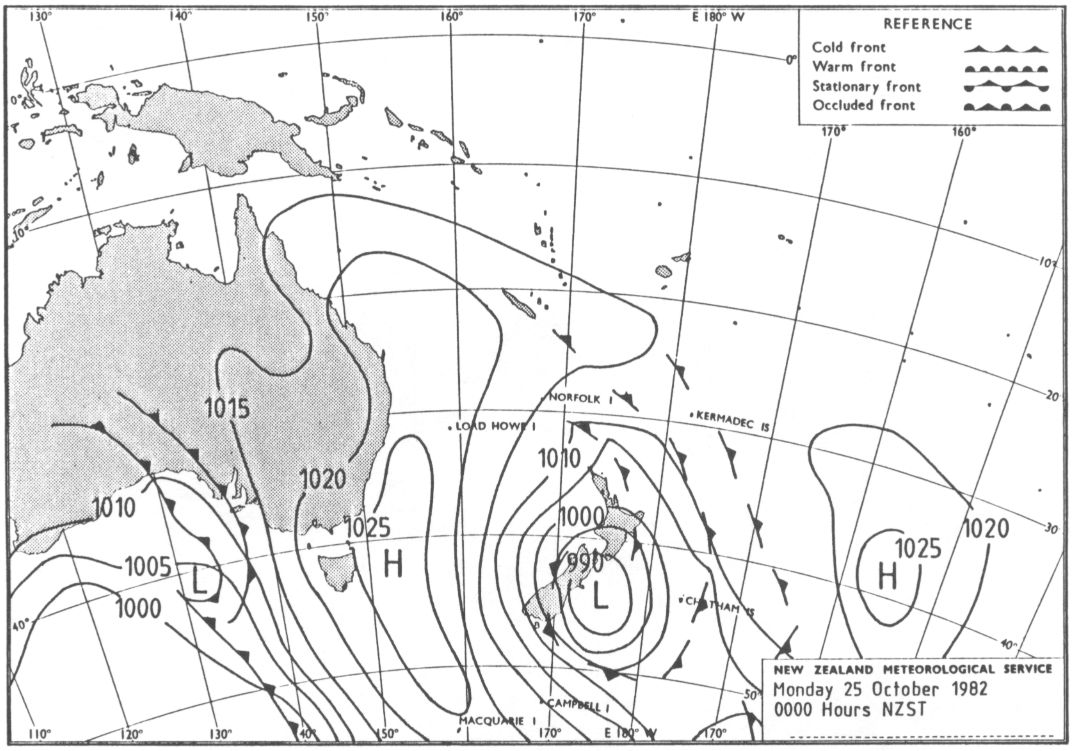


FIG. 5: After Passage of a Major Trough - Southeasterly Flow

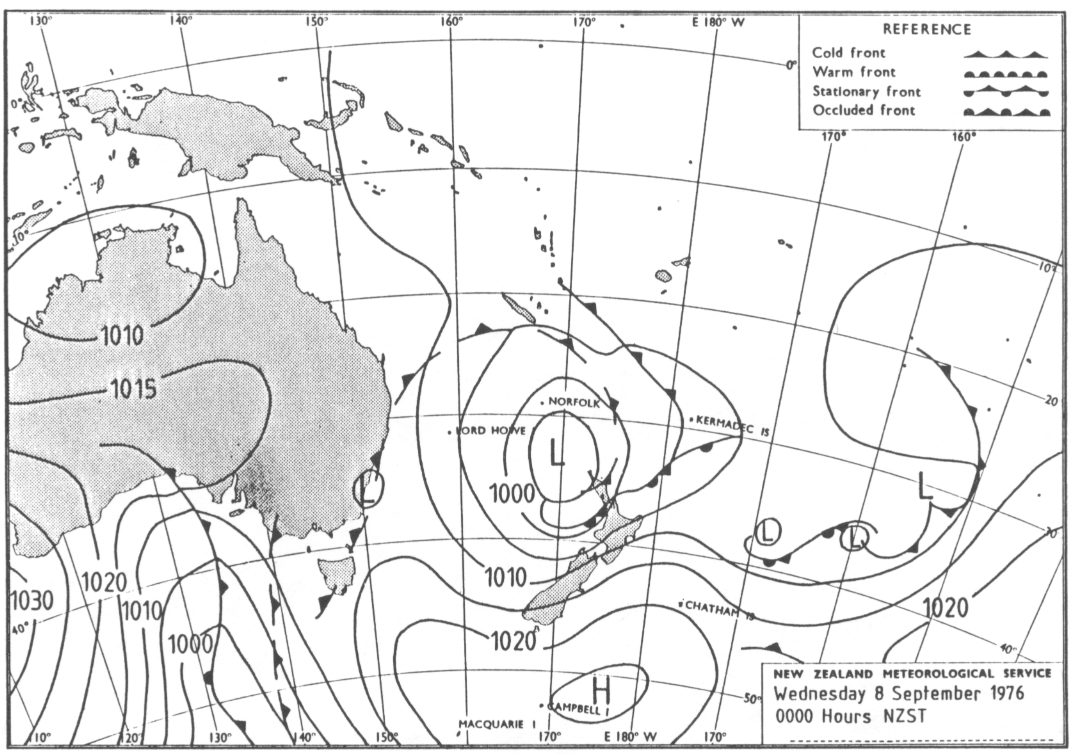


FIG. 6: Low Index Situation

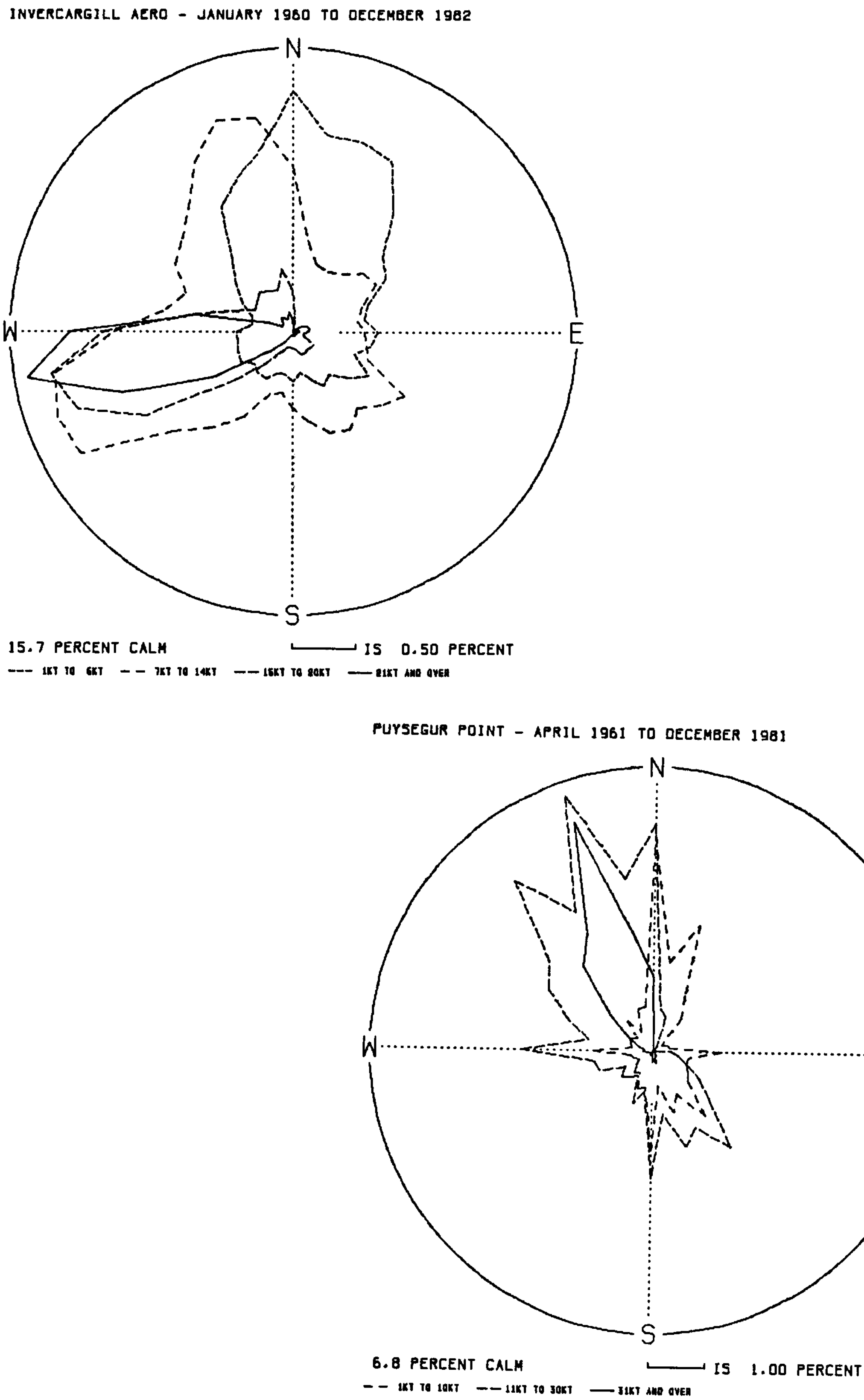


FIG. 7: Wind Roses for Invercargill and Puysegur Point

3. WIND

In the previous section typical weather situations were discussed in conjunction with the directions of airstreams, and Invercargill's wind data were cited to provide relative frequencies for the different weather types. These frequencies are approximately : westerly winds 33%, northerly winds 25%, easterly winds 14%, southerly winds 12% and calm conditions 16%. The wind direction at a particular locality is very greatly influenced by the local topography (the funnelling of westerly winds through Foveaux Strait in Invercargill's case) and so these frequencies will only approximately apply elsewhere. Wind speeds are also subject to topographical influence. The frequencies of different ranges of wind speed from different directions are shown for both Invercargill and Puysegur Point in Fig. 7. For the lighter winds, northerlies prevail at both places but at Puysegur Point southeasterlies are nearly as prevalent. However, at higher wind speeds, the prevalence of northerlies at Invercargill decreases and westerlies become most frequent, while at Puysegur Point northwesterlies take over with still a major contribution from southeasterlies, until at gale force and above winds are nearly exclusively northwesterly.

The wind rose for Invercargill was drawn using hourly data and that for Puysegur Point using 3-hourly data. Unfortunately, the only other wind data currently available for the Southland area are the once a day estimates taken at 9 a.m. at climatalogical stations (some of these stations also provide wind run data). A selection of the stations (including Invercargill to provide a comparison between the 9 a.m. data and readings taken throughout the day) were used to provide the directional data presented in Fig. 8 and the speed data presented in Table 1. Both the Invercargill roses, in Fig. 8, are of similar shape and the 9 a.m. frequencies of Table 1 approximate the "24hr" frequencies; so the 9 a.m. data are probably representative for the whole day. Since the Winton rose is similar to the Invercargill roses, this distribution is probably representative for the southern coastal area west of the Waiau River and south of the Takitimu Mountains and the Taringatura and Hokonui Hills. The other distributions are probably strongly influenced by local topography, e.g. Mid Dome lies between the Eyre and Garvie Mountains which lie in a southwest to northeast direction.

As regards wind speed, for the places shown in Table 1, Milford Sound and West Arm tend to have the lightest winds while Invercargill tends to have the strongest. Winton's wind speed distribution is unusual with most winds in the 1 to 10 knot range and very few calms but a high frequency of winds over 23 knots. The number of days of gales per year once again shows Invercargill to have stronger winds than elsewhere.

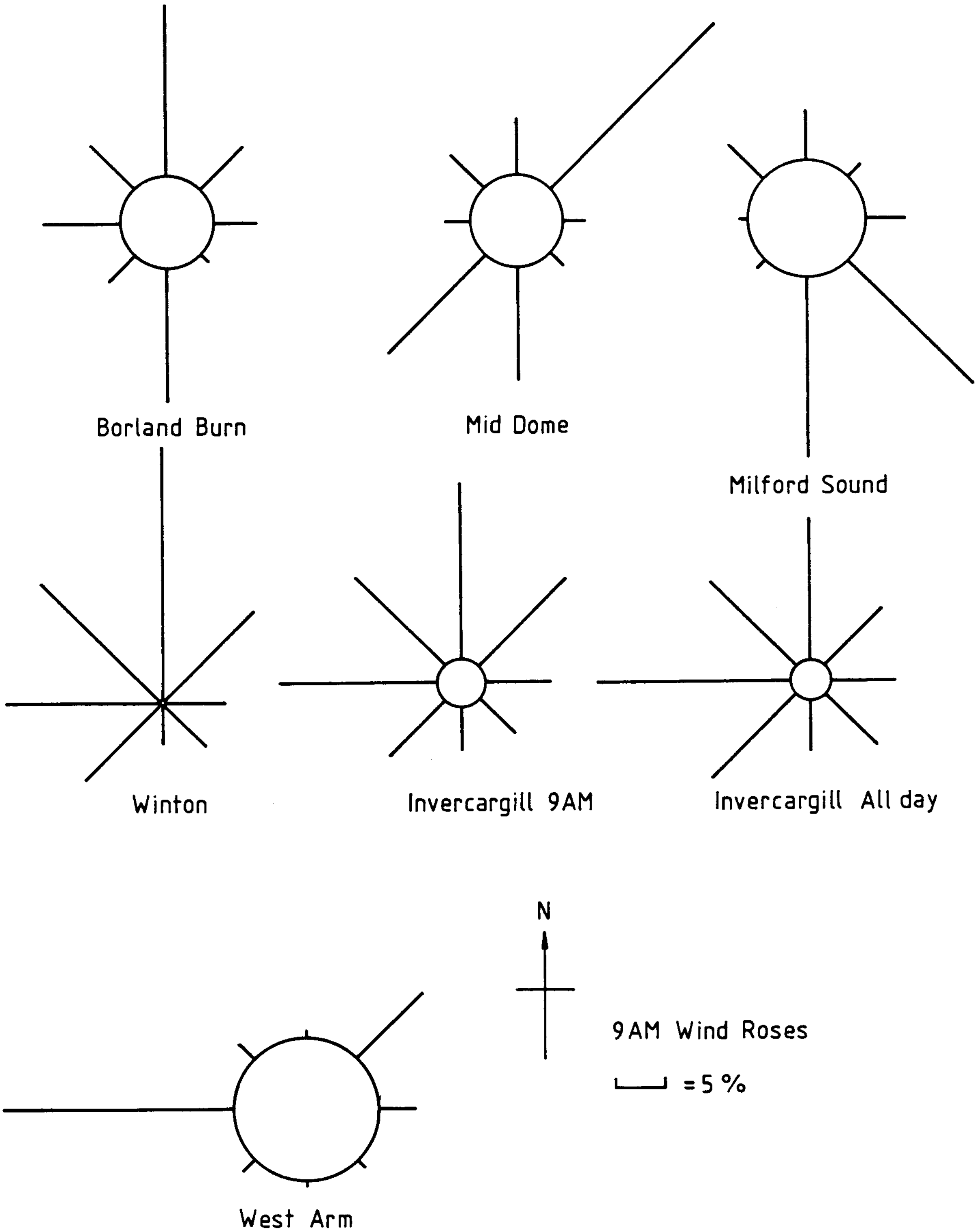


FIG. 8: Wind Roses from 9 a.m. Data taken at Climate Stations
(Radii of centre circles = Percentage of calms divided by 8)

TABLE 1: Mean Annual Number of Days Recording Gales(*) and Mean Annual Frequencies of Wind Speed at 9 a.m. (%)

Station	Gales	Calms	1-10 Kt	11-16 Kt	17-22 Kt	>22 Kt
Mid Dome	2.9	38.4	45.0	8.9	4.8	2.9
Invercargill	10.3	17.4	49.5	18.7	7.7	6.7
Milford Sound	5.7	47.9	45.6	4.6	1.2	0.7
Winton	2.8	5.9	81.8	5.0	2.1	5.2
West Arm	0.4	59.4	33.6	2.9	2.3	1.8
Borland Burn	---	39.3	53.1	3.1	2.5	2.0
Invercargill (24hr)		15.7	47.7	20.0	10.3	6.3

(*A gale is recorded for a day if at some time during the day the mean wind speed over a 10 min interval was over 33 knots)

The remainder of this section will mainly consider data from Invercargill which have been shown above to be representative for southern areas although Invercargill's winds are stronger than for places away from the coast. For all other Southland places Invercargill can be taken as a rough guide but winds will generally be lighter and directions influenced by local topography. However, for well exposed places as on high ridges, in favourably orientated valleys and especially about Foveaux Strait and other exposed coasts, the winds would often be stronger than those at Invercargill and again with directions influenced by local topography.

Returning to Fig. 7, it can be seen that the wind at Invercargill falls into several natural categories, e.g. strong westerlies, 25 knots and over from 230 to 290 degrees, or moderate northwesterlies, 9 to 16 knots from 310 to 360 degrees etc. The wind is determined not only by the local pressure pattern but by that over a much larger area, and this pressure distribution can be categorised by a zonal pressure index and a meridional pressure index. The relationship between the wind and pressure pattern can be examined as the frequencies with which wind categories occur when the pressure indices have certain values. Midday indices were used and an average for the corresponding afternoon's winds at Invercargill was determined by finding that category, from those listed at the bottom of Table 2, which could be used for the majority of that afternoon's hourly winds.

Calms were omitted since their dependence on the indices is very weak, and since 88% of strong winds are westerly other strong winds were also omitted. The result of examining the period January 1960 to December 1982 is summarised in Table 2, where Z is the noon pressure at 40 degrees south 170 degrees east less that at 50 degrees south 170 degrees east, M is the noon pressure at 45 degrees south 180 degrees less that at 45 degrees south 160 degrees east, and the units of Z and M are hPa. Each entry gives the frequency and probability of a wind category's occurrence with the particular indices shown. For example, 59 percent of all afternoons when the majority of the hourly winds are moderate/fresh southeasterly occur when the Z index is less than or equal to zero hPa and when the M index is less than 5hPa. However, given that the Z index is less than or equal to zero hPa and that the M index is less than 5hPa, then, there is a probability of 0.43 that the afternoon winds will fall into the moderate/fresh southeasterly category.

TABLE 2: Frequency and Probability of Occurrence of Wind Categories at Invercargill for Different Ranges of the Indices Z and M which are defined in text

Indices	Wind category	Frequency / Probability
Z≤0, M<5	Mod/fsh SE	59% / .43
	Mod/fsh NE	21% / .04
	Lght winds	21% / .44
	Mod W	8% / .08
0<Z≤10, M<5	Mod W	49% / .36
	Fsh W	30% / .18
	Lght winds	25% / .37
	Mod/fsh SE	13% / .07
10<Z≤19, M<5	Fsh W	44% / .40
	Stg W	39% / .16
	Mod W	21% / .23
	Mod/fsh NW	13% / .07
	Lght winds	6% / .13
Z>19, M<5	Stg W	47% / .43
	Fsh W	15% / .30
	Mod/fsh NW	10% / .12
	Mod W	4% / .10
Z≤10, M≥5	Mod/fsh NE	60% / .09
	Lght winds	37% / .63
	Mod/fsh SE	25% / .15
	Mod/fsh NW	10% / .04
	Mod W	9% / .08
Z>10, M≥5	Mod/fsh NW	62% / .42
	Mod/fsh NE	14% / .03
	Lght winds	10% / .29
	Mod W	9% / .13
	Stg W	8% / .04
	Fsh W	7% / .08

1. Strong westerlies........over 24 kt / 230 to 290 degrees
2. Fresh westerlies...........17-24 kt / 210 to 300 degrees
3. Moderate westerlies.........9-16 kt / 210 to 300 degrees
4. Mod/Fresh northwesterlies...9-24 kt / 310 to 360 degrees
5. Mod/Fresh southeasterlies...9-24 kt / 090 to 200 degrees
6. Mod/Fresh northeasterlies...9-24 kt / 010 to 080 degrees
7. Light winds.................1-8 kt / all directions

Tables 3 and 4 show the seasonal variations in both the wind direction and mean wind speed. The prevalence of westerly winds is easily seen and their spring/summer maximum, whereas in winter calm conditions and northerlies predominate. The sea breeze component at Invercargill can also be seen in Table 3, where southeasterly and southerly directions in summer take up 18% of the time but only 8% in winter. The mean wind speeds from Winton, Gore and Stewart Island are derived from wind run measurements made with cup-counters. Invercargill has higher mean wind speeds, as suggested earlier, but all the stations of Table 4 have a similar annual cycle of variation, with higher mean speeds in spring and to a lesser extent in summer, whereas autumn and especially winter have lower mean speeds. This annual variation is shown more clearly in the last line of Table 4, e.g. in January, the four stations shown average winds speeds 14% higher than their annual means.

TABLE 3: Mean Seasonal Frequency of Wind Direction at Invercargill (%)

	Spring	Summer	Autumn	Winter
N	13.4	9.4	13.9	19.4
NE	6.7	5.9	8.5	12.7
E	6.0	5.9	8.8	7.0
SE	7.7	10.4	6.6	5.0
S	5.6	8.0	4.5	3.5
SW	13.5	16.7	10.9	8.2
W	22.9	23.1	20.6	12.1
NW	13.3	8.3	11.1	12.1
CALM	10.9	12.4	17.8	20.1

TABLE 4: Monthly and Annual Mean Wind Speeds (Kt)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Winton	6.7	6.1	5.7	5.5	5.3	4.6	4.7	5.2	6.4	7.5	7.3	6.7	6.0
Gore	7.2	6.8	6.1	6.2	6.7	6.0	6.3	6.2	7.6	7.6	7.8	6.9	6.8
Stewart Island	6.6	6.1	5.9	4.2	5.2	4.7	5.2	4.5	5.7	6.1	6.1	5.4	5.5
Invercargill	10.4	9.5	8.9	8.6	8.0	7.4	6.4	7.1	9.2	10.5	10.9	10.1	8.9
Average % difference from year	+14	+5	-2	-11	-7	-16	-15	-15	+6	+17	+17	+7	

Table 5 shows that, as is usual, afternoons are the windiest times of day. In the mornings calm conditions are most frequent, then northwest to north winds, which are partly local land breezes, and finally westerlies. However, by afternoon the westerlies are the most frequent and in the evening are nearly as frequent as calm conditions. The least frequent directions during the morning are south to southeast but the summertime sea breeze masks this minimum later when northeasterlies are the least frequent.

TABLE 5: Diurnal Variation of Wind at Invercargill

Time of Day	00-05hr	06-11hr	12-17hr	18-23hr
Mean Speeds (Kt)	7.2	8.5	11.9	9.1
% Frequency of Wind Direction				
350-010	11.8	13.7	6.6	6.8
020-040	8.0	9.4	3.7	4.1
050-070	4.6	5.7	5.1	3.9
080-100	3.7	3.9	4.4	4.6
110-130	4.3	3.5	4.4	7.3
140-160	2.1	2.4	7.1	6.5
170-190	1.7	2.1	6.0	4.0
200-220	3.5	3.7	5.6	5.1
230-250	8.1	9.0	19.5	14.4
260-280	10.8	12.3	18.1	14.6
290-310	6.6	6.7	5.3	5.6
320-340	10.5	11.1	7.3	7.6
CALM	24.2	16.5	6.8	15.4

The wind gust data for Invercargill in Table 6 show a higher number of gusty days than average but still considerably less than for Wellington.

TABLE 6: Average Number of Days per Year with Gusts over 33 and 51 knots

Station	Period	33 Kt	51 Kt
Invercargill	1954-1980	102	12
Auckland	1962-1979	57	3
New Plymouth	1954-1979	80	6
Wellington	1972-1979	213	63
Christchurch	1954-1980	52	3
Dunedin	1956-1980	68	6

4. RAINFALL

4.1 Mean Annual Rainfall and its Variability

The spatial distribution of Southland's rainfall is given in Fig. 9 which clearly shows both its dependance on elevation and exposure to the main rain bearing airflows from the west. In Fiordland which has both high elevation and western exposure, the rainfall is very high, and is among the highest in New Zealand and the world. Near the eastern border of Fiordland, which can be taken to be Lakes Te Anau and Manapouri and the Waiau Valley, there is a sharp decrease eastwards in rainfall where the isohyets are close together in Fig. 9. The decrease flattens out after the 1200mm isohyet and, apart from a few areas of high ground and Stewart Island, the remainder of Southland has a fairly uniform rainfall. An important feature is that the rainfall varies by a factor of ten times over the area with falls of less than 800mm in some inland parts and of over 8000mm about the western ranges.

Table 7 gives the mean and extreme annual rainfalls for a selection of stations; also the period over which the mean was taken and the variability ("coefficient of variation") during that period. The variability is the ratio of the standard deviation to the mean expressed as a percentage, and for comparison Table 8 lists variabilities for other main centres around New Zealand. The average variability of the Southland stations is 14.4% which is similar to other western or southern places whereas in the east the variability is considerably more (e.g. Gisborne Harbour at 23%).

TABLE 7: Annual Rainfall Means(mm), Minima and Maxima (Amount in mm and year) and Coefficient of Variation (CoV %)

Station	Period	Annual Mean	Minimum Amount	Minimum Year	Maximum Amount	Maximum Year	CoV
West Arm	1960-71	3672	3015	1962	4323	1967	12.6
Manapouri	1951-80	1180	783	1974	1537	1957	14.2
Monowai	1920-80	1167	846	1943	1566	1980	15.3
Milford Snd	1930-80	6267	4244	1976	8368	1958	15.6
Puysegur Pt	1914-80	2243	1451	1918	3104	1957	13.2
Athol	1925-68	827	571	1966	1028	1936	13.3
Dunrobin	1949-80	957	702	1966	1449	1957	17.9
Otautau	1949-80	1088	843	1950	1515	1972	15.6
Gore	1943-71	836	622	1947	1074	1965	14.1
Hokonui Frst	1935-80	997	576	1947	1343	1972	15.6
Invercargill	1940-80	1042	780	1947	1448	1972	12.7
Bluff Res.	1935-66	994	743	1943	1337	1957	14.5
Oban	1914-75	1470	1138	1943	1950	1972	12.5

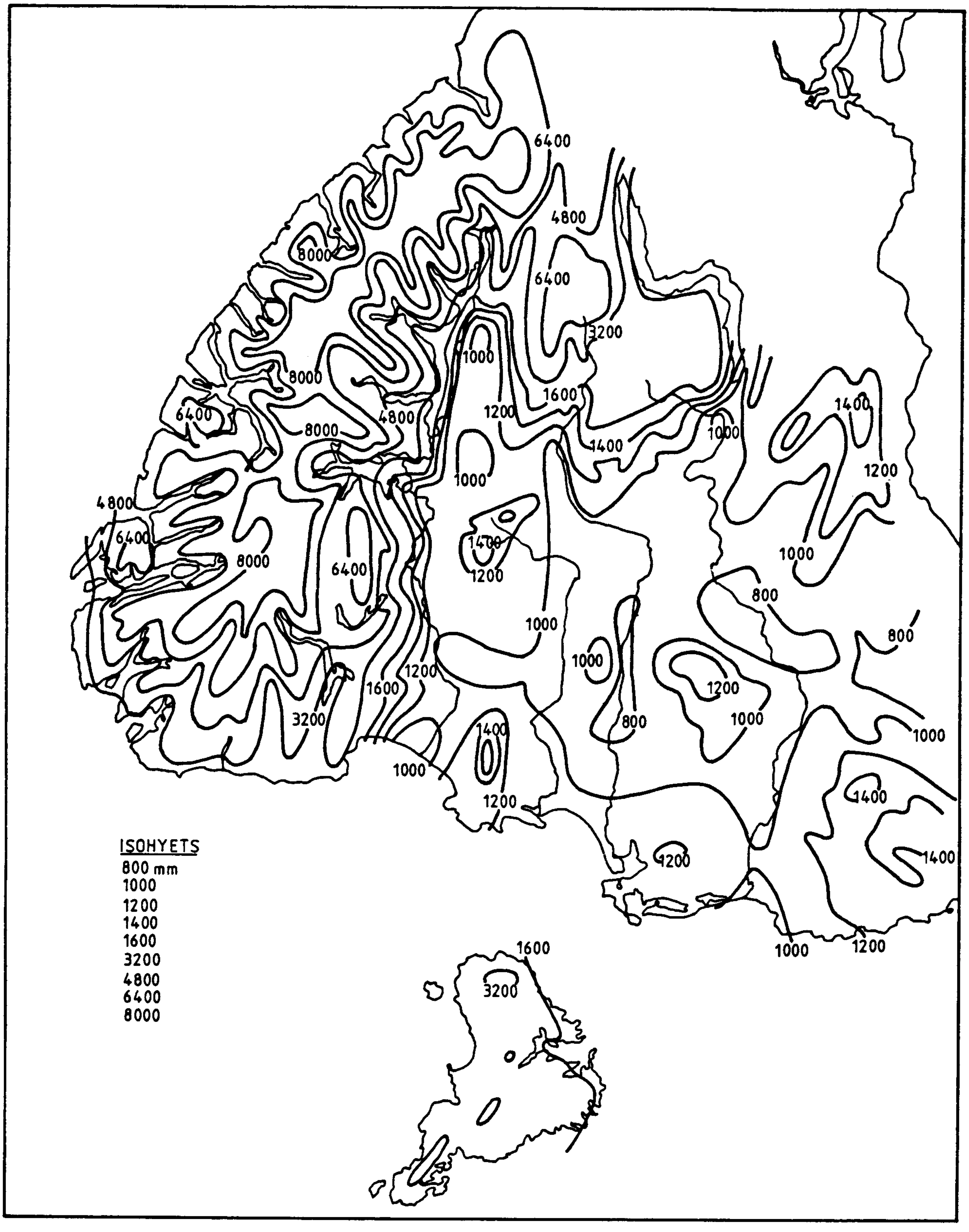


FIG. 9: Distribution of Mean Annual Rainfall

TABLE 8: Rainfall Coefficients of Variation for Selected New Zealand Centres

Auckland (Albert Park)	1853-1978	19.4%
New Plymouth	1864-1973	15.5%
Gisborne Harbour	1878-1969	23.0%
Wellington (Kelburn)	1928-1978	16.8%
Reefton	1904-1978	14.2%
Christchurch	1894-1978	22.1%
Dunedin (Musselburgh)	1918-1978	15.2%

For the period 1936 to 1980 Fig. 10 shows the year by year variation in the annual rainfall averaged over the Southland area. The averaging was performed by taking the mean of the normalised annual rainfalls of several stations (i.e. an ordinate value of 1, for example, corresponds to an average rainfall over the Southland area for that year of one standard deviation above normal). Fig. 10 shows no simple pattern, but, if a change from one year to the next of less than one standard deviation is defined as persistence then persistence prevails about 70% of the time.

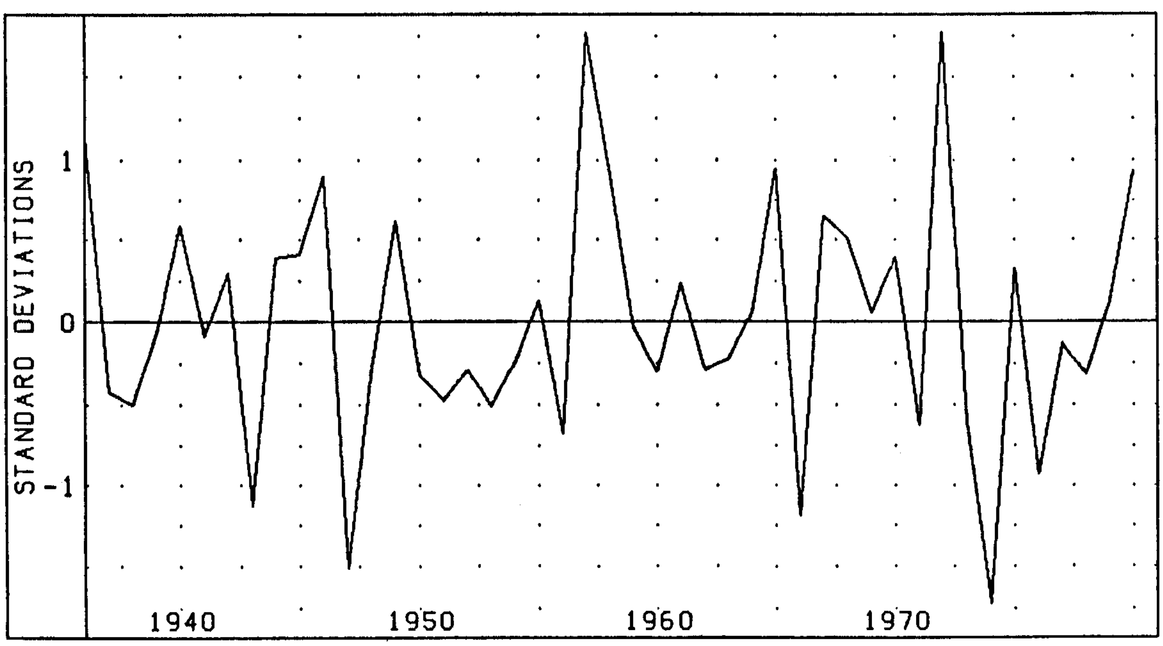


FIG. 10: Areally Averaged Annual Rainfalls 1936 to 1980

If twelve month periods other than January to December were considered then although much of the above is still valid, different periods of maximum and minimum falls are likely to occur. The 5 driest and 5 wettest twelve month periods for Invercargill during the period 1940 to 1980 are shown in Table 9. When the 50 driest and 50 wettest twelve month periods for Invercargill are tested using the Chi-square Test, no bias is found for any month starting a dry or wet period.

TABLE 9: Ranked Maxima and Minima Rainfalls (mm) over 12 Month Periods at Invercargill

Minima Start Date	Minima Amount	Maxima Start Date	Maxima Amount
Dec 1973	751	Nov 1971	1460
Jan 1947	781	Dec 1971	1450
Mar 1974	786	Jan 1972	1448
Nov 1955	795	Oct 1971	1420
Apr 1943	797	May 1957	1417

4.2 Variation of Rainfall over the Year

The month by month variation in rainfall for selected stations is shown in Fig. 11. The driest months of the year are usually July, August and September, which can be seen more clearly in Fig. 12 where data from 45 stations, each with about 30 or more years of record, were used. An average was taken over these stations of the difference of each month's mean rainfall from an even distribution through the year. For example, a +10% month (i.e. May in Fig. 12) would on average have a rainfall 10% greater than that calculated from : (mean annual times the number of days in the month divided by 365). Fig. 12 falls into 3 "seasons" indicated by the dashed lines which show the average difference from even over the "season"; these "seasons" are not the same as the usual seasons when winter is June/July/August, spring is September/October/November, summer is December/January/February and autumn is March/April/May. In this case, "winter" has an average of 17% below the even distribution, and so only 21% of the mean annual rainfall, while "autumn" has an average of 12% above giving 28% of the year's rain, and both "spring" and "summer" are only 2.5% above with 25.5% each of the year's rain. If these figures are compared with those for the standard seasons (Table 10), then, it can be seen that the standard seasons tend to smooth out the seasonal variation since winter receives 23% of the annual total compared to "winter" with 21%; similarly autumn receives 27% and "autumn" 28%.

Table 10 uses the standard seasons and from the comparison with other centres around New Zealand it can be seen that Southland's autumn is similar to other places whereas spring and summer are wetter than elsewhere and winter is drier. In general and especially in summer Southland has lower variablility. Differences between the seasons seem small but a more marked difference can be seen in Table 11 where the 50 smallest rainfalls accumulated over 3 months at Invercargill, and the 50 greatest, are used.

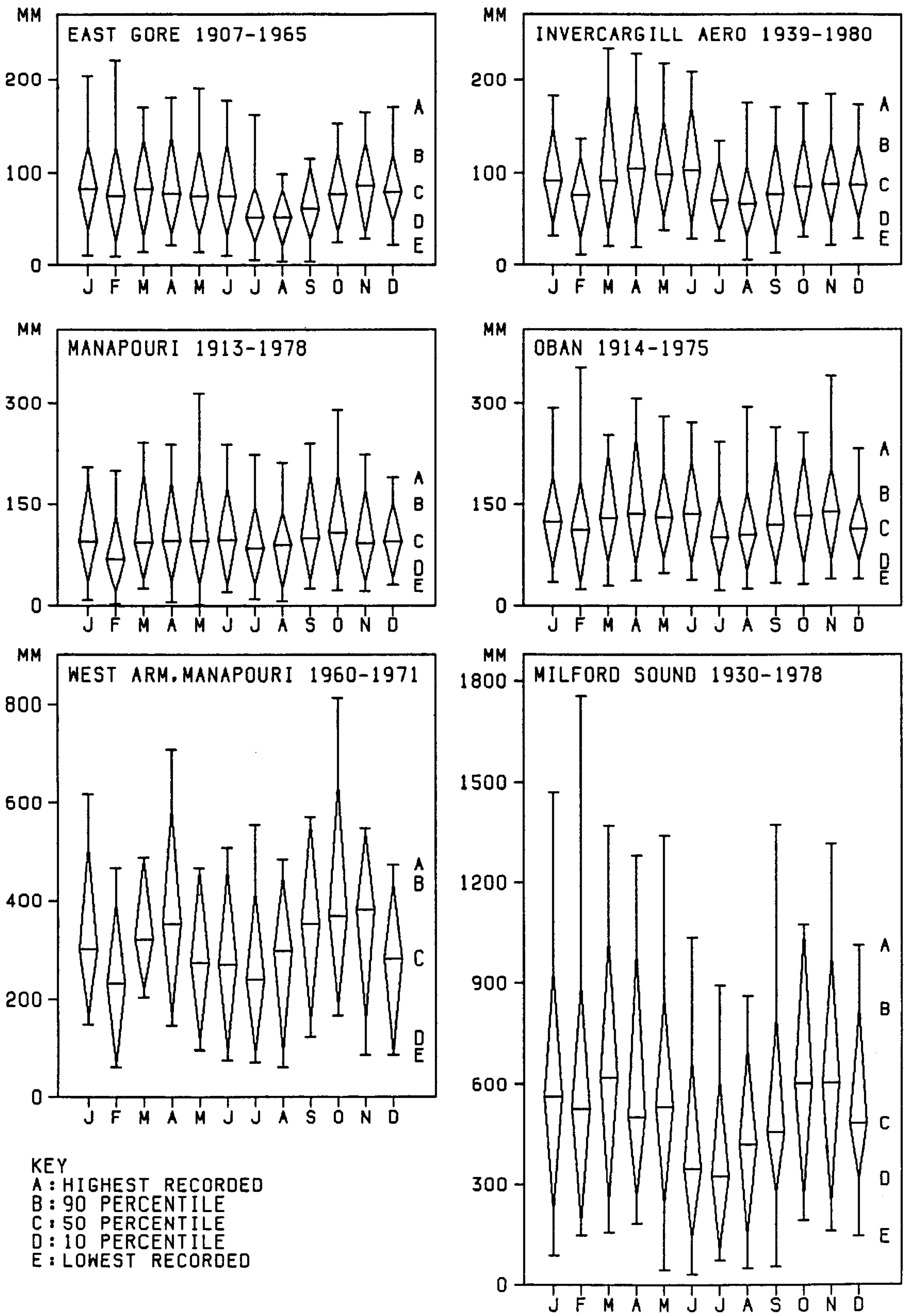


FIG. 11: Monthly Rainfall Statistics

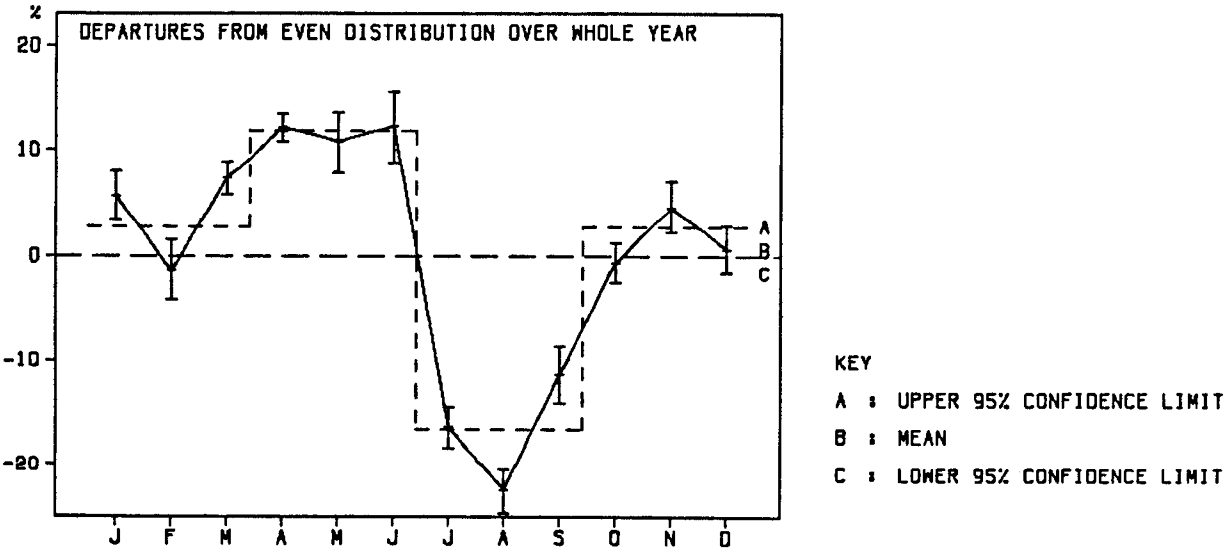


FIG. 12: Annual Cycle of Rainfall
("Seasons" referred to in text shown by dashed lines)

TABLE 10: Seasonal Rainfalls (as % of Annual) and the Seasonal Coefficients of Variation (CoV %) for the same periods as in Tables 7 and 8

Station	Summer		Autumn		Winter		Spring	
	Mean	CoV	Mean	CoV	Mean	CoV	Mean	CoV
West Arm	23	27	28	29	21	26	28	32
Manapouri	22	32	26	35	23	28	29	32
Monowai	23	33	27	34	24	33	26	32
Milford Snd	27	34	28	33	18	24	27	27
Puysegur Pt	24	22	27	21	24	24	25	27
Athol	26	29	28	33	22	29	24	30
Dunrobin	25	37	27	35	23	31	25	34
Otautau	22	21	30	31	25	29	23	27
Gore	27	17	27	34	21	24	25	19
Hokonui Frst	26	26	28	32	22	25	24	25
Invercargill	24	18	28	31	23	24	25	27
Bluff Res.	26	30	26	31	24	29	24	31
Oban	23	29	27	29	23	25	27	28
AVERAGE	24	27	27	31	23	27	26	29
Auckland	19	46	26	37	32	27	23	28
New Plymouth	22	39	24	31	30	25	24	25
Gisborne	19	48	30	46	32	32	19	43
Wellington	20	40	24	30	32	27	24	27
Reefton	22	31	24	29	27	32	27	27
Christchurch	24	41	27	44	28	41	21	42
Dunedin	26	33	27	39	24	34	23	27

TABLE 11: Distribution of Start Months of the 50 Maximum and the 50 Minimum 3-month Rainfalls at Invercargill

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minima	2	3	3	1	2	8	13	8	5	3	1	1
Maxima	3	7	8	14	4	1	-	2	4	2	5	-

TABLE 12: Maximum Monthly Falls as Percentage of Mean Annual (Periods the same as Table 7)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
West Arm	17	13	13	19	13	14	15	13	16	22	15	13
Manapouri	21	17	20	20	27	20	19	24	20	24	19	16
Monowai	26	22	20	19	21	21	17	24	25	25	19	19
Milford Snd	23	28	22	20	21	17	14	14	22	17	21	16
Puysegur Pt	20	17	18	16	18	20	13	14	22	17	19	14
Athol	16	19	26	25	25	20	22	16	12	24	20	16
Dunrobin	20	20	22	20	24	17	15	22	23	19	32	20
Otautau	21	13	20	25	25	24	15	20	18	14	18	16
Gore	16	15	17	21	22	17	15	12	16	14	16	19
Hokonui Frst	20	22	20	22	21	17	15	19	17	15	20	17
Invercargill	18	29	22	22	21	20	13	17	16	17	18	17
Bluff Res	16	24	20	16	23	22	13	22	14	20	22	15
Oban	20	24	17	21	19	19	16	20	18	18	23	16
AVERAGE	20	20	20	20	22	19	15	18	18	19	20	17

Average for all months = 19%

TABLE 13: Minimum Monthly Falls as Percentage of Mean Annual (Periods the same as Table 7)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
West Arm	4.0	1.7	5.5	4.0	2.6	2.0	1.9	1.7	3.4	4.5	2.3	2.3
Manapouri	0.7	0.2	2.0	0.4	0.1	1.5	0.8	0.5	2.0	1.8	1.7	2.5
Monowai	0.9	0.2	0.5	0.9	0.6	0.5	0.4	1.2	2.2	1.3	1.0	2.0
Milford Snd	1.4	2.3	2.5	3.0	0.7	0.5	1.1	0.8	0.9	3.1	2.6	2.3
Puysegur Pt	2.7	1.8	2.6	2.8	2.6	3.2	2.9	1.8	3.2	3.8	2.8	3.0
Athol	2.5	1.9	0.8	1.5	3.1	1.1	1.0	0.5	0.2	1.2	1.3	1.2
Dunrobin	3.0	1.5	3.1	3.4	2.0	1.3	1.3	0.8	2.3	1.0	1.9	1.7
Otautau	2.4	1.1	2.8	3.6	2.6	2.6	2.0	0.7	1.7	2.1	2.0	3.1
Gore	4.1	2.8	2.0	1.7	1.7	3.0	1.3	0.8	0.5	2.5	3.8	2.9
Hokonui Frst	2.8	2.3	1.1	2.5	2.0	2.7	2.2	0.7	1.6	2.6	2.0	2.3
Invercargill	3.1	1.2	2.0	1.9	3.6	2.8	2.6	0.7	1.3	3.0	2.1	2.8
Bluff Res	2.9	1.5	2.0	2.3	3.4	3.4	1.8	1.2	1.7	2.2	3.5	4.1
Oban	2.3	1.5	1.8	2.5	3.3	2.5	2.2	1.6	2.2	2.0	2.7	2.7
AVERAGE	2.5	1.5	2.2	2.4	2.2	2.1	1.7	1.0	1.8	2.4	2.3	2.5

Average for all months = 2.0%

It can be seen in Table 11 that of the 50 minima, 13 cover the July/August/September period (i.e. the dry period of Fig. 12) whereas only 8 cover the standard winter. Similarly, of the 50 maxima, 14 cover April/May/June (i.e. the wet period of Fig. 12) and 8 cover the standard autumn.

Maximum and minimum monthly falls are shown in Table 12 and Table 13 as percentages of the mean annual rainfall. The variation over the year in the maxima is similar to that shown in Fig. 12 with the smallest maximum in July and the largest in May. The largest maximum ever recorded, regardless of month, for each of these stations is at least 22% of the annual mean rainfall, and ranges up to 32.0% at Dunrobin. The variation over the year in the minima is also similar to Fig. 12 with the smallest mimimum in August but the month of the largest is not well defined. The smallest minimum ever recorded, regardless of month, for these stations is at most 1.8% of the annual mean rainfall and ranges down to 0.1% at Manapouri.

4.3 Raindays, Duration and Persistence of Rain

Since most rainfall gauges are only read once a day, the rate of rainfall can usually only be expressed as so many millimetres/day; the rainday can be variously defined as the 0.1mm rainday, 1mm rainday etc. (i.e. a day is considered to be a 1mm rainday if 1mm or more of rain fell). However, some stations do provide data from which the number of hours of rain and its average intensity and variation during the day etc can be determined.

TABLE 14: Seasonal and Annual Average Number of 1mm Raindays (Periods same as Table 7)

Station	Summer	Autumn	Winter	Spring	Year
Milford Sound	44	45	42	50	181
Puysegur Point	49	57	58	57	221
Oban	44	49	50	50	193
Monowai	29	38	37	38	142
Invercargill	36	42	40	38	156
Dunrobin	26	31	28	32	117
Gore	34	35	33	35	137
Kaitaia	23	32	47	35	137
Auckland	24	33	46	36	139
Gisborne	21	29	37	25	112
Christchurch	18	22	24	19	83
Reefton	34	35	38	44	151

From Table 14 it can be seen that western and southern parts of Southland have more raindays than other parts of New Zealand including other parts of Southland. Generally summer is the season with the least raindays, the number in North Island

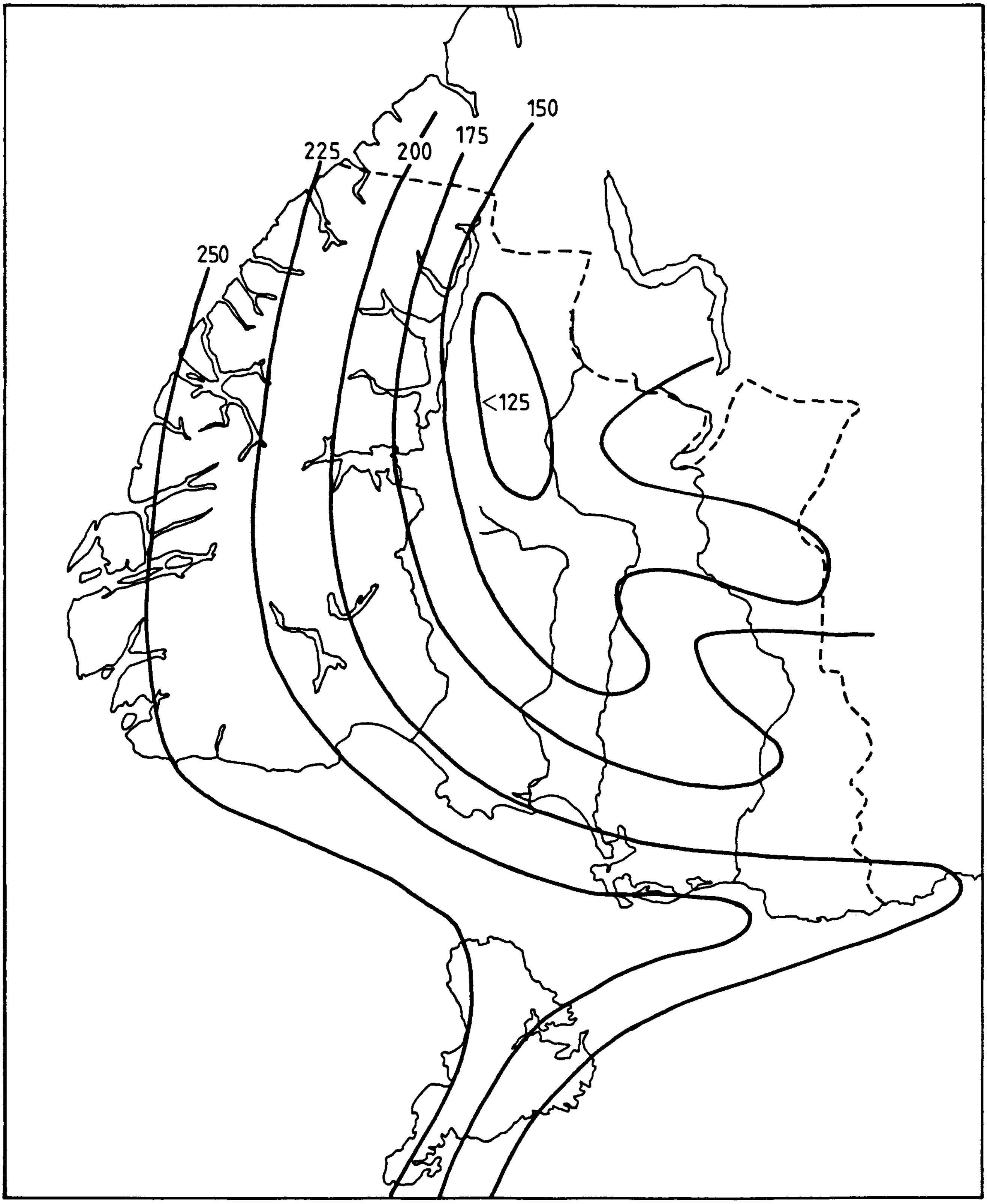


FIG. 13: Distribution of the Annual Number of 0.1mm Raindays

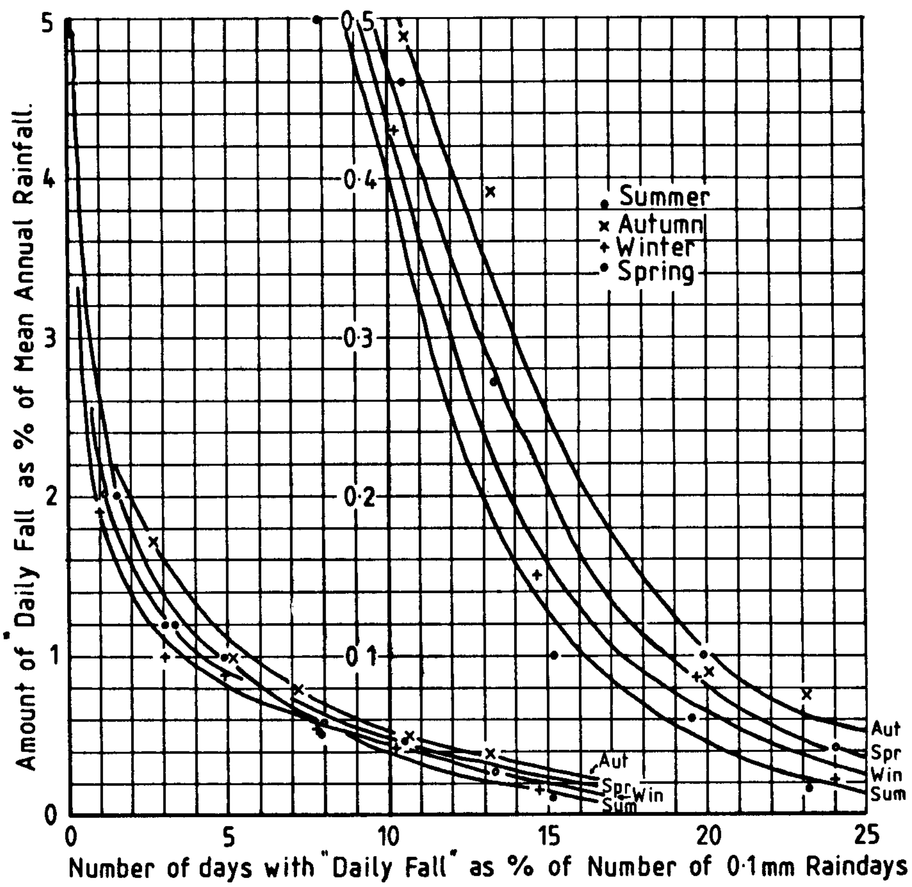


FIG. 14: Number of Seasonal Raindays of Various Amounts (Related to the mean annual rainfall and the number of 0.1mm raindays)

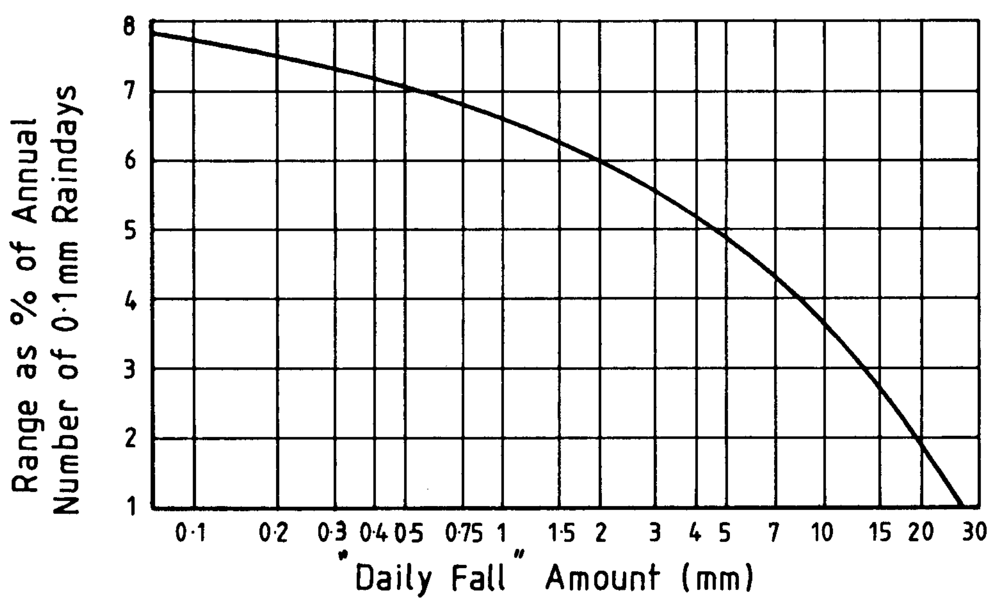


FIG. 15: Range of Number of Raindays for Various Daily Falls

summers being considerably less than the winter maximum there. The seasonal variation in Southland is small and the maximum number can occur in any season although spring is slightly favoured as the season of most raindays.

The spatial distribution of the mean annual number of 0.1mm raindays is shown in Fig. 13, while Fig. 14 in conjunction with Figs 9 and 13 provides a means of calculating the number of raindays of any other amount of rain for each season at all places in the Southland region; that is, not just for those places where rainfall has been measured on a daily basis but for all places. Averages from 25 long-term stations gave the points shown in Fig. 14 and back-checking the curves against the original data a mean error of about 5% was found. For example, to within 5% the number of 10mm raindays in winter at Tuatapere is found as follows :

1. Fig. 9 gives 1000mm as the mean annual rainfall.

2. 10mm to 1000mm gives 1% for ordinate entry to Fig. 14.

3. Using this and winter curve, 3.6% results.

4. Fig. 14 gives 200 as the number of 0.1mm raindays.

5. 3.6% of 200 gives 7 days with 10mm or more of rain in winter at Tuatapere.

An average value results from this procedure and the approximate range of this mean can be found from Fig. 15 (also obtained by averaging data from long-term stations). Continuing the example, from Fig. 15 a range of 3.6% is given for 10mm raindays; therefore, the range at Tuatapere is about nil to 14days.

From the order of the curves in Fig. 14 it can be seen that on average autumn has the maximum number of raindays followed by spring, then winter and lastly summer with the minimum number. However, towards the left of Fig. 14, where higher daily falls are considered, the order of the seasons changes to autumn still with the most, then summer, spring and lastly winter. Therefore, it appears that the winter minimum of rainfall largely results from there being fewer heavy falls rather than fewer actual days of rain.

The data shown in Table 15 are for Invercargill and are not available for any other station in the Southland region. However, it is likely that the data are representative for places along and near to the south coast. Whereas in the west more hours of rain with higher average intensities are likely, while inland areas to the east of Lakes Te Anau and Manapouri probably have fewer wet hours and lower average intensities. A Chi-square test of the monthly diurnal variation data against an even distribution through the day shows only February to be significantly different. However, if a test is performed against the annual mean distribution, not even February is significantly different. This suggests that the maximum of rainfall in the early morning is a year round effect and probably due to local convergence between the night-time land breezes and the prevailing westerlies through Foveaux Strait.

TABLE 15: Duration, Rate and Diurnal Variation at Invercargill

	J	F	M	A	M	J	J	A	S	O	N	D	YR
1948-1970 Average duration of rainfall (hrs)													
	49	43	53	53	57	70	47	42	46	54	53	48	613
Equivalent percentage of total time													
	6.6	6.3	7.2	7.4	7.7	9.7	6.3	5.7	6.1	7.3	6.7	6.5	7.0
Average rate of rainfall (mm/hr)													
	1.9	1.9	1.7	1.9	1.6	1.5	1.6	1.5	1.7	1.6	1.7	1.9	1.7
1949-1966 Rain from 07hr to 17hr													
Number of hours with at least 0.5mm of rain per hour													
	19	18	25	26	28	33	20	17	18	18	24	18	264
Number of days with at least 8 hours of rain at 0.5mm/hour													
	0.2	0.1	0.3	0.2	0.4	0.4	0.3	0.1	0.1	0.3	0.4	0.1	2.9
1945-55 Diurnal variation of total rainfall (%)													
00-06hr	27	37	27	28	26	25	21	27	31	26	31	29	28
6-12hr	20	29	27	28	27	24	22	26	23	25	24	22	25
12-18hr	22	14	21	21	24	22	30	21	23	25	22	22	22
18-24hr	31	20	25	23	23	28	26	25	23	24	24	26	25

The average persistence of various amounts of rain per day over various numbers of days is given for selected stations in Table 16. For example, at Milford Sound on 46% of all days no rain falls and 6% of all 7 day periods are also dry but 21% of all 4 day periods have between 12.1 and 25mm of rain per day or 47% (i.e. 21+18+8) of all 4 day periods have over 12.1mm per day. In general, all stations in Table 16 have a maximum at Nil-Rain/1-day but there is a subsidary maximum in the 1-day column and this increases across the table while the Nil-Rain maximum decreases. So that, by the 15-day column the Nil-Rain maximum has decreased to 1% or less while the other has increased to about 35 or 40%. The row of Table 16 which has this subsidary maximum is the row encompassing that amount equal to the mean annual fall divided by 365.

TABLE 16: Persistence of Rain (i.e. % of N-day periods with various average daily amounts of rain)

N-days	1	2	3	4	5	7	10	15	1	2	3	4	5	7	10	15
Amount	Milford Sound								Puysegur Point							
Nil Rain	46	31	22	15	11	6	2	1	31	17	10	6	3	1	1	1
0.1 - 1mm	5	7	8	7	7	5	3	1	10	12	12	11	10	7	4	1
1.1 - 2mm	3	4	4	4	4	4	3	2	8	9	9	9	9	9	7	5
2.1 - 4mm	4	6	6	7	7	7	7	6	11	14	16	18	19	20	22	22
4.1 - 8mm	6	8	10	11	12	14	15	15	15	20	24	27	30	35	40	47
8.1 -12mm	4	6	8	9	10	12	14	16	9	12	14	16	16	18	19	20
12.1-25mm	11	14	18	21	23	27	32	38	11	13	13	12	12	10	7	5
25.1-50mm	10	14	16	18	19	19	20	20	4	3	2	1	1	1	1	0
over 50mm	11	10	8	8	7	5	4	2	1	1	1	1	1	0	0	0
Amount	Athol								Manapouri							
Nil Rain	65	47	35	26	19	11	4	1	62	45	33	24	18	10	4	1
0.1 - 1mm	7	14	20	24	27	28	28	24	6	12	15	18	20	21	20	16
1.1 - 2mm	5	8	12	14	16	20	23	27	4	6	9	11	13	17	18	20
2.1 - 4mm	6	11	14	17	19	23	28	34	5	10	13	17	19	22	27	32
4.1 - 8mm	8	11	12	13	14	15	15	13	8	13	16	18	19	21	24	26
8.1 -12mm	4	5	4	4	4	3	1	1	5	6	7	8	7	7	6	4
12.1-25mm	4	4	3	2	1	1	1	0	7	7	6	4	4	2	1	1
over 25mm	2	1	1	1	1	0	0	0	3	1	1	1	1	0	0	0
Amount	Invercargill								Oban							
Nil Rain	44	26	16	10	7	3	1	1	41	24	14	8	5	2	1	0
0.1 - 1mm	16	23	26	27	26	24	20	14	9	15	18	19	18	16	12	7
1.1 - 2mm	8	11	15	17	18	20	23	26	9	11	14	15	16	16	17	16
2.1 - 4mm	10	15	18	20	23	29	32	38	11	16	18	21	23	27	31	36
4.1 - 8mm	11	14	17	19	19	20	21	21	13	18	21	23	25	27	30	33
8.1 -12mm	5	6	6	5	5	4	3	1	7	8	9	9	9	9	8	7
12.1-25mm	5	4	3	2	1	1	1	1	8	7	6	5	4	3	2	1
over 25mm	2	1	1	1	0	0	0	0	3	1	1	1	1	0	0	0

4.4 Dry Periods

A dry spell may be defined as 15 or more days with less than 1.0mm of rain per day and a very dry spell as 15 or more days with no rain at all. To a large extent the spatial frequency distribution of the dry spells follows the mean annual rainfall distribution (compare Fig. 9 with Fig. 16) with fewer occurring in the west and south where the rain is heaviest but becoming more frequent inland and in the east. However, although Milford Sound has a considerably higher mean annual rainfall, there were 17 very dry spells and 24 dry spells there between

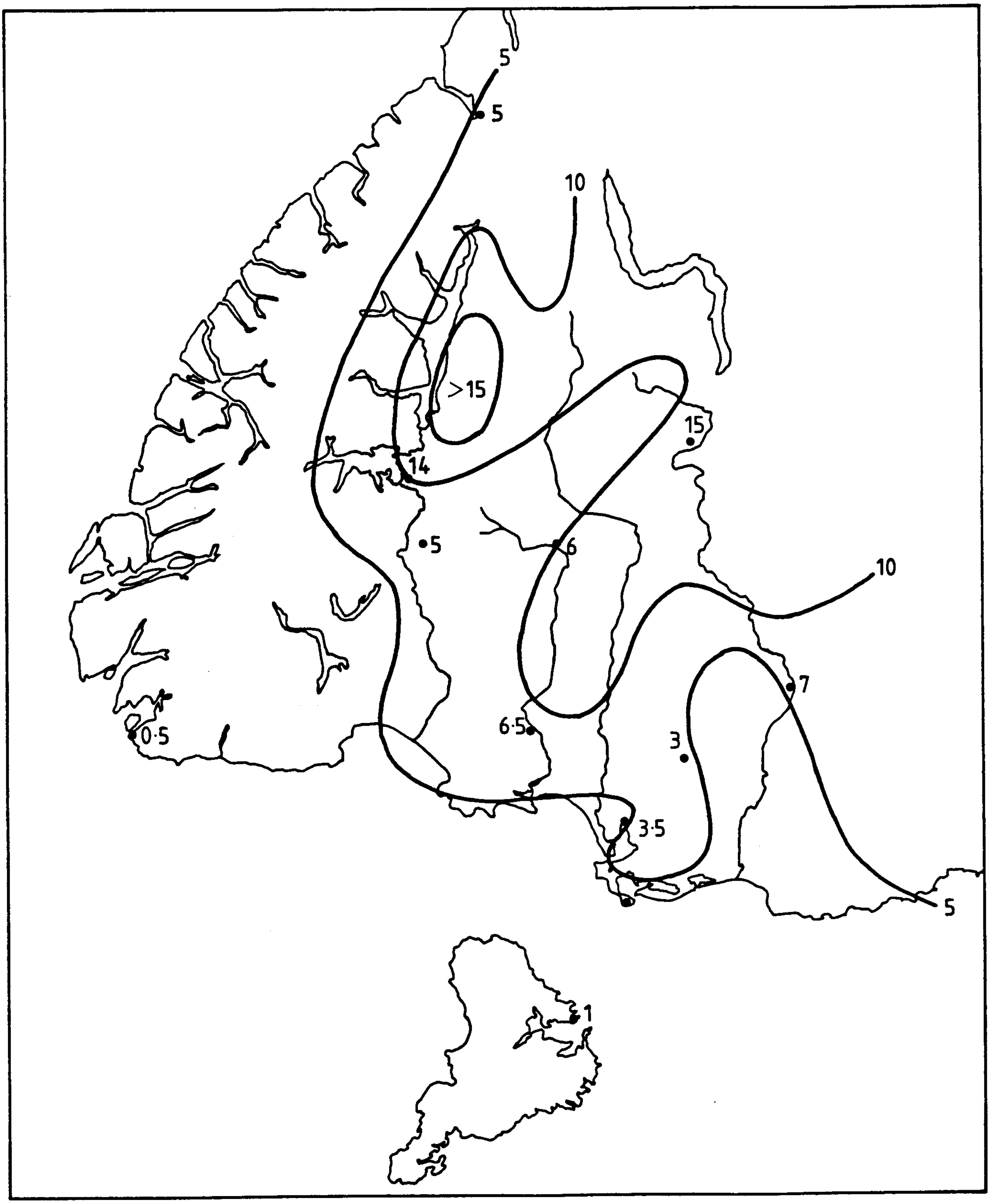


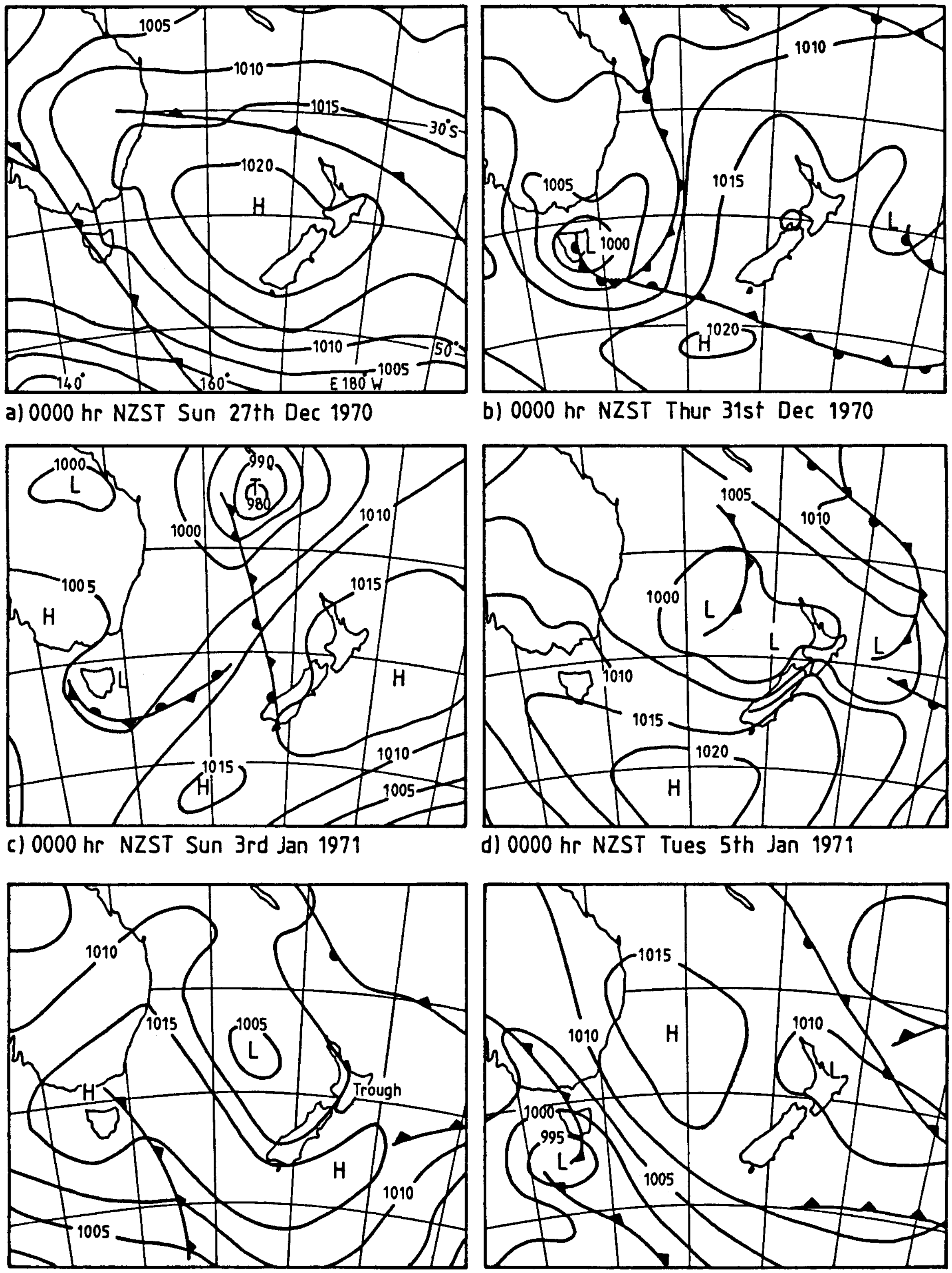
FIG. 16: Distribution of Dry Spells in the 1970's
(also longer term number of dry spells
per decade at selected places)

July 1932 and December 1980, whereas Oban which has only 25% as much rain per year had no very dry spells and only 5 dry spells between December 1914 and April 1975. Also plotted on Fig. 16 are the dry spells per decade for the stations of Table 17; the periods over which the dry spells were counted are as given in Table 7 and so do not correspond exactly with the contours of Fig. 16 where only data from the 1970's were used. For these same periods and stations, there appears to be a tendency for August and September to have more very dry spells and dry spells than other months of the year.

TABLE 17: Very Dry Spell and Dry Spell Statistics (Periods the same as Table 7)

Station	Number/ Decade	Mean and Max Length (days)		Start Date of Longest
VERY DRY				
Manapouri	11.0	17	29	26 May 1922
Monowai	1.5	20	26	25 Oct 1943
Milford Sound	3.5	16	20	15 Jun 1937
Puysegur Point	0.3	15	16	28 Aug 1976
Athol	7.0	17	28	5 Sep 1935
Dunrobin	2.0	19	23	28 Oct 1969
Otautau	2.3	18	21	5 Apr 1980
Gore	2.8	15	17	29 Jul 1957
Hokonui Forest	1.0	16	19	14 Jan 1948
Invercargill	0.5	16	18	20 Oct 1953
Oban	Nil very dry spells Dec 1914-Apr 1975			
DRY				
Manapouri	14.0	19	36	30 Apr 1929
Monowai	5.0	19	31	30 Jan 1971
Milford Sound	5.0	17	22	9 Jun 1978
Puysegur Point	0.5	15	16	23 Sep 1960
Athol	15.0	18	36	7 Aug 1937
Dunrobin	6.0	18	23	30 Jan 1971
Otautau	6.5	18	25	24 Apr 1954
Gore	7.0	17	23	15 Apr 1971
Hokonui Forest	3.0	18	23	6 Aug 1968
Invercargill	3.5	19	24	2 Apr 1980
Oban	1.0	16	17	25 Aug 1961

Very dry spells and dry spells are not normally widespread over the Southland region but Fig. 17 and Fig. 18 give example analyses from 2 periods when dry weather affected the whole area. From 26th December 1970 to 9th January 1971 no rain fell at Manapouri, Milford Sound, Gore and Hokonui Forest while at Puysegur Point, Otautau, Invercargill and Oban dry spell conditions prevailed. Also, in 1976 from 28th August until 11th September no rain fell at Manapouri, Milford Sound, Puysegur Point and Invercargill and at Monowai, Otautau and



a) 0000 hr NZST Sun 27th Dec 1970

b) 0000 hr NZST Thur 31st Dec 1970

c) 0000 hr NZST Sun 3rd Jan 1971

d) 0000 hr NZST Tues 5th Jan 1971

e) 0000 hr NZST Thur 7th Jan 1971

f) 0000 hr NZST Sat 9th Jan 1971

FIG. 17: Charts from the Dry Spell of 26/12/1970 to 9/1/1971

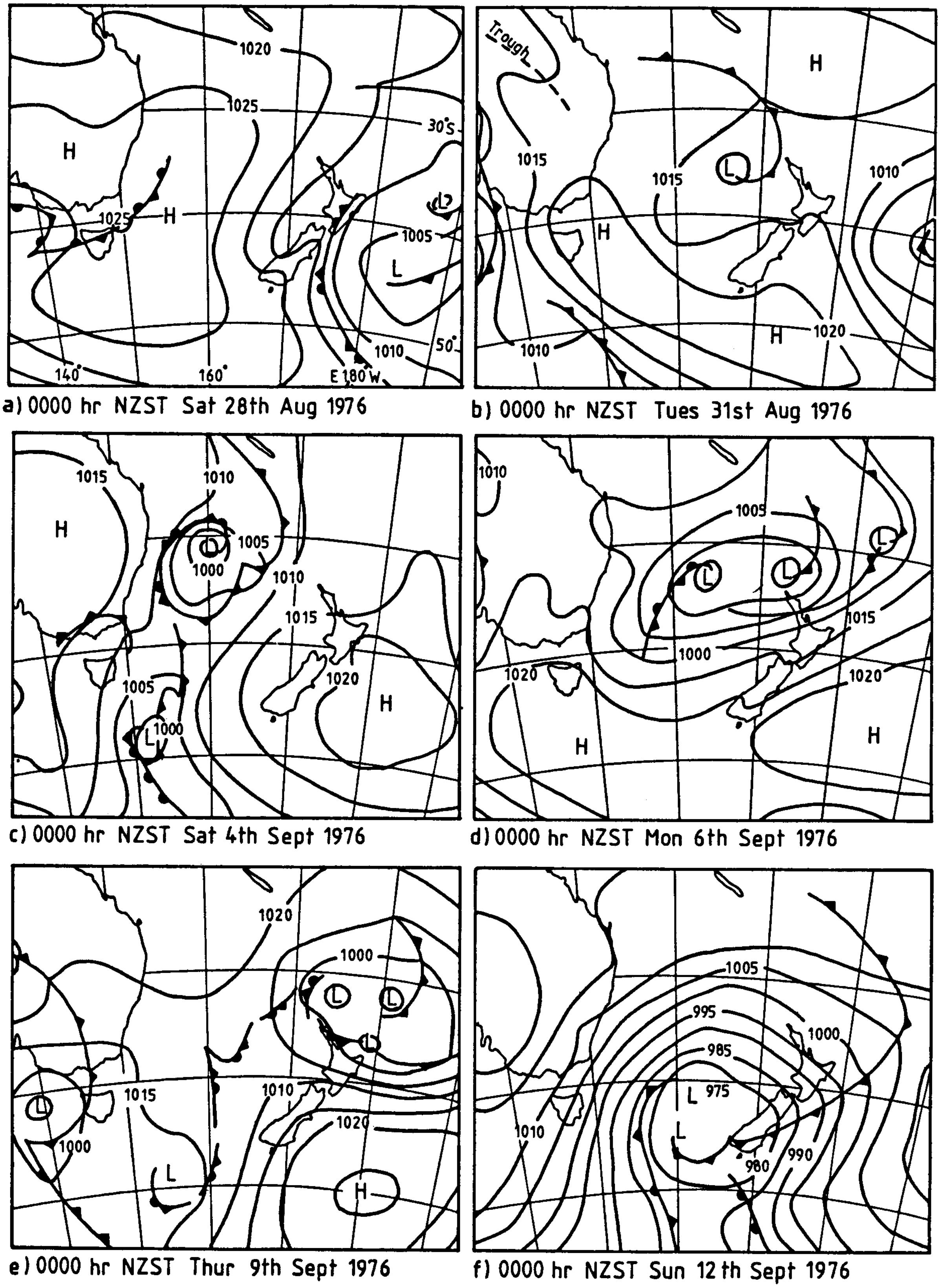


FIG. 18: Charts from the Dry Spell of 26/8/1976 to 11/9/1976

Hokonui Forest dry spell conditions prevailed. Both of these periods started after a wet south or southwest flow was displaced by a moving anticyclone which subsequently became almost stationary to the east or south of the South Island, while cyclonic development took place over the northern Tasman Sea. This low index pattern of low pressure in the north and high pressures in the south can be persistent, and in both cases here only moved when a major trough moved into the New Zealand area from the south of Australia. On other occasions when the dry conditions are less widespread a ridge may be persistent over Southland; also, for eastern areas, the western ranges provide a great deal of sheltering and dry spell conditions can persist in north or northwesterly airstreams.

4.5 Wet Periods

The maximum extremes of annual and monthly periods have already been discussed and so this section will examine periods of a few days or less. The majority of rain gauges are only read once a day, so only periods of over a day are normally dealt with, but at stations with automatic gauges shorter periods can be considered. These short period heavy falls have been summarised by Coulter and Hessell (1980) as Depth-Duration -Frequency Tables and extracts from their publication are given in Tables 18 and 19.

TABLE 18: Depth(mm)-Duration(hrs)-Frequency(/yr) Data at Selected Manual Gauge Stations

Return period		2yr	5yr	10yr	20yr	50yr
Milford	24hr	284	368	424	478	547
Sound	48hr	363	476	550	622	714
(1930-78)	72hr	406	521	598	672	767
Puysegur	24hr	83	110	128	145	167
Point	48hr	101	131	151	170	195
(1914-78)	72hr	114	146	167	188	214
Athol	24hr	50	63	72	80	91
(1925-68)	48hr	57	72	82	92	105
	72hr	62	77	87	97	109
Oban	24hr	53	70	81	92	106
(1914-75)	48hr	69	89	103	116	133
	72hr	83	105	121	135	154

TABLE 19: Depth(mm)-Duration(min or hrs)-Frequency(/yr) Data at Invercargill (i.e. a station with an Automatic Gauge)

Return Period	Durations 10min	20min	30min	1hr	2hr	6hr	12hr	24hr	48hr	72hr
2yr	5	6	8	11	15	26	33	41	51	61
5yr	6	9	11	15	20	32	40	50	63	75
10yr	7	10	13	18	23	35	45	57	71	84
20yr	8	12	15	21	27	39	50	63	79	93
50yr	10	14	18	24	31	44	56	71	89	104

Examples of the interpretation of these tables follow :

1. At Milford Sound a fall over 72hr of 767mm or more can be expected not more frequently than once every 50 years (Table 18).

2. At Invercargill a fall of 11mm or more in 1hr can be expected, on average, once in 2 years (Table 19).

Tomlinson (1980) has produced areal estimates for short period rainfall intensities (Fig. 19). Rainfall amounts for other durations and other return periods can be found by following the scheme outlined on Page 34.

The rainfall amounts so far discussed in this section are extreme values which may occur at any time of the year, whereas Table 20 gives the mean monthly and annual values of the maximum 1, 2 and 3-day rainfalls. Also the rainfall amounts shown in Table 20 refer to periods starting at 9 a.m. whereas the 24-hour periods of Fig. 19(d) refer to a period starting at any time during the day. If the monthly values of Table 20 are averaged to give their annual mean it is found that, to a good approximation, this is half the annual value. Also, to a good approximation, it is found that the 2-day amount at a station is 1.33 times the 1-day amount and the 3-day is 1.50 times the 1-day. The smallest maxima of Table 20 generally occur in July, August or September and this is more clearly seen in Table 21 where, for a number of Southland stations, the mean monthly maxima are related to their annual mean. From Table 21, it can be seen that over the Southland region July has the smallest maximum rainfalls which average 77% of the annual mean of the monthly maxima and that March has the largest which average 18% more than the mean.

For any place in the Southland area, an estimate of the mean annual maximum 1-day rainfall can be obtained from Fig. 19(d) since it is approximately 0.7 times the 24hr/5yr return period amount (as can be seen by comparing Table 20 to Table 18). Furthermore since (as stated above) the mean annual maximum 1-day rainfall is approximately twice the mean monthly amount,

TABLE 20: Mean Maximum 1, 2 and 3-day Rainfalls (mm)
(Periods the same as Table 7)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1-DAY													
Milford Snd	137	153	165	146	119	94	86	96	119	136	141	144	264
Puysegur Pt	44	42	45	43	34	34	27	33	35	39	40	39	76
Athol	27	24	27	23	19	20	16	17	17	21	24	21	46
Oban	27	26	28	27	24	24	20	19	25	26	28	25	49
2-DAY													
Milford Snd	193	197	219	198	172	135	122	140	173	192	190	193	360
Puysegur Pt	56	54	59	56	47	47	38	45	46	54	54	53	99
Athol	33	28	32	29	27	26	24	25	21	26	28	27	55
Oban	36	36	38	38	35	35	28	29	35	36	38	34	67
3-DAY													
Milford Snd	224	230	250	229	207	164	142	163	205	224	220	219	411
Puysegur Pt	66	63	68	67	59	57	47	54	54	63	63	62	114
Athol	36	31	36	33	32	31	28	28	24	28	31	29	61
Oban	44	42	46	47	43	44	35	35	41	43	48	40	83

TABLE 21: Areal Average of Mean Maximum 1, 2 and 3-day Rainfall
Related to Mean Monthly Maxima Averaged over the Year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
% Diff	12	7	18	10	-3	-9	-23	-16	-9	3	8	2
Factor	1.12	1.07	1.18	1.10	0.97	0.91	0.77	0.84	0.91	1.03	1.08	1.02

estimates can be made for any month by multiplying half the annual amount by the appropriate factor given in Table 21; that is, an estimate can be made for all places in the Southland region and not just for those places where rainfall has been measured on a daily basis. Also, the 2 and 3-day maximum rainfalls are 1.33 and 1.50 times the 1-day as previously stated. The estimates obtained in this way were found on average to be within 8% of the observed values. For example, if maximum falls are required at a locality where from Fig. 19(d) the 24hr/5yr return period amount is 75mm, say, then:-

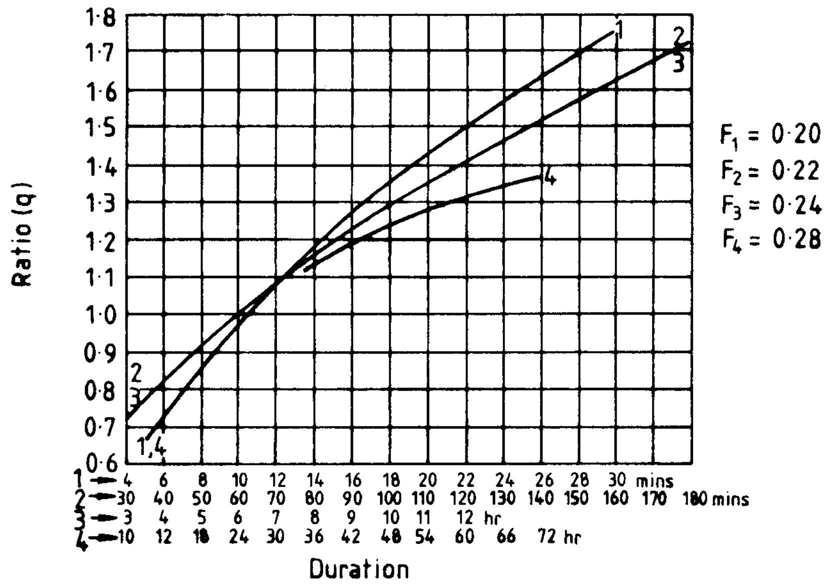
1. Mean annual maximum 1-day amount is 75 X 0.7 = 52.5mm.

2. Thus mean monthly maximum 1-day amount is 52.5/2 = 26.3mm.

3. For April, the maximum 1-day amount is 26.3 X 1.1 = 29mm.

4. Or the 2-day amount, for April, is 29 X 1.33 = 39mm etc.

1. Take the 5 year return period value P from Fig. 19.
2. The standard error of P is $S_P = 0.08 \times P$.
3. Take the rainfall duration ratio Q from the graph below.
4. The standard error of Q is $S_Q = F_i \times |Q - 1|$, i = 1, 2, 3 or 4.



5. Take the return period conversion ratio R1 from the table below.
6. The standard error of R1 is S_{R1} and is also tabulated below.

Return Period Conversion Table

Return Period (years)	Ratio to 5 year Value (R1)	(R2)	Standard Error (S_{R1})	(S_{R2})
1.1	0.425	0.478	0.099	0.073
1.5	0.614	0.650	0.067	0.049
2.0	0.726	0.751	0.048	0.035
2.3	0.777	0.798	0.039	0.028
3.0	0.855	0.869	0.025	0.018
4.0	0.939	0.944	0.011	0.008
5.0	1.000	1.000	0.000	0.000
10.0	1.182	1.165	0.031	0.023
15.0	1.284	1.258	0.049	0.036
20.0	1.356	1.323	0.062	0.045
25.0	1.411	1.373	0.071	0.052
30.0	1.456	1.414	0.079	0.058
40.0	1.527	1.478	0.091	0.067
50.0	1.582	1.528	0.101	0.073
60.0	1.626	1.568	0.108	0.079
70.0	1.664	1.602	0.115	0.084
80.0	1.696	1.632	0.120	0.088
90.0	1.725	1.658	0.125	0.092
100.0	1.751	1.681	0.130	0.095

7. The desired estimate is then given by $PP = P \times Q \times R1$
8. The standard error of PP is given by

$$S_{PP} = \sqrt{P^2 \times Q^2 \times S_{R1}^2 + P^2 \times R1^2 \times S_Q^2 + Q^2 \times R1^2 \times S_P^2}$$

NB: Use R1 for durations of 5 to 90minutes and R2 for more than 90minutes.

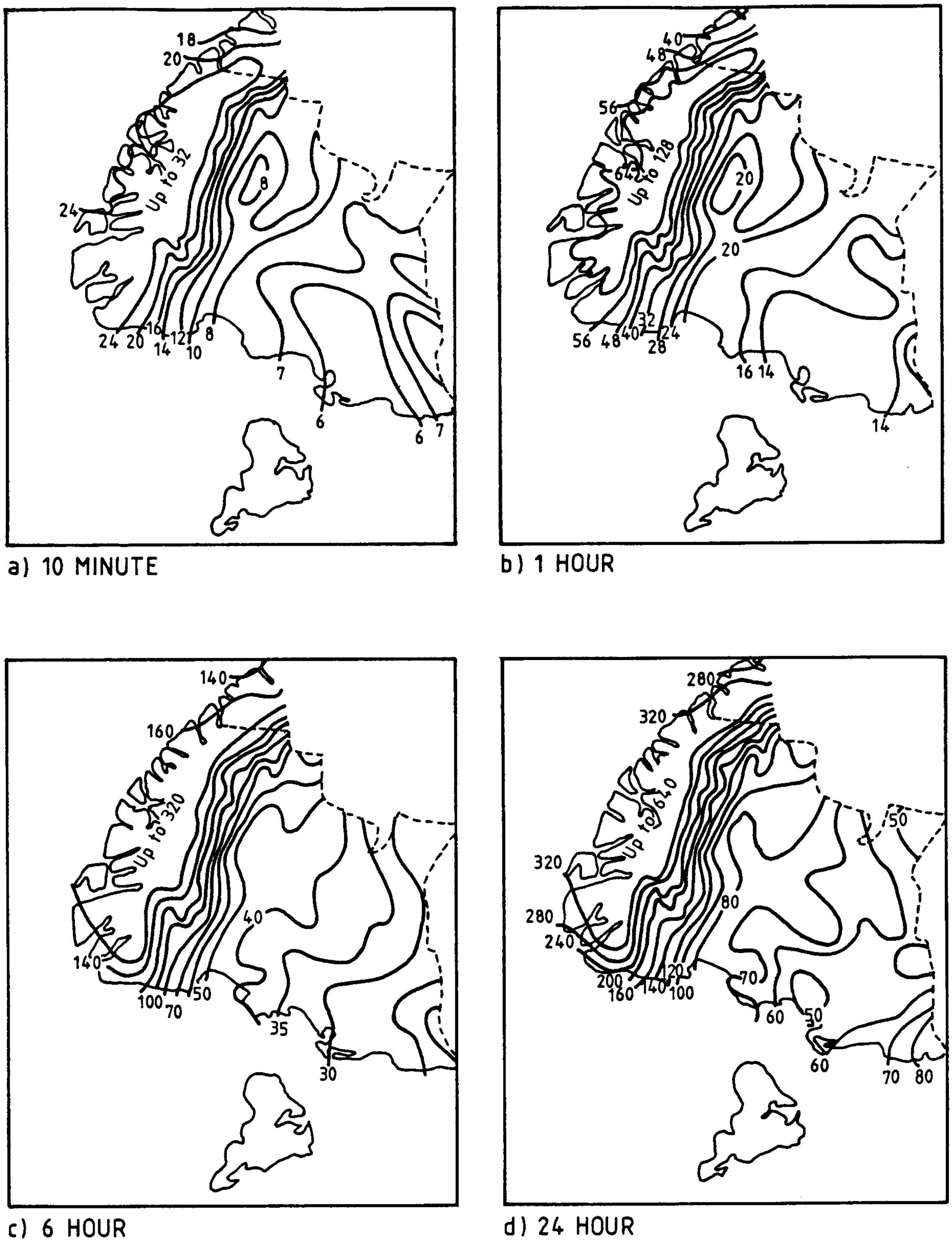


FIG. 19: Distribution of Short Period Heavy Rainfalls (with 5-year return period and isohyets in mm)

Of the heavy rainfall situations which have caused flooding, 3 have been examined :

December 12th to 14th 1948 (Edie,1950).
A succession of fronts and especially the warm front shown in Fig. 20(a) brought heavy rain to western areas. Then, further rain was brought by the moist northwesterlies between the almost stationary anticyclone near Northland and a depression which deepened as it approached Southland.

October 13th and 14th 1978 (Hessell and Lopdell,1979).
A quasi-stationary front over Southland was embedded in a deep northwesterly flow and produced steady moderate to heavy rain in many Southland areas.

January 16th and 17th 1980 (Hessell and Renwick,1980).
A trough moved eastwards across Southland and developed into a deep depression east of Otago with a strong southerly flow bringing steady moderate to heavy rain to many Southland places.

Table 22 gives the 2 or 3-day rainfalls for these periods at selected stations. The second value is the maximum ever recorded for that month or "M" if it is the maximum value. The last value is the average maximum 2 or 3-day rainfall for that month.

<u>TABLE 22:</u> Flood Rainfalls : Maximum Falls : Average Falls
(All falls in mm, see text for explanation of "M")

Station	Dec 1948(3-day)	Oct 1978(2-day)	Jan 1980(2-day)
Milford Snd	499 : M : 219	477 : 560: 192	182 : 544: 193
Puysegur Pt	54 : 116: 66	90 : 149: 66	52 : 143: 56
Manapouri	------	76 : 83: 38	36 : 91: 36
Monowai	100 : 103: 40	41 : 113: 36	66 : 86: 34
Dunrobin	------	94 : M : 36	74 : 123: 41
Otautau	------	63 : M : 29	84 : M : 34
Gore	25 : 73: 32	101 : M : 34	94 : M : 43
Hokonui Frst	37 : 86: 35	94 : M : 27	85 : M : 31
Invercargill	20 : 79: 32	67 : 68: 28	77 : M : 32

A report on the January 1984 floods is being prepared as this publication goes to press; on the 26th January 1984, 24-hour rainfalls in many places exceeded values which might be expected only once every 100 years and new maximum 1-day records were set.

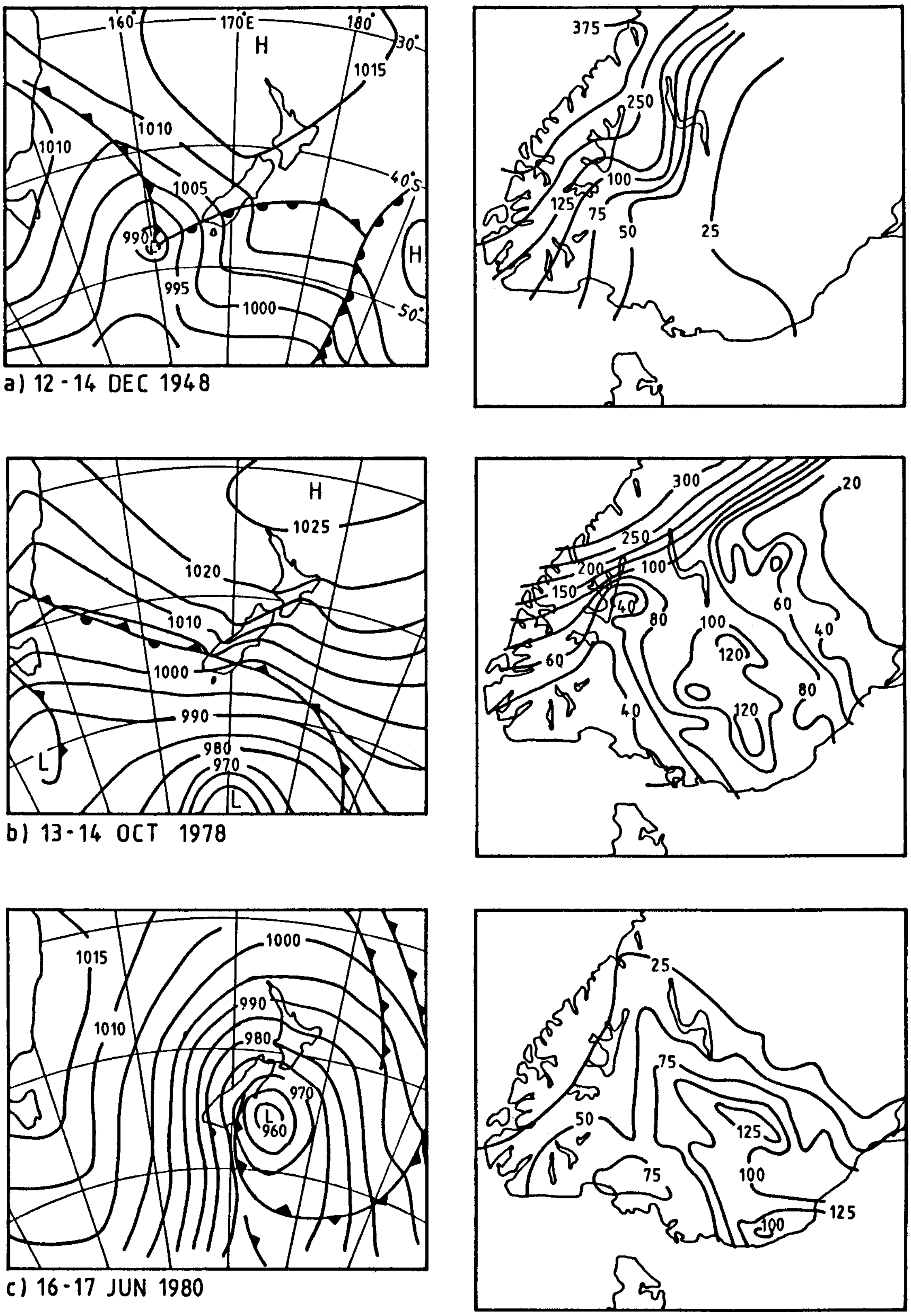


FIG. 20: Flood Situation Charts and Total Rainfall Amounts (mm)

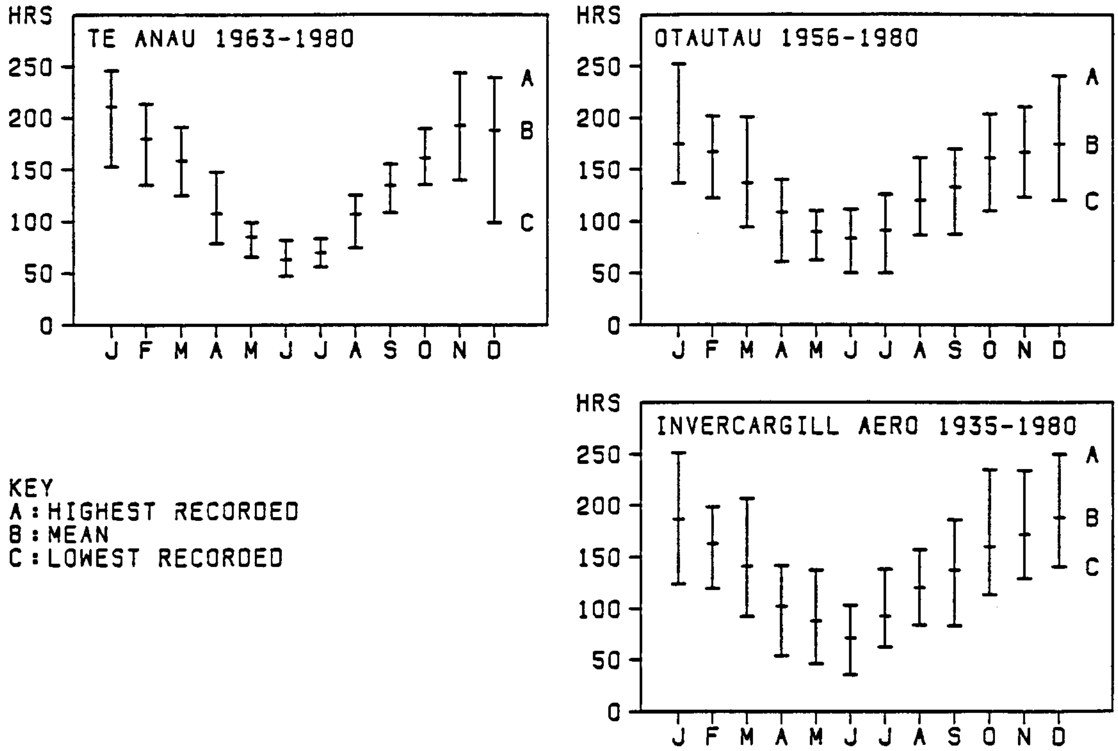


FIG. 21: Monthly Sunshine Statistics

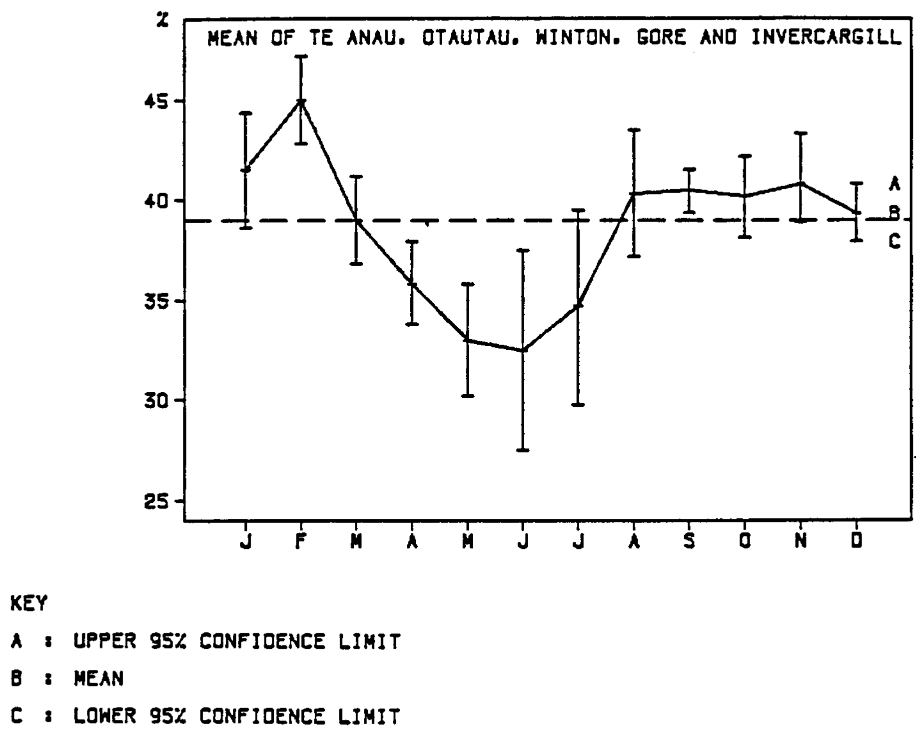


FIG. 22: Annual Cycle of Sunshine as Percentage of Possible

5. SUNSHINE AND TEMPERATURE

5.1 Sunshine

Sunshine hours have only been recorded in the east where the average sunshine is fairly uniform at between 1600 and 1700 hours per year. Although sunshine data are not available for western areas, further north the sunshine amounts east and west of the main ranges are not very different. Therefore, low level localities in Fiordland probably receive about 1600hours of sun a year and higher elevations 200 to 300 hours less. Those places where recorders are sited experience slightly less than 40% of the possible sunshine hours whereas most of New Zealand receives 45 to 50%. However, to the south of New Zealand there is much less sunshine (e.g. Campbell Island receives only 16% of the possible sunshine); so Southland lies

TABLE 23: Persistence of Sunshine (i.e. % of N-day periods with various average daily amounts of sunshine)

N-days	1	3	5	10	1	3	5	10
Amount	Otautau				Winton			
Nil	10.7	0.7	0.0	0.0	10.0	0.6	0.1	0.0
0.1 to 1hr	13.5	6.2	2.6	0.6	12.8	5.5	2.0	0.6
1.1 to 2hr	10.0	9.6	8.4	4.8	10.1	8.7	7.8	3.5
2.1 to 3hr	9.0	15.2	17.1	18.3	8.0	13.4	13.9	14.4
3.1 to 4hr	8.6	16.5	18.1	20.3	7.6	16.6	17.0	18.7
4.1 to 5hr	7.4	14.7	17.0	19.4	7.5	13.5	16.6	21.0
5.1 to 6hr	7.2	11.5	14.0	16.3	7.4	11.7	15.9	17.0
6.1 to 7hr	8.3	9.7	10.6	13.6	7.7	10.2	11.6	13.9
7.1 to 8hr	7.3	6.9	6.8	5.3	7.3	7.9	6.5	7.1
8.1 to 9hr	5.4	4.3	3.7	1.0	6.5	5.0	5.3	3.0
9.1 to 10hr	3.9	2.5	1.0	0.4	5.4	3.7	2.4	0.6
10.1 to 11hr	3.8	1.6	0.6	0.0	3.8	1.7	0.7	0.2
over 11hr	4.9	0.6	0.1	0.0	5.9	1.5	0.2	0.0
Amount	Gore				Invercargill			
Nil	10.5	0.4	0.0	0.0	10.7	0.6	0.0	0.0
0.1 to 1hr	13.7	6.4	2.7	0.9	14.0	7.8	3.6	0.9
1.1 to 2hr	8.7	8.9	7.6	4.5	10.7	11.8	11.2	8.6
2.1 to 3hr	8.7	14.2	15.8	15.5	9.3	14.6	16.3	18.5
3.1 to 4hr	8.1	15.6	17.5	18.8	8.6	15.1	16.6	17.7
4.1 to 5hr	8.0	14.2	16.1	20.7	8.1	14.0	16.9	18.6
5.1 to 6hr	7.3	11.8	14.4	17.0	6.1	12.0	13.8	17.6
6.1 to 7hr	7.4	9.7	11.1	11.6	7.6	8.6	9.6	10.2
7.1 to 8hr	6.0	6.6	6.2	6.6	7.0	6.5	5.8	4.8
8.1 to 9hr	6.6	5.5	4.5	2.9	5.6	4.2	3.5	2.2
9.1 to 10hr	5.0	3.4	2.7	1.3	4.5	2.1	1.8	0.7
10.1 to 11hr	3.9	1.8	1.0	0.2	3.1	1.8	0.8	0.2
over 11hr	6.1	1.5	0.4	0.0	4.7	0.9	0.1	0.0

on the border between the sunny latitudes north of 45 degrees south and the much cloudier latitudes to the south.

The monthly average and extreme sunshine hours at selected stations is shown in Fig. 21 while Fig. 22 shows an areal average of the percentage of possible sunshine.

The persistence of sunshine from day to day is shown in Table 23 which for periods of 1,3,5 and 10 days gives the percentage frequency of different sunshine amounts. For example, at Otautau 14% of all 5-day periods receive an average of 6 hours sunshine per day or at Winton only about 6% of all days receive over 11 hours of sunshine. From Table 23 it can be seen that there have never been 10 consecutive sunless days at the places shown and that there is little chance of even 3 sunless days. However, one day in 10 is sunless and there are no more than 2 hours of sun on one day in 3. If the 1600 hours of annual sunshine were evenly distributed over the year there would be about 4.4 hours per day; so the highest frequencies in Table 23 which are associated with 4 to 5 hours sun/day over 10 day periods are not unexpected.

5.2 Radiation

An Eppley Pyranometer at Invercargill is the only long-term instrument in the Southland area which measures radiation and Table 24 shows the long-term means derived from it. Table 24 also gives radiation estimates from sunshine normals using de Lisle's (1966) regression equation and data from instruments at Auckland and Wellington. The values from around the Southland area are all much the same and always lower than those from Auckland and Wellington with the winter months proportionally much lower than the rest of the year.

TABLE 24: Mean Solar Radiation (MegaJoules/Square Metre/Day)

	Invercargill Eppley	Invercargill Calcd	Otautau	Winton	Gore DSIR	Auckland Airport	Kelburn W'gton
Jan	21.1	20.2	20.6	20.5	21.2	24.5	23.5
Feb	18.3	17.6	18.0	18.2	17.3	21.5	20.0
Mar	12.8	12.7	13.2	13.2	13.1	16.5	14.9
Apr	7.9	8.1	9.0	8.8	8.5	12.1	10.3
May	4.9	5.3	5.8	5.8	5.6	8.7	6.5
Jun	3.8	3.8	4.2	4.2	3.9	6.9	5.2
Jul	4.5	4.7	5.0	5.1	4.9	8.0	5.5
Aug	7.4	7.4	8.0	7.8	7.7	10.2	8.1
Sep	11.7	11.1	11.5	11.6	11.1	14.0	12.7
Oct	16.3	15.5	16.0	16.3	15.8	17.7	17.7
Nov	20.2	19.0	19.0	19.1	18.9	22.1	21.3
Dec	22.2	21.0	20.6	21.2	20.5	24.6	23.0
Year	12.6	12.2	12.6	12.7	12.4	15.6	14.1

5.3 Air Temperature

Air temperatures are measured in a standard meteorological screen in which the thermometers are sheltered and positioned about 1.2m above the ground. At climate stations readings are taken at 9 a.m. of the actual temperature and the maximum and minimum temperatures during the previous 24 hours. The range of temperature is the maximum less the minimum, and the mean temperature is taken to be the average of the maximum and minimum. A key factor which determines the mean annual temperatures is, of course, the latitude of the area concerned; so that Southland, which all lies within a couple of degrees of latitude, will have similar mean temperatures throughout. However, elevation, proximity to the sea and the general exposure of the particular locality also affect temperature. These effects can be seen in the differences of the annual temperatures for the stations shown in Table 25.

TABLE 25: Annual Averages of the Daily Maximum, Minimum and Mean Temperatures also the Daily Range (all in $^{\circ}C$)

Station	Height	Maximum	Mean	Minimum	Range
Milford Sound	3m	14.3	10.3	6.2	8.1
Te Anau	215m	14.8	9.3	3.7	11.1
Borland Saddle	991m	9.0	5.4	1.8	7.2
East Gore	75m	15.3	10.2	4.9	10.4
Invercargill	0m	14.3	9.6	4.9	9.4
Auckland	8m	18.4	14.8	11.2	7.2
New Plymouth	27m	17.1	13.1	9.1	8.0
Napier	2m	18.8	14.1	9.4	9.4
Wellington	126m	15.6	12.5	9.4	6.2
Christchurch	30m	16.2	11.3	6.4	9.8
Hokitika	39m	15.4	11.3	7.2	8.2
Dunedin	1m	15.6	9.9	4.2	11.4

The coastal stations (Milford Sound and Invercargill) are similar except for Milford's higher minimum which is probably due to it being sheltered from cold southerly airstreams; while inland, East Gore and Te Anau have higher maxima and larger ranges of temperature. Temperatures generally decrease with elevation reducing by about 6$^{\circ}C$ for every 1000 metres as can be seen in the slightly lower temperatures at Te Anau compared to East Gore. Borland Saddle at nearly 1000 metres above sea level also shows the effect of elevation on temperature. Southland's temperatures are cooler than for other parts of New Zealand since it is the southernmost part (this can be seen in Table 25 which also shows annual temperatures for a selection of places outside Southland).

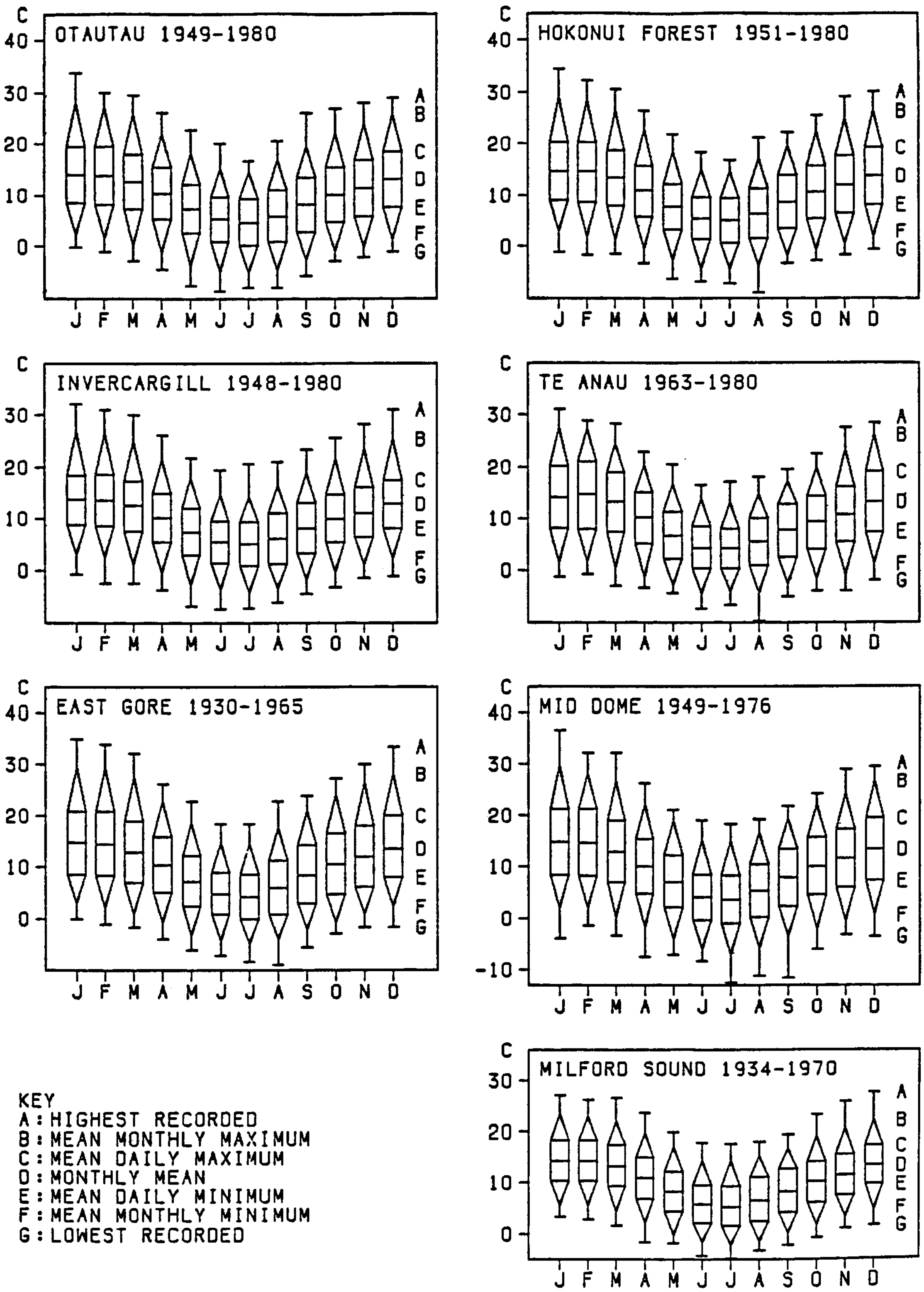


FIG. 23: Monthly Temperature Statistics

For selected stations over the Southland area, Fig. 23 shows the variation of temperature through the year. Milford Sound which has the smallest range of temperatures is probably representative of the west coast and, if allowance is made for the effect of elevation, of the western ranges as well. Mid Dome is the station with the largest range and is probably representative of elevated sites in the east. All the other stations which are at low levels in the east, are similar with mean summer maxima of about 20°C but extremes of 30 to 35°C and mean winter minima of about 0°C and extremes down to -5 to -10°C.

5.4 Frosts

Ground frosts are said to occur when the grass temperature (taken by a horizontally positioned thermometer 2.5cm above a closely cut grass surface) falls below -1.0°C. Air frosts occur when the temperature in the screen falls below 0°C. Since the overnight decrease in temperature at particular places is dependent on local characteristics (fall of ground, type of surface etc.), the distributuion of frosts and their intensities are generally very variable over small areas. However, from Table 26, it can be seen that apart from Milford Sound, little difference exists between the Southland stations.

TABLE 26: Monthly and Annual Mean Values of : (A) Grass Minimum (°C), (B) Days of Ground Frost, (C) Days of Air Frost

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Milford Sound 1961-70													
A	8.7	8.8	7.8	4.3	2.2	-0.2	0.0	0.9	2.6	4.0	4.9	7.3	4.3
B	0.1	-	-	1.6	4.9	14.4	14.9	10.9	5.6	2.2	1.5	-	56.1
C	-	-	-	0.1	1.8	7.4	10.6	5.9	0.9	0.1	-	-	26.8
Te Anau 1963-80													
A	5.9	5.4	4.9	2.5	-0.8	-2.5	-2.6	-2.4	-0.5	1.3	2.2	4.7	1.5
B	2.2	1.5	3.7	7.7	14.9	17.7	18.1	16.8	12.4	9.8	6.8	1.9	113.5
C	0.4	0.4	0.6	2.5	6.5	12.7	12.3	11.3	5.3	3.2	1.9	0.5	57.6
East Gore 1920-65													
A	6.1	5.7	4.4	2.3	-0.3	-1.7	-2.7	-2.0	-0.1	2.0	3.9	5.9	2.0
B	0.7	1.3	3.3	6.5	14.8	19.5	22.7	20.3	13.1	7.0	2.5	0.9	112.6
C	-	0.1	0.2	1.3	6.0	11.2	14.5	10.4	3.9	1.3	0.3	-	49.2
Invercargill Airport 1948-80													
A	6.3	5.8	4.8	3.0	0.3	-1.4	-2.3	-2.1	0.1	2.4	3.6	5.5	2.2
B	2.2	2.7	4.3	6.6	12.6	16.9	20.2	19.2	12.4	6.9	4.8	2.3	111.1
C	0.1	0.1	0.4	1.5	5.8	9.5	12.6	10.5	4.0	1.3	0.5	-	46.3

Table 27 gives a comparison with other New Zealand areas, Milford Sound and Hokitika South are similar but the other Southland stations are much frostier than elsewhere.

TABLE 27: Mean Days of Ground Frost per Year for Selected New Zealand Centres

Albert Park, Auckland	1909-70	4
New Plymouth	1922-70	7
Napier	1925-70	38
Kelburn, Wellington	1928-70	16
Hokitika South	1944-65	61
Christchurch	1905-70	89
Musselburgh, Dunedin	1947-70	79
Invercargill Airport	1948-80	111

5.5 Earth Temperatures

Earth temperatures are measured at 9 a.m. at climate stations at depths of 10 and 30cm, and also at 1m at a few stations. Table 28 gives the annual variation at these depths for two Southland stations. It can be seen that they are very similar and are probably representative for lowland areas of the east. Any variation would be due to different aspects at particular localities, the soil composition and drainage.

Except during the summer, the 10cm temperatures are less than the mean air temperature, but at 30cm the earth temperature is only less than that of the air during July, August and September; and at one metre the time lag is even greater with colder temperatures in the spring. The 30cm temperature is always higher than that at 10cm and higher than that at a metre during spring and summer. Except in early summer, the one metre temperature is higher than that at 10cm. The diurnal variation is very small at one metre, 1 or 2°C at 30cm and up to about 8°C at 10cm.

TABLE 28: Monthly and Annual Mean Earth Temperatures (°C) at : (A) 10cm, (B) 30cm, (C) 1m.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Winton 1965-80													
A	14.7	14.0	12.3	9.2	6.3	3.6	3.1	4.1	6.2	8.6	11.3	13.9	8.9
B	16.3	16.0	14.4	11.6	8.4	5.7	4.9	5.9	7.9	10.1	12.7	15.1	10.8
C	14.9	15.3	14.6	12.9	10.5	8.3	6.9	7.2	8.3	9.7	11.6	13.5	11.1
Invercargill Airport 1951-80													
A	14.1	13.6	12.1	9.5	6.7	4.6	3.5	4.3	6.5	9.0	11.1	13.3	9.0
B	15.2	15.1	13.9	11.6	8.8	6.4	5.1	5.8	7.8	10.1	12.2	14.2	10.5
C	13.9	14.3	14.0	12.7	10.7	8.7	7.2	6.9	7.9	9.5	11.2	12.7	10.8

6. OTHER ELEMENTS

TABLE 29: Mean Annual Number of Days of these Other Elements

Station	Period	Height	Thunder	Hail	Snow	Fog
Milford Sound	1935-80	3m	15.1	5.3	2.2	2.2
West Arm	1960-70	180m	6.9	1.6	8.9	34.6
Otautau	1949-80	55m	1.9	3.8	3.7	9.7
Winton	1965-80	44m	2.4	6.0	3.3	9.0
Gore	1943-71	72m	0.9	3.3	4.4	17.4
Hokonui Forest	1951-80	46m	3.8	5.4	4.4	7.0
Woodlands	1971-80	47m	7.0	16.7	2.5	11.5
Invercargill	1948-80	0m	8.9	27.3	5.0	50.0
Stewart Island	1975-80	3m	5.3	16.6	2.9	4.2
Auckland	1930-80	49m	10.5	4.6	0.1	9.8
New Plymouth	1944-80	27m	14.9	7.8	0.1	18.1
Napier	1930-80	2m	4.9	1.1	0.0	3.7
Wellington	1928-80	126m	4.6	10.0	1.2	10.6
Christchurch	1953-80	30m	2.2	5.4	2.4	49.9
Hokitika	1963-80	39m	19.6	11.2	0.6	17.4
Dunedin	1962-80	1m	6.9	11.2	7.2	64.0

6.1 Thunder and Hail

Thunder is most frequent in the west with, for instance, an average of 15 days a year at Milford Sound, but is only about half as frequent around the south coast. For hail, which like thunder is also associated with cumulonimbus clouds, these frequencies are reversed with the south coast having the most days and the west many fewer. In both cases, the frequencies in inland eastern places is less with, for example, only a day or so of thunder per year being reported at Gore while at Te Anau (not shown in Table 29) only one day of hail was recorded between 1963 and 1976.

The distribution of hail and thunder is fairly even through the year with possibly a slight minimum of hail from December to April and slight maxima of thunder in May and also November and December. Neale (1977) found that over the period 1924 to 1973, a severe hailstorm (i.e. one which either caused damage or had stones at least 0.5cm long) occured every 2 or 3 years. These storms were equally frequent about the coast and inland during October to March in the east, but, during the rest of the year and at any time in the west no such storms were reported.

6.2 Snow

At altitudes where temperatures are about or below the freezing point, $0\,^{o}C$, snow can lie without melting. Mean temperatures decrease by about 6 °C per 1000 metres of ascent; therefore, with winter sea level mean temperatures of about 6 °C, suitable conditions for extensive snowfields will only exist during the winter months at altitudes of at least 1000 metres. However, at lower levels snow is reported on about 3 to 5 days a year (see Table 29); it is rare at these levels before May and after November, and is most frequent in June and July. Heavy snowstorms are not common with only five seriously affecting Southland during the decade 1966-75 (Neale and Thompson, 1977).

6.3 Fog

The strong dependence of the frequency of fog on locality is shown well in Table 29. There have been other climate stations in Invercargill (all within 3km of each other), and over the period 1928-60 these reported on average only 2 or 3 days a year compared to the 50 days at the Airport (which is manned 24 hours a day and so many of the fog observations there will be from the night). Autumn and winter are the foggiest times of the year.

7. DERIVED CLIMATIC PARAMETERS

7.1 Soil Water Balance

Water held in the soil is depleted by evaporation and plant transpiration. It will be replaced by rainfall and, if the soil becomes saturated, the excess ("runoff") is assumed to be lost by surface or subsurface drainage or goes to replenish deep soil storage. The soil water balance may be calculated if the following assumptions (Coulter, 1973) are made :-

1. Soil moisture capacity is assumed to be constant (75mm is often used for medium soils but the capacity can be adjusted as appropriate).

2. Rainfall will be taken up by the soil until its capacity is reached, after which the excess becomes runoff.

3. Soil water is depleted at a steady rate by evapotranspiration until it is used up or replenished.

4. If the soil water is used up then the extra unmet demand (i.e. the deficit) is a measure of irrigation requirements.

It can be seen from Table 30 that there is very little water deficit in the soils of Southland and that runoff occurs the whole year round. However, the values of Table 30 are average values and in an individual month there may well be an actual deficit and no runoff.

TABLE 30: Mean Monthly and Annual Water Balance Data (mm) : (A) Average Runoff, (B) Average Deficit.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Milford Sound 1930-70													
A	511	490	531	508	495	378	330	386	467	528	541	470	5635
B	-	-	-	-	-	-	-	-	-	-	-	-	-
Mid Dome 1950-71													
A	13	8	15	43	51	89	69	36	23	25	20	15	407
B	8	5	3	-	-	-	-	-	-	-	-	3	19
East Gore 1907-65													
A	8	8	10	23	36	48	41	28	20	20	20	10	272
B	8	8	5	3	-	-	-	-	-	-	-	3	27
Hokonui Forest 1951-71													
A	8	5	20	48	63	76	46	30	30	28	28	20	402
B	3	3	-	-	-	-	-	-	-	-	-	-	6
Invercargill Airport 1940-70													
A	8	5	23	51	61	89	48	43	36	36	28	15	443
B	3	3	3	-	-	-	-	-	-	-	-	-	9

TABLE 31: Mean Monthly and Annual 9 a.m. Atmospheric Moisture : (A) Vapour Pressure (hPa), (B) Relative Humidity (%).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Milford Sound 1934-70													
A	13.1	13.1	12.2	10.0	8.7	7.3	7.0	7.4	8.5	9.6	10.7	12.3	10.0
B	83	87	89	89	88	88	87	87	87	85	81	81	86
Mid Dome 1949-71													
A	11.2	11.4	10.4	9.0	7.5	6.0	5.7	6.2	7.0	8.4	9.0	10.4	8.5
B	70	75	78	80	82	81	82	78	72	66	67	69	75
East Gore 1928-65													
A	12.2	12.1	11.1	9.5	7.8	6.8	6.4	6.8	8.0	9.3	10.3	11.8	9.3
B	76	79	83	85	86	87	86	84	79	76	73	73	81
Hokonui Forest 1951-71													
A	12.5	12.4	12.0	10.1	8.4	7.2	6.8	7.4	8.5	9.6	10.7	11.8	9.8
B	73	76	81	83	86	86	87	83	77	72	71	72	79
Invercargill Airport 1948-70													
A	12.5	12.4	11.8	10.0	8.2	7.4	6.9	7.3	8.7	9.7	10.4	11.5	9.7
B	78	80	85	87	89	89	89	87	84	77	74	75	83

7.2 Vapour Pressure and Relative Humidity

The amount of water held in the air can be presented in various ways. Vapour pressure is the part of the total atmospheric pressure resulting from the amount of water vapour present. Relative humidity relates the amount of water present to the amount necessary to saturate the air and, unlike the vapour pressure, is dependent on the temperature and will, therefore, have a large diurnal variation.

It can be seen from Table 31 that there is no great variation in either vapour pressure or relative humidity over the Southland area; Milford Sound is slightly moister than the others and Mid Dome slightly drier. Over the year the vapour pressure is lowest in winter, but because of the lower air temperature winter is the time of highest relative humidity.

7.3 Degree-Day Totals

The computation of degree-day totals above and below different temperatures has been discussed by Robertson and Coulter (1973). The number of "growing" or "cooling" degree-days over

TABLE 32: Mean Monthly and Annual Degree-Days
Growing Degree-Days with Bases: (A) 5 °C, (B) 10 °C.
Heating Degree-Days with Bases: (C) 10 °C, (D) 15 °C.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Milford Sound													
A	295	266	264	180	108	39	39	63	109	161	192	257	1973
B	141	127	112	50	11	1	1	2	9	30	52	106	641
C	1	1	3	20	61	130	137	101	51	24	10	4	543
D	39	34	61	122	205	279	291	254	192	149	109	65	1802
Mid Dome													
A	301	266	242	152	71	21	15	33	86	151	199	248	1785
B	150	129	96	37	7	-	-	1	7	33	66	102	627
C	4	3	9	37	106	177	201	146	76	39	18	9	826
D	47	42	81	152	254	327	356	301	219	163	108	77	2127
Gore													
A	313	274	260	169	84	35	26	57	116	181	219	276	2010
B	160	136	111	42	8	1	-	2	14	50	80	125	729
C	2	2	5	24	89	145	165	110	50	25	11	4	632
D	37	36	66	134	236	294	319	264	186	133	89	55	1849
Invercargill Airport													
A	270	238	229	150	75	35	24	48	98	153	186	236	1742
B	118	101	82	29	4	-	-	1	8	31	52	87	514
C	3	3	8	29	91	135	158	118	62	34	16	7	665
D	57	56	87	150	242	285	313	273	204	159	116	82	2025

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a particular period is the sum of the daily departures of the mean temperature above the chosen base, and days not reaching that base are not included. These totals are useful in assessing a region's suitability for a new crop; since different crops require different accumulated growing degree-day totals to reach maturity. They are also useful in assessing air-conditioning requirements. Alternatively, the number of "heating" degree-days is the sum of the daily departures below a particular base, and days exceeding the base are not included. These totals are useful in estimating energy requirements for heating. Table 32 shows the mean monthly and annual values of these for some places in Southland.

8. SUMMARY

Southland is both the most southerly and most westerly part of New Zealand and generally is the first to be influenced by weather systems moving onto the country from the west or south. It is well exposed to these systems, although western parts of Fiordland are sheltered from the south and the area east of the main ranges is partially sheltered from the north or northwest. The prevailing winds are westerly and moderate or stronger winds from other directions are rare. However, light winds occur more than half the time in most areas except about the south coast where strong winds are very frequent. Spring is the windiest time of the year and winter the least windy. Winter is also the driest time of the year whereas autumn is the wettest. There are two distinct rainfall regions; firstly, the western ranges with annual falls of over 8000mm in some parts are among the rainiest places on earth. Secondly, the drier eastern lowlands and hills form a complete contrast with annual falls of between 1200mm and 800mm. The interannual variability of the rainfall is smaller than in other New Zealand districts and dry spells of more than one or two weeks are not common. Temperatures are on average lower than over the rest of the country with more frosts and less sunshine.

The information given above is as comprehensive as possible for a publication of this size and it is hoped will prove useful to climate related industries and activities such as agriculture, tourism, fishing, building etc.

REFERENCES

Coulter, J.D., 1973. A Water Balance Assessment of New Zealand Rainfall. *J. Hydr. (N.Z.), 12: 83-91.*

Coulter, J.D. and J.W.D. Hessell, 1980. The Frequency of High Intensity Rainfalls in New Zealand, Part II. *N.Z. Met. S. Misc. Pub. 162.*

de Lisle, J.F., 1966. Mean Daily Insolation in New Zealand. *N.Z. J. of Sci., 9: 992-1005.*

Edie, E.G., 1950. Weather Situation, December 1948, Which Caused Flooding of Some Southland Rivers. *N.Z. Met. S. Circ. Note No.51.*

Hessell, J.W.D. and J.H.A. Lopdell, 1979. The Southland/Otago Floods of October 1978. *N.Z. Met. S. Tech. Inf. Circ. No. 171.*

Hessell, J.W.D. and J.A. Renwick, 1980. The Otago/Southland Floods of January 1980. *N.Z. Met. S. Tech. Inf. Circ. No. 178.*

Neale, A.A., 1977. A Climatology of Severe Hailstorms in New Zealand. *N.Z. Met. S. Tech. Note 230.*

Neale A.A. and G.H. Thompson, 1977. Meteorological Conditions Accompanying Heavy Snowfalls in Southern New Zealand. *N.Z. Met. S. Tech. Inf. Circ. No. 155.*

New Zealand Planning Tribunal, 1980. *Planning and the Regions.* N.Z. Local Govt. Commission.

Reid, S.J., 1980. Frequencies of Low Level Free Atmospheric Wind Flows in Northern and Southern New Zealand. *N.Z. Met. S. Tech. Note 240.*

Robertson, N.G. and J.D. Coulter, 1973. The Calculation of Degree-day Totals Above or Below any Base. *N.Z. Met. S. Tech. Note 224.*

Tomlinson, A.I., 1980. The Frequency of High Intensity Rainfalls in New Zealand, Part I. *National Water and Soil Conservation Organisation Tech. Note No. 19.*