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CIRCULAR  
208**

**Rainfall distribution over  
Southland and Otago in a  
south-southwest airflow —  
a case study**

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**New Zealand Meteorological Service**

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**Technical Information Circular 208**

**UDC 551.577.3 (931.3)**

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**New Zealand Meteorological Service  
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Wellington**

# RAINFALL DISTRIBUTION OVER SOUTHLAND AND OTAGO IN A SOUTH-SOUTHWEST AIRFLOW - A CASE STUDY

A. Fraser

## 1 INTRODUCTION

A study of radar echo patterns over Southland in westerly and southwesterly airflows has already been completed (Horridge and Revell 1983). In the case of southwest airflows, two distinct areas of echo maxima were found, near the lee of Stewart Island and near the Hokonui hills (45 km NE of Invercargill). It was considered, that in southwest airflows the topography of Stewart Island did have an influence on the distribution of showers, but did not form a complete barrier.

However, personal observations over the years seemed to show that if the flow was from the south-southwest, then only infrequent and very light showers would occur in and around Invercargill, whereas large and active showers could be seen passing to the west and to the east.

A south-southwest airflow occurred on 15 and 16 June 1987, which provided the opportunity to examine more closely the distribution of rainfall in this type of airflow. By 0900 hours (local time) on the 15th, the flow was south-southwest through a fairly deep layer and apart from minor fluctuations, stayed in this direction until 0900 hours on the 16th. I was thus able to plot the 24 hours values of rainfall from the raingauge network over the area to see the effect of the south-southwest flow. Most frequently, an airflow of this nature does not fall so neatly into a convenient time frame without the winds backing further to the southeast or veering back towards the west, preventing an analysis of this type.

## 2 SITUATION

Figure 1 shows the synoptic situation at 1800 hours on 15 June 1987. During the night of 14-15 June, a front passed across the south of the South Island, and a trough sharpened in the area between the South Island and the Chatham Islands. By 0600 hours on the 15th, a south-southwest airflow was becoming established over the south of the South Island, and this flow extended up to 500 mb by 1200 hours. The passage of a minor trough at the 700-500 mb level occurred that afternoon, and the southerly jet stream on the western side of the main trough was over Invercargill at 0000 hours on the 16th.

Widespread shower activity followed the front. The radiosonde flight at 1200 hours on the 15th showed the 500 mb height to be 5307 m, with the temperature at that level  $-36^{\circ}\text{C}$ . The freezing level was 840 m at this time, decreasing to 700 m, 12 hours later.

During the period under examination, Invercargill recorded only a few light showers on the afternoon of the 15th, with a total 24 hour rainfall of a trace. Average cloudiness for the 24 hour period was 3.4 octars. For most of the 24 hour period, extensive shower activity could be seen passing to the west and more distantly to the east.

With the low freezing levels, many inland areas above 400 m recorded snowfalls.

The weak front bringing surface winds to the west at 1200 hours on the 16th, also brought showers to Invercargill. The front is analysed to the southwest of Tasmania.

### 3 THE PATTERN OF RAINFALL

Figures 2a, 2b and 2c show the pattern of rainfall over Otago and Southland in the 24 hours up till 0900 hours on the 16th. The isohyets are drawn at 2 mm intervals. The long zone of low rainfall, less than 1 mm, and extending some 100 km north-northeast of Stewart Island, is the most prominent feature. The rapid increase in rainfall to the west of the zone is demonstrated by Hedgehope recording 0.2 mm, Forest Hill lying 9 km westnorthwest recording 6.3 mm, and Winton, a further 8 km to the northwest, recording 11.7 mm. Moving east of the zone, the increase is shown with Invercargill recording a trace, Gorge Road 30 km to the east recording 3.6 mm, and then to Quarry Hills a further 25 km east, recording 19.8 mm.

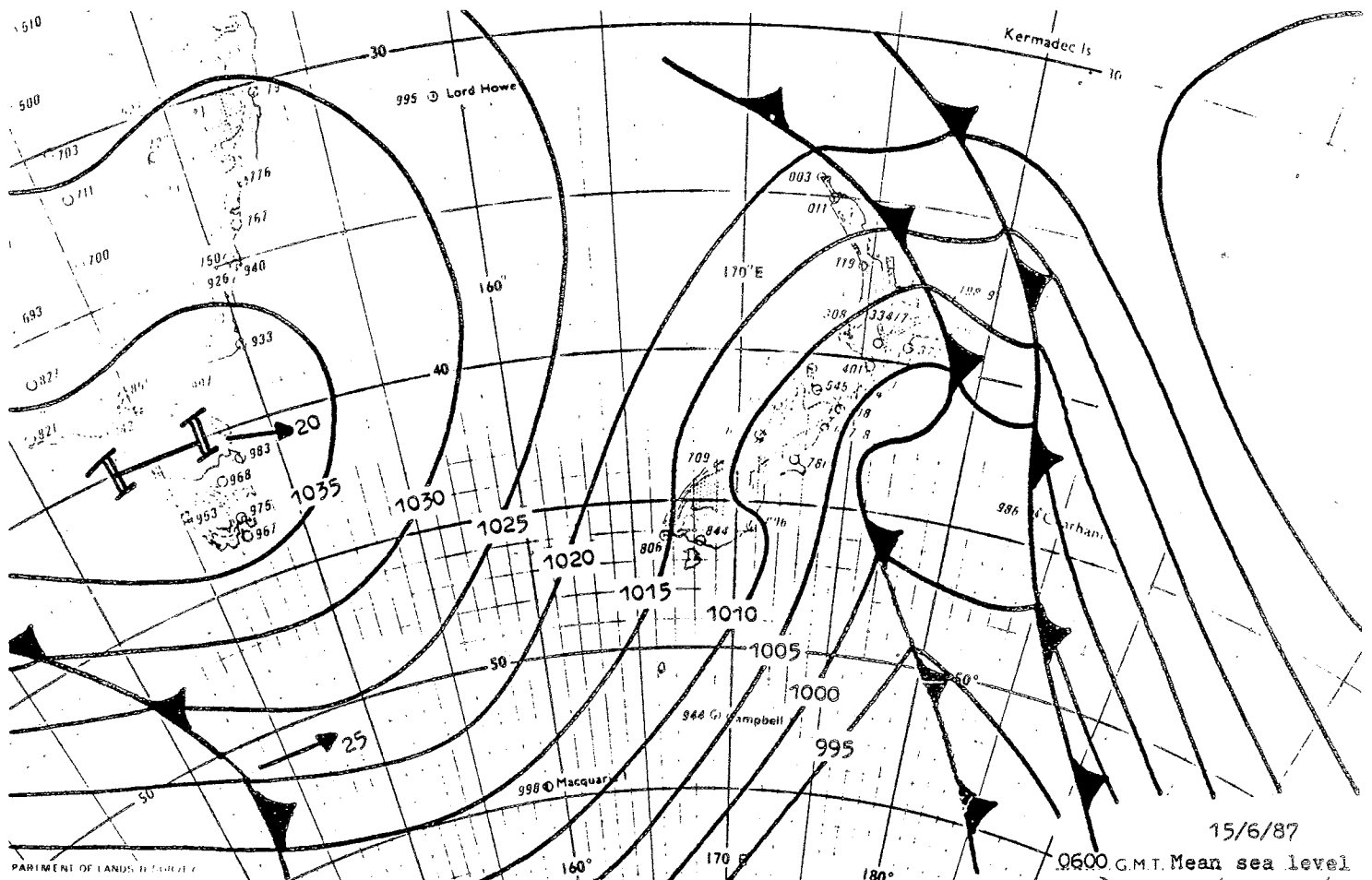


Figure 1. Synoptic map at 1800 hours 15.6.87

Figure 2a. 24 hours Isohyets from 0900 hours 15.6.87 - 0900 hours 16.6.87 (Isohyets at 2 mm intervals)

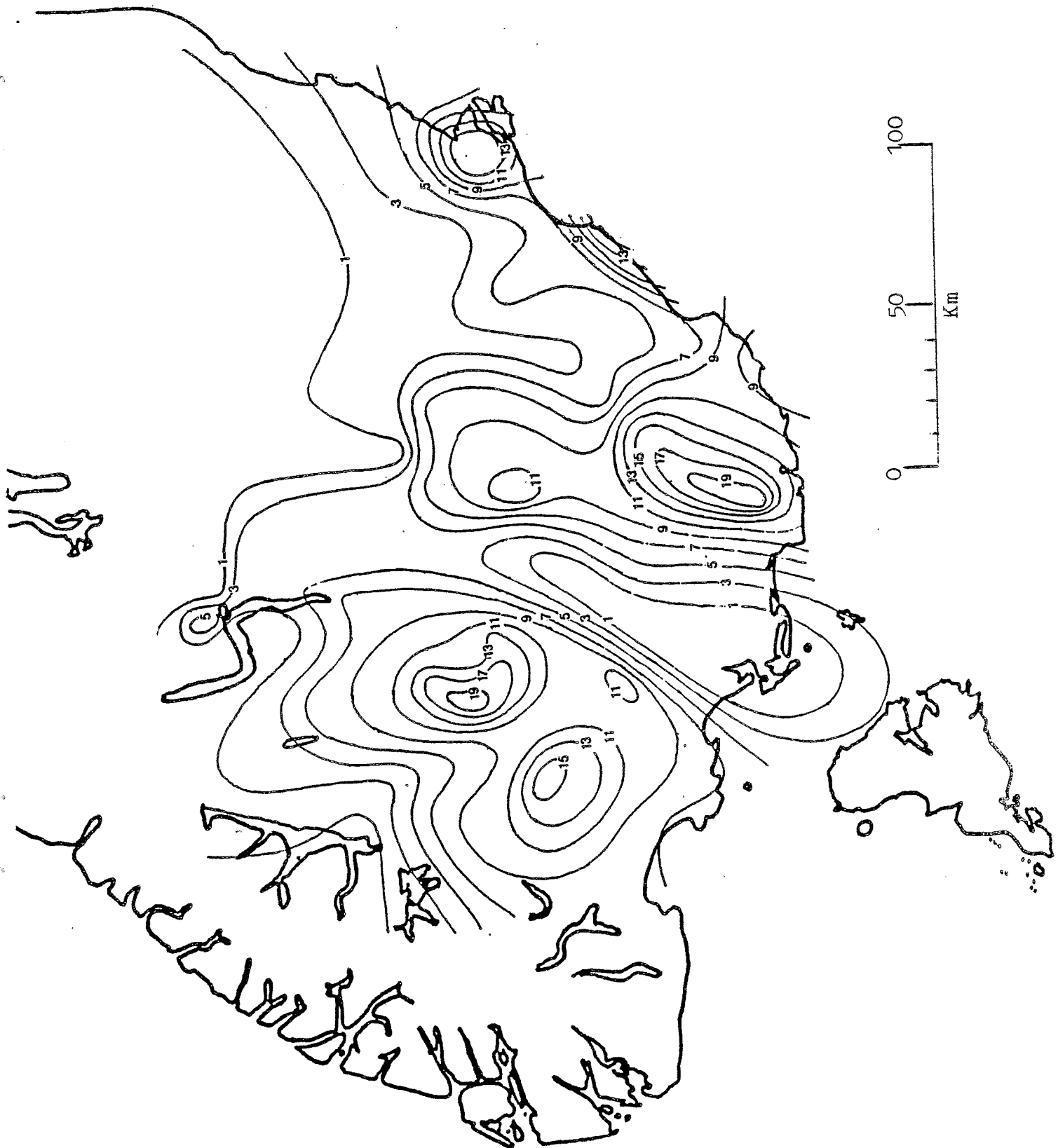


Figure 2b. Isohyet map with terrain above 300 m and location of place names mentioned in text.

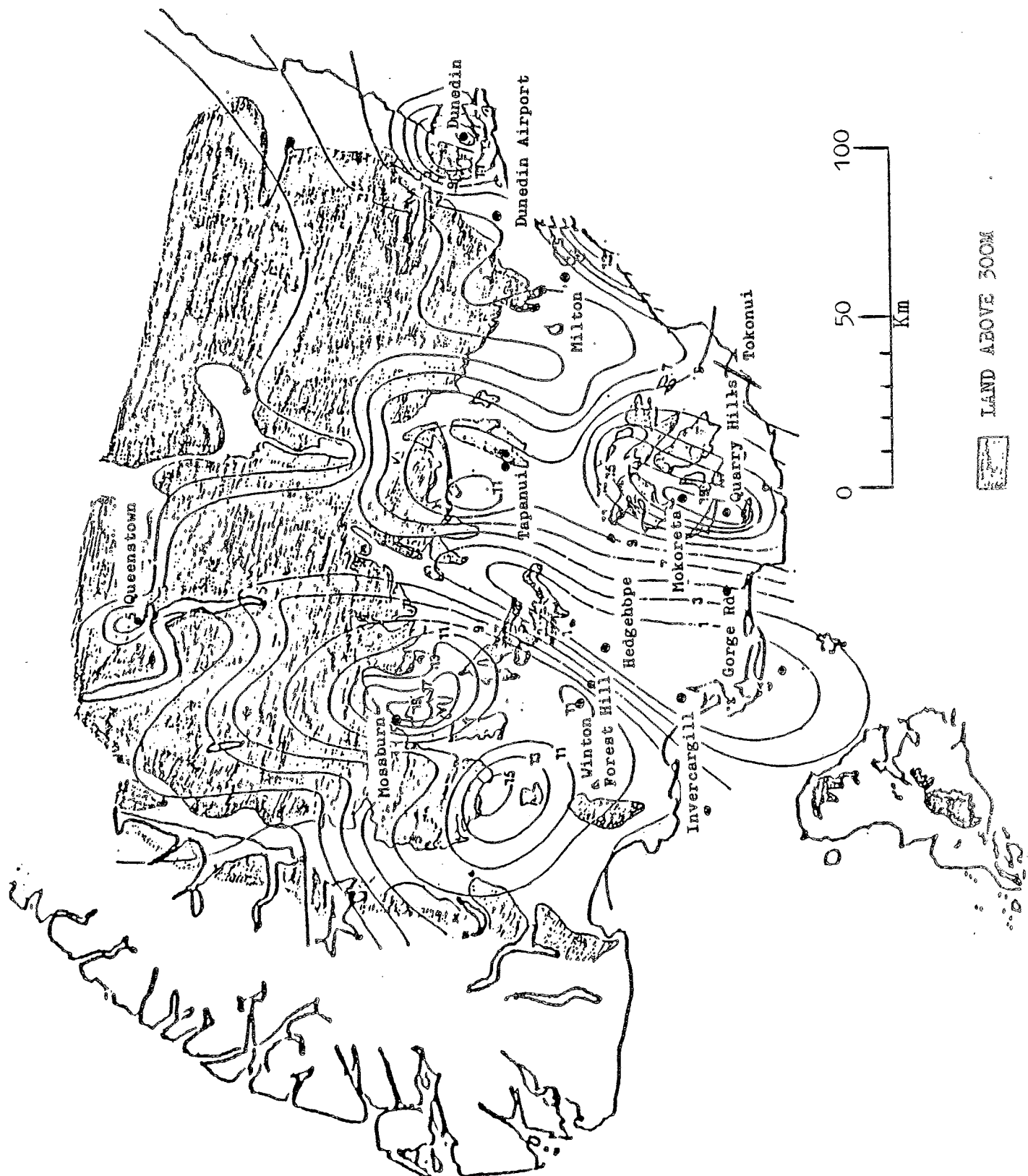
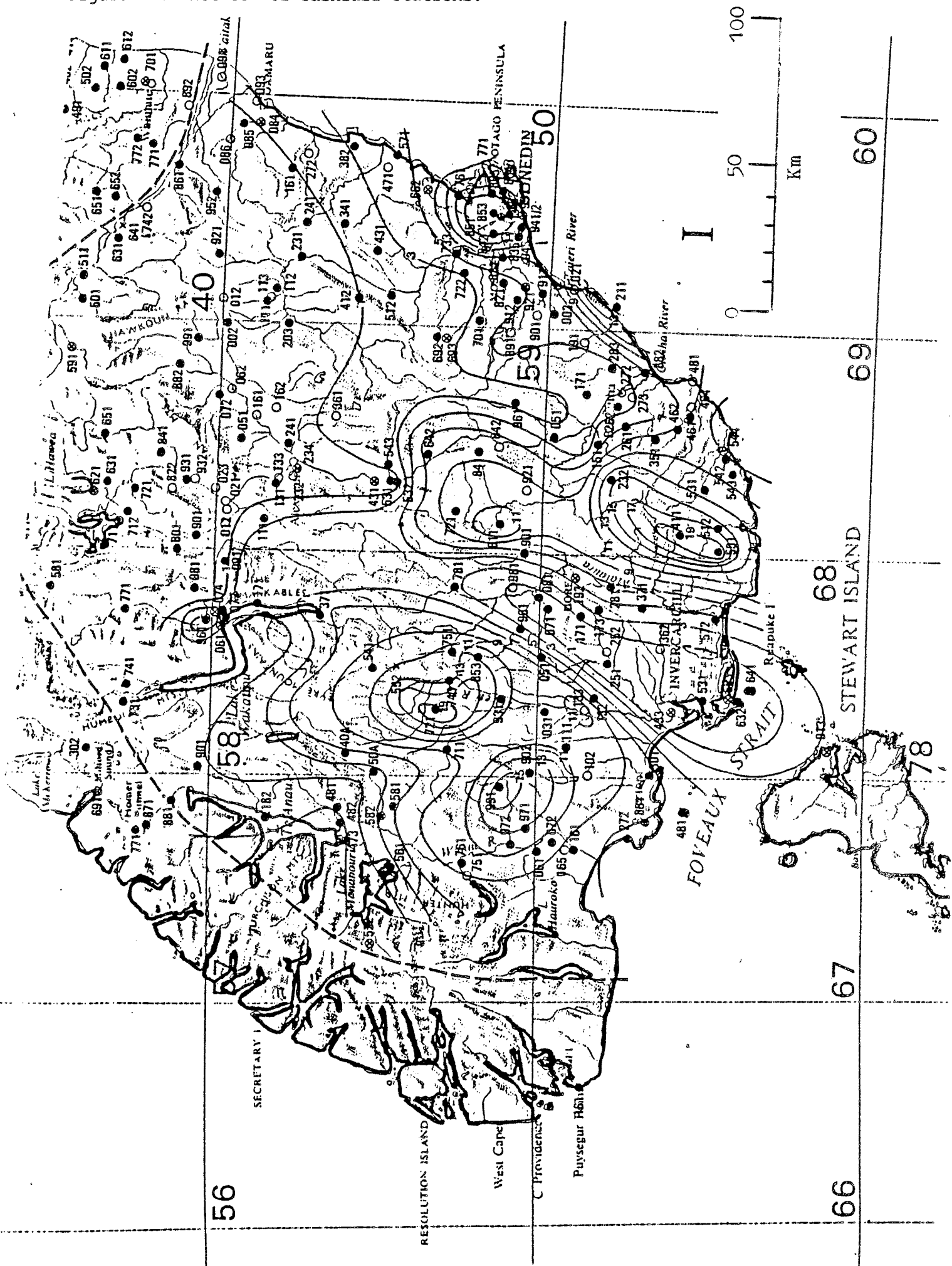


Figure 2c. Network of rainfall stations.



Over Western Southland there are two maxima. The southern one lies on the southern end of the Takitimu Mountains, which rise to above 1500 m. The northern maximum lies just to the south of West Dome, a peak rising to above 1200 m some 15 km to the north of Mossburn, with the more substantial Eyre Mountains a little further to the north and northeast, rising to 1800 m.

Over Eastern Southland there are also two maxima. The southerly one, and most pronounced, lies over the Tokonui-Mokoreta area. The peaks of the hills in this area rise up to 700 m, although the majority are 400-600 m. The other maximum occurs near Tapanui. The Blue Mountains lie just east of Tapanui and rise to 900 m, and to the north, the land gradually rises towards the ranges of Central Otago with elevations greater than 1500 m.

Another small maximum occurs around Queenstown, where the general trend of topography to the south allows the passage of showers in a south-southwest flow.

Another small, but marked maximum, occurs on the coast just east of Milton. The terrain between Milton and the coast rises to about 400 m and the coast at this point bends outward a little, which would increase its exposure to south-southwest airflows. The same applies to the Dunedin City and Otago Peninsula area, which also has a marked maximum, although the terrain in this area is much higher with several peaks exceeding 600 m.

#### 4 UPPER AIR DATA

Figure 3 summarises the six hourly upper air wind soundings made at Invercargill, during the period from 0600 hours on the 15th until 1200 hours on the 16th.

The upper winds at 0600 hours on the 15th had already swung markedly to the south-southwest below 7,000 feet, and the winds up to 500 mb had followed suit by 1200 hours. The passage of an upper trough at the 700-500 mb level is marked at 1800 hours by a veering of the winds to the west at these levels, although the winds below remained south-southwest. The sounding at 0000 hours on the 16th shows the passage of the major upper trough, with the winds above 500 mb becoming straight southerly and increasing to over 100 kn. Little change occurred on the next flight six hours later, although the lower winds were decreasing, as a weak ridge approached the area. By 1200 hours on the 16th, the lower winds from the surface to 5,000 feet, had veered to the west, and upper level speed maximum had moved away.

Figure 4 examines the orientation of the zone of low rainfall, and Figure 5 more closely analyses aspects of the upper air field. From this, it appears that the movement of showers over the area is most closely defined by the mean of wind direction between the surface and 700 mb. If the gradual narrowing of the area with low rainfall to the north, represents the small variation in direction of the airflow in the 24 hour period, then this also confirms the steering field of the showers to be the surface to 700 mb mean direction.



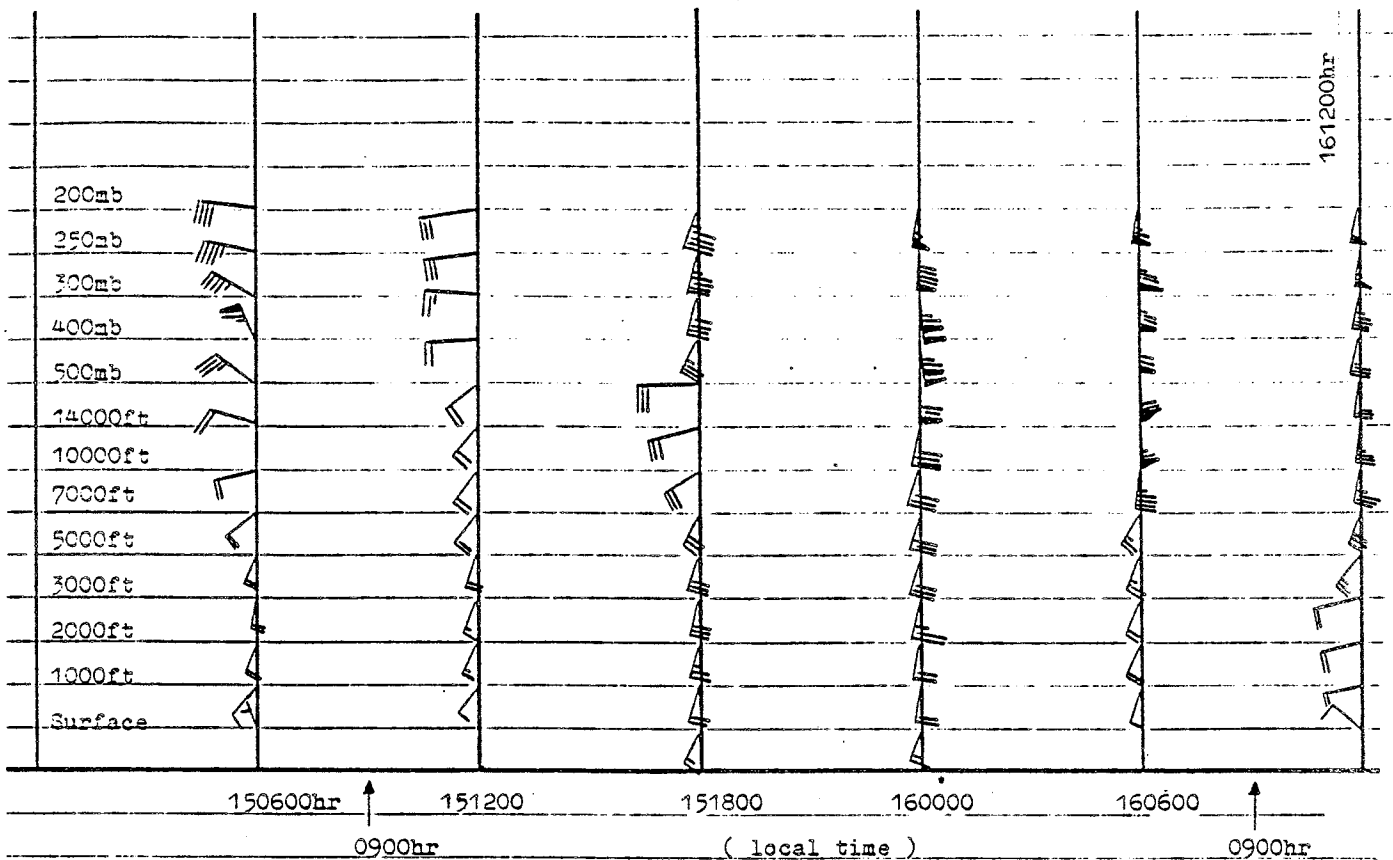


Figure 3. Upper wind summary at Invercargill

## 5 WEATHER RADAR REPORTS

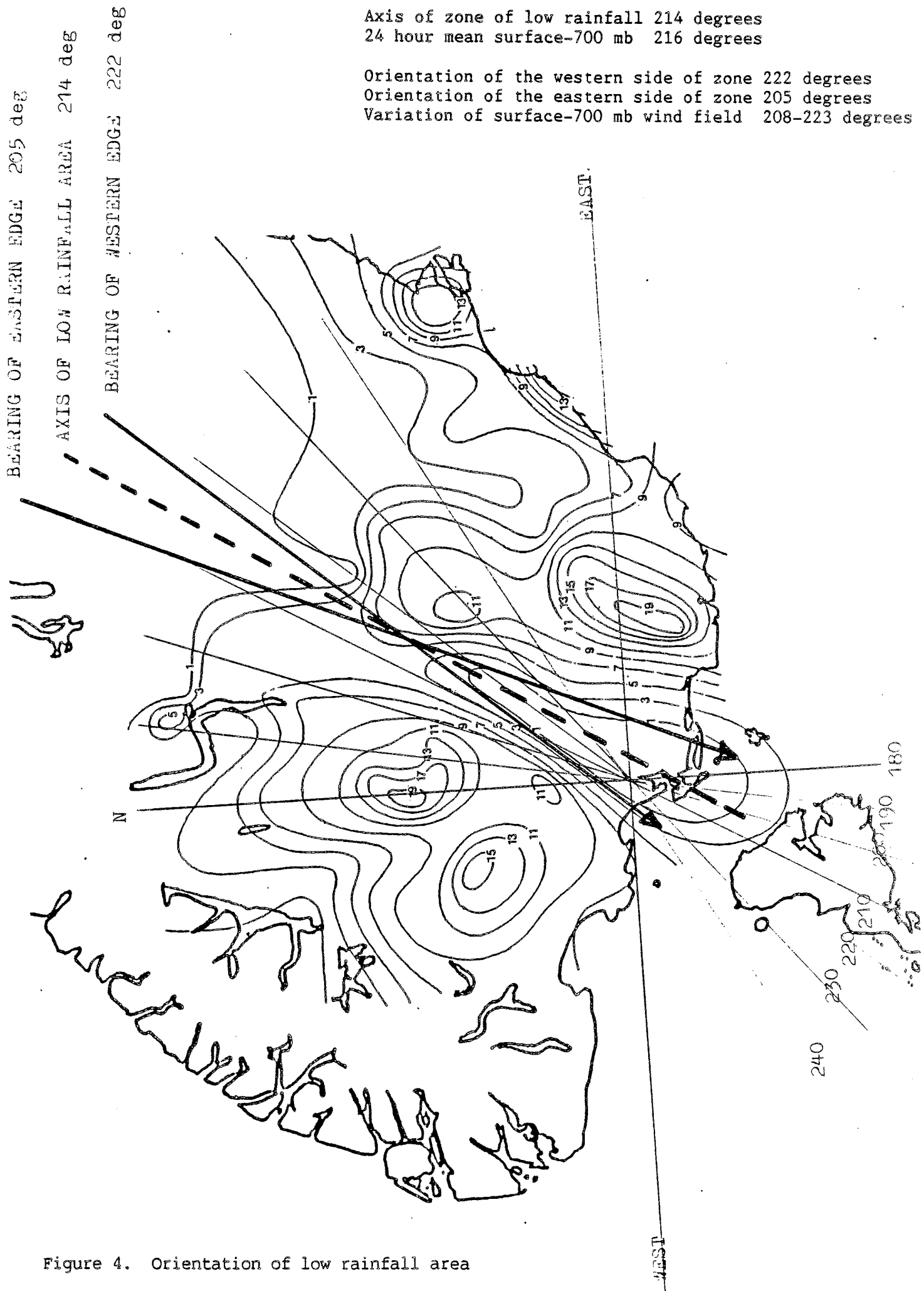
Invercargill does regular radar weather surveillance sweeps. Copies of those completed during the period under study appear as Figures 6a-e. The approximate boundary of the area with less than 1 mm of rainfall has been marked on each.

Figure 6a shows the 0630 hours rarep and the 1030 hours rarep. At 0630 hours, broken rain areas lie inland of Invercargill, showing the trailing edge of the middle cloud layers associated with the front. Scattered cells dot the area to the south of the coast. By 1030 hours, the shower activity has increased and spread inland. The zone of low rainfall is nearly shower free, apart for one cell in the westernmost part of the zone.

Figure 6b shows the rareps at 1430 hours and 1630 hours. Both show showers within the low rainfall area, and it was during this time that Invercargill experienced the only showers to fall in the 24 hour period. My own observation of the showers during this time, showed that they originated from cumulonimbus clouds, which were in a state of decay as they approached and passed to the northeast. I feel the extent of the radar returns drawn at this time may have been exaggerated by confusing the rain returns with the permanent ground clutter, which makes accurate definition (especially within 25 km of the station) rather difficult. The same problem occurs with the rising terrain further away from the station, for example the Hokonui Hills lie to the west of Gore, and it is quite likely this permanent echo is responsible for the 'shower' extending across the zone of low rainfall in the 1630 hours rarep.

Axis of zone of low rainfall 214 degrees  
24 hour mean surface-700 mb 216 degrees

Orientation of the western side of zone 222 degrees  
Orientation of the eastern side of zone 205 degrees  
Variation of surface-700 mb wind field 208-223 degrees



	Time (local)	a	b	c	d
a surface to radar echo tops	150900	230	239	223	251
b 700mb level	151200	218	220	218	237
c surface to 700mb level	151800	231	232	213	224
d surface to 300mb level	160000	204	207	208	192
	160600	216	190	213	197
	160900	222	192	218	208
	24 hour mean	220	213	216	218

Upper winds 0900hr 15/6/87 to 0900hr 16/6/87  
(0900hr winds based on mean of 0600 and 1200hr flights)

Figure 5. Mean wind direction from surface to radar echo tops

Figure 6c shows the 1930 hours and 2230 hours rareps. In both, showers are widespread over the seas to the south and also are spreading well inland. However, the zone of low rainfall is, shower free.

Figure 6d, the 0030 hours and 0430 hours rareps on the 16th show much the same story, with only the 0030 hours rarep showing cells with the zone of low rainfall, this time passing through the southernmost point of the zone. At 0430 hours, there is a noticeable decrease in shower activity as the weak ridge moves towards the area.

Figure 6e shows the 0630 hours rarep on the 16th, with the showers having become confined to the western and eastern parts of Foveaux Strait. Also shown, is a map marking the extent of the permanent radar returns affecting the Invercargill radar.

It is acknowledged, that even the more experienced staff have difficulty in accurately locating showers around the permanent returns on the radar. The main problem is that if a shower is found lying next to and merging with a permanent echo, then it is all too easy to exaggerate the size of the shower by including part of the permanent echo. This may account for some of the larger returns drawn on most of the rareps in the area 80-100 km north-west of Invercargill, as this is where the Takitimu Mountains and foothills leave quite sizeable permanent returns.

It is interesting that the 1430 hours and 1630 hours rareps on the 15th show shower tops of 19-20,000 feet, a marked jump from the tops reported before and after this time. This increase in tops is probably associated with the passage of the minor upper trough as discussed in the summary of upper winds. This maximum in shower activity coincides with the time Invercargill recorded light showers, and was followed by a slight freshening in the surface winds, and an increase in the rate of rise of pressure. Invercargill's hourly Metar reports for the 15th and 16th of June are shown in Figure 7.

Figure 6a. Rareps.

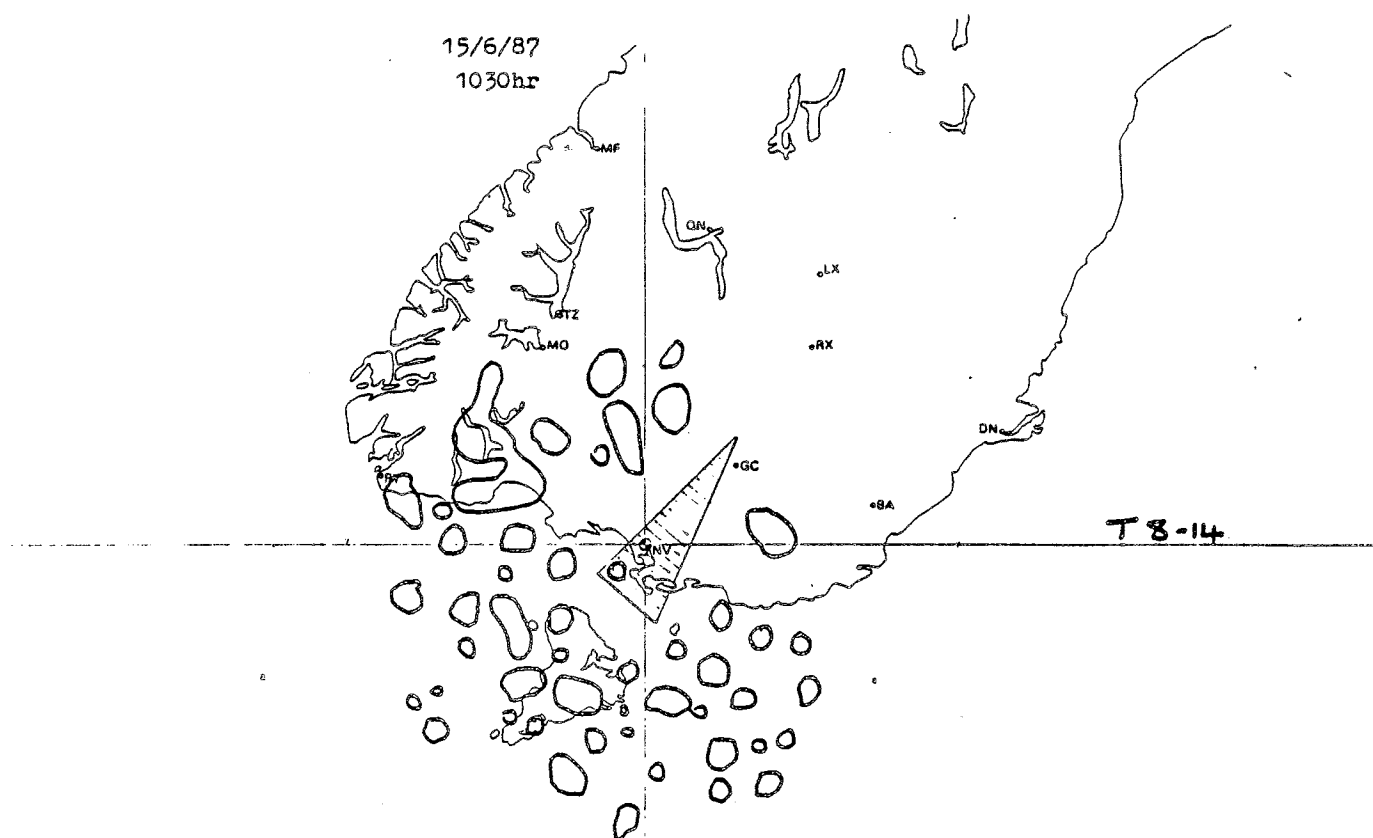
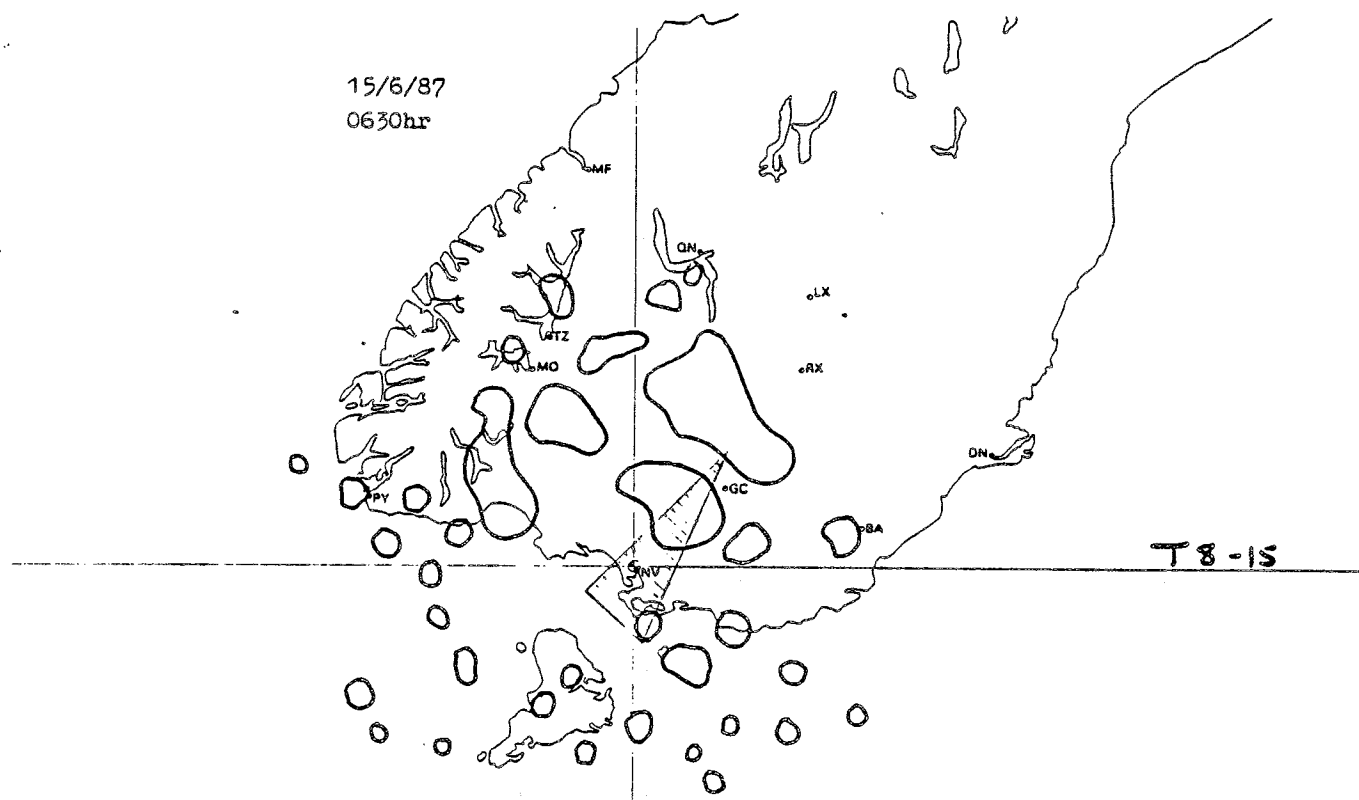


Figure 6b. Rareps.

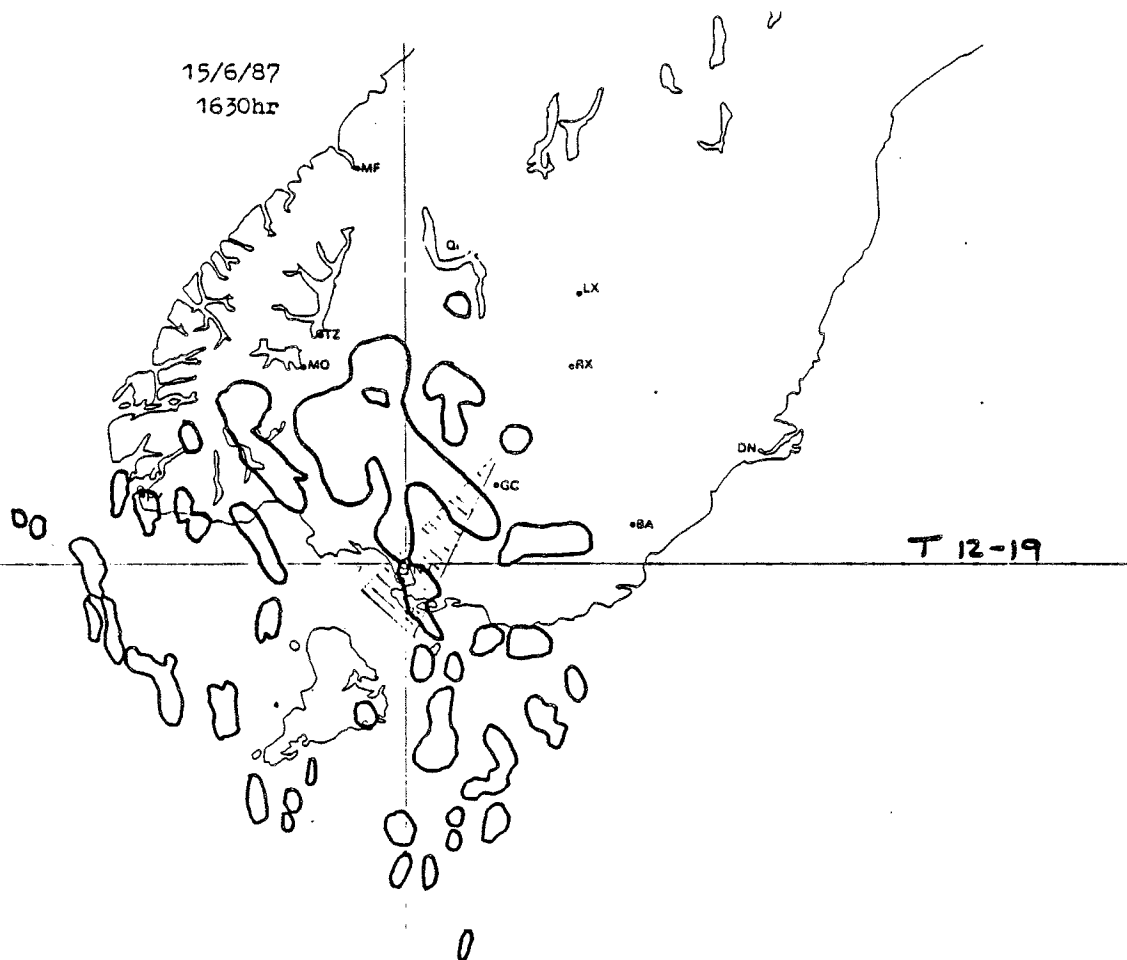
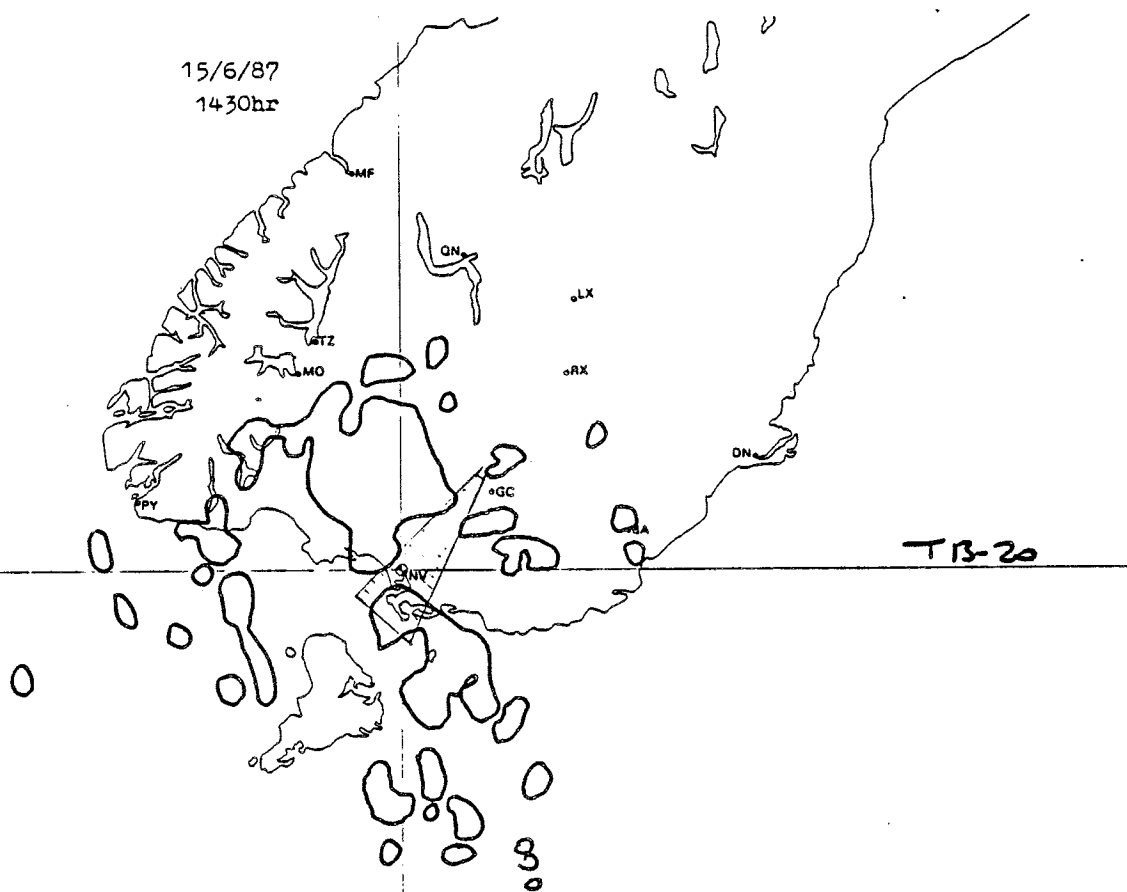


Figure 6c. Rareps.

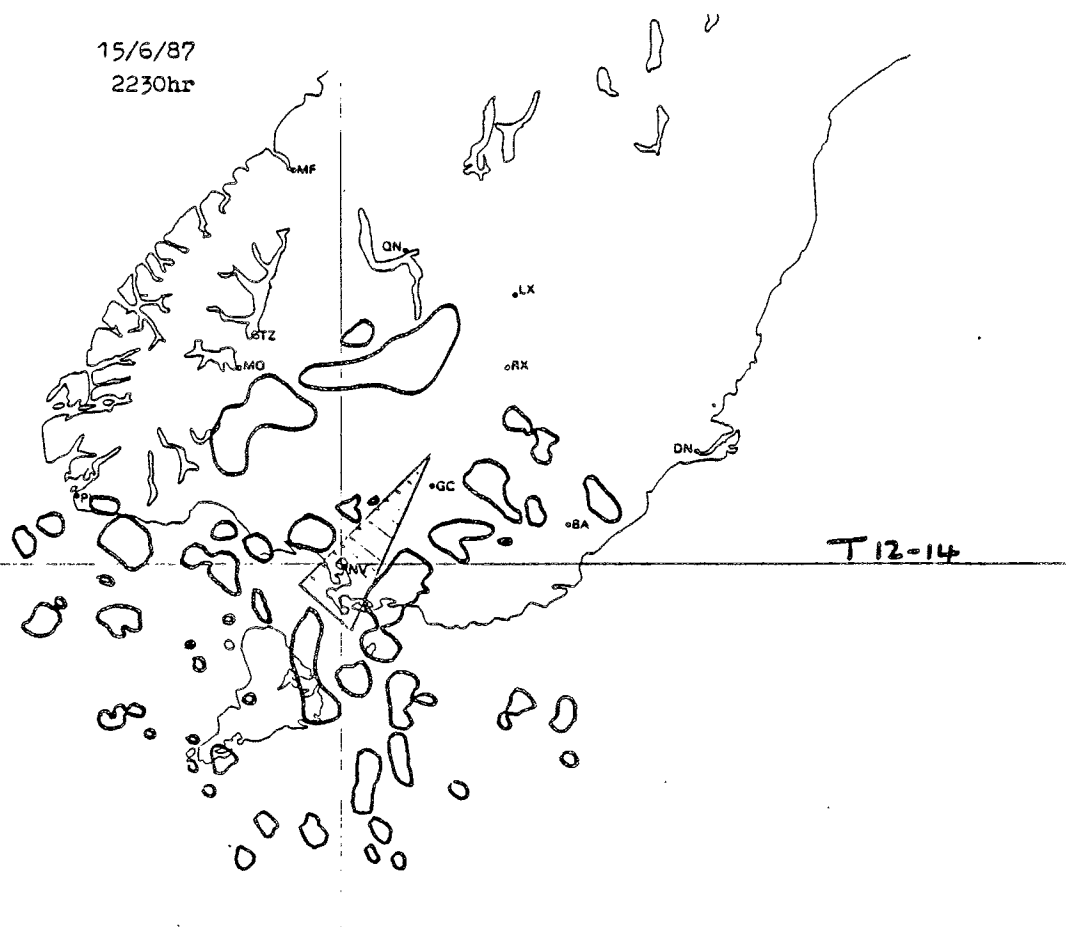
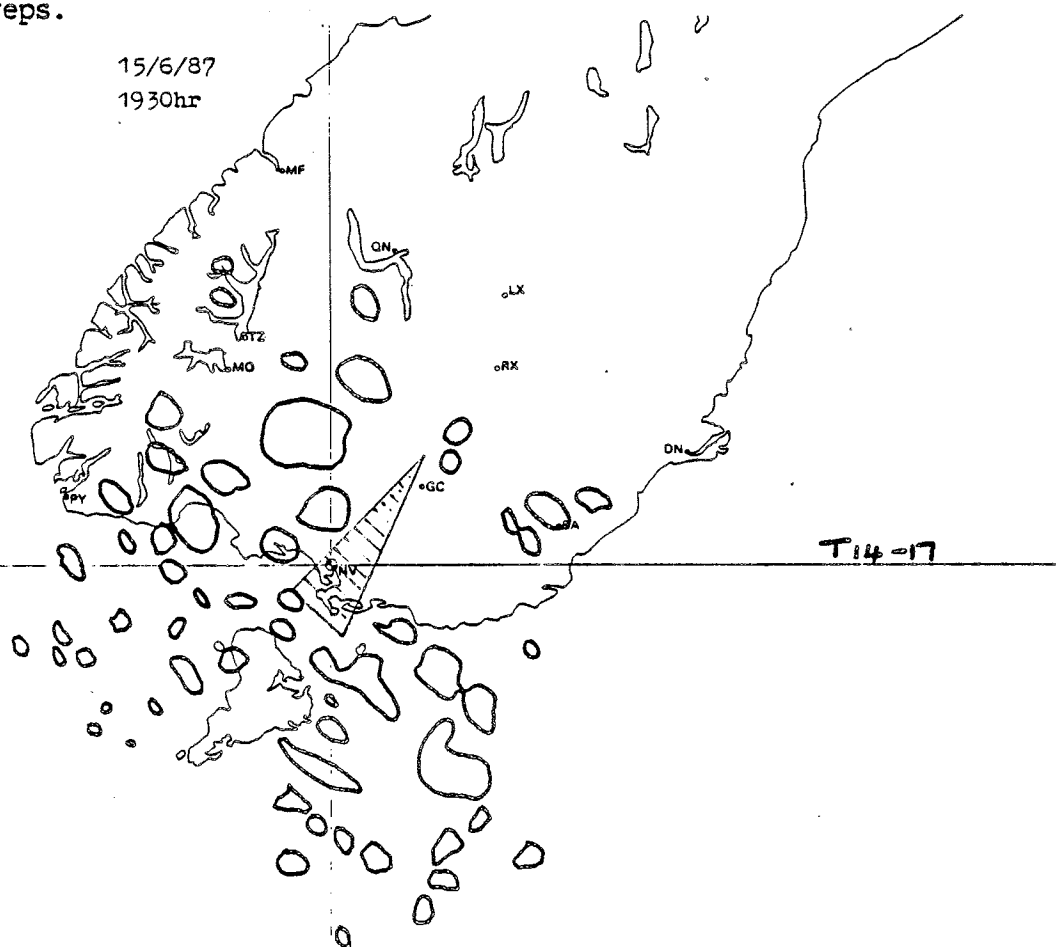


Figure 6d. Rareps.

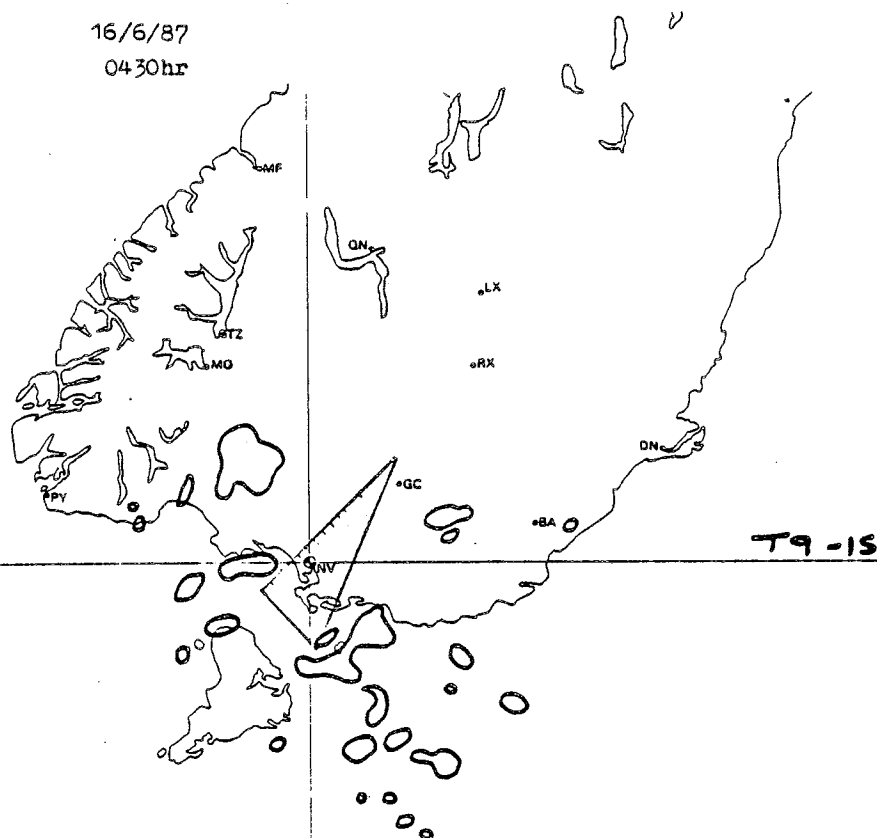
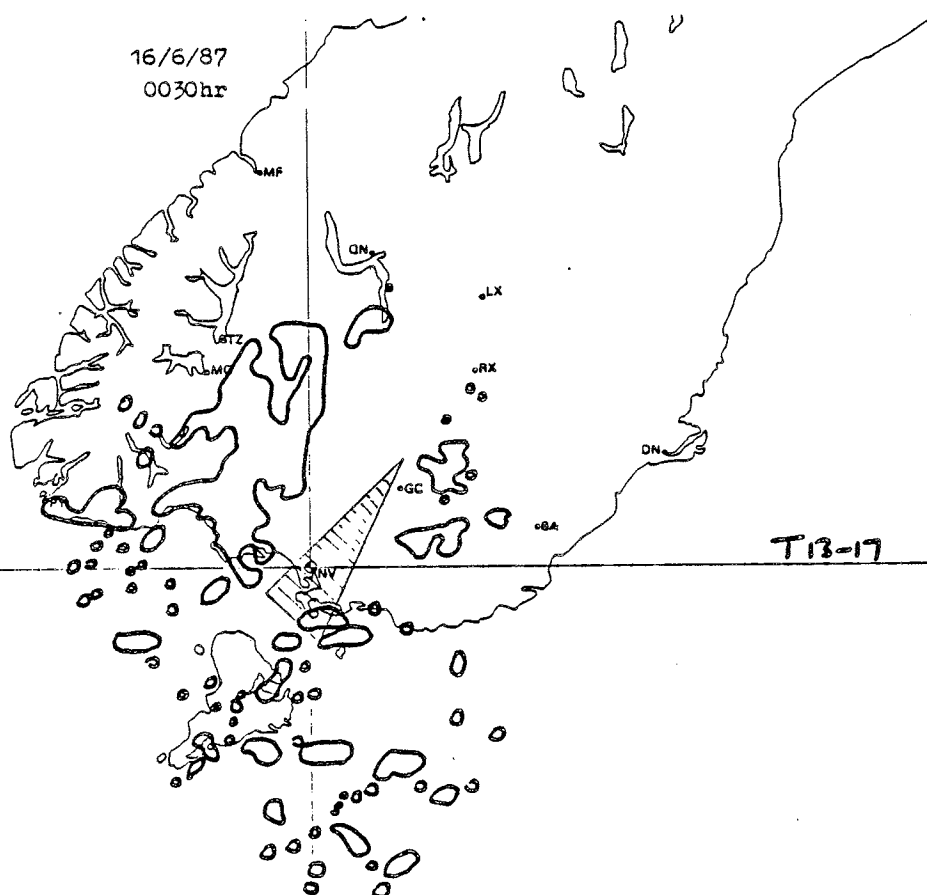


Figure 6e. Rarep, and map of permanent echo returns.

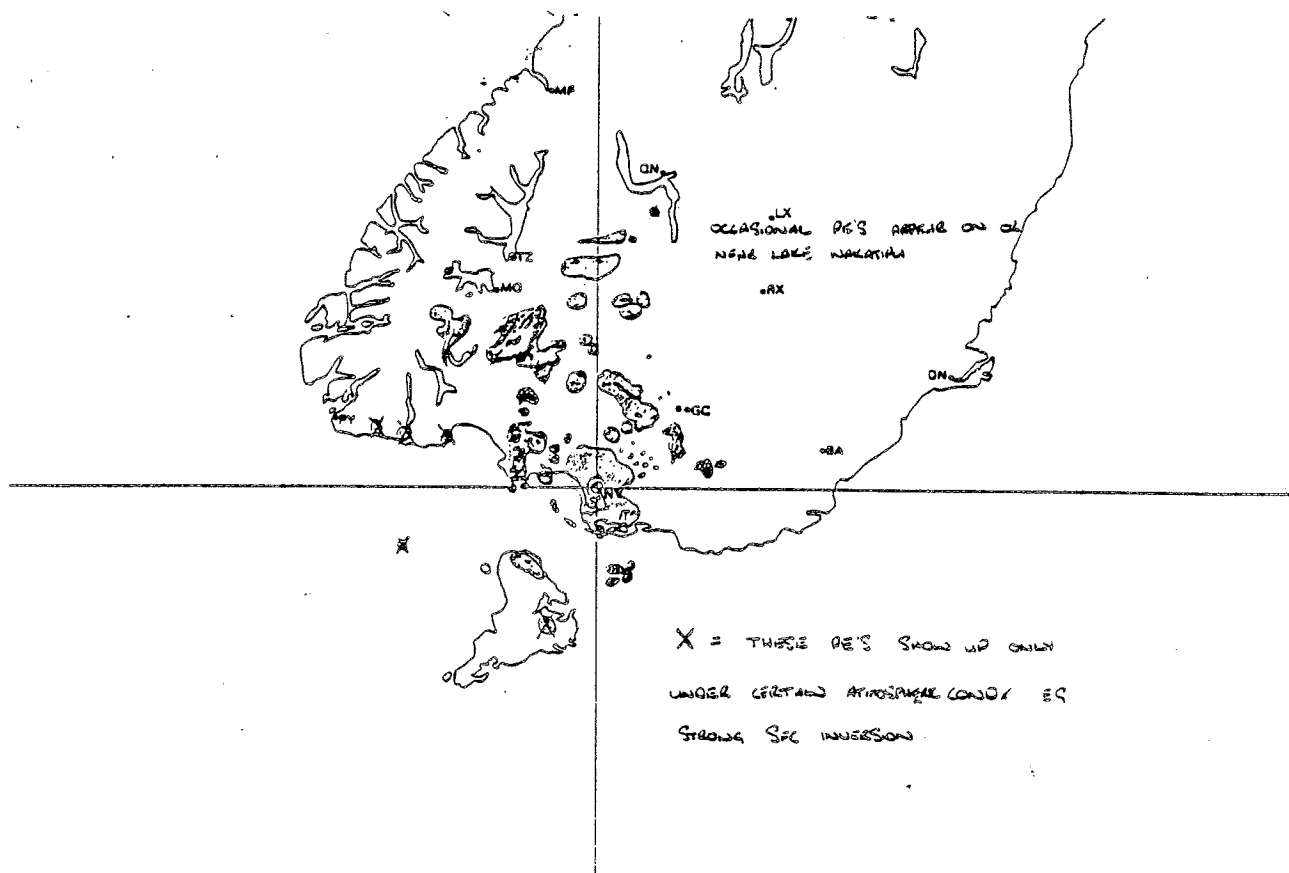
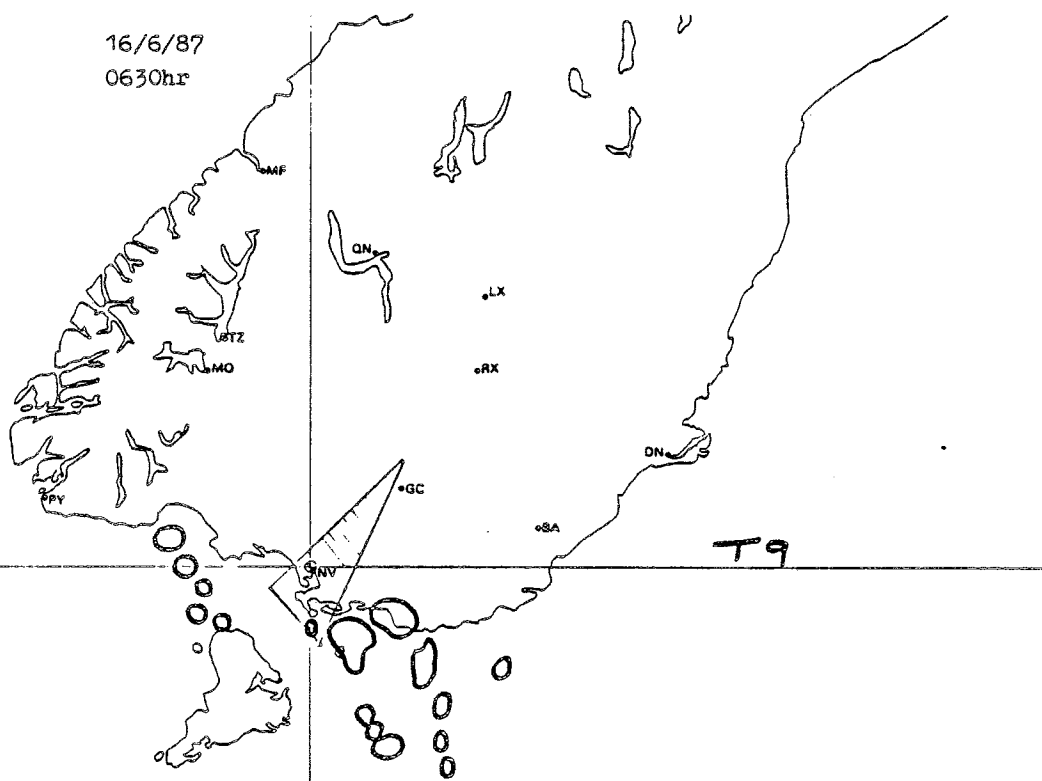




Figure 7. Hourly metar reports at Invercargill 15 and 16 June 1987

\*Do not transmit.      \*\*METAR must prefix all messages when transmitted      NOTE: Equals sign to be transmitted at the end of each report.

**NOTE: Equals sign to be transmitted at the end of each report.**

Station No.	Year	Month	Local Date
344	87	06	16
1 2 3	4 5	6 7	8 9

MINISTRY OF TRANSPORT

NEW ZEALAND METEOROLOGICAL SERVICE

**\*\*METAR REPORT**

MET 352

1983

NOTE—Reports are entered to Local Time Date

STATION 344

MONTH June 19 87

LOCAL TIME	ICAO Loc-ation indicator	G.M.T. Hours & Mins.	SURFACE WIND			HORIZONTAL VISIBILITY Meters or Kilometers	PRESENT WEATHER	INDIVIDUAL CLOUD LAYERS				TEMPERATURE			DEW POINT			PRESSURE (QNN or QFF)		REMARKS	End of Message Indicator	Do Not Transcribe										
			°	Knots	Maximum Gust Knots			N	C	B	h	N	C	B	h	(M)	T	/	(M)			T	d	P	H	H	P	P	T	W	RH	RRR
			°	Knots	Maximum Gust Knots																											
Hour	CCCC	GGgg	ddd	W	U U L L m m	WWW	www	N C B h	N C B h	N C B h	N C B h	(M)	T	/	(M)	T	d	P	H	H	P	P			(M)	°C	%	mm & tenths				
10 11			12 13 14	15 16	17 18 19	20 21 22 23	24 25	26 27 28 29 30 31	32 33 34 35 36 37	38 39 40 41 42 43	44 45 46 47 48 49	50	51 52	/	53	54 55	56 57 58 59 60							61	62 63	64 65	66 67 68					
00	NZLV	1200	140	11	/	50km	15	1Cb022					04	/	m	01	10177									02	64					
01	NZLV	1300	200	11	/	50km	15	1Cb023	3Ac100				03	/	m	00	10182								02	78						
02	NZLV	1400	210	07	/	50km	15	1Cb025					03	/	m	00	10187								02	76						
03	NZLV	1500	220	08	/	50km	15	1Cb012	1Cb023				02	/	m	01	10193								01	82						
04	NZLV	1600	230	07	/	50km	15	1Cb015	1Cb023				04	/	m	01	10194								02	72						
05	NZLV	1700	000	00	/	50km	15	2Cb018	1Cb025				01	/	m	01	10196								02	82						
06	NZLV	1800	010	06	/	50km	15	1Cb018	5Sc000				02	/	m	00	10199								01	87						
07	NZLV	1900	010	06	/	50km	15	1Cb018	3Cb030	7Ac080			02	/		00	10202								01	89						
08	NZLV	2000	340	05	/	50km	15	2Cb018	5Sc040	7Ac090			02	/		01	10210								02	89	T					
09	NZLV	2100	010	07	/	25km	25kts	1Cb018	4Sc040	6Ac080			03	/		01	10210								02	89						
10	NZLV	2200	280	10	/	50km	15	1Cb018	7Sc040				07	/		01	10206								05	68						
11	NZLV	2300	310	10	/	40km	15	3Cb018	5Sc000	7Ac080			08	/		01	10204								05	56	T					
12	NZLV	0000	320	11	/	20km	30kts	1St002	3Cb013	7As120			05	/		00	10205															

The pattern in hourly rainfall at Dunedin Airport, shown below, shows an increase in shower activity some two to three hours later.

<u>15.6.87</u>		<u>16.6.87</u>	
09-10	TCE	00-01	TCE
10-11	TCE	01-02	1
11-12	TCE	02-03	TCE
12-13	...	03-04	2
13-14	...	04-05	...
14-15	1	05-06	...
15-16	1	06-07	...
16-17	TCE	07-08	TCE
passage of trough		08-09	TCE
17-18	20		
18-19	5		
19-20	8		
20-21	3		
21-22	8		
22-23	2		
23-24	TCE		

## 6 STEWART ISLAND

Stewart Island lies about 30 km offshore from the south coast, separated from it by Foveaux Strait. Roughly triangular in shape, it has an area of 1746 km<sup>2</sup>.

Figure 8 shows the topography of Stewart Island. Rugged terrain up to 750 m dominates the southern and central parts of the Island, and another chain of hills, rising to 980 m at Mount Anglem, dominates the northern extremity of the Island. The orientation of the northern feature is such, that it lies at right angles to a south-southwest flow, and is able to disturb an airflow from this direction to the maximum.

## CONCLUSION

On this occasion, Stewart Island formed an almost complete barrier to the showery south-southwest flow. In the 24 hours up till 0900 hours on the 16th, rainfall amounted to less than 1 mm, in a long path downwind of Stewart Island, in contrast with an average of 7-9 mm over exposed coastal areas, and peak totals of 15-19 mm over significant topographical features.

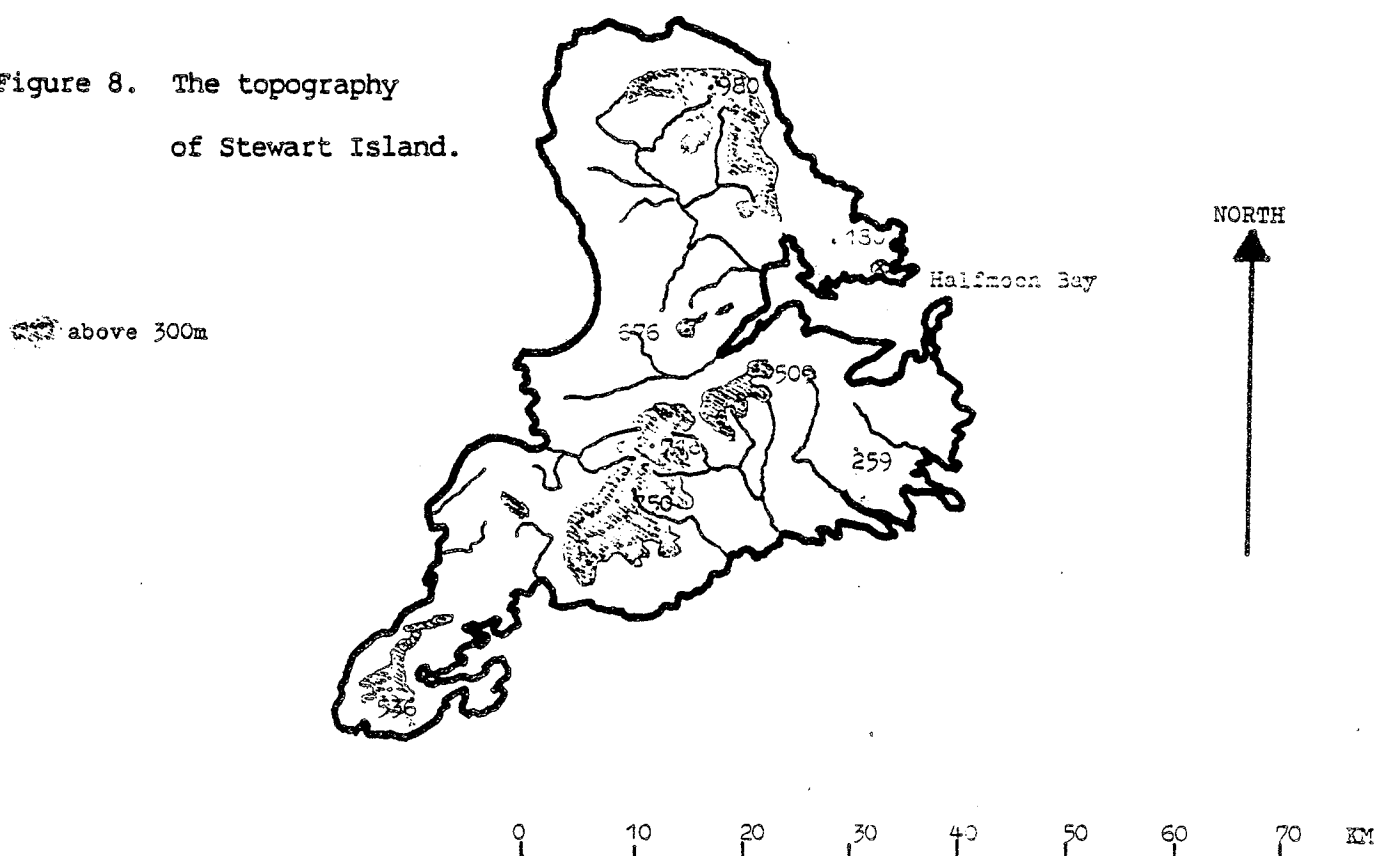
The gradual narrowing of the zone, with low low rainfall to the north, may reflect the small variations in the airflows direction during the 24 hour period, this is supported by the analysis of the upper winds during the period under examination.

The critical range of direction for which Invercargill could expect some shelter, would be from about 190 to 230 degrees. Any further veering of the wind to the west would result in showers spreading over Invercargill. A direction between 230 degrees and about 245 degrees, could still see the shadow effect in evidence to the southeast of the city.

The factors contributing to the observed pattern are likely to be complex. Downdraughts and turbulence in the lee of Stewart Island may break up the inflow at lower levels into the cumulonimbus clouds leading to their rapid decay. The removal of moisture by precipitation on the windward slopes of Stewart Island would lead to a drying of the atmosphere downwind of Stewart Island, a point supported by the relative lack of cloud at Invercargill.

The maxima of rainfall to the east and west of the area with low rainfall are perhaps not just the result of orographic enhancement. The flow around an 'isolated' obstacle, such as Stewart Island, could result in the formation of cloud bands or 'streets' downwind from the corners of the Island, leading to an increase in the frequency of showers in these areas. There is some evidence, for the formation of shower streets in the rareps used in this study, and also from observation from Invercargill, where the shower activity could be seen to the west and east, in almost unbroken lines for considerable periods. However, the maximum to the east of Milton and around Dunedin, would appear to be a result of topography and exposure to the airflow, and the influence of topography on the other maxima is perhaps the dominant factor.

Figure 8. The topography  
of Stewart Island.



While this may be regarded as a classic lee clearance, it is probable the rain shadow would not be so marked in late spring summer and early autumn, that as stronger surface heating would assist in the redevelopment in convective activity over land areas.

#### References

R.A. Horridge and C.G. Revell 1983. Radar echo patterns in Southland in Westerly and Southwesterly airstreams. N.Z. Meter. Serv. Technical note no. 255.