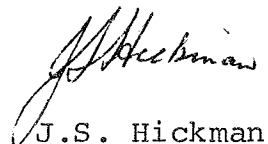


NEW ZEALAND METEOROLOGICAL SERVICE

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THE OTAGO/SOUTHLAND FLOODS
OF JANUARY 1980

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1. Introduction

On the afternoon and night of 16 January 1980 parts of Otago and Southland were, for the second time within two years, subjected to extremely severe flooding. Such flooding was previously unknown within living memory but reports are still in existence of a similar event in September 1878.

As on the occasion of 13/14 October 1978 the town of Kelso was evacuated and flood water subsequently reached the eaves of the houses. Civil emergencies and consequent evacuations were also declared at other towns in the area including Mataura but in general due to the shorter duration of the flooding in 1980 damage was less severe than in 1978. Extra floodbanking completed at Mataura after the previous flood prevented most of the town from being inundated. Damage occurred in West Otago to roads, the railway and to telephone lines. Several bridges were washed away. Stock losses were particularly severe in the Tapanui district, (one farm losing 1200 sheep) but due to massive evacuations in the Clutha delta losses were comparatively light (Otago Daily Times, 18/19 January 1980).

Compared with the 1978 flood the 1980 event was of much shorter duration and affected a smaller area. However western Southland which was not badly affected on the earlier occasion suffered more in the 1980 event with flooding in the lower catchments of the Waiau and Aparima rivers.

2. The Synoptic Situation

In the days preceding Wednesday 16 January 1980, a period of northwesterly winds over a long fetch in the North Tasman Sea drew large mass of warm, moist tropical air southwards to the New Zealand region. The presence of this air, combined with the subsequent formation of an extremely deep depression off the Otago coast led to the high rainfalls.

A cold front passing across New Zealand on 14 January brought a brief period of heavy rain to Otago and Southland as it moved eastwards. Associated rainfalls were typically 20-40mm.

At midnight on 15 January, on the sea level charts, a trough of low pressure with central pressure about 986 millibars (mb) lay in the mid-Tasman Sea, having progressed north-eastwards from Tasmania in the previous 12 hours. The northwesterly jet stream on the eastern side of the associated upper level trough continued its steady eastward movement, spreading onto the North Island from the morning of the 16th. At midday on the 16th, the axis of the sea-level trough lay at about 168°E , while at 300 mb, a broad trough extended over the Tasman Sea. Figure 2 shows the position of the sea-level trough at midday on the 16th. At this stage, winds were light over much of the South Island, with cloudy skies and humid conditions prevailing in most places. The upper air temperature sounding (tephigram) for Invercargill at midday 16th shows the considerable amount of moisture in the air as well as the relative warmth of the air through a deep layer of troposphere. (Fig.3).

While the core of the upper level jet stream remained over the northern half of the North Island, winds at 300 mb over the South Island decreased, increasing the amount of cyclonic shear vorticity in the area just east of the South Island, making this a favourable place for further cyclonic development. The 300 mb analysis for midnight on the 16th (Fig.4) showed the strong gradient over the North Island while a closed cyclonic circulation appeared to be forming just north of Invercargill.

From midday on the 16th., rapid upper air cooling began to take place in the New Zealand area, with a decrease of 93 geopotential metres (gpm) in the 1000-500 mb thickness field at Christchurch between midday and midnight on the 16th. (This corresponds approximately to a mean cooling of about 4.5°C of the lower 5500 m of the atmosphere.) During this time, central pressures in the sea-level trough deepened about 15 mb to 962 mb, while the main low-pressure centre moved southeastwards from the eastern Tasman Sea to just east of Taiaroa Head.

By midnight on the 16th, the strong cold sea-level southerly flow in the rear of the trough had reached Fiordland, with Puysegur Pt reporting a 45 knot southerly wind and continuous heavy rain. Rain had also begun to fall over much of Southland. The effect of the rapid cooling which took place over the South Island may be seen in the tephigram for Invercargill at midnight on the 16th (Fig.5). The cold air reached to 700 mb (approximately 3 km altitude) and the average cooling in this layer was about 5°C . There was potentially much warmer air above. The great height of the moist layer is also evident.

The most widespread rain fell between midnight on the 16th and 6 am on the 17th, during which time the most rapid development of the sea-level feature took place, with the central pressure dropping a further 8 mb to 954 mb in 6 hours. Extremely rapid cooling continued to take place in the lower atmosphere during this period, with a decrease of a further 116 gpm in the 1000-500 mb thickness field at Christchurch between midnight 16th and midday 17th and a decrease of 111 gpm at Invercargill (representing an average cooling of about 5.5° for the layer).

From its position just off Taiaroa Head, the sea-level depression began to move slowly eastward as it deepened, with strong south to southwest winds, up to 60 knots in coastal places, spreading over Otago and Southland (Fig.6). The satellite photograph for 3 am on the 17th (Fig.7) shows the extent of the mixed stratiform/convective cloud over the south of the South Island associated with strong upward motion and heavy rainfall during the morning of the 17 January. At this time, the centre of the sea-level depression was at approximately 46°S , 173°E .

During Thursday 17 January, the depression began to move rapidly away to the southeast with rain easing from the west in Southland and Otago. For example, at 6pm on the 17th, Roxburgh reported 'light' rain, while winds in the region had dropped approximately 20 knots.

3. Rainfall

3.1 The Observations

The N.Z. Meteorological Service maintains a rainfall network over the whole country. This is manned largely by voluntary observers who have contributed greatly to our knowledge of the rainfall regime. The Southland Catchment Board also has stations in the region and rainfalls from the two sources have been used in this study.

The gauges are mainly manual and are read daily at 9 a.m. There are also four automatic gauges in the area which showed that the flood producing rain which was reported on two days from the manual gauge stations, in fact occurred within a 24 hour period from 2 pm on 16 January to 2 pm on 17 January. Thus the two day rainfalls have been used to draw 24 hr isohyets (Fig.8). As in the 1978 occasion ground drainage problems prevented the automatic gauge at Gore from functioning continuously and part of the trace has been interpolated with the help of the readings from the adjacent manual gauge. Figure 9 has been constructed from the automatic gauge pluviographs.

3.2 Rainfall Intensity

From the autographic records (Fig.9) it can be seen that rainfall accumulated at the three gauges at about the rate of 6mm/hour being in the 'moderate to heavy' category. The flooding was caused by the persistence of rain of this intensity over a period of some 20 hours at each site. The heavy rain commenced and ceased at Invercargill some 4 hours earlier than that further east. This may be a useful guide in anticipating future floods in the Pomahaka region in this type of meteorological situation.

The rain was largely distributed in response to orographic stimulation and the rainfalls were very steady. The most intense rain recorded was in the vicinity of 8mm/hr at Gore though it is probable that hourly intensities were occasionally twice this value in the areas of greatest total rainfall.

3.3 Calculation of Rare Rainfall Intensities

The assessment of a return period in years, T_y , is made using a widely accepted statistical method developed by Gumbel (1958). T_y is assessed from the annual maxima of rainfall of particular durations observed at specific sites. These maxima are assumed to fit a theoretical distribution, the extreme value distribution, given by

$$P(x) = \exp(-e^{-Y})$$

where y is the 'reduced variate' of x . This method is explained fully in Coulter and Hessel (1980),

Errors in assessing T_y stem from many sources. The chief of these is inadequate sampling. A high probability of T_y being reliable is only achieved with sampling periods of the order of 30 years or more. It must be recognised too, that maxima do not always belong uniquely to one distribution and that unusual meteorological phenomena can cause 'outliers' (values not fitting the theoretical distribution).

In popular language the rainfall occurring for a T_y of 100 years and for a duration of 24 hours is often associated with the '100 year flood', though such values may occur more than once in any particular 100 year period. The calculation of T_y is made assuming the period sampled is representative of the entire population of 24 hour rainfalls. T_y is a best estimate only and should be considered as such. It must also be recalled that there are many other factors other than local 24 hour rainfall contributing to flooding at a particular site.

A notable example is given by the town of Kelso where two '100 year floods' have occurred within two years. Tapanui is the nearest station to Kelso with a long (82 years) rainfall record. Although calculated 100 year rainfalls for 24 hours durations were exceeded there in 1978 they were not on the 1980 occasion. Tapanui is a short distance downstream from Kelso on the Pomahaka river. Moa Flat, also in the Pomahaka catchment lies upstream from Kelso and has records for 22 complete years. Observed rainfalls for the 1978 (90mm) and 1980 (112mm) events both exceeded the 100 year calculated figure (84mm) based on the 22 year records. At the Moa Flat then, the sampling period on which the calculations were based appears inadequate and recomputation including the latest data in the sample will substantially improve the predictive value.

3.4 The Rainfall Frequencies for Various Durations

The maximum rainfall intensities and their frequencies (expressed as return periods) for January 1980 are shown in Table 1. Ty is the return period in years.

Table 1. Automatic gauge maximum rainfall intensities and frequencies for the month of January 1980 (0.1mm units)

Duration	Balclutha			Invercargill			Roxburgh			Hilltop *		
	Amount	Date	Ty	Amount	Date	Ty	Amount	Date	Ty	Amount	Date	Ty
10 min	28	14	<2	32	14	<2	58	14	2-5			
20 min	35	16	<2	53	16	<2	59	14	<2			
30 min	49	16	<2	65	16	<2	59	14	<2			
1 hr	79	16	<2	91	16	<2	79	16	<2			
1 hr	142	16	2-5	152	16	2-5	119	16	<2	150	16	-
6 hr	285	16	5-10	307	16/17	2-5	213	16	<2	410	16	-
12 hr	476	16/17	10-20	492	16/17	10-20	316	16/17	2-5	720	16/17	-
24 hr	693	16/17	10-20	737	16/17	>50	431	16/17	2-5	875	16/17	-
48 hr	737	16/17	5-10	770	16/18	10-20	542	15/17	2-5	920	15/17	-
72 hr	768	15/18	5-10	883	16/19	10-20	598	14/17	5-10	1000	15/17	-

* Hilltop at Dipton is a Southland Catchment Board gauge. The shorter duration depths could not be extracted from the pluviograph and frequencies are not available from this record.

The greatest ten minute intensities occurred several days before 16 January and at all stations the 14th was a day of widespread moderate rain which occurred in association with a frontal passage. This produced a four year return period event for the 10 min duration at Roxburgh (Coulter and Hessel, 1980). The rainfall on the 14th was probably responsible for generally saturating the ground so that almost all of the rain which fell on 16/17th became runoff. At Tapanui for example 43.5 mm fell on the 14th and this was preceded by 17 mm on each of the 12th and 13th. Both the three days rainfall 12/14th inclusive (114mm) and the seven days rainfall 12/18th inclusive (177mm) occur in less than 0.5% of autumns (March to May) at Tapanui. Similarly at Invercargill the total for the seven days 13/19th March occurs in less than 0.3% of all seven-days autumn periods. These frequencies came from unpublished tabulations of the frequency of N-day rainfalls produced in the Climatological Section of the N.Z. Meteorological Service.

Table 1 shows that the 24 hour duration rainfall at Invercargill was the rarest occurrence of the recorded depths from the three Meteorological Service automatic raingauges having a return period estimated at greater than 50 years. The maximum return period durations at Balclutha were 10-20 years for the 12 hr and 24 hr durations, though using Balclutha's record to scale the 24 hour rainfalls at nearby stations these are also found to have return periods of the order of 50 to 100 years. There is at present no means of assessing the rarity of the intensities at Dipton but these are thought, by comparison with those at Invercargill, to have return periods greater than 50 years for durations 6 hr - 72 hr and indicate the extent of the unusually heavy falls

4. Comparison with the October 1978 Flood

Section 4.1

The synoptic events leading to the two floods were quite different.

In the 1978 flood the rainfall occurred in association with a stationary front embedded in a westerly airflow. The front was very long; it could be detected on satellite pictures as extending from near Western Australia to the South Island and was associated with a depression some 1000 km southeast of New Zealand. The rainfall was widespread with the heaviest falls in the Southern Alps, where rain fell for several days. (Hessel and Lopdell, 1979).

In contrast the January 1980 flood occurred with the development of a depression very close to the south Island. The strong upward motion field associated with this development and the strong onshore southerly winds that resulted led to a different distribution of rainfall, the heaviest rains occurring in the Catlins Ranges of the Otago-Southland border as well as in the Pomahaka, Waikaka and Waikaia catchments.

Surface pressures during the 1978 flooding were generally over 1000 mb but were exceptionally low over eastern Otago in the 1980 storm dropping to a near record low of 962 mb at Taiaroa Head. (The lowest pressure ever recorded at a New Zealand land station is 954 mb which occurred in 1939 coincidentally on 16 January and also at Taiaroa Head.)

4.2. Rainfall Distributions

Figure 10 shows the differences in maximum 24 hour duration rainfalls for the January 1980 event minus that of October 1978. It can be seen immediately that the rainfalls along the Southern Alps were insignificant in January 1980 whereas they were of major importance in contributing to the widespread nature of the flooding over the whole of the Clutha catchment on the previous occasion. In the 1980 storm rainfalls were higher in the Pomahaka, Waikaia and Waikaka catchments by about 25 mm this maximum also affecting the headwaters of the Taieri river. This analysis is compatible with claims of the inhabitants of these areas that the flooding there was more severe (though of shorter duration) in 1980 than in 1978. There is also a 25mm maximum over Dunedin city and the lower Taieri catchment.

The greatest positive anomalies (50 mm) occurred in the Catlins region, and in the lower Waiau catchment of western Southland. Neither of these areas was greatly affected in 1978 but in January 1980 they were both exposed to the full force of the southerly winds, the orographic and funnelling effects apparently causing the rainfall maxima. However it appears that some degree of sheltering may have been afforded the Aparima and Oreti catchments by the presence upwind of Stewart Island. Although 24 hour maximum rainfalls in these basins and in that of the Mataura were similar to those of the earlier occasion there was less rainfall in the headwaters of these rivers in the several days immediately prior to the times of maximum rainfalls and their tendency to flood was apparently reduced accordingly.

4.3 Areas of Flooding

Figure 11 shows the areas of the two events over which 24 hour duration rainfalls exceeded the 50 year return period values in the respective storms. Much of the common area of the two anomalies consists of the lightly populated Catlins region and the whole of the Clutha Valley is excluded from the January 1980 isoline which encloses about 6500 km². The area enclosed by the October 1978 isoline is 13050 km² and extends further inland, this being significant for downstream flooding leading to broader flood peaks. The other causes of flooding cannot be discussed here.

4.3 Remarks from Rainfall Observers

Perhaps one of the best means of comparing the two events is to consider comments from the observers. Many of them make comments in the space provided on their rainfall return form and these are often found to be of great value.

Remarks made relevant to the 16/17 January rainfall were: -
 "Wind gusts over 90 kts 0500 hrs" - Cape Saunders;
 "Flooding equal to 1978" - Waikaia;
 "Flood mid-month bigger on Waimea river than Oct. 1978 - Kaweku:
 "Heavy rain, storm force wind" - Roxburgh;
 "Very heavy rain on the 16th - flooding very much like the 1978 Oct. floods" - Tima (Ettrick);
 "Rain was as heavy as the 1978 Oct floods. Up to 150mm fell locally" - Whitecomb;
 "Severe flooding at Kelso. Stock losses from exposure heavy" - Leithen Glen;
 "100.5 mm - most rainfall I can remember in one 24 hrs" - The Mains, Waikaka;
 "Floods on 17th by far the worst in history ..."
 - Heale Ridge (Limehills);
 "Some very heavy falls of rain, the wettest on my records on the 16th" - Gummies Bush;
 "Very wet month (floods to record levels of '78)" - Tuapeka Mouth;
 "Continuous storm of 16th 17th caused near record flood"
 -Te Houka, Waiwera South.

Many other reports commented on the strong winds, the heavy rain and the consequent flooding and stock losses.

5. Conclusion

The comparison of the two floods (referred to as '100 year' floods by the local inhabitants and the press) occurring within an interval of sixteen months, is interesting. It must be pointed out that the area which experienced severe flooding on both the 13/14 October 1978 and 16/17 January 1980 was comparatively small. This is principally a result of two factors; the differing rainfall distribution patterns of the two storms and the smaller areas of high total rainfall in the second storm. During the first event wind was of little significance especially as temperatures were moderate but the low surface temperatures 6°C to 9°C at sea level) and gale to storm force winds contributed greatly to exposure and consequent stock losses on the second occasion when wind damage to structures and trees was also of significance.

The predominant lower tropospheric wind direction on the first occasion was northwesterly and although widespread heavy rain occurred over the greater area of Otago and Southland the highest falls were in the Southern Alps and consequently flooding affected the entire catchment basins of the southward and eastward-flowing rivers. Moreover heavy rain commenced

in the mountains several days before the heavy falls in the east and the rivers were already running high throughout the greater part of their length at that time.

On the latter occasion although there had been a single day's rain with the frontal passage on the 14th, apart from wetting the soil to capacity (so that all further rains immediately became run-off) the effects with respect to flows would have been largely dissipated on the 16th, even in the lower reaches of the rivers. As the predominant wind direction of the second storm was southerly no significant rain fell in the mountains except in the Waiau catchment and the areas of heaviest rain were those exposed to the south. The major rivers, the Clutha and Mataura, received heavy rain only in the lower parts of their catchments but their tributaries the Waikaia, Waikaka and Pomohaka etc. were vulnerable to this regime and experienced floods similar to those of the earlier occasion.

Not surprisingly some residents of these river valleys who were flooded out for the second time in a little over a year have expressed the opinion that severe floods could now be expected more frequently than in the past (Otago Daily Times 19 Jan). They should realise that the meteorological causes of the two floods rather than being similar are greatly dissimilar and that an overall climatic trend related to a change in the hemispheric general circulation cannot necessarily be inferred. A predominant characteristic of the current rainfall regime, as pointed out by Tomlinson (1980) is that of great rainfall variability similar to the periods 1890-99 and 1910-1940. At present it seems logical to regard the two floods as coincidental manifestations of a highly variable non-permanent regime.

6. Acknowledgements

Our thanks are due in the first place to the observers who continue to provide reliable rainfall returns. It is their lot that the most wanted information is obtained under the most unpleasant circumstances. We would like also to thank the Chief Engineer of the Southland Catchment Board for supplementing the rainfall data obtained from the Meteorological Service network. We are indebted to Mr Michael Sloane who drafted the figures and to others in the Service's Rainfall section for assistance with the data.

7. References

- Coulter, J.D. and J.W.D. Hessel, 1980: The Frequency of High Intensity Rainfalls in New Zealand, Part II. *N.Z. Met. S. Misc. Pub. 162*, ISSN 0110-6937.

- 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.*
- Gumbel, E.J., 1958: *Statistics of Extremes.* Columbia University Press. New York.
- Tomlison, A.I., 1980: The Frequency of High Intensity Rainfalls in New Zealand, *Part I. Tech. Pub. No.19.* National Water and Soil Conservation Organisation. ISSN 0110-4144.

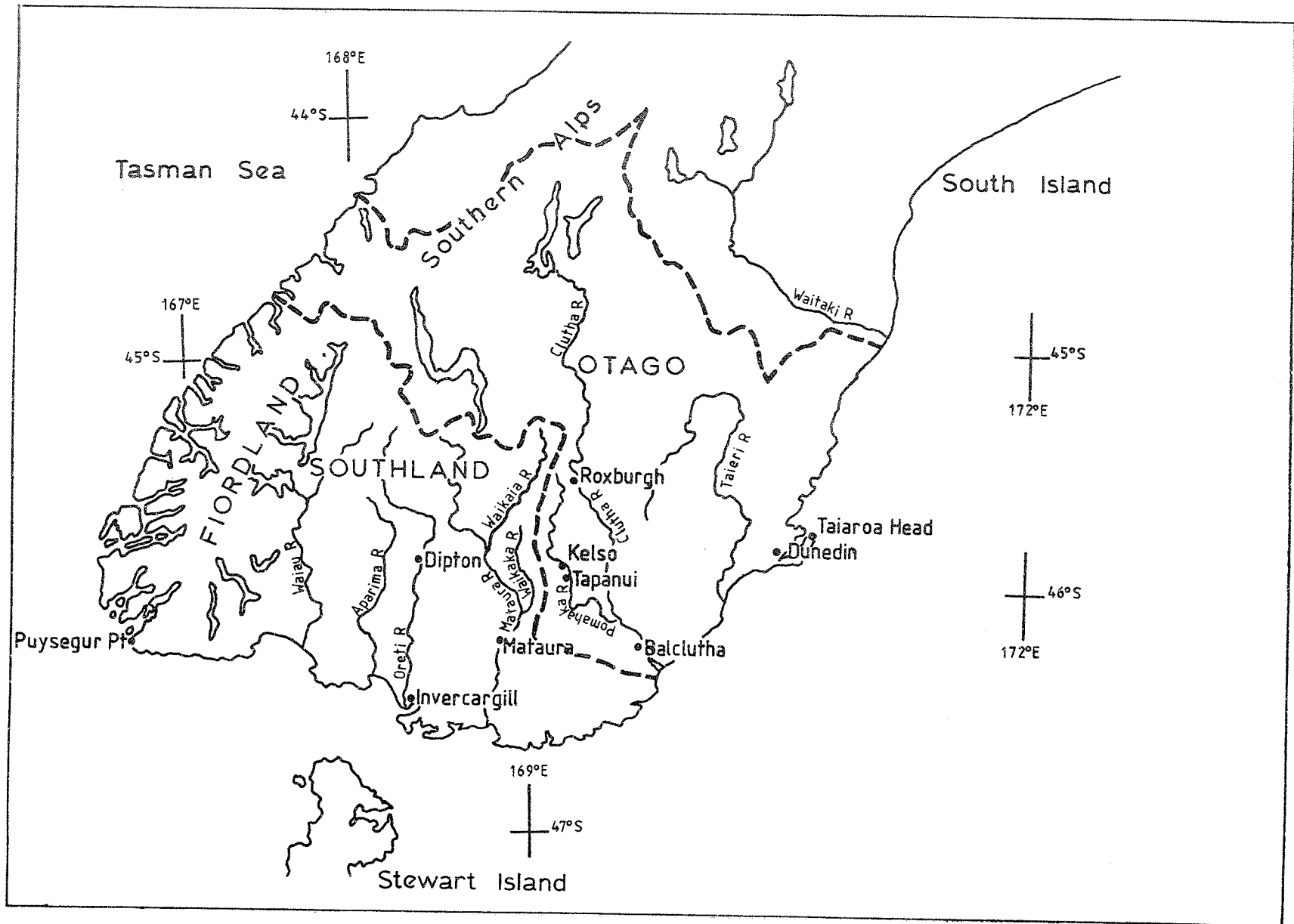


Fig. 1: Locations referred to in the text.

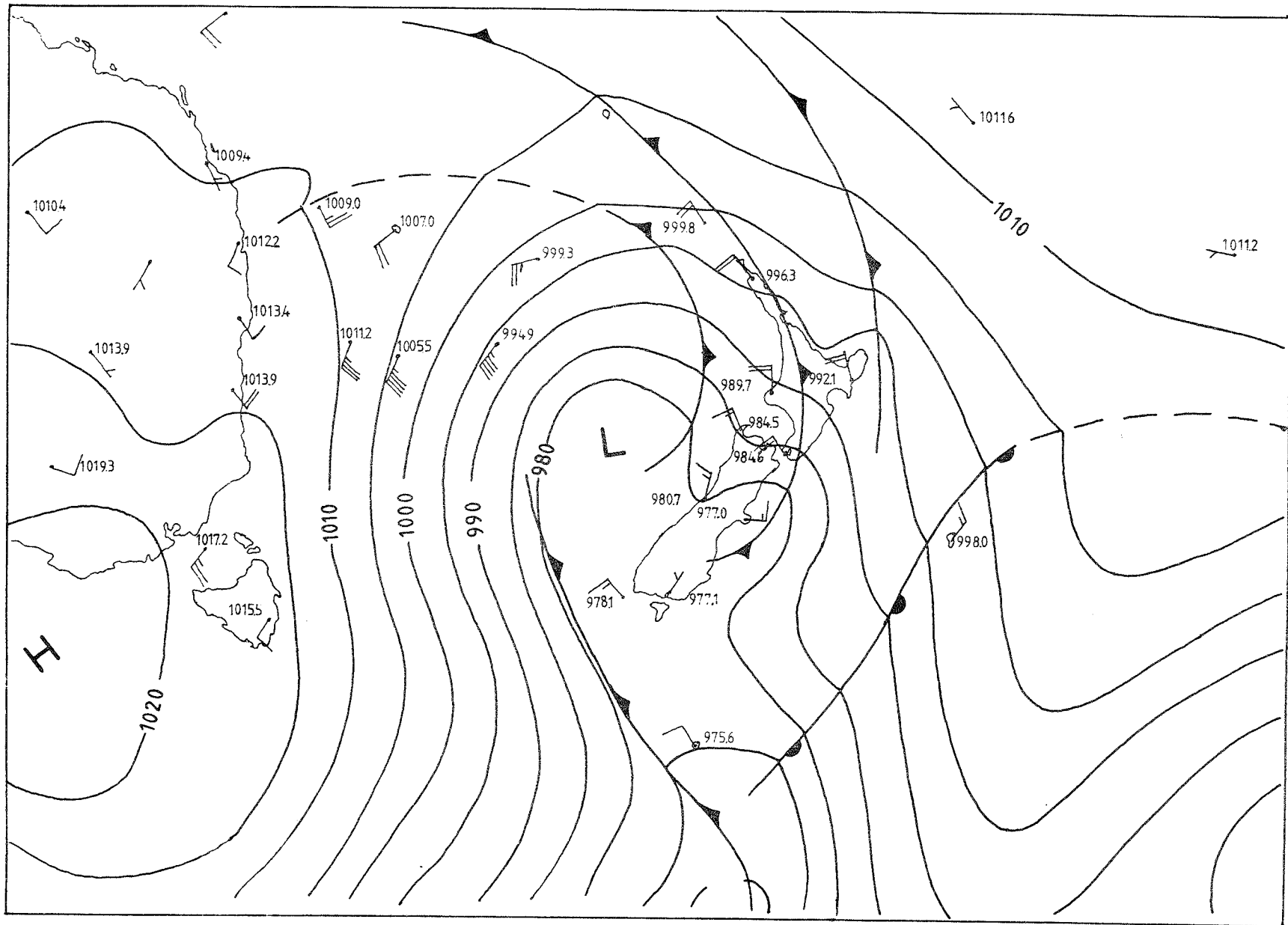



Fig. 2: Mean-sea-level analysis at 0000 hrs GMT 16 January 1980. Pressures are plotted in millibars and wind shafts indicate the direction from which the wind is blowing. Speeds are indicated to the nearest five knots (kt). e.g.  indicate a westerly wind of 25 kt.

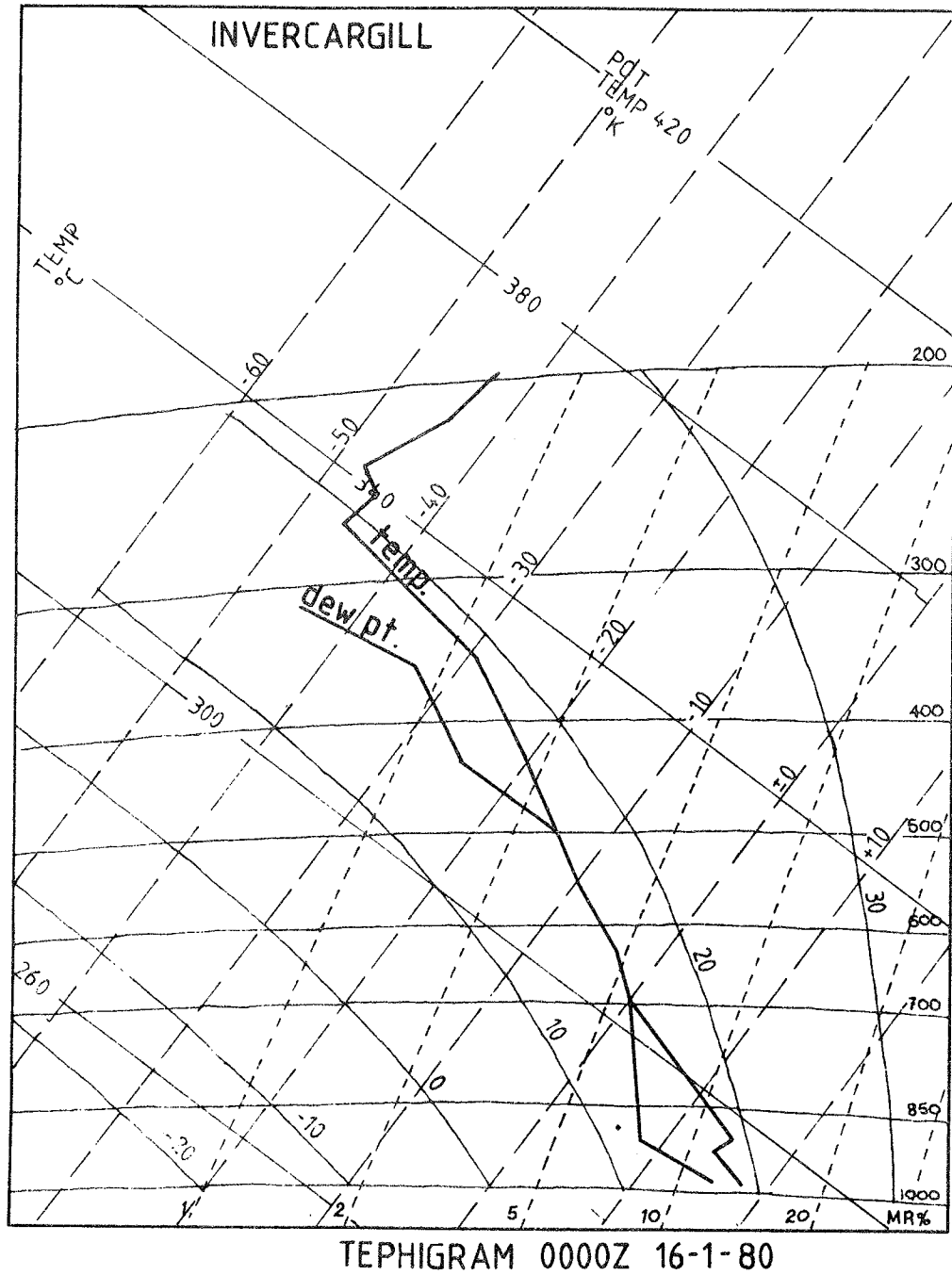


Fig. 3: Upper air temperature and dewpoint soundings from Invercargill at 0000 hrs GMT 16 January 1980, plotted on a tephigram. The relatively warm air extends up to the 350 millibar (mb) pressure surface and the air is saturated between 700 mb and 500 mb.

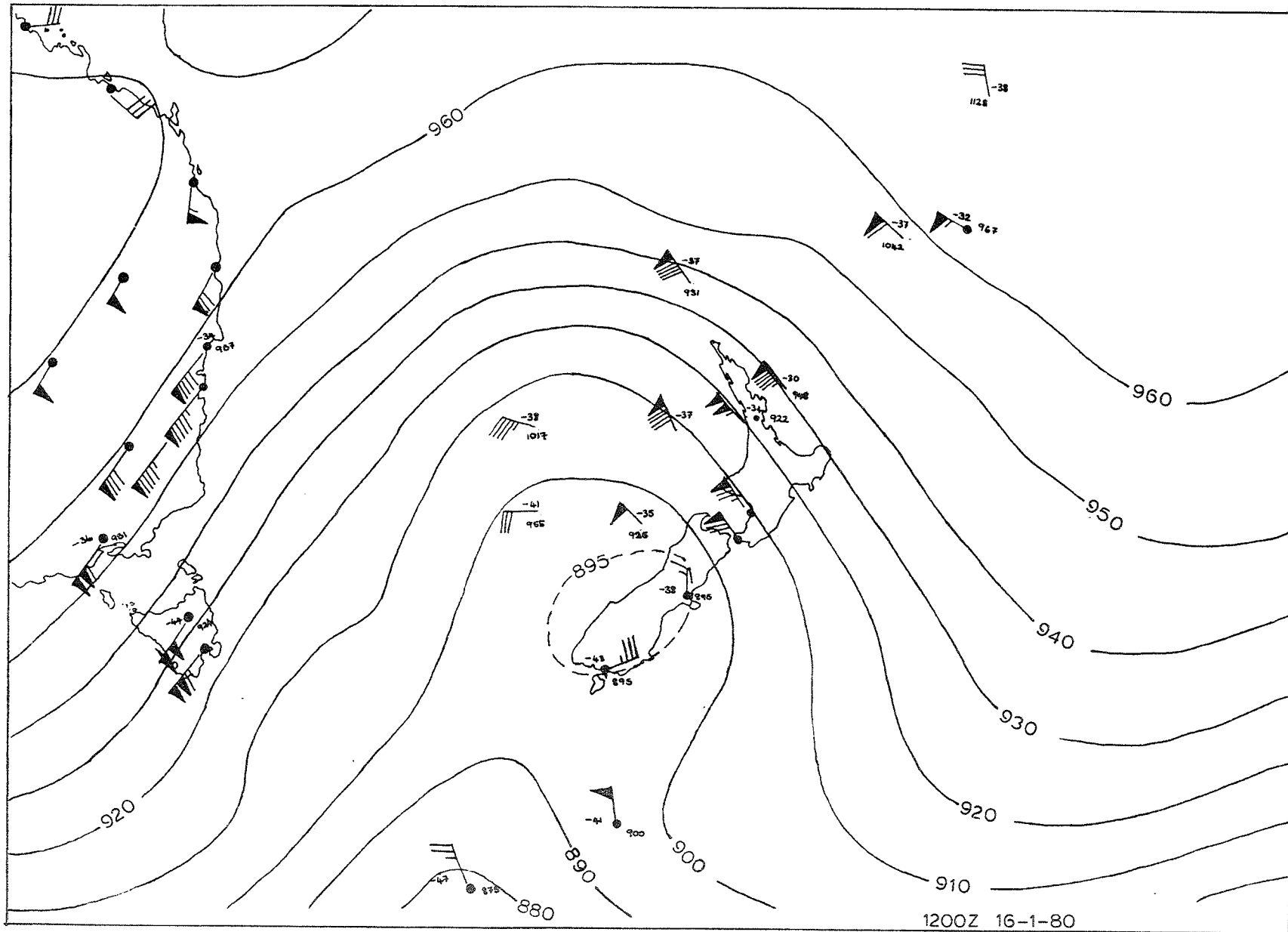


Fig. 4: Contours and observations of the 300 millibar pressure surface 1200 hrs GMT 16 January 1980. Heights shown are in decametres. The flags indicate wind direction and speed; each triangle represents 50 kts.

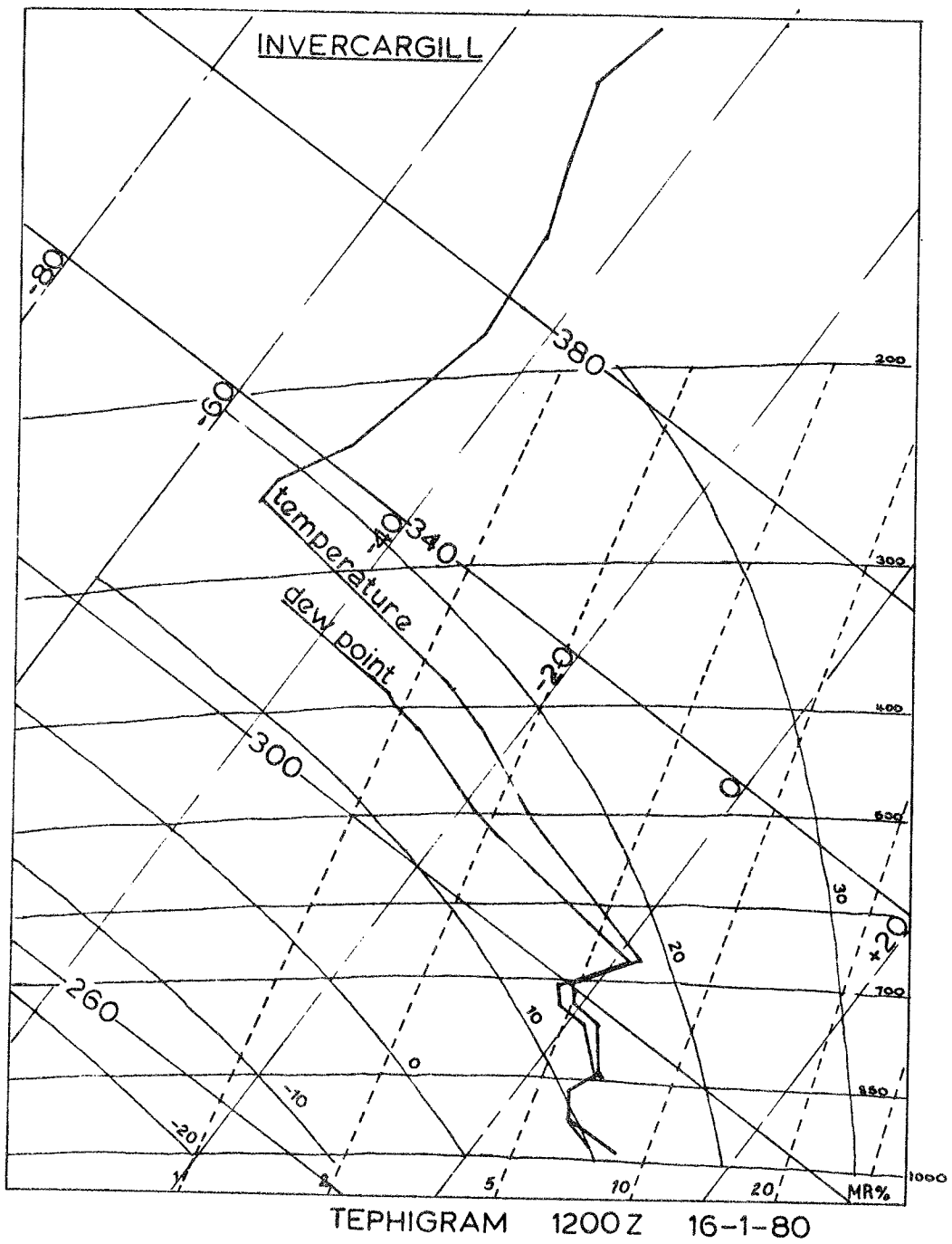


Fig. 5: Upper air temperature and dewpoint soundings from Invercargill at 1200 hrs GMT 16 January 1980. At this stage the cold saturated air had penetrated to the 700 mb level - about 300 decametres altitude.

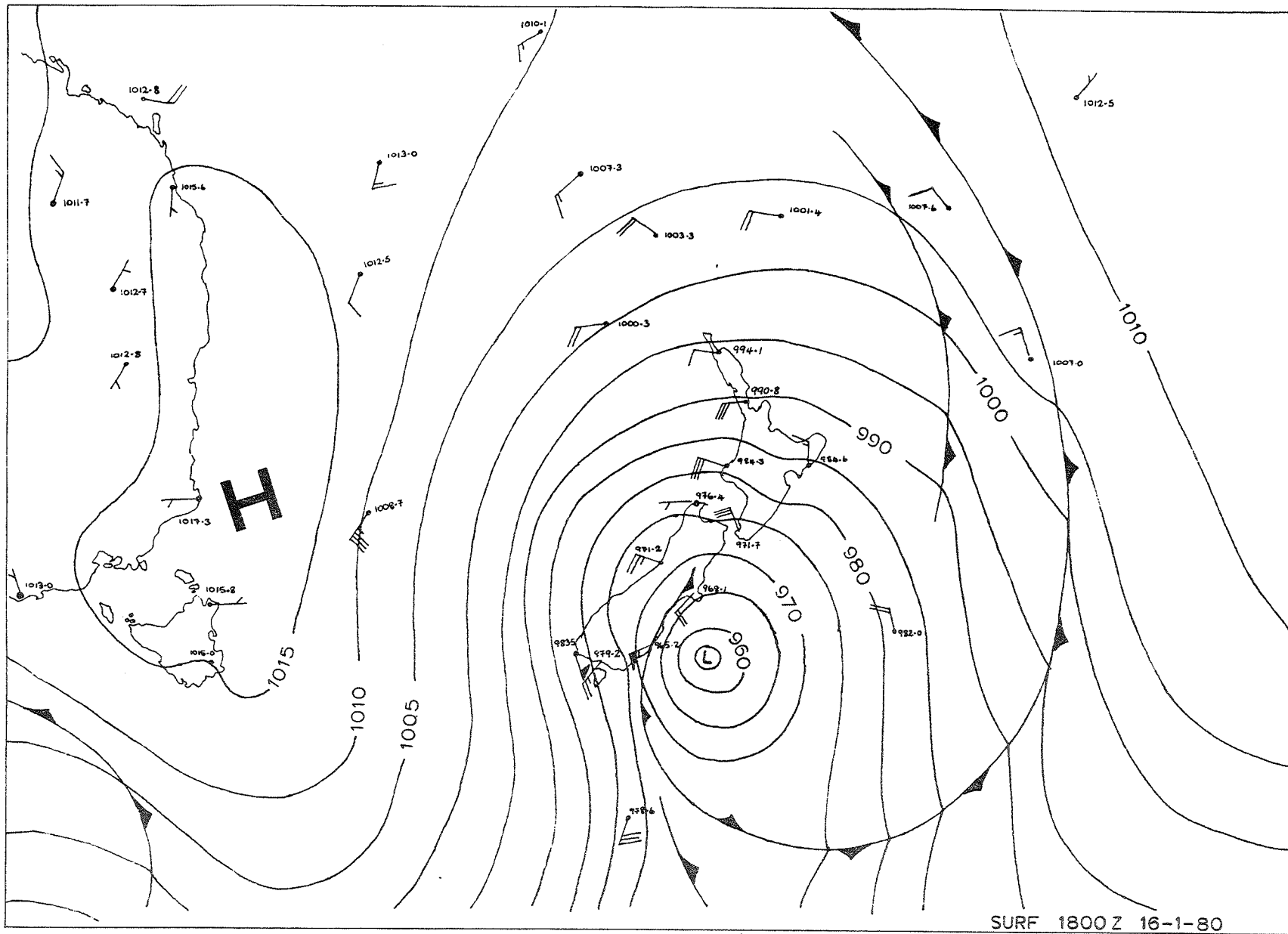


Fig. 6: Mean-sea-level analysis at 1800 hrs GMT 16 January 1980. The symbols have their usual meanings.

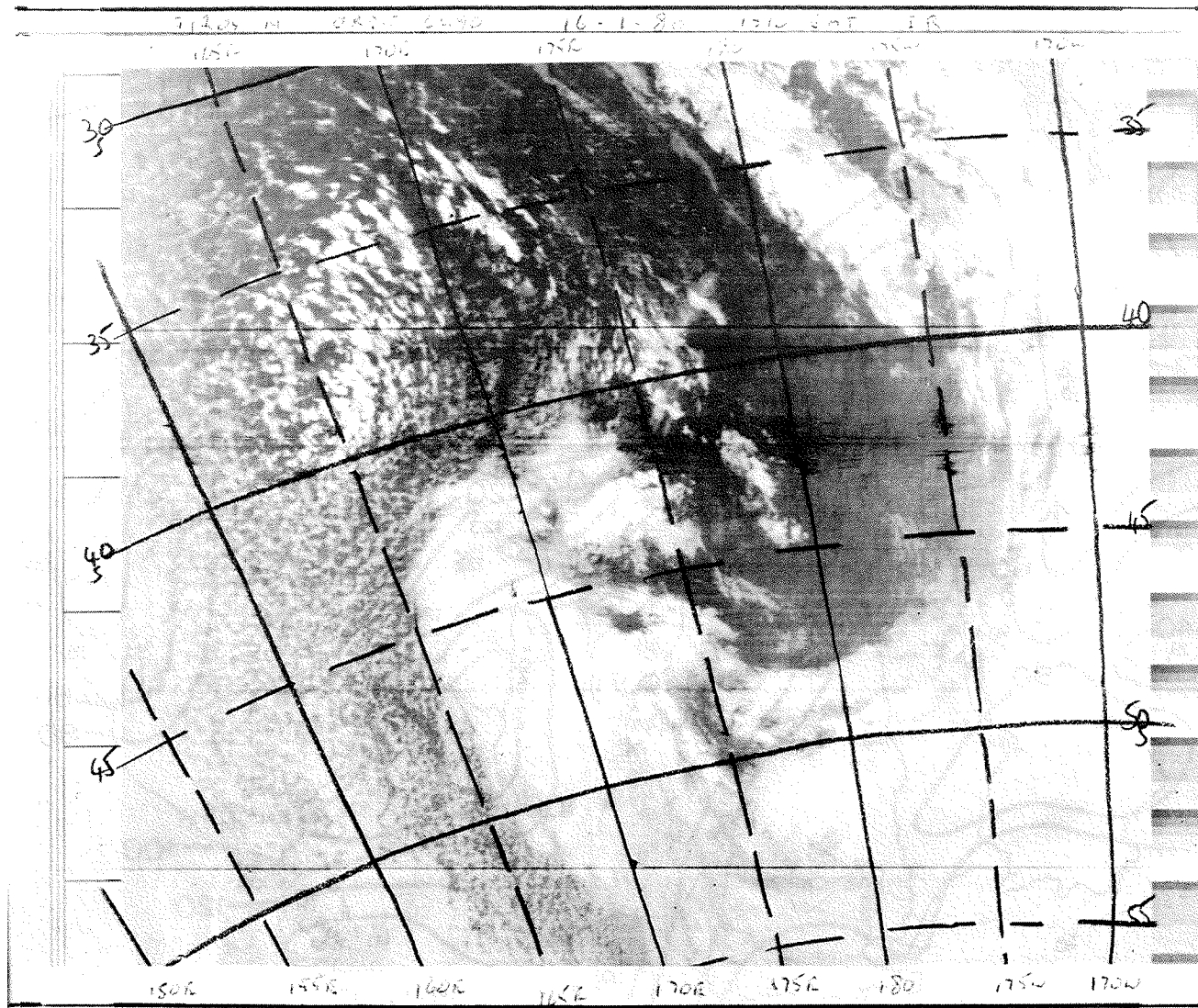


Fig. 7: Infrared photograph from the satellite TIROS-N at 1510 hrs GMT 16 January 1980. The Upper Pomahaka catchment contains the point 45.5°S , 169°E with the Waikaia and Waikaka catchments to the west also under the dense cloud mass.

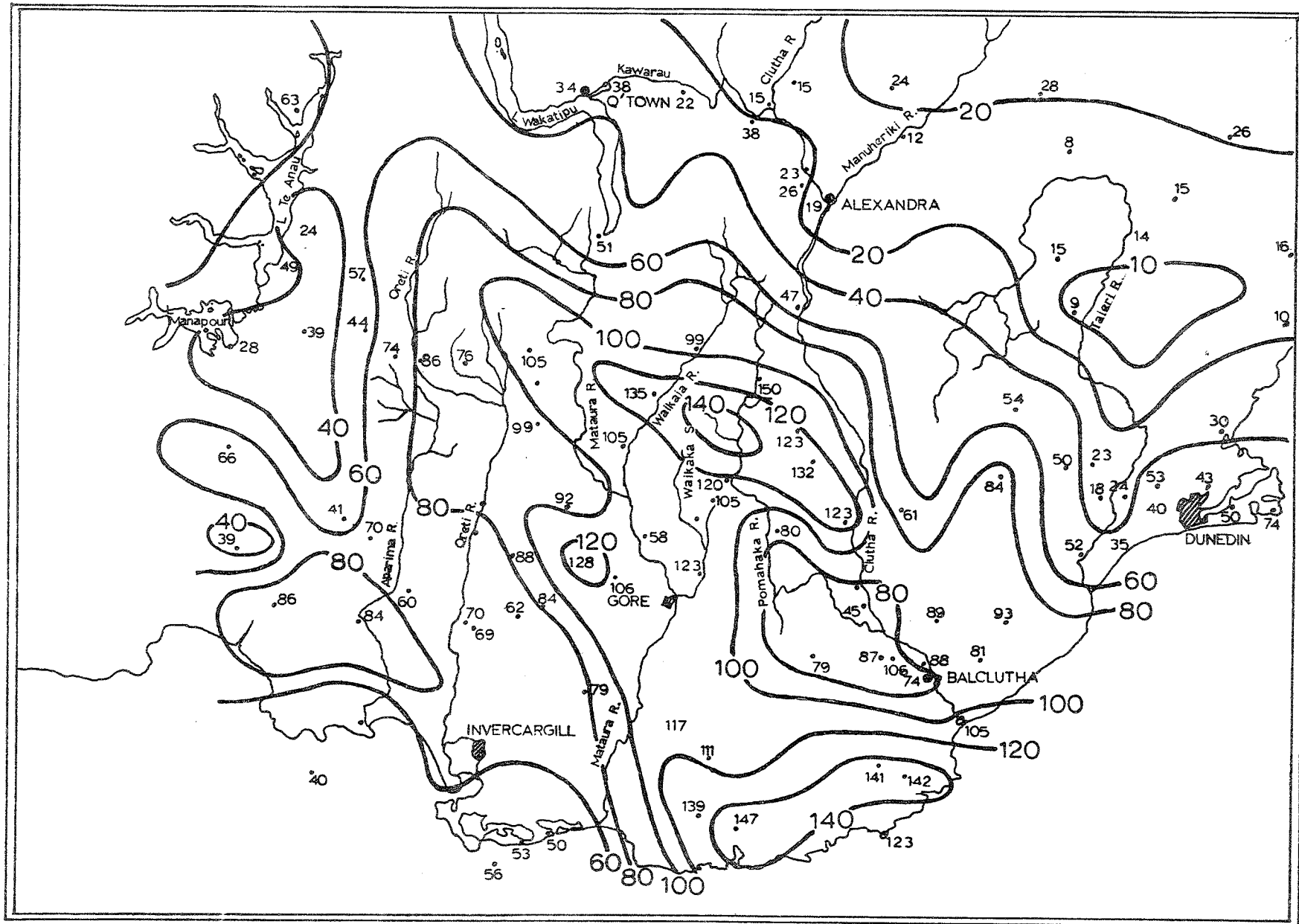


Fig. 8: Isohyets (mm) of the 24 hr rainfall from 0200 hrs GMT 16 January 1980. Rainfalls greater than 140 mm occurred over the Pomahaka and Waikaka catchments and in the Catlins ranges.

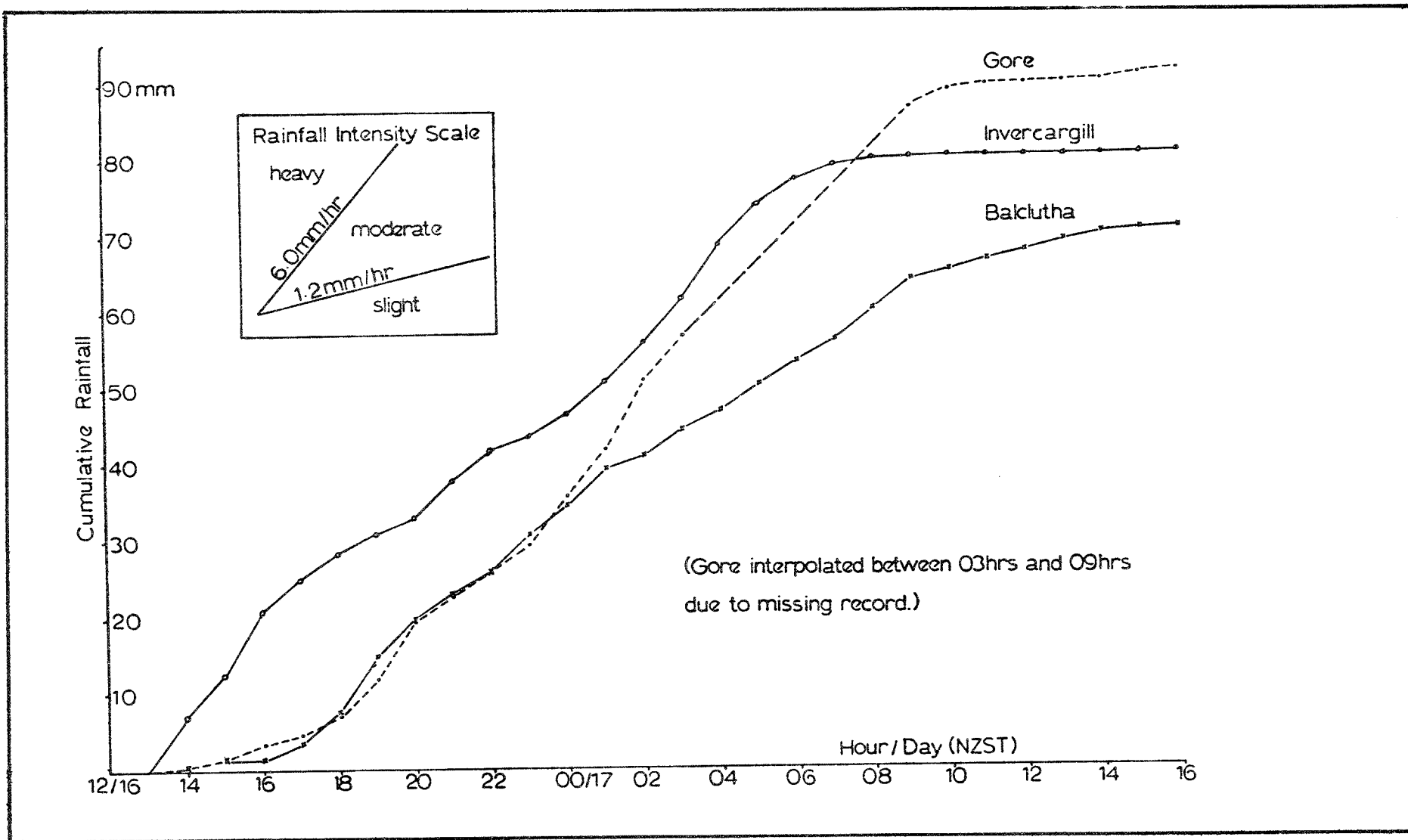


Fig. 9: Rainfall accumulations at Gore, Invercargill and Balclutha from 1400 hrs NZST (0200 GMT) 16 January to 1600 hrs on 17 January.

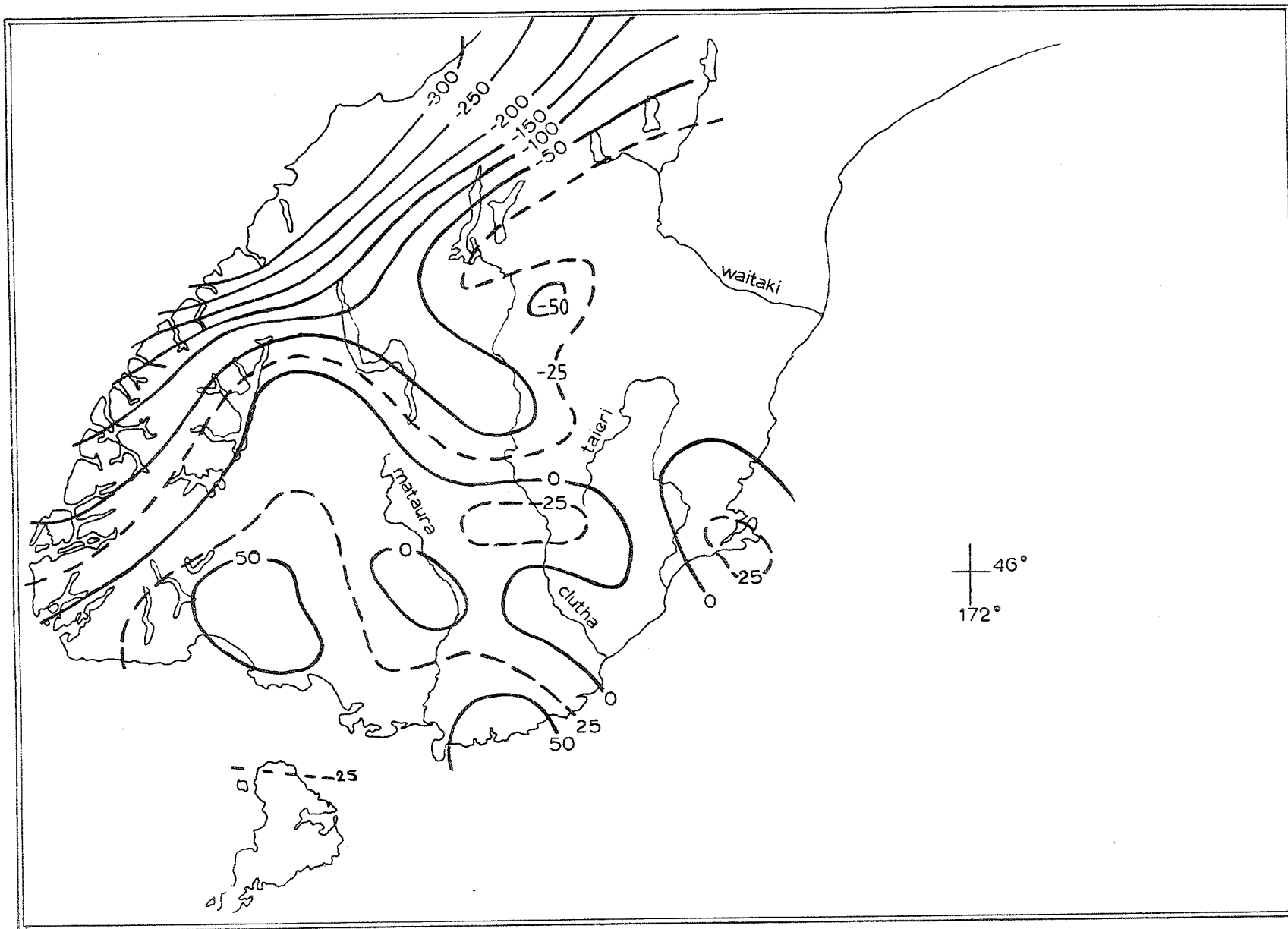


Fig.10: Differences in maximum 24 hrs rainfall between the two storms (1980 minus 1978). Large negative quantities occur over the Southern Alps.

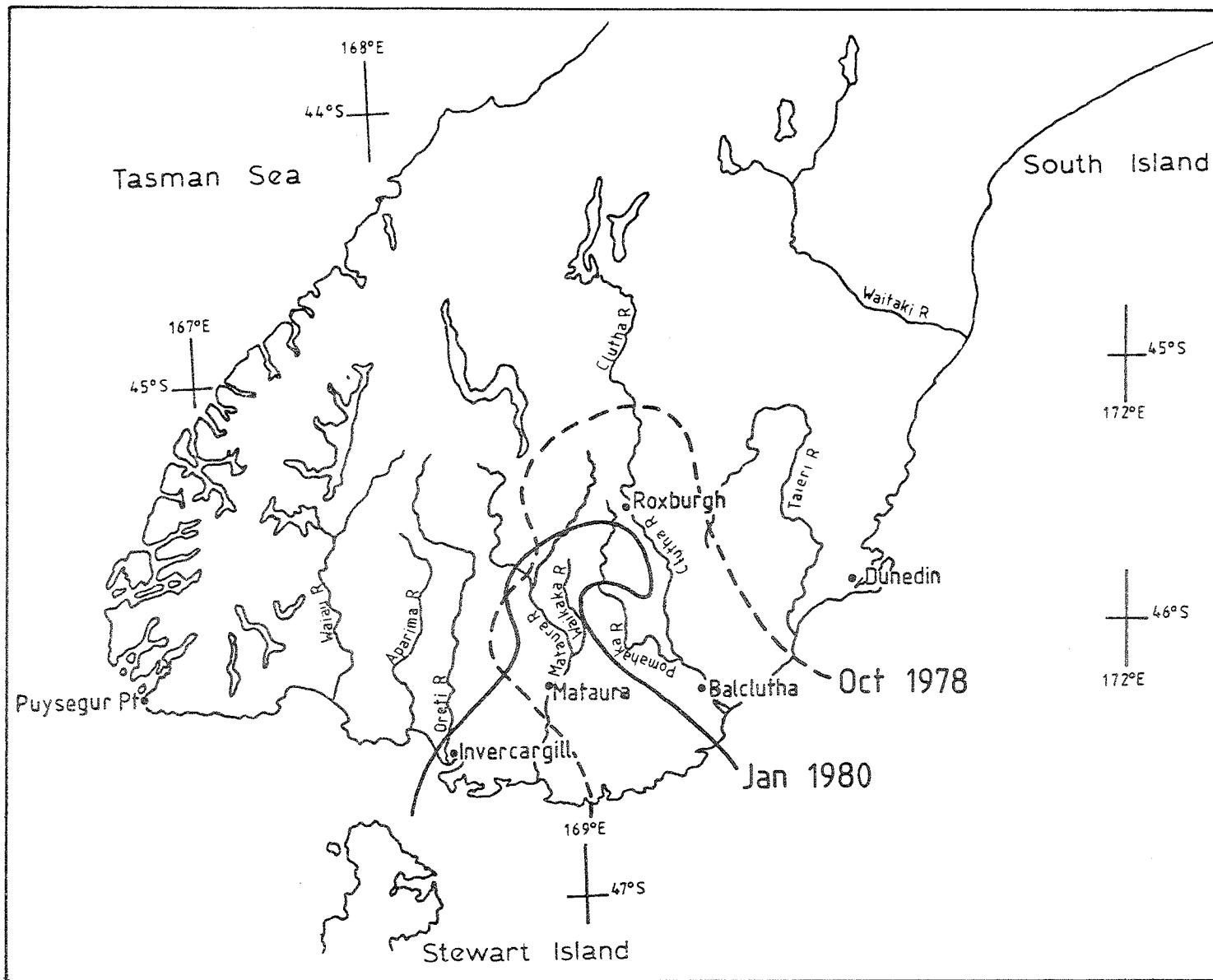


Fig.11: Areas in which maximum 24-hour rainfalls exceeded the 50 year return period values for the storms of October 1978 and January 1980.