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AN INSTABILITY LINE IN THE WAIKATO-BAY OF PLENTY REGION

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Abstract

A shallow pressure trough which intensified in a southerly airstream over the North Island brought a rapid change from clear skies to thunderstorms. The thundery trough was related to a vorticity source in the lee of a mountain barrier as a sharpening upper trough approached. This type of instability line is most liable to occur in the spring and early summer months.

Introduction

Many studies, (Byers and Rodebush (1948), Sullivan (1963)), have shown that the occurrence of strong convective phenomena in regions outside major cyclonic systems and fronts requires the presence of some mechanism to create or locally intensify low level convergence. Thunderstorms do not occur at random even in a potentially unstable environment.

Such mechanisms are usually present in association with recognisable features on the surface weather map, though these can be weak or poorly defined on the usual scale of synoptic analysis.

In order to permit the interpretation of prognostic flow patterns in terms of local weather, further study of small-scale systems is desirable.

Such a system was the instability line which developed over the Waikato-Bay of Plenty region (Fig. 1) on 31 October 1966. By combining the sparse synoptic information with detailed raingauge records, radar reports and observers' remarks a coherent picture of this travelling system can be obtained.

All times in this paper are given in N.Z.S.T.

Synoptic Situation

The National Weather Forecasting Centre analysis at noon 30 October shows a diffuse cold front across the North Island with a trough east of the South Island (Fig. 2a). 24 hours later the front lay to the east of the North Island. The trough east of the South Island had been replaced by a high cell and a weak trough had appeared over the North Island (Fig. 2b).

The course of the development at the surface is shown in the series of maps (Fig. 3) by isobars drawn at 1mb intervals and by surface winds together with reports of cumulonimbus cloud and precipitation.

At 0900 hours a minor trough was located over the volcanic plateau region north of the principal mountain ranges across the North Island. By noon the small closed low which had developed within the trough was intensifying and sea breezes were well established in coastal areas. In the early afternoon when there is normally a diurnal fall of pressure a positive tendency of 0.5mb/3 hr was reported from the Bay of Plenty and a negative tendency of more than 1.5mb/3 hr from Hamilton. During this time thunderstorms occurred in the area of rising pressure. Some evidence for a low level inflow towards the trough was provided by the veering of surface winds (to the north). The pressure field relaxed slowly during the late afternoon and evening.

These analyses show that an organised instability system developed in the region but it was inadequately defined by the routine synoptic observations and customary analysis procedures. Further information on the structure of the system is provided by rainfall and radar observations.

Rainfall

Rainfall over the North Island for the rain-day ending 0900 hours 1 November was caused entirely by the passage of the trough. The distribution shown in Fig. 4 reveals the areas in which thunderstorm cell development was most persistent. Although arranged in a band across the Island, showers and thunderstorms were concentrated in limited areas and clusters of cells propagated along well-defined paths, especially in the Waikato. The whole system travelled towards the north or northwest. The western branch as shown by the rainfall pattern developed in the ranges north of Taupo and followed closely the course of the Waikato River. In the Hamilton district one official station recorded over $2\frac{1}{2}$ in. of rain while lightning interrupted power supplies in the city until about 2100 hours. North of Te Kauwhata (thunderstorm at 2015 N.Z.S.T.) the cell development apparently deviated to the right slightly, towards the Maramarua district where the system finally decayed just before midnight.

The influence of the hills bordering the river on the development of convective cells is clearly shown. The low-lying Thames Valley region received little precipitation (none in parts).

Places affected by the storm had almost continuous rain of varying intensity for 2 to 3 hours. Nearly all autographic records showed a period of heavier rain, usually at the beginning. The time of this heavy rain together with the radar echo patterns and the few instrumental records of surface wind, pressure and temperature changes were used in constructing the isochrones of Fig. 5.

The sequence of changes in weather at most stations was characteristic of a passing thunderstorm squall line; a wind shift and temperature drop with rising pressure as the edge of the down-draught passed, followed up to 30 minutes later by rain. There were no reports of very strong gusts. In the zone which was not affected, e.g. Wairakei (see Fig. 1) temperature followed the normal diurnal course.

Radar

At 1630 hours the Auckland radar showed a line of scattered strong echoes, tops 30000 ft, extending from just west of Te Kuiti to southeast of Hamilton to the northern Kaimai ranges. These were probably echoes from the leading edge of the system, the squall front, as rain was still falling 30 or 40 miles to the south at that time while skies to the north were clear with dry air being reported. At 2030 hours an area of echoes 30 miles by 10 miles lay 30 to 60 miles southeast of Auckland. By 2230 N.Z.S.T. this area had contracted to an isolated moderate echo. However a band of echoes, tops 10,000 ft, then extended from north of Great Barrier Island along the Coromandel Peninsula to northwest of Waihi where rain had stopped at 2135 hours. This was associated with the seaward portion of the trough, a weak convergence line between south and southeast winds. This line of showers passed over eastern Northland in the early morning of 1 November and by mid-morning the whole system, now very weak, had moved off to the north.

Upper Winds

A cyclonic bend in the upper flow which crossed the South Island on 30 October became sharper as it advanced slowly onto the North Island on 31 October (Fig. 5). There were indications of a small vortex developing up to the 700mb level at 1200 hours (Fig. 6) while by 0000 hours 1 November this had extended up to 300 mb. The south to southeast flow in the lowest 10000 ft at 1200 hours 31 October was therefore directed almost perpendicular to the main axis of mountain ranges across the North Island.

Stability

Soundings at Auckland and Waiouru, both of which were outside the area immediately affected by the trough, are shown in Fig. 8. Values of wet bulb potential temperature, θ_w, and of wet bulb potential temperature corresponding to a state of saturation θ_S. are given in Table 1 for selected pressures in these soundings.

Auckland 1966	0000 hours 31 Oct.			1200 hours 31 Oct.		
	Pmb	θw °C	θs °C	Pmb	θx °C	θs °C
	900	8.8	10.4	1010	10.5	-
	800	10.1	11.4	900	6.0	-
	710	10.6	11.6	850	9.5	10.0
	600	9.5	11.4	750	7.8	12.5
	550	11.8	12.7	680	9.5	13.4
	500	12.2	12.7	600	10.0	12.0
				500	11.0	12.0

Waiouru 1966	1200 hours 30 Oct.			1200 hours 31 Oct.		
	P	θw	θs	P	θw	θs
	900	13.2	-	920	9.5	-
	800	10.8	-	800	8.0	-
	700	9.4	-	770	7.3	-
	600	10.2	12.8	740	8.2	-
	500	-	12.5	700	7.7	-
				650	7.5	-
				600	9.2	10.8
				500	10.0	11.4

TABLE 1: Temperature soundings from Auckland and Waiouru. P = pressure level in mb, θw = wet bulb potential temperature and θs = saturated wet bulb potential temperature, both in °C.

The first sounding of each pair was made at about the time of passage of the cold front. The second sounding (during daytime on 31 October shows cooler air at both stations behind the front (refer Table 1). However at Auckland dry bulb temperatures had risen about 2°C betweem 800 and 600mb and there was an inversion of 4°C near 850mb. Auckland was probably just within the area influenced by the ridge extending from the Tasman Sea towards the extreme north of the North Island (Fig. 2b) and this appears to have been a subsidence inversion. In addition a wind shear hodograph, not shown, for 0600 hours 31 October indicated cold air advection up to 500mb except for the layer 850-700mb where little or slight warm advection was indicated.

Although the maximum temperature in the Auckland area during the afternoon (θw = 13-14°C) would have been just sufficient to release instability, cumulonimbus cloud was seen only in the distance. This indicates that the inversion may have been maintained in part by the downward branch of a vertical circulation associated with the thunderstorm system itself. This is also inferred from the low relative humidities recorded. At Hamilton during the two hours immediately preceding the arrival of the trough from the south the relative humidity was constant at only 36%.

The Waiouru sounding at 1200 hours 31 October showed no stable layers below the tropopause and only convective instability through most of the layer up to 650mb. Again, further surface heating could have released the instability but values of θw in the area were too low for intense convection to develop and only scattered orographic showers occurred south of the mountains.

Over the northern slopes of the central North Island plateau, where the trough was located on the morning of the 31 October (Fig. 2) the low level inversion is likely to have been weak or even absent (as at Waiouru). Air flowing from the ridge over the southern part of the North Island towards the trough would have tended to acquire increasing cyclonic vorticity with accompanying convergence. In addition, at 300mb (Fig. 7) the change in shape of the 9100m. and 9200m. contours indicates increasing cyclonic curvature with little change in shear of the flow around the upper trough approaching the area from the west. Consequently lapse rates throughout the troposphere would have tended to increase. Values of θw in the adiabatic layer near the surface of 13-14°C and of θs in the middle troposphere of 10-11°C appear to have been reached. Potential buoyancy in cumulonimbus cloud is proportional to the excess of θw over θs in these layers respectively and it is reasonable to assume from the evidence presented that this excess was greatest in the immediate vicinity of the surface trough.

Therefore in a narrow zone across the Island conditions were favourable for strong development of convective cloud by midday. Sea breezes suppressed convection near the coasts and fed moist air into the interior. Probably of more importance in the present connection is the fact that in the area to the north of the trough convection was suppressed generally by an inversion above which the air was convectively unstable (as at Auckland, Table 1). There was therefore a marked front-like contrast in weather and stability along the north side of the trough. This was the basic characteristic of the structure of the narrow zone along which instability was being released in an organised fashion and which is termed an 'instability line'.

The absence of precipitation in the narrow belt between the main mountain divide and the trough (Fig. 3) is also consistent with such a structure.

Climatological Aspects

Thundery systems of this type develop occasionally in the Waikato-Bay of Plenty area during late Spring and early Summer, usually in a weak trough or in a cyclonic southerly flow. There is a peak or secondary peak of thunder-days in this season (Table 2) when cool unstable air masses are relatively frequent, a major jet stream lies to the north and the surface is readily heated.

Such systems are rare in late Summer when warm stable air masses predominate with the principal jet stream located usually to the south of the North Island.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maramarua 1947-1960	0.4	0.5	0.5	0.5	0.8	0.4	0.3	0.4	0.3	1.4	1.3	0.8
Ruakura 1939-1960	0.9	0.5	1.0	0.7	1.1	1.1	0.4	1.3	0.9	0.9	1.5	1.3
Arapuni 1951-1960	0.7	0.3	0.9	0.4	0.4	0.3	0.4	0.4	0.5	1.1	0.8	1.1
Rotorua 1886-1947	1.2	1.2*	0.3	0.3	0.1	0.4	0.1	0.2	0.4	0.6	1.1	1.1
Tauranga 1941-1960	0.5	0.5	0.7	1.0	0.9	0.5	0.4	1.0	0.4	1.0	1.0	0.7

*The high frequency of February occurrences does not appear in the records from neighbouring stations, e.g. Whakarewarewa.

TABLE 2. Frequency of days with thunder.

Summary

A minor trough followed by a pressure surge passed on to the southern part of the North Island on the evening of 30 October, 1966. By the following morning this weak feature was located north of the principal mountain barrier across the North Island. It intensified slightly during the day owing to a process of lee cyclogenesis brought about by the low level flow against the mountains aided by surface heating. With the isallobaric effect this intensifications would have resulted in low-level convergence into the trough and accompanying decrease in stability. At the same time the approach from the west of a sharpening upper level trough resulted in the instability extending through a deep layer. The thermal structure of the environment led to the creation of a narrow zone of instability in association with the surface trough.

It is highly probable that cold downdraughts undercutting the neighbouring warm air formed the mechanism directly responsible for releasing instability along the north edge of the zone. This edge advanced like a cold front as the whole system progressed slowly northward.

Surface heating was still sufficient in the evening for the most active cells to produce sufficiently strong downdraughts for storms to continue 3-4 hours after darkness over the hilly terrain between the Waikato and Thames Valleys. The persistence of these cells cannot be explained in terms of the Browning-Ludlam model (1962) because winds aloft were too light to sustain a major steady updraught. The vertical shear between the surface and 500mb surface was about 20 knots at noon later decreasing to about 10 knots. This instability line provided a notable example of how meso-scale circulations develop in association with the orography.

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J. Met. 5 275-280.

Browning, K.A. and Ludlam, F.H., 1962:
Airflow in Convective Storms. Q.J.R. Met.S. 88 : 117-135

Sullivan, W.G. Jr., 1963:
Low Level Convergence and Thunderstorms in Alaska;
M.W.R., 91, 89-92

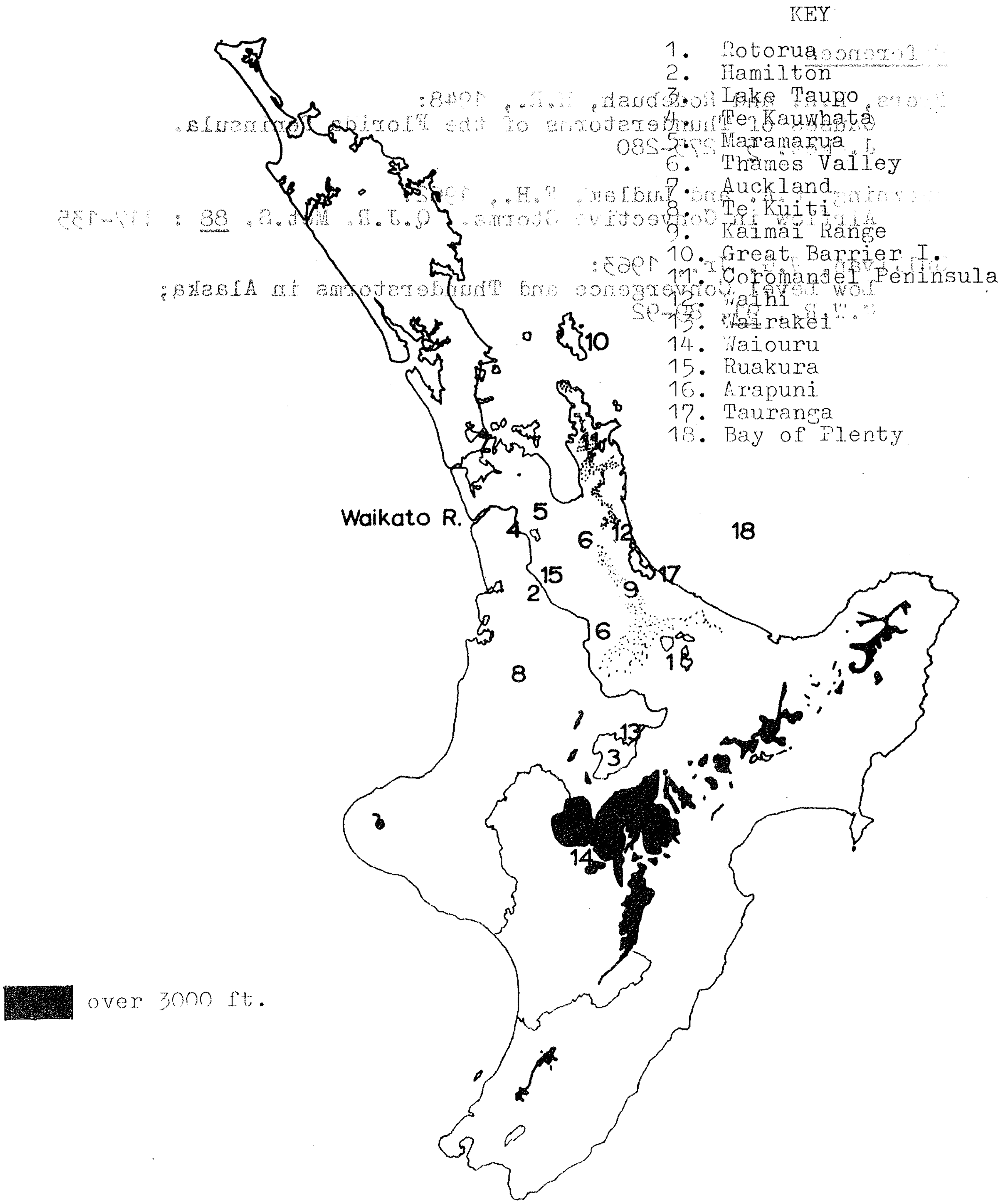


Fig. 1. The North Island showing places referred to in the text.

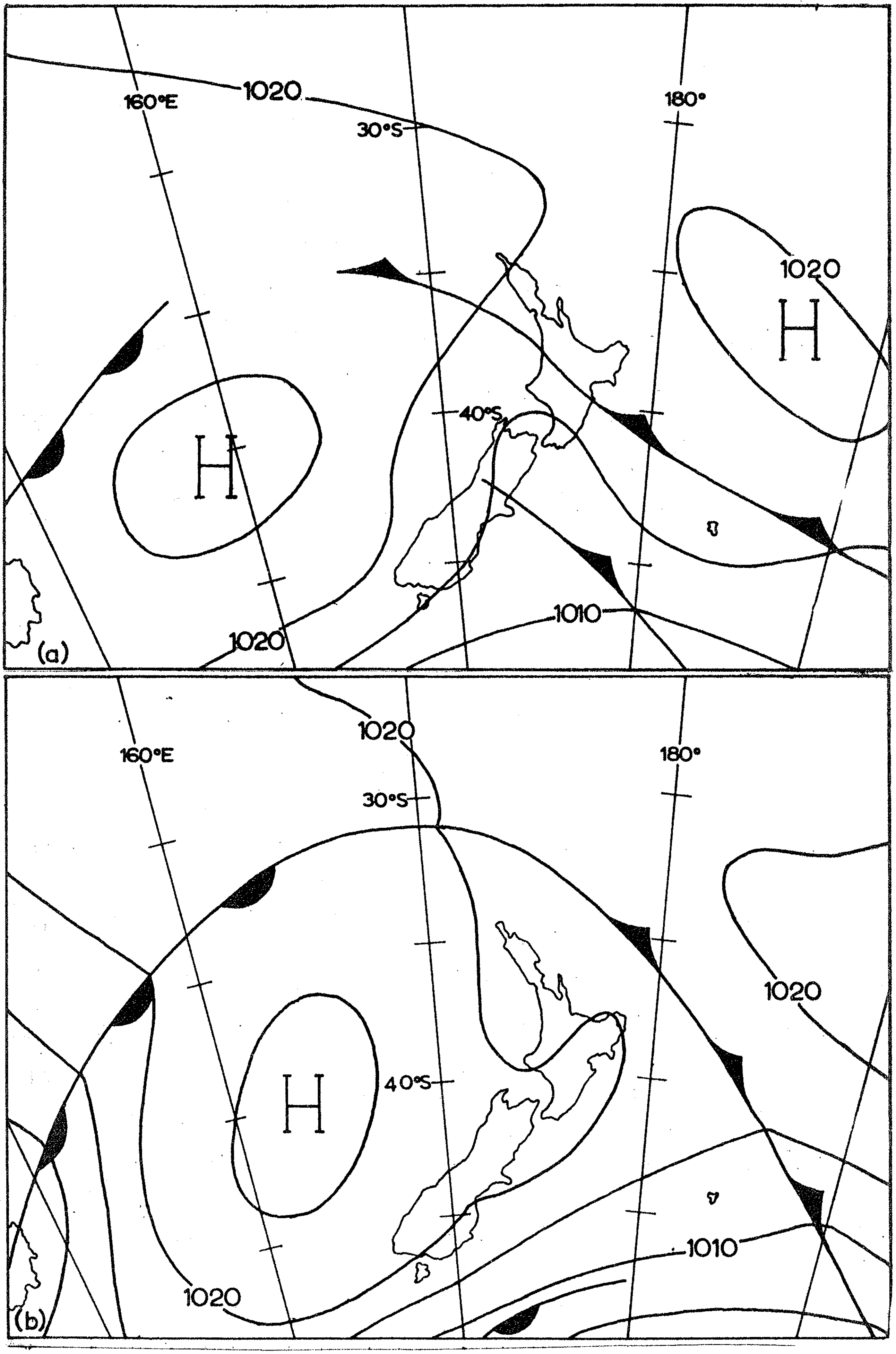


Fig. 2. (a) M.S.L. Analysis 1200 hours 30 October, 1966

(b) M.S.L. Analysis 1200 hours 31 October, 1966

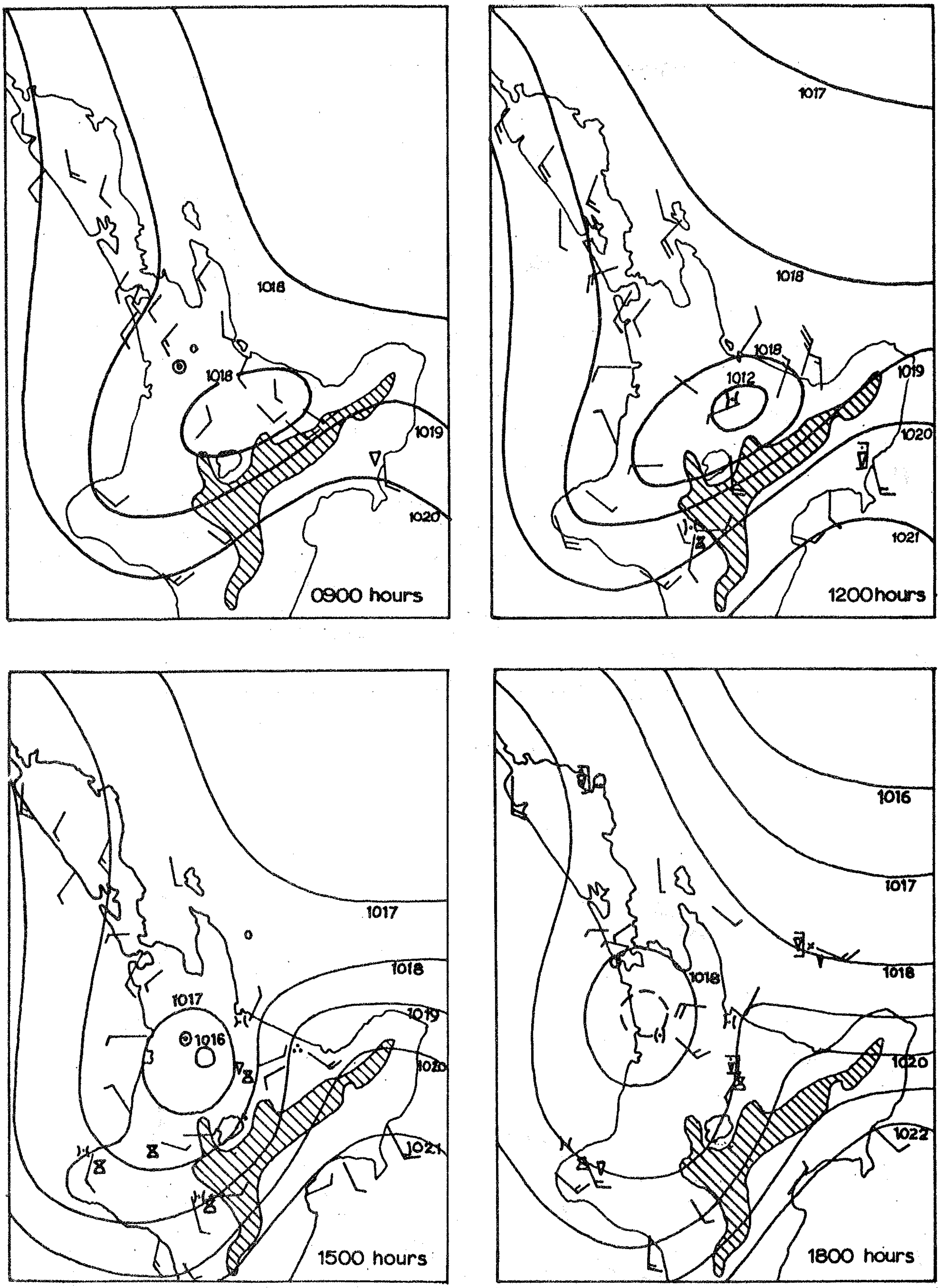
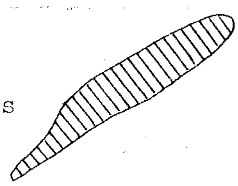


Fig. 3. M.S.L. Pressure Field 31 October, 1966

Principal mountain ranges 

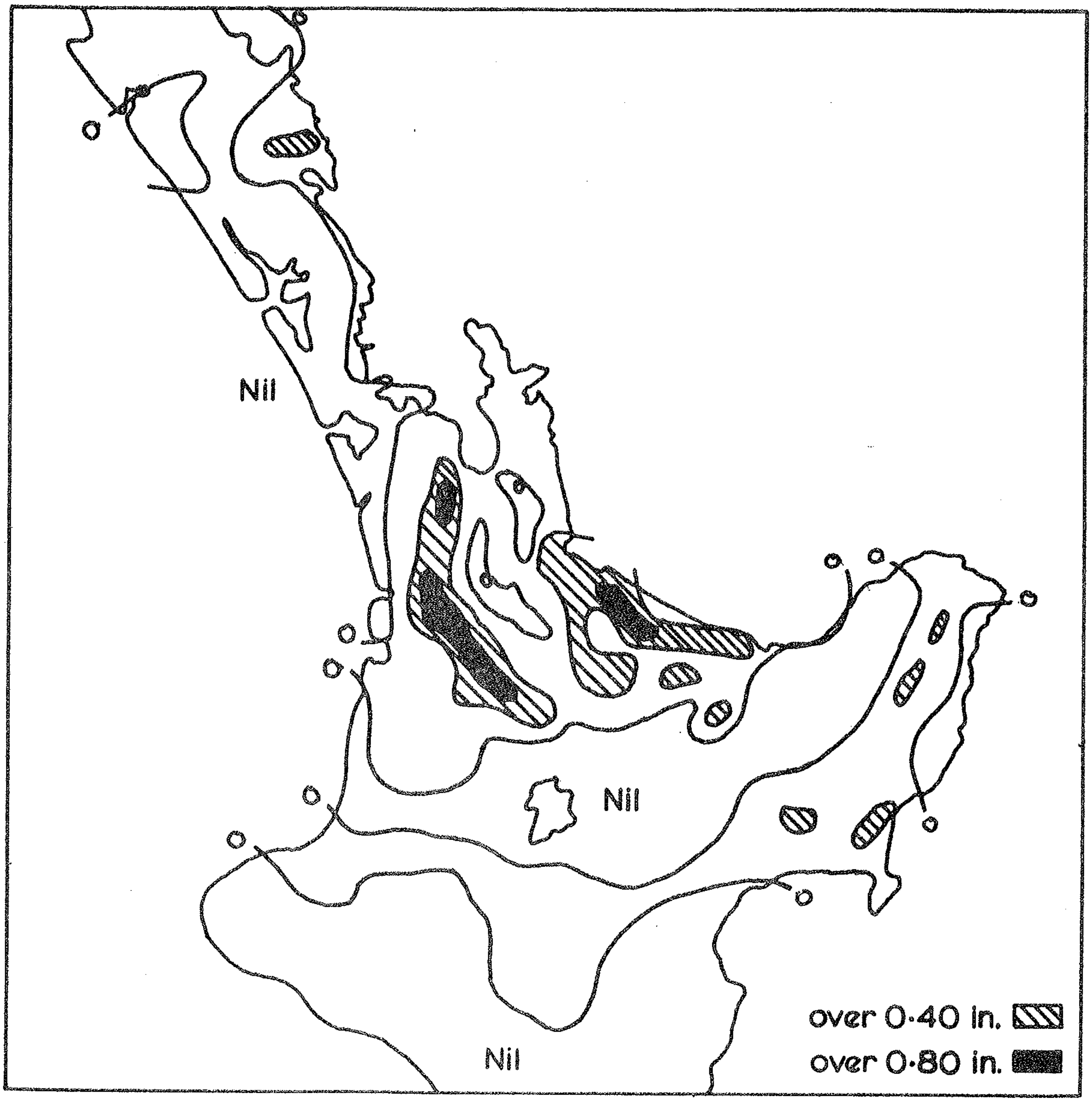


Fig. 4. Rainfall for 24 hours ending 0900 N.Z.S.T.
1 November, 1966

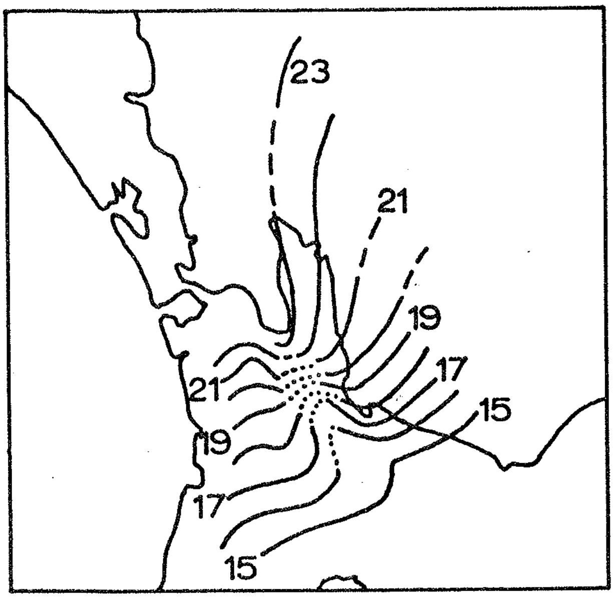


Fig. 5. Isochrones of passage of instability line.
Times in hours N.Z.S.T.

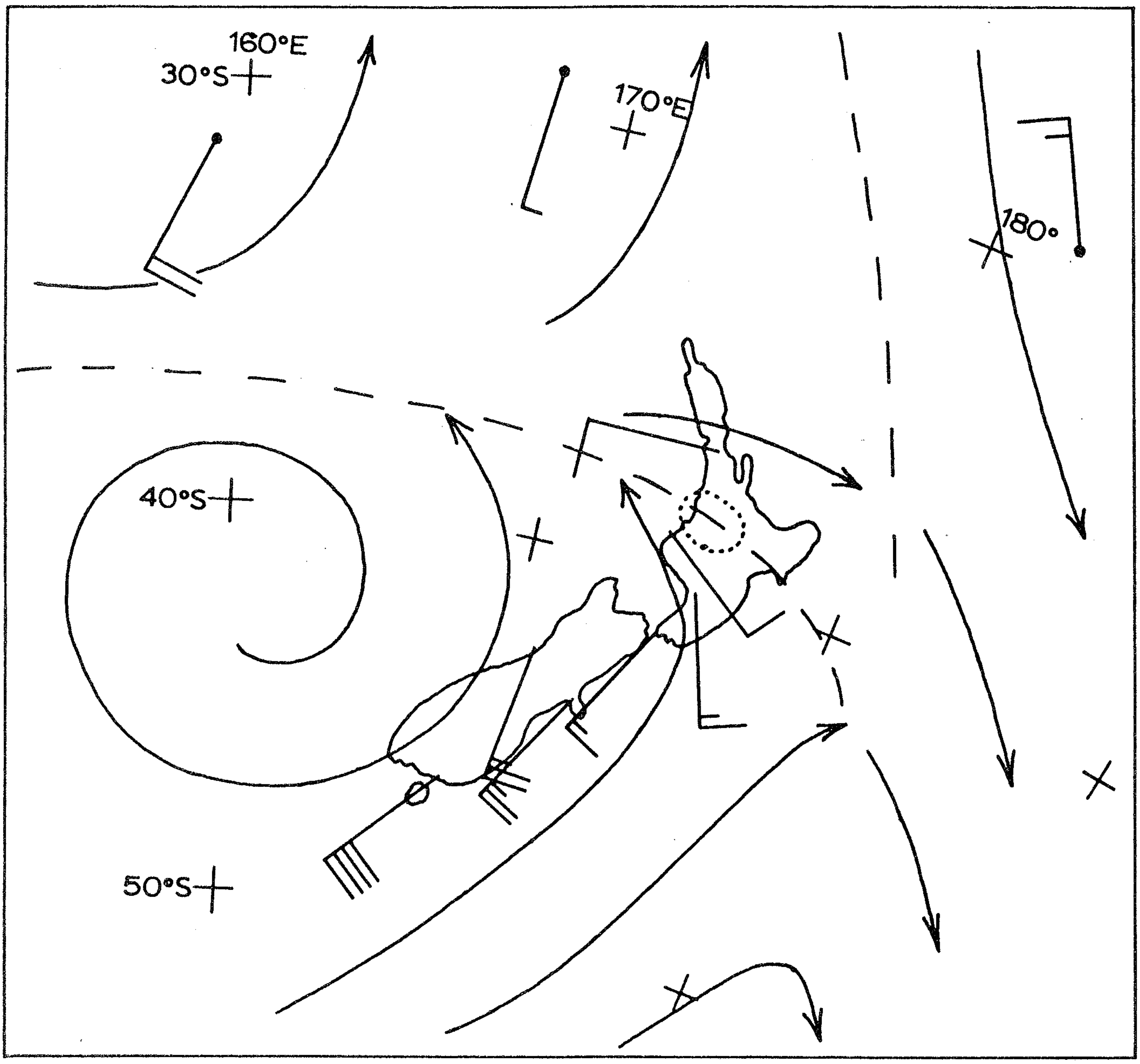


Fig. 6. 700mb Streamlines at 1200 hours 31 October, 1966.

Main discontinuities

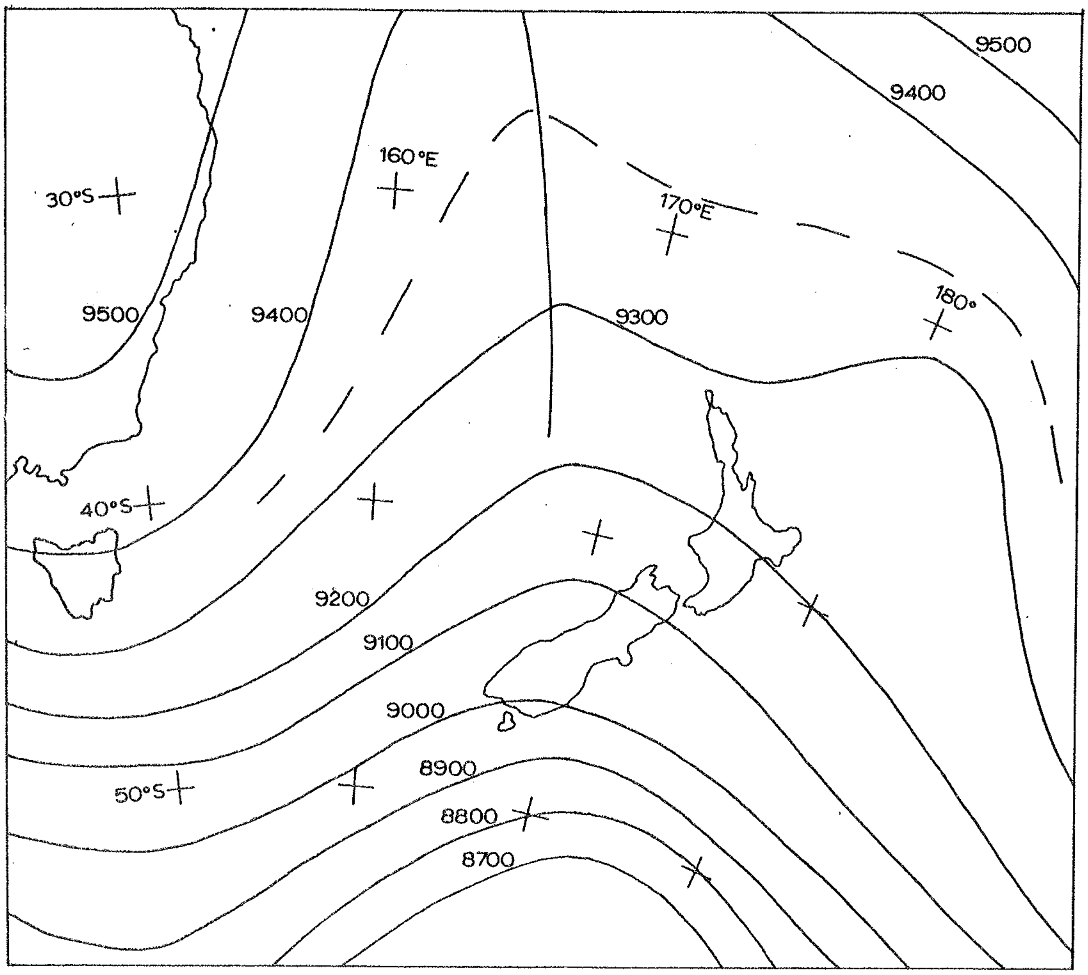


Fig. 7. (a) 300mb Analysis 1200 hours 30 October, 1966

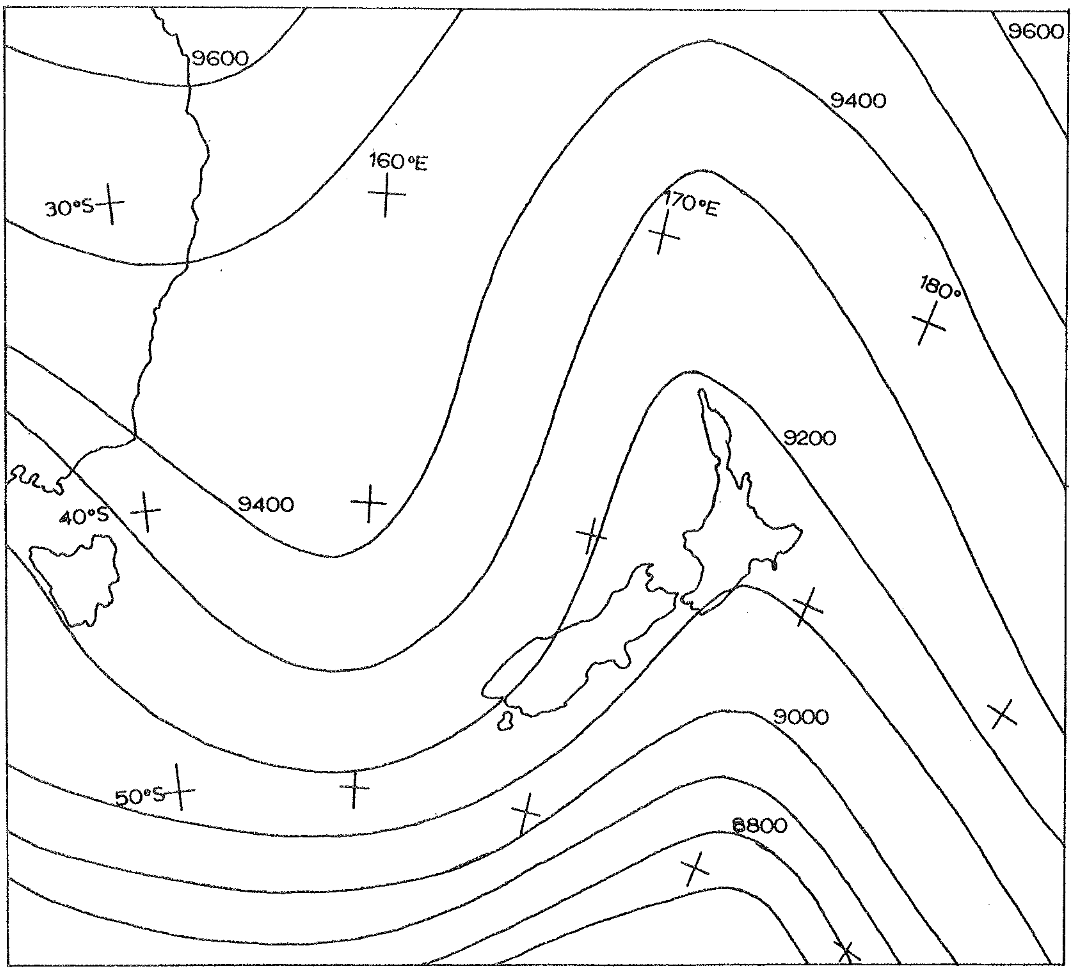


Fig. 7. (b) 300mb Analysis 1200 hours 31 October, 1966

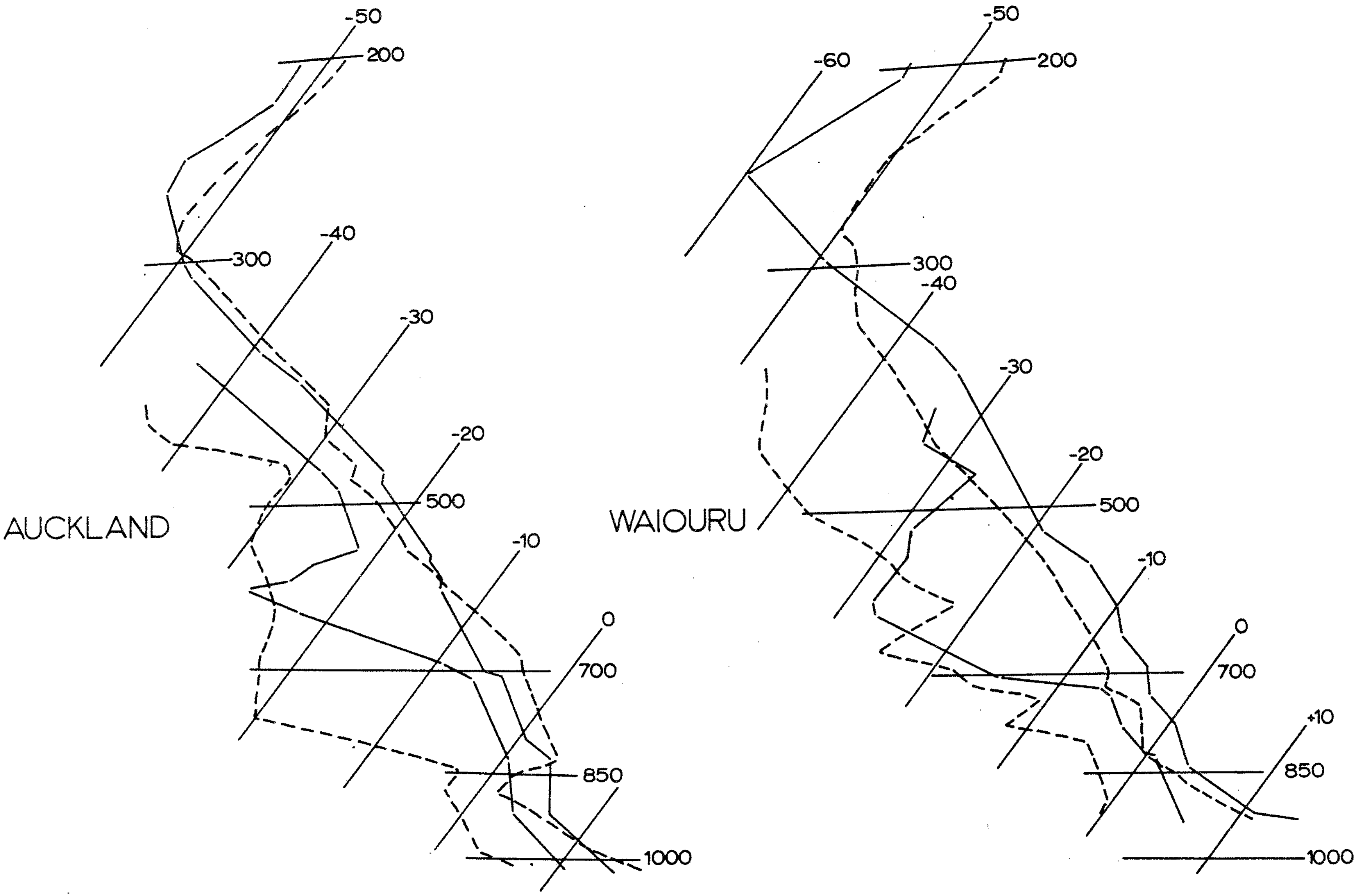


Fig. 8. Dry Bulb and Dew Point Temperature Soundings:

Auckland ——— 00 hours N.Z.S.T. 31 October, 1966   Waiouru ——— 12 hours N.Z.S.T. 30 October, 1966

- - - - - 12 hours N.Z.S.T. 31 October, 1966   - - - - - 12 hours N.Z.S.T. 31 October, 1966