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CONVECTIVE PRECIPITATION IN A DRY SUMMER

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CONVECTIVE PRECIPITATION IN A DRY SUMMER

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Abstract

In a drier-than-normal summer month characterised by periods of low dew-point depression, separated by frontolytic trough passages with brief moist intervals, the precipitation which fell over the central and northeastern part of the North Island during one nine-day inter-trough period was predominantly convective in character and varied considerably both in time and space. While some regions, both coastal and about the inland ranges, experienced no rain, there were falls of over three inches inland and over two inches about the coast; representing between 40 and 60 per cent of the average monthly rainfall.

Differential heating led to both (a) afternoon and evening showers, predominantly over the inland high country, and (b) overnight showers when convection over the sea after sunset led to the development of precipitating cumulus clouds that advected across adjacent land areas. The troposphere between the surface and 500 mb, while containing a similar quantity of water vapour to that present on the average during the same month in the previous five years (three of which were wetter than normal), was further than usual from saturation because temperatures were generally two to three degrees Celsius higher than average.

These conditions caused afternoon and evening showers to be less widespread than normal, being restricted to those regions where the input of heat at the surface was large enough to provide sufficient energy to enable the convective currents to break through the existing subsidence inversion and release the latent instability present in the atmosphere.

Introduction

January 1970 was dry and sunny over the North Island with rainfall for the month down to as little as 25% of normal. Long periods of large dew point depression were separated by frontolytic trough passages accompanied by brief moist intervals. Two such troughs passed on 19 and 29 January, and during the nine-day period between, precipitation over the central and northeastern part of the North Island was largely the result of convection. The purpose of this report is threefold: (1) to show the large variation in time and space that is characteristic of this type of precipitation; (2) to deduce that, because the troposphere was further than usual from being saturated, vigorous convection leading to afternoon and evening showers was less widespread than usual and restricted to those regions where sufficient heat energy, sensible and latent, could be made available to the convection currents to enable them to penetrate through the subsidence inversion and release the latent instability present in the atmosphere; and (3) to show that rain, occurring on several nights in Bay of Plenty was due, on this occasion, not to showers which originated inland in the afternoon and evening, but to convection after sunset over the relatively warm bay waters; showers from such a source advected across the coast in the synoptic-scale onshore wind flow.

Both Revell (1969) and Neale (1970) have investigated the occurrence of summer convection in the north of the North Island. In general these studies have been concerned with convection developing in association with weak synoptic-scale disturbances; however the present report deals with convection occurring in a predominantly anticyclonic regime.

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

Synoptic Situation

The general synoptic situation existing during the inter-trough period from 20 to 28 January is illustrated by a series of sea level and 500 mb analyses for 1200 hours daily (Figs 1 to 3). This period can be divided conveniently into three parts:

(1) the ridge period, commencing with the development on 20 January of a deep tropospheric ridge extending from the east onto northern New Zealand (Figs 1a, 1b), and continuing through to 23 January (Figs 2a, 2b);

(2) the transitional period, about 24 January (Figs 2c, 2d) when a weak frontolytic trough affected the east coast of the North Island while anticyclogenesis took place east of the South Island;

(3) the upper anticyclone period, lasting from 25 January (Figs 2e, 2f) through to 28 January (Figs 3e, 3f), during which time an upper level anticyclone covered the North Island while a surface ridge extended in from the east.

Rainfall Observations

Rainfalls for twentyfour-hour periods ending at 0900 hours daily were available from the network of reporting points shown in Fig. 4; some of these were equipped with automatic gauges which enabled an estimate to be made of the time and intensity of the rain. Additional information was available from synoptic reporting stations, from the author's observations in Bay of Plenty, and from weather surveillance radar reports; however, only the northwestern and southern extremities of the region came within range of this radar surveillance.

Places referred to in the text are shown in Fig. 5.

In the following discussion of each day's rainfall, the convention has been adopted of crediting each 24-hour rainfall to the date of the day on which the rainfall period began, e.g. rainfall for 21 January would be that measured in the period from 0900 hours 21 January to 0900 hours 22 January.

Rainfall 20 January (Fig. 6)

A ridge of high pressure, extending in from the east, became established over northern New Zealand, while a frontolytic trough passed away to the east and southeast of the country. A dry, subsiding west-southwest airstream covered the area under study, and only an isolated patch of light rain was recorded.

Rainfall 21 January (Fig. 7)

The ridge persisted and at sea level its axis moved slowly southwards in the region of the Coromandel Peninsula. A northwesterly airstream flowed over the area giving some widely-scattered patches of rain.

In the Thames-Paeroa region this rain fell in the afternoon and evening, while in the eastern Bay of Plenty it occurred at night (about midnight at Opotiki).

Rainfall 22 January (Fig. 8)

The sea level ridge continued its slow movement southward until it became almost stationary near Rotorua at 1800 hours.

Satellite pictures (not shown) at about 0800 hours and 1200 hours revealed that at the earlier time a fifty per cent overall cloud cover was evenly distributed over both land and sea, while four hours later the sea was relatively clear of cloud while the land area was more than half covered. Synoptic observations showed that this concentration of cloud continued in the afternoon; from a uniform

6/8 cover at 1200 hours over the western and southern Bay of Plenty, the central plateau and adjacent ranges, cloud decreased first near the coast and later some distance inland. The author's observations in eastern Bay of Plenty indicated little low cloud during daylight, with the vertical depth of this cloud decreasing as the day progressed. By evening the main cloud concentration was in the area of the central plateau, followed there by rain from about 1900 to 0300 hours the following day.

As on the previous day, rain in the Thames-Kaimai region fell in the afternoon and evening.

In Bay of Plenty the rain fell at night (from about 0000 to 0500 hours) while at East Cape rain was reported at 2100 hours.

Rainfall 23 January (Fig. 9)

The ridge, slow-moving at sea level near Rotorua, maintained its intensity while anticyclogenesis occurred east of the South Island. Satellite pictures (Fig. 10) show a frontal cloud band on the northern side of the region of anticyclogenesis. By 1200 hours rising pressures had appeared over eastern New Zealand on the northern side of this frontal cloud; the leading edge of this pressure surge was marked by a band of broken cumulus visible on the satellite picture (Fig. 10b). As this pressure surge travelled northwards over Hawke's Bay in the afternoon, diurnal heating over the land increased the instability of the atmosphere, especially about the ranges where rain commenced as early as 1100 hours at Gwavas in the south, and reached Esk and Onepoto about 1400 hours. Some showers spread later to coastal areas, affecting the Napier region about 1700 hours and Wairoa at 2200 hours. These coastal showers lasted only a few hours, but about the ranges rain continued through the night and into the next day; this rain initially the result of convection, turned into an orographically induced fall following the development of onshore southeasterly winds behind the pressure surge.

As was the case on the previous day, rain over the central plateau fell in the evening and night from about 1900 to 0400 hours. The surface southeasterly airflow, behind the east coast pressure surge, became established over the eastern part of the plateau an hour or two before the onset of the rain and could have increased the intensity of the convection currents since one locality recorded a fall of 2.20 inches.

Rain in the Gisborne district fell principally between 1300 and 2300 hours, before the arrival of the pressure surge, and was apparently the result of diurnal heating. Scattered rain which fell from midnight to beyond 0900 hours can be attributed to orographic effects in the post-surge southeasterly flow.

For the third night rain fell in Bay of Plenty; this time it occurred between about 2000 and 0300 hours.

Rain in the Tauranga-Coromandel region commenced about 0500 hours and continued past 0900 hours. It was due to the advection from the east of a moist region of air visible as a localised cloudy area in the satellite pictures. This cloudy region lay over the sea east of Coromandel on the morning of 23 January (Fig. 10a), and by midday the following day had moved onto the Coromandel Peninsula (Fig. 11a).

Rainfall 24 January (Fig. 12)

Rain was more widespread than on the other days, and this coincided approximately with the 'transitional period' referred to in the section on Synoptic Situation. Anticyclogenesis was continuing in the area between New Zealand and Chatham Islands, while the frontolytic cloud band remained near the east coast of the North Island (Fig. 11a).

In Hawke's Bay the predominantly orographic rains continued from the previous night, becoming partly convective in nature in the afternoon and evening before a clearance occurred about midnight. This cessation of rain was due as much to the synoptic-scale wind flow changing from onshore to offshore, as to the ending of diurnal heating.

Over the central plateau the sequence was almost identical to that of the previous days, with rain falling between about 1700 and 0500 hours.

Rain in Bay of Plenty and Gisborne fell principally after sunset, commencing about 2000 hours and lasting until 0600 hours.

Some destabilisation of the troposphere in the transitional period, when one anticyclonic regime was replaced by another, accounts for the increase in intensity and extent of the showers in Bay of Plenty and over the central plateau. An indication of the intensity of the convection on this day is given by the occurrence of a thunderstorm at Taupo and the recording, on weather surveillance radar, of echo tops to 29,000 ft over the plateau.

Rainfall 25 January (Fig. 13)

The ridge of high pressure at sea level became reestablished over Bay of Plenty while an upper level anticyclone developed over the North Island. The subsidence accompanying the development of this system prevented showers from forming over most of the region; however, about the central plateau there was usual diurnal variation resulting in rain developing between about 1200 and 1800 hours and lasting until 0600 hours.

Rainfall 26, 27 and 28 January (Figs 14 to 16)

The anticyclonic system completely dominated the region over these three days, and despite a weakening that set in on the last day with the approach from the west of the next low pressure trough, rainfalls each day were isolated and light.

A satellite picture taken at midday 27 January (Fig. 11b) shows the central and eastern part of the North Island to be completely clear of cloud; a condition which was typical of these three days.

Figure 17 shows the total rainfall occurring during the nine-day period from 0900 hours 20 January to 0900 hours 29 January. This illustrates not only the considerable spatial variation in the rainfall distribution, but also the absence of any marked orographic bias.

Discussion

Figure 18 shows, day by day, the times when the main rain fell over the several parts of the region under study. In Hawke's Bay there was a period of rain lasting over twentyfour hours and associated with the arrival of a decaying frontal cloud band; although this rain had a convective character at times, especially when it commenced, there was a definite contribution caused by the ascent of moist air passing over the ranges. The Gisborne rains were less prolonged but rather similar in character to those in Hawke's Bay. Over the Coromandel-Kaimai area, the advection from the east of a localized moist region gave showers one morning, otherwise showers occurred in the period from midday to late at night.

It was over the central plateau and Bay of Plenty that there was a very marked preference for rain to fall at a particular time of day. In Bay of Plenty rain fell at night and into the early morning, while over the central plateau it fell in the afternoon-evening-night period.

Although showers which develop over the main ranges in the afternoon and evening do sometimes drift across Bay of Plenty at night, such an occurrence definitely did not take place on this occasion; firstly the wind-flow throughout the troposphere did not contain an offshore component, and secondly, personal observation by the author confirmed that precipitating cumulus moved southwards from their region of origin over the waters of the bay.

These showers in Bay of Plenty occurred on four nights, 21 to 24 January, when, except for a temporary destabilisation of the troposphere on 24 January, a subsidence inversion was present between 800 mb and 650 mb at both Auckland and Waiouru (Fig. 19). During this four-day period, convective condensation levels at Auckland were between 2000 and 3000 feet, while the mean subsidence inversion level was just below 700 mb. If allowance is made for, (1) some penetration of the inversion by the rising cloud before entrainment of dry environmental air and lack of buoyancy arrest its ascent, and (2) an enhancement of the convection near the coastline due to the increased low level convergence brought about by the change in surface friction as air flows from sea to land, then cumulus clouds with a vertical depth of at least 10,000 feet could have occurred over coastal areas of Bay of Plenty. As these clouds advect further inland they encounter an increasingly hostile environment; not only is there no surface moisture source, but the clouds are approaching the dry, subsiding part of the land-breeze regime. For these reasons rainfall amounts tend to diminish with increasing distance from the coast.

In the anticyclonic regimes which prevailed at this time, the level of the dry, stable layer, or subsidence inversion lay at or below the 700 mb level; this placed an upper limit on the height to which most convective clouds could rise, and in fact, except for the temporary destabilization of the troposphere during the transition from one anticyclonic regime to another, cumulus clouds over the high country of eastern Bay of Plenty and Gisborne were restricted to very shallow, non-precipitating clouds.

Figure 19 shows that while the convective condensation level was near to or above the level of the subsidence inversion on days when significant precipitation was not recorded over the central plateau, it was below the level of the subsidence inversion on those days when appreciable rain fell over the plateau. Some of these latter days were also occasions when only very shallow cumulus occurred over the ranges further east. It is suggested that the plateau, acting as a high-level heat source, imparted sufficient energy to the convective currents to enable them to break through the dry, stable inversion layer and realise the latent instability present in the atmosphere.

Table 1 shows the average temperature and humidity at standard levels in the troposphere up to 500 mb, and allows a comparison between conditions during (a) the nine-day period 20-28 January, 1970, (b) the whole of January 1970, and (c) the average of the last five Januarys - 1966-1970.

Standard Level	Average 20-28 Jan.1970			Average January 1970			January Average 1966-1970		
	TT	MR	RH	TT	MR	RH	TT	MR	RH
1000mb	23	12.3	73	21.3	11.5	73	19.5	10.7	77
850mb	12	6.8	66	11.2	5.8	62	9.6	5.5	65
700mb	5	2.4	-	3.8	2.3	-	3.3	2.4	-
500mb	-10	0.8	-	-11.9	0.8	-	-12.8	0.9	-

TABLE 1. Average values of temperature (TT), mixing ratio (MR), and relative humidity (RH) at standard levels in the atmosphere.

Climatological summaries for these five Januarys show that two were drier, and three wetter than normal, so that any bias in the averages is likely to be towards wetter-than-normal conditions. However, it is apparent that at 500 mb and 700 mb the water vapour content of the air (mixing ratio - given in gms of water vapour per kgm of dry air) was almost the same in January 1970 as the average for the last five Januarys, while in 1970 there was more water vapour at 1000 mb and 850 mb than in the earlier Januarys.

The southern hemisphere as a whole, and the New Zealand area in particular, is an oceanic region, and consequently it is not surprising to find that the amount of water vapour in the lower part of the troposphere varies little from one January to the next. What is significant in Table 1 is the variation in the temperatures between 1970 and the 5-year average; these were two to three degrees Celsius higher in 1970, and consequently the atmosphere was further from saturation than is usual in January.

Conclusions

January 1970 was a drier-than-average month with rainfalls in some northeastern and central parts of the North Island only 25% of normal. In the absence of general rain associated with synoptic-scale low pressure troughs, precipitation was of a predominantly convective nature and had, characteristically, a large variability in time and space.

Comparing January 1970 with the average of the past five Januarys (1966-1970), it was revealed that the lower part of the troposphere, from the surface to 500 mb, was further from saturation in 1970 than usual; this was not due to a decrease in the water vapour content of the air (which in fact tended to be greater in 1970) but to the fact that temperatures were two to three degrees Celsius higher than normal.

Differential heating of the lower layers of the atmosphere led to two separate patterns of rainfall which recurred on several days in different localities. During the daytime, heating of the land surface led to convection over the inland high country, but in general the anticyclonic subsidence prevented the development of cumulus deep enough to produce precipitation; only over the central plateau region, where the extended high-level heat source provided enough energy, were the rising currents of air able to break through the inversion and realise the potential instability available in the atmosphere.

In the evening, the cooling of the land areas adjacent to the waters of Bay of Plenty created a heat source over the bay which enabled cumulus clouds to develop there. Carried along by the gentle synoptic-scale flow, these cumulus advected over the coastline with their height increased through the action of increased lower level convergence brought about by the change in surface friction. Rainfall from this mechanism occurred at night and was in general a maximum close to the coast and tended to decrease with increasing distance inland.

References

Neale, A.A., 1970: Modification of rainfall from a weak synoptic system by terrain and diurnal heating - a case study. N.Z.Met.S. Tech. Note No. 187 (Unpublished).

Revell, C.G., 1969: A case study of the meso-scale rainfall variations in northern New Zealand. N.Z.Met.S. Tech. Note No. 181 (Unpublished).

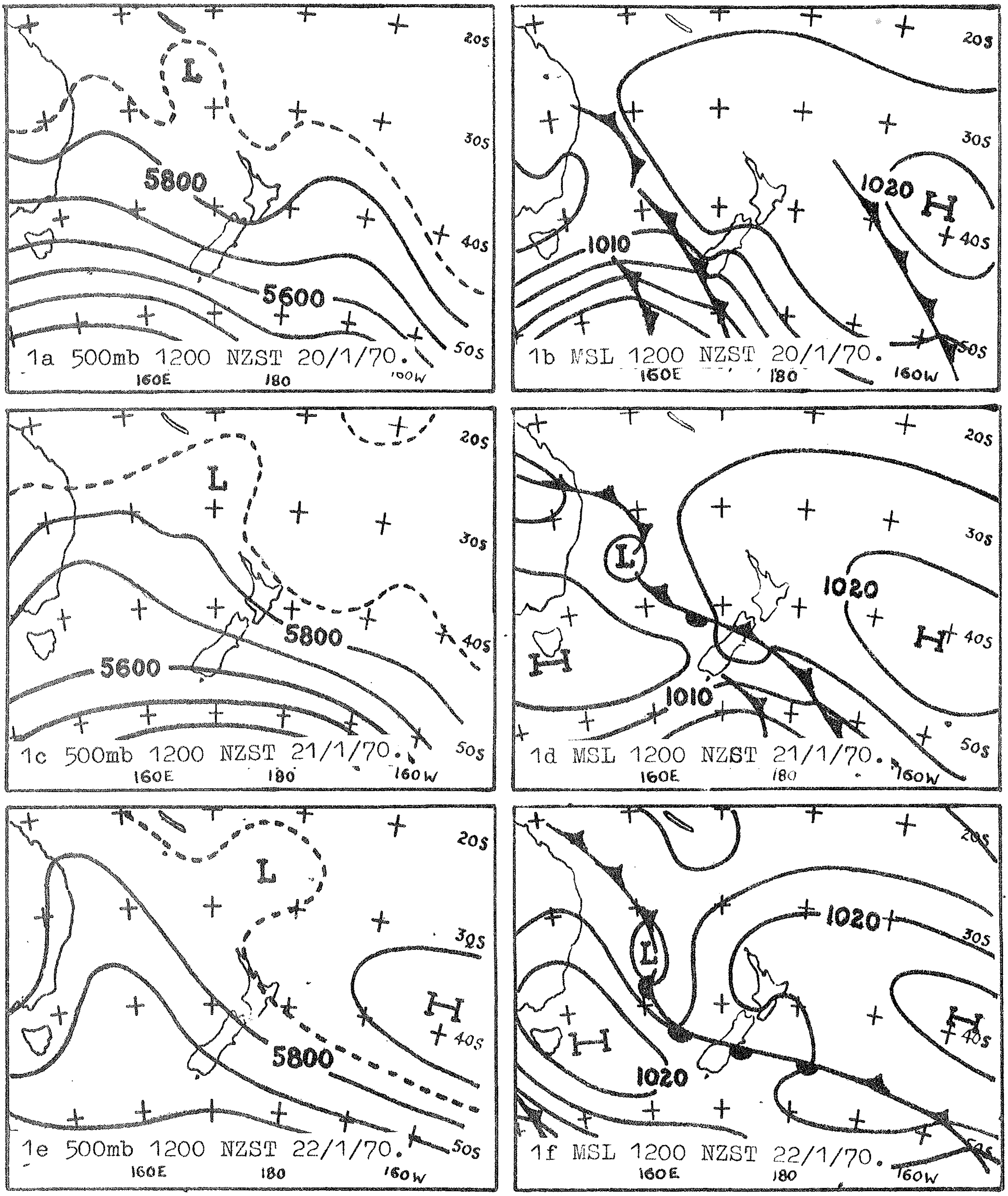


FIG.1. 500mb and MSL analyses 20-22 January 1970.

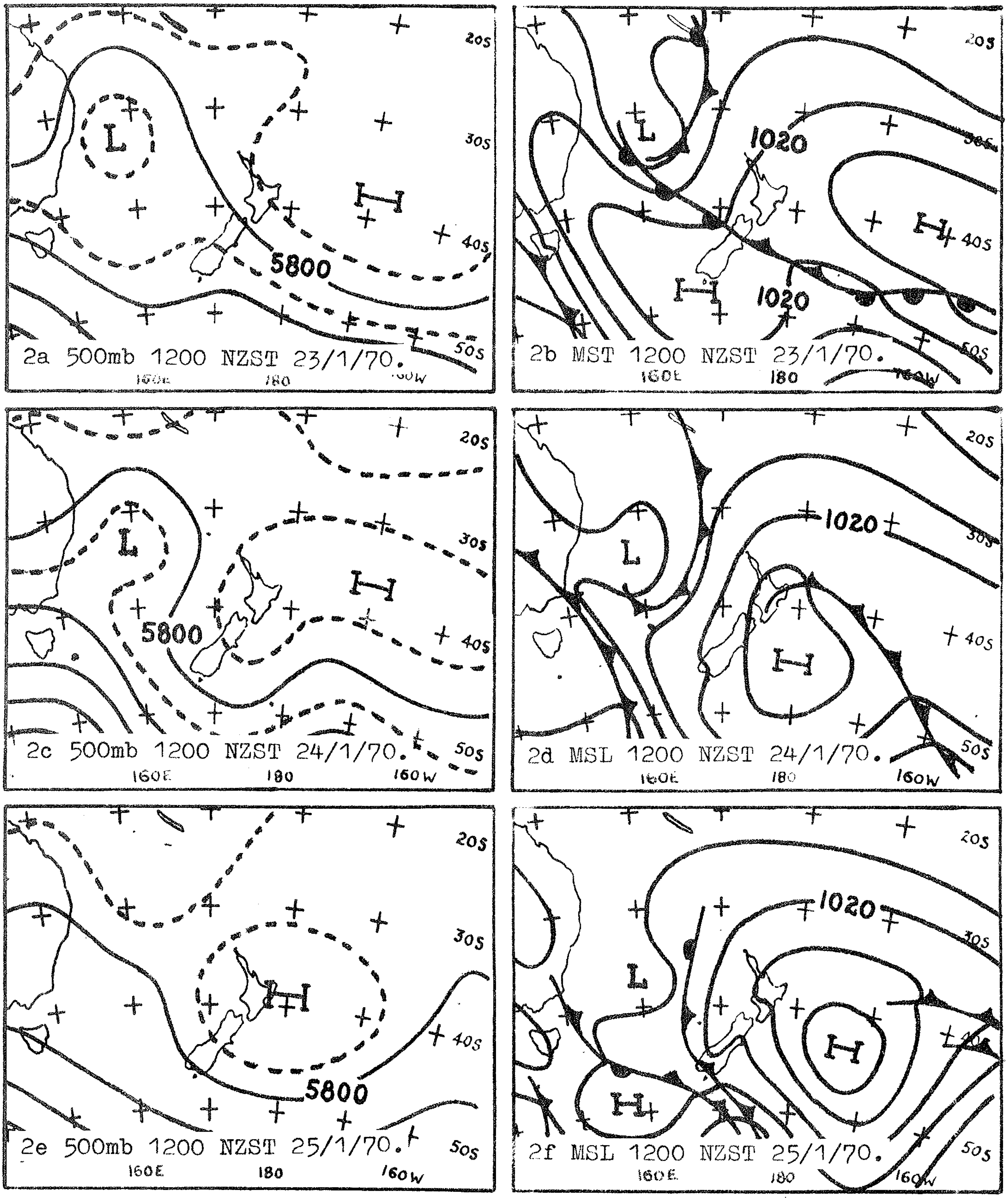


FIG.2. 500mb and MSL analyses 23-25 January 1970.

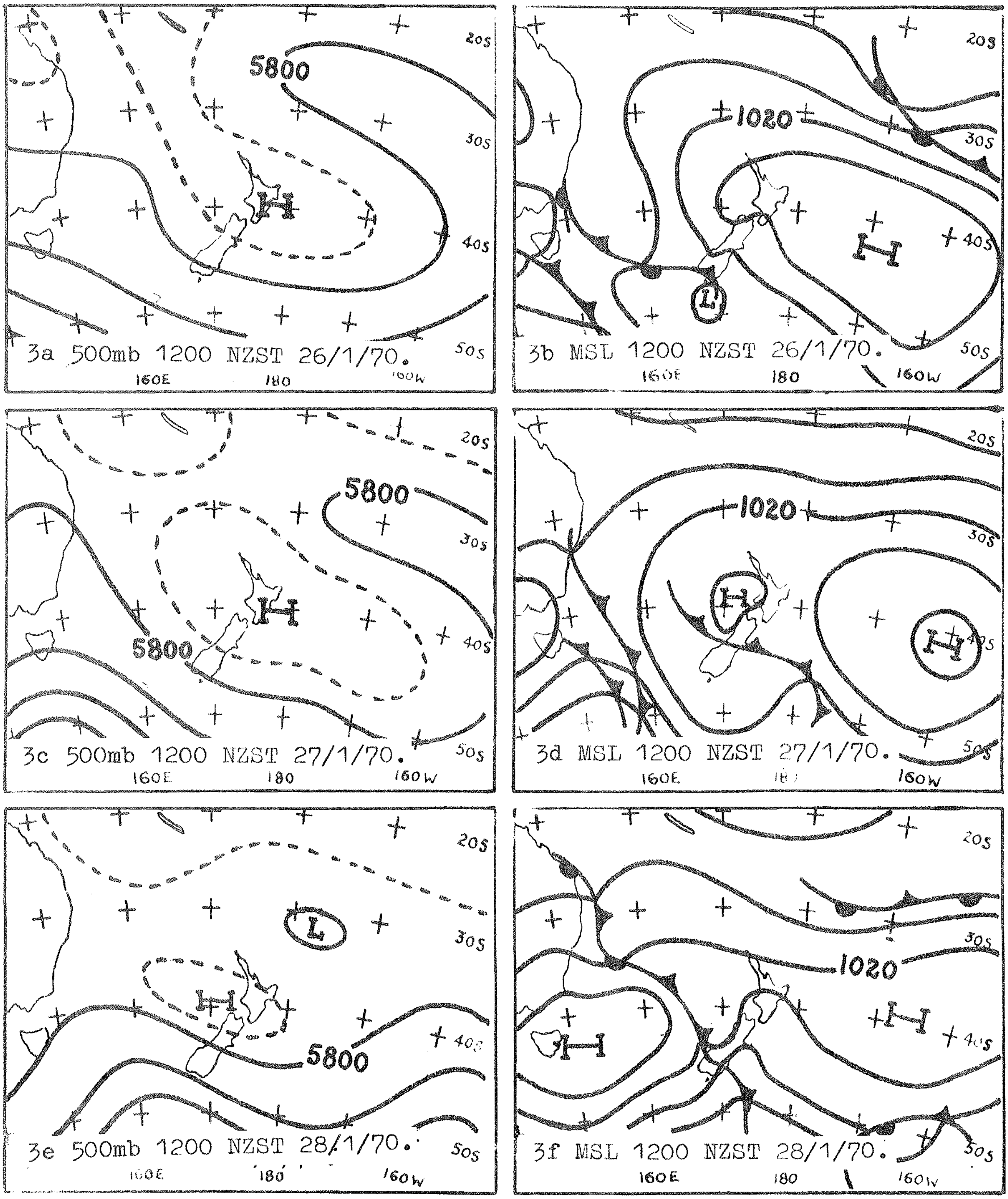


FIG.3. 500mb and MSL analyses 26 - 28 January 1970.

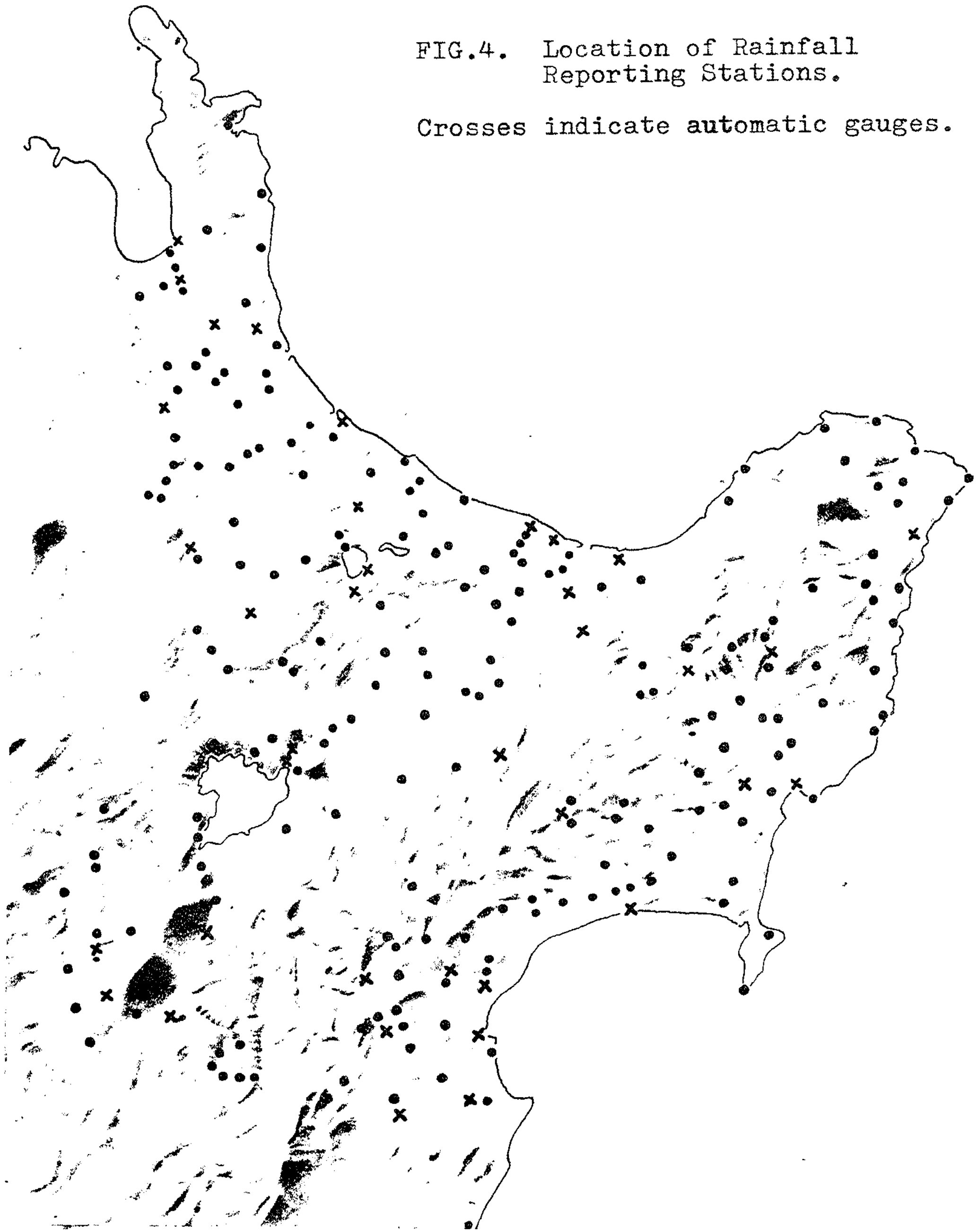


FIG.4. Location of Rainfall Reporting Stations.

Crosses indicate automatic gauges.

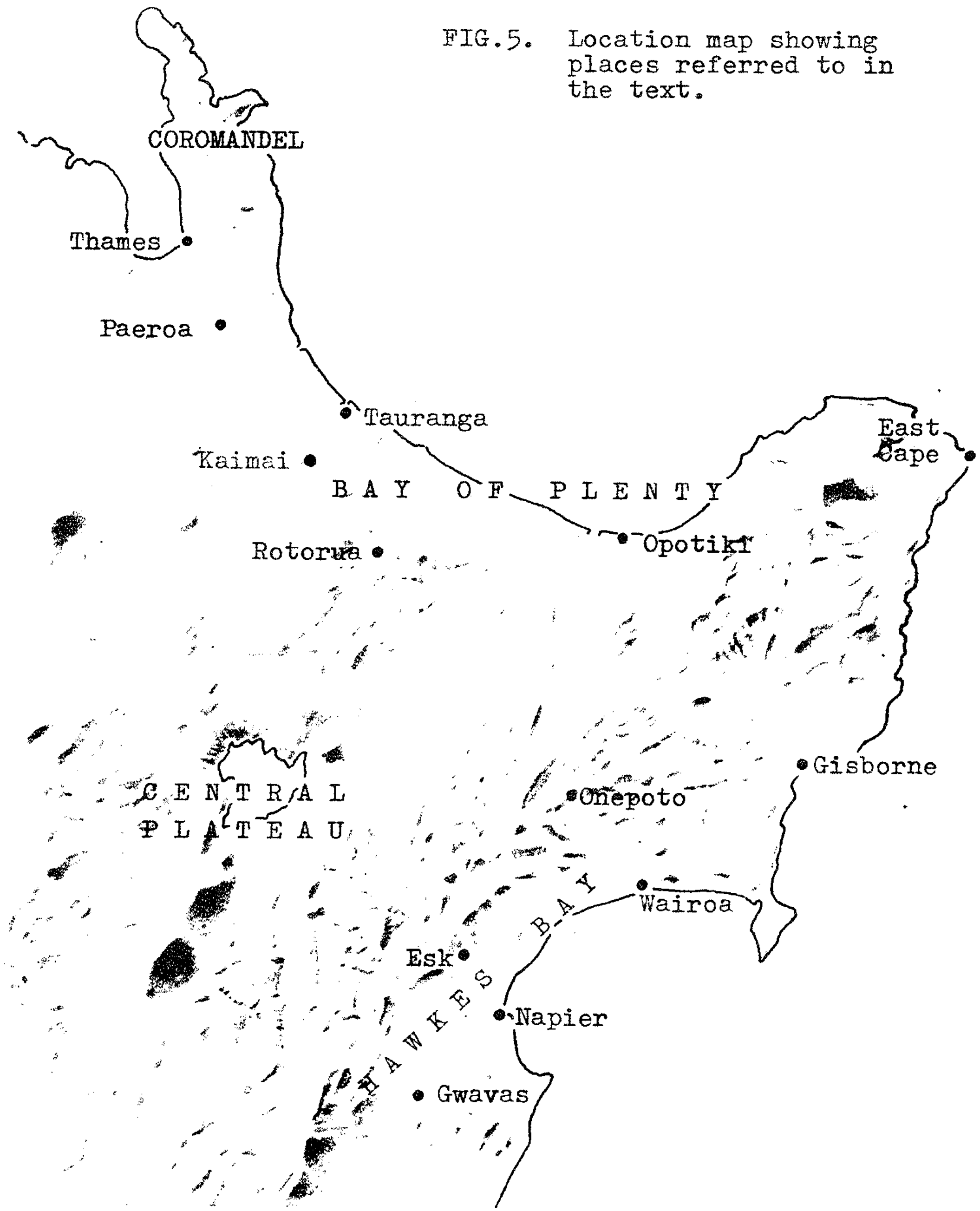


FIG.5. Location map showing places referred to in the text.

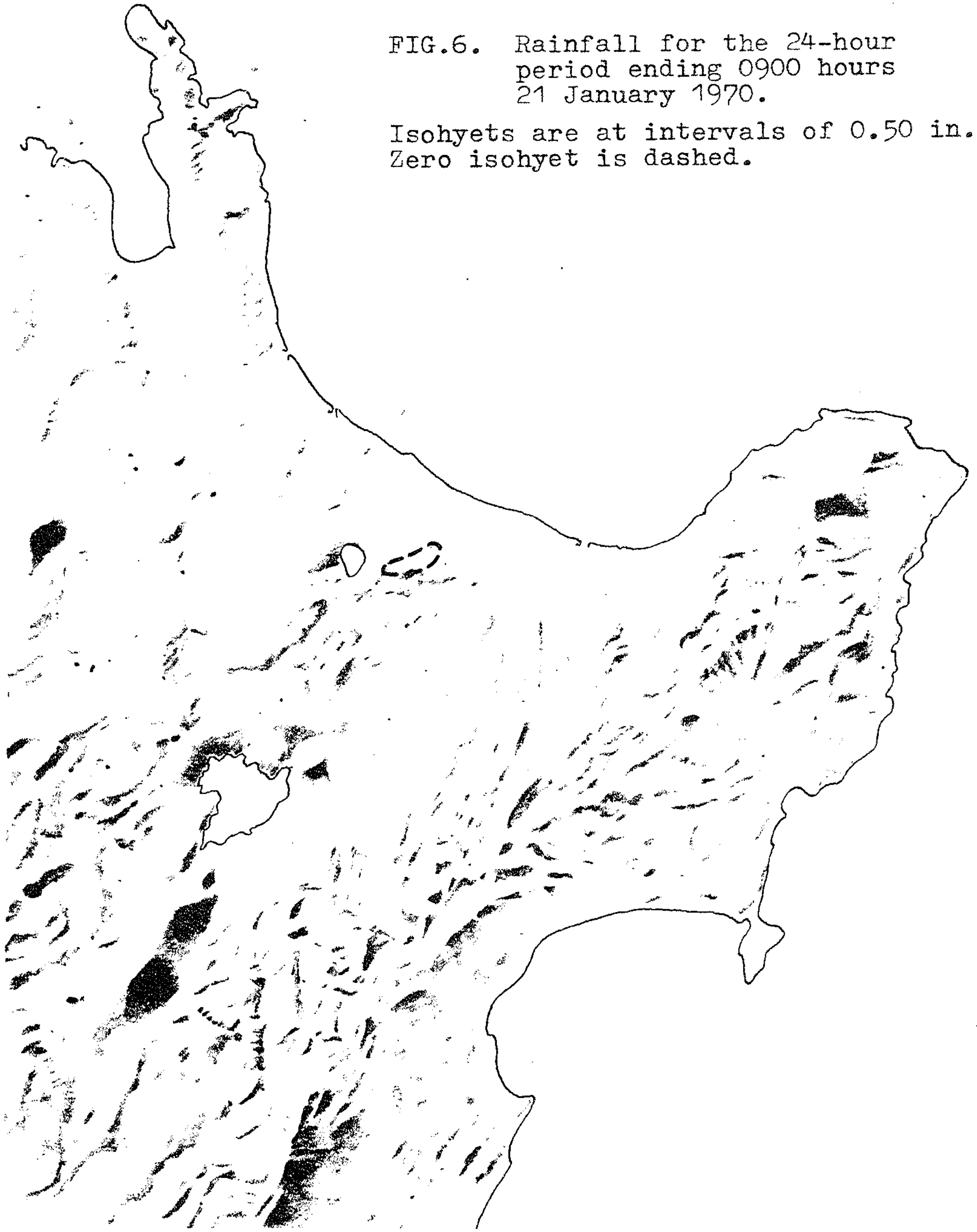


FIG.6. Rainfall for the 24-hour period ending 0900 hours 21 January 1970.

Isohyets are at intervals of 0.50 in. Zero isohyet is dashed.

FIG.7. Rainfall for the 24-hour period ending 0900 hours 22 January 1970.

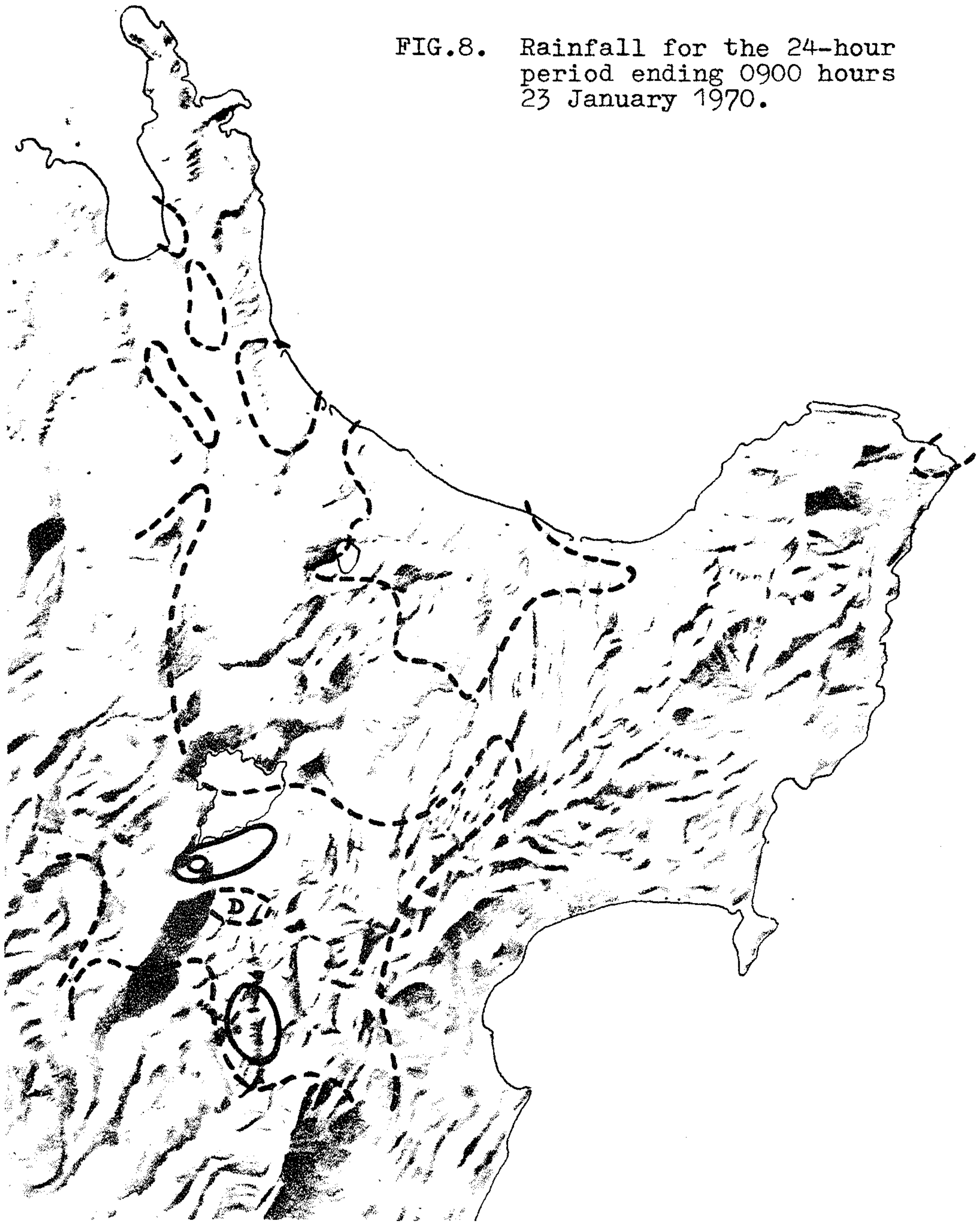


FIG.8. Rainfall for the 24-hour period ending 0900 hours 23 January 1970.

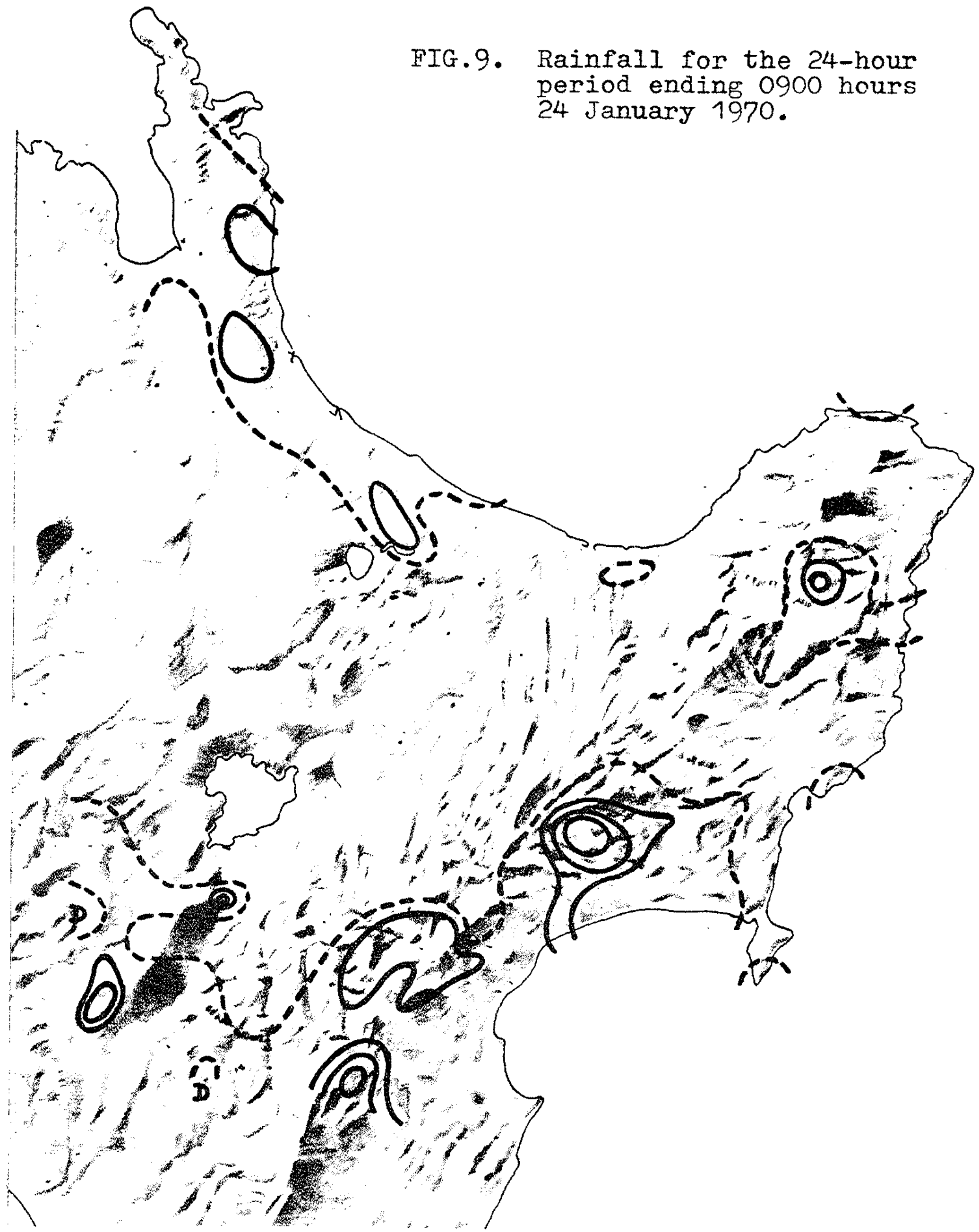
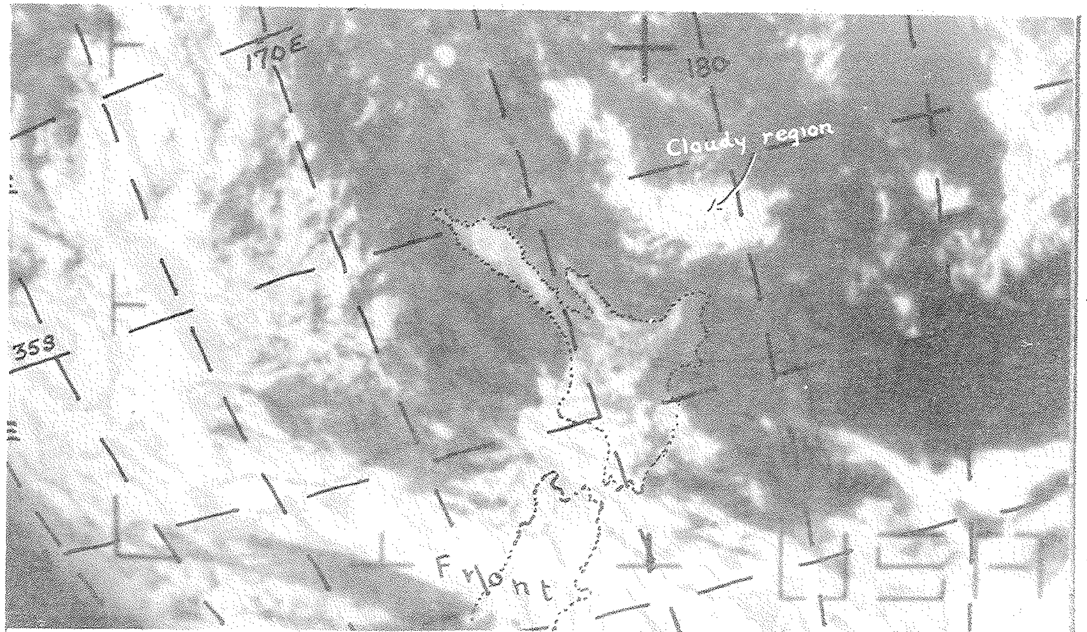
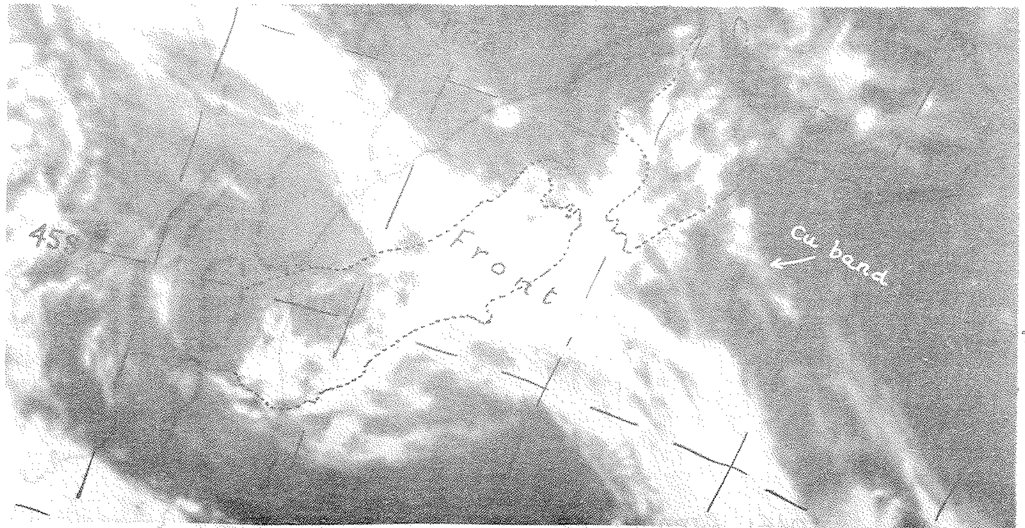


FIG.9. Rainfall for the 24-hour period ending 0900 hours 24 January 1970.

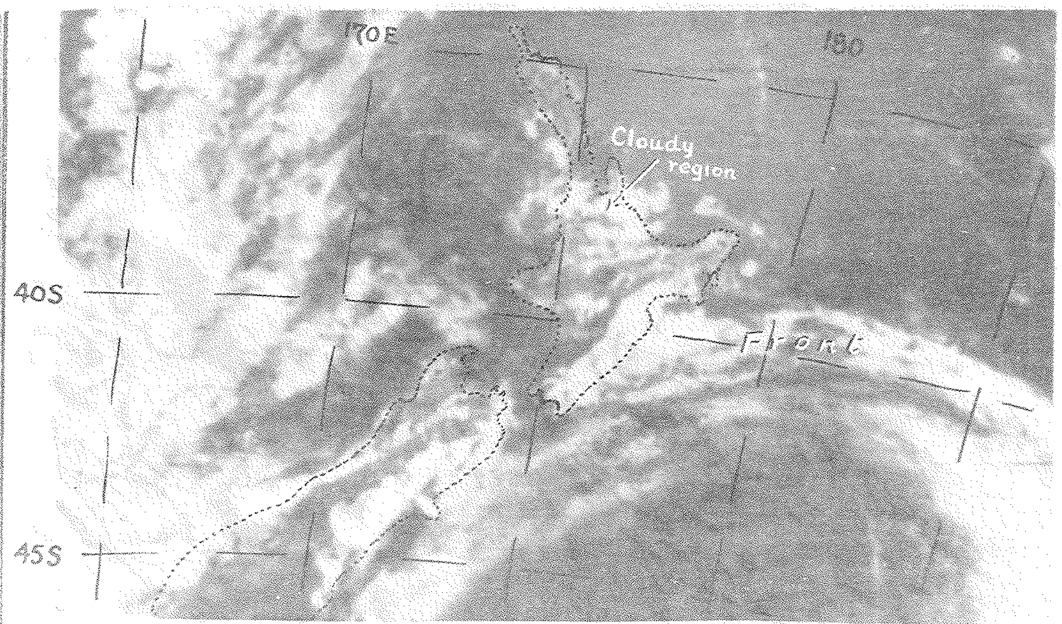


10a ESSA 8, Orbit 5061, 0854 hours 23 January 1970.

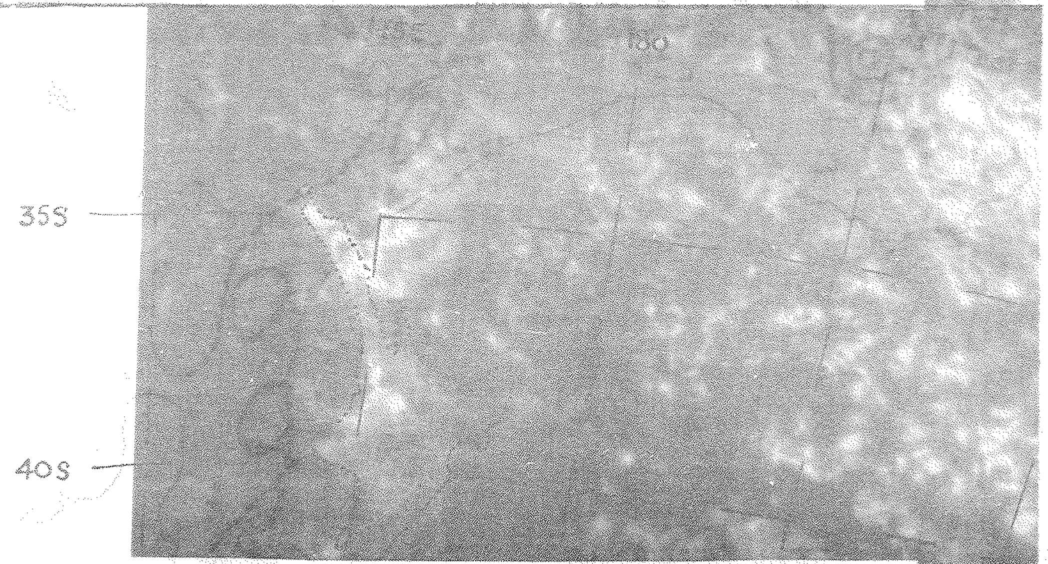


10b NIMBUS 3, Orbit 3803, 1245 hours 23 January 1970.

FIG.10. Satellite pictures of cloud cover in the New Zealand region.



11a NIMBUS 3, Orbit 3816, 1205 hours 24 January 1970.



11b NIMBUS 3, Orbit 3856, 1142 hours 27 January 1970.

FIG.11. Satellite pictures of cloud cover in the New Zealand region.

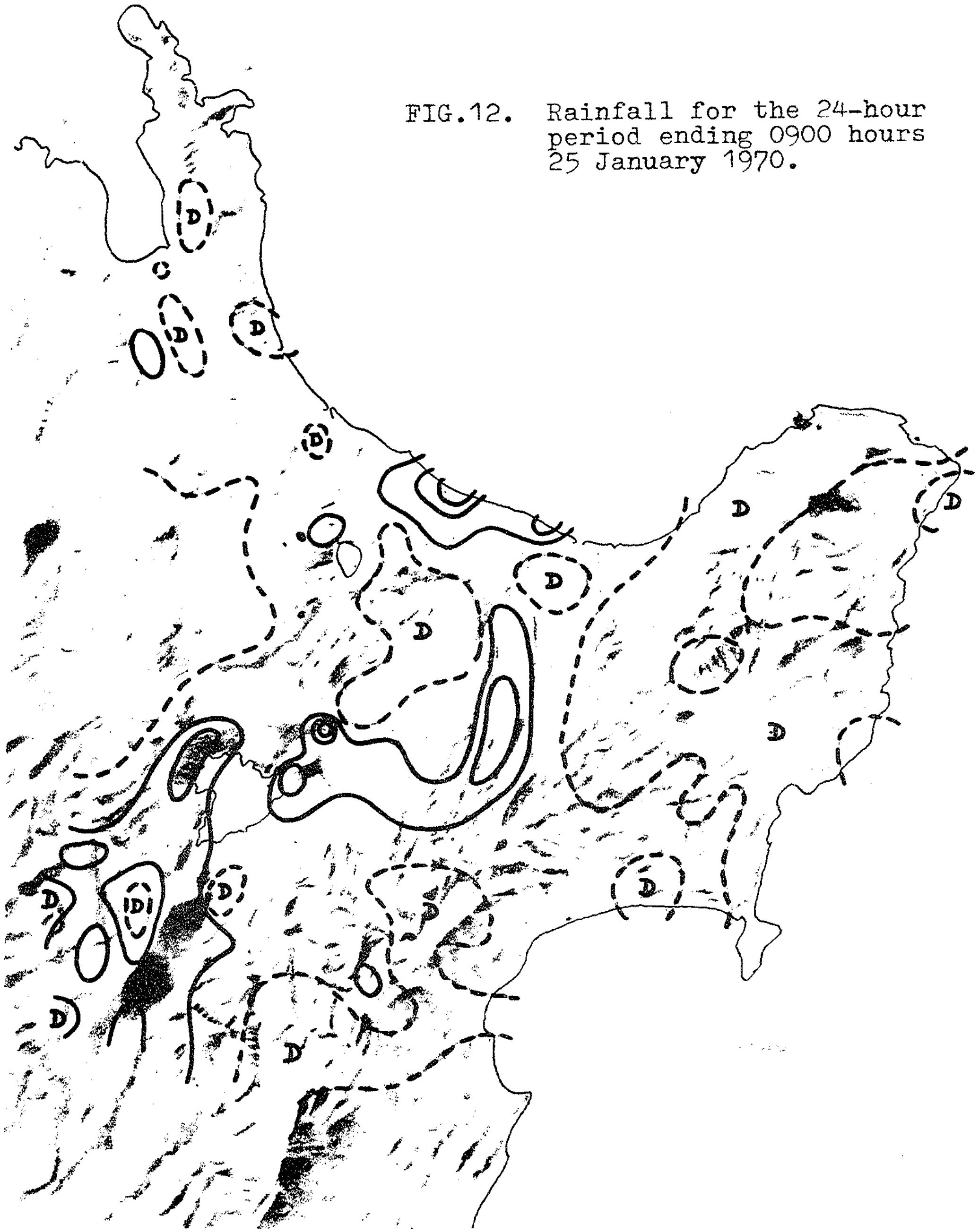


FIG.12. Rainfall for the 24-hour period ending 0900 hours 25 January 1970.

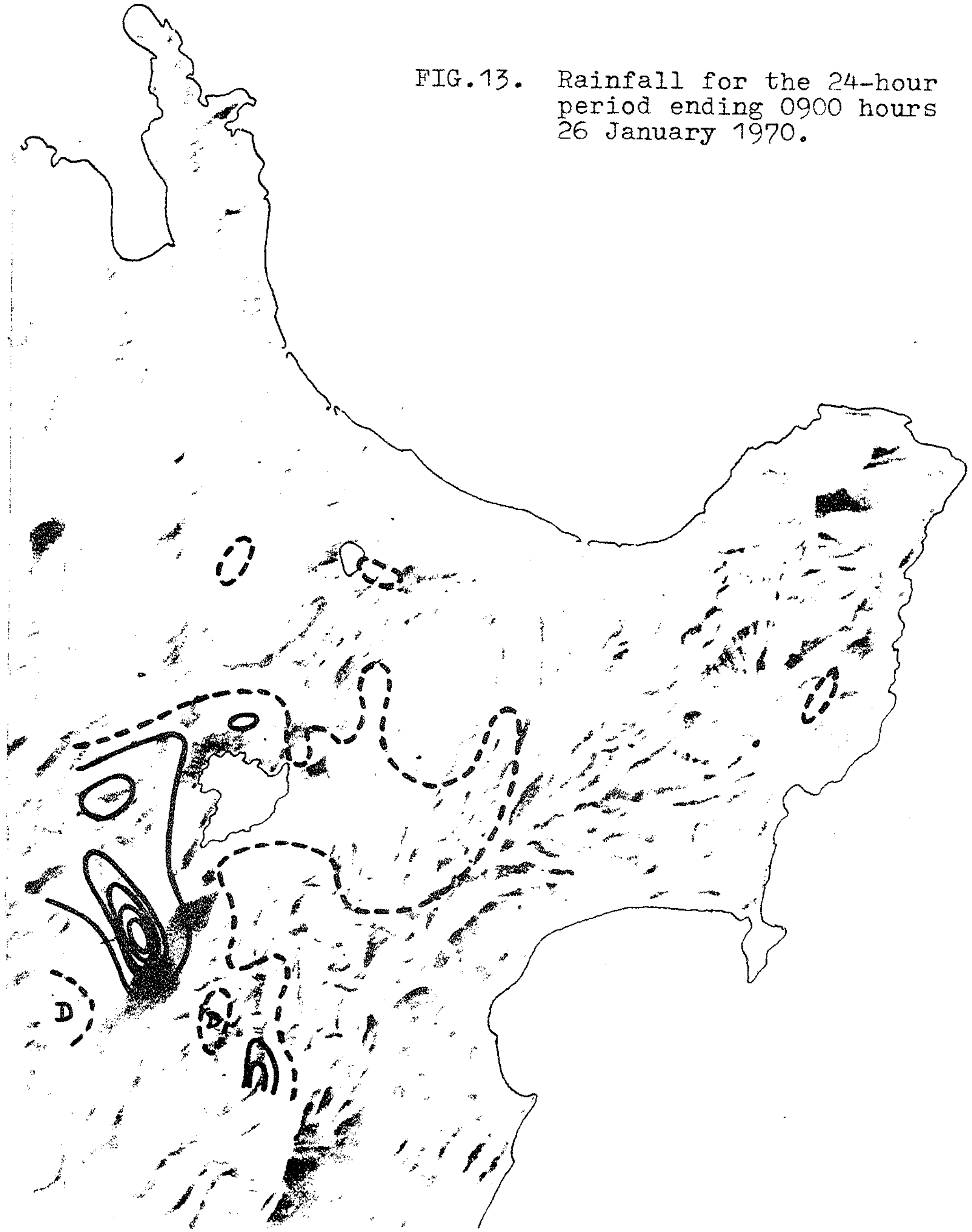


FIG.13. Rainfall for the 24-hour period ending 0900 hours 26 January 1970.

FIG.14. Rainfall for the 24-hour period ending 0900 hours 27 January 1970.

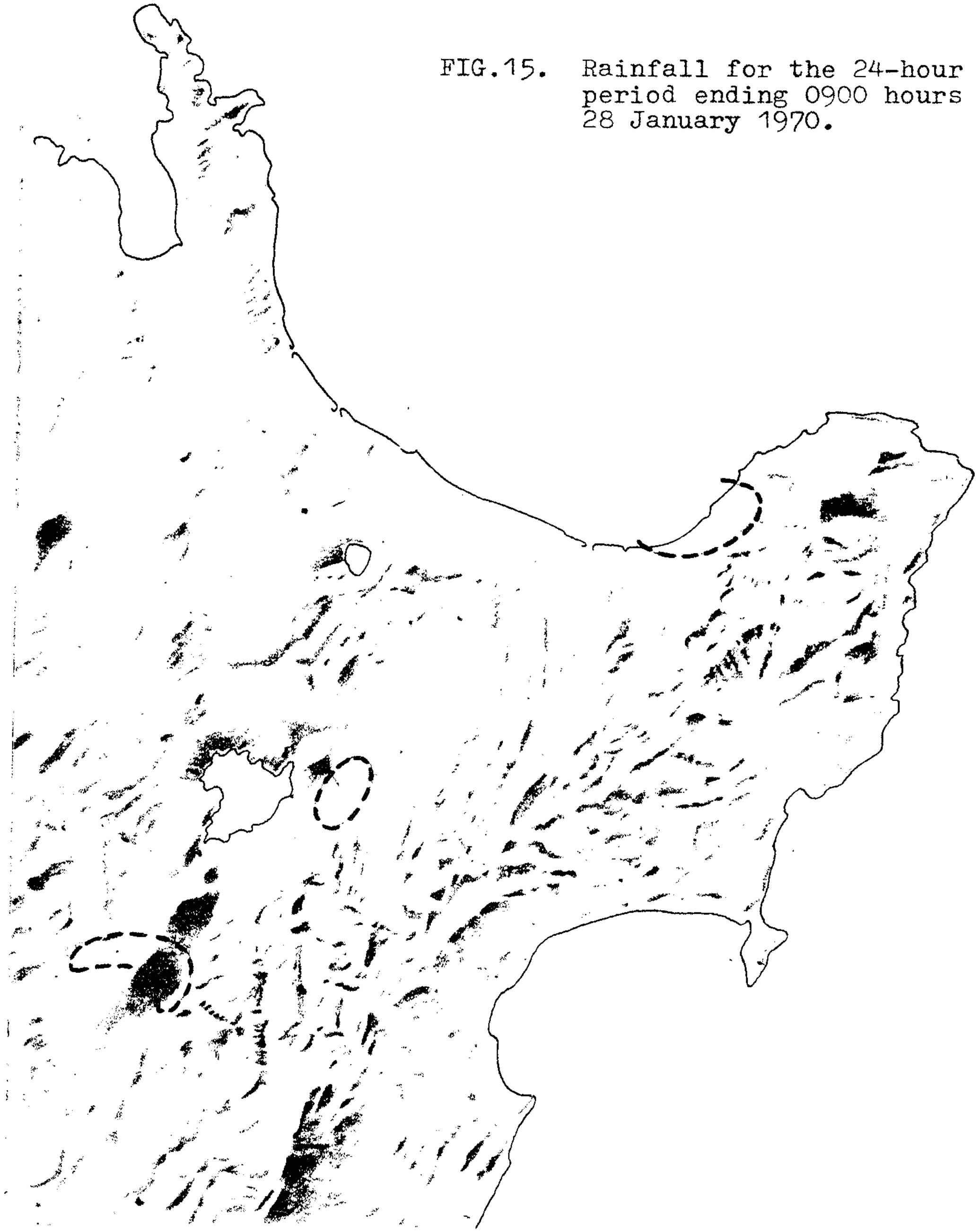


FIG.15. Rainfall for the 24-hour period ending 0900 hours 28 January 1970.

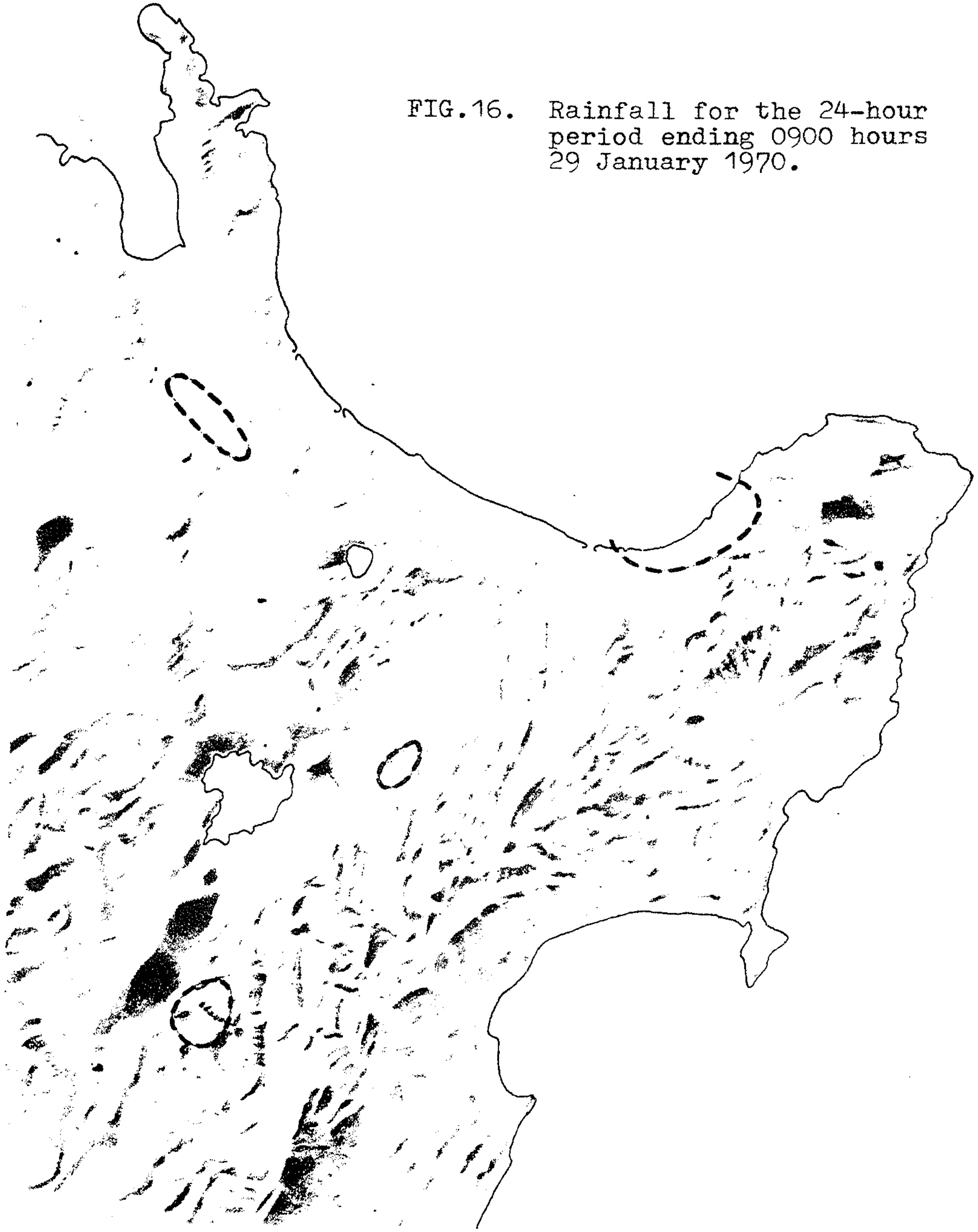


FIG.16. Rainfall for the 24-hour period ending 0900 hours 29 January 1970.

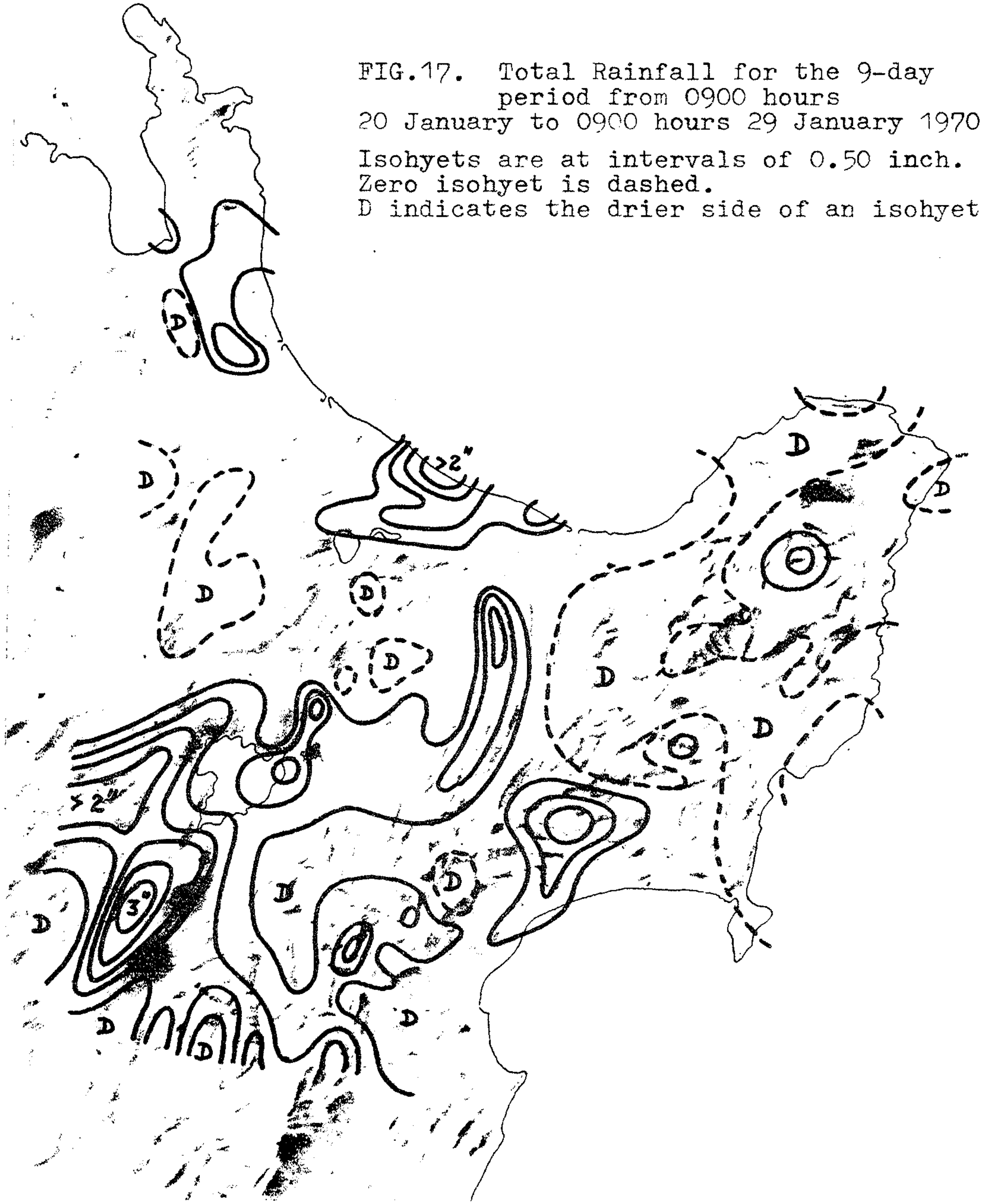
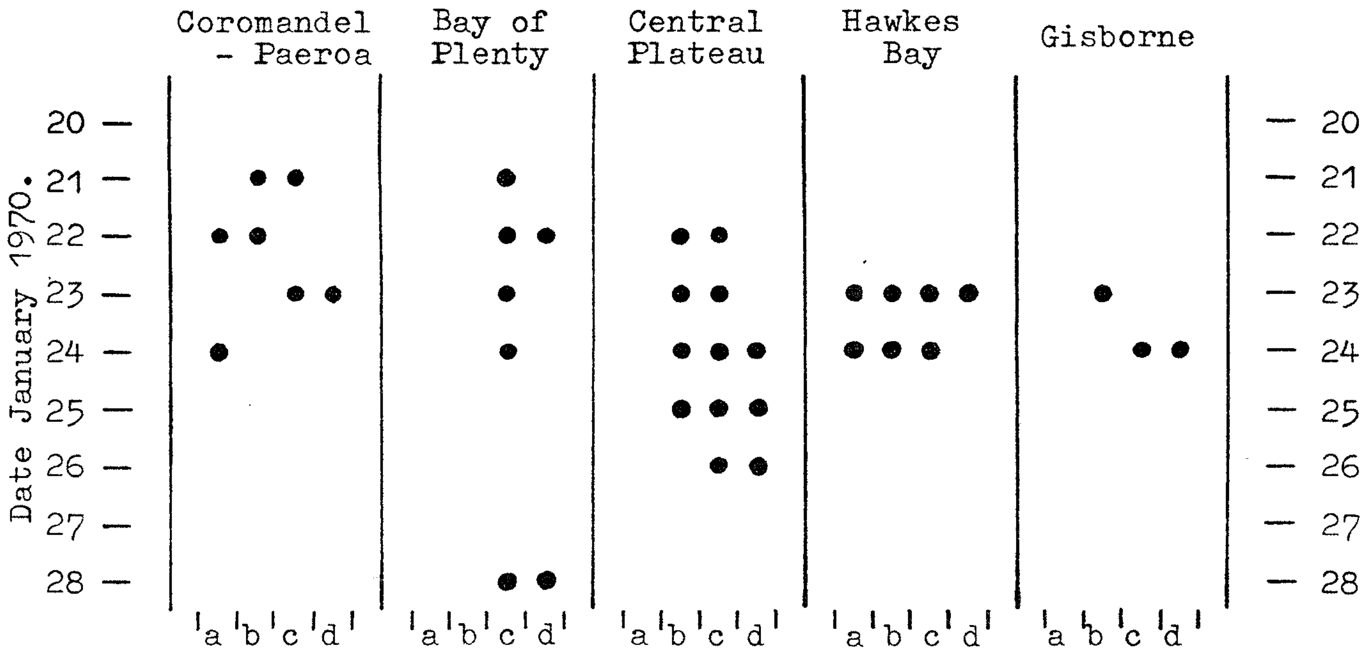


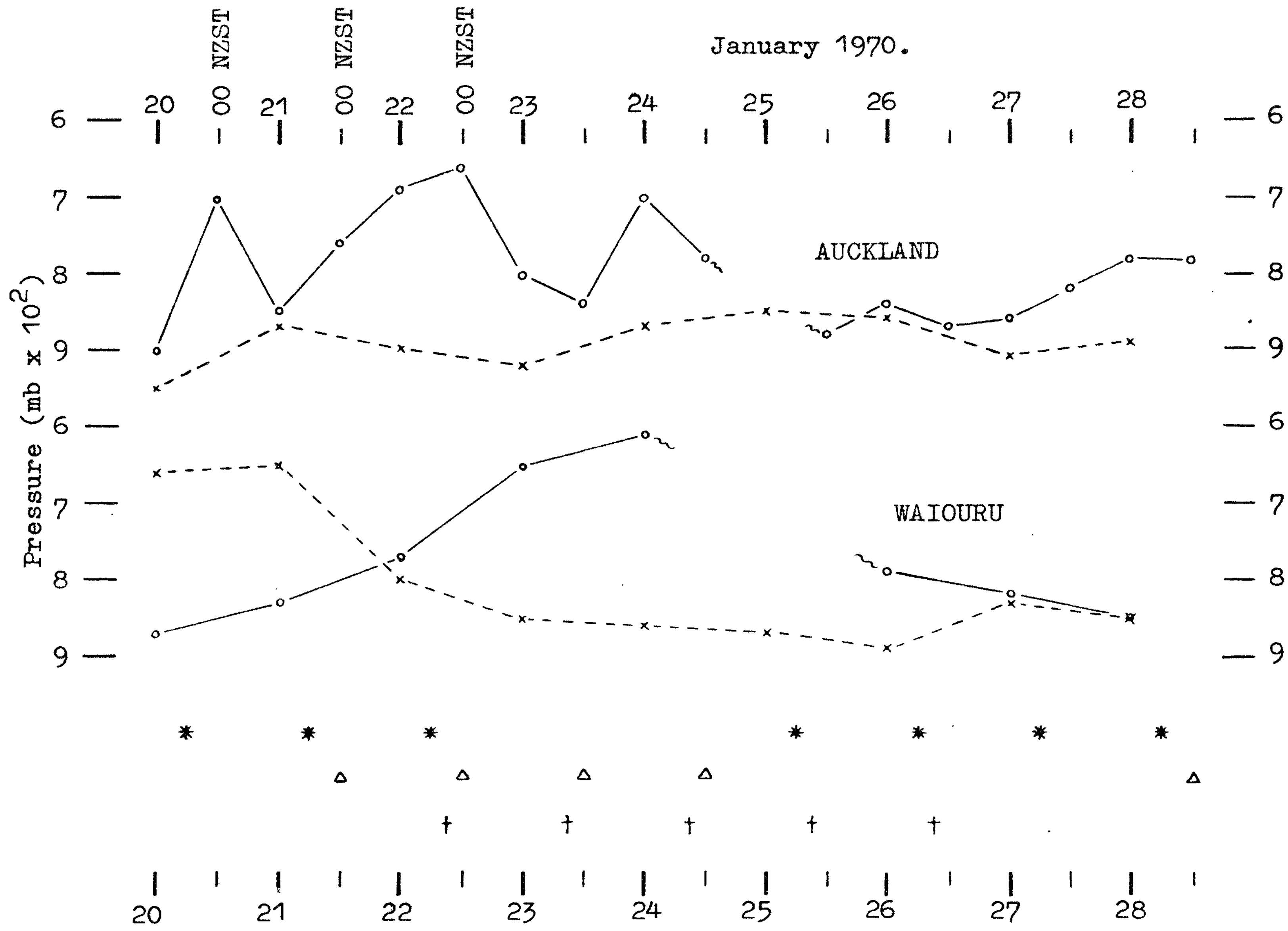
FIG.17. Total Rainfall for the 9-day period from 0900 hours 20 January to 0900 hours 29 January 1970.

Isohyets are at intervals of 0.50 inch.
Zero isohyet is dashed.
D indicates the drier side of an isohyet.



a = 0900-1500 hours, b = 1500-2100 hours, c = 2100-0300 hours, d = 0300-0900 hours NZST.

FIG. 18. Times of occurrence of the main periods of precipitation in the central and northeastern parts of the North Island.



* - afternoons with a marked absence of convective cloud over inland eastern Bay of Plenty.

△ - nights with rainfall in Bay of Plenty.

† - evenings with rainfall over the Central Plateau.

FIG. 19. Time sections for Auckland and Waiouru showing the height of the subsidence inversion (solid line) and the height of the convective condensation level (dashed line).