NEW ZEALAND METEOROLOGICAL SERVICE

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METEOROLOGICAL EFFECTS OF THE STORM IN THE NEW ZEALAND AREA

18 - 21 JULY 1978

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Summary

The storm of 18-21 July 1978 was notable for the severe damage in and about the town of Te Aroha and for the large sea waves generated east of the Northland coast. Winds in Te Aroha are estimated to have reached force 11 and gusted to 90-100 kt (approximately 45-50) m/s and the waves off the Northland coast probably reached 15 m. The return period of the winds at Te Aroha is about 30-50 years but the 15 m sea waves may be a more frequent event.

1. Introduction

A depression originating to the north of New Zealand moved over the country during the period 18-21 July 1978 (Fig. 1). Rain started falling in the north of the country on 18 July and the easterlies on the south-side of the depression reached their greatest intensity on the 19th. The synoptic situation at midday is shown in Fig.2. The frontal zone, associated with the belt of strongest winds, moved south over the North Island during the day and was over the South Island by midnight. The system was weakening by this stage but continued to affect New Zealand for the two following days.

The winds in Te Aroha were highest during the early morning on 19 July 1978. A survey of damage in the town was made by Borough Council staff a few hours after the winds moderated. Out of a total of about 1300 houses, 10 had suffered major structural damage and almost 120 had cladding removed. In addition, 8 other buildings (excluding garages) had major structural damage. Farm buildings in the surrounding area suffered heavily and power and telephone services were not restored for several days. A noteworthy event in this storm was the loss of several rail wagons off the bridge across the Waihou River at Te Aroha.

Damaging winds occur in the vicinity of Te Aroha quite frequently. Only a month previously, on 17 June 1978, a house near the township was badly damaged by easterly winds. From 1920 to 1960 the Meteorological Service gathered 41 reports of high winds in Te Aroha from newspaper items. Nevertheless, the extent and severity of the damage in the 19 July 1978 storm suggest that this storm was a more extreme event than most.

Some details of a previous severe occurrence of high winds at Te Aroha are given by Barnett (1938). This occurred in the early hours of the morning on 26 March 1936 in a very similar synoptic situation. Te Aroha was a smaller town at this time and apart from disruption of power and telephone services, only two houses were wrecked and several more lost corrugated iron from their roofs.

2. Winds

2.1 Wind Strength

Synoptic reporting stations in the north of New Zealand (for locations see Fig.1) had increasing easterly winds on 18 July 1978. By midday the wind, averaged over a 10-minute period, was more than 50 kt* at Cape Reinga and Mokohinau Island and more than 40 kt at the television tower on Mt Te Aroha, 1000 m above the town. The next 6-hourly synoptic report at 1800 hours NZST gave a speed of 65 kt at Cape Reinga, but at midnight the mean speed had dropped to 45 kt. However, that at Mokohinau had increased to 80 kt, and the wind on Mt Te Aroha was about 70 kt with gusts to over 100 kt. At about 0430 hours on 19 July 1978 the mean speed on Mt Te Aroha reached 80 kt and there was a gust to 119 kt. The power went off at about the same time and no further recordings were made for 6 hours, by which time the winds were averaging 66 kt and gusting to 84 kt.

The highest gust recorded during the storm is given in Table 1 for anemometers in areas affected by the storm. The wind and date of the most recent previous occurrence with a higher gust speed is also given and also the highest gust recorded together with its date and the period of the record.

The highest gust recorded by anemograph in this storm was 119 kt on top of Mt Te Aroha. However, the instrument had only been installed about one month previously and there was therefore little record for comparison and the event has been omitted from Table 1. The highest gust in the table is 95 kt at Cape Reinga. It was exceeded 2 years previously, and in fact, was almost equalled in a storm in June 1978. The anemometer is 208 m above sea level on a ridge where the air-flow is probably accelerated considerably above its sea-level speed. On the other hand, the much lower gust of 62 kt at Whenuapai has not been exceeded since 1944, although there have been gusts almost as high on a number of occasions. This anemometer is well exposed, far from buildings and other large obstacles, on reasonably level ground. At most other stations the gust speed was not remarkable, with the exception of Levin, where it was equal to the highest since records began in 1967.

Daily wind runs are given in Table 2 for stations at which the storm produced the highest runs for the month of July 1978. In all cases the wind run was exceeded on another day within the previous three years. The record wind runs are also in the table and in many cases are much higher than values reached in the July storm.

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* 1 kt = .515 m/s. All mean speeds are 10-minute averages and gust speeds are measured maxima. The instrumental response is sufficient to accurately measure those of 3-5 sec. duration.

Table 1. Highest gusts recorded during the storm on 18 and 19 July 1978. For locations see Fig. 3.

Station	Period Highest Gust of Record	Highest Gust °T/kt	Previous Higher Gust °T/kt	Date	Record Highest Gust °T/kt	Date
Cape Reinga	74-	060/95	060/108	8. 4.76	060/108	8. 4.76
Kaitaia Aero	50-	090/64	060/71	28. 6.77	080/96	14. 3.59
Whangarei Aero	54-	100/61	010/63	11. 3.75	330/86	15. 9.69
Marsden Point	61-62 69-	130/80	050/83	28. 6.77	050/83	28. 6.77
Leigh	73-	100/65*	270/69	13. 9.76	050/81	14. 6.75
Warkworth	73-	090/70	270/71	22. 5.75	270/71	22. 5.75
Whenuapai	41-	110/62	270/63	18.11.44	270/63	18.11.44
Auckland City	62-	090/61	230/62	11.12.76	250/67	21. 9.72
Auckland Aero	62-	100/54	340/58	19. 4.78	200/68	22. 5.75
Tauranga Aero	42-	100/50	090/57	17. 6.78	220/64	15. 4.69
Whakatane Aero	59-	010/41	260/49	11. 7.78	080/79	10. 4.68
Rotorua Aero	65-	120/51	250/55	17. 5.77	250/55	17. 5.77
East Cape	74-	090/66	350/68	13. 7.78	210/75	26. 4.75
Waiouru	70-	090/65	020/72	15. 7.76	020/72	15. 7.76
Palmerston North Aero	40-51 65-	140/50	270/54	22.11.77	240/67	26.11.68
Levin	42-43 67-	100/69	-	-	290/69	26.11.68
Nelson Aero	40-	140/50	360/53	30. 4.77	060/82	22. 2.44

* Some of the record was lost because of a power failure and a higher value may have occurred. A non-standard instrument.

Table 2. Highest daily wind runs during the storm 18-21 July 1978.

Station	Period of Record	Wind Run km	Previous Higher Run km	Date	Record Wind Run km	Date (Month & Year)
Kaikohe	73-	741	766	18. 6.78	1375	8/75
Leigh	67-	1192	1308	9. 8.76	1424	8/71
Woodhill Forest	48-	517	667	16. 6.78	933	8/67
Thames	59-	753	769	28. 1.76	872	5/59
Waihi	46-	611	622	24.10.77	824	9/47
Rotoehu Forest	38-	600	613	19. 7.77	661	4/76
Whakarewarewa, Rotorua	71-	391	464	31.12.77	542	5/77
Otara, Auckland	71-	582	603	16. 6.78	819	8/76
Mercer	77-	704	893	17. 6.78	893	6/78
Ruakura, Hamilton	71-	539	548	17. 6.78	740	3/75
Rukuhia, Hamilton	71-	751	776	6. 9.76	949	3/75
Cambridge Nursery	77-	772	777	17. 6.78	777	6/78
Massey University	71-	682	818	13. 1.78	929	3/74

The daily wind runs in Table 2 represent a mean wind speed averaged over a 24-hour period up to 0900 hours on each day. The largest values can be expected when high winds last for 24 hours, over a day and the following night. These conditions do not appear to have been fulfilled in the present storm because the high winds did not last long enough, and at many of the stations occurred partly before and partly after 0900 hours on 19 July 1978.

2.2 Wind Damage

A summary of the wind damage in Table 3 lists the major areas where losses occurred, the sort of damage which was observed, and the corresponding Beaufort force and wind speed. It should be noted that the equivalent speed is an average and applies to the standard anemometer height of 10 m when it is exposed over open flat ground.

Table 3. Summary of wind damage and Beaufort force

Area	Wind damage	Beaufort force	Equivalent speed kt
Northland	Warkworth and Wellsford: shattered windows, broken power lines, roofing removed. East coast beaches eroded and ship damaged, Beaufort force 11 offshore (see section 4).	9-10	41-55
Auckland	Pleasure boats wrecked, roofing iron removed, trees blown over, lightly constructed buildings blown over.	9-10	41-55
Hauraki Plains	20 houses damaged Paeroa, devastation in some areas Te Aroha and environs, train blown off tracks at Te Aroha.	10-11	48-63
Manawatu-Rangitikei	High tension lines down. Power cuts Levin & Foxton, iron roofs blown off in Levin. Kimbolton & Rangiwahia badly hit. Railways good shed collapsed in Ashurst.	9-10	41-55
Nelson	Trees uprooted, tiles off roofs, power cuts.	9-10	41-55

Table 4 contains the areas with major losses due to wind damage. In each area appropriate anemometer stations are listed with the exposure of the instrument and the maximum 10-minute mean velocity measured during the storm.

Table 4. Exposures and maximum mean speeds at New Zealand Meteorological Service anemometer stations.

Area	Station and exposure		Highest velocity mean kt
Northland	Cape Reinga:	Ridge-top site subject to acceleration.	060/72
	Kaitaia Aero:	Reasonable exposure.	110/42
	Mokohinau Is.	Cliff-top site subject to acceleration.	*090/80
	Whangarei Aero:)	Good local exposure but	100/42
	Marsden Point)	winds affected by nearby hills.	130/56
	Warkworth:	On tower 33 m above country with low hills.	090/44
Auckland	Whenuapai:	Good exposure.	110/36
	Auckland City:	On seven-storied building 32 m above ground just west of the central city.	*100/37
Hauraki Plains	Mt Te Aroha:	About 1000 m above Plains on a TV mast 126 m above ground.	*090/80
Rangitikei	Waiouru:	Poorly exposed among buildings.	100/37
Manawatu	Palmerston North Aero:	Good exposure.	160/38
	Levin:	Good exposure.	090/44
Nelson	Nelson Aero:	Good local exposure but wind affected by nearby hills.	130/38

* No continuous recording. Higher values may have occurred.

A comparison of Tables 3 and 4 shows that the anemometers at Cape Reinga, Mokohinau Island, and Mt Te Aroha recorded winds substantially in excess of the Beaufort equivalents. This can be attributed to acceleration over the orographic features on which the instruments stand, and in the case of Mt Te Aroha, partly to the great height of the anemometer. The other wind velocities in Table 4 are rather lower than the Beaufort scale equivalents, with the exception of those at Marsden Point where the anemometer is mounted on a pier and is exposed to the wind flowing over the sea.

The Beaufort equivalents refer to winds measured over open, flat ground. At such sites the gustiness of the wind is relatively small whereas in New Zealand even those anemometers with good local exposure are subject to high gusts probably generated by nearby hills. The amount of damage, on which the Beaufort force is based, will depend on the extremes of the wind force as well as the average value. Thus, in real exposures the mean wind speed may be lower than the Beaufort equivalent but be compensated for by higher gusts. The wind also varies greatly within a general area and it is probable that higher winds occurred than were measured at some of the anemometers given in Table 4.

2.3 Wind at Te Aroha

The peculiarly high incidence of easterly gales at Te Aroha is almost certainly a result of the orography of the Kaimai ranges. These present a ramp-like barrier to easterly airstreams ending with a sharp escarpment. This latter feature is most pronounced at Te Aroha and tends to amplify the downward flow in the lee leading to enhancement of the wind on the plains at the foot of the slope. A similar mechanism might have been present in Manawatu and Nelson.

Damage in the town of Te Aroha was slight in that part immediately under the lee slopes of the mountain. Further away from the range damage was severe and widespread, consistent with a wind of Beaufort force 11. An examination of a barograph trace made during the storm shows several large pressure fluctuations in addition to the continuous fluctuations associated with short period gustiness. They probably represent especially large gusts, resembling squalls, which may have been responsible for much of the structural damage.

The Te Aroha barogram also gives an indication of the sequence of events at Te Aroha. There seems to have been a steady build-up in the velocity of the wind during the night of 18-19 July 1978 until 0730 hours on the 19th. At 0800 hours an abrupt increase of pressure of 3 mb coupled with a marked decrease in the pressure fluctuations suggests a decrease of wind of about 30 kt. A large isolated pressure fluctuation occurred just after 0400 hours, followed by another two at about 0700.

The magnitude of the pressure fluctuations implies a maximum gust at least 20 kt greater than the mean speed. Gauld (1979) has estimated a speed of 86 kt from fractured light standards. Maximum gust speeds over 90 kt have been recorded at anemometers with open exposure on fairly flat ground in other devastating winds, e.g. the 1959 Northland cyclone and the 1975 Canterbury wind storm. Gust speeds over 100 kt have occurred at hill-top sites and within Wellington City in the April 1968 storm. It is thought that 90-100 kt is the best estimate of the maximum gust in Te Aroha on 19 July 1978.

Present engineering standards (N.Z. Standard 4203, 1976) require that buildings be designed to withstand forces which arise when a gust of a given duration strikes the structure. In the vicinity of Te Aroha the basic design gust (the maximum 3-sec gust with a 50-year return period) implied by Fig. 6 of the standard is 36 $^{m}/s$ (70kt). Te Aroha is noted for the strong winds associated with the Kaimai Ranges whereas at points further from the range the same standard applies but orographic enhancement of the wind is less pronounced. It is plausible to use a large topographic correction factor S, in Te Aroha but this procedure is of doubtful validity. The application of the standard is also affected by considerations of the duration of the gusts in Te Aroha and of their return periods. It has been suggested earlier in this section that the gusts were rather large and would therefore last for more than 3-sec. The return period is considered in the next section.

2.4 Return Period of the Storm

The high gust recorded at Whenuapai suggests a long return period for a similar storm. However, there have been a number of gusts from the east which have reached 61 kt, and because the gusts at other anemographs have been exceeded in other recent storms it can be argued that it is no more than a local effect. Nevertheless, Whenuapai is a well-exposed anemometer and is remarkably free of the anomalously high maximum gusts which occur at other New Zealand stations. The Whenuapai wind record starts in 1941. Between 1930 and 1941 an anemometer was operating at Hobsonville, within a few km of Whenuapai. It is noteworthy that the highest gust at this station was 57 kt and occurred on 26 March 1936; the day of the Te Aroha windstorm described by Barnett (1938).

Mokohinau Island has had an anemometer for many years, but there is no pen recorder attached to the instrument and so there is no record of the maximum gusts. However, the station has a fairly complete record of 6-hourly reports of mean wind speed. The maximum one-year values for directions between 040° and 100° have been plotted on Gumbel paper (Gumbel, 1958) for the years from 1961 to 1978 (Fig. 4). The directions have been limited to airstreams within 30° of the perpendicular to the Kaimai ranges. This is because the orographic effects are weaker for other directions. Also the accelerating effect of Mokohinau Island on airstreams from other directions will also probably be different.

The upper set of plotted points in Fig. 4 represents the annual maxima of the Mokohinau winds. They have been ranked and plotted with a recurrence interval of $\frac{N+1}{m}$ years, where N is the number of annual maxima and m is the rank. The parameters of a Fisher-Tippett type 1 distribution have been calculated using the Lieblein fitting procedure recommended by Thom (1966) and the line in Fig. 4 has then been plotted. This suggests that the return period of an 80-kt wind from between 040° and 100° is about 35 years.

Another set of plotted points in Fig. 4 gives the annual maxima of the Gisborne minus Kaitaia pressure difference for the years 1962 to 1978. The highest value, 28.3 mb, was reached at 0400 hours on 19 July 1978 and corresponds to a return period of about 33 years.

The Gisborne minus Kaitaia pressure difference was chosen as a measure of the strength of the northeasterly geostrophic gradient. It represents an average value over a horizontal distance of 600 km and is largest for depressions whose centres pass close to Kaitaia and which have a relatively large diameter. Large values of the parameter are mostly accompanied by E to NE winds at Mokohinau and gales at Te Aroha. The depression on 26 March 1936 moved southeast over Northland, and the East Cape minus North Cape pressure difference (obtained from Barnett (1938)) reached 28 mb, comparable with the value on 19 July 1978.

The combination of the strongest E to NE wind at Mokohinau Island in at least 18 years and the largest Gisborne minus Kaitaia pressure difference in at least 17 years shows that the storm on 19 July 1978 was an exceptional event. An extreme value analysis suggests that the return period of each parameter is about 35 years. However, the points in Fig. 1 may belong to a population represented by a slightly curved law. This uncertainty suggests that the return period should be given by a range of years, and because the return period of the combination of events is likely to be a little greater than each event separately, a range between 30 and 50 years is chosen.

The wind at Te Aroha has a similar return period provided that there is no unusual mesoscale factor increasing the wind. The Kaimai ranges affect all easterlies. It is known that the stability of an airstream affects the strength of an orographic disturbance. On 19 July 1978 the atmosphere was stable at low-levels in the vicinity of the occluded front (Fig. 2) which was also the zone of strongest wind. It is thought that this is a rather normal situation with a depression of this type and should not increase the return period.

3. Rainfall

Daily rainfall totals for a selection of stations are given in Table 3. The previous higher occurrences are also given together with the month and year of the occurrence. Most of the rainfalls have been exceeded within the previous few years. although those at Thames and Paeroa have not been exceeded since a storm in February 1967. Flooding occurred in Thames on the morning of 19 July 1978 when the Kauaeranga River burst its banks.

Kauaeranga Forest in the catchment of this river recorded a heavier fall in August 1976 but on this occasion the area of high rainfall did not extend as far as Thames.

Table 3. Daily rainfalls measured during the storm 18-21 July 1978

Station	Highest Rainfall in July Storm mm	Date July '78	Previous Higher Fall mm	Date	
Kaikohe	109	18	123	13. 6.75	
Glenbervie Forest	127	18	156	16. 6.78	
Whangarei	115	18	124	12. 1.76	
Whangapoua Forest	115	18	127	21. 6.78	
Coromandel	107	18	124	17. 6.78	
Chiltern	160	18	171	6. 7.76	
Thames	97	18	149	2. 2.67	
Kauaeranga Forest	165	18	204	9. 8.76	
Paeroa	115	18	123	2. 2.67	
Te Aroha	121	18	163	19. 7.77	
Ruatoria	223*	18-19	292*	3-4.12.74	* 2 days
Picton	125	19	140	15. 5.72	
Akaroa	77	19	104	3. 7.77	

High rainfalls also occurred in the hill country about and inland of Ruatoria, near East Cape, as well as in some places in the northeast of the South Island. The Ruatoria rainfall is a 2-day value with approximately equal amounts on the 18th and 19th. Stations west of Ruatoria which have broken records and are not included in Table 3 had very large falls over the 3 days from the 18th to the 20th inclusive. Gate Station recorded 442 mm in this period and Brigadoon, Mangaoparo had 451 mm.

4. Maritime Effects of the Storm

This storm caused costly damage on the New Zealand coast and severely affected shipping. Up to thirty metres of foreshore were lost in some areas north of Auckland. Beach protection work proved no barrier to the seas and was dismantled by a combination of high tides and powerful waves.

The predicted high tide at Auckland at 0605 NZST on 19 July 1978 was 3.1 m above datum. A spring tide a few days later was expected to reach 3.6 m and a neap tide earlier in the month to reach 2.8 m. Nevertheless, one report gives the tide as 0.7 m above the predicted level, an augmentation which is quite possible in view of the low barometric pressure and the strong onshore wind.

Large waves were generated by the wind. At 1800 hours on 18 July 1978 a fishing boat reported "colossal easterly swells" at the Three Kings Islands. Mokohinau Island reported very high seas at midnight, a category which is rarely used in lighthouse reports. One ship approaching Auckland had its forecastle flooded when high waves broke some steel doors. The ship turned broadside on to the wind when the engine stopped. This ship, the Iron York, 8453 tons, did not send any meteorological reports but in a press report it was claimed the waves were bridge-high (15 m).

Another ship, the British Commodore, was approaching New Zealand from the north on the 18 and 19 July 1978. For two days as the ship moved to the south at about half the speed of the depression, within the westerly airstream lying north of the centre, it was reporting swells over 10 m high. Most of the swells were reported to come from the southeast and apparently originated in the easterlies on the south side of the depression. In one report a confused swell of 13 m was coupled with waves of 11m. One crewman died on this ship during the storm and another on the container ship Austral Ensign. One man was washed off a tug in the Bay of Islands.

Further south, the tanker Erne passed through the zone of strongest easterlies at 1800 hours on 19 July 1978. At a position 25 km east of Cape Turnagain, south of Hawke Bay, it reported easterlies of 45 kt, swell of 10 m, and 5 m waves. A rainfall observer at Le Bons Bay (Mr Dalglish) near the tip of Banks Peninsula, reported on 20 July "the roughest seas and highest tides seen for many years. Severe scouring and sand hills washed back for half a chain or more" (i.e. about 10 m). Beach erosion was also reported in Stewart Island. Ship reports off the Canterbury and Otago coasts give swell heights of 4 or 5 m.

The evidence indicates a weakening of the easterly airstream as it moved to the south, consistent with other data. Within the zone of highest winds off the Northland coast wave heights probably did reach 15 m. Such heights could be generated in a violent storm (Beaufort force 11) in which the surface wind speeds averaged 60 kt. This speed is consistent with the wind reports at Mokohinau Island and Mt Te Aroha and the upper air measurements at Auckland.

Intense depressions passing over the seas east of Northland may not register as extreme events using the parameters of section 2.4. An example of such an event was the storm on 13-14 June 1968 in which the 740 ton ship Maranui foundered off Coromandel Peninsula. This depression moved southeast on a track away from the Northland coast and the maximum value of the Gisborne minus Kaitaia pressure was only 21 mb. Nevertheless, the Mokohinau wind reached 80 kt but because it was from 130°, the event does not appear in Fig. 4. Wave heights were probably comparable with those on 19 July 1978 and the return period of such waves will be less than 30 years but probably more than 10 years.

5. Conclusions

The storm of 18-21 July 1978 is notable for the high winds which accompanied it. Over the land the direct effects of the wind were most marked on 19 July 1978 in the town of Te Aroha and the surrounding district. In Northland, Auckland, Manawatu and Nelson there was also considerable damage on this day. The maximum gust at Whenuapai had not been exceeded for 34 years and that at Levin for at least 12 years. Some heavy rainfalls were measured between 18 and 20 July but the daily totals have all been exceeded within recent years. The swell waves generated by the easterlies on the south side of the storm affected the New Zealand coast between 18 and 21 July. Eastward-facing beaches along the whole length of the country were eroded. Waves as high as 15 m were reported off the Northland coast at the height of the storm but off the Otago coast waves were only about 5 m.

The damage in Northland, Auckland, Manawatu and Nelson is consistent with winds of Beaufort force 9-10. In Te Aroha and the surrounding district average speeds are estimated to have reached force 10-11 with gusts of 90-100 kt. Over the seas east of Northland mean speeds of 60 kt probably covered extensive areas during the early morning hours of the 19 July 1978. The distribution of the damage over the land south of Auckland indicates the importance of mountain ranges in increasing the low-level winds on the lee-side.

The return period of the storm and of easterly winds of this strength at Te Aroha is estimated to be 30-50 years. For design purposes a 3-sec gust speed of 50 m/s (97 kt) is probably adequate for Te Aroha. The return period of the sea waves east of the Northland coast is expected to be less than 30 years because of storms on paths away from the land.

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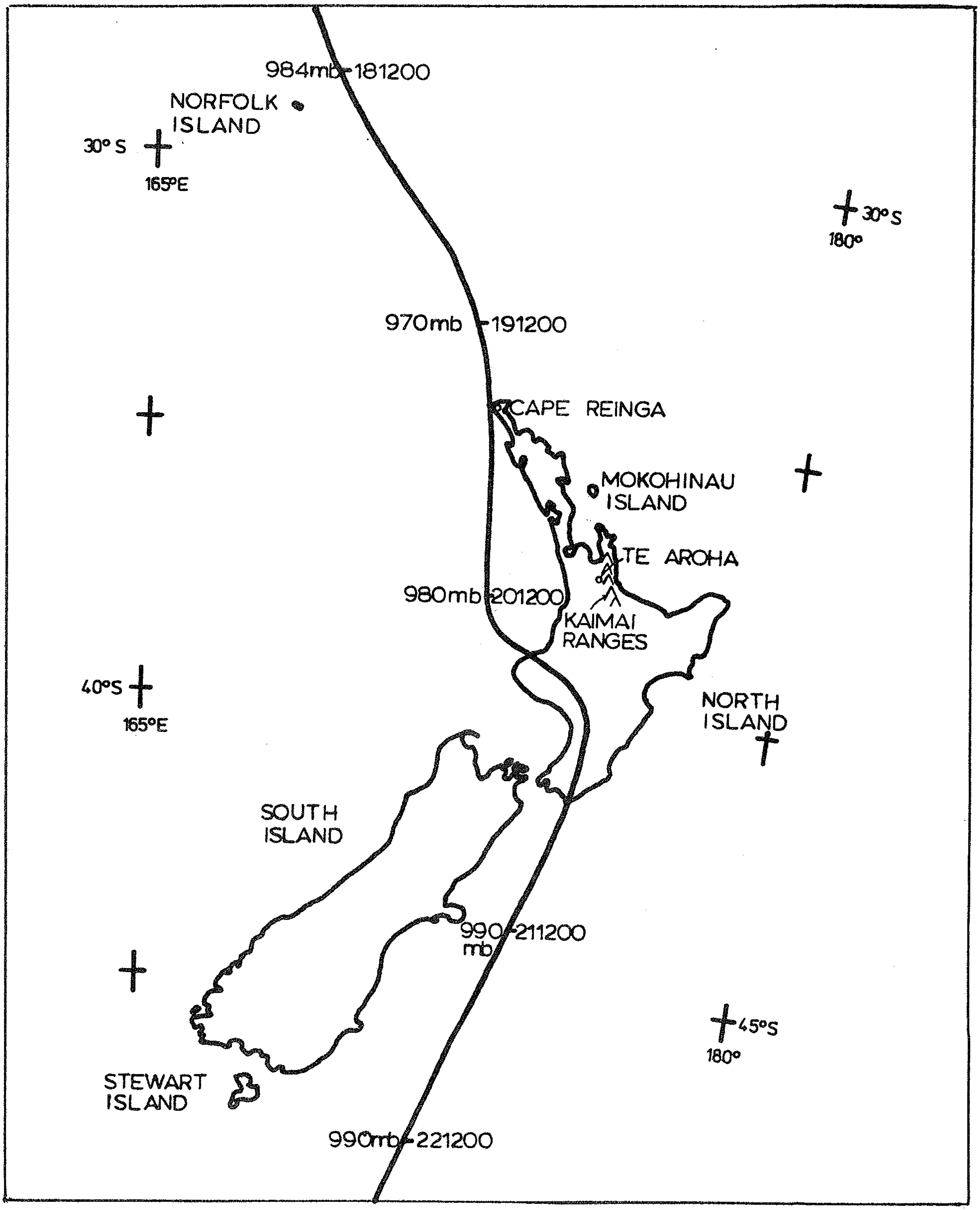

Fig. 1. Track and central pressure of depression which moved over New Zealand during 18-21 July 1978. The day and time (NZST) are given with the central pressure.

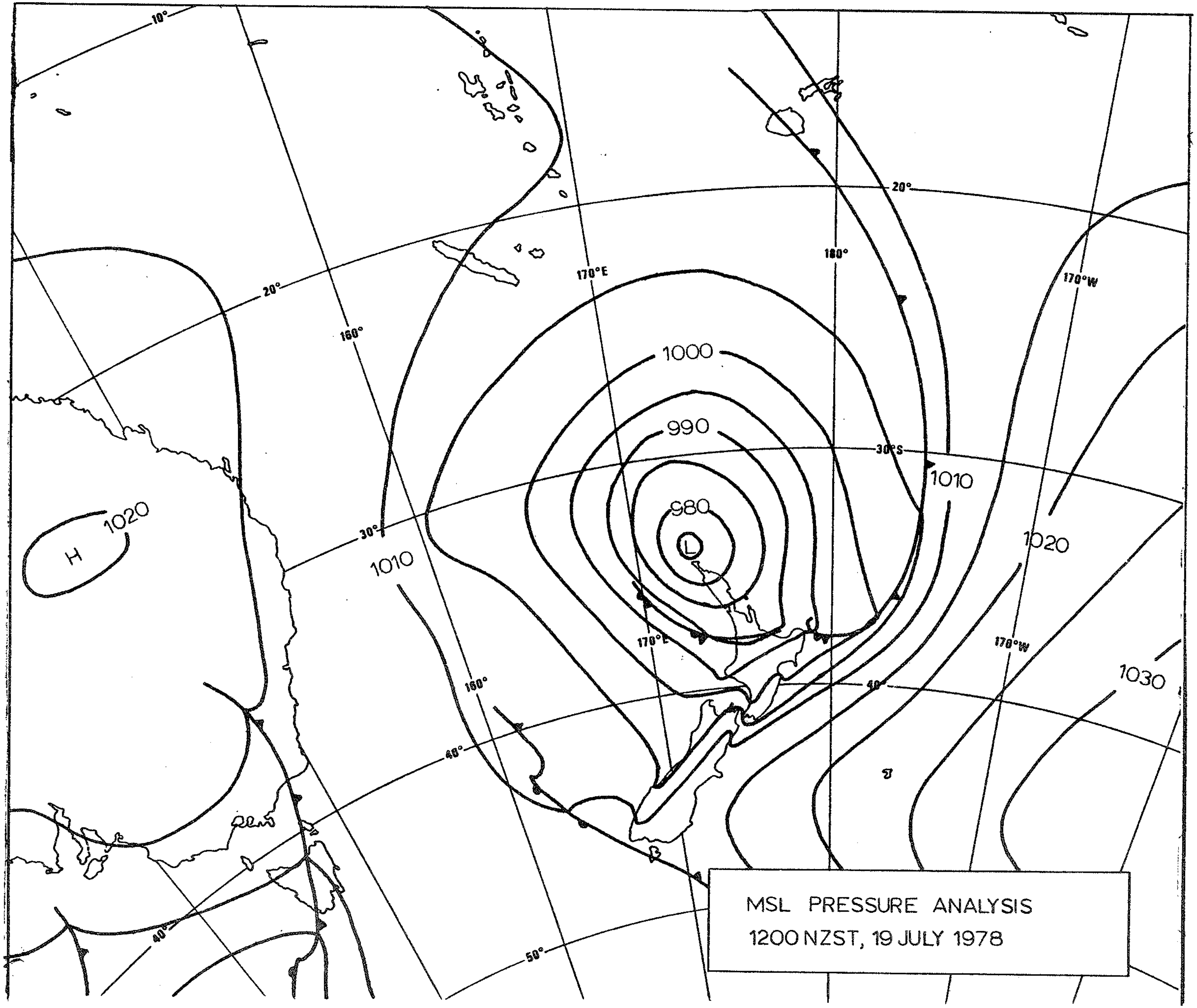

Fig. 2. Synoptic situation at midday on 19 July 1978.

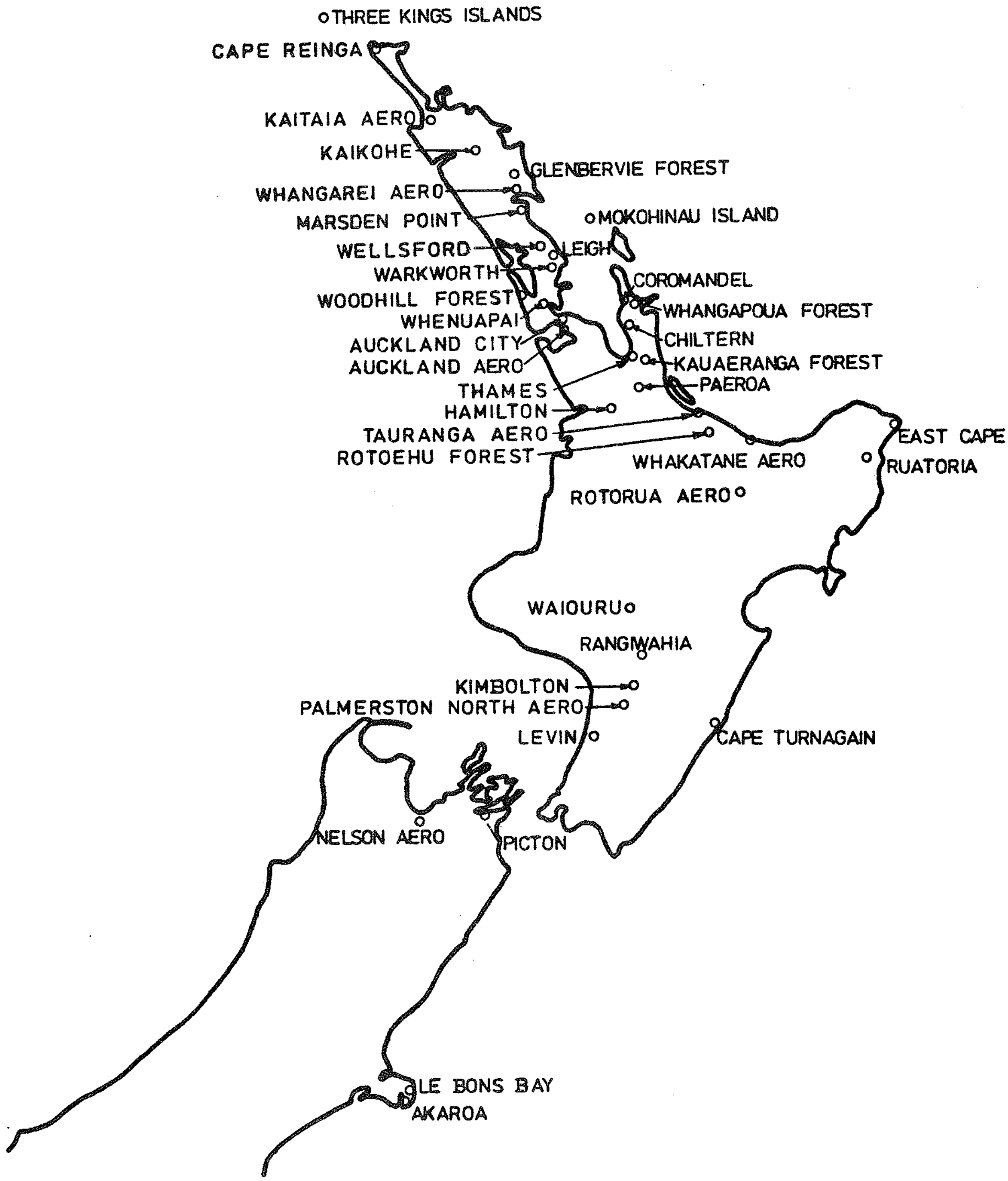

Fig. 3. Location of places mentioned in the text.

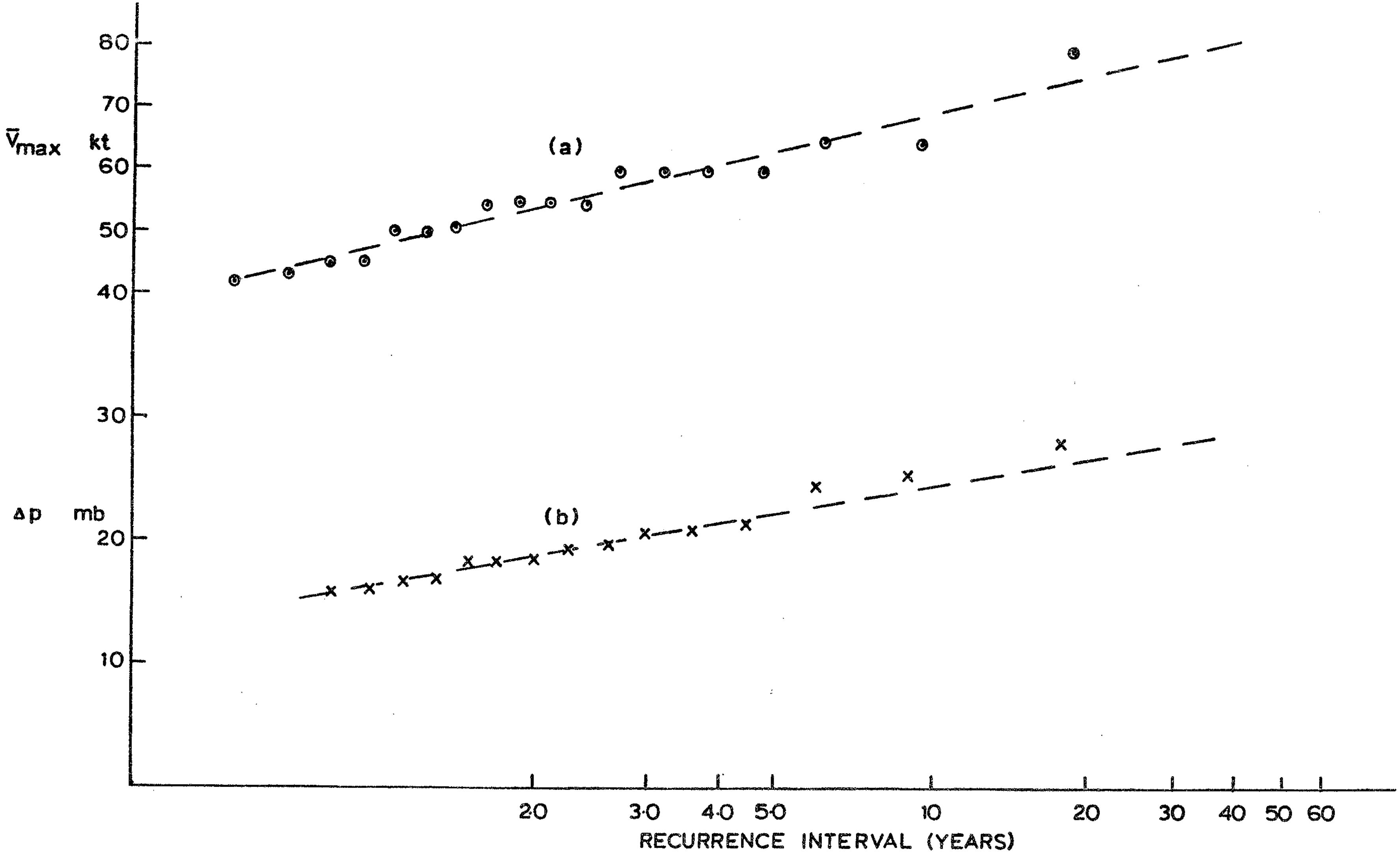

Fig. 4(a). Values of the maximum mean wind speed at Mokohinau Island in successive periods of 12 months from April 1961 - March 1979 (inclusive). A line of best fit is also given. The wind speeds are limited to those from directions between 040° to 100°.

(b) Annual maximum values of the pressure difference Gisborne minus Kaitaia 1962-1978 (inclusive). The values in two years fell below 16 mb and are not shown.