



MINISTRY OF TRANSPORT

NEW ZEALAND METEOROLOGICAL SERVICE

THE WEATHER AND CLIMATE OF THE CHATHAM ISLANDS

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PREFACE

This publication is the thirteenth in the series of reports on the weather and climate of specific regions of New Zealand. The first seven were published as sections of the National Resources Survey produced by the Town and Country Planning Branch of the Ministry of Works and Development and were later reprinted as components of N.Z. Meteorological Service Miscellaneous Publication 115. Compilation of the resources survey has been discontinued. However, the Meteorological Service Miscellaneous Publication Series 115 is continuing and it is proposed to produce articles within the series for all regions of New Zealand.

Previous issues in the Miscellaneous Publications Series 115 were :-

115(1)	Bay of Plenty	(1963)
115(2)	Northland	(1964)
115(3)	Nelson	(1965)
115(4)	Otago	(1968)
115(5)	Hawkes Bay	(1971)
115(6)	Wanganui	(1972)
115(7)	Waikato-Coromandel- King Country	(1974)
115(8)	Gisborne	(1980)
115(9)	Taranaki	(1981)
115(10)	Westland	(1982)
115(11)	Wairarapa	(1982), and
115(12)	Marlborough	(1983)

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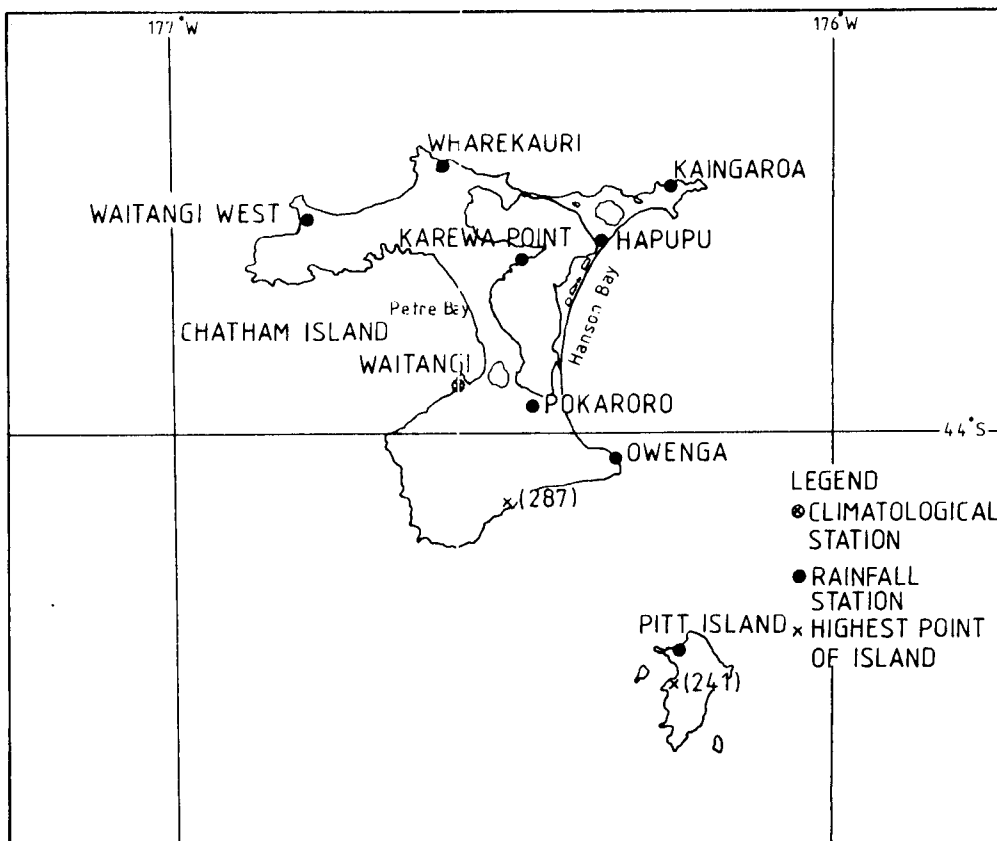


FIG.1: CHATHAM ISLANDS - METEOROLOGICAL STATION LOCATIONS.

THE WEATHER AND CLIMATE OF THE CHATHAM ISLANDS

C.S. Thompson

ABSTRACT

The weather of the Chatham Islands is marked by rapid changes of conditions. The Chatham Islands are typified by windy cloudy conditions.

The climate is dominated by the surrounding ocean, and extremes of temperatures are rare. Rainfall is moderate and reliable with a winter maximum. Despite the high number of rain days some soil water deficiency is likely to occur during summer, and a small water surplus during winter.

1. Introduction

The Chatham Islands (Fig.1) are situated in the Southwest Pacific Ocean, approximately 750 km east of New Zealand. They are the largest of the outlying groups of islands adjacent to New Zealand. The island group consists of the main island (Rekohu or Chatham Island) and Pitt Island (Rangiaura) as well as several tiny outliers.

Chatham Island, an area of 900 km², is roughly T-shaped. There is a large lagoon (area 186km²) which covers much of the central portion of the island. Northern and central areas are mostly low-lying with several volcanic cones rising to 180m. In contrast, the southern portion is a much dissected remnant of a plateau area, which rises from sea level near the lagoon, to a height of nearly 300m along the southern coastline (Allan, 1929).

Pitt Island has an area of 63km². The island's coastline is bounded on many places by steep cliffs rising 70-100m to a highly dissected plateau which covers much of the island. The highest part of the island is an outcrop of volcanic rock rising to 241m.

The first official weather records were made in 1878 from the Waitangi district by a local resident, Mr A. Shand. Since then, an almost continuous record has been kept there, and it contains the only climatological station operating in the islands. In 1957, the New Zealand Meteorological Service established an office at Waitangi to carry out a surface and upper air reporting programme. The site is well exposed, and observations are generally representative of the weather conditions

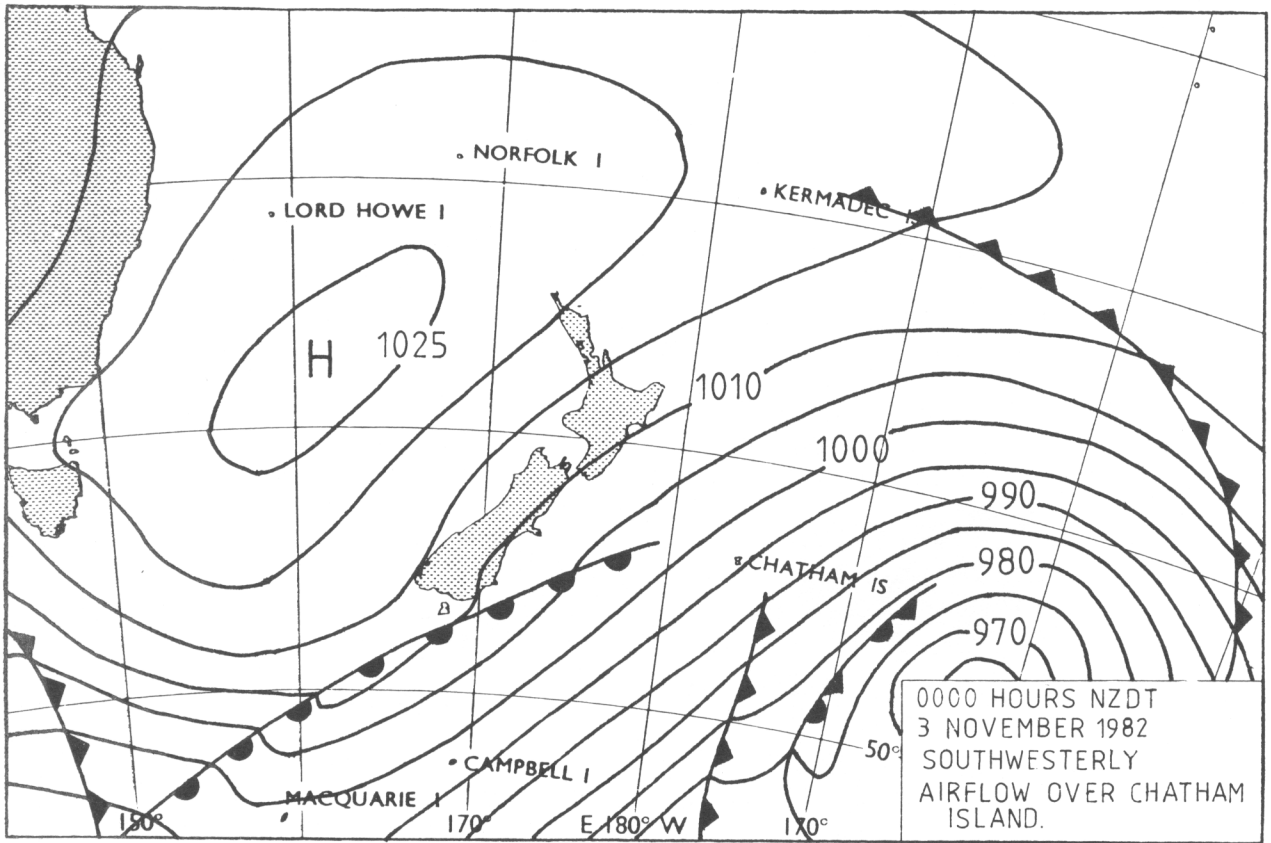


FIG. 2a: MSL ANALYSIS FOR 3 NOVEMBER 1982

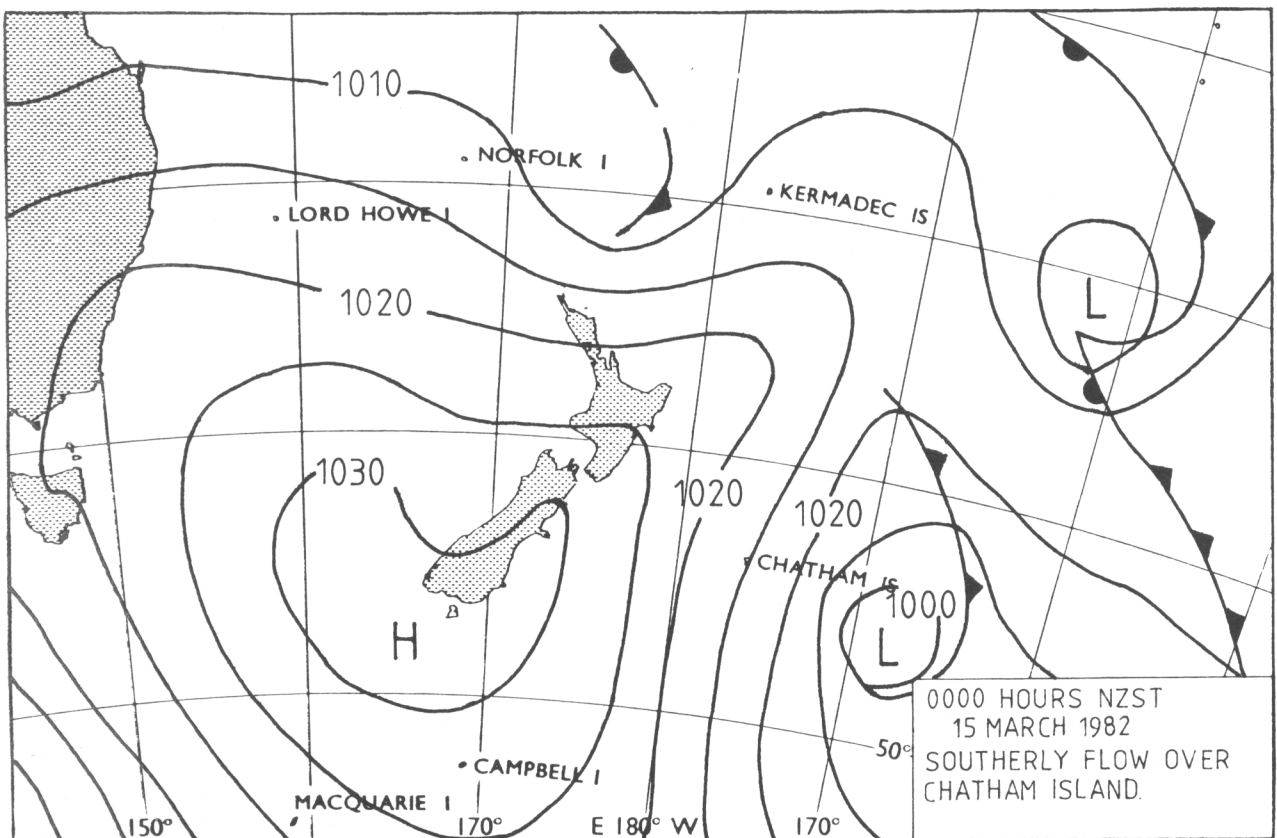


FIG. 2b: MSL ANALYSIS FOR 15 MARCH 1982.

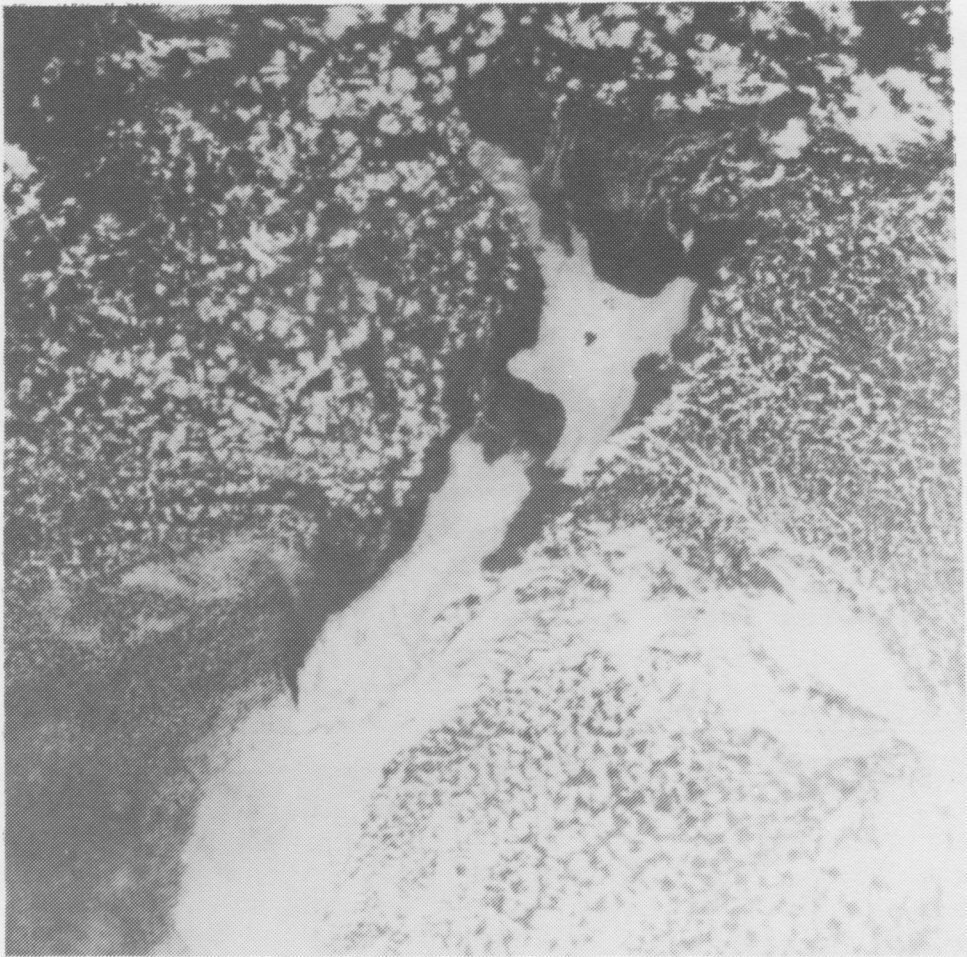


FIG.3A SATELLITE VIEW OF CLOUD DISTRIBUTION IN A SOUTHWEST AIRSTREAM OVER THE CHATHAM ISLANDS.

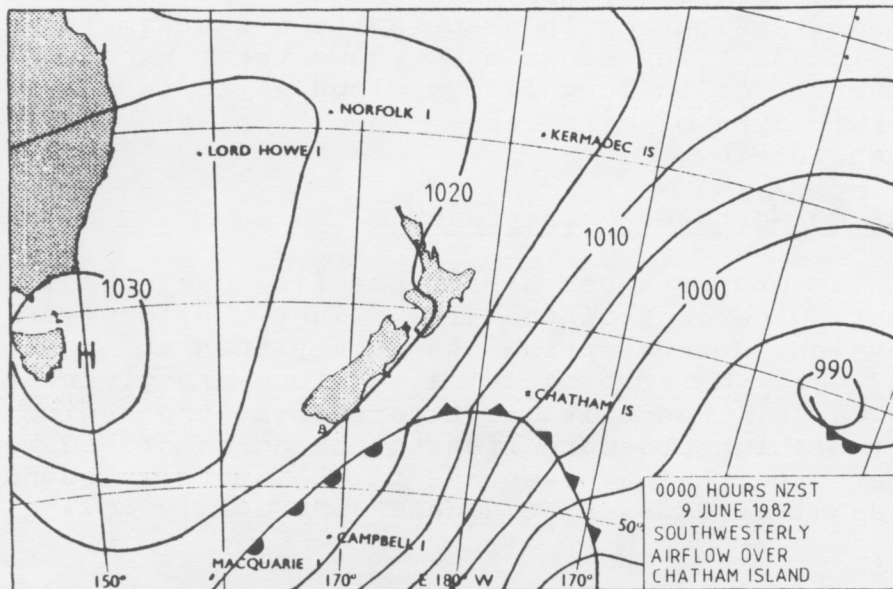


FIG. 3b: MSL ANALYSIS FOR 9 JUNE 1982.

experienced over most of the island. Rainfall is currently being recorded from a further five locations, four on Chathams and the other on Pitt Island. Figure 1 shows the locations from which data were gathered for this publication.

2. Weather Sequences Affecting the Chatham Islands

A characteristic of the atmospheric circulation in the New Zealand region is the absence of semi-permanent anticyclones. Daily surface weather maps show a series of eastward moving anticyclones over the Tasman Sea/New Zealand area, separated by troughs of low pressure or depressions. These large-scale synoptic features affect the day-to-day weather of the Chatham Islands and also determine the broad climatic features of the region.

Examples follow of some common weather patterns and their associated weather.

2.1 South to Southwest Airstreams

South to southwest airstreams are by far the most frequent to cover the Chatham Islands, occurring about 35 percent of the time. When anticyclones are centred in the Tasman Sea, and pressures are low to the east of Chathams, southwesterlies flow over the Islands (Fig. 2a). However, when an anticyclone is centred south of New Zealand, the airstream is southerly (Fig. 2b). In slow-moving situations, conditions may last for up to 7 to 10 days, but 2 or 3 days is more usual.

These situations are associated with cool, shivery weather and cloudy skies. Strong to gale southwest or south winds are not uncommon. Hail is not infrequent, and precipitation amounts are generally small.

A satellite picture taken at 2am on 9 June 1982 of the cloud distribution in a southwest airstream is displayed in Fig. 3a. The cloud mass shows the typical cellular structure of the cumuliform cloud which is characteristic of this type of airstream. The associated weather map is given in Fig. 3b.

2.2 West to Northwest Airstreams

West or northwest airstreams flow over the islands about 30 percent of the time. They are, however, more prevalent during spring and summer than at other times of the year. Meteorological situations are given in Fig. 4a, b. Westerly airstreams cover the region when a belt of high pressure lies to the north of New Zealand, together with low pressures to the south. Embedded in these airstreams are frequent and rapidly moving cold

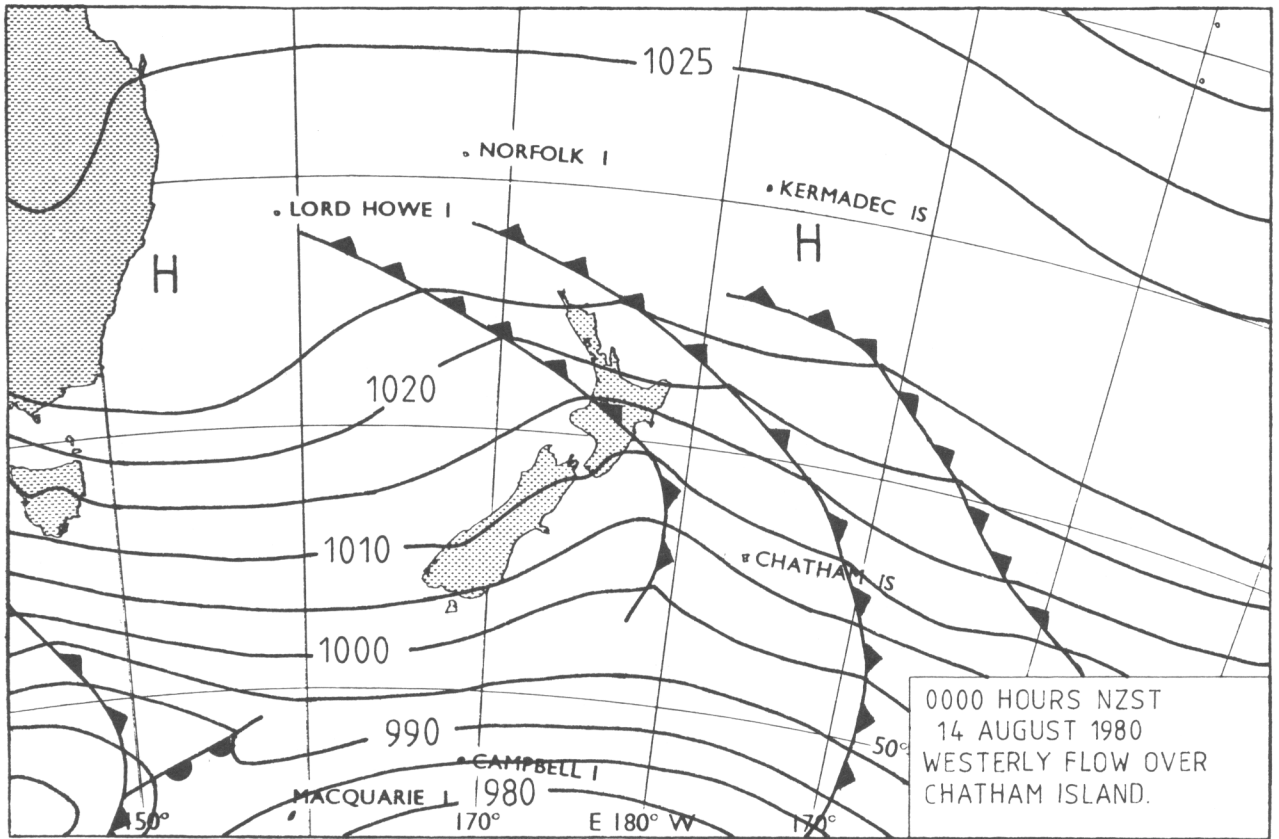


FIG. 4a: MSL ANALYSIS FOR 14 AUGUST 1980.

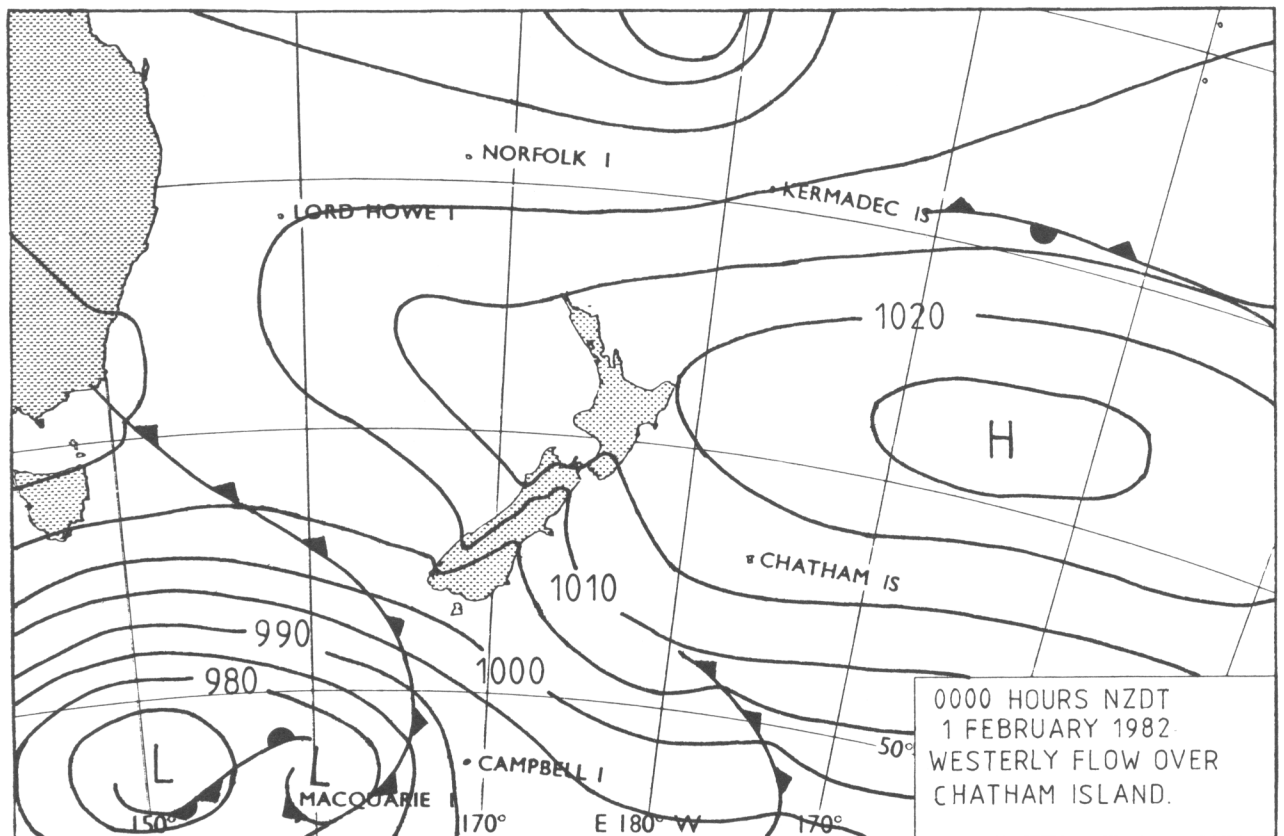


FIG. 4b: MSL ANALYSIS FOR 1 FEBRUARY 1982.

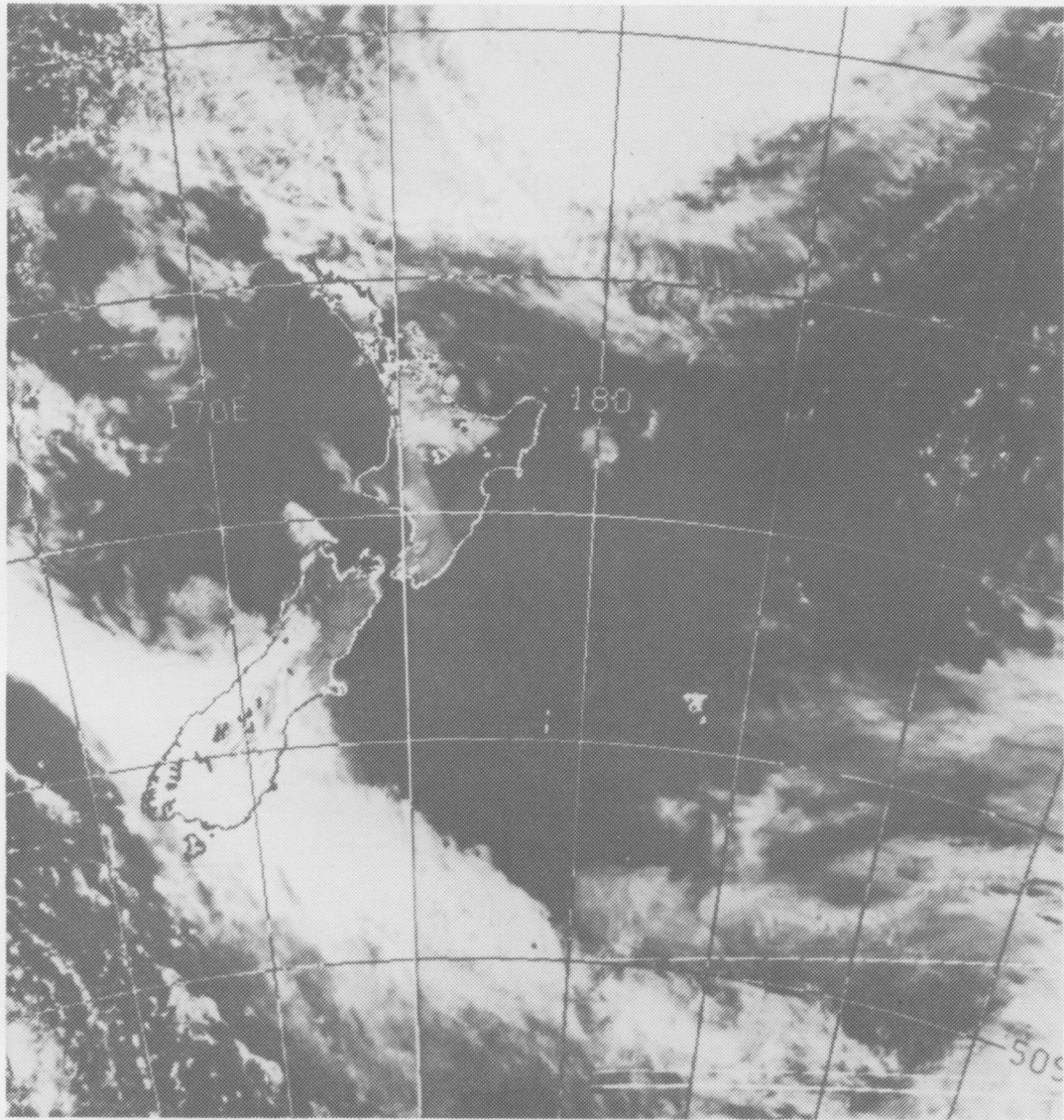


Fig.5. Satellite view of cloud free zone over Chatham Islands on 1 February 1982.

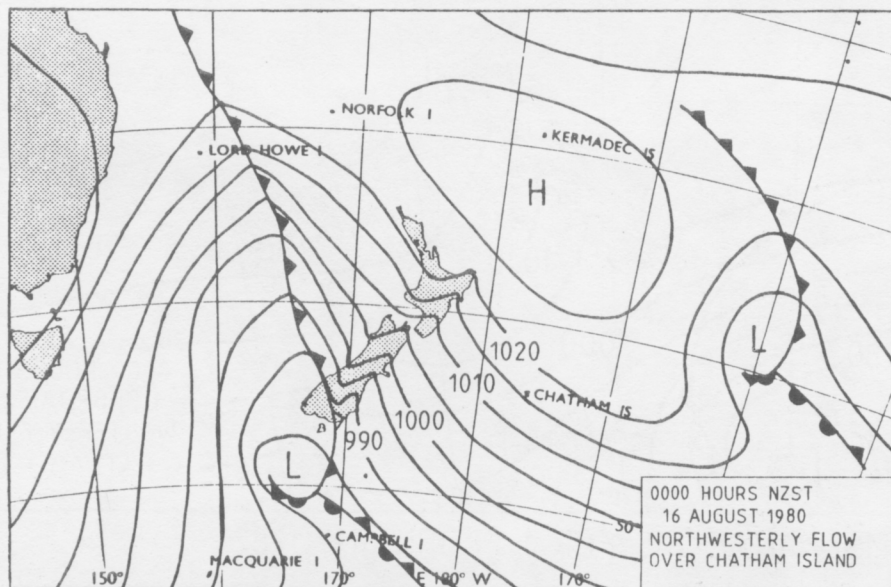


FIG 6a: MSL ANALYSIS FOR 16 AUGUST 1980.

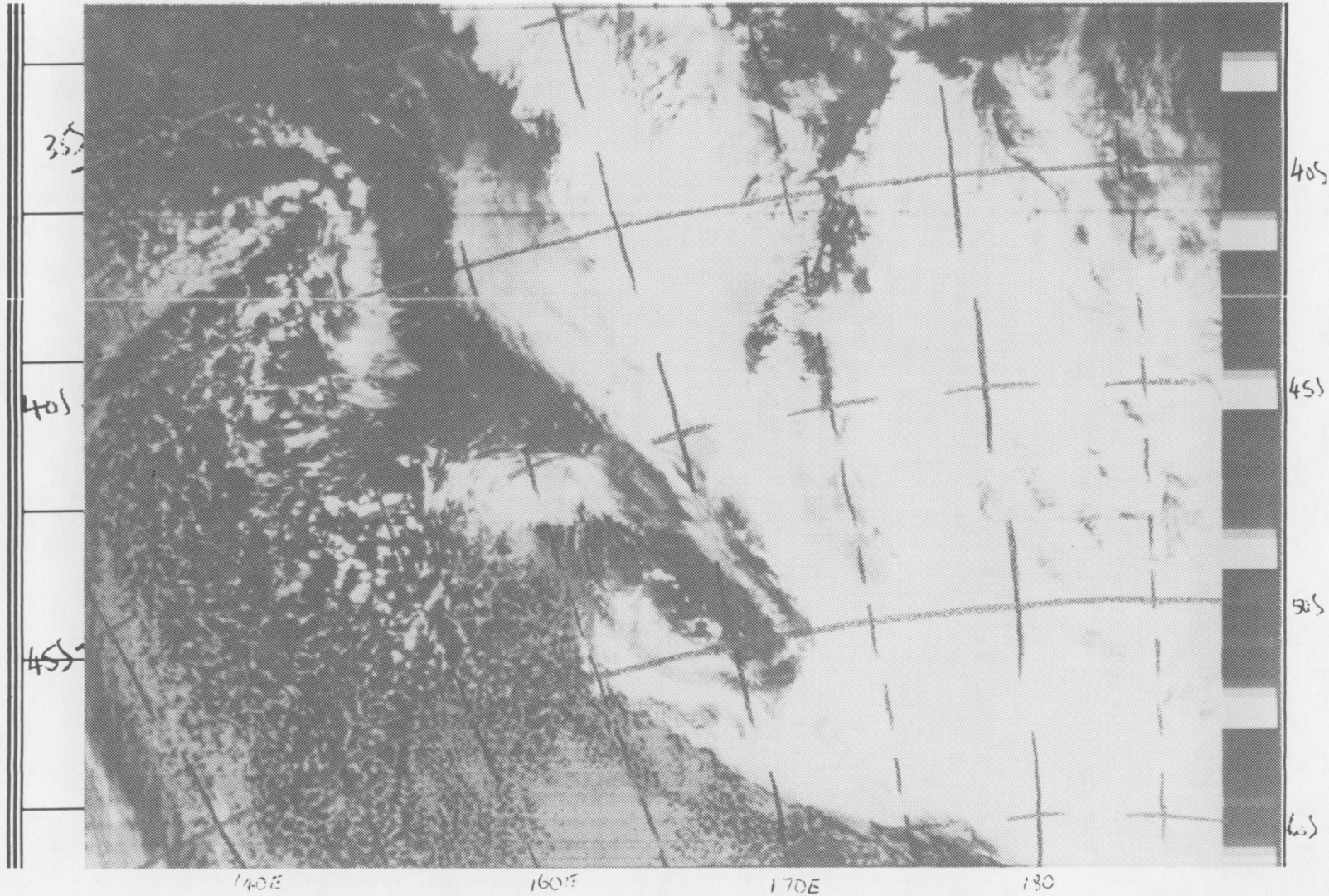


Fig.6b. Satellite view of cloud structure over Chatham Islands on 16 August 1980.

fronts which bring showers to the Chatham Islands (Fig. 4a). If, on the other hand, frontal systems are spaced well apart (Fig. 4b) fine sunny, yet windy conditions are likely, due to the anticyclonic curvature of the isobars between the fronts.

A satellite picture taken on 1 February 1982 is given in Fig. 5. This view of the Southwest Pacific shows an extensive area of clear skies, and corresponds to the belt of high pressure shown in Fig. 4b. Nine hours of bright sunshine occurred at Waitangi and, although windy, a maximum temperature of 21° C was reached.

A strong northwesterly situation at the Chatham Islands is given in Fig. 6a for 16 August 1980. Strong to gale force northwest winds were observed with cloudy skies. The cold front crossed the islands mid-morning on 17 August 1980 accompanied by very light rain. There were further showers in the cold south to southwest airflow following the cold front.

A satellite view of northwesterly conditions over the Chatham Islands area is given in Fig. 6b for about 8am on 16 August 1980. East of the cold front is an extensive sheet of cirrus cloud. This cloud is also covering the Chatham Islands. The cold air which affected the islands on 17 August 1980 can be seen following the cold front, as can a cluster of cumulonimbus clouds shaped like an inverted comma. This comma-shaped cloud is centred near 40° S, 160° E.

2.3 North to Northeast Airstream

North or northeast airstreams flow over the Chatham Islands for about 15 percent of the time (Fig. 7a,b). They are characterised by a relatively mild and humid airstream which flows between a large anticyclone to the east of the Chathams and a low pressure area to the west. These situations may be slow-moving when the anticyclone blocks the movement of the depression. Heavy falls of rain are frequently a feature of these situations, both in the flow ahead of the front, and also with the front.

On 15 June 1981 (Fig. 7b) there were strong northeasterly winds, and rain began to fall from about 7pm. Rain continued during the following two days, with some heavy falls recorded at Waitangi as the front approached late on 17 June 1981. The front crossed the Chatham Islands during the mid-afternoon of 18 June 1981 and was followed by westerly winds and clearing conditions. Daily rainfall totals for the 4 days, 16-19 June 1981, were 2 mm, 21 mm, 40 mm and 10 mm.

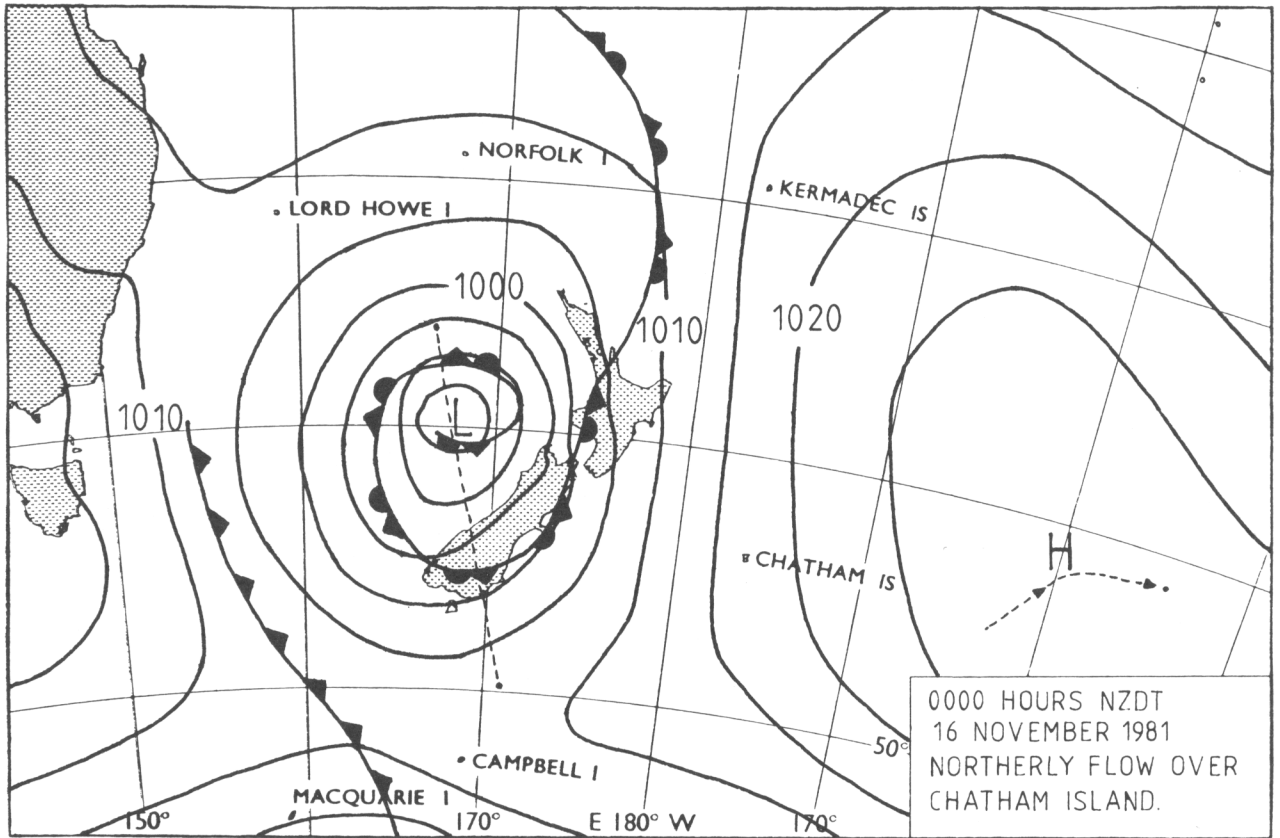


FIG. 7a: MSL ANALYSIS FOR 16 NOVEMBER 1981.

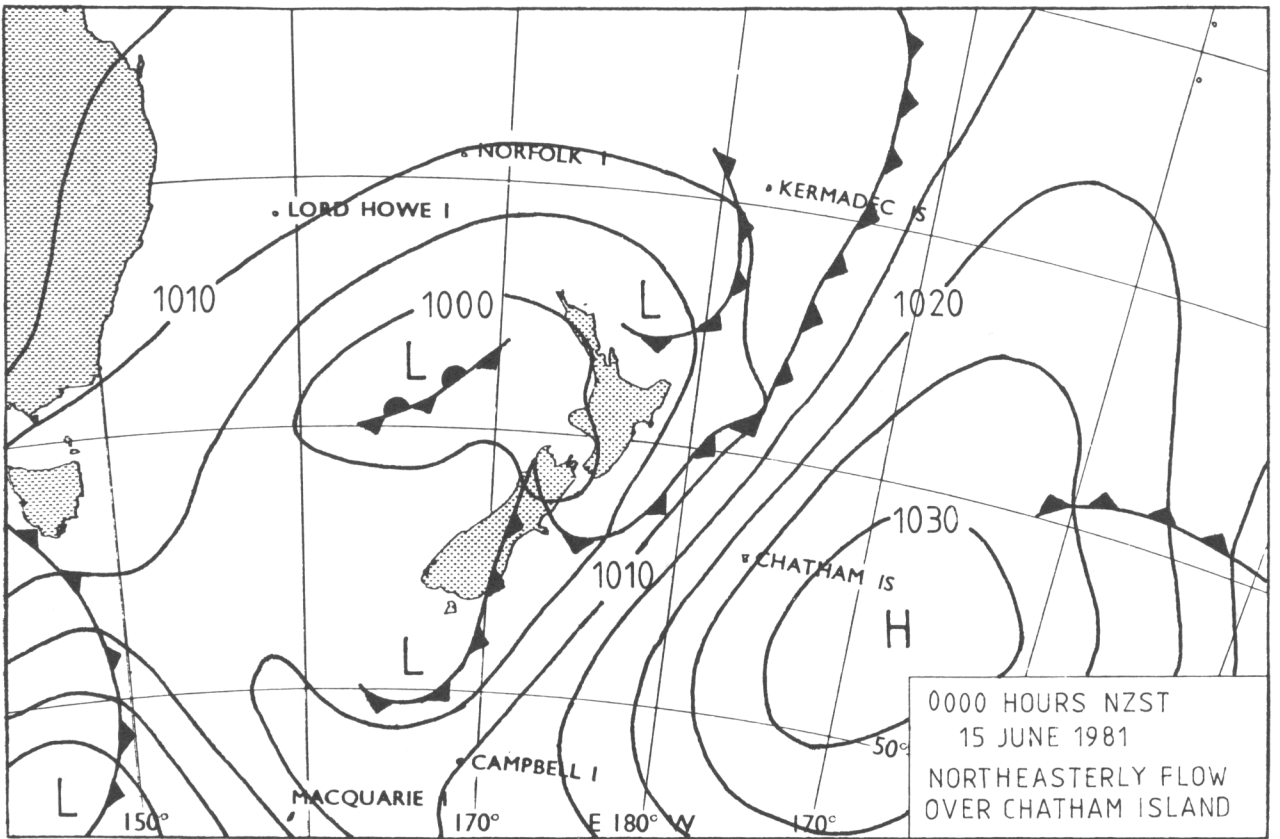


FIG. 7b: MSL ANALYSIS FOR 15 JUNE 1981.

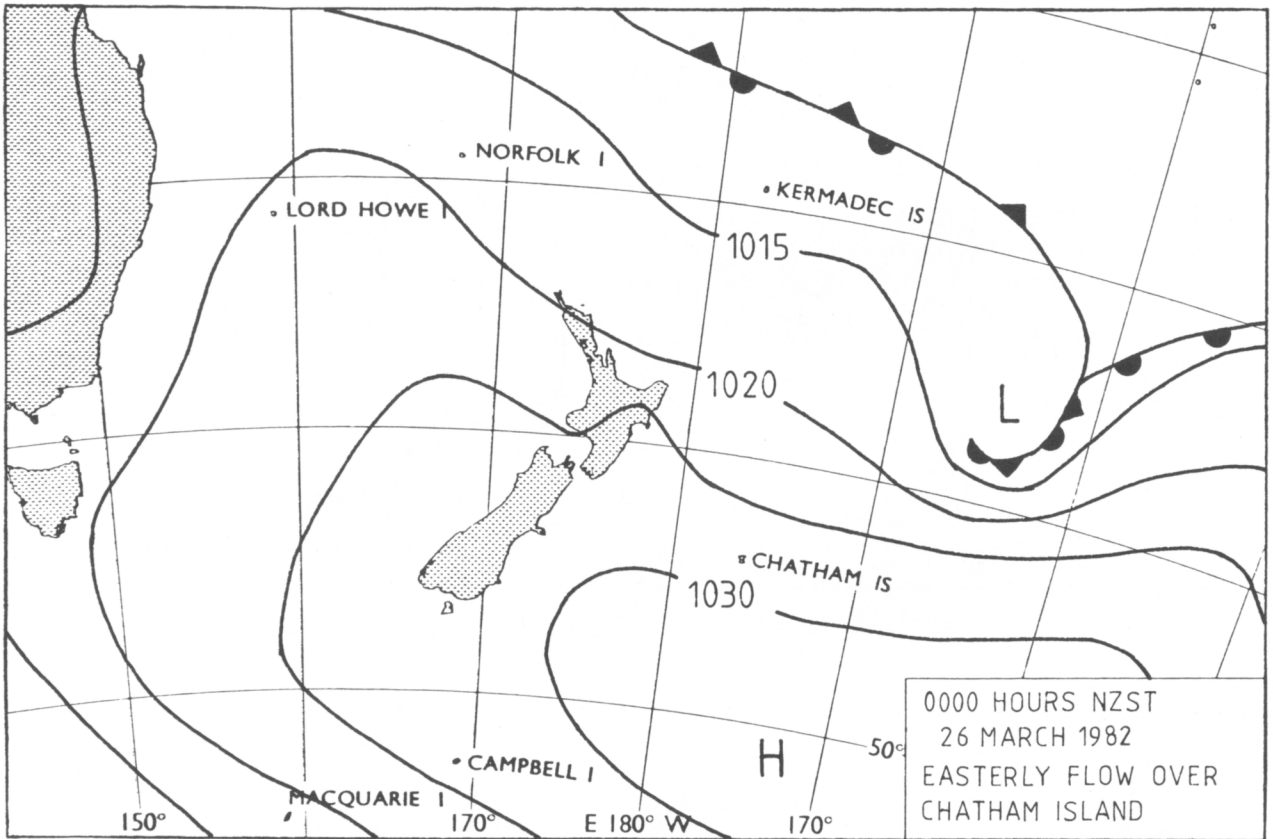


FIG.8: MSL ANALYSIS FOR 26 MARCH 1982.

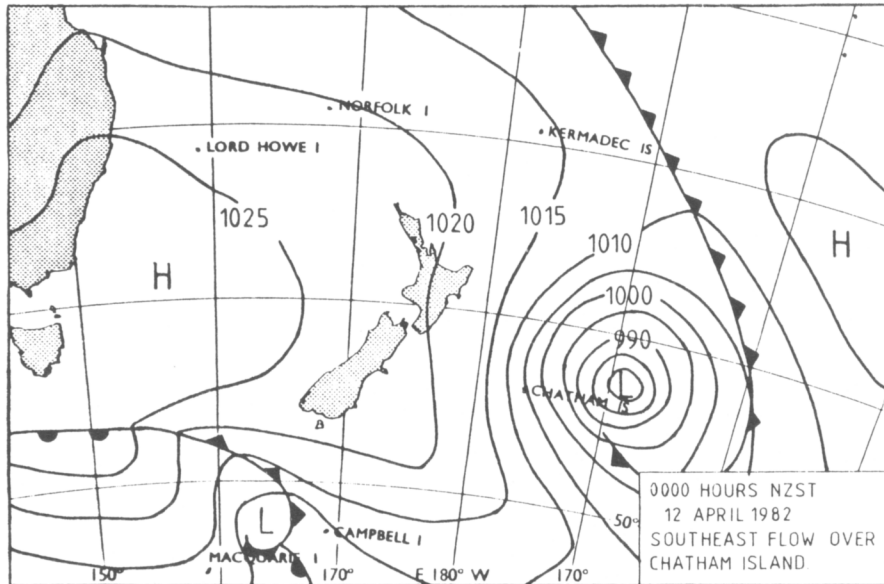


FIG. 9a MSL ANALYSIS FOR 12 APRIL 1982.

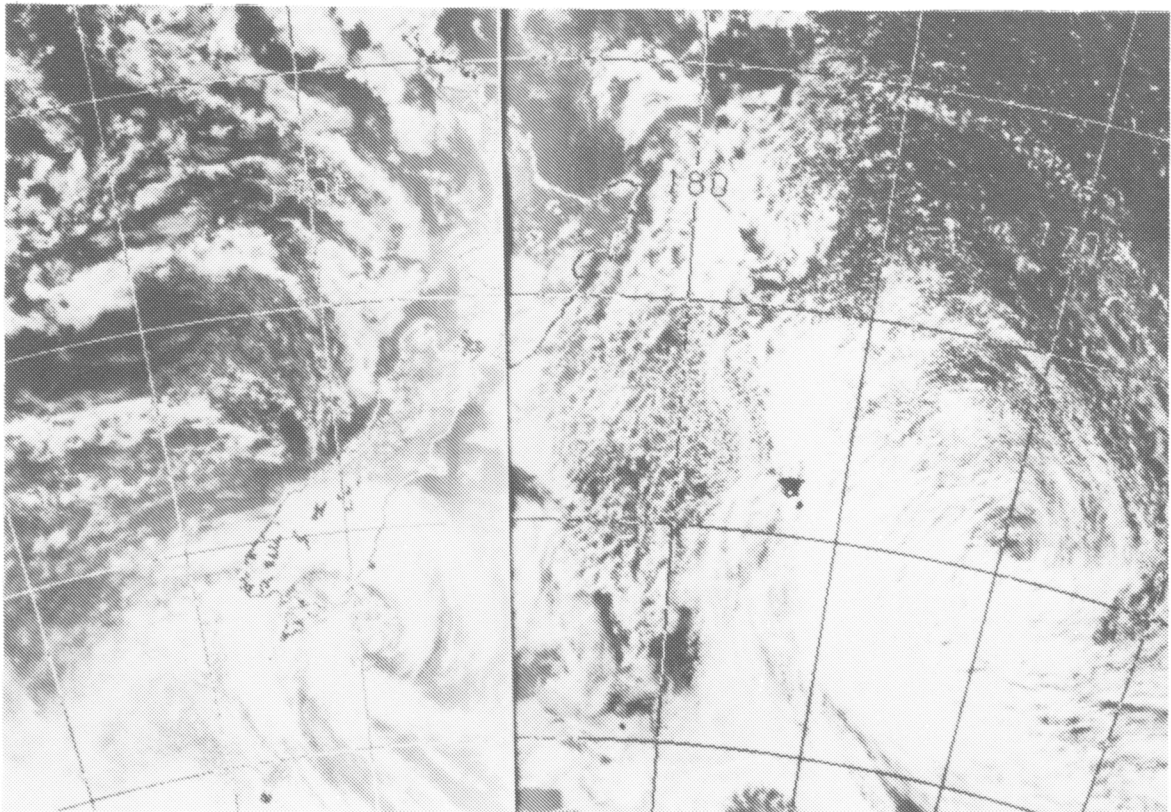


Fig.9b. Satellite view of cloud structure over Chatham Islands taken at about 2.15 pm on 12 August 1982.
Note depression centre at 44°S, 170°W.

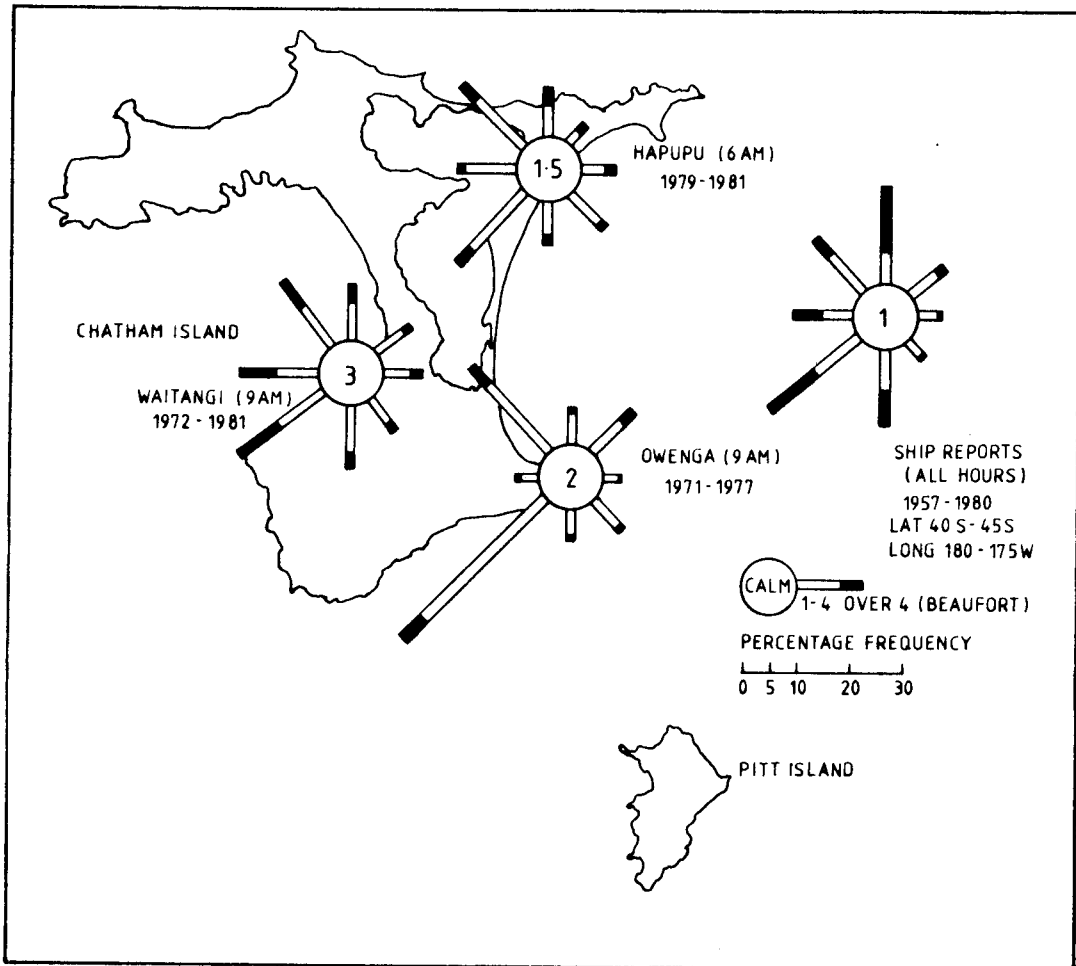


FIG.10: MEAN ANNUAL FREQUENCY (BEAUFORT FORCE) OF WIND DIRECTION

2.4 East to Southeast Airstreams

East to southeast airstreams affect the Chatham Islands about 15 percent of the time. Figure 8 is an example of an easterly airstream flowing over the Chatham Islands. Although cloudy, drizzly conditions are usual, fine weather normally prevails so long as the centre of the anticyclone is west of the Chatham Islands.

An example of a southeasterly airflow over the Chatham Islands is shown in Fig. 9a. Southeasterly conditions are typically associated with depressions which pass to the north or east. In most cases, these airstreams persist for no more than one or two days at a time but bring strong or gale force winds and periods of rain. A satellite picture taken on 12 April 1982 is shown in Fig. 9b. This view shows the deep depression displayed in Fig. 9a as lying east of Chathams. The Chatham Islands lie on the edge of the occluded frontal band, and just east of cumuliform cloud in the cold southeasterlies.

3. Climatic Elements

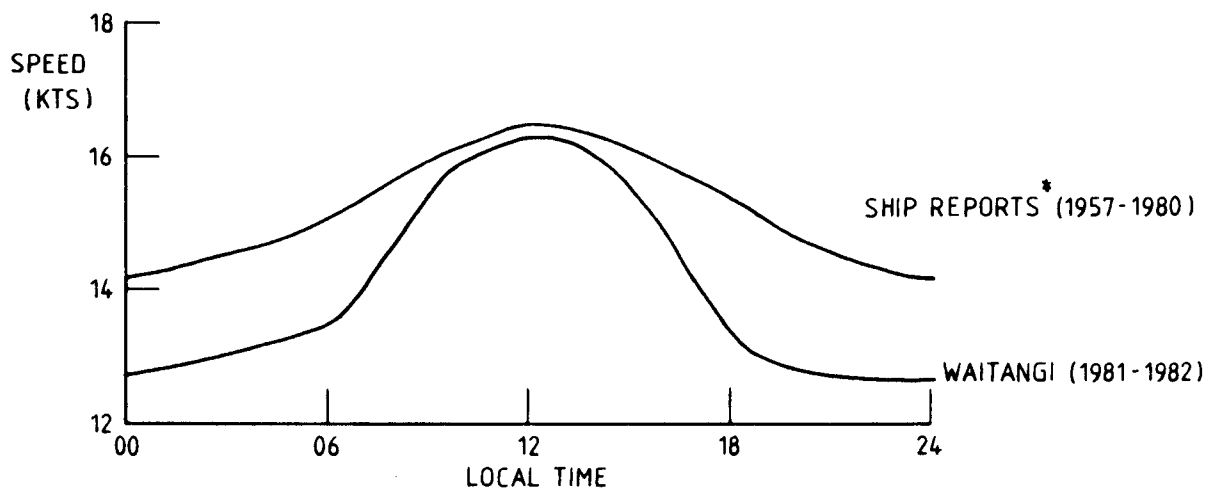
3.1 Wind

The prevailing wind direction over the southern oceans of the world in the zone above the earth's boundary layer is westerly. At the surface, the main wind directions on the Chatham Islands are from the westerly quarter (Fig. 10) with southwesterlies predominating. As well as for Waitangi, Owenga on the southeast end of Chatham Island and Hapupu in the northeast, data are also available for ships at sea in the Chathams area. An analysis has been included of ship's reports between 40° and 45° S and 180° and 175° W for the years 1957 to 1980.

Over the oceans surrounding the islands, there is a notable lack of easterlies, though northerlies and southerlies as well as westerlies are relatively frequent. Hapupu, formerly an airstrip aligned north-northwest to south-southeast, has lines of trees on either side. This accounts for the high frequency of calms. The wind rose at Hapupu has a rather uniform distribution. In northerly or southerly airstreams the wind often flows parallel to the runway, being influenced by the wide gap in the plantation.

At Waitangi, southwesterlies predominate, occurring on average 20 percent of the time and nearly half having speeds in excess of Beaufort force 4. Northwesterly winds are the second most frequent wind direction. Despite visual observations being made at Owenga, southwesterly and northwesterly winds are again common.

FIG.11: ANNUAL AVERAGE DIURNAL VARIATION OF HOURLY WIND SPEEDS



* DATA DERIVED FROM SHIP REPORTS BETWEEN LAT 40-45S, LONG 180-175W.

Wind on the islands is a marked feature of the climate; calm conditions are rare. The mean speed is about 14 knots, and calms occur for only 2 or 3 percent of the time. Comparing the "windiness" at the Chatham Islands with some South Island, New Zealand sites of similar latitudes, the mean speeds at Christchurch, Timaru, Dunedin and Invercargill are 8 knots, 6 knots, 7 knots and 9 knots respectively.

During the day, there is a small diurnal variation of 3 knots in the wind speed over the islands with the strongest winds frequently occurring about the middle of the day (Fig. 11). This variation (21 percent of the average speed) results from the heating and cooling effects of the land. The diurnal variation of the wind over the land is more marked than that over the sea where the mean speed is 15.5 knots and the range from minimum to maximum is 2.2 knots (14 percent of the average speed). Diurnal variations in the wind speed over the South Island are greater. At Dunedin, for example, the variation is 5.5 knots, and at Christchurch the value is 6.1 knots.

Gale force winds (mean speeds over 33 knots) are encountered on an average of 14 days each year, mostly during the months of May to September. Forty-four days of gale were reported in 1919, and there have been a further 6 occasions when over 25 days of gale were observed in a single year. Gales generally blow from the southwest, and have a tendency to develop when cyclogenesis occurs southeast of the islands. Under these conditions it is not unusual for strong to gale force winds to blow for up to 7 days at a time. Because southwesterly conditions cover a large area of ocean to the south of the islands, prolonged periods of high winds from the southwest allow a sufficient time for heavy seas and swell to be generated. Petre Bay on the western side of Chatham Island is totally exposed to the sea in such conditions.

The southwestern parts of Chatham Island are most affected by cold southwesterly airstreams. Many trees along the southern and western coasts and in other exposed positions on the island are misshapen and lean northeastwards (Capper, 1983 pers. comm.). The winds in these areas and in Pitt Strait are at times reported as being stronger than those observed in Waitangi.

Strong winds (over 21 knots) blow for nearly 16 percent of the time, and autumn and winter have the highest frequencies of strong winds. Strongest winds mostly blow from the west or southwest (Table 1).

Seasonal data from Waitangi are given in Table 1. Winds from the westerly quarter prevail all year round. A further 25 percent of all winds blow from between north and east, and in winter with depressions to the north of high latitude anticyclones, easterly conditions may become established for several days.

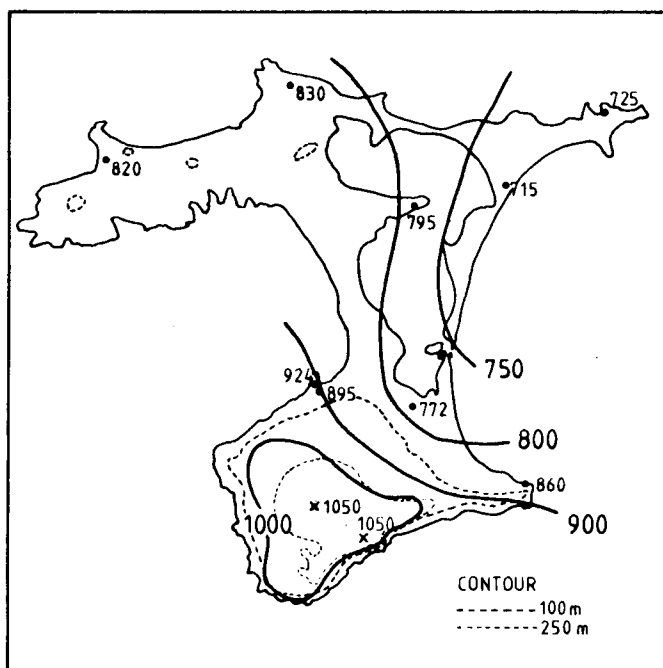


FIG.12: MEAN ANNUAL RAINFALL CHATHAM ISLAND PERIOD 1951 - 1980

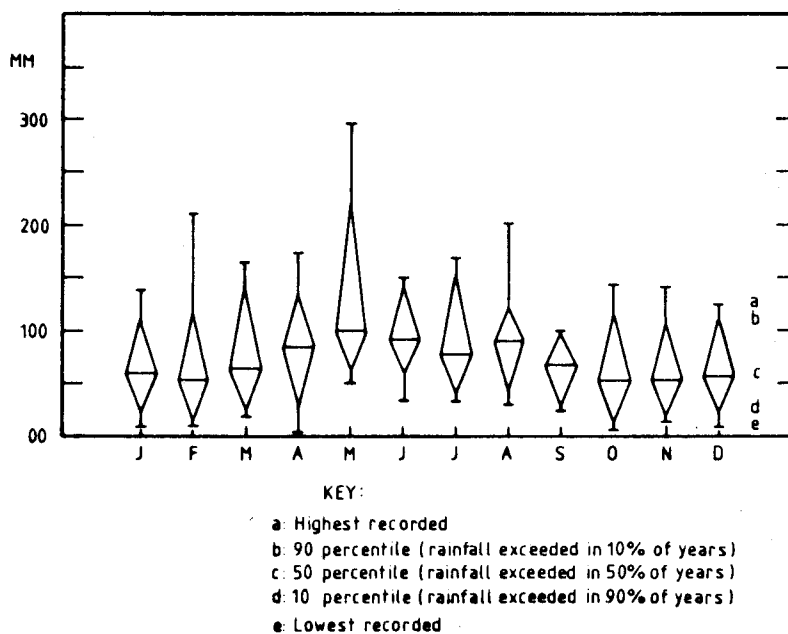


FIG.13: MEAN MONTHLY RAINFALL FOR WAITANGI, CHATHAM ISLANDS 1951 - 1978.

3.2 Rainfall

Much of the rain that falls over the Chatham Islands is associated with fronts or depressions, or airmass showers in southerly airstreams. Nearly half of the rainfall (Table 2) occurs when the wind is from the southwesterly quadrant although the more intensive falls are usually with northwesterly and northerly winds.

The pattern of mean annual rainfall is displayed in Fig. 12. This map was drawn from estimates or a 30 years average for a standard period, 1951-80. Rainfall has never been officially measured on the southern plateau, but Cockayne (1902) noted that the rainfall was greater there than at Waitangi. The spatial variation displayed in Fig. 12 shows the northeastern side of Chatham Island to be drier than at Waitangi. This could result from the fact that the main rain bearing winds are southwesterlies, and despite the highlands being under 300m in altitude, there is still some degree of orographic sheltering.

Rainfall statistics are given in Table 3 for all available sites on the Chatham Islands, and for Waitangi in Fig. 13.

There is a late autumn and winter maximum in the rainfall, and a summertime minimum. May is usually the wettest month and over 100 mm can be expected in most places. The driest months tend to be either November or December.

3.2.1 Rainfall Variability

Rainfall variability (coefficient of variation) is defined as the ratio of the seasonal/annual standard deviation to its corresponding mean value. Table 4 gives an indication of the rainfall variability at Waitangi and Owenga.

While there is some inter-annual variability (of the order of 12 to 15 percent), there is most variation in the summer rainfalls over the islands due mainly to the lower average rainfall in this season.

The number of rain days, of at least 0.1 mm, is considerable when compared with many places in New Zealand. At Waitangi, it rains on 225 days each year, while at Auckland there are 183 days, Wellington 162 days and Christchurch 120 days. Wet days (1.0 mm or more of rain) occur at Waitangi on 134 days.

Rain falls mostly in light showers or as drizzle, is of short duration and occurs frequently. While heavy rainfalls are rather exceptional, there is usually one day each year when over 40 mm are measured at Waitangi. The maximum one-day fall in the Waitangi area since 1878 is 133 mm which fell on 16 August 1936. The number of raindays each season is given in Table 5.

While there are 134 wet days at Waitangi, there are approximately 120 days on the drier northeastern part of the island, and at least 150 days are likely on the southern plateau.

3.3 High Intensity Rainfalls

An autographic raingauge at Waitangi has been operating since 1957. The charts have been analysed for the annual maximum rainfalls for selected durations varying from 10 minutes to 72 hours, and Coulter and Hessel (1980), using the extreme-value theory, have calculated depth-duration-frequency data for Waitangi. This appears in Table 6.

An example of the interpretation of this table is as follows. A 12-hour rainfall (12H) equal to or greater than 61 mm can be expected to occur once every 10 years ($T=10$).

Rainfall intensities are influenced by the surrounding topography and normally increase with altitude. Higher rainfall intensities can therefore be expected on the southern highlands of Chatham Island and on the high country of Pitt Island.

3.4 Dry periods on the Chatham Islands

"Dry periods" can be defined as 14 or more consecutive days with little or no rain. They can be classified as "dry spells" (no more than 1.0mm of rain each day) or as "meteorological droughts" (no measurable rainfall).

On the Chatham Islands, dry spells have been experienced 108 times since records were first taken in 1878. Nearly 75 percent of these occurred in the months November to March. This corresponds to the time when rainfall variability is greatest and total amounts least, due to a ridge of mean high pressure over northern New Zealand. Cold fronts passing over the Chatham Islands in this season are subsequently weak as they impinge into the southern limits of the high pressure zone.

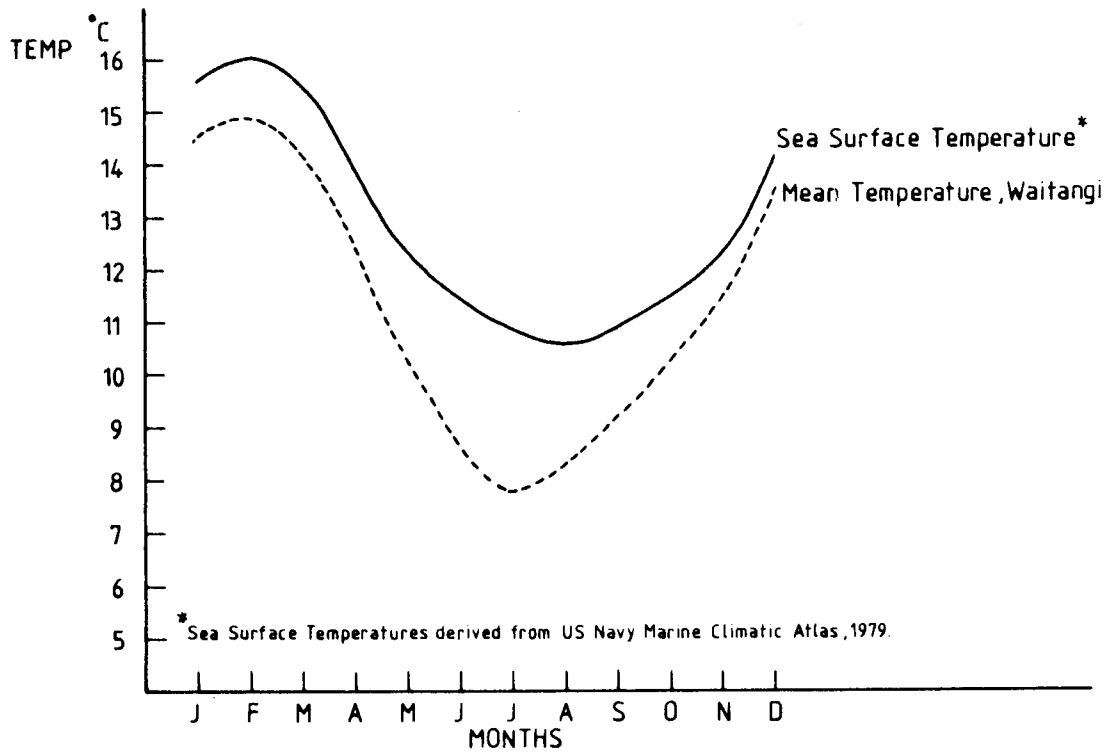


FIG.14: MEAN SEA AND AIR TEMPERATURES , CHATHAM ISLANDS .

The longest meteorological drought persisted for 30 days from 24 March 1933 to 22 April 1933. During this time the wind was mostly from the westerly quarter at a mean speed of about 7-10 knots. A belt of high pressure persisted to the north of the islands which moved slowly northwards. It is, however, exceedingly rare for such dry conditions to last for more than 20 days. There have been only six occasions in 104 years of record.

Dry conditions can also be assessed in terms of the minimum total rainfall over specific periods of time. (Table 7). The table indicates that driest conditions are more likely during the warmer months of the year.

3.5 Wet Weather Periods

Wet periods on the Chatham Islands can be identified by considering the maximum rainfall totals for specific daily and monthly periods. The maximum total falls for various periods of time are displayed in Table 8.

This table shows that for the longer periods (over one month), there were wet conditions during 1913-14 and again in 1957.

Waitangi's three-month rainfall has exceeded 350 mm 20 times since 1956, 400 mm 9 times and 450 mm 3 times. At the same time there have been only 7 occasions out of a possible 376 when the three monthly fall was less than 100 mm. The six-month rainfall has exceeded 700 mm only 3 times. It is interesting to note here that most wet weather periods occur during the cooler months (April to October) of the year and seldom during summer.

3.6 Temperatures

The temperature regimes of small islands are influenced by the prevailing wind flows with their associated airmass characteristics, and hence by the surrounding sea surface temperatures. Since the Chatham Islands are situated in a zone of strong and rather persistent westerlies, the daily and annual temperature variations are small. In general, summer temperatures reach 17°C to 18°C, and during winter the minima are 5°C to 6°C in all months.

The influence of the sea surface temperatures on the islands is great. Average monthly values of sea temperatures are shown with the mean temperatures from Waitangi (Fig. 14). Mean temperatures are calculated as being half of the sum of the mean daily maximum and the mean daily minimum temperature for a particular month.

The mean temperature range of 7°C is quite small due to the modifying effects of the sea. At all times the sea temperatures are warmer than the mean temperatures measured on land but the differences are greatest during winter.

As previously mentioned, extremes of temperatures are rare. In summer, maximum temperatures exceeding 20°C can be expected on about 14 days each year. During winter, air frosts on the Chatham Islands are measured on about 1 day every two years.

Temperature summaries for various locations in the Waitangi district are given in Tables 9 to 12.

On Pitt Island, the only other island of any size, Florence (1900) noted that the northeast side of the island was slightly warmer than Chatham Island. This is probably due to the sheltering from the ever present wind by the high southward facing land.

Mean air temperatures usually decrease with height above mean sea level, reducing by about 0.6°C for each 100 m increase in altitude. Temperature soundings taken at Waitangi indicate the mean monthly temperatures at 275 m (the height of the southern high country) to be on average about 1.5°C colder than the temperatures at Waitangi. These are shown in Table 13.

3.7

Cloud cover

During daylight hours, the average amount of total cloud is 5.9 oktas (Tables 14, 15). (An "okta" is one eighth of the visible sky). There is little variation at any time of the year. In the morning (at 9am) the mean amount of cloud is 6.0 oktas. At midday and in the afternoon the mean amount is 5.8 oktas (Table 15). There appears to be a small variation in cloud cover over the islands. Mean 9am values at Owenga and Hapupu are 5.6 and 5.5 oktas respectively. It is expected that the higher southern areas of the island would experience cloudier conditions than Waitangi.

Clear skies or little cloud, i.e. not more than 2 oktas of cloud cover, averaged over a year at 6 am, 12 noon and 6 pm, occur on 49, 39 and 54 days respectively. Overcast skies (more than 6 oktas of cloud cover) average 213, 202, and 198 days respectively. Seasonal distribution of clear and cloudy skies at Waitangi is given in Table 16.

3.8 Sunshine

Because of the high degree of cloudiness, the islands receive on average about 1350-1550 hours of bright sunshine each year, i.e. about 30-40 percent of the possible sunshine. Waitangi receives 1431 hours of sunshine a year. Estimates of annual sunshine, based on a comparison of morning cloud cover at Owenga and Hapupu with the cloud amount at Waitangi, show that these places could expect about 1550 hours of sunshine. The southern highlands are cloudier than Waitangi, and it is estimated therefore that an average of 1350 hours of sunshine a year is possible. Details of the sunshine regime are given in Table 17.

There are about 40-50 days each year when no sunshine is recorded. Waitangi has an average of 55 days; 9 days in summer, 18 days in winter, 15 days in spring and 13 in autumn.

An application of the use of daily sunshine information at Waitangi is the frequency of sunshine of specified amounts during a single day, or the average daily sunshine over several successive days (N-Days sunshine, Table 18). This table indicates that there is virtually no likelihood of having 5 or more consecutive sunless days, although there is a 15 percent chance that any single day will be without sun. Lists of extreme sunshine totals for Waitangi are presented in Table 19.

3.9 Fog

Fog on the Chatham Islands is reported on about 21 days each year. Since 1878, there have been only four occasions when more than 30 days of fog per year have been observed. In 1903 and 1904 there were 34 days; 1909, 36 days; and 1966, 32 days. It is mostly advection (or sea) fog and very occasionally frontal fog. Both types can occur at any time of the day and are fairly evenly distributed throughout the year. Sea fogs will form when a warm humid northerly airmass is cooled to below its dew point by a colder sea. Sea fog over the islands can be persistent but will normally lift to low stratus during daylight hours.

On occasions in moist northwesterly or northerly airstreams, fog or stratus cloud may be present on the northeastern side of the island and on the southern highlands when there is no indication of this at Waitangi.

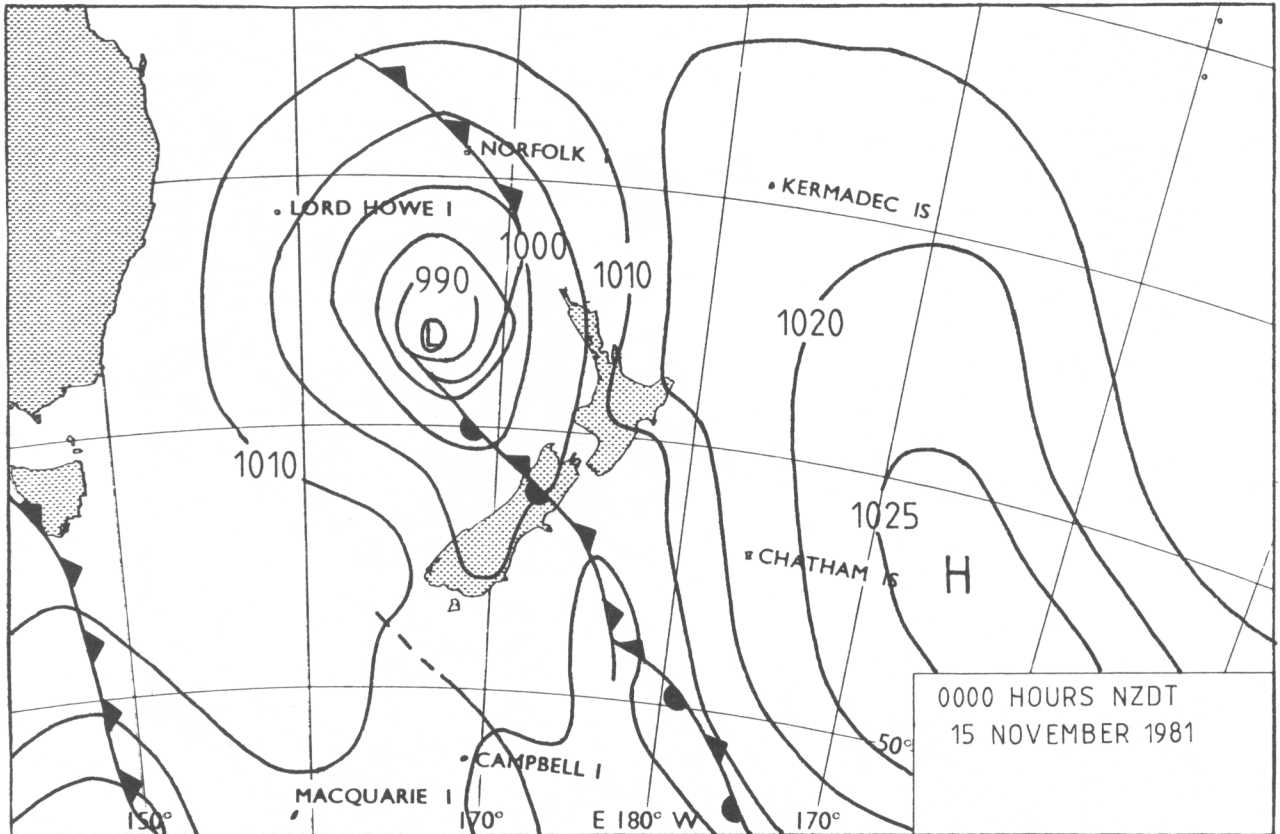


FIG.15: MSL ANALYSIS FOR 15 NOVEMBER 1981

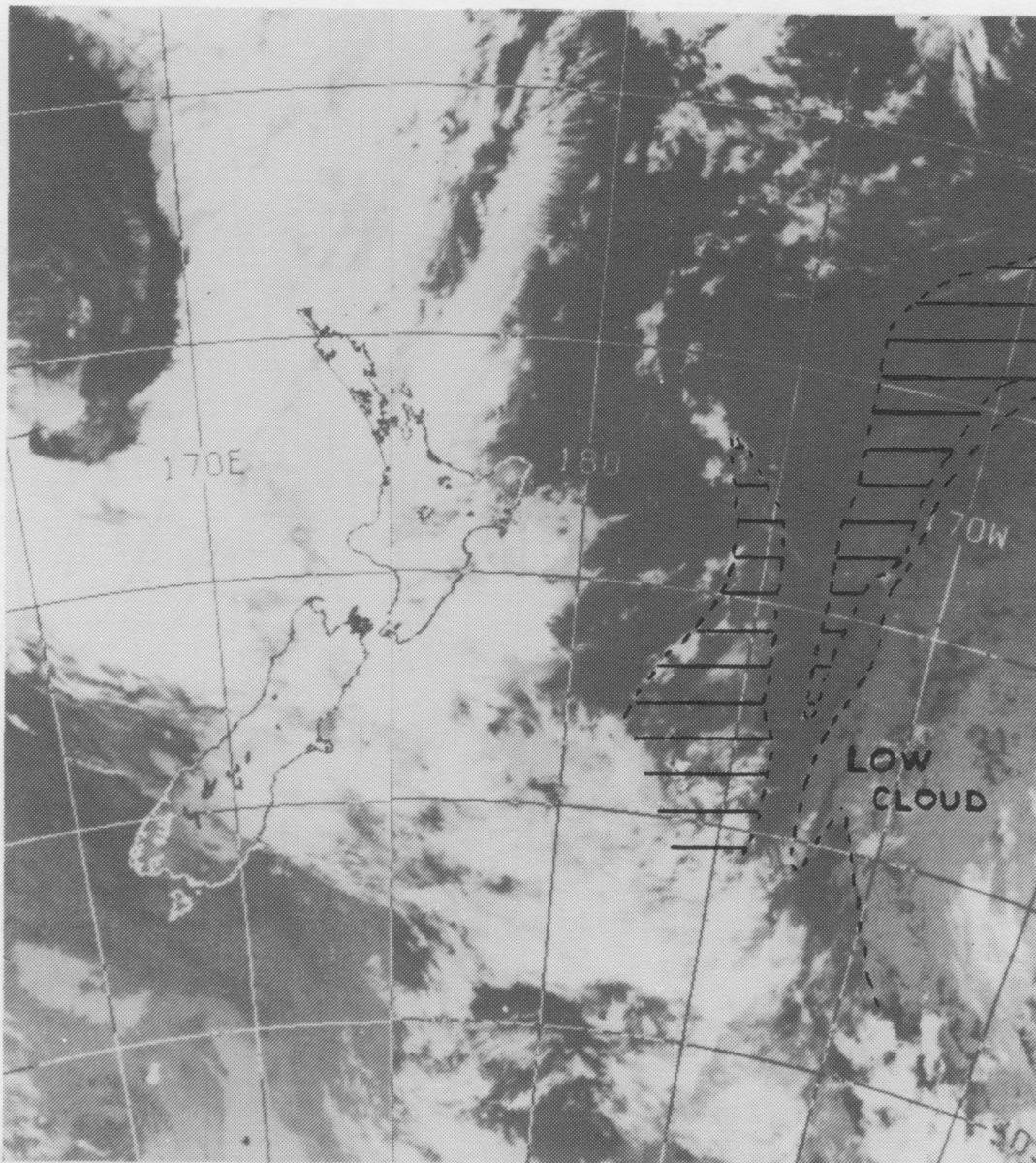


Fig.16. Satellite view of fog over Chatham Islands on 15 November 1981.
Fog or low cloud is indicated by hatching.

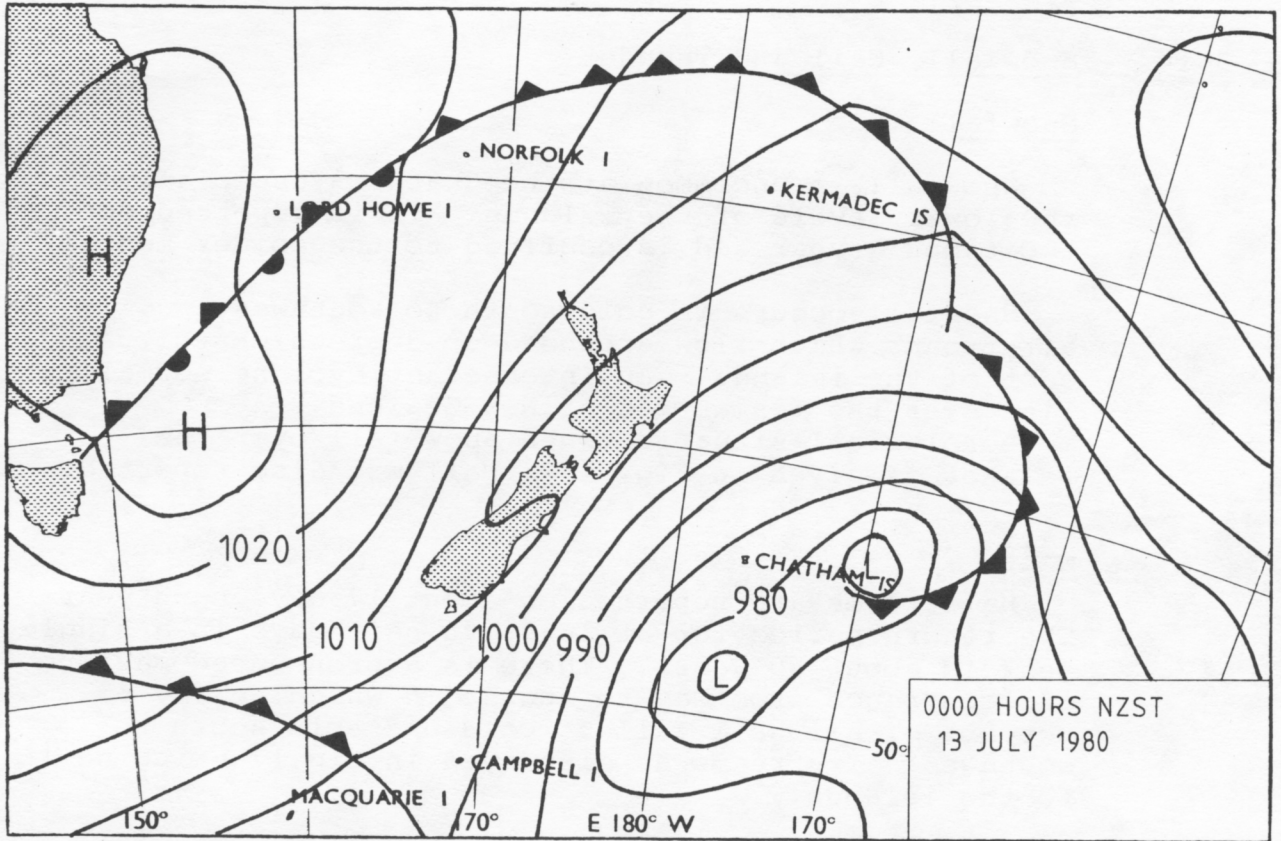


FIG. 17: MSL ANALYSIS FOR 13 JULY 1980, WHEN SNOW AND HAIL FELL AT CHATHAM ISLANDS.

A meteorological situation when fog was reported most of the day at Waitangi is shown in Fig. 15. A corresponding satellite picture (Fig. 16) shows a streak of low cloud/fog (enclosed by hatched lines) extending northwards from the Chatham Islands. This fog band lies within the warm sector of a frontal system.

3.10 Snowfall, Hail and Thunder

Snowfall

Snowfall is uncommon at the Chathams especially on the lower levels of the islands. It is reported one or two times a year and is confined to the colder months.

Snowfall occurs in cold south to southwest airstreams which flow around deep depressions situated east of the islands. An intense anticyclone normally lies over the Tasman Sea or New Zealand. A meteorological situation when snow fell over the islands is given in Fig. 17. Hail was also reported.

Hail

Hailstorms are reported on about 17 days each year. The return period for at least 25 hail days in a single year is about 50 years. There is a pronounced maximum of occurrence from May to August in which nearly 65 percent of all hail falls. Cold unstable south to southwest airstreams as displayed in Fig.17 bring hail to the islands.

Thunder

On average there are 4 days of thunder each year at the Chatham Islands, and 10 days of thunder in a year are likely once every 50 years. Although fairly evenly distributed throughout the year, there is a tendency for thunderstorms to occur more frequently from April to June and especially during the night. Meteorological situations associated with thunderstorms usually occur with cold unstable showery southwesterlies, or cold fronts crossing the islands.

3.11 Vapour Pressure and Relative Humidity

Water vapour is an important constituent of the atmosphere. The moisture content of the atmosphere is commonly represented by water vapour pressure and/or relative humidity. Vapour pressure is that part of the total atmospheric pressure which results from the presence of water vapour. Table 20 gives mean values of vapour pressure for 0900 and 1500 hours.

The table shows that there is no appreciable variation in the values of vapour pressure during the day. Vapour pressure, unlike relative humidity is not influenced by temperature, and tends to be constant within air masses which have similar characteristics. There is however a significant intra-annual variation.

Vapour pressure decreases with altitude because of lower air temperatures. Estimates at the highest point of the Chatham Islands, made using Hann's method (cited in List, 1966) are also shown in Table 20. They are about 90 percent of the low land values.

Relative humidity expresses the vapour pressure of an air sample as a percentage of the saturated vapour pressure the air can hold at the same temperature. Due to the marine environment of the islands, relative humidities remain high all year round (Table 21). The daily variation is small when compared with other locations in New Zealand. Christchurch for example has a mean diurnal variation of 30 percent in January and 20 percent in July, while at Wellington the values are 18 percent and 10 percent.

3.12 Degree-Days

Various writers (Cockayne, 1902; Madden, 1953) have noted that the Chatham Islands are suitable for certain types of agricultural/horticultural activities. With suitable protection from the wind (such as shelter belts which set up their own microclimate) many fruits and vegetables are grown. The suitability of the climate for a particular crop to grow successfully can be assessed from the concept of 'degree-days'.

Growing degree-days are accumulations of mean temperature above a specified threshold. Table 22 gives growing degree-day data for Waitangi. For example for a successful harvest of peas, between 650-800 growing degree-days are required above a threshold of 5°C during the August to February period. Peas can be grown quite successfully on the Chatham Islands as there are over 1400 growing degree-days between August and February.

3.13 Soil Water Balance

Soil water balance studies have been found useful for a variety of agricultural, hydrological and engineering activities including estimates of pasture growth, river flow and hydro-electricity assessments. Coulter (1973) proposed a water balance model which assumed:-

- (i) an arbitrary soil moisture capacity;
- (ii) a soil water depletion at a constant rate due to evaporation and plant transpiration (evapotranspiration); and
- (iii) an increase of soil moisture by rainfall until the soil capacity is reached. Further rainfall leads to run off.

The Chatham Islands are covered with extensive areas of peat. If it is assumed that the peat layer is drained and is only one metre thick, then the soil moisture capacity is about 400 mm. A daily water balance summary for Waitangi is presented in Table 23.

It is apparent from the table that there is some water deficit during summer, and a water surplus during winter. Furthermore, both water surplus and deficit each occur one year in two, but not necessarily in the same year.

4. Climate of the Seas Surrounding the Chatham Islands

4.1. Sea State

Exploration of the ocean's resources frequently requires sea conditions which are not too "rough". Since the wind is ever present at and around the Chatham Islands, so too are there locally generated sea waves, and swell which originates from outside the area. Wind wave and swell reports are routinely made by ships in the area. Table 24 presents a wave and swell analysis for a 5° square surrounding the islands. Rough seas and high swells (heights over 3m) occur 9 percent and 47 percent of the time respectively. Predominant wave directions are from the south or southwest and also from the north. Most swells arriving in the Chatham's area originate in the strong westerly wind zone to the south and southwest of New Zealand, as well as in southwesterly airstreams which frequently blow between New Zealand and the islands.

4.2 Sea Surface Temperatures

The fishing industry is becoming increasingly aware of the benefits to be gained from a knowledge of sea temperatures (Taylor and Thompson, 1980), both in terms of fisheries management and in planning. Mean monthly sea temperatures are shown in Fig.14. This diagram displays the annual march of sea surface temperatures, with highest temperatures in February and the lowest in August. The annual variation is about 5.5°C. This is quite a large variation when compared with a tropical region near Fiji whose annual change is only 1.5°C.

4.3 Iceberg Sightings

Icebergs have been sighted only once at the Chatham Islands. This was in October 1892. One stranded on Chatham Island and others were seen in Pitt Strait, Petre and Hansen Bays (Shand, 1894). Other independent observations of icebergs were reported between the islands and New Zealand. At that time no living person on Chatham Island had heard of such an occurrence previously.

5. Summary

Although rain falls on the Chatham Islands on over 200 days a year, amounts are generally small. Most rain falls as showers in southerly airstreams, but occasional heavy rains are associated with warm northerlies.

The Islands are surrounded by the vast South Pacific Ocean. Temperature extremes are rare because of the ever present wind and also due to the influence of the oceans in modifying passing airstreams. Fishing plays a big role in the economic well-being of the Island's community, but rough seas and strong winds can curtail this activity. Gale force winds can blow for several days on end.

The climate of the Chatham Islands has been found suitable for sheep farming, and there are areas where, with suitable shelter, orchards and vegetable gardens are highly productive.

In summary the islands are a cool, cloudy, windswept region.

6. References

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TABLE 1:

Seasonal Frequency per Thousand Observations of Winds
for specified speed and direction categories,
Waitangi 1970-1978.

Frequencies based on hourly data from 0600-1800 hours.

<u>SPRING</u> (Sep., Oct., Nov.)								<u>SUMMER</u> (Dec., Jan., Feb.)							
SPEED(KT)	1-3	4-10	11-16	17-21	22-27	28+	TOTAL	SPEED(KT)	1-3	4-10	11-16	17-21	22-27	28+	TOTAL
DIR								DIR							
N	2	20	33	28	10	1	93	N	2	22	36	26	9	1	97
NE	3	27	28	17	4	0	79	NE	1	29	35	11	1	0	78
E	2	23	26	12	7	3	72	E	2	25	37	21	7	2	94
SE	2	22	21	13	5	1	65	SE	3	21	32	15	9	3	83
S	4	32	31	20	8	2	97	S	4	24	33	18	7	0	87
SW	2	33	58	49	32	12	184	SW	2	28	54	54	24	10	171
W	4	63	64	37	24	15	208	W	6	70	66	33	19	13	208
NW	2	34	57	53	30	7	184	NW	3	39	64	42	15	4	167
							CALM								CALM
							17								15
TOTAL	21	254	318	228	119	41		TOTAL	23	258	357	221	92	34	
	TOTAL OBSERVATIONS USED						9490		TOTAL OBSERVATIONS USED						9355
<u>AUTUMN</u> (Mar., Apr., May)								<u>WINTER</u> (Jun., Jul., Aug.)							
SPEED(KT)	1-3	4-10	11-16	17-21	22-27	28+	TOTAL	SPEED(KT)	1-3	4-10	11-16	17-21	22-27	28+	TOTAL
DIR								DIR							
N	3	27	38	25	8	2	103	N	2	22	34	20	7	3	88
NE	4	32	25	13	5	0	79	NE	4	29	39	17	8	4	101
E	4	25	19	13	6	2	68	E	4	28	27	17	8	6	89
SE	5	25	20	10	6	3	69	SE	8	34	25	19	8	1	94
S	8	43	38	18	6	1	113	S	8	56	45	22	13	4	146
SW	2	46	73	55	33	17	225	SW	4	46	66	45	31	20	211
W	3	41	44	32	25	29	173	W	3	29	34	32	22	16	137
NW	2	36	45	36	20	5	144	NW	3	23	34	22	13	4	98
							CALM								CALM
							25								35
TOTAL	31	274	301	201	108	59		TOTAL	36	267	303	193	108	58	
	TOTAL OBSERVATIONS USED						9588		TOTAL OBSERVATIONS USED						9573

TABLE 2: Rainfall and Wind Direction at Waitangi

Percentage frequency of occurrence of rain with wind direction

Direction	N	NE	E	SE	S	SW	W	NW	CALM
Occurrence	10.9	7.9	7.6	11.2	11.3	23.8	11.4	14.4	1.3

TABLE 3A: Mean Monthly/Annual Rainfall (mm)

	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Year (Normal)</u>	
Waitangi														
1951-1980	57	58	75	84	114	97	86	83	66	59	57	59	895	895
Chatham Island Radio														
1958-1963	73	73	97	84	120	102	75	80	50	69	35	54	912	929
Pokaroro														
1959-67	48	67	97	92	88	79	62	77	49	35	47	40	787	772
Waitangi West														
1975-79	67	48	67	82	125	80	106	56	81	57	66	58	893	828
Owenga														
1971-80	70	54	71	77	119	88	94	64	63	58	46	41	845	863

TABLE 3B: Estimates of Annual Normal Rainfall (mm) 1951-1980

Based a limited data (less than 3 years)

Karewa Point	795
Hapupu Airfield	715
Wharekauri	830
Kaingaroa	725
Pitt Island	900

TABLE 4: Rainfall Variability (%)

	<u>Summer</u>	<u>Autumn</u>	<u>Winter</u>	<u>Spring</u>	<u>Annual</u>
Waitangi	33.1	25.0	25.6	24.9	12.9
Owenga	49.0	31.7	26.6	29.4	14.7

TABLE 5: Seasonal Raindays at Waitangi

<u>Rainfall of at least</u>	<u>Summer</u>	<u>Autumn</u>	<u>Winter</u>	<u>Spring</u>	<u>Annual</u>
0.1mm	46	55	72	57	224
1.0mm	24	36	44	30	134

TABLE 6: Depth - Duration - Frequency of Rainfall
calculated for Waitangi, Chatham Islands
1957-1978.

<u>Duration</u>	<u>10m</u>	<u>20m</u>	<u>30m</u>	<u>1H</u>	<u>2H</u>	<u>6H</u>	<u>12H</u>	<u>24H</u>	<u>48H</u>	<u>72H</u>
<u>Return Period (years)</u>										
T=2	6	8	10	14	20	31	39	51	59	65
T=5	8	12	14	19	27	43	52	66	86	97
T=10	9	14	16	22	32	51	61	76	104	119
T=20	11	16	19	25	36	58	69	85	121	140
T=50	12	18	22	29	41	68	80	97	144	167

TABLE 7: Minimum Rainfall (mm) for Consecutive Days
 of Months at Waitangi (1957-1982)

(a)	<u>Consecutive Days</u>	<u>Rainfall Amount</u>	<u>End Date of Sequence</u>
	20	0.3	5 January 1962
	30	1.8	9 March 1967
	60	18.0	25 February 1971
	80	31.0	26 March 1971
	100	49.2	22 April 1971
(b)	<u>Calendar Months</u>	<u>Rainfall Amount</u>	<u>End Date of Sequence</u>
	1	5	October 1963
	3	45	April 1971
	6	178	April 1971
	9	373	April 1971
	12	556	September 1971

TABLE 8: Maximum Rainfall (mm) for Consecutive Days or Months

(a) Waitangi Meteorological Office (1956-1982)

<u>Duration</u>	<u>Rainfall</u>	<u>End Date of Period</u>
1 day	96	10 February 1976
3 day	149	10 February 1976
5 day	193	10 February 1976
7 day	194	10 February 1976
10 day	215	24 May 1957
20 day	275	25 May 1957
30 day	329	4 June 1957
60 day	421	1 June 1957
1 month	296	May 1957
3 month	488	June 1957
6 month	744	August 1978
9 month	1015	July 1957
12 month	1331	May 1957

(b) Chatham Island Radio * (1978-1963)

1 day	1326	16 August
1 month	372	May 1957
3 month	598	July 1913
6 month	945	August 1913
9 month	1266	July 1913
12 month	1585	August 1913

* Includes data from earlier sites

- (a) Whangamarino
- (b) Chatham Island Radio

TABLE 10: Mean Diurnal Variation of Temperature * at Waitangi - Fixed Hours (1970-1981)

Time (NZST)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
00	12.8	13.2	12.6	11.4	9.6	7.9	7.1	7.6	8.5	9.0	10.0	11.8
06	13.4	13.6	12.8	11.9	9.8	8.1	7.3	7.9	8.6	9.5	10.8	12.8
12	16.3	16.7	15.8	14.3	11.6	9.9	9.4	10.0	11.0	11.9	13.1	15.3
18	15.0	15.2	14.1	12.4	10.1	8.4	7.9	8.5	9.4	10.3	11.7	14.0

* Daily Maxima and Minima seldom coincide with these fixed observation times.

TABLE 11: Extreme Temperatures for various Waitangi Sites

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
(a) Maximum													
Whangamarino			22.4	22.8	21.7	20.6	18.3	16.7	16.1	16.1	20.0	21.7	23.3
Chatham Island Radio			22.5	23.8	22.2	19.4	18.4	14.9	14.0	15.4	17.3	17.1	19.8
Meteorological Office			22.4	23.2	22.3	20.3	18.4	16.2	14.1	14.7	15.3	17.7	19.4
(b) Minimum													
Whangamarino			2.8	1.7	1.1	0.0	-0.6	-1.1	-1.7	-2.2	-1.1	-1.1	-0.6
Chatham Island Radio			2.8	4.4	2.2	1.9	-0.7	-1.7	-2.9	-0.5	0.0	1.1	2.3
Meteorological Office			5.0	4.7	3.9	2.1	1.1	-0.7	-0.5	-2.3	-0.4	0.0	1.1

TABLE 12:

Cumulative frequency per thousand observations of daily
Temperature less than T Degrees

A. Daily Maximum Temperature

T.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Sum	Aut	Win	Spr	Warm	Cool	Year
< 6.0							3	7							3			2	1
< 7.0						33	10	16							20			10	5
< 8.0					3	73	77	61						1	71			36	18
< 9.0					23	170	232	168	37	3				8	190	13		105	53
<10.0					71	327	407	326	117	29	3			24	353	50	1	213	107
<11.0				3	194	540	584	500	293	136	33			66	541	154	6	374	191
<12.0		4		27	403	703	794	697	510	319	123	3	2	145	732	318	26	571	300
<13.0		7	19	90	594	820	945	916	750	523	287	36	14	236	895	520	73	758	418
<14.0	23	14	65	240	742	937	997	984	920	687	477	100	47	350	973	695	153	877	518
<15.0	81	57	165	430	884	990	1000	1000	987	868	647	213	119	494	997	834	265	954	612
<16.0	223	198	307	620	952	1000			1000	968	783	358	261	626	1000	918	415	986	703
<17.0	371	375	465	777	994					994	923	526	425	745		973	573	998	787
<18.0	526	534	645	917	1000				1000	980	713	593	853		993	993	719	1000	861
<19.0	713	640	819	980						997	848	736	933		999	999	834		918
<20.0	855	802	926	993					1000	942	868	973		1000	921	1000	921		961
<21.0	945	933	977	1000						997	959	992			976		976		988
<22.0	981	986	1000							1000	989	1000		1000	995		995		997
<23.0	1000	1000											1000				1000		1000

(Table 12 Continued)

T.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Sum	Aut	Win	Spr	Warm	Cool	Year
B. Daily Minimum Temperature																			
<-2.0								3							1			1	
<-1.0								3							1			1	
< 0.0						10		7							5			3	1
< 1.0						27	23	16							22			11	6
< 2.0					16	67	103	55	13		3			5	75	6	1	42	22
< 3.0				3	42	137	184	142	63	16	13			15	154	31	3	97	50
< 4.0				7	103	247	310	239	117	87	40	3	1	37	265	81	8	184	97
< 5.0		4		20	216	410	455	345	247	174	93	13	6	79	403	171	22	308	166
< 6.0	23	14		47	345	543	565	484	353	255	183	23	20	132	530	264	48	424	237
< 7.0	61	28	42	127	458	660	729	629	503	397	277	55	49	210	673	392	98	563	332
< 8.0	139	85	119	220	613	777	819	768	660	539	407	100	109	319	788	535	178	696	439
< 9.0	207	163	226	340	745	847	916	877	783	661	543	197	189	438	880	663	279	805	544
<10.0	329	265	342	443	848	920	981	952	890	794	647	307	301	546	951	777	389	897	645
<11.0	448	396	458	597	903	960	994	987	967	887	793	429	425	653	980	882	520	950	736
<12.0	558	530	610	730	926	980	1000	1000	993	968	877	594	562	755	994	946	650	978	815
<13.0	690	671	726	837	971	993			1000	990	970	748	704	845	998	987	774	992	884
<14.0	794	774	800	913	994	1000				1000	997	890	821	902	1000	999	862	999	931
<15.0	907	873	881	973	1000						1000	965	916	951		1000	933	1000	967
<16.0	974	919	952	993								997	965	982			973		987
<17.0	1000	986	997	1000								1000	996	999			997		999
<18.0		1000	1000										1000	1000			1000		1000

Note: Summer is December, January, February, etc,
Cool Season is May - October,
Warm is November - April.

TABLE 13: Estimated Mean Monthly Temperatures ($^{\circ}\text{C}$) at 275m
on Chatham Island highlands
(This corresponds to the Southern Highland area on
Chatham Island)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temp	13.0	13.4	12.6	11.0	8.9	7.2	6.3	6.7	7.6	8.3	10.1	12.0	10.0

TABLE 14: Mean Monthly Cloud Cover (Oktas) at Waitangi 1971-1980

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Cloud cover	5.8	5.8	5.9	6.1	5.9	5.7	5.7	6.0	6.0	5.8	5.8	6.0	5.9

TABLE 15: Diurnal Variation of Cloud Cover (Oktas) 1971-1980

Time	:	0600	0900	1200	1500	1800
Cloud cover	:	5.9	6.0	5.8	5.8	5.7

TABLE 16: Number of days by seasons of cloud cover
at Waitangi (1971-1980)

TIME (NZST)	Clear skies or little cloud (0, 1, 2 oktas)				Overcast (7, 8 oktas)			
	SUM	AUT	WIN	SPR	SUM	AUT	WIN	SPR
0600	10	12	16	11	59	57	41	56
1200	12	8	7	12	50	53	50	49
1800	11	13	15	15	50	52	46	50

TABLE 19: Extreme Sunshine Totals (Hours) for selected periods at Waitangi (1972-1981)

Period (Days)	Maximum		Minimum	
	Sunshine	Up to Date	Sunshine	Up to Date
3	42.4	4 January 1975	Nil	Frequent
5	57.6	5 January 1975	Nil	19 March 1974
7	73.4	5 January 1975	1.1	12 January 1975
10	93.8	3 February 1979	3.7	8 December 1978
15	134.8	5 January 1975	9.0	25 June 1978
20	163.6	5 February 1979	15.6	25 June 1978
30	244.8	3 February 1979	31.2	20 June 1974
60	444.8	17 February 1979	98.4	26 July 1972

TABLE 20: Mean Monthly/Annual Vapour Pressure (hPa*)

(a)	0900 Hours	Period:	1956-1980										
(b)	1500 Hours	Period:	1970-1981										
(c)	0900 Hours Estimates at 275m												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
a	13.8	14.2	13.8	12.6	10.9	9.7	9.2	9.6	10.2	10.8	11.5	13.3	11.6
b	13.8	14.1	13.4	12.4	10.6	9.6	9.4	9.8	9.7	10.9	11.6	13.4	11.6
c	12.5	12.8	12.5	11.4	9.9	8.8	8.3	8.7	9.2	9.7	10.4	12.0	10.5

* hPa Hectopascal. This is equivalent to millibars.

TABLE 21: Mean Monthly Relative Humidity (%) at Selected hours

TIME (NZST)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0000	87	87	85	86	84	86	88	88	88	88	88	89
0600	86	86	86	86	85	86	87	88	88	87	86	87
0900	81	83	84	85	87	86	86	86	85	83	82	83
1200	75	74	74	77	79	80	81	81	80	79	78	78
1500	76	75	76	79	80	81	81	82	81	80	79	78
1800	79	80	81	84	84	85	86	86	86	83	82	82
Daily	82	82	82	83	83	84	86	86	86	84	83	84
Mean DV*	12	14	11	9	6	7	8	8	8	9	9	12

* Diurnal Variation (DV) has been estimated before "rounding" from one decimal place.

TABLE 22: Growing Degree Days above Base Temperature (oC)
at Waitangi (1972-1981)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Base Temp													
5	295	274	283	232	152	101	91	105	131	165	192	275	2296
10	140	135	128	84	25	10	4	7	14	31	51	121	750
15	22	23	17	4							1	12	79

TABLE 23: Daily Water Balance Summary for Waitangi (1958-1982)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
PE* (mm)	131	102	83	50	32	26	25	36	55	83	107	124	854
RR (mm)	56	57	68	78	101	96	89	79	69	59	48	55	855
DE (mm)	4	12	12	4	0	0	0	0	0	0	0	0	32
ND (day)	1	4	5	3	1	0	0	0	0	0	0	0	14
RO (mm)	0	0	0	0	0	4	12	13	9	1	0	0	39
NR (day)	0	0	0	0	0	1	2	2	2	0	0	0	7

- * PE - Potential evapotranspiration (Penman Method)
- RR - Rainfall
- DE - Amount of evapotranspiration deficit
- RO - Amount of runoff
- ND - Number of days with cooler deficit
- NR - Number of days with runoff

TABLE 24:

Wind waves and swell analysis (1957-1980)

Area: Lat. 40-45S; Lon. 180-175W

Frequencies are parts per thousand observations

WIND	WAVE HEIGHT (m)						TOTAL	DIR	SWELL HEIGHT (m)						TOTAL
	0.5	1.5	3.0	6.5	10.0	CALM			SWELL	0.5	1.5	3.0	6.5	10.0	
DIR	-1.0	-2.5	-6.0	-10.0	10.0	CALM	TOTAL	DIR	-1.0	-2.5	-6.0	-10.0	10.0	CALM	TOTAL
N	126	85	13				6 230	N	7	69	40	3			118
NE	50	18	8				5 81	NE	8	47	25	1			81
E	23	15					5 44	E	3	10	12				25
SE	15	6					4 26	SE	3	18	5	1			27
S	55	81	8				3 147	S	12	87	89	3		3	194
SW	60	97	35	6			4 202	SW	5	76	163	18	1		264
W	57	55	9				4 125	W	4	37	41	5			88
NW	77	44	12				1 134	NW	4	45	38	1			89
CONFUSED	4						8 12	CONFUSED	7	33	22				52 114
TOTAL	468	402	84	6		40	TOTAL	54	420	437	33	1	55		
	TOTAL OBSERVATIONS USED						777		TOTAL OBSERVATIONS USED						728

WAVE PERIOD	WAVE HEIGHT (m)						TOTAL	PERIOD	SWELL HEIGHT (m)						TOTAL
	0.5	1.5	3.0	6.5	10.0	CALM			SWELL	0.5	1.5	3.0	6.5	10.0	
2-3	233	115	5				354								
4-5	93	174	21				13 301	6	12	52	22				86
6-7	19	84	31				1 134	6-7	19	153	174	14			360
8-9	5	21	24				50	8-9	10	100	132	5		1	248
10-11		1	4	4			9	10-11	3	48	48	8		52	159
12-13					3		3	12-13	7	37	38	1	1	1	86
14+	1						1	14+	1	8	8	4			22
CONFUSED	113	8				27	147	CONFUSED	3	22	14				38
TOTAL	464	403	85	7		41	TOTAL	55	421	436	33	1	55		
	TOTAL OBSERVATIONS USED						754		TOTAL OBSERVATIONS USED						730

(Table 24 Continued)

WIND HEIGHT	WAVE HEIGHT (m)						TOTAL	SWELL DIR	SWELL HEIGHT (m)						CONF	TOT
	0.5 -1.0	1.5 -2.5	3.0 -6.0	6.5 -10.0	10.0	CALM			6	6-7	8-9	10-1	12-3	14+		
0.5-1.0	40	1				6	47	N	26	46	23	16	5			117
1.5-2.5	280	111	13			16	421	NE	12	33	15	12	4	1	3	81
3.0-6.0	159	239	37			1	436	E	7	10	5		3		1	26
6.5-10.0	4	12	12	6		1	36	SE		15	8	3	1			27
10.0			1				1	S	11	67	60	26	19	8	1	193
CALM	4	37	13			4	59	SW	7	94	85	26	34	10	8	264
								W	8	41	14	14	7	1	3	87
								NW	10	29	29	8	8		5	89
								CONFUSED	5	25	7	55	3	1	20	116
TOTAL	487	400	77	6		30		TOTAL	86	359	246	160	85	22	42	
	TOTAL OBSERVATIONS USED						675		TOTAL OBSERVATIONS USED						732	