COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF EXTERNAL AFFAIRS

AUSTRALIAN NATIONAL ANTARCTIC RESEARCH EXPEDITION

A.N.A.R.E. REPORTS

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VOLUME I

Heard And Macquarie Islands, 1948.

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Part I (c) Discussion

ISSUED BY THE ANTARCTIC DIVISION, DEPARTMENT OF EXTERNAL AFFAIRS MELBOURNE
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PREFATORY NOTE

The meteorological work of the Australian National Antarctic Research Expedition at Heard and Macquarie Islands during 1948 was carried out by officers of the Meteorological Branch of the Department of the Interior.

On their return to Australia Messrs. A.V. Gotley and A.R. Martin, senior meteorological officers at Heard and Macquarie Islands respectively, together with Mr. W.J. Gibbs, Supervising Meteorologist, Research Section, were given the task of preparing a report on the meteorological aspects of the Expedition during 1948 by The Director of the Meteorological Branch.

This report forms Part 1 of Volume 1 of the A.N.A.R.E. Reports, Series D, and is issued in three sections -

(a) Results of Observations made at Heard and Macquarie Islands during 1948;

(b) Analysed Weather Charts of the Southern Ocean;

(c) Discussion of the Observations and Charts.

"Perhaps you may think it worth while some day to establish......meteorological stations on these (Heard's Islands) or some other points in the region of the "brave west winds" of the southern hemisphere. I know of no enterprise in the meteorological way that, at so small an expenditure of time and money, gives promise of richer rewards than this does, both practically to the mariner and scientifically to the philosopher."

Letter of M.F. Maury, United States Navy
Department to Admiral Fitz Roy,
British Admiralty,
February 25th, 1859.

C O N T E N T S

THE ESTABLISHMENT OF THE METEOROLOGICAL STATIONS

A. HEARD ISLAND

History. Heard Island was discovered in 1833 by the English sealer and explorer, Peter Kemp, on a voyage from Kerguelen Island to the Antarctic. However, Kemp did not publish his discovery and the island takes its name from John Heard, an American merchant captain who rediscovered it independently in 1853. For the following twenty years Heard Island was exploited by American sealers for its rich supplies of elephant seal. Three scientific expeditions - the "Challenger" Expedition of 1874, the "Gauss" Expedition of 1902 and the B.A.N.Z.A.R. Expedition of 1929 - called in at the island for periods ranging from six hours to a week, but it was not until the establishment of the present Australian research station by the A.N.A.R. Expedition that any systematic observations of the meteorology of the island were recorded.

Geography. Heard Island (Lat. 53°S, Long. $73\frac{1}{2}^{\circ}$E) is situated approximately 2400, 2300 and 900 nautical miles from the nearest coastlines of the continents of Australia, Africa and Antarctica respectively. The nearest island group is the Kerguelen Archipelago slightly less than 300 nautical miles to the north-west.

Figure 1 shows the general configuration of Heard Island. It is roughly circular in shape and slopes steeply upward, forming the impressive and almost symmetrical mountain mass known as "Big Ben" at a general height of between 7500 and 8000 feet. The mountain is of volcanic origin, and a number of cones project above the general level of the old crater; of these Mawson Peak, at an elevation of slightly more than 9000 feet, is the highest point on the island. Subdued volcanic activity still persists and smoke and steam have been noticed issuing from fissures in Mawson Peak on many occasions since the establishment of the station.

At the northern end of the island, Laurens Peninsula and Rogers Head Peninsula are connected to the main body of the island by a low-lying sandy isthmus.

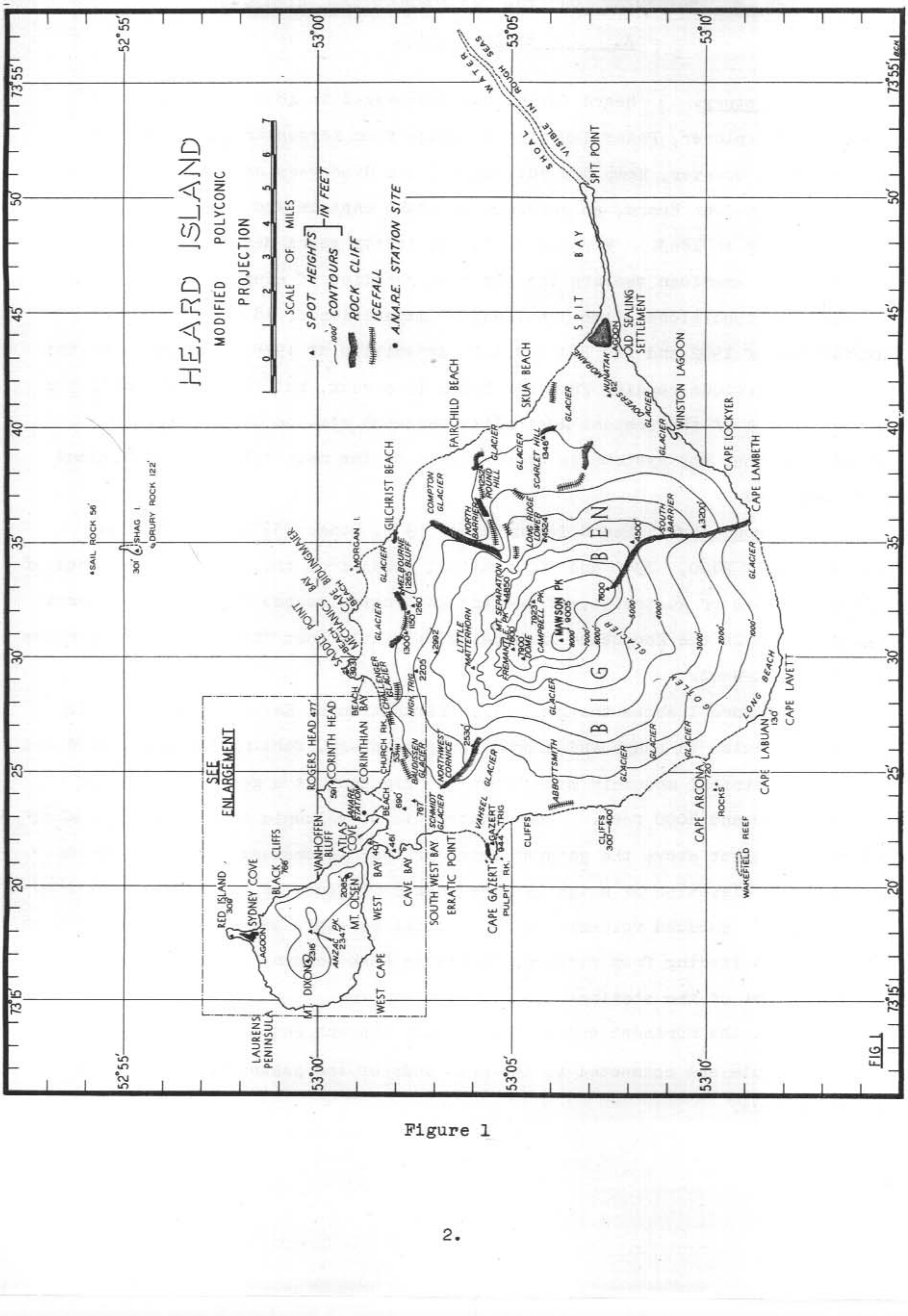

HEARD ISLAND
MODIFIED POLYCONIC
PROJECTION
SCALE OF MILES
SPOT HEIGHTS
CONTOURS IN FEET
ROCK CLIFF
ICEFALL
A.N.A.R.E. STATION SITE
SEE ENLARGEMENT
BIG BEN
MAWSON PK
SPIT BAY
SPIT POINT
SHOAL WATER VISIBLE IN ROUGH SEAS
SKUA BEACH
FAIRCHILD BEACH
GILCHRIST BEACH
WINSTON LAGOON
CAPE LOCKYER
CAPE LAMBETH
CAPE LAVETT
CAPE LABUAN
LONG BEACH
CAPE ARCONA
WAKEFIELD REEF
CAPE GAZERT
ERRATIC POINT
SOUTH WEST BAY
CAVE BAY
WEST BAY
WEST CAPE
MT. DIXON
MT. OLSEN
LAURENS PENINSULA
RED ISLAND
SYDNEY COVE
BLACK CLIFFS
ATLAS COVE
CORINTH HEAD
ROGERS HEAD
CORINTHIAN BAY
SADDLE POINT
CAPE BIDLINGMAIER
MORGAN I.
SAIL ROCK 56'
SHAG I.
DRURY ROCK 122'
OLD SEALING SETTLEMENT
FIG 1

Figure 1

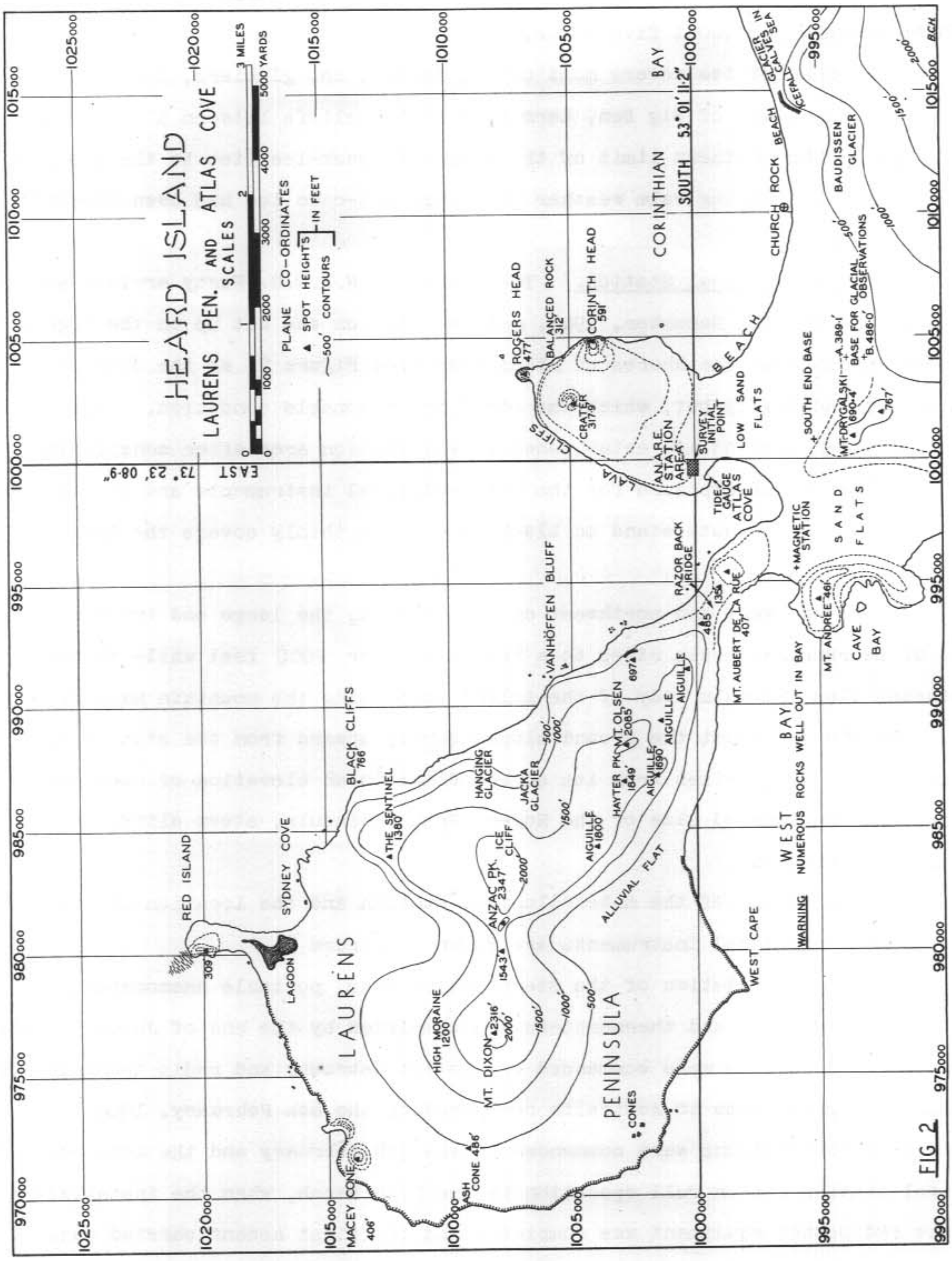

HEARD ISLAND
LAURENS PEN. AND ATLAS COVE
SCALES
PLANE CO-ORDINATES
▲ SPOT HEIGHTS } IN FEET
—500' CONTOURS
3 MILES
5000 YARDS
EAST 73° 23' 08·9"
SOUTH 53° 01' 11·2"
RED ISLAND
SYDNEY COVE
LAGOON
BLACK CLIFFS
THE SENTINEL
HANGING GLACIER
JACKA GLACIER
VANHÖFFEN BLUFF
ROGERS HEAD
BALANCED ROCK
CORINTH HEAD
CORINTHIAN BAY
CRATER
LAVA CLIFFS
ANARE STATION AREA
SURVEY INITIAL POINT
LOW SAND FLATS
BEACH
CHURCH ROCK
BEACH
GLACIER IN CALVES SEA
ICEFALL
BAUDISSEN GLACIER
BASE FOR GLACIAL OBSERVATIONS
SOUTH END BASE
MT. DRYGALSKI
TIDE GAUGE
ATLAS COVE
RAZOR BACK RIDGE
MAGNETIC STATION
SAND FLATS
MT. AUBERT DE LA RUE
MT. ANDREE
CAVE BAY
WEST BAY
NUMEROUS ROCKS WELL OUT IN BAY
WARNING
WEST CAPE
AIGUILLE
HAYTER PK.
MT. OLSEN
ALLUVIAL FLAT
ANZAC PK.
ICE CLIFF
HIGH MORAINE
MT. DIXON
LAURENS
PENINSULA
CONES
ASH CONE
MACEY CONE
FIG 2

Figure 2

A long narrow sand and boulder spit at the south-eastern end of the island extends seaward for about five miles, ending in shoal waters.

Permanent ice covers most of the island, and glaciers, descending to the sea on all sides of Big Ben, terminate in ice cliffs between 50 and 100 feet high. The northern limit of the Antarctic pack-ice lies to the south of Heard Island but during calm weather in winter pan-cake ice has been observed in Atlas Cove.

Meteorological Station. The pioneer A.N.A.R.E. Party arrived at Heard Island on 11th December, 1947, and the station was set up on the Rogers Head Peninsula near the shores of Atlas Cove (see Figure 2) at the site of an old British Admiralty hut, which was still in reasonable condition. The meteorological section was established in the station area after considering the dual factors of exposure for the meteorological instruments and protection for the huts. The huts stand on black sand which thinly covers the lava bedrock.

To the west and northwest of the station, the large and imposing mass of Laurens Peninsula rises to a height of over 2000 feet while to the southeast lies the main body of the island comprising the mountain mass of Big Ben. To the northeast the ground slopes gently upward from the station to Corinth Head, which rises from its surroundings to an elevation of over 500 feet. On the seaward side of the Rogers Head Peninsula, steep cliffs drop abruptly to the sea.

The layout of the meteorological station and the location of the various meteorological instruments are shown in Figure 3.

The installation of the Stevenson screens, portable anemometer, barometer, barograph and thermometers was completed by the end of January 1948. Synoptic observations were commenced on the 1st February and radio transmission of meteorological data to Australia commenced on the 8th February, 1948. Upper wind observations were commenced on the 9th February and the meteorological station was in full operation by the 27th March, when the installation of the radiosonde equipment was completed and the first ascent carried out.

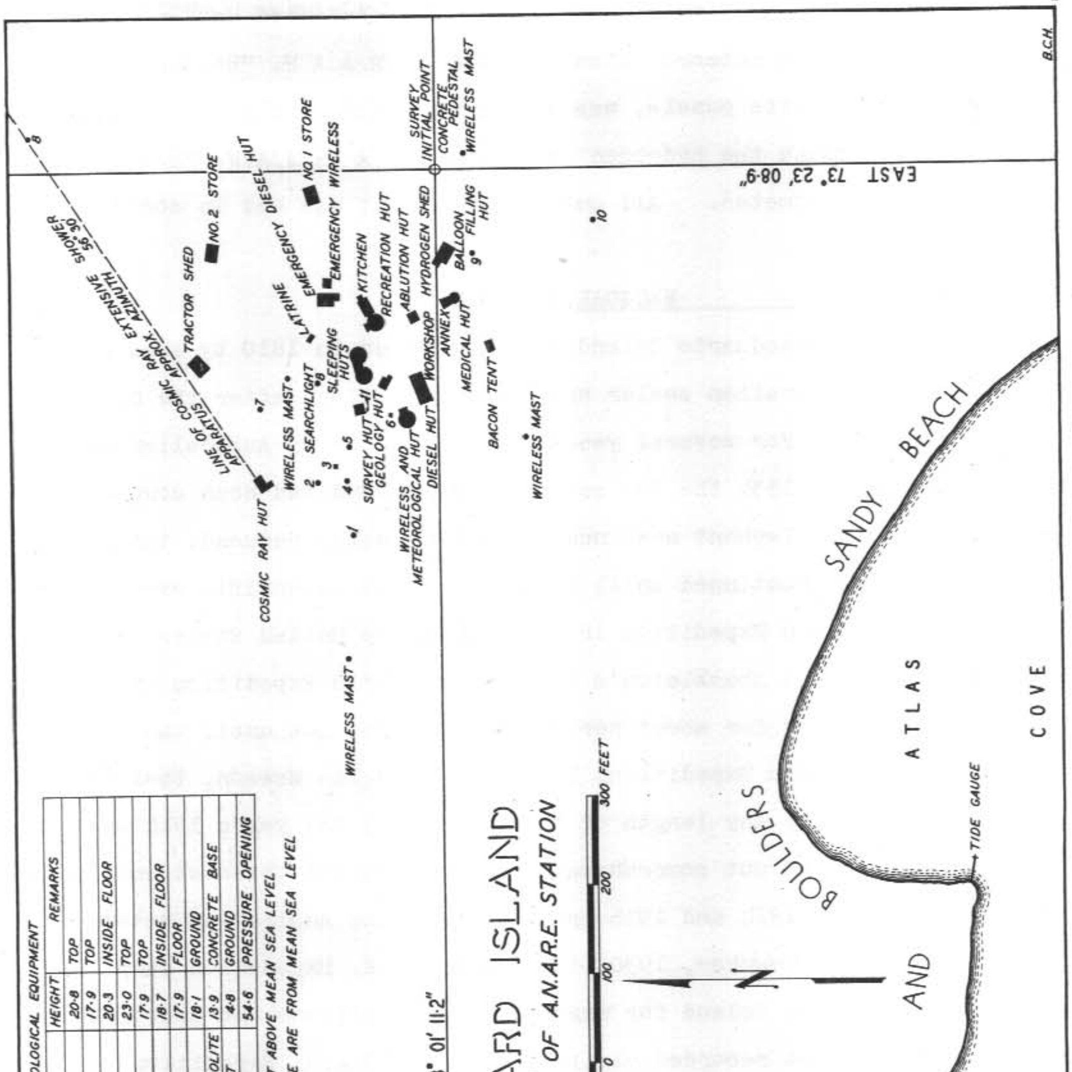

HEARD ISLAND
PLAN OF AN.A.R.E. STATION
KEY TO METEOROLOGICAL EQUIPMENT
INSTR. NO. | INSTRUMENT | HEIGHT | REMARKS
1 | RAY SONDE AERIAL | 20·8 | TOP
2 | RAIN GAUGE | 17·9 | TOP
3 | CLIMAT. SCREEN | 20·3 | INSIDE FLOOR
4 | ANEMOMETER | 23·0 | TOP
5 | PLUVIOGRAPH | 17·9 | TOP
6 | RAY SONDE SCREEN | 18·7 | INSIDE FLOOR
7 | SUNSHINE RECORDER | 17·9 | FLOOR
8 | CLOUD SEARCHLIGHT | 18·1 | GROUND
9 | METEOROLOGICAL THEODOLITE | 13·9 | CONCRETE BASE
10 | BALLOON RELEASE MAST | 4·8 | GROUND
11 | DINES ANEMOMETER | 54·6 | PRESSURE OPENING
SURVEY INITIAL POINT 7·62 FEET ABOVE MEAN SEA LEVEL
ALL HEIGHTS IN COLUMN 3 ABOVE ARE FROM MEAN SEA LEVEL
SOUTH 53° 01' 11·2"
EAST 73° 23' 08·9"
100 0 100 200 300 FEET
LINE OF COSMIC RAY APPARATUS
APPROX. AZIMUTH EXTENSIVE SHOWER 56 30'
COSMIC RAY HUT
TRACTOR SHED
NO. 2 STORE
DIESEL HUT
NO. 1 STORE
EMERGENCY WIRELESS
EMERGENCY DIESEL
LATRINE
SEARCHLIGHT
SLEEPING HUTS
KITCHEN
RECREATION HUT
ABLUTION HUT
HYDROGEN SHED
WORKSHOP
SURVEY HUT
GEOLOGY HUT
WIRELESS AND METEOROLOGICAL HUT
DIESEL HUT
WIRELESS MAST
ANNEX
MEDICAL HUT
BALLOON FILLING HUT
BACON TENT
SURVEY INITIAL POINT
CONCRETE PEDESTAL
LOW
CLIFFS
ROCKS
AND
BOULDERS
SANDY BEACH
TIDE GAUGE
ATLAS
COVE
ATLAS
ROADS
FIG 3
B.C.H.

Figure 3

A circular U.S. Signal Corps Hut of prefabricated design was used as a combined radio and meteorological hut and a R.A.A.F. "Borden" Hut, prefabricated of masonite panels, was used as a balloon-filling hut and later extended to accommodate the hydrogen generators. A R.A.A.F. "H/F-D/F" Hut housed the Dines Anemometer. All outside equipment was set in concrete foundations.

B. MACQUARIE ISLAND

History. Macquarie Island was discovered in 1810 by Frederick Hasselborough, an Australian sealer who named the island after the Governor of New South Wales. For several years it was visited by Australian and New Zealand sealers. By 1834 the fur seals on the island had been completely exterminated and the elephant seal numbers were greatly reduced, though intermittent sealing continued until 1919. Several scientific expeditions - Bellinghausen's Russian Expedition in 1820, Wilkes's United States Exploring Expedition in 1839, and Shackleton's British Antarctic Expedition in 1909 - called in at the island for short periods, but it was not until the visit of the Australian Antarctic Expedition, led by Sir Douglas Mawson, that the island was occupied for any length of time. During the years 1912 and 1913 this expedition carried out comprehensive meteorological observations, which were continued during 1914 and 1915 by staff from the Australian Meteorological Bureau. In November, 1930, the B.A.N.Z.A.R. Expedition ship "Discovery" visited the island for magnetic determinations and zoological observations - the last recorded visit until the A.N.A.R. Expedition established a permanent research station in 1948.

Geography. Macquarie Island (Lat. $54\frac{1}{2}^{\circ}$S, Long. 159°E) is situated approximately 800, 600 and 900 nautical miles from the nearest coastlines of Tasmania, New Zealand and Antarctica respectively. The nearest islands are Campbell Island and Auckland Island, each about 400 nautical miles to the north-east.

Figure 4 shows the general configuration of Macquarie Island. It is a narrow island about 21 miles long and 2 miles wide, lying approximately in a north-south direction. Most of the island consists of a plateau at a general elevation of 600 to 800 feet, rising in places to low rounded spurs

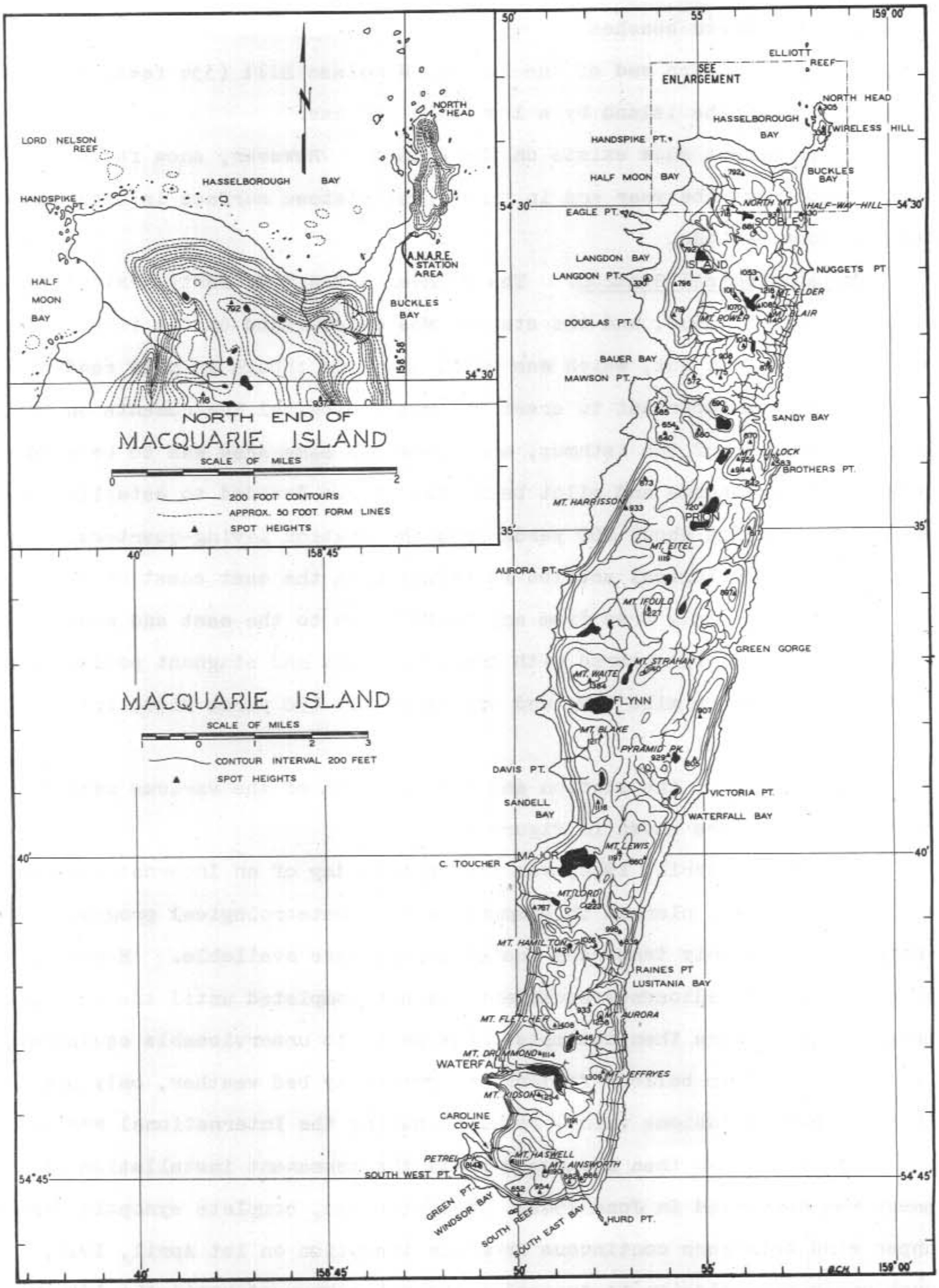

NORTH END OF
MACQUARIE ISLAND
SCALE OF MILES
200 FOOT CONTOURS
APPROX. 50 FOOT FORM LINES
SPOT HEIGHTS
LORD NELSON REEF
HASSELBOROUGH BAY
HANDSPIKE PT.
HALF MOON BAY
NORTH HEAD
A.N.A.R.E. STATION AREA
BUCKLES BAY
MACQUARIE ISLAND
SCALE OF MILES
CONTOUR INTERVAL 200 FEET
SPOT HEIGHTS
SEE ENLARGEMENT
ELLIOTT REEF
NORTH HEAD
WIRELESS HILL
HASSELBOROUGH BAY
HANDSPIKE PT.
HALF MOON BAY
BUCKLES BAY
EAGLE PT.
NORTH MT.
HALF-WAY-HILL
SCOBLE L.
LANGDON BAY
LANGDON PT.
ISLAND L.
NUGGETS PT
MT. ELDER
MT. POWER
MT. BLAIR
DOUGLAS PT.
BAUER BAY
MAWSON PT.
SANDY BAY
MT. TULLOCK
BROTHERS PT.
MT. HARRISSON
PRION L.
MT. EITEL
AURORA PT.
MT. IFOULD
GREEN GORGE
MT. STRAHAN
MT. WAITE
FLYNN L.
MT. BLAKE
PYRAMID PK.
DAVIS PT.
SANDELL BAY
VICTORIA PT.
WATERFALL BAY
C. TOUCHER
MAJOR L.
MT. LEWIS
MT. LORD
MT. HAMILTON
RAINES PT
LUSITANIA BAY
MT. FLETCHER
AURORA
MT. DRUMMOND
WATERFALL L.
MT. JEFFRYES
MT. KIDSON
CAROLINE COVE
PETREL PK.
MT. HASWELL
MT. AINSWORTH
SOUTH WEST PT.
GREEN PT.
WINDSOR BAY
SOUTH REEF
SOUTH EAST BAY
HURD PT.

Figure 4

and hills of 1200 to 1400 feet. The edge of the plateau falls away abruptly to the sea or to narrow beaches.

At the northern end of the island, Wireless Hill (336 feet) is joined to the main mass of the island by a low, flat isthmus.

No permanent snow exists on the island. However, snow falls at intervals throughout the year and in winter the plateau surface is often snow-covered for long periods.

Meteorological Station. The pioneer A.N.A.R.E. Party arrived at the island on 7th March, 1948, and the station was established on the isthmus near the old A.A.E. 1911-14 Hut, which was still standing though in poor condition.

As it was important to erect the meteorological instruments on the most exposed portion of the isthmus, and since the same area was to be used for the release of radiosonde and pilot balloons, it was decided to establish the meteorological section about 200 yards from the station living-quarters.

The meteorological section is situated on the east coast of the isthmus and is completely free from any obstruction to the east and west. The isthmus, a shingle strip covered with grass hummocks and stagnant pools, is a little more than half a mile long and approximately 150 yards wide, lying about 20 feet above sea-level.

The layout of the station and the location of the various meteorological instruments are shown in Figure 5.

As the 1st April, 1948, was the initial day of an International Aerological Period, it was planned to commence a full meteorological programme from that date, although only temporary installations were available. However, installation of the radiosonde equipment was not completed until the 2nd April. Radiosonde flights were then attempted, but owing to unserviceable equipment, lack of facilities for balloon filling and extremely bad weather, only one flight (and that of dubious value) resulted during the International Period. Radiosonde flights were then abandoned until the permanent installation of equipment was completed in June 1948. Nevertheless, complete synoptic reports and upper wind data were continuous from the inception on 1st April, 1948, although radio transmission to Australia was not commenced until the 17th May, 1948.

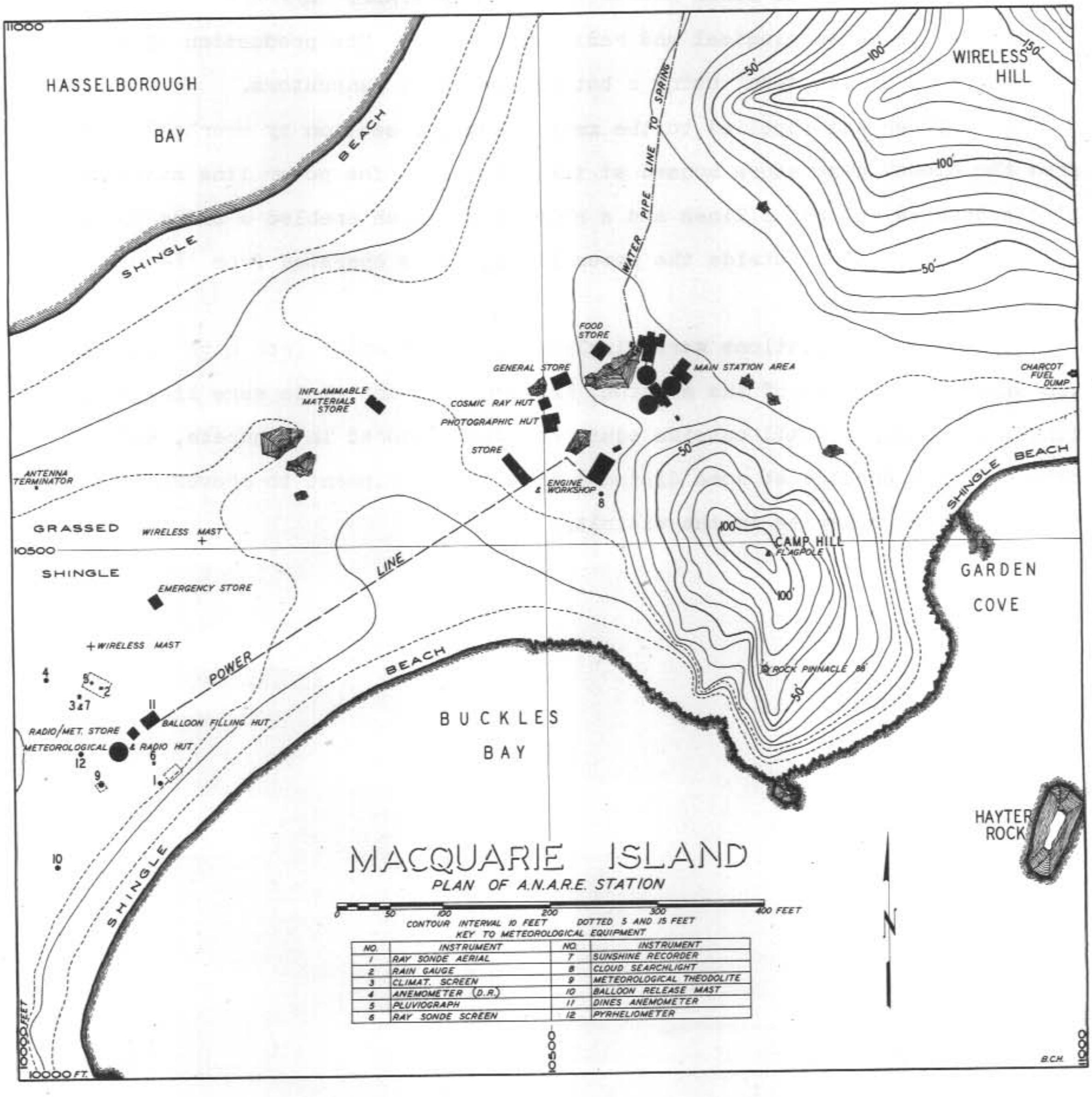

HASSELBOROUGH
BAY
SHINGLE
BEACH
WATER PIPE LINE TO SPRING
WIRELESS HILL
FOOD STORE
GENERAL STORE
MAIN STATION AREA
INFLAMMABLE MATERIALS STORE
COSMIC RAY HUT
PHOTOGRAPHIC HUT
STORE
ENGINE & WORKSHOP
CHARCOT FUEL DUMP
ANTENNA TERMINATOR
GRASSED
WIRELESS MAST
SHINGLE
EMERGENCY STORE
WIRELESS MAST
POWER LINE
CAMP HILL
FLAGPOLE
GARDEN COVE
ROCK PINNACLE 88'
SHINGLE BEACH
RADIO/MET. STORE
BALLOON FILLING HUT
METEOROLOGICAL & RADIO HUT
BUCKLES BAY
HAYTER ROCK
MACQUARIE ISLAND
PLAN OF A.N.A.R.E. STATION
0 50 100 200 300 400 FEET
CONTOUR INTERVAL 10 FEET DOTTED 5 AND 15 FEET
KEY TO METEOROLOGICAL EQUIPMENT
NO. INSTRUMENT NO. INSTRUMENT
1 RAY SONDE AERIAL 7 SUNSHINE RECORDER
2 RAIN GAUGE 8 CLOUD SEARCHLIGHT
3 CLIMAT. SCREEN 9 METEOROLOGICAL THEODOLITE
4 ANEMOMETER (D.R.) 10 BALLOON RELEASE MAST
5 PLUVIOGRAPH 11 DINES ANEMOMETER
6 RAY SONDE SCREEN 12 PYRHELIOMETER
N
11000
10500
10000 FT.
B.C.H.

Figure 5

A circular U.S. Signal Corps Hut of prefabricated design housed both the meteorological and radio equipment, and a R.A.A.F. "Borden" Hut, prefabricated of masonite panels, was used as a balloon-filling hut and subsequently also housed the Dines Anemometer. A R.A.A.F. "H/F-D/F" Hut was used as a store for meteorological and radio equipment. The production of hydrogen was performed in the open, using a battery of three generators.

Power was supplied to the meteorological section by overhead lines from the diesel generators housed at the station. The power line standards also supported telephone lines and a relay line which enabled a cloud searchlight, situated just outside the power house, to be operated from the meteorological hut.

All installations were firmly secured, as apart from high winds and the exposed situation of the section, massive elephant seals were liable to cause much damage. All outside equipment was anchored in concrete, and barriers were erected at some distance from this equipment to prevent elephant seals forming rookeries in the vicinity.

INSTRUMENTS AND OBSERVATIONAL METHODS

SURFACE OBSERVATIONS

Synoptic Hours. Observations were carried out at each of the Greenwich Mean Time synoptic hours, with the exception of 2100 hours at Heard Island.

Atmospheric Pressure. Two mercurial barometers of Kew pattern were mounted adjacent to each other in the radio-meteorological hut and one was used as the station barometer. As a routine check of this instrument, simultaneous readings of the two barometers were compared at regular intervals.

A continuous record of station level pressure was obtained from a weekly barograph, installed on a sponge-rubber cushion close to the station barometer. This instrument was reset to correct station level pressure each week when the chart was changed, the correct reading being noted on each chart.

Temperature. All thermometers were mounted in a Stevenson screen, which was set in concrete in the best possible place of exposure and firmly guyed. Dry bulb readings were obtained from a mercurial thermometer, with which a similar thermometer used for radiosonde base line checks was regularly compared.

A continuous record of air temperature was obtained from a daily thermograph set up near the thermometers. The thermograph was reset to the correct temperature each day when the chart was changed.

Extremes of temperature were obtained from a maximum thermometer and a minimum thermometer.

Humidity. Relative humidity and dewpoint were obtained from the dry and wet bulb thermometer readings. During periods when the wet bulb temperatures were below freezing point, the wet bulb muslin was moistened with water before the synoptic hour so that a thin film of ice coated the wet bulb at the synoptic hour.

A continuous record of relative humidity was obtained from a daily hygrograph, installed near the dry and wet bulb thermometers. The hygrograph was reset to the correct relative humidity each day when the chart was changed.

Wind. A continuous record of wind speed and direction was obtained from a Dines anemometer, erected at a height of 10 metres above the station buildings (i.e. about 13 metres above the ground).

Wind speed and direction were indicated in the meteorological office by the installation of a distance-reading electrical anemometer.

The twenty-four hour run of wind in miles was obtained from a cup counter anemometer. Unfortunately, the cup anemometer at Macquarie Island was destroyed during a hurricane in September 1948.

Precipitation. Precipitation was measured by means of a rain gauge, supplemented by a snow gauge.

A continuous record of precipitation was obtained from a Casella daily pluviograph provided with a small heating element to prevent interruption of the record during freezing conditions.

Sunshine. The duration of sunshine was measured by a Campbell-Stokes recorder. Owing to the high latitudes of the stations the duration of sunshine in the summer exceeded the hours for which the recording card was graduated so that it was necessary to instal a supplementary recorder. This was of the same pattern, but so mounted that a continuous record of sunshine over a period of twenty-four hours could be obtained.

Cloud Heights. During hours of darkness, the height of the base of low clouds was observed by using a searchlight which projected a vertical beam. Clinometer readings were obtained using a 500-foot base line.

On other occasions, the ceiling height was determined by reference to the topography of the island or by estimation from the rate of ascent of a pilot balloon.

Difficulties with Instruments.

Salt spray, sand and precipitation blowing into the Stevenson screen caused considerable trouble and necessitated frequent cleaning of the screen and instruments. Some measure of protection was afforded the autographic instruments by covering them with fine mesh gauze.

The thermometers in the screen were liable to be shaken out of position during squally weather, and were therefore secured with strips of sponge rubber. Despite this, the readings of the maximum and minimum thermometers were obviously incorrect at times. On such occasions, the extremes of temperature were taken from the record of the thermograph.

In periods of strong wind, the force of the wind on the vertically-suspended hair element of the hygrograph was mechanically transmitted to the recording pen. By covering the instrument with fine mesh gauze, the excessive wind pressure was effectively damped.

During periods of heavy snow fall, or of freezing rain, the pressure head and suction holes of the Dines anemometer became blocked with snow or ice. This resulted in loss of record for short periods until the blockage could be cleared manually.

The measurement of precipitation, particularly snow, was difficult during periods of strong or gusty winds, as frequently the precipitation was blown out of the funnel before entering the gauge. The loss of record may have amounted to ten percent at Macquarie Island but was possibly compensated in part by blown snow drift at Heard Island.

The use of a supplementary sunshine recorder to extend the range of record resulted in the duplication of part of the trace. This was taken into account in reading the total hours of sunshine.

UPPER AIR OBSERVATIONS

Time of Observation. A radiosonde ascent was attempted daily at between 0800 hours and 0900 hours G.M.T.

A pilot balloon ascent was scheduled for every six hours from 0500 hours G.M.T., but owing to the high incidence of low cloud and precipitation, ascents were irregular.

Pressure, Temperature and Humidity Soundings. A Friez type radiosonde was carried aloft by a 350-gram balloon inflated to give a rate of ascent of approximately 300 metres per minute. In strong winds an extra free lift was required to ensure that the radiosonde would clear all obstructions.

Wet batteries were used in the radiosonde as a rule to ensure a good performance, but if a rough release was anticipated dry batteries were used. These batteries required warming before use and were stored in a heated hut.

The transmitter signals were received on equipment located in the meteorological hut, and were recorded on a high-speed potentiometer. The receiver aerial was a dipole antenna firmly secured by insulated guywires.

Base Line Check. Base line checks were carried out in a Stevenson screen which was aspirated by means of an electric fan.

Release. The release of the radiosonde in squally conditions presented certain difficulties. As a result of experience, methods employed to facilitate release under these circumstances were considerably modified.

Originally the practice recommended was to hoist the balloon in a canopy to the top of a thirty-foot mast while the attached transmitter was held downwind. The balloon was released by means of a rip cord, the transmitter being released when the suspension cord from the balloon was taut. It was found, however, that hoisting the balloon to the top of the release mast was extremely difficult in boisterous weather and usually proved disastrous to the balloon.

The method of release later adopted was to run with the balloon and attached radiosonde until the balloon attained sufficient height to enable the radiosonde to clear the ground on release.

In particularly squally conditions, the two-string method of release was more practicable. The radiosonde on the normal suspension was held below the balloon while the balloon was played out on a separate very long cord. At the moment the balloon commenced to ascend in an eddy current, both the balloon and transmitter were simultaneously released. Under the conditions of release, this procedure proved quite successful. (This method has since been superseded by the use of a "string unwinder").

Temperature Profiling. It was intended to make a detailed study of the lowest 500 feet of the troposphere by means of both temperature and humidity elements suspended from a captive balloon. An inflated envelope with stabilising fins, of Kytoon pattern, was held captive by means of a cable which incorporated the leads from the suspended elements to the potentiometer recorder used in radiosonde ascents. Lack of success in obtaining data was due mainly to insulation breakdown in the cable, caused by local weather conditions.

Upper Wind Observations. The pilot balloon theodolite was permanently installed on a wallhead, and provided with a metal weather-proof cover. Only black or white balloons were available and this limited observations under certain conditions.

The pilot balloons were susceptible to cold temperatures, the rubber becoming very brittle. Heating before inflation was necessary and the balloons were stored in a heated hut.

Ascents during hours of darkness were carried out, but successful release of the balloon with a lighted candle lantern attached was difficult during periods of strong winds or squally conditions.

Hydrogen Generation. Hydrogen was successfully produced, at the low temperatures experienced, using caustic soda solution and ferrosilicon in a generator.

At Heard Island greater quantities of chemicals than normal were required to ensure a friable residue. At Macquarie Island, sea water was used in the generation, and proved highly satisfactory both as regards the hydrogen produced and the friability of residue.

DISCUSSION OF RESULTS OF OBSERVATIONS

A. HEARD ISLAND

SURFACE OBSERVATIONS

Station Level Pressure. The mean monthly pressure during the eleven months of observations ranged from 983.1 mbs in August to 998.2 mbs in September.

The minimum monthly pressure range was 38.6 mbs in April, and the maximum monthly pressure range 75.7 mbs in August.

The absolute minimum pressure, recorded on October 9th, was 941.5 mbs, while the absolute maximum pressure, recorded on September 24th, was 1027.1 mbs, an extreme range of 85.6 mbs.

The decile, median and ninth-decile values of pressure are shown for each month in Figure 6. The minimum in August and the maximum in September are well defined. The maximum range for any one partition value over the eleven months analysed is seen to be only 19 mbs. (first decile). The small seasonal variation in pressure is further emphasized by grouping and comparing three-monthly values, the greatest range for any of the selected decile series in this case being only 7 mbs.

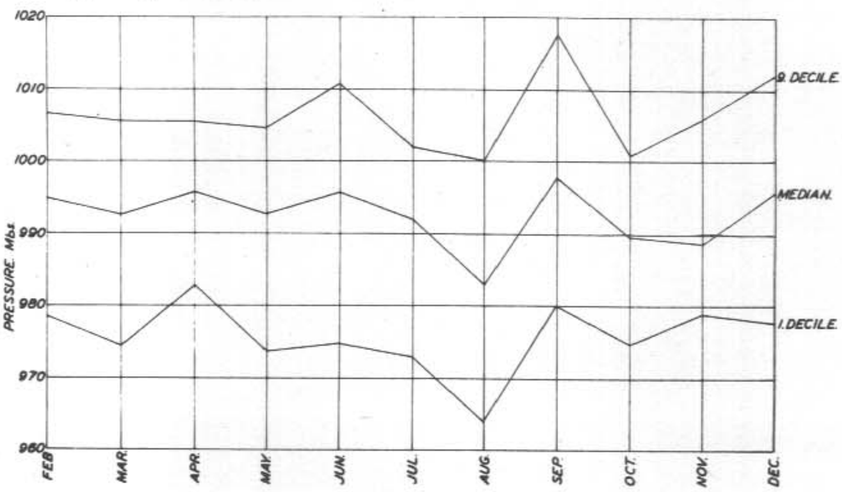


Figure 6

A frequency distribution of readings in intervals of 10 mbs shows a maximum for the 980-990 mb interval in the spring period as against a maximum for the 990-1000 mb group during the autumn and winter periods. The percentage frequency of occurrence of values of pressure, in 10 mb intervals, during the three seasons analysed is shown in Figure 7. (The seasons at both Islands lag behind those observed in lower latitudes, e.g. spring comprises the months October, November and December.)

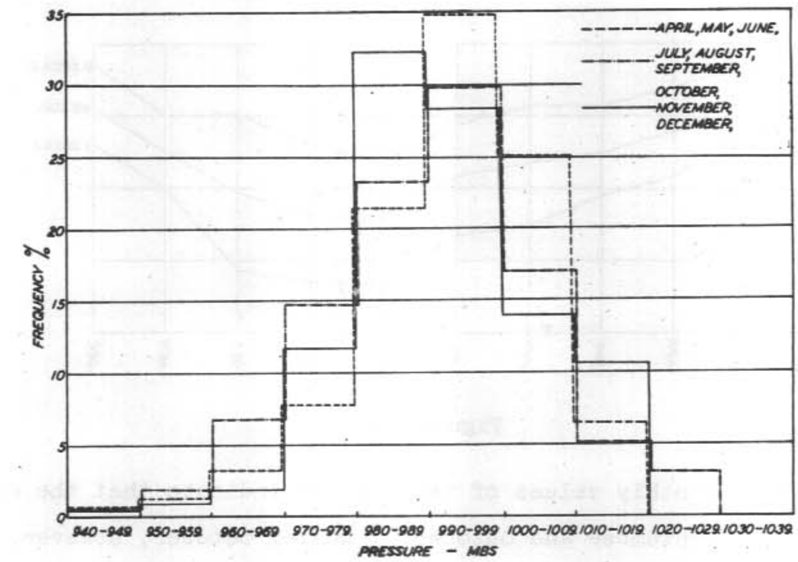


Figure 7

A large monthly range of pressure and a small seasonal variation are to be expected in the parallels of latitude in which Heard Island is situated, as great cyclonic storms pass through this area at all periods of the year and it is reasonable to assume that pressure values recorded during 1948 are representative of this particular area.

<u>Temperature.</u> The mean monthly temperature ranged from 27.8°F in August to 36.5° in February.

The maximum monthly temperature range was 25.9°F in October.

The minimum temperature, recorded on 23rd August and on the 15th September, was 16.0°F, while the maximum, recorded on the 12th February, was 47.7°F. The absolute range was thus 31.7°F.

The decile, median and ninth-decile values of temperature are shown for each month in Figure 8. The maximum range for any one partition value over the eleven months analysed is seen to be only 10.7°F. (first decile).

The minima in August and the maxima in February are well defined, suggesting that these months are the mid-months of the winter and summer seasons respectively.

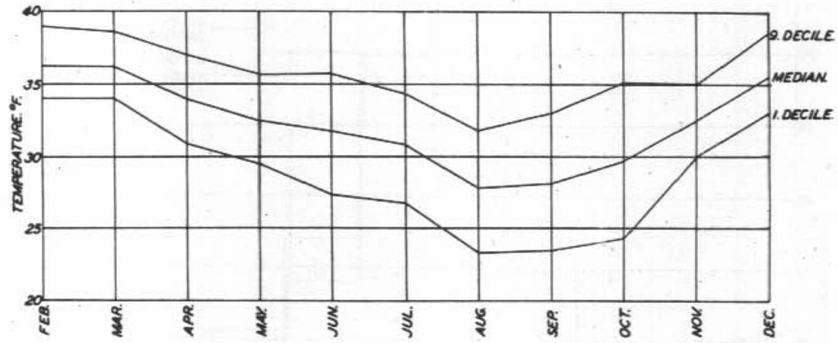


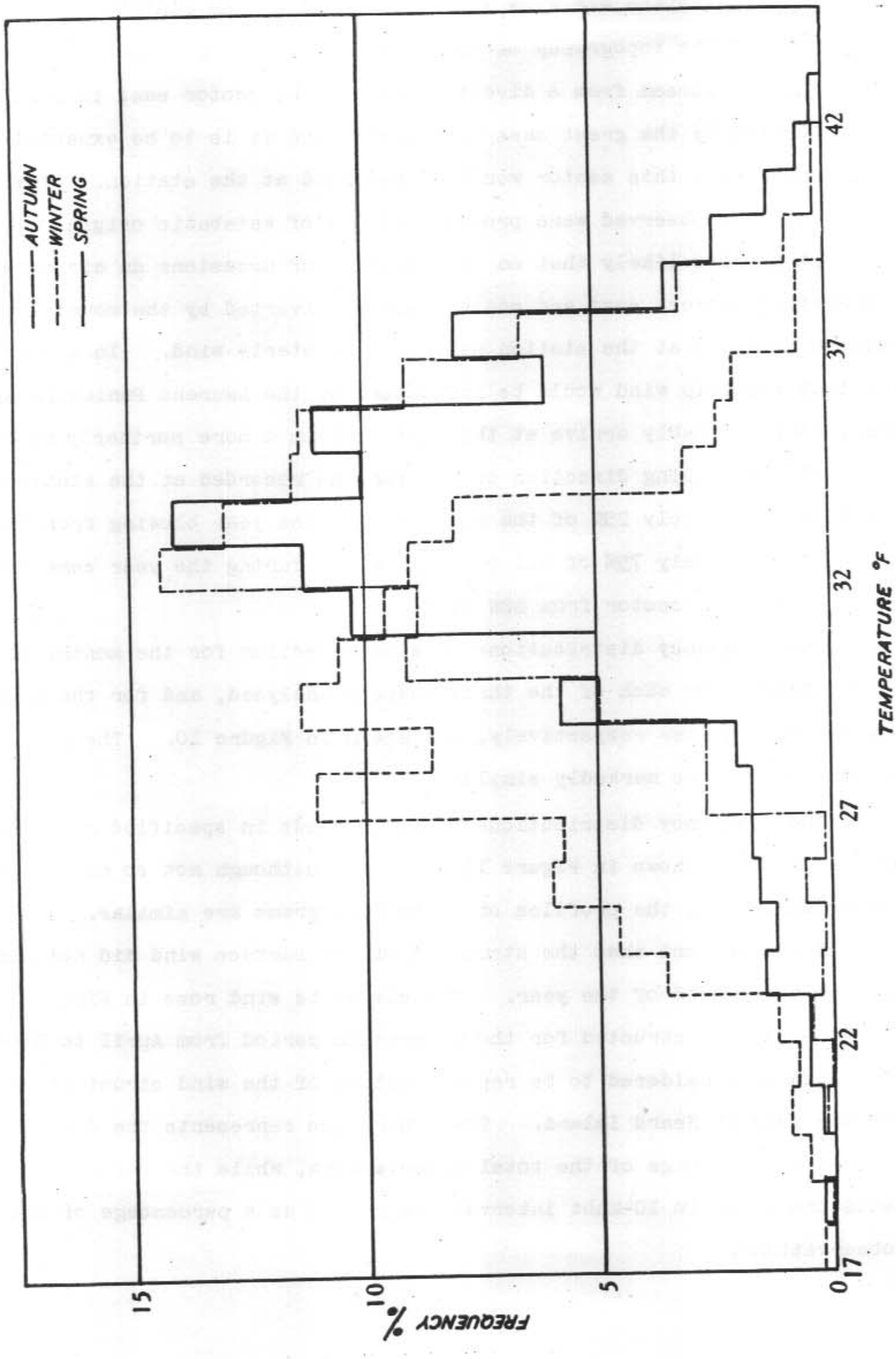
Figure 8

The mean monthly values of temperature indicate that the coldest months were August, September and October. During October, however, higher individual temperatures occurred than during July, and as the observations only embrace one particular year, the months July, August and September have been taken as the winter season.

The seasonal variation in temperature was small, as already indicated by a comparison of selected decile values for each month. This is further emphasised by comparing mean values taken over three-monthly periods, the maximum range in this case being only 3.7°F.

The frequency of occurrence of temperatures in 1°F intervals during each of the three seasons is shown in Figure 9.

Owing to the marine character of the station, the presence of a great mass of permanent ice and snow in the vicinity, and its situation in the path of cold outbreaks at all periods of the year, it is reasonable to assume that the temperatures experienced during 1948 are representative of the particular area.



AUTUMN
WINTER
SPRING
FREQUENCY %
0
5
10
15
TEMPERATURE °F
17
22
27
32
37
42

Figure 9

Wind. Surface air flow in the vicinity of the station is to some extent affected by the topography of the island. At the present site of the anemometer, an air stream from a direction within the sector east to south would be deflected by the great mass of Big Ben, and it is to be expected that few winds from within this sector would be recorded at the station. The few which were actually observed were probably mainly of katabatic origin.

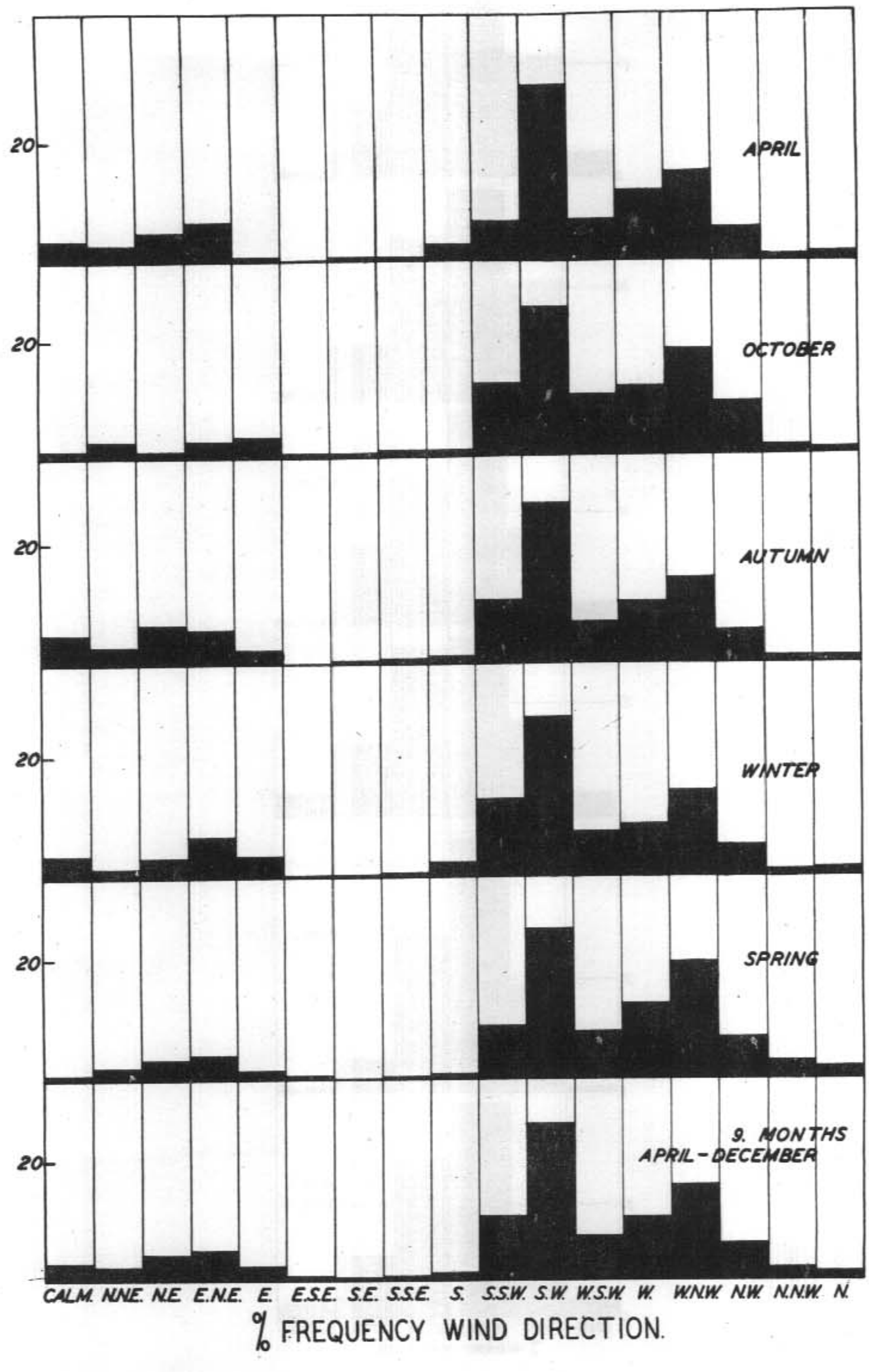
It appears likely that on the majority of occasions an air stream from a direction between east and south would be diverted by the mountain mass and would be recorded at the station as a south-westerly wind. In a similar manner a true westerly wind would be influenced by the Laurens Peninsula and, if strong, would probably arrive at the station from a more northerly direction.

The prevailing direction of the wind as recorded at the station was south west, approximately 25% of the winds during the year blowing from this quarter. Approximately 75% of all observed winds during the year came from directions within the sector from SSW to NW.

The frequency distributions of wind direction for the months of April and October, for each of the three seasons analysed, and for the nine months April to December respectively, are shown in Figure 10. The profiles of these histograms are markedly similar.

The frequency distributions of wind speeds in specified ranges for the same periods are shown in Figure 11. Again, although not so marked as in the case of direction, the profiles of these histograms are similar.

It is evident that the structure of the surface wind did not vary greatly with the period of the year. The composite wind rose in Figure 12 has therefore been constructed for the nine-month period from April to December inclusive, and is considered to be representative of the wind structure at all times of the year at Heard Island. The inner rose represents the direction expressed as a percentage of the total observations, while the outer rose represents the speed in 10-knot intervals expressed as a percentage of the total observations.



APRIL
OCTOBER
AUTUMN
WINTER
SPRING
9. MONTHS APRIL - DECEMBER
20
CALM. N.N.E. N.E. E.N.E. E. E.S.E. S.E. S.S.E. S. S.S.W. S.W. W.S.W. W. W.N.W. N.W. N.N.W. N.
% FREQUENCY WIND DIRECTION.

Figure 10

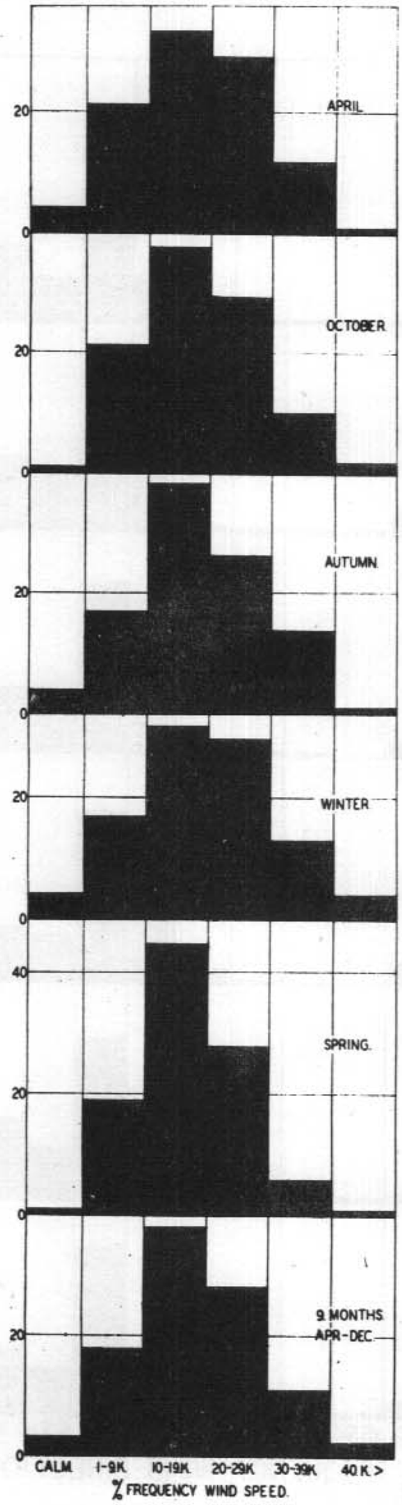

APRIL
OCTOBER
AUTUMN.
WINTER
SPRING.
9 MONTHS
APR-DEC.
20
0
40
CALM
1-9K
10-19K
20-29K
30-39K
40 K >
% FREQUENCY WIND SPEED.

Figure 11

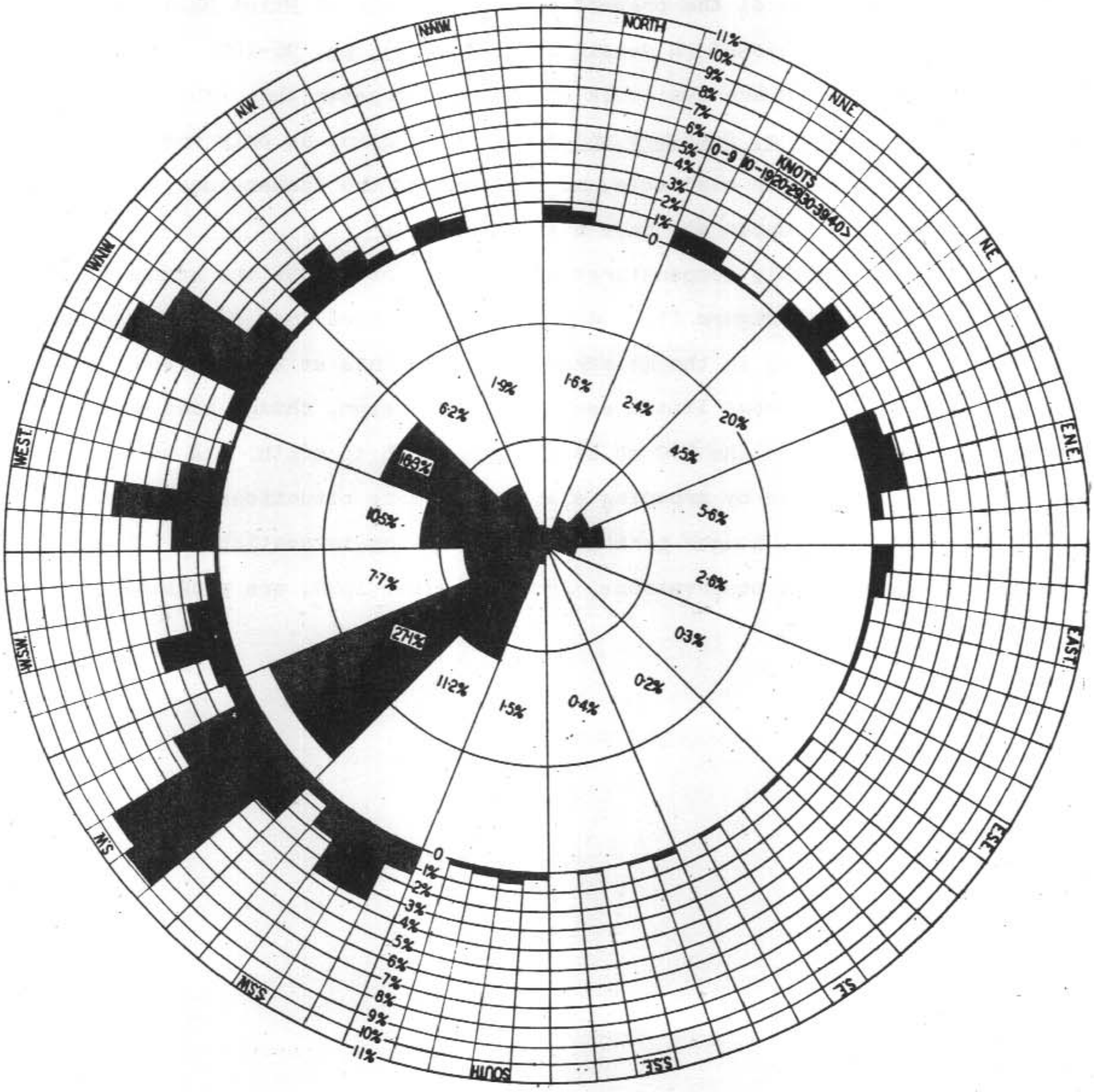

NORTH
NNE
NE
E.N.E.
EAST
ESE
SE
S.S.E.
SOUTH
SSW
SW
WSW
WEST
WNW
NW
NNW
KNOTS
0-9
10-19
20-29
30-39
40>
1·9%
1·6%
2·4%
2·0%
4·5%
5·6%
2·6%
0·3%
0·2%
0·4%
1·5%
11·2%
27·1%
7·7%
10·5%
16·3%
6·2%

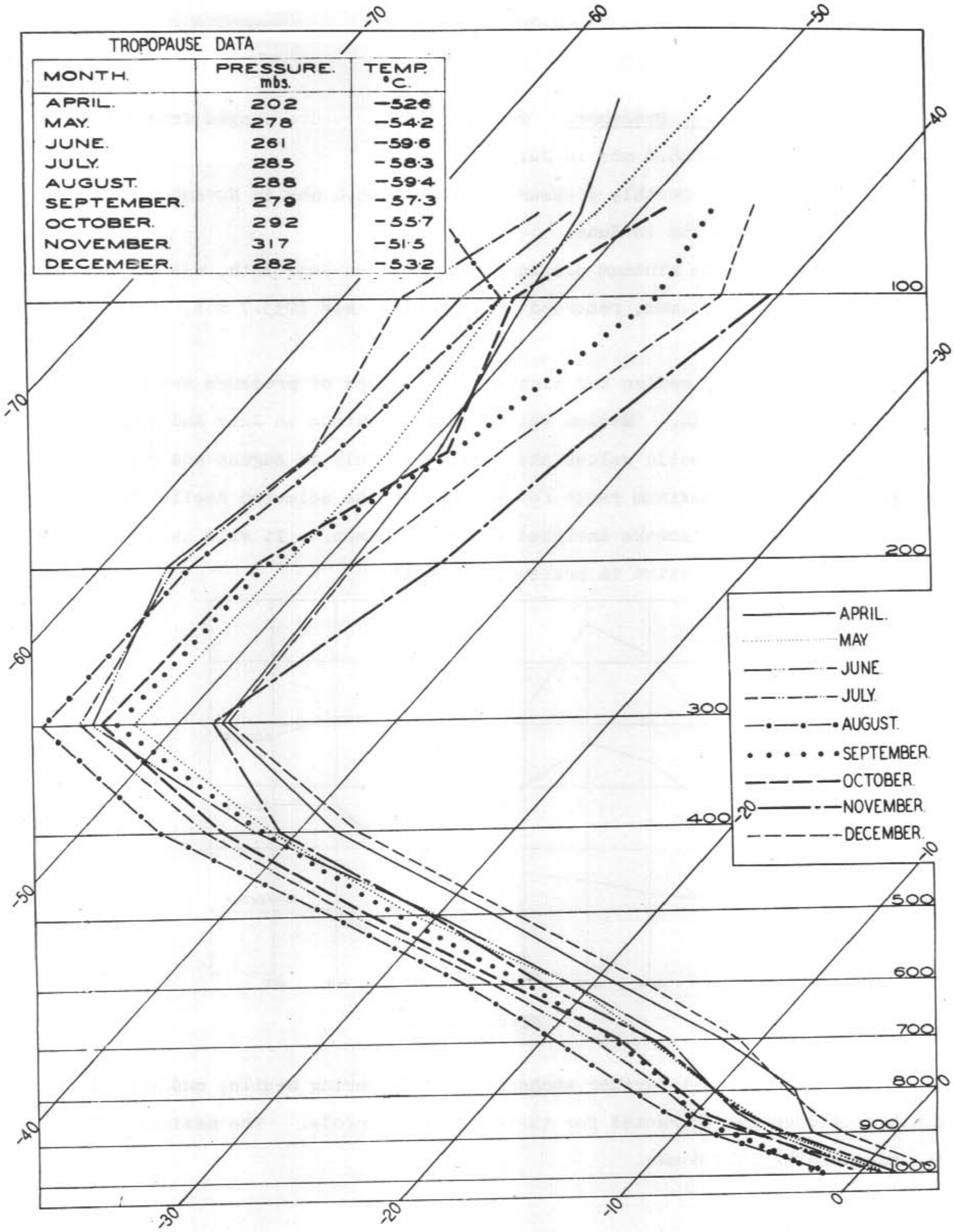
Figure 12

UPPER AIR OBSERVATIONS

Winds. The weather conditions were unsuitable for consistent observation of upper winds by visual methods. This, together with the effect of the topography of the island, has made any discussion of upper winds of little value at the present time. Results of Pilot Balloon observations are published in detail in Part I (a), pp. 96-100. It will be seen that few data are available for heights greater than 1800 metres.

Temperature, Pressure and Humidity. Again, as only one year's observations are so far available, no analyses of the temperature, pressure and humidity of the upper air have been attempted.

Mean monthly temperatures have been plotted for the standard isobaric surfaces in Figure 13. As might be expected from the lack of any great seasonal changes in the meteorological elements at the surface, the atmosphere in depth shows little seasonal fluctuation, though considerable variations occur above the 400 mb level from month to month. A valuable analysis could be made by grouping similar isobaric situations, but this has been deferred until a longer period of observations is available. Detailed results of radiosonde observations, April-December 1948, are published in Part I (a), pp. 80-88.



TROPOPAUSE DATA

MONTH.	PRESSURE. mbs.	TEMP. °C.
APRIL.	202	−52.6
MAY.	278	−54.2
JUNE.	261	−59.6
JULY.	285	−58.3
AUGUST.	288	−59.4
SEPTEMBER.	279	−57.3
OCTOBER.	292	−55.7
NOVEMBER.	317	−51.5
DECEMBER.	282	−53.2

Figure 13

B. MACQUARIE ISLAND

SURFACE OBSERVATIONS

Station Level Pressure. Mean monthly pressure ranged from 989.9 mbs in September to 1006.0 mbs in July.

The minimum monthly pressure range was 45.4 mbs in November, while the maximum was 77.9 mbs in June.

The absolute minimum pressure, recorded on June 28th, was 948.1 mbs, while the absolute maximum, recorded on July 24th, was 1033.7 mbs, an extreme range of 85.6 mbs.

The decile, median and ninth-decile values of pressure are shown for each month in Figure 14. Median values show a maximum in July and a minimum in October, and the decile values show maxima in July or August and minima in September. The maximum range for any one of the selected decile series (ninth) over the nine months analysed was only 20 mbs. It will thus be seen that the seasonal variation in pressure is small.

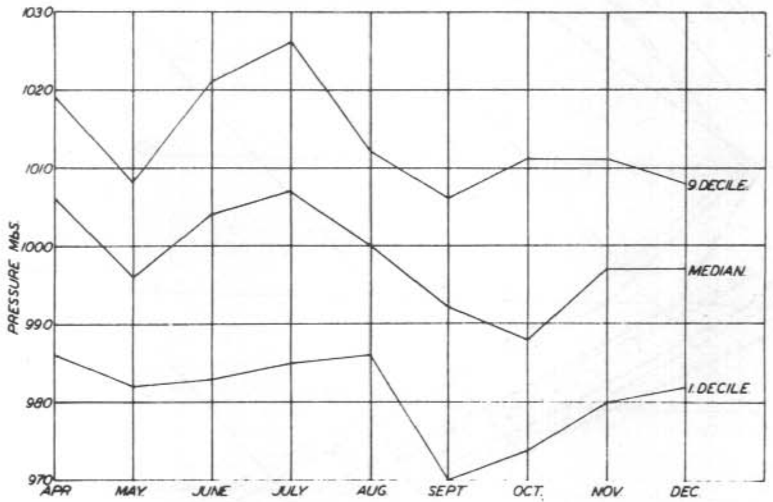


Figure 14

This is still further emphasised by comparing decile, median and ninth decile values extracted for three-monthly periods. The maximum range in this case is only 8 mbs.

A frequency distribution of readings in 10 mb intervals shows a maximum for the 1000-1010 mb interval in the autumn as against a maximum for the 990-1000 mb interval in the winter and spring periods. The frequency of occurrence of values of pressure, in 10 mb intervals, during the three seasons analysed, is shown in Figure 15.

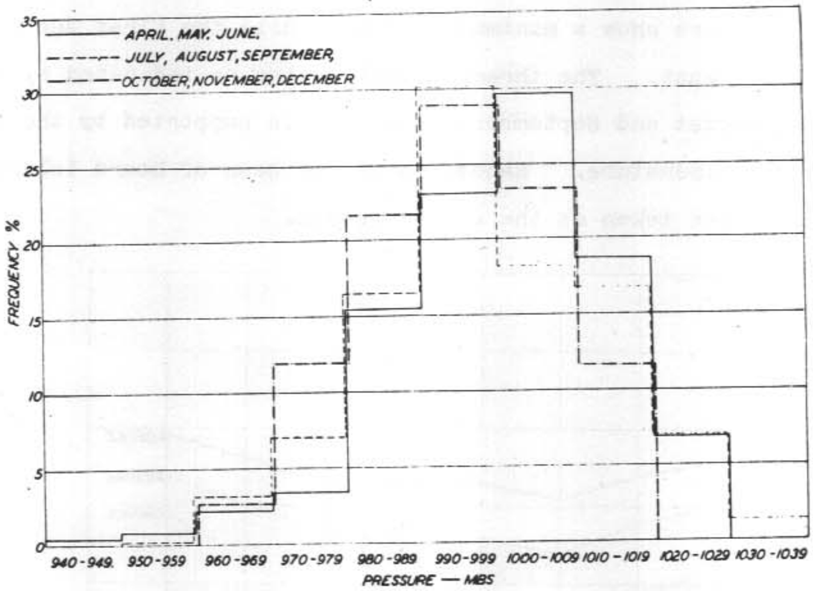


Figure 15

As in the case of Heard Island, a large monthly range of pressure and a small seasonal variation are to be expected, and it is reasonable to assume that pressure values recorded during 1948 are representative of this particular area.

Temperature. The mean monthly temperature ranged from 37.2°F in July to 42.6° in December. (Records commenced in April).

The maximum monthly temperature range was 19.6°F in June.

The absolute minimum temperature, recorded on 29th June, was 25.4°F and the absolute maximum, recorded on 11th December, was 47.8°F. The absolute range was thus 22.4°F.

The decile, median and ninth-decile values of temperature are shown for each month in Figure 16. The maximum range for any one partition value (first decile) over the nine months analysed was only 8.5°F. The small seasonal variation is further shown by comparing mean values taken over three-monthly periods, the maximum range in this case being only 3°F. The median and ninth-decile values show a minimum in July, while the first decile values show a minimum in August. The three coldest months as indicated by these series are July, August and September; and this is supported by the mean monthly values of temperature. Hence, as in the case of Heard Island, these three months have been taken as the winter season.

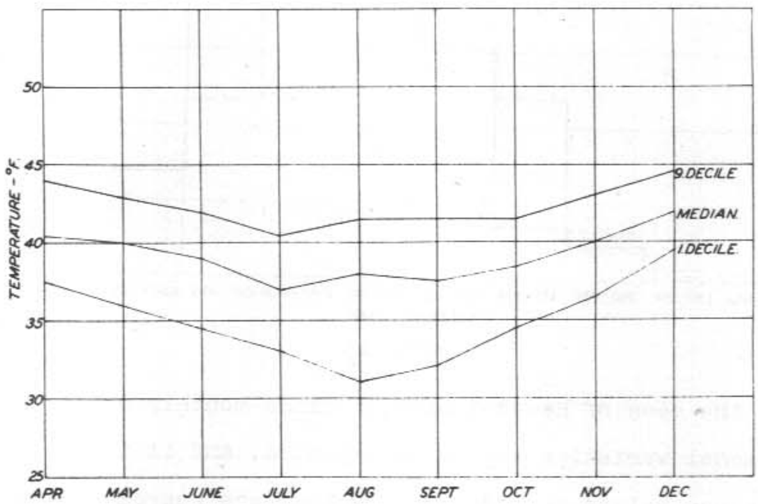
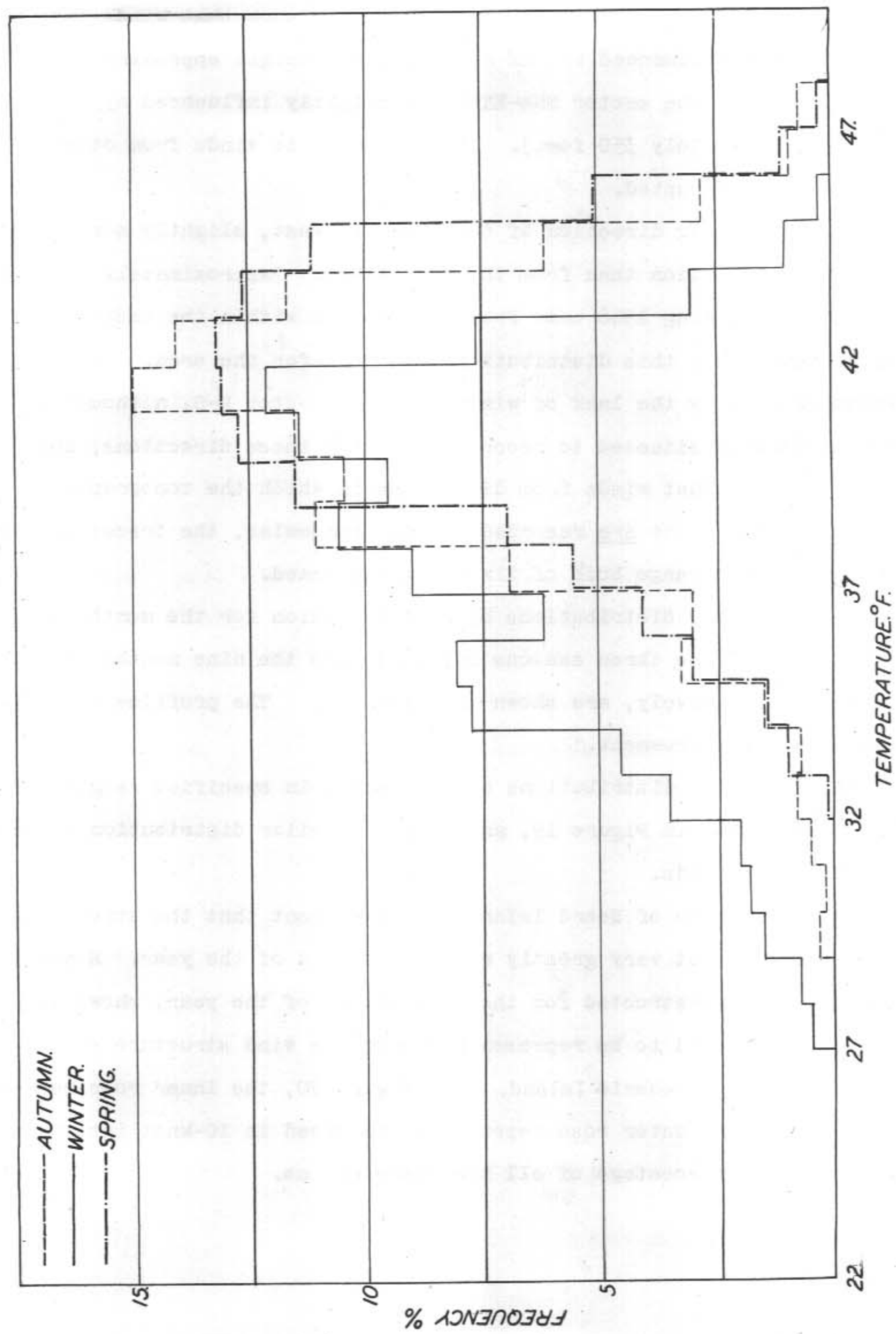


Figure 16

The frequency of occurrence of temperatures in 1°F intervals during each of the three seasons analysed is shown in Figure 17.



AUTUMN.
WINTER.
SPRING.
15
10
5
FREQUENCY %
22
27
32
37
42
47
TEMPERATURE °F.

Figure 17

Wind. The exposure of the anemometer was such that winds from the sector SSW-WSW were influenced by the main plateau (height approximately 800 feet), and winds from the sector NNE-ENE were slightly influenced by Wireless Hill (height approximately 350 feet). The exposure to winds from other directions was uninterrupted.

The prevailing direction of the wind was west, slightly more winds coming from this direction than from the north-west. Approximately 70 percent of the total winds during 1948 came from a direction within the sector W-NW, and it is believed that this distribution is normal for the area. This belief is supported firstly by the lack of winds from the sector E-S, although the anemometer is ideally situated to record winds from these directions, and secondly by the fact that winds from directions in which the topography of the island causes interference are recorded on the anemometer, the traces in these cases covering a wide range both of direction and speed.

The frequency distributions of wind direction for the months April and October, each of the three seasons analysed, and the nine months period April-December respectively, are shown in Figure 18. The profiles of these histograms show good agreement.

The frequency distributions of wind speed in specified ranges for the same periods are shown in Figure 19, and again a similar distribution is shown for the different periods.

As in the case of Heard Island, it is evident that the structure of the surface wind did not vary greatly with the period of the year. Hence the composite wind rose constructed for the nine months of the year, shown in Figure 20, is considered to be representative of the wind structure at all times of the year at Macquarie Island. In Figure 20, the inner rose represents the direction, and the outer rose represents the speed in 10-knot intervals each expressed as a percentage of all the observations.

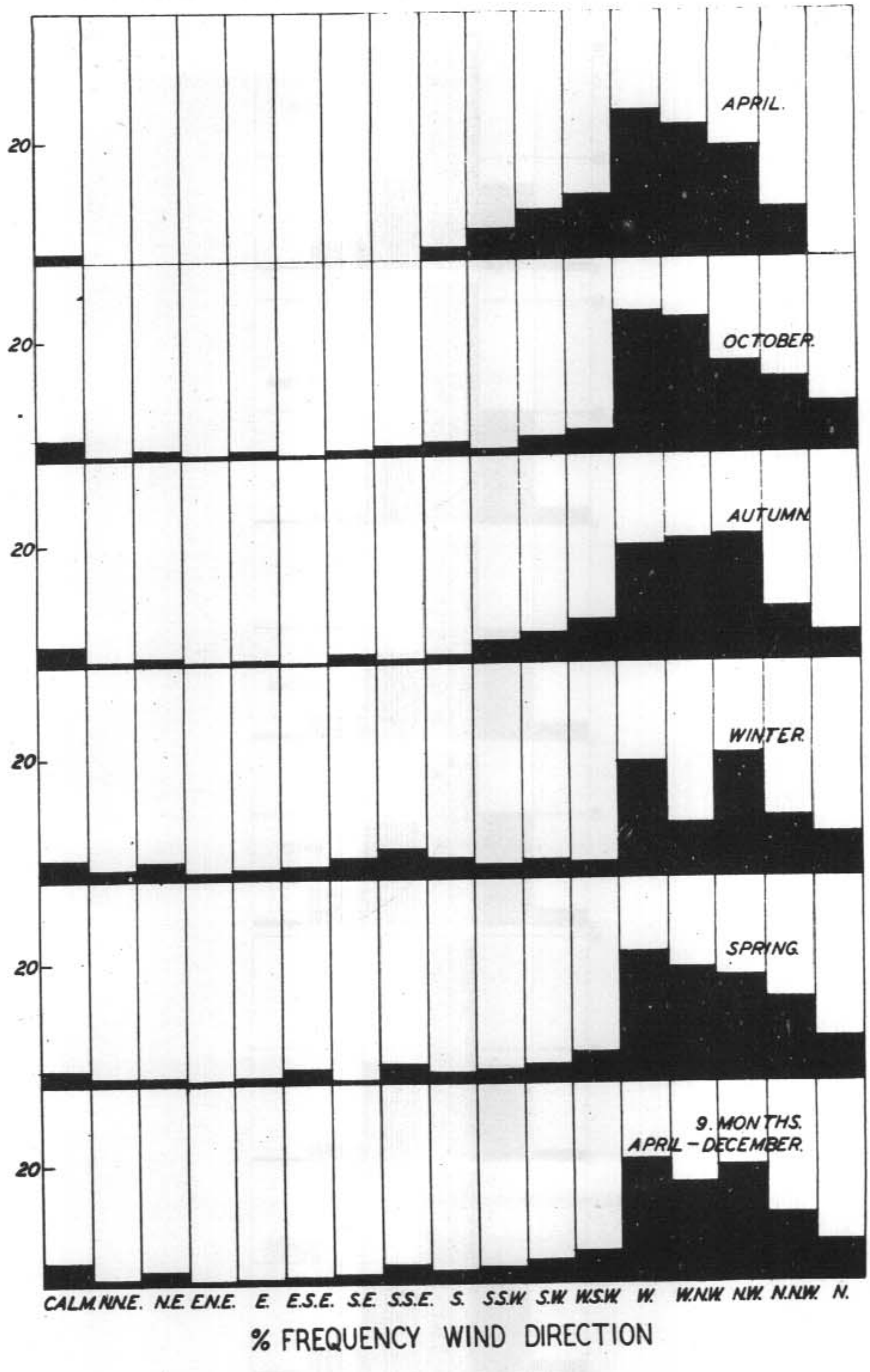

20
APRIL.
20
OCTOBER.
20
AUTUMN
20
WINTER.
20
SPRING.
20
9. MONTHS.
APRIL - DECEMBER.
CALM NNE. N.E. E.N.E. E. E.S.E. S.E. S.S.E. S. S.S.W. S.W. W.S.W. W. W.N.W. N.W. N.N.W. N.
% FREQUENCY WIND DIRECTION

Figure 18

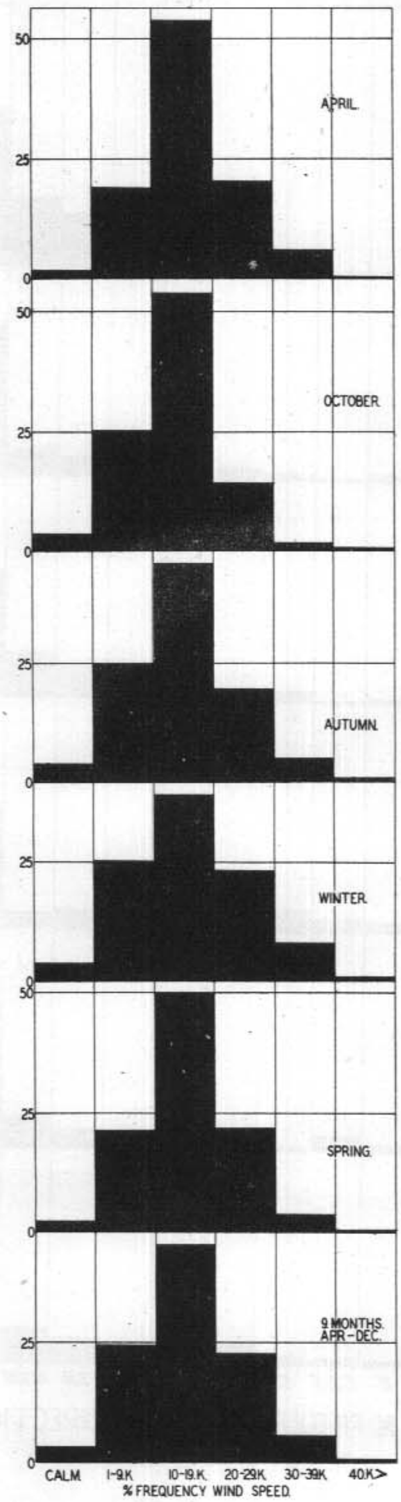

50
25
0
APRIL.
OCTOBER.
AUTUMN.
WINTER.
SPRING.
9 MONTHS. APR-DEC.
CALM
1-9.K.
10-19.K.
20-29.K.
30-39.K.
40.K.>
% FREQUENCY WIND SPEED.

Figure 19

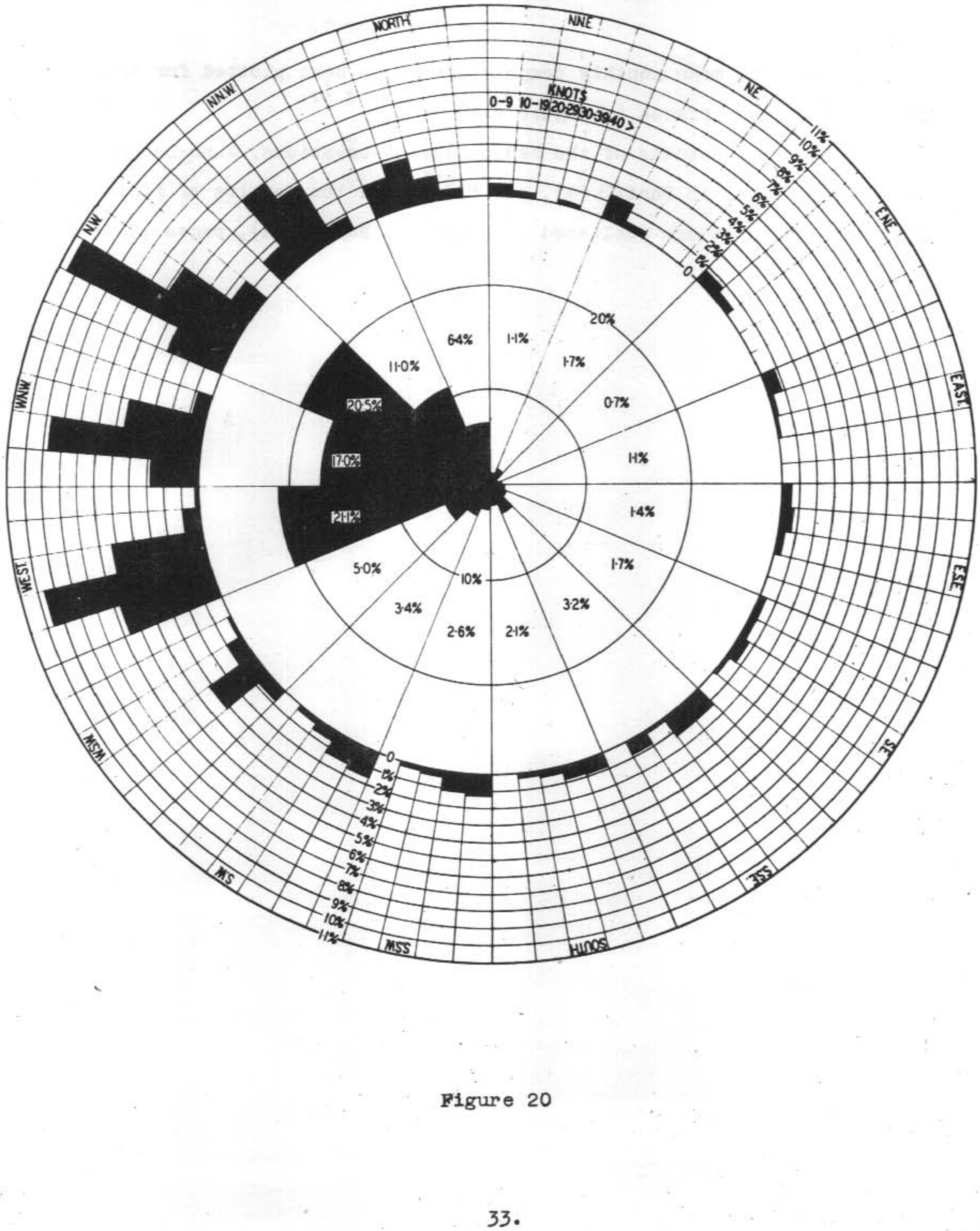

NORTH
NNE
NE
ENE
EAST
ESE
SE
SSE
SOUTH
SSW
SW
WSW
WEST
WNW
NW
NNW
KNOTS
0-9 10-19 20-29 30-39 40 >
11%
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0
20%
10%
6·4%
1·1%
1·7%
1·7%
0·7%
1·1%
1·4%
1·7%
3·2%
2·1%
2·6%
3·4%
5·0%
21·1%
17·0%
20·5%
11·0%

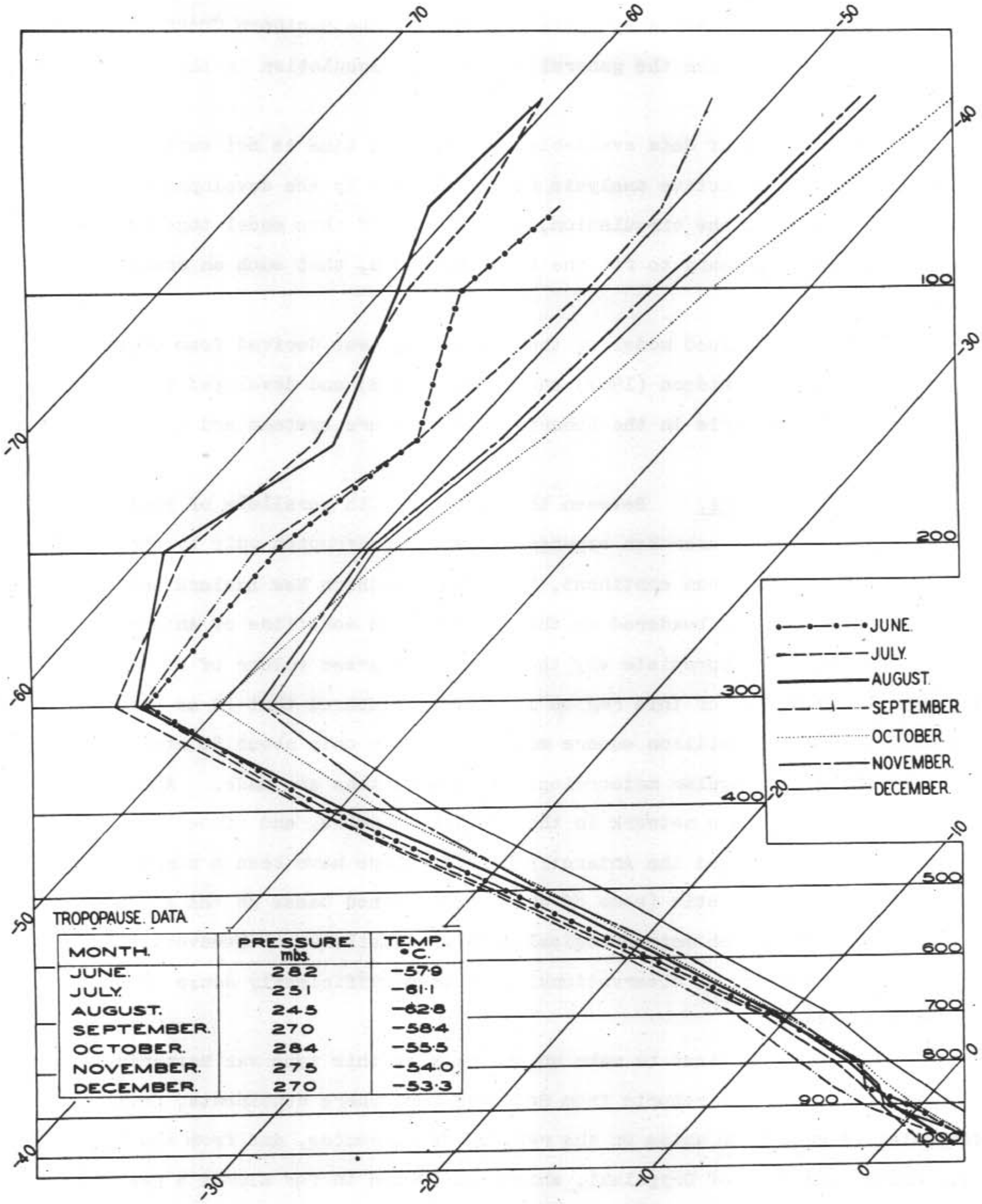
Figure 20

UPPER AIR OBSERVATIONS

As in the case of Heard Island, discussion of the upper air observations has been deferred until a longer series of observations is available.

However, mean monthly temperatures have been plotted for the standard isobaric surfaces in Figure 21.

Detailed results of the radiosonde observations, June-December 1948, are published in Part I (a), pp. 89-95, and the results of pilot balloon observations are published in detail in Part I (a), pages 101-109.



MONTH.	PRESSURE. mbs.	TEMP. °C.
JUNE.	282	−57·9
JULY.	251	−61·1
AUGUST.	245	−62·8
SEPTEMBER.	270	−58·4
OCTOBER.	284	−55·5
NOVEMBER.	275	−54·0
DECEMBER.	270	−53·3

Figure 21

SYNOPTIC ANALYSIS

In order to make a synoptic analysis of the Southern Ocean area, it is necessary to postulate the general pattern of circulation in the Southern Hemisphere.

The amount of data available at any given time is not sufficient to make a completely deductive analysis and it is only by the development of a generalised model of the circulation, and the use of this model together with any adjustments necessary to fit the available data, that such an analysis is possible.

The generalised model of the circulation was derived from consideration of the works of Kidson (1947) and Palmer (1942) and developed by reference to geographical criteria in the behaviour of pressure systems and associated fronts.

Previous Work. Between the 40th and 70th parallels of south latitude extends an almost unbroken expanse of ocean interrupted only by the southern tip of the South American continent, Tasmania, southern New Zealand and a few scattered islands, and bordered on the south by the coastline of Antarctica. It is not difficult to appreciate why there is not a great volume of literature on the synoptic analysis of this region if it is remembered that in an area of approximately thirty million square miles there are only about 50 stations at which detailed and regular meteorological observations are made. Whaling vessels supplement this network in the southern summers, and since 1773, when James Cook first crossed the Antarctic Circle, there have been a number of expeditions to the Antarctic (some of which established bases on the continent) in the records of which meteorological data are available. However, at no stage has the network of observational data been sufficiently dense to invite synoptic analysis.

One of the first to make an analysis of this type was Meinardus (1901-3), who used the reports from Southern Hemisphere continents, from Kerguelen Island, from ships on the regular trade routes, and from the "Gauss" (the expedition ship of Drygalski, which was frozen in for almost a year at Latitude 66°S, Longitude 90°E).

Unfortunately, Meinardus used charts based on Mercator's projection, which seriously distorts the shape of systems extending over a range of latitude, particularly in higher latitudes, to such a degree as to make the task of synoptic analysis very inconvenient and the interpretation of the results extremely difficult. Probably as a result of this Meinardus did not attempt an analysis south of Latitude 50°S except in the Graham Land sector, although reports from the "Gauss" and from Kerguelen Island provided an opportunity to attempt an analysis of the area between those two points.

At the time the "Gauss" was frozen in the pack ice, the "Discovery" was wintering in the Ross Sea. Using the reports from these two ships, and from other ships and the continents of the Southern Hemisphere, Hepworth (1913) drew daily synoptic charts for a period of two years (1902-3) for the Southern Hemisphere. These charts, although on a more suitable projection than that used by Meinardus, suffer from being reproduced on a very small scale. Also, Hepworth drew only that portion of the chart in the immediate vicinity of the available reports, so that the charts are difficult to interpret.

Another early attempt at synoptic analysis in high southern latitudes was that of Simpson (1919) who used the results of observations from the respective bases of Scott and Amundsen to make synoptic analyses of the Ross Sea area.

The emphasis of the meteorologists of the various expeditions during the early part of this century was on the collection of data. At that time techniques of analysis were just being developed and ideas of frontal analysis were only gradually emerging.

One of the first to attempt an analysis over the Southern Ocean using frontal techniques was Kidson (1947) who utilised the reports from Australia, New Zealand and the Australian Antarctic Expedition stations at Macquarie Island and Cape Denison in producing daily analysed charts for the year February 1912 - January 1913. Although Kidson's charts were not published until 1947, they were prepared during the thirties when frontal analysis was very much in the developmental stage in Australasia.

Undoubtedly the outstanding contribution to the subject of synoptic analysis of the Southern Oceans was made by Palmer (1942) who, after a comprehensive review of existing literature, gives examples of synoptic analysis over Australia and over the Southern Ocean, making liberal use of ships' reports during the Polar Year 1932-33 and re-analysing a few days of the "Gauss" reports to derive a synoptic analysis of the South-Indian Ocean for three days in 1902. Further papers by Palmer (1943) and Ramage (1944) examine the local problems of the analysis of the Ross Sea area and their implications in Southern Hemisphere meteorology. Since 1945 there has been considerable activity in Antarctica and the amount of data becoming available, especially from pilot balloon and radiosonde observations, will require considerable time to analyse thoroughly. Some preliminary and rather tentative recent papers are those of Lamb (1949), Robin (1949), Langford (1948) and Gibbs (1949).

The study of previous work shows that there is a great amount of data available from previous expeditions which awaits synoptic analysis by modern methods, but that surface observations from coastal regions of Antarctica are subject to strong local influence in many cases, and generally do not assist synoptic analysis to the same extent as reports from sea areas.

<u>The Problem.</u> The fact that routine meteorological observations are now available from Heard Island and Macquarie Island suggests the possibility of making regular synoptic analyses over the area between these islands and the continents of Australia and Antarctica. If it is possible to make such an analysis there is good reason to suppose that it would be of considerable assistance in making forecasts for periods of one day to a week for the Australian region. The problem is to discover whether, with the extremely sparse network of observations available, a sufficiently reliable analysis can be produced. It is not anticipated that this report, based on data for 1948, will yield a conclusive solution, but it is hoped that the preliminary findings will form an effective groundwork for the analysis of data gathered during the succeeding years of operation of the island stations.

Geography. The geography of Heard Island and Macquarie Island has already been discussed and the following is a brief review of the geography of the Antarctic Continent and the surrounding Ocean.

A map of Antarctica produced by the Commonwealth Department of the Interior, Australia, and its accompanying Handbook (1939) give an idea of the amount known about Antarctica. They show that the configuration of the coastline is unknown in some places and that knowledge of the topography is only approximate for much of the surface of the continent. Generally, it appears that the continent is covered by a vast plateau of ice rising to about 10,000 feet above mean sea-level, interrupted by mountain chains which in places reach an altitude of 15,000 feet. It is to be expected that this huge mass of ice has a profound influence on the behaviour of the atmosphere in its vicinity. Surrounding the continent is a belt of pack-ice which shows considerable variation in character and extent, being for the most part continuous, but continually breaking and reforming on its margin. Charts showing the position of the edge of the pack-ice have been constructed by Mackintosh and Herdman (1940), but these are based on relatively few observations and should be taken as an approximation to actual conditions. They show that the pack reaches its greatest extent in the period September to October and contracts to its minimum extent in the period February to March.

A map of the mean sea surface temperatures of the Southern Ocean (1943) shows a generally regular alignment of sea surface isotherms roughly along the parallels of latitude. Certain concentrations of isotherms resulting from convergence of ocean currents are noticeable, the most pronounced of them extending roughly along the 45th parallel in the Marion Island - Heard Island region.

Finally, when considering the geography of Antarctica it is important to bear in mind that the area of the continent is almost twice that of Australia. The stereographic projection preferred for meteorological work is not an equal-area projection and thus tends to give the impression that Antarctica, in comparison with other continents, is smaller than is actually the case.

<u>The Anticyclones.</u> A study of synoptic charts of the Australian region gives the impression that anticyclones are the dominant influence in Southern Hemisphere circulation. Impressed by this, Russell (1893) attributed to them the control of Australian weather. Kidson (1925), from inspection of a great many Australian synoptic charts, pointed out the constancy of the mean rate of displacement of the anti-cyclones to the east and was deeply impressed by the role they played in atmospheric circulation. However, a study of upper charts reveals that, in general, the migrating anticyclones of the middle latitudes are cold and do not appear on the upper charts. Hence they control the circulation of air only in the shallow surface layer below about 2,000 to 4,000 feet and it is therefore difficult to believe that they play any but a passive role in the determination of weather processes.

Palmer (1942) considered that "the migratory anticyclone is formed in the South Indian Ocean and is not the permanent system envisaged by Russell, Lockyer and Kidson." Here it should be noted that not all the anticyclones of the Australian region are of the cold type. Warm anticyclones do occur and they exert a much greater influence on the circulation than those of the cold type.

In addition to the anticyclones of the middle latitudes there is the area of high pressure thought to exist over the Antarctic Continent. It was long known that pressure generally reached a minimum about Latitude 60°S, and the charts of Hepworth (1913) and Meinardus (1901-3) indicate the existence of an anticyclone over the Antarctic. As a relatively small proportion of the area of the continent lies below 3,000 feet, it is rather fruitless to discuss a fictitious mean sea-level pressure pattern. The discussions of the topography of pressure surfaces beneath and over the continent by Simpson (1919) and Meinardus (1938) appear somewhat hypothetical. It is clear, however, that pressures at the coastline of the continent are generally higher than those to seaward. Palmer (1943) has examined a situation in the Ross Sea area in which it is shown that an anticyclone to the south over Antarctica extends to the tropopause. It appears that, in addition to the migratory anticyclones of the middle latitudes, the rarer warm cells of these latitudes, and the peripheral ring of higher pressure around the Antarctic continent, anticyclones also occur between latitudes 50°S and 70°S. These anticyclones, as shown by Kidson's and Palmer's charts and reports from Heard Island and Macquarie Island, may be either of the cold or warm type, the latter being quite intense on occasions and analogous to the "blocking" high of the Northern Hemisphere.

There is little doubt that the migrating anticyclones of middle latitudes almost invariably move from west to east. Palmer (1942) suggests that they form in the South Indian Ocean, implying an initial movement from south-west to north-east. Such a hypothesis seems oversimplified. Certainly the anticyclones which appear in the Heard Island region do seem to move to the north-east on many occasions but it is doubtful whether all anticyclones appearing over the west coast of Australia originate in the vicinity of Heard Island.

The Depressions. The existence in the Southern Ocean of a series of great depressions with a general eastward movement was first indicated by barometer readings from sailing ships en route to Australia. Hepworth (1913) observed pressure minima overtaking his vessel in regular succession during a voyage from South Africa to Australia. Meinardus (1901-3) indicated that the strong easterly winds experienced at the "Gauss" winter station were the result of intense depressions to the north. Simpson (1919) mistakenly considered that the depressions of the Southern Ocean were not of major importance in the general circulation, his error being mainly due to his use of observations from the Ross Sea area which appear to be strongly influenced by local topographical affects.

Kidson (1947) considered that the majority of the great depressions of the Southern Ocean develop as frontal waves which "very seldom have a complete wind circulation....owing to the steep poleward pressure gradient associated with the prevailing westerly winds". He pointed out that some of the great depressions appear to originate as tropical or mid-latitude cyclones of non-frontal origin.

Palmer (1942) concluded that "the great depressions are the result of activity of the Indian (Ocean) Polar Front: they develop....in comparatively low latitudes in the Western Indian Ocean."

Neither Kidson nor Palmer gives an exact picture of his ideas regarding the tracks followed by the great depressions, but their published charts show that they consider that the depressions originate in relatively low latitudes as frontal waves, travel rapidly from north-west to south-east until they reach their maximum intensity and the occlusion process begins (generally between latitudes 50°S and 60°S), then re-curve and move at a slower rate in a direction from west to east. Robin (1949) remarks that the travel of cyclones in the Graham Land region is "roughly eastward, and appears to depend mainly on the direction and latitude of the pack-ice edge".

It seems that the depressions of the Southern Ocean reach their maximum intensity between latitudes 50°S and 60°S where their general direction of movement is towards the east or south-east. In lower latitudes depressions are generally much less intense, are of the frontal wave or frontless tropical type, and vary considerably in direction of movement. It is thought likely that in many cases the troughs or col areas between the mid-latitude migrating anticyclones are simply northward extensions of the pressure minima of the great southern depressions. Palmer (1942) mentions that "certain meteorologists....(believe) that the low pressure areas lying between the migratory cells of the anticyclonic belt are simply "troughs" equivalent to the troughs sometimes found between the cells in the North Pacific and Atlantic highs". He disagrees with this view, stating that "the autographic records reproduced in both Lammert's and Kidson's papers....are sufficient to demonstrate the fallacy of these assumptions." This is too sweeping a statement and it is likely that the truth lies somewhere between the two viewpoints. Not all the col areas contain fronts and some of the changes experienced between migrating pressure cells are non-frontal.

Ramage (1944) mentions the principle of "parallel action" which implies that "features of the (Southern Hemisphere) circulation differ very slightly from those experienced in the Northern Hemisphere". This analogy can be carried too far. In the first place, there are no adequate reporting networks in the Southern Hemisphere in the latitudes corresponding to those of the Northern Hemisphere in which methods of synoptic analysis have been developed. Secondly, there is a vast difference between the two hemispheres in the matter of situation of land and water masses. In the Northern Hemisphere the land masses of North America, Europe and Asia extend northward beyond the Arctic Circle, surrounding the Arctic Ocean. In the Southern Hemisphere the Antarctic continent extends from the pole to about latitude 70°S, while between 70°S and 40°S the Southern, South Pacific and South Atlantic Oceans are interrupted only by the isolated land areas of Tasmania, the South Island of New Zealand and the southern extremity of South America. As continents, and in particular their coastlines, undoubtedly exert a profound influence on the circulation pattern it appears likely that there will be considerable differences between the circulations of the two hemispheres, particularly with regard to the movement of depressions and anticyclones. There is reason for believing that the great southern depressions move more regularly than those of the Northern Hemisphere where the Icelandic and Aleutian lows form such a major feature of the circulation and, as Robin (1949) suggests, the great depressions tend to move along the pack-ice edge rather than across it.

To sum up, in regard to the pressure systems of the Southern Ocean:-

(i) the mid-latitude anticyclones generally exhibit a regular eastward movement and are frequently separated by nonfrontal "col" areas,

(ii) higher latitude cold anticyclones move generally to the northeast and may develop into warm type systems,

(iii) the great depressions of the Southern Ocean have their origin in latitudes lower than 40°S on the majority of occasions and may form as frontal waves or non-frontal depressions,

(iv) at latitudes lower than 40°S these depressions vary considerably in their direction of movement, but in higher latitudes this is mainly to the south-east or east, and in the vicinity of the pack-ice the depressions move in a general easterly direction along its margin.

The above viewpoints have been developed gradually as the result of a daily synoptic analysis of the Southern Ocean. It is not practicable to reproduce all the charts which form the evidence on which these conclusions are based, nor is it claimed that this evidence is conclusive.

However, as mentioned previously, with the restricted reporting network available, it is necessary to begin with a comprehensive hypothesis of the circulation patterns, and the above summary outlines the behaviour of surface pressure systems and is subject to correction in the light of further experience and supplemented networks.

The Fronts. In a study of the literature relevant to pressure systems over the Southern Ocean we are faced with some differences of interpretation regarding the concept of a front and the methods of frontal analysis. Petterssen (1940, pp. 303 et seq) has given a comprehensive review of the development of the frontal concept. He points out that J. Bjerknes began by identifying the "steering line" and "squall line" of a depression and later, in a joint paper with H. Solberg, replaced these terms by "warm front" and "cold front". Later these two authors extended their ideas and advanced the concept of the polar front, on which waves develop and intensify and become major depressions. During this period Bergeron developed the idea of air masses, which was complementary to the polar front theory of Bjerknes and Solberg. Most synoptic analysts accept this theory, which implies the situation of a homogeneous "warm" air mass overlying a denser homogeneous "cold" air mass, the two being separated by an inclined surface or transition layer.

In practice many analysts take considerable liberties with the classical frontal theory, modifying it in order to make the scheme of analysis fit the observational data.

In Australia this tendency to modify the classical theory has been in evidence from the earliest attempts at frontal analysis in the region. As Palmer (1942) points out, Lammert and Kidson found considerable difficulty in fitting a conventional analysis to observational data from the Australian Region. Palmer himself (1942) had some difficulty in postulating a hypothesis to explain the frontal phenomena over Australia and finally concluded that they were frequently occlusions of the cold front type.

During the period of hostilities in the S.W. Pacific (1942-45) the emphasis of Australian meteorology shifted to the tropics and experience soon showed that frontal methods were inadequate in this region. Gibbs attempted to modify frontal theory to account for low latitude phenomena and published these ideas in two papers (1943, 1944), and as a result of further experience in low latitudes investigated methods of tropical analysis (1945a, 1945b). These methods were largely non-frontal and recognised only rare occurrences of fronts. There was a natural reluctance to discard frontal analysis as the main tool for forecasting in low latitudes, especially as aircrews were conversant with weather types associated with the frontal model, but it was considered necessary to do this in order to improve the reliability of synoptic analyses and forecasts.

The rather negative results achieved from the application of frontal concepts in low latitudes naturally led to an investigation of their validity over the southern portion of the Australian continent. This resulted in the development of a modified version of the classical frontal theory, which included the notion of the "coastal front" as outlined by Cassidy (1945a, 1945b)

With the establishment of reporting stations at Heard Island and Macquarie Island (Australian Meteorological Service), at Campbell Island (New Zealand Meteorological Service) and at Marion Island (South African Meteorological Service) there was presented an opportunity to attempt a synoptic analysis of the Southern Hemisphere.

With the co-operation of the Directors of the Meteorological Services of the United Kingdom, Rhodesia, South Africa and Argentina, the Officer-in-Charge of the U.S. Southern Hemisphere Project, and the Fleet Meteorological Officer, R.N., Simonstown, South Africa, synoptic charts of the Southern Ocean for various periods have been obtained. A comparison of these charts shows the wide divergence of methods of frontal analysis which exists today.

There appear to be three main reasons for these differences. Firstly, as yet no commonly accepted basis for methods of frontal analysis has been established. Secondly, there are conflicting ideas regarding frontal nomenclature and zones of major frontogenesis in the Southern Hemisphere. Thirdly, owing to the very scanty network of reports from latitudes higher than 40°S in the Southern Hemisphere, two analysts using the same model and data may produce different frontal analyses over the Southern Ocean.

However, of the three factors contributing to the lack of uniformity in analyses over the Southern Ocean, the first and second appear to cause the greatest disparities.

The Bjerknes model of development of wave cyclones and their movement, frontal movement and associated phenomena, has been adopted as the basis of analyses, but it has been difficult to find a statement of frontogenesis to adopt as a model. The classical work of Bjerknes V., Bjerknes J., Solberg and Bergeron (1934, pp. 762 et seq) indicates that frontogenesis occurs along the axis of dilatation of a stationary deformation field. Using this assumption and maps of mean surface pressure of the Northern Hemisphere, the positions of the principal fronts of that Hemisphere have been traced along the axes of dilatation of the deformation fields associated with this pressure pattern. Fronts are traced in the deformation fields between the Aleutian low and the semi-permanent Pacific high and between the Icelandic low and the semi-permanent Atlantic high. The fronts formed in these deformation fields are called polar fronts. The polar front in mid-Atlantic evidently has its mean position at about 40°N in the northern winter and at about 50°N during the northern summer. In addition an arctic front is identified extending from the centre of the Aleutian and Icelandic lows to the eastward. A further "trade-wind front" is identified in the "col" areas of the middle latitude belt of high pressure.

Bergeron (1928) amplified the original idea of frontogenesis by introducing the air mass concept and stating that frontogenesis will occur when two air masses are brought together by a deformation field. Petterssen (1940), as previously stated, suggests that for major frontogenesis an isotherm concentration and a deformation field are necessary. In the Southern Hemisphere the principal isotherm concentrations are in the regions of the convergence of ocean currents or along the coastlines including that of Antarctica or the edge of the pack ice which fringes it.

Neither Kidson (1947) nor Palmer (1942) presents convincing ideas regarding the origin of fronts in the Southern Hemisphere. Kidson believed that fronts extend more or less meridionally from Australian latitudes to Antarctica but an examination of his charts clearly shows that he is concerned mainly with deformation fields rather than with air masses. If it is agreed that a front is a boundary between two air masses of different density, then the speed of the front must be intimately related to the trajectory of the denser air mass. It is quite evident from Kidson's charts that he did not fully consider the relationship between pressure pattern and air trajectory, for on trajectory considerations his frontal movements are not plausible. Palmer's analyses may be divided into two categories - those for the Australasian region and those for the Southern Ocean. The Australasian analyses were made over the period of a year but the Southern Ocean analyses were for a limited period only. Palmer's conclusion that the meridional front of Australia develops from occlusion of the polar front of the South Indian Ocean, while plausible, is based on insufficient evidence.

To summarise, the manner of development and movement of depressions and anticyclones over the Southern Ocean is fairly well established. There are minor differences of opinion regarding the origin and movement of the systems, but the broad picture as seen by various workers is substantially the same. The frontal picture on the other hand presents a number of fundamental differences stemming from different concepts of the origin, nature and development of fronts.

Technique of Analysis. It is clear that the usual technique of synoptic analysis is unsuitable for application to the Southern Ocean. Observing points are widely scattered and vast expanses are entirely lacking in observations so that the normal practice of plotting and analysing charts for three-hour or six-hour intervals is uneconomical. At the same time it is necessary to compensate for the lack of adequate spatial coverage by careful attention to the time-sequence of observations from reporting stations. It is impossible to attempt a Southern Ocean analysis unless six-hourly observations are available from these isolated reporting stations, and three-hourly observations are highly desirable. In practice only one chart a day is analysed but no observations are plotted on this chart since observations at 24-hourly intervals plotted on charts are likely to unduly influence the analyst. Observations from Marion Island, Heard Island, Macquarie Island, Campbell Island and from ships in the Southern Ocean are plotted in the meteorogram form shown below -

The observations are plotted with time-sequence from right to left. As systems generally have an approximate west-east movement, this gives a rough idea of the spatial distribution of elements. Upper wind observations are plotted in "snake" form and radiosonde observations on the "skew T - log p" diagram (CMB Form F160).

The analyses over the Australasian region southward to about latitude 45^{o}S are transferred from the charts of the Central Analysis Section, Meteorological Branch, Melbourne, and when the scope of the analyses is extended, analyses from South Africa and South America are also taken into account.

It has been assumed that the surface wind approximates the gradient wind and that pressure systems persist in identity whilst changing rapidly in intensity at times. It is considered that depressions frequently deepen rapidly between Marion and Heard Islands but as a rule gradually fill to the east of Heard Island.

The coastline of Antarctica, or the edge of the pack-ice fringing it, is regarded as the major frontogenetical region. The antarctic front moving northward from this frontogenetical area becomes the "polar front" of the Southern Hemisphere. It is assumed that wave development occurring on this front in middle latitudes results in the development of a major depression, which, on nearing the Antarctic coastline, causes the outbreak of a fresh mass of antarctic air with a new antarctic front as its forward boundary. The older polar fronts gradually dissolve as the modification of the old antarctic air behind them reduces the density contrast across the front. It is believed that fronts, of a type which may be designated "sub-tropical", form in the deformation fields of the cols between the middle latitude "highs" and that the types of front experienced over the Australian continent are the antarctic (polar) front, the sub-tropical front or the Australian Coastal front. As the general movement of depressions and anticyclones is steadily from west to east, the meridional flux of air from south to north in the lowest levels of the atmosphere is not a continual phenomenon but occurs in occasional outbreaks. A general west-east alignment of antarctic (polar) fronts is therefore favoured. In Southern Ocean analyses the main interest lies in the disposition of these antarctic (polar) fronts during the vigorous stage of their life history, and therefore their movements are not traced after they have degenerated into the frontolytic stage.

DISCUSSION OF ANALYSED CHARTS

Part 1 (b) of this volume contains analysed charts for June and December, 1948. The analyses were made to record certain ideas regarding the movement of pressure and frontal systems over the Southern Ocean, and aim to demonstrate a concept of the genesis and behaviour of the polar front based on the rigid definition of a front as a density discontinuity.

It is realised that these charts do not explain all the significant weather occurring over the region as, for instance, that associated with non-frontal wind shifts occurring ahead of the polar front which are thought to be similar in character to the "polar trough" described by Riehl (1945). However, it is regarded as most important that the frontal concept should not be amended to include shear lines without a density discontinuity. The fact that significant hydrometeors occur other than in association with a front points to the need for a wider scope of analysis rather than for the amendment of the frontal concept.

The charts for June are based mainly on the observations from Marion, Heard, Macquarie and Campbell Islands, whilst the analyses over the Australasian region southward to latitude 45°S have been taken from the synoptic charts of the Central Analysis Section, Meteorological Branch, Melbourne.

During the period from the 1st to the 5th of June it is postulated that the polar front has a general latitudinal alignment with waves L_A, L_B, L_C which gradually occlude but maintain an eastward movement, although the speed of translation slackens. During this period the depression L_E moves from a position off the west coast of Australia to a position south of the continent, having associated fronts which may be either old polar fronts or sub-tropical fronts.

A depression L_G which moves from Marion Island to Heard Island between the 3rd and the 4th, becomes occluded on the 5th in a position south-east of Heard Island, and the southerly flow of air induced by it causes an antarctic front, which had formed along the Antarctic coastline on the 4th, to be swept northward.

During the next few days this antarctic front takes over the role of the polar front, the former polar front becoming gradually weaker and appearing over the south-west corner of the Australian continent on the 8th.

Meanwhile an outbreak of southern air over New Zealand contains the anticyclone H_C, which was apparent as a "bubble" high to the north of Heard Island on the 1st.

The location to the south-east of Heard Island of the depression L_N, which occluded between Marion and Heard Islands and subsequently moved slowly south-east, results in a further northward surge of a new Antarctic front in the vicinity of Heard Island on the 13th, and this becomes the new polar front. About this time depressions L_O and L_R appear in the vicinity of the south-west corner of the continent and move south-south-east. A further depression L_U appears in this vicinity on the 16th suggesting that these may be wave cyclones on either an old polar front or a sub-tropical front. Further new cold outbreaks behind antarctic fronts occur on the 19th and the 26th, in each case in association with an occluded polar front depression which has approached the Antarctic continent in the vicinity of Heard Island. In the latter case the central pressure value of the depression is less than 945 mb. Although this depression is intense the polar front does not move over the Australian continent until waves develop on it in the vicinity of latitude 45^oS.

From these charts for June 1948, it will be seen that the major depressions of the region analysed appear from the vicinity of Marion Island, where they generally are unoccluded and therefore young wave cyclones. These depressions move south-east until they reach the vicinity of latitude 60^oS after which they appear to drift eastwards. During this month the process of replacement of old polar fronts by new antarctic fronts appears to have occurred mainly in the vicinity of Heard Island. It is possible that this is an illusion resulting from the disposition of the observing stations but it is considered likely that a denser network would confirm the impression.

It has been impossible to reproduce all the data on which the analyses are based although the synoptic observations from Heard Island and Macquarie Island are contained in Part 1 (a) of this volume. However, certain situations have been selected to illustrate the background of the analyses. The times are local times, five hours ahead of G.M.T. at Heard Island, and ten hours ahead of G.M.T. at Macquarie Island.

The first situation to be considered in greater detail is that at Heard Island for the period 17th - 18th June, 1948. Here the polar front has a roughly west-east alignment and on the 17th a wave (L_Q) passes along the front, followed on the 18th by another wave (L_S) with occluding fronts.

Figure 22 shows the variation of pressure, wind, temperature, dewpoint and hydrometeors between 0300 hours and 2400 hours on the 17th. A definite warm frontal passage is discernible at about 1100 hours and is reported as such in the station observation book. From the observations of 2300 hours on the 17th and 0500 hours on the 18th, it appears that a cold front passage occurred between these hours.

Figure 23 shows the variation of pressure, wind, temperature, dewpoint and hydrometeors between 0300 hours and 2400 hours on the 18th. The figure suggests a warm front passage at the station at about 0900 hours and a cold front passage at about 1730 hours. The station reported warm and cold front passages respectively at 0640 hours and 1815 hours. From Figure 23 it will be seen that the changes in the elements do not occur synchronously; for instance, the temperature rise at about 1100 hours occurred about five hours after the interruption of the pressure fall. The wind shift associated with this temperature rise is indefinite and may be said to have occurred at either 0800 hours or 1100 hours.

The cold front passage is also poorly defined from surface observations, and assumptions must be made to the effect that the frontal passages at the surface are "blurred" by orographic or other effects.

Figure 24 gives a comparison of the upper temperatures and humidities at 1330 hours on the 18th with those at 1335 hours on the 19th. The ascent on the 18th was made in the warm sector whilst that of the 19th was made in the cold air some time after the cold front passage.

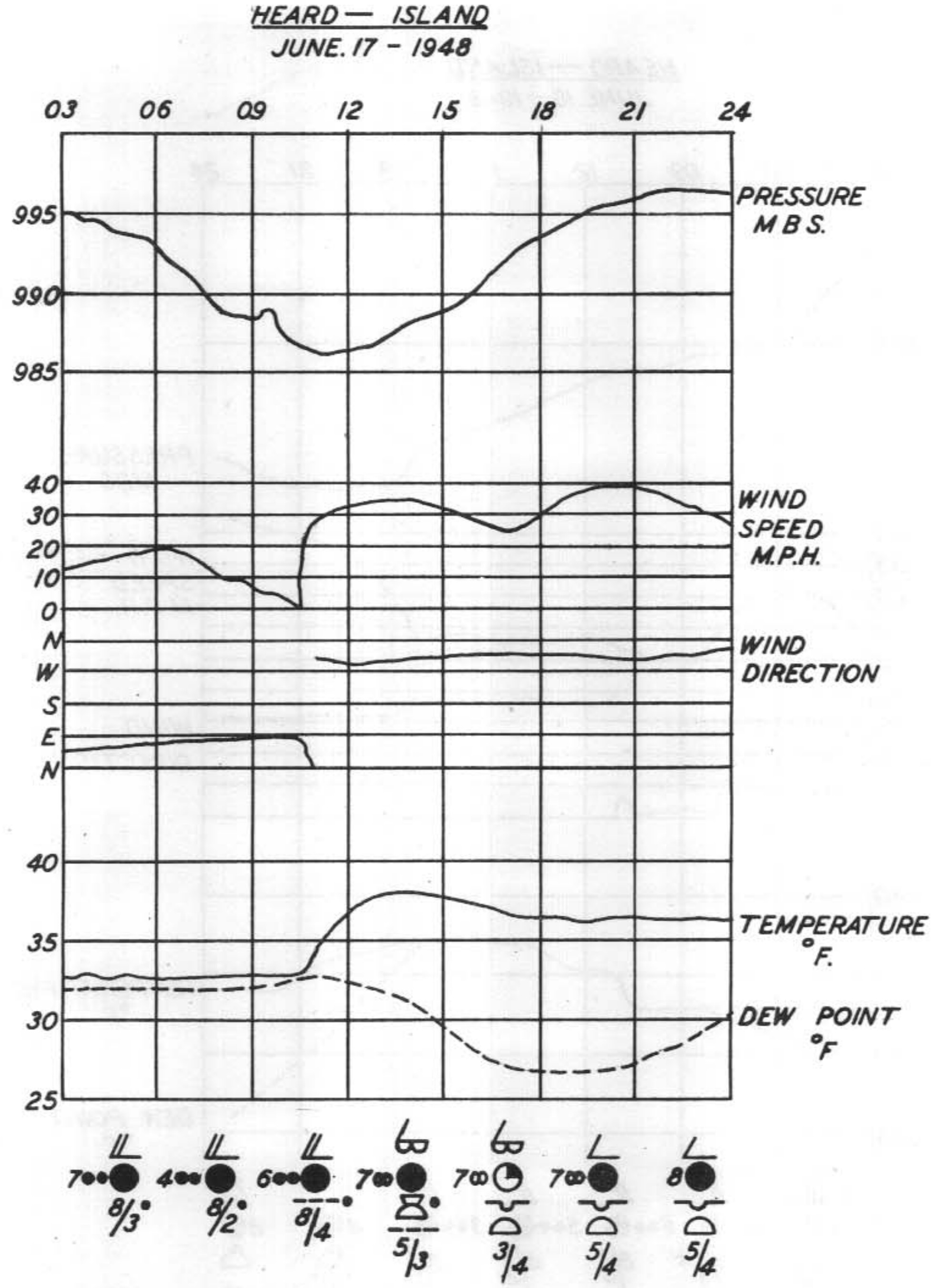

HEARD — ISLAND
JUNE. 17 - 1948
03 06 09 12 15 18 21 24
995
990
985
PRESSURE MBS.
40
30
20
10
0
WIND SPEED M.P.H.
N
W
S
E
N
WIND DIRECTION
40
35
30
25
TEMPERATURE °F.
DEW POINT °F
8/3
8/2
8/4
5/3
3/4
5/4
5/4

Figure 22

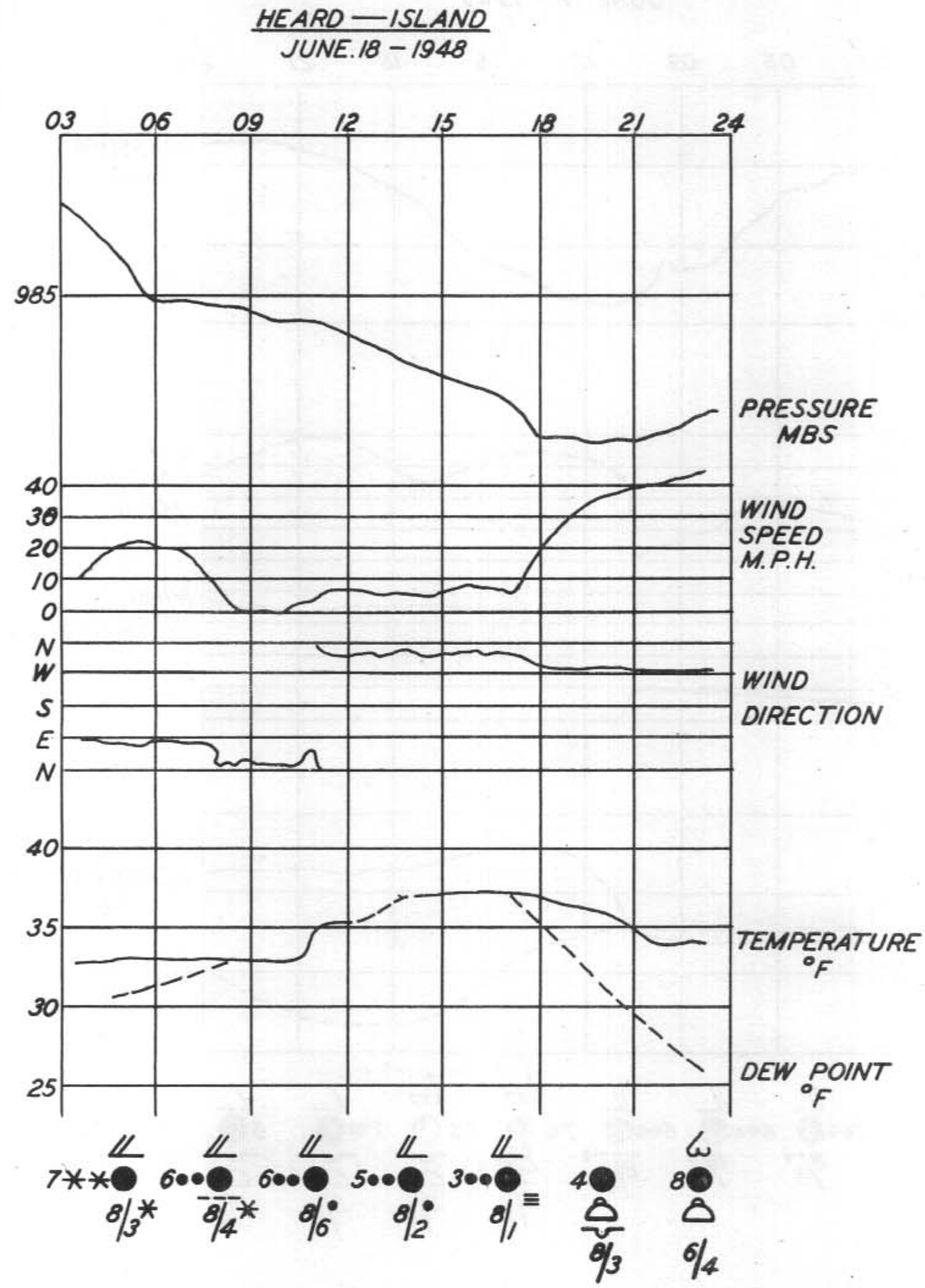
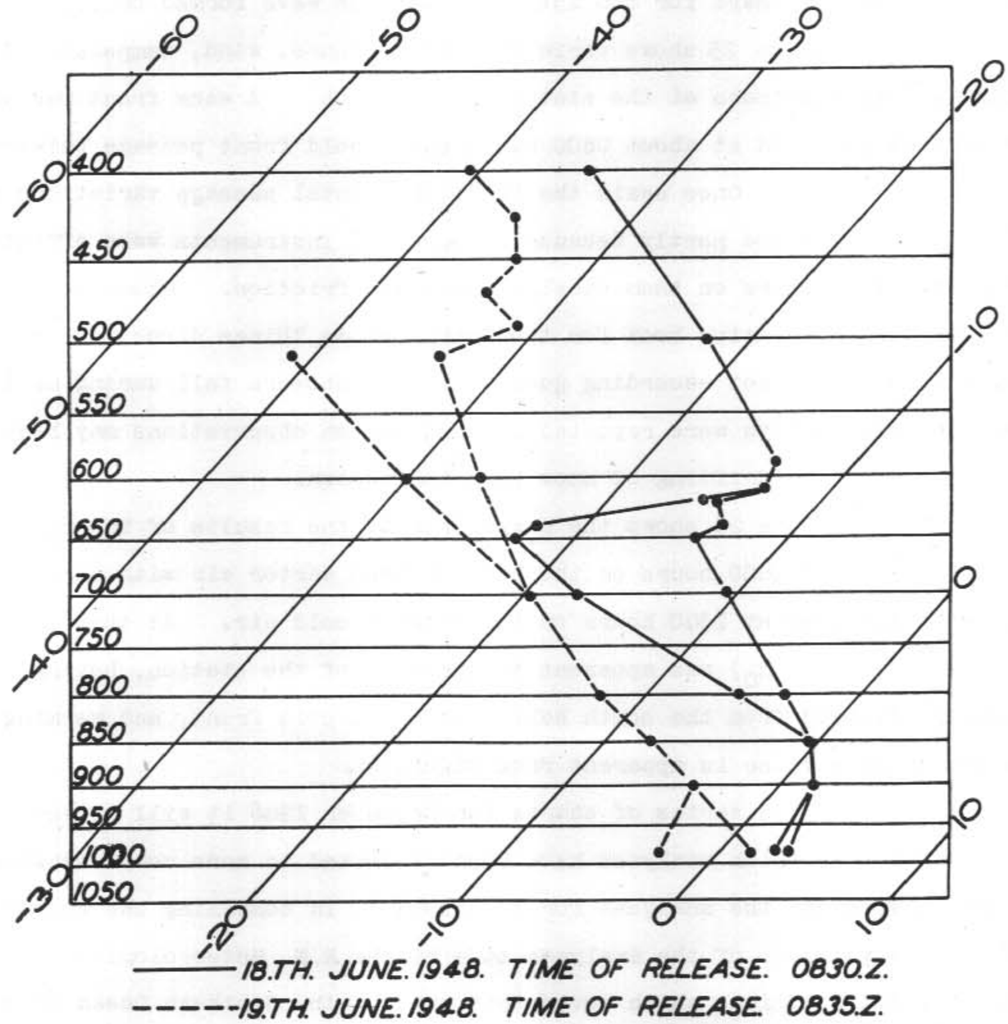

HEARD — ISLAND
JUNE. 18 – 1948
03
06
09
12
15
18
21
24
985
PRESSURE MBS
40
30
20
10
0
WIND SPEED M.P.H.
N
W
S
E
N
WIND DIRECTION
40
35
30
25
TEMPERATURE °F
DEW POINT °F

Figure 23



400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
-60
-50
-40
-30
-20
-10
0
10
18.TH. JUNE. 1948. TIME OF RELEASE. 0830.Z.
19.TH. JUNE. 1948. TIME OF RELEASE. 0835.Z.

Figure 24

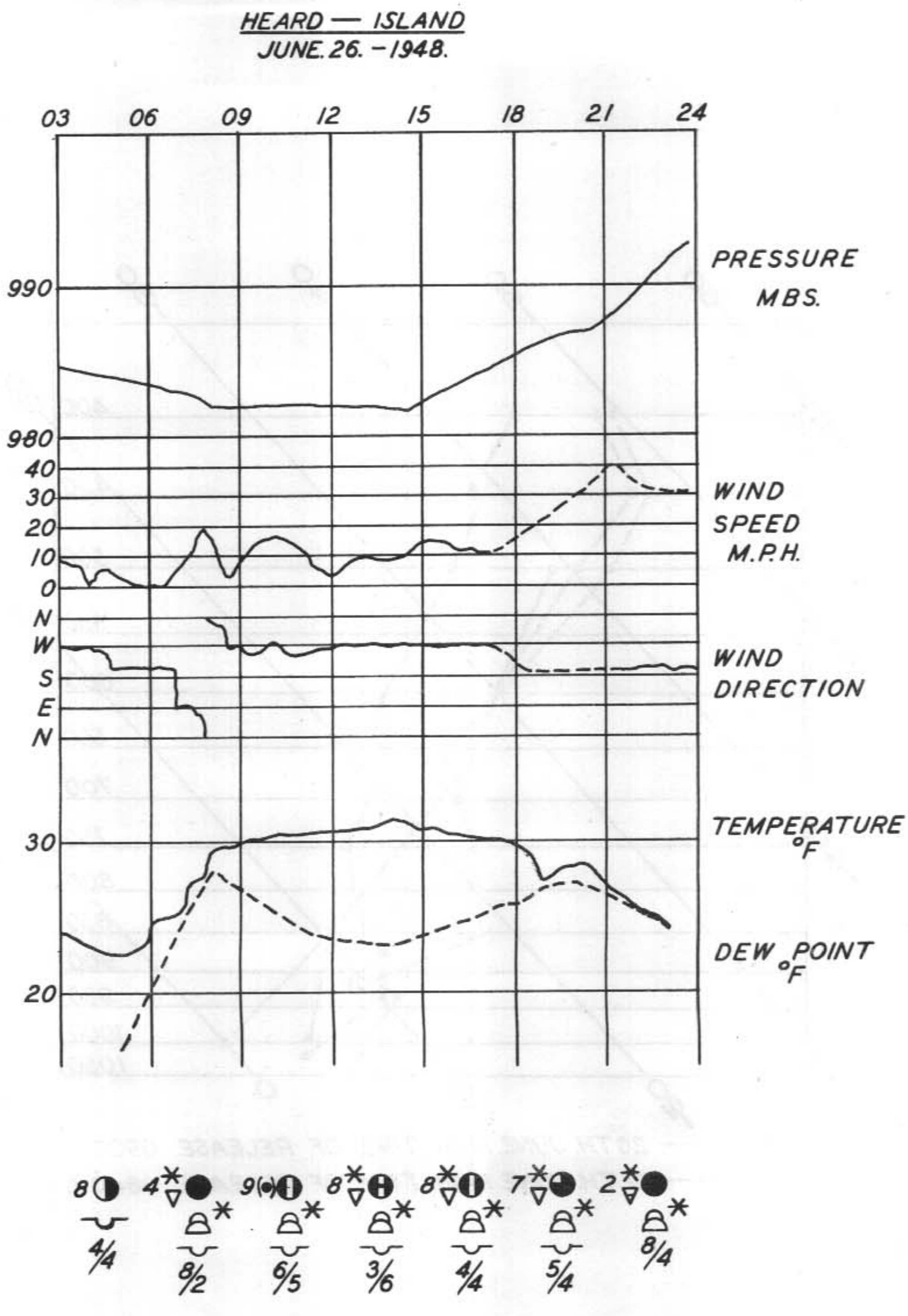
It will be seen that the warm sector air is some 8°C warmer than the cold air at most levels.

The next situation considered is that occurring at Heard Island on the 26th June. An intense depression (L_a) passed to the east of the station on the 24th but by the 26th observations suggest the passage of a further shallow wave. It is postulated that an antarctic front was in the trough shown on the chart for the 25th and that the wave formed on this front.

Figure 25 shows variations of pressure, wind, temperature, dewpoint and hydrometeors at the station on the 26th. A warm front passage seems to have occurred at about 0800 hours and a cold front passage between 1500 and 1800 hours. Once again the textbook frontal passage variations are "blurred", in this case partly because autographic instruments were affected by freezing of moisture on them causing excessive friction. Observers' remarks in the observation book for the 26th include "Dines direction freezing" and "Dines not recording gusts". Snow showers fell during most of the day and deep drifts were reported so that screen observations may have been affected by the drifting of snow into the screen.

Figure 26 shows the comparison of the results of the radiosonde ascent commenced at 1400 hours on the 26th in warm sector air with those of the ascent commenced at 1340 hours on the 27th in cold air. At this later time an anticyclone (H_0) was apparent to the west of the station, having presumably advanced from the south behind the antarctic front, and warming of air aloft by subsidence is apparent from Figure 26.

In the series of charts for December 1948 it will be seen that the area over which analyses have been attempted is more comprehensive than that covered by the analyses for June 1948. In compiling the charts for December, use was made of the analyses made by the R.N. Meteorological Office, Simonstown, South Africa, which cover that part of the Southern Ocean from longitude 70°W to longitude 50°E, analyses issued by the Meteorological Services of South Africa and Argentina, and analyses from the U.K. Meteorological Office in the Falkland Islands. Over continental Australia the analyses of the Central Analysis Section of the Commonwealth Meteorological Bureau, Melbourne, were used as a guide. Reports at six - or three-hourly intervals were available from the Falkland Islands, South Georgia, Graham


HEARD — ISLAND
JUNE. 26. - 1948.
03
06
09
12
15
18
21
24
PRESSURE
MBS.
990
980
40
30
20
10
0
WIND
SPEED
M.P.H.
N
W
S
E
N
WIND
DIRECTION
TEMPERATURE
°F
30
20
DEW POINT
°F
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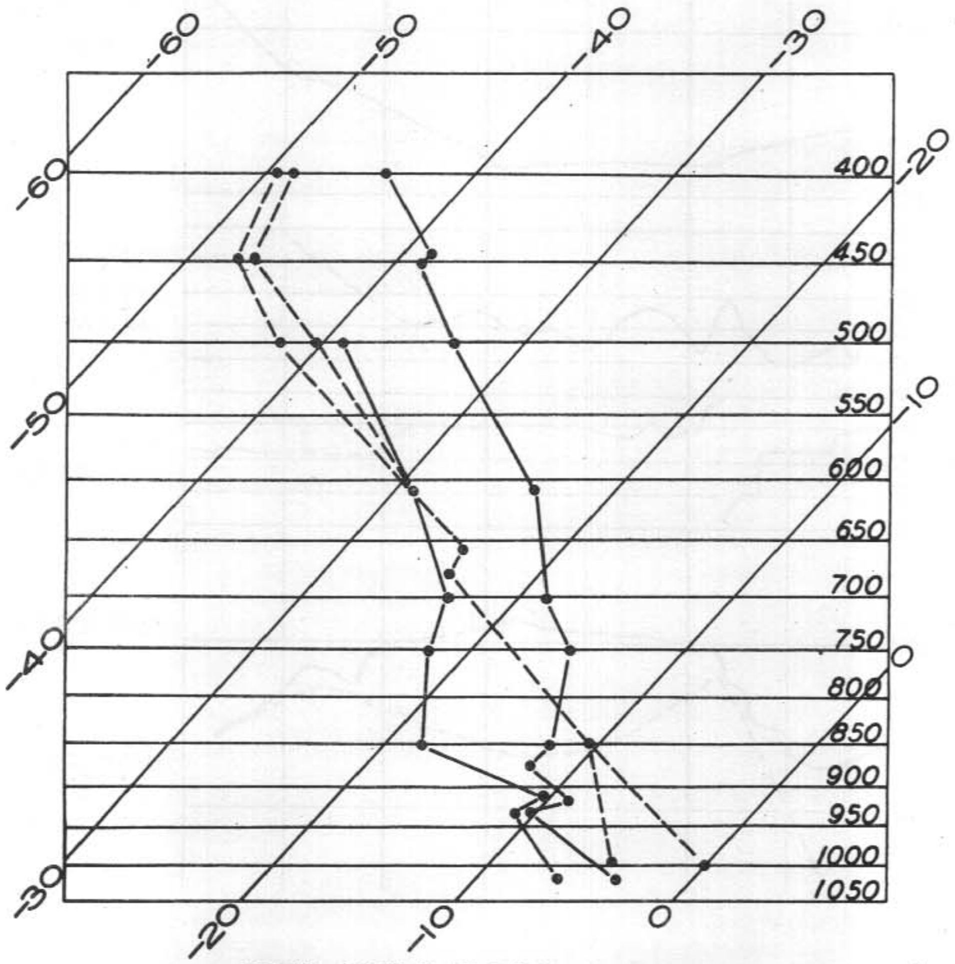
8/2
6/5
3/6
4/4
5/4
8/4

Figure 25



------- 26TH. JUNE. 1948. TIME OF RELEASE. 0900. Z.

——— 27. TH. JUNE. 1948. TIME OF RELEASE. 0840. Z.

Figure 26

Land, Marion Island, Heard Island and Macquarie Island and from about eight ships at latitudes greater than $50^{o}S$.

The charts for the first three days in December show a continuous polar front from South America to the longitude of New Zealand but by the 4th, the retardation of the movements of lows "F" and "G" has caused a northward displacement of the front in their vicinity and a new antarctic front appears to the south of South America. A depression (L_C) which was in evidence in the Great Australian Bight on the 1st, intensifies and by the 5th has become a major feature in the vicinity of Macquarie Island where the polar front is drawn into its circulation. On the 8th the old polar front moves over the southwest corner of Australia but has become very weak and the antarctic front is now assuming the role of the polar front. It will be noted that from reports available two depressions (L_F and L_L) appear to have maintained their identity throughout the first half of the month, moving slowly eastwards along latitude $60^{o}S$, and being connected at first with the old polar front and later with the antarctic front which on the 15th is regarded as the dominant polar front of the circulation.

On the 15th a wave (L_T) is apparent on this front near South America and in the ensuing days develops into an intense depression in the vicinity of the Falkland Islands with rapid occlusion of the front. On the 16th a wave (L_V) develops in a similar manner near Tasmania and by the 20th is an intense depression near Macquarie Island.

On the 21st a wave (L_X) is evident, from Marion Island reports, on the old polar front and by the 23rd it passes Heard Island as an intense low with the fronts partly occluded. It subsequently drifts to the east, its attendant cold front moving over the southwest corner of Australia, and the depression, now less intense, later moves to the south of Macquarie Island and causes a fresh outbreak of antarctic air over that station on the 30th.

The main impression gained from these charts for December 1948 is that the depressions form in the vicinity of latitude $40^{o}S$, move southeast and intensify until reaching latitudes 55^{o} - $60^{o}S$, and then generally drift to the east, often retaining their identity for ten days or more.

A more detailed description of an indivudual case is now given for Macquarie Island for the period 29th - 30th December, 1948, Figure 27.

MACQUARIE — ISLAND

DECEMBER 29 —— DECEMBER 30 1948

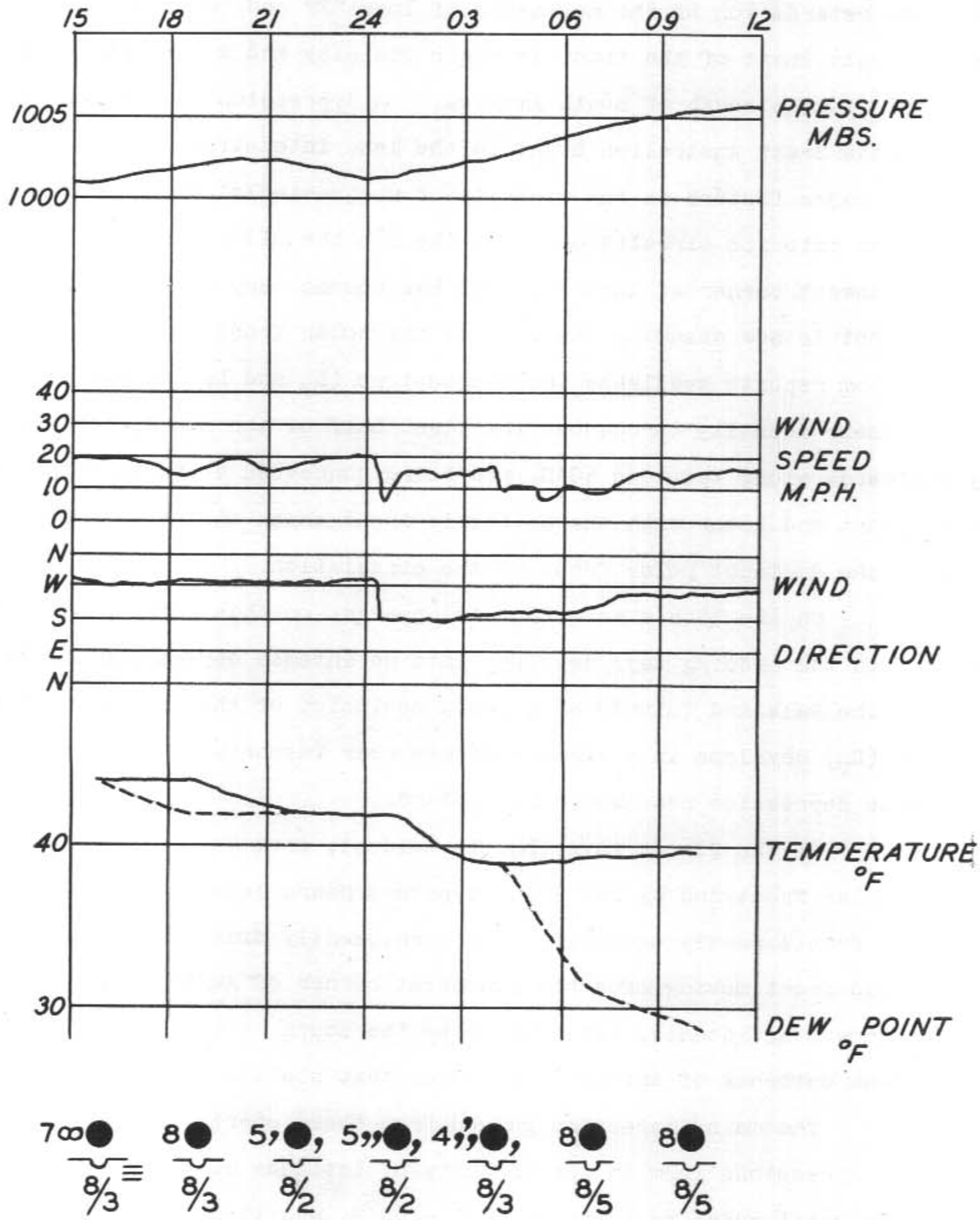


Figure 27

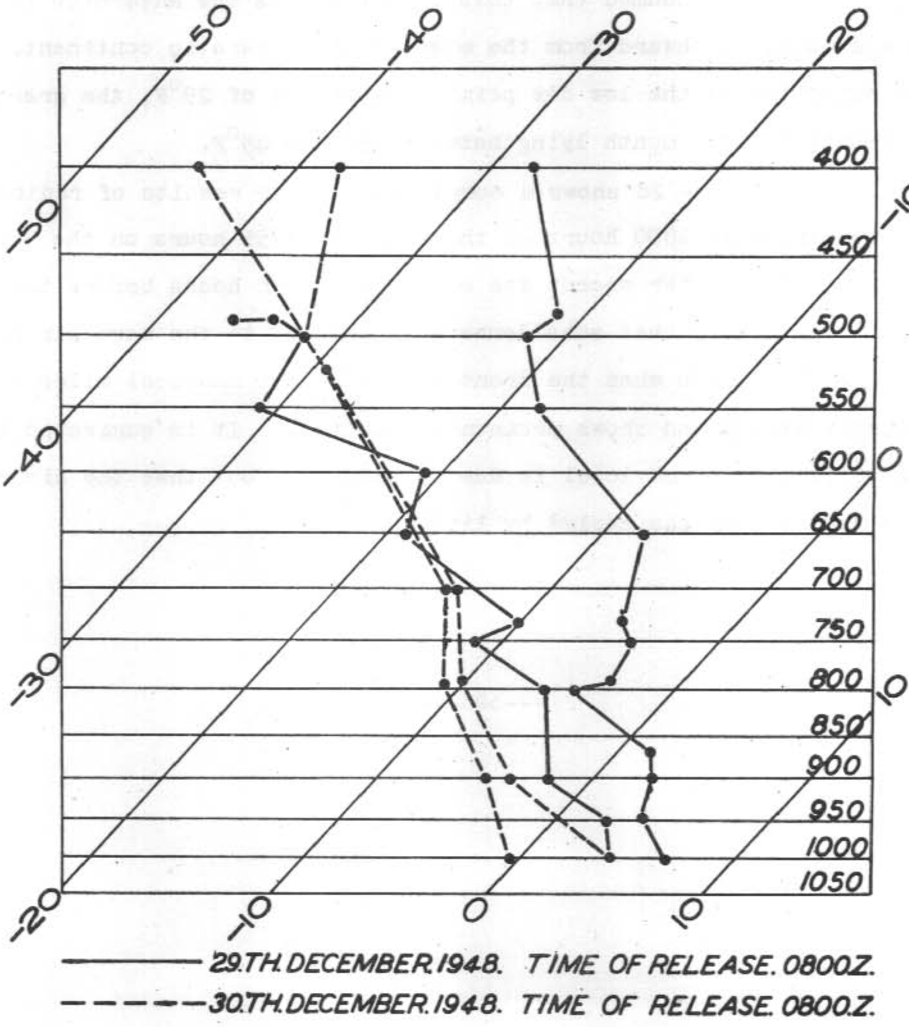

-50
-40
-30
-20
-10
0
10
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
29.TH. DECEMBER. 1948. TIME OF RELEASE. 0800Z.
30.TH. DECEMBER. 1948. TIME OF RELEASE. 0800Z.

Figure 28

showing the changes of pressure, wind, temperature, dew point and hydrometeors from 1500 hours on the 29th to 1200 hours on the 30th.

A cold frontal passage is clearly indicated at about 0030 hours on the 30th. There is a marked shift in wind direction from West to South, there is a $3^{o}F$ drop in temperature and, when precipitation ceases allowing a representative reading, it is seen that the drop in dew point is about $13^{o}F$. It is assumed that this cold front is the antarctic front, which formed and moved northward from the edge of the Antarctic continent. This view is supported by the low dew point temperature of $29^{o}F$, the great majority of dew points for the month lying between 35^{o} and $45^{o}F$.

Figure 28 shows a comparison of the results of radiosonde ascents commenced at 1800 hours on the 29th and 1755 hours on the 30th respectively. The earlier ascent was made some seven hours before the frontal passage and indicates that subsidence has occurred in the warm air mass. The latter ascent was made when the front was about 250 nautical miles to the north of Macquarie Island and shows pronounced cooling. It is suggested that cooling below the 750 mb level is due to advection but that the air above that level is warm sector air cooled by lifting.

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E R R A T A

VOLUME 1 PART 1 (a)

Pages (vi) and (viii)	..	The code numbers corresponding to each type of present weather have been omitted. These numbers follow in numerical sequence to those on Pages (v) and (vii) respectively.
Page (xii)	..	The second line should read - 6 Cirrus and Cirrostratus, often in bands converging.
Page 61	..	Observations are for the month of July, 1948.
Page 73	..	Insert observation for 2200 hours on the 10th November, 1948, as follows : 10 22 0136 37 35 31 00 - 98 8 03 1 8 6 5 - - 5 - - 42 35 000 - - - 90
Page 75	..	Delete the following observations on the 23rd November, 1948 - 23 01 9982 44 44 etc 23 04 9989 44 44 etc and insert them on page 78 as the 0100 hours and 0400 hours observations on the 23rd December, 1948.
Page 82	..	On June 16th, the 900 mb. temperature should be negative.
Page 84	..	On August 1st the 300 mb height should be 854.
Pages 80 - 95	..	In the results of Radiosonde observations a blank occurring in the temperature column, when other data for the same level is given, indicates a temperature of zero at that level.