AUSTRALASIAN ANTARCTIC EXPEDITION
1911-14
UNDER THE LEADERSHIP OF SIR DOUGLAS MAWSON, O.B.E., D.Sc., B.E., F.R.S.

SCIENTIFIC REPORTS
SERIES B
VOL. VI

METEOROLOGY.

DISCUSSIONS OF OBSERVATIONS.

AT

ADÉLIE LAND, QUEEN MARY LAND AND MACQUARIE ISLAND.

BY
EDWARD KIDSON, O.B.E., D.Sc., F. Inst. P., F.R.S.N.Z.,
Late Director Meteorological Office, Dominion of New Zealand.

WITH THIRTY FIGURES IN TEXT, AND SIXTY-FIVE TABLES.

PRICE: TWENTY SHILLINGS.

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PREFACE

An unusually extensive range of meteorological data from the Antarctic and sub-Antarctic Regions of the Australasian Quadrant is a feature of the records of our Expedition. Such has been published in tabular form as volumes III, IV, and V of this series. Before these volumes were printed, I was fortunate in securing the co-operation of Dr. Edward Kidson, who agreed to study our tabulated data and to prepare for publication a summary and discussion thereon.

For a number of years Dr. Kidson devoted much of his leisure time to the study of Antarctic meteorology. At an early stage he undertook the reduction, tabulation and publication of the meteorological data of Shackleton's British Antarctic Expedition of 1907–09. During this period of devotion to Antarctic meteorology he was able to visit Europe and America on two occasions, there to make personal contact with the leading exponents of polar meteorology and for discussion and inquiry into all aspects of the subject. It is thus we are assured that his contributions Volumes VI and VII herewith are an efficient and masterful rendering of his task.

Volume VII is mainly an atlas of weather charts for the Australasian Antarctic region covering 365 consecutive days. Herein is clearly demonstrated for the first time the repercussion of Antarctic atmospheric disturbances upon the weather of Australia and New Zealand. Volume VI is a detailed analysis of the records of the various climatic factors at each of the Expedition's observing base stations; also discussion concerning the bearing thereof on the broader question of Antarctic climatology in general.

Dr. Kidson's task was eventually completed, though not quite concluded, when he died suddenly and unexpectedly. Fortunately, by that time, Vol. VII had been completed and Volume VI required only an introductory chapter of a general nature and a final section dealing with the meteorological records of sledging parties.

Thus, though untimely death has not seriously curtailed his contribution to our Antarctic Reports, it robbed the ranks of Australasian meteorologists of their ablest exponent.

Dr. Edward Kidson was a First Class Honours graduate of Canterbury College (New Zealand University) in Mathematics and Physics. After graduation he spent some years on the staff of the Carnegie Institute of Washington, engaged in magnetic surveys in various parts of the world and on the research ship *Carnegie*. Between the years 1915–1917 he was engaged on war service in Europe. He was then appointed in charge of the Watheroo Magnetic Observatory in Western Australia, and soon afterwards became Assistant Director of the Commonwealth Meteorological Service. Later he was called upon to reorganise the Meteorological Office of the Dominion of New Zealand, and became director, which post he occupied until his death. Dr. Kidson stood in the front rank of British meteorologists and, had he lived, outstanding ability in the realm of Terrestrial Physics would undoubtedly have secured for him further recognition. His portrait is reproduced as a frontispiece to this volume.

Further particulars of the life of the late Dr. Edward Kidson appear in an obituary notice supplied by Dr. M. A. F. Barnett, his successor as Director of the Meteorological Office of the Dominion of New Zealand, and published in the transactions of the Royal Society of New Zealand for the year 1939.

Upon the death of Dr. Kidson the manuscript of these two volumes was collected from amongst his papers and the M.S. prepared for publication by Dr. Barnett, for whose help we are greatly indebted. We are also indebted to Dr. Seelye for help in proofing.

There has been no attempt to supply the missing chapters of Volume VI, originally contemplated by the author.—D.M.

EDWARD KIDSON, O.B.E., M.A., D.Sc., F Inst. Phys.

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CHAPTER I

EDITORIAL NOTE.—With the exception of Chapter I, all the manuscript for this volume had been completed at the time of Dr. Kidson's death. There can be little doubt that this chapter was to be in the nature of a general introduction to the detailed discussion of the observational material which is included in the succeeding chapters. Its preparation was, no doubt, being postponed until the remainder of the volume had been brought into its final form. Dr. Kidson left no indication as to the manner in which he intended to treat this chapter, or of its scope, and as the remaining chapters are self-contained, it has been thought inadvisable that anyone else should attempt to write an introduction—*M. A. F. Barnett.*

CHAPTER II

TEMPERATURE

I.—ADELIE LAND AND QUEEN MARY LAND

1.—Instruments and Methods.

Notes regarding the instruments and their exposure at Adélie Land are given in Volume IV of this series containing the "tabulated and reduced records". The tabulated values were derived from the records of a weekly thermograph by Messrs. Short & Mason, Ltd. in which the recording element was a bimetallic spiral. No details regarding the instrument are given. The usual difficulties due to the severity of Antarctic conditions were experienced. Drifting snow was especially troublesome owing to the almost continuous high winds.

The readings of the thermograph were, however, controlled by those of mercury thermometers and the final accuracy may be regarded as quite satisfactory.

In addition to hourly values, the daily maximum and minimum were read from the thermograph traces. These, together with their time of occurrence and the daily range as derived from them, are tabulated for each day.

At Queen Mary Land the procedure was very much the same, but the thermograph gave considerable trouble and there are a number of long breaks in the record. These are filled to a certain extent by the three-hourly eye observations, but in some months the number of days with no observations is still considerable.

In the tabulations contained in Volumes II, III, and IV of this series, it was the general practice not to give a daily mean for days when some observations were missing, or to use these days in determining the diurnal variation. For the purposes of the present discussion the gaps have been filled wherever possible. In some cases, probable values could be got by reference to the original records, but in other cases interpolations had to be made. At Queen Mary Land, when 3–hourly observations are available, it is clear that a satisfactory daily mean can be obtained, while hourly values can be interpolated to a close degree of approximation. In consequence of this incorporation of additional values, and of errors in computation in the original tables, it will frequently be found that the figures used in this volume differ from those printed in the others. These remarks apply to other elements besides temperature.

2.—Topography.

The location of the two Bases in reference to the Southern Ocean and the Antarctic Continent is shown in Fig. 1. A more detailed map of the Adélie Land and King George V Land region is given in Fig. 2. The coastline runs fairly evenly in a west-northwest to east-southeast direction but is indented by a number of bays, on one of which, Commonwealth Bay, the expedition's headquarters were situated. It is important to notice that for over 50 miles to the eastward and over 100 to the westward, there was open sea at all times of year. Further to the eastward, there were the great tongues of the Mertz and Ninnis glaciers with fields of floe ice attached to them, while to the west, beyond the distance mentioned, impenetrable pack extended for many miles off-shore.

Around the Base itself was an area of exposed or semi-exposed rock surface, consisting of granitic gneiss and some morainic material, but this was too small to exercise any important influence on the thermal conditions.

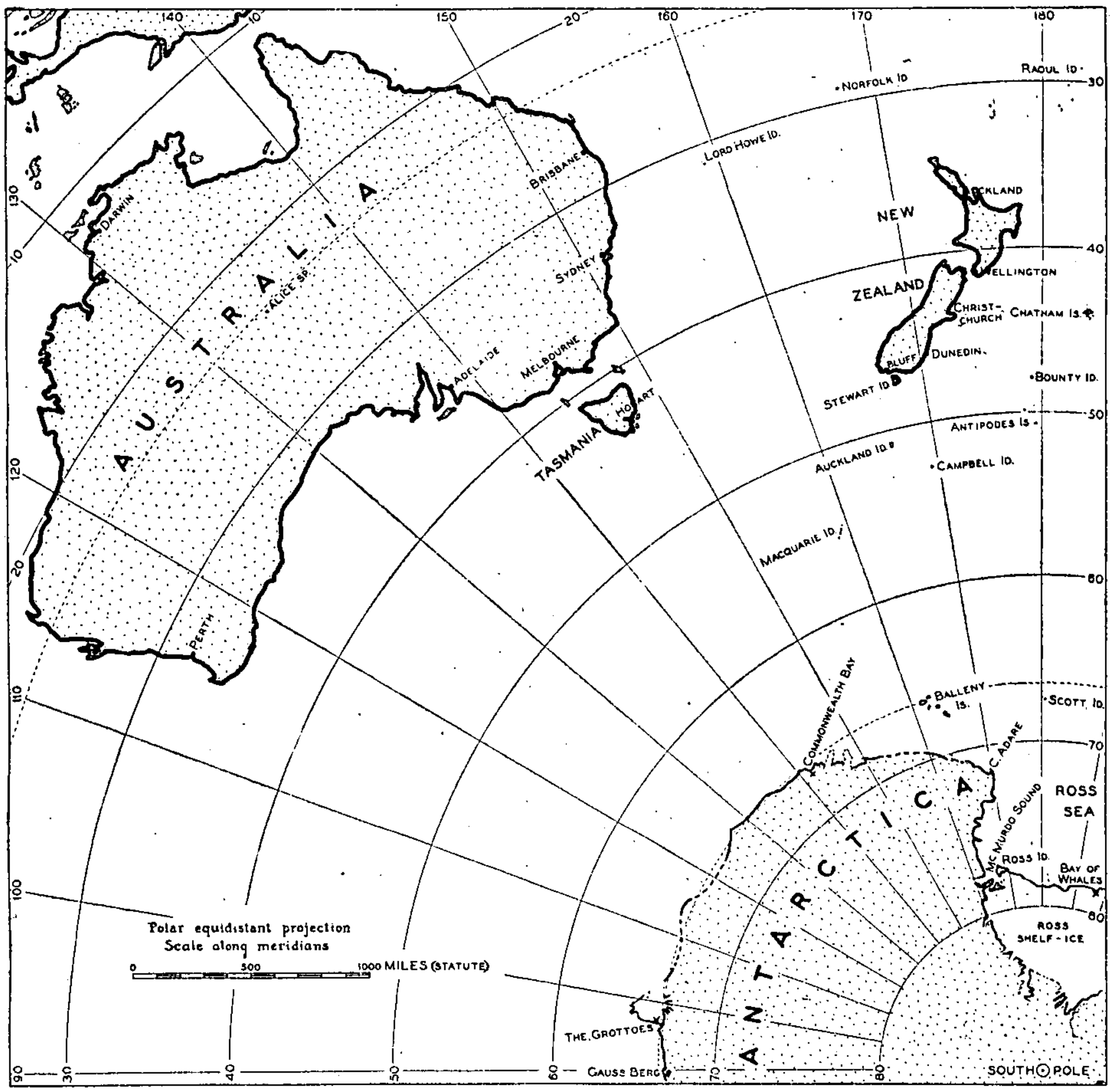

FIG. 1.

The slopes of the great ice shelf of the Antarctic Continent rise from the shore probably to the centre of the continent. At the furthest point reached by the Southern Party under Robert Bage, which was approximately 150 miles inland, the ice surface was 6,000 feet (1,800m.) above sea level. The main ice divide to the southward is unlikely anywhere to be less than 7,000 feet (2km.) in altitude and it may be anything from 200 miles to 1,000 miles and more from the coast in different directions. Certainly the coast in this region must receive the drainage of cold air from an enormous hinterland. The sea being kept open on the coast, a temperature of 28° F. and upwards must be maintained there. In any but the warmest summer months, therefore, there must be a very marked contrast between the thermal conditions on either side of the shore line. There was, consequently, an almost continuous rush of cooled air from the interior out over

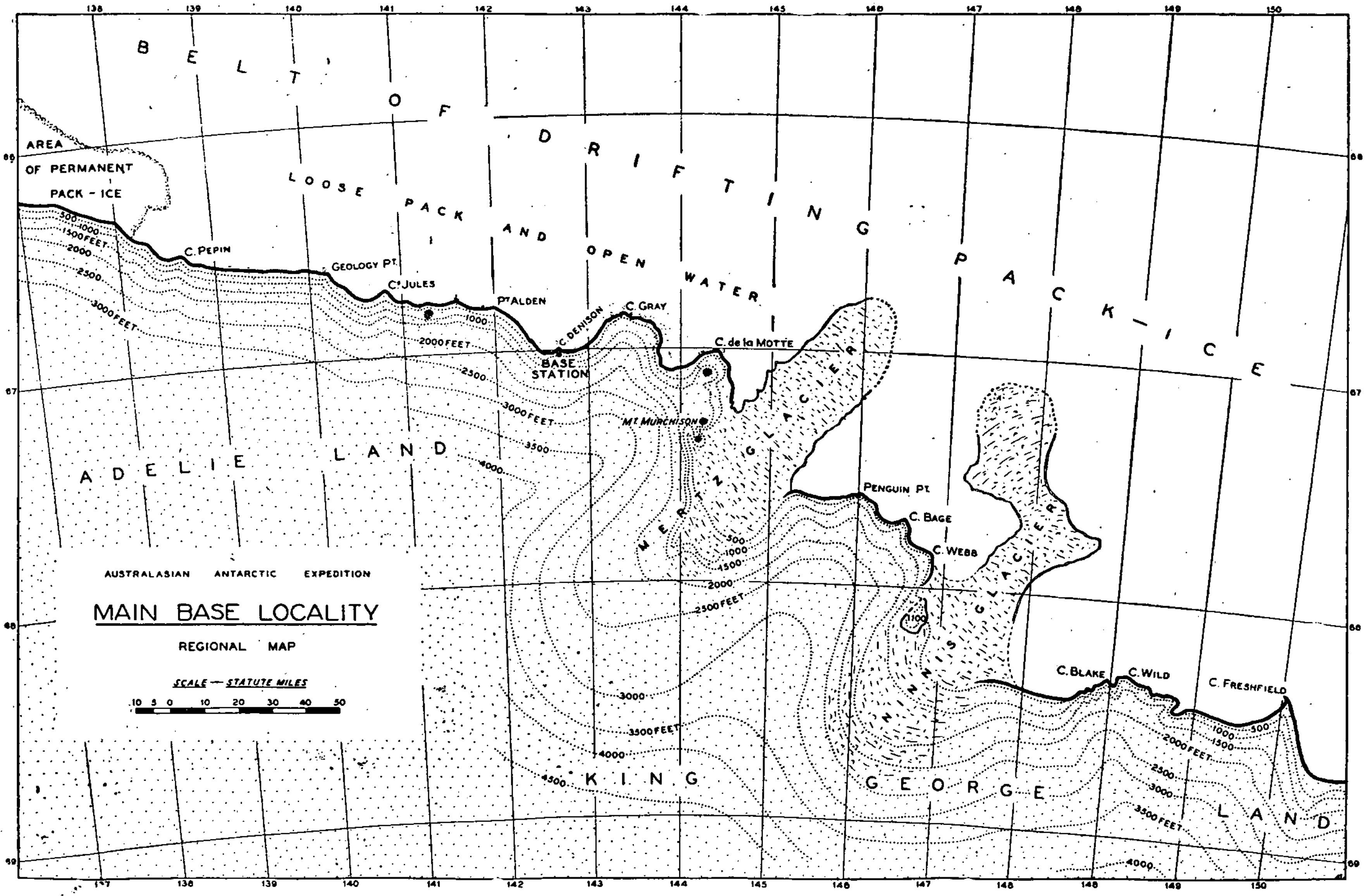
AUSTRALASIAN ANTARCTIC EXPEDITION
MAIN BASE LOCALITY
REGIONAL MAP
SCALE — STATUTE MILES
10 5 0 10 20 30 40 50
BELT OF DRIFTING PACK-ICE
LOOSE PACK AND OPEN WATER
AREA OF PERMANENT PACK - ICE
C. PEPIN
GEOLOGY PT.
C. JULES
PT. ALDEN
C. DENISON
C. GRAY
BASE STATION
C. de la MOTTE
MT. MURCHISON
MERTZ GLACIER
NINNIS GLACIER
PENGUIN PT.
C. BAGE
C. WEBB
C. BLAKE
C. WILD
C. FRESHFIELD
ADELIE LAND
KING GEORGE LAND

FIG. 2.

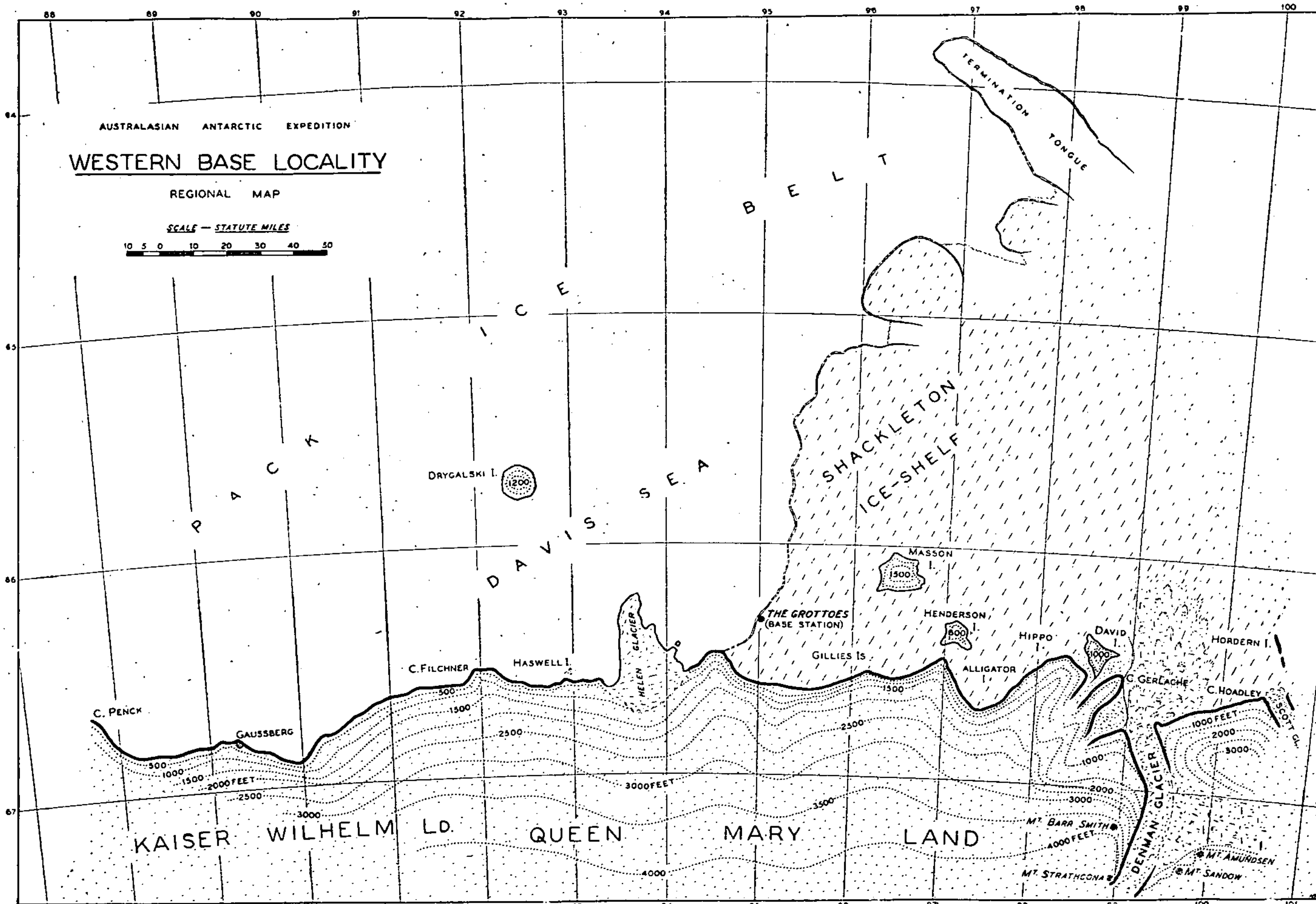
AUSTRALASIAN ANTARCTIC EXPEDITION
WESTERN BASE LOCALITY
REGIONAL MAP
SCALE — STATUTE MILES
10 5 0 10 20 30 40 50
TERMINATION TONGUE
PACK ICE BELT
DAVIS SEA
SHACKLETON ICE-SHELF
DRYGALSKI I.
1200
MASSON I.
1500
HENDERSON I.
800
THE GROTTOES (BASE STATION)
GILLIES IS
HIPPO I.
DAVID I.
1000
ALLIGATOR I.
HORDERN I.
C. GERLACHE
C. HOADLEY
SCOTT GL.
HELEN GLACIER
HASWELL I.
C. FILCHNER
C. PENCK
GAUSSBERG
DENMAN GLACIER
MT. BARR SMITH
MT. STRATHCONA
MT. AMUNDSEN
MT. SANDOW
KAISER WILHELM LD.
QUEEN MARY LAND
500
1000
1500
2000 FEET
2500
3000
3000 FEET
3500
4000
4000 FEET

FIG. 3.

the sea. The regular downward slope from the interior would prevent any stagnation of cold air. Directly its density became greater than that of the free air at the same level, air cooled by the snow surface would be carried by gravity down the slope towards the sea. The temperature of the sheet of downward flowing cooled air could, therefore, never be very greatly below that of the air above it.

Though the temperature at Adélie Land should, therefore, be lower than that some distance off-shore, it should be much higher than that over level or only very gently sloping ice-surfaces such as the Great Ross Barrier and parts of the interior of the continent. The comparatively steep slope of the land surface and the presence of the open sea on the coast ensure that cooled air is drained off the land by a continuous process, whereas in the Ross Sea region accumulations are removed by occasional blizzards when the pressure distribution favours southerly winds.

Owing to the continued strong winds one would expect rather small annual and diurnal variations of temperature, and generally speaking the temperature should be much steadier than in, for instance, McMurdo Sound where it is possible for an intensely cold layer to form over the snow or ice surface.

At Queen Mary Land, the base was on a floating tongue of shelf-ice with a level top, some distance (about 14 miles) from the shores of the continent. The conditions were, therefore, very different from those at Adélie Land and the cold layer was frequently in existence. A detailed map of the region adjacent to the Queen Mary Land base station appears as Fig. 3.

3.—The Temperature Observations.

Mean Temperatures.—The monthly mean temperatures deduced from tabulations of the hourly values are given in Table I. The annual variation as derived from all the observations is given in Fig. 4. The mean temperature is 8.9° F. at Adélie Land, which

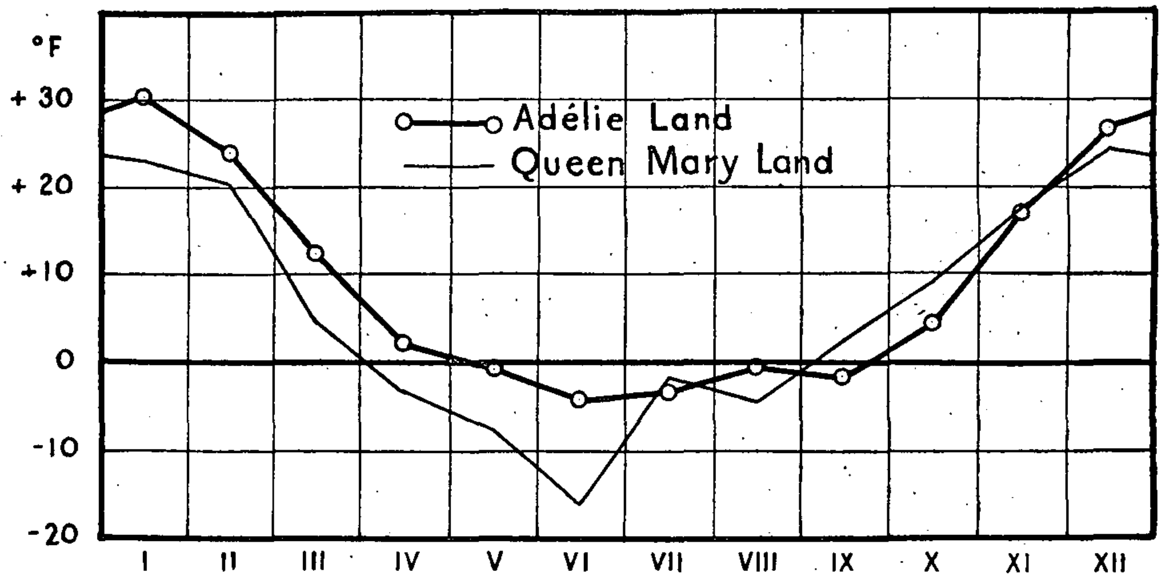

FIG. 4.—Annual Variation of Temperature.

TABLE I.

Temperature—Monthly Means.

Degrees Fahrenheit.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
Adélie Land.													
1912...	...	22·8	11·0	1·9	—3·4	—6·8	—4·2	—2·5	—1·7	7·1	18·1	26·8	......
1913...	30·3	25·3	13·6	2·5	1·9	—2·0	—2·8	1·3	—1·3	2·3	16·3	27·4*	......
Means	30·3	24·0	12·3	2·2	—0·8	—4·4	—3·5	—0·6	—1·5	4·7	17·2	27·0	8·9

* From 14 days only, weighted ½.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
Queen Mary Land.													
1912...	...	...	4·8*	—3·0	—7·5	—15·2	—1·9	—4·9	1·8	9·3	17·8	24·8	5·8
1913...	23·1	20·2	...	...	...	...	...	...	...	...	...	...	

* Many days are missing in March, April, October, and February; *see* Tables in Vol. V.

TABLE II.

Temperature—Harmonic Analysis of Annual Variation.

$$dT = a_1 \sin(\theta + A_1) + a_2 \sin(2\theta + A_2) + a_3 \sin(3\theta + A_3).$$

Adélie Land.						Queen Mary Land.					
a_1	A_1	a_2	A_2	a_3	A_3	a_1	A_1	a_2	A_2	a_3	A_3
°F.	°	°F.	°	°F.	°	°F.	°	°F.	°	°F.	°
16.5	81	4·8	68	0·7	110	17·2	97	3·2	54	0·7	185

may be compared with 0.7° F. for McMurdo Sound* 7.0° F. for Cape Adare†, and -14.4° F. for Framheim†. The mean derived from one year's observations at Queen Mary Land is only 5.8° F. but for corresponding periods the Queen Mary Land mean is only 2.7° F. below that of Adélie Land. Similarly, during the eleven months of 1912 when records were being obtained contemporaneously at the two stations, the temperature at Cape Evans was only 4.4° F., in the mean, below that at Adélie Land. 1912 was the windiest year experienced in McMurdo Sound.

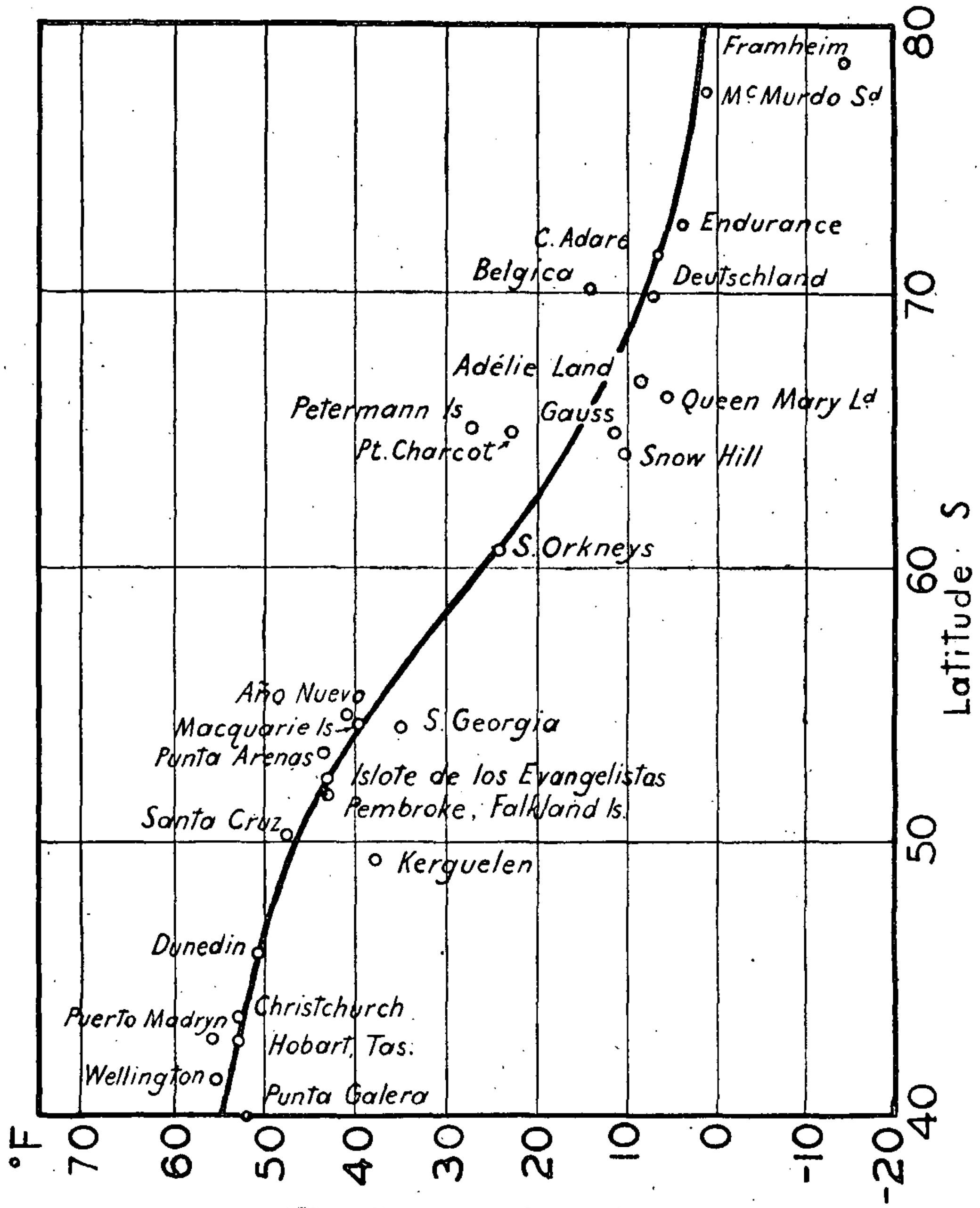

FIG. 5.—Temperature at Southern Stations.

The mean temperatures at numbers of Southern Hemisphere stations south of Latitude 40° are compared in Fig. 5. Between Latitudes 40° and 50° the rate of decrease

* E. Kidson. *British Antarctic Expedition.* 1907–1909, Meteorology, Melbourne, page 20.

† G. C. Simpson. *British Antarctic Expedition.* 1910–1913, Meteorology, Vol. I, page 83.

of temperature appears relatively small. Thereafter there is a rapid decrease until the Antarctic Circle is reached. Between Macquarie Island and Adélie Land the rate is 2.5° F. per degree of Latitude. This is a region of very strong westerly winds and the general circulation is very active. The figure suggests that the temperature in the free air falls off at a reduced rate again between the Antarctic Circle and the Pole. In the summer, the gradient is very slight. The actual surface temperature recorded at these high latitudes depends very much on the nature of the exposure. On an extensive and level snow surface such as the Ross Barrier or the Polar Plateau, the cold surface layer will be most intensively developed. In such positions the surface temperature may be as much as 20° F. or more below that of the free air. At Framheim, the difference is probably not far from this. The intensity of this inversion will be diminished by the presence in the neighbourhood of a station of bare earth or rock in summer, open sea or high land. It will be less marked also over ice than over fresh snow. The line drawn in Fig. 5. is intended in Antarctic Latitudes to indicate what would be the mean temperature for each latitude for stations at which the surface inversion was only poorly developed. The Cape Adare station did not receive directly the surface drainage of cold air from any large area of the interior; it was surrounded on three sides by sea which was often free of ice; and it was at the base of a cliff down which the prevailing wind blew. Its temperatures should, therefore, be fairly representative of the general air masses of the region. Reasons have been given for thinking that the surface inversion was not very strongly marked at Adélie Land. The nearness of the slopes of Mt. Erebus and of the sea, which was often open, and the strong winds experienced would prevent it from being very pronounced, on the average, at Cape Evans. At Queen Mary Land, in spite of the similarity of its general location on the Antarctic coast to that of Adélie Land or Cape Adare, it is more prominent, its intensity being about equivalent to that at Cape Evans, while at Framheim, as already indicated, it reached a very high degree of development. The intensity of the inversion is fairly well indicated by the amplitude of the diurnal variation of temperature. The *Belgica, Deutschland* and *Endurance* were drifting in pack which never presents an unbroken surface of snow-covered ice over a very large area. The positions given for these vessels, which drifted over long courses, are mean ones. The year in which the *Endurance* was drifting in the Weddell Sea was shown by the records from the South Orkneys to have been a particularly calm and cold one*. The high temperatures experienced West of Graham Land on the *Belgica* and at Port Charcot and Peterman Island have been discussed by other writers. They were apparently due principally to the prevalence of northeasterly winds. Very probably the sea currents were warmer there also, and the sea freer from pack ice than on the east side of Graham Land, where temperatures seem rather low. The very low temperature at Kerguelen is attributed by Schott† to the low latitudes reached by the coast of the Antarctic Continent in that region.

Annual Variation.—The annual variations shown in Fig. 4 are of a similar type to those observed at other stations in this quarter of the Antarctic and apparently as far north as Macquarie Island. The Queen Mary Land curve displays some irregularities as would be expected in view of the small amount of data on which it is based, but that

* R. C. Mossman. The Meteorological results of the Shackleton Antarctic Expedition 1914–1917 (Weddell Sea Party): Preliminary Notice. Q.J.R. Met. Soc. 47, 1921, pp. 63–70.

† G. Schott. *Geographie des Indischen und Stillen Oceans.* Hamburg, 1935.

for Adélie Land probably approaches fairly closely to the normal. The maximum occurs in December or January. It is in January at Macquarie Island and Adélie Land but at McMurdo Sound December has a higher mean than January. Probably the maximum would normally occur earlier as the latitude increases but the data are not sufficient to determine this point. Following the maximum there is a rapid fall until April, May, or June. For Adélie Land and McMurdo Sound it is April, but for Macquarie Island June. At the other Antarctic Stations, Queen Mary Land, Cape Adare, and Framheim, also, the fall continues until May or June, but if a sufficient number of years' observations were available, it would probably be found that the normal thing is for the rapid fall to cease in April. Thereafter, temperature remains fairly constant for several months. From October onwards there is a rapid rise to the summer maximum.

Records from the South American Quarter of the Antarctic do not exhibit the almost constant average temperatures in winter. When the Antarctic results only had to be accounted for, it was easy(*,†) to find an explanation of the uniform winter temperatures in the constant conditions of the winter night, the rapid rise in spring being due to the increasing solar radiation and the corresponding fall in autumn to the solar radiation decreasing again.

The loss by radiation in winter is almost balanced by the heat transported by winds from lower latitudes, and only a gradual fall takes place. The explanation is, however, not very satisfactory for Adélie Land where the sunless period is short, and fails altogether in the case of Macquarie Island. There must, therefore, be other factors which contribute to the production of this kind of annual variation. Among these are, first, the great lag of the minimum temperature of the ocean behind that of solar radiation, which tends to delay the rise of air temperature until the spring and, next, the effect of the great land areas which tend to cool the air rapidly in the autumn and early winter in accordance with the decrease in solar radiation. The result is a very flat minimum extending from winter to spring. The difference between the times of maximum temperature over land and sea is not so marked.

The harmonic analyses of the annual variations at Adélie Land and Queen Mary Land are given in Table II. Throughout this book, in the analysis of annual variations, time is counted from the beginning of the year, the January mean corresponding to 15° and the other months following at intervals of 30°. In Simpson's discussion of the results of the *Terra Nova* expedition and my own discussion of those of the *Nimrod* expedition, the zero point coincides with the January mean. At McMurdo Sound, the annual term lags 18 days behind the solar radiation while for Adélie Land the lag is 20 days and for the one year at Queen Mary Land, 3 days. The six-monthly terms at Queen Mary Land and Adélie Land differ in phase from that at McMurdo Sound by less than a month but there is no relation between the four-monthly terms.

Diurnal Variation.—The diurnal variations for Adélie Land and Queen Mary Land are given for each month and the four seasons separately in Tables III and IV and Figs. 6 and 7. In the discussion of the McMurdo Sound results, since temperature lagged little behind solar radiation, Simpson regarded the months November, December and

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* G. C. Simpson. *British Antarctic Expedition.* 1910–1913, Meteorology, Vol. I.

† E. Kidson. *British Antarctic Expedition.* 1907-1909. Meteorology, Melbourne.

TABLE III.

Temperature—Mean Diurnal Inequalities.

Adélie Land. Degrees Fahrenheit.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period.																								
I.	—1·5	—2·3	—2·5	—2·6	—3·0	—2·7	—2·3	—1·8	—0·8	—0·3	+0·6	+1·0	+1·7	+2·2	+2·4	+2·4	+2·4	+2·2	+1·9	+1·5	+1·0	+0·5	—0·2	—0·9
II.	—1·8	—2·2	—2·4	—2·6	—2·6	—2·5	—1·9	—1·4	—0·8	+0·3	+1·2	+2·3	+2·6	+2·7	+2·8	+2·8	+2·7	+2·2	+1·4	+0·4	—0·1	—0·6	—0·9	—1·6
III.	—1·0	—1·4	—1·5	—1·7	—1·9	—1·8	—1·8	—1·4	—0·8	—0·2	+0·6	+1·4	+2·0	+2·4	+2·4	+2·4	+2·0	+1·5	+1·1	+0·6	0·0	—0·4	—0·4	—0·8
IV.	—0·4	—0·6	—0·7	—0·6	—0·6	—0·6	—0·5	—0·4	—0·2	+0·2	+0·6	+0·8	+0·9	+1·0	+1·0	+0·8	+0·6	+0·2	0·0	0·0	—0·2	—0·4	—0·4	—0·5
V.	0·0	0·0	0·0	—0·2	—0·2	—0·4	—0·3	—0·2	0·0	+0·1	+0·1	+0·6	+0·6	+0·4	+0·4	+0·2	0·0	+0·2	0·0	—0·2	—0·2	0·0	0·0	0·0
VI.	+0·4	+0·5	+0·4	+0·2	+0·2	+0·2	+0·2	+0·1	—0·1	—0·2	—0·2	0·0	0·0	—0·1	—0·3	—0·4	—0·2	—0·3	—0·4	—0·2	—0·2	—0·2	+0·2	+0·4
VII.	—0·2	—0·2	—0·1	+0·1	0·0	0·0	0·0	0·0	0·0	+0·1	+0·4	+0·6	+0·5	+0·4	+0·2	—0·1	—0·3	—0·1	—0·2	—0·2	—0·2	—0·2	—0·2	—0·2
VIII.	—0·3	—0·2	—0·3	—0·4	—0·5	—0·3	—0·3	—0·4	—0·2	+0·2	+0·6	+1·2	+1·0	+0·9	+0·6	+0·4	0·0	—0·2	—0·2	—0·3	—0·2	—0·3	—0·2	—0·4
IX	—1·5	—1·6	—1·6	—1·6	—1·6	—1·8	—1·6	—1·2	—0·6	+0·2	+1·2	+2·2	+2·6	+2·4	+2·2	+2·0	+1·5	+1·0	+0·6	0·0	—0·2	—0·5	—1·1	—1·4
X	—2·2	—2·6	—2·8	—3·2	—3·2	—3·2	—2·5	—1·7	—0·7	+0·2	+1·4	+3·0	+3·3	+3·6	+3·8	+3·5	+3·1	+2·4	+1·4	+0·6	0·0	—0·8	—1·2	—1·8
XI	—3·6	—4·2	—4·8	—4·9	—4·5	—3·8	—3·0	—1·9	—0·6	+0·8	+1·8	+3·3	+3·9	+4·2	+4·5	+4·4	+4·2	+3·6	+3·0	+2·0	+0·8	—0·6	—1·8	—2·7
XII	—3·1	—3·9	—4·4	—4·4	—4·4	—3·9	—3·0	—1·9	+0·5	+0·6	+1·6	+2·6	+3·1	+3·3	+3·8	+3·6	+3·5	+3·2	+2·9	+2·4	+1·5	+0·2	—1·0	—2·3
Summer (XII, I, II)	—2·1	—2·8	—3·1	—3·2	—3·3	—3·0	—2·4	—1·7	—0·4	+0·2	+1·1	+2·0	+2·5	+2·8	+3·0	+2·9	+2·9	+2·5	+2·1	+1·4	+0·8	0·0	—0·7	—1·6
Autumn (III, IV, V)	—0·5	—0·7	—0·7	—0·8	—0·9	—0·9	—0·9	—0·7	—0·3	0·0	+0·4	+0·9	+1·2	+1·3	+1·3	+1·1	+0·9	+0·6	+0·4	+0·1	—0·1	—0·3	—0·3	—0·4
Winter (VI, VII, VIII)	0·0	0·0	0·0	0·0	—0·1	0·0	0·0	—0·1	—0·1	0·0	+0·3	+0·6	+0·5	+0·4	+0·2	0·0	—0·1	—0·2	—0·3	—0·2	—0·2	—0·2	—0·1	—0·1
Spring (IX, X, XI)	—2·4	—2·8	—3·1	—3·2	—3·1	—2·9	—2·4	—1·6	—0·6	+0·4	+1·5	+2·8	+3·3	+3·4	+3·5	+3·3	+2·9	+2·3	+1·7	+0·9	+0·2	—0·6	—1·4	—2·0
Year	—1·2	—1·6	—1·7	—1·8	—1·8	—1·7	—1·4	—1·0	—0·4	+0·2	+0·8	+1·6	+1·8	+2·0	+2·0	+1·8	+1·6	+1·3	+1·0	+0·6	+0·2	—0·3	—0·6	—1·0
(V, VI, VII)	+0·07	+0·10	+0·10	+0·03	0·00	—0·07	—0·03	—0·03	—0·03	0·00	+0·10	+·040	+0·37	+0·23	+0·10	—0·10	—0·17	—0·07	—0·20	—0·20	—0·20	—0·13	0·00	+0·07

TABLE IV.

Temperature—Mean Diurnal Inequalities.

Queen Mary Land. Degrees Fahrenheit.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period.																								
1912.																								
III	—2·6	—2·4	—2·7	—2·8	—2·9	—2·5	—1·7	—0·6	—0·5	+1·3	+2·7	+4·1	+4·9	+5·4	+5·2	+4·0	+1·9	+0·2	—0·8	—1·2	—1·2	—2·3	—2·6	—2·5
IV	—1·5	—1·4	—1·4	—1·2	+0·5	+0·8	+0·8	+1·1	+1·4	+1·7	+2·1	+2·6	+2·6	+2·7	+2·9	+0·6	—1·1	—1·7	—2·7	—3·0	—2·3	—1·6	—1·3	—1·5
V	+0·1	+0·1	—0·1	+0·1	+0·3	—0·1	—0·2	—0·5	—0·7	—0·4	—0·4	—0·3	+0·2	+0·3	+0·2	+0·3	+0·3	+0·4	+0·7	+0·5	+0·2	+0·2	+0·1	0·0
VI	+0·2	+0·3	+0·3	+0·5	+0·3	—0·2	—0·2	—0·2	—0·6	—0·9	—0·8	—0·6	—0·3	—0·2	0·0	+0·2	+0·1	+0·1	+0·1	—0·1	+0·1	+0·3	+0·4	+0·5
VII	+0·8	+0·5	+0·1	—0·4	—0·3	—0·8	—1·1	—1·4	—1·7	—1·3	—0·5	+0·2	+0·2	+0·2	+0·4	+0·9	+1·1	+0·9	+0·6	+0·5	+0·3	+0·5	+0·7	+0·9
VIII	—0·2	+0·1	0·0	—0·1	—0·3	—0·5	—0·5	—0·7	—0·5	+0·1	+0·8	+1·1	+1·3	+1·3	+1·1	+0·6	+0·6	—0·4	—0·5	—0·6	—0·6	—0·6	—0·4	—0·4
IX	—1·3	—1·3	—1·4	—1·1	—1·0	—0·8	—0·4	+0·2	+0·7	+0·7	+1·4	+1·6	+1·7	+1·6	+1·5	+1·1	+0·4	0·0	—0·3	—0·1	—0·6	—0·8	—1·0	—1·3
X	—2·8	—3·2	—3·5	—3·6	—3·5	—2·9	—2·0	—0·5	+1·1	+2·7	+3·1	+3·6	+4·2	+4·5	+4·8	+4·4	+2·8	+2·0	+0·2	—0·9	—2·0	—2·2	—2·7	—2·4
XI	—5·4	—5·7	—6·0	—5·1	—4·0	—3·0	—1·4	+0·7	+2·1	+2·4	+4·2	+5·3	+5·6	+5·9	+6·2	+5·2	+4·3	+2·9	+0·9	—0·9	—2·3	—3·6	—5·3	—5·3
XII	—6·9	—7·4	—7·4	—6·4	—5·3	—3·7	—1·8	+0·2	+2·7	+3·6	+4·4	+4·9	+5·3	+5·9	+6·2	+6·2	+5·7	+5·2	+3·3	+0·9	—1·4	—3·6	—5·1	—6·3
1913.																								
I	—6·4	—7·9	—8·4	—8·1	—6·9	—5·9	—4·1	—1·6	+0·7	+2·6	+5·2	+6·2	+7·1	+7·7	+8·0	+7·5	+6·8	+6·0	+3·4	+1·7	—0·4	—2·4	—4·1	—5·6
II	—5·0	—6·0	—6·4	—6·4	—6·1	—5·2	—3·6	—1·3	+0·9	+2·2	+3·5	+5·0	+5·3	+6·2	+6·6	+6·6	+5·6	+5·0	+3·0	+1·0	—0·8	—2·6	—3·3	—4·6
Summer (XII, I, II)	—6·1	—7·1	—7·4	—7·0	—6·1	—4·9	—3·2	—0·9	+1·4	+2·8	+4·4	+5·4	+5·9	+6·6	+6·9	+6·8	+6·0	+5·4	+3·2	+1·2	—0·9	—2·9	—4·2	—5·5
Autumn (III, IV, V)	—1·3	—1·2	—1·4	—1·3	—0·9	—0·9	—0·6	—0·2	—0·2	+0·7	+1·3	+2·0	+2·6	+2·8	+2·7	+1·8	+0·7	—0·1	—0·6	—0·9	—0·9	—1·5	—1·2	—1·3
Winter (VI, VII, VIII)	+0·3	+0·3	+0·1	0·0	—0·1	—0·5	—0·6	—0·8	—0·9	—0·7	—0·2	+0·2	+0·4	+0·4	+0·5	+0·6	+0·6	+0·2	+0·1	—0·1	—0·1	+0·1	+0·2	+0·3
Spring (IX, X, XI)	—3·2	—3·4	—3·6	—3·3	—2·8	—2·2	—1·3	+0·1	+1·3	+2·3	+2·9	+3·5	+3·8	+4·0	+4·2	+3·6	+2·6	+1·6	+0·3	—0·6	—1·6	—2·2	—3·0	—3·0
Year	—2·6	—2·8	—3·1	—2·9	—2·5	—2·1	—1·4	—0·4	+0·4	+0·9	+2·1	+2·8	+3·2	+3·4	+3·6	+3·2	+2·5	+1·8	+0·8	—0·1	—0·9	—1·6	—2·0	—2·4

January as the summer season. But at Adélie Land the temperature lag is greater and it seems more appropriate to put the commencements of the seasons a month later. December, January and February are, consequently, regarded as summer, and so on for the other seasons. The classification is the same, therefore, as would be adopted in lower latitudes.

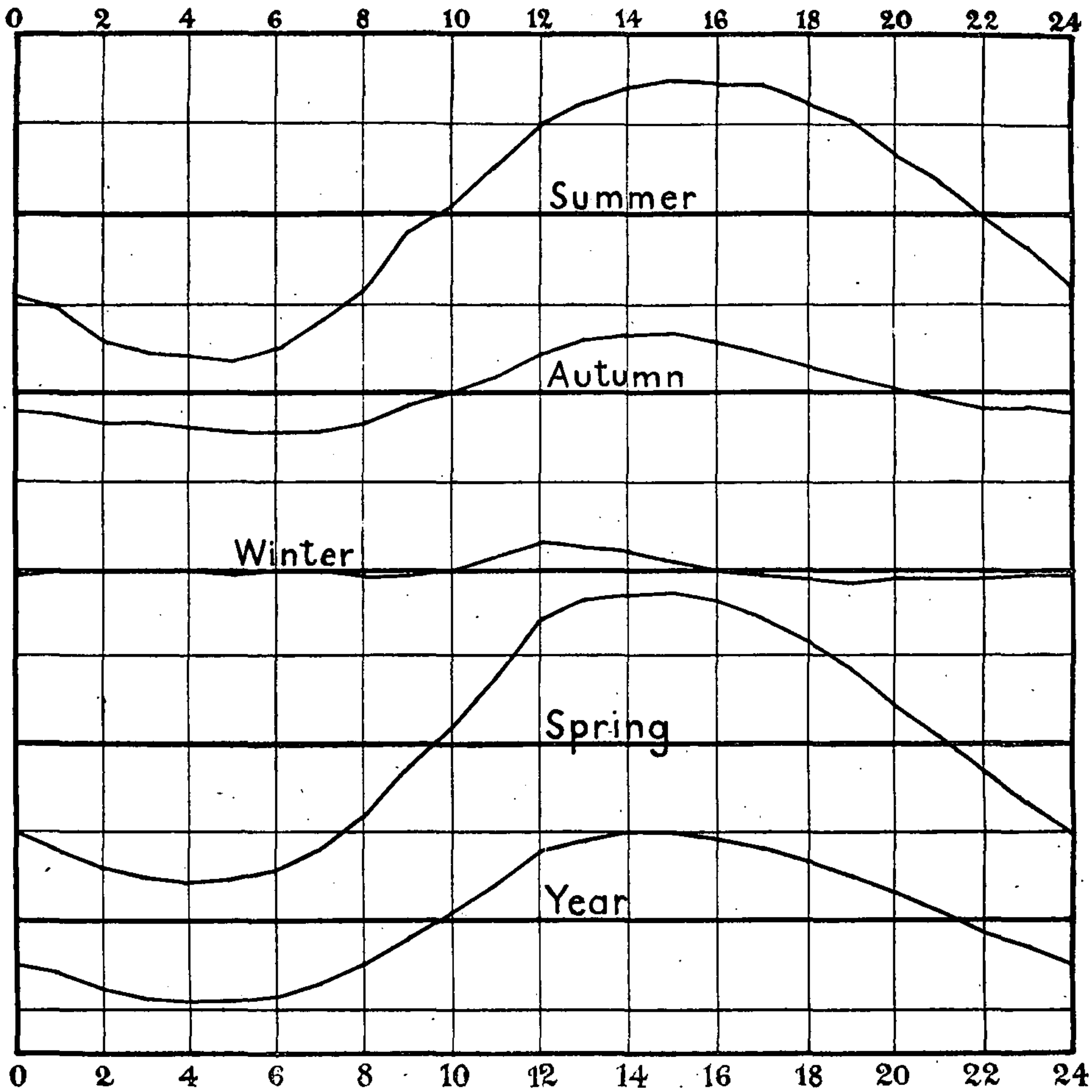


FIG. 6.—Diurnal Variation of Temperature, Adélie Land. One Vertical Division equals 2° Fahrenheit.

The diurnal variation at Adélie Land is low for an Antarctic station. This was to be expected in view of the persistent high winds. The range is very much greater in spring than in autumn and, in fact, the greatest range occurs in November. This has been shown (*,†) in the discussion of the McMurdo Sound data to be characteristic of a

* G. C. Simpson. *British Antarctic Expedition.* 1910–1913, Meteorology, Vol. 1.

† E. Kidson. *British Antarctic Expedition,* 1907–1909, Meteorology, Melbourne

region in which there is a change in the nature of the surface at the end of spring. In McMurdo Sound the change consists in the removal of the snow covering from the land surface and the snow-covered sea ice from the sea. A slight effect of a similar kind is to be expected at Adelie Land owing to the exposure of an increased area of rock surface in summer and the clearing of much of the pack ice from the sea. Where the station is

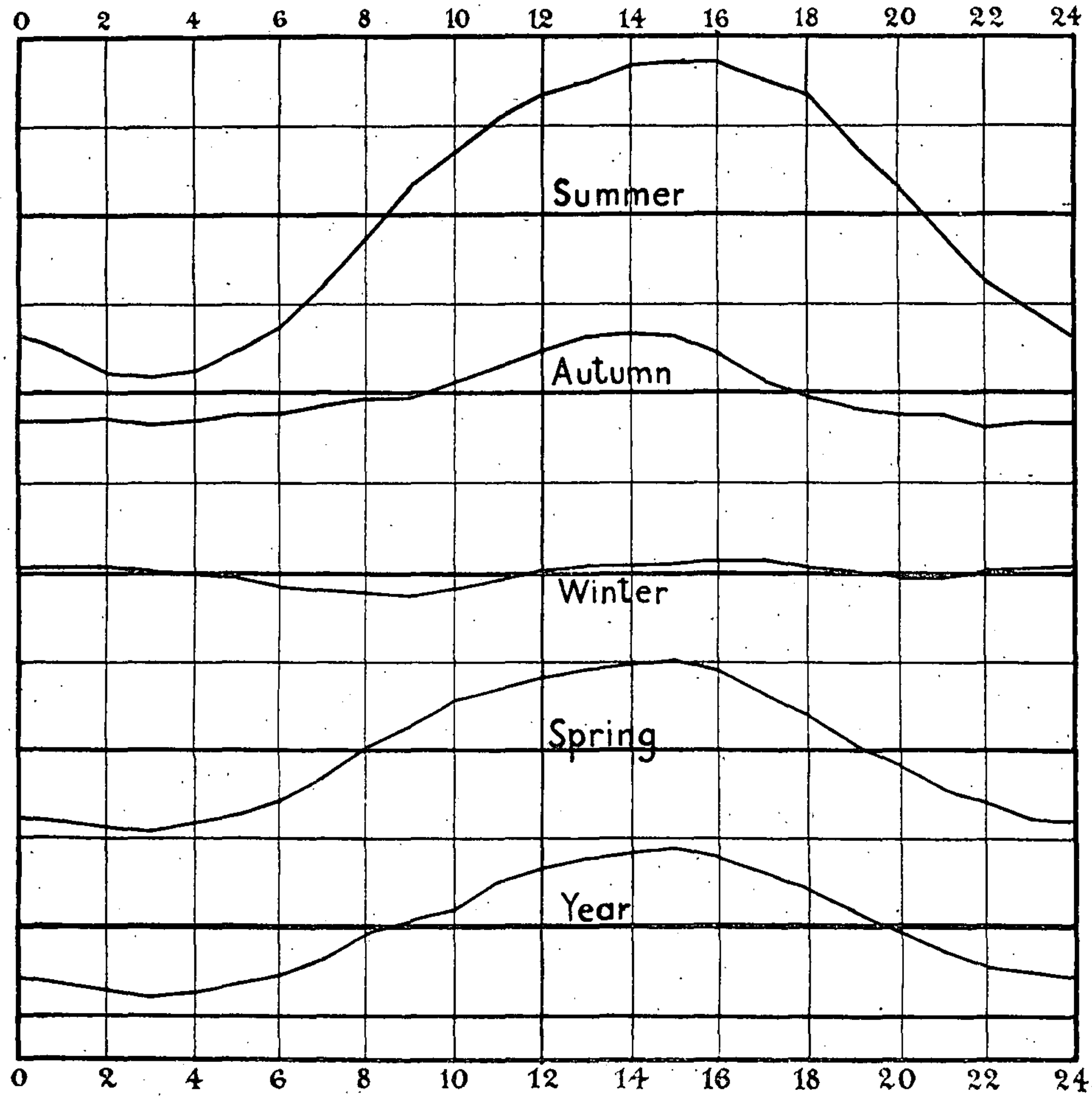


FIG. 7.—Diurnal Variation of Temperature, Queen Mary Land. One Vertical Division equals 4° Fahrenheit.

surrounded by a snow surface, which reflects the greater part of the solar radiation, absorbing little, and at the same time freely radiates its own heat, a very shallow cold layer of air tends to form over the surface. Consequently, any heat communicated to the surface warms the air in immediate contact with it, but owing to the stability of the cold layer, the effect is confined to it or possibly to the lower portions of it only. The heat cannot be carried away by convection. The cold, surface air layer therefore responds readily to changes in solar radiation, and the diurnal variation is large. There are other causes working in the same direction. In the summer months at Adélie Land, the temperature frequently reaches freezing point towards midday and the heat received from the sun thereafter is spent mainly in melting ice. The temperature, therefore, tends to remain fairly constant. This accounts for the flat maximum of the summer diurnal variation curve and, in part, for the relatively low range. But in addition, the temperature is much higher in summer than in spring and the general circulation less vigorous. The amount of air transported from lower latitudes, is smaller and the contrast between its temperature and that of the air over the Antarctic less marked. The cold layer is, therefore, for these reasons, also, less strongly developed and the range of diurnal variation reduced in consequence.

Most of the effects mentioned are felt to some extent in autumn but in the seasons as chosen the amount of solar radiation is much less in autumn than in spring. In the absence of data from the upper air it is not possible to be more specific in accounting for the precise details of the variation.

In winter, the amount of solar radiation is very small. There is still a slight diurnal variation of the normal type with a maximum in the afternoon. There are, however, considerable departures from the normal type of curve. Minima occur at about 8 hours and 19 hours and maxima at 2 hours and 12 hours. The number of observations is not sufficient to ensure the reality of this apparent effect but it seems to be generally confirmed by the Queen Mary Land results. There is a suggestion that, in addition to the slight normal type of variation, there is another according to which the temperature tends to be high when pressure is falling and *vice versa*. If there is such an effect it should be produced through the medium of wind changes. The recording of the diurnal variation of the wind at Adélie Land was unfortunately interfered with to some extent by irregularities in the clock drive of the recording drum. Most of the apparent diurnal variation shown in winter is due to this irregularity, and it is impossible to isolate the true variation, which could, in any case, only be very slight. In consequence, it is not possible to trace any connection between variations of wind and those of pressure and temperature. At McMurdo Sound, a relation between the winter diurnal variations of pressure, wind and temperature was found (*) but it was such that wind and temperature were high when pressure was low The geographical conditions are, however, different from those at Adélie Land and there is no reason for expecting that the variations should be of precisely the same nature. Pressure gradient for a southerly wind at Adélie Land, for example, may produce a similar effect to one for a westerly wind in the McMurdo Sound.

In the last line of Table III are given the mean inequalities, to hundredths of a degree for the three months, May, June, and July when solar radiation is least. The departures are rather smaller than for the winter season chosen but a slight diurnal variation of the normal type is still shown. There are, however, rather more definite indications of a half-daily variation independent of solar radiation, which might be due to a corresponding one in wind.

At Queen Mary Land, where the station was surrounded on three sides by a snow surface, and winds were lighter, the cold layer was much more intense than at Adélie Land. The temperature was, therefore, lower and the diurnal variation almost double.

* E. Kidson. *British Antarctic Expedition*—1907-1909: Meteorology, Melbourne.

TABLE V.

Temperature—Harmonic Analysis of Diurnal Variation.

$$dT = a_1 \sin(\theta + A_1) + a_2 \sin(2\theta + A_2) + a_3 \sin(3\theta + A_3).$$

Period.	Adélie Land.						Queen Mary Land.					
	a_1	A_1	a_2	A_2	a_3	A_3	a_1	A_1	a_2	A_2	a_3	A_3
	°F.	°	°F.	°	°F.	°	°F.	°	°F.	°	°F.	°
I	2·7	203	0·2	106	0·0	...	...	...	...	...	...	...
II	2·8	218	0·3	38	0·1	343	...	...	...	...	...	...
III	2·1	212	0·5	28	0·0	...	...	...	...	...	...	...
IV	0·8	232	0·2	46	0·0	...	...	...	...	...	...	...
V	0·2	230	0·2	58	0·0	...	...	...	...	...	...	...
VI	0·3	35	0·2	42	0·0	...	...	...	...	...	...	...
VII	0·3	284	0·1	57	0·1	229	...	...	...	...	...	...
VIII	0·5	248	0·4	60	0·2	234	...	...	...	...	...	...
IX	2·1	226	0·5	42	0·2	250	...	...	...	...	...	...
X	3·4	219	0·6	42	0·0	...	...	...	...	...	...	...
XI	4·7	217	0·2	127	0·1	337	...	...	...	...	...	...
XII	4·2	213	0·5	154	0·1	315	...	...	...	...	...	...
Summer (XII, I, II)	3·2	212	0·2	164	0·1	318	7·2	230	0·2	205	0·4	24
Autumn (III, IV, V)	1·0	218	0·3	35	0·0	...	1·7	247	0·7	30	0·3	157
Winter (VI, VII, VIII)	0·2	271	0·2	37	0·1	228	0·4	164	0·4	19	0·0	...
Spring (IX, X, XI)...	3·4	219	0·4	51	0·1	182	3·9	243	0·3	48	0·2	54
Year	1·9	218	0·2	57	0·1	260	3·2	234	0·3	29	0·1	77

Furthermore, the diurnal variation increased until January. In November it was less than in any of the summer months. For one very incomplete year of observations, the curves for the different seasons are remarkably smooth.

The harmonic analyses of the diurnal variations are given in Table V. For Adélie Land, data for each month, the seasons, and the year are given but for Queen Mary Land, the number of observations was not sufficient to give reliable values for the individual months. The 24-hour term is by far the most important at both stations. The characteristics are in accordance with what has been said above. At Adélie Land the amplitude in spring is greater than that in summer. The spring amplitude at Queen Mary Land is greater than that at Adélie Land but the summer amplitude is much greater still and more than twice that at Adélie Land. The phase at Queen Mary Land is about an hour in advance of that at the main station. The 12-hour terms are small and of doubtful significance. This is more emphatically the case as regards the 8-hour terms.

Extreme Temperatures.—Maximum and minimum temperatures were determined apparently from the thermograms. The thermograph would probably be somewhat less sensitive than ordinary thermometers and would possibly show some hysteresis during rapid temperature changes. The ranges recorded are, therefore, almost certainly less than would have been given by ordinary thermometers, especially at Queen Mary Land. It must be remembered too, in connection with Tables VI and VII that the Adélie Land observations cover only 14 days in December, 1912, while at Queen Mary Land there are many observations missing in most months.

Table VI contains data regarding the means of the daily maxima and minima. At Adélie Land the mean maximum ranges from 33.6° F. in January 1913 to -2.4° F. in June 1912, and the mean minimum from 26.0° F. in January 1913 to -10.5° F. in June 1912. At Queen Mary Land the corresponding figures are 32.7° F. in January 1913, -6.8° F. in June 1912, 14.4° F. in December 1912 and -23.1° F. in June 1912. The columns headed C give the difference between the mean temperatures as derived respectively from the mean of the maxima and minima and from hourly readings. The mean daily range is much smaller at Adélie Land than at Queen Mary Land. At Adélie Land, the mean of the daily maxima and minima gives, as would be expected, a close approximation to the mean temperature, being only 0.05° F. too low in the mean for the year. At Queen Mary Land, however, the difference is considerable. Once more the effect of the cold layer is seen. This may frequently affect the screen for short intervals and thus produce an unduly low minimum.

The absolute maxima and minima are given in Table VII. The effect of the constant wind at Adélie Land is again very marked. Temperatures are high and the range low. The extreme maximum was 43.1° F. which occurred in February 1912, and the extreme minimum -28.2° F. occurring in May, 1912. The mean monthly range was 34.5° F.

The highest temperature recorded at Queen Mary Land was 39° F. in December 1912 and January 1913, and the lowest -42° F. in July 1912, the extreme range being 10° F. greater than at Adélie Land. The mean monthly range was 46.4° F.

The Queen Mary Land data are very similar to those obtained in any year at McMurdo Sound where, also, the cold layer has a considerable influence.

TABLE VI.

Temperature—Extremes.

Degrees Fahrenheit.

	Adélie Land.									Queen Mary Land.						
	Mean Daily Max. A.			Mean Daily Min. B.			Mean of A & B.	Mean Daily Range.	C.	Mean Daily Max. A.		Mean Daily Min. B.		Mean of A & B.	Mean Daily Range.	C.
	1912.	1913.	Mean.	1912.	1913.	Mean.				1912.	1913.	1912.	1913.			
I ...	...	33·6	33·6	...	26·0	26·0	29·8	7·6	—0·5	...	32·7	...	12·0	22·4	20·7	—0·7
II ...	27·7	29·1	28·4	16·6	20·9	18·8	23·6	9·6	—0·4	...	28·2	...	9·1	18·6	19·1	—1·1
III ...	15·0	18·4	16·7	5·9	9·7	7·8	12·2	8·9	—0·1	13·4	...	— 5·4	...	4·0	18·8	—0·8
IV ...	6·0	5·8	5·9	—2·4	—1·5	—2·0	2·0	7·9	—0·2	1·6	...	— 8·9	...	— 3·6	10·5	—0·6
V ...	2·7	5·8	4·2	—6·7	—1·7	—4·2	0·0	8·4	0·8	—1·9	...	—13·5	...	— 7·7	11·6	—0·2
VI ...	—2·4	2·7	0·2	—10·5	—5·3	—7·9	—3·8	8·1	0·6	—6·8	...	—23·1	...	—15·0	16·3	0·2
VII ...	0·5	0·3	0·4	—9·6	—8·0	—8·8	—4·2	9·2	—0·7	7·1	...	—10·9	...	—1·9	18·0	0·0
VIII ...	1·5	5·7	3·6	—6·8	—2·7	—4·8	—0·6	8·4	0·0	2·2	...	—12·5	...	—5·2	14·7	—0·3
IX ...	3·1	4·1	3·6	—7·0	—5·5	—6·2	—1·3	9·8	0·2	6·9	...	—4·5	...	1·2	11·4	—0·6
X ...	11·7	7·9	9·8	1·9	—2·6	—0·4	4·7	10·2	0·0	16·5	...	2·1	...	9·3	14·4	0·0
XI ...	24·0	22·2	23·1	12·7	10·6	11·6	17·4	11·5	0·2	25·9	...	6·8	...	16·4	19·1	—1·4
XII ...	31·6	31·4*	31·5	20·8	22·8*	21·5	26·5	10·8	—0·5	32·6	...	14·4	...	23·5	18·2	—1·3
Mean ...	...	...	13·4	...	...	4·3	8·9	9·2	—0·05	...	...	...	...	...	16·1	—0·57

* 14 days only; weighted ½.

TABLE VII.

Temperature—Absolute Extremes.

Degrees Fahrenheit.

	Adélie Land.							Queen Mary Land.				
	Maximum.		Minimum.		Range.			Maximum.		Minimum.		Range.
	1912.	1913.	1912.	1913.	1912.	1913.	Mean.	1912.	1913.	1912.	1913.	
I	...	39·6	...	19·6	...	20·0	20·0	...	39	...	—4	43
II	43·1	35·2	— 1·7	13·5	44·8	21·7	33·2	...	35	...	—2	37
III	32·9	36·0	— 9·2	— 0·5	42·1	36·5	39·3	19	...	—15	...	34
IV	21·6	31·1	—15·2	—15·1	36·8	46·2	41·5	16	...	—21	...	37
V	21·8	17·5	—28·2	—14·5	50·0	32·0	41·0	15	...	—32	...	47
VI	7·8	17·8	—26·5	—18·0	34·3	35·8	35·0	10	...	—39	...	49
VII	16·7	11·5	—24·3	—16·6	41·0	28·1	34·6	27	...	—42	...	69
VIII	18·6	20·0	—26·8	—13·4	45·4	33·4	39·4	21	...	—41	...	62
IX	18·8	29·0	—19·3	—27·5	38·1	56·5	47·3	21	...	—38	...	59
X	22·7	18·3	— 3·8	—13·1	26·5	31·4	29·0	25	...	—17	...	42
XI	34·1	30·9	— 1·5	— 3·0	35·6	33·9	34·8	36	...	— 8	...	44
XII	35·0	35·0	15·8	16·5	19·2	18·5	18·8	39	...	5	...	34
Year	43·1	39·6	—28·2	—27·5	71·3	67·1	69·2	39	...	—42	...	81

TABLE VIII.

Temperature—Interdiurnal Variation.

Adélie Land. Degrees Fahrenheit.

Period.	3h.		6h.		9h.		12h.		15h.		18h.		21h.		24h.		Means.	
	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
1912.																		
II	4·9	5·0	4·9	5·8	6·5	4·3	5·3	4·6	3·3	3·7	2·7	3·9	4·2	4·7	4·4	4·8	...	...
III	3·9	4·2	3·6	4·3	3·7	4·1	4·7	3·9	4·0	4·9	4·2	4·2	4·1	3·7	4·6	4·1	...	...
IV	7·3	5·4	8·1	5·2	8·2	5·2	7·8	6·5	7·9	5·2	5·5	5·7	5·8	4·8	6·4	6·0	...	...
V	6·7	8·0	7·5	7·0	6·6	5·4	5·9	6·3	6·8	6·4	6·6	7·0	6·6	7·1	8·3	7·7	...	...
VI	6·1	5·5	4·8	6·1	4·0	5·5	4·9	5·0	4·0	5·4	4·0	5·8	4·8	4·5	4·7	5·4	...	...
VII ...	6·6	7·3	9·3	5·9	8·0	6·3	7·4	7·9	6·2	8·9	7·2	6·4	6·6	7·5	7·1	5·7	...	...
VIII ...	4·6	6·5	5·4	6·0	5·8	6·2	5·6	5·8	4·5	5·8	4·7	6·5	5·5	5·6	5·5	7·1	...	...
IX	5·4	5·6	6·5	5·3	5·1	6·0	5·0	6·3	5·3	5·7	5·4	6·8	4·9	7·1	5·6	5·7	...	...
X	4·6	4·2	4·7	4·6	4·4	4·5	4·8	3·9	4·6	4·1	4·6	4·1	4·0	4·1	4·5	4·4	...	...
XI	5·0	3·3	5·2	3·9	4·3	4·6	5·0	4·0	4·1	3·8	3·8	3·7	4·2	3·5	3·3	5·1	...	...
XII ...	3·2	3·3	2·2	2·0	2·0	1·8	1·6	1·7	1·4	2·0	2·0	2·1	2·4	2·2	3·4	2·1	...	...
1913.																		
I	3·4	3·4	2·9	3·3	3·2	3·3	2·7	2·3	2·0	1·9	1·8	2·2	1·7	2·4	2·6	3·2	...	...
II	4·8	4·8	4·0	4·9	5·3	3·1	4·0	3·4	2·7	3·1	4·4	2·5	3·3	3·7	4·1	4·9	...	...
III	5·0	5·3	4·9	5·1	5·0	5·9	6·3	6·4	4·9	6·6	4·2	5·7	5·3	5·4	6·4	5·0	...	...
IV	6·4	3·7	6·0	3·9	4·9	3·3	4·3	4·4	5·3	4·7	5·6	5·5	5·9	4·9	5·4	4·4	...	...
V	4·7	5·3	3·9	5·3	3·4	6·0	4·8	4·5	5·5	4·7	4·7	6·0	4·9	5·0	4·5	6·1	...	...
VI	5·8	6·5	5·9	6·0	5·6	5·7	5·0	5·5	4·8	5·2	5·8	4·7	4·7	6·3	4·8	7·2	...	...
VII ...	5·8	5·7	6·4	5·5	8·1	4·8	7·6	5·2	5·8	5·1	6·1	4·8	5·3	4·7	6·5	4·6	...	...
VIII ...	6·0	5·8	7·5	5·5	6·4	6·0	6·9	6·8	6·6	6·0	6·1	5·7	5·6	5·4	5·0	6·3	...	...
IX	7·0	5·4	7·8	5·9	7·4	7·1	7·3	7·4	5·6	6·4	6·2	5·5	7·1	5·2	6·2	5·2	...	...
X	5·1	5·1	5·7	5·0	5·6	4·9	4·3	5·3	5·2	4·4	4·7	4·0	5·0	4·4	4·8	4·8	...	...
XI	4·6	4·4	3·8	5·5	3·8	5·0	4·3	4·4	5·0	4·4	3·7	6·2	3·2	3·9	4·4	3·4	...	...
XII ...	3·2	2·7	2·4	3·7	3·5	3·7	4·0	4·0	3·0	2·2	2·6	1·7	2·6	2·6	3·3	1·9	...	...

Means.

Period.	3h. +	3h. −	6h. +	6h. −	9h. +	9h. −	12h. +	12h. −	15h. +	15h. −	18h. +	18h. −	21h. +	21h. −	24h. +	24h. −	Means. +	Means. −
I	3·4	3·4	2·9	3·3	3·2	3·3	2·7	2·3	2·0	1·9	1·8	2·2	1·7	2·4	2·6	3·2	2·5	2·8
II	4·8	4·9	4·4	5·4	5·9	3·7	4·6	4·0	3·0	3·4	3·6	3·2	3·8	4·2	4·2	4·8	4·3	4·2
III	4·4	4·8	4·2	4·7	4·4	5·0	5·5	5·2	4·4	5·8	4·2	5·0	4·7	4·6	5·5	4·6	4·7	5·0
IV	6·8	4·6	7·0	4·6	6·6	4·2	6·0	5·4	6·6	5·0	5·6	5·6	5·8	4·8	5·9	5·2	6·3	4·9
V	5·7	6·6	5·7	6·2	5·0	5·7	5·4	5·4	6·2	5·6	5·6	6·5	5·8	6·0	6·4	6·9	5·7	6·1
VI	6·0	6·0	5·4	6·0	4·8	5·6	5·0	5·2	4·4	5·3	4·9	5·2	4·8	5·4	4·8	6·3	5·0	5·6
VII ...	6·2	6·5	7·8	5·7	8·0	5·6	7·5	6·6	6·0	7·0	6·6	5·6	6·0	6·1	6·8	5·2	6·9	6·0
VIII ...	5·3	6·2	6·4	5·8	6·1	6·1	6·2	6·3	5·6	5·9	5·4	6·1	5·6	5·5	5·2	6·7	5·7	6·1
IX	6·2	5·5	7·2	5·6	6·2	6·6	6·2	6·8	5·4	6·0	5·8	6·2	6·0	6·2	5·9	5·4	6·1	6·0
X	4·8	4·6	5·2	4·8	5·0	4·7	4·6	4·6	4·9	4·2	4·6	4·0	4·5	4·2	4·6	4·6	4·8	4·5
XI	4·8	3·8	4·5	4·7	4·0	4·8	4·6	4·2	4·6	4·1	3·8	5·0	3·7	3·7	3·8	4·2	4·2	4·4
XII ...	3·2	3·1	2·3	2·6	2·5	2·4	2·4	2·5	1·9	2·1	2·2	2·0	2·5	2·3	3·4	2·0	2·6	2·4
Summer (XII, I, II) ...	3·8	3·8	3·2	3·8	3·9	3·1	3·2	2·9	2·3	2·5	2·5	2·5	2·7	3·0	3·4	3·3	3·1	3·1
Autumn (III, IV, V) ...	5·6	5·3	5·6	5·2	5·3	5·0	5·6	5·3	5·7	5·5	5·1	5·7	5·4	5·1	5·9	5·6	5·5	5·3
Winter (VI, VII, VIII) ...	5·8	6·2	6·5	5·8	6·3	5·8	6·2	6·0	5·3	6·1	5·6	5·6	5·5	5·7	5·6	6·1	5·8	5·9
Spring (IX, X, XI) ...	5·3	4·6	5·6	5·0	5·1	5·4	5·1	5·2	5·0	4·8	4·7	5·1	4·7	4·7	4·8	4·7	5·0	4·9
Year ...	5·1	5·0	5·2	5·0	5·2	4·8	5·0	4·8	4·6	4·7	4·5	4·7	4·6	4·6	4·9	4·9	4·9	4·8

Variability—Interdiurnal Variation.—As one measure of the variability of temperatures, the interdiurnal variations have been tabulated for every third hour of the day. The positive variations or occasions when the temperature was higher than that on the preceding day at the same hour, were tabulated separately from the negative, on which the change was in the opposite direction. The mean values for each month at Adélie Land are given in the first part of Table VIII. The second portion gives the monthly means as derived from the two years combined, December 1912 being given double weight in the December mean. The means for each season and the year follow. The magnitude of temperature variations of short period in the Antarctic depends largely on the intensity of the surface inversion. In still weather the snow surface cools rapidly by radiation. The cold surface air layer thus formed is liable to be broken up and swept away by the wind causing the temperature often to rise even more suddenly than it fell. The variability is much less at Adélie Land than at other Antarctic stations. It is least in summer and greatest in winter, while in autumn it is greater than in spring. In summer, temperature gradients in the north and south direction are slight and changes of wind consequently cause smaller changes of temperature. The ice being little colder than the air, also, there is little tendency for the cold layer to form. The reverse is the case in winter. In autumn, the surface temperature of the land is falling rapidly while in spring it is rising. Consequently, the cold layer forms more readily in the former season.

The mean values are generally smaller for negative than positive variations.

Spring and summer both show a definite diurnal variation in variability but in the remaining seasons none can be identified with certainty. The diurnal variation is much the greatest in summer. It follows the diurnal variation of temperature with the sign reversed fairly closely. The variability is particularly slight in the mid-day and afternoon hours of the warmer months because whatever the temperature has been at night, it tends to rise to 32° F. towards mid-day and remains constant there for some hours. The diurnal variation of temperature is, of course, much less over the sea than over the land so that the diurnal variation of temperature implies a diurnal variation in the north to south temperature gradient. No doubt the diurnal variation of variability is controlled to some extent by that of wind, but since the latter resembles the variation of temperature, it is impossible to distinguish between the two effects with the amount of data available. There is no apparent relationship with pressure. The diurnal variation is similar to that observed by the *Deutschland* expedition (*).

The interdiurnal variation as measured by the differences between daily means is given in Table XIX. The highest changes recorded in any month or the year also are shown. The results are very similar to those for the interdiurnal variation of the hourly values but one-fifth smaller in average magnitude.

Table IX shows the frequency of occurrence of variations between certain limiting values. It is here seen that the low mean values for negative variations are due to small negative changes being more frequent than small positive changes. This phenomenon has been explained (†) as being due to the tendency of the cold layer to

* K. Knoch. Die Ergebnisse der meteorologischen Beobachtungen der Deutschen Antarktischen Expedition, 1911–1912.

† G. C. Simpson. *British Antarctic Expedition,* 1910–1913, Meteorology, Vol. I.

TABLE IX.

Temperature—Interdiurnal Variation: Frequency of Different Values.

Adélie Land. Degrees Fahrenheit.

Period.	Range.		3h.		6h.		9h.		12h.		15h.		18h.		21h.		24h.		Total.
	From.	To.	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	
	°	°																	
Summer	0·0	3·0	33	31	48	32	26	44	35	44	45	45	41	49	46	36	31	38	624
	3·1	6·0	16	22	10	20	19	22	16	17	18	12	16	16	14	20	21	21	280
	6·1	9·0	12	11	7	6	6	6	4	9	3	7	3	3	4	8	5	8	102
	9·1	12·0	1	3	1	4	6	2	3	1	...	1	2	2	1	2	2	4	35
	12·1	15·0	1	1	2	...	...	...	1	1	1	...	...	...	1	...	2	...	10
	15·1	18·0	1	...	1	1	1	...	...	...	...	...	...	...	...	...	...	...	4
	18·1	21·0	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	1
Autumn	0·0	3·0	32	43	32	44	36	43	34	44	30	40	37	35	33	45	30	44	602
	3·1	6·0	19	22	23	25	18	27	19	22	22	25	21	26	20	21	21	18	349
	6·1	9·0	13	14	11	11	17	12	15	17	16	18	19	11	15	14	13	19	235
	9·1	12·0	13	12	9	14	6	13	7	7	5	8	6	12	11	9	11	8	151
	12·1	15·0	4	6	5	4	3	2	4	6	8	3	2	3	1	6	4	5	66
	15·1	18·0	1	2	2	1	4	1	4	2	2	4	3	5	1	5	4	5	46
	18·1	21·0	2	1	1	1	1	1	1	1	2	...	3	1	3	...	...	1	19
	21·1	24·0	...	...	1	...	...	...	...	1	...	1	...	...	...	...	1	...	4
Winter	0·0	3·0	27	30	24	35	27	34	24	37	31	34	31	30	33	35	34	29	495
	3·1	6·0	28	23	18	22	19	27	27	26	32	24	24	30	25	19	28	26	398
	6·1	9·0	21	18	21	21	13	18	16	11	19	10	23	13	20	14	16	10	264
	9·1	12·0	9	7	10	10	17	8	12	6	10	6	7	6	10	15	9	13	155
	12·1	15·0	2	9	7	7	7	7	7	8	2	8	5	9	4	5	5	6	98
	15·1	18·0	4	3	6	1	3	...	2	2	1	1	1	1	1	2	4	4	36
	18·1	21·0	2	...	...	1	...	1	1	2	2	3	1	3	1	...	...	...	17
	21·1	24·0	...	1	...	1	1	2	1	2	...	1	...	...	...	...	...	...	9
Spring	0·0	3·0	32	42	31	37	40	28	43	34	36	42	45	38	45	41	39	37	610
	3·1	6·0	26	23	31	26	28	21	20	25	29	19	19	18	23	19	26	22	375
	6·1	9·0	17	10	15	11	19	18	21	12	15	13	24	8	14	12	19	14	242
	9·1	12·0	10	9	8	9	5	6	5	5	8	4	9	11	11	6	8	8	122
	12·1	15·0	5	5	4	2	4	5	5	4	6	5	3	3	4	3	3	2	63
	15·1	18·0	1	1	1	4	4	2	2	2	2	1	1	1	1	3	2	2	30
	18·1	21·0	1	...	3	...	...	1	1	1	...	...	...	2	...	...	...	...	9
	21·1	24·0	...	...	...	...	1	...	1	...	...	2	...	...	...	...	...	...	4
	24·4	27·0	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1
Year	0·0	3·0	124	146	135	148	129	149	136	159	142	161	154	152	157	157	134	148	2,331
	3·1	6·0	89	90	82	93	84	97	82	90	101	80	80	90	82	79	96	87	1,402
	6·1	9·0	63	53	54	49	55	54	56	49	53	48	69	35	53	48	53	51	843
	9·1	12·0	33	31	28	37	34	29	27	19	23	19	24	31	33	32	30	33	463
	12·1	15·0	12	21	18	13	14	14	17	19	17	16	10	15	10	14	14	13	237
	15·1	18·0	7	6	10	7	12	3	8	6	5	6	5	7	3	10	10	11	116
	18·1	21·0	5	1	4	2	1	3	4	4	4	3	4	6	4	...	...	1	46
	21·1	24·0	...	1	1	1	2	2	2	3	...	4	...	...	...	...	1	...	17
	24·1	27·0	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1

TABLE X.

Temperature—Interdiurnal Variation. Maximum Values.

Adélie Land. Degrees Fahrenheit.

Period.	3h.		6h.		9h.		12h.		15h.		18h.		21h.		24h.		Highest.	
	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
1912—																		
II ...	16·1	8·8	16·2	11·9	17·9	11·3	18·7	9·0	13·5	9·1	9·4	11·9	12·5	11·0	12·5	10·8	18·7	11·9
III ...	11·2	12·1	12·8	10·6	15·9	9·5	16·6	11·9	15·3	15·1	16·1	17·3	10·6	15·3	11·3	13·9	16·6	17·3
IV ...	13·9	15·7	14·6	14·5	17·0	15·0	19·7	16·6	18·5	15·8	19·5	16·9	21·0	16·0	16·7	18·0	21·0	18·0
V ...	20·5	17·2	23·0	18·7	19·8	20·4	16·4	23·5	14·4	23·5	19·5	16·3	17·2	16·4	17·7	20·7	23·0	23·5
VI ...	17·0	15·4	12·4	19·5	11·8	22·2	14·6	21·5	11·0	20·8	9·9	11·0	10·1	13·9	14·4	15·2	17·0	22·2
VII ...	20·1	21·2	17·0	23·8	23·2	22·3	23·7	21·0	20·5	19·6	15·1	18·1	17·5	17·2	15·9	18·0	23·7	23·8
VIII ...	19·4	16·6	15·1	15·4	14·1	18·5	14·7	23·4	12·0	23·8	13·7	18·2	14·6	13·7	16·5	15·2	19·4	23·8
IX ...	13·6	14·3	13·2	15·1	17·7	14·2	18·2	12·5	16·0	14·6	16·0	19·4	16·9	17·7	16·7	15·5	18·2	19·4
X ...	19·4	12·8	19·2	13·9	16·1	12·5	13·0	11·3	14·7	8·6	13·0	11·0	10·8	10·4	14·6	11·2	19·4	13·9
XI ...	13·7	11·9	17·4	10·8	17·4	10·7	16·3	7·7	11·2	8·1	8·3	10·0	8·5	9·0	7·7	9·0	17·4	11·9
XII ...	8·4	9·7	6·8	8·0	3·9	3·3	4·7	6·4	3·9	6·4	5·3	5·9	6·3	4·9	6·2	4·7	8·4	9·7
1913—																		
I ...	7·7	8·0	8·5	7·4	10·4	7·6	8·5	6·4	4·5	6·4	4·1	9·2	5·2	8·0	8·0	9·9	10·4	9·9
II ...	13·6	12·7	13·3	16·1	11·2	12·1	10·2	12·8	5·4	8·7	9·0	7·5	9·2	9·1	13·0	11·1	13·6	16·1
III ...	19·9	14·8	17·5	13·7	17·8	15·3	13·9	13·9	14·0	12·3	18·2	12·9	20·4	17·1	23·0	16·5	23·0	17·1
IV ...	14·6	8·6	12·5	9·3	8·9	11·5	13·3	19·8	13·7	20·2	12·6	19·1	14·7	13·8	16·5	8·5	16·5	20·2
V ...	11·6	14·1	11·5	14·3	12·3	11·3	15·0	17·2	13·5	17·4	11·8	14·0	11·2	12·9	14·1	14·0	15·0	17·4
VI ...	16·5	11·5	14·3	12·0	12·5	12·9	10·0	14·3	8·0	14·6	9·6	12·5	11·6	11·8	14·9	11·2	16·5	14·6
VII ...	13·0	13·6	14·9	12·8	16·6	12·7	20·2	15·5	19·2	14·5	13·5	13·1	19·7	16·8	16·0	17·9	20·2	17·9
VIII ...	15·7	14·6	16·6	14·4	16·1	13·8	16·2	17·4	13·7	18·2	11·7	18·1	10·2	14·2	12·3	15·0	16·6	18·2
IX ...	17·9	17·3	18·4	16·4	21·1	19·8	21·9	24·8	15·9	21·8	13·8	12·8	14·6	14·3	16·5	15·2	21·9	24·8
X ...	14·8	12·3	14·8	11·7	13·1	12·1	11·3	18·0	10·0	15·6	10·7	9·9	10·4	12·2	12·9	12·0	14·8	18·0
XI ...	12·0	13·7	8·0	15·7	7·6	16·6	8·8	18·8	9·5	21·9	9·4	18·2	11·1	11·4	10·7	11·4	12·0	21·9
Summer ... (mean).	10·3	9·5	10·0	9·8	9·6	7·5	9·2	7·9	5·9	7·2	6·2	8·3	7·4	7·6	9·0	8·5	11·7	11·2
Autumn ... (mean).	15·3	13·8	15·3	13·5	15·3	13·8	15·8	17·4	14·9	17·4	16·2	16·0	15·8	15·2	16·6	15·2	19·1	18·9
Winter ... (mean).	17·0	15·4	15·0	16·4	15·8	17·0	16·6	18·8	14·0	18·6	12·2	15·2	14·0	14·6	15·0	15·4	18·9	20·1
Spring ... (mean).	15·2	13·7	15·2	14·0	15·5	14·4	14·9	15·5	12·6	15·1	11·8	13·6	12·0	12·5	13·2	12·4	17·2	18·3
Year ...	14·4	13·1	13·9	13·4	14·0	13·2	14·1	14·9	11·8	14·6	11·6	13·4	12·3	12·5	13·4	12·9	16·7	17·1

form in most types of weather unless the wind is very strong. In agreement with this view, the effect is much less marked at Adélie Land than at most other Antarctic stations. The excess of small negative values is greatest in autumn, when the temperature over the land is falling. It is small in summer when temperature gradients are low. In spring, when the temperature of the ice surface is rising, it is converted into a deficit.

Moderate negative changes are less frequent than moderate positive, but large variations are almost equally frequent for both signs.

The variations, Table X, in the maximum values are in accordance with the foregoing. The highest listed change in twenty-four hours is -24.8° F., which occurred between noon on the 15th and noon on the 16th September, 1913.

Corresponding data for Queen Mary Land are contained in Tables XI to XIII. The values for individual months are not given because several of them are incomplete. The seasonal means are weighted to allow for this.

TABLE XI.

Temperature—Interdiurnal Variation.

Queen Mary Land. Degrees Fahrenheit.

Period.	3h.		6h.		9h.		12h.		15h.		18h.		21h.		24h.		Mean.	
	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
Summer (XII, I, II)	7·6	7·9	5·0	5·3	3·4	3·2	2·7	3·0	2·5	2·7	3·4	3·2	4·7	4·0	7·3	5·9	4·6	4·4
Autumn (III, IV, V)	8·5	9·4	8·6	9·2	8·3	9·3	9·1	7·7	9·4	6·7	7·4	8·1	8·4	7·7	8·7	8·9	8·6	8·4
Winter (VI, VII, VIII)	11·8	11·2	12·1	10·7	11·6	9·9	11·4	8·9	10·4	10·8	11·4	10·8	12·2	12·2	12·7	13·2	11·7	10·7
Spring (IX, X, XI)	8·3	8·1	7·0	7·4	5·4	5·1	4·7	5·0	5·0	4·4	6·2	4·5	7·3	5·5	8·0	7·1	6·5	5·9
Year	9·0	9·2	8·2	8·2	7·2	6·9	7·0	6·2	6·8	6·2	7·1	6·7	8·2	7·4	9·2	8·8	7·8	7·4

The results are, for the most part, similar in kind to those for Adélie Land, but in accordance with the views set forth, the amount of variation is much greater. So, also, are the diurnal and annual variations. The mean is slightly higher than that found by the *Deutschland* on the pack ice of the Weddell Sea, and also than that at Cape Adare and Cape Evans, but less than that at Framheim.

In the mean, positive variations are again greater than negative, but it is surprising to find that this is due to an excess of large positive variations. There is no systematic excess of small negative values. The explanation previously given for the lower mean value of the negative variations, therefore, apparently, breaks down.

The greatest change recorded is +44° F. between 15 hours on the 8th and 15 hours on the 9th August, 1912. This is rather less than the highest value recorded on the *Deutschland* expedition.

TABLE XII.

Temperature—Interdiurnal Variation. Frequency of Different Values.

Queen Mary Land. Degrees Fahrenheit.

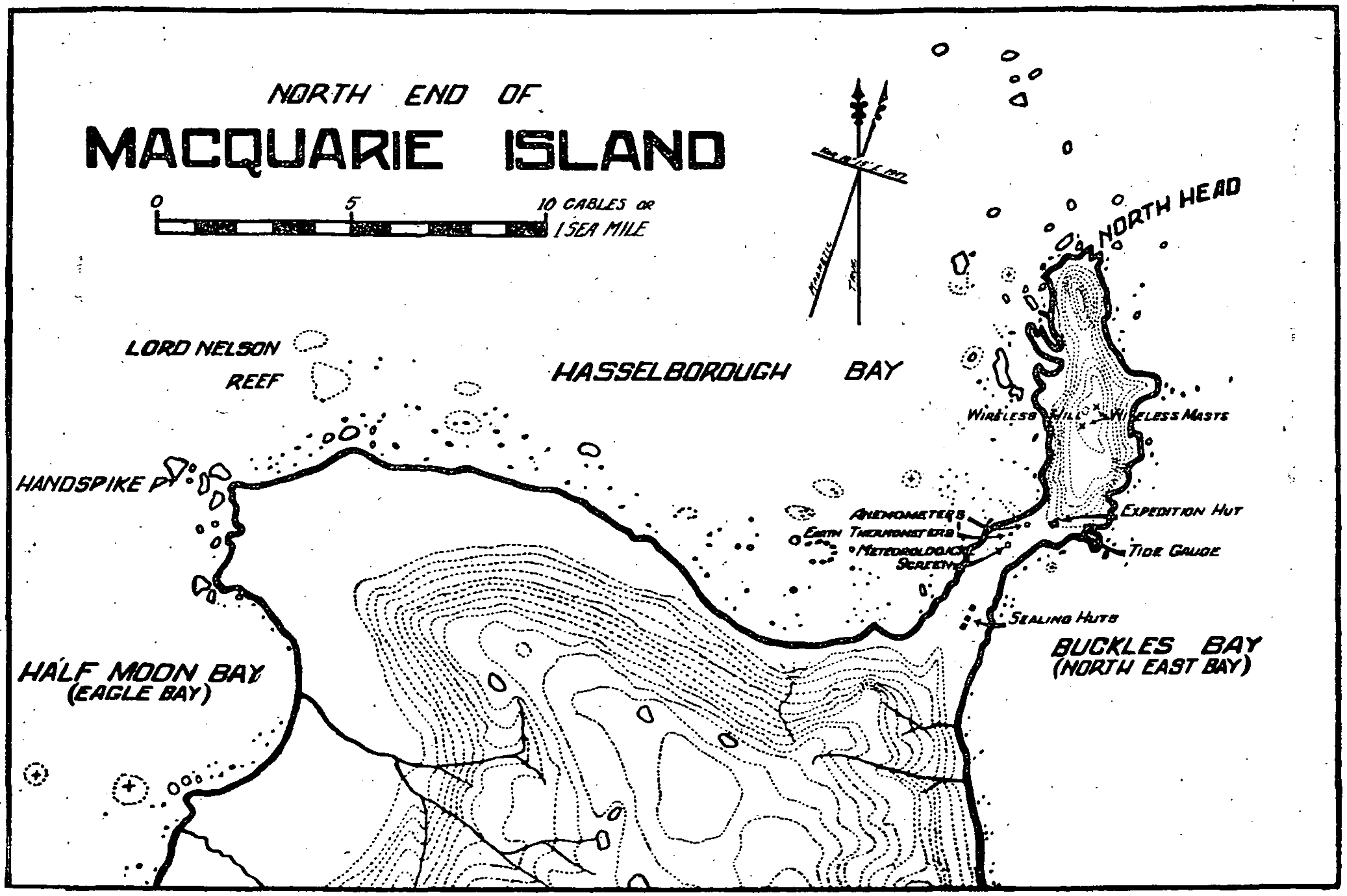
Period.	Range.		3h.		6h.		9h.		12h.		15h.		18h.		21h.		24h.		Total.
	From.	To.	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	
	°	°																	
Summer	0	3	9	18	15	16	25	27	28	22	30	29	26	18	14	25	10	16	328
	4	6	6	8	11	12	5	8	12	11	8	6	11	15	13	10	8	11	155
	7	9	8	9	4	6	4	4	...	3	2	2	2	2	1	4	8	4	63
	10	12	3	5	3	3	3	2	1	1	...	1	1	2	7	3	3	6	44
	13	15	4	...	1	1	...	...	...	...	...	...	1	...	...	1	3	3	14
	16	18	...	2	1	1	...	...	...	...	...	...	...	...	...	...	1	1	6
	19	21	1	1	1	...	...	...	...	...	...	...	...	...	...	...	1	...	4
	22	24	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
	25	27	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	1
Autumn	0	3	7	7	7	6	9	3	6	6	5	12	8	6	7	8	8	7	112
	4	6	9	4	8	4	6	6	4	9	3	6	6	7	5	5	9	4	95
	7	9	2	1	2	1	4	2	2	4	4	3	3	6	4	4	1	3	46
	10	12	2	4	1	5	1	6	5	3	4	3	7	...	5	1	2	1	50
	13	15	...	2	2	4	3	7	2	4	2	3	1	2	2	4	1	3	42
	16	18	3	2	3	5	1	1	3	2	3	3	...	2	3	1	4	1	37
	19	21	3	3	2	...	1	...	...	1	...	...	1	1	2	1	3	5	23
	22	24	...	1	...	...	1	...	...	...	...	...	1	1	...	1	1	...	6
	25	27	1	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	3
	28	30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	31	33	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1
	34	36	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	1
Winter	0	3	10	8	11	10	14	11	8	12	8	9	9	11	8	10	9	2	150
	4	6	5	4	4	11	2	10	3	11	12	7	5	6	8	4	8	7	107
	7	9	4	11	2	6	2	8	9	12	9	8	11	9	4	5	3	10	113
	10	12	9	11	8	2	4	6	9	6	3	3	3	6	6	6	5	8	95
	13	15	2	3	3	4	6	1	2	2	3	9	5	2	5	7	4	6	64
	16	18	3	2	3	6	2	5	2	2	5	5	2	5	3	5	4	...	54
	19	21	7	1	4	2	7	4	...	3	1	2	4	3	3	4	4	4	53
	22	24	2	1	5	4	2	5	4	2	...	1	2	2	4	3	3	3	43
	25	27	1	3	1	3	1	...	1	2	2	...	1	1	2	...	2	2	22
	28	30	...	1	1	1	...	...	...	...	1	2	...	1	1	2	1	3	14
	31	33	...	2	...	...	1	...	...	...	...	...	...	1	...	...	1	1	6
	34	36	2	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	3
	37	39	...	...	...	...	...	...	1	...	...	...	2	...	...	1	2	...	6
	40	42	...	...	1	...	1	...	1	...	1	...	...	...	1	...	...	...	5
	43	45	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1
Spring	0	3	8	8	9	10	18	15	22	18	24	22	18	25	16	14	11	10	248
	4	6	8	8	16	6	13	11	15	7	6	6	6	6	8	14	10	8	148
	7	9	12	4	10	5	9	4	6	2	9	4	7	6	5	3	6	7	99
	10	12	10	6	5	8	2	2	3	4	4	2	4	2	2	4	4	5	67
	13	15	2	4	2	4	2	4	1	3	1	1	3	...	3	1	5	3	39
	16	18	1	2	3	1	...	...	...	...	...	2	2	1	3	2	4	1	22
	19	21	1	2	...	...	...	...	...	...	...	...	1	1	2	...	1	1	9
	22	24	...	...	...	...	...	...	...	...	...	...	...	...	2	1	...	...	3
	25	27	...	...	1	...	...	...	...	...	...	...	...	...	...	...	1	...	2
	28	30	1	...	...	...	1	...	1	...	1	...	...	...	...	...	...	...	4
Year	0	3	34	41	42	42	66	56	64	58	67	72	61	60	45	57	38	35	838
	4	6	28	24	39	33	26	35	34	38	29	25	28	34	34	33	35	30	505
	7	9	26	25	18	18	19	18	17	21	24	17	23	23	14	16	18	24	321
	10	12	24	26	17	18	10	16	18	14	11	9	15	10	20	14	14	20	256
	13	15	8	9	8	13	11	12	5	9	6	13	10	4	10	13	13	15	159
	16	18	7	8	10	13	3	6	5	4	8	10	4	8	9	8	13	3	119
	19	21	12	7	7	2	8	4	...	4	1	2	6	5	7	5	9	10	89
	22	24	3	2	5	4	3	5	4	2	...	1	3	3	6	5	4	3	53
	25	27	2	3	3	3	2	...	1	2	2	...	1	1	2	...	4	2	28
	28	30	1	1	1	1	1	...	1	...	2	2	...	1	1	2	1	3	18
	31	33	...	2	...	...	1	...	...	...	1	...	...	1	...	...	1	1	7
	34	36	2	...	...	...	...	...	1	...	...	...	...	1	...	...	...	...	4
	37	39	...	...	...	...	...	...	1	...	...	...	2	...	...	1	2	...	6
	40	42	...	...	1	...	1	...	1	...	1	...	...	...	1	...	...	...	5
	43	45	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1

TABLE XIII.

Temperature—Interdiurnal Variation. Maximum Values.

Queen Mary Land. Degrees Fahrenheit.

Period.	3h.		6h.		9h.		12h.		15h.		18h.		21h.		24h.		Highest.		No. of Days.
	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	
1912.																			
III	21	22	20	17	22	14	12	11	14	14	15	20	18	20	21	20	22	22	14
IV	21	13	20	12	18	14	16	13	9	8	12	9	11	9	12	13	21	14	7
V	26	21	27	18	26	18	34	19	26	18	31	18	24	22	19	22	23	21	31
VI	35	31	41	27	33	24	42	24	42	23	37	25	27	22	32	30	42	31	30
VII	35	28	24	28	21	24	16	26	19	29	20	35	30	38	38	32	38	38	31
VIII	27	31	26	27	40	24	38	26	44	28	39	21	42	30	39	30	44	31	31
IX	28	19	27	15	29	14	30	15	28	16	20	21	23	23	25	21	30	23	29
X	12	16	18	18	13	12	10	10	9	8	13	9	22	16	17	14	22	18	21
XI	16	19	13	13	10	9	4	7	11	13	13	8	21	13	18	16	21	19	30
XII	15	19	8	16	8	10	6	7	6	10	7	10	11	10	15	18	15	19	31
1913.																			
I	24	16	17	11	11	9	5	10	8	9	13	10	12	14	19	15	24	16	31
II	20	18	20	14	12	10	11	5	8	8	10	6	12	11	25	14	25	18	16
Autumn (Mean).	23	22	24	18	24	16	25	16	20	16	23	19	21	21	20	21	22	22	...
Winter (Mean).	32	30	30	27	31	24	32	25	35	27	32	27	33	30	36	28	37	31	...
Spring (Mean).	29	18	29	15	17	12	15	11	19	12	15	13	22	17	20	17	24	20	...
Summer (Mean).	20	18	15	14	10	10	7	7	7	9	10	9	12	12	20	16	21	18	...
Year	26	22	24	18	20	16	20	15	20	16	20	17	22	20	24	20	26	23	...


NORTH END OF
MACQUARIE ISLAND
0 5 10 CABLES OR
1 SEA MILE
Magnetic
True
NORTH HEAD
LORD NELSON
REEF
HASSELBOROUGH BAY
HANDSPIKE Pt
Wireless Hill
Wireless Masts
Anemometers
Earth Thermometers
Meteorological Screen
Expedition Hut
Tide Gauge
Sealing Huts
BUCKLES BAY
(NORTH EAST BAY)
HALF MOON BAY
(EAGLE BAY)

II.—MACQUARIE ISLAND

1.—Instruments and Methods, Location, Etc.

A few remarks regarding the instruments and their location are given, together with photographs, in Volume III of this series. A map of the immediate vicinity of the Base Station appears as fig. 8 herewith. The instruments consisted apparently of wet and dry bulb and maximum and minimum thermometers and a thermograph. The latter was of the bi-metallic spiral type by Short & Mason. These instruments together with a hair hygrograph, were housed in a Stevenson screen of the large size adpoted by the Commonwealth Meteorological Bureau of Australia. The screen was erected in an open space covered with coarse grass and herbage on a low-lying isthmus at the north-east extremity of the island. The height above sea level was of the order of 10 feet. Local Mean Time was used throughout and eye observations were made at 9, 15, and 21 hours.

Hourly readings of temperature are tabulated from the thermograph records. These are said to have been mediocre at times and, on a few occasions, the instrument was clogged with snow. These blemishes are, however, very slight and the mean values are no doubt quite reliable.

Errors in computation are numerous in Volume III though not so serious as with the Adélie Land records. For the purposes of the present discussion, some short breaks have been filled by interpolated values in preference to omitting days when a proportion of the hourly observations were available.

It should be borne in mind that Macquarie Island is a small island in a very windy and cloudy region in the Southern Ocean, far from any other land. The island is 22 miles long and has a maximum width of 3½ miles. The isthmus on which the meteorological station was located was only about 200 metres wide.

2.—Observations.

Mean Temperatures.—The monthly mean temperatures together with notes regarding their derivation are given Table XIV. The means for December, 1913, to November, 1914, the year for which the records were lost, were computed from the 09.00, the maximum and the minimum readings. When using the 09.00 observations allowance was made for the diurnal variation of temperature, but the necessary corrections were very small. The year 1912 was the warmest and 1914 the coldest, the difference between the two, 1.4° F., being rather considerable. The means of the daily maxima and minima show the same effect. The winter half-year (May to October) was warmest in 1912 and coldest in 1914, 1915 being rather warmer than 1913. This is the same order as that of the mean temperatures. The summer half-year, 1911–12, was evidently warm, the next two were of about equal temperature, while that of 1914–15 was cold.

At Adélie Land, it will be remembered, 1912 was colder than 1913.

The mean temperature for the year is very close to the value to be expected for the latitude of Macquarie Island.

TABLE XIV.

Temperature.

Macquarie Island. Degrees Fahrenheit.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
							Mean Temperature.						
1912 ...	44·6	43·0	41·9	40·9	40·1	38·1	38·1	38·3	38·6	39·7	41·4	43·8	40·7
1913 ...	43·2	42·4	42·3	40·7	37·3	36·3	36·7	38·2	37·0	38·8	39·6	43·0	39·6
1914 ...	44·0	44·0	42·7	41·3	39·9	37·4	35·6	36·2	36·7	36·0	37·6	39·7	39·3
1915 ...	41·3	42·0	42·0	39·7	39·0	37·2	38·1	37·8	39·2	37·1	39·5	...	...
Means ...	43·3	42·8	42·2	40·6	39·1	37·4	37·1	37·6	37·9	37·9	39·5	42·2	39·8
							Mean Daily Maximum.						
1912 ...	48·0	45·3	43·9	43·2	42·0	40·6	40·7	41·0	41·1	42·5	44·5	47·2	43·3
1913 ...	46·7	45·5	44·8	42·9	40·0	39·1	39·8	40·4	40·0	41·4	42·9	46·3	42·5
1914 ...	46·8	47·0	44·7	43·5	42·3	40·4	38·4	38·9	39·8	39·7	41·1	43·2	42·2
1915 ...	44·1	44·8	44·4	42·0	41·3	39·5	40·6	40·3	41·3	40·0	42·9	...	...
Means ...	46·4	45·6	44·4	42·9	41·4	39·9	39·9	40·2	40·6	40·9	42·8	45·6	42·6
							Mean Daily Minimum.						
1912 ...	41·7	41·0	39·5	38·1	37·2	35·4	35·1	35·1	36·0	36·7	38·8	40·7	37·9
1913 ...	39·5	39·3	39·8	37·8	34·2	32·7	33·7	35·9	33·5	35·3	36·3	40·0	36·5
1914 ...	41·6	41·3	40·4	38·8	37·0	33·9	32·8	33·4	33·2	31·7	34·3	36·7	36·3
1915 ...	38·4	39·5	39·2	36·6	36·2	34·2	35·0	35·0	36·6	33·9	36·7	...	...
Means ...	40·3	40·3	39·7	37·8	36·2	34·0	34·2	34·8	34·8	34·4	36·5	39·1	36·8
							Difference between Hourly Mean and Mean of Maximum and Minimum.						
	−0·1	−0·1	+0·1	+0·3	+0·3	+0·3	+0·1	+0·1	+0·2	+0·2	−0·2	−0·2	+0·1

NOTE.—In November, 1913, there are no observations after the 23rd. Values from December, 1913, to November, 1914, inclusive, are derived from telegraphic weather reports, which gave the reading at 09·00 hours, the maximum and the minimum.

TABLE XV.

Temperature—Harmonic Analysis of Annual Variation.

$$dT = a_1 \sin(\theta + A_1) + a_2 \sin(2\theta + A_2) + a_3 \sin(3\theta + A_3).$$

	a_1	A_1	a_2	A_2	a_3	A_3
	°F.	°	°F.	°	°F.	°
Macquarie Is. ...	3·05	55	0·54	22	0·23	102
Chatham Is. ...	6·00	60	0·53	337	0·26	50

Annual Variation.—The mean monthly temperatures as derived from the four years' observations are plotted in Fig. 9., together with the corresponding values for the means of the daily maxima and minima. January is the warmest month and July the coldest, but an interesting feature is that between June and October, the mean temperature changes but little. This effect is shown also in both the maximum and the minumum temperatures.

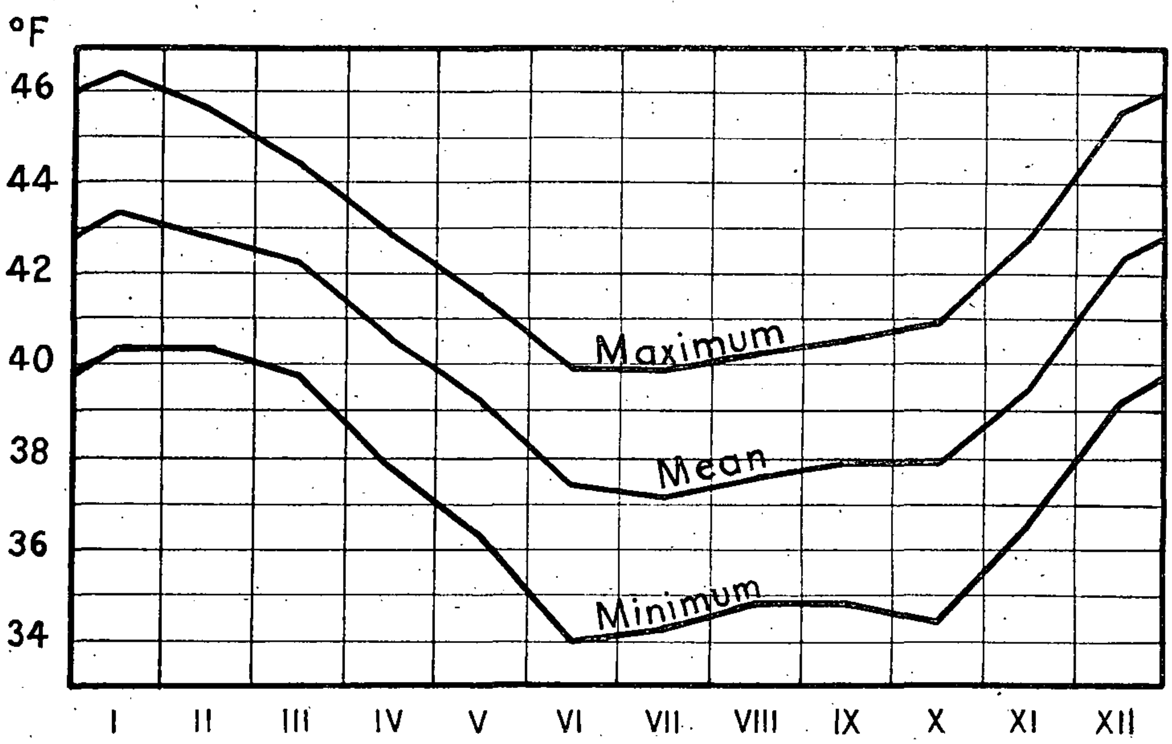


FIG. 9.—Macquarie Island Annual Variation of Temperature.

The harmonic analysis of the annual variation together with corresponding figures for Chatham Island, is given in Table XV. The 12-months term is the most important. It is less than a fifth of the magnitude of the corresponding terms at Adélie Land and Queen Mary Land. At Chatham Island, in Latitude 43°52′S., which is much the same size as Macquarie Island and also far from any other land, but where the Meteorological Station was about half-a-mile inland, the range in mean monthly temperature is 12.2° F. or practically double that at Macquarie Island. At Auckland, New Zealand, the range is 15.0° F., at Wellington 14.6° F., and at Christchurch, where conditions approach nearer to the continental type, 18.1° F.

The annual term at Macquarie Island is 26 and 42 days respectively later in phase than those for Adélie Land and Queen Mary Land. The apparent lateness is partly due to the long period of uniform temperatures from June to October. This may be seen from a comparison with Chatham Island, where February is almost as warm as January, while December is considerably colder, indicating a later phase than at Macquarie Island. October, however, is 5° warmer than the coldest month, July, compared with only 0.8° at Macquarie Island. Consequently, in the harmonic analysis, the annual term is earlier in phase at Chatham Island than at Macquarie Island. The amplitude is almost twice as great at Chatham Island.

TABLE XVI.

Temperature—Diurnal Inequalities.

Macquarie Island. Degrees Fahrenheit.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period. I	—1·2	—1·3	—1·4	—1·4	—1·2	—1·0	—0·5	—0·1	+0·7	+1·0	+1·4	+1·7	+1·7	+1·7	+1·4	+1·1	+0·7	+0·2	—0·2	—0·3	—0·7	—0·7	—0·8	—1·0
II	—1·0	—0·9	—0·8	—0·9	—0·8	—0·7	—0·3	—0·0	+0·6	+0·9	+1·1	+1·5	+1·5	+1·4	+1·1	+0·9	+0·5	+0·2	—0·1	—0·5	—0·6	—0·7	—0·8	—0·9
III	—0·5	—0·5	—0·4	—0·5	—0·6	—0·6	—0·6	—0·3	+0·2	+0·5	+0·8	+0·9	+1·0	+0·9	+0·9	+0·6	+0·4	+0·0	—0·2	—0·2	—0·2	—0·3	—0·4	—0·4
IV	—0·5	—0·6	—0·5	—0·4	—0·4	—0·4	—0·3	—0·0	+0·3	+0·5	+0·6	+0·7	+0·8	+0·7	+0·5	+0·3	+0·1	—0·1	—0·2	—0·2	—0·1	—0·3	—0·5	—0·4
V	—0·4	—0·4	—0·3	—0·3	—0·3	—0·3	—0·2	—0·1	+0·2	+0·3	+0·5	+0·5	+0·6	+0·6	+0·5	+0·2	+0·1	—0·0	—0·1	—0·1	—0·1	—0·3	—0·4	—0·5
VI	—0·2	—0·1	—0·0	—0·1	—0·1	—0·0	—0·0	—0·0	+0·3	+0·3	+0·3	+0·4	+0·3	+0·2	+0·1	+0·1	+0·0	—0·1	—0·2	—0·2	—0·2	—0·2	—0·3	—0·2
VII	—0·1	—0·2	—0·4	—0·3	—0·3	—0·2	—0·3	—0·3	—0·2	+0·0	+0·1	+0·2	+0·3	+0·2	+0·3	+0·2	+0·2	+0·2	+0·1	+0·1	—0·0	—0·0	—0·1	—0·0
VIII	—0·4	—0·3	—0·3	—0·3	—0·3	—0·2	—0·2	—0·1	+0·2	+0·4	+0·5	+0·8	+0·9	+0·6	+0·4	+0·2	+0·0	—0·1	—0·2	—0·2	—0·3	—0·3	—0·4	—0·4
IX	—0·5	—0·5	—0·6	—0·5	—0·6	—0·5	—0·4	—0·2	+0·2	+0·4	+0·7	+0·8	+1·0	+0·8	+0·6	+0·6	+0·3	+0·0	—0·1	—0·2	—0·3	—0·4	—0·5	—0·5
X	—0·4	—0·3	—0·5	—0·6	—0·7	—0·7	—0·4	—0·2	+0·4	+0·6	+0·7	+0·7	+0·9	+0·9	+0·7	+0·5	+0·4	+0·0	—0·1	—0·2	—0·1	—0·3	—0·3	—0·5
XI	—0·9	—1·1	—1·2	—1·3	—1·2	—0·9	—0·4	+0·1	+0·7	+1·1	+1·5	+1·6	+1·6	+1·6	+1·5	+1·0	+0·6	+0·2	—0·3	—0·5	—0·6	—0·7	—0·9	—0·9
XII	—1·2	—1·2	—1·1	—1·0	—1·0	—0·7	—0·2	+0·2	+0·6	+0·9	+1·2	+1·6	+1·8	+1·8	+1·6	+1·1	+0·6	+0·2	—0·2	—0·6	—0·8	—1·0	—1·1	—1·2
Summer (XII, I, II)	—1·1	—1·1	—1·1	—1·1	—1·0	—0·8	—0·3	—0·0	+0·7	+0·9	+1·2	+1·6	+1·7	+1·6	+1·4	+1·0	+0·6	+0·2	—0·2	—0·5	—0·7	—0·8	—0·9	—1·0
Autumn (III, IV, V)	—0·5	—0·5	—0·4	—0·4	—0·4	—0·4	—0·4	—0·1	+0·2	+0·4	+0·6	+0·7	+0·8	+0·7	+0·6	+0·4	+0·2	+0·0	—0·2	—0·2	—0·1	—0·3	—0·4	—0·4
Winter (VI, VII, VIII)	—0·2	—0·2	—0·2	—0·2	—0·2	—0·1	—0·2	—0·1	+0·1	+0·2	+0·3	+0·5	+0·5	+0·3	+0·3	+0·2	+0·1	+0·0	—0·1	—0·1	—0·2	—0·2	—0·3	—0·2
Spring (IX, X, XI)	—0·6	—0·6	—0·8	—0·8	—0·8	—0·7	—0·4	—0·1	+0·4	+0·7	+1·0	+1·0	+1·2	+1·1	+0·9	+0·7	+0·4	+0·1	—0·2	—0·3	—0·3	—0·5	—0·6	—0·6
Year	—0·6	—0·6	—0·6	—0·6	—0·6	—0·5	—0·3	—0·1	+0·4	+0·6	+0·8	+1·0	+1·0	+0·9	+0·8	+0·6	+0·3	+0·1	—0·2	—0·3	—0·3	—0·4	—0·6	—0·6

Data from three years less one December.

Diurnal Variation.—The diurnal variation is shown in Table XVI, by means of average diurnal inequalities, for each month, the four seasons, and the year. The values for the four seasons and the year are plotted in Fig. 10. The amplitude is highest in January but the December value is only slightly smaller. Similarly, though the June amplitude is the smallest, there is little difference between June and July. The temperature is highest at 13 hours at all seasons of the year, which is very early for a land station. The small lag is due to proximity to the ocean and to the fact that accumulations of warm air are soon swept away by the winds. At night time the temperature is remarkably uniform, being controlled, apparently, by the temperature of the sea.

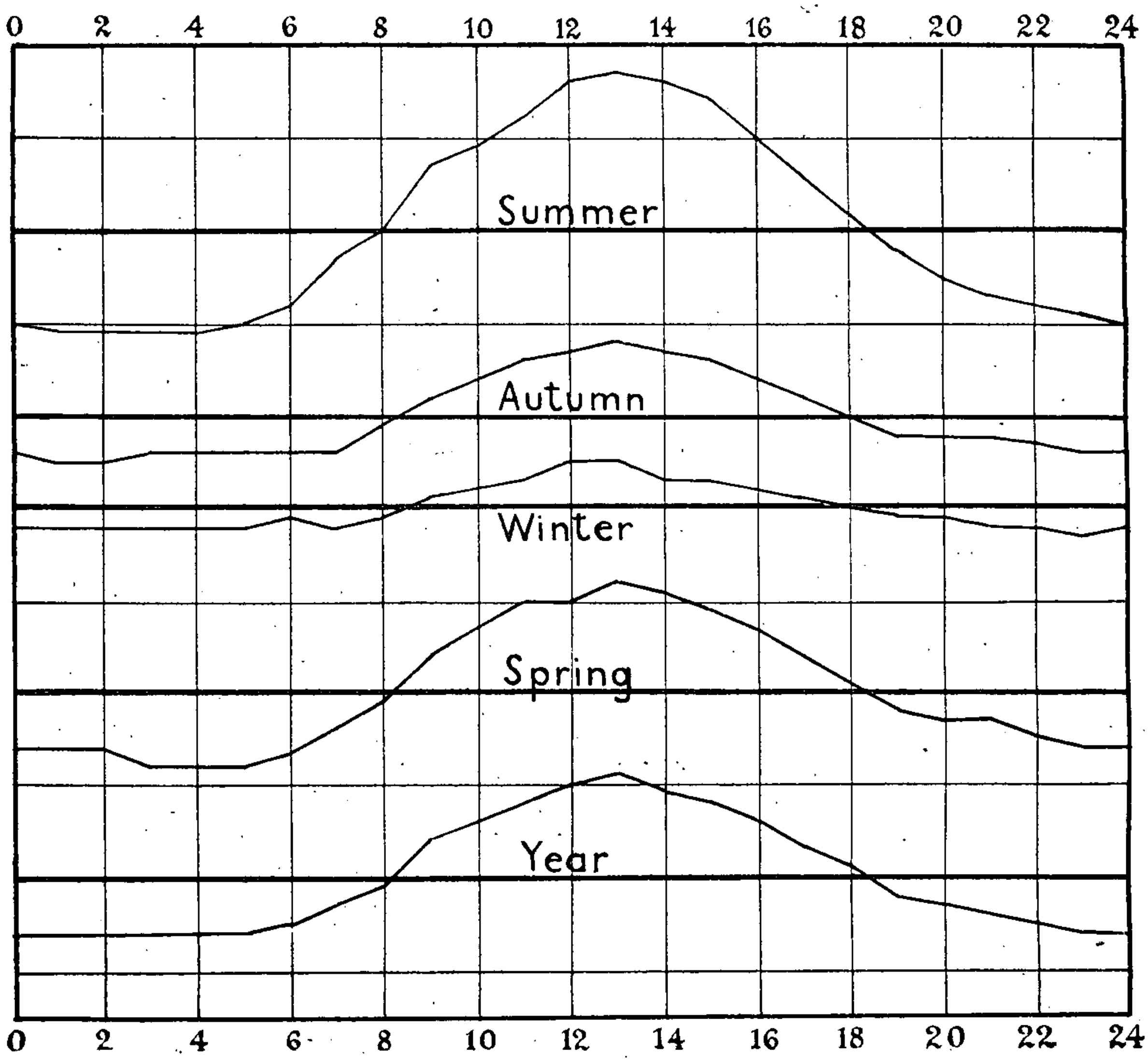


FIG. 10.—Macquarie Island—Diurnal Variation of Temperature. One Vertical Division equals one Degree Fahrenheit.

The range of variation, even in January, is only 3.1° F. compared with 8.2° F. and 13.3° F. at Adélie Land and Queen Mary Land, respectively.

The mean daily range for the year as derived from readings of maximum and minimum thermometers, is 5.8° F. compared with 10.3° F. at Chatham Island, 11.7° F. at Auckland, 12.2° F. at Wellington, and 16.7° F. at Christchurch.

TABLE XVII.

Temperature—Harmonic analysis of Diurnal Variation.

Macquarie Island.

$$dT = a_1 \sin(\theta + A_1) + a_2 \sin(2\theta + A_2) + a_3 \sin(3\theta + A_3).$$

Period.	a_1	A_1	a_2	A_2	a_3	A_3
	°F.	°	°F.	°	°F.	°
I	1·40	247	0·35	87	0·04	93
II	1·20	252	0·27	69	0·04	325
III	0·72	242	0·30	64	0·05	284
IV	0·60	253	0·18	90	0·06	241
V	0·47	251	0·11	70	0·07	259
VI	0·26	281	0·07	73	0·04	318
VII	0·27	208	0·07	68	0·01	214
VIII	0·50	260	0·20	70	0·10	254
IX	0·70	246	0·22	66	0·04	287
X	0·67	243	0·27	80	0·06	360
XI	1·41	250	0·37	84	0·09	63
XII	1·48	253	0·27	54	0·05	128
Summer (XII, I, II)	1·38	251	0·30	70	0·03	102
Autumn (III, IV, V)	0·57	250	0·19	73	0·06	249
Winter (VI, VII, VIII)	0·31	254	0·11	58	0·04	278
Spring (IX, X, XI)	0·92	247	0·28	78	0·04	12
Year	0·80	250	0·21	73	0·03	301

TABLE XVIII.

Temperature—Absolute Extremes.

Macquarie Island. Degrees Fahrenheit.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Maximum	51·2	52·0	49·3	47·8	45·3	44·0	44·5	45·2	45·1	45·0	49·0	53·0
Minimum	34·5	32·1	33·0	31·7	27·8	22·7	23·0	26·3	23·1	24·0	24.0	33·0

The phase of the 24-hour term seems, from Table XVII, to be constant throughout the year, as also does that of the 12-hour term. Both are earlier in phase than the corresponding terms at Adélie Land and, still more, at Queen Mary Land. The 8-hour term is irregular in phase and amplitude and does not appear to have much significance. It is very small.

Extreme Temperatures.—The mean daily maxima and minima are tabulated for each month in Table XIV, and the averages for each month during the four years are computed from them. The latter are plotted in Fig. 9. The insular character of the Macquarie Island climate is, again, the most important feature. The annual range is small and is almost equal for the two quantities, whereas at land stations, the range in the maximum is generally the larger. Even at Chatham Island the difference is 2.6° F.

Table XVIII contains the absolute extremes. The total range in the four years is 30° F. At Chatham Island in a similar period one would expect a range of about 40° F. and over New Zealand, on the average, about double the Macquarie Island range. The range of variation of the extreme maxima, from winter to summer, is also very small. That of the extreme minima is greater. On rare occasions, the air does stagnate for brief intervals over the island and no doubt there is a drift of cold air from the higher land on to the isthmus on which the meteorological station stood, and fairly severe frosts are caused. But screen temperatures below freezing are not very common at any time of year. The highest temperature recorded was only 53° F. and the lowest 22.7° F.

There is close agreement between the monthly mean temperatures as derived from the means of the daily maxima and minima and from the means of the hourly values, respectively (see Table XIV). From November to February, the mean of the maximum and minimum is slightly higher, but for the remainder of the year the reverse is the case.

It was evidently easier for a cold layer to collect over the land in winter than a warm layer in summer.

Variability.—In Table XIX are tabulated data regarding the interdiurnal variability of temperature at Macquarie Island as derived from the daily means. First are given the mean values of positive and negative changes and next those for changes of either sign. Then follow the highest positive and negative departures recorded in each month and the year. Corresponding data for Adélie Land are also given. The values given are derived from all available data. On the average, there is little difference in magnitude between positive and negative departures. On the whole, at Macquarie Island, positive variations appear to be greater round about summer, and negative in the winter half year, but there is no great regularity. The variation at Adélie Land is about double that at Macquarie Island. For a small island in the midst of the ocean the maximum values at Macquarie Island are fairly high. The annual variation in magnitude of the interdiurnal variation is similar to that of temperature reversed. It is natural to attempt to ascribe this annual variation to a corresponding one in the north to south temperature gradient. But the annual variation of temperature is unlikely to be greater than that at Macquarie Island for a considerable distance to the southward, so that the temperature gradient would, at least, not be greater in winter than in summer. To the northward there is undoubtedly an increase in the annual variation of temperature gradients, therefore, one would expect a greater interdiurnal variation in summer than in winter. It is the characteristics of the general circulation of the atmosphere in this region which determines the nature of the interdiurnal variability. This is, in all probability, determined by the poleward temperature gradients but in the whole troposphere, not at the surface. Vertical as well as horizontal

TABLE XIX.

Temperature—Interdiurnal Variation from Daily Means.

Stated in Degrees Fahrenheit

Period.	Macquarie Island.					Adélie Land.				
	Mean.			Maximum.		Mean.			Maximum.	
	+	−	Mean.	+	−	+	−	Mean.	+	−
I	1·50	1·43	1·46	5·8	3·6	1·83	1·85	1·84	5·5	4·3
II	1·18	0·99	1·08	4·5	2·8	3·35	3·06	3·18	13·0	9·3
III	1·51	1·40	1·45	5·2	5·5	3·85	4·05	3·96	13·1	13·2
IV	1·92	2·23	2·07	5·7	5·7	4·87	4·33	4·42	14·4	14·0
V	2·43	2·14	2·28	6·9	8·8	4·52	4·88	4·70	15·1	17·0
VI	2·39	2·49	2·44	11·2	7·5	3·69	4·42	4·04	9·0	12·1
VII	2·01	2·85	2·38	6·1	7·6	5·58	5·30	5·45	16·7	18·8
VIII	2·10	2·66	2·35	6·7	6·1	4·91	5·18	5·05	13·2	17·5
IX	2·57	1·93	2·23	6·0	8·3	5·24	5·35	5·29	15·1	14·6
X	2·42	2·33	2·38	7·7	5·4	4·01	3·68	3·84	12·3	10·9
XI	1·62	1·86	1·73	5·1	6·4	3·57	3·20	3·41	11·8	15·4
XII	1·50	1·36	1·43	5·6	4·7	1·37	1·40	1·39	5·1	4·1
Year ...	1·93	1·97	1·94	11·2	8·8	3·90	3·89	3·88	16·7	18·8

movements are important. Too much significance has been attached to surface temperature gradients and changes. For example, very large changes occur on the southern coast of Australia especially in spring and summer. Many of these are due to changes in the afternoon from a hot, dry northerly wind with clear skies to a cool moist southerly, with cloud. But on these occasions a large part of the change is due to the large diurnal variation in clear weather over the land and the very steep lapse rates which occur in the early afternoon. The fall of temperature at the surface is by no means a measure of the difference in internal energy of the air masses involved. It is not in summer, but in winter that most rain falls in this area. It is not easy to get a satisfactory measure of the significant north to south temperature gradient in the Australia-New Zealand Quadrant of the Southern Hemisphere, apart from the complications introduced by the effect of the Australian Continent. This is illustrated in

Fig. 11, which shows the mean temperature differences between various stations in the different months. For example, the annual variation at Dunedin, though considerably less than at inland stations in New Zealand, is much greater than that at Macquarie Island. Hence we have in Fig. 11, a maximum difference between Dunedin and Macquarie Island in February and a minimum in July. The difference between Wellington and Dunedin, however, has a different annual variation, the maximum being in May or June and the minimum in October. Between Auckland and Wellington the annual variation is small. The maximum is in late summer and early autumn while there is a flat minimum from winter to spring. For the whole difference between Auckland and Dunedin, the maximum is in April and the minimum in September to October. Most of these variations are of only local significance. There is also drawn in Fig. 11. a curve showing one third of the temperature difference between Norfolk Island and Macquarie Island. This is probably the best measure available of the general surface temperature gradient in the region. The annual variation is not large. The maximum is in February and the minimum in August.

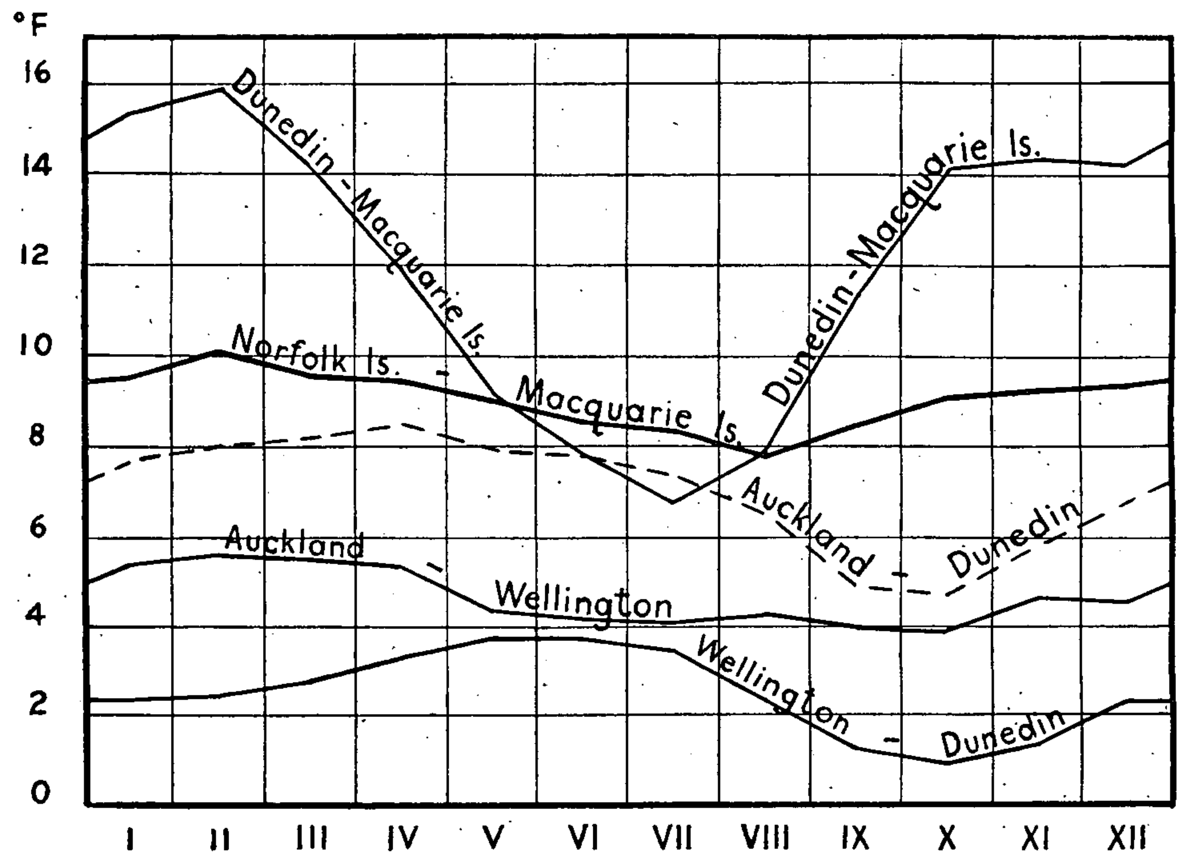


FIG. 11.—Temperature differences.

CHAPTER III

PRESSURE

I.—ADÉLIE LAND AND QUEEN MARY LAND

1.—Instruments and Methods.

Very brief notes regarding the instruments used at the Antarctic Stations will be found in Volumes IV and V of the present series in which are given hourly values of the air pressure in inches of mercury reduced to mean sea level and standard gravity. The hourly values were obtained from the traces of large barographs by Messrs. Short & Mason Ltd., the scale value being 2.5 inches to 1 inch of pressure. Unfortunately, there was evidently stiffness in the bearings at some stage in the lever systems of the barographs, as is shown by vertical movements of the traces taking place in a series of sudden steps. The effect is much less noticeable on the Queen Mary Land than on the Adélie Land traces. In order to reduce this effect to a minimum the instruments were tapped at frequent intervals. A certain amount of inaccuracy, however, undoubtedly remained, particularly at Adélie Land. The barograms were controlled by readings of mercury barometers. These were of the Kew pattern but whether of Marine or Station type is not known to the writer. There were sufficient checks to ensure that both barometers gave readings of a satisfactory accuracy. The barometer was read every six hours at Adélie Land and, usually, every three hours at Queen Mary Land. At Adelie Land the record was complete from the 2nd February, 1912 to the 14th December, 1913. The full program was not established at Queen Mary Land until the end of March, 1912. Thence onward the record was continued, except for short breaks, until the 18th February, 1913.

TABLE XX.

Pressure—Monthly Means.

Inches.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
							Adélie Land.						
1912 ...	...	29·268	29·080	29·098	29·030	29·040	29·141	29·131	29·496	28·978	29·178	29·149	...
1913 ...	29·151	29·176	29·374	29·147	29·282	29·445	29·051	29·237	29·004	28·912	29·297	29·442*	...
Means ...	29·151	29·222	29·227	29·122	29·156	29·242	29·096	29·184	29·250	28·945	29·238	29·247	29·173
							Queen Mary Land.						
1912 ...	...	...	29·018	29·053	29·085	29·043	28·997	29·041	29·289	28·890	29·126	29·111	...
1913 ...	29·187	29·151	...	...	...	...	...	...	...	...	...	...	29·083

* 14 days only, weighted ½.

2.—The Observations.

Mean Pressure.—The monthly mean pressures will be found in Table XX. In Fig. 12. are plotted corresponding means for Cape Evans, Adélie Land and Queen Mary Land. Each curve shows the low value for October and the abnormally high one for September, but otherwise there is surprisingly little correspondence. Though the Adélie Land means are generally lower than those for Cape Evans, this is not always the case. The coefficient of correlation between the 11 monthly means is only +0.67. The Queen Mary Land values are more definitely lower but the correlation with Cape Evans for 10 months, including the short record for March at Queen Mary Land is only +0·64. The correlation between the 12 monthly means given for Queen Mary Land and the corresponding means for Adelie Land is +0·81, indicating a closer relationship.

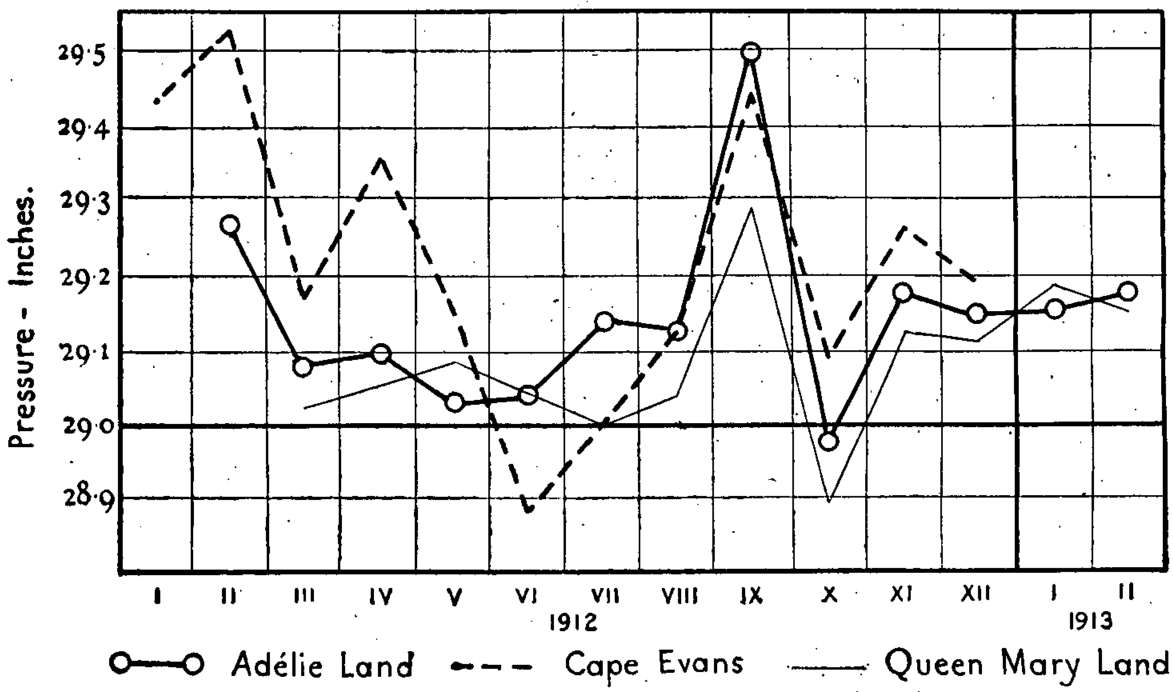


FIG. 12.—Comparison of monthly pressures.

According to Simpson (*) the pressure at McMurdo Sound is approximately 0·12 inch higher than at Captain Amundsen's Base at Framheim and 0·07 higher than at Cape Adare. From the simultaneous observations in 1912, Cape Evans is, on the average 0·065 inch higher than Adélie Land. Similarly, for the days on which there were contemporaneous observations, Adélie Land is, on the average, 0·045 inches higher than Queen Mary Land. From 5 years observations at McMurdo Sound the writer(†) found a mean pressure of 29·243 inches. From the above figures, therefore, we may take as preliminary values of the normal pressure at the various stations,—Framheim 29·12, McMurdo Sound 29·24, Cape Adare 29·17, Adélie Land 29·18, and Queen Mary Land 29·13 inches. From similar reasoning the normal at the Gauss Station would be 29·03. This value seems too low. The implicit assumption in these calculations that there is no variation of mean pressure between the three McMurdo Sound stations may be inaccurate. Furthermore the probable error of the difference between Hut Point and Gauss Station, on which the value for the latter is based, is high. Part

* G. C. Simpson. *British Antarctic Expedition.* 1910–1913, Meteorology.

† E. Kidson. *British Antarctic Expedition*—1907–1909 : Meteorology, Melbourne.

of the difference between the figures for Queen Mary Land and Gauss Station might, nevertheless, be accounted for by the steep pressure gradient outward from the Antarctic coast, due, doubtless, to the accumulation of cold air there.

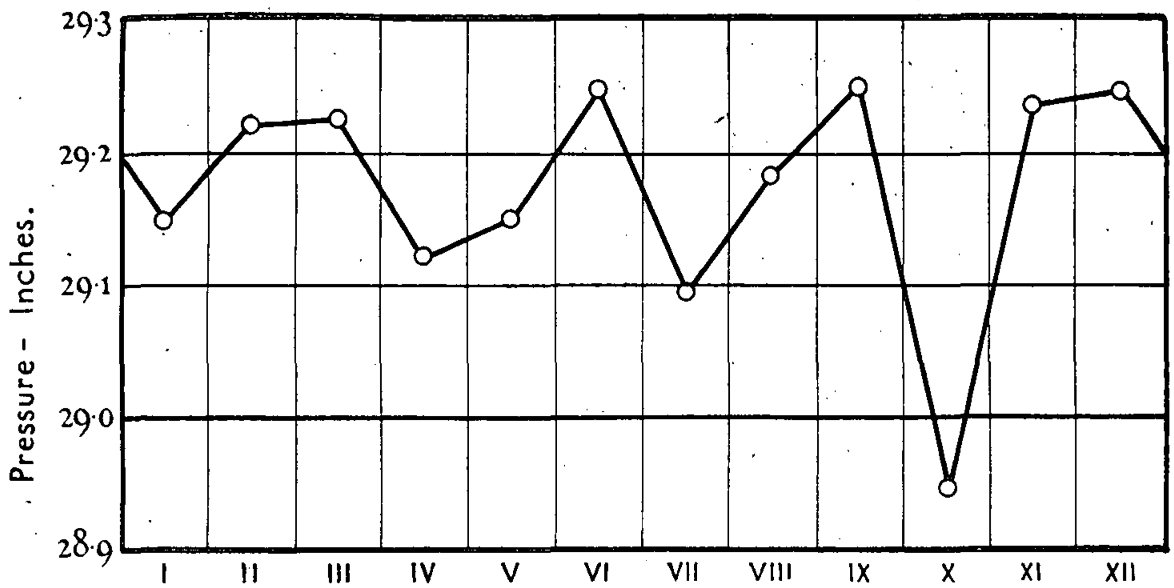


FIG. 13.—Annual Variation of Pressure, Adélie Land.

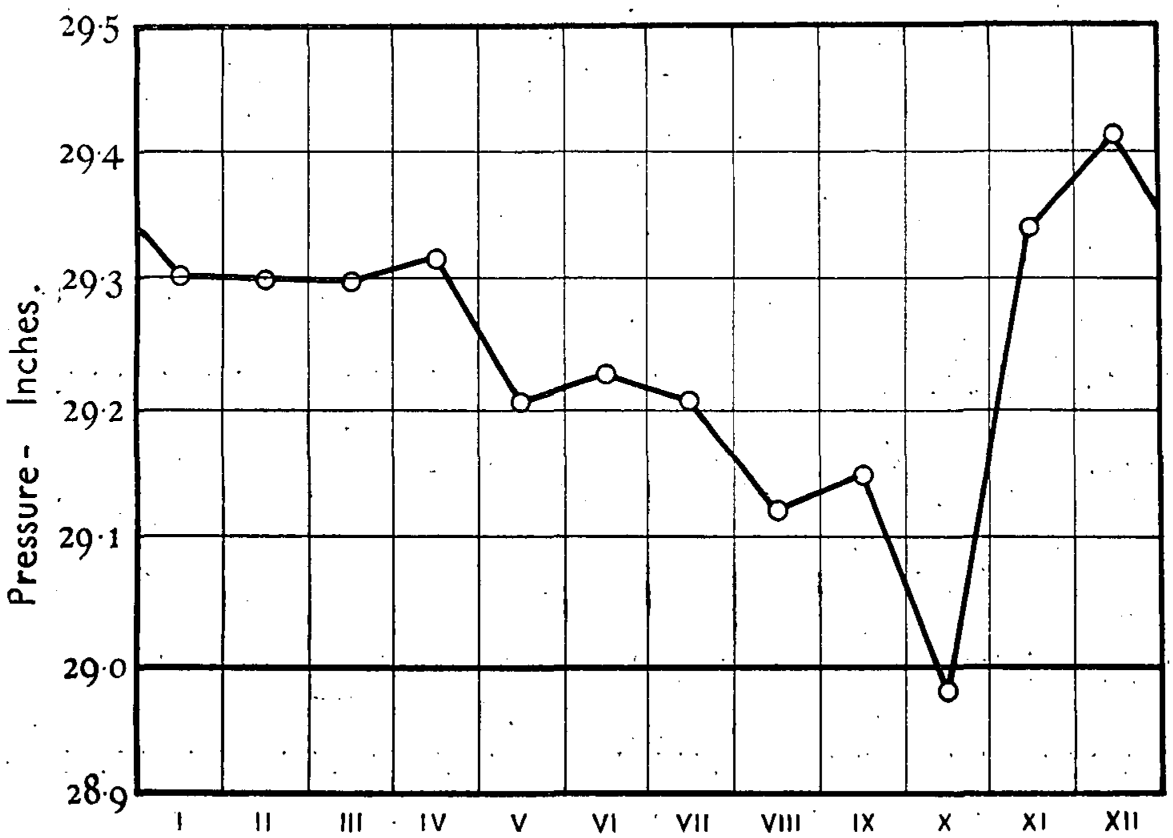


FIG. 14. Annual Variation of Pressure at Antarctic Stations; Ross Sea to Queen Mary Land.

Annual Variation.—Fig. 13 shows the mean pressure for each month at Adélie Land as derived from the 22½ months observations available. The number of observations is clearly not sufficient to give much idea of the annual variation. Fig. 14,

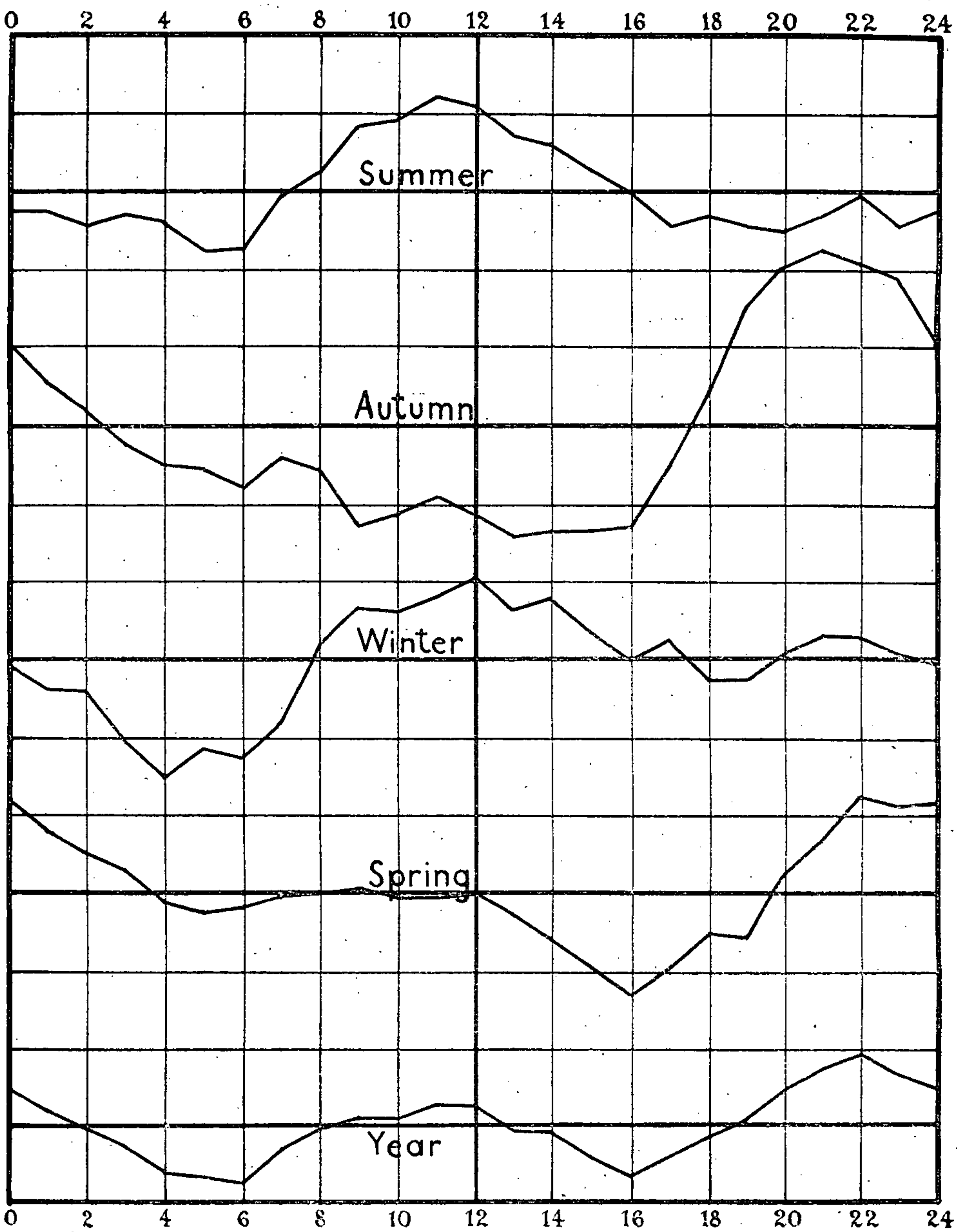


FIG. 15.—Diurnal Variation of Pressure, Adélie Land. One Vertical Division equals 0·004 inch.

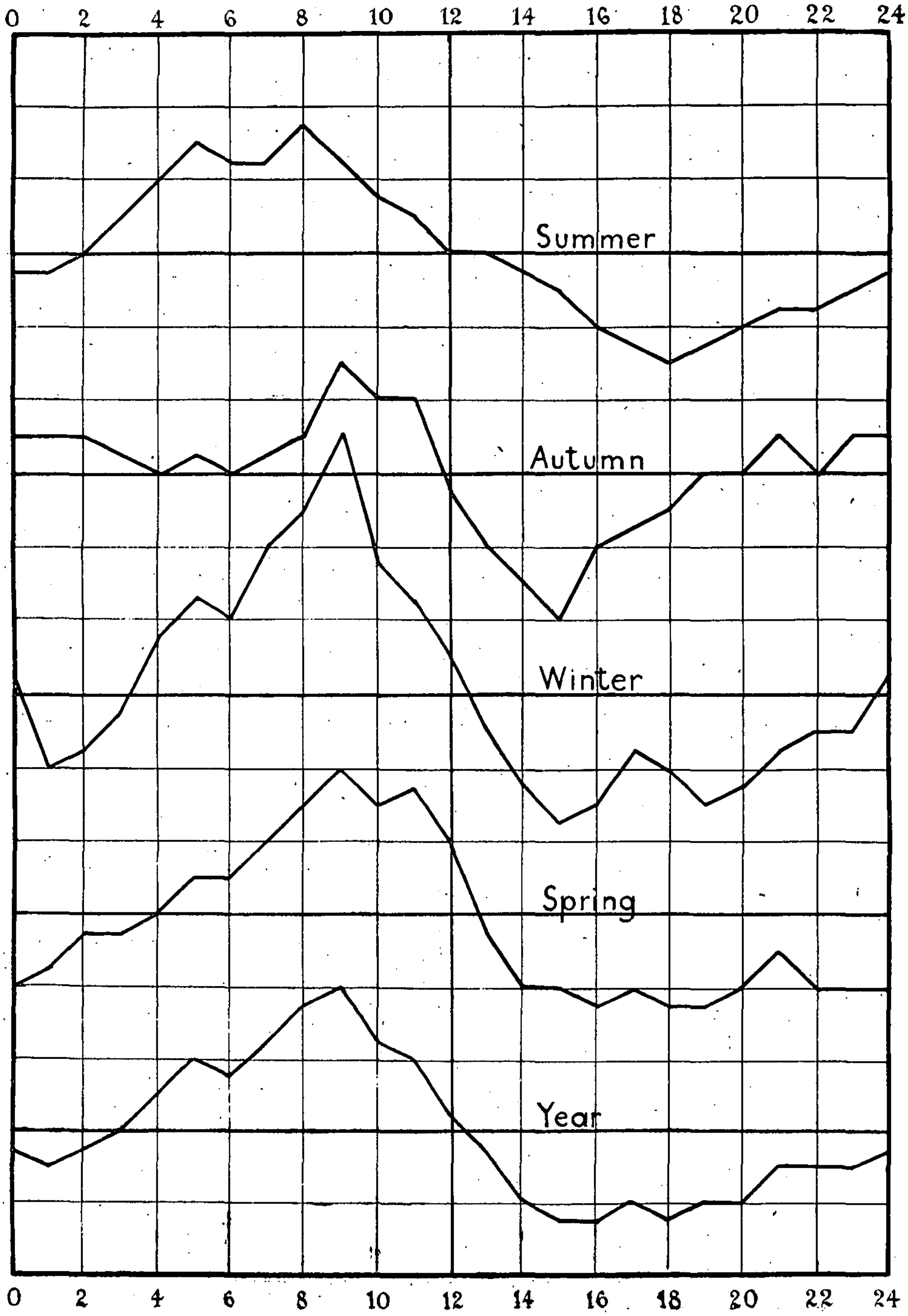


FIG. 16.—Diurnal Variation of Pressure, Queen Mary Land. One Vertical Division equals 0·004 inch.

TABLE XXI.

Pressure—Diurnal Inequalities.

Adélie Land. Thousandths of an Inch.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period.																								
*I	—2	—3	—2	—2	—3	—3	0	+1	+6	+5	+8	+5	+1	+2	+1	—1	—3	—2	0	+1	—1	—3	—5	—4
II	+1·5	+1·5	+1·5	+2·0	—1·5	—1·0	+1·0	+1·5	+3·0	+2·5	+3·0	+2·5	+1·0	0·0	—1·5	—1·5	—2·5	—2·0	—3·5	—4·0	—1·5	+1·5	+1·0	+1·0
III	+2·0	—3·0	—6·0	—5·5	—6·5	—7·0	—4·5	—4·0	—4·0	—2·0	0·0	+1·5	+0·5	—0·5	—2·0	—1·5	+1·5	+2·5	+6·5	+7·0	+8·0	+6·0	+4·5	+4·5
IV	0·0	—2·5	—4·5	—7·0	—8·0	—7·5	—7·0	—6·0	—6·5	—3·0	—1·0	—1·0	—1·5	—0·5	+0·5	+0·5	+1·5	+2·5	+7·0	+8·0	+8·0	+6·0	+7·0	+5·5
V	+4·5	+7·5	+8·0	+6·5	+8·0	+5·5	+7·0	+3·0	—4·5	—8·5	—9·5	—15·0	—15·5	—15·0	—14·0	—14·0	—9·0	+0·5	+5·0	+9·5	+11·5	+13·0	+11·0	+2·5
VI	0·0	—4·0	—9·5	—14·5	—12·5	—12·5	—10·5	—3·5	—1·0	—1·0	+2·5	+6·5	+7·0	+9·0	+8·0	+7·0	+6·5	+2·0	+2·0	+4·0	+5·0	+5·0	+3·0	+2·5
VII	—0·5	—1·5	+2·5	+1·5	+1·5	—1·5	+0·5	+5·0	+6·0	+4·5	+1·5	—3·0	—7·5	—7·0	—9·5	—9·0	—5·0	—1·5	0·0	+3·0	+4·0	+3·0	+1·0	—1·0
VIII	—4·0	—3·5	—6·0	—5·0	—2·5	—1·0	+0·5	+0·5	+3·0	+4·0	+6·0	+9·5	+8·0	+8·0	+6·0	+2·0	+1·5	—3·5	—5·0	—6·0	—5·0	—4·5	—3·5	—2·5
IX	+6·0	+5·5	+3·5	+1·5	0·0	—0·5	+1·5	+1·5	+2·0	+1·0	+1·0	+2·0	—0·5	—2·5	—4·0	—7·0	—7·0	—4·5	—3·5	—2·0	0·0	+2·0	+4·0	+7·0
X	+0·5	+1·5	+2·0	+1·0	0·0	—1·5	—1·5	—1·5	—2·0	—1·5	—0·5	—2·0	—3·5	—3·0	—4·5	—5·0	—0·5	0·0	—1·0	+3·5	+5·0	+6·5	+4·5	+1·0
XI	+3·0	—1·0	—1·5	—4·0	—3·0	—0·5	—0·5	0·0	+1·0	0·0	—1·0	0·0	0·0	—1·5	—3·0	—3·5	—4·0	—1·5	—2·5	+1·0	+3·0	+6·5	+5·0	+6·0
*XII	—5	—7	—6	—8	—6	—6	—3	0	+2	+5	+6	+8	+9	+8	+7	+4	+1	+1	0	—1	—1	—1	—4	—2
†Summer (XII, I, II)	—1·0	—1·8	—1·2	—1·5	—3·0	—2·8	—0·2	+1·0	+3·5	+3·8	+5·0	+4·5	+3·0	+2·5	+1·2	0·0	—1·8	—1·2	—1·8	—2·0	—1·2	—0·2	—1·8	—1·0
Autumn (III, IV, V)	+2·2	+0·7	—0·8	—2·0	—2·2	—3·0	—1·5	—2·3	—5·0	—4·5	—3·5	—4·5	—5·5	—5·3	—5·2	—5·0	—2·0	+1·8	+6·2	+8·2	+9·2	+8·3	+7·5	+4·2
Winter (VI, VII, VIII)	—1·5	—1·7	—4·3	—6·0	—4·5	—5·0	—3·2	+0·7	+2·2	+2·5	+3·3	+4·3	+2·5	+3·3	+1·5	0·0	+1·0	—1·0	—1·0	+0·3	+1·3	+1·2	+0·2	—0·3
Spring (IX, X, XI)	+3·2	+2·0	+1·3	—0·5	—1·0	—0·8	—0·2	0·0	+0·3	—0·2	—0·2	0·0	—2·0	—2·3	—3·8	—5·2	—3·8	—2·0	—2·3	+0·8	+2·7	+5·0	+4·5	+4·7
†† Year	+0·7	—0·2	—1·2	—2·5	—2·7	—2·9	—1·3	—0·2	+0·2	+0·4	+1·2	+1·1	—0·4	—0·4	—1·6	—2·6	—1·6	—0·6	+0·3	+1·8	+3·0	+3·6	+2·6	+1·9

* Means derived from one month only. † Derived from one December, one January and two Februaries, weighted equally. †† From mean of four seasons equally weighted.

TABLE XXII.

Pressure—Diurnal Inequalities.

Queen Mary Land. Thousandths of an Inch.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period.																								
1912.																								
IV	+12	+12	+7	+5	+1	—4	—5	—5	—3	—9	—9	—14	—16	—16	—15	—9	—5	+1	+6	+11	+14	+13	+14	+15
V	—8	—7	—5	—4	+1	+3	+7	+9	+15	+18	+17	+12	+7	+3	0	+2	—1	—5	—5	—10	—10	—13	—11	—10
VI	—6	—3	0	+4	+8	+8	+12	+16	+22	+13	+13	+8	+3	—2	—9	—9	—5	—10	—12	—13	—12	—11	—8	—7
VII	—3	+3	+7	+13	+14	+13	+17	+16	+21	+11	+8	+3	—6	—15	—16	—15	—15	—15	—16	—13	—6	—4	—2	+10
VIII	—4	—8	—9	—8	—8	—8	—4	—1	—2	—4	—6	—6	—2	+2	+4	+5	+10	+12	+11	+10	+10	+8	+5	—1
IX	+4	+6	+7	+7	+8	+4	+2	+5	+4	+2	+2	—3	—8	—11	—13	—11	—8	—10	—6	—4	—2	—2	0	+1
X	—8	—8	—10	—10	—6	—4	+2	+5	+11	+11	+13	+9	+7	+4	+3	0	+1	+1	—1	—1	—2	—4	—5	—6
XI	—4	—1	+1	+4	+5	+7	+8	+8	+8	+5	+5	+6	—1	—4	—3	—5	—5	—7	—7	—7	—3	—5	—7	—6
XII	—4	—5	—2	—1	+3	0	0	+2	+2	+2	+3	+3	+4	+2	+3	—1	—2	—4	—4	—2	—2	—3	—2	—3
1913.																								
I	+2	+2	+4	+8	+10	+11	+10	+12	+9	+7	+4	—1	—3	—4	—7	—9	—9	—9	—9	—9	—5	—4	—3	+1
II	0	+2	+3	+5	+6	+4	+4	+7	+3	+1	—1	—3	—1	0	—1	—2	—5	—5	—3	—1	—2	—1	—1	—1
Summer (XII, I, II)	—1	0	+2	+4	+6	+5	+5	+7	+5	+3	+2	0	0	—1	—2	—4	—5	—6	—5	—4	—3	—3	—2	—1
Autumn (III, IV, V)	+2	+2	+1	0	+1	0	+1	+2	+6	+4	+4	—1	—4	—6	—8	—4	—3	—2	0	0	+2	0	+2	+2
Winter (VI, VII, VIII)	—4	—3	—1	+3	+5	+4	+8	+10	+14	+7	+5	+2	—2	—5	—7	—6	—3	—4	—6	—5	—3	—2	—2	+1
Spring (IX, X, XI)	—3	—1	—1	0	+2	+2	+4	+6	+8	+6	+7	+4	—1	—4	—4	—5	—4	—5	—5	—4	—2	—4	—4	—4
Year	—2	—1	0	+2	+4	+3	+5	+7	+8	+5	+4	+1	—1	—4	—5	—5	—4	—5	—4	—4	—2	—2	—2	—1

however, shows a composite curve of annual variation derived from one year's observations at Framheim, five in McMurdo Sound, two at Cape Adare, two at Adélie Land and one at Queen Mary Land, each monthly mean being given equal weight. It probably gives a fair representation of the nature of the annual variation of pressure on the Antarctic Continent and particularly in this quarter. The principal features are (a) a maximum in December, (b) a subsidiary maximum in April, (c) a fall then to a minimum in October, followed by (d) a remarkably rapid rise in November. Simpson's data indicate that the annual variation was higher at Framheim than at McMurdo Sound and Fig. 12 also suggests an increase with latitude.

Diurnal Variation.—The mean diurnal inequalities, corrected for non-cyclic variation, for each month, the four seasons, and the year for Adélie Land and Queen Mary Land respectively, will be found in Tables XXI and XXII, while Figs. 15 and 16 give curves for the four seasons and the year. The values in the tables are in thousandths of an inch. The mean diurnal variation is to a large extent obscured in the monthly values by random variations. Most of the means for the seasons show two maxima, one in the late morning and the other in the late evening, with minima in between. At Adélie Land, in some seasons the first maximum is the more prominent and in others the second. This was the case also at McMurdo Sound (†). In the mean for the year there is little difference, according to the data at present available, between the morning and evening maxima at McMurdo Sound but the morning minimum is the lower. At Adélie Land the evening maximum is the higher and the morning minimum the lower but the curves for the four seasons differ markedly from one another. It is, therefore, not certain that the same result would be given by the mean for a large number of years.

At Queen Mary Land, where less than a year's observations are available, the curves are naturally less smooth than at the other stations. They are, however, more consistent and the morning maximum is definitely the greater in all. The evening maximum is not at all prominent. The afternoon minimum is much the lower.

At McMurdo Sound the maxima are at approximately 10 and 21 hours respectively, while at Adélie Land they are an hour later at 11 and 22 hours respectively. The morning maximum is at 9 hours at Queen Mary Land. The time of the evening one is uncertain but is most probably at 21 hours. The minima are at approximately 5 and 16 hours at McMurdo Sound and 6 and 16 hours at Adelie Land. The times of the Queen Mary Land minima, again, are uncertain but 1 hour and 17 hours appear the most probable. Thus the phase of the variation is considerably earlier at Queen Mary Land than at Adélie Land. The range is very similar at McMurdo Sound and Adélie Land but at Queen Mary Land it is much greater than at the other stations.

Table XXIII gives the harmonic analyses of the diurnal variation. Three terms are given. For Adélie Land no term after the second is significant. For Queen Mary Land it is possible that the third term has some significance. The amplitude of the 24-hour term is ·0012 inch at Adélie Land for the year while at Queen Mary Land it is ·0050 inch. These may be compared with ·0016 inch at McMurdo Sound. Queen Mary Land is probably the least windy of the three stations and has the largest diurnal

† E. Kidson. *British Antarctic Expedition.* 1907–1909, Meteorology, Melbourne.

TABLE XXIII.

Pressure—Harmonic Analysis of Diurnal Variation.

$$dP = a_1 \sin(\theta + A_1) + a_2 \sin(2\theta + A_2) + a_3 \sin(3\theta + A_3).$$

	Adélie Land.						Queen Mary Land.					
	a_1	A_1	a_2	A_2	a_3	A_3	a_1	A_1	a_2	A_2	a_3	A_3
	in.	°	in.	°	in.	°	in.	°	in.	°	in.	°
Summer (XII, I, II)	·0026	274	·0019	109	·0004	341	·0051	347	·0005	223	·0008	171
Autumn (III, IV, V)	·0060	115	·0031	178	·0005	184	·0027	28	·0027	182	·0018	355
Winter (VI, VII, VIII)	·0028	230	·0025	120	·0003	67	·0065	339	·0035	187	·0012	48
Spring (IX, X, XI)	·0027	71	·0025	129	·0007	239	·0052	326	·0023	170	·0010	335
Year	·0012	135	·0023	140	·0002	250	·0050	342	·0022	190	·0004	17
V, VI, VII	·0031	98	·0030	176	·0002	144	...	...	...	...	...	...

TABLE XXIV.

Pressure—Comparison of Calculated and Observed Amplitude and Phase of Semi-diurnal Variation.

Station.	Latitude.	Longitude.	Phase.			Amplitude.		
			Computed.	Observed.	C—O.	Computed.	Observed.	C/O.
	°S	°	°	°	°	in.	in.	
Framheim	78·6	163·6W	77	59	+18	·0033	·0025	1·3
McMurdo Sd.	77·6	166·5E	134	140	— 6	·0037	·0021	1·8
Adélie Land	67·0	142·7E	168	140	+28	·0049	·0023	2·1
Queen Mary Land ...	66·3	95·0E	221	190	+31	·0025	·0022	1·1
Gauss Station	66·0	89·6E	226	221	+ 5	·0021	·0017	1·3
Macquarie Is. ...	54·5	159·0E	153	174	—21	·0085	·0062	1·4

variation of temperature. One is tempted to ascribe the greater amplitude of the 24-hour term to these facts. In the year with which we are concered, however, the amplitude was greatest in winter when the temperature variation is very small. The relation to temperature variation is therefore not clear.

The semi-diurnal variation as has been found elsewhere is, considering its magnitude, remarkably constant in amplitude and phase at both stations. For the annual curve, the amplitude is ·0023 inch and the phase angle 140° at Adélie Land while at Queen Mary Land the figures are ·0022 inch and 190°. For McMurdo Sound they are ·0021 inch and 140°. Simpson (†) analysed the diurnal variation of pressure in various parts of the world into two terms, one representing a wave progressing round the Earth, and the other an oscillation between Pole and Equator. The first component is constant in phase according to local time and the second according to universal time in all parts of the world. The phase of the resultant variation therefore varies from place to place. The first component is expressed by —

$$0{\cdot}937 \cos^3 \varphi \sin (2\theta + 154°).$$

and the second by—

$$0{\cdot}137 (\sin^2 \varphi - \tfrac{1}{3}) \sin (2 \theta + 105° - 2\lambda)$$

where φ is the latitude, θ the time, and λ the longitude, and the pressure is in millimetres. In Table XXIV is a comparison of the observed and computed amplitudes and phases for several of the stations in this quarter of the Antarctic.

The computed amplitudes are too high, but in view of the complexity of the phenomenon and its small magnitude, the agreement especially as regards phase is rather surprising. It has now been fairly well established, especially by recent work of G. I. Taylor and C. L. Pekeris, that the 12-hour pressure variation is a resonance wave in the atmosphere initiated by solar heating, but the physical theory of the precise form of the vibration as brought out by Simpson's work has not been evolved.

Non-Periodic Variations.—Table XXV contains some data regarding variability at Adélie Land. First are given the absolute maxima and minima for each month followed by the difference between them. The value of 30·430 in September, 1912, is extraordinarily high for an Antarctic Station and probably the highest ever recorded. Strangely enough, the lowest reading recorded was 27·774 inches in September, 1913. This, again, is an extremely low value. It is lower than any reading recorded in McMurdo Sound. The monthly range is very high, the average being 1·398 inches compared with 1·10 inches for McMurdo Sound. In July, 1913, the value was 2·037 inches. The range is greatest in winter and least in summer while in autumn it is greater than in spring. The next two columns show the greatest departures in each month from the mean for the month. The negative departures are in most cases greater than the positive. The last three columns give the means of the daily maxima and minima in each month and the mean daily range. The latter is very large but not so large as that at South Georgia which Simpson gives as 0·311 inch. The annual variation is similar to that of the monthly range. The total range for the 22½ months was 2·556 inches.

Another measure of the variability is the interdiurnal variation. This has been tabulated from the hourly values for 6, 12, 18 and 24 hours at Adélie Land, at which hours eye observations were made of the barometer. The mean values for each month

† G. C. Simpson. *British Antarctic Expedition*—1910-1913 : Meteorology.

TABLE XXV.

Pressure—Variability, Maxima and Minima.

Adélie Land. Inches.

Period.		Absolute.			Difference from Mean for Month.		Mean Daily.		
		Maximum.	Minimum.	Range.	Abs. Max.	Abs. Min.	Maximum.	Minimum.	Range.
1912.									
II	...	29·806	28·285	1·521	·538	·983	29·365	29·161	·204
III	...	29·532	28·581	·951	·452	·499	29·204	28·968	·236
IV	...	29·911	28·130	1·781	·813	·968	29·251	28·920	·331
V	...	30·030	28·447	1·583	1·000	·583	29·225	28·882	·343
VI	...	29·492	27·965	1·527	·452	1·075	29·216	28·859	·357
VII	...	29·798	28·319	1·479	·657	·822	29·338	28·013	·325
VIII	...	29·715	28·383	1·332	·584	·748	29·301	28·970	·331
IX	...	**80·430**	28·620	1·810	·934	·876	29·623	29·374	·249
X	...	29·330	28·370	·960	·352	·608	29·086	28·879	·207
XI	...	29·751	28·375	1·376	·573	·803	29·278	29·083	·195
XII	...	29·699	28·578	1·121	·550	·571	29·230	29·063	·165
1913.									
I	...	29·491	28·673	·818	·340	·478	29·221	29·103	·118
II	...	29·529	28·227	1·302	·353	·949	29·263	29·045	·218
III	...	30·040	28·483	1·557	·666	·891	29·482	29·262	·220
IV	...	29·864	28·538	1·326	·717	·609	29·284	28·923	·361
V	...	30·015	28·700	1·315	·733	·582	29·394	29·142	·252
VI	...	29·984	28·812	1·172	·539	·633	29·577	29·354	·223
VII	...	29·850	27·813	2·037	·799	1·238	29·200	28·893	·307
VIII	...	29·998	28·218	1·780	·761	1·019	29·396	29·067	·329
IX	...	29·537	*27·774*	1·763	·533	1·230	29·138	28·693	·445
X	...	29·620	28·235	1·385	·708	·677	29·036	28·816	·220
XI	...	29·734	28·880	·854	·437	·417	29·393	29·202	·191
Whole Period	...	30·430	27·774	2·556	...	...	...	...	...
Mean	...	...	...	1·398	·613	·785	...	...	·265

TABLE XXVI.

Pressure—Mean Interdiurnal Variation.

Adélie Land. Inches.

Hour L.M.T.	Sign.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Year.
							From Hourly Values.							
6	+	·113	·125	·200	·233	·220	·254	·290	·283	·196	·157	·137	·131	·198
	—	·132	·151	·151	·272	·251	·203	·278	·289	·209	·136	·167	·185	·205
	Mean	·120	·137	·170	·249	·235	·225	·284	·286	·203	·146	·149	·155	·202
12	+	·099	·181	·211	·237	·237	·209	·308	·224	·164	·149	·152	·148	·198
	—	·124	·162	·203	·276	·268	·260	·287	·310	·227	·190	·141	·133	·220
	Mean	·109	·174	·207	·253	·252	·237	·293	·260	·197	·166	·147	·140	·209
18	+	·146	·213	·202	·277	·283	·264	·244	·240	·188	·155	·154	·125	·210
	—	·113	·170	·215	·238	·229	·248	·280	·304	·256	·199	·174	·158	·221
	Mean	·129	·188	·208	·257	·253	·256	·260	·269	·220	·174	·162	·140	·215
24	+	·107	·191	·196	·281	·273	·264	·290	·318	·195	·155	·166	·145	·218
	—	·137	·146	·177	·220	·218	·229	·281	·275	·214	·194	·158	·156	·206
	Mean	·118	·164	·186	·249	·242	·245	·286	·295	·205	·172	·162	·151	·212
Mean	+	·115	·175	·202	·255	·251	·247	·282	·263	·185	·154	·152	·136	·206
	—	·125	·157	·186	·250	·240	·239	·282	·293	·226	·178	·159	·157	·213
	Mean	·119	·166	·193	·252	·245	·241	·281	·278	·206	·165	·155	·146	·209
							From Daily Means.							
	+	·086	·146	·162	·248	·189	·181	·247	·198	·149	·140	·131	·111	·166
	—	·098	·132	·168	·179	·212	·199	·224	·271	·206	·139	·116	·133	·173
	Mean	·091	·139	·165	·211	·202	·190	·235	·229	·176	·139	·124	·122	·169

TABLE XXVII.

Pressure—Interdiurnal Variation, Percentage Frequency of Various Ranges. From Hourly Values.

Adélie Land. Inches.

Period	Negative.														Positive.												
	From / To	1·200 / 1·299	1·100 / 1·199	1·000 / 1·099	·900 / ·999	·800 / ·899	·700 / ·799	·600 / ·699	·500 / ·599	·400 / ·499	·300 / ·399	·200 / ·299	·100 / ·199	·000 / ·099	·000 / ·099	·100 / ·199	·200 / ·299	·300 / ·399	·400 / ·499	·500 / ·599	·600 / ·699	·700 / ·799	·800 / ·899	·900 / ·999	1·000 / 1·099	1·100 / 1·199	1·200 / 1·299
6 hrs. Summer	...	...	...	...	...	...	...	...	0·8	0·8	3·1	9·2	12·3	17·7	28·5	16·2	5·4	5·4	0·8	...	...	...	...	...	...	...	...
Autumn	...	...	...	...	0·5	...	1·1	...	1·6	4·4	6·0	9·3	13·7	13·9	13·9	12·0	8·2	6·0	4·9	3·8	0·5	...	...	...	...	...	...
Winter	...	...	...	...	0·5	1·1	1·6	1·1	1·6	5·5	4·4	8·8	10·9	15·9	9·8	12·6	7·1	7·7	4·4	2·2	2·2	1·6	0·5	0·5	...	...	...
Spring	...	...	...	...	...	...	...	1·1	0·5	1·6	3·8	8·2	13·1	19·4	21·0	15·9	9·8	1·6	3·3	0·5	...	...	...	...	...	...	...
Year	...	...	...	...	0·3	0·3	0·7	0·6	1·2	3·2	4·4	8·8	12·5	16·7	17·5	14·0	7·8	5·2	3·5	1·8	0·7	0·4	0·1	0·1	...	...	...
12 hrs. Summer	...	...	...	...	...	...	...	...	0·8	0·8	4·5	8·3	14·4	22·0	22·7	11·4	9·8	2·3	3·0	...	...	...	...	...	...	...	...
Autumn	...	...	...	...	...	...	2·2	...	3·3	2·2	6·7	7·8	12·2	13·3	15·0	10·0	11·1	6·7	5·6	2·2	1·1	...	...	...	...	...	...
Winter	...	...	...	0·5	0·5	0·5	1·1	3·2	4·3	4·3	2·7	7·0	8·1	13·5	12·4	12·4	14·6	5·4	3·8	2·2	1·6	1·1	...	...	...	...	0·5
Spring	...	...	...	...	...	0·6	...	...	1·7	3·3	5·0	6·7	11·1	16·7	21·1	20·0	7·2	3·9	2·2	0·6	...	...	...	...	...	...	...
Year	...	...	...	0·1	0·1	0·3	1·2	0·9	2·7	2·8	4·7	7·4	11·2	16·0	17·5	13·6	10·8	4·7	3·7	1·3	0·7	0·3	...	...	...	...	0·1
18 hrs. Summer	...	...	...	...	...	...	...	...	0·8	3·0	2·3	7·6	15·2	23·5	15·9	15·2	11·4	2·3	2·3	...	...	0·8	...	...	...	...	...
Autumn	...	...	...	0·5	...	1·1	1·1	...	2·2	2·7	5·5	11·5	12·6	15·6	11·7	10·4	12·6	3·8	3·3	3·8	1·1	...	...	0·5	...	...	...
Winter	...	...	...	...	0·5	0·5	0·5	1·6	4·4	5·5	6·6	6·6	8·8	12·1	15·4	11·5	10·4	4·4	6·6	2·2	2·2	...	...	...	...	0·5	...
Spring	...	...	...	...	...	...	1·6	0·5	2·7	1·6	2·7	7·6	9·7	16·5	24·1	15·7	8·1	4·3	2·2	2·7	...	...	...	...	...	...	...
Year	...	...	...	0·1	0·1	0·4	0·9	0·6	2·6	3·2	4·4	8·4	11·3	16·4	16·8	13·0	10·6	3·8	3·7	2·3	0·9	0·1	...	0·1	...	0·1	...
24 hrs. Summer	...	...	...	...	...	...	...	0·8	...	1·5	2·3	9·2	19·1	19·1	22·1	13·0	6·9	4·6	0·8	...	0·8	...	...	...	...	...	...
Autumn	...	...	...	...	...	...	0·5	3·3	1·6	2·2	6·5	8·7	12·5	19·6	13·6	7·6	8·7	6·5	2·7	2·7	1·6	1·6	...	...	...	...	...
Winter	...	...	...	...	...	...	1·1	3·3	2·2	7·7	4·4	11·6	8·3	14·3	9·9	7·7	12·1	6·6	4·4	4·4	0·6	1·1	...	...	0·6	0·6	...
Spring	...	...	...	...	...	...	0·6	1·1	1·1	2·8	3·9	8·3	11·6	17·4	18·5	17·1	9·9	2·8	2·8	1·7	0·6	...	...	...	...	...	...
Year	...	...	...	...	...	...	0·6	2·2	1·3	3·7	4·4	9·4	12·4	17·5	15·6	11·2	9·6	5·2	2·8	2·4	0·9	0·7	...	...	0·1	0·1	...
Year Mean	...	...	...	0·1	0·2	0·3	0·7	1·1	2·0	3·2	4·5	8·5	11·9	16·6	16·8	13·0	9·6	4·7	3·3	2·0	0·8	0·4	0·1	0·1	0·0	0·1	0·0
July Mean	...	...	...	0·4	...	0·4	1·2	2·8	3·2	6·1	3·6	7·3	8·5	14·5	12·1	10·9	10·9	4·0	4·4	4·8	1·2	1·6	...	0·4	...	...	0·8
January Mean	...	...	...	...	...	...	...	...	...	0·8	1·6	6·4	12·1	20·9	31·5	13·7	8·9	2·4	1·6	...	...	...	...	...	...	...	...
Summer Mean	...	...	...	...	...	...	...	0·2	0·6	1·5	3·0	8·6	15·2	20·6	22·3	14·0	8·4	3·6	1·7	...	0·2	0·2	...	...	...	...	...
Autumn Mean	...	...	...	0·1	0·1	0·3	1·2	0·8	2·2	2·9	6·2	9·3	12·8	15·6	13·6	10·0	10·2	5·8	4·1	3·1	1·3	0·4	...	...	...	...	...
Winter Mean	...	...	...	0·1	0·4	0·5	1·1	2·3	3·1	5·8	4·5	8·5	9·0	13·9	11·9	11·0	11·0	6·0	4·8	2·8	1·6	1·0	0·1	0·1	0·1	0·1	0·1
Spring Mean	...	...	...	...	...	0·1	0·6	0·7	1·5	2·3	3·8	7·7	11·4	17·5	21·2	17·2	8·8	3·2	2·6	1·4	0·1	...	...	...	...	...	...

are given in Table XXVI. If there is any diurnal variation it is probably very small and no importance can be attached to the differences between the different hours shown by the table. The mean value for the year for changes of both signs is 0·209 inch. The annual variation is again similar to that of the monthly and daily ranges. The winter mean 0·267 inch is almost twice the summer one of 0·144 inch, while the values for autumn and spring are 0·230 and 0·175 inch respectively. The negative changes are in the mean greater than the positive ones in most months, but by no means invariably so. It is difficult to say merely from an inspection of the barograms precisely how this difference arises. There is no great asymmetry, in the mean, between the rising and falling arms of pressure maxima and minima. The explanation probably is that the pressure is often high and fairly uniform but with a slight rising tendency.

The last three rows of Table XXVI give the interdiurnal variation as derived from the daily means. It has the same characteristics as that derived from the hourly values but is approximately one fifth smaller.

The nature of the annual variation in variability is brought out very clearly in Table XXVII which gives the percentage frequency of various ranges of the interdiurnal change as derived from the hourly values. Figures are given for July when the variability is greatest, January when it is least, for the four seasons, and for the year. The difference between January and July and summer and winter are very striking, the range being much more restricted in the summer months. It is not till high values are reached that negative changes become more frequent than positive.

Changes of over an inch in 24 hours were recorded on 7 occasions. Of these, 5 were positive changes and only 2 negative. They were associated with four separate pressure movements on 12–13 May, 1912, 24–25 June, 1912, 22–24 July, 1912, and 10–12 July, 1913. Of these, the last two were accompanied by both up and down variations of over an inch in 24 hours. The greatest change was a rise of 1·215 inch from 13 hours on the 23rd to 13 hours on the 24th June, 1912.

The figures show that the variability of pressure at Adélie Land, and the same is true of Queen Mary Land, is very high but it probably increases for some considerable distance northwards over the Southern Ocean.

The annual variation of variability appears to be associated closely with that of temperature. This was pointed out by Knoch in connection with the *Deutschland* observations in the Weddel Sea as discussed by him (Berlin 1924). It is surprising that there is little correlation with pressure. The controlling factor may be the poleward gradient of temperature. On the latter, frontal activity may be expected to depend and hence the steepness of pressure gradients in frontal zones.

Pressure Waves.—Pressure waves in the Antarctic have been discussed by numerous authors. The barograms of any antarctic station are characterized by marked rises and falls of pressure, of periods of the order of several days, which often show considerable regularity. The same "waves" are usually apparent on the traces of all stations in the same region. When the distance between stations becomes of the order of 1,000 miles, however, the correspondence between the barograms becomes much less marked and it is usually difficult, for example, to identify a wave which passes Adélie Land with one which has passed Queen Mary Land some days before. In Australia the problem is much easier since the waves are seen to correspond with the passage of moving anticyclones and intervening troughs. Even there, however, conditions are far from simple and it is by no means always possible to say what should be regarded as an anticyclone, when an anticyclone has disappeared, or when a new one has formed. This problem has been discussed in Volume VII of this series. Waves sometimes appear to die out while at other times fresh ones form. In the Antarctic, conditions would be less favourable than in Australia even if there were a close network of stations but with the few records available they become very baffling. It is, of course, possible to set some definite criterion as to what should be regarded as a wave and so eliminate the personal element in their identification. But pressure fluctuations vary with latitude and, as we have just seen, with season. A criterion which is appropriate for one station and season is, therefore, usually not so for another. At the same time, a wave which can be quite definitely traced over a long course may in a certain part be much reduced in amplitude by what may be called fortuitous circumstances. The waves, therefore, are very elusive quantities whose properties it is very difficult to specify. It would be possible to apply a periodogram analysis to the barograms or to search for and determine the amplitude of waves of various periods which are believed to exist in other parts of the world. This has frequently been done, especially by German authors. But the writer does not find these methods very convincing, or their results of much practical value.

During the period under discussion the maxima and minima on the Queen Mary Land curves were usually very marked. 345 days' record are available and 72 distinct maxima were noted, as shown in the first part of Table XXVIII. This gives a mean length of wave of 115 hours and a mean range from crest to trough of 0·517 inches.

TABLE XXVIII.—*Pressure Waves at Queen Mary Land.*

	Period.	No. of Waves.	Mean Length of Wave.	Mean Range.
			hours.	inches.
First Count	Year (345 days)	72	115	0·517
	IV–IX	43	102	0·580
	X–III	29	134	0·423
Second Count	Year (345 days)	54	153	0·598
	IV–IX	30	147	0·713
	X–III	24	162	0·452

For the winter half-year from April to September there were 43 waves of length 102 hours and range 0·580 inches. For the other half-year the figures are 29, 134 and 0·423 respectively. The greater length found for the waves in the summer half-year is nevertheless, due to the smaller amplitude of pressure changes and consequent recognition of fewer waves. Some of the waves chosen were less prominent than others or occurred in closer proximity to others than usual. It was, therefore, possible to make a second choice, of the more prominent waves the results of which are given in the second part of Table XXVIII. The mean length of wave so obtained is 153 hours. This is practically the same as that found for McMurdo Sound by Simpson and consequently the figures are more comparable with his than those from the first count. The mean for 5 years at McMurdo Sound is a wave length of 152 hours and a range of 0·558 inches. The range is rather less than that at Queen Mary Land.

In a similar manner waves can be picked out on the Adélie Land curves which give the same average length as that found at McMurdo Sound. A few additional ones might have been included but those chosen certainly include all the more prominent ones. The figures for these, as derived from the whole period at Adélie Land together with the corresponding data for McMurdo Sound are given in Table XXIX. The range is considerably greater at Adélie Land than at McMurdo Sound, as would have been expected. The annual variation is similar for the two regions but less pronounced as regards wave length at Adélie Land than in McMurdo Sound. This is probably not real but due to the greater amplitude of the waves and to more being, consequently, picked out in summer.

From April, 1912, to January, 1913, while 51 or 66 waves according to the first or second count, were passing Queen Mary Land, 55 or 58 anticyclones according to two separate estimates were crossing Australia. Similarly while 53 of the waves above dealt with were passing Adélie Land, 66 or 70 anticyclones were crossing Australia. It will be seen, therefore, that the period of the Antarctic waves is very similar to that of the passage of anticyclones to the northwards.

TABLE XXIX.—*Pressure Waves at Adélie Land.*

Adélie Land.				McMurdo Sound.	
Period.	No of Waves.	Mean Length of Wave.	Mean Range.	Mean Length of Wave.	Mean Range.
		hours.	inches.	hours.	inches.
Summer	18	175	0·532	197	0·464
Autumn	27	158	0·732	152	0·473
Winter	32	138	0·784	131	0·652
Spring	29	152	0·736	142	0·595
Year	106	153	0·715	152	0·558

The monthly means of pressure at Adélie Land were correlated with those at various stations in temperate latitudes in the Southern Hemisphere but no statistical significance could be attached to the results.

II.—MACQUARIE ISLAND

1.—Instruments and Methods.

Volume III of this series contains tables of the hourly values of pressure reduced to sea level at the Macquarie Island Station for the periods from the 1st January, 1912, to the 30th November, 1913, and the 1st December, 1914, to 30th November, 1915. The records for the intervening period were unfortunately lost when the relieving vessel disappeared with all hands. Even for this period, however, there are available the readings at 9 a.m. and 6 p.m. which were communicated daily to Australia by wireless telegraphy.

The details supplied with regard to the instruments and methods of reduction are very meagre. The meteorological staff at Macquarie Island was, however, all seconded from that of the Commonwealth Meteorological Bureau and there is no doubt that the readings of the mercury barometer were reduced according to the methods approved internationally at the time and that the barometer itself had developed no important error. It was situated at only 30 feet (9m.) above sea level so that the altitude correction can introduce no complications. The hourly readings of pressure were derived from the records of a barograph standardized by readings of the barometer at 9, 15 and 21 hours local mean time. Both barometer and barograph were, so far as is known to the writer, of the same type as those used at the Antarctic Stations. The barograph was a very good one, the trace quite satisfactory and the record unbroken, except as the result of the disaster above mentioned.

2.—Observations.

Mean Pressure and Annual Variation.—The monthly mean pressures are given in Table XXX. For the months when only two observations were available per day, the mean of these was reduced to the mean of day by means of corrections derived from the diurnal variation in the other months. The correction required, is, however, very slight. In the same table are given the corresponding means for the New Zealand Stations Dunedin, Christchurch and Wellington. The accuracy of the Dunedin readings for 1912 is not high owing to the health of the observer failing. The barometer was probably reading 0·060 inch lower than in the following years. The correlations between the pressures at Macquarie Island and in New Zealand are surprisingly low. For the monthly means they are +0·44 for Dunedin and +0·40 for Christchurch. The correlation between Christchurch and Dunedin on the other hand is +0·96. The latitudes are respectively, Macquarie Island 54° 30′ S., Dunedin 45° 52′ S., and Christchurch 43° 31′ S. The New Zealand figures are based on 9 a.m. readings only.

TABLE XXX.

Pressure—Monthly Means.

Inches.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Year.
							Macquarie Island.						
1912 ...	29·399	29·610	29·539	29·526	29·645	29·603	29·824	29·544	29·373	29·284	29·620	29·434	29·538
1913 ...	29·179	29·443	29·540	29·651	29·535	29·634	29·489	29·632	29·389	29·347	29·430	29·552	29·484
1914 ...	29·379	29·581	29·754	29·585	29·580	29·540	29·604	29·507	29·409	29·281	29·343	29·408	29·498
1915 ...	29·382	29·459	29·455	29·516	29·615	29·408	29·548	29·705	29·401	29·308	29·111	...	...
Means ...	29·335	29·521	29·572	29·570	29·594	29·546	29·616	29·597	29·393	29·305	29·376	29·465	29·491
							Wellington (9h.).						
1912 ...	29·829	30·016	29·935	29·912	30·137	29·901	29·995	30·081	29·560	29·871	29·867	29·966	29·922
1913 ...	29·831	29·949	29·944	30·157	29·780	30·084	29·946	29·870	30·113	29·921	29·671	29·769	29·920
1914 ...	29·978	29·959	30·099	29·908	30·017	29·955	29·963	30·076	30·148	30·091	29·893	29·834	29·993
1915 ...	29·918	29·892	29·990	30·071	30·150	29·805	30·219	30·093	30·017	29·849	29·685	...	...
Means ...	29·889	29·954	29·992	30·012	30·021	29·936	30·031	30·030	29·960	29·933	29·779	29·856	29·949
							Christchurch (9h.).						
1912 ...	29·764	29·957	29·879	29·846	30·099	29·843	30·039	30·007	29·474	29·775	29·801	29·876	29·863
1913 ...	29·721	29·858	29·840	30·085	29·780	30·011	29·872	29·831	29·982	29·834	29·602	29·721	29·845
1914 ...	29·841	29·892	30·053	29·816	30·020	29·890	29·887	30·010	30·028	29·962	29·771	29·704	29·906
1915 ...	29·815	29·790	29·936	29·994	30·056	29·735	30·116	30·039	29·897	29·725	29·544	...	...
Means ...	29·785	29·874	29·927	29·935	29·989	29·870	29·978	29·972	29·845	29·824	29·680	29·767	29·870
							Dunedin (9h.).						
1912 ...	29·691	29·906	29·836	29·817	30·025	29·758	30·001	29·895	29·413	29·676	29·730	29·774	29·794
1913 ...	29·708	29·857	29·838	30·087	29·763	30·010	29·885	29·854	29·942	29·828	29·606	29·750	29·842
1914 ...	29·842	29·900	30·048	29·789	30·020	29·884	29·891	30·002	30·029	29·936	29·769	29·689	29·900
1915 ...	29·806	29·767	29·951	29·992	30·049	29·748	30·105	30·022	29·865	29·689	29·516	...	...
Means ...	29·762	29·858	29·918	29·921	29·964	29·850	29·970	29·943	29·812	29·782	29·655	29·738	29·848

TABLE XXXI.

Pressure—Harmonic Analysis of Annual Variation at Macquarie Island.

$$dP = a_1 \sin(\theta + A_1) + a_2 \sin(2\theta + A_2) + a_3 \sin(3\theta + A_3).$$

a_1	A_1	a_2	A_2	a_3	A_3
in. 0·125	° 309	in. 0·032	° 33	in. 0·060	° 178

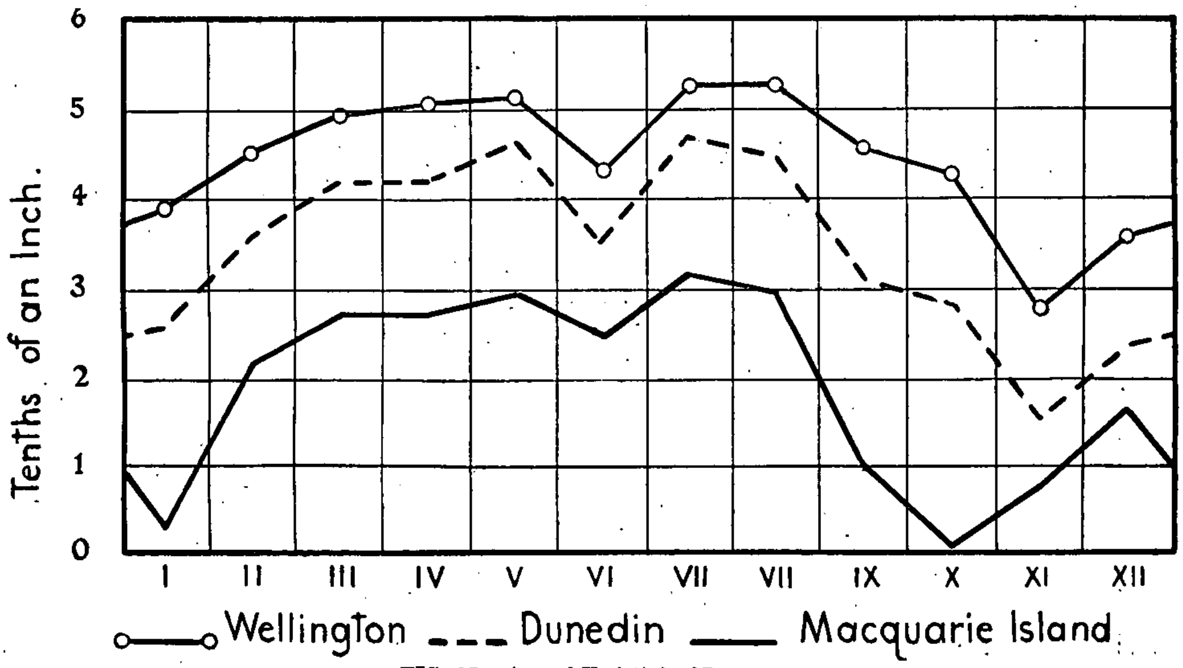


FIG. 17.—Annual Variation of Pressure.

In Fig. 17. are plotted the monthly means given in Table XXX for the 3 to 4 years record at Wellington, Dunedin and Macquarie Island respectively. The difference between Macquarie Island and the other stations is 0·2 inch greater than shown in the figure. The annual mean derived from these monthly means at Macquarie Island is 0·357 inches lower than that for Dunedin, 0·379 inches than that for Christchurch and 0·458 than that for Wellington. The average difference between Auckland (Lat. 36° 51′ S.) and Dunedin is 0·158 inches. These figures indicate mean westerly components of gradient winds between Auckland and Dunedin of 10·5 miles per hour (5 m/s) and between Dunedin and Macquarie Island of 20 miles per hour (9 m/s) approximately. Fig. 18. shows the monthly mean pressures at 9 a.m. for Wellington and Dunedin as derived from 74 and 72 years respectively, the scale is double that of Fig. 17. The

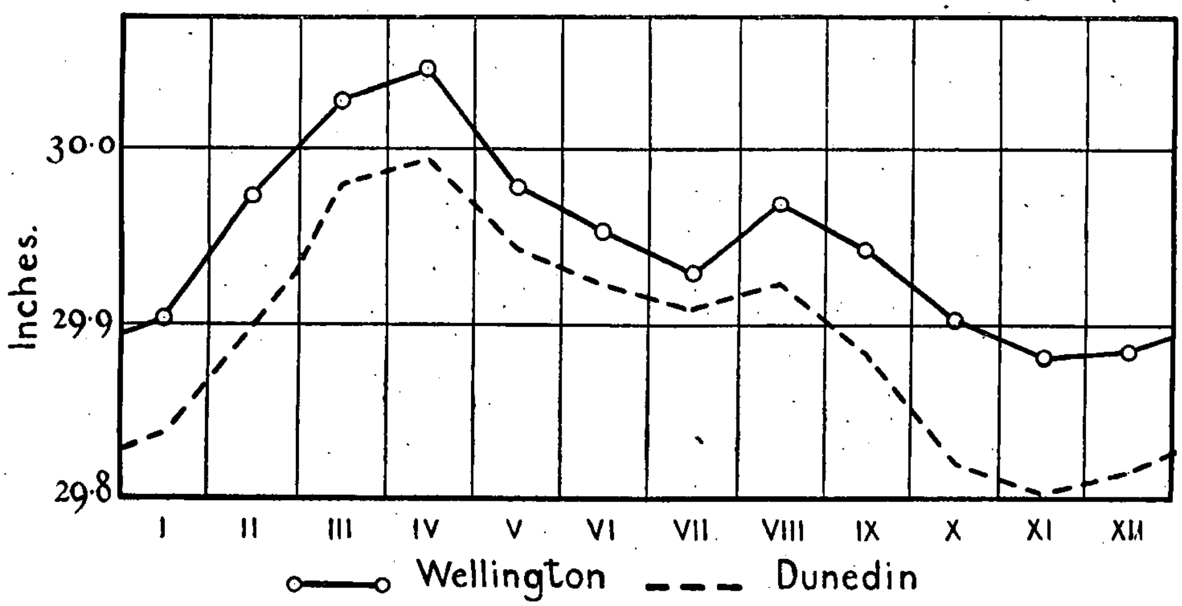


FIG. 18.—Annual Variation of Pressure.

figure shows that four years is far from sufficient to give an accurate idea of the normal annual variation of pressure. The second maximum appearing on the New Zealand curves becomes more important as the latitude decreases.

Table XXXI gives the result of a harmonic analysis of the annual variation but its significance is uncertain.

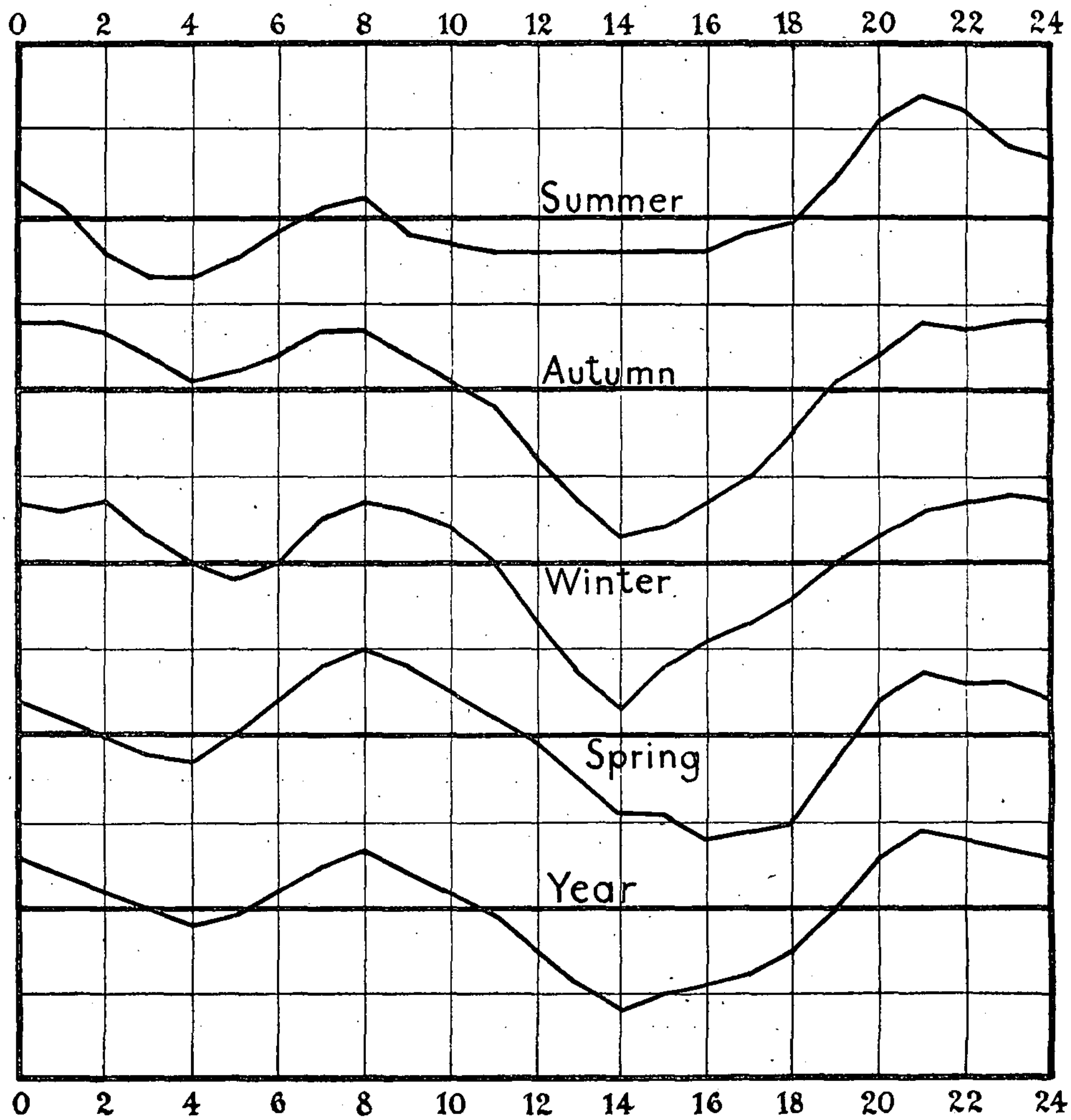


FIG. 19.—Diurnal Variation of Pressure, Macquarie Island. One Vertical Division equals 0·01 inch.

TABLE XXXII.

Pressure—Diurnal Inequalities.

Macquarie Island. Thousandths of an Inch.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period. I	—3	—6	—10	—9	—9	—5	—2	0	—4	—4	—3	—3	—4	—2	0	0	+1	+4	+8	+13	+16	+13	+8	+2
II	—3	—7	—8	—9	—6	—2	+2	+7	+5	+5	+3	+2	+1	—1	—2	—2	—4	—7	—1	+7	+8	+5	+4	—2
III	+2	—2	—6	—8	—6	—1	+4	+6	+5	+4	+2	—2	—4	—8	—11	—9	—7	—2	+4	+8	+11	+8	+5	+5
IV	+8	+6	+3	0	0	+2	+4	+4	+1	—1	—3	—7	—11	—15	—13	—11	—8	—4	0	+3	+7	+7	+9	+8
V	+14	+16	+15	+12	+11	+11	+13	+11	+5	+1	—4	—16	—23	—27	—24	—19	—15	—9	—1	+2	+5	+7	+9	+12
VI	+13	+14	+9	+5	+1	+2	+5	+5	+2	—2	—6	—14	—19	—23	—17	—13	—10	—6	+1	+4	+9	+11	+13	+14
VII	—1	+1	—4	—5	—6	0	+6	+11	+11	+13	+10	+2	—6	—13	—9	—7	—6	—4	—1	+1	+4	+3	+2	—1
VIII	+7	+6	+4	0	—2	—1	+3	+6	+4	+1	—3	—9	—14	—14	—9	—7	—5	—2	+1	+4	+6	+8	+9	+8
IX	+8	+5	+3	+1	+1	+5	+10	+15	+11	+9	+5	—1	—8	—14	—13	—16	—13	—12	—7	—1	+4	+5	+5	+6
X	—2	—2	—2	—1	+4	+7	+12	+14	+15	+12	+7	+2	0	—6	—9	—15	—17	—17	—8	0	+2	+1	+1	—1
XI	+1	—3	—7	—8	—4	—1	+2	+2	—2	—5	—5	—5	—6	—7	—5	—5	—4	—1	+6	+13	+14	+11	+11	+6
XII	+9	0	—2	—3	0	+2	+3	0	—6	—10	—12	—12	—10	—10	—9	—9	—3	0	+4	+14	+18	+17	+13	+12
Summer (XII, I, II)	+1	—4	—7	—7	—5	—2	+1	+2	—2	—3	—4	—4	—4	—4	—4	—4	—2	—1	+4	+11	+14	+12	+8	+4
Autumn (III, IV, V)	+8	+7	+4	+1	+2	+4	+7	+7	+4	+1	—2	—8	—13	—17	—16	—13	—10	—5	+1	+4	+8	+7	+8	+8
Winter (VI, VII, VIII)	+6	+7	+3	0	—2	0	+5	+7	+6	+4	0	—7	—13	—17	—12	—9	—7	—4	0	+3	+6	+7	+8	+7
Spring (IX, X, XI)	+2	0	—2	—3	0	+4	+8	+10	+8	+5	+2	—1	—5	—9	—9	—12	—11	—10	—3	+4	+7	+6	+6	+4
Year	+4	+2	0	—2	—1	+2	+5	+7	+4	+2	—1	—5	—9	—12	—10	—9	—8	—5	0	+6	+9	+8	+7	+6

Data are from three years less one December.

TABLE XXXIII.

Pressure—Harmonic Analysis of Diurnal Variation at Macquarie Island.

$$dP = a_1 \sin(\theta + A_1) + a_2 \sin(2\theta + A_2) + a_3 \sin(3\theta + A_3).$$

Period.	a_1	A_1	a_2	A_2	a_3	A_3
	in.	°	in.	°	in.	°
I	·0074	155	·0057	192	·0022	175
II	·0018	240	·0061	164	·0019	163
III	·0028	87	·0080	172	·0002	47
IV	·0085	65	·0048	170	·0011	39
V	·0180	48	·0059	197	·0028	9
VI	·0140	66	·0053	174	·0028	34
VII	·0038	348	·0077	169	·0028	16
VIII	·0076	71	·0047	177	·0027	47
IX	·0096	21	·0073	159	·0015	48
X	·0094	349	·0075	162	·0018	194
XI	·0063	120	·0063	180	·0024	167
XII	·0112	101	·0056	188	·0032	163
Summer	·0053	129	·0057	177	·0023	170
Autumn	·0096	56	·0061	179	·0014	21
Winter	·0076	58	·0059	173	·0028	32
Spring	·0055	28	·0070	166	·0012	158
Year	·0065	53	·0062	·174	·0007	93

Diurnal Variation.—The mean diurnal inequalities corrected for non-cyclic variation for each month, the four seasons and the year are given in thousandths of an inch, in Table XXXII. Curves for the four seasons and the year are plotted in Fig. 19. The data are obviously not sufficient to give an accurate normal curve, even for the year. But in the latter case the approximation is probably fairly close. The morning maximum is lower than the evening one but the difference is not great. The afternoon minimum is, however, considerably below the morning one. The maxima occur at 8 and 21 hours and the minima at 4 and 14 hours respectively. At Wellington the maxima occur at 9 and 22 hours approximately, the former being the higher. The minima are at 4 and 16 hours respectively, the latter being much the more pronounced.

Table XXXIII gives the harmonic analysis of the diurnal inequalities. For the year, terms from the 4th to the 6th are very small. They are, therefore, not tabulated for any of the periods. The 24-hour term, as usual, shows considerable variation in both amplitude and phase. In the mean it is approximately equal to the 12-hour term. The latter is fairly consistent throughout, especially in phase. At Wellington the mean amplitude and phase as given by Dr. C. J. Seelye,* in a paper to be published, are 0·0128 inch and 162° for the 12-hour and 0·0049 and 359° for the 24-hour term, respectively. The amplitude of the 24-hour term is, therefore, about 20% lower at Wellington than at Macquarie Island but the phase at Macquarie Island is about 4 hours in advance. The amplitude of the 12-hour term at Wellington is about double that at Macquarie Island but the phase is much the same. The figures for the 8-hour term at Wellington are 0·0010 inch and 40°. The amplitude is, therefore, about the same at both stations but the phase at Macquarie Island is approximately 1 hour in advance.

The amplitude and phase of the 12-hour term as computed from Simpson's formula are given in Table XXIV. The computed amplitude was 1·35 times the observed while the phase was 21° or 0·7 hours later. As is usually found with the 8-hour term, there is a very large change of phase at the equinoxes. This is accompanied by a great decrease in amplitude which is probably the effect of the change in phase. This term, therefore, behaves at Macquarie Island in a similar manner to that at other stations.

Non-Periodic Variations.—Table XXXIV contains data similar to those previously given for Adélie Land. The extreme minima and maxima at the two places do not differ very greatly. Macquarie Island has the greater range but also the longer record. The extreme maximum at Adélie Land was, however, probably an unusually high one. The highest reading at Macquarie Island was 30·531 inches on the 23rd June, 1913, and the lowest 27·765 on the 12th April, 1913. The mean monthly range was 1·557 inches compared with 1·398 inches at Adélie Land. On every occasion except two the departure of the minimum from the mean of the month was greater than that of the maximum. The barometer may remain steady at high but not at very low values, and the excursions to low values are of briefer duration than those to high. The mean daily range is 0·307 compared with 0·265 inch at Adélie Land. The annual variation in the monthly and mean daily ranges is much less marked than in the Antarctic. The range is less from November to January than in the other quarters but little else can be affirmed with regard to it.

* N.Z. J. Sci. & Tech., 21 (1940) 241B–255B.

TABLE XXXIV.

Pressure—Variability, Maxima and Minima.

Macquarie Island. Inches.

Period.	Absolute.			Difference from Mean for Month.		Mean Daily.		
	Maximum.	Minimum.	Range.	Abs. Max.	Abs. Min.	Maximum.	Minimum.	Range.
1912 I ...	30·109	28·553	1·556	0·710	0·846	29·541	29·228	0·313
II ...	30·065	28·727	1·338	0·455	0·883	29·758	29·448	0·310
III ...	30·379	28·656	1·723	0·840	0·883	29·702	29·435	0·267
IV ...	30·226	28·796	1·430	0·700	0·730	29·692	29·369	0·323
V ...	30·148	28·753	1·395	0·503	0·892	29·799	29·473	0·326
VI ...	30·176	28·737	1·439	0·573	0·866	29·762	29·425	0·337
VII ...	30·450	29·069	1·381	0·626	0·755	29·954	29,690	0·264
VIII ...	30·275	28·313	1·962	0·731	1·231	29·707	29,379	0·328
IX ...	30·103	28·535	1·568	0·730	0·838	29·483	29·257	0·226
X ...	29·964	28·412	1·552	0·680	0·872	29·438	29·106	0·332
XI ...	30·134	28·842	1·292	0·506	0·786	29·744	29·478	0·266
XII ...	29·903	28·775	1·128	0·469	0·659	29·576	29·291	0·285
1913 I ...	29·763	28·015	1·748	0·584	1·164	29·317	29,028	0·289
II ...	29·960	28·753	1·207	0·527	0·680	29·580	29·248	0·332
III ...	30·098	28·700	1·398	0·558	0·840	29·677	29·391	0·286
IV ...	30·340	*27·765*	2·575	0·689	1·886	29·808	29·457	0·351
V ...	30·250	28·674	1·576	0·715	0·861	29·683	29·408	0·275
VI ...	**30·531**	28·642	1·889	0·897	0·992	29·793	29·487	0·306
VII ...	29·998	28·761	1·237	0·509	0·728	29·669	29·300	0·369
VIII ...	30·369	28·594	1·775	0·737	1·038	29·784	29·496	0·288
IX ...	30·438	28·417	2·021	1·049	0·972	29·580	29·193	0·387
X ...	30·108	28·471	1·637	0·761	0·876	29·516	29·149	0·367
XI ...	29·903	28·931	0·972	0·473	0·499	29·560	29·306	0·254
1914 XII ...	30·107	28·684	1·423	0·699	0·724	29·561	29·254	0·307
1915 I ...	30·182	28·578	1·604	0·800	0·804	29·530	29·222	0·308
II ...	30·076	28·619	1·457	0·617	0·840	29·618	29·290	0·328
III ...	30·229	28·408	1·821	0·774	1·047	29·598	29·283	0·315
IV ...	30·347	28·676	1·671	0·831	0·840	29·679	29·350	0·329
V ...	30·133	28·546	1·587	0·518	1·069	29·775	29·418	0·357
VI ...	30·096	28·362	1·734	0·688	1·046	29·559	29·268	0·291
VII ...	30·030	28·337	1·693	0·482	1·211	29·706	29·361	0·345
VIII ...	30·229	29·014	1·215	0·524	0·691	29·815	29·592	0·223
IX ...	29·985	28·518	1·467	0·584	0·883	29·552	29·232	0·320
X ...	30·226	28·661	1·565	0·918	0·647	29·438	29·164	0·274
XI ...	29·669	28·204	1·465	0·558	0·907	29·250	28·977	0·273
Whole Period ...	30·531	27·765	2·766	...	...	...	...	...
Means ...	30·143	28·585	1·557	0·658	0·898	...	...	0·307

TABLE XXXV.

Pressure—Percentage Frequency of Times of Maxima and Minima at Macquarie Island.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12
Maxima	2·5	2·9	3·2	4·1	2·3	2·5	7·0	6·4	9·7	4·3	4·3	2·0
Minima..................	4·7	3·1	4·0	5·6	3·8	4·7	2·7	2·0	2·2	2·7	4·7	5·8
Maxima or minima...	3·6	3·0	3·6	4·8	3·0	3·6	4·8	4·2	6·0	3·5	4·5	3·9

Hour L.M.T.	13	14	15	16	17	18	19	20	21	22	23	24
Maxima	3·6	1·8	1·1	3·2	1·8	1·8	5·0	5·4	8·8	7·3	5·7	3·2
Minima..................	5·4	8·5	4·7	4·5	4·9	7·8	2·7	2·9	2·9	1·6	4·2	4·0
Maxima or minima...	4·5	5·2	2·9	3·8	3·4	4·8	3·8	4·2	5·9	4·4	5·0	3·6

TABLE XXXVI.

Pressure—Interdiurnal Variation.

Macquarie Island. Inches.

Year.	Sign.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.	From—
1912...	+	·279	·275	·273	·242	·255	·311	·216	·288	·190	·250	·213	·209	...	Hourly Values.
	—	·242	·274	·270	·229	·249	·233	·214	·239	·179	·253	·234	·226	...	
	+	·211	·242	·224	·140	·246	·272	·171	·250	·136	·205	·182	·217	...	Daily Means.
	—	·222	·256	·232	·195	·174	·191	·206	·206	·170	·197	·216	·178	...	
1913...	+	·254	·287	·235	·280	·238	·254	·315	·252	·324	·269	·200	...	...	Hourly Values.
	—	·229	·242	·250	·271	·243	·221	·276	·258	·290	·331	·244	...	...	
	+	·220	·220	·227	·248	·181	·247	·234	·238	·267	·262	·153	...	...	Daily Means.
	—	·224	·209	·189	·244	·237	·163	·216	·219	·210	·273	·202	...	...	
1914...	+	...	...	...	...	...	...	...	...	...	...	...	·246	...	Hourly Values.
	—	...	...	...	...	...	...	...	...	...	...	...	·254	...	
	+	...	...	...	...	...	...	...	...	...	...	...	·205	...	Daily Means.
	—	...	...	...	...	...	...	...	...	...	...	...	·227	...	
1915...	+	·187	·258	·220	·294	·319	·251	·247	·158	·228	·212	·222	...	...	Hourly Values.
	—	·286	·263	·259	·222	·239	·239	·221	·173	·293	·244	·227	...	...	
	+	·163	·223	·160	·211	·282	·233	·199	·113	·219	·181	·178	...	...	Daily Means.
	—	·258	·198	·219	·218	·182	·211	·177	·137	·259	·217	·217	...	...	
Mean	+	·235	·274	·242	·267	·270	·273	·258	·230	·250	·244	·211	·229	·249	Hourly Values.
	—	·251	·260	·259	·240	·244	·231	·238	·224	·248	·276	·235	·238	·245	
	Mean	·243	·267	·251	·252	·256	·251	·248	·227	·249	·259	·222	·234	·247	
	+	·195	·229	·202	·198	·231	·251	·202	·196	·208	·215	·171	·213	·208	Daily Means.
	—	·234	·221	·212	·220	·193	·188	·200	·190	·211	·229	·212	·198	·208	
	Mean	·212	·225	·207	·208	·210	·215	·201	·193	·210	·221	·189	·204	·208	

TABLE XXXVII.

Pressure—Diurnal Variation of Interdiurnal Variation.

Macquarie Island. Inches.

Period.	Hour L.M.T.	+	—	Diff.	Period.	Hour L.M.T.	+	—	Diff.
	4	·210	·246	—·036		4	·255	·244	+·011
	8	·219	·254	—·035		8	·251	·252	+·001
XI, XII, I	14	·226	·252	—·026	II, III, IV	14	·266	·271	—·005
	21	·248	·218	+·030		21	·270	·244	+·026
	4	·243	·234	+·009		4	·234	·249	—·015
	8	·268	·220	+·048		8	·242	·245	—·003
V, VI, VII	14	·281	·248	+·034	VIII, IX, X	14	·249	·249	·000
	21	·275	·250	+·025		21	·240	·251	—·011
	4	·236	·243	—·007					
	8	·245	·242	+·003					
Year	14	·255	·254	+·001					
	21	·258	·241	+·017					

When the barograms were being examined for pressure waves, the impression was gained that maxima occurred more frequently near midnight than at other times. The hours at which maxima and minima occurred during the period covered by Table XXXIV, above, were therefore tabulated. The results are given in Table XXXV. This shows a much higher correlation than was expected between the time of occurence of maxima and minima and the diurnal variation of pressure. The correlations with the mean diurnal inequalities were +0·70 for the frequency of occurrence of maxima and — 0·72 for that of minima. The mean frequency of maxima for the three hours about the morning maximum is 7·7 per cent or two and a half times that for the three about the afternoon minimum which was 2·2 per cent. The corresponding figures for the minima are 2·3 and 6·2 per cent respectively. In view of the fact that the mean range of the diurnal inequalities is less than 0·02 inch, the effect is very marked. The variability is rather greater at the times of the diurnal maxima than at others, the total frequency of maxima and minima having a correlation of +0·22 with the diurnal inequalities.

In Table XXXVI are given values for each month of the interdiurnal variation. The first two rows in each case, which are listed as being from hourly values, contain the means of the positive and negative difference as derived from the hourly values at the hours 4, 8, 14, and 21 of local time. These hours were chosen because they are those of the maxima and minima of the diurnal variation and it was thought that if there was any diurnal variation of the interdiurnal variation the values at these hours would probably serve best to bring it out. The next two rows contain corresponding values from the daily means as derived from the means of 24-hourly values. The final section of the table shows for each month the means for the three years combined. The last but three and the last lines of this section give mean values regardless of sign. The interdiurnal variation is considerably greater than at Adélie Land but the annual variation of it is very small. The only thing that can be said about its nature being that there is apparently a slight minimum in the summer months. The final means are 0·247 inch for the hourly values and 0·208 inch for the daily means as compared with 0·209 inch and 0·169 inch respectively for Adelie Land. Unpublished data for Wellington, New Zealand, prepared by Dr. Seelye *indicate a small annual variation with a minimum in summer. The variability at Wellington is, however, less than at either Adélie Land or Macquarie Island.

Table XXXVII shows mean values for each of the four hours mentioned grouped together for the three-monthly periods, November, December, January and so on and for the whole year. These figures show that the diurnal variation must be very small. For the negative variations the 14-hour value is larger than the other three which are nearly equal. For the positive variations the 4-hour value is the lowest and the 21-hour one the highest, but only a little above that for 14 hours. There is, therefore, probably a slight diurnal variation. 21 hours is the time of the principal maximum of the diurnal variation of pressure while 14 hours is the principal minimum.

In contradistinction with the Antarctic stations the mean of the positive values of the interdiurnal variation differs very little from that of the negative. For the whole year the mean of the positive values is slightly the higher whereas at the Antarctic

* Loc. cit

TABLE XXXVIII.

Pressure—Interdiurnal Variation: Percentage Frequencies of Various Ranges. From Hourly Values.

Macquarie Island. Inches.

Negative.

Period.	From To	1·200 1·299	1·100 1·199	1·000 1·099	0·900 0·999	0·800 0·899	0·700 0·799	0·600 0·699	0·500 0·599	0·400 0·499	0·300 0·399	0·200 0·299	0·100 0·199	0·000 0·099
4 hrs.	...	...	0·1	...	0·2	0·1	0·8	1·0	2·6	4·7	7·6	7·1	13·1	11·8
8 hrs.	...	...	0·1	0·3	...	0·2	1·0	1·1	2·8	3·9	6·7	8·5	10·8	14·7
14 hrs.	...	0·1	...	0·2	...	0·9	0·6	1·6	2·4	4·7	6·5	8·6	11·3	13·2
21 hrs.	...	0·2	0·1	...	0·3	0·3	0·6	0·9	2·8	4·8	6·7	9·7	10·9	14·6
Mean	...	0·05	0·1	0·1	0·1	0·4	0·7	1·2	2·7	4·5	6·9	8·5	11·5	13·6
XI	...	...	...	...	...	0·3	0·3	0·6	3·1	5·0	5·8	8·3	11·4	12·5
VII	...	0·3	...	...	...	0·3	...	0·5	4·0	3·8	7·8	8·4	13·4	12·9
XI, XII, I	...	...	0·1	0·1	...	0·2	0·6	1·3	3·2	4·9	5·1	7·6	10·9	13·7
II, III, IV	...	0·2	0·2	0·3	0·2	0·2	1·1	1·6	2·2	4·2	6·5	9·2	10·7	13·9
V, VI, VII	...	...	0·1	0·1	0·2	0·8	0·4	0·7	2·4	4·3	7·5	9·5	12·3	14·3
VIII, IX, X	...	...	...	...	0·1	0·3	0·8	1·1	3·0	4·7	8·1	7·6	12·0	12·4

Positive.

Period.	0·000 0·099	0·100 0·199	0·200 0·299	0·300 0·399	0·400 0·499	0·500 0·599	0·600 0·699	0·700 0·799	0·800 0·899	0·900 0·999	1·000 1·099	1·100 1·199	1·200 1·299	1·300 1·399	1·400 1·499	1·500 1·599
4 hrs.	14·4	12·5	7·8	6·8	3·8	2·6	1·7	0·4	0·7	0·1	...	...	0·1	...	...	...
8 hrs.	11·8	14·2	8·3	6·3	3·7	2·5	1·4	0·8	0·4	0·2	...	...	0·1	...	...	...
14 hrs.	13·8	11·9	7·2	5·4	4·2	3·8	1·4	0·6	0·7	0·3	0·2	0·2	...	0·1	...	...
21 hrs.	11·8	11·9	8·2	6·5	3·7	2·4	1·6	0·9	0·5	0·5	...	0·1	...	...	...	0·1
Mean	13·0	12·6	7·9	6·2	3·9	2·9	1·5	0·7	0·5	0·2	0·05	0·05	0·07	0·02	...	0·02
XI	12·2	18·1	8·9	5·8	5·3	2·5	...	...	...	...	...	...	...	...	...	...
VII	11·3	12·1	8·1	6·7	4·3	3·0	2·4	0·3	0·3	...	...	0·3	...	...	...	...
XI, XII, I	14·2	14·0	9·4	6·1	4·3	2·4	0·8	0·3	0·5	...	...	0·1	...	...	...	...
II, III, IV	12·7	11·4	8·3	6·2	4·2	2·8	1·5	1·4	0·7	0·1	0·1	...	...	...	...	0·1
V, VI, VII	11·7	11·9	7·1	5·6	3·6	3·5	2·2	0·3	0·4	0·7	0·1	0·1	0·1	0·1	...	...
VIII, IX, X	13·5	13·4	6·8	7·1	3·3	2·7	1·5	0·7	0·5	0·1	...	...	0·2	..	...	...

stations it was distinctly lower. In Table XXXVII the difference between the positive and negative variations is given for the four quarters of the year already mentioned. These values indicate that the positive values are generally higher in the winter and lower in the summer. The reason probably is that conditions are simpler in summer than in winter. In the latter season fronts, and especially secondary fronts are more numerous. When a series of fronts passes in one general low pressure trough there is usually a sharp rise of pressure after the last of them.

Table XXXVIII gives for Macquarie Island similar data to those of Table XXVII for Adélie Land, namely the percentage frequency of occurrence of various ranges of interdiurnal variation as derived from the hourly values of pressure. The steps are again in hundredths of an inch. The first four rows give the data for 4, 8, 14, and 21 hours respectively. Such diurnal variation as there is in the interdiurnal variation is again, however, seen to be slight and the figures do not determine its nature. The next row gives the mean for the whole period. It shows the wider distribution of ranges than that at Adélie Land and that the positive changes, in addition to having several higher values than occur amongst the negative, are on the average, the greater. The next row, giving the means for November, illustrates the case of a month when the variation is relatively low, while the following one, for July, gives that of a month with fairly high average values. The last four rows give the means for four quarters separately. Again, it is clear that the annual variation is much smaller than in the Antarctic. It is seen, also, that the negative changes tend to be the greater in the summer months and the positive in the winter. This is in agreement with data of the preceding table. The most outstanding feature, however, is the uniformity of the data for all periods.

The greatest change recorded in any 24 hours was a rise of 1·607 inches at 20 hours from the 12th to the 13th April, 1913. During the preceding 24 hours there had been a fall of 1·275 inches, a value exceeded only on four occasions, one of which occurred at the preceding hour. From 29·936 inches at 8 hours on the 10th April, the pressure fell to 27·765 inches at 20 hours on the 12th and subsequently rose to 29·401 inches by 21 hours on the 13th. During one interval of 5 hours the rise was 0·471 inch. Winds of whole gale force, first from the northwest and the later from the southwest, were reported at Macquarie Island during this storm. The greatest fall recorded in 24 hours was 1·303 inches from 22 hours on the 19th to 22 hours on the 20th July, 1915. In the three years there were 20 cases of changes of over an inch.

Pressure Waves.—Pressure maxima and minima appear on the Macquarie Island barograms with approximately the same frequency as on those of the Antarctic Stations. What has been said with regard to the other stations as to the difficulty of deciding what to call a wave applies in this case also. Traces are available for three years less one December. On these 187 distinct maxima were picked out giving a period of 136 hours. But of these maxima 139 appeared to be more pronounced and regular than the rest. If this were regarded as the true number of waves it would give a period of 183 hours. This gives a fair idea of the degree of uncertainty in the identification of separate waves. However, it is again possible to make a plausible choice of 166 prominent and fairly regular maxima giving a period of 153 hours, or the same as at the other stations. Data regarding the average range of the waves thus chosen are given in Table XXXIX.

TABLE XXXIX.—*Pressure Waves at Macquarie Island.*

Period.	No. of Waves.	Mean Length of Waves.	Mean Range.	Period.	No. of Waves.	Mean Length of Waves.	Mean Range.
		hours.	inches.			hours.	inches.
I	14		0·711	IX	13		0·879
II	14		0·875	X	16		0·839
III	13		0·875	XI	14		0·794
IV	13		0·926	XII	8		0·754
V	18		0·850	XI, XII, I ...	36	157	0·770
VI	14		0·906	II, III, IV ...	40	162	0·887
VII	16		0·889	V, VI, VII ...	48	138	0·865
VIII	13		0·848	VIII, IX, X ...	42	158	0·854
				Year ...	166	153	0·847

The outstanding feature as compared with the other stations is the uniformity of the range throughout the year. Largely no doubt owing to this fact, the period, also, is much more uniform. It is easier to pick out maxima when they are pronounced. The range is, however, definitely less in November, December and January than in the other months, and if allowance were made for the fact that more waves were listed during May, June and July than in the other months, it would be found that the range was greatest in those months. On the whole, therefore, the annual variation in the amplitude of pressure waves appears to be of the same nature at Macquarie Island as at the Antarctic Stations and to follow the sun rather closely. The amplitude is much greater even than that at Adélie Land.

TABLE XL.

Wind—Mean Velocities.

Adélie Land. Miles per Hour.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
1912 ...	...	26·2	44·6	46·0	54·4	51·1	50·0	52·9	48·8	50·2	36·9	29·5	...
1913 ...	28·1	38·7	51·0	47·9	50·7	46·9	55·6	44·0	35·5	46·3	37·3	...	...
Means ...	28·1	32·4	47·8	47·0	52·6	49·0	52·8	48·4	42·2	48·2	37·1	29·5	42·9

CHAPTER IV

WIND

I.—ADÉLIE LAND

1.—Instruments and Methods.

The wind was the outstanding feature of the climate of the Adélie Land station and the one about which most has been written. There is certainly no place yet known which approaches it for the average run of the wind or the continuity of winds of gale force or over. The principal recording instrument was a Robinson Cup Anemometer apparently with 3 inch cups and 7·4 inch arms. The anemometer was fixed directly on to a box which contained the recording apparatus. The box was mounted on top of a small peak on a ridge to the east of the Expedition's hut and 94 feet above mean sea level. The exposure is well shown in the plates of Volume IV of this series. The cups were, presumably, a little over a foot above the box. The box appears to have been about two feet square and the top approximately three feet above the top of the ridge. Except for the nearness to the top of the ridge, which would disturb the air stream in the vicinity, the exposure appears to have been as good as could have been obtained. The anemometer was tested while still on its box in a wind tunnel after the return of the expedition and the velocities tabulated may be considered accurate for the particular exposure. The recording gear integrated the run of the wind on a daily chart. The tracing pen would begin at the bottom of the chart, rise to the top after a run of 100 miles, then fall to the bottom and begin again. It is thus possible to determine the run in any given interval. The slope of the trace at any time can be used, also, to give an approximate estimate of the velocity over a very short period. There were some periods when the anemometer failed to record but most of these were adequately filled in by personal estimates as described in Volume IV. The wind direction was recorded by a separate instrument mounted on another small peak near to the Robinson instrument. When this was out of action, the direction was obtained partly from observations of a vane on the thermometer screen and partly from eye observations. The changes in direction, were however, so slight that the recording of direction seldom presented any difficulty. Observations on the southern journey gave for a long distance inland the same direction for the wind as that on the coast. The direction, therefore, was evidently representative of the region.

2.—The Observations.

Monthly Mean Velocities and Annual Variation.—The mean velocity for each month is given in Table XL, while the annual variation as derived from the 22 months is plotted in Fig. 20. These data were extracted from Table I in Vol. IV which gives hourly values of wind velocity and direction together with monthly means for each hour, the mean for the month, and, for each day, the total run and the maximum and minimum hourly runs. The outstanding feature is, of course, the enormously high mean velocities recorded. The mean for July, 1913, was 55·6 miles per hour while that for May, 1912,

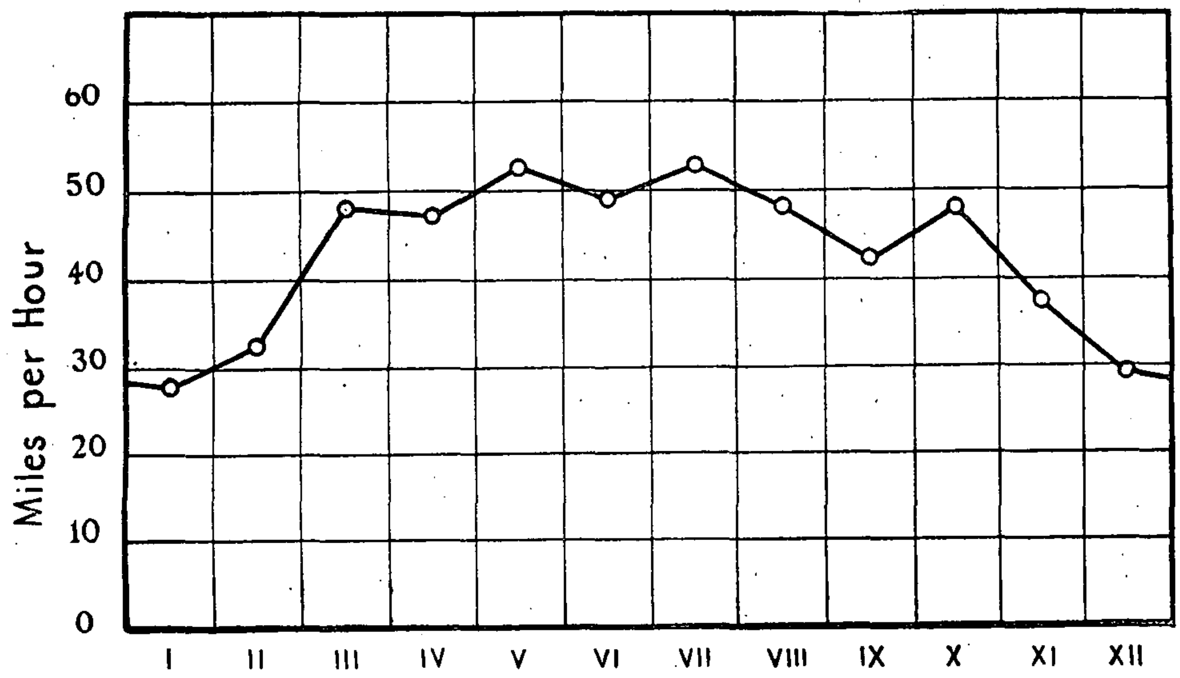


FIG. 20.—Annual Variation of Wind Velocity, Adélie Land.

was 54·4. The lowest mean in any month was 26·2 miles per hour in the first month, February, 1912. The mean of the twelve monthly means is 42·9 miles per hour. The highest average velocity for one day was 80·6 miles per hour on the 16th August, 1913, while the greatest hour's run was 96·0 miles in that preceding midnight of the 5th July, 1913. The wind was, of course, almost entirely a katabatic wind due to the cataracting down from the interior of air cooled by the snow surface. This point has already been discussed in Chapter II. So far as can be told, the snow surface presented a practically unbroken slope for distances inland of the order of 500 geographical miles rising in the process to altitudes of 7,000 to 10,000 feet (2 to 3 km). The wind near the Base was clearly much stronger than the average for the region. It is possible that there was some feature of the topography which caused a special concentration of the wind into this particular area. This would then be one of the reasons why the sea was kept open at Commonwealth Bay. This question is discussed further in a later chapter. In any case, the fact that the sea, with its temperature never varying greatly from its freezing point (about 28°·5 F.), was always open ensured that there was a steep temperature gradient from sea to land. This undoubtedly was the principal reason for the great strength of the winds. Most of the coast is bordered by extensive fields of pack ice which when snow-covered would have radiative properties similar to those of the inland ice sheet. The presence of this would be similar in effect to a reduction of both slope and temperature gradient and consequently lead to a reduction of the speed of katabatic winds. In general, the atmosphere must, as would be expected from the rate at which it was being cooled and the smoothness of the surface, have been very stable and the wind extraordinarily free from turbulence. This was shown by the steadiness of the velocity and direction. In the strongest winds the direction fluctuated over little more than a compass point. So marked was the steadiness that men were able to lean on the wind. The Meteorologist, C. T. Madigan, found that in a wind registering 90 miles per hour he could lean forward, supported by the wind, and touch the ground with his hand. The fact that the Robinson anemometer functioned for so long also proves that the wind could not have been very gusty. On the other hand, the wind often made a great noise and when it was calm at the Base the roaring of the wind on the plateau to the south was frequently audible, so that there must have been a certain amount of turbulence. The very strong wind must usually have been shallow. Unfortunately, there is no means of telling the depth of the katabatic layer.

Little is to be learned from the observations of direction except that when the wind was light the direction became more southeasterly, approaching more nearly to the gradient wind direction. The prevailing direction and the direction of all strong winds was S x E. Departures from directions between S and SE appear to have had little significance. Judging from Madigan's description these occurred at times when the wind was light, and when they blew the normal current still prevailed at some height above the surface. As this raised current reached the shore it was checked and large-scale eddies were formed. The processes are illustrated in Vol. IV by means of a sketch. The character of these wind changes as well as the katabatic nature of the wind system is illustrated by the following remarks by Madigan :

"Considerable interest attaches to these periods of comparative calm and variable winds. Several phenomena were peculiar to them, including small whirlwinds raising snow, like miniature "willy-willys" with their dust columns in Australia, and also low fracto-cumulus cloud forming rapidly over the coast line, swirling round, drifting north and quickly re-evaporating. During the calms the wind could frequently be heard roaring on the plateau to the south, and sometimes the snow drift could be seen whirling down to the coast to the west, showing the coastal calm to be local. Often, too, clouds of drift were observed passing overhead at the 1,000 feet level or higher. On several occasions, sledging parties coming in from five miles south reported strong winds at about this level, and walked down into a calm at the hut.

"That these furious winds did not extend far out to sea was proved by the ship's observations. Captain J. K. Davis commanding the *Aurora*, in the ship's story, in "The Home of the Blizzard," states that by keeping about three miles from the shore he seemed to be beyond the reach of the more violent gusts. In another place, while at anchor close inshore at Commonweath Bay, he describes conditions during one of the "calms" in the following words:—"To the north, violent gusts appeared to be travelling in various directions, but, to our astonishment these gusts, after approaching our position at a great rate, appeared to curve upwards; the water close to the ship was disturbed, and nothing else. This curious phenomenon lasted for about an hour and then the wind came with a rush from the South-East, testing the anchor chains in the more furious squalls." A shifting of the wind from South to East as the coast is left is also noted in the ship's narrative."

The particular case described by Captain Davis was evidently one in which over the ocean to the north a strong northerly wind was blowing. For a time, this was able to hold up the katabatic wind before it reached Commonwealth Bay but after a while the northerly was finnaly displaced and the katabatic wind again prevailed. The dividing line between the two winds would be very disturbed with many whirlwinds and much vertical movement. At the time of this occurrence the station was located between the cold front and the occlusion of a cyclone. The pressure gradient would be for northerly winds. The setting in of the katabatic wind was apparently some time in advance of the passage of the occlusion and the change of the gradient wind to a southerly direction.

The mechanism of the production of the spells of light variable winds or calms at the Adélie Land Base appears to have been varied. On some occasions it was probably similar to that described above, when there was a conflict between a northerly gradient wind and the southerly katabatic wind. But this was certainly not always the case. Generally, when these spells occurred there was a layer of cold air on the ground over which the strong katabatic wind continued to blow at a higher level. It is unfortunate that the wind directions tell practically nothing regarding the weather processes in the region. When a depression was passing to the north the wind speed in general increased.

Fig. 20 suggests that the annual variation of velocity is rather simple with a minimum in summer and a flat maximum in winter. In the case of a katabatic wind such as this, one would expect the speed to depend principally on the landward temperature gradient, and since the temperature off shore varies very little the temperature gradient should have a close inverse relationship with the temperature at the Base Station. There should, therefore, be a negative correlation between temperature and wind speed. The annual variation confirms this. Between the monthly means of temperature and wind velocity for the 22 months for which there are complete records we find a correlation of —0·81 which is as close as would have been expected. The wind velocity must be influenced also, of course, by the pressure gradients. With the mean pressures at Adélie Land the correlation is negligible.

Diurnal Variation.—The mean diurnal inequalities of velocity for each hour of the day for each month are plotted in Fig. 21. The 1912 values are indicated by continuous lines and those of 1913 by broken ones. This figure is included principally for the sake of a valuable warning which may be taken from it. During the earlier part of the stay at Adélie Land the anemometer charts were changed at 10 a.m. From the 18th February to the 1st April, 1913, the instrument was not functioning and the winds recorded are from personal estimates. When the anemometer again took up the running on April 2nd, the time of changing the charts was altered to 11 a.m. If the curves for April to November be examined it will be seen that in those for 1912 there are a number of small peaks and troughs which occur with considerable regularity at certain hours of the day. These, the writer found very puzzling. The difficulty was increased when it was found that in the corresponding 1913 data, there were the same peaks and troughs *but that they occurred an hour later.* The question then arose as to whether there could have been an error of an hour in the times listed from April, 1913, onwards. Correspondence ensued with Madigan which proved that the times were correctly recorded but that the time of changing the chart had definitely been moved forward an hour. There was nothing visible in the records themselves to indicate any defect in the functioning of the clock of the recorder. Nevertheless, the only possible

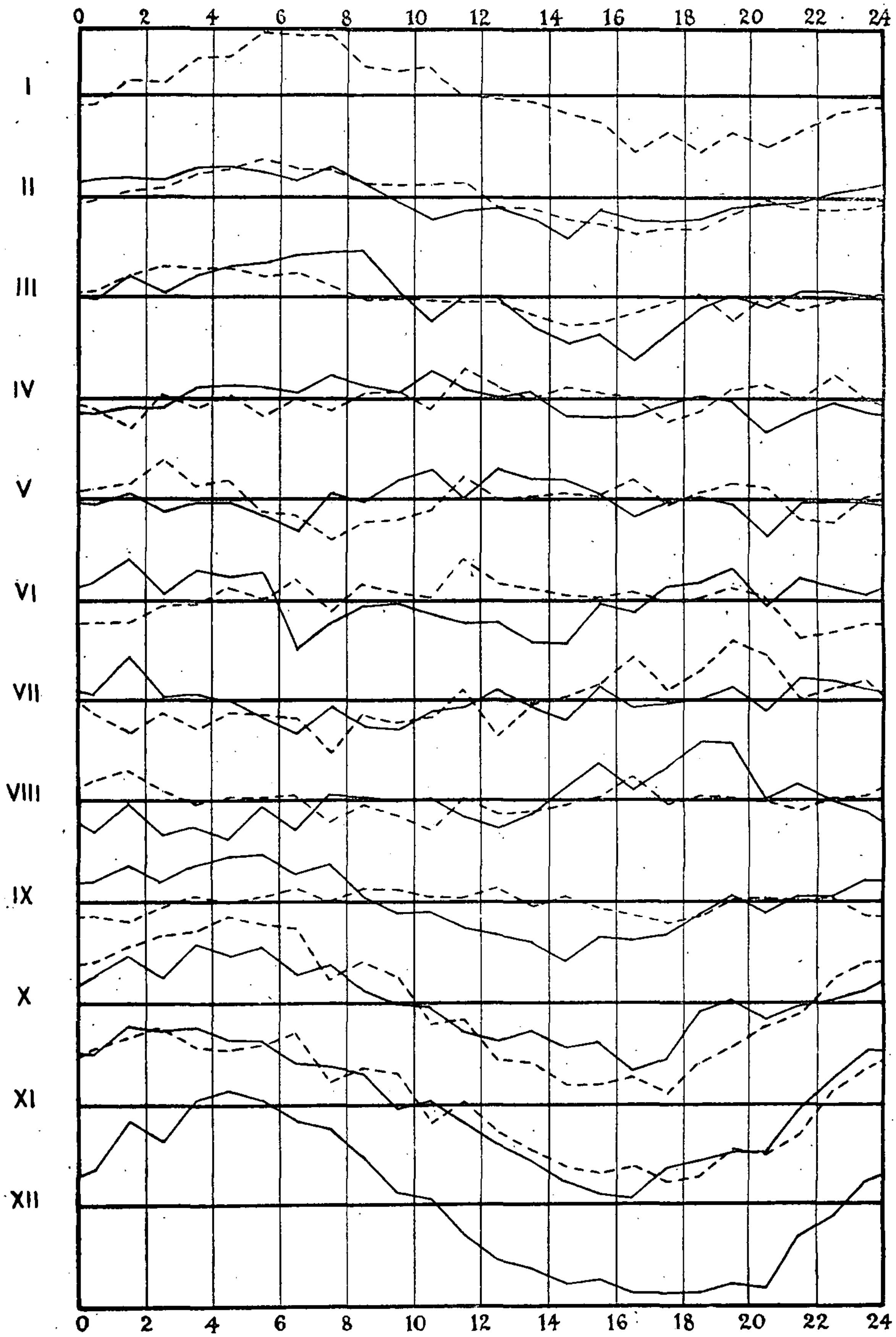


FIG. 21.—Diurnal Variation of Wind Velocity, Adélie Land, continuous lines, 1912; broken lines, 1913. One Vertical Division equals 9 miles per hour.

conclusion is that there were numerous slight variations in its rate. The defect is a very serious one and one which it was very difficult to anticipate. An additional complication in this case was that from early in 1913 Madigan had to use charts ruled by himself. It is clear, however, that his rulings were sufficiently accurate. The variable clock rate is very unfortunate and introduces a considerable uncertainty as to the precise significance of the diurnal variation data.

Table XLI gives the mean diurnal inequalities for each month as derived from the two years' record. Following them are the means for each season and the year. There are also added the means for the months May to July when there was least solar radiation. The data for the four seasons and the year are plotted in Fig. 22. The principal feature of the diurnal variation is a maximum at 5 hours and a minimum at 17 hours. The variation is greatest in spring and early summer, October to December. It is rather less in autumn than in spring. Except that the wind changes lag somewhat

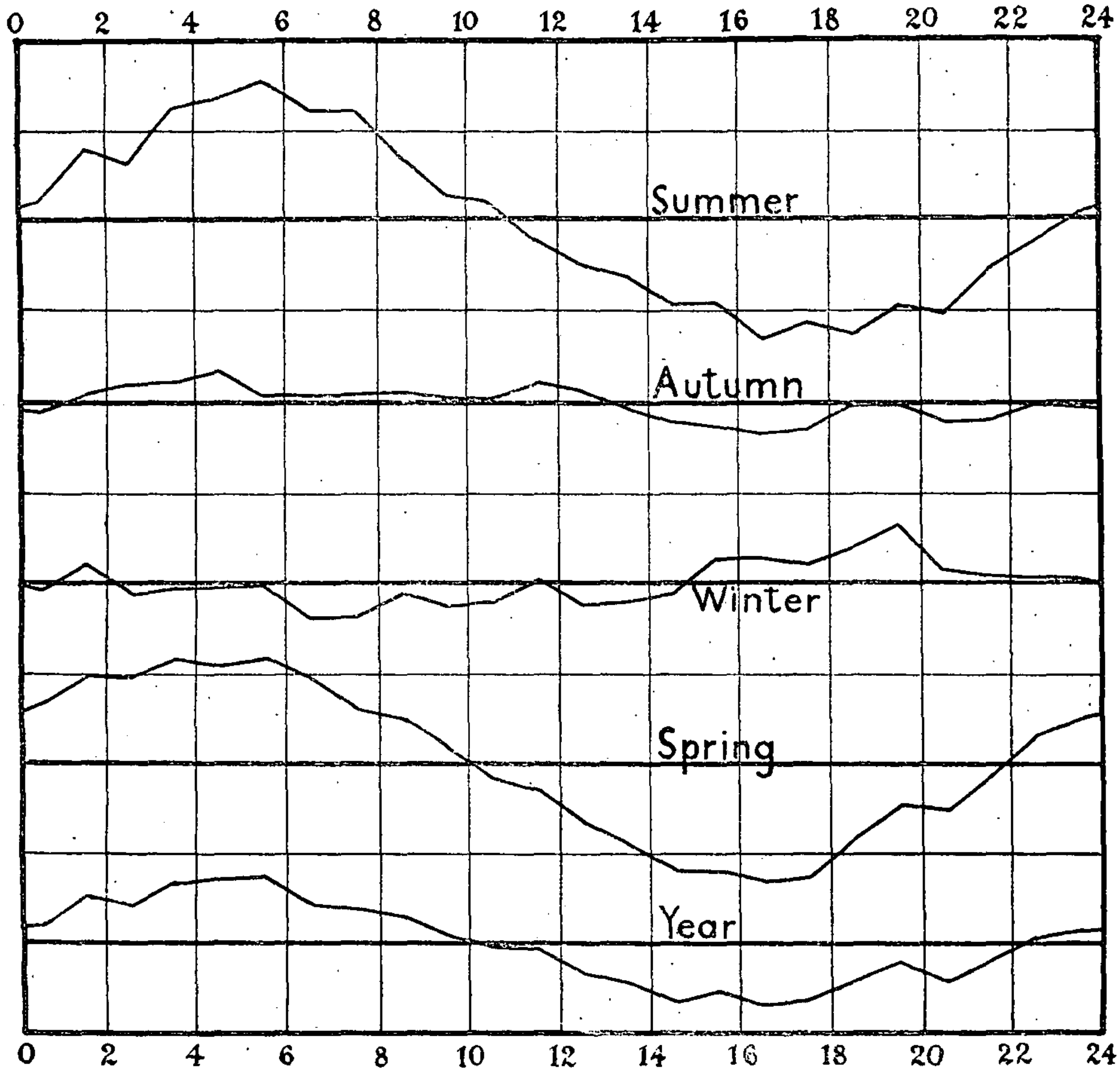


FIG. 22.—Diurnal Variation of Wind Velocity, Adélie Land. One Vertical Division equals 4 miles per hour.

TABLE XLI.

Wind—Mean Diurnal Inequalities of Velocity. Corrected for Non-Cyclic Variation.

Adélie Land. Miles per Hour.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period. I	—0·9	+1·3	+0·9	+3·3	+3·5	+5·8	+5·2	+5·2	+2·7	+2·2	+2·4	0·0	—0·2	—0·6	—1·8	—2·3	—4·9	—3·1	—4·7	—3·4	—4·5	—3·0	—1·5	—1·0
II	+0·6	+1·1	+1·2	+2·2	+2·5	+2·8	+1·8	+2·6	+1·4	+0·2	—0·6	0·0	—1·0	—1·4	—2·8	—1·8	—2·7	—2·4	—2·4	—1·0	—0·4	—0·5	—0·3	0·0
III	+0·1	+1·8	+1·4	+2·2	+2·6	+2·4	+2·8	+2·3	+1·8	+0·2	—1·2	—0·2	—0·4	—2·2	—3·3	—2·8	—3·5	—1·9	—0·4	—1·0	—0·5	—0·3	+0·2	+0·1
IV	—1·2	—1·8	0·0	+0·1	+0·8	0·0	+0·3	+0·6	+0·9	+0·5	+0·8	+1·8	+0·6	+0·2	—0·4	—0·5	—0·7	—1·2	—0·4	+0·3	—0·8	—0·8	+0·9	—0·6
V	+0·2	+1·1	+1·1	+0·4	+0·7	—1·3	—2·2	—1·6	—1·1	0·0	+0·8	+1·0	+1·4	+1·0	+1·2	+0·4	+0·1	—0·4	+0·4	+0·4	—1·2	—1·0	—1·0	0·0
VI	—0·2	+0·8	0·0	+1·2	+1·6	+1·2	—1·4	—1·4	+0·4	+0·2	—0·5	+0·8	—0·2	—1·4	—1·6	0·0	—0·2	+0·6	+1·0	+2·0	0·0	—0·8	—0·8	—0·6
VII	—0·4	+0·4	—0·4	—1·0	—0·6	—1·4	—2·3	—2·6	—1·8	—2·4	—1·2	+0·2	—1·2	—0·4	—0·6	+1·4	+1·6	+0·4	+1·4	+3·4	+1·6	+1·2	+1·5	+1·5
VIII	—0·5	+1·2	—1·0	—1·2	—1·5	0·0	—1·0	—0·6	0·0	—0·7	—1·1	—0·6	—1·7	—1·0	+0·4	+1·9	+1·6	+1·4	+2·8	+2·6	+0·1	+0·3	+0·2	—0·2
IX	+0·2	+0·7	+0·7	+2·0	+2·0	+2·4	+1·8	+1·6	+0·8	+0·2	—0·2	—1·0	—0·8	—2·1	—2·4	—2·0	—2·3	—2·4	—1·2	+0·4	—0·2	+0·4	+0·5	+0·2
X	+3·0	+4·6	+4·0	+5·8	+5·8	+5·8	+4·6	+2·7	+2·3	+1·0	—1·2	—1·9	—4·2	—4·0	—5·6	—5·3	—6·3	—6·6	—3·1	—1·8	—1·8	—0·7	+1·2	+2·0
XI	+4·6	+6·5	+6·7	+5·9	+5·4	+5·6	+4·9	+2·7	+3·0	+1·2	—0·6	—0·6	—3·0	—4·6	—6·3	—7·1	—7·0	—6·4	—5·8	—4·2	—4·4	—1·7	+1·8	+4·0
XII	+3·3	+7·6	+5·9	+9·5	+10·4	+9·7	+7·7	+7·0	+4·3	+1·1	+0·7	—2·7	—4·8	—5·7	—6·9	—6·7	—7·9	—7·9	—7·8	—7·1	—7·4	—2·9	—0·9	+2·1
Summer (XII, I, II)	+1·0	+3·3	+2·7	+5·0	+5·5	+6·1	+4·9	+4·9	+2·8	+1·2	+0·8	—0·9	—2·0	—2·6	—3·8	—3·6	—5·2	—4·5	—5·0	—3·8	—4·1	—2·1	—0·9	+0·4
Autumn (III, IV, V)	—0·3	+0·4	+0·8	+0·9	+1·4	+0·4	+0·3	+0·4	+0·5	+0·2	+0·1	+0·0	+0·5	—0·3	—0·8	—1·0	—1·4	—1·2	—0·1	—0·1	—0·8	—0·7	0·0	—0·2
Winter (VI, VII, VIII)	—0·4	+0·8	—0·5	—0·3	—0·2	—0·1	—1·6	—1·5	—0·5	—1·0	—0·9	+0·1	—1·0	—0·9	—0·6	+1·1	+1·0	+0·8	+1·7	+2·7	+0·6	+0·2	+0·3	+0·2
Spring (IX, X, XI)	+2·6	+3·9	+3·8	+4·6	+4·4	+4·6	+3·8	+2·3	+2·0	+0·8	—0·7	—1·2	—2·7	—3·6	—4·8	—4·8	—5·2	—5·1	—3·4	—1·9	—2·1	—0·7	+1·2	+2·1
Year	+0·7	+2·1	+1·7	+2·6	+2·8	+2·8	+1·8	+1·5	+1·2	+0·3	—0·2	—0·3	—1·3	—1·8	—2·5	—2·1	—2·7	—2·5	—1·7	—0·8	—1·6	—0·8	+0·2	+0·6
V, VI, VII	—0·1	+0·8	+0·2	+0·2	+0·6	—0·5	—2·0	—1·9	—0·8	—0·7	—0·3	+0·7	0·0	—0·3	—0·3	+0·6	+0·5	+0·2	+0·9	+1·9	+0·1	—0·2	—0·1	+0·3

January from 1913 observations only. February 1913 partly interpolated. March 1913 from non-instrumental observations. December from 1912 observations only.

TABLE XLII.

Wind—Harmonic Analysis of Diurnal Variation of Velocity.

Adélie Land. Miles per Hour.

$$dV = a_1 \sin(\theta + A_1) + a_2 \sin(2\theta + A_2) + a_3 \sin(3\theta + A_3).$$

	a_1	A_1	a_2	A_2	a_3	A_3
		°		°		°
I	4·3	352	0·4	279	0·5	174
II	2·3	18	0·4	239	0·3	222
III	2·4	24	0·6	225	0·4	264
IV	0·7	310	0·4	166	0·4	250
V	0·4	226	1·0	41	0·7	320
VI	0·3	78	0·5	268	0·9	318
VII	1·9	152	0·0	283	0·3	286
VIII	1·2	168	0·7	266	0·6	44
IX	1·9	30	0·6	217	0·4	236
X	5·6	32	0·3	213	0·3	246
XI	6·1	28	1·0	84	0·3	28
XII	8·9	20	0·9	334	0·4	112
Summer (XII, I, II)	5·1	12	0·4	304	0·3	170
Autumn (III, IV, V)	0·8	4	0·1	87	0·4	284
Winter (VI, VII, VIII)	1·1	154	0·4	272	0·4	336
Spring (IX, X, XI)	4·7	30	0·3	149	0·2	258
Year	2·4	24	0·1	274	0·2	276
V, VI, VII	0·7	154	0·3	19	0·6	314

TABLE XLIII.

Wind—Mean Velocities.

Macquarie Island. Miles per Hour.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Year.
1912 ...	8·9	11·1	11·2	11·4	13·1	13·4	13·3	15·4	11·3	17·5	15·2	15·1	13·1
1913 ...	15·3	14·4	11·6	17·0	13·6	13·7	14·1	13·9	16·4	19·3	10·6	14·1	14·5
1914 ...	22·9	21·3	18·7	18·7	23·9	22·5	17·7	22·9	27·3	29·1	20·9	21·1	22·2
1915 ...	16·8	11·8	18·6	11·8	14·0	16·4	23·6	14·4	17·2	20·3	13·5	...	16·2
Means ...	16·0	14·6	15·0	14·7	16·2	16·5	17·2	16·6	18·0	21·6	15·0	16·8	16·5

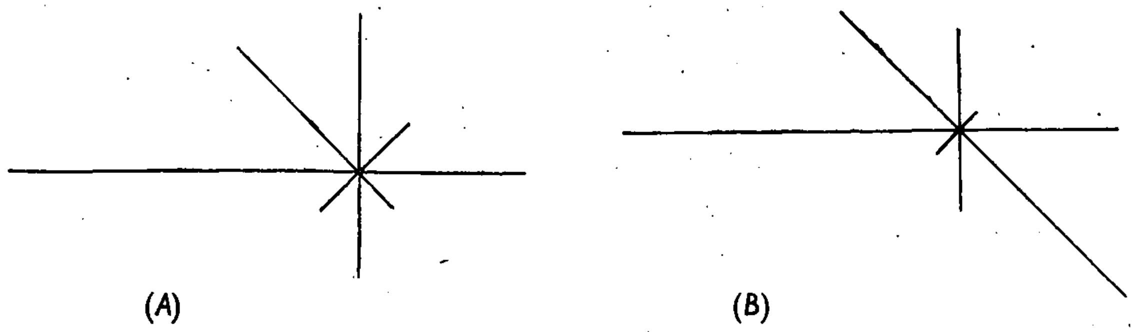
16 days only in January, 1912. Values from December, 1913 to November, 1914, inclusive derived from mean of 09 and 18 hours observations increased by 0·1 m.p.h. Records incomplete from December, 1914 to February, 1915 inclusive.

behind those of temperature, especially at the maximum in the afternoon, the wind variation is very similar to that of temperature with the sign reversed. For temperature, however, the variation was greatest in November while for wind it was greatest in December. This difference in behaviour was probably due to a local effect on the coast. There, in December the temperature would frequently approach freezing point. The effect of this on the diurnal variation has already been discussed in Chapter II. Inland, the freezing point would seldom be reached and the diurnal variation of temperature would probably increase until December. The wind variation would follow the average temperature variation over the whole of the surrounding ice surface.

Table XLII gives the harmonic analysis of the data in Table XLI. As in the case of temperature the 24-hour term is the only one of any importance. In winter it is small and of doubtful significance. The phases in the other seasons are fairly consistent. If Table XLI be compared with Table III giving the corresponding data for the diurnal variations of temperature it will be seen that for the 24-hour term, in the months when the diurnal variation is of any considerable amplitude, there is a fairly close correspondence, the wind variation being about 13 hours behind the temperature in phase, that is in the reverse direction and with a lag of one hour. The second and third terms in the analysis are small and, in view of the irregularity of the clock rate, it is impossible to say what is their significance. The diurnal inequalities for the quarter May to July are not very different from those for June to August, and again it is unfortunately not possible to place any reliance on the very small variation shown for these winter months. An increase of temperature on the land would mean a decrease of the gradient from sea to land and, consequently, a decrease of the katabatic wind. This accounts for the nature of the relationship between wind and temperature.

In Table II of Volume IV are given the frequency of occurrence of various ranges of mean daily velocity in 10 miles per hour steps. The most frequent velocity in each month, not unnaturally, tended on the whole to increase with the average velocity for the month. For the whole period the most frequent range of the mean daily velocity was 40–50 miles per hour. The range from 50 to 60 miles per hour was more frequent than that from 30 to 40 miles per hour.

Cloud Movement.—In the Meteorological Journal for Adélie Land there are given observations of the direction of movement of clouds. The percentage frequency of occurrence of various directions for upper (cirriform) middle (alto) and lower clouds is shown in Fig. 23 by means of wind roses. It is very difficult to estimate to what extent the figures are representative of average conditions. The occasions when it was possible to observe the motion were relatively infrequent; observation must have been difficult; and on many occasions the identification of the type of cloud must have been very uncertain. The results are, nevertheless, valuable. For the cirrus cloud there is a great preponderance of directions from between north and west, the total percentage for the three directions N, NW, and W being 61 of which 31 per cent. were from W. The alto-cumulus still shows a marked preponderance of movement from the west but there is a greater proportion of south-easterlies than with the cirrus. The most frequent direction for the lower cloud was south-east. This was probably mostly very low cloud and when the upper movement was from northerly or westerly directions, the chances of the sky being obscured by drift or low cloud would be great. The observations suggest that at moderate heights the prevailing winds are from the west. There are numerous other grounds for believing this.



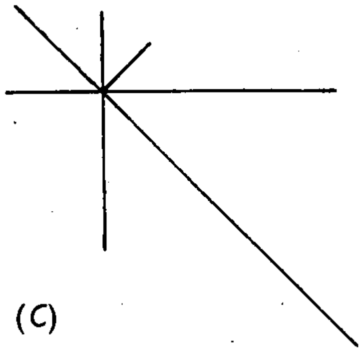


FIG. 23.—Cloud movement, Adélie Land.
(*A*) Upper.
(*B*) Middle.
(*C*) Lower.

II.—MACQUARIE ISLAND

1. Instruments and Methods.

The principal wind recording instrument at Macquarie Island was an anemobiagraph recording velocity only. The registering part of this is actuated by forces of pressure and suction transmitted from a head of the type used in the Dines pressure-tube anemometer. Individual gusts are recorded. This instrument was mounted on one of a small clump of rocks. The vane was only about 18 inches above the top of the rock and the exposure was, therefore, far from ideal. The installation is shown in Fig. 1, Plate IV of Volume III of this series. Except for the small height of the head and the effect of the rocks, the immediate surroundings were open. The relation of the station, which was on a low-lying spit, to the high peninsula to the north-east and the mainland of the island can be gathered accurately from the maps in the introduction to Volume III and the photographs in Plate III. For a portion of the time the daily run in miles was also recorded by means of a Robinson Anemometer. This was set up near the anemobiagraph but appears to have projected to a height of about 7 feet above the rocks. This would account partly for its giving higher average velocities than the anemobiagraph. It is not known to the writer, however, whether the indications of the Robinson Anemometer were reduced to true velocities. The velocities recorded undoubtedly tend to under-estimate considerably the windiness of the site since the anemometer heads were lower than at most stations. This is confirmed by the remarks in the weather journal. The direction was determined by visual observations at 9, 15, and 21 hours from January to October, 1912, and at 9, 12, 15, 18 and 21 hours thereafter until January, 1915. From February to November, 1915, the direction was recorded continuously by an anemometer designed by Mr. H. A. Hunt, Commonwealth Meteorologist, Australia.

The anemometer site would be protected by the high land of the mainland, rising to upwards of 900 feet, from winds in the south-west quadrant. The effect of this sheilding cannot be estimated but it may account for some of the preponderance of north-west winds over south-west. There would be some interference also of north-easterly winds by the "Wireless Hill" but this was probably not important.

For the period for which the records were lost, wind directions and velocities are available at 9 and 18 hours from the wireless reports sent to Australia.

2. The Observations.

Monthly Mean Velocities and Annual Variation.—The monthly mean velocities from Table V of Volume III are given in Table XLIII. The values for the months from December, 1913, to November, 1914, are from the wireless reports mentioned above. They have been increased by 0·1 miles per hour to reduce them to the mean of day, the correction being derived from the mean diurnal variation in other months. The mean velocity for the period is a high one, especially if allowance be made for the small height to which the anemometer projected above the surface.

The windiest month was October, 1914, with the very high average of 29·1 miles per hour. 1914 was a very windy year and in 9 months the average exceeded 20 miles per hour. This was the year of probably the worst drought ever experienced in Australia. From other evidence, the writer had concluded that there was rather more movement than usual from the west in this year in Australia and New Zealand. Storm activity was, in general, slight.

The period of observation is too short for any very definite conclusions to be reached with regard to the annual variation of velocity. The monthly means from the last row of Table XLIII are plotted in Fig. 24. The clearest indication is that the

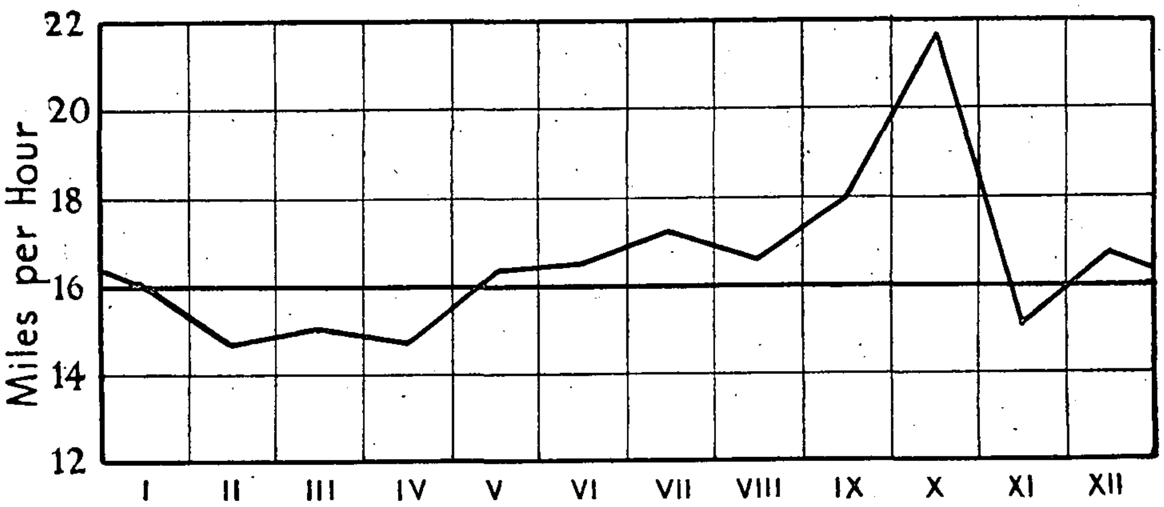


FIG. 24.—Annual Variation of Wind Velocity, Macquarie Island.

TABLE XLIV.

Wind—Percentage Frequency of Various Directions.

Macquarie Island.

Month	Year	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm.
I	1912	4·3	2·0	...	...	...	...	18·0	2·0	4·0	...	...	4·7	11·3	4·0	45·7	4·0	...
	1913	3·2	0·6	0·6	...	...	...	...	0·6	0·6	0·6	5·8	14·4	18·4	12·8	30·6	5·4	6·4
	1914	3·2	...	4·8	...	3·2	1·6	4·8	3·2	4·8	...	1·6	3·2	21·0	9·7	22·6	12·9	3·2
	1915	9·4	...	1·6	...	2·4	0·8	4·8	...	0·8	3·2	2·4	5·6	22·8	9·2	13·6	8·6	14·8
	Mean	5·0	0·6	1·8	...	1·4	0·6	6·9	1·4	2·6	1·0	2·4	7·0	18·4	8·9	28·1	7·7	6·1
II	1912	2·7	1·3	...	...	2·6	...	...	...	2·7	2·7	10·7	5·3	22·6	20·0	26·7	2·7	...
	1913	9·2	1·6	0·8	...	...	...	...	2·4	1·6	0·8	5·0	12·4	17·8	15·0	19·8	7·8	5·8
	1914	7·1	1·8	1·8	...	...	...	...	...	...	3·6	1·8	5·4	28·6	14·3	19·6	12·5	3·6
	1915	3·2	0·8	...	...	0·8	...	...	0·8	4·0	...	2·4	4·0	4·0	14·2	30·8	1·6	33·4
	Mean	5·6	1·4	0·6	...	0·8	...	...	0·8	2·1	1·8	5·0	6·8	18·2	15·9	24·2	6·2	10·7
III	1912	5·3	...	...	...	...	...	...	...	2·0	...	12·0	15·0	22·7	7·3	27·0	8·7	...
	1913	3·2	1·8	0·6	...	1·8	...	4·8	4·8	2·0	1·2	3·8	12·2	18·4	13·6	9·6	3·2	19·0
	1914	9·7	...	...	...	...	...	6·5	1·6	...	1·6	1·6	6·5	14·5	14·5	22·6	14·5	6·5
	1915	12·8	2·0	1·2	1·6	...	...	...	...	...	...	2·2	8·9	5·3	15·0	30·2	13·2	7·6
	Mean	7·8	1·0	0·4	0·4	0·4	...	2·8	1·6	1·0	0·7	4·9	10·6	15·2	12·6	22·4	9·9	8·3
IV	1912	4·3	2·0	...	2·0	...	...	...	...	4·0	3·3	11·7	7·7	23·3	13·3	23·7	4·7	...
	1913	0·6	...	...	...	...	...	1·2	...	...	1·2	5·0	17·0	14·4	24·4	23·2	3·8	9·2
	1914	8·3	6·7	...	...	3·3	1·7	6·7	5·0	...	...	3·3	6·7	18·3	5·0	13·3	16·7	3·3
	1915	6·0	0·2	0·3	0·3	0·4	0·1	2·4	0·3	0·8	1·3	0·1	1·8	4·7	27·0	27·5	6·3	20·5
	Mean	4·8	2·2	0·1	0·6	0·9	0·4	2·6	1·3	1·2	1·4	5·0	8·3	15·2	17·4	21·9	7·9	8·2
V	1912	6·3	...	...	...	...	...	...	...	...	...	4·0	7·7	18·3	20·7	33·3	9·7	...
	1913	0·6	...	...	...	...	...	2·4	2·4	9·0	4·2	13·2	7·8	18·0	11·0	16·8	4·8	9·8
	1914	4·8	...	...	...	...	...	...	...	...	1·6	4·8	11·3	19·4	19·4	24·2	12·9	1·6
	1915	9·9	1·9	0·6	...	...	...	0·7	1·2	0·4	0·5	0·4	0·9	5·1	8·9	30·2	8·4	30·9
	Mean	5·4	0·5	0·2	...	...	...	0·8	0·9	2·4	1·6	5·6	6·9	15·2	15·0	26·1	9·0	10·6
VI	1912	1·0	...	2·0	1·0	...	...	...	3·0	2·0	2·0	10·0	10·3	27·4	23·3	18·0	...	...
	1913	2·4	...	...	...	...	...	1·2	1·2	6·2	2·4	4·6	11·8	18·2	26·2	6·6	5·0	14·2
	1914	8·3	...	...	...	...	...	...	1·7	1·7	6·7	8·3	6·7	10·0	18·3	18·3	16·7	3·3
	1915	5·1	0·8	2·8	0·3	3·4	3·2	0·2	...	1·0	2·6	4·0	6·8	6·2	4·9	21·3	12·8	24·6
	Mean	4·2	0·2	1·2	0·3	0·8	0·8	0·4	1·5	2·8	3·4	6·6	8·9	15·4	18·2	16·0	8·6	10·5
VII	1912	2·0	1·0	...	...	...	...	5·0	...	3·0	...	3·0	12·0	26·0	15·0	30·0	2·0	1·0
	1913	1·8	1·8	0·6	...	...	...	...	1·8	5·4	3·4	5·4	4·0	9·8	14·6	23·8	5·2	22·4
	1914	6·5	4·8	3·2	3·2	1·6	3·2	1·6	1·6	4·8	4·8	8·1	9·7	11·3	8·1	9·7	12·9	4·8
	1915	3·8	0·7	0·3	0·7	...	...	1·7	...	1·5	...	...	0·5	4·6	21·3	36·7	17·9	10·3
	Mean	3·5	2·1	1·0	1·0	0·4	0·8	2·1	0·8	3·7	2·0	4·1	6·5	12·9	14·8	25·0	9·5	9·6
VIII	1912	3·0	3·0	...	...	3·0	1·0	2·0	...	4·3	3·0	1·0	7·7	16·7	19·3	23·3	8·7	4·0
	1913	4·6	...	1·4	0·6	0·6	...	...	1·8	5·2	1·8	2·6	1·2	6·2	7·6	37·4	14·0	15·0
	1914	8·1	3·2	...	1·6	...	...	...	3·2	3·2	...	3·2	11·3	9·7	17·7	25·8	12·9	...
	1915	5·0	0·6	0·5	2·6	1·4	2·0	1·3	2·3	0·6	0·4	0·1	2·4	14·7	15·5	17·0	10·3	23·3
	Mean	5·2	1·7	0·5	1·2	1·2	0·8	0·8	1·8	3·3	1·3	1·7	5·6	11·8	15·0	25·4	11·5	10·6
IX	1912	10·3	3·0	...	1·0	3·3	4·3	5·7	5·7	6·7	2·0	2·0	5·7	7·0	9·7	12·3	9·3	12·0
	1913	2·6	2·4	0·6	...	1·8	0·6	2·0	2·0	3·2	2·0	8·0	6·0	12·8	11·2	30·6	6·6	7·6
	1914	1·7	1·7	1·7	...	...	...	...	...	1·7	...	1·7	11·7	20·0	25·0	23·3	11·7	...
	1915	2·0	...	1·0	1·0	5·1	2·4	1·0	2·2	0·6	...	...	2·5	7·7	15·1	19·6	16·8	23·0
	Mean	4·2	1·8	0·8	0·5	2·6	1·8	2·2	2·5	3·0	1·0	2·9	6·5	11·9	15·2	21·4	11·1	10·6
X	1912	3·0	1·0	...	...	2·0	1·0	...	...	1·0	1·0	2·0	16·0	29·3	10·0	20·3	9·7	3·7
	1913	5·6	3·2	...	...	...	...	2·4	0·6	0·6	1·2	1·8	7·0	20·8	23·8	26·8	3·2	3·0
	1914	1·6	...	...	...	...	...	...	...	3·2	...	3·2	12·9	33·9	27·4	14·5	1·6	1·6
	1915	0·1	0·5	...	...	2·2	4·2	0·6	7·9	2·0	2·8	3·4	13·0	5·4	34·7	8·8	2·9	11·5
	Mean	2·6	1·2	...	...	1·0	1·3	0·8	2·1	1·7	1·2	2·6	12·2	22·4	24·0	17·6	4·4	5·0
XI	1912	1·8	...	...	...	...	0·6	0·6	3·8	4·0	2·6	8·2	11·6	22·0	15·4	20·8	6·0	2·6
	1913	5·8	1·6	2·2	3·2	2·4	0·8	5·8	7·2	4·6	1·6	4·4	2·2	18·0	16·0	5·8	2·4	16·0
	1914	5·0	3·3	1·7	...	...	...	...	3·3	1·7	5·0	8·3	11·7	21·7	21·7	11·7	5·0	...
	1915	3·3	0·6	4·2	1·2	1·0	1·3	1·0	2·4	0·7	0·6	0·5	3·4	8·6	31·4	10·6	5·0	24·2
	Mean	4·0	1·4	2·0	1·1	0·8	0·7	1·8	4·2	2·8	2·4	5·4	7·2	17·6	21·1	12·2	4·6	10·7
XII	1912	1·8	0·6	0·6	2·4	0·6	...	0·6	0·6	4·2	...	4·2	6·2	9·0	23·8	28·8	11·6	5·0
	1913	16·1	1·6	...	...	3·2	...	...	6·5	6·5	3·2	1·6	3·2	16·1	12·9	12·9	8·1	8·1
	1914	6·2	0·8	...	1·6	3·4	2·4	4·0	4·0	2·4	6·4	12·6	...	21·2	14·4	13·4	4·8	2·4
	Mean	8·0	1·0	0·2	1·3	2·4	0·8	1·5	3·7	4·4	3·2	6·1	3·1	15·4	17·0	18·4	8·2	5·2

TABLE XLV.

Wind—Percentage Frequency of Various Directions.

Macquarie Island. From all Observations.

Month.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
I	5·0	0·6	1·8	...	1·4	0·6	6·9	1·4	2·6	1·0	2·4	7·0	18·4	8·9	28·1	7·7	6·1
II	5·6	1·4	0·6	...	0·8	...	...	0·8	2·1	1·8	5·0	6·8	18·2	15·9	24·2	6·2	10·7
III	7·8	1·0	0·4	0·4	0·4	...	2·8	1·6	1·0	0·7	4·9	10·6	15·2	12·6	22·4	9·9	8·3
IV	4·8	2·2	0·1	0·6	0·9	0·4	2·6	1·3	1·2	1·4	5·0	8·3	15·2	17·4	21·9	7·9	8·2
V	5·4	0·5	0·2	...	...	...	0·8	0·9	2·4	1·6	5·6	6·9	15·2	15·0	26·1	9·0	10·6
VI	4·2	0·2	1·2	0·3	0·8	0·8	0·4	1·5	2·8	3·4	6·6	8·9	15·4	18·2	16·0	8·6	10·5
VII	3·5	2·1	1·0	1·0	0·4	0·8	2·1	0·8	3·7	2·0	4·1	6·5	12·9	14·8	25·0	9·5	9·6
VIII	5·2	1·7	0·5	1·2	1·2	0·8	0·8	1·8	3·3	1·3	1·7	5·6	11·8	15·0	25·4	11·5	10·6
IX	4·2	1·8	0·8	0·5	2·6	1·8	2·2	2·5	3·0	1·0	2·9	6·5	11·9	15·2	21·4	11·1	10·6
X	2·6	1·2	...	...	1·0	1·3	0·8	2·1	1·7	1·2	2·6	12·2	22·4	24·0	17·6	4·4	5·0
XI	4·0	1·4	2·0	1·1	0·8	0·7	1·8	4·2	2·8	2·4	5·4	7·2	17·6	21·1	12·2	4·6	10·7
XII	8·0	1·0	0·2	1·3	2·4	0·8	1·5	3·7	4·4	3·2	6·1	3·1	15·4	17·0	18·4	8·2	5·2
Mean	5·0	1·3	0·7	0·5	1·1	0·7	1·9	1·9	2·6	1·8	4·4	7·5	15·8	16·3	21·6	8·2	8·8

TABLE XLVI.

Wind—Number of Gales per Month.

Macquarie Island. 3 Years' Observations.

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
9	6	6	6	8	10	11	5	9	12	5	8	94

TABLE XLVII.

Wind—Percentage Frequency of Gales from Different Directions.

Macquarie Island.

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
5·0	1·6	0·6	...	0·3	...	2·2	0·3	1·2	2·2	5·0	8·7	22·2	13·7	25·9	10·9

variation is slight. There appears to be a minimum in late summer and early autumn and a maximum in spring, October being the month with the highest average velocity. Experience in southern New Zealand tends to confirm these features and they are probably real, though the specially high average speed in October is probably to some extent fortuitous.

Wind Directions.—Table VI of Vol. III gives the percentage frequency with which winds occurred from each direction, for each month, and for each hour of the day at which the direction was recorded. This information is summarized in Table XLIV which gives the figures for each month as derived from the mean of all the observations on each day. The table includes the percentage of calms. It will be seen that during the first six months no calms at all were recorded. This would suggest that the different observers had rather different criteria for a calm. An inspection of the anemograms, however, suggests that the difference was due principally to trouble experienced with the recording instrument. There seems a tendency at times for the pen to sink from the correct velocity to a low reading and for it to stick at low values. Furthermore, the record sometimes extends considerably beyond the zero line. It is not possible to say what was the source of the trouble but possibly the freezing of the liquid in the recorder and the condensation of moisture or rime on various parts were responsible for some of it. Table XLV gives the mean frequency of different directions for each month as derived from all observations. In each month is shown the overwhelming frequency of winds from the western semicircle, and especially from the north-west quadrant, 53·7 per cent of the winds came from W, WNW, or NW. A further 15·7 per cent is added by WSW and NNW. The excess of NW over SW is probably exaggerated by the exposure but there can be no doubt that it is a real feature. From directions between NNE and SSE, the total frequency is only 8·1 per cent. The period of observations, again, is too short for very definite conclusions to be drawn with regard to the annual variation in direction. It must be slight but the westerly component is most prominent in the three months October, November and December,

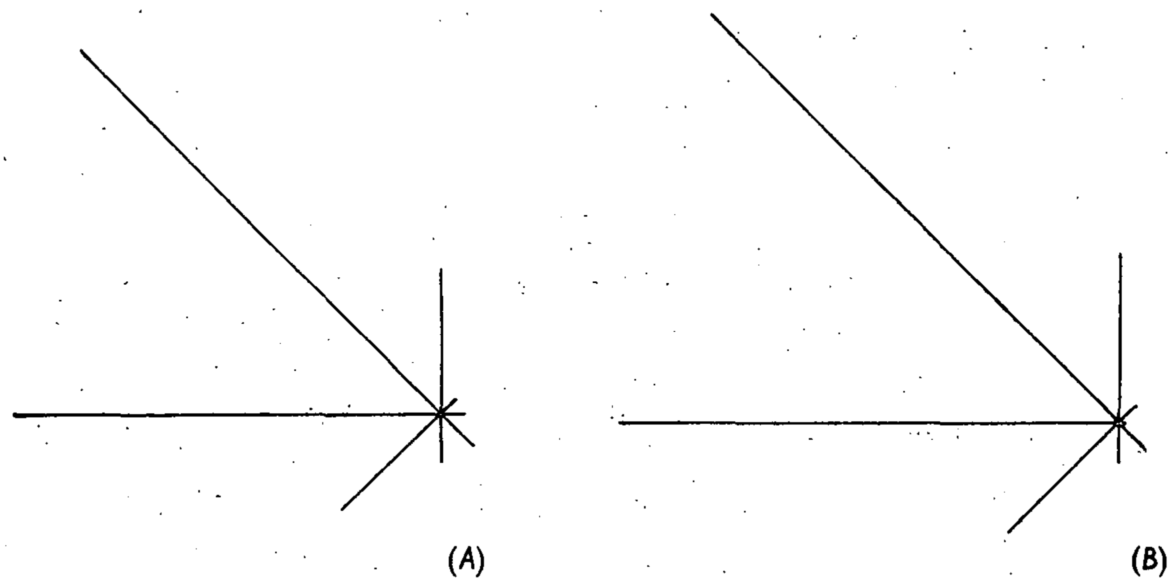


FIG. 25.—Percentage Frequencies.—(*A*) of all Winds and (*B*) of Gales.—from various directions, Macquarie Island.

especially the first. It is least prominent from July to September while there appears to be a secondary maximum in the late autumn. This is in general agreement with conditions in New Zealand. The variation is due principally to a corresponding variation in the strength of the westerly wind component. October, it will be remembered, is the month of lowest average pressure in the Antarctic.

Gales.—In Table XLVI are the average number of gales for each month observed in three years. The figures were taken from the "Daily Weather Remarks" published in Volume III. The following Table XLVII shows the percentage recorded from each direction. Again an overwhelming proportion come from the north-west quadrant. The excess is more marked for gales than for all winds. This is brought out more clearly in Fig. 25 which gives wind roses for all winds and gales respectively. There are occasional gales from an easterly direction. The Tables show the extremely stormy character of the weather at Macquarie Island. There is a rapid increase in storminess from New Zealand southwards.

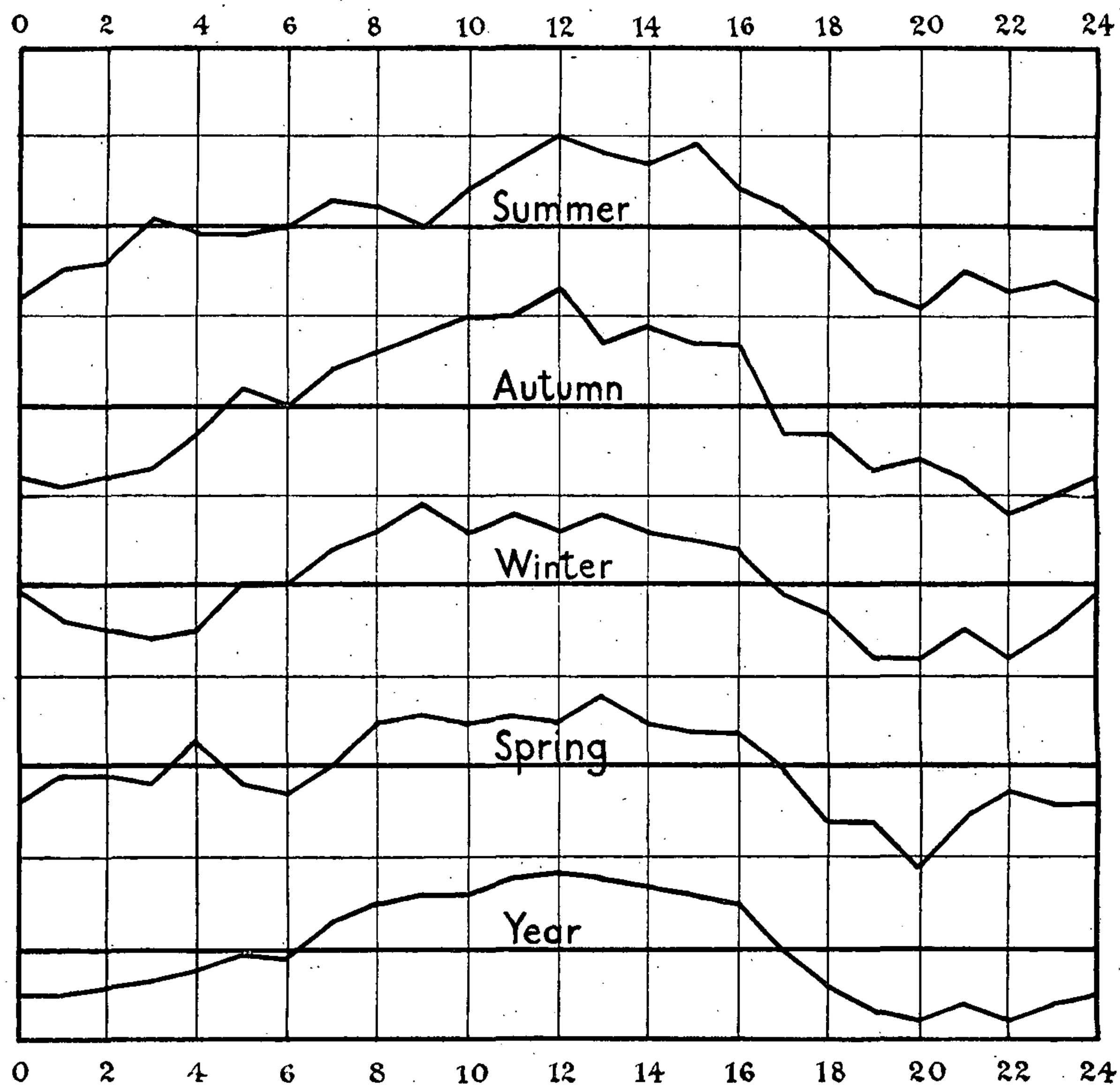


FIG. 26.—Diurnal Variation of Wind Velocity, Macquarie Island. One Vertical Division equals 1 mile per hour.

TABLE XLVIII.

Wind—Diurnal Inequalities of Velocity.

Macquarie Island. Tenths of Miles per Hour.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period. I	—8	—9	0	—10	—1	0	+5	+3	+1	+8	+13	+16	+11	+7	+10	+5	+3	0	—8	—16	—8	—11	—3	—6
II	+1	0	+6	+1	0	—3	0	—4	—7	—5	—2	+2	+7	+12	+10	+5	+6	+3	—2	—3	0	—4	—8	—10
III	—8	—8	—1	+3	+8	0	+3	0	+3	+5	+3	+4	+3	+4	+3	+7	+1	0	—4	—5	—10	—5	—8	—4
IV	—15	—14	—13	—3	0	—2	+7	+5	+9	+17	+14	+21	+9	+8	+8	+11	—3	—4	—7	—4	—6	—13	—12	—11
V	—4	—3	—7	—8	—2	+1	+3	+13	+13	+8	+12	+14	+9	+14	+10	+2	—6	—4	—9	—9	—9	—17	—11	—10
VI	—10	—9	—7	—2	+5	+2	+2	+9	+16	+7	+11	+12	+10	+5	+4	+3	+1	—3	—11	—11	—9	—10	—8	—2
VII	—4	—4	—6	—8	—3	+6	+5	+4	+3	+5	+5	+2	+5	+10	+7	+5	+2	+2	—4	—7	—1	—8	—3	—1
VIII	+3	—2	—4	—6	—2	—7	+4	+6	+7	+6	+7	+5	+9	+4	+4	+3	—7	—8	—9	—7	—6	—6	—5	—1
IX	+3	+1	0	—3	—5	—8	—9	+1	+12	+10	+5	+6	+13	+7	+4	+2	—4	—9	—4	—12	—10	—4	—4	—4
X	—3	—2	—4	+4	+1	—2	+3	+4	+2	0	+5	+3	+1	+7	+6	+6	+7	0	—6	—10	+1	+2	—1	—2
XI	—3	—1	—2	+7	—2	+1	+5	+9	+3	+6	+9	+7	+9	+2	+3	+5	—2	—8	—7	—11	—9	—7	—7	—7
XII	—8	—4	—2	+6	—2	+3	+4	+7	+6	+8	+10	+11	+6	+3	+8	+1	—3	—10	—10	—9	—8	—5	—8	—7
Summer (XII, I, II)	—5	—4	+1	—1	—1	0	+3	+2	0	+4	+7	+10	+8	+7	+9	+4	+2	—2	—7	—9	—5	—7	—6	—8
Autumn (III, IV, V)	—9	—8	—7	—3	+2	0	+4	+6	+8	+10	+10	+13	+7	+9	+7	+7	—3	—3	—7	—6	—8	—12	—10	—8
Winter (VI, VII, VIII)	—4	—5	—6	—5	0	0	+4	+6	+9	+6	+8	+6	+8	+6	+5	+4	—1	—3	—8	—8	—5	—8	—5	—1
Spring (IX, X, XI)	—1	—1	—2	+3	—2	—3	0	+5	+6	+5	+6	+5	+8	+5	+4	+4	0	—6	—6	—11	—6	—3	—4	—4
Year	—5	—4	—3	—2	0	—1	+3	+5	+6	+6	+8	+8	+8	+7	+6	+5	0	—4	—7	—8	—6	—8	—6	—5

Diurnal Variation.—In Table XLVIII will be found the mean diurnal inequalities at each hour for each month, the four seasons, and the year as derived from all the available data. January, 1912, was weighted only one half in computing the means for that month. The figures for the seasons and the year are plotted in Fig. 26. The variation is small, the range in the mean for the year being only 1·6 miles per hour. The velocities tabulated were the instantaneous mean velocities at the hour. The direction, when given, is also that at the hour. In the mean, the maximum velocity occurs at about noon or a little after and the minimum between 20 and 21 hours. The variation is obviously, principally at least, a temperature effect. There would be some variation with season owing to changes in both the amplitude of the temperature variation and the length of day. These are partly shown by the curves in the figure. But the wind velocity also has an effect. Thus in months with high velocity the amplitude would be small and in those with low velocity, high. This is illustrated by the departures for October and April respectively. The curves show the smallest amplitude in spring and the greatest in autumn. In addition to the effects mentioned, it is probable that the atmosphere is more stable in autumn than in spring and the increase of velocity with height, therefore, also greater. This would result in a greater change in velocity due to the turbulence in the surface layers induced by the heating of the ground. The curves in Fig. 26 are not very smooth and there are some features unaccounted for. It may be that there is some diurnal variation in velocity in the general winds over the surrounding ocean but it is not possible to disentangle any such effect from chance variation and the immediate local effect due to the diurnal heating and nocturnal cooling of the land surface. Table XLIX gives the harmonic analysis of the curves shown in Fig. 26. The constancy in phase of the 24-hour term is remarkable. The annual variation in its amplitude is brought out clearly.

TABLE XLIX.

Wind—Harmonic Analysis of Diurnal Variation of Velocity.

Macquarie Island. Miles per Hour.

$$dV = a_1 \sin(\theta + A_1) + a_2 \sin(2\theta + A_2) + a_3 \sin(3\theta + A_3).$$

Period.	a_1	A_1	a_2	A_2	a_3	A_3
Summer (XII, I, II)	0·70	282°	0·30	20°	0·11	189°
Autumn (III, IV, V)	1·05	282	0·09	317	0·03	162
Winter (VI, VII, VIII)	0·73	286	0·16	89	0·20	105
Spring (IX, X, XI)	0·55	288	0·31	47	0·11	97
Year	0·75	284	0·18	47	0·08	115

Gustiness.—For some months in Table V of Volume III there is given the maximum gust for each day. In the introduction it is stated that these "are rather doubtful records. The registrations were obtained from different devices constructed by the meteorologist on the island, . . ." There does not appear to be any reason why they should not have been read directly from the daily traces of the anemobiagraph. However, owing to the exposure the significance of the gust values is somewhat uncertain.

The gustiness (as determined by the ratio of the range in gusts to mean velocity) has been measured for a few cases of winds, from each of the principal directions. It has already been suggested that the winds would be interfered with to some extent by the nearby high country. This is confirmed by the gustiness recorded by the anemobiagraph. Winds from the north-east quadrant were affected by Wireless Hill 350 ft. (107m.) high on the peninsula lying in that direction. The top of the hill was about a third of a mile away. Similarly, winds from between S x W and W x S were obstructed by the high country of the mainland which at a distance of a mile rose to over 900 feet (280m.). Winds from both these quarters exhibited a high and characteristic gustiness. It is generally possible to recognize their occurrence by the appearance of the trace. In an E to NE wind with a mean velocity, according to the trace, of about 14 miles per hour the gustiness was about 2. The average for several strong SW or WSW winds was 1·6. There is no doubt that, even if not interfered with, south-westerly winds would often have been very gusty and squally. Thus in a S gale on the 2nd August, 1912, with frequent squalls of snow and soft hail and very low temperatures, the gustiness was 0·96. Again on the 28th April with a SSW wind of 12 to 18 miles per hour and hail squalls, the gustiness was 1·09. Winds from between west and south behind a cold front or occlusion were often accompanied by hail squalls. On these occasions there was a typical trace on both thermograph and anemobiagraph. On the latter it would be very ragged with frequent squalls of which the principal frequency was usually somewhat less than an hour. In these winds there would, of course, be rapid heating at the surface. Winds from the SE were probably much more stable. They were much less turbulent. A fresh SSE gale with a recorded velocity of 28 miles per hour on the 18th June, 1912, had a gustiness of 0·7. In a fresh SE wind registering 16-18 miles per hour on the 8th July, 1912, the weather being fine and sunny, the gustiness was 0·5. In another SSE wind of 19-20 miles per hour on the 1st September, 1912, the sky being overcast, it was 0·45.

In the north-west quadrant the gustiness generally increased as the wind became more westerly. Often when the air was warm the gustiness in northerlies would become very slight, indeed almost disappear. On these occasions the atmosphere was obviously very stable. Low cloud and very often fog was present. This state of affairs was very marked at times in the area between the cold front and occlusion of a depression. On the afternoon of the 10th April, 1912, for example, the weather being foggy and mild, there was scarcely any gustiness until the recorded velocity in a NW wind rose above 10 miles per hour. On the 18th July, 1912, in a moderate to strong NW wind registering 14 miles per hour, the weather being very cloudy and mild, the gustiness was 0·2.

The gustiness in examples of various types of wind from between north and west is given in Table L. Quick run records are available for some of the typical gales. In this case half an hour's trace covered about 15 inches and the structure of the wind is clearly shown.

TABLE L.—*Examples of Gustiness in North to West Winds at Macquarie Island.*

Date.	Time.	Direction.	Recorded Velocity.	Gustiness.	Remarks.
1912.			m.p.h.		
March 11 ...	Afternoon ...	NNW.	12	1·0	Steady rain. Mild temperatures.
" 16 ...	Day ...	NW.	16–17	0·5	Light steady rain. Wind changed to SW at 21 hours.
" 17 ...	Afternoon ...	W-WNW.	13–19	0·7	Fine.
April 12 ...	Noon ...	NW.	32–36	0·75	Whole gale preceding a front.
" 17 ...	Afternoon ...	W-WNW.	12	0·53	Overcast with misty showers.
May 2 ...	Morning ...	W.	12–19	1·4	Strong westerly gale. A squally trace.
" 3 ...	Morning ...	NW.	16–19	0·35	Fresh to strong NW wind.
" 4 ...	Afternoon ...	W.	28	1·30	Stong W. gale. Maximum gust 52 m.p.h.
" 20 ...	Noon ...	NNW.	30	0·55	Fresh gale.
" 22 ...	21 h. ...	NW.	22–27	0·8	Moderate NW gale and light rain.

The effect of the diurnal variation of temperature was often recognizable on the traces in the reduced velocity and gustiness in the night hours.

Cloud Movement.—The wind roses in Fig. 27 show the relative frequency with which upper, middle and lower clouds, respectively, moved from different directions. In the case of cirrus and alto clouds the observations were so weighted that each day on which an observation was made is given equal weight. For lower clouds the observations were very much more numerous and each was given equal weight. At each level there is a marked preponderance of movement from the north-west quadrant. For the upper clouds north-west with 38·2 per cent is the most frequent direction. Alto clouds show a much smaller frequency of movement from the north than the cirrus. West is the most frequent direction with 40·3 per cent. For low cloud, the frequency of N, NW, W and SW movements are 12·3, 29·9, 30·5, and 13·8 per cent, respectively. The percentage of south-west increases as the height falls.

The roses shown represent the mean frequencies for the year. The annual variation appears to be slight and the observations are not sufficient to give a reliable indication of it. It is not stated whether a nephoscope was used in making the observations. In Mr. Tulloch's year the percentage of movement of low cloud from the north is considerably greater than during Mr. Ainsworth's regime. The difference seems greater than could be accounted for by true differences between the years. Possibly one consistently recorded the direction of rather lower cloud than the other. There seems little doubt that at Macquarie Island there is a resultant air flow from the north of considerable magnitude. It is unlikely, however, to be so pronounced as the cloud observations indicate. There is certainly a great preponderance of movement from the west over that from the east. The excess of north-westerly winds at Macquarie Island appears to be due to a flow from that direction out of south-eastern Australia. It accounts partly, at least, for the higher temperatures recorded at Macquarie Island than in some other longitudes in the same zone, for example, in the Kerguelen region. It may also account for the relative absence of icebergs south of the Tasman Sea.

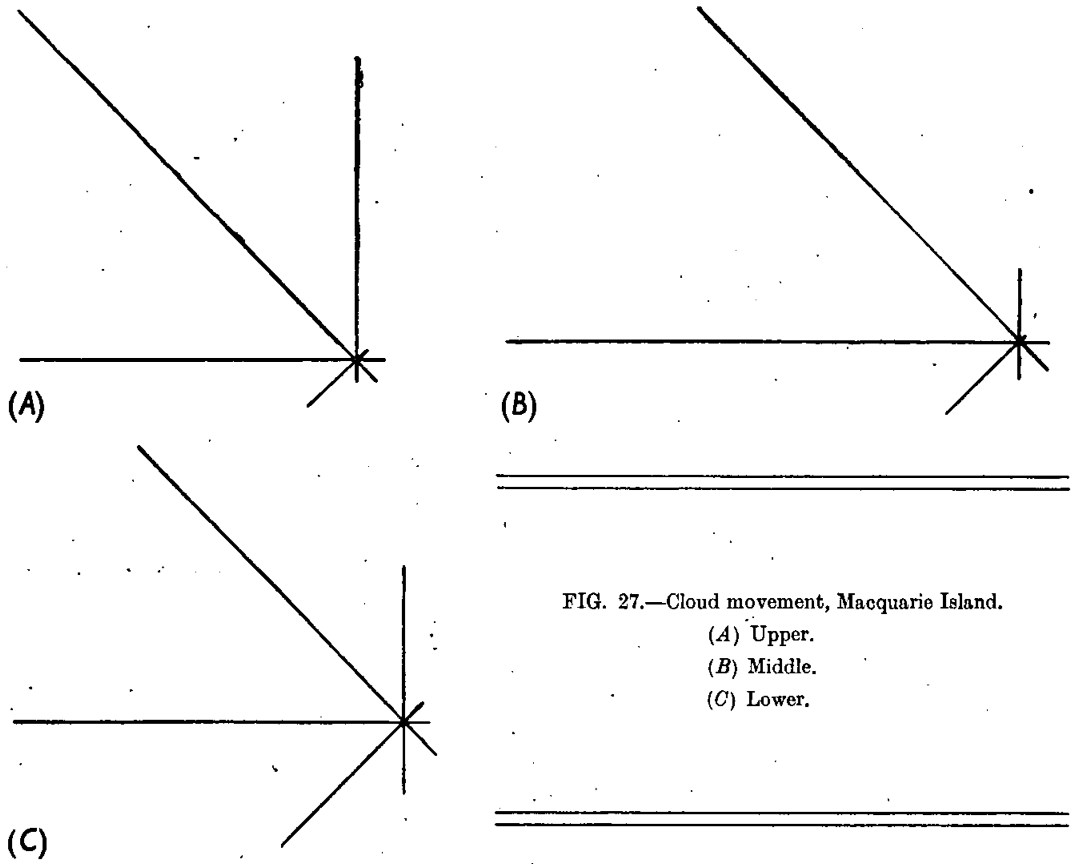


FIG. 27.—Cloud movement, Macquarie Island.
(*A*) Upper.
(*B*) Middle.
(*C*) Lower.

CHAPTER V

PRECIPITATION, HUMIDITY, SUNSHINE, CLOUD AND PHENOMENA

I.—ADÉLIE LAND AND QUEEN MARY LAND

1. Precipitation.

At Adélie Land a "snow gauge" consisting of a piece of stove pipe somewhat over 8 inches in diameter and standing 3 ft. 6 in. (about 1 m.) above the ground was erected and the snow which it caught carefully measured. The results are given in Table XIV of Vol. IV under the heading "Snowfall." But the measurement of snowfall is very difficult at any Antarctic station owing, first, to the strength of the winds and, second, to the frequent presence in the air of drift snow. The wind eddies round a gauge tend to carry the snowflakes out of it, at least if the gauge is unprotected, while it is impossible to distinguish between snow which has fallen direct from the sky and drift snow picked up from the ground and subsequently deposited in the gauge. Under the conditions obtaining at the Adélie Land Base the measurement of precipitation appears to present an almost hopeless problem. The significance of the data in the table referred to is, therefore, extremely uncertain. The amount measured in the 22 months from the 16th February, 1912, to the 15th December, 1913, was equivalent to 118·41 inches of rainfall.

There was, however, other valuable evidence regarding the rate of snowfall and the amount of the annual accumulation. Thus, Mr. Madigan erected a depot cairn on the summit of the broad-topped Mount Murchison on the 21st November, 1912. The top of the depot flag was 10 feet above the surface. Seven weeks later, on the 7th January, the flagpole projected only four feet above the snow surface. Mount Murchison is close to the coast. The top is 1870 feet (560 m.) above sea-level and considerably higher than the surrounding country. There was, therefore, no question of the accumulation of drift snow and the increase in depth would certainly give an underestimate of the precipitation on the peak. On the other hand, the precipitation might be considerably more than the average for the surrounding area. Furthermore, the amount would be above most of the katabatic wind and the drifting snow carried by it, so that the ablation would probably be less than at lower levels. In December, 1913, just over a year after the depot was erected, there had been an accumulation of 9 feet of consolidated snow. Observations and photographs taken elsewhere by the Expedition indicate annual accumulations of snowfall of the order of 1 to 3 metres.

It may be mentioned that during the period in which six feet of snow was accumulating on Mount Murchison the equivalent of only 0·05 inch of rain was measured in the snow gauge at the Base.

The observations indicate that snow was more frequent and heavier in winter than in summer, which is probable on other grounds. No rainfall was observed though, especially in the warmer part of the year, the rounded pellets of "sago snow" were recorded on numbers of occasions. Presumably there has been some melting to produce this kind of snow.

Next to the wind, the drift snow was the most prominent feature of the climate of the Adélie Land Base. The members of the expedition not only had to learn to face winds previously considered unendurable in such a climate but for a large part of the time had, in addition, to carry out their routine work in an all obscuring drift. A special technique had to be developed. Thus in the winter nights the magnetic observer, steering a devious course so that he could make up on the rocks the leeway lost on the bare snow surface, creeping on all fours, and determining his whereabouts by feel, might take over an hour to cover a few hundred yards to his observation hut or back. Mr. Madigan says "it was quite rare to have a high wind without drift, which was continuous for weeks on end." According to his account, the top of the 60-feet wireless mast was never out of the drift. When, in clear weather at the hut, drift was seen to the east or west, it appeared to be several hundred feet in height. These statements refer, presumably, to times when the drift current was completely established. The amount of drift was measured by means of a hollow tin cone placed 2 feet 6 inches above ground on the windward side of a box 3 ft. x 2 ft. 6 in. x 3 ft. high. The cone was truncated so that there was an orifice $\frac{3}{4}$ inch in diameter at the apical end. The snow passing through this orifice would nearly all be deposited in the box. Assuming that the drift current had an average depth equivalent to 100 feet at a density equal to that at the gauge, it was estimated that the amount of snow swept into the sea per annum would be equivalent to a belt of water 1.2 miles wide and 100 feet deep extending along the coast. There is no doubt that enormous quantities of snow are carried out to sea in this way and that it is, in this particular region, the most important means by which precipitation is drained from the land.

At Queen Mary Land the precipitation was heavy but no precise estimates of its amount are available to the writer. There was thick and heavy drift during storms but drift generally was much less persistent than at Adélie Land. In that locality, ice movement was probably the most important form of drainage.

The questions of precipitation, snow accumulation, ice flow, transport of snow by drifts currents, and other forms of ablation will be discussed by Sir Douglas Mawson with the more extensive data at his disposal in the volume on "Glaciology." There is no doubt, however, that at both Adélie Land and Queen Mary Land, the precipitation, for glacierized regions was high and the same must be true for much of the Antarctic coast line between Cape Adare and Queen Mary Land.

2. Relative Humidity.

The humidity was recorded at Adélie Land by means of two hair hygrographs, apparently used alternatively. The instruments were adjusted from time to time at temperatures of about 50° F. by causing them to read 96 per cent after the hairs had been surrounded for two hours by wet muslin. The recording was done in the thermometer screen. In February, 1912, and November and December, 1913, the readings of the hygrographs were compared with values derived from wet and dry bulb thermometers. In most cases the hygrometer gave the lower readings and the differences were sometimes large. The accuracy of the results obviously cannot have been high but it seems, on the whole, probable that they give a correct impression of the humidity over ice at the station. When the air was full of drift, the humidity was always very high. When it was clear, however, surprisingly low values were often obtained. Table X of Vol. IV gives hourly values of relative humidity for the period from the 1st February, 1912, to the 14th December, 1913. Humidities below 40 per cent were sometimes recorded. Mean values from all the observations for each of the twelve months are given in Table LI. The dryness of the air is surprising. Certainly it would, in general, have been descending rapidly from high altitudes and the effect of the descent would be to raise the temperature and decrease the relative humidity. On the other hand, there would have been some cooling at the surface, otherwise the air would not have descended. Furthermore, since the current was in contact with a snow surface, it would have been continually absorbing moisture from it. Under the conditions existing at Adélie Land, however, the drainage of cold air was extraordinarily effective, so that the extent to which the air was cooled over the land was smaller than in most cases of the kind. At the same time, there would be some temperature gradient to the southward so that the moisture content of the air at its source would be low. Again, the slope of the land near the Base was probably steeper than the average for the locality and the descent, therefore, more rapid. In any case, the supply of water vapour by evaporation from the snow surface and subsequent distribution by turbulence was not nearly sufficient to counteract the loss of relative humidity due to descent. The results suggest again that, in drift-free weather at least, the wind current was very stable. Once drift was picked up, saturation or something near it was maintained by evaporation from the suspended snow particles.

Table LII contains the mean diurnal inequalities for each hour of each month and of the year. The diurnal variation is very slight but is clearly caused by the diurnal variation of temperature. The humidity is, on the average, highest at 6 or 7 a.m. and lowest in the early afternoon.

TABLE LI.

Humidity—Mean Relative Humidity.

Adélie Land. Per cent.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
1912 ...	...	67	75	81	78	63	65	68	53	66	61	58	...
1913 ...	73	70	85	94	93	84	84	89	91	77	65	51	...
Means ...	73	68	80	88	86	74	74	78	72	72	63	56	74

Some breaks, particularly in April, 1912 and September, 1913. 14 days only in December 1913, which is weighted only ½.

TABLE LII.

Humidity—Mean Diurnal Inequalities of Relative Humidity.

Adélie Land. Per Cent.

Hour L.M.T.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period.																								
I	0	0	—1	0	—1	—1	—1	0	—1	0	—2	—2	—2	—2	—1	—1	—1	—1	+1	+1	+2	+1	+1	0
II	—0·5	0·0	+1·0	+0·5	+1·5	+1·5	+1·0	+0·5	+1·0	—0·5	—1·0	—1·0	—0·5	+0·5	0·0	—1·5	—1·0	0·0	+0·5	+1·0	+0·5	0·0	—0·5	—0·5
III	+2·5	+2·0	+2·5	+2·0	+2·0	+2·0	+1·5	+1·5	+0·5	0·0	—0·5	—1·5	—1·0	—1·0	—2·0	—1·5	—1·0	—1·5	0·0	0·0	+0·5	+1·0	+0·5	+0·5
IV	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5	+1·0	+1·0	+1·0	+1·0	+0·5	+0·5	0·0	0·0	—0·5	—1·0	—1·0	—1·0	—1·0	—1·0	—1·0	—1·0	0·0	0·0
V	—1·0	—0·5	0·0	—0·5	0·0	+0·5	0·0	0·0	—0·5	—0·5	—0·5	—0·5	—1·0	—1·0	—1·0	—1·5	—1·0	—1·0	0·0	+0·5	+1·0	+0·5	+0·5	0·0
VI	—1·5	—2·5	—0·5	0·0	—0·5	+0·5	0·0	0·0	—2·0	0·0	—0·5	—1·0	—1·5	—0·5	0·0	+0·5	+1·0	+1·5	+1·5	+1·5	—1·0	+1·5	+1·0	+1·0
VII	+1·0	+1·5	+1·0	+0·5	+0·5	+1·0	+0·5	0·0	0·0	+1·5	+1·5	0·0	—1·0	—1·0	—1·0	—1·0	0·0	+1·0	0·0	+0·5	0·0	0·0	+0·5	+0·5
VIII	0·0	0·0	0·0	—0·5	0·0	0·0	0·0	+0·5	+1·0	+0·5	+0·5	+0·5	0·0	+0·5	0·0	+1·0	+0·5	+0·5	0·0	0·0	+0·5	0·0	0·0	0·0
IX	—2·0	—1·5	—0·5	0·0	+1·0	+0·5	+0·5	+0·5	+0·5	+0·5	0·0	0·0	—1·0	—1·0	—1·0	—1·0	—1·0	—1·0	0·0	—0·5	—0·5	—0·5	—0·5	—0·5
X	+1·5	+1·5	+0·5	+0·5	+0·5	+1·0	+1·5	+1·0	+1·0	+0·5	—0·5	0·0	0·0	0·0	—1·0	—1·5	—1·5	—2·0	—2·5	—2·0	—1·5	—1·5	—1·0	—0·5
XI	+1·0	+2·0	+2·0	+1·0	+1·5	+1·5	+1·5	+1·5	0·0	+0·5	—0·5	—0·5	—1·5	—1·5	—1·5	—1·5	—1·5	—1·5	—1·0	—1·0	—0·5	0·0	+1·5	+0·5
XII	+0·7	0·0	—0·7	0·0	0·0	+1·0	+1·0	+0·3	+0·3	+1·0	—0·3	—1·7	—2·3	—2·7	—1·7	0·0	+0·7	—0·7	+1·0	+0·3	+0·3	+1·7	+0·3	+0·3
Year	+0·2	+0·2	+0·4	+0·3	+0·5	+0·8	+0·7	+0·6	+0·2	+0·4	—0·3	—0·6	—1·0	—0·8	—0·9	—0·8	—0·6	—0·6	0·0	0·0	+0·2	+0·2	+0·2	+0·1

TABLE LIII.

Bright Sunshine—Monthly Totals.

Adélie Land. Hours.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	...
1912 ...	...	239·0	154·1	22·8	10·6	...	...	33·3	226·9	251·5	309·7	370·2	...
1913 ...	173·0	127·0	91·5	74·1	5·3	...	...	7·4	77·7	208·9	273·9	80·4	...

December, 1913, total from 14½ days only.

TABLE LIV.

Bright Sunshine—Mean Number of Hours.

Adélie Land.

Hour L.M.T. From / To	0 / 1	1 / 2	2 / 3	3 / 4	4 / 5	5 / 6	6 / 7	7 / 8	8 / 9	9 / 10	10 / 11	11 / 12	12 / 13	13 / 14	14 / 15	15 / 16	16 / 17	17 / 18	18 / 19	19 / 20	20 / 21	21 / 22	22 / 23	23 / 24	Month	Possible
Period. I	...	...	1·4	8·9	11·2	10·4	11·8	11·9	11·6	8·9	8·2	8·4	7·5	8·5	7·6	7·4	9·3	9·2	7·8	8·1	10·5	4·4	...	...	173·0	648·8
II	...	...	...	0·2	1·8	6·0	10·1	11·3	12·3	12·6	11·9	12·7	12·6	12·6	12·2	12·2	11·8	12·5	12·2	10·2	6·4	1·6	...	...	183·0	471·1
III	...	...	...	...	...	0·4	2·8	7·8	10·4	10·8	11·0	12·7	12·2	13·0	12·4	10·6	10·3	7·6	1·0	0·0	...	...	...	...	122·8	389·6
IV	...	...	...	...	...	...	...	0·1	2·2	4·2	5·6	7·1	7·9	8·1	7·2	4·6	1·4	...	...	...	...	...	...	...	48·4	262·4
V	...	...	...	...	...	...	...	...	...	0·4	2·0	2·0	1·6	1·2	0·6	0·0	...	...	...	...	...	...	...	...	8·0	144·8
VI	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13·9
VII	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	90·1
VIII	...	...	...	...	...	...	...	...	0·2	1·4	3·0	4·3	5·0	4·0	1·4	0·8	0·2	...	...	...	...	...	...	...	20·4	225·0
IX	...	...	...	...	...	0·2	4·2	9·1	13·2	15·0	15·9	17·0	17·4	16·2	15·8	13·8	10·8	3·6	...	...	...	...	...	...	152·3	333·5
X	...	...	...	0·3	4·8	11·0	14·2	16·0	16·1	16·8	18·7	18·6	18·8	18·8	18·1	17·7	15·7	14·0	9·4	1·2	...	...	...	...	230·2	462·5
XI	...	...	2·7	10·3	14·3	15·0	15·7	17·2	16·8	18·0	18·5	18·5	18·6	18·4	18·2	17·6	17·3	17·3	16·1	15·0	6·4	0·4	...	...	291·8	571·4
XII	...	...	6·4	11·1	14·6	17·1	16·9	17·1	16·0	16·5	16·2	14·7	16·8	19·1	17·3	18·3	16·6	15·7	15·5	15·3	13·5	5·8	...	...	300·5	719·5
Year	...	...	10·5	30·8	46·7	60·1	75·7	90·5	98·8	103·6	111·0	116·0	118·4	119·9	110·8	103·0	93·4	79·9	62·0	49·8	36·8	12·2	...	...	1530·4	4332·6

3. Bright Sunshine.

The duration of bright sunshine was recorded by means of a Campbell-Stokes Recorder. A good deal of record was lost owing to the sun being obscured by drifting snow when, above the drift, it was shining brightly. This was especially the case when the sun's altitude was low. On some such occasions the number of hours during which the sun was "gleaming through" the drift was noted by the observers. The instrument was exposed fully to the northern semi-circle of the horizon. To the south, however, the ice cap subtended a maximum angle of elevation of about 6°, decreasing to zero in the east and west directions. Mr. Madigan states that the ice to the south cut off little sunshine that would have been recorded. The sun had to reach a considerable altitude before it was able to burn a trace on the record card. From the 10th May to the 5th August, 1912, and the 21st May to 30th August, 1913, the sunshine was too weak to produce any burn. For these periods the time during which the sun was visible was recorded by the meteorological observers. Table XIII of Vol. IV gives the duration of sunshine for each hour of the day and the total for each month. There is also given the "theoretical length of day" for each day. This represents the time the sun's centre would be above the horizon, neglecting refraction.

In Table LIII are given the total number of hours of sunshine recorded by the instrument in each month. 1912 was generally more sunny than 1913. In September, 1912, the amount of sunshine was remarkable. October, November and December, 1912, were also sunny. None of these months was stormy and the high pressure in September, 1912, has already been mentioned.

Table LIV contains the mean amounts of bright sunshine in hours for each hour and for each month as derived from the two years' observations. The mean for the year, in view of the stormy character of the climate, the long periods with a low sun, and the frequent occurrence of thick drifting snow makes quite a respectable total. In Table XIII of Vol. IV there were 5·0, 53·2, 56·7, 10·1, 32·8, and 49·3 hours in February, April, May, June, July and August, 1912, and 16·8, 4·7, 34·4, and 45·1 hours in May, June, July, and August, 1913, respectively, when the sun is recorded as being visible though not producing any burn on the Campbell-Stokes Recorder. These figures obviously, however, cannot be complete. Table LIV gives the possible duration as calculated by Mr. Madigan. The percentage of possible recorded in the winter months is zero or very low. But there is no means of deciding whether this is, to any extent, due to the sky being cloudier in winter than at other seasons or solely to the low altitude of the sun. In the years concerned, spring was certainly the sunniest season. The afternoon was sunnier than the morning in nearly every month. In the mean for the year it was definitely so.

4. Cloud Amount.

Table XII of Vol. IV gives observations of the amount of cloud at the hours 6, 12, 18, and 24 of local time for each day at Adélie Land, together with the means for each month. In the introduction it is stated that the figure given represents "the proportion of the sky actually covered by cloud, the remainder being blue sky." Ten represents a completely covered sky, as with nimbus, but the cloud amount for a sky covered with cirro-cumulus would normally be 7 or 8, depending on how closely packed the small masses of cloud were. On the many days of dense drift it was often impossible to tell whether the sky was covered or not, and in doubtful cases the letter 'D' for drift is inserted." The occasions on which 'D' was recorded are disregarded in computing the monthly means in Vol. IV. These means are summarized in Table LV. In this Table the left-hand side gives the mean cloud amount for the four hours of observation, for each month, the four seasons, and the year, as derived from the individual means given in Table XII of Vol. IV. The right-hand side gives the corresponding figures when 'D' is taken to represent overcast conditions and replaced by 10. This appears to be the more usual procedure. Probably something between the two values would best represent the actual conditions. The right-hand side gives the more uniform values. The estimation of the amount of cloud at a polar station offers well-known difficulties. In the first place, the rigorous conditions make observations extremely arduous, and next, the sky is often partially or completely obscured by drift snow. Then, the estimation of cloud amount at night is always very troublesome. The observations, especially in winter, therefore, cannot be expected to have a high degree of accuracy. Conditions should be best at mid-day when there was most light. The figures for this hour should give a good measure of the relative cloudiness. The mean amount of cloud is surprisingly low, especially when one remembers the extreme cloudiness of the Southern Ocean. Two factors would contribute to this, the first is the absence of convection and the second is the subsidence which would usually be taking place in winds with a southerly component. In view of the conditions, the records of sunshine and cloud amount confirm each other satisfactorily. Winter and spring were the least cloudy, while autumn was the most cloudy season. It does not seem safe to draw any conclusions with regard to the diurnal variation of cloudiness.

In Table LVI are listed for each of the four seasons and the year the percentage frequency of occurrence at noon of different amounts of cloud. The occasions on which drift 'D' was recorded are treated separately. The most frequently recorded amount is 10, completely overcast. The next is 0, completely clear. Amount 1 was also of frequent occurrence. There has evidently been a slight bias towards recording half-clouded. If allowance be made for this it would appear that this amount was the least frequent and that there was a gradual increase in frequency for both greater and smaller amounts until 8 and 2 were reached respectively. Beyond these amounts, the increase is rapid at both extremities of the table. Several expeditions to this quarter of the Antarctic appear to have been struck by the frequency of occurrence of lenticular, or as they have called them "whaleback" clouds. Reports of these appear in the Adélie Land journal and those of sledging expeditions. There are rather frequent entries in the journal of cumulo-nimbus cloud. These clearly do not refer to true cumulo-nimbus but to cumuliform cloud from which precipitation was falling, or appeared likely to fall.

5. Phenomena.

There was not a great wealth of phenomena recorded at Adélie Land. Possibly this was due to frequent presence of drifting snow. Amongst the remarks in the journal, the records of snow falling in round white pellets are worthy of mention. This form

TABLE LV.

Mean Amount of Cloud.

Adélie Land.

	Excluding Occasions of Dense Drift.					Occasions of Dense Drift Counted Overcast.				
Hour L.M.T.	6	12	18	24	Mean.	6	12	18	24	Mean.
Period.										
I	7·0	7·6	7·3	7·0	7·2	7·1	7·8	7·3	7·0	7·3
II	7·0	6·1	5·9	5·9	6·2	7·4	6·1	6·0	6·1	6·4
III	5·3	6·6	6·8	5·3	6·0	6·4	6·8	6·8	6·3	6·6
IV	6·0	6·0	5·6	4·5	5·5	7·5	7·0	6·7	6·4	6·9
V	3·5	5·1	4·2	5·6	4·6	7·0	6·2	6·3	7·2	6·7
VI	4·2	5·0	4·2	4·2	4·4	5·1	5·5	5·0	4·8	5·1
VII	2·8	4·6	3·5	3·4	3·6	3·2	4·7	3·8	4·4	4·0
VIII	4·5	5·6	4·2	4·2	4·6	5·2	5·8	4·6	5·2	5·2
IX	4·6	4·8	5·0	4·0	4·6	4·6	4·8	5·1	4·1	4·6
X	4·2	4·6	4·6	3·7	4·3	4·6	4·8	4·8	4·1	4·6
XI	4·8	5·0	4·2	4·6	4·6	5·7	5·2	4·7	4·9	5·1
XII	5·1	5·4	5·7	5·3	5·4	5·3	5·4	6·0	5·4	5·5
Summer (XII, I, II)	6·4	6·4	6·3	6·1	6·3	6·6	6·4	6·4	6·2	6·4
Autumn (III, IV, V)	4·9	5·9	5·5	5·1	5·4	7·0	6·7	6·6	6·6	6·7
Winter (VI, VII, VIII)	3·8	5·1	4·0	3·9	4·2	4·5	5·3	4·5	4·8	4·8
Spring (IX, X, XI)	4·5	4·8	4·7	4·1	4·5	5·0	4·9	4·9	4·4	4·8
Year	4·9	5·5	5·1	4·8	5·1	5·8	5·8	5·6	5·5	5·7

TABLE LVI.

Cloud—Percentage Frequency of Different Amounts at Noon.

Adélie Land.

	Amount.											
	0	1	2	3	4	5	6	7	8	9	10	D
Summer	12	14	1	4	4	5	4	1	7	10	37	1
Autumn	9	11	5	4	2	5	3	4	5	5	28	19
Winter	19	17	5	3	3	3	3	4	3	3	31	5
Spring	25	15	3	6	3	3	2	4	2	4	31	3
Year	16·2	14·2	4·1	4·2	2·8	4·0	2·8	3·5	4·1	4·8	31·5	7·8

TABLE LVII.

Falls of Spherical Snow.

Adélie Land.

Date.	Remarks.
1912.	
7 II	Tapioca.
27 II	Tapioca.
28 II	Tapioca; light to heavy; diameter $1\frac{1}{3}$ mm.
12 VII	Small spherical particles.
22 VIII	Tapioca.
24 VIII	Tapioca.
21 IX	Light tapioca.
4 XI	Sago.
8 XII	Sago; heavy fall.
1913.	
26 I	Tapioca; light fall.
27 I	Tapioca; light fall.
3 II	Tapioca.
18 II	Tapioca.
23 II	Sago; light fall.
27 II	Sago.
8 III	Tapioca; light fall.
15 III	Sago.
5 VIII	Sago; heavy fall.
20 IX	Sago; fell in large balls.
25 X	Sago; light.
16 XI	Sago.

of snow is usually referred to as "sago" or "tapioca" snow owing to its resemblance to these substances. In general, tapioca refers to particles of a larger size. The occurrences of this are listed in Table LVII.

No *rain*, *thunder*, or *lightning* were observed.

Fog was recorded on four occasions but there were probably others on which it could not be seen on account of drifting snow.

The optical phenomena do not appear to have been particularly striking. *Halos* were recorded on 43 days and parhelia on 2. In every case the halo of 22° appears to have been concerned. *Coronae* were, as usual at polar stations, often noted and were frequently bright. They were recorded on 25 days, all except one being lunar coronae. Four were double. On one occasion when it was foggy the corona was without colour. The radii observed ranged mainly from 1°·0 to 4°·5 but the solar corona had a radius of 7°·5. In view of the common occurrence of spherical snow it seems likely that some of these coronae were produced by ice particles of that nature. Most of those with very small diameters were probably due to ice particles of some kind.

The frequent occurrence of drifting snow in high winds was highly favourable to the development of static electricity on all exposed objects. This is recorded frequently in the journal as "*St. Elmo's Fire*."

The roaring of the wind in the distance when it was calm at the base was observed on numbers of occasions. It is recorded several times, also, that the wind came in fierce gusts interspersed with brief calms.

II.—MACQUARIE ISLAND

1.—Precipitation.

The Macquarie Island station, as previously stated, was situated on a narrow isthmus. Sea spray used, at times, to be carried right across the Isthmus. For this reason, unfortunately, Mr. Ainsworth decided that measurements of precipitation would be unreliable and did not take them. The amount of spray collected could scarcely be very important. In the last year of occupation precipitation was observed and the monthly totals are given in the first part of Table LVIII. For the year from December, 1914, to November, 1915, the total was 45·86 inches. Precipitation was also observed in part of 1914, although at that time, apparently, the observers had not entire confidence in the measurements. The totals for May to October, 1914, in Table LVIII are from data available in New Zealand and are sufficiently accurate. Using them and deriving monthly means, we get an annual total of 48·21 inches. The monthly totals ranged from 3·22 inches in February and 3·24 in October to 5·15 in January. Precipitation in this region is extremely frequent but usually either light and intermittent or of the shower type. The last part of the table gives the maximum day's fall in each month. No very heavy falls were recorded, 0·86 inch being the highest. The majority are small or moderate.

The second part of the table contains for each month the number of days on which precipitation was observed. Until December, 1913, these are taken from Mr. Ainsworth's diary in Table XI of Vol. III. For the following year they are extracted from Table XII which gives a synopsis of the daily weather reports to Australia by wireless

TABLE LVIII.

Precipitation.

Macquarie Island.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Year.
						Total Fall—Inches.							
1914 ...	...	...	...	...	4·20	4·60	4·05	3·80	4·53	5·10	...	3·58	...
1915 ...	5·15	3·22	4·53	4·44	3·95	3·44	3·93	3·73	3·29	3·24	3·36	...	...
Means ...	5·15	3·22	4·53	4·44	4·08	4·02	3·99	3·76	3·91	4·17	3·36	3·58	48·21
						Number of Days of Rain.							
1912 ...	26	25	25	21	25	23	21	27	23	29	17	20	282
1913 ...	27	21	25	20	26	19	24	19	21	21	14	15	252
1914 ...	19	20	16	17	24	20	16	23	14	22	22	28	241
1915 ...	28	22	28	28	30	29	31	29	30	25	29	...	...
						Maximum Fall in a Day—Inches.							
1914 ...	...	...	...	...	...	...	...	...	...	...	...	0·47	...
1915 ...	0·79	0·68	0·78	0·39	0·74	0·45	0·86	0·64	0·48	0·33	0·43	...	0·86

telegraphy. It is to be expected that in these brief notes, since a continuous watch was not kept, numbers of occasions on which there was precipitation at night would be missed. The proportion of wet days throughout both periods, and particularly the second, is considerably less than when actual measurements were made. For that year the number of days totalled 337. It must be stated, however, that 1913 and particularly 1914 were dry years in Australia. In New Zealand, also, 1914 was one of the driest years on record. 1915 was considerably wetter in both countries, especially the latter portion. In July and September, 1915, some precipitation was recorded on every day.

It seems, therefore, that Macquarie Island would have an average of approximately 40 to 50 inches of precipitation per annum falling on about 300 days. This agrees with what we know of conditions to the south of New Zealand.

2.—Relative Humidity.

Tabulations of hourly values of the relative humidity are contained in Table III of Vol. III. They are derived from the records of a hair hygrograph standardized thrice daily by readings of the ordinary wet and dry bulb psychrometer. For the year for which

TABLE LIX.

Humidity.

Macquarie Island.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
						Mean Relative Humidity Per Cent.							
1912 ...	89	94	94	95	95	93	91	90	93	87	88	90	91
1913 ...	90	95	95	95	91	90	89	92	91	94	94	97	93
1914 ...	95	96	89	92	94	92	90	92	91	86	91	93	92
1915 ...	91	93	91	89	93	92	91	94	94	92	94	...	92
Means ...	91	94	92	93	93	92	90	92	92	90	92	93	92

Values for December, 1913, to November, 1914, inclusive, derived from wireless reports of 9 a.m. observations. Values given are reduced to mean for day.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
						Vapour Pressure—Inches.							
1912 ...	·259	·261	·250	·245	·238	·214	·211	·212	·219	·216	·230	·258	...
1913 ...	·251	·257	·241	·255	·202	·196	·196	·213	·203	·222	·238	...	...
1914 ...	...	...	...	...	...	...	...	...	...	...	...	·228	...
1915 ...	·239	·248	·246	·214	·223	·208	·212	·215	·226	·210	·228	...	...
Means ...	·250	·255	·246	·238	·221	·206	·206	·213	·216	·216	·229	·243	·228

In November, 1913, observations are available till the 23rd only. In January, 1915, observations are missing for several days.

TABLE LX.

Humidity—Mean Diurnal Inequalities of Relative Humidity.

Macquarie Island. Per Cent.

Hour L.M.T. ...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Period. I	+1·7	+2·0	+2·3	+1·7	+0·7	+0·3	—0·7	—1·0	—1·3	—2·0	—1·7	—2·7	—2·7	—3·0	—2·7	—2·0	—1·0	—0·3	+1·0	+1·0	+2·3	+1·7	+1·7	+2·3
II	+0·3	+0·7	+0·3	+0·3	+0·7	0·0	—0·3	—0·7	—0·7	—1·0	—1·3	—2·0	—1·0	—1·7	—2·0	—1·3	—0·7	0·0	+0·7	+1·0	+0·3	+1·7	+1·3	+0·7
III	+0·3	0·0	0·0	—0·3	—0·3	+0·3	—0·3	—0·3	—0·3	—0·3	—0·3	—0·3	0·0	—0·3	—0·3	+0·3	0·0	+0·7	+0·7	+1·3	+0·7	+1·0	+0·3	0·0
IV	0·0	+0·3	+0·3	0·0	+0·3	0·0	—0·3	0·0	+0·3	—0·3	—0·7	0·0	—1·0	—0·7	+1·3	+1·0	+0·7	0·0	+0·3	—1·0	+0·3	0·0	—0·3	—1·0
V	—0·7	—0·7	—1·0	—1·0	0·0	+0·3	0·0	0·0	+0·3	—1·0	—1·0	—1·3	—0·7	—0·3	+0·3	+0·7	+0·3	0·0	0·0	+0·3	+1·3	+0·3	—0·3	—0·7
VI	+0·3	+0·3	0·0	—0·3	+0·3	+0·7	+0·3	+0·7	—0·3	0·0	—0·7	—0·3	—0·7	—0·7	0·0	—0·3	—0·7	0·0	0·0	—0·7	—1·0	+0·3	0·0	0·0
VII	+0·7	+1·0	+1·0	+0·7	+1·0	+0·7	—0·3	—0·7	—0·3	—0·7	—0·7	—0·3	—0·7	—0·7	0·0	0·0	+0·3	+0·7	+0·3	+0·3	+1·0	+0·3	0·0	+0·3
VIII	+0·3	+0·3	+0·3	0·0	+0·7	0·0	—0·3	—0·7	+0·7	—0·3	—0·7	—0·7	—1·3	—1·3	—0·3	—0·7	—1·0	—0·7	—0·3	—0·3	+1·0	+0·3	+0·7	+0·7
IX	—0·7	—0·7	0·0	0·0	—0·7	0·0	+0·3	—0·7	+0·3	0·0	—0·7	—1·3	—0·7	—0·3	+1·3	+0·3	0·0	+0·3	+0·7	+0·7	+1·7	+1·0	+0·7	+0·7
X	+1·7	0·0	+0·3	+0·3	+0·3	0·0	—1·3	—1·7	—2·0	—2·3	—1·3	—1·0	—0·7	—1·0	—1·0	—0·7	+0·3	+0·3	+1·0	+0·7	+1·0	+1·0	+1·3	+1·7
XI	+1·7	+1·0	+1·7	+1·3	+0·7	+0·7	—0·7	—0·7	—1·7	—1·3	—2·3	—3·0	—2·7	—2·3	—2·0	—0·7	—0·7	0·0	0·0	+0·7	+0·3	+1·0	+1·0	+1·3
XII	+1·0	+1·0	+1·5	+1·0	+1·0	+1·0	+1·5	+0·5	—0·5	—0·5	—1·0	—1·5	—2·0	—2·5	—4·5	—3·0	—1·0	0·0	+1·0	+0·5	—0·5	+1·0	+0·5	+2·0
Summer (XII, I, II)	+1·0	+1·2	+1·4	+1·0	+0·8	+0·4	+0·2	—0·4	—0·8	—1·2	—1·3	—2·1	—1·9	—2·4	—3·1	—2·1	—0·9	—0·1	+0·9	+0·8	+0·7	+1·5	+1·2	+1·7
Autumn (III, IV, V)	—0·1	—0·1	—0·2	—0·4	0·0	+0·2	—0·2	—0·1	+0·1	—0·5	—0·7	—0·5	—0·6	—0·4	+0·4	+0·7	+0·3	+0·2	+0·3	+0·2	+0·7	+0·4	—0·1	—0·6
Winter (VI, VII, VIII)	+0·4	+0·5	+0·4	+0·1	+0·7	+0·5	—0·1	—0·2	0·0	—0·3	—0·7	—0·4	—0·9	—0·9	—0·1	—0·3	—0·5	0·0	0·0	—0·2	+0·3	+0·3	+0·2	+0·3
Spring (IX, X, XI)	+0·9	+0·1	+0·7	+0·5	+0·1	+0·2	—0·6	—1·0	—1·1	—1·2	—1·4	—1·8	—1·4	—1·2	—0·6	—0·4	—0·1	+0·2	+0·6	+0·7	+1·0	+1·0	+1·0	+1·2
Year	+0·6	+0·4	+0·6	+0·3	+0·4	+0·3	—0·2	—0·4	—0·4	—0·8	—1·0	—1·2	—1·2	—1·2	—0·8	—0·5	—0·3	+0·1	+0·4	+0·4	+0·7	+0·8	+0·6	+0·6

observations were lost, 9 a.m. readings are available from the wireless reports. These were reduced to mean of day before being incorporated with the remainder in the monthly means listed in Table LIX. The humidity is very high and very uniform, averaging 92 per cent for the whole period. There is no indication of an appreciable annual variation. The lowest monthly means were 86 per cent in October, 1914, and 87 per cent in October, 1912. These were months of frequent high winds from a westerly quarter and the low humidities are probably largely a Föhn effect caused by the high land of the mainland. Humidities below 70 per cent are rare. Values below 60 and even 50 per cent are, however, listed on a number of occasions. Usually they continue only over brief periods and in a considerable proportion of the cases the temperature at the time was below freezing. There does not, as a rule, appear to be anything in the other weather conditions to account for them. They are likely to be subject to a considerable probable error. The majority, however, occur in winds from the south-westerly quadrant and, again, there was probably some Föhn effect due to the mountains of the mainland.

In Table LX are the mean diurnal inequalities of the relative humidity for each hour of the day for each month, the four seasons, and the year. The driest time is in the early afternoon and the most humid at night. The range is greatest in summer, when it amounts to 4·8 per cent. In autumn and winter it is very small. For the average for the whole year the range is 2 per cent.

Table IV of Vol. III gives hourly values of vapour pressure as derived from those of temperature and relative humidity. The monthly means are given in the second part of Table LIX. The annual variation follows the temperature fairly closely but with some lag. The mean for the year is 0·228 inch (7·7 mb.).

3.—Bright Sunshine.

Sunshine was recorded by means of a Campbell-Stokes Sunshine Recorder. From Mr. Newman's introductory remarks to Vol. III it appears that the instrument was designed for lower latitudes and that the cards did not provide for more than 12 hours of sunshine in summer. Furthermore, the "Wireless Hill" in winter cut off the sun till nearly noon from the position in which the recorder was located in 1912 and 1913. During Mr. Tulloch's regime in 1915 it was, however, moved to the top of the Wireless Hill so that this objection was removed. It is stated, also, that the sun was often too weak to burn the card. In January, 1915, there was a break of 5 days during which the observer was absent.

The hourly totals of sunshine recorded are given in Table VIII of Vol. III. The monthly totals are reproduced in Table LXI. They are subject to the limitations mentioned above and, in addition, those noted at the foot of the table. They serve, however, to indicate how meagre is the amount of strong sunshine experienced in these regions. Doubtless there were many occasions when the sun was visible to the naked eye yet failed to produce any record. But the total duration of these periods was not very large and, in any case, the heating power of the sun would be very small. The total recorded for the year from December, 1914, to November, 1915, was 380·8 hours and there appears to be no reason for not regarding this as a fairly close

TABLE LXI.

Bright Sunshine—Total Hours.

Macquarie Island.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	...
1912 ...	78·4	45·5	48·4	20·3	4·9	0·0	0·0*	...	21·1	47·3	38·5	66·1	...
1913 ...	123·4	61·8	40·4	15·1*	...	...	...	16·0*	22·8	9·1*	...	...	...
1914 ...	...	...	...	...	...	...	...	...	...	...	...	51·9	...
1915 ...	43·0*	72·8	38·1	13·0	11·8	0·0	4·2	4·8	19·0	34·8	87·4	...	...

* For 20 days only in July, 1912; 12 in April, 1913; 28 in August, 1913; 11 in October, 1913; and 26 in January, 1915.

TABLE LXII.

Cloud—Mean Amount.

Macquarie Island. Tenths.

Year.	Hour. L.M.T.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
1912 ...	9	8·4	8·8	8·9	8·3	8·2	9·1	8·0	8·8	9·5	8·1	9·4	8·4	8·7
	15	8·2	9·1	9·0	8·9	9·1	9·2	8·6	8·5	9·3	9·0	9·3	8·2	8·9
	21	9·3	8·9	7·4	7·8	7·6	8·2	6·7	7·8	8·5	8·2	9·2	8·7	8·2
1913 ...	9	6·8	8·1	8·5	8·3	8·2	8·3	7·9	8·3	8·7	8·5	8·1	8·8	8·1
	15	7·3	8·7	8·5	8·9	9·1	8·6	8·1	8·5	8·9	9·3	8·0	...	...
	21	7·7	7·7	8·4	7·8	7·6	8·4	6·3	7·3	7·7	8·7	8·7	...	...
1914 ...	9	8·2	8·9	9·0	8·9	9·2	8·3	8·7	9·2	8·5	9·2	8·9	9·2	8·8
	15	...	...	...	...	...	...	...	...	...	...	...	8·6	...
	21	...	...	...	...	...	...	...	...	...	...	...	9·3	...
1915 ...	9	9·7	8·8	8·8	9·0	9·5	9·5	8·9	9·6	9·6	9·0	8·0	...	...
	15	9·1	8·1	8·7	8·9	8·8	9·5	8·7	9·6	9·1	8·9	8·3	...	...
	21	9·5	8·2	8·6	8·5	7·5	7·8	8·6	9·5	8·6	9·5	8·2	...	...
Means....	9	8·3	8·6	8·8	8·6	8·8	8·8	8·4	9·0	9·1	8·7	8·6	8·6	8·7
	15	8·2	8·6	8·7	8·9	9·0	9·1	8·5	8·9	9·1	9·1	8·5	8·4	8·8
	21	8·8	8·3	8·1	8·0	7·6	8·1	7·2	8·2	8·3	8·8	8·7	9·0	8·3
	Means....	8·4	8·5	8·5	8·5	8·5	8·7	8·0	8·7	8·8	8·9	8·6	8·7	8·6

approximation to the total amount of bright sunshine experienced during this period. In June, 1915, none was recorded and the maximum amount in any month was 123·4 hours in January, 1913. The spring of 1915 was very dull. The climate of the region is certainly a very gloomy one.

4.—Cloud Amount.

In Table LXII are given the monthly means of the amount of cloud at various hours of Local Mean Time as listed in Tables X and XII of Vol. III. The degree of cloudiness is high at each of the observation hours. There is no reliable indication of any annual variation in cloudiness though the winter half year is probably rather more cloudy than the summer one. In the means for all the observations, 15 hours is the cloudiest and 21 hours the least cloudy time. The estimates at the latter hour may, however, be affected by the fact that they were nearly all made in darkness. It is perhaps significant that in November, December and January, when there would be some daylight at 21 hours, the highest means are for this hour.

Table LXIII gives the percentage frequency, with which different cloud amounts were observed. At 62·6 per cent of the observations the sky was overcast. There is a gradual and fairly regular decrease in the percentage of smaller amounts till for clear sky there is only one per cent. In three years less one month it was recorded only on 33 occasions of which 22 were at 21 hours when it would often be difficult to detect small amounts of cloud. There is no significant indication of any variation of the frequency of different amounts with the time of day or the season of the year. In Table LXIII there is a slight preference shown for cloud amount 5 at the expense of the neighbouring ones but that is not surprising.

5.—Phenomena.

One phenomenon about which data from the region are particularly interesting is the *thunderstorm*. With regard to this there are three entries in the journal. On the evening of the 13th May, 1913, a "Lightning flash in NW" is reported. On the 8th August, 1913, the entry is,—"Sheet lightning in SE at 22·10; several discharges in rapid succession." And finally, on the evening of the 7th March, 1915, "a severe thunderstorm approached from NE and lasted till 22 hrs., Lightning."

The optical phenomena were not very striking. *Rainbows* are mentioned on 18 days and *fog bows* on 7. *Coronae* are recorded 18 times and *halos* 13, but no complex displays were seen. There were two cases of *glazed frost*.

Hail showers are very frequent in cold air masses to the south of New Zealand. The number of days in each month on which they were registered in the weather diary at Macquarie Island are shown in the first part of Table LXIV. Mr. Ainsworth recorded them on 85 days in 1912 and on 73 days during 10½ months of 1913. It is clear that Mr. Tulloch soon ceased to record them in 1915. Practically all the hail would be "small hail".

The island is surrounded by sea of which the temperature is considerably above freezing point. The *snowfall* consequently is not very heavy and snow does not lie continuously for long periods even on the mountain tops. In the second part of Table LXIV are given the number of days on which snow was recorded in the weather

TABLE LXIII.

Cloud—Percentage Frequency of Different Amounts.

Macquarie Island.

Tenths.	10	9	8	7	6	5	4	3	2	1	0
%	62·6	8·3	7·2	5·9	3·1	3·6	2·3	2·7	2·0	1·3	1·0

TABLE LXIV.

Phenomena—Frequency of Occurrence.

Macquarie Island. Days.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Total.
							Hail.						
1912 ...	5	5	8	10	7	12	8	9	7	9	4	3	85
1913 ...	6	6	5	6	10	5	10	6	9	8	2	...	...
1914 ...	...	...	...	...	...	...	...	...	...	...	...	4	...
1915 ...	4	2	3	2	0	0	0	1	0	0	0	...	...
							Snow.						
1912 ...	1	0	5	8	8	9	8	6	6	6	3	1	61
1913 ...	4	4	0	4	16	10	10	7	9	7	3	(1	...
1914 ...	0	1	...	...	5	5	6	8	3	12	5)	6	...
1915 ...	4	2	3	12	7	10	11	10	5	12	8	...	...
							Snow Lying.						
1912 ...	...	...	0 (2)	1 (4)	3 (2)	2 (6)	3 (3)	4	3 (2)	...	...	...	...
1913 ...	...	...	...	1 (5)	6	8	6	...	3	...	...	...	...
1915 ...	1	...	1	3	1	9	3	...	1	3	...	...	...
							Ground Frosts.						
1912 ...	...	...	...	...	...	9	14	10	7	4	1	0	...
1913 ...	0	1	0	4	14	16	14	13	19	14	6	...	...
1914 ...	...	...	...	...	...	...	...	...	...	...	...	1	...
1915 ...	0	0	3	4	9	13	10	8	6	11	2	...	...
							Frost Days.						
1912 ...	0	0	0	0	4	3	4	5	5	1	0	0	22
1913 ...	0	0	0	0	8	10	11	4	11	5	3	...	...
1914 ...	...	...	...	...	...	...	...	...	...	...	...	0	...
1915 ...	0	0	0	1	3	11	6	7	2	9	1	...	...
	0	0	0	0·3	5·0	8·0	7·0	5·3	6·0	5·0	1·3	0	38

Observations for 23 days only in June, 1912, and 27 days only in January, 1915. Temperature observations for 23 days only in November, 1913.

remarks. Sometimes there were only a few flakes and often the record is only of brief showers. Mr. Ainsworth observed snow on 61 days in 1912, and Mr. Tulloch on 90 days in his year. The figures enclosed within brackets indicate the number of times snow was reported in the wireless messages from December, 1913, to November, 1914. They are obviously not complete at least in the earlier months but indicate generally that the frequency of snow was much the same as in other years. On the 20th May, 1913, there is an observation of "frequent powdery and sago snowfalls" while on the 9th June, 1913, one of "light snow and ice spiculae in morning" is recorded. The third part of Table LXIV gives the number of days on which snow lay on the ground, presumably around the station, which was near sea level. At first, also, Mr. Ainsworth recorded days on which he saw snow lying on the high levels. The figures for these are given in brackets alongside those for snow on the low levels. They are unlikely to be quite complete, even for the months for which they are given, owing to the frequency of low cloud obscuring the mountains.

During his first year Mr. Ainsworth kept what was apparently a fairly complete record of the occasions when the mountains were obscured by low cloud. In 1912, this occurred on 102 days. This would mean cloud below, at least, 1000 feet. Later the record appears less complete and Mr. Tulloch did not continue it.

The fourth part of Table LXIV records the number of days of *ground frost*, that is, days on which the minimum temperature on the grass fell below 30°·4 F. The observations did not commence until the 9th June, 1912. They give an average for the year of about 78 frosts. In view of the small area of the Island, and the temperature of the ocean, this seems surprisingly large. The lowest minimum temperature recorded on the grass was 19°·3 F. on the 5th September, 1915; 21°·3 F. was recorded on two occasions. The ground was reported frozen on 44 days.

Fog was recorded on approximately 147 days in 35 months. The precise significance of this figure is, of course, somewhat problematical since at that time the ideas as to what constituted a fog were rather indefinite. Fog is certainly of frequent occurrence.

The last part of Table LXIV gives the number of *frost days* or days on which the temperature in the screen fell below 32° F. The figures give an average of 38 days for the year. From December to April there are practically none. They are relatively numerous in the spring, as many being recorded in October as in May. The lag of the temperature behind the sun at Macquarie Island is shown very markedly by the late fall in autumn and the late rise in spring. Even in New Zealand there is a liability to cold spells and sudden snowfalls late in the year.

Ice days, when the temperature fails to reach freezing point, were experienced on four occasions, one in June, 1913, two in June, 1915, and one in July, 1915. The lowest maximum was 29°·0 F. on the 18th June, 1915.

6.—Sea Temperatures.

Sea temperatures were observed at a point on the shore of the north-east peninsula at Macquarie Island, to the south-east of the Meteorological Station. Observations were made at 9 and 15 hours. The average temperatures thus observed

TABLE LXV.

Sea Temperature—Means.

Macquarie Island. Degrees Fahrenheit.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Mean.
							09·00 Hours.						
1912 ...	44·2	41·9	41·0	40·4	39·0	38·7	38·1	38·0	39·3	40·0	41·8	44·2	...
1913 ...	44·0	41·5	41·1	40·8	38·6	37·2	37·1	37·6	37·2	38·4	40·1	...	...
1914 ...	...	...	...	...	...	...	...	...	...	...	...	41·8	...
1915 ...	42·1	42·4	41·3	40·2	39·0	38·8	38·5	39·1	39·2	38·5	40·3	...	...
Means ...	43·4	41·9	41·1	40·5	38·9	38·2	37·9	38·2	38·6	39·0	40·7	43·0	40·1
							15·00 Hours.						
1912 ...	45·2	42·6	41·7	40·9	39·3	38·9	38·7	38·5	39·7	40·4	42·4	45·1	...
1913 ...	44·9	42·3	41·9	41·1	38·7	37·3	37·3	37·9	37·6	39·0	41·3	...	...
1914 ...	...	...	...	...	...	...	...	...	...	...	...	42·2	...
1915 ...	42·9	43·2	41·7	40·5	39·3	38·8	38·7	39·4	39·6	39·1	41·0	...	...
Means ...	44·3	42·7	41·8	40·8	39·1	38·3	38·2	38·6	39·0	39·5	41·6	43·6	40·6

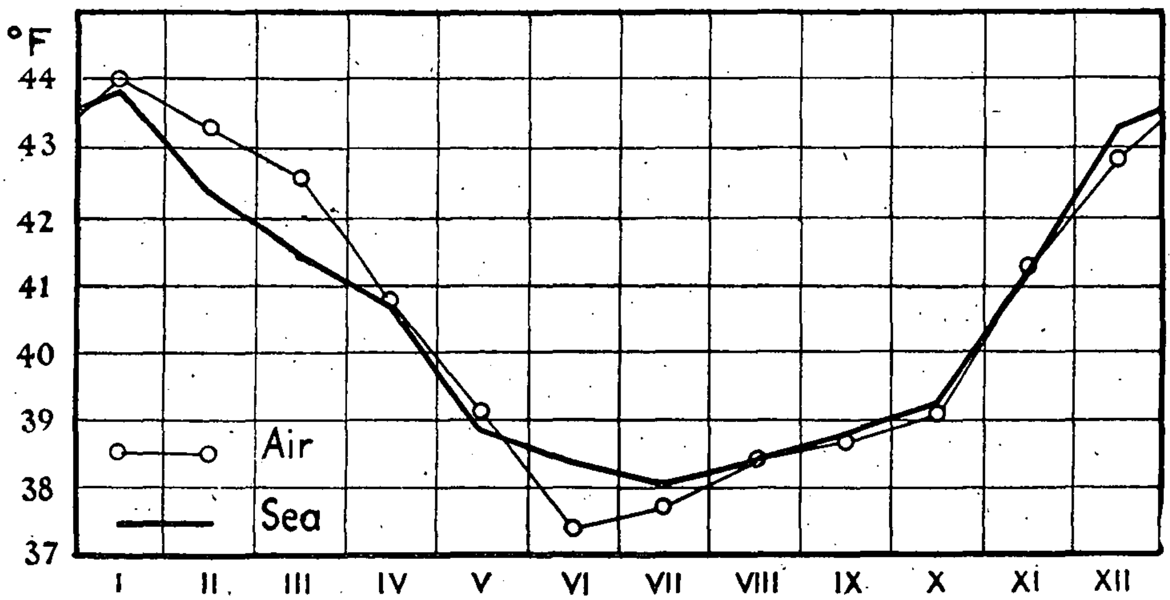


FIG. 28.—Macquarie Island—Comparison of Sea and Air Temperatures, Macquarie Island.

in each month are compared in Fig. 28 with those of the air temperature at the same hours. The differences are usually small. Furthermore, the sea temperatures observed did not differ greatly from those taken from the *Aurora* when she was anchored in the vicinity. But the Macquarie Island temperatures must have been influenced by the presence of the land and it is doubtful to what extent the information they give is independent. On the average, the sea temperature recorded at 15 hours was 0·6° F. warmer than that at 9 hours. This must be considerably greater than the temperature variation in the open sea between those hours. In any case, the mean air temperatures in any month at Macquarie Island probably differ little from those of the sea surface. The monthly means for each year and each observation hour are given separately in Table LXV.

7.—Sealers' Log.

The log of the weather at Macquarie Island kept for somewhat under two years by Otto Bauer's sealing party and published in Volume V. is obviously not complete. It shows, however, that the weather experienced was similar to that recorded by the Australasian Antarctic Expedition in the following years. Snow was recorded most frequently in winter and was more frequent in spring than in autumn. One significant difference between the Sealers' and the Expedition's recorders is that the former records a slightly greater proportion of winds from the SW than the NW quadrant. They also record more south-westerly gales. The reason for this seems doubtful. The exposure appears to have been freer at the Expedition's station than at the Sealers' huts. It has already been suggested, however, that too great a proportion of north-westerly winds was recorded at the former, and the truth probably lies somewhere between the two records.

CHAPTER VI

GENERAL CONSIDERATION

1.—Introduction.

The circulation of the atmosphere and the weather processes in the region covering Australia and New Zealand and the Antarctic areas to the south of them have been considered in Volume VI in relation to the weather charts published as Vol. VII therewith. Other important questions connected with the meteorology of Antarctica are,—

1. The annual amount of precipitation and the annual amount of accumulation of snow on the surface of the ice sheet.
2. The radiation balance.
3. The influence of the Antarctic on the climate of other parts of the world.

The observations under discussion throw little direct light on those difficult subjects. Furthermore, owing to his isolation and the very marked limitations to the literature available, a worker in the Southern Hemisphere suffers a severe handicap in any attempt to discuss them at all fully. The following remarks will, therefore, be of a very brief nature.

2.—Precipitation.

For reasons already given, particularly the impossibility of distinguishing between freshly falling snow and drift picked up by the wind, the direct measurement of precipitation in the Antarctic appears to be an insoluble problem. The only hope, therefore, would seem to lie in tackling it by indirect methods. It is possible to measure the annual accumulations of snow and a certain amount of information regarding it has been gathered from several parts of the Antarctic. The amount accumulated depends, however, not only on the amount of precipitation but also on the proportion carried into the sea and on how the remainder is distributed. The latter depends on the topography and on the strength and nature of the winds. Thus, at the Adélie Land Base there was no net accumulation, while at places not far distant there was heavy deposition. It will, therefore, require observations from many well distributed stations to determine the average accumulation. The estimation of the amount of drift snow carried into the sea presents at least equal difficulties. It also is very variable from point to point on the coast line. At Adélie Land where there were almost continuous strong gales, the amount was enormous but even at places at no great distance away it would be very much less. A certain amount of ablation of the snow surface takes place through evaporation into the air but it is relatively unimportant, totalling on the average, not more than a very few inches in the year. The loss by thawing also is comparatively unimportant. Except where there is bare rock on the coast it is very small. A large portion of the snow actually melted must freeze again.

If the ice-sheet is in a static condition as regards size, which is probably very nearly the case, at least so far as an interval of a few years is concerned, the amount of snow accumulated on the surface will be equivalent to the amount of ice carried into the sea by the sheet, including the glaciers flowing from it. This should be capable of determination by means of observations of the thickness and rate of movement of the ice sheet at its periphery.

If it were possible to measure the degree to which the surrounding ocean was cooled by the flow of ice and the drift snow carried into it from the continent, that also would give a measure of the total precipitation.

Finally, if one knew the amount of moisture carried by air currents flowing respectively inwards and outwards across the borders of the continent and either their speeds or the average period for which the air lay over the land, the precipitation could be determined.

It seems to the writer that the last method is the most promising. The annual variation of temperature over the ocean off the Antarctic coast is very small. The temperature of the sea surface is kept approximately at the melting point of salt water, say 28·5° F. The mean temperature of the air is unlikely to differ greatly from that. It will be assumed that the relatively warm and moist air from the north crosses the Antarctic coast line at a temperature of 32° F. By coast line is here meant the edge of the practically continuous sheet of ice covering the region. This edge may be the true coast, a barrier-ice edge, or the edge of the pack ice where it is permanently almost continuous with the coast. We shall further assume, first that in 20 days, on the average, enough of the moist air will have passed over the perimeter to flood the whole continent and, finally, that before returning to the coast all the water vapour in the lowest two kilometres will be precipitated. The first of these assumptions can only be a very rough approximation to the truth but is probably of the right order. The moist air would be raised through being forced up by both the cold air over the continent and the continent itself. The latter rises rapidly from the coast in most parts and the highest part is above 3 km. The average rise of the warm air is likely to exceed 2 km. but the effectiveness of an uplift for producing precipitation decreases with the altitude. In rising to such a height, the air would lose a large part of its total water content. The estimate that it would lose the equivalent of all the water vapour in the lowest two kilometres seems reasonable. According to computations by Simpson in "Some Studies in Terrestrial Radiation" (Memoirs of the Royal Meteorological Society, Vol. II, No. 16), this would equal 4 mm. of precipitable water. The humidities used by Simpson in the layers concerned would vary from about 68 per cent at the bottom to 58 per cent at the top. These are probably much too low for conditions over the Southern Ocean, so we shall assume that the precipitation is equivalent to 5 mm. of rain. This is the average amount in 20 days. In the year it would amount to about 90 mm. or 3·6 inches. The falls would, of course, be much heavier on the rim of the continent than at the Pole. The assumptions made would involve a mean poleward velocity of the moist air across the perimeter of the Antarctic of about 1·5 miles per hour. Actually, the flow would have to be greater than this since some of the air entering the continent would be returning after only a short excursion northward which would not give it time to lose the amount of moisture nor reach the temperature postulated.

The above calculation is of the roughest nature. Some day it may be possible to make it fairly precise, but with our present knowledge it is not worth while attempting anything more refined. Evaporation and reprecipitation over the ice sheet is neglected but is probably slight. If one considers the problem on these lines, however, it is difficult to image that the average precipitation at the Pole can amount to as much as 2 inches per annum.

3.—The Radiation Balance.

The principal feature of the contribution of the Antarctic to the radiation balance on the atmosphere arises from the fact that the snow covered surface must reflect back approximately three quarters of the incident solar radiation unchanged. The constituents of the atmosphere absorb only a small fraction of the relatively short-wave radiation. At the same time, the snow surface radiates practically as a black body at the temperatures occurring at the surface of the Earth. A surface of bare land or of water, though it would radiate heat equally at the same temperature as the snow surface would absorb much more of the incident solar radiation. The Antarctic Continent with its attached ice masses is a much more efficient refrigerator than would be a bare land or water surface in the same latitudes and conditions. This is a well-known fact and has been frequently discussed. At the same time, the Antarctic Continent with its high interior, its fairly symmetrical distribution about the Pole, and with an immense ocean surrounding it, is ideally situated for communicating its cooling effects to lower latitudes. In the Northern Hemisphere, there is no such large area covered with permanent snow, and the access of ocean waters to the polar regions is much more restricted. Antarctica is, therefore, generally held responsible for the Southern Hemisphere being colder than the Northern. If it were to become desiccated, to sink below the ocean surface, or to migrate to lower latitudes, therefore, the temperature of the Southern Hemisphere, and indeed of the world, might rise.

But though the above arguments are qualitatively sound, we are not able to evaluate them quantitatively, and their importance can certainly be exaggerated. Thus the reflecting power of clouds for solar radiation is approximately equal to that of a snow surface and the average amount of cloud over a large part of the Southern Ocean is over 8 tenths. Thus the difference between the proportions reflected from Antarctica and from the surrounding ocean is not so great as might, at first sight, be supposed. Furthermore, owing to the great average height of the Antarctic Continent, the altitude from which the reflection takes place is probably not very different in the two cases. Again, the cloud surfaces also give out practically the same amount of radiation as a black body at their temperatures. The snow surface, owing to the absence of conduction and convection beneath it, cools to a lower temperature than would a cloud surface at the same height. The amount of outgoing radiation would consequently be less. This, therefore, may be a factor in reducing the efficiency of the Antarctic as a refrigerator. Then, by its mere bulk it greatly reduces the mass of air that can collect in the polar regions. It does not seem to the writer that we are yet able to calculate, even approximately, the effect of the Antarctic Continent on the heat balance of the atmosphere, still less what would be the effect of possible changes in conditions there. All such radiation problems are immensely complicated by the wide variations in the amount and state of the water substance in the atmosphere in both time and space. When to the other difficulties is added the fundamental one that the radiative properties of water vapour are quite inadequately known, it is not surprising to find that solutions of these problems are, at present, only very approximate. The processes in the very high levels of the atmosphere, though exercising a relatively unimportant role in the immediate balance of radiation may in the long run become very important.

From what has been said in earlier chapters regarding the small annual variation of temperature over the Southern Ocean, and bearing in mind the free radiation from water vapour and the upper surfaces of clouds, it seems clear that the variations at high levels in the atmosphere must be greater than at the surface. From this the writer has argued that the tropopause must be higher in winter than in summer. The stratosphere is likely, also, to be colder.

The rate at which the snow surface cools by radiation and the low temperatures sometimes reached, indicate that the effective temperature of the superincumbent space must be very low. The amount of water vapour above it, therefore, must be very small, especially in the stratosphere. This is important in connection with theories as to processes in the ionosphere.

4.—The Influence of the Antarctic on the Climates of other parts of the World.

The above subject is bound up with that in the preceding section and has already been discussed to some extent. The Antarctic must obviously exert a great cooling effect on the Southern Hemisphere and hence on the world. It cools both the air and the ocean. Cold deep currents from the Antarctic extend into the Northern Hemisphere. Furthermore, in its ice covering, the continent has an enormous reservoir of cold which must tend towards stabilizing the existing climatic regime. If the land were removed and the Antarctic were covered by ocean, the resulting field of pack ice about the Pole might be smaller in extent than the present size of Antarctica and the pack ice surrounding it. The surface temperature would almost certainly be higher on the average. There would be greater evaporation. The amount of solar radiation absorbed, as suggested in the previous section, may, however, not be much greater. The higher surface temperatures may lead to greater loss of heat by radiation. The increased amount of water vapour may work in the same direction. There are two aspects of such a change in the land distribution to be considered. First, there is the effect on the climate of the polar regions themselves, and second, on that of the rest of the world. If the Antarctic were covered by ocean, its own climate would almost certainly be milder, as is that of the Arctic today. But its cooling effect on the whole atmosphere might possibly be increased. It is difficult to say what would be the net effect on the general circulation.

As regards temperate latitudes, it does not seem to the writer that sufficient consideration is given to the difference between the effects, on the climate of the world, of the land masses of temperate latitudes in the Northern Hemisphere and the ocean in those of the Southern. Too much attention is concentrated on the cold areas on the eastern sides of the continents. The most important effect of the continents on the thermal structure of the atmosphere and the general circulation appears to the writer to be the reduction in the amount of water vapour supplied by evaporation. It is suggested that the lower mean temperature of the Southern Hemisphere is due to the higher humidity of the atmosphere, which leads to a more active circulation and a freer loss of heat by radiation.

It has been argued by many that the most important factor in the production of an extension of glaciation such as occurred in Pleistocene times would be an increase in precipitation and this is more likely to be produced by an increase rather than a decrease of temperature. This argument has been especially elaborated by Sir George Simpson who assumes that the increase of temperature is brought about by an increase of solar radiation. See, for example, his paper on "World Climates during the Quaternary Period" in the Quarterly Journal of the Royal Meteorological Society, Vol. 60, No. 257, October, 1934. It would no doubt be generally admitted that where snow now accumulates and glaciers form, an increase in the amount of precipitation would result in an extension of the glaciation. But the extent to which this could stand an increase of temperature is very difficult to determine. There must, of course, be an equatorward limit beyond which an increase of precipitation with the same proportions of rain and snow as at present certainly could not lead to increased average accumulation of snow. In New Zealand, where in the Southern Alps, which have a very high precipitation, glaciers reach almost to sea level in latitudes between 43° S and 46° S, the importance of the amount of precipitation seems to be confirmed. Again, the Kaikouras, in latitude 42° S about, which rise almost to 9,000 feet but which have a much smaller precipitation than the Southern Alps, have no permanent snowfield and show few signs of previous glaciation. The glaciers which have been mentioned, however, rise in the highest parts of the Southern Alps where there are many peaks rising to over 9,000 feet and the maximum height is over 12,000 feet. Except on the narrow glaciers themselves, there is no permanent snow below 7,000 feet (2km.). That is, the permanent snow is confined, practically, to heights at which the mean temperature is below freezing point. This height is well above that of maximum precipitation, which in New Zealand, according to the evidence available is below 4,000 feet. Again, the accumulation of snow in the Southern Alps is much more rapid in July than in October, though there in little difference in precipitation. There is little doubt, too, that the total accumulation is less in October than in July or August. All these facts point to the great importance of temperature, and the proportion of precipitation falling in the solid form, rather than the total amount of precipitation.

In the North Island of New Zealand on Mt. Egmont, which has an extremely heavy precipitation, the snow is reduced annually to very small proportions and occasionally disappears entirely, except for that collected in the hollow of the crater at the summit. There is not even a rudimentary glacier. Mt. Egmont is 8,260 feet high and the annual rainfall at the 3,000 feet level on its eastern side is approximately 300 inches. One cannot believe that it is dearth of precipitation that is the reason for the lack of glaciers here. Still less likely does it seem that an increase of precipitation accompanied by a rise of temperature could produce glaciation. The collecting area is certainly small. To the eastward is Mt. Ruapehu which, though it has a much smaller rainfall has a rather larger collecting area and is further inland. Mt. Ruapehu is 9,000 feet high and has a permanent snowfield with two rudimentary glaciers. On the nearby cone of Ngauruhoe, 7,500 feet, there is no permanent snow. In Tasmania, where there is a large collecting field at an altitude of between 3,000 and 5,000 feet the western portion of which has a rainfall of over 100 inches, there is no permanent snowfield. Tasmania's mean latitude is rather over 42° S.

In the so-called sub-Antarctic islands of New Zealand, including the Auckland and Campbell Islands, there is nothing approaching a permanent snowfield. Even at Macquarie Island in latitude 54° 30′ S to 54° 50′ S, the summit of which rises somewhat above 1,000 feet, the same is the case. The mean temperature would nowhere approach freezing point. All these islands carried glaciers in the Pleistocene. Precipitation is very frequent and averages about 50 inches per annum. Both humidity and cloudiness are very high. Conditions, except the high winds and the small area of the islands, favour the preservation of a snow-covering. Kerguelen, though in lower latitudes than Macquarie Island has lower temperatures. The summit of its highest peak rises above 6,000 feet but it has permanent snowfields extending to below 4,000 feet. On the west coast glaciers descend to the sea. Conditions are more favourable for the development of glaciation than at Macquarie Island in that the altitude, the collecting area, and the precipitation, at any rate on the western side, are all greater. The state of glaciation, appears, however, to correspond fairly closely with that at altitudes having corresponding temperatures in the Southern Alps in New Zealand. Similar remarks apply to Heard Island and the Crozets. Conditions are not quite the same in any two of the island groups, so that comparison is difficult, but so long as the precipitation exceeds a certain value, which doubtless varies inversely as the latitude, the degree of glaciation appears to depend almost entirely on the temperature.

It is very difficult to imagine that the Southern Ocean could not cope with any increase in the amount of ice produced by an increase of precipitation resulting from higher temperatures. The greater melting power is likely more than to counterbalance the increased ice formation and snow deposition.

So far as Australia, New Zealand, and the southern islands are concerned, therefore, the writer is convinced that a marked fall of temperature would be necessary to produce the conditions at the maxima of glaciation in Pleistocene times.

In the Antarctic conditions are different. The temperature is continuously below freezing point so that any increase in precipitation means a larger amount of snow deposited. If it were accompanied by a rise of temperature, however, the area of pack ice off the coast is likely to be reduced. This would lead to an increase in the katabatic winds and consequent increased ablation. On the other hand, if with lower temperatures the continent collected a permanent fringe of sea ice, the ablation would be much reduced. It is, therefore, difficult to estimate what the net effect of changes would be. It would seem to require a very low precipitation indeed to produce ar extensive dry desert of bare land or a "cold interglacial" in polar latitudes. Otherwis(it is very difficult to imagine how conditions of extreme glaciation can be maintainec in the centre of the high and very extensive Antarctic Plateau where the precipitation must be very low.

A class of theory of climatic change which probably has more adherents at present than that developed by Sir George Simpson, and one which, in various forms, has been popular for over half a century, is the "Astronomical Theory." This type of theory ascribes past changes of climate principally to changes of the inclination of the Earth's axis to the plane of its orbit and of the eccentricity of the orbit. The advantage of this theory is that the astronomical changes are periodic and can be calculated with considerable accuracy. The most authoritative recent discussion of the basis of the astronomical theory is that given by Milankovitch in Köppen and Geiger's *Handbuch der Klimatologie*, Band I, Teil A, under the title of "Mathematische Klimalehre und Astronomishe Theorie der Klimaschwankungen." It is not proposed to discuss here Milankovitch's treatment of the radiation problem to which a number of serious objections can be taken. For example, he treats the atmosphere as a grey body, the absorption of solar radiation is taken as being proportional to the amount of atmosphere traversed, the reflection of solar radiation by the Earth and the atmosphere is treated as if it all took place at the Earth's surface, the atmosphere is assumed to be still, and the calculations are all for a land surface or a land surface covered by ice. The cumulative effects of all these simplifications on the accuracy of the calculations must be very serious. The last one is particularly important when applying the theory to the Southern Hemisphere where so large a proportion of the surface is ocean. The theory is based principally on the effect of variations in the latitudinal distribution, mainly in high latitudes. From these variations are deduced corresponding ones in temperature. The general circulation of the atmosphere would tend to reduce very much the calculated temperature differences. In the Southern Hemisphere, also, the radiation changes would be very much less effective in high latitudes owing to the high degree of cloudiness. A very large fraction of the solar radiation is reflected back unchanged from the clouds of the Southern Ocean and the snow of the Antarctic Continent. Milankovitch's theory depends very largely, too, on the assumption that the effective factor in causing the accumulation of snow and ice is a cool summer. This can scarcely be very important, however, in the Antarctic where the temperature is well below freezing point all the year round. In temperate, and probably also, Antarctic regions of the Southern Hemisphere, too, precipitation is heaviest in winter so that summer temperatures are relatively less important than in many parts of the Northern Hemisphere, for example, in Switzerland, for the accumulation of snow. The annual variation of temperature over the Southern Ocean is very small. It is to be remembered, also, that the total radiation received by a hemisphere changes very little owing to the astronomical causes considered. Milankovitch's theories do not seem to account for the Pleistocene glaciation of the small sub-Antarctic Islands of New Zealand, nor for any considerable fluctuation in the glaciation in Antarctica. Another difficulty with regard to the theory is that it does not give simultaneous glaciation in the two hemispheres.

During the past 50 years there has been a marked retreat of glaciers in practically all parts of the world in which they occur. This retreat has not been explained by meteorologists and until we can do this, claims to accounting for ice ages are likely to continue to prove unconvincing to geologists and others.

5.—The Distribution of Pressure and Temperature and its Annual Variations.

Figures 29 and 30 are intended to indicate the general nature of the distribution of pressure and temperature in the region extending from 35° S to 80° S in the area extending southward from Australia and New Zealand. Conditions actually differ, of course, from meridian to meridian and, over large areas, are far from being well-known,

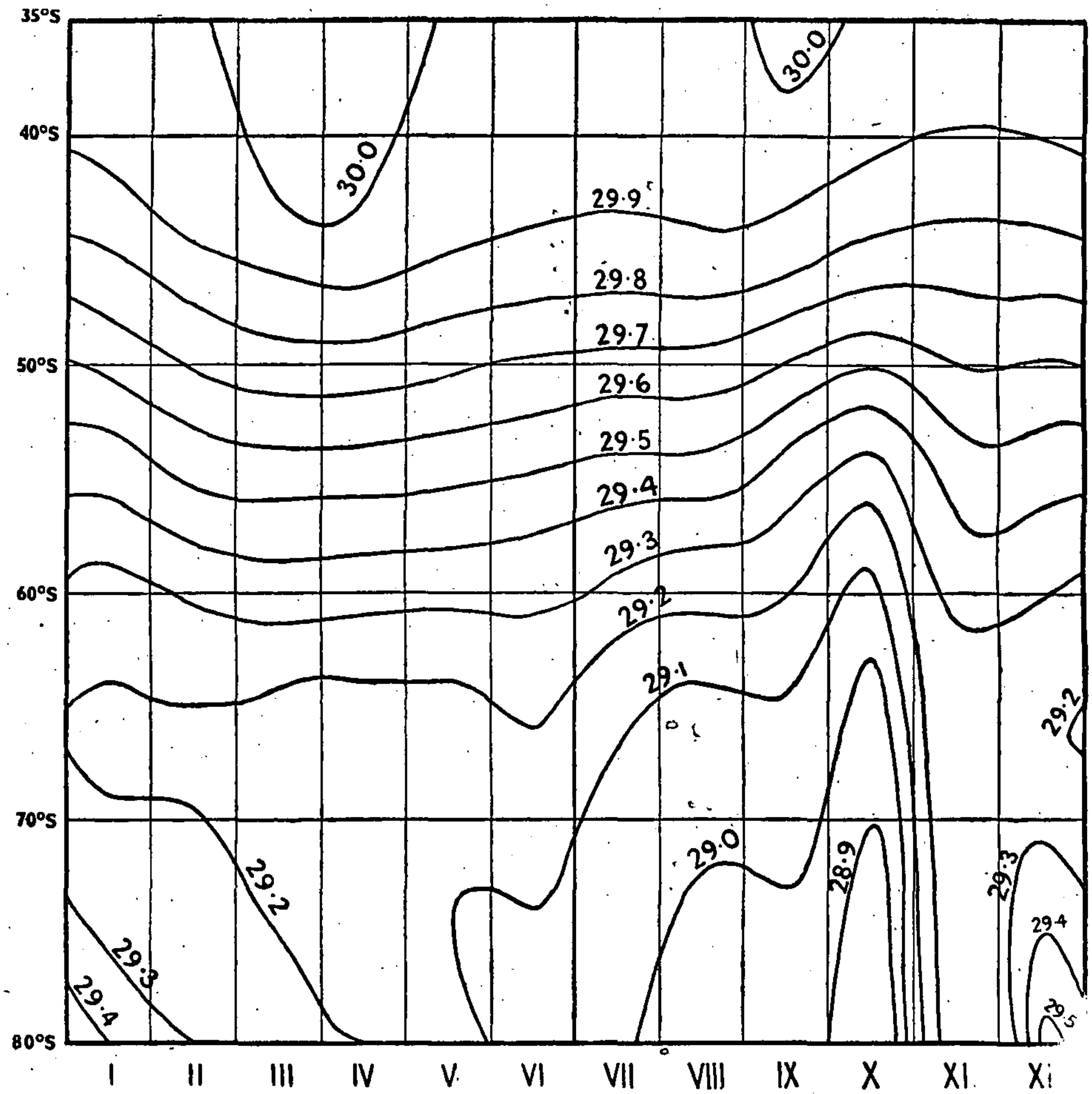


FIG. 29.—Diagram showing variation with latitude of monthly pressure change.

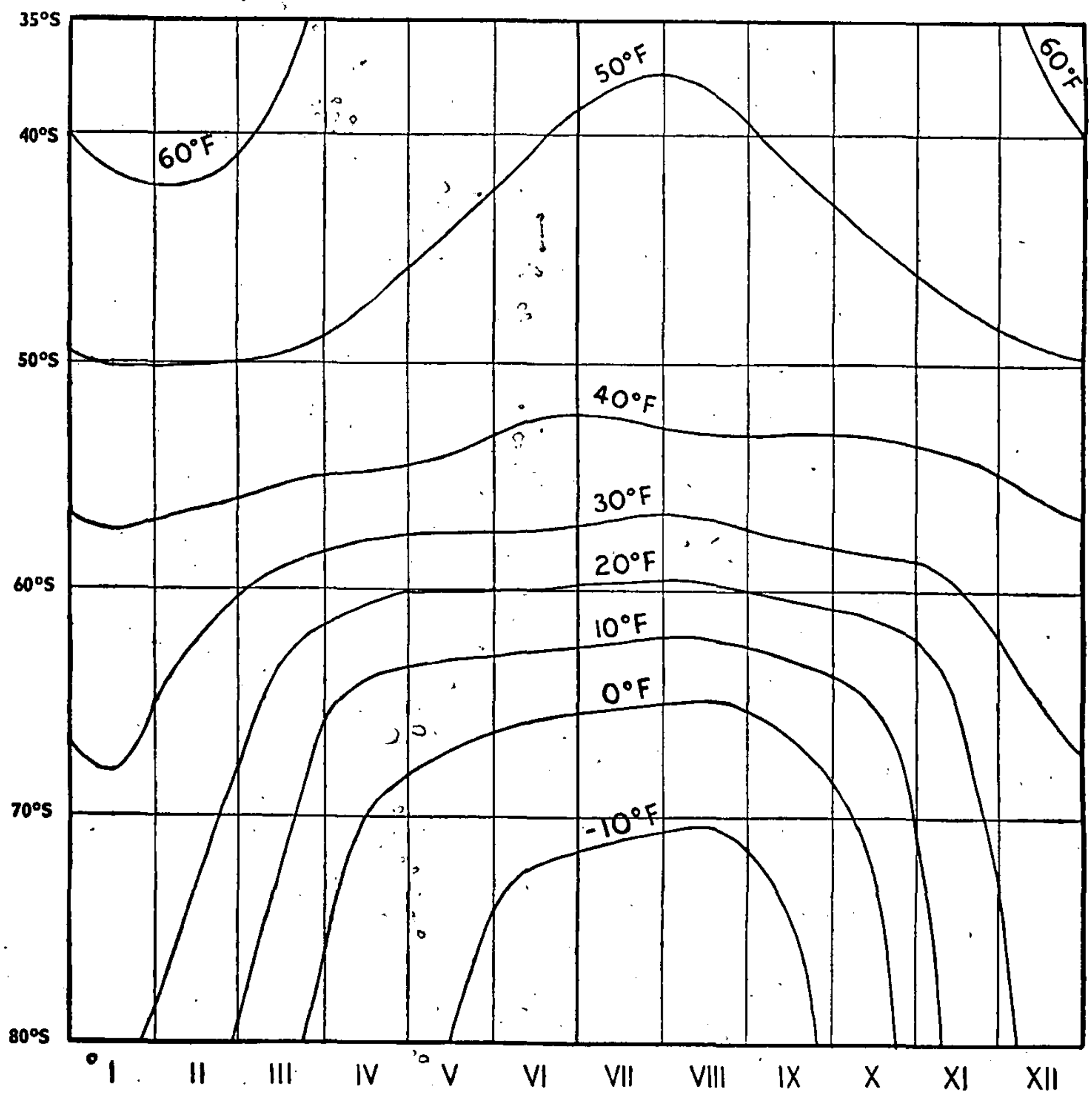


FIG. 30.—Diagram showing variation with latitude of monthly temperature change.

so that no great accuracy is claimed. The pressure data are intended to refer to exposures little affected by the presence of land. The rise of pressure along the Antarctic coast, for example, is largely neglected, the conditions resembling more those over the Ross Sea and the Great Barrier. Similarly for temperature the distribution is such as might be found in the temperate latitudes on small islands and in the Antarctic in places where the surface inversion was not strongly marked.

Figure 29 shows in the north an annual variation of pressure with two approximately equal maxima at the end of March and in September, respectively. Proceeding southward the second maximum becomes earlier and gradually disappears. There is a steep southward gradient in temperate latitudes in spring, especially October. In the Antarctic there is rapid increase of pressure in the latter part of October and the early part of November prior to the rise to the maximum in December. The pressure thus changes, in December, from being near the principal minimum in low latitudes to being at a marked maximum in the Antarctic.

The temperature has a fairly simple annual variation in low latitudes with a moderate amplitude. The southward gradient is slight. Over the Southern Ocean, the gradient increases, while the annual variation becomes slight with a flat minimum in winter. In the south the annual variation becomes large, owing to the predominance of a snow or ice surface. The winter minimum is still flat, but decreases in width as the latitude increases. Gradients are very slight in summer in the Antarctic.

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