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.

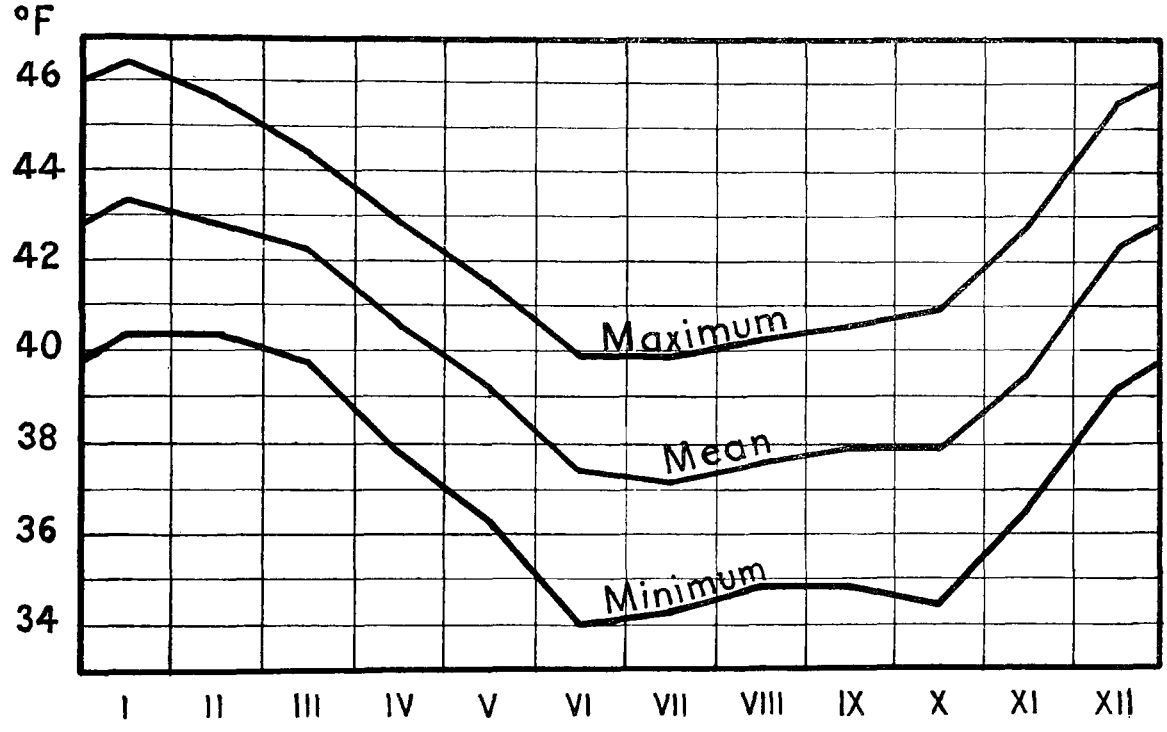

FIG. 9.—Macquarie Island Annual Variation of Temperature.

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.

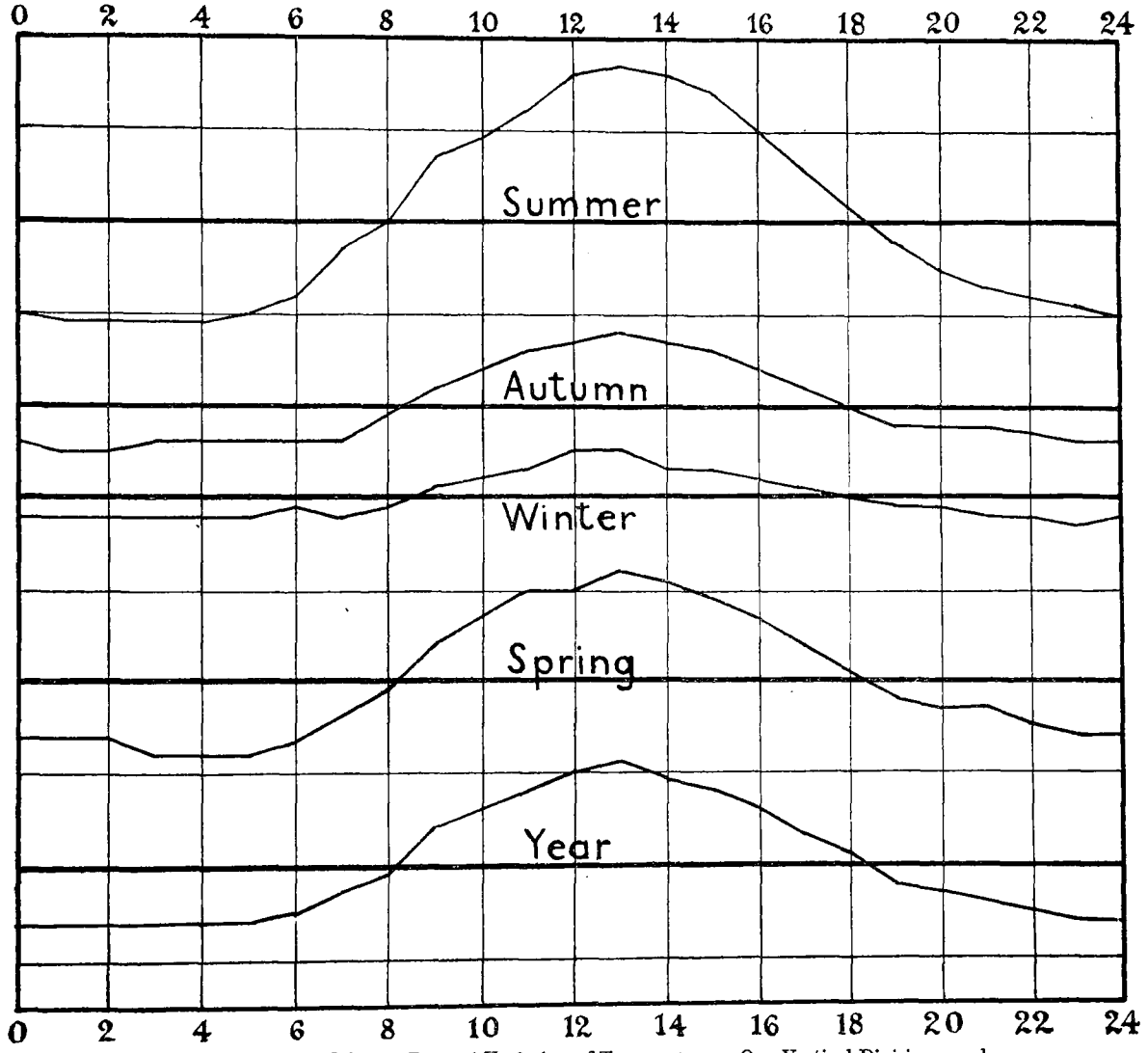

FIG. 10.—Macquarie Island—Diurnal Variation of Temperature. One Vertical Division equals one Degree Fahrenheit.

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	1·49	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.

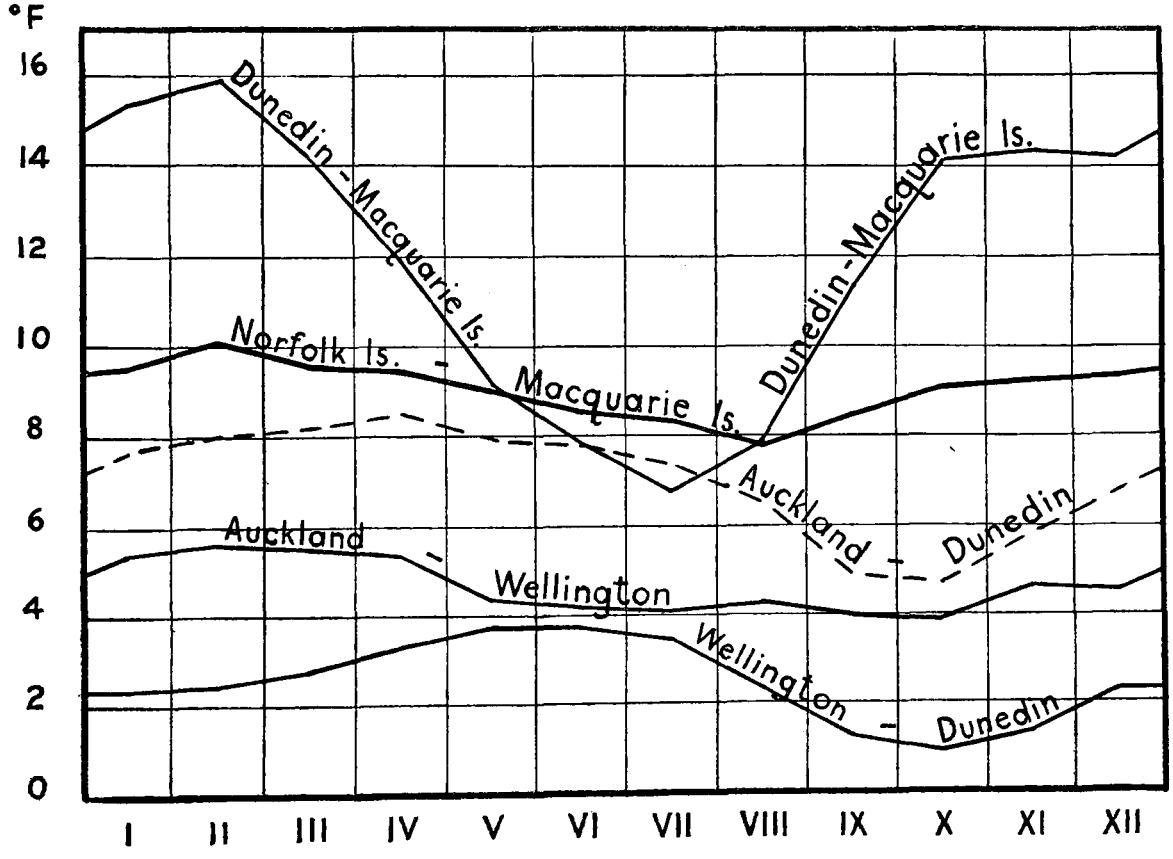

FIG. 11.—Temperature differences.