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WEATHER AND CLIMATE OF CAMPBELL ISLAND

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Abstract: The position of Campbell I. relative to the large-scale weather systems of the subantarctic oceans and its rugged terrain make it a cloudy, bleak, windswept island with a moderate rainfall spread over more than 300 days a year.

Some typical meteorological situations affecting Campbell I. are described and the individual elements of its climate are considered in detail.

Lying 640 km south of New Zealand (lat. 52.5° S, long. 169° E), Campbell I. is situated north of the latitudes usually traversed by the centers of the great cyclonic storms of the southern oceans and south of the paths usually taken by the travelling anticyclones of subtropical latitudes. It is in a region of strong and persistent westerly winds. The island is about 120 sq. km in area and the coastline mainly precipitous. The surface is rugged and hilly, with 10 peaks over 300 m in height. The highest is 569 m. The combination of its position relative to the large-scale weather systems and its broken terrain makes Campbell I. a cloudy, bleak, wind-swept island with a moderate rainfall, which however, is spread over more than 300 days a year.

The extensive areas of peat with which the island is mainly covered are a consequence of the climate with its low temperatures, low annual sunshine amounts and moderate rainfall. There is little soil and the peat varies in depth from a few cm to over 12 m (Bailey and Sorensen, 1962).

Although the island was discovered in 1810, meteorological observations were not made in a systematic fashion until 1904 when some instruments were installed at the sheep station in Tucker Cove on Perseverance Harbor. Monthly averages for some climatic elements during January 1905–October 1907, together with a short account of the climate are given by Marshall (1909). Although there were shepherds on the island until 1931 no further observations appear to have been published until after 1945. Since 1945, a summary of climatological observations on Campbell I. has been published each year in the "Meteorological Observations" of the New Zealand Meteorological Service (Misc. Pub. 109).

In 1941, the New Zealand Government established coast watching stations on both Campbell and Auckland Is. to report on the presence of any enemy shipping. Regular meteorological observations were made at two sites on Auckland I. (Port Ross, July 1941–March 1945, and Carnley Harbor, May 1941 – April 1944) and at Tucker Cove, Campbell I. (lat. 52°33′ S, long. 169°06′ E). After the war, the station at Campbell I. was established on a permanent basis under the control of the New Zealand Meteorological Service and since then has provided regular weather reports, both of surface and upper air conditions. With its companion Australian station at Macquarie I., together they have furnished the only regular synoptic reports from a vast area of the Southern Ocean. These reports are

of the greatest value not only for day-to-day weather forecasting in the New Zealand area, but also in adding to a general understanding of the meteorology of the region.

Because of the broken nature of the island surface, it is impossible to find an observing site which would be unaffected by local conditions. From July 1941 to March 1957 observations were made on a small level area 500 m from the head of Tucker Cove in Perseverance Harbor. This site is in a sheltered valley oriented almost N–S. Since April 1957 the observing site has been at a less protected position on a spur in Perseverance Harbor about 650 m S of Beeman Hill (lat. 52°33′ S, long. 169°07′ E). It is somewhat sheltered from winds between NW and NNE and between SE and S. Winds here are generally gusty and the converging valleys sometimes give rise to violent squalls. Surface, radiosonde and radio-wind observations are now made at this site.

Weather systems affecting Campbell Island

A better understanding of the weather and climate of Campbell I. can be gained by considering the progression of the weather systems, between sub-tropical and subantarctic latitudes, which pass over the Australia–New Zealand area. If a series of surface weather maps for this area is studied, it is found that a succession of anticyclones moves across Australia, the Tasman Sea and New Zealand at intervals predominantly of 6 or 7 days. The centers of the anticyclones may pass to the N of New Zealand, across or sometimes even to the S of the country. The first type of path is more likely in winter and spring and the other two in summer and autumn. Not all of these anticyclones directly affect Campbell I.

Each anticyclone is separated from the next by a trough which is a zone of relatively low pressure. On the eastward side of the trough the wind is from a northerly quarter and on the westward side from a southerly or westerly quarter. Any marked differences in temperature between the air masses on the eastern and western sides of the trough usually result in the appearance of a cold front separating them. It is generally oriented NW or N to SE or S. The front may extend southwards to a deep depression centered somewhere between latitudes 55° S and the Antarctic Continent (see fig. 1). Sometimes this whole system of anticyclones, intervening front and depression in the far south moves eastwards across the New Zealand–Campbell I. area unchanged. As the cold front moves over Campbell I. it is preceded by strong, gale force winds often accompanied by violent gusting. The frontal passage is marked by a period of rain followed by a wind change to a westerly or southerly quarter and shower or hail conditions. Although frontal passages across Campbell I. are frequent, the above straightforward sequence of events is rather rare. It is not usual for an anticyclone to move from Australia, across New Zealand and out to the east without changing its intensity, speed and direction of movement. Connected with these changes are developments in the low pressure trough, which is an unstable region where depressions may form.

Depressions may originate in the Tasman Sea or in the Australian Bight (fig. 1). From the region of formation they tend to move in a SE direction growing in intensity as they move and sometimes passing over or near Campbell I. on their way to the southern oceans. Also anticyclones, on paths well S of their usual positions, sometimes move over Campbell I.

Although for much of the time the weather on the island is controlled by the passage

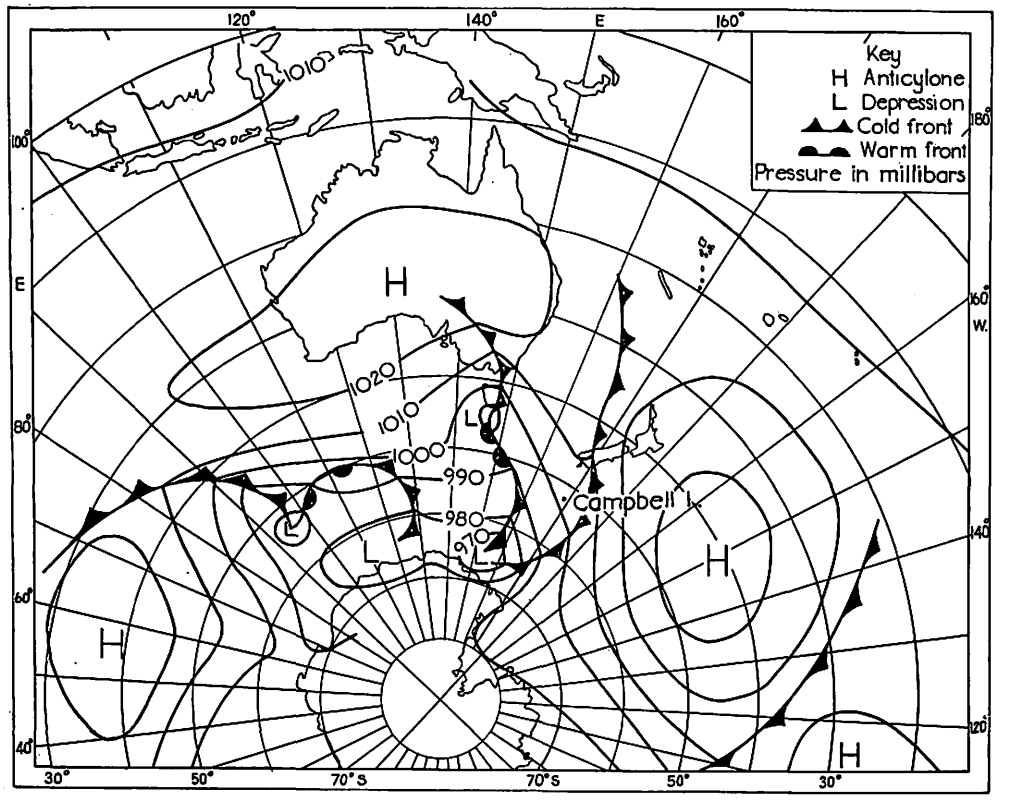

Fig. 1. Surface weather map for 00 GMT 18. V. 1962. Between each pair of anticyclones frontal systems extend southwards to depressions in the southern oceans. A new depression has formed S of Tasmania.

of cold fronts moving across from the west, it is not uncommon to find depressions or anticyclones in its neighborhood.

Anticyclones in the Campbell Island area

An estimate of the mean number of anticyclones passing over Campbell I. each month can be found from the surface pressure record. Having regard to the latitude of Campbell I., the passage of an intense anticyclone over the island is taken here as occurring when the 2100 GMT pressure is 1020 mb or more on one day or on several consecutive days.

In table 1 are given: a) the monthly mean number of anticyclone passages near Campbell I.; b) the mean daily (2100 GMT) M.S.L. pressure for each month and; c) the highest (2100 GMT) M.S.L. pressure in each month. All figures refer to the period 1941–62.

The highest pressure so far recorded on the island is 1038.6 mb. The above figures show that intense anticyclones are liable to move across Campbell in any month and that, on the average, the number of anticyclones crossing is greatest in winter and least in spring. During the passage over Campbell of an anticyclone, the weather usually remains overcast with periods of drizzle.

Table 1.

(a) Mean No. of anticyclone passages

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1.1	1.2	1.3	1.7	1.8	1.3	2.0	2.0	1.4	1.0	0.8	1.0

(b) Mean daily M.S.L. pressure (mb) (2100 GMT)

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1004.3	1005.2	1005.7	1005.2	1005.6	1003.8	1007.4	1005.9	1004.4	1003.2	1000.8	1002.8

(c) Maximum M.S.L. pressure (mb) (2100 GMT)

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1028.2	1030.0	1029.0	1032.4	1037.0	1038.2	1038.1	1030.0	1035.0	1037.3	1028.2	1038.2

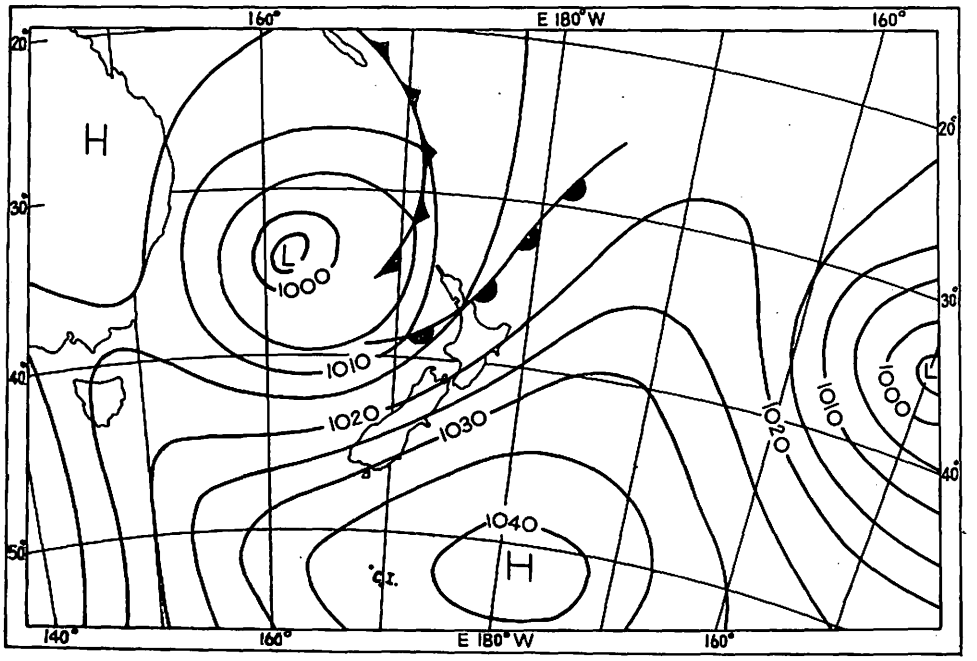

Fig. 2. Surface weather map for 00 GMT 26. VII. 1959, showing an intense anticyclone in high latitudes.

An intense anticyclone passed over Campbell I. in July 1959 (fig. 2). On 12 July and anticyclone moved on to northern New Zealand from the Tasman Sea. It was slow moving and by 21 July covered the whole of New Zealand being oriented NE–SW. A high pressure center formed in the far S on the 22nd. The northern center weakened while the southern center intensified. The anticyclone moved off Campbell on the 28th and from 22–27 July the M. S. L. pressure on the island was more than 1020 mb. During that period, however, there were only 2.8 hours of sunshine and the rainfall each day was as shown below:

Date: July	22	23	24	25	26	27
Daily rainfall (cm)	Trace	0	Trace	0.03	0.05	0.13

The almost continuous cloud cover during the passage of this intense anticyclone, which produced a maximum pressure of 1035 mb at Campbell I., was caused by a subsidence inversion in the upper air and moist air in the lower layers. The daily radiosonde flight showed that the temperature at 850 mb level (about 1500 m) was up to 5° C warmer than that at 900 mb level (about 900 m). Below the inversion the air was saturated, but above, the relative humidity had dropped to 20–35%.

Passage of depressions in the Campbell Island area

If we consider the passage of a deep depression as occurring when the 2100 GMT pressure was 990 mb or less either on one day or on two or more consecutive days, then an estimate of the average number of depression passages, per month during 1941–62 is given in table 2. The lowest minimum pressure each month is also given for the same period.

Table 2.

(a) Mean number of depression passages

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1.9	1.7	1.5	2.3	2.1	2.2	1.4	1.9	2.1	2.2	2.3	2.2

(b) Lowest minimum M.S.L. pressure (mb) at 2100 GMT

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
968.0	970.5	966.5	965.4	966.5	965.3	963.7	948.2	953.6	970.1	961.7	959.9

The lowest pressure so far recorded is 947.4 mb. Deep depressions can be expected to

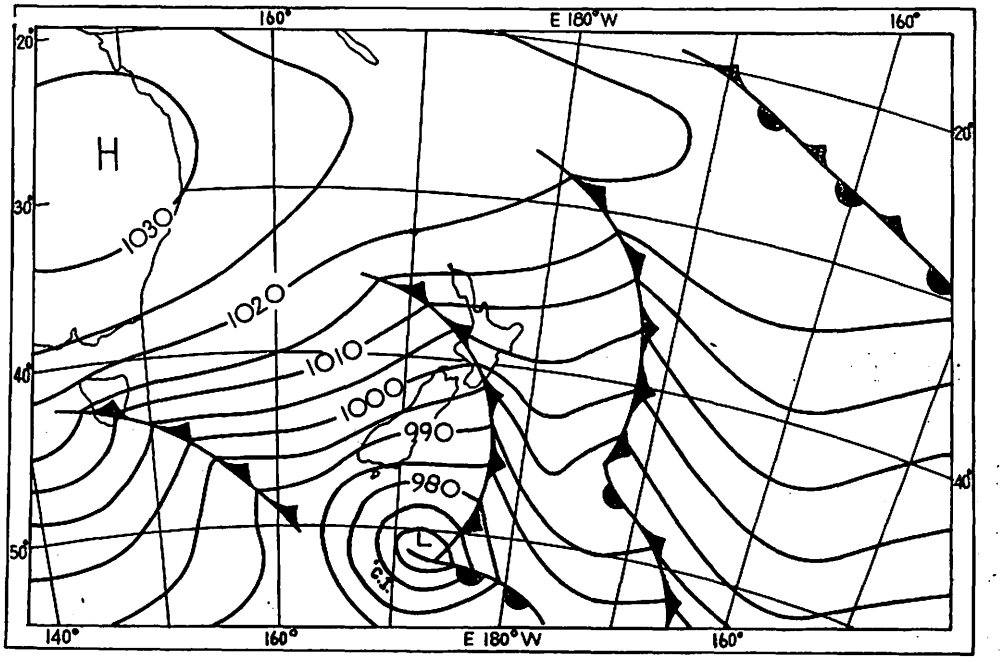

Fig. 3. Surface weather map for 18 GMT 26. VI. 1961, showing the movement of a deep depression over Campbell I.

pass near Campbell any time during the year and the number of depression passages tends to have not very marked maxima and minima in spring and winter respectively. An example of a depression crossing Campbell is shown in fig 3. On a cold front approaching the SW of the South Island of New Zealand, a wave depression formed on 26 June 1961, deepened rapidly and moved in a southeastward direction over Campbell. On the 26th the wind at Campbell was fresh WNW and the weather cloudy to overcast with intermittent rain. 2.9 cm of rain fell during the day. After the depression moved over on the 27th, the wind became fresh to strong SE and all day there was continuous rain accompanied with some snow. 4.9 cm of rain fell.

Climatic elements

The climate of Campbell I. is only the long-term effect of the passage of anticyclones, depressions and fronts as briefly described above. The climatic elements when taken together and considered from this long-term viewpoint make up the climate and are considered separately below:

Wind: Because of the broken and rugged nature of the island, the surface wind direction and speed is very much influenced by local effects. It is impossible to find a place where the measured surface wind would be representative of the flow over the whole island. Since 1961 upper winds have been regularly measured and in the lower layers of the atmosphere the mean flow is from WNW to W. The mean wind at the mid-season months for the years 1961–62 at a height of 1500 m is given in table 3.

Table 3. Mean wind at 850 mb (approx. 1500 m) for 1961-62
Direction (dd) in degrees true, speed (ff) in kts.

Jan.		Apr.		Jul.		Oct.	
dd	ff	dd	ff	dd	ff	dd	ff
273	27	272	33	265	23	282	32

At the surface, winds from a westerly quarter predominate in all seasons and the seasonal distribution of wind direction measured at 00 GMT during the period 1943–52 is given in table 4.

Table 4. Percentage distribution of surface wind direction
(by seasons) at Tucker Cove 1943–52.

	N	NE	E	SE	S	SW	W	NW	Calm (0–3 kts)
Spring	9.4	2.6	1.8	2.5	6.7	13.3	31.8	28.9	3.0
Summer	11.5	4.0	4.1	2.7	5.8	14.6	25.1	28.4	3.8
Autumn	12.5	2.4	1.8	2.1	4.8	14.0	32.8	26.3	3.3
Winter	10.8	3.0	2.6	2.5	6.2	16.3	27.2	24.4	7.0

Strong winds tend to be more frequent in spring than in other seasons and in all seasons tend to be more frequent in the middle of the day than in the early morning or at night. The percentage frequency of seasonal winds greater than 16, 33 and 47 knots at 6 a. m., noon and midnight is given in table 5.

Both the Tucker Cove and Beeman Hill observing sites are sheltered to some extent from the W and at the former site winds between N and W are channelled down the valley

Table 5. Diurnal variation of percentage frequency of strong winds at Tucker Cove 1943–52.

	06 NZST			12 NZST			24 NZST		
	Winds greater than			Winds greater than			Winds greater than		
	16	33	47 kts	16	33	47 kts	16	33	47 kts
Spring	46.4	7.0	0.2	52.9	5.2	0.1	45.8	7.3	0.3
Summer	41.8	4.5	0.2	46.5	3.5	0.3	42.2	5.2	0.3
Autumn	42.8	4.0	0.3	46.4	5.2	–	43.0	4.8	0.1
Winter	43.0	6.9	0.2	44.6	7.0	0.1	41.1	7.0	0.3

and tend to become very gusty. For experimental purposes an anemometer was temporarily erected on the summit of St. Col Peak (295 m) and comparisons were made between the wind force there and at a number of sites on the leeward side. The average ratios of wind force for different directions at St. Col Peak to that of Sheep Camp (a site near the old homestead in Tucker Cove) during May–August 1950 are given in table 6.

Table 6. Average ratio St. Col Peak wind to Sheep Camp wind according to direction during May–August 1950.

Wind Direction	N	NE	E	SE	S	SW	W	NW	No. of observations
Ratio $\frac{\text{St. Col}}{\text{Sheep Camp}}$	2.1	1.0	1.9	2.2	1.6	1.3	1.7	2.2	721

On one occasion, gusts estimated to be greater than 122 kts were recorded at the ex-

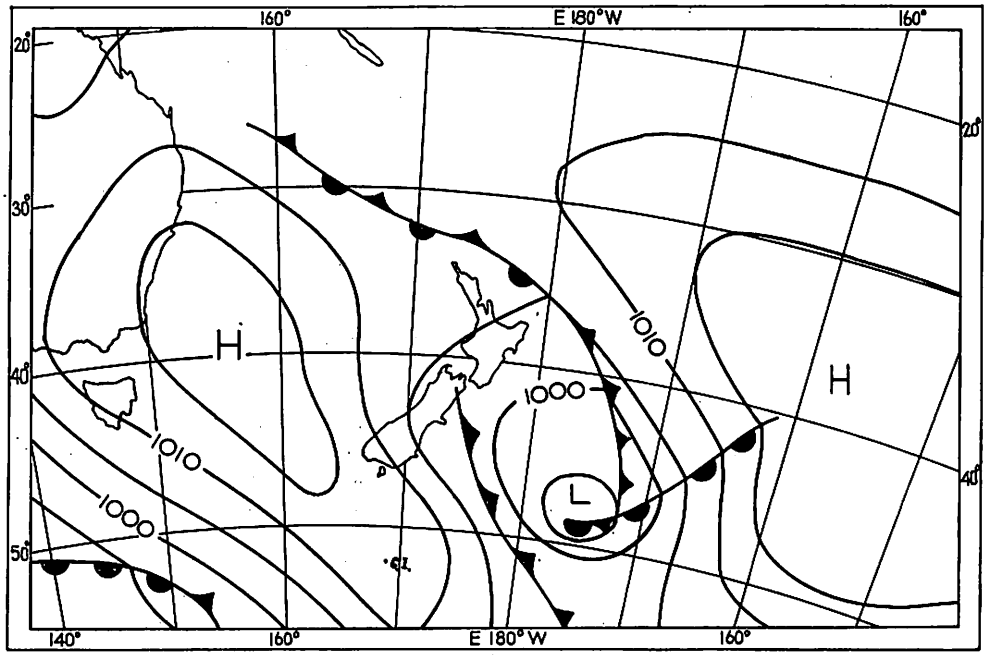

Fig. 4. Surface weather map for 18 GMT 12. II. 1962, showing a ridge of high pressure extending over Campbell I. which experienced 12.6 hrs. of sunshine on this day.

posed site on St. Col Peak and for a 6 hour period on the same day the wind at Sheep Camp averaged 55 kts. On peaks higher than St. Col even stronger winds will occasionally be experienced.

Cup counter anemometers were operated for two years at both the Sheep Camp and St. Col Peak sites. During this period the average daily wind run at St. Col Peak was 1190 km and at Sheep Camp 665 km. The highest daily run at St. Col Peak was 1711 km and at Sheep Camp 1044 km.

Sunshine humidity and cloud: The U. S. Navy, Marine Climatic Atlas of the World (1957) shows that S of New Zealand cloudiness increases considerably. Campbell I. receives on the average only 653 hours of bright sunshine each year compared with an average of 1670 hours at Invercargill in the S of the South Island of New Zealand. The mean monthly totals of sunshine during 1941–57 are given in table 7.

Table 7. Mean monthly hours of sunshine Tucker Cove, 1941–57.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Hours of sunshine	92	80	61	36	21	12	15	27	54	67	89	99	653

The smallest number of sunshine hours yet recorded in any one year is 534 and largest number 830. There are on the average about 130 sunless days each year and 15 consecutive days without sunshine have been recorded. The smallest number of sunless days a year so far recorded is 109 and the greatest number 148. Skies are usually overcast in the early morning (there is an average of 291 days a year of overcast at 9 a.m.), but frequently the cloud breaks somewhat during the day. The island increases its own cloudiness by causing the normally moist airstream to be lifted in crossing its hilly surface. Overcast conditions are frequently observed over the island while only broken cloud is seen over the sea. From the sea, the island has been observed to have a cap of cloud which streams downwind.

At the surface the mean monthly relative humidity at 9 a. m. is more that 80% in all months, having its greatest value in late autumn and winter and its smallest in spring and early summer. On the average the relative humidity in spring and summer decreases from early morning to mid-afternoon each day by about 10%. In autumn and winter the decrease is about 5%.

The lowest 1000 m or so of the atmosphere which would be concerned in cloud formation by the lifting process are also usually moist. The average percentage of occasions each month when the relative humidity at the 900 mb level (about 900 m) during 1956–61 which was greater than or equal to 80% is shown in table 8.

For comparison purposes similar figures are given for Invercargill in the South Island of New Zealand. Both sets of figures are taken from the daily radiosonde flights.

Although skies are predominantly cloudy or overcast and the amount of sunshine small, there are by contrast occasional days of brilliant sunshine. During 1942–62 there were on the average 14 days each year when the daily sunshine amount was at least 8 hours and between 4 and 5 days when it was at least 10 hours.

On 13 February 1962 there were 12.6 hours of sunshine. On this occasion a ridge of high pressure extended on to Campbell I. which was covered by light, cool southwesterly winds up to 100 mb (about 16200 m) (fig. 4). The air was dry up to 500 mb (about

Table 8. Percentage of occasions on which the relative humidity at the 900 mb level equalled or exceeded 80% during 1956-61.

Campbell I.

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
76	66	72	68	75	70	71	72	69	67	64	73

Invercargill (South I., N. Z.)

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
24	33	41	35	38	40	37	38	25	30	28	32

5500 m) where humidity measurement ceased, and exceptionally good surface visibility was reported.

Rainfall: The average monthly rainfall and number of raindays at Tucker Cove during 1941–57 are shown in table 9.

Table 9. Mean monthly rainfall (cm) and number of raindays at Tucker Cove (1941-57).

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Annual
Rainfall	12.5	10.7	14.2	12.4	13.7	12.2	10.2	11.4	12.2	12.2	11.9	11.7	145.3
Rain days	26	24	28	27	28	28	28	29	27	28	26	26	325

The variation of monthly rainfall is shown in fig. 5, where the rainfall exceeded on 90%, 50% and on 10% of occasions is plotted. The mean annual fall of 145.3 cm is spread fairly evenly throughout the year with a slight autumn maximum and the number of raindays great. Although much of the rainfall is in the form of light rain or drizzle, heavy falls are sometimes experienced during the passage across the island of a depression and its associated frontal system. The intensity of rainfall likely to be reached once every

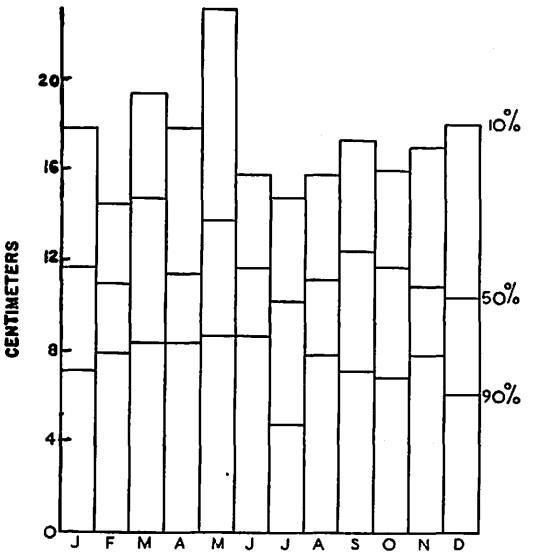

Fig. 5. Variation of monthly rainfall at Tucker Cove, Campbell I. during 1941–57. Rainfall exceeded on 90%, 50% and 10% of months is shown.

2, 5, 10, 20 and 50 years is shown in table 10. These figures were calculated, using the theory of extreme values, from 21 years of recording raingauge data.

Table 10. Computed rainfall intensity - frequency (cm) at Campbell I. (21 years record).

Return period (yrs.)	2	5	10	20	50
Duration of fall (hrs.)					
1	1.0	1.3	1.3	1.5	1.8
6	2.5	3.3	3.8	4.3	4.8
12	3.6	4.6	5.3	6.1	6.9
24	4.9	6.6	7.6	8.7	10.2
48	6.1	8.2	9.7	10.9	12.7
72	6.9	9.7	11.5	13.3	15.5

Because of the hilly surface of the island and the high winds experienced, the distribution of rainfall will be irregular.

Snow may fall in any month and on the average there are 41 days of snow a year. The falls however, are usually light and on only about 11 of these days does the snow lie on the ground. On about 63 days a year there are falls of hail which may occur in any month. Thunder and lightning are uncommon.

Temperature: As would be expected on a small island situated in a zone of strong and persistent westerly winds, both the annual and daily variations of temperature are small. The monthly mean temperature has its greatest value (9.4° C) in January and its smallest (4.5° C) in June-July. The mean daily range each month has its largest value (4.7° C)

Table 11. Temperatures (C.) at Tucker Cove 1941–1957.

Air Temperatures. Approximate mean ½ (Max. + Min.).

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
9.4	9.2	8.5	7.1	6.1	4.5	4.5	4.7	5.4	6.1	7.2	8.4

Mean daily max.

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
11.8	11.7	10.7	9.2	8.1	6.4	6.6	6.9	7.7	8.5	9.8	11.2

Mean monthly max.

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
15.8	15.1	14.6	12.4	11.1	9.2	9.8	9.4	10.1	11.6	13.6	14.3

Mean daily min.

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
7.0	6.8	6.2	5.1	4.1	2.5	2.4	2.6	3.1	3.7	4.4	5.7

Mean monthly min.

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
2.6	1.9	1.3	0.2	-1.4	-2.2	-2.9	-2.3	-2.5	-1.8	-0.9	0.3

Earth temperatures at 30 cm

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
10.6	10.2	9.2	7.6	6.2	4.6	4.2	4.4	5.2	6.3	8.1	9.8

Sea temperatures (1943–55)

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
9.7	9.5	9.2	8.2	7.4	6.2	5.9	6.1	6.5	7.0	7.8	9.2

in December and its smallest value (3.3° C) in June.

The greatest and least screen temperatures so far measured are 19.1° C and –6.3° C respectively. The mean and extreme monthly temperatures for Tucker Cove are summarised in Table 11.

Mean monthly earth temperatures taken at a depth of 30 cm and sea temperatures taken mostly in Tucker Cove during 1943–55 are also given in Table 11.

Both ground frosts and screen frosts can occur in any month. There are on the average at Tucker Cove about 44 ground frosts a year and the number per month ranges from 1 or fewer in summer to about 10 in July. At the same place there are about 27 screen frosts a year and the monthly maximum is about 6 in July. There have only been 3 occasions during 1941–60 when the maximum daily temperature failed to reach 0° C.

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