MEMOIRS OF THE ROYAL METEOROLOGICAL SOCIETY,
VOL. IV. NO. 36

WORLD WEATHER V

BY

SIR GILBERT T. WALKER, C.S.I., SC.D., PH.D., F.R.S., AND
E. W. BLISS, M.A., M.SC.

1. After working out the correlation coefficients between the seasonal values of pressure temperature or rainfall at a number of representative places scattered over the earth it is vital to derive from them some connected schemes of relationship; and although the attempts made to group relationships in terms of the southern oscillation, the North Atlantic oscillation, and the North Pacific oscillation (denoted in future by S.O., N.A.O., and N.P.O.) have presumably helped to clarify ideas, they are still not as definite as they might be.[1] Thus the North Atlantic oscillation is generally regarded as expressing the tendency for pressure to be low near Iceland in winter when it is high near the Azores and south-west Europe; and this distribution is of course associated with high temperature in north-west Europe and low temperature off the Labrador coast. But if the question is asked, What is the relationship between, say, the temperature at Moscow and the N.A.O.? there is at present no series of figures to indicate the amplitude of that oscillation in successive years; all that is possible is to correlate the Moscow temperature with the figures of eight or ten of the representative "centres" which are known to be controlled by the N.A.O. Now in choosing a series of figures to represent that oscillation in successive years we must aim at getting the closest relationships between the series and the data of the representative centres, and naturally the process for deriving it has been tentative. We might divide the centres of the oscillation into two groups, those in the first group tending to have positive departures when those in the second are below normal; and we might further suppose that a, b, c represent the proportional departures of three strongly marked members of the first group, and d, e two less marked members of that group; and that f, g and h, i, j stand for strongly and less strongly marked members of the second group. Then we might take $(a+b+c-f-g)$ as a first approximation for the oscillation as a whole. On correlating this first approximation with the data of the individual centres we might find that while a, c, and g have coefficients of ·78, ·75, and −·82 respectively, b has only ·64 and must therefore go into the less strongly marked or B group, and perhaps the coefficient of i shows that it ought now to go into the more strongly marked or A group. So as a second approximation we try $(a+c-f-g-i)+{\cdot}7(b+d+e-h-j)$, and after one or two more experiments we find a formula consistent with its relationships.

---

[1] Thus in his *Manual of Meteorology*, II., 1928, p. 339, Sir Napier Shaw remarks "the general impression which we derive from the voluminous literature of correlation is bewildering."

THE NORTH ATLANTIC OSCILLATION

2. Although the effects of this oscillation persist for some months, the closest relationships are shown in the winter period December to February, and the formula for the oscillation will therefore naturally be based on winter values. The methods indicated lead to the expression—

(Vienna press.) + (Bodö temp.) + (Stornoway temp.) + ·7(Bermuda press.)
− (Stykkisholm press.) − (Ivigtut press.) − ·7(Godthaab temp.)
+ ·7(Hatteras + Washington temp.)/2.

The units of all these series were chosen so that their standard deviations were $\sqrt{20}$ and the relationships of the five A centres and the three B centres with the N.A.O. so defined are—

A centres	
Vienna press.	·76
Stornoway temp.	·84
Bodö temp.	·86
Stykkisholm press.	−·80
Ivigtut press.	−·84

B centres	
Bermuda press.	·66
½ (Hatteras + Washington temp.)	·72
Godthaab temp.	−·70

The corresponding value for Azores pressure is ·50 only, which excludes Azores from a place in the formula. Of course if we were dealing with entirely random figures the sum of four series with the same standard deviations would have a coefficient with each of the component series which would average ·5; but with eight series the average will be $8^{-\frac{1}{2}}$ or ·35, and the above figures are much too large to be explained in that way. The series of numerical values of these A and B centres and the N.A.O. departures will be found in the Appendix.

The relationships with the N.A.O. of pressure, temperature, and rainfall over a wider area are given in Charts 2, 3, 4, which give the correlation coefficients for representative stations; for any of these the index number will be found in the key Chart 1, and the details regarding the station are then available in Table I. In all charts coefficients based on less than 30 years are distinguished by brackets; and relationships with the rainfall of regions (of which the individual stations are given in Table X) are enclosed in circles. It is better to use the data of some of the stations in outlying regions, even with only 14 years available, rather than to ignore them; and their coefficients must be looked upon as conveying suggestions rather than facts: so caution must be exercised over all figures in brackets. In the temperature Chart 3 it will be seen that in addition to the well-known warming in north-west Europe and cooling in Labrador, with coefficients as big as +·86 and −·70, there is a warming in the south-east of the United States with coefficients up to ·70, and a cooling in the region to the south-east from Trinadad to Irak, the coefficient of the Cape Verde Islands being −·48 and of Cairo −·60. It is a natural conjecture that the warming in the U.S.A. may be due to a more northerly path of the "lows" and a more southerly direction in the winds, the cooling of the Cape Verde Islands to a more northerly direction in the winds, and the lower temperatures from Egypt to Irak to a more southerly track of winter rain-bearing depressions. The chart of rainfall, 3, naturally shows an area of positive coefficients round Iceland, where the pressure coefficient was negative, and an area of negative coefficients over south-west Europe where the pressure coefficients are positive; but the correspondence of the rainfall and pressure coefficients is quite rough.

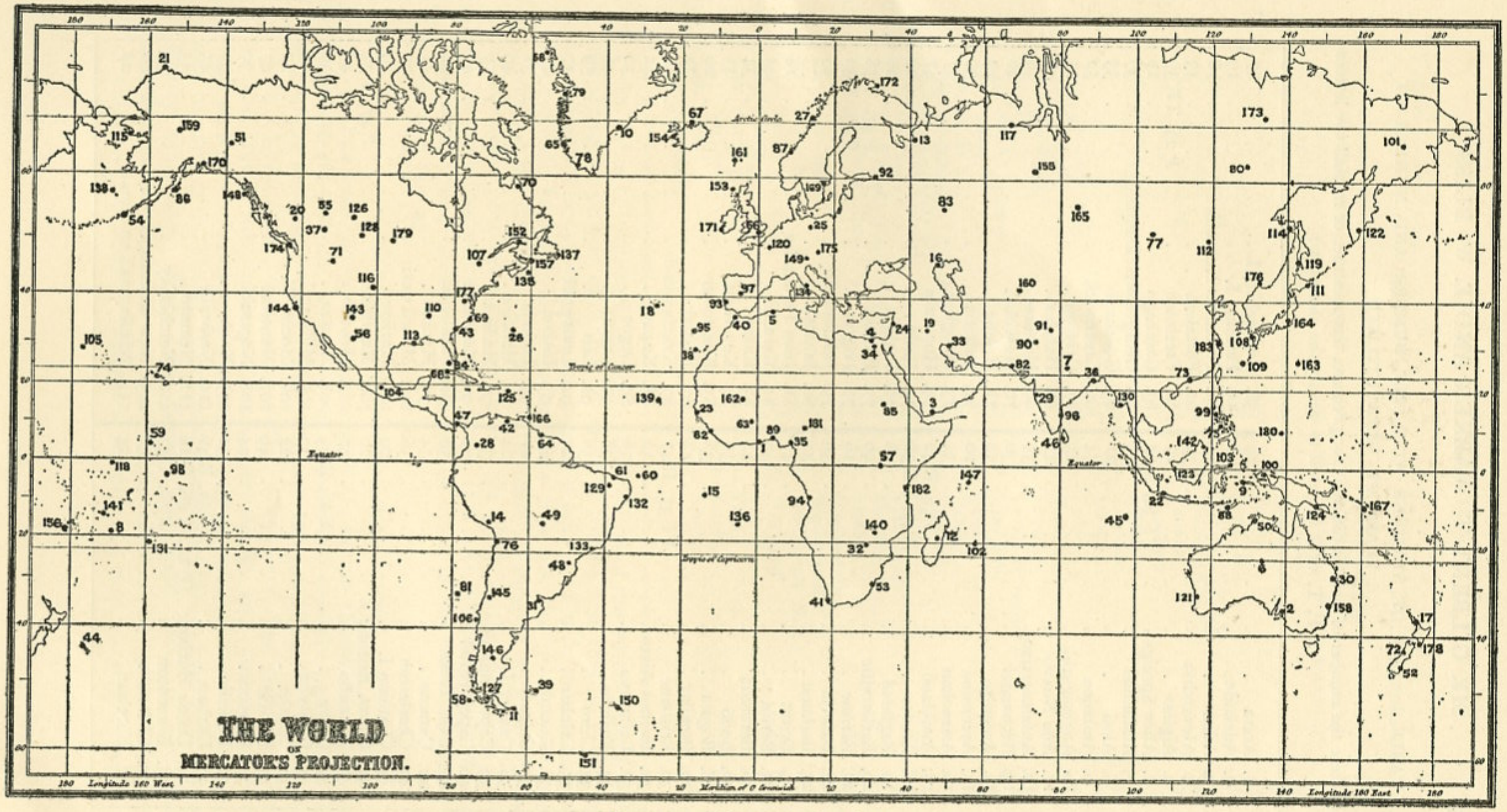


CHART I.—Key map of stations.

TABLE I—LIST OF STATIONS WITH KEY NUMBER AND NUMBER OF YEARS OF DATA UTILISED

(Where the number of years is different for pressure, temperature, or rainfall the letters P, T, or R are used to specify the elements.)

1. Accra	29
2. Adelaide	46
3. Aden	39
4. Alexandria	33
5. Algiers	27
6. Alice Springs	PT 38, R 47
7. Allahabad	43
8. Alofi	21
9. Amboina	44
10. Angmagsalik	25
11. Año Nuevo	22
12. Antananarivo	35
13. Archangel	30
14. Arequipa	19
15. Ascension	20
16. Astrachan	34
17. Auckland	T 52, R 42
18. Azores	P 49, TR 30
19. Baghdad	28
20. Barkerville	40
21. Barrow	16
22. Batavia	56
23. Bathurst	37
24. Beirut	41
25. Berlin	46
26. Bermuda	42
27. Bodö	56
28. Bogota	38
29. Bombay	42
30. Brisbane	PT 37, R 47
31. Buenos Aires	52
32. Bulawayo	28
33. Bushire	38
34. Cairo	56
35. Calabar	22
36. Calcutta	43
37. Calgary	47
38. Canary I.	24
39. Cape Pembroke	31
40. Cape Spartel	27
41. Cape Town	56
42. Caracas	34
43. Charleston	56
44. Chatham I.	20
45. Cocos, Keeling I.	20
46. Colombo	47
47. Colon	T 18, R 43
48. Curityba	39
49. Cuyaba	24
50. Darwin	49
51. Dawson	24
52. Dunedin	51
53. Durban	PT 36, R 46
54. Dutch Harbour	P 14, T 28, R 18
55. Edmonton	P 36, T 47
56. El Paso	44
57. Entebbe	24
58. Evangelists I.	27
59. Fanning I.	19
60. Fernando Noronha	18
61. Fortaleza	43
62. Freetown	P 29, TR 39
63. Gambago	19
64. Georgetown (Demarara)	30
65. Godthaab	53
66. Greenwich	52
67. Grimsey	45
68. Habana	47
69. Hatteras	56
70. Hebron	26
71. Helena	43
72. Hokitika	30
73. Hongkong	37
74. Honolulu	47
75. Iloilo	20
76. Iquique	26
77. Irkutsk	P 47, T 38
78. Ivigtut	P 43, T 30
79. Jakobshavn	45
80. Jakutsk	33
81. Juan Fernandez	18
82. Karachi	45
83. Kasan	34
84. Key West	45
85. Khartoum	20
86. Kodiak	32
87. Kristiansund	46
88. Kupang	42
89. Lagos	30
90. Lahore	48
91. Leh	39
92. Leningrad	37
93. Lisbon	43
94. Loanda	31
95. Madeira	40
96. Madras	55
97. Madrid	45
98. Malden I.	T 26, R 34
99. Manila	41
100. Manokwari	22
101. Markovo	19
102. Mauritius	P 47, T 35
103. Menado	43
104. Mexico	39
105. Midway I.	18
106. Mocha W.	25
107. Montreal	47
108. Nagasaki	39
109. Naha	P 30, T 39
110. Nashville	45
111. Nemuro	45
112. Nerchinsky	37
113. New Orleans	46
114. Nikolayevsk on Amur	28

TABLE I—*continued*

115. Nome	22
116. North Platte	48
117. Obdorsk	27
118. Ocean I.	17
119. Ochiai	22
120. Paris	49
121. Perth (Austr.)	41
122. Petropavlovsk	24
123. Pontianak	44
124. Port Moresby	23
125. Porto Rico	30
126. Prince Albert	46
127. Punta Arenas	35
128. Qu' Appelle	47
129. Quixeramobim	26
130. Rangoon	42
131. Rarotonga	27
132. Recife	44
133. Rio de Janeiro	47
134. Rome	50
135. Sable I.	22
136. St. Helena	32
137. St. John's (N.F.)	44
138. St. Paul's I.	17
139. St. Vincent (Cape Verde I.)	41
140. Salisbury (Rhod.)	26
141. Samoa	39
142. Sandakan	32
143. Santa Fe	39
144. San Francisco	46
145. Santiago	56
146. Sarmiento	21
147. Seychelles	30
148. Sitka	P 23, T 36
149. Sonnblick	34
150. South Georgia	22
151. South Orkneys	21
152. Southwest Point (Anticosti)	38
153. Stornoway	55
154. Stykkisholm	51
155. Surgut	36
156. Suva, Fiji	47
157. Sydney (Nova Sc.)	44
158. Sydney (N.S.W.)	46
159. Tanana	22
160. Tashkent	34
161. Thorshavn	51
162. Timbuctu	14
163. Titizima	20
164. Tokyo	43
165. Tomsk	34
166. Trinidad	41
167. Tulagi (Solomon I.)	T 18, R 29
168. Upernivik	42
169. Upsala	46
170. Valdez	18
171. Valencia	51
172. Vardo	P 43, T 55
173. Verkhoyansk	27
174. Victoria (B.C.)	35
175. Vienna	P 47, R 39
176. Vladivostok	34
177. Washington	56
178. Wellington (N.Z.)	45
179. Winnipeg	P 40, T 54
180. Yap	18
181. Yola	19
182. Zanzibar	P 39, T 29
183. Zikawei	42

In Table II[2] will be found some relationships of the winter N.A.O. with the spring conditions of March to May; it will be seen that there are six coefficients of ·4 or over; but the biggest is only – ·52 with temperature at Cape Verde Islands. In order to throw light on the problem of foreshadowing the character of the N.A.O. some coefficients with conditions in November have been worked out and are given in the same table; the results are disappointing and indicate that the foreshadowing of the winter and spring conditions can better be made at the end of December or perhaps January.

THE NORTH PACIFIC OSCILLATION

3. Data from the north of this region are not so abundant as they are for the North Atlantic, and the first collection of maxims regarding it is due to the forecasters of the U.S. Weather Bureau (*Weather Forecasting in the United States*, chap. xiii., 1916). They noted that pressure variations at Hawaii were opposed to those over Alaska and Alberta, and that high pressure in Alaska meant a more southerly track of "lows" and more rain in parts of the United States and liability to cold weather east of the Rocky Mountains. Since then perhaps the chief result of statistical examination has been the unexpected association of low pressure in the

---

[2] Hereafter D-F stands for December to February, and M-M, J-A, S-N for the subsequent quarters.

TABLE II—N.A.O. WITH CONDITIONS BEFORE, CONTEMPORARY, AND AFTER

Element and locality	No. of years	Before N.A.O.	Contemp.	After N.A.O.
		Nov.	D-F	M-M
Pressure				
Bermuda	54	16	66	28
Ivigtut	47	−20	−84	−16
Stykkisholm	56	−14	−80	−28
Vienna	56	10	76	0
Temperature				
Godthaab	53	−12	−70	−38
Hatteras	56	34	70	42
Kristiansund	46	8	84	44
St. Vincent (Cape Verde I.)	42	−14	−48	−52
Stornoway	55	10	84	10
Ice				
Barents Sea	31	J-A −24	...	April + May −44
Greenland	45	April-July 10	...	April-July −2
Newfoundland, 1900–26	27	Mar.-July 22	...	Mar.-July 42
Newfoundland, 1875–1912	38	Mar.-Aug. −14	...	Mar.-Aug. 64
Sea-water temperature				
15°-25° N., 35°-45° W.	27	S-N −2	D-F −28	M-M −24

northern region with low temperature in the Aleutian Islands (Dutch Harbour), and it now appears that the association with high temperature in south-west Canada is even more marked.

The formula finally adopted for the N.P.O. is—

$$\begin{aligned}\{\text{Honolulu press.}\} + \tfrac{1}{3}\{\text{Qu'Appelle} + \text{Calgary} + \text{Prince Albert temp.}\}\\ - \tfrac{2}{3}\{(\text{Sitka, Fort Simpson, or Juneau press.}) + (\text{Dawson press.})\\ + (\text{Nome press.})\} - \{\text{Dutch Harbour temp.}\}.\end{aligned}$$

Here the fractions $\frac{2}{3}$ and $\frac{1}{3}$ have been used because the quantities multiplied by them relate to places not far enough apart to be independent.

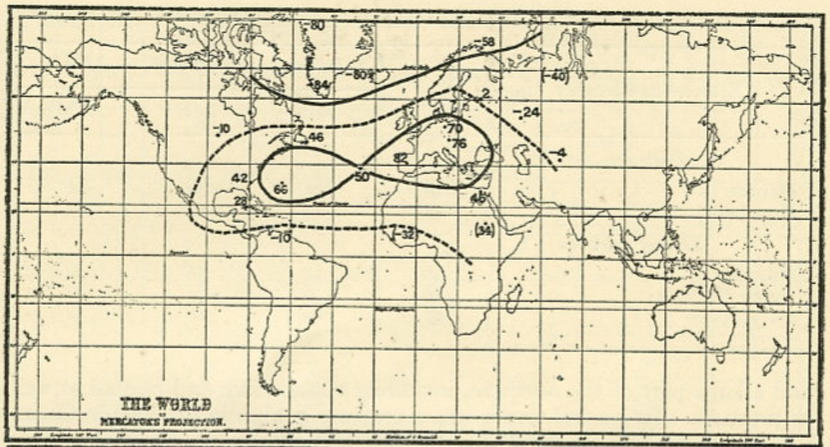
The coefficients of the four factors with the N.P.O. thus defined are respectively ·80, ·86, −·86, and −·74: details will be found in the Appendix.

The coefficients with the N.P.O. of pressure, temperature, and rainfall over a wider area are given in Charts 5, 6, 7. A comparison of 5 and 6 with 2 and 3 shows that the features of the N.P.O. occur decidedly farther south than those of the N.A.O.; but in spite of the wide difference in the conditions there is a marked similarity in the temperature effects, there being positive coefficients in Canada and eastern China, and negative in eastern Siberia and the south of the United States. In Table III are to be found some representative relationships with the conditions in the succeeding spring and with the previous November.

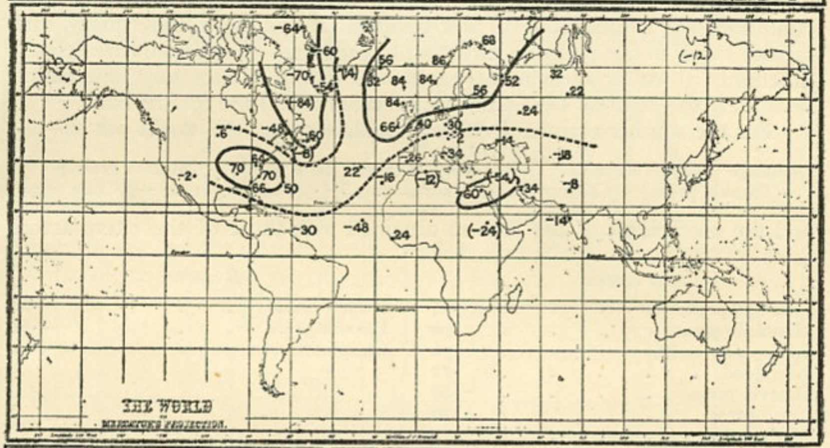
The Southern Oscillation

4. Beginning with the opposition of pressure between Sydney and Buenos Ayres noticed by Hildebrandsson in 1897, there has developed a complicated set of relationships extending over the southern hemisphere

2



3



4

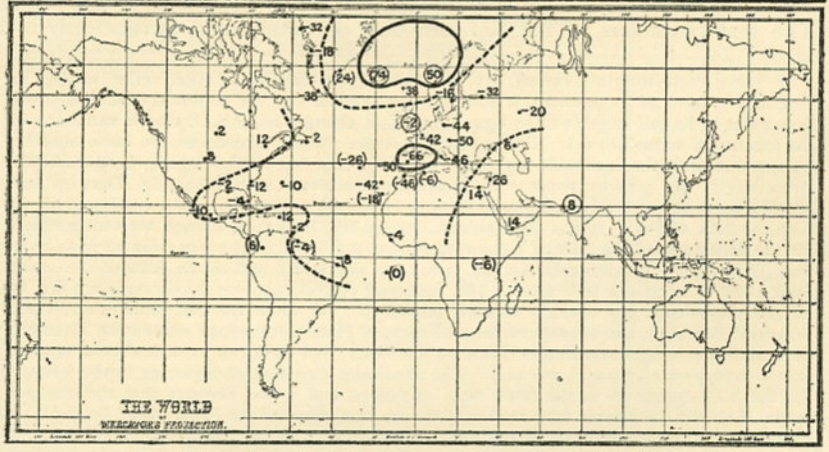


CHART 2.—N.A.O. with contemporary pressure of D-F.
CHART 3.—N.A.O. with contemporary temperature of D-F.
CHART 4.—N.A.O. with contemporary rainfall of D-F.

TABLE III—N.P.O. WITH CONDITIONS BEFORE, CONTEMPORARY, AND AFTER

Element and locality	No. of years	Before	Contemp.	After
		Nov.	D-F	M-M
Pressure				
Dawson	28	−32	−86	−2
Honolulu	47	28	80	28
Temperature				
Batavia	49	42	56	46
Dutch Harbour	29	0	−74	−6
Qu' Appelle	47	16	86	36

and a large part of the northern, including temperature and rainfall as well as pressure. In general terms, when pressure is high in the Pacific Ocean it tends to be low in the Indian Ocean from Africa to Australia; these conditions are associated with low temperatures in both these areas, and rainfall varies in the opposite direction to pressure. Conditions are related differently in winter and summer, and it is therefore necessary to examine separately the seasons December to February and June to August.

For the southern winter J-A the formula for the S.O. works out as—

(Santiago press.) + (Honolulu press.) + (India rain) + (Nile flood) + ·7(Manila press.)
− (Batavia press.) − (Cairo press.) − (Madras temp.) − ·7(Darwin press.) − ·7(Chile rain);

and the coefficients of the S.O. so obtained with those of these ten factors are[3]—

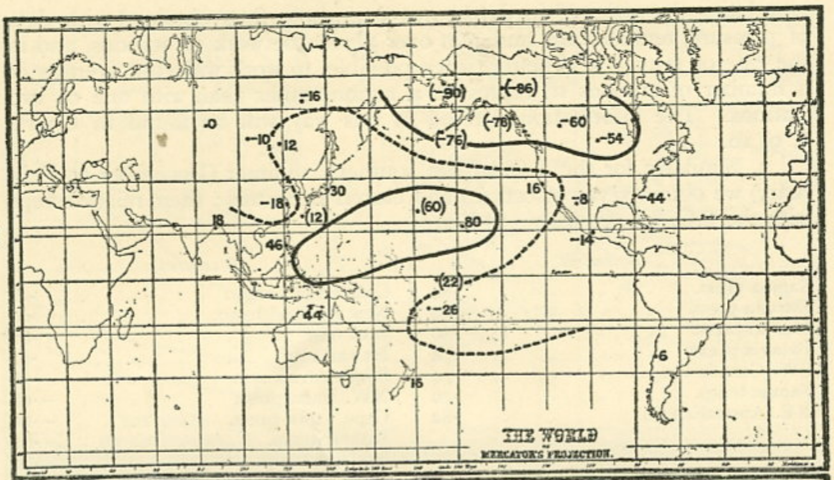
A centres		*B centres*	
Santiago press.	·84	Manila press.	·66
Honolulu press.	·76	Darwin press.	−·68
India rain	·76	Chile rain	−·60
Nile flood	·72		
Batavia press.	−·80		
Cairo press.	−·76		
Madras temp.	−·72		

The real characters of the S.O. can only be determined satisfactorily by

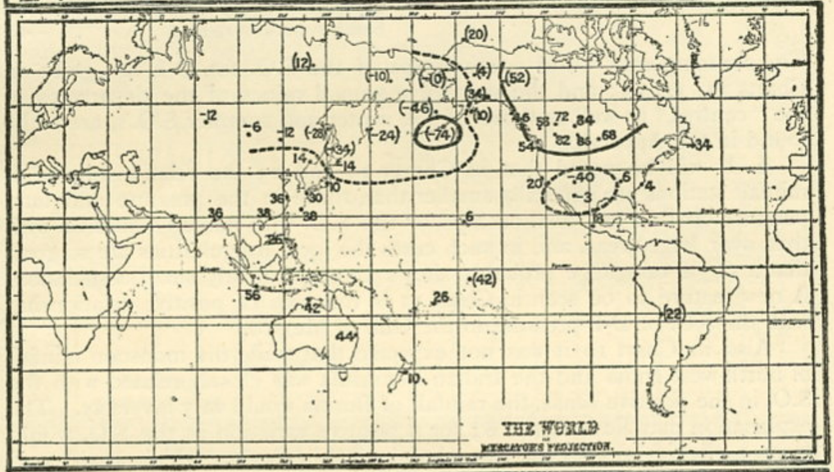
---

[3] When correlating a series of, say, 56 terms with a number of other series varying in length, say, from 48 to 56 terms, it is customary to work out the standard deviation of the first series in its full length and to ignore the slight changes in its S.D. due to variations in the number of terms utilised. In general the errors thereby introduced are quite small by comparison with the inevitable errors of sampling, due to not having far longer series. Accordingly, the present paper was practically completed with Honolulu, Darwin, and Manila pressures and Chile rain as B centres, Honolulu pressure having a coefficient of ·68 with the S.O. of J-A. It was then pointed out by Mr. Bliss that, though the unit adopted for the departures of the S.O. of J-A was such that the S.D. of the series from 1875 to 1930 was $\sqrt{20}$ or 4·47, the departure for the year 1877 was −16; and so the S.D. of the series from 1878 to 1930 was only 4·01. The necessary corrections were accordingly applied to all the coefficients, but a slight blemish remained. For while Darwin, Manila, and Chile remained B centres, the increase in the coefficient of Honolulu pressure made it an A centre: thus while the weight attached to Honolulu had been ·7/(6 + 2·8), or ·079, it should as an A centre have been 1/(7 + 2·1), or ·110. The remaining nine centres occurring in the formula for the S.O. remained in the same class as before, and it was obvious that the changes made, if all the coefficients were recomputed with new values of the S.O., would be small by comparison with the inevitable errors due to other causes; in fact the recomputed series of the S.O. differed in no year by more than unity from the original series. It would therefore have been pedantic to regard the small change in the coefficient of Honolulu as justifying retabulation.

5



6



7

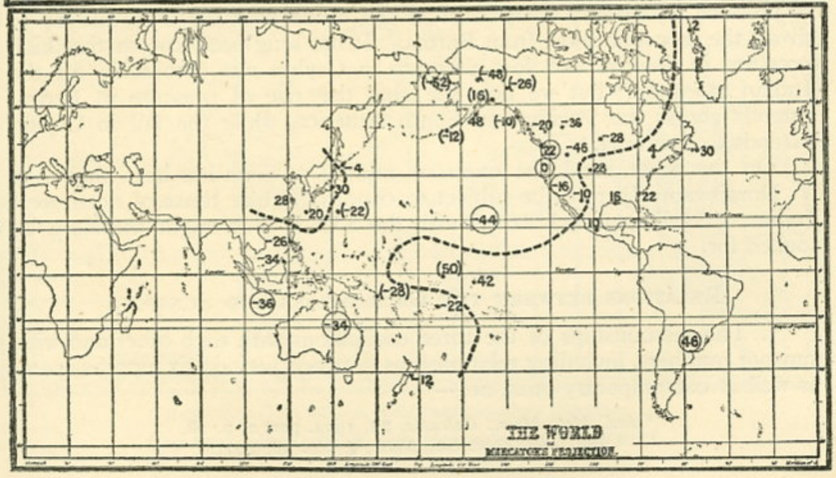


CHART 5.—N.P.O. with contemporary pressure of D-F.
CHART 6.—N.P.O. with contemporary temperature of D-F.
CHART 7.—N.P.O. with contemporary rainfall of D-F.

correlating the series of its departures as a whole thus obtained with data of pressure, temperature, and rain over a wide network of stations, and in the case of rainfall it is better, when possible, to work with the average of a number of stations to represent a region rather than with one or two stations. The information derived in this way will be found in Charts 8, 9, 10.

5. Similarly for the S.O. of the southern summer (December to February) we obtain seven A centres and eleven B centres; their relationships with the S.O. for the season D-F are—

A centres		*B centres*	
Samoa press.	·84	Charleston press.	·52
Darwin press.	−·90	New Zealand temp.	·60
Manila press.	−·86	Java rain	·62
Batavia press.	−·74	Hawaii rain	·62
SW. Canada temp.	−·74	South Africa rain	·56
Samoa temp.	−·76	NW. India press.	−·68
NE. Australia rain	·82	Cape Town press.	−·66
		Batavia temp.	−·62
		Brisbane temp.	−·60
		Mauritius temp.	−·68
		South American rain	−·62

The contemporary world relationships of the S.O. for D-F are given in Charts 11, 12, 13; and the successive annual values of the departures of the "centres," as well as those of the winter and summer S.O.'s, are to be found in the Appendix.

6. It will be noted that in Charts 10 and 13 the relationships with rainfall stations are generally smaller than those in the pressure and temperature charts; but relationships of the S.O. with rainfall would be with that over large areas, and in such cases the local irregularities are so great that a single raingauge probably shows a comparatively small association. A new feature to be seen in Chart 11 is the area of positive relationship with the S.O. of D-F pressure in the Gulf of Mexico.

Also in Chart 10 it was not expected that while the monsoon rainfall of north-west India and the Indian Peninsula was closely related with the S.O. in the positive sense, the rainfall of Burma would vary inversely. The explanation may lie in Chart 8; for a positive variation in the S.O. would mean a rise of pressure in Bengal and a fall in Ceylon, which would tend to produce an easterly component in the winds over the Bay, and so to divert the monsoon away from Burma. It has long been known that high pressure in Bengal and low pressure in Ceylon was favourable for the Indian monsoon,[4] but we now see that the rise of pressure in Bengal extends across the Pacific and South America, while the fall in Ceylon extends to Australia.

On the other hand, the monsoon rainfall of Siam has been shown by V. Doraiswamy Iyer[5] to be subject to conditions like those of north-west India: a coefficient such as ·70 with the S.O. of J-A might therefore be looked for.

RELATIONS BETWEEN THE OSCILLATIONS AND SUNSPOTS

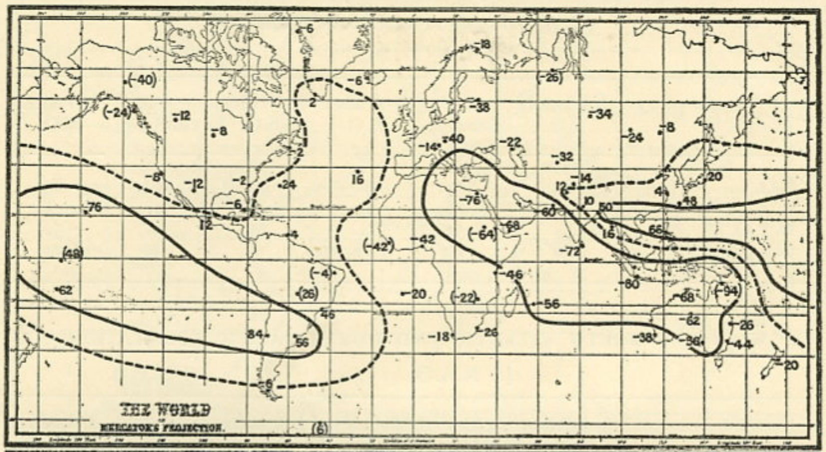
7. The relationships of the three oscillations with each other and with sunspot numbers, including relationships between periods six months apart, as well as contemporary ones, are—

---

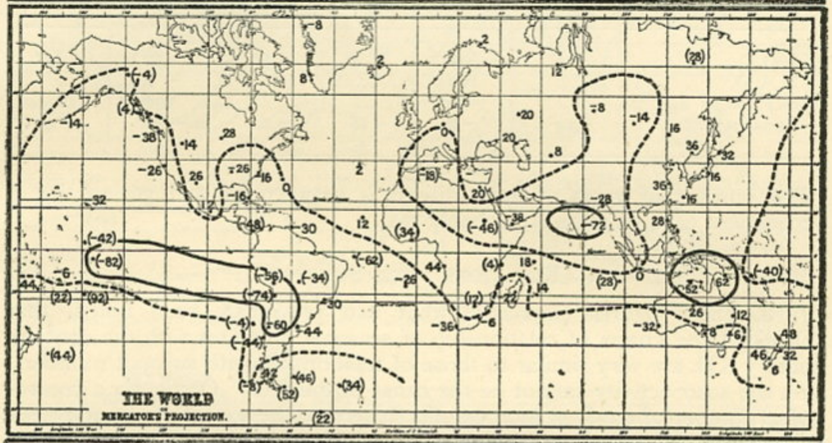
[4] *Ind. Met. Mem., Calcutta*, **23**, 1922, part 2, p. 28.

[5] *Ind. Met. Dept. Sci. Notes*, **4**, No. 38, 1931.

8



9



10

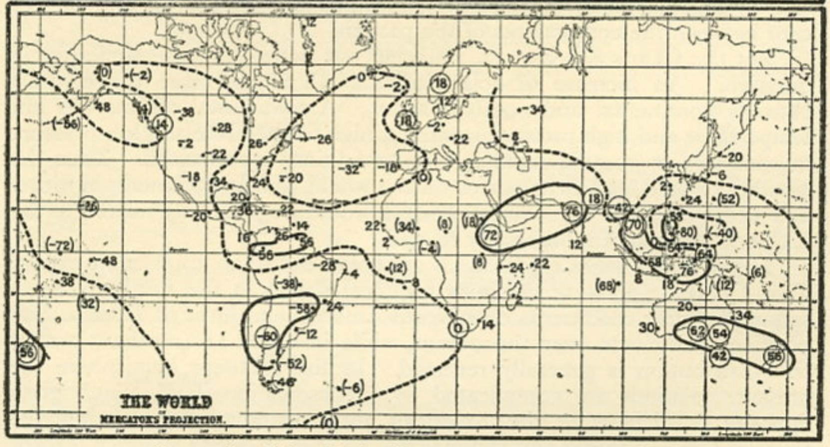


CHART 8.—S.O. of J-A with contemporary pressure.
CHART 9.—S.O. of J-A with contemporary temperature.
CHART 10.—S.O. of J-A with contemporary rainfall.

WITH THE SOUTHERN OSCILLATION

	(*a*) D-F			(*b*) J-A		
	J-A before S.O.	D-F contemp.	J-A after S.O.	D-F before S.O.	J-A contemp.	D-F after S.O.
S.O. . . .	84	100	20	20	100	84
N.A.O. . .	...	- 6	...	2	...	8
N.P.O. . .	...	- 52	...	14	...	- 52
Sunspots . .	26	20	18	8	20	20

WITH THE NORTH ATLANTIC AND NORTH PACIFIC OSCILLATIONS

	(*c*) N.A.O.			(*a*) N.P.O.		
	J-A before N.A.O.	D-F contemp.	J-A after N.A.O.	J-A before N.P.O.	D-F contemp.	J-A after N.P.O.
S.O. . . .	4	6	- 4	- 52	- 52	14
N.A.O. . .	...	100	...	...	- 4	...
N.P.O. . .	...	- 4	...	...	100	...
Sunspots . .	- 12	- 8	- 18	- 20	- 16	- 4

The number of years of data utilised is between 46 and 56, so that a coefficient of ·4 or more is probably real.

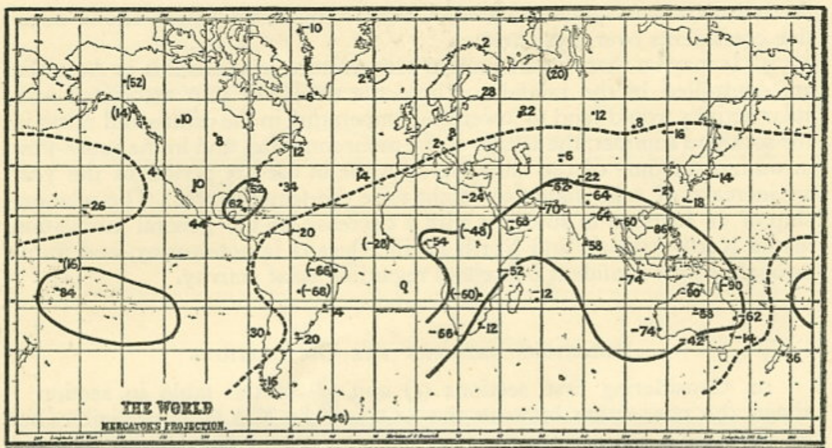
Relations with Sunspots

8. These figures emphasise what had previously been noted, that although the charts of relationship of seasonal pressures with the contemporary S.O. are very similar to those of relationship with sunspot numbers, yet the solar activity cannot be the cause of the S.O. Obviously a control of a number of stations in a certain pattern to the extent of 20 or 25 per cent by sunspots cannot explain relationships of between 80 and 90 per cent between the components of the pattern.

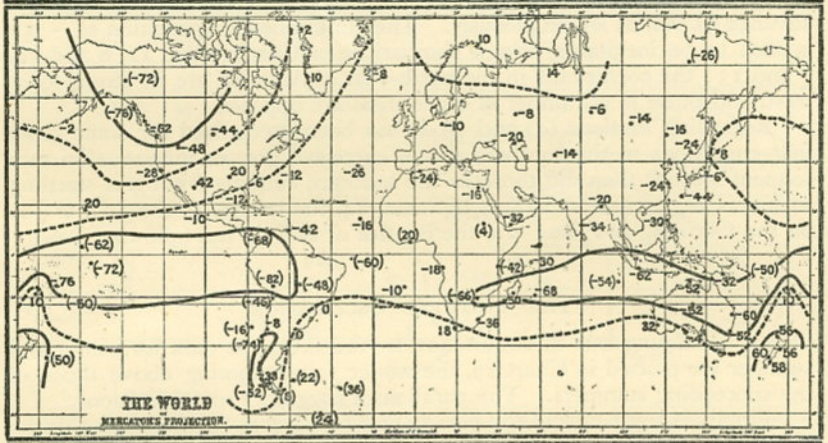
But the Charts 8, 9 and 11, 12 bring out more fully the similarity in question. An increase of solar radiation should increase the contrast between continental and ocean climates. A continental climate has low temperature and high pressure in winter, high temperature and low pressure in summer; in oceanic climates these conditions are reversed. Thus the similarity would lead us to expect, on the whole, that in continents in winter and oceanic islands in summer pressure would be positively related to the S.O. and temperature negatively related.

In the charts these expectations are borne out to an appreciable extent. Thus Chart 8 (pressure northern summer) shows in the northern hemisphere negative coefficients over North America and most of Eurasia, and positive coefficients over the oceans, while in Chart 11 (northern winter) this distribution is generally reversed. In the southern hemisphere the pressure relations are complicated by the oscillation itself, which gives opposite coefficients in the American and Australian regions, but the reversal between winter and summer can be seen in South America (except Santiago) and in New Zealand. Similarly Chart 9 (temperature, northern summer) shows positive coefficients over most of the continental areas of

11



12



13

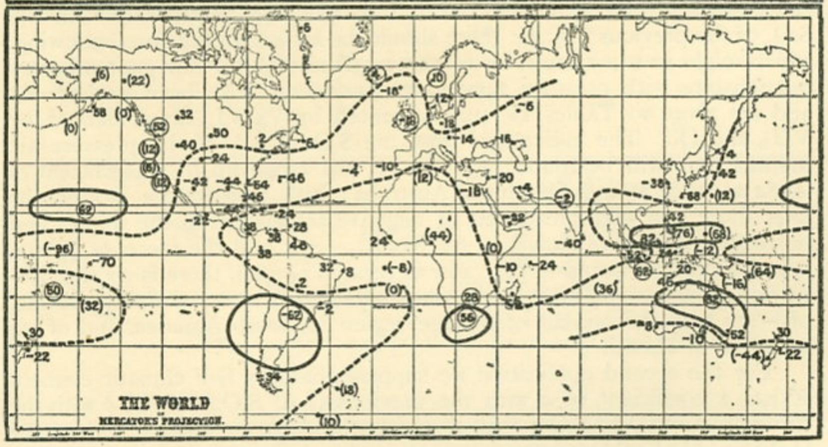


CHART 11.—S.O. of D-F with contemporary pressure.
CHART 12.—S.O. of D-F with contemporary temperature.
CHART 13.—S.O. of D-F with contemporary rainfall.

the northern hemisphere, whereas Chart 12 (northern winter) shows negative coefficients over these areas.

9. It may be that the anomalous temperature relationships in Australia are controlled by the rainfall. There the excess of rain associated with solar activity would tend to lower the temperature in the centre and north in the southern summer, the season of the monsoon rains, and in the south-west in winter, the time of the rains there; while in the dry period of the year an increase of solar radiation might raise the temperature. The relationship of an increase in sunspots with a decrease in the general circulation in the North Atlantic and North Pacific Oceans is noteworthy, and warns us against over-confident inferences regarding solar activity.

RELATIONS BETWEEN THE OSCILLATIONS

10. Considering first sections (*c*) and (*d*) of the table in section 7 above, the connection between the S.O. and the N.A.O. is negligible, but the S.O. has a considerable negative influence on the N.P.O. six months in advance as well as simultaneously. The simultaneous opposition of $-\cdot 52$ is seen to be inevitable from a comparison of Charts 5 and 11, 6 and 12, 7 and 13; the coefficients in the north-west of America are in strong contrast, and those in a number of other areas are opposed.

Regarding sections (*a*) and (*b*), it has been recognised for some years that conditions in the southern winter exercised greater influence on subsequent seasons than did those in the southern summer; but it is startling to see as big a contrast as that between ·84, the control of the S.O. of J-A on the following D-F, and ·20, the control of D-F on the following J-A.

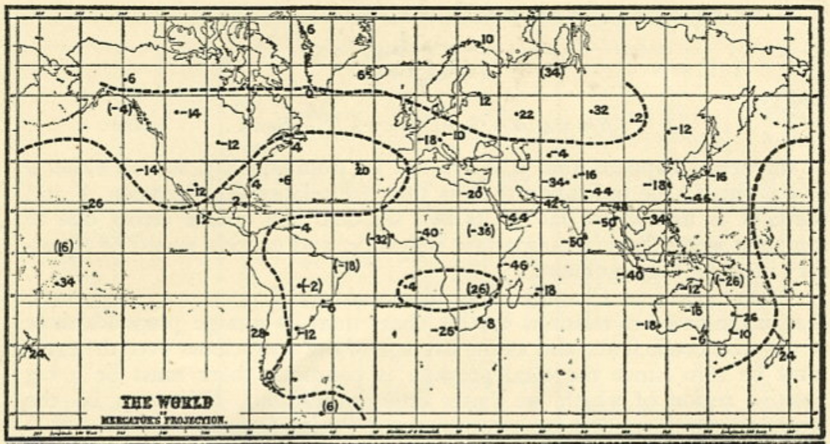
THE SOUTHERN OSCILLATION

11. Confining our attention now to the S.O., the data for winter and summer are plotted in Chart 19, the winter values coming above those of the succeeding summers. The parallelism suggests two applications.

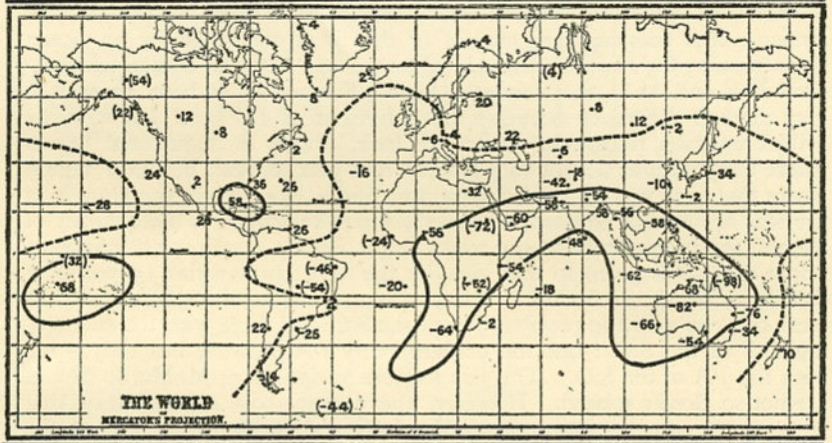
Firstly, if any factor of the period D-F has a close relationship with the contemporary S.O. it should have a corresponding relationship with the S.O. of the previous J-A, *i.e.* there should be a six months' foreshadowing, which might in some cases be of value. A number of non-contemporary relationships with pressure, temperature, and rain have been worked out and are given in Tables IV (supplemented by V), VI (supplemented by VII), and IX. The indications from the S.O. of J-A of the pressure six months later will be found in Chart 15, and range up to a coefficient of $-\cdot 82$ at Alice Springs in central Australia; with temperature six months later there is a widespread belt of negative association in the tropics and north-west America (Batavia $-\cdot 68$, Samoa $-\cdot 74$, and the mean of Winnipeg, St. Paul, St. Louis $-\cdot 50$); and as regards rainfall, there is an anticipatory coefficient of ·64 with the monsoon rainfall of North and East Australia, of $-\cdot 72$ with the rainfall of a large region in South America, and of ·54 with that of Hawaii.

For the second application we suppose that any D-F climatic element X has a coefficient of a with the previous (J-A) S.O., and of b with the contemporary (D-F) S.O.; then denoting the departures of X and of the (J-A) and (D-F) S.O.'s by x, y, z we may determine the extent to which X is "controlled" by the contemporary or the previous S.O. by finding the coefficients of the regression equation $x = py + qz$.

14



15



16

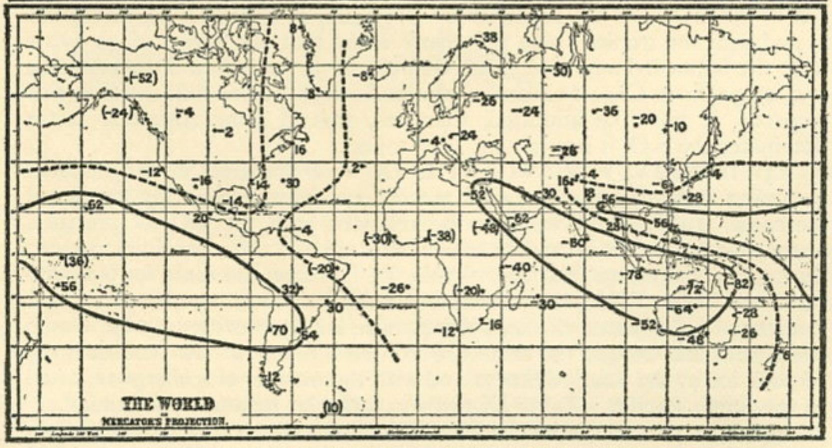


CHART 14.—S.O. of J-A with pressure of D-F before.
CHART 15.—S.O. of J-A with pressure of D-F afterwards.
CHART 16.—S.O. of D-F with previous pressure of J-A.

Thus we solve the equations

$$a = p + {\cdot}84q,$$
$$b = {\cdot}84p + q,$$

and get

$$p = 3{\cdot}4\,(a - {\cdot}84b),\ q = 3{\cdot}4\,(b - {\cdot}84a).$$

It frequently happens that a, b are not far from equality, so that either p or q is small; the indication then is that the relationship between X and the S.O. is limited to one of its two seasons. Of course errors due to sampling would have an important influence, and caution would be necessary in using the argument.

With regard to Chart 11 Mr. Bliss makes the interesting suggestion that in the pressure relations on this chart there is a large preponderance of negative coefficients, and as the average of the coefficients over the earth must be zero (since the total pressure is constant), there must be a big positive region of which we have little indication. This may be the Antarctic continent or a large region in the Pacific Ocean.

12. One of the most natural inferences to draw from exceptional persistence of a seasonal temperature is that it is controlled by an ocean temperature; for example, there is a c.c. of ·94 between Samoa temperatures D-F and M-M three months later. Further, if, as here, there is a very marked difference between the behaviour of D-F and J-A it is, as Hildebrandsson remarked, natural to look, not in the equatorial region where temperatures do not vary greatly from year to year, but in a region where there are very marked differences; and a likely place therefore is in the seas around the Antarctic continent, where variations in the quantity of ice and the temperature of the water might be the dominating influence. Some support is given to this idea by the very short series (5 years) of data from McMurdo Sound, of which the pressure for the quarter S-N has c.c.'s of − ·76 with the previous J-A of the S.O. and − ·78 with the succeeding D-F of the S.O.; but the contemporary J-A pressure has only − ·04 with the J-A of the S.O. The temperature variations at McMurdo Sound are not so closely related. However, the figures show no indication that the pressure or temperature of McMurdo Sound is physically prior to the J-A of the S.O., and the relations are not nearly as close as those of regions in and near the tropics; also the charts show that the series of 22 years from the South Orkneys and South Georgia, of 34 years from Punta Arenas, and of 31 from Cape Pembroke cannot be regarded as influential in this respect. It must be admitted, therefore, that if some Antarctic factor dominates the S.O. it has not yet been found.

13. Tables IV, V, VI, VII, VIII, IX were prepared in the hope of obtaining light on the physical antecedents of the S.O. by empirical methods. In Table IV we have the relations with the S.O. of pressure, at the standard stations and at others selected for their possible interest, during five successive quarters. Table VI contains the same for temperature. In Table VIII are the results for the sea-water temperatures in a number of 10° squares, the data being those kindly provided by the Dutch Meteorological Office; the table also contains relations with the quantity of pack ice at the South Orkneys and with the number of icebergs reported in the South Pacific. Table IX deals in a similar manner with rainfall.

14. As a part of the mechanism which provides the persistence from the S.O. of J-A to that of D-F we notice in Table IV that the S-N pressures in the region represented by north-west India, Allahabad, Calcutta, Rangoon, Manila, Batavia, and Darwin have coefficients averag-

TABLE IV—S.O. WITH PRESSURE OF VARIOUS SEASONS

Station	No. of years	S.O., J-A					S O., D-F				
		Before S.O.		Con-temp.	After S.O.		Before S.O.		Con-temp.	After S.O.	
		D-F	M-M	J-A	S-N	D-F	J-A	S-N	D-F	M-M	J-A
Allahabad . .	43	−44	−18	10	−70	−54	18	−78	−64	−38	16
Batavia . .	50	−40	−54	−80	−84	−62	−78	−78	−74	−52	−10
Cairo. . .	48	−20	−12	−76	− 8	−32	−52	10	−24	−40	−18
Calcutta . .	43	−48	−30	50	−78	−58	56	−78	−64	−52	2
Cape Town .	52	−26	12	−18	4	−64	−12	8	−66	−16	−20
Charleston .	52	4	−14	− 2	12	36	−14	8	52	20	8
Darwin . .	48	−12	−40	−68	−68	−68	−72	−76	−90	−50	−14
Honolulu . .	45	26	36	76	26	−28	62	38	−26	−14	20
Manila . .	42	−34	−38	66	−66	−58	56	−76	−86	−74	−10
NW. India .	50	−34	−16	−28	−64	−52	− 6	−78	−68	−54	− 4
Rangoon . .	42	−50	−40	16	−78	−56	28	−62	−60	−56	14
Rio de Janeiro .	47	− 6	6	46	16	4	30	8	−14	−14	6
Samoa . .	39	34	58	62	36	68	56	32	84	50	24
Santiago . .	52	28	48	84	30	22	70	22	30	32	6
South Orkneys .	21	6	− 4	6	8	−44	10	16	−48	44	48

TABLE V—S.O. OF J-A WITH PRESSURE OF M-M BEFORE

Station	No. of years	Press. M-M	Station	No. of years	Press. M-M
Aden	40	−20	Iceland	56	4
Archangel . .	30	16	Mauritius . . .	51	−28
Azores . . .	53	−14	Sitka	24	−16
Beirut . . .	46	−30	San Francisco . .	50	36
Bermuda . . .	46	−10	Tokyo	43	−18
Central Siberia . .	55	18	Vardo	47	6
Hongkong . .	37	− 4	Wellington . .	49	26
Ivigtut . . .	42	24	Zanzibar . . .	34	−20

ing −·74 with the previous J-A of the S.O., and have coefficients averaging −·75 with the subsequent D-F of the S.O.; and the product of ·74 and ·75, *i.e.* ·55, gives a rough measure of the coefficiency of such a factor.

In Table VI the station which promises most for the persistence of the S.O. is Malden Island, whose 26 years of S-N temperature have a c.c. of −·98 with the J-A of the S.O. and −·82 with the previous D-F. But −·98 is impossibly large, and comparison with the corresponding numbers of −·56 and ·64 for the adjacent Fanning Islands suggests that the observations have not been always accurately recorded.[6] No series are included in this table covering less than 18 years, and the stations fall naturally into three groups: a northerly one with negative signs, a southerly one

---

[6] A Melbourne report of 1927 says "from time to time the caretakers have been without education, sometimes Kanakas, and it is quite possible that the records will be very imperfect."

TABLE VI—RELATIONS OF TEMPERATURE WITH THE S.O.

(All seasons of temperature)

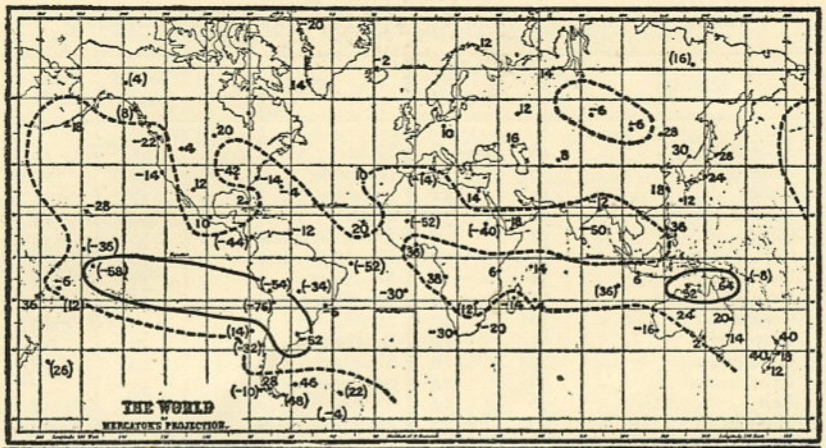
Station	n	S.O., J-A					S.O., D-F				
		Before S.O.		Con-temp.	After S.O.		Before S.O.		Con-temp.	After S.O.	
		D-F	M-M	J-A	S-N	D-F	J-A	S-N	D-F	M-M	J-A
Alofi, Niue I.	21	-42	-26	22	0	-44	12	6	-50	8	38
Año Nuevo	22	8	34	52	60	-2	48	74	8	20	18
Arequipa	19	20	-4	-56	-60	-56	-54	-64	-82	-60	-24
Auckland	52	22	28	48	52	46	40	66	56	40	26
Batavia	52	30	4	0	-52	-68	6	-48	-62	-54	-34
Brisbane	44	0	-2	12	-18	-46	20	-8	-60	-62	-40
Cape Pembroke	31	-22	8	42	26	14	46	36	16	28	18
Chatham I.	20	-16	4	44	24	54	26	34	50	12	30
Cocos, Keeling I.	20	18	-18	28	34	-66	36	52	-54	-38	-44
Colon	18	-8	-16	-48	-28	-76	-44	-20	-68	-62	-38
Darwin	49	26	22	46	36	-44	52	46	-52	-54	-14
Dunedin	51	12	32	6	38	46	12	56	58	46	2
Evangelists I.	27	-22	0	-8	28	-52	-10	34	-52	-12	-12
Fanning I.	19	-38	-52	-42	-56	-52	-36	-64	-62	-48	-60
Fernando Noronha	18	-14	4	-62	-2	-54	-52	-8	-60	-72	-64
Honolulu	44	-6	18	-32	-22	0	-28	-14	20	8	-42
Iquique	26	8	-34	-74	-52	-42	-76	-86	-46	-32	-8
Juan Fernandez	18	-44	-26	-4	-12	-22	14	6	-16	-2	2
Loanda	31	38	22	44	26	-24	38	42	-18	-4	-2
Madagascar	35	-14	-4	-22	-56	-60	-14	-40	-50	-48	-38
Madras	49	16	24	-72	-24	-46	-50	-12	-34	-22	-24
Malden I.	26	-40	-48	-82	-98	-76	-58	-82	-72	-68	-66
Manila	36	36	0	28	-14	-36	36	-4	-30	-76	-52
Mauritius	35	16	-14	14	-52	-58	4	-50	-68	-68	-52
Mocha W.	25	-24	-14	-44	12	-54	-32	4	-74	-34	-6
North America	48	12	8	14	-6	-50	-6	0	-28	-12	18
Punta Arenas	34	-24	-14	42	48	-32	28	36	-38	-12	28
Samoa	41	-38	-38	-6	-48	-74	-6	-42	-76	-66	-34
Santo Domingo, Philippines	20	22	-14	16	14	-52	32	42	-40	-24	-50
South Georgia	22	-12	6	34	14	26	22	10	36	42	2
South Orkneys	22	-14	-8	22	-12	28	-4	-2	24	36	18
Suva, Fiji	47	8	16	44	38	6	36	36	10	24	20
Tulagi	18	-12	-46	-40	-34	-60	-8	-14	-50	-64	-48
Walvis Bay	11	22	22	-12	-34	6	24	-32	-20	32	-42
Yap	18	-38	-4	14	-2	40	18	-6	22	-32	-32

with positive signs, and an intermediate group with positive signs at one time of year and negative at another.

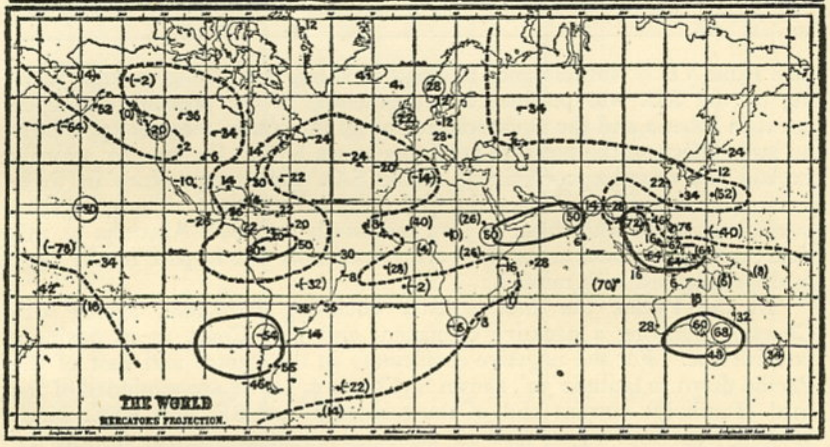
The temperature relationships which provide the persistence of the S.O. are less close than those of pressure; and the same remark applies to the factors which tend to produce the J-A variations of the S.O.

15. In Table VIII some of the series contain only 12 years and cannot give more than rough approximations. In the Atlantic the biggest relationships are with the last two squares, and the differences between the coefficients of these adjacent areas show that longer series are desirable. In the Indian Ocean, however, the first four squares, to the south of Ceylon, are in fair agreement and show that the S.O. in the relatively inactive D-F period produces a marked negative effect on sea temperatures lasting for half a year, just as it does on air temperature at Mauritius and Manila

17



18



19

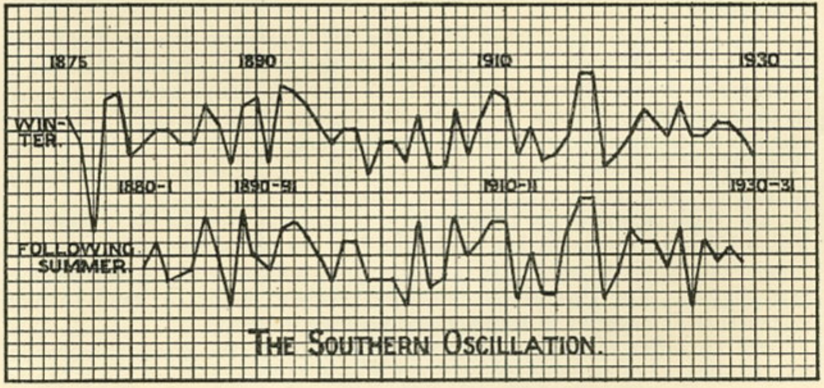


CHART 17.—S.O. of D-F with previous temperature of J-A.
CHART 18.—S.O. of D-F with previous rainfall of J-A.
CHART 19.—Variations of the S.O.

TABLE VII—S.O. OF J-A WITH TEMPERATURE OF M-M BEFORE

Station	No. of years	Temp. M-M	Station	No. of years	Temp. M-M
Alice Springs	46	- 6	Naha	38	-26
Archangel	30	12	Nashville	49	10
Berlin	51	12	Nemuro	37	-14
Buenos Aires	50	-32	Perth	40	-14
Cairo	52	4	Ponta Delgada	30	-34
Cape Town	54	-10	Rio de Janeiro	50	- 4
Durban	36	- 8	St. Helena	33	-12
Dutch Harbour	30	-42	San Francisco	50	2
Godthaab	50	20	Santiago	50	-30
Hatteras	55	18	Seychelles	30	14
Honolulu	45	18	Siberia	40	-12
Kristiansund	46	22	Stornoway	55	2
Leh	38	32	Tokyo	44	2
Madeira	40	-32	Zanzibar	29	-22
Mexico	30	8			

(see Table VI). But reference to Chart 11 shows that, though a strengthening of the S.O. will produce a strengthening of the pressure difference between Siberia and the equatorial region to the south, there is apparently no large effect on the pressure gradients at sea level. So we can scarcely explain the negative coefficients of the S.O. with temperature in these squares by a positive relationship with the wind strength. These negative coefficients agree with those in Java and north and east Australia at this time; and in the land areas they are presumably due in part to the large positive relations with rainfall.

In the Pacific the first square, enclosing Honolulu, agrees with Chart 9 in having a negative coefficient and with Chart 12 in having a positive one. For the negative coefficients in the centre and east of the Pacific down to latitude 30°, shown in Charts 9, 12, we are reminded of the cold Humboldt current and of the relatively cool SE. and ESE. winds blowing from over it, so that an increased circulation might furnish the explanation.

16. The concluding lines of Table VIII confirm the previous impression that, although a strengthening of the S.O. produces in winter a decrease in the number of icebergs at the South Orkneys and an increase in the number of icebergs in the South Pacific, these effects are not big enough to justify a theory that the physical origin of the S.O. lies in the Antarctic. The association of large numbers of icebergs with abundant rainfall in India had previously been noticed.[7]

17. With regard to the relationships of rainfall with the S.O. given in Table IX it will be seen that while the J-A season of the S.O. exercises much control, six months later the subsequent influence of the D-F season is negligible. For Hawaii the rainfall coefficient, being opposed to that of pressure, is negative in summer and positive in winter.

18. In order to form a concrete impression of the contrast between the conditions of persistence of the J-A and D-F seasons of the S.O. we may compare Charts 16, 17, 18, the conditions of pressure, temperature, and rainfall of J-A that are favourable for the S.O. a half-year later with Charts 8, 9, 10, which express the pressure, temperature, and rainfall

---

[7] *Ind. Met. Mem., Calcutta*, **21**, part 8, 1914.

TABLE VIII—S.O. WITH SEA-WATER TEMPERATURE AND AMOUNTS OF ICE

Area	No. of years	S.O., J-A					S.O., D-F				
		Before S.O.		Con-temp.	After S.O.		Before S.O.		Con-temp.	After S.O.	
		D-F	M-M	J-A	S-N	D-F	J-A	S-N	D-F	M-M	J-A
Atlantic Ocean											
15°-25° N. 35°-45° W.	27	32	24	0	-8	-2	10	0	-18	-44	-36
5°-15° N. 35°-45° W.	12	24	-4	6	-20	8	2	-2	10	-18	14
15°-25° N. 25°-35° W.	26	16	8	-2	-14	4	6	-6	-14	-38	-24
5°-15° N. 25°-35° W.	27	24	20	18	-6	2	18	-6	-8	-38	-28
0°-10° S. 0°-10° W.	12	24	6	38	16	-14	28	8	-32	-10	34
10°-20° S. 0°-10° W.	12-16	14	48	4	4	-2	-22	-32	-16	64	28
10°-20° S. 0°-10° E.	12	40	-4	0	-44	6	-8	-52	8	32	-2
Indian Ocean											
0°-10° N. 70°-80° E.	30	8	2	14	-60	-38	12	-68	-48	-76	-74
0°-10° S. 70°-80° E.	10-29	4	-4	-24	-32	-20	-22	-42	-38	-58	-62
0°-10° N. 80°-90° E.	30	14	-6	20	-32	-58	22	-42	-74	-92	-68
0°-10° S. 80°-90° E.	15-28	2	-16	-8	-40	-42	-12	-34	-30	-58	-62
10°-20° S. 90°-100° E.	12	-4	-18	42	8	-2	42	38	2	-36	40
Pacific Ocean											
20°-30° N. 150°-160° W.	12	6	2	-14	14	58	12	14	54	-46	-54
20°-30° N. 140°-150° W.	12	0	6	4	22	38	26	32	44	-34	-42
Pack-ice											
South Orkneys	13-24	-2	...	-32	...	-16	2	...	-8	...	-34
Icebergs											
South Pacific	25	28	...	18	...	26	4	...	38	...	8

conditions of the actual S.O. of J-A. It is the close similarity of these maps that makes the persistence. But if we look through Tables IV, VI, VIII, IX for all the coefficients numerically exceeding ·40 giving a

TABLE IX—S.O. WITH RAINFALL OF VARIOUS SEASONS

Region and season	No. of years	S.O., J-A					S.O., D-F				
		Before S.O.		Con-temp. J-A	After S.O.		Before S.O.		Con-temp. D-F	After S.O.	
		D-F	M-M		S-N	D-F	J-A	S-N		M-M	J-A
India, Penin. + NW., June-Sept.	55	...	...	76	...	...	50	...	...	...	− 2
Nile, July-Oct.	55	...	...	72	...	...	50	...	...	...	26
Chile, April-Oct.	55	...	...	− 60	...	...	− 54	...	...	...	− 18
NE. Australia, Oct.-April	56	2	...	...	...	64	...	...	82	...	...
S. America, Oct.-April	49	− 16	...	...	...	− 72	...	...	− 62	...	...
Java, Oct.-Feb.	51	− 12	...	...	...	46	...	...	62	...	...
Hawaii, D-F and J-A	45	12	...	− 26	...	54	− 30	...	62	...	2
S. Africa, Oct.-April	51	8	...	...	...	44	...	...	56	...	...
S. Rhodesia, Oct.-April	31	− 46	...	...	...	34	...	...	28	...	...
Tasmania, May-Sept.	47	...	...	42	...	...	48	...	...	...	20
Ganges level, May	47	...	− 50	...	...	...	...	...	...	− 4	...
Himalaya snow accumulation, May	44	...	− 46	...	...	...	...	...	...	− 30	...

half-yearly foreshadowing of the S.O. of J-A, ignoring those based on fewer than 30 years of data, we only find the pressures of India (Calcutta, − ·48; Allahabad, − ·44; Rangoon, − ·50) and the rainfall of Southern Rhodesia (− ·46). For the season M-M immediately preceding the S.O. some additional relationships with pressure and temperature are given in Tables V and VII. The corresponding factors exceeding ·40 are the pressures of Batavia (− ·54), Samoa (+ ·58), Santiago (+ ·48), the temperature at Dutch Harbour (− ·42), and in May the Himalayan snowfall (− ·46) and the height of the Ganges (− ·50).

It follows that if there are a number of areas whose rainfall is dependent on the S.O. it is in general easier to foreshadow rainfall of D-F than rainfall of J-A.

METHOD OF COMPUTING

19. The method of computing here adopted is that described[8] in the *Quarterly Journal*, **52**, 1926, pp. 74-5. In order to facilitate the work of others the reduced data of the stations used as representatives of the different oscillations are given in the Appendix.

SECULAR CHANGE

20. A user of statistical methods will be fortunate if he does not come upon two series whose shortlived variations are obviously similar in character but which have a negative correlation coefficient; and the explanation lies in the fact that during the period covered by the series there is a marked general trend, or continuous slow variation, in opposite directions. Experience shows that, on the one hand the magnitude of

---

[8] The departures from normal of the data in successive seasons are expressed as integers, the units being such that the standard deviation is $\sqrt{20}$, the departures thus ranging from about − 12 to + 12. Then, after practice, the correlation coefficient between any two of the series extending over about 50 years can be worked out in under three-quarters of a minute.

such trends is occasionally considerable, and on the other that there often is little cause for believing in their reality; either the bed of a river whose flood levels are recorded has been silting up, or the bulb of a thermometer has altered gradually in volume, or a raingauge has been screened to an increasing extent by trees, or a barometer has undergone a series of shifts to places ever higher or lower. Now, if the secular change thus produced is artificial its effect should, if possible, be eliminated; and even if it is real it is of little interest in the present investigation. Obviously the variations of such a factor as temperature are made up of surges of very different lengths; there are those due to the passage of cyclones or weather phases of several days' duration, those due to seasonal abnormality, and those due to real or apparent secular change. Now the simultaneous readings of thermometers or other meteorological instruments at two places may respond in the same or in opposite manners to disturbances of these different durations; and we must separate out the corresponding relationships. We are perfectly justified in getting rid of disturbances of a few days by considering a series S made up of quarterly means; and if we have 40 years' data of these and were interested in the long-period disturbances of the winter season we might form a series S' by smoothing over, say, 25 winters and so consisting of 15 terms. The series got by subtracting S' from S would be practically free from the slow changes and would be suitable for studying such surges as those of the S.O.; but as it would contain only 15 terms it would be unsuited for determining correlation coefficients. Hence we adopt the theoretically less perfect plan of choosing for S' the straight line of best fit and so retaining all the 40 terms; the slope of S' is got by working out the coefficient of S with the lapse of time, and the details of the process may be found in a paper by Dr. Brooks.[9]

Corrections have been applied to all series used in the formulæ for the three oscillations whose coefficients with time were greater than ·1; for smaller coefficients the changes would be insignificant. But the importance of the corrections may be gathered from the fact that from June to August the coefficient of Samoa temperature with the S.O. was − ·54 before secular change was eliminated, and afterwards − ·06.

I would gratefully acknowledge the never-failing helpfulness of Dr. C. E. P. Brooks with regard to sources of data.

SUMMARY

In order to form more definite ideas regarding the oscillations named the North Atlantic, the North Pacific, and the Southern series of figures have been derived to express the variations of each, and from these have been obtained their relations with pressure, temperature, and rainfall over wide regions as well as the relations of the three oscillations with each other and with sunspots.

The southern oscillation in the southern winter is found to be extremely persistent, and its departure has a c.c. of ·84 with that of the following summer, thus providing a basis for foreshadowing seasonal conditions. The effects of Antarctic conditions and of ocean temperatures are considered, but a satisfactory physical basis for the oscillations has still to be found.

---

[9] The secular variation of climate, *Geog. Rev., New York, N.Y.*, **11**, 1921, p. 120.

TABLE X—REGIONS AND THE STATIONS INCLUDED IN THEM

Pressure

Central Siberia.—Eniseisk and Irkutsk.

NW. India.—Lahore and Karachi.

Temperature

North America.—St. Louis, St. Paul, and Winnipeg.

New Zealand.—Wellington and Dunedin.

Siberia.—Surgut, Irkutsk, and Tomsk.

SW. Canada.—Calgary, Edmonton, Prince Albert, Qu' Appelle, and Winnipeg.

Rainfall

EUROPE

British Isles: see *British Rainfall.*

Iceland.—Berufjord, Grimsey, Stykkisholm, and Vestmanno.

Norway.—See *Geofys. Publ.*, **1**, No. 3, 1919.

ASIA

Burma: see *Ind. Met. Mem.* **23**, part 2, 1922.

India, W.—This stands for Peninsula + NW. India: see reference for Burma.

India, NW.: see *Ind. Met. Mem.* **25**, 1928, p. 108.

Java: see publications of the Batavia Observatory.

Siam.—This includes the whole country except the narrow strip along the Malay Peninsula. See *Ind. Met. Dept. Sci. Notes*, **4**, 1931, p. 69.

AFRICA

Cape Province.—Cape Town, Port Elizabeth, Worcester, Piquetberg.

South Africa.—Given in World Weather IV, *Mem. R. Meteor. Soc.*, No. 24, 1930, p. 92.

Southern Rhodesia: see annual meteorological reports, Salisbury.

AMERICA

Barbados: see reports on the Department of Agriculture, 1924–25, p. 14, and report for the period 1898–1907, p. 35.

British Columbia.—Victoria and Barkerville.

Chile.—La Serena, Valparaiso, Santiago, Concepcion, Mocha W., Valdivia, Punta Galera, Ancud, Puerto Montt.

Pacific States: see Monthly Weather Review, 1921, p. 213.

South America, SE.—Rio de Janeiro, Alto da Serra, Curityba (Brazil); Mision Inglesa, Villa Rica and Asuncion (Paraguay); Montevideo (Uruguay); Salta, Tucuman, Posadas, Corrientes, Catamarca, Goya, Concordia, Cordoba, San Juan, Mendoza, Buenos Aires, Ajo-General Lavalle, General Acha, Mar del Plata, Bahia Blanca (Argentina).

AUSTRALASIA

Australia, NE.—Given in World Weather IV, p. 92.

New Zealand.—Gisborne, Riversdale (Inglewood), Gwavas (Tikokino), Masterton, Pakawau, Nelson, Bealey, Balclutha, Nightcaps, Rotorua, Wellington, Hokitika, Auckland, Christchurch, Dunedin.

South Australia.—Blinman, Streaky Bay, Cape Borda, Wallaroo, Robe, Bordertown, Mt. Gambier, Port Lincoln, Georgetown, Adelaide.

Tasmania.—Deloraine, Glenora, Goulds Country, Hobart, Launceston, Great Lake, Int Lyell, Oatlands, Scottsdale, South Bruni, Stanley, Swansea, and Waratah.

Victoria, N.—Swan Hill, Echuca, Yarrawonga, Warracknabeal, Charlton, Bendigo, Mooroopna, Dookie, Horsham, St. Arnaud.

PACIFIC ISLANDS

Hawaii.—Grove Farm, Kilauea, Koloa, Molokoa and Honolulu (Kauai); Hakalau, Honokua, Kapapala Ranch, Kapoho, Kohala Mission, Kukaian Mill and Pepeekeo (Hawaii).

Samoa.—Apia and Pago-Pago.

TABLE XI—SOURCES OF DATA

General. Pressure, Temperature, and Rain

1. *Réseau Mondial*, 1910–24. London, H.M. Stationery Office.
2. World Weather Records, *Washington, D.C., Smithsonian Misc. Collection*, **79**, 1927. Corrections, 1929.
3. F. M. Exner: *Wien, Sitz Ber. Ak. Wiss.*, Abt. IIa, **133**, 1924, p. 307.

Sea-water Temperature

Publications of the Meteorological Office, De Bilt.

Precipitation

(When information is contained in one of the above sources the fact is not further indicated below.)

EUROPE

4. British Isles: *British Rainfall, London*, 1924, and following years; MSS. of Dr. J. Glasspoole.
5. Norway: B. J. Birkeland, *Geofys. Publ. Oslo*, **1**, No. 3, Oslo, 1919; also MSS.

ASIA

6. Burma: *Calcutta Ind. Met. Mem.* **23**, part 2, 1922; also **25**, 1928, pp. 15-108.
7. India: *Calcutta Ind. Met. Mem.* **23**, part 2, 1922; also **25**, 1928, pp. 15-108.
8. Ganges: *Ind. Met. Dept. Sci. Notes*, **1**, 1929, p. 65.
9. Himalayan snow: *Ind. Met. Dept. Sci. Notes*, **1**, 1929, p. 65.

AFRICA

10. Nile floods: MSS. of Physical Dept., Cairo.

AUSTRALASIA

11. South Australia: MSS. of the Commonwealth Meteorologist.
12. New Zealand: MSS. of Dr. Kidson.

AMERICA

13. United States: Reports of the Chief of the Weather Bureau, Washington; Climatological data by sections; *Monthly Weather Review.*
14. Porto Rico: MSS. of the Weather Bureau, San Juan, Porto Rico.
15. Chile: Publicacion No. 20 Instituto Meteorologico de Chile, *Recopilacion ae sumas de agua caida en Chile*, 1849–1915, Santiago, 1917; *Anuario Meteorologico de Chile*, Santiago.
16. Argentina: MSS. from Buenos Aires.
17. Uruguay: MSS. from Montevideo.
18. Brazil: MSS. from Rio de Janeiro.

POLYNESIA

19. Hawaii: Climate of the United States by sections, 2nd edn., Washington, 1926; MSS. of Dr. Marvin.
20. Samoa: Reports of the Apia Observatory.
21. Ocean Island: *Q.J.R. Meteor. Soc.*, **44**, 1918, p. 50.
22. Christmas Island (Indian Ocean): MSS. of Meteorological Office, Edinburgh.

ARCTIC

23. *Isforholden i de arktika have, Copenhagen*, 1918 and following years.

ANTARCTIC

24. Information about icebergs, from MSS. of the London Meteorological Office and from the *Marine Observer* (H.M. Stationery Office). About pack-ice, from *Ind. Met. Mem.* **24**, 1924, p. 326, and MSS. from Dr. Kemp.

LIST OF TABLES

LIST OF CHARTS

APPENDIX

For use by other investigators there are given below the working values of the departures of the three oscillations and of the centres used in tabulating them, *i.e.* the series of pressure, temperature, or rainfall which are most representative of the oscillations. In order to facilitate future extension of the series there will be found in the final "Reference Table" for each of the series: (*a*) the normal value; (*b*) the "unit," *i.e.* the numerical value in ordinary units of the mean pressure, the mean temperature, or the total rainfall of the period which corresponds to unity in the working departure tables; and (*c*) the annual secular change, *i.e.* the value which has to be subtracted from the data of any year for each year which has lapsed since the middle year of the series. For example, the published values of Stornoway temperature for December 1930 and January and February 1931 are 42°·9, 39°·9, and 39°·4 F., of which the mean is 40°·73; the annual secular change is given as +·041, so that the increase produced by this since 1903, the middle year of the series 1875–1930, is 28 × ·041 or 1·15. Thus the corrected value for the winter in question will be 40·73 − 1·15 or 39·6; also the normal is 39·4, so that the departure is 0·2, and as the value of a working unit is 0·33 the nearest integer in the departure in the table of working units is +1.

N.A.O. DATA, D-F

Year of January	Positive Group						Negative group			N.A.O.
	Press.		Temp.				Press.		Temp.	
	Bermuda	Vienna	Bodö	Stornoway	Hatteras	Washington	Iceland	Ivigtut	Godthaab	
1875	6	-5	-7	-5	-1	-3	6	...	6	-5
1876	5	2	1	1	7	4	-1	...	2	2
1877	-3	-5	-7	0	-4	-5	-2	...	2	-3
1878	-3	4	5	5	1	5	1	...	4	2
1879	-4	-9	-5	-10	-5	-4	7	0	8	-8
1880	8	8	5	6	11	9	-1	-3	-4	7
1881	-7	-3	-11	-10	-7	-8	12	9	8	-11
1882	7	11	4	10	5	5	-4	-6	-4	9
1883	7	1	1	1	-2	-2	-3	-6	-3	3
1884	3	3	5	4	3	1	-3	-1	-10	5
1885	-4	-1	1	0	0	-4	-1	0	...	-1
1886	-5	0	-3	-3	-4	-3	4	4	-1	-4
1887	...	2	5	0	1	-1	-3	-5	-4	4
1888	0	-2	-4	-2	0	-1	7	7	3	-4
1889	-1	0	0	5	-2	1	1	0	0	1
1890	7	7	8	7	11	13	-4	-8	-3	9
1891	2	7	9	4	3	3	1	-3	-2	5
1892	-2	-3	-2	-4	1	3	3	7	2	-4
1893	-3	-3	-9	-4	-6	-6	4	0	6	-6
1894	6	4	5	1	4	3	-8	-8	-5	7
1895	-3	-7	-2	-7	-4	-5	8	7	7	-8
1896	-6	4	6	6	-2	1	0	2	-2	2
1897	-4	-1	-2	-3	-3	-1	0	0	-2	-2
1898	-2	5	3	3	1	2	-4	0	-6	4
1899	4	1	-6	1	-2	-4	-1	-4	-3	1
1900	-2	-6	-8	-3	-2	0	4	8	2	-6
1901	-10	2	0	2	-4	-2	2	0	5	-2
1902	-6	-4	-3	-5	-7	-4	5	7	4	-7
1903	2	5	6	4	5	0	-6	-8	-1	6
1904	0	-4	1	-2	-8	-8	-3	-4	2	-1
1905	3	4	-1	4	-8	-9	2	-1	1	0
1906	3	1	3	1	1	3	-5	-2	-5	4
1907	7	0	-1	-1	0	0	0	1	-2	1
1908	4	0	-1	3	0	-1	-1	0	-2	1
1909	5	2	4	5	7	5	-2	-1	4	4
1910	4	-6	1	-6	-1	-2	-5	2	-5	-1
1911	6	1	2	6	0	0	-1	-2	-3	3
1912	-2	-3	-2	2	-2	-4	-1	-1	2	-1
1913	8	4	1	4	8	7	-5	-9	2	6
1914	-5	0	1	4	1	2	-2	-4	-4	2
1915	0	-9	-3	-4	2	1	-3	2	-3	-2
1916	4	-3	-4	0	1	2	-1	-1	4	-1
1917	-2	-6	-4	-6	0	-1	10	3	11	-7
1918	-5	3	-3	-2	-7	-8	6	8	0	-5
1919	-5	-5	-1	-2	2	5	4	...	1	-3
1920	0	1	0	...	-3	-5	-4	-2	0	1
1921	-1	2	3	7	3	4	0	1	-3	3
1922	1	-1	-1	3	3	1	-7	-3	-6	3
1923	3	-3	1	6	2	0	-3	-2	3	2
1924	1	-3	0	1	2	4	3	2	5	-1
1925	6	6	10	5	4	3	-5	-2	-5	7
1926	-5	-2	-2	0	1	1	2	-2	7	-2
1927	1	1	0	3	4	2	3	...	3	0
1928	2	3	2	-4	2	3	0	...	2	0
1929	3	4	1	-5	2	2	8	...	...	-1
1930	...	1	10	-2	5	5	-3	...	...	5

N.P.O. DATA, D-F

Year	Positive group				Negative group				N.P.O.
	Press.	Temp.			Press.			Temp.	
	Honolulu	Calgary	Pr. Albert	Qu' Appelle	Dawson	Nome	Sitka, Fort Simpson *or* Juneau	Dutch Harbour	
1882	...	...	...	...	...	...	-7	4	2
1883	...	...	...	...	...	...	4	-2	-1
1884	-7	1	...	-4	...	...	5	3	-5
1885	-5	-3	-3	-8	...	...	3	2	-5
1886	3	4	-3	2	...	...	-1	-1	2
1887	1	-8	-3	-8	...	...	-1	...	-2
1888	-9	-4	0	-4	...	...	...	...	-8
1889	7	7	8	9	...	...	...	...	9
1890	-3	-8	-8	-5	...	...	...	...	-6
1891	-4	4	4	6	...	...	...	...	1
1892	2	5	2	3	...	...	...	...	3
1893	-4	-3	-4	-4	...	...	6	...	-6
1894	5	0	-4	-3	...	...	0	...	1
1895	1	-2	1	1	...	...	5	...	-2
1896	-1	2	2	4	...	...	-8	...	4
1897	8	4	3	4	...	...	-5	...	7
1898	0	3	3	3	...	...	-1	...	2
1899	0	-2	-1	-2	...	...	1	...	-1
1900	0	3	1	2	...	...	-5	...	3
1901	-5	5	3	3	...	...	4	...	-2
1902	1	6	9	7	-2	...	-2	...	4
1903	3	3	2	1	1	...	0	...	1
1904	0	-1	-1	-2	4	...	3	...	-3
1905	-1	0	1	2	1	...	6	...	-2
1906	3	6	7	6	-3	...	-4	-5	5
1907	-5	-7	-5	-3	-3	6	7	2	-5
1908	7	8	9	8	-9	-8	-1	-5	8
1909	8	-4	-4	-1	3	0	-3	3	1
1910	3	-1	1	-1	1	1	2	-1	0
1911	-3	-4	-4	-4	5	1	1	3	-4
1912	2	4	-1	-1	-1	-4	-1	0	2
1913	3	2	-2	-1	1	-1	2	1	0
1914	4	4	3	4	-5	-5	-6	0	5
1915	1	2	2	3	-3	-4	-1	0	2
1916	-7	-5	-3	-4	5	7	2	0	-5
1917	-1	-4	-7	-8	3	5	3	-2	-3
1918	-6	-5	-8	-7	4	6	-2	2	-5
1919	10	6	7	4	-9	-6	-6	-10	10
1920	-5	2	1	-1	5	5	10	2	-5
1921	1	3	6	6	-7	-3	-9	-11	8
1922	1	-3	-1	-2	3	1	5	2	-2
1923	-2	-2	-2	-4	5	4	4	4	-5
1924	3	3	4	5	-4	-1	-5	-7	5
1925	0	-5	-6	-4	5	5	-1	1	-3
1926	-2	11	10	8	-7	-6	-6	-1	6
1927	1	-2	-2	-3	-3	-3	-3	6	0
1928	2	0	-1	-1	3	-4	4	6	-2
1929	-2	-3	-5	-5	-1	...	5	7	-4
1930	-10	-6	-8	-3	...	...	3	...	-8

S.O. DATA, J-A

Year	Positive group					Negative group					S.O., J-A
	Press.			Rain		Press.			Temp.	Rain	
	Santiago	Honolulu	Manila	India	Nile	Batavia	Darwin	Cairo	Madras	Chile	
1875	2	...	...	4	1	0	...	-4	4	...	2
1876	-2	...	...	-3	1	1	...	1	3	-2	-2
1877	-12	...	...	-12	-10	19	...	11	10	2	-16
1878	4	...	...	4	5	-1	...	-9	0	2	5
1879	2	...	...	1	3	-5	...	-10	-6	0	6
1880	-6	...	...	-3	-1	2	...	1	-1	8	-4
1881	0	...	...	1	-3	3	...	1	4	2	-2
1882	3	...	...	3	-5	-3	1	5	1	-2	0
1883	2	5	...	-1	1	3	-1	5	-2	-1	0
1884	-3	5	...	4	-4	3	1	7	4	-2	-2
1885	-3	-5	...	-2	0	4	5	-1	-1	-1	-2
1886	2	10	...	-1	-2	-6	-5	2	-10	-5	4
1887	-7	-5	5	3	6	1	1	-5	-5	3	1
1888	-8	-3	-6	-3	-7	5	5	-2	-2	6	-5
1889	4	1	7	2	0	-2	-3	-4	-4	-3	4
1890	1	...	6	1	5	0	-4	-7	-9	-2	5
1891	-3	-1	-4	-1	1	7	7	2	10	3	-5
1892	5	4	4	7	7	-4	-2	-4	-8	-5	7
1893	7	9	5	4	1	-5	-2	-1	-6	-4	6
1894	3	9	2	6	9	0	1	-4	1	-3	4
1895	-1	-3	-2	-1	6	-2	0	0	-3	-2	1
1896	-3	2	-4	-1	4	5	7	2	3	-1	-2
1897	3	0	4	1	-1	2	2	0	3	-2	0
1898	0	-1	-4	-1	4	-3	1	-1	1	2	0
1899	-7	-1	-3	-11	-7	2	2	4	5	11	-7
1900	-5	-5	-2	3	0	-3	-6	2	6	7	-2
1901	-2	-4	0	-4	-1	-1	-1	-1	2	3	-2
1902	-2	-6	-5	-3	-7	2	4	2	1	5	-5
1903	2	0	2	2	0	-3	-3	1	-5	-3	2
1904	-7	-2	-7	-5	-3	2	2	5	1	11	-6
1905	-7	-2	-1	-7	-6	4	3	3	7	4	-6
1906	6	-1	2	2	0	-3	-4	-1	-3	0	3
1907	-3	-7	-8	-3	-7	-1	-4	2	3	-3	-4
1908	3	5	2	7	4	1	-1	3	4	-5	2
1909	6	7	6	2	4	-3	-6	-1	-6	-8	6
1910	-1	4	5	3	0	-9	-7	-4	-6	-4	5
1911	2	-3	-6	-6	-2	4	5	5	5	-7	-4
1912	3	-1	-1	0	-4	-1	-3	-2	4	-4	0
1913	0	-1	2	-3	-12	3	3	9	4	2	-5
1914	-7	-5	-1	7	-1	6	8	3	1	4	-4
1915	1	-4	3	-4	-6	-3	-4	-1	-1	2	-1
1916	10	7	2	6	7	-7	-9	-9	-4	-6	9
1917	5	9	2	11	6	-6	-11	-4	-8	-6	9
1918	-4	-8	0	-9	-4	7	3	7	2	0	-6
1919	-2	-1	-6	2	-1	3	3	9	-1	6	-4
1920	2	-2	-8	-7	0	-2	-9	2	3	-1	-1
1921	8	0	-1	1	-1	-3	-5	-4	-1	0	3
1922	0	1	-4	1	2	-4	-1	-3	1	1	1
1923	-3	1	-2	-1	3	1	4	3	0	-1	-1
1924	5	6	6	1	2	2	-1	-6	1	-7	4
1925	-3	-1	-1	-1	-3	3	2	-1	-3	-2	-1
1926	-4	-3	10	3	2	3	3	1	3	2	-1
1927	2	2	3	2	-1	2	1	-3	0	0	1
1928	2	1	...	-1	1	-2	3	-5	0	-2	1
1929	0	-1	...	-2	8	5	7	0	0	-3	-1
1930	-7	-5	...	...	...	2	5	-2	...	4	-4

S.O., D-F

Year of J-F	Positive group							Negative group					
	Press.		Temp.	Rain				Press.					Temp.
	Samoa	Charleston	N. Zealand	NE. Australia	Java	Hawaii	South Africa	Batavia	Cape	Darwin	Manila	N. W. India	Batavia
1882	...	6	-3	-1	-7	...	-5	-2	1	2	...	-1	4
1883	...	6	7	-2	-1	...	-5	-2	-3	-5	...	-2	-1
1884	...	-1	-8	-4	-2	...	-4	7	3	3	...	5	-4
1885	...	-6	-3	-3	-1	...	-9	5	0	2	...	5	-5
1886	...	-5	1	-4	-4	-3	1	0	-1	1	...	0	2
1887	...	5	8	6	4	2	2	-4	1	-7	-1	-6	-1
1888	...	0	-2	-1	0	7	-1	4	5	1	4	3	-5
1889	...	-3	2	-6	-7	-5	-2	7	4	9	4	3	8
1890	...	10	4	10	-2	5	5	-6	-3	-6	-6	-7	4
1891	-5	-4	-1	3	-1	2	8	3	-5	0	3	2	-2
1892	1	2	2	-7	-9	3	4	0	0	5	1	-2	3
1893	4	-5	-1	-1	3	2	1	-2	-7	-2	0	-1	-4
1894	5	7	2	7	-1	4	6	-1	-4	-3	1	1	-6
1895	4	0	6	3	2	-1	3	0	-3	0	1	0	-4
1896	1	-3	3	5	-2	0	-3	0	-2	0	4	-2	1
1897	0	3	4	-6	-5	-3	-2	2	3	6	5	2	10
1898	-1	1	-4	7	-3	3	0	-6	-1	-5	-4	-6	0
1899	5	3	1	2	6	-6	-1	-2	1	-2	-5	-4	-5
1900	-4	0	-5	-8	-1	-5	-4	2	2	5	2	-2	0
1901	-5	-4	-5	-1	-1	-1	1	4	-2	2	3	6	1
1902	-1	-10	-2	-10	1	-2	-1	4	3	1	1	6	-2
1903	-7	-2	-9	-1	-9	3	-7	6	8	6	8	7	7
1904	5	4	2	5	5	5	0	-4	-3	-6	-7	0	-6
1905	-5	4	-7	-3	6	-6	-4	5	11	4	5	7	0
1906	-4	0	-8	-4	-3	-6	-4	0	5	2	0	-4	9
1907	-2	8	4	0	5	7	10	-2	-7	-4	-1	-6	-3
1908	-1	-4	2	5	2	-3	-5	-2	5	-2	-2	-2	1
1909	2	-1	-5	-3	2	-2	8	-5	-2	-1	-5	1	2
1910	3	1	4	7	4	2	-1	-7	-3	-7	-6	-6	2
1911	2	7	-1	6	5	7	1	-1	-1	-6	-4	-2	-2
1912	-10	-6	-9	-4	4	-4	-2	2	1	4	4	0	2
1913	0	1	0	3	2	-1	-1	2	-3	1	3	4	3
1914	0	-6	2	0	-2	-3	-6	9	7	6	8	9	4
1915	-5	-4	-4	-6	-2	-3	-1	4	-3	7	4	6	5
1916	4	4	5	-2	5	4	-3	-2	0	-6	-11	-2	-2
1917	10	-4	7	6	7	4	2	-7	-9	-5	-6	-6	-6
1918	5	-2	4	8	9	5	4	-2	-3	-7	-4	-2	-14
1919	-7	-6	-5	-4	-5	-2	-4	6	5	5	6	6	3
1920	-7	-2	-3	-4	-3	-2	-1	2	0	0	2	2	-2
1921	7	-3	0	3	2	9	2	-6	-9	-5	-3	-6	-1
1922	3	1	0	3	-2	5	-4	-3	-3	-3	-1	-2	-3
1923	2	3	0	-1	-3	5	3	-4	2	-2	-3	-4	-2
1924	1	2	8	-1	-8	-1	-2	-1	0	3	2	1	3
1925	0	3	0	3	2	-6	10	-3	-4	-3	-7	-2	-4
1926	-7	-11	-1	-6	-8	-8	-5	6	5	7	8	5	2
1927	6	1	2	1	-4	-3	-4	-2	-4	2	0	-2	0
1928	-1	3	1	1	-3	5	1	0	3	6	1	0	4
1929	-2	-3	-2	3	-2	0	-3	-4	-2	-2	...	0	0
1930	...	7	-6	...	-8	2	...	2	0	2	...	-2	1

S.O., D-F DATA

Year of J-F	Negative group					S.O., D-F
	Temp.				Rain	
	Brisbane	Mauritius	Samoa	SW. Canada	S. America	
1882	...	...	...	...	3	-2
1883	...	...	...	...	2	2
1884	...	...	...	...	-4	-4
1885	...	...	...	-6	2	-3
1886	...	...	...	-1	0	-2
1887	-1	...	...	-8	-6	6
1888	-9	...	...	-4	-3	0
1889	3	...	...	8	9	-8
1890	-4	...	1	-7	-6	7
1891	-3	...	2	5	-5	0
1892	-1	...	-2	3	3	-2
1893	-3	...	-7	-4	-7	4
1894	-1	...	-4	-3	-10	5
1895	-5	2	-6	0	-2	3
1896	5	-7	-1	2	-5	0
1897	-3	3	3	3	1	-4
1898	-5	5	0	3	-2	2
1899	-3	2	-1	-2	3	2
1900	-2	8	6	2	1	-4
1901	3	1	5	4	-2	-4
1902	6	-5	6	7	-3	-4
1903	11	2	2	2	5	-8
1904	3	-6	-5	-2	3	5
1905	1	0	5	1	2	-5
1906	0	2	5	7	-2	-4
1907	-1	-8	0	-6	-5	6
1908	0	0	-2	8	-2	0
1909	-1	0	-4	-3	-1	2
1910	0	-2	-5	0	0	5
1911	-1	-3	0	-4	-5	5
1912	12	7	12	1	8	-7
1913	-2	-8	2	0	3	0
1914	3	3	6	3	5	-6
1915	2	2	3	2	7	-6
1916	0	-1	-4	-3	-3	4
1917	-5	-4	-8	-7	-7	9
1918	-8	-9	-10	-7	-5	9
1919	3	9	1	5	6	-7
1920	-5	1	7	0	4	-3
1921	-1	-5	1	4	6	4
1922	-1	2	-1	-2	-3	2
1923	5	-1	2	-3	-4	2
1924	8	4	-4	4	-1	-2
1925	-6	-1	-3	-5	-2	4
1926	5	4	1	8	1	-8
1927	-5	0	-4	-3	3	2
1928	-7	5	3	0	2	-1
1929	4	-3	-1	-6	-5	1
1930	-2	...	1	...	2	-1

REFERENCE TABLE

Centre	Normal	Unit	Annual secular change
Stykkisholm press. D-F	747·0 mm.†	0·99	...
Ivigtut ,, ,,	749·5 mm.	0·79	−·027
Vienna ,, ,,	745·2 mm.*	0·61	...
Bermuda ,, ,,	29·935 in.†	0·0114	+·00041
Stornoway temp. D-F	39·4° F.	0·33	+·041
Bodö ,, ,,	−1·7° C.	0·33	...
Godthaab ,, ,,	−9·2° C.	0·54	+·024
Washington ,, ,,	35·0° F.	0·69	...
Hatteras ,, ,,	46·4° F.	0·74	...
Juneau press. D-F	29·76 in.†	0·028	...
Nome ,, ,,	29·79 in.†	0·028	...
Dawson ,, ,,	28·82 in.†	0·023	...
Honolulu ,, ,,	29·97 in.†	0·0072	+·00071
Dutch Harbour temp. D-F	32·2° F.	0·42	...
Prince Albert ,, ,,	0·7° F.	1·02	+·171
Calgary ,, ,,	15·7° F.	1·02	+·109
Qu' Appelle ,, ,,	4·3° F.	1·04	+·153
Batavia press. J-A	757·0 mm.†	0·079	...
Santiago ,, ,,	718·4 mm.*†	0·139	+·0050
Cairo ,, ,,	747·1 mm.†	0·126	+·0046
Madras temp. J-A	88·0° F.	0·274	+·024
India W. rain J-S	27·6 in.	1·05	−·061
Honolulu press. J-A	29·98 in.†	0·0051	...
Darwin ,, ,,	29·91 in.	0·0051	+·00085
Manila ,, ,,	754·3 mm.†	0·098	+·0185
Chile rain A-O	112 cm.	4·8	...
Nile flood J-O	67 × 10⁹ c.m.	2·7	−0·49
Darwin press. D-F	29·73 in.	0·0068	+·00151
Manila ,, ,,	757·8 mm.†	0·173	...
Batavia ,, ,,	756·7 mm.†	0·124	...
Samoa ,, ,,	756·3 mm.	0·145	+·0153
Charleston ,, ,,	30·087 in.†	0·0071	...
NW. India ,, ,,	29·585 in.†	0·0047	...
Cape Town ,, ,,	29·94 in.†	0·0050	+·00024
SW. Canada temp. D-F	6·1° F.	1·0	+·129
Samoa ,, ,,	26·3° C.	0·132	+·0281
Mauritius ,, ,,	78·2° F.	0·153	−·015
Batavia ,, ,,	25·7° C.	0·090	+·0121
Brisbane ,, ,,	76·7° F.	0·253	...
New Zealand ,, ,,	59·5° F.	0·351	...
NE. Australia rain O-A	30·0 in.	1·57	−·0693
Java ,, O-F	143·7 cm.	22·5	−1·14
South Africa ,, O-A	14·0 in.	0·656	−·0314
Hawaii ,, D-F	21·0 in.	1·82	+·104
South America ,, O-A	74 cm.	1·77	...

* Not corrected to latitude 45°. † Not corrected to sea level.

PRINTED IN GREAT BRITAIN
BY R. & R. CLARK, LIMITED, EDINBURGH