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WORLD WEATHER, VI

THE DISCUSSION BY

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AND THE TABULATION BY

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SUMMARY

THE fluctuations of pressure, temperature, and rainfall in winter in the region of the North Atlantic had been studied as a connected system in the last paper of this series; and a similar system is now shown to hold in the spring, summer, and autumn. But the amount of persistence is small, so that the results are of little value for foreshadowing weather; nor does a consideration of the trade wind region lead to success in this respect.

Similarly the Southern Oscillation which was found active in the summer and winter seasons over a large part of the globe is now shown to function in the two remaining seasons: and while that of March to May has little control over the following quarter, the Southern Oscillation of September to November has a correlation coefficient of ·90 with the Oscillation of December to February. Thus there are a number of relationships of between ·60 and ·82 available for foreshadowing weather.

1. The previous papers in this series[1] have dealt primarily with the winter seasons of the North Atlantic and North Pacific Oceans, and with the winter and summer seasons of the Southern Oscillation. These appear to be the most characteristic times of the year; but conditions in the remaining seasons may be of scientific importance, so that a wider survey is desirable. Rather than effect this by adding more thousands to the existing mass of correlation coefficients between individual stations, the synthetic method of the last paper has been followed; and in the following study of the North Atlantic and the Southern Oscillations relationships have been determined with the numbers representing the seasonal fluctuations as a whole.

THE NORTH ATLANTIC OSCILLATION

2. In the North Atlantic fluctuations resembling those which prevail in winter occur, though to a less marked degree, through the year. In order to exhibit the effect of winter conditions on those of spring

[1] "World Weather, III," *London, Mem. R. Meteor. Soc.*, **2**, No. 17, 1928; "World Weather, IV," *London, Q.J.R. Meteor. Soc.*, **56**, 1930, p. 359; "World Weather, V," *London, Mem. R. Meteor. Soc.*, **4**, No. 36, 1932.

Chart 1 has been prepared, giving the correlation coefficients of the series representing the North Atlantic Oscillation in winter, as already worked out,[2] with the spring (March to May) temperatures over a wide region.

The stations will be recognized by the use of Chart 1 and Table I. of "World Weather, V"; and a comparison with Chart 3 of that paper shows that while the effect of the N.A.O. on the neighbourhood of Leningrad and C. Verde I. is as great as the effect of the winter N.A.O. on contemporary temperature, the persistence is in general small.

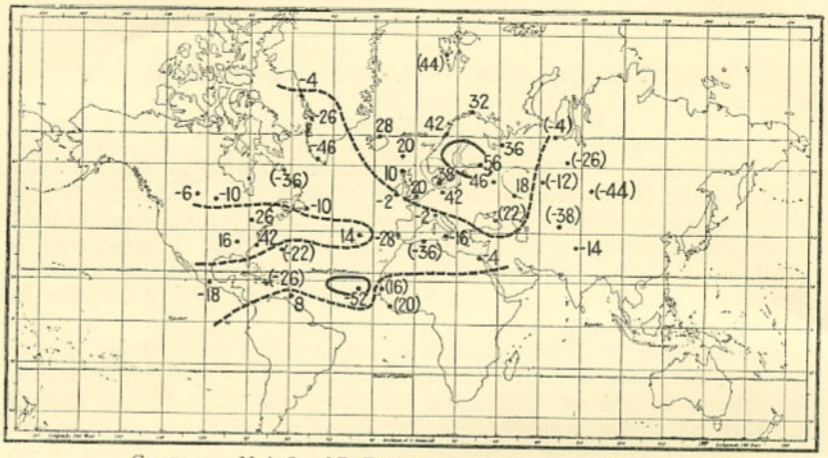

CHART 1.—N.A.O. of D–F with temperature of following M–M.

Turning now to contemporary relations in spring, methods similar to those previously adopted ("World Weather, V," pp. 53, 54) give, as a representation of the spring oscillation the expression – {Stykkisholm press.} – {Ivigtut press.} + {Azores press.} + {Bodo temp.} – {(Ivigtut + Godthaab) temp.} + ·7{Stornoway temp.}.

The relationships of contemporary pressure and temperature with this formula are given in Charts 2, 3 which thus indicate the character of the N.A. oscillation in spring. These are very similar to those of winter ("World Weather, V," p. 59); and though the relationships are somewhat less close, they are far too large to be due to accident. Those of the quantities included in the formula are – ·86, – ·84, ·82, ·76, – ·74, and ·62, respectively, while the average of the six coefficients which would be produced by chance from such a formula is about ·42. The working values of the departures of these six factors (see "World Weather, V," p. 78) and the numbers for the spring N.A.O. will be found in Table A. of the Appendix. Chart 3 contains an unexpected feature: an increase in the circulation of the North Atlantic has as big an effect in raising temperature in S.W. Canada as it has in the north of Norway; at Calgary the coefficient is ·66, while at Gjesvar it is ·60 and at Vardo ·70.

3 The relations of the series of numbers representing the character of the N.A.O. in spring with the temperature of the following summer

[2] "World Weather, V," p. 79.

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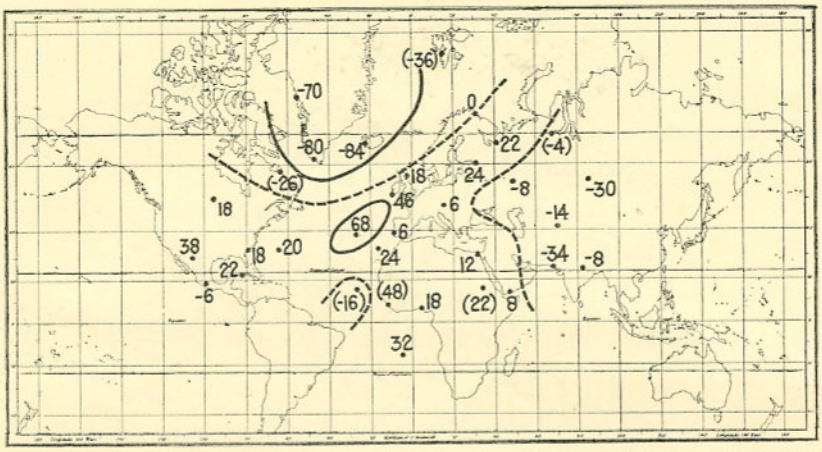

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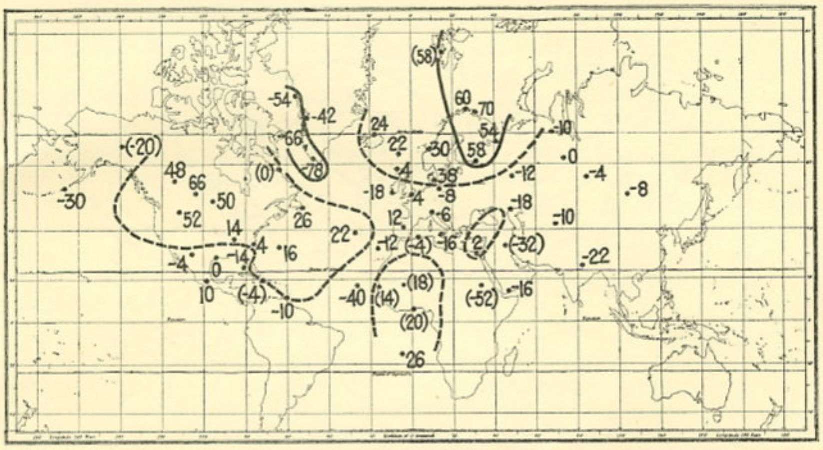

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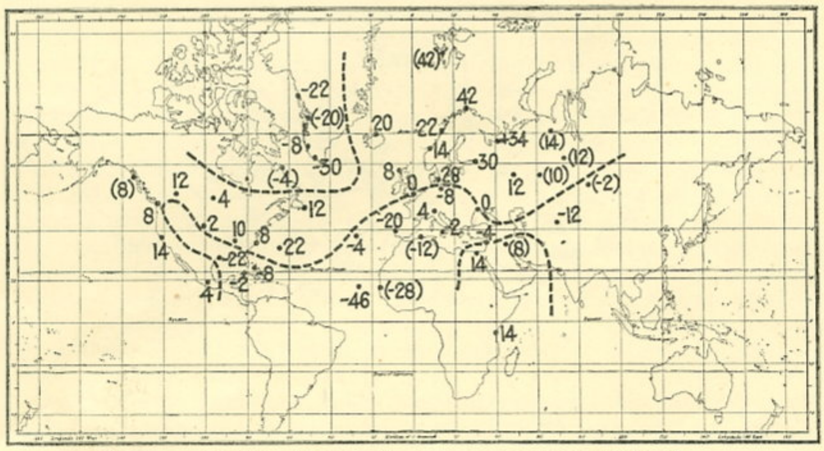

CHART 2.—N.A.O. of M–M with pressure of contemporary M–M.
CHART 3.—N.A.O. of M–M with temperature of contemporary M–M.
CHART 4.—N.A.O. of M–M with temperature of following J–A.

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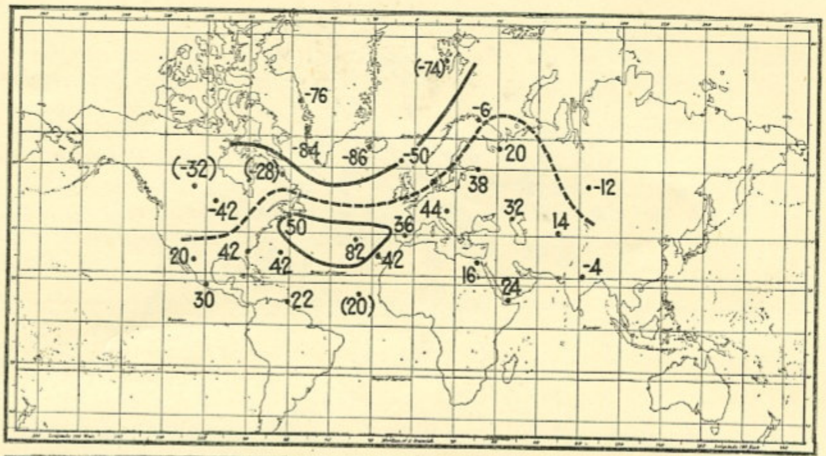

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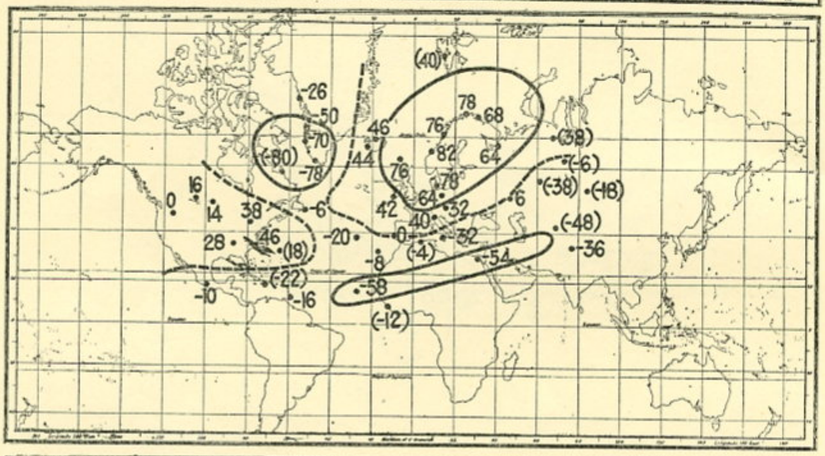

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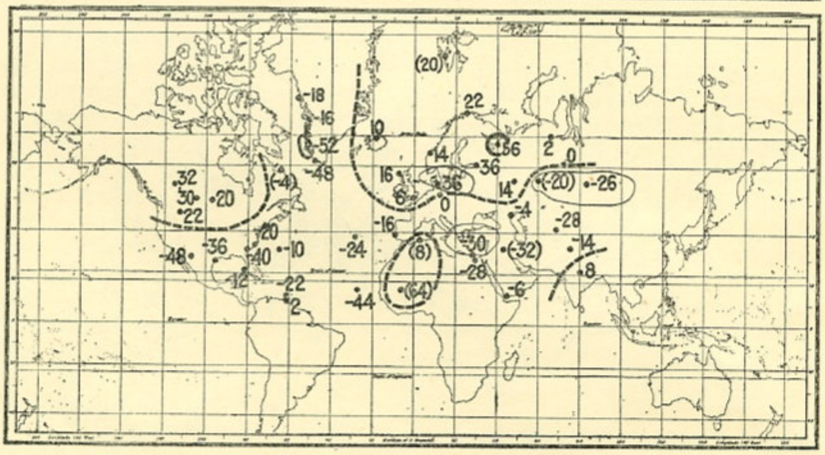

CHART 5.—N.A.O. of J–A with pressure of contemporary J–A.
CHART 6.—N.A.O. of J–A with temperature of contemporary J–A.
CHART 7.—N.A.O. of J–A with temperature of following S–N.

(June to August) are shown in Chart 4. The effect produced is small.

The expression for the summer (J–A) fluctuation proves to be: – {Stykkisholm press.} – {Ivigtut press.} – {(Godthaab + Ivigtut) temp.} + {Vardo temp.} + {Azores press.}; and the coefficients of these with the joint expression are – ·84, – ·80, – ·74, + ·70 and ·68, respectively.

The relationships of the summer fluctuation with contemporary pressure are shown in Chart 5, and with temperature in Chart 6.

For the table of data for the summer see Table B of the Appendix.

4. The effect of the summer N.A.O. upon temperature in autumn is given in Chart 7. From this a coefficient of – ·54 at Calgary, though based on the data of 44 years, has been excluded; it is not supported by the neighbouring stations and is probably influenced by accidental conditions. The only coefficients based on 40 years or more as big as ·48 are those at Archangel, S.W. Greenland, and El Paso.

For the autumn (S–N) fluctuation of the N.A.O. the expression is: – {Stykkisholm press.} – {Ivigtut press.} + {Bodo temp.} – {Godthaab temp.} + {Vienna press.} + {Stornoway temp.}; with these series the correlation coefficient of the expression for the N.A.O. is: – ·82, – ·76, + ·72, – ·72, + ·68, and + ·68. Here Ivigtut and Stykkisholm have the biggest coefficients and might have been treated as of weight unity, the weight of the rest being ·7; but they are too close together to be independent, so that their weight should on that account be reduced, say to ·7, and in that case all the terms would have approximately the same weight. The data for this season are given in Table C. of the Appendix, and the relations with contemporary pressures and temperatures in Charts 8 and 9. From Chart 10, which gives the relations with the temperatures of the succeeding winter, it will be seen that these are too small to have any value for prediction.

5. The chief hope of reliable production of the N.A.O. would appear to lie in the effects, found by Brooks and others, of previous conditions in the regions of the S.E. and N.E. trades. A suggestive and valuable account will be found in *Geophysical Memoir*, No. 33, of the London Meteorological Office, 1926; there a lag extending to 15 months is naturally interpreted as due to the time occupied by the ocean waters in travelling to the neighbourhood of the Antilles and thence across the Atlantic. Results of considerable promise for forecasting were derived from the data of the N.E. trades as indicated by (*a*) pressure at the Azores (Ponta Delgada), Gibraltar, and Sierra Leone; from (*b*) the S.E. trades as given by the wind velocity at St. Helena; from (*c*) the pressures at Havana, Bermuda, Charleston; and (*d*) from the rainfall (May to October) at Havana. But, unhappily, the data available to Brooks were generally limited to the years 1891 to 1915, and the addition of subsequent years has very materially reduced the closeness of the relationships, even after the effects of secular variation have been removed: the results obtained will be found in Tables I. to VII. below. Of these Table I. deals with the S.E. trades, Tables II.–IV. with stations regarded as likely to control the N.E. trades, and V., VI. with stations suggested as affecting conditions within the N.A.O.

In these as in subsequent tables of correlation coefficients the values have been multiplied by a hundred so as to simplify printing. The effect of secular change has been removed.

(Thus the coefficient of the M–M wind at St. Helena with the N.A.O. of S–N of the following year is + ·14).

TABLE I.—SOUTH-EAST TRADES AND THE NORTH ATLANTIC OSCILLATION

Relationship of velocity at St. Helena with the subsequent N.A.O., based on data of 30 to 33 years.

Season of trade wind	Lag in quarters						
	1	2	3	4	5	6	7
D–F .	18	8	22	8	2	−10	8
M–M .	20	30	−2	−28	−20	14	−20
J–A .	−32	18	26	−18	−2	−2	18
S–N .	0	6	−14	6	−2	−4	0

TABLE II.—AZORES PRESSURE AND THE SUBSEQUENT N.A.O. : $n=37$

Season of Azores pressure	Lag in quarters				
	1	2	3	4	5
D–F . .	12	22	10	10	−32
M–M . .	32	−8	14	20	18
J–A . .	−6	−10	18	14	−4
S–N . .	−2	0	12	24	10

TABLE III.—PRESSURE AT LISBON OR MADRID AND THE SUBSEQUENT N.A.O. : $n=46$

Season of pressure	Lag in quarters				
	1	2	3	4	5
Madrid D–F .	34	30	2	−28	−36
Madrid M–M .	2	−14	10	18	12
Lisbon J–A .	2	18	28	30	12
Madrid S–N .	22	24	16	12	−8

TABLE IV.—PRESSURE AT FREETOWN (SIERRA LEONE) AND THE SUBSEQUENT N.A.O. : $n=26$

Season of pressure	Lag in quarters				
	1	2	3	4	5
D–F . .	22	10	−2	4	10
M–M . .	12	−8	2	30	−2
J–A . .	14	14	6	24	16
S–N . .	−10	26	2	6	0

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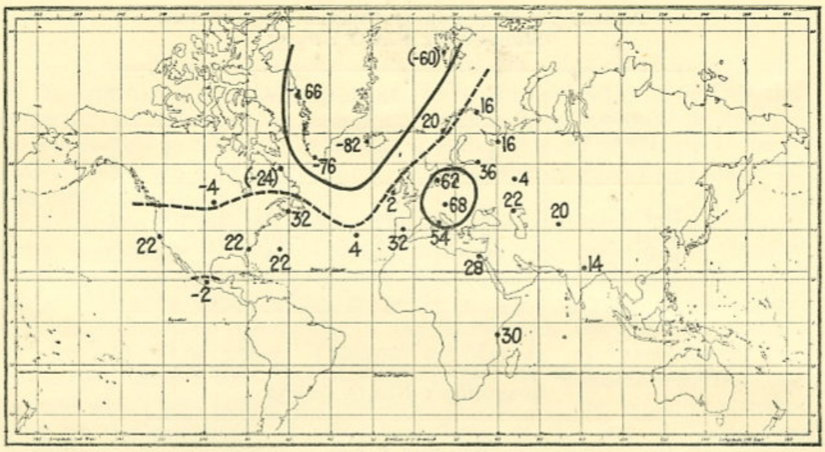

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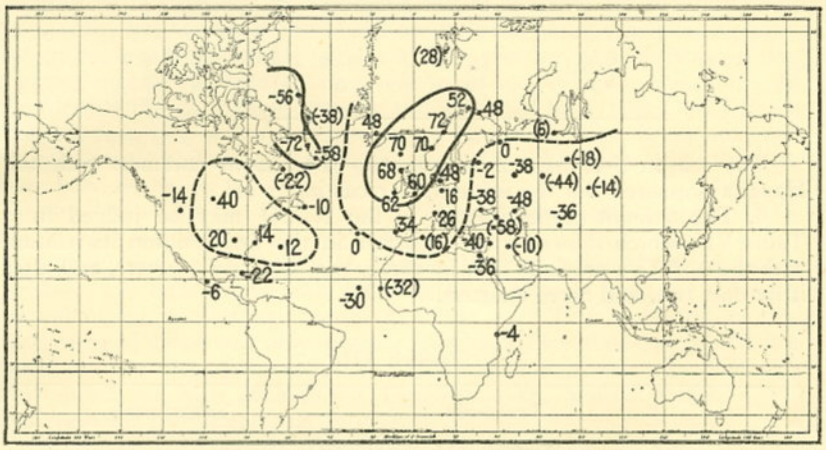

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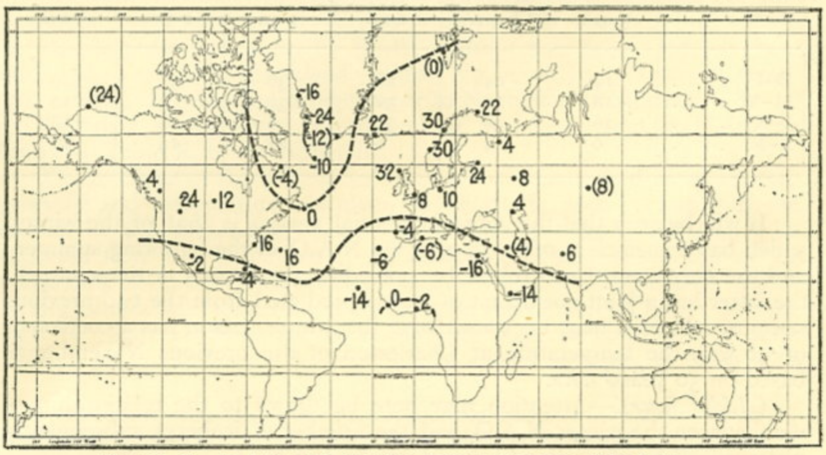

CHART 8.—N.A.O. of S–N with pressure of contemporary S–N.
CHART 9.—N.A.O. of S–N with temperature of contemporary S–N.
CHART 10.—N.A.O. of S–N with temperature of following D–F.

TABLE V.—PRESSURE AT CHARLESTON AND THE SUBSEQUENT N.A.O. : $n=55$

Season of pressure	Lag in quarters			
	1	2	3	4
D–F . .	8	20	− 2	− 8
M–M . .	2	− 8	− 10	+ 8
J–A . .	8	− 10	16	20
S–N . .	− 4	6	− 8	− 6

TABLE VI.—RAIN AT HAVANA FROM MAY TO OCTOBER AND THE SUBSEQUENT N.A.O. : $n=52$

Season of N.A.O.			
S–N	D–F	M–N	J–A
− 10	2	0	− 18

The season S–N has, of course, two months in common with the Havana pressure : but the value for forecasting is *nil.*

6. The amount of persistence in the N.A.O. may be judged from Table VII. which shows for each quarter in the first column its relation with the N.A.O.'s previous to it by three, two, and one quarters, and after it by one, two, and three quarters.

TABLE VII.

	Previously			Subsequently		
	3 qrs.	2 qrs.	1 qr.	1 qr.	2 qrs.	3 qrs.
D–F . .	14	− 04	26	36	38	0
M–M . .	− 18	14	36	30	4	14
J–A . .	16	38	30	8	− 4	− 18
S–N . .	0	4	8	26	14	16

It will be seen that the most influential season is that of the winter, which has a coefficient of + ·38 with the N.A.O. of the following summer ; and the season most controlled by preceding conditions is the summer : the latter has a joint coefficient of ·42 as predicted from the two previous seasons. Here it may be stated that the winter season has a coefficient of ·40 with the temperature at Charleston of the previous November as based on 50 years' data.

(*Added later*).—Attention may here be drawn to the relationship of ·60 between the winter N.A.O. and the number of icebergs subsequently observed off Newfoundland from March to July.[3]

[3] See Presidential Address, Section A, *Brit. Assoc. Rept.*, 1933, p. 41.

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7. It may be remembered that while the S.O. of J–A had a coefficient of ·84 with that of the D–F following, its coefficient with the S.O. of the previous D–F was only ·20, an amount useless for purposes of prediction. It was largely in the hope of finding a useful amount of persistence from season to season that a preliminary study of the quarters M–M and S–N has been effected.

8. *Season, March to May.*—The expression adopted is – {Batavia press. (n = 59, r = – ·80)} – {Calcutta press. (n = 59, r = – ·74)} + {Samoa press. (44, ·68)} – {Himalayan snow (58, – ·68)} + {Santiago press. (59, ·60)}. Here, as usual, n stands for the number of years of data; and r is the correlation coefficient of the factor with the joint expression for the S.O. The period is March to May in all cases except the Himalayan snow; for this the figures aim at representing, not the amount which falls during any particular period, but the quantity actually lying on the mountains of north-west India at the end of May; this depends on the amount of melting as well as of actual precipitation; and its quantity has for many years been carefully estimated, partly from photographs made at Simla during periods of clear weather, and partly by putting together reports prepared by civil officers in the regions in question. In the formula the data from Batavia and Calcutta have larger coefficients than the rest, but, as they are too near to be independent, it has not been thought worth while to give them the greater weight that would otherwise have been desirable.

The data of the five factors and of the resulting character of the S.O. are given in Table D. of the Appendix.

The relations of the S.O. of M–M with the distribution of contemporary pressure and temperature will be seen in Charts 11 and 12, and with rainfall of the succeeding quarter in Chart 13. The last is rather disappointing as there are only seven coefficients exceeding ·45 which are based on data of 34 years or more. These are: Siam ·46, the Nile ·48, N.W. India ·50, New Zealand ·50, Curityba – ·50, Malden Island – ·52, and Amboina (Moluccas) ·72.

9. *Season, September to November.*—The expression obtained for this quarter is – {Darwin press. (n = 52, r = – ·90)} – {Batavia press. (59, – ·84)} – {Manila press. (47, – ·84)} – {N.W. India press. (59, – ·78)} + {Java rain, (54, + ·78)} + ·7{Auckland temp. (59, + ·62)} – ·7{Batavia temp. (59, – ·60)}. The period is September to November in all cases.

The data of the seven factors and of the consequent S.O. will be found in Table E. of the Appendix.

The relations of the S.O. of S–N with the distribution of contemporary pressure and temperature are given in Charts 14 and 15, and with the rainfall of the succeeding quarter D–F in Chart 16.[4] As might be expected from the coefficient of ·84 between S.O. of J–A and that of the succeeding D–F, the effect of the S.O. of S–N upon the succeeding rainfall is more important than that of M–M upon the rainfall of J–A. Accordingly in Chart 16 there are 19 coefficients not less than ·5. Of these Table VIII. contains the information of eleven stations or areas with

[4] Unfortunately when these were computed and the Charts 14 to 17 drawn, the expression used for the S.O. had unit weight for the last two factors instead of weight ·7. But actual recalculation of a number of coefficients show that the mean change involved is less than a third of the mean error due to sampling, and the repetition of the work seems unjustifiable.

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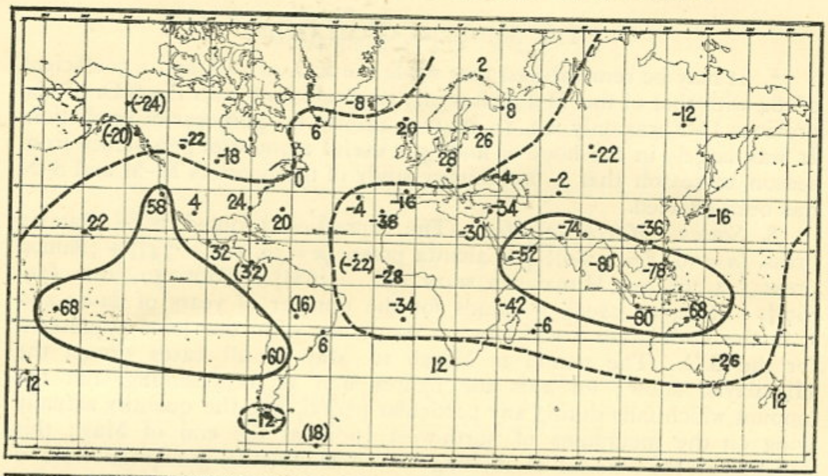

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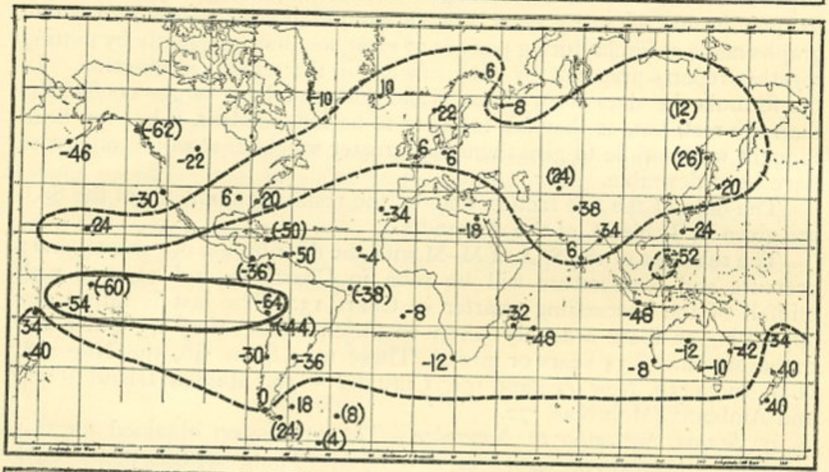

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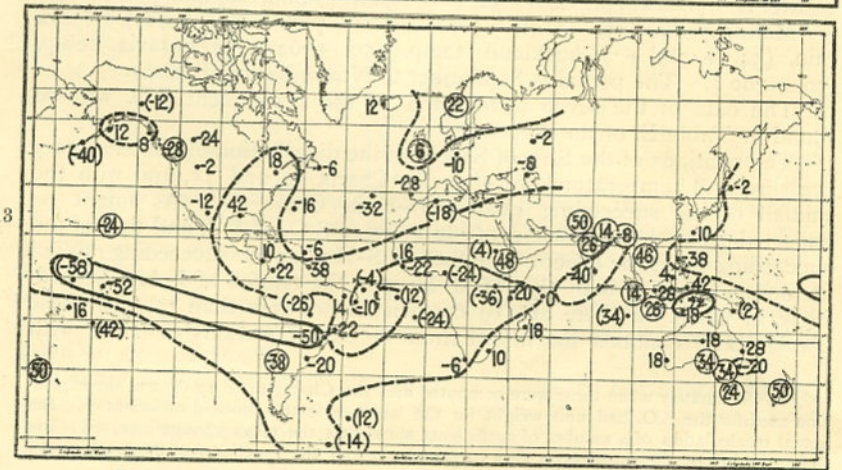

CHART 11.—S.O. of M–M with pressure of contemporary M–M.
CHART 12.—S.O. of M–M with temperature of contemporary M–M.
CHART 13.—S.O. of M–M with following J–A rainfall.

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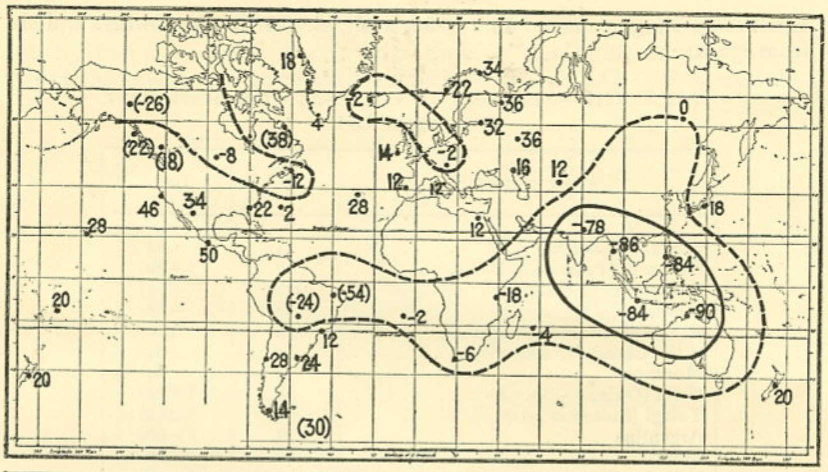

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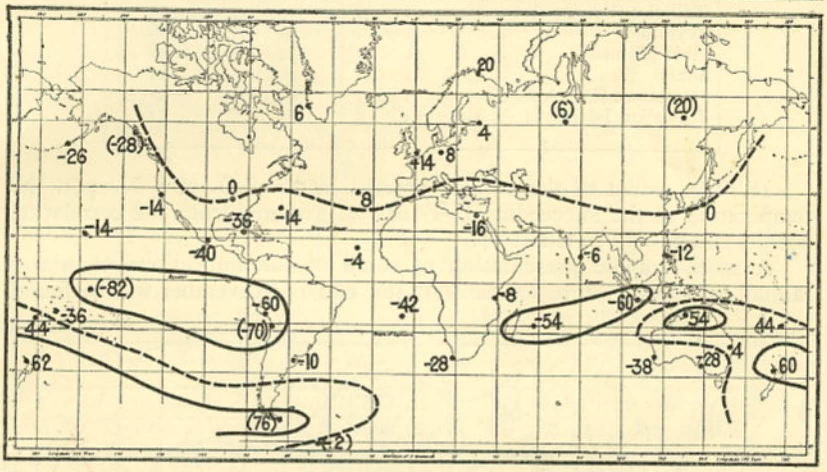

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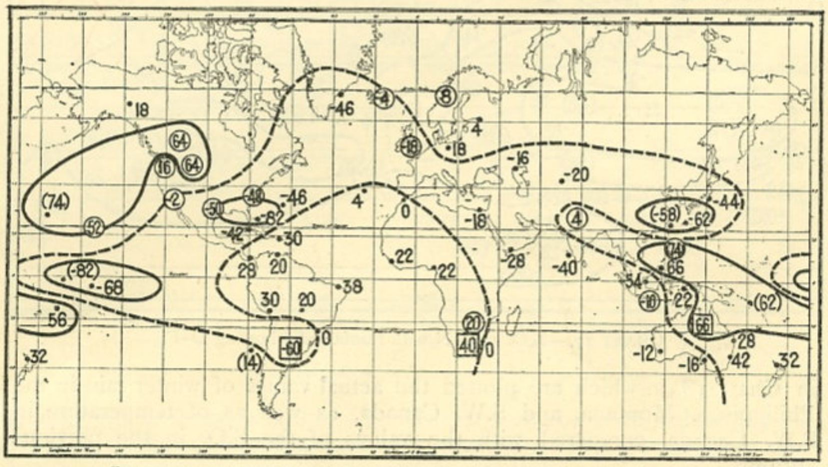

CHART 14.—S.O. of S–N with pressure of contemporary S–N.
CHART 15.—S.O. of S–N with temperature of contemporary S–N.
CHART 16.—S.O. of S–N with rainfall of following D–F.

coefficients ranging from ·60 to ·82, available for foreshadowing, and six from ·52 to ·58.

TABLE VIII.—RELATIONS OF S.O., S–N, WITH SUBSEQUENT RAINFALL, D–F

Place of rainfall	n	100 r
Nassau, Bahamas	41	−82
Ocean I. (1 station)	17	(−82)
Philippines (4 stations)	28	(74)
Malden I.	34	−68
British N. Borneo (1 station)	22	(66)
S.W. Canada (7 stations)	37	64
Montana	38	64
Naha (Okinawa Shima)	29	(−62)
Tulagi (Solomon Islands)	29	(62)
Argentina	25	(−60)
Florida	42	−60
Taihoku (Formosa)	24	(−58)
Wyoming	41	56
Apia (Samoa)	34	56
Idaho	40	54
Pontianak (Dutch Borneo)	42	−54
Hawaiian Islands (10 stations)	45	52

10. The extent of the control exerted by the S.O. of S–N upon the temperature of the succeeding D–F may be gathered from the correlation coefficients plotted in Chart 17.

A more graphic presentation of some of the indications of winter rainfall and temperature available at the end of November will be found

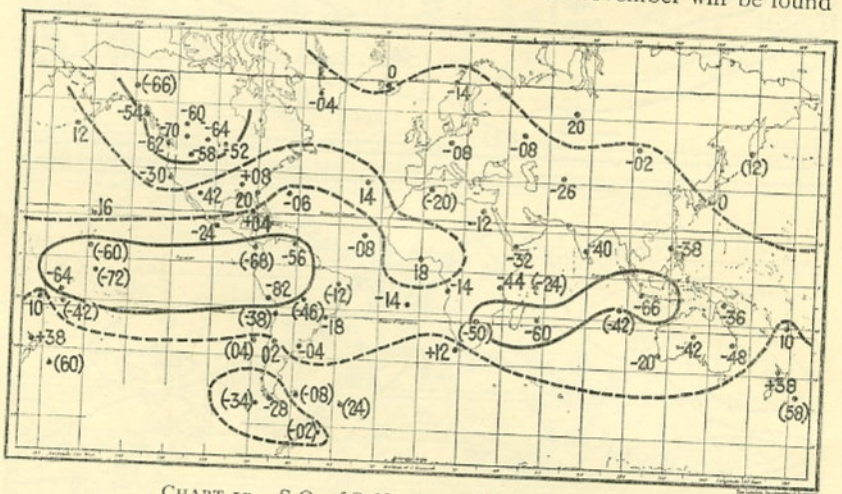

CHART 17.—S.O. of S–N with rainfall of following D–F.

in Chart 18, in which are plotted the actual values of winter rain in the Philippines, Montana, and S.W. Canada, as well as of temperature in S.W. Canada, compared with the values of the S.O. in the previous autumn.

11. For any possibility of forecasting the winter conditions of the North Atlantic or North Pacific from those of the Southern Oscillation, we should look to the correlation coefficients of the S.O. of S–N with the

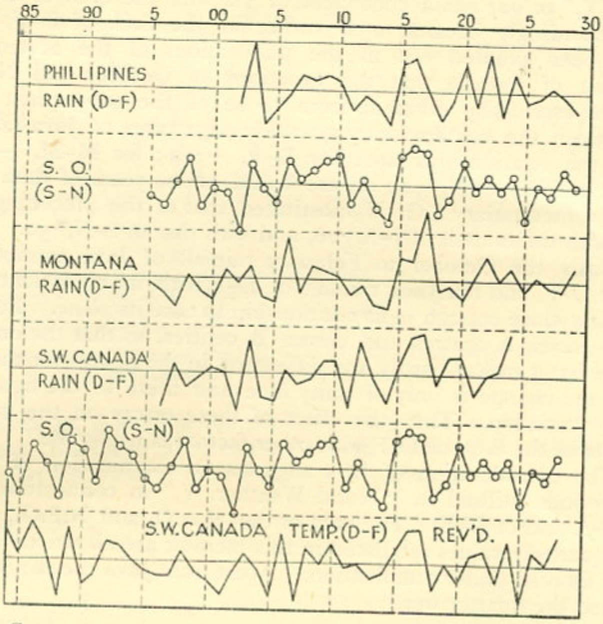

CHART 18.—Actual values of the S.O. of S–N with actual values during the following D–F of rainfall in the Philippines, Montana, and S.W. Canada, and of the temperatures (reversed) in S.W. Canada.

D–F values of the N.A.O. and the N.P.O. These are ·06 and −·54, and even the second is too small to have much practical value by itself.

The relations between the numbers defining the S.O.'s of the different

TABLE IX.—RELATIONSHIP BETWEEN THE VALUES OF THE S.O. for (*a*) one season, and (*b*) that for a previous or a subsequent season. Here *n* lies between 49 and 59.

(*a*) Season in question	(*b*) Season			
	2 quarters before	1 quarter before	1 quarter after	2 quarters after
D–F	84	90	68	20
M–M	60	68	62	36
J–A	20	62	82	84
S–N	36	82	90	60

seasons will be found in Table IX. The persistence is considerable; for the least coefficient between successive seasons is ·62 between M–M and J–A, and the greatest is ·90 between S–N and D–F.

(Thus the coefficient between the S.O.'s of J–A and S–N of the same year is ·82.)

12. The need of an important correction arises in connection with the rainfall of Java, of which that of October to February (see "World Weather, V," p. 62) has a coefficient of ·62 with the S.O. of D–F: this rainfall accordingly became a B centre in the S.O. of D–F. It has, however, been pointed out in the publications of the Meteorological Department of Batavia that the variations of October and November rainfall are essentially different from those of the subsequent months. Thus between the contemporary quarterly departures of Java rain and of the S.O. the relationships are: for D–F, −·14; for M–M, −·02; for J–A, ·34; and for S–N, ·72; all are based on 49 years of data at least. If for the contemporary S.O. is substituted that of the preceding quarter, we have with the rainfall of J–A, ·26, and with that of S–N, ·50.

Obviously the October to February rainfall of Java cannot be a B centre for D–F, and the Java rainfall of D–F with its coefficient of −·14 is not nearly close enough in its relationship to take its place. Fortunately there were seven A centres and eleven B centres, so that the omission of one of the latter makes hardly any difference in the figures for the S.O. as a whole: the change is only of unity here and there in the figures representing its variation. Thus the effect of these errors on the correlation coefficients of the S.O. of D–F with other factors is negligible.

13. The consideration of Java suggests an examination of the other rainfall periods utilised in "World Weather, V," in connection with the S.O. of J–A and of D–F. The data of the N.A.O. and N.P.O., as well as the new quarterly values tabulated in this memoir are all strictly limited to the three months under examination. Apart from Java the rainfall periods that exceed the quarter were:

S.O. of J–A ("World Weather, V," p. 60.)	A. India, June–Sept. A. Nile flood, July–Oct. B. Chile, April–Oct.
S.O. of D–F ("World Weather, V," p. 62.)	A. N.E. Australia, Oct.–Feb. B. S. Africa, Oct.–April. B. S. America, Oct.–April.

All these periods of rainfall have been taken as representing the wet season and they may, therefore, be used when examining the possibility of forecasting. But they are not appropriate as factors contributing to the numerical values of the S.O. of J–A or D–F, when the intermediate quarters M–M and S–N are also in question. Undoubtedly when another 15 years of data are available, and the tables are all recomputed, it will be necessary to tabulate the rainfall factors for strictly quarterly periods; but as the number of factors for the S.O. of J–A is ten, and of D–F fifteen, I am convinced that the labour of recomputing at this stage would not be justified by the minute changes that would ensue.

14. In the last *Memoir* on this subject the closest relationship of temperature with the world weather was that of Arequipa,[5] with −·82 between its D–F value and that of the contemporary S.O. The data used were limited to 19 years and as the result could not be relied upon Arequipa was not employed as a centre. A utilisation of the data of 31 years now available confirms the former result and Table 10 shows that there are close relationships with the S.O. at other times of year. Chart 19 gives

[5] "World Weather, V," Table VI. p. 70.

the plotted values of the S.O. for S–N followed by those of Arequipa temperature and of the S.O. for the succeeding D–F.

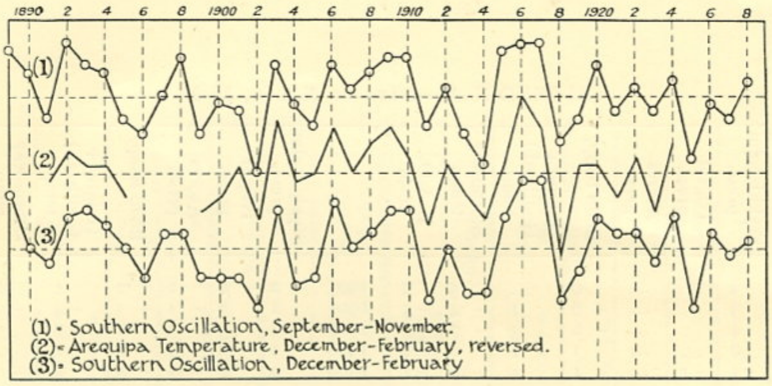

CHART 19.—Actual values of the S.O. of S–N with actual values for the succeeding D–F of temperature at Arequipa (reversed) and the S.O.

The data of Arequipa temperature are given in Appendix F. : it is unfortunate that these observations should have terminated before their great interest had been established.

TABLE X.—RELATIONSHIP OF AREQUIPA TEMPERATURE WITH THE S.O. ($n=31$)

Season of Arequipa temperature	Season of quarterly values of S.O.				
	Two before Arequipa	One before	Con-temporary	One after	Two after
D–F . .	-74	-82	-84	-50	-16
M–M . .	-76	-76	-64	-32	-16
J–A . .	-30	-46	-62	-58	-62
S–N . .	-56	-58	-60	-2	-44

APPENDIX A.—Data of N.A.O., M–M

	Stykkisholm press.	Ivigtut press.	Azores press.	Bodo temp.	(Ivigtut + Godthaab) temp.	Stornoway temp.	N.A.O. M–M		Stykkisholm press.	Ivigtut press.	Azores press.	Bodo temp.	(Ivigtut + Godthaab) temp.	Stornoway temp.	N.A.O. M–M
1875	−2	...	...	0	...	5	3	1905	−2	−6	1	−2	4	1	1
1876	3	...	...	−6	1	−4	−5	1906	1	3	−1	−3	−4	−5	−2
1877	4	...	...	−6	3	−7	−7	1907	−4	−3	3	2	−7	3	5
1878	0	...	...	1	2	2	0	1908	−1	−3	5	−1	1	0	2
1879	−1	−1	...	−1	1	−10	−2	1909	4	4	−5	−8	8	−1	−7
1880	−1	−7	...	−1	−1	3	3	1910	−2	3	4	4	−2	3	3
1881	1	−1	...	−11	6	−2	−5	1911	−1	−5	2	1	−1	4	3
1882	−2	2	...	−2	−7	2	2	1912	−4	−5	4	1	1	6	4
1883	2	4	...	4	−1	−3	−1	1913	−10	−6	5	3	−5	1	7
1884	−3	1	...	2	−6	2	3	1914	−4	−2	6	0	−4	5	5
1885	1	3	...	−2	0	−3	−2	1915	2	4	−6	−7	4	0	−5
1886	2	1	...	3	−1	−4	0	1916	5	6	−3	−1	9	−2	−6
1887	3	5	...	−1	−5	−2	−1	1917	5	8	−7	−9	5	−4	−9
1888	6	9	...	−9	3	−5	−9	1918	−1	−5	0	4	−6	7	5
1889	−1	−3	...	1	−2	4	3	1919	2	...	1	1	1	2	0
1890	−5	−4	...	8	−1	4	6	1920	−7	−2	2	10	−2	2	6
1891	5	6	...	−2	0	−12	−6	1921	−7	−5	5	8	−6	7	8
1892	5	4	...	−2	3	−8	−6	1922	2	1	5	1	3	−2	0
1893	−3	−3	...	−3	−2	9	3	1923	0	−5	−1	3	4	−1	0
1894	−5	−1	1	9	−7	2	6	1924	9	10	−12	−2	5	−4	−10
1895	−3	−4	−2	0	4	4	1	1925	2	3	2	1	−2	1	0
1896	−6	−3	8	1	−5	8	7	1926	3	...	−2	3	4	6	0
1897	−7	−4	2	2	−6	−5	4	1927	0	...	0	1	2	0	0
1898	−2	1	−2	1	−1	−1	0	1928	4	...	−7	3	8	4	−4
1899	5	7	−5	−11	3	−3	−8	1929	7	−5	−4	1	9	5	−2
1900	4	2	0	−3	4	−1	−3	1930	4	2	−1	7	5	1	−1
1901	−2	2	−5	0	1	2	−1	1931	5	5	−9	1	3	1	−5
1902	1	2	0	−3	−2	0	−1	1932	9	...	...	...	...	1	...
1903	−8	−4	4	5	−8	−1	7								
1904	−8	−5	2	2	−6	−2	5								

APPENDIX B.—Data of N.A.O., J–A

	Stykkisholm press.	Ivigtut press.	(Godthaab + Ivigtut) temp.	Vardo temp.	Azores press.	N.A.O. J–A		Stykkisholm press.	Ivigtut press.	(Godthaab + Ivigtut) temp.	Vardo temp.	Azores press.	N.A.O. J–A.
1875	4	...	−3	2	...	3	1905	−3	−2	−3	1	−2	2
1876	−13	...	−1	6	...	8	1906	−1	−1	−2	−2	−2	0
1877	1	...	3	−3	...	−4	1907	3	9	−3	3	0	−2
1878	1	...	1	−4	...	−3	1908	−1	−1	2	0	2	1
1879	−2	2	0	−5	...	−2	1909	−3	−5	2	0	8	4
1880	2	−1	2	−1	...	−2	1910	4	6	3	−8	3	−4
1881	−5	−3	−5	−9	...	1	1911	3	5	2	0	−2	−3
1882	−3	4	−5	0	...	1	1912	4	7	4	−3	1	−4
1883	1	4	−5	1	...	0	1913	0	−4	−1	5	6	4
1884	−5	−3	−10	0	...	5	1914	−2	−5	−7	3	5	6
1885	1	1	−1	−1	..	−1	1915	6	7	4	3	−5	−5
1886	−11	−5	−3	0	...	6	1916	2	−1	5	0	−4	−2
1887	1	−1	−1	0	...	0	1917	5	6	10	0	3	−4
1888	5	0	4	−4	...	−5	1918	−1	5	−6	−2	1	1
1889	−3	−4	−3	2	...	4	1919	...	...	−4	5	7	8
1890	−4	−2	−2	4	...	4	1920	−3	−4	−3	10	2	6
1891	4	2	5	−5	...	−5	1921	1	1	−4	7	−1	3
1892	3	2	2	−7	...	−5	1922	−8	−6	−8	9	8	11
1893	2	3	2	−6	...	−4	1923	−5	−2	0	1	4	4
1894	−7	−8	−5	8	4	8	1924	2	0	6	2	4	0
1895	−1	6	1	−1	−2	−3	1925	−1	−6	−6	3	5	6
1896	−1	0	−2	3	3	2	1926	1	...	3	−5	−4	−4
1897	0	5	−1	1	−4	−2	1927	4	...	3	4	−1	−1
1898	−5	−2	−6	7	−9	3	1928	5	...	10	0	−9	−7
1899	−3	−4	2	−4	1	1	1929	7	...	7	−2	...	−4
1900	1	−1	5	−9	−2	−4	1930	−3	2	0	6	−2	2
1901	−7	−9	−5	1	4	7	1931	8	7	9	...	1	−7
1902	9	8	2	−9	−9	−10	1932	3	...	...	...	...	...
1903	3	8	−1	−4	−4	−5							
1904	2	−3	4	0	−7	−3							

APPENDIX C.—DATA OF N.A.O., S–N

	Stykkisholm press.	Ivigtut press.	Bodo temp.	Godthaab temp.	Vienna press.	Stornoway temp.	N.A.O. S–N
1875	5	...	−5	5	−7	−5	−7
1876	7	...	−3	3	−2	−2	−4
1877	−4	...	−1	0	1	−8	−1
1878	5	...	3	5	−7	−2	−4
1879	2	4	−1	−2	1	−5	−2
1880	6	12	−9	5	−1	−4	−8
1881	−3	−7	3	−5	3	2	5
1882	−5	−1	4	−8	−8	−3	2
1883	−8	−4	4	−7	0	−2	5
1884	−2	−3	5	...	6	1	4
1885	−1	4	−5	−6	−6	−6	−3
1886	−4	0	7	−2	1	2	4
1887	7	7	−1	1	−7	−6	−7
1888	−1	4	−8	−2	5	−1	−1
1889	−1	1	8	−3	1	0	3
1890	−6	−1	1	−6	1	4	4
1891	−8	−6	4	−5	1	−1	5
1892	−1	4	2	2	2	−7	−2
1893	3	10	−5	7	−3	−5	−7
1894	0	1	−3	−3	2	0	0
1895	−3	1	1	0	4	−1	1
1896	4	7	0	...	−4	−4	−5
1897	2	−1	5	0	11	0	3
1898	−6	−2	1	...	1	5	4
1899	−5	0	1	−6	6	4	5
1900	−5	−4	0	−5	1	−2	3
1901	0	−1	7	0	0	4	3
1902	−2	−4	−4	0	5	6	3
1903	1	3	−4	...	−1	2	−2
1904	−3	−3	−1	−5	3	1	3
1905	2	0	−7	4	−8	−2	−5
1906	−5	0	2	−3	3	7	4
1907	−3	−1	4	−2	3	2	3
1908	−5	−7	0	2	10	11	7
1909	1	4	−4	1	−4	−1	−3
1910	7	10	−4	−3	−4	−1	−5
1911	0	−5	−2	4	−1	−2	−1
1912	1	−1	−3	1	0	−3	−2
1913	−4	−1	1	−5	0	6	4
1914	−1	−6	1	−2	−3	5	3
1915	6	3	−7	9	−4	1	−6
1916	−2	−4	−1	5	−2	6	1
1917	−4	2	0	−5	0	−2	1
1918	−4	...	7	−4	1	−3	4
1919	...	3	−7	5	−5	−6	−7
1920	−9	−7	10	−7	9	10	12
1921	0	−4	−3	2	10	6	3
1922	5	1	1	1	−2	−2	−2
1923	−5	4	1	4	−4	−7	−3
1924	−1	−1	9	−1	5	4	5
1925	7	1	−4	7	−3	−2	−5
1926	5	...	−3	4	−2	−4	−5
1927	7	...	−5	7	0	−2	−6
1928	6	−4	−1	8	−3	2	−3
1929	−5	−3	4	−1	−1	2	3
1930	4	7	0	6	−4	2	−4
1931	−2	−2	−1	...	3	7	4
1932	1	...	−3	...	−1	2	−1

APPENDIX D.—DATA OF S.O., M–M

	Batavia press.	Calcutta press.	Samoa press.	Himalayan snow	Santiago press.	S.O. M–M		Batavia press.	Calcutta press.	Samoa press.	Himalayan snow	Santiago press.	S.O. M–M
1875	−4	−3	...	...	5	6	1905	10	7	−5	8	−2	−9
1876	−7	−5	...	4	−4	1	1906	3	−1	−2	6	1	−3
1877	7	9	...	8	−11	−12	1907	3	5	−1	8	2	−4
1878	4	10	...	8	−5	−10	1908	−2	−1	−2	0	1	1
1879	−8	−4	...	−6	2	7	1909	−6	1	4	−3	1	4
			...										
1880	−3	−2	...	−3	1	3	1910	−5	−3	3	0	7	5
1881	3	1	...	−4	−1	0	1911	1	−2	0	7	7	0
1882	−1	−1	...	−6	3	4	1912	6	4	0	3	2	−3
1883	−1	−5	...	6	−2	−1	1913	−5	−4	−3	1	5	3
1884	0	−3	...	4	−5	−2	1914	7	7	−5	1	3	−5
			...										
1885	5	4	...	8	−2	−7	1915	10	4	−5	0	2	−5
1886	−4	2	...	0	4	2	1916	−4	−3	5	−4	4	6
1887	−3	−9	...	−6	0	6	1917	−7	1	12	−3	4	7
1888	3	−3	...	−4	−7	−1	1918	4	−3	−1	−1	1	0
1889	6	3	...	−1	0	−3	1919	2	4	−3	6	−5	−6
1890	−7	−5	2	−4	4	6	1920	0	1	0	8	−2	−3
1891	4	4	0	8	−1	−5	1921	−3	−7	0	−7	−2	4
1892	−7	−9	−2	−6	4	7	1922	−2	−2	3	3	2	2
1893	−2	−1	13	0	2	5	1923	−4	−1	−7	4	1	−1
1894	−1	−6	6	−3	4	6	1924	−3	−2	2	6	4	1
1895	1	−1	10	−3	6	5	1925	0	−2	−3	−1	−1	0
1896	0	−5	−5	−6	1	2	1926	6	7	−1	4	2	−4
1897	3	1	0	3	−4	−3	1927	−6	−4	1	0	1	3
1898	−7	−2	−1	−3	−7	1	1928	−5	−1	−2	0	2	2
1899	0	−3	−1	−3	−9	−1	1929	1	1	1	−3	2	1
1900	8	6	−5	0	−13	−9	1930	2	−1	−2	3	1	−1
1901	0	4	−1	3	2	−2	1931	3	1	4	1	4	1
1902	3	0	−2	−3	−13	−4	1932	1	1	−6	−1	1	−2
1903	−3	2	−9	3	−2	−4	1933	−2	3	3	3	2	0
1904	−5	−4	0	3	−3	1							

APPENDIX E.—Data of S.O., S–N

	Darwin press.	Batavia press.	Manila press.	N.W. India press.	Java rain	Auckland temp.	Batavia temp.	S.O. S–N		Darwin press.	Batavia press.	Manila press.	N.W. India press.	Java rain	Auckland temp.	Batavia temp.	S.O. S–N
1875	..	−1	..	0	..	−4	−1	−1	1905	4	5	5	1	−1	−4	4	−4
1876	..	1	..	5	..	6	−5	0	1906	−4	−2	−7	0	8	−1	−2	4
1877	..	12	..	7	..	0	6	−9	1907	2	0	1	−2	3	1	−4	1
1878	..	−7	..	−9	..	3	4	6	1908	0	−2	−4	−1	4	−2	−4	3
1879	..	−3	..	1	3	4	−5	3	1909	−2	−3	−7	−4	6	3	−3	5
1880	..	4	..	6	3	3	−7	0	1910	−3	−5	−1	−6	8	3	−3	6
1881	..	−3	..	−8	−4	3	0	2	1911	5	3	7	2	1	−4	1	−4
1882	−4	−3	..	−1	4	−1	−9	4	1912	1	−1	−4	4	4	−3	−1	1
1883	−6	0	..	0	0	−4	−7	2	1913	7	7	5	6	0	1	3	−5
1884	−2	1	..	3	−1	−3	−3	−1	1914	10	5	9	6	−6	−6	6	−9
1885	5	8	..	2	−4	−3	1	−5	1915	−2	−4	−7	−8	4	6	2	6
1886	−8	−5	..	−3	4	−1	−3	5	1916	−4	−10	−6	−8	6	4	0	7
1887	−2	0	1	3	2	−4	−8	0	1917	−4	−6	−4	−8	5	6	−5	7
1888	2	2	8	8	−6	−7	4	−7	1918	6	6	4	4	−6	−4	4	−6
1889	−10	−5	−1	−6	4	4	−3	6	1919	4	1	2	0	−3	−10	0	−3
1890	−6	2	−3	3	4	4	−10	3	1920	−2	−5	−1	−5	5	−1	−3	4
1891	2	3	3	1	−7	4	5	−3	1921	1	2	3	3	−2	2	−1	−2
1892	−8	−6	−4	−6	4	8	−5	7	1922	0	−3	−1	0	−3	3	0	1
1893	−6	−1	−1	0	2	12	−5	4	1923	4	2	−3	0	−7	3	5	−2
1894	−2	0	−2	−3	4	1	−2	3	1924	−2	−2	1	0	2	4	1	2
1895	0	2	1	2	−4	−3	2	−3	1925	6	5	6	7	−8	−4	8	−8
1896	4	5	5	0	−5	−2	6	5	1926	0	−3	−1	−3	−6	−1	7	−1
1897	−3	1	0	−2	0	−3	2	0	1927	4	1	4	−1	−4	−1	3	−3
1898	−5	−6	−5	−4	4	0	−3	5	1928	0	−1	−6	−3	−2	6	4	2
1899	6	7	2	6	−2	−1	−1	−5	1929	1	−2	−1	1	−7	2	6	−2
1900	1	0	−1	5	1	1	3	−1	1930	8	6	9	6	−3	−6	7	−8
1901	4	3	−1	0	−1	−1	1	−2	1931	2	−1	−1	0	−3	1	6	−1
1902	9	7	8	7	−7	−10	5	−10	1932	0	−2	−1	−6	−4	4	6	1
1903	−2	−2	−2	−5	5	6	−2	4	1933	−2	−4	−1	−4	..	1	1	2
1904	2	3	3	3	7	−6	−4	−1	..	..	..	..	..	..	..	..	..

APPENDIX F.—Data of Arequipa Temperature

	D–F	M–M	J–A	S–N		D–F	M–M	J–A	S–N
1892	1	1	2	−3	1910	−6	−4	−1	−2
1893	−3	−6	−7	−2	1911	−2	−3	0	5
1894	−1	−2	3	0	1912	7	4	1	−5
1895	−1	−1	7	5	1913	−1	−4	−2	−2
1896	3	0	−5	−3	1914	3	3	3	−4
1897	...	...	...	...	1915	6	12	1	−2
1898	...	...	...	...	1916	−1	−5	−13	−10
1899	...	...	...	...	1917	−10	−8	−7	−9
1900	5	8	5	8	1918	−6	−6	3	5
1901	3	4	4	4	1919	11	4	4	4
1902	−1	4	4	5	1920	−1	−1	1	−1
1903	6	−1	−3	−3	1921	−1	−1	−1	2
1904	−7	−5	0	−1	1922	3	4	−1	3
1905	1	0	5	2	1923	−2	0	4	6
1906	0	2	−3	−1	1924	5	2	−2	−2
1907	−6	−1	−2	1	1925	−4	−1	4	5
1908	0	1	−2	−8					
1909	−4	−9	−8	−3					

Discussion

Dr. F. J. W. Whipple, President, said he thought everyone wished to congratulate Sir Gilbert Walker and Mr. Bliss on the remarkable progress which they were continuing to make in this highly important investigation. It seemed to him very wonderful that they were able to obtain such remarkable consistency with such very small correlation coefficients. It was very striking how these correlations of about ·2, dotted over a considerable area, which in themselves seemed insignificant, were yet significant when taken together. He wondered whether any investigation had been made as to the way in which the theory of probable error should be applied in cases of this sort. Correlation coefficients taken in this wholesale manner seemed to him to be rather different from correlation coefficients taken singly and discussed in detail.

Professor D. Brunt said that without time to study it it was scarcely possible to discuss this paper in detail. He hoped that eventually Sir Gilbert would be able to develop a method for forecasting the weather of the British Isles. At present this did not seem to be possible, as the correlation coefficients for the British Isles were distinctly small. There was the real difficulty that it was not often possible to characterise our summers as wet or dry, warm or cold, as our weather was subject to wide fluctuations even within one season. It looked as though any serious attempt at long period forecasting for this country would have to start with a period of less than three months, possibly with a ten-day interval such as that of the forecasts made for Germany by Dr. F. Baur. He had been told in Germany during the past summer that these forecasts were very successful, but he rather doubted whether equal success could be expected for the British Isles, in view of the rapid fluctuations in weather to which we are subjected.

Mr. H. Fairfield Smith mentioned that meteorologists who require to deal with multiple measurements might find something of interest in recent biological work done under the direction of Professor R. A. Fisher. (*Ann. Eug. London*, 6, 1935, pp. 352-371; *ibid.* 7, 1936, pp. 179-188, 240-250; and *Biometrika*, *Cambridge*, 28, 1936, pp. 149-178.)

Sir Gilbert Walker in reply said he thought that while, as the President had remarked, the coefficients of ·2 appeared to support each other, they were still liable to the usual sampling errors. Their consistency arose because an "accidental" high pressure or low temperature over a season had a fairly uniform influence over a wide area, producing a sampling error that was largely the same over that area.

With regard to the British Isles, this paper represented his first effort at making any forecasts for that region and he had found it more difficult than he had expected. He thought Prof. Brunt was not far wrong when he said that forecasts for a short period only would be possible. The correlation between the months was very small. With regard to the combination of a number of factors in the manner used by Prof. Fisher, he believed that in this sort of work aiming at very great accuracy was a waste of time. He had experimented with a number of formulae and had found that great precision did not have sufficient effect on the results to make it worth the trouble involved. The use of simplified methods might cause a loss of accuracy of something like a fifth of the inevitable sampling error, but the output was probably multiplied by ten or twenty. In exploring work he considered that this was fully justified.