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WORLD WEATHER IV

SOME APPLICATIONS TO SEASONAL FORESHADOWING

BY

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1. Relationships between seasonal characteristics over the world have been applied to the working out of formulae for seasonal prediction in several regions. For the monsoon rainfall of India the formula[1] of 1908 gave a correlation coefficient of ·58, and more recent formulae[2] gave coefficients for North-West India and the Peninsula each of ·76; for the Nile Bliss[3] found a coefficient of ·72 based on the data of 44 years, and for the height of the river Parana in Brazil[4] ·72 based on 32 years. The fuller information available since the publication of our paper "World Weather III."[5] when applied to the Ceara region[6] in Brazil, conspicuous for its liability to drought, gave a coefficient of ·82; but conditions in other countries require examination, and the following paper deals with a first selection of these.

We regard it as of great importance that applications of statistical methods should not be penalised by extravagant claims; and the relationships hitherto found are not close enough to justify a prediction in years in which the indications are not strongly marked, and of these the number depends on the value of R. The word "forecast" is associated with prediction on every occasion, and so it seems wiser not to speak of statistical methods as providing seasonal "forecasts"; we would therefore prefer to speak of "foreshadowing" as indicating a vaguer prediction than is habitually made in daily forecasting.

THE WINTER TEMPERATURE OF SOUTH-WEST CANADA.

2. Examination shows that the winter temperature of the region of Canada represented by Winnipeg has closer relationships than has the mean of Winnipeg, St. Louis and St. Paul, which was included in the tables in "World Weather III."; and for Winnipeg temperature, December to February, the chief coefficients are

[1] *Memoirs of Indian Meteorological Department*, **21**, Pt. 2, 1910.
[2] *Ibid.* **24**, Pt. 10, 1924.
[3] *London, Mem. R. Meteor. Soc.* **1**, No. 5, 1926, p. 81.
[4] *Ibid.* **2**, No. 14, 1928, p. 43.
[5] *Ibid.* **2**, No. 17, 1928.
[6] *Beitr. Physik Atmosph.* **14**, 1928, pp. 88-93.

CORRELATION COEFFICIENTS WITH WINNIPEG TEMPERATURE, DECEMBER TO FEBRUARY.

(Heavy type indicates coefficients which exceed the probable greatest due to pure chance.)

Element and locality.	No. of years.	June to Aug. 2 quarters before.	Sept. to Nov. 1 quarter before.	Dec. to Feb. contemporary quarter.
PRESSURE.				
Alaska	23	+·02	−·28	**−·52**
C. Siberia	49	+·18	−·24	+·14
San Francisco	52	+·18	−·02	−·18
Charleston	50	+·16	−·02	−·44
Azores	51	+·10	−·10	+·30
Tokyo	43	−·36	−·04	+·32
Cairo	53	+·34	+·14	+·30
Honolulu	42	**−·50**	−·30	**+·56**
Port Darwin	43	**+·52**	**+·58**	**+·52**
Mauritius	50	+·32	−·22	−·10
TEMPERATURE.				
Dutch Harbour	42	0	+·12	−·16
Batavia	52	+·28	+·58	+·72
Cape Town	53	+·44	+·16	−·22
Madras	52	+·56	+·50	**+·58**
St. Helena	33	+·44	+·32	+·20
RAIN.				
India Peninsula	50	**−·56**	...	...
N.W. India	50	−·54	...	...
Nile flood	53	−·52	...	...
Java	46	...	...	−·38

3. On extending the area under consideration Calgary, Edmonton, Prince Albert and Qu'Appelle were found to behave similarly to Winnipeg, but Dawson behaved differently. For the former group of five stations, which we may call South-West Canada, the closest relationships between the winter temperature, December to February, and previous conditions elsewhere are with Honolulu and Port Darwin pressures (June to August), with the monsoon rainfalls of India (North-West India and the Peninsula) and of the Nile flood,[7] and with Madras temperature (June to August). The coefficients between them, based in general on about 44 years' data, are—

	Honolulu.	Port Darwin.	Monsoon.	Madras.
Canada	−·56	+·62	−·60	+·58
Honolulu		−·62	+·54	−·56
Port Darwin			−·54	+·72
Monsoon				−·50

and the regression equation between their proportional departures is—

$$\{\text{Canada}\} = \begin{matrix} -\cdot 15 \{\text{Honolulu}\} + \cdot 24 \{\text{Port Darwin}\} \\ -\cdot 30 \{\text{Monsoon}\} + \cdot 17 \{\text{Madras}\} \end{matrix}$$

From this we find $R = \cdot 72$.

[7] The departure of "monsoon rainfall" used has been the mean of the proportional departures of North-West India, the Peninsula and the Nile: by "proportional" we mean that each has been divided by its own standard deviation.

If Madras were omitted the formula would become—

$$\{\text{Canada}\} = -\cdot18\ \{\text{Honolulu}\} + \cdot34\ \{\text{Port Darwin}\} - \cdot32\ \{\text{Monsoon}\}$$

and $R = \cdot71$.

4. In the following comparison between the actual temperature of South-West Canada and the calculated value, the year is that of the January in the winter foreshadowed. The results are plotted in Fig. 1.

DEPARTURES FROM NORMAL OF WINTER TEMPERATURES IN SOUTH-WEST CANADA.

(Actual and Calculated. ° F.)

Year.	0	1	2	3	4	5	6	7	8	9	
188	...	...	...	...	...	−9	−3	−11	−6	6	Act.
	...	...	...	...	...	−2	1	− 6	−3*	1	Cal.
189	−9	3	1	−5	−4	−2	1	2	2	−3	Act.
	−3	−6	3	−6	−5	−4	−1	0	−1	−1	Cal.
190	1	3	7	1	−2	0	7	− 6	8	−3	Act.
	5	0	3*	4	−1	3	5	− 1	3	−1	Cal.
191	0	−3	2	0	4	3	−2	− 6	−6	7	Act.
	−3	−3	5	2	5	3	3	− 4	−7	6	Cal.
192	2	6	0	−1	6	−3	11	0	2	...	Act.
	2	2	0	1	4	0	3	1	0	3	Cal.

* Less than 2·8.

The value of ·84 *ks* (see *Q.J.R. Meteor. Soc.*, 1926, p. 79) is 2·8° F., and it is only when the calculated departure equals or exceeds this limit (*i.e.* lies outside the lower pair of horizontal lines in Fig. 1) that a pre-

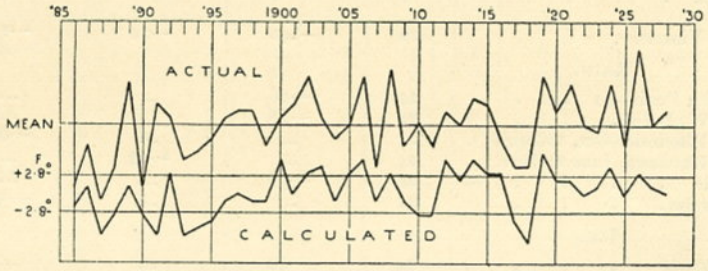

FIG. 1.[8]—S.W. Canada winter temperature: departures from normal
{S.W. Canada} = −·15 {Honolulu} + ·24 {Port Darwin}
−·30 {Monsoon} + ·17 {Madras}. $R = \cdot72$.

diction can be made with a 4 : 1 chance of success. Out of the 44 years there are 23 in which this condition is satisfied (printed above in heavy type), and out of these 23 there are 19 successes, two failures, and in two cases the winters were normal.

[8] The blocks for the illustrations for Figs. 1, 3 and 4 have been kindly supplied by The Clarendon Press, Oxford.

Winter Temperature at Dawson, North-West Canada.

5. With winter temperature at Dawson the chief coefficients, based on only 24 years of data, are—

Correlation Coefficients with Dawson Temperature, December to February.

(Heavy type indicates coefficients which exceed the probable greatest due to pure chance.)

Element and locality.	No. of years.	June to Aug. 2 quarters before.	Sept. to Nov. 1 quarter before.	Dec. to Feb. contemporary quarter.
Pressure.				
Iceland	24	−·20	+·04	−·02
Alaska	17	0	0	+·02
Azores	24	+·02	−·12	−·14
Charleston	24	+·26	0	−·34
San Francisco	24	+·12	−·18	−·14
Tokyo	24	−·22	−·12	+·28
Cairo	24	+·46	+·04	−·10
Honolulu	24	**−·56**	−·24	+·28
Port Darwin	24	+·48	+·50	+·44
Mauritius	24	+·42	+·16	−·14
Samoa	24	−·46	−·38	−·30
S. America	24	−·54	−·30	+·10
Zanzibar	24	+·54	+·30	+·38
Temperature.				
Dutch Harbour	23	+·04	+·16	−·06
N. America	24	+·46	−·04	+·22
Siberia	20	+·16	+·12	−·06
Honolulu	24	+·38	+·14	−·04
Batavia	24	−·24	+·24	+·40
St. Helena	24	+·24	+·26	+·38
Mauritius	24	−·38	+·32	**+·52**
Cape	24	+·14	+·14	−·36
St. Vincent	20	−·40	−·20	−·12
Rain.				
India Peninsula	24	−·26	...	...
N.W. India	24	**−·66**	...	...
S. Rhodesia, Oct. to April	24	...	...	**−·60**
S. Rhodesia, June to Nov.	24	...	−·22	...
Nile	24	−·38	...	...
Parana	21	...	...	**+·54**
Ice.				
Barents	24	−·20	...	...
Sunspots	24	−·40	−·34	−·32

6. The table of cross coefficients between Dawson temperature and June to August pressures at Honolulu, South America, Zanzibar and Port Darwin are—

	Honolulu.	S. America.	Zanzibar.	Port Darwin.
Dawson	−·56	−·54	+·54	+·48
Honolulu		+·58	−·26	−·62
South America			−·24	−·52
Zanzibar				+·28

The rainfall of North-West India has not been included because it is not supported by that of the Peninsula or Nile floods.

Hence we find for the regression equation—

$$\{\text{Dawson}\} = -\cdot26\ \{\text{Honolulu}\} - \cdot26\ \{\text{S. America}\} + \cdot39\ \{\text{Zanzibar}\} + \cdot07\ \{\text{Port Darwin}\}$$

with $R = \cdot72$.

Here a prediction can only have a 4: 1 chance when the indicated departure is 3·45° F. or over: this condition is satisfied 11 times in

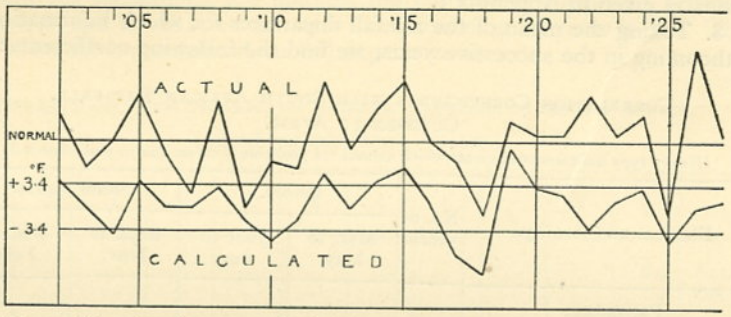

FIG. 2.—Departure from normal of Dawson temperature, December to February. {Dawson temperature} = −·26 {Honolulu} −·26. {S. America} +·39 {Zanzibar} +·07 {Port Darwin}. $R = \cdot72$.

24 years, and in 10 out of the 11 times the prediction would have been successful, the 11th occasion being a normal winter. The figures are given in the following table (heavy type denoting the 11 occasions referred to above) and illustrated in Fig. 2; the year is that of the January at Dawson.

DEPARTURES FROM NORMAL OF WINTER TEMPERATURES AT DAWSON.
(Actual and calculated. ° F.)

Year.	0	1	2	3	4	5	6	7	8	9	
190	...	...	4	−4	0	7	−2	−8	6	−10	Act.
	...	...	4	0	−4	4	0	0	3	− 2	Cal.
191	−3	−4	9	−1	5	9	0	−3	−11	3	Act.
	−5	−2	5	0	4	6	1	−7	−10	9	Cal.
192	1	1	7	1	4	−11	14	1	...	...	Act.
	3	2	−3	1	3	− 5	0	1	2	...	Cal.

THE SUMMER RAINS OF SOUTH AFRICA.

7. The first step when considering the rainfall of a large region is to ascertain whether it is homogeneous; and, if not, to divide the region into smaller areas which are sufficiently uniform in their behaviour. As might be expected, the winter rains of the extreme South-West of Africa, which are due to depressions travelling from the west like the winter rains of South-West Australia, depend on conditions other than those of the summer rains which are brought by moist winds from the Indian Ocean; but examination shows that the rainfall of Natal is largely

independent of that of the area to its west—consisting of the southern margin of the Transvaal, the east of British Bechuanaland, the Orange Free State and Cape Province (except the south-west). Natal has therefore been considered separately. The stations chosen to represent South Africa are Johannesburg, Kroonstad, Bloemfontein, Kimberley, Griquatown, Herschel, Aliwal North, Colesberg, Middleburg, Carnarvon, King William's Town, Port Elizabeth, Graaf Reinet, Beaufort West, Fraserburg; and the table of departures of rainfall, October to April, in inches, is given in Appendix I.

8. Taking the mean of the rainfall departures for which information is forthcoming in the successive years, we find the following coefficients:

CORRELATION COEFFICIENTS WITH SOUTH AFRICAN RAINFALL, OCTOBER TO APRIL.

(Heavy type indicates coefficients which exceed the probable greatest due to pure chance.)

Element and locality.	No. of years.	Before.		Same season.	
		Mar. to May.	June to Aug.	Sept. to Nov.	Dec. to Feb.
PRESSURE.					
Cairo	48	−·02	**−·42**	+·04	**−·32**
Honolulu	41	+·14	**+·44**	+·14	−·12
Port Darwin	44	−·18	**−·42**	**−·48**	**−·46**
Mauritius	48	0	+·08	+·26	+·26
Samoa	36	+·30	+·34	+·08	+·24
Cape Town	48	+·32	−·06	+·10	**−·54**
S. America	48	+·24	+·34	**+·38**	+·06
TEMPERATURE.					
Dutch Harbour	43	−·34	−·10	−·20	−·04
Honolulu	45	+·06	−·26	−·16	−·32
Batavia	47	+·12	−·12	−·28	+·10
St. Helena	33	−·34	−·22	−·22	−·12
Mauritius	32	+·08	+·16	**−·46**	**−·46**
Samoa	36	−·22	−·20	−·36	**−·50**
Cape Town	48	−·26	−·28	−·06	+·06
S. Orkneys	23	−·06	+·28	+·20	+·34
Ano Nuevo	23	−·04	+·50	+·38	−·04
Perth	40	−·10	−·38	−·18	+·16
RAINFALL.					
Java	47	...	...	...	**+·36**
S. Rhodesia	28	...	...	...	**+·68**
Peninsula (Indian)	48	...	+·24	...	...
N.W. India	48	...	**+·46**	...	...
Nile, July–Oct.	48	...	**+·48**	...	...
Nile, July–Sept.	48	...	**+·46**	...	...
Parana	39	...	...	...	−·26
SUNSPOTS	48	+·04	+·14	0	+·10

9. The closest relationship is with temperature from June to August at Ano Nuevo; but as this is based on only 23 years, while other relationships are based on 44 years and upwards, it may be ignored until further experience confirms it. The table of coefficients between South African rain, Honolulu pressure (June to August), Port Darwin pressure (June to September), and the mean of the Nile flood departures and of the monsoon of North-West India (June to September) is—

	Honolulu.	Port Darwin.	Nile and India.
South Africa . .	+·44	−·42	+·54
Honolulu . . .		−·60	+·56
Port Darwin . .			−·50

The consequent regression equation is—

South African rain =·13 {Honolulu} −·14 {Port Darwin} +·39 {Nile+N.W. India}

leading to $R = \cdot 58$. If, however, the first eight years, of which the rainfall data are incomplete, are ignored, the correlation coefficient between the actual and forecast values over the remaining 40 years is ·72. The table of actual and calulated rainfall departures is—

DEPARTURES FROM NORMAL OF SUMMER RAINFALL IN SOUTH AFRICA.

(Actual and calculated. Inches.)

Year.	0	1	2	3	4	5	6	7	8	9	
187	...	...	...	...	...	...	...	...	...	0·0	Act.
	...	...	...	...	...	...	...	...	...	1·4	Cal.
188	−2·1	6·6	−2·7	−2.6	−1·9	−5·1	0·6	1·5	0·1	−1·0	Act.
	1·8	0·4	0.4	0·5	0·6	0·9	0·1	1·9	1·4	−0·8	Cal.
189	4·0	5·7	3·3	0·9	4·3	2·5	−1·6	−1·3	0·1	−0·5	Act.
	1·1	**2·3**	−0·5	**2·5**	**2·2**	**2·7**	0·9	0·2	0·6	0·5	Cal.
190	−2·2	0·7	−0·3	−4·6	−0·2	−2·9	−2·8	6·7	−3·7	5·3	Act.
	−2·3	0·5	−1·1	**−2·6**	0·1	−1·2	**−2·7**	−0·2	**−2·4**	1·6	Cal.
191	−0·6	0·1	−2·0	−1·3	−4·4	−0·7	−2·3	1·1	2·5	−3·3	Act.
	1·5	0·5	**−2·1**	−1·0	**−3·3**	−1·2	**−2·6**	**2·1**	**3.2**	**−3·4**	Cal.
192	−0·7	1·2	−2·7	1·7	−2·0	5·8	−4·4	−3·2*	0·1*	...	Act.
	−0·9	−1·1	−0·8	−0·1	−0·9	0·3	−1·8	−0·6	−1·5	...	Cal.

* Added after computing of correlations.

The graph depicting these is Fig. 3. The limit of indicated departure for justifying a forecast is 2·04 inches of rain, and out of 50 years there are

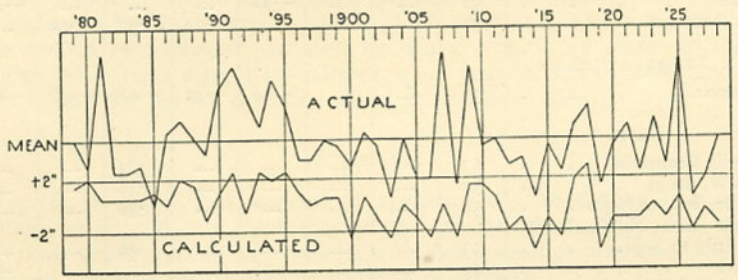

FIG. 3.—S. Africa rainfall, October to April. {S. Africa} =·13 {Honolulu} −·14 {Port Darwin} +·39 {Nile+India}. $R = \cdot 58$.

14 (denoted by heavy type) in which this has occurred; in all of these the sign of the departure is correct.

Natal.

10. The data studied are those of Durban, New Hanover, Pietermaritzburg, Stanger and Verulam; the periods range in length from 30 to 33 years, except that for Durban, which covers 50 years. Like that of the previous region, the rainfall of Natal is in excess when pressure in the Indian Ocean is in defect, i.e. it belongs to the first group of the southern oscillation; but the relationships are less close and there is only a short series of years as yet available.

The Summer Rainfall of Australia.

11. Inasmuch as Australia gets important rain in its western and southern regions from winter depressions as well as summer rain along its northern and eastern coastal districts, it has seemed wise to begin with the simpler problem—that of the rainfall brought by moist winds from the north and north-east—and to limit consideration to the Kimberley Division of West Australia, Northern Territory and Queensland. The stations used are—(Western Australia) Derby and Hall's Creek; (Northern Territory), Darwin, Katherine, Victoria Downs, Daly Waters, Borroloola, Powell's Creek, and Tennant's Creek; (Queensland) McDonnell, Coen, Maytown, Normanton, Georgetown, Cardwell, Cloncurry, Hughenden, Bowen, Mackay, Carrandotta, Winton, Clermont, Springsure, Gladstone, Taroom, Maryborough, Charleville, Thargomindah and Brisbane. Their seasonal departures from October to April are given in Appendix II., and the results for the whole region in the table on p. 90.

Correlation Coefficients with Australia Rain, October to April.

(Heavy type indicates coefficients which exceed the probable greatest due to pure chance.)

Element and locality.	No. of years.	Two years before.		Year before.			Same season.	
		Dec.-Feb.	June-Aug.	Dec.-Feb.	Mar.-May.	June-Aug.	Sept.-Nov.	Dec.-Feb.
Pressure.								
Honolulu	45	−·06	·10	·16	**·50**	**·52**	**·34**	−·16
Port Darwin	46	·12	·02	−·10	−·24	−·74	**−·72**	−·74
Port Darwin, June to Sept.	46	...	...	...	...	**−·72**	...	...
Mauritius	51	...	...	...	−·06	−·34	·08	−·10
Samoa	36	...	...	...	·42	·34	·10	**·50**
Cape	52	...	...	−·18	...	...	...	**−·40**
S. America	58	...	·22	...	·34	**·52**	**·42**	...
Temperature.								
Samoa	36	...	...	−·26	−·42	−·08	**−·46**	**−·66**
Rain.								
India Peninsula	53	...	...	...	...	·34	...	...
N.W. India	53	...	...	...	...	·38	...	...
Nile, July to Sept.	58	...	...	...	...	·36	...	...
Nile and N.W. India, July to Sept.	53	...	...	...	...	**·40**	...	...
Java	47	...	...	−·06	...	...	...	**·52**
S. Rhodesia	28	...	...	−·48	...	...	...	·06
S. Africa	48	...	...	·12	...	...	...	·38
Parana	39	...	...	−·02	...	...	...	**−·50**
Sunspots	58	...	...	...	...	...	...	·08

12. The correlation coefficients with the most promising world centres are as shown in the previous table.

13. The closest relationships with antecedent seasons are with pressures at Honolulu (March to August), Port Darwin (June to August), and South America (June to August); and the cross coefficients are—

	Honolulu.	Port Darwin.	S. America.
Australia . . .	+·62	−·74	+·52
Honolulu . . .		−·58	+·48
Port Darwin . . .			−·50

Thus—

$$\{\text{Australia}\} = \cdot 25\,\{\text{Honolulu}\} - \cdot 53\,\{\text{Port Darwin}\} + \cdot 14\,\{\text{S. America}\}$$

Hence it follows that $R = \cdot 79$, and the shortest series of years on which the formula rests is 45. It appears unnecessary to include Southern Rhodesia until its series is longer, though this would probably raise R to above ·80.

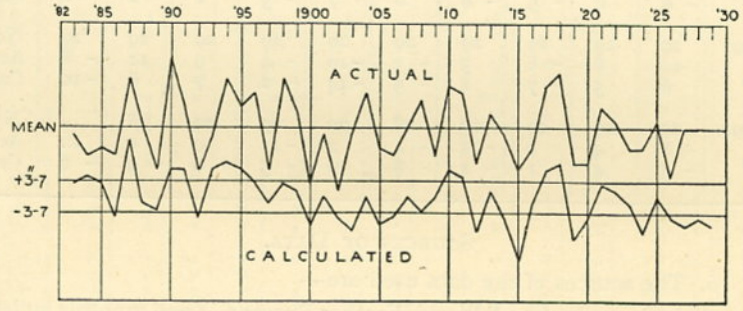

FIG. 4.—Australia rainfall October to April. ·25{Honolulu Press. M-A} −·53 {Port Darwin Press. J-A} +·14 {S. America Press. J-A}. Limit for predictions 3·7 inches. $R = \cdot 79$.

14. The table on p. 90 contains the number of stations in each year, beginning with 1871 when there were already eight stations, and the actual rainfall departures in inches with the departures given by the formula since 1883 for comparison.

The requirement for a justifiable prediction is a departure of at least 3·7 inches in the calculated rainfall. This amount has been equalled or exceeded on 29 occasions (denoted by heavy type) in 47 years; of these 24 give the correct sign, 2 are failures, 2 are years of normal rain, and in the last year the rainfall data are not as yet available here.

SUMMARY.

15. It is urged that instead of speaking of "forecasting" seasonal rainfall we should say "foreshadowing" it, for forecasting is a more ambitious term, and has associations with daily weather predictions made on every occasion with a high probability of success.

Statistical methods have been applied to foreshadowing the winter temperatures of Western Canada ($R = \cdot 71$), Dawson ($R = \cdot 72$), the summer rains of South Africa, excluding Natal ($R = \cdot 72$), and the summer rains of Northern and North-Eastern Australia ($R = \cdot 79$).

DEPARTURES FROM NORMAL OF AUSTRALIAN SUMMER RAINFALL.
(Actual and calculated departures in inches.)

Year.	0	1	2	3	4	5	6	7	8	9	
187	...	8	9	14	16	16	16	16	16	15	No.
	...	0	3	9	2	12	− 4	4	− 3	7	Act.
	...	...	...	...	...	...	...	...	...	...	Cal.
188	16	17	17	18	18	23	25	25	27	27	No.
	3	2	− 1	− 2	− 6	− 4	− 6	11	0	− 9	Act.
	...	...	...	3	5	3	− 5	13	− 1	− 3	Cal.
189	28	28	29	29	29	29	29	29	29	29	No.
	16	5	− 10	− 1	11	5	8	− 9	11	3	Act.
	7	6	− 4	6	9	6	3	− 2	3	2	Cal.
190	29	29	29	29	29	29	29	29	29	29	No.
	− 13	− 2	− 15	− 2	8	− 5	− 6	0	7	− 6	Act.
	− 6	0	− 5	− 8	0	− 7	− 5	1	− 2	0	Cal.
191	29	29	29	29	29	29	29	29	29	29	No.
	10	8	− 8	3	− 1	− 10	− 4	9	12	− 8	Act.
	6	5	− 7	1	− 5	− 14	− 2	7	8	− 10	Cal.
192	29	29	29	29	28	29	29	29	28	...	No.
	− 8	4	2	− 4	− 4	2	− 11	0	0	...	Act.
	− 5	4	1	− 2	− 8	0	− 5	− 6	− 4	− 6	Cal.

SOURCES OF DATA.

16. The sources of the data used are—

Canadian Temperature: "World Weather Records"[9] and monthly bulletins of the Canadian Meteorological Service.

Honolulu Pressure: "World Weather Records"[9] and *Monthly Weather Review, Washington.*

Port Darwin Pressure: "World Weather Records."[9]

Peninsula and North-West India rain: *India Meteor. Mem.* **23**, 2, p. 36.

Nile floods: *Mem. R. Meteor. Soc.* **1**, No. 5, and MSS. of Physical Department, Cairo.

South Africa: (1) "Report from the Select Committee on Droughts, Rainfall, and Soil Erosion." The Parliament of the Union of South Africa, 1914.

(2) "World Weather Records."[9]

(3) MSS. of Dr. J. R. Sutton of Kimberley, South Africa.

(4) MSS. of C. Stewart, Chief Meteorologist, Union of South Africa.

Australia: The data have been extracted from two publications: "Results of Rainfall Observations made in Queensland," Melbourne, 1914; and "Results of Rainfall Observations made in South Australia and the Northern Territory," Melbourne, 1918; as well as from MSS. kindly supplied by Mr. Hunt, the Commonwealth Meteorologist.

[9] *Washington, Smithsonian Miscellaneous Collection,* **79**, 1927.

APPENDIX I.—Summer Rainfall of South Africa, October to April.

(Departures from normal in inches.)

The year of Jan. to Apr.	Johannesburg.	Kroonstad.	Bloemfontein.	Kimberley.	Griquatown.	Herschel.	Aliwal North.	Colesberg.	Middleburg.	Carnarvon.	King William's Town.	Port Elizabeth.	Graaf Reinet.	Beaufort West.	Fraserburg.
1875	..	..	..	..	..	..	..	..	..	..	..	6	..	..	..
1876	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..
1877	..	..	..	..	..	..	..	..	..	..	..	−1	..	..	..
1878	..	..	..	−5	..	..	..	..	..	..	..	0	..	..	..
1879	..	..	−1	−2	..	..	..	−5	−4	−2	..	3	..	−5	−2
1880	..	1	−4	−6	..	..	..	−5	−5	1	..	2	..	−2	−1
1881	..	15	17	15	..	..	..	1	5	3	..	0	..	1	2
1882	..	−1	−5	0	..	..	..	−1	−4	−4	..	−5	−3	−2	−2
1883	..	−1	−2	−5	..	−5	..	−5	−3	−2	..	0	−2	−3	−1
1884	..	−7	−4	−3	2	−5	1	−1	−4	0	..	−2	−5	−1	−2
1885	..	−1	−9	−7	−6	−11	−6	−7	−5	0	..	−5	−3	−3	−2
1886	..	5	−3	−5	0	−3	2	−1	2	4	6	−1	2	−1	1
1887	..	6	−1	0	0	−3	5	1	1	0	5	2	5	0	0
1888	..	5	0	4	0	−2	2	1	−2	−1	0	−3	−1	−1	−1
1889	−9	−5	5	−4	−1	−1	4	2	−3	2	−5	0	1	−1	0
1890	−10	−2	8	6	3	−1	3	6	4	6	12	3	8	6	8
1891	10	7	8	9	10	7	11	7	12	2	1	−5	5	0	1
1892	−5	5	10	6	3	8	3	6	3	0	3	3	3	0	1
1893	−5	6	−1	−2	−1	7	1	1	4	1	3	−2	−1	2	0
1894	3	6	3	7	11	6	−1	5	7	1	9	1	6	4	3
1895	−3	−2	8	2	7	4	7	5	2	2	1	−3	1	4	2
1896	−11	5	−1	−2	−2	−6	1	1	−1	0	2	−4	−2	−3	−1
1897	−1	−2	0	2	−4	3	0	−3	−2	−1	−2	−6	0	−3	−1
1898	−4	−8	1	0	0	2	3	5	0	−1	4	1	0	−1	0
1899	−8	0	−7	2	0	4	5	1	0	0	−2	−1	1	−2	−1
1900	−4	3	..	1	..	1	−10	−5	−6	2	−8	−3	−1	0	1
1901	2	−2	..	5	1	−3	−5	4	..	3	3	−2	0	2	1
1902	3	3	..	2	0	3	0	−4	..	0	−5	−2	0	−2	−2
1903	−4	−4	..	−2	−3	−8	−6	−7	−7	−4	−5	−1	−3	−5	−5
1904	3	−1	1	4	−2	−1	−3	−2	−4	0	2	2	0	−1	−1
1905	−5	−4	1	−3	−3	−3	−6	−3	−4	−2	−8	0	−3	−2	2
1906	−2	−6	−7	1	−3	−3	−7	−9	−2	−1	1	0	−1	0	−3
1907	7	7	8	8	4	12	13	8	9	3	7	5	2	6	2
1908	−6	−5	−6	−1	−5	−3	−4	−6	−7	−2	−5	3	−4	−2	−2
1909	16	7	5	4	4	7	6	6	..	4	−2	4	5	5	3
1910	1	1	−5	−2	−2	1	−2	1	..	−1	−5	4	−2	3	0
1911	−3	−2	1	−7	1	3	0	1	..	0	2	2	2	3	−1
1912	−6	1	−5	−1	−6	6	−2	−2	−4	−3	−4	−2	−2	2	−2
1913	−8	−5	−4	−1	1	−1	−2	1	−1	0	1	−3	0	0	3
1914	−5	−5	−10	−6	−5	−11	−8	−3	−5	−1	−1	−1	−3	1	−3
1915	11	−1	4	0	−3	3	4	−7	−6	−2	−6	−2	−2	−2	−2
1916	1	−1	−1	−4	−7	−2	−4	−3	−2	−4	−5	3	−4	−1	−1
1917	4	0	1	−2	2	−3	−2	2	2	4	−2	4	4	0	3
1918	28	−2	−3	−4	2	−7	−2	1	3	2	5	4	3	8	−1
1919	1	−3	−5	−3	−3	−8	−2	−7	−7	−4	−5	1	−5	1	0
1920	−8	1	1	4	2	−3	−3	1	−3	1	−8	1	3	−2	2
1921	3	−2	−1	0	−1	−4	−2	3	−6	4	2	3	4	9	6
1922	1	−1	−11	−4	−7	−9	−8	−5	−2	−2	−2	3	2	3	1
1923	3	4	4	−3	−1	9	4	−2	−2	0	8	5	−2	0	−2
1924	−6	−7	−2	−4	−3	−1	1	1	−4	1	2	−6	0	−1	−1
1925	3	8	3	9	9	17	12	14	2	5	5	1	0	0	−1
1926	−7	−1	−3	−7	−6	−2	−6	−6	−5	−4	−6	2	−4	−6	−3
1927	−8	4	−2	−4	−5	−5	0	−7	−4	−8	8	−4	−5	−3	−5
1928	−2	−2	−5	1	4	3	1	−5	−6	1	−3	10	2	3	0
Mean rainfall	31	21	19	14	11	23	17	13	12	6	17	7	10	7	5

APPENDIX II.—Summer Rainfall of

(Departure from

	Derby.	Hall's Creek.	Darwin.	Katherine.	Victoria Downs.	Daly Waters.	Borroloola.	Powell's Creek.	Tennant's Creek.	McDonnell.	Coen.	Maytown.	Normanton.	Georgetown.	Cardwell.
1866	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...
1867	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1868	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1869	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1870	...	...	0	...	...	...	...	...	...	...	...	...	...	...	...
1871	...	...	− 2	...	...	...	...	...	...	...	...	...	...	...	...
1872	...	...	17	...	...	...	...	...	...	...	...	...	...	...	15
1873	...	...	3	5	...	15	...	...	...	...	...	...	8	13	45
1874	...	...	− 1	7	...	2	...	4	0	...	...	...	2	17	5
1875	...	...	− 3	11	...	14	...	7	2	...	...	...	14	29	2
1876	...	...	3	7	...	1	...	− 3	5	...	...	...	− 8	4	− 9
1877	...	...	7	0	...	17	...	13	8	...	...	...	− 2	14	34
1878	...	...	− 11	5	...	− 5	...	− 10	1	...	...	...	− 18	0	− 3
1879	...	...	16	12	...	6	...	1	3	...	...	...	11	5	...
1880	...	...	3	− 2	...	− 1	...	− 1	0	...	...	...	− 3	− 5	12
1881	...	...	− 5	− 9	...	− 8	...	2	1	...	...	...	10	− 1	25
1882	...	...	− 11	− 2	...	− 6	...	− 6	0	...	...	...	− 4	6	32
1883	...	...	4	− 10	...	− 2	...	1	− 4	...	...	...	− 4	− 3	− 23
1884	...	...	6	− 5	...	3	...	− 5	− 2	...	...	...	− 24	− 6	− 25
1885	...	...	9	− 3	...	− 3	...	− 1	9	...	...	− 15	− 6	12	− 23
1886	22	...	− 2	− 6	− 7	− 2	...	− 4	2	...	...	− 3	− 20	− 1	− 21
1887	− 1	...	2	− 2	12	11	...	5	7	...	...	18	13	21	39
1888	12	...	9	− 2	− 2	− 7	...	− 4	− 3	7	0	17	− 6	− 4	− 6
1889	− 4	...	− 14	0	− 4	0	...	− 4	9	− 22	− 17	− 10	− 24	− 12	− 32
1890	− 2	...	6	6	1	5	11	3	2	31	18	19	28	13	49
1891	5	...	13	− 6	− 5	− 10	14	− 5	− 3	− 5	− 6	6	13	9	9
1892	− 9	− 8	− 15	− 21	− 8	− 12	− 14	− 9	− 7	− 14	− 10	− 8	− 20	− 12	− 26
1893	− 3	1	1	− 6	− 12	− 3	− 11	− 9	− 7	− 7	− 5	− 3	− 18	− 3	− 29
1894	− 1	5	2	4	0	0	26	14	12	13	21	9	20	13	60
1895	− 11	− 2	10	4	1	10	6	18	4	12	4	3	11	5	2
1896	9	9	19	3	6	5	14	6	6	8	4	2	− 3	22	15
1897	− 9	− 4	− 2	− 1	− 5	− 2	− 15	− 3	− 7	− 27	− 20	− 15	− 6	− 4	− 28
1898	1	1	15	38	3	4	23	− 5	− 3	20	8	21	12	3	− 13
1899	32	4	0	23	13	12	23	12	− 3	1	− 8	9	− 6	− 1	− 10
1900	− 9	− 2	− 17	− 10	− 8	− 18	− 19	− 9	− 10	− 40	− 27	− 20	− 18	− 6	− 21
1901	− 12	− 1	− 6	14	9	0	4	5	− 6	− 20	12	− 7	7	− 3	22
1902	− 7	− 4	− 8	− 18	− 11	− 10	− 12	− 7	− 9	2	− 25	− 17	− 21	− 16	− 33
1903	− 2	15	− 15	− 7	2	− 6	− 10	0	3	3	9	19	2	7	8
1904	10	16	16	20	28	16	1	19	10	15	− 2	22	7	3	42
1905	− 11	− 13	3	− 10	− 12	− 6	− 5	− 7	− 5	− 12	− 12	1	1	− 14	− 27
1906	− 14	− 13	− 31	− 14	− 11	− 11	− 13	− 9	− 5	− 21	− 25	− 16	− 11	− 10	8
1907	18	5	− 4	12	3	− 5	1	8	1	16	17	− 4	− 5	− 1	− 2
1908	0	− 5	7	11	2	3	2	− 4	8	2	30	10	8	6	23
1909	− 4	− 5	2	− 11	− 8	− 12	− 1	− 4	− 11	− 5	− 6	− 10	− 8	− 7	− 11
1910	− 5	− 1	13	9	− 1	6	6	11	6	21	34	15	20	4	22

AUSTRALIA, OCTOBER TO APRIL.

normal in inches.)

Cloncurry.	Hughenden.	Bowen.	Mackay.	Carrandotta.	Winton.	Clermont.	Springsure.	Gladstone.	Taroom.	Maryborough.	Charleville.	Thargomindah.	Brisbane.	
...	...	...	...	...	...	...	−13	...	...	...	...	...	−15	1866
...	...	...	...	...	...	...	6	...	...	...	...	...	20	1867
...	...	...	...	...	...	...	−11	...	...	...	...	...	−12	1868
...	...	...	...	...	...	...	13	...	...	...	...	...	6	1869
...	...	...	...	...	...	...	6	...	...	...	...	...	25	1870
...	...	− 1	3	...	...	2	− 3	...	4	− 4	...	...	5	1871
...	...	− 1	−12	...	...	0	−11	...	2	12	...	...	6	1872
...	...	9	− 7	...	...	3	9	4	8	7	...	...	8	1873
...	...	− 3	− 8	...	...	− 1	0	− 7	− 5	8	...	...	8	1874
...	...	40	21	...	...	9	...	7	3	20	1	...	15	1875
...	...	−17	−16	...	...	9	...	−10	− 6	− 1	−10	...	− 8	1876
...	...	− 3	7	...	...	0	− 4	− 8	− 2	− 7	...	...	−11	1877
...	...	4	8	...	...	− 8	0	− 3	− 3	− 6	...	...	5	1878
...	...	− 2	29	...	...	5	− 2	13	− 3	2	...	...	6	1879
...	...	0	11	...	...	7	12	− 3	...	5	...	5	2	1880
...	...	5	17	...	...	3	− 3	10	...	− 4	2	− 6	2	1881
...	...	− 6	− 4	...	...	11	2	− 2	...	−12	1	3	−13	1882
...	...	− 2	7	2	...	− 6	− 6	−14	...	17	5	1	4	1883
...	...	− 1	19	− 3	...	− 5	− 4	−12	...	−15	− 3	− 5	−17	1884
− 8	− 3	−14	−12	3	− 3	− 8	− 4	−11	− 3	− 6	− 5	3	−10	1885
−10	− 9	−10	−25	− 5	− 4	−12	− 6	−14	− 4	− 7	− 7	0	− 7	1886
10	16	4	4	9	15	12	11	8	14	13	6	12	25	1887
4	4	−16	0	7	1	− 6	− 5	7	− 1	−10	− 3	7	− 4	1888
− 8	− 1	−11	−15	− 3	− 6	− 4	− 9	−10	− 3	−12	− 1	− 4	−10	1889
8	7	12	47	− 2	13	21	16	26	20	14	30	4	35	1890
21	18	− 1	27	0	11	13	4	6	2	−13	21	10	−11	1891
− 2	− 8	−16	−30	− 5	− 3	−10	− 7	− 8	− 4	8	− 8	− 6	16	1892
−10	− 9	27	−19	− 6	− 8	− 3	− 2	41	8	38	− 4	0	43	1893
13	13	22	24	6	11	− 2	2	− 6	5	12	11	0	0	1894
8	4	6	20	8	6	− 8	8	6	0	14	0	− 3	11	1895
− 6	0	31	8	3	− 5	13	9	11	5	11	13	− 1	10	1896
− 1	− 5	− 7	−35	0	− 6	−10	−10	−18	− 5	−13	− 6	2	− 8	1897
0	6	18	53	2	− 3	14	5	41	5	20	3	3	26	1898
− 7	− 6	10	− 6	− 2	− 2	0	− 1	9	2	− 1	− 9	− 2	−10	1899
−11	− 8	−21	−21	− 6	− 9	−11	− 9	−11	− 4	−17	−11	− 5	− 4	1900
− 1	− 9	5	1	− 3	− 2	−12	−10	−14	−10	− 3	− 8	− 6	−10	1901
−13	−11	−26	−30	− 7	− 9	−17	−13	−23	−13	−24	−11	− 8	−24	1902
5	−10	− 4	−17	2	− 5	−12	− 5	−16	− 6	−19	0	2	−13	1903
20	0	−16	− 9	7	3	− 2	4	− 1	− 2	− 5	5	0	− 6	1904
− 8	− 2	2	4	− 4	− 8	0	0	14	2	4	0	0	− 8	1905
− 1	2	− 2	−13	− 4	9	0	9	7	10	− 6	3	8	2	1906
− 1	− 4	−12	−21	5	− 6	− 5	3	− 2	− 2	− 1	− 1	− 3	−12	1907
9	9	5	5	6	3	9	5	7	9	8	1	3	7	1908
− 5	0	− 8	−25	2	− 2	− 4	− 5	−10	− 2	− 8	5	0	−17	1909
1	5	40	51	1	1	9	7	8	4	− 7	6	− 1	− 3	1910

APPENDIX II.—

	Derby.	Hall's Creek.	Darwin.	Katherine.	Victoria Downs.	Daly Waters.	Borroloola.	Powell's Creek.	Tennant's Creek.	McDonnell.	Coen.	Maytown.	Normanton.	Georgetown.	Cardwell.
1911	− 8	0	5	− 9	10	8	2	− 6	− 7	15	29	26	20	− 2	24
1912	4	− 1	− 2	0	5	− 4	− 7	− 1	− 5	− 24	− 19	− 13	1	− 9	− 11
1913	− 7	− 4	− 5	− 4	− 5	− 11	− 1	− 1	7	7	3	26	9	− 3	19
1914	− 5	− 1	− 9	− 6	− 7	− 6	− 2	− 9	− 4	24	30	− 7	9	2	9
1915	− 1	9	− 7	− 11	− 1	− 9	− 7	0	3	− 23	− 13	− 18	− 18	− 12	− 44
1916	3	− 1	3	4	− 8	− 4	2	− 11	− 4	8	− 8	− 2	− 7	2	− 23
1917	23	0	26	6	− 4	0	− 1	5	3	13	− 3	13	12	15	11
1918	1	5	13	9	2	1	3	2	7	7	1	2	20	3	39
1919	1	− 5	− 3	− 14	− 5	− 3	− 1	− 3	11	− 13	− 12	− 14	− 1	− 15	− 33
1920	0	− 11	− 6	− 12	− 8	− 7	− 3	− 2	− 5	− 23	− 17	− 11	0	− 2	− 15
1921	1	3	7	6	5	12	8	17	12	11	33	− 5	6	− 7	− 15
1922	− 6	8	10	− 5	4	6	4	6	− 7	3	12	2	19	0	5
1923	− 2	− 1	10	0	8	5	3	− 1	0	13	11	− 20	− 12	− 12	− 39
1924	− 21	− 6	− 12	4	3	− 9	− 3	− 3	− 5	− 6	− 14	− 9	3	− 6	− 11
1925	− 11	− 5	10	− 4	7	10	10	1	− 4	20	9	0	10	4	− 1
1926	10	15	− 12	− 16	− 2	− 8	− 17	7	− 1	− 32	− 25	− 18	− 27	− 21	− 46
1927	9	5	− 21	− 11	10	5	− 7	− 2	0	8	− 4	− 5	− 13	− 1	26
1928	− 12	− 8	− 23	− 7	− 9	− 7	− 11	− 4	− 7	− 1	5	0	4	− 12	− 19
Mean rainfall	25	20	59	38	23	26	27	17	13	63	45	36	38	30	73

Continued.

Cloncurry.	Hughenden.	Bowen.	Mackay.	Carrandotta.	Winton.	Clermont.	Springsure.	Gladstone.	Taroom.	Maryborough.	Charleville.	Thargomindah.	Brisbane.	
14	9	20	9	− 4	1	8	3	29	4	9	6	0	8	1911
− 3	− 3	− 24	− 35	0	− 1	− 14	− 9	− 18	− 6	− 5	− 9	0	− 11	1912
2	2	3	24	− 2	5	− 4	− 5	14	2	15	7	4	1	1913
− 4	− 1	− 7	4	− 1	− 1	− 4	− 9	− 11	− 6	8	− 3	− 5	− 14	1914
− 3	− 5	− 23	− 32	− 4	− 7	− 11	− 10	− 2	− 5	− 14	− 5	− 5	− 13	1915
0	1	− 14	− 17	3	2	− 6	− 7	− 13	− 3	− 12	− 7	− 1	− 2	1916
8	17	12	13	10	15	33	18	1	7	0	20	4	− 5	1917
5	20	53	75	1	16	24	30	0	7	12	1	1	0	1918
4	− 9	− 13	− 25	4	− 2	− 9	− 10	− 18	− 7	− 20	− 5	− 5	− 21	1919
2	− 3	− 11	− 20	8	− 1	− 10	− 10	− 21	− 9	− 12	− 5	− 6	− 14	1920
0	0	− 6	14	7	3	− 3	− 4	− 11	0	7	1	4	− 2	1921
− 2	− 1	0	− 20	− 3	9	6	− 1	16	− 5	1	− 7	− 5	− 5	1922
− 9	0	− 22	− 28	− 2	− 4	− 1	− 3	− 6	− 2	− 3	− 1	0	− 12	1923
− 4	6	− 5	− 18	− 3	7	− 2	3	− 3	1	...	4	− 2	− 12	1924
7	− 3	8	− 10	2	4	− 5	2	− 13	12	6	4	2	− 4	1925
− 9	− 15	− 13	− 31	− 4	− 10	− 13	− 7	− 13	− 1	− 7	− 3	3	− 10	1926
− 3	− 3	− 3	− 7	− 5	− 7	− 2	8	13	− 2	7	− 4	− 7	16	1927
− 11	− 9	10	43	...	− 9	6	12	14	13	21	1	− 5	24	1928
17	17	34	57	8	13	22	20	32	19	34	14	8	34	Mean rainfall