DEPARTMENT OF PHYSICS.

VOLUME 1. 1939. NUMBER 3.

FORESHADOWING SUMMER RAIN IN QUEENSLAND.

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DATE OF PUBLICATION:

4TH OCTOBER, 1939.

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SUMMARY.

Statistical methods are used to study the relationship between rainfall in seven selected districts in Queensland and world weather. The control of the southern oscillation (June-August) varies from ·56 in the Ipswich district to ·75 in the Roma district. Correlation coefficients with previous pressures, temperatures, and rainfalls in other regions are given. From these coefficients formulæ are derived for foreshadowing the November-January rain in five of the districts, the December-February rain in two, the January-April rain and the October-December rain in one each, the total correlation coefficients ranging from ·72 to ·81. With predictions limited to those which have a 4 : 1 chance of success, the "performance" of the formulæ over eight years beyond the period used in computing the correlation coefficients is satisfactory.

INTRODUCTION.

It is well known that seasons in different parts of the world are not independent of one another, but are often closely connected, even at places which are widely separated. With the gradually increasing recognition of the unity of the earth's atmosphere and of the consequent dependence of local weather sequence on the state of the general circulation, considerable attention has been paid to the relations existing between seasonal features in different parts of the world.

Sir Gilbert Walker introduced the idea that world weather is dominated by three fluctuations or oscillations of pressure, known as the North Atlantic (N.A.O.), the North Pacific (N.P.O.) and the Southern (S.O.) Oscillations. Since the N.A.O. and the N.P.O. exercise their control mainly over regions in the Northern Hemisphere, we in Australia are more concerned with the S.O., which may be briefly described as a fluctuation of pressure between the Indian and the Pacific Oceans, low pressure in the former area being usually associated with an excess of pressure in the latter.

Walker has gradually developed the principal features of this oscillation, discovering regions over which variations are linked together. The positive area where high pressure corresponds to an increase in the general circulation extends from Bengal across the Pacific to South America, while the negative area of contemporary low pressure over the Indian Ocean embraces a large portion of Africa on the one side, and the continent of Australia on the other. Of particular interest is the close relation which exists between pressure, temperature, and rainfall, high pressures in the Pacific being associated with low temperature and high rainfall over large areas in tropical and sub-tropical regions, the terms "high" and "low" referring to seasonal deviations from the local average for the corresponding period.

After finding by a preliminary investigation the most representative stations, Walker has chosen a series of figures to represent the variations of each oscillation for the four quarters of the year, December-February, March-May, June-August, September-November, and from these have been obtained the relations of the S.O. with pressure, temperature, and rainfall over wide regions. Walker's formula (1932) for the June-August S.O. is:—

(Santiago pressure) + (Honolulu pressure) + India rain
+ (Nile flood) + ·7 (Manila pressure) — (Batavia pressure)
— (Cairo pressure) — (Madras temperature)
— ·7 (Darwin pressure) — .7 (Chile rain)

That conditions in the southern winter exercise greater influence on subsequent seasons than those in the southern summer is strikingly confirmed by the correlation coefficient of ·84 between the June-August S.O. and the following December-February S.O., while the control of the December-February S.O. on the following June-August S.O. is only ·20 (Walker, 1932). Hence any factor which has a close relationship with the contemporary December-February S.O., should have a corresponding relation with the S.O. of the previous June-August, which is extremely persistent, i.e. there should be a three month's foreshadowing which is of practical value in seasonal forecasting. After finding centres with which the season in question varies, a regression equation involving data available at the beginning of the season is worked out, and from the equation the most probable departure from average of the element considered can be determined.

Sir Gilbert Walker (1930) in studying the summer rainfall (October-April) of the Kimberley division of West Australia, Northern Territory, and Queensland found that an abundant monsoon tends to be preceded by high pressure at Honolulu and South America, and by low pressure in Northern Australia. He obtained a formula which had a coefficient of ·79 with the summer rainfall of North Australia. H. M. Treloar (1934) also obtained formulae with coefficients of ·71, ·51, and ·54 for the rain in the Darwin, Pine Creek, and Victoria River Downs districts in North Australia.

Rain over different parts of such a large area as that investigated by Walker may be controlled by various factors, and the object of this research was to find what relationships the rainfall of Queensland bore to the S.O. and, if possible, to develop formulae which would be directly applicable to foreshadowing the rainfall in restricted districts in Queensland.

1. METHOD OF INVESTIGATION.

To obtain districts homogenous with regard to rainfall, adjacent stations whose average annual rainfalls were of the same magnitude were selected, then three-monthly averages were compared. It was intended to represent each district by the average of six stations, but in two instances lack of suitable data reduced the number of stations to four.

Having obtained three-monthly averages for the summer rainfall in various districts, the departures over a period of forty-five years were correlated with the previous June-August S.O. It was found that the November-January rain in five districts in south-east Queensland gave correlation coefficients with the S.O., ranging from ·56 to ·75. The Downs and Roma districts in the south-east appeared to be a local centre or focus, values falling off as we proceed either inland or down the Brisbane Valley through the Ipswich district.

In the north, another centre was found in the Charters Towers and Georgetown districts, where the December-February rain gave correlations of ·71 and ·60 respectively with the previous June-August S.O., while the Charters Towers October-December rain also gave a correlation of ·69.

Attempts were made to find relationships with the late summer rain, but only in the Springsure district where the January-April rain had a correlation of ·62 was any success attained.

Relationship with the S.O. having been established the various district rainfalls were correlated with values of pressure, temperature, or rainfall for selected months, at various centres controlled by the S.O. For convenience in calculation, "reduced departures" for the various elements were used in working out the correlation coefficients and only those coefficients which satisfied Walker's (1914) criterion for reliability were used in formulae.

As several coefficients satisfied the reliability criterion, they were further tested by extending the correlations from forty-five to fifty-three years. There was an appreciable falling off in value with some of the coefficients and in selecting the elements to be used in the various formulae, not only the magnitude of the correlation coefficients was taken into account, but also their consistency over the extended period.

TABLE I.

ANNUAL AND QUARTERLY RAINFALL AVERAGES IN INCHES FOR REPRESENTATIVE STATIONS IN DISTRICTS SELECTED.

Districts.		Stations.				
Key No. Fig. 1.	Name.	Key No. Fig. 1.	Name.	Annual. Average.	Quarterly Average. Quarter.	Quarterly Average. Average.
I	St. George ..	1	Bollon	18	Nov.-Jan...	6
		2	Dirranbandi	18	Nov.-Jan...	6
		3	St. George	20	Nov.-Jan...	6
		4	Welltown	21	Nov.-Jan...	7
II	Downs	5	Allora	27	Nov.-Jan...	10
		6	Dalby	26	Nov.-Jan...	9
		7	Goondiwindi ..	24	Nov.-Jan...	8
		8	Inglewood	26	Nov.-Jan...	9
		9	Pittsworth	28	Nov.-Jan...	10
		10	Warwick	27	Nov.-Jan...	10
III	Ipswich	11	Esk	39	Nov.-Jan...	13
		12	Ipswich	33	Nov.-Jan...	12
		13	Laidley	31	Nov.-Jan...	13
		14	Mundoolun	37	Nov.-Jan...	13
		15	Nanango	31	Nov.-Jan...	11
IV	Roma..	16	Miles	26	Nov.-Jan...	9
		17	Mitchell	23	Nov.-Jan...	8
		18	Roma	23	Nov.-Jan...	8
		19	Surat	23	Nov.-Jan...	7
		20	Taroom	27	Nov.-Jan...	10
		21	Yeulba	25	Nov.-Jan...	9
V	Springsure	22	Banana	27	Nov.-Jan...	10
		23	Camboon	28	Nov.-Jan...	10
		24	Clermont	27	Nov.-Jan...	10
		25	Duaringa	28	Nov.-Jan...	11
		26	Emerald	25	Nov.-Jan...	9
		27	Springsure	26	Nov.-Jan...	9
VI	Charters Towers ..	28	Charters Towers ..	25	Dec.-Feb...	13
		29	Clarke River ..	25	Dec.-Feb...	15
		30	Pentland	26	Dec.-Feb...	14
		31	Ravenswood ..	27	Dec.-Feb...	16
VII	Georgetown	32	Chillagoe	32	Dec.-Feb...	22
		33	Croydon	28	Dec.-Feb...	20
		34	Cumberland ..	27	Dec.-Feb...	20
		35	Georgetown ..	32	Dec.-Feb...	23
		36	Gilbert River ..	31	Dec.-Feb...	23
		37	Mount Surprise ..	30	Dec.-Feb...	21
V	Springsure	22	Banana	27	Jan.-Apr...	12
		23	Camboon	28	Jan.-Apr...	12
		24	Clermont	27	Jan.-Apr..	15
		25	Duaringa	28	Jan.-Apr...	16
		26	Emerald	25	Jan.-Apr...	12
		27	Springsure	26	Jan.-Apr...	13
VI	Charters Towers ..	28	Charters Towers ..	25	Oct.-Dec. ..	6
		29	Clarke River ..	25	Oct.-Dec. ..	5
		30	Pentland	26	Oct.-Dec. ..	5
		31	Ravenswood ..	27	Oct.-Dec. ..	6

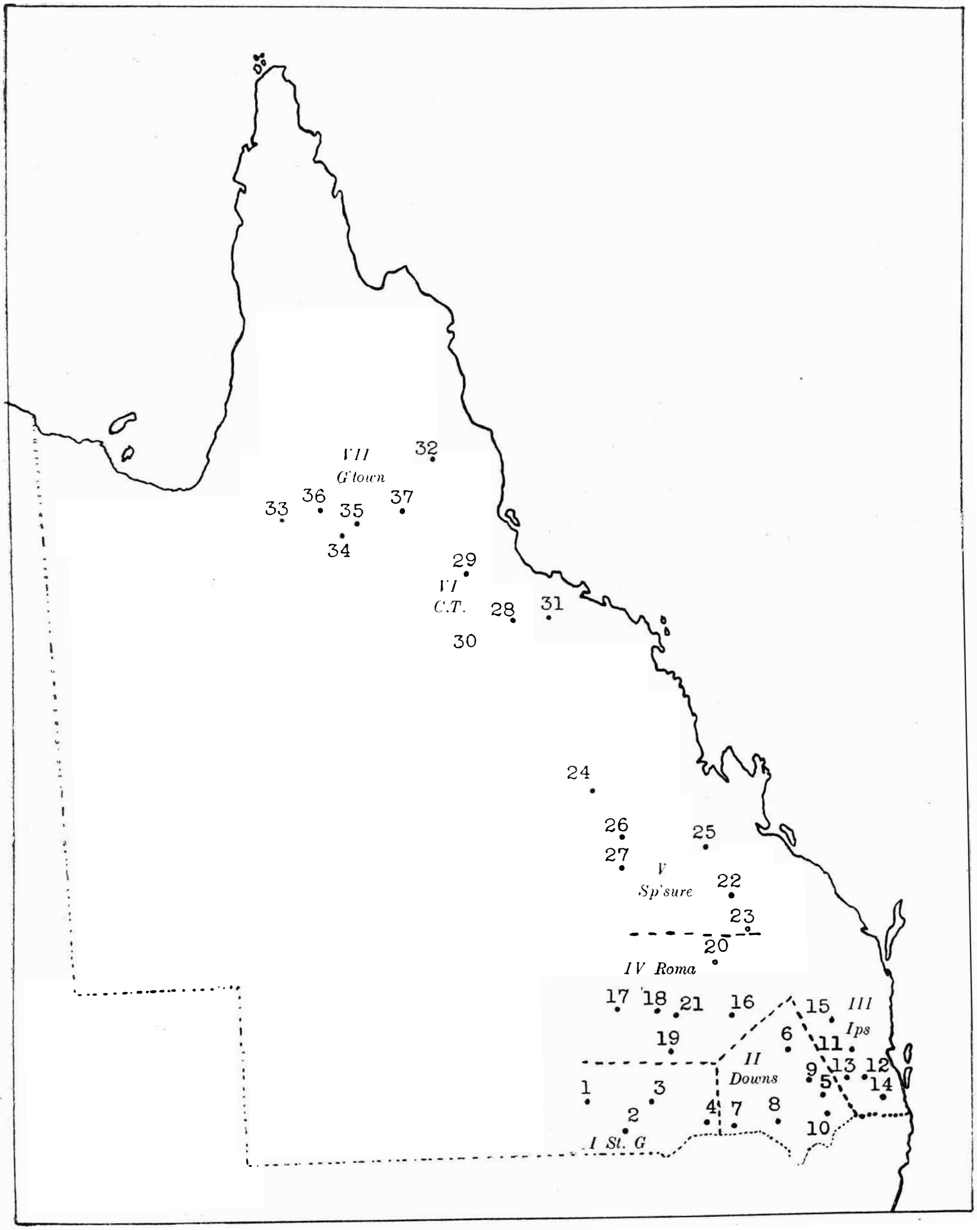

FIG. 1.—Location of Representative Stations and Districts. Key in Table I.

TABLE II.

Correlation Coefficients with Queensland Rain. (All Coefficients have been Multiplied by 100.)

Element, Locality, and Period.	No. of Years.	St. George. Nov.-Jan.	Downs. Nov.-Jan.	Ipswich. Nov.-Jan.	Roma. Nov.-Jan.	Spring-sure. Nov.-Jan.	Charters Towers. Dec.-Feb.	George-town. Dec.-Feb.	Spring-sure. Jan.-Apr.	Charters Towers. Previous Oct.-Dec.
S.O. June-August	45	62	71	56	75	67	71	60	62	69
Pressure—										
Alexandria June-August ..	42	− 53	− 58	− 51	− 57	− 51	− 42	− 42	− 40	− 40
July-September ..		− 47	− 61	− 57	− 52	− 48	− 40	− 37	− 42	..
Antanarivo June-August ..	40	− 38	− 35	− 36	− 52	− 48	− 45	− 41	− 55	− 48
July-September ..		− 32	− 48	− 48	− 48	− 45	− 48	− 51	− 61	..
Buenos Aires June-August ..	45	34	48	43	47	45	43	31	43	38
July-September ..		17	40	29	40	42	42	34	44	..
Cochin June-August ..	45	− 43	− 52	− 49	− 52	− 53	− 57	− 65	− 51	− 65
July-September ..		− 50	− 56	− 54	− 59	− 65	− 64	− 63	− 57	..
Colombo June-August ..	45	− 49	− 57	− 53	− 60	− 51	− 57	− 63	− 56	− 62
July-September ..		− 52	− 61	− 56	− 65	− 60	− 65	− 61	− 62	..
Darwin June-August ..	45	− 41	− 57	− 51	− 58	− 54	− 64	− 60	− 63	− 62
July-September ..		− 30	− 54	− 53	− 56	− 54	− 67	− 65	− 66	..
August-October ..		..	..	..	..	..	− 66	− 66	− 68	..
Honolulu May-July	44	..	..	61	66	..	..	..	52	..
June-August ..		55	64	63	65	63	61	40	50	48
July-September ..		43	59	57	54	61	62	41	48	..
Santiago June-August ..	45	44	50	36	52	48	51	39	42	60

TABLE II.—*continued.*

CORRELATION COEFFICIENTS WITH QUEENSLAND RAIN. (ALL COEFFICIENTS HAVE BEEN MULTIPLIED BY 100.)—*continued.*

District:		St. George.	Downs.	Ipswich.	Roma.	Spring-sure.	Charters Towers.	George-town.	Spring-sure.	Charters Towers.
Period:		Nov.-Jan.	Nov.-Jan.	Nov.-Jan.	Nov.-Jan.	Nov.-Jan.	Dec.-Feb.	Dec.-Feb.	Jan.-Apr.	Previous Oct-Dec.
Element, Locality, and Period.	No. of Years.									
Temperature—										
Darwin June-August	45	..	..	..	..	..	..	36	48	56
August-October		..	..	..	..	..	..	..	55	..
Madras June-August	45	— 51	— 50	— 42	— 53	— 45	— 48	— 57	— 47	— 58
July-September		— 48	— 54	— 49	— 55	— 46	— 50	— 61	— 47	..
Rain—										
Cape York Peninsula (1) July-Sep.	42	53	59	44	63	39	38	20	24	..
East Indies (2) June-August ..	45	59	55	47	65	62	63	60	55	61
July-September ..		61	56	50	67	69	68	60	65	..
Cape York and East Indies July-September	42	66	68	55	75	63	61	45	51	..

(1) Cape York Peninsula rain is the average of the rain at Stations Coen, Maytown, Moreton, Palmerville.

(2) East Indies rain is the average of the rain at Stations Amboina, Medan, Menado, Padang, Pontianak.

TABLE III.

Regression Equations.

(All coefficients have been multiplied by 100.)

District Rain.	Elements used in Regression Equations.	Coefficients between Selected Elements.	Regression Equations between Proportional Departures.	R.
St. George Nov.-Jan. (St.G.)	Alexandria Press. June-Aug. (A.) Cochin Press. July-Sept. (C.) .. Honolulu Press. June-Aug. (H.) .. Cape York and East Indies Rain July-Sept. (C.Y.)	H. C.Y. C. A. St.G. 55 66 − 50 − 53 H. 66 − 47 − 47 C.Y. − 59 − 50 C. 34	(St.G.) = ·13 (H.) + ·38 (C.Y.) − ·14 (C.) − ·24 (A.)	·72
Downs Nov.-Jan. (Do.)	Colombo Press. July-Sept. (Co.) . Honolulu Press. June-Aug. (H.) .. Madras Temp. July-Sept. (M.) .. Cape York and East Indies Rain July-Sept. (C.Y.)	Co. H. M. C.Y. Do. − 61 64 − 54 68 Co. − 51 66 − 62 H. − 50 66 M. − 55	(Do.) = − ·22 (Co.) − ·08 (M.) + ·28 (H.) + ·32 (C.Y.)	·76
Ipswich Nov.-Jan. (I.)	Alexandria Press. July-Sept. (A.) Cochin Press. July-Sept. (C.) .. Darwin Press. June-Aug. (D.) .. Honolulu Press. June-Aug. (H.) ..	A. C. D. H. I. − 57 − 54 − 51 63 A. 28 38 − 63 C. 49 − 47 D. − 51	(I.) = ·25 (H.) − ·14 (D.) − ·27 (C.) − ·28 (A.) ..	·73
Roma Nov.-Jan. (R.)	Alexandria Press. June-Aug. (A. Cochin Press. July-Sept. (C.) .. Honolulu Press. June-Aug. (H.) .. Cape York and East Indies Rain July-Sept. (C.Y.)	H. C.Y. C. A. R. 65 75 − 59 − 57 H. 66 − 47 − 47 C.Y. − 59 − 50 C. 34	(R.) = ·195 (H.) + ·405 (C.Y.) − ·19 (C.) − ·21 (A.)	·81

TABLE III.—*continued.*

REGRESSION EQUATIONS—*continued.*

(All coefficients have been multiplied by 100.)

District Rain.	Elements used in Regression Equations.	Coefficients between Selected Elements.					Regression Equations between Proportiona Departures.	R·
			E.	H.	C.	A.		
Springsure Nov.-Jan. (S.)	East Indies Rain July-Sept. (E.) . .	S.	69	63	− 65	− 51	(S.) = ·275 (E.) + ·24 (H.) − ·31 (C.) − ·165 (A.) . .	·79
	Honolulu Press. June-Aug. (H.) . .	E.		60	− 63	− 46		
	Cochin Press. July-Sept. (C.) . .	H.			− 47	− 47		
	Alexandria Press. June-Aug. (A.)	C.				− 34		
			H.	C.	D.			
Charters Towers Dec.-Feb. (C.T.)	Honolulu Press July-Sept. (H.) . .	C.T.	62	− 64	− 67		(C.T.) = ·28 (H.) − ·33 (C.) − ·36 (D.)	·79
	Cochin Press. July-Sept. (C.) . .	H.		− 47	− 52			
	Darwin Press. July-Sept. (D.) . .	C.			51			
			D.	C.	M.			
Georgetown Dec.-Feb. (G.)	Darwin Press. July-Sept. (D.) . .	G.	− 65	− 63	− 61		(G.) = − ·34 (D.) − ·34 (C.) − ·22 (M.)	·76
	Cochin Press. July-Sept. (C.) . .	D.		51	62			
	Madras Temp. July-Sept. (M.) . .	C.			52			
			H.	D.	An.	Co.		
Springsure Jan-Apr. (S.)	Honolulu Press. May-July (H.) . .	S.	52	− 68	− 61	− 62	(S.) = ·18 (H.) − ·37 (D.) −·22 (An.) − ·13 (Co.) . .	·75
	Darwin Press. Aug.-Oct. (D.) . .	H.		− 52	− 36	− 52		
	Antanarivo Press. July-Sept. (An.)	D.			62	63		
	Colombo Press. July-Sept. (Co.) . .	An.				74		
			C.	Sa.	D.	E.		
Charters Towers Oct.	Cochin Press. June-Aug. (C.) . .	C.T.	− 65	60	56	61	(C.T.) = ·22 (Sa.) + ·26 (D.) + ·26 (E.) − ·29 (C.) . .	·79
	Santiago Press. June-Aug. (Sa.) . .	C.		− 46	− 48	− 55		
	Darwin Temp. June-Aug. (D.) . .	Sa.			42	56		
	East Indies Rain June-Aug. (E.)	D.				29		

2. RELATIONS BETWEEN DISTRICT RAINFALLS AND WORLD WEATHER.

Fig. 1 shows the location of the districts discussed and the representative stations within them, the key to these being included in Table I.

In Table II the relations between Queensland rain and meteorological elements at other centres are indicated. The correlation coefficients with Honolulu June-August pressure were consistently high, but those with Buenos Aires and Santiago, the other stations representing conditions in the Pacific, were much lower.

Darwin, Cochin, and Colombo, the last two being too near to be independent, were the stations representing conditions in the Indian Ocean, whose pressure had the closest relationship with Queensland rain.

There was also a relationship between winter rain in the Cape York Peninsula and the East Indies, and the Queensland rain in the following summer. Probably the winter rain is an index of the same influences that control the summer rainfall.

3. FORESHADOWING FORMULAE.

Table III shows the nine regression equations which were obtained, together with the correlation coefficients from which they were derived and the resultant total correlation coefficient R.

Sir Gilbert Walker (1926) has pointed out that data which indicates a decidedly abnormal season is not likely to mislead, but an anticipation based on conditions only slightly abnormal has little value. He urges, therefore, that the issuing of forecasts be restricted to years in which the departure foreshadowed is greater than ·842 ks, where $k^2 = 1 - R^2$, R being the total correlation coefficient and s the standard deviation of the element foreshadowed. Walker shows that there is a 4 : 1 chance that such departures will have the correct sign, and the formulae obtained for Queensland rain have been tested from that standpoint. This means that only foreshadowed departures which are greater than the above limit and have the wrong sign are regarded as failures. When the actual rain corresponding to a foreshadowed departure is average, the forecast is considered a partial failure.

Tables IV and V give a detailed comparison of the actual departures with those calculated from the formulae for the November-January Ipswich rain and the November-January Springsure rain, these formulae being selected as those giving the best and worst ''performances'' respectively.

TABLE IV.

DEPARTURES IN INCHES FROM AVERAGE NOVEMBER-JANUARY IPSWICH RAIN.

Average 12·4 Inches.

Black figures indicate departures greater than ·84ks = 2·8

.. all data not available. — failure. ... partial failure.

Year.		0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
188	(Calc.) ..							..	..	..	— 2
	(Act.) ..							— 1	12	— 4	— 3
189	(Calc.) ..	**7**	..	— 2	**5**	**4**	**6**	0	0	3	1
	(Act.) ..	8	1	— 2	2	1	8	3	0	11	— 2
190	(Calc.) ..	— **5**	— **5**	— 1	— 2	1	— **4**	— 2	— 1	— **5**	— 1
	(Act.) ..	— 3	— 5	— 9	— 3	— 4	1 —	1	— 4	— 3	— 4
191	(Calc.) ..	2	**4**	— **4**	0	— **4**	— **3**	— 1	**6**	**8**	— **6**
	(Act.) ..	4	6	— 8	— 3	— 4	— 4	— 6	4	8	— 9
192	(Calc.) ..	— 2	— 1	1	0	— 1	**4**	— 3	— 1	2	— 1
	(Act.) ..	— 1	— 2	3	— 2	— 2	1	1	8	3	1
193	(Calc.) ..	— 1	— **4**	2	— 1	0	— 1	— 1	0	2	
	(Act.) ..	— 1	— 4	— 1	1	3	2	— 3	— 7	3	

Departures from 1931-1938 were added after computing correlations.

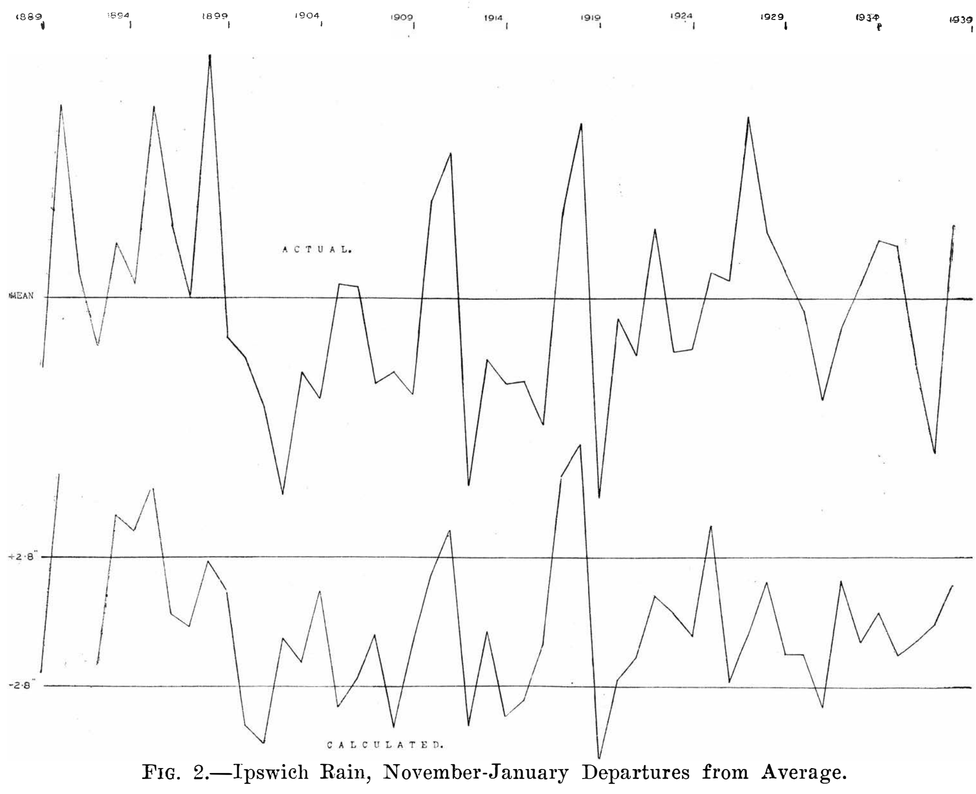

FIG. 2.—Ipswich Rain, November-January Departures from Average.

Only when the calculated departure is greater than 2·8, i.e. lies outside the lower pair of horizontal lines in Fig. 2, can a prediction be made with 4 : 1 chance of success. Out of forty-nine years there are seventeen in which this condition is satisfied, and out of these there are 16 successes and 1 failure, 14 being the expected number of successes.

TABLE V.

DEPARTURES IN INCHES FROM AVERAGE NOVEMBER-JANUARY SPRINGSURE RAIN.

Average 10·8 inches.

Black figures indicate departures greater than ·84ks = 2·6.
.. all data not available.
▬ fail re.
... partial failure.

Year.		0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
188	(Calc.) ..							..	..	..	– **4**
	(Act.) ..							– 6	5	– 3	– 5
189	(Calc.) ..	**7**	..	– **3**	**3**	**4**	**6**	0	– **3**	2	**3**
	(Act.) ..	7	4	– 1	– 2 ▬	– 1 ▬	4	4	– 3	4	0
190	(Calc.) ..	– **5**	– **6**	– 2	– **3**	**3**	– **4**	– **3**	1	– **3**	0
	(Act.) ..	– 3	– 7	– 8	– 2	1	1 ▬	– 2	– 1	2 ▬	– 4
191	(Calc.) ..	2	**6**	– **5**	1	– **3**	– **4**	– 1	**10**	**8**	– 7
	(Act.) ..	4	6	– 6	– 3	– 3	– 5	– 4	9	20	– 6
192	(Calc.) ..	– **3**	– 3	1	0	– **3**	**5**	– 2	– 1	**3**	– 2
	(Act.) ..	– 5	– 1	0	1	– 4	6	– 1	2	4	0
193	(Calc.) ..	– 1	– **4**	**3**	– **3**	**4**	1	– 2	0	2	
	(Act.) ..	2	– 6	– 2 ▬	0 ...	– 2 ▬	1	– 2	– 5	0	

Departures from 1931-1938 were added after computing correlations.

Only when the calculated departure is greater than 2·6, i.e. lies outside the lower pair of horizontal lines in Fig. 3, can a prediction be made with a 4 : 1 chance of success. Out of forty-nine years there are thirty in which this condition is satisfied, and out of these there are 23 successes, 6 failures, 1 partial failure, 24 being the expected number of successes.

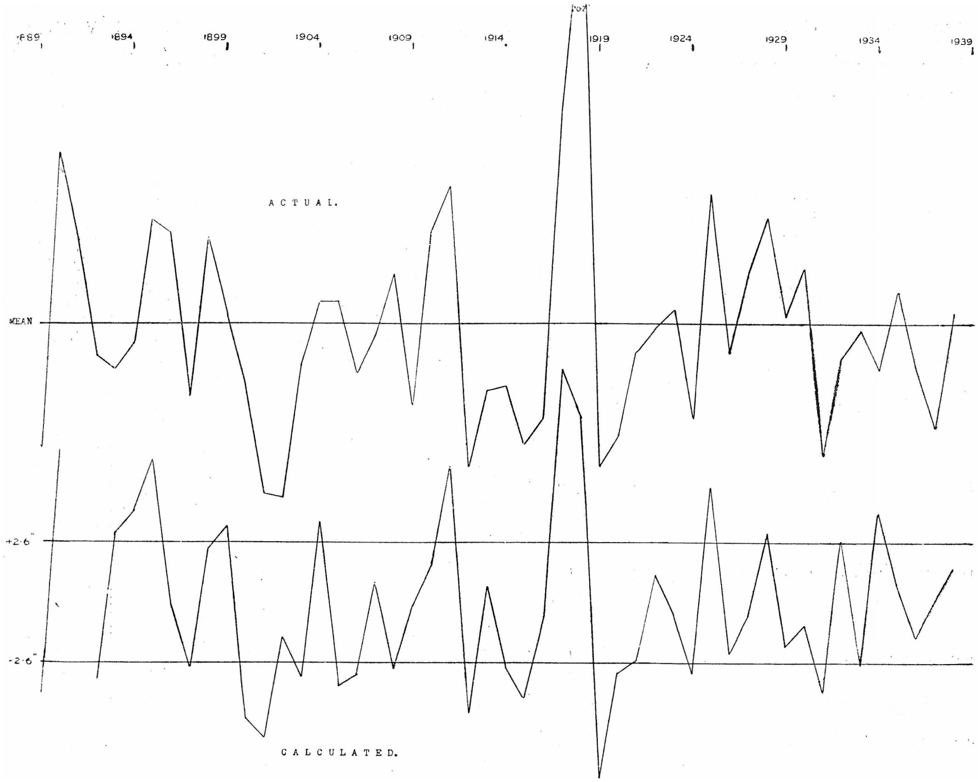

FIG. 3.—Springsure Rain, November-January Departures from Average.

The correlation coefficients used in the formulae were based on data from 1886-1930, the years being those of the January for which rain is foreshadowed. With each of the nine formulae the number of successful forecasts possible during that period was greater than the number expected on the assumption of a 4:1 chance of success.

The real test of any formulae is its "performance" over a series of years beyond the period used in its formation. At the time of writing, data as far as 1938 is available, so that it is possible to test the formulae for eight years beyond the period used in computing the correlations. With the nine formulae obtained there were two instances—the Springsure November-January rain and the Charters Towers October-December rain—in which the actual number of successes during 1931-1938 did not equal the expected number. This is not unexpected, as a 4:1 chance of success does not mean four successful forecasts out of every five issued, but that these will be the average figures over a long period. Taking all possible forecasts during the fifty-three year period—

1886-1938—those for the November-January Springsure rain were the only ones in which the number of successes (23) was less than the number (24) necessary for the 4 : 1 ratio to hold.

TABLE VI.

"PERFORMANCE" OF FORMULAE.

(*a*) Used in computing correlation coefficients.
(*b*) Added after computing coefficients.

District and Period.	R.	No. of Years.	No. of Forecasts Issued.	No. of Failures.	No. of Partial Failures.	No. of Successes.	Expected No. of Successes.
St. George Nov.-Jan. ..	·72	(*a*) 41	19	3	0	16	15
		(*b*) 8	1	0	0	1	1
		49	20	3	0	17	16
Downs Nov.-Jan.	·76	(*a*) 41	25	3	1	21	20
		(*b*) 8	2	0	0	2	2
		49	27	3	1	23	22
Ipswich Nov.-Jan.	·73	(*a*) 41	16	1	0	15	13
		(*b*) 8	1	0	0	1	1
		49	17	1	0	16	14
Roma Nov.-Jan.	·81	(*a*) 41	25	1	2	22	20
		(*b*) 8	3	0	1	2	2
		49	28	1	3	24	22
Springsure Nov.-Jan. ..	·79	(*a*) 41	26	4	0	22	21
		(*b*) 8	4	2	1	1	3
		49	30	6	1	23	24
Charters Towers Dec.-Feb. ..	·79	(*a*) 44	28	3	2	23	22
		(*b*) 8	3	1	0	2	2
		52	31	4	2	25	25
Georgetown Dec.-Feb. ..	·76	(*a*) 45	24	2	1	21	19
		(*b*) 8	2	0	0	2	2
		53	26	2	1	23	21
Springsure Jan.-Apr... ..	·75	(*a*) 39	19	1	1	17	15
		(*b*) 8	2	0	0	2	2
		47	21	1	1	19	17
Charters Towers Oct.-Dec. ..	·79	(*a*) 45	28	2	0	26	22
		(*b*) 8	3	0	2	1	2
		53	31	2	2	27	25

It is recognised that in forming the regression equations from elements which give the higher coefficients, elements are chosen for which the random variations tend to be in the same direction as those caused by the correlations sought, with the result that R, the total correlation coefficient obtained, may indicate higher correlations than actually exist. The effect of reducing R is to increase the minimum departure which can be forecast with a 4 : 1 chance of success. Thus, with lower values of R, fewer forecasts would be issued, but those omitted would be the ones with least chance of success, so that the tendency would be for some of the failures to be eliminated.

This is the case with the November-January Springsure rain. Taking the value of R to be ·79 as calculated, 30 forecasts were possible in forty-nine years, and of these only 23 were successful, 24 being the expected number of successes. Suppose the actual value of R were lower, e.g. ·75, then only 25 forecasts would be possible, but of these 21 would be successful, the expected number of successes being 20, i.e. out of the 5 forecasts (1897, 1908, 1914, 1932, 1933) eliminated, 3 would be unsuccessful ones. Thus, if further tests indicate that the calculated value of R in any formula is too high, it could be replaced by the actual value. This would result in fewer forecasts being possible, but would make it probable that the 4 : 1 ratio would continue to hold.

There are, of course, occasions on which no forecast can be issued, although the actual rain is such as to call for one. It must be understood that the non-issuing of a forecast does not imply average rain. If this limitation is borne in mind, it is seen from Table VI that seven of the formulae have maintained the 4 : 1 ratio during the eight years it has been possible to test them beyond the period used in calculating the correlation coefficients.

SOURCES OF DATA.

A. Queensland Rain—

1. 1885-1935. ''Queensland Monthly Rainfall Tables,'' compiled by Mr. I. Jones from monthly data issued by the Divisional Meteorologist, Brisbane.
2. 1936-1938. Monthly rainfall sheets issued by the Divisional Meteorologist, Brisbane.
3. 1930-1938. Exceptions: Welltown and Mundoolun data from MS. received from Commonwealth Meteorological Bureau, Brisbane.

B. Pressures, Temperatures, and East Indies Rain—

1. 1885-1930. ''World Weather Records,'' Smithsonian Miscellaneous Collection, Vols. 79 and 90.
2. 1931-1938. MSS. received from individual stations.

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THOMAS GILBERT HOPE, Acting Government Printer, Brisbane.