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Predisposition of the Upper Air Structure in March to May over India to the subsequent Monsoon Rainfall of the Peninsula

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ABSTRACT. In search of new factors for foreshadowing monsoon rainfall in the Indian Peninsula, radiosonde data of various stations in India have been tried. High correlation coefficients between contour heights at certain stations and Peninsula rainfall series have enabled us to choose a number of useful factors. Regression equations have been worked out using suitable combinations of these factors. The closeness of the estimates obtained with the help of these regression formulae, to the actual rainfall values suggests the potentialities of these factors as forecasting tools.

1. Introduction.

Attempts at estimating in advance the monsoon rainfall of India have been made in the past for nearly eighty years. The earlier workers Blanford (1884) and Eliot (1887) used antecedent factors based on past data as guides, while Walker (1906) introduced the correlation coefficient as the objective measure of inter-relationship. Several papers* have been published detailing the methods of Seasonal Forecasting of the monsoon rainfall of India. These are based on a statistical study of 'factors' from different parts of the world. Regression equations based on 4 to 5 factors are being used to forecast the monsoon rainfall in Peninsula and Northwest India.

In connection with the preparation of the 'Review of seasonal forecasting methods in India' recently undertaken, Jagannathan† made a close examination of the factors in use for forecasting the seasonal rainfall. It has been found that with the inclusion of all available additional data, some of the factors have exhibited considerable decline in the C.Cs and consequently in the multiple C.C. In respect of most of our factors the C.Cs are less than 0·4 which is the limit (Grant 1956) at which one can expect potentially useful forecasts on about at least a fifth of the occasions. Further the addition of a large number of factors with low C.C. does not increase the multiple C.C. and in fact beyond the second or third factor, the improvement is very little and statistically insignificant. This appears to be primarily due to the difficulty in finding factors which have very low inter C.Cs. The multiple C.Cs for most of the regression formulae in use are 0·6 to 0·7 and as such these account only for less than half the variations in the rainfall. The regression equations evolved on the basis of common period data have much smaller multiple C.Cs which account only for less than 30 per cent of the variation indicating that during the recent past most of the factors in use have almost lost their influence. It appears that in most of the series considered there must be certain unknown trends that give high correlations temporarily

*A fairly exhaustive bibliography of papers which have a bearing on the seasonal forecasting in India have been given in a review of the seasonal forecasting methods (*Loc. cit.*)

†P. Jagannathan, "Seasonal forecasting in India—a review"—submitted for publication as a Memoir of the India Meteorological Department

while with the larger series of data, the C.Cs decrease considerably in value. Known trends in the series can be eliminated by standard methods but unknown ones present the difficulties.

In the light of these results it seemed desirable to take into consideration the behaviour of the relationship only in the recent past 15–20 years and evolve regression equations. As long as the physical significance of the factors is not apparent and the factors have to be chosen on the basis of correlation coefficients, it appears that it would be desirable to choose two or at the most three factors which show high degree of relationship during the recent past.

In the search for new factors, the upper air which is being increasingly explored suggested as the most prospective field. In fact Eliot recognised the influence of upper winds on the intensity of the monsoon as early as 1920. The various upper wind factors in use at present are shown in Table 1.

2. Upper air data

Upper air soundings by radiosonde have been made systematically in India for the past nearly 15 years. Here the results of studies made with the upper air data of Indian stations are reported.

Table 2 gives the location of stations used and the period and nature of data utilised.

The monthly means of contour heights at different pressure levels 850, 700, 600, 500 and 400 mb during the months January to June have been correlated with the monsoon rainfall in the Peninsula. Available data of evening ascents have been utilised except in cases where only one morning ascent was available, these morning ascents were utilised. Here the same nomenclature as is current in the Department is used. Peninsula comprises of Maharashtra, Gujarat, Madhya Pradesh (excluding the old Madhya Bharat, Bhopal and Vindhya Pradesh areas), Interior Mysore North, Coastal Mysore (excluding South Kanara), Telangana and Coastal Andhra Pradesh. There is a remarkable consistency in the order and sign of the C.Cs between neighbouring stations, heights and between consecutive months.

The C.Cs which deserve attention are—

(*i*) Jodhpur, New Delhi and Allahabad for levels 700, 600, 500 and 400 mb during the month of March.

(*ii*) Poona Bombay, Visakhapatnam, Madras and Trivandrum for levels 850, 700, 600, 500 and 400 mb during the month of May.

(*iii*) Calcutta for levels 600, 500 and 400 during the months of March and April.

Whether or not we are able to account satisfactorily for the physical nature of the relationships, even the existence of high C.Cs can be used for forecasting purposes, if such trends are maintained in subsequent years.

The high positive C.Cs between the Peninsula rainfall and contour heights (above 850 mb) over North India suggest that higher the levels of pressure surfaces, in other words, higher the mean temperature of the air column above 1·5 km in the month of March the larger the amount of rainfall over the Peninsula during the subsequent monsoon. It thus appears that the thermal structure of the upper atmosphere over North India as early as March may determine to a large extent the intensity of the subsequent monsoon rainfall in the Peninsula. Further the conditions in May over the Peninsula itself practically at all levels indicate a fairly close but inverse relationship indicating that the higher the pressure surfaces, *i.e.*, the higher the temperature of air over Peninsula in May, the weaker the subsequent monsoon. Considering these results, the North Indian stations, *viz.*, New Delhi, Allahabad and Jodhpur have been grouped together. Similarly the Peninsula stations have been considered in two groups, one group consisting of Bombay Madras and Visakhapatnam and the other consisting of Bombay, Madras and Trivandrum. The C.Cs for these groups are given at the end of Table 3.

On the basis of the above, a number of derived characters of upper air suggest themselves as suitable factors for predicting monsoon rainfall over the Peninsula. The C.Cs of the various prospective factors together with their means and standard deviations are given in Table 4.

The inter-correlation coefficients between the various factors chosen are given in Table 5. Taking into account the inter-correlations, factors have been suitably grouped and Table 6 gives the successive stages of the regression equations, their multiple C.Cs and the percentage of variance accounted at each stage. As already stated, due to inter-relationship between the different factors, the addition of factors beyond the third, did not show any material improvement; the regression formulae were, therefore, restricted to those with three factors only.

From this table it is seen that in most of the groupings, the first two factors account for over 80 per cent of the variation while the third factor accounts for less than 10 per cent. Further addition of factors is not of much practical use. The test of significance for the regression coefficients shows that in almost all groups of 3 factors, only first 2 regression coefficients are significant while the third is insignificant. Only in the group F_1, F_7, F_{11} all the three are significant, showing that each of the factors account for a significant proportion of the total variation in monsoon rainfall. It is realised that the correlations are based on at the most 15 years data. Nevertheless it is of interest to note that during the years under consideration there is such close relationship between the factors. The factors which together account for as much as 90 per cent of the variation in the monsoon rainfall of the Peninsula are to be found in Table 6 in the order in which they are introduced and the percentage variance accounted by them individually.

It is also seen from Table 6 that there are quite a few groups of factors which together account for over 90 per cent of the total variation. The important features brought out by this table are—

(*i*)	Height of 500 mb surface in March over 'North India' (F_1)	55%
	Height of 500 mb surface in May over 'Northeast Peninsula' (F_6)	36%
	F_1F_6	91
(*ii*)	Thickness between 700 and 500 mb surface in March over Calcutta (F_{11})	62%
	Height of 600 mb surface in May over 'Northeast Peninsula' (F_7)	21%
	Height of 500 mb surface in March over 'North India' (F_1)	10%
	F_{11} F_7 F_1	93
(*iii*)	Height of 400 mb surface in March over 'North India' (F_2)	57%
	Height of 500 mb surface in May over 'Northeast Peninsula' (F_6)	32%
	Thickness between 850 and 400 mb surface in May over Calcutta (F_{13})	2%
	F_2 F_6 F_{13}	91
(*iv*)	Height of 500 mb surface in March over 'North India' (F_1)	55%
	Height of 600 mb surface in May over 'Northeast Peninsula' (F_7)	34%
	Height of 500 mb surface in March, April over Calcutta (F_3)	2%
	F_1 F_7 F_3	91

Thus the important factors to give pre-indication of the monsoon over the Peninsula are—

(*a*) Height of the 500 or 400 mb surface in March over 'North India' (F_1 or F_2) which if taken as the first factor accounts for about 55% of the variance.

(*b*) Thickness between 700 and 500 mb surafce in March over Calcutta (F_{11}) which if taken as the first factor accounts for slightly over 60% of the variance.

(*c*) Height of 500 or 600 mb surface in May over Peninsula (F_6) taken as a second factor explains a further 30% of the total variation.

3. Verification

Out of the various regression formulae worked out as shown in Table 6, the following three have been chosen, each of which contains three factors—

(1) Formula with factors F_1, F_7 and F_{11} — R ·964

(2) Formula with factors F_8, F_{10} and F_{12} — R ·959

(3) Formula with factors F_2, F_6 and F_{13} — R ·953

With the help of each of these, estimates of the monsoon rainfall departures have been worked out and have been compared with the actual departures in Table 7.

For evolving the regression equations given in Table 6, data upto 1958 have been utilised, while for the regression formula with five factors in current use in the Department, available data upto 1953 have been used. As is evident from the high multiple C.Cs the calculated values obtained by different formulae using radiosonde data are quite comparable with the actual values. The skill score in respect of different formulae can be estimated only on the basis of their performance in the subsequent years. However, the fair agreement of the estimated values for 1959 with the actual value is of interest. A similar study in respect of monsoon rainfall of Northwest India is proposed to be discussed separately.

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TABLE 1

Upper wind data in Seasonal Forecasting

Description of factor	Used for forecasting	Year in which intro-duced	Correlation Coefficients (for period) 11-20	21-30	31-40	41-50	51-57	Entire period
Agra west winds 5-8 km (Sep II+Oct I)	Winter precipitation in "NW India"	1936	+·92	+·15	+·40	+·16	—·03	+·36
Agra easterly winds 2 km (Mar)	Monsoon rainfall in "NW India"	1956		+·02	+·37	+·66	—·18	+·34
Calcutta E'ly winds 2 km (May)	Monsoon rainfall in "NW India"	1956		—·62	—·49	—·71	+·38	—·35
Calcutta E'ly winds 4 km (May)	Monsoon rainfall in "Peninsula"	1956		—·39	—·19	—·71	+·41	—·03
Bangalore N'ly winds 6 km (Apr)	Monsoon rainfall in "Peninsula"	1956		+·40	+·47	+·56	+·91	+·38

TABLE 2

Radiosonde stations and the data used

Stations	Lat. (N)	Long. (E)	Altitude (m)	Period for which data utilised
1. Jodhpur	26°18′	73° 01′	233	1947—1958
2. New Delhi	28 35	77 12	227	1944—1958
3. Allahabad (Bamrauli)	25 26	81 44	103	1945—1958
4. Calcutta	22 32	88 20	21	1944—1958
5. Veraval	20 55	70 22	17	1945—1958
6. Nagpur	21 09	79 07	309	1947—1958
7. (*a*) Poona	18 32	73 51	560	1944—1958
(*b*) Bombay*	19 07	72 50	5	
8. Visakhapatnam	17 42	83 18	57	1945—1958
9. Madras	13 04	80 15	13	1947—1958
10. Trivandrum	8 29	76 57	73	1948—1958

*Poona was closed in 1956 and Bombay started simultaneously. The data of the two stations have been pooled for the study here

TABLE 3

Correlation Coefficients between the Peninsula rainfall of the SW monsoon and height of pressure surfaces

(NOTE—The C.Cs, multiplied by 100 are given below)

Station	Period of data	Pressure surface (mb)				
		850	700	600	500	400
		JANUARY				
Jodhpur	1947—58	—08	+07	+22	+41	+59*
New Delhi	1944—58	—11	—15	—06	+05	+13
Allahabad	1945—58	—04	—01	+07	+23	+45
Calcutta	1945—58	—24	—10	—06	+10	+19
Veraval	1945—58	—15	—15	—16	—14	—07
Nagpur	1947—58	—13	—02	—05	+03	+02
Poona/Bombay	1945—58	—27	—29	—31	—31	—25
Visakhapatnam	1945—58	—11	—04	+01	+06	+14
Madras	1947—58	—03	+09	+04	+20	+25
Trivandrum	1948—58	—16	+06	+23	+35	+45
		FEBRUARY				
Jodhpur	1947—58	+11	+30	+35	+41	+52
New Delhi	1944—58	—03	+07	+15	+23	+30
Allahabad	1945—58	+05	+16	+22	+37	+52
Calcutta	1945—58	—17	+03	+14	+35	+53*
Veraval	1945—58	—05	—11	—24	—13	—04
Nagpur	1947—58	+17	+14	+04	+05	+06
Poona/Bombay	1945—58	—16	—24	—41	—35	—22
Visakhapatnam	1945—58	—02	—12	—05	—02	+05
Madras	1947—58	+03	—22	—22	—12	+05
Trivandrum	1948—58	—10	—16	—32	00	+03

*Significant at 5 per cent level

TABLE 3 *(contd)*

Station	Period of data	Pressure surface (mb)				
		850	700	600	500	400
		MARCH				
Jodhpur	1947—58	+37	+76**	+80**	+81**	+76**
New Delhi	1944—58	+31	+55*	+63*	+72**	+74**
Allahabad	1945—58	+20	+68**	+78**	+82**	+84**
Calcutta	1944—58	+01	+46	+60*	+69**	+60*
Veraval	1945—58	+41	+42	+35	+31	+17
Nagpur	1947—58	+30	+53	+45	+33	+31
Poona/Bombay	1945—58	+44	+45	+40	+23	+28
Visakhapatnam	1945—58	+34	+58*	+41	+42	+44
Madras	1947—58	+33	+18	+21	+10	—07
Trivandrum	1948—58	+05	00	+10	+10	+10
		APRIL				
Jodhpur	1946—58	—14	+26	+43	+49	+54
New Delhi	1944—58	—06	+09	+14	+25	+21
Allahabad	1945—58	—16	+18	+33	+40	+48
Calcutta	1944—58	+03	+21	+39	+56*	+63*
Veraval	1945—58	—15	—14	—19	—29	—29
Nagpur	1947—58	—05	—06	—01	—19	+17
Poona/Bombay	1944—58	—26	—28	—26	—24	—17
Visakhapatnam	1945—58	—40	—06	—21	—13	—03
Madras	1947—58	—55	—62*	—56	—52	—34
Trivandrum	1948—58	—43	—45	—34	—27	—20

*Significant at 5 per cent level   **Significant at 1 per cent level

TABLE 3 (*contd*)

Station	Period of data	Pressure surface (mb) 850	700	600	500	400
		MAY				
Jodhpur	1946—58	—58*	—16	+09	+29	+42
New Delhi	1944—58	—32	—16	+01	+24	+31
Allahabad	1945—58	—43	—28	—02	+09	+35
Calcutta	1944—58	—40	—35	—14	+18	+38
Veraval	1945—58	—43	—48	—50	—45	—38
Nagpur	1947—58	—45	—49	—14	—23	00
Poona/Bombay	1944—58	—45	—59*	—54*	—55*	—28
Visakhapatnam	1945—58	—50	—57*	—68**	—65*	—65*
Madras	1947—58	—68*	—64*	—73**	—70*	—60*
Trivandrum	1948—58	—53	—51	—46	—38	—28
Jodhpur, New Delhi and Allahabad (Representative of North India)	March	+19	+54*	+66**	+74**	+76**
	April	—17	+13	+27	+34	+36
	May	—43	—24	—01	+22	+36
Poona/Bombay, Madras and Visakhapatnam	March	+55*	+65**	+45	+28	+21
	April	—28	—38	—36	—36	—36
	May	—48	—62*	—69**	—64*	—52*
Poona/Bombay, Madras and Trivandrum	March	+33	+36	+29	+09	+01
	April	—69**	—48	—40	—41	—33
	May	—46	—59*	—62*	—60*	—44

*Significant at 5 per cent level **Significant at 1 per cent level

TABLE 4

Factors, with their means and standard deviation and the C.Cs with Peninsula rain

	Factor	Abbreviation	Mean (gpm)	S.D. (gpm)	C.Cs	Probable error of C.Cs
F_1	Height of 500 mb in March over New Delhi, Jodhpur and Allahabad	H_{500N3}	5772·7	31·0	+·7442	·0877
F_2	Height of 400 mb in March over New Delhi, Jodhpur and Allahabad	H_{400N3}	7432·1	47·0	+·7582	·0837
F_3	Height of 500 mb in March and April over Calcutta	$H_{500C3/4}$	5823·9	29·2	+·6845	·1041
F_4	Height of 500 mb in May over Madras	H_{500M5}	5876·1	13·4	—·7004	·0999
F_5	Height of 400 mb in May over Madras and Visakhapatnam	H_{400MV5}	7592·2	14·8	—·7122	·0966
F_6	Height of 500 mb in May over Bombay, Madras and Visakhapatnam	$H_{500MVB5}$	5871·0	20·2	—·6392	·1156
F_7	Height of 600 mb in May over Bombay, Madras and Visakhapatnam	$H_{600MVB5}$	4417·5	13·4	—·6880	·1033
F_8	Height of 500 mb in May over Bombay, Madras, Visakhapatnam and Trivandrum	$H_{500MVBT5}$	5877·6	12·1	—·6693	·1095
F_9	Height of 600 mb in May over Bombay, Madras and Trivandrum	$H_{600MBT5}$	4419·3	12·7	—·6242	·1192
F_{10}	Thickness between 850/400 mb in March over New Delhi, Jodhpur and Allahabad	$T_{850/400N3}$	5932·9	45·1	+·7602	·0830
F_{11}	Thickness between 700/500 mb in March over Calcutta	$T_{700/500C3}$	2677·2	21·3	+·7874	·0749
F_{12}	Thickness between 600/400 mb in April over Calcutta	$T_{600/400C4}$	3130·8	28·7	+·6924	·1020
F_{13}	Thickness between 850/400 mb in May over Calcutta	$T_{850/400C5}$	6106·3	28·1	+·5488	·1361

TABLE 5

Inter-correlation coefficients between various factors

(The C.Cs are multiplied by 100)

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}
Peninsula rainfall	+74	+76	+68	—70	—71	—64	—69	—67	—62	+76	+79	+69	+55
F_1	1·00	+98	+67	—42	—60	—06	—16	—33	—11	+95	+71	+71	+47
F_2		1·00	+71	—41	—60	—10	—19	—36	—14	+99	+78	+74	+44
F_3			1·00	—49	—49	—22	—25	—33	—23	+69	+92	+79	+76
F_4				1·00	+87	+84	+80	+98	+74	—60	—40	—50	—42
F_5					1·00	+89	+53	+72	+41	—38	—48	—53	—16
F_6						1·00	+90	+79	+84	—16	—35	—29	—22
F_7							1·00	+92	+97	—24	—32	—40	—41
F_8								1·00	+91	—13	—23	—46	—44
F_9									1·00	—19	—29	—40	—45
F_{10}										1·00	+78	+73	+40
F_{11}											1·00	+75	+60
F_{12}												1·00	+66
F_{13}													1·00

TABLE 6

Regression Equations

Factors used	Prediction formula for monsoon rain in Peninsula (R_1)	Multiple C.C. R	Percentage of variance accounted R^2
F_1	$+\cdot 1042(F_1)-5\cdot 3753$	·744	55
F_1F_3	$+\cdot 0725(F_1)+\cdot 0504(F_3)-4\cdot 2753$	·786	62
F_1F_6	$+\cdot 0994(F_1)-\cdot 1287(F_6)+4\cdot 1113$	·955	91
F_1F_7	$+\cdot 0913(F_1)-\cdot 1896(F_7)-1\cdot 1195$	·943	89
F_1F_9	$+\cdot 0961(F_1)-\cdot 1886(F_9)-1\cdot 1465$	·925	86
$F_1F_3F_7$	$+\cdot 0739(F_1)+\cdot 0288(F_3)-\cdot 1803(F_7)-\cdot 7056$	·953	91
$F_1F_6F_{13}$	$+\cdot 0924(F_1)-\cdot 1241(F_6)+\cdot 0167(F_{13})+4\cdot 1884$	·959	92
$F_1F_7F_{13}$	$+\cdot 0913(F_1)-\cdot 1897(F_7)-\cdot 0001(F_{13})-1\cdot 1171$	·943	89
$F_1F_7F_{11}$	$+\cdot 0626(F_1)-\cdot 1688(F_7)+\cdot 0616(F_{11})-4\cdot 1525$	·964	93
$F_1F_3F_9$	$+\cdot 0789(F_1)+\cdot 0281(F_3)-\cdot 1782(F_9)-0\cdot 7684$	·935	87
$F_1F_9F_{13}$	$+\cdot 0982(F_1)-\cdot 1937(F_9)-\cdot 0056(F_{13})-1\cdot 1655$	·925	86
F_2	$+\cdot 0700(F_2)-\cdot 0470$	·758	57
F_2F_6	$+\cdot 0645(F_2)-\cdot 1217(F_6)+8\cdot 9833$	·945	89
F_2F_7	$+\cdot 0602(F_2)-\cdot 1834(F_7)+3\cdot 4771$	·940	88
F_2F_{13}	$+.0630(F_2)+\cdot 0379(F_{13})-\cdot 0611$	·792	63
$F_2F_6F_{13}$	$+\cdot 0589(F_2)-\cdot 1161(F_6)+\cdot 0226(F_{13})+8\cdot 4100$	·953	91
$F_2F_7F_{13}$	$+\cdot 0590(F_2)-\cdot 1795(F_7)+\cdot 0055(F_{13})+3\cdot 4127$	·941	89
F_3	$+\cdot 1017(F_3)-\cdot 2306$	·685	47
F_3F_6	$+\cdot 0848(F_3)-\cdot 1101(F_6)+7\cdot 9904$	·847	72
F_3F_7	$+\cdot 0812(F_3)+\cdot 1786(F_7)-2\cdot 8662$	·868	75
F_8F_{10}	$-\cdot 2073(F_8)+\cdot 0657(F_{10})+16\cdot 1249$	·952	91
F_8F_{11}	$-\cdot 1842(F_8)+\cdot 1360(F_{11})+5\cdot 9947$	·932	87
$F_8F_{10}F_{12}$	$-\cdot 2334(F_8)+\cdot 0787(F_{10})-\cdot 0304(F_{12})+18\cdot 6589$	·959	92
F_{10}	$+\cdot 0732(F_{10})-\cdot 2083$	·760	58
$F_{10}F_6$	$+\cdot 0649(F_{10})-\cdot 1133(F_6)+8\cdot 1446$	·923	85
$F_{10}F_7F_{13}$	$+\cdot 0578(F_{10})-\cdot 1070(F_7)+\cdot 0301(F_{13})+7\cdot 7057$	·939	88
F_{11}	$+\cdot 1604(F_{11})-10\cdot 1829$	·787	62
$F_{11}F_7$	$+\cdot 1288(F_{11})-\cdot 1374(F_7)-4\cdot 9889$	·912	83

TABLE 6 *(contd)*

Level of significant for R

Level	Factors 1	2	3
5 per cent	·514	·627	·703
1 per cent	·641	·732	·793

Comparing the values of R in the above table with those at 5 per cent and 1 per cent levels of significance it is noticed that all the values of R are significant at 1 per cent level

TABLE 7

Comparison of actual and calculated rainfall departure for Peninsula

Year	Estimated departures using formulae involving FACTORS			Actual departures	Forecasted departures by the formula in use*
	F_1, F_7, F_{11}	F_8, F_{10}, F_{12}	F_2, F_6, F_{13}		
1944	+6·4	+15·1	+7·1	+6·0	+0·9
1945	+4·4	+8·9	+5·1	+5·5	+5·8
1946	+2·9	+5·2	+2·8	+3·3	+1·4
1947	+3·2	+7·5	+3·7	+3·5	+3·9
1948	—3·0	+0·4	—1·3	—2·8	—1·3
1949	+0·5	+0·4	—1·1	+3·0	+1·4
1950	—1·9	—1·2	—2·0	—1·2	—0·1
1951	—5·1	—4·3	—4·3	—5·3	—3·8
1952	—3·5	—4·9	—4·8	—6·2	—1·9
1953	+3·9	+5·1	+4·4	+4·1	—7·0
1954	+5·1	+6·1	+5·2	+6·2	—1·3
1955	+6·1	+7·2	+5·5	+5·2	—4·7
1956	+8·9	+11·6	+8·5	+8·0	—4·8
1957	—1·7	—1·7	—1·7	—2·5	+0·3
1958	+6·5	+2·7	+5·6	+5·6	—0·6
1959	+7·5	+7·9	+6·1	+11·2	—3·7

*In this column are shown the departures obtained by forecast formula, in use in the Department, *viz.*, Monsoon rain Peninsula = —·067 (S. Rhodesia rain Oct—Apr) + 1·825 [S. American Pressure ½ (Apr + May)]—·0183 (Java rain Oct—Feb) + ·912 (Bangalore N'ly winds April) —·559 (Calcutta E'ly winds May)—4·307