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Forecasting of pentad rainfall character in Kerala coast during July

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ABSTRACT. Utilising the 700-mb level, 5-day mean and 1-day mean (*i.e.*, mean of 00 and 12 GMT) charts preceding the occurrence of extreme abnormal and extreme subnormal rainfall in Kerala, significant parameters have been obtained. These parameters have been used in evolving the scheme based on contingency technique for forecasting pentad rainfall anomaly in Kerala. In this scheme, forecast for the next 5-day period is issued after every two or three days, depending on the periods of the mean 700-mb contour charts for overlapping pentads.

1. Introduction

Methods utilising contingency technique have been developed by a number of workers for forecasting rainfall during short and medium periods. Jagannathan and Ramamurthi (1961) developed a method for forecasting 5-day rainfall anomaly over Bombay. Working on similar lines, Sajnani (1964) obtained a method for forecasting 5-day rainfall for Calcutta. In this method, suitable upper air parameters like 5-day mean or 1-day contour heights at 700 and 500-mb levels at significant stations, are obtained after studying the contrasting upper air features associated with abnormal and subnormal rainfall at the station. These parameters, hereafter called the predictors, were tested for statistical significance and pairs of these were graphically correlated with the next pentad rainfall anomaly by means of scatter diagram. The points on the scatter diagram are divided into three classes which may be respectively associated with three classes of the predictand, *viz.*, abnormal, normal and subnormal. Contingency tables are prepared and finally after applying contingency techniques as given by Wahl *et al.* (1952) and Lund and Wahl (1955), predictand class (*i.e.*, rainfall anomaly) is obtained.

The main requirements of the application of contingency techniques of forecasting are — (*a*) no class should have a frequency of less than 5 per cent of the total frequency and (*b*) statistical stability of the significance of the predictands should be maintained over long periods of time.

In the present study, it is proposed to apply the contingency technique to the forecasting of next pentad rainfall character in Kerala. The 5-day mean 700-mb charts considered are those for overlapping pentads, the overlap being 2 or 3 days, for example, 3—7 July and 5—9 July, 15—19 July and 18—22 July. The rainfall anomaly considered is for the subsequent 5-day period. In the scheme to be evolved forecast of pentad rainfall character in Kerala coast would be issued every 2 or 3 days, depending on the periods of the pentads for which mean 700-mb charts are available. The area for which rainfall anomaly is to be forecast is shown in Fig. 1.

2. Classification of pentad rainfall anomaly

Rainfall anomaly for each of the pentads is available for the stations, Trivandrum, Cochin and Kozhikode in Kerala. It has been obtained on the basis of data for period 1921—50. As mentioned by Pant (1964), the limits of rainfall for classification of rainfall anomaly are fixed in such a way that each character of the pentad rainfall anomaly of every station, *viz.*, abnormal, normal and subnormal, has equal probability of one-third. From the pentad rainfall anomaly at the three stations, the same for Kerala was obtained as follows. When all stations had the same character, *e.g.*, abnormal then that character, *viz.*, abnormal, was taken for rainfall anomaly of Kerala. In all other cases, the rainfall anomaly was obtained by obtaining the total pentad rainfall of the three stations and finding out whether this total was above the sum of the limits for the three stations for abnormal rainfall, for subnormal rainfall or between the two. In the first case, the rainfall anomaly for the area has been taken as abnormal; in the second case, subnormal and in the last case, normal. Suppose, R_T, R_C, R_K are pentad rainfall for the three stations Trivandrum, Cochin and Kozhikode, R_{TA}, R_{CA}, R_{KA} the limits of abnormal rainfall and R_{TS}, R_{CS}, R_{KS} the limits of subnormal rainfall for these stations respectively. Then, if $(R_T + R_C + R_K)$ is equal to or greater than $(R_{TA} + R_{CA} + R_{KA})$, pentad rainfall for Kerala is abnormal, if less than or equal to $(R_{TS} + R_{CS} + R_{KS})$, rainfall is subnormal and if it is less than $(R_{TA} + R_{CA} + R_{KA})$ but greater than $(R_{TS} + R_{CS} + R_{KS})$ rainfall is normal. In this way, rainfall anomaly for Kerala for all the pentad in July for the years 1957 to 1964 was classified as abnormal, normal and subnormal.

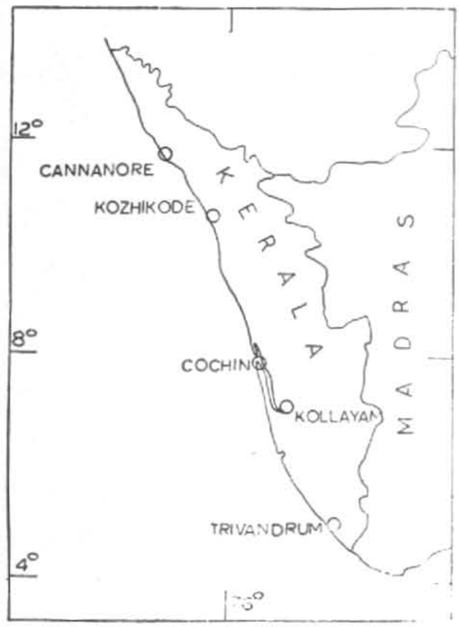

Fig. 1. Map showing Kerala with stations

If the limits for the classes are obtained on the basis of areal rainfall and then Kerala rainfall is classified as abnormal, normal and subnormal, the classification would differ slightly from that obtained earlier, in case the 5-day rainfall at any two of the three stations in Kerala is highly correlated. The correlation coefficients were worked out. These are given below —

Pairs of stations	C. C.
Trivandrum and Kozhikode	0·71
Trivandrum and Cochin	0·73
Cochin and Kozhikode	0·83

These are highly significant at 1 per cent level of significance. In view of this, the two methods of classifying the rainfall of Kerala would lead to small differences in classification which could well be within the range of fluctuations due to random sampling. Moreover, class limits are based on a certain period of data and these are supposed to hold for a different period on the basis of which the method of forecasting has been evolved and verified. Hence the procedure adopted in this study to obtain the class limits for Kerala rainfall from the class limits for individual stations seems to be justifiable.

3. Method of selection of predictors

Parameters which could be considered are (*i*) mean pentad contour height on isobaric surface for the preceding pentad, (*ii*) mean daily contour height of 00 and 12 GMT on day just preceding the pentad for which rainfall anomaly is to be forecast and (*iii*) change from mean pentad contour height to the contour height on the last day of the preceding pentad; this would hereafter be referred to as contour height trend during the pentad.

The question that arises next is, what are the isobaric levels and the locations for which the above parameters should be considered? 5-day mean 700-mb contour height charts giving the contour height at grid points formed by intersection of latitudes and longitude at 5° or 10° interval and covering the area 5°N to 50°N and 15°E to 145°E are available for the period 1957 to 1964. These are based on radiosonde data for the two ascents at 00 and 12 GMT. Similar charts for mean pentad contour height anomaly are also available. Contour height charts for other isobaric surfaces are not available. Hence it was decided to confine the study to 700-mb parameters and to see how far the parameters at this isobaric level are useful in the prediction of pentad rainfall anomaly.

In this study, data for July for the years 1957 to 1961 have been used for evolving the technique and data for July 1962—1964 have been used for verification of the technique.

To obtain the locations for which parameters are significantly related to pentad rainfall anomaly over Kerala, the following stepwise procedure was adopted. In principle, this was similar to that followed by Ramaswamy (1958) and Jagannathan and Ramamurthi (1961) in their studies. Pentads of extreme abnormal and extreme subnormal rain were selected. These were taken as pentads in which all the three stations in Kerala had abnormal or subnormal rain.

By considering (*i*) the mean contour height for the preceding non-overlapping pentads, (*ii*) contour height trend for the preceding non-overlapping pentads and (*iii*) mean contour height on preceding day, the corresponding composite charts for extreme abnormal and subnormal rainfall were obtained. These charts cover the area from 5°N to 35°N and 50°E to 100°E. From these, the corresponding difference charts were prepared. Significance of the differences at the grid-points was tested by *t*-test. The elements at the grid-points which were significant at 5 per cent level were considered as predictors.

4. Chief features of the composite charts

Fig. 2(a) shows the composite 5-day mean 700-mb contour chart preceding the pentad of extreme abnormal rain in Kerala and Fig. 2(b), similar composite chart for extreme subnormal

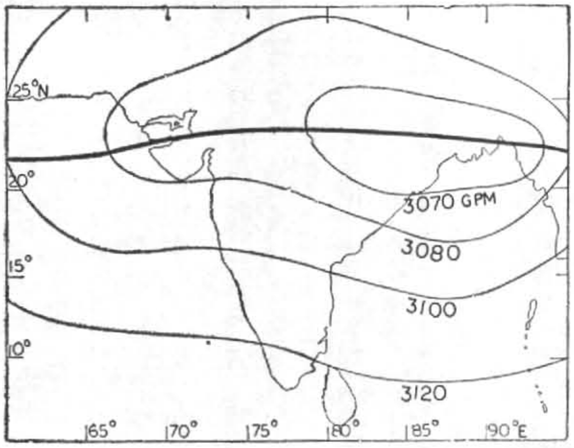

Fig. 2(a). Composite 5-day mean 700-mb contour chart preceding the pentad of extreme abnormal rainfall in Kerala
(Thick line—Trough axis; Heights in geopotential metres)

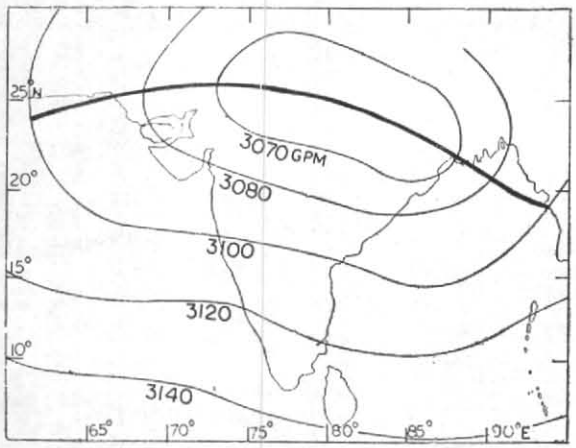

Fig. 2(b). Composite 5-day mean 700-mb contour chart preceding the pental of extreme subnormal rainfall in Kerala
Trough axis is shown by thick line

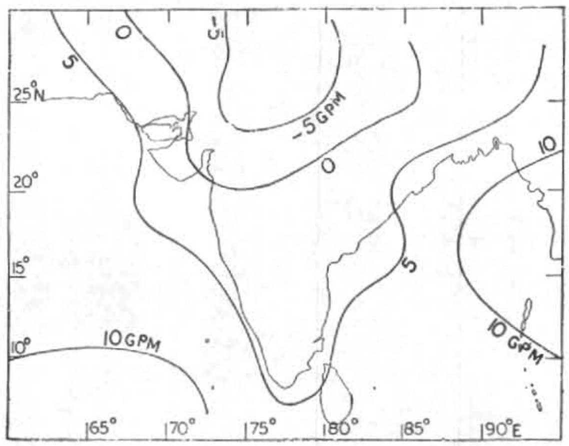

Fig. 2(c). Difference chart (extreme subnormal chart *minus* extreme abnormal chart) for Kerala

rain. It is seen that in the composite chart for extreme abnormal rain the axis of the monsoon trough between longitudes 70° and 80°E runs along 23°N, while in the composite chart for extreme subnormal rain, the axis of the monsoon trough in the same longitudinal belt lies north of 25°N. Fig. 2(c) is the differrence chart, subnormal *minus* abnormal composite charts. The differences are generally small, less than 5 gpm, over India and neighbourhood, but are much larger over distant areas, suggesting that marked differences in pentad rainfall over Kerala are associated not so much with contour heights over India as with those over distant areas. The 5 per cent significant contour heights in the preceding pentads are those at the grid points 25°N 50°E (near Bahrein), 15°N 100°E (near Bangkok), 12·5°N 92·5°E (near Port Blair), 20°N 100°E, 10°N 100°E, 12·5°N 97·5°E, 15°N 95°E, 20°N 95°E, 17·5°N 92·5°E. The heights at the grid points 25°N 50°E and 15°N 100°E are significant at 1 per cent level. Of these, the first three grid points which are close to radiosonde stations were taken into consideration so that later when the technique is developed the mean pentad heights at these radiosonde stations could be used in applying the technique to forecasting next pentad rainfall anomaly for Kerala.

Fig. 3(a) gives the composite chart of contour height trend during the pentad preceding the pentad of extreme abnormal rain; Fig. 3(b) is composite trend chart preceding extreme subnormal pentad rainfall; and Fig. 3(c) is the difference of these two charts, subnormal *minus* abnormal composite trend charts. The following important points emerge from these charts —

(*i*) The trend during pentad preceding the pentad of extreme abnormal rain is much smaller than the trend during pentad preceding the pentad of extreme subnormal rain. This means much more stability of the contour chart during the pentad

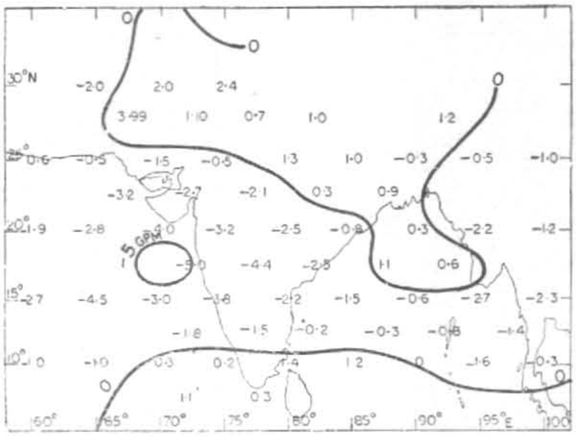

Fig. 3(a). Composite chart of contour height trend during pentad preceding the pentad of extreme abnormal rainfall in Kerala

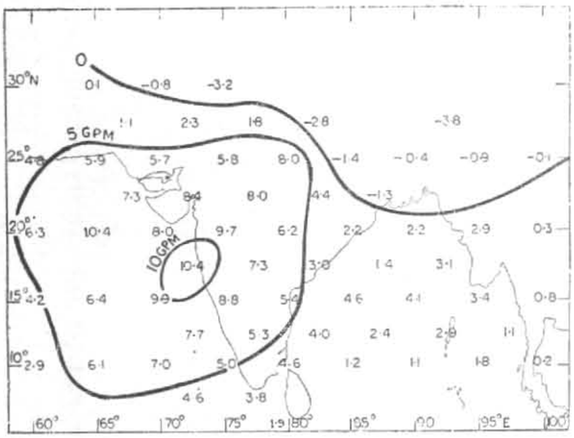

Fig. 3(b). Composite chart of contour height trend during pentad preceding the pentad of extreme subnormal rainfall over Kerala

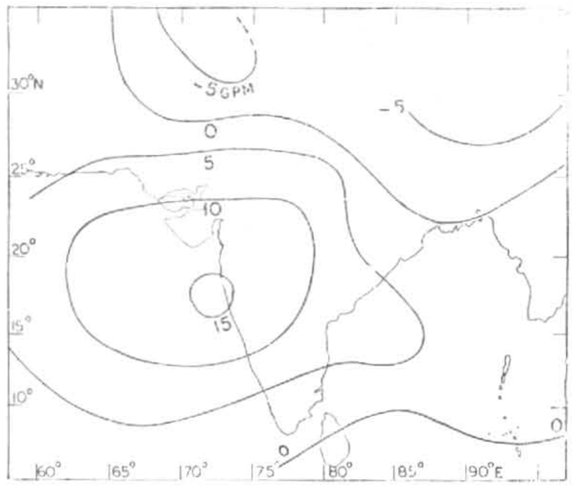

Fig. 3(c). Difference trend chart (extreme subnormal contour height trend chart *minus* extreme abnormal contour height trend chart) in Kerala

preceding the pentad of extreme abnormal rain than that of the contour chart during the pentad preceding the pentad of extreme subnormal rain.

(*ii*) Sizeable positive trend at 17·5°N and 72·5°E during the pentad preceding the pentad of extreme subnormal rain is associated with the shift of the monsoon trough axis north of 25°N during the next pentad. This has also been found in an earlier study of the trough axis by Mooley (1965). Thus, by taking into consideration the trend at 17·5°N 72·5°E we take into account a parameter which is linked to the trough axis location.

(*iii*) The difference between the two trends is maximum at the point 17·5°N 72·5°E (near Bombay) and this is found to be highly significant.

Fig. 4(a) is the composite chart of mean contour height (mean of 00 and 12 GMT) on days just preceding the pentad of extreme abnormal rain in Kerala. The corresponding composite chart for extreme subnormal rain is given in Fig. 4(b). The difference chart is given in Fig. 4(c). In the abnormal chart the axis of monsoon trough between 70° and 80°E lies along 23°N but in the subnormal chart the trough axis between 70° and 80°E lies north of 25°N. Two centres are noticed on the difference chart—one at 17·5°N 72·5°E and other near 15°N 95°E. The differences at the grid points 17·5°N 72·5°E, 15°N 95°E, 15°N 100°E are significant at 1 per cent and the difference at 12·5°N 92·5°E is significant at 5 per cent level. Of these, the first and the third, being close to radiosonde stations at Bombay and Bangkok respectively were taken into consideration.

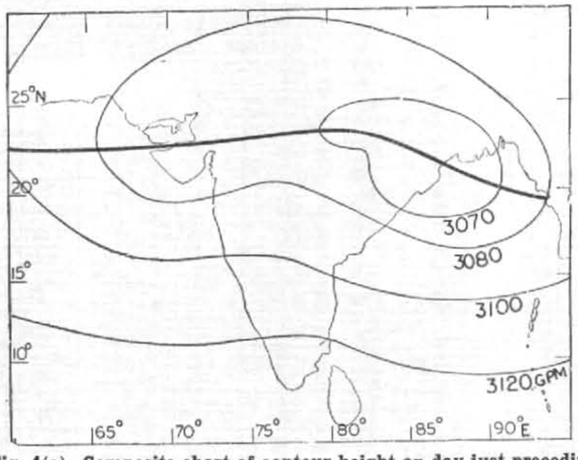

Fig. 4(a). Composite chart of contour height on day just preceding the pentad of extreme abnormal rain in Kerala

Trough axis is shown in thick line

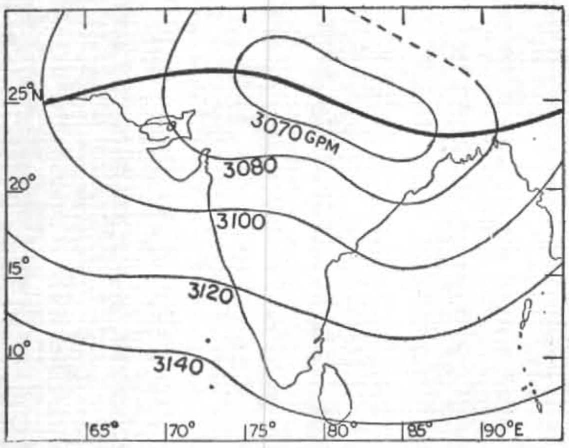

Fig. 4(b). Composite chart of contour height on day just preceding the pentad of extreme subnormal rain in Kerala

Trough axis is shown in thick line

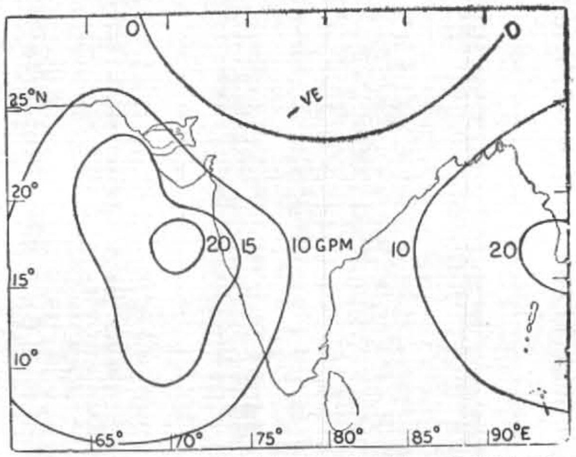

Fig. 4(c). Difference chart (contour height on day just preceding subnormal pentad rainfall *minus* contour height on day just preceding abnormal pentad rainfall) in Kerala

As the preceding day's height at 17·5°N 72·5°E is related to the trough axis between 70°E and 80°E, the preceding day's trough axis is indirectly taken into consideration by taking into account this particular parameter.

5. Actual predictors selected

The predictors which could be taken into consideration are —

(*i*) Mean contour height at 25°N 50°E during the preceding pentad.

(*ii*) Mean contour height at 15°N 100°E during the preceding pentad.

(*iii*) Mean contour anomaly at 12·5°N 92·5°E during the preceding pentad.

(*iv*) Contour height trend during the preceding pentad.

(*v*) Mean daily contour height at 17·5°N 72·5°E on day just preceding pentad for which rainfall has been considered.

(*vi*) Mean daily contour height at 15°N 100°E on day just preceding pentad for which rainfall is considered.

By following graphical methods similar to those utilised by Jagannathan and Ramamurthi (1961) and Sajnani (1964) a selection of pairs of predictors was made. The above six predictors were paired. The values for each pair of predictors for each pentad and rainfall anomaly (the predictant) in the next 5-day period were utilised in preparing the scatter diagrams. The points on the scatter diagram were separated into three areas α, β and γ by smooth curves in such a way that most of the points falling in area α were those corresponding to abnormal rain, in area β those corresponding to normal rain and in area γ those corresponding to subnormal rain. Of the possible predictor pairs, only those three which gave the best separation into three classes α, β, γ were selected. A predictor pair leads to three predictor classes α, β, γ such that in classes

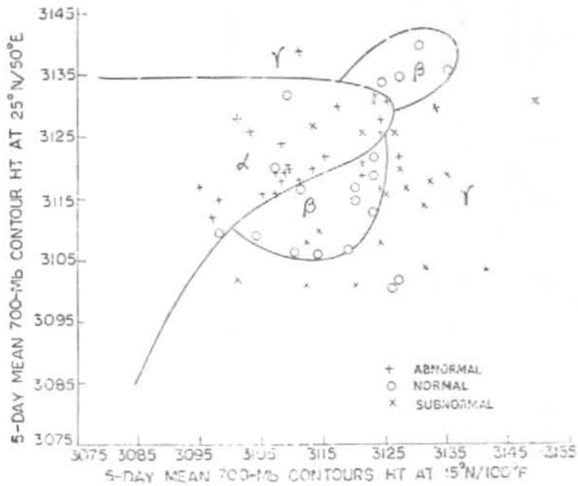

Fig. 5(a). Rainfall anomaly over Kerala — Predictor Pair 1

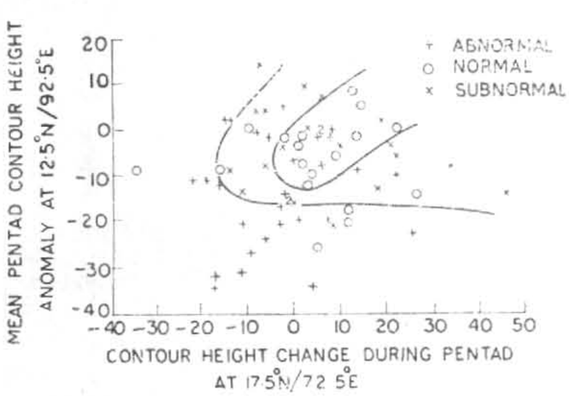

Fig. 5(b). Rainfall anomaly in Kerala — Predictor Pair 2

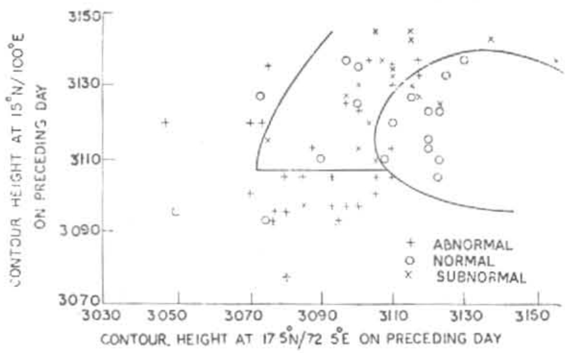

Fig. 5(c). Rainfall anomaly in Kerala — Predictor Pair 3

α, β, and γ there is a high probability of abnormal, normal and subnormal rain respectively. The scatter diagrams are given in Figs. 5(a), 5(b) and 5(c).

6. Forecast

These features revealed by the scatter diagrams were then subjected to a "Contingency test". For this purpose the relationship between the predictor and the predictand has been estimated by the 'Shannon Information Ratio' and the significance of the ratios thus obtained were determined in the similar manner suggested by Holloway and Woodbury (1955) and adopted by Jagannathan and Ramamurthi (1961) and others subsequently in similar types of investigations.

The combined effect of the several predictors selected is obtained as the product of the normalised contingency ratios R'_{ij} separately in each predictand class for the appropriate class i of each predictors. The class j of the predictand for which the product is maximum is selected as the forecast class for the element. The normalised contingency ratio R'_{ij} required in the computation of the forecast are tabulated in Table 1 in the form $10+\log_{10}R'_{ij}$ so that the values obtained from this table are added instead of multiplied for the purpose of estimating the relative combined effect of the predictors.

7. Verification

The foregoing scheme of forecasting pentad rainfall character was worked out by utilising the data for the period July 1957 to 1961. To test its validity it should be applied to a period which has not been utilised and verify the forecasts obtained against the actuals. For this purpose, forecasts of pentad rainfall anomaly were prepared for pentads in July 1962 to 1964. Table 2 gives the result of verification.

Table 3 gives the percentage of occasions of occurrence of forecast anomaly in a particular category. It can be seen that about two-thirds

TABLE 1

Values of ($\log_{10} R'_{ij} + 10$) based on data for period (1957-1961)

Predictor class	Rainfall character		
	Anbormal	Normal	Subnormal
	Predictor pair I		
α	10·3288	9·5539	9·4059
β	9·5125	10·3681	9·6730
γ	9·5125	9·6425	10·3833
	Predictor pair II		
α	10·2756	9·8826	9·1906
β	9·7331	10·2704	9·8553
γ	9·6988	9·6144	10·3385
	Predictor pair III		
α	10·3173	9·7018	9·2277
β	9·4866	10·3349	9·6653
γ	9·7267	9·7454	10·3009

TABLE 2

Verification of forecasts

Actual rainfall character	Forecast rainfall character			Total
	Abnormal	Normal	Subnormal	
Abnormal	13	1	1	15
Normal	5	4	3	12
Subnormal	2	2	7	11
Total	20	7	11	38

TABLE 3

Percentage of occurrence of forecast rainfall character in different categories

Actual rainfall character	Forecast rainfall character		
	Abnormal	Normal	Subnormal
Abnormal	65	14	9
Normal	25	57	27
Subnormal	10	29	64
Total	100	100	100

TABLE 4

Percentage of actual rainfall character correctly forecast

Actual rainfall character	Forecast rainfall character			Total
	Abnormal	Normal	Subnormal	
Abnormal	87	7	6	100
Normal	42	33	25	100
Subnormal	18	18	64	100

of the abnormal and subnormal rainfall forecasts are correct.

Table 4 gives the percentage of actual anomaly correctly forecast. 87 per cent of actual abnormal rain was correctly forecast, while 64 per cent of actual subnormal rain was correctly forecast.

The skill score is the ratio $(R—E)/(T—E)$ where R is number of correct forecast, E is the number of forecasts expected to be correct by chance and T is the total number of forecasts issued. The skill score comes out to be (24—13.3)/(38—13.3), *i.e.*, .44. This is comparable with the skill score of .46 obtained by Jagannathan and Ramamurthi (1961) for Bombay and by Sajnani (1964) for Calcutta.

8. Conclusions

The study has revealed that parameters on 700-mb chart provide useful information for forecasting pentad rainfall anomaly in Kerala and as such it would be preferable to continue the preparation of the chart for this isobaric level. It appears worthwhile pursuing similar studies for other areas. A full study would involve the preparation of isobaric charts at other levels, examination of useful parameters at all the levels and selection of the best among these. But till such a study becomes feasible it is felt that the utility of 700-mb chart from the view-point of forecasting next pentad rainfall anomaly for the various areas of India should be fully explored.

Maintenance of statistical stability of the significance of the parameters utilised in such methods of forecasting pentad rainfall anomaly is essential and hence such stability should be tested from time to time.

9. Acknowledgements

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