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An objective method for forecasting five-day rainfall over Delhi during July and August

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ABSTRACT. The present study is an attempt to evolve a technique for forecasting pentad rainfall over Delhi for the month of July and August. Composite charts for conditions antecedent to excessive and deficient rainfall, during the pentad under consideration, are prepared. The contrasting features of the circulation patterns revealed in these composite charts are taken as guides to picking up crucial station pairs whose relative heights could be taken as representative of the contrasting features. From dot diagrams of rainfall character (as A, N and S) and pairs of pressure-height co-ordinates the relationship between the predictor and predictant are worked out on the basis of contingency technique. The forecast scheme gives a skill score of ·55.

1. Introduction

Various workers have attempted to forecast weather conditions 4–7 days ahead. These are of great use for industry, communication and agriculture. Such forecasts are of special significance during the monsoon season in India. Jagannathan and Ramamurthi (1961), Sajnani (1964) have utilized objective methods for prediction of rainfall over Bombay, Calcutta respectively for 5-day period during the monsoon months. Such a method shows good skill and, therefore, the present study has been undertaken, as part of a programme for the prediction of rainfall over selected network of stations in India.

2. Scope of the study

In the present study attempt is being made to evolve a technique for predicting 5-day rainfall during the monsoon season over Delhi.

3. Method of analysis

The method adopted here is exactly the same as originally developed by Jagannathan and Ramamurthi (1961). In brief, composite upper air charts relating to conditions antecedent to excessive rainfall and deficient rainfall during the pentads under consideration, are prepared. The contrasting features revealed in these composite charts are taken as guides to picking out crucial pairs of stations whose relative heights could be taken as representative of the contrasting feature. Dot diagrams showing the rainfall character at Delhi as abnormal, normal and subnormal against the pairs of pressure height values along the co-ordinate system are prepared. If the separation of the plot into fairly distinct classes are achieved, the significance of this parameter is further tested by t-test. About three such parameters are chosen, jointly to give the forecast indication of the subsequent rainfall character.

The relationship between the predictor and the predictand are worked on the basis of the contingency teachnique and the total information provided by all the three predictors indicate the prediction.

4. Data utilised

For the purpose of this study, 5-day rainfall amount at New Delhi for standard pentads from 1950—1962 has been considered as the predictand and it has been classified into one of the three classes, *i.e.*, abnormal, subnormal and normal, each having equal probability. The rainfall data for 30 years 1921–1950 have been used for working out the limits of abnormal and subnormal rainfall for each pentad. The values of rainfall showing the lower limit of abnormal class and the upper limit of subnormal class have been shown in Table 1.

The upper air data at 12 radiosonde stations antecedent to the rainfall pentads have been used as the predictors and have been taken from the scrutinised upper air data of evening ascents for 1950–1962.

The forecast scheme thus evolved has been tested on data of three years which are not included in the evolution of the technique, *viz.*, 1963—65.

5. Rainfall over Delhi during the monsoon season

The monsoon sets over Delhi in the later part of June and withdraws during the first half of September. The mean number of rainy days in the two months (June and September) is small being 4·2 and 4·6 days respectively. The monsoon is fully established in the months of July and August when the mean number of rainy days is 9. The mean monthly rainfall for July and August is 7·03″ and 7·23″ respectively which is nearly double the amount for June and September. The frequency curves (Fig. 1) for number of rainy days show that for June and September in most of the years there are smaller number of rainy days (1–3 days),

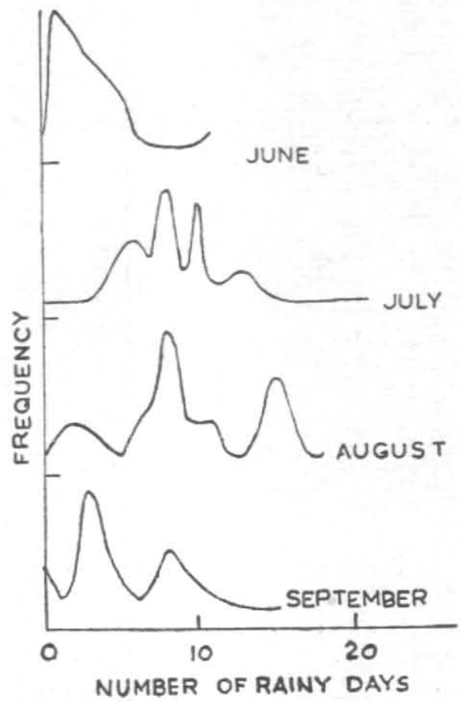

Fig. 1

whereas for July and August 7 or 8 rainy days in a month are quite common. The present study is an attempt to study the pentad rainfall forecast for July and August.

Here the techniques evolved for predicting rainfall of the different pentads of July and August are reported. It was found that rainfall of June and September which are mainly associated with the movement of depressions, do not lend itself to treatment in a similar manner. However, a separate study has been undertaken to evolve a forecasting scheme for the other two months of June and September.

6. Composite charts

Composite charts are found very useful in understanding the particular type of broad scale circulation pattern associated with weather situation at the target station. Therefore, six spells of abnormal and subnormal rainfall occasions were selected for each of these two months and upper air data antecedent to these occasions were used to prepare 5-day and 1-day mean composite charts for 700 and 500-mb pressure levels. The data for preparation of these charts were taken from the scrutinised radiosonde data of 1950-1962.

7. Features of the composite charts

The salient features revealed by the composite charts, for July, shown in Figs. 2(a) and 2(b) are utilised for picking up crucial parameters. However, there are quite a number of important features which may be of considerable value to the synoptic meteorologist. These are discussed below.

July— 5-day mean composite chart for 700 mb for abnormal rainfall occasion reveals presence of a high or a positive anomaly over Bombay and negative anomaly over the entire coastal region of the Bay of Bengal. On the other hand in the composite chart for the subnormal, the region of positive anomaly is shifted northwestwards from Bombay, the entire coastal area of the Bay of Bengal turns positive and a negative anomaly area prevails over the foot-hills and the Indo-Gangetic plain. This may synoptically mean that the 700-mb monsoon trough axis gets shifted from the normal position to the foot-hills giving rise to break monsoon conditions. The changes in 5-day mean 500-mb composite charts, are well-marked. For the abnormal occasion the positive anomaly reflected at 700-mb chart is well-marked. The northern part of India, east of 80°E, is under positive anomaly and the remaining part of India including the peninsula is under negative anomaly. For the subnormal occasion the positive anomaly over Bombay is reversed to negative and the situation in rest of the country is generally reversed.

1-day 700-mb composite charts reveal larger anomalies than the 5-day mean values, because in the latter case the larger changes get smoothened out. In the abnormal case there is a positive anomaly region situated over Uttar Pradesh and the entire peninsula south of 20°N is under negative

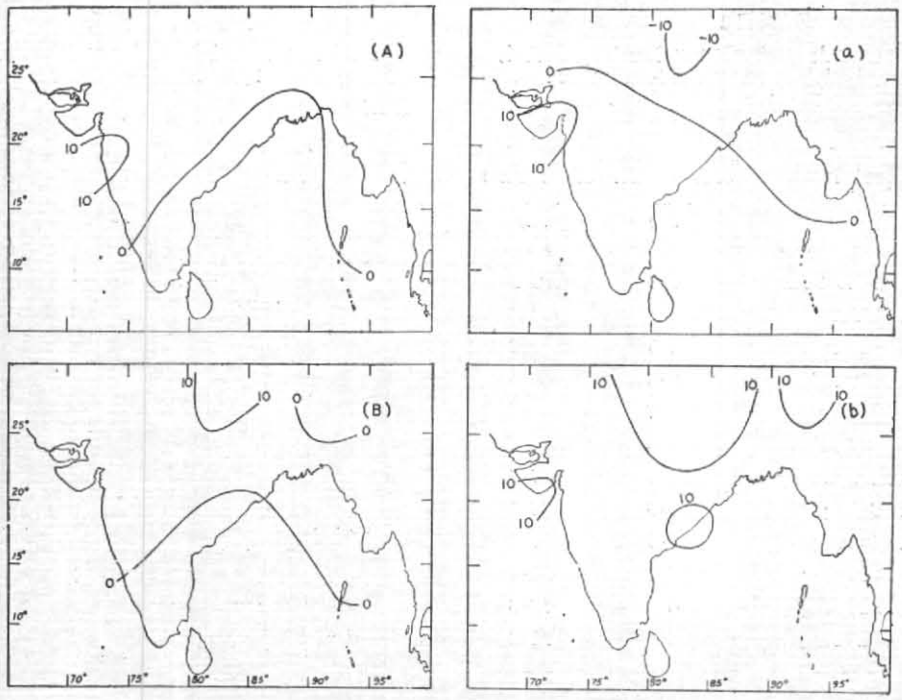

Fig. 2(a). Composite anomaly charts for 700-mb level — July

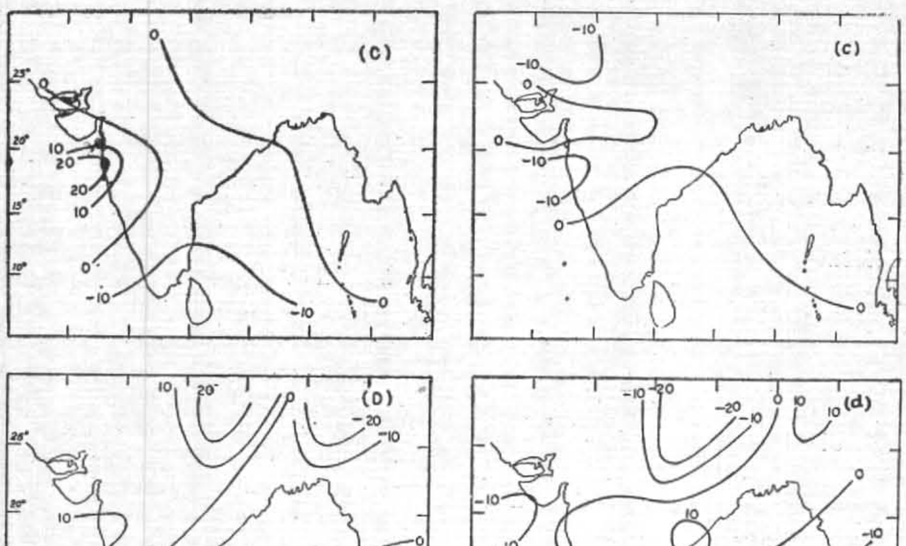

Fig. 2(b). Composite anomaly charts for 500-mb level—July

(A), (C) — 5-day mean anomaly chart antecedent to abnormal rainfall at Delhi
(a), (c) — 5-day mean anomaly chart antecedent to subnormal rainfall at Delhi
(B), (D) — 1-day mean anomaly chart antecedent to abnormal rainfall at Delhi
(b), (d) — 1-day mean anomaly chart antecedent to subnormal rainfall at Delhi

TABLE 1

Values of the lower limit A of abnormal and upper limit S of subnormal rainfall at New Delhi during each pentad from 30 June to 28 August

Pentad No.	Pentad period*	Upper limit S of subnormal rain (mm)	Lower limit A of abnormal rain (mm)
37	30 Jun to 4 Jul	0·3	8·9
38	5 to 9 Jul	2·0	26·4
39	10 to 14 Jul	2·5	29·2
40	15 to 19 Jul	2·8	24·9
41	20 to 24 Jul	11·7	48·5
42	25 to 29 Jul	6·9	29·7
43	30 Jul to 3 Aug	11·9	47·7
44	4 to 8 Aug	10·9	36·1
45	9 to 13 Aug	3·6	19·8
46	14 to 18 Aug	2·1	21·6
47	19 to 23 Aug	0	16·0
48	24 to 28 Aug	0	21·6

anomaly. In the subnormal case the position of the anomalies is significantly different. However, there appears no change over Uttar Pradesh. 1-day 500-mb composite charts reveal the presence of a strong positive anomaly over Uttar Pradesh and adjoining places of Madhya Pradesh and Bihar in the abnormal case. On the northeastern part of the country there exists a large negative anomaly. In the sub-normal case the positions of the anomalies are reversed.

Composite anomaly charts for August also reveal similar characteristic features.

8. Graphical correlation

With the help of composite charts some preliminary selection of the predictors were made for graphical correlation. The values* of predictors X_i and Y_i were plotted against the values of rainfall (W_i) in a particular pentad as $A(+)$, N (o) and S ($\times$). The predictor pairs which showed clear-cut grouping were selected for the final stage in which these were tested by some standard method for significance, discussed in the later part, others were rejected. The selected predictors were classified according to their values into three different groups α, β and γ, so that association between the predictand classified as A, N and S could be determined by the contingency analysis.

9. Statistical analysis of the predictors

Once the contingency tables were prepared using the classification from scatter diagram shown in Fig. 3 some significance of the predictors could be evaluated by calculating the "Shannon Information ratio" given by—

$$I_c = 1 - \frac{\sum_{i=1}^{k} f_i \log f_i - \sum_{i=1}^{k} \sum_{j=1}^{l} f_{ij} \log f_{ij}}{N \log N - \sum_{j=1}^{l} f_j \log f_j}$$

where f_{ij} is the observed frequency in the i^{th} row and j^{th} column of a table composed of k rows and l columns of predictor and predictand class respectively. N is the size of the sample.

For an infinite size of the sample the "Information ratio" tends to zero, if there exists no relationship between the predictors and predictand. To test the significance of relationship revealed by the table it is often suggested to compare the value of I_c with the "Expected Information ratio" I_E as defined by Gringorton. If I_c is greater than the value of I_E at 95 per cent confidence limit, it is assumed that there exists significant relationship between the predictor and the predictand.

$$L_{(I_E)} = \frac{\frac{1}{2}\chi^2}{N \log N - \sum_{j=1}^{l} f_j \log f_j}$$

where χ^2 is taken for (k—1) (l—1) degrees of freedom and at 95 per cent confidence limit. The values of I_c and $L_{(I_E)}$ for various pairs of predictors which were finally chosen are shown in Table 2.

TABLE 2

Predictors, their information ratios I_c and 95 per cent upper confidence limits $L_{(I_E)}$

Predictors	I_c	(L_{IE})
JULY		
(1) 5-day mean 700-mb height over Visakhapatnam and Bombay	0·1957	0·1172
(2) 5-day mean 500-mb height over Visakhapatnam and Bombay	0·2802	0·1217
(3) 5-day mean 500-mb height over Allahabad and Visakhapatnam	10·0872	0·0750
AUGUST		
(1) 700-mb height over Calcutta and Visakhapatnam	0·2154	0·0985
(2) 700-mb height over Gauhati and Visakhapatnam	0·3294	0·1510
(3) 5-day mean 700-mb height over Visakhapatnam and Allahabad	0·2627	0·1035

*Please see Table 4

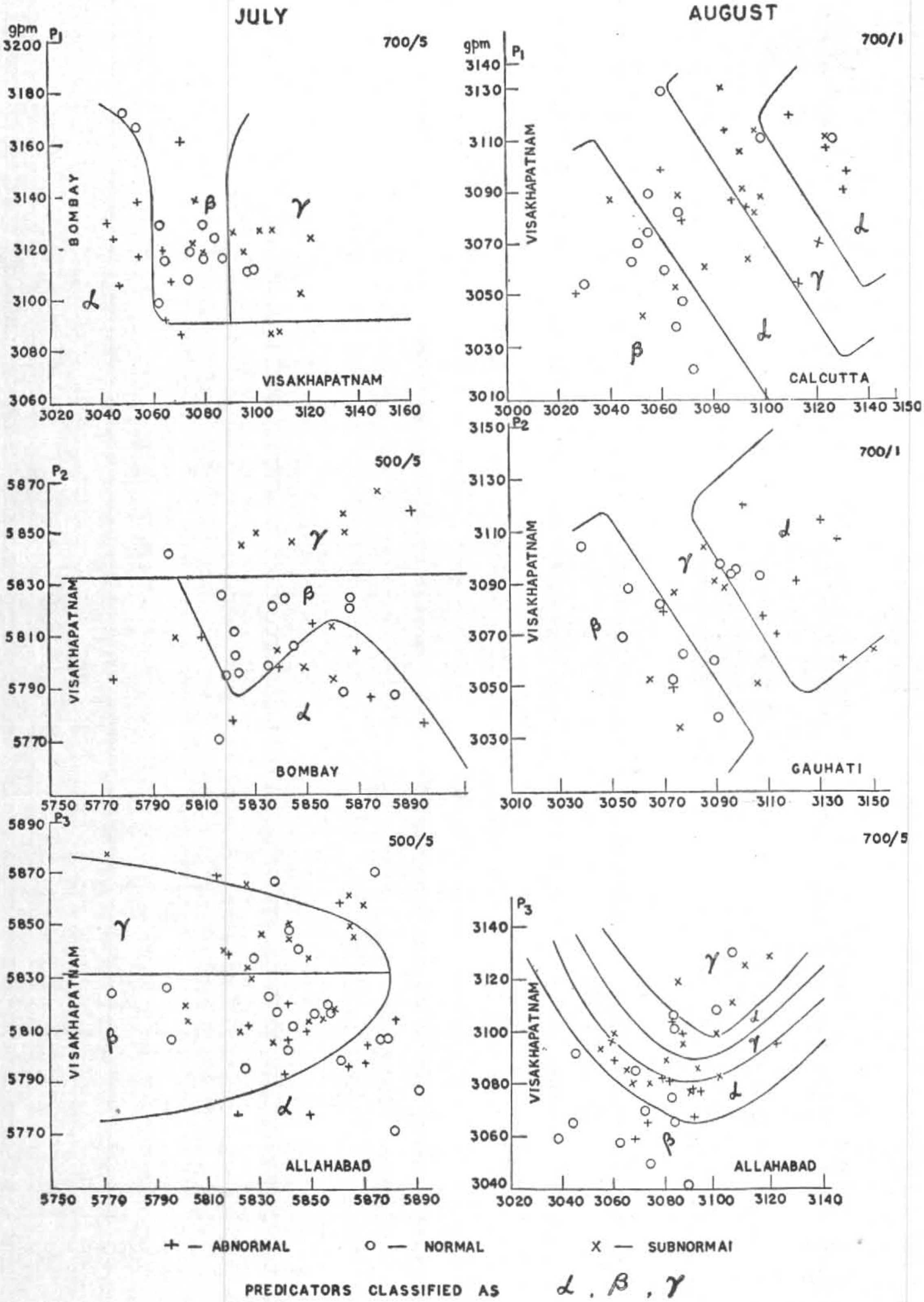

Fig. 3. Scatter diagram

The pressure height level and composite period are indicated as 700/5, 700/1 etc.
700/5 means 5-day mean height at 700-mb level

TABLE 3

Values of (10·0000 + log R'_{ij}) based on data for period 1950—1962

Predictor No.	Class	Predictand class					
		July			August		
		A	*N*	*S*	*A*	*N*	*S*
I	α	10·2610	9·6395	9·8908	10·2645	9·6981	9·9723
	β	9·8454	10·2127	9·7777	9·5401	10·2751	9·8407
	γ	9·8652	9·8450	10·2601	9·7985	9·4344	10·3216
II	α	10·2324	9·6734	9·8527	10·2734	9·9460	9·3269
	β	9·6861	10·2565	9·7967	9·8155	10·1815	9·8642
	γ	9·8036	9·6960	10·3007	9·5230	9·7778	10·3661
III	α	10·2166	9·9866	9·6569	10·2290	9·7637	9·8989
	β	9·8562	10·1212	9·9622	9·8883	10·3336	9·0693
	γ	9·7971	9·7816	10·2425	9·5600	9·7823	10·3065

TABLE 4

Pentad periods to which rainfall forecasts relate and the corresponding periods for the composite 5-day and 1-day charts of upper air contour anomalies

Pentad periods to which rainfall forecasts relate		Periods to which upper air data (for the preparation of composite 5-day charts) relate	Dates to which upper air data (for the preparation of composite 1-day charts) relate
Pentad No.	Period		
	JULY		
37	30 Jun—4 Jul	24 —28 Jun	28 Jun
38	5—9 Jul	29 Jun—3 Jul	3 Jul
39	10—14 Jul	4—8 Jul	8 Jul
40	15—19 Jul	9—13 Jul	13 Jul
41	20—24 Jul	14—18 Jul	18 Jul
42	25—29 Jul	19—23 Jul	23 Jul
	AUGUST		
43	30 Jul—3 Aug	24—28 Jul	28 Jul
44	4—8 Aug	29 Jul—2 Aug	2 Aug
45	9—13 Aug	3—7 Aug	7 Aug
46	14—18 Aug	8—12 Aug	12 Aug
47	19—23 Aug	13—17 Aug	17 Aug
48	24—28 Aug	18—22 Aug	22 Aug

10. Predictors chosen

(A) *July*

(*i*) *5-day mean 700-mb height over Visakhapatnam and Bombay*

This represents contrasting features at 700-mb level. In the abnormal case there is positive anomaly region over Bombay and the entire east coast is under a negative anomaly while in the subnormal case, the entire coastal area turns positive and the positive anomaly is shifted from Bombay. Therefore, Bombay and Visakhapatnam, a station on the east coast have been chosen.

(*ii*) *5-day mean 500-mb height over Bombay and Visakhapatnam*

As the features revealed in 700-mb charts are well marked at this level too the same pair have been chosen.

(*iii*) *5-day mean 500-mb height over Allahabad and Visakhapatnam*

In the abnormal occasion the eastern parts of northern India lie in an area of positive anomaly and the whole of peninsula is under a negative anomaly. Therefore, the stations Allahabad and Visakhapatnam have been chosen.

(B) *August*

(*i*) *700-mb height over Calcutta and Visakhapatnam*

This pair of predictors have been chosen because there is marked change associated with occasions of abnormal and subnormal rainfall. The positive anomaly which prevails along the entire eastern parts of the country in one case turns negative in other case and the change over is well marked over these places.

(*ii*) *700-mb height over Gauhati and Visakhapatnam*

These have also been chosen for similar reasons as mentioned above.

(*iii*) *5-day mean 700-mb height over Visakhapatnam and Allahabad*

The change over from abnormal to subnormal occasion is well marked over the Indo-Gangetic plain. Therefore, the station Allahabad has been chosen.

11. Forecast Scheme

If f_{ij} is the observed frequency in the (i,j) cell and f_{ij}° is the frequency expected on the hypothesis of independence, then $f_{ij}^{\circ} = (S_j \times S_i)/N$ where S and S_i are the marginal totals.

The contingency ratio R_{ij} is given by $R_{ij} = f_{ij}/f_{ij}^{\circ}$ However, if the sample size in the various contingency tables is not the same then the "Normalised Contingency Ratio" is to be calculated—

$$R'_{ij} = 1 + (R_{ij} - 1)\left[f_{ij}^{\circ} \times \frac{kl}{N_{\circ}}\right]^{\frac{1}{2}}$$

where $N_{\circ}$ is the largest value of N in the different contingency tables.

Finally, if the forecast is to be made out from a series of such tables, the product of the normalised contingency ratio is to be taken to represent the integrated effect.

$$\Pi_j = \prod_{i=1}^{k} R'_{ij}$$

Or $$\log_{10} \Pi_j = \sum_{i=1}^{k} \log R'_{ij}$$

The class of predictand having largest log sum is selected as the forecast. The value 10 is added to $\log R'_{ij}$ to avoid negative values. The values have been tabulated in Table 3.

12. Verification of forecast and skill score

The scheme of forecast was tested for working out the skill score, on three years' data. Out of 28 cases verified, it yielded correct forecast on 20 occasions. The results are shown below—

		Predicted class			Total
		A	*N*	*S*	
Observed class	*A*	7	1	3	11
	N	0	4	2	6
	S	1	1	9	11
	Total	8	6	14	28

If T is the total number of forecasts and C is the number of correct forecasts, then skill score S is given by —

$$S = (C-E)/(T-E)$$

where E is the number of correct forecasts on climatological basis. Skill score for this scheme works out to be ·55.

13. Acknowledgement

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