SESSION VIII

PREDICTION OF MONSOON

CHAIRMAN : DR. D. B. SHAW

Meteorological Office, Bracknell, U.K.

Indian J. Met. Hydrol. Geophys. (1978), **29**, 1 & 2, 397-402

551.553.21 : 551.509.31 : 551.577 (543)

An objective method of weekly rainfall anomaly over central India

U. S. DE, R. N. KESHAVAMURTY, K. S. JOSHI, D. V. VAIDYA,
P. V. PILLAI, R. CHELLAPA and S. K. DAS

Meteorological Office, Pune

ABSTRACT. The present investigation is an attempt to evolve a technique for forecasting weekly rainfall anomaly over central India (east and west Madhya Pradesh and Vidarbha). Composite circulation anomaly charts for conditions antecedent to active and weak monsoon spells were used as guides to pick up parameters of predictive value, like the zonal wind shear over Peninsula in the lower and middle tropospheres. A relationship using contingency technique has been used to prepare a forecast scheme. Testing of the scheme on independent data yields encouraging results.

1. Introduction

Fluctuations in rainfall activity during the southwest monsoon period are well known. The need for predicting in advance fluctuations on the time scale of five to seven days has long been felt. This is the aim of medium-range forecasting. Till the time numerical prediction models in the tropics can be used with reasonable success on this time scale, there is an urgent need for developing statistical and synoptic techniques.

2. Method

Circulation features antecedent to spells of excessive and deficient rainfall over central India (east M.P., west M.P. and Vidarbha) were studied. Composite charts were prepared to select crucial parameters which had some predictive value. Scatter diagrams showing weekly rainfall anomaly over central India and various parameters were prepared. The selection of parameters was not restricted to one level as has been done by several earlier workers. The significace of the parameters was further tested by χ^2 test against the null hypothesis of no association. Subsequently the relationship between the predictor and predictand is worked out on the basis of contingency technique. It may be emphasised here that the predictors which are chosen are taken from the wind data and are more reliable in the tropics as compared to the height values. Earlier workers Jagannathan and Ramamurthy (1961), Sajnani (1964) and others using a similar technique have taken the height values of the constant pressure surfaces for their prediction scheme. The scheme was developed by using the data from 1965 to 1970. The forecast scheme thus evolved has been tested on data for seven years which are not included in the evolution of the technique (1961-1964; 1974-1976).

The salient features of the composite anomaly charts for strong and weak monsoon situations have been presented by Alexander* *et al.* (1978) earlier and are not discussed here again. The crucial predictors which showed some predictive skill and were statistically significant in giving the weekly rainfall forecast are given in Table 1.

3. Statistical analysis of the predictor

From the scatter diagrams, contingency tables were prepared using the ranges of predictors which were associated with a particular range of weekly rainfall anomaly (either excess, normal or deficient, scanty). Significance of predictors could be evaluated by calculating the 'Shannon Information Ratio' given by,

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

TABLE 1

	Predictor	I_C	$L(I_E)$ (at 95%)
1	(Calcutta-Bhubaneswar) Surface pressure gradient anomaly, two days before	0·0867	0·0551
2	(Jabalpur-Nagpur) Surface pressure gradient anomaly, three days before	0·0641	0·0514
3	(Allahabad-Jabalpur) Surface pressure gradient anomaly, one day before	0·1506	0·0507
4	(Allahabad-Jabalpur) Surface pressure gradient anomaly, two days before	0·0834	0·0507
5	(Allahabad-Jabalpur) Surface pressure gradient anomaly, three days before	0·1438	0·0507
6	(Madras-Nagpur) Zonal shear anomaly, one day before 700 mb	0·0631	0·0606
7	(Trivandrum-Bombay) Zonal shear anomaly, one day before, 700 mb	0·0733	0·0542 (at 90%)
8	(Madras-Nagpur) Zonal shear anomaly, one day before, 850 mb	0·0853	0·0617
9	(Port Blair-Calcutta) Zonal shear anomaly, one day before, 850 mb	0·0787	0·0574
10	(Visakhapatnam-Calcutta) Zonal shear anomaly, one day before 850 mb	0·0619	0·0569
1	N. component anomaly, New Delhi, two days before, 200 mb	0·0742	0·0551

where f_{ij} is the observed frequency in the ith row and jth 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 predictor 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 Grigorton. 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.

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

where χ^2 is taken for $(k-1) \times (l-1)$ degrees of freedom 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.

4. Predictors chosen

The final choice of predictors from the possible factors mentioned earlier was done by a process of elimination. The values of I_C and values of $L(I_E)$ were taken into consideration for finally selecting the predictors. However, some predictors like (Allahabad-Jabalpur) surface pressure gradient anomaly, one and two days before and (Calcutta-Bhubaneswar) surface pressure gradient anomaly, two days before did not perform well and were dropped out from the list of predictors. Similarly zonal shear anomaly at 700 mb, between Bombay and Trivandrum and (Jabalpur-Nagpur) surface pressure gradient anomaly, three days before were given up due to low valnes of I_C.

Therefore the six predictors in Table 2 were used to verify forecasting scheme (Figs. 1-6).

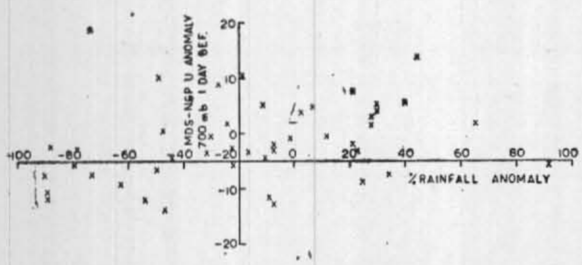

Fig. 1. *U* anomaly at 700 mb for Madras-Nagpur *vs* % of rainfall anomaly one day before the week

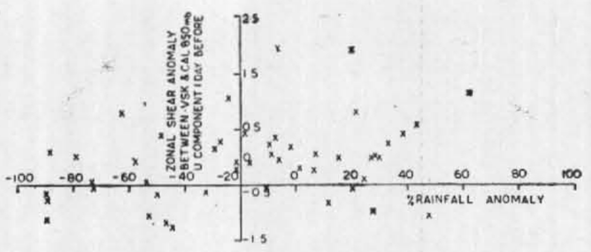

Fig. 4. Zonel shear anomaly between Visakhapatnam and Calcutta 850 mb, *U* component one day before *vs* % rainfall anomaly

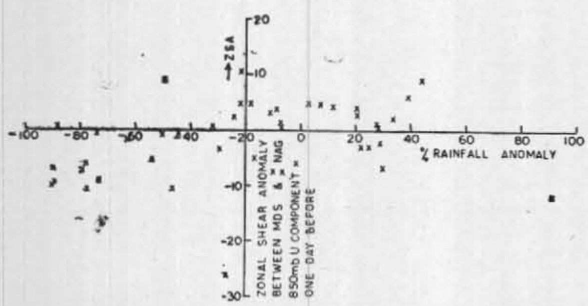

Fig. 2. Zonal shear anomaly between Madras-Nagpur 850 mb, *U* component one day before *vs* weekly rainfall anomaly

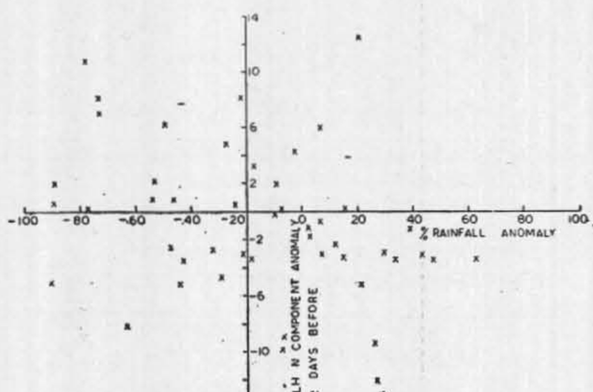

Fig. 5. 200 mb New Delhi (N component anomaly) two days before *vs* % rainfall anomaly

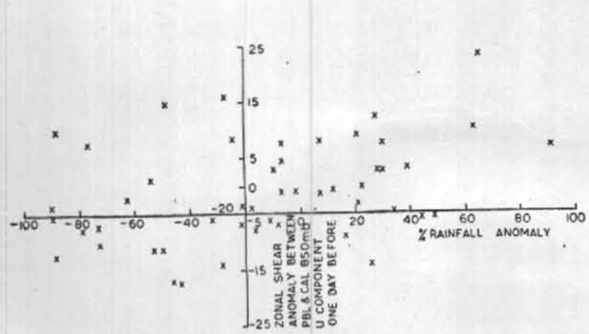

Fig. 3. Zonal shear anomaly between Port Blair and Calcutta 850 mb, *U* component one day before *vs* % rainfall anomaly.

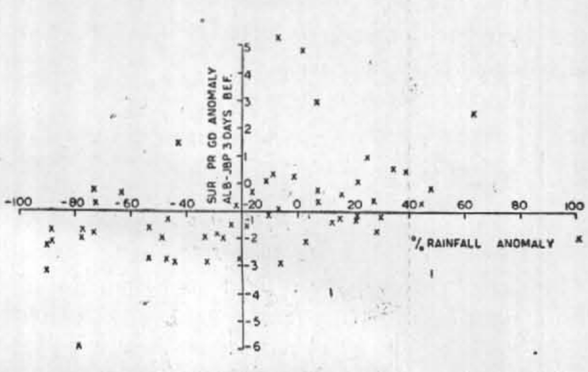

Fig. 6. Allahabad-Jabalpur three days before surface pressure gradient anomaly *vs* % rainfall anomaly

TABLE 2

	Predictor	I_C	$L\ (I_E)$
1	(Madras-Nagpur) Zonal shear anomaly, 700 mb, one day before	0·0631	0·0606
2	(Madras-Nagpur) Zonal shear anomaly, 850 mb, one day before	0·0853	0·0612
3	(Port Blair-Calcutta) Zonal shear anomaly, 850 mb, one day before	0·0787	0·0574
4	(Visakhapatnam-Calcutta) Zonal shear anomaly, 850 mb, one day before	0·0619	0·0569
5	N. comp. anomaly, New Delhi 200 mb, two days before	0·0742	0·0551
6	(Allahabad-Jabalpur) Surface pressure gradient anomaly, three days before	0·1438	0·0507

TABLE 3

Values of (10.000+log R_{ij}') based on data for 1965-1970

	Predictor	Class	Predictand	
			EN	*DS*
1	(Madras-Nagpur) Zonal shear anomaly, 700 mb, one day before	⩾−5·0 mps <−5·0 mps	10·0829 9·8489	9·8906 10·1241
2	(Madras-Nagpur) Zonal shear anomaly, 850 mb, one day before	⩾ 0 mps < 0 mps	10·1160 9·8534	9·8277 10·1160
3	(Port Blair-Calcutta) Zonal shear anomaly, 850 mb, one day before	⩾−5·0 mps <−5·0 mps	10·0984 9·8377	9·8534 10·1366
4	(Vishakhapatnam-Calcutta) Zonal shear anomaly, 850 mb, one day before	⩾−0·5 mps <−0·5 mps	10·0813 9·8395	9·8759 10·1283
5	N. comp. anomaly, New Delhi, 200 mb, two days before	⩾ 0 mps < 0 mps	9·8420 10·1009	10·1334 9·8495
6	(Allahabad-Jabalpur) Surface pressure gradient anomaly, three days before	⩾−1·0 mb <−1·0 mb	10·1582 9·7874	9·7144 10·1534

5. Forecast scheme

If f_{ij} is the observed frequency in the (i, j) cell and f_{ij}^0 is the frequency expected on the hypothesis of independence, then

$$f_{ij}^0 = \frac{S_j \times S_i}{N}$$

where S_j and S_i are the marginal totals.

The contingency ratio R_{ij} is given by $R_{ij} = f_{ij}/f_{ij}^0$. However, if the sample size in the various contingency tables is not the same than R_{ij} the 'normalised contingency ratio' is to be calculated.

$$R_{ij}' = 1 + (R_{ij} - 1)\left[f_{ij}^0 \times \frac{kl}{N_0} \right]^{1/2}$$

where N_0 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

$$\log_{10} \pi_j = \sum_{i=1}^{k} \log_{10} R_{ij}'$$

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 are given in Table 3.

6. Verification of forecast

Using the six predictors, the scheme of forecast was tested for working out the skill score on seven years data. Out of 66 cases verified, it yielded correct forecast on 47 occasions. The results are shown below.

Observed class	Predicted class		
	EN	DS	Total
EN	27	7	34
DS	12	20	32
Total	39	27	66

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

$$S = \frac{(C-E)}{(T-E)}$$

where E is the number of correct forecasts on climatological basis.

The skill score for this scheme works out to be 0·42.

It may be mentioned here that cases of extreme failure were very few. In only two cases when the weekly rainfall was predicted, 'Deficient' or 'Scanty', the actual rainfall was 'Excess'. In no case the observed rainfall was 'Scanty' when it was predicted to be 'Excess' or 'Normal'.

7. Some additional factors

As a further refinement, it was attempted to select predictors which will give a three class forecast scheme, *i.e.*, Excess, Normal and Deficient/Scanty. The combinations of following predictors were used.

(1) Tashkent 300 mb height anomaly and (Madras-Nagpur) 850 mb, zonal shear anomaly, one day before.

(2) Tashkent 300 mb height anomaly and (Port Blair-Calcutta) 850 mb, zonal shear anomaly, one day before.

(3) (Madras-Nagpur) 850 mb, zonal shear anomaly and (Port Blair-Calcutta) 850 mb, zonal shear anomaly, one day before.

These predictors were tried on a sample of a few years and it was observed that they could be used as supplimentary factors. Further tests are necessary to arrive at conclusive stage regarding the use of these predictors.

Acknowledgements

The authors wish to express their thanks to Deputy Director General of Observatories (Forecasting) for his keen interest in this work, useful discussions and unstinted support. Thanks are also due to all the members of Investigation and Development Unit of the DDGF's Office for collection of basic data and computations. Thanks are due to S/Shri S.S. Bhondve, A.R. Murudkar and Robert Kalanke for preparation of diagrams and tracings for the paper.

REFERENCES

Alexander, George *et al.* 1978 *Indian J. Met. Hydrol. Geophys.* **29**, 1 & 2, pp. 76-87.

De, U. S. 1967 *Indian J. Met. Geophys.*, **18**, **3**, pp. 355-362.

Holloway, J. L. and Woodbury, Max. A. 1955 Applications of information theory and discriminant function analysis to weather forecasting and forecast verifications. Univ. Penn. Inst. for Coop. Res.

Jagannathan, P. and Ramamurthi, K. M. 1963 *Aust. met. Meg.*, **41**, p. 42.

Lund, I. A. and Wahl, E. W. 1955 An objective system for preparing operational weather forecasts. Air Force surveys in Geophysics, No. 75-AFCRC.

REFERENCES (contd)

Namias, J. 1947 Extended forecasting by mean circulation methods, U. S. Weather Bureau.

Namias, J. and Clapp, P. F. 1951 *Compendium of Meteorology*, Am. met. Soc., pp. 551-568.

Namias, J. *et al.* 1958 *Mon. Weath. Rev.*, **86**, pp. 467-476.

Sajnani, P. P. 1964 *Indian J. Met. Geophys.*, **15**, 2, pp. 149-162.

Saha, K. R. and Mooley, D. A. 1968 Medium Range Forecasting, FMU Rep. No. IV-17.

Wahl, E. W. and White, R. M. 1952 Construction and application of contingency tables in weather forecasting. Air Force surveys in Geophysics, No. 19-AFCRC.