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Forty-day mode and medium range forecasting

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सार — विभिन्न अन्वेषकों द्वारा हाल ही के अनुसंधानों से यह प्रदर्शित किया है कि मानसून क्षेत्र के ऊपर वर्षा, मेघाच्छन्नता तथा परिसंचरण में चालीस-दिवसीय बहुलक का अस्तित्व रहता है । प्रस्तुत अनुसंधान में भारतीय महाद्वीप के ऊपर वर्षा के माध्यम परिसर पूर्वानुमान के लक्ष्य के लिए इस अर्द्धस्थायी आवर्ती बहुलक की क्षमता के परखने का एक प्रयास किया गया है । इस उद्देश्य के लिए एक पंचवर्षीय (सन् 1979–83 ई०) अवधि के भारत के ऊपर वर्षा और माध्य साप्ताहिक परिसंचरण लक्षणों का विश्लेषण किया गया है । यह देखा गया है कि यह आवर्तन वर्ष प्रति वर्ष और उसी वर्ष एक क्षेत्र से दूसरे क्षेत्र में परिवर्तन होता रहता है । माध्यम परिसर वर्षा पूर्वानुमान के लिए सम्भव प्राचलों के रूप में जो विद्यमान गतिज प्राचलों का उपयोग किया जा सकता है उनकी तुलना में वर्षा अथवा परिसंचरण चालीस–दिवसीय बहुलक अपेक्षाकृत अधिक निपुणता प्रदर्शित करता प्रतीत नहीं होता है ।

ABSTRACT. Recent investigations by different workers have pointed out the existence of a forty-day mode in the rainfall, cloudiness and circulation over the monsoon area. In the present investigation an attempt has been made to examine the potentiality of this quasi-stationary periodic mode for the purpose of medium range forecasting of rainfall over the Indian subcontinent. The analyses of the rainfall and mean weekly circulation features over India have been carried out for this purpose for a period of 5 years (1979-83). It is observed that this periodicity is variable from year to year and also from one area to the other in the same year. As compared to the existing dynamical parameters which can be used as potential parameters for the medium range rainfall forecasting, the forty-day mode in rainfall or circulation does not seem to have a better skill.

1. Introduction

Yasunari (1981), in continuation of his earlier investigations, has shown the existence of a quasi-periodic forty-day mode in the various meteorological parameters during the summer monsoon over the Indian subcontinent. Sikka and Gadgil (1980) have also indicated that maximum cloudiness zone moved northwards during the summer monsoon season with quasi-stationary periodicity of about 4-6 weeks.

Alexander *et al.* (1978) studied the active-break cycle of rain over central India. Using extensive series of composite charts of mean flow patterns they showed that occurrence of active rain spells of rain over central India was preceded by the development of an anomaly trough in the lower troposphere to the south and its northward progression. However, this phenomenon gave only a few days lead time for its being used as a parameter for prediction.

Existence of shorter period oscillations in the monsoon rainfall due to synoptic disturbances and the changes in circulation associated with and/or preceding these oscillations have also been reported. Periodicities of the order of four to six days and twelve to fifteen days in the rainfall over the country were also reported by Ananthakrishnan and Keshavamurty (1970), Bhalme and Parasnis (1975) and Krishnamurti and Bhalme (1976) and Moghe (1958).

In the present investigation an attempt has been made to examine whether the low frequency forty-day mode can be used as a quantitative aid to MRF as is being speculated.

The pulsatory character of the monsoon is known to the meteorologists ever since the classical work of Eliot reported in the early part of the present century. However, in recent years through use of spectrum and harmonic analysis techniques scientists have been able to discover some more latent periodicities. The central problem in the medium range weather forecasting is to identify the exact role of these periodic variations and their applicability in individual years for smaller areas of the size of a meteorologically homogeneous zone. Furthermore, it is essential to extract the exact quantitative parameters out of these periodicities to be able to predict the amount of rainfall or its departures from normal for an area of the size of meteorological subdivisions 3-7 days in advance.

2. Methodology

In order to examine the presence of '40-day mode' two important parameters, *i.e.*, mean weekly zonal wind shear anomaly at 850 mb and weekly rainfall anomaly were taken up. The former is an important predictor in the existing medium range prediction scheme which is being operationalised for the central parts of the country and latter could be a potential predictor. The mean

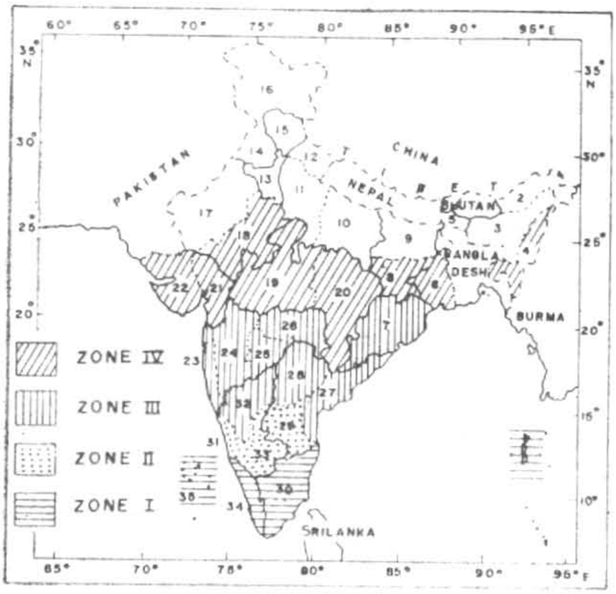


Fig. 1. Zones (I-IV) in meteorological sub-divisions of India

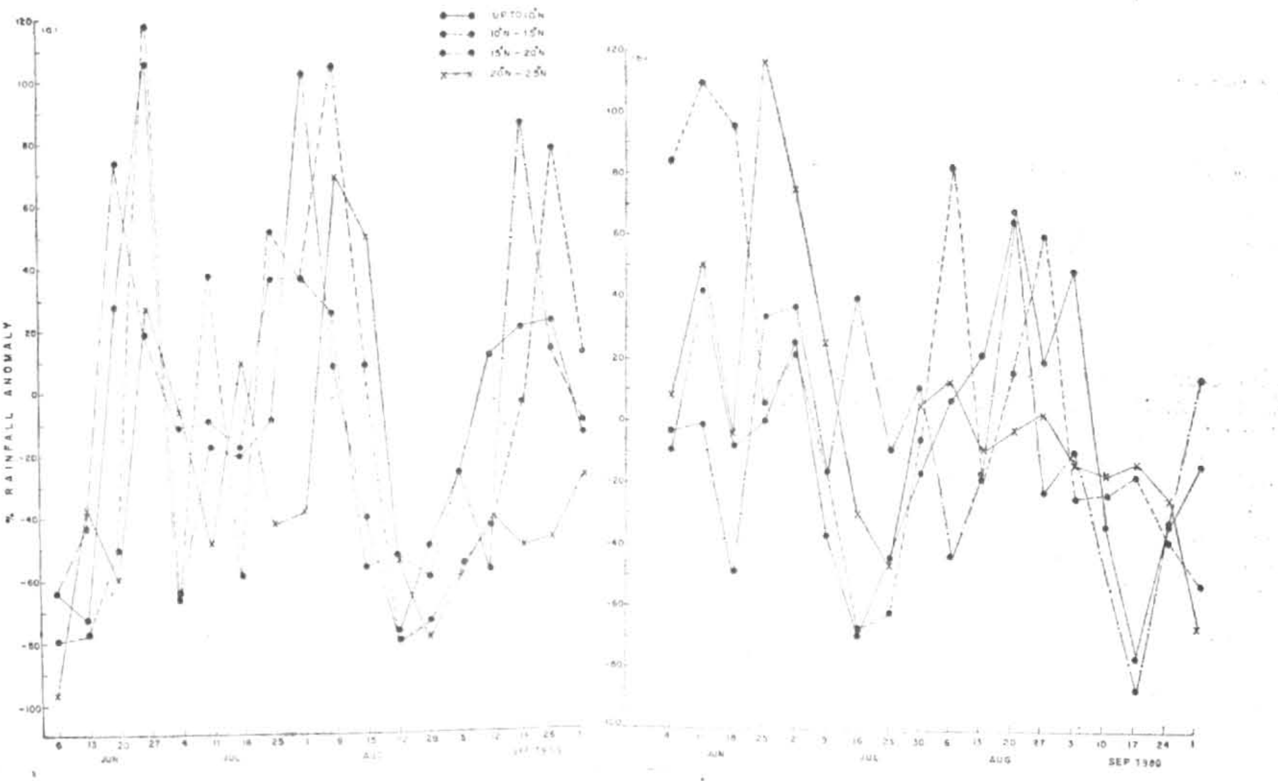


Fig. 2(a) Fig. 2(b)

Fig. 2. Variations of weekly rainfall for the years 1979 and 1980

TABLE 1

Rainfall peaks

Year	I (Upto 10° N)	II (10-15° N)	III (15-20° N)	IV (20-25° N)	Remarks
1979	20/6	—	—	—	
	—	27/6	27/6	27/6	Northward progression from belt-I but simultaneous in all belts
	—	11/7	11/7	—	Irregular
	—	—	—	18/7	
	25/7	—	25/7	—	
	1/8	1/8	—	—	
	—	—	8/8	8/8	Northward progression from belt I
	19/9	—	—	—	
	—	26/9	26/9	—	Northward progression from belt I upto belt III and simultaneous with belt II
1980	11/6	11/6	11/6	11/6	Simultaneous no northward progression
	—	—	—	25/6	
	2/7	2/7	2/7	—	Do.
	16/7	—	—	—	Do.
	30/7	—	—	—	Do.
	—	—	6/8	6/8	
	20/8	20/8	—	—	Northward progression but followed by suppression of rainfall in belts III & IV for a prolonged period
	—	—	27/8	27/8	
	3/9	3/9	—	—	No northward progression, simultaneous in belts I & II
1981	3/6	—	—	3/6	Abrupt peaks in rainfall
	10/6	10/6	—	—	Progression upto belt II only
	—	24/6	—	24/6	Irregular progression
	—	—	1/7	—	Do.
	—	—	—	15/7	Do.
	29/7	—	—	—	Northward progression but simultaneous in belts II & III
	—	5/8	5/8	—	
	—	—	—	12/8	
	19/8	19/8	19/8	—	Simultaneous in three belts
	23/9	23/9	23/9	—	
	—	—	—	30/9	
1982	2/6	2/6	—	—	Irregular
	—	—	9/6	—	Do.
	23/6	23/6	—	23/6	Simultaneous in all belts except III

TABLE 1 (*contd*)

Year	I (Upto 10° N)	II (10-15° N)	III (15-20° N)	IV (20-25° N)	Remarks
	—	—	30/6	—	Northward progression upto belt III only
	14/7	14/7	—	—	
	—	—	21/7	—	
	4/8	4/8	—	4/8	Simultaneous in three belts
	18/8	18/8	18/8	—	
	—	—	—	25/8	
	—	—	8/9	—	No northward progression
	22/9	22/9	22/9	—	Simultaneous in three belts
	—	—	—	29/9	
1983	15/6	—	—	—	Northward advance, but simultaneous in three belts (II, III & IV)
	—	22/6	22/6	22/6	
	20/7	—	—	—	
	—	27/7	27/7	27/7	Simultaneous in three belts
	—	—	—	10/8	
	17/8	17/8	17/8	—	Simultaneous in three belts
	—	—	7/9	—	Irregular
	—	14/9	—	—	Do.
	21/9	—	21/9	21/9	Simultaneous in all belts except II

circulation charts are prepared on a regular basis in the medium range forecasting unit of this office. By resolving the mean winds into zonal and meridional components, the zonal wind shear $\triangle u/\triangle y$ is evaluated. The zonal wind shear anomaly is obtained by subtracting the long term climatological mean values of $\triangle u/\triangle y$ from that of a particular week.

The total weekly rainfall and the percentage departures all over India has been collected for the period June to September from 1979 to 1983. The rainfall data have been then arranged into nearly zonal strips with complete meteorological sub-divisions of India as smallest unit (Fig. 1). The zonal belts are :

(i) **Belt No. I** : From southernmost tip of the country upto about 10° N (including Arabian Sea and Bay Islands).

(*ii*) Belt No. II: Area approximately between 10° & 15° N overland.

(*iii*) Belt No. III: Area approximately between 15° & 20° N overland.

(*iv*) Belt No. IV: Area approximately between 20° & 25°N overland.

The percentage departures of weekly rainfall has been computed for each week for the period (1979-1983) for these four strips using the actual and normal rainfall values for the particular sub-division. The variation of the weekly rainfall for 1979 and 1980 are shown in Figs. 2(a) and 2(b).

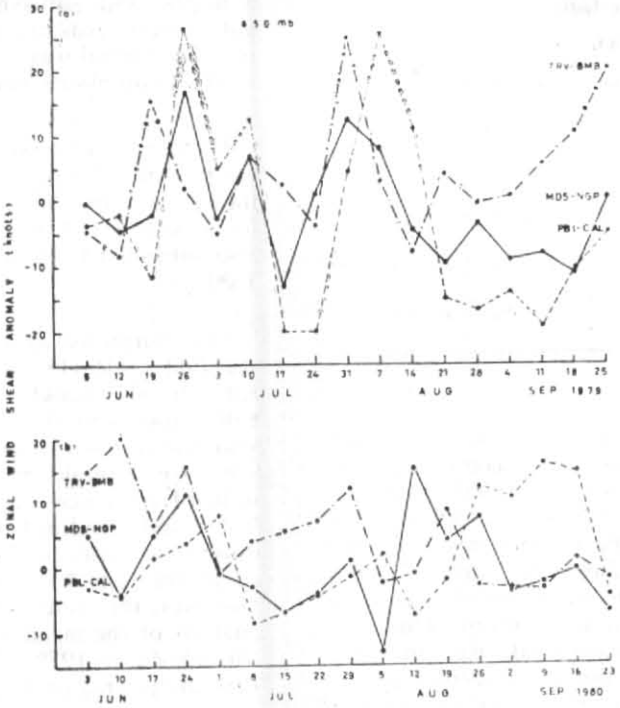
The weekly mean circulation charts which are prepared by the medium range forecasting unit of the office of Deputy Director General of Meteorology (Weather Forecasting) have been used to work out the 850 mb mean weekly zonal shear anomalies for the same period. These are shown for the same years in Figs. 3(a) and 3(b).

These are subjected to harmonic analysis to identify any stable periodicity and its relation to the periodicity in weekly rainfall anomalies.

3. Discussions

The important features observed in the weekly rainfall anomalies during the period 1979-83 for the above four nearly zonal belts were analysed. The positive rainfall anomaly peaks in these four belts from south to north were tabulated for the five summer monsoon seasons and are shown in Table 1. The movement of a quasi-periodic wave from south to north in rainfall can be located by taking a crest or a trough in the rainfall graphs. By tracing whether a regular systematic progression occurs from southern to the northern belts the fact can be established. The dates given in the Table 1 refer to the end date of the week to which the accumulated rainfall peak had occurred. The number of peaks in a season is not constant and varied between 3 and 5 in individual years.

The rainfall peaks in southern belt do not always seem to precede an enhancement of rainfall in the immediate northern belt. The timing of the first peak in a season and subsequent peaks are also variable. However, a



Figs. 3 (a & b). 850 mb mean weekly zonal wind shear anomalies for (a) June-September 1979 and (b) June-September 1980

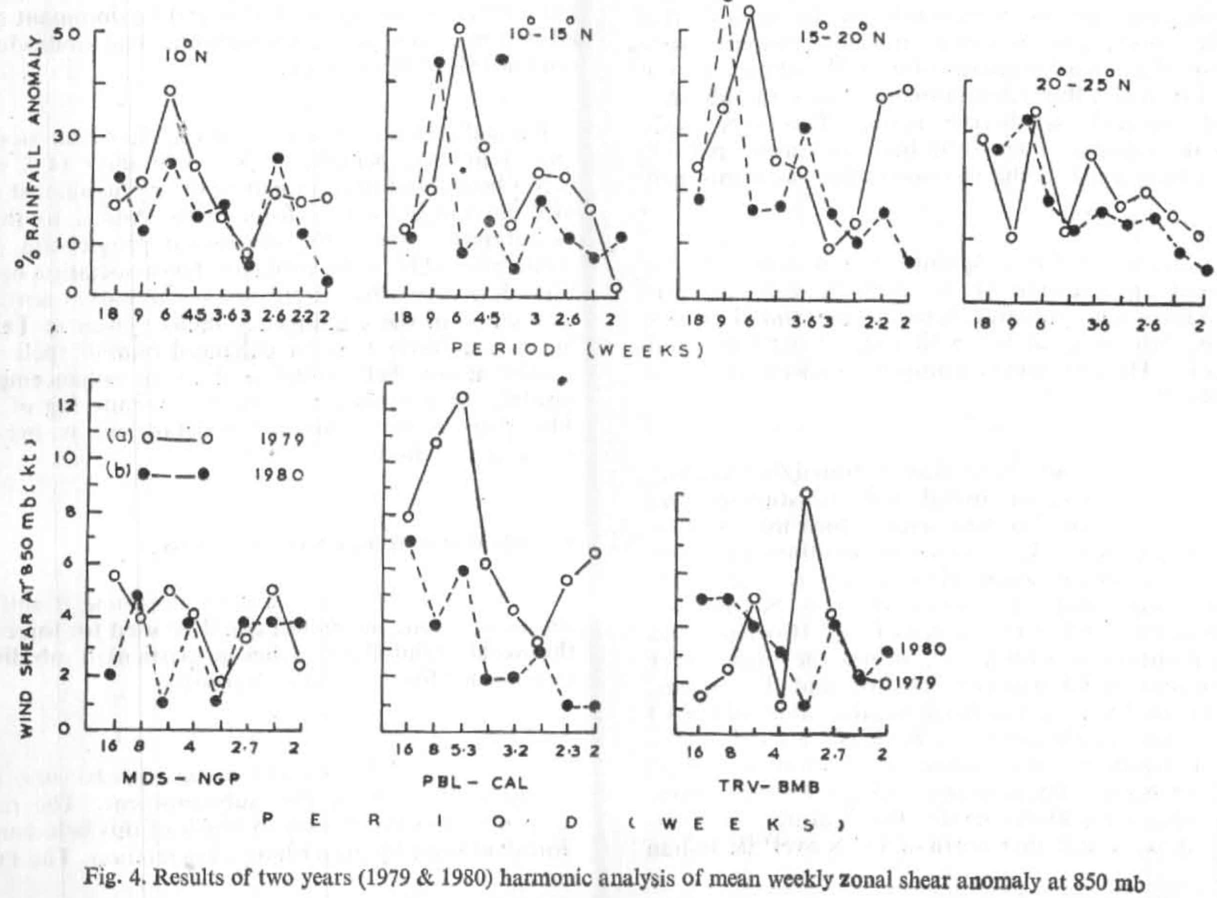


Fig. 4. Results of two years (1979 & 1980) harmonic analysis of mean weekly zonal shear anomaly at 850 mb

TABLE 2

Contingency Indices

(1979-83)

Between zonal belt No.	No lag	One week lag	Two-week lag
I and II	0.2698	0.2034	0.1090
II and III	0.2131	0.2373	0.0179
III and IV	0.0806	0.0526	0.1754

significant fact that emerges out of this analysis is that sometimes all the four belts reach the maxima in rainfall in the same week. Sometimes the rainfall in all the four belts was simultaneously below normal. The rainfall peaks (positive rainfall anomalies) sometimes occurred in the northern belts first without any earlier rainfall peak in the southern strip. On occasions, however, a regular northward progression was noticed. Thus, the weekly rainfall anomalies in individual years in these four belts are apparently not due to a regular quasi-periodic northward progression. It is very well known that normal dates of monsoon onset isochrones (which signifies enhanced rainfall activity) shows a progression northward. However, vagaries of the monsoon onset and its further advance over the sub-continent in individual years are not explainable by any quasi-periodic oscillation. "Active" and "break" cycles in summer monsoon rains are not explainable on the basis of the forty-day mode and its northward progression. Termination of a break occurred often with formation of a depression in the Bay which usually causes an enhancement of rain in the northern belts only. This is, perhaps, due to the complex interaction between various periodicities which exist in the monsoon flow as mentioned earlier.

In order to obtain a quantitative measure of the northward progression of the rainfall peaks, contingency tables were prepared between the rainfall of two adjoining belts with no lag, with a lag of one week and two weeks. The computed contingency indices are shown in Table 2.

Joshi *et al.* (1980) have demonstrated that contingency indices (CI) are useful tools in studying the association between two parameters which may not be linearly correlated. It is seen that contingency index which is a measure of association between rainfall of the two strips does not vary uniformly from belt to belt. The maximum CI between belts I and II occurs with no lag (concurrent week), *i.e.*, within the same week while maximum CI between belts III and IV occurs with a lag of 2 weeks. Furthermore, the values of the CI decrease between the adjoining belts as we move northwards. It would mean that the modulation of rainfall beyond 15°N is influenced less and less by the northward propagating 40-day mode. This feature is not surprising if we recall that north of 15° N over the Indian sub-continent oscillations of the monsoon trough and synoptic and sub-synoptic scale disturbances propagating westwards are known to influence the rainfall in a substantial way. Thus, over this area the 40-day mode is completely masked.

Harmonic analysis technique was adopted to work out predominant periodicities in the rainfall anomalies in these four strips. Mean zonal shear anomalies at 850 mb for these five years between selected pairs of stations were also subjected to harmonic analysis. These are given in Table 3.

The harmonic analysis revealed that apart from the seasonal cycle (18 to 16 weeks) the dominant periodicity in the weekly rainfall anomalies for these four belts varies from 9 weeks to 2.3 weeks. Even in the same year the dominant period in all the belts is not the same, for example, in 1980 the peaks in the periodicities in belt I are 6 weeks and 2.6 weeks while in belt II it is 9, 4.5 and 3 and in belt III it is 9, 3.6 and 2.2. Only during one year, *i.e.*, 1979 out of the five years examined all the belts have same dominant period of 6 weeks. However, the same consistency is not seen in harmonic analysis of the mean weekly zonal shear anomaly at 850 mb during 1979. The results for two years 1979 and 1980 are plotted in Fig. 4.

It is a matter of considerable importance that the near 40-day mode was not seen for the 1972 as reported by Yasunari in the mean cloudiness data over the Indian region. Present analysis also brings out the fact that the existence of this mode during the bad monsoon year, like 1979, does not mean that it will be dominant during all bad monsoon years. 1982, another bad monsoon year, does not show this feature.

The authors are, therefore, of the view that in individual years the periodicity of 30-50 days (4-7 weeks) is too broad and uncertain to be of any significant use in medium range weather forecasting. Added to this the uncertainties about the northward progression of the mode also adds to the problem. The association between rainfall of two strips decreases as one moves northward as seen from the contingency indices given in Table 2. So it is unlikely that an enhanced rainfall spell in the southernmost belt would lead to an enhancement of rainfall in northern belts after a definite lag of time. This point is also examined in detail and is presented in the next section.

4. Application in Medium Range Forecasting

An attempt has been made to examine if this low frequency mode in rainfall could be used for forecasting the weekly rainfall anomalies in particular sub-division as is needed for operational purposes.

It was assumed that the mode appears first in the southernmost belt in the sub-continent. The rainfall in a sub-division which is to north of this belt could be foreshadowed by prescribing a lag relation. The rainfall

TABLE 3

Year	Rainfall belt in I	II	III	IV	Mean zonal shear anomaly at 850 mb MDS-NGP	PBL-CAL	TRV-BMB
1979	*6.0, 2.6	*6.0, 3.0	*6.0, 2.2	18.0, *6.0, 3.6, 2.6	*16.0, 5.3, 2.3	*5.3, 2.0	5.3, *3.2
1980	6.0, *2.6	*9.0, 4.5, 3.6, 3.0	*9.0, 3.6, 2.2	*9.0, 3.6, 2.6	*8.0, 4.0	*16.0, 5.3, 2.7	16.0, *8.0, 2.7
1981	*18.0, 4.5	*6.0, 3.6	*6.0, 3.6, 2.6	*6.0, 3.6, 2.2	*9.0, 3.6	9.0, *4.5	18.0, *6.0, 3.0, 2.0
1982	*9.0, 2.6	*9.0, 3.0, 2.2	3.6, *2.6	*18.0, 3.0, 2.2	4.0, 2.7, *2.0	*3.5, 2.0	*16.0, 4.0, 2.7, 2.0
1983	*16.0, 4.0, 2.3	*16.0, 4.0, 2.3	5.3, *3.2	*6.0, 2.2	*3.2	*3.2	*4.0, 2.3

*Period with largest amplitude.

amounts, categorised into 4 classes (Excess, Normal, Deficient and Scanty) in the belt I were used as a predictor for the weekly rainfall in two sub-divisions, east and west Madhya Pradesh. Two lags were used (*i*) one week & (*ii*) two weeks. The rainfall in these sub-divisions were predicted as Excess, Normal, Deficient or Scanty depending on whether it was Excess, Normal, Deficient or Scanty in the belt I in an earlier epoch.

The results of verification showed that the percentage of correct forecasts in four classes (Excess, Normal, Deficient and Scanty) of weekly rainfall departures varied between 30 and 40%. The percentage of correct forecasts improved to about 60% when the classes were reduced to two only (Excess and Normal or Deficient and Scanty). The results are summarised below :

	East Madhya Pradesh	West Madhya Pradesh
(*i*) One week lag	55% (0.08)	59% (0.22)
(*ii*) Two weeks lag	60% (0.21)	35% (—0.19)

The figures in the brackets indicate skill score (Heidke).

The medium range forecasting techniques for several areas have been developed by studying the mean circulation features through objective techniques (Alexander *et al.* 1978). The skill scores obtained by the present method appears significantly lower than those using dynamical parameters associated with weekly mean and anomaly flow patterns, as reported by De (1982).

The use of periodic or quasi-periodic oscillation of meteorological parameters in weather forecasting has long history. However, the success in this approach is limited. The usefulness of the near forty-day mode in the weekly rainfall pattern over the Indian region in medium range forecasting appears to be doubtful.

5. Conclusions

The analysis of weekly rainfall data over the Indian sub-continent reveals :

(*i*) The near 40-day mode has large year to year variation and is not the dominant mode in every year/region over the sub-continent.

(*ii*) The northward progression of rainfall peaks from south to north is not very regular and it is difficult to predict with accuracy the enhancement or suppression of rainfall over northern parts of the sub-continent from this phenomenon.

(*iii*) For areas of the size of the average meteorological sub-division the technique, if applied for medium range forecasting, yields skill scores which are significantly lower than those obtained by statistical techniques using dynamical parameters from the weekly mean flow patterns (De 1982-83).

Acknowledgements

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