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On some aspects of monsoon onset over India

A. CHOWDHURY, R. K. MUKHOPADHYAY and K. C. SINHA RAY

Meteorological Office, Pune

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सार — विभिन्न क्षेत्रों में मानसून के अग्रगमन की प्रकृति और आंकड़ों का अध्ययन एक रोचक और चुनौतीपूर्ण विषय है क्योंकि इसका भारत में फसलों की सफलता और विफलता के साथ बहुत गहरा संबंध है। इस अध्ययन में जलवायु विज्ञान संबंधी 15 प्रमुख स्टेशनों में सन् 1921-86 ई० की अवधि के लिए मानसून के आरम्भ होने की तारीखों का विश्लेषण किया गया है। इसमें मानसून के आरम्भ होने की तारीखों और दक्षिण-पश्चिम मानसून वर्षा के मध्य संभावित सहयोग का पता लगाने का भी प्रयास किया गया था।

सामान्यतः मानसून के देर से आने या जल्दी आरम्भ होने से मानसून के अनुवर्ती आचरण या मौसम के दौरान कुल वर्षा के संबंध में किसी प्रकार का संकेत नहीं मिल सका।

ABSTRACT. Study of data and nature of advance of monsoon into different parts is an interesting and challenging topic, since it is closely linked to success or failure of crops in India. In this study, dates of onset of monsoon for the period 1921-86 at 15 climatologically important stations were analysed. Attempt was also made to find out possible association between dates of onset and the southwest monsoon rainfall.

Late or early onset of monsoon, in general, was not found to provide any clue about the subsequent behaviour of monsoon or the total rainfall during the season.

1. Introduction

In India, agriculture is the mainstay of million of teeming population. With crops predominantly dependent on natural rainfall, the most spectacular climatic event of agricultural relevance is the occurrence of the commencement of the monsoon rains. Defining and declaring onset of monsoon at a place unequivocally, is beset with difficulties. It depends upon the interest in view. A synoptic meteorologist would declare onset based on prevailing airmass characteristics or synoptic situations. A hydrologist may prefer cumulative rainfall in a fixed period of time while an agriculturist would define onset based on distribution of rainfall. The India Meteorological Department, however, fixes dates of onset of summer monsoon with reference to the rather sharp increase shown by the 5 days mean of the rainfall and changes in the circulation pattern. Other preceptible changes associated with the monsoon advance are decreased temperature from the torried heat of May and surface winds having predominant westerly direction. The normal dates, thus, fixed is first seen in the south Andaman Sea around third week of May and gradually advances northwestwards. Over the southern tip of the country it is seen generally by 1 June. By end of June nearly the whole of the country except extreme west Rajasthan is covered by the monsoon.

A number of studies have been made on the onset of monsoon over different places. Bhullar (1952) studied dates of monsoon onset over Delhi based on 50 years data (1901-50) and fixed mean date as 2 July with a standard deviation of 7-8 days. Ramdas *et al.* (1954) determined dates of establishment of southwest monsoon over the west coast of India from commencement of persistent daily rainfall. Ananthakrishnan *et al.* (1967) concluded that onset dates as determined by India Met. Dep. is subjective. Subbaramayya and Bhanukumar (1978) attempted to evolve a guiding principle for fixing onset dates taking into consideration significant changes in cloud amount, rainfall and temperature occurring at the onset time. Recently Ananthakrishnan and Soman (1988), by superpose epoch analysis, were able to prove that a sharp and spectacular increase in daily rainfall heralds monsoon onset over Kerala.

Dates of monsoon onset and associated features have also been studied by Ramamurthy and Keshav murthy (1964), Ananthakrishnan *et al.* (1967), Ananthakrishnan (1970), Subbaramayya *et al.* (1984), Mathur (1986), Deshpande *et al.* (1986) etc.

The aim of the present study is the statistical examination of onset dates of monsoon over selected stations. It is also proposed to find out if these dates have any bearing to the seasonal rainfall.

2. Criteria for monsoon onset and data set

In fixing the date of onset of monsoon over different areas rainfall as a parameter has the over-riding importance. However, exact quantification of rainfall for this purpose is rather difficult and hence experience

TABLE 1

Characteristics of onset dates

Station/ Sub-div.	Mean date	S.D. (days)	C.V. (%)	Earliest onset	Delayed onset
Trivandrum (Kerala)	31 May	7.4	24	14 May 1960	18 Jun 1972
Goa (Konkan)	11 Jun	6.7	16	21 May 1962	26 Jun 1959
Hyderabad (Telangana)	11 Jun	7.3	17	20 May 1922	25 Jun 1958, 1983
Bombay (Konkan)	11 Jun	6.8	16	28 May 1925	28 Jun 1974
Nagpur (Vidarbha)	12 Jun	7.1	17	28 May 1925	26 Jun 1959, 1983, 1985
Calcutta (Gangetic West Bengal)	12 Jun	7.9	18	24 May 1926, 1938	26 Jun 1959
Ahmedabad (Gujarat)	19 Jun	9.6	19	29 May 1925	9 Jul 1948
Patna (Bihar Plains)	17 Jun	7.1	15	29 May 1956	3 Jul 1926
Allahabad (East Uttar Pradesh)	21 Jun	8.2	16	3 Jun 1922	14 Jul 1982
Jaipur (East Rajasthan)	27 Jun	9.8	17	3 Jun 1922	16 Jul 1959
Lucknow (West Uttar Pradesh)	26 Jun	8.0	14	3 Jun 1922	14 Jul 1982
Delhi (Haryana)	30 Jun	8.4	14	3 Jun 1922	17 Jul 1947
Simla (Himachal Pradesh)	1 Jul	8.7	14	3 Jun 1922	17 Jul 1947, 1965
Amritsar (Punjab)	1 Jul	8.8	14	3 Jun 1922	20 Jul 1982
Jaisalmer (West Rajasthan)	3 Jul	9.0	14	3 Jun 1922	14 Jul 1986

of forecaster becomes useful. Factors such as clouds isobaric gradients, circulation features in lower and upper troposphere, etc serve as qualitative guide to the forecaster. Past cases of monsoon onset have been determined in Meteorological Office, Pune using pentad rainfall. Successive pentad rainfall from May onwards are plotted. The pentad which unambiguously reveal an abrupt and sustained increase in rainfall, is identified. The central date of this pentad is taken as date of onset of monsoon over the station. The data base available in MSS form has been utilised in the study. The main consideration in this approach is the presumption that transition from pre-monsoon thunderstorm activity to the commencement of rainfall of the monsoon is associated with a spectacular rise.

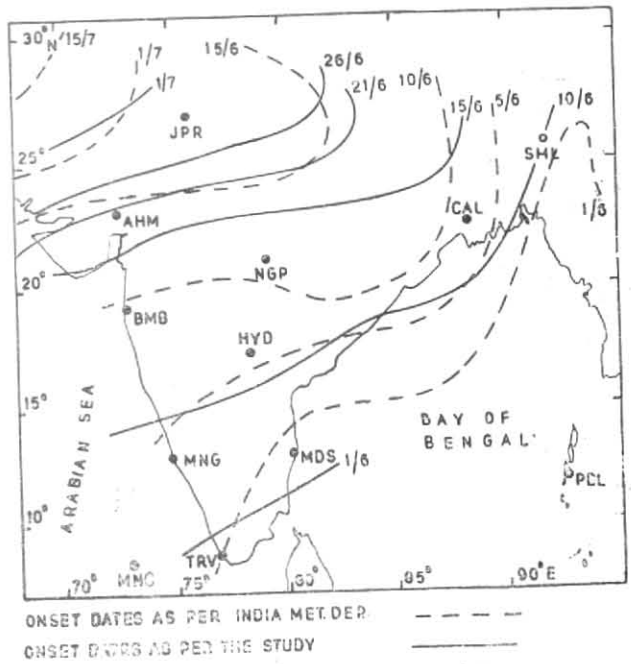

Fig. 1. Isochrones of mean onset dates

Analysis of 5-day rainfall for selected stations for 1988 revealed that dates of onset determined by this method were within 2 days of those declared by India Met. Dep. in 60%, and within 4 days within 80% of the cases studied. Only in extreme west Rajasthan bordering the Thar desert and the Western Himalayas, somewhat large departures between the two dates were observed. In Western Himalayas, in many years, onset may not be sharp enough to enable unique differentiation between pre-monsoon rainfall due to passage of western disturbances and the regular rainfall associated with the monsoon. Over the desertic areas of Rajasthan, sustained rainfall of significant amounts seems to be rare and as such it is quite possible that the dates determined by pentad analysis may differ by wide margin with those of IMD.

By and large, it may be said, the method of determining onset date by pentad rainfall gives a correct picture of the actual onset over India.

The present study utilises data from 1921 to 1986 (66 years) in respect of the following 15 stations:

Climatic type	*Stations*
Equatorial	: Trivandrum
Heavy rainfall, coastal	: Goa, Bombay
Tropical rainy	: Calcutta, Patna
Tropical continental	: Hyderabad, Nagpur, Allahabad, Lucknow
Himalayan	: Simla
Semi-arid	: Ahmedabad, Jaipur, Delhi, Amritsar
Arid	: Jaisalmer

The dates of onset at any place have been reckoned from 1 May in the analysis. Thus 1 May is taken as 1, 2 May as 2 and so on.

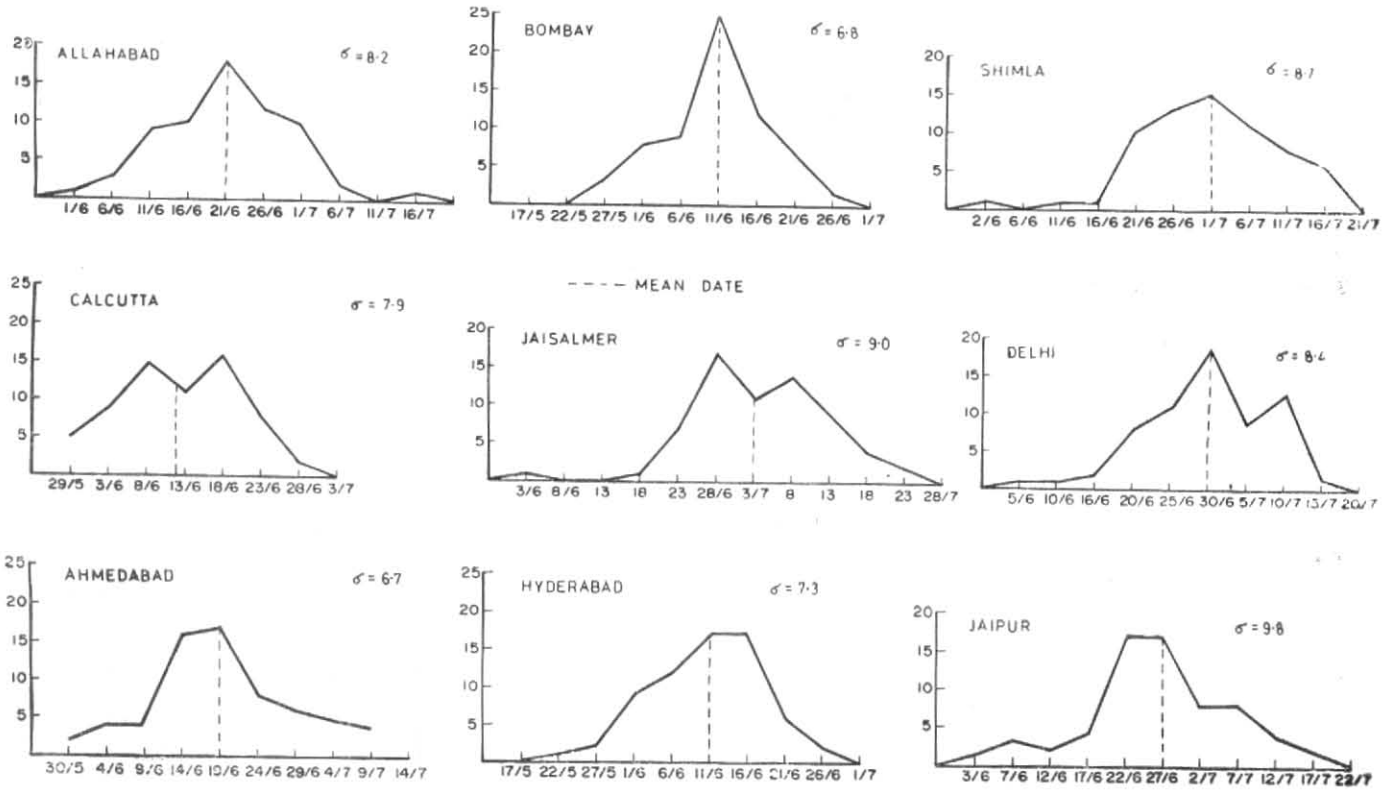

Fig. 2. Frequency distribution of dates of onset

3. Results and discussion

3.1. *Mean date and its variation*

The mean dates for 15 stations have been plotted and isochrones are drawn and shown in Fig. 1. For the sake of comparison the normal dates of the monsoon onset, in vogue in the India Met. Dep. (1943) are also given in the figure. Over some areas (*e.g.*, the Peninsula) there is remarkable coincidence between the dates worked out in the present study and that given in the India Met. Dep. publications. Over Gujarat, north Madhya Pradesh, Uttar Pradesh, Bihar and Gangetic West Bengal, some divergence between the two is noticed. The lag between the two dates, however, is not large enough to be statistically significant. On the other hand over northwest India, the dates are earlier by 5-10 days. This is particularly so, over extreme west Rajasthan where the mean onset may be the first week of July.

The information on mean date, its SD, CV and extremes are given for 15 stations in Table 1. It is seen that SD of the mean dates is generally lowest, *i.e.*, about 7 days over the Peninsula. Over east Uttar Pradesh, Bihar and West Bengal it is $\simeq$ 8 days while over northwest India it is relatively large (about 10 days). The mean picture is seldom realised and is often disturbed in individual years. As may be seen in Table 1, there have been instances when the monsoon was 3-4 weeks earlier than normal. Delay by 2-3 weeks in some years over different parts of India is also not uncommon. An examination of the cases of delayed monsoon with the drought climatology prepared by Chowdhury *et al.* (1988) reveals that though some cases of delay have synchronised with the drought years, at many of the stations, in spite of delayed onset, the subsequent rainfall over the area has generally been good.

The variability of the onset is, by and large, lowest (*i.e.*, $\simeq$14%) over northwest India. Over other areas it is marginally higher. Remarkably, the advance of monsoon over the extreme south of the country is highly variable, where at Trivandrum CV attains the maximum value of 24%. Large variations in the first onset of summer monsoon over Indian Peninsular region may, therefore, be taken as a normal feature of monsoon system.

3.2. *Frequency distribution of onset dates*

The frequency distribution of the dates of establishment of the monsoon has also been worked out. For a few selected stations it is shown in Fig. 2. Most of the stations demonstrated a single peak, generally coinciding with the mean date of the monsoon onset and the pattern resembled approximately a Gaussian distribution (Fig. 2 a). In some cases a secondary maxima, *albeit* less conspicuous compared to the primary one, is observed (Fig. 2b). This second peak occurs 5-10 days earlier or later than the major peak. Sometimes no unique peak is seen and two peaks of nearly same amplitude, spaced within 5 days are observed (Fig. 2 c). Such cases suggest that in case the primary peak which is near to the mean date, is missed in a year there should be no cause for alarm and there is a high chance that onset could still be within subsequent 5-10 days.

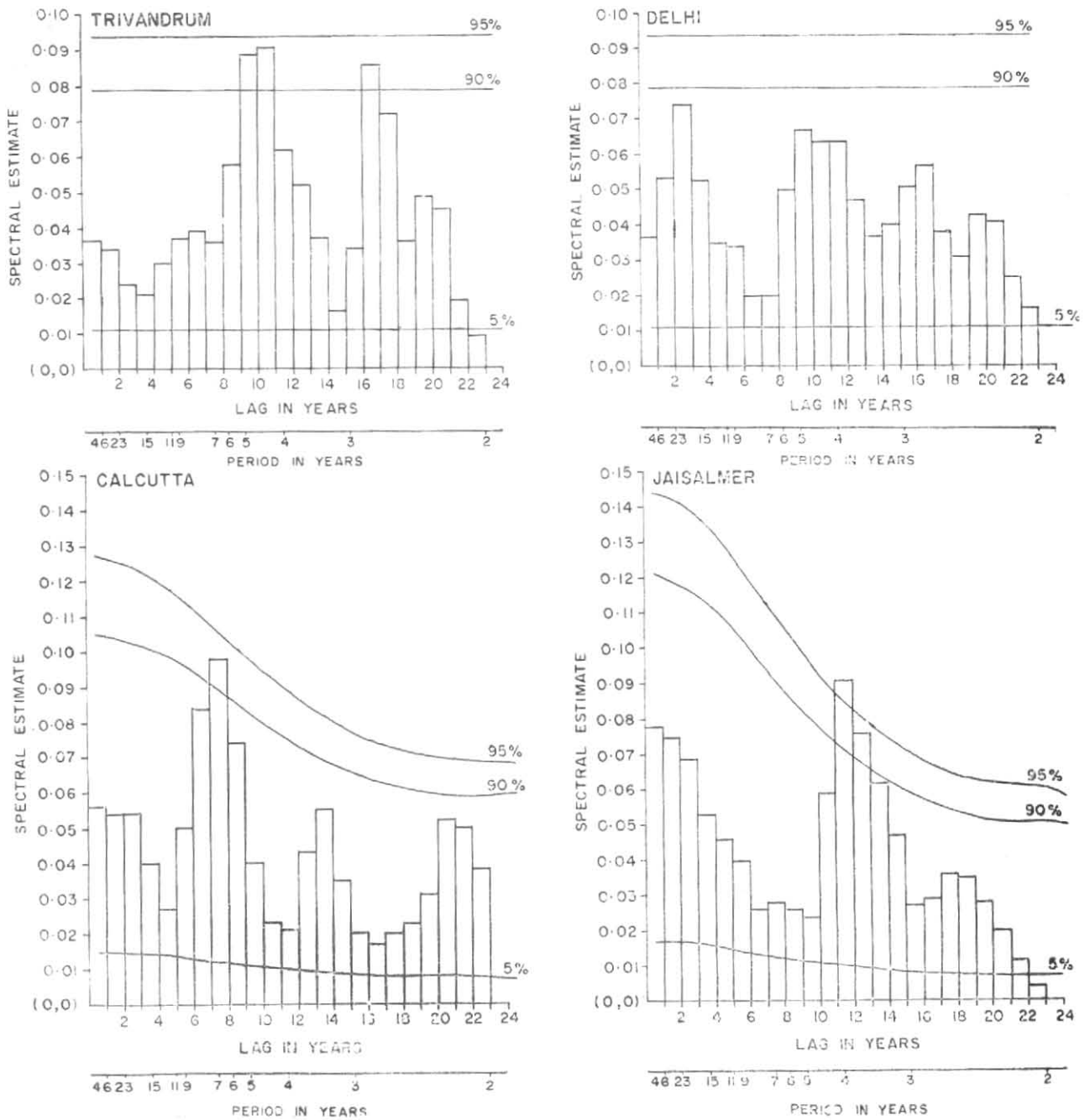

Fig. 3. Power spectrum of the dates of monsoon onset

With a view to determine statistically the nature of frequency distribution of the onset dates of monsoon for different stations, the series were tested for normality by using Fisher's g_1 and g_2 statistics (Fisher 1951) and comparing them with their standard errors. The results are depicted in Table 2. Since g_1 represents asymmetry of the distribution, the positive values, though small, show that values lower than the mean are slightly more frequent at nearly all stations. On the other hand, g_2 is a measure of kurtosis. The positive values observed at the stations indicate somewhat higher frequency of extreme and model values than the normal.

For any series to be normally distributed [g_1/S.E. (g_1)] and [g_2/S.E. (g_2)] should not exceed 1.96 at 5% level of significance and 2.58 at 1% level. Table 2 reveals that the onset dates of monsoon over northwest India, represented by Delhi, Amritsar, Jaisalmer follow a normal distribution.

3.3. *Analysis of periodicities and long term trend*

(a) *Spectrum analysis* — The onset dates were subjected to power spectrum analysis. For four selected stations, the results of the analysis is shown in Fig. 3. The 95 and 90% significant levels are also indicated

TABLE 2

Normality tests

Station	g_1	g_2	g_1/S.E(g_1)	g_2/S.E.(g_2)
Allahabad	0.019	2.916	0.075	—2.941*
Amritsar	0.113	3.575	0.340	—1.452
Bombay	0.000	2.774	0.000	—4.895*
Calcutta	0.003	2.444	0.014	—6.416*
Delhi	0.206	3.557	0.644	—1.360
Goa	0.006	2.555	0.027	—4.401*
Jaipur	0.030	2.997	0.146	—4.076*
Jaisalmer	0.254	4.032	0.659	—0.971
Nagpur	0.001	2.421	0.003	—6.967*
Trivandrum	0.001	2.849	0.004	—4.405*

*Significant at 5% level

TABLE 3

Significant values of t_k

Decade	Stations			
1921-30	Hyderabad, (—2.79)	Bombay, (—1.87)	Nagpur, (—2.44)	Calcutta, (—1.95)
	Lucknow, (—1.73)	Simla, (—1.80)	Amritsar, (—1.73)	
1931-40	Delhi, (—2.13)	Simla, (—2.13)	Amritsar, (—2.06)	Jaisalmer, (—1.69)
1961-70	Simla, (1.80)	Amritsar, (1.80)	Patna, (—1.87)	

in the figure. The spectral estimates appears to be randombly distributed. None of the peaks is found significant at 95% level except Jaisalmer where a peak of about 4 year periodicity, equivalent to about 11 years lag is significant. In the monsoon onset, other prominent periodicity, though not statistically significant, is of 2-3 year observed at Trivandrum corresponding to the well known quasi-biennial oscillations.Thus in general, it may be concluded that none of the peaks in the monsoon onset dates show any periodicity.

(b) *Decadal averages* — As has been seen above, the entire data series does not show any periodicity. It was, therefore, thought appropriate to examine whether any trend exists in this time span. For this purpose, the period under study was divided into six decades, *viz.*, 1921-30, 1931-40, 1941-50, 1951-60, 1961-70, 1971-80. This analysis could throw light on the variations taking place in the onset dates with time. For this purpose we compute t_k given by :

$$t_k = T_k \left[\frac{k\,(n-2)}{n-k-k\,T_k^2} \right]^{\frac{1}{2}}$$

where, $T_k = (\bar{x}_k - \bar{x}) / s$

n is the data set, k the number of years included in the period (*i.e.*, 10) and s the S.D.

For a normal distribution it can be shown that t_k is distributed as 't' with $n-2$ degrees of freedom. Significant values of t_k at 5% level for one tailed test are shown below the stations in Table 3.

Significantly lower than average dates, *i.e.*, early onset are seen at many stations during 1921-30 decade. Stations in northwest India also reveal lower than average dates in 1931-40 decade, while delayed monsoon, *i.e.*, more than average, could be seen at Simla and Amritsar in 1961-70 decade. Onset dates in the remaining cases were not found significantly different from the average date.

Thus decadal average are, in general, not signicantly different from the average or mean dates for the entire 1921-86 period.

3.4. *Association with monsoon rainfall*

Divergent views exist on association between monsoon onset and the seasonal rainfall totals. Whereas laymen believe that a delayed onset would result in a poor monsoon, meteorologists in general do not subscribe to this opinion.

Association of summer monsoon rainfall with the date of onset over an area is, thus, a matter of controversy. No doubt early onset coupled with late withdrawal of monsoon in a year widens duration of the rainy season and perhaps enhances the rainfall. On the contrary, early withdrawal, particularly associated with delayed onset of monsoon, curtails the rainy period and could cause deficient rainfall. In this study an attempt has been made to find out if the date of onset of rainfall at a particular place is related with the seasonal rainfall over the meteorological sub-division in which it is located. Correlations were found significant (at 5% level), between the date of onset at Ahmedabad and rainfall over Gujarat (*i.e.*, —0.295), at Allahabad and east Uttar Pradesh rainfall (*i.e.*, —0.340), and Simla and Himachal Pradesh rainfall, (*i.e.*, —0.333). The correlation coefficient between advance of monsoon at Patna and seasonal rainfall over Bihar plains was —0.240, which was marginally significant at 5% level of significance. In the rest of the cases, the correlations were numerically smaller than 0.11 and were, thus, insignificant. Over these areas, the seasonal rainfall may be considered independent of date of onset of southwest monsoon. The negative correlation of onset dates with the seasonal rainfall in Bihar plains, east Uttar Pradesh and Himachal Padesh may be attributed to the nature of the frequency curve of these dates. In these sub-divisions, the distribution is either single peaked or flat (Fig. 2 a) while for stations like Delhi, Jaisalmer etc (Fig. 2 b) also situated north of 25°N, are mostly bimodal with a second peak occurring later. This indicates that if the most probable onset date from climatological point of view, in these subdivisions is missed for once, possibility of sub-normal or deficient seasonal rainfall cannot be ruled out. Over the three meteorological sub-divisions in the west coast, Dhar *et al.* (1980) also found that rainfall during monsoon season does not have any association with the onset dates. In areas where correlation is significant, they are, however, too small to be at any practical utility. By and large, the onset dates were found to bear negative, though statistically insignificant, correlation with the seasonal rainfall. This is not difficult to understand. As mentioned in Sec. 2, the onset dates are

reckoned from 1 May. A large value in the figure could indicate delayed monsoon. Mathur (1986) also found negative correlation between onset dates over Punjab and Haryana and seasonal rainfall. The present study clearly brings out that the monsoon flow is fluctuatcry in nature. It is quite possible that a weak current at the onset time or a delayed establishment of monsoon could, in due course, get strengthened, increasing the seasonal rainfall and brightening the monsoon prospects.

To examine if the onset of monsoon over southern tip of India has any relationship with the seasonal rainfall over the country, correlation was also worked out between the date of onset over Trivandrum and the average monsoon rainfall over India. The area weighted average rainfall data for the country as a whole was obtained from Mooley and Parthasarathy (1984). This data was supplemented from computations made in the study. The correlation between the two was —0.12 and was insignificant. It is thus evident that the seasonal rainfall over India as a whole is independent of the time of establishment of monsoon over Trivandrum.

4. Conclusions

Specification of an objective criteria for determining monsoon onset by including explicitly and implicitly parameters characteristic of monsoon, is not an easy preposition. No wonder each method, for location furnishes dates of onset differing with those of the other. The present study uses data generated by the analysis of 5-day rainfall. The following results could be drawn from the study :

(*i*) The onset dates over northwest India follow a normal distribution pattern, while over other areas, no unique distribution could be observed.

(*ii*) The SD of the onset dates generally range between 7 and 9 days, the larger values being over northwest India.

(*iii*) Power spectra of onset dates does not show any uniquely significant peak.

(*iv*) The onset dates over most of the stations are not found to exercise any significant influence on the monsoon rainfall over the meteorological sub-divisions in which the stations are located. At Allahabad, Simla and Ahmedabad, however, a significant correlation was found between dates of onset and the seasonal rainfall over corresponding Met. sub-division.

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