

Fluctuations in the pattern of distribution of SW monsoon rainfall over Rajasthan and their association with sunspot cycle

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(Received 13 February 1974)

ABSTRACT. The yearly pattern of distribution of rainfall during the SW monsoon season for each of the years 1901 to 1950 for stations over Rajasthan are represented by six derived parameters. Year to year variation of these parameters, describing the distribution of monsoon rainfall, has been studied for nine representative stations over Rajasthan.

Polynomial trend analysis of the time series of parameters indicate oscillatory features and power spectrum analysis reveal certain significant periods corresponding to sunspot cycle or quasi-biennial oscillation. On examination of the monsoon circulation features such as the surface pressure anomalies and frequency of breaks in monsoon over India suggest that breaks in the monsoon are more during sunspot maximum than during sunspot minimum. It is also observed that frequency of storms and depression is less during sunspot maximum than during the sunspot minimum.

1. Introduction

In spite of the systematic nature of the monsoon rainfall, year to year total rainfall as well as its distribution during the season, show large variations. Fluctuations in the intensity and pattern in monsoon rainfall are to a large extent associated with the frequency of depressions, which traverse the Indo-Gangetic plain from east to west.

In a detailed study of rainfall data of Rajasthan, Rao (1958) concludes that there is no significant trend in seasonal or annual rainfall of Rajasthan. Ananthakrishnan and Pathan (1971) have presented results of analysis of mean pentad rainfall over India and neighbourhood. These show a variety of patterns of rainfall over the area. Jagannathan and Bhalme (1967) made a pilot study of monsoon pentad rainfall of northeast India for determining the variations in the pattern and linking them up with physical features. In their study it was reported that rainfall pattern experienced significant contrast between the different sunspot epochs suggesting the differential intensification of the seasonal trough of low pressure.

In the present study year to year variations in the derived parameters, that make up the distribution of rainfall during SW monsoon season over Rajasthan, have been examined by fitting orthogonal polynomial and power spectrum analy-

sis. The variation of rainfall distribution parameters parallel to sunspot cycle along with some monsoonal circulation features at different sunspot epochs are reported.

2. Data and method of analysis

The rainfall of the 25 pentads, comprised within the period 31 May to 2 October corresponding to the 31st and the 55th pentads, of the 'IGY Calendar', for the period of 1901 to 1950 for nine stations (Fig. 1) have been studied. The pattern of distribution of rainfall during this period has been broken into five orthogonal components such that the rainfall at time t can be represented as

$$R(t) = A_0 F_0(t) + A_1 F_1(t) + \dots + A_5 F_5(t) \quad (2.1)$$

where $F_r(t)$ is a function of the r th degree in time and the coefficients A_r are independent of time. These functions have the property of mutual orthogonality such that $\int F_r F_s dt = 0$, the integration running over the entire period under consideration. Due to this property the influence of the several functions are independent of each other and the coefficients of the polynomial indicate the extent of the influence of the different components independent of one another. Thus the coefficients can serve as independent parameters of the rainfall distribution for comparison between the different stations as also between different

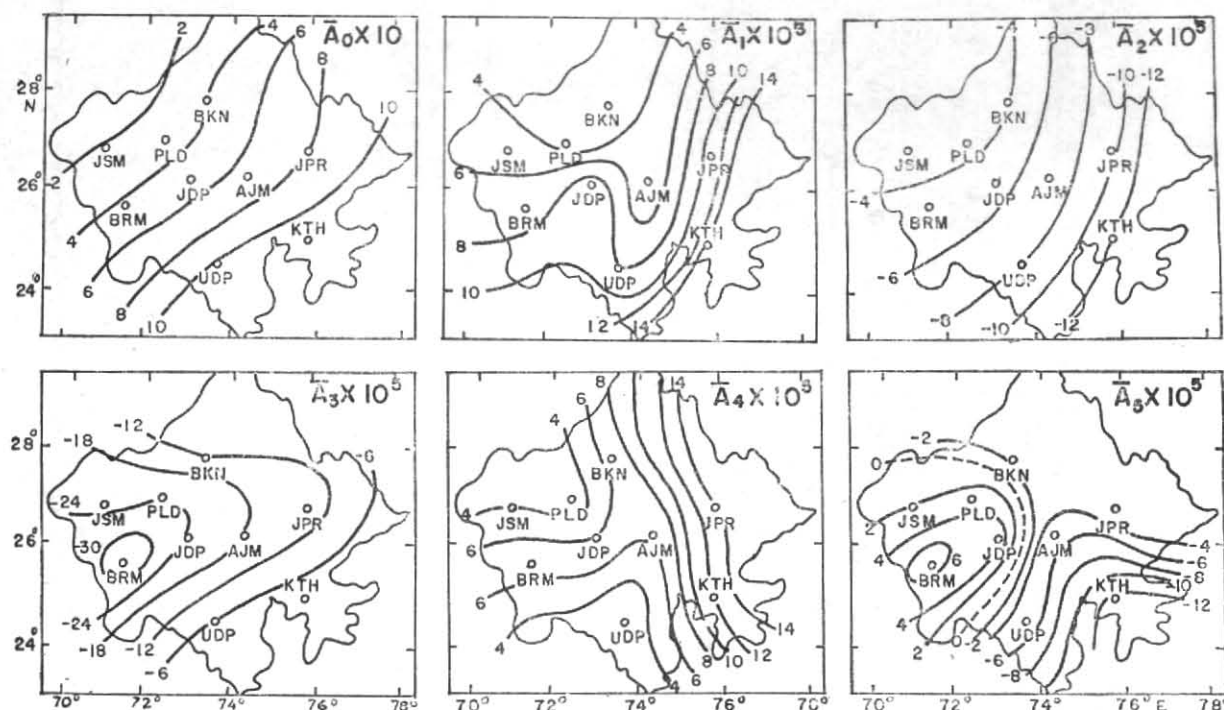


Fig. 1. Distribution parameters over Rajasthan

TABLE 1 (a)

Statistics of rainfall distribution parameters

Station	A_0				$A_1 \times 10^2$				$A_2 \times 10^2$			
	M	S.D.	C.V.	S.E.	M	S.D.	C.V.	S.E.	M	S.D.	C.V.	S.E.
Ajmer	·71	·32	44	·04	·04	·31	627	·04	·70	·48	69	·06
Barmer	·40	·26	65	·02	·07	·19	276	·02	·49	·47	95	·06
Bikaner	·40	·22	55	·03	·03	·18	521	·02	·43	·41	94	·05
Jaipur	·82	·34	42	·04	·10	·34	315	·04	·88	·59	66	·08
Jaisalmer	·24	·16	69	·02	·04	·12	277	·01	·29	·26	91	·03
Jodhpur	·50	·29	58	·04	·09	·27	297	·02	·51	·52	101	·07
Kotah	1·11	·44	39	·06	·14	·37	257	·05	1·16	·71	61	·09
Phalodi	·32	·19	59	·02	·03	·19	593	·02	·32	·31	95	·04
Udaipur	·90	·35	38	·04	·07	·35	475	·05	·76	·60	78	·08

TABLE 1(b)

Statistics of rainfall distribution parameters

Station	$A_3 \times 10^3$				$A_4 \times 10^3$				$A_5 \times 10^3$			
	M	S.D.	C.V.	S.E.	M	S.D.	C.V.	S.E.	M	S.D.	C.V.	S.E.
Ajmer	—·17	·96	539	·13	·07	·33	461	·04	—·05	·43	850	·06
Barmer	—·35	·85	239	·11	·07	·23	335	·03	·06	·54	553	·04
Bikaner	—·11	·64	547	·09	·07	·24	325	·03	—·03	·32	928	·04
Jaipur	—·14	·96	664	·13	·14	·32	229	·04	—·03	·43	1416	·06
Jaisalmer	—·20	·57	282	·08	·04	·15	334	·02	·02	·22	807	·03
Jodhpur	—·23	·76	326	·10	·06	·26	409	·03	·05	·47	863	·06
Kotah	—·07	1·21	1721	·17	·12	·41	322	·05	—·11	·61	515	·08
Phalodi	—·23	·60	251	·08	·03	·23	718	·03	·03	·33	920	·04
Udaipur	—·06	1·00	1536	·14	·01	·33	3245	·04	—·05	·56	995	·07

M—Mean; S. D.—Standard Deviation; C.V.—Coefficient of variation (%); S.E.—Standard Error

TABLE 2
Total count of the significant spectral peaks

Parameter	A_0	A_1	A_2	A_3	A_4	A_5	Total count
Total No. of peaks							
QBO	3	7	2	7	2	5	26
Sunspot cycle	5	0	8	1	0	0	14
Other cycles	5	1	3	2	4	0	15
Total	13	8	13	10	6	5	55

years. These will be referred to as distribution parameters and these are obtained by a well known method of fitting 5th degree polynomial (Fisher and Yates 1963).

3. Distribution parameters

The parameters representing the pattern of distribution of the rainfall during the monsoon in each of the years 1901 to 1950 at the nine stations have been calculated and the mean values of the different parameters, their standard deviations, coefficient of variations and standard errors of the mean are calculated (Table 1 a-b). The standard errors of the means indicate the extent of significance of the mean values of the parameters. Distribution of the mean values of the parameters over Rajasthan is also shown in Fig. 1, where,

A_0 — The coefficient in the first term represents the mean 5-day rainfall of the season at the station. As such the areal distribution of A_0 over the area represents the mean rainfall distribution during the season.

A_1 — Measures the gradient of the linear trend in the rainfall with the advance of the season. A positive value indicates a general increase of rainfall with the advance of the season, while a negative value indicates decrease. Over the entire Rajasthan this parameter is positive but small indicating a general increasing linear trend with the advance of the monsoon. A significant increase is seen over the Aravallis.

A_2 — The coefficient of the second-degree term is negative over entire Rajasthan indicating the rainfall on account of this pattern attains a maximum during the middle of the season. This feature increases eastward.

A_3 — This component is negative over the area indicating that the rainfall associated with this pattern attains a maximum during the second half of the season and minimum during the first half. This feature is significant over the Aravallis.

A_4 — This component indicates oscillatory features in the rainfall with peaks and troughs

alternating in about six weeks. It is practically insignificant over the area.

A_5 — This component indicates oscillation in the rainfall with peaks and troughs alternating in about 4 weeks. This is also practically insignificant in the mean.

Even though some of the mean parameters are not significant at some stations, they exhibit a good deal of continuity revealing their geographic dependence.

4. Trend analysis

In order to examine trend or long term variations, orthogonal polynomials of the 5th degree were fitted to the time series of the distribution parameters. None of the stations show significant trend in the parameter A_0 , i.e., in seasonal rainfall which is in conformity with the conclusions made by Rao (1958). A_1 for Udaipur and A_2 for Bikaner showed significant fifth degree trend indicating oscillation in these parameters with a period of 20 years. A_4 for Phalodi showed a third degree oscillation, i.e., with a period of about 35 years. A_5 for Udaipur showed a fourth degree trend.

5. Power spectrum analysis

The fluctuations noticed in the parameters may perhaps be due to any systematic oscillation, or due to any aperiodic variations. To ascertain the frequency of such oscillations, the time series of all the distribution parameters were subjected to power spectrum analysis. The computational procedure outlined in the WMO technical note (1966) on climatic change was adopted for this study. The power spectra were calculated with the maximum lag of 15 years.

Fig. 2 shows some of the power spectra of the distribution parameters and Table 2 gives the total count for significant spectral peaks for six parameters of all the stations.

The quasi-biennial oscillation (QBO) is seen to be predominant in the distribution parameters, while the sunspot and other cycles are also present in more or less in equal number of counts. Several atmospheric phenomena are associated with the sunspot cycles even though cause-effect relationship is still obscure and hence one will be justified in considering them as probable.

The following are the salient features of the analysis —

A_0 — Significant QBO in A_0 is observed at Barmer and Jaipur while at Bikaner, Kotah, Jodhpur, Phalodi and Udaipur such oscillations are more or less the same as that of sunspot cycle.

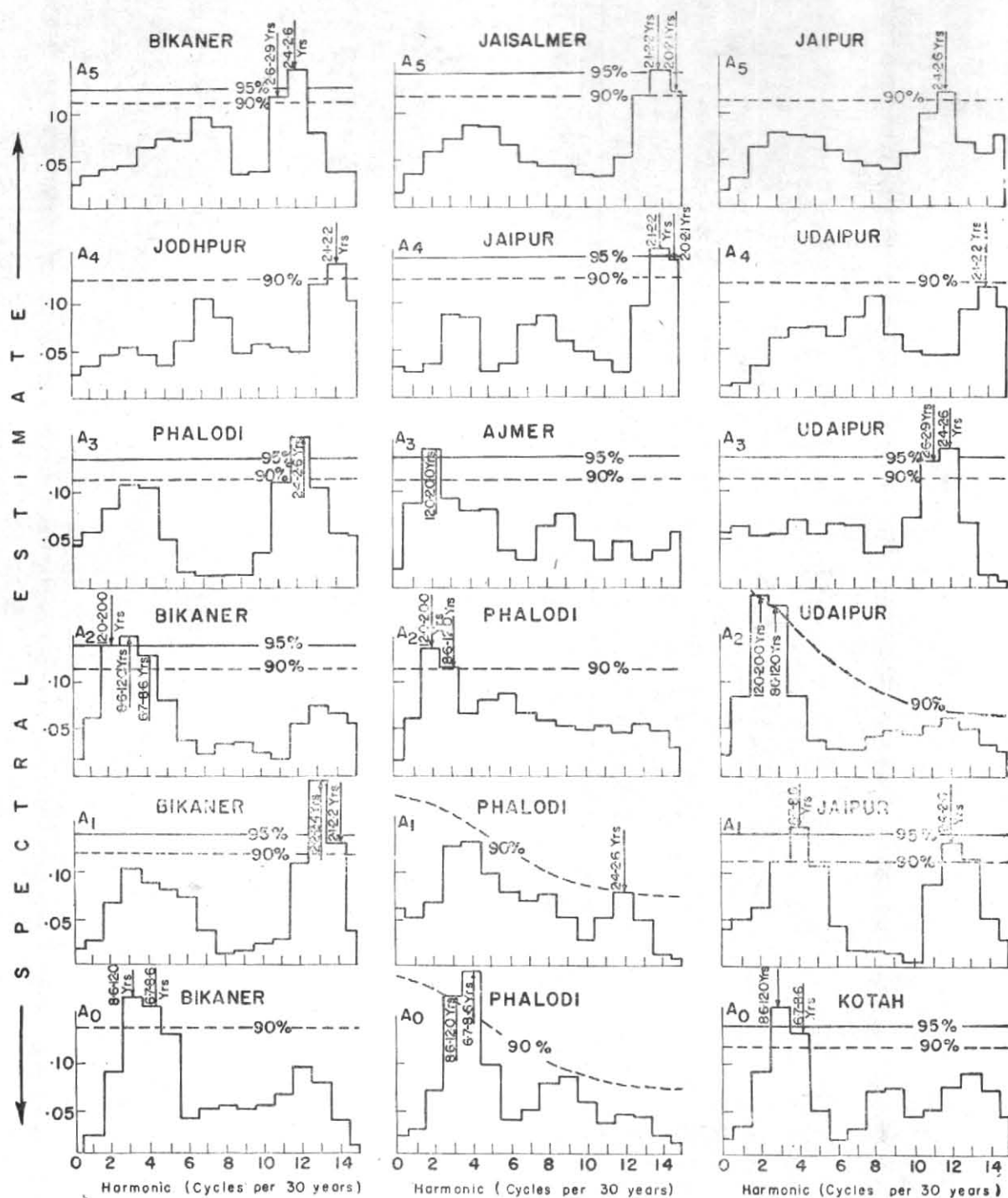


FIG. 2. Power spectra of rainfall distribution parameters

A_1 — QBO is predominantly observed in the 1st degree component at all the stations except Ajmer, Kotah and Udaipur.

A_2 — Fluctuations observed in the 2nd degree component over Barmer, Bikaner, Phalodi and Udaipur are about that of the sunspot cycle while at Jaipur the fluctuations is that of QBO.

A_3 — All the stations show QBO except Ajmer which reveal sunspot cycle in the 3rd degree component.

A_4 — The fourth degree component shows QBO at Jaipur and Jodhpur.

A_5 — Jaisalmer, Bikaner, Jaipur and Kotah show QBO in the 5th degree component.

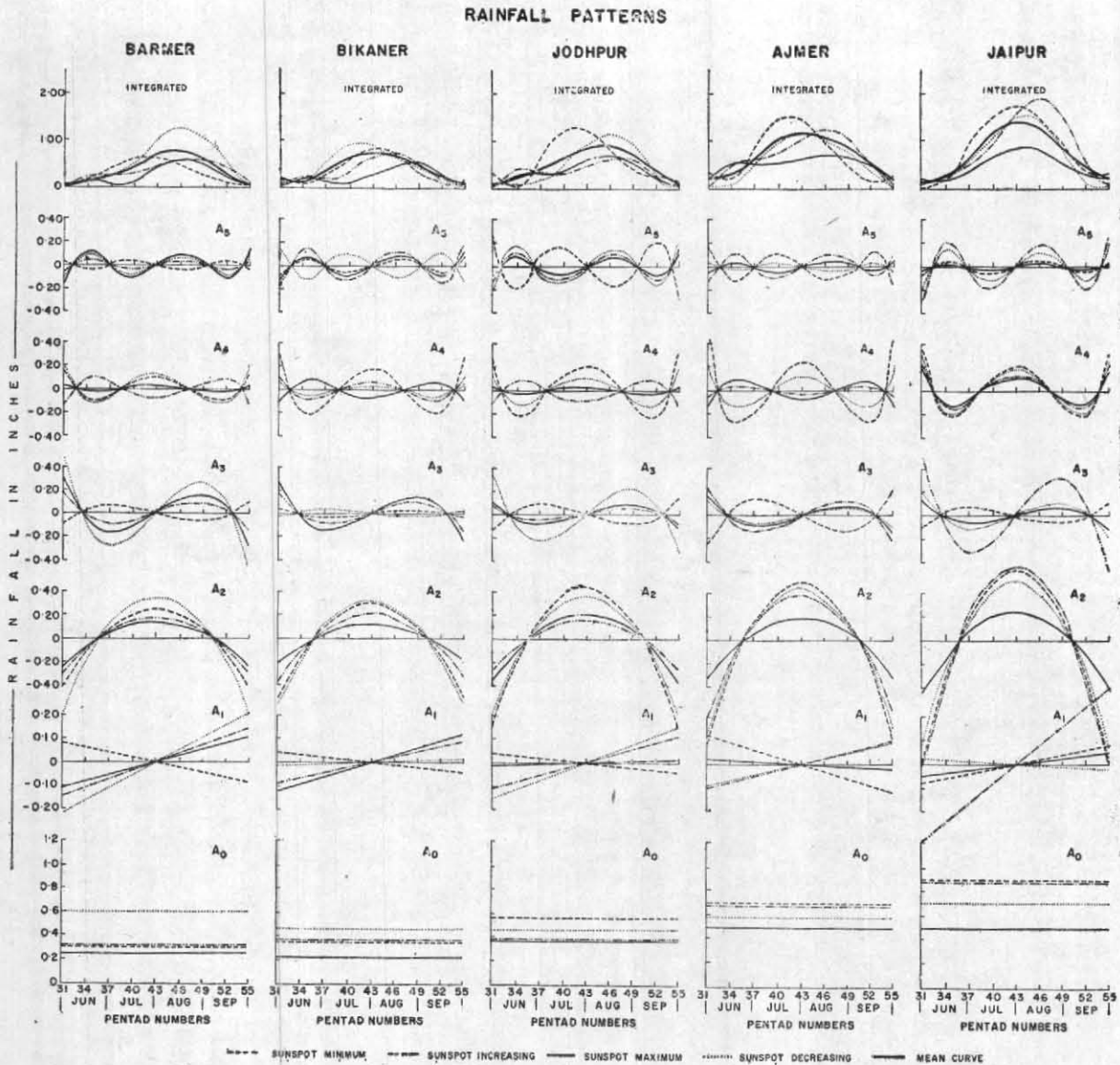


Fig.3

6. Variation associated with sunspot epochs

The above analysis shows that the several characteristic parameters representing the pattern of distribution of monsoon rainfall experienced oscillations corresponding to that of the sunspot cycle. The composite patterns, corresponding to the epochs of maximum, minimum, increasing and decreasing in sunspot cycle have been obtained by pooling together the different years of like sunspot character, and are presented here. The contrasting variations in the component patterns of the rainfall distribution associated with the four epochs along with the integrated patterns are shown in Fig. 3. This figure exhibits significant contrast in the component patterns, suggesting

that rainfall distribution during the season takes different patterns during the different sunspot epochs. The variations in parameters associated with sunspot cycle are shown in Fig. 4. The values of the parameters are plotted at different sunspot epoch after totalling parameters of the years of like sunspot character and taking their mean. It is seen from the Fig. 4 that variations of A_0 and A_4 parameters of the stations presented, are mostly opposite in phase to the sunspot curve where as A_2 parameters are more or less parallel to the sunspot curve.

The spatial distribution of the anomalous variations between sunspot epochs specified by $\Delta A_r = \bar{A}_{r(\max)} - \bar{A}_{r(\min)}$ are shown in Fig. 5.

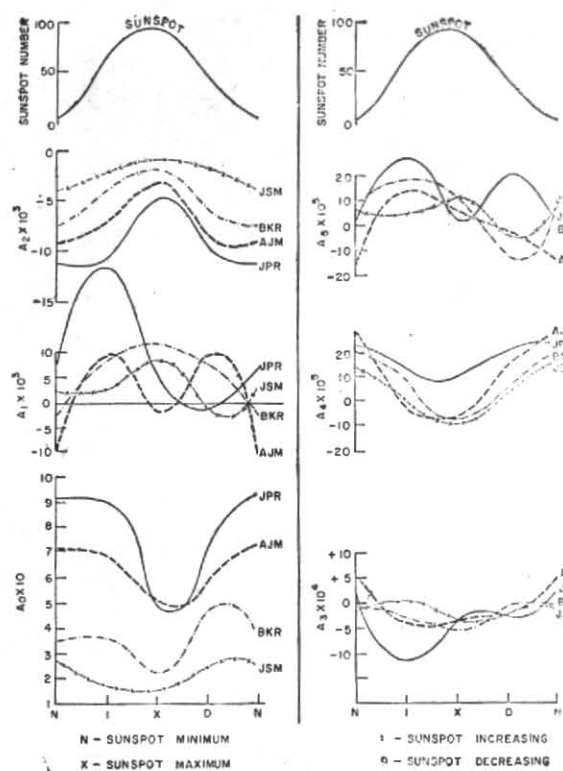


Fig. 4. Variation of distribution parameters with sunspot cycle

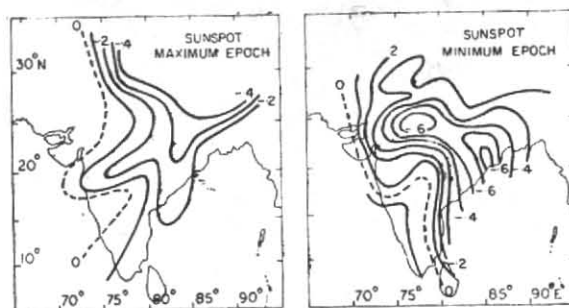


Fig. 6. Surface pressure departure (mb) during monsoon season

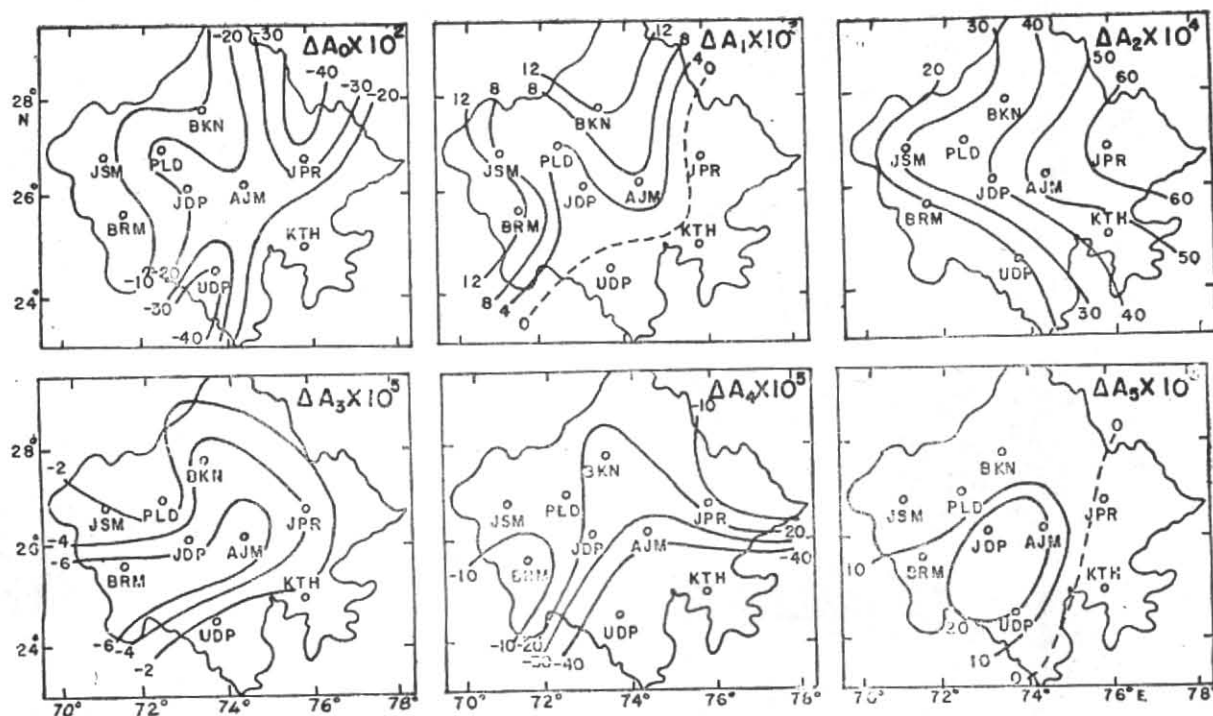


Fig. 5. Anomalous variations between sunspot epochs

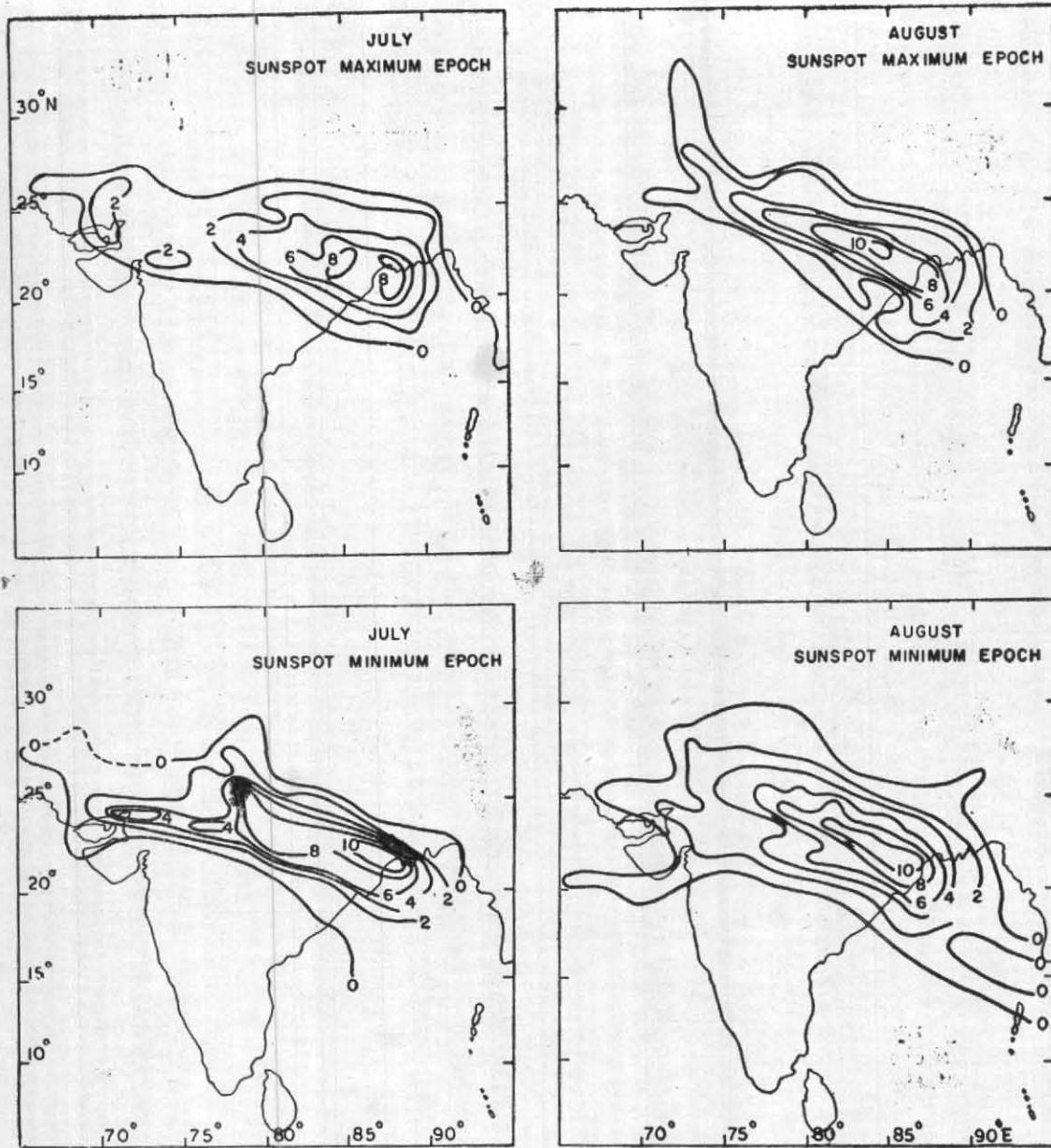


Fig. 7. Frequency of storms and depressions (1901-1950)

The following are the salient features of the variations associated with sunspot :

A_0 — At all the stations mean rainfall during sunspot minimum is larger than that during sunspot maximum.

A_1 — The anomalies are positive over the west Rajasthan and insignificant over the rest of the area, indicating that rainfall due to this component over west Rajasthan increases with the advance of the season during the period of sunspot maximum over that during sunspot minimum.

A_2 — The anomalies are positive at all the stations, indicating rainfall maxima during the middle of the season due to this component are elevated during sunspot minimum.

A_3 — The anomalies are all negative, indicating the maximum in this component pattern which occurs during the later half of the season is enhanced during sunspot in maximum.

A_4 — The anomalies are all negative, indicating that maximum in the rainfall associated with this pattern occur more predominantly during sunspot minimum.

A_5 — The anomalies though not significant over the whole area, are positive in the west and negative in the east.

7. Anomalous circulation features associated with sunspots

The foregoing analysis clearly brings out that the rainfall distribution during the monsoon season takes different patterns during the different sunspot epochs. However, as the intensities of the variations differ over different parts, it appears that the influence of sunspots as evidenced by the differential rainfall patterns should have arisen due to changes introduced in the atmospheric circulation features.

7.1. The composite surface pressure field associated with sunspot maximum and sunspot minimum epochs (Fig. 6) shows that during sunspot maximum, the core of the negative pressure departures lies near the foot of the Himalayas, a condition usually associated with 'break monsoon' while during sunspot minimum this core is situated further south over Orissa-Madhya Pradesh-east Rajasthan as in the active monsoon condition.

7.2. Table 3 (extracted from Ramamurthy 1969) shows frequency of 'breaks in the monsoon' during July and August of the different years. It can be seen that the total number of days of 'break in the monsoon' are significantly larger during sunspot maximum than during sunspot minimum epoch.

7.3. It is well known that the fluctuations in the intensity of rainfall during monsoon are to a large extent associated with the series of storms and depressions which have their origin over the head Bay of Bengal and to their movement. The number of storms and depressions, which crossed 1-degree square during the two epochs in respect of the normally strong monsoon months July and August are shown in Fig. 7. It is seen that the frequency of storms and depressions is more during sunspot minimum than during sunspot maximum. Further the length of the tracks of storm are longer and more diverse during sunspot minimum than during sunspot maximum.

TABLE 3

Year	Days of breaks Sunspot min.	Year	Days of breaks Sunspot max.
1901	4	1906	28
1912	11	1918	23
1923	0	1928	12
1933	7	1938	0
1943	0	1948	3
Total	22		66

8. Conclusions

The analysis has brought out the characteristic patterns of the distribution of monsoon rainfall over the different parts of Rajasthan. Power spectrum analysis of the time series of the distribution parameters, show some indication of sunspot cycle. The QBO is predominantly observed in some of the parameters. The study reveals that the rainfall distribution during the monsoon takes different patterns during the different sunspot epochs. However, as the intensities of the variations differ over different parts, it appears that the influence of sunspots as evidenced by differential pattern should have arisen due to changes introduced in the atmospheric circulation features. Examination of surface pressure anomalies and frequency of breaks in monsoon reveal that breaks in the monsoon are more during sunspot maximum than during minimum. It is also observed that the frequency of storms/depressions is less and tracks shorter during sunspot maximum than during the sunspot minimum.

Acknowledgements

It is a pleasure to acknowledge the keen interest taken by Dr. K. R. Saha, Assistant Director (FRD) in the present work. The work was initiated when the author was working in Climatology and Hydrometeorology Division. The problem was suggested by Shri P. Jagannathan who took continuous interest in the present work. The author is grateful for his help and guidance.

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