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# FLUCTUATIONS, TRENDS AND PERIODICITIES IN RAINFALL OVER CENTRAL INDIA

1. Several studies have been made in the past to determine presence of trend or periodicity in monsoon rainfall over India. Walker (1910), pioneer in monsoon studies, did not observe any perceptible changes or trends in rainfall during the period 1841- 1908. Agarwal (1952) studied rainfall for central India and found a steady (though statistically insignificant) change in the period 1908-40. Pramanik and Jagannathan (1953) observed a weak increasing linear trend in rainfall over Nagpur. Parthasarthy and Dhar (1976), based on 1901-60 data for Madhya Pradesh (M.P.), found an increasing trend in annual rainfall in both east and west Madhya Pradesh. Based on data from 1871-1988, Parthasarthy *et al.* (1990) found 52 negative and 66 positive rainfall departures. Subbaramayya and Naidu (1992) using rainfall data for the period 1871-1988 found decreasing significant trend in monsoon rainfall towards the end of the previous century which ended by 1904 in west central India, while rainfall increased from 1940 to 1946 in central India.

1.1. The aim of the present study is to critically examine rainfall over the central India and to find presence of trend (positive or negative) and periodicity in the rainfall series.

2. In this study, seasonal (June to September) rainfall data for east M.P., west M.P. and Vidarbha regions (central India) for the period of 118 years, *i.e.*, 1875-1992, have been considered. The data have been collected from the records of the Additional Director General of Meteorology (Research), Pune.

3. Table 1 contains mean monsoon and annual rainfall, coefficient of variation(CV) and the proportion of seasonal rainfall to the total annual as a percentage. It is seen from the table that east M.P. is the rainiest among the three sub-divisions. The variability ranges between 15 to 19 % for both monsoon and annual rainfall in M.P., whereas it is slightly more in Vidarbha. The monsoon rainfall contributes to over 87% of annual totals with the highest of 91% in west M.P. As such, the present study is confined to the rainfall for the monsoon season only. The presence of trend, or

**TABLE 1**
**Mean sub-divisional rainfall and coefficient of variation(CV)**

| Sub-division | Mean rainfall (cm) | | Coefficient of Variation (%) | | Monsoon/ Annual (%) |
|---|---|---|---|---|---|
| | M | A | M | A | |
| East M.P. | 118.0 | 133.4 | 15.5 | 15.4 | 88.5 |
| West M.P. | 094.8 | 104.2 | 18.8 | 18.7 | 91.0 |
| Vidarbha | 093.8 | 107.6 | 20.3 | 19.9 | 87.2 |

M - Monsoon, A - Annual, M.P. - Madhya Pradesh

**TABLE 2**
**Statistical test parameters for monsoon rainfall**

| Sub-division | Von-Neumann ratio (V) | Mann Kendall rank statistic ($\tau$) | Spearman rank statistic ($\gamma_s$) |
|---|---|---|---|
| East M.P. | 2.23 | -0.08 | -0.12 |
| West M.P. | 1.99 | -0.09 | -0.13 |
| Vidarbha | 2.25 | -0.06 | -0.05 |

randomness has been examined by subjecting the monsoon rainfall series to the Mann Kendall rank statistic, the Spearman rank statistic, the Von Neumann ratio and low pass filter. Cramer's test has been used for comparison of means of sub periods with the mean of the whole period. Power spectrum and correlogram analysis have been used to find any hidden periodicity. Intercorrelation amongst the rainfall of the three sub-divisions was determined to find, spatial coherence, if any, in rainfall occurrence.

3.1 (a) To determine presence of trend, the following techniques were adopted in the study. By computing the correlation between rainfall and the time (by assigning dummy variable to time), presence of trend has been examined. In this study, the correlations and slopes of the regression lines were found very low, negative and insignificant, suggesting absence of any significant systematic increase or decrease in rainfall in central India.

(b) Independence of successive observations has been examined by computing Von-Neumann ratio (Table 2). At 5% level of significance, no trend could be noticed in all the three sub- divisions of central India.

(c) The Mann Kendall rank statistic (also given in Table 2) shows that the values for all the three sub-divisions are negative and very near to zero suggesting absence of significant trend in rainfall. No significant trend was observed when the data series of each sub-division was subjected to Spearman rank statistics (Table 2).

(d) The long term trend present in a series can also be examined if the variations in the shorter wavelength of the series are suppressed by means of a "low pass filter". The weights used in the present study were the nine ordinates of Gaussian probabilities curve (WMO 1966). The actual and filtered rainfall series for all the three sub-divisions are shown in Fig.1. It is found that during 1875 to 1889, there is an increasing trend in all the three sub-divisions, whereas during 1890-1900 there is decreasing trend. After that, there is general increase upto about 1935 and subsequently a slight decreasing trend is observed in all the three sub-divisions (Parthasarthy and Dhar 1976).

3.2 (a) Periodicities in rainfall for central India have been examined by subjecting the data to correlgram analysis by computing auto-correlations from lag 1 to 40. Except in west M.P., in none of the other sub-divisions, the auto-correlations were found significant. Only one auto-correlation coefficient for 20 years lag is found significant at 5% level in west M. P.

(b) When the data was subjected to power spectrum analysis (unfiltered series) it revealed the presence of cycles of period exceeding 80 years. The "digital difference filter", which is normally used to remove low frequency oscillations (high period oscillations), was applied. The equation used for difference filter is

$$Y_t = (X_t - X_{t-1})$$

Where $Y_t$ is the filtered series and $X_t$ is the unfiltered series. The spectra of the filtered rainfall series for the three sub-divisions are shown in Fig.2, which also contain significant values at 95% level. The spectrum in each case is indicative of white noise. The significant spectral peaks at 95% level have periodicities of 11.7 years, 10.25 years and 6.3 years in case of west M.P., 20.5 years and 16.4 years in case of east M.P. and 16.4 years and 11.7 years in case of Vidarbha. The near 11-year cycle observed at west M.P. and Vidarbha corresponds to well known and well documented solar cycle. The approximate cycle of 22 years at east M.P. can be considered as the "double sun spot cycle", also observed by Bhalme (1975). It may be noted that Parthasarthy and Dhar (1976) also observed the sunspot cycle for both the sub-divisions of M.P.

3.3 (a) Since year-to-year trend in rainfall was not seen, it was thought appropriate to determine, if for a long scale, say a decade or more, the rainfall has a trend. In this study the monsoon rainfall series was split up into three 30 - year period, *i.e.*, 1901-30, 1931-60 & 1961-90 and tested for significance by subjecting it to Cramer's (1946) test. The results of the analysis are given in Table 3. It is seen that in 1931-40 in east M.P. and Vidarbha the rainfall increases significantly by 9% and 15% respectively at 5% level compared to the long term mean. The rainfall increased from the long term mean by 12% in west M.P. in 1941-50 decade which was also significant at 1% level (Parathasarthy and Dhar 1976). In the remaining decades the monsoon rainfall

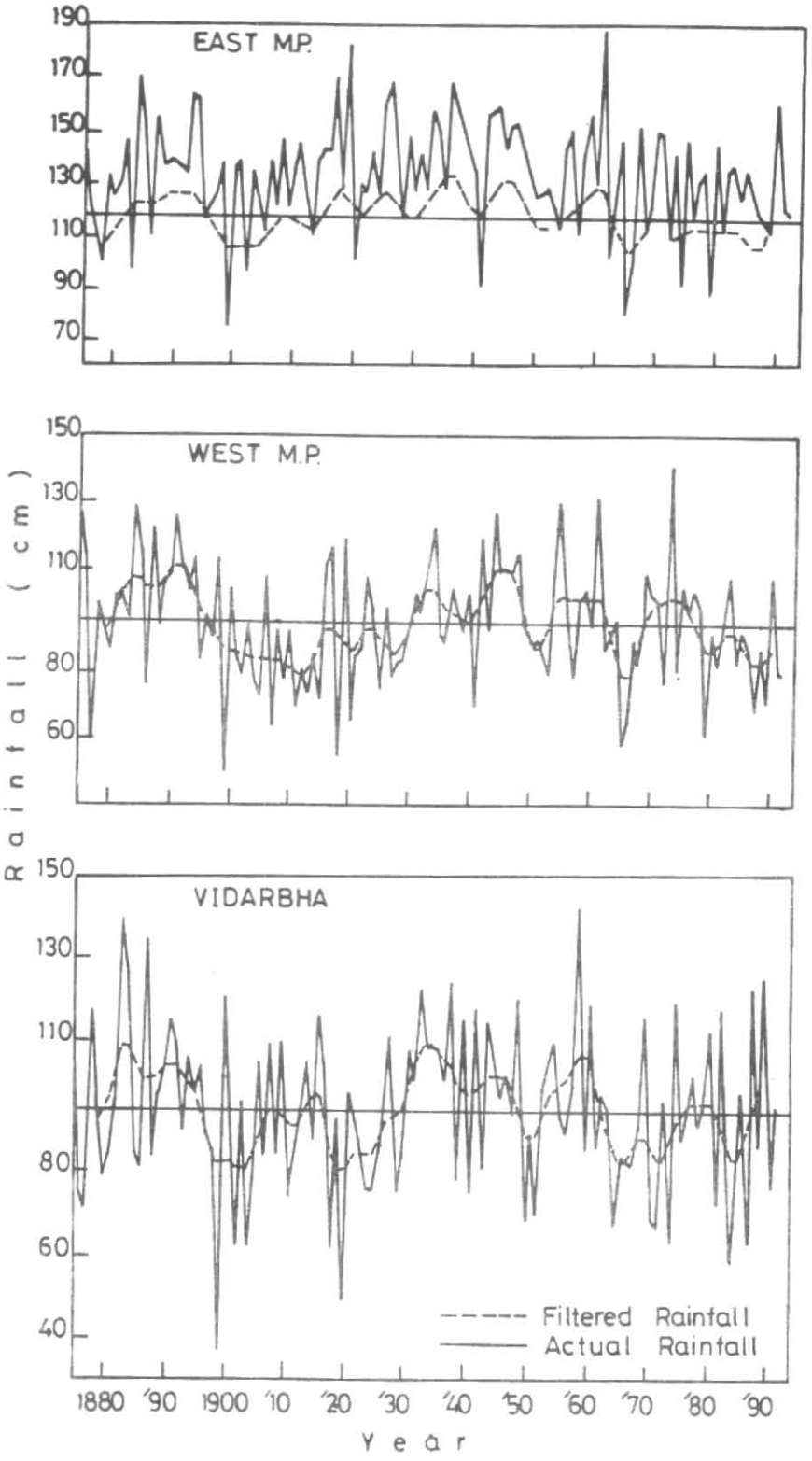


Fig.1. Actual and filtered rainfall (cm)

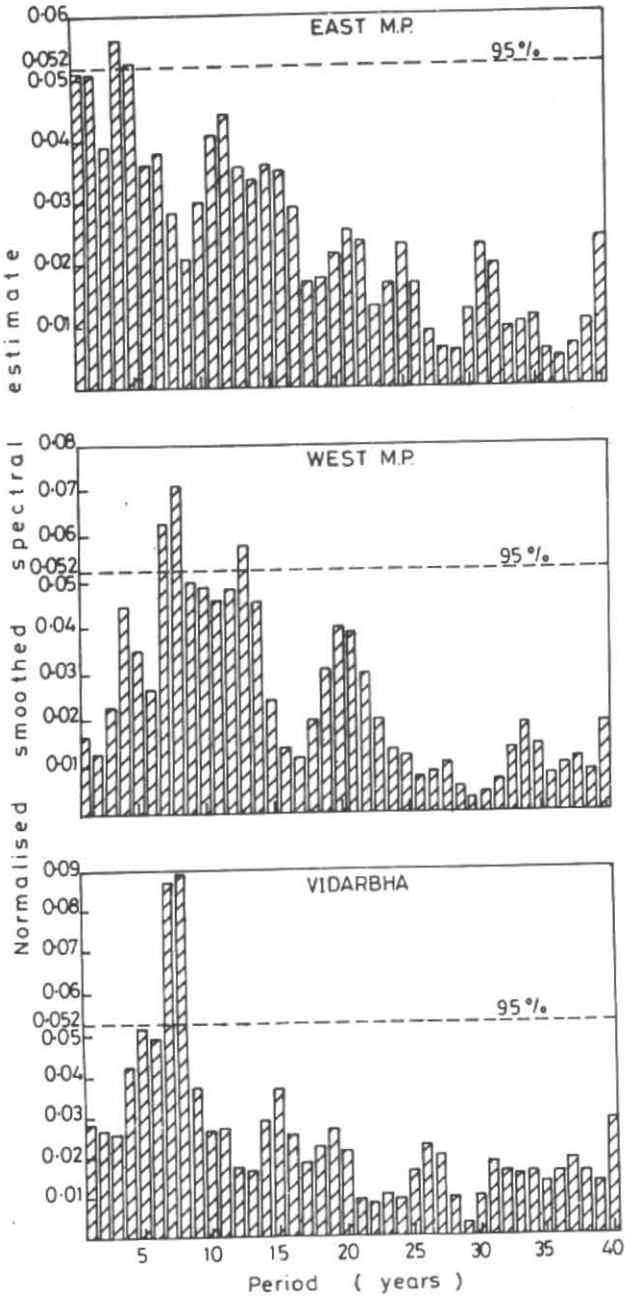


**Fig.2.** Power spectrum of monsoon rainfall (filtered series) harmonic (cycles per 80 years) for maximum lag of 40 years

difference was not found to be statistically significant from the long term mean. The 30 - year period rainfall when subjected to statistical tests, did not reveal any significant difference among the mean rainfall for each of the three periods nor with the normal rainfall. This was the case in all the three meteorological sub-divisions.

(b) When the series was split up into two parts, *i.e.*, 1875-1950 and 1951-1992 and subjected to the above analysis, only over east M.P. during 1875-1950, the rainfall was found to have increased by 15% from long term average which was significant at 5% level.

3.4. Generally rainfall in a particular location or region is seen to be spatially related with that in adjoining locations or regions. This is because rainfall in tropics (except that occurring in pre-monsoon season) is generally associated with large scale synoptic systems. In the present study the spatial coherence in rainfall in three sub-divisions was attempted by working out inter-correlation of rainfall between them. The result of the analysis is depicted in Table 4. The correlation between rainfall over west and east M.P. was found as 0.67 and that between west M.P. and Vidarbha was 0.60 which were significant at 5% level. On the other hand correlation between east M.P. and Vidarbha was 0.43 which was also significant at 5%.

4. From the foregoing discussions the following conclusions can be drawn:

(*i*) In the three sub-divisions the coefficient of variation varied between 15 and 20%.

(*ii*) From the decadal analysis it is observed that in 1931 - 40 in east M.P. and Vidarbha and in 1941-50 in east M.P. the monsoon rainfall significantly differed from its long term average.

(*iii*) An increasing trend during 1875 to 1889, and a decreasing trend between 1890 and 1900 in all the three sub-divisions was seen. Weak decreasing trend was also observed after 1940.

(*iv*) The rainfall series in each case is indicative of white- noise and thus free from persistence.

(*v*) Spatial coherence has been observed in rainfall occurrence in west M. P. and Vidarbha.

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**TABLE 3**

**Student's 't' values for decadal averages for monsoon rainfall**

| Decade | East M.P. | West M.P. | Vidarbha 1901-10 |
|---|---|---|---|
| 1901-10 | -1.20 | -1.66 | -0.97 |
| 1911-20 | 0.32 | -1.47 | -1.18 |
| 1921-30 | 0.83 | -0.70 | -0.94 |
| 1931-40 | 2.00* | 1.69 | 2.70* |
| 1941-50 | 1.14 | 2.20* | 0.84 |
| 1951-60 | -0.06 | 0.56 | 0.94 |
| 1961-70 | -0.42 | -0.29 | -0.29 |
| 1971-80 | -1.05 | 0.58 | -0.95 |
| 1981-90 | -1.54 | -0.87 | -0.07 |

*significant at 5% level

**TABLE 4**

**Inter-correlation between rainfall in three sub-divisions**

| Sub division | West M.P. | East M.P. | Vidarbha |
|---|---|---|---|
| West M.P. | 1.00 | 0.67 | 0.60 |
| East M.P. | 0.67 | 1.00 | 0.43 |
| Vidarbha | 0.60 | 0.43 | 1.00 |

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D.M. RASE

*Meteorological Office, Pune - 411005, India*

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