

## Fluctuations of regional scale atmospheric features in relation to monsoon activities

D. K. PAUL, V. R. MUJUMDAR, P. V. PURANIK, S. P. GHANEKAR,  
V. R. DESHPANDE and D. R. SIKKA

*Indian Institute of Tropical Meteorology, Pune*

**सार** - इस शोधपत्र में मानसून की तीव्र सक्रियताओं के संबंध में क्षेत्रीय मानसून परिचालन के 1979 और 1987 (खराब मानसून) और 1983 और 1988 (अच्छे मानसून) के दौरान कुछ लक्षणों के उतार-चढ़ाव का परीक्षण किया गया है। विश्लेषण से पता चलता है कि कुछ मौसम विज्ञान संबंधी लक्षणों में चार ऋतुओं के दौरान 30-50 दिन और 10-20 दिन जैसे दो बेहतर समय मानों में उच्चावचन करते हैं।

**ABSTRACT.** The paper examines the fluctuations of some features of the regional monsoon circulation in relation to extreme activities of monsoon for the years 1979 and 1987 (bad monsoon) and 1983 and 1988 (good monsoon). The analysis indicates that some of the meteorological features fluctuated on two preferred time scales, viz., 30-50 days and 10-20 days during the four seasons.

### 1. Introduction

Indian summer monsoon has shown considerable interannual variability in the recent years with the years of extreme drought and excess rain occurring randomly. The years that have experienced such extreme variation of deficient and excess rainfall in the preceding decade were 1979, 1982, 1986 and 1987 (deficient) and 1983 and 1988 (excess). In 1987 the percentage departure of rainfall from normal of the country as a whole was -19%, whereas, in 1988 it was excess by 17%, comparable to the years 1979 (-16%) and 1983 (13%). Such anomalous performance of monsoon in interannual scale must have association with the anomalous circulation features on planetary, as well as regional scale. In the planetary scale the linkage between the monsoon performance over India and the anomalous *El Nino*/southern oscillation events have been studied in details by many workers, for example, Sikka (1980), Rasmusson and Carpenter (1983), Mooley and Parthasarathy (1983) and Shukla and Paolino (1983). The specific relationship between the anomalous circulation pattern in the planetary as well as regional scale and the below normal rainfall over the country during 1987 has been brought out in a report on the scientific aspects of the failure of monsoon that year (IMD 1987).

In this paper the evolution of some of the parameters of the regional monsoon circulation have been examined and their effect on the behaviour of Indian summer monsoon in the interannual scale are discussed.

### 2. Regional parameters and data utilised

#### 2.1. Meridional pressure gradient over Peninsular India (zonal index)

During the monsoon season large meridional pressure gradient exists across India. Sea level pressure difference

between Trivandrum (8.5° N, 77° E) and Nagpur (21° N, 79° E), is considered to give a fair measure of this pressure gradient south of monsoon trough. This parameter gives an indication of strength of the low level westerly flow over Peninsula (Paul *et al.* 1981). Strong westerly winds are noticed when the monsoon trough is well marked and is positioned in its normal position. The daily zonal index, for the period from May to September for the years 1987 and 1988 as well as 1979 and 1983, is subjected to time-section and power spectrum analyses.

#### 2.2. Lower tropospheric wind over Peninsular India

Weekly upper level wind anomaly data for the radiosonde stations over Peninsular India for the period May to September 1987 and 1988 are analysed in details.

#### 2.3. Low level relative vorticity

A gross measure of large scale lower tropospheric relative vorticity within the trough region is adopted in the form of horizontal shear of the zonal wind component between 28° N and 20° N along 80° E. The day to day fluctuation of the horizontal wind shear for the period May to September 1987 and 1988 are discussed.

#### 2.4. Sea-level pressure anomaly field

Pressure anomaly field over the Indian monsoon region fluctuates at different quasi-periodicities. The negative pressure anomalies are usually associated with the active monsoon condition over India. The persistent positive anomaly would adversely affect the wind distribution and hence the moisture convergence over India leading to the weak or break monsoon conditions. A pressure anomaly index based on pressure anomaly data averaged over 13 grid points of 5° Lat./Long. squares including the central points (diamond grids)

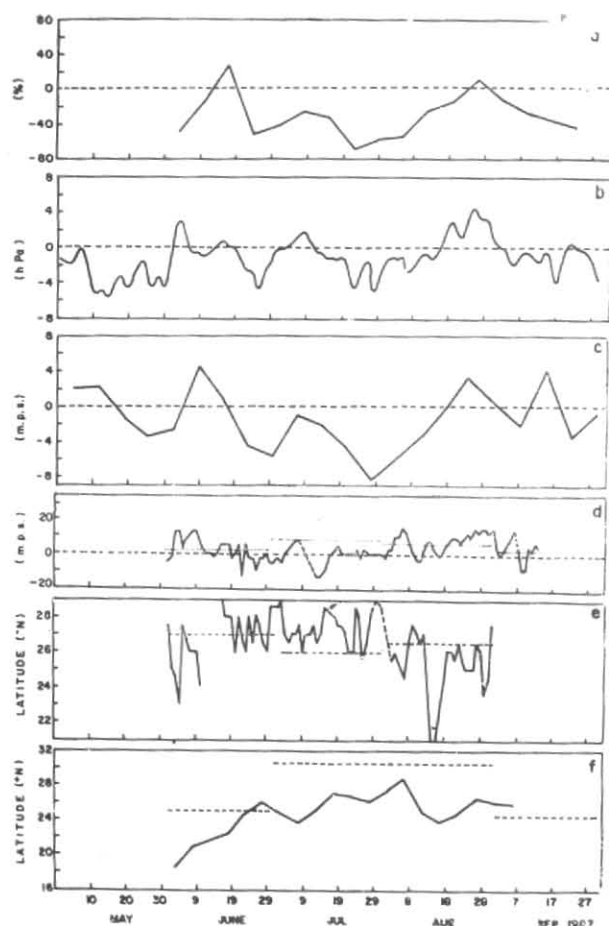


Fig. 1. Time-series of (a) area weighted rainfall over India, (b) zonal index anomaly, (c) 850 hPa wind anomaly at Mangalore, (d) low level (900 hPa) horizontal wind shear between 28°N and 20°N, (e) daily latitudinal position of the axis of monsoon trough along 80°E and (f) latitudinal position of the axis of 200 hPa ridge for the year 1987

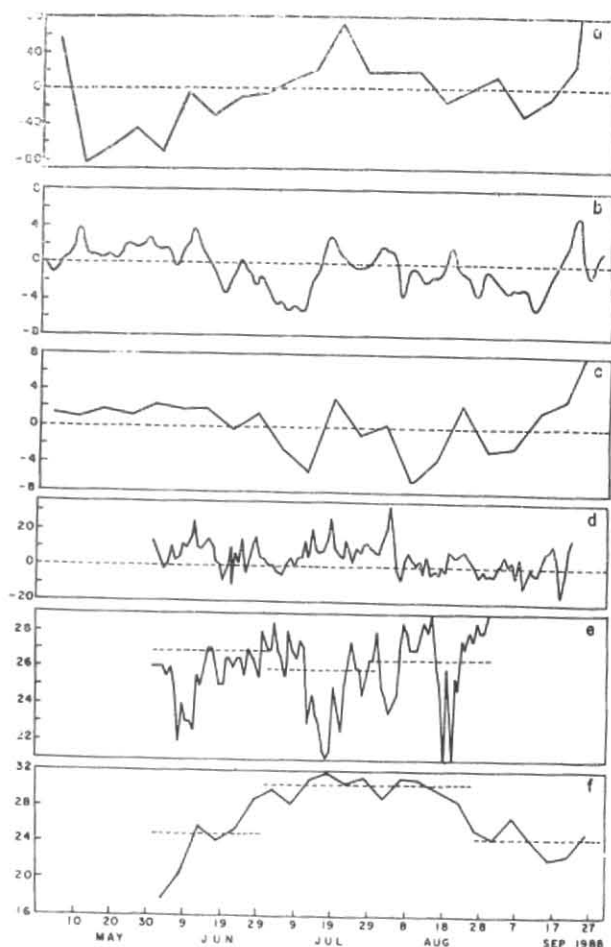


Fig. 2. Time-series of: (a) area weighted rainfall over India, (b) zonal index anomaly, (c) 850 hPa wind anomaly at Mangalore, (d) low level (900 hPa) horizontal wind shear between 28°N and 20°N, (e) daily latitudinal position of the axis of monsoon trough along 80°E and (f) latitudinal position of the axis of 200 hPa ridge for the year 1988

over entire India excluding the northeastern parts are obtained for the period from May to September 1987 and 1988. The indices are subjected to power spectrum analysis.

#### 2.5. Position of monsoon trough

The monsoon trough controls the moisture convergence and rainfall distribution of the country in space and time. Northward migration of the trough brings break monsoon condition while southerly position is generally considered favourable for well distributed rainfall. Daily latitudinal position of axis of monsoon trough along 80°E meridian for the months June to September for the years 1987 and 1988 are analysed in meridional time-section.

#### 2.6. Maximum cloud zone

Monsoon performance is linked with active-break cycle of monsoon within the season which in turn is related to intermittent northward progression of the near equatorial ITCZ and the associated organised

convective cloud zones on the time scale of 30 to 40 days (Sikka and Gadgil 1980, Sikka *et al.* 1986). A prolonged break or frequent active spell of monsoon may lead to deficient or excess rainfall respectively for the season as a whole. The satellite cloud coverage are utilised to delineate the daily latitudinal position of the Maximum Cloud Zone (MCZ).

#### 2.7. 200 hPa ridge axis

The strong easterly flow (tropical easterly jet) over the southern Peninsula during the monsoon season is associated with divergent outflow from the anticyclonic centre over Tibetan region. Highly organised moist convection over north Bay of Bengal and northeast India is supported by the large scale divergent flow pattern. A southward shift of this upper tropospheric ridge from its normal position is likely to affect the organised convection over the area. The 5-day mean latitudinal position of the axis of 200 hPa ridge averaged over meridional belt 70° to 90°E for the period from June to September 1987 and 1988 are examined.

### 3. Results

#### 3.1. Analysis in time series

Figs. 1 and 2 show the daily/weekly variation of the parameters chosen for the years 1987 and 1988 respectively. Sections (a) to (f) in Figs. 1 and 2 represent respectively, the distribution of area weighted mean percentage departures from normal of weekly rainfall over India (a), daily variation of zonal index (b), 850 hPa weekly zonal wind anomaly over Mangalore (c), daily value of 900 hPa zonal wind shear between  $28^{\circ}$  and  $20^{\circ}$  N along  $80^{\circ}$  E (d), daily latitudinal position of axis of monsoon trough along  $80^{\circ}$  E (e) and 5-day mean latitudinal position of 200 hPa sub-tropical ridge axis across the longitudinal belt  $70^{\circ}$ - $90^{\circ}$  E (f).

The performance of the monsoon over India, as a whole, can be looked into from the weekly progress of monsoon rainfall over India. The weekly rainfall of 28 out of 35 sub-divisions of India have been considered to obtain the area weighted mean percentage departure from normal of weekly rainfall over main land of India. Rainfall over five sub-divisions of eastern India comprising of West Bengal, Assam and neighbourhood, as well as the island sub-divisions of Lakshadweep and Bay islands are not taken into consideration. The distribution of area weighted mean weekly rainfall anomaly for the season 1987 showed persistent below normal rainfall ( $-30$  to  $-70\%$ ) for a period of nearly 8 weeks from middle of June to middle of August (Fig. 1a). This prolonged dry spell within the season coincided with the persistent anomalous behaviour of the regional parameters under study. Zonal index remained below normal for most of the period (Fig. 1b) indicating weak pressure gradient over the Peninsula. Persistent lower tropospheric easterly wind anomaly over the Peninsula (Fig. 1c) indicated that the monsoon westerlies were considerably below their normal strength during the dry spell. The low level zonal wind shear was negative (anticyclonic) during the period from 22 June to 4 July and 10-17 July and positive but below normal (weak cyclonic with magnitude not exceeding 5 m.p.s.) for rest of the dry period (Fig. 1d). The axis of the monsoon trough along  $80^{\circ}$  E lay north and 200 hPa ridge axis remained south of their respective normal positions throughout the dry spell (Figs. 1e & f).

Monsoon activity revived during the later half of August 1987. The mean weekly rainfall over India reached its normal limit, meridional pressure gradient strengthened and the easterly wind anomaly over Peninsula changed to westerly anomaly indicating strengthening of monsoon westerlies. The low level cyclonic shear over the monsoon trough region strengthened and the monsoon trough along  $80^{\circ}$  E rapidly shifted to south of its normal position. The time-series analysis of the above parameters for the season 1987, suggests that, in the sub-seasonal scale, the regional parameters fluctuated from extreme negative anomaly to positive anomaly, which also coincided with the weakening and strengthening of the monsoon rainfall activity over India. The analysis also suggests that the major phase changes in the regional parameters occur in two dominant time scales of about 10 to 20 days and 30 to 50 days within the monsoon season. In 1987 the parameters remained anomalously negative for a longer spell over 40 days resulting into weak monsoon condition for a prolonged period. This can be seen from Fig. 1(b), which showed recurrence

of major peaks of positive zonal index anomaly at an interval of 13, 20 and 41 days. Similar periods of oscillation are seen in other parameters too.

The monsoon season of 1988 is characterized by active monsoon conditions over India for major part of the period, interspersed with occasional weak monsoon conditions for short periods during mid-June to early July in the beginning of the season and during mid-August and early September in the established phase of the monsoon (Fig. 2a). A distinct change is seen in the daily/weekly fluctuation of the regional parameters during the season 1988. The fluctuations in the zonal index and lower tropospheric westerly wind anomalies occurred more frequently (Figs. 2b and c) compared to that in the season 1987. Low level zonal wind shear was cyclonic and above normal during most parts of the season, attaining a maximum magnitude of 25-35 m.p.s. during the period of peak monsoon activity as compared to the highest magnitude of 15 m.p.s. reached in 1987 (Figs. 1d and 2d). The cyclonic shear was below normal during the weak monsoon periods which also coincided with the periods of easterly wind anomaly (weak westerly). The axis of monsoon trough along  $80^{\circ}$  E also remained close to or south of its normal position for most of the time except for a short period during the weak monsoon phases (Fig. 2e). It is well known that a disturbance forming in the Bay of Bengal is responsible for the southward migration of the eastern end of the monsoon trough. The southernmost position of the axis of monsoon trough along  $80^{\circ}$  E during 8-12 June, 19-20 June, 12-22 July, 2-5 August and 20-22 August were associated with depressions which formed over north Bay of Bengal or low pressure areas over the monsoon trough region. Fig. 2(e) also suggests that the southward excursion of the monsoon trough recurred at an interval of 10 to 15 days during the season. The 200 hPa ridge axis remained close to or to the north of its normal position (Fig. 2f).

Fig. 3 shows the daily distribution of zonal index anomaly of 1979 and 1983. Notice the similarity in the oscillation of the zonal index between the years 1987 and 1979, as well as 1988 and 1983 in the figure. The anomalously positive peaks of the zonal index in 1979 were also few and recurred sequentially at an interval of 13, 31 and 50 days (Fig. 3) with negative anomaly persisting for a longer period of over 40 days from middle of August till the end of the season quite similar to that of 1987. Year 1983 showed more frequent fluctuation of zonal index anomaly with varied periods ranging from 10-15 days to 20-25 days. The year 1983 witnessed an uninterrupted monsoon activity without any break and was one of the best monsoon years of the decade.

Following Sikka and Gadgil (1980) the satellite cloud imageries of U. S. weather satellites and INSAT-1B were analysed for the years 1979, 1983, 1987 and 1988 to delineate the daily latitudinal position of the axis of maximum cloud zone (MCZ). Fig. 4 shows the daily variation of the axis of MCZ (solid lines) and northern and southern limits (dashed line) of MCZ for the period from June to August for the four years under study. The figure suggests suppression of large scale convection over the Indian region for a prolonged period both in 1979 and 1987. The epochs of northward progression of MCZ recurred at an interval of 30 to

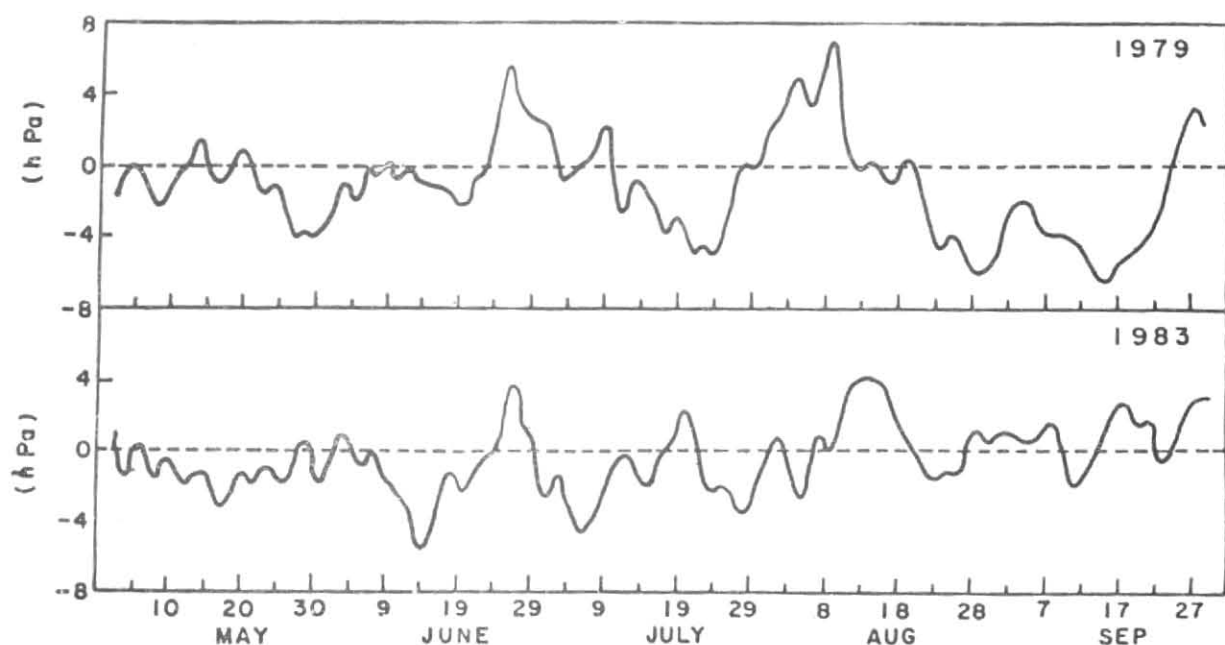


Fig. 3. Daily distribution of zonal index anomaly for the year 1979 and 1983

50 days in both the years. The situation is quite different in 1983 and 1988 where more frequent northward propagating epochs of MCZ were witnessed at an interval of 10 to 15 days.

### 3.2. Power spectrum analysis

The time series of 153 days (May to September) of zonal index anomaly data for the four years, as well as the pressure anomaly index data for the two years 1987 and 1988 were subjected to the power spectrum analysis. Fig. 5 illustrates the smooth spectral estimates of zonal index and pressure anomaly index. The zonal index spectrum for 1979 and 1987 shows a major peak near 50 days and another peak near 15 days (both significant at 1% level). In 1988 the peak near the range of 15-17 days was more significant (at 1%) than the peak near 50 days (at 5%). Zonal index anomaly in 1983 showed a prominent peak near 25 days and minor peak near the range of 10-12 days. Spectrum of pressure anomaly index for 1987 also showed significant peaks near 30-50 days as well as near 15 days. In 1988 the only significant peak was in the range of 15 to 17 days.

## 4. Discussion

The time-series analysis of the regional scale monsoon parameters suggest that the failure of monsoon rains in 1979 and 1987 must be associated with the persistent

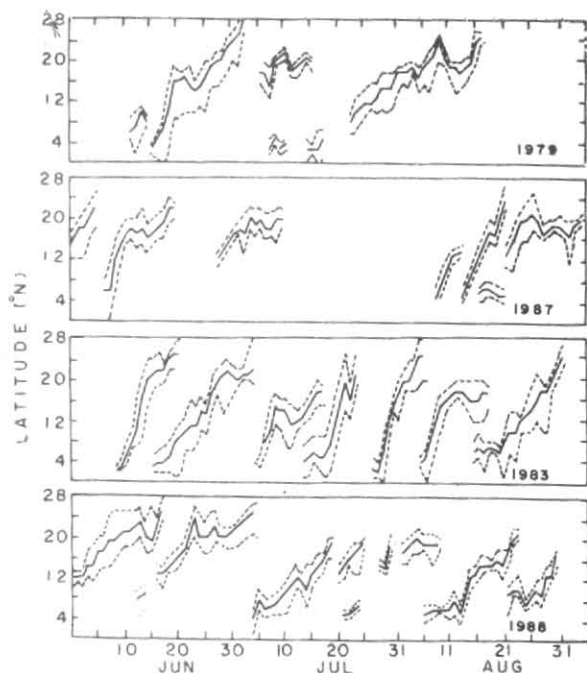


Fig. 4. Daily variation of the latitude of the axis of the MCZ (solid line); and northern and southern limits (dotted line) of the MCZ and the location of the 700 mb trough (dashed line) at  $90^{\circ}$  E for the years 1979, 1987, 1983 and 1988

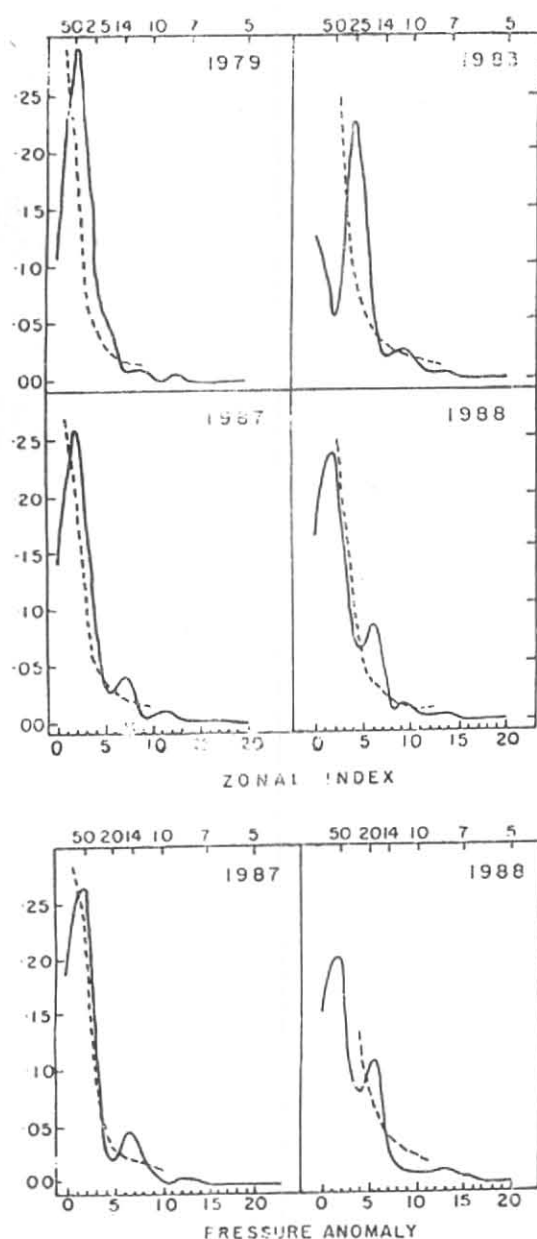


Fig. 5. Power spectrum of zonal index for 1979, 1983, 1987 and 1988 and pressure anomaly index for 1987 and 1988

anomalously negative feature of the regional scale parameters, which was responsible for the suppression of large scale organised convection over the Indian region.

The power spectrum analyses have indicated that the parameters in the regional scale fluctuated in two dominant low frequency modes, viz., 10-20 days and 30-50 days. In the sub-seasonal scale the oscillation switched from one range of periodicity to other, i.e., from 10-20 day periods (or less than 30-day periods) to near 50-day periods. The season, as a whole, may show some bias for a particular range of periodicity, e.g., the year 1983 and 1988 showed definite bias for the 10-20 day mode of oscillations, whereas near 50-day oscillation dominated the season 1987 and 1979. Thus, if during the season the dominant period is 10-20 days or near 30 days, the season is expected to be good monsoon year

TABLE 1

Year	Variance explained in %	
	10-20	30-50
1979	7	18
1987	12	18
1983	13	5
1988	13	7

The variance explained in percentage for both 10-20 and 30-50 day time scale for the four years

and when the period shifts more towards near 50-day periodicity the season is more likely to be a deficient season.

The usual recursive band pass filters (Murakami 1979) were applied to the time-series of zonal index anomaly for the four years to extract the filtered data sets into 30-50 days and 10-20 days time frame. After obtaining the filtered data sets the variance explained for 10-20 day mode and 30-50 day mode were worked out. Table 1 shows the variance explained in percentage for both 10-20 and 30-50 day time scale for the four years. The table illustrates that the variance explained by 30-50 day mode was more (nearly twice) than the variance explained by 10-20 day for the years of deficient monsoon rainfall like, 1979 and 1987 whereas for the good monsoon years 1983 and 1988, it was the other way.

##### 5. Conclusion

The analysis of four years of data suggests that in the sub-seasonal scale, the regional monsoon circulation undergoes changes, in which the regional parameters fluctuate in two dominant quasi-periodicities, viz., 10-20 days and 30-50 days. 10-20 days or near 30 days fluctuation is found to be dominant in the years 1983 and 1988 which are the years of good monsoon activity. The period of fluctuation shifted to near 50 days in 1979 and 1987 with prolonged spell of suppressed convecting activity resulting into deficient rainfall over the country. Thus, a knowledge about the period of oscillation at the commencement of monsoon would prove useful in the long range prediction of overall monsoon performances. This needs further studies in the larger scale to understand the phase relationship between super synoptic scale convective episodes over different parts of the regions, viz., western Pacific, southeast Asia, eastern Pacific-central American regions and Indian monsoon region.

##### Acknowledgements

The authors thank the Director General of Meteorology for supplying the data used in this study. Their thanks are also to Smt. Usha V. Bhide and Shri R. H. Kripalani for their help and valuable suggestions.



## References

- India Met. Dep., 1987, 'Report on scientific aspects of failure of summer monsoon rains over India in 1987', 26 pp. + diagrams.
- Mooley, D.A. and Parthasarathy, B., 1983, 'Indian Summer Monsoon and *El Nino*', *Pur. appl. Phys.*, **121**, 339-352.
- Murakami, M., 1979, 'Large scale aspect of deep convective activity over Gate area', *Mon. Weath. Rev.*, **107**, 994-1013.
- Paul, D.K., Mujumdar, V.R. and Sikka, D.R., 1982, 'Analogue in the southwest monsoon', *Mausam*, **33**, pp. 121-130.
- Rasmusson, E.M. and Carpenter, T. H., 1983, 'Relationship between Eastern Pacific Sea surface temperature and rainfall over India and Srilanka', *Mon. Weath. Rev.*, **111**, 517-528.
- Sikka, D.R., 1980, 'Some aspects of the large scale fluctuations of summer monsoon rainfall over India in relation to fluctuations in the planetary and regional circulation parameters', *Proc. Indian Acad. Sci.*, **89**, pp. 179-195.
- Sikka, D. R. and Gadgil, S., 1980, 'On the maximum cloud zone and ITCZ over Indian longitudes during southwest monsoon', *Mon. Weath. Rev.*, **108**, 1840-1853.
- Sikka, D.R., Paul, D.K., Deshpande, V.R., Mujumdar, V.R. & Puranik, P.V., 1986, 'Sub-seasonal scale fluctuations of the ITCZ over the Indo-Pacific region during the summer monsoon season—Part I : Features over the Indian region', *Proc. Indian Acad. Sci. (Earth Planet. Sci.)*, **95**, 1, March 1986, 47-73.
- Shukla, J. and Paolino, D.A., 1983, 'The southern oscillations and long range forecasting of summer monsoon rainfall', *Mon. Weath. Rev.*, Sept. 1983, **111**, 1830-1837.