

## Secular variations and trends in the occurrence of monsoon synoptic systems and its impact on central India rainfall

D. M. RASE, M. P. SHEVALE and S. I. M. RIZVI

*Meteorological Department, Pune – 411 005, India*

*(Received 7 June 2005, Modified 14 May 2009)*

**e mail : dineshmrase@rediffmail.com**

**सार** – मानसून अवदाबों, निम्न दाब तरंगों तंत्रों (एल.पी.एस.) और वर्षा के समय एल.पी.एस. दिनों की संख्या की महत्ता और उनका कृषि और जल पर अप्रत्यक्ष रूप से पड़ने वाले प्रभाव सुविदित हैं।

इस शोध-पत्र में वर्ष 1901 से 2000 तक की अवधि के आँकड़ों का उपयोग करते हुए इन तंत्रों में वार्षिक परिवर्तनशीलता के पैटर्नों की जाँच की गई है। किसी भी नियमित पैटर्न की विद्यमानता का पता लगाने के लिए ऊपर बताए गए प्राचलों का दशकीय विश्लेषण किया गया है। समय के साथ इनकी प्रवृत्ति का पता लगाने का प्रयास किया गया है। इन तंत्रों का मध्य भारत में होने वाली वर्षा से पड़ने वाले प्रभाव का पता लगाया गया है और उनका विवेचन किया गया है।

पहले प्राप्त हुए परिणामों के अनुरूप इस अध्ययन से भी यह निष्कर्ष निकला है कि अवदाबों कि बारम्बारता में कमी की प्रवृत्ति पाई गई है जिसकी भरपाई हाल ही के वर्षों में भारतीय क्षेत्रों में एल.पी.एस. दिनों की बढ़ोतरी से हो गई है। भारतीय क्षेत्र में एल.पी.एस. दिनों की संख्या के साथ मध्य भारत की वर्षा का महत्वपूर्ण संबंध है।

**ABSTRACT.** Importance of monsoon depressions, Low Pressure Systems (LPS) and the number of LPS days on rainfall and hence indirectly on agriculture and hydrology, is well recognized.

In this paper the pattern of annual variability in these systems have been examined using data from 1901-2000. The above mentioned parameters have been subjected to decadal analysis to detect presence of any regular pattern. An attempt has been made to find its tendency with time. Impact of these systems on central India rainfall has been determined and discussed.

The study endorses the earlier findings that there is a decreasing trend in the frequency of depressions which has been compensated with increase in LPS days over Indian region in recent years. The rainfall over central India is more significantly related with a number of LPS days over Indian region.

**Key words** – Depressions, Trend, Low pressure systems (LPS), LPS days.

### 1. Introduction

Among the weather systems, monsoon depressions in the south Asia occupy a unique position in synoptic meteorology. Their regularity in appearance during June to September, prominent seasonality, the normal path it traverse and above all its rain bearing potential in giving well distributed rainfall are some of its characteristic features. Depressions and lows are the major contributors to rainfall. Rainfall associated with a low occurs over a relatively much wider area than that associated with depressions; hence, the lows and the depressions are both considered equally important in respect of their contributions to the Indian monsoon rainfall.

India Meteorological Department (IMD), defines a Low Pressure Systems (LPS) as a low pressure area when the sustained maximum surface wind speed associated with the system is  $< 17$  kt; a depression if the wind speed is 17-27 kt, and a deep depression if the wind speed is 28-33 kt. A Cyclonic Storm (CS) is defined as the weather system when associated wind speed  $\geq 34$  kt. Interior areas of the country receive their major amount of rainfall due to these traveling low-pressure systems that originate in the Bay of Bengal and move along the seasonal monsoon trough, giving weather enroute. Monsoon depression is generally believed to be responsible for the widespread rainfall in different parts of India. The general declining tendency in their formation noticed in recent years, is,

TABLE 1

Mean frequency and coefficient of variability of monsoon systems and rainfall over central India

Month / season	Mean dep.	C.V. (%)	Mean LPS	C.V. (%)	Mean LPS days	C.V. (%)	Mean rainfall (cm)	C.V. (%)
June	1.8	66	2.8	43	10.9	53	13.8	46
July	2.0	68	3.4	38	13.9	41	34.1	25
August	2.4	56	3.6	33	17.0	40	32.4	25
September	2.2	55	3.2	34	16.0	36	18.3	46
Season	8.4	37	13	17	57.7	21	98.6	16

undoubtedly, a cause of great concern both to agriculturists and economic planners.

Kumar and Dash (2001), from the decadal analysis, reported considerable decrease in the number of depressions, in recent decades. Singh and Mohapatra (2001) also observed a decreasing trend in the depressions formed in the Bay of Bengal during monsoon season. Analyzing a long period of data, Dash *et al.* (2004) found that the number of low pressure systems has been increasing during last two decades but the unfavourable dynamic conditions do not permit their intensification into depressions and cyclones. Jadhav and Munot (2004) also found that the number of LPS days have significantly increased during the period 1971-1990. Mohapatra and Mohanty (2004) found that though the frequency of cyclonic disturbances has decreased in recent years, the frequency of lows is higher, keeping the total frequency of LPS, almost unchanged. Jadhav and Munot (2007) have found that the frequency of LPS has neither decreased nor increased significantly but the duration of LPS has significantly increased.

In view of its importance, this subject has drawn attention of research workers for a long time. Rao (1976) concluded that profound influence of monsoon depressions, on rainfall is much more than their number would suggest. Mooley and Shukla (1989) found that frequency of LPS has no relation with Indian Summer Monsoon Rainfall (ISMR); rather a positive correlation exists between the total number of days of LPS and ISMR. The monsoon systems from Bay of Bengal, in their north-west travel, affect central India significantly (Mooley & Shukla, 1989).

The aim of the present study is to examine variations and trend in the formation of monsoon depressions, LPS, the number of days of LPS and their impact on the monsoon rainfall over central India. It was considered worthwhile to determine, quantitatively, the rainfall, each system can bring to the area.

## 2. Data and methodology

The study utilizes 100-year's data (1901 - 2000) of the depressions, LPS and LPS days over the Bay of Bengal, Arabian Sea and the land surface and rainfall for central India comprising of three sub-divisions (east Madhya Pradesh including Chhatisgarh, west Madhya Pradesh and Vidarbha) during June to September. The synoptic data have been collected from the records of the IMD Pune and that published by Jadhav and Munot (2004). The rainfall data have been collected from National Data Centre, Office of the Additional Director General of Meteorology (Research) Pune.

Monthly and seasonal climatology of the systems have been prepared and analyzed. Decadal mean and its variability have been computed and tested through Crammer's test.

A low pass filter is applied to suppress individual fluctuations to detect tendency. The weights used in the filter are the nine ordinates of Gaussian probabilities curve (WMO 1966). A powerful tool to detect presence of cycles and periodicity is the power spectrum analysis. The computational procedure outlined in the WMO Technical Note (1966) is adopted in the present study. The maximum lag for 33 years has been chosen.

The area weighted rainfall for central India have been computed and regressed to determine the extent to which these systems exert influence on rainfall and the results are discussed.

## 3. Results and discussion

### 3.1. Pattern of variability

Monsoon systems generally form over the Bay of Bengal and the Arabian Sea. Under favourable situations, they also form over land areas adjoining the Bay. A few of them also form first as cut-off-lows from the high amplitude westerly trough (Prasad and Rao, 1974).

According to Saha *et al.* (1981) nearly 85% of depressions are the remnants of typhoons from South China Sea which emerge into the Bay after crossing Indo – China peninsula.

The mean frequency and coefficient of variability of monsoon systems are presented in Table 1. It is noticed from the table that nearly two depressions form in each of the monsoon months. August month accounts for the maximum number (nearly 28%), of the total depressions during the monsoon season (IMD 1971). The number of LPS and LPS days are also higher in the month of August though the highest rainfall occurs in July.

In month-to-month analysis, no depression formed in as many as in 13 years. During July, a maximum number of 5 depressions (during the years 1904, 1927, 1929, 1943, 1944) have been observed. July, did not witness any depression in as large as 16 different years but not in any of them, the central India registered deficient rainfall. This perhaps suggests that depressions alone do not singularly influence rainfall in the monsoon season over India (Dhar *et al.*, 1978). During August, maximum numbers of 5 depressions (formed during 1908, 1911, 1919, 1924, 1964 and 1982) and no depression formed in 8 years. September witnessed maximum number of 4 depressions each in 1905 and 1926 and they were absent in 8 years.

Maximum number of low pressure areas (*i.e.*, 6) formed, in the month of August during 1919, 1959, 1982 and 1989; in July during 1943, 1958 and 1961 and in June during 1904. Season's highest number lows (*i.e.*, 18) occurred in the year 1975. In case of LPS days, maximum number, *viz.*, 32 days are observed in August each in 1944 and 1984 followed by in September (31 days) in 1961. The season's highest LPS days were 82 noticed in each of the year 1977 and 1994 which are well known as active monsoon years.

### 3.2. Trend and periodicity

#### 3.2.1. Low pass filter analysis

Pattern of fluctuations in yearly frequency of depression, LPS, LPS days and seasonal rainfall are examined for trend by applying low pass filter. The actual and filter series are shown in Figs. 1 (a-d).

The number of monsoon depressions clearly shows significant decreasing trend from 1928 onwards [Fig. 1(a)] with embedded fluctuations. They are decreasing at an annual rate of 0.15. Such downward tendency has also been observed by Singh and Mohapatra (2001) and Dash *et al.* (2004).

The pattern of variability in number of LPS was found oscillatory in nature [Fig. 1(b)]. A striking

TABLE 2

Decadal statistics of monsoon systems and rainfall over central India

Decade	Depression (number)	LPS (number)	LPS days	Rainfall (cm)
1901-1910	<b>11.5*</b>	13.9	55.5	91.1
1911-1920	9.1	<b>11.4*</b>	<b>49.9*</b>	93.9
1921-1930	<b>11.3*</b>	13.4	57.3	98.2
1931-1940	9.2	11.7	<b>49.2*</b>	<b>110.2*</b>
1941-1950	9.9	13.9	55.4	107.4
1951-1960	7.3	12.2	<b>50.1*</b>	99.2
1961-1970	7.5	12.5	54.2	98.1
1971-1980	7.7	14.3	<b>70.7*</b>	98.1
1981-1990	<b>5.2*</b>	13.6	<b>70.3*</b>	94.4
1991-2000	<b>2.8*</b>	12.5	60.4	93.5

(\* Significant at 5% level)

observation was that during the period 1975-1995, these are above their long term normal mean of 13.0 (vide Table 1).

A wavy pattern in the number of LPS days was observed [Fig. 1(c)] till 1964. Subsequently LPS days increased prominently from 1965 to 1979 at the rate of 2 days per year but a decreasing tendency is seen there after till 2000 with a fall of 0.35 days per year. However, they are higher than normal in recent years.

Analysis of the central India monsoon rainfall revealed general increasing trend till 1950 and later decreasing trend till the end of the century [Fig. 1(d)]. Thus, the data analyzed appears to be generally trend less.

All these indicate that decrease in depression has been compensated with increase in LPS/LPS days. It endorses the earlier findings of Mohapatra and Mohanty (2004, 2006), Mooley and Shukla (1989).

#### 3.2.2. Linear trend analysis

In case of LPS, LPS days and monsoon rainfall the linear correlations with time (year) are observed as 0.05, 0.06 and -0.02 respectively, which are very low and statistically insignificant. However there is a significant (at 5% level) declining trend in case of number of depressions with correlation coefficient equal to -0.72.

#### 3.2.3. Decadal variations

The decadal variations in monsoon systems and rainfall are given in Table 2. A maximum of 11.5 was seen in the decades 1901 to 1910. The last decade of last

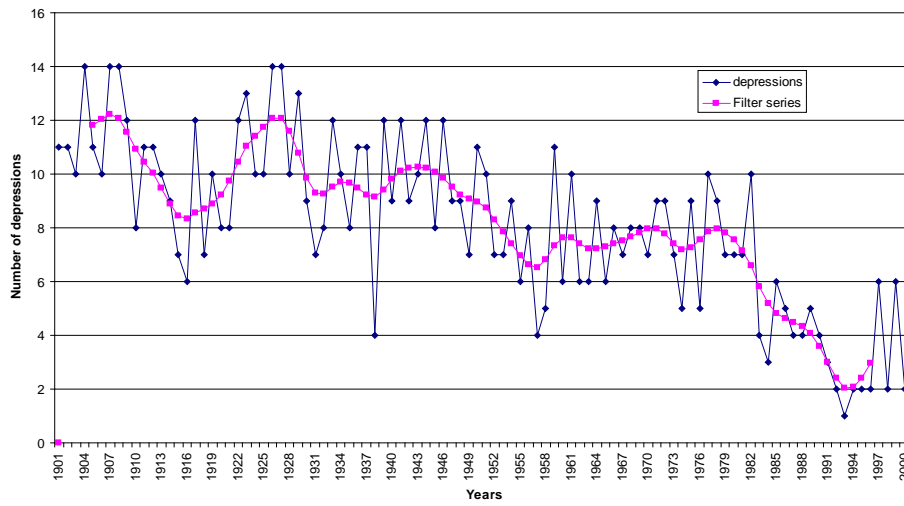


Fig. 1(a). Low pass filter analysis for the monsoon depression

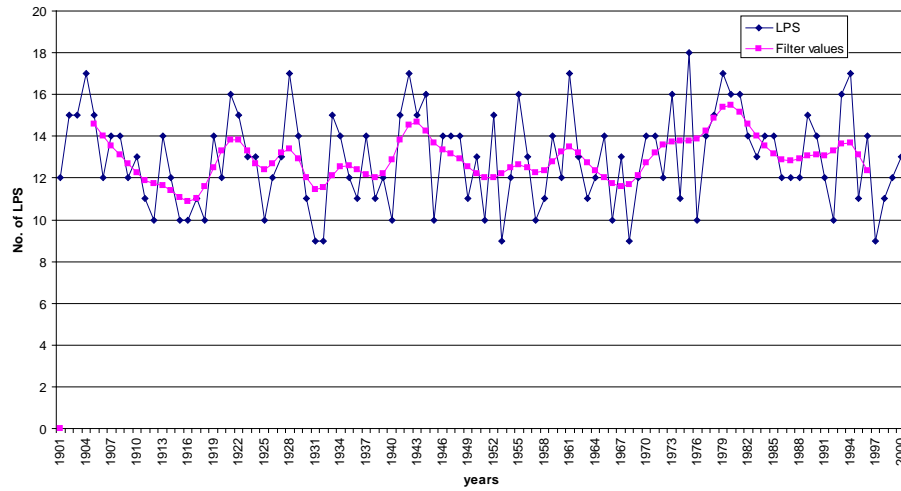


Fig. 1(b). Low pass filter analysis for low pressure system

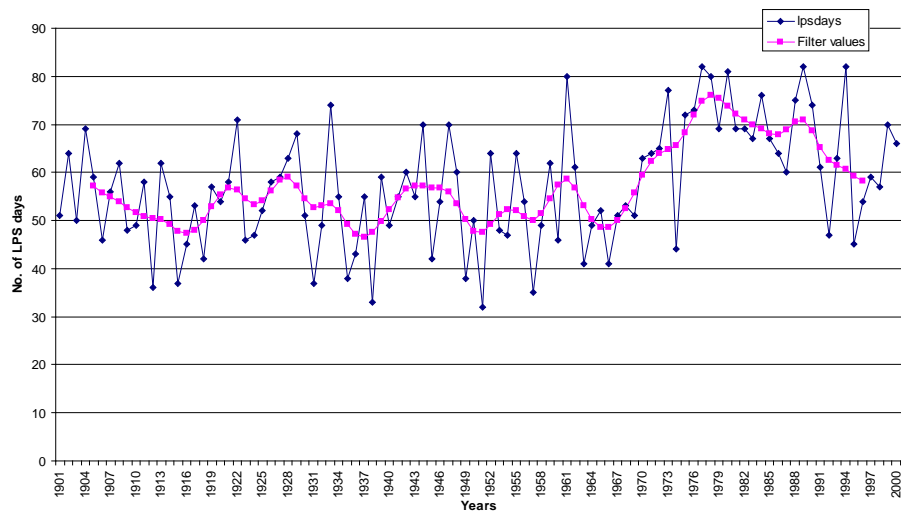
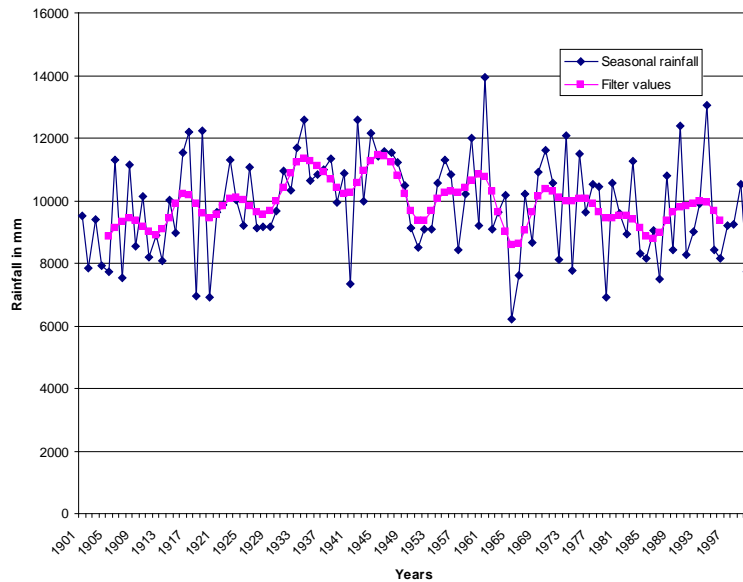


Fig. 1(c). Low pass filter analysis for LPS days



**Fig. 1(d).** Low pass filter analysis for seasonal rainfall over central India

century recorded the lowest frequency with just 2.8 depressions. Raghvendra (1973) also obtained decade-wise number of depressions using data from 1890 to 1969. A considerable difference was seen between his results with that in the present study which can be ascribed to different periods for the decade chosen by him. Kumar *et al.* (2002) also observed declining tendency in the number of depressions after 1970. When the Crammer's test is applied to the decadal data it is observed that during the decades 1901-1910 and 1921-1930 depressions are significantly higher at 5 % level. However during the decade 1981-1990 and 1991-2000, the depressions are significantly less (Dandekar and De, 2001; Kumar and Dash 2001).

During the decade 1911-1920 both LPS and LPS days was significantly less from their overall mean. In case of LPS days during the decades 1931-1940 and 1951-1960 the LPS days were also significantly less and during the decade 1971-1980 and 1981-1990, they were significantly higher at 5 % level. The decade 1931-1940 received significantly more rainfall than the long term mean of 98.6 cms. However during this decade, the LPS days were significantly less. Hence the central India rainfall could not be explained by the number of depressions/LPS/LPS days.

### 3.2.4. Periodicity and cycles

To detect presence of cycles and periodicity, all four elements, *viz.*, depression, LPS, LPS days and seasonal rainfall are subjected to power spectrum analysis. The

spectrum analyses are shown in Figs. 2 (a-d). Fig. 2 (a) revealed existence of a prominent cycle of 2.4 - 2.5 years for monsoon depression at 95% level endorsing the earlier findings of Singh and Mohapatra, (2001). Bhalme (1972) also found significant peak at 95% level with the periodicity of 2.3 to 2.5 years which corresponds to Quasi Biennial Oscillation (QBO).

Analysis of number of LPS [Fig. 2(b)] revealed a significant cycle of 4.7 years at 95% level. This oscillation with periodicity of 4.7 years corresponds to the well known periodicity of El Nino cycles.

Analysis of LPS days [Fig. 2(c)] revealed a significant cycle of 2.7 – 2.8 years at 95% level, analogous to the QBO.

A significant peak is observed at 2 - 3 years in monsoon rainfall at 90% level [Fig. 2(d)] which corresponds to QBO.

In case of central India rainfall and LPS, spectrum of white noise [*i. e.*, the series free from persistence (WMO 1966)] is observed where as in case of depression and LPS days spectrum of red noise is observed, *i.e.*, the amplitude of the spectrum will tend to decrease from the longer to the shorter wavelengths.

### 3.3. Impact of systems on monsoon rainfall

In order to examine the influence of synoptic systems on the monsoon rainfall, correlation approach has

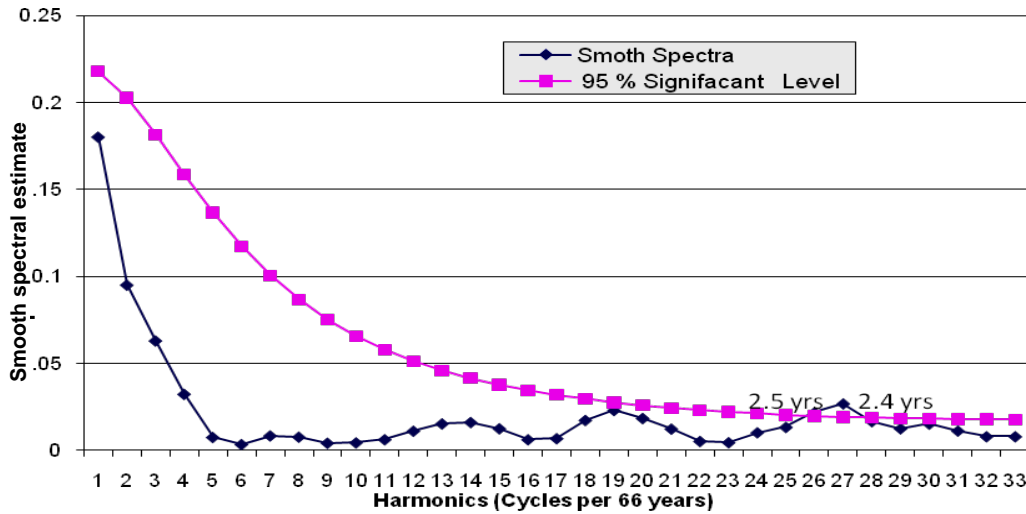


Fig. 2(a). Power spectrum for number of depressions per year significant periodicities are shown in the curve

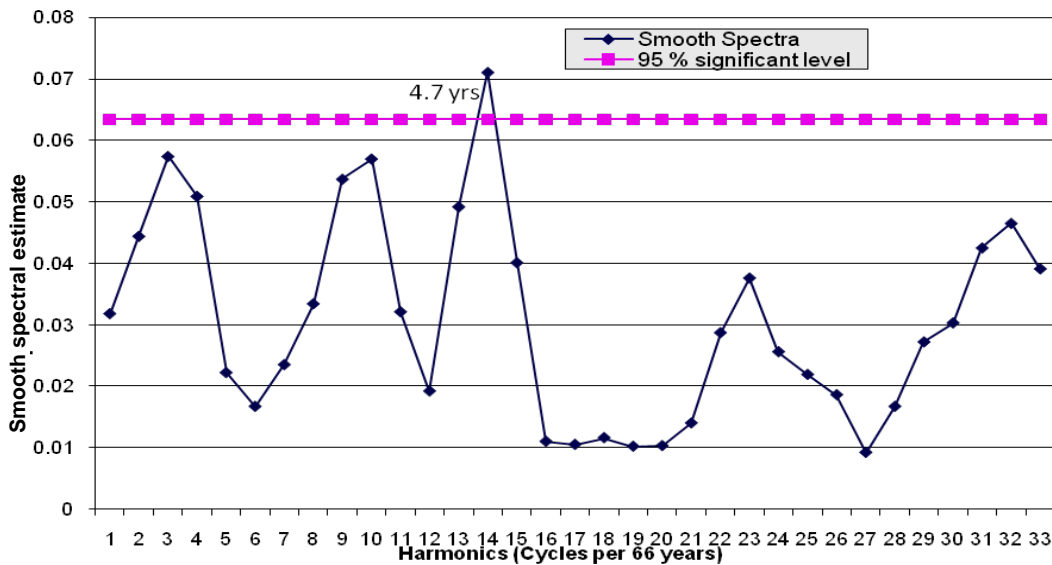


Fig. 2(b). Power spectrum for number of LPS per year significant periodicities are shown in the curve

been adopted. The correlation coefficients of area weighted rainfall with monsoon depressions, LPS and LPS days are 0.13, 0.18 and 0.19 respectively. The low value of correlation coefficient clearly shows that the parameters chosen above do not necessarily exert significant influence over central India rainfall, (Dhar and Rakhecha, 1976; Chowdhury, 1983; Dhar *et al.* 1980 etc).

However the correlation between area weighted central India rainfall and LPS & LPS days are significant at 10% level. Jadhav (2002) also found the significant

impact of LPS days on central India monsoon rainfall. Over Orissa, Mohapatra and Mohanty (2004) found that rainfall is more related with the LPS days than with the frequency of LPS.

#### 4. Conclusions

The following conclusions emerge from the analysis:

- (i) The study endorses the earlier findings that decrease in frequency of depressions has been compensated with

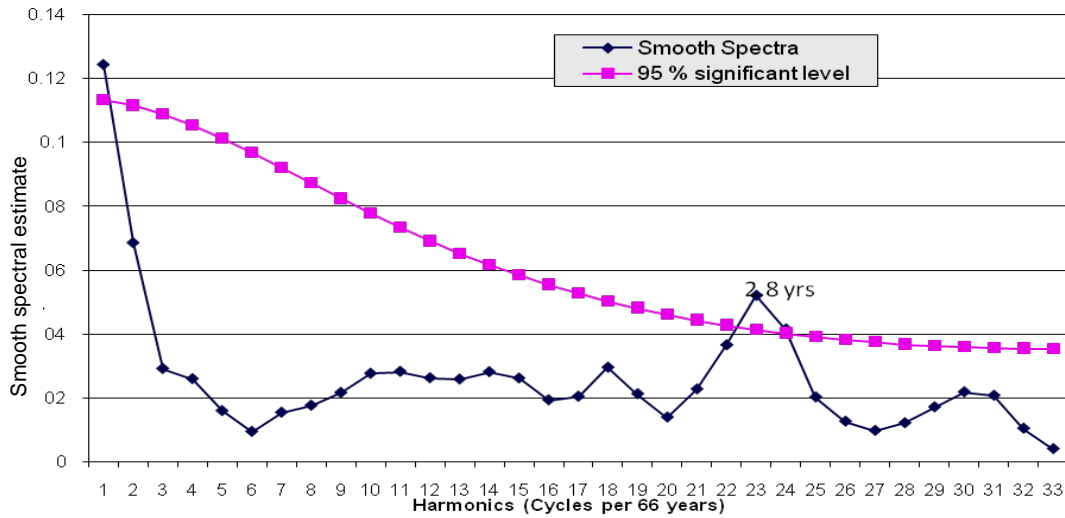


Fig. 2(c). Power spectrum for number of LPS days per year significant periodicities are shown in the curve

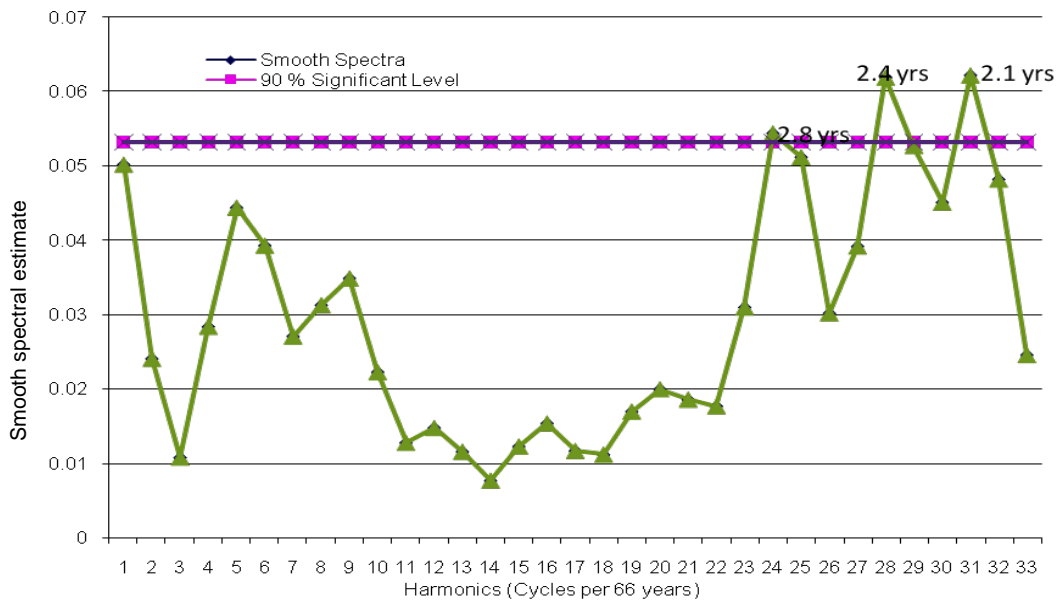


Fig. 2(d). Power spectrum for seasonal rainfall significant periodicities are shown in the curve

increase in LPS/LPS days over Indian region in recent years.

(ii) Seasonal monsoon rainfall over central India does not depend on the number of depressions forming in Bay of Bengal. It has more significant relationship with the number of LPS days.

(iii) Except in LPS, periodicity of 2-3 years is present in depression, LPS days and central India rainfall which

corresponds to QBO. The number of LPS in a year shows a periodicity of 4.7 years.

*Acknowledgements*

The authors are thankful to Deputy Director General of Meteorology (Weather Forecasting) and Deputy Director General of Meteorology (Training) for providing necessary facilities to undertake the study. The authors would like to express their gratefulness to

Dr. A. Chowdhury Retired Deputy Director General of Meteorology (Agrimet.) Pune for useful discussions. Thanks are also due to officers/colleagues who helped in completion of the study.

#### References

- Bhalme, H. N., 1972, "Trends and quasi biennial oscillation in the cyclonic disturbances over the Indian region", *Indian J. Met. & Geophys.*, **23**, 3, 355-358.
- Chowdhury, A., 1983, "Structural features of monsoon depressions over India", Ph. D thesis submitted to Nagpur University.
- Dash, S. K., Kumar, J., Rajendra and Shekhar, M. S., 2004, "On the decrease in frequency of monsoon depressions over the Indian region", *Curr. Sci.*, **86**, 10, 1404-1411.
- Dandekar, M. M. and De, U. S., 2001, "Trends in monsoon depression during recent decades", Proc. of TROPMET 2001, 663-666.
- Dhar, O. N. and Rakhecha, P. R., 1976, "Does absence of tropical disturbances cause deficient rainfall in north Indian sub-division during the monsoon months?", Proc. Ind. Nat. Sc. Acad., **42A**, 81-89.
- Dhar, O. N., Kulkarni, A. K. and Ghose, G. C., 1978, "Rainfall distribution over Indian sub-divisions during the wettest and the driest monsoons of the period 1901-1960", *Hydrologiques, Sci. Bul.*, **23**, 2, 213-221.
- Dhar, O. N., Rakhecha, P. R. and Mandal, B. N., 1980, "Is the number of cyclonic disturbances traversing India during a monsoon season related to that season?", *Int. J. Climatol.*, **19**, 1153-1159.
- India Meteorological Department, 1971, "Forecasting Manual Part III", Southwest Monsoon.
- Jadhav, S. K. and Munot, A. A., 2007, "Increase in SST of Bay Bengal and its consequences on the formation of low pressure systems over the Indian region during summer monsoon season", *Mausam*, **58**, 3, 391-395.
- Jadhav, S. K. and Munot, A. A., 2004, "Statistical study of the low pressure systems during summer monsoon season over the Indian region", *Mausam*, **55**, 1, 15-30.
- Jadhav, S. K., 2002, "Summer monsoon low pressure systems over the Indian region and their relationship with the sub-divisional rainfall", *Mausam*, **53**, 2, 177-186.
- Kumar, J., Rajendra and Dash, S. K., 2001, "Inter-decadal variations of monsoon depressions and their epochal relationships with rainfall and other tropical feature", *Int. J. Climatol.*, **21**, 759-771.
- Kumar, J., Rajendra, Dash, S. K. and Thapliyal, V., 2002, "Climatic effects of decreasing frequencies monsoon depressions in recent decades NNN characteristics of Break monsoon and rainfall", Proceeding of TROPMET 2002, 193-201.
- Mohapatra, M. and Mohanty, U. C., 2004, "Some characteristics of low pressure systems and summer monsoon rainfall over Orissa", *Current Science*, **87**, 9, 1245-1255.
- Mohapatra, M. and Mohanty, U. C., 2006, "Spatio - temporal variability of summer monsoon rainfall over Orissa in relation to low pressure systems", *J. Earth Syst. Sci.*, **115**, 2, April 2006, 203-218.
- Mooley, D. A. and Shukla, J., 1989, "Main features of the west-moving summer monsoon low pressure systems which form over the Indian region during the summer monsoon season and their relationship with the monsoon rainfall", *Mausam*, **40**, 2, 137-152.
- Prasad, K. and Rao, D. K., 1974, "Case studies of westerly waves in the development of monsoon depression", *Indian J. Met. & Geophys.*, **25**, 2, 265-268.
- Raghavendra, V. K., 1973, "A statistical analysis of the number of tropical storms and depression in the Bay of Bengal during 1890-1969", *Indian J. Met. & Geophys.*, **24**, 2, 125-130.
- Rao, Y. P., 1976, "Southwest monsoon", Met. Mon., synoptic meteorology No. 1/1976, India Met. Deptt.
- Saha, K. R., Sanders, R. and Shukla, J., 1981, "Westward propagating Predecessors of monsoon depression", *Mon. Wea. Rev.*, **109**, 330-344.
- Singh, O. P. and Mohapatra, M., 2001, "Long term trends and oscillations in the frequency of monsoon depressions; long term changes and trends in the atmosphere", Vol. II, 288-291, New Age International (P) Limited, Publishers, New Delhi.
- World Meteorological Organization, 1966, "Climatic Change", W.M.O. Tech. Note No. 79.