International Conference on Frontiers in Life and Earth Science
© 2018 IJSRST | Volume 5 | Issue 1 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X

Long Term Fluctuations and Global Teleconnections in the Monsoonal Rainfall and Associated Floods of the Mahi Basin : Western India

Uttam V. Pawar [1], Pramodkumar S. Hire[*2]
Department of Geography, HPT Arts and RYK Science College, Nashik, Maharashtra, India

ABSTRACT

This paper examines the long term fluctuations and global teleconnections in the monsoonal rainfall and associated floods of the Mahi Basin from western India. In order to analyze rainfall and associated floods, the rainfall data for monsoon season of the Mahi Basin have been obtained for last 149 years (1857-2005) from India Meteorological Department (IMD), Pune. The discharge data of the Wanakbori site, procured from Kadana Dam flood control cell, have been used to show its association with the monsoonal rainfall. Time series analysis, percent departure from mean, Normalized Accumulated Departure from Mean (NADM), Mann-Kendall test and conditional probability technique for El Nino and Southern Oscillation (ENSO) have been used for the analyses of monsoonal rainfall data of the Mahi Basin and its effect on floods. The results indicate year to year variations in the monsoon rainfall with significant departure from mean rainfall of the Mahi Basin. It is observed that majority of the floods are associated with positive departure from mean rainfall. The NADM shows epochal behavior of high and low monsoon rainfall of the basin and the Mann-Kendall test reveals statistically significant decreasing trend in the monsoon rainfall of the basin. The analysis of ENSO reveals that the probability of the occurrence of the floods in the Mahi basin is high during cold (La Nina) event than warm (El Nino) event.

Keywords : Mahi Basin, monsoonal rainfall, global teleconnection, rainfall trend, floods

I. INTRODUCTION

The Indian monsoon is very complex phenomena. The intensity, amount and pattern of rainfall, therefore floods, over the India show significant variations. Therefore, analysis of long term fluctuation in the monsoon rainfall and associated floods in the river basins of the Indian subcontinent is one of the major aspects of investigation in the field of flood-hydrometeorology. Several studies have been carried out on the monsoon rainfall trend at India or regional level but very few at basin scale. Since, it is not possible to predict the exact future trend of rainfall and frequency and magnitude of floods, but change detection can be done on the basis of past records.

According to Kale [1] high magnitude floods are associated with the increased precipitation in the basin. . Mooley and Parthasarthy [2], Parthasarthy et.al [3], and Kripalani and Kulkarni [4] identified significant variation in the monsoon conditions over the Indian territory during last few decades. It is well known fact that the Indian monsoon has significant teleconnection with the sea surface temperature (SST) anomalies of the eastern and central equatorial Pacific Ocean and El Nino. Rasmussen and Carpenter [5], and Shukla and Paolino [6] noticed that during warm El

Nino phase Indian Summer Monsoon Rainfall (ISMR) over Indian Peninsula is suppressed. The rainfall trends and floods over various river basins of India have been studied by Kale [1], Mirza et.al. [7], and Rao [8]. According to investigation by Singh et. al. [9] rainfall over the Indus, Brahmaputra, Ganga, Cauvery and Krishna Basins increasing and decreasing over Narmada, Tapi, Mahi, Sabarmati, Godavari and Mahanadi Basins. The main objective of the paper is, therefore, to find out long term fluctuations and global teleconnections of the monsoon rainfall and their association with the floods in the Mahi Basin.

II. DATA AND METHODOLOGY

The Mahi River is the third major west flowing interstate river of India located in Western India. It originates from north of Vindhyas near the village Mindha in Sardarpur tehsil in Dhar district of Madhya Pradesh at an elevation of 500 m above ASL. It flows for a total length of 583 km. The average gradient of the river is 0.00086. It flows northward through Madhya Pradesh state and turns northwest to enter Rajasthan state. Subsequently, it abruptly changes its course in southwest direction to flow through Gujarat state. It drains into a wide estuary at the Gulf of Khambhat; a part of Arabian Sea. Mahi Basin extends over a catchment area of 34,842 km^2. The basin is located in the heart of the classical Indian summer monsoon which regulates the river regime and flood characteristics. The basin receives more than 90% of the rainfall during monsoon season (June-September). The mean monsoon rainfall of the basin is 687 mm.

III. METHODS AND MATERIAL

The major objective of this investigation is to understand the long term fluctuations and global teleconnection in the monsoon rainfall and their association with floods in the Mahi Basin. Therefore, monsoon (June-September) rainfall data were obtained from India Meteorological Department (IMD), Pune. Besides, data on sea surface temperature (SST) anomaly averaged over the central and eastern Pacific Ocean, published by Wright [10] for the period (1901-1982) and for 1983 onwards were obtained from Climate Predication Centre (CPC) of National Oceanic and Atmospheric Administration (NOAA) to understand the global teleconnection with the monsoon rainfall and floods in the Mahi Basin. The peak discharge data for Wanakbori site have been obtained from Kadana Dam flood control cell. The data of major flood events have been collected through several field surveys and published research articles. The monsoon rainfall data for the period of about 150 years (1857-2005) are suitable for understanding the long-term trends over the Mahi basin. To appraise the long term fluctuations in the monsoon rainfall and associated floods, time series plot, percent departure from mean, normalized accumulated departure from mean (NADM), Mann-Kendall test are used. In addition to this, index of ENSO has been applied understand global teleconnection with monsoon rainfall and floods in the basin.

IV. RESULTS AND DISCUSSION

A. Inter-monsoon rainfall variability and associated floods

The interannual and inter seasonal variation in rainfall are significant characteristics of Indian monsoon. A spatio-temporal variation in the floods of the Indian River basins is mainly significant due to differences in the distributional pattern of monsoon over the Indian subcontinent during the south-west monsoon. Similar to other monsoon dominated rivers of India, Mahi River also shows significant inter seasonal variation in the rainfall and flood events. Figure 1 shows that prior to 1900s rainfall was above average, but inter-monsoonal variability was low. The period from 1900 to 1930 experienced greater fluctuations and the rainfall appears to be below average for many years. Inter monsoon variability was characterized by increased frequency and magnitude of floods on the Mahi River mainly after 1930s.

The pattern of variation in the monsoon rainfall is also depicted by the plots of departure from mean expressed as percentage of mean, for the Mahi Basin (Figure 2). The plot reveals that the rainfall sometimes varies by as much as about ±90%. Most of the floods in the basin were occurred when monsoon rainfall was positive from mean and very few years experienced floods during negative departure from mean. The analysis indicates that out of 22 major floods of the Mahi Basin 18 were occurred when rainfall was above average and only four floods were observed when rainfall was below average. The peak flood on record i.e. 1973 flood had occurred when the when monsoon rainfall was +68% from the mean. It is, therefore, concluded that above-average monsoonal rainfall in the basin produces large floods.

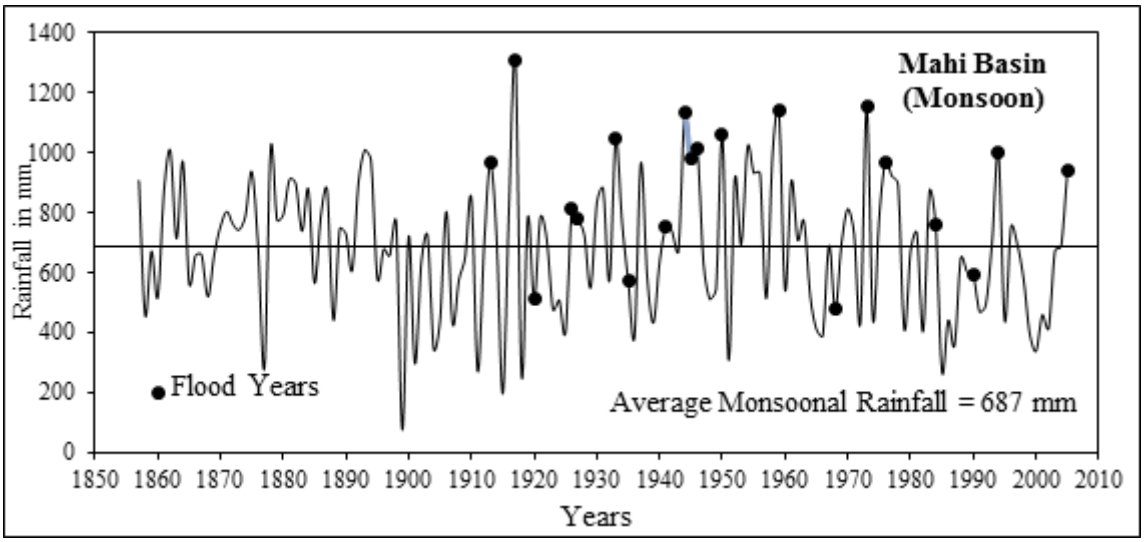

Figure 1. Inter-monsoon rainfall variability in the Mahi Basin

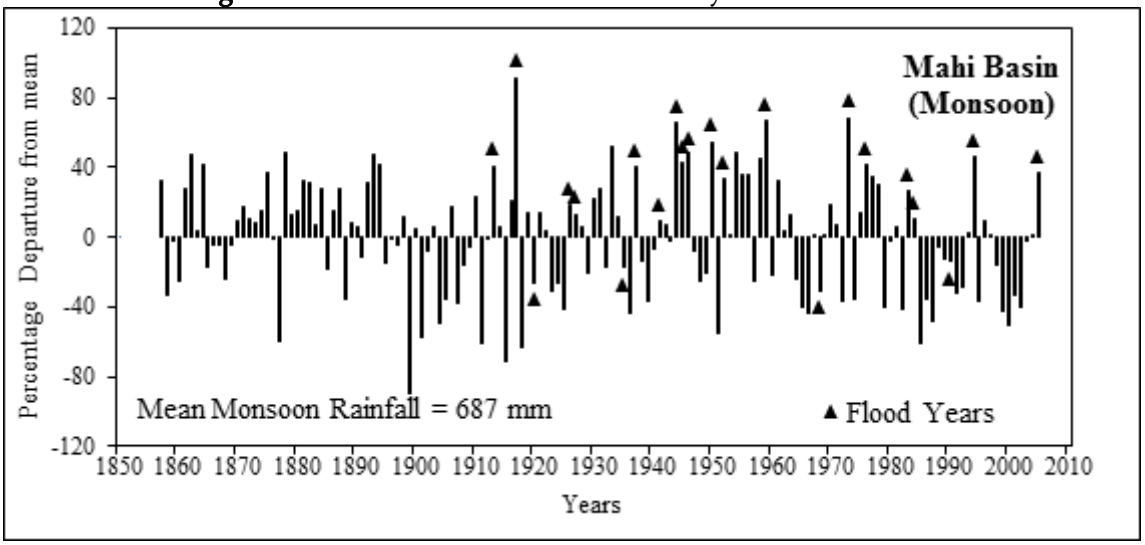

Figure 2. Percentage departures from mean rainfall of the Mahi Basin

B. **Normalized Accumulated Departure from Mean (NADM) and Floods**

In order to highlight and emphasis the long-term trends and identify periods of high and low rainfall, the normalized accumulated departure from mean (NADM) method has been applied. The NADM is the accumulated departure from arithmetic mean, divided by the largest absolute number in order to plot between -1 and +1 [1]. The NADM plot shows above average rainfall conditions characterized by positive slopes (rising limbs) and the periods of below-average

rainfall are represented by negative slopes (declining limbs). The analysis of NADM indicates epochal behaviour of the monsoon over the Mahi Basin. The major epochs of monsoon rainfall fluctuation are 1857-1898 wet, 1899-1930 dry, 1931-1978 wet and 1979-2005 dry (Figure 3).

The NADM graph clearly illustrates that most of the floods had occurred when rainfall was above average (rising limb) and very few floods were experienced during below average (declining limb) rainfall. A comparison of the NADM graph with the plot of large floods in Mahi Basin clarifies that the period of below average monsoon rainfall was associated with low frequency of floods and above average monsoon rainfall (1930s to 1990s) was associated with high frequency and large magnitude of floods in the Mahi Basin.

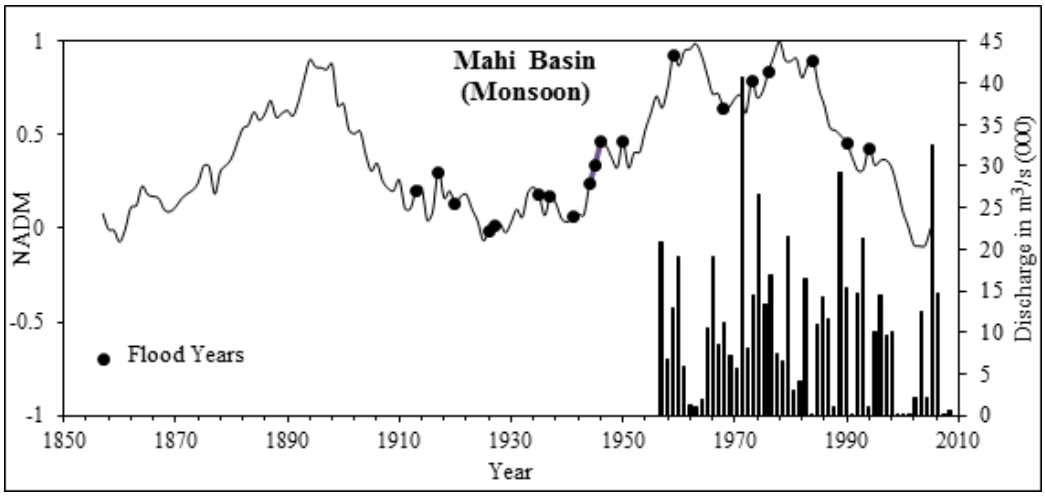

Figure 3. Normalized Accumulated Departure from Mean (NADM) and Discharge

C. Detection of changes in the monsoon rainfall and floods

It apparently appears that the frequency and magnitude of large floods has increased in recent decades. In order to verify whether the trend reflected in the monsoonal rainfall, the non-parametric Mann-Kendall test has been applied to the monsoon rainfall data of the Mahi Basin (1857- 2005). Mann-Kendall's τ and z scores are obtained for the Mahi Basin and have been summarized in Table 1. The analyses based on of monsoon rainfall trend/change over the Mahi Basin show decreasing trend for about last 150 years i.e. is from 1857 to 2005. However, it is not statistically significant at 0.05 levels.

Table 1. Nature Of Changes/Trends In Annual Rainfall Records Based On Mann-Kendall Test

Station	Period	N	Tau (τ)	Z Score	Trend/Change
Mahi Basin	1857-2005	14	0.09378	1.70	Decreasing*

N = number of observations; * = Statistically significant at 0.05 level

D. El Nino and Southern Oscillation (ENSO) and floods in the Mahi Basin

It is very well known fact that variations in the Indian summer monsoon rainfall (ISMR) are linked with El Nino and Southern Oscillation (ENSO) phenomena [11], [12]. Therefore, it is necessary to understand connection between ENSO and rainfall while studying floods in the Mahi Basin. The technique adopted by Eltahir for the Nile River was used. The index is averaged over the monsoon season (June - October). The data on the basis of SST (-0.5°C and +0.5°C) as advocated by Eltahir [13] and Patil [14] were categorized into cold, warm and normal conditions. Figure 4 gives the categories of the annual rainfall of the Mahi Basin and ENSO index. Table 2 indicates that the probability of having high monsoon rainfall

in the Mahi Basin is more during cold and normal conditions (40% to 44%) and very low during warm ENSO conditions (48%).

Table 2. Conditional Probability Of The Monsoon Rainfall Over Mahi Basin Given The SST Index Of ENSO (N = 149 Years)

Basin		Cold	Normal	Warm
Mahi Basin	High	0.44	0.4	0.2
	Normal	0.19	0.22	0.32
	Low	0.37	0.38	0.48

Low < 10% and High > 10

Table 3 shows that the frequency of occurrence of floods is generally high during the cold and normal rainfall years. The result of the conditional probability and occurrence of floods clearly indicates that 17 floods in the Mahi Basin have been occurred during normal and La Nina conditions and seven during warm ENSO conditions. Therefore, it can be stated that monsoon rainfall and associated floods of the Mahi Basin have significant teleconnection with ENSO events.

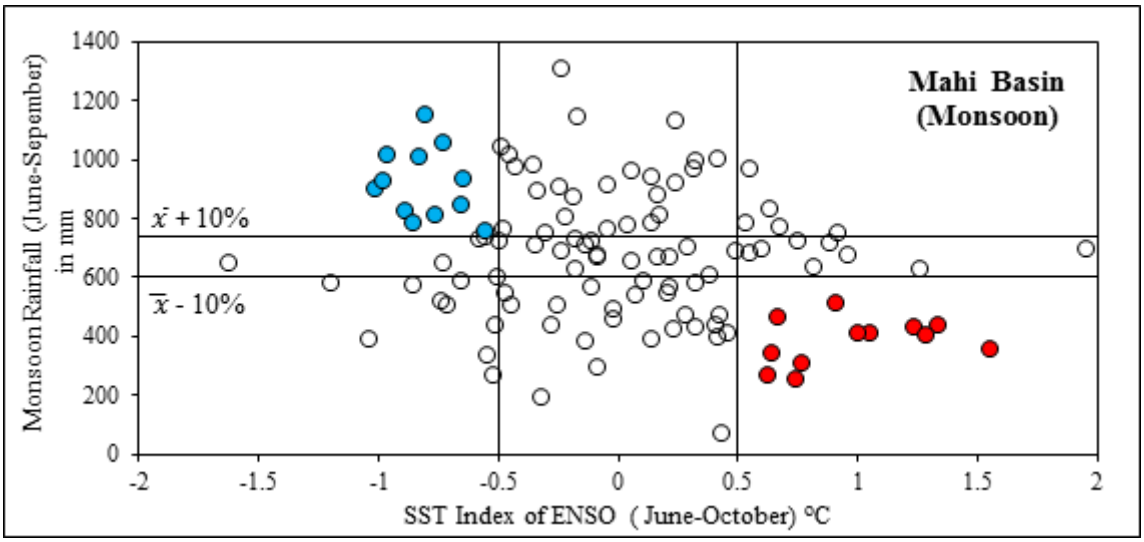

Figure 4. Categories of annual rainfall and ENSO index of the Mahi Basin; Data source: IMD

Table 3. Occurrence of floods and its relation with the annual rainfall and SST index of ENSO.

Basin	Rainfall	Cold	Normal	Warm
Mahi Bain	Above Normal	1944, 1945, 1946,1950, 1959,1973, 1983	1913, 1917, 1919, 1926, 1927, 1933, 1937, 1944, 1945,	1930, 1941, 1952, 1976, 1994, 2006
	Normal		1943	-
	Below Normal		1935, 1990	1968

Below-normal < 10% and above-normal >10%

V. CONCLUSIONS

The time series of monsoon rainfall reveal remarkable inter-monsoonal variability in rainfall. Long term temporal variations in the monsoon rainfall indicates some notable years when monsoon rainfall was above (high) and below (low) average rainfall of the basin.The analysis of percent departure from mean indicates that out of 22 major floods of the Mahi Basin 18 were occurred when rainfall was above average and only four floods were observed when rainfall was below average. The peak flood on record i.e. 1973 flood had occurred when the when monsoon rainfall was +68% from the mean. It is, therefore, concluded that above-average monsoonal rainfall in the basin produces large floods.

The major epochs of monsoon rainfall fluctuation are: 1857-1898 wet, 1899-1930 dry, 1931-1978 wet and 1979-2005 dry. The NADM graph clearly illustrates

most of the floods had occurred when rainfall was above average (rising limb) and very few floods were experienced during below average (declining limb) rainfall.

The analysis of monsoon rainfall over the Mahi Basin based non-parametric Mann-Kendall test, show decreasing trend for about last 150 years i.e. is from 1857 to 2005. Therefore, it can be stated that monsoon rainfall and associated floods of the Mahi Basin have significant teleconnection with ENSO events.

VI. ACKNOWLEDGEMENTS

Dr. Pramodkumar S. Hire is grateful to Science and Engineering Research Board, Department of Science and Technology, Government of India for financial support to conduct this research work (Project Number: EMR/2016/002590 dated February 21, 2017). The authors are thankful to Professor Vishwas S. Kale for his helpful and constructive comments and suggestions. Authors are grateful to Dr. Rajendra Gunjal, Ms. Snehal Kasar, Dr. Archana Patil and Ms. Gitanjali Bramhankar for their support in data collection and in the field.

VII. REFERENCES

[1] V.S. Kale, Long-period fluctuations in Monsoon floods in the Deccan Peninsula, India. Journal of Geological Society of India, v. 53, 1999, pp. 5-15.

[2] D.A .Mooley, B. Parthasarthy, Fluctuations of all-India summer monsoon rainfall during 1871-1978. Climatic Change, v. 6, 1984, pp. 287-301.

[3] B. Parthasarathy, K. Rupa Kumar, A.A. Munot, Evidence of secular variations in Indian monsoon rainfall-circulation relationship. Journal of Climatology, v. 4, 1991, pp.927-938.

[4] R.H. Kripalani, A. Kulkarni, Climatic impact of El Niño/La Niña on the Indian monsoon: A new perspective. Weather, v. 52, 1997, pp. 39-46.

[5] E.M. Rasmussen, T.H. Carpenter, The relationships between eastern equatorial Pacific sea surface temperature and rainfall over India and Sri Lanka.Monsoon Weather Review, v. 111, 1983, 517-528.

[6] J. Shukla, D.A. Paolino, The Southern Oscillation and the Long-range forecasting of summer monsoon rainfall over India. Monthly Weather Review, v. 111, 1983, 1830-1853.

[7] M. Q. Mirza, R. A. Warrick, N. J. Ericksen, and G. J. Kenny, Trends and persistence in precipitation in Ganges, Brahmaputra and Meghna river basins. Hydrology Science Journal, v.43, 1998, pp. 845-858.

[8] P.G. Rao, Climatic changes and trends over a major river basin in India. Climate Res., v.2, 1993, pp. 215-223.

[9] N. Singh, N.A. Sontakke, H. N. Singh, and A. K. Pandey, Recent trend in spatio-temporal variation of rainfall over Indian Investigation into basin-scale rainfall fluctuations. IAHS Publication No. 296, 2005, pp. 273-282.

[10] P.B. Wright, Homogenized long-period Southern Oscillation indices. International Journal of Climatology, v. 9, 1989, 33-54.

[11] C.F. Ropelewski, and M.S. Halpert, Global and regional scale precipitation patterns associated with the El Nino/Southern Oscillation. Monthly Weather Review, v. Ill, pp. 1987. 517-528.

[12] R.P. Kane, Relationship between southern oscillation/El Nino and rainfall in some tropical and midlatitude regions. Proceedings of Indian Academy of science, v. 98, 1989, pp. 223-235.

[13] E.A.B. Eltahir, El Nino and the natural variability in the flow of the Nile River Water Resources Research, v. 32, 1996, pp. 131-137.

[14] A.D. Patil, Bedrock channel of the Par River; its forms and processes. Unpublished Ph.D. Thesis, Tilak Maharashtra Vidyapeeth, Pune, 2018.