MAUSAM, **65**, 1 (January 2014), 103-108

551.577.3

# Trends in precipitation extremes over Central India

D. P. DUBEY and *G. KRISHNAKUMAR

*Meteorological Centre, Bhopal (India)*

* *India Meteorological Department, Pune (India)*

(*Received 18 January 2012, Modified 12 July 2013*)

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

**सार** – इस शोध पत्र में लगभग सौ वर्ष के दैनिक वर्षा आँकड़ों का उपयोग करते हुए मध्य भारत में अतिविषम वर्षा की घटनाओं के जलवायविक लक्षणों का अध्ययन किया गया है। 1901 से 2010 तक की अवधि के मध्य भारत (मध्य प्रदेश, छत्तीसगढ़ और विदर्भ के) के 350 स्टेशनों के दैनिक वर्षा आँकड़ों की समय श्रृंखला का विश्लेषण किया गया है। दैनिक वर्षा को (*i*) 7 < r*f* < 12 से. मी., (*ii*) r*f* ≥ 12 से. मी. और (*iii*) वार्षिक अधिकतम (चौबीस घंटेवार वर्षा) में वर्गीकृत किया गया है तथा उनकी घटनाओं, पैटर्न और विशेषताओं की जाँच की गई है। यह देखा गया है कि दीर्घ अवधि में मॉनसून की मौसमी (जून से सितम्बर) वर्षा में किसी प्रकार का रूझान नही मिला है जबकि अतिविषम वर्षा (≥ 7 से. मी.) के समय वर्षा में कमी और वृद्धि का रूझान देखा गया है। विभिन्न भौगोलिक क्षेत्रों में अतिविषम वर्षा की घटनाओं की आवृत्ति के कम्पोजिट चार्ट तैयार किए गए जिससे मध्य भारत के अधिकतम वर्षा के संभावित क्षेत्रों की पहचान की गई है। इस शोध पत्र में मध्य भारत में मौसम की चरम घटनाओं के लिए जिम्मेदार सिनॉप्टिक मौसम प्रणालियों की भी जाँच की गई और इस पर चर्चा की गई।

**ABSTRACT.** Climatic characteristics of occurrence of extreme rainfall events over central India are studied by using about 100 years of daily rainfall data. The time series comprising of daily rainfall data set 350 stations in the Central parts of India (comprising of the states Madhya Pradesh, Chattisgarh and Vidarbha ) for the period 1901 – 2010 have been analysed. The daily rainfall (rf) has been classified under the categories of (*i*) 7< rf < 12 cm, (*ii*) rf ≥ 12 cm and (*iii*) annual extreme (24 hourly rainfall) and their events, patterns and significance have been examined. It is seen that the long-term does not indicate any trend in the monsoon seasonal (June to September) rainfall; however there are decreasing and increasing trends in the extreme rainfall (≥7cm) events. The composite charts of frequency of occurrence of extreme rainfall events located in various geographical areas have been prepared and thereby identifying the possible highest rainfall areas over central India. The synoptic weather systems responsible for the extreme events over central India were also examined and discussed in this paper.

**Key words** – Extreme events, Synoptic disturbances, Significant trend.

## 1. Introduction

In recent years, the country witnessed incidences of heavy precipitation events, flash floods over different regions and particularly over metro cities, *viz*., Mumbai (in July, 2005), Chennai (in October and December) and Bangalore (in October 2005) causing heavy damages in economy, loss of life, etc. Extreme rainfall events cause damages in the form of landslides, flash floods, crop loss, etc., which further have impacts on society as well as the environment. A proper assessment of likely incidences of such events and their trends would be helpful to the planners in their disaster mitigation and implementations. The changes in extreme rainfall events and that in the mean rainfall patterns over whole of India have been studied and many have analyzed such events in India to verify their trend patterns over different regions.

Roy and Balling (2004) showed that there is an increasing trend over the western parts of India and decreasing to a neutral trend over the eastern half of the country except the northeastern parts. Goswami *et al*. (2006) used the daily gridded rainfall data sets and examined the trend of extreme rainfall over India and they have reported an increase in the frequency and the magnitude of extreme rain events and a significant decreasing trend in the frequency of moderate events over central India. Rajeevan *et al.* (2008) used 104 years of gridded dataset over central India similar to Goswami *et al.* (2006) and examined the variability and long-term trends of extreme rainfall events. Guhathakurta (2011) pointed out that for the study on extreme events, use of real or actual station data is more realistic than the gridded dataset. Further, in the gridded datasets, extreme events will not be captured on most of the occasions due to


**Fig. 1.** Meteorological sub-divisions over central India

interpolation or averaging scheme used in gridding. Hence, Guhathakurta *et al*. (2011) have considered the actual daily rainfall for over 6000 stations and examined the trends over the country as a whole. There is a general need to obtain a clear idea about the impact of climate change on the extreme weather events of the country.

The monsoon over India is characterized by heavy to very heavy rainfall events leading to floods over different region. These are found to be caused by interaction of basic monsoon flow with orography and synoptic disturbances over the region (Dhar and Nandargi, 1993). Smith (1979) showed a small scale cyclonic circulation can interact with orography to cause enhanced rainfall. Dubey and Balakrishnan (1994) observed that spatial distribution of heavy rainfall is maximum over central Madhya Pradesh both in intensity and frequency. There are other phenomena such as global warming due to increased green house gases which also may increase extreme precipitation events attributed to increase in moisture levels, thunderstorm activities and large scale storm activity.

Therefore, understanding the changes in extreme weather events is more important than the changes in mean pattern for which trends of heavy and very heavy rainfall events are to be studied. Since a large amount of the variability of rainfall is related to the occurrence of extreme rainfall events and their intensities, there is a need

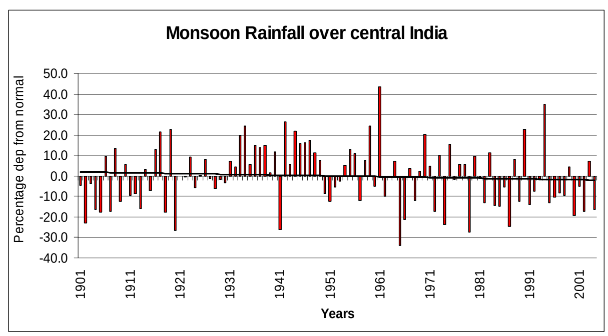



**Fig. 2.** Monsoon rainfall over central India

to know the magnitudes of extreme rainfall events over different parts of our country.

Central India is a unique region with the characteristic features of seasonal rainfall and annual patterns due to synoptic systems and orographic influences of Vindhyachal and Satpura ranges. The patterns of precipitation and intensity of rainfall events over this region would be more interesting as already revealed by earlier studies. However, the heavy rainfall events were not examined along with the synoptic situations, particularly relating to the systems over the region. Therefore, an attempt is being made to examine the heavy rainfall events over the Central Indian region comprised of the states Madhya Pradesh, Chattisgarh and

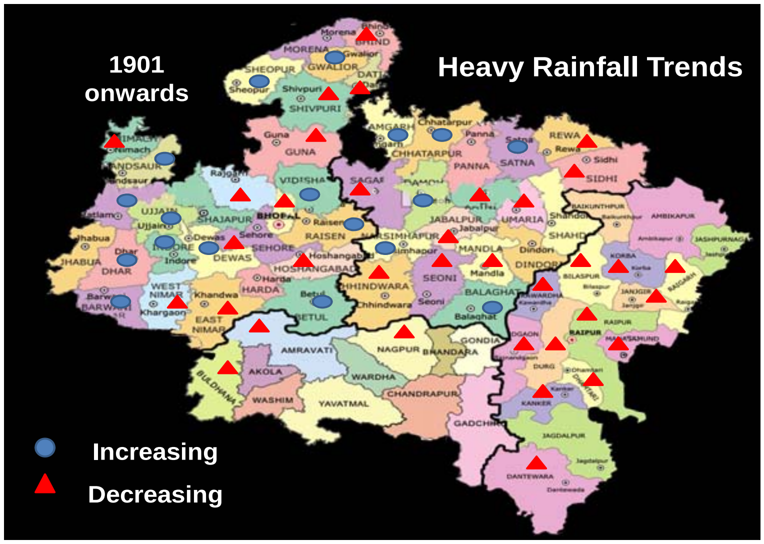



**Fig. 3.** Heavy rainfall trend over central India

Vidarbha, by considering the rainy days under three categories along with the systems associated during the southwest monsoon period (June-September).

## 2. Data and methodology

The rainfall data of 110 years (1901-2010) over 350 representative stations from the states of Madhya Pradesh (MP), Chattisgarh (CHG) and Vidarbha (VID) distributed in the region of Central India (Fig. 1). The necessary quality control has been carried out and the missing data (very few) for these stations have been filled up. As per IMD definition a 'rainy day' is a day when the rainfall amount is equal to or exceeding 2.5 mm. Further, these rainy days are classified into heavy and very heavy rainfall day in the case the day's rainfall amount is equal to or exceeding 7 cm and 12 cm respectively. The daily rainfall (rf) events have been classified into 3 sub-groups. (*i*) $0 < rf < 7$cm (*ii*) $7 \leq rf < 12$ cm (*iii*) $rf \geq 12$ cm. The frequency per month data series was prepared using the number of days with rainfall under these categories. In addition to these, the annual extreme series of 24-hourly rainfall events also has been prepared station wise and later considered for those representing corresponding districts. Then, the district wise patterns have been examined and the results are discussed. The rainfall days (frequency) are taken as time series and for considering the trend patterns in the study area. However, since the category of (*i*) does not fall under the extreme category, the other subgroups were only considered in the study. The rainy days with heavy rainfall over different stations and their frequencies were found out for the spatial patterns of extreme rainfall events during monsoon months, season (June-September) and the year as a whole. To identify the trend patterns, Mann-Kendall technique was applied on these data series of rainy days with these extreme rainfall data by calculating the Kendall's tau statistic. Further, to determine the increase or decrease, we have adopted least square linear fit of the data. The advantage of linear regression is that it provides an estimate of slope, confidence interval and quantifies goodness of fit. The slope thus computed helps in identifying the trend line whether significant at 95% level.

The long term trend has been worked out with the data since 1901 till 2010 or latest period available. For the recent period trends, data from 1971 onwards were considered. These trends have also been compared with those trend patterns worked out by the earlier studies. In addition, the spatial distribution of extreme rainfall events (heavy and very heavy rainfall) in association with the synoptic systems were also brought out and analyzed.

## 3. Results and discussion

It is interesting to note that the seasonal rainfall during monsoon over central India does not show any significant trend (Fig. 2). It is the same observed for the annual rainfall. However month to month and on sub-divisional scale, have shown remarkable trends. The rainy days (monthly frequency) were first computed under the two categories *i.e.*, for heavy rainfall ($7$ cm $\leq rf < 12$ cm) and very heavy rainfall ($rf \geq 12$ cm) over these stations located in different districts over the study region. The trend was tested using the Mann-Kendall tau statistic on different scales of monsoon months, season and annually. It is found to be an excellent tool for trend detection in different applications (Guhathakurta *et al*., 2008). The

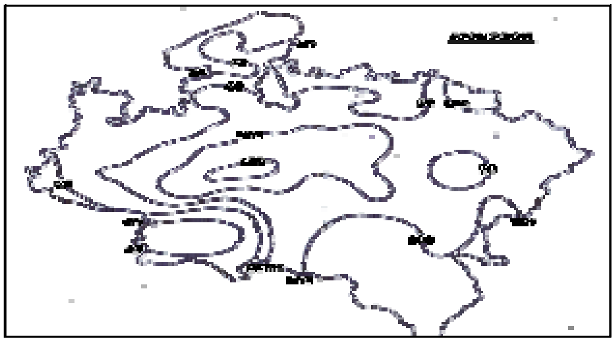


**Fig. 4.** Number of occurrence of heavy rainfall days (average in terms of hundred) during monsoon (June-September)

trend patterns of the frequencies are presented in Fig. 3. The trends patterns with the annual data were found to exhibit similar trends as like monsoon season. In the foregoing sections the trend analyses are discussed with regard to the main regions of MP, CHG and VID which form parts of the Central India.

### 3.1. *Heavy rainfall events (i.e., 7 ≤ rf < 12 cm)*

Over Madhya Pradesh during monsoon season, the heavy rainfall events are respectively about 23%, 34%, 32% and 11% in the months of June, July, August and September. The performance and the trend patterns of the frequency of the events over different districts of the regions under consideration. In the recent period, the heavy rainfall events are with increasing trends which indicates a growing concern.

In all, 59% of the stations did not show any trend. 19% of stations have shown positive significant trends. The positive significance trend is observed over east part of central region, *i.e.*, east Madhya Pradesh while negative trend is observed in western parts of the region. For the time series 1971-2010, 31% stations show increasing trend 47 % decreasing trend and 22% stations indicate no trend.

### 3.2. *Very heavy rainfall events (rf ≥ 12 cm)*

The frequency analyses on the occurrences of very heavy rainfall events over all the parts of central India indicate that the events are although present but not found to be significantly higher as is the case of heavy rainfall events. Also the patterns of such events are quite varying for different regions. Period significantly, in major parts of the central India.

It is seen that during the monsoon season, 54% of the stations did not show any trend. 32% of stations have shown positive significant trends. The positive significance trend is observed over west part of central region while central and eastern parts have shown positive trends.

**TABLE 1**

**Percentage of occurrences of heavy rainfall (7.5 ≤ rf < 12.5 cms)**

| Station | June | July | August | September |
|---|---|---|---|---|
| Central India | 16 | 40 | 34 | 10 |
| Madhya Pradesh | 23 | 34 | 32 | 11 |
| Chhattisgarh | 29 | 32 | 26 | 13 |
| Vidarbha | 23 | 35 | 31 | 11 |

**TABLE 2**

**Systems associated with heavy rainfall (7.5 ≤ rf < 12.5 cms)**

| System | June | July | August | September | Monsoon |
|---|---|---|---|---|---|
| Deep Depression | 10 | 6 | 6 | 0 | 5 |
| Depression | 10 | 4 | 13 | 14 | 10 |
| Low | 38 | 48 | 48 | 45 | 46 |
| Cyclonic circulation | 42 | 42 | 33 | 41 | 39 |

**TABLE 3**

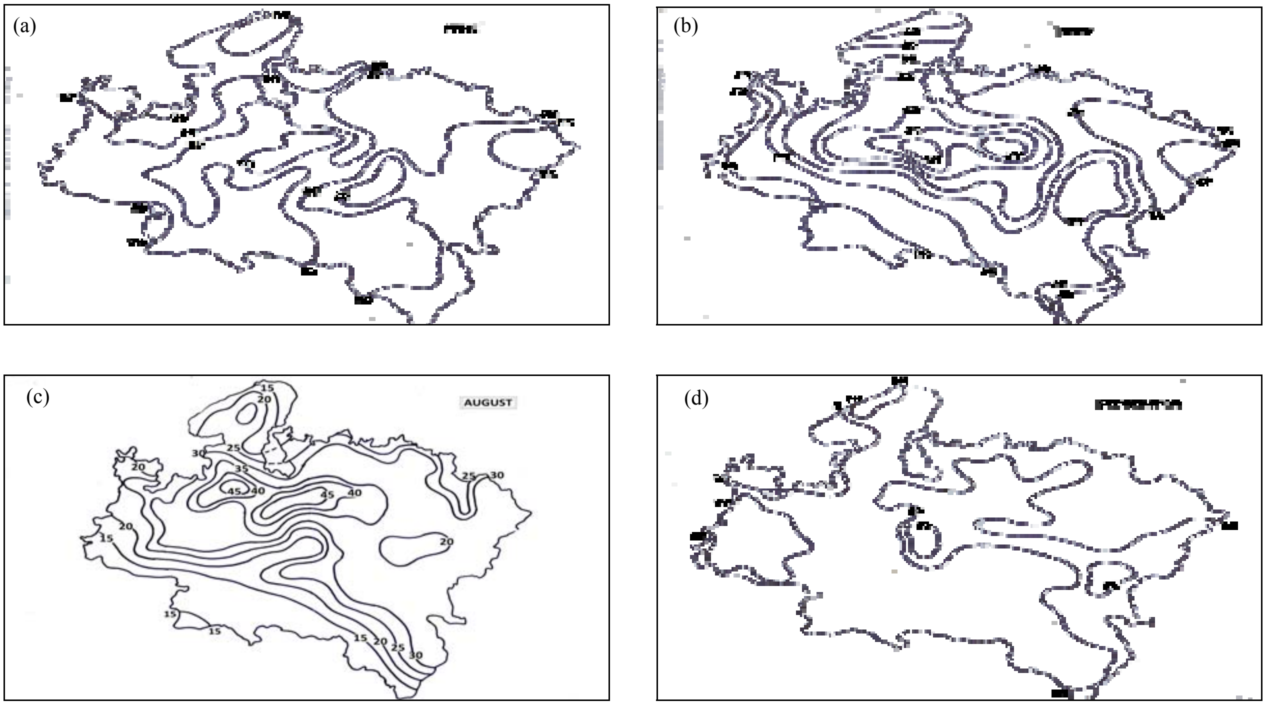
**Systems associated very heavy rainfall (≥ 12.5 cms)**

| System | June | July | August | September | Monsoon |
|---|---|---|---|---|---|
| Deep Depression | 14 | 10 | 13 | 0 | 9 |
| Depression | 9 | 7 | 12 | 15 | 11 |
| Low | 45 | 50 | 46 | 50 | 48 |
| Cyclonic circulation | 32 | 33 | 29 | 35 | 32 |

The time series of seasonal rainfall averaged over the regions indicated the west MP with increasing trends while the eastern parts of MP and the CHG and VID parts with decreasing trends. Most of the VID stations also have showed decreasing patterns of rainfall. These regions were analysed with events of moderate rainfall (those cases of heavy and very heavy events) which have provided a significant decreasing trend patterns for about 70% of stations.

### 3.3. *Systems associated with the rainfall events*

The heavy rainfall events having destructive potential are predominantly associated with oceanic disturbances right from the stage of Depression, Cyclonic Storms, etc, Therefore, while studying the heavy rainfall events, the occurrences due to the oceanic disturbances and cyclonic circulations over the land causing excess rainfall also becomes important and merit for consideration. Over the central parts of India, the heavy




**Figs. 5(a-d).** Number of occurrence of heavy rainfall days (average in terms of hundred) during (a) June (b) July (c) August and (d) September

rainfall days (rf) with $7.5 \leq rf < 12.5$ cm are computed from the available data for all the months during the monsoon season. The same are presented in Table 1. Also, the associated systems (from Cyclonic circulation to DD) causing the heavy rainfall events ($7.5 \leq rf < 12.5$ cm ) and very heavy rainfall events ( $rf \geq 12.5$ cm) during the study period were considered to prepare the Tables 2 & 3. As the number of heavy rainfall days is significantly higher during monsoon season, the intra-seasonal variation of the number of heavy rainfall days are analysed by considering monthly average during individual monsoon months. The results of the analysis are present in Tables 1.

The Table 1 shows that the occurrences of heavy rainfall are increasing from June and became maximum in July. It then decreases towards September. The occurrences of heavy rainfall over central India were 16% in June, 40% in July, 34% in August and 10% in September. About 75% occurrences of heavy rainfall is in the month of July and August. The highest frequency of heavy rainfall in all the sub divisions found in the month of July and lowest in September.

The spatial pattern of number of heavy rainfall days over central India during monsoon months is shown in Fig. 4 and Figs. 5(a-d). It is found that the occurrences of heavy rainfall has a well defined maxima over central parts of the region.

The onset of monsoon takes place in the month of June over southeastern part of central region *i.e.* over Chhattisgarh and then progress northwest wards but does not cover the entire region before the end of the month in some years. Thus, the maximum intensity and occurrence of rainfall can be expected over south east central region. In July and August the highest frequency of heavy rainfall lies over central parts of the region. Frictional convergence and pressure gradient contribute towards more rainfall in the central parts of the region. The fluctuations of yearly variation of heavy rainfall is maximum in August, probably because of "break in monsoon" which is having maximum frequency in August. For the month of September a large number of weather systems recurve towards the north of northeast on reaching central MP with consequent shift in the rain-belt from southwest to north/northeast sector.

The variation of frequency of occurrence of heavy and very heavy rainfall were studied in the light of antecedent synoptic situations. It was confirmed from 400 case studies that low pressure area producing around 50% of the total number of heavy and very heavy rainfall in July. The next higher is by upper air cyclonic circulation. The least heavy and very heavy rainfall is received by deep depression Tables 2 & 3. It is surprising to note that deep depressions have no impact in producing heavy and very heavy rainfall in September.

The systems lay over northeast Madhya Pradesh (north of 22º N and east of 80º E) give rise to heavy and very heavy rainfall over central parts of the region. It is not worthy that the systems give rise to very heavy rainfall 200 km away from the centre in the left forward sector. Lesser amounts of rainfall are normally recorded close to the centre of the systems. Further, those systems reaching the north eastern parts of the Central India, are influenced by orography as Vindhyachal and Satpura ranges lie on the either side of their track causing increased convergence.

## 4. Conclusions

The present study and analyses on the extreme rainfall events have brought out some important results leading to the following main conclusions:

(*i*) The monsoon rainfall over Central Indian region is without any significant change and mainly random in nature over a long period of time.

(*ii*) The number of stations showing increasing trends of heavy rainfall is mostly concentrated in SW MP and in parts of central and NE MP while increasing trend of very heavy rainfall scattered in all over MP.

(*iii*) Spatial distribution shows that the frequency of occurrence of heavy rainfall is more than very heavy rainfall over M. P.

(*iv*) It is observed that frequency of occurrences of heavy rainfall is the highest in July and lowest in September. Very heavy rainfall events also show a similar trend. Spatial distribution of heavy rainfall shows maximum over central parts of the region by rather than depressions and cyclonic storms. 48% of heavy rainfall is produced by low pressure area during monsoon period June-September. The maximum frequency of such systems is in the month of July.

*Acknowledgements*

The authors are thankful to DGM, ADGM ( R ) and DDGM, RMC, Nagpur for their encouragement and support for this study. The authors are also thankful to Shri H. Abdullah AM-II, Shri Beohar AM-II, Shri U. K. Pandey, SA, Shri R. K. Agrawal SA and Smt. Surabhi Purohit, UDC for calculations and typing the manuscript. The authors wish to thank the referee for providing useful comments.

**References**

Dhar, O. N. and Nandergi, S., 1993, "Spatial distribution of severe rainstorms over India and their associated rainfall depths", *Mausam*, **44**, 373-380.

Dubey, D. P. and Balakrishnan, T. K., 1994, "A study of heavy and very heavy rainfall over Madhya Pradesh for the period 1977 to 1987" *Mausam*, **45**, 326-329.

Goswami, B. N., Venugopal, V., Sengupta, D., Madhusoodanan, M. S. and Xavier, P. K., 2006, "Increasing trend of extreme rain events over India in a warming environment", *Science*, **314**, 1442-1445.

Guhathakurta, P. and Rajeevan, M., 2008, "Trends in rainfall pattern over India", *Int. J. Climatol*., **28**, 1453-1469.

Guhathakurta, P., Sreejith, O. P. and Menon, P. A., 2011, "Impact of Climate change on extreme rainfall events and flood risk in India", *J. Earth Syst. Sci*., **120**, 3, June 2011, 359-373.

Rajeevan, M., Bhate, J. and Jaswal, A. K., 2008, "Analysis of variability, and trends of extreme rainfall events over India using 104 years of gridded daily rainfall data", *Geophys. Res. Lett*., **35**, L18707, doi: 10.1029/2008GL035143.

Roy, Shouraseni Sen and Balling, Jr R. C., 2004, "Trends in extreme daily precipitation on indices in India", *Int. J. Climatol*., **24**, 457-466.

Smith, R. B., 1979, "The influence of mountains on the atmosphere", *Advances in Geophysics*, **21**, 187-230.