

Trends in 24 Hours Maximum Rainfall in Humid Environments of Agartala, Northeast India

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ABSTRACT: An increase in extreme rainfall events has been reported in different parts of the world including India. Analysis of 24 hours (h) maximum rainfall, the highest amount of total rainfall in a day in a particular year, may provide valuable information for better planning during the floods. In the present study, the trends in 24 h maximum rainfall is studied under global warming circumstances of Agartala, a humid site of Tripura (northeast India), during 20th century from 1901 to 2003. Trends in 24 h maximum rainfall were investigated using both parametric and non-parametric methods, and the magnitude of significant trends were obtained through the linear regression test. The average annual rainfall at Agartala during 20th century is found to be 2186.12 mm, with standard deviation (coefficient of variation) of 608.30 mm (27.83 %) and about 67% (28%) of total annual rainfall is received during the months of June to October in the monsoon (March to May in the pre-monsoon) season. Agartala witnessed statistically significant increasing trends by using the Mann-Kendall test (Z statistics of 2.01) in 24 h maximum rainfall. Significant increases in 24 h maximum rainfall were observed at the rate of 6.13 mm/decade by using the linear regression test over Agartala. Increasing extreme rainfall events may have serious implications on water resources management in terms of frequent floods in Tripura.

KEYWORDS: 24 hours; maximum rainfall; trend; Mann-Kendall; Agartala; humid.

1. INTRODUCTION

In recent years, climate changes and human activities have resulted in dramatic changes in eco-hydrological patterns, which in turn have led to the changes in hydrological processes in many basins around the world. This may have caused serious water resources problems in various regions. Impact of climate change may be relatively severe with reduction in water availability in different parts of the globe. Accurate prediction of precipitation, one of the main components of the hydrologic cycle, is necessary because it is crucially involved in estimation of water yields from watersheds, safe yields of ground water basins and stream flow depletion in river basins, etc. Rainfall also plays vital role in the water balance of single or multi-purpose water projects for irrigation, hydro-power, water transport, flood control, urban and industrial water uses. Thus, accurate knowledge of distribution of precipitation is a key factor in hydrology, climatology, agronomy and ecological studies in a given region.

Increase in extreme rainfall events in India were reported by Sen Roy and Balling (2004). Increase was found to be the strongest in a region extending from the northwestern Himalayas in Kashmir through most of the Deccan Plateau in the southern peninsular region of India (Sen Roy and Balling, 2004). Goswami et al. (2006) reported that the Northeast and the west coast of India were regions of high mean and high variability of rainfall events. Extreme rainfall events causes severe damage to human life, crops, and disruption of life and infrastructure in the Northeast region (Jhajharia et al., 2012). Since, no previous study on behaviour of extreme rainfall event and total rainfall over Agartala under humid climatic conditions was available, the present study was carried out with the following objectives: (1) to estimate the statistical properties of total rainfall and extreme rainfall event in terms of 24 hours (h) maximum rainfall during 20th century; (2) to investigate the trends in 24 h maximum rainfall using the Mann-Kendall test; and (3) to estimate trends in total annual rainfall for 103 years starting from 1901 to 2003.

II. MATERIALS AND METHODS

2.1. Study area and meteorological data

Agartala station (IMD code No. 42724) is situated Tripura state (northeast India), which is bounded on the eastern sides by states of Assam and Mizoram and on the north, west, south and southeast by Bangladesh. Agartala ($23^{\circ}53'$ N Latitude, $91^{\circ}15'$ E Longitude and elevation of 16.00 m above mean sea level), a humid site, has received heavy monthly total rainfall varying from 914.10 mm (June) to 109.96 mm (July) during June to August in monsoon season. The location of Agartala site is shown in Fig. 1. The annual data of total rainfall were collected for last 103 years (1901-2003) from India Meteorological Department (IMD) Pune, Maharashtra. Similarly, the data of the 24 h maximum rainfall of Agartala were also obtained for the duration of 103 years from 1901 to 2003 from IMD. There were two missing values, and these missing values of total rainfall in a year were replaced by the average annual rainfall of Agartala. Mean monthly temperature and relative humidity over Agartala is found to be about 22.6°C and 76% respectively. Also, mean monthly values of wind speed, sunshine duration and pan evaporation over Agartala are 5.9 km/h, 6.4 h and 3.7 mm/day, respectively (Jhahharia et al., 2009).



Fig. 1. Location map of Agartala (Tripura) in India
(Source: www.mapsofindia.com)

2.2. Mann-Kendall test for trend analysis

Most trend analysis that uses long term monitoring data is conducted to determine if there are changes in data over time. Several parametric and non-parametric methods are used to analyze trends in climate change studies. In parametric analysis, actual values of variables are used to determine the trend considering data are normally distributed. While non-parametric tests utilize the rank of the data than their actual values. The null distribution of non-parametric test statistic can be determined without regard to the shape of the parent population distribution, and is less affected by outliers in data. The Mann-Kendall test (Mann, 1945; Kendall, 1975), one of the most widely used non-parametric tests, is used to detect trend in any time series. The value of the test statistic denoting trend is determined and the significance of test statistic is assessed by comparing the values of the standard normal variate (Z), which is computed as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & S < 0 \end{cases}$$

Where, Var (S) is variance of the S statistic. The value of test statistics is computed, and if the absolute value of Z is more than 1.96, then there is statistically significant trend in the series at the 5% level of significance. The magnitude of trend was obtained through linear regression, a commonly used parametric test.

III. RESULTS AND DISCUSSION

The highest (lowest) value of annual total rainfall over Agartala was found to be 5211.7 mm in 1988 (963.8 mm in 1982). The average total annual rainfall at Agartala during 20th century is found to be 2186.12 mm, with standard deviation (coefficient of variation) of 608.30 mm (27.83 %) and about 67% (28%) of total annual rainfall is received during the months of June to October in the monsoon (March to May in the pre-monsoon) season. During the first half and the second half of the 20th century, the mean of total annual rainfall were found to be 2040.9 mm and 2375.4 mm, respectively over Agartala. The statistical properties of total rainfall are shown in Table 1. The mean (maximum) value of 24 h maximum rainfall are found to be 149 mm (880 mm in 1988) with standard deviation and coefficient of variation of 92.24 mm and 62% at Agartala. During the first half and the second half of the 20th century, the mean of 24 h maximum rainfall were found to be 130.3 mm and 167 mm, respectively.

Table 1. Statistical Properties of Total Annual Rainfall and 24 h Maximum Rainfall

| S. No. | Parameter | Mean (mm) | Maximum (mm) | Minimum (mm) | Standard Deviation (mm) | Coefficient of variation (%) | Coefficient of skewness |
|--------|-----------------------|-----------|--------------|--------------|-------------------------|------------------------------|-------------------------|
| 1 | Total Rainfall | 2186.1 | 5211.7 | 963.8 | 608.31 | 27.83 | 1.61 |
| 2 | 24 h Maximum Rainfall | 148.9 | 880.0 | 51.0 | 92.24 | 61.98 | 5.47 |

Identification of trends in 24 h maximum rainfall

Trends in total annual rainfall and 24 h maximum rainfall at Agartala was obtained using the Mann-Kendall (MK) test. The Z statistic values obtained through the MK test for both the total annual rainfall and 24 h maximum rainfall at Agartala were found to be 1.54 and 2.01, respectively. Results revealed that Agartala witnessed no trends in total rainfall in annual time scale even at 10% level of significance. Fig. 2 shows the time series of annual total rainfall for 20th century from 1901 to 2003 over Agartala. The dotted (broken) line shows linear trend line in total rainfall at Agartala, which is increasing at the rate of 27.3 mm/decade (although statistically non-significant). However, results revealed statistically significant increasing trends in 24 h maximum rainfall at 5% level of significance at Agartala. Significant increases in 24 h maximum rainfall were observed at the rate of 6.13 mm/decade by using the linear regression test during 103 years from 1901 to 2003. Fig. 3 shows the time series and trend line of 24 h maximum rainfall during the 20th century over Agartala. Various research studies carried out in the humid environments of northeast India reported significant increasing trends in temperature and decreasing trends in wind speed (Jhajharia et al., 2009; Jhajharia and Singh, 2011). Jhajharia et al. (2012) reported statistically significant decreasing trends in the evapotranspiration under humid climatic conditions of northeast India.

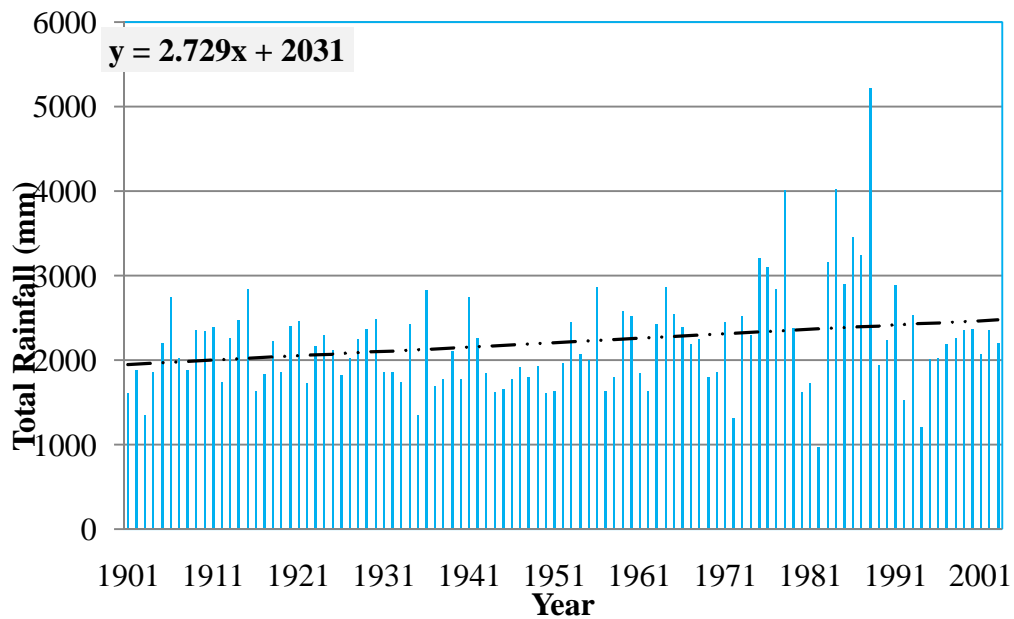


Fig. 2. Time series of total annual rainfall over Agartala (Tripura) from 1901-2003

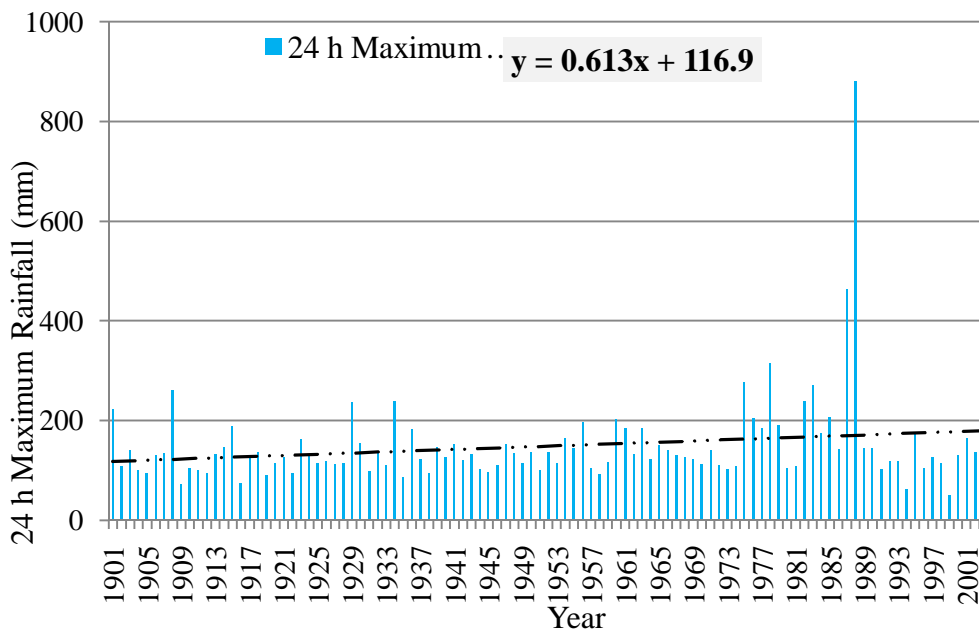


Fig. 3. Time series of 24 h Maximum Rainfall over Agartala (1901-2003)

Table 2. Wet Years based on Percent Departure at Agartala (1901 to 2003)

| S. No. | Year | Percent Departure (%) |
|--------|------|-----------------------|
| 1 | 1906 | 25.70 |
| 2 | 1915 | 29.56 |
| 3 | 1936 | 29.34 |
| 4 | 1941 | 25.52 |
| 5 | 1956 | 31.11 |
| 6 | 1964 | 30.96 |
| 7 | 1975 | 46.52 |
| 8 | 1976 | 41.86 |
| 9 | 1977 | 29.64 |
| 10 | 1978 | 83.36 |
| 11 | 1983 | 44.11 |
| 12 | 1984 | 84.24 |
| 13 | 1985 | 32.64 |
| 14 | 1986 | 57.90 |
| 15 | 1987 | 47.93 |
| 16 | 1988 | 138.40 |
| 17 | 1991 | 31.91 |

The percent departure of annual rainfall for each year from the average annual rainfall of Agartala was estimated for all the one hundred three years. Based on this, wet years were identified which occurred at Agartala during 20th century. A wet year is defined as that particular year in which the percent departure value of annual rainfall from the average annual rainfall is more than 25% at the given site. Table 2 shows the number of wet years, their percent departure values and the year of the occurrence of the wet events at Agartala. It is clear that there are total 17 wet events out of 103 years at Agartala with the lowest and the highest percent departure values varying from 25.52% and 138.4% in 1941 and 1988, respectively.

Table 2 reveals that there are only four wet years during the first half of the 20th century at Agartala, and all the wet years percent departure values are less than 30%. However, all the remaining (eleven) wet events occurred during the second half of the 20th century over Agartala. Further, it is observed that two decades, i.e., 1971-1980 and 1981-1990, witnessed the highest number of wet events at Agartala. During the decade from 1971-1980, four consecutive wet events were witnessed from 1975 to 1978 in the range of 29.6 – 83.4% at Agartala. Similarly, six consecutive wet years were witnessed from 1983 to 1988 varying from 32.6 – 138.4 % during the decade from 1981-1990 over Agartala. Thus, it is very likely that 24 h maximum rainfall may have created flood-like situations in these two decades from 1971 to 1990 at Agartala. Jhajharia et al. (2012) have reported that heavy rainfall events causes severe damage to human life, crops and disruption of life and infrastructure in the northeast region of India.

IV. SUMMARY AND CONCLUSIONS

Understanding the pattern of rainfall occurrence in a region is essential in planning economical uses of water resources as it plays a critical role in irrigation planning and is needed for determination of water demands of crops. Therefore, identifying trends in rainfall under climate change is important for understanding the effect of rainfall changes on water resources, agriculture, etc. An attempt has been made in the present study to estimate the trends in total rainfall and heavy rainfall events at Agartala during the 20th century in northeast India. The trends in 24 h maximum rainfall in the humid environment of the study area were identified using the MK test. The average annual rainfall at Agartala during 20th century is found to be 2186.12 mm, with the highest (lowest) annual rainfall of 5211.7 mm occurring in 1988 (963.8 mm in 1982). About 67% (28%) of total annual rainfall is received during June to October in the monsoon (March to May in the pre-monsoon season) at Agartala.

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Statistically significant increasing trends in 24 h maximum rainfall at 5% level of significance were witnessed at the rate of 6.13 mm/decade. On the other hand, no trend in total annual rainfall was witnessed even at 10% level of significance over Agartala. During two decades period from 1971 – 1990, ten wet years were witnessed from 1975 to 1978 and 1983 to 1988 varying from 29.6 – 138.4 % of departure from the average annual rainfall over Agartala. The floods of 1987, 1988, 1992 and 1995 were quite severe in various regions of Assam (Mitra 2004). Agartala witnessed the highest annual rainfall (5211.7 mm) and the heaviest 24 h maximum rainfall (880 mm) in 1988, which is in total agreement with the occurrence of one of the worst recorded floods in 1987 and 1988 in Assam as reported by Mitra (2004). Therefore, the extreme rainfall events in Agartala (Tripura) may have devastating effects on the fragile ecosystems in the northeastern region of country having rainforests and the most wet places in the world.

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