Statistical analysis of monsoon rainfall distribution over West Bengal, India

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ABSTRACT. Seasonal, monthly and daily rainfall characteristics of meteorological sub-divisions of Sub Himalayan West Bengal (SHWB) and Gangetic West Bengal (GWB) have been studied using rainfall data of 23 stations of India Meteorological Department (IMD) over the state of West Bengal. The two subdivisions have distinctive characteristics, though two stations lying in the plain region of SHWB have behaviour more alike the stations of GWB. Krishnagar is a station with least seasonal rainfall in the entire state. Kurtosis and Skewness of the seasonal rainfall distribution have been studied and found that, for most of the stations they lie within reasonable limits. From the time series analysis, it is found that the seasonal rainfall has no trend.

Key words – Kurtosis, Skewness, Time series analysis, ANOVA.

1. Introduction

It is well-known that the normal position of axis of the monsoon pressure trough extends from Ganganagar, Rajasthan in the north to the head Bay of Bangal in the south. Moist convective process is the dominant forcing event over Gangetic West Bengal (GWB) during the monsoon period. Apart from that, different low pressure systems like low, depression, deep depression and cyclonic circulation penetrate into or form over GWB during this period. In its wake substantial amount of precipitation occurs over this region during monsoon period.

Two meteorological sub-divisions of India Meteorological Department (IMD) cover the entire state of West Bengal. The part of the state south to the river Ganges falls under GWB and the region, north to the river is called Sub Himalayan West Bengal (SHWB). The topography of SHWB is highly varying in nature, it contains plain land in the south to foot-hill Himalayan zone to high mountains further north. As monsoon pressure trough shifts northward during break monsoon phase to the foot-hill Himalayan region, heavy precipitation occurs over this region. The situation is significantly accentuated because of the orography. So the entire state of West Bengal experiences sufficient rain during this season, though the amount is much higher in SHWB.

Flood during the monsoon season is a perennial problem in West Bengal. In order to manage flood...
including its prediction, we need to understand the characteristics of monsoon precipitation distribution over the state. Besides that, nearly 80% of total annual precipitation over this region occurs during this period. As the main economy of the state is still agriculture, we need to understand the nature of distribution of monsoon rain in order to decide the agricultural strategy. It should also be stressed that many industries need water and to decide the location of such industries, we should have a clear idea about the availability of water over different regions.

Incidentally, some works have already come out featuring different aspects of monsoon rain over West Bengal. Prasad and Ram (1989) have studied long term variation in rainfall at Jalpaiguri, North Bengal and, Das and Mukhopadhyay (1996) have presented wet and dry spell behaviour during monsoon months over two North Bengal districts. On the other hand, Biswas and Gupta (1993) have worked on monsoon variability over the entire state due to different positions of the monsoon trough. Basu (1981, 2001) and Basu et al. (2004) have studied the monsoon characteristics over West Bengal more extensively. While in one work (1981) Basu studied its variability over Damodar Valley catchment area only, in another work (2001) he worked mainly on the month-wise variation of monsoon rain over the entire state. In their work (2004), Basu and others presented district-wise variability of monsoon rain. In the present work we are using around 30 years (1970-2000) rainfall data over 23 meteorological stations of IMD. While 17 stations fall under GWB region, the rest 6 stations fall under SHWB region. The present work has revealed many new characteristics of monsoon rainfall over different stations of West Bengal.

2. Data

Daily rainfall data have been collected for 23 meteorological stations of IMD from 1970 to 2000. The stations are well distributed over entire West Bengal (Fig. 1). While 6 stations fall under SHWB, the rest 17 stations fall under GWB. Availability of data for different stations has large variation; while Dumdum (22.65° N, 88.45° E) and Purulia (23.33° N, 86.42° E) stations have 31 years of continuous data, Burdwan (23.23° N, 87.85° E) has only 7 years of data. Whenever available data points for a month fall below 25, we have rejected the entire data set. Otherwise the accumulated rainfall for a month has been adjusted by correcting on pro-rata basis. In case of monthly or seasonal study, we are considering...
only that data set which has full data for the entire season. In case of classification of daily rainfall data, only the data points of the seasons under consideration are being taken into account. In case of time series we need continuous data and such data is available for significant number of years for 4 stations only, all in GWB, namely Dum dum (31 years), Purulia (31 years), Alipore (30 years) and Midnapore (29 years). Accordingly, time series analysis has been performed for these 4 stations only.

3. Methodology

In the present work various simple statistical procedures have been applied in order to reveal the

monsoon variability over different regions of West Bengal. Various parameters under the following headings have been evaluated for each of 23 stations:

3.1. Seasonal rainfall

The months of June, July, August and September constitute the monsoon season. Number of years of seasonal rainfall, total number of rainy days involved, total amount of seasonal rainfall in mm, mean seasonal rainfall/year, maximum and minimum seasonal rainfall and the standard deviation of the seasonal rainfall are presented in Table 1.
3.2. Monthly rainfall

The same parameters in Table 1 are considered individually for each of the four months of June, July, August and September and only the important points are discussed in Section 4.2.

3.3. Daily rainfall

Average rain/day, average rain/rainy day, highest daily rain and date of highest daily rain are presented in Table 2. Daily rain in mm is considered to belong to one of the following six classes as used by IMD:

- Trace: $> 0$ and $< 2.5$
- Light: $\geq 2.5$ and $< 10$
- Moderate: $\geq 10$ and $< 30$
- Rather heavy: $\geq 30$ and $< 70$
- Heavy: $\geq 70$ and $< 130$
- Very heavy: $\geq 130$ and $< 250$
- Extreme Heavy: $\geq 250$

In order to be considered as a rainy day, the rainfall must be above trace.

Histogram for each of the observation stations is prepared considering the above mentioned daily rainfall range distribution.

3.4. Skewness and Kurtosis of seasonal rainfall

Coefficient of Skewness $g$ is given by, $g = M_3 / S^3$, where $M_3$ is the third moment of a variable $X$ about the mean $\bar{X}$ and $S$ is the standard deviation.

$$M_3 = 1/N \sum_{i=1}^{N} (X_i - \bar{X})^3$$

If $g$ is positive, the longer tail of the distribution is towards the right and when $g$ is negative, the longer tail of the distribution is towards the left.

Coefficient of Kurtosis $K$, a measure of the degree of peakedness of the distribution, is evaluated using the formula $K = M_4 / S^4$, where $M_4$ is the 4-th moment of a variable $X$ about the mean $\bar{X}$ and $S$ is again the standard deviation.

$$M_4 = 1/N \sum_{i=1}^{N} (X_i - \bar{X})^4$$

When $K = 3$, the distribution is normal,

- $> 3$, the distribution is more peaked i.e., sharp,
- $< 3$, the distribution is less peaked i.e., flattened.

To test the significance of the above descriptive statistics i.e., the Coefficient of Kurtosis ($K$) and the Coefficient of Skewness ($g$), the respective standard errors, viz. $SE_K$ and $SE_g$ have been calculated using the formulae (Tabachnick and Fidell, 1996):

$$SE_K = \sqrt{24/N}, \quad SE_g = \sqrt{6/N},$$

where $N$ is the number of population.

If $-2 \times SE_K < K < 2 \times SE_K$ and $-2 \times SE_g < g < 2 \times SE_g$, then it may be concluded that these statistics fall within the expected range of chance fluctuations in the respective statistics. If $K$ lies outside the range, the distribution is either sharply peaked or flattened than the normal distribution.

Similarly, if $g$ lies outside the specified range, then the observed distribution is asymmetric (Brown, 1997).

3.5. Time series analysis

For time series analysis the method of moving averages has been adopted to get an idea about the basic trend of the available time series data of seasonal monsoon rainfall.

Some important points to be mentioned here, that, if a series of yearly figures are given, the seasonal fluctuations (whose period is generally a year) is automatically eliminated. Next, to smooth out the cyclical fluctuations, usually the period of moving averages is taken as the distance between two 'peaks' or two 'depressions'. But since, in the present study it is found that the period of cycle is not uniform (4, 5 or 6 years), so the period has been taken as 5 years, which is the mean or average duration of the cycles (Goon et al., 2008). Another reason behind the selection of this period is due to the low-pass linear model (Christensen, 1991).

Since the graphs of the actual values of seasonal rainfall and the trend values against time suggest that the
trend is not linear, so there is a possibility of over estimation or under estimation by this method.

The ANOVA (Analysis of variance) test for relationship (Goon et al., 1976) between the time and rainfall, time being the independent variable and rainfall, the dependent one, also reveals that there is no linear or non-linear relation between them, so no such least square curve could be fitted to the data for future prediction.

Instead, an attempt has been made to get an idea about the mean or average monsoon rainfall by constructing 95% confidence interval of the mean rainfall and its standard deviation.

4. Results and discussion

4.1. Seasonal rain

The contour of mean seasonal rainfall is plotted in Fig. 2. Obviously the minimum seasonal rainfall is centred at Krishnanagar and it increases towards the north as well as the south.

The standard deviations in seasonal rain of two high hill stations are quite diverse. While, standard deviation of seasonal rainfall in Darjeeling is lowest among the six SHWB stations, the same for the foot hill stations are almost similar and close to that of Kalimpong. Two plain land stations have substantially less standard deviation.

The maximum seasonal rainfall (Table 1) over different stations in GWB does not differ much. The value is lowest at Krishnanagar, though it is not much different from some other stations. Digha, a sea coast station has maximum seasonal rainfall. The highest and lowest value of minimum seasonal rainfall occurs at Haldia, a station not far from the sea coast and Krishnanagar.

The years on which maximum seasonal rainfall occurs over GWB vary widely, some years repeat for maximum and minimum seasonal rainfall over the stations. The years of maximum and minimum seasonal rainfall over different stations do not overlap except in 1987.

4.2. Monthly rainfall

When we consider the mean monthly rainfall over four different months of June, July, August and September during the monsoon season, the pattern of variation does not change much from its seasonal counterpart. We are presenting here only the salient features of monthly rainfall distribution. One can conclude that among the six stations of SHWB, the two foot-hill stations have maximum rainfall in each of the four months. Then come Darjeeling and Kalimpong within a certain range and the lowest value in the range comes from Balurghat and Maldah. Among the stations of GWB, Krishnanagar has the lowest average rainfall in three months except July. In July, the mean rainfall of Krishnanagar exceeds the corresponding value for Purulia and Digha. Though Digha is a sea-coast station, it has the lowest mean rain in the month of July of all the stations in West Bengal. On the whole, all the stations of GWB have comparatively close mean monthly values. When we come to maximum and minimum monthly rainfall, the maximum monthly rainfall always occurs either at Kuchbihar or Jalpaiguri among the six stations of SHWB. Dum Dum has highest monthly maximum rainfall in three months except August. In fact, the other station close by i.e., Alipore, in general, lags behind. In the month of August, maximum monthly rainfall at Dum Dum is much less compared to many other stations including Alipore. Bankura experiences highest maximum rainfall in this month.

4.3. Daily rainfall

Among the six stations of SHWB, maximum daily rainfall (Table 2) attains highest value at Kuchbihar. On the other hand, the corresponding value at the other foot-hill station i.e., Jalpaiguri is comparatively quite low. Maximum daily rainfall is quite low at Kalimpong and Darjeeling, it is lowest among all stations of SHWB and GWB. The stations, Balurghat and Maldah have almost similar maximum daily rainfall, but the value is
TABLE 2
Daily rainfall at different stations

| Division | Station Name | Average rain per day (mm) | Average rain per rainy day (mm) | Highest recorded 1-day rainfall (mm) | Date of highest 1-day rainfall |
|----------|--------------|---------------------------|-------------------------------|-------------------------------------|-------------------------------|
| SHWB     | Balurghat    | 10.1                      | 24.8                          | 619.6                               | 01 Jun, 1980                  |
|          | Darjeeling   | 17.0                      | 25.3                          | 157.4                               | 30 Jun, 1976                  |
|          | Jalpaiguri   | 23.4                      | 38.0                          | 474.0                               | 10 Jul, 1999                  |
|          | Kalimpong    | 15.9                      | 30.2                          | 218.0                               | 22 Jul, 1971                  |
|          | Kuchbihar    | 23.3                      | 39.5                          | 971.9                               | 06 Jun, 1986                  |
|          | Maldah       | 9.9                       | 23.0                          | 701.8                               | 12 Sep, 1982                  |
| GWB      | Alipore      | 10.6                      | 21.6                          | 383.2                               | 06 Jun, 1984                  |
|          | Bagati       | 9.6                       | 21.6                          | 280.2                               | 28 Sep, 1978                  |
|          | Bankura      | 9.3                       | 21.2                          | 257.0                               | 27 Aug, 1987                  |
|          | Berhampore   | 9.9                       | 22.4                          | 260.0                               | 19 Sep, 2000                  |
|          | Burdwan      | 10.6                      | 23.8                          | 253.0                               | 04 Sep, 1970                  |
|          | Canning      | 11.3                      | 22.5                          | 270.9                               | 05 Jun, 1984                  |
|          | Contai       | 9.8                       | 23.8                          | 375.8                               | 31 Aug, 1973                  |
|          | Diamondharbour | 10.4               | 22.2                          | 237.2                               | 05 Jun, 1984                  |
|          | Digha        | 9.6                       | 23.2                          | 325.3                               | 09 Jun, 1988                  |
|          | Dumdum       | 10.9                      | 21.7                          | 369.6                               | 28 Sep, 1978                  |
|          | Haldia       | 11.6                      | 23.2                          | 270.2                               | 21 Jun, 1998                  |
|          | Krishnanagar | 7.4                       | 19.8                          | 222.2                               | 04 Sep, 1970                  |
|          | Midnapore    | 10.2                      | 22.0                          | 293.8                               | 16 Aug, 1974                  |
|          | Purulia      | 9.2                       | 20.4                          | 236.6                               | 24 Sep, 1999                  |
|          | Sagar Island | 10.9                      | 25.1                          | 254.4                               | 12 Jun, 1988                  |
|          | Sriniketan   | 9.5                       | 21.9                          | 341.8                               | 27 Sep, 1978                  |
|          | Uluberia     | 10.8                      | 23.3                          | 409.3                               | 29 Sep, 1978                  |

substantially higher than the various stations over GWB. The years of maximum daily rainfall are completely dispersed and non-overlapping. However, it occurs in three stations in the month of July and two stations have same experience in the month of June.

In case of the stations of GWB, the maximum daily rainfall lies within the range of 222-409 mm. Krishnanagar experiences the lowest daily maximum rainfall. The years of maximum daily rainfall for different stations of GWB are quite disperse, but the year of occurrence is 1978 for four stations, 1984 for three stations and 1988 for two stations. Otherwise, the years are distinct for the rest nine stations. Among the four months of monsoon season, eight stations of GWB experience maximum daily rainfall in September, six stations in June, three in August and none in July.

The average rainfall per day as well as per rainy day is highest at the two hill stations. In case of Darjeeling the average rain/rainy day is not much different from the two plain land stations as well as the other stations of GWB. But average rain per day is significantly higher at Darjeeling and comes close to that of Kalimpong. This happens, as the number of rainy days is highest at Darjeeling among all stations of SHWB and GWB. The two plain land stations of SHWB have both average rain/rainy day and average rain/day like the stations of GWB.
In case of GWB stations, the average rainfall/day values are close by and lie within the range of 9.3 - 11.6 mm, if Krishnanagar is not considered. The average rainfall/rainy day lies within the range of 20.4 - 25.1 mm for all the stations except Krishnanagar. For Krishnanagar, the value is slightly low.

In the next, let us put the daily rainfall of each station in one of the seven classes given in Section 3.3. Among the six stations of SHWB, moderate rain dominates in four stations of high hill and foot hill regions. There exist significant number of extreme heavy and very heavy rainfall days in case of Kuchbihar and Jalpaiguri, but extreme heavy rainfall days are totally absent for Darjeeling and Kalimpong. A representative histogram for daily rainfall of different classes is given for Kuchbihar [Fig. 3(a)]. Moderate rain dominates in high hill as well as foot hill stations. Whereas, light rain dominates in Balurghat, Maldah has maximum concentration of trace rain. Darjeeling, Kalimpong, Balurghat and Maldah have significantly less number of very heavy rainfall days. Fig. 3 is representative histogram of daily rainfall distribution for Darjeeling.

Among the seventeen stations of GWB, the three classes of trace, light and moderate rainfall exist almost in equal strength in seven stations i.e., Alipore, Dumdum, Canning, Contai, Diamondharbour, Sagar Island and Sriniketan. A histogram of daily rainfall distribution observed at Alipore is presented in Fig. 3(c). Light rainfall has distinct maximum strength in seven stations i.e. Bagati, Bankura, Berhampore, Krishnanagar, Midnapore, Purulia and Uluberia; where as trace rainfall has a distinct peak in only one station, Digha. Burdwan is the only station, where a peak for moderate rain dominates among the other classes. In case of Haldia, both light and moderate rainfall appear with almost equally high intensity. A representative figure for Haldia is given in Fig. 3(d). It should be mentioned that many of the stations of GWB experience extreme heavy rainfall though the occasion may be much less compared to the number at foot hill Himalayan stations.

4.4. Skewness and Kurtosis

Highest value of Skewness as well as Kurtosis occurs at Balurghat. Kurtosis varies between 2 and 4 for the other five stations. So except Balurghat, the density distribution for the seasonal rainfall for the last five
TABLE 3

Skewness and Kurtosis of seasonal rainfall

| Division | Station   | Size (N) | SkewS | 2 × StErr(SkewS) Comment | KurtS | 2 × StErr(KurtS) Comment |
|----------|-----------|----------|-------|--------------------------|-------|--------------------------|
| SHWB     | Balurghat | 20       | 1.17  | ±1.09545 Not significant | 4.34  | ±2.19089 Not significant |
|          | Darjeeling| 11       | 1.25  | ±1.47710 significant | 3.69  | ±2.95420 Not significant |
|          | Jalpaiguri| 15       | 0.86  | ±1.26491 significant | 2.87  | ±2.52982 Not significant |
|          | Kalingpong| 11       | -0.08 | ±1.47710 significant | 3.61  | ±2.95420 Not significant |
|          | Kuchbihar | 22       | 0.47  | ±1.04447 significant | 3.00  | ±2.08893 Not significant |
|          | Maldah    | 26       | 0.10  | ±0.96077 significant | 2.43  | ±1.92154 Not significant |
| GWB      | Alipore   | 30       | 0.79  | ±0.89443 significant | 3.37  | ±1.78885 Not significant |
|          | Bagati    | 27       | -0.43 | ±0.94281 significant | 2.92  | ±1.88562 Not significant |
|          | Bankura   | 18       | 0.38  | ±1.15470 significant | 2.29  | ±2.30940 significant     |
|          | Behrampur | 20       | 0.50  | ±1.09545 significant | 2.38  | ±2.19089 Not significant |
|          | Burdwan   | 7        | 0.28  | ±1.85164 significant | 2.28  | ±3.70328 significant     |
|          | Canning   | 17       | -0.87 | ±1.18818 significant | 3.62  | ±2.37635 Not significant |
|          | Cantai    | 18       | 0.78  | ±1.15470 significant | 3.36  | ±2.30940 Not significant |
|          | Diamondharbour | 15   | 0.23  | ±1.26491 significant | 1.75  | ±2.52982 significant     |
|          | Digha     | 17       | 1.42  | ±1.18818 Not significant | 5.98  | ±2.37635 Not significant |
|          | Dum Dum   | 31       | 0.51  | ±0.87988 significant | 2.18  | ±1.75977 Not significant |
|          | Haldia    | 15       | 0.41  | ±1.26491 significant | 2.46  | ±2.52982 significant     |
|          | Krishnanagar | 16  | 0.22  | ±1.22474 significant | 1.91  | ±2.44949 significant     |
|          | Midnapore | 29       | 0.06  | ±0.90972 significant | 2.62  | ±1.81944 Not significant |
|          | Purulia   | 31       | 0.49  | ±0.87988 significant | 3.08  | ±1.75977 Not significant |
|          | Sagar Island | 25   | 0.00  | ±0.97980 significant | 2.38  | ±1.95959 Not significant |
|          | Srinketan | 28       | 0.10  | ±0.92582 significant | 2.44  | ±1.85164 Not significant |
|          | Uluberia  | 20       | 0.08  | ±1.09545 significant | 2.52  | ±2.19089 Not significant |

stations is more towards normal distribution (Gupta, 2008). This is also evident from the value of Skewness. Coefficient of Skewness is between 1 and 0, for majority of the stations of GWB (Table 3) i.e., the density curve for rainfall may be roughly described as having a longer tail on the positive, or it is almost symmetric about the mean. So, the distribution is slightly longer towards the higher rainfall side. Maximum value of skewness reaches a higher value of 1.42 for Digha, a situation alike the kurtosis value. On the other hand, only two stations, namely Bagati and Canning have negative value of skewness, though the value is higher than -1.

Unfortunately, there is no hard and fast rule about the above mentioned descriptive statistics, because interpreting them depends on the type and purpose of the test being analyzed.

Since in the present analysis, ‘g’ lies within the specified range in most of the cases (Table 3), so it can be inferred that the distribution of the seasonal rainfall of West Bengal follows almost the symmetric nature of the normal distribution.

Kurtosis for seasonal rainfall distribution in case of fifteen stations of GWB lies between 4 and 2 (Table 3) i.e., the density curve of rainfall has either positive or
Fig. 4(a). Seasonal rainfall against time (year) along with 5 year moving average for Alipore

Fig. 4(b). Seasonal rainfall against time (year) along with 5 year moving average for Dumdum
Fig. 4(c). Seasonal rainfall against time (year) along with 5 year moving average for Midnapore

Fig. 4(d). Seasonal rainfall against time (year) along with 5 year moving average for Purulia
negative excess, which indicates that the density curve of the observed rainfall has either more sharp or less sharp peak than the normal density curve. So, the seasonal rainfall for fifteen stations have a distribution close to normal. It is slightly below 2 in case of Krishnanagar. The value is close to 6 in case of Digha, a sea-coast station. So, the seasonal rainfall distribution over various years has a sharp peak in case of Digha.

But, as ‘K’ lies outside the specified range in majority of cases, so the distribution of the seasonal rainfall is either flattened or sharply peaked as indicated by the Kurtosis Statistics. However, the existence of flat or peaked distribution does not create, as such, any serious problem in the present analysis. However, it cannot be mathematically proved that the coefficient of Kurtosis (K) really gives a measure of peakedness of the density curve. In practice, examples can be found where ‘K’ does not reflect the actual situation, though such examples are rare (Gupta, 2008).

4.5. Time Series Analysis, ANOVA and Confidence interval

The graphs of the actual values of the seasonal monsoon rainfall against time (year) [Figs. 4(a-d)] reveal that the relationship between them is likely to be non-linear. But the application of the technique of ANOVA in the study of relationship between the time (year) and the seasonal monsoon rainfall in Purulia, Dumdum, Alipore and Midnapore [Table 4(a)] shows that there is no such relationship (either linear or non-linear) between them.

### Table 4(a)

ANOVA for testing the relationship between seasonal rainfall and time

| Station | Source  | Degrees of Freedom | Sum of Squares | Mean Squares | F(Obs) | F(5%)  | F(1%)  | Remarks |
|---------|---------|--------------------|----------------|--------------|--------|--------|--------|---------|
| Alipore | Between | 29                 | 686674.00      | 23678.41     | 0.9048 | 1.600  | 1.945  | Fail    |
|         | Within  | 90                 | 2355186.00     | 26168.73     | 0.7430 | 1.595  | 1.936  | Fail    |
| Dumdum | Between | 30                 | 621582.00      | 20719.40     | 1.0558 | 1.605  | 1.954  | Fail    |
|         | Within  | 93                 | 2593157.00     | 27883.41     | 0.7339 | 1.595  | 1.936  | Fail    |
| Midnapore | Between | 28               | 629741.00      | 22490.75     | 1.0557 | 1.605  | 1.954  | Fail    |
|         | Within  | 87                 | 1853293.00     | 21302.22     | 0.7430 | 1.595  | 1.936  | Fail    |
| Purulia | Between | 30                 | 410458.00      | 13681.93     | 0.7339 | 1.595  | 1.936  | Fail    |
|         | Within  | 93                 | 1733749.00     | 18642.46     |        |        |        |         |

### Table 4(b)

Confidence interval for mean seasonal rainfall and standard deviation

| Station | 95% Confidence Interval for | Lower (mm) | Upper (mm) | Range (mm) |
|---------|-----------------------------|------------|------------|------------|
| Alipore | Mean                        | 1196.4493  | 1387.3776  | 190.9282   |
|         | Standard deviation          | 245.1002   | 413.7227   | 168.6225   |
| Dumdum  | Mean                        | 1239.6394  | 1415.3347  | 175.6953   |
|         | Standard deviation          | 233.1930   | 393.6236   | 160.4306   |
| Midnapore | Mean                       | 1144.7705  | 1334.0295  | 189.2590   |
|         | Standard deviation          | 234.7192   | 396.1998   | 161.4806   |
| Purulia | Mean                        | 1049.8942  | 1192.6671  | 142.7729   |
|         | Standard deviation          | 189.4967   | 319.8654   | 130.3687   |
From the diagrams [Figs. 4(a-d)] of trend fitted by the method of moving averages to the data of seasonal monsoon rainfall, the trend appears to be non-linear.

Finally, a comparison of the lengths of 95% confidence intervals [Table 4(b)] for mean rainfall and standard deviation, for the above mentioned four stations suggests that the best interval has been obtained for Purulia, though the lengths of the respective confidence intervals for the other stations are not very poor. In this respect, it is worth mentioning that the length of the interval can be used as an inverse measure of precision of the interval estimate; of the two confidence intervals, the one having the smaller length is obviously preferable (Gupta, 2008).

5. Conclusion

The foot-hill and high-hill stations of SHWB have much higher seasonal rainfall compared to plain land stations of SHWB and those of GWB. When compared between foot-hill and high-hill stations of SHWB, the foot-hill stations have higher seasonal rainfall. Krishnanagar has the lowest seasonal rainfall among the stations of SHWB and GWB.

Maximum daily rainfall is found to occur at Kuchbihar and it is also significantly high at the two plain land stations of SHWB. The same is much less over the stations of GWB. Among the stations of the state, Krishnanagar has minimum value of maximum daily rainfall. The region towards the head Bay of Bengal is quite different from land area over GWB, from the standpoint of monsoonal precipitation.

The average rainfall per day as well as per rainy day in addition to no. of rainy days, which are important for agriculture land, is very high at the foot-hill stations, compared to all other stations of the state. When we consider individual days of rain, only the two foot hill stations have significant number of extreme heavy (> 250 mm) as well as very heavy rainfall days.

The ANOVA reveals that there exists neither linear nor non-linear relationship between time (in year) and monsoon seasonal rainfall. Not only that, from trend analysis one can conclude that irregular fluctuations are present in the time-series of monsoon seasonal rainfall in the stations being considered, which are either wholly unaccountable or may be caused by some unforeseen events.

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