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Statistical analysis of monsoon rainfall distribution over West Bengal, India

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सार – पश्चिमी बंगाल में भारत मौसम विज्ञान विभाग के 23 केन्द्रों के वर्षा के आँकड़ों का उपयोग करते हुए उप हिमालयी पश्चिमी बंगाल (एस. एच. डब्ल्यू. बी.) और गांगेय पश्चिमी बंगाल (जी. डब्ल्यू. बी.) के मौसम विज्ञानिक उपखंडों के मौसमी, मासिक और दैनिक वर्षा के लक्षणों का अध्ययन किया गया है। दो उपखंडों के लक्षण विशिष्ट रहे जबकि उप हिमालयी पश्चिमी बंगाल के मैदानी क्षेत्र के दो केन्द्रों के लक्षण गांगेय पश्चिमी बंगाल के केन्द्रों के समान रहे। समूचे राज्य में कृष्ण नगर स्टेशन में सबसे कम मौसम वर्षा हुई। मौसमी वर्षा वितरण के कुरटोसिस और स्क्यूनेस का अध्ययन किया गया अैर यह पता चला कि अधिकांश केन्द्रों में वर्षा यथोचित सीमा के अंदर हुई। समय श्रृंखला विश्लेषण से यह पता चला है कि कोई प्रवृति नही है।

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.

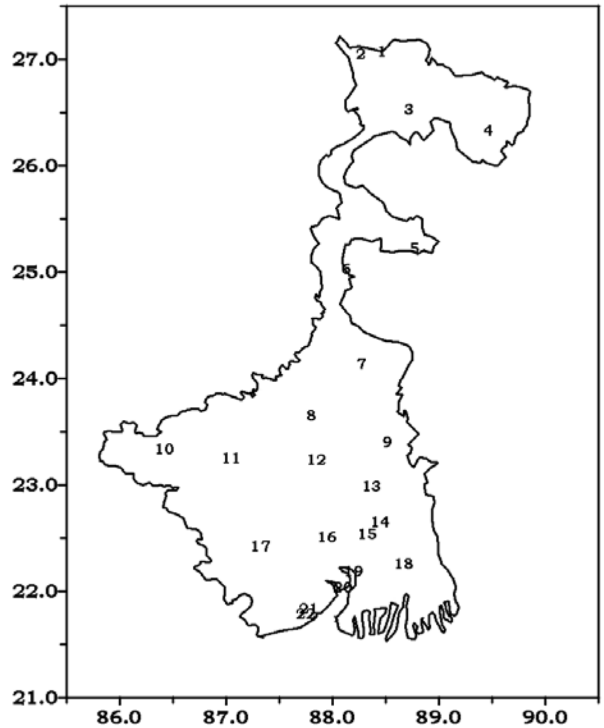
Key words – Kurtosis, Skewness, Time series analysis, ANOVA.

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



STATION NAME	INDEX	LAT	LON
KALIMPONG	1	27.07	88.47
DARJEELING	2	27.05	88.27
JALPAIGURI	3	26.53	88.72
KUCHBIHAR	4	26.33	89.47
BALURGHAT	5	25.22	88.78
MALDAH	6	25.03	88.13
BEHRAMPORE	7	24.13	88.27
SRINIKETAN	8	23.65	87.80
KRISHNANAGAR	9	23.40	88.52
PURULIA	10	23.33	86.42
BANKURA	11	23.25	87.05
BURDWAN	12	23.23	87.85
BAGATI	13	22.98	88.37
DUMDUM	14	22.65	88.45
ALIPORE	15	22.53	88.33
ULUBERIA	16	22.50	87.95
MIDNAPORE	17	22.42	87.32
CANNING	18	22.25	88.67
DIAMONDHARBOUR	19	22.18	88.20
HALDIA	20	22.03	88.10
DIGHA	21	21.83	87.78
CONTAI	22	21.78	87.75
SAGAR ISLAND	23	21.75	88.05

Fig. 1. Map of West Bengal with station locations

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

TABLE 1

Seasonal rainfall characteristics over different stations

Division	Station Name	Number of years of rainfall	Average number of rainy (days/ Season)	Mean seasonal Rainfall (mm)	Standard deviation of seasonal rainfall (mm)	Max. Seasonal Rainfall (Year)	Min. Seasonal Rainfall (Year)
SHWB	Balurghat	20	50	1230.7	323.59	1980	1986
	Darjeeling	11	82	2070.4	268.68	1971	1994
	Jalpaiguri	15	75	2853.2	618.36	1998	1971
	Kalimpong	11	64	1936.8	605.51	1984	1980
	Kuchbihar	22	72	2837.9	563.97	1988	1979
	Maldah	26	53	1206.3	422.04	1987	1972
GWB	Alipore	30	60	1292.2	302.80	1984	1982
	Bagati	27	54	1175.3	295.52	1999	1982
	Bankura	18	53	1130.0	271.08	1987	1976
	Berhampore	20	54	1206.0	255.21	1971	1985
	Burdwan	7	54	1296.6	159.99	1971	1969
	Canning	17	62	1383.7	196.27	1999	1982
	Contai	18	50	1194.1	282.79	1993	1987
	Diamondharbour	15	57	1264.8	246.58	1984	2000
	Digha	17	51	1175.1	321.88	1993	1983
	Dumdum	31	61	1330.0	282.14	1978	1998
	Haldia	15	61	1414.1	204.88	1999	1998
	Krishnanagar	16	46	908.8	343.21	1970	1979
	Midnapore	29	57	1240.6	295.06	1993	1983
	Purulia	31	55	1121.6	230.09	1978	1982
	Sagar Island	25	53	1333.6	215.89	1973	1979
	Sriniketan	28	53	1159.7	275.58	1971	1982
	Uluberia	20	57	1316.1	323.90	1978	1979

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 Dumdum (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	:	≥ 2.5 and < 10
Moderate	:	≥ 10 and < 30
Rather heavy	:	≥ 30 and < 70
Heavy	:	≥ 70 and < 130
Very heavy	:	≥ 130 < 250
Extreme Heavy	:	≥ 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 $\overline{X}$ and S is the standard deviation.

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

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 $\overline{X}$ and S is again the standard deviation.

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

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*. SEK and SES have been calculated using the formulae (Tabachnick and Fidell, 1996):

SEK = $\sqrt{}$ 24/ N, SES = $\sqrt{}$ 6/N, where N is the number of population.

If $-2 \times SEK < K < 2 \times SEK$ and $-2 \times SES < g < 2 \times SES$, 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

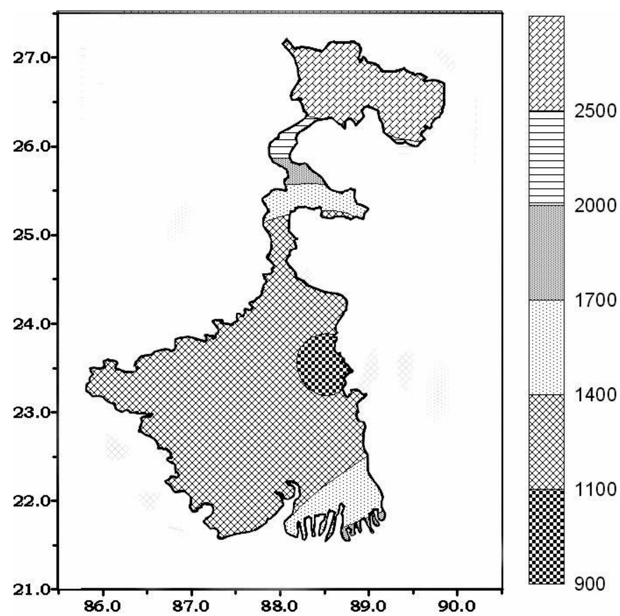


Fig. 2. Contour of monsoon seasonal rainfall over West Bengal

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. Dumdum 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 Dumdum 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

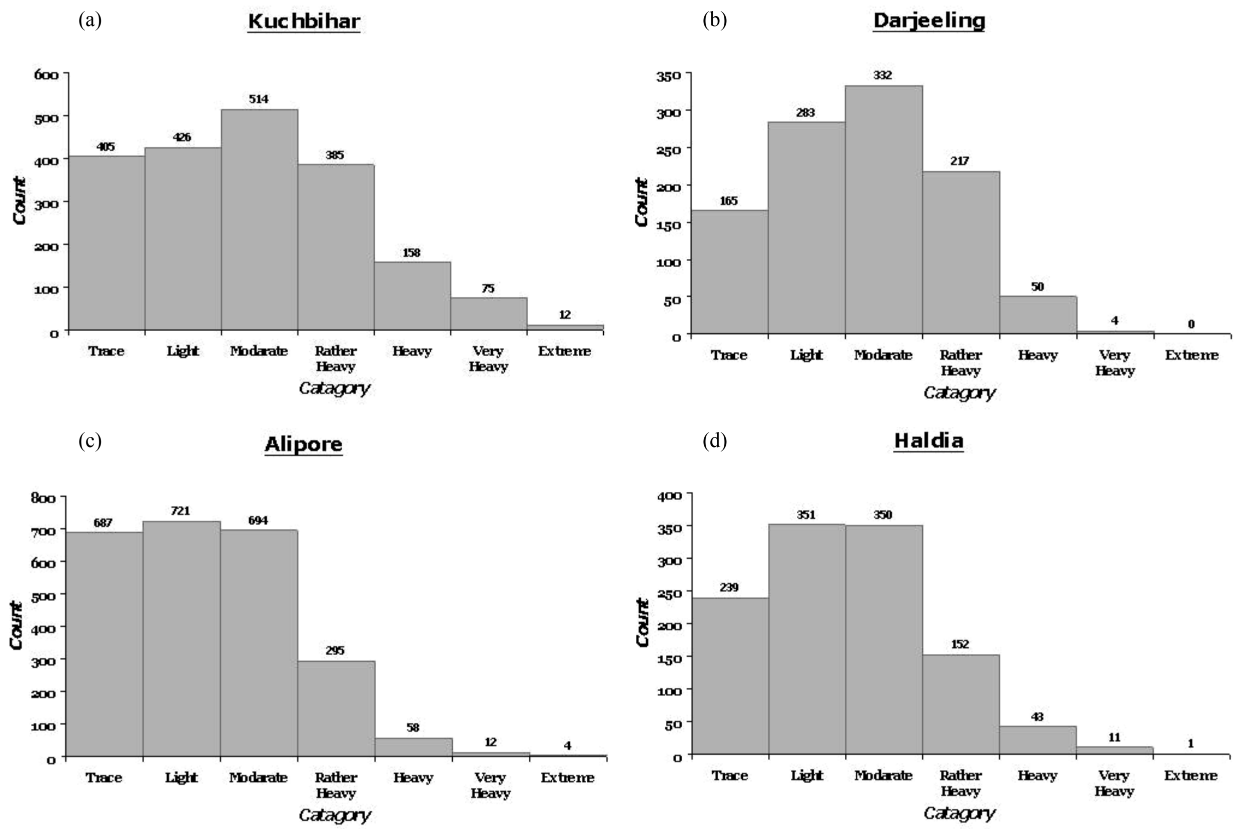
Daily rainfall at different stations

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 foot 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.



Figs. 3(a-d). Histogram of daily rainfall at (a) Kuchbihar, (b) Darjeeling, (c) Alipore and (d) Haldia

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
	Kalingpang	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
	Dumdum	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
	SagarIsland	25	0.00	±0.97980	significant	2.38	±1.95959	Not significant
	Sriniketan	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

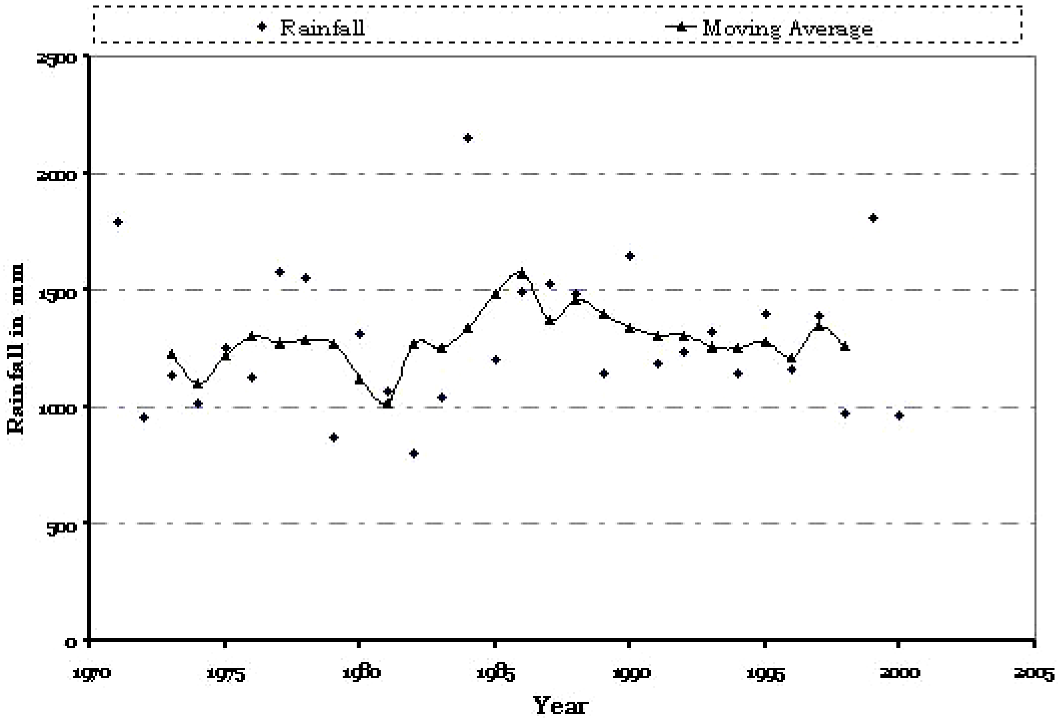


Fig. 4(a). Seasonal rainfall against time (year) along with 5 year moving average for Alipore

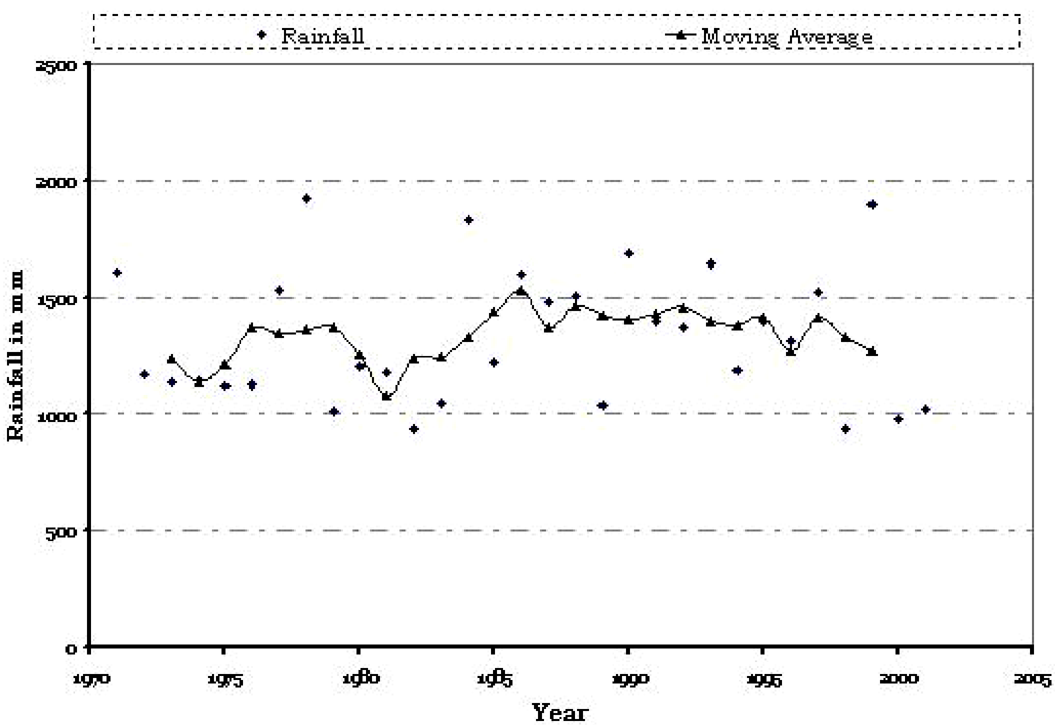


Fig. 4(b). Seasonal rainfall against time (year) along with 5 year moving average for Dumdum

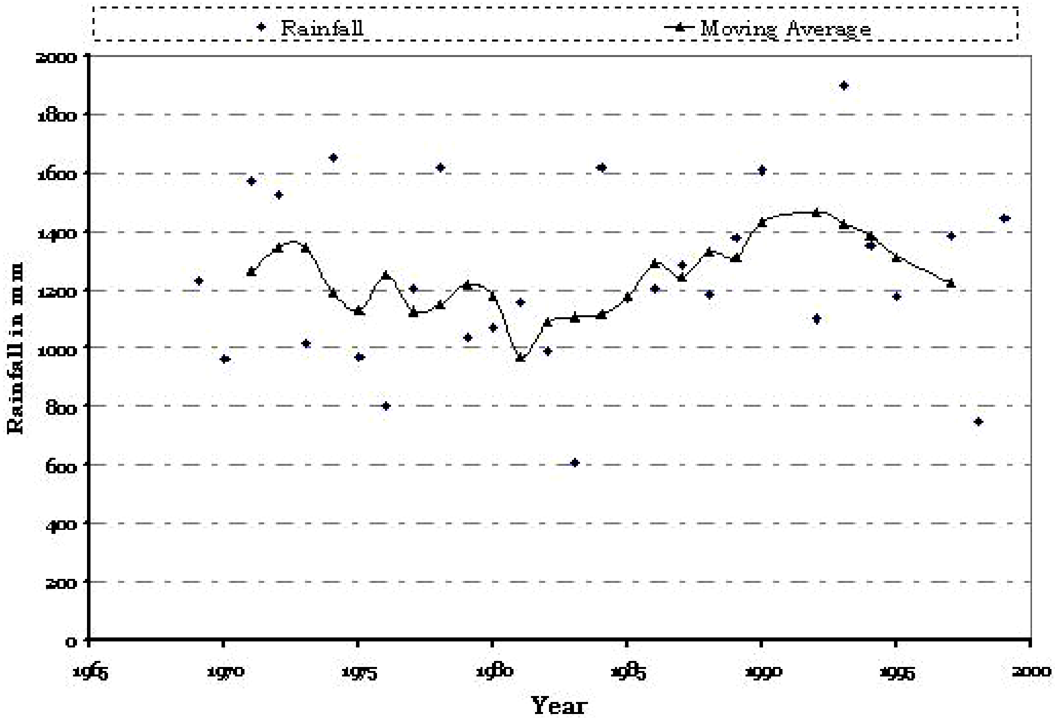


Fig. 4(c). Seasonal rainfall against time (year) along with 5 year moving average for Midnapore

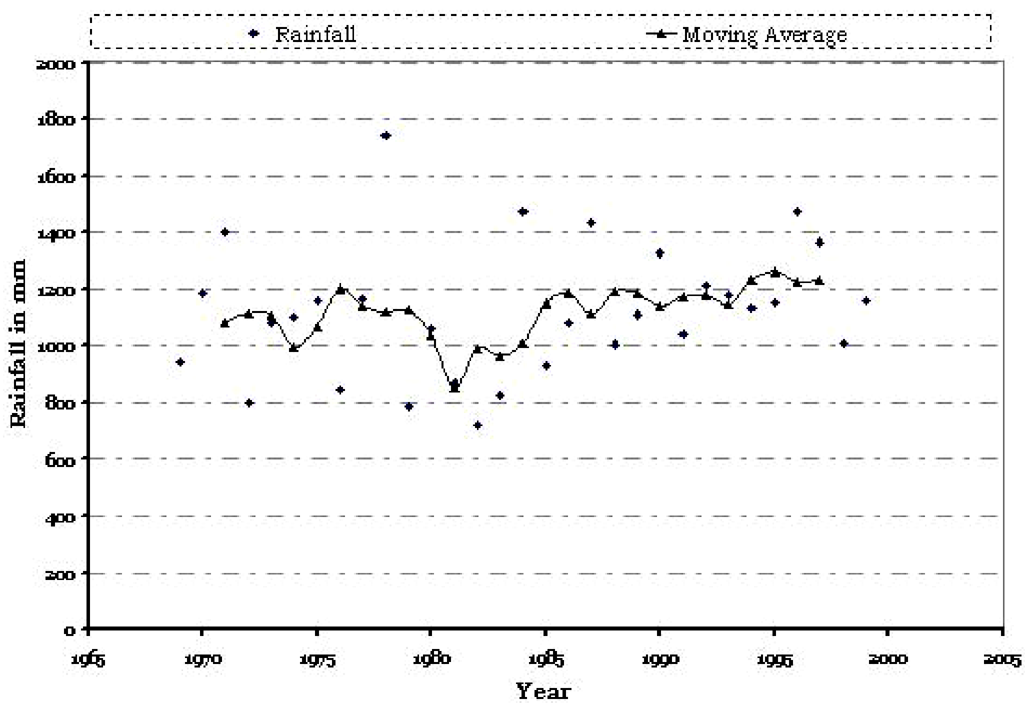


Fig. 4(d). Seasonal rainfall against time (year) along with 5 year moving average for Purulia

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	0.904836	1.600	1.945	Fail
	Within	90	2355186.00	26168.73				
Dumdum	Between	30	621582.00	20719.40	0.743073	1.595	1.936	Fail
	Within	93	2593157.00	27883.41				
Midnapore	Between	28	629741.00	22490.75	1.055794	1.605	1.954	Fail
	Within	87	1853293.00	21302.22				
Purulia	Between	30	410458.00	13681.93	0.733912	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

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.

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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