MAUSAM, **55**, 3 (July 2004), 409-418

551.577.3 : 551.553.21 (541.2)

Statistical analysis of rainfall distribution and trend of rainfall anomalies districtwise during monsoon period over West Bengal

G. C. BASU, U. BHATTACHARJEE and R. GHOSH

Regional Meteorological Centre, Kolkata - 700027, India

(*Received 16 May 2002, Modified 15 December 2003*)

सार – इस शोध–पत्र में पश्चिम बंगाल के विभिन्न जिलों की 68 वर्षों (1931 से 1998 तक) की मानसून वर्षा वितरण के साँख्यिकी विश्लेषण का अध्ययन किया गया है। प्रत्येक जिले में हुई ऐसी वर्षा के वितरण की प्रकृति को समझने के लिए वर्षा का संवेग उसके वैषम्य गुणांक और कर्टोसिस जैसे साँख्यिकी प्राचलों का आकलन किया गया है। लीस्ट स्केयर पद्धति के माध्यम से उपयुक्त समाश्रयण रेखाओं द्वारा दो मौसम वैज्ञानिक उपखंडों, पश्चिम बंगाल के उपहिमालय क्षेत्र और पश्चिम बंगाल के ही गांगेय क्षेत्र के प्रत्येक जिले की मानसून वर्षा (जून से सितम्बर) की असमानताओं का भी अध्ययन किया गया है तथा पश्चिम बंगाल के प्रत्येक जिले में हुई वर्षा की प्रवृत्तियो के परिणामों का इस शोध–पत्र में विवेचन किया गया है।

ABSTRACT. The statistical analysis of rainfall distributions in different districts of West Bengal during monsoon period for 68 years (1931-98) have been studied in this paper. The statistical parameters such as moments, coefficient of skewness and kurtosis have been computed to understand the nature of such rainfall distribution in each district. The rainfall anomalies during monsoon period (June–September) have also been studied for each district of two meteorological Sub-divisions, Sub-Himalayan West Bengal (SHWB) and Gangetic West Bengal (GWB) by fitting regression lines through 'Least Square Method' and results for rainfall trends for each district of West Bengal have been discussed in this paper.

Key words – Moments, Skewness, Kurtosis, Rainfall anomalies, Rainfall trends.

1. Introduction

Frequent floods occur in some districts of West Bengal in almost every year. These floods are due to heavy downpour (rain-spells) in some parts or other during monsoon season. Moreover, the geographical position and geomorphic character of this region are also responsible to aggravate the flood situation in West Bengal. Almost 80% of annual rainfall in West Bengal occurs during monsoon season. Hence, the extensive study of rainfall during monsoon period over West Bengal is essential.

Basu (2001) in his earlier paper studied the monsoon rainfall variability over West Bengal for each monsoon month. The monsoon rainfall distribution and it variability over Damodar Valley Catchment has also been discussed by Basu (1981). Biswas and Gupta (1993) have studied the monsoon rainfall variability over West Bengal in respect of different positions of the monsoon trough. Lakshmanaswamy and Jindal (1990) have examined the variability of area weighted annual and monsoon rainfall for 35 met. sub-divisions of India with a view to find any increase or decrease trends of rainfall over India by dividing 88 period (1901–1988) into three sub-periods of 30, 30 and 28 years. Jagannathan and Parthasarthy (1973) have studied the trend and periodicity of monsoon rainfall from June to September in India. Bhargava (2002) has studied the statistical parameters of skewness and kurtosis of wind distributions characteristic for 57 stations over India during monsoon period.

In this paper, statistical parameters of monsoon rainfall for all the districts of West Bengal have been found out to study the nature of asymmetry and peakedness by computing coefficient of skewness and kurtosis respectively. Districtwise trend of rainfall anomaly during monsoon period have also been studied in this paper with comparison of such rainfall anomaly patterns in two met. sub-divisions, namely, Gangetic West Bengal (GWB) and Sub Himalayan West Bengal (SHWB).

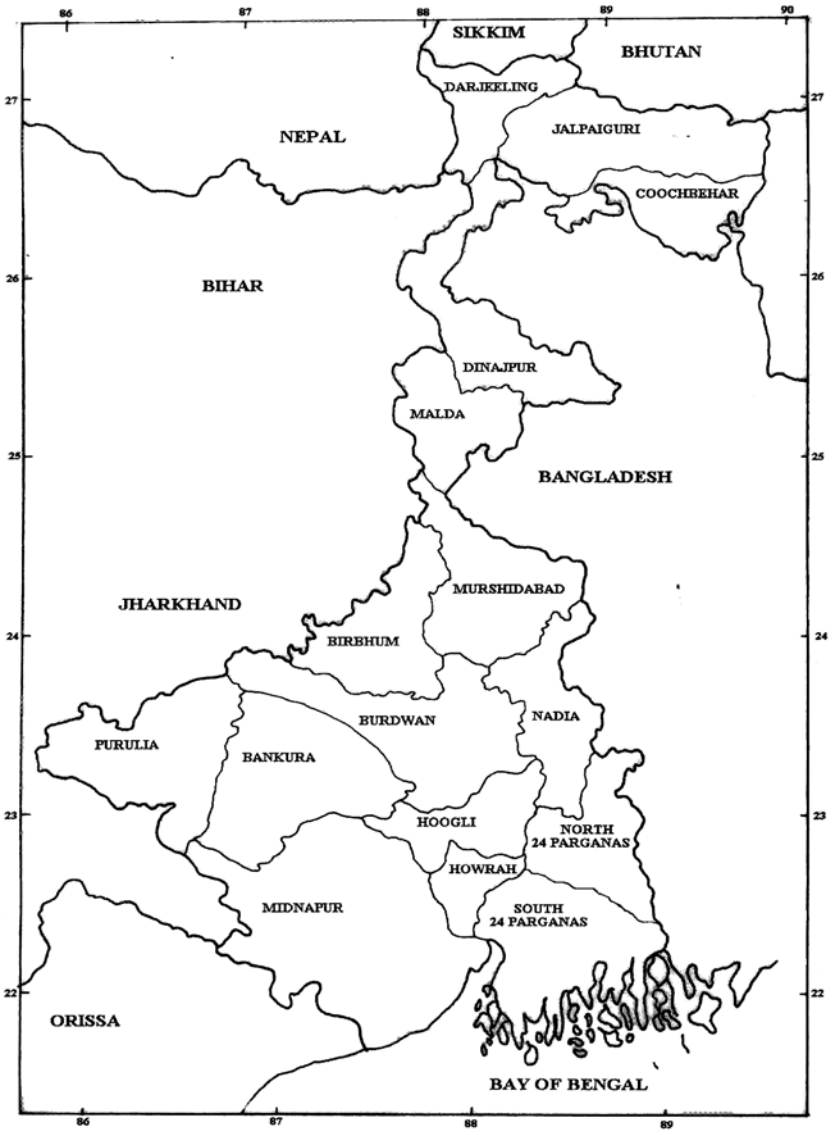


Fig. 1. District wise map of two met. sub-division of West Bengal

2. Data uses and processing

Rainfall data for monsoon period (June to September) of 69 stations in West Bengal from 1931 to 1998, so far available, have been collected from IMD, Pune and RMC, Kolkata. Statistical moments and trend of monsoon rainfall anomaly for 16 districts of two met. Sub-divisions (5 numbers of SHWB and 11 numbers of GWB) of West Bengal have been found out. The location of all the 16 districts of West Bengal are shown in Fig. 1.

3. Methodology

In the fundamental theory of the measure of statistical moments by following Spiegel (1972), the departure from symmetry of rainfall distribution and its degree of peakedness during monsoon period for all districts of West Bengal have been calculated by computing moments, coefficient of skewness and kurtosis. The trends of monsoon rainfall anomalies districtwise over West Bengal have been calculated by fitting 'Least

square method' and adopted the procedure for analysis of time series of the rainfall data, as suggested by Croxton, *et al*. (1979).

3.1. *Asymmetry of rainfall distribution*

The moment of co-efficient of Skewness (g_1) for rainfall distribution for number of years is given by

$$g_1 = \frac{m_3}{s^3}$$

where, m_3 is the third moment of variable '*X*' about the mean 'M' and 's' is the standard deviation.

$$m_3 = \frac{1}{N}\sum_{i=1}^{N}(X_i - M)^3$$

and,

$$s = \sqrt{\frac{\sum_{i=1}^{N}(X_i - M)^2}{N}}$$

when, g_1 is positive (positively skew), the longer tail of the distribution is towards right and, g_1 is negative (negatively skew), the longer tail of the distribution is towards left.

3.2. *Measure of peakedness of rainfall distribution*

Kurtosis is the measure of the degree of peakedness of rainfall distribution for number of years and the moment of co-efficient of kurtosis is given by

$$g_2 = \frac{m_4}{s^4}$$

where, 'm_4' is the 4^{th} moment of variable '*X*' about the mean 'M' and 's' is the standard deviation.

$$m_4 = \frac{1}{N}\sum_{i=1}^{N}(X_i - M)^4$$

when,

g_2 = 3, the distribution is mesokurtic (normal)

> 3, the distribution is more peaked, *i.e*., sharp (leptokurtic)

< 3, the distribution is less peaked, *i.e*., flattened (platykurtic).

3.3. *Trend of rainfall*

The trend of monsoon rainfall anomaly for 68 years (1931–98) for different districts of West Bengal are fitted by a regression line, as discussed by Basu and Basu (2001) and is given by,

$$Y_c = l + mX_i$$

Where, X_i corresponds to the *i*-th year of which the trend value of rainfall (Y_c) for each year is to be determined; 'l' and 'm' are constants to be evaluated by 'least square method',

$$l = \frac{\sum Y_i}{N}$$

and,

$$m = \frac{\sum X_i Y_i}{\sum X_i^2}$$

The analysis of rainfall anomaly during monsoon period for all the districts of West Bengal have been done by fitting regression lines by considering mid year (1964- 65) as origin with X_i unit half year.

4. Result and discussion

4.1. *Statistical moments of co-efficient of skewness and kurtosis*

The mean, standard deviation, coefficients of skewness and kurtosis of monthly rainfall for the months of June, July, August and September and monsoon rainfall (June to September) for all the districts are given in Tables 1 to 5. The coefficients of skewness and kurtosis are tested and found that if the coefficient of skewness is between ± 0.6 and kurtosis is between 2 and 4, then the rainfall distribution is normal.

TABLE 1

Statistical moments of rainfall in different districts of West Bengal during the month of June

District	Mean rainfall	Standard deviation	Skewness	Kurtosis
		Met. sub-division : SHWB		
Darjeeling	513.17	166.292	0.391	3.032
Jalpaiguri	713.92	238.731	0.337	3.191
Coochbehar	692.04	225.100	-0.024	2.495
Dinajpur	297.06	145.852	0.953	3.394
Malda	231.19	119.700	0.718	3.299
		Met. sub-division : GWB		
Murshidabad	226.11	100.334	0.781	3.723
Birbhum	213.64	86.183	0.898	3.395
Burdwan	209.69	96.749	1.480	8.975
Nadia	245.22	140.942	2.552	14.464
Purulia	206.55	120.700	2.385	13.417
Bankura	220.55	118.877	2.671	16.971
Hoogli	272.54	149.835	1.387	5.532
N. 24 Parganas	274.15	125.152	1.262	4.961
Midnapur	253.87	112.460	0.601	2.832
Howrah	274.15	132.770	0.966	4.188
S. 24 Parganas	271.63	120.598	1.053	4.647

TABLE 2

Statistical moments of rainfall in different districts of West Bengal during the month of July

District	Mean rainfall	Standard deviation	Skewness	Kurtosis
		Met. sub-division : SHWB		
Darjeeling	751.55	190.169	-0.221	2.537
Jalpaiguri	856.30	311.876	0.651	2.952
Coochbehar	744.67	277.605	0.303	2.468
Dinajpur	354.75	110.264	0.386	3.099
Malda	340.47	135.261	0.744	3.219
		Met. sub-division : GWB		
Murshidabad	315.54	128.662	0.707	3.205
Birbhum	303.94	97.198	0.393	2.694
Burdwan	302.82	108.899	0.949	4.084
Nadia	260.10	134.030	1.175	4.680
Purulia	299.32	98.354	0.357	3.101
Bankura	315.25	132.955	2.148	9.750
Hoogli	306.11	105.195	0.114	2.846
N. 24 Parganas	335.01	123.900	0.457	2.694
Midnapur	315.05	93.203	0.239	3.113
Howrah	340.74	133.138	0.787	4.421
S. 24 Parganas	349.29	103.406	0.231	3.041

TABLE 3

Statistical moments of rainfall in different districts of West Bengal during the month of August

District	Mean rainfall	Standard deviation	Skewness	Kurtosis
		Met. sub-division : SHWB		
Darjeeling	583.73	209.795	-0.090	3.420
Jalpaiguri	655.17	271.379	1.200	4.253
Coochbehar	537.19	260.253	1.248	5.404
Dinajpur	295.52	121.839	1.147	6.400
Malda	318.18	156.811	1.527	5.691
		Met. sub-division : GWB		
Murshidabad	280.05	108.177	0.786	3.234
Birbhum	320.23	119.281	0.576	3.251
Burdwan	302.01	101.894	0.824	4.300
Nadia	268.74	118.966	1.029	4.621
Purulia	308.59	94.075	0.470	2.329
Bankura	323.21	140.788	1.760	6.935
Hoogli	308.32	121.513	0.790	3.203
N. 24 Parganas	332.25	120.133	1.043	3.316
Midnapur	332.47	106.973	0.802	3.726
Howrah	358.82	148.857	0.764	3.334
S. 24 Parganas	356.97	110.721	0.687	3.238

TABLE 4

Statistical moments of rainfall in different districts of West Bengal during the month of September

District	Mean rainfall	Standard deviation	Skewness	Kurtosis
		Met. sub-division : SHWB		
Darjeeling	447.46	162.871	0.906	4.000
Jalpaiguri	542.99	230.628	0.734	4.192
Coochbehar	488.96	230.470	0.768	3.160
Dinajpur	298.90	138.349	0.758	3.908
Malda	266.88	129.889	1.067	3.952
		Met. sub-division : GWB		
Murshidabad	235.99	104.236	0.897	4.073
Birbhum	239.10	119.858	1.736	8.361
Burdwan	225.66	105.232	1.249	4.958
Nadia	193.92	107.282	1.340	5.630
Purulia	247.34	115.422	1.085	4.438
Bankura	231.91	111.237	1.120	4.623
Hoogli	236.49	123.586	1.588	6.868
N. 24 Parganas	267.99	133.624	1.888	7.539
Midnapur	285.75	123.626	0.992	3.459
Howrah	269.82	143.527	1.467	5.966
S. 24 Parganas	306.38	126.556	1.224	4.650

TABLE 5

Statistical moments of rainfall in different districts of West Bengal during the Monsoon Period (June – September)

District	Mean rainfall	Standard deviation	Skewness	Kurtosis
		Met. sub-division : SHWB		
Darjeeling	2303.25	406.298	0.087	2.830
Jalpaiguri	2768.37	526.037	0.473	3.266
Coochbehar	2460.25	518.425	0.411	2.613
Dinajpur	1241.46	272.485	0.446	2.502
Malda	1156.72	319.124	0.593	4.065
		Met. sub-division : GWB		
Murshidabad	1068.06	214.408	0.103	2.219
Birbhum	1086.86	242.826	0.642	3.064
Burdwan	1037.64	203.466	0.488	3.468
Nadia	989.21	300.369	0.757	3.786
Purulia	1056.72	211.584	0.442	2.906
Bankura	1065.75	274.686	1.805	8.306
Hoogli	1073.38	323.352	-0.091	3.289
N. 24 Parganas	1212.71	266.420	0.376	2.365
Midnapur	1187.14	220.826	0.510	3.195
Howrah	1142.59	377.149	-0.632	3.349
S. 24 Parganas	1284.28	225.257	0.512	2.984

It is observed from Tables 1 to 4, in the SHWB, the coefficients of skewness and kurtosis are significant for most of the districts in the months of August and September. In these districts, the monthly rainfall distribution is either positively skewed or leptokurtic type or both. This means that heavy rainfall cases have high frequency in the months of August and September.

In GWB, the coefficients of skewness and kurtosis are significant for more districts in June as compared to July and August. During September all the districts have significant coefficients.

The monsoon rainfall distribution is almost normal in all the districts in SHWB whereas, for the districts of Birbhum, Nadia and Bankura of GWB, it is positively skewed and for Bankura district it is more peaked.

4.2. *Trends of monsoon rainfall anomalies*

4.2.1. *Met sub-division SHWB*

The trends of rainfall anomalies (Y_c) in each of the five districts in this sub-division namely, Coochbehar, Dinajpur, Jalpaiguri, Malda and Darjeeling during monsoon period for 68 years (1931-98) are fitted by regression lines [Figs. 2(a-e)] and equations of such lines are given below.

$Y_c = 6.639\,X - 229.04$ for Coochbehar

$Y_c = 0.464\,X - 16.03$ for Dinajpur

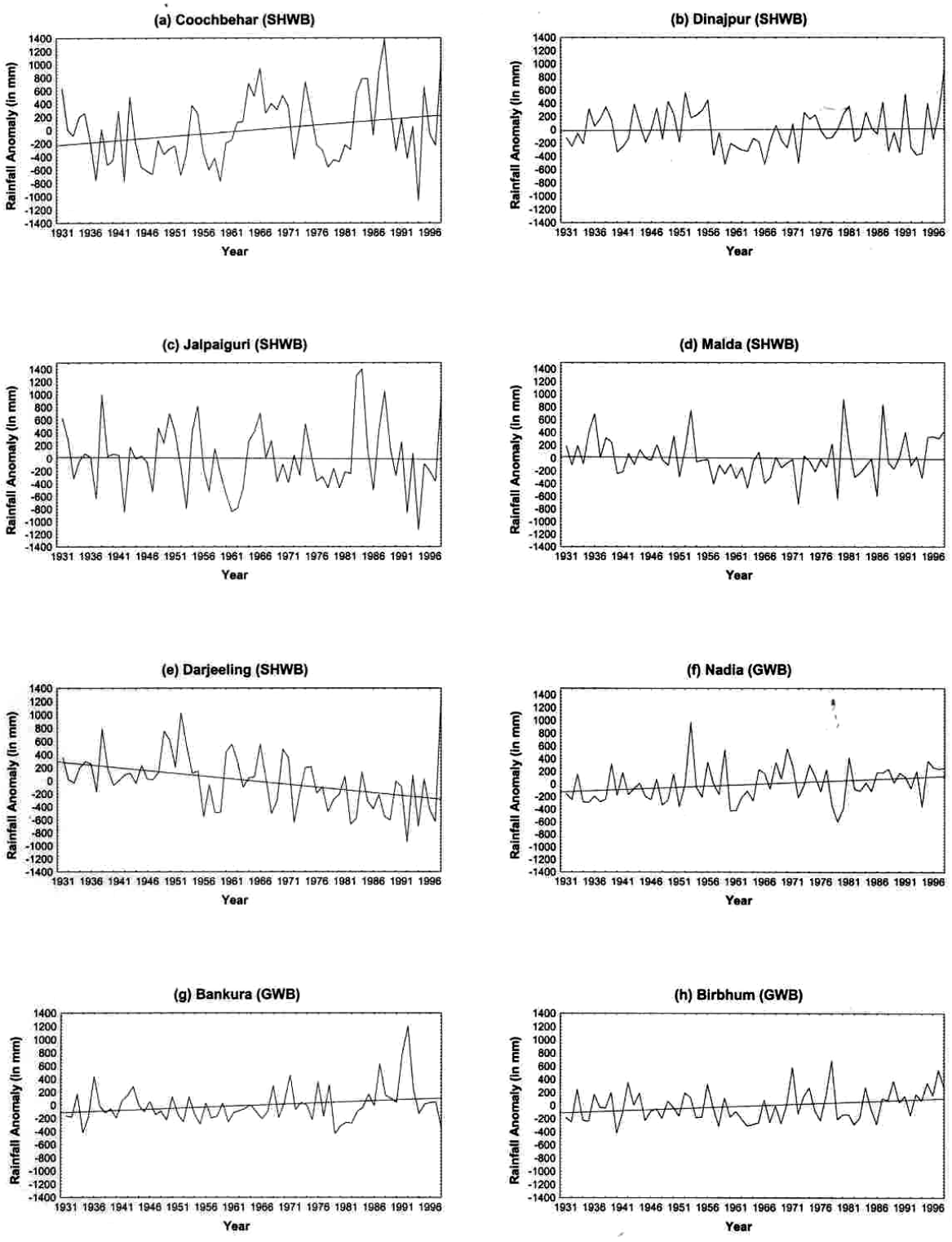
$Y_c = -0.546\,X + 18.84$ for Jalpaiguri

$Y_c = -0.642\,X - 22.15$ for Malda

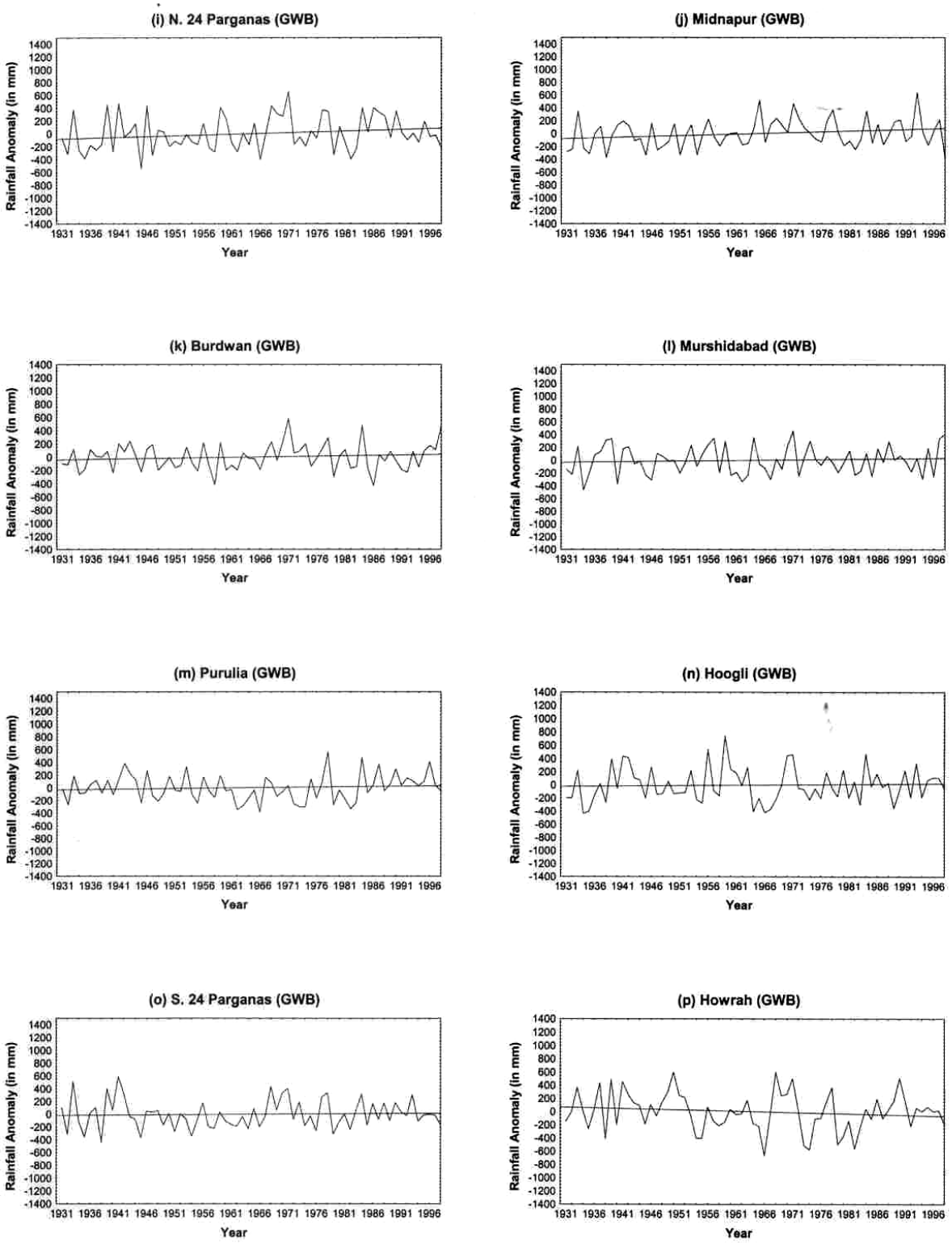
$Y_c = -8.455\,X - 291.69$ for Darjeeling

Origin of each trend line is 1964-65, X units half-year.

It is found from the slopes of above trends of monsoon rainfall anomalies of SHWB that the rainfall trends are increasing higher in the district of Coochbehar (6.639) and comparatively less increasing in the district of Dinajpur (0.464). However, the same trends are



Figs. 2(a-h). Trend of monsoon rainfall anomalies in different districts of two met. Sub-divisions of West Bengal



Figs. 2(i-p) (Contd.). Trend of monsoon rainfall anomalies in different districts of two met. Sub-divisions of West Bengal

decreasing maximum in the district of Darjeeling (–8.455) and comparatively less decreasing in the districts of Malda (– 0.642) and Jalpaiguri (– 0.546).

By the trend analysis of monsoon rainfall anomalies in SHWB, it signifies that those anomalies are greater in later half period (*i.e.*, after 1965) in the districts of Coochbehar and Jalpaiguri [Figs. 2(a-c)] while those are less accordingly in the districts of Malda, Darjeeling and Dinajpur [Figs. 2d, 2e & 2b].

4.2.2. *Met sub-division GWB*

The trends of rainfall anomalies (Y_c) in each of the eleven districts in this sub-division namely, Nadia, Bankura, Birbhum, North 24 Parganas, Midnapur, Burdwan, Murshidabad, Purulia, Hoogli, South 24 Parganas and Howrah, during monsoon period for 68 years are fitted by regression lines [Figs. 2f to 2p] and equations of such lines are given below.

$Y_c = 3.624\ X - 125.04$ for Nadia

$Y_c = 3.321\ X - 114.59$ for Bankura

$Y_c = 3.286\ X - 113.36$ for Birbhum

$Y_c = 2.448\ X - 84.45$ for North 24 Parganas

$Y_c = 2.333\ X - 80.51$ for Midnapur

$Y_c = 1.183\ X - 40.81$ for Burdwan

$Y_c = 0.900\ X - 31.05$ for Murshidabad

$Y_c = 0.898\ X - 30.98$ for Purulia

$Y_c = 0.667\ X - 23.02$ for Hoogli

$Y_c = 0.504\ X - 17.38$ for South 24 Parganas

$Y_c = -2.016\ X - 69.56$ for Howrah

Origin of each trend line is 1964-65, X units half-year.

It is found from the slopes of above trends of monsoon rainfall anomalies in all the districts of GWB that the rainfall trends are increasing in nature for all the districts in this sub-division except in the district of Howrah (–2.016), where it is decreasing. The increasing trends of rainfall are maximum in the district of Nadia (3.624) and that of minimum in the district of South 24 Parganas (0.504).

By the trend analysis of monsoon rainfall anomalies in GWB, it signifies that those anomalies are greater in the district of Bankura [Fig. 2(g)] in the later half period (*i.e*. after 1965) while those are the least in the district of South 24-Parganas [Fig. 2(o)].

5. Conclusive remarks

By the study of districtwise monsoon rainfall distribution and its trends of rainfall anomalies in two met. sub-divisions (SHWB and GWB) of West Bengal, the following salient features are revealed.

(*i*) The coefficients of skewness and kurtosis are significant (positively skewed and leptokurtic) for most of the districts in the months of August and September in SHWB. In GWB, the coefficients are significant for most of the districts in June and for all the districts in September. High values of coefficient of skewness and kurtosis shows heavy rainfall cases have high frequency.

(*ii*) The monsoon seasonal rainfall is normal for all the districts of SHWB and in GWB, it is normal for most of the districts except Bankura, Birbhum and Nadia.

(*iii*) The highest trend of monsoon rainfall anomalies of increasing nature is noticed in the district of Coochbehar, whereas the same anomalies of decreasing nature is noticed in the district of Darjeeling in the sub-division SHWB. But, the trend of monsoon rainfall anomalies in all the districts of the sub-division GWB are almost of increasing nature, except in the district of Howrah, where the trend is of decreasing nature. The maximum increasing trend of the rainfall anomalies is noticed in the district of Nadia in this sub-division. The main significance of study of trend for rainfall anomalies during monsoon season over West Bengal is to find out the nature of variation of monsoon rainfall district-wise and sub-division-wise for long period.

By the analysis of skewness and kurtosis and the trends of rainfall anomalies during monsoon period for all districts of West Bengal state, a clear picture regarding the nature of monsoon rainfall distribution and its future trends, district-wise, sub-division-wise and month wise are revealed. The method as mentioned in this paper may be applied to study the nature of monsoon rainfall for other states also by following similar procedure.

Acknowledgements

Authors would like to express their sincere thanks to Shri R. N. Goldar, D.D.G.M., Regional Meteorological Centre, Kolkata for pursuing the study and encouragement

in this work. Special gratitude is rendered to Late S. K. Ghosh, AM-II for his valuable contributions in processing data. Thanks are also due to Shri R. N. Halder, S.A. for compilation of data, and Shri D. Roy, Draftsman for drawing diagram.

References

Basu, G. C., 2001, "A feature of monsoon rainfall and its variability with comparative study in meteorological sub-divisions of West Bengal", *Mausam*, **52**, 4, 736-746.

Basu, G. C., 1981, "A study of monsoon rainfall and its variability over Damodar Valley Catchment area", *Vayu Mandal*, **11**, 3&4, 52-54.

Basu, G. C. and Basu, S. K., 2001, "A probabilistic study of monsoon daily rainfall at Calcutta by Markovian model and trend of rainfall during monsoon season", *Mausam*, **52**, 2, 371-378.

Bhargava, P. K., 2002, "Estimation of monsoon wind characteristics in India", *Mausam*, **53**, 1, 19-30.

Biswas, B. and Gupta, K., 1993, "Variability of southwest monsoon rainfall over West Bengal", *Mausam*, **44**, 4, 353-358.

Croxton, F. E., Cowden, D. J. and Klein, S., 1979, "Applied General Statistics", 3rd ed., Prentice Hall India Pvt. Ltd. New Delhi, **12**, 229-248.

Jagannathan, P. and Parthasarathi, B., 1973, "Trends and periodicities of rainfall over India", *Mon.Weath.Rev*., **101**, 4, 371-375.

Lakshmanaswamy, B. and Jindal, O. P., 1990, "Statistical analysis on the variability of area weighted rainfall over India", *Mausam*, **41**, 4, 569- 574.

Spiegel, M. R., 1972, "Schaum's Outline of Theory and Problems of Statistics", McGraw Hill Book Co., UK, **5**, 89-98.