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## A FEATURE OF MONSOON RAINFALL AND ITS VARIABILITY WITH COMPARATIVE STUDY IN METEOROLOGICAL SUB-DIVISIONS OF WEST BENGAL

1. West Bengal state gets about 80% of annual rainfall during monsoon season on which crop production of this state is mainly dependant on it. Moreover, excess rainfall sometimes cause catastrophic flood in some parts of the state due to overflow of river banks. Thus, to simulate excess or deficit of rainwater, the nature of variation of monsoon rainfall of this state for different districts are required to be studied. This state is meteorologically divided into two sub-divisions. One is Sub-Himalayan West Bengal (SHWB) in the north and the other one is Gangetic West Bengal (GWB) in the south.

Basu (1981) in his earlier paper has studied monsoon rainfall distribution and its variability over Damodar Valley Catchment area for different monsoon months and for the monsoon period as a whole, Ramasastri *et al.* (1988) have studied rainfall characteristics in Belgaum district of Karnataka through statistical analysis. Jagannathan and Parthasarthy (1973) have studied the rainfall oscillation and its periodicity in India during monsoon season (June-September). Biswas and Gupta (1993) have studied the variability of monsoon rainfall over West Bengal in relation to the different positions of the monsoon trough (over West Bengal) during July to September. Suresh (1996) has studied the variability of seasonal and inter-annual rainfall in nine meteorological sub-divisions of peninsular region of India. Das (1968) has suggested that the study of the coefficient of variation of monsoon rainfall of different regions can help to decide in which parts of India the long range prediction would be useful.

In this paper, district-wise average rainfall and the coefficient of variation of such rainfall in different monsoon months and the total monsoon period as a whole over West Bengal have been studied and analysed. A comparative study of rainfall distribution in two meteorological sub-divisions of West Bengal, *viz.* SHWB and GWB have been undertaken here. The existence of uniformity or otherwise in rainfall amongst different stations in each districts of West Bengal for different monsoon months have been calculated in this paper by statistical method.

2. West Bengal state is bounded by Bangladesh in eastern side, Assam and Sikkim in northern side, Bihar and Orissa in Western side and in its south is the Bay of Bengal.

The northern part of met. sub-division SHWB is bounded by the hills of Himalayan ranges which play an important role in rainfall distribution/activities in pre-monsoon and south-west monsoon seasons. An ample quantity of rainfall are received in south-west monsoon season in this region than any other season. The SHWB has got five districts, namely, Darjeeling, Jalpaiguri, Coochbehar, Dinajpur and Malda. The slopping of the above districts are generally north to south. Floods are very common in some districts of this region almost every monsoon year. The frequent flood in the districts of SHWB are due to overflow of river banks – Teesta, Mathabhanga, Bhagirathi etc. for their geographical positions and geomorphic character of the region.

In met. sub-division GWB, the northern parts are combination of hilly and plain areas, whereas the southern part areas are mainly plain lands. The GWB has got eleven districts, namely Murshidabad, Birbhum, Nadia, Purulia, Bankura, Burdwan, Hooghli, Howrah, Midnapur, North 24 Parganas and South 24 Parganas. Amongst them three districts namely Midnapur, North 24 Parganas and South 24 Parganas are the coastal districts of West Bengal. Flash floods occur in coastal districts of GWB due to excessive rainfall and overflow of water from river Ganga, and its tributaries.

3. Rainfall data, so far available, during monsoon period (June to September) from 1931 to 1998 of 69 stations in West Bengal (21 numbers in SHWB and 48 numbers in GWB) have been collected from India Meteorological Department, Pune and Regional Meteorological Centre, Calcutta.

Statistical parameters like average rainfall and coefficient of variation of rainfall for each of the monsoon months and the total monsoon period for all the districts in two met. Sub-divisions (SHWB and GWB) have been calculated by computer.

4.1. *Analysis of monsoon rainfall* - The coefficient of variation (in percent) of rainfall for all the stations in West Bengal (Fig.1) have been calculated by the formula

$$CV = (S/A) \times 100$$

where, *S* is the standard deviation and *A* is the average rainfall.

The average rainfall (*A*) and coefficient of variation (*CV*) for all stations and for all monsoon months are plotted on maps. Iso-pleths of such values are drawn on maps to analyse and to locate the region of high and low values. A comparative study of monsoon rainfall in two met. sub- divisions has been done.



Fig. 1. Stations considered in different districts of West Bengal for rainfall variability study during monsoon period

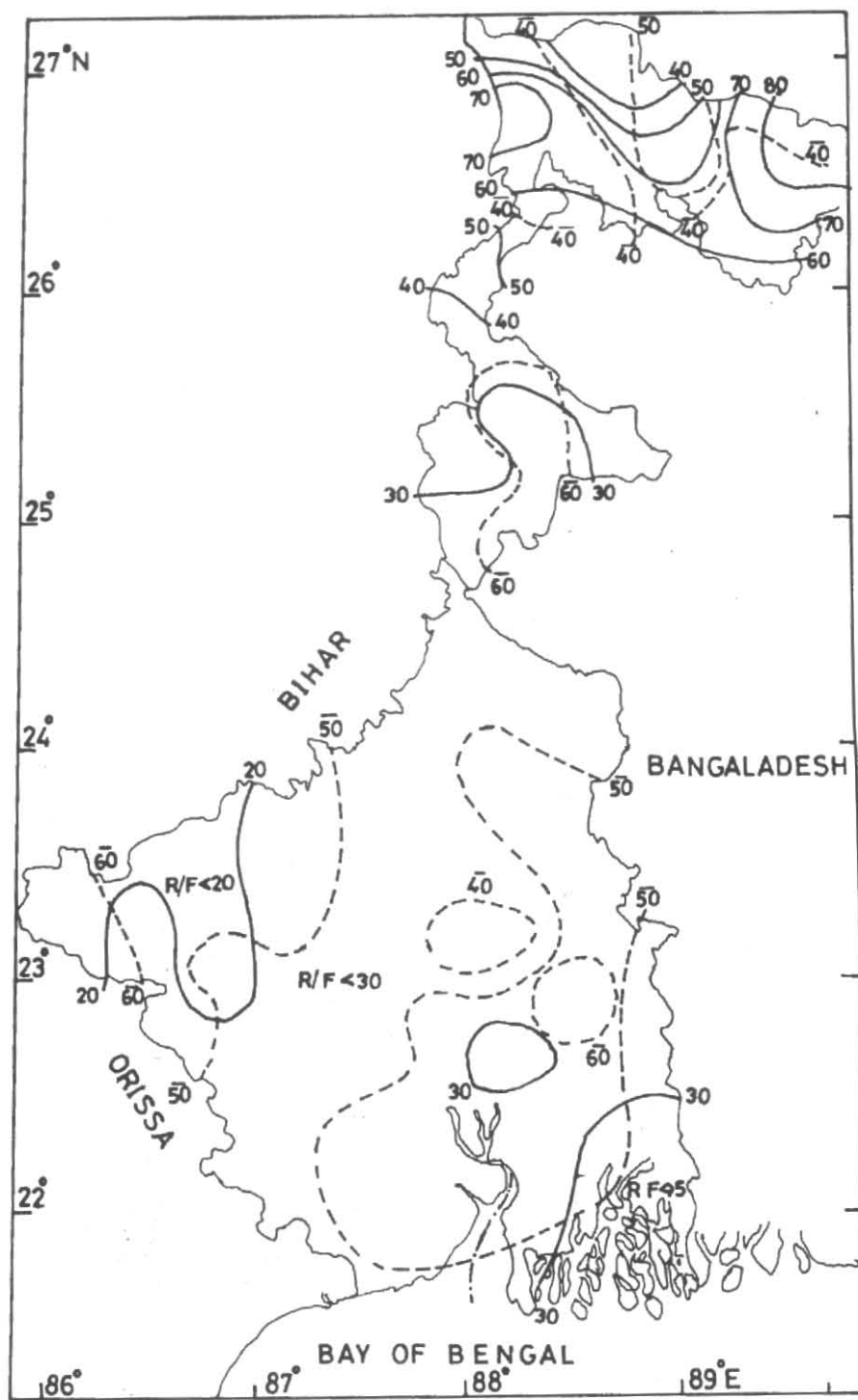


Fig. 2. Isopleths of average rainfall in cm (solid lines) and co-efficient of variation in percent (dash lines) during the month of June in West Bengal

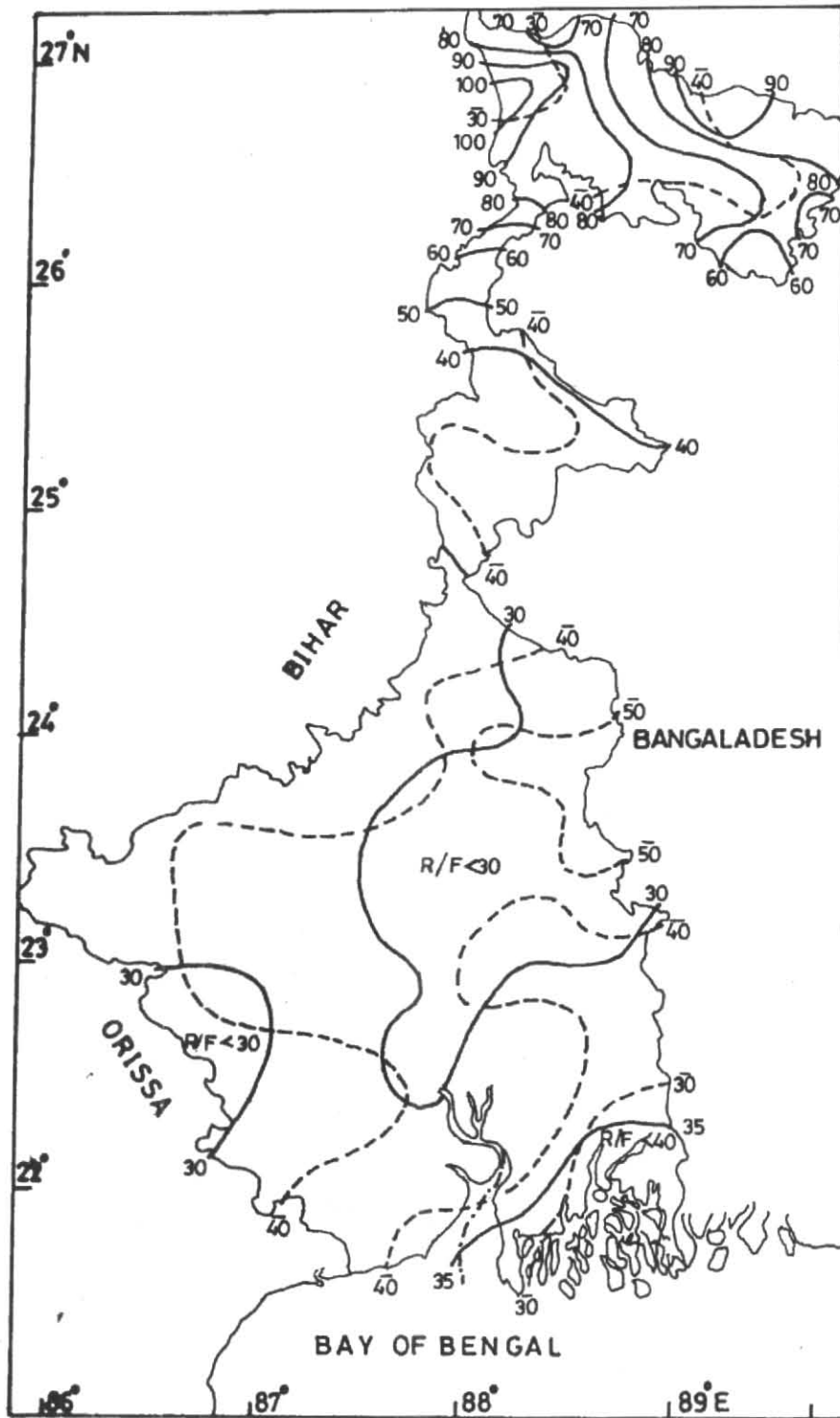


Fig. 3. Isopleths of average rainfall in cm (solid lines) and co-efficient of variation in percent (dash lines) during the month of July in West Bengal

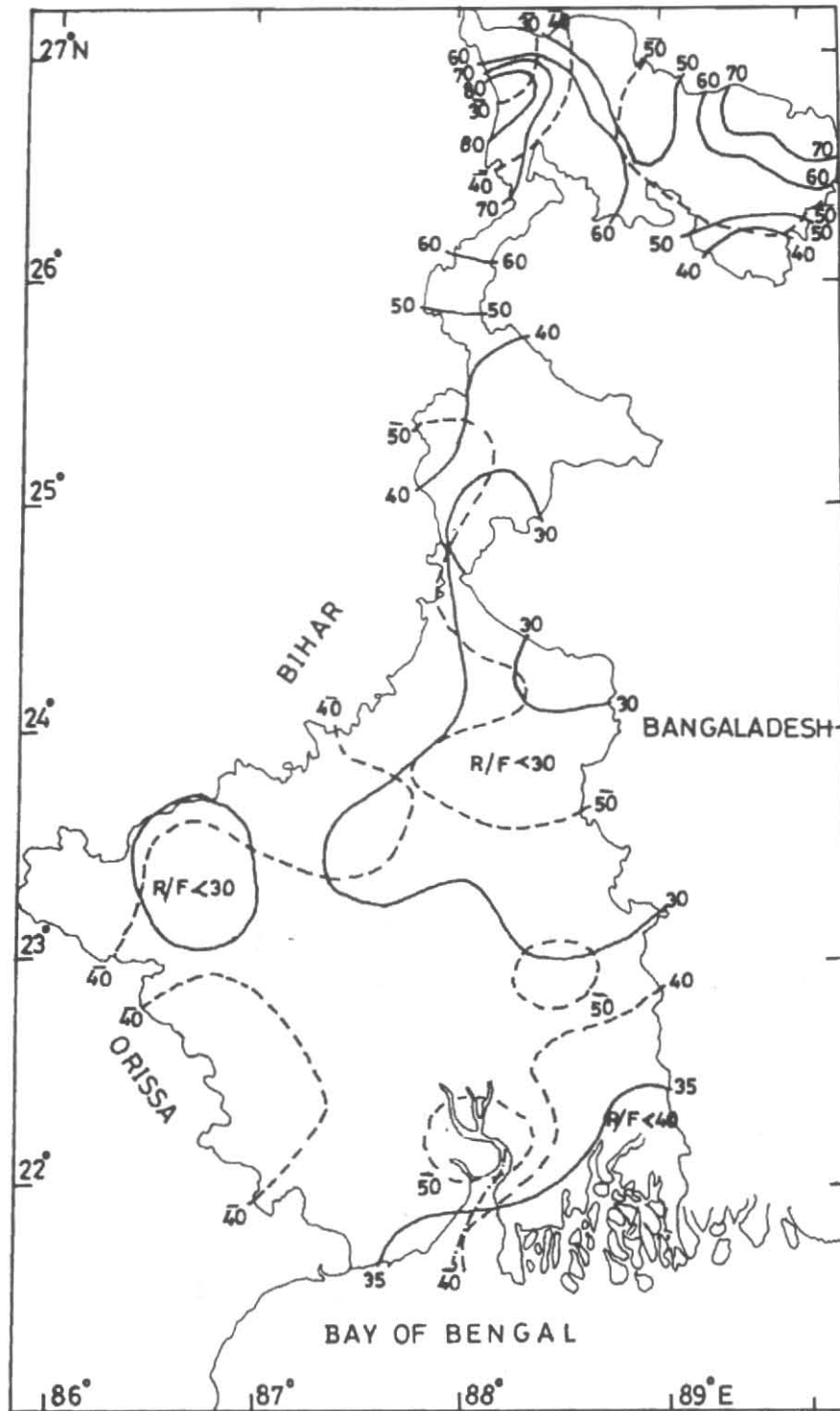


Fig. 4. Isopleths of average rainfall in cm (solid lines) and co-efficient of variation in percent (dash lines) during the month of August in West Bengal

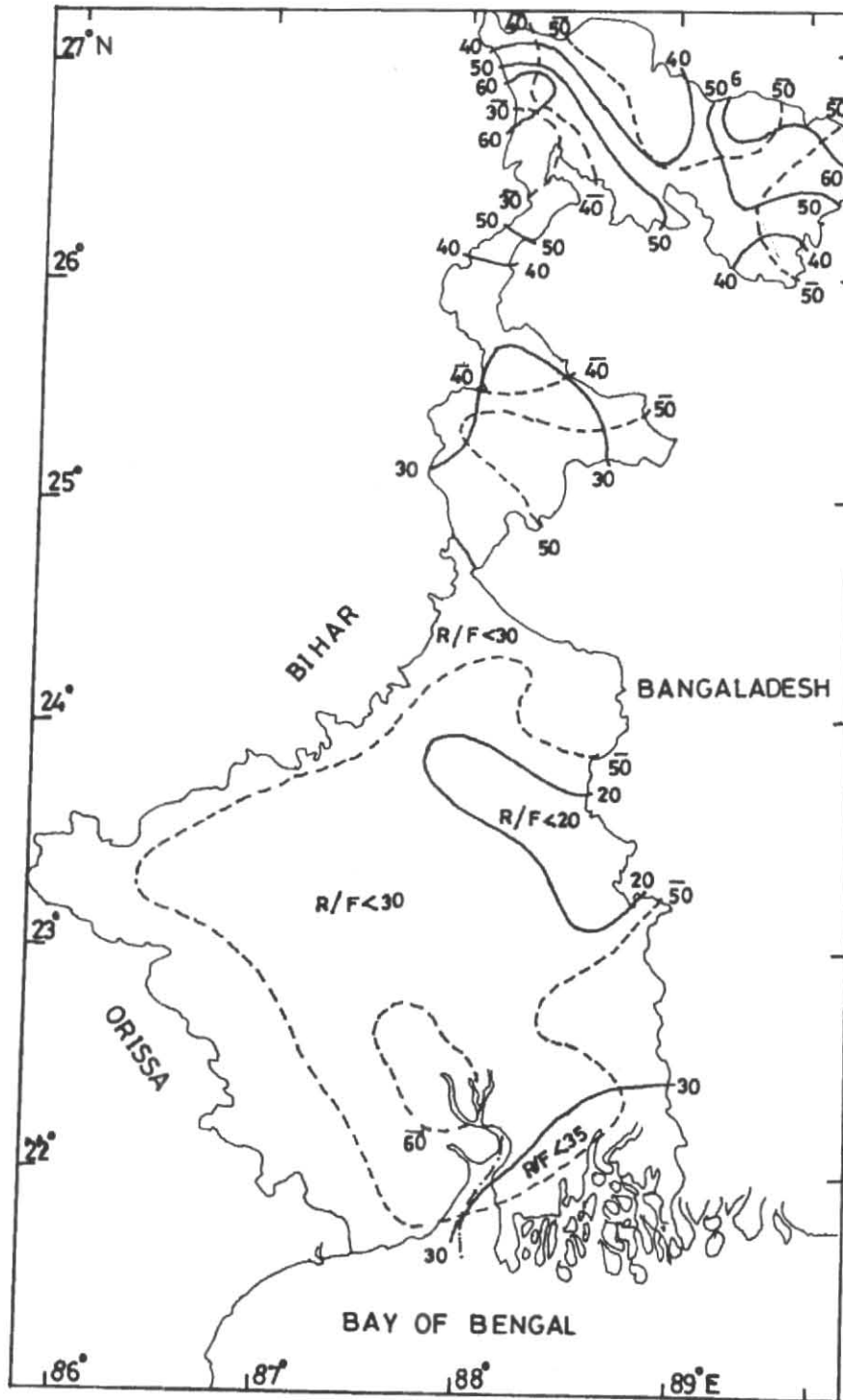


Fig. 5. Isopleths of average rainfall in cm (solid lines) and co-efficient of variation in percent (dash lines) during the month of September in West Bengal

4.2. *L-test for uniformity in rainfall variability of stations in each district* - To know whether uniformity exists between several values of standard deviations ( $S^2$ 's) of different stations in each districts of West Bengal, the criterion of *L-test* is required as suggested by Croxton and Cowden (1979) and is given by

$$L = \frac{n \sqrt{(S_1^2)^{n_1} \times (S_2^2)^{n_2} \times \dots \times (S_i^2)^{n_i} \times \dots \times (S_k^2)^{n_k}}}{\frac{1}{n} (n_1 S_1^2 + n_2 S_2^2 + \dots + n_i S_i^2 + \dots + n_k S_k^2)}$$

Where  $S_i$  is the standard deviation of rainfall of  $i$ -th station;  $n_i$  is the number of years of available data of the  $i$ -th station;  $k$  is the number of stations in a district; and

$$n = \sum_{i=1}^k n_i$$

Thus *L-test* is the ratio of the geometric mean ( $G$ ) of  $S_i^2$ 's to the arithmetic mean ( $M$ ) of  $S_i^2$ 's. The more divergent in the values of  $S_i^2$ 's amongst different stations, the greater the difference between  $G$  and  $M$ .

When all  $S_i^2$ 's are same,  $L=1.0$ , the uniformity is maximum and  $L=0$  represents a condition of maximum non-uniformity, i.e.  $0 < L < 1$ .

5.1. *Average rainfall and coefficient of variation in SHWB in monsoon months* - In June, average rainfall varies between 80 and 30 cm. The maximum average rainfall occurs between 70 and 80 cm in the western part of Darjeeling district and the eastern part of Jalpaiguri district. The minimum average rainfall occurs around 30 cm in the southern part of Dinajpur and Malda districts. Thus, the average rainfall decreases from north to south in this met. sub-division as shown in Fig. 2. The coefficients of variation of rainfall during this month vary between 30% and 60% and values of the same increase in reverse order in this met. sub-division.

In July, average rainfall varies between 100 and 40 cm. The maximum average rainfall occurs between 90 and 100 cm in the west of Darjeeling and northeast of Jalpaiguri districts, whereas minimum of the same occurs around 40 cm in the south of Dinajpur and Malda districts. The order of decrease of the average rainfall from north to south is also maintained in this month like previous month in this met. sub-division, as shown in Fig.3. The coefficients of variation of rainfall vary between 30% to 40% during this month.

In August, average rainfall varies between 90 and 30 cm. The maximum average rainfall occurs between 80 and 90 cm in the west of Darjeeling district, whereas the minimum occurs between 30 and 40 cm in the south of Dinajpur and Malda districts in the met. sub-division, as shown in Fig.4. The coefficients of variation of rainfall vary between 30% and 50% in this sub-division.

In September, average rainfall varies between 60 and 30 cm. The maximum average rainfall occurs between 50 and 60 cm in the western part of Darjeeling district and eastern part of Jalpaiguri district, while the minimum occurs around 30 cm in the south of Dinajpur and Malda districts in this sub-division, as shown in Fig. 5. The coefficients of variation vary between 30% and 50% in the met. sub-division like previous month.

5.2. *Average rainfall and coefficient of variation in GWB in monsoon months (Table 1)* - In June, average rainfall varies between 30 and 20 cm. The maximum average rainfall around 30 cm occurs in the southeastern part in the sub-division, i.e. eastern part of South 24 Parganas, southern part of North 24 Parganas, northeast of Howrah and south of Hooghli districts, whereas, minimum rainfall within 20 cm occurs in Purulia district, as shown in Fig. 2. It is seen that the rainfall is less in northwestern part than the southeastern part in the met. sub-division as the monsoon progress gradually. The coefficient of variation of rainfall vary between 40% and 60% in this sub-division.

In July, average rainfall varies between 35 and 30 cm. The maximum average rainfall around 35 cm occurs in extreme southeast part of South 24 Parganas, south of North 24 Parganas and west of Purulia districts, while the minimum rainfall within 30 cm occur in northeastern parts of the met. sub-division, i.e. east of Burdwan and Nadia districts, also southwest Bankura and northwest of Midnapur districts, as shown in Fig. 3. The coefficients of variation of rainfall vary between 30% and 50% in this sub-division.

In August, average rainfall varies between 35 and 25 cm. Large part in the north of the met. sub-division experience average rainfall within 30 cm, while the southern part gets rainfall above 30 cm, i.e. between 30 and 35 cm, as shown in Fig. 4. The coefficients of variation of rainfall vary between 30% and 50% in this sub-division.

In September, average rainfall varies between 30 and 20 cm in the large part of this sub-division. The maximum average rainfall above 30 cm but less than 35 cm are experienced in southeastern part of South 24 Parganas district in the met. sub-division, while the minimum

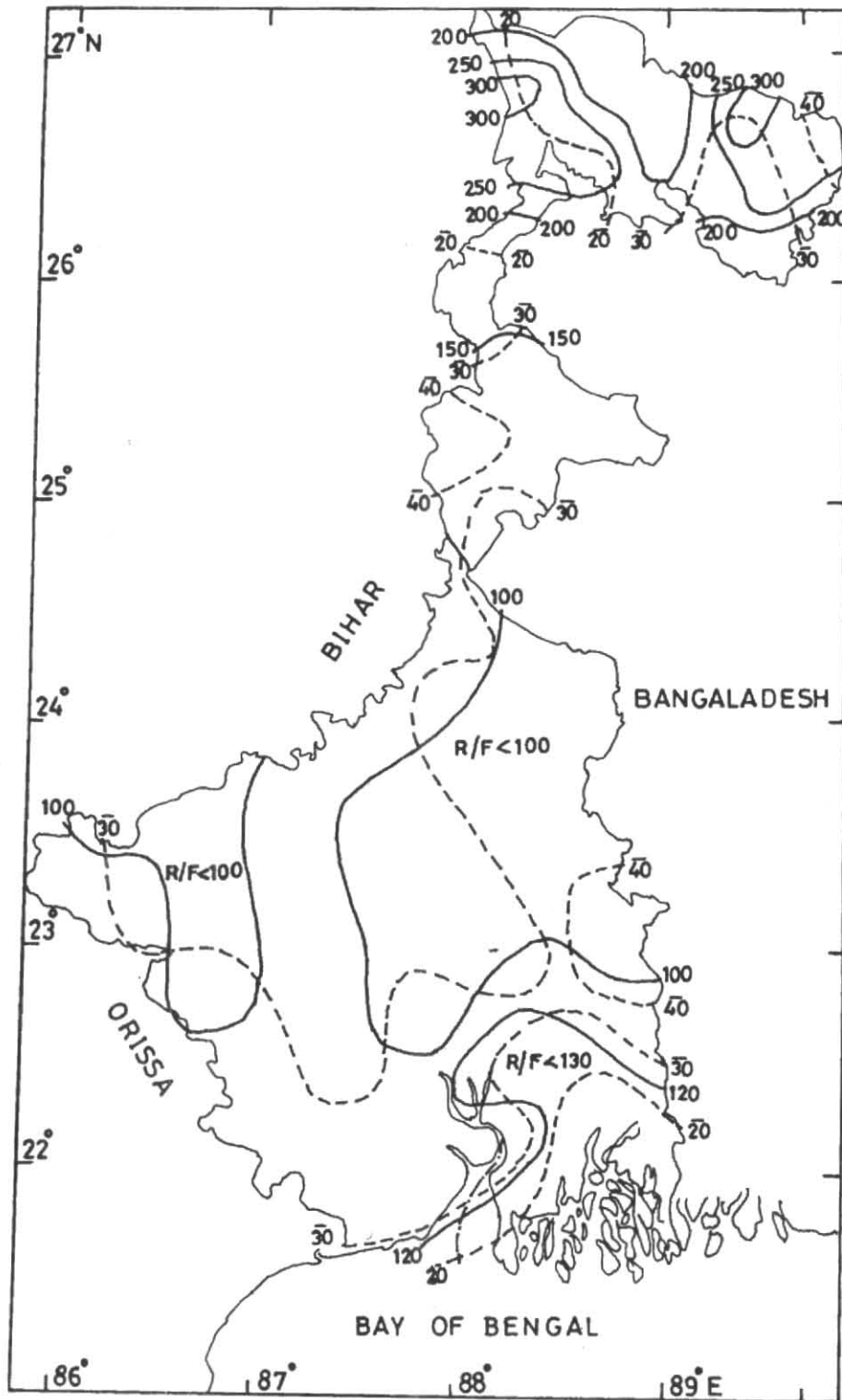


Fig. 6. Isopleths of average rainfall in cm (solid lines) and co-efficient of variation in percent (dash lines) during total monsoon period (June – September) in West Bengal



TABLE 1

Average and coefficient of variation of rainfall during monsoon months for different districts of West Bengal

S. No.	Districts	June		July		August		September		Monsoon	
		Average	C.V.	Average	C.V.	Average	C.V.	Average	C.V.	Average	C.V.
<b>Met Sub-division : Sub-Himalayan West Bengal</b>											
1	Darjeeling	513.2	32.4	751.5	25.3	583.7	35.9	447.5	36.4	2303.3	17.6
2	Jalpaiguri	713.9	33.4	856.3	36.4	655.2	41.4	543.0	42.5	2768.4	19.0
3	Coochbehar	692.0	32.5	699.3	39.7	492.2	52.9	462.0	49.9	2460.3	21.1
4	Dinajpur	297.1	49.1	354.7	31.1	295.5	41.2	298.9	46.3	1085.1	31.9
5	Malda	231.2	51.8	340.5	39.7	318.2	49.3	266.9	48.7	1156.7	27.6
<b>Met Sub-division : Gangetic West Bengal</b>											
1	Murshidabad	226.1	44.4	315.5	40.8	280.1	38.6	236.0	44.2	1068.1	20.1
2	Birbhum	207.8	41.5	300.5	32.3	334.9	35.6	237.1	50.5	983.6	26.9
3	Nadia	245.2	57.5	260.1	51.5	268.7	44.3	193.9	55.3	989.2	30.4
4	Bankura	209.9	57.5	294.5	45.1	314.5	44.8	229.2	48.5	1065.7	25.8
5	Purulia	206.5	58.4	299.3	32.9	308.6	30.5	247.3	46.7	1057.3	19.9
6	Burdwan	209.5	46.2	284.7	38.2	281.4	36.2	215.1	48.9	942.0	23.0
7	Hooghly	272.5	55.0	306.1	34.4	308.3	39.4	236.5	52.3	1129.1	24.0
8	Howrah	274.1	48.4	340.7	39.1	358.8	41.5	269.8	53.2	1142.6	33.0
9	Midnapore	253.9	44.3	315.1	29.6	332.5	32.2	285.7	43.3	1187.1	18.6
10	South 24 Parganas	271.6	44.4	349.3	29.6	357.0	31.0	306.4	41.3	1284.3	17.5
11	North 24 Parganas	274.1	45.7	335.0	37.0	332.3	36.2	268.0	50.0	1204.5	22.7

within 20 cm occurs in the Nadia district, as shown in Fig. 5. The coefficients of variation of rainfall vary between 50% and 60% in this met. sub-division.

6. *Total monsoon rainfall distribution and the coefficient of variation of rainfall in met. sub-divisions* - In met. sub-division SHWB, the maximum average rainfall during monsoon period is around 300 cm in the extreme western part of Darjeeling and eastern part of Jalpaiguri districts. The average rainfall ranging between 200 and 250 cm occurs in the south and northwest part of Darjeeling and north Coochbehar districts. The average rainfall ranging from 150 to 200 cm occurs in the northern part of Dinajpur, northeastern part of Darjeeling, west of Jalpaiguri and southern part of Coochbehar districts. The minimum average rainfall occur below 150 cm, i.e. between 100 and 150 cm occurs in the southern part of

Dinajpur and Malda districts. It is seen from the above that the monsoon rainfall is gradually decreasing from north to south in this region, as shown in Fig. 6. The coefficients of variation of rainfall vary between 20% and 40% in this sub-division.

In met. sub-division GWB, the maximum average rainfall between 120 and 140 cm occurs in South 24 Parganas district during monsoon period. The average rainfall between 100 and 120 cm occurs in the southern parts of both Midnapur and North 24 Parganas districts. The average rainfall around 100 cm occurs in all northern parts of North 24 Parganas, Hooghly and Midnapur districts, Bankura and Purulia districts and west of Birbhum district. The minimum average rainfall below 100 cm, i.e. between 80 and 100 cm occurs in Murshidabad, Nadia, Burdwan and east of Birbhum

TABLE 2  
District-wise L-test value of rainfall in West Bengal during monsoon months

S.No.	Districts	No. of stations	June	July	August	September
<b>Met Sub-division : Sub-Himalayan West Bengal</b>						
1	Darjeeling	4	0.922	0.943	0.875	0.867
2	Jalpaiguri	7	0.893	0.900	0.955	0.923
3	Coochbehar	4	0.992	0.976	0.956	0.977
4	Dinajpur	4	0.915	0.940	0.993	0.939
5	Malda	3	0.981	0.975	0.937	0.972
<b>Met Sub-division : Gangetic West Bengal</b>						
1	Murshidabad	5	0.816	0.958	0.931	0.983
2	Birbhum	4	0.966	0.971	0.946	0.987
3	Nadia	3	0.921	0.886	0.962	0.916
4	Bankura	3	0.912	0.957	0.979	0.970
5	Purulia	6	0.950	0.977	0.942	0.975
6	Burdwan	5	0.957	0.973	0.966	0.995
7	Hooghly	4	0.923	0.893	0.969	0.942
8	Howrah	2	0.987	0.998	0.984	0.875
9	Midnapur	7	0.970	0.960	0.968	0.931
10	South 24 Parganas	5	0.980	0.983	0.950	0.973
11	North 24 Parganas	4	0.958	0.989	0.973	0.954

districts in the sub-division, as shown in Fig. 6. The coefficients of variation of rainfall vary between 20% and 40%. The variations around 30% cover wide area in this met. sub-division.

7. By comparative study from Figs. 2 to 6, it reveals that the highest average rainfall range during all the monsoon months and the total monsoon period as a whole is double in the met. sub-division SHWB than that of the met. sub-division GWB, while the lowest range of the same is slightly greater in SHWB than that of the GWB. But, there is no such remarkable changes in the coefficients of variation of rainfall in two met. sub-divisions during the monsoon months and the total monsoon period, June to September.

8. *L-test for uniformity of rainfall* - The test for the existence of uniformity in rainfall variability amongst different stations in each district of West Bengal in two met. sub-divisions SHWB and GWB, for each of the monsoon month can be understood by L-test, as shown in Table 2. The minimum value of L-test in SHWB is 0.867 in September at Darjeeling district where the same in GWB is 0.816 in June at Murshidabad district, which indicates less uniformity. The maximum value of L-test indicates the highest uniformity which occur in SHWB are

0.992 and 0.993 in June at Coochbehar district and in August at Dinajpur district respectively and the same occur in GWB is 0.998 in July at Howrah district.

9. (i) It is seen that the isohyetal lines are more steep in SHWB than that of GWB in all the monsoon months throughout the monsoon period in West Bengal and SHWB gets much rainfall density (per unit area) than that of GWB in monsoon season. The highest average rainfall range around 300 cm in SHWB is double than that of GWB (120-140 cm) during monsoon period. The peak monsoon month July, the maximum average rainfall occur in the order between 90 and 100 cm in the north of SHWB, while the same occur around 35 cm in the extreme southeast part of South 24 Parganas district in GWB.

(ii) The coefficients of variation of rainfall throughout the monsoon period are slightly less in SHWB than GWB. The higher the rainfall value in the region, the coefficients of variation is less. By the study of the long period of rainfall data, it is seen that whenever monsoon rainfall is scanty, the variability of rainfall is high.

(iii) By L-test, the ranges of variation in uniformity of rainfall variability during monsoon period amongst the stations in all districts of SHWB is less than that of GWB. The maximum uniformity is 0.998 in July at Howrah district and the minimum of such value is 0.816 in June at Murshidabad district both in GWB. As discussed in section 4.2., it can be depicted that the maximum value of L-test in the district indicates the rainfall variability among the stations in the district of highest uniformity while the minimum value of the same gives less uniformity.

10. The author would like to express his sincere thank to Dr. M. K. Guha, DDGM, Regional Meteorological Centre, Calcutta for pursuing the study and for encouragement in this work. The author wishes to express his sincere thanks to Dr. D. K. Rakshit, Retd. Director. Dept. of Science and Technology, Govt. of India, for his valuable comments. The author also wishes to express thank to the ADGM(R), Pune for the supply of necessary rainfall data. Thanks are also due to S/Sh. B. K. Dakua, AM-II, R.N. Halder, S.A. for compilation of data, and to Smt. Indrani Roy, S.O. and Sh. Utpal Bhattacharjee, S.O. for computer output and to Sh. D. Roy, Draughtsman for drawing figures.

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 10 July 2000, Modified 6 June 2001