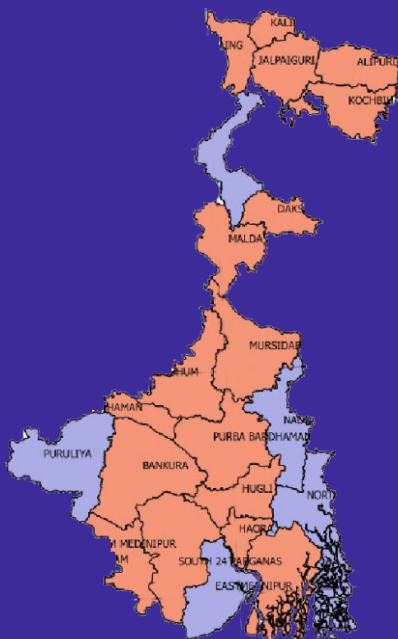




**CLIMATE RESEARCH AND SERVICES  
INDIA METEOROLOGICAL DEPARTMENT  
MINISTRY OF EARTH SCIENCES  
PUNE**

# **Observed Rainfall Variability and Changes over West Bengal State**



**Met Monograph No.: ESSO/IMD/HS/Rainfall Variability/29(2020)/53**

**Pulak Guhathakurta, Shirish Khedikar, Preetha Menon,  
Ashwini Kumar Prasad, S T Sable and S C Advani**



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## DOCUMENT AND DATA CONTROL SHEET

1	Document Title	Observed Rainfall Variability and Changes Over West Bengal State
2	Issue No.	ESSO/IMD/HS/Rainfall Variability/29(2020)/53
3	Issue Date	January 2020
4	Security Classification	Unclassified
5	Control Status	Uncontrolled
6	Document Type	Scientific Publication
7	No. of Pages	27
8	No. of Figures	42
9	No. of References	3
10	Distribution	Unrestricted
11	Language	English
12	Authors	Pulak Guhathakurta, Shirish Khedikar, Preetha Menon, Ashwini Kumar Prasad, S.T. Sable and S C Advani
13	Originating Division/ Group	Climate Research Division/ Climate Application & User Interface Group/ Hydrometeorology
14	Reviewing and Approving Authority	Director General of Meteorology, India Meteorological Department, New Delhi
15	End users	Central and State Ministries of Water resources, agriculture and civic bodies, Science and Technology, Disaster Management Agencies, Planning Commission of India
16	Abstract	India is in the tropical monsoon zone and receives plenty of rainfall as most of the annual rainfall during the monsoon season every year. However, the rainfall is having high temporal and spatial variability and due to the impact of climate changes there are significant changes in the mean rainfall pattern and their variability as well as in the intensity and frequencies of extreme rainfall events. The report brings the result of the analysis based on the recent 30 years of data (1989-2018) on the mean spatial rainfall pattern as well as mean spatial pattern of different rainfall events, trends and variability as well as extreme rainfall events during the monsoon months and annual for the state.
17	Key Words	Rainfall trend, variability, extreme events, dry days

## **1. Introduction**

The state of West Bengal extending from the Bay of Bengal on the south to the sub-Himalayan region to the north and from hills and Gangetic plains of Jharkhand and Bihar on the West to riverine Bangladesh with innumerable deltas of the Ganges and the Brahmaputra, has climate of varied nature in view of its geographical location. It lies roughly between 21°30'N and 27°11'N latitude and 85°49'30"E and 89°54'E longitude. Front piece gives the orographic features of the state. The state is bounded on the north by Sikkim, Bhutan and by the mighty chain of Himalayas; on the west by Nepal and the districts of Santhal Parganas viz., Deoghar, Godda, Sahebganj, Dumka, Singhbhum East and Singhbhum West, Dhanbad, Hazaribagh, Ranchi, Singhbhum in Jharkhand, Purnea in Bihar and the districts of Mayurbhanj and Balasore in Orissa, on the south by the Bay of Bengal; and on the east by the districts of Kamrup, Garo hills in Assam and Bangladesh.

West Bengal contains tracts of very different physical features like alluvial plains of the Ganges together with its deltas and a small portion of the sub-Himalayan region which form the main part of Darjeeling district. The part of West Bengal, west of Bhagirathi lies outside the true delta. The eastern portion of this tract is low and of alluvial formation; but farther west laterite begins to predominate and the surface rises and becomes more and more undulating and rocky, until at last it merges in the uplands of Chhota Nagpur. The part of West Bengal east of Bhagirathi and south of the Padma is formed out of the Ganges delta. North Bengal lies north of the Padma and is wholly alluvial with the exception of the sub-Himalayan region in the district Darjeeling.

Many studies available on the observed trends and variability of rainfall and also extreme rainfall events over India, but all the studies are based on past 100 years or more data and also the recent years are not included (Guhathakurta et al, 2015; Guhathakurta et al, 2011; Guhathakurta & Rajeevan, 2008 etc). Also, there are limited studies on district rainfall trends and variability of West Bengal state. In the present report all the analysis of observed rainfall patterns, trends and variability have been done based on recent past 30 years (1989-2018) that will help to have idea of the recent changes for climate change adaptation and management by the state authorities.

## **2. Data and Methodology**

Daily Rainfall data from 1989 to 2018 is considered for analysis of trend variability and mean rainfall patterns. From the daily rainfall data monthly rainfall series of each stations are computed and then monthly district rainfall series has been constructed by considering arithmetic average of all the station rainfall values within the district. The monthly rainfall series of the state has been computed by using area weighted rainfall values of all the districts within the state. Fig.1 gives the location of the districts of the state. The objective of the analysis is to:



1. Identify the spatial pattern of the mean rainfall
2. Understand district wise observed rainfall trend and variability in annual and SW monsoon season (June, July, august and September).

Daily station rainfall data is utilized for identification of the mean spatial patterns and rainfall intensity trends. From mean and standard deviation (SD), the coefficient of variation (CV) is calculated as follows:

$$\text{Coefficient of variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

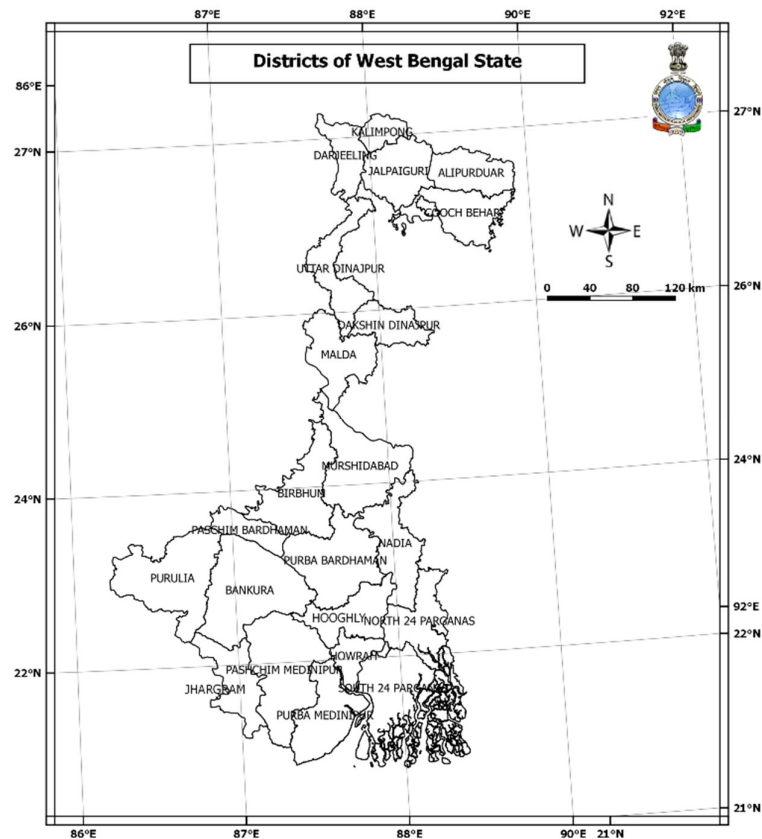


Fig. 1 Location of the districts of West Bengal

### 3. State rainfall mean and variability and trend

Table 1 shows the mean rainfall (mm) and coefficient of variation of the state for the monsoon months, southwest monsoon season and annual during the period 1989-2018. It can be seen that the state gets highest rainfall 30% of south west monsoon rainfall in July month while the August month get 26% of the south west monsoon rainfall. Both June and September receive 22 % of south west monsoon rainfall. Also around 77 % of annual rainfall receives during the southwest monsoon season only. The variability of monsoon or annual rainfall is also very less (14%).

	June	July	August	September	JJAS	Annual
<b>Mean</b>	318.0	431.8	361.1	307.7	1418.7	1851.4
<b>C V</b>	20.3	19.1	18.9	28.2	13.9	13.5

Table 1 Mean rainfall (mm) and coefficient of variation of the state for the monsoon months, southwest monsoon season and annual

Fig. 2 and 3 show the time series of rainfall in mm for the months of June, July, August, September and southwest monsoon season, annual respectively. The trend lines are also displayed for each of the series. Monthly rainfall of June, seasonal and annual rainfall shows significant decreasing trend while remaining months do not show any significant decreasing trend.

During the last 30 years, highest rainfall of June received in the year 2008 (445.8mm) and for July received in the year 2007(638 mm) and while highest rainfall of 494.7 in August received in the year 1996 and 482.2 mm in September received in the year 1995. Highest annual rainfall of 2384.5mm and highest southwest monsoon rainfall of 1814.2 mm received in the year 1990 and 1999 respectively.

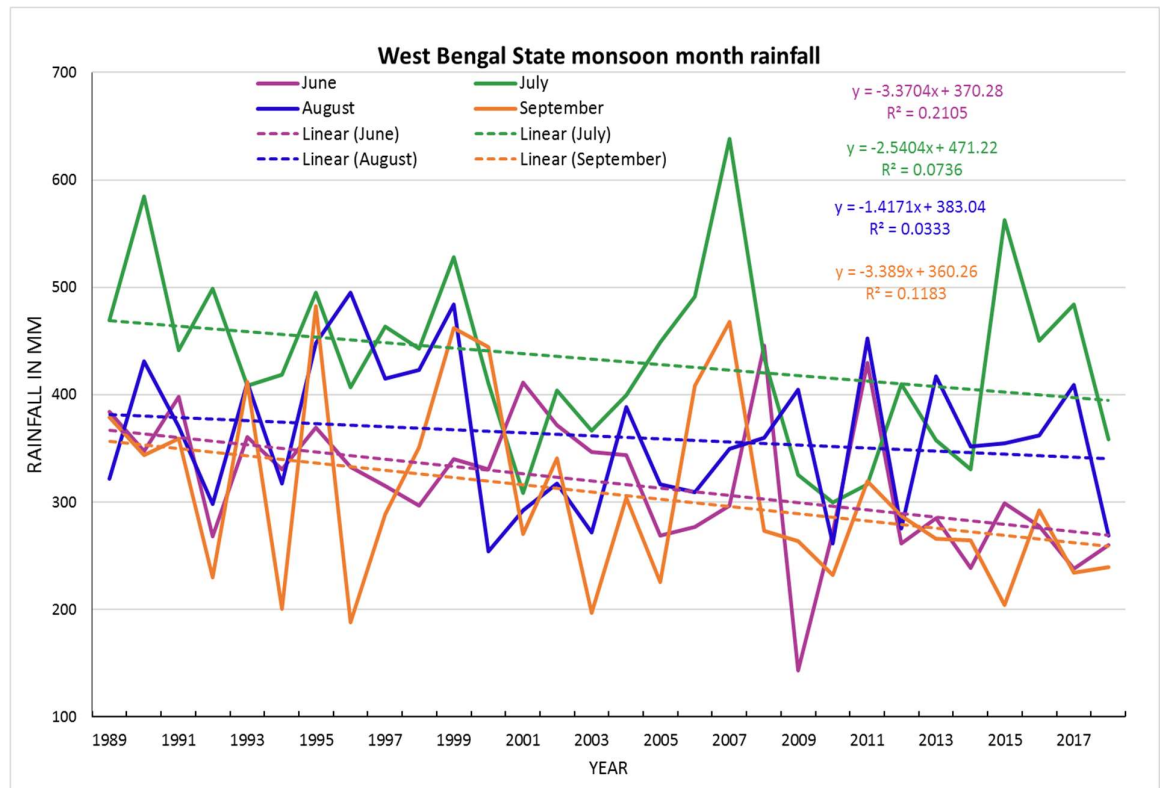


Fig. 2 Time series of rainfall in mm for the months of June, July, August, September and trends

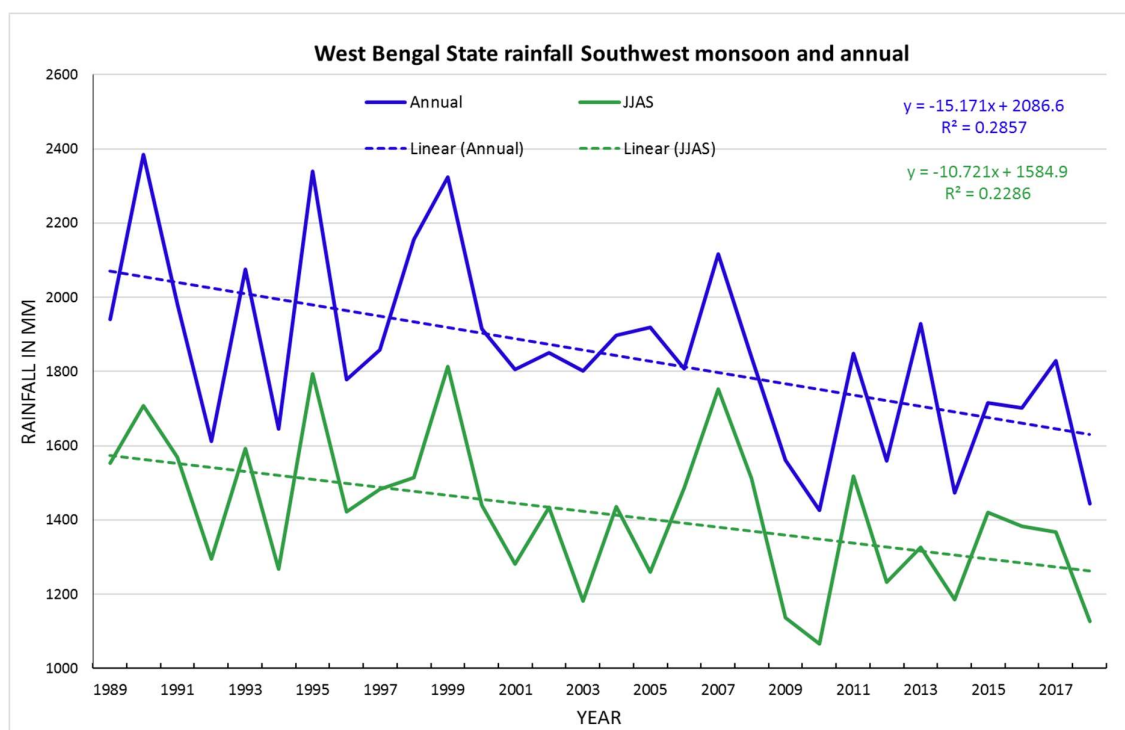


Fig. 3 Time series of rainfall in mm for the southwest monsoon season and annual trends

#### 4. District rainfall mean, variability and trend

##### 4.1 Mean and coefficient of variation

Table 2 gives the rainfall statistics for the districts of West Bengal for the four monsoon months, southwest monsoon season and annual while Fig.4-5 shows the spatial pattern of these statistics. It can be seen that three northern districts viz. Cooch Behar, Darjeeling, Jalpaiguri receive highest rainfall over other districts during all the months and season. Rainfall receives over these districts are around 600-800 mm in June, 700-1000mm in July, 550-700mm in August, 450-550mm in September and during the SW monsoon 2300-3000 mm and annual 3000-3800mm. Lowest rainfall during both SW monsoon season (887.9 mm) and annual rainfall (1259.4 mm) receives over Nadia district.

DISTRICT	JUNE		JULY		AUGUST		SEPTEMBER		MONSOON		ANNUAL	
	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV
Bankura	244.7	52.2	357.0	35.1	317.8	39.4	255.7	45.1	1153.7	39.6	1489.7	44.0
Birbhum	232.9	32.7	363.3	37.9	298.7	30.3	281.7	62.3	1176.6	24.8	1492.6	20.7
Burdwan	225.2	41.5	318.4	36.7	278.3	33.4	245.6	40.4	1067.4	20.9	1359.0	16.7
Cooch Behar	599.7	28.4	724.4	39.4	592.9	82.9	443.3	44.6	2360.1	30.6	3049.8	25.3
Darjeeling	642.2	32.8	850.1	25.0	683.3	28.1	491.6	29.6	2667.2	17.2	3334.3	16.1
Hoogly	242.4	48.5	312.3	40.1	272.5	48.5	226.3	47.4	1047.6	42.3	1359.7	51.5
Howrah	249.9	57.5	390.7	55.1	291.5	46.4	289.8	56.6	1210.1	52.3	1466.2	49.0
Jalpaiguri	773.5	34.2	936.0	29.8	696.3	36.5	526.7	34.3	2932.6	16.4	3720.9	14.5
Malda	237.2	52.1	339.1	43.3	302.3	50.1	308.9	69.5	1182.6	35.1	1521.4	29.3
Manbhum Purulia	239.3	59.9	322.3	41.0	297.6	32.0	254.7	42.0	1149.9	41.9	1381.5	52.2
East Midnapore	278.8	37.8	367.5	32.0	360.4	32.0	336.8	44.0	1343.5	18.3	1813.1	17.5
Murshidabad	231.5	43.0	327.0	46.4	240.3	40.4	267.3	70.7	1066.0	33.9	1384.3	33.8
Nadia	175.9	60.8	264.0	56.0	189.5	55.0	218.5	81.3	887.9	46.3	1259.4	48.9
24 Parganas N	254.2	34.8	359.3	33.6	315.8	33.5	277.4	45.3	1206.8	19.0	1661.1	14.3
24 Parganas S	283.4	38.7	463.4	39.5	383.0	38.6	314.8	38.0	1444.6	20.1	1959.2	28.6
Dinajpur North	276.1	58.9	408.8	67.9	329.6	60.6	292.7	71.5	1296.9	61.8	1518.4	50.4
Dinajpur South	237.4	59.6	311.8	62.7	261.5	61.2	250.9	60.9	955.9	54.1	1285.5	51.0
West Midnapore	283.9	54.8	355.7	33.0	318.9	30.8	262.5	37.2	1220.9	24.3	1639.7	26.9
Kolkata	279.4	46.0	395.7	43.1	357.8	38.8	325.9	46.1	1367.5	31.9	1852.3	29.9

Table 2. Rainfall statistics for the districts of West Bengal for the four monsoon months, southwest monsoon season and annual

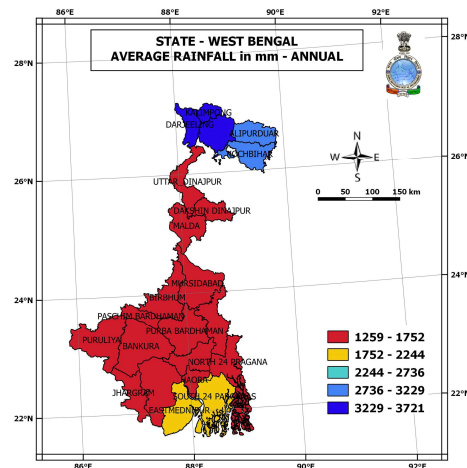
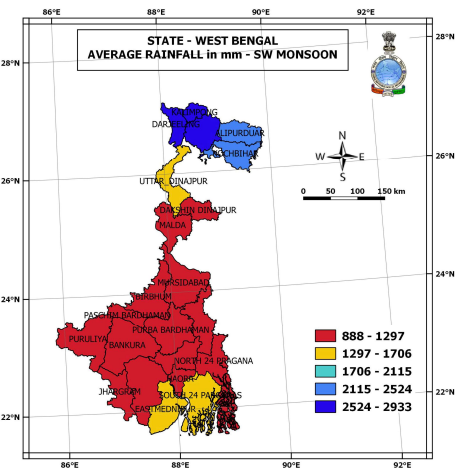
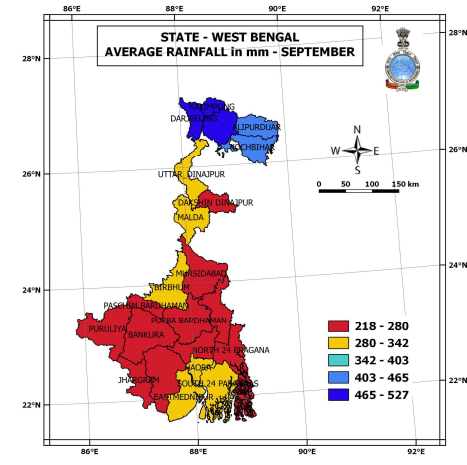
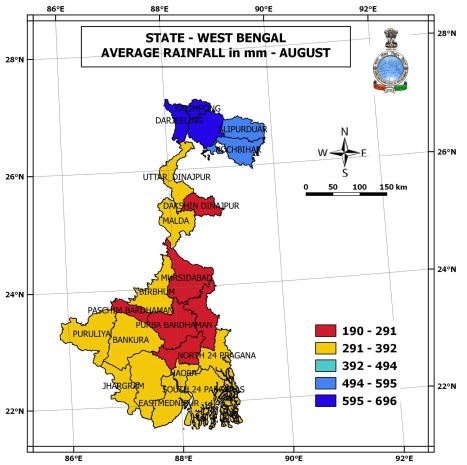
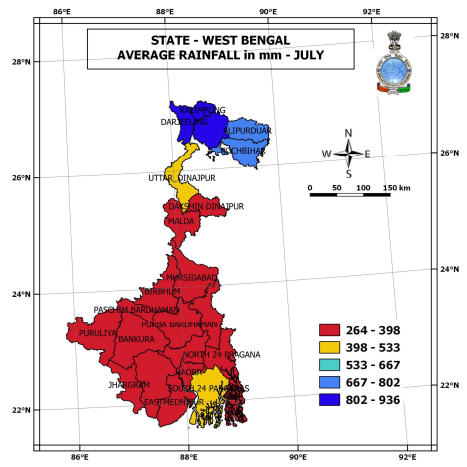
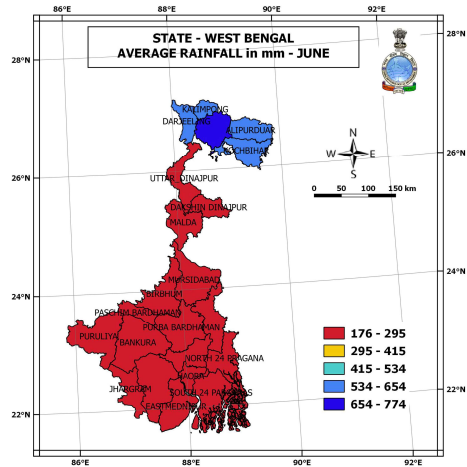


Fig.4 Mean rainfall pattern over districts of West Bengal

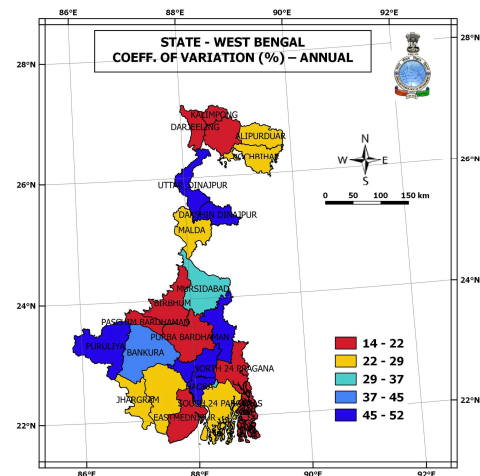
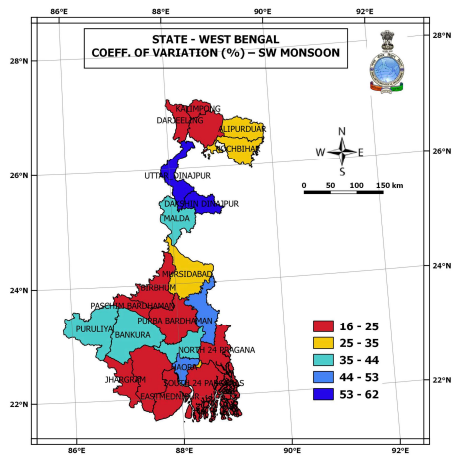
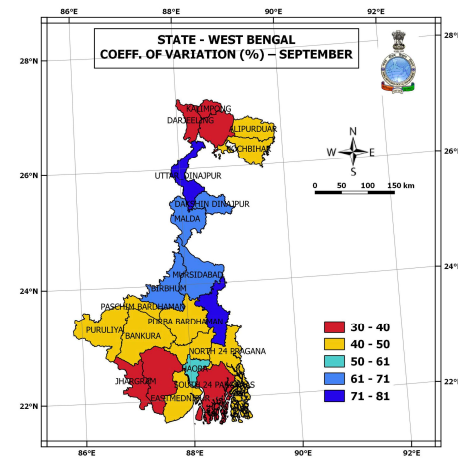
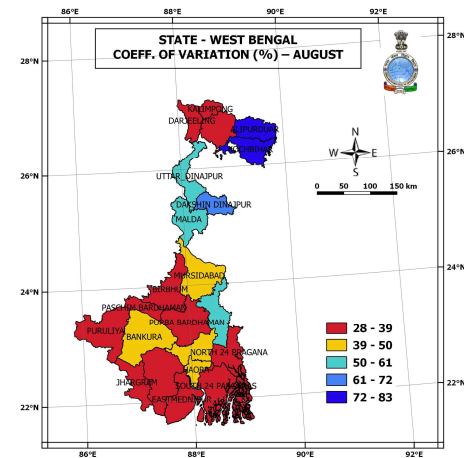
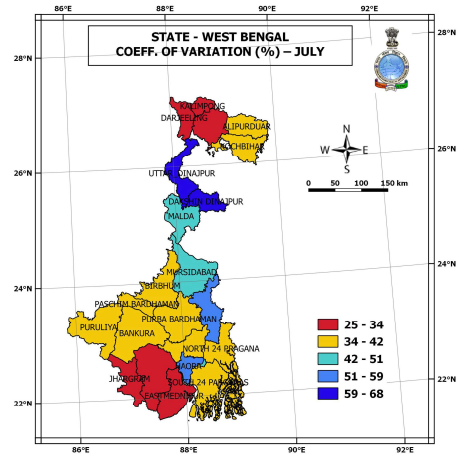
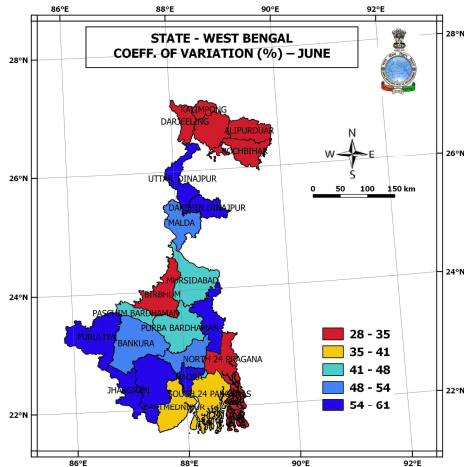
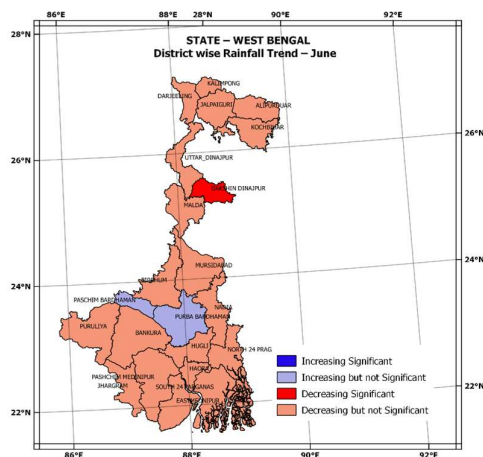


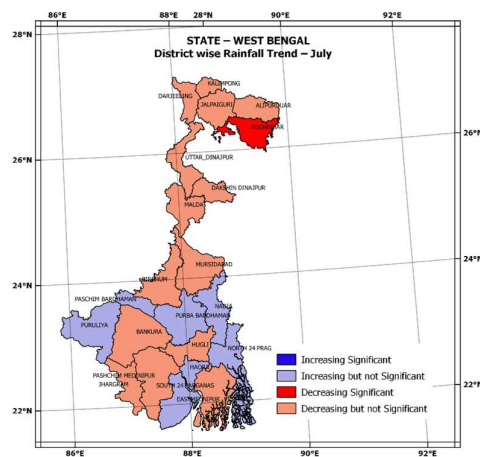
Fig.5 Coefficient of Variation (%) over districts of West Bengal

## 4.2 Trend in district rainfall

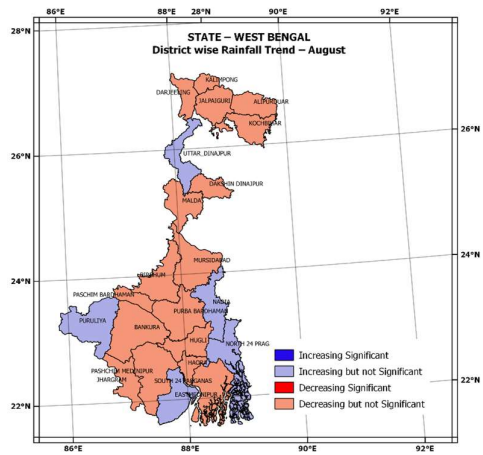
Fig.6 shows the trends in district rainfall for (a) June, (b) July (c) August (d) September (e) JJAS and (f) annual. It can be seen that June rainfall has shown significant decreasing trend in the district Dakshin Dinajpur while no other districts has shown any significant increasing/decreasing trend. For the July month only significant trend has been noticed in Cooch Behar district (significant decreasing trend). No district has shown any significant increasing/decreasing trend in August rainfall while September rainfall of Dakshin Dinajpur, Uttar Dinajpur, Malda, Howrah districts has shown significant decreasing trend. During the whole southwest monsoon season Cooch Behar, Howrah, Malda, South 24 Parganas and Dakshin Dinajpur districts has shown significant decreasing trend. For the annual rainfall Cooch Behar, Malda, South 24 Pargana, Murshidabad, Birbhum, Purulia, Jhargram, Pushchim Mednapur and Dakshin Dinajpur districts show significant decreasing trend.



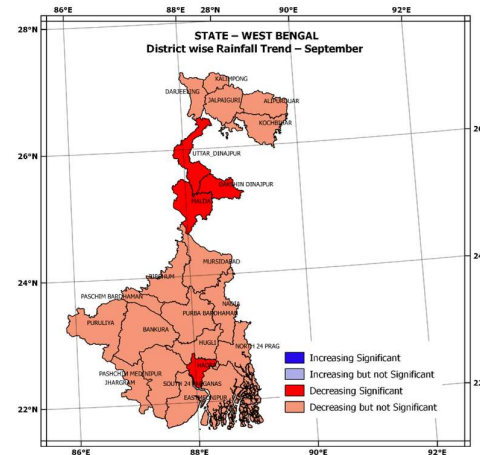
a



b



c



d



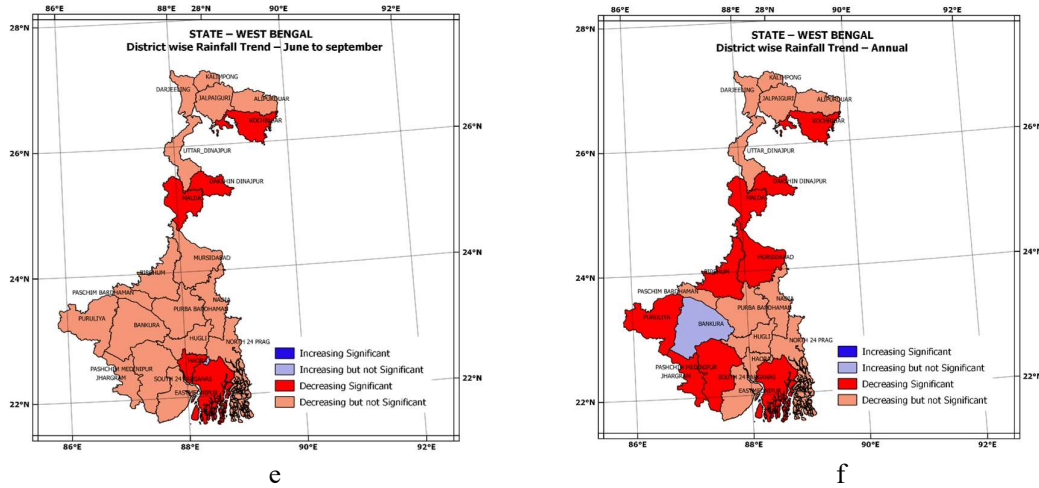


Fig.6 Trends in district rainfall for (a) June, (b) July (c) August (d) September (e) JJAS and (f) annual

## 5. Analysis of Average frequencies for rainfall events of different intensities

### 5.1 Average frequency of Rainy days

The average frequency of rainy days is calculated for West Bengal for June, July, August, September, June to September and Annual. Figure 7 shows that in the month of June the maximum number of rainy days lies in the range of 17 to 20 days especially in some parts of Kalimpong, Jalpaiguri and Darjeeling districts. In the range of 15 to 17 rainy days observed in Alipurduar, Cooch Behar and Uttar Dinajpur. While in remaining districts rainy days lies in the range of 8 to 13 days.

Figure 8 shows that in the month of July the maximum number of rainy days lies in the range of 22 to 24 days especially in some parts of Kalimpong, Jalpaiguri and Darjeeling districts. In the range of 20 to 22 rainy days observed in Alipurduar, Cooch Behar and Uttar Dinajpur. While in remaining districts rainy days lies in the range of 13 to 18 days.

Figure 9 shows that in the month of August the maximum number of rainy days lies in the range of 19 to 21 days especially in some parts of Kalimpong, Jalpaiguri and Darjeeling districts. In the range of 12 to 14 rainy days observed in Malda, Murshidabad, Purba Burdhan, Nadia, Uttar Dinajpur and Dakshin Dinajpur. While in remaining districts rainy days lies in the range of 14 to 19 days.

Figure 10 shows that in the month of September the maximum number of rainy days lies in the range of 15 to 17 days especially in some parts of Kalimpong, Jalpaiguri and Darjeeling districts. In the range of 12 to 15 rainy days observed in Alipurduar, Cooch Behar, Howrah and South 24 Parganas. While in remaining districts rainy days lies in the range of 9 to 12 days.

Figure 11 shows that during June to September (Monsoon) the maximum number of rainy days



lies in the range of 69 to 76 days especially in some parts of Kalimpong, Jalpaiguri and Darjeeling districts. In the range of 55 to 69 rainy days observed in Alipurduar, Cooch Behar, Howrah and South 24 Parganas. While in remaining districts rainy days lies in the range of 42 to 55 days.

Figure 12 shows that during the entire year the maximum number of rainy days lies in the range of 97 to 109 days especially in some parts of Kalimpong and Jalpaiguri districts. In the range of 86 to 97 rainy days observed in Darjeeling, Alipurduar, and Cooch Behar. While in remaining districts rainy days lies in the range of 51 to 86 days.

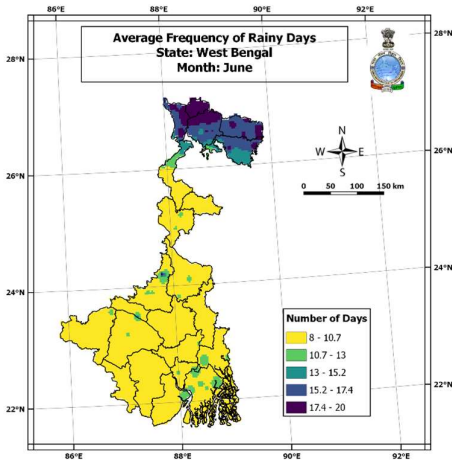


Fig. 7 Average frequency of rainy days: June

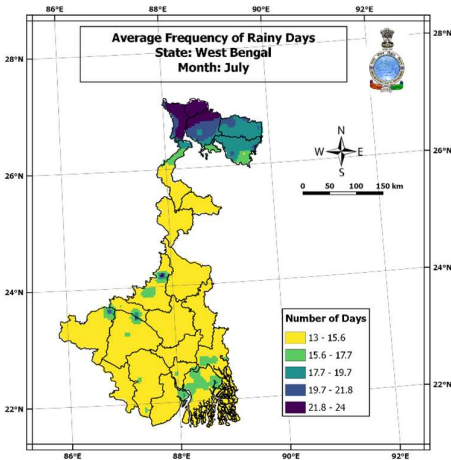


Fig. 8 Average frequency of rainy days: July

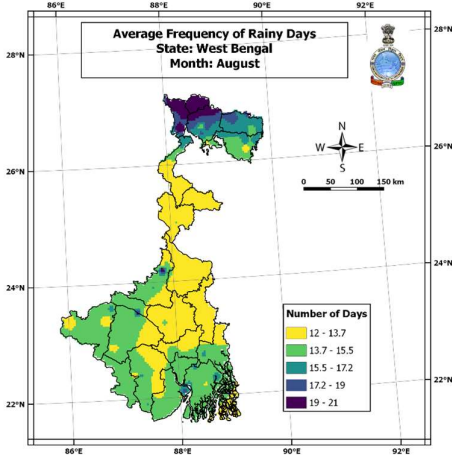


Fig. 9 Average frequency of rainy days: August

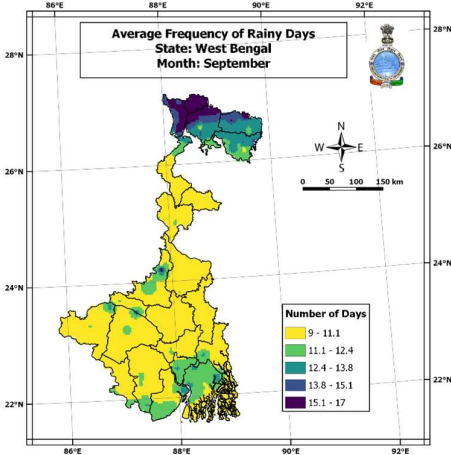


Fig. 10 Average frequency of rainy days: September

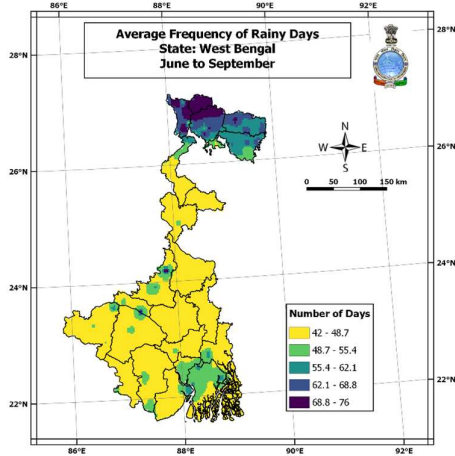


Fig. 11 Average frequency of rainy days: JJAS

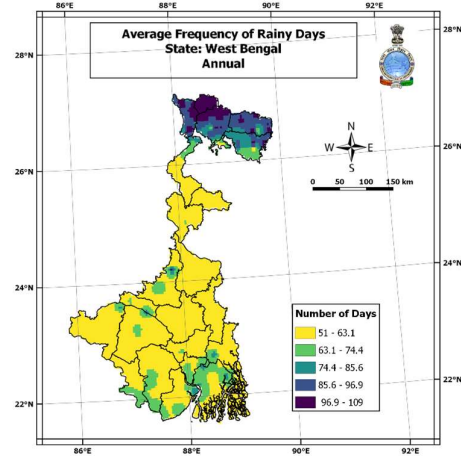


Fig. 12 Average frequency of rainy days: Annual

## 5.2 Average frequency of Heavy rainfall days

The average frequency of Heavy rainfall days is calculated for West Bengal for June, July, August, September, June to September and Annual. Figure 13 shows that in the month of June the maximum number of heavy rainfall days lies in the range of 2 to 4 days especially in some parts of Kalimpong, Jalpaiguri Darjeeling, Alipurduar and Cooch Behar districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.4 to 2 days.

Figure 14 shows that in the month of July the maximum number of heavy rainfall days lies in the range of 2.7 to 5 days especially in some parts of Kalimpong, Jalpaiguri Darjeeling, Alipurduar and Cooch Behar districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.6 to 2.7 days.

Figure 15 shows that in the month of August the maximum number of heavy rainfall days lies in the range of 2 to 3 days especially in some parts of Kalimpong, Jalpaiguri Darjeeling, Alipurduar and Cooch Behar districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.5 to 2 days.

Figure 16 shows that during September the maximum number of heavy rainfall days lies in the range of 1.5 to 2 days especially in some parts of Kalimpong, Jalpaiguri Darjeeling, Alipurduar and Cooch Behar districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.5 to 1.5 days.

Figure 17 shows that during June to September the maximum number of heavy rainfall days lies in the range of 7.7 to 12 days especially in some parts of Kalimpong, Jalpaiguri Darjeeling,

Alipurduar and Cooch Behar districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 2 to 7.7 days.

Figure 18 shows that during the entire year the maximum number of heavy rainfall days lies in the range of 9 to 14 days especially in some parts of Kalimpong, Jalpaiguri Darjeeling, Alipurduar and Cooch Behar districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 2 to 9 days.

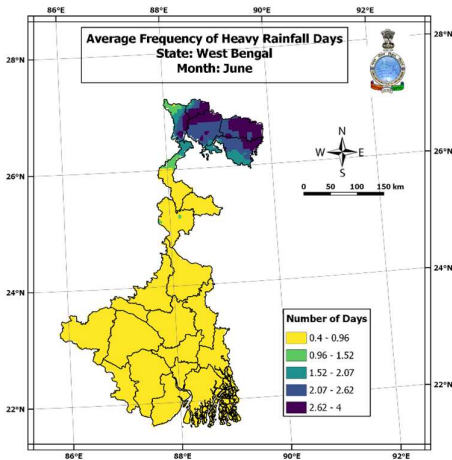


Fig. 13 Average frequency of heavy rainfall days: June

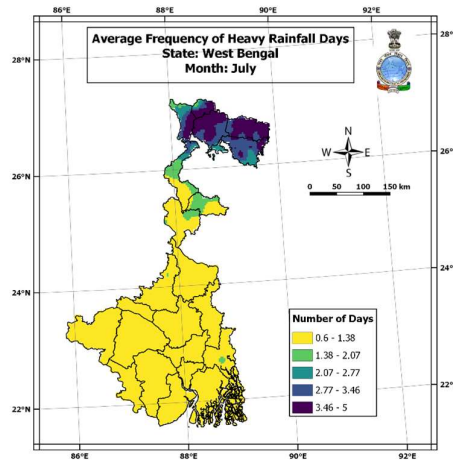


Fig. 14 Average frequency of heavy rainfall days: July

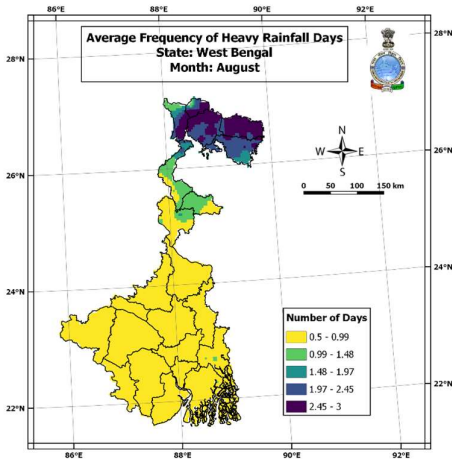


Fig. 15 Average frequency of heavy rainfall days: August

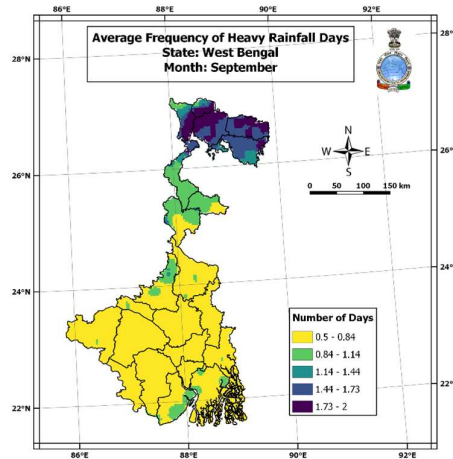


Fig. 16 Average frequency of heavy rainfall days: September

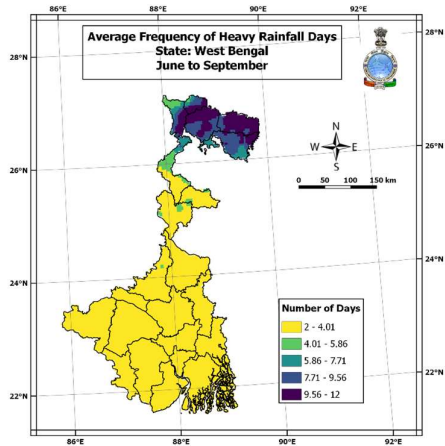


Fig. 17 Average frequency of heavy rainfall  
days: JJAS

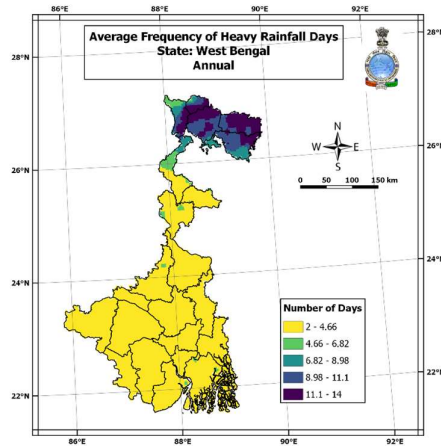


Fig. 18 Average frequency of heavy rainfall  
days: Annual

### 5.3 Average frequency of Dry days

The average frequency of dry days is calculated for West Bengal for June, July, August, September, June to September and Annual. Figure 19 shows that in the month of June the maximum number of dry days lies in the range of 16 to 19 days especially in some parts of Jhargram, Bankura, Paschim, Burdhaman, Birbhum, Murshidabad, Malda, Uttar Dinajpur and Dakshin Dinajpur districts. While minimum number of dry days lies in the range of 8 to 10 days especially in some parts of Alipurduar, Kalimpong, Cooch Behar and Jalpaiguri districts. Whereas in remaining districts, the number of dry days lies in the range of 10 to 16 days.

Figure 20 shows that in the month of July the maximum number of dry days lies in the range of 12 to 14 days especially in some parts of Purulia, Jhargram, Bankura, Paschim Burdhaman, Birbhum, Murshidabad, Malda, Uttar Dinajpur and Dakshin Dinajpur districts. While minimum number of dry days lies in the range of 5 to 7.5 days especially in some parts of Kalimpong and Jalpaiguri districts. Whereas in remaining districts, the number of dry days lies in the range of 7.5 to 12 days.

Figure 21 shows that in the month of August the maximum number of dry days lies in the range of 14 to 16 days especially in some parts of Murshidabad, Malda, Uttar Dinajpur and Dakshin Dinajpur districts. While minimum number of dry days lies in the range of 8 to 10 days especially in some parts of Kalimpong and Jalpaiguri districts. Whereas in remaining districts, the number of dry days lies in the range of 10 to 14 days.

Figure 22 shows that in the month of September the maximum number of dry days lies in the range of 16 to 18 days especially in some parts of Purulia, Paschim Burdhaman, Birbhum, Malda, Uttar Dinajpur and Dakshin Dinajpur districts. While minimum number of dry days lies in the range of 11 to

13 days especially in some parts of Kalimpong and Jalpaiguri districts. Whereas in remaining districts, the number of dry days lies in the range of 13 to 16 days.

Figure 23 shows that during June to September the maximum number of dry days lies in the range of 55 to 61 days especially in some parts of Purulia, Jhargram, Bankura, Paschim Burdhan, Birbhum, Murshidabad, Malda, Uttar Dinajpur and Dakshin Dinajpur districts. While minimum number of dry days lies in the range of 32 to 38 days especially in some parts of Kalimpong and Jalpaiguri districts. Whereas in remaining districts, the number of dry days lies in the range of 38 to 55 days.

Figure 24 shows that in the month of during the entire year the maximum number of dry days lies in the range of 227 to 254 days especially in some parts of Jhargram, Bankura, Paschim Burdhan, Darjeeling, Uttar Dinajpur and Dakshin Dinajpur districts. While remaining districts, the number of dry days lies in the range of 120 to 227 days.

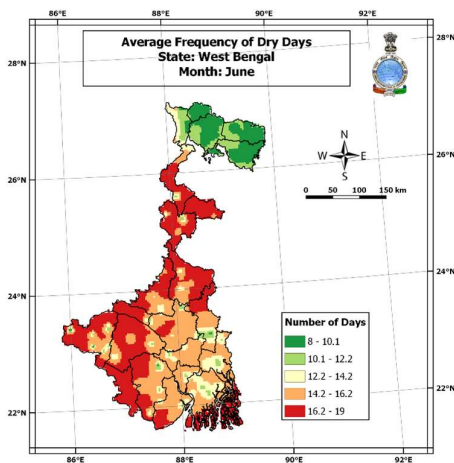


Fig. 19 Average frequency of dry days: June

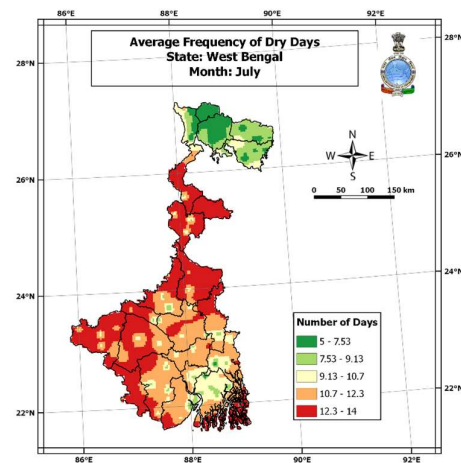


Fig. 20 Average frequency of dry days: July

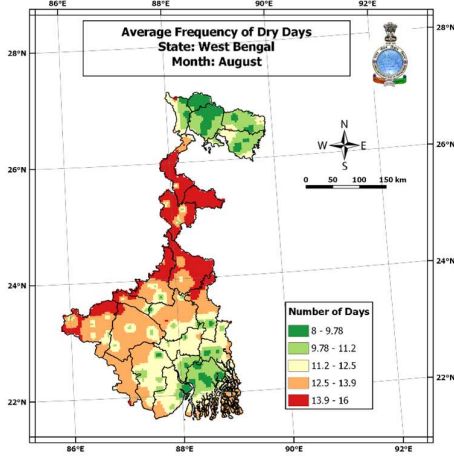


Fig. 21 Average frequency of dry days:  
August

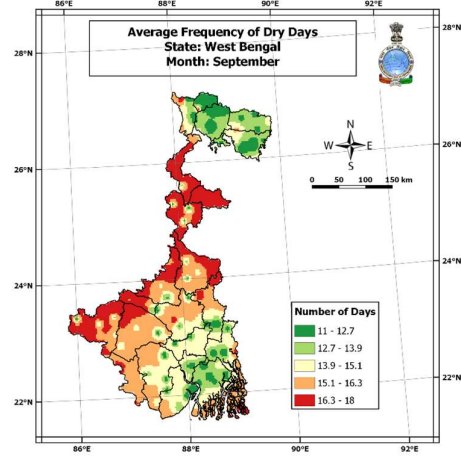


Fig. 22 Average frequency of dry days:  
September

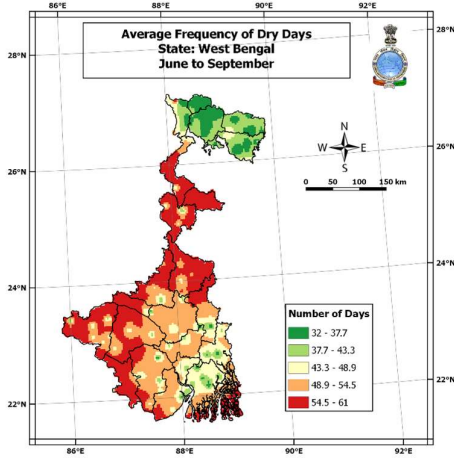


Fig. 23 Average frequency of dry days: JJAS

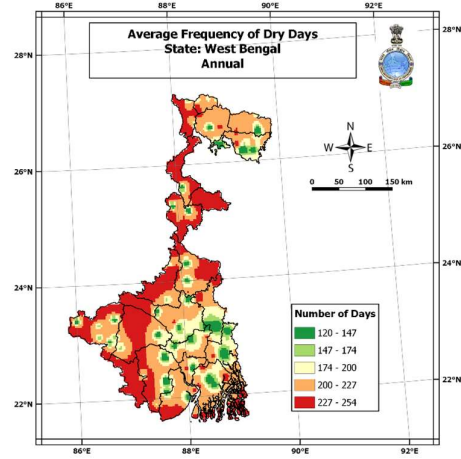


Fig. 24 Average frequency of dry days: Annual

## 6 Trends in the frequencies of different rainfall events

### 6.1 Trend in frequency of Rainy days

The Trend in frequency of rainy days is calculated for the rain gauge stations of West Bengal for June, July, August, September, June to September and Annual. Figure 25 shows that in the month of June there is a significant increase in Rainy days in stations in Kalimpong and Purulia districts. Whereas there is a significant decrease in Rainy days in stations in Jalpaiguri, Dakshin Dinajpur, Murshidabad, Birbhum, Purba Burdhan, Nadia, Hoogly, Howrah, Purba Midnapore and Pashchim Midnapore districts. While remaining districts did not show any significant change.

Figure 26 shows that in the month of July there is a significant increase in Rainy days in stations



in Kalimpong, Birbhum Purba Burdhan, Paschim Burdhan, Pashchim Midnapore, Howrah, South 24 Parganas and Nadia districts. Whereas there is a significant decrease in Rainy days in stations in Cooch Behar, Alipurduar, Jalpaiguri and Hoogly districts. While remaining districts did not show any significant change.

Figure 27 shows that in the month of August there is a significant increase in Rainy days in stations in Kalimpong, Pashchim Midnapore, Paschim Burdhan, South 24 Parganas and Nadia districts. Whereas there is a significant decrease in Rainy days in stations in Cooch Behar, Darjeeling, Purba Burdhan, Dakshin Dinajpur and Bankura districts. While remaining districts did not show any significant change.

Figure 28 shows that in the month of September there is a significant increase in Rainy days in stations in Kalimpong, Paschim Burdhan and Nadia districts. Whereas there is a significant decrease in Rainy days in stations in Alipurduar, Cooch Behar, Dakshin Dinajpur, Purba Midnapore and Birbhum districts. While remaining districts did not show any significant change.

Figure 29 shows that in the month of June to September there is a significant increase in Rainy days in stations in Kalimpong, Jalpaiguri, Pashchim Midnapore, Paschim Burdhan, Purba Burdhan, Bankura, and Nadia districts. Whereas there is a significant decrease in Rainy days in stations in Cooch Behar, Malda, Hoogly, Purba Midnapore and Murshidabad districts. While remaining districts did not show any significant change.

Figure 30 shows that in the month of during the entire year there is a significant increase in Rainy days in stations in Purulia, Kalimpong, Jalpaiguri, Pashchim Midnapore, Paschim Burdhan, Purba Burdhan and Nadia districts. Whereas there is a significant decrease in Rainy days in stations in Cooch Behar, Malda, Hoogly, Purba Midnapore, Darjeeling, Birbhum, Dakshin Dinajpur and Murshidabad districts. While remaining districts did not show any significant change.

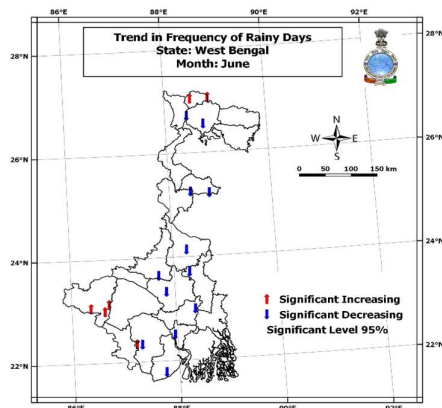


Fig. 25 Trend in frequency of rainy days: June

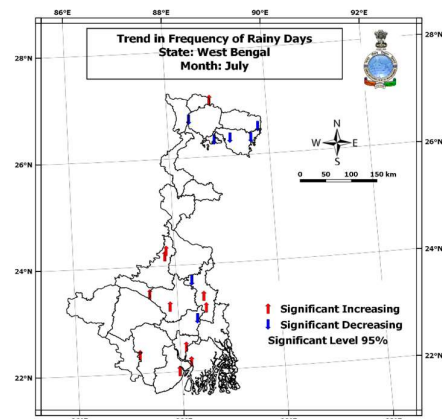


Fig. 26 Trend in frequency of rainy days: July

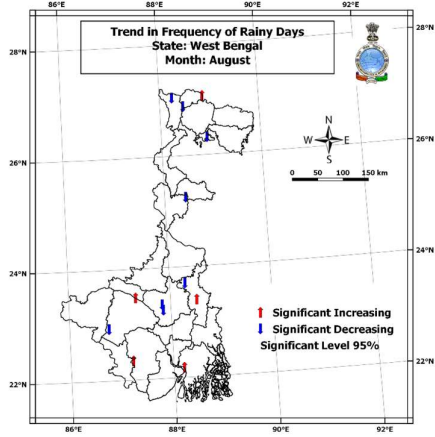


Fig. 27 Trend in frequency of rainy days: August

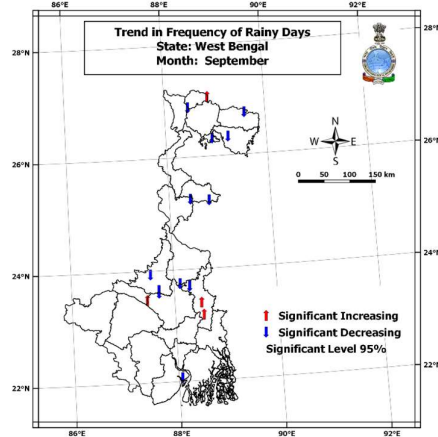


Fig. 28 Trend in frequency of rainy days:  
September

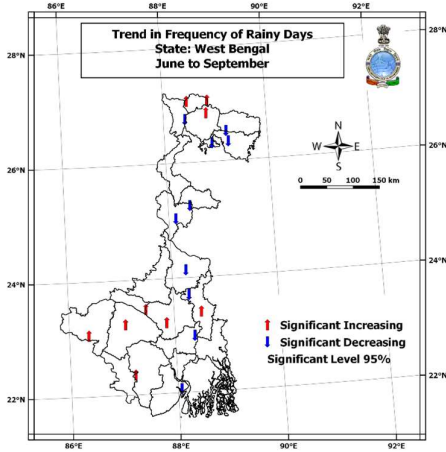


Fig. 29 Trend in frequency of rainy days: JJAS

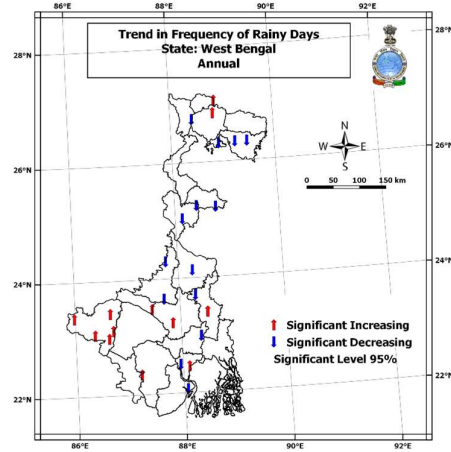


Fig. 30 Trend in frequency of rainy days:  
Annual

## 6.2 Trend in frequency of Heavy rainfall days

The Trend in frequency of Heavy days is calculated for West Bengal for June, July, August, September, June to September and Annual. Figure 31 shows that in the month of June there is a significant increase in Heavy rainfall days in Kalimpong, Hoogly, South 24 Parganas districts. Whereas there is a significant decrease in Heavy days in Malda, Nadia, North 24 Parganas, Pashchim Midnapore and Purba Midnapore districts. While remaining districts did not show any significant change.

Figure 32 shows that in the month of July there is a significant increase in Heavy rainfall days in Kalimpong, Darjeeling, Birbhum, PurbaBurdhman, Purba Midnapore and Howrah districts. Whereas there is a significant decrease in Heavy days in Cooch Behar and Murshidabad districts. While



remaining districts did not show any significant change.

Figure 33 shows that in the month of August there is a significant increase in Heavy rainfall days in Cooch Behar, Bankura, South 24 Parganas and Purba Midnapore districts. Whereas there is a significant decrease in Heavy rainfall days in Malda district only. While remaining districts did not show any significant change.

Figure 34 shows that in the month of September there is a significant increase in Heavy rainfall days in Alipurduar, Purulia and Pashchim Midnapore districts. Whereas there is a significant decrease in Heavy rainfall days in Malda, Jalpaiguri and Cooch Behar districts. While remaining districts did not show any significant change.

Figure 35 shows that during June to September there is a significant increase in Heavy rainfall days in Kalimpong, Jalpaiguri, Purulia, Bankura, Purba Burdhan, Purba Midnapore and South 24 Parganas districts. Whereas there is a significant decrease in Heavy rainfall days in Malda, Murshidabad and Birbhum districts. While remaining districts did not show any significant change.

Figure 36 shows that in the month of during the entire year there is a significant increase in Heavy rainfall days in Alipurduar, Bankura, Birbhum, Jalpaiguri, Purulia, Purba Midnapore, Pashchim Midnapore, North 24 Parganas, South 24 Parganas and Kalimpong districts. Whereas there is a significant decrease in Heavy rainfall days in Malda, Nadia, Birbhum and Murshidabad districts. While remaining districts did not show any significant change.

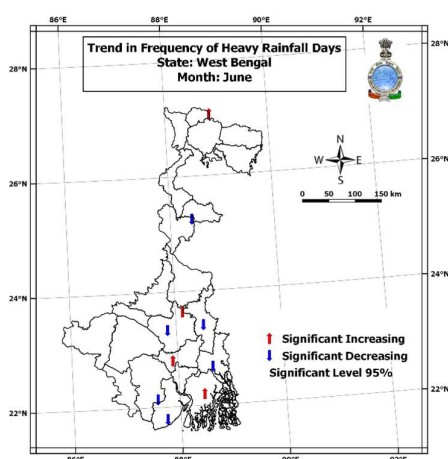


Fig.31 Trend in frequency of heavy rainfall days: June

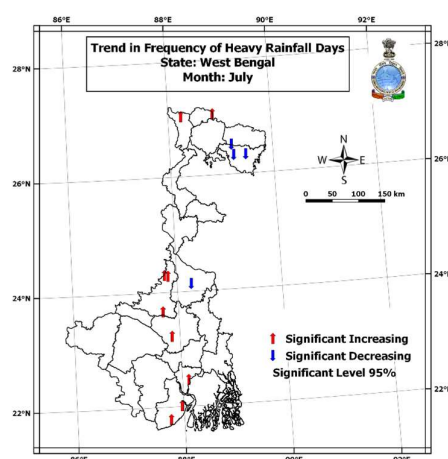


Fig. 32 Trend in frequency of heavy rainfall days: June

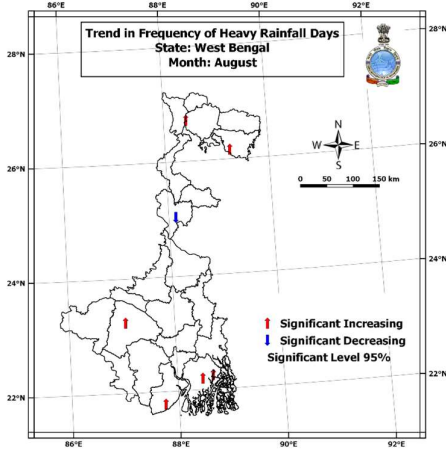


Fig. 33 Trend in frequency of heavy rainfall days: August

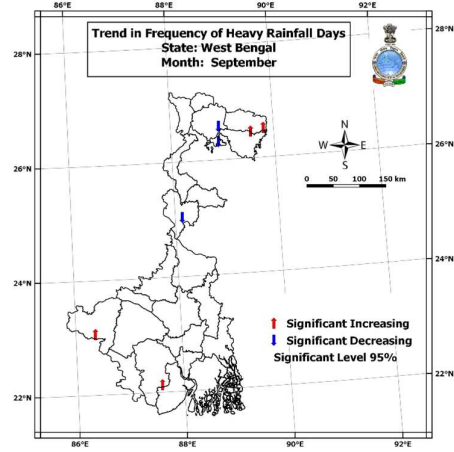


Fig. 34 Trend in frequency of heavy rainfall days: September

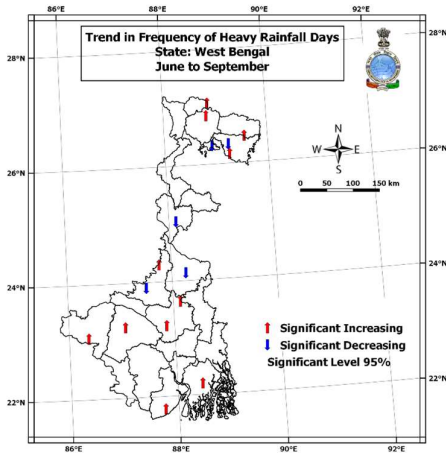


Fig. 35 Trend in frequency of heavy rainfall days: JJAS

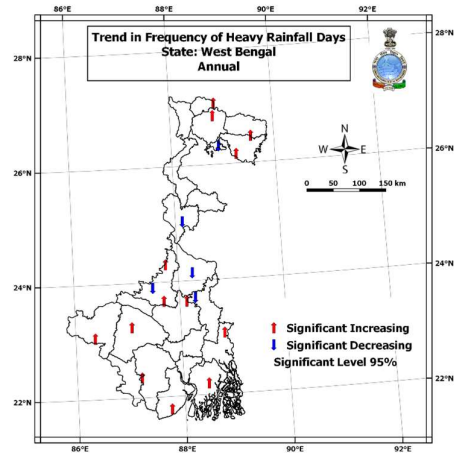


Fig. 36 Trend in frequency of heavy rainfall days: Annual

### 6.3 Trend in frequency of Dry days

The Trend in frequency of dry days is calculated for West Bengal for June, July, August, September, June to September and Annual. Figure 37 shows that in the month of June there is a significant increase in dry days in almost all districts except Malda, Uttar Dinajpur, Darjeeling and Kalimpong districts. Whereas there is a significant decrease in dry days in only in Nadia district.

Figure 38 shows that in the month of July there is a significant increase in dry days in Purulia, Darjeeling, Cooch Behar, Dakshin Dinajpur, North 24 Parganas and Pashchim Midnapore districts. Whereas there is a significant decrease in dry days in Bankura, PurbaBurdhman and South 24 Parganas districts. While remaining districts did not show any significant change.

Figure 39 shows that in the month of August there is a significant increase in dry days in Alipurduar, Bankura, PurbaBurdhman, Paschim Burdhman, Cooch Behar, Darjeeling, Jalpaiguri, Jhargram, Malda, Purulia, Purba Midnapore, Pashchim Midnapore, Murshidabad, Nadia, North 24 Parganas, Dakshin Dinajpur, Kolkata and Kalimpong districts. Whereas there is a significant decrease in dry days in only in Jalpaiguri district. While remaining districts did not show any significant change.

Figure 40 shows that in the month of September there is a significant increase in dry days in almost all districts except Uttar Dinajpur, Darjeeling, Jhargram, Howrah and Hoogly districts. Whereas there is a no significant decrease in dry days observed in any district.

Figure 41 shows that in the month of June to September there is a significant increase in dry days in almost all districts except Uttar Dinajpur, Darjeeling, Jhargram and Hoogly districts. Whereas there is a no significant decrease in dry days observed in any district.

Figure 42 shows that in the month of during the entire year there is a significant increase in dry days in almost all districts except Uttar Dinajpur, Jhargram and Dakshin Dinajpur districts. Whereas there is a significant decrease in dry days in Birbhum and Murshidabad districts.

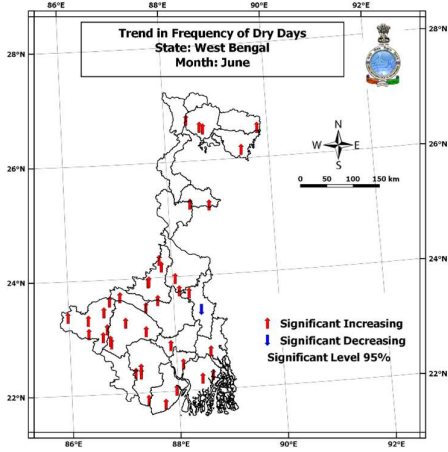


Fig. 37 Trend in frequency of dry days: June

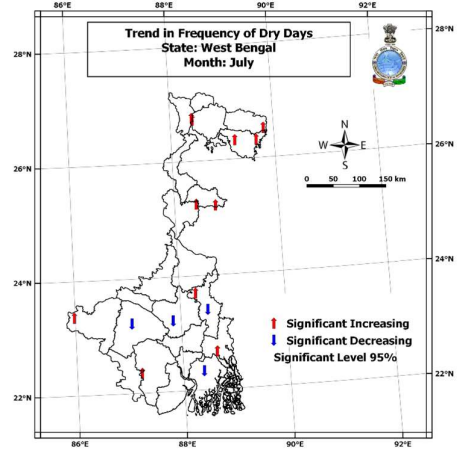


Fig. 38 Trend in frequency of dry days: July

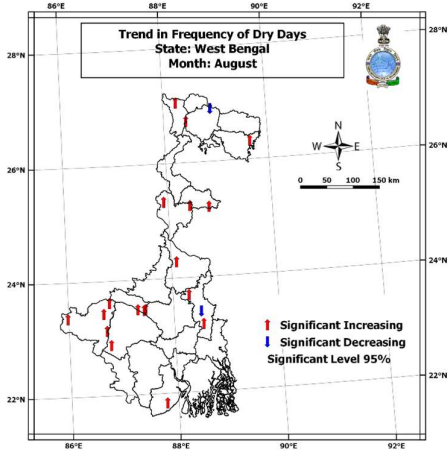


Fig. 39 Trend in frequency of dry days: August

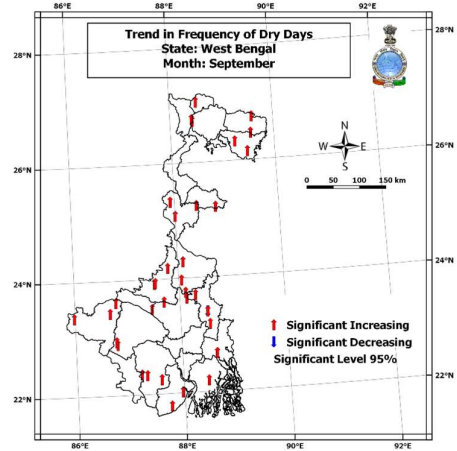


Fig. 40 Trend in frequency of dry days: September

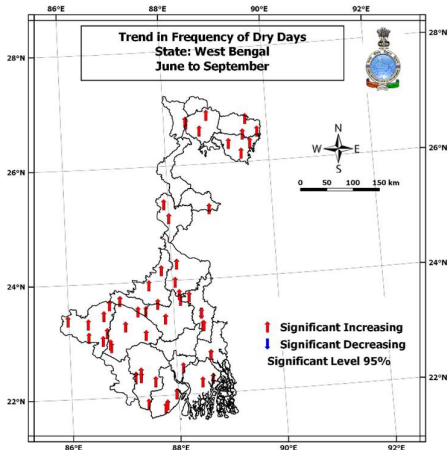


Fig. 41 Trend in frequency of dry days: JJAS

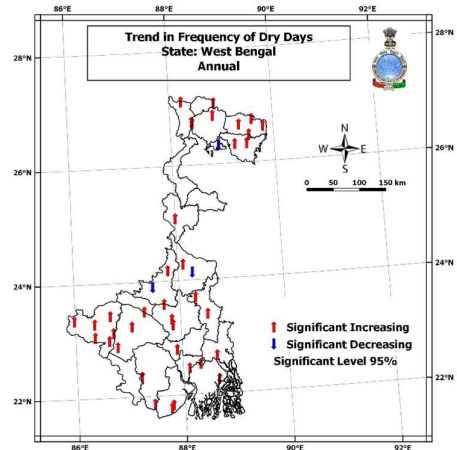


Fig. 42 Trend in frequency of dry days: Annual

## 7. Conclusions

In the present study we have investigated the rainfall pattern and its variability and also changes based on recent 30 years data. In the analysis we have considered monsoon months, the monsoon season and annual scale. The spatial scale has been considered from state to district for study of rainfall total and stations are being considered for seeing intensities of rainfall. The analysis brought many significant features of rainfall pattern and can be used for water agricultural managements. Some of the important results can be summarized as:

- West Bengal gets maximum rainfall in July (30% of SW monsoon rainfall) followed by August (26 % of SW monsoon rainfall).
- 77% of annual rainfall receives during southwest monsoon rainfall (June – September).
- Howrah, Manbhum Purulia and Dinajpur North districts receive 82-85% of annual rainfall in SW monsoon season while Nadia, 24 Parganas North and 24 Parganas South districts receive 70-74% of annual rainfall in SW monsoon season.
- Monthly rainfall of June, seasonal and annual rainfall shows significant decreasing trend while remaining months does not show any significant decreasing trend.
- Maximum rainfall receives during the SW monsoon season over the Jalpaiguri district (2933 mm) while Nadia district receive lowest rainfall (888 mm).
- Maximum rainfall receives during the year over Jalpaiguri district (3721 mm) while Nadia district receives lowest annual rainfall of 1260 mm.
- For the annual rainfall Cooch Behar, Malda, South 24 Pargana, Murshidabad, Birbhum, Purulia, Jhargram, Pashchim Midnapur and Dakshin Dinajpur districts show significant decreasing trend.
- Northern part of Sub Himalayan West Bengal regions receive on an average 69-76 rainy days (daily rainfall  $\geq 2.5$ mm) out of 122 days of SW monsoon season while most of the parts of Gangetic West Bengal region gets 42-49 rainy days..

- ✚ For heavy to extremely heavy rainfall ( daily rainfall  $\geq 6.5\text{mm}$ ) Northern part of Sub Himalayan West Bengal region gets 10-12 days during the SW monsoon season, Gangetic West Bengal and Southern part of Sub Himalayan West Bengal region get around 2-4 heavy to extremely heavy rainfall days.
- ✚ In many districts of South Sub Himalayan West Bengal regions and western Gangetic West Bengal Number of dry days were maximum during the SW monsoon season (55-61 dry days out of 122 days) was well as in 365 days (227-254 dry days) have been noticed of West Bengal.
- ✚ During the period June to September there is a significant increase in the frequency of Rainy days in stations in stations in Kalimpong, Jalpaiguri, Pashchim Midnapore, Paschim Burdhan, Purba Burdhan, Bankura and Nadia districts. Whereas there is a significant decrease in Rainy days in in stations Cooch Behar, Malda, Hoogly, Purba Midnapore and Murshidabad districts.
- ✚ During the entire year there is a significant increase in Rainy days in Purulia, Kalimpong, Jalpaiguri, Pashchim Midnapore, Paschim Burdhan, Purba Burdhan and Nadia districts. Whereas there is a significant decrease in Rainy days in Cooch Behar, Malda, Hoogly, Purba Midnapore, Darjeeling, Birbhum, Dakshin Dinajpur and Murshidabad districts.
- ✚ During the period June to September there is a significant increase in Heavy rainfall days in Kalimpong, Jalpaiguri, Purulia, Bankura, Purba Burdhan, Purba Midnapore and South 24 Parganas districts. Whereas there is a significant decrease in Heavy rainfall days in Malda, Murshidabad and Birbhum districts. While remaining districts did not show any significant change.
- ✚ During the entire year there is a significant increase in Heavy rainfall days in Alipurduar, Bankura, Birbhum, Jalpaiguri, Purulia, Purba Midnapore, Pashchim Midnapore, North 24 Parganas, South 24 Parganas and Kalimpong districts. Whereas there is a significant decrease in Heavy rainfall days in Malda, Nadia, Birbhum and Murshidabad districts.
- ✚ During June to September there is a significant increase in dry days in almost all

districts except Uttar Dinajpur, Darjeeling, Jhargram and Hoogly districts. Whereas there is a no significant decrease in dry days observed in any district.

- ✚ During the entire year there is a significant increase in dry days in almost all districts except Uttar Dinajpur, Jhargram and Dakshin Dinajpur districts. Whereas there is a significant decrease in dry days in Birbhum and Murshidabad districts.

**Acknowledgement:**

The authors acknowledge Secretary, MOES, DGM, India Meteorological Department and Head, Climate Research and Services for guidance, suggestions and encouragement to carry out the works. Acknowledge also to Hydrology section and National Data Centre of India Meteorological Department Pune for making availability of the data.

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**The report brings out observed rainfall variability and trends over the state as an impact of climate change based on recent 30 years of data ( 1981 - 2018 )**

**Rainfall pattern of monsoon months, south west monsoon season and annual of the state and it's districts as well as extreme rainfall event of different intensity of stations are analysed.**

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