Observed Rainfall Variability and Changes over Meghalaya State

Pulak Guhathakurta, P P Bhagwat, U S Satpute, Preetha Menon, Ashwini Kumar Prasad, S T Sable and S C Advani
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<td>Pulak Guhathakurta, P P Bhagwat, U S Satpute, Preetha Menon, Ashwini Kumar Prasad, S.T. Sable and S C Advani</td>
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<td>Director General of Meteorology, India Meteorological Department, New Delhi</td>
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<td>Central and State Ministries of Water resources, agriculture and civic bodies, Science and Technology, Disaster Management Agencies, Planning Commission of India</td>
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<td><strong>16</strong></td>
<td><strong>Abstract</strong></td>
<td>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.</td>
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<td><strong>Key Words</strong></td>
<td>Rainfall trend, variability, extreme events, dry days</td>
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1. Introduction

Meghalaya state is situated in the northeastern region of India. The state is bounded on the north and east by Assam and on the south and west by Bangladesh. Meghalaya is spread over an area of 22,429 square kilometers, and lies between 25°01' N and 26°05' N latitude and 89°50' E and 92°52’ E longitude.

The state has mostly hilly terrain with elevations varying from 150 metres to 1965 metres above mean sea level having Khasi hills in central part, Jaintia hills in eastern part and Garo hills in western part and some plain area of low elevation. The state of Meghalaya, literally meaning the abode of clouds, is geographically known as the "Meghalaya Plateau". The boundary of the plateau in the state is not well defined in the north due to the broken hill ranges. The state capital is Shillong which is located in Khasi Hills at an altitude of 1496 m. The state has physiographic variation with hills and plants/trees, in the northern and western parts which are highly dissected while in the south the slopes are steep and regular with dense forest.

The Garo hills region is characterized by the presence of the Tura and Arbellaranges running parallel in the east-west direction. The Tura range is about 50 km long, runs from Siju to Tura and it has the highest peak as Nokrek peak with an altitude of 1412 m. The Arbellarange up to height 999 m runs parallel to the Tura range towards its north. It gradually increases in height and join Tura towards the South. The remaining parts of the Garo Hills consist of hill ranges running from north to south with elevations varying from 450 to 600 m.

The central and eastern parts of the plateau (Khasi and Jaintia hills regions) have a more even topography. This region of the plateau is characterized by many penne plain surfaces, flat-topped hills and numerous rivers. The highest point of the plateau is Shillong peak with an elevation of about 1965 m and this is the highest in the entire state.

The topography of the Khasi and Jaintia Hills can be characterized into the following three parts based on their physiographic characteristics:
1. The northern undulating hills,
2. The central upland zone and
3. The southern plateau.

The northern hills with an elevation ranging from 170 to 820 m generally slope towards the Brahmaputra river. It is almost flat above an elevation of 490 m. Some central and eastern upland areas with an average elevation of about 1500 m or more which cover more than one-third of the central and eastern region of Meghalaya and run from west to east and act as a watershed between Surma Valley in
Bangladesh and Brahmaputra Valleys in Assam. Steep slopes are seen in the southern parts of the central and eastern Meghalaya plateau which have significant orographic features.

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 Meghalaya 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:

\[
\text{Coefficient of variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100
\]
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 31% of south west monsoon rainfall in July month while the June month get 30% of the south west monsoon rainfall. August and September receive 23% and 17% of south west monsoon rainfall. Also 71% of annual rainfall receives during the southwest monsoon season only. The variability of monsoon or annual rainfall is also very less 21%.

<table>
<thead>
<tr>
<th></th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>JJAS</th>
<th>Annual</th>
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<tr>
<td><strong>Mean</strong></td>
<td>801.5</td>
<td>825.1</td>
<td>612.6</td>
<td>463.2</td>
<td>2702.4</td>
<td>3784.3</td>
</tr>
<tr>
<td><strong>CV</strong></td>
<td>33.0</td>
<td>40.2</td>
<td>40.4</td>
<td>46.2</td>
<td>24.9</td>
<td>21.5</td>
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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, southwest monsoon season and annual respectively. The trend lines are also displayed for each of the series. Monthly rainfall, seasonal and annual rainfall show significant decreasing trend. In the monthly rainfall, June and July rainfall show significant decreasing trend while August rainfall show increasing trend and September rainfall show decreasing trend. Both seasonal and annual rainfall show decreasing trend. During the last 30 years, highest rainfall of June and August received in the year 1995 (1728.4 mm, 1131.5 mm respectively), July in the year 2004 (1730.1 mm), and of September in the year 2007 (784.4 mm). Highest annual rainfall and southwest monsoon rainfall received in the year 1995 (5440.8 mm and 4566.1 mm 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 1 gives the rainfall statistics for the districts of Meghalaya for the four monsoon months, southwest monsoon season and annual while Fig. 4-5 show the spatial pattern of these statistics. It can be seen that three coastal districts viz., East Khasi Hills district receive highest rainfall over other districts during all the months and season. Rainfall receives over this district is around 1367 mm in June, 1431 mm in July, 949 mm in August, 630 mm in September and during the SW monsoon 4376 mm and annual 6019 mm. Lowest rainfall receives during the SW monsoon season over Ri-Bhoi district (1424.1 mm) while South Garo Hills district receives lowest annual rainfall (2024.1 mm).

<table>
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<tr>
<th>DISTRICT</th>
<th>JUNE</th>
<th>JULY</th>
<th>AUGUST</th>
<th>SEPTEMBER</th>
<th>MONSOON</th>
<th>ANNUAL</th>
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<tr>
<td></td>
<td>MEAN</td>
<td>CV</td>
<td>MEAN</td>
<td>CV</td>
<td>MEAN</td>
<td>CV</td>
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<tr>
<td>EAST GARO HILLS</td>
<td>638.7</td>
<td>40.4</td>
<td>689.9</td>
<td>53.5</td>
<td>599.6</td>
<td>70.5</td>
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<tr>
<td>WEST GARO HILLS</td>
<td>796.0</td>
<td>65.0</td>
<td>729.1</td>
<td>62.6</td>
<td>556.0</td>
<td>58.9</td>
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<tr>
<td>EAST KHASI HILLS</td>
<td>1366.5</td>
<td>39.9</td>
<td>1430.7</td>
<td>47.3</td>
<td>948.8</td>
<td>53.2</td>
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<tr>
<td>WEST KHASI HILLS</td>
<td>617.4</td>
<td>42.8</td>
<td>775.1</td>
<td>48.9</td>
<td>536.0</td>
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<td>JAITIA HILLS</td>
<td>1051.6</td>
<td>56.5</td>
<td>972.4</td>
<td>58.1</td>
<td>753.5</td>
<td>68.2</td>
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<td>RI-BHOI</td>
<td>347.4</td>
<td>40.9</td>
<td>390.7</td>
<td>48.0</td>
<td>366.7</td>
<td>37.0</td>
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<td>SOUTH GARO HILLS</td>
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<td>48.0</td>
<td>446.4</td>
<td>54.1</td>
<td>355.9</td>
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Table 2. Rainfall statistics for the districts of Meghalaya for the four monsoon months, southwest monsoon season and annual
Fig. 4 Mean rainfall pattern over districts of Meghalaya
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 districts West Khasi Hills and West Garo Hills while no district has shown any significant increasing trend. For the July and August months, significant decreasing trend has been noticed in Ri-Bhoi and West Garo Hills districts while September rainfall has not shown any significant trend. During the whole southwest monsoon season only one district viz. East Garo Hills has shown significant increasing trend. For the annual rainfall five districts viz. West Garo Hills, South Garo Hills, Ri Bhoi, West Jaintia Hills and East Jaintia Hills shows significant decreasing trend.
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 Meghalaya 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 18 to 20 days especially in parts of East Khasi Hills, West Khasi Hills, West Jaintia Hills and East Jaintia Hills districts. While minimum number of rainy days lies in the range of 12 to 14 days especially in East Garo Hills, South Garo Hills districts, some parts of North Garo Hills, West Garo Hills, Southwest Garo Hills, West Khasi hills and Southwest Khase Hills districts. Whereas in remaining districts, the number of rainy days lies in the range of 12 to 18 days.

Figure 8 shows that in the month of July the maximum number of rainy days lies in the range of 20 to 21 days especially in some parts of East Khasi Hills, West Khasi Hills, West Jaintia Hills, East Jaintia Hills and West Garo Hills districts. While minimum number of rainy days lies in the range of 15 to 17 days especially in East, South and North Garo Hills, and in some parts of district viz., Southwest Garo Hills; whereas in remaining districts, the number of rainy days lies in the range of 17 to 20 days.

Figure 9 shows that in the month of August the maximum number of rainy days lies in the range of 18 to 19 days especially in East Khasi Hills, West Khasi Hills, West Jaintia Hills and East Jaintia Hills districts. While minimum number of rainy days lies in the range of 13 to 15 days especially in North and East Garo Hills and in some parts of West, South, and Southwest Garo Hills, West Khasi Hills, West Jaintia Hills, Southwest Khase Hills and Ri Bhoidistricts. Whereas in remaining districts, the number of rainy days lies in the range of 15 to 18 days.

Figure 10 shows that in the month of September the maximum number of rainy days lies in the range of 14 to 16 days especially in some parts of East Khasi Hills, West Khasi Hills, West Jaintia Hills, East Jaintia Hills and West Garo Hills districts. While minimum number of rainy days lies in the range of 11 to 12 days especially in North and East Garo Hills and in some parts of West, South, and Southwest Garo Hills, West Khasi Hills, West Jaintia Hills, Southwest Khase Hills and Ri Bhoidistricts. Whereas in remaining districts, the number of rainy days lies in the range of 12 to 14 days.

Figure 11 shows that during June to September the maximum number of rainy days lies in the range of 68 to 73 days especially in some parts of East Khasi Hills, West Khasi Hills, West
Jaintia Hills and East Jaintia Hills districts. While minimum number of rainy days lies in the range of 49 to 54 days especially in East, North and South Garo Hills and in some parts of Southwest and West Garo Hills, West and Southwest Khasi Hills, East Jaintia Hills, West Jaintia Hills and Ri Bhoi districts. Whereas in remaining districts, the number of rainy days lies in the range of 54 to 68 days.

Figure 12 shows that during the entire year the maximum number of rainy days lies in the range of 105 to 114 days especially in some parts of East Khasi Hills, West Khasi Hills, West Jaintia Hills and East Jaintia Hills districts. While minimum number of rainy days lies in the range of 70 to 79 days especially in East, North and South Garo Hills and in some parts of West and Southwest Garo Hills, West, Southwest Khasi Hills and Ri Bhoi districts. Whereas in remaining districts, the number of rainy days lies in the range of 79 to 105 days.
5.2 Average frequency of Heavy rainfall days

The average frequency of Heavy rainfall days is calculated for Meghalaya 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 4 to 6 days especially in some parts of East Khasi Hills and West Jaintia Hills districts. While minimum number of Heavy rainfall days lies in the range of 1 to 2 days especially in North Garo Hills, Ri Bhoi and some parts of East, West and Southwest Khasi Hills, West Jaintia Hills and East Jaintia Hills, West, South, East, and Southwest Garo Hills districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 2 to 4 days.

Figure 14 shows that in the month of July the maximum number of heavy rainfall days lies in the range of 5 to 6 days especially in some parts of East Khasi Hills district. While minimum number of Heavy rainfall days lies in the range of 1 to 2 days especially in North Garo Hills, Ri Bhoi and some parts of East, West and Southwest Khasi Hills, West Jaintia Hills and East Jaintia Hills, West, South, East, and Southwest Garo Hills districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 2 to 5 days.

Figure 15 shows that in the month of August the maximum number of heavy rainfall days lies in the range of 3.4 to 4 days especially in some parts of East Khasi Hills district. While minimum number of Heavy rainfall days lies in the range of 0.8 to 1.5 days especially in North Garo Hills, Ri Bhoi and some parts of East, West and Southwest Khasi Hills, West Jaintia Hills and East Jaintia Hills, West, South, East, and Southwest Garo Hills districts. Whereas in
remaining districts, the number of Heavy rainfall days lies in the range of 1.5 to 3.4 days.

Figure 16 shows that during September the maximum number of heavy rainfall days lies in the range of 2 to 3 days especially in some parts of East Khasi Hills and West Jaintia Hills districts. While minimum number of Heavy rainfall days lies in the range of 0.6 to 1.0 days especially in North Garo Hills, Ri Bhoi and some parts of East, West and Southwest Khasi Hills, West Jaintia Hills and East Jaintia Hills, West, South, East, and Southwest Garo Hills districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 1 to 2 days.

Figure 17 shows that during June to September the maximum number of heavy rainfall days lies in the range of 14.2 to 16.9 days especially in some parts of East Khasi Hills district. While minimum number of Heavy rainfall days lies in the range of 1 to 6.2 days especially in North Garo Hills, Ri Bhoi and some parts of East, West and Southwest Khasi Hills, West Jaintia Hills and East Jaintia Hills, West, South, East, and Southwest Garo Hills districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 6.2 to 14.2 days.

Figure 18 shows that during the entire year the maximum number of heavy rainfall days lies in the range of 19.5 to 24 days especially in some parts of East Khasi Hills district. While minimum number of Heavy rainfall days lies in the range of 4 to 8.3 days especially in North Garo Hills, Ri Bhoi and some parts of East, West and Southwest Khasi Hills, West Jaintia Hills and East Jaintia Hills, West, South, East, and Southwest Garo Hills districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 8.3 to 19.5 days.
5.3 Average frequency of Dry days

The average frequency of dry days is calculated for Meghalaya 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 14 to 15 days especially in some parts of West, North, South, East, and Southwest Garo Hills, West and Southwest Khasi Hills districts. While minimum number of dry days lies in the range of 7 to 9 days especially in some parts of West, East Khasi Hills, West, East Jaintia Hills and Ri Bhoi districts. Whereas in remaining districts, the number of dry days lies in the range of 9 to 14 days.
Figure 20 shows that in the month of July the maximum number of dry days lies in the range of 11 to 13 days especially in South and East Garo Hills and in some parts of West, North and Southwest Garo Hills, West and Southwest Khasi Hills, West Jaintia Hills and Ri Bhoi districts. While minimum number of dry days lies in the range of 6 to 8 days especially in some parts of West, East Khasi Hills, West, East Jaintia Hills and Ri Bhoidistricts. Whereas in remaining districts, the number of dry days lies in the range of 8 to 11 days.

Figure 21 shows that in the month of August the maximum number of dry days lies in the range of 12.5 to 14 days especially in North, South and East Garo Hills and in some parts of West and Southwest Garo Hills, West and Southwest Khasi Hills, West Jaintia Hills and Ri Bhoi districts. While minimum number of dry days lies in the range of 8 to 9.5 days especially in some parts of West Garo Hills, West, East Khasi Hills, West and East Jaintia Hills districts. Whereas in remaining districts, the number of dry days lies in the range of 9.5 to 12.5 days.

Figure 22 shows that in the month of September the maximum number of dry days lies in the range of 15 to 16 days especially in North, South and East Garo Hills and in some parts of West and Southwest Garo Hills, West and Southwest Khasi Hills and Ri Bhoi districts. While minimum number of dry days lies in the range of 11 to 12.2 days especially in some parts of West, East Khasi Hills, West and East Jaintia Hills and Ri Bhoidistricts. Whereas in remaining districts, the number of dry days lies in the range of 12.2 to 15 days.

Figure 23 shows that during June to September, the maximum number of dry days lies in the range of 48.7 to 53 days especially in South and East Garo Hills and in some parts of West, Southwest and North Garo Hills, While minimum number of dry days lies in the range of 32 to 36.5 days especially in some parts of West, East Khasi Hills, West and East Jaintia Hills and Ri Bhoidistricts. Whereas in remaining districts, the number of dry days lies in the range of 36.5 to 48.7 days.

Figure 24 shows that during the entire year the maximum number of dry days lies in the range of 228.1 to 235 days especially in South Garo Hills and in some parts of West, East and Southwest Garo Hills, West, Southwest Khasi Hills districts. While minimum number of dry days lies in the range of 201 to 208.5 days especially in some parts of East Khasi Hills, West and East Jaintia Hills and Ri Bhoidistricts. Whereas in remaining districts, the number of dry days lies in the range of 208.5 to 228.1 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 raingauge stations of Meghalaya for June, July, August, September, June to September and Annual.

Figure 25 shows that in the month of June there is no significant increase or decrease in Rainy days in any district.

Figure 26 shows that in the month of July there is a significant decrease in Rainy days in stations in East Khasi Hills districts. While remaining districts did not show any significant change.

Figure 27 shows that in the month of August there is a significant decrease in Rainy days in stations in Ri Bhoi district. 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 South West Khasi Hills district. Whereas there is a significant decrease in Rainy days in stations in West Garo Hills and Ri Bhoi 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 decrease in Rainy days in stations in West Garo Hills, Ri Bhoi and East Khasi Hills districts. While remaining districts did not show any significant change.

Figure 30 shows that during the entire year there is a significant decrease in Rainy days in Ri Bhoi, East Khasi Hills and West Jaintia Hills 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 rainfall days is calculated for Meghalaya 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 South West Khasi Hills district. Whereas there is a significant decrease in Heavy rainfall days in West Jaintia Hills district. While remaining districts did not show any significant change.

Figure 32 shows that in the month of July there is a significant decrease in Heavy rainfall days in West Jaintia Hills district. 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 East Khasi Hills district. While remaining districts did not show any significant change.

Figure 34 shows that in the month of September there is a significant decrease in Heavy rainfall days in West Jaintia Hills district. While remaining districts did not show any significant change.

Figure 35 shows that during June to September there is a significant decrease in Heavy rainfall days in West Garo Hills and West Jaintia Hills districts. While remaining districts did not show any significant change.

Figure 36 shows that during the entire year there is a significant decrease in Heavy rainfall days in West Garo Hills and West Jaintia Hills 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 Meghalaya for June, July, August, September, June to September and Annual.

Figure 37 and 38 shows that in the month of June and July respectively there is no significant increase or decrease in dry days in any district.

Figure 39 shows that in the month of August there is a significant increase in dry days in East Khasi Hills and Ri Bhoi districts. Whereas there is a significant decrease in dry days in West Garo Hills and East Khasi Hills districts. 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 Ri Bhoi district. Whereas there is a significant decrease in dry days in West Khasi Hills and South West Khasi Hills districts. While remaining districts did not show any significant change.

Figure 41 shows that in the month of June to September there is a significant increase in dry days in East Khasi Hills district. Whereas there is a significant decrease in dry days in East, West Khasi Hills, West Garo Hills and West Jaintia Hills districts. While remaining districts did not show any significant change.

Figure 42 shows that during the entire year there is a significant increase in dry days in East Khasi Hills district. Whereas there is a significant decrease in dry days in East, West Khasi Hills, West Garo Hills and West Jaintia Hills districts. While remaining districts did not show any significant change.
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:

- Meghalaya gets maximum rainfall in July (31% of SW monsoon rainfall) followed by June (30% of SW monsoon rainfall).

- 71% of Annual rainfall receives during southwest monsoon rainfall (June–September).

- South Garo Hills district receive 74.3% of Annual rainfall in SW monsoon season while Ri Bhoi district receive 67.2% of Annual rainfall in SW monsoon season.

- It can be seen that June rainfall has shown significant decreasing trend in the district West Khasi Hills and West Garo Hills while no district has shown any significant increasing trend. For the July and August months, significant decreasing trend has been noticed in Ri-Bhoi and West Garo Hills district while September rainfall has not shown any significant trend.

- During the whole southwest monsoon season only one district viz. East Garo Hills has shown significant increasing trend. For the annual rainfall five districts viz. West Garo Hills, South Garo Hills, Ri Bhoi, West Jaintia Hills and East Jaintia Hills shows significant decreasing trend.

- Maximum rainfall received during the SW monsoon in East Khasi Hills (4376 mm) while Ri Bhoi district received lowest rainfall (1424 mm).

- Maximum rainfall received during the entire year in East Khasi Hills (6019 mm) while South Garo Hills district received lowest rainfall (2024 mm).
Significant decreasing trend in SW monsoon rainfall has been noticed in West Garo Hills and West Jaintia Hills districts while no district shows significant increasing trend.

In annual rainfall, significant decreasing trend has been noticed in West Garo Hills and West Jaintia Hills districts while no district shows significant increasing trend.

Some parts of East, West Khasi Hills and East, West Jaintia Hills districts received on an average 68-73 rainy days (daily rainfall >=2.5mm) out of 122 days of SW monsoon season while East, North and South Garo Hills districts and in some parts of districts viz., Southwest and West Garo Hills, West and Southwest Khasi Hills, East Jaintia Hills, West Jaintia Hills and Ri Bhoi gets 49-54 rainy days.

For heavy to extremely heavy rainfall (daily rainfall >=6.5mm) East Khasi Hills district gets 14-17 days during the SW monsoon season, whereas North Garo Hills, Ri Bhoi and some parts of East, West and Southwest Khasi Hills, West Jaintia Hills and East Jaintia Hills, West, South, East, and Southwest Garo Hills districts get around 1-6 heavy to extremely heavy rainfall days.

Number of dry days is maximum over South and East Garo Hills and in some parts of West, Southwest and North Garo Hills (49-53) dry days out of 122 days during the SW monsoon season while on an average (228-235) dry days in 365 days have been noticed in South Garo Hills and in some parts of West, East and Southwest Garo Hills, West, Southwest Khasi Hills districts of Meghalaya.

During the period June to September there is a significant decrease in Rainy days in West Garo Hills, Ri Bhoi and East Khasi Hill districts.

During the entire year there is a significant decrease in Rainy days in Ri Bhoi, East Khasi Hills and West Jaintia Hills districts.

During the period June to September there is a significant decrease in Heavy rainfall days in West Garo Hills and West Jaintia Hills districts.

During the entire year there is a significant decrease in Heavy rainfall days in West Garo Hills and West Jaintia Hills districts.
During June to September there is a significant increase in dry days in East Khasi Hills district. Whereas there is a significant decrease in dry days in East, West Khasi Hills, West Garo Hills and West Jaintia Hills districts.

During the entire year there is a significant increase in dry days in East Khasi Hills district. Whereas there is a significant decrease in dry days in East, West Khasi Hills, West Garo Hills and West Jaintia Hills districts.
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References:

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 its districts as well as extreme rainfall event of different intensity of stations are analysed.