Observed Rainfall Variability and Changes over Arunachal Pradesh State
Observed Rainfall Variability and Changes Over Arunachal Pradesh State

Pulak Guhathakurta, Shirish Khedikar, Preetha Menon, Ashwini Kumar Prasad, Neha Sangwan and S C Advani
<table>
<thead>
<tr>
<th>1</th>
<th>Document Title</th>
<th>Observed Rainfall Variability and Changes Over Arunachal Pradesh State</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Issue No.</td>
<td>ESSO/IMD/HS/Rainfall Variability/02(2020)/26</td>
</tr>
<tr>
<td>3</td>
<td>Issue Date</td>
<td>January 2020</td>
</tr>
<tr>
<td>4</td>
<td>Security</td>
<td>Unclassified</td>
</tr>
<tr>
<td></td>
<td>Classification</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Control Status</td>
<td>Uncontrolled</td>
</tr>
<tr>
<td>6</td>
<td>Document Type</td>
<td>Scientific Publication</td>
</tr>
<tr>
<td>7</td>
<td>No. of Pages</td>
<td>27</td>
</tr>
<tr>
<td>8</td>
<td>No. of Figures</td>
<td>42</td>
</tr>
<tr>
<td>9</td>
<td>No. of References</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Distribution</td>
<td>Unrestricted</td>
</tr>
<tr>
<td>11</td>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>12</td>
<td>Authors</td>
<td>Pulak Guhathakurta, Shirish Khedikar, Preetha Menon, Ashwini Kumar Prasad, Neha Sangwan and S C Advani</td>
</tr>
<tr>
<td>13</td>
<td>Originating Division/Group</td>
<td>Climate Research Division/ Climate Application &amp; User Interface Group/ Hydrometeorology</td>
</tr>
<tr>
<td>14</td>
<td>Reviewing and Approving Authority</td>
<td>Director General of Meteorology, India Meteorological Department, New Delhi</td>
</tr>
<tr>
<td>15</td>
<td>End users</td>
<td>Central and State Ministries of Water resources, agriculture and civic bodies, Science and Technology, Disaster Management Agencies, Planning Commission of India</td>
</tr>
<tr>
<td>16</td>
<td>Abstract</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>
</tr>
<tr>
<td>17</td>
<td>Key Words</td>
<td>Rainfall trend, variability, extreme events, dry days</td>
</tr>
</tbody>
</table>
1. Introduction

Arunachal Pradesh is situated in the northeastern part of India in the eastern Himalayas. The state is located between 26°30’N and 29°30’N latitude and 91°30’E and 97°30’E longitude with an area of 83,743 km². It is bounded by Myanmar to the east (440 km), China (1080 km), to the north and northeast, Bhutan to the west (160 km) and Assam to the south. The low region of Arunachal Pradesh bordering Assam is a part of the plains of Brahmaputra river in the south. The state is mostly mountainous where the altitude is up to about 7,090 metres above mean sea level with several high hills along the northern borders criss-crossed with ranges running north-south. The extreme north and northeastern regions are covered with snow throughout the year however, general tendency of hills is found sloping towards the plains of Assam. The state is mostly covered by several hills of elevation more than 2000 m, being high hills - Kangte, Nyegi Kangsang, Gorichen, Eastern Gorichen, Patkai etc. However, parts of Lohit, Changlang and Tirap districts are covered by the Patkai hill. All districts of the state have hills of peak height more than 2500 m. Wild jungles with hilly terrain remain throughout 82% of total areas of state, rock and snow about 8%, leaving a modest 10% in towns and farm-land.

The topography of Arunachal Pradesh is characterized by an undulating hilly terrain, enchanting river valleys and majestic peaks. There is a wide variation in the topography of land with elevation from 150 m to 7090 m above mean sea level. The climate within the state varies from place to place due to significant variation in elevation and topography.

There are 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 the state Arunachal Pradesh. 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 station are computed and then monthly district rainfall series has been constructed by considering arithmetic average of all the station rainfall values within the district. Fig.1 gives the location of the districts of the state. The monthly rainfall series of the state has been computed by using area weighted rainfall values of all the districts within 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 Arunachal Pradesh**

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 June month get 28% of the south west monsoon rainfall. August and September receive 22% and 21% of south west monsoon rainfall. Also more than 64% of annual rainfall receives during the southwest monsoon season only. The variability of monsoon rainfall is 22% while in annual is 17%.
Table 1 Mean rainfall (mm) and coefficient of variation of the state for the monsoon months, southwest monsoon season and annual

<table>
<thead>
<tr>
<th></th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>JJAS</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>485.6</td>
<td>526.8</td>
<td>389.0</td>
<td>360.9</td>
<td>1762.3</td>
<td>2741.6</td>
</tr>
<tr>
<td><strong>C V</strong></td>
<td>30.3</td>
<td>31.0</td>
<td>37.5</td>
<td>34.7</td>
<td>21.7</td>
<td>16.8</td>
</tr>
</tbody>
</table>

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. Only June and annual rainfall shows significant decreasing trend while rest of the months and seasonal rainfall not showing any significant increasing/decreasing trend. All months along with seasonal and annual rainfall show decreasing trend.

During the last 30 years highest rainfall of July, August and Monsoon season received in the year 1998 (806.1 mm, 776.4 mm and 2626.4 mm respectively) while highest rainfall June and annual received in the year 1990 (857.2 mm and 3604 mm respectively). Whereas, the highest rainfall for September month (693.3 mm) is received in the year 2012.
4. **District rainfall mean, variability and trend**

4.1 **Mean and coefficient of variation**

Table 2 gives the rainfall statistics for the districts of Arunachal Pradesh 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 for all the monsoon months, Monsoon season and Annual rainfall the districts viz. East Siang and Lower Dibang Valley receive highest rainfall over all the other districts of the state.

Rainfall receives over these districts are around 640-770 mm in June, 845-1000 mm in July, 530-630 mm in August, 480-580 mm in September and during the SW monsoon 2500-3000 mm and annual 3550-4500 mm.

Lowest rainfall during SW monsoon season (460.9 mm) as well as during annual rainfall (845.5 mm) received over Lower Subansiri district. Thus there is large spatial variability of rainfall in south west monsoon as well as annual rainfall in the central part of the state itself with lowest rainfall value of the state receives at the western part while highest rainfall value of the state being
received at the eastern parts of central Arunachal Pradesh. Except for the districts like Dibang Valley, Papu Pare, Upper Siang and Upper Subansiri (where June rainfall is highest among the monsoon months) July is the highest rain receiving month.

<table>
<thead>
<tr>
<th>DISTRICT</th>
<th>JUNE MEAN</th>
<th>JUNE CV</th>
<th>JULY MEAN</th>
<th>JULY CV</th>
<th>AUGUST MEAN</th>
<th>AUGUST CV</th>
<th>SEPTEMBER MEAN</th>
<th>SEPTEMBER CV</th>
<th>MONSOON MEAN</th>
<th>MONSOON CV</th>
<th>ANNUAL MEAN</th>
<th>ANNUAL CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anjaw</td>
<td>270.7</td>
<td>50.9</td>
<td>294.6</td>
<td>51.3</td>
<td>198.5</td>
<td>62.0</td>
<td>159.6</td>
<td>62.3</td>
<td>923.5</td>
<td>50.3</td>
<td>2235.5</td>
<td>52.6</td>
</tr>
<tr>
<td>Changlang</td>
<td>356.4</td>
<td>34.9</td>
<td>447.3</td>
<td>41.3</td>
<td>341.3</td>
<td>41.3</td>
<td>280.9</td>
<td>45.4</td>
<td>1425.9</td>
<td>36.3</td>
<td>2381.4</td>
<td>37.0</td>
</tr>
<tr>
<td>Dibang Valley</td>
<td>227.3</td>
<td>69.8</td>
<td>187.8</td>
<td>78.2</td>
<td>208.4</td>
<td>58.0</td>
<td>163.0</td>
<td>52.2</td>
<td>786.6</td>
<td>53.4</td>
<td>1932.5</td>
<td>47.4</td>
</tr>
<tr>
<td>East Kameng</td>
<td>347.0</td>
<td>61.0</td>
<td>370.7</td>
<td>69.2</td>
<td>286.3</td>
<td>68.3</td>
<td>266.3</td>
<td>60.6</td>
<td>1270.3</td>
<td>64.1</td>
<td>1800.0</td>
<td>62.4</td>
</tr>
<tr>
<td>East Siang</td>
<td>772.0</td>
<td>44.3</td>
<td>1019.6</td>
<td>48.1</td>
<td>630.5</td>
<td>61.2</td>
<td>567.4</td>
<td>47.4</td>
<td>2989.5</td>
<td>36.8</td>
<td>4165.9</td>
<td>46.7</td>
</tr>
<tr>
<td>Kurung Kumey*</td>
<td>292.5</td>
<td>52.8</td>
<td>403.8</td>
<td>53.6</td>
<td>276.2</td>
<td>43.1</td>
<td>283.6</td>
<td>62.4</td>
<td>1208.7</td>
<td>35.2</td>
<td>2023.7</td>
<td>37.6</td>
</tr>
<tr>
<td>Lohit</td>
<td>378.0</td>
<td>33.9</td>
<td>465.0</td>
<td>37.7</td>
<td>353.7</td>
<td>43.6</td>
<td>304.5</td>
<td>49.1</td>
<td>1501.3</td>
<td>27.2</td>
<td>2479.4</td>
<td>38.3</td>
</tr>
<tr>
<td>Lower Dibang Valley</td>
<td>723.8</td>
<td>55.6</td>
<td>968.2</td>
<td>51.4</td>
<td>589.2</td>
<td>72.9</td>
<td>579.1</td>
<td>71.2</td>
<td>2860.3</td>
<td>46.6</td>
<td>4442.4</td>
<td>50.9</td>
</tr>
<tr>
<td>Lower Subansiri</td>
<td>113.6</td>
<td>61.2</td>
<td>146.7</td>
<td>59.6</td>
<td>124.9</td>
<td>56.9</td>
<td>75.8</td>
<td>55.8</td>
<td>460.9</td>
<td>53.4</td>
<td>845.5</td>
<td>51.8</td>
</tr>
<tr>
<td>Papum Pare</td>
<td>696.0</td>
<td>46.4</td>
<td>612.6</td>
<td>51.3</td>
<td>507.8</td>
<td>52.1</td>
<td>434.6</td>
<td>57.1</td>
<td>2251.0</td>
<td>49.2</td>
<td>3353.6</td>
<td>51.4</td>
</tr>
<tr>
<td>Tawang</td>
<td>207.7</td>
<td>54.5</td>
<td>313.4</td>
<td>58.7</td>
<td>274.8</td>
<td>51.8</td>
<td>216.2</td>
<td>51.9</td>
<td>1012.1</td>
<td>52.9</td>
<td>1759.2</td>
<td>51.7</td>
</tr>
<tr>
<td>Tirap</td>
<td>523.0</td>
<td>68.2</td>
<td>533.3</td>
<td>61.8</td>
<td>453.8</td>
<td>66.3</td>
<td>294.9</td>
<td>62.1</td>
<td>1805.0</td>
<td>58.5</td>
<td>2619.0</td>
<td>53.8</td>
</tr>
<tr>
<td>Upper Siang</td>
<td>502.4</td>
<td>66.1</td>
<td>449.6</td>
<td>65.9</td>
<td>303.9</td>
<td>80.5</td>
<td>433.9</td>
<td>77.9</td>
<td>1689.9</td>
<td>66.7</td>
<td>3201.8</td>
<td>54.5</td>
</tr>
<tr>
<td>Upper Subansiri</td>
<td>258.8</td>
<td>58.5</td>
<td>243.7</td>
<td>62.0</td>
<td>186.5</td>
<td>63.6</td>
<td>205.0</td>
<td>80.6</td>
<td>894.0</td>
<td>58.6</td>
<td>1491.7</td>
<td>53.7</td>
</tr>
<tr>
<td>West Kameng</td>
<td>566.0</td>
<td>60.9</td>
<td>574.6</td>
<td>56.4</td>
<td>500.3</td>
<td>58.7</td>
<td>450.7</td>
<td>62.8</td>
<td>2091.6</td>
<td>50.5</td>
<td>2813.6</td>
<td>49.9</td>
</tr>
<tr>
<td>West Siang</td>
<td>516.8</td>
<td>58.8</td>
<td>589.5</td>
<td>67.5</td>
<td>374.5</td>
<td>62.8</td>
<td>370.7</td>
<td>55.5</td>
<td>1851.5</td>
<td>57.1</td>
<td>2744.1</td>
<td>50.0</td>
</tr>
</tbody>
</table>

*Based on data for the period 1966-1985

Table 2. Rainfall statistics for the districts of Arunachal Pradesh for the four monsoon months, southwest monsoon season and annual
Fig. 4 Mean rainfall pattern over districts of Arunachal Pradesh
Fig. 5 Coefficient of Variation (%) over districts of Arunachal Pradesh
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 such as West Kameng, East Kameng, Lower Subansiri, West Siang, Central Siang, Dibang Valley, Changlang, Tirap and Longding while only Upper Siang district has shown significant increasing trend.

For the July month significant increasing trend has been noticed in Upper Siang, Lower Subansiri and Papum Pare districts while Siang, West Siang, Lower Subansiri, East Kameng, West Kameng, Tirap and Longding districts shown significant decreasing trend.

During August month significant increasing trend has been noticed in Dibang Valley and Upper Siang districts, while Siang, West Siang, West Kameng, Tirap and Longding districts shown significant decreasing trend.

In September month only Upper Siang district have shown significant increasing trend in rainfall whereas West Kameng, East Kameng, Tirap and Longding districts has shown significant decreasing trend.

But in case of whole southwest monsoon season only two districts viz Upper Siang and Upper Subansiri have shown significant increasing trend, whereas West Kameng, East Kameng, Papum Pare, Lower Subansiri, West Siang, Central Siang, Changlang Tirap and Longding districts has shown significant decreasing trend.

For the annual rainfall four districts viz. Upper Siang, Upper Subansiri, Lower Dibang Valley and Tawang show significant increasing trend while West Kameng, East Kameng, Papum Pare, Lower Subansiri, West Siang, Central Siang, Changlang Tirap and Longding districts showed 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 Arunachal Pradesh 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 16 to 18 days especially in some parts of East Kameng, Papum Pare, East Siang and Lohit districts. While minimum number of rainy days lies in the range of 11 to 12 days especially in some parts of Tawang, Kurung Kumey, Kra Daadi, Upper Subansiri, West Siang, Upper Siang and Dibang Valley districts. Whereas in remaining districts, the number of rainy days lies in the range of 12 to 16 days.

Figure 8 shows that in the month of July the maximum number of rainy days lies in the range of 19 to 20 days especially in some parts of East Kameng, Papum Pare, East Siang and Lohit districts. While minimum number of rainy days lies in the range of 14 to 16 days especially in some parts of West Kameng, Tawang, Kurung Kumey, Kra Daadi, Upper Subansiri, West Siang, Upper Siang and Dibang Valley districts. Whereas in remaining districts, the number of rainy days lies in the range of 16 to 19 days.

It can be inferred from the figure 9 that in the month of August the maximum number of rainy days lies in the range of 15 to 17 days especially in some parts of Lohit, Changlang and Papum Pare districts. While minimum number of rainy days lies in the range of 12 to 13 days only in part of Upper Siang districts. Whereas in remaining districts, the number of rainy days lies in the range of 13 to 15 days.

Figure 10 shows that in the month of September the maximum number of rainy days lies in the range of 13 to 14 days especially in some parts of East Kameng, Papum Pare and East Siang districts. While minimum number of rainy days lies in the range of 10 to 11 days especially in some parts of West Kameng, Tawang, Kurung Kumey, Kra Daadi, Upper Subansiri, Anjaw, West Siang, Upper Siang and Dibang Valley districts. Whereas in remaining districts, the number of rainy days lies in the range of 11 to 13 days.

During June to September the maximum number of rainy days lies in the range of 57 to 61 days especially in some parts of East Siang and Lohit districts and that is shown in figure 11. While minimum number of rainy days lies in the range of 41 to 45 days especially in some parts of Upper Siang, Siang and Tawang districts. Whereas in remaining districts, the number of rainy days lies in the range of 45 to 57 days.
Figure 12 shows that during the entire year the maximum number of rainy days lies in the range of 102 to 111 days especially in some parts of East Siang, Lohit and Changlang districts. While minimum number of rainy days lies in the range of 68 to 77 days especially in some parts of Tawang, West Kameng, Kurung Kumei, Kra Daadi, Upper Subansiri, West Siang, Siang, Upper Siang and Dibang Valley districts. Whereas in remaining districts, the number of rainy days lies in the range of 77 to 102 days.
5.2 Average frequency of Heavy rainfall days

The average frequency of Heavy rainfall days is calculated for Arunachal Pradesh 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 1.8 to 2.1 days especially in some parts of East Siang and Papum Pare districts. While minimum number of Heavy rainfall days lies in the range of 0.6 to 0.9 days especially in some parts of West Siang, Siang, Upper Siang, Dibang Valley, Anjaw, Changlang, Tirap and Longding districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.9 to 1.8 days.

Figure 14 shows that in the month of July the maximum number of heavy rainfall days lies in the range of 2.4 to 3 days especially in some parts of East Siang and Lohit districts. While minimum number of Heavy rainfall days lies in the range of 0.9 to 1.3 days especially in some parts of Tawang, East Kameng, Kurung Kumey, Kra Daadi, Upper Subansiri, West Siang, Siang, Upper Siang, Dibang Valley, Anjaw, Changlang, Tirap and Longding districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 1.3 to 2.4 days.

It can be observed from figure 15 that in the month of August the maximum number of heavy rainfall days lies in the range of 1.6 to 2 days especially in some parts of East Siang district. While minimum number of Heavy rainfall days lies in the range of 0.5 to 0.8 days especially in some parts of Upper Siang and Anjaw districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.8 to 1.6 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 East Siang and Lohit districts. While minimum number of Heavy rainfall days lies in the range of 0.3 to 0.6 days especially in some parts of Upper Siang and Anjaw districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 0.6 to 1.5 days.

The maximum number of heavy rainfall days during June to September lies in the range of 7 to 8 days that especially in some parts of East Siang and Lohit districts, shown in figure 17. While minimum number of Heavy rainfall days lies in the range of 3 to 5 days especially in some parts of Longding, Upper Siang and Anjaw districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 3 to 9 days.

Figure 18 shows that during the entire year the maximum number of heavy rainfall days lies in the range of 8.4 to 10 days especially in some parts of East Siang and Lohit districts. While minimum number of Heavy rainfall days lies in the range of 3 to 4.8 days especially in some parts of Tawang, East Kameng, Kurung Kumey, Kra Daadi, Upper Subansiri, West Siang, Siang, Upper Siang, Dibang Valley, Anjaw, Changlang, Tirap and Longding districts. Whereas in remaining districts, the number of Heavy rainfall days lies in the range of 1.3 to 2.4 days.

Fig. 13 Average frequency of heavy rainfall days: June
Fig. 14 Average frequency of heavy rainfall days: July
5.3 Average frequency of Dry days

The average frequency of dry days is calculated for the raingauge stations of Arunachal Pradesh 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 15 to 17 days especially in some parts of Kurung Kumey, Kra Daadi, Upper Subansiri, West Siang, Siang, Upper Siang, Dibang Valley and Anjaw districts. While minimum number of dry days lies in the range of 9 to 11 days especially in some parts of Papum Pare, East Siang and Changlang districts. Whereas in remaining districts, the number of dry days lies in the range of 11 to 15 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 Tawang, Kurung Kumey, Kra Daadi, Upper Subansiri,
West Siang, Siang, Upper Siang, Dibang Valley and Anjaw districts. While minimum number of dry days lies in the range of 8 to 10 days especially in some parts of Papum Pare, East Siang and Changlang districts. Whereas in remaining districts, the number of dry days lies in the range of 10 to 12 days.

It can be seen from figure 21, in the month of August the maximum number of dry days lies in the range of 15 to 16 days especially in some parts of Upper Siang and Lohit districts. While minimum number of dry days lies in the range of 11 to 12 days especially in some parts of Papum Pare, East Siang and Changlang districts. Whereas in remaining districts, the number of dry days lies in the range of 12 to 15 days.

Figure 22 shows that in the month of September the maximum number of dry days lies in the range of 17 to 18 days especially in some parts of Dibang Valley, Lower Dibang Valley, Anjaw and Lohit districts. While minimum number of dry days lies in the range of 13 to 15 days especially in some parts of Papum Pare, East Siang and Changlang districts. Whereas in remaining districts, the number of dry days lies in the range of 15 to 17 days.

As can be seen from figure 23 that during June to September the maximum number of dry days lies in the range of 54 to 58 days especially in some parts of Kurung Kumey, Kra Daadi, Upper Subansiri, West Siang, Upper Siang, Dibang Valley, Anjaw and Lohit districts. While minimum number of dry days lies in the range of 39 to 43 days especially in some parts of Papum Pare, Upper Siang, East Siang and Changlang districts. Whereas in remaining districts, the number of dry days lies in the range of 43 to 54 days.

Figure 24 shows that in the month of during the entire year the maximum number of dry days lies in the range of 228 to 239 days especially in some parts of Tawang, West Kameng, East Kameng, Kurung Kumey, Kra Daadi, Upper Subansiri, West Siang, Upper Siang, Dibang Valley, Anjaw, Lower Dibang Valley and Lohit districts. While minimum number of dry days lies in the range of 185 to 196 days especially only in some parts of Upper Siang district. Whereas in remaining districts, the number of dry days lies in the range of 196 to 228 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 Arunachal Pradesh for June, July, August, September, June to September and Annual. Figure 25 shows that in the month of June there is no significant increase in Rainy days in any station, but there is a significant decrease in Rainy days is observed in station in only in Upper Siang district. While remaining districts did not show any significant change.

Figure 26 shows that in the month of July there is no significant increase or decrease in Rainy days is observed in any station.

In the month of August (figure 27) there is a significant increase in Rainy observed in station coming in Lohit district, but there is a no significant decrease in Rainy days is observed in any station.

Figure 28 shows that in the month of September there is no significant increase in Rainy days in any station, but there is a significant decrease in Rainy days is observed in station in only in East Kameng district. While remaining districts did not show any significant change.

As depicted in figure 29 in the month of June to September there is no significant increase in Rainy days in any station, but there is a significant decrease in Rainy days is observed in station in Upper Siang, Anjaw, Lohit, Namsai and Changlang district.

Figure 30 shows that in the month of during the entire year there is no significant increase in Rainy days in any station, but there is a significant decrease in Rainy days is observed in station in East Kameng, Upper Siang, Anjaw, Lohit, Namsai and Changlang district.
6.2 Trend in frequency of Heavy rainfall days

The Trend in frequency of Heavy days is calculated for Arunachal Pradesh for June, July, August, September, June to September and Annual. Figure 31 shows that in the month of June there is no significant increase in Heavy rainfall days in district. Whereas there is a significant decrease in Heavy days only in East Kameng district.

In the month of July there is significant increase in Heavy rainfall days only in Papum Pare district. Whereas there is no significant decrease in Heavy days observed in any district and that can be observed from figure 32.
In the month of August (Figure 33) there is significant increase in Heavy rainfall days only in Lohit district. Whereas there is no significant decrease in Heavy days observed in any district.

Figure 34 shows that in the month of September there is significant increase in Heavy rainfall days only in Upper Siang district. Whereas there is a significant decrease in Heavy days only in East Kameng district.

During June to September there is no significant increase in Heavy rainfall days in district. Whereas there is a significant decrease in Heavy days in East Kameng and Changlang districts and that is presented in the figure 35.

Figure 36 shows that in the month of during the entire year there is no significant increase in Heavy rainfall days in district. Whereas there is a significant decrease in Heavy days only in East Kameng district.
The Trend in frequency of dry days is calculated for Arunachal Pradesh 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 only in East Kameng district. Whereas there is no significant decrease in dry days in any districts.

In the month of July (figure 38) there is a neither significant increase nor significant decrease in dry days observed in any district.

In the month of August there is a significant increase in dry days only in East Kameng district. Whereas there is no significant decrease in dry days in any districts and that shown in figure 39.

Figure 40 shows that in September there is a significant increase in dry days only in East Kameng district. Whereas there is no significant decrease in dry days in any districts.

During the period June to September (Figure 41) there is a significant increase in dry days only in East Kameng district. Whereas there is a significant decrease in dry days in Upper Siang and Anjaw 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 only in East Siang district. Whereas there is a significant decrease in dry days in Upper Siang and Anjaw 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:

- Arunachal Pradesh gets maximum rainfall in July (30% of SW monsoon rainfall) followed by June (28% of SW monsoon rainfall).
- 64% of annual rainfall receives during southwest monsoon rainfall (June – September).
- East Siang and West Kameng districts receive 72-74% of annual rainfall in SW monsoon season while Anjaw and Dibang Valley districts receive 40-41% of annual rainfall in SW monsoon season.
- Only June month shows significant decreasing trend while rest of the months not showing any significant increasing/decreasing trend.
- Maximum rainfall receive during the SW monsoon season over the West Kameng district (2092 mm) while Dibang Valley district receive lowest rainfall (787 mm).
- Maximum rainfall receive during the year over the districts in Lower Dibang Valley district (4442 mm) while Lower Subansiri district receives lowest annual rainfall of 846 mm.
- During SW monsoon rainfall only two districts viz Upper Siang and Upper Subansiri has shown significant increasing trend, whereas West Kameng, East Kameng, Papum Pare, Kurung Kumey, Kra Daadi, Lower Subansiri, West Siang, Central Siang, Changlang Tirap and Longding districts has shown significant decreasing trend.
In annual rainfall four districts viz. Upper Siang, Upper Subansiri, Lower Dibang Valley and Tawang show significant increasing trend while West Kameng, East Kameng, Papum Pare, Kurung Kumey, Kra Daadi, Lower Subansiri, West Siang, Central Siang, Changlang Tirap and Longding districts showed significant decreasing trend.

Some parts of East Siang and Lohit districts receive on an average 57-61 rainy days (daily rainfall ≥2.5mm) out of 122 days of SW monsoon season while some parts of Upper Siang, Siang and Tawang districts gets 41-45 rainy days.

For heavy to extremely heavy rainfall (daily rainfall ≥6.5mm) some parts of East Siang and Lohit districts gets 7-8 days during the SW monsoon season, while some parts of Longding, Upper Siang and Anjaw districts get around 3-5 heavy to extremely heavy rainfall days.

Number of dry days is maximum over some parts of Kurung Kumey, Kra Daadi, Upper Subansiri, West Siang, Upper Siang, Dibang Valley, Anjaw and Lohit districts (54-58 dry days out of 122 days) during the SW monsoon season, while on an average 228-239 dry days in 365 days have been noticed in some parts of Tawang, West Kameng, East Kameng, Kurung Kumey, Kra Daadi, Upper Subansiri, West Siang, Upper Siang, Dibang Valley, Anjaw, Lower Dibang Valley and Lohit districts of Arunachal Pradesh.

During the period June to September there is no significant increase in Rainy days in any station, but there is a significant decrease in Rainy days is observed in station in Upper Siang, Anjaw, Lohit, Namsai and Changlang district.

During the entire year there is no significant increase in Rainy days in any station, but there is a significant decrease in Rainy days is observed in station in East Kameng, Upper Siang, Anjaw, Lohit, Namsai and Changlang district.

During the period June to September there is no significant increase in Heavy rainfall days in district. Whereas there is a significant decrease in Heavy days in East Kameng and Changlang districts.
During the entire year there is no significant increase in Heavy rainfall days in district. Whereas there is a significant decrease in Heavy days only in East Kameng district.

During June to September there is a significant increase in dry days only in East Kameng district. Whereas there is a significant decrease in dry days in Upper Siang and Anjaw districts. While remaining districts did not show any significant change.

During the entire year there is a significant increase in dry days only in East Siang district. Whereas there is a significant decrease in dry days in Upper Siang and Anjaw districts. While remaining districts did not show any significant change.
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.

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 it’s districts as well as extreme rainfall event of different intensity of stations are analysed.