Observed Rainfall Variability and Changes over Nagaland State

Pulak Guhathakurta, Sakharam Sanap, Preetha Menon, Ashwini Kumar Prasad, Neha Sangwan and S C Advani
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<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>
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<td>17</td>
<td>Key Words</td>
<td>Rainfall trend, variability, extreme events, dry days</td>
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1. Introduction

Nagaland state is situated in the extreme northeastern part of India. The state lies between 25°06’N and 27°04’N latitudes, and between 93°20’E and 95°15’E longitudes having an area of 16,579 sq.km. Nagaland is bounded by Arunachal Pradesh and part of Assam on the north, Manipur on the south, Assam on the west and Myanmar country on the east. The state is mostly mountainous except those plain areas bordering Assam valley. The plain area of low elevation in the state is limited to Dimapur and some part of Peren, Wokha, Mokokchung, Longleng and Mon districts adjoining areas with Assam state. The capital of Nagaland is Kohima situated at an elevation of about 1400 meters above mean sea level. The topography of the state is much dissected, full of hill ranges, which break into a wide chaos of spurs and ridges. The Naga Hills rise from Assam border in to about 600 m and further rise to the southeast, where Mount Saramati in Kiphire and Tuensang districts has high elevation. The highest peak in the state is about 3840 m at Mount Saramati in Kiphire district. The Naga Hills merge with the Patkairange of Myanmar. The other hill’s peaks in Nagaland are Japfu (3014 m) in Kohima district, Mol Len (3104 m) and Kupamedzu (2620 m) both in Phek district. The hilly terrain is mostly covered with dense trees and plants.

Nagaland state is drained by a number of seasonal and perennial rivers. The major rivers of Nagaland are Doyang, Dikhu, Dhansiri, Tizu, Jhanji, Nanung, Tsurong or Disai, Tsumok, Menung, Dzu, Langlong, Zunki, Likimro, Lanye, Dzuza, Milak Manglu etc. The state is mostly covered by the first four major rivers. Dhansiri, Doyang and Dikhu flow northward in the state and merge into the Brahmaputra. While Tizu river flows towards east and joins the Chindwin river in Myanmar.

Many studies are 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). There are limited studies available for the Nagaland 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 the analysis of trend variability and mean rainfall patterns. From the daily rainfall data monthly rainfall series of each stations are computed. 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. 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:

\[
\text{Coefficient of variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100
\]
2. State rainfall mean and variability and trend

Table 1 shows the mean rainfall (mm) and coefficient of variation for monsoon months (June, July, August and September), southwest monsoon season and annual for the period 1989-2018. Contribution of the July month to SW monsoon seasonal rainfall is highest (30 %), followed by August (27 %), June (24 %) and September (19 %) and. About 68 % of the annual rainfall is received in SW monsoon season only. The variability of SW monsoon and annual rainfall is 24.5 and 23.1 % respectively.

<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>Mean</td>
<td>259.1</td>
<td>330.9</td>
<td>303.3</td>
<td>232.7</td>
<td>1126.0</td>
<td>1664.6</td>
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<tr>
<td>CV</td>
<td>35.8</td>
<td>29.4</td>
<td>32.5</td>
<td>39.1</td>
<td>24.5</td>
<td>23.1</td>
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Table 1. Nagaland state mean rainfall (mm) and coefficient of variation (%) for the monsoon months, southwest monsoon season and annual.

Fig. 2 and 3 show the time series of rainfall (mm) and trend for the months of June, July, August, September, southwest monsoon season and annual respectively. Analysis indicates that neither monthly rainfall nor seasonal or annual rainfall show statistically significant increasing/decreasing trend. June shows decreasing statistically insignificant trend. July, August and September indicate upward trend in rainfall however it is found that July shows non-significant increasing while August and September shows significantly increasing. Both seasonal (SW monsoon) and annual rainfall show increasing trend (statistically significant).

During the last 30 years highest rainfall for the month of June received (55.4 mm) in year 1990, for the month of July it was in the year 1992 (679 mm) while highest rainfall received for the month August was in the year 1993 (686.7 mm) and of 463.9 mm rainfall received in September of year 1992. Highest SW monsoon rainfall of 1922.1 mm in 1992 year and highest rainfall (2717.8 mm) received in the year 1991.
Fig. 2 Time series of rainfall (mm) for the months of June, July, August, September and trends.

Fig. 3 Time series of rainfall (mm) for the southwest monsoon season and annual trends.
3. District rainfall mean, variability and trend

3.1 Mean and coefficient of variation

Table 2 depicts the rainfall statistics for the districts of Nagaland and spatial pattern of these statistics is presented in Figure 4-5. Districts from Northern, Central and southwestern region receive more rainfall as compare to South Eastern region of the Nagaland. District Kiphire and Phek receive less amount of rainfall in all monsoon months as well as in SW monsoon season. For the month of June, Northern and central Nagaland district receives rainfall in the range of 276-312 mm, Dimapur, Kohima and Peren districts records rainfall in the range of 206-276 mm. For Kiphire it is in the range of 135-170 mm while for Phek district it is in the range of 170-206 mm. Kiphire records less amount of rainfall (182-231 mm) in July followed by Dimapur, Peren and Phek (231-280 mm). Remaining districts records the rain in the range of 281-429 mm in July with highest in Mokokchung and Mon (380-429 mm) districts. For August, Kiphire and Phek districts rainfall in the range of 160-238 mm. Rest of district records mean rainfall in the range of 238-355 mm for the month of August. For September, Kiphire and Phek districts rainfall in the range of 110-173 mm. Rest of district records mean rainfall in the range of 173-267 mm, for the month of September. For SW monsoon, Mon, Mokokchung, Wokha, Kohima, Tensang, Longleng and Zunheboto district records 1040-1342 mm of rainfall followed by Dimapur, Peren (889-1040 mm) while comparatively less rainfall is received in Phek (738-889 mm) and Kiphire (587-738 mm) districts. For annual timescale, districts Mon, Mokokchung, Wokha, Zunheboto, Tuensang, Kohima, Longleng records mean rainfall in the range 1706-1915 mm while it is in the range of 1287-1496 mm for Dimapur, Peren and Khipire, Phek in range of 869-1287 mm.

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<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>
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<td>428.7</td>
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<td>141</td>
<td>247.9</td>
<td>141</td>
<td>1342.3</td>
<td>67</td>
<td>1914.7</td>
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<td>TUENSANG</td>
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<td>189</td>
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<td>193</td>
<td>239.1</td>
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<td>178.2</td>
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<td>917.9</td>
<td>91</td>
<td>1326.3</td>
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<td>162</td>
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<td>221</td>
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<td>869.0</td>
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<td>1252.0</td>
<td>49</td>
<td>1809.9</td>
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<td>ZUNHEBOTO</td>
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<td>339.8</td>
<td>188</td>
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<td>234.2</td>
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<td>1163.8</td>
<td>90</td>
<td>1662.1</td>
<td>84</td>
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Table 2. Rainfall statistics for the districts of Nagaland for the four monsoon months, southwest monsoon season and annual
Fig. 4 Mean rainfall pattern for districts of Nagaland
Fig. 5 Coefficient of Variation (%) over districts of Nagaland
4.2 Trend in district rainfall

The Spatial trend in rainfall for SW monsoon months, SW monsoon season and annual is shown in figure 6. In June, Significantly decreasing rainfall trend is observed for Longleng, Zunheboto, Mokokchung, Kiphire, Peren and Tuensang while Significantly increasing rainfall trend for Phek district, rest of districts shows non-significant trend. Districts Zunheboto, Mokokchung, Peren shows significantly decreasing trend while rest of district shows non-significant rainfall trend in July, Mokokchung, Zunheboto, Kiphire, Peren and Kohima shows significantly decreasing trend while Tuensang, Phek, Longleng shows significantly increasing trend in rainfall in August and Mokokchung, Zunheboto, Kohima, and Peren districts shows significantly decreasing trend in rainfall while Phek diastric shows significantly increasing trend in rainfall in for September. For both SW monsoon season and annual, Mon, Kohima, Mokokchung, Zunheboto and Kiphire districts indicate significantly decreasing trend in rainfall, significantly increasing trend in rainfall is seen for the district Dimapur. Tuensang district shows significantly increasing trend in rainfall for annual time scale. Rest of the districts not mentioned above for SW monsoon months, season and annual are either show upward or downward trend, but found to be statistically insignificant.
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

Average frequency of rainy days for SW monsoon months, SW monsoon season and annual is presented in figure 7-12. Average frequency of rainy days for Mon, Phek and Kohima districts is high for all time scales. In June (July) it is 16-17 (17-20) days for Mon, Phek and Kohima districts and it is in the range of 12-16 (13-17) days for rest of the districts. In August (September) it is 15-17 (12-14) days for Mon, Phek and Kohima districts and it is in the range of 12-15 (10-12) days for rest of the districts. SW monsoon season (annual) average frequency of rainy days recorded are 57-66 (94-108) days for Mon, Phek and Kohima districts and it is in
the range of 45-57 (74-94) days for rest of the districts.
5.2 Average frequency of Heavy rainfall days

Average frequency of rainy days for June, July, August, September, SW monsoon season and annual is presented in figure 13-18. Districts, Kohima, Phek and parts of Peren and Mon records average frequency of heavy rainfall days in the range of 0.2-0.43 (0.3-0.59) days for the months of June (July). Remaining districts records heavy rainfall days in the range of 0.5-1 (0.7-1) day for June (July). For the month of August, Phek district records average frequency of heavy rainfall days in the range of 0.2-0.4 days and for remaining districts it is in the range of 0.4 to 1 day however, Longleng and parts of Mokonchung, Tuensang and Mon indicate the average frequency of heavy rainfall days in the range of 0.6 to 1 day. In the month of September for Mon and Phek districts average frequency of heavy rainfall days is 0.1-0.2 while remaining stations it is in the range of 0.26 to 1 day. Spatial pattern of average frequency of heavy rainfall days for SW monsoon indicate that district Mon and Phek records lowest frequency of heavy rainfall days, rest of the region it is in the range of 1-3 days. Annual spatial pattern in average frequency of heavy rainfall days shows that district Mon, and parts of Phek, Kohima records highest number of rainfall days (2.5-4 days). Remaining districts it is in the range of 1-2.5 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

Average frequency of dry days indicates that district Mon, parts of Kohima and Phek records a lesser number of dry days compare to rest of the region for all timescales. Average frequency of dry days is in the range of 9-11.5 days for June, 8-11 days for July, 11-13 days for August, 13-15 days for September, 40-47 days for SW monsoon season and 217-228 days for annual in district Mon, parts of Kohima and Phek. In remaining districts, it is in the range of 12-15 days for June and July, 13-16 days for August, 14-17 days for September, 47-57 days for SW monsoon and 228-245 days for annual respectively.
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 statistically significant trends in frequency of rainy days at 95% of significant level is computed for the rain gauge stations of Nagaland state for June, July, August, September, SW monsoon season and annual (Figure 25-30). June, July and August do not show statistically significant trend in average rainy days for any station/district. One station each from Phek and Kohima district depicts statistically significant upward (downward) trend in frequency of rainy days for the month of September as well as SW monsoon season. However, only one station from Kohima district show decreasing trend for annual.
6.2 Trend in frequency of Heavy rainfall days

The statistically significant trends in frequency of heavy rainfall days at 95% of significant level for the rain gauge stations of Nagaland for June, July, August, September, SW monsoon and annual is shown in figure 31-36. There is no statistically significant trend in frequency of heavy rainfall days for the month of June and August. One station each from Phek district for July, SW monsoon season and annual indicate upward trend in frequency of heavy rainfall days. One station from Peren district depicts the statistically significant decreasing trend in heavy rainfall days for the month of September.
Fig. 31 Trend in frequency of heavy rainfall days: June

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

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
6.2 Trend in frequency of Dry days

The statistically significant trends in frequency of heavy rainfall days at 95% of significant level for the rain gauge stations of Nagaland for June, July, August, September, SW monsoon and annual is shown in figure 37-42. One station from Mon district for July, August, SW monsoon and annual indicate statistically significant downward trend in dry days. Decreasing trend in frequency of dry days is reported for one station of Phek district in September. One station from Phek district also indicate the upward trend in frequency of dry days for annual timescale. There is no significant trend in frequency of dry days for the month of June.

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
7. Conclusions

In present report, we investigated the rainfall pattern, variability and change for Nagaland state based on recent 30 years (1989-2018) of data. Here we considered, June, July, August and September, SW Monsoon season and annual time scales for the analysis. The district spatial patterns are considered to study rainfall total and stations are considered to study rainfall intensities. This study brought out many significant features of the rainfall pattern which can be utilized for the water and agricultural management. Some of the important findings are summarized below:

- Nagaland state receives maximum rainfall in the month of July (30 % of SW monsoon rainfall) followed by August (27 %), June (24.0 %) and September (20 %). Contribution of the SW monsoon rainfall to annual total is 68 %.

- Time series analysis indicates that monthly rainfall, June and July shows non-significantly decreasing trend in rainfall and August and September shows significantly increasing trend in rainfall. Seasonal and annual rainfall show statistically significant decreasing trend.
Districts from Northern and southwestern region receive more rainfall as compare to South Eastern region of the Nagaland. District Kiphire and Phek receive less amount of rainfall in all monsoon months as well as in SW monsoon season.

For SW monsoon season and annual Kohima, Mon, Mokokchung, Zunheboto and Kiphire districts indicate significantly downward trend in rainfall. However, Dimapur, TuenSang, Longleng district indicate significantly increasing trend in mean rainfall for SW monsoon season.

SW monsoon season (annual) average frequency of rainy days recorded are 57-66 (94-108) days for Mon, Phek and Kohima districts and it is in the range of 45-57 (74-94) days for rest of the districts.

Spatial pattern of average frequency of heavy rainfall days for SW monsoon indicate that district Mon and Phek records lowest frequency of heavy rainfall days, rest of the region it is in the range of 1-3 days. Annual spatial pattern in average frequency of heavy rainfall days shows that district Mon, and part of Phek, Kohima records highest number of rainfall days (2.5-4 days). Remaining districts it is in the range of 1-2.5 days.

Average frequency of dry days is in the range 40-47 days for SW monsoon season and 217-228 days for annual in the district of Mon, parts of Kohima and Phek, in remaining districts, it is in the range of 47-57 days for SW monsoon and 228-245 days for annual respectively.

June, July and August do not show statistically significant trend in average rainy days for any station/district. One station each from Phek and Kohima district depicts statistically significant upward (downward) trend in frequency of rainy days for the month of September as well as SW monsoon season. However, only one station from Kohima district show decreasing trend for annual.
There is no statistically significant trend in frequency of heavy rainfall days for
the month of June and August. One station each from Phek district for July, SW monsoon
season and annual indicate upward trend in frequency of heavy rainfall days. One station
from Peren district depicts the statistically significant decreasing trend in heavy rainfall
days for the month of September.

One station from Mon district for July, August, SW monsoon and annual indicate
statistically significant downward trend in dry days. Decreasing trend in frequency of dry
days is reported for one station of Phek district in September. One station from Phek
district also indicate the upward trend in frequency of dry days for annual timescale.
There is no significant trend in frequency of dry days for the month of June.
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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.