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Analysis of rainfall trends over Tripura

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सार — भारत में वर्षा में बहुत अधिक कालिक और स्थानिक परिवर्तनशीलता होती है। वर्षा की परिवर्तनशीलता विभिन्न क्षेत्रों के लोगों की आजीविका और खानपान को प्रभावित करती है। इस अध्ययन में उत्तर-पूर्वी राज्य त्रिपुरा के दो स्टेशनों, अगरतला और कैलाशहर में वर्ष 1955-2017 की अवधि में वर्षा की प्रवृत्तिक का अध्ययन किया गया है। राज्य में 2000 मिमी से अधिक वर्षा का वार्षिक औसत रहा है, जिसमें से लगभग 60% मॉनसून ऋतु और लगभग 30% मॉनसून पूर्व ऋतु के दौरान होता है। इसी अवधि के दौरान दो स्टेशनों में ऋतुनिष्ठ और वार्षिक वर्षा, वर्षा के दिनों और भारी वर्षा की प्रवृत्तिद का विश्लेषण करने का प्रयास किया गया है। इन प्रवृत्तियों के महत्व का पता लगाने के लिए गैर-पैरामीट्रिक मान-केंडल परीक्षण का उपयोग किया गया है। दोनों स्टेशनों पर वृद्धि और कमी दोनों तरह की प्रवृत्तायाँ देखी गई हैं। अगरतला में मॉनसून पूर्व ऋतु के दौरान वर्षा, वर्षाके दिनों और भारी वर्षा में वृद्धि की प्रवृत्तियाँ तथा अन्य सभी ऋतुओं में और वार्षिक पैमाने पर कमी की प्रवृत्तियाँ पाई गई हैं। कैलाशहर में, वर्षा की मात्रा (वर्षा के दिन और भारी वर्षा) मॉनसून पूर्व और मॉनसून ऋतु (मॉनसून पूर्व ऋतु) के दौरान बढ़ती हुई पाई जाती है। वार्षिक पैमाने पर भी कैलाशहर में, वर्षा और वर्षा के दिनों में वृद्धि की प्रवृत्ति देखी गई है। इस स्टेशन पर अन्य सभी ऋतुओं में प्राचलों में कमी की प्रवृत्तिा देखी गई है। अगरतला में मॉनसून में वर्षा के दिनों में उल्लेखनीय कमी देखी गई है, जबकि दोनों स्टेशनों पर कोई अन्य प्रवृत्ति महत्वपूर्ण नहीं पाई गई है।

ABSTRACT. Rainfall in India has very high temporal and spatial variability. The rainfall variability affects the livelihood and food habits of people from different regions. In this study, the rainfall trends in two stations in the north-eastern state of Tripura, namely Agartala and Kailashahar have been studied for the period 1955-2017. The state experiences an annual mean of more than 2000 mm of rainfall, out of which, about 60% occurs during the monsoon season and about 30% in pre-monsoon. An attempt has been made to analyze the trends in seasonal and annual rainfall, rainy days and heavy rainfall in the two stations, during the same period.Non-parametric Mann-Kendall test has been used to find out the significance of these trends. Both increasing and decreasing trends are observed over the two stations. Increasing trends in rainfall, rainy days and heavy rainfall are found at Agartala during pre-monsoon season and decreasing trends in all other seasons and at annual scale. At Kailashahar, rainfall amount (rainy days & heavy rainfall) is found to be increasing during pre-monsoon and monsoon seasons (pre-monsoon season). At annual scale also, rainfall and rainy days show increasing trends at Kailashahar. The parameters are showing decreasing trends during all other seasons at the station. Rainy days over Agartala show a significantly decreasing trend in monsoon, whereas no other trend is found to be significant over both the stations.

Key words – Rainfall, Rainy days, Heavy rainfall, Mann-Kendall test, Tripura.

1. Introduction

Rainfall is a very important climate parameter. In a large country like India, rainfall has high variability in both temporal and spatial scale. The north-eastern region of India is one of the highest rainfall-receiving regions in the country. Goswami *et al.* (2006) stated the high mean and variability of rainfall events in northeast India and found that the local orography of the region influences highly on its rainfall. Guhathakurta and Revadekar (2017) studied the decadal variation of rainfall for the four homogenous regions and found that rainfall deficiency was largest during the decade 2001-2010 for northeast India. Tripura is one of the eight states in northeast India. It is the third-smallest state in India. Its area is 10,491 km^2 and is bordered by Bangladesh to the north, south and west and the Indian states of Assam and Mizoram to the east. It comes under the meteorological subdivision of Nagaland, Manipur, Mizoram and Tripura (NMMT) as classified by India Meteorological Department. For the state as a whole, Tripura receives an annual average rainfall of about 2200mm.

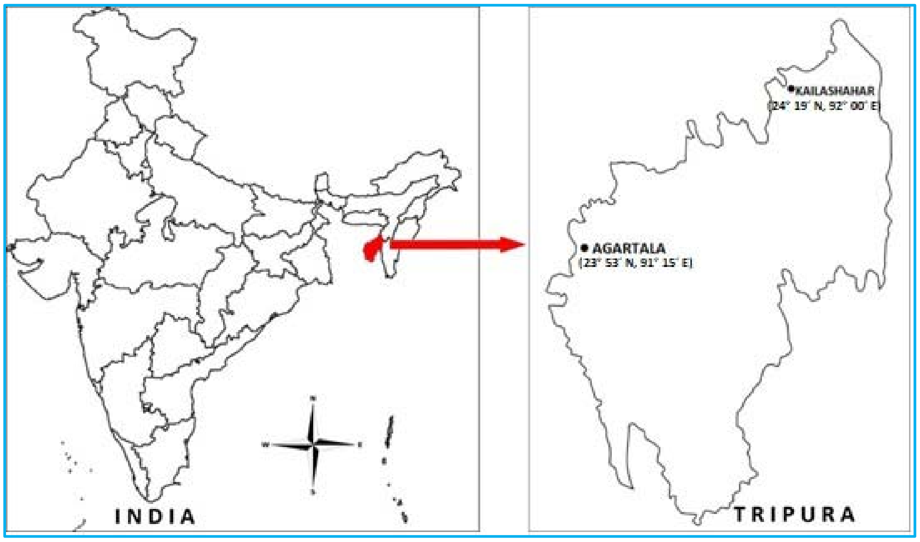


Fig. 1. Map of Tripura with location of the two stations

TABLE 1

Metadata of the observatories

Station Name	Station Code	District	Lat. Long.	Altitude
Agartala	42724	West Tripura	23° 53´ N, 91° 15´ E	17m
Kailashahar	42618	Unakoti	24° 19´ N, 92° 00´ E	29m

The objective of the present study is to find whether there is any trend in the seasonal and annual rainfall pattern in two stations of Tripura, namely, Agartala and Kailashahar. The location of the two stations are shown in Fig. 1. The trend of Indian summer monsoon rainfall for all 36 subdivisions has been analyzed by Guhathakurta and Rajeevan (2008) and found a decreasing trend for monsoon and increasing trends for all other seasons and annual scale in NMMT. Laskar *et al*. (2014) has performed trend analysis of temperature and rainfall of selected stations over north-east India and found a significantly decreasing trend of monsoon rainfall at Agartala during 1954-2012.

An important aspect about rainfall pattern is its distribution. Because only the annual or seasonal rainfall at a place does not give sufficient information regarding its capacity to support agriculture. For agricultural purpose focus should be given to three main characteristics of rainfall, how much it rains, when it rains and what is the intensity of the rainfall events, *i.e.*, its amount, frequency and intensity. The values of these characteristics change from place to place, day to day, month to month, season to season and year to year. For proper utilization of water resource, precise knowledge of these three main characteristics is essential. Therefore, variation of total rainfall has been taken for study. And for the temporal distribution of rainfall, number of rainy days has been considered. For the purpose of intensity of the rainfall events trend of heavy rainfall is studied. Study of heavy rainfall events is important because such events may lead to disasters and damage of crops some times. The trend is analyzed season wise for all the seasons and on annual scale. Das *et al*. (2015) analyzed the seasonal and annual rainfall amount for the two stations and no statistically significant trend was found.

2. Data and methodology

For this study daily rainfall data recorded at IMD's two observatories, Agartala and Kailashahar (Table 1) during the period 1955-2017 are used. The data have been obtained from the National Data Centre, Climate Research and Services, Pune and Meteorological Centre, Agartala. The missing data were replaced with the help of the ratio method of missing data.

For study of heavy rainfall and rainy days, IMD's criteria of daily rainfall equals to or greater than 64.5mm for defining heavy rainfall (Table 2) and 2.5mm for

TABLE 2

Categories of rainfall intensity as defined by IMD

Rainfall Category	Rainfall (in mm)
Very Light Rainfall	Trace - 2.4
Light Rainfall	2.5 - 15.5
Moderate Rainfall	15.6 - 64.4
Heavy Rainfall	64.5 - 115.5
Very Heavy Rainfall	115.6 - 204.4
Extremely Heavy Rainfall	>204.4
Exceptionally Heavy Rainfall	When the amount is a value near about the highest recorded rainfall at or near the station for the month or season. However, this term will be used only when the actual rainfall amount exceeds 12 cm

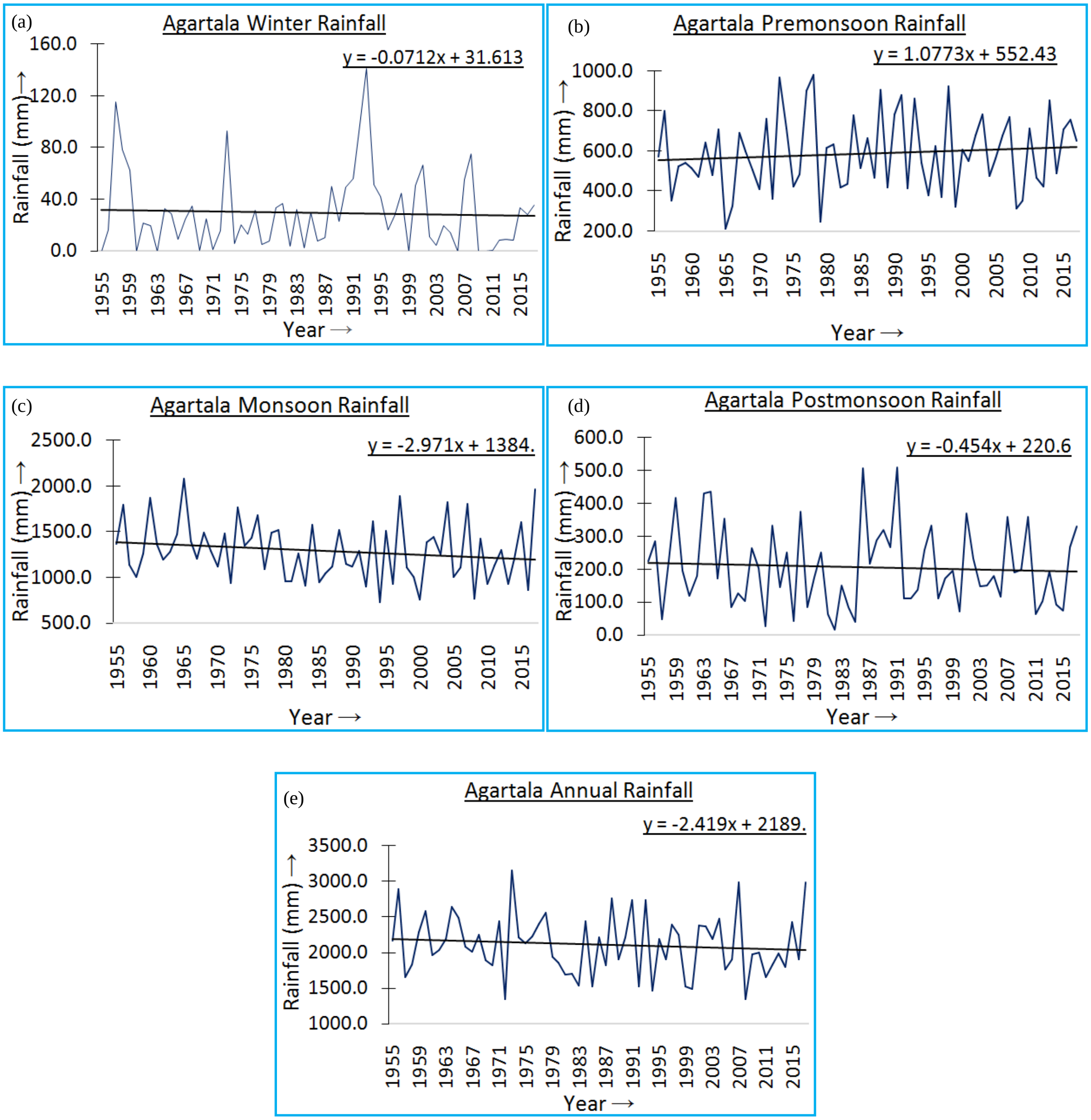
TABLE 3

Monthly, seasonal and annual rainfall, rainy days and heavy rainfall events over Agartala & Kailashahar

Month/Season	Agartala			Kailashahar		
	Rainfall	Rainy Days	Heavy Rainfall	Rainfall	Rainy Days	Heavy Rainfall
January	7.7	0.6	0.0	9.1	0.6	0.0
February	19.5	1.8	0.0	37.6	1.9	0.0
March	62.3	3.0	0.1	100.9	4.3	0.3
April	188.3	7.8	0.4	266.1	10.0	0.8
May	340.0	12.3	1.0	446.2	14.6	1.6
June	404.4	15.6	1.2	461.5	17.9	1.3
July	361.6	15.7	1.0	366.6	18.0	0.8
August	283.7	15.3	0.7	371.8	17.9	1.0
September	228.5	11.8	0.4	285.3	13.9	0.7
October	156.4	6.9	0.4	172.6	7.0	0.5
November	37.9	1.5	0.1	39.9	1.6	0.1
December	10.2	0.5	0.0	13.7	0.6	0.0
Winter	27.3	2.4	0.0	46.7	2.5	0.0
Pre-monsoon	590.5	23.1	1.5	813.2	28.9	2.7
Monsoon	1278.2	58.4	3.4	1485.2	67.7	3.7
Post-monsoon	204.5	8.9	0.6	226.1	9.2	0.7
Annual	2100.5	92.8	5.6	2571.3	108.3	7.1

defining rainy days has been considered. For the analysis of linear trend in time series, linear regression analysis is used to obtain the relationship of the form of $y=a+bx$, where, x is the time in years and the equation shows the variation of the independent variable y with respect to time. A positive (negative) value of b shows an increasing (decreasing) trend of the variable y with time.

Non-parametric tests are widely used for analyzing the trends in several atmospheric data, due to their less sensitivity to outliers and missing values. In this study, the significance of the increasing or decreasing trends of the variables are tested using the non-parametric Mann-Kendall test (Mann, 1945). If the computed value of Mann-Kendall test statistic Z has a value greater (smaller)



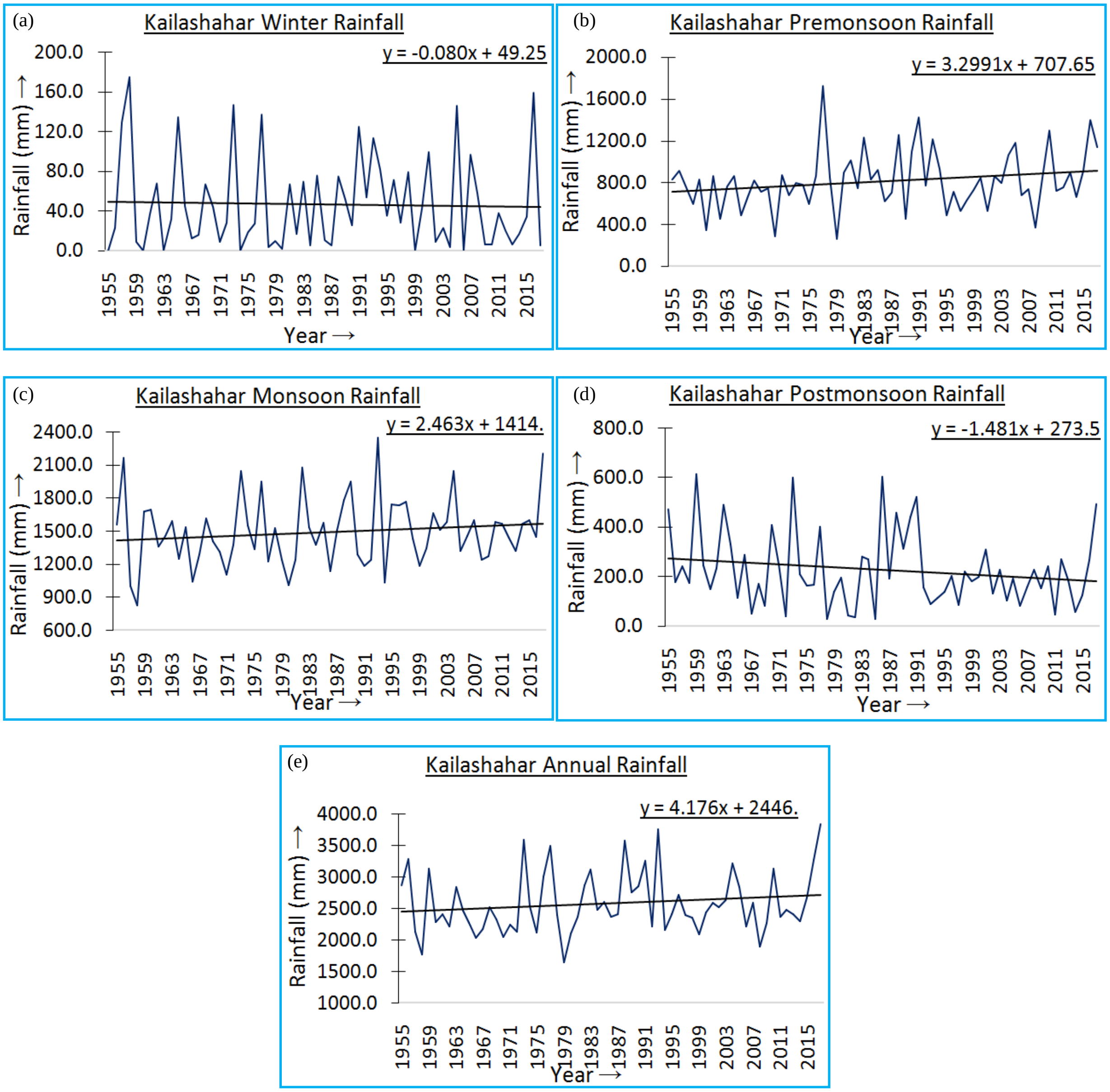
Figs. 2 (a-e). Plots of seasonal and annual rainfall in Agartala

than +1.96 (-1.96), it suggests a significant increase (decrease) in trend of the variable at 5% significance level.

3. Results and discussion

3.1. *Comparison of means*

It is seen from Table 3 that both the stations show almost similar pattern of rainfall. However, most of the values of the rainfall parameters are higher in Kailashahar as compared to Agartala. Presence of higher hill ranges towards the east of Kailashahar may be one of the reasons for more rainfall in the station compared to Agartala. Similar to most of the other parts of India, Monsoon is the main rainy season of the state. For both the stations, about 60% of the annual rainfall and more than 60% of the rainy days are observed in monsoon. Heavy rainfall events are also highest in monsoon. In pre-monsoon also, the state receives a significant amount of rainfall as this season contributes to about 30% of the



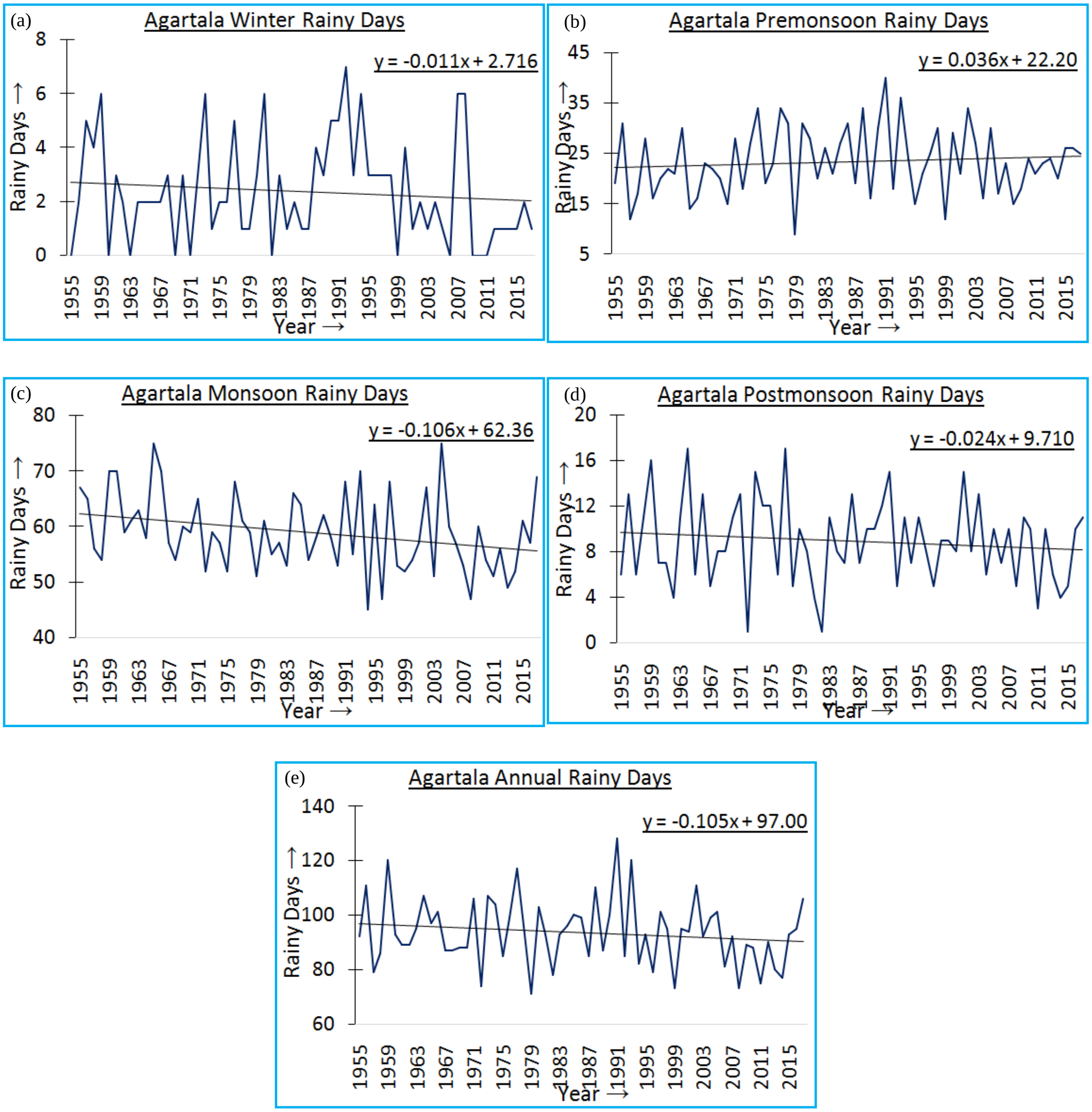
Figs. 3 (a-e). Plots of seasonal and annual rainfall in Kailashahar

state's annual rainfall. The rainfall in pre-monsoon season is mainly of convective nature and thunderstorms are accompanied with rainfall. Singh *et al*. (2011) found that the average number of thunderstorm days in both the stations are more than 12 in April and more than 15 in May. The post-monsoon season contributes about 10% of the annual rainfall, whereas rainfall in winter is only 1-2% of the annual value.

3.2. *Trend of seasonal and annual rainfall*

The time series and linear trends of seasonal and annual rainfall over Agartala are shown in Figs. 2 (a-e). From the plots it has been observed that there is a decrease in rainfall trend for all the seasons except for pre-monsoon season. A decreasing trend is also observed for annual rainfall also. However, the analysis from Mann-Kendall test shows that none of these increasing or decreasing trends are of statistical significance.

From Figs. 3 (a-e) it is seen that the seasonal rainfall in Kailashahar shows increasing trends for monsoon and pre-monsoon and decreasing trends for winter and post-monsoon. The annual rainfall also shows slight increasing trend. But similar to Agartala, these trends also not found to be statistically significant.



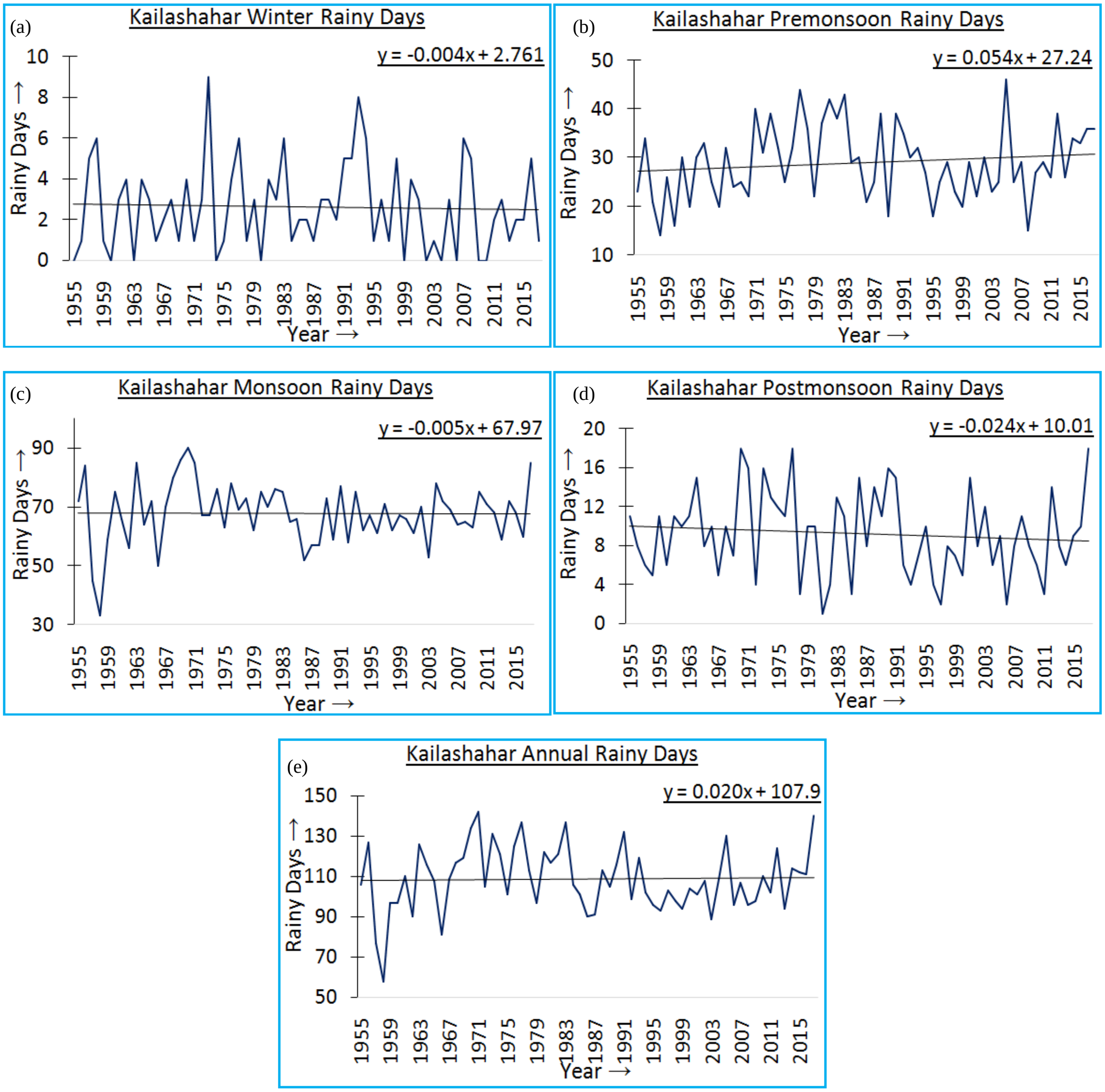
Figs. 4 (a-e). Plots of seasonal and annual rainy days in Agartala

Guhathakurta *et al*. (2020) found decreasing trends of rainfall in West Tripura and Unakoti districts during southwest monsoon season as well as at annual scale during the 30 years period of 1989-2018.

3.3. *Trend of rainy days*

In Figs. 4 (a-e), the time series and linear trends of rainy days for Agartala are shown on seasonal and annual scale. These trends are similar to the seasonal and annual rainfall trends, which shows decreasing trend for all seasons except in pre-monsoon and on annual scale. From Mann-Kendall non-parametric test, it is found that only monsoon season shows a statistically significant decreasing trend at 5% significance level, while all other trends are of no statistical significance.

After analyzing the time series of rainy days in Kailashahar as shown in Figs. 5(a-e), it is found that, the rainy days show increasing trend for pre-monsoon season,



Figs. 5 (a-e). Plots of seasonal and annual rainy days for Kailashahar

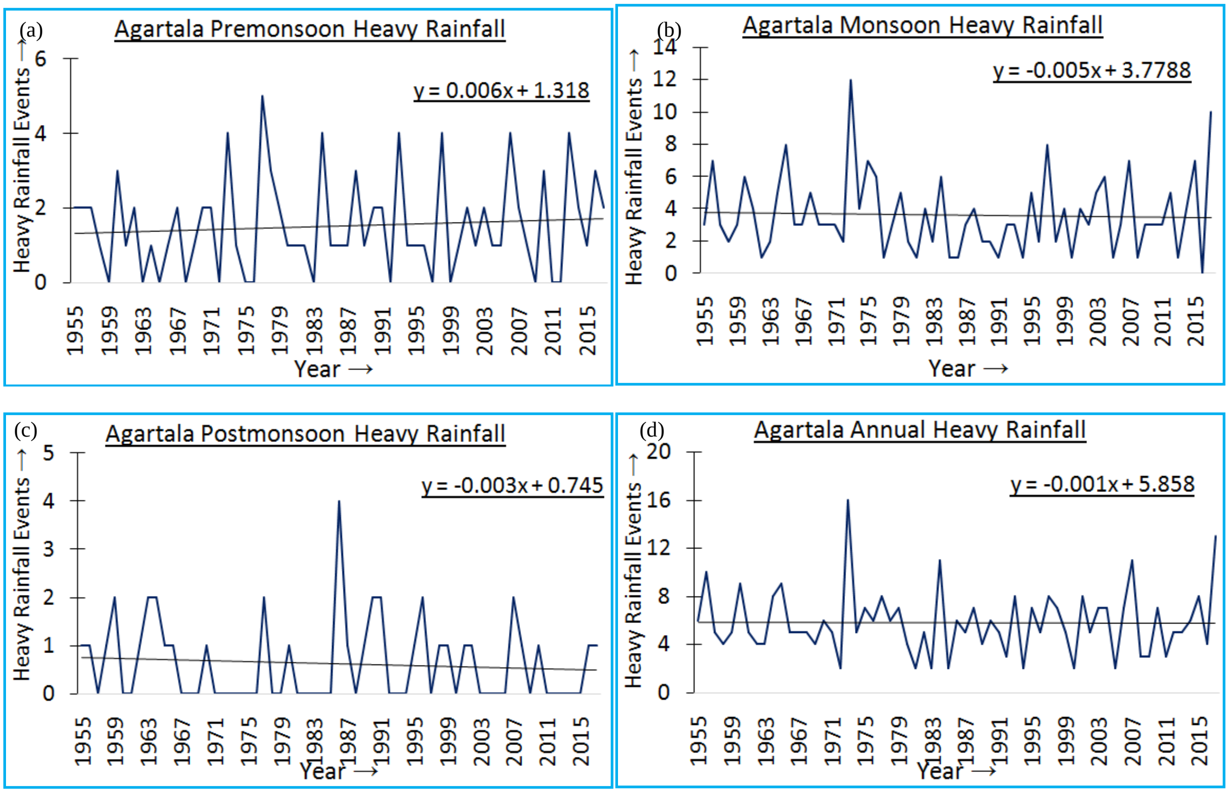
while decreasing trends are found for all other seasons and annual scale. But these trends do not show any statistical significance.

Guhathakurta *et al*. (2020) also did not find any significant trend in rainy days at the two stations in monsoon season and at annual scale during the 30 years period of 1989-2018.

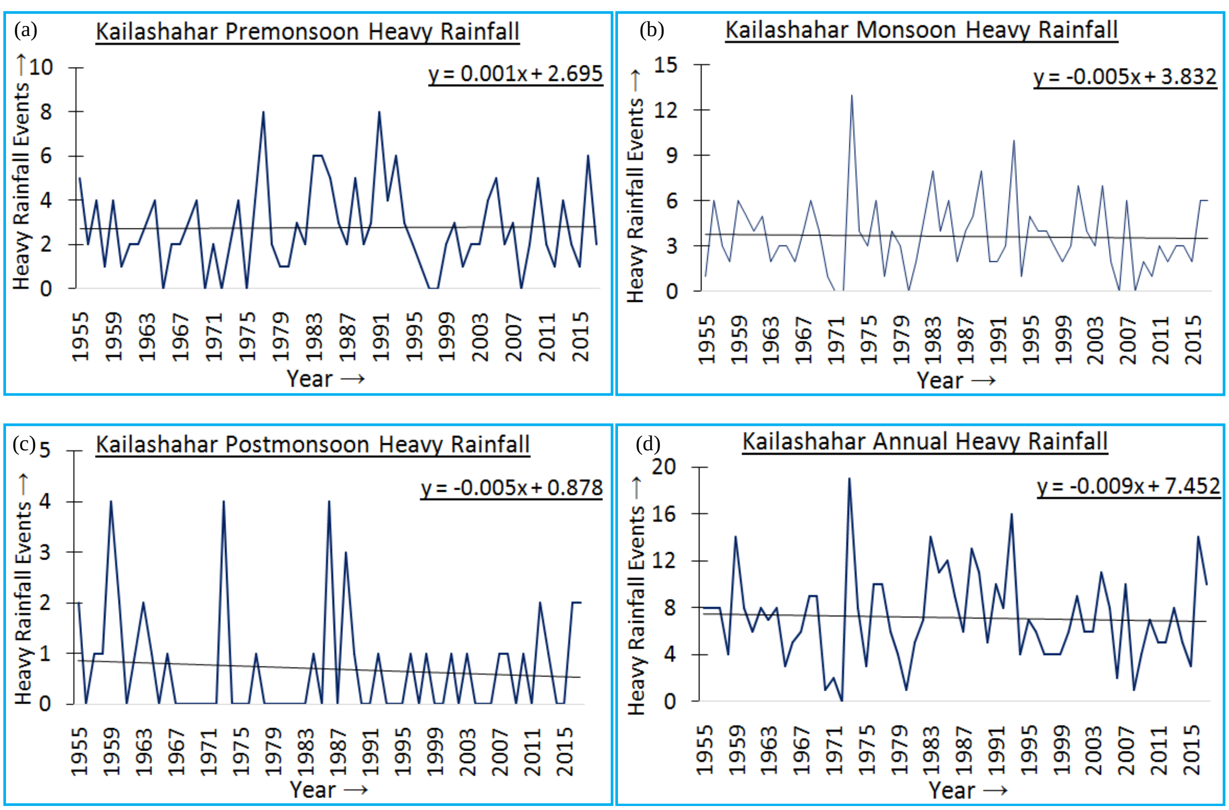
3.4. *Trend of heavy rainfall events*

The time series and linear trends of heavy rainfall events in Agartala during pre-monsoon, monsoon, post-monsoon and annual scale are shown in Figs. 6 (a-d). It shows a slight decreasing trend in monsoon, post-monsoon and annual scale and an increasing trend in pre-monsoon season. But these trends are not found to be statistically significant. Heavy rainfall events are quite rare in winter. During the period of study only two such events have been observed in Agartala during winter, hence its trend has not been analyzed.

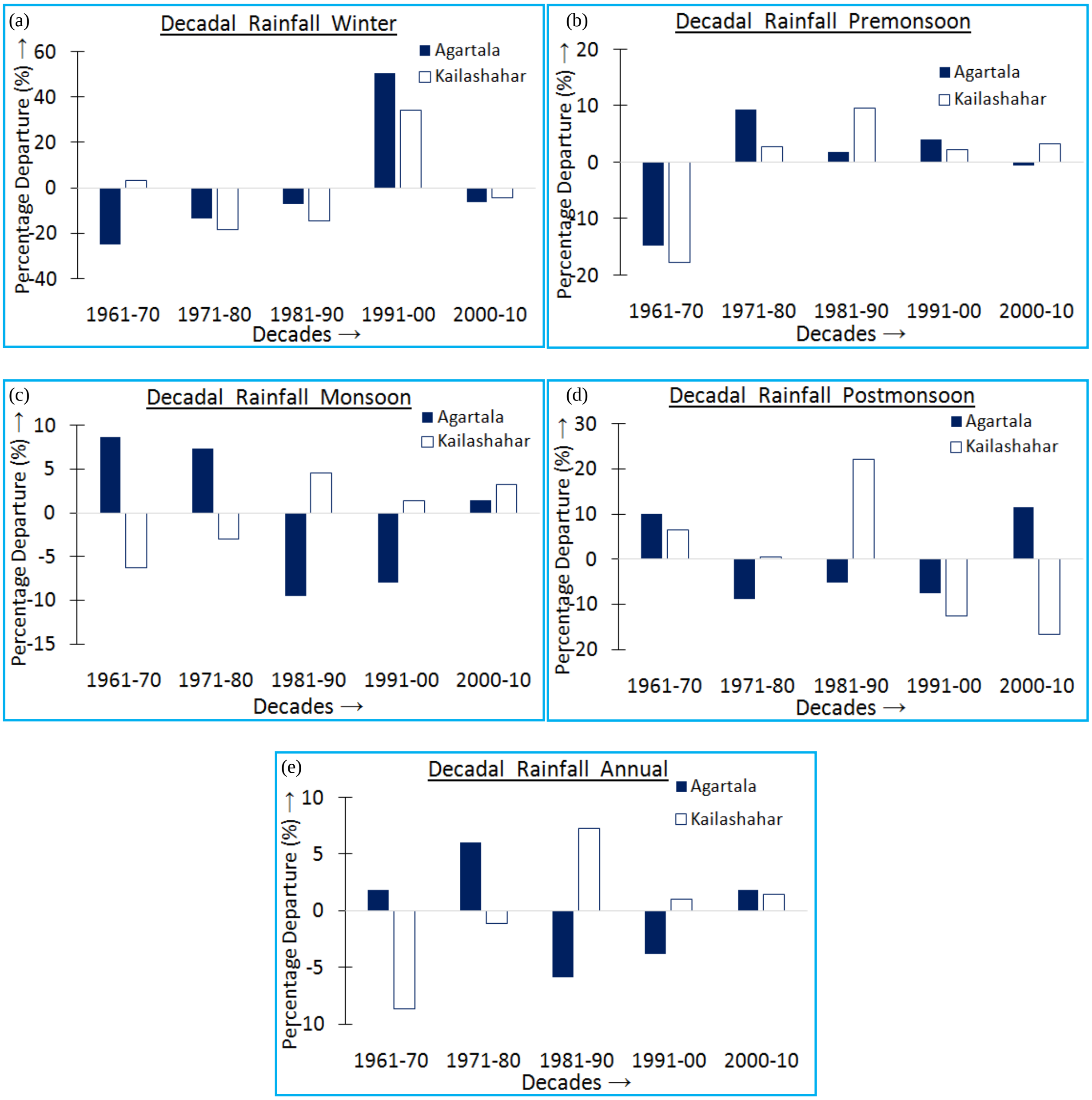
Time series and linear trends of heavy rainfall events over Kailashahar are shown in Figs. 7 (a-d), which shows increasing trend in pre-monsoon season and decreasing trends for monsoon and post-monsoon seasons and on



Figs. 6 (a-d). Plots of seasonal and annual heavy rainfall events in Agartala



Figs. 7 (a-d). Plots of seasonal and annual heavy rainfall events in Kailashahar



Figs. 8 (a-e). Plots of decadal variation of rainfall at Agartala and Kailashahar

annual scale. Mann Kendall test reveals that all these trends are statistically insignificant. Only three heavy rainfall events were recorded in winter during the period of study and hence the trend is not analyzed. Guhathakurta *et al*. (2020) found significantly decreasing trends of heavy rainfall at one station of Unakoti district during southwest monsoon season as well as at annual scale during the 30 years period of 1989-2018.

Most of the trends in this study have been found to be negative. These results can be compared with Guhathakurta and Revadekar (2017), who have found decreasing trends in northeast India after 1960.

3.5. *Decadal variation in rainfall*

Apart from the annual variation in rainfall, it has been observed that southwest monsoon rainfall exhibits significant multidecadal variations in the Indian region (Guhathakurta and Rajeevan, 2008). In view of the importance of decadal variation in rainfall, many researchers have studied the same at different scales.

Guhathakurta *et al*., 2014 have studied such variation for Indian summer monsoon rainfall and found that there is a decreasing trend in decadal rainfall during the period 1961-2010. At smaller scale (station level), studies on decadal variation of rainfall have been studied by Seetharam, 2003 for Jalpaiguri and Kavi, 1988 for Bangalore. A similar attempt has been made here for the two stations under study for the decades 1961-70, 1971-80, 1981-90, 1991-2000 and 2001-10.

It has been observed from Fig. 8 that during the winter and pre-monsoon seasons, decadal rainfall departures mostly show similar patterns over the two stations. However, there is a large variation in the decadal variations of the two stations during the monsoon and post-monsoon seasons. During the monsoon season, 1981-90 is the decade with highest negative departure at Agartala, but the same is with the highest positive departure at Kailashahar in the period of study. Similarly, the *vice-versa* is observed during the decade 1961-70 also, which is the decade with highest positive departure for Agartala and highest negative departure for Kailashahar. 2000-10 is the only decade when the departure is on the same side of the axis in monsoon. Similarly, in the post-monsoon season, 1961-70 and 1991-2000 are the only two decades where the departures fall in the same side of the axis. Since the annual rainfall is mostly dominated by monsoon, a similar pattern is observed in annual rainfall also.

4. Conclusions

In the present analysis, an attempt has been made to find the trends of rainfall in the state of Tripura during the period 1955-2017. For this purpose, two stations namely Agartala and Kailashahar have been taken for study. For trends analysis, rainfall amount, rainy days and heavy rainfall events on seasonal and annual timescale have been considered. Both increasing and decreasing trends are found for rainfall parameters. All the three parameters show increasing trends in pre-monsoon season over both the stations. Increasing trends are also observed for rainfall in monsoon season and annual rainy days over Kailashahar, while the parameters show decreasing trends for all other seasons for both Agartala and Kailashahar. But they were not found to be statistically significant, except rainy days in monsoon season for Agartala, which is showing a significant decreasing trend. The decadal variation of rainfall over the two stations has also been studied for the five decades 1961-70, 1971-80, 1981-90, 1991-2000 and 2001-10. It has been observed that during the winter and pre-monsoon seasons, the decadal variations of rainfall over the two stations mostly follow similar patterns. However, there exist large variation during the monsoon and post-monsoon seasons.

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