Study of Trends in Rainfall, Temperature and Rainy days of Pantnagar, Uttarakhand using Moving Average Method

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Abstract

Trend studies of rainfall and temperature have been of great concern during the past century as well as today because of the consideration has been given to global climate change by the scientific community. The study of trends in rainfall and temperature are very important for a country like India whose food security and economy are dependent on the timely availability of water such as 83% water used for agriculture sector, 12% for industrial sector and only 5% for domestic sector(source: MoWR, GOI, 2017-18). So the present study attempted to know the trend of rainfall, mean maximum temperature, mean minimum temperature and rainy days of Pantnagar for the period (1961-2018) and (1981-2018) Respectively. For this purpose, rainfall data have been collected from Agro-meteorological observatory, Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar Udhamsinghnagar district (Uttarakhand).

Keywords: Trend, rainy days, seasonal variation.

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1 Introduction

Precipitation is a major component of the hydrological cycle (**Liu, 2017; Moazami and Najafi, 2021).**The total rainfall and its distribution at a given place or localities are of vital importance, notonly for the production of crops, but in execution of field operations which contribute to the production. The knowledge of distribution and pattern of rainfall can, however be acquired by studying the data for a long period. Such a study helps in bringing out the salient features, suchas annual and monthly rainfall and rainy days, the monotonic trends, or if any and the quantitative estimates of the trends with respect to time.

Several attempts have been made to evaluate the trend and variability of climatic variables in the state (**Singh and Mal, 2014**). The information would be valuable in suggesting suitable cropping pattern and varieties of crops. Considering about facts the present study on rainfall was formulated. Abnormal variations in key parameters of climate viz rainfall and temperature affect the hydrological processes and availability of water resources (**Mondal and Majumdar,2012**).Although climate change is a broad area of research the changing pattern of precipitation deserves urgent and systematic attention as it will affect the availability of food supply (**Dore, 2005**). In order to discover how the climate may change in future, it is essential to understand how the concentrations of atmospheric elements may change which affect the Earth's energy system (**Chakraborty et al., 2013**). Studies have found that human activities have contributed to an increase in concentration of atmospheric greenhouse gases contributing to intensification of heavy rainfall events (**Min et al., 2011**)Spatial rainfall variability has been proved as non-negligible to accurate stream flow prediction (**Singh, 1993 and Zoccatelli et al., 2011**).Furthermore, the change of spatial rainfall variability itself has been shown to be more impactful on floods than the component of rainfall intensity (**Peleg et al., 2022**).Many organizations/institutions across the world have created gridded precipitation datasets with extensive spatial and temporal coverage in order to get around the issue of sparse and uneven distribution of observatories (**Kanda et al., 2020**)

Uttarakhand, a 27th state of the country is one of the hilly states of the Himalaya. It is spread over53483 Km^{2}. Meteorological stations Pantnagar has been selected in zone of Uttarakhand for proposed study. Monthly rainfall, mean maximum, minimum temperature & Rainy days of Pantnagar station have been collected from agro-meteorological observatory, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (Uttarakhand) for the duration 1961 to 2018. Trend study has been carried out for observed rainfall, mean maximum temperature, mean minimum temperature & Rainy days at annual & seasonal scale for station.

Objective

In the present study the objective was to study the trend in observed climatic parameters (rainfall, mean maximum temperature, mean minimum temperature and rainy days) at annual and seasonalscale at Pantnagar University.

2 Materials and Methods

This chapter deals with description of study area; data used and presentation methods in present study to show the trends in rainfall, mean maximum temperature, mean minimum temperature and rainy days at annual and seasonal scale.

Description of Study Area

For Pantnagar station, monthly data of rainfall, mean maximum temperature & mean minimum temperature have been collected from agro-meteorological observatory, Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (Uttarakhand) for the duration 1961 to 2018 (58 years).Climate of this zone is humid subtropical type characterized by hot, usually humid summers and mild to cool winters. When monsoon is well developed, rainfall often shows peak in summer. Most of the summer rainfall occurs during thunderstorms that develop due to intense surface heating and strong subtropical angle. Figure 2.1 shows the index map of study area.

Four seasons have been taken up for study viz. winter (December to February), pre-monsoon (March to May)), monsoon (June to September) and post-monsoon (October to November).Table 2.1 shows the description of observed station data used in study.

Table 2.1: Observed station data

Station	Mean sea level	Coordinate	Rainfall	Maximum temperature	Minimum temperature
Pantnagar	243.8 m	29° N 79° 30’ E	√	√	√

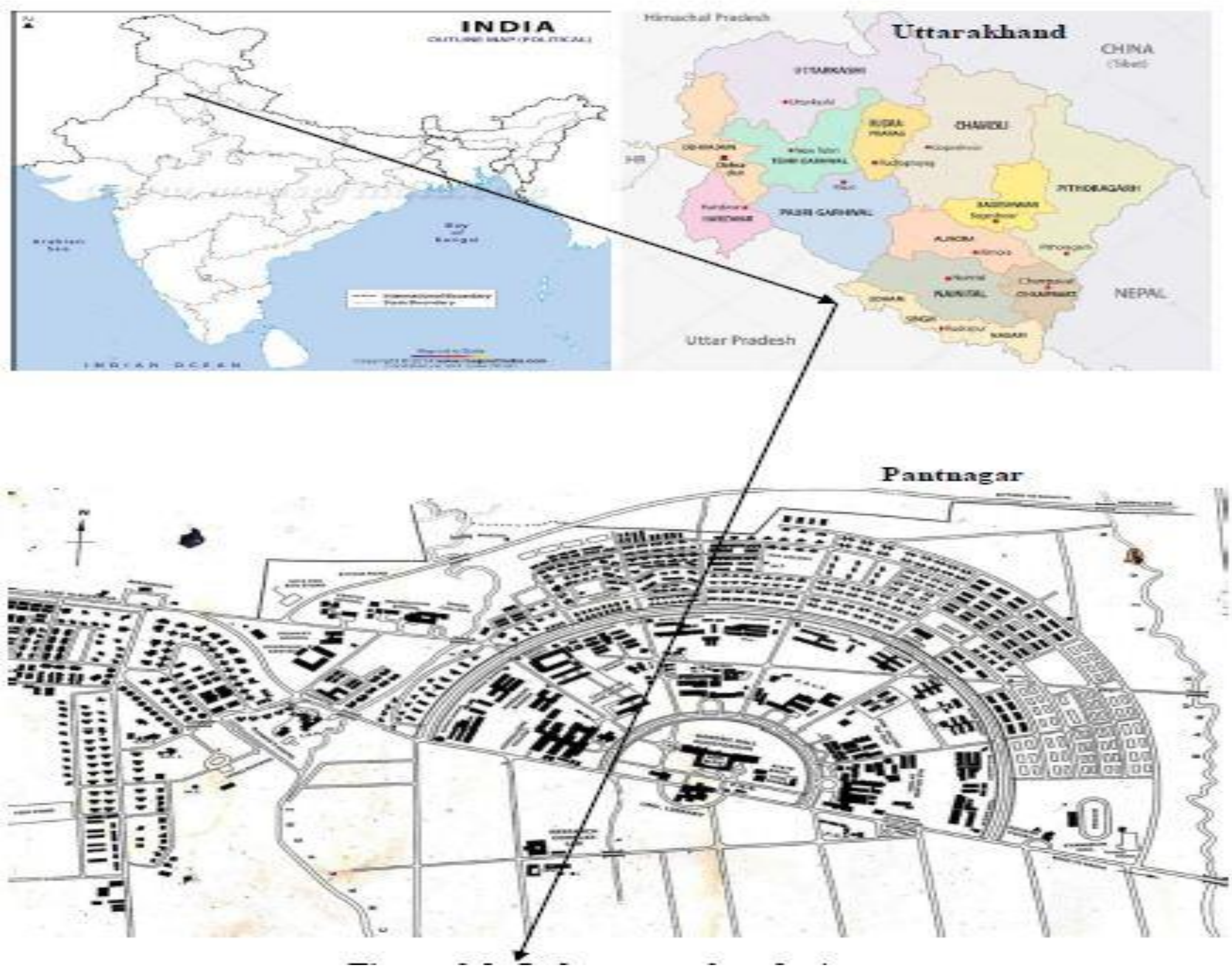

Figure 2.1: Index map of study Area

Large Scale Atmospheric Data

The large-scale atmospheric variables are categorized in two groups viz. Observed predictors andModelled predictors. Observed predictors are NCEP-NCAR (National Centre for Climate Prediction – National Centre for Atmospheric Research Analysis) reanalysis datasets. It is a very comprehensive observational database prepared by collaboration of NCEP and NCAR **(Kalnay*etal*., 1996)**. It is used for calibrating and validating the model. Modelled predictors are simulated data of GCM CanESM2 (Second generation Canadian Earth System Model) under Coupled Modelled Intercomparison Project-5 (CMIP5) in present study. It is used to generate future climate scenarios. For Pantnagar station, NCEP-NCAR data have been extracted from netcdf file which has been downloaded from website http://www.esrl.noaa.gov/*psd/*. NCEP-NCAR reanalysis datasets are in gridded form (2.5 latitude × 2.5 longitude). CanESM2 model data corresponding to RCP 4.5 have been extracted from netcdf file which has been downloaded from the website of Earth System Grid federation https://esgf-node.llnl.gov/projects/esgf-llnl/. ArcGIS software has been used to extract the data from netcdf file for desired grid. CanESM2 model datasets are in gridded form (2.1825 latitude × 2.1825 longitude).

Methodology

Moving Average

The graphical representation of rainfall in any of the above three methods may not show any trend or cyclic pattern present in the data. The moving average curve smoothens out the extreme variations and indicate the trend or cyclic pattern, if any, more clearly. It is also known as the moving mean curve. The procedure to construct the moving average curve is as follows. The moving average curve is constructed with a moving period of m year where m is generally taken to be 3 or 5 years. Let X_1, X_2, ……….,X_n be the sequence of given annual rainfall in the chronological order. Let $y_i$denote the ordinate of the moving average curve for the ith year. Then for m=3, $y_i$is computed from

$$y_2 = \frac{X_1+X_2+X_3}{3}$$

$$y_3 = \frac{X_2+X_3+X_4}{3} \quad \text{….. (2.1)}$$

$$y_i = \frac{X_{i-1}+X_i+X_{i+1}}{3}$$

$$y_{n-1} = \frac{X_{n-2}+X_{n-1}+X_n}{3}$$

As can be seen from equation (2.1) the computed value of y corresponds in time to the middle value of the x's being averaged and therefore it is convenient to use odd values of m. A moving average of m applied to a sequence of n values yields a sequence of (n-2k) values, where k= (m- 1)/2. For any general m, the y terms can be expressed as

$$y_i = \frac{1}{m}\sum_{j=i-k}^{i+k} x_j \; ; for i = k+1, k+2, \dots\dots\dots.., (n-k) \quad \text{….. (2.2)}$$

Although it is possible to use moving averages with any m, it is necessary that m be small compared to n. The moving average technique can be applied to other hydrological parameters aswell such as temperature, wind speed etc. A 3-year moving mean average curve superimposed over the original sequence.

Generally, no persistent regular cycles can be expected in the annual rainfall data. However, annual or seasonal cycles may be noticed when the moving average curve is constructed for monthly rainfall data.

The different methodologies used in the present study to detect the trends in observed climatic parameters and downscaled climatic projections and to perform downscaling are as follows-

Basic statistical parameters

(i) Standard deviation (SD)

It enumerates the amount of dispersion or variation in the dataset. Higher values of SD signify that data points are spread out over a wide range of values while lower values signify that data points are near to mean value mathematically, SD is given by:

$$SD=\frac{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2}}{n} \quad \text{..... (2.3)}$$

Where,

X_i= value of observation

$\bar{X}$= Mean of

observations n=

number of

observations

(ii) Coefficient of Variance (CV)

Coefficient of variance is an index of reliability of dataset. If value of CV is less then data isconsidered reliable. It is expressed as:

$$CV=\frac{SD}{\bar{X}}\times 100 \qquad \text{….. (2.4)}$$

Where

CV= coefficient of varianceSD =

Standard Deviation

$\bar{X}$= Mean of observations

(iii) Skewness

Skewness indicates the departure from symmetry or lack of symmetry in the dataset. Positive value of coefficient of skewness shows positively skewed data and negative value of coefficient of skewness shows negatively skewed data.

$$\text{Coefficient of skewness} = \frac{Mean - Mode}{SD} = 3 \times \frac{Mean - Median}{SD} \qquad \text{….. (2.5)}$$

(iv) Kurtosis

Kurtosis is the extent to which the peak of a unimodal probability distribution deviates from the shape of a normal distribution. If it is more pointed the distribution is lepokurtic. If it is flatter it is platykurtic. The coefficient of Kurtosis is the average of the fourth power of the standardized deviations from the mean.

$$\text{Kurtosis} = \frac{\sum_{i=1}^{N}\left(\frac{(x_i-\bar{x})^4}{N}\right)}{S^4} \qquad \ldots..\ (2.6)$$

Where,

$\bar{X}$= mean of observations

S= standard deviation

N= sample size

3. Results and Discussions

The methodology discussed in chapter 2 has been applied. The results obtained are shown in the form of Tables and Figures. These chapters demonstrate the results obtained on applying methods viz. Mann-Kendall test, Sen's slope estimator, multiple linear regression based on downscaling, in Materials and Methods chapter Statistical downscaling model (SDSM) as also explained. All results for Pantnagar station have been shown.

The following figure 3.1 represents the 3 and 5 year moving average curves of rainfall for Annual season for 58 years of Pantnagar. The trend line with an increasing slope of 5.6987. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

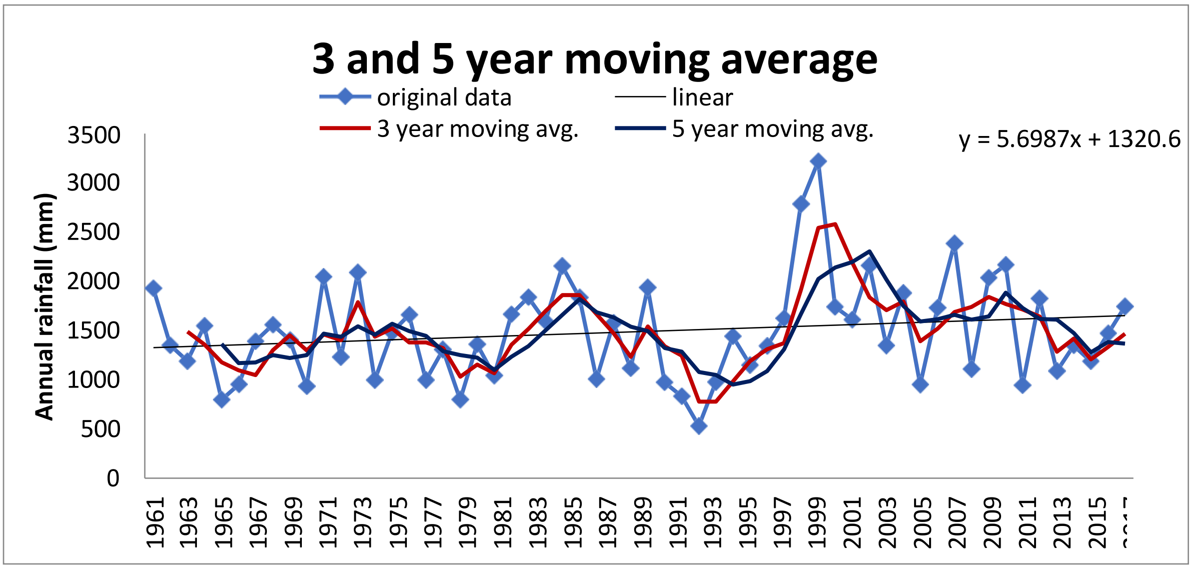

Figure 3.1 Variation of 3 and 5 year Moving Mean Average Rainfall (Annual)

The following figure 3.2 represents the 3 and 5 year moving average curves of rainfall for Pre- monsoon season for 58 years of Pantnagar. The trend line with an increasing slope of 0.8115. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

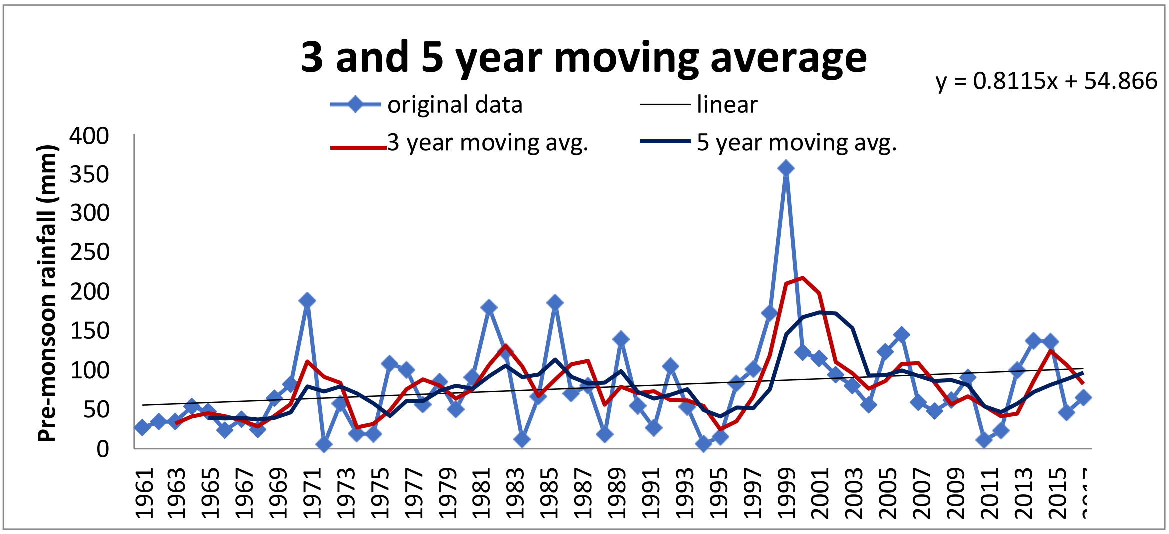

Figure 3.2 Variation of 3 and 5 year moving mean Average Rainfall (Pre-monsoon)

The following figure 3.3 represents the 3 and 5 year moving average curves of rainfall for Monsoon season for 58 years of Pantnagar. The trend line with an increasing slope of 4.7149. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

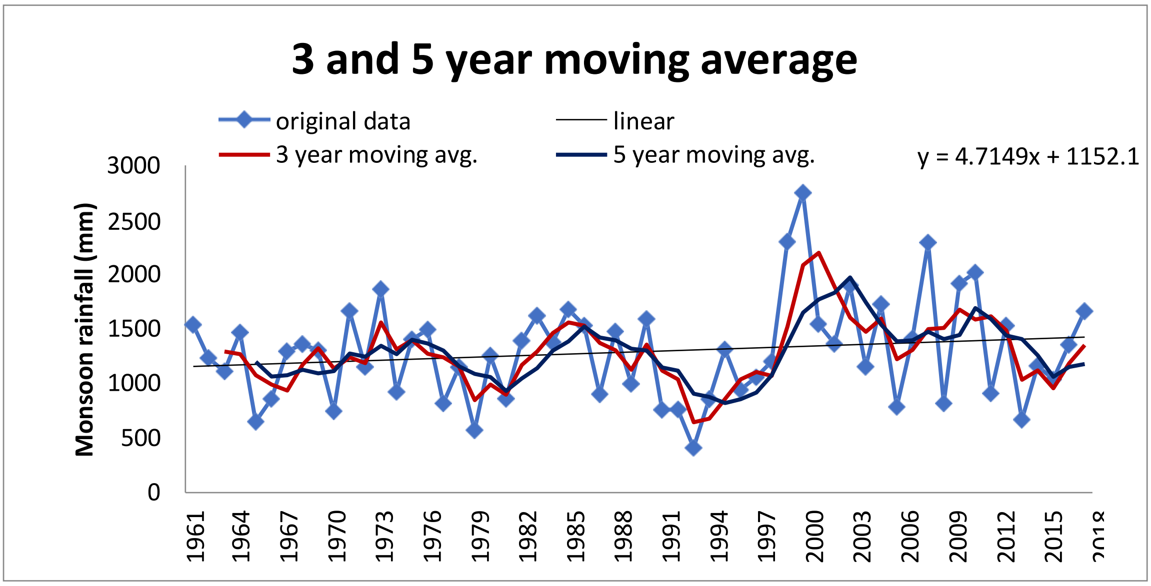

Figure 3.3 Variation of 3 and 5 year moving mean Average Rainfall (Monsoon)

The following figure 3.4 represents the 3 and 5 year moving average curves of rainfall for post- monsoon season for 58 years of Pantnagar. The trend line with a decreasing slope of -0.1239. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

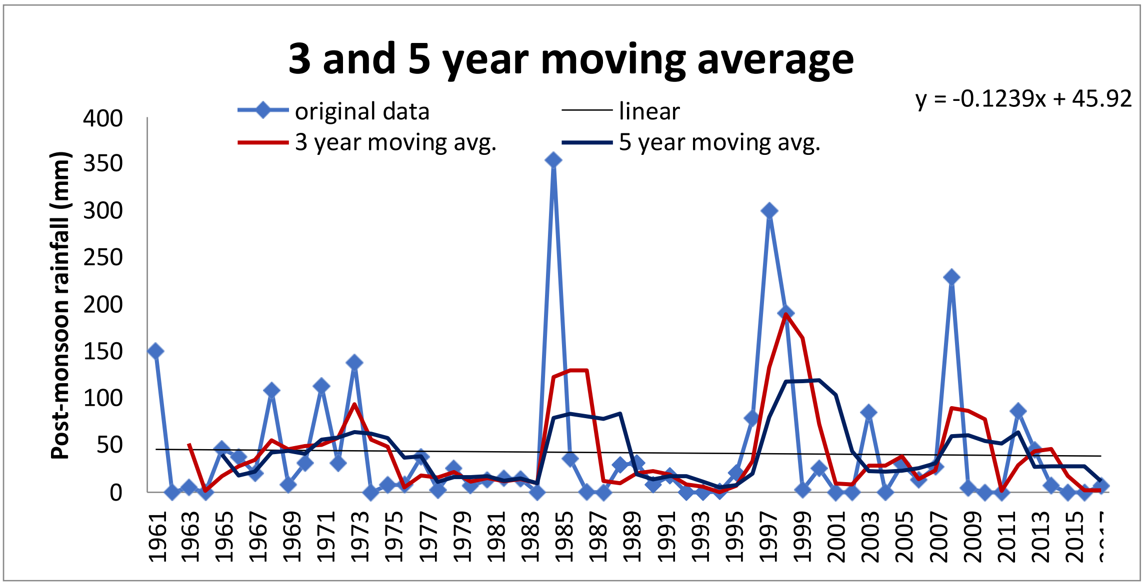

Figure 3.4 Variation of 3 and 5 year moving mean Average Rainfall (Post-monsoon)

The following figure 3.5 represents the 3 and 5 year moving average curves of rainfall for winter season for 58 years of Pantnagar. The trend line with an increasing slope of 0.2963. Though the variations in the original data are smoothened out to some extent in the moving average curve,no apparent trend or cyclicity is visible in the moving average curve.

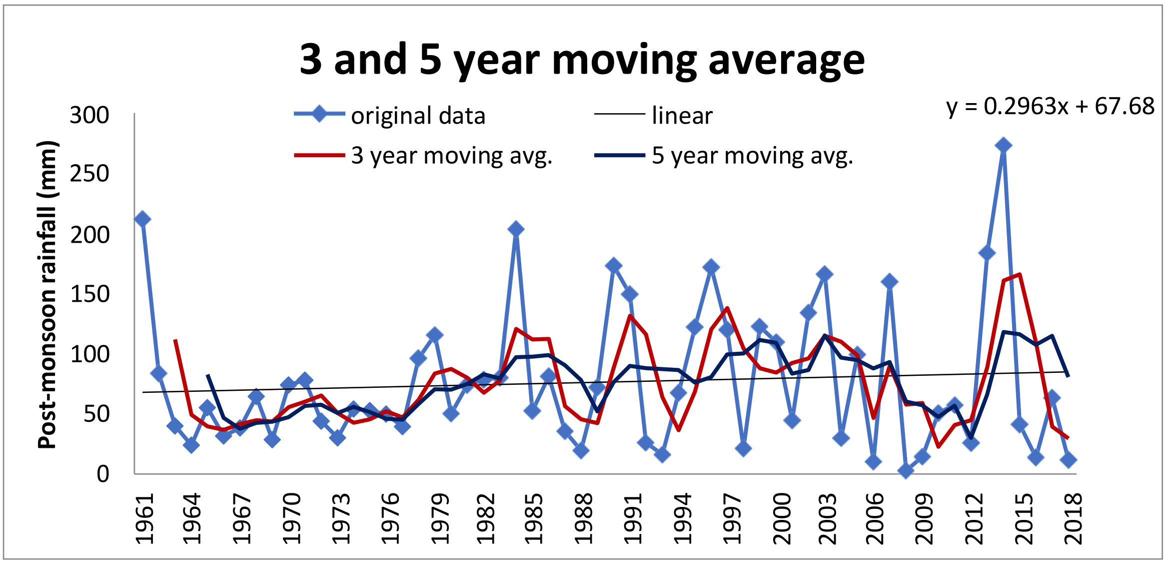

Figure 3.5 Variation of 3 and 5 year moving mean Average Rainfall (winter)

The following figure 3.6 represents the 3 and 5 year moving average curves of mean maximumtemperature for Annual season 58 years of Pantnagar.

The trend line with a decreasing slope of 0.1803. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

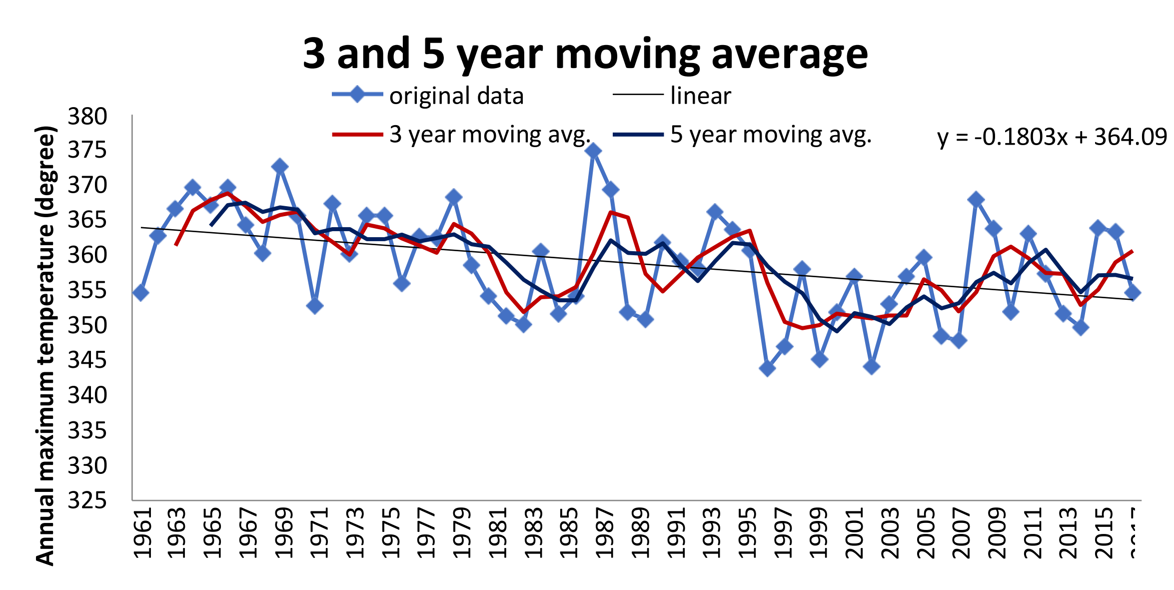

Figure 3.6 Variation of 3 and 5 year moving mean Average mean maximum temperature (Annual)

The following figure 3.7 represents the 3 and 5 year moving average curves of mean maximum temperature for Pre-monsoon season for 58 years of Pantnagar. The trend line with a decreasing slope of -0.0395. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

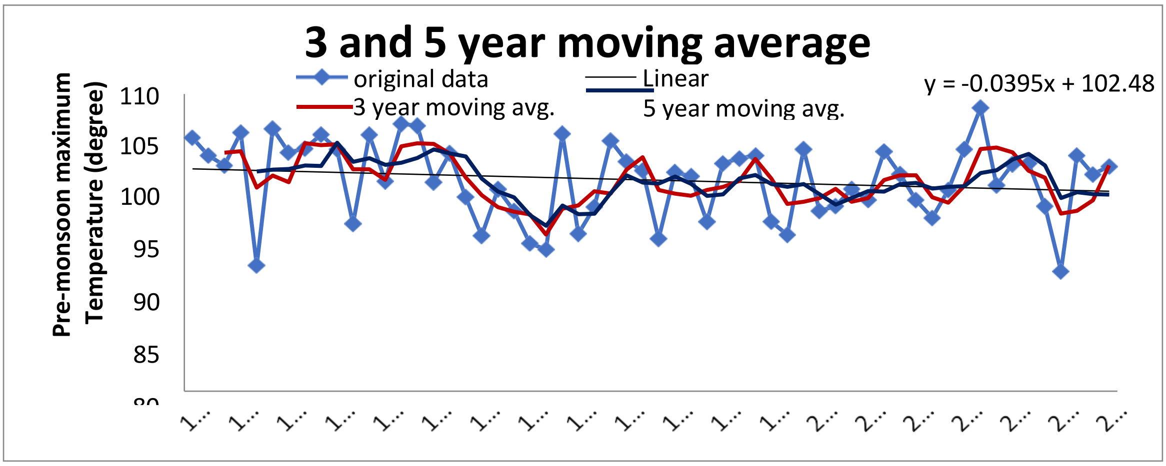

Figure 3.7 Variation of 3 and 5 year moving mean Average mean maximum temperature (Pre-monsoon)

The following figure 3.8 represents the 3 and 5 year moving average curves of mean maximum temperature for Monsoon season for 58 years of Pantnagar. The trend line with a decreasing slope of -0.0479. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

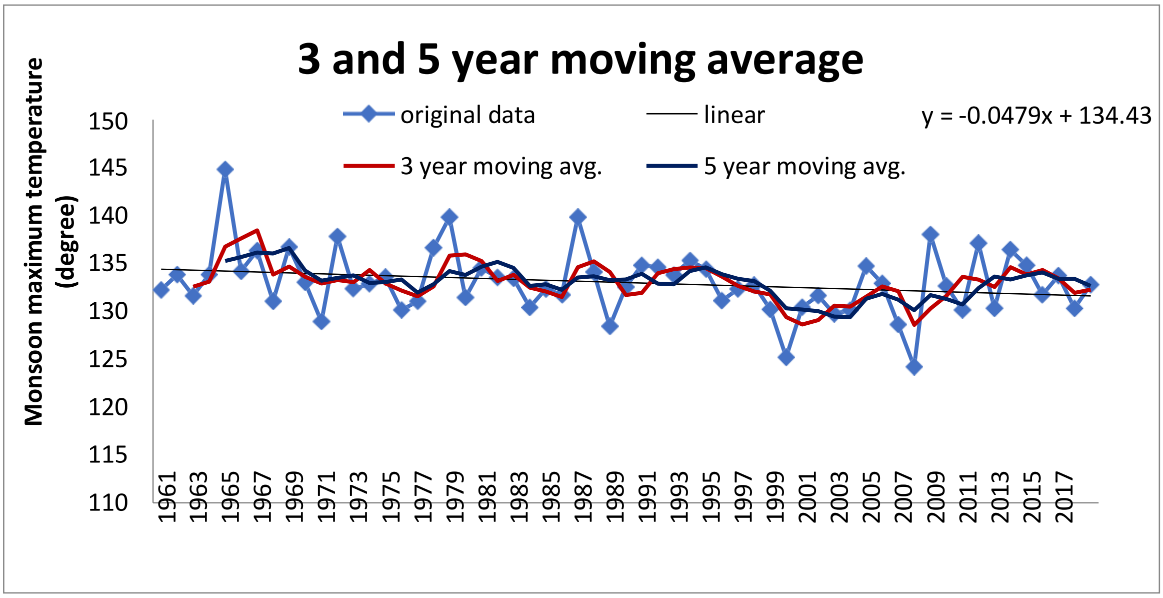

Figure 3.8 Variation of 3 and 5 year moving mean Average mean maximum temperature (Monsoon)

The following figure 3.9 represents the 3 and 5 year moving average curves of mean maximum temperature for Post-monsoon season for 58 years of Pantnagar. The trend line with a decreasingslope of -0.0063. Though the variations in the original data are smoothened out to some extent inthe moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

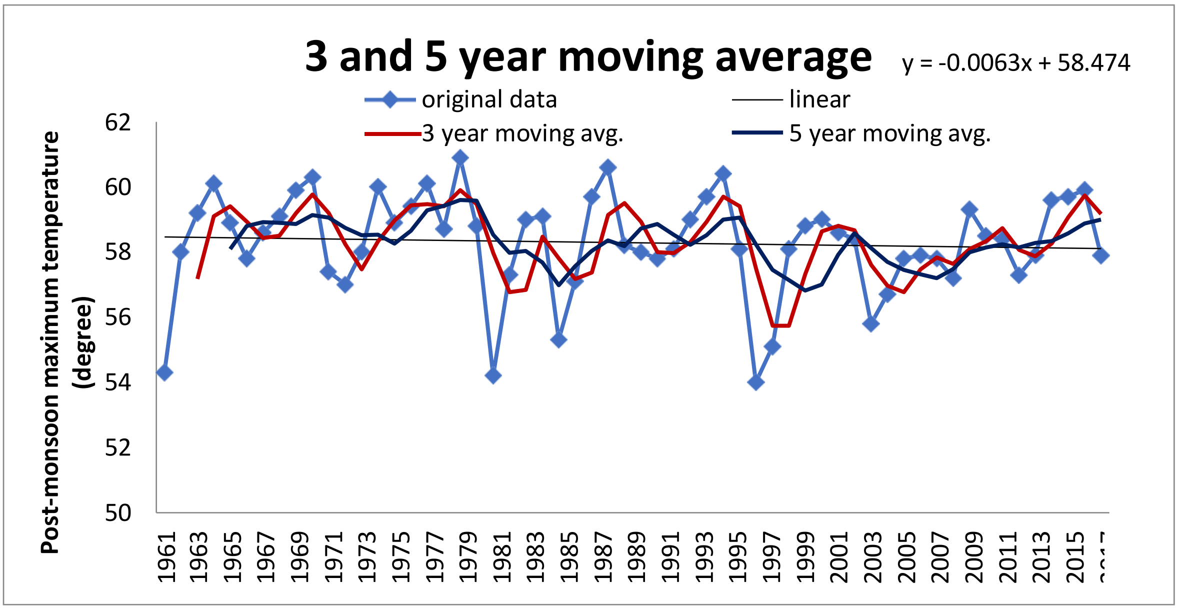

Figure 3.9 Variation of 3 and 5 year moving mean Average mean maximum temperature (Post-monsoon)

The following figure 3.10 represents the 3 and 5 year moving average curves of mean maximum temperature for winter season for 58 years of Pantnagar. The trend line with an increasing slope of -0.0845. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

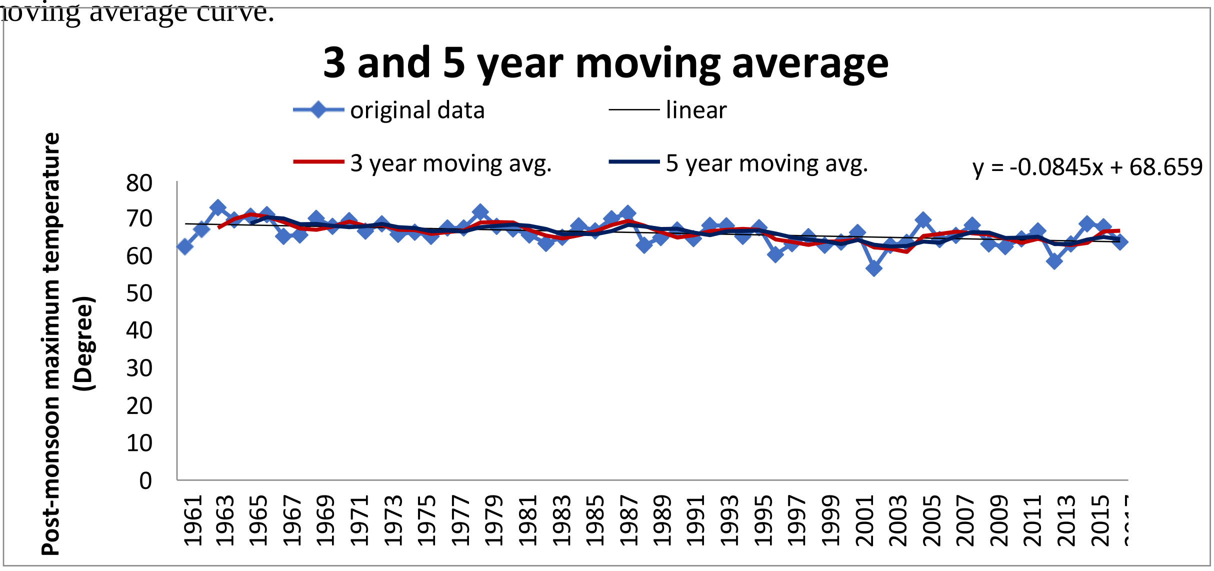

Figure 3.10 Variation of 3 and 5 year moving mean Average mean maximum temperature (winter)

The following figure 3.11 represents the 3 and 5 year moving average curves of mean minimum temperature for Annual season for 58 years of Pantnagar. The trend line with an increasing slope of 0.3817. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

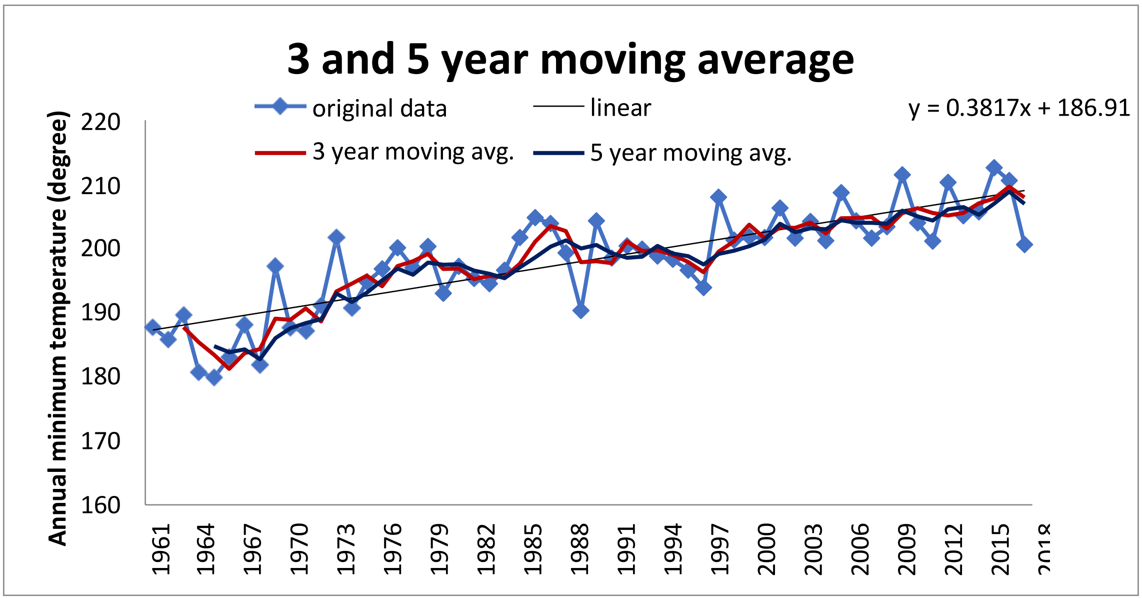

Figure 3.11 Variation of 3 and 5 year moving mean Average mean minimum temperature (Annual)

The following figure 3.12 represents the 3 and 5 year moving average curves of mean minimum temperature for Pre-monsoon season for 58 years of Pantnagar. The trend line with an increasing slope of 0.1166. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

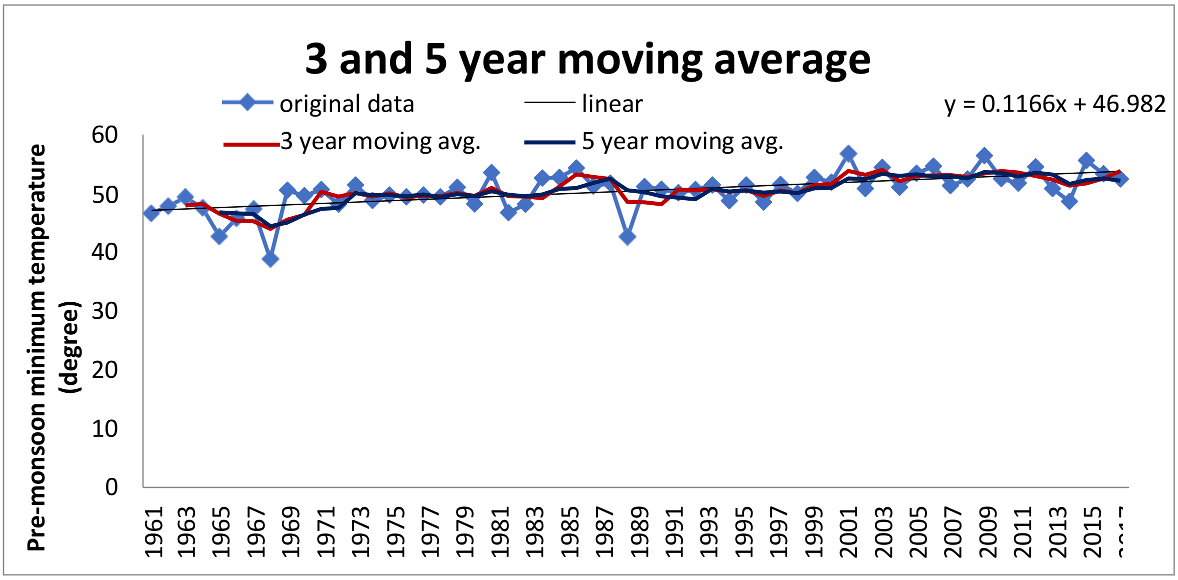

Figure 3.12 Variation of 3 and 5 year moving mean Average mean minimum temperature (Pre-monsoon)

The following figure 3.13 represents the 3 and 5 year moving average curves of mean minimum temperature for Monsoon season for 58 years of Pantnagar. The trend line with an increasing slope of 0.0929. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

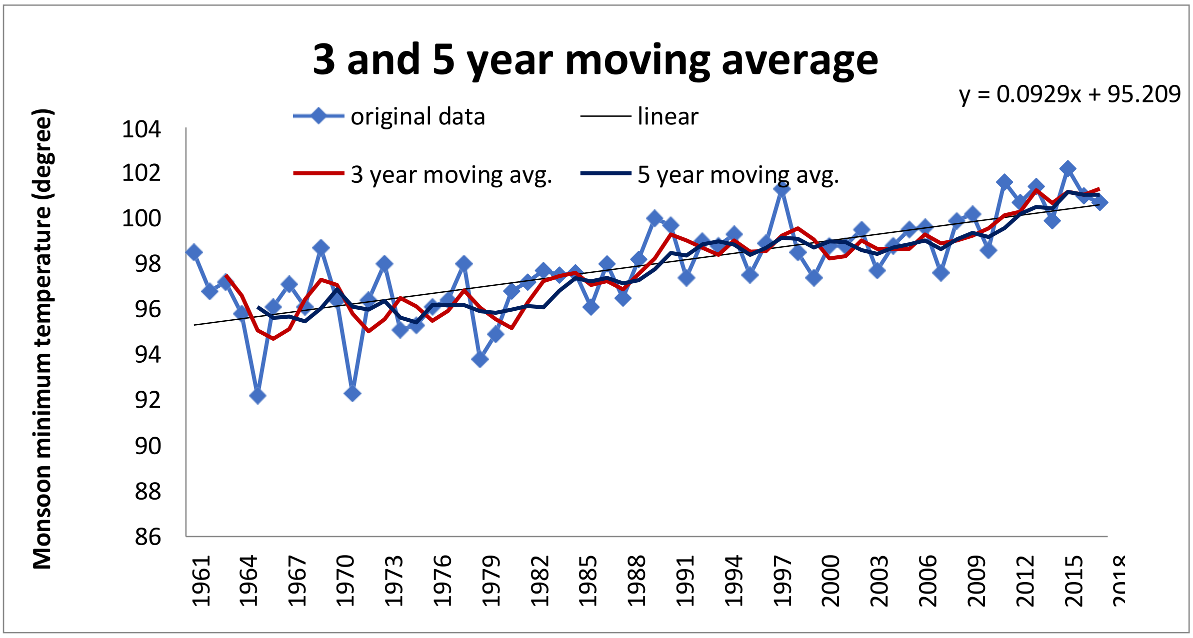

Figure 3.13 Variation of 3 and 5 year moving mean Average mean minimum temperature (Monsoon)

The following figure 3.14 represents the 3 and 5 year moving average curves of mean minimum temperature for post-monsoon season for 58 years of Pantnagar. The trend line with an increasing slope of 0.0532. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

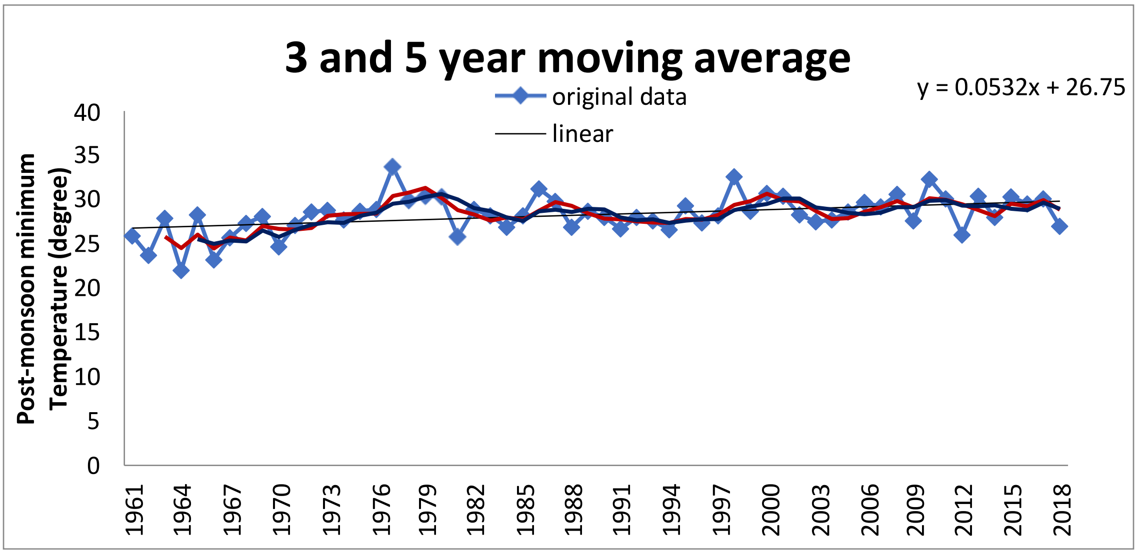

Figure 3.14 Variation of 3 and 5 year moving mean Average mean minimum temperature (Post-monsoon)

The following figure 3.15 represents the 3 and 5 year moving average curves of mean minimum temperature for winter season for 58 years of Pantnagar. The trend line with an increasing slope of 0.1189. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

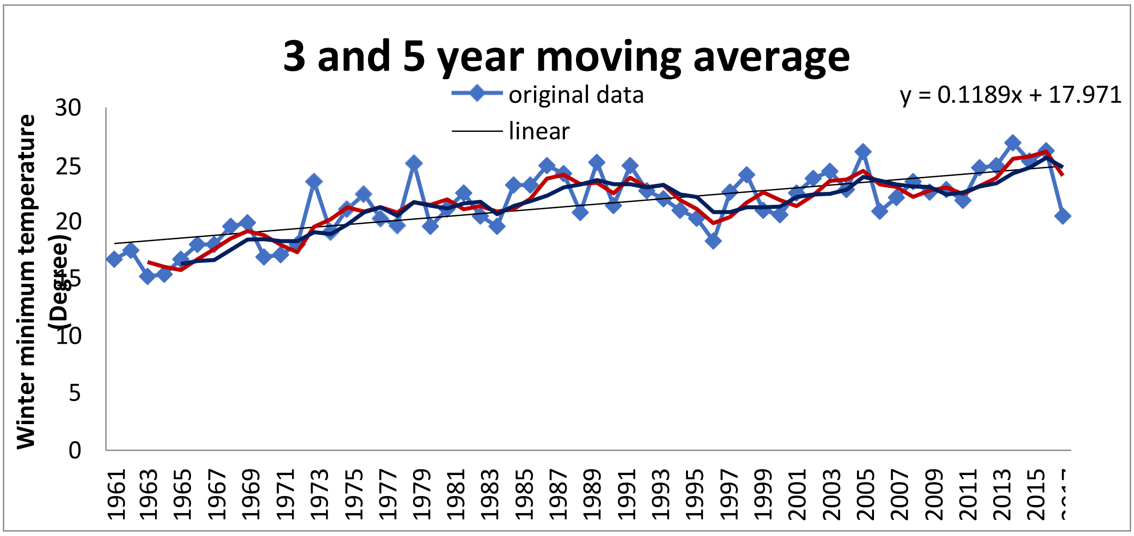

Figure 3.15 Variation of 3 and 5 year moving mean Average for mean minimum temperature (winter)

The following figure 3.16 represents the 3 and 5 year moving average curves of rainy days for Annual season for 58 years of Pantnagar. The trend line with a decreasing slope of -0.1685. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

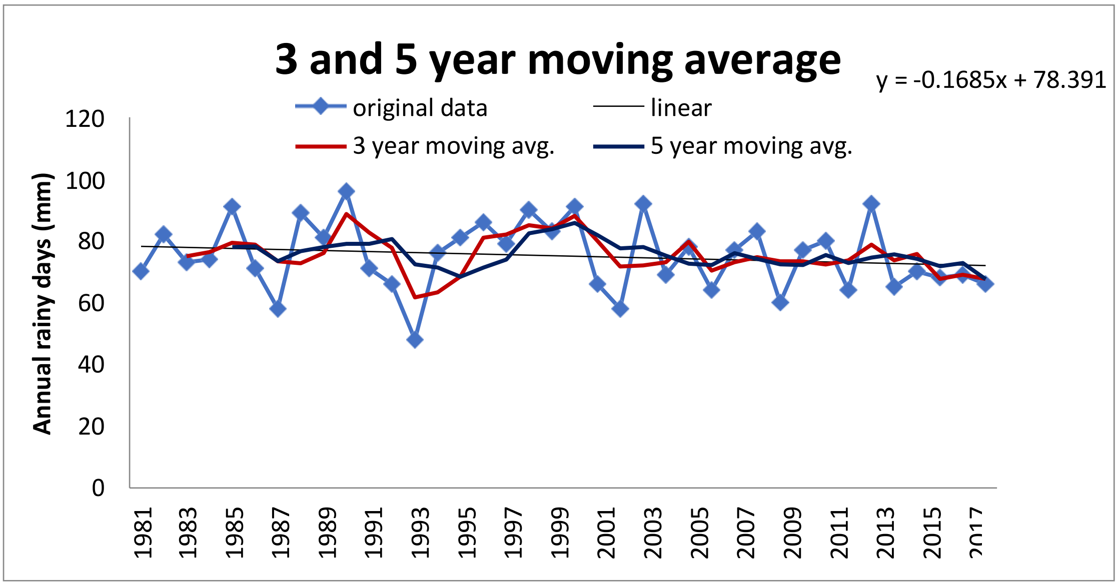

Figure 3.16 Variation of 3 and 5 year moving mean Average for rainy days (Annual)

The following figure 3.17 represents the 3 and 5 year moving average curves of rainy days for Pre-monsoon season for 58 years of Pantnagar. The trend line with a decreasing slope of -0.0252. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

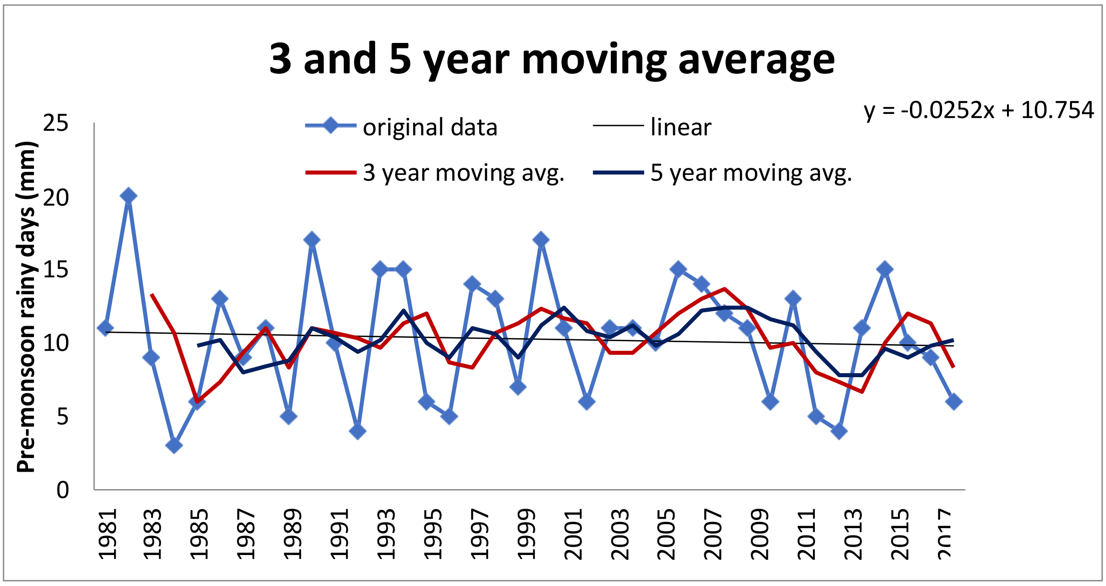

Figure 3.17 Variation of 3 and 5 year moving mean Average for rainy days (Pre-monsoon)

The following figure 3.18 represents the 3 and 5 year moving average curves of rainy days for Annual season for 58 years of Pantnagar. The trend line with a decreasing slope of -0.0121. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

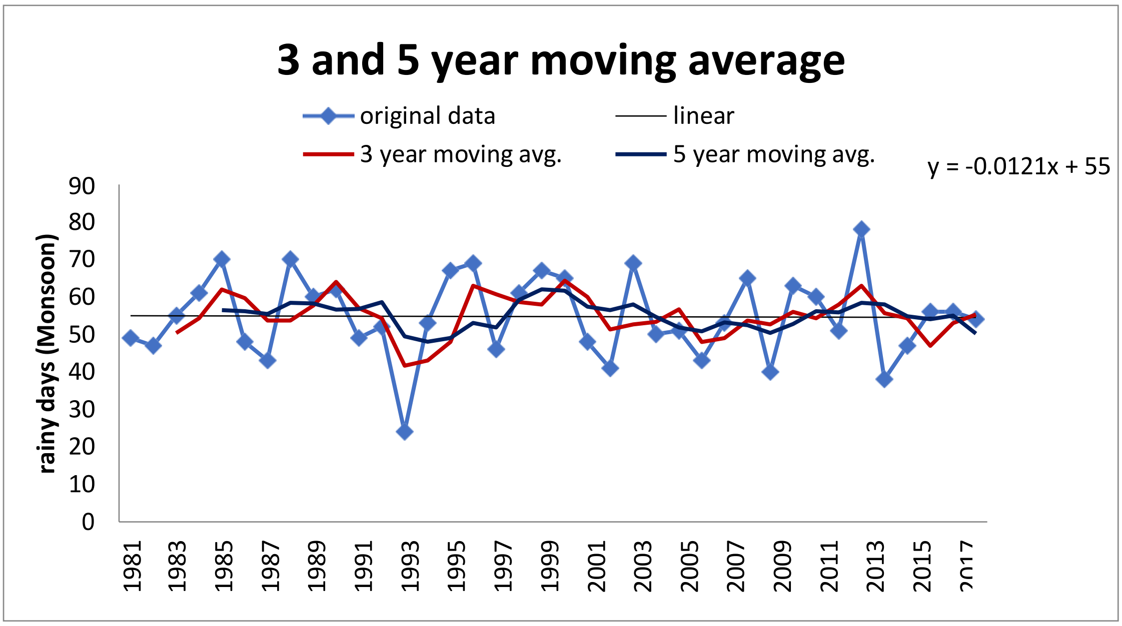

Figure 3.18 Variation of 3 and 5 year moving mean Average for rainy days (Monsoon)

The following figure 3.19 represents the 3 and 5 year moving average curves of rainy days for Post-monsoon season for 58 years of Pantnagar. The trend line with a decreasing slope of - 0.0241. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

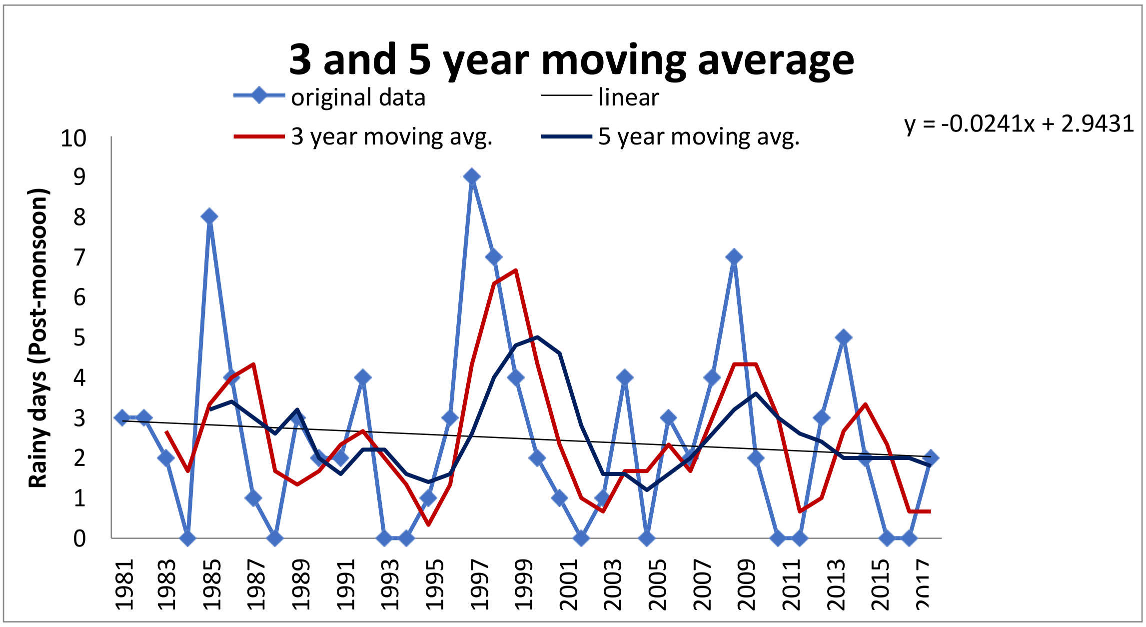

Figure 3.19 Variation of 3 and 5 year moving mean Average for rainy days (Post-monsoon)

The following figure 3.20 represents the 3 and 5 year moving average curves of rainy days for winter season for 58 years of Pantnagar. The trend line with a decreasing slope of -0.1071. Though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve.

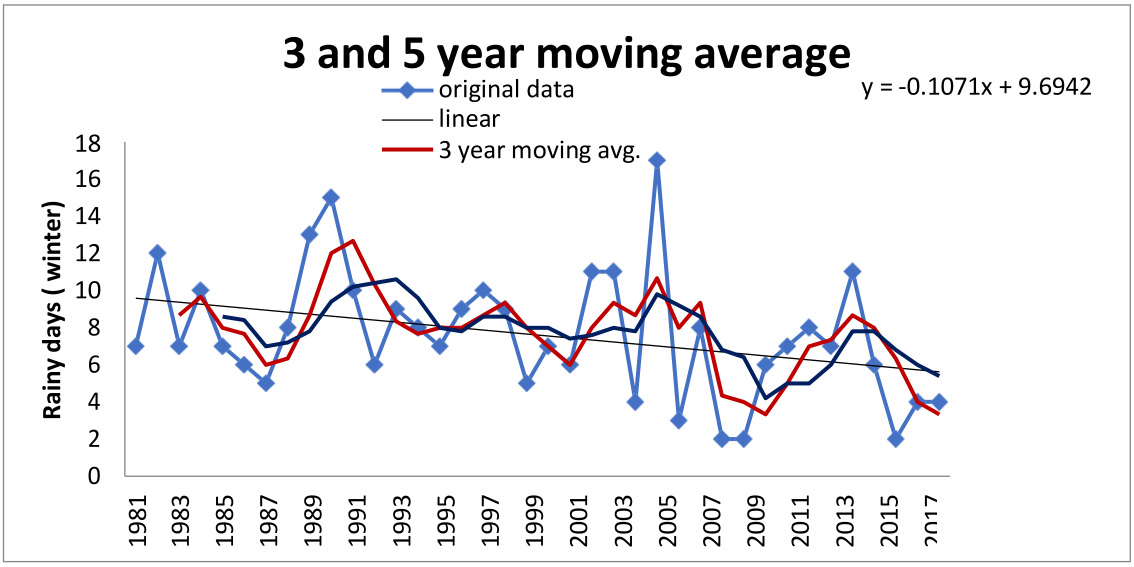

Figure 3.20 Variation of 3 and 5 year moving mean Average for rainy days (winter)

The mean, coefficient of variation (%) and its percentage contribution has been delineated in Table4.1. The mean (1961- 2018) annual, monsoon rainfall of Pantnagar is 124.05, and 347.83 mm respectively. Mean (1981 - 2018) pre-monsoon, post-monsoon and winter rainy days are 390, 94, and289 days respectively. The month of may receive highest monthly rainfall of 2623.2 mm spread over654 rainy days followed by the month of July. Very less rainfall is received during the month of October November and December. The standard deviation (SD) and coefficient of variation (CV) of the monthly rainfall and rainy days indicate high degree of variability associated in the monthly rainfall and rainy days in all the months barring few. In case of monthly rainfall, the coefficient of variation is less significant in the months of June, July, August and September (CV < 75%) however,in case of rainy days May to September have less variability (CV < 75%). Monsoon rainfall has minimum coefficient of variation that is 34.56% than pre-monsoon 76.59 %. Winter rainfall has highest coefficient of variation of 72.48%. In case of rainy days, Monsoon rainy days has minimum coefficient of variation 18.47 % than pre-monsoon (40.94%). Winter rainy days has highestcoefficient of variation of 49.13 %.

Table 3.1 Stastical properties of Rainfall data from the period (1961-2018)

Months	Arithmetic Mean	Standard Deviation	Variance	COV (%)	Coefficient of Skew	Coefficient of Kurtosis	Median
Jan	28.4931	28.6933	823.306	100.7	1.1408	0.6617	21.1
Feb	34.7552	42.1699	1778.296	121.33	1.567	1.6631	17.2
March	18.7983	23.3631	545.833	124.28	1.6445	2.0754	9.3
April	14.7776	19.8592	394.389	134.39	1.9882	3.7602	7.9
May	45.2276	53.2356	2834.029	117.71	3.0057	13.0108	29.6
June	186.5	143.3498	20549.16	76.86	1.756	3.2909	162.1
July	437.2879	163.9469	26878.595	37.49	0.2259	-0.2077	412.4
Aug	419.7241	194.3782	37782.874	46.31	0.8676	2.5912	396.3
Sep	247.6862	180.7531	32671.69	72.98	1.108	0.6992	208.8
Oct	38.6155	72.2357	5217.9968	187.06	2.7743	8.1325	8.1
Nov	3.6483	7.3052	53.3657	200.24	2.3303	4.5686	0.0
Dec	13.1724	20.2647	410.6585	153.84	2.4976	7.2674	5.0
Winter	24.7673	17.9507	322.22	72.48	0.8605	0.5677	24.0
Pre-monsoon	26.2678	20.1182	404.74	76.59	1.9388	6.6088	21.5
Monsoon	347.83	120.22	14455.04	34.56	0.588	0.2804	347.7
Post-monsoon	96.65	66.86	4471.38	69.19	1.0975	1.0424	78.7
Annual	124.05	42.59	1814.18	34.33	0.8783	1.344	118.7

Table 3.2 Stastical properties of Rainy Days from the period (1981-2018)

Months	Arithmetic Mean	Standard Deviation	Variance	COV (%)	Coefficient of Skew	Coefficient of Kurtosis	Median
Jan	2.7632	2.658	4.3478	75.46	0.3707	-0.871	2.5
Feb	3.4474	2.5255	7.0647	77.1	1.1376	1.6586	3.0
March	3.0	1.8701	6.3784	84.18	1.052	1.3037	3.0
April	2.5526	2.7204	3.4972	73.26	1.1432	2.5551	2.0
May	4.7105	4.0373	7.4004	57.75	0.0846	-0.2968	5.0
June	9.3947	4.1347	16.2994	42.97	0.3852	-0.19	9.0
July	17.6579	4.3877	17.096	23.42	-1.382	3.3558	18.0
Aug	17.2105	5.0498	19.2518	25.49	-1.1301	2.8053	18.0
Sep	10.5	2.0851	25.5	48.09	0.5058	0.3582	10.0
Oct	1.7632	0.956	4.3478	118.26	1.1448	0.7519	1.0
Nov	0.7105	1.5341	0.9139	134.55	1.2175	0.5046	0.0
Dec	1.3947	11.2773	2.3535	109.99	1.229	1.2462	1.0
Winter	2.5405	1.2481	1.5577	49.13	0.2500	-0.1540	2.7
Pre-monsoon	3.4211	1.4007	1.9621	40.94	0.1513	-0.6471	3.7
Monsoon	14.7544	2.7254	7.4275	18.47	-0.5233	0.0111	15.0
Post-monsoon	4.3246	1.9459	3.7867	45.00	0.4426	0.3262	6.3
Annual	6.2588	0.9398	0.8832	15.02	-0.0919	-0.4550	75.0

4 Conclusion

It can be concluded from the results obtained from the study that high degree of variability associated in the monthly rainfall and rainy days in all the months except few.In case of monthly rainfall, the coefficient of variation is less significant in the months of June, July, August and September however, in case of rainy days May to September have less variability. Monsoon rainfall has minimum coefficient of variation than pre-monsoon. Winter rainfall has highest coefficient of variation. In case of rainy days, Monsoon rainy days has minimum coefficient of variation than pre-monsoon. Winter rainy days has highest coefficient of variation.

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