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RESEARCH ARTICLE

CHARACTERIZATION AND ANALYSIS OF THE TREND OF CLIMATE VARIABLE (TEMPERATURES) FOR THE NORTH EASTERN REGION OF THE INDIA

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ABSTRACT

Trend analysis of climatic variables has received a great deal of attention from researchers recently. By trend analysis of the climate variables the better prediction of the weather conditions and consequences can be taking place. The main aim of this study was to investigate trends in maximum (Tmax) and minimum (Tmin) air temperatures in the annual and seasonal time-scales for six stations in the hilly region of North East India during 1901-2000. From the results it is clear that the majority of the trends in the annual and seasonal Tmax and Tmin time series showed increasing tendency during the last decades while the increasing trends in the Tmin series were stronger than those in the Tmax series.

INTRODUCTION

Based on global circulation models, it has been recommended that a doubling of ambient CO_2 concentrations might increase the global mean air temperature by 1.4–5.8 °C from the pre-industrial level (Komatsua *et al.*, 2007). There has been recent evidence of anthropogenic changes in the earth's climate related to these increases and the further changes are anticipated (Haskett *et al.*, 2000). However, air temperatures don't rise uniformly in all regions around the world (Rosenberg *et al.*, 2003). Changes in global mean air temperature (T_{mean}) are a useful indicator of climate change and variability. A greater understanding of the causes of some of the changes has been gained over the past few decades by considering related changes in other variables.

Other thermometric variables that have raised similar interests are the monthly mean maximum (T_{max}) and minimum (T_{min}) air temperatures. This is because of changes in T_{mean} can be due to changes in T_{max} or T_{min} or the changes in both (Del Rio *et al.*, 2007). Long-term temporal trends in T_{max} or T_{min} time series have been studied in many areas of the world including: United States (Karl *et al.*, 1990; De Gaetano, 1996), Spain (Esteban-Parra and Rodrigo, 1995;Serra *et al.*, 2001; del Rio *et al.*, 2007), Czech and Slovak (Brazdil *et al.*,1995), Poland (Wibig and Glowicki, 2002), Italy (Brunetti *et al.*,2000), China (Su *et al.*, 2006), India (Gadgil and Dhorde, 2005; Dhorde *et al.*, 2009; Sharad K. Jain and Vijay Kumar, 2012;Sonali, D. P., Kumar N.,2013; Subah & Sikka, 2014). Recently in India (Kumar *et al* 2014) analyzed the changes in the maximum, minimum and mean air temperatures. The analysis was subjected for seasonal, annual and monthly basis and revealed a tendency towards warmer years all around with significant warmer winter and more increase in minimum temperatures. The annual maximum, minimum and mean temperatures have increase by 1.41 ^{0}C, 1.63 ^{0}C and 1.49 ^{0}C respectively. The seasonal analysis indicates that the tendency is more pronounced in winter followed by post- monsoon, pre-monsoon and monsoon season. A part from this it is also found that the Mountains are major climate determinant and large-scale orography has a pronounced effect on atmospheric flow pattern. A precise understanding of the spatial and temporal behavior of climate parameters in mountainous areas are hampered by the lack of observational data (Beniston *et al.*, 1997) and Yinghui *et al.*, 2015 detected the strong relationships between temperature trends and elevation. Climate change concerns in the Himalayan region are diverse and range from droughts, floods, landslides, human health, biodiversity, endangered species, agricultural livelihood and food security (Barnett *et al.*, 2005).Immerzeel W., 2008 studied the historical climate variation and future climate change for the entire Brahmaputra Basin. Historical temperature trends analyzed

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from 1900- 2002 for Tibetan Plateau, the Himalayan belt and the floodplains & predicted the biggest risk of climate change lies in the associated flooding in the densely populated Floodplains. The previous study indicates that the climatic parameters varying region to region, its magnitude and impacts differs with spatial and temporal scale. Large-scale orography is also extremely significant parameter for the climate change study. Considering relevant points from the earlier studies conducted over the global and regional level, the present study investigated at local level to understand the warming trend in last century in the study area. The annual and seasonal temperature variations were also analyzed in order to understand the trend.

Study area, data and materials

Dikhow river is the south bank tributary of river Brahmaputra. The Dikhow catchment is located between $94^0$28'49" E to $95^0$09'52" E longitude and $26^0$52'20" N to 26^0 03'50" N latitude and covers an area of 3100.17 Km^2. The watershed receives an average annual rainfall of 2323.5 mm, July month alone accounts for nearly 19.8% and November to January months together account for only 3.0% of annual rainfall at Sibsagar. August is the hottest month and January is the coldest month with monthly mean maximum and minimum daily temperatures of nearly 32.0^0C and 25.4^0C, and 23.0^0C and 10.2^0C, respectively. Mean relative humidity is highest in August and lowest in April. The prevailing winds at 8:30 and 17:30 hours generally blow from N-NE sector towards S-SW sector throughout the year. Annual average wind speed is 3.8 km/h with April and July having the highest mean wind speed of 5.4 km/h and December having the lowest mean wind speed of 1.7 km/h. Locations of study area and stations were shown in Fig. 1 and Table 1, respectively. The monthly observed temperature (max and min) and rainfall data were procured from Indian Meteorological Department, Pune, India for Six stations from 1961-2002. A data set of six stations in the north eastern part of India with long-term maximum and minimum air temperatures data for the period 1901–2000 were analyzed in this study. The annual and monthly data were provided by the Indian Meteorological Department. Monthly values were averaged to obtain seasonal (winter, summer and monsoon) temperature for each of the six stations. Seasons were defined as follows: winter (December, January & February), summer (March, April & May) and monsoon (June, July, August & September). The station choice was based on the desire to have a wide spread and availability of data. The geographic location of the stations and description can be seen in Fig. 1 and Table 1. The homogeneity of the temperature records was analyzed. The double-mass curve analysis (Kohler, 1949) was used to the T_{max} and T_{min} time series of each station. The Results of the double-mass curves of all stations are almost a straight line, and no obvious breakpoints are detected in the time series.

METHODOLOGY

Trend analysis

A large number of tests can be used for trend detection in long time series of meteorological and hydrological records (Tabari *et al.*, 2011b). In the present study, non-parametric (Mann–Kendall, Sen's slope estimator) methods were used to detect the temperature trends. Non -parametric methods have the advantage of being not assuming any distribution form for the data and have power similar to its parametric competitors (Zhang *et al.*, 2008). To eliminate the influence of serial correlation on the Mann– Kendall test. Von Storch (1995) proposed to pre-whiten the series before applying the Mann – Kendall test, i.e., to remove serial correlation from the series. The brief descriptions of the used statistical methods are as follows:

Mann Kendall test

The Mann– Kendall test is a non-parametric test for identifying trends in time series data. The test compares the relative magnitudes of sample data rather than the data values themselves (Gilbert, 1987). One advantage of this test is that the data need not conform to any particular distribution. The second advantage of the test is its low sensitivity to abrupt breaks due to in homogeneous time series (Jaagus, 2006). Mann (1945) originally used this test and Kendall (1975) subsequently derived the test statistic distribution.

According to this test, the null hypothesis H_0 states that the deseasonalized data (x1 ,…,xn) is a sample of n independent and identically distributed random variables. The alternative hypothesis H 1 of a two-sided test is that the distributions of xk and xj are not identical for all k , j ≤ n with k ≠ j . The test statistic S , which has mean zero and a variance computed by Eq. (3), is calculated using Eqs. (1) and (2) , and is asymptotically normal:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(xj - xi) \quad (1)$$

$$\mathrm{sgn}(xj - xi) = \begin{Bmatrix} 1 \ldots .\text{ if } (xj - xi) > 0) \\ 0 \cdots \text{ if } (xj - xi) = 0 \\ -1 \cdots \text{ if } (xj - xi) < 0 \end{Bmatrix} \quad (2)$$

$$v(s) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} ti(ti-1)(2ti+5)}{18} \quad (3)$$

where n is the number of data points, m is the number of tied groups (a tied group is a set of sample data having the same value), and ti is the number of data points in the i th group. In cases where the sample size n N 10, the standard normal variable Z is computed by using Eq. (4)

$$Zmk = \begin{Bmatrix} \frac{s-1}{\sqrt{var(s)}}, when\ s > 0 \\ 0 \ldots \ldots \ldots when\ s = 0 \\ \frac{s+1}{\sqrt{var(s)}}, when\ s < 0 \end{Bmatrix} \quad (4)$$

Positive values of Z indicate increasing trends, while negative values of Z show decreasing trends. When testing either increasing or decreasing monotonic trends at the α significance level, the null hypothesis was rejected for an absolute value of Z greater than Z1 − α/2, obtained from the standard normal cumulative distribution tables (Partal and Kahya, 2006; Modarres and Silva, 2007). In this research, significance level of α = 0.05 was applied.

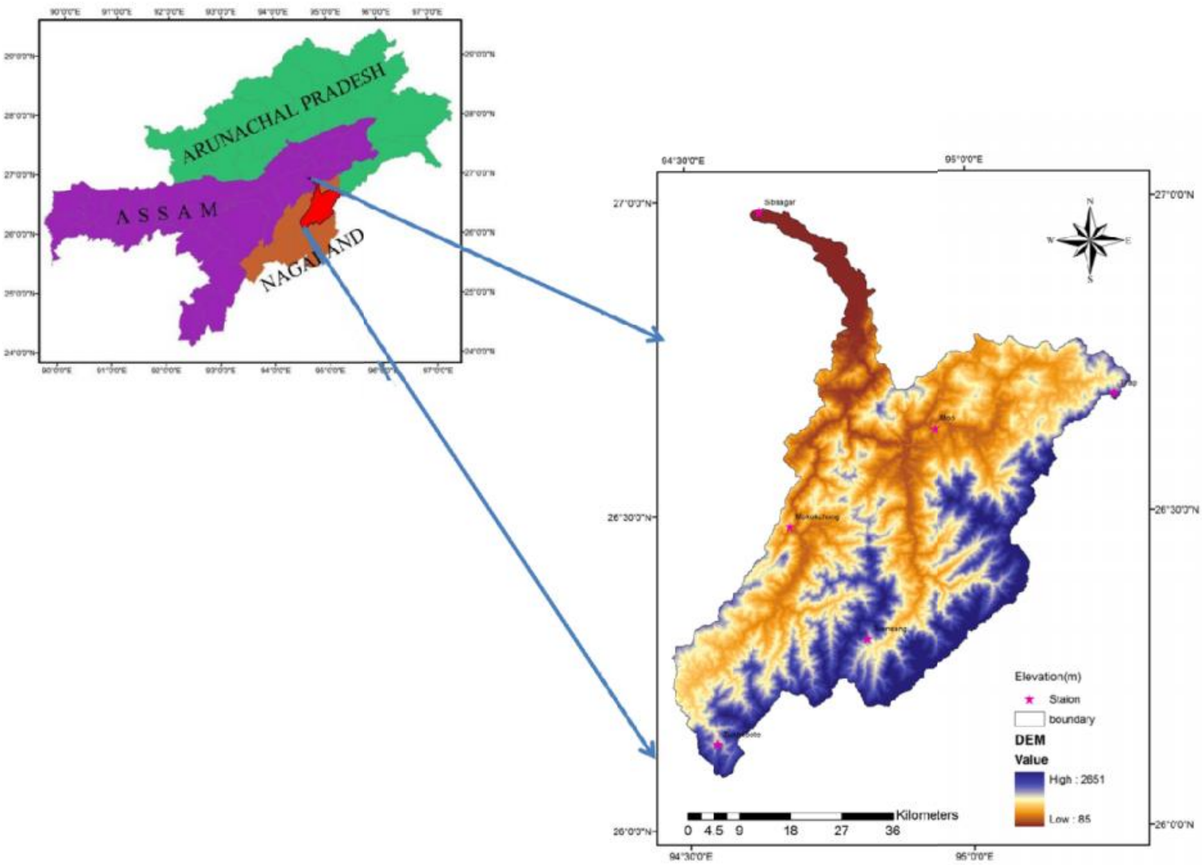


Fig.1 Map of the Dikhow Catchment with Location of the stations

Table 1 stations considered for the study

S.N.	State	Station	Latitude (° 'N)	Longitude (° 'E)	Altitude (m)	Area
1	Assam	Sibsagar	26°58'59"N	94°37'59"E	98	94.07
2	Nagaland	Mokokchung	26°28'54"N	94°40'37"E	1045	300.04
3	Nagaland	Mon	26°38'9"N	94°56'32"E	776	1247.08
4	Arunachal Pradesh	Tirap	26°41'9"N	95°15'29"E	1500	28.19
5	Nagaland	Tuensang	26°18'13"N	94°48'59"E	1369	1265.69
6	Nagaland	Zunheboto	26°8'14"N	94°32'53"E	1302	158.69

Table 2 Mann Kandall and Sen' slope in Annual T_{max} and Annual T_{min}

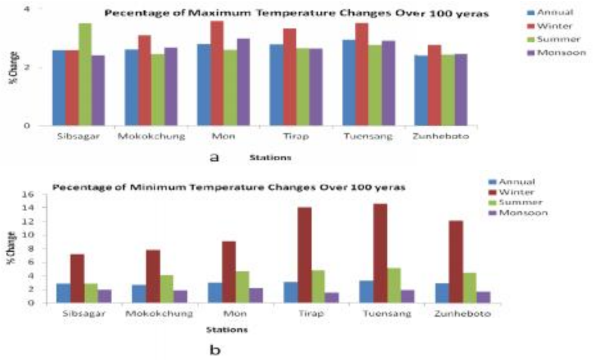
		T_{max}			T_{min}		
S.N.	Station	Normalized test statistics (Z)	Trends at (95% CL)	c	Normalized test statistics (Z)	Trends at (95% CL)	Sen's slope (°C /year)
1	Sibsagar	4.083	Increasing	0.0039	4.817	Increasing	0.0059
2	Mokokchung	4.239	Increasing	0.0042	5.251	Increasing	0.0066
3	Mon	4.453	Increasing	0.0044	5.401	Increasing	0.0069
4	Tirap	4.025	Increasing	0.004	5.071	Increasing	0.0061
5	Tuensang	4.175	Increasing	0.0042	5.306	Increasing	0.0066
6	Zunheboto	4.213	Increasing	0.004	5.123	Increasing	0.0063

Table 3 Mann Kandall and Sen' slope in Seasonal T_{max}

		T_{max}								
		Winter			Summer			Monsoon		
S.N.	Station	Normalized test statistics (Z)	Trend at (95% CL)	Sen's slope (°C /year)	Normalized test statistics (Z)	Trend at (95% CL)	Sen's slope (°C /year)	Normalized test statistics (Z)	Trend at (95% CL)	Sen's slope (°C /year)
1	Sibsagar	2.972	Increasing	0.0061	2.504	Increasing	0.0057	2.31	Increasing	0.0024
2	Mokokchung	3.447	Increasing	0.007	2.643	Increasing	0.0065	2.981	Increasing	0.0038
3	Mon	3.747	Increasing	0.0077	2.735	Increasing	0.0068	2.991	Increasing	0.0044
4	Tirap	3.308	Increasing	0.0065	2.55	Increasing	0.0061	2.54	Increasing	0.0027
5	Tuensang	3.551	Increasing	0.0069	2.622	Increasing	0.0065	2.124	Increasing	0.0034
6	Zunheboto	3.753	Increasing	0.0065	2.712	Increasing	0.0062	2.792	Increasing	0.0033

Table 4 Mann Kandall and Sen' slope in Seasonal T_{min}

		T_{min}								
		Winter			Summer			Monsoon		
S.N.	Station	Normalized test statistics (Z)	Trend at (95% CL)	Sen's slope (°C /year)	Normalized test statistics (Z)	Trend at (95% CL)	Sen's slope (°C /year)	Normalized test statistics (Z)	Trend at (95% CL)	Sen's slope (°C /year)
1	Sibsagar	3.78	Increasing	0.0072	3.354	Increasing	0.0062	2.31	Increasing	0.0059
2	Mokokchung	3.874	Increasing	0.007	3.525	Increasing	0.0064	2.981	Increasing	0.0074
3	Mon	3.955	Increasing	0.0072	3.692	Increasing	0.0065	2.991	Increasing	0.0081
4	Tirap	4.016	Increasing	0.0086	3.316	Increasing	0.0061	2.54	Increasing	0.0064
5	Tuensang	4.028	Increasing	0.0088	3.551	Increasing	0.0064	2.124	Increasing	0.0072
6	Zunheboto	3.961	Increasing	0.0087	3.41	Increasing	0.0067	2.792	Increasing	0.007



Sen's slope estimator

If a linear trend is present in a time series, then the true slope (change per unit time) can be estimated by using a simple non-parametric procedure developed by Sen (1968). The slope estimates Q_i of N pairs of data are calculated by equation (5).

$$Q_i = \frac{x_j - x_k}{j-k} \qquad i= 1....N \qquad (5)$$

Where x_j and x_k are data values at times j and k (j>k) respectively. The Sen's estimator of slope derives from the above N values of Qi and equals to their median. When there is only one datum in each time period, then N = n (n - 1) / 2, where n corresponds to the number of time periods. The N values of slopes are ranked from the smallest to largest and if N is odd, Sen's estimator of slope is calculated by equation (6)

$$Q_{Me} = Q_{[(n+1)/2]} \qquad (6)$$

On the other hand, in case that N is even, the estimator of slope is calculated by equation (7).

$$Q_{Me} = \frac{1}{2}[Q_{(n/2)} + Q_{(n+2)/2} \qquad (7)$$

Distribution free CUSUM test

This is one of the best methods to find out the abrupt change in the time series. This is non-parametric rank-based method tests whether the means in two parts of a record are different for an unknown time of change. In particular, successive observations are compared with the median of the series in order to detect a change in the mean of a time series after a number of observations (Kundzewicz and Robson 2004). The test statistic Vk of a time series data is the cumulative sum (CUSUM) of the k signs of the difference from the median (a series of values of -1 or +1) starting from the beginning of the series.

RESULTS AND DISCUSSION

The analysis of trends for the data sets (annual and seasonal) for minimum temperature and maximum temperature described in Table 2, Table 3 and Table 4 were carried out using Mann Kendall nonparametric test. The statistical significance of trends is indicated by p value (not shown in table) and the direction and the magnitude were computed by Sen's slope method. A value of 0.05 was chosen as a significance level for two sided test. Based upon this significance level, Normalized Test Statistic Z values greater than 1.96 or smaller than 1.96 respectively, indicates a significant positive or negative trend. The distribution-free CUSUM test was applied in order to test the hypothesis concerning the existence of a step (shift) change in annual minimum and annual maximum temperature time series during the study period (1901-2000). The maximum values of the statistic v_k have reached the critical values at 95% confidence level (the value of v_k is 13.735), signifying that there was statistically significant step change identified in temperature datasets.

Annual Temperature Trends

Mann Kendall statistics and Sen's slope test for both annual T_{max} and annual T_{min} has been given by Table 2. Trends are considered statistically significant at the 95% confidence level. According to the results, six out of six stations were dominated by significant increasing trend of annual T_{max} and annual T_{min}. None of the stations showed statistically significant decreasing trends in annual T_{max} and annual T_{min}. The positive trends of annual T_{max} found in this paper are in good agreement with the results obtained for other territories in India such as (Kumar *et al* 2014) and Subah & Sikka (2014). And partial agreement with (Sharad K. Jain and Vijay Kumar, 2012) regarding trends in temperature, larger increase in annual minimum temperatures was found than annual maximum temperature is good agreement with the study of Kumar et .al 2014. The variation in slope of Annual T_{max} was 0.039 to 0.044^{0}C per Decade, and 0.059 to 0.069 ^{0}C per Decade for annual T_{min} was identified. Shift were detected in year 1978 and 1945, for T_{min} and T_{max} respectively (not presented in table), Fig. 2 (a) and (b) indicating the percentage change over the century, changes were found in both annual T_{min} and T_{max} over the 100 years. Greater change was observed in T_{min} rather than T_{max} over the 100 years in terms of percentage change by mean. The percentage change in annual maximum temperature of all the six region of north east are almost same as comparable so by that temperature trend the situation of the all the places in north east region are quite similar. Despite these the annual temperature changes of the Mon, Tirap and Tuensang are slightly high comparable to other region of the North east so that places show the different climate. Still there is more variability at the Tuensang according to temporal trend in the annual max temperature change.

Trends in Seasonal Temperature Maximum

Seasonal analysis of temperature data was carried out for the three seasons: winter, summer and monsoon. The results of trend analysis of seasonal T_{max} were presented in Table 3. For the winter, summer and monsoon season the trend is increasing significantly for all the stations in the study area. The trends in T_{max} for winter season are predominantly increasing by six out of six stations followed by summer and monsoon. Slope varying from 0.061 to 0.077 ^{0}C per decade in winter, from 0.057 to 0.067 ^{0}C per decade in summer and 0.24 to 0.044 ^{0}C per decade in monsoon. The largest change in winter season was found for all the stations except the Sibsagar. It was maximum up to 3.59 % at Mon. Sibsagar exhibited different behavior from other stations it was showing highest changes in summer followed by winter and monsoon, however Zunheboto and Tirap exhibited the highest percentage changed in winter followed by summer and monsoon from, moreover highest changed were found in winter, followed by monsoon and summer at Mokochung, Mon and Tuensang stations. It was a clearly identified that the winter maximum temperature changing largely for the study area.

Trends in Seasonal Temperature Minimum

Table 4 presented the seasonal trends (winter, summer and monsoon) in T_{min}. No significantly decreasing trends were found in winter, summer and monsoon for all stations. Statistically increasing trends were identified for all the stations in all the season. Variation of Sen's slope from 0.070 to 0.088 ^{0}C per decade in winter, 0.061 to 0.067 ^{0}C per decade for summer and 0.059 to 0.081 ^{0}C per decade for monsoon were identified. The winter followed by summer and monsoon seasons were exhibited the highest to lowest percentage change. Maximum change (15.21%) at Tunesang and minimum change (7.15%) at Sibsagar were observed for winter season. Not more than 4.45 % in summer and 2.21 % in monsoon season were observed. Winter season was very identical to showing greater changes in minimum temperature.

CONCLUSIONS

The analysis documented that there is an overall warming trend in the catchment, more pronounced for minimum temperatures, making warmer winters. The conclusions drawn from the study are listed below.

1. The trend is positive for all seasons, while it is the largest for winter minimum temperature, showing an evidence a warmer winter in the in hilly region.
2. The trend in annual T_{max} and T_{min} averaged over all six stations was 0.041°C and 0.064 °C per decade, respectively. T_{max} and T_{min} warming trends were more obvious in winter than in summer and monsoon. The highest magnitude increases 3.59 % and 15.21% for T_{max} and T_{min} respectively. The shifts were found in year 1978 and 1945, for T_{max} and T_{min} respectively.
3. The percentage change in summer maximum temperature of the sibasagar region of north east is quite high compare to other region but in minimum change in temperature is quite low so by this change in the annual temperature we can warn the people for the situation occurring due to the high temperature change and affect the life.
4. The change in max temperature during the winter season is fluctuating to each places of the North east region. Max temperature change recorded at Mon and Tuensang with slight higher than the Tirap and Mokokchung. At Sibsagar and Zunheboto are found the same max temperature change different to other places in the region. Thus in winter season there are great fluctuation can be seen at the different places of the north east region.
5. During the monsoon season the max temperature change at all the six places are same so that almost all places show the equal trend of the monsoon in North east region. By the depicted fact during the analysis however Mon and Tuensang has been recorded the slight change in monsoon conditions comparable to other places because of the higher change in max temperature during the season.
6. The percentage change in minimum temperature change is same annually as well as during the monsoon season so the annual overall situations due to minimum temperature changes are the same in the North east region. Besides these during the monsoon season Mon area showing the little different trend according to our analysis.
7. The change in min temperature during the winter season is also fluctuating. A great change has been found by the analysis between the group (Tirap, Tuensang) to group (Sibsagar, Mokokchung and Mon). Thus in winter season there are great fluctuation can be seen at the different places of the north east region due to minimum temperature change too. Zunheboto region of the North east group show the middle level of minimum temperature change compare to higher and lower min temp change hence this will show the slight different condition of the climate. During the winter.
8. According to the Sen's slope for the minimum temperature change the trend in temperature change are same for all weather conditions provided that there are higher values of the sen's slope annually however for the maximum temperature change govern Sen's slope due to steep change in monsoon season the annual max temperature behaviour show the variety in change.
9. The precipitation and cloud conditions are generally based at the variability of the temperature as well as the pressure with the wind condition so by this climate variable we can be in better position of forecasting of the weather conditions too.
10. The clear warming trend in the valley will certainly have an impact on the precipitation pattern. Hence, an additional study will be helpful in order to understand the precipitation change as a result of temperature change through quantification of discharge, provided that ground data are available for the verification.
11. As for normalized test statistics behaviour correspond the trend in temperature change for both the maximum as

well as minimum temperature change are showing the same trend but with higher value for the Monsoon season hence the Monsoon season max and min temperature change values affect much and more for the annual statistics for the temperature change perspectives.

Applications and Future Scope of Research

Trend analyses for the climate variable play a very important role to predict the weather condition and the precipitation in the environment during the cloudy conditions simultaneously with the cause and effect of the disastrous situations. There are enough scope for the betterment of life of human, conservation of the biodiversity and energy harvesting with the natural resources with the right data and outcomes of the temporal change of the climate conditions or the trend analysis. In further work we will focus at the global warming effect by the temporal change by the trend analysis of the climate variable with correlations of life of the living organism, here also the temperature will play a very crucial role along with the pressure conditions and the wind speed along with the constituents of the air or in the environment.

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