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Statistical Assessment of Temperature Trends and Change Points in Telangana State, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This study aimed to analyse the trends and changes in long-term monthly and annual temperature patterns in Telangana state, India. For this study monthly temperature data of Telangana state from January 1960 to December 2022 was collected from the IMD website. The linear regression trend line and the non-parametric tests, such as Mann-Kendall test, Modified-Mann Kendall test and Innovative trend analysis tests, were used to understand the trend present in the temperature data of Telangana state. To gain insights into temperature pattern, we applied Pettit's test. This test helps identify the changes in temperature data, contributing to a deeper

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understanding of the overall trends. Wallis and Moore test was used to test the randomness of the temperature data under consideration.

Results: An Increasing trend pattern was seen in the linear regression trend method for given temperature data. The modified Mann-Kendall test results revealed noteworthy significant trends (* $P < 0.05$) in January, November, and December, while remaining months showed non-significant trends (NS), suggesting no significant change in temperature patterns. The statistically significant trends (* $P < 0.05$) were observed in Pre-Summer, Post-Summer, and annual temperature patterns. However, no significant trend (NS) was observed in summer temperatures in the modified Mann-Kendall test. The innovative trend results suggested that most of the trend slopes are positive in nature, indicating an overall increasing trend in temperature for the analysed months and seasonal periods. The Pettit's test results unveiled significant shifts in temperature across months January, November, December, Pre summer, Post Summer and Annual temperature patterns.

Conclusion: These findings can be valuable for understanding climate patterns and informing decision-making processes related to adaptation and mitigation strategies, and help to create the appropriate policy measures in advance.

Keywords: Trend analysis; change point analysis; temperature patterns; modified mann-kendall test; wallis-moore test; innovative trend analysis; Pettit's test.

1. INTRODUCTION

"The Earth's climate is currently going through more extreme and intense weather events than ever before, and these are projected to become even more frequent in the near future. The future climatic change, though will have its impact globally but will be felt severely in developing countries with agrarian economies like India" [1]. "One significant consequence is the increasing occurrence of extreme temperatures. Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heatwaves will occur more often and last longer" [2]. "Temperature can have significant impact on various aspects of life and the environment. Fluctuations in temperature can also affect ecosystems, agricultural productivity and the distribution of plant and animal species. There is a general consensus among the researchers on the fact that there would be significant reduction in agricultural productivity in developing countries as a result of climate change" [3].

"Telangana, situated in the arid and semi-arid climatic zones of India, is characterized by its scorching summers and relatively mild winters. The state's climatic conditions present a vivid picture of extremes, with the yearly mean maximum temperature 42°C and mean minimum temperatures hovering around 22-23°C. In the year 2008, World Bank report confirmed that the adverse impact of climatic change can lead to a substantial reduction in the agricultural income in Telangana region" [4]. "Moreover, rural livelihood sector in the state is further exposed to the climatic changes and therefore, it is seen to be at a greater risk than few other Indian states" [5].

"In view of recent unprecedented occurrence of weather extremes at global as well as regional level, it is essential to examine climate variations at time scales of seasons to decades" [6]. "Analyses of at least 30 years of data of these elements provide a proper understanding of the climate of a particular region" [7]. Statistical analysis is essential because it provides a robust framework for understanding historical climate trends and variability. By analyzing data using statistical methods, we can identify patterns, trends, and potential areas of vulnerability, helping us make more informed decisions and develop effective climate mitigation and adaptation plans in all the sectors especially in agriculture.

This data-driven approach enhances our preparedness and resilience in the face of climate change. Sarita Gajbhiye Meshram et al. [8] assessed "spatio temporal temperature variability in Chhattisgarh State, India, from 1901 to 2016". Junli Li et al. [9] in his study employed "Innovative Trend Analysis (ITA) to assess trends in five natural hazards affecting agricultural areas in China from 1989 to 2014". In the study [10], "the temperature data of 125 stations (1941 to 2012) out of 212 stations of India have been analysed to evaluate trends and homogeneity using various statistical tests". "Rainfall and temperature trends were studied for Jagtial district of Telangana state using Mann-Kendall and Sen's slope estimate" [11].

In this study, we conducted trend analysis using both parametric and non-parametric methods, including linear regression trend and tests such as the Mann-Kendall test, Sen's slope estimate, Modified Mann-Kendall test, and Innovative trend analysis. To gain insights into the temperature pattern changes, we even applied Pettit's test. The paper is structured into various sections, starting with the methodological framework covering basic descriptive statistics, linear regression trend, Mann-Kendall test, Sen's slope estimation, Modified-Mann Kendall test, Innovative trend analysis and change point analysis. Results obtained from each section are explored and discussed in the Results and Discussion sections, with the final outcomes highlighted in the Conclusion section.

2. MATERIALS AND METHODS

2.1 Study Area

The research was carried out in the Indian state of Telangana which lies in south-central section of India, bordered on the north by Maharashtra, the northeast by Chhattisgarh and Odisha, the southeast and south by Andhra Pradesh, and the west by Karnataka. Telangana is in Deccan Plateau's north-eastern corner at 15° 46′ and 19° 47′ north latitude and 77° 16′ and 81° 43′ east longitude. In the study, the examination will encompass the ten former districts in Telangana. These districts will serve as key units of analysis to investigate various aspects. For this study, the daily temperature data of Telangana state was considered from past 62 years i.e. from 1960-2022 and data was collected from the IMD Website. (https://colab.research.google.com/github/sukantjain/Python/blob/main/IMDLIB.ipynb).

Fig. 1 depicts the study area map of Telangana State. To study the variability in Temperature pattern, different trend analysis methods have been employed on temperature data of Telangana. The information gathered was tabulated, evaluated and statistically analysed in order to understand the trend in temperature of Telangana state.

2.2 Trend Analysis

Trend analysis is a statistical and analytical method used to identify and evaluate patterns or tendencies within a dataset over time. It is commonly employed in various fields, including finance, economics, environmental science, and other research disciplines. The primary goal of trend analysis is to recognize and understand the underlying patterns or movements in the data, which can help in making predictions, forming insights, and informing decision-making processes. In this research, parametric and non-parametric test were used for assessing the temperature patterns in Telangana state. Linear regression analysis, Mann-Kendall's test, Sen's slope estimator, Modified Mann-Kendall test were used. The study utilized an innovative trend analysis method known as Innovative Trend analysis, which played a crucial role in identifying emerging patterns. Additionally, Pettit's test was employed to analyze the change points effectively.

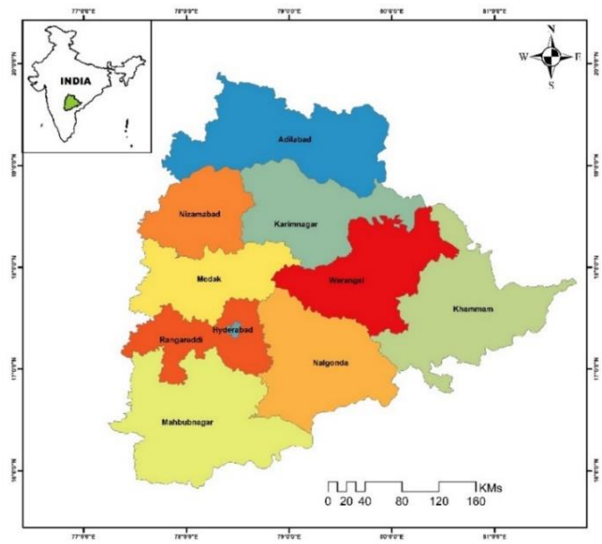

Fig. 1. Study area Map of the Telangana state

2.2.1 Linear regression analysis

Linear regression analysis stands out as one of the widely employed parametric models for trend detection in a given data series. This approach involves applying a linear equation to the collected dataset, establishing a relationship between two variables: the dependent and independent variables. The linear regression model is typically defined by the following equation:

$$Y = a + mX \tag{1}$$

Where Y is the dependent variable, X is the independent variable, m is the slope of the line, a is the intercept constant. The t-test is used to determine whether the linear trends are significantly different from zero at the 5% significance level.

2.2.2 The mann–kendall's trend test

"The purpose of the Mann-Kendall (MK) test is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. A monotonic upward (downward) trend means that the variable consistently increases (decreases) through time, but the trend may or may not be linear. The MK test can be used in place of a parametric linear regression analysis, which can be used to test if the slope of the estimated linear regression line is different from zero. The regression analysis requires that the residuals from the fitted regression line be normally distributed; an assumption not required by the MK test, that is, the MK test is a non-parametric (distribution-free) test" [12].

Let x_1, x_2, x_3, x_n represents n data points, where x_j represents the data points at time j. The Mann-Kendal statistic (S) is given in the following equation:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \tag{2}$$

Where x_i and x_j are the annual values in years' j and i, $j>i$ respectively and N is the number of data points. The values of $sign$ (xj − xi) = 0. This statistic represents the number of positive

differences minus number of negative differences for all the differences considered. For large sample (N>10), the test is conducted using Z statistic with the following mean and variances:

The utilization of the Z statistic for large samples (N > 10) is justified by the Central Limit Theorem, ensuring the normality of the distribution of sample means.

$$E[S] = 0 \tag{3}$$

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p-1}^{q} t_p\,(t_p - 1)(2t_p + 5)\right] \tag{4}$$

Where q is the number of tied groups and tp is the number of observations in the p^{th} group. Computing the MK test statistic, Z_{MK}, is performed as follows:

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if S < 0 \end{cases} \tag{5}$$

A positive and negative value of Z_{MK} indicate that the data tend to increase or decrease with time, respectively. To test either an upward or downward monotonic trend at α level of significance and H_0 is rejected if $|Z_{MK}| \geq Z_{1-\alpha/2}$.

2.2.3 Sens's slope estimator

Sen's slope serves as a valuable tool for detecting the strength of a trend within a dataset devoid of serial autocorrelation. This method is particularly applicable in scenarios where a linear trend can be reasonably assumed [12].

$$f(t) = Q_t + B \tag{6}$$

Where Q is the slope, B is a constant and t is time. To get the slope estimate Q, the slopes of all the data value pairs are calculated using the following equation:

$$Q_i = \frac{x_j - x_k}{j-k} \tag{7}$$

Where x_j and x_k are the data values at time j and $k(j > k)$, respectively. If there are n values x_j in the time series, there will be as many as $N = \frac{n(n-1)}{2}$ slope estimates Q_t. The N values of Q_t. are ranked from the smallest to the largest and the Sen's estimator is:

$$Q = \begin{cases} Q_{\left[\frac{n(n+1)}{2}\right]},\ if\ N\ is\ odd\ or \\ 1/2(Q_{\left[\frac{N}{2}\right]} + Q_{\left[\frac{N+2}{2}\right]}),\ if\ N\ is\ even \end{cases} \tag{8}$$

To obtain the estimate of B in equation $f(t)$ the n values of differences $x_i - Q_{ti}$ values are calculated. The median of the values gives an estimate of B.

2.2.4 Modified mann-kendall test

The Mann-Kendall trend test serves as a robust non-parametric statistical tool utilized for identifying trends within time series data. Its primary function is to detect monotonic trends, whether they are increasing or decreasing, over time. This method is especially resilient when analyzing data that deviates from a normal distribution. Furthermore, it effectively addresses concerns regarding serial correlation through the implementation of a variance correction approach. The variance of the statistic is calculated as follows:

$$V^*(S) = V(S)\frac{n}{n^*} \tag{9}$$

Where $\frac{n}{n^*}$ is a correction factor. V(S) is calculated as in the original MK test. The null hypothesis H_0 indicates that there is no trend in the given series. In such a way, the null hypothesis is rejected when the Z-transformed statistic value is greater than the Z critical value at 5% level of significance ($|Z_{MMK}| \geq Z_{1-\alpha/2}$).

2.2.5 Innovative trend analysis (ITA) method

Many research studies worldwide have used the innovative trend analysis (ITA) approach [13,14] along with various other methods to explore differences in climatological, meteorological, and hydrological data time series series around the world due to its advantages over other non-parametric approaches. The trustworthiness of ITA is proven, however, by matching its results to those with the MK test results. The initial stage in this strategy is to divide time series data into 2 equal halves and position each one in increasing order separately. The second stage involves, the first $1/2$ of the sub-series $(X_i; i = 1,2 \ldots \frac{n}{2})$ positioned at *X*-axis, with the second $1/2$ $(X_j; j = \frac{n}{2}+1, \frac{n}{2}+2 \ldots n)$ is positioned at *Y*-axis of cartesian coordinate system, both the axes (vertical & horizontal) necessarily have the same range. Data values accumulating at the area of triangulation below or above the linear line specify an upward trend or a downward trend within the time series. On computing the average difference between the X_j and X_i values at every point, the increasing or downward longitudinal trend in the time series can be evaluated. The horizontal and vertical distance from the linear line can be used to calculate this absolute difference. The first half of the time series is used to determine the trend change. As a result, the indicator of trend is derived by dividing the mean difference between the linear line and the time series first $1/2$. On multiplying by ten the ITA trend indicator has represented the scale of the Sen's slope estimator and MK test at a 10% significance level as shown in the equation (10):

$$D = \frac{1}{n}\sum_{i=1}^{n}\frac{10(Y_j - Y_i)}{\mu} \tag{10}$$

Here, *D* denotes the indicator of trend, *n* the number for data points in each sub-series, Y_i and Y_j denote the 1st and 2nd sub-series data points, respectively μ denotes the first subseries average. However, the +ve or −ve values of *D* represent an increasing or decreasing trend, respectively.

2.3 Change Point Analysis

Change point analysis, also known as change point detection, is a statistical technique used to identify points in a time series or sequence of data where a significant shift or change in the underlying process occurs. The primary goal is to pinpoint the moments when there is a distinct alteration in the statistical properties of the data.

2.3.1 Pettit's test

The approach after Pettitt (1979) is commonly applied to detect a single change-point [12] in hydrological series or climate series with continuous data. It tests the null hypothesis (H_o): The T number of variables follow one or more distributions that have the same location parameter (no change), against the alternative: a change point exists. The non-parametric statistic is defined as:

$$K_T = max\left|U_{t,T}\right|, \tag{11}$$

where

$$U_{t,T} = \sum_{i=1}^{t}\sum_{j=t+1}^{T} sgn(X_i - X_j) \tag{12}$$

The change-point of the series is located at K_T, provided that the statistic is significant. The significance probability of K_T is approximated for p ≤ 0.05 with

$$p \simeq 2\exp\left(\frac{-6K_T^2}{T^3+T^2}\right) \tag{13}$$

3. RESULTS AND DISCUSSION

For this study, temperature data was collected for Telangana state from the year 1960 to 2022. The temperature data was analysed to estimate the trend and further analysis. The data was tabulated and the descriptive statistics, namely mean, standard deviation (SD), coefficient of variation (CV), skewness and kurtosis were depicted in Table 1, as presented.

The temperature variability appears to be relatively low, with the coefficient of variation (CV) of the average monthly temperatures ranging from 2.51% to 4.28%, indicating a comparatively narrow spread of data points. However, May and October have the highest coefficient of variation (3.27), indicating relatively high variability in temperature compared to mean. The value of skewness is ranging from -0.92 to 0.57 and kurtosis is ranging from -0.87 to 1.33. The highest values of skewness were found in August, i.e., 0.57 slightly skewed to the right and highest values of kurtosis was found in May, i.e.,1.33 indicating leptokurtic.

Table 2 depicts the summary statistics for the pre-summer, summer, post-summer and annual temperature. Pre-summer and summer seasons have higher temperatures compared to post-summer. The standard deviation is highest in Pre-summer, indicating greater variability in temperatures during this period. The coefficient of variation was relatively low across all seasons, indicating low to moderate relative variability compared to the mean. Skewness values suggest slight positive skewness in Pre-Summer and Post-Summer, while summer shows slight negative skewness. Annual temperature distribution is almost symmetric. Kurtosis values indicate that Pre-Summer, Summer, and Annual distributions have almost mesokurtic, while post-summer distribution is leptokurtic, indicating heavier tails and a sharper peak. Similar findings were found in previous relevant studies [15].

3.1 Trend of Annual Temperature

Fig. 2 represents the monthly annual temperature of Telangana. The linear regression analysis was carried out for annual temperature. It indicated that linear trend line falling on the time series for annual temperature from 1960-2022. The value of the coefficient of determination (R^2) of 0.2394 indicates the proportion of the variance in the dependent variable y that is predictable from the independent variable x. In this case, approximately 23.94% of the variance in annual temperature can be explained by the linear relationship with time, while the remaining variance is unexplained or due to other factors. Overall, this information suggests that linear regression method is not a better fit for the data under consideration indicated by the relatively low R^2 value. Similar linear regression analysis for the temperature variability during the period 1980-2019 in Jagtial district of Telangana state was found in earlier studies [11].

Table 3 depicts that there is no significant difference in the variances of temperature between individual months or seasons as evidenced by the p-values exceeding 0.05. However, there is a significant difference in the variance of temperature across the entire year (Annual) with a p-value of 0.02 according to the Wallis and Moore test. The modified Mann-Kendall test was employed for analysis due to its enhanced efficiency in handling autocorrelation within the data [16].

3.2 Results of Temperature Trend Analysis Using Modified Mann-Kendall Test and Sens Slope Estimator

The Modified Mann-Kendall test results for monthly temperature data were depicted in Table 4. The results reveal noteworthy significant trends (* $p < .05$) in January, November, and December, with Sen's slopes of 0.022, 0.027, and 0.031, respectively. The remaining months show non-significant trends (NS), suggesting no significant change in temperature patterns during those months.

The findings indicate statistically significant trends (* $p < .05$) in Pre-Summer, Post-Summer, and Annual temperature patterns, with Sen's slopes of 0.014, 0.013, and 0.012, respectively. However, there is no significant trend (NS) observed in summer temperatures, suggesting stability in temperature during this season. Various studies [15] and [17] provide similar results of trend with Modified Mann-Kendall test.

The results from both the Mann-Kendall test and the modified Mann-Kendall test exhibit a high degree of similarity. The Z values obtained from the modified Mann-Kendall test, which incorporates specific corrections, align closely with the standard Mann-Kendall Z values. This suggests that, in this particular analysis, the corrections applied to the Z values did not significantly alter the overall trend detection outcome.

3.3 Innovative Trend Analysis of Temperature

The trend slope, trend indicator, Lower Confidence Level (LCL) and Upper Confidence Level (UCL) at 90%, 95% and 99% of annual and seasonal temperature of Telangana state was depicted in Table 6.

The results suggest that most of the trend slopes are positive in nature indicating an overall increasing trend in temperature for the analysed months and seasonal periods. However, some months i.e., April, June, July, August and September have trend slopes close to zero, suggesting relatively stable temperatures during these periods. There are trends present in the data, but they are generally small in magnitude. For majority of the months and seasonal periods, the trend slopes fall within these confidence limits, indicating statistically significant temperature trends. This suggests that the observed changes in temperature are not likely due to random variation but rather represent meaningful trends over time. [18] where Innovative trend analysis accurately identifies the trends compared to the non-parametric tests.

Table 1. Descriptive statistics of monthly temperature data of Telangana state

Month	Mean	SD	CV	Skewness	Kurtosis
January	29.98	0.94	3.14	-0.35	0.14
February	32.95	0.95	2.87	0.31	0.06
March	36.47	1.04	2.86	-0.09	-0.87
April	39.21	1.01	2.58	0.02	0.35
May	40.50	1.33	3.27	-0.92	1.33
June	35.79	1.53	4.28	-0.24	-0.61
July	31.72	0.96	3.03	0.41	1.23
August	30.76	0.77	2.51	0.57	-0.13
September	31.52	0.80	2.54	-0.0006	-0.48
October	31.89	1.04	3.27	0.34	-0.41
November	30.44	0.89	2.95	-0.002	-0.14
December	29.37	1.00	3.42	0.44	0.31
Average	30.35	0.96	3.25	0.25	0.23

Table 2. Descriptive statistics of annual and seasonal temperature pattern

	Mean	SD	CV	Skewness	Kurtosis
Pre-Summer	31.47	0.81	2.56	0.10	0.31
Summer	37.99	0.77	2.04	-0.25	0.39
Post-Summer	30.95	0.61	1.99	0.60	2.09
Annual	33.39	0.47	1.41	-0.06	0.19

Table 3. Wallis and Moore phase frequency test for seasonal and annual temperature data

Parameter	Z transformed test statistic	p-value
January	0.10	0.92
February	0.81	0.42
March	0.40	0.68
April	0.40	0.68
May	1.92	0.05
June	0.10	0.97
July	0.80	0.41
August	0.40	0.68
September	0.71	0.47
October	0.40	0.68
November	1.11	0.26
December	0.70	0.47
Pre summer	0.81	0.41
Summer	0.20	0.84
Post Summer	0.40	0.68
Annual	2.32	0.02

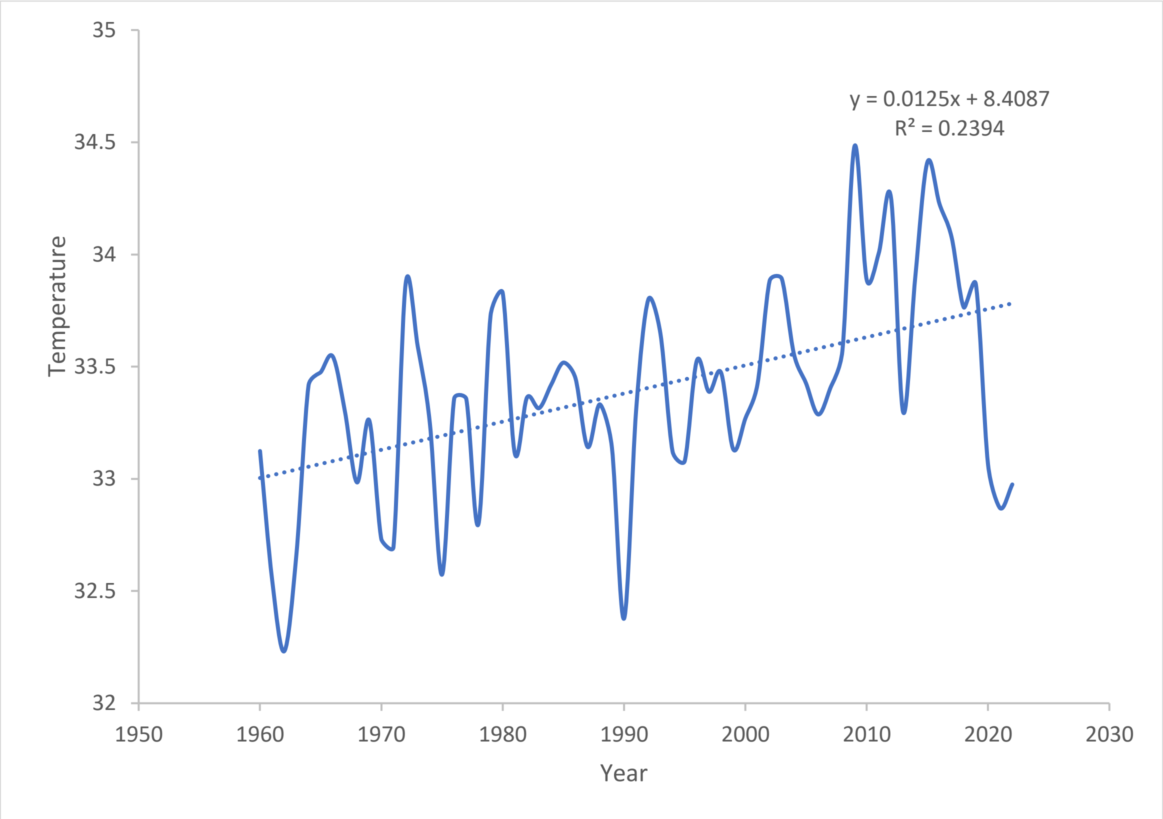

Fig. 2. Trend of annual Temperature of Telangana from 1960-2022

Table 4. Modified Mann-Kendall test of trend analysis of monthly temperature data

Parameter	Corrected Zc	P-Value	Trend	Sen's slope
January	4.01	0.00	*	0.022
February	0.88	0.37	NS	0.006
March	1.56	0.11	NS	0.011
April	1.43	0.15	NS	0.010
May	1.62	0.10	NS	0.012
June	0.14	0.89	NS	0.002
July	0.48	0.62	NS	0.003
August	1.22	0.22	NS	0.007
September	1.06	0.28	NS	0.006
October	1.42	0.15	NS	0.011
November	3.67	0.00	*	0.027
December	4.39	0.00	*	0.031

*NS - Non-significant trend * - significant trend*

Table 5. Modified Mann-Kendall test of trend analysis of annual and seasonal temperature data

Parameter	Corrected Zc	P-Value	Trend	Sen's slope
Pre summer	2.63	0.008	*	0.014
Summer	1.25	0.210	NS	0.007
Post Summer	3.03	0.002	*	0.013
Annual	2.51	0.010	*	0.012

*NS - non-significant trend * - significant trend*

Table 6. Innovative trend analysis (ITA) of seasonal and Annual Temperatures of Telangana state

Parameter	Trend slope	Trend Indicator	α=0.10		α=0.05		α=0.01	
			LCL	UCL	LCL	UCL	LCL	UCL
January	0.02	0.23	-0.002	0.002	-0.002	0.002	-0.003	0.003
February	0.01	0.11	-0.002	0.002	-0.002	0.002	-0.003	0.003
March	0.01	0.12	-0.001	0.001	-0.001	0.001	-0.002	0.002
April	0.00	0.05	-0.001	0.001	-0.002	0.002	-0.002	0.002
May	0.01	0.10	-0.003	0.003	-0.004	0.004	-0.005	0.005
June	0.00	0.07	-0.003	0.003	-0.003	0.003	-0.005	0.005
July	0.00	0.09	-0.002	0.002	-0.002	0.002	-0.003	0.003
August	0.00	0.07	-0.001	0.001	-0.001	0.001	-0.001	0.001
September	0.00	0.06	-0.001	0.001	-0.001	0.001	-0.001	0.001
October	0.01	0.11	-0.0009	0.0009	-0.001	0.001	-0.001	0.001
November	0.02	0.29	-0.001	0.001	-0.001	0.001	-0.001	0.001
December	0.03	0.34	-0.001	0.001	-0.001	0.001	-0.002	0.002
Pre summer	0.02	0.17	-0.001	0.001	-0.002	0.002	-0.002	0.002
Summer	0.01	0.08	-0.001	0.001	-0.001	0.001	-0.002	0.002
Post Summer	0.01	0.16	-0.001	0.001	-0.001	0.001	-0.002	0.002
Annual	0.01	0.13	-0.0009	0.0009	-0.001	0.001	-0.001	0.001

Table 7. Change point detection of monthly and annual temperature (1960–2022)

Parameter	Pettit's test		Temperature	
	p-value	Year of shift	Pre	Post
January	0.009*	1987	28.44	30.12
February	0.478	2000	33.06	34.53
March	0.548	1990	34.61	36.83
April	0.451	1997	38.31	39.63
May	0.395	1982	40.13	40.87
June	1.000	1998	37.39	34.07
July	0.867	1991	31.04	33.55
August	0.215	2003	29.91	30.80
September	0.263	1983	31.33	31.78
October	0.400	1975	30.51	33.61
November	0.000*	1998	30.49	31.01
December	0.000*	1994	28.06	30.06
Pre summer	0.036*	2000	31.30	32.33
Summer	0.313	1971	37.06	38.57
Post Summer	0.009*	1999	30.70	31.35
Annual	0.004*	2000	33.13	33.42

** - significant change*

3.4 Results of Change Point Analysis

The Pettit's test results unveil significant shifts in temperature across months January, November, December, Pre summer, Post Summer and Annual temperature patterns. Notable significant increases were observed in January, November, December, Pre-summer, Post-Summer, and Annual temperatures following detected change-points. January experienced a substantial rise of 1.68 °C in 1987, while November and December both displayed significant increases, with November seeing a rise of 0.52 °C in 1998 and December experiencing a 2.00 °C increase in 1994. Pre-Summer temperatures increased by 1.03 °C in 2000, and post-summer temperatures rose by 0.65 °C in 1999. The Annual temperature showed a slight increase of 0.29 °C in 2000. These findings underscore the dynamic nature of temperature fluctuations throughout the year and highlight specific periods of noteworthy temperature changes, offering insights into potential climate trends and their implications. Various studies [19] and [20] provide similar results of change point with Pettit's change point analysis.

4. CONCLUSION

This study used parametric method, i.e. linear regression trend and non-parametric tests such as Modified-Mann Kendall test and Innovative trend analysis to identify the long-term trends to analyse monthly, seasonal and annual temperature patterns in the Telangana State (1960 to 2022). From the Modified Mann-Kendall test, the significant increasing trend of temperature was observed in the month of January, November, December, Pre-summer, post-summer and annual patterns. Besides, we found non-significant trend in the remaining months, and summer season showed no significant trend of temperature in Telangana state. The innovative trend results suggested that most of the trend slopes are positive in nature indicating an overall increasing trend in temperature for the analysed months and seasonal periods. The Pettit's test results unveiled significant shifts in temperature across months January, November, December, Pre summer, Post Summer and Annual temperature patterns. For majority of the months and seasonal periods, the trend slopes fall within these confidence limits, indicating statistically significant temperature trends. These findings can be valuable for understanding climate patterns and informing decision-making processes related to adaptation and mitigation strategies and help to create the appropriate policy measures in advance. It contributes new insights into the field by providing a comprehensive statistical assessment of temperature trends and change points specially focused on Telangana state. Additionally, understanding temperature trends and change points enables farmers to better plan their crop schedules and management practices. Knowledge of how temperatures are evolving over time allows for adjustments in planting dates, selection of crop varieties, and irrigation strategies to optimize yields and minimize risks associated with temperature extremes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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