A

Dissertation Report

On

"SPATIAL TREND ANALYSIS OF TEMPERATURE IN UTTAR PRADESH FOR LAST CENTURY"

Master of Technology

in

Water Resources Engineering

Submitted by

ANIL CHOUDHARI

(2014PCW5076)

Under supervision of

Dr. Pawan Kalla
Assistant Professor

Dr. Mahender Choudhary
Associate Professor

DEPARTMENT OF CIVIL ENGINEERING
MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

June 2016

A

Dissertation Report
On

"SPATIAL TREND ANALYSIS OF TEMPERATURE IN UTTAR PRADESH FOR LAST CENTURY"

This Dissertation is submitted as a partial fulfillment of the Master of Technology Program in Water Resources Engineering

Submitted by
ANIL CHOUDHARI
(2014PCW5076)

Under supervision of

Dr. Pawan kalla
Assistant Professor

Dr. Mahender Choudhary
Associate Professor

DEPARTMENT OF CIVIL ENGINEERING
MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

June 2016

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE

I hereby declare that the dissertation which is being presented in this report entitled **"SPATIAL TREND ANALYSIS OF TEMPERATURE IN UTTAR PRADESH FOR LAST CENTURY"** in the partial fulfilment of the requirement for the award of the **Degree of M. Tech** and submitted in the Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur is an authentic record of my own work under the supervision of Dr.Pawan Kalla Assistant Professor and Dr.Mahender Choudhary Associate Professor, Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur.

The work presented in this dissertation embodies the results of own work and studies carried out by me and have not been submitted for the award of any other degree of this or any other institute.

Anil Choudhari

(2014PCW5076)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Dr.Pawan Kalla — Dr.Mahender choudhary

Assistant professor — Associate Professor

Date:

Place:

ACKNOWLEDGEMENT

I have taken efforts in this thesis. However, it would not have been possible without the kind support and help of many individuals. I would like to extend my sincere thanks to all of them.

I am highly indebted to Dr. Pawan kalla and Dr.Mahendra Choudhary for their guidance, constant supervision as well as for providing necessary information and also for their support in the project.

I would like to thank to Prof. Gunwant Sharma, head of the department of civil engineering MNIT, Jaipur, for allowing me to work on this thesis topic.

I would like to thank to Prof. A. K. Vyas, convener DPGC department of civil engineering MNIT, Jaipur, for allowing me to work on this thesis topic.

I would like to thank to Mr. Deepak Kumar Prajapat, Research Scholar in department of civil engineering MNIT, Jaipur, for help me in work.

I am thankful to all the members of teaching staff as well as non-teaching staff, civil engineering department for their contribution to complete my work.

I would like to express my gratitude towards my parents for their unconditional love and support which helped me to complete my work.

My thanks and appreciations also go to my friends and colleagues in doing the thesis work and people who have willingly helped me out with their abilities, without their contribution it would have been very difficult to complete my work.

ANIL CHOUDHARI

2014PCW5076

Dedicated to my beloved Parents

Mr. Mahiram Choudhary

&

Mrs. Jamana Devi

and other Family Members

Table of Contents

1. INTRODUCTION 3
   1.1 Classification of time series 4
      1.1.1 Continuous or discrete time series:- 4
      1.1.2 Deterministic and stochastic time series:- 4
      1.1.3 Univariate and multivariate time series:- 4
   1.2 Components of time series 4
      1.2.1 Secular Trend 5
      1.2.2 Seasonal Variations 5
      1.2.3 Cyclical Variations or Oscillatory Variation 6
      1.2.4 Irregular Variation 6
   1.3 Applications of Trend analysis 6
      1.3.1 Climatology 6
      1.3.2 Groundwater hydrology 6
      1.3.3 Irrigation water management 7
   1.4 Assumptions in Time Series Analysis 7
   1.5 Problem Statement 8
   1.6 Objectives of the study 8
2 LITERATURE REVIEW 13
3 STUDY AREA AND DATA COLLECTION 25
4 METHODOLOGY 29
   4.1 Mann-Kendall (MK) test - 29
   4.2 Modified Mann Kendall Test - 31
   4.3 Theil - Sen's estimator 32
   4.4 Change magnitude as percentage of mean 33
   4.5 Mann-Whitney-Pettit-t Method (MWP) 33
5 RESULTS AND DISCUSSION 37
   5.1 ANNUAL TEMPERATURE 38
      5.1.1 Average annual temperature- 38
      5.1.2 Minimum annual temperature 38
      5.1.3 Maximum annual temperature 38

5.2 Seasonal Temperature Trends 40
5.2.1 Winter Temperature Trends 40
5.2.1.1 Average winter temperature 40
5.2.1.2 Minimum winter temperature……..……40
5.2.1.3 Maximum winter temperature…… . ……40
5.2.2 Summer Temperature Trends..... 42
5.2.2.1 Average summer temperature…… ……42
5.2.2.2 Minimum summer temperature …… ……42
5.2.2.3 Maximum summer temperature…….....……..42
5.3 Monthly Temperature Analysis..... 44
5.3.1 January average temperature trends..... 44
5.3.2 February average temperature trends..... 45
5.3.3 March average temperature trends..... 46
5.3.4 April average temperature trends..... 47
5.3.5 May average temperature trend- 47
5.3.6 June average temperature trends..... 48
5.3.7 July average temperature trends- 49
5.3.8 August average temperature trends..... 50
5.3.9 September average temperature trends 51
5.3.10 October minimum temperature trends 52
5.3.11 November average temperature trends 53
5.3.12 December average temperature trends..... 54
6 Conclusion 57
7 REFERENCES 61
8 APPENDIX A …….65.

LIST OF FIGURE

Figure 1 Study area (All districts of Uttar Pradesh).....26
Figure 2 Maximum (a ,c & d) and minimum (b & e) significant increasing trends in average annual (a &b) and minimum annual (c ,d & e) temperature.....39
Figure 3 Maximum (a,,c,d & f) and minimum (b,e, g & h) significant increasing trends in average winter (a &b), minimum winter (c & d) temperature and maximum winter temperature (e & f).....41
Figure 4 Minimum (a) and maximum (b) significant increasing trends in minimum summer (a &b) 43
Figure 5 Maximum (a) and minimum (b) significant change trends in average temperature of January.....44
Figure 6 Maximum (a & b) and minimum (c, d &e) significant change trends in average temperature of February.....45
Figure 7 Maximum (a) and minimum (b) significant change trends in average temperature of March.....46
Figure 8 Maximum (a) and minimum (b,c& d) significant change trends in average temperature of April.....47
Figure 9 Maximum (a,b & c) and minimum (d) significant change trends in average temperature of June.....48
Figure 10 Maximum (a &b) and minimum (c, d & e) significant change trends in average temperature of July 49
Figure 11Maximum (a) and minimum (b) significant change trends in average temperature of August.....50
Figure 12Maximum (a,b &c) and minimum (d & e) significant change trends in average temperature of September 51
Figure 13 Maximum (a & b) and minimum (c) significant change trends in average temperature of October 52
Figure 14Maximum (a & b) and minimum (c & d) significant change trends in average trends of November.....53
Figure 15 Maximum (a) and minimum (b, c & d) significant change trends in average temperature of December.....54

LIST OF TABLES

Table 1: Results of the statistical tests for average annual temperature 67
Table 2Results of the statistical tests for minimum annual temperature 69
Table 3 Results of the statistical tests for maximum annual temperature..... 71
Table 4 Results of the statistical tests for average winter temperature..... 73
Table 5 Results of the statistical tests for minimum winter temperature..... 75
Table 6 Results of the statistical tests for maximum winter temperature 77
Table 7Results of the statistical tests for average summer temperature 79
Table 8Results of the statistical tests for minimum summer temperature 81
Table 9 Results of the statistical tests for average temperature of January 83
Table 10 Results of the statistical tests for average temperature of February 85
Table 11 Results of the statistical tests for average temperature of March 87
Table 12 Results of the statistical tests for average temperature of April 89
Table 13 Results of the statistical tests for average temperature of May 91
Table 14 Results of the statistical tests for average temperature of June 93
Table 15 Results of the statistical tests for average temperature of July..... 95
Table 16 Results of the statistical tests for average temperature of August 97
Table 17 Results of the statistical tests for average temperature of September..... 99
Table 18 Results of the statistical tests for average temperature of October..... 101
Table 19 Results of the statistical tests for average temperature of November..... 103
Table 20 Results of the statistical tests for average temperature of December 105

Abstract

Trend analysis is a prominent area of interest for both climatology and hydrology for investigating climate change scenarios and to enhance the efficacy of climate impact research. Trend analysis of a time series data consists of the magnitude of trends and its statistical significance. Trend analysis plays an important role in identifying variations in the pattern of observed time series data and to predict the climate change for future by identifying changes in climatic variables like temperature. Climate change detection through trend analysis is an active area of research and available methods have many uncertainties in assessment and prediction of climate change. It has been noticed that Climatic variables are location specific & climate trends are not available at regional scale for a same time. This work aims to analyze the trend of temperature which is one of the most important climatic variable for detecting changes in climate. The study area is Uttar Pradesh state of India. In this study area various statistical methods have been implemented for analyzing trend and shift of trend for climatological variables. Every method has its own pros and cons. The most commonly used methods for trend analysis are Mann–Kendall test, Sen's slope estimator test and Pettit test. The first two methods are used to detect monotonic trend direction and change in magnitude over time and Pettit test is used to detect possible change points.

The work is carried out on the trend analysis of maximum, minimum & mean temperature at annual, seasonal and monthly scales for 70 districts of Uttar Pradesh (India). Statistical trend analysis techniques, namely the Mann– Kendall (MK) test, Sen's slope estimator, Modified Mann-Kendall (MMK) and Pettit-t test has been used to examine trends (1901–2002).

CHAPTER 1
INTRODUCTION

CHAPTER 1

1. INTRODUCTION

Trend may be defined as "long-term change in the mean level". The changes may occur either gradually as a trend or abruptly as a step change. Time series analysis comprises various methods for analyzing time series data in order to assess and predict climatic change. Time series data is a sequence of observations collected over intervals of time. Each time series describes a phenomenon as a function of time. In other words, Time series are analyzed for understanding the underlying structure and function of climatic conditions which helps in making future predictions for the study. Time series analysis is generally used when there are 50 or more data points available in a series. The trend analysis aims to determine the trend, structure and noise for a study area using series data. The trend is associated with the long-term predictions for climate change, structure is related to short-term functioning of the system and the noise is composed of very short-term components. Understanding of time series provides a way to analyze series data and also to predict future changes in the climate. Time series forecasting is an application of a model, which helps in predicting the future conditions on the basis of previously observed values. The assessment can be done for temperature and rainfall as well on monthly and annually basis. Trend analysis is a robust method of time series data analysis which involves comparison of the same variable for a long time period. Trend analysis of a time series examine the magnitude and statistical significance of climatic variables. There are various parametric and non-parametric tests which are used for trend analysis of time series. The non-parametric tests of trend analysis are used mostly because the assumption of the parametric approach (i.e. normality, linearity and independence) are not satisfied by hydro-climatologic data most of the time. (Huth and Pokorna, 2004; Van Belle and Hughes, 1984; Helsel and Hirsch, 1988). Non-parametric methods are found to be suitable for commonly skewed data and the sample size should be large for this. (Hirsch et al, 1982). Non-parametric methods are not only tend to be more resistant to a misinterpretation of the data (e.g. outliers) but also give the results closer to their parametric counterparts and lay well within the confidence limits. (Huth and Pokorna, 2004). The non-parametric test has the ability to distinguish the null

hypothesis and alternative hypothesis. Mann-Kendall (MK) test (Mann, 1945 and Kendall, 1975) for monotonic trends Performs well in comparison to the parametric test (Van Belle and Hughes, 1984). On the basis of above discussion we can say that non parametric methods for trend analysis are the most suitable one. Mann-Kendall test is generally used for trend detection (rising, decreasing or no trend) and Sen's estimator test (non-parametric test) is used to estimate the magnitude (change per unit time) of trend in hydro-meteorological time series.

1.1 Classification of time series

Time series can be classified into following category:

1.1.1 **Continuous or discrete time series**:-

When observations are made at every instant of time, series is called continuous time series and when observations are taken only at specific time, usually equally spaced, it is called discrete time series e.g. Thermometer readings at met station (continuous) and annual number of road accident (discrete).

1.1.2 **Deterministic and stochastic time series:-**

If future values of time series can be predict exactly by past values, it is said to be deterministic time series. If the future is partially determined by the past values, so that exact predictions are impossible than time series is stochastic.

1.1.3 **Univariate and multivariate time series:-**

If only one variable is measured simultaneously over time, the time series is called univariate time series. While in multivariate more than one variable are measured simultaneously over time. e.g. monthly CO2 concentrations (univariate)

1.2 Components of time series

The time series may be affected by the number of causes or fluctuations, which are its characteristics. The types of movements characterizing a time series are called components

of time series or elements of a time series. These components can be grouped into four categories:

1.2.1 Secular Trend

1.2.2 Seasonal Variations

1.2.3 Cyclical Variations

1.2.4. Irregular Variations

1.2.1 Secular Trend

Secular Trend is also called long term trend or simply trend. The secular trend refers to the general tendency of data to grow or decline over a long period of time. For example the population of India over years shows a definite rising tendency. Mathematically the secular trend may be classified into two types,

- Linear Trend
- Curvi-Linear Trend or Non-Linear Trend

When trend values for the time series are plotted on a graph paper and if it gives a straight line then it is called a linear trend which means the rate of change is constant for linear trend on the other side there is a varying rate of change for nonlinear trend.

1.2.2 Seasonal Variations

Seasonal variations occur in the time series due to the rhythmic forces which occurs in a regular and periodic manner (period of less than one year). Seasonal variations occur during a period of one year and have the same pattern year after year. Here the period of time may be monthly, weekly or hourly. There occur seasonal fluctuations in a time series due to two factors.

- Due to natural forces

- Manmade convention

The most important factor causing seasonal variations is the climate changes in the climate and weather conditions such as rain fall, humidity, heat etc.

1.2.3 Cyclical Variations or Oscillatory Variation

This is a short term variation occurs for a period of more than one year. The rhythmic movements in a time series with a period of oscillation(repeated again and again in same manner) more than one year is called a cyclical variation and the period is called a cycle.

1.2.4 Irregular Variation

It is also called Accidental or Random Variations. The three variations trend, seasonal and cyclical variations are called as regular variations, but almost all the time series including the regular variation contain another variation called as random variation. This type of fluctuations occurs in random way or irregular ways which are unforeseen, unpredictable and due to some irregular circumstances which are beyond the control of human being such as earthquakes, wars, floods, famines etc.

1.3 Applications of Trend analysis

Trend analysis has been applied in a variety of fields in the past such as hydrology, climatology, geology, oceanography, seismology, etc.

1.3.1 Climatology

- Precipitation/ precipitation with other data
- Air and water temperature
- Climate change
- Evapotranspiration

1.3.2 Groundwater hydrology

Wilson et al. (1992) established groundwater quality changes caused by anthropogenic activities with the help of a time-series analysis of well water quality data from a 1964 – 1965 survey. Lee and Lee (2003) evaluated and quantified the potential of natural attenuation of groundwater at a petroleum-contaminated site in an industrial area of Seoul, Korea. Eight rounds of groundwater sampling and subsequent chemical analyses were performed for a period of 3 years.

1.3.3 Irrigation water management

Gupta and Chauhan (1986) studied the stochastic structure of weekly irrigation requirements of a crop by considering the irrigation requirement time series as an additive model with trend, periodicity and stochasticity as its components. Time Series Analysis is also used for many other applications such as:

- Economic Forecasting
- Sales Forecasting
- Stock Market Analysis
- Process and Quality Control

1.4 Assumptions in Time Series Analysis

Time series analysis of any phenomenon or variable is basic on following basic assumptions -

- ✓ Time series data set has at least one systematic pattern. The most common patterns are trends and seasonality. Trends are generally linear or quadratic. Seasonality is a trend that repeats itself systematically over time.
- ✓ The data exhibits enough of a random process so that it is hard to identify the systematic patterns within the data.

Time series analysis techniques often employ some type of filter to the data in order to dampen the error. Other potential patterns have to do with lingering effects of earlier observations or earlier random errors. There are numerous software programs that will analyze time series, such as SPSS, JMP, and SAS/ETS. For those who want to learn or are comfortable with coding, Mat-lab, S-PLUS, and R studio software are other software packages that can perform time series analyses. Excel can be used if linear regression analysis is all that is required (that is, if all you want to find out is the magnitude of the most obvious trend). Also, inherent patterns in the data may dampen or enhance the effect of an intervention; in time series analysis, patterns are accounted for within the analysis.

Observations made over time can be either discrete or continuous. Both types of observations can be equally spaced, unequally spaced, or have missing data. Discrete measurements can be recorded at any time interval, but are most often taken at evenly spaced intervals. Continuous measurements can be spaced randomly in time, such as measuring earthquakes as they occur because an instrument is constantly recording, or can entail constant measurement of a natural phenomenon such as air temperature, or a process such as velocity of an airplane. Time series are very complex because each observation is somewhat dependent upon the previous observation, and often is influenced by more than one previous observation. Random error is also influential from one observation to another. These influences are called autocorrelation dependent relationships between successive observations of the same variable. The challenge of time series analysis is to extract the autocorrelation elements of the data, either to understand the trend itself or to model the underlying mechanisms.

1.5 Problem Statement

As we are all aware that climate change is ever serious problem and it need to be understood and proper adaptation and mitigation image should be taken up. For optimum selection of adaptation and mitigation strategies correct assessment of climate change is very necessary. There are numbers of techniques like time series analysis of climatic data are available which can be used for assessment climate change. So far this is a new area and there is a lot of uncertainties available in climate change assessment and prediction. So still there is a need to do further research for accurate assessment of climate change.

1.6 Objectives of the study

The chief objective of this research is to investigate the annual, seasonal and monthly temperature trends over Uttar Pradesh. The outcomes will give the Sen's slope, percentage change and change point which will help to determine temperature change variations over the entire Uttar Pradesh with the shifts (change point in term of time) for all districts. Results will not only help to understand the past climatic conditions, timing and severity of extreme events, but also would support to forecast the future climatic conditions, extreme events and its severity.

In chapter 2, we have discussed literature review which includes recent advances of research in the trend analysis

Chapter 3 comprises the study area including data used.

Chapter 4 includes the detailed methodology of the thesis work. It fully describes the annual, seasonal and monthly temperature trends.

Chapter 5 includes results and discussion, in the end conclusion of the work followed by references used during the research work.

CHAPTER 2
LITERATURE REVIEW

CHAPTER 2

2 LITERATURE REVIEW

The main objective of this chapter was to conduct an exhaustive literature review of past climate change studies with the aim of identifying the types of changes in climatic data. This chapter includes researches which have been done in recent years on trend analysis.

Kundu, A. et al. (2015), focuses on the long term trends of meteorological parameters like precipitation, temperature, solar radiation, wind direction etc. of Udaipur district, Rajasthan which is mainly located in semi-arid zone in India. In this study the authors used Mann Kendall test and Sen's slope estimator to find out the annual variability. There are both increasing and decreasing trends of meteorological parameters obtained by this MK test, suggesting overall significant changes in the study area.

Roy, A.D., (2015), intends to fill up some of the research lacunas. It analyses the spatio-temporal variation of seasonal maximum, minimum temperatures and rainfall conditions with an assemblage of monthly data for the years 1901 -2002 in Rajasthan. It also uses Mann-Kendall trend test to identify climate change scenarios existing in the region. The result shows significant increase in temperatures and decrease in monsoon rainfall in most parts of the state. The analysis also showed a delayed onset of monsoon resulting in increase in post monsoon rainfall. The analysis was mapped to assist in decision making and risk reduction measures. In this study, an analysis of the monsoon rainfall trends which contributes the maximum share of precipitation shows are rather different spatial scenario. The expanse of declining rainfall trends along the southern districts has enlarged in comparison to the pre monsoon season. The south west and south eastern districts, to experience a decreasing rainfall.

Ram, B. et al. (2015), studied temporal variation in temperature over Junagadh (Saurashtra Region) of Gujarat, India, India, during the period 1980-2011. The long-term change in temperature has been evaluated by Mann–Kendall rank statistics and linear trend. An important aspect of the present study is the significant cooling trend in mean annual temperature, which is more predominant during winter season. authors studied the temperature for Junagadh (Saurashtra region) Gujarat, India during the period 1980-

2007 and observed a cooling trend, but not significant at any level. Against this background, in the present study, temperature data during the period 1980-2011 have been studied. The result indicates significant slightly decrease in winter temperature at 0.01 level. This suggests that the last decade has witnessed a phenomenal epoch in temperature series, leading to a decreasing trend from non-significant to significant.

Arora, M. et al. (2015), studied the impact of climate change is projected to have different effects within and between countries. Information about such change is required at global, regional and basin scales for a variety of purposes. Author performed an investigation to identify trends in temperature time series of 125 stations distributed over the whole of India. Arora, applied Mann-Kendall test to detect monotonic trends in annual average and seasonal temperatures. Author worked with three variables related to temperature, viz. mean, and mean maximum and mean minimum for analysis on both an annual and a seasonal basis. The result of this study was found that the percentage of significant trends obtained is high enough. The trends observed for the three variables on both an annual and a seasonal basis has been shown. It was found that there is a rising trend in most cases, except for mean pre-monsoon temperature, mean monsoon temperature, pre-monsoon mean minimum temperature and monsoon mean minimum temperature.

Patle, G.T., et al., (2014), studied global warming, climate change and its consequences in North-Eastern region of India. Patle correlates the agriculture with climate change. This study examines the impact of climate change on rainfall using the trend analysis technique for the four districts of Arunachal Pradesh. In this study the author showed that agriculture in the state of Arunachal Pradesh is dependent on rainfall and variability in rainfall due to climate change is expected to threaten the food production in future. Author used Mann-Kendall test at 5% significance level to detect trend analysis in Arunachal Pradesh. The daily time series rainfall data for the period 1971-2007 were analyzed statistically for each district separately. The results of Mann Kendall test showed decreasing trend in annual mean rainfall in east Siang, upper Siang and lowers Dibang valley and no trend in the west Siang district over the period of 1971-2007. The results showed a decreasing pattern of rainfall in post monsoon season which may affect the vegetable and fruit production in the winter season.

Pingale, S.M. et al. (2014), studied the trend analysis of the mean (monsoon season, non-monsoon season and annual). Author studied the extreme annual daily rainfall and temperature at the spatial and temporal scales for all the 33 urban centers of the arid and semi-arid state of Rajasthan, India. Pingale, used statistical trend analysis techniques, namely the Mann–Kendall test and Sen's slope estimator, to examine trends (1971–2005) at the 10% level of significance. As a result of this study the author observed both positive and negative trends in mean and extreme events of rainfall and temperature in the urban centers of Rajasthan State. The spatial variations of the trends in mean (monsoon season, non-monsoon season and annual) and extreme annual daily rainfall and temperature were also determined using the inverse-distance-weighted (IDW) interpolation technique. The results of IDW interpolation are very helpful in identifying trends and variability in mean and extreme rainfall and temperature in space and time. This study is helpful for those reasons where good quality data is not available.

Sonali, P. et al., (2013), performed his study for trend analysis of annual, monthly and seasonal maximum and minimum temperatures (t_{max}, t_{min}) in India. Recent trends in annual, monthly, winter, pre-monsoon, monsoon and post-monsoon extreme temperatures (t_{max}, t_{min}) have been analyzed for three time slots viz. 1901–2003, 1948–2003 and 1970–2003. This study shows that during last three decades minimum temperature trend is present in India as well as in all temperature homogeneous regions of India either at annual or at any seasonal level (winter, pre-monsoon, and monsoon, post-monsoon). Author agrees with the earlier observation that the trend in minimum temperature is significant in the last three decades over India (Kothawale et al., 2010). Sonali, conclude that Sequential MK test reveals that most of the trend both in maximum and minimum temperature began after 1970 either in annual or seasonal levels. This detailed analysis done by Sonali is very useful to find out the likely influence of temperature change on hydrologic cycle, environmental resources and future water resources management of the country.

Gocic, M. et al. (2013), analyzed annual and seasonal trends of seven meteorological variables for twelve weather stations in Serbia during 1980–2010. Gocic, used non-parametric Mann-Kendall and Sen's methods to determine whether there was a positive or negative trend in weather data with their statistical significance. In this study the increasing

trends were indicated in both annual and seasonal minimum and maximum air temperatures' series. The relative humidity decreased significantly in summer and autumn, while the vapor pressure had a significant increasing trend in spring, summer and autumn. Besides, no significant trends were detected in summer and winter precipitation series. In general, the results of using the Mann-Kendall and Sen's tests demonstrated the good agreement of performance in detection of the trend for meteorological variables. This study showed that the results of using Mann-Kendall and Sen's slope estimator statistical tests pointed out the agreement of performance which exists in the detection of the trend for the meteorological variables. The findings of this study can help in further analysis of possible causes of the increase or decrease in the reference evapotranspiration.

Chakraborty, S. et al. (2013), did his study on spatial and temporal variability of rainfall at Seonath sub basin in Chhattisgarh State (India) for 49 years (1960-2008). Author applied Mann-Kendall (MK) or Modified Mann-Kendall (MMK) (nonparametric) and Spearman's rho test (parametric) to detect the trend. Trend magnitude was also detected using Sen's slope. Author has also applied to detect change points. He used ArcGIS 9.3 to investigate the environmental trend. Author showed the results a downward trend in annual and seasonal rainfalls by both the trend methods. The results of this study showed an increase in irrigation water demand for agricultural crops in most of the region due to high variability in rainfall pattern. The findings are helpful for planning and efficient use of agricultural water resources.

Duhan, D. et al. (2013), study the spatial and temporal variability of precipitation at 45 districts of the Madhya Pradesh (MP), India over the period of 102 years (1901–2002) on annual and seasonal basis. He used Mann–Kendall test and Sen's slope estimator test were used to detect monotonic trend direction and magnitude of change over time on annual and seasonal basis. In this study the author used cumulative deviations and Pettit-Mann–Whitney test to detect possible change points. Change in percentage was also discussed in terms of percentage change over mean. Duhan, also used ArcGIS 9.3 to explore the spatial distribution of trends, linear regression value of each station on seasonal and annual basis. With the help of this study Duhan showed west MP faced increase in annual precipitation than East MP during the period of 1901–1978. However, the East MP showed more

decrease than west MP during the period of 1979–2002. According to this study the most probable year of change was 1978 in annual precipitation.

Jain, S.K., et al. (2013), reviewed all the studies pertaining to trends in rainfall, rainy days and temperature all over India. Author used Sen's non-parametric estimator of slope to estimate the magnitude of trend. The statistical significance of this test has been assessed by the Mann–Kendall test. Jain, conclude that there are differences in the results of the various studies of trend analysis, and there is no clear picture available for rainfall trend. Regarding trends in temperature, the mean maximum temperature series showed a rising trend at most of the stations; it showed a falling trend at some stations. The mean minimum temperature showed a rising as well as a falling trend. At most of the stations in the south, central and western parts of India a rising trend was found. Some stations located in the north and northeastern India showed a falling trend in annual mean temperature. Most of the data used in trend analysis pertained to the stations located in urban areas and these areas are sort of heat islands. This article also highlights the need of a network of baseline stations for climatic studies.

Kousari, M.R. et al., (2013), investigates the trends of maximum air temperature (T max) in three time scales including annual, seasonal, and monthly time series in 32 synoptic stations in the whole of Iran during 1960–2005. First, nonparametric Mann–Kendall test after removal of the lag-1 serial correlation component from the T max time series was used for trend detection and spatial distribution of various trends was mapped. Second, Sen's slope estimator was used to determine the median slope of positive or negative T max trends. Third, 10-year moving average low-pass filter was applied to facilitate the trend analysis and the smoothed time series derived from the mentioned filter were clustered in three clusters for each time series and then were plotted to show their spatial distribution patterns in Iran. Results of this study, showed that there are considerable significant positive trends of T max in warm months including April, June, July, August and September and warm seasons. These trends can be found in an annual time scale which indicated almost 50% positive trends. However, cold months and seasons did not exhibit a remarkable significant trend.

Capparelli, V. et al. (2013), presents a study on a nonlinear spatiotemporal analysis of 1167 station temperature records from the United States Historical Climatology Network covering the period from 1898 through 2008. We use the empirical mode decomposition method to extract the generally nonlinear trends of each station. The statistical significance of each trend is assessed against three null models of the background climate variability, represented by stochastic processes of increasing temporal correlation length. We find strong evidence that more than 50% of all stations experienced a significant trend over the last century with respect to all three null models. A spatiotemporal analysis reveals a significant cooling trend in the South-East and significant warming trends in the rest of the contiguous U.S. It also shows that the warming trend appears to have migrated equator ward. This shows the complex spatiotemporal evolution of climate change at local scales.

Tabari, H. et al. (2011), studied Trend analysis of climatic variables has received a great deal of attention from researchers recently. The main aim of this study was to investigate trends in maximum (Tmax) and minimum (Tmin) air temperatures in the annual, seasonal and monthly time-scales for 19 synoptic stations in the arid and semi-arid regions of Iran during 1966–2005. From the results it is clear that the majority of the trends in the annual, seasonal and monthly T_{max} and T_{min} time series showed increasing tendency during the last decades, while the increasing trends in the T_{min} series were stronger than those in the T_{max} series. The trend in annual T_{max} and T_{min} averaged over all 19 stations was 0.090 and 0.444 °C per decade, respectively. Tabari, used Mann–Kendall test, the Sen's slope estimator and the linear regression for trend analysis. The results of this study can contribute to a better understanding of regional temperature behavior in the study area.

Mohsin, T. et al, (2010), studied the longterm trends (31–162 years) of temperature change have been analyzed for the Greater Toronto Area (GTA). Annual and seasonal time series for a number of urban, suburban, and rural weather stations are considered. Non-parametric statistical techniques such as Mann–Kendall test and Theil-Sen slope estimation are used primarily for the assessing of the significance and detection of trends, and the sequential Mann test is used to detect any abrupt climate change. Statistically significant trends for annual mean and minimum temperatures are detected for almost all stations in the GTA. Winter is found to be the most coherent season contributing substantially to the

increase in annual minimum temperature. The analyses of the abrupt changes in temperature suggest that the beginning of the increasing trend in Toronto started after the 1920s and then continued to increase to the 1960s.

Kumar, V. et al, (2010), studied study of precipitation trends is critically important for a country like India whose food security and economy are dependent on the timely availability of water. In this work, monthly, seasonal and annual trends of rainfall have been studied using monthly data series of 135 years (1871–2005) for 30 sub-divisions (sub-regions) in India. Half of the sub-divisions showed an increasing trend in annual rainfall, but for only three (Haryana, Punjab and Coastal Karnataka), this trend was statistically significant. For the whole of India, no significant trend was detected for annual, seasonal, or monthly rainfall. Annual and monsoon rainfall decreased, while pre-monsoon, post-monsoon and winter rainfall increased at the national scale. Rainfall in June, July and September decreased, whereas in August it increased, at the national scale.

Pal, I. et al, (2009), investigates the long-term trends and variations of the monthly maximum and minimum temperatures and their effects on seasonal fluctuations in various climatological regions in India. The magnitude of the trends and their statistical significance were determined by parametric ordinary least square regression techniques and the variations were determined by the respective coefficient of variations. The results showed that the monthly maximum temperature increased, though unevenly, over the last century. Minimum temperature changes were more variable than maximum temperature changes, both temporally and spatially, with results of lesser significance. The results of this study are good indicators of Indian climate variability and its changes over the last century.

Gadgil, A. et al. (2005), studied temporal variation in temperature over Pune city, India, during the period 1901–2000. The long-term change in temperature has been evaluated by Mann–Kendall rank statistics and linear trend. The analysis reveals significant decrease in mean annual and mean maximum temperature. This decrease in temperature is more pronounced during the winter season, which can be ascribed to a significant increase in the amount of suspended particulate matter (SPM) in the ambient air during the last decade. An important aspect of the present study is the significant cooling trend in mean

annual temperature, which is more predominant during winter season. The summer season also shows significant cooling trend due to decrease in T_{max}. This cooling trend in Pune's temperature is supported by studies conducted by other researchers (Rupa Kumar and Hingane, 1988). These authors studied the temperature for Pune during the period 1876–1986 and observed a cooling trend, but not significant at any level. Against this background, in the present study, temperature data during the period 1901–2000 have been studied. The result indicates significant decrease in winter temperature at 0.01 level. This suggests that the last decade has witnessed a phenomenal epoch in temperature series, leading to a decreasing trend from non-significant to significant. Contrary to this, the monsoon season shows warming trend. This may be due to significant increase in the low cloud amount during this season.

Kahya, E. et al, (2004), presents trends computed for the 31-year period of monthly stream flows obtained from 26 basins over Turkey. Four non-parametric trend tests (the Sen's T, the Spearman's Rho, the Mann-Kendall, and the Seasonal Kendall which are known as appropriate tools in detecting linear trends of a hydrological time series) are adapted in this study. Moreover, the Van Belle and Hughes' basin wide trend test is included in the analysis for the same purpose. Homogeneity of trends in monthly stream flows is also tested using a procedure developed by Van Belle and Hughes. Thus, this study includes a complete application of both the Van Belle and Hughes' tests for homogeneity of trends and basin wide trend (originally developed for trend detection in water quality data) on a hydro climatic variable. As a result, basins located in western Turkey, in general, exhibit downward trend, significant at the 0.05 or lower level, whereas basins located in eastern Turkey show no trend. In most cases, the first four tests provide the same conclusion about trend existence. Use of the Seasonal Kendall, which involves a single overall statistic rather than one statistic for each season, is justified by the homogeneity of trend test. Moreover, some basins located in southern Turkey exhibit a global trend, implying the homogeneity of trends in seasons and stations together, based on the Van Belle and Hughes' basin wide trend test.

Burn, D.H. et al, (2002), describes the development and application of a procedure that identifies trends in hydrologic variables. The procedure utilizes the Mann-Kendall non

parametric test to detect trends, a permutation approach to estimate the test distribute, and accounts for the correlation structure in the data in determining the significance level of the test results. The research investigates 18 hydrologic variables that reflects different parts of the hydrologic cycle.

Yue, S. et al, (2002), investigated using Monte Carlo simulation the interaction between a linear trend and a lag-one autoregressive (AR(1)) process when both exist in a time series. Simulation experiments demonstrated that the existence of serial correlation alters the variance of the estimate of the Mann–Kendall (MK) statistic; and the presence of a trend alters the estimate of the magnitude of serial correlation. The results of this study indicate that the commonly used pre-whitening procedure for eliminating the effect of serial correlation on the MK test leads to potentially inaccurate assessments of the significance of a trend; and certain procedures will be more appropriate for eliminating the impact of serial correlation on the MK test.

CHAPTER 3

STUDY AREA AND DATA COLLECTION

3 STUDY AREA AND DATA COLLECTION

Uttar Pradesh is that the largest state of India on the basis of population. The state is featheredged by Rajasthan to the west, Haryana and Delhi to the northwest, Uttarakhand and Kingdom of Nepal to the north, Bihar to the east, Madhya Pradesh to the south and states of Jharkhand and Chhattisgarh to the south east. It covers 243,290 sq. kilometers (93,933 sq mi), equal to 6.88% of the entire space of India and is that the fourth Largest Indian State by area. The state is split into 75 districts. Geographically (Fig.1), State extends from 26° 51′ 0″ N latitude and 80° 54′ 36″ E longitude. The Himalaya border the state on the north however the plains that cowl most of the state are clearly completely different from those high mountains. State includes a wet subtropical climate and experiences four seasons the winter in Gregorian calendar month and Feb is followed by summer between March and should and also the monsoon season between Gregorian calendar month and Sep. Summers are extreme with temperatures unsteady anyplace between 0 °C and 50 °C in elements of the state. The Gangetic plain varies from dry to sub-humid. The mean annual rain ranges from 650 metric linear unit with in the southwest corner of the state to a thousand metric linear unit within the jap and southeastern elements of the state. Primarily a summer development, the Bay of geographical region branch of the Indian monsoon is that the major bearer of rain in most elements of state. It's the south-west monsoon that brings most of the rain here, though rain thanks to the western disturbances and north-east monsoon additionally contribute tiny quantities towards the general precipitation of the state. My present study, monthly average and annual and minimum and maximum for annual average temperature data during the Period 1901-2002 for 70 districts of Uttar Pradesh were downloaded from Indian Meteorological Department (IMD) site India water portal**.** Annual and seasonal (winter & summer) data have been computed from the basic temperature data for each district. December, January and February are considered for the analysis of winter temperature as these three months record lower temperatures and March, April and May are Months with highest mean maximum temperatures so these months are considered as summer Season.

Figure 1 Study area (All districts of Uttar Pradesh)

CHAPTER 4
METHODOLOGY

CHAPTER 4

4 METHODOLOGY

A large number of tests are performed for trend detection of long term time series of meteorological and hydrological records. For the detection of significant trends in climatologic time series these tests can be classified as parametric and non-parametric methods. Parametric trend tests require data to be independent and normally distributed, while non-parametric trend tests require only that the data be independent. In this study, non-parametric methods were used to detect the trend, its magnitude and shift. Following non-parametric tests are mostly used for trend analysis of temperature time series.

4.1 Mann-Kendall trend test

4.2 Modified Mann-Kendall test

4.3 Sen's slope method

4.4 Change in percentage

4.5 Mann-Whitney Pettit test

4.1 Mann-Kendall (MK) test -

Mk test is the rank based nonparametric test and recently used by several researchers to detect trends in temperature data (De la casa and Nasello, 2010, 2012; Krishna Kumar et al., 2011; Tabari et al., 2011). It is based on the test statistic S defined as:

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i)$$

Where,$x_1, x_2, x_3, \ldots\ldots\ldots x_n$ represent n data points wherex_j represents the data point at time j.

A very high positive value of S is an indicator of an increasing trend, and very low negative value indicates a decreasing trend.

$$sgn(x_j - x_i) = \begin{cases} 1 \ldots\ldots if(x_j - x_i) > 0 \\ 0 \ldots\ldots if(x_j - x_i) = 0 \\ -1 \ldots\ldots if(x_j - x_i) < 0 \end{cases}$$

It has been documented that when n≥10, the statistic S is approximately normally distributed with the mean

E(S) = 0

And its variance is

$$\text{VAR(S)} = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18}$$

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 t is the number of data points in the ith group.

The standard test statistic Z is computed by as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} if S > 0 \\ 0 \qquad\quad if S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} if S > 0 \end{cases}$$

Positive values of Z indicate increasing trends while negative Z values show decreasing trends. The null hypothesis, H0, is meaning that no significant trend is present, is accepted if the test statistic Z is not statistically significant, i.e.$-Z\alpha_{/2} < Z < Z\alpha_{/2}$, where $Z\alpha_{/2}$ is the standard normal deviate. Testing trends is done at the specific α significance level

The Mann-Kendall test is essentially limited to testing the null hypothesis that the data are independent and identically distributed. Our time series data may diverge from this assumption in two ways. First there may be autocorrelation and second may be a seasonal component. To eliminate these factors we can use annual data but this has the effect of reducing the power. For strong positive autocorrelation in the series, the effect of using annual totals will reduce the effect of this autocorrelation substantially and the loss of power is, perhaps, not expected to be too much.

4.2 Modified Mann Kendall Test -

Pre-whitening is being used for detecting a trend in the time series in the presence of autocorrelation (Cunderlik and burn, 2004). Nonetheless, pre-whitening is stated to reduce the rate of detection of significant trend in the Mann-Kendall test (Yue et al., 2003). Thus, the Modified MK test (Rao et al., 2003) has been used for trend detection of an autocorrelation series. In the present study, the autocorrelation between ranks of the observationsρ_k has been estimated after subtracting an estimate of a non-parametric trend such as Sen‟s median slope from the data. Significant valuesρ_k of have only been used for calculating the variance of correction factor $(\frac{n}{n_s^*})$, as the variance of S is underestimated for the positively auto correlated data.

$$\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} * \sum_{k=1}^{n-1} (n-k)(n-k-1)(n-k-2)\,\rho_k$$

Where, n represents the actual number of observations, Represented as an effective number of observations to account for the autocorrelation in the data.$\rho_k$is considered as the autocorrelation function for the ranks of observations. The corrected variance is calculated as (Rao et al., 2003)

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

Where, V(S) is the form of equation below:

$$\text{VAR(S)} = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18}$$

Where,t_i is consider as number of ties up to sample i. the best statistic is computed as below

$$Z_c = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} if S > 0 \\ 0 \quad if S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} if S > 0 \end{cases}$$

Z_cHere follows a standard normal distribution. A positive (negative) value of Z signifies an upward (downward) trend. A significance level α is also utilized for testing either an upward or downward monotonic trend (a two tailed test). IfZ_c appears greater than$Z_{\alpha/2}$, where α depicts the significance level. Then the trend is considered as significant.

4.3 Theil - Sen's estimator

If a linear trend is present, the true slope (change per unit time) can be estimated by using a simple non-parametric procedure developed by Sen (1968b). The slope of n pairs of data points was estimated using the Theil-Sen's estimator (Theil, 1950 and Sen, 1968) which is given by the following relation:

$$\beta = median\left(\frac{x_j - x_i}{j-i}\right) \qquad For\ all\ i < j$$

In which$1 < j < I < n$ and β | is the robust estimate of the trend magnitude. A positive value of β indicates an „upward trend", a negative value of β indicates a „downward trend" (Xu et al., 2007).

4.4 Change magnitude as percentage of mean

Some trends may not be evaluated to be statistically significant while they might be of practical interest and vice versa (YUE and Hashino, 2003). For the present study, change percentage has been computed by approximating it with a linear trend. That is change percentage equals median slope multiplied by the period length divided by the corresponding mean, expressed as percentage (Pc) followed by Tue and Hashino (2003).

$$percent\ change(\%) = \frac{\beta \times period\ length}{mean} \times 100$$

4.5 Mann-Whitney-Pettit-t Method (MWP)

The Pettitt's test is a nonparametric test that requires no assumption about the distribution of data. The Pettitt's test is an adaptation of the rank-based Mann-Whitney test that allows identifying the time at which the shift occurs.

Consider a time series $\{x_1, x_2, \dots \dots x_n\}$ with a length n. let t be the time of the most likely change point. Two samples, $\{x_1, x_2, \dots \dots x_t\}$ and $\{x_1, x_2, \dots \dots x_n\}$, can then be derived by dividing the time series at time t. An index,U_t , is derived by:

$$U_t = \sum_{i+1}^{t} \sum_{j=i+1}^{t} sgn(x_j - x_i)$$

Where,

$$sgn(x_j - x_i) = \begin{cases} 1 \dots \dots . if(x_j - x_i) > 0 \\ 0 \dots \dots . if(x_j - x_i) = 0 \\ -1 \dots \dots . if(x_j - x_i) < 0 \end{cases}$$

A plot ofU_t against t for a time series with no change point would results in a continually increasing value of$|U_t|$. However, if there is a change point (even a local change point) then $|U_t|$

Would increase up to the change point and then begin to decrease. The most significant change point t can be identified as the point where the value of $|U_t|$ is maximum.

$$K_t = max_{1 \leq t \epsilon T} |U_t|$$

The approximated significance probability P (t) for a change point (Pettit, 1979) is given by:

$$P = 1 - \exp\left[\frac{-6\mathrm{K}_\mathrm{t}^2}{\mathrm{n}^3 + \mathrm{n}^2}\right]$$

The change point is statistically significant at time t with a significance level of α when probability P (t) exceeds (1-α).

CHAPTER 5
RESULTS AND DISCUSSION

CHEPTER 5

5 RESULTS AND DISCUSSION

The outcomes of the tests give the trend in terms of its slope, percentage change from its mean and the change point. Tables are formed for annual, seasonal and monthly (average temperature only) temperature shown in appendix A. The present study deals with an examination of variability and trends in annual, seasonal and monthly temperature variables (maximum, minimum and mean temperatures) for the 70 districts of Uttar Pradesh, India. The significant increase in annual temperature is 0.011°C/year at Mirzapur in the minimum and 0.006°C/year temperature at Lalitpur in the mean temperature. The significant increase in winter temperature is 0.011°C/year at Mirzapur and Unnao in the minimum temperature, 0.014°C/year at Kheri in the maximum temperature and 0.014°C/year at Kheri in the mean temperature. The significant increase in summer temperature is 0.012°C/year at Gautam Buddha nagar in the minimum temperature and no significant value for the mean temperature. Analysis on monthly time step indicates the significant warming trend in the all Months in the mean temperature during the analysis period of 1901 to 2002. Results show that there is increasing trends in winter and summer temperature in minimum temperature while decreasing trends in summer maximum temperature. The increasing temperature could affect agriculture in several ways such as quantity and quality of crops in terms of productivity, growth rates, photosynthesis and transpiration rates, moisture availability etc. Seasonal temperature is an important climatic factor which can have profound effects on the yield of crops. Increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce the yield. A 1°C increase in temperature may reduce yields of wheat, soybean, mustard, groundnut, and potato by 3-7%. Productivity of most crops to decrease only marginally by 2020 but by 10-40% by 2100 due to increases in temperature, rainfall variability, and decreases in irrigation water. The major impacts of climate change will be on rain fed or un-irrigated crops, which is cultivated in nearly 60% of cropland. A temperature rise by 0.5°C in winter temperature is projected to reduce rain fed wheat yield by 0.45 tonnes per hectare in India (Lal et al., 1998). This may ultimately affect the food security and economy of state and country.

5.1 ANNUAL TEMPERATURE

5.1.1 Average annual temperature-

The average annual temperature trendin all districts of Uttar Pradesh is increasing. The table no.1 (Appendix A) shows the significance of the trends at 95 %(20 districts) and 99% (40 districts) confidence interval. The significant increase in temperature from its mean is maximum for Lalitpur and minimum for kannauj, shown in figure 2 (a & b). The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of 0.005°C/year) at Lalitpur and minimum (@ of 0.003°C/year) at kannauj. The results of Pettit-t test shows that the change in temperature start after the year 1940 in most of the districts of U.P.In the some of the districts the change point is 1945-46 and 1937.

5.1.2 Minimum annual temperature

The minimum annual temperature trend in all districts of Uttar Pradesh is increasing. The table no.2 shows the significance of the trends at 95% (21 districts) and 99% (39 districts) confidence interval for entire Rajasthan. The significant increase in temperature from its mean is maximum for Mirzapur and Unnao and minimum for Mathura, shown in figure 2(c, d & e). The results of Pettit-t test are shown in table no.2 gives the change point. The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of 0.011°C/year) at Mirzapur & Unnao and minimum (@ of 0.005°C/year) at Mathura. According to Pettit-t test shows that the change in temperature start after the year 1954-55,1968-1969 and1975 in most of the districts of U.P. In the some of the districts the change point is 1940, 1947 and 1951.

5.1.3 Maximum annual temperature

The maximum annual temperature results show the mixed trends for Uttar Pradesh. None of the districts of Uttar Pradesh is showing the significant trends for maximum annual temperature. So there is no district with major increase or decrease temperature. The results of Pettit-t test shows in table no.3 give the minor change point.

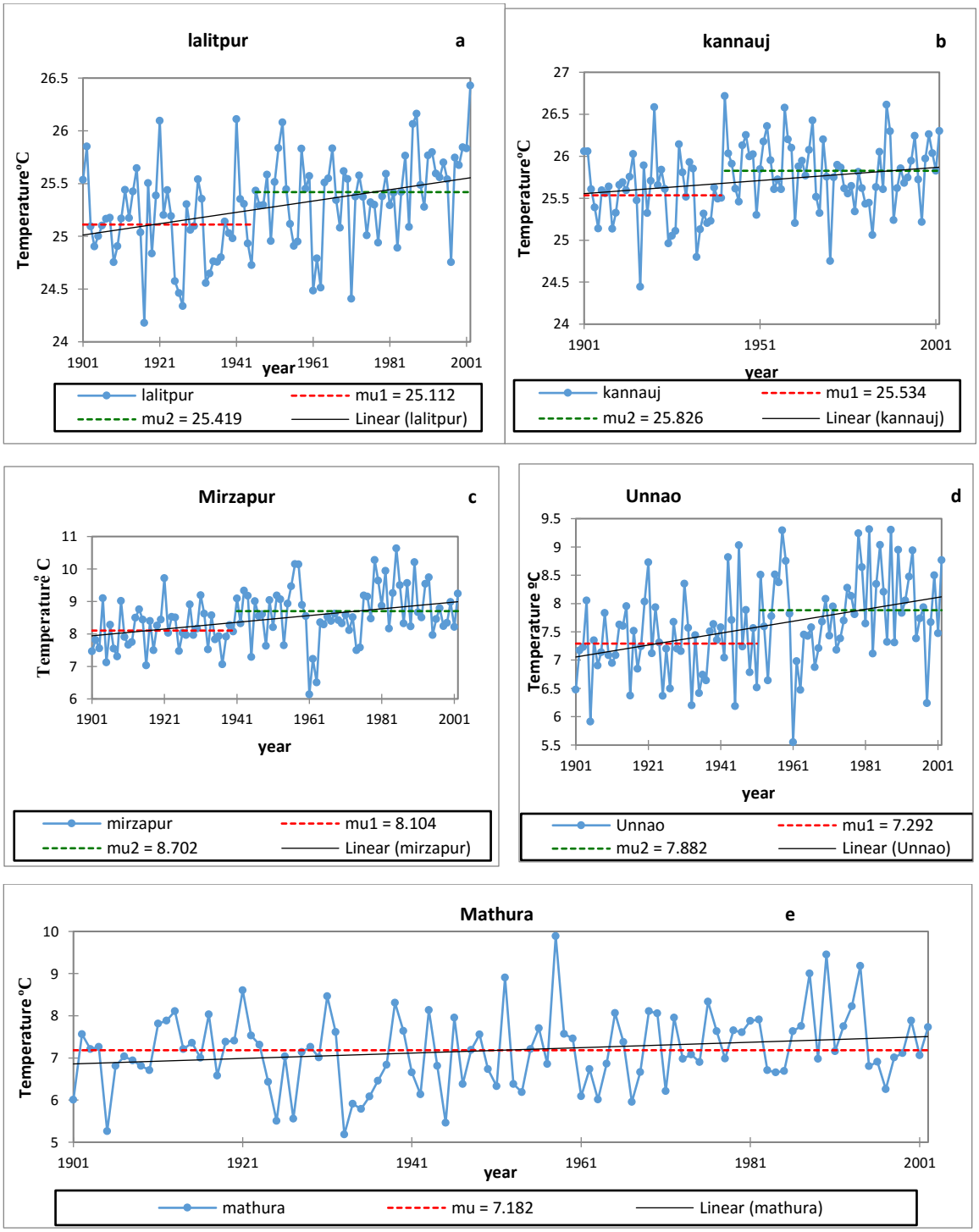


Figure 2 Maximum (a ,c & d) and minimum (b & e) significant increasing trends in average annual (a &b) and minimum annual (c ,d & e) temperature

5.2 Seasonal Temperature Trends

5.2.1 Winter Temperature Trends

5.2.1.1 Average winter temperature

The average winter temperature trends for all the districts of Uttar Pradesh is increasing. All of the districts have significant trends at 99% (70 districts) confidence interval. The significant increase in temperature from mean is maximum for Kheri and minimum for Mathura, shown in figure 3(a &b). The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of 0.012°C/year) at Kheri and minimum (at the rate of 0.0071°C/year) at Mathura. The table no.4 (Appendix A) shows the significance of the trends and Pettit-t test results for entire Uttar Pradesh. The pettit-t test shows that most of the districts have a shift in year 1941-42, 1945 and 1951 in most of the districts of U.P. In the some of the districts the change point is 1938, 1940 and 1942.only Khushinagar is temperature is shift of year 1937.

5.2.1.2 Minimum winter temperature

The minimum winter temperature trend analysis results show that there is increasing in trends for all the districts of Uttar Pradesh. The significant increase in temperature from mean is maximum for Mirzapur, Unnao and Varanasi and minimum for Jyotibaphule Nagar, shown in figure 3 (c, d & e). The table no.5 shows the significance of the trends at 95% (24 districts) and 99%(27 districts)confidence interval. The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of 0.011°C/year) at Mirzapur, Unnao & Varanasi and minimum (at the rate of 0.005°C/year) at Jyotibaphule Nagar. Pettit-t test results show that for most of the districts the shift is around year 1954-55, 1968, 1975 and 1978. Only in the East of the state the shift years are around 1940, 1942 and 1957.

5.2.1.3 Maximum winter temperature

All the districts are showing the increased trends. The table no.6 shows the significance of the trends at 95 %(9 districts) and 99 %(61 districts) confidence interval. The maximum significant increases in maximum winter temperature from mean occur in Kheri and minimum in Mirzapur & Chandauli as shown in figure 3 (f, g & h). The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of 0.014°C/year) at Kheri and minimum (at the rate of 0.008°C/year) at Mirzapur and Chandauli. The Pettit-t

test show thatmost of the districts have a shift in year 1940 and 1945 in most of the districts of U.P. In the some of the districts the change point is 1951.only Mathura is temperature is shift of year 1932.

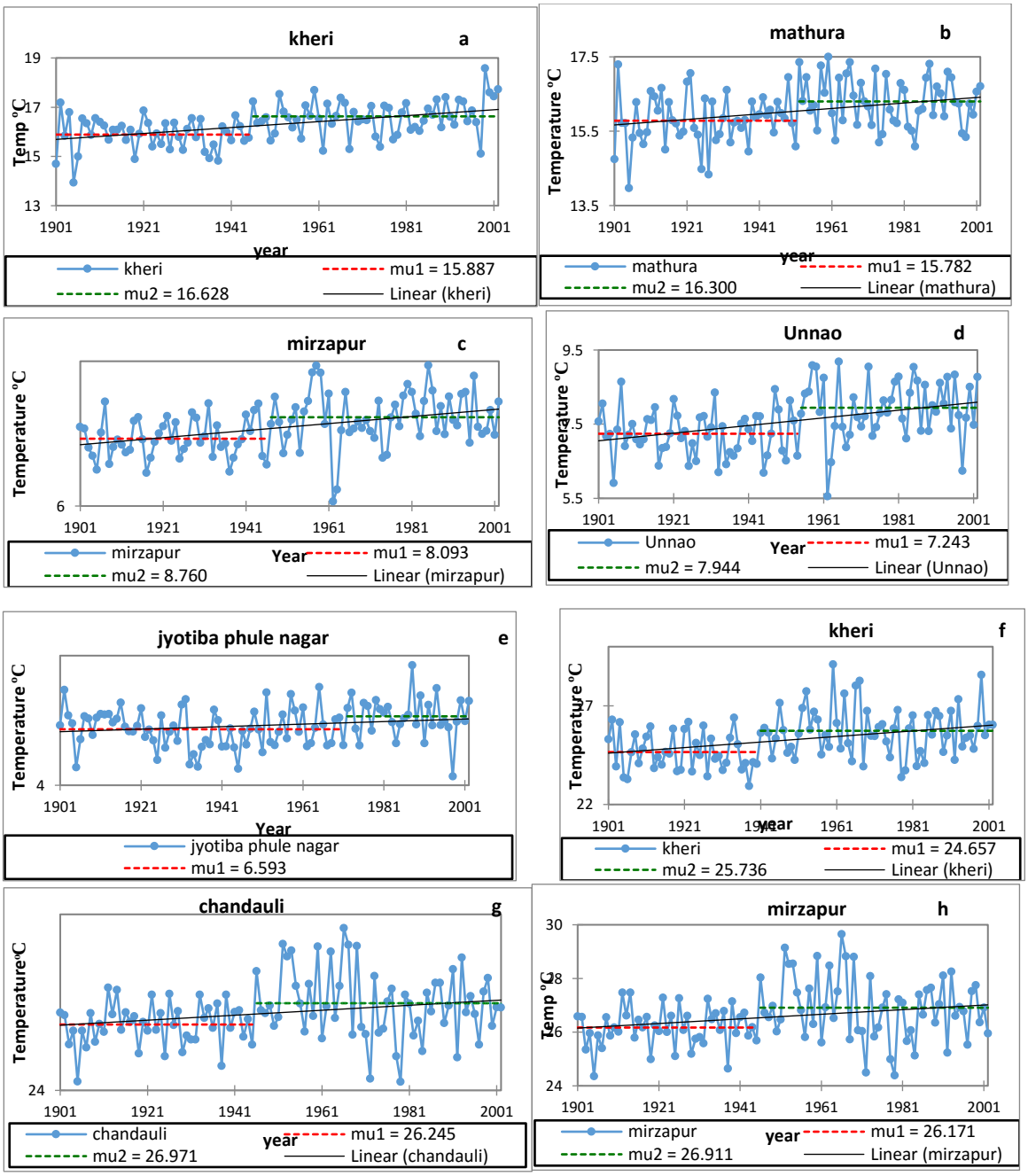


Figure 3 Maximum (a,,c,d & f) and minimum (b,e, g & h) significant increasing trends in average winter (a &b), minimum winter (c & d) temperature and maximum winter temperature (e & f)

5.2.2 Summer Temperature Trends

5.2.2.1 Average Summer Temperature

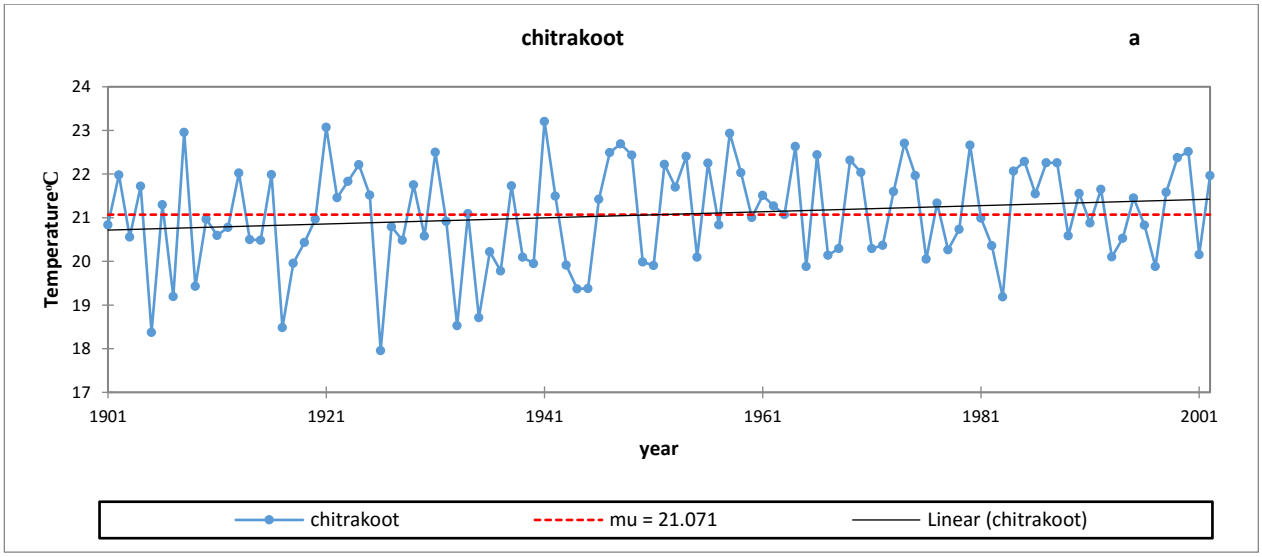
The average summer temperature results show the mixed trends for Uttar Pradesh. None of the districts of Uttar Pradesh is showing the significant trends for average summer temperature. So there is no district with major increase or decrease temperature. The results of Pettit-t test shows in table no.7 give the minor change point.

5.2.2.2 Minimum summer temperature

The minimum summer temperature trend analysis results show that there is increasing in trends for all the districts of Uttar Pradesh. The significant increase in temperature from mean is maximum for Gautam Buddha nagar and minimum for chitrakoot, shown in figure 4 (a & b). The table no.8 shows the significance of the trends at 95% (13 districts) and 99% (15 districts) confidence interval. The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of 0.012°C/year) at Gautam Buddha nagar and minimum (at the rate of 0.006°C/year) at chitrakoot. Pettit-t test results show that the all districts the shift is around year 1945-46.

5.2.2.3 Maximum summer temperature

Maximum summer temperature is same as the annual maximum temperature for Uttar Pradesh. So the temperature trends will be same.



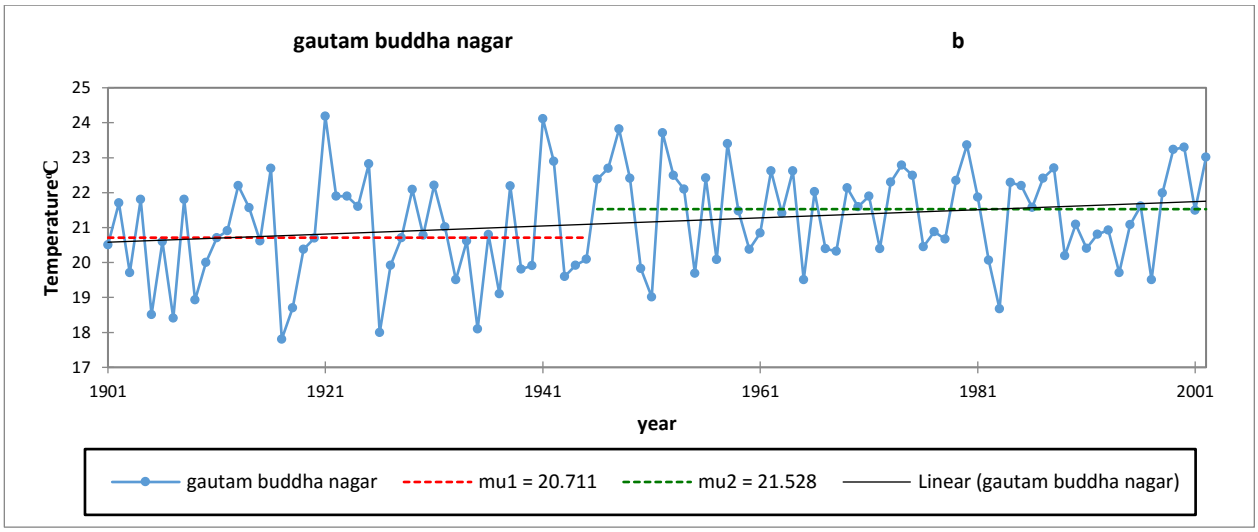


Figure 4 Minimum (a) and maximum (b) significant increasing trends in minimum summer (a &b)

5.3 Monthly Temperature Analysis

5.3.1 January average temperature trends

The January average temperature trend analysis results show that there is increasing in trends for all the districts of Uttar Pradesh .The significance increase in January average temperature from its mean is maximum in Bahraich and minimum in Barabanki shown in figure5. The table no.9 (Appendix A) shows the significance of the trends at 95 % (1 districts) and 99% (1 districts) confidence interval and the results of pettit-t test. The substantial rate of annual change in temperature is maximum (at the rate of 0.006°C/year) at Bahraich and minimum (at the rate of 0.005°C/year) at Barabanki. The pettit-t test results show that for most of the districts have a shift in year 1945, 1947 and 1957 in most of the districts of U.P. In the some of the districts the change point is 1937, 1942 and 1964.only Etawah is temperature is shift of year 1955.

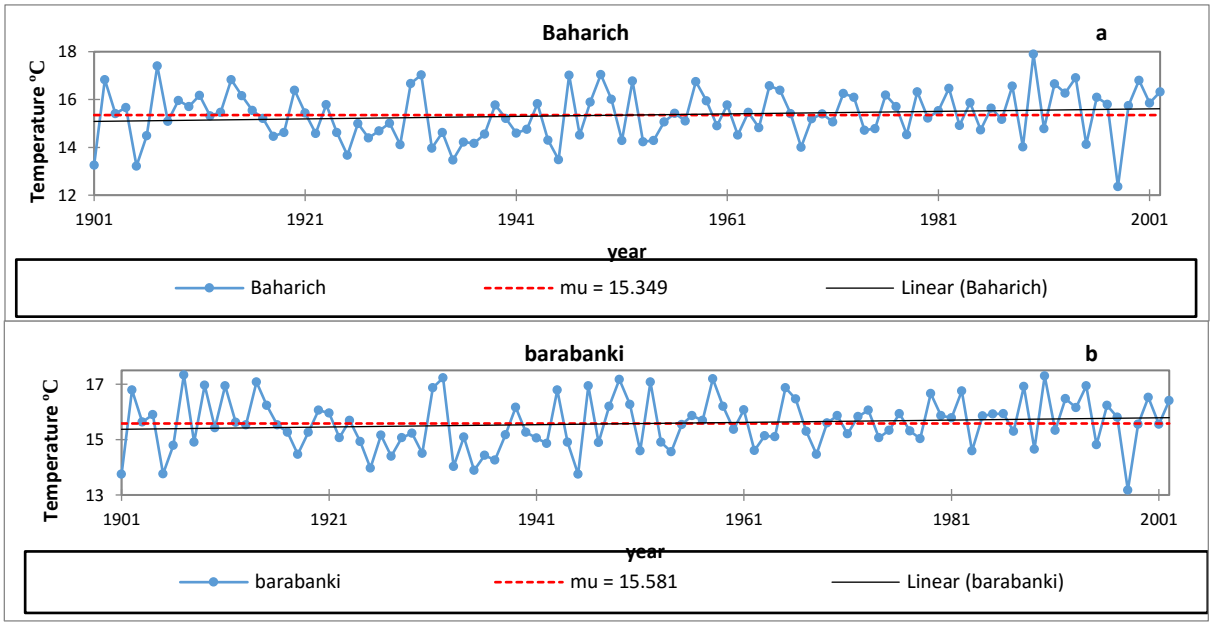


Figure 5 Maximum (a) and minimum (b) significant change trends in average temperature of January

5.3.2 February average temperature trends

All the districts of Rajasthan are seen to have experienced increasing trends in average February temperature. The significance increase from its mean temperature is maximum in Pilibhit, Kheri and minimum inKhushinagar, Ballia and Deoria, shown in figure 6 . The table no.10 (Appendix A) shows the significance of the trends at 99% for all districts in confidence interval. The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of 0.015°C/year) atPilibhit, Kheriand minimum (at the rate of 0.009°C/year) at Khushinagar, Ballia and Deoria. Pettit-t test results show that most of the districts have a shift in year 1940 and 1945 in most of the districts of U.P. In the some of the districts the change point is 1951. Gautam Buddhanagar and Mathura is temperature is shift of year 1932.

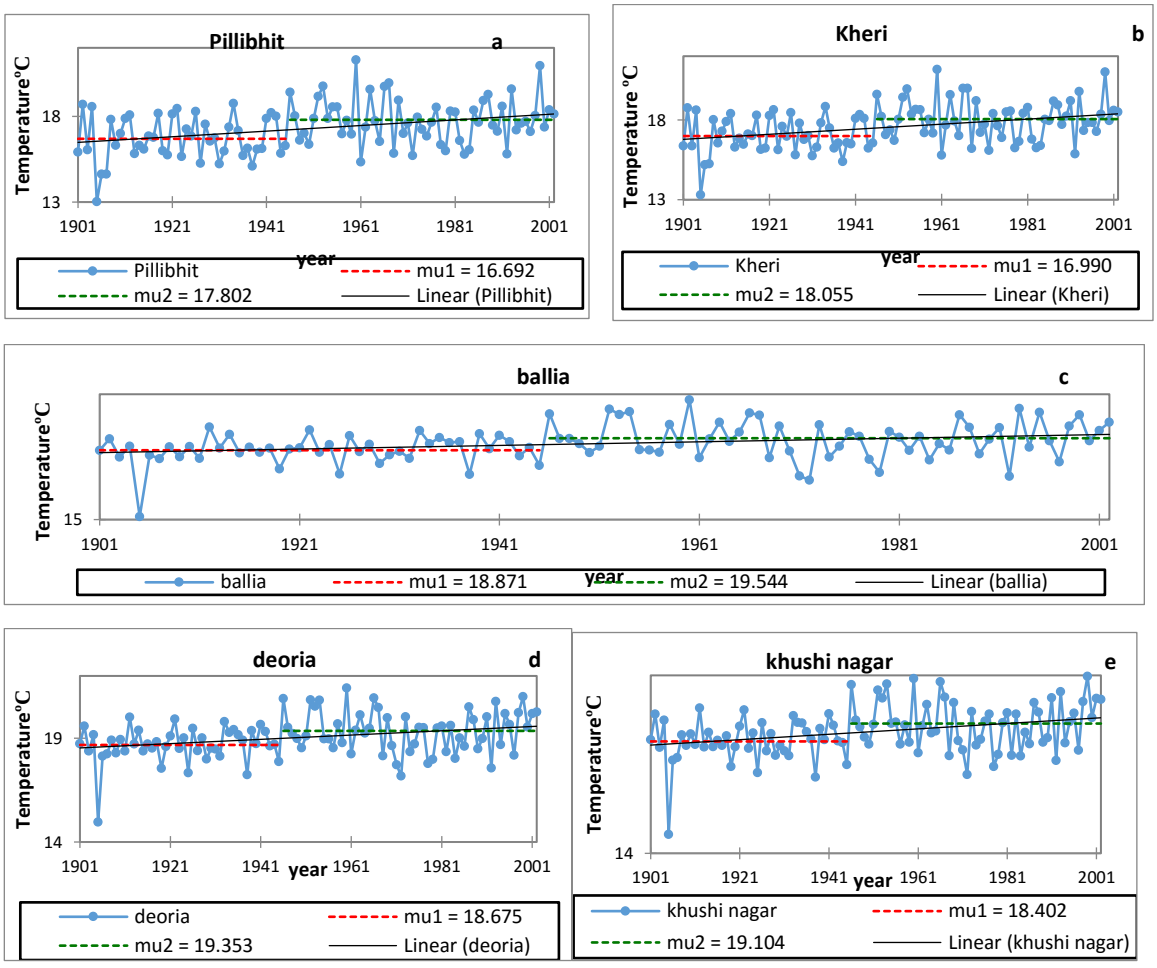


Figure 6 Maximum (a & b) and minimum (c, d &e) significant change trends in average temperature of February

5.3.3 March average temperature trends

All the districts of Uttar Pradesh are seen to have experienced increasing trends. Significance increase in temperature from its mean is maximum in Lalitpur and minimum in Etawah as shown in figure 7. The table no.11 shows the significance of the trends only at 90% (5 districts) confidence interval. The substantial rate of annual change in temperature (sen's slope) is maximum (at the rate of 0.0082°C/year) at Lalitpur and minimum (at the rate of 0.0073°C/year) at Etawah. The Pettit-t test show that most of the districts have a shift in year 1920 and 1940 in most of the districts of U.P. In the some of the districts the change point is 1915 and 1917.

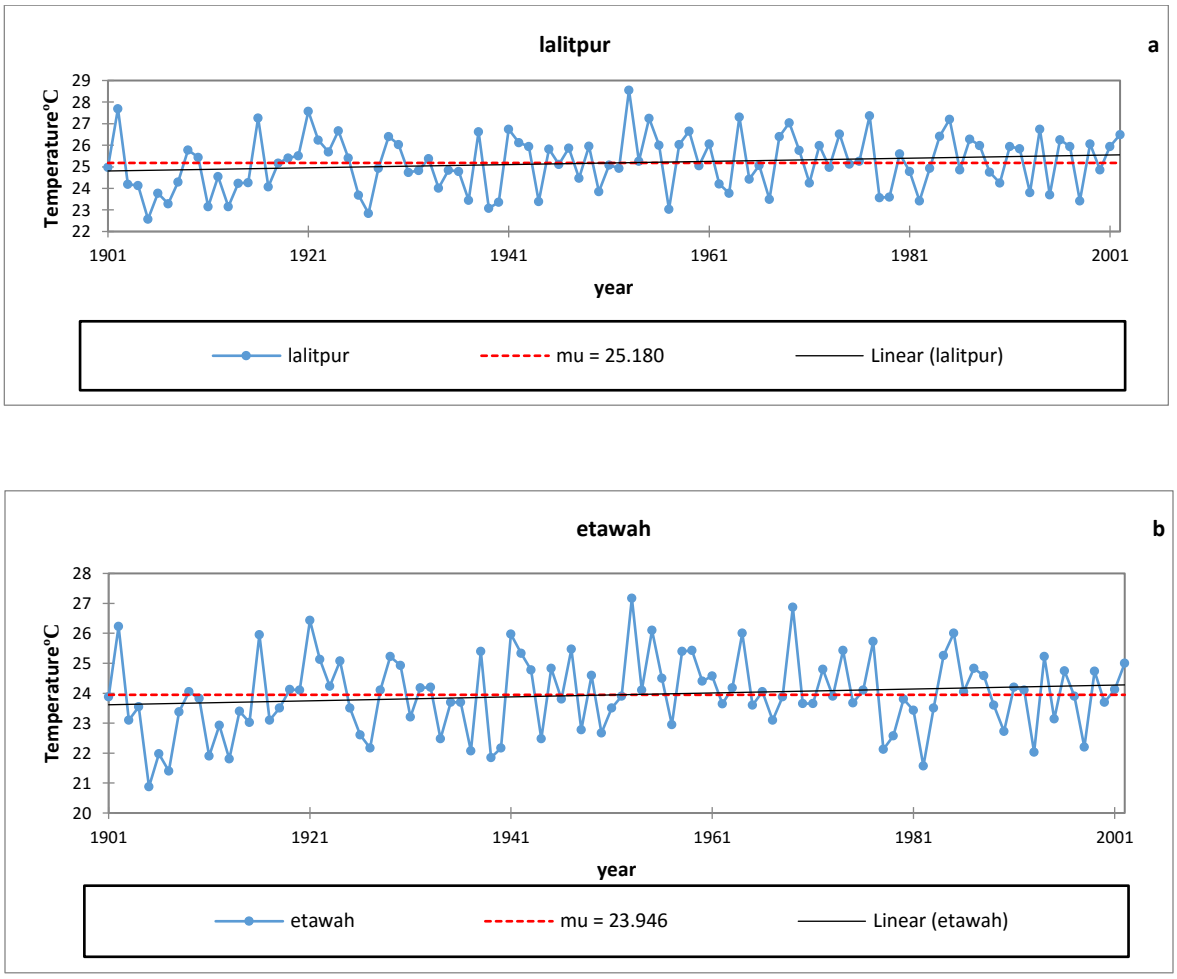


Figure 7 Maximum (a) and minimum (b) significant change trends in average temperature of March

5.3.4 April average temperature trends

For April average temperature all the districts of Rajasthan are seen to have experienced increasing trends. The significance increase in temperature from its mean is maximum in Baghpat and minimum in Banda, Fatehpur and Kanpur nagar shown in figure 8. The table no.12 shows the significance of the trends at 95% (14 districts) and 99% (13 districts) confidence interval and pettit-t test results. The substantial rate of annual change in temperature (sen's slope) is maximum (at the rate of 0.012°C/year) at Baghpat and minimum (at the rate of 0.006°C/year) at Banda, Fatehpur and Kanpur nagar. The shift detection test results show that the most of temperature shift year is 1945-46.

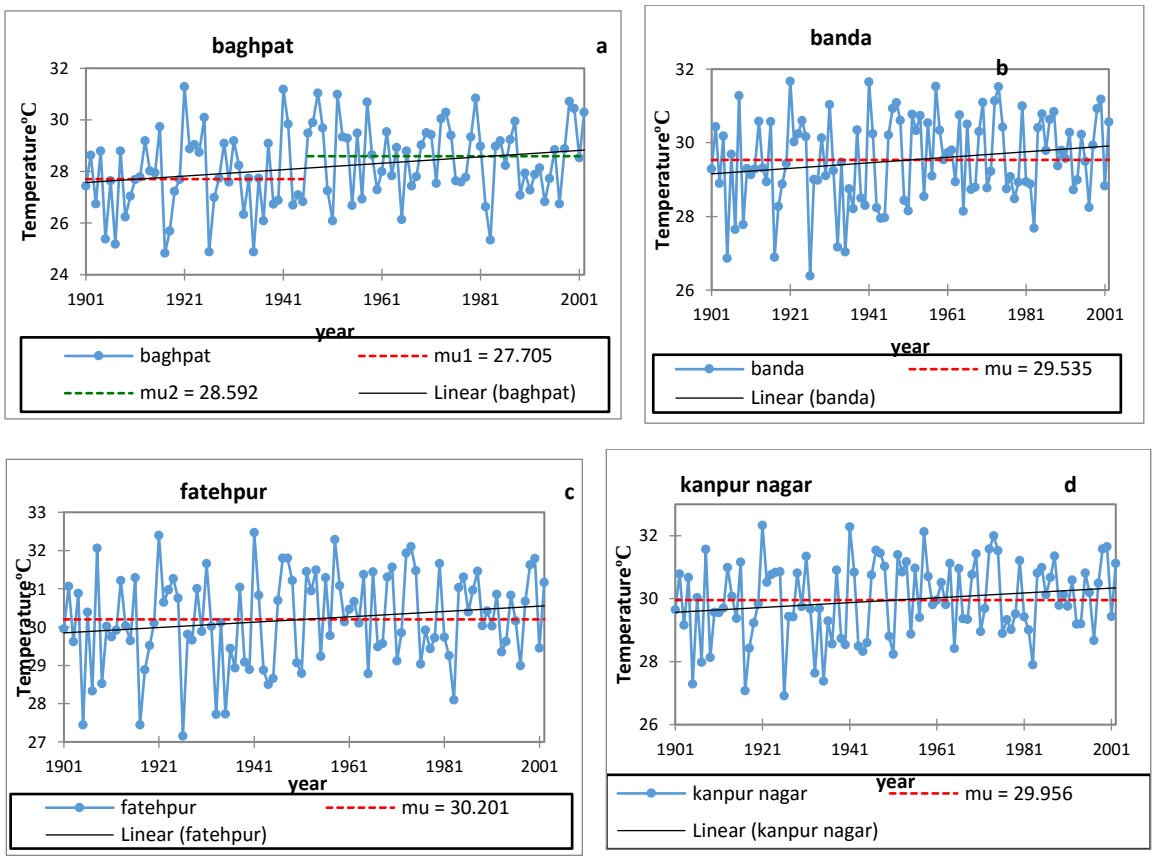


Figure 8 Maximum (a) and minimum (b,c& d) significant change trends in average temperature of April

5.3.5 May average temperature trend-

In this month there is no significant trend found in any district of U.P shown in Table no. 13.

5.3.6 June average temperature trends

Most of the districts of Uttar Pradesh are seen to have experienced decreasing trends. Only Maharaj Ganj districts having the increasing trends. The significance decrease in temperature from its mean is maximum in Agra, Firozabad and hathras and minimum in Lucknow, shown in figure 9. The table no.14 shows the significance of the trends at 95% (9 districts) & 99% (25 districts) confidence interval. The substantial rate of annual change in temperature (sen's slope) is maximum (at the rate of -0.014°C/year) at Agra, Firozabad and Hathras and minimum (at the rate of -0.006°C/year) at Lucknow. The Pettit- t test results show that most of the districts have a shift in year 1969 in most of the districts of U.P. In the some of the districts the change point is 1965 and 1967. Khushinagar and Maharajganj is temperature is shift of year 1922.

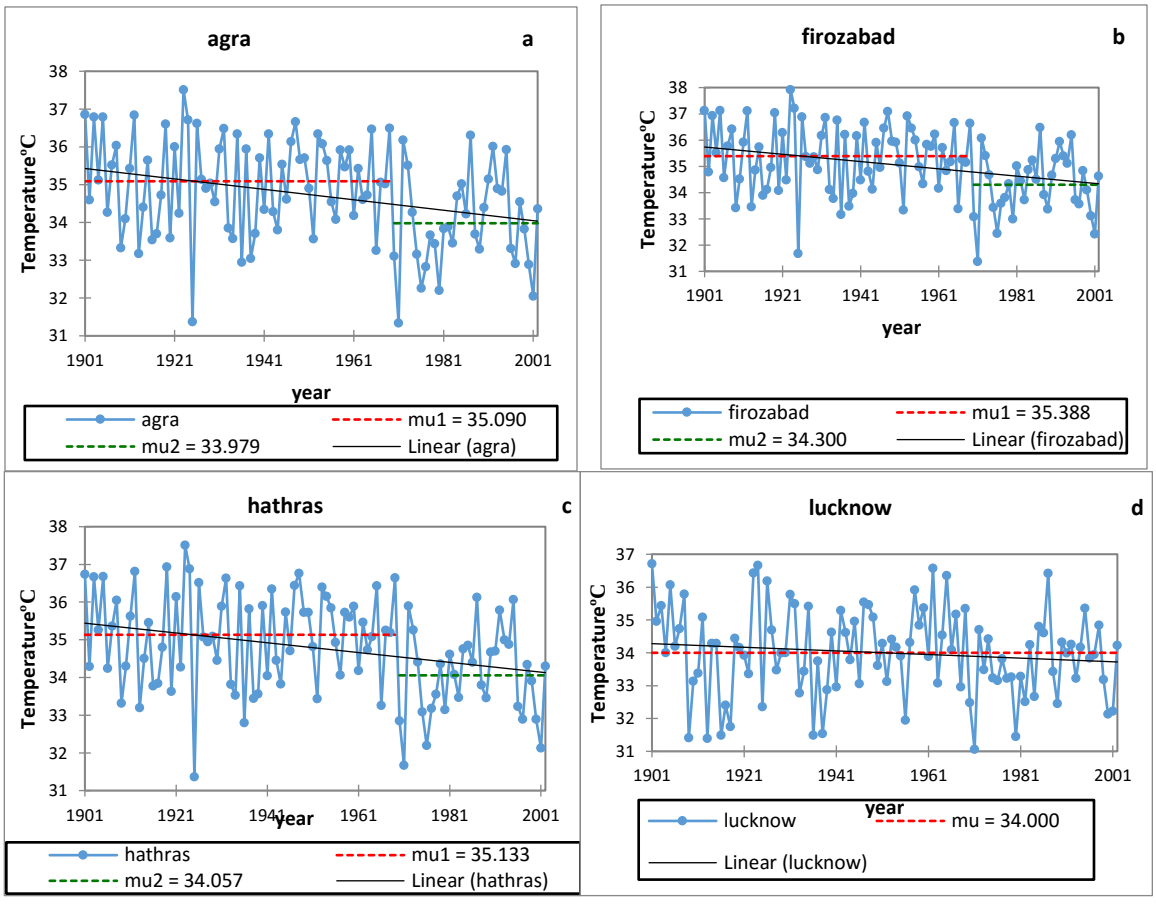


Figure 9 Maximum (a,b & c) and minimum (d) significant change trends in average temperature of June

5.3.7 July average temperature trends-

In this month all the districts of Uttar Pradesh are seen to have experienced decreasing trends except khushinagar.The significance decrease in temperature from its mean is maximum in Agra,Firozabad and Hathras and minimum in Faizabad, Lucknow and Pilibhit shown in figure 10. The table no.15 shows the significance of the trends at 95% (16 districts) & 99% (8 districts) confidence interval and the results of Pettit-t test. The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of -0.008°C/year) at Agra and Firozabad and minimum (at the rate of - 0.003°C/year) at Faizabad, Lucknow and Pilibhit. The Pettit-t test results show that the districts have a shift in year 1918 and 1966 in most of the districts of U.P. In the some of the districts the change point is 1924, 1955 and 1973.

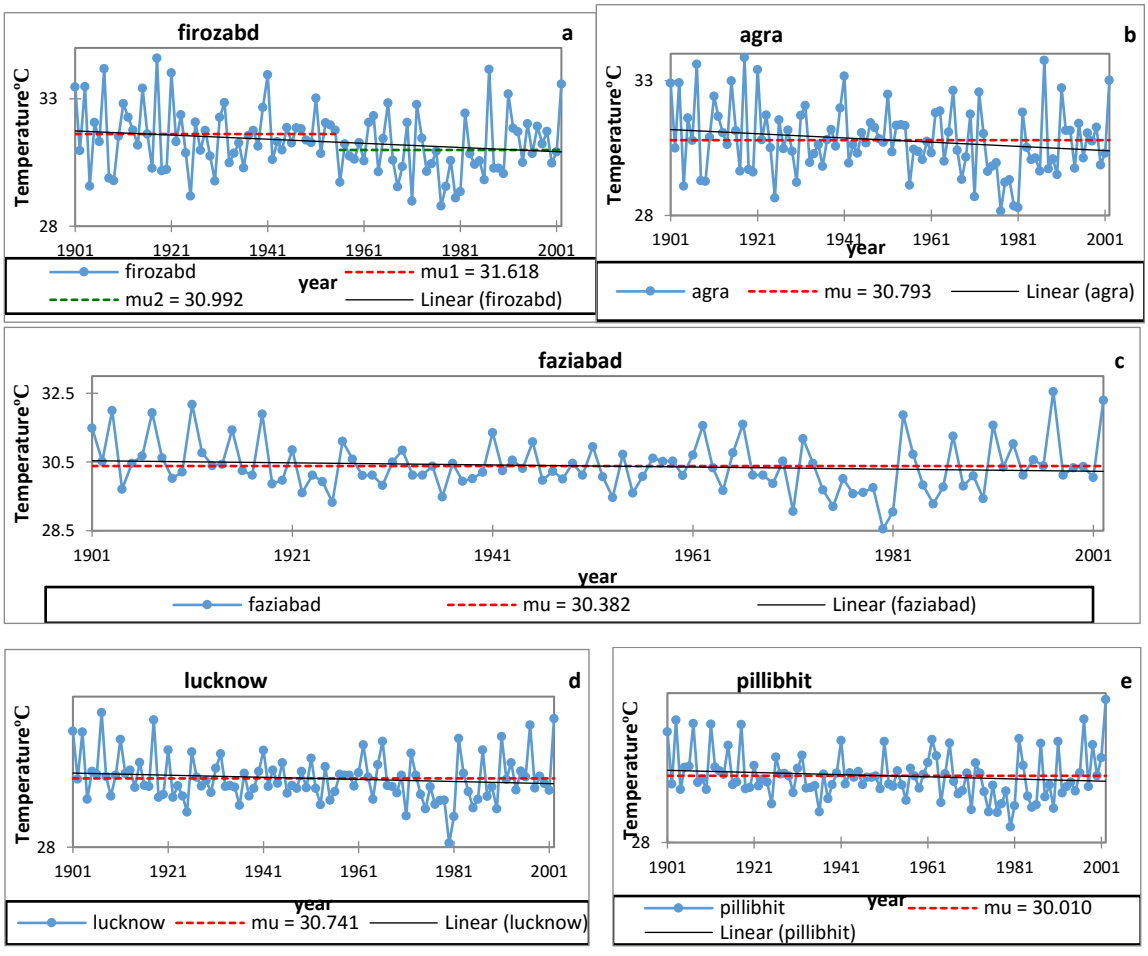


Figure 10 Maximum (a &b) and minimum (c, d & e) significant change trends in average temperature of July

5.3.8 August average temperature trends

All the districts of Rajasthan are seen to have experienced decreasing trends. The significance decrease in temperature from its mean is maximum in Saharanpur and minimum in Bareilly shown in figure11 and table no.16. In this month only 4 districts Bareilly, Rampur, Saharanpur and Shahjahanpur is having significant trend at 95% confidence interval. The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of -0.005°C/year) at Saharanpur and minimum (at the rate of -0.002°C/year) at Bareilly. ThePettit-t test shows that the temperature shift year for this month has large variability. In central part of Uttar Pradesh the shift year is around 1965 and 1920. In the some of the districts the change point is 1915, 1951, 1947 and 1966.

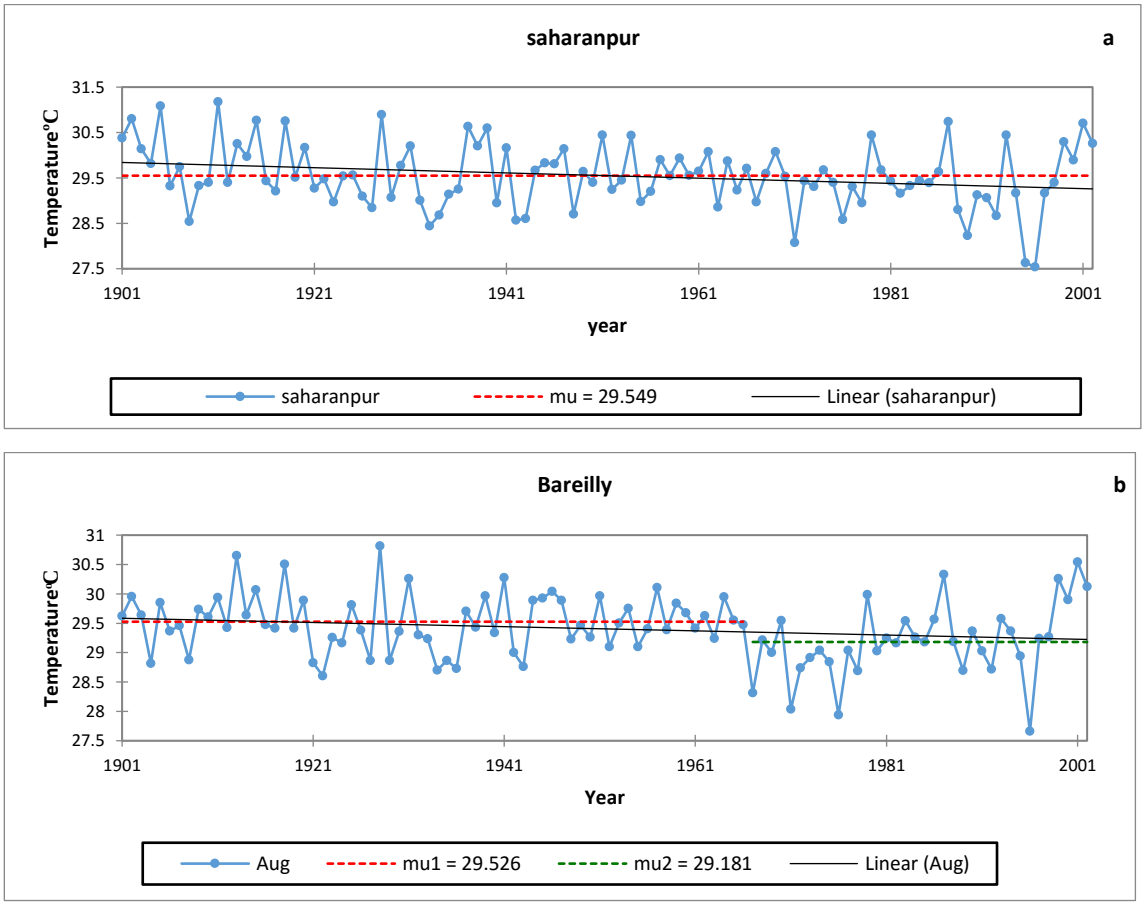


Figure 11Maximum (a) and minimum (b) significant change trends in average temperature of August

5.3.9 September average temperature trends

In this month all the districts of Uttar Pradesh are seen to have experienced decreasing trends except Lalitpur. The significant decrease in temperature from its mean is maximum in Etah,Firozabad and Mainpuri and minimum in Chandauli and Sonbhadra as shown in figure 12. The table no.17 shows the significance of trends at 95% (16 districts)&99 % (30 districts) confidence interval, Sen's slope and the results of Pettit-t test. The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of -0.007°C/year) at Etah,firozabad and Mainpuri and minimum (@ of -0.002°C/year) at Chandauli and Sonbhadra The Pettit-t test results show that the districts have a shift in year 1961 in most of the districts of U.P. In the some of the districts the change point is 1947, 1952 and 1956. Kushinagar, Maharajganj and Siddharth Nagar districts have a shift in year 1986.

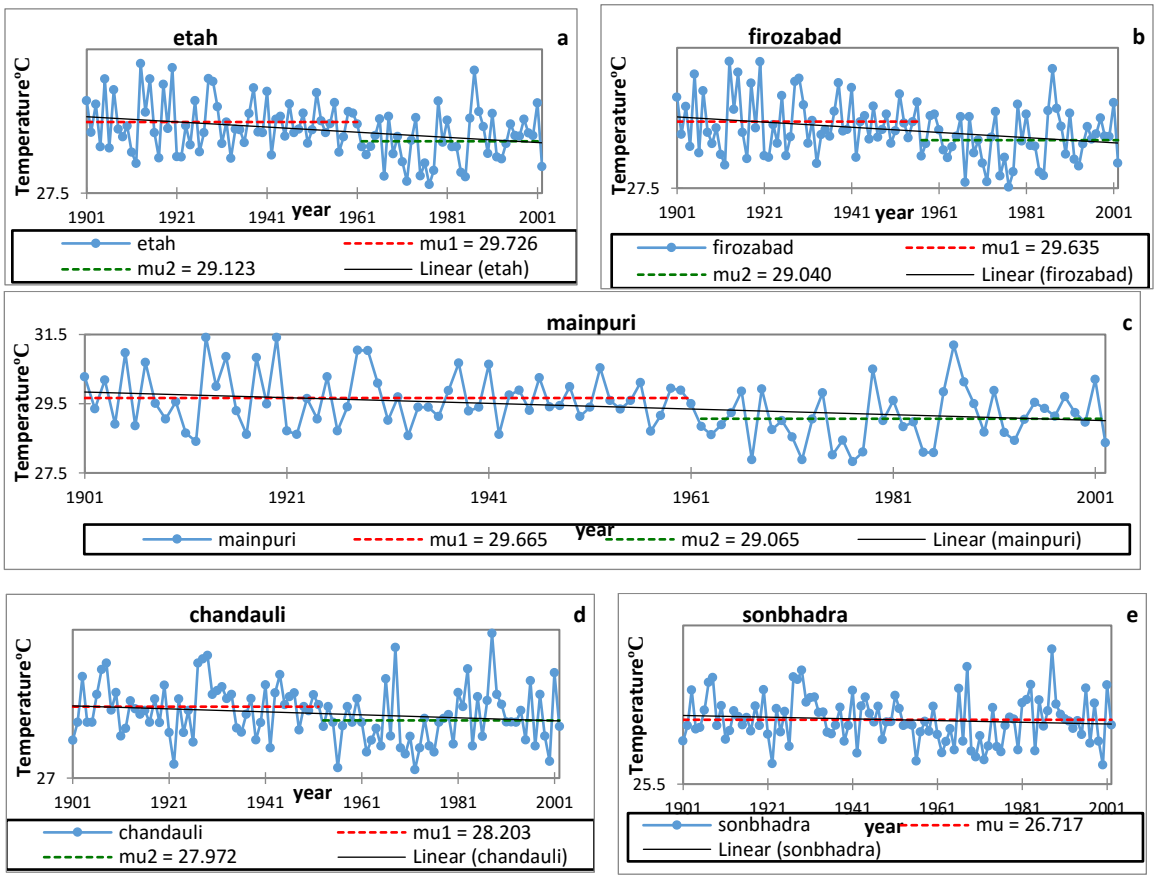


Figure 12Maximum (a,b &c) and minimum (d & e) significant change trends in average temperature of September

5.3.10 October minimum temperature trends

In this month 67 districts of Uttar Pradesh are seen to have experienced increasing trends. In other remaining 3 districts trends are decreasing. The significance increase in temperature from its mean is maximum in Chitrakoot and Sant Ravidas nagar and minimum in Kannauj as shown in figure 15. The table no.18 shows the significance of the trends at 95% (10 districts) and 99% (22 districts) confidence interval, Sen's slope and the results of Pettit-t test. The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of 0.008°C/year) at Chitrakoot and SantRavidasnagarand minimum (at the rate of 0.003°C/year) at Kannauj. According to Pettit-t test results show that the districts have a shift in year 1962 in most of the districts of U.P. In the some of the districts the change point is 1920 and 1973. Kushinagar and Siddharth Nagar districts have a shift in year 1948.Only Khushinagar districts temp shift in year 1978.

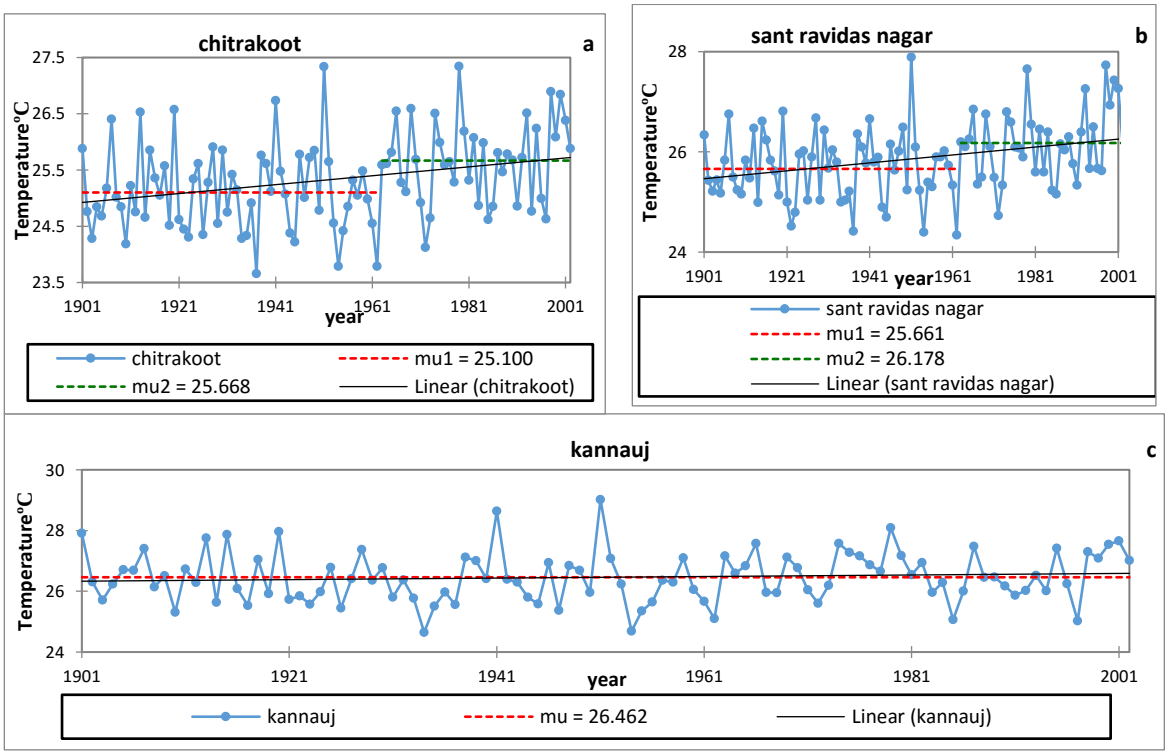


Figure 13 Maximum (a & b) and minimum (c) significant change trends in average temperature of October

5.3.11 November average temperature trends

In this month all districts of Rajasthan are seen to have experienced increasing trends. The significant increase in temperature from its mean is maximum in Chitrakoot,Kaushambi and minimum in Mathura, Saharanpur as shown in figure14. The table no.19 shows the significance of the trends at 95% (4 districts) and 99 % (65 districts) confidence interval, Sen's slope and the results of pettit-t test. Budaun do not have significant trends. The substantial rate of annual increase in temperature (Sen's slope) is maximum (at the rate of 0.020°C/year) at Chitrakoot ,Kaushambi and minimum (at the rate of 0.008°C/year) at Mathura, saharanpur. The Pettit- t test results show that the districts have a shift in year 1939 and 1961 in most of the districts of U.P. In the some of the districts the change point is 1954,1962 and 1967. Kushinagar and Siddharth Nagar districts have a shift in year 1948.

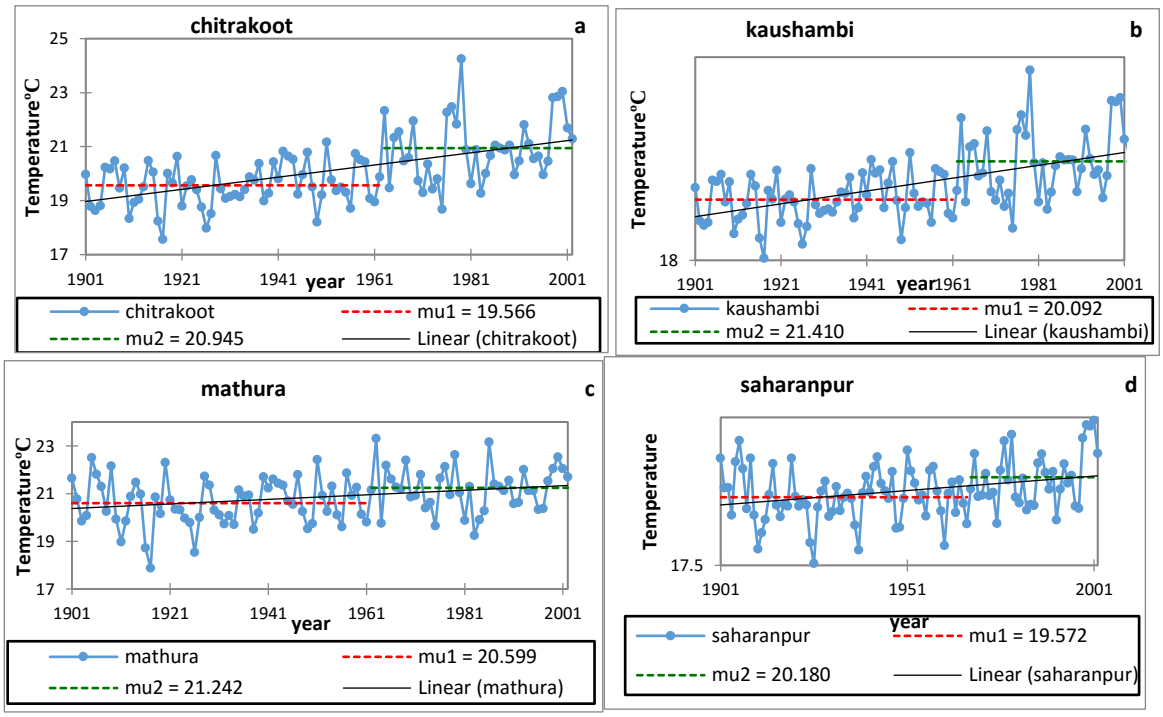


Figure 14Maximum (a & b) and minimum (c & d) significant change trends in average trends of November

5.3.12 December average temperature trends

In this month all districts of Uttar Pradesh are seen to have experienced increasing trends. The significant increase in temperature from its mean occur is maximum in Sonbhadra and minimum in Maharajganj,Mathura and Saharanpur as shown in figure15. The table no. 20 shows the all districts are significance level of 99 %(70 districts) confidence interval. The substantial rate of annual change in temperature (Sen's slope) is maximum (at the rate of 0.019°C/year) at Sonbhadra and minimum (at the rate of 0.0011°C/year) at Maharajganj, Mathura and Saharanpur. The Pettit-t test results show that the most of the districts have shift year 1940 and 1950-51. The districts in North and East (4 districts) have shift year around 1956.The shift year for Allahabad,Kaushambi,Pratapgarh and Rae Bareli is 1942.

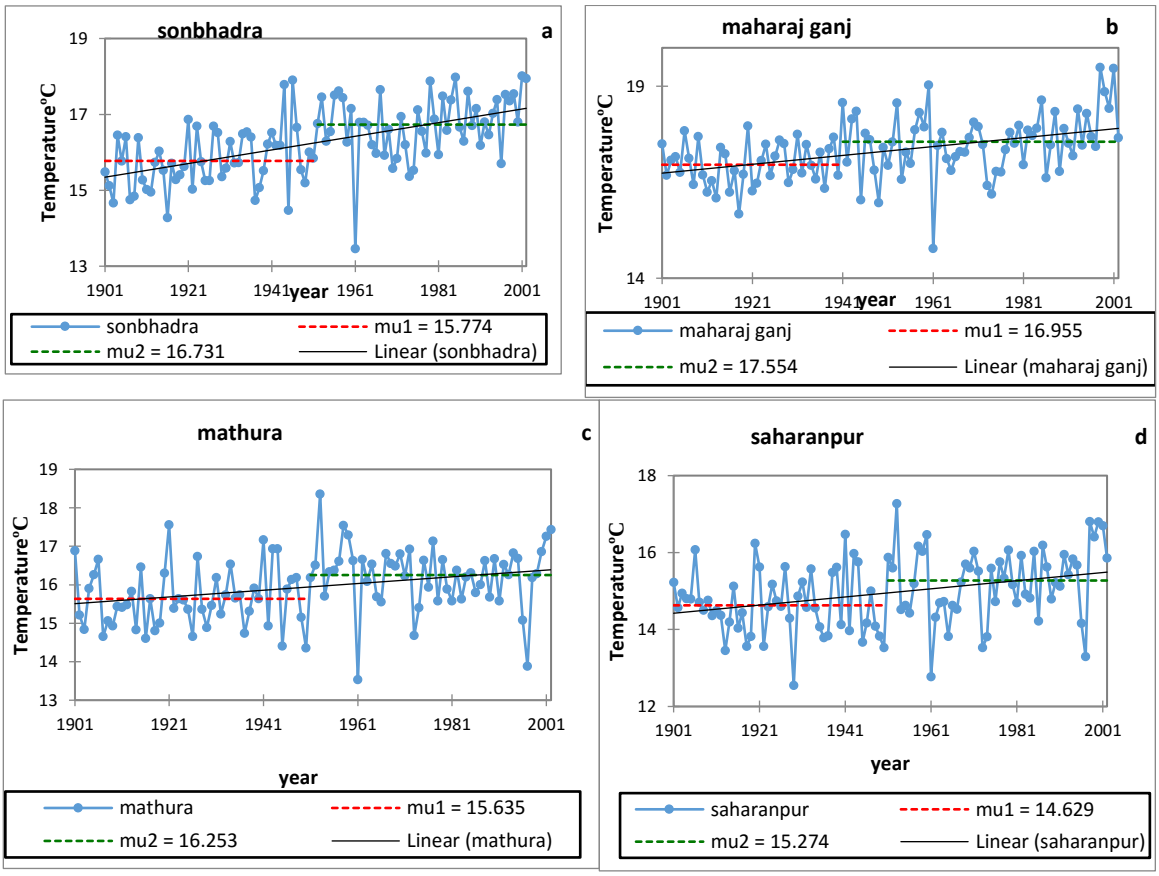


Figure 15 Maximum (a) and minimum (b, c & d) significant change trends in average temperature of December

CHAPTER 6
CONCLUSIONS

CHAPTER 6

6 Conclusion

In the present study, the trends in mean, maximum and minimum temperature (annually, monthly and seasonally) were determined for the 70 districts of Uttar Pradesh State. This was carried out using the non-parametric Mann–Kendall (MK) test. The Sen's slope and percentage changes in rainfall and temperature were also estimated over the study period (1901-2002). Both positive and negative trends were observed in monthly, seasonal and annual temperature. For average temperature and minimum temperature positive trends were observed while in maximum temperature both positive and negative trends were obtained in annual temperature. The conclusions drawn from the study are as follows-

- The significant increase in annual Minimum temperature is 0.011°C/year at Mirzapur (South) and Unnao(Centre) While mean temperature is increasing 0.006°C/year at Lalitpur(South-West) and maximum temperature there is no significant value.
- The significant increase in winter Minimum temperature is 0.011°C/year at Mirzapur (South) and Unnao(Centre) While maximum temperature 0.014°C/year at Kheri(North-East) and 0.012°C/year at Kheri (North-East) in the mean temperature.
- The significant increase in summer temperature is 0.012°C/year at Gautam Buddha Nagar (North-West) in the minimum temperature and no significant value for the maximum and mean temperature.
- Analysis on monthly time step indicates the significant warming trend in the all months in the mean temperature during the analysis period of 1901 to 2002.
- The probable change year (shift) in annual temperature is between 1954 & 1955 for minimum temperature and 1940 for mean temperature.
- The probable change year (shift) in winter temperature is between 1941 to 1951 for mean temperature, 1954 & 1955 and 1968 for minimum temperature and 1940 & 1945 for maximum temperature.

- The probable change year (shift) in summer temperature is between 1945 for minimum temperature. The maximum & mean temperature are various change shift years.
- The Trends analysis is extremely helpful to search out the probably influence of activity on hydrologic circle, environmental resources and future water resources management of the Uttar Pradesh state.

REFERENCES

7 REFERENCES

- Arora, M. and Goel, N.K., "Evaluation of temperature trends over India", Hydrological Sciences Journal, 50:1, 81-93, (2005).
- Burn, D.H. and Elnur, M.A.H., "Detection of hydrologic trends and variability", Journal of Hydrology 255, 107-122(2012).
- Capparelli, V., Franzke, C., Vecchio, A. and Watkings, N.W., "Aspatiotemporal analysis of U.S. station temperature trends over the last century", Journal of Geophysical Research: Atmospheres, Vol. 118, 1-8 (2013).
- Chakraborty, S., Pandey, R.P., Chaube, U.C. and Mishra, S.K., "Trend and variability analysis of rainfall series at Seonath River Basin, Chhattisgarh (India)", IJASER, Volume: 2 Issue: 4, ISSN No 2277-9442(2013).
- Chinchorkar, S.S., Khardiwar, M.S. and Sayyad, F.G., "A Study of Maximum and Minimum Temperatures Trends at Junagadh (Saurashtra Region) of Gujarat, India", Current World Environment, Vol. 10(1), 321-329(2015).
- Choudhary, B.U., Das, A., Ngachan, S.V., Slong, A., Bordoloi, L.J. and Chaudhary, P., "Trend Analysis of Long Term Weather Variables in Mid Altitude Meghalaya, North-East India", Journal of Agricultural Physics, Vol.12, No.1, 12-22(2012).
- Dhuan, D. and Pandey, A., "Statistical analysis of long term spatial and temporal trends of precipitation during 1901-2002 at Madhya Pradesh, India", Atmospheric Research 122, 136-149(2013).
- Duhan, D., Pandey, A., Gahalaut, K.P.S. and Pandey, R.P.," Spatial and temporal variability in maximum, minimum and mean air temperature at Madhya Pradesh in central India", C.R. Geoscience 345, 3-21 (2013).
- Gadgil, A. and Dhorde, A., "Temperature trends in twentieth century at Pune, India", Atmospheric Environment 39, 6550-6556(2005).
- Gocic, M. and Trajkovic, S., "Analysis of changes in meteorological variables using Mann-Kendall and Sen's slope estimator statistical tests in Serbia", Global and Planetary Change 100, 172-182(2013).
- Jain, S.K. and Kumar, V., "Trend analysis of rainfall and temperature data for India", Current Science, Vol. 102, No.1 (2012).

- Jhajharia, D.and Singh, V.P., “Trends in temperature, diurnal temperature range and sunshine duration in Northeast India”, International Journal of Climatology 31, 13531367(2011).
- Kahya, E. and Kalayci, S., “Trend analysis of streamflow in Turkey”, Journal of Hydrology 289, 128-144(2004).
- Kausari, M.R., Ahani, A. and Hendizadeh, R., “Temporal and spatial trend detection of maximum air temperature in Iran during 1960-2005”, Global and Planetary Change 111, 97-110(2013).
- Khavse, R., Deshmukh, R., Manikandan, N. and Kaushik, D., “Statistical Analysis of Temperature and Rainfall Trend in Raipur District of Chhattisgarh”, Current World Environment, Vol.10 (1), 305-3012(2015).
- Kumar, V., Jain, S.K. and Singh, Y., “Analysis of long term rainfall trends in India”, Hydrological Sciences Journal 55(4), 484-496(2010).
- Kundu, A., Chatterjee, S., Dutta, D. and Siddiqui, A.R., “Meteorological Trend Analysis in Western Rajasthan(India) using Geographical Information System and Statistical Techniques”, Journal of Environment and Earth Science ISSN 2224-3216, Vol.5, No.5,(2015).
- Machiwal, D. and Jha, M.K., “TIME SERIES ANALYSIS OF HYDROLOGIC DATA FOR WATER RESOURCES PLANNING AND MANAGEMENT: A REVIEW”, J. Hydrol. Hydromech 54, 237–257 (2006).
- Onoz, B. and Bayazit, M, “The Power of Statistical Tests for Trend Detection”, Turkish J. Eng. Env. Sci. 27,247-251(2003).
- Pal, I., and Tabbaa, A.A. “Long-term changes and variability of monthly extreme temperatures in India”, Theor. Appl. Climatol. 100, 45-46(2010).
- Patle, G.T. and Libang, A., “Trend analysis of annual and seasonal rainfall to climate variability in North-East region of India”, JANS 6(2), 480-483 (2014).
- Pingle, S.M. and Khare, D., Jat, M.K. and Adamowski, J. “Spatial and temporal trends of mean and extreme rainfall and temperature for the 33 urban centers of the arid and semi-arid state of Rajasthan, India”, Atmospheric Research 138, 73-90, (2014).
- Rao P.G.,” Climate changes and trends over a major river basin in India”, Climate Research, Vol.2, 215-223, 1993.

- Rao, A.R. and Hamed, K.H., "A modified Mann-Kendall trend test for auto correlated data", Journal of Hydrology 204, 182-196(1998).
- Robert, M.H., James, R.S., and Richard, A.S.," Techniques of Trend Analysis for Monthly Water Quality Data", Water Resources Research, Vol. 18, No.1, 107121(1982).
- Roy, A.D., "Trend detection in Temperature and Rainfall over Rajasthan during the last century", Asian Research Consortium Vol.5, No.2, ISSN 2249-7315 (2015).
- Safari, B., "Trend Analysis of the Mean Annual Temperature in Rwanda during the Last Fifty two Years", Journal of Environmental Protection 3, 538-551(2012).
- Sayemuzzaman, M. and Jha, M., "Seasonal and annual precipitation time series trend analysis in North Carolina, United States", Atmospheric Research 137, 183194(2014).
- Sonali, P. and Kumar, N., "Review of trend detection methods and their application to detect temperature change in India", Journal of Hydrology 476, 212-227 (2001).
- Tabari, H. and Talaee, P.H.,"Analysis of trends in temperature data in arid and semiarid regions of Iran", Global and Planetary Change 79, 1-10(2011).
- Tanzina, M. and William, A.G., "Trend analysis of long term temperature time series in the Greater Toronto Area", Theor. Appl. Climatol.101, 311-227, (2010).
- Yue, S., Pilon, P., Phinney, B. and Cavadias, G., "The influence of autocorrelation on the ability to detect trend in hydrological series", Hydrological process 16, 18071829(2002).

APPENDIX A

Table 1: Results of the statistical tests for average annual temperature

S. N.	DIstrict	Mean	Mann-Kendall Test		Modified-MK Test		Sen's slope	%Change In temprature	Shift detection test
			Zmk	P-value	Zmmk	P-value			
1	Agra	25.672	1.110	0.267	0.786	0.432	0.0018	0.007	1937
2	Aligarh	25.485	1.972	0.049	1.525	0.127	0.0026	0.010	1940
3	Allahabad**	25.467	3.571	0	2.920	0.004	0.0044	0.017	1940
4	Ambedkar Nagar**	25.929	3.394	0.001	3.006	0.003	0.0044	0.017	1940
5	Auraiya	25.683	2.215	0.027	1.941	0.052	0.0030	0.012	1940
6	Azamgarh**	25.984	3.475	0.001	3.036	0.002	0.0045	0.017	1940
7	Baghpat*	24.816	2.180	0.029	2.455	0.014	0.0032	0.013	1945
8	Bahraich**	25.312	3.082	0.002	2.690	0.007	0.0045	0.018	1940
9	Ballia**	25.988	3.423	0.001	3.035	0.002	0.0041	0.016	1940
10	Balrampur**	25.497	3.001	0.003	2.594	0.009	0.0041	0.016	1940
11	Banda**	25.135	3.597	0	3.180	0.001	0.0048	0.019	1940
12	Barabanki**	25.557	3.244	0.001	2.781	0.005	0.0045	0.017	1940
13	Bareilly	25.084	1.775	0.076	1.390	0.165	0.0029	0.011	1940
14	Basti**	25.780	3.279	0.001	2.882	0.004	0.0045	0.017	1940
15	Bijnor	24.492	1.836	0.066	1.598	0.110	0.0030	0.012	1940
16	Budaun	25.356	1.882	0.060	1.467	0.142	0.0029	0.011	1940
17	Buland Shahar*	25.271	2.469	0.014	1.990	0.047	0.0035	0.014	1945
18	Chandauli**	25.337	3.799	0	3.658	0	0.0047	0.018	1940
19	Chitrakoot**	24.971	3.710	0	3.221	0.001	0.0049	0.019	1940
20	Deoria**	25.808	3.452	0.001	3.218	0.001	0.0040	0.016	1940
21	Etah	25.625	1.868	0.062	1.443	0.149	0.0027	0.010	1940
22	Etawah	25.697	1.995	0.046	1.746	0.081	0.0028	0.011	1940
23	Farrukhbad	25.588	2.180	0.029	1.938	0.053	0.0030	0.012	1940
24	Fatehpur**	25.834	3.050	0.002	2.666	0.008	0.0041	0.016	1940
25	Faziabad**	25.750	3.316	0.001	2.954	0.003	0.0046	0.018	1940
26	Firozabad	25.752	1.619	0.105	1.165	0.244	0.0023	0.009	1940
27	Gautam buddha nagar	25.156	2.374	0.018	1.896	0.058	0.0035	0.014	1945
28	Ghaziabad**	24.949	2.498	0.012	2.815	0.005	0.0037	0.015	1945
29	Ghazipur**	25.880	3.580	0	3.181	0.001	0.0044	0.017	1940
30	Gonda**	25.556	3.140	0.002	2.748	0.006	0.0044	0.017	1940
31	Gorakhpur**	25.787	3.299	0.001	3.100	0.002	0.0042	0.016	1940
32	Hamirpur**	25.301	3.244	0.001	2.940	0.003	0.0044	0.017	1940
33	Hardoi*	25.534	2.458	0.014	2.156	0.031	0.0035	0.014	1940
34	Hathras	25.618	1.428	0.153	1.026	0.305	0.0021	0.008	1937
35	Jalaun*	25.423	2.657	0.008	2.355	0.019	0.0036	0.014	1940
36	Jaunpur**	26.044	3.568	0	3.154	0.002	0.0043	0.017	1940
37	Jhansi**	25.249	3.285	0.001	2.954	0.003	0.0044	0.017	1940
38	Jyotiba phule nagar*	24.991	2.215	0.027	2.135	0.033	0.0032	0.013	1940

39	Kannauj*	25.712	2.284	0.022	2.022	0.043	0.0030	0.012	1940
40	Kanpur dehat*	25.648	2.417	0.016	2.139	0.032	0.0033	0.013	1940
41	Kanpur Nagar*	25.690	2.648	0.008	2.276	0.023	0.0036	0.014	1940
42	Kaushambi**	25.551	3.337	0.001	2.849	0.004	0.0043	0.017	1940
43	Kheri*	25.253	2.741	0.006	2.401	0.016	0.0042	0.017	1940
44	Kushi nagar**	25.599	3.447	0.001	3.164	0.002	0.0042	0.016	1940
45	Lalitpur**	25.284	3.900	0	3.490	0	0.0058	0.023	1945
46	Lucknow**	25.763	3.273	0.001	2.814	0.005	0.0042	0.016	1940
47	Maharaj ganj**	25.536	3.250	0.001	2.977	0.003	0.0041	0.016	1940
48	Mahoba**	25.032	3.744	0	4.150	0	0.0049	0.020	1940
49	Mainpuri	25.775	1.966	0.049	1.535	0.125	0.0026	0.010	1940
50	Mathura	25.455	0.919	0.358	0.649	0.516	0.0015	0.006	1937
51	Mau**	25.950	3.484	0	3.096	0.002	0.0043	0.017	1940
52	Meerut**	24.861	2.276	0.023	3.109	0.002	0.0035	0.014	1945
53	Mirzapur**	25.264	3.889	0	4.637	0	0.0046	0.018	1940
54	Moradabad	24.986	1.989	0.047	1.720	0.085	0.0031	0.012	1940
55	Muzaffarnagar	24.695	1.943	0.052	1.755	0.079	0.0029	0.012	1945
56	Pilibhit	24.984	1.978	0.048	1.694	0.090	0.0030	0.012	1940
57	Pratapgarh**	26.054	3.481	0	3.018	0.003	0.0041	0.016	1940
58	Rae Bareli**	26.024	3.169	0.002	2.732	0.006	0.0041	0.016	1940
59	Rampur	24.931	1.608	0.108	1.255	0.210	0.0027	0.011	1940
60	Saharanpur	24.342	1.579	0.114	1.279	0.201	0.0024	0.010	1940
61	Sant kabir nagar**	25.765	3.293	0.001	3.090	0.002	0.0041	0.016	1940
62	Sant Ravidas nagar**	25.347	3.551	0	3.399	0.001	0.0044	0.017	1940
63	Shahjahanpur	25.250	2.151	0.031	1.871	0.061	0.0031	0.012	1940
64	Shrawasti**	25.354	3.010	0.003	2.614	0.009	0.0043	0.017	1940
65	Siddharth Nagar**	25.598	3.071	0.002	2.616	0.009	0.0040	0.016	1940
66	Sitapur**	25.421	3.053	0.002	2.685	0.007	0.0044	0.017	1940
67	Sonbhadra**	24.478	4.256	0	5.369	0	0.0052	0.021	1946
68	Sultanpur**	25.974	3.409	0.001	2.996	0.003	0.0044	0.017	1940
69	Unnao*	25.821	2.836	0.005	2.438	0.015	0.0039	0.015	1940
70	Varanasi**	25.473	3.681	0	3.869	0	0.0044	0.017	1940

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 2Results of the statistical tests for minimum annual temperature

S. N.	District	mean	Mann-Kendall		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra**	7.297	2.539	0.011	3.592	0	0.007	0.095	1955
2	Aligarh*	6.950	2.472	0.013	2.472	0.013	0.007	0.105	1968
3	Allahabad	8.660	1.506	0.132	1.842	0.066	0.004	0.061	1942
4	Ambedkar Nagar**	8.584	2.565	0.010	2.565	0.010	0.007	0.086	1975
5	Auraiya**	7.003	3.337	0.001	4.278	0	0.010	0.136	1955
6	Azamgarh**	8.757	2.741	0.006	2.741	0.006	0.007	0.085	1975
7	Baghpat*	6.587	2.513	0.012	2.123	0.034	0.007	0.110	1968
8	Bahraich*	7.999	2.452	0.014	2.077	0.038	0.008	0.101	1969
9	Ballia**	8.942	2.385	0.017	3.137	0.002	0.006	0.070	1975
10	Balrampur*	8.454	2.044	0.041	2.044	0.041	0.007	0.079	1969
11	Banda**	7.424	3.533	0	5.491	0	0.010	0.137	1942
12	Barabanki**	7.960	3.160	0.002	3.160	0.002	0.009	0.112	1968
13	Bareilly	6.995	2.076	0.038	1.779	0.075	0.008	0.110	1957
14	Basti*	8.503	2.198	0.028	2.198	0.028	0.007	0.082	1975
15	Bijnor*	6.428	2.501	0.012	2.092	0.036	0.009	0.140	1971
16	Budaun*	6.857	2.073	0.038	2.073	0.038	0.006	0.094	1955
17	Buland Shahar*	6.835	2.458	0.014	2.458	0.014	0.007	0.106	1968
18	Chandauli**	8.403	3.588	0	4.682	0	0.010	0.116	1940
19	Chitrakoot**	7.751	3.765	0	5.383	0	0.011	0.136	1942
20	Deoria	8.914	1.663	0.096	1.663	0.096	0.005	0.052	1978
21	Etah**	6.869	2.539	0.011	2.933	0.003	0.007	0.108	1955
22	Etawah**	6.971	3.161	0.002	4.070	0	0.009	0.129	1955
23	Faizabad**	8.304	2.617	0.009	2.617	0.009	0.008	0.095	1975
24	Farrukhbad**	6.996	2.851	0.004	2.851	0.004	0.008	0.113	1955
25	Fatehpur**	7.840	3.666	0	4.219	0	0.010	0.130	1942
26	Firozabad**	6.982	2.738	0.006	4.700	0	0.008	0.119	1955
27	Gautum buddha nagar**	6.793	2.602	0.009	2.602	0.009	0.008	0.119	1968
28	Ghaziabad*	6.679	2.556	0.011	2.556	0.011	0.008	0.113	1968
29	Ghazipur**	8.758	3.097	0.002	3.097	0.002	0.008	0.088	1975
30	Gonda*	8.260	2.287	0.022	2.287	0.022	0.007	0.089	1969
31	Gorakhpur	8.746	1.845	0.065	1.845	0.065	0.005	0.062	1975
32	Hamirpur**	7.109	3.432	0.001	5.875	0	0.010	0.137	1968
33	Hardoi**	7.315	3.126	0.002	3.126	0.002	0.008	0.114	1968
34	Hathras**	7.072	2.466	0.014	3.865	0	0.007	0.098	1955
35	Jalaun**	7.009	3.574	0	6.548	0	0.010	0.137	1954
36	Jaunpur**	8.618	3.221	0.001	4.048	0	0.009	0.101	1975
37	Jhansi**	7.788	3.094	0.002	5.806	0	0.009	0.114	1964
38	Jyotiba phule nagar	6.738	1.868	0.062	1.614	0.106	0.006	0.089	1971
39	Kannauj**	7.115	3.287	0.001	3.287	0.001	0.009	0.129	1955

40	Kanpur dehat**	7.127	3.681	0	6.396	0	0.010	0.136	1954
41	Kanpur Nagar**	7.263	3.912	0	5.935	0	0.010	0.143	1954
42	Kaushambi**	8.049	3.669	0	4.624	0	0.010	0.128	1942
43	Kheri*	7.635	2.579	0.010	2.197	0.028	0.009	0.116	1975
44	Kushi nagar	8.899	1.642	0.101	1.642	0.101	0.005	0.058	1978
45	Lalitpur**	9.369	2.819	0.005	5.707	0	0.008	0.091	1964
46	Lucknow**	7.824	3.811	0	3.811	0	0.010	0.133	1968
47	Maharaj ganj	8.834	1.833	0.067	1.833	0.067	0.006	0.062	1978
48	Mahoba**	7.587	3.285	0.001	4.397	0	0.010	0.127	1968
49	Mainpuri**	6.945	2.729	0.006	3.150	0.002	0.008	0.119	1955
50	Mathura*	7.182	1.836	0.066	2.351	0.019	0.005	0.075	1968
51	Mau*	8.868	2.472	0.013	2.472	0.013	0.007	0.076	1975
52	Meerot*	6.609	2.336	0.019	2.336	0.019	0.007	0.106	1968
53	Mirzapur**	8.468	3.895	0	5.126	0	0.012	0.124	1940
54	Moradabad	6.781	1.827	0.068	1.554	0.120	0.007	0.101	1955
55	Muzaffarnagar*	6.483	2.403	0.016	2.108	0.035	0.007	0.106	1968
56	Pilibhit*	7.251	2.458	0.014	2.067	0.039	0.009	0.127	1957
57	Pratapgarh**	8.382	3.233	0.001	3.480	0.001	0.009	0.112	1975
58	Rae Bareli**	8.045	3.822	0	4.311	0	0.010	0.130	1975
59	Rampur	6.885	2.105	0.035	1.782	0.075	0.008	0.115	1957
60	Saharanpur*	6.183	2.518	0.012	2.143	0.032	0.008	0.129	1968
61	Sant kabir nagar	8.640	1.917	0.055	1.917	0.055	0.006	0.067	1975
62	Sant Ravidas nagar**	8.276	3.652	0	4.792	0	0.010	0.126	1940
63	Shahjahanpur*	7.164	2.382	0.017	2.058	0.040	0.008	0.111	1955
64	Shrawasti*	8.191	2.281	0.023	1.979	0.048	0.007	0.089	1975
65	Siddharth Nagar*	8.692	2.010	0.044	2.010	0.044	0.006	0.070	1978
66	Sitapur*	7.726	2.886	0.004	2.496	0.013	0.009	0.116	1968
67	Sonbhadra**	8.319	3.762	0	5.480	0	0.010	0.116	1940
68	Sultanpur**	8.365	3.128	0.002	3.128	0.002	0.008	0.099	1975
69	Unnao**	7.587	4.117	0	4.117	0	0.011	0.139	1951
70	Varanasi**	8.395	3.580	0	4.637	0	0.010	0.120	1940

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 3 Results of the statistical tests for maximum annual temperature

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra	41.995	-1.287	0.198	-1.166	0.244	-0.0049	-0.0117	1956
2	Aligarh	41.566	-1.321	0.186	-1.202	0.229	-0.0051	-0.0123	1956
3	Allahabad	41.699	-0.159	0.874	-0.151	0.880	-0.0006	-0.0015	1960
4	Ambedkar Nagar	41.369	-0.506	0.613	-0.609	0.542	-0.0018	-0.0043	1960
5	Auraiya	42.414	-0.477	0.633	-0.477	0.633	-0.0021	-0.0050	1956
6	Azamgarh	41.430	-0.457	0.648	-0.523	0.601	-0.0016	-0.0040	1960
7	Baghpat	40.277	-1.087	0.277	-1.181	0.238	-0.0040	-0.0100	1956
8	Bahraich	40.343	0.090	0.929	0.090	0.929	0.0005	0.0012	1960
9	Ballia	41.053	-0.344	0.731	-0.385	0.700	-0.0012	-0.0029	1961
10	Balrampur	40.171	0.220	0.826	0.220	0.826	0.0007	0.0018	1960
11	Banda	41.717	0.136	0.892	0.136	0.892	0.0006	0.0014	1960
12	Barabanki	41.193	-0.078	0.938	-0.069	0.945	-0.0003	-0.0008	1975
13	Bareilly	40.998	-0.370	0.711	-0.370	0.711	-0.0013	-0.0032	1960
14	Basti	40.901	-0.185	0.853	-0.176	0.860	-0.0006	-0.0015	1960
15	Bijnor	39.897	-0.625	0.532	-0.625	0.532	-0.0025	-0.0064	1956
16	Budaun	41.529	-0.992	0.321	-0.992	0.321	-0.0038	-0.0090	1956
17	Buland Shahar	41.059	-1.344	0.179	-1.223	0.221	-0.0050	-0.0121	1956
18	Chandauli	41.158	-0.723	0.470	-0.694	0.488	-0.0027	-0.0067	1961
19	Chitrakoot	41.407	-0.017	0.986	-0.017	0.986	-0.0001	-0.0001	1960
20	Deoria	40.464	-0.055	0.956	-0.060	0.952	-0.0003	-0.0007	1961
21	Etah	42.073	-1.087	0.277	-1.087	0.277	-0.0043	-0.0103	1956
22	Etawah	42.372	-0.919	0.358	-0.919	0.358	-0.0038	-0.0089	1956
23	Faizabad	41.224	-0.463	0.644	-0.437	0.662	-0.0015	-0.0036	1960
24	farrukhbad	42.133	-0.555	0.579	-0.555	0.579	-0.0018	-0.0043	1956
25	Fatehpur	42.460	0.049	0.961	0.049	0.961	0.0002	0.0004	1960
26	Firozabad	42.293	-1.333	0.183	-1.214	0.225	-0.0046	-0.0109	1956
27	Gautum buddha nagar	40.907	-1.327	0.184	-1.201	0.230	-0.0051	-0.0125	1956
28	Ghaziabad	40.443	-1.330	0.184	-1.479	0.139	-0.0046	-0.0113	1956
29	Ghazipur	41.308	-0.561	0.575	-0.659	0.510	-0.0018	-0.0045	1961
30	Gonda	40.732	-0.171	0.865	-0.171	0.865	-0.0007	-0.0016	1960
31	Gorakhpur	40.543	-0.049	0.961	-0.050	0.960	-0.0003	-0.0007	1960
32	Hamirpur	42.073	-0.119	0.906	-0.119	0.906	-0.0004	-0.0009	1956
33	Hardoi	41.792	-0.208	0.835	-0.208	0.835	-0.0010	-0.0025	1975
34	Hathras	41.862	-1.394	0.163	-1.259	0.208	-0.0052	-0.0124	1956
35	Jalaun	42.175	-0.489	0.625	-0.489	0.625	-0.0020	-0.0048	1956
36	Jaunpur	41.954	-0.523	0.601	-0.802	0.422	-0.0019	-0.0046	1960
37	Jhansi	41.685	-0.087	0.931	-0.079	0.937	-0.0003	-0.0007	1956
38	Jyotiba phule nagar	40.577	-1.154	0.249	-1.478	0.140	-0.0042	-0.0103	1956
39	Kannauj	42.375	-0.364	0.716	-0.364	0.716	-0.0013	-0.0030	1956

40	Kanpur dehat	42.428	-0.246	0.806	-0.246	0.806	-0.0009	-0.0022	1956
41	Kanpur Nagar	42.351	-0.020	0.984	-0.020	0.984	-0.0001	-0.0003	1958
42	Kaushambi	42.036	-0.020	0.984	-0.018	0.986	0.0000	-0.0001	1962
43	Kheri	40.658	0.012	0.991	0.012	0.991	0.0000	0.0001	1975
44	Kushi nagar	39.716	0.286	0.775	0.295	0.768	0.0011	0.0027	1920
45	Lalitpur	41.253	0.396	0.692	0.396	0.692	0.0018	0.0044	1935
46	Lucknow	41.816	0.009	0.993	0.009	0.993	0.0000	0.0001	1975
47	Maharaj ganj	39.643	0.257	0.797	0.257	0.797	0.0010	0.0025	1920
48	Mahoba	41.572	0.156	0.876	0.186	0.852	0.0005	0.0012	1934
49	Mainpuri	42.443	-0.888	0.375	-0.888	0.375	-0.0035	-0.0082	1956
50	Mathura	41.454	-1.235	0.217	-1.107	0.268	-0.0049	-0.0117	1956
51	Mau	41.131	-0.353	0.724	-0.412	0.680	-0.0010	-0.0026	1961
52	Meerot	40.262	-1.191	0.234	-1.353	0.176	-0.0042	-0.0105	1956
53	Mirzapur	41.258	-0.466	0.642	-0.443	0.658	-0.0013	-0.0032	1961
54	Moradabad	40.685	-1.009	0.313	-1.009	0.313	-0.0040	-0.0098	1956
55	Muzaffarnagar	40.122	-1.003	0.316	-0.931	0.352	-0.0036	-0.0090	1970
56	Pilibhit	40.642	-0.061	0.952	-0.077	0.938	-0.0003	-0.0006	1975
57	Pratapgarh	42.268	-0.150	0.880	-0.180	0.857	-0.0005	-0.0011	1962
58	Rae Bareli	42.375	0.038	0.970	0.033	0.973	0.0001	0.0002	1975
59	Rampur	40.616	-0.492	0.623	-0.492	0.623	-0.0022	-0.0055	1960
60	Saharanpur	39.915	-0.639	0.523	-0.589	0.556	-0.0023	-0.0059	1970
61	Sant kabir nagar	40.576	-0.159	0.874	-0.158	0.875	-0.0007	-0.0016	1960
62	Sant Ravidas nagar	41.415	-0.463	0.644	-0.440	0.660	-0.0014	-0.0035	1961
63	Shahjahanpur	41.331	-0.208	0.835	-0.208	0.835	-0.0011	-0.0028	1975
64	Shrawasti	40.176	0.211	0.833	0.211	0.833	0.0009	0.0021	1960
65	Siddharth Nagar	40.122	0.121	0.903	0.107	0.915	0.0004	0.0010	1960
66	Sitapur	41.057	0.040	0.968	0.040	0.968	0.0002	0.0004	1975
67	Sonbhadra	40.191	-0.353	0.724	-0.314	0.754	-0.0015	-0.0038	1961
68	Sultanpur	41.903	-0.399	0.690	-0.479	0.632	-0.0012	-0.0028	1960
69	Unnao	42.230	-0.029	0.977	-0.029	0.977	-0.0001	-0.0002	1975
70	Varanasi	41.379	-0.480	0.631	-0.464	0.643	-0.0020	-0.0048	1961

"No Significant District"

Table 4 Results of the statistical tests for average winter temperature

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra**	16.33	3.513	0	3.513	0	0.008	0.0526	1941
2	Aligarh**	15.81	4.302	0	4.302	0	0.010	0.0652	1951
3	Allahabad**	17.16	4.938	0	6.953	0	0.010	0.0633	1942
4	Ambedkar Nagar**	17.31	5.285	0	9.621	0	0.010	0.059	1941
5	Auraiya**	16.32	4.43	0	4.43	0	0.01	0.0615	1941
6	Azamgarh**	17.50	5.115	0	7.918	0	0.010	0.0592	1941
7	Baghpat**	15.22	4.337	0	4.337	0	0.010	0.068	1951
8	Bahraich**	16.55	4.762	0	5.615	0	0.011	0.069	1945
9	Ballia**	17.66	4.814	0	6.524	0	0.009	0.0528	1940
10	Balrampur**	16.97	4.644	0	7.973	0	0.009	0.0581	1945
11	Banda**	16.68	4.6	0	6.072	0	0.009	0.0595	1942
12	Barabanki**	16.66	5.1	0	7.16	0	0.010	0.0634	1945
13	Bareilly**	15.80	4.039	0	3.499	0	0.010	0.0675	1951
14	Basti**	17.18	5.381	0	10.132	0	0.009	0.0564	1941
15	Bijnor**	15.08	4.135	0	3.502	0	0.010	0.0698	1951
16	Budaun**	15.79	4.247	0	4.247	0	0.010	0.0655	1951
17	Buland Shahar**	15.62	4.424	0	5.047	0	0.010	0.0684	1951
18	Chandauli**	17.22	5.317	0	7.183	0	0.010	0.0626	1942
19	Chitrakoot**	16.80	4.753	0	6.286	0	0.010	0.0612	1942
20	Deoria**	17.55	4.719	0	13.189	0	0.008	0.0508	1938
21	Etah**	15.94	4.149	0	4.149	0	0.01	0.063	1945
22	Etawah**	16.27	4.308	0	4.308	0	0.010	0.0618	1945
23	Faizabad**	17.00	5.491	0	9.556	0	0.010	0.0595	1945
24	Farrukhbad**	16.13	4.427	0	4.427	0	0.009	0.0605	1945
25	Fatehpur**	17.04	4.626	0	6.146	0	0.009	0.0583	1942
26	Firozabad**	16.12	4.031	0	4.031	0	0.009	0.0602	1941
27	Gautum buddha nagar**	15.56	4.25	0	4.25	0	0.010	0.0681	1951
28	Ghaziabad**	15.32	4.392	0	4.392	0	0.010	0.069	1951
29	Ghazipur**	17.55	5.071	0	6.335	0	0.010	0.0577	1940
30	Gonda**	16.88	5.043	0	8.64	0	0.010	0.0607	1945
31	Gorakhpur**	17.42	5.074	0	9.979	0	0.009	0.054	1941
32	Hamirpur**	16.52	4.545	0	5.83	0	0.01	0.0603	1945
33	Hardoi**	16.29	4.638	0	6.245	0	0.010	0.0619	1945
34	Hathras**	16.00	3.866	0	3.866	0	0.009	0.057	1951
35	Jalaun**	16.36	4.447	0	4.447	0	0.010	0.0621	1951
36	Jaunpur**	17.46	5.095	0	8.171	0	0.010	0.0607	1941
37	Jhansi**	16.86	4.513	0	4.513	0	0.010	0.0614	1951
38	Jyotiba phule nagar**	15.44	4.496	0	4.477	0	0.010	0.0707	1951
39	Kannauj**	16.31	4.482	0	4.482	0	0.009	0.0603	1945

40	Kanpur dehat**	16.45	4.459	0	4.459	0	0.009	0.0587	1941
41	Kanpur Nagar**	16.52	4.539	0	5.854	0	0.009	0.0591	1941
42	Kaushambi**	17.10	4.733	0	6.317	0	0.010	0.0607	1942
43	Kheri**	16.30	4.545	0	5.051	0	0.012	0.0739	1945
44	Kushi nagar**	17.45	4.615	0	14.611	0	0.008	0.0459	1937
45	Lalitpur**	18.02	4.213	0	4.558	0	0.010	0.0577	1951
46	Lucknow**	16.71	5.037	0	7.222	0	0.010	0.0629	1945
47	Maharaj ganj**	17.37	4.632	0	6.936	0	0.008	0.0492	1938
48	Mahoba**	16.79	4.632	0	5.998	0	0.010	0.06	1951
49	Mainpuri**	16.17	4.239	0	4.239	0	0.009	0.0594	1945
50	Mathura**	16.04	2.935	0.003	2.935	0.003	0.007	0.0445	1951
51	Mau**	17.60	4.933	0	8.04	0	0.009	0.0557	1940
52	Meerot**	15.22	4.444	0	4.431	0	0.010	0.0692	1951
53	Mirzapur**	17.23	5.239	0	7.02	0	0.010	0.0634	1942
54	Moradabad**	15.53	4.23	0	4.157	0	0.010	0.0678	1951
55	Muzaffarnagar**	15.09	4.511	0	4.526	0	0.010	0.0683	1951
56	Pilibhit**	15.95	4.071	0	3.521	0	0.011	0.07	1945
57	Pratapgarh**	17.33	4.993	0	6.929	0	0.010	0.0609	1941
58	Rae Bareli**	17.09	4.979	0	7.04	0	0.010	0.061	1941
59	Rampur**	15.61	3.976	0	3.428	0.001	0.011	0.0704	1951
60	Saharanpur**	14.83	4.013	0	5.253	0	0.009	0.0667	1951
61	Sant kabir nagar**	17.33	5.248	0	10.381	0	0.009	0.0542	1941
62	Sant Ravidas nagar**	17.09	5.141	0	7.298	0	0.010	0.0629	1942
63	Shahjahanpur**	16.05	4.349	0	4.203	0	0.010	0.0651	1945
64	Shrawasti**	16.72	4.724	0	6.321	0	0.010	0.0634	1945
65	Siddharth Nagar**	17.22	4.707	0	5.924	0	0.009	0.0524	1945
66	Sitapur**	16.40	4.927	0	6.716	0	0.011	0.069	1945
67	Sonbhadra**	16.95	5.34	0	6.102	0	0.011	0.0648	1951
68	Sultanpur**	17.16	5.268	0	9.619	0	0.010	0.0617	1941
69	Unnao**	16.67	4.91	0	6.787	0	0.009	0.0592	1941
70	Varanasi**	17.20	5.219	0	7.094	0	0.010	0.0621	1942

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 5 Results of the statistical tests for minimum winter temperature

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra	7.361	1.689	0.091	1.641	0.101	0.005	0.066	1955
2	Aligarh	6.562	2.351	0.019	1.666	0.096	0.005	0.083	1972
3	Allahabad**	8.267	4.031	0	4.028	0	0.011	0.135	1947
4	Ambedkar Nagar*	8.57	2.793	0.005	2.454	0.014	0.008	0.088	1975
5	Auraiya*	7.037	2.958	0.003	2.336	0.019	0.009	0.125	1955
6	Azamgarh**	8.763	2.868	0.004	2.868	0.004	0.008	0.088	1975
7	Baghpat*	6.671	2.024	0.043	2.024	0.043	0.006	0.092	1968
8	Bahraich*	7.968	2.472	0.013	2.472	0.013	0.007	0.091	1955
9	Ballia**	8.962	2.585	0.01	2.854	0.004	0.007	0.08	1975
10	Balrampur*	8.425	2.281	0.023	2.493	0.013	0.006	0.071	1969
11	Banda**	7.424	3.64	0	2.944	0.003	0.01	0.133	1947
12	Barabanki**	7.932	3.415	0.001	2.959	0.003	0.009	0.116	1954
13	Bareilly*	7.028	1.94	0.052	2.124	0.034	0.007	0.097	1955
14	Basti*	8.479	2.255	0.024	1.956	0.05	0.007	0.078	1975
15	Bijnor*	6.474	2.304	0.021	2.304	0.021	0.008	0.124	1957
16	Budaun*	6.884	1.72	0.085	1.72	0.085	0.006	0.081	1955
17	Buland Shahar	6.894	1.85	0.064	1.707	0.088	0.005	0.08	1968
18	Chandauli**	8.411	3.938	0	3.918	0	0.011	0.127	1954
19	Chitrakoot**	7.754	3.898	0	3.62	0	0.01	0.133	1947
20	Deoria	8.929	1.697	0.09	1.438	0.15	0.005	0.055	1975
21	Etah	6.926	1.888	0.059	1.729	0.084	0.006	0.08	1955
22	Etawah*	7.023	2.602	0.009	2.223	0.026	0.008	0.112	1955
23	Faizabad**	8.27	2.889	0.004	2.889	0.004	0.008	0.095	1969
24	Farrukhbad*	7.013	2.481	0.013	2.162	0.031	0.007	0.101	1955
25	Fatehpur**	7.847	3.689	0	3.003	0.003	0.01	0.133	1954
26	Firozabad	7.049	1.937	0.053	1.755	0.079	0.006	0.086	1955
27	Gautum buddha nagar	6.861	1.746	0.081	1.927	0.054	0.006	0.084	1968
28	Ghaziabad*	6.75	2.09	0.037	2.291	0.022	0.006	0.089	1968
29	Ghazipur**	8.776	3.079	0.002	3.128	0.002	0.009	0.1	1940
30	Gonda*	8.232	2.452	0.014	2.452	0.014	0.007	0.089	1955
31	Gorakhpur	8.74	1.749	0.08	1.484	0.138	0.005	0.059	1975
32	Hamirpur**	7.115	3.319	0.001	2.804	0.005	0.009	0.129	1954
33	Hardoi**	7.308	3.342	0.001	2.807	0.005	0.009	0.122	1955
34	Hathras	7.139	1.619	0.105	1.602	0.109	0.004	0.062	1955
35	Jalaun*	7.034	3.374	0.001	2.591	0.01	0.009	0.13	1955
36	Jaunpur**	8.632	3.392	0.001	4.231	0	0.009	0.108	1951
37	Jhansi*	7.819	2.912	0.004	2.246	0.025	0.008	0.101	1964
38	Jyotiba phule nagar	6.775	1.752	0.008	1.752	0.008	0.005	0.077	1971

39	Kannauj*	7.125	3.117	0.002	2.377	0.017	0.009	0.123	1955
40	Kanpur dehat**	7.14	3.568	0	2.99	0.003	0.01	0.135	1954
41	Kanpur Nagar**	7.263	3.782	0	3.147	0.002	0.01	0.141	1954
42	Kaushambi**	8.056	3.846	0	4.084	0	0.01	0.127	1947
43	Kheri**	7.628	2.42	0.016	2.65	0.008	0.008	0.102	1955
44	Kushi nagar	8.901	1.535	0.125	1.286	0.199	0.005	0.051	1978
45	Lalitpur	9.39	2.411	0.016	1.868	0.062	0.007	0.079	1964
46	Lucknow**	7.8	3.964	0	3.341	0.001	0.01	0.134	1954
47	Maharaj ganj	8.823	1.68	0.093	1.413	0.158	0.004	0.05	1978
48	Mahoba*	7.593	3.114	0.002	2.428	0.015	0.009	0.119	1954
49	Mainpuri	6.995	2.033	0.042	1.652	0.098	0.007	0.096	1955
50	Mathura	7.239	0.96	0.337	0.967	0.333	0.003	0.041	1964
51	Mau	9.129	0.804	0.422	0.788	0.431	0.003	0.028	1975
52	Meerot*	6.671	2.021	0.043	2.021	0.043	0.007	0.099	1971
53	Mirzapur**	8.459	4.291	0	5.203	0	0.011	0.132	1946
54	Moradabad	6.816	1.602	0.109	1.602	0.109	0.006	0.082	1957
55	Muzaffarnagar*	6.547	2.2	0.028	2.2	0.028	0.007	0.1	1971
56	Pilibhit**	7.291	2.299	0.022	2.561	0.01	0.008	0.111	1955
57	Pratapgarh**	8.388	3.447	0.001	3.859	0	0.01	0.119	1951
58	Rae Bareli**	8.035	4.007	0	3.31	0.001	0.011	0.134	1951
59	Rampur*	6.926	1.891	0.059	2.073	0.038	0.007	0.095	1957
60	Saharanpur*	6.24	2.374	0.018	2.374	0.018	0.007	0.117	1968
61	Sant kabir nagar	8.629	1.848	0.065	1.571	0.116	0.005	0.061	1975
62	Sant Ravidas nagar**	8.278	3.982	0	4.036	0	0.011	0.131	1951
63	Shahjahanpur*	7.179	2.469	0.014	2.568	0.01	0.008	0.108	1955
64	Shrawasti*	8.161	2.374	0.018	2.374	0.018	0.006	0.077	1955
65	Siddharth Nagar	8.663	2.143	0.032	1.852	0.064	0.005	0.063	1969
66	Sitapur*	7.692	2.961	0.003	2.54	0.011	0.008	0.109	1955
67	Sonbhadra**	8.303	4.265	0	3.839	0	0.011	0.128	1946
68	Sultanpur**	8.348	3.461	0.001	3.295	0.001	0.009	0.103	1954
69	Unnao**	7.573	4.086	0	3.355	0.001	0.011	0.141	1954
70	Varanasi**	8.403	3.973	0	4.009	0	0.012	0.129	1951

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 6 Results of the statistical tests for maximum winter temperature

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra*	25.703	2.435	0.015	2.435	0.015	0.009	0.037	1940
2	Aligarh**	24.945	2.903	0.004	2.903	0.004	0.011	0.045	1940
3	Allahabad*	26.581	2.420	0.016	2.420	0.016	0.009	0.034	1945
4	Ambedkar Nagar**	26.677	2.889	0.004	4.007	0	0.011	0.039	1945
5	Auraiya**	26.147	2.614	0.009	2.754	0.006	0.010	0.039	1940
6	Azamgarh**	26.894	2.819	0.005	4.123	0	0.010	0.039	1945
7	Baghpat**	23.939	3.618	0	3.618	0	0.012	0.048	1951
8	Bahraich**	25.555	3.423	0.001	3.862	0	0.013	0.052	1940
9	Ballia**	27.054	2.435	0.015	2.936	0.003	0.009	0.032	1945
10	Balrampur**	26.079	3.004	0.003	4.360	0	0.012	0.044	1940
11	Banda**	26.446	2.744	0.006	2.901	0.004	0.010	0.038	1945
12	Barabanki**	25.827	3.082	0.002	4.191	0	0.012	0.045	1940
13	Bareilly**	24.942	3.227	0.001	3.476	0.001	0.014	0.054	1940
14	Basti**	26.503	2.920	0.003	3.258	0.001	0.011	0.040	1945
15	Bijnor**	23.917	3.348	0.001	3.738	0	0.014	0.058	1950
16	Budaun**	25.048	3.053	0.002	3.383	0.001	0.012	0.050	1940
17	Buland Shahar**	24.616	3.149	0.002	3.517	0	0.012	0.048	1951
18	Chandauli**	26.651	2.625	0.009	2.625	0.008	0.007	0.031	1945
19	Chitrakoot*	26.324	2.435	0.015	2.435	0.015	0.010	0.037	1945
20	Deoria**	26.849	2.701	0.007	3.852	0	0.010	0.037	1945
21	Etah**	25.381	2.886	0.004	2.886	0.004	0.011	0.044	1940
22	Etawah**	26.051	2.681	0.007	2.681	0.007	0.011	0.040	1940
23	Faizabad**	26.283	3.027	0.002	3.330	0.001	0.011	0.043	1945
24	Farrukhbad**	25.714	2.831	0.005	2.831	0.005	0.011	0.043	1940
25	Fatehpur**	26.725	2.579	0.010	2.734	0.006	0.010	0.037	1945
26	Firozabad**	25.637	2.695	0.007	2.695	0.007	0.010	0.040	1940
27	Gautum buddha	24.506	3.131	0.002	3.131	0.002	0.011	0.046	1951
28	Ghaziabad**	24.115	3.117	0.002	3.499	0	0.012	0.048	1951
29	Ghazipur**	26.973	2.689	0.007	3.083	0.002	0.009	0.034	1945
30	Gonda**	26.036	3.071	0.002	4.231	0	0.011	0.044	1940
31	Gorakhpur**	26.727	2.747	0.006	3.199	0.001	0.010	0.037	1945
32	Hamirpur**	26.504	2.646	0.008	3.432	0.001	0.010	0.038	1945
33	Hardoi**	25.683	2.990	0.003	3.472	0.001	0.012	0.045	1940
34	Hathras**	25.199	2.677	0.007	2.677	0.007	0.011	0.042	1940
35	Jalaun**	26.342	2.620	0.009	2.620	0.009	0.011	0.040	1945
36	Jaunpur**	26.932	2.712	0.007	3.974	0	0.010	0.036	1945
37	Jhansi**	26.613	2.646	0.008	2.646	0.008	0.010	0.039	1945

38	Jyotiba phule nagar**	24.363	3.261	0.001	3.677	0	0.013	0.054	1940
39	Kannauj**	26.004	2.819	0.005	2.819	0.005	0.010	0.039	1940
40	Kanpur dehat**	26.304	2.744	0.006	2.903	0.004	0.010	0.038	1945
41	Kanpur Nagar**	26.291	2.761	0.006	2.923	0.003	0.010	0.038	1945
42	Kaushambi*	26.637	2.281	0.023	2.407	0.016	0.009	0.034	1945
43	Kheri**	25.313	3.392	0.001	4.595	0	0.014	0.054	1940
44	Kushi nagar**	26.552	2.718	0.007	3.263	0.001	0.009	0.035	1945
45	Lalitpur**	27.368	2.836	0.005	3.601	0	0.010	0.038	1951
46	Lucknow**	26.041	2.860	0.004	3.580	0	0.011	0.042	1940
47	Maharaj ganj**	26.521	2.796	0.005	3.388	0.001	0.010	0.036	1945
48	Mahoba*	26.649	2.487	0.013	2.487	0.013	0.010	0.037	1945
49	Mainpuri**	25.847	2.724	0.006	2.724	0.006	0.010	0.040	1940
50	Mathura*	25.086	2.411	0.016	2.411	0.016	0.009	0.035	1932
51	Mau**	26.993	2.640	0.008	4.009	0	0.010	0.036	1945
52	Meerot**	23.980	3.209	0.001	3.594	0	0.012	0.051	1951
53	Mirzapur**	26.584	2.530	0.011	2.530	0.011	0.008	0.032	1945
54	Moradabad**	24.501	3.412	0.001	3.854	0	0.014	0.058	1940
55	Muzaffarnagar**	23.814	3.392	0.001	3.797	0	0.012	0.052	1951
56	Pilibhit**	24.988	3.152	0.002	4.365	0	0.014	0.056	1940
57	Pratapgarh*	26.830	2.371	0.018	2.501	0.012	0.009	0.034	1945
58	Rae Bareli**	26.651	2.741	0.006	2.891	0.004	0.010	0.037	1945
59	Rampur**	24.604	3.345	0.001	3.723	0	0.013	0.058	1940
60	Saharanpur**	23.580	3.345	0.001	3.788	0	0.012	0.052	1950
61	Sant kabir nagar**	26.646	2.825	0.005	3.288	0.001	0.010	0.037	1945
62	Sant Ravidas nagar*	26.503	2.362	0.018	2.362	0.018	0.008	0.032	1945
63	Shahjahanpur**	25.328	3.068	0.002	4.203	0	0.013	0.051	1940
64	Shrawasti**	25.740	3.290	0.001	4.650	0	0.013	0.049	1940
65	Siddharth Nagar**	26.418	2.773	0.006	3.223	0.001	0.010	0.037	1945
66	Sitapur**	25.488	3.259	0.001	4.446	0	0.013	0.050	1940
67	Sonbhadra*	26.129	2.753	0.006	2.353	0.019	0.009	0.033	1945
68	Sultanpur**	26.535	2.834	0.005	2.808	0.005	0.011	0.040	1945
69	Unnao**	26.209	2.836	0.005	3.529	0	0.011	0.041	1945
70	Varanasi*	26.632	2.521	0.012	2.521	0.012	0.008	0.031	1945

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 7Results of the statistical tests for average summer temperature

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra	32.894	-0.434	0.665	-0.434	0.665	-0.0013	-0.0039	1975
2	Aligarh	32.503	0.194	0.846	0.179	0.858	0.0006	0.0019	1937
3	Allahabad	31.790	0.344	0.731	0.332	0.740	0.0009	0.0028	1946
4	Ambedkar Nagar	32.492	0.347	0.729	0.347	0.729	0.0008	0.0023	1940
5	Auraiya	33.012	-0.330	0.742	-0.319	0.749	-0.0009	-0.0027	1975
6	Azamgarh	32.517	0.208	0.835	0.208	0.835	0.0005	0.0015	1940
7	Baghpat	31.392	0.893	0.372	0.827	0.408	0.0028	0.0090	1937
8	Bahraich	31.653	0.619	0.536	0.619	0.536	0.0016	0.0052	1940
9	Ballia	32.336	-0.035	0.972	-0.035	0.972	-0.0001	-0.0002	1962
10	Balrampur	31.638	0.439	0.660	0.439	0.660	0.0015	0.0048	1940
11	Banda	32.248	0.020	0.984	0.020	0.984	0.0001	0.0001	1975
12	Barabanki	32.259	0.359	0.720	0.359	0.720	0.0012	0.0036	1940
13	Bareilly	31.758	0.049	0.961	0.043	0.966	0.0001	0.0004	1940
14	Basti	32.208	0.411	0.681	0.411	0.681	0.0010	0.0032	1940
15	Bijnor	30.911	0.549	0.583	0.549	0.583	0.0018	0.0058	1940
16	Budaun	32.255	0.121	0.903	0.106	0.916	0.0003	0.0008	1940
17	Buland Shahar	32.126	0.306	0.759	0.282	0.778	0.0011	0.0034	1937
18	Chandauli	31.995	-0.359	0.720	-0.355	0.723	-0.0011	-0.0034	1975
19	Chitrakoot	31.992	-0.043	0.965	-0.043	0.965	-0.0002	-0.0005	1975
20	Deoria	31.899	0.370	0.711	0.370	0.711	0.0009	0.0028	1920
21	Etah	32.763	0	1	0	1	0	0	0
22	Etawah	33.037	-0.437	0.662	-0.437	0.662	-0.0013	-0.0040	1960
23	Faizabad	32.991	-0.173	0.862	-0.173	0.862	-0.0003	-0.0009	1975
24	farrukhbad	32.647	0.052	0.958	0.050	0.960	0.0001	0.0004	1940
25	Fatehpur	32.368	0.457	0.648	0.457	0.648	0.0013	0.0041	1940
26	Firozabad	33.023	-0.295	0.768	-0.295	0.768	-0.0008	-0.0023	1960
27	Gautum buddha nagar	31.990	0.477	0.633	0.439	0.661	0.0016	0.0049	1937
28	Ghaziabad	31.660	0.642	0.521	0.589	0.556	0.0021	0.0066	1937
29	Ghazipur	32.369	-0.090	0.929	-0.094	0.925	-0.0003	-0.0009	1975
30	Gonda	32.009	0.590	0.555	0.590	0.555	0.0015	0.0046	1940
31	Gorakhpur	31.923	0.396	0.692	0.396	0.692	0.0008	0.0026	1920
32	Hamirpur	32.556	-0.078	0.938	-0.078	0.938	-0.0003	-0.0010	1975
33	Hardoi	32.432	0.110	0.913	0.110	0.913	0.0003	0.0009	1975
34	Hathras	32.747	-0.093	0.926	-0.086	0.932	-0.0004	-0.0012	1939
35	Jalaun	32.820	-0.396	0.692	-0.396	0.692	-0.0012	-0.0036	1975
36	Jaunpur	32.838	-0.081	0.935	-0.081	0.935	-0.0003	-0.0009	1975
37	Jhansi	32.483	-0.191	0.849	-0.191	0.849	-0.0006	-0.0019	1960

38	Jyotiba phule nagar	31.662	0.341	0.733	0.315	0.753	0.0010	0.0033	1939
39	Kannauj	32.887	-0.165	0.869	-0.160	0.873	-0.0004	-0.0013	1975
40	Kanpur dehat	32.926	-0.257	0.797	-0.250	0.803	-0.0007	-0.0020	1975
41	Kanpur Nagar	32.876	-0.110	0.913	-0.110	0.913	-0.0003	-0.0010	1975
42	Kaushambi	32.610	-0.159	0.874	-0.159	0.874	-0.0004	-0.0012	1975
43	Kheri	31.704	0.324	0.746	0.324	0.746	0.0009	0.0029	1940
44	Kushi nagar	31.526	0.377	0.742	0.377	0.742	0.0008	0.0038	1940
45	Lalitpur	32.117	0.538	0.591	0.538	0.591	0.0015	0.0048	1940
46	Lucknow	32.683	0.306	0.759	0.259	0.795	0.0007	0.0023	1940
47	Maharaj ganj	31.287	0.763	0.445	0.763	0.445	0.0017	0.0054	1920
48	Mahoba	32.143	-0.058	0.954	-0.058	0.954	-0.0003	-0.0008	1940
49	Mainpuri	33.005	-0.176	0.860	-0.176	0.860	-0.0005	-0.0015	1960
50	Mathura	32.447	-0.153	0.878	-0.153	0.878	-0.0003	-0.0009	1975
51	Mau	32.328	0.104	0.917	0.111	0.912	0.0004	0.0011	1940
52	Meerot	31.450	0.636	0.525	0.584	0.560	0.0021	0.0067	1937
53	Mirzapur	32.050	-0.301	0.764	-0.301	0.764	-0.0008	-0.0025	1975
54	Moradabad	31.647	0.246	0.806	0.246	0.806	0.0009	0.0028	1940
55	Muzaffarnagar	31.168	1.064	0.287	0.983	0.326	0.0032	0.0102	1940
56	Pilibhit	31.492	-0.020	0.984	-0.020	0.984	-0.0001	-0.0003	1940
57	Pratapgarh	33.039	-0.064	0.949	-0.064	0.949	-0.0002	-0.0006	1975
58	Rae Bareli	33.084	0.084	0.933	0.084	0.933	0.0002	0.0006	1975
59	Rampur	31.518	0.049	0.961	0.043	0.966	0.0002	0.0005	1940
60	Saharanpur	30.687	1.249	0.212	1.249	0.212	0.0038	0.0125	1940
61	Sant kabir nagar	31.959	0.335	0.737	0.335	0.737	0.0007	0.0023	1940
62	Sant Ravidas nagar	32.176	-0.272	0.786	-0.272	0.786	-0.0007	-0.0021	1975
63	Shahjahanpur	31.972	0.168	0.867	0.168	0.867	0.0004	0.0014	1940
64	Shrawasti	31.598	0.503	0.615	0.503	0.615	0.0014	0.0044	1940
65	Siddharth Nagar	31.645	0.489	0.625	0.489	0.625	0.0011	0.0036	1920
66	Sitapur	32.047	0.428	0.669	0.428	0.669	0.0012	0.0038	1940
67	Sonbhadra	31.057	-0.350	0.726	-0.346	0.729	-0.0010	-0.0032	1975
68	Sultanpur	32.819	0.179	0.858	0.179	0.858	0.0004	0.0012	1940
69	Unnao	32.899	0.087	0.931	0.087	0.931	0.0003	0.0008	1975
70	Varanasi	32.203	-0.390	0.696	-0.390	0.696	-0.0009	-0.0029	1975

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 8Results of the statistical tests for minimum summer temperature

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra**	21.851	1.715	0.086	2.734	0.006	0.008	0.036	1945
2	Aligarh**	21.427	2.151	0.031	2.856	0.004	0.011	0.052	1945
3	Allahabad	21.594	1.240	0.215	1.240	0.215	0.005	0.024	1946
4	Ambedkar Nagar	21.866	1.090	0.276	1.360	0.174	0.005	0.021	1946
5	Auraiya**	21.539	1.717	0.086	2.906	0.004	0.007	0.032	1945
6	Azamgarh	21.917	1.050	0.294	1.050	0.294	0.004	0.020	1946
7	Baghpat**	20.689	2.218	0.027	2.821	0.005	0.011	0.055	1945
8	Bahraich	21.237	0.815	0.415	0.815	0.415	0.004	0.017	1946
9	Ballia	21.969	0.558	0.577	0.558	0.577	0.003	0.011	1946
10	Balrampur	21.339	0.729	0.466	0.729	0.466	0.003	0.016	1946
11	Banda*	20.994	1.608	0.108	2.053	0.040	0.007	0.032	1945
12	Barabanki	21.506	1.185	0.236	1.185	0.236	0.005	0.024	1946
13	Bareilly	20.685	1.185	0.236	1.456	0.145	0.006	0.029	1945
14	Basti	21.797	0.983	0.326	0.983	0.326	0.004	0.019	1946
15	Bijnor	20.114	1.486	0.137	1.913	0.056	0.007	0.036	1945
16	Budaun*	20.922	1.850	0.064	2.410	0.016	0.008	0.040	1945
17	Buland Shahar**	21.243	2.116	0.034	2.835	0.005	0.011	0.050	1945
18	Chandauli	21.413	0.899	0.369	0.899	0.369	0.004	0.017	1946
19	Chitrakoot*	21.071	1.475	0.140	2.504	0.012	0.006	0.029	1945
20	Deoria	21.739	0.630	0.528	0.630	0.528	0.002	0.011	1946
21	Etah**	21.315	1.966	0.049	2.563	0.010	0.009	0.044	1945
22	Etawah**	21.638	1.755	0.079	3.110	0.002	0.007	0.033	1945
23	Faizabad	21.704	1.102	0.271	1.102	0.271	0.005	0.023	1946
24	Farrukhbad*	21.064	1.833	0.067	2.426	0.015	0.008	0.040	1945
25	Fatehpur*	21.639	1.550	0.121	2.357	0.018	0.006	0.029	1945
26	Firozabad*	21.676	1.995	0.046	2.368	0.018	0.009	0.044	1945
27	Gautum buddha nagar**	21.168	2.383	0.017	3.191	0.001	0.012	0.055	1945
28	Ghaziabad**	21.028	2.119	0.034	2.739	0.006	0.010	0.049	1945
29	Ghazipur	21.769	0.827	0.408	0.827	0.408	0.004	0.016	1946
30	Gonda	21.492	0.977	0.328	0.977	0.328	0.004	0.020	1946
31	Gorakhpur	21.697	0.867	0.386	0.867	0.386	0.003	0.015	1946
32	Hamirpur**	21.053	1.611	0.107	5.243	0	0.007	0.031	1945
33	Hardoi	21.129	1.261	0.207	1.609	0.108	0.006	0.030	1945
34	Hathras**	21.611	2.131	0.033	3.503	0	0.010	0.049	1945
35	Jalaun**	21.547	1.642	0.101	2.582	0.010	0.006	0.030	1945
36	Jaunpur	21.992	1.044	0.297	1.312	0.189	0.004	0.018	1946
37	Jhansi	21.813	1.550	0.121	1.435	0.151	0.006	0.030	1945
38	Jyotiba phule nagar*	20.822	1.746	0.081	2.321	0.020	0.009	0.042	1945

39	Kannauj*	21.304	1.746	0.081	2.307	0.021	0.008	0.036	1945
40	Kanpur dehat**	21.373	1.703	0.089	2.814	0.005	0.007	0.031	1945
41	Kanpur Nagar*	21.355	1.619	0.105	2.158	0.031	0.006	0.029	1945
42	Kaushambi	21.555	1.425	0.154	1.425	0.154	0.006	0.029	1945
43	Kheri	21.047	0.902	0.367	0.902	0.367	0.004	0.018	1946
44	Kushi nagar	21.502	0.697	0.486	0.697	0.486	0.003	0.013	1946
45	Lalitpur	22.264	1.677	0.094	1.553	0.121	0.007	0.032	1945
46	Lucknow	21.647	1.330	0.184	1.330	0.184	0.006	0.027	1946
47	Maharaj ganj	21.468	0.810	0.418	0.810	0.418	0.004	0.016	1946
48	Mahoba*	21.109	1.628	0.104	2.327	0.020	0.007	0.032	1945
49	Mainpuri**	21.444	1.995	0.046	3.372	0.001	0.009	0.042	1945
50	Mathura**	21.531	2.041	0.041	2.621	0.009	0.010	0.048	1940
51	Mau	21.864	0.810	0.418	0.810	0.418	0.003	0.016	1946
52	Meerot*	20.780	1.903	0.057	2.459	0.014	0.010	0.046	1945
53	Mirzapur	21.456	1.041	0.298	1.041	0.298	0.004	0.019	1946
54	Moradabad	20.712	1.504	0.133	1.887	0.059	0.007	0.035	1945
55	Muzaffarnagar*	20.379	1.903	0.057	2.419	0.016	0.010	0.050	1945
56	Pilibhit	20.705	0.867	0.386	0.867	0.386	0.004	0.022	1946
57	Pratapgarh	22.050	1.298	0.194	1.298	0.194	0.005	0.024	1946
58	Rae Bareli	21.942	1.385	0.166	1.742	0.082	0.006	0.027	1945
59	Rampur	20.637	1.119	0.263	1.427	0.154	0.006	0.030	1945
60	Saharanpur*	19.674	2.004	0.045	2.519	0.012	0.010	0.053	1945
61	Sant kabir nagar	21.706	0.879	0.379	0.879	0.379	0.004	0.016	1946
62	Sant Ravidas nagar	21.416	1.105	0.269	1.105	0.269	0.004	0.021	1946
63	Shahjahanpur	20.750	1.232	0.218	1.550	0.121	0.006	0.030	1945
64	Shrawasti	21.284	0.729	0.466	0.707	0.480	0.003	0.014	1946
65	Siddharth Nagar	21.501	0.636	0.525	0.636	0.525	0.003	0.012	1946
66	Sitapur	21.240	1.084	0.278	1.084	0.278	0.005	0.024	1946
67	Sonbhadra	20.855	0.919	0.358	0.919	0.358	0.004	0.018	1946
68	Sultanpur	21.921	1.081	0.280	1.359	0.174	0.005	0.021	1946
69	Unnao	21.585	1.492	0.136	1.899	0.058	0.006	0.030	1945
70	Varanasi	21.500	0.905	0.365	1.156	0.248	0.004	0.017	1946

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

MONTHLY TEMPERATURE

Table 9 Results of the statistical tests for average temperature of January

S.N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra	15.047	0.781	0.434	0.742	0.457	0.002	0.017	1957
2	Aligarh	14.475	1.229	0.219	1.386	0.165	0.003	0.027	1957
3	Allahabad	16.164	1.087	0.277	1.417	0.156	0.004	0.023	1942
4	Ambedkar Nagar	16.125	1.073	0.283	1.206	0.227	0.003	0.023	1945
5	Auraiya	15.081	0.998	0.318	0.935	0.349	0.003	0.022	1947
6	Azamgarh	16.359	0.873	0.382	1.08	0.28	0.002	0.017	1938
7	Baghpat	13.959	1.506	0.132	1.673	0.094	0.004	0.035	1948
8	Bahraich**	15.349	1.674	0.094	2.582	0.009	0.006	0.041	1945
9	Ballia	16.548	0.559	0.577	1.105	0.268	0.001	0.009	1937
10	Balrampur	15.768	1.451	0.147	1.626	0.103	0.004	0.031	1945
11	Banda	15.625	0.972	0.331	1.03	0.302	0.003	0.023	1947
12	Barabanki*	15.581	1.556	0.119	2.132	0.032	0.005	0.032	1945
13	Bareilly	14.517	0.957	0.338	0.957	0.338	0.004	0.033	1957
14	Basti	15.95	1.257	0.208	1.306	0.191	0.004	0.025	1945
15	Bijnor	13.734	1.295	0.195	1.295	0.195	0.005	0.041	1957
16	Budaun	14.45	1.133	0.257	1.276	0.202	0.004	0.028	1957
17	Buland Shahar	14.26	1.295	0.195	1.467	0.142	0.004	0.031	1964
18	Chandauli	16.245	0.807	0.419	0.915	0.359	0.003	0.018	1937
19	Chitrakoot	15.776	1.076	0.282	1.151	0.249	0.003	0.025	1945
20	Deoria	16.317	0.679	0.496	0.833	0.404	0.002	0.016	1937
21	Etah	14.579	1.061	0.288	1.196	0.231	0.003	0.022	1957
22	Etawah	14.966	0.891	0.373	0.834	0.404	0.003	0.023	1955
23	Farrukhbad	14.881	1.032	0.302	1.158	0.247	0.003	0.022	1957
24	Fatehpur	16.015	0.943	0.345	1.012	0.311	0.003	0.021	1942
25	Faziabad	15.82	1.373	0.169	1.433	0.152	0.004	0.027	1945
26	Firozabad	14.767	0.899	0.368	0.907	0.364	0.003	0.023	1957
27	Gautam buddha nagar	14.212	1.313	0.189	1.632	0.102	0.004	0.031	1948
28	Ghaziabad	14.039	1.333	0.182	1.641	0.101	0.004	0.034	1948
29	Ghazipur	16.487	0.714	0.475	0.908	0.363	0.001	0.011	1942
30	Gonda	15.674	1.466	0.142	1.646	0.099	0.004	0.03	1945
31	Gorakhpur	16.143	1.084	0.278	1.058	0.289	0.003	0.022	1945
32	Hamirpur	15.381	1.018	0.308	1.19	0.233	0.003	0.025	1947
33	Hardoi	15.179	1.275	0.202	1.271	0.202	0.004	0.031	1945
34	Hathras	14.679	1.026	0.306	1.05	0.293	0.003	0.023	1957
35	Jalaun	15.161	1.052	0.292	0.994	0.32	0.003	0.024	1947
36	Jaunpur	16.343	0.928	0.353	1.064	0.287	0.003	0.018	1942

37	Jhansi	15.658	1.041	0.297	1.152	0.249	0.003	0.023	1964
38	Jyotiba phule nagar	14.091	1.102	0.271	1.23	0.218	0.004	0.032	1957
39	Kannauj	15.131	0.969	0.332	1.071	0.283	0.003	0.021	1947
40	Kanpur dehat	15.342	0.992	0.321	0.967	0.333	0.003	0.021	1947
41	Kanpur Nagar	15.501	0.936	0.349	0.865	0.386	0.003	0.021	1947
42	Kaushambi	16.068	1.087	0.276	1.391	0.164	0.003	0.027	1942
43	Kheri	15.087	1.622	0.104	1.857	0.063	0.006	0.041	1945
44	Kushi nagar	16.172	1.157	0.247	1.134	0.256	0.003	0.022	1945
45	Lalitpur	16.932	1.147	0.251	1.383	0.166	0.003	0.022	1964
46	Lucknow	15.714	1.489	0.136	1.593	0.111	0.004	0.031	1945
47	Maharaj ganj	16.093	1.159	0.246	1.017	0.308	0.003	0.022	1945
48	Mahoba	15.688	1.061	0.289	1.722	0.085	0.003	0.024	1964
49	Mainpuri	14.818	0.847	0.397	0.946	0.344	0.003	0.021	1955
50	Mathura	14.765	0.636	0.525	0.784	0.433	0.002	0.016	1964
51	Mau	16.452	0.677	0.498	0.763	0.445	0.002	0.012	1937
52	Meerut	13.92	1.532	0.125	1.879	0.06	0.005	0.037	1948
53	Mirzapur	16.299	0.939	0.347	0.995	0.319	0.003	0.019	1942
54	Moradabad	14.177	1.078	0.281	1.191	0.238	0.004	0.031	1957
55	Muzaffarnagar	13.788	1.509	0.131	1.675	0.093	0.005	0.041	1948
56	Pilibhit	14.696	1.107	0.268	1.036	0.299	0.005	0.035	1957
57	Pratapgarh	16.24	1.11	0.266	1.462	0.143	0.003	0.022	1942
58	Rae Bareli	16.039	1.214	0.225	1.318	0.187	0.004	0.027	1945
59	Rampur	14.294	0.948	0.342	0.948	0.342	0.004	0.031	1957
60	Saharanpur	13.485	1.573	0.115	1.572	0.115	0.005	0.043	1945
61	Sant kabir nagar	16.041	1.237	0.215	1.203	0.228	0.003	0.024	1945
62	Sant Ravidas nagar	16.131	1.026	0.304	1.334	0.182	0.003	0.021	1942
63	Shahjahanpur	14.846	1.142	0.253	1.267	0.204	0.004	0.032	1957
64	Shrawasti	15.533	1.587	0.112	2.406	0.016	0.005	0.035	1945
65	Siddharth Nagar	16.009	1.228	0.219	1.228	0.219	0.004	0.024	1945
66	Sitapur	15.304	1.657	0.097	1.883	0.059	0.006	0.041	1945
67	Sonbhadra	16.093	0.985	0.324	0.886	0.375	0.003	0.021	1937
68	Sultanpur	16.031	1.203	0.229	1.26	0.207	0.003	0.024	1945
69	Unnao	15.703	1.105	0.269	1.19	0.234	0.004	0.026	1945
70	Varanasi	16.221	0.971	0.331	1.113	0.266	0.002	0.018	1942

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 10 Results of the statistical tests for average temperature of February

S. N.	District	Mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra**	17.917	2.719	0.006	2.719	0.006	0.011	0.059	1940
2	Aligarh**	17.346	2.961	0.003	2.961	0.003	0.011	0.068	1940
3	Allahabad**	18.711	2.848	0.004	2.848	0.004	0.01	0.058	1945
4	Ambedkar Nagar**	18.826	3.325	0	3.295	0	0.011	0.059	1945
5	Auraiya**	18.042	2.853	0.004	2.853	0.004	0.011	0.062	1940
6	Azamgarh**	19.044	3.229	0.001	3.879	0	0.011	0.058	1945
7	Baghpat**	16.504	3.001	0.002	3.001	0.002	0.012	0.075	1951
8	Bahraich**	17.863	3.371	0	5.098	0	0.013	0.076	1945
9	Ballia**	19.247	2.955	0.003	3.803	0	0.009	0.048	1945
10	Balrampur**	18.274	3.235	0.001	4.607	0	0.012	0.066	1945
11	Banda**	18.206	2.886	0.003	2.886	0.003	0.011	0.061	1945
12	Barabanki**	18.071	3.325	0	3.895	0	0.012	0.068	1945
13	Bareilly**	17.231	3.255	0.001	3.866	0	0.014	0.084	1940
14	Basti**	18.658	3.244	0.001	3.214	0.001	0.011	0.061	1945
15	Bijnor**	16.453	3.166	0.001	3.638	0	0.01	0.089	1950
16	Budaun**	17.313	3.145	0.001	3.146	0.001	0.013	0.076	1940
17	Buland Shahar**	17.099	3.05	0.002	3.05	0.002	0.012	0.075	1940
18	Chandauli**	18.853	3.241	0.001	3.856	0	0.0100	0.053	1945
19	Chitrakoot**	18.306	2.937	0.003	2.937	0.003	0.011	0.062	1945
20	Deoria**	19.054	3.059	0.002	3.849	0.001	0.009	0.051	1945
21	Etah**	17.555	3.128	0.001	3.128	0.001	0.012	0.068	1940
22	Etawah**	18.031	2.963	0.003	2.963	0.003	0.011	0.063	1940
23	Farrukhbad**	17.686	3.067	0.002	3.067	0.002	0.012	0.068	1940
24	Fatehpur**	18.582	2.897	0.003	2.897	0.003	0.01	0.058	1945
25	Faziabad**	18.448	3.348	0	3.317	0	0.011	0.064	1945
26	Firozabad**	17.811	2.874	0.004	2.874	0.004	0.011	0.064	1940
27	Gautam buddha	16.991	2.891	0.003	2.891	0.003	0.012	0.071	1932
28	Ghaziabad**	16.684	2.926	0.003	2.926	0.003	0.012	0.075	1951
29	Ghazipur**	19.135	3.142	0.001	3.892	0	0.0100	0.052	1945
30	Gonda**	18.275	3.391	0	4.735	0	0.012	0.066	1945
31	Gorakhpur**	18.899	3.195	0.001	3.869	0	0.01	0.053	1945
32	Hamirpur**	18.131	2.934	0.003	2.934	0.003	0.011	0.061	1945
33	Hardoi**	17.746	3.209	0.001	3.761	0	0.012	0.071	1940
34	Hathras**	17.541	2.807	0.004	2.807	0.004	0.011	0.064	1940
35	Jalaun**	18.138	2.879	0.003	2.879	0.003	0.011	0.063	1945
36	Jaunpur**	19.047	3.056	0.002	3.056	0.002	0.01	0.055	1945
37	Jhansi**	18.544	3.001	0.002	3.001	0.002	0.011	0.062	1945

38	Jyotiba phule nagar**	16.895	3.287	0.001	3.772	0	0.014	0.087	1940
39	Kannauj**	17.904	2.981	0.002	2.981	0.002	0.011	0.062	1940
40	Kanpur dehat**	18.097	2.862	0.004	2.862	0.004	0.011	0.061	1940
41	Kanpur Nagar**	18.115	3.004	0.002	3.004	0.002	0.011	0.062	1940
42	Kaushambi**	18.631	2.842	0.004	2.842	0.004	0.011	0.061	1945
43	Kheri**	17.584	3.371	0	4.124	0	0.015	0.087	1945
44	Kushi nagar**	18.794	3.053	0.002	3.738	0	0.009	0.049	1945
45	Lalitpur**	19.538	3.2	0.001	3.2	0.001	0.011	0.06	1951
46	Lucknow**	18.185	3.244	0.001	3.787	0	0.011	0.064	1945
47	Maharaj ganj**	18.717	3.012	0.002	4.333	0	0.01	0.055	1945
48	Mahoba**	18.359	2.931	0.003	2.931	0.003	0.011	0.062	1945
49	Mainpuri**	17.865	3.03	0.002	3.03	0.002	0.011	0.062	1940
50	Mathura**	17.435	2.648	0.008	2.648	0.008	0.01	0.058	1932
51	Mau**	19.153	3.004	0.002	4.563	0	0.01	0.055	1945
52	Meerut**	16.591	3.053	0.002	3.053	0.002	0.013	0.082	1950
53	Mirzapur**	18.812	3.177	0.001	3.177	0.001	0.01	0.055	1945
54	Moradabad**	16.982	3.336	0	3.862	0	0.014	0.087	1940
55	Muzaffarnagar**	16.4	3.053	0.002	3.053	0.002	0.014	0.085	1950
56	Pilibhit**	17.312	3.18	0.001	3.875	0	0.015	0.09	1945
57	Pratapgarh**	18.892	2.934	0.003	2.934	0.003	0.01	0.057	1945
58	Rae Bareli**	18.665	3.111	0.001	3.111	0.001	0.01	0.061	1945
59	Rampur**	17.018	3.203	0.001	3.811	0	0.015	0.091	1940
60	Saharanpur**	16.072	3.067	0.002	3.067	0.002	0.013	0.086	1950
61	Sant kabir nagar**	18.808	3.249	0.001	3.833	0	0.01	0.056	1945
62	Sant Ravidas nagar**	18.649	2.871	0.004	2.871	0.004	0.01	0.055	1945
63	Shahjahanpur**	17.439	3.296	0	3.906	0	0.013	0.078	1940
64	Shrawasti**	17.994	3.307	0	4.935	0	0.013	0.073	1945
65	Siddharth Nagar**	18.572	3.142	0.001	3.643	0	0.011	0.06	1945
66	Sitapur**	17.733	3.313	0	4.918	0	0.013	0.076	1945
67	Sonbhadra**	18.543	3.33	0	3.33	0	0.01	0.058	1945
68	Sultanpur**	18.671	3.206	0.001	3.206	0.001	0.011	0.06	1945
69	Unnao**	18.199	3.122	0.001	3.122	0.001	0.011	0.065	1945
70	Varanasi**	18.787	3.03	0.002	3.03	0.002	0.01	0.054	1945

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 11 Results of the statistical tests for average temperature of March

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra	23.909	1.431	0.152	1.431	0.152	0.0066	0.027	1940
2	Aligarh	23.219	1.561	0.118	1.561	0.118	0.0073	0.031	1940
3	Allahabad	24.56	1.225	0.221	1.052	0.292	0.0054	0.022	1917
4	Ambedkar Nagar	24.719	1.179	0.238	1.003	0.315	0.0051	0.021	1915
5	Auraiya	23.96	1.546	0.121	1.546	0.121	0.0069	0.028	1940
6	Azamgarh	24.84	1.179	0.238	0.999	0.317	0.0044	0.018	1915
7	Baghpat	22.238	1.425	0.153	1.425	0.153	0.0067	0.029	1940
8	Bahraich	23.704	1.439	0.149	1.423	0.154	0.0074	0.031	1920
9	Ballia	24.77	1.144	0.252	0.974	0.329	0.0046	0.018	1915
10	Balrampur	23.977	1.335	0.181	1.347	0.177	0.0063	0.026	1920
11	Banda	23.945	1.555	0.119	1.361	0.173	0.0064	0.026	1940
12	Barabanki	24.163	1.61	0.107	1.373	0.169	0.0066	0.027	1920
13	Bareilly	22.655	1.465	0.142	1.465	0.142	0.0086	0.037	1920
14	Basti	24.421	1.385	0.166	1.187	0.234	0.0058	0.023	1920
15	Bijnor	21.846	1.393	0.163	1.393	0.163	0.0078	0.035	1920
16	Budaun	22.915	1.613	0.106	1.613	0.106	0.0081	0.035	1940
17	Buland Shahar	22.909	1.489	0.136	1.489	0.136	0.007	0.03	1940
18	Chandauli	24.385	1.33	0.183	1.123	0.261	0.0052	0.021	1915
19	Chitrakoot	24.041	1.387	0.165	1.198	0.231	0.0061	0.025	1917
20	Deoria	24.616	1.009	0.312	0.871	0.383	0.0047	0.018	1915
21	Etah	23.366	1.616	0.106	1.616	0.106	0.0075	0.032	1940
22	Etawah*	23.946	1.654	0.098	1.654	0.098	0.0073	0.03	1940
23	Farrukhbad	23.375	1.593	0.111	1.593	0.111	0.0074	0.031	1940
24	Fatehpur	24.507	1.367	0.171	1.189	0.234	0.0058	0.024	1915
25	Faziabad	24.399	1.46	0.144	1.243	0.213	0.0061	0.024	1920
26	Firozabad*	23.754	1.801	0.071	1.801	0.071	0.0075	0.031	1940
27	Gautam buddha nagar	22.811	1.492	0.135	1.492	0.135	0.0067	0.029	1940
28	Ghaziabad	22.535	1.425	0.154	1.425	0.154	0.0067	0.029	1940
29	Ghazipur	24.791	1.162	0.245	0.983	0.325	0.0044	0.017	1915
30	Gonda	24.143	1.422	0.154	1.218	0.222	0.0065	0.026	1920
31	Gorakhpur	24.587	1.131	0.258	0.971	0.331	0.0049	0.019	1920
32	Hamirpur	23.954	1.581	0.113	1.581	0.113	0.007	0.029	1940
33	Hardoi	23.585	1.535	0.124	1.338	0.181	0.0077	0.032	1940
34	Hathras	23.494	1.549	0.121	1.549	0.121	0.0069	0.029	1940
35	Jalaun	24.108	1.619	0.105	1.619	0.105	0.0068	0.028	1940
36	Jaunpur	24.972	1.185	0.235	1.005	0.314	0.0045	0.018	1915
37	Jhansi	24.436	1.631	0.102	1.631	0.102	0.0074	0.03	1940
38	Jyotiba phule nagar	22.477	1.425	0.154	1.425	0.154	0.0078	0.034	1940
39	Kannauj	23.747	1.538	0.123	1.538	0.123	0.0067	0.028	1940

40	Kanpur dehat	24.011	1.561	0.118	1.561	0.118	0.0062	0.025	1940
41	Kanpur Nagar	24.085	1.46	0.144	1.46	0.144	0.0063	0.025	1940
42	Kaushambi	24.511	1.191	0.233	1.025	0.305	0.0057	0.023	1917
43	Kheri	23.242	1.414	0.157	1.211	0.225	0.0076	0.032	1920
44	Kushi nagar	24.417	1.223	0.221	1.235	0.216	0.0051	0.021	1920
45	Lalitpur*	25.179	1.812	0.069	1.812	0.069	0.0082	0.032	1940
46	Lucknow	24.295	1.682	0.092	1.44	0.149	0.0069	0.028	1940
47	Maharaj ganj	24.266	1.387	0.165	1.403	0.161	0.006	0.024	1920
48	Mahoba*	24.016	1.717	0.085	1.717	0.085	0.0075	0.031	1940
49	Mainpuri*	23.692	1.688	0.091	1.688	0.091	0.0079	0.033	1940
50	Mathura	23.377	1.402	0.161	1.402	0.161	0.0057	0.024	1940
51	Mau	24.791	1.168	0.242	0.994	0.32	0.0045	0.018	1915
52	Meerut	22.269	1.292	0.196	1.292	0.196	0.0068	0.03	1940
53	Mirzapur	24.461	1.373	0.169	1.172	0.241	0.005	0.021	1917
54	Moradabad	22.51	1.474	0.14	1.474	0.14	0.008	0.035	1940
55	Muzaffarnagar	21.905	1.309	0.19	1.309	0.19	0.007	0.031	1940
56	Pilibhit	22.73	1.468	0.142	1.278	0.201	0.0089	0.039	1920
57	Pratapgarh	24.932	1.295	0.195	1.107	0.268	0.0053	0.021	1915
58	Rae Bareli	24.652	1.468	0.141	1.261	0.207	0.0062	0.025	1940
59	Rampur	22.472	1.497	0.134	1.497	0.134	0.0086	0.038	1920
60	Saharanpur	21.341	1.371	0.171	1.371	0.171	0.0073	0.034	1940
61	Sant kabir nagar	24.505	1.176	0.239	1.013	0.311	0.0051	0.021	1915
62	Sant Ravidas nagar	24.459	1.275	0.202	1.091	0.274	0.0047	0.019	1917
63	Shahjahanpur	22.936	1.489	0.136	1.301	0.193	0.0081	0.035	1920
64	Shrawasti	23.779	1.321	0.186	1.311	0.189	0.0072	0.03	1920
65	Siddharth Nagar	24.242	1.205	0.228	1.221	0.222	0.0061	0.025	1920
66	Sitapur	23.731	1.483	0.138	1.273	0.202	0.0069	0.028	1920
67	Sonbhadra	23.896	1.48	0.138	1.277	0.201	0.0052	0.021	1917
68	Sultanpur	24.743	1.379	0.167	1.172	0.241	0.0056	0.022	1915
69	Unnao	24.245	1.544	0.122	1.338	0.181	0.0063	0.026	1940
70	Varanasi	24.512	1.344	0.178	1.139	0.254	0.005	0.02	1915

*Significant at 90% Confidence interval. **Significant at 99% Confidence interval.

Table 12 Results of the statistical tests for average temperature of April

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra*	29.82	1.761	0.078	2.351	0.018	0.0086	0.028	1945
2	Aligarh**	29.31	2.223	0.026	2.601	0.009	0.0111	0.037	1945
3	Allahabad	29.92	1.064	0.287	1.064	0.287	0.0047	0.015	1946
4	Ambedkar Nagar	30.23	1.035	0.301	1.138	0.254	0.0045	0.015	1946
5	Auraiya**	30.01	1.619	0.105	2.764	0.005	0.0074	0.024	1945
6	Azamgarh	30.28	0.968	0.332	1.066	0.286	0.0041	0.013	1946
7	Baghpat**	28.20	2.301	0.021	2.935	0.003	0.0124	0.043	1945
8	Bahraich	29.41	0.887	0.374	0.887	0.374	0.0041	0.013	1946
9	Ballia	30.26	0.401	0.687	0.401	0.687	0.0021	0.006	1946
10	Balrampur	29.53	0.801	0.423	0.801	0.423	0.0034	0.011	1946
11	Banda**	29.53	1.59	0.111	2.911	0.003	0.0065	0.022	1945
12	Barabanki	29.80	1.165	0.243	1.473	0.141	0.0054	0.018	1946
13	Bareilly	28.96	1.214	0.224	1.489	0.136	0.0061	0.021	1945
14	Basti	30.10	1.069	0.284	1.069	0.284	0.0042	0.013	1946
15	Bijnor	27.99	1.471	0.141	1.84	0.065	0.0076	0.027	1945
16	Budaun*	29.15	1.752	0.079	2.201	0.027	0.0089	0.03	1945
17	Buland Shahar**	29.00	2.171	0.029	2.838	0.004	0.011	0.038	1945
18	Chandauli	29.73	0.711	0.476	0.789	0.43	0.0026	0.008	1946
19	Chitrakoot	29.42	1.391	0.164	1.745	0.081	0.0057	0.019	1945
20	Deoria	29.98	0.505	0.612	0.505	0.612	0.0021	0.006	1946
21	Etah**	29.57	1.992	0.046	2.637	0.008	0.0103	0.034	1945
22	Etawah*	30.00	1.68	0.092	2.342	0.019	0.0076	0.025	1945
23	Farrukhbad*	29.59	1.694	0.09	2.238	0.025	0.0082	0.027	1945
24	Fatehpur*	30.20	1.541	0.123	2.03	0.042	0.0065	0.021	1945
25	Faziabad	30.04	1.124	0.261	1.414	0.157	0.0054	0.018	1946
26	Firozabad**	29.83	1.986	0.046	2.66	0.007	0.0097	0.032	1945
27	Gautam buddha nagar**	28.84	2.498	0.012	3.231	0.001	0.0113	0.039	1945
28	Ghaziabad**	28.58	2.182	0.029	2.853	0.004	0.0108	0.037	1945
29	Ghazipur	30.16	0.714	0.475	0.793	0.427	0.0029	0.009	1946
30	Gonda	29.75	1.052	0.292	1.052	0.292	0.0048	0.016	1946
31	Gorakhpur	29.94	0.741	0.459	0.741	0.459	0.0034	0.011	1946
32	Hamirpur**	29.68	1.61	0.107	2.901	0.003	0.007	0.023	1945
33	Hardoi	29.62	1.286	0.198	1.683	0.092	0.0067	0.022	1945
34	Hathras**	29.54	2.194	0.028	3.049	0.002	0.0109	0.036	1945
35	Jalaun*	29.95	1.572	0.115	2.267	0.023	0.0069	0.023	1945
36	Jaunpur	30.43	0.933	0.351	1.361	0.173	0.0038	0.012	1946
37	Jhansi	29.95	1.549	0.121	1.652	0.098	0.0066	0.022	1945
38	Jyotiba phule nagar*	28.65	1.616	0.106	2.044	0.041	0.0089	0.031	1945

39	Kannauj*	29.87	1.665	0.095	2.331	0.019	0.0074	0.024	1945
40	Kanpur dehat*	29.96	1.57	0.116	2.105	0.035	0.0068	0.022	1945
41	Kanpur Nagar*	29.95	1.633	0.102	2.194	0.028	0.0065	0.021	1945
42	Kaushambi	29.95	1.338	0.181	1.682	0.092	0.0054	0.018	1945
43	Kheri	29.30	1.011	0.311	0.981	0.326	0.0047	0.016	1946
44	Kushi nagar	29.64	0.734	0.462	0.854	0.392	0.0029	0.009	1946
45	Lalitpur	30.12	1.752	0.079	1.627	0.103	0.0072	0.024	1945
46	Lucknow	30.05	1.335	0.181	1.678	0.093	0.0059	0.019	1946
47	Maharaj ganj	29.59	0.754	0.451	0.754	0.451	0.0034	0.011	1946
48	Mahoba	29.54	1.624	0.104	1.78	0.075	0.0069	0.023	1945
49	Mainpuri**	29.84	1.821	0.068	2.636	0.008	0.0095	0.031	1945
50	Mathura**	29.31	2.119	0.034	3.474	0	0.0104	0.035	1945
51	Mau	30.20	0.702	0.482	0.702	0.482	0.0034	0.011	1946
52	Meerut*	28.34	1.943	0.052	2.542	0.011	0.0106	0.037	1945
53	Mirzapur	29.72	0.945	0.344	0.945	0.344	0.0038	0.012	1946
54	Moradabad	28.69	1.546	0.121	1.918	0.054	0.0074	0.025	1945
55	Muzaffarnagar*	27.98	1.911	0.055	2.434	0.014	0.0106	0.038	1945
56	Pilibhit	28.95	0.936	0.348	0.886	0.375	0.0044	0.015	1946
57	Pratapgarh	30.48	1.139	0.254	1.435	0.151	0.0051	0.016	1946
58	Rae Bareli	30.44	1.358	0.174	1.759	0.078	0.006	0.019	1945
59	Rampur	28.72	1.11	0.266	1.362	0.172	0.0064	0.022	1945
60	Saharanpur*	27.48	1.853	0.063	2.361	0.018	0.0103	0.037	1945
61	Sant kabir nagar	29.96	0.786	0.431	0.786	0.431	0.0036	0.011	1946
62	Sant Ravidas nagar	29.76	0.997	0.318	1.096	0.272	0.0041	0.013	1946
63	Shahjahanpur	29.21	1.142	0.253	1.391	0.163	0.0062	0.021	1945
64	Shrawasti	29.44	0.806	0.419	0.806	0.419	0.0036	0.012	1946
65	Siddharth Nagar	29.70	0.638	0.522	0.638	0.522	0.0029	0.009	1946
66	Sitapur	29.54	1.066	0.286	1.331	0.182	0.0055	0.018	1946
67	Sonbhadra	28.94	0.731	0.464	0.806	0.419	0.003	0.009	1946
68	Sultanpur	30.34	1.147	0.251	1.447	0.147	0.0051	0.016	1946
69	Unnao*	30.09	1.501	0.133	1.992	0.046	0.0069	0.022	1945
70	Varanasi	29.85	0.818	0.413	0.901	0.367	0.0034	0.011	1946

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 13 Results of the statistical tests for average temperature of May

S.N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra	34.122	0.133	0.894	0.133	0.894	0.001	0.002	1935
2	Aligarh	33.628	0.263	0.792	0.263	0.792	0.001	0.003	1934
3	Allahabad	33.903	-0.0404	0.967	-0.035	0.971	-0.0001	-0.001	1961
4	Ambedkar Nagar	33.643	-0.171	0.864	-0.149	0.881	-0.001	-0.001	1961
5	Auraiya	34.281	0.133	0.894	0.133	0.894	0.001	0.001	1934
6	Azamgarh	33.707	-0.196	0.844	-0.171	0.863	-0.001	-0.002	1961
7	Baghpat	32.391	0.696	0.485	0.604	0.546	0.003	0.01	1934
8	Bahraich	32.691	0.098	0.921	0.099	0.921	0.001	0.001	1961
9	Ballia	33.501	-0.208	0.835	-0.179	0.857	-0.001	-0.002	1961
10	Balrampur	32.667	-0.026	0.979	-0.023	0.981	-0.0001	-0.0003	1961
11	Banda	33.742	0.245	0.805	0.247	0.804	0.001	0.002	1934
12	Barabanki	33.446	-0.104	0.917	-0.094	0.924	-0.0004	-0.001	1962
13	Bareilly	32.846	0.292	0.77	0.297	0.765	0.001	0.003	1934
14	Basti	33.222	-0.254	0.799	-0.222	0.823	-0.001	-0.002	1961
15	Bijnor	31.941	0.505	0.612	0.437	0.661	0.002	0.007	1934
16	Budaun	33.356	0.349	0.726	0.349	0.726	0.001	0.004	1934
17	Buland Shahar	33.21	0.231	0.817	0.231	0.817	0.001	0.003	1934
18	Chandauli	33.426	-0.431	0.666	-0.381	0.703	-0.001	-0.004	1961
19	Chitrakoot	33.568	0.13	0.896	0.115	0.908	0.001	0.001	1961
20	Deoria	32.935	-0.063	0.949	-0.054	0.956	-0.0003	-0.001	1961
21	Etah	33.883	0.413	0.679	0.413	0.679	0.001	0.004	1934
22	Etawah	34.255	0.171	0.864	0.171	0.864	0.001	0.002	1934
23	Farrukhbad	33.816	0.231	0.817	0.231	0.817	0.001	0.003	1934
24	Fatehpur	34.465	0.095	0.923	0.095	0.923	0.0005	0.001	1961
25	Faziabad	33.477	-0.248	0.803	-0.221	0.825	-0.001	-0.003	1961
26	Firozabad	34.198	0.231	0.817	0.231	0.817	0.001	0.003	1935
27	Gautam buddha nagar	33.124	0.066	0.946	0.058	0.953	0.0002	0.001	1934
28	Ghaziabad	32.674	0.315	0.752	0.276	0.782	0.001	0.005	1934
29	Ghazipur	33.59	-0.266	0.791	-0.247	0.804	-0.001	-0.002	1961
30	Gonda	33.067	-0.133	0.894	-0.119	0.905	-0.001	0.00212	1961
31	Gorakhpur	32.961	-0.043	0.965	-0.037	0.971	0.00	0.0003	1961
32	Hamirpur	33.967	0.208	0.835	0.208	0.835	0.0001	0.0025	1934
33	Hardoi	33.676	-0.002	0.997	-0.002	0.997	0	0	1961
34	Hathras	33.913	0.239	0.811	0.239	0.811	0.001	0.003	1935
35	Jalaun	34.139	0.026	0.979	0.026	0.979	0.00	0.0002	1956
36	Jaunpur	34.132	-0.208	0.835	-0.183	0.854	-0.001	-0.002	1961
37	Jhansi	33.919	0.161	0.871	0.161	0.871	0.001	0.002	1934

38	Jyotiba phule nagar	32.698	0.344	0.731	0.344	0.731	0.001	0.004	1934
39	Kannauj	34.139	0.176	0.86	0.176	0.86	0.001	0.002	1934
40	Kanpur dehat	34.286	0.083	0.933	0.083	0.933	0.0004	0.001	1956
41	Kanpur Nagar	34.251	0.049	0.961	0.049	0.961	0.0002	0.0005	1961
42	Kaushambi	34.154	-0.031	0.974	-0.031	0.974	0	0	1961
43	Kheri	32.756	0.063	0.949	0.064	0.948	0.0002	0.0006	1962
44	Kushi nagar	32.297	0.156	0.875	0.136	0.891	0.0004	0.001	1961
45	Lalitpur	33.777	0.396	0.692	0.47	0.638	0.0021	0.006	1934
46	Lucknow	33.994	0.031	0.974	0.033	0.974	0.0002	0.0006	1962
47	Maharaj ganj	32.194	0.017	0.986	0.015	0.988	0	0	1961
48	Mahoba	33.639	0.352	0.724	0.352	0.724	0.001	0.003	1934
49	Mainpuri	34.191	0.346	0.728	0.346	0.728	0.001	0.004	1934
50	Mathura	33.638	0.061	0.951	0.052	0.957	0.0003	0.001	1934
51	Mau	33.473	-0.185	0.853	-0.159	0.873	-0.0004	-0.001	1961
52	Meerut	32.439	0.479	0.631	0.421	0.673	0.002	0.008	1934
53	Mirzapur	33.553	-0.211	0.832	-0.185	0.852	-0.0006	-0.001	1961
54	Moradabad	32.695	0.306	0.759	0.306	0.759	0.001	0.004	1934
55	Muzaffarnagar	32.149	0.621	0.534	0.542	0.587	0.003	0.011	1934
56	Pilibhit	32.613	0.199	0.841	0.204	0.838	0.001	0.002	1938
57	Pratapgarh	34.381	-0.034	0.972	-0.031	0.975	-0.0001	-0.0003	1961
58	Rae Bareli	34.453	0.052	0.958	0.052	0.958	0.0001	0.0003	1962
59	Rampur	32.555	0.294	0.768	0.254	0.798	0.001	0.005	1934
60	Saharanpur	31.671	0.777	0.436	0.683	0.494	0.003	0.012	1934
61	Sant kabir nagar	32.966	-0.147	0.882	-0.127	0.898	-0.0004	-0.001	1961
62	Sant Ravidas nagar	33.628	-0.346	0.728	-0.307	0.758	-0.001	-0.003	1961
63	Shahjahanpur	33.076	0.196	0.844	0.203	0.839	0.001	0.002	1934
64	Shrawasti	32.615	0.043	0.965	0.043	0.964	0.0002	0.0006	1961
65	Siddharth Nagar	32.605	-0.063	0.949	-0.065	0.947	-0.0002	-0.0007	1961
66	Sitapur	33.225	0.031	0.974	0.032	0.973	0.0001	0.0005	1962
67	Sonbhadra	32.626	-0.135	0.891	-0.121	0.903	-0.0004	-0.001	1961
68	Sultanpur	34.086	-0.205	0.837	-0.181	0.856	-0.0008	-0.002	1961
69	Unnao	34.278	0.075	0.939	0.075	0.939	0.0002	0.0005	1961
70	Varanasi	33.604	-0.323	0.746	-0.285	0.775	-0.001	-0.003	1961

"No Significant District"

Table 14 Results of the statistical tests for average temperature of June

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperatur	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra**	34.731	-3.141	0.001	-3.574	0	-0.0147	-0.042	1969
2	Aligarh**	34.562	-2.804	0.005	-3.078	0.002	-0.0128	-0.036	1969
3	Allahabad	33.409	-1.662	0.096	-1.662	0.096	-0.0091	-0.027	1969
4	Ambedkar Nagar	33.595	-0.871	0.384	-0.933	0.351	-0.0042	-0.012	1969
5	Auraiya**	34.735	-2.621	0.008	-2.945	0.003	-0.0121	-0.034	1969
6	Azamgarh	33.556	-0.844	0.398	-0.844	0.398	-0.0045	-0.013	1969
7	Baghpat*	33.584	-1.972	0.048	-2.118	0.034	-0.009	-0.026	1969
8	Bahraich	32.853	-0.644	0.519	-0.796	0.425	-0.0024	-0.007	1969
9	Ballia	33.239	-0.537	0.591	-0.537	0.591	-0.0025	-0.007	1967
10	Balrampur	32.71	-0.289	0.772	-0.563	0.573	-0.001	-0.002	1969
11	Banda*	33.464	-1.685	0.091	-2.125	0.033	-0.0085	-0.025	1967
12	Barabanki	33.521	-1.091	0.275	-1.301	0.193	-0.0049	-0.014	1969
13	Bareilly**	33.464	-2.009	0.044	-3.188	0.001	-0.0085	-0.025	1969
14	Basti	33.301	-0.647	0.517	-0.578	0.563	-0.0026	-0.008	1969
15	Bijnor	32.798	-1.755	0.079	-1.694	0.091	-0.0064	-0.019	1969
16	Budaun**	34.249	-2.564	0.01	-3.73	0	-0.0114	-0.033	1969
17	Buland Shahar**	34.158	-2.547	0.01	-2.797	0.005	-0.0112	-0.032	1969
18	Chandauli	32.818	-1.081	0.279	-1.081	0.279	-0.0065	-0.019	1967
19	Chitrakoot	32.987	-1.723	0.084	-1.723	0.084	-0.009	-0.027	1967
20	Deoria	32.777	-0.297	0.765	-0.251	0.801	-0.0012	-0.004	1967
21	Etah**	34.831	-2.954	0.003	-3.343	0	-0.0134	-0.038	1969
22	Etawah**	34.845	-2.853	0.004	-3.258	0.001	-0.0134	-0.038	1969
23	Farrukhbad*	34.529	-2.512	0.011	-2.463	0.013	-0.0113	-0.032	1969
24	Fatehpur**	34.305	-1.922	0.054	-2.783	0.005	-0.0096	-0.028	1969
25	Faziabad	33.576	-0.821	0.411	-0.885	0.375	-0.0039	-0.011	1969
26	Firozabad**	35.036	-3.122	0.001	-3.532	0	-0.0146	-0.041	1969
27	Gautam buddha nagar**	34.001	-2.408	0.016	-2.605	0.009	-0.0113	-0.033	1969
28	Ghaziabad*	33.717	-2.249	0.024	-2.401	0.016	-0.0092	-0.027	1969
29	Ghazipur	33.355	-0.881	0.377	-0.881	0.377	-0.0045	-0.013	1969
30	Gonda	33.201	-0.592	0.553	-0.779	0.435	-0.0028	-0.008	1969
31	Gorakhpur	32.863	-0.462	0.643	-0.408	0.682	-0.0018	-0.005	1969
32	Hamirpur**	34.019	-1.836	0.066	-3.036	0.002	-0.0089	-0.026	1965
33	Hardoi**	33.998	-1.844	0.065	-8.848	0	-0.0084	-0.024	1969
34	Hathras**	34.784	-3.015	0.002	-3.341	0	-0.014	-0.04	1969
35	Jalaun**	34.362	-2.266	0.023	-3.317	0	-0.0112	-0.032	1965
36	Jaunpur**	33.95	-1.231	0.218	-1.231	0.218	-0.0067	-0.019	1969
37	Jhansi**	33.57	-2.217	0.026	-3.158	0.001	-0.0104	-0.031	1965

38	Jyotiba phule nagar*	33.632	-2.139	0.032	-2.352	0.018	-0.0091	-0.027	1969
39	Kannauj*	34.648	-2.359	0.018	-2.317	0.021	-0.0108	-0.031	1969
40	Kanpur dehat**	34.53	-2.292	0.021	-2.769	0.005	-0.0106	-0.031	1969
41	Kanpur Nagar**	34.42	-2.067	0.038	-3.638	0	-0.0096	-0.027	1969
42	Kaushambi*	33.716	-1.876	0.061	-2.321	0.02	-0.0107	-0.031	1969
43	Kheri	33.046	-1.011	0.311	-1.667	0.095	-0.0038	-0.011	1967
44	Kushi nagar	32.143	0.141	0.887	0.141	0.887	0.0005	0.001	1922
45	Lalitpur	32.444	-1.471	0.141	-1.471	0.141	-0.0078	-0.023	1960
46	Lucknow**	34.001	-1.451	0.146	-4.416	0	-0.0066	-0.019	1969
47	Maharaj ganj	32.073	0.133	0.894	0.141	0.888	0.0004	0.001	1922
48	Mahoba*	33.242	-1.642	0.101	-2.526	0.011	-0.0084	-0.025	1965
49	Mainpuri**	34.979	-2.934	0.003	-3.292	0	-0.0136	-0.038	1969
50	Mathura**	34.387	-2.775	0.005	-2.973	0.002	-0.0137	-0.039	1969
51	Mau	33.304	-0.731	0.464	-0.731	0.464	-0.0034	-0.011	1969
52	Meerut*	33.563	-1.908	0.056	-1.981	0.047	-0.0085	-0.0253	1969
53	Mirzapur	32.871	-1.405	0.159	-1.405	0.159	-0.0076	-0.023	1969
54	Moradabad*	33.547	-2.182	0.029	-2.462	0.013	-0.0092	-0.027	1969
55	Muzaffarnagar	33.366	-1.734	0.082	-1.597	0.111	-0.0078	-0.023	1969
56	Pilibhit**	32.911	-1.604	0.108	-2.605	0.009	-0.0056	-0.016	1967
57	Pratapgarh	34.244	-1.694	0.091	-1.694	0.09	-0.0085	-0.024	1969
58	Rae Bareli	34.352	-1.648	0.099	-2.091	0.036	-0.0084	-0.024	1969
59	Rampur	33.268	-2.113	0.034	-3.337	0	-0.0085	-0.025	1969
60	Saharanpur	32.908	-1.598	0.109	-1.281	0.199	-0.0067	-0.021	1969
61	Sant kabir nagar	32.947	-0.451	0.651	-0.401	0.687	-0.0019	-0.005	1969
62	Sant Ravidas nagar	33.131	-1.587	0.112	-1.587	0.112	-0.0083	-0.025	1969
63	Shahjahanpur**	33.621	-1.925	0.054	-3.164	0.001	-0.008	-0.023	1969
64	Shrawasti	32.735	-0.425	0.671	-1.089	0.276	-0.0013	-0.004	1969
65	Siddharth Nagar	32.623	-0.043	0.965	-0.061	0.951	-0.0002	-0.0006	1969
66	Sitapur	33.372	-1.151	0.249	-1.855	0.063	-0.0051	-0.015	1967
67	Sonbhadra	31.595	-0.891	0.373	-1.033	0.301	-0.0059	-0.018	1969
68	Sultanpur	34.027	-1.197	0.231	-1.197	0.231	-0.0061	-0.018	1969
69	Unnao**	34.324	-1.833	0.066	-4.994	0	-0.0092	-0.026	1969
70	Varanasi	33.147	-1.321	0.186	-1.321	0.186	-0.007	-0.021	1967

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 15 Results of the statistical tests for average temperature of July

S. N.	District	Mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra*	30.792	-1.772	0.076	-2.316	0.021	-0.008	-0.026	1966
2	Aligarh*	31.264	-1.749	0.081	-2.016	0.043	-0.006	-0.021	1955
3	Allahabad	29.463	-1.384	0.166	-1.752	0.079	-0.004	-0.015	1918
4	Ambedkar Nagar	30.426	-1.616	0.105	-1.829	0.067	-0.003	-0.011	1918
5	Auraiya*	30.871	-1.601	0.109	-2.047	0.041	-0.006	-0.019	1966
6	Azamgarh	30.308	-1.593	0.111	-1.868	0.061	-0.003	-0.012	1918
7	Baghpat	30.912	-1.549	0.121	-1.811	0.071	-0.005	-0.018	1924
8	Bahraich	30.113	-1.321	0.186	-1.202	0.229	-0.002	-0.009	1918
9	Ballia	30.127	-0.873	0.382	-0.873	0.382	-0.002	-0.006	1918
10	Balrampur	30.09	-1.043	0.296	-1.047	0.294	-0.002	-0.006	1966
11	Banda	29.354	-1.231	0.218	-1.468	0.142	-0.003	-0.013	1918
12	Barabanki	30.418	-1.523	0.126	-1.741	0.081	-0.003	-0.011	1918
13	Bareilly*	30.455	-1.931	0.053	-2.178	0.029	-0.005	-0.016	1966
14	Basti	30.283	-1.467	0.142	-1.701	0.089	-0.002	-0.008	1918
15	Bijnor*	30.216	-1.801	0.071	-2.001	0.045	-0.005	-0.017	1973
16	Budaun**	31.106	-1.957	0.051	-2.625	0.008	-0.006	-0.02	1955
17	Buland Shahar	31.125	-1.292	0.196	-1.486	0.137	-0.005	-0.016	1924
18	Chandauli	29.233	-1.506	0.131	-1.875	0.061	-0.004	-0.014	1918
19	Chitrakoot	28.826	-1.246	0.212	-1.539	0.123	-0.003	-0.013	1918
20	Deoria	29.908	-0.795	0.426	-0.795	0.426	-0.001	-0.004	1973
21	Etah**	31.379	-1.899	0.057	-2.616	0.008	-0.007	-0.024	1955
22	Etawah**	30.931	-1.674	0.094	-3.538	0	-0.006	-0.021	1955
23	Farrukhbad*	31.182	-1.778	0.075	-2.369	0.017	-0.005	-0.019	1966
24	Fatehpur*	30.461	-1.451	0.146	-2.416	0.015	-0.004	-0.015	1966
25	Faziabad	30.381	-1.511	0.131	-1.438	0.151	-0.003	-0.011	1918
26	Firozabad**	31.329	-1.917	0.055	-2.617	0.008	-0.008	-0.026	1955
27	Gautam buddha nagar	30.943	-1.315	0.188	-1.511	0.131	-0.004	-0.015	1924
28	Ghaziabad	30.883	-1.286	0.198	-1.461	0.143	-0.004	-0.013	1924
29	Ghazipur	30.005	-1.269	0.204	-1.494	0.135	-0.003	-0.011	1918
30	Gonda	30.248	-1.564	0.117	-1.453	0.145	-0.002	-0.009	1918
31	Gorakhpur	30.041	-1.301	0.193	-1.498	0.133	-0.001	-0.005	1973
32	Hamirpur	29.799	-1.298	0.194	-1.452	0.146	-0.004	-0.015	1954
33	Hardoi	30.856	-1.437	0.151	-1.586	0.112	-0.003	-0.012	1966
34	Hathras**	31.255	-1.951	0.051	-2.576	0.009	-0.008	-0.027	1955
35	Jalaun	30.064	-1.497	0.134	-1.882	0.059	-0.005	-0.018	1954
36	Jaunpur	30.397	-1.601	0.109	-1.939	0.052	-0.004	-0.014	1918
37	Jhansi	29.021	-1.151	0.249	-1.514	0.129	-0.004	-0.014	1955
38	Jyotiba phule nagar	30.773	-1.506	0.131	-1.668	0.095	-0.004	-0.015	1924
39	Kannauj*	31.123	-1.648	0.099	-2.218	0.026	-0.005	-0.018	1966
40	Kanpur dehat*	30.692	-1.607	0.107	-2.032	0.042	-0.005	-0.018	1966

41	Kanpur Nagar	30.731	-1.607	0.107	-1.777	0.075	-0.005	-0.017	1966
42	Kaushambi	29.741	-1.321	0.186	-1.659	0.097	-0.004	-0.015	1918
43	Kheri	30.319	-1.497	0.134	-1.497	0.134	-0.003	-0.009	1918
44	Kushi nagar	29.674	-0.717	0.473	-0.717	0.473	-0.001	-0.003	1973
45	Lalitpur	27.853	-0.676	0.498	-0.676	0.498	-0.002	-0.008	1918
46	Lucknow*	30.741	-1.503	0.132	-2.151	0.031	-0.003	-0.011	1918
47	Maharaj ganj	29.702	-0.734	0.462	-0.688	0.491	-0.001	-0.003	1966
48	Mahoba	28.863	-0.948	0.342	-1.066	0.286	-0.003	-0.012	1918
49	Mainpuri*	31.378	-1.891	0.058	-2.561	0.011	-0.007	-0.025	1955
50	Mathura*	30.956	-1.798	0.072	-2.075	0.037	-0.007	-0.025	1973
51	Mau	30.119	-1.327	0.184	-1.327	0.184	-0.002	-0.009	1918
52	Meerut	30.886	-1.515	0.129	-1.743	0.081	-0.004	-0.015	1973
53	Mirzapur	28.986	-1.384	0.166	-1.777	0.075	-0.004	-0.014	1918
54	Moradabad*	30.622	-1.859	0.063	-2.069	0.038	-0.005	-0.017	1963
55	Muzaffarnagar**	30.829	-1.905	0.056	-2.562	0.01	-0.006	-0.019	1973
56	Pilibhit**	30.009	-1.833	0.066	-2.684	0.007	-0.003	-0.012	1966
57	Pratapgarh	30.539	-1.535	0.124	-1.892	0.058	-0.004	-0.014	1918
58	Rae Bareli*	30.782	-1.471	0.141	-2.242	0.024	-0.004	-0.014	1918
59	Rampur*	30.385	-1.971	0.048	-2.541	0.011	-0.005	-0.017	1966
60	Saharanpur**	30.484	-2.466	0.013	-3.302	0	-0.007	-0.024	1972
61	Sant kabir nagar	30.113	-1.295	0.195	-1.504	0.132	-0.001	-0.005	1966
62	Sant Ravidas nagar	29.331	-1.278	0.201	-1.621	0.105	-0.004	-0.013	1918
63	Shahjahanpur	30.629	-1.454	0.145	-1.811	0.071	-0.003	-0.011	1966
64	Shrawasti	30.051	-1.321	0.186	-1.316	0.187	-0.002	-0.007	1918
65	Siddharth Nagar	29.991	-0.917	0.359	-0.863	0.388	-0.001	-0.003	1966
66	Sitapur	30.484	-1.544	0.122	-1.451	0.146	-0.003	-0.009	1918
67	Sonbhadra	27.696	-1.315	0.188	-1.684	0.092	-0.003	-0.013	1918
68	Sultanpur*	30.595	-1.532	0.125	-2.208	0.027	-0.004	-0.013	1918
69	Unnao	30.919	-1.526	0.126	-1.791	0.073	-0.004	-0.014	1966
70	Varanasi	29.522	-1.521	0.128	-1.911	0.055	-0.004	-0.014	1918

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 16 Results of the statistical tests for average temperature of August

S.N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra	29.038	-1.026	0.304	-1.145	0.252	-0.002	-0.009	1965
2	Aligarh	29.537	-0.497	0.618	-0.561	0.574	-0.001	-0.004	1915
3	Allahabad	28.172	-0.881	0.377	-0.881	0.377	-0.001	-0.004	1928
4	Ambedkar Nagar	29.209	-1.249	0.211	-1.464	0.143	-0.001	-0.005	1951
5	Auraiya	29.139	-1.249	0.211	-1.181	0.237	-0.002	-0.009	1966
6	Azamgarh	29.186	-1.379	0.167	-1.379	0.167	-0.001	-0.005	1951
7	Baghpat	29.429	-0.884	0.376	-0.982	0.325	-0.002	-0.008	1921
8	Bahraich	29.079	-1.379	0.167	-1.231	0.218	-0.001	-0.006	1920
9	Ballia	29.277	-1.599	0.109	-1.599	0.109	-0.002	-0.006	1965
10	Balrampur	29.146	-0.896	0.37	-0.982	0.325	-0.001	-0.004	1920
11	Banda	27.917	-1.269	0.204	-1.127	0.259	-0.002	-0.007	1951
12	Barabanki	29.123	-1.278	0.201	-1.278	0.201	-0.001	-0.005	1933
13	Bareilly*	29.404	-1.867	0.061	-2.069	0.038	-0.002	-0.011	1966
14	Basti	29.175	-1.203	0.228	-1.203	0.228	-0.001	-0.004	1951
15	Bijnor	29.452	-1.591	0.111	-1.408	0.158	-0.003	-0.011	1920
16	Budaun	29.605	-1.22	0.222	-1.317	0.187	-0.002	-0.008	1966
17	Buland Shahar	29.571	-0.462	0.643	-0.445	0.656	-0.001	-0.003	1920
18	Chandauli	28.122	-0.963	0.335	-0.963	0.335	-0.001	-0.003	1915
19	Chitrakoot	27.455	-0.873	0.382	-1.019	0.308	-0.001	-0.004	1934
20	Deoria	29.158	-1.472	0.141	-1.607	0.108	-0.001	-0.006	1961
21	Etah	29.616	-0.884	0.376	-1.089	0.275	-0.002	-0.006	1965
22	Etawah	29.116	-1.261	0.207	-1.205	0.228	-0.002	-0.009	1965
23	Farrukhbad	29.479	-1.387	0.165	-1.505	0.132	-0.002	-0.009	1966
24	Fatehpur	29.001	-1.416	0.156	-1.441	0.149	-0.002	-0.007	1947
25	Faziabad	29.15	-1.107	0.267	-1.107	0.267	-0.001	-0.004	1928
26	Firozabad	29.449	-0.766	0.443	-0.945	0.344	-0.002	-0.006	1965
27	Gautam buddha nagar	29.329	-0.138	0.889	-0.133	0.893	-	-0.0005	1920
28	Ghaziabad	29.419	-0.471	0.637	-0.436	0.662	-0.001	-0.003	1920
29	Ghazipur	29.023	-1.434	0.151	-1.434	0.151	-0.002	-0.006	1965
30	Gonda	29.026	-1.18	0.237	-1.181	0.237	-0.001	-0.004	1920
31	Gorakhpur	29.161	-1.272	0.203	-1.272	0.203	-0.001	-0.004	1951
32	Hamirpur	28.266	-1.228	0.219	-1.081	0.279	-0.002	-0.008	1951
33	Hardoi	29.442	-1.591	0.111	-1.407	0.159	-0.002	-0.009	1966
34	Hathras	29.427	-0.621	0.534	-0.701	0.482	-0.001	-0.005	1965
35	Jalaun	28.398	-1.431	0.152	-1.346	0.178	-0.002	-0.01	1959
36	Jaunpur	29.181	-1.391	0.164	-1.391	0.164	-0.001	-0.006	1947
37	Jhansi	27.367	-0.974	0.329	-1.055	0.291	-0.002	-0.008	1959
38	Jyotiba phule nagar	29.559	-0.962	0.335	-0.857	0.391	-0.001	-0.006	1920
39	Kannauj	29.444	-1.341	0.179	-1.264	0.206	-0.002	-0.009	1965

40	Kanpur dehat	29.068	-1.411	0.158	-1.305	0.191	-0.002	-0.009	1966
41	Kanpur Nagar	29.226	-1.191	0.233	-1.033	0.301	-0.002	-0.007	1966
42	Kaushambi	28.344	-0.989	0.322	-1.674	0.094	-0.001	-0.004	1928
43	Kheri	29.352	-1.792	0.072	-1.579	0.114	-0.002	-0.009	1966
44	Kushi nagar	29.078	-0.997	0.318	-1.111	0.266	-0.001	-0.003	1951
45	Lalitpur	26.248	-0.656	0.511	-0.656	0.511	-0.001	-0.005	1985
46	Lucknow	29.455	-1.286	0.198	-1.286	0.198	-0.002	-0.006	1928
47	Maharaj ganj	29.012	-0.549	0.582	-0.605	0.544	-0.001	-0.001	1961
48	Mahoba	27.301	-1.066	0.285	-1.066	0.285	-0.002	-0.008	1951
49	Mainpuri	29.563	-0.939	0.347	-1.022	0.306	-0.002	-0.007	1965
50	Mathura	29.157	-0.676	0.498	-0.756	0.449	-0.002	-0.007	1985
51	Mau	29.188	-1.576	0.114	-1.576	0.114	-0.001	-0.005	1965
52	Meerut	29.591	-0.994	0.319	-0.845	0.397	-0.002	-0.007	1920
53	Mirzapur	27.835	-0.847	0.396	-0.847	0.396	-0.001	-0.003	1920
54	Moradabad	29.534	-1.298	0.194	-1.149	0.251	-0.002	-0.008	1920
55	Muzaffarnagar	29.631	-1.564	0.117	-1.623	0.104	-0.003	-0.012	1920
56	Pilibhit	29.268	-2.171	0.029	-1.929	0.053	-0.003	-0.012	1966
57	Pratapgarh	29.199	-1.174	0.241	-1.407	0.159	-0.001	-0.005	1928
58	Rae Bareli	29.431	-1.382	0.166	-1.643	0.101	-0.002	-0.007	1928
59	Rampur*	29.429	-1.795	0.072	-1.976	0.048	-0.003	-0.011	1966
60	Saharanpur*	29.549	-2.107	0.035	-2.107	0.035	-0.005	-0.017	1920
61	Sant kabir nagar	29.171	-1.093	0.274	-1.093	0.274	-0.001	-0.004	1951
62	Sant Ravidas nagar	28.107	-0.867	0.385	-0.867	0.385	-0.001	-0.003	1928
63	Shahjahanpur*	29.328	-1.879	0.061	-2.066	0.038	-0.003	-0.011	1966
64	Shrawasti	29.032	-1.252	0.211	-1.126	0.261	-0.001	-0.005	1920
65	Siddharth Nagar	29.132	-0.948	0.343	-1.032	0.301	-0.001	-0.004	1961
66	Sitapur	29.294	-1.413	0.157	-1.208	0.226	-0.002	-0.007	1920
67	Sonbhadra	26.781	-0.375	0.707	-0.375	0.706	-	-0.001	1915
68	Sultanpur	29.283	-1.246	0.212	-1.503	0.132	-0.001	-0.004	1928
69	Unnao	29.491	-1.208	0.226	-1.059	0.289	-0.002	-0.007	1966
70	Varanasi	28.307	-0.867	0.385	-0.867	0.385	-0.001	-0.003	1920

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 17 Results of the statistical tests for average temperature of September

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra*	28.919	-1.851	0.064	-2.335	0.019	-0.005	-0.019	1956
2	Aligarh*	29.431	-2.102	0.035	-2.102	0.035	-0.006	-0.022	1961
3	Allahabad**	28.122	-2.544	0.011	-3.568	0	-0.004	-0.014	1952
4	Ambedkar Nagar	29.077	-1.486	0.137	-1.261	0.206	-0.002	-0.009	1947
5	Auraiya**	28.991	-2.481	0.013	-3.181	0.001	-0.006	-0.021	1961
6	Azamgarh	29.064	-1.555	0.119	-1.404	0.16	-0.002	-0.008	1949
7	Baghpat*	29.127	-2.091	0.036	-2.052	0.041	-0.005	-0.021	1961
8	Bahraich	28.797	-0.893	0.371	-0.893	0.371	-0.001	-0.006	1961
9	Ballia	29.183	-1.151	0.249	-1.081	0.279	-0.001	-0.004	1947
10	Balrampur	28.869	-0.769	0.441	-0.769	0.441	-0.001	-0.004	1961
11	Banda*	27.879	-1.945	0.051	-2.322	0.021	-0.004	-0.014	1952
12	Barabanki	28.966	-1.607	0.107	-1.607	0.107	-0.002	-0.009	1961
13	Bareilly*	29.048	-2.165	0.031	-2.165	0.031	-0.004	-0.014	1961
14	Basti	29.009	-1.258	0.208	-1.258	0.208	-0.002	-0.006	1961
15	Bijnor**	28.775	-1.833	0.066	-2.643	0.008	-0.004	-0.015	1961
16	Budaun*	29.336	-2.388	0.016	-2.388	0.016	-0.006	-0.022	1961
17	Buland Shahar**	29.363	-1.945	0.051	-2.681	0.007	-0.005	-0.021	1961
18	Chandauli**	28.091	-1.761	0.078	-3.043	0.002	-0.002	-0.011	1952
19	Chitrakoot**	27.479	-2.102	0.035	-3.083	0.002	-0.003	-0.013	1952
20	Deoria	29.084	-0.885	0.376	-1.023	0.306	-0.001	-0.003	1947
21	Etah**	29.483	-2.571	0.01	-2.571	0.01	-0.007	-0.025	1961
22	Etawah**	29.058	-2.466	0.013	-3.181	0.001	-0.006	-0.021	1956
23	Farrukhbad**	29.265	-2.613	0.008	-2.613	0.008	-0.006	-0.021	1961
24	Fatehpur**	28.831	-2.593	0.009	-3.846	0	-0.004	-0.016	1952
25	Faziabad	29.003	-1.571	0.116	-1.571	0.116	-0.002	-0.008	1961
26	Firozabad*	29.366	-2.402	0.016	-2.402	0.016	-0.007	-0.025	1956
27	Gautam buddha nagar*	29.252	-1.841	0.065	-2.511	0.012	-0.005	-0.019	1961
28	Ghaziabad*	29.167	-1.651	0.098	-2.267	0.023	-0.004	-0.016	1961
29	Ghazipur	28.933	-1.501	0.133	-1.542	0.122	-0.002	-0.007	1947
30	Gonda	28.863	-1.231	0.218	-1.231	0.218	-0.001	-0.006	1961
31	Gorakhpur	29.072	-1.185	0.235	-1.345	0.178	-0.001	-0.006	1947
32	Hamirpur**	28.173	-1.902	0.057	-3.725	0	-0.004	-0.014	1953
33	Hardoi**	29.178	-2.469	0.013	-3.729	0	-0.004	-0.015	1961
34	Hathras*	29.361	-2.145	0.031	-2.145	0.031	-0.006	-0.023	1961
35	Jalaun**	28.298	-2.001	0.045	-3.341	0	-0.004	-0.017	1953
36	Jaunpur	28.999	-2.122	0.033	-1.814	0.069	-0.003	-0.011	1952
37	Jhansi	27.429	-1.101	0.271	-1.376	0.168	-0.002	-0.009	1953
38	Jyotiba phule nagar*	29.164	-1.726	0.084	-2.464	0.013	-0.004	-0.016	1961
39	Kannauj**	29.214	-2.616	0.008	-2.616	0.008	-0.006	-0.021	1961

40	Kanpur dehat**	28.888	-2.506	0.012	-3.975	0	-0.005	-0.021	1960
41	Kanpur Nagar**	29.019	-2.619	0.008	-3.907	0	-0.005	-0.018	1961
42	Kaushambi**	28.255	-2.715	0.006	-3.701	0	-0.004	-0.015	1952
43	Kheri	28.959	-1.246	0.212	-1.246	0.212	-0.002	-0.007	1961
44	Kushi nagar	28.987	-0.509	0.611	-0.582	0.561	-0.0002	-0.001	1986
45	Lalitpur	26.608	0.144	0.885	0.174	0.861	0.0004	0.001	1978
46	Lucknow*	29.235	-2.003	0.045	-2.003	0.045	-0.003	-0.012	1961
47	Maharaj ganj	28.903	-0.561	0.574	-0.561	0.574	-0.001	-0.002	1986
48	Mahoba**	27.382	-1.393	0.163	-2.628	0.008	-0.003	-0.011	1953
49	Mainpuri**	29.424	-2.758	0.005	-2.758	0.005	-0.007	-0.026	1961
50	Mathura*	29.029	-2.041	0.041	-2.406	0.016	-0.006	-0.021	1961
51	Mau	29.083	-1.393	0.163	-1.267	0.205	-0.001	-0.006	1947
52	Meerut**	29.203	-1.882	0.059	-2.672	0.007	-0.005	-0.017	1961
53	Mirzapur**	27.795	-2.041	0.041	-6.703	0	-0.003	-0.011	1952
54	Moradabad**	29.118	-2.029	0.042	-2.788	0.005	-0.005	-0.017	1961
55	Muzaffarnagar**	29.119	-2.217	0.026	-3.105	0.001	-0.006	-0.021	1961
56	Pilibhit	28.817	-1.581	0.113	-1.581	0.113	-0.003	-0.011	1961
57	Pratapgarh**	29.012	-2.463	0.013	-2.671	0.007	-0.004	-0.014	1952
58	Rae Bareli**	29.214	-2.599	0.009	-3.221	0.001	-0.004	-0.015	1961
59	Rampur*	29.019	-2.001	0.045	-2.001	0.045	-0.004	-0.015	1961
60	Saharanpur**	28.848	-2.547	0.011	-2.745	0.006	-0.006	-0.023	1961
61	Sant kabir nagar	29.049	-1.131	0.258	-1.131	0.258	-0.001	-0.005	1947
62	Sant Ravidas nagar**	27.999	-2.472	0.013	-3.535	0	-0.004	-0.014	1952
63	Shahjahanpur*	29.012	-2.018	0.043	-2.548	0.011	-0.004	-0.014	1961
64	Shrawasti	28.761	-1.003	0.315	-1.003	0.315	-0.001	-0.005	1961
65	Siddharth Nagar	28.907	-0.795	0.426	-0.795	0.426	-0.001	-0.004	1986
66	Sitapur	29.034	-1.633	0.102	-1.633	0.102	-0.003	-0.009	1961
67	Sonbhadra**	26.717	-1.234	0.216	-3.801	0	-0.002	-0.007	1952
68	Sultanpur*	29.112	-2.087	0.036	-2.087	0.036	-0.003	-0.012	1961
69	Unnao**	29.289	-2.425	0.015	-3.601	0	-0.005	-0.016	1961
70	Varanasi**	28.251	-2.159	0.031	-2.991	0.002	-0.003	-0.011	1952

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 18 Results of the statistical tests for average temperature of October

S.N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra	26.603	0.763	0.445	1.025	0.305	0.002	0.011	1962
2	Aligarh	26.639	0.399	0.689	0.671	0.501	0.001	0.004	1962
3	Allahabad**	25.891	3.009	0.002	3.955	0	0.007	0.028	1962
4	Ambedkar Nagar**	26.811	2.318	0.021	2.851	0.004	0.005	0.019	1962
5	Auraiya*	26.397	1.396	0.162	2.368	0.017	0.004	0.016	1962
6	Azamgarh**	26.798	2.421	0.015	2.993	0.002	0.005	0.021	1962
7	Baghpat	26.095	-0.746	0.455	-1.357	0.174	-	-0.005	1920
8	Bahraich	26.235	1.414	0.157	1.096	0.272	0.003	0.013	1962
9	Ballia*	26.761	2.874	0.004	2.393	0.016	0.006	0.023	1973
10	Balrampur	26.535	1.775	0.075	1.401	0.161	0.004	0.015	1962
11	Banda**	25.531	2.483	0.013	3.363	0	0.007	0.027	1962
12	Barabanki	26.325	2.015	0.043	1.696	0.089	0.004	0.018	1962
13	Bareilly	26.003	1.451	0.146	1.327	0.184	0.004	0.015	1973
14	Basti	26.734	2.108	0.035	1.697	0.089	0.004	0.017	1962
15	Bijnor	25.603	0.618	0.536	0.584	0.558	0.001	0.007	1973
16	Budaun	26.341	1.029	0.303	1.029	0.303	0.003	0.011	1962
17	Buland Shahar	26.488	0.306	0.759	0.444	0.656	0.001	0.003	1968
18	Chandauli**	25.875	2.963	0.003	3.816	0	0.006	0.026	1973
19	Chitrakoot**	25.322	3.067	0.002	4.161	0	0.008	0.032	1962
20	Deoria*	26.782	2.608	0.009	2.088	0.036	0.006	0.023	1973
21	Etah	26.601	0.772	0.441	0.982	0.325	0.002	0.008	1962
22	Etawah	26.476	1.361	0.173	1.855	0.063	0.004	0.015	1962
23	Farrukhbad	26.416	1.301	0.193	1.503	0.132	0.003	0.011	1962
24	Fatehpur**	26.325	2.414	0.015	3.291	0.001	0.006	0.024	1962
25	Faziabad	26.621	2.096	0.036	1.932	0.053	0.004	0.017	1962
26	Firozabad	26.704	0.688	0.491	0.923	0.355	0.002	0.008	1962
27	Gautam buddha nagar	26.378	0.127	0.898	0.155	0.876	0.000	0.0005	1968
28	Ghaziabad	26.177	0.156	0.875	0.256	0.797	0.000	0.001	1920
29	Ghazipur*	26.583	2.584	0.009	2.529	0.011	0.006	0.023	1973
30	Gonda	26.447	1.611	0.107	1.262	0.206	0.003	0.014	1962
31	Gorakhpur	26.778	2.331	0.019	2.183	0.028	0.006	0.021	1973
32	Hamirpur**	25.813	2.122	0.033	2.751	0.005	0.006	0.024	1962
33	Hardoi	26.269	1.795	0.072	2.05	0.041	0.004	0.017	1962
34	Hathras	26.701	0.477	0.633	0.844	0.398	0.001	0.005	1962
35	Jalaun*	26.036	1.749	0.081	2.245	0.024	0.006	0.021	1962
36	Jaunpur**	26.714	2.681	0.007	3.363	0	0.006	0.024	1962
37	Jhansi**	25.855	2.165	0.031	2.862	0.004	0.007	0.029	1962
38	Jyotiba phule nagar	26.162	0.803	0.421	1.145	0.251	0.002	0.009	1973

39	Kannauj*	26.462	1.312	0.189	2.123	0.033	0.003	0.013	1962
40	Kanpur dehat**	26.279	1.616	0.106	2.719	0.006	0.005	0.019	1962
41	Kanpur Nagar**	26.309	1.645	0.099	2.751	0.005	0.004	0.018	1962
42	Kaushambi**	25.985	2.937	0.003	4.129	0	0.007	0.031	1962
43	Kheri	26.128	1.526	0.126	1.136	0.255	0.003	0.014	1962
44	Kushi nagar*	26.727	2.509	0.012	2.564	0.011	0.006	0.024	1948
45	Lalitpur	26.608	0.144	0.885	0.174	0.861	0.000	0.002	1978
46	Lucknow*	26.421	2.243	0.024	2.243	0.024	0.005	0.021	1962
47	Maharaj ganj*	26.681	2.295	0.021	2.346	0.018	0.005	0.02	1972
48	Mahoba**	25.527	2.359	0.018	3.069	0.002	0.007	0.028	1962
49	Mainpuri	26.637	0.871	0.384	1.148	0.251	0.002	0.009	1962
50	Mathura	26.588	0.176	0.859	0.316	0.751	0.001	0.002	1962
51	Mau*	26.771	2.619	0.008	2.218	0.026	0.005	0.022	1973
52	Meerut	26.126	0.078	0.937	0.129	0.897	0.000	0.0007	1920
53	Mirzapur**	25.691	3.035	0.002	3.726	0	0.007	0.028	1962
54	Moradabad	26.044	1.075	0.282	1.006	0.314	0.003	0.011	1962
55	Muzaffarnagar	25.96	-0.263	0.792	-0.425	0.671	-	-0.003	1920
56	Pilibhit	25.902	1.526	0.126	1.188	0.234	0.004	0.017	1962
57	Pratapgarh**	26.638	2.851	0.004	5.124	0	0.007	0.027	1962
58	Rae Bareli**	26.615	2.732	0.006	3.532	0	0.006	0.025	1962
59	Rampur	25.931	1.289	0.197	1.183	0.236	0.003	0.014	1973
60	Saharanpur	25.525	-0.633	0.526	-0.962	0.335	-	-0.007	1920
61	Sant kabir nagar	26.75	2.311	0.021	1.868	0.061	0.005	0.019	1973
62	Sant Ravidas nagar**	25.863	3.085	0.002	5.372	0	0.008	0.029	1962
63	Shahjahanpur	26.101	1.685	0.091	1.531	0.125	0.004	0.016	1962
64	Shrawasti	26.329	1.483	0.137	1.167	0.243	0.003	0.013	1962
65	Siddharth Nagar	26.661	2.223	0.026	1.802	0.071	0.004	0.017	1948
66	Sitapur	26.224	1.535	0.124	1.208	0.226	0.004	0.015	1962
67	Sonbhadra**	24.719	3.134	0.001	3.806	0	0.007	0.029	1973
68	Sultanpur**	26.723	2.591	0.009	2.591	0.009	0.006	0.022	1962
69	Unnao**	26.421	1.992	0.046	3.207	0.001	0.005	0.021	1962
70	Varanasi**	26.084	2.787	0.005	3.537	0	0.007	0.027	1962

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 19 Results of the statistical tests for average temperature of November

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra*	21.074	3.031	0.002	2.541	0.011	0.0105	0.049	1961
2	Aligarh**	20.725	3.489	0	3.095	0.002	0.0116	0.055	1961
3	Allahabad**	20.67	5.753	0	3.952	0	0.0194	0.093	1961
4	Ambedkar Nagar**	21.464	5.291	0	4.285	0	0.0158	0.073	1956
5	Auraiya**	20.818	4.264	0	3.095	0.001	0.0149	0.072	1961
6	Azamgarh**	21.526	5.343	0	4.294	0	0.0158	0.073	1956
7	Baghpat**	20.109	3.713	0	3.041	0.002	0.0113	0.056	1967
8	Bahraich**	21.166	3.958	0	3.546	0	0.0119	0.056	1939
9	Ballia**	21.716	5.291	0	4.265	0	0.0160	0.073	1962
10	Balrampur**	21.481	4.183	0	3.807	0	0.0122	0.057	1938
11	Banda**	20.173	5.711	0	4.256	0	0.0198	0.098	1962
12	Barabanki**	20.912	5.314	0	4.191	0	0.0159	0.076	1939
13	Bareilly**	20.721	3.689	0	2.878	0	0.0106	0.051	1939
14	Basti**	21.537	4.872	0	3.951	0	0.0150	0.069	1956
15	Bijnor*	20.018	3.209	0.001	2.529	0.011	0.0090	0.045	1939
16	Budaun	20.802	3.703	0	2.706	0.006	0.0113	0.054	1939
17	Buland Shahar**	20.538	3.761	0	2.917	0.003	0.0121	0.059	1961
18	Chandauli**	20.669	5.849	0	4.546	0	0.0194	0.093	1961
19	Chitrakoot**	20.106	5.753	0	4.199	0	0.0204	0.101	1962
20	Deoria**	21.774	4.898	0	4.567	0	0.0139	0.063	1956
21	Etah**	20.921	3.426	0.001	2.582	0.009	0.0111	0.053	1939
22	Etawah**	20.895	3.918	0	2.975	0.002	0.0139	0.066	1961
23	Farrukhbad**	20.977	4.062	0	3.017	0.002	0.0132	0.063	1939
24	Fatehpur**	20.774	5.609	0	3.912	0	0.0192	0.092	1962
25	Faziabad**	21.321	5.231	0	4.136	0	0.0159	0.074	1956
26	Firozabad**	20.956	3.299	0.001	2.712	0.006	0.0114	0.054	1961
27	Gautam buddha nagar**	20.464	3.761	0	2.988	0.002	0.0128	0.062	1962
28	Ghaziabad**	20.244	3.813	0	3.174	0.001	0.0123	0.061	1967
29	Ghazipur**	21.451	5.404	0	4.379	0	0.0170	0.079	1961
30	Gonda**	21.264	4.821	0	3.909	0	0.0146	0.068	1956
31	Gorakhpur**	21.752	4.883	0	4.488	0	0.0139	0.064	1956
32	Hamirpur**	20.351	5.123	0	4.182	0	0.0182	0.089	1962
33	Hardoi**	20.882	4.924	0	3.739	0	0.0150	0.071	1939
34	Hathras**	20.882	3.085	0.002	3.012	0.002	0.0104	0.049	1961
35	Jalaun**	20.606	4.542	0	3.273	0.001	0.0161	0.078	1961
36	Jaunpur**	21.354	5.661	0	4.191	0	0.0174	0.081	1962
37	Jhansi**	20.806	4.262	0	3.231	0.001	0.0165	0.079	1962

38	Jyotiba phule nagar**	20.403	3.726	0	2.995	0.002	0.0113	0.055	1939
39	Kannauj**	20.915	4.299	0	3.267	0.001	0.0144	0.069	1961
40	Kanpur dehat**	20.682	4.611	0	3.365	0.001	0.0162	0.078	1961
41	Kanpur Nagar**	20.682	5.094	0	3.931	0	0.0172	0.083	1961
42	Kaushambi**	20.621	5.658	0	4.096	0	0.0204	0.096	1961
43	Kheri**	21.005	3.831	0	3.377	0	0.0115	0.054	1939
44	Kushi nagar**	21.883	4.476	0	4.135	0	0.0125	0.057	1954
45	Lalitpur**	21.332	4.121	0	3.476	0	0.0173	0.081	1962
46	Lucknow**	20.813	5.563	0	4.222	0	0.0174	0.083	1956
47	Maharaj ganj**	21.876	4.357	0	3.996	0	0.0122	0.055	1954
48	Mahoba**	20.448	5.068	0	4.112	0	0.0190	0.092	1962
49	Mainpuri**	21.037	3.663	0	2.777	0	0.0128	0.061	1961
50	Mathura**	20.857	2.619	0.008	2.604	0.009	0.0086	0.042	1961
51	Mau**	21.646	5.343	0	4.765	0	0.0155	0.071	1962
52	Meerut**	20.215	3.643	0	2.948	0.003	0.0113	0.056	1967
53	Mirzapur**	20.531	5.886	0	4.488	0	0.0195	0.095	1962
54	Moradabad**	20.451	3.565	0	2.634	0.008	0.0105	0.051	1939
55	Muzaffarnagar**	20.072	3.348	0.001	2.669	0.007	0.0098	0.048	1967
56	Pilibhit*	20.734	3.356	0.001	2.465	0.013	0.0098	0.047	1939
57	Pratapgarh**	21.204	5.794	0	3.943	0	0.0186	0.087	1961
58	Rae Bareli**	21.045	5.696	0	4.005	0	0.0185	0.088	1961
59	Rampur*	20.535	3.356	0	2.441	0.014	0.0093	0.045	1939
60	Saharanpur**	19.781	2.868	0.004	2.277	0.022	0.0086	0.043	1967
61	Sant kabir nagar**	21.713	4.881	0	4.502	0	0.0142	0.065	1956
62	Sant Ravidas nagar**	20.559	5.875	0	4.064	0	0.0196	0.095	1961
63	Shahjahanpur**	20.884	4.195	0	3.287	0	0.0128	0.061	1939
64	Shrawasti**	21.319	4.022	0	3.615	0	0.0118	0.055	1938
65	Siddharth Nagar**	21.627	4.366	0	4.017	0	0.0123	0.056	1954
66	Sitapur**	20.908	4.684	0	3.595	0	0.0136	0.064	1939
67	Sonbhadra**	19.864	5.684	0	4.531	0	0.0197	0.099	1961
68	Sultanpur**	21.262	5.554	0	3.872	0	0.0170	0.079	1956
69	Unnao**	20.756	5.366	0	4.029	0	0.0174	0.084	1961
70	Varanasi**	20.762	5.808	0	4.069	0	0.0183	0.087	1962

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.

Table 20 Results of the statistical tests for average temperature of December

S. N.	District	mean	Mann-Kendall Test		Modified-MK Test		Sen's Slope	% Change in temperature	Shift Detection Test
			Zmk	P-value	Zmmk	P-value			
1	Agra**	16.074	4.293	0	4.744	0	0.013	0.083	1951
2	Aligarh**	15.672	4.929	0	4.930	0	0.015	0.097	1950
3	Allahabad**	16.617	6.069	0	6.069	0	0.018	0.106	1942
4	Ambedkar Nagar**	17.011	5.855	0	6.269	0	0.015	0.088	1940
5	Auraiya**	15.855	5.161	0	5.506	0	0.015	0.096	1951
6	Azamgarh**	17.133	5.925	0	5.925	0	0.015	0.089	1940
7	Baghpat**	15.234	4.537	0	4.537	0	0.014	0.088	1950
8	Bahraich**	16.481	4.649	0	7.240	0	0.013	0.081	1956
9	Ballia**	17.211	5.598	0	5.598	0	0.016	0.092	1940
10	Balrampur**	16.904	4.808	0	10.113	0	0.012	0.073	1956
11	Banda**	16.238	5.661	0	6.018	0	0.016	0.096	1951
12	Barabanki**	16.339	5.774	0	14.221	0	0.015	0.094	1940
13	Bareilly**	15.694	4.169	0	5.340	0	0.013	0.084	1956
14	Basti**	16.958	5.506	0	13.345	0	0.014	0.081	1940
15	Bijnor**	15.074	3.684	0	5.069	0	0.012	0.080	1950
16	Budaun**	15.643	4.765	0	4.765	0	0.015	0.096	1950
17	Buland Shahar**	15.522	5.071	0	5.071	0	0.016	0.100	1950
18	Chandauli**	16.584	6.295	0	6.295	0	0.018	0.110	1951
19	Chitrakoot**	16.356	5.858	0	5.858	0	0.017	0.102	1951
20	Deoria**	17.301	5.404	0	5.317	0	0.013	0.077	1940
21	Etah**	15.707	4.725	0	5.027	0	0.014	0.091	1950
22	Etawah**	15.838	5.081	0	5.400	0	0.015	0.097	1951
23	Farrukhbad**	15.853	5.193	0	5.561	0	0.015	0.093	1950
24	Fatehpur**	16.541	5.725	0	6.106	0	0.016	0.098	1951
25	Faziabad**	16.750	5.734	0	14.954	0	0.015	0.088	1940
26	Firozabad**	15.820	4.655	0	5.063	0	0.015	0.091	1951
27	Gautam buddha nagar**	15.522	4.860	0	4.860	0	0.015	0.098	1950
28	Ghaziabad**	15.259	4.765	0	4.765	0	0.015	0.096	1950
29	Ghazipur**	17.048	6.052	0	6.052	0	0.017	0.097	1940
30	Gonda**	16.703	5.459	0	17.698	0	0.014	0.084	1940
31	Gorakhpur**	17.241	5.505	0	7.917	0	0.013	0.077	1940
32	Hamirpur**	20.352	5.124	0	4.182	0	0.018	0.089	1962
33	Hardoi**	15.967	5.390	0	11.294	0	0.015	0.094	1950
34	Hathras**	15.827	4.487	0	4.879	0	0.014	0.086	1950
35	Jalaun**	15.806	5.361	0	5.718	0	0.016	0.101	1951
36	Jaunpur**	17.002	6.057	0	6.057	0	0.016	0.096	1940
37	Jhansi**	16.420	5.178	0	5.072	0	0.016	0.099	1951
38	Jyotiba phule nagar**	15.379	4.577	0	5.929	0	0.014	0.094	1950
39	Kannauj**	15.936	5.225	0	5.608	0	0.015	0.091	1951
40	Kanpur dehat**	15.936	5.392	0	5.750	0	0.015	0.096	1951

41	Kanpur Nagar**	15.981	5.424	0	5.812	0	0.015	0.092	1951
42	Kaushambi**	16.623	5.977	0	5.977	0	0.017	0.103	1942
43	Kheri**	16.249	4.360	0	6.024	0	0.014	0.085	1956
44	Kushi nagar**	17.368	4.713	0	5.297	0	0.012	0.067	1940
45	Lalitpur**	17.643	4.782	0	4.782	0	0.015	0.087	1951
46	Lucknow**	16.247	5.942	0	6.407	0	0.016	0.097	1950
47	Maharaj ganj**	17.319	4.528	0	15.069	0	0.011	0.066	1940
48	Mahoba**	16.368	5.390	0	5.750	0	0.016	0.095	1951
49	Mainpuri**	15.866	4.762	0	5.069	0	0.014	0.088	1951
50	Mathura**	15.950	3.580	0	3.944	0	0.011	0.066	1950
51	Mau**	17.207	5.835	0	5.835	0	0.015	0.088	1940
52	Meerut**	15.182	4.398	0	4.398	0	0.014	0.090	1950
53	Mirzapur**	16.601	6.271	0	6.271	0	0.018	0.109	1951
54	Moradabad**	15.456	4.236	0	5.626	0	0.014	0.089	1950
55	Muzaffarnagar**	15.130	4.025	0	4.025	0	0.013	0.083	1950
56	Pilibhit**	15.866	3.863	0	5.164	0	0.013	0.081	1956
57	Pratapgarh**	16.877	6.023	0	6.023	0	0.017	0.100	1942
58	Rae Bareli**	16.590	6.107	0	6.537	0	0.017	0.100	1942
59	Rampur**	15.539	3.970	0	5.045	0	0.013	0.081	1956
60	Saharanpur**	14.958	3.299	0.001	4.246	0	0.011	0.073	1950
61	Sant kabir nagar**	17.153	5.520	0	8.078	0	0.013	0.078	1940
62	Sant Ravidas nagar**	16.530	6.194	0	6.194	0	0.018	0.111	1951
63	Shahjahanpur**	15.902	4.710	0	8.837	0	0.014	0.088	1950
64	Shrawasti**	16.651	4.620	0	10.077	0	0.013	0.076	1956
65	Siddharth Nagar**	17.095	4.852	0	13.596	0	0.012	0.070	1940
66	Sitapur**	16.193	5.158	0	7.870	0	0.015	0.090	1950
67	Sonbhadra**	16.253	6.167	0	6.559	0	0.019	0.115	1951
68	Sultanpur**	16.806	6.130	0	6.560	0	0.016	0.095	1940
69	Unnao**	16.130	5.797	0	6.269	0	0.016	0.096	1940
70	Varanasi**	16.620	6.321	0	6.321	0	0.018	0.108	1951

*Significant at 95% Confidence interval. **Significant at 99% Confidence interval.