TEMPORAL ANALYSIS OF TEMPERATURE TRENDS IN THE METROPOLITAN AREA OF LAHORE, PAKISTAN

S. Zia, S. A. Shirazi*, M. N. Bhalli* and R. Alam*

Department of Geography, Lahore College for Women University, Lahore, Pakistan
*Department of Geography, University of Punjab, Lahore, Pakistan

Corresponding Author: sz_25@yahoo.com

ABSTRACT: The impact of temperature change has been analyzed which has diverse effects on global, regional, and local scale. It is a significant step for planning climate change strategy. This research aims to investigate temperature trends on seasonal and annual basis for five decades (1962-2012) of Lahore metropolitan area (LMA) which covers an area of about 2306 sq. km. In order to detect trends in temperature time series, linear regression test of parametric statistics has been applied. Temperature variables included mean (MAT), mean maximum (MMxT), and mean minimum (MMiT), which were considered for analyzing both on annual and seasonal basis. Anomalies of temperature were plotted and it was observed that percent of annual mean temperature, and mean minimum temperature were increased at the rate of 2.5 and 5.5 percent per year, respectively. While, Mean Maximum temperature had decreased at the rate of 0.6 percent a year. Each year was divided into four seasons, (a) winter, (b) hot-dry spring, (c) monsoon and (d) post-monsoon. The percentages of significant trends obtained for each parameter in the different seasons, showed an increasing temperature trend during eight months of year except in June to September where non-significant temperature trends were observed.

Keywords: Temperature, linear regression test, annual trend, seasonal trend

INTRODUCTION

Global temperature rising was a major theme and serious issue of this millennium and temperature is one parameter for finding out the state of climate anywhere. Temperature trend was defined by (Parry, 2007) as a gradual and regular movement in time series, in which the value averages increase or decrease, was termed as trend. Climate change research has been conducted all over the world including Pakistan.

Yue and Hashino, (2003) performed temporal analysis for duration of 1900 to 1996 and investigated temperature trends. Trends were found to be significant through statistical test analysis but increases were found more profound in winter and spring. Domonkos and Tar, (2003) studied the long-term changes for observing temperature and precipitation data series in Hungary from1901 to 1998. They applied both the Student's t test to find linear trends and Mann–Kendall test. With the help of the results and analysis of tests it was concluded that in 20th century increase of mean temperature was not statistically significant but annual precipitation rate was considerably lessened. Turkes and Sumer, (2004) investigated Tmax, Tmin and temperature range in Turkey from 1929 to 1999 to find geospatial and temporal pattern of trends. Maximum temperature increase was not really considerable with minute changes. However, cooling in comparison was found to be significant in most parts of the country usually throughout the year.

Vose, (2005) found global Tmin rise more intensely by 0.20°C per decade than global Tmax by 0.14°C per decade in USA. From 1950 to 2004, producing a significant negative diurnal temperature range (DTR) with rate of -0.07°C per decade. However, global Tmin and Tmax were raised at almost same rate of 0.29°C per decade. Gadgil and Dhorde (2005) studied temporal changes in temperature in Pune city of India, from 1901 to 2000. He applied linear regression. Result of analysis revealed statistically significant decline in MAT and Tmax. Zhang et al., (2009) investigated the spatial as well as temporal patterns of temperature extremes with implication of non parametric test Mann–Kendall and parametric linear regression test. Result of analysis showed that Tmin has stronger and statistically significant increasing trend than Tmax seasonally. The changes of the Tmax were more with significant warming trends than Tmin in its occurrence and intensity. Recently, Sajjad et al., (2009) investigated about the correlation between urbanization and temperature variability. They applied regression method to investigate temperature transform from 1950-2007 by dividing it into two equal phases for MAT (mean annual temperature). MMiT (mean minimum temperature) and MMxT (mean maximum temperature) were also analyzed for entire time period. Authors found prominent change in MMiT

which was 2.51 ^{o}C. However, MMxT almost remain same. On basis of MMiT and MMxT, MAT was analyzed with 0.89 ^{o}C increment. Studies on the temporal variability and trends in temperature were very limited for LMA. Therefore, this study presented long-term temperature trend analyses by utilizing monthly and annual time series data of LMA over the last five decades. The aim was to evaluate change in temperature trends.

MATERIALS AND METHODS

Study area: Located at 31^{o} 15' to 31^{o}42' north latitude and 74 ^{o} 01' to 74^{o}39' east longitude, Lahore is bounded on the northern and western side by Sheikhupura district, on the eastern side with its center lying within 25 km of international border with India and on the south by Kasur district. The Ravi River passes away from the north side of Lahore. It is part of capital of the province of Punjab and is the growing metropolis of the country. Under the jurisdiction of LDA, now, Lahore has been given the name of LMA which is an area not only comprised of Lahore district, but also having some parts of Kasur district and Ferozewala Tehsil of Sheikhurpura district. It covers an area of 2,306 sq km. it slopes from 213 m (700 ft) above mean sea level in north-east to 208 m (683 ft) in the south-west (NESPAK, 2004).

Dataset: In order to study the temporal trend of temperature, monthly meteorological data including monthly average and seasonal average including maximum and minimum temperature, was collected from Pakistan Metrological Department (PMD) Jail road met station of Lahore. Data of time series covered last five decades from 1962 to 2012. The collected temperature data was in centigrade scale.

Data analysis: Three different data time series of T (max), T (min), T (mean), for the specified study area were analyzed by Pearson correlation and Linear regression method. A statistical test gives scholar fundamental insight for formulating decisions quantitatively for a process or processes (Von Storch, 1999).

For this purpose, firstly data was complied and T (max), T (min), T (mean), was calculated by monthly averages on seasonal and yearly basis. Then, Scatter plots in graphing feature of SPSS 19.0, were used to understand structures and distributions of variables in order to select what types of test was opt either linear, Spearman or Kendal test to analyze data series.

After plotting, the graph of these variables observed data positions in direction from the lower left-hand corner of the graph to the upper right. So, linear regression test was applied to understand relationship between temperature and MAT.

For annual analysis of temperature, quantitative measurement of temperature including its different parameters, were used as dependent variable and the independent variable was time period on yearly basis. It was analyzed by the following formula; (Seber and Lee, 2012 p.35)

$Y = \alpha + \beta x + e$

Where,

Y-Outcome of temperature (A) a) MAT; b) MMxT and; c) MMiT

(B) (a) Winter; (b) Hot dry Spring; (c) Summer; and (d) Autumn

X - Time unit: (A) year; (B) season

$\alpha + \beta x$ - Linear (systematic) relation between *Y* and *X*

α - Mean of *Y* when *X*=0 (*Y*-intercept)

β - Variation in mean of *Y* when *X* increases (slope)

e - Random error term

Here, for both datasets concentrating on three groups of statistics including the coefficients, the significance tests, and the R square statistic from this output were interpreted for each data time series of temperature (Seber and Lee, 2012).

RESULTS AND DISCUSSION

Annual-Based Analysis of Temperature Trends (1962-2012):

MAT: MAT temperature increased at LMA from 23.8^{o}C to 25.6^{o}C and degree of temperature change was seen to increase. MAT showed an increasing trend during the last five decades with the 2002, 2004, and 2009 as the warmest years and 1983 as lowest recorded MAT year in the series (Figure. 1). The warmest years on record were 2002, 2004 and 2009 by temperature of 25.6^{o}C over the long-term from 1962 to 2012. Warmest years of the study period (1962–2012) were typically observed during last decade. The trend line also indicated almost linear trend of the MAT over the 5 decades observation period from 1962 to 2012.

Increase of the temperatures could be apparently cleared from 1990s to onwards in temperature data series. Warming and increasing trend in LMA was confirmed by the results and enumerated by an increasing trend with 2.5 percent increase per year.

MMxT*:* The R^{2} value for MMxT was -0.017 which showed a high negative correlation between years and temperature. Data line of equation showed a decreasing trend of temperature at a significant level of 95% and because P-value was greater than 0.05.

Values of unstandardized coefficient obtained for regression statistics showed that for every unit increase in year, it was expected 0.005 unit decrease in temperature, holding all other factors constant.

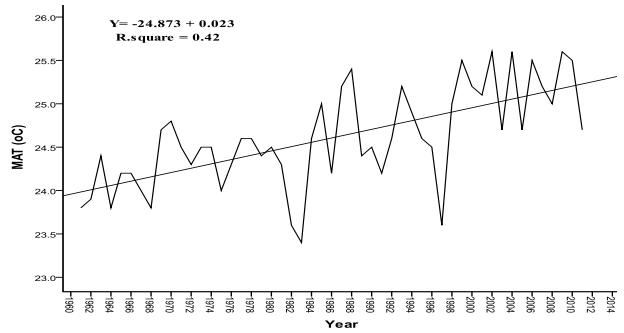

Figure 1: MAT Anomalies

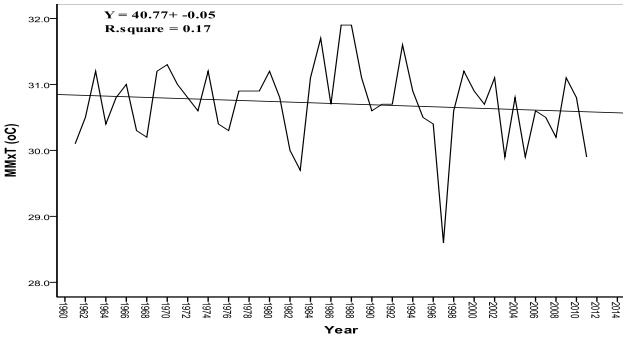

Figure 2: MMxT Anomalies

MMiT: By analyzing MMiT for whole phase (1962-2012), the significant warming trend was observed. The obtained R^2 value was 0.75 which showed a good positive correlation between years and temperature. Line of equation showed that there was an increasing trend of temperature at a significant level of 95% and because P-value was less than 0.05.

By following was the same interpretation rule for MAT and MMxT, it was interpreted for MMiT that for every unit increase in a year, it was expected a 0.055 unit increase in temperature, holding all other factors constant.

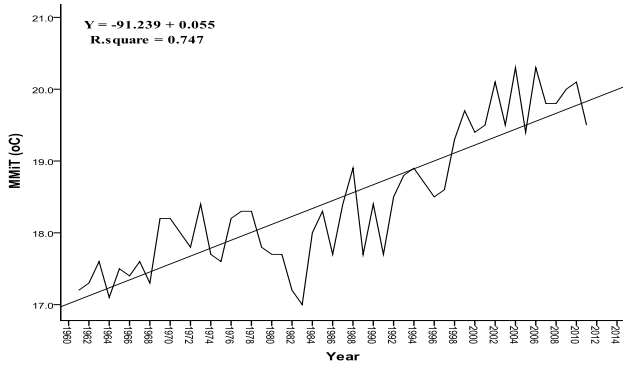

Figure 3: MMiT Anomalies

Seasonal-Based Analysis of Temperature Trend (1962-2012): Lahore experiences four seasons which includes Winters (Dec- Feb) with few western disturbances causing rains, Hot and dry (Spring March - May), Summer (June-Sep) with dusty rain storms, Heat wave periods, rainy Monsoon and dry but pleasant Autumn from October to November (Heiden, 2011).

Winters: The R^2 value for winter season was 0.318 which showed as a low positive correlation between years and winter temperature the months of December to February. Line of equation showed that there was an increasing trend of temperature at a significant level of 95% and because P-value was less than 0.05.So, it was concluded that for every unit increase in a year, it was expected of a .032 unit increase in temperature of winter season, holding all other factors constant.

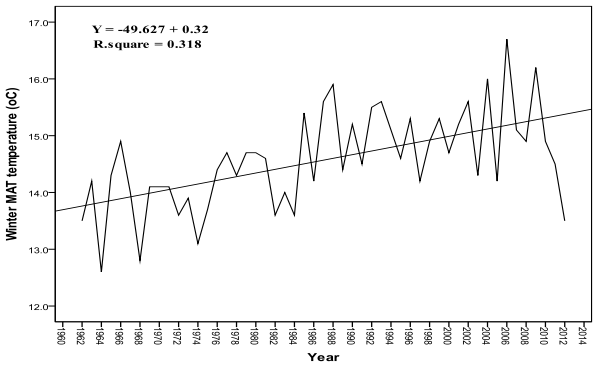

Figure 4: Mean temperature of winter (1962-2012)

By analyzing seasonal based trends of mean temperatures, maximum warming trends were seen in winter season. All figured trends were positive during the last 50 years period from 1962 to 2012 with 3.2 percent increase in temperature per year.

Hot dry spring: The R^2 value for hot dry spring was 0.253 which showed a low positive correlation between years and hot spring temperature for the months of March and April. Line of equation showed that there was an increasing trend of temperature at a significant level of 95% and because P-value was less than 0.05. So, it was concluded that for every unit increase in year, it was expected of a .044 unit increase in temperature of spring season, holding all other factors constant.

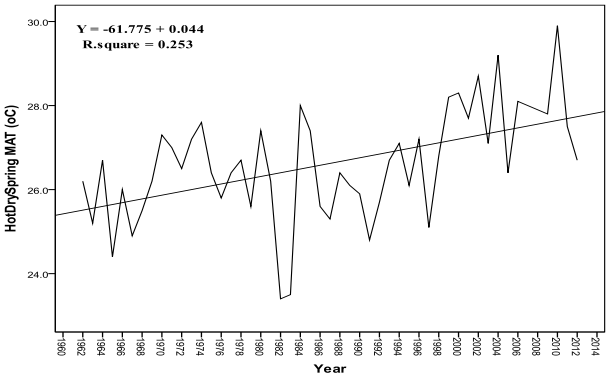

Figure 5: Mean temperature of hot dry (1962-2012)

Summer mean temperature: In summer, slightly decreasing trends were observed at LMA with 6 percent unit decrease per year. The R^2 value was 0.031 which showed a high negative correlation between years and summer temperature for the months of May and September. Line of equation showed that there was a decreasing trend of temperature at a significant level of 95% and because P-value was less than 0.05. So, it was concluded that for every unit increase in year, it was expected of a .006 unit decrease in temperature of summer season, holding all other factors constant.

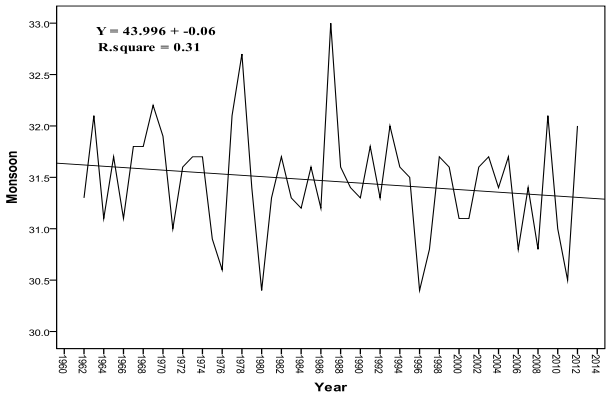

Figure 6: Mean temperature of summer (1962-2012)

Autumn mean temperature: The R^2 value was 0.281 which showed a low positive correlation between years and winter temperature for the months of December to February. Line of equation showed that there was an increasing trend of temperature at a significant level of 95% because P-value was less than 0.05. So, it was concluded that for every unit increase in a year, it was expected of a .032 unit increase in temperature of winter season, holding all other factors constant.

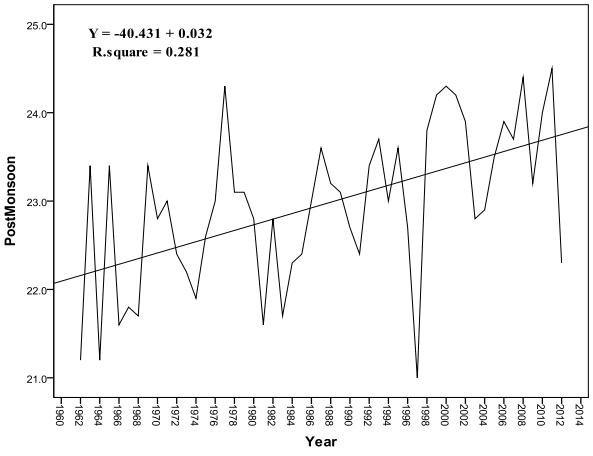

Figure 7: Mean temperature of autumn (1962-2012)

Results illustrated real and clearer picture that the change of temperature over the fifty-one years study period was higher for MMxT than MMiT. The analysis of meteorological data for the defined period indicated an increase of 5.5 percent per year in the average minimum temperature and decrease of 0.6 percent per year in the average maximum temperature of Lahore. Moreover, by comparing results of all seasonal trends of mean temperatures in last five decades, the strongest warming trends were observed in all seasons except summer. The most significant increasing trend appeared in the hot dry spring months of March, April and May in LMA. As a results showed that temperature has increased by 0.032°C for winter season, 0.044°C for hot-dry spring and by 0.032°C per year respectively for the post-monsoon. On the other hand, it was observed that summer temperature decreased by 0.006 °C per year.

Conclusion: By analysis, it was proved that temperature records were observed with some increasing trend either minor or major for the LMA with detailed insight during selected time period from 1962-2012. So, it was an alarming situation to some extent and making it crucial to realize its expected disturbances to city managers and policy makers in environmental setting and human life within LMA with constant rate of change in temperature trends.

Acknowledgements: This research paper is an excerpt of M. Phil thesis of the first author.

REFERENCES

Domonkos, P., and K. Tar. Long-term changes in observed temperature and precipitation series 1901–1998 from Hungary and their relation to larger scale changes. Theoretical and applied climatology, 75(3-4): 131-147 (2003).

Gadgil, A., and A. Dhorde. Temperature trends in twentieth century at Pune, India. Atmospheric Environment, 39(35): 6550-6556 (2005).

Heiden, P. Pakistan: ABDO Publishing Company. (2011).

NESPAK. LDA Integrated Master Plan for Lahore 2021: Volume I – Existing scenario. 2004-2021 (2004).

Parry, M. L. (Ed.). Climate Change 2007: Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Fourth Assessment Report of the IPCC Intergovernmental Panel on Climate Change (Vol. 4). UK: Cambridge University Press (2007).

Sajjad, S., S. A. Shirazi, M. A. Khan, and A. Raza. Urbanization effects on temperature trends of Lahore during 1950-2007. International J.

Climate Change Strategies and Management, 1(3), 274-281 (2009).

Seber, G. A., and A. J. Lee. Linear regression analysis (Vol. 936). John Wiley and Sons, p. 35 (2012).

Türkeş, M., and U. Sümer. Spatial and temporal patterns of trends and variability in diurnal temperature ranges of Turkey. Theoretical and applied climatology, 77(3-4): 195-227 (2004).

Von Storch, H. Misuses of statistical analysis in climate research (pp. 11-26). Springer Berlin Heidelberg (1999).

Vose, R. S. Reference station networks for monitoring climatic change in the conterminous United States. J. of climate, 18(24): 5390-5395 (2005).

Yue, S., and M. Hashino. Temperature trends in Japan: 1900–1996. Theoretical and applied climatology, 75(1-2): 15-27 (2003).

Zhang, Q., C. Y. Xu., Z. Zhang. and Y. D. Chen. Changes of temperature extremes for 1960–2004 in Far-West China. Stochastic Environmental Research and Risk Assessment, 23(6): 721-735 (2009).