40 Years of Surface Air Temperature Trend of Madurai City, Tamil Nadu, India

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Abstract— Surface air temperature data of Madurai city, Tamil Nadu state, India were analyzed using statistical techniques to demark the signs of climate change. Seasonal and annual trends were analyzed for the 1961-2000 period surface air temperature data of Madurai city and the distinct temporal distribution of the temperature was found from the study. The trends of Tmax (maximum temperature), Tmin (minimum temperature) and TM (Mean Temperature) were plotted and compared. The average annual temperatures of Tmax, Tmin and TM have raised 0.080C, 0.60C and 10C respectively. Summer average temperature raised 20C and other seasons have also got 10C temperature rise in 40years. The confidences were computed for to identify the temperature trend of Madurai city. The confidence values are positive and imply the warming of surface air temperature. The trends of annual and seasonal temperatures and confidence were compared for two periods: 1961-1980 & 1981-2000 to identify the pattern of temperature trend in Less Urbanized Period (LUP) and More Urbanized Period (MUP). The positive correlation with urbanization of temperature was noticed from the study. The Diurnal Temperature Range (DTR) also evaluated and the results support the warming effects of the surface air temperature in Madurai city in recent years.

Key words: Surface Air Temperature, Warming, Temperature Rise, Diurnal Temperature & Climate Change

I. INTRODUCTION

Climate change is the most debatable topic in 21st century, Scientists are dedicatedly taking efforts on modeling of climate scenarios and it has been in attention and actions taken by all countries to reduce the climate change impacts. Intergovernmental Panel of Climate Change, an intergovernmental body, which was established to tackle the effect of Climate Change and it is an urgent need to the living hood. Hence the climate sensitivity has been studied at regional and local level and mitigation and adaptation measures are taken with the better understanding climate parameters. The rainfall, humidity and temperature are the climate factors have been studied extensively by the climatologists all over the world to quantify the changes. The historical records are used to detect the changes and to construct the climate future models. The temperature is having a vital role in the earth and atmosphere sciences which had been affected by the regional and local climate scenarios.

Over the last 50 years global average surface air temperature has increased ($+0.74^0C \pm 0.18^0C$) at great rate in 1905-2005. (IPCC 2007) Vose et al., (2005) found that the global Minimum temperature (Tmin) increased more rapidly than maximum temperature during 1950-2004 and reported that Tmin and Tmax increased up to $+0.29^0C$.

This paper examined the decadal trends of annual and seasonal temperature trends of Maduai city, Tamil Nadu, India. Usually, the surface air temperature is affected due to land use/ cover and urbanization (Bonan, 2001: Kalnay and Cai, 2003) and aerosol loading (Wild et al., 2007). Urbanization and land use/ cover changes are reaching maximum in recent years in the study area and the impact of climate change also prominently evidenced through temperature and rainfall trends.

II. STUDY AREA

The study area located in N 9^058' and E 77^0 10' and the physiography of the surrounding area of the city is structured hills, and Vaigai river is flowing across the city. The study area is in tropical climate zone which is a hotter environment. The population of Madurai is 10,16,885 in 2011. The area of the city is 248 km^2. The average rainfall in the district is 857.6mm and the mean temperatures are around 34^0C in days and 18^0C in nights.

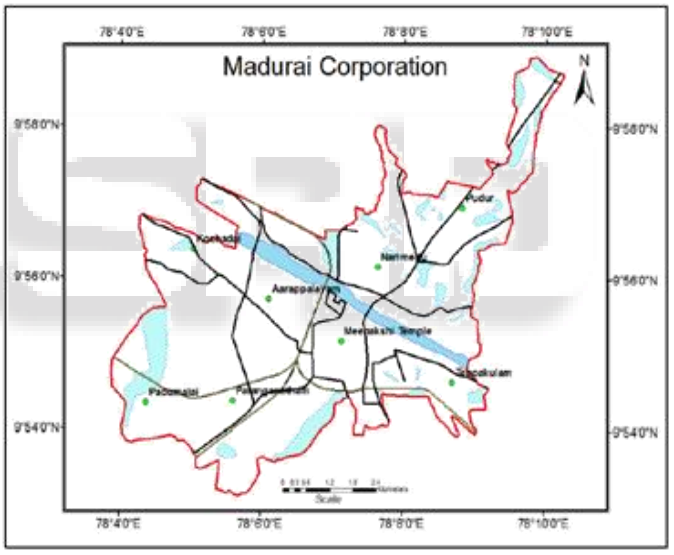

Fig. 1: Study Area – Madurai City

III. DATA AND METHODOLOGY

Daily and Monthly mean temperature data for Madurai district have collected from Indian Meteorological Division, Chennai and for this study 1961- 2000 data were used. Using the Data Completeness Assurance method seasonal and annual averages were computed mentioned in Stafford et al. (2000) and Vose et al. (2005). This method is used to minimize the misinterpretation of data. Seasonal and annual averages and linear least square regression trends were analyzed in this study. Using standard meteorological definitions, seasons were defined as winter (DJF), Summer (MAM), Spring (JJA) and Fall (SON). The temperature trends and precipitation of the two periods: 1961-1980 and 1981-2000 were compared and the statistical significance in the temperature trends was determined. The standard errors were used to indicate the inclination of actual temperature ranges from the mean temperature. The variations of

temperature ranges at 95% confidence level were also computed to demark the significant warming or cooling in the climate.

IV. Result and Discussion

The average annual and seasonal surface air temperatures were computed for 1961-2000 period for Madurai city. The mean temperature (TM) was calculated from average daily maximum and minimum temperatures. The monthly mean of Maximum temperature (Tmax), minimum temperature (Tmin) and Mean temperature (TM) were plotted and linear regression trends were also drawn for 1961-2000 period. The Tmax ranges from 33^0C to 36^0C, Tmin ranges from 23^0C to 26^0C and TM ranges from 28^0C to 30^0C.Many researchers have analysed annual and seasonal trends of surface air temperature and precipitation throughout the world (Al Bhuhari 2010; Croitoru et al. 2012; Karpouzos et al. 2010; Partal and Kahya 2006; Sum et al. 2010; Smadi 2006; Smadi and Zgohoul 2006; Serra et al. 2001) The annual trends of Madurai city have been changed harmonically, but they have gradually upraised in recent years. The average maximum temperature, minimum temperature and the mean temperature were raised to 0.8^0C, 0.6^0C and 1^0C respectively. From this investigation, a strong warming has noticed in Madurai city in 1961-2000 period. (Fig.2)

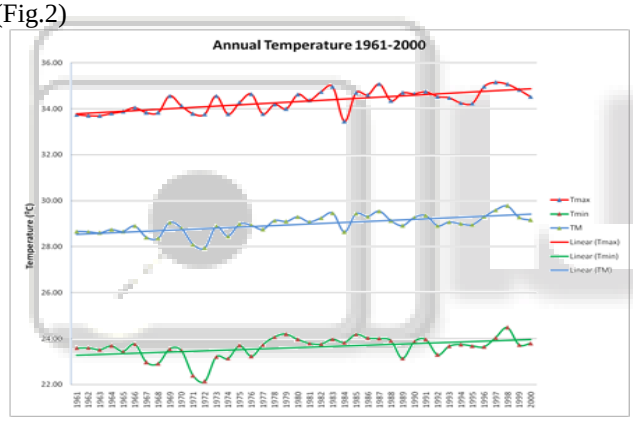

Fig. 2: Annual Temperature 1961-2000

A detailed investigation was conducted in seasonal temperature ranges that reveals stronger warming have been experienced in 1961-2000 summer periods. The average Tmax of the summer has risen to 20C and other seasons were also get warm up to 10C both in day and night time. (Fig. 3, 4, 5 & 6) The rise of night time temperature indicated the effect of greenhouse gases and urbanization. The linear regression trend lines were also formulated against the temperature trends in all seasons. The linear trend lines are moving upward, which denotes the stronger warming in Madurai city.

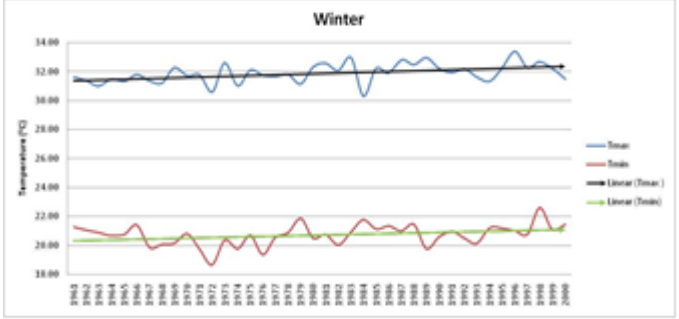

Fig. 3: Winter Temperature 1961-2000

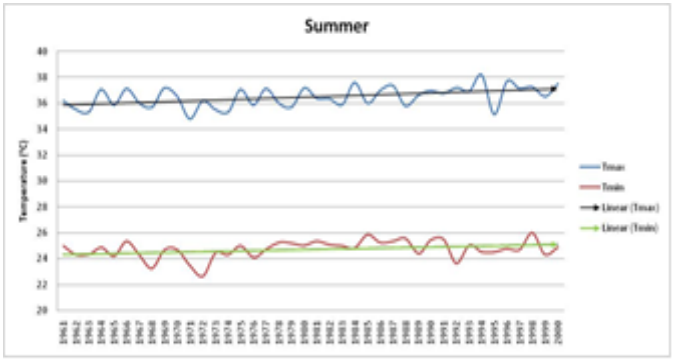

Fig. 4: Summer Temperature 1961-2000

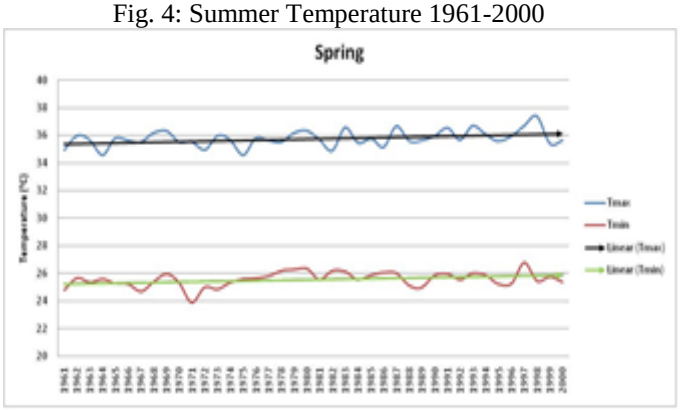

Fig. 5: Spring Temperature 1961-2000

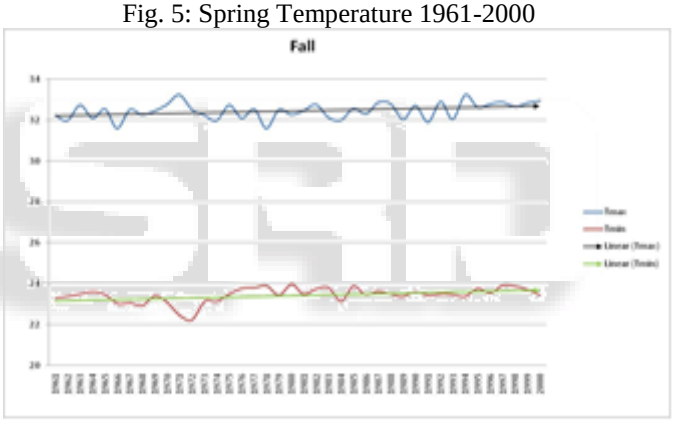

Fig. 6: Fall Temperature 1961-2000

The warming of surface air temperature was assured by evaluating the confidence level computed from the standard deviation. For the reliable results, the significance of the confidence level has been calculated at 95% confidence level. Cordero et al. (2011) studied the California state temperature trends and used confidence level (at 95%) to detect the warming and cooling stations of the state. The positive values indicate the warming and negative values indicate the cooling effects of surface air temperature. The temperature trend of Madurai city has positive confidence values and indicates statistically significant warming at 95% confidence level. Tmax and Tmin both are having the values of standard error 0.046 and linear regression trend upraised up to (at 95% confidence value) +0.140C and these values are disclosed the definite rise of average surface air temperature in Madurai city in 1961-2000. Similarly, the seasonal temperatures also have positive confidence level values that mean warming has reported in all seasons. (Table.1)

1961-2000	Winter Tmax	Winter Tmin	Summer Tmax	Summer Tmin	Spring Tmax	Spring Tmin	Fall Tmax	Fall Tmin	Annual Tmax	Annual Tmin	T Mean
Mean	31.89	20.72	36.49	24.73	35.78	25.58	32.46	23.44	34.32	23.62	28.97
Standard Deviation	0.66	0.73	0.81	0.69	0.59	0.53	0.40	0.37	0.46	0.46	0.40
Standard Error	10.58	11.20	10.51	11.20	10.94	11.06	11.08	10.70	8.44	10.66	8.85
Confidence	0.20	0.23	0.25	0.21	0.18	0.17	0.12	0.11	0.14	0.14	0.12

Table 1: Statistical significance of Annual Average Temperature for 1961-2000

Population and urbanization are the major forcing factors for the climatic instability. The effect of population and urbanization on climate was studied from the comparison of surface air temperature 1961-1980 & 1981-2000. The population density of Madurai city was increased after 1980, hence the period 1981-2000 may considered as More Urbanized Period and 1961-1980 also taken as Less Urbanized Period in this study. Dhorde et al. (2009) studied the impact of urbanization in four major cities of India and they correlated the temperature trends of two different periods (LUP & MUP). Rao, Jaswal and Kumar evaluated 15 cities, but they revealed that there were no significant changes in temperature due to urbanization. Even so, De & Dandekar (2011) conveyed that many urban locations of India is getting warming in recent years and are vulnerable to climate hazards. Madurai city is one of the growing city in state Tamil Nadu, India which also having higher population and industrialization since 1950s. The city is well known for the floating population in daytime. In this study, maximum daytime, night time and mean temperature of LUP and MUP were plotted to identify the periodical changes of temperature trends. The temperature changes were significantly noticed in those two periods. (Fig.7 & Table.2)

The seasonal and annual means of the two periods were mentioned in Table.2 and depicted the changes occurred in recent years. The standard deviation, standard error and confidence intervals of the two periods were in different ranges and having positive confidence trend.The temperature trends are having increasing tendency both day and night time. The rise in minimum temperature is one of the effects of urbanization that is reported in Mumbai (Dhorde et al. 2009). In this case both minimum and maximum temperature have been showing increasing tendency. This also suggests that urbanization is not only the cause for the temperature rise but it is among one of many causes like, regional scale atmospheric aerosols, CO_2 emission etc.,

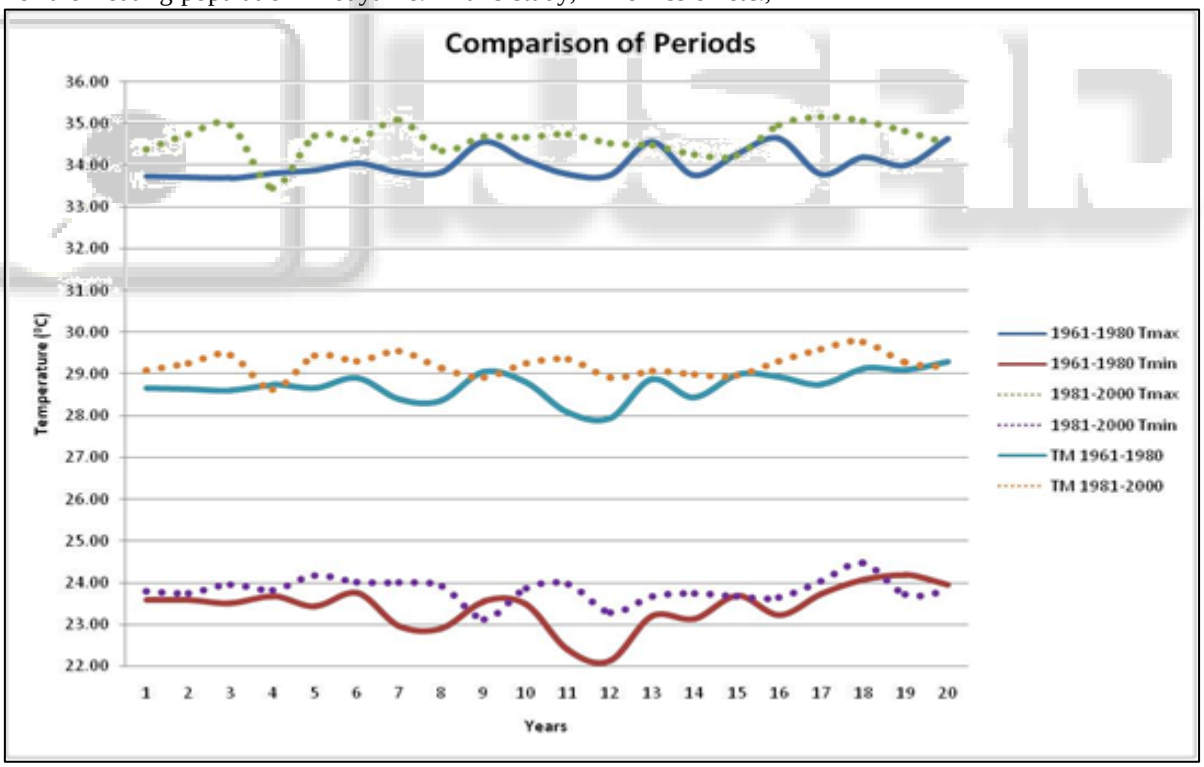

Fig. 7: Comparison of Annual Average Temperature for 1961-1980 & 1981-2000 periods

Confidence	Winter Tmax	Winter Tmin	Summer Tmax	Summer Tmin	Spring Tmax	Spring Tmin	Fall Tmax	Fall Tmin	Annual Tmax	Annual Tmin
1961-1980	0.22	0.33	0.32	0.31	0.23	0.26	0.17	0.19	0.15	0.23
1980-2000	0.32	0.29	0.35	0.26	0.29	0.20	0.18	0.09	0.18	0.14

Tabl. 2: Comparison of Confidences of 1961-1980 & 1981-2000 periods

Fig. 8: Comparison of Confidence Intervals for 1961-1980 & 1981-2000 periods

The confidences of two periods were also investigated and the results depicted that the minimum temperatures are not showing increasing trend with respect to urbanization and population growth. However, maximum temperature is having positive relationship with urbanization and increased in recent years. The Tmax confidence of winter, summer, spring and average annual are high in MUP, Tmin confidence of Winter, Summer, Spring and average annual are high in LUP and during Fall the values of Tmax and Tmin are not significantly changed in MUP. (Table.2 & Fig.8 & 9)

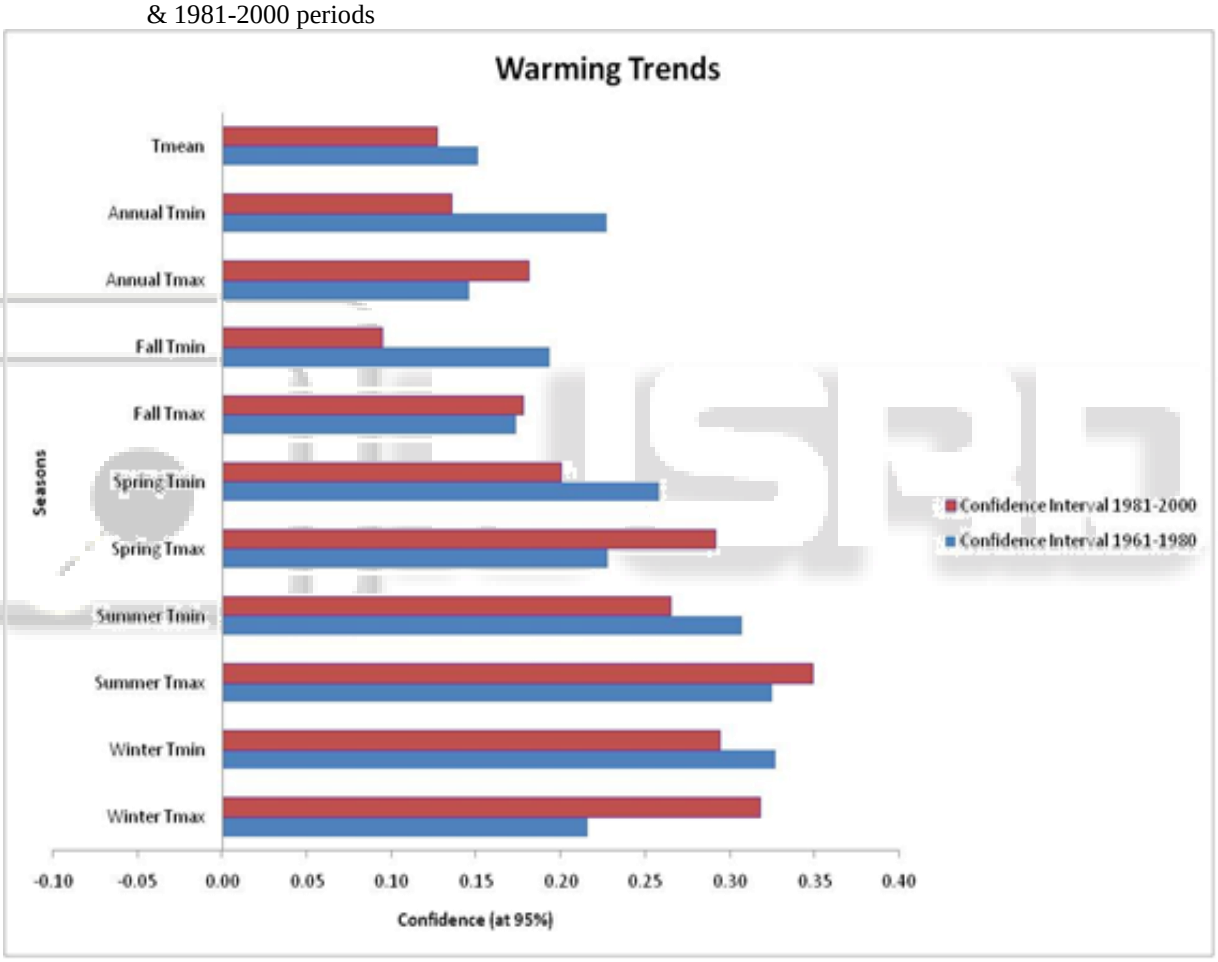

Fig. 9: Confidence Levels for 1961-1980 & 1981-2000 periods

Mean monthly diurnal temperature range is derived from differences between maximum and minimum temperature. DTR has taken as an indicator of large scale climate changes. Karl et al. (1991) disclosed that the significant decrease or extreme of mean temperature has reflected in DTR. Jones (1992) has investigated monthly extreme Tmax and Tmin of Sudan and reported that the trend of DTR was similar to the surface air temperature trends. Similar to annual and seasonal mean temperature the DTR also has been changed due to the climate forcing mechanisms. Mean DTR of Madurai city has been ranged from 4.80C to 5.810C in 1961-2000 period (Fig.10). In 1984, the lowest temperature has reported (4.810C) and maximum DTR has reported in 1972, 1975, 1990 and 1996. An increase or decrease of DTR is having a close relationship with urbanization. Decrease in DTR implies the increase of night time temperature and urban hear islands. In this case, both Tmin and Tmax has risen which is the result of collective natural and anthropogenic factors. Hence a more detailed regional investigation is needed to quantify the impacts of urbanization on warming.

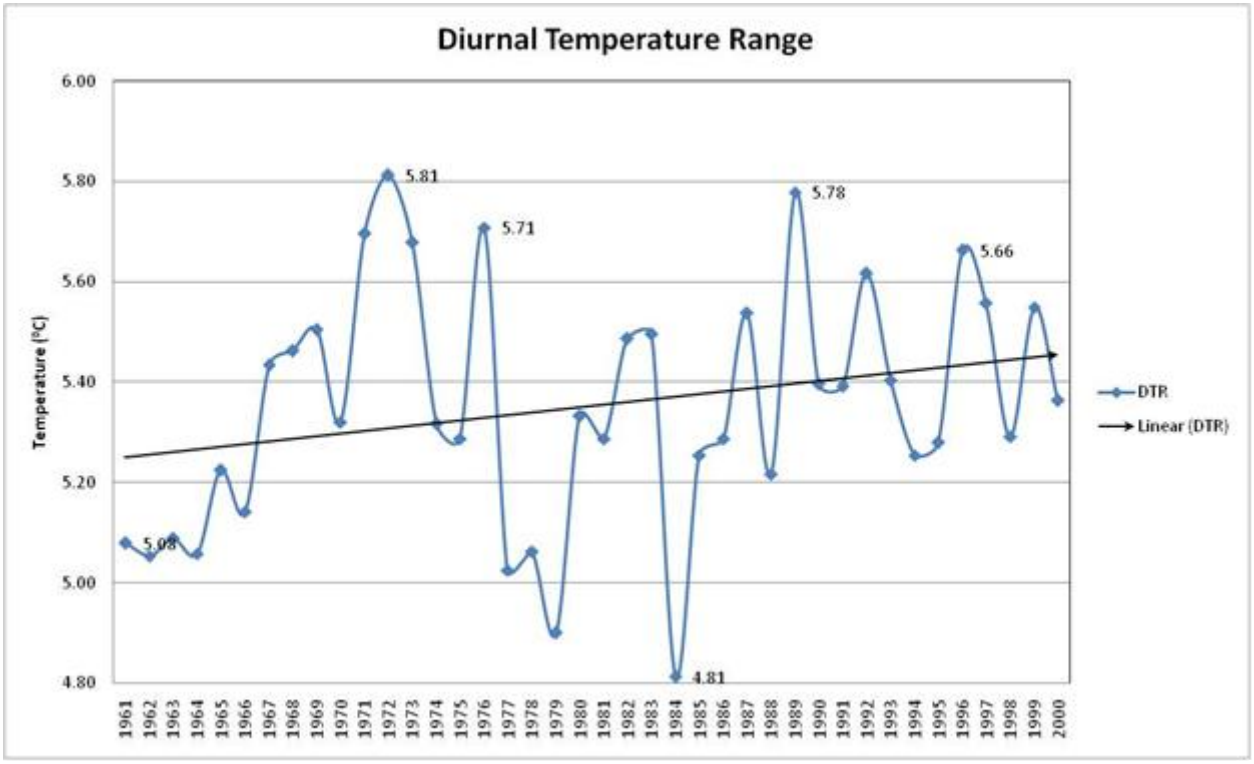

Fig. 10: Diurnal Temperature Ranges for 1961-2000 periods

V. Conclusion

In this study seasonal and annual surface air temperature trends were analyzed using statistical techniques. Annual mean Tmax, Tmin and TM were increased for 0.8^0C, 0.6^0C and 1^0C respectively. Tmax, Tmin and TM of 1961-2000 were observed and the increasing tendency of summer, winter, spring and fall was noticed in Madurai city. Particularly, summer has $+2^0$C rise in Tmax and 1^0C rise in Tmin. Other all seasons have the 1^0C rise of mean Tmax and Tmin. For the statistical significance of temperature trends, the confidence also computed and it shows positive warming indices. Strong warming trend was detected in MUP. When compared with LUP, the mean annual and seasonal temperatures were increased in MUP. The annual average Trends of MUP is overlying above the trends of LUP. This indicates the positive correlation of temperature with urbanization and population growth. The DTR variations are also the important outcome which reveals the impact of urbanization in Madurai climate. Both Tmin and Tmax were raised similarly DTR also had risen. The impact of greenhouse gases reflected in increase of Tmin and as well as the Tmax has rose due to the local and regional climate forcing factors. But, a significant warming sign reported in Madurai city from this investigation. From the results, increased aridity and surface and ground water resources will be subjected to risk. May be the further climatological studies can be attribute more information regarding the forcing mechanisms of Madurai city climate.

VI. Acknowledgement

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