Maximum and Minimum Temperature trends during 1970-2009 at Pune, India

1. Introduction

Changes in the environmental conditions in big cities is due the impacts of urbanization, land use, increased population and high rate of pollution. Climatic change is one of the most important issues of present times. Unlike the greenhouse gases, which have a predominantly warming effect, atmospheric aerosols could either warm or cool the atmosphere depending upon the size, distribution and optical properties. Of all the climatic elements, temperature plays a major role in detecting climatic change brought about by urbanization and industrialization. It is now recognized that urbanization and changing land-use influence minimum temperature. Due to very high levels of energy consumption and friction in cities, significant amount of waste heat is stored in the walls of buildings and streets which gets released during the night, thereby making the night warmer. Local temperature is thus one of the major climatic elements to record environmental changes brought about by industrialization and urbanization. In view of the importance of air temperature, as indicated above, it would be of interest to study the long-term variation of surface air temperature in Pune city, for the last four decades, of which the last decade saw phenomenal rise in urbanization and industrialization.

This paper, therefore, attempts to study temporal variation in temperature over Pune city, India, during the period 1971–2009.

Some past studies:

A study (Hingane, 1996) estimates rising trends of 0.84 and 1.39 °C per 100 years in the mean surface temperature calculated for Mumbai and Kolkata, respectively. Another study by Thapliyal and Kulshreshtha (1991) on temperature trends over Indian cities indicates a slight warming within the limits of 1 SD between 1901 and 1990. Another important important study by A. Gadgil et. al. is the significant cooling trend in mean annual temperature, which is more predominant during winter season. The study also revealed that the summer season shows significant cooling trend due to decrease in T_{max}. On the contrary the monsoon season shows warming trend. This attributed this to significant increase in the low cloud amount during this season. This cooling trend in Pune's temperature is also 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.

Objective

Therefore, the objective of the present work is to investigate the annual and seasonal temperature trends over Pune. It is also of interest to find out whether the overall change in temperature is due to change in minimum or maximum temperature. This will help to know changes in night and day temperatures as well.

Physiological features of Pune:

Pune, centbelonging to Maharashtra state of India, is located in a basin surrounded by uplands and hills. It is situated on the western margin of the Deccan plateau, few miles away from the

main range of the Western Ghats, at the confluence of rivers Mula and Mutha. The climate of the city is on the whole dry and invigorating. The temperature characteristics of Pune city are reported in Table 1, which indicates higher variability during March, June and November which are the transition months . The mean monthly temperature is high (29.8°C) in May while December witnesses a low (20.2°C). However, the mean maximum temperature for April is (37.7°C) more than that of May (36.9°C). The high mean monthly temperature in May can be attributed to higher mean minimum temperature as compared to that of April. The low mean temperature in December is due to lower maximum temperature than that of January. Although there is not much difference in mean temperature of December and January.
(to copy from climatology of pune district)

Table - 1
Monthly and seasonal temperature mean

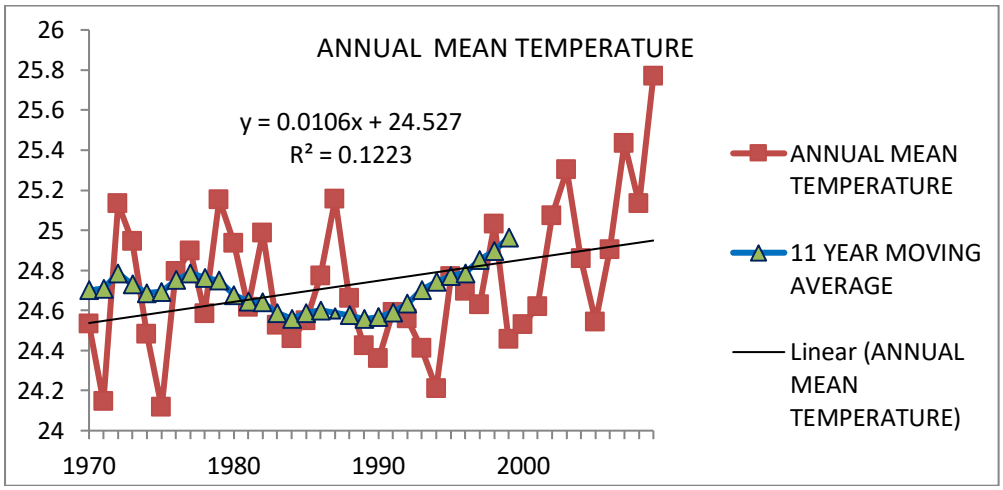
MONTH	MAX TEMP (°C)	MIN TEMP (°C)	MEAN TEMP (°C)	STD. DEV.	CV
JAN	29.8	11.1	20.4	1.8	3.1
FEB	32.1	12.2	22.2	2.0	4.1
MAR	35.6	15.8	25.7	2.1	4.4
APR	37.7	19.9	28.8	1.9	3.6
MAY	36.9	22.6	29.8	1.4	2.0
JUN	31.8	23.0	27.4	1.9	3.6
JUL	28.3	22.3	25.3	1.1	1.3
AUG	27.5	21.6	24.6	0.9	0.9
SEP	29.4	20.9	25.1	1.2	1.5
OCT	31.5	18.5	25.0	1.6	2.6
NOV	30.3	14.5	22.4	2.2	5.0
DEC	29.1	11.3	20.2	1.9	3.5
ANNUAL	**31.7**	**17.8**	**24.7**	**3.4**	**11.4**
Winter	**30.3**	**11.5**	**20.9**	**2.1**	**4.3**
Summer	**36.7**	**19.4**	**28.1**	**3.2**	**10.5**
Monsoon	29.2	22.0	25.6	2.1	4.6
Post Monsoon	30.9	16.5	23.7	2.3	5.5

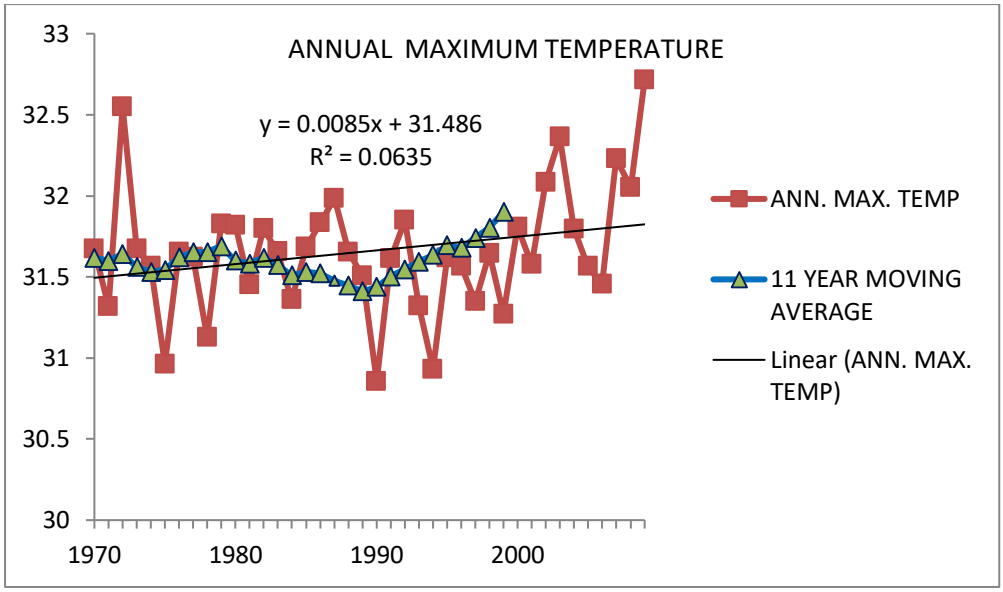
2. Data and methodology

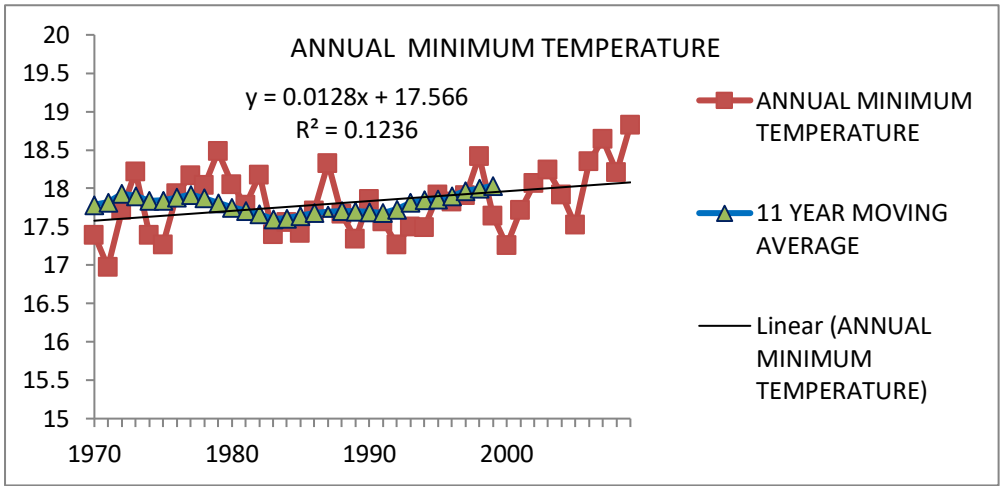
Daily maximum and minimum temperature data during the period 1970–2009 were obtained from India Meteorological Department (IMD), Pune. From the basic temperature data, mean maximum (T_{max}), mean minimum (T_{min}) and mean temperature, along with their standard deviation (SD) and coefficient of variation have been computed for each month and four seasons, viz winter, summer, monsoon and post- monsoon, that are depicted in Table 1. December, January and February are considered for the analysis of winter temperature as these 3 months record lower temperatures (Table 1). While computing the mean for winter season December of the previous year is included. March, April and May are months with highest mean maximum temperatures and, therefore, represent the summer season. June to September months constitute monsoon season and October & November are considered as post monsoon These data were then subjected to a 11-year running mean to find the trends. A linear trend line was added to the series to simplify the trend.

3/ Annual Temperature trends

The mean annual, T_{max} C and T_{min} C along with 11-year moving mean and trend line are presented in Fig. 1. The mean annual temperature shows a significant long-term increasing trend. However, it can be seen from the figure that there had been a relatively cooler period during 1988–2006. Similar features are also seen in annual T_{min} C and T_{max} C with slight same cool periods. A conspicuous cooling after mid-1950s can be seen in both T_{min} and T_{max} temperatures. However, it is observed that there is no significant trend in T_{min}, while T_{max} shows cooling trend, significant at 0.05 level.




ANNUAL MAXIMUM TEMPERATURE
y = 0.0085x + 31.486
R² = 0.0635
33
32.5
32
31.5
31
30.5
30
1970
1980
1990
2000
ANN. MAX. TEMP
11 YEAR MOVING AVERAGE
Linear (ANN. MAX. TEMP)

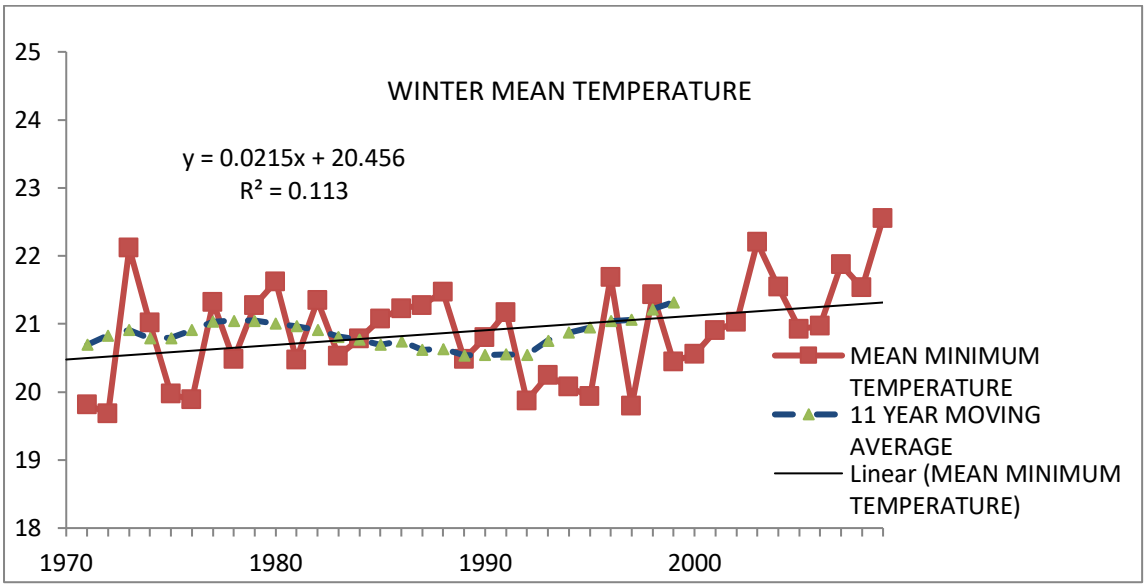

ANNUAL MINIMUM TEMPERATURE
y = 0.0128x + 17.566
R² = 0.1236
20
19.5
19
18.5
18
17.5
17
16.5
16
15.5
15
1970
1980
1990
2000
ANNUAL MINIMUM TEMPERATURE
11 YEAR MOVING AVERAGE
Linear (ANNUAL MINIMUM TEMPERATURE)

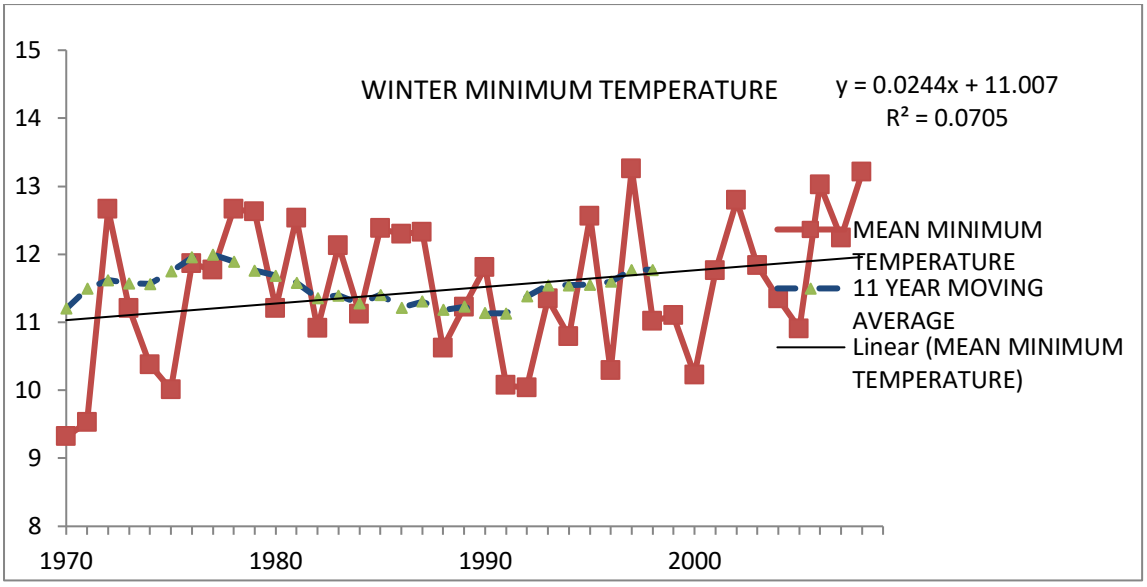
4. **Seasonal temperature trends**

The mean temperature and the T_{max} C and T_{min} C for winter, summer, monsoon and post monsoon seasons during the period 1970–2009 are presented in Fig. 2. The figure also gives 11-year moving average of the temperature.

4.1 Winter Season

The winter mean temperature clearly depicts two epochs of
shows an increasing trend in spite of intermittent increases, which is statistically significant at 0.01 level (Table 2). T_{min} and T_{max} also show cooling. However, this cooling trend of T_{min} is significant at 0.01 level. The T_{max} during winter though shows decrease, is not statistically significant. The 11-year running mean indicates that winter temperature is increasing up to mid-1950s and then decreasing. While minimum temperature depicts two epochs of warming around mid-1920s and mid-1950s, significant decrease in winter mean temperature can be attributed to predominant decline in minimum temperature (Fig. 2).





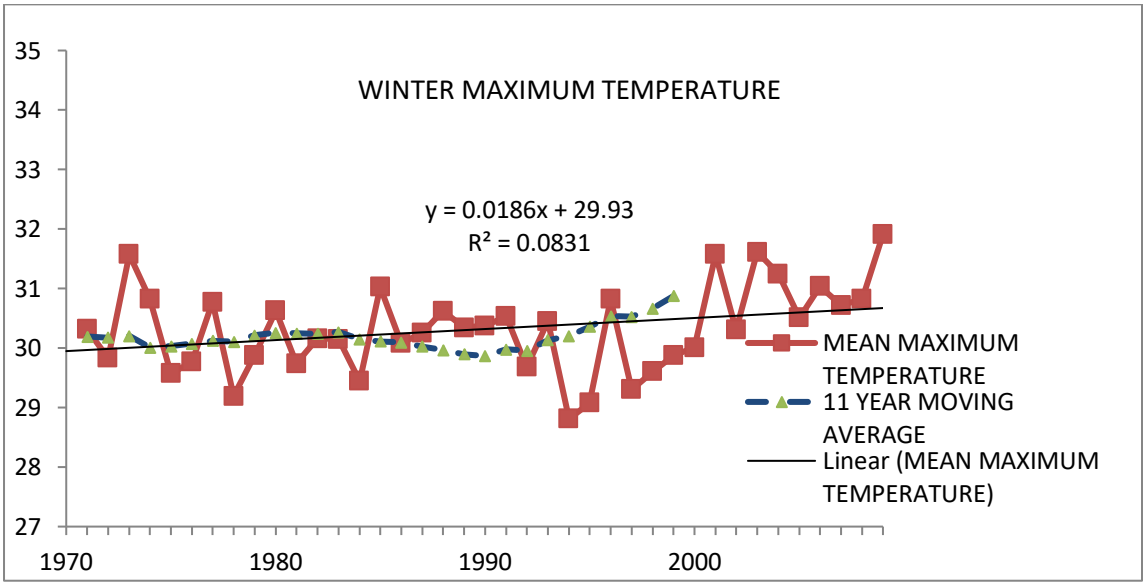
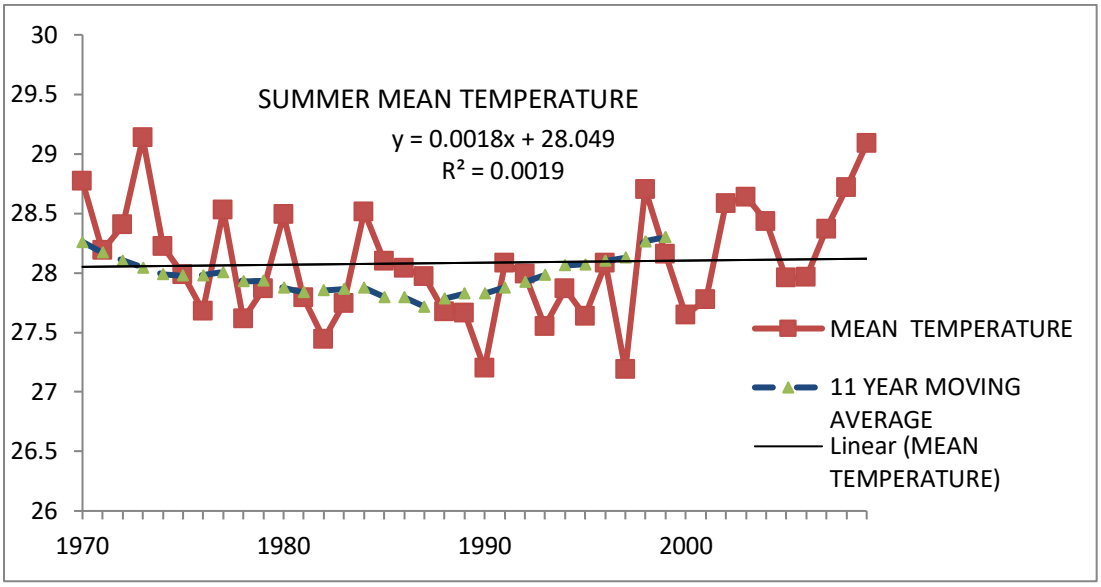
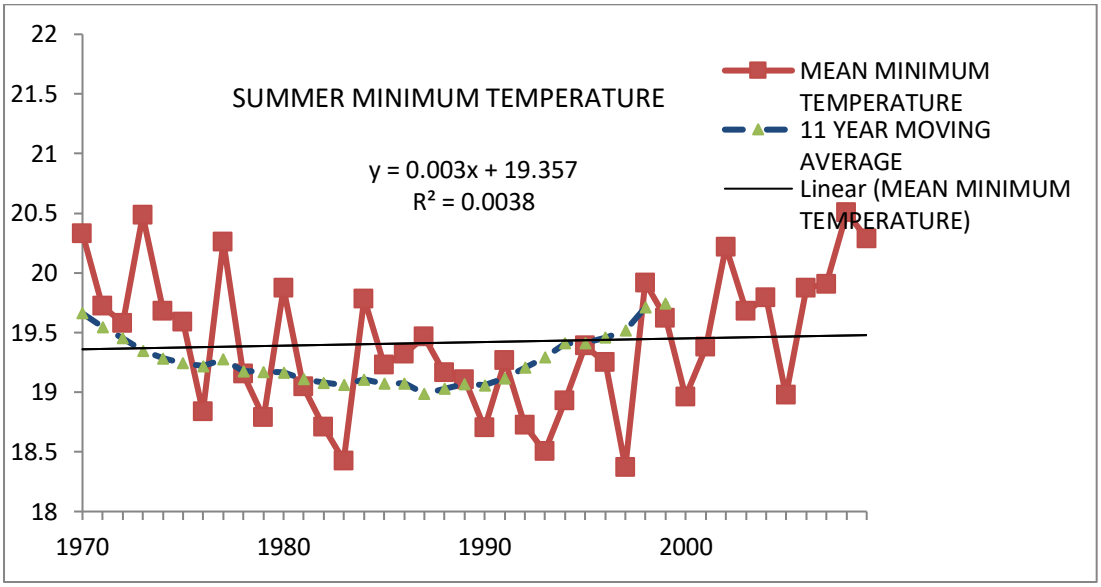


Fig.2 Temperature trends for winter, summer, monsoon and post monsoon seasons at Pune.

4.2. Summer

The summer mean temperature also shows a decreasing trend, significant at 0.05 level. However, unlike winter season this decrease is caused by significant fall in maximum temperature. The Mann–Kendall test indicates that T_{max} decrease is significant at 0.05 level, while T_{min} shows no particular significant trend. Therefore, it can be inferred that daytime temperatures in summer are significantly decreasing. The 11-year running mean indicates that the temperature during summer was higher during 1940s to early 1960s after which it has come down.


SUMMER MEAN TEMPERATURE
y = 0.0018x + 28.049
R² = 0.0019
30
29.5
29
28.5
28
27.5
27
26.5
26
1970
1980
1990
2000
MEAN TEMPERATURE
11 YEAR MOVING AVERAGE
Linear (MEAN TEMPERATURE)


SUMMER MINIMUM TEMPERATURE
y = 0.003x + 19.357
R² = 0.0038
22
21.5
21
20.5
20
19.5
19
18.5
18
1970
1980
1990
2000
MEAN MINIMUM TEMPERATURE
11 YEAR MOVING AVERAGE
Linear (MEAN MINIMUM TEMPERATURE)

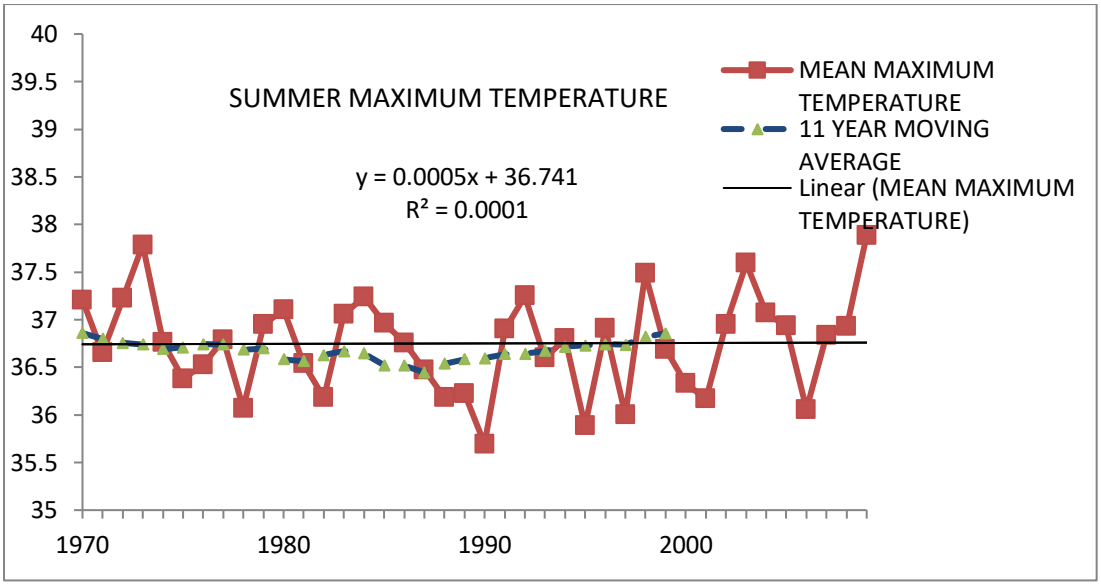
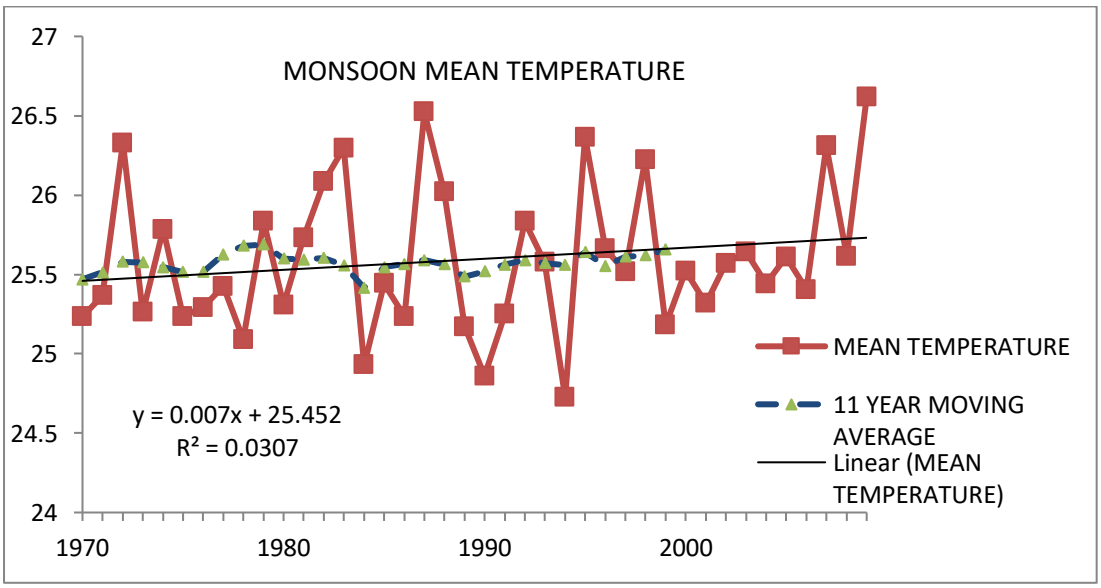


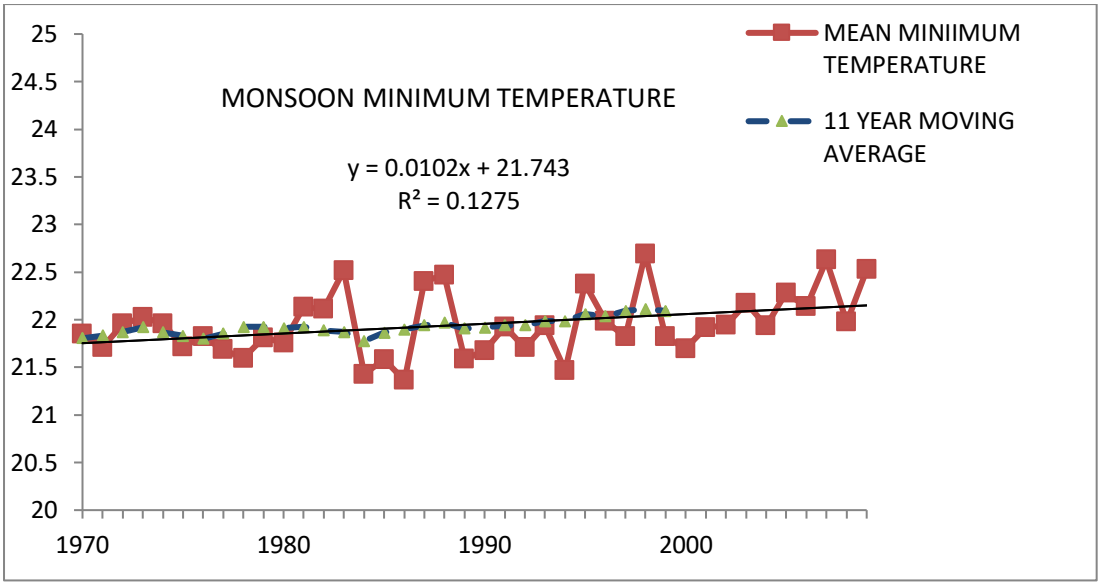
Fig.3 Temperature trends for summer season at Pune.

4.3. Monsoon

The monsoon season, on the contrary, depicts a significant increase in the mean temperature. This is due to the increase in T_{min} being significant at 0.01 level. This indicates that the night temperatures during recent years have gone up during monsoon.

t-Test when applied (Table 3) indicates that annual mean temperatures decrease at 0.05 level and of all seasonal temperatures, winter mean T_{min} and monsoon T_{min} trends are significant at 0.01 level. Thus, all the trends are also well-supported statistically.





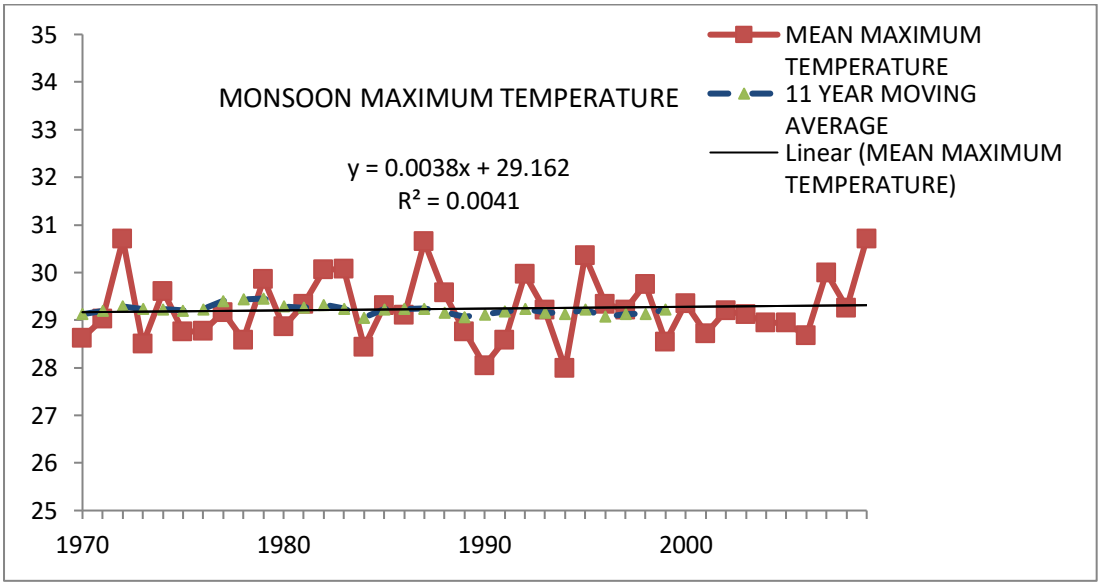
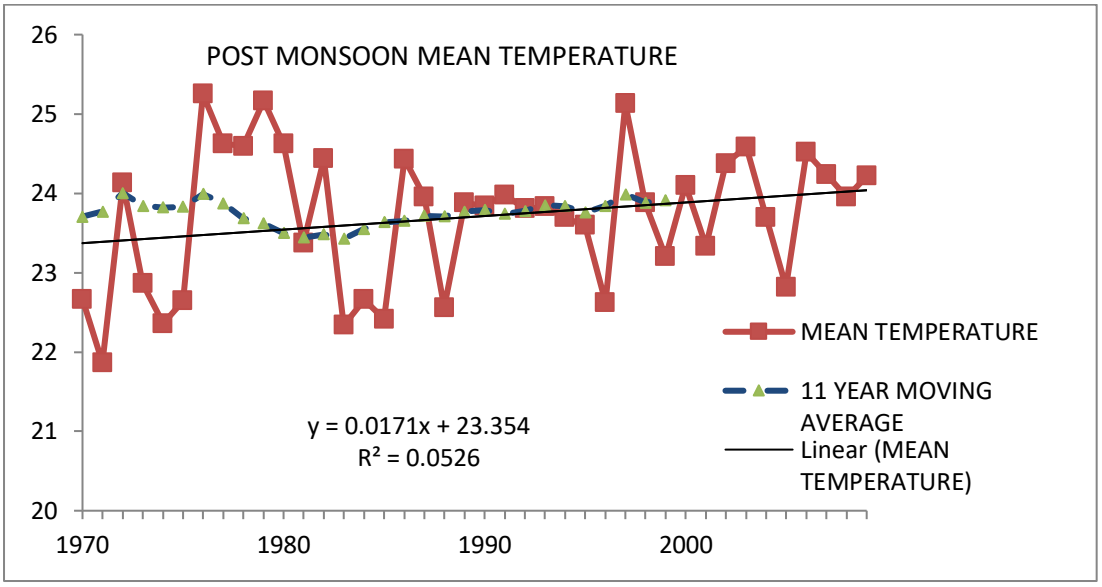
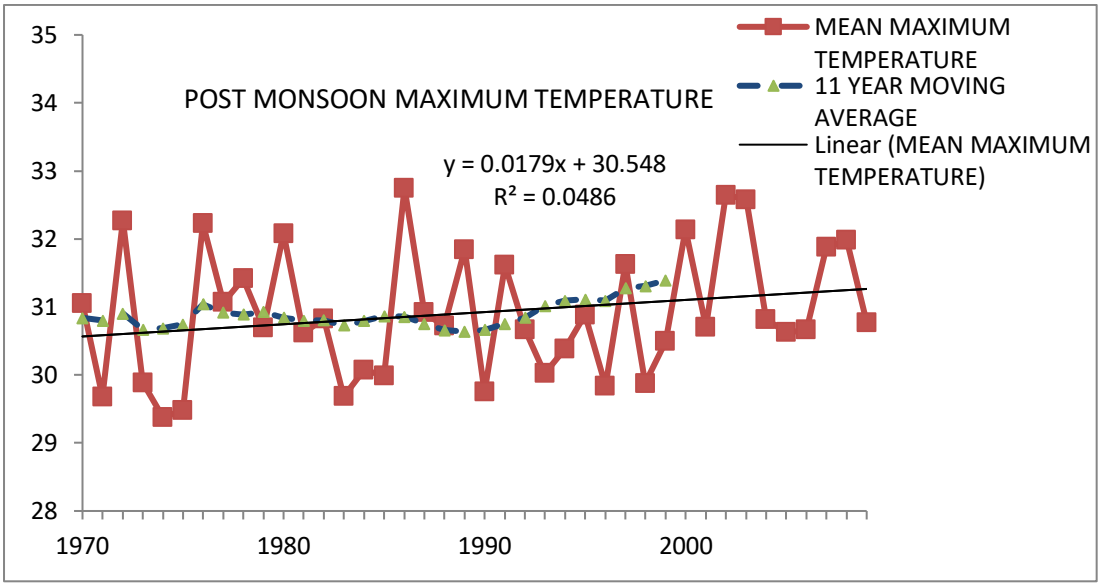


Fig.4 Temperature trends for monsoon season at Pune.

4.4.Post Monsoon

The monsoon season, on the contrary, depicts a significant increase in the mean temperature. This is due to the increase in T_{min} being significant at 0.01 level. This indicates that the night





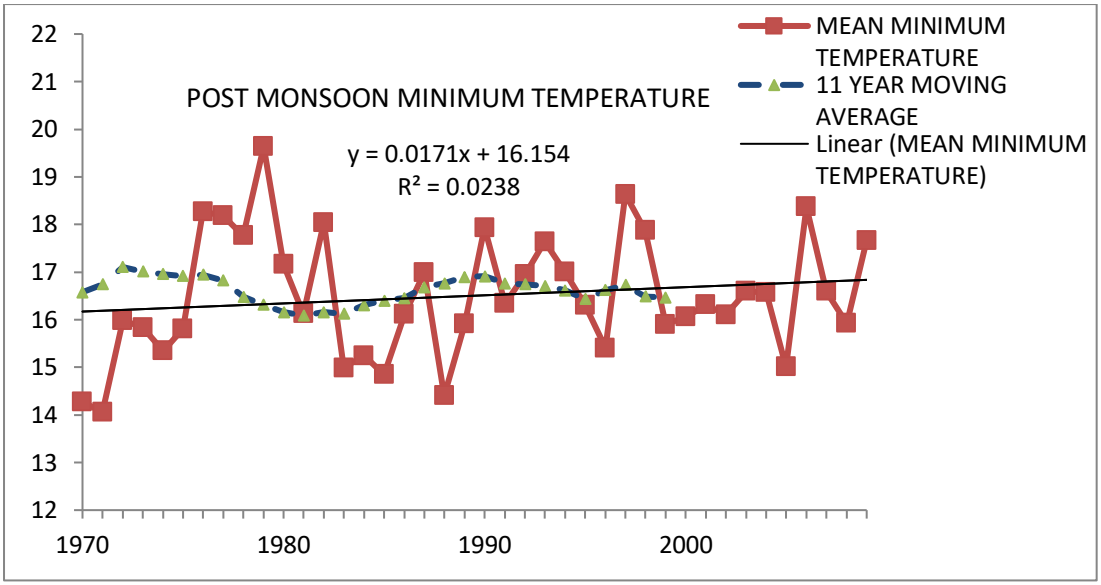


Fig.4 Temperature trends for post monsoon season at Pune.

7. Conclusion

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.

Recently, anthropogenic aerosols are recognized as providing a significant and yet uncertain perturbation on the global radiation balance in terms of overall cooling effect (Charlson et al., 1987 and Charlson et al., 1992; Boucher and Lohmann, 1995). In the present study, it is observed that SPM levels at Pune are significantly increasing since 1994. The observed cooling trend for the city, therefore, may be attributed to the upward trend of SPM in the ambient air, which the city has witnessed, due to phenomenal increase in urbanization during the last two decades. However, the relationship between aerosol concentration, distribution and anthropogenic pollution needs to be examined, before quantifying the impact of indirect forcing of anthropogenic aerosols. Otherwise, it is difficult to interpret the above results in terms of cause and effect. Regular measurements and long-