

## Temperature variability and trends over Pune

H. P. DAS, A. K. DHOTRE and D. M. RASE\*

*Meteorological Office, Pune – 411 005, India*

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\*e mail : [dineshmrase@rediffmail.com](mailto:dineshmrase@rediffmail.com)

**सार** – इस शोध पत्र में पुणे में ग्रीष्म और शीत ऋतुओं के दौरान एवं न्यूनतम तापमान की विशिष्टताओं का अध्ययन करने के लिए 25 वर्षों (1976–2000) के प्रतिदिन के अधिकतम एवं न्यूनतम तापमान के आँकड़ों की जाँच की गई है।

मार्च से मई के माह में अधिकतम तापमान की प्रभाव सीमा  $\geq 40^\circ\text{सें.}$  पाई गई है। जबकि शीत ऋतु में इसकी प्रभाव सीमा  $\leq 8^\circ\text{सें.}$  जनवरी एवं फरवरी के माह में प्रेक्षित की गई है। कुछ चुनिन्दा अंतरालों में तापमानों के वास्तविक दिनों की संख्या निर्धारित की गई है और ऋतु की प्रचण्डता का अध्ययन करने के लिए इसका विश्लेषण किया गया है। पुणे एवं उसके चारों ओर के क्षेत्र में औद्योगिकीकरण के जलवायविक प्रभावों से तापमान एवं वर्षा पर भी इसके प्रभावों का पता चला है।

पुणे में औद्योगिकीकरण के परिणामस्वरूप इस स्थान के तापमान (अधिकतम, न्यूनतम और वार्षिक) में गिरावट देखी गई है।

**ABSTRACT.** In the present study, daily maximum and minimum temperature data of Pune for 25 years (1976-2000) have been examined to study characteristics of maximum and minimum temperature during summer and winter seasons.

Between March to May the threshold of maximum temperature observed  $\geq 40^\circ\text{C}$  was considered. While for winter season, a threshold of  $\leq 8^\circ\text{C}$  was used between January and February. Actual number of days with temperature in selected intervals were determined and analysed to study severity of the season. Climatic effects of industrialization in and around Pune on temperature and rainfall have also been explored.

Industrialisation at Pune has been found to result in fall in temperature (maximum, minimum and annual), at this location.

**Key words** – Maximum temperature, Minimum temperature, Temperature trend, Global warming.

### 1. Introduction

Everyday, huge amount of CO<sub>2</sub> and other green house gases (GHGs) are injected into the atmosphere primarily due to massive use of fossil fuels and rapid industrialisation. The GHGs are the chief cause for global warming taking place at an unprecedentedly alarming rate. A recent report of WMO (2001) perceives the 1990-decade as the warmest decade record for the earth.

Most of the recent studies on the environmental and socio-economic effects of climate changes concentrate mainly on climatic averages instead of taking into account, the variability of climate, *e.g.*, the occurrence of extreme climate events (Parry *et al.*, 1988, Adams *et al.*, 1990, etc.). Much information is available on historical

and long term changes in atmospheric parameters like temperature and rainfall (Baron 1992, Higgins *et al.*, 1998, etc.). Unfortunately, not much is known about their short period (*e.g.*, decade, pentad or less) characteristics, except on some extreme phenomena like random occurrences of droughts, cold or heat spells etc. One of the many effects of global climatic change is the shortening of winter and lengthening of summer; persistent high temperatures during summer adding to its severity, are also being observed in some parts of the world.

For India, the India Met. Department considers January and February as the winter months while the period March to May is taken to constitute the summer season.

In view of the reported global warming (IPCC, 1995) it was thought appropriate to examine if this phenomena was also observed at isolated locations. Effect of industrialization and urbanization on temperature trend is yet another objective studied. With this aim in view, maximum, minimum and mean yearly and seasonal temperatures of a single station Pune have been studied.

## 2. Data and method of analysis

The study pertains to Pune (18° 32' N, 73° 51' E, 559 m a.s.l.) located over the Deccan plateau. Daily maximum temperature (*i.e.*, day temperature) and minimum temperature (*i.e.*, night temperature) data for each of the twelve months of the year were collected from the records of the India Meteorological Department. Pune for the 25 year period (1976 to 2000). Information on the number of industries has been collected from the Bureau of Economics and Statistics, Govt. of Maharashtra, Pune. For a given year, the mean temperature of a month was calculated by averaging the mean monthly maximum and minimum temperature values. The mean temperature of the year was then calculated by averaging the 12 mean monthly temperature values. Based on 30 years data from 1951-1980, the India Meteorological Department (1999) has prepared "normal" for different meteorological parameters for different years. The mean temperatures worked out in this study have been compared with 1951-80 "normal" as the overlapping period is only 5 years. This will confirm if the two data sets are compatible with each other.

Very few studies are available in India on the problem of intensity of summer (Sharma *et al.*, 1997). It is common experience that people are less able to cope up with heat when the temperature equals or exceeds 40 °C (Driscoll, 1985). In many regions of the country, this also leads to hyper-thermia or the sunstroke. India Meteorological Department (2001) defines heat waves using this limiting temperature. A reasonable estimate of severity of summer could be the number of days with maximum (or day) temperature 40 °C within the summer season. In a similar manner severity of winter could be the number of days when night temperature was  $\leq 8$  °C in the winter season.

The data were also smoothened and tested for presence of possible trends by moving average. The mean summer maximum temperature, the mean minimum temperature in winter and the mean yearly temperatures have also been similarly examined. Fluctuations in day/night temperatures were analysed in relation to the

variations in number of industries in and around Pune. Correlation and regression approach were adopted for this purpose. The data of number of industries used was available only for the period 1978 to 2000.

## 3. Temperature climatology of Pune

In this study the coldest month at Pune was January when the mean temperature worked out is 9.9 °C. In the same way April is the hottest month with mean temperature of 37.4 °C. The "normal" temperatures for these two months were found to be 11.4 °C and 38.1 °C respectively. A comparison between the two sets suggests cooling in the coldest month by 1.5 °C which is rather large, and cooling in maximum temperature by 0.7 °C in the April which seems within the accepted range of fluctuations.

The "normal" also brings out that the highest temperature attained was 43.3 °C in the month of May 1989 whereas the lowest value of 1.7 °C has been observed in the month of January 1935.

## 4. Results and discussion

### 4.1. Evaluation of severity of summer and winter

Evaluation of intensity of summer or winter is rather a complex proposition. Human health nutrition resources available to fight these extremes are some of the factors, which determine the extent to which the human beings exposed to severe climatic situations can tolerate, without significant harm to their bodies. Presuming that a normal person in the tropics has the in-built capacity to bear the extremes to some extent, number of days when the maximum or minimum temperatures exceed or fall below certain thresholds can perhaps be a suitable indicator in categorizing the severity of summer/winter. In this paper we have studied the severity of summer and winter seasons. The simplest and easily comprehensible method is to analyse number of days with day temperature  $\geq 40$  °C (for summer severity) and night temperature  $\leq 8$  °C (to denote winter severity). The same is discussed below:

On an average, day temperature  $\geq 40$  °C at Pune were nearly 6 days in any summer season. In some years such days could be just one, while in others it could be as large as 11. Days with the maximum temperature 42 °C or more is rather a rare phenomenon in Pune; in the total period of 25 years analysed, such days were seen only on seven occasions. Thus, it appears, the summer in Pune could hardly be harsh or torrid.

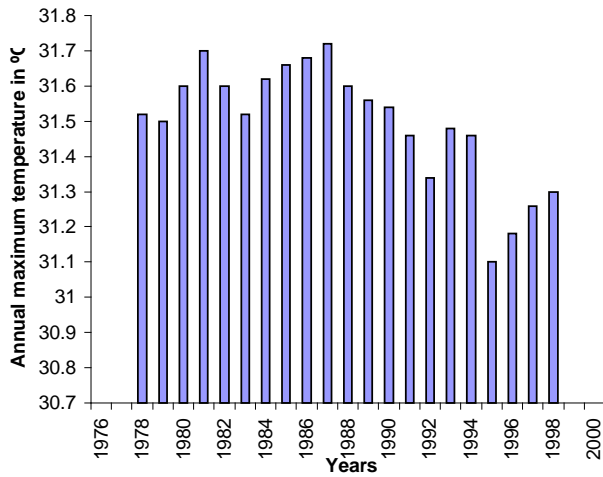


Fig. 1. Annual maximum temperature of Pune (5 year mean)

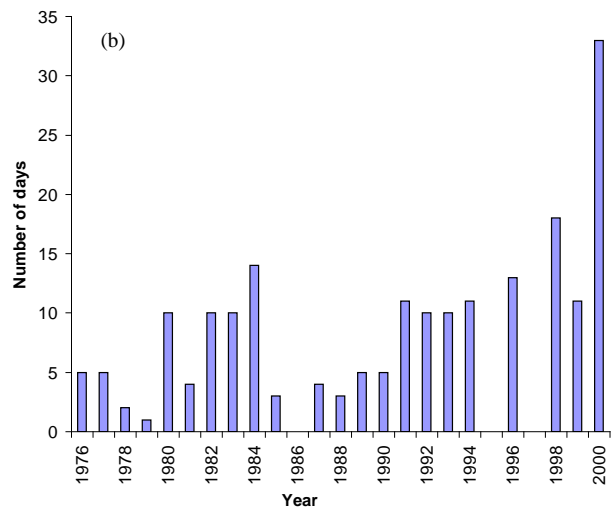
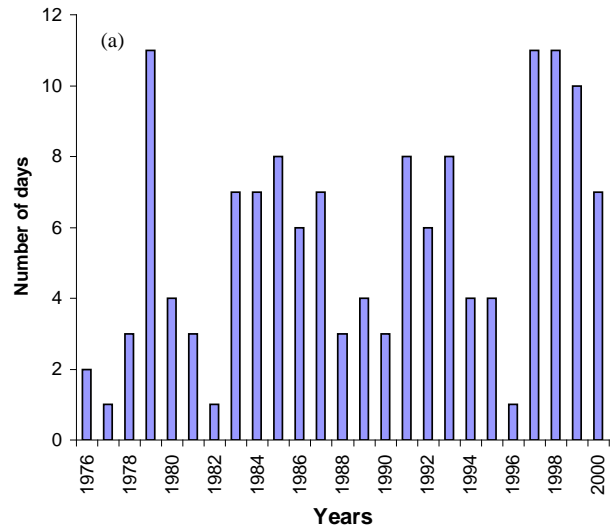
As regards winter severity it is observed that on an average the temperature could fall below 8 °C on seven days in the season. Analysis of night temperature revealed that, occasions of minimum temperature  $\leq 6$  °C do occur in significantly large numbers. For instance, during the winter of 1981-82, the night temperature fell below 6 °C on four days while in 1996-97 and 2000-01, such days were three in each year. Temperatures  $\leq 4$  °C are a rarity in Pune.

4.2. Examination of trends : recent scenario

Earth’s climate has been changing both on global and regional scales. Whether it has changed on local scale is often a matter of controversy. People in general, based on personal experience; however, seem to have an impression that weather patterns are changing. They believe summers in their areas are getting hotter and winter shorter and warmer which is a direct consequence of the global warming.

The mean annual temperature found in the study was 24.7 °C whereas the “normal” gives this value as 25.0. Thus it seems temperatures during 1976-2000 is 0.3 °C cooler than the “normal”. Only in one year, *i.e.*, in 1979 the mean annual temperature during the study period was more than the long-term normal temperature.

Hingane *et al.* (1985) analyzed data of 73 well-distributed stations and found that only at 30 stations the mean annual temperature has a rising trend while at the rest of stations it had either a declining tendency or was trend-less. Recently, Padagalwar (2007) while analyzing 7 stations temperature data of Marathwada and Telangana found that over 70 % of the stations reported falling temperature tendency.



Figs. 2(a&b). (a) Days with maximum temperature more than 40° C, at Pune and (b) number of days with minimum temperature less than 8° C, at Pune

The mean temperatures during the two seasons, *viz.*, summer and winter were also analysed to find any sustained regular pattern. No significant trend in the mean daily maximum temperatures for summer season was observed. However, the day temperature for the year as a whole, when subjected to 5 year moving average and analysed, did bring out certain fascinating features (Fig. 1). A slow steady rise could be seen till about 1987. The mean daily maximum temperatures then seem to have fallen, drastically so, between 1987 and 1995, at an average rate of 0.025° C per year. The concluding years of the last millennium seems to have witnessed a gradual rise in mean annual maximum temperature at Pune, in complete agreement with the recent observations on global warming (WMO 2001, 2003). Number of days with day temperature  $\geq 40$  °C is shown in Fig. 2(a). No

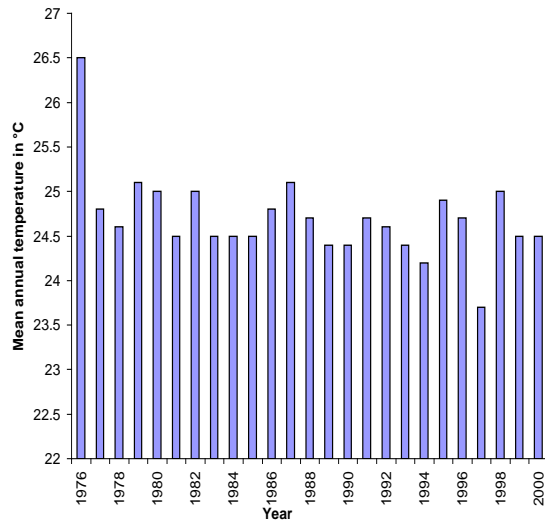


Fig. 3. Variation in mean annual temperature

systematic pattern in such days was seen. However, the figure suggests that such days were five or more between 1983-87, while between 1997-2000 there was a significant rise in number of these days.

Analysis of mean minimum temperature for the year as a whole revealed a general decrease till 1997 while night temperature for the winter season revealed fluctuations within 1 °C from year to year, but without any trend.

Analysis of number of days with night temperature  $\leq 8$  °C [Fig. 2(b)] revealed marked increase from 1986 to 1994 and a conspicuously large frequency of 33 days in 2000.

In addition to above, mean yearly temperature from 1976 to 2000 has also been analysed (Fig. 3). The analysis revealed, contrary to what has been observed elsewhere in the world, a general fall in its value at Pune between 1976 to 2000. Based on data for 1901 to 1987 Rupakumar *et al.* (1994) found a rising trend in minimum temperature at some cities of India and attributed it mainly to rise in the maximum temperature. However, all temperature parameters considered in the present study, unmistakably show that, so far as Pune is concerned, the temperature has declined in the last quarter of the 20<sup>th</sup> century, similar to what has been observed by Padagalwar (2007) recently, at Aurangabad and Hyderabad.

Globally, according to WMO (2003), 1991-2000 decade has witnessed three warmest years, viz., 1998, 1995 and 1997 in decreasing order of severity. The decade as such was the warmest decade since instrumental records came into being from 1860s. However day

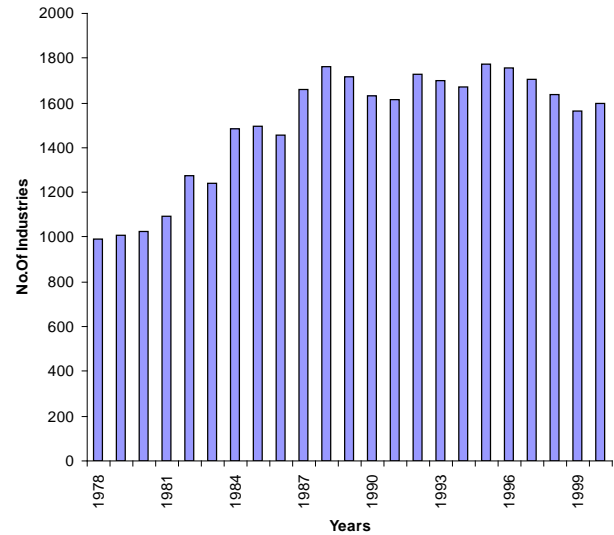


Fig. 4. Number of industries in Pune

temperatures, during this decade at Pune were found to be 0.5 °C below normal while the minimum or night temperature was 0.4 °C below normal. Karl *et al.* (1993) based on data of 494 stations in the United States found substantial and significant increase in night or minimum temperature, Sinha Ray *et al.* (1997) and Sahai (1998) have also found an increasing tendency in mean temperature in some of the cities in India and attributed it partly to the rise in minimum temperature. Landsberg (1981) postulated that increase in urbanization would differentially warm the minimum temperature relative to the maximum temperature and attributed it to the “heat island effect”.

#### 4.3. Climatic effect of industrialization

One of the most visible and well-accepted evidence in recent years is the gradual increase in the atmospheric pollution and aerosols. These aerosols also alter the heat budget of atmosphere. In India some attempts on the effect of industrialization on climate seems to have been made earlier (Ramana Rao and Ramana Murthy, 1973; Rupakumar and Hingane, 1988, etc).

The yearly growth of number of industries around Pune from 1978 to 2000 is depicted in Fig. 4. These industries (both large and medium scale) cover metals, chemicals, pharmaceuticals, agro-based etc., each of which release huge amount of particulate matter into air. In the present study the available data of number of industries in and around Pune were correlated with seasonal rainfall and mean yearly maximum, minimum and mean temperature separately. The correlation between number of industries and the rainfall was insignificant which suggests that number of industries do not have significant influence on rainfall over Pune (Rase 1996).

Correlation coefficients between number of industries and maximum, minimum and mean yearly temperatures are found as  $-0.15$ ,  $-0.38$  and  $-0.30$  respectively which are statistically insignificant. The negative correlation observed between temperature and number of industries is not surprising. A study on temperature trend at some of the industrialized cities in India by Rupakumar and Hingane (1988) revealed a falling tendency. The more the industries, the more likely are increase in sub particulate matter, thus reducing the transparency of the atmosphere. Our results are also in agreement with those by Srivastava *et al.* (1992) and Soni and Kannan (2003).

## 5. Conclusions

(i) In Pune, there appears to be a slow and steady increase in the mean daily maximum temperature for the year as a whole during 1976-1987, where after there is a steady fall up to 1997 and a marginal rise thereafter.

(ii) During summer season the day temperature in Pune exceed  $40^{\circ}\text{C}$  on nearly six days while in the winter season night temperature fall below  $8^{\circ}\text{C}$  on seven days.

(iii) Annual variation of number of days with daily maximum temperature  $\geq 40^{\circ}\text{C}$  do not reveal any systematic pattern though such days were relatively larger during 1997-2000.

(iv) Number of days with night temperature  $\leq 8^{\circ}\text{C}$  seems to have registered a rising trend between 1986 and 1994.

(v) In Pune the incidence of slight decrease of maximum, minimum and mean annual temperatures which occurred in the last decade of the 20<sup>th</sup> century has coincided with rising number of industries, which could be a causal factor in effecting the decreasing trend.

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