

ON VARIATION AND PREDICTION OF DAILY MAXIMUM TEMPERATURE OVER PUNE.

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ABSTRACT: The bio-environmental study of Pune city, situated at 550 metres ASL on the lee of Sahyadri mountain range reveals that the city experiences discomfort during 1130 - 1730 hours during the months of April and May due to oppressive heat. This paper, therefore, studies variations in daily maximum temperature for fifteen years (1971-85) and investigates heat wave events over Pune. An attempt has also been made to develop an objective method to forecast daily maximum temperature during April and May.

The analysis reveals that the persistence of rising tendency of maximum temperature is noted at the most for 4 days and of decreasing one for 3 days. Three moderate heat waves during the study period are reported in June preceding the onset of south-west monsoon either over Kerala or south Maharashtra. The multiple regression model of maximum temperature on dry bulb and dew point temperatures at 0830 hours predicted the element correctly within 1.5 deg. C on 70 % of the occasions.

A region (or a station) is said to be in the grip of a 'moderate heat wave', according to the convention of India Meteorological Department (IMD), when the recorded Tmax is above normal by 6° C to 7° C and it will be called a 'severe heat wave' if the Tmax is 8° C or more above normal. From March to July, spells of abnormally hot weather - heat waves - occasionally occur in certain parts of India. Raghavan (1965) was the first to analyse the climatological aspects of severe heat waves over India on the basis of the data from 1911 - 1961. Bedekar et al (1974) extended Raghavan's study of heat waves taking into consideration data for later years 1962-67. A few micro level studies related to variations in Tmax and its forecasting for various cities have been reported (Raghavendra' 1956; Srinivasan and Hashim, 1967; Banerjee and Choudhury, 1972; Pandharinath and

Arunachalam, 1981; Mohan et. al., 1986; Dubey and Balkrishnan, 1989 etc.). This paper is a study of the behaviour of the changes in daily maximum temperature (Tmax) and attempts to forecast it for Pune. Pune city (18 31' N latitude and 73 51' E longitude at an altitude of 550 metres ASL), situated on the lee of the Sahyadri mountain range is 48 km from the crestline and about 100 km from the Arabian Sea. The climate of the city has been one of the major factors attracting people from all over India. Bio-environmental study of Pune indicates that the high degree of discomfort (according to Thom, 1955, discomfort is defined as the situation where 100% people feel uncomfortable due to oppressive weather with an Index of <60 or >80) is experienced during 0230 to 6000 hours from November to March and during 1130 to 1730 hours in April and May due to excessive cold and heat respectively

(Deosthali, 1996). This paper studies the severe summers over Pune with respect to nature and frequency of heat waves.

DATA SOURCES AND METHODOLOGY

Present study is based on the daily data of dry (Db) and wet bulb temperatures recorded at 0830 IST and Tmax from March to June for the period 1971 to 1985. Data have been collected from the IMD, Pune.

Analysis of Tmax has been carried out in three steps as given below :-

- I. Persistency of the phenomenon of Tmax for the number of days has been worked out by classifying the changes in Tmax. These changes are grouped into three categories, viz. 'No Change', 'Rise' and 'Fall'. 'No Change' includes the change in Tmax from previous day value $\pm 1^{\circ}\text{C}$ while the 'Rise' or 'Fall' relate to changes in increasing and decreasing trend from the previous day value by greater than $\pm 1^{\circ}\text{C}$ respectively. Percentage occurrence of the cases for all the months of the study period under each category is computed.
- II. In order to identify heat waves, the departures of maximum temperature from normal of different magnitudes are classified as per the meteorological convention given by the IMD (1971) and the percentage of occurrences in each month are calculated against their ranges. The synoptic analysis of the atmospheric conditions associated with the heat wave phenomena are carried out. In addition, isanomalous charts of Tmax on those days were studied to trace the areal coverage of heat wave condition over the sub-continent.
- III. Using the forecasting method given by Pandharinath and Arunachalam (1981) and Mohan et al (1986) four different

multiple regression equations on the basis of dew point (Td) temperature ranges have been developed using Db and Td temperatures at 0830 IST as independent variates and Tmax as dependent variate. Daily data for the months of April and May for the period of 1971-80 have been analysed. The independent data for the month of April and May for the years 1984 and 85 were put to test the equations.

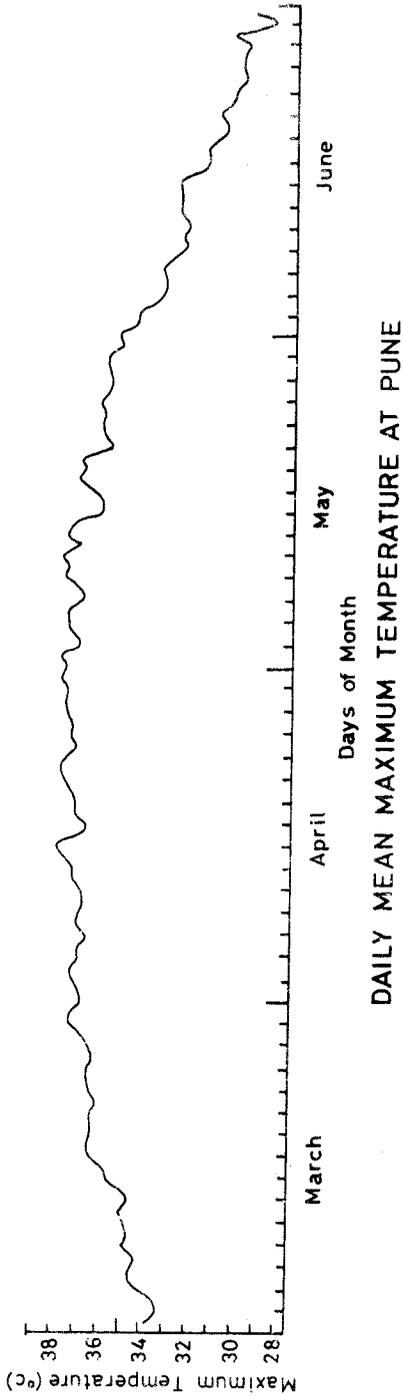
RESULTS AND DISCUSSION

Persistence tendency of Tmax

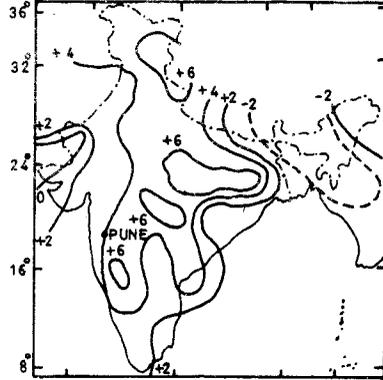
Daily distribution of mean Tmax over Pune is illustrated by the fig.1. During March temperature rises steeply while in April the rise is gradual. May and June mark the fall in mean Tmax. Daily change in mean Tmax during the four months exhibits a wave pattern with a peak of 38.8°C during latter half of April. Fluctuations in the parameter are more pronounced during May and June which may be associated with the thunderstorm activity and rainspells of monsoon respectively.

Results of the analysis of persistence of Tmax are presented in Table 1. All the three types of persistence tendencies show fall in number of cases with increasing number of days. The change for one day persistence accounts for $>60\%$ of the cases of each month, while two day persistence for 20% of the cases. 'No Change' situation lasting from 3 to 8 days in all the months is also significant. However, the persistence of rising Tmax as long as 7 days is observed in March. On the contrary, persistency of decreasing Tmax is reported at the most for 4 days in June.

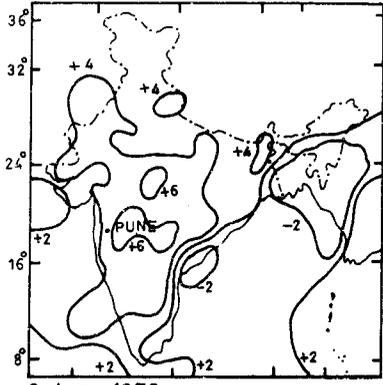
Largest occurrence of changes for all the months is reported under near normal category. It is important to note that severe heat wave situations have not existed at Pune during the period under study. However 3 moderate



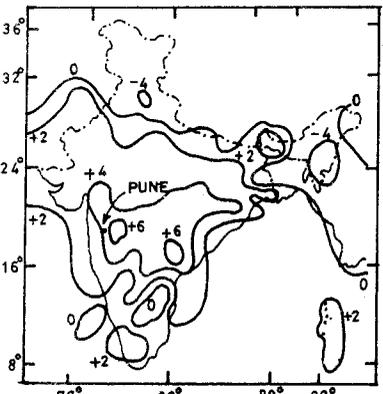
DEPARTURE OF MAXIMUM TEMPERATURE FROM NORMAL



19 June 1972



9 June 1979



16 June 1979

SOURCE IMD, PUNE

Fig. 2

Fig. 1 : Daily mean maximum temperature at Pune

Fig. 2 : Departure of maximum temperature from normal

Table 1
Percentage of occurrence of persistence (days)
NO CHANGE IN Tmax

No. of Days	1	2	3	4	5	6	7	8
March	17.9	7.9	4.5	4.0	2.5	0.5	1.0	4.5
April	22.8	8.2	4.7	3.9	1.5	0.8	0.4	0.4
May	15.6	12.6	4.2	3.4	1.5	0.0	0.8	0.4
June	19.9	8.4	3.4	2.7	1.5	0.4	0.4	0.8

RISE IN Tmax

No. of Days	1	2	3	4	5	6	7	8
March	23.4	4.5	3.0	0.5	0.0	0.0	0.5	0.0
April	26.0	3.9	2.0	0.4	4.8	0.0	0.0	0.0
May	25.2	5.4	0.8	0.4	0.0	0.0	0.0	0.0
June	26.4	3.4	0.0	0.4	0.0	0.0	0.0	0.0

FALL IN Tmax

No. of Days	1	2	3	4	5	6	7	8
March	19.4	6.0	0.0	0.0	0.0	0.0	0.0	0.0
April	19.4	5.0	0.4	0.0	0.0	0.0	0.0	0.0
May	24.4	3.8	1.5	0.0	0.0	0.0	0.0	0.0
June	21.8	7.3	2.7	0.4	0.0	0.0	0.0	0.0

HEAT WAVES

In order to identify heat wave events daily Tmax data from March to June for 1971-85

has been scrutinized. Table 2 presents the percentage occurrence of changes in Tmax from normal.

Table 2
Percentage of Departure from Normal

Month	Nearly Normal +1 to-1	Above Normal +2 to+3	Apprec Above Normal +4 to+5	Marked Above Normal +6 to+7	Severe Heat Wave ≥8	Below Normal -2 to-3	Apprec Below Normal -4 to-5	Marked Below Normal -6 to-7
March	63.0	17.5	1.2	0.0	0.0	11.8	5.8	0.9
April	69.2	16.9	1.2	0.0	0.0	8.8	3.3	0.8
May	61.3	18.9	3.9	0.0	0.0	14.5	1.2	0.3
June	43.8	21.5	7.6	0.7	0.0	17.8	6.2	2.4

waves have been experienced during June. They are reported on 19 June 1972, 9 June 1979 and 19 June 1979. June is characterised by larger variations in T_{max} from the normal. The maps of isanomalous lines for T_{max} over India are presented (Fig. 2). The isanomalous line of +6 deg. celsius in figure 2a encloses northeastern Madhya Pradesh and adjoining Utter Pradesh, Bihar, Vidarbha and Madhya Maharashtra. This region of India is in the grip of moderate heat wave. The synoptic conditions were a sea level trough running along and off the west coast. The northern limits of the southwest monsoon as identified by the IMD runs from Karwar to Baghdogra through Nellore and west central Bay. The figure 2b reveals that the moderate heat wave was prevailing over central part of the country that includes Maharashtra and adjoining central Madhya Pradesh. Under the influence of low trough over east-central Arabian Sea, according to the IMD sources, southwest monsoon is likely to set over Lakshdweep and Kerala within the following 3 days. Figure 2c indicates that T_{max} was markedly above normal over north coastal Andhra Pradesh and around Pune. Monsoon was expected to arrive into Goa and south Maharashtra during the following 2 days.

The synoptic analysis given above may be summarised that heat wave conditions have

largely prevailed over Pune region after or at the onset of southwest monsoon in Kerala and Karnataka.

PREDICTION OF DAILY T_{MAX}

The multiple regressions of T_{max} (y) on Db and Td are as follows,

- i) When 0830 IST Td is $\leq 10^{\circ}\text{C}$
 $y = 29.3 + 0.33 \text{ Db} + 0.09 \text{ Td}$
- ii) When 0830 IST Td is $> 10^{\circ}\text{C}$ and $\leq 15^{\circ}\text{C}$
 $y = 31.7 + 0.36 \text{ Db} - 0.17 \text{ Td}$
- iii) When 0830 IST Td is $> 15^{\circ}\text{C}$ and $\leq 20^{\circ}\text{C}$
 $y = 31.0 + 0.59 \text{ Db} - 0.46 \text{ Td}$
- iv) When 0830 IST Td is $> 20^{\circ}\text{C}$
 $y = 19.0 + 0.7 \text{ Db} - 0.03 \text{ Td}$

The standard error of estimates is progressively increasing with increasing Td ranges as 1.27, 1.29, 1.68 and 2.03°C respectively. In addition the multiple regression was also computed for the entire data as one series and is given as

$$v) \quad y = 30.92 + 0.42 \text{ DB} - 0.24 \text{ Td}$$

The standard Error of Estimate of this equation is 1.7°C . Classified equations (i-iv) as well as the general equation (v) have been developed for the data set of April and May, 1971-80. The error is calculated for the estimates from the observed values of T_{max} and is presented in the Table 3.

Table 3
Error distribution in the degrees Centigrade
Magnitude of error in absolute values (1971-80)

	$\leq \pm 0.5$	$\pm 0.6 - \pm 1.0$	$\pm 1.1 - \pm 1.5$	$\geq \pm 1.6$	Total
Estimate 1	159 (27)	130 (22)	85 (14)	220 (37)	594 (100)
Estimate 2	182 (31)	132 (22)	100 (17)	180 (30)	594 (100)

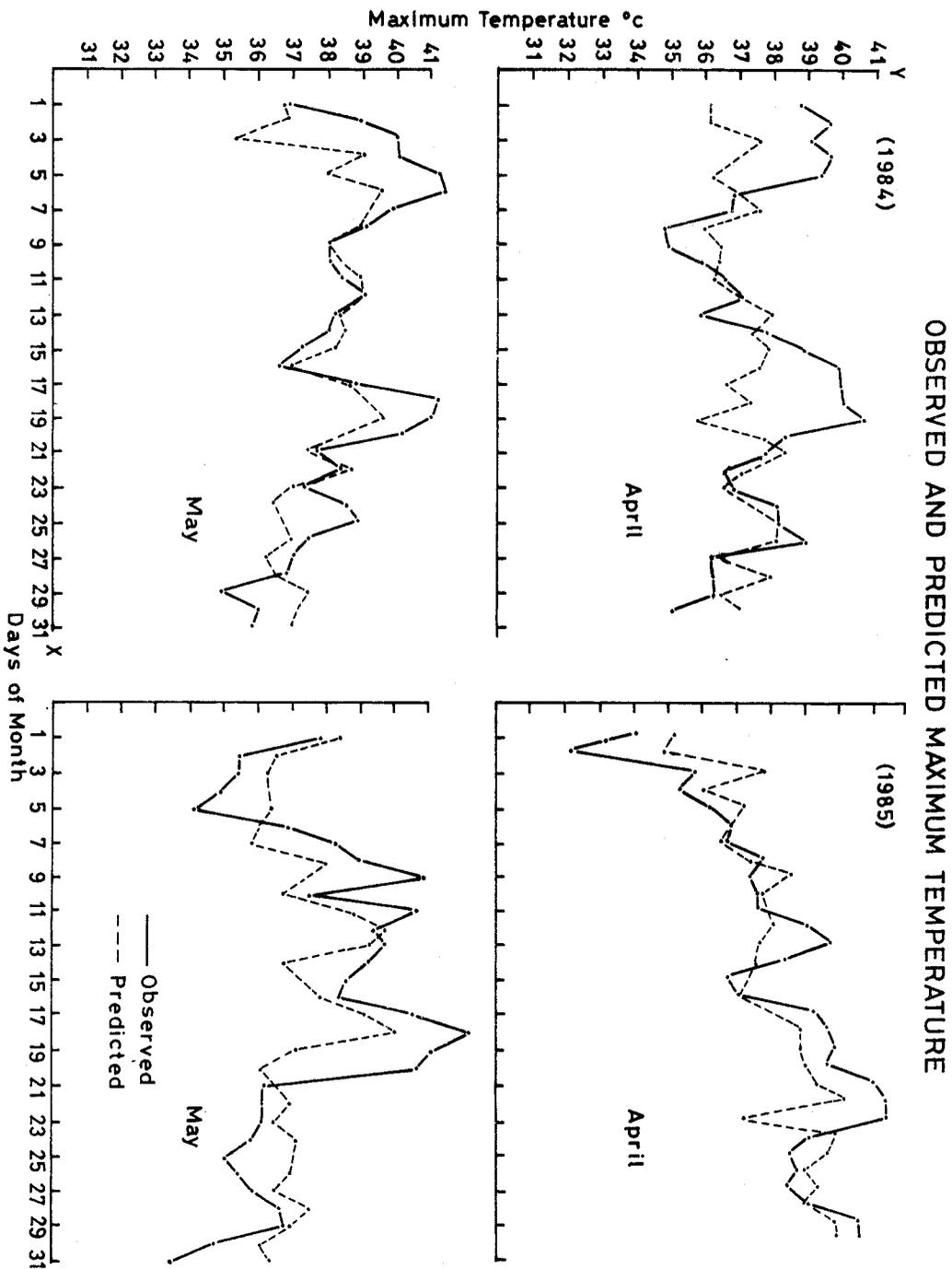


Fig. 3 : Observed and predicted maximum temperature

The figures in parenthesis indicate the percentage frequency of the Tmax event in a particular error category. The estimates under -I are obtained from the use of general equations (v), while the estimates under - II from the classified equations (i-iv). The general and classified equations have provided an accuracy of within ± 1.5 deg.celsius on 63% and 70% of

the occasions respectively. The classified equations giving relatively higher accuracy were tested for the data of April and May of 1984 and 85 and the results are demonstrated in the figure 3. In addition, the results of the test in which the absolute value of the error against the actual Tmax on the day for the different ranges are indicated in the Table 4.

Table 4
Test data for April, May 1984 and 85
Error distribution ($^{\circ}$ C)

	$\leq \pm 0.5$	$\pm 0.6 - \pm 1.0$	$\pm 1.1 - \pm 1.5$	$> \pm 1.6$	Total
Actual Tmax range	No of days				
33.1 - 34.0	-	-	1	1	2
34.1 - 36.0	4	2	4	7	17
36.1 - 38.0	23	12	9	8	52
38.1 - 40.0	14	10	3	10	37
Total No. of days	41	25	19	37	122

Table 5
Test data for April, May 1984 and 85
Error distribution ($^{\circ}$ C)

	$\leq + 0.5$	$\pm 0.6 - \pm 1.0$	$\pm 1.1 - \pm 1.5$	$\geq \pm 1.6$	Total
TD range					
≤ 10.0	3	3	-	-	6
10.1 - 15.0	11	7	3	5	26
15.1 - 20.0	27	12	15	22	76
> 20.1	-	3	1	10	14
Total :	41	25	19	37	122

It is seen that out of 122 days considered for testing the results, 87% of the days had the Tmax between 34 to 40 deg. C. It is also seen when the Tmax ranged between 34 to 36 deg. C., 36 to 38 and 38 to 40 deg. C the forecasts are correct within ± 1.5 deg. C on 59, 85 and 73 percent of the occasions respectively.

However it is noticed that when actual Tmax are more than 40 deg. c the results are not satisfactory.

Table 5 reveals that out of 122 days 84% of the days had morning dew point between 10.1 and 20.0 deg. C. It is interesting to note that when

the dew point temperature ranges from 10.1 to 15.0 and 15.1 to 20.0 deg. C. the forecasts are correct within ± 1.5 deg. C on 81 and 71% of the occasions respectively. However when dew point approaches to 20 deg. C, the forecasts on 71% of the occasions are not satisfactory.

After close inspection of the test data it is observed that when an actual Tmax approaches and/or reaches 40 deg. C advection of dry, hot air from the surrounding areas might be contributing to the rise of Tmax. On other occasions an isolated local thunderstorm may occur when the dew point fall steeply with intensified convective activity in the afternoon. The figure 3 illustrates the daily march of the observed and estimated Tmax.

Conclusions

(a) Persistence of 'No Change' situation for 3 to 8 days is the feature of all months. However, Pune experiences rising tendency of Tmax at the most for 4 days and the falling tendency at the most for 3 days.

(b) Over Pune severe heat waves have not prevailed during the period under study. However, 3 moderate heat waves were reported after or at the onset of monsoon in Kerala and Karnataka. When the front of convergence of hot, dry continental air from North India and cool moist maritime air from the Indian ocean liles to the South of Maharashtra, the Madhya Maharashtra and Marathwada region are likely to be in the grip of the heat wave. Thus the bio-climatic discomfort over Pune during April and May is not due to the occurrence of severe heat waves.

(c) The model developed in this study for numerical prediction of the daily Tmax of Pune provides an accuracy within ± 1.5 deg. C on 70% of the occasions. The model under-estimates on a few occasions when observed Tmax approaches 40 deg. C whereas it over-estimates when a thunderstorm develops in the late afternoon.

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