551.524.3

LONG-TERM VARIATION OF SURFACE TEMPERATURE IN THE VIDARBHA REGION

1. There seems to be general agreement among many scientists that global surface temperature has been increasing over the past 100 years by 0.3 - 0.6° C, presumably due to the enhanced greenhouse effect, as a result of the increasing concentrations of CO_2 and other greenhouse gases into the atmosphere. This warming trend, however, has exhibited considerable temporal and spatial variability (Jones *et al*., 1986; Hansen and Lebedeff, 1987; Srivastava *et al*., 1992).

The hemispheric and global averages may mask details concerning spatial patterns of climatic change. This further emphasizes that regional scale studies on temperature change would be quite relevant.

In India long term variation of surface temperature has been studied in the past by quite a few scientists; notables amongst them are those by Pramanik and Jagannathan (1954), Jagannathan (1963), Jagannathan and Parthasarathy (1972), Hingane *et al*. (1985), Rupakumar *et al*. (1987), Rupakumar and Hingane (1988) and Srivastava *et al*. 1992.

In view of the importance of regional scale study of surface temperature, this paper proposes to analyze long term variation of mean, maximum and minimum temperature as well as diurnal temperature range in the Vidarbha region.

2.1. *Data sets* - Temperature data used in this study have been obtained from the National Data Centre, IMD, Pune. Data for 11 stations (Fig. 1), namely Nagpur (C) (NGP), Akola (C) (AKL), Amraoti (AMT), Gondia (GND), Buldhana (BDN), Sironcha (SRC), Chandrapur (CHN), Pusad (PSD), Bramhapuri (BMP), Yeotmal (YOT) and Wardha (WRD), for which long period good quality data are available, have been considered. At least one station has been considered from each of the 9 districts of the region. Data availability period is different for different stations; for a few stations the availability period is quite substantial (95 years), however, for the majority of the stations data are available for a period of 35 years spanning from 1961 to 1995; so this 35-year period has been considered in the present study.

Data have been gathered in the form monthly maxima and minima temperatures. No month was used if more than 10 days of data were missing. In the final temperature data set, about 1% of the months were

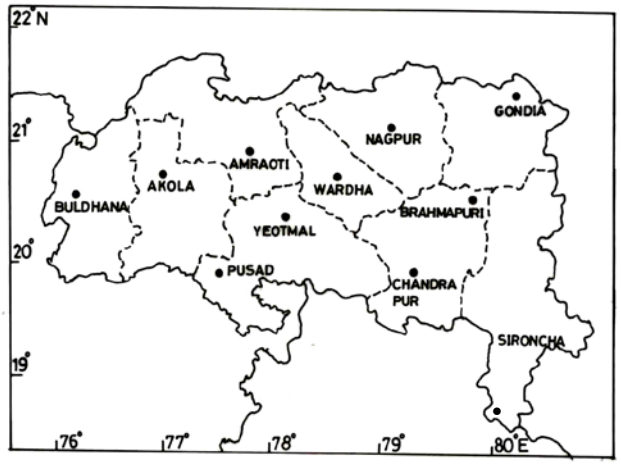


Fig. 1. Locator map of Vidarbha presenting geographical locations of the eleven stations

missing (with 2% being the highest value for a single station). In the case of missing values, the mean value for the month over the period of record was computed and inserted in place of missing value.

2.2. *Variables and statistics* - Several temperature variables have been analyzed in this study: mean, maxima, minima temperatures and diurnal temperature range. Monthly values were averaged to arrive at seasonal and annual values. The seasons are winter (December - February), pre-monsoon (March - May), monsoon (June - September) and post-monsoon (October - November).

For the time series of each variable a linear least-square regression line was fitted, and the change was calculated from the end points of the regression lines. Spatial variation of changes in summer maximum, winter minimum and annual mean temperature for the period 1961 to 1995 over Vidarbha has been studied by plotting their respective values and conducting isopleth analysis. Throughout this study, ΔTX, ΔTN, ΔTM, and ΔTR refer to the change over the past 35 years in the maxima, minima, mean temperatures and diurnal temperature range respectively.

Taking into account the 11 stations, for which long period data are available, temperature pattern for the entire Vidarbha region has also been investigated.

3.1. *Changes in temperature variables* - Changes in temperature variables (maxima, minima, mean temperatures and diurnal temperature range) during the 35-year period (1961-95) at individual locations as well as for the region as a whole have been computed and presented in Table 1.

TABLE 1

Temperature change at 11 individual stations and over the Vidarbha region during 1961-95

	Winter				Summer				Monsoon				Post-monsoon				Annual			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Nagpur (C)	-1.7*	-0.3	-1.5**	-1.0*	-1.4**	-0.3	-1.2*	-0.9	-0.1	-0.1	0.0	-0.1	-1.1	0.6	-1.7*	-0.3	-1.0*	0.0	-1.0*	-0.5
Akola (C)	-0.6	1.0	-1.6**	0.2	-0.2	0.5	-0.7	0.2	0.2	0.6**	-0.5	0.4	-0.4	2.0*	-2.5*	0.8	-0.2	1.0*	-1.1*	0.4
Amraoti	0.2	0.1	0.0	0.2	0.4	-0.9	1.3*	-0.2	0.6	-0.3	0.7	0.2	0.1	0.1	0.4	0.1	0.3	-0.2	0.6	0.1
Gondia	0.7	0.1	0.5	0.4	0.2	-0.9	1.0	-0.3	1.1**	-0.5	1.5*	0.3	0.8	-0.3	1.1**	0.2	0.8**	-0.3	1.1*	0.2
Buldhana	-1.1**	-1.2**	0.2	-1.1*	-0.7	-1.1	0.5	-0.9**	-0.5	-0.7	0.2	-0.6	-1.0	-0.8	-0.2	-0.9	-0.7*	-0.9**	0.2	-0.8*
Sironcha	-0.4	-0.1	-0.5	-0.2	0.6	-3.1*	3.7*	-1.2**	-0.1	-2.3**	2.2**	-1.2**	-0.3	-0.3	0.0	-0.3	0.0	-1.6**	1.5*	-0.8**
Chandrapur	0.8	0.8	0.0	0.8	0.9	-0.3	1.2**	0.3	0.6	-0.5	1.2**	0.1	1.2	0.9	0.3	1.1	0.9*	0.1	0.8**	0.5**
Pusad	0.0	0.2	-0.2	0.1	0.3	0.2	0.2	0.2	0.2	0.8*	-0.6	0.5	-0.2	0.9	-1.1	0.3	0.1	0.5	-0.4	0.3
Bramhapuri	-0.2	-1.1	0.9	-0.7	-0.2	-0.3	0.1	-0.3	-0.3	-1.5	1.2	-0.9	-0.4	-1.1	0.7	-0.7	-0.2	-1.0	0.7	-0.6
Yeotmal	-0.1	-0.4	0.3	-0.2	-0.2	-1.1	0.9	-0.6	0.3	-0.3	0.6	0.0	-0.3	0.1	-0.4	-0.1	0.0	-0.4	0.4	-0.2
Wardha	-0.6	-1.2**	0.7	-0.9	-0.5	-0.1	-0.4	-0.3	-0.5	-0.1	-0.4	-0.3	-0.8	0.7	-1.5**	0.0	-0.5	-0.2	-0.3	-0.4
Vidarbha	-0.5*	0	-0.5	-0.2*	-0.2	-1.3*	1.1*	-0.7*	-0.4*	-1.0*	0.6*	-0.7*	-0.6	0.0	-0.6	-0.3	-0.4*	-0.6*	0.2	-0.5*

* Significant at 1% I = ΔTX, III = ΔTR
** Significant at 5% II = ΔTN, IV = ΔTM
TX/TN/TR/TM - Maximum / Minimum/Diurnal Range/ Mean temperature in °C
Δ Denotes change during 35 (1961-95) years

For the individual locations, changes in annual mean temperature, summer maximum temperature and winter minimum temperature have been highlighted. However, for the region as a whole changes in all the temperature variables (maxima, minima, mean temperatures and diurnal temperature range) have been discussed.

The summer maximum temperature (TX) has been found to drop by 1.4° C / 35 years at Nagpur (C) and this drop is statistically significant at 5% level. Winter minimum (TN) temperature has also been found to drop by 1.2° C / 35 years at Buldhana and Wardha which is statistically significant at 5% level. Changes in annual mean temperature (TM) data revealed that though Buldhana and Sironcha recorded a statistically significant drop of 0.8° C / 35 years, yet at Chandrapur annual TM has, infact, risen significantly by 0.5° C / 35 years.

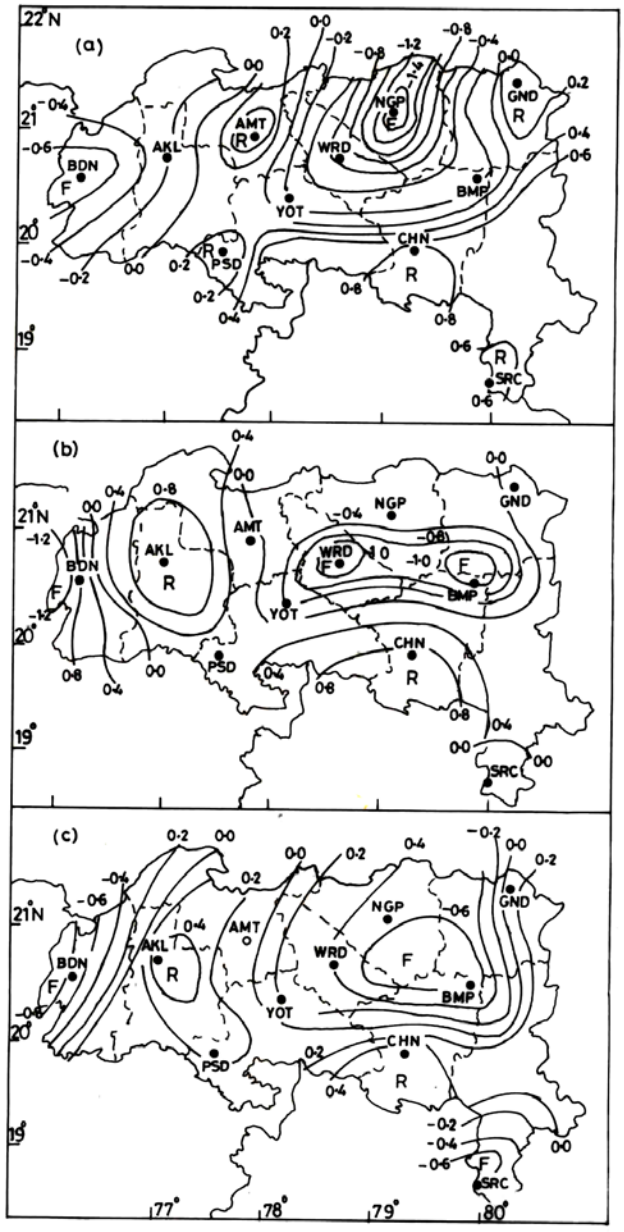
Over the region as a whole, maximum temperature (TX) has fallen significantly in winter and monsoon seasons (-0.4 to -0.5° C / 35 years); minimum temperature (TN) also recorded significant drop (-1.0 to -1.3° C / 35 years) in summer and monsoon seasons. Mean temperature (TM) has fallen significantly in winter, summer and monsoon seasons (-0.2 to -0.7° C / 35 years). Contrary to this, temperature range (TR) has shown an increasing tendency in summer and monsoon seasons mainly due to conspicuous drop in TN.

3.2. *Spatial variation of changes in temperature variables* - Spatial variation of changes (1961 to 1995) in maximum (summer), minimum (winter) and mean temperature (annual) have been presented respectively in Figs. 2 (a-c).

Summer maximum temperature [Fig. 2(a)] has fallen by 1.4° C in and around Nagpur; a secondary fall of 0.6° C has also been noticed in the extreme western part of the region in the Buldhana district. However, southern part of the Chandrapur district and extreme southeastern part of the region (in and around Sironcha) recorded a rise of more than 0.6° C.

Winter minimum temperature [Fig. 2(b)] fell by 1.2° C in the extreme western part of the region in the Buldhana district; besides there are two pockets, central part of Wardha and northeastern part of Chandrapur and adjoining Gondia districts, where secondary drop of 1.0° C observed. Like summer maximum temperature, southern part of the Chandrapur district also saw a rise of 0.8° C in winter minimum temperature.

In the extreme western part of the region fall in annual mean temperature [Fig. 2(c)] has been found to be 0.8° C. Southern part of Nagpur district and adjoining southwestern part of Gondia and small patch in northern part of Chandrapur and eastern part of Wardha districts



Figs. 2(a-c). Spatial pattern of changes (1961-95) in (a) Summer maximum temperature, (b) Winter minimum temperature and (c) Annual mean temperature

also saw a secondary fall of 0.6° C. Unlike summer maximum temperature, in the extreme southeastern part of the region, around Sironcha, annual mean temperature fell by 0.6° C.

3.3. *Temperature pattern for the region* - Smoothed values (9 point Gaussian low-pass filter) of annual and seasonal maximum, minimum, mean temperature and diurnal temperature range, for Vidarbha as a whole, have been presented in Fig. 3.

Annual maximum temperature showed [Fig. 3(a)] a gradual decrease till early 80's after that slight increase is observed. Similar features have been noticed in winter season. In summer and monsoon the pattern is inconsistent and in post-monsoon season some sort of cyclicity roughly of about 10 years observed till early 80s, thereafter temperature appears to have nearly plateaued.

Annual minimum temperature variation revealed [Fig. 3(b)] a sharp rise till 1978 followed by a sharp fall thereafter. Summer, monsoon, and winter pattern also showed similar features but rise and fall were less sharp. Post-monsoon variation did not show a clear pattern.

The annual as well as seasonal DTR pattern indicated [Fig. 3(c)] an increasing pattern of late, mainly attributed to the conspicuous fall in minimum temperature.

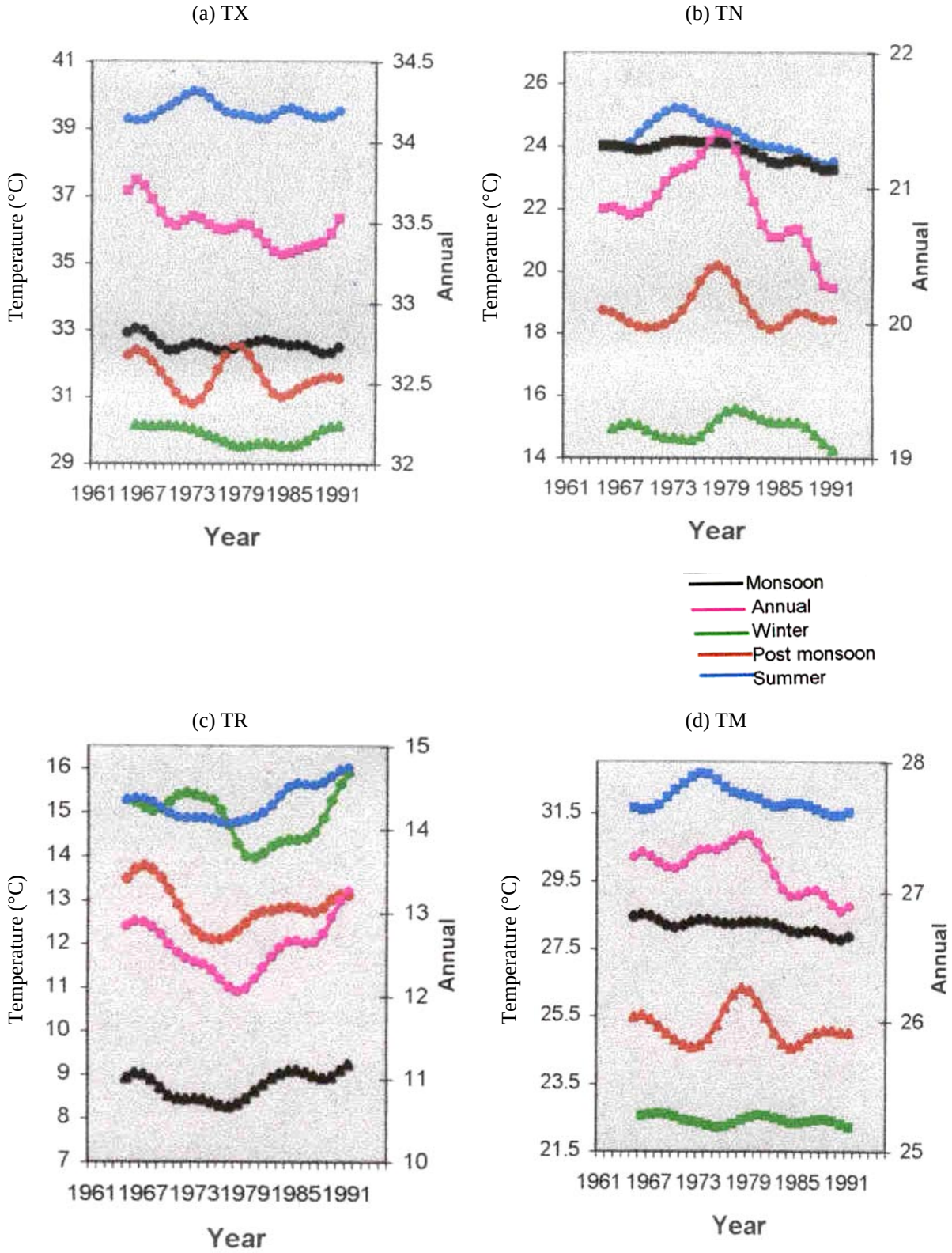
Mean annual temperature over the region showed [Fig. 3(d)] a decreasing tendency, which has also been observed in other seasons barring post-monsoon wherein the pattern is inconsistent.

4.1. Summer maximum [at Nagpur (C)], winter minimum (at Buldhana and Wardha) and annual mean temperature (at Buldhana and Sironcha) dropped significantly during the study period of 35 years (1961-95). In contrast, Chandrapur recorded a significant rise of 0.5° C / 35 years in annual mean temperature.

4.2. Over the region as a whole, maximum in winter and monsoon seasons, minimum in summer and monsoon and mean temperature in winter, summer and monsoon seasons dropped significantly. Contrary to this, temperature range (TR) has shown an increasing tendency in summer and monsoon seasons mainly due to conspicuous drop in TN.

4.3. Spatial variation indicates that summer maximum, winter minimum and annual mean temperature fell at the extreme western part of the region. However, at the extreme southeastern part though summer maximum temperature rose, yet a drop of 0.6° C noticed in annual mean temperature.

4.4. Over the region as a whole, annual maximum temperature shows a gradual decrease till early 80's after that slight increase is observed. Similar features have been noticed in winter season. In summer and monsoon the pattern is inconsistent and in post-monsoon season some sort of cyclicity roughly of about 10 years observed till early 80s.



Figs. 3(a-d). Variation of seasonal and annual temperature over Vidarbha, 1965-95. TX/TN/TR/TM – Maximum/Minimum/Diurnal range/Mean temperature

4.5. 1978 followed by a sharp fall thereafter. Summer, monsoon, and winter also show similar features barring the sharpness in rise and fall. Post-monsoon shows inconsistency in pattern.

4.6. The entire annual as well as seasonal DTR pattern shows an increasing tendency of late, mainly attributed to the conspicuous fall in minimum temperature.

4.7. Mean annual temperature over the region shows a decreasing tendency, which has also been observed in other seasons barring post-monsoon wherein the pattern is inconsistent.

5. The authors are thankful to Dr. S. K. Dikshit, ADGM (R) and Dr. (Mrs.) B. Shyamala, DDGM (C) for their encouragement. Thanks are also due to Dr. A. K. Mukherjee, Retd. ADGM and Dr. A. Choudhury, Retd. DDGM (Agri. Met.), IMD, for discussions and helpful suggestions.

References

Hansen, J. and Lebedeff, S., 1987, "Global trends of measured surface air temperature", *J. Geophys. Res*., **92**, 13345-13372.

Hingane, L. S., Rupa Kumar, K. and Ramana Murthy, Bh. V., 1985, "Long term trends of surface air temperature in India", *J. Climatol*., **5**, 521-528.

Jagannathan, P., 1963, "Trends in the characteristic variation of temperature in the arid and semi-arid regions", *Indian J. Met. Geophys*., **14**, 3-22.

Jagannathan, P. and Parthasarathy, B., 1972, "Fluctuations in the seasonal oscillations of temperature in India", *Indian J. Met. Geophys*., **23**, 15-22.

Jones, P. D., Raper, S. C. B., Wigley, T. M. L., Wright, P. B., 1986, "Global temperature variations between 1861-1984", *Nature*, **23**, 421-434.

Pramanik, S. K. and Jagannathan, P., 1954, "Climate Change in India – II", Temperature, *Indian, J. Met. Geophys*., **5**, 29-47.

Rupa Kumar, K. and Hingane, L. S., 1988, "Long term variations of surface air temperature at major industrial cities of India", *Climate Change*, **13**, 287-307.

Rupa Kumar, K., Hingane, L. S. and Ramana Murthy, Bh. V., 1987, "Variation of tropospheric temperatures over India during 1944-85", *J. Climate Appl. Met*., **26**, 304-314.

Srivastava, H. N., Dewan, B. N., Dikshit, S. K., Prakash Rao, G. S., Singh, S. S. and Rao, K. R., 1992, "Decadal trends in climate over India", *Mausam*, **43**, 7-20.

JAYANTA SARKAR
A. S. GADGIL*

India Meteorological Department, Pune, India
**University of Pune, India*
(*8 July 2003, Modified 24 September 2004*)