NOTES

Variation of Tropospheric Temperatures over India during 1944–85

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ABSTRACT

Variation of air temperature at the surface and at four levels in the troposphere, viz., 850, 700, 500 and 200 mb, over India have been studied using the data at ten radiosonde stations for 31 to 42 years during 1944–85. Seasonal as well as annual mean temperature series have been obtained, and the general features of the variations are discussed. Quantitative study of the temperature changes is made by evaluating the linear trends.

Surface temperatures do not show appreciable trends during the last three decades over India, but at the upper levels there was a trend reversal around 1958, from warming to cooling. There is a distinct contrast between the northern and southern Indian stations during 1958–85, in that the former have shown significant cooling while the latter have shown no trends. Port Blair, the island station considerably south, however, shows slight cooling during this period. The rate of cooling increases with height, particularly at the northern stations. There is no marked interseasonal contrast in the temperature trends at upper levels.

1. Introduction

With the availability of a reasonably long time series of radiosonde data all over the world, considerable attention has been drawn toward the variations in upper-air temperatures over the past three decades. Starr and Oort (1973), using data for six years during 1958–63, showed that the mean temperature of the atmosphere (1000–50 mb) in the Northern Hemisphere fell by about 0.6°C, though they pointed out that such a rate of decrease could not persist. Later, in a series of articles, Angell and Korshover (1975, 1977, 1978, 1983) used more data and dealt extensively with the global temperature variations in the troposphere and stratosphere during the period 1958–81. These studies dealt with the mean temperatures of different isobaric layers, derived from the thickness values. It was concluded that at the surface and in the tropospheric (850–300 mb) layer, the hemispheric and global cooling during the first decade of the interval 1958–81 was more than compensated by warming during the second decade. In contrast to this cooling and warming, there was gradual global cooling in the 300–100 mb layer during most of the interval 1958–81, leading to an increase in tropospheric lapse rate in the last decade.

Global-scale studies of temperature variation as mentioned above mask much regional detail. Few studies have been reported regarding the regional characteristics of tropospheric temperature variation. A regional-scale study of the tropospheric temperature variations over India could be useful in the context of the growing concern about the effects of increasing CO_2 and volcanic dust on the tropospheric temperatures. Though the cause and effect aspects of the problem are not considered in the present paper, an attempt will be made to present a comprehensive description of the changes that are taking place in this part of the atmosphere.

2. Data and analysis

As of 1 January 1980, there are about 25 radiosonde stations in India reporting various upper-air observations (India Meteorological Department, 1980). Of these, 15 stations were found to be unsuitable for climatic-change studies, either due to insufficient data length or due to a large number of missing data. In the present paper, data have been analyzed for 10 stations (Table 1) fairly spread over the country (Fig. 1), for periods ranging from 31 to 42 years. Mean monthly temperature data have been collected for the surface and at four levels in the troposphere, viz., 850, 700, 500 and 200 mb. The source of data is the *Monthly Climatic Data for the World* (NOAA/WMO) during 1949–85, and the data prior to 1949 have been obtained from the data archives of the India Meteorological Department at Pune. There are a few gaps in the data up to about 1960, and these missing values have been estimated by regression techniques from the data at neighboring significantly correlated stations. The problem of missing data has mainly been encountered for the 200 mb level. However, data for well-established stations like Delhi are in excellent form, where only a couple of values had to be estimated. Gauhati contained relatively more gaps in the data, and this fact must be kept in mind while examining the series for that station. Thus, after filling all of the gaps in the data, continuous series of upper-air temperatures for

TABLE 1. Data periods and radiosonde instrumental changes at the stations under study.

Station	Latitude (°N)	Period of data*	Date of introduction of AM-type** radiosonde	Radiosonde type in use before introducing AM-type**
Delhi	28.58	1945–85	7 Dec 1967	C
Jodhpur	26.30	1946–85	22 Feb 1969	C
Gauhati	26.18	1955–85	19 Feb 1968	C
Calcutta	22.65	1944–85	1 May 1968	C
Nagpur	21.10	1945–85	12 Nov 1968	F
Bombay	18.90	1955–85	1 Jan 1968	F
Visakhapatnam	17.72	1946–85	2 May 1971	F
Madras	13.00	1949–85	19 Jul 1970	F
Trivandrum	8.48	1948–85	1 Oct 1970	F
Port Blair	11.67	1950–85	7 Dec 1970	F

* This is for the 850 mb level; data length is less for higher levels, particularly for 200 mb level, at a few stations (see Figs. 2–6).

** AM: Audio-modulated; C: Chronometer, F: Fan.

all 12 months for these 10 stations have been obtained for further analysis.

In this connection, it is necessary to discuss certain aspects of the quality and reliability of the data. The radiosonde instrumentation was changed around 1968 in India, when audio-modulated type (AM-type) sondes were introduced at all stations (India Meteorological Department, 1980). Prior to that, the northern Indian stations were using Chronometer type (C-type) and southern stations Fan type (F-type) sondes (See Table 1). Some studies have reported that the C-type radiosondes recorded systematically higher temperatures than the F-type sondes (e.g., Ananthakrishnan et al., 1966). Information regarding the AM-type in comparison with other types is not readily available. However, it may be noted from the remarks of Van de Boogaard (1977) and Joseph (1983) that the inhomogeneities caused by these changes may not be appreciable at 500 mb and below. Angell also states that he encountered similar problems in his studies, but he did not apply corrections to the data with the assumption that the errors, if any, would be damped out upon space-averaging (personal communication, 1985). The authors are of the opinion that, in addition to the difficulties involved in choosing a correction factor, any correction factor chosen arbitrarily will be highly subjective and is likely to add to the data problems. Therefore, with the hope that errors would be minimal at lower levels, and cautiously interpreting the results for higher levels, the authors have proceeded with the original data.

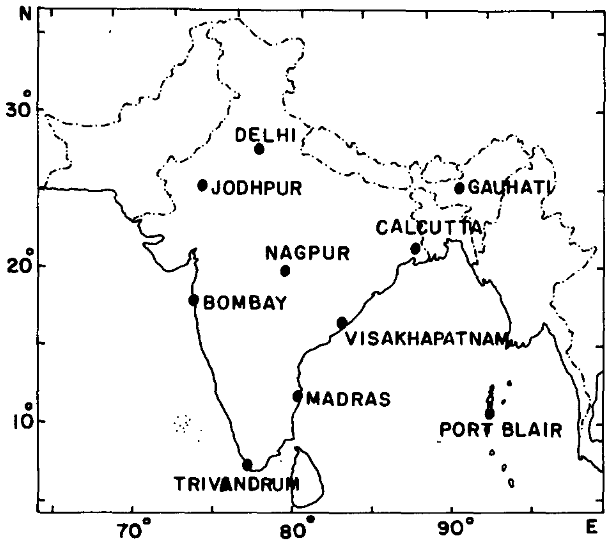

FIG. 1. Locations of stations for which data have been used.

The monthly means for upper-air temperatures are based on twice daily observations (0000 and 1200 UTC) from 1963 onward. Prior to this, there had been some variation in the observational times, but they were all either nighttime or early morning observations, and the problems of radiational shielding of the radiosondes are assumed to be negligible. Monthly mean surface air temperatures are calculated by averaging maximum and minimum temperatures.

Four seasonal averages, viz., winter (December–February), premonsoon (March–May), monsoon (June–September) and postmonsoon (October and November), as well as annual averages, have been obtained for all of the stations, thus forming five basic series for each level at each station. An all-India set of time series is also obtained by an arithmetic average of the corresponding data at all ten stations. All of the series have been examined for long-term variations, and linear trends have been computed. The significance of the trend has been tested, after allowing for the autocorrelation present in the series, by inflating the variance by a factor given by Wigley and Jones (1981):

$$f^2(N, r) = \left[\frac{1+r}{1-r} - \frac{2r(1-r^N)}{N(1-r)^2}\right]$$

where r is the lag-1 autocorrelation and N is the number of data points. The linear trends are given as temperature changes in degrees Celsius per ten years.

A cursory examination of data for all levels other than the surface level, for the northern Indian stations in particular, has shown a trend reversal around the year 1958 (see Figs. 3–6). In view of this, computation of a linear trend over the full data period may not be meaningful, and the data have been segmented into two periods: (i) up to 1958 and (ii) 1958–85. Linear trends have been computed separately for these two periods for all stations. For comparison, the trends in surface temperatures have also been computed over the period 1958–85. Trends during the period of uniform instrumental use, 1970–85, have been computed and compared with the trends obtained for the overall period 1958–85.

3. Results

a. *General features of tropospheric temperature variation over India*

The mean annual temperatures at the surface and at the 850, 700, 500 and 200 mb levels are presented in Figs. 2–6 for all ten stations as well as the all-India average. The broken curves in the figures represent nine-point Gaussian low-pass filtered values. Some important features are mentioned below.

1) SURFACE

The surface temperature is conspicuous because of its flat and trendless nature at all of the stations during the period of study (Fig. 2). Hingane et al. (1985) examined the long-term trends of surface air temperature

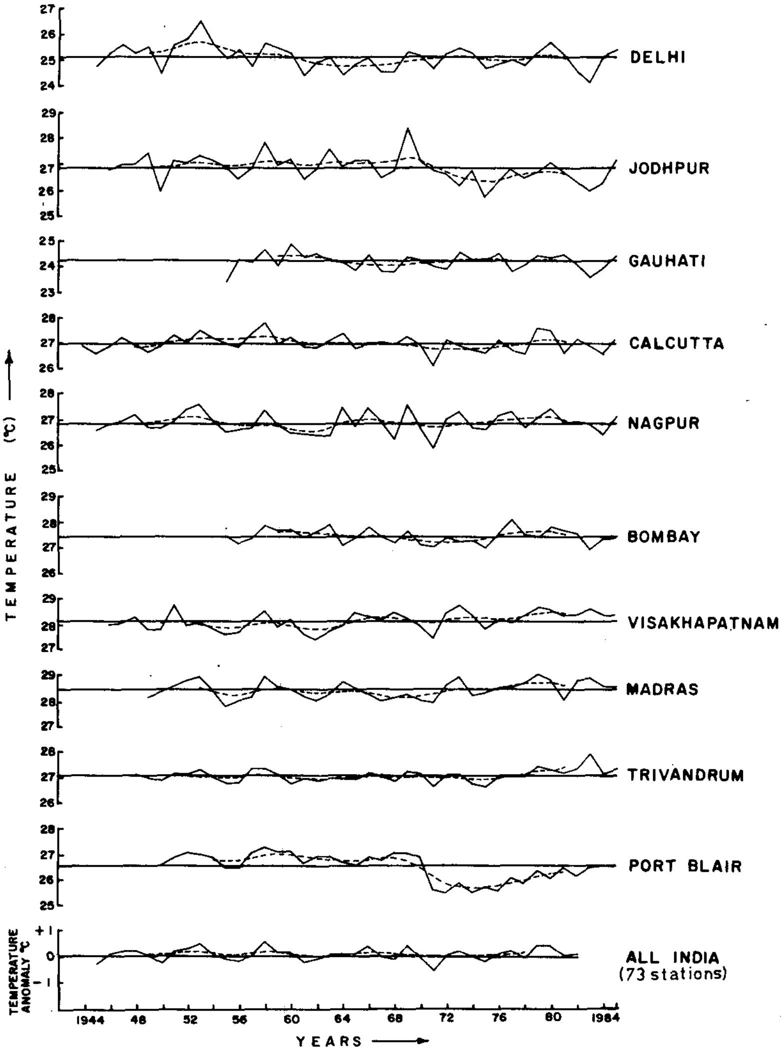

FIG. 2. Variation of annual mean surface air temperature over India along with Gaussian low-pass filter. Horizontal lines indicate respective period averages.

in India using data from 73 stations. They found that the surface air temperature has increased by about 0.4°C during the past century. Their study did not include analysis of the series over shorter segments. The latter portion of their annual temperature curve for all of India, corresponding to the period 1945–82, is reproduced in Fig. 2 for examination. It is clear that the temperatures have remained nearly constant over this period. This feature obviously indicates that the significant warming reported by them was predominantly the result of increasing temperatures up to the 1950s.

2) 850 MB

At the 850 mb level (Fig. 3), all of the stations, most conspicuously the northern stations, suggest trend reversal from warming to cooling around 1958.

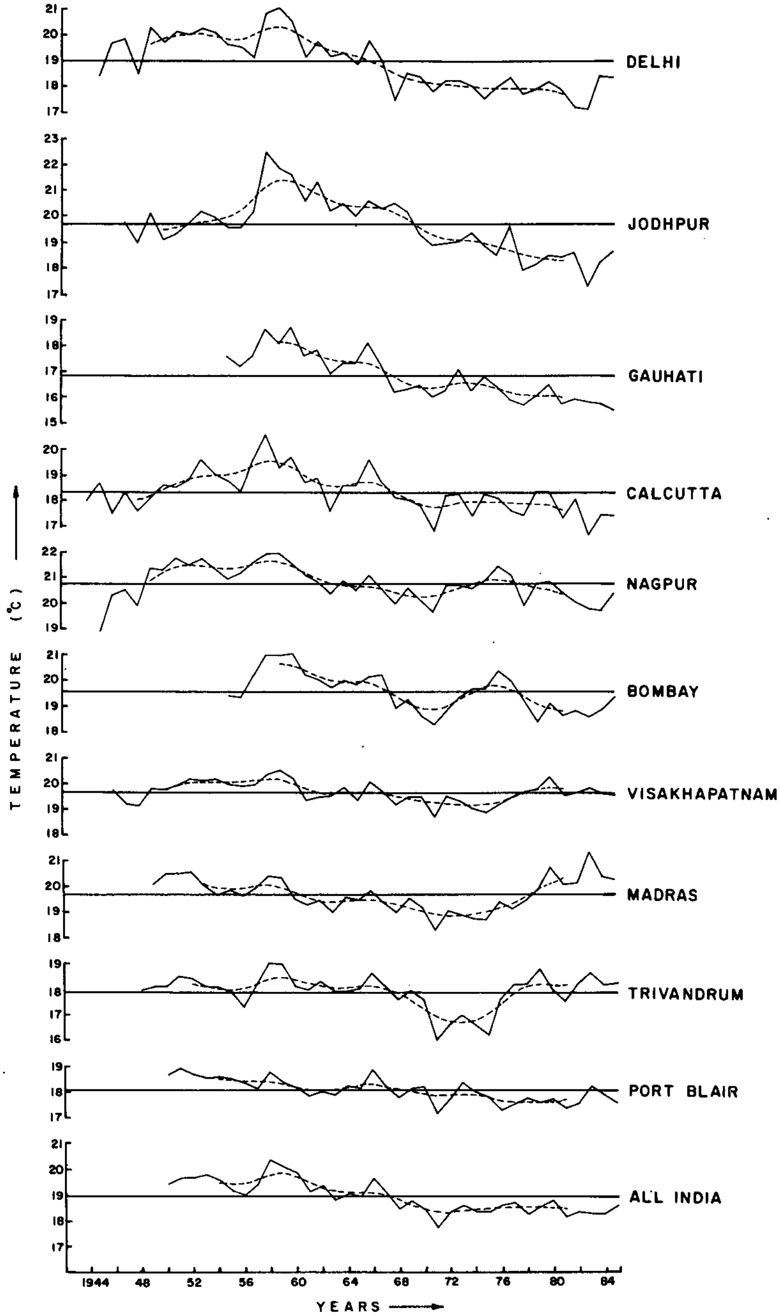

FIG. 3. Variation of annual mean upper-air temperature at 850 mb over India along with Gaussian low-pass filter.

However, at Nagpur and Bombay the post-1958 cooling ceases in the early 1970s, giving rise to a warming trend up to 1976. This feature is most conspicuous at Bombay. Also, the southern coastal stations Visakhapatnam, Madras and Trivandrum show warming during the 1970s, while Port Blair, an island station, shows cooling up to 1976.

The all-India average temperature for the 850 mb level shows continuous cooling until about 1972 and remains stable thereafter.

3) 700 MB

The temperature variations at this level (Fig. 4) are almost similar to those observed at 850 mb (Fig. 3).

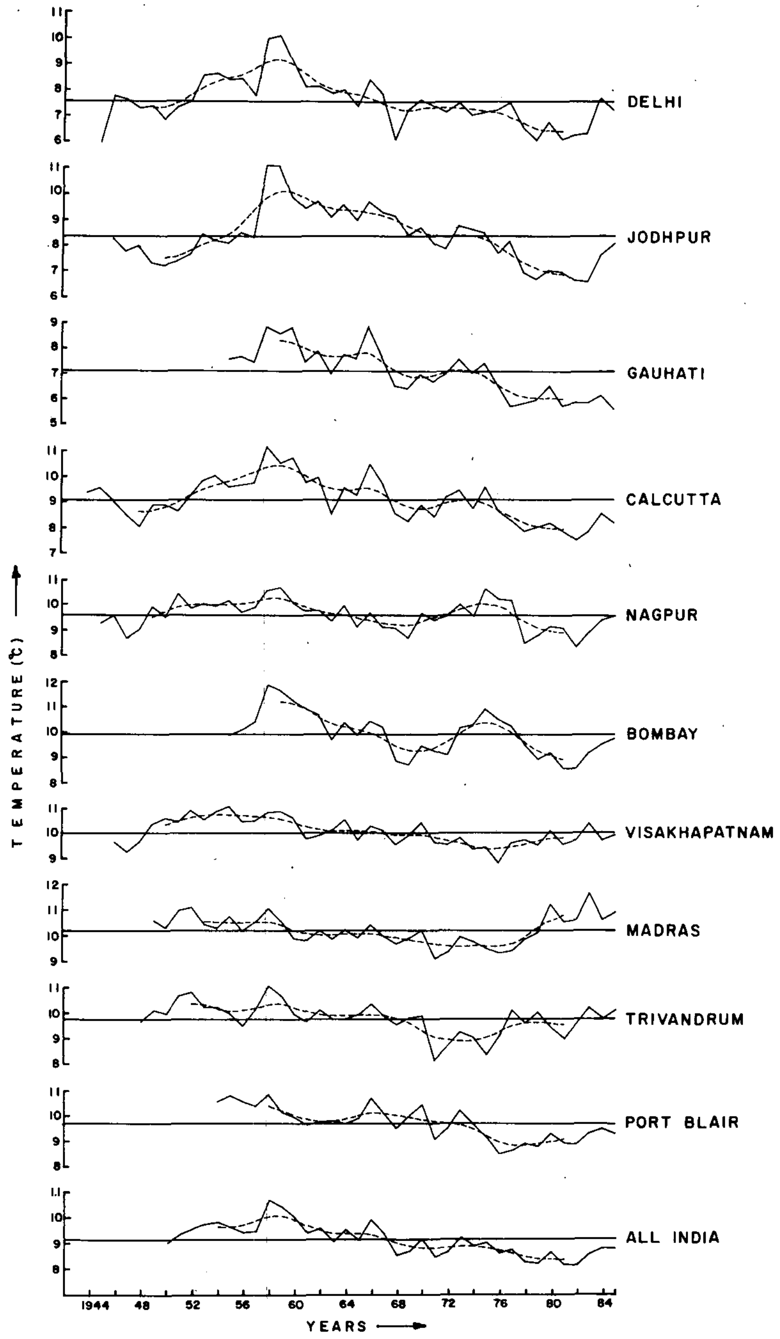

FIG. 4. As in Fig. 3 but at 700 mb.

The trend reversal around 1958 is more conspicuous at this level, particularly for the northern stations.

4) 500 MB

The trend reversal around 1958 is very prominently seen at the 500 mb level (Fig. 5). It may be seen that the post-1958 cooling slackens during early 1970s and even turns into a warming at some of the northern stations (Gauhati and Calcutta), but there is a rapid cooling again in the late 1970s. At the southern stations, the variations are almost similar to those observed at the 850 and 700 mb levels; however, the warming during late 1970s becomes more conspicuous at the 500 mb level. It can also be seen that almost all stations show a warming tendency toward the end of the record (during the early 1980s). The all-India average prominently shows the trend reversal around 1958 at this level.

5) 200 MB

Analysis of the 200 mb temperature series becomes difficult as the effect of radiosonde instrumental

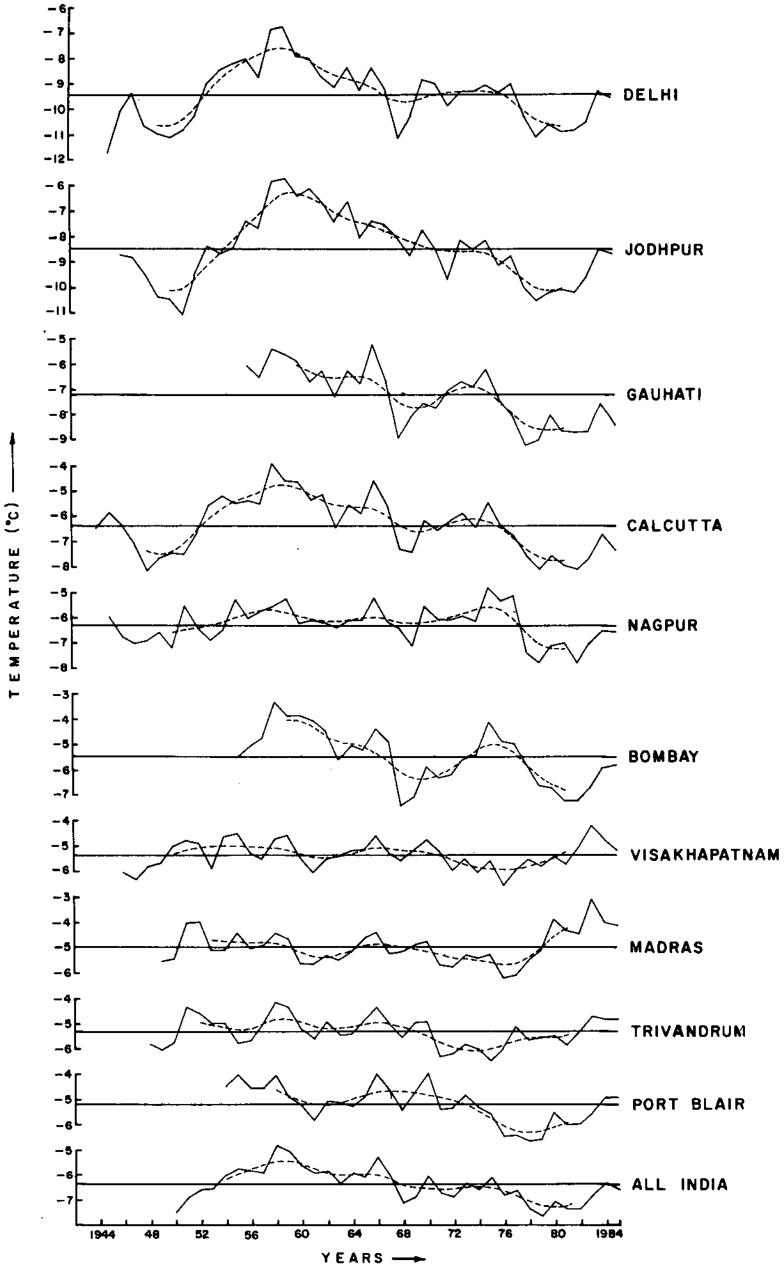

FIG. 5. As in Fig. 3 but at 500 mb.

changes becomes alarmingly large at this level. The exceptionally low temperatures at about the time of changeover during 1968–70 to AM-sonde (Fig. 6) cannot be attached any meteorological significance, as remarked by Van de Boogaard (1977), because they had not been corroborated by neighboring non-Indian stations (also see Parker, 1985). It may also be noted that the effect of instrumental changeover is predominantly seen at the northern Indian stations. This is obviously due to the overestimation of temperature by the C-type radiosondes (Ananthakrishnan et al., 1966) used by the northern Indian stations as compared to the F-type used by the southern stations until the time of the changeover to AM-type. In spite of these constraints, some general comments can be made about the temperature changes at the 200 mb level. The year-to-year variation of temperature at this level is larger than that at the other levels at all stations. The trend reversal noticed around 1958 at the lower levels is not so well defined at this level. At the southern stations, there is some evidence of warming during the early 1960s, most conspicuously at Port Blair. The warming during the early 1970s and cooling thereafter is very predominant at Bombay and Nagpur. A tendency of the temperature to increase after about 1979 is seen at all stations, particularly at the southern stations. The all-India average shows an almost continuous cooling up to 1979 and warming thereafter.

b. Linear trends of tropospheric temperatures in India

1) SURFACE

The linear trends of seasonal as well as annual surface air temperatures have been computed for the period 1958–85 for comparison with those of upper-air temperatures (Table 2). Most of the trends are not significant at the 5% level, indicating the stability of surface air temperatures during this period. The all-India av-

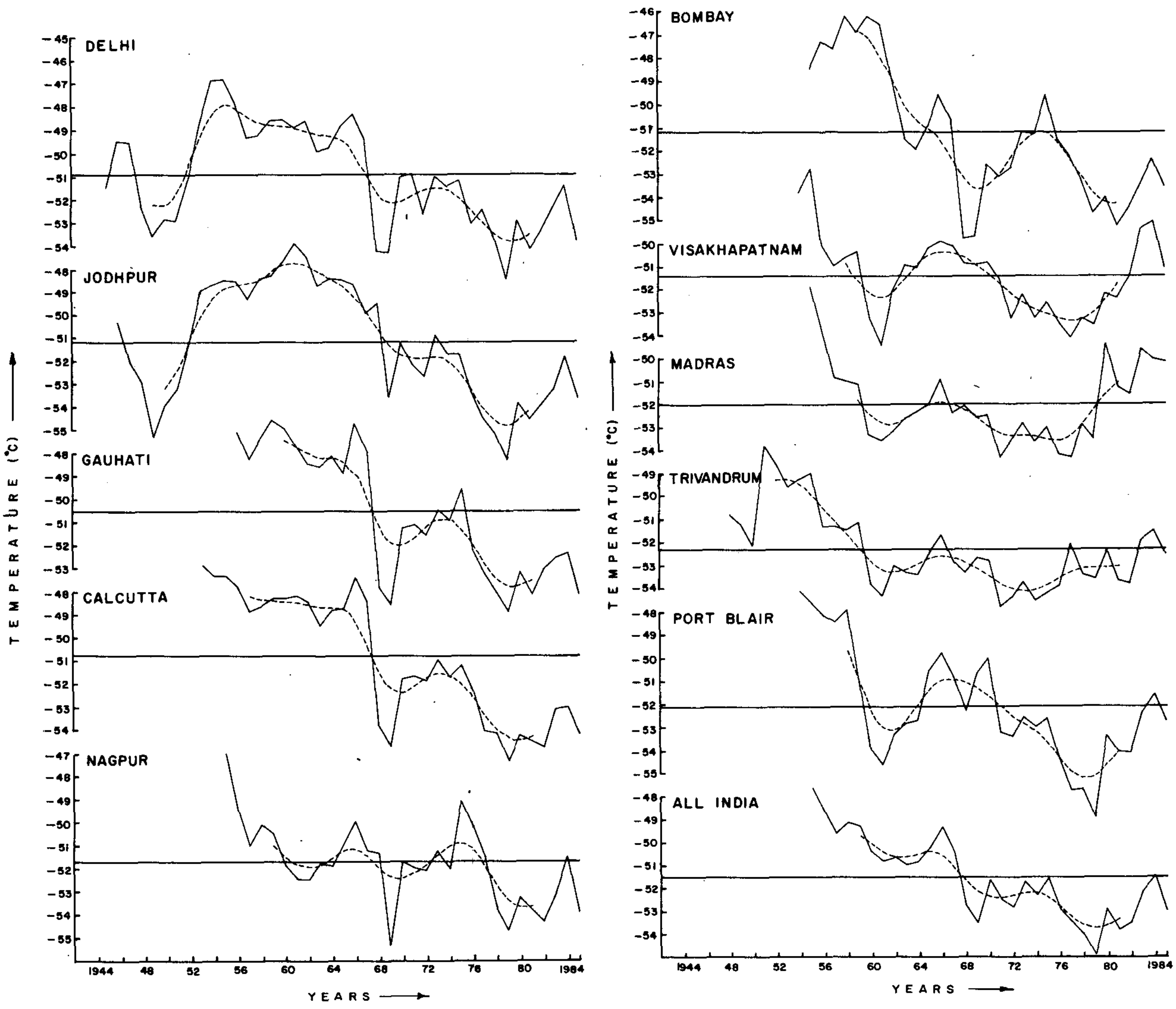

FIG. 6. As in Fig. 3 but at 200 mb.

TABLE 2. Linear trends of surface air temperature in °C/10 years during the period 1958–85.

Station	Winter	Premonsoon	Monsoon	Postmonsoon	Annual
Delhi	−0.05	−0.11	−0.08	0.02	−0.06
Jodhpur	−0.51	−0.39	−0.12	−0.29	−0.31
Gauhati	−0.17	−0.14	−0.12	0.09	−0.09
Calcutta	−0.21	−0.34*	0.01	0.26	−0.08
Nagpur	−0.08	0.16	0.07	0.15	0.08
Bombay	−0.23	−0.10	0.07	−0.07	−0.07
Visakhapatnam	0.31	0.13	0.12	0.21	0.19
Madras	0.09	0.24	0.02	0.08	0.11
Trivandrum	0.17	0.25*	0.10	0.05	0.15
Port Blair	−0.66	−0.40	−0.17	−0.39	−0.38
All India[†]	−0.04	−0.11	−0.02	0.25	−0.01

* Significant at the 5% level.

[†] Based on data at 73 stations over the period 1958–82.

erage surface air temperatures do not show significant trends during 1958–82 either (Table 2).

2) UPPER LEVELS

The linear trends (in °C/10 years) evaluated in upper-air temperatures for the segmented periods, (i) up to 1958 and (ii) 1958–85, are given in Tables 3 and 4, respectively. In some cases, trends for the earlier period (up to 1958) could not be obtained due to very few data points.

(i) Trend reversal around 1958. During the period up to 1958, there is considerable warming at many of the stations (Table 3). Most of the trends noticed are not significant, presumably due to the short data length. The annual trends obtained for the later period, 1958–85, are also shown in this table for comparison. The results clearly demonstrate trend reversal at the northern stations, as mentioned earlier.

(ii) Trends during 1958–85. The four northern Indian stations Delhi, Jodhpur, Gauhati and Calcutta have shown a predominant cooling trend over the past 28 years at all levels (Table 4). The linear trend values, which ranged from −1.8° to −3.2°C per 10 years for 200 mb and from −0.5° to −1.7°C per 10 years for the lower levels, are all highly significant. The larger cooling trends at 200 mb may be attributed partly to the instrumental changes, whose effects are believed to become more predominant above the 300 mb level (Van de Boogaard, 1977). The cooling trends at Nagpur and Bombay are less significant. The trends at the southern stations Visakhapatnam, Madras and Trivandrum are small and are mostly not significant. The island station Port Blair shows significant cooling (trend values ranged from −0.2° to −0.5°C per 10 years) at the lower levels.

An overview of the trends for different stations, seasons and levels indicates that there is a cooling trend all over. This feature is well reflected in the all-India average series showing highly significant cooling trends (Table 4). The linear trends in the upper-air temperatures over the period considered do not exhibit marked interseasonal contrast.

(iii) Trends during the period of uniform instrumental use. In view of the instrumental changes over the study period, the remarkable cooling trends at the northern stations (Table 4) naturally prompt one to be more cautious in interpretation. The nature of trends during the period of uniform radiosonde instrumentation, 1970–85, would be worth examining in this context. The trends in the annual mean temperatures are evaluated for this period and are presented in Table 3 for comparison with those for the period 1958–85. All of the stations north of, and including, Bombay and the island station Port Blair show large cooling trends during 1970–85, the period of uniform instrumentation, as is the case during 1958–85. The values are higher at higher levels. However, the trends are not statistically significant at the 5% level, presumably due to the short data length. The three southern peninsular stations Visakhapatnam, Madras and Trivandrum show warming trends at all levels during this period. The all-India average series (Table 3) also shows a cooling trend above the 700 mb level, in agreement with the trends during 1958–85. Thus, the large cooling trend noticed at the northern stations is obviously not just a result of the instrumental change.

4. Discussion

In most of the temperature-trend studies, CO_2 and volcanic eruptions are the most sought-after causal factors. However, as Angell and Korshover (1983) remarked, detection of an unambiguous signal of CO_2 effect will be difficult and will not be helped by volcanic eruptions, which tend to cool the troposphere and warm the stratosphere, the opposite of the changes associated with a CO_2 increase. Further, most of the cause and effect explanations lean heavily on the model predictions, which are not without constraints. Thus, it is

TABLE 3. Linear trends in the mean annual upper-air temperatures in °C/10 years over different segments of the data period.

Station	Level (mb)	Until 1958	1958–85	1970–85
Delhi	200	2.9	−2.0*	−1.5
	500	2.8	−1.0*	−0.9
	700	1.7*	−1.0*	−0.6
	850	0.7	−1.0*	−0.2
Jodhpur	200	4.3	−2.8*	−1.6
	500	2.4	−1.5**	−0.9
	700	1.5	−1.4**	−1.1
	850	1.3	−1.4**	−0.8*
Gauhati	200	—	−2.7*	−2.1
	500	—	−1.0*	−1.1
	700	—	−1.0**	−1.0
	850	—	−1.0**	−0.6*
Calcutta	200	—	−2.6*	−2.1
	500	1.6	−1.1**	−1.3
	700	1.0	−1.0**	−0.8
	850	1.3*	−0.8**	−0.3
Nagpur	200	—	−0.8	−1.7
	500	0.8	−0.4	−1.1
	700	0.8*	−0.4	−0.6
	850	1.5	−0.4	−0.2
Bombay	200	—	−2.4	−1.5
	500	—	−0.9	−0.7
	700	—	−0.7	−0.5
	850	—	−0.7	−0.1
Visakhapatnam	200	—	−0.1	1.3
	500	0.9	0.0	0.4
	700	1.0	−0.3	0.1
	850	0.7	−0.1	0.5
Madras	200	—	0.5	2.7*
	500	0.5	0.3	1.3
	700	0.0	0.2	1.1
	850	−0.5	0.2	1.5*
Trivandrum	200	−0.4	−0.1	1.3
	500	0.8	−0.2	0.7
	700	0.4	−0.3	0.8
	850	0.2	−0.1	1.3
Port Blair	200	—	−1.0	−0.6
	500	—	−0.4	−0.4
	700	—	−0.5*	−0.4
	850	−0.4	−0.3*	−0.1
All India	200	—	−1.4*	−0.6
	500	2.7*	−0.6*	−0.4
	700	1.1	−0.6*	−0.3
	850	0.2	−0.6*	0.1

* Significant at the 5% level.
** Significant at the 1% level.

difficult to put forth a tenable hypothesis to account for the observed changes in the temperatures. Nevertheless, it would be useful to consider a causal mechanism with some plausible logic, and a few important aspects of the present study will be highlighted in this connection.

Except for the three southern peninsular stations, the remaining stations show a high cooling rate at the 200 mb level relative to the lower levels. A general increase of the cooling rate with height is also evident. These features lead to an increasing lapse rate in the troposphere, particularly over the northern parts of the country. Though the stratospheric data could not be considered in the analysis due to sparsity of data, the increasing lapse rate at higher levels is an important aspect of the CO_2 signal. However, the behavior of the southern stations, which is quite different from that of their northern counterparts, poses some complications. This difference could be due to the different circulation features dominating the regions. The northern region comes under midlatitude influences, particularly in winter, which make the northern region distinctly different from the southern. These differences might play some role in modifying the climatic change effects. Again, Port Blair is an island station, away from the mainland, and its differences from its counterparts in southern India could also have been due to differences in local climatic and geographic features.

It may be interesting to compare the observed variations in the Indian temperatures with those in the global climatic zones as studied by Angell and Korshover (1983). For the tropics as well as northern temperate latitudes, they found cooling from 1958 to about 1970 and warming thereafter. This feature, as pointed out earlier, is seen only at the southern peninsular stations in India. The northern stations and Port Blair show a continuous decrease during the period 1958–85, though the rate of cooling appears to be relatively less in the last decade. The continuous cooling noticed at northern Indian stations does not fit into the global or climatic-zone averages presented by Angell and Korshover (1983).

Atmospheric models, on the basis of radiation interplay, suggest that there would be cooling in the troposphere following volcanic eruptions sufficiently powerful to inject appreciable amounts of gases and particulates into the stratosphere (Harshvardhan and Cess, 1976; Hansen et al., 1978; Robock, 1983). However, Angell and Korshover (1984), on comparing the effects of Agung and El Chichón eruptions on the tropospheric temperatures, found significant differences between the two, demonstrating the complexity of interpreting these effects. They also brought out the role of El Niño/Southern Oscillation in confounding the effects of El Chichón on the tropospheric temperatures. Examination of the seasonal and annual mean tropospheric temperatures in the present study (see Figs. 2–6) does show feeble indication of cooling at lower levels around 1963, the year of eruption of Mount Agung (Indonesia), but it is very difficult to distinguish between this and other unassociated cooling instances. However, the effects of El Chichón become hardly discernible around 1982 in Figs. 2–6. Further work (separating the superposed effects of CO_2, volcanic eruptions and El Niño) is required to get a clear picture of causal mechanisms for the tropospheric temperature variations.

TABLE 4. Linear trends in °C/10 years of upper-air temperatures during the period 1958–85.

Station	Level (mb)	Winter	Premonsoon	Monsoon	Postmonsoon	Annual
Delhi	200	−2.1*	−1.8**	−2.0*	−2.2*	−2.0*
	500	−1.2*	−0.9*	−1.0**	−0.9*	−1.0*
	700	−0.9*	−1.1*	−0.9*	−0.9	−1.0*
	850	−1.1**	−1.3*	−0.9*	−0.8*	−1.0*
Jodhpur	200	−2.8*	−2.5*	−3.2**	−2.9**	−2.8*
	500	−1.4*	−1.1*	−1.7**	−1.7*	−1.5**
	700	−1.5**	−1.3**	−1.3**	−1.5**	−1.4**
	850	−1.4**	−1.6**	−1.3**	−1.4*	−1.4**
Gauhati	200	−2.5*	−2.3*	−3.2*	−2.5*	−2.7*
	500	−1.2*	−0.9	−1.1**	−0.9*	−1.0*
	700	−1.1**	−1.2**	−0.9**	−1.0*	−1.0**
	850	−1.2**	−1.3**	−0.7*	−0.6**	−1.0**
Calcutta	200	−2.7*	−2.3*	−2.7*	−2.7*	−2.6*
	500	−1.3*	−1.1*	−1.1**	−0.9*	−1.1**
	700	−1.3*	−0.9*	−0.8**	−0.8*	−1.0**
	850	−1.2**	−0.9*	−0.5*	−0.5	−0.8**
Nagpur	200	−0.8	−0.5	−1.0*	−1.0	−0.8
	500	−0.5	−0.2	−0.5*	−0.5	−0.4
	700	−0.5	−0.3	−0.2	−0.6	−0.4
	850	−0.5*	−0.6	−0.1	−0.3	−0.4
Bombay	200	−2.2	−1.9	−2.7	−2.5	−2.4
	500	−0.7	−0.7	−1.2*	−0.8	−0.9
	700	−0.6	−0.7	−0.7	−0.9	−0.7
	850	−1.0*	−0.7*	−0.3	−0.9*	−0.7
Visakhapatnam	200	0.1	−0.4	0.1	−0.1	−0.1
	500	−0.1	−0.3	0.0	0.3	0.0
	700	−0.4*	−0.3	−0.2	−0.2	−0.3
	850	−0.4	0.0	0.0	0.0	−0.1
Madras	200	0.5	0.1	0.8	0.8	0.5
	500	0.3	0.3	0.3	0.5	0.3
	700	0.1	0.2	0.3	0.2	0.2
	850	0.2	0.4	0.2	0.2	0.2
Trivandrum	200	−0.1	−0.3	0.1	0.1	−0.1
	500	−0.2	−0.4	−0.1	0.0	−0.2
	700	−0.2	−0.2	−0.3	−0.1	−0.3
	850	−0.1	−0.1	−0.1	0.0	−0.1
Port Blair	200	−0.8	−0.8	−1.4	−0.8	−1.0
	500	−0.3	−0.3	−0.6	−0.4	−0.4
	700	−0.5*	−0.4*	−0.5*	−0.5*	−0.5*
	850	−0.3	−0.2	−0.3**	−0.3	−0.3*
All India	200	−1.3*	−1.3*	−1.5*	−1.4*	−1.4*
	500	−0.7*	−0.5*	−0.7**	−0.6	−0.6*
	700	−0.7*	−0.6*	−0.6*	−0.6*	−0.6*
	850	−0.7**	−0.6*	−0.4	−0.5*	−0.6*

* Significant at the 5% level.
** Significant at the 1% level.

5. Conclusions

The following are the main conclusions from this study:

1) Annual as well as seasonal surface temperatures do not show appreciable trends during the last three decades over India.

2) There had been warming at all levels up to 200 mb, particularly at the northern Indian stations, from the late 1940s up to 1958 and cooling thereafter.

3) There is a distinct contrast between the northern and southern Indian stations during 1958–85 in that the former have shown significant cooling while the latter have shown no trends. Port Blair, an island sta-

tion considerably south, however, has shown significant cooling at the lower levels.

4) The southern Indian stations show cooling in the first decade and warming in the last decade during 1958–85, in agreement with the results reported by Angell and Korshover.

5) The rate of cooling increases with height, particularly at the northern stations.

6) The cooling at the northern Indian stations is clearly seen even during the period of uniform instrumentation.

7) There is no marked interseasonal contrast in the trends of upper-air temperatures.

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