MAUSAM, **57**, 3 (July 2006), 437-444

551.524.36 : 551.521

Pre-monsoon maximum temperatures over New Delhi, Mumbai & Chennai and possible solar influence

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(*Received 26 October 2004, Modified 13 October 2005*)

सार – वर्ष 1951 से 2001 तक की 51 वर्षों की अवधि के लिए नई दिल्ली, मुम्बई और चेन्नै में मानसून पूर्व अधिकतम तापमान में सामान्य विभिन्नताओं के सौर क्षोभ [सूर्य के धब्बों (एस. एस.) की संख्या के वार्षिक औसत के संबंध में आकलन] के साथ संभावित संबंध का सांख्यिकीय रूप से विश्लेषण किया गया है। तापमान के श्रृंखलाबद्ध आँकड़ों के आधार पर केवल चेन्नै के लिए तापमान में वृद्धि की प्रवृत्ति को छोड़कर अन्य सभी केंद्रों पर लगभग 3 वर्षों के अन्तराल पर इसकी पुनरावृति का पता चला है । सौर अवस्थाओं (वृद्धि दर निदर्श का उपयोग करके) की विभिन्नताओं के विश्लेषण से सूर्य की न्यूनतम और अधिकतम अवस्थाओं के दौरान 73 प्रतिशत मामलों में तापमान में वृद्धि की प्रवृत्ति का पता चला है । गत वर्ष के मानसून पूर्व तापमान और सूर्य के धब्बों की संख्या के वार्षिक औसत के बीच सहसंबंध के गुणांक रूप से सकारात्मक होने का पता चला है जब सूर्य के धब्बों की संख्या का वार्षिक औसत लगभग 140 के चरम मान से अधिक हो जाता है और यह (+0.647) नई दिल्ली के संबंध में महत्वपूर्ण है । यह परिणाम पूर्वी भारत के केंद्रों के लिए किए गए इसी तरह के अध्ययनों के अनुरूप है ।

ABSTRACT. The general variations of pre-monsoon maximum temperature over New Delhi, Mumbai and Chennai for the 51 years period from 1951 to 2001 and its possible association with solar activity [estimated in terms of annual mean sunspot (SS) numbers] have been analysed statistically. The temperature series indicate an approximate periodicity of 3 years for all the stations with an increasing trend for Chennai only. Analysis of the variations with respect to solar phases (using a growth rate model) indicates an increasing trend of temperature in 73% cases during solar minimum to maximum phases. The correlation coefficient between pre-monsoon temperature and annual mean SS nos. of the preceding year indicate a positive association when the latter exceeds some critical value approximately 140 and it (+0.647) is significant for New Delhi. The present result is consistent with similar studies for stations over eastern India.

Key words – Pre-monsoon maximum temperature, Periodicity, Solar phase, Correlation coefficient, Critical sunspot number.

1. Introduction

The radiation from the Sun reaching the Earth's atmosphere is not only non-uniform in space and time but also sometimes becomes highly energetic depending on different solar activities (Zheleznyakov, 1970). These activities are associated with variations of solar magnetic field and change in sunspot (SS) numbers periodically (Priest, 1982).

It is known that the solar activities have the potential to influence the geomagnetic activities which, in turn, can influence the earth's climatic parameters significantly (King 1974, Raja Rao *et al*. 1978, Bucha 1980). Also the solar activities have a positive influence for the variations of different ionospheric conditions and the later have some impact on the earth's middle and lower atmosphere too (Angell and Korshover 1973, Bates 1977, Hargreaves 1980). Thus changes in earth's lower atmosphere and climatic parameters, at least partially, are expected by the solar activities either through a change in the geomagnetic activity or change in the upper atmosphere.

Since SS number at any time may be considered as a good measure of solar activity many attempts have been made during the last few decades (Sengupta 1957, Jagannathan and Bhalme 1973, Wilcox 1975, Bhalme and Mooley 1981, Mohankumar and Devanarayan 1984, Ananthakrishnan and Parthasarathy 1984 and many others) to correlate the SS number with different meteorological parameters. Chakraborty and Bandyopadhaya (1986, 1987, 1988, 1989) analysed the variations of different meteorological aspects with solar phases and indicated the existence of a critical SS number

TABLE 1

Mean seasonal temperature ($\bar{T}$) in °C and their dispersions (D%) during different spells

Period	New Delhi		Mumbai		Chennai	
	$\bar{T}$	D%	$\bar{T}$	D%	$\bar{T}$	D%
1951-2001	35.04	3.22	33.01	1.54	35.51	1.94
1951-1960	35.58	3.09	33.04	1.81	34.91	2.21
1961-1970	34.97	2.26	32.97	1.00	35.43	1.97
1971-1980	35.22	2.47	33.08	1.48	35.58	1.63
1981-1990	34.54	4.89	32.90	2.37	35.63	1.37
1991-2000	34.99	2.63	33.05	1.00	35.95	1.45

around which the said influence varies considerably and is significant. However, the results of different authors are yet to appear as fully consistent and as a result a few scientists (Pittock 1983) possess some critical view on the existence of solar-terrestrial interactions and thus to investigate the same further studies appear necessary.

The present study is an investigation in the same line for the meteorological aspect-Pre-monsoon maximum temperature. It is known that maximum solar wind encounters the northern hemisphere during this season and the seasonal maximum temperature is also maximum during pre-monsoon months. Thus an attempt has been made to investigate the general variations of the pre-monsoon temperature over the three stations - New Delhi (28° 35′ N, 77° 12′ E), Mumbai (19° 05′ N, 72° 52′ E) and Chennai (13° 00′ N, 80° 11′ E) during the 51 years period from 1951 to 2001 and their possible association with solar activity.

2. Data

The mean monthly maximum temperatures for the pre-monsoon months of March, April and May during the period of study have been obtained from National data Centre, India Meteorological Department, Pune and the annual mean SS numbers have been obtained from the Indian Institute of Astrophysics, Bangalore.

3. General characteristics of variation of pre-monsoon maximum temperatures

3.1. *Mean, dispersion and trend*

The pre-monsoon temperature (*T*) of any particular year has been obtained by taking the mean of temperatures during March, April and May. From the time series of *T* we obtain their mean ($\bar{T}$) and standard deviations. Expressing the standard deviations as percentage of mean their dispersions (D%) have been computed. It is observed (Table 1) that the mean seasonal temperature is more over Chennai than the other two stations though the dispersion is maximum over New Delhi. Next $\bar{T}$ and D% during different decades have been computed to observe the decadal variations over all the three stations. However, the difference of the decadal mean values of the stations and their corresponding long term means are not statistically significant.

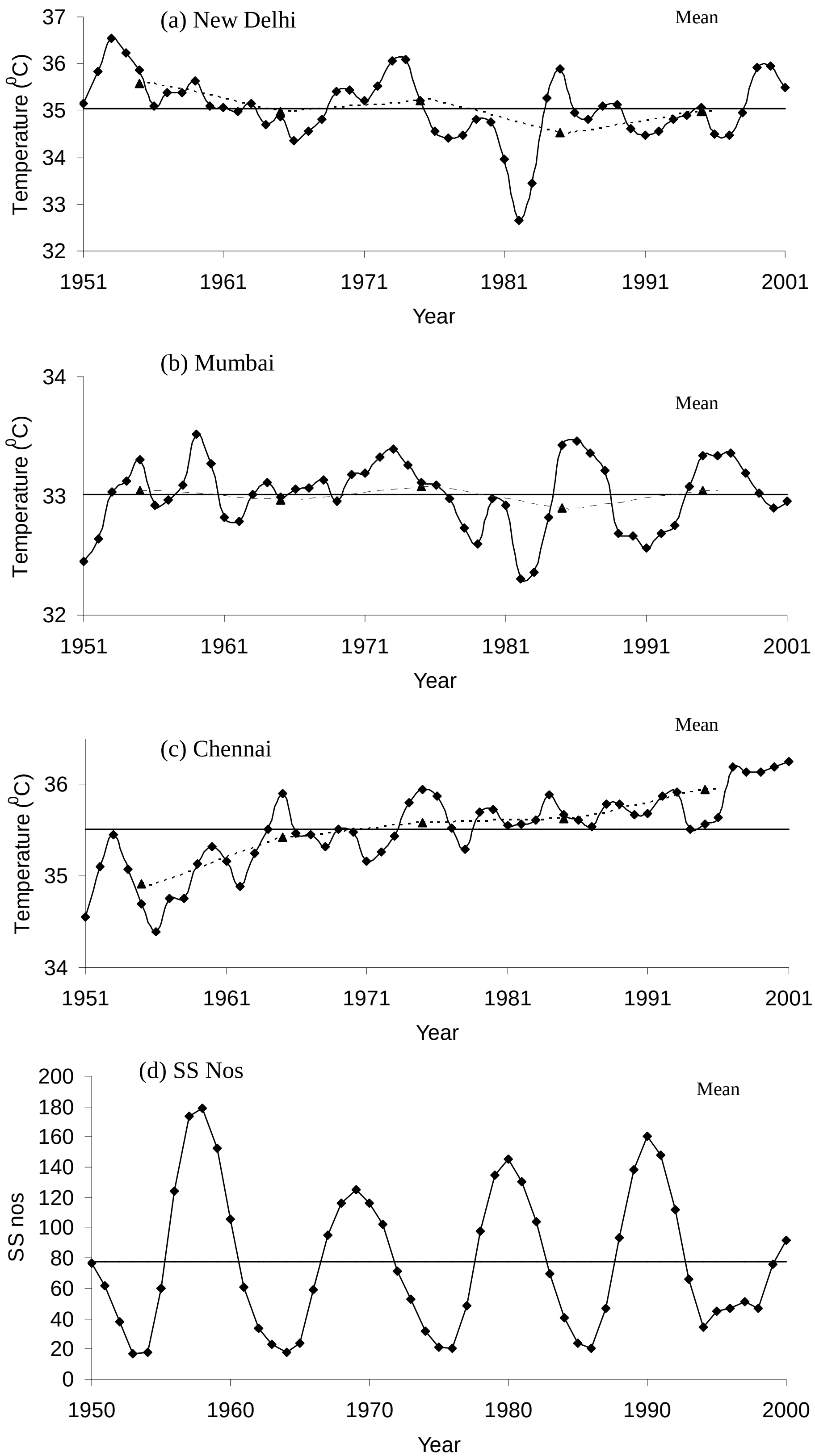
Next to have an idea of the trend of the temperature series we apply three point Gaussian low pass filter (Mitchell *et al*., 1966) to smooth the series by avoiding the effect of high frequencies, if any [Figs. 1(a-c)]. The long term mean values have been shown by horizontal continuous lines and the decadal mean values are joined by dotted lines. However, these do not apparently reveal any specific trend during the period under consideration for New Delhi and Mumbai though for Chennai an increasing trend can be observed.

3.2. *Periodicity*

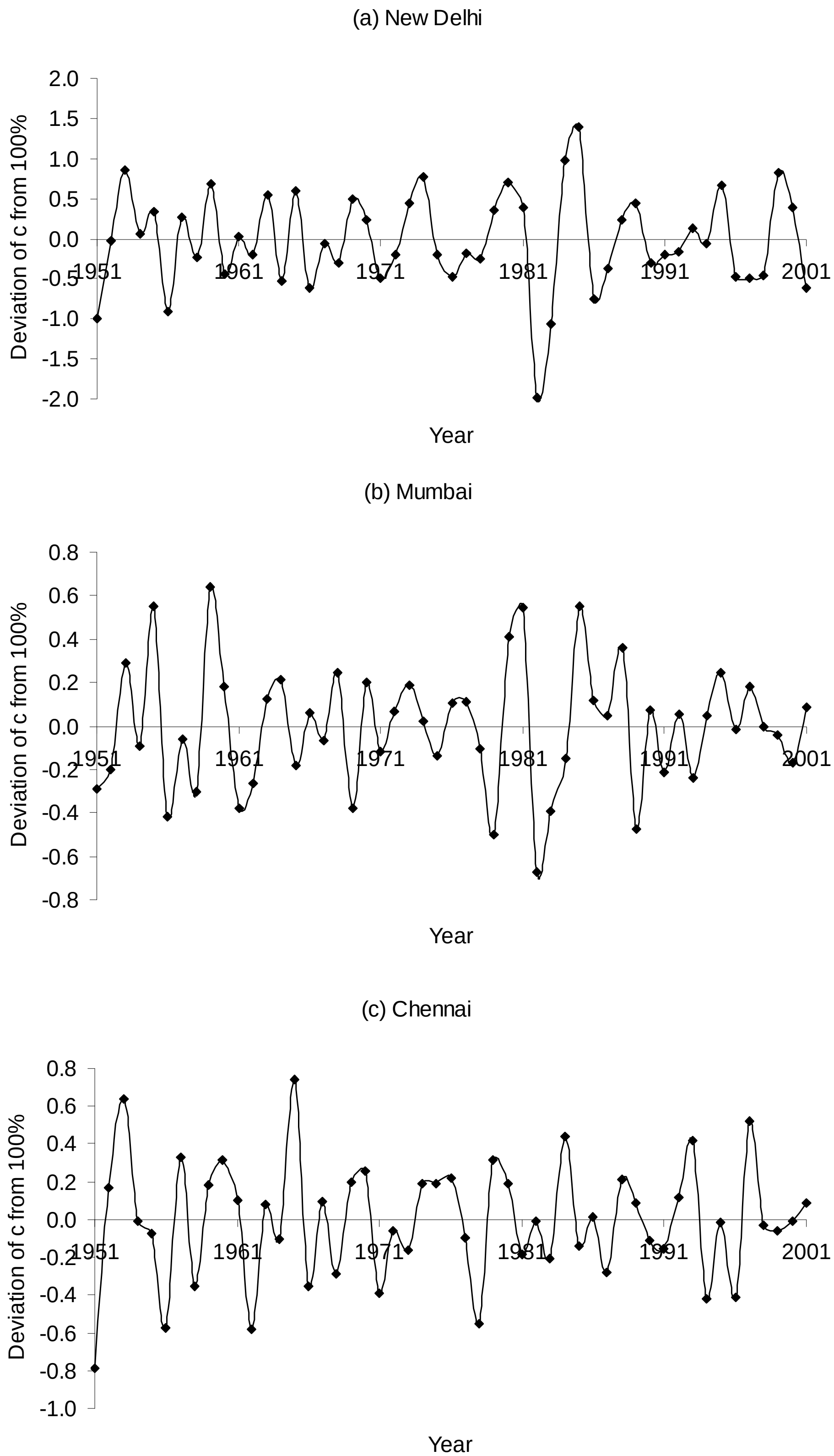
Let us now examine the periodicity of variation of the pre-monsoon temperatures over different stations. There may exist a seasonal variation (S), specific trend (P), cyclic periodicity (C) and irregular variation (I) in the raw temperature data (*T*). Let us assume that *T* is expressed as *T* = SPCI.

To investigate the cyclic periodicity of the pre-monsoon temperatures let us proceed with the following steps (Spiegel, 1981) :

(*i*) Divide the pre-monsoon temperatures of all the years by their mean. The mean of all these values (in %) will represent the seasonal index (S). Then divide the pre-



Figs. 1(a-d). The temperature series over (a) New Delhi, (b) Mumbai and (c) Chennai and the (d) SS nos. of the previous years after applying three point Gaussian low pass filter



Figs. 2(a-c). Cyclic variations of temperature over (a) New Delhi, (b) Mumbai and (c) Chennai

TABLE 2

Growth rate (GR) of SS numbers and temperatures of the following years during different solar phases

SS Phases	GR of SS. No. (%)	GR (%) of seasonal maximum temperature of the following years over		
		New Delhi	Mumbai	Chennai
1954-1957 (min-max)	+251	+1.3	+0.5	+1.4
1957-1964 (max-min)	-34	-1.2	-0.3	0.0
1964-1970 (min-max)	+54	+0.5	+0.4	0.0
1970-1976 (max-min)	-32	-0.1	0.0	0.0
1976-1979 (min-max)	+123	+1.2	-0.5	+1.1
1979-1986 (max-min)	-30	-0.7	+0.3	-0.4
1986-1991 (min-max)	+65	+0.1	-0.8	+0.4
1991-1995 (max-min)	-44	+0.9	+0.7	+0.3
1995-2000* (min-)	+46	+0.6**	-0.2	+0.1

* 2001 was SS max year with SS no. 118.2
** with temperature data upto 2002 *i.e.*, with respect to SS no. of 2001

monsoon temperatures of all the years by S. The resulting data is now equivalent to *T*/S = PCI.

(*ii*) Next to remove any inherent trend divide *T*/S of all the years by the corresponding values obtained by applying 3 point Gaussian low pass filter to obtain *T*/SP = CI (in %).

(*iii*) For diminishing, if not eliminating I, we apply further the low pass filter to the series of CI, when the resulting data becomes equivalent to *T*/SPI = C.

(*iv*) The deviations of C (from 100%) are now computed and plotted against each year for the different stations [Figs. 2(a-c)]. These deviations indicate the percentage of error that may occur in determining the periodicity.

As the range of these deviations is between -0.9 to +0.9% only, it can be said considering the average time interval between the peaks and troughs [Figs. 2(a-c)] that there exist a cyclic periodicity of pre-monsoon temperatures which is approximately 2.8 years for all the three stations in the present study. Similar periodicity of pre-monsoon temperature ranging from 2.2 to 2.8 years have also been observed for different stations in eastern India (Chakraborty and Bondyopadhaya, 1988).

4. Variation with solar activity

In this section let us investigate the possible solar influence on the pre-monsoon maximum temperatures keeping in mind that the influence of solar radiation on the earth's atmosphere is not instantaneous (Roberts, 1979). Since the study is with temperatures of the pre-monsoon months it appears suitable to consider the annual mean SS numbers of the preceding years. The SS numbers during the period 1950-2000 after applying 3 point Gaussian low pass filter have been shown in Fig. 1(d).

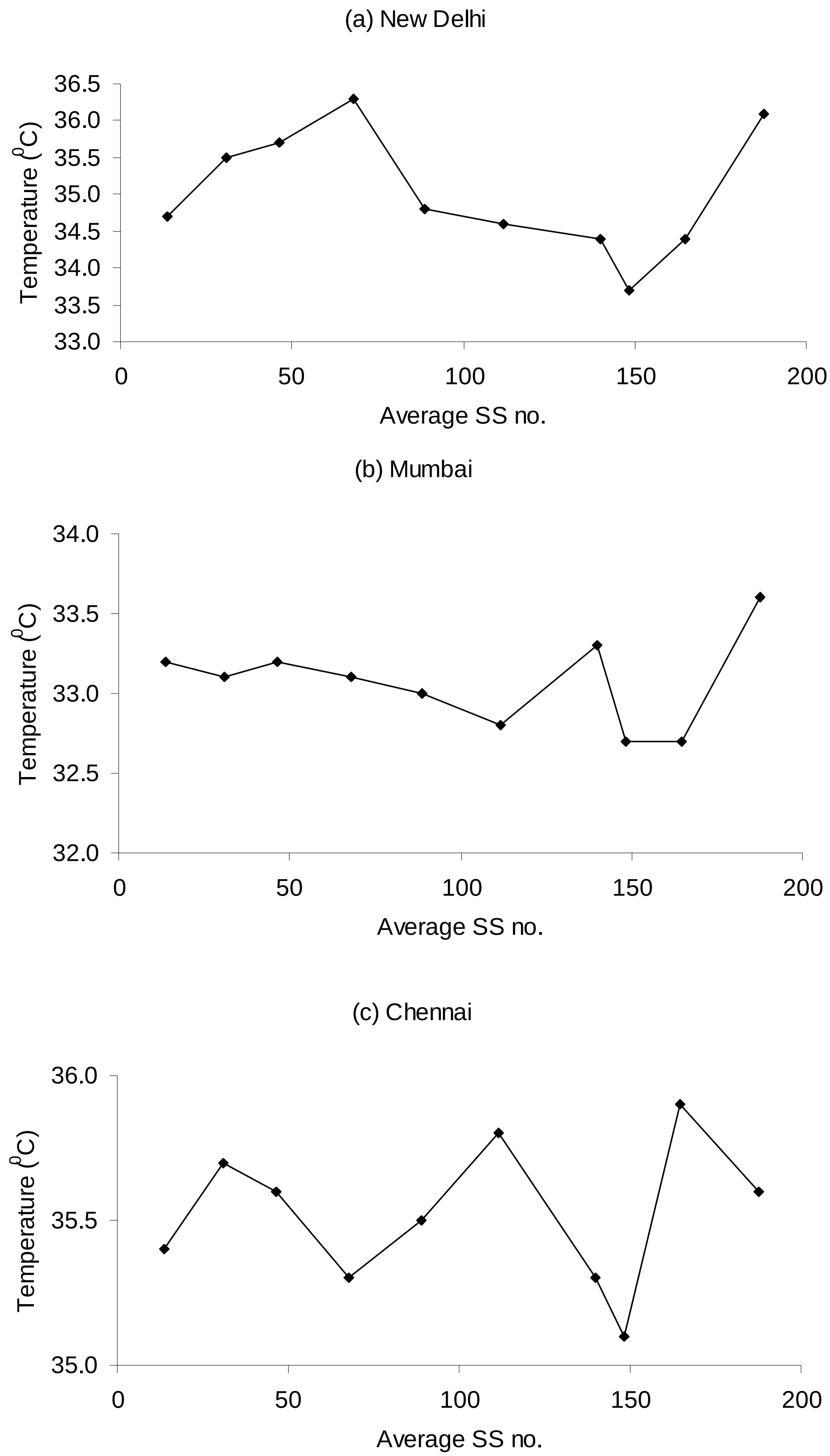
4.1. *Variation with respect to solar phases*

It is known that every solar cycle (having period approximately 11 years) consists of two phases - solar maximum to minimum and solar minimum to maximum. Let us attempt to study the variations of temperatures of the following years with SS numbers with respect to solar phases using the growth rate model

$$X_{n+i} = X_i (1+g)^n$$

Where X_i and X_{n+i} represent the temperature or SS number in i^{th} and $(n+i)^{th}$ year and g is the growth rate at $(n+i)^{th}$ year with respect to the i^{th} year. Now if n represents the interval in year from one solar maximum (minimum) to the next solar minimum (maximum) year, the values of growth rate as computed are given in Table 2. The following are the main observations :

(*i*) The growth rate of SS numbers varies in a wide range from -44% to +251% while that of temperature is very less, only from -1.2% to +1.3%. Further the



Figs. 3(a-c). Average variations of temperature with SS nos. over (a) New Delhi, (b) Mumbai and (c) Chennai variations of the growth rates over Mumbai and Chennai are less than that over New Delhi.

(*ii*) During solar minimum to maximum phases (when SS no. increases) the growth rates of seasonal temperatures are positive in 11 cases out of 15 (*i.e*., 73%), which implies that in those cases the seasonal temperature of following years increase with the increasing phases of the SS nos. But during the solar maximum to minimum phases the growth rates are negative in 5 cases out of 12 (*i.e*., 42%), which implies that unlike the solar minimum to maximum phases no definite conclusion can be drawn during maximum to minimum phases. This result is consistent with similar study with temperatures over stations in eastern India (Chakraborty and Bondyopadhaya, 1988).

4.2. *Variations with respect to SS numbers*

The correlation coefficients (using the standard Kerl-Pearson's product moment formula) between seasonal mean temperatures and annual mean SS numbers of the previous years (*i.e*., 1950-2000) have been calculated. The values of correlation coefficients (CC) have been obtained as -0.171 for New Delhi, -0.227 for Mumbai and -0.054 for Chennai. These values of CC are low and also not statistically significant. Thus it is difficult to comment any association from these values of CC.

Now to investigate the variations of seasonal temperatures with different ranges of SS numbers we compute and plot the mean values of temperatures of the following years against mean values of SS numbers for different intervals [Figs. 3(a-c)], taking conveniently SS intervals of width 20. It may be observed from [Figs. 3(a-c)] that for lower values of SS numbers the variations of temperature are not very significant, but for all the three stations minimum value of temperature is observed when average SS number ~148, exceeding which the temperature again increases considerably. In fact the decreasing trend of temperature becomes significant when the average SS number crosses the value ~140. In a similar analysis with temperatures over different stations in eastern India a similar decreasing trend in the neighborhood of SS number 140 has been observed (Chakraborty and Bondyopadhaya, 1988) which was designated as critical SS number exceeding which the temperature again increases significantly.

It may be interesting to calculate the CC between SS number and seasonal temperatures of the following years when the former attains a relatively high value. The values of CC have been computed for SS number ≥ 140 (since 140 is the lower limit in the SS interval 140-160). These values are +0.647 for New Delhi, +0.547 for Mumbai and +0.216 for Chennai. It is observed that all these values of CC are positive and much higher than those obtained earlier when the CC were calculated considering SS numbers of all the years and further it is significant at 95% confidence level for New Delhi. This indicates a positive association with higher values of SS numbers. It may be mentioned here that studies on the variations of solar constant also show maximum increase during solar maximum years (Domingo, 1976). Based on this it appears that the increase of SS (which are the source of extraordinary radiation from the Sun) may enhance some meteorological parameters, but its absence will not necessarily imply the reverse situation, hence one cannot always expect significant values of CC when the same is calculated for all the years irrespective of solar phases and SS numbers.

5. Conclusion and remarks

The present study reveals the following salient features :

(*i*) During the period of analysis the variations of pre-monsoon maximum temperature is only between 1.5 to 3.2%. Their decadal variations indicate an increasing trend for Chennai only. However, for all the three widely distributed stations the temperature series show a periodicity of approximately 3 years.

(*ii*) During solar minimum to maximum phases the pre-monsoon maximum temperature increases in 73% cases with increase of SS nos, while during solar maximum to minimum phases no such conclusion can be drawn.

(*iii*) The average nature of variation of pre-monsoon maximum temperature and SS no. indicate the existence of some critical SS no. (≈140) when a significant decrease in temperature is noticed and for further higher values of SS no. the temperature increases considerably. The association is positive (as revealed from the value of CC) with SS nos. ≥ 140 and it is significant for New Delhi.

The existence of critical SS no. in this study and similar other studies possibly through a light for further investigations on solar-terrestrial interactions. However, for its establishment more and more similar studies (with wider period of data) are required, particularly to investigate any latitudinal dependence of the association.

Acknowledgement

The authors are grateful to the referee for his valuable comments in improving the paper.

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