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VARIATION OF PRE-MONSOON TEMPERATURE OVER EASTERN INDIA AND THE SOLAR ACTIVITY

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Variation of pre-monsoon maximum temperature and its association with solar activity (measured in terms of annual mean sunspot no.) has been studied for five stations in eastern India in the latitude belt 11°40′ N to 26°32′ N. It is observed that there exists a declining tendency of temperature after 1969 and a rough periodicity of 2–3 years. Analysis of growth rate model indicates that during solar minimum to maximum phase in 3/4th of the cases the temperature increases with increase of sunspot number. The correlation coefficient between premonsoon temperature and the annual mean sunspot number of the preceding year is significant (= + 0.40) for Port Blair (11°40′ N) only. This observation is consistent with the average nature of temperature variation with sunspot number. Also the existence of a critical value of sunspot number (≈ 140) is also indicated for which a sharp drop of temperature is observed, although this drop may be slightly latitude-dependent.

Key Word : Pre-monsoon Maximum Temperature; Correlation Coefficient; Critical Sunspot Number

INTRODUCTION

MANY successful investigations have been made during the last three decades on the influence of solar activity on meteorological aspects e.g. atmospheric circulation[1], rainfall[2–6] flood and drought area,[7] onset of monsoon[8] etc. Some scientists, however, possess a critical view to this[9] and some others possess a very optimistic view.[10,11]

The present authors in their different works[3,4,8,12] have tried to analyse the solar influences on the basis of its phases (sub-cycles, 11 years and 22 years solar cycle). Perhaps some new insight is obtainable by this approach. Mohankumar and Devanarayanan[13,14] have shown that the stratopause temperature and mesospheric mean temperature have almost in phase relationship with solar cycle.

The present work is an investigation for the influence of solar activity on surface temperature during the Indian pre-monsoon season (March to May). In fact,

the months of March, April and May are very much prone to thunderstorm activity in eastern India and also the seasonal maximum temperature is maximum during this period in comparison to other seasons. It is also known that maximum solar wind encounters the northern hemisphere during this season. Naturally, therefore, to characterise the pre-monsoon temperature as a function of solar activity (measured in terms of annual mean sunspot number) may be an interesting study. For this purpose we select five well distributed stations in eastern India viz. Port Blair (11°40′ N, 92°46′ E), Sagar Island (21°45′ N, 88°08′ E), Calcutta (22°32′ N, 88°20′ E) Malda (25°02′ N, 88°08′ E) and Jalpaiguri (26°32′ N, 84°43′ E) and analyse the pre-monsoon temperature during the period 1953 to 1985. The data have been collected from the monthly meteorological reports of the India Meteorological Department.

General Characteristics of Pre-Monsoon Maximum Temperature

Mean and dispersion

To study the characteristic variation of the pre-monsoon maximum temperature of the five representative stations for the period 1953–85, we first compute the mean temperature ($\bar{T}$) and dispersion (D) about the mean temperature (obtained from standard deviations), *vide* Table I. It may be observed that in the latitude belt under consideration (*a*) the mean temperature ($\bar{T}$) maintains higher value in the neighbourhood of 23.5°N (i.e. for Calcutta and Malda), (*b*) the dispersion (D) about the mean varies from 1.7 per cent (for Sagar Island) to 4.2 per cent (for Malda).

TABLE I

Mean ($\bar{T}$) and Dispersion (D per cent) of temperature during different spells

Station	1953–85		1953–69		1970–85	
	$\bar{T}$(°C)	D%	$\bar{T}$(°C)	D%	$\bar{T}$(°C)	D%
Port Blair	31.8	1.9	32.1	1.7	31.5	1.7
Sagar Island	31.1	1.7	31.2	1.3	31.1	2.0
Calcutta	35.3	2.6	35.8	1.8	34.7	2.4
Malda	35.3	4.2	35.6	2.7	34.9	5.5
Jalpaiguri	30.6	3.2	30.6	3.4	30.7	3.2

Trend

To find the trend the 3-year moving average values of temperature ($\tilde{T}$) are calculated and plotted (Fig. 1). It appears from Fig. 1 that since the fifties as we approach towards the recent years a declining tendency of temperature exists (considering the values of $\bar{T}$ on the two sides of the mean). It may also be noted that the difference between the mean temperatures ($\bar{T}$) during 1953–69 and

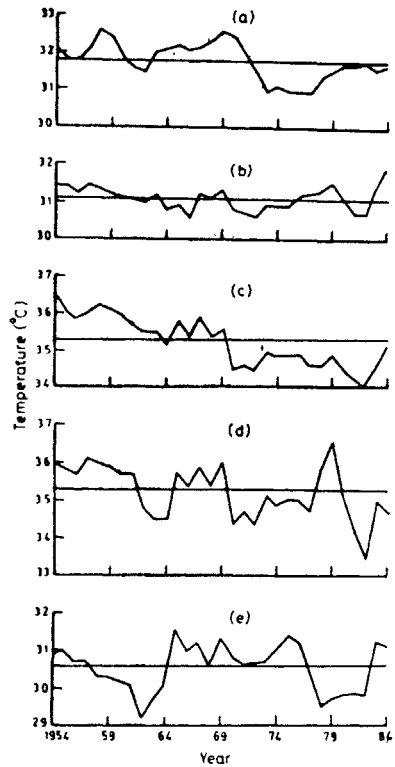

FIG 1 3 year's moving average of pre-monsoon max. temp. over (*a*) Port Blair, (*b*) Sagar Island, (*c*) Calcutta, (*d*) Malda, (*e*) Jalpaiguri.

1970–85 (*vide* Table I) are statistically significant for the stations Port Blair, Calcutta and Malda, being maximum for Calcutta.

Periodicity

Now there may exist a seasonal variation (S), specific trend (T), cyclic periodicity (C) and irregular variations (I) in the raw temperature data (Y). Let us assume that Y may be expressed as $Y = STCI$.

To investigate the cyclic periodicity (C) we proceed with the following steps :

(1) Divide pre-monsoon temperature of all the years by their mean. The mean of all these values (in per cent) will represent the seasonal index (S). Then divide the pre-monsoon temperature of all the years by S. The resulting data is now equivalent to $Y/S = TCI$.

(2) Next to remove the trend (T) divide Y/S of all the years by the corresponding 3-year's moving average values to obtain $Y/ST = CI$ (in per cent).

(3) For diminishing, if not eliminating I, we further compute 3-year's moving average values of CI when the resulting data (in per cent) becomes equivalent to $Y/STI = C$.

(4) The deviations of C (from 100 per cent) are now computed and plotted against each year for the five different stations. These deviations indicate the percentage of error that may occur in the forecast of periodicity.

As these deviations are only between 1 per cent to 2.5 per cent we may conclude, considering the average time interval between the peaks and the troughs, from Fig. 2 that there exists a periodicity of pre-monsoon maximum temperature and it is approximately 2.7 years for Port Blair and Malda, 2.5 years for Sagar Islands, 2.2 years for Calcutta and 2.8 years for Jalpaiguri.

Growth Rate of Temperature during Solar Half Cycle

In this section we attempt to study the variation of temperature with sunspot (S.S.) number during solar minimum to maximum and solar maximum to minimum phases using a growth rate (G.R.) model

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

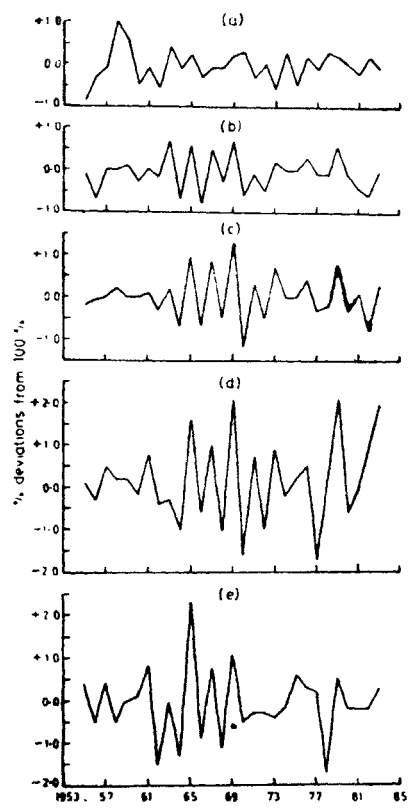

Fig 2 Cyclic variation of temperature over (*a*) Port Blair, (*b*) Sagar Island, (*c*) Calcutta, (*d*) Malda, (*e*) Jalpaiguri.

where X_i and X_{n+i} represent the temperature or sunspot value in ith and $(n + i)$-th year, g is the growth rate at $(n + i)$th year with respect to the ith year. Now if n represents the interval in year from one solar maximum (minimum) to the next minimum (maximum) the value of GR (g) as computed are given in Table II. The following are the main observations :

TABLE II

Growth rate of S.S. number and maximum temperature of the following years during different S.S. phases

S.S. Phases	G.R. of S.S. no. (%)	G.R. of maximum temperature of the following years (%) over				
		Port	Sagar	Calcutta	Malda	Jalpaiguri
1954–57 (min.–max.)	+ 251	+ 1.1	+ 0.4	+ 0.3	+ 1.0	+ 0.2
1957–64 (max.–min.)	— 34	— 0.4	— 0.8	— 0.7	— 0.6	+ 0.8
1964–70 (min.–max.)	+ 54	+ 0.2	— 0.9	— 1.0	— 1.6	— 0.4
1970–76 (max.–min.)	— 32	— 0.5	+ 0.8	+ 0.8	+ 1.1	— 0.2
1976–79 (min.–max.)	+ 123	+ 0.7	+ 0.4	+ 0.8	+ 1.9	+ 0.4
1979–84 (max.–)	— 24	0.0	+ 0.2	+ 0.3	— 0.3	+ 1.0

(a) The GR (g) of S.S. varies from–34 per cent to + 251 per cent while that of temperature fluctuates between–1.6 per cent to + 1.9 per cent.

(b) During solar minimum to maximum phase (i.e. when S.S. number increases) the GR(g) of temperature is positive in 73 per cent cases which implies that in those cases the temperature increases as S.S. no. increases. But during solar maximum to minimum phase no such definite conclusion can be drawn.

ASSOCIATION BETWEEN PRE-MONSOON MAXIMUM TEMPERATURE AND SUNSPOT NUMBER

Correlation Cofficient

For understanding the degree of dependence, if any, between pre-monsoon maximum temperature with the solar activity we now calculate for all the stations the correlation coefficients (using the standard Kerl-Pearson's product moment formula) between the annual mean sunspot (S.S.) number and the temperature of the following year. The results shown against the stations are as follows :

Port Blair : +0.40, Sagar Island : —0.08,
Calcutta : — 0.10, Malda : +0.05,
Jalpaiguri : —0.26.

Among all these values the Correlation Cofficient is significant (at 2 per cent level as obtained using student's *t*-test) for Port Blair only. The positive value indicates that with the increase of S.S. number the pre-monsoon maximum temperature of the following year increases. However, it is not known whether the station Port Blair shows such a significant correlation due to its peculiar position surrounded by the sea or for its position in low latitude.

Histogram

For further investigation we can have the histograms of the seasonal maximum temperatures against S.S. number of the preceding year taking, for convenience, S.S. number interval 20 (*vide* Fig.3) taking the computed data from Table III. Next for each S.S. interval the points representing average temperature and average S.S. number are joined (since in the span of our analysis S.S. number was never between 160 and 180, the last two points representing average values in the histogram are joined by dotted lines). One may note, considering the line segments in the frequency polygons, that except for Port Blair the magnitudes of increase or decrease of maximum temperature with the increase of S.S. number are almost equal, whereas for Port Blair the overall increasing tendency is predominant. This

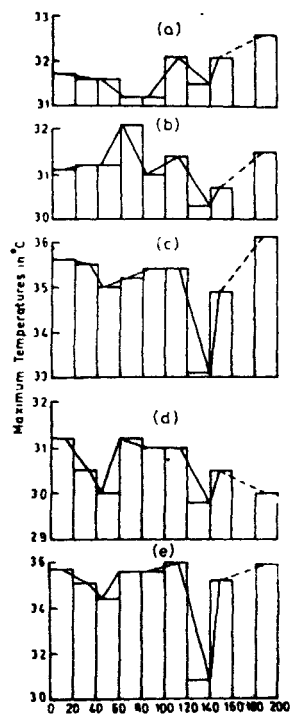

FIG 3 Average variation of temperature with S. S. number over (*a*) Port Blair, (*b*) Sagar Island (*c*) Calcutta, (*d*) Malda, (*e*) Jalpaiguri.

TABLE III

Average seasonal maximum temperature and average S.S. number of the preceding year

S.S. range	Average S.S.no.	Average Maximum Temperature (°C) over				
		Port Blair	Sagar Island	Calcutta	Malda	Jalpaiguri
0–20	12.5	31.7	31.1	35.6	35.7	31.2
>20–40	32.5	31.6	31.2	35.5	35.1	30.5
>40–60	43.5	31.6	31.2	35.0	34.4	30.0
>60–80	61.5	31.2	32.1	35.2	35.6	31.2
>80–100	84.3	31.2	31.0	35.4	35.6	31.0
>100–120	112.1	32.1	31.4	35.4	36.0	31.0
>120–140	139.8	31.5	30.3	33.1	30.8	29.8
>140–160	148.1	32.1	30.7	34.9	35.2	30.5
>160–180	—	—	—	—	—	—
>180–200	187.5	32.6	31.5	36.1	35.9	30.0

justifies the significant and insignificant values of the correlation coefficients for Port Blair and other stations respectively.

Critical S.S. Number

The most important point which is observed from the histograms is a sudden drop of seasonal maximum temperature in the neighbourhood of S.S. number 140. If S.S. number exceeds 140 the temperature, however, increases. It may be mentioned here that the result obtained by Chakraborty and Bandyopadhaya[3,4,8] for similar studies on rainfall over West Bengal and onset of Indian south-west monsoon reveals the existence of some critical value of S.S. number in the neighbourhood of 140. The magnitudes of decrease of temperature (ΔT) in the neighbourhood of S.S. number 140 are, however, not equal. When S.S. number increases by 20 from its value at 120 the decrease (ΔT) from the mean temperature of the respective stations are as follows :

Station	Port Blair	Sagar Island	Calcutta	Malda	Jalpaiguri
ΔT(°C)	−0.3	−0.8	−2.2	−4.5	−0.8

This result indicates that in the latitude belt of our analysis (11°40′N to 26°32′N) the value of ΔT increases with increase of latitude and becomes maximum at Malda (25°02′N), and thereafter again decreases.

CONCLUSION AND REMARK

The results of the present study lead to the following conclusions :

(*i*) The variation of mean maximum temperature during the pre-monsoon season over the latitude belt 11°40′N to 26°32′N in eastern India is only between

1.7 per cent to 4.2 per cent. There exists, however, a declining tendency of temperature after 1969, mainly for Calcutta. Also the temperature series shows a rough periodicity between 2 to 3 years for the stations under consideration.

(*ii*) In general, during solar minimum to maximum phase the temperature increases in 73 per cent cases as S.S. number increases, while during solar maximum to minimum phase, no such conclusion can be drawn.

(*iii*) For Port Blair, a station in the lowest latitude (11°40'N) under consideration, the Correlation Coefficient (= +0.40) is significant. This may be due to its geographical position. For other stations there exist two opposite tendencies when S.S. number approaches 140 from either side.

(*iv*) The average nature of variation of temperature with the increase of S.S. number indicates the existence of some critical value ($\approx$ 140) of S.S. number in the neighbourhood of which a sharp drop in temperature is found. Moreover, this decrease of temperature for critical S.S. number is probably dependent on the latitude of the place and it is maximum at Malda (25°02'N).

(*v*) In studying the solar-terrestrial relationships the sunspot nos. are usually taken as a parameter expressing the solar behaviour. Now the solar radiation (corpuscular and electromagnetic) passes through the ionosphere and earth's upper atmosphere and hence it is possible that solar activity will take some time before affecting the meteorological surface phenomenon like surface temperature. Hence while investigating the influence of solar activity on temperature during early months (March to May) of any year we consider the annual mean S.S. number of the preceding year. In fact, when the S.S. number of the same year is taken it has been found that the results are not as significant as it is in the present analysis.

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