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Influence of Solar Activity on Regional Temperature in India

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***Abstract*— The response of the Indian regional average temperature to the variation of sunspot number during 102 years has been investigated. This involves the correlation, regression and T test studies between the sunspot number and the average temperature for the six different regions of India during the period 1901-2002.From the statistical analysis we have found the results that there is significant connection between solar activity and the surface temperature of six different regions of India. There is a strong connection between solar maximum of solar cycle and corresponding temperature of the cities.**

***Index Terms*— Average temperature, Sunspot Number, Solar Maximum and Solar Minimum .**

I. INTRODUCTION

The Sun is the main source of the energy for our Earth. Any change in the energy from the Sun received at the Earth's surface will therefore affect our climate. A more active Sun is a brighter slightly hotter Sun and hence the Earth is little hotter. When the Sun is more active there are more flares and eruptive activity that causes rapid increase in the solar winds, causing ionization storms in the Earth's atmosphere with result heating. When the Sun is more active the Earth's magnetic shield to diffuse more cosmic rays from reaching into our atmosphere. Therefore more active sun causes warming effect.

Sunspot number are temporary phenomena on the surface of the Sun that appears visibly as dark spots compared to surrounding regions with a diameter of about 37,000 km. Sunspots are produced due to intense activity which inhibits convection, forming areas of reduced temperature, although they are roughly 3000 -4000 k. Sunspot numbers vary in a cyclic manner with a characteristic time of about 11 and 22 years.

Many studies have proved that the solar irradiation variation influence the surface and atmospheric temperature. Therefore solar variation could play a significant role on the climatic change. some of the notable work in this regards are the positive correlation between the sunspot cycle length and the land temperature of the northern hemisphere from 1861 to 1989 by Christensen and Lassen[1] ,Correlation between the sunspot number and annual surface air temperature from 1881 to 2004 in Egypt[2] .The effect of solar activity on temperature in the equatorial mesosphere has been studied in 1973[3] Beer et al.(1994) found a good phase coherency between secular variations in the Northern Hemisphere temperature and concentration cosmogenic ^{10}Be in Greenland ice[4]. Mitchell et al.(1977) have shown the presence of 22 year solar cycle in the rhythm of droughts in the eastern USA after 1610 AD[5]. Almeky et al have shown that the increasing trend in temperature with increase in solar activity in Saudi Arabia during last four decades[6]. Rajamoorthy et.al studied the influence of the solar activity on the global temperature, particularly in Northern Hemisphere, Southern Hemisphere, Global and Tropical region temperature. From the correlative and regression analysis found the results that there is a strong connection between solar maximum of solar cycle and temperature of the Earth[7].

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II. TEMPERATURE TREND IN INDIA

According to the latest estimate by IPCC (2007) Earth's linearly averaged surface temperature has increased by 0.74^{0}C during the period 1901-2005. Easterling et al. reported that the temperature range between day time high temperature and night time low temperature decreased for most part of the world during the period 1950-1993[8].According to the data kept by the Ministry of Earth Sciences, the rate of increase in mean temperatures over India in the last three decades has been relatively higher than in the previous decades. The maximum and minimum temperatures, averaged over the country as a whole, have also been showing an increasing trend. The average maximum temperature in the decade 2000-2010 was 1.27 degree higher than that in the decade 1901-1910. The corresponding difference in the average minimum temperature was relatively less at 0.54 degree Celsius.Amit Dhorde, et al. have shown that increasing trend in seasonal and annual temperature of four major cities in India during the last century{9].D.R.Kothawale et al. have reported that all India mean annual temperature has increased by 0.05^{0}C for the period 1991-2003[10].

III. METHODOLOGY

In this paper, we study the solar influence on climate using temperature and sunspot number. We used monthly average temperature data of selected region for the period of 102 years. The monthly minimum, maximum and average temperature data set for the state and district wise for the period 1901-2003 are available through India water portal data archival (www.indiawaterportal.org). We have calculated the mean yearly temperature by taking average over 12 months (January-December) in yearly mean temperature of individual years.

Sunspot number is the solar activity parameter available and well documented on monthly and yearly average basis for continuous long periods of time (http://solarscience.msfe.nasa.gov/).The relationship

between temperature of six cities of different places in India and Sunspot number has been studied at different level for extracting some physical meaning to the Sun-climate relationship. We have selected the regions randomly, there is no specific reason. The purpose of this paper is to find the statistical relationship between the average temperature of six cities and the solar activity .

IV. RESULTS AND DISCUSION

Fig-1a shows the temperature variation of six regions between the years 1901 and 2002 and Fig-1b shows the Sunspot variation from the beginning of the 20th century. The temperature variations are not same for the six regions .The correlation coefficients (CC) estimated between the average temperature and the sunspot numbers for the period 102 years gave the values are 0.19 for Pune, 0.20 for Patna 0.08 for Ahmedabad,.10 for Bangalore ,0.13 for Delhi and 0.2 for Kolkata.

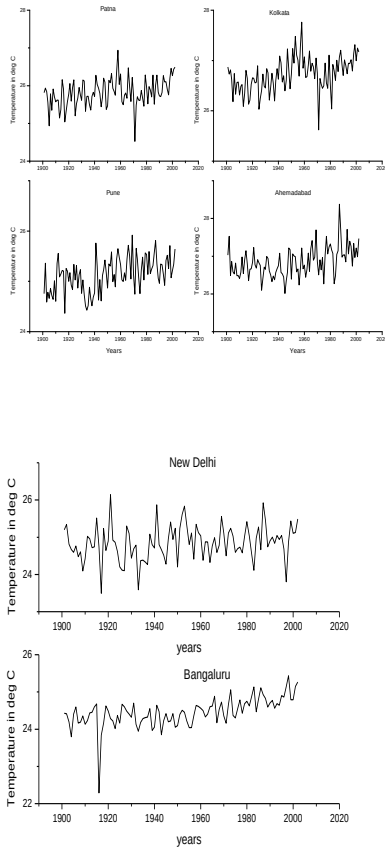


Fig-1(a) Temperature variation

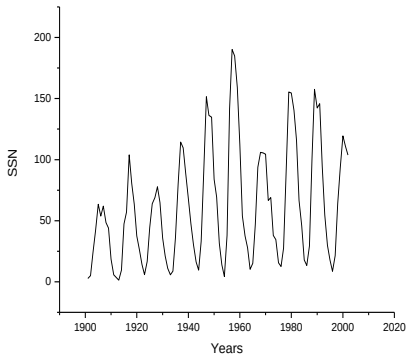


Fig 1(b) SSN variation

These values are slightly significant and the Skewness values are -0.192 for Pune and -0.185 for Patna, 0.73 for Ahmedbad,-1.45 for Bangalore , -0.0819 for Delhi and -0.113 for Kolkata..These values indicate that the temperature trend are not same in all regions. In order to obtain strong connection between solar activity and Earth climate, our estimation carried out into different level. We have considered the period of eleven solar maximum and twelve solar minimum and also considered maximum Sun spot number and corresponding temperature of the region for the 23 solar cycle.

A.Solar Maximum

Solar maximum is the period of maximum solar activity in the solar cycle. During the solar maximum, magnetic field of the Sun is highly distorted. The Sun takes about

eleven years to go from one solar maximum to another and twenty two years to complete one full cycle. During the solar maximum, there is a slight increase in solar energy. When the sunspots are maximum, large numbers of solar particles are ejected from the Sun surface. Statistical analysis between regional temperature and the sunspot number during solar maximum shows a statistically significant relationship(Table 1). The Correlation and Regression coefficients are estimated between regional temperature and Sunspot numbers for the period of eleven solar maximum gave values shown in the table1.Since correlation coefficients are subject to error due to sampling, these values can be better interpreted only through probable errors.

Table 1.Statistical studies between Sunspot numbers and Regional temperature in India During Solar maximum.

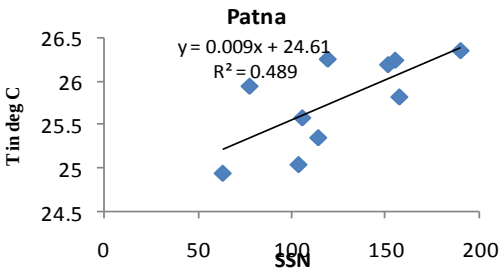
S.N	Region	CC	RC	Error	P Value	T Value	Remarks
1	Patna	0.7	0.7	0.0038	0.28	7.90	Significant
2	Pune	0.64	0.68	0.033	0.04	7.96	Significant
3	Kolkata	0.77	0.77	0.034	0.009	7.87	Highly significant
4	Ahmadabad	0.37	0.369	0.036	0.29	7.82	Significant
5	New Delhi	0.086	0.086	0.0662	0.807	7.98	Slightly significant
6	Bangalore	0.34	0.348	.02	.032	8.01	Significant

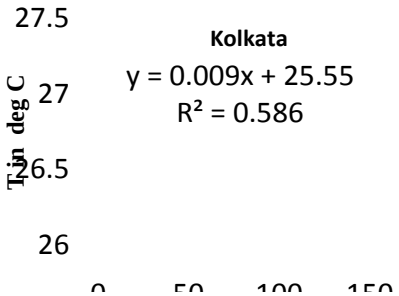
Table 2.Statistical studies between Sunspot numbers and Regional temperature in India During Solar Minimum

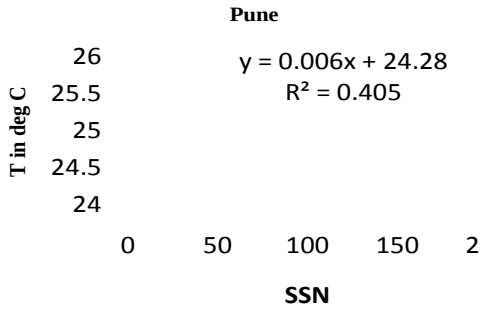
S.NO	Place	CC	R.C	Error	P Value	T Value	Remarks
1	Patna	0.29	0.29	0.20	0.403	-15.6	Insignificant
2	Pune	0.65	0.65	0.192	0.03	-15.11	Insignificant
3	Kolkata	0.506	0.51	0.211	0.11	-16.5	Insignificant
4	Ahmadabad	0.69	0.69	0.188	0.02	-6.6	Insignificant
5	Bangalore	0.68	0.683	0.1805	0.020	-14.56	Insignificant
6	New Delhi	0.49	0.49	0.173	0.154	-14.32	Insignificant

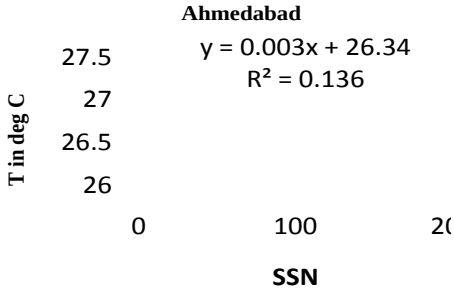
Table 3.Statistical studies between maximum Sunspot numbers of every solar cycle and Regional temperature in India

S.NO	Place	CC	R.C	Error	P Value	T Value	Remarks
1	Patna	0.385	0.385	4.85	0.27	9.39	Insignificant
2	Pune	0.413	0.413	2.374	0.374	9.61	Insignificant
3	Kolkata	0.32	0.32	2.97	0.262	9.3	Insignificant
4	Ahmadabad	o.473	0.473	3.191	0.167	9.4	Insignificant
5	Bangalore	0.0639	0.0639	2.0211	0.849	9.65	Insignificant
6	New Delhi	0.33	0.33	6.54	0.354	9.4	Insignificant









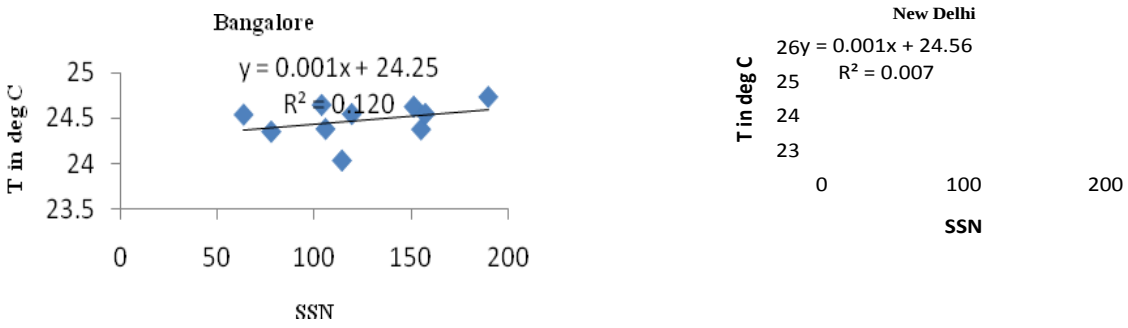
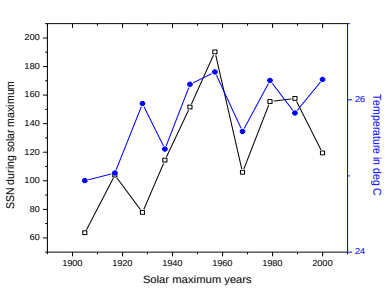
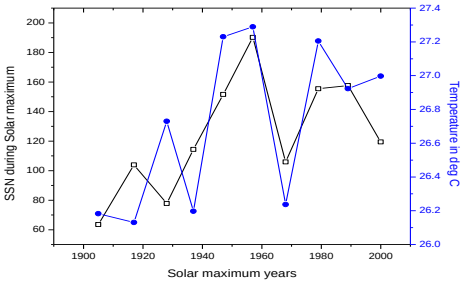


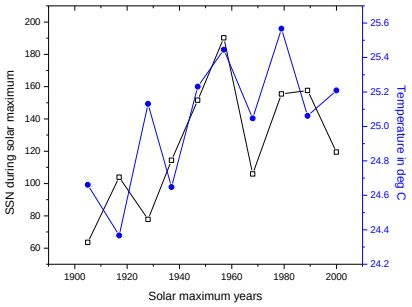
Fig-2 Linear fit analysis between Solar maximum and temperature



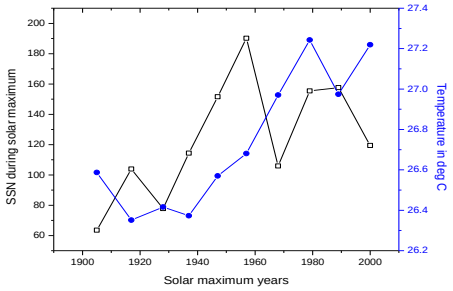
I. Patna



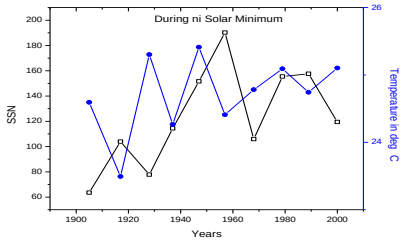
II. Kolkata



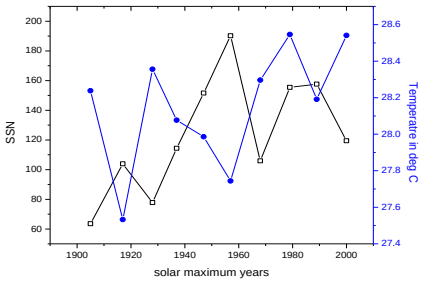
III. Pune



IV. Ahmedabad



v. Delhi



VI. Bangalore

Fig-3 Connection between Solar maximum and Regional temperature

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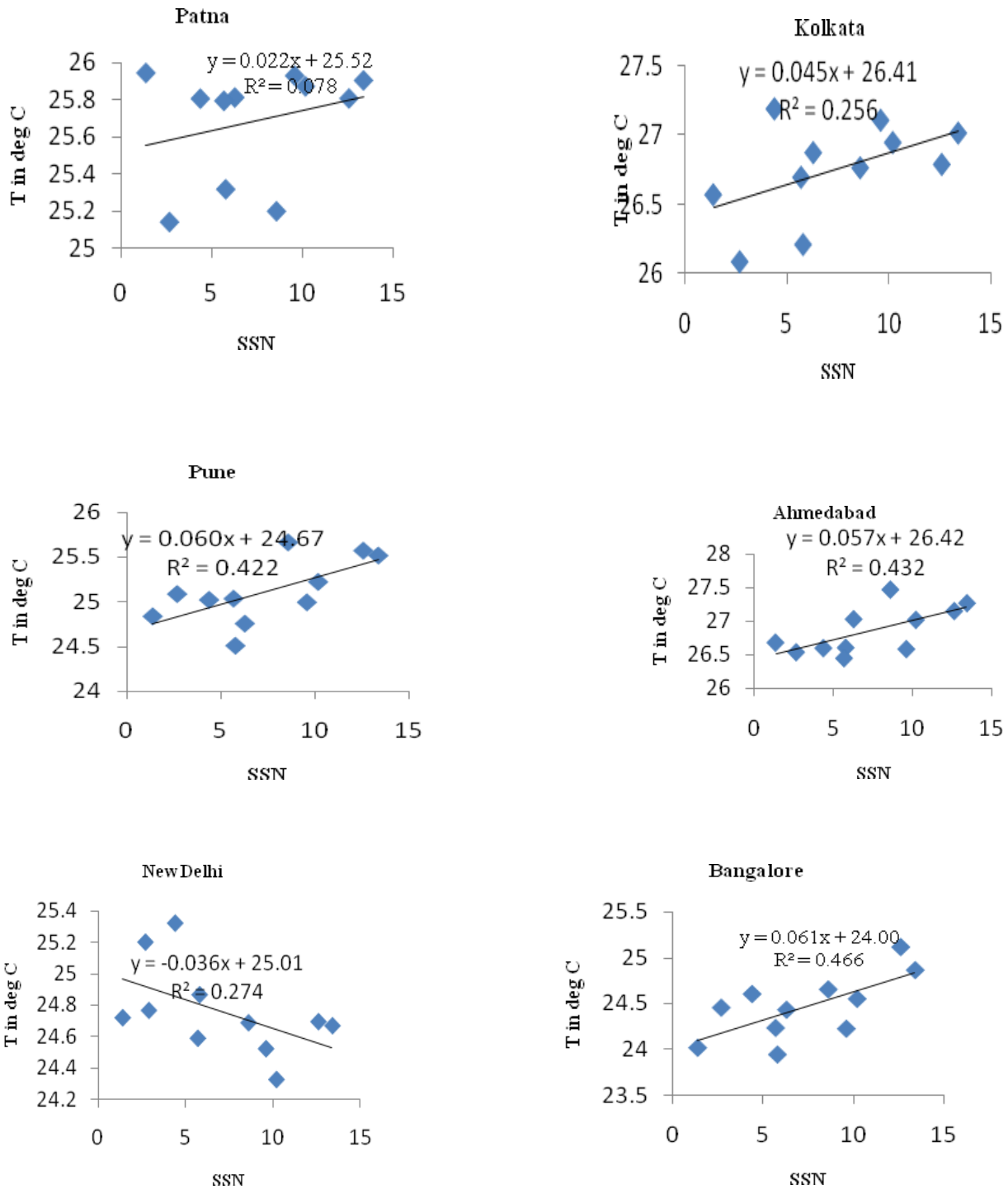


Fig-4 Linear fit analysis between solar minimum and Regional temperature.

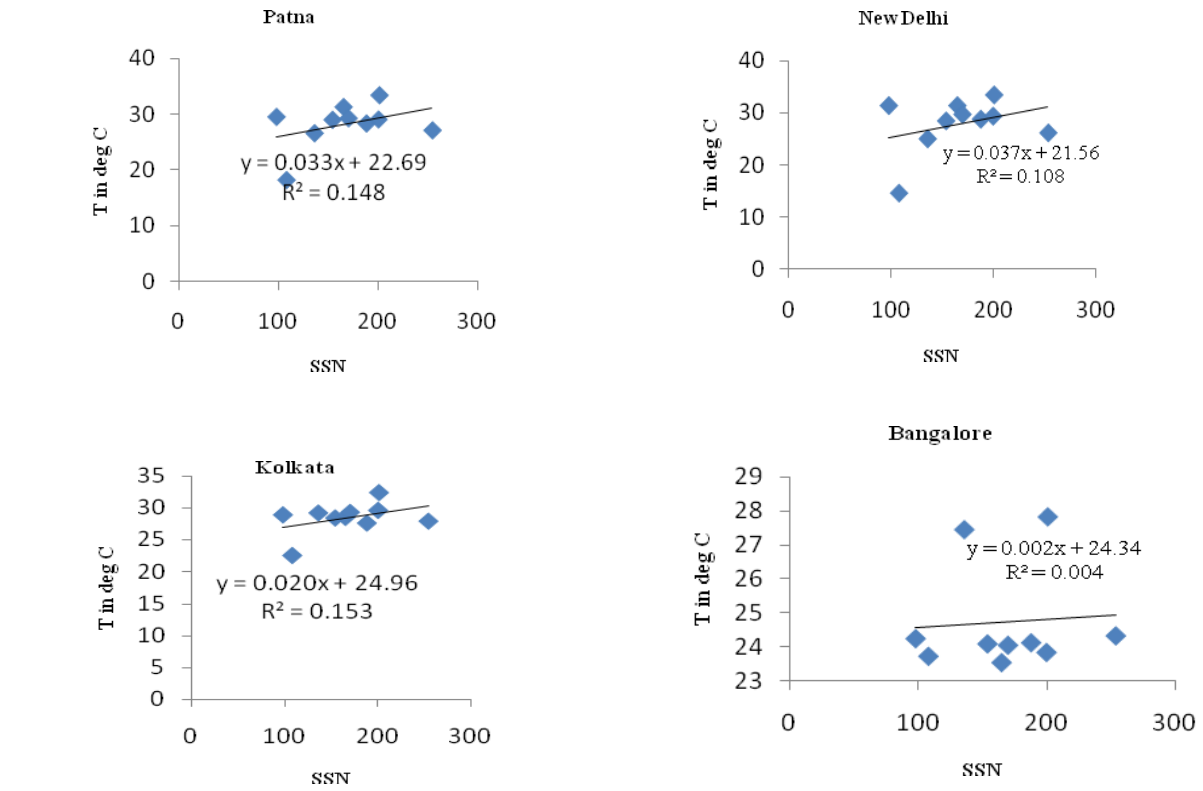
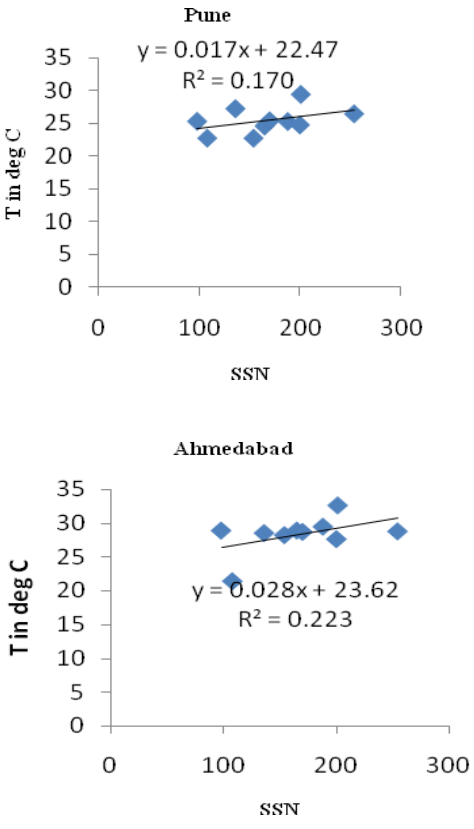


Fig-5 Linear fit between maximum SSN and corresponding Regional temperature during every solar cycle.



The probable errors involved in this analysis have been found and tabulated. Since the probable errors are very much smaller than the magnitude of the correlation coefficients of all regions, then the CC and RC values are considered to be significant. Applying the student 'T' test for the six regions, the computed values (given in the table 1) are very much higher than the tabular value (3.25) at 1% level of significance and 9 degrees of freedom. These values are highly supported that solar maximum influence the regional temperature. All the slopes are positive (Fig 2) and hence CC and RC values are significant.

B.Solar Minimum

Solar minimum is the period of minimum or no solar activity in the solar cycle .During the solar minimum, solar activity diminishes and often does not occur for days at a time. During the year 2008 there were 266 days in which the sun free from sunspots and 260 days were spotless days in the year 2009. The correlation (CC) and regression (RC) estimated between the average temperature and the sunspot numbers for the period of twelve solar minimum are given in the table 2. All the values are insignificant because the CC values are less than the magnitudes of probable error.Similarly RC values are insignificant because corresponding P values are high. Applying the student 'T'test for the twelve solar minimum, the computed values of T are very much less than the tabular value (2.073) at five percent level of significance and ten degrees of freedom. Hence the CC and RC values are highly insignificant for the six regions during solar minimum.

C. Maximum Sunspot Numbers during the Solar Cycles

Statistical analysis can also be carried between maximum Sunspot number of the solar cycle and corresponding

temperature of the region. The analysis is given in the table 3.Fig-4 shows the linear fit analysis between maximum SSN and corresponding regional temperature. We have obtained high correlation coefficients and regression coefficients values but the probable errors involved in this analysis are very high. The magnitudes of the probable errors are nearly equal to10 times greater than the CC values and P values also very high. Therefore the influence of maximum sunspot numbers for every solar cycle on the regional temperature is not highly significant

V.Conclusion

From the statistical analysis we have found the results that there is a connection between solar activity and regional temperature in different places of India. Low positive correlation coefficients are obtained in all the six regions when calculation carried out between yearly average temperature and the Sunspot number, indicates there is small changes in the temperature corresponding variation in sunspot number. The high positive correlation coefficients and regression coefficients are obtained during solar maximum indicate that the regional temperature increased during the solar maximum. From our analysis the influence of solar minimum and maximum sunspot number for every solar cycle are not significant.

Acknowledgment

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