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Correlative study on Solar activity and all India rainfall: Cycle to Cycle Analysis

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ABSTRACT
The solar energy gets absorbed in the atmospheric system and acts as a basic driving force for the climate dynamics. The energy output of the sun varies on all timescales. The best known variation is the regular fluctuations in the number of sunspots, which shows up as small dark regions on the solar disk, and affect the energy output of the sun. This variation has the potential to induce fluctuations in the climate, especially the rainfall. In the present paper we try to establish a relationship between the all India rainfall and the Sunspot numbers. We use a non-parametric statistical rank correlation to find the significance between the sunspot numbers and rainfall. The results indicate an anti correlation between the sunspot and rainfall. The all India rainfall is maximum when the sunspot numbers are minimum and vice versa. This suggests that the climate indeed is influenced by the solar activity. As such its effect cannot be ignored in analysing rainfall cycles.

INTRODUCTION

India is fortunate to experience the heavy rainfall spell in all seasons due to both tropical and extra tropical weather systems. Almost 60% of India receives rainfall from the summer monsoon. The contribution of the other monsoons, like post monsoon, northeast monsoon and pre monsoon seasons, is only significant to a particular region of the country. In the last few years the Indian subcontinent is witnessing a considerable failure of south west monsoon that has led to droughts. As monsoons can bring in both rain spells and wet spells it is essential to study also the abnormalities to better predict the monsoon rainfalls.

The main cause for the abnormalities in rainfall is anticipated to be due to the localized anthropogenic influence over the climate and environment, like degradation of forest coverage, depletion of surface and subsurface water resources and some unknown factors. Another possible reason is the periodicities in the occurrence of solar activity and the rainfall activity (Hiremath and Mandi, 2004). Present study is aimed at in bringing out a correlation between the solar activity (sunspot numbers) and rainfall over the Indian subcontinent. Solar energy drives the earth's climatic system and has the potential to directly alter the climate. The sun's energy is always varying due to spatial and temporal variability of the large scale magnetic field structures. The most outstanding activity of the sun is the sunspot numbers.

The sunspots have cool and dark features compared to the ambient medium. Sunspot has a diameter of about 37,000km and appears at the photosphere of the sun. The temperature within the sunspot is about 4600K. The number of sunspots peaks once in every 11.1 years. Researchers have shown that the 1861-1989 sunspot numbers showed a remarkable parallelism with the simultaneous variation in the Northern hemisphere mean temperature. This has evoked the interest of many scientists, leading to study of the solar cycle and related activity. Significant studies have been carried to establish a correlation with Indian rainfall occurrences (Hiremath, 2006; Jagannathan and Bhalme, 1973; Bhattacharya and Narasimha, 2005).

DATA AND METHODOLOGY

We have utilized 130 years (1871-2009) of sunspot data and rainfall data (Parthasarathy, et al 1993). The sunspot numbers are obtained from National Geophysical Data Centre, Boulder, Colorado, USA. The rainfall data are available on a monthly, seasonal and annual series. The rainfall data was procured from Indian Meteorological Department, Chennai. We consider the seasonal months of spring, summer, autumn and winter. The nomenclature used for the study is shown in Table 1.

The raw data of rainfall for the seasonal months over India and the sunspot numbers for the same months are considered. A spearman rank correlation coefficient (Press et al 1992) is calculated in this paper. This correlation determines whether two variables correlate and provide a measure of strength of their relationship.

The Spearman rank correlation is a non parametric rank correlation technique used in cases where the data is on the ordinal scale. This test uses the rank order and not the actual values for determining the association between the two sets of values. So, it is a rank correlation. To study the amount or degree of correlation between two variables say X and Y, we compute the Spearman rank correlation as follows.

$$\rho = 1- [(6*\sum d^2) / (n^3-n)]$$

where ρ is the Spearman correlation coefficient. To evaluate this equation the raw data is first ranked with Rank 1 to the smallest number and Rank n to the n^{th} largest number. Next we obtain a set of rank difference scores as ($d = \text{Rank}_X - \text{Rank}_Y$). The sum of the difference in rank of paired values is zero i.e $\sum d = 0$. Using this we calculate $\sum d^2$. This rank correlation coefficient varies from -1 to 0 to +1. If two variables of X and Y are equal or tied, they are given the average of the rank values that could have been assigned if no ties recurred. The spearman rank coefficient becomes less efficient if there are more ties in the data.

Table 2 represents the correlation values between the sunspot numbers and the All India rainfall

Table 1: Nomenclature of the data

SEASONS	MONTHS CONSIDERED	NAME
Winter	January February	JF
spring	March April May	MAM
Southwest monsoon	June, July, August, September	JJAS
Northeast monsoon	October, November, December.	OND

Table 2: Correlation analysis between sunspot data and rainfall data

Cycle No.	Rainfall Area	Cycle area	Year	Length of cycle	JF	MAM	JJAS	OND	ANN
12	14290.8	4655.79	1878-1889	12	-0.25	-0.38	-0.58	0.18	-0.66
13	13794.1	5715.95	1890-1901	12	0.12	0.16	0.56	0.51	0.54
14	13326.2	4497.39	1902-1913	12	0.49	0.03	0.12	-0.54	-0.36
15	11752	5393.75	1914-1923	10	-0.04	0.28	0.01	0.35	0.22
16	11768.5	4877.09	1924-1933	10	0.84	-0.22	-0.41	-0.22	-0.52
17	12919.4	7454.16	1934-1944	11	-0.10	0.11	-0.25	0.47	-0.06
18	11875.8	9046.71	1945-1954	10	-0.20	0.37	-0.36	0.07	0.60
19	12249	11319.6	1955-1964	10	0.31	0.00	-0.18	0.28	-0.01
20	13705.3	8592.98	1965-1976	12	0.30	-0.21	0.01	-0.29	0.03
21	11442.1	10001.2	1977-1986	10	0.02	-0.13	0.07	-0.20	-0.07
22	11767.7	9316.84	1987-1996	10	-0.56	0.21	-0.18	-0.56	-0.01
23	14984.2	7962.9	1997-2008	11	0.04	-0.31	-0.69	-0.05	-0.77

data. The first column represents the solar cycle number, the second column gives the area of rainfall occurrence, the third column gives the area of sunspot occurrences, the fourth column represents cycle period, the fifth to the last column represents the length of each cycle, from the sixth to last column the correlation coefficient for the different seasonal months of JF, MAM, JJAS, OND and ANN for annual data of rain fall. The areas of rainfall and sunspot cycle were calculated using the trapezoid rule.

The absolute values of the correlation coefficient are plotted against the sunspot cycle area. A good least square fit is given to the correlation graphs. The raw data of the rainfall and sunspot occurrences are plotted by the side of the correlation graph. Fig. 1 represents the correlation graphs and the raw data graphs, which are plotted for the seasonal months of India.

RESULTS AND DISCUSSION

Table 2 provides the correlation values that exhibit a correspondence between the sunspot and the rainfall activity. The results of the table show both negative and positive correlation. However, over a longer duration of the sunspot cycles there is a good influence of the sunspot on the rainfall. The trend in the values may be due to the uncertainties present in the rainfall data for 130 years. The input is subject to uncertainty, as a result of measurement errors and systematic errors due to the random nature of rainfall. The precipitation pattern may be influenced by the irregular topography. The large variability in altitude, slope and aspect may increase variability by means of processes such as rain shading and strong winds. Accurate estimation of the spatial distribution of rainfall over large areas is complicated (Tao, Tao et al, 2009). Irrespective of the signs there is a significant relationship between the sunspot number and the rainfall occurrences. The sign of the correlations merely indicates the strength of the relevance between sunspot number and the rainfall. Thus a weak sunspot activity will give heavier rainfall and a strong sunspot activity will give lower rainfall. The raw data graph in Fig. 2 shows that the peak for sunspot is high when the corresponding peak

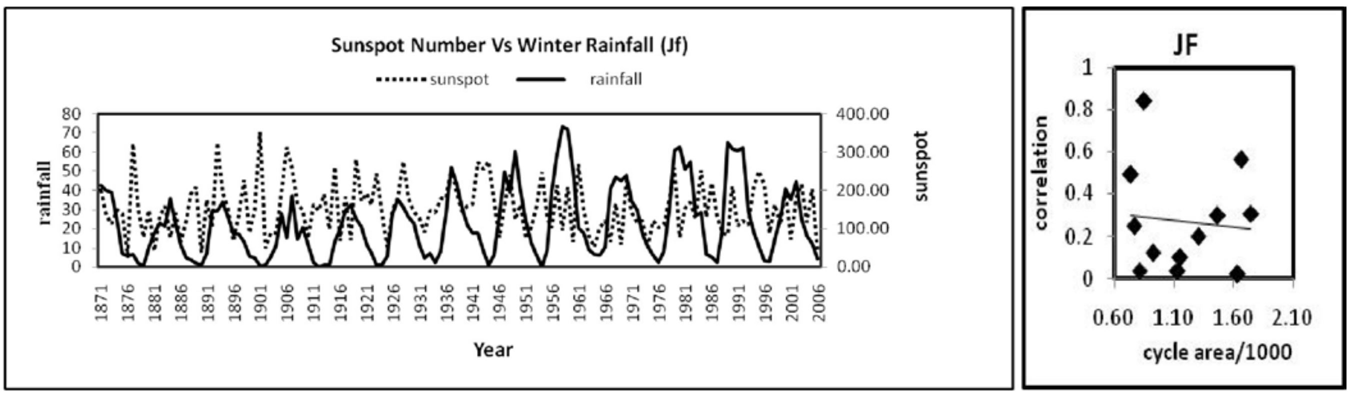

Figure 2a. Raw data and the corresponding correlation graph for the seasonal months of January and February

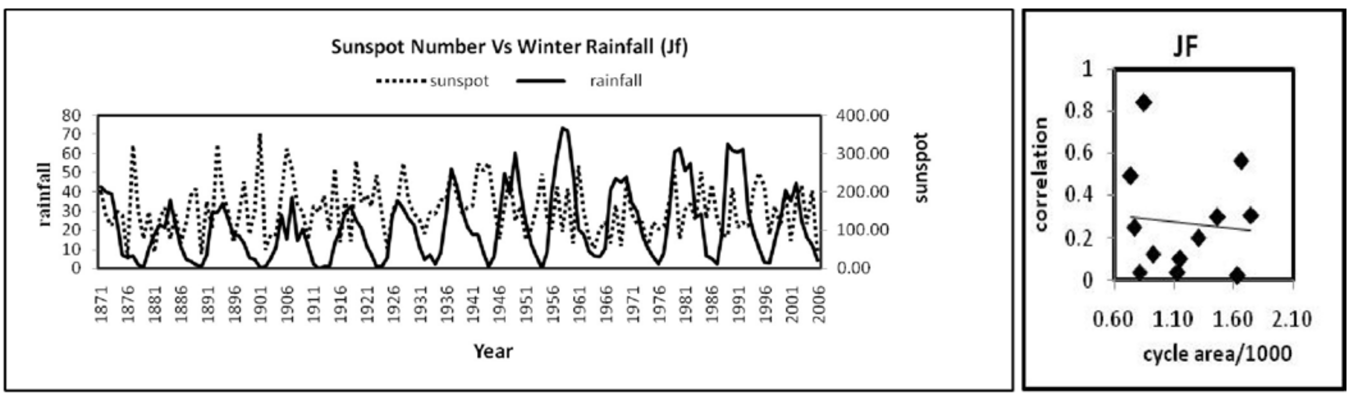

Figure 2b. Raw data and the corresponding correlation graph for the seasonal months of March, April and May

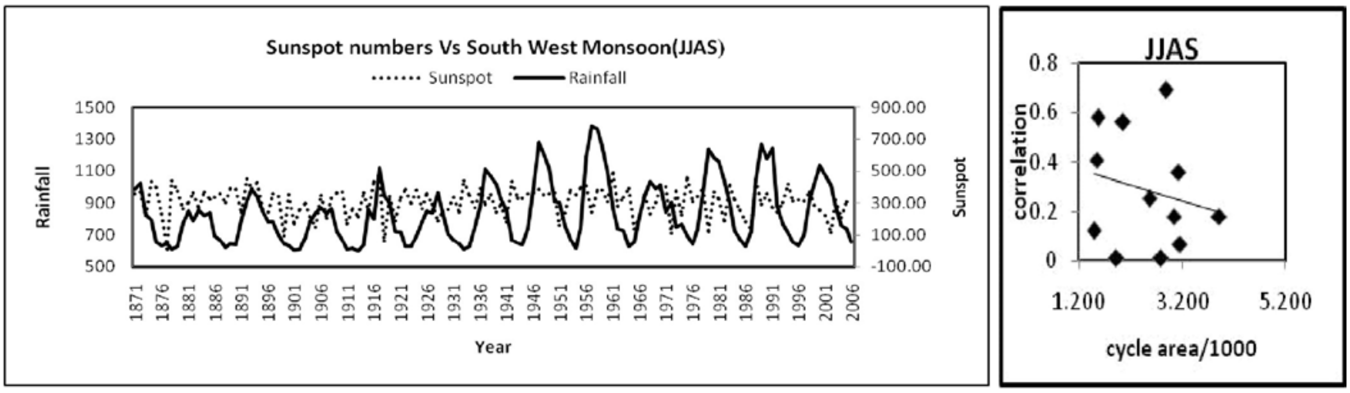

Figure 2c. Raw data and the corresponding correlation graph for the seasonal months of June, July, August, September

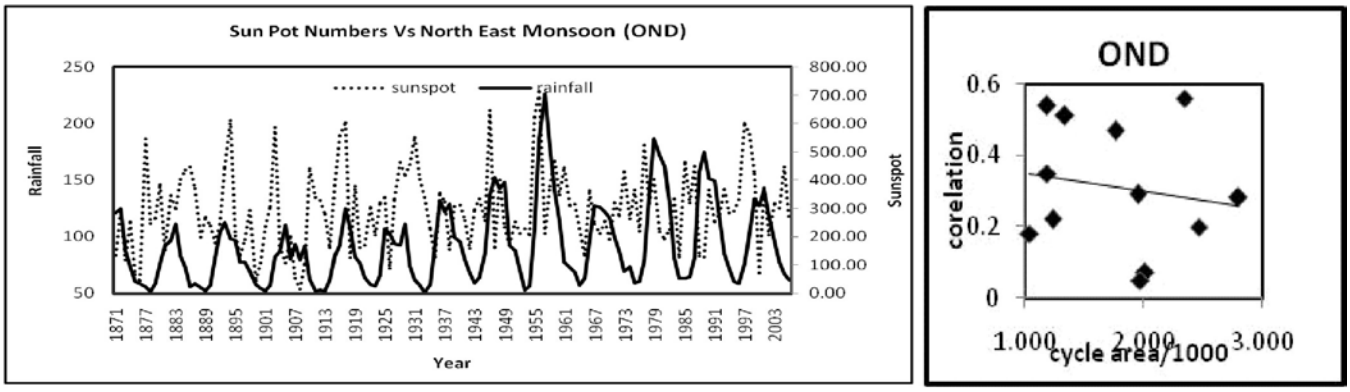

Figure 2d. Raw data and the corresponding correlation graph for the seasonal months of October, November and December

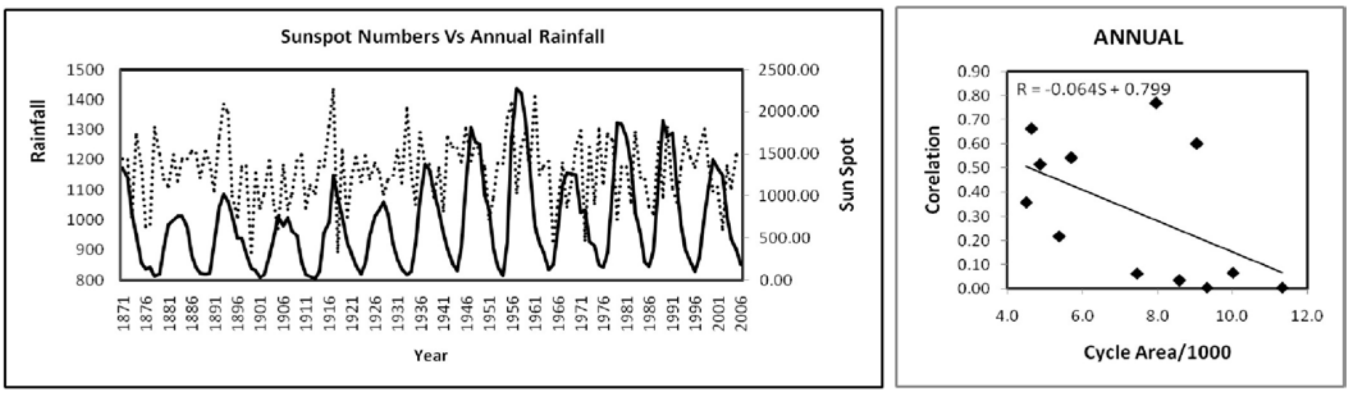

Figure 2e. Raw data and the corresponding correlation graph computed annually

for the rainfall is low, suggesting the sunspot and the rainfall activity are inversely proportional. The correlation graph is plotted against the seasonal sunspot cycle area and the correlation values of the seasonal months. The scatter graph shows a negative trend in the correlation. This gives more emphasis on the inverse correlation between the sunspot activity and the rainfall occurrences.

CONCLUSION

From the correlation table one can infer that for a moderate to higher significance the sunspot number is related to rainfall all over India. The overall trend of the data shows that the rain fall activity is high for low sunspot activity and low rainfall activity for higher sunspot occurrences. The physical reason for the above said statement is that the nucleation of water molecule in the atmosphere is brought about by the cosmic rays, when the sunspot numbers increase. Such an activity creates a magnetic flare, which will hinder the entry of the cosmic rays in to the atmosphere. This inturn suppresses the aggregation of water molecules in the atmosphere.

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