Does solar variability affect Indian (Tropical) weather and climate? : An assessment

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Abstract. Monthly, seasonal and annual data of all India rainfall, minimum and maximum temperatures, representing Indian weather and climate, and geomagnetic index aa, as proxy for solar variability, have been utilized. About hundred years' data of these parameters were divided into six groups on the basis of intensity/amount of all India summer monsoon rainfall. Using the method of superposed analysis, simultaneous variations in rainfall, minimum and maximum temperatures, and geomagnetic indices were obtained in different months, season (i.e. monsoon) and years after dividing the whole period into six groups of very low to very high rainfall years. We present evidence that, (i) decreasing (increasing) solar activity during Indian summer monsoon months appears to influence the temperature in the season, (ii) Indian summer monsoon rainfall is higher (lower) during the periods of decreasing (increasing) solar activity in monsoon months, and (iii) Indian summer monsoon period is cooler during the years of higher summer monsoon rainfall. We found evidence that Indian (Tropical) weather and climate is affected by solar variability. It is proposed that in order to improve the predictive capability of Indian weather and climate, the assessment of contributions, and careful monitoring of solar variability may be useful.

Index Terms. Rainfall, solar variability, temperature, weather and climate.

1. Introduction

The relationship between solar activity and terrestrial weather/climate is one of the most interesting and controversial problems. Past studies of possible relationship between rainfall and solar activity have been found to be positive, negative or even no correlation between them; such contradictory results still elude the scientific community from complete understanding of the influence of the sun on the climate/weather in general and the rainfall in particular (e.g. see, Hoyt and Schatten, 1997; Kane, 1999 and references therein).

Both the Indian rainfall and temperature are, in general, inversely related to sunspot number, although the results of some of the studies are conflicting (e.g. see Jagannathan and Bhalme, 1973; Parthasarthy and Mooley, 1978; Bhalme et al., 1981 and references their in).

The influence of solar activity on the Indian monsoon rainfall has been studied recently by Hiremath and Mandi (2004) and Bhattacharya and Narasimha (2005) using Indian rainfall data of past 120 years or so. Hiremath and Mandi (2004) found that spring and southwest monsoon rainfall variability has significant positive correlations with the sunspot activity during the corresponding period. Bhattacharya and Narasimha (2005) found that the average rainfall is higher during periods of greater solar activity. Earlier studies related to association between the sunspot numbers and monsoon rainfall variability show a moderate to strong correlation. Neff et al. (2001) suggested that one of the primary controls on centennial to decadal scale changes in tropical rainfall and monsoon intensity is variations in solar activity. Thus the whole area seems to be complex and needs further study.

2. Results and discussion

We have utilized ninety years of continuous data of Indian weather/climate (All India rainfall and temperature), and proxy data representative of solar variability (geomagnetic indices aa) for the period 1901 to 1990. For this analysis, we preferred the use of aa indices instead of sunspot numbers. Although a good indicator of solar variability, Sunspot do not directly affect the interplanetary environment. However, aa indices, treated as a measure of turbulent plasma in the ecliptic plane, represented disturbances (in the ecliptic plane) at the position of the earth.

We applied the method of superposed analysis and found the values of aa indices for each month for the whole period (1901-1990) and obtained the expected symmetric semi-annual wave with peaks of almost equal amplitudes in March and September (Fig. 1). If there is no external agent (e.g. solar variability) that can significantly influence (increase/decrease) the level of geomagnetic activity in certain periods of a year, we should expect to observe a perfectly symmetric semi-annual wave with equal amplitudes in both halves of the year. However, if and when there is considerable solar variability in certain periods of a year (e.g. June/July/August/September Indian summer monsoon months), then one should observe an asymmetric semi-annual wave with lower or higher peak in later half part of the wave depending whether the solar activity is decreasing or increasing in summer monsoon months (for example), as the level of geomagnetic activity is directly affected by the solar variability.

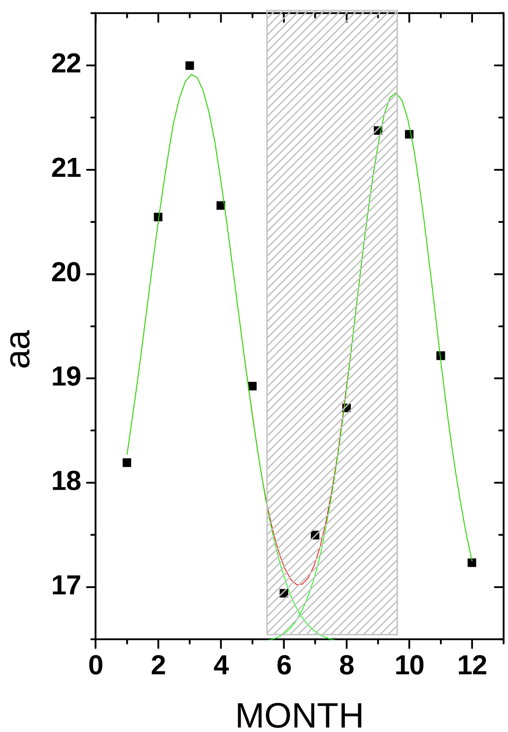

Fig. 1. Average monthly aa values for the total period (1901-1990) showing nearly symmetric semi-annual wave.

In order to study the solar variability effects, the whole data period (1901-1990) was divided into six groups of years, on the basis of all-India summer monsoon rainfall viz. years of; very low rainfall (< 750 mm, Group-I), low rainfall (751 mm to 800 mm, group-II), near normal low rainfall (801 mm to 850 mm, group-III), near normal high rainfall (851 mm to 900 mm, group-IV), high rainfall (901mm to 950mm, group-V) and very high rainfall (> 950 mm, group-VI). Monthly data of aa index for respective years of each group were then subjected to superposed analysis and aa values from January to December for all the groups were obtained. Adopting the same procedure for data analysis we obtained the averages of climate/weather parameters, namely, rainfall, maximum and minimum temperatures for each group, for January to December months. Superposed epoch procedure was also adopted to find the average values of all three parameters for total period (1901-1990) in all the 12 months, January to December. The values so obtained for each month were then subtracted from group values of respective months. In this way Δ Rainfall (mm), ΔT_{max} (^{0}C), ΔT_{min} (^{0}C) for each month in all six groups were obtained. These values are plotted in Figs. 2(a), 2(b), 2(c), 2(d), 2(e), and 2(f) for group I, II, III, IV, V, and VI respectively. A comparison of aa, Δ Rainfall, $\Delta T_{max,}$ and ΔT_{min} during very – low and low rainfall years

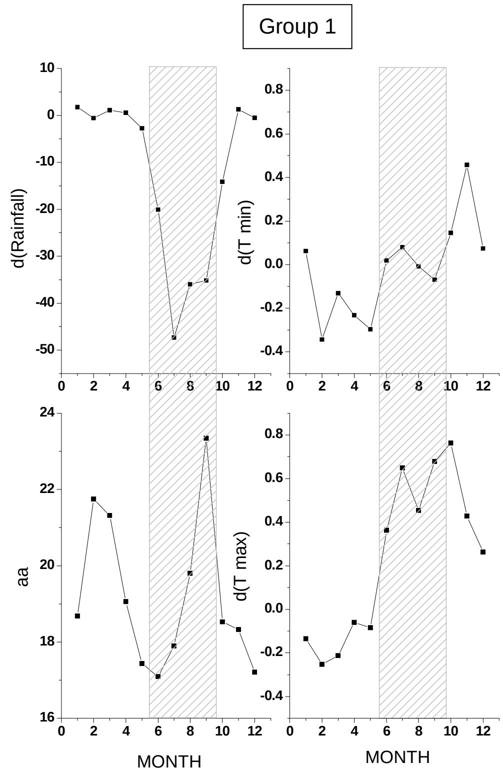

Fig. 2a. Average aa values, Δ Rainfall, mean values ΔT_{max} and $\Delta T_{min,}$ for very low rainfall periods.

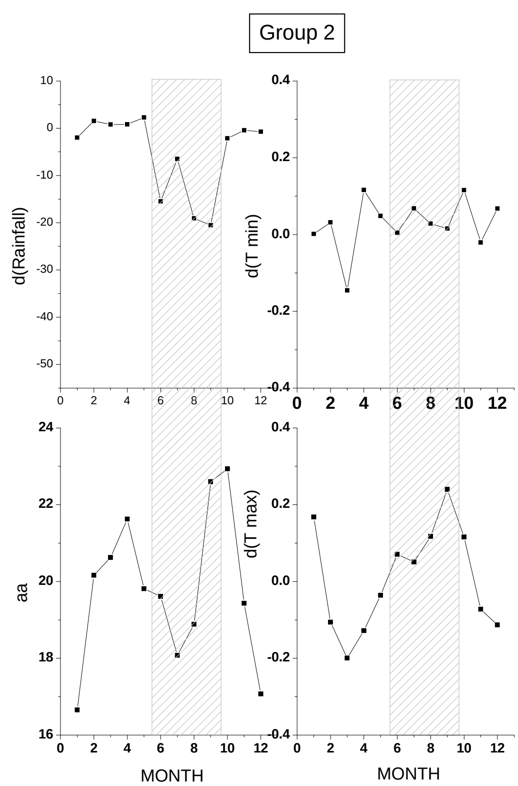

Fig. 2b. Same as Fig. 2a for low rainfall periods.

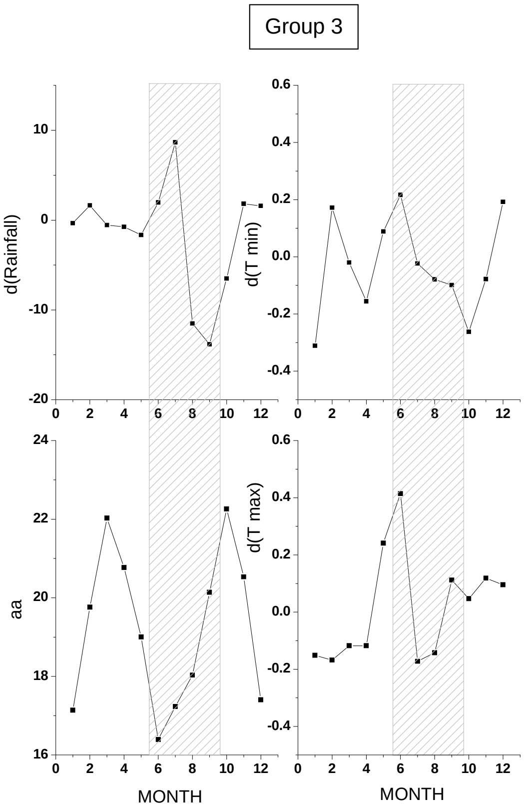

Fig. 2c. Same as Fig. 2a for near-normal rainfall periods.

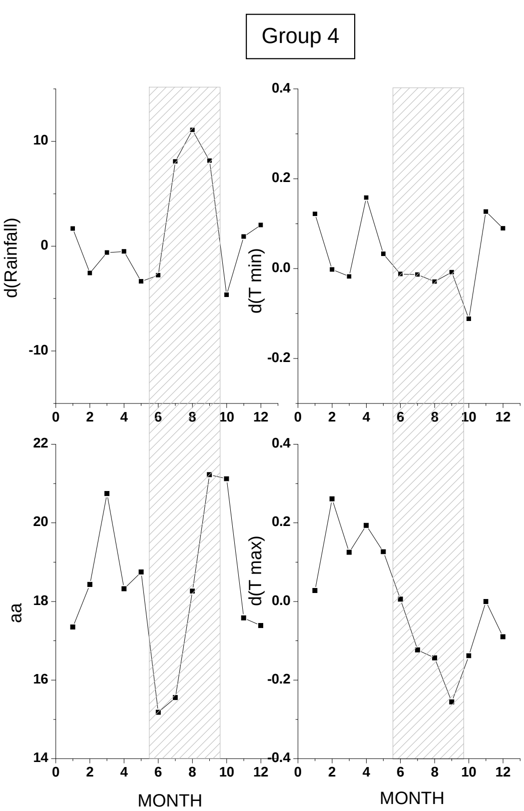

Fig. 2d. Same as Fig. 2a for near-normal heavy rainfall periods.

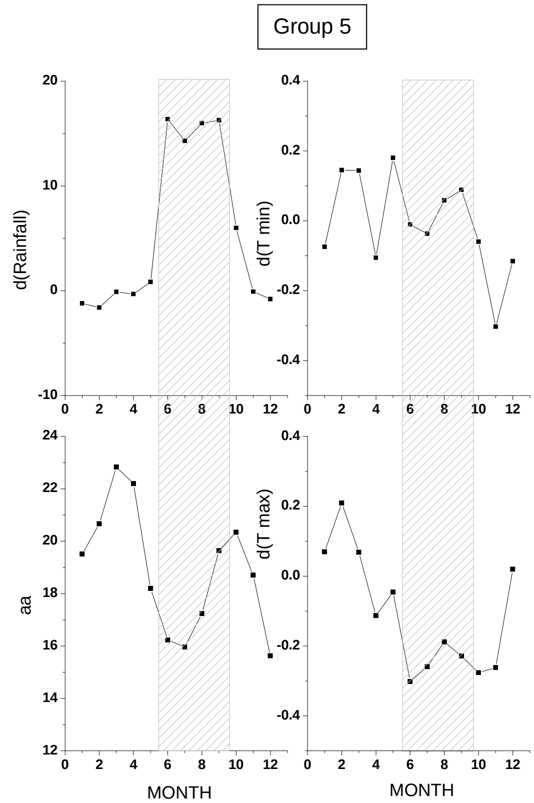

Fig. 2e. Same as Fig. 2a for heavy rainfall periods.

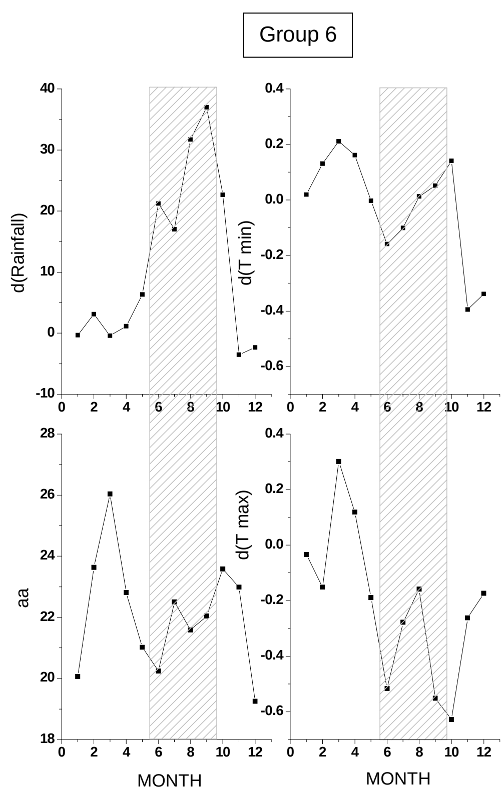

Fig. 2f. Same as Fig. 2a for very heavy rainfall periods.

(Figs. 2(a), 2(b)) shows that increasing solar variability (we consider enhanced aa peak in September/October as compared to March/April peak in a particular group as an indication of increasing solar variability in summer monsoon months) is associated with lower Indian summer rainfall monsoon and higher temperature, (Δ T_{max}) in corresponding months. In near-normal rainfall periods (Figs. 2(c) and 2(d)), there is almost no difference in aa March/April and September/October peaks. Moreover in these periods the average value of Δ T_{max} is almost zero in summer monsoon months. However, in heavy and very-heavy rainfall periods (Figs. 2(e) and 2(f)) the second peak in aa in September/October is much smaller compared to that of March/April, indicating that the solar activity is most probably decreasing in summer monsoon months. Thus, from Figs. 2(e) and 2(f) we see that the decreasing solar activity in summer monsoon periods is associated with increase in summer monsoon rainfall and decreased temperature.

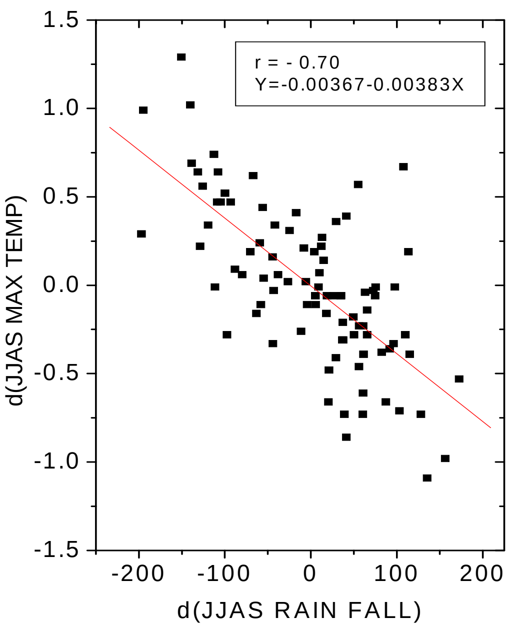

Fig. 3. Scatter plot between departures in Indian summer monsoon rainfall and T_{max} alongwith the best fit line.

To show the relationship between rainfall in summer monsoon months and maximum temperature in the same periods, we did a linear regression analysis between the deviations in two parameters for the period 1901-1990 (Fig. 3). The fitted equation with high correlation coefficient (r=-0.70) provides a good inverse relationship between the rainfall and maximum temperature.

Some of the previous studies have suggested that on decadal, multi-decadal, and centennial scale, variability in solar activity might have significant impact on regional climate and could have caused severe droughts and floods in the past (e.g. see, Agnihotri et al., 2002 and references therein). Study of 6000-year record of changes in drought and precipitation in northern China has led Hong et al. (2001) to conclude that the widespread global drought variability is consistent with the assumption of an external global force such as solar force. They found that most of the dry and warm periods over the last 6000-years correspond well with stronger solar activity and relatively wet and cold periods correspond well with relatively weaker solar activity.

Periodicities in occurrence of rainfall variability are almost similar to periodicities in the sunspot occurrence activity (Hiremath and Mandi, 2004). Another study (Verschuren et al., 2000) of rainfall and drought patterns in equatorial east Africa during the past 1100 year reported severs drought during periods coinciding periods concluding with phases of high solar solar activity with intervening epochs of increased precipitation periods of low solar activity. This results contrasts that of Agnihotri et al. (2002) who found that, on decadal and multi-decadal time scale, the intensity of the Indian monsoon have decreased during periods of solar minimum during last millennium.

3. Conclusions

Our results suggest the existence of connection between, Indian rainfall, Indian Climate and Solar variability at annual or even seasonal scale. Increasing (decreasing) solar activity is associated with lower (higher) rainfall and higher (lower) temperature. Good correlation between rainfall, temperature and solar variability provides convincing evidence for solar forcing of climate variability at annual and even seasonal scale.

References

R. Agnihotri, K. Dutta, R. Bhusan and B. L. K. Somayajulu, “Evidence for solar forcing on the Indian monsoon during the last millennium”, *Earth and Planet. Sci. Lett.*, vol. 198, pp. 521-527, 2002.

H. N. Bhalme, R. S. Reddy, D. A. Mooley and B. V. Ramanamurty, “Solar activity and Indian weather/climate”, *Earth and Planet. Sci.,* vol. 90, pp. 245-262, 1981.

S. Bhattacharyya and R. Narasimha, “Possible association between Indian monsoon rainfall and solar activity”, *Geophys. Res. Lett.*, vol. 32, L05813, 2005.

K. M. Hiremath and P. I. Mandi, “Influence of the solar activity on the Indian monsoon rainfall”, *New Astron*., vol. 9, pp. 651-662, 2004.

Y. T. Hong, Z. G. Wang, H. B. Jiang, Q. H. Lin, B. Hong, Y. X. Zhu, Y. Wang, L. S. Xu, X. T. Leng and H. D. Li, “A 6000-year record of change in drought and precipitation in northeastern China based on a Δ^{13}C time series from peat cellulose”, *Earth and Planet. Sci. Lett.*, vol. 185, pp. 111-119, 2001.

D. V. Hoyt and K. H. Schatten, *The role of the sun in climate change*, Oxford: Oxford University Press, 1997, pp. 125-142.

P. Jagannathan and H. N. Bhalme, “Changes in the pattern of distribution of southwest monsoon rainfall over India associated with sunspots”, *Mon. Weather Rev.*, vol. 101, pp. 691-700, 1973.

R. P. Kane, “Sun-weather/climate relationship an update”, *Indian Space Research Organization*, Banglore, Scientific Note ISRO-SN-11-99, 1999.

U. Neff, S. J. Burns, A. Mangini, M. Mudelsee, D. Fleitmann and A. Matter, “Strong coherence between solar variability and the monsoon in Oman between 9 and 6 kyr ago”, *Nature*, vol. 411, pp. 290-293, 2001.

B. Parthasarthy and D. A. Mooley, “Some features of a long homogeneous series of Indian summer monsoon rainfall”, vol. 106, pp. 771-781, 1978.

D. Verschuren, K. R. Laird and B. F. Cumming, “Rainfall and drought in equatorial east Africa during the past 1,100 years”, *Nature*, vol. 403, pp. 410-414, 2000.