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The effect of 10.7 cm solar flux on the monsoon rainfall over India

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ABSTRACT

The present study attempts to find a probable correlation between the solar cycle and Monsoon Rainfall in India, using the S-Component of the 10.7cm Solar Radio Flux, measured at Ottawa by Remote Sensing Techniques, which varies in response to the Solar Activity, as the representative of the activity of the Sun. Results show a possibility of the Solar activity playing a role in determining the amount of rainfall over a particular region. The general trend is increase in rainfall amount with increase in the solar activity. A possible explanation is suggested for all the observations.

Key words: Solar activity, Solar Flux, Monsoon Rainfall, Monsoon Depressions (MD), Monsoon Low (ML), Mid Tropospheric Cyclone (MTC), Sea Surface Temperature (SST) and Southern Oscillation Index (SOI).

INTRODUCTION

In India over 70% of the annual rainfall is recorded during South West Monsoon. Generally speaking, the monsoon winds reach the extreme south of Indian peninsula near around 1st of June. Thereafter it gets divided into two branches. The Arabian Sea branch moves northwards. The Bay of Bengal branch moves northwards up to the central Bay of Bengal and rapidly spreads over most of Assam by the 1st week of June. On reaching the southern periphery of the Himalayas, it gets deflected westwards and progresses towards the Gangetic Plains. By mid July, the Monsoon reaches Kashmir and remaining country but as a much feeble current. The normal stay of monsoon over India is for about 100 days beginning from 1st June. But unlike the onset, withdrawal of Monsoons is a gradual process. It withdraws from North West (NW) India by the beginning of September and from the rest of the country by first fortnight of October.

Indian summer monsoon, exhibits a wide spectrum of variability, on daily, sub-seasonal, inter-annual, decadal and centennial time scales**.** Major synoptic systems associated with south-west monsoon are Monsoon Depressions (MD) and Monsoon Lows (ML) which form over North Bay of Bengal, north of 18°N and adjoining land areas and move west-north-westwards towards northwest India during the four summer monsoon months of June to September. Another important synoptic system of the Asian summer monsoon is the Mid Tropospheric Cyclone (MTC). These synoptic scale weather systems are embedded in the large scale monsoon circulation which has significant control on the temporal and spatial distribution of the rainfall associated with them and also on their motion.

The important teleconnections are El Nino/Southern Oscillation (ENSO), Indian Ocean and Atlantic Ocean Sea Surface Temperature (SST), Indian Ocean Oscillation and land surface conditions. The global teleconnections of Indian summer monsoon rainfall variability has been studied extensively. It has been found that in the south Asian region two of the major precipitation maxima associated with areas of intensive convective activity are located near the Bay of Bengal and in the vicinity of Philippines. The variations of monthly mean outgoing longwave radiation in the two regions are poorly correlated, particularly in the decade of 1980s. (Wang and Fan, 1999). Monsoon rainfall variations and teleconnections over south and east Asia have been studied by Kripalani and Kulkarni (2001). Role of Indian Ocean in the ENSO-Indian summer teleconnection in the NCEP climate forecast system has been studied by Achuthavarier et al., 2011. The influence of Sea Surface Temperature (SST) on Indian subdivisional monthly rainfall, namely spatial and temporal influences are investigated by Maity and Nagesh Kumar (2007).

Earlier Studies

The relationship between El Nino events and Indian monsoon has been studied by many researchers since 1980 based on same methodology and same correlation. (Sikka, 1980; Pant and Parthasarathy, 1981; Keshavamurthy, 1982; Rasmusson and Carpenter,1983; Barnett, 1983; Mooley and Parthasarathy,1984; Webster and Yang, 1992; Krishna Kumar et al., 1999; Krishnamurthy and Goswami, 2000; Pai, 2003; Kane, 2005; Krishna Kumar et al., 2006 ; Rajeevan and Pai, 2007). One of the most important results is that there is an inverse relationship between the El Nino events and Indian Summer Monsoon Rainfall (ISMR). The Indian summer monsoon is weaker than normal during the El Nino years, and that the relationship is opposite for La Nina. Sikka (1980), Pant and Parthasarathy (1981), Rasmusson and Carpenter (1983) have shown that there is an increased propensity of droughts during El Nino and of excess rainfall during La Nina.

Most of severe droughts over India occurred in association with the El Nino events. However, there is no one-to-one relationship between them. Different scenarios involving shifts in the Walker and Hadley circulations have been put forward to explain the occurrence or nonoccurrence of drought during El Nino years (e.g., Ju and Slingo, 1995; Goswami, 1998; Slingo and Annamalai, 2000; Lau and Wu, 2001).

Plenty of results are available on the space-time variability of the Southern Oscillation (SO). A possible relationship between the Southern Oscillation and ISMR was first demonstrated by Walker, (1924). Several of the predictor parameters used by Walker for long range forecasts of ISMR were some measures of the Southern Oscillation (SO).

In 1980s, more studies were taken up to explore the relationship of ISMR with Southern Oscillation. Association between ISMR and the Southern Oscillation Index (SOI) has also been studied (Pant and Parthasarathy, 1981;Parthasarathy and Pant,1985). The SOI used is the difference of normalized sea level pressure between Tahiti (central Pacific) and Darwin (northern Australia), two stations located in the core regions of the circulation systems associated with the Southern Oscillation. The SOI values of different months and standard seasons show opposite tendencies during the deficient and excess years of ISMR. In 1990s, SOI and Darwin pressure tendency were used as the predictors in long range forecast models (Gowarikar et al., 1989, 1991). However, this parameter was not used as a predictor due to weakening of its statistical correlation with ISMR in the forecast models used by Indian Meteorological Division (IMD) in the later years (Rajeevan et al., 2006).

The role of the sea surface temperature over the Arabian Sea on the southwest monsoon over India has been a subject of debate for a long time (Pisharoty, 1965; Saha and Bhavadekar, 1973; Shukla and Misra, 1977; Weare, 1979; Joseph and Pillai, 1984). Observational studies on the relationship between the Indian Ocean Sea Surface Temperature (SST) and the Indian monsoon mostly focused on the correlative aspect of the relationships (Saha, 1970; Cadet and Diehl, 1984; Joseph et al., 1994; Clark et al., 2000; Rajeevan et al., 2002). It is important to note that seasonal variations of the SST over this region are very large, but the inter-annual variations are very weak. The relationship between the Arabian Sea SST and monsoon rainfall had been reexamined by removing the large amplitude high frequency noise and very low-frequency long-term trends (Rao and Goswami, 1988). They found that there exists a homogenous region in the south-eastern Arabian sea where the March-April (MA) SST anomalies significantly correlate with the seasonal (June to September) rainfall over India. The relationship of SSTs over south Indian Ocean with ISMR has been addressed (Verma, 1990). The importance of SST anomalies over the equatorial Indian Ocean, which influenced ISMR adversely during the 1987 El-Nino has been emphasized (Krishnamurti et al., 1989). The study suggests a strong correlation between ISMR and Pacific SST anomalies than with Indian Ocean SST anomalies (Shukla and Paolino, 1983).

Solar Activity and Rainfall

The influence of solar activity on climate has been a matter of debate for a long time. That solar activity affects the North Atlantic Oscillations (NAO) was also shown by Kodera and Kuroda (2002). They showed that during solar maximum phases, the NAO covers the northern hemisphere and extends to the stratosphere by contrast to the minima phases when it remains confined to the Atlantic sector and the troposphere. That solar activity plays an important role in influencing the precipitation on land and annual precipitation in Beijing is closely related to the variation of sunspot number has been observed by Zhao et al., (2004). It has been found that Indian rainfall is strongly correlated with the sunspot activity and overall trend is that during the period of low sunspot activity occurrence of rainfall is high compared to the period of high sunspot activity. (Hiremath, 2006). Recent study of the solar influence on the monsoon rainfall over Tamilnadu shows negative correlations between occurrences of sunspot number and rainfall activities (Selvaraj and Aditya, 2012). That the climate is influenced by the solar activity and all India rainfall is maximum when the sunspot numbers are minimum i.e. an anti correlation exists between rainfall and sunspot numbers (Selvaraj et al., 2013).

The activity of the Sun is expressed through various solar indices. Directly observed solar features e.g. sunspots, plages, flares are highly reflected by these solar indices. Solar indices measure solar emissions at different wavelengths e.g. the 2800 MHz radio flux, the 530.3 nm Fe XIV coronal line intensities, the total solar irradiance. The best known and longest activity indices is the 10.7cm (2800 MHz) solar radio flux measured daily by the National Research Council of Canada since 1947. It is observed that variable component of solar parameters play a significant role on different atmospheric phenomena (Saha et al., 2011; Midya et al., 1999).

It has been reported that during the period 1700-1985, more El Ninos (63%) occurred in coastal Peru during the sunspot minima or in descending phase than in maxima or the ascending phase (37%) (Mendoza et al., 1991).The signature of solar activity variability in meteorological parameters has been studied (Tsiropoula, 2003). The Sun's output varies on a wide range of time scales from minutes to the billion year time scale of solar evolution. They appear quasi-periodically and can be divided into short (transient episodes solar activity like ares or Coronial Mass Ejections), intermediate term variations (16-month cycle discovered recently), long–term variations (11-year solar cycle, the 22-year Hale cycle of magnetic activity, the 80 to 90-year Gleissberg cycle, the 180 to 200 year de Vries cycle).

Walker (1924) reported the effect of sunspots on rainfall taking into account representative stations for the whole world. It has been concluded that for peninsular and northwest India, the apparent positive correlation between Rainfall in India and Sunspot activities, as reported by Walker and others does not hold good during recent sunspot cycles (Satakopan, 1946). A study on possible association between Indian Monsoon Rainfall and solar activity is made by Bhattacharyya and Narasimha (2005). Recent advances in reconstruction of the past climate with fine temporal resolution clarified the relationship between the solar cycles and the monsoon rainfall in South Oman with multiple time scales from decadal to millennial (Neff et al., 2001; Burns et al., 2002; Fleitmann et al., 2003). The direct cause of higher rainfall in South Oman was explained by stronger northward surface winds (Burns et al., 2002; Fleitmann et al., 2003). However, the mechanism of how the change in solar activity produces a regional circulation change remains unexplained.

A variation of $\delta^{18}O$ in stalagmites is related to the precipitation amount during the monsoon season. The relationship between the precipitation in South Oman and solar activity can be understood using modern meterological datasets spanning from surface to 10 hPa. An equivalent relationship was first provided between the solar activity and the Indian Ocean monsoon found by paleoclimate studies. Next, an investigation was made on the processes whereby solar activity produces such effect. (Kodera, 2004)

Monsoon has been an intriguing puzzle since long. A number of climate records show correlations between solar cycles and climate, but the absolute changes in solar intensity over the range of decades to millennia are small and the influence of solar flux on climate is not well established. (Neff et al., 2001, Bhattacharyya and Narasimha, 2005).

It has now been established that a strong contribution to the total solar radiation occurred at 10.7 cm. Covington also showed that the 10.7 cm Solar Flux correlates with indices of solar activity such as Sunspot Number, Total Sunspot Area (Covington, 1948).

Determination of the strength of solar radio emission in a 100MHz-wide band centered on 2800 MHz (corresponding to a wavelength of 10.7 cm) averaged over an hour is made by 10.7 cm solar flux measurement. It is emitted primarily from the coronal plasma trapped in magnetic field over the active region, expressed in solar flux units (sfu, 1 sfu= 10^{-22} $Wm^{-2}Hz^{-1}$) and is a basic indicator of solar activity. It can vary from values below 50 to values above 300. Typically values in excess of 200 occur in periods of peak solar cycle. It comprises a time-varying mix of up to three principal emission mechanisms which may be differently distributed over the solar disk and may vary independently with time. It is used as a proxy for other solar emissions which are more difficult to obtain. (Tapping, 2013). The advantage of using the 10.7 cm index over others is that, the measurement of 10.7 cm Flux is completely objective and can be done in any weather.

In this study the Slowly Varying Component of 10.7cm Flux is computed since it is expected that while the Basic component remains steady over the years, the Variable component that depends directly on solar activity may be associated with the variability of different weather systems or Circulations.

Methods and Analysis

The area-weighted average of the daily rainfall at more than 300 rain-gauge stations spread across India is often used as an index of monsoon activity, and its cumulative value for monsoon period (June–September) is called the all-India summer monsoon rainfall (ISMR). Data for the monthly average for the period 1947-2006 has been taken from the website of Indian Institute of Tropical Meteorology (IITM, Pune). Whole Indian region has been divided into seven homogeneous regions namely North Mountainous India (NM India), North-East India(NE India), North Central India (NC India), North West India(NW India), North Peninsular India (NP India), South Peninsular India(SP India) and East Peninsular India (EP India).

The daily data for the relative sunspot number and 10.7 cm solar flux, adjusted to 1 AU (March – May) are taken from the official website of the US National Oceanic and Atmospheric Administration (NOAA), http://www.ngdc.noaa.gov/ngdc.html for the above-mentioned period.

The variable component of 10.7 cm solar flux is calculated by plotting the relative sunspot number against the 10.7 cm solar flux shown in Figure 1.

Calibration curve is drawn considering 10.7 cm solar radio flux and relative sunspot number data for large number of days and from that calibration curve, variable component is calculated for our required monsoon period.

Extrapolating to zero sunspot area, the line of the most probable relation between 10.7 cm solar flux and relative sunspot number, the basic component is obtained

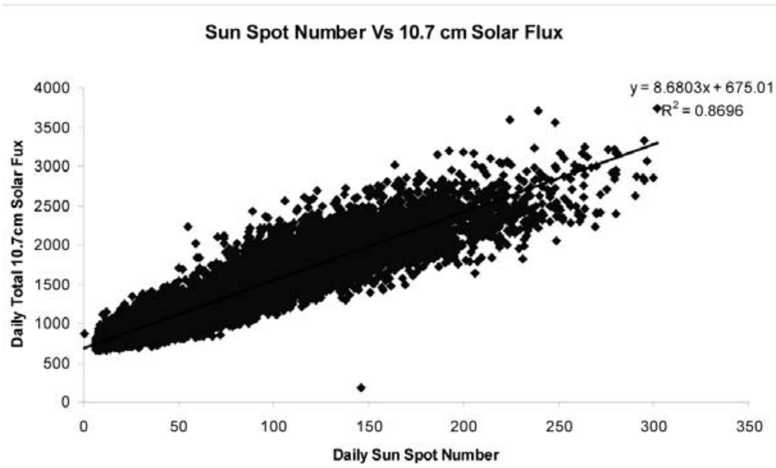

Figure 1. Variation of Daily sunspot against daily 10.7 cm solar Flux.

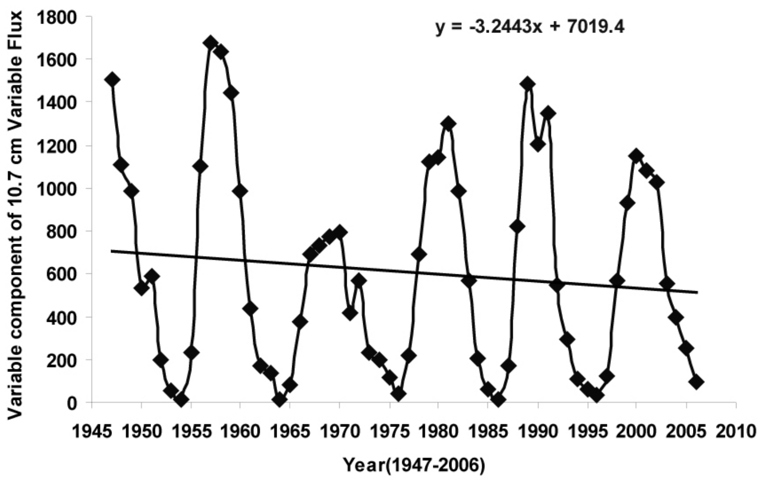

Figure 2. Variation of variable component of 10.7 cm solar flux during monsoon period for the period 1947-2006 (data only for monsoon months).

and it is the quiet sun emission. The emission above the base level is called the variable component of 10.7 cm solar flux which is computed from daily value of 10.7 cm solar flux adjusted to 1 AU. The time series analysis of monsoon rainfall over the above mentioned period has been performed along with time series analysis of variable components of 10.7 cm solar flux to evaluate the effect of solar activity over precipitation.

RESULTS AND DISCUSSION

Variation of 10.7 cm variable flux and rainfall during Monsoon period:

Figure 2 shows the trend of variation of variable components of 10.7 cm solar flux during monsoon (June-September) period.

Figures 3(a-h) show the trends of monsoon rainfall over All India, NM India, NE India, NC India, NW India, NP India, SP India and EP India respectively. Thus, it is found that both F10.7 and Summer Monsoon Rainfall show an approximate sinusoidal pattern of the same nature but overall, there appears to be a decreasing trend for both emission of 10.7 cm Solar Flux as well as the Monsoon Rainfall for all the regions during the chosen period of study.

Rainfall is a complicated phenomena. There are different factors which are related to rainfall. Heavy rainfall occurs near the equator and decreases with the increase in the latitude i.e. towards polar regions. Rainfall tends to be heavier near coastlines as main source of moisture for rainfall is evaporation from oceans. Rainfall is influenced by pressure and temperature variation in a particular area. Presence of mountains produce orographic rainfall. So point to point regression is quite unexpected. In some cases, the trend is not so significant, but it is clear that there is an overall decreasing trend in all cases.

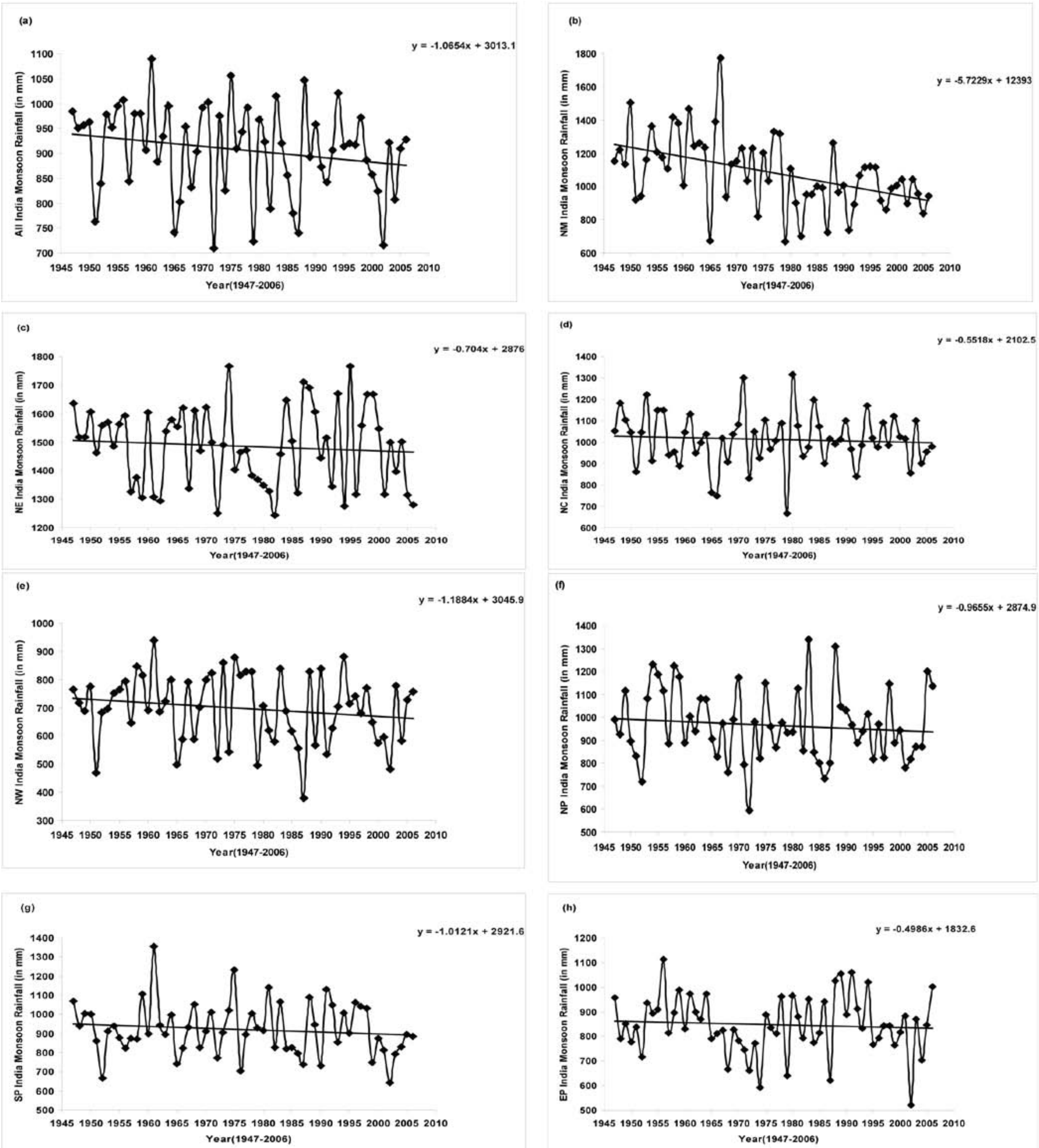

Figure 3. Trends of monsoon rainfall over (a) All India, (b) NM India, (c) NE India, (d) NC India, (e) NW India, (f) NP India, (g) SP India and (h) EP India for the period 1947-2006.

With the increase of magnetospheric activities, decrease of cosmic ray is quite expected. It may affect the decrease of cloud formation. Again, if cloud formation is significant, rainfall may not occur in large scale due to the decrease of other rain forming constituents. In our analysis increase of rainfall is due to large availability of rain producing elements.

CONCLUSIONS

In an earlier communication, it is shown that variable component of 10.7 cm solar flux has a significant effect on different atmospheric phenomena (Saha et al., 2011; Midya and Saha, 2011)

Bhalme and Mooley found a highly significant (approximately 22 years) solar cycle in flood area index and weak quasi periodicity of 2.7 to 3.0 years (Quasi Biennial Oscillation, QBO)in drought area index for India for monsoon season (Bhalme and Mooley 1980, 1981).

From Cross–spectrum analysis they showed that the approximate 22 years cycle in the flood area index is related to double sunspot cycle.

It is quite expected that variable component of 10.7 cm solar flux plays a significant role for the production of water molecules in the vapour state and hence rainfall rate will be affected with variation of variable component of 10.7 cm solar flux.

Our result shows that rainfall trend (both monsoon and total) decreases with the decrease of variable component of 10.7 cm solar flux. This fairly agrees with our explanation.

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Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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