Influence of solar activity on the rainfall over India

K. M. Hiremath

Indian Institute of Astrophysics, Bangalore-560034, India

Abstract. We use 130 years data of Indian rainfall for studying correlative effects due to solar cycle and activity phenomena. Among all the seasons of the Indian rainfall activity, the Indian Monsoon rainfall, with a high significance, is positively correlated with the sunspot and irradiance activities. We subject the Indian Monsoon rainfall and the sunspot occurrence activities with FFT and wavelet analysis. It is found that both the activities have a common periodicity of 22 year indicating that the solar cycle and activity phenomena strongly influence the rainfall activity. We conjecture a possible physical connection between occurrence of the rainfall variability and the sunspot activity and, the flux of galactic cosmic rays (GCR). Some of the negative correlations from the cycle-to-cycle variations are interpreted as the aerosol effects due to either intermittent volcanic eruptions or due to intrusion of interstellar dust particles in the earth's atmosphere.

Index Terms. Galactic cosmic rays, Indian rainfall, interstellar dust particles, solar activity.

1. Introduction

Owing to proximity, the sun predominantly influences the earth's atmosphere and the climate. The previous studies (Hiremath and Mandi, 2004, and references there in; Hiremath, 2005) amply demonstrate the influence of solar forcing over the earth's global climate and the environment.

The sun is a gigantic plasma laboratory that is pervaded by a large-scale (~ solar size) magnetic field (~ 1 Gauss) of primordial origin (Hiremath and Gokhale, 1995) that varies on diffusion time scale (~ billion of years). A small scale (~ 100-1000 Km) magnetic filed (~ 1000-3000 Gauss) structures like sunspots, plages, etc., that are supposed to originate by an unknown dynamo mechanism vary on time-scales of few months to decades. The sun also produces the transient phenomena like flares and coronal mass ejections that transfer energy, mass, momentum and high energy particles to the planetary environments. The last but not least, the sun's constant emission of radiation, though it varies by ~ 0.1% on time scales of 11 years, keeps the planetary environments warm enough and helps in sustaining the life on the earth.

Although the earth's clouds-the source of rainfall variability-are tropospheric phenomena and are close to the earth's surface, the sun can influence the earth's rainfall variability in many ways. One can expect that the sun can influence the clouds and the rainfall activity by mediating through GCR that is the source of ions. Since the cloud formation is a function of the ambient temperature, any changes in the earth's atmospheric ambient temperature due to solar irradiance variations directly influence the formation of the cloud drops and hence the rainfall variability. Aim of present study is to examine the solar activity phenomena on the rainfall variability over India. For comparison, we use the results of previous correlative study (Hiremath and Mandi, 2004) between the occurrence of the sunspots and the rainfall variability.

2. Data and analysis

We consider 130 years (1871-2000) data of the sunspot numbers and the Indian rainfall (Parthasarathy et al., 1993; http://www.tropmet.res.in) occurrence variability for correlative and periodic analysis. Parthasarthy et.al. (1993) have compiled a homogeneous set of rainfall data from the 14 meteorological subdivisions covering the northwestern and central parts of India (about 55% of the total area of the country). This rainfall variability has similar characteristics and associations with the regional or global circulation parameters. In Fig 1, we illustrate the yearly means of the sunspot number, solar irradiance and the rainfall (in mm) variabilities. For the 1871-2000, the rainfall data is available in monthly, seasonal (including the spring, the southwest, the northeast and the winter monsoon) and the annual (averaged for the period of 12 months) rainfall data. We follow the similar nomenclature (JF-*winter rainfall* for the months of January and February; MAM-*spring* rainfall for the months of March, April and May; JJAS-*southwest monsoon for* the months of June, July, August and September; OND-*northeast monsoon* for the months of October, November and December) as in the previous study (Hiremath and Mandi 2004). The technical definition of *monsoon* is a seasonal reversal in the prevailing wind direction. It is most often applied to the seasonal reversal of the wind direction along the shores of the Indian Ocean that blow from the southwest during the months of JJAS and from the northeast during the months of OND. The reversal of the monsoon winds is mainly due to the differential heating between the continental areas and the oceans as a result of zenithal march of the Sun. We also give similar nomenclature (i.e., JF, MAM, JJAS and OND) for the sunspot number and irradiance data. For the years (1871-2000), we use the sunspot occurrence data from the National Geophysical Data Center (http://www.ngdc.noaa.gov/STP/SOLAR/SSN/ssn.html). As for the solar irradiance variations and for the year 1882-2000, we use the data kindly provided by Dr. Lean (Naval Research Laboratory, USA).

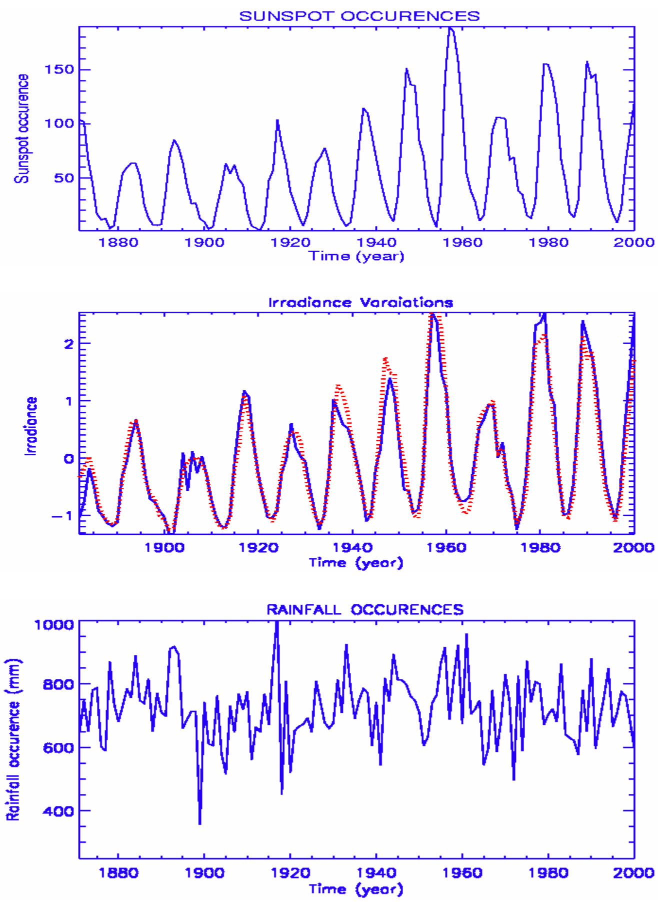

Fig 1. The variation of the solar and the rainfall activities. The top panel indicates the sunspot activity; the middle panel represents the sunspot (blue continuous line) and the irradiance (red dotted line) activities. The last panel represents the rainfall activity.

From the year 1880 onwards, the monthly irradiance data consists of the total and UV (200-295 nm) irradiance activities that are reconstructed from the ground and space based observations (Lean, 2000).

Following methods are used to know the influence of solar activity on the rainfall variability: (i) using correlative analysis, we study long (>1 year) term influence of the solar activity and, (ii) both the solar activity and the rainfall variability indices are subjected to FFT and wavelet analysis.

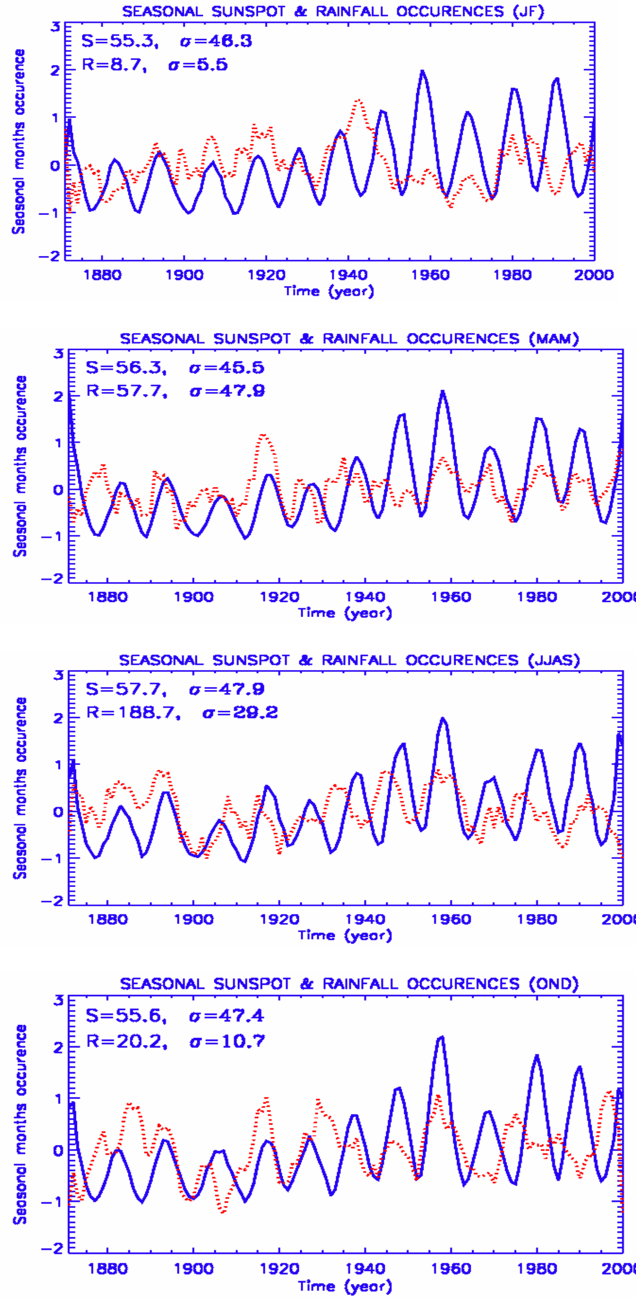

Fig. 2. The seasonal sunspot and rainfall occurrence variabilities. From the top, the first illustration represents the months of JF, the second illustration represents for the months of MAM, the third panel represents the months JJAS and the last panel for the months of OND. In all the panels, the red dotted curve is the rainfall occurrences and blue continuous line is the sunspot occurrence. For different seasonal data, S is the mean of the sunspot activity, R is the rainfall variability and sigma is the standard deviation from the mean for both the variabilities.

In order to know the long-term influence of solar activity on the rainfall variability, we compute the Spearman Rank-Order correlation coefficient and its significance. We find with a high significance that annual mean rainfall and sunspot occurrence variabilities do not show any correlation at all.

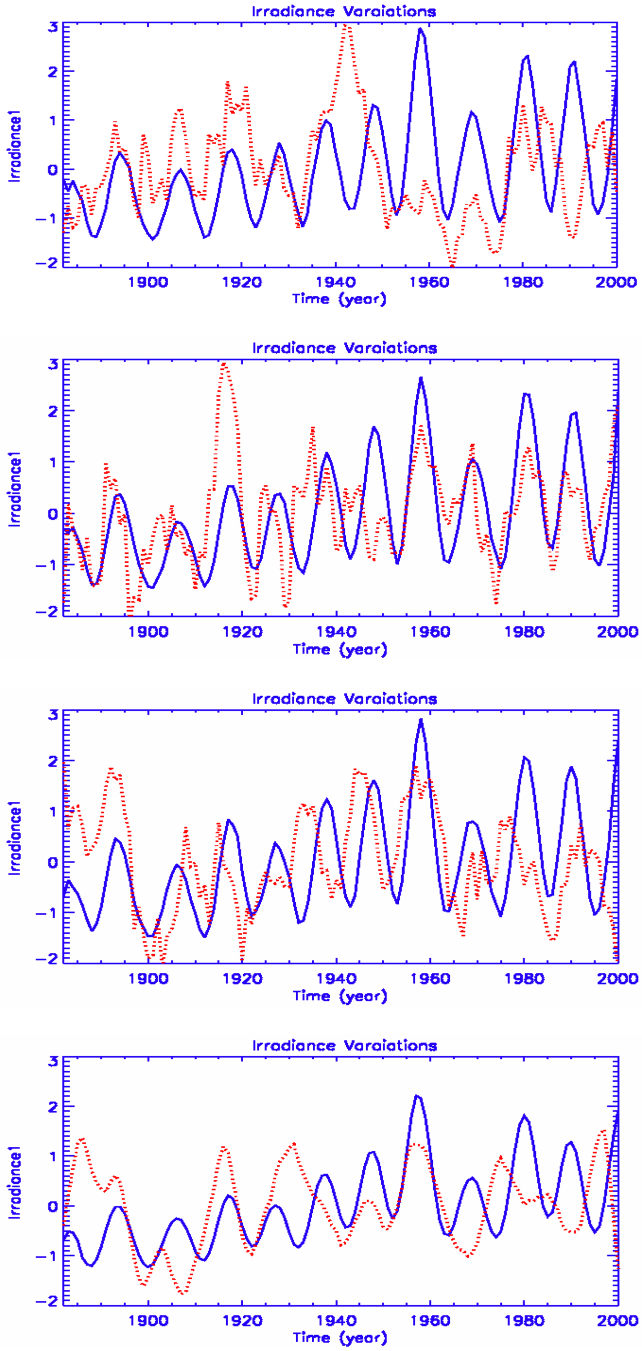

Fig 3. The seasonal rainfall variability (the red dotted line) and the irradiance variability (blue continuous line) for the 200-295 nm wave length range. From the top: the first illustration represents the seasonal months of JF, the second illustration for the months of MAM, the third panel represents for the months of JJAS and the last panel for the months of OND.

This trend remains same for the irradiance data also. The obvious reason must be a combination of different seasonal rainfall variabilities, viz., the spring, southwest and northwest monsoons and the winter rainfall that may have different characteristics of the occurrences. Thus we separate these seasonal rainfalls for testing any good correlation with the solar activity. For the seasonal data sets, after combining the monthly data sets for a particular year, we compute means and standard deviations (SD). Since the seasonal data set is noisy, we smooth the same by four points moving average. In Figs. 2 and 3, we present the seasonal rainfall (red dotted line) variability and the solar (blue continuous) activity. For easy comparison of two sets, in both the figures, the data set is presented as a deviation from the mean and then is normalized to their respective SD. From these results we find that the spring and southwest monsoon rainfall variabilities, with a high significance, strongly correlate with both the sunspot and irradiance activities.

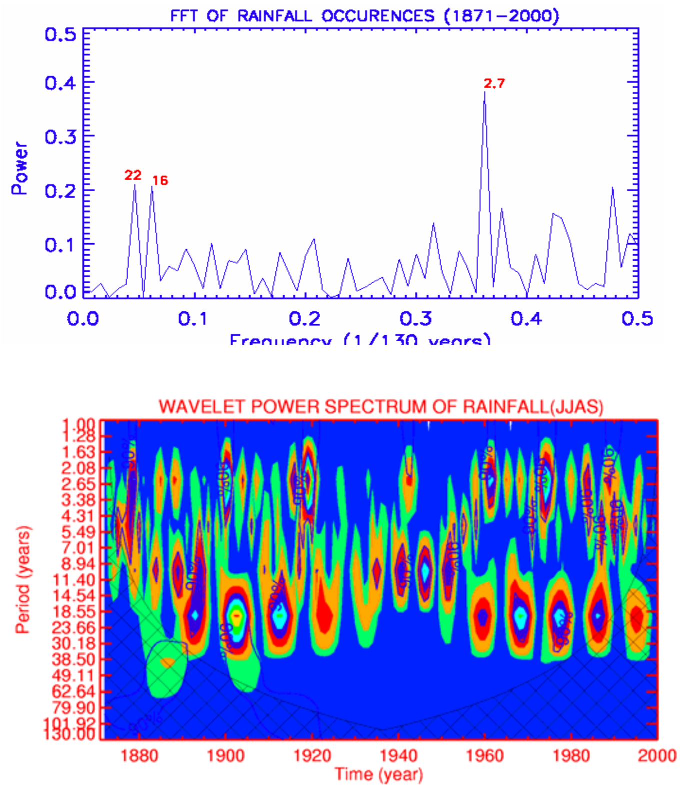

Fig. 4. The periodic analyses of the southwest monsoon (JJAS) rainfall variability. The top panel represents power spectrum versus frequency from the FFT analysis and all the periods detected (with > 3 sigma levels) are in years. The lower panel represents concentration of power from the wavelet analysis.

3. Periodicities in the occurrence of the solar and the rainfall variabilities

From the strong correlation of the solar and the rainfall variability, it is clear that the local perturbations of the ambient medium at the level of the rain forming region must lead to waves and oscillations that result in periodic behavior of the rainfall variability. In order to maintain such periodic behavior, either local or external forcing is necessary. Except the local phenomenon (El Nino oscillations) whose periodicity is in the range of 3-6 years, one cannot explain other periodicities detected from the following FFT and wavelet analyses. Thus, one can safely assume that the external periodic forcing to the earth's atmosphere may be the sun that manifests itself with many periodicities (~ minutes to decades) in the solar variabilities. Since the solar periodicities are well known, we do not subject either sunspot or irradiance activities with the FFT and wavelet analysis. In Fig 4, we present the FFT spectrum (top panel) and the wavelet power spectrum (lower panel) of the rainfall variability. It is interesting to note from Fig 4 that the detected periods are similar to the periods detected in the solar phenomena. Thus the sun indeed influences 2-3 years to decadal scale periodicities on the occurrence of the Indian rainfall variability.

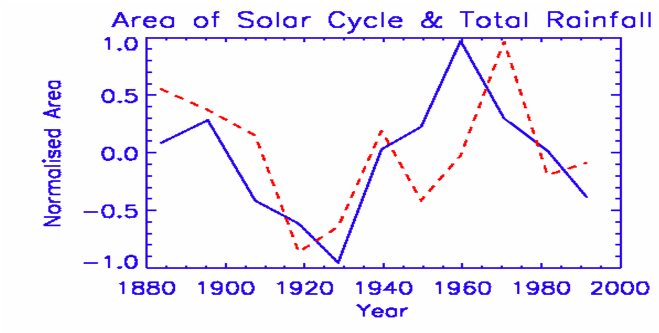

Fig 5. The normalized areas of the sunspot cycle and the corresponding areas of the rainfall variabilities are plotted against the middle of the year of each successive cycle. The red dashed line represents the rainfall variability and the continuous line represents the sunspot activity.

4. Long-term variation of the areas of the solar cycle and areas of the rainfall variability

In order to explore further the long-term association between the sunspot and the monsoon rainfall variabilities, we combined all the annual data set and computed areas of the solar cycle as defined in our previous study (Hiremath and Mandi, 2004). In Fig 5, we present the data that have been detrended and normalized to their respective maximum areas. It is important to note that association between the rainfall and the sunspot variability is very strong (with a correlation of 62% and of very high significance 96%).

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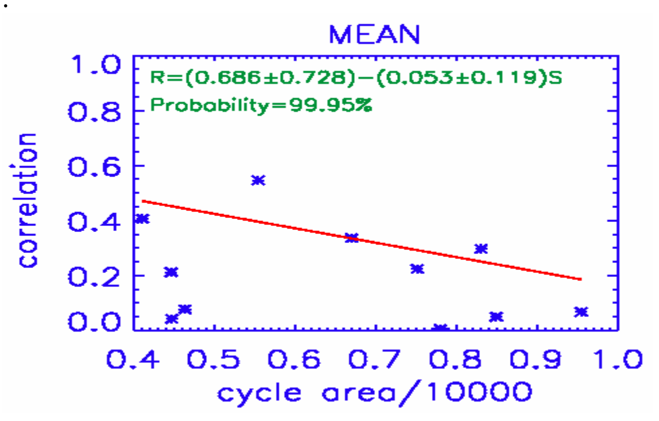

Fig 6. Different cycle-to-cycle variations of the correlation coefficients (absolute values) are plotted against the cycle area. The red continuous line is obtained from the linear least-square fit.

5. Discussion and conclusion

Although all the results of the present correlative study strongly indicates the one-to-one correspondence between the rainfall and solar activity, physics of the linkage between these two activities is unclear. The recent satellite observations (Svensmark and Fris-Christensen, 1997) show that there is a positive correlation between the cloud cover in the Earth's atmosphere and the flux of GCR. Since the flux of GCR is anti-correlated with the sunspot activity, one would expect a similar relationship between the amplitudes of the rainfall and the sunspot variabilities for all the solar cycles. That is precisely we obtain anti-correlation in the Fig 6.

In Fig 6, we illustrate the absolute values of the correlation coefficients for different 11 cycles with respect to their solar cycle areas. The results in the previous sections indicate that on long-term time scales (>22 years), we get positive correlation between the rainfall and solar activity. However, on 11-year time scales and in some of the solar cycles, we get negative and very low correlation coefficients (that are taken as absolute values and are presented in Fig 6). Some of the negative correlations between the occurrences of the rainfall and solar activities are interpreted as effects of aerosols on the rain forming clouds due to intermittent volcanic eruptions or due to intrusion of interstellar dust particles in the earth's atmosphere.

The GCR activity is a source of ions in the earth's atmosphere. We know that the condensation of water vapor into water drops is modified by the ions in the atmosphere. Thus any change in the GCR activity correspondingly affects the rainfall variability. To put it in precise way, as the intensity of the GCR is inversely proportional to the solar activity, increase in solar activity results in reducing the intensity of the GCR flux. This ultimately results in both reducing the activity in nucleation of the cloud particles and suppression of the rainfall variability (Parker, 1999). Overall conclusions of the present study are: (i) the *spring* and the *southwest monsoon* rainfall variabilities strongly correlate with the solar activity, (ii) the FFT and the wavelet analyses of the annual rainfall variability show the similar periodicities as those found in the solar activity indices and, (iii) there appears to be a *causal* connection between the rainfall variability, the solar activity and the GCR flux.

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