

# A study of relation between Sunspot numbers and occurrence of Forbush decreases

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**Abstract:-**An abrupt decrease  $\geq 3\%$  and slow recovery lasting in several days in cosmic ray intensity is termed as Forbush decreases. Large concentration of magnetic fields in certain locations on the photosphere is called sunspot. In the present study, we have studied the relation between Forbush decrease and solar activity. Sunspot numbers proved a reliable and easily available solar parameter, particularly in cosmic ray modulation. To carry out study, data was taken from Neutron Monitors. Number of Forbush decrease events along with sunspot number  $R_z$  was plotted. The overall results are encouraging that shows a prominent relationship between occurrence of Forbush decrease events and 11 year sunspot solar activity cycles.

**Key Words :** Forbush decrease, Cosmic rays intensity, Sun spots

## Introduction:

Forbush decrease is well known sporadic variation in cosmic ray intensity. A rapid decrease in cosmic ray intensity followed by slow recovery is called as Forbush decrease. The first observation of Forbush decrease was made in 1938 by Forbush. Forbush decreases are the most spectacular events in the cosmic ray intensity observations (Forbush, 1938; Lockwood, 1971). These are generally characterized by sudden decrease in cosmic ray intensity with the total time of decrease varying between few hours to days. Recovery of the intensity to the predecrease level can last from few days to a week or more. Thus, in general, the cosmic ray Forbush Decreases (Fds) has a rapid rate of decrease and slow recovery where the major portion of the decreasing phase is completed within 12-24 hours. There are instances when the maximum rate of decrease exceeded 2% per hour at sea level, high latitude neutron monitoring stations. A typical Forbush decreases of magnitude  $> 5\%$  may include a pre-decrease and pre-increase as

well as the post increase during the period of its recovery. Generally, recovery of the intensity following a Forbush decrease follows exponential law with the time constant showing a wide variability from about a day to many weeks or sometimes even months. This rate of recovery is not clearly associated with the magnitude of the initial decrease or with the associated continuing magnetic activity (e.g. Sandstrom, 1965; Lockwood, 1971; Kane, 1975; Kane, 2003). Sometimes, complete recovery is not observed in Forbush decreases.

In fact during the previous solar cycles, there were many Fds of amplitude greater than 5% observed by the high latitude neutron monitors. For large Fds ( $\approx 20\%$  to  $25\%$ ) the integral cosmic ray intensity at the top of the atmosphere is reduced by a factor of about two (Webber, 1962; Lockwood, 1971). The onset of Forbush decreases do not always start from a constant level but very often it is associated with small pre-increase in cosmic ray intensity ( $\approx 2-3\%$ ) preceding the onset of Fd. The pre-increase is usually of very short duration ( $\approx$  few hours) though it may also extend sometimes to longer periods.

The characteristics of the Forbush decreases and their correlation with a number of solar and geophysical parameters have been obtained by a number of investigators (Dorman, 1965, 1974; Forbush, 1966, 1974; Lockwood & Webber, 1962, 1987; Lockwood, 1971; Agarwal and Singh, 1975; Nagasima, 1997; Rao, 1972; Venkatesan and Baddruddin, 1990; Mc Kibben et al., 1995; Mori et al., 1996; Wibberenz et al., 1998; Belov et al., 2001; Ifedili, 2004).

Large concentration of magnetic fields in certain locations on the photosphere is called sunspots. These were first observed by Galileo in 1610 and the observations have since then continued. The sunspots occur in groups and vary in number from 0 to few hundreds (250 or 300) in a period of 11 years (Solar Cycle). The sunspots appear dark because their temperature is low (about 4500°k) as compared to the temperature of other regions of the bright solar disc. Their sizes vary from 1000 km to even 50,000 km in diameter. Each sunspots have two regions.

(i) Umbra : Which is the dark central area and  
(ii) Penumbra: which is the less dark and filamentary around the edges. They appear as bright regions surrounding the sunspots in the light of calcium k-line or hydrogen H $\alpha$ -line in spectro-heliograms. A large sunspot group may contain as many as 400 spots of different sizes. The relative sunspot number (R) on the visible disc is derived using an experimental formula suggested by Wolf in 1949 viz.

$$R = K (10 g + S)$$

Where 'K' is the scale factor, which is usually less than unity and depends on the individual observatory, 'g' is the number of sunspots groups (factor 10 is arbitrary) and 'S' is the total number of distinct sunspots. The number of sunspots varies with a periodicity of 11-years. Sunspot numbers, observed on the disk is treated as a measure of the solar activity since this number can vary from no spot condition i.e. number zero to as high as 350 to 400. Sunspots undergo a well-known cycle of about 11.5 years (varying irregularly by about one year), during which their numbers grow and decrease again.

The cosmic ray intensity variations have been studied using the neutron monitor count rates. The systematic study of the time variations of relativistic cosmic rays started almost about 70 years ago using ground based detectors. The ground based observations and insitu-space observations of cosmic ray intensity and its anisotropies and their relationship with other interplanetary parameters provide the base to understand the variational characteristics of the cosmic ray intensity.

More than six decades have been ranged since the ground based continuous observations of cosmic ray intensity were started by Forbush in 1938 and also three decades have been passed since to initiation of various space crafts experiments. We are now in position to study the long-term cosmic ray modulation. Cosmic ray intensity variations as a function of solar cycle have been recognized with the maximum intensity occurring approximately seven months after sunspot minima. The minima and maxima of a solar activity cycle is defined on the basis of number of sunspots. Long-term cosmic ray intensity has been studied by a number of cosmic ray scientists (Moral 1976; Shrivastava et al, 1989; Singh et al 1999). **Forbush** 1958 have found that the cosmic ray variation lagged behind the solar activity 6 to 12 months.

#### Data Analysis:

The cosmic ray intensity data used in this work come from Kiel Neutron Monitor . Kiel Neutron Monitor is in Germany at latitude 54<sup>0</sup>. longitude 10<sup>0</sup> and altitude 54m.

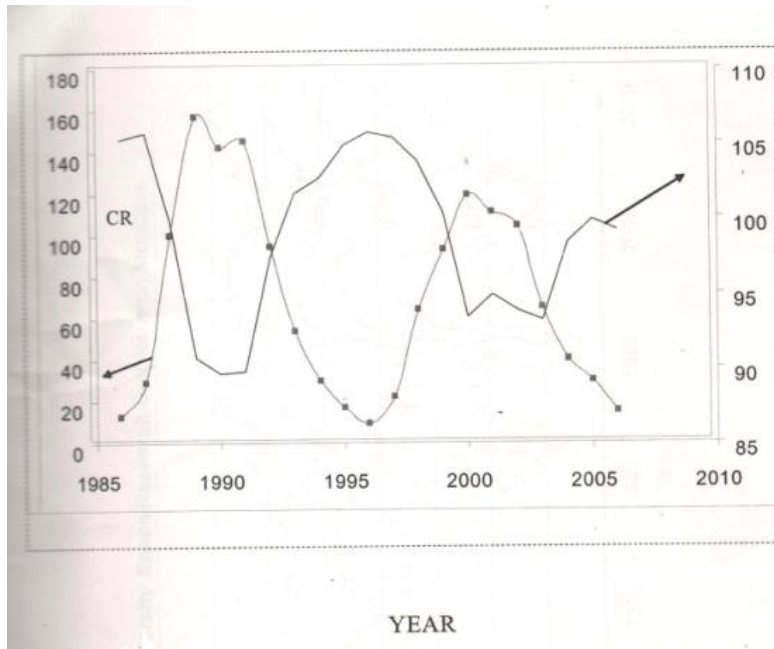
#### Results and Discussion:

In this section, we have studied the long-term relationship between Forbush decrease magnitude and solar activity. Sunspot number is proved a reliable and easily available solar parameter, particularly in cosmic ray modulation studies. To show the long-term cosmic ray intensity and sunspot number we have plotted the yearly mean values of cosmic rays and sunspot numbers  $R_z$  for the period of 1985 to 2010 as shown in Fig. 1, which covers the solar cycle 23. In this figure yearly mean values of Kiel cosmic ray counts rates are plotted against the yearly mean values of sunspot numbers. In this work sunspot numbers  $R_z$  is taken as a solar parameter. We have plotted a frequency histogram by taking the Fd number for each year of solar cycles. Fd events are taken from the Mt Washington neutron monitor stations from 1954 to 1985 and for the rest of the period. Fds have been sorted out from the hourly plots of Kiel neutron monitor station. Number of Fd events along with sunspot number  $R_z$  are plotted in Fig.3. It can be inferred from the figure that Fds become more frequency as sunspot number increases. Larger number of Fd events are observed during the

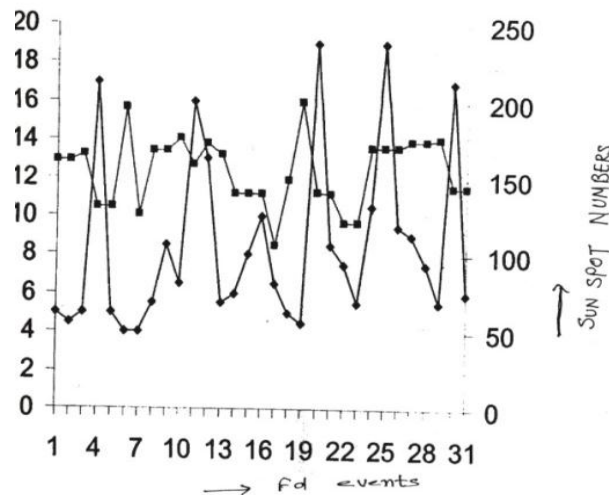
high solar activity period. It is also seen that Fd events are more frequent during ascending phase of solar cycle. Results of Fig. 3 indicate a possible relationship between occurrence of Fd events and 11-year sunspot solar activity cycles. **The year 1996 is minimum sunspot activity period and a next minimum is seen in end of year 2007.** To show the relationship between Forbush decrease magnitude and sunspot number Rz, we have also plotted the magnitude of Fd events and corresponding Rz mean

values for the period of 1989 to 2001. Magnitude of each individual event of Forbush decreases are linearly plotted with mean sunspot number during the event periods as depicted in Figure 2. It is noted from the analysis that the large magnitude of Fds is coincides with the high sunspot numbers.

The results presented in this paper are based on cosmic ray intensity neutron monitor data and solar parameters, which have been used to confirm many of the findings reported here.



**Fig 1** shows the yearly values of cosmic ray intensity variation along with Sunspot numbers for the period of 1985 to 2006. Dotted point show yearly mean values of Sunspot numbers Rz.



**Fig 2** Shows the Forbush decreases magnitudes along with sunspot numbers.

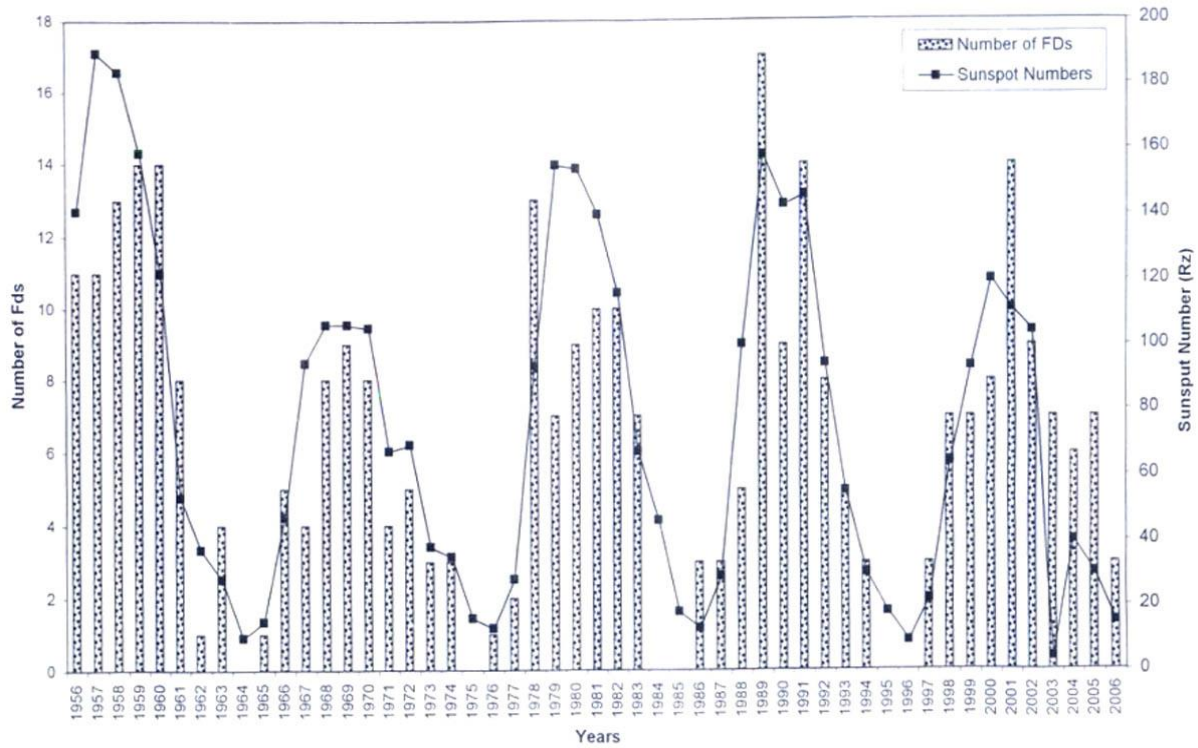


Fig. 3 Frequency histogram showing the year wise distribution of Forbush decreases from 1956 to 2006 alongwith yearly mean values of sunspot numbers.

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