Forbush Decrease correlated to Geomagnetic storm and Interplanetary magnetic field

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Abstract

In this present study, we find a correlation between cosmic ray intensity (CRI) and geomagnetic activity i.e. geomagnetic storm (GSs) Dst≤-50 nT and interplanetary magnetic field (IMF) for three consecutive solar cycles (SC) from (1986-2016). We found that the variation between CRI and GSs for most of the year showed similar behavior. The peak depression for CRI found on occurrence day of GSs. We have additionally found that CRI depends reciprocally on IMF as a result of the IMF applies force on the charged particle that comes with Coronal mass ejections (CMEs) and drives the CRI. The correlation between CRI and Dst found to be positive whereas for CRI and IMF it is negative which give strength to our finding. For rising and ending phase of these SC we found very less number of GSs hence these years correspond to solar minima. As the CRI value changes, it change space weather condition near earth surface also CRI disturbed psychological activity. Cosmic ray is known to damage DNA and cause mutation leads to cancer and other diseases too. To find the possible relation between these parameters we incorporate the analysis technique by the superposed-epoch method.

Keywords

Geomagnetic storm; Interplanetary magnetic fields; Solar cycle; Forbush decrease

Introduction

Cosmic ray intensity (CRI) and geomagnetic activity are two different phenomena which are affected by various solar and interplanetary parameters. Hence it is important to study the CRI in relation with various geomagnetic conditions. A large number of studies are being done continuously to correlate the geomagnetic storm variation with CRI by many researchers for last several decades. The study has been performed to analyze the association between CRI and GS for the Solar cycle 22, 23, 24 (1986-2016). Neutron monitor stations of the world wide network are available to provide the pressure-corrected values of the CRI. A Forbush decrease is a transient and speedy decrease within the observed galactic cosmic ray intensity (GCRI) lasting for many days (Forbush, 1938). The work towards that field started by **Lockwood, 1971; Sandstrom, 1965; Barouch and Burlaga, 1975** and **Quinby, 1973** recent work summarized by **Kharayat et al., 2016**. It generally agrees that the variation in the interplanetary magnetic field is responsible for FDs. The magnitude of FDs depends on the dimensions of CME, the strength of flux in CME and also the proximity of CME to earth. The rise or fall in CRI typically preceding FDs. The determined FDs profiles look remarkably the same as the IMF profiles. The FDs usually lag the IMF by a couple of hours. The lag corresponds to the time taken by high energy protons to diffuse into the magnetic field which opposes these high energy protons. The CME initiated by solar flare was emitted at terribly high speed and directed toward earth results FDs it conjointly expected that high interplanetary shocks generated in interplanetary space result in cosmic ray storm. Recent studies of FDs with CME have established that the FDs are strongly related to CMEs **(Cane, 2000)**.

A geomagnetic storm is a major disturbance of earth's magnetic field that occurs when there's an exchange of energy from solar radiation into space atmosphere. These storms results due to variation in the solar radiation that produces changes in current, plasma and field in earth magnetic field. The frequency of GSs will increase and decrease with the solar cycle. CME-driven storms are quite common throughout the peak section of the Solar Cycle, whereas CIR-driven storms dominant throughout solar minima of the solar cycle **(Tsurutani et al., 1995)**. The strength of a GS is measured by the Dst or Kp index **(Gonzalez et al., 1994)**. A Geomagnetic Storm has three phases initial, main and recovery. The size of a geomagnetic storm is classified as moderate (−50 nT > minimum of Dst > −100 nT), intense (−100 nT > minimum Dst > −250 nT) or super-storm (minimum of Dst < −250 nT) for our study we choose moderated GMs −50 nT > minimum of Dst > −100 nT. CIRs produces when fast Solar-Wind streams emanating from coronal holes interact with slow streams. CIRs cause both cosmic-ray deflection and geomagnetic storms **(Yan and Lazarian 2002).**

2. Data and Method

In order to find the association between CRI and GS, we used a Chree analysis by the superposed epoch method. Superposed epoch analysis also known as Chree analysis after a paper by Charles chree. The prevalence days of GSs are used as zero days. The CRI information was taken from the Moscow nucleon Monitor Station (cri.izmiran.rssi.ru/mosc/main.html). The pressure-corrected daily mean data were accustomed determine CRI. The daily mean values of the Dst index, of the interplanetary flux (IMF B), and therefore the sunspot number (SSN) were taken from the Omni web information center (omniweb.gsfc.nasa.gov/form/dx1.html). In order to calculate the correlation coefficient between these parameters, we used unbinned data (data not divided into intervals) with the time resolution of one day (daily mean average). The daily mean average values are selected for a meticulous outcome. Now the above 5 values are taken into consideration which is assumed as -1,-2,-3,-4,-5 days. Similarly below 5 values are assumed as +1, +2, +3, +4, +5 days. Preceding in a regular manner a table with the column of data is drafted for several years. After this the average value of these days (-5 to +5) is calculated and the graph between 2 parameters for the several years plotted. Than we calculated the coefficient of correlation between these parameters for individual years within the period 1986 – 2016, so we took the average of these values to find out the correlations.

3. Results and Discussion

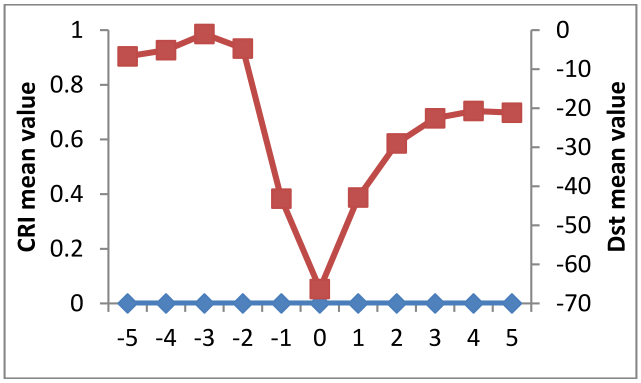
Based on our study of solar cycle 22, 23 and 24 from year 1986 to 2016 we noted that toward rising and ending phase of solar cycle the number of GSs are very less or almost zero these years correspond to solar minima while the number of GSs for midyear of these SC is very high these years correspond to Solar Maxima.

3.1. CRI and GS

On investigating **Figure 1** we found that, for most of the year's maximum increase in CRI takes place on the prevalence day of geomagnetic storm or onset day of GSs, because the frequency of FDs is highest during the solar maxima **(M. papailiou et al., 2013)**, while toward rising and ending phase of SC 22 there are only a few or no CRI correspond to GSs because these are the year of solar minima. For the solar cycle 23 **Figure 2** the variation in CRI value shows similarity with GSs for most of the years and the strongest decrease in CRI observed on occurrence day of GSs or just one day after onset day of GSs except the rising phase of SC for which there is no definite relation between CRI and Dst is found. The similarity between these parameter is due to that they both produces by same solar process. The peak depression in CRI and GSs does not coincide for every year that also founded by **(Jain et al 2007)**, Dst lags some hour from the peak value of CRI min. From the study of SC 24 **Figure 3** we found that CRI shows similar inverse relation with GSs as observed in solar cycle 22. For rising and ending phase of sc 24 there is no Dst value (-50 nT > minimum of Dst > -100 nT) observed and the CRI shows maximum value on onset day of Dst value for the years (2010, 2011, 2012, 2013, 2014 and 2015) it is probably correspond to solar maxima since the number of storms during solar maxima is high correspond to that of solar minima hence large amount of CME directed toward earth which cause high value of cosmic ray. The outcome is in good favour with the results of **Kharayat (2016)** and **Shrivastava (2001)**, who concluded that for most of the year of Solar Cycle 23, CRI diminishes during the low Dst value.

From our study of FDs events, we found that almost all the event are accomplished by GSs of Dst $\leq$ 50 nT and it establishes that CMEs are the major cause for large GSs Dst<100nT (Zhang et al. 2003). On the analysis of solar SC 22, 23, 24 we observed that the peak depression for CRI and GSs does not coincide in every year for some Dst lags by some hour from peak value of CRI minimum. Our result shows good correlation with result of **(Jain et al. 2007, M. L. Cauhan 2011)** who also predict the same. The correlation coefficient between these two parameters found to be (0.65) which shows that these two parameters are highly correlated with each other.

Variation of CRI with Dst for SC 22



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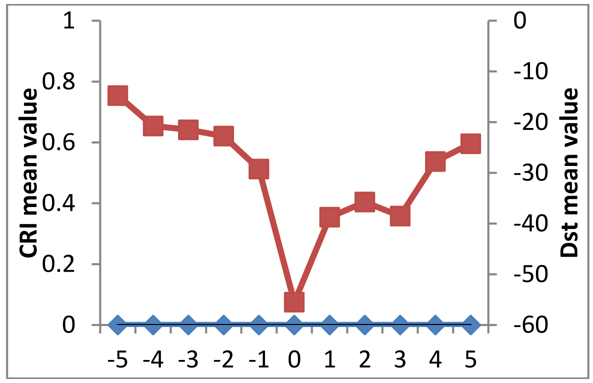

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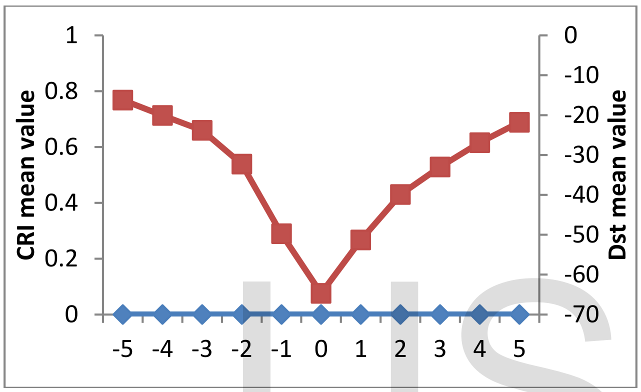

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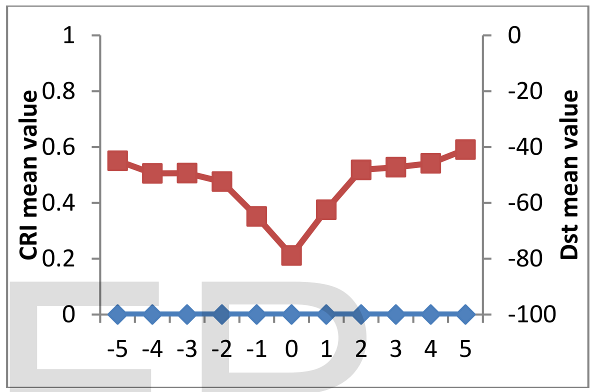

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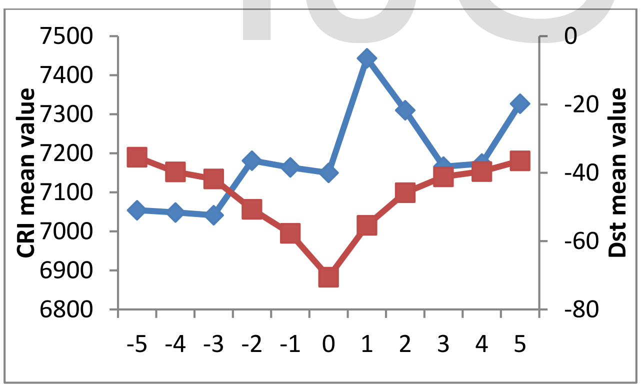

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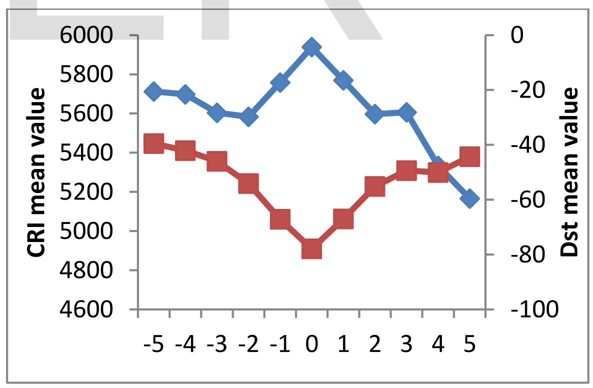

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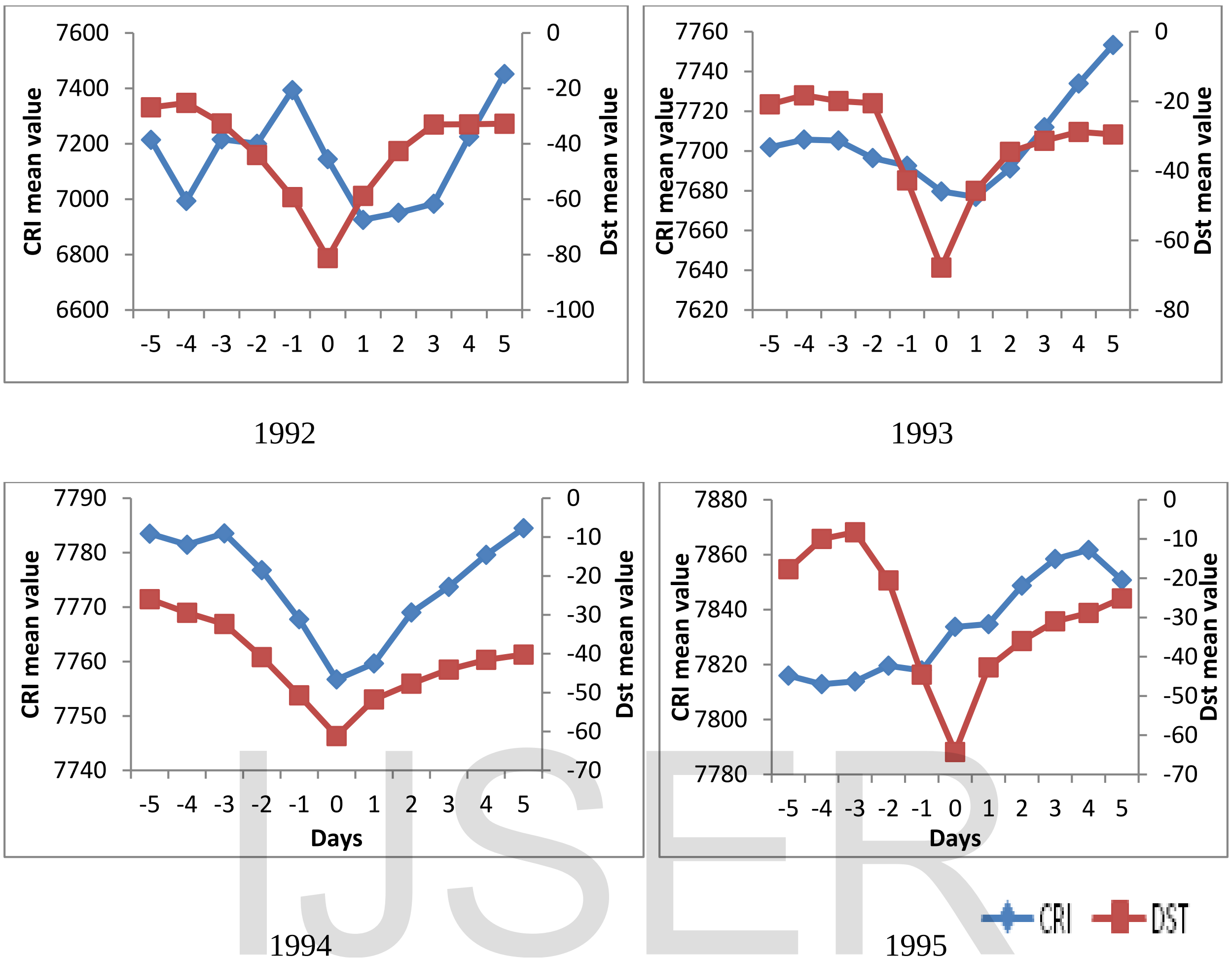
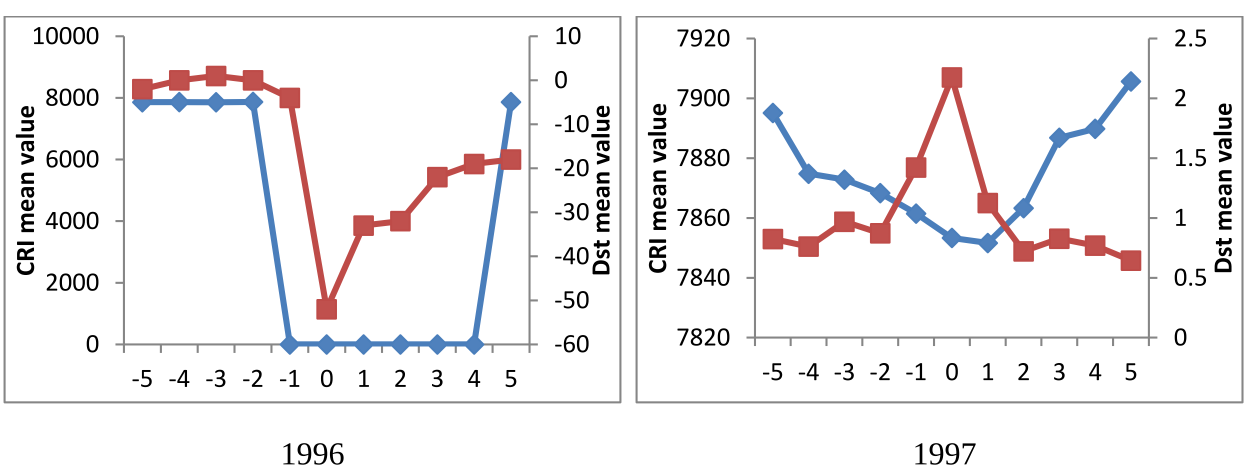
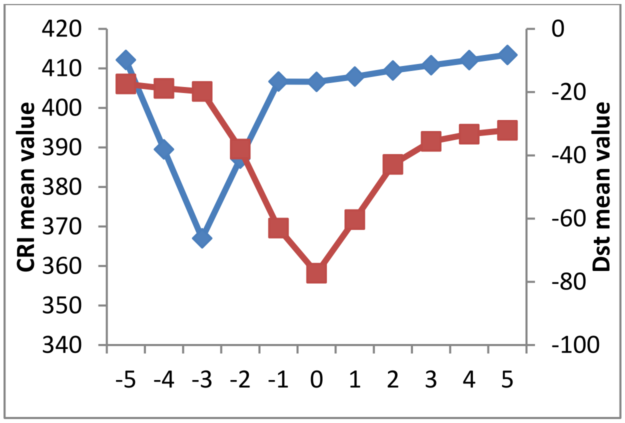


Figure 1 The result of the Chree examination from −5 to +5 days as for zero-epoch days. The variation of the mean estimation of the Dst and Cosmic-ray intensity appears. Zero days compare to the beginning day of event of GSs during1986 – 1995.

Variation of CRI with Dst for SC 23





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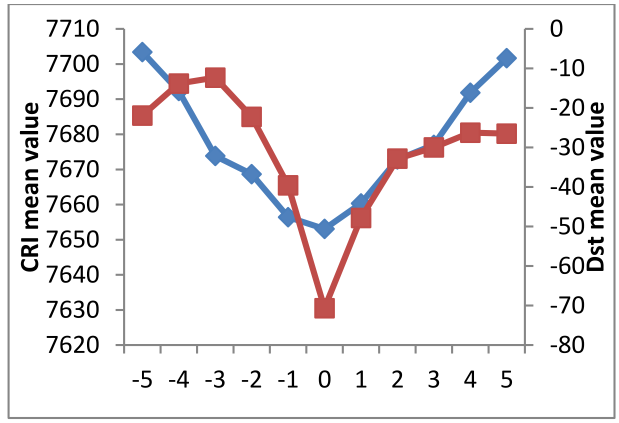

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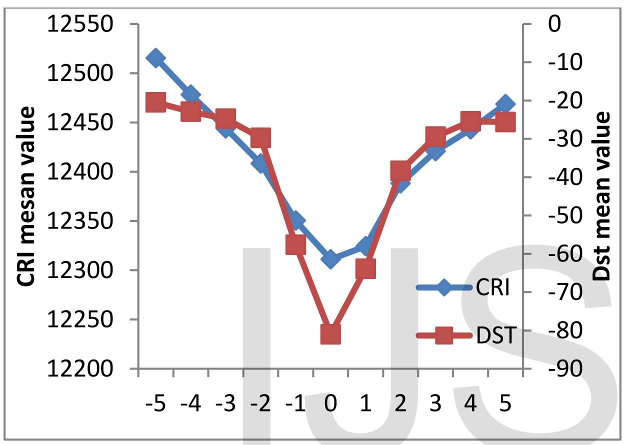

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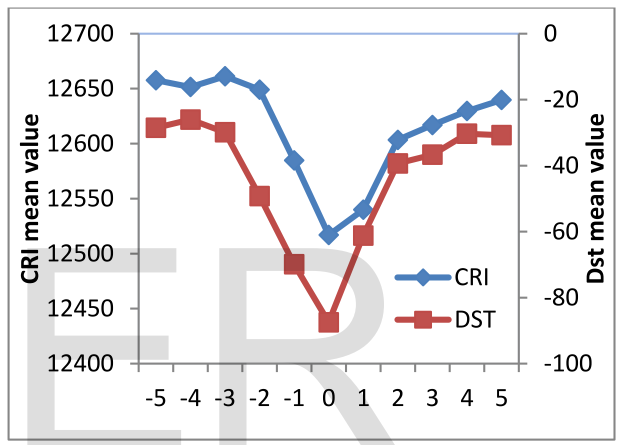

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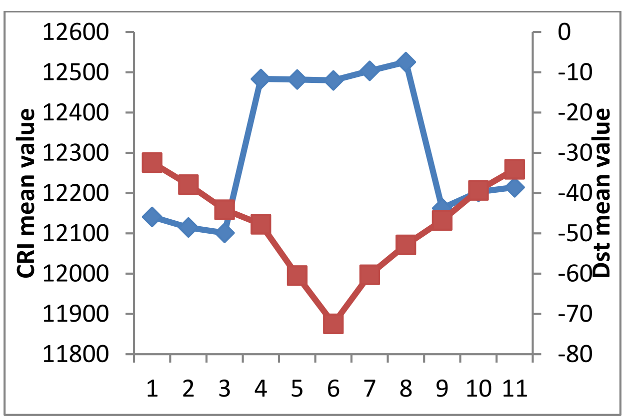

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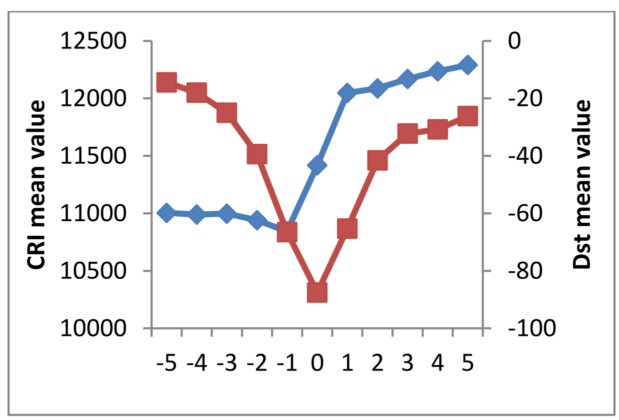

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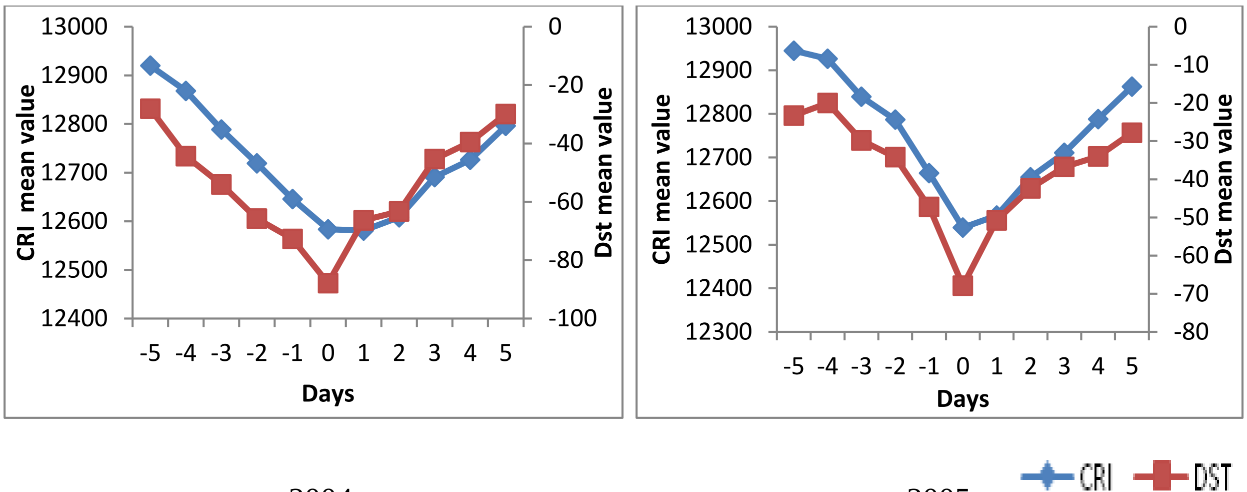
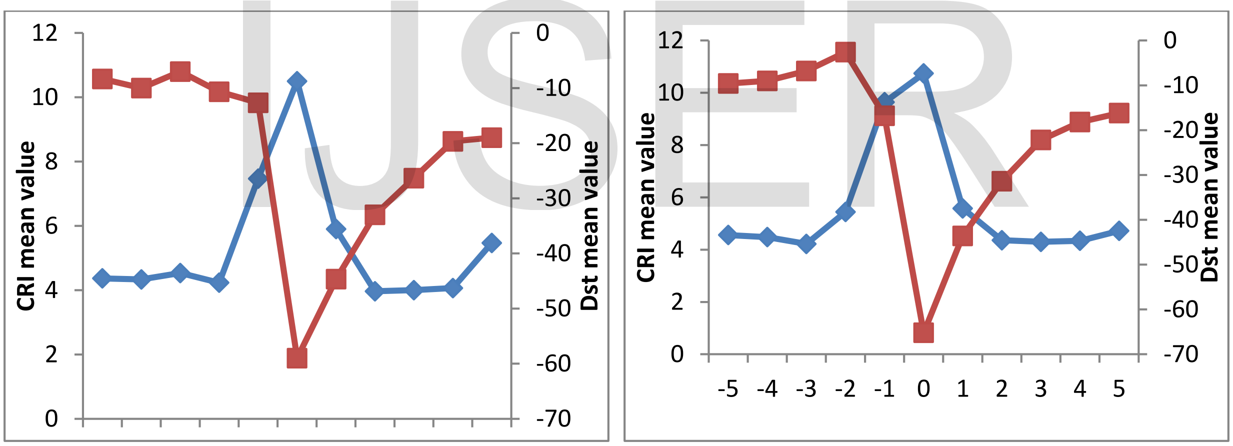


2004 2005

Figure 2 The aftereffect of the Chree examination from −5 to +5 days as for zero-epoch days. The variation of the mean estimation of the Dst and Cosmic-ray intensity is appeared. Zero days compare to the beginning day of event of GSs during1997 – 2006.

Variation of CRI with Dst for SC 24



2010 2011

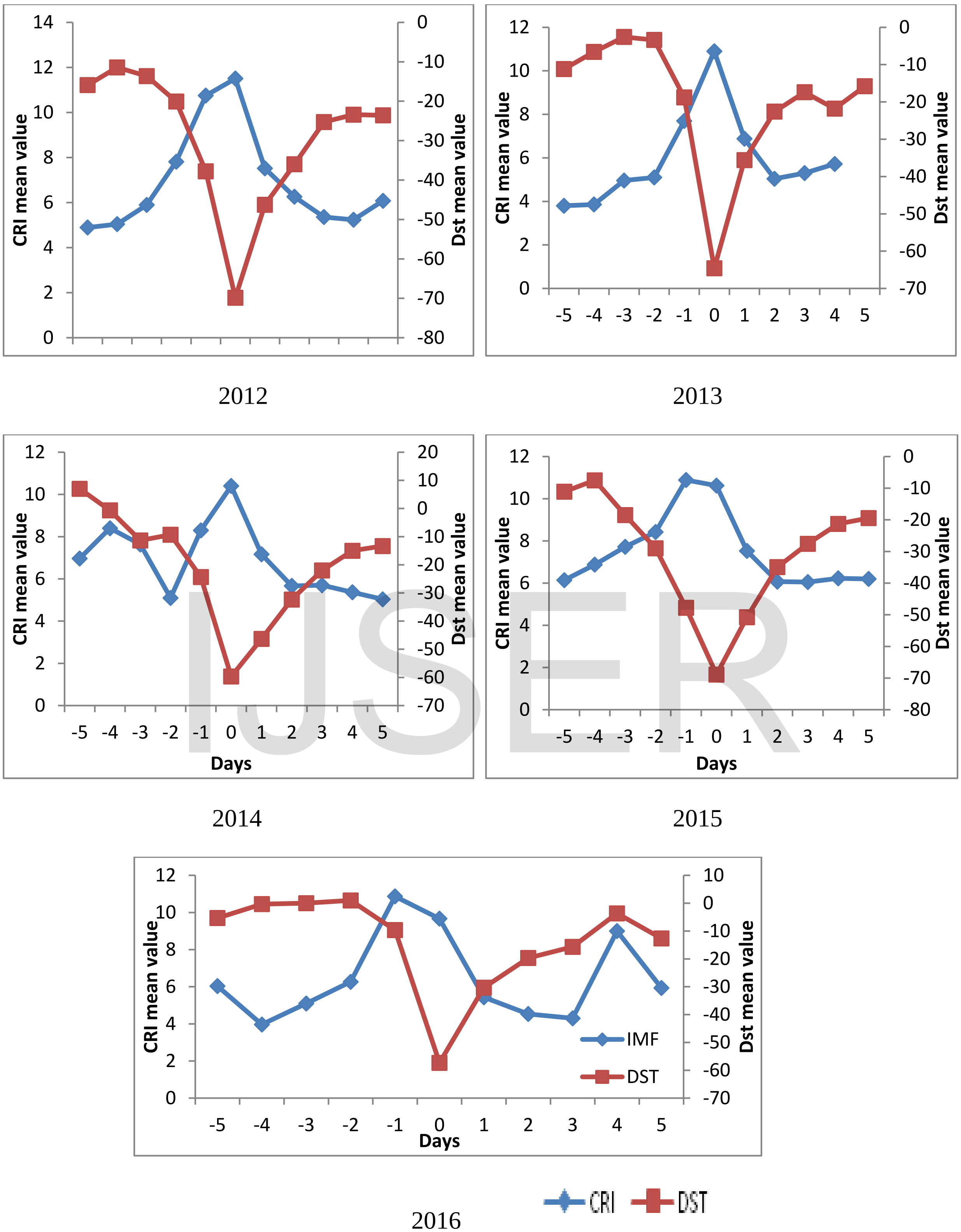


Figure 3 The result of the Chree examination from −5 to +5 days as for zero-epoch days. The variation of the mean estimation of the Dst and Cosmic-ray intensity is appeared. Zero days compare to the beginning day of event of GSs during 2006 – 2016.

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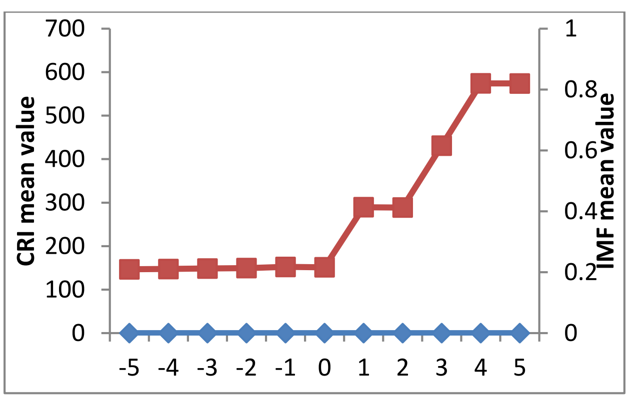
3.2. CRI and IMF

IMF is a part of Sun M.F. that carried into interplanetary space by solar wind. IMF play important role in interact of the solar wind with earth M.F. during solar minima M.F. of the Sun looks like to earth M.F. also IMF modulated geletic cosmic ray intensity in the heliosphere (**Ahowalia H.S**. 2013). The cosmic ray through turbulent sheath region as the CME propagate from Sun to earth was important for the explanation of FDs (Arunbabu et al. 2013).

From the analysis of **Figure 4** SC 22, 23, 24 (1996-2017) we examine the alliance between CRI and IMF and concluded that decrement in CRI takes place with the increment in IMF for ample of years. We also noted that maximum decrease in CRI takes place on same day or after one day of IMF our finding shows good agreement with finding of **Agrawal and Mishara,** 2008, **Kharayt et al**. 2016. The lag is due to the time taken by high energy charged particle to diffuse into the magnetic field via cross-field diffusion. Solar energetic particle ejected in the form of ionized plasma from Sun as the interplanetary M.F. increases these charge particle experience magnetic force (Lorentz force) due to which they deviated from its path so the number of ionized particle reaches toward earth surface decrease which decrease CRI strength. Also the correlation coefficient between CRI and IMF B comes out to be -.53 hence both these parameters are anti-correlated. The outcome is in good favors with the result of **Duggal 1983.**

Variation of CRI with IMF for SC 22



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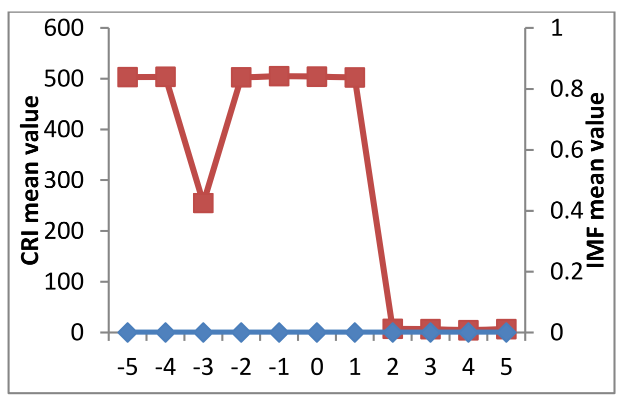

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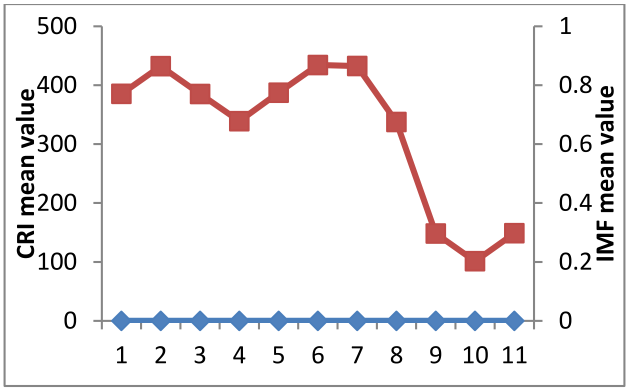

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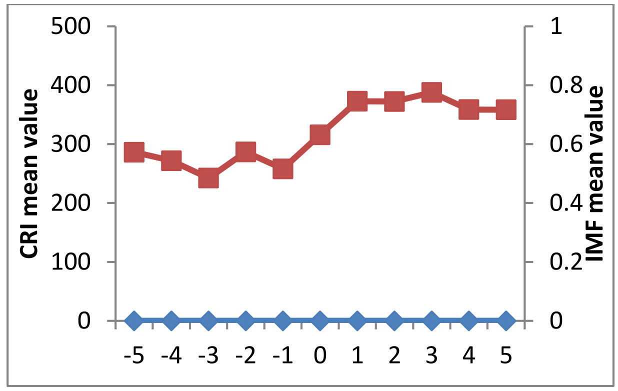

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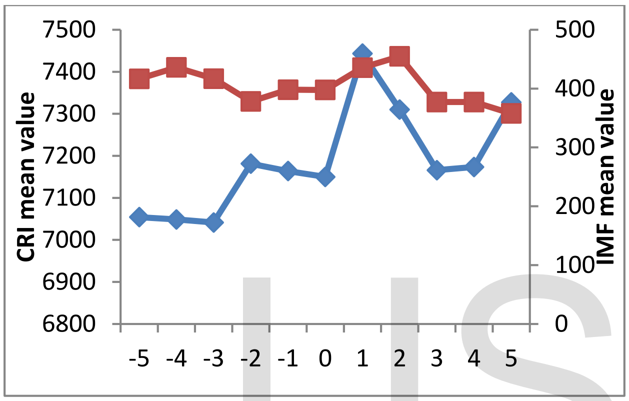

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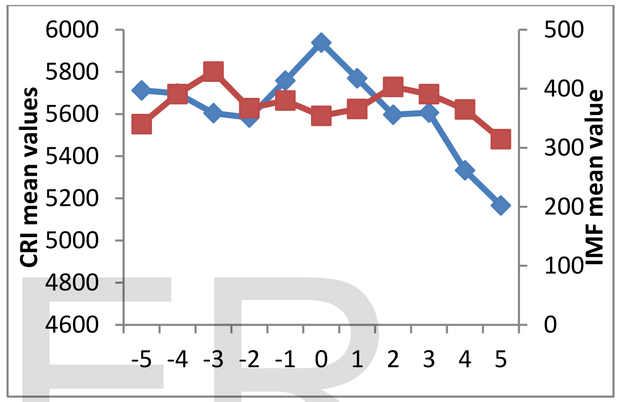

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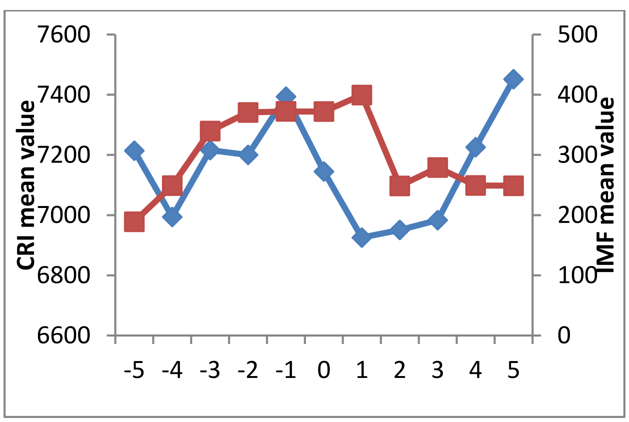

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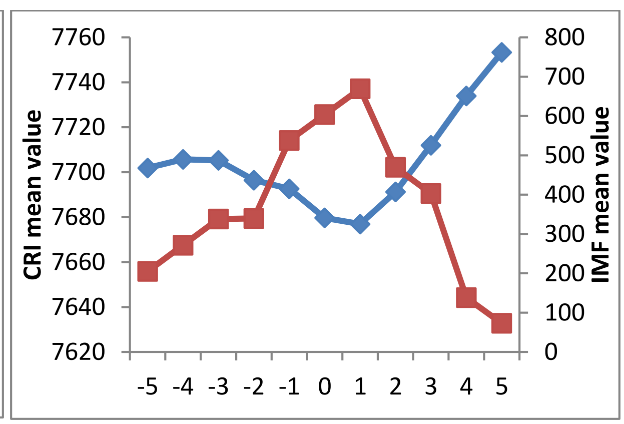

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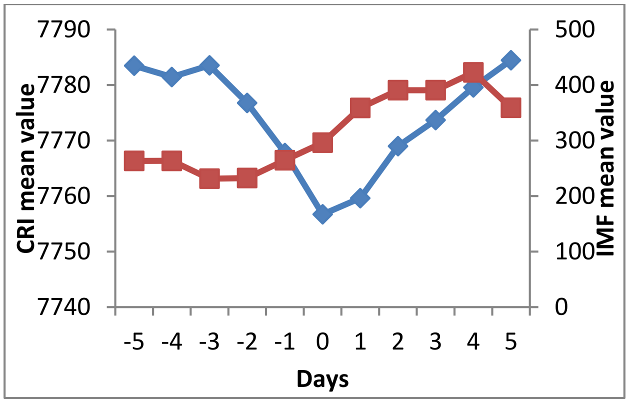

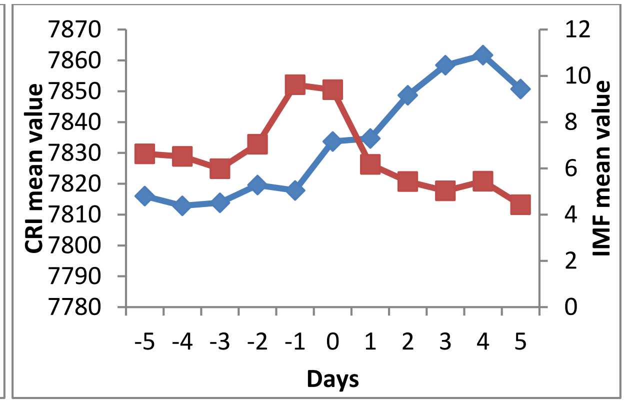

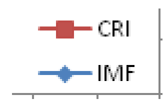

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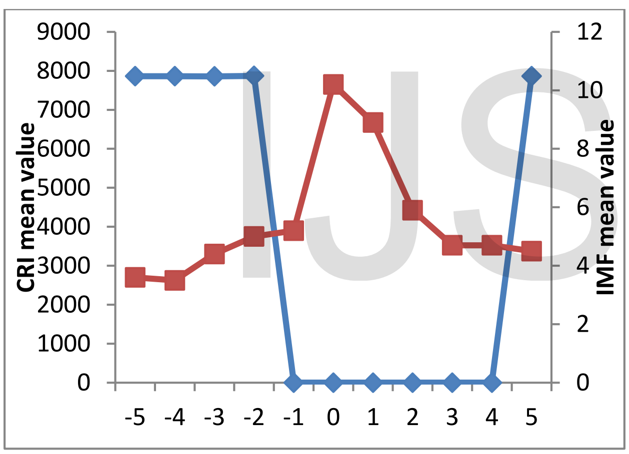
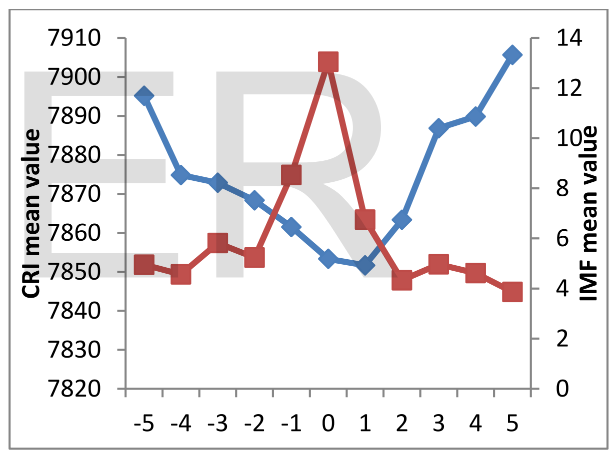
Variation of CRI with IMF for SC 23





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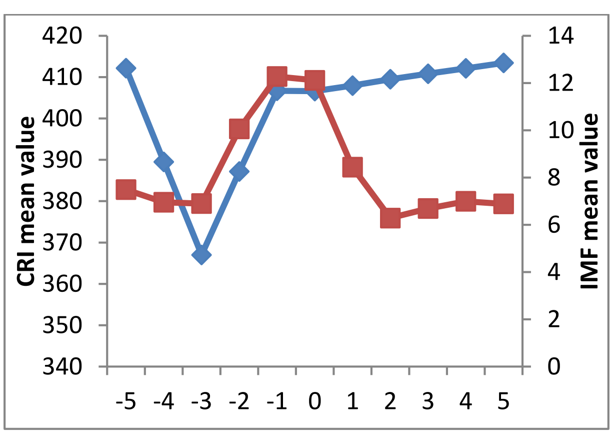

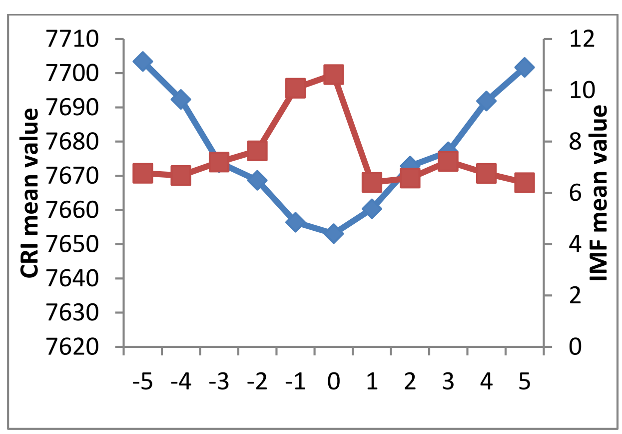

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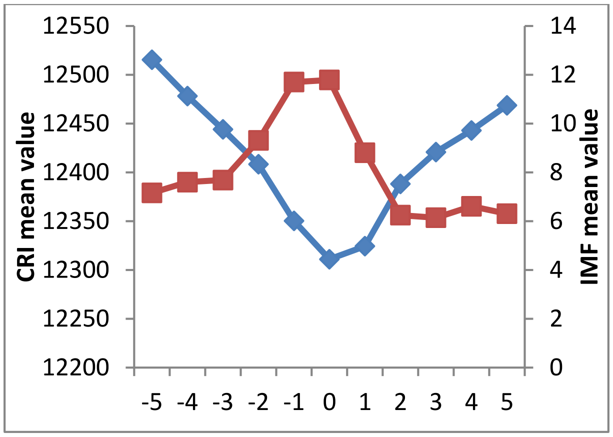

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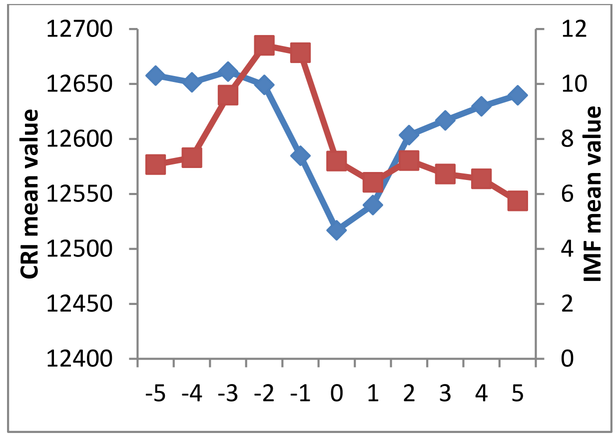

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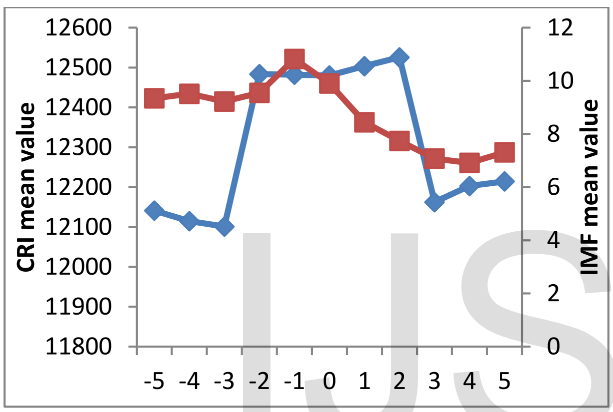

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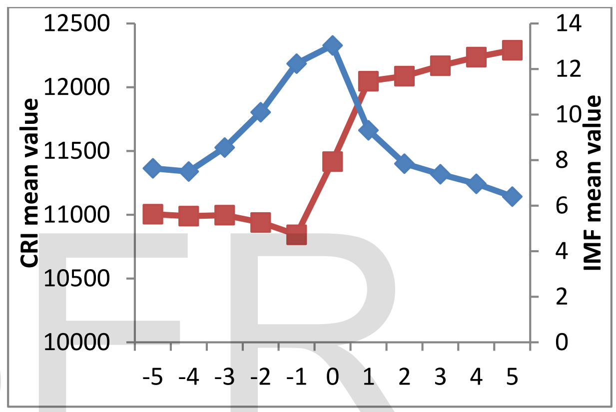

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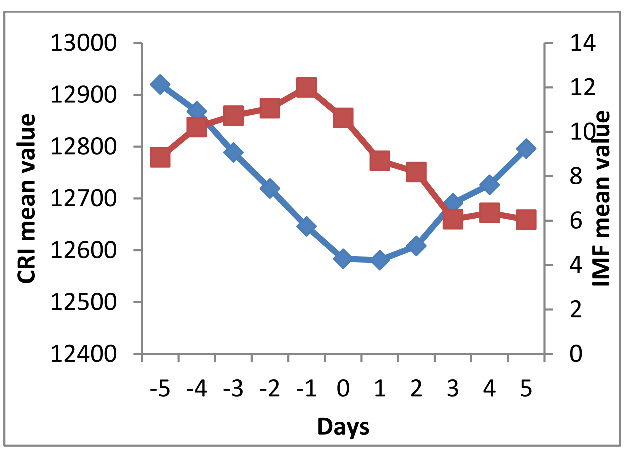

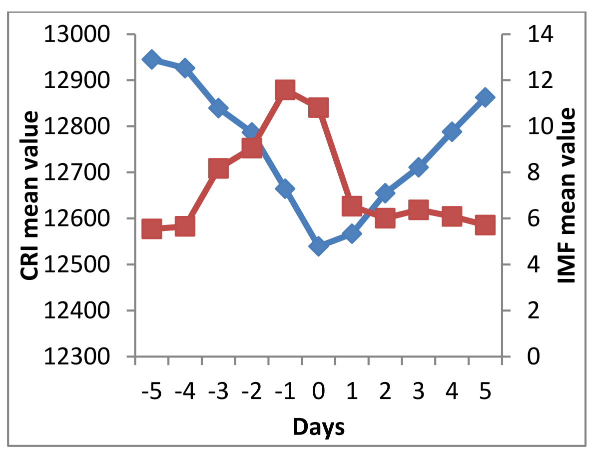

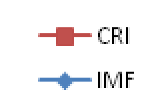

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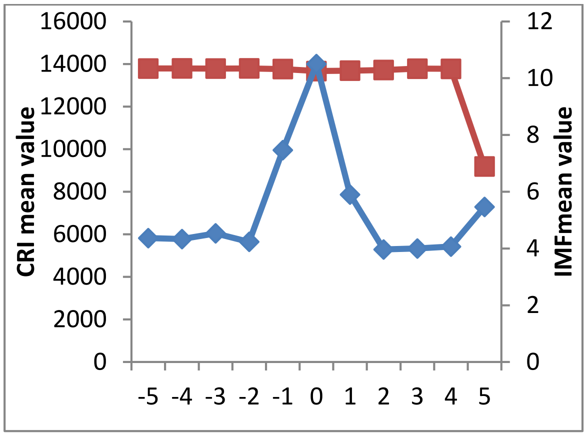
Variation of CRI with IMF for SC 24:



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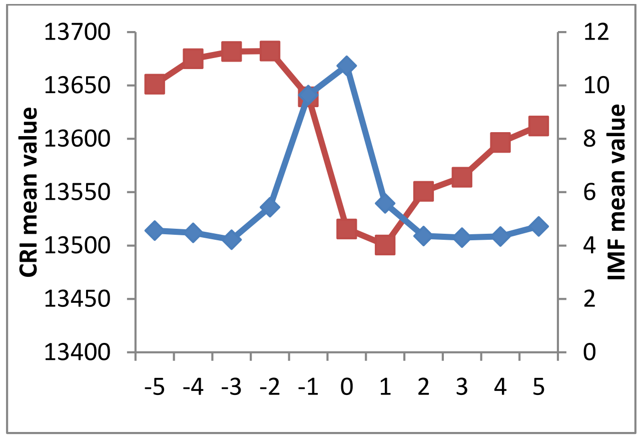

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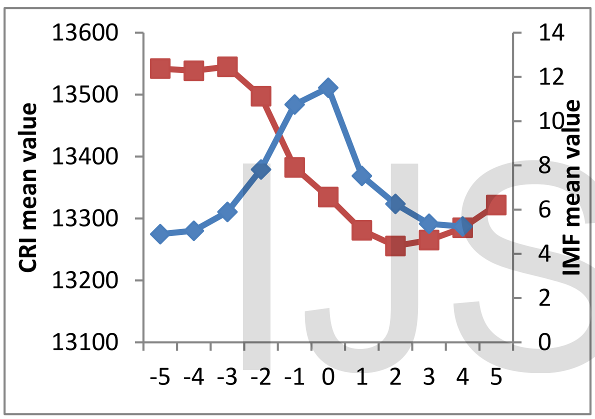

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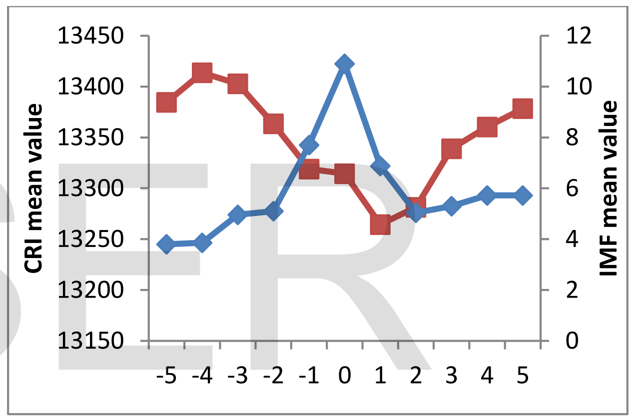

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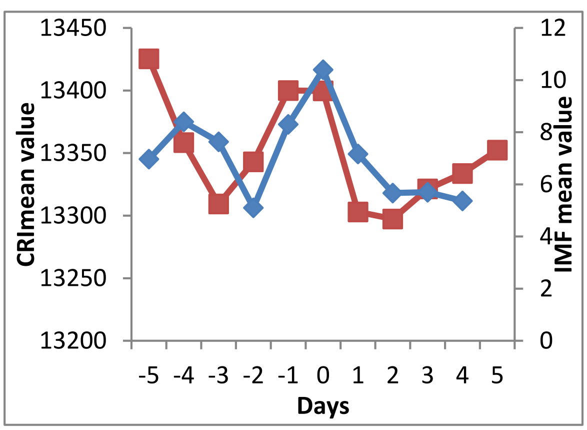

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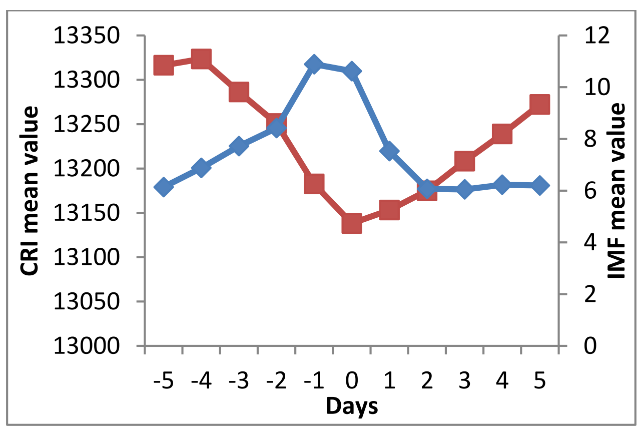

2015

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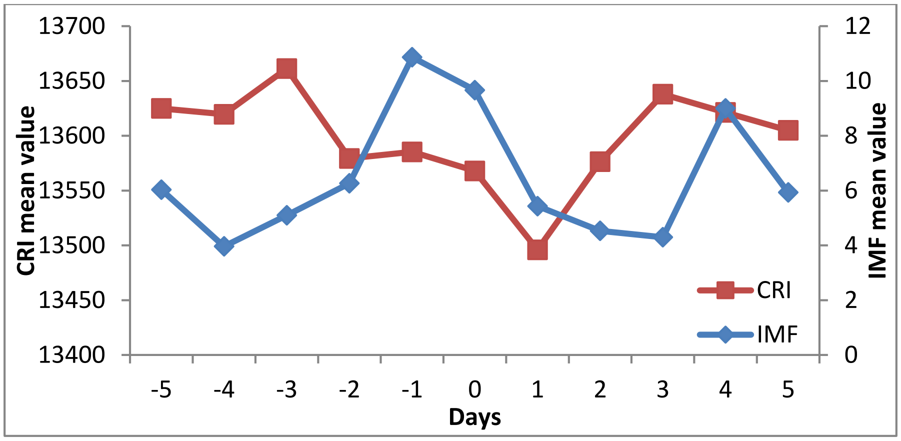
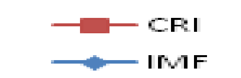




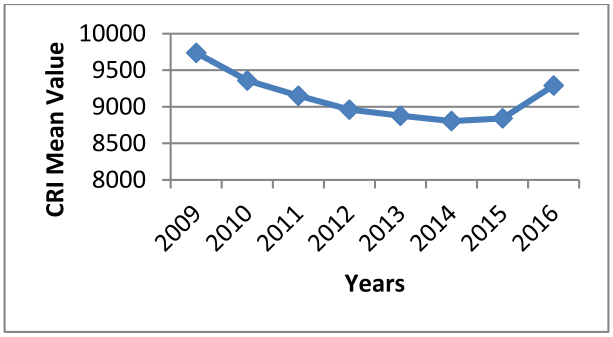
2016

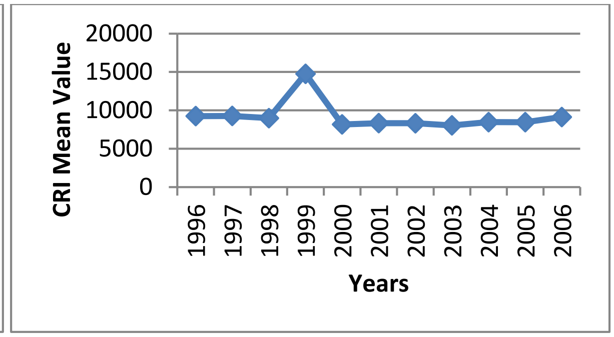
Figure 4 The result of Super posed epoch analysis from -5 to +5 days with respect to zero-epoch day. The discrepancy of mean value of the IMF and CRI is demonstrated. Zero day accord with the trigger day of happening of GS during 1986-2016.

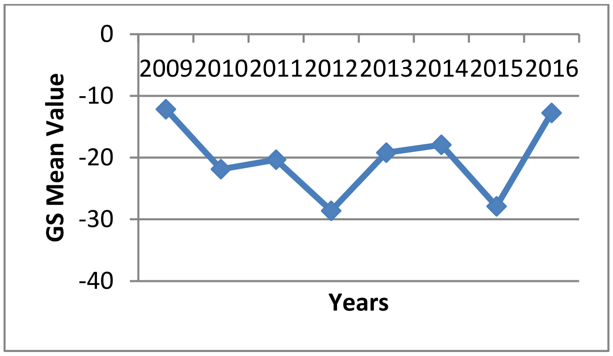
5. Comparison between Solar Cycle 24 and 23

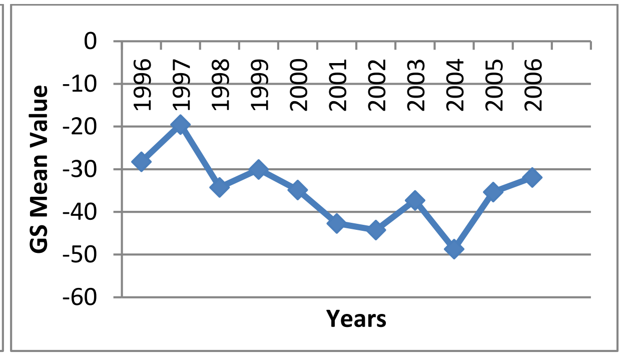
To analyze the variation of CRI, Dst index, IMF for solar Cycle 24 (2008-2016) and 23 (1996-2008), the average value of these parameters are calculated for respective years and so the graph is outlined for solar Cycle 23 and 24. With a comparative study we came to the conclusion that the graph of Dst index, IMF demonstrate a sort of akin fluctuation for the solar Cycle 23 and 24 while an slightly strange behavior has been found in the context of CRI. For solar Cycle 24 the strongest decrement observed in CRI whereas for solar Cycle 23 the rising and ending phase displays relatively an unchanging value and an upswing in CRI takes place in 1999. No GSs occurred in 2007 and 2008 for solar Cycle 23.

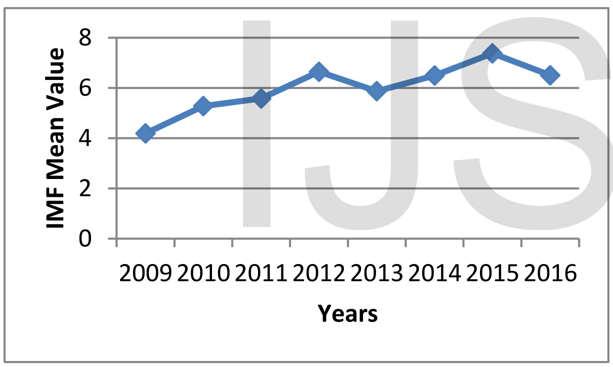
Solar Cycle 24 **Solar Cycle 23**

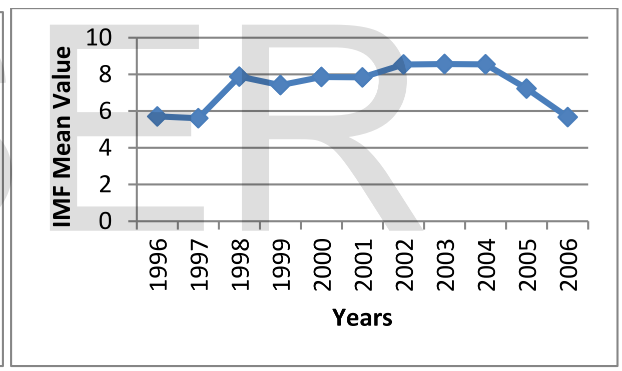












5. Conclusions

On the basis of the investigation done for Solar Cycle 22, 23, 24 we found following results

i) CRI decreases in a similar pattern for most of the year as Dst (−50 nT > minimum of Dst > −100 nT) but peak depression for both CRI and Dst does not coincide.

ii) There shows an anticorrelation between CRI and total IMF B CRI decreases with increase in the Interplanetary Magnetic Field.

iii) CRI and Dst are highly correlated with each other which shows that CME is most effective parameter cause FDs and GSs.

iv) For SC 22 and 24, the variation between all these parameters shows similarity and the geomagnetic activities comparatively less than SC 23.

v) The FDs typically lag the IMF B by a few hours.

Vi) Reason for less geomagnetic activity in cycle 24 is mainly due to an anomalous expansion of CME and less magnetosphere energy transfer.

vii) Heart rate changes can strongly react to cosmic ray intensity and this relation becomes more relevant during strong cosmic ray events. Also during high geomagnetic activity the number of traffic accidents increases.

6. Importance

From the investigation of variation of CRI with GSs for the SC 22, 23, 24 we watched it differs in a comparative way to that of Dst consequently FDs is unequivocally connected with GSs. Since they convey data on the structure of Astrophysical sources in our neighborhood and in addition our universe, CRI additionally a decent instrument to predict Space climate. In my opinion, it's necessary to investigations the association between CR intensity and climate changes like (cloudiness, raining, and surface temperature) not only through statistical analysis but additionally by the Space-based observatory and association between high local intensity regions in word local atmosphere.

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