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Variation of Solar Activity Parameters with Cosmic Ray intensity and Comparison of Solar Cycle 23-24

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ABSTRACT

In this paper we have studied a significant relation between Cosmic Ray Intensity (CRI) and Solar activity parameter. The study is extended to solar cycle 23-24. In the present work, yearly average of Sunspot number (SSN), Total solar irradiance (TSI) and magnetic field (B) have been used to correlate with yearly average cosmic ray intensity. Comparison has been drawn between the successive solar cycles and it has been noticed that for two solar cycles the cosmic ray intensity is anti correlated with sunspot number, Total solar irradiance and magnetic field. We find the correlation coefficient of cosmic ray intensity with sunspot number as well as Total solar irradiance which are relatively large and anti correlated during solar cycle 23-24. However the magnetic field shows a positive correlation with Total solar irradiance and sunspot number and correlation coefficient for sunspot number and Total solar irradiance is R= 0.80 for solar cycle 23-24. While as interplanetary magnetic field is significantly correlated with sunspot number and value of correlation coefficient is 0.61.

Keywords : Cosmic Rays, Sunspot Number, Total Solar Irradiance, Interplanetary Magnetic Field

I. INTRODUCTION

Cosmic rays are atoms, subatomic particles, neutrons, and electrons, which have much higher energy than the background fluid, the solar wind, inside the heliosphere. Depending on their origin, cosmic rays can be divided into three categories, galactic cosmic rays (GCRs), anomalous cosmic rays (ACRs), and solar energetic particles. GCRs come from outside of the heliosphere, are trapped by galactic magnetic field, and are possibly accelerated by supernova shocks. GCRs travel at close to the speed of light. ACRs originally come from the neutral interstellar wind and are accelerated by the termination shock. The neutral interstellar wind flows through the heliosphere with an average speed at tens of kilometers per second and encounters almost no resistance because it is neutral. When these neutral atoms get close to the Sun, some of them become charged due to photo-ionization or charge exchange. These new-born ions (called "pick-up" ions in the literature) are then carried out to the termination shock by the solar wind and are accelerated there. Because of the diffusion process, these particles can be observed at 1 AU. Compared to GCRs, ACRs are low-energy and low speed particles. The SEPs are particles injected to space by solar flares or associated with coronal mass ejections (CMEs) and accelerated close to the solar surface or accelerated well away from the Sun. These SEPs can be accelerated directly by the electric field through magnetic reconnection or by shocks through diffusive shock acceleration. These processes transform electromagnetic energy into kinetic energy.

The source of solar activity is the variation of the solar magnetic field, which is usually manifested by sunspots on the solar surface. The number of sunspots visible on the sun is not constant, but varies over an 11-years known as the solar cycle. The 11-years is not constant, but varies between about 9.5 to 12.5 years as discussed by Mursula and Ulich. At a typical solar minimum, few sunspots are visible, and occasionally none at all can seen.Those that do appear are at higher latitudes. As the sunspot cycle progresses, the number of sunspots increase and they move closer to the equator of the sun, a phenomenon described by Sporer's law. Sunspots usually exist as pairs with opposite magnetic polarity. The magnetic polarity of the leading sunspot alternates every solar cycle, so that it will be a north magnetic pole in one solar cycle and a south magnetic pole in the next.

The solar wind is quasi-neutral, fully ionized plasma which is ejected from the solar corona into the interplanetary space [6, 7]. The solar wind results from the huge pressure difference between the hot plasma at the base of the corona and the interstellar medium. The existence of continuous solar wind streams was first suggested by Ludwig Biermann [11] based on his studies of the acceleration of plasma structures in comet tails, and the detailed mathematical theory of solar wind was put forward by Eugene Parker [8, 9]. The solar wind starting subsonically at the base of the corona accelerates to supersonic speeds. At 1 Astronomical Unit (AU,the mean distance between the Sun and the Earth), the solar wind has an average density of~$5cm^{-3}$ and an average flow speed of 450 km/s. The mean travel time of solar wind from the Sun to the Earth is 3.5×10^5 seconds (4 days). The solar magnetic fields frozen into the solar wind are transported into space with the solar wind and are known as the interplanetary magnetic field (IMF). The IMF at 1 AUhas an average magnetic field of 7.0 nT [10].

The term 'solar constant' is used to describe the amount of solar energy (W/m^2) of all wavelengths received by a flat surface, at top of the earth's atmosphere, perpendicular to the solar beam at the mean distance of the earth from the Sun. For a long time, people believed that the sun was a constant star. However, astronomical observation revealed that the sun's radiation is not constant (Hickey et al.1981). As the sun's radiation is now known to vary slightly, the term 'solar constant' is not appropriate, and instead should be referred to as 'total solar irradiance'. The total solar irradiance changes from day by day, year to year and century to century.

II. METHODS OF ANALYSIS

In this correlation analysis we have taken data of sunspot number, total solar irradiance , interplanetary magnetic field and cosmic ray intensity for the solar cycle 23 and 24. We have taken the data of Oulu (0.81 GV), Kiel (2.29 GV) and Beijing (9.56 GV) neutron monitors for the analysis. In this study we have selected the monthly mean data and yearly mean data of above cited parameters. Most of the data of solar activity parameters have been taken from the website of Omni Web and Solar Geophysical data books (monthly publication of NOAA). The pressure corrected cosmic ray data of Oulu, Kiel and Beijing have been used.

III. Results and Discussion

In the present paper we have done a detailed correlative analysis between solar activity parameters and cosmic ray intensity. The correlation coefficients have been derived for the period of 1996 to 2016,which covers the solar cycle 23 and 24. Coefficient of correlation is found to be negative and high for the most of period. However, it changes positive to negative and negative to positive quite frequently. Fig. 1 shows that TSI variations are positive variation with sun spot number (SSN) i.e. both have minimum value in 1996 and 2008 and both have maximum value in 2002 and 2016. They are positively correlated (R=0.80) TSI value variations is about 1361± 0.790 in our study period 1996 to 2016. Fig 2 shows correlation curve for the year value of sunspot number and cosmic ray intensity (Moscow) for the period 1996 to 2016 and correlation between CRI with SSN is negative. Fig 3 shows correlation curve for the year value of TSI and CRI(Kiel) for the period 1996 to 2016 and correlation between CRI and TSI is negative (-0.681).Fig 4 shows that IMF variations are positive variation with SSN for the period 1996 to 2016. Fig 5 shows cross plot between TSI and CRI of Kiel for the period 1996 to 2016. For solar cycle 23, the TSI shows increasing phase from 1996 to 2000 and then decreasing phase from 2001 to 2008. At the same time CRI decreases for the period 1996 to 2000 and then shows increasing phase from 2001 to 2008. Thus it is clear that for solar cycle 23 TSI and CRI are anti-correlated.

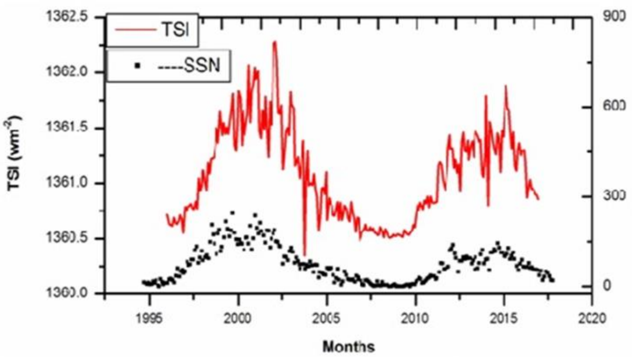


Fig 1.shows the yearly variation of SSN and TSI for solar cycle 23 and 24.

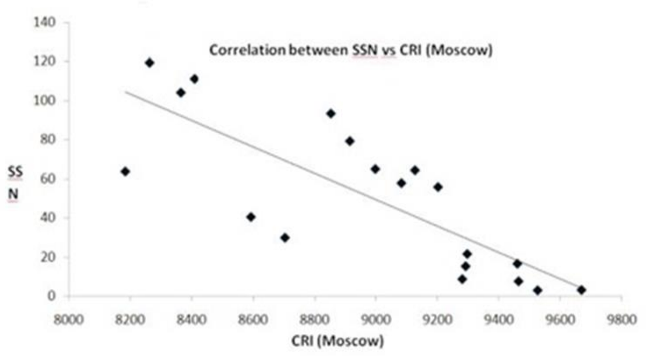


Fig.2 Correlation between yearly value of sunspot number and cosmic ray intensity (Moscow) for the period 1996 to 2016.

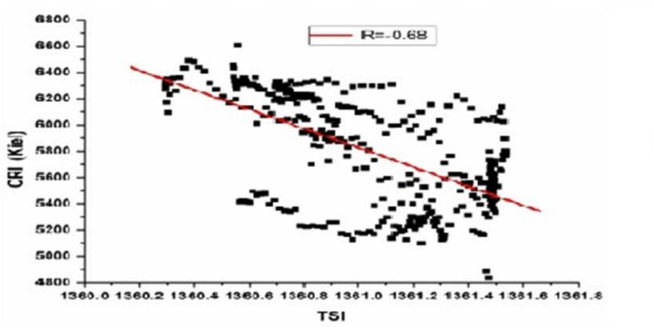


Fig 3 shows cross correlation curve for the year value of TSI and CRI(Kiel) for the period 1996 to 2016 and correlation between CRI and TSI is negative (-0.681)

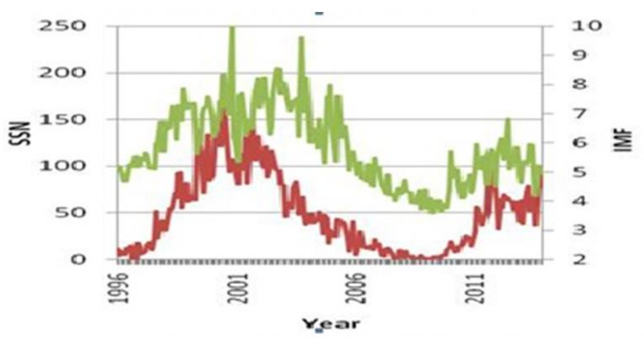
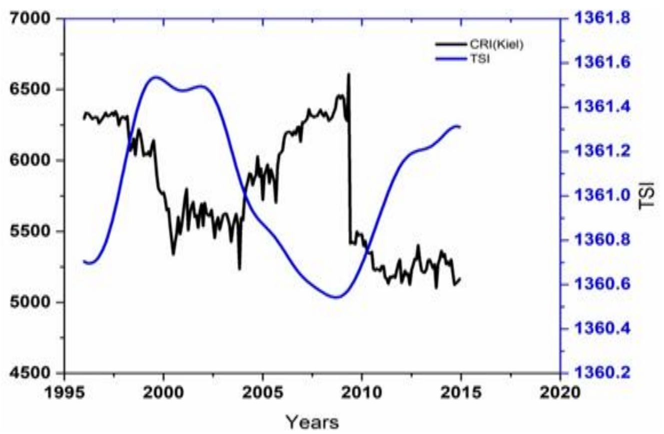


Fig 4 shows monthly variation of Sunspot Number with IMF for Solar Cycle 23 and 24



IV. Conclusions

The most probable value of total solar irradiance representative of solar minimum is 1361.152 ± 0.638 Wm−2. TSI and SSN have a positive variation and according to solar cycle variation TSI vitiates about 1.276 Wm-2 . The correlation coefficient between cosmic ray intensity and sunspot number is negative. The negative correlation with correlation coefficient (R= -0.68)has been found between yearly mean of the total solar irradiance and cosmic ray intensity at Kiel and it was found that CRI and TSI was in anti-phas e for the period 1996 to 2016. Note that TSI variations are similar in both solar cycle 23 and 24 but the peak annual mean sunspot numbers are lower during Cycle 24 than cycle 23. The total solar irradiance variations may have impact on the solar – terrestrial relations. Therefore the phases of the total solar irradiance can have some significance on the terrestrial climate variation.

V. Acknowledgement

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VI. REFERENCES

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