Journal of Advances in Science and Technology
Vol. 21, Issue No. 1, March-2024, ISSN 2230-9659

DOI: https://doi.org/10.29070/0pg0wv28

Solar Activities and Heliospheric Variations in Cosmic Rays Intensity in Solar Cycle 24

Mansu Masram [1] *

1. Assistant Professor, Department of Physics, Govt.P.G. College Multai, Betul (M.P.), India
m.b.masram@gmail.com

Abstract: Modulations and short-term periodicities in solar activity were analyzed using various proxies, including the solar flare index (FI), cosmic ray intensity (CRI), sunspot area (SSA), sunspot number (SSN), and solar radio flux (F10.7). In Solar Cycle 24, both the maximum phase and the peak activity phase are components of the solar rotational period, representing a non-Rieger-type short-term periodicity. The periodogram and wavelet power spectra of SSN, SSA, F10.7, MCI, FI, and CRI revealed distinct short-term variations. During periods of maximum solar activity, the heliosphere can be affected for up to 27 days. At the peak of Solar Cycle 24, cross-correlation coefficients and temporal delays between CRI and solar activity parameters were computed, with estimated delays of approximately 200 days for SSN, 46 days for SSA, 281 days for MCI, 39 days for FI, and 47 days for F10.7.

Keywords: solar activity, flares, sunspots

---------------------------x---------------------------

INTRODUCTION

Cosmic rays, which are very energetic particles that come from distant stars are everywhere in the cosmos. Our solar system is one of several planetary systems that these cosmic rays' impact. But their space journey isn't an easy one. Solar and heliospheric features become more significant as they approach the heliosphere via the interstellar medium. Science has focused heavily on solar and heliosphere modulation using cosmic-rays c forces alter the power and Galaxy of cosmic ray energy levels. A grasp of this modulation is necessary for a comprehensive comprehension of cosmic-ray propagation, which includes its impacts on space missions, space weather, and potential consequences for the ecosystems of Earth and other planets. The interaction between cosmic-ray modulation and solar and heliosphere variables has been the subject of extensive study by astronomers and satellites for a considerable amount of time (Potgieter 2013). The acceleration and deceleration of the solar wind, changes to the solar magnetic field and intense particle explosions events on the sun are all examples of solar activity. It has a significant impact on the heliospheric environment and, therefore, the propagation of cosmic rays.

Prior research has examined the impact of solar variability on geomagnetism and cosmic rays by combining data from ground-based detectors, most notably the worldwide network of ultra neutron monitors, with information about other solar geophysical parameters. The Sun-Earth relationship describes the connection between these two celestial bodies. An unsolved mystery in cosmic ray studies is the nature of both the short-term fluctuations in cosmic ray intensity (CRI) and the long-term shifts in galactic cosmic rays. Numerous studies have demonstrated that cosmic ray flux is influenced by the 11-year solar cycle of sunspot activity. It reaches its lowest point at the solar cycle's peak and its highest during the stationary phase. Variations in cosmic ray intensity exhibit a one- to two-year lag relative to the solar cycle. In 1971, Lockwood identified an intrinsic relationship between the neutron monitor's count rate and the neutron current plate's lean angle at the onset of the modulation cycle. In 1991, Kota and Jokipii utilized a combined drift-diffusion model to examine the effects of cosmic rays on co-rotating interaction zones.

A wide variety of cosmic events, including as supernova explosions and active galactic nuclei, release these very energetic particles, most of which are protons and atomic nuclei. When these particles reach Earth's atmosphere, they ionize the air molecules and produce secondary particles like muons and electrons. Possible atmospheric effects of this ionization include changes to aerosol and cloud condensation nuclei (CCN) generation. Our planet's temperature, cloud structure and development, and radiation budget are all potentially affected by this process. Cosmic rays from the sun and the galaxy are the two main origins of these rays. Changes in solar activity are tightly correlated with changes in cosmic ray intensity and atmospheric temperature, which both show swings over distinct timescales.

LITERATURE REVIEW

Singh et.al (2018) At the Moscow Super Neutron Monitoring Station, we analyzed the correlation between several variables, including sunspot number (SSN), monthly fluctuations in average cosmic ray intensity (CRI) counting rates, mid cut-off rigidities (~2.42 GV), and solar radio flux at 10.7 cm (F10.7) across Solar Cycles 22–24. Measurements of F10.7 cm (2800 MHz) and SSN during the study period provided clear indicators of solar activity. The Fast Fourier Transform (FFT) approach was employed to examine the long- and medium-term periodicities of SSN and F10.7. Our findings revealed that during Solar Cycles 22–24, the increasing phase of CRI with F10.7 cm lagged behind SSN.

Singh, et al.(2023) Through the years 2009–2019, this work has examined the correlation between solar activity metrics such the interplanetary magnetic field (IMF), sunspot numbers (SSN), and solar flare index (SFI) and fluctuations in cosmic ray intensity (CRI). Our empirical evidence suggests a negative correlation between the following variables: solar flare index (SFI), sunspot number (SSN), subject to the following: the cosmic ray intensity (CRI), the interplanetary magnetic field (IMF), and (i) The correlation between the two variables is 0.84, with the CRI being related to the annual average values of the Interplanetary Magnetic Field (IMF). (iii) There is a -0.94 correlation between the CRI and the annual average values of SSN, and a -0.95 correlation between the CRI and the annual average values of SFI.

Ross, et al.(2019) When comparing cycles with even and odd numbers, is clearly seen in the plots of SSN vs GCR. In accordance with earlier research, the data was fitted to both linear and elliptical models, with the former showing that it was the better match for solar-activity cycles with even numbers and the latter showing that it was the better fit for cycles with odd numbers. Applying these methodologies to Solar Cycle 24, we find that the GCR intensity and SSN were two to four months apart in Cycle 24, which is in line with the pattern of past activity cycles, but somewhat longer than in even-numbered cycles. The hysteresis study confirmed that the linear fit is a more accurate representation of Cycle 24 than the elliptical model, which is consistent with past even-numbered cycles and does not demonstrate a substantial improvement.

Mishra, et al.(2016) Cosmological ray intensity (CRI), sunspot area of whole disc (SSA), and sunspot number (SSN) were measured monthly at Oulu and Moscow during cycles 23 and 24 NMs. To gain a deeper understanding of cosmic ray modulation patterns and variations in solar activity, scientists analyzed this data. Between July 2008 and August 2009, SSN remained exceptionally low for an extended period. During this phase of the solar cycle, the time lag was observed to be four months at one site and ten months at another, based on the maximum correlation coefficient. The duration of Solar Cycle 23 was estimated to be between thirteen and fourteen months. In addition, scientists studying this solar cycle have found that the running cross correlation function, in contrast to previous cycles, maintains a relatively long period at its highest value of about -0.8 to -0.9. Furthermore, the variation in SSN and SSA is strongly correlated for both cycles (r >.92). The peculiar character of solar cycle 24 prompted a comparison with earlier cycles' tracks of cosmic ray alteration.

METHODOLOGY

Our research is based on a four-year data collection covering the solar maximum of Solar Cycle 24, incorporating daily observations of SSN, SSA, solar radio flux (F10.7), the modified coronal index (MCI), solar FI, and CRI, along with other solar activity indicators. The SSN data is sourced daily from the World Data Centre under the SILSO project.

ANALYSIS METHODS

We calculated the maximum durations of the short-term features and CRI of solar cycle 24 using three different methods. The FFT, the R Rob Per, and the Morlet wavelet power spectra techniques. To further estimate periodicity, the R program RobPer analysis was used, which makes use of the L2 model, a least squares regression approach.

Cross–Correlation Analysis

One popular way to find the phase connection between various solar activities is to use cross-correlation analysis (CCA). In order to determine we used this approach to determine the magnitude of the solar activity-CRI cross-correlation as assessed by SSN, SSA, F10.7, MCI, and FI.

$$CC(C/S) = \frac{\sum_{i=1}^{n}[C(i) - \bar{C}][S(i + \triangle) - \bar{S}]}{(n-1)\sigma_C \sigma_S},$$

S¯ stands for in this context, solar activity (SSN, MCI, and FI) and C¯ for average CRI values. The variables σC and σS stand for the standard deviations of these two variables., while the symbol! indicates the time that has passed since the delay.

RESULT

In 2012–2013, from 2013 to 2015, this research used a mixed-phase polarity field with an A value greater than zero, and a value less than zero. In order to represent the polarity or direction of a field, one uses positive fields, represented by A > 0, and negative fields, A 0, to do the same. Solar cycle 24's decreased activity is what sets it apart from its predecessor, which may have produced massive FDs, as fewer solar events were associated with it. A statistical link between SSN and SSA was observed by Li et al. (2016) for the period range of 1874 May to 2015 April. In contrast to SSA distributions, which tend to decline monotonically, SSN distributions tend to grow at the outset before declining generally, their research shows. Beyond that, they have shown a proportional relationship between the statistically significant fit SSN and SSA quadratically and linearly.

The R Rob Per periodogram analysis of SSN, SSA, F10.7, MCI, FI, and CRI data over a range of 10–600 days reveals a solar rotational period of approximately 26 days. This method identifies a brief interval during which these parameters exhibit periodic variations.

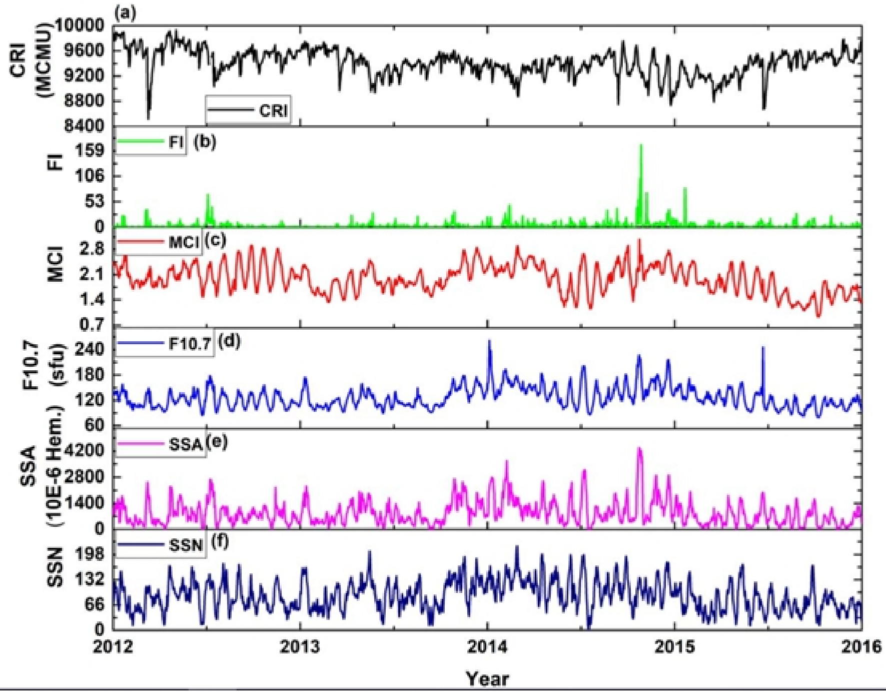

Figure 1: Illustrates the time profiles of daily data variations for multiple variables over the period from 2012 to 2016.

It takes about 124 days, 139 days, and 179 days for SSN, about 148 days, and about 183 days for SSA, about 179 days for F10.7, about 137 days, and about 183 days for MCI, about 143 days, and about 172 days for FI, and about 120 days, 141 days, and about 162 days for CRI. Among the prominent short-term durations, we found were 274, 277, 266, 247, 283, and 316 individual days for SSN, SSA, F10.7, MCI, and CRI, in that order. Notable but relatively brief time spans are also included in Table 1. According to Table 1, the SSN and MCI periods were quite similar, lasting around 135 days. This is likely the fifth harmonic, with CRI being the sixth harmonic, based on a 27-day timeframe. A considerable period of around 53 days, which corresponds to the second harmonic, is shared by the three variables SSN, SSA, and FI of approximately 27 days. Notable lengths of around 183 days were seen in the SSA and MCI, which is roughly 27 days shorter than the 7th harmonic. It is also called the Rieger-type phase when solar cycle 24 is at its strongest, which is from 2012 to 2015.

According to the R Rob Per periodogram, data from SSN, SSA, F10.7, MCI, FI, and CRI consistently indicate a solar rotational period of approximately 26 days when analyzed over a time range of 10–600 days. The R Rob Per method identifies a brief interval during which these parameters exhibit periodic variations. The wavelet spectra show significant red noise errors, as indicated by the thin dashed line. Additionally, the Fourier spectra not only highlight this two-millennium peak but also reveal smaller peaks, which may provide insights into the grand solar cycles discussed in Section 3, occurring at intervals of 216, 363, and 471 years.

Figure 4 shows the results of the wavelet and Fourier spectra, which were applied to the solar irradiance data made by Vieira and others in 2011, which cover the period from 9000 BC to 2000 AD. The wavelet transform clearly shows a broad peak between 2100 and 2400 years ago, whereas

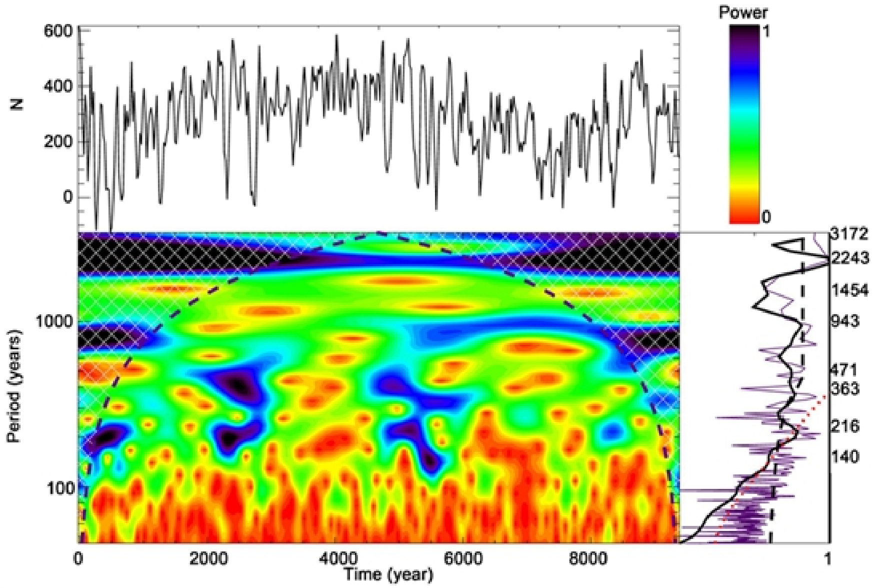

Figure 2: On the left side of the graph, we can see the wavelet spectrum, which is obtained during the Holocene period from the total solar irradiance, N, as represented by the colour bar in the top plot.

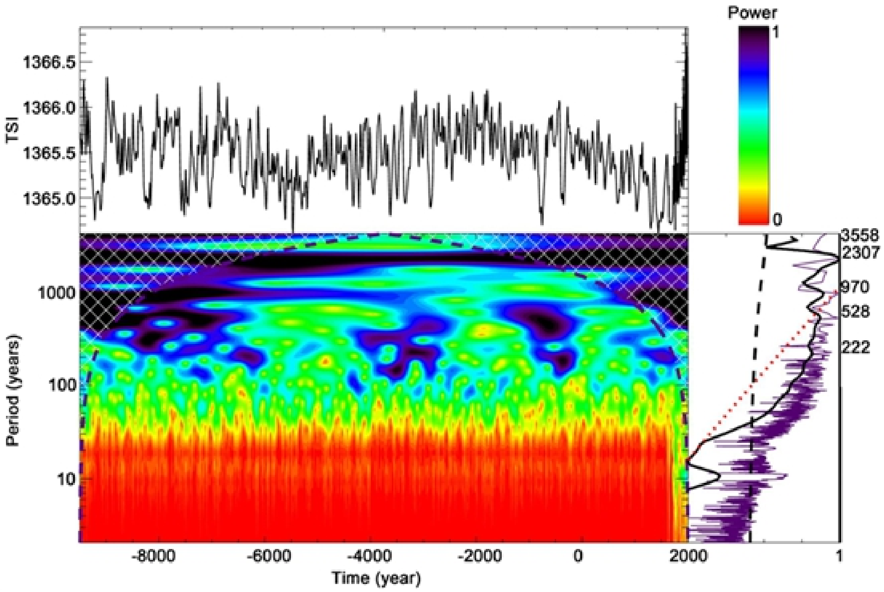

Figure 3: Using In the top plot, we can see the total solar irradiance, N, computed for the Holocene, and in the bottom left-hand image, we can see the wavelet spectrum.

At 2307 years, a prominent peak is seen by the Fourier and global wavelet spectra. The red noise in this dataset has been significantly decreased, and the confidence level is lower than 95%. In addition to the classical Eleven-year cycle zenith at 10.7 years, the Fourier spectrum revealed great solar cycle maxima at222,374, and 528 years. According to additional solar and planetary studies, the Hall statt cycle occurs every 2200–2400 years, which is very near to the 2100–2200-year baseline oscillation period.

CONCLUSION

Under these conditions, the CRI shows a very strong association when coupled matching solar activity metrics that display distinct degrees of latency. Data on power spectra taken during a 27-day window shows that CRI is helispherical and that there is a phase relationship between it and SSN, MCI, FI, SSA, and F10.7. The heliosphere effect's behavior on Earth is controlled by solar magnetic activity, which is a mixed process. The heliosphere nature and periodic short-term change, this research provides more insightful knowledge of the physical characteristics of the sun. At its height in solar cycle 24, magnetic flux would periodically erupt from the sun interior into the solar active area.

References

1. Mishra, V. & Mishra, A. (2016). Study of solar activity and cosmic ray modulation during solar cycle 24 in comparison to previous solar cycle. Indian Journal of Physics. 90. 10.1007/s12648-016-0895-9.
2. Ross, Eddie & Chaplin, William. (2019). The Behaviour of Galactic Cosmic-Ray Intensity During Solar Activity Cycle 24. Solar Physics. 294. 10.1007/s11207-019-1397-7.
3. Singh, Puspraj & Patel, Nand & Singh, Shivgopal & Soni, Shiva. (2023). Study of cosmic ray intensity with solar activity parameters for the solar cycle 24. International Journal of Innovative Research and Growth. 12. 10.26671/IJIRG.2023.3.12.107.
4. Singh, Prithvi & Tiwari, C. & Saxena, A. (2018). Heliospheric Modulation of Cosmic Rays and Solar Activity during Solar Cycles 22-24. Proceedings of the International Astronomical Union. 13. 147-148. 10.1017/S1743921318001497.
5. Sham Singh, A. P. Mishra, interaction of solar plasma near-earth with reference to geomagnetic storms during maxima of solar cycle 24, Indian J Phys. 1227-1234 (2015)
6. Singh, S., Mishra, A.P. Cosmic ray intensity increases during high solar activity period for the solar cycles 22 and 23. Indian J Phys 93, 139–145 (2019)
7. Sham Singh, divya Shrivastava and a.m. Mishra, effect of solar and interplanetary disturbances on space weather, Indian J Sci. Res. 3 (2) 121-125, (2012)
8. Prasad, A., Roy, S., Ghosh, K. et al. Investigation of Hemispherical Variations of Soft X-Ray Solar Flares during Solar Cycles 21 to 24. Sol Syst Res 55, 169–182 (2021)
9. Potgieter MS. Solar modulation of cosmic rays. Living Rev Solar Phys. 2013; 10:1–66.
10. Diehl R, Lugaro M, Heger A, Sieverding A, Tang X, Li KA, Lie T, et al. The radioactive nuclei and in the Cosmos and in the solar system. Publ Astron Soc Aust. 2016;38: e062.