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Study of Solar Activity And Cosmic Ray Modulation During Solar Cycles 24 and 25

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ABSTRACT:

Monthly SSN and CRI data from Neutron Monitors (NM) at Oulu (Cut off Rigidity=0.8 GV) and Moscow (Cut off Rigidity=2.3 GV) were used to analyse solar activity fluctuation and cosmic ray modulation during cycles 24 and 25.The sunspot minimum lasted for months during the start of solar cycles 24 and 25. Solar cycle 25 resembles 24. Oulu NM measured Earth's maximum Galactic Cosmic Ray strength in April 1964, during cycle 24's solar minimum. The peak SSN in cycle 24 is low compared to previous solar cycles (19-23). According to the Sunspot Index and Long-term Solar Observations (SILSO, https://wwwbis.sidc.be/silso), Solar Cycle 25 began in December 2019 with a minimum smoothed Sunspot Number 1.8. SSN-CRI correlation and regression analysis during solar cycles 24 and 25 have been estimated and compared. Due to solar cycles 24 and 25, solar activity and cosmic ray modulation have been compared to prior cycles (Data up to October, 2022).

KEYWORDS : Solar Activity, Neutron Monitors (NM), Galactic Cosmic Rays.

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INTRODUCTION:

The lowest of the 11-year sunspot cycle is when galactic cosmic rays are strongest [1, 2]. CRI has a 22-year cycle with flat-topped and sharpened maxima. Theories of cosmic ray modulation based on the Sun's magnetic field reversal every 11 years and the heliosphere's large-scale magnetic field curvature and gradient drifts have been discussed [3-6].

Monthly data from a worldwide network of neutron monitoring sites with varying cut-off rigidities is typically used to investigate cosmic ray modulation over the long term. It just so happens that the sweet spot for highest energy response and efficient solar modulation occurs in the 0.5-20 GeV region, where neutron monitors are most sensitive to cosmic rays. It has been shown before that the long-term change of solar activity has an anti-correlation with its effect on cosmic rays, and that this time lag may vary over different parts of the solar cycles[7 and references therein]. Research into the relationship between SSN and CRI across the solar activity cycle has been conducted using the statistical method of "running cross correlation" [7–10]. Unless there are compelling reasons to employ alternative readily available solar parameters (or indices), the SSN can be utilised with confidence as a solar parameter for any correlative investigation, at least on a monthly average basis (as reported) [11]. Numerous studies [7, 8, 10, 12, 13, 14] have evaluated cosmic ray intensity across previous solar cycles using various solar parameters. We examined solar activity fluctuation and cosmic ray modulation throughout solar cycle 24 and the lowest and ascending part of cycle 25 using monthly SSN and CRI data from Oulu and Moscow Neutron Monitors (Cut off Rigidity=0.8 & 2.3 GV) (up to October, 2022).

MATARIAL AND METHODS:

This research illustrates solar activity using SSN as a solar parameter and monthly mean CRI data from the Oulu Neutron Monitor (Cut off Rigidity=0.8 GV) and Moscow Neutron Monitor (2.3 GV). Since April 1964, https://cosmicrays.oulu.fi has provided cosmic ray data for Oulu NM, whereas http://cr0.izmiran.rssi.ru/mosc/main.htm provides data for Moscow NM. The website provided SSN data. (http://www.sidc.be/silso/DATA/SN_m_tot_V2.0.txt). In order to demonstrate the typical cyclewise behaviour of CRI modulation, we have computed the correlation coefficient between SSN and CRI with no time lag.

RESULTS AND DISCUSSION:

We have used the monthly average intensity of NMs in Oulu and Moscow to test the long-term consistency of the CRI data (Figure 1). The data from these two sites have been analysed, and they indicate a strong correlation (r >.98) for solar cycle 24. Therefore, for the following analysis, we have used the data of one Oulu NM station.

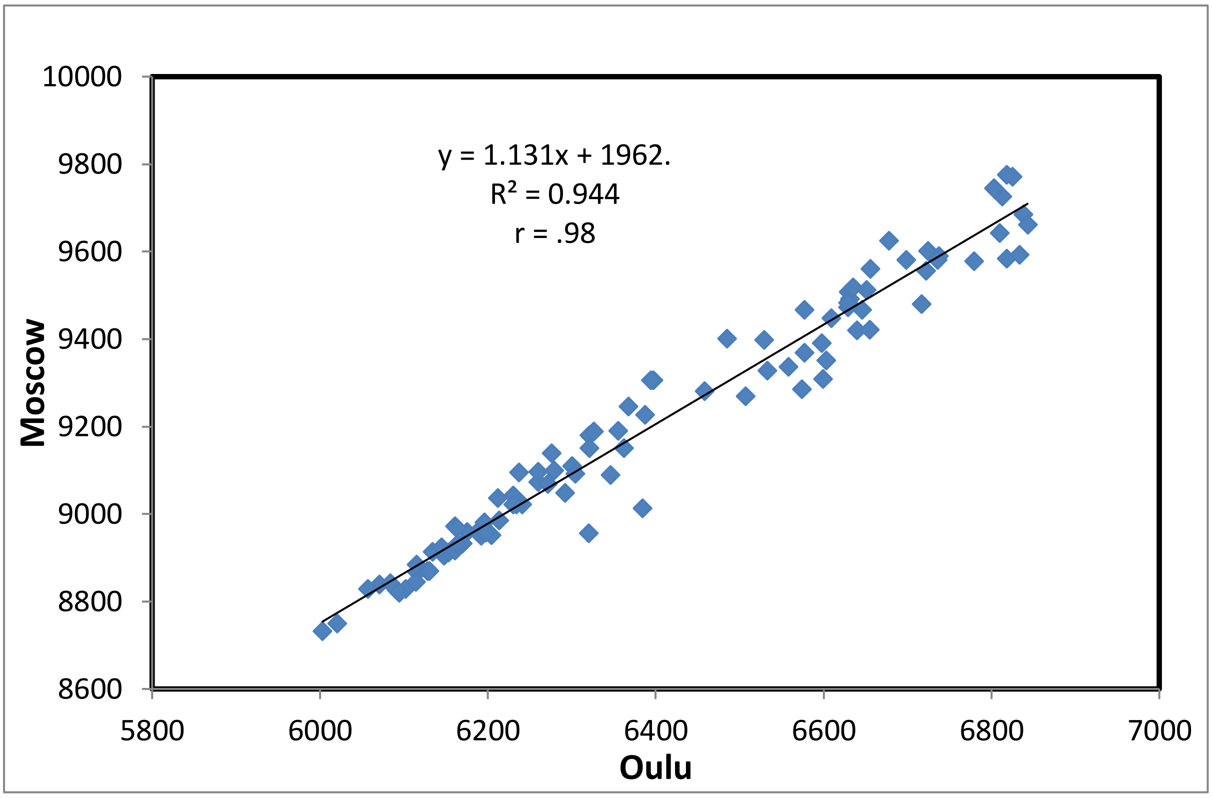

Figure 1: Shows the cross correlation between the count rates of Oulu and Moscow Neutron Monitors.

Figure 2 shows the qualitative behaviour of CRI (Oulu NM) count rates corrected to 100% in December 2009 and SSN with its smooth value (13-months moving average) during solar cycles 24 and 25 at their minimum and increasing phases. Figure 2 shows that SSN is negatively correlated with CRI, but there is a lag. Anti-correlation changes qualitatively with time. CRI and SSN fluctuate similarly in cycles 24 and 25. Cycle 24 had a minimum SSN value of 0, however cycle 25 had 0.2. (Feb. & April 2020). At the start of solar cycles 24 and 25, the sunspot low lasted for months. Oulu & Moscow NM recorded Earth's maximum

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Galactic cosmic rays during cycle 24's solar minimum.

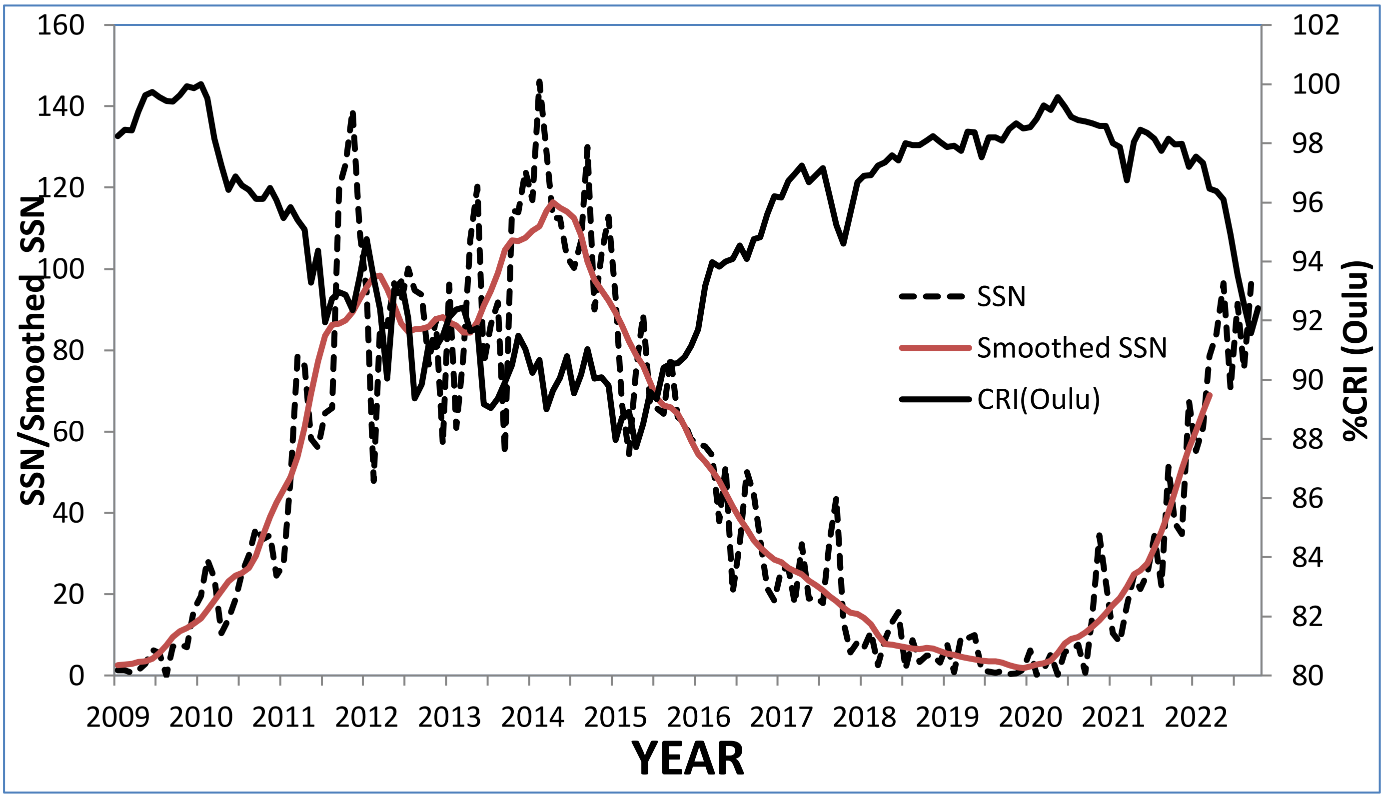

Figure 2: Shows the long term variation of SSN, Smoothed SSN and %CRI (Oulu NM) for the solar cycles 24 & 25.

We plotted SSN and CRI to see their average quantitative relationship (Figure 3). 3. Cycles 24 and 25 show separate SSN-CRI linear trend lines.The best fit line for solar cycle 25 is seen to lie above the trend line for cycle 24, implying that the amount of CRI is high during cycle 25 for the same level of SSN as during cycle 24.

These parameters have nearly identical cross correlation coefficients (without time-lag) (~ -0.87 and ~ -0.84) for solar cycles 24 and 25. Though there is a modest difference in the amount of CRI between cycles 25 and 24, the correlation between SSN and CRI for these two cycles does not appear to have changed in a single direction.

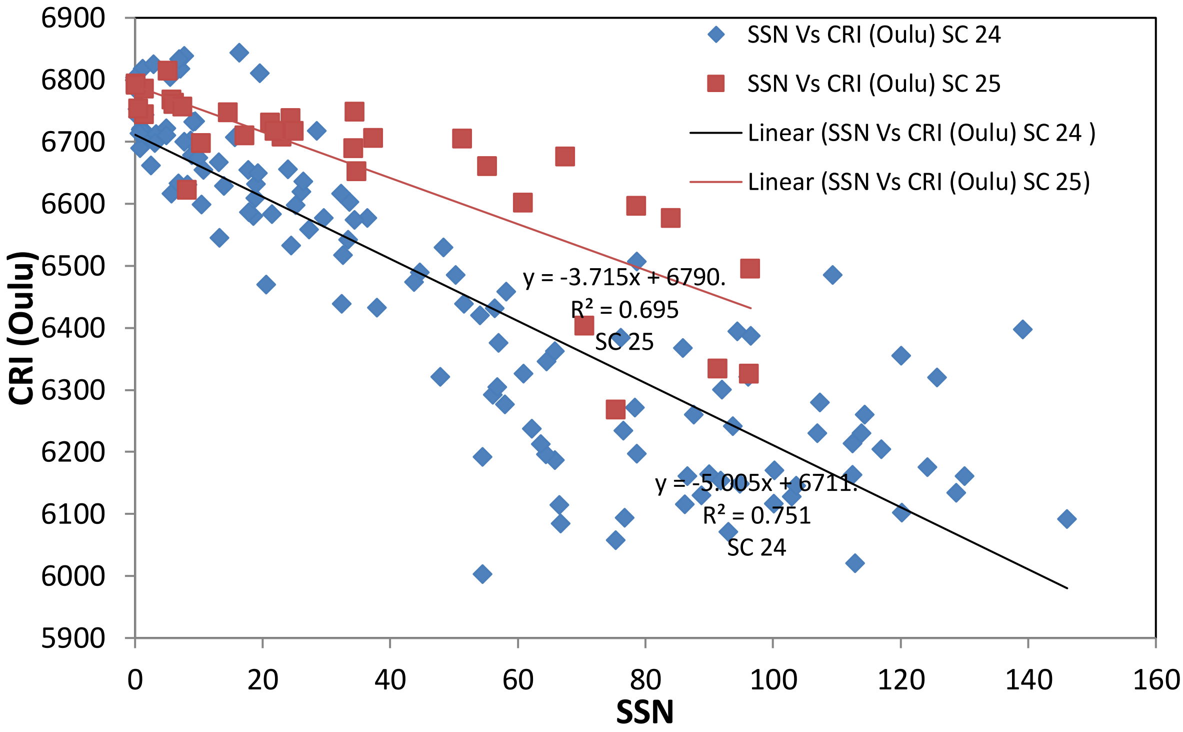

Figure 3 : Cross plot between SSN and CRI (Oulu) for cycles 24 & 25.

Diffusion, convection, and adiabatic slowing effects, where particles in the heliosphere are steered by interplanetary magnetic field lines, including drift processes, still explain how the sun impacts galactic cosmic rays. Polarity and large-scale magnetic fields distinguish solar cycles. Peak solar activity flips the solar magnetic field every 11 years[8]. Thus, when the sun reaches successive peaks, its polarity shifts. To explain the odd-even cycle, the effects of interplanetary magnetic field curvature on cosmic ray particle passage should be examined [10].

Cosmic rays modulate uniquely throughout solar cycle 24 [15]. CR modulation with solar activity (SA) increase has been much lower since 2009 [16]. This investigation confirms that solar cycle 24 had exceptionally low activity and high CRI [15, 16]. A new discovery [17] suggests that cycles 24 and 25 are similar because to their long duration, low sunspot activity, and similar correlation coefficients between SSN and CRI.Till now, the similarity in solar activity at the minimum and ascending phase of these two cycles has given us a rare window of opportunity to learn about cosmic ray modulation during the extraordinarily low activity periods of the cycles.

CONCLUSION:

Given that Solar Cycle 24 is thought to be quite average, the inclusion of the similarly active Solar Cycle 25 (through October 2022) only serves to complicate matters. To the extent that the empirical modulation provides a reasonable standard deviation between the observed and predicted values, it will be a valuable tool for future solar cycle research and space-weather forecasting. Scientists learned about the Sun's special place within the heliosphere and the value of cosmic rays for studying space weather thanks to the 11-year solar cycle, the Forbush decreases in cosmic-ray intensity, and the high-energy solar particles measured at the Earth by neutron monitors, known as ground level enhancements.Cosmic rays are utilised to diagnose solar and interplanetary processes and measure solar variability. [18, and the references therein].

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