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# STUDY OF COSMIC RAY INTENSITY WITH SOLAR AND GEOMAGNETIC PARAMETERS DURING SC 19 TO SC 24.

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**Abstract**- Entire world is facing with very serious global climatic and environmental changes problem in the last three centuries. Enormous amount of matter and energy are the chief constituents of the supergiant Universe. Our planetary system including Earth is controlled by the super energetic Sun and by the whole Galactic world. The tremendous amount of energy in various forms released from stars, and galaxies, including the Sun, empowers our Earth in a very fascinating way. The most abundant highly energetic and penetrating cosmic radiation reaches our planet, which is perhaps assumed to be responsible for life on Earth by various researchers; how these cosmic radiations play a key role in climatic changes in our solar system including Earth's environment. Sunspot formation, Solar radio flux emissions, radio bursts (Solar Flares explosion), Coronal Mass Ejections, Solar Wind Plasma emissions, and ejections of Solar Proton Events, etc. are most abundant phenomena happening in the Sun. The mean time lag observed between cosmic ray intensity and solar activity parameters are estimated to be approximately 0 to 4 months for Oulu & Rome, and 0 to 3 months for Moscow Neutron Monitor stations from 1954 to 2021. The average time lag observed was approximately 0 to 15 months between CRI and Solar Flux 2800 MHz, during this period, SC 19 to 24. It is found that most of the solar activity parameters SSN, GSF, SFI, CI, and SF 2800 MHz are highly anti-correlated (~ -0.8832 to -0.9667) with cosmic ray intensity for all these stations. SSN Total (SIDC-SILSO) shows high anti-correlation with CRI count rates for Oulu and Moscow Cosmic ray neutron monitor stations. A moderate correlation was observed for Rome CRI counts with Sunspot numbers. $C(t) \approx -0.807$ for both Oulu and Moscow and $C(t) \approx -0.433$ for Rome NM stations count rates with SSN. Solar activity parameter such as Sunspot number correlates with various solar indices i.e., Grouped Solar Flare, Solar Flare Index, Coronal Index, and Solar Flux 2800MHz. All these Solar parameters GSF, SFI, CI, and SF 2800 MHz shows a strong positive correlation with SSN. $C(t) \approx 0.843$ for SSN-GSF, $C(t) \approx 0.818$ for SSN-SFI, $C(t) \approx 0.913$ for SSN-CI, $C(t) \approx 0.981$ and $C(t) \approx 0.983$ for SSN-Solar Flux 2800 MHz for SC19 to SC 24, the high positive correlation found during the whole period of investigation April 1954 to December 2020. SSN shows moderate correlation with Geomagnetic parameters i.e., with AA [$C(t) \approx 0.362$], with Ap [$C(t) \approx 0.433$],

with Kp [C(t) ≈ 0.412], with Cp [C(t) ≈ 0.412] and with C9 [C(t) ≈ 0.414]. Solar Flux 2800MHz shows a strong negative correlation with Cosmic ray counts, for Oulu C(t) ≈ -0.814, for Moscow C(t) ≈ -0.814, and moderate correlation coefficient C(t) ≈ -0.428 for Rome stations during the same period.

**Keywords-** Sunspot number (SSN), Grouped solar flares (GSF), Coronal index (CI), Solar flare index (SFI), Solar flux 2800 MHz, Solar activity cycle, Cosmic Ray Intensity (CRI)

**1. Introduction-** It is well known that a very large amount of broadly spread uncountable radiations of different wavelengths from outside came to the Earth regularly. The formation of a sunspot is a continual process in varied manners in the Sun. The sunspot is responsible for the changes in the Earth-Sun climate. Scientists and researchers found that the cosmic rays from the Universe based on galactic nuclei and supernovae explosion have a very close interrelationship in changing solar activity and Earth's geomagnetic variation. Every incident on the sun has a direct effect on our planetary system resulting in climatic changes. Oulu, Moscow & Rome CRI count rates are used for the correlative study with different solar activity parameters from April 1954 to July 2021 (SC 19 to SC 24 & Pre SC 25). Solar activity parameters show a strong positive correlation with each other and also with geomagnetic parameters i.e., with AA, Ap, Kp, Cp, and C9. The maximum correlation coefficient, probable error & Time -Lag have been calculated between CRI and various Solar activity parameters. A very high degree of anti-correlation is observed between CRI (Oulu, Moscow & Rome) count rate with SSN, Solar Flux 10.7 cm, GSF, SFI, CI, and Solar Flux 2800MHz. Mishra V. K. & Mishra A. P. [9] introduced solar activity indices e.g. SSN, 10.7 cm solar flux, tilt angle (solar/ interplanetary index), cosmic ray flux, and green coronal index (used for space weather studies) for the study of long term CRI variations, which is produced due to the changes in solar magnetic activity having 11- year periodicity. Rathod Munika, Gupta Meera, and Shrivastava A.K. [11] analyzed variation of solar flare activity along with 11-year cyclic sunspot activity during solar magnetic activity cycle 20 to 24 and find out correlation coefficient for SSN-GSF. Aslam, O.P.M., and Badruddin [1] studied solar modulation of galactic cosmic rays during solar minimum, including the declining phases of solar cycles 20,21,22 and 23. Gupta M., Narang S.R., Mishra V.K., Mishra A.P. [4] used low (Oulu), middle (Kiel), and High (Huancayo) cut-off rigidity neutron monitor station's monthly mean value of CRI data for investigation, and established relationship of CRI with SSNs and TA for the period 1976 to 2015, from SC 21 to 24. Gupta Meera, Mishra V.K.& Mishra A.P. [3,5] studied the interrelationship between solar radio bursts and sunspot numbers for the 21,22, and 23 solar cycles, a very strong positive correlation being remarked. They also studied the correlation between CRI-SSN, and CRI-TA for negative polarity (qA <0) and positive polarity (qA>0), and find out the correlation coefficient for both negative and positive solar magnetic activity cycle without time log and with time

log situations. The same investigation was repeated with the solar flare index. Multi-parametric effect of solar activity on cosmic ray observation performed by V. K. Mishra, Meera Gupta, B.N. Mishra, S.K. Nigam & A.P. Mishra [10] found that the strength of multiple correlations is different for the different phases of the solar cycle. Meera Gupta and his collaborators [2] investigate cosmic ray intensity with SSN and also studied the cross-correlation between tilt angle with SSN during SC 21, 22, and 23. Tripathi R. & Mishra A.P. [12] studied characteristics and features of severe geomagnetic storms that occur during solar cycle 23 for both S and G types of a solar storm and their association with coronal mass ejections for partial & halo coronal mass ejections. Gupta, M., Rathod, M. and Shrivastava, A.K. [6] studied the various solar activity parameters and their interrelationship from solar cycles20 to 24. Gupta, M. [7] analyzed and concluded that the green CI is a better parameter for solar-terrestrial studies. Mishra, A.P., Mishra, B.N., Gupta, M. and Mishra, V.K. [8] examined the heliospheric distribution of bright solar flares and the association of Forbush Decreases with flares and coronal mass ejections. Tiwari et al. [13] inspected the Anomalous behavior of cosmic ray diurnal anisotropy during descending phase of the solar cycle-22.

**2. Methods of Analysis and Data Detection Techniques-** Monthly means of cosmic ray neutron monitor count rates as CRI (Oulu, Moscow & Rome) data have been used for the study. Solar parameters such as monthly means of International Sunspot numbers SSN Total (SIDC-SILSO), Grouped Solar flares GSF, Solar flare index SFI, Coronal index CI of green line XIV 5303 Å, Solar Flux (SF) 2800 MHz data has been used for the study. The long-term monthly average data has been taken for investigation, the period from 1954 to 2021, using geomagnetic disturbances index AA, Ap, Kp, Cp, and C9. 30 Month running average (smoothed) data of various solar parameters with CRI have been used for the correlative study. A detailed correlative study has been performed between CRI and Geomagnetic parameters, CRI with solar activity parameters, and Geomagnetic indices with solar activity parameters.

**3. Observational Results and Discussions-** The mean time lag observed between cosmic ray intensity and solar activity parameters is estimated to be about 0 to 4 months for Oulu, Moscow & Rome NM stations from 1954 to 2021. The average time lag observed between CRI and Solar Flux 2800 MHz is found to be 0 to 15 months for SC 19 to SC 24. It is found that most of these solar activity parameters are highly negatively or anti-correlated (~ -0.8832 to -0.9667) with cosmic ray intensity for all these stations.

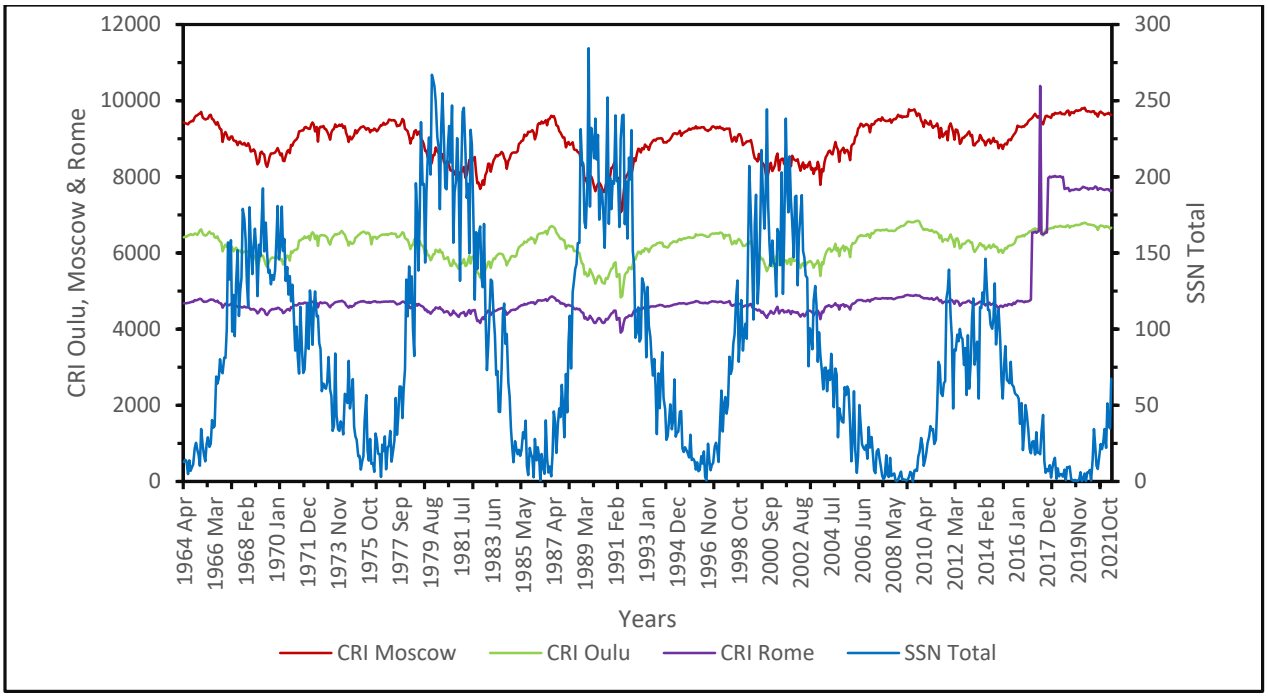


**Fig. 1** Graph between SSN Total and CRI (Oulu, Moscow & Rome) during SC 20 to SC 24 (Period April 1964 to December 2021).

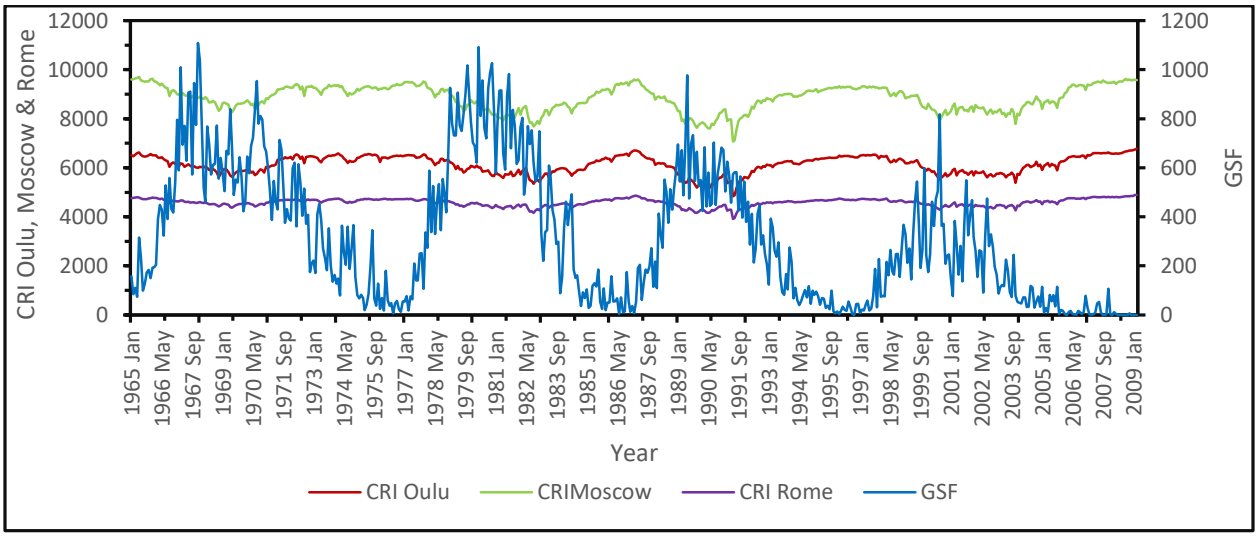


**Fig.2** shows the graph between GSF Vs CRI Oulu, Moscow & Rome during January 1965 to March 2009.

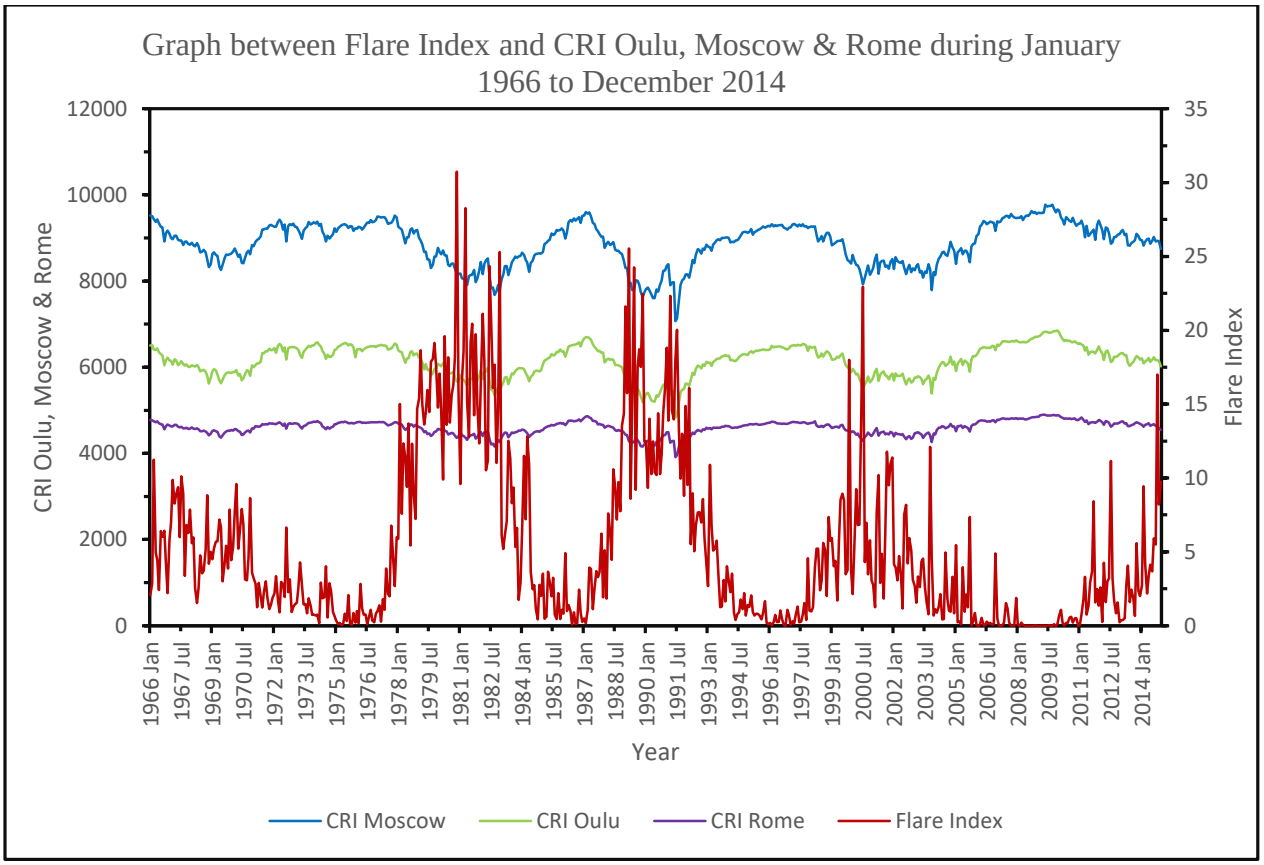


**Fig.3** Graph between Flare Index Vs CRI Oulu, Moscow & Rome during January 1966 to December 2014..

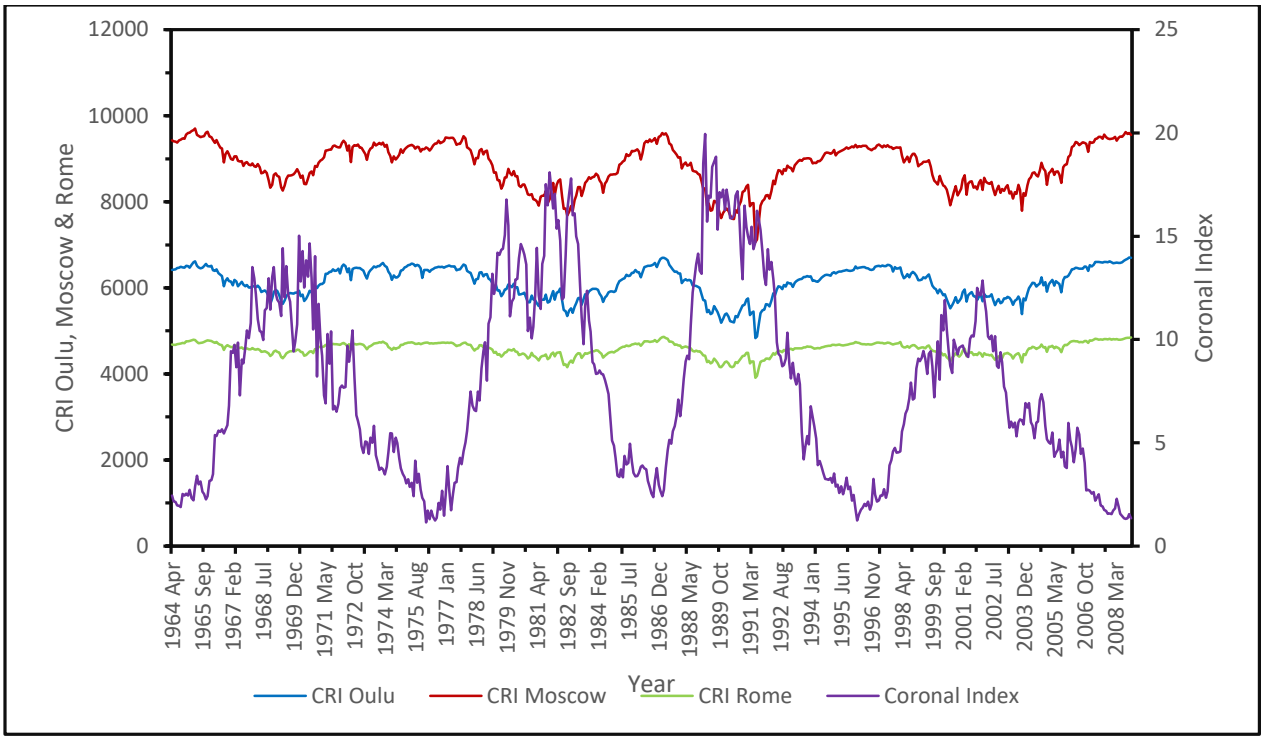


**Fig.4** Graph between Coronal Index Vs CRI Oulu, Moscow & Rome during April 1964 to December 2008.

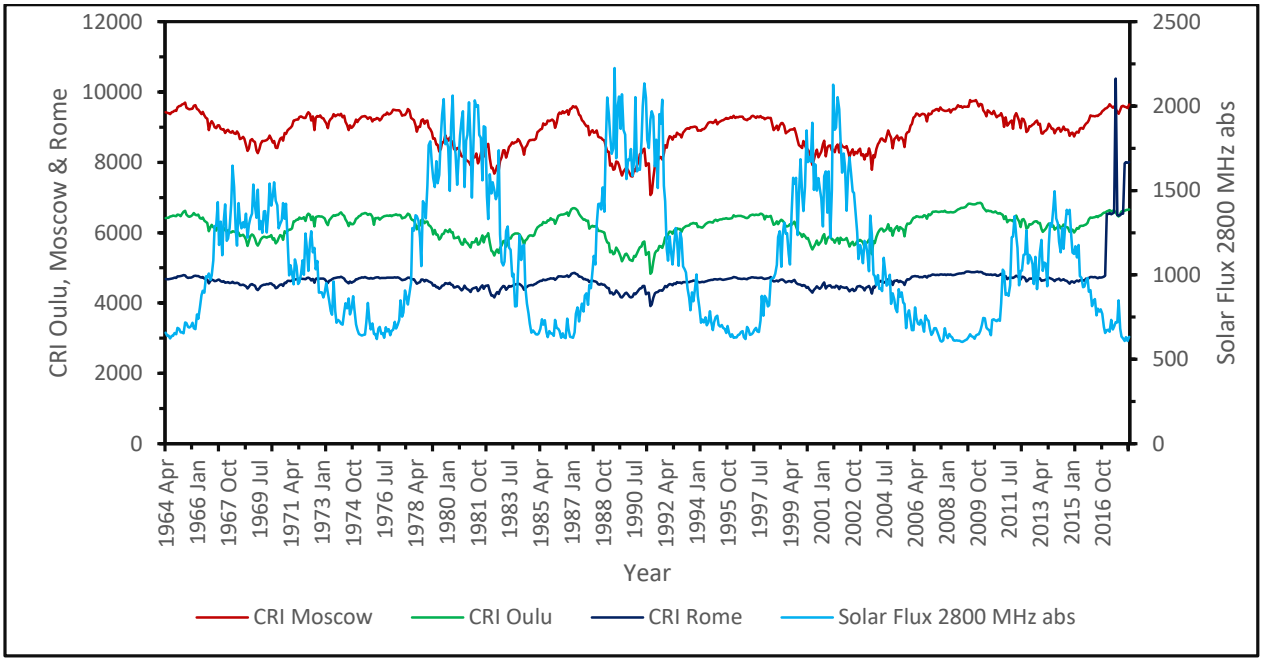


**Fig.5** Shows the Graph between Solar Flux 2800 MHz abs Vs CRI Oulu, Moscow & Rome during April 1964 to April 2018.

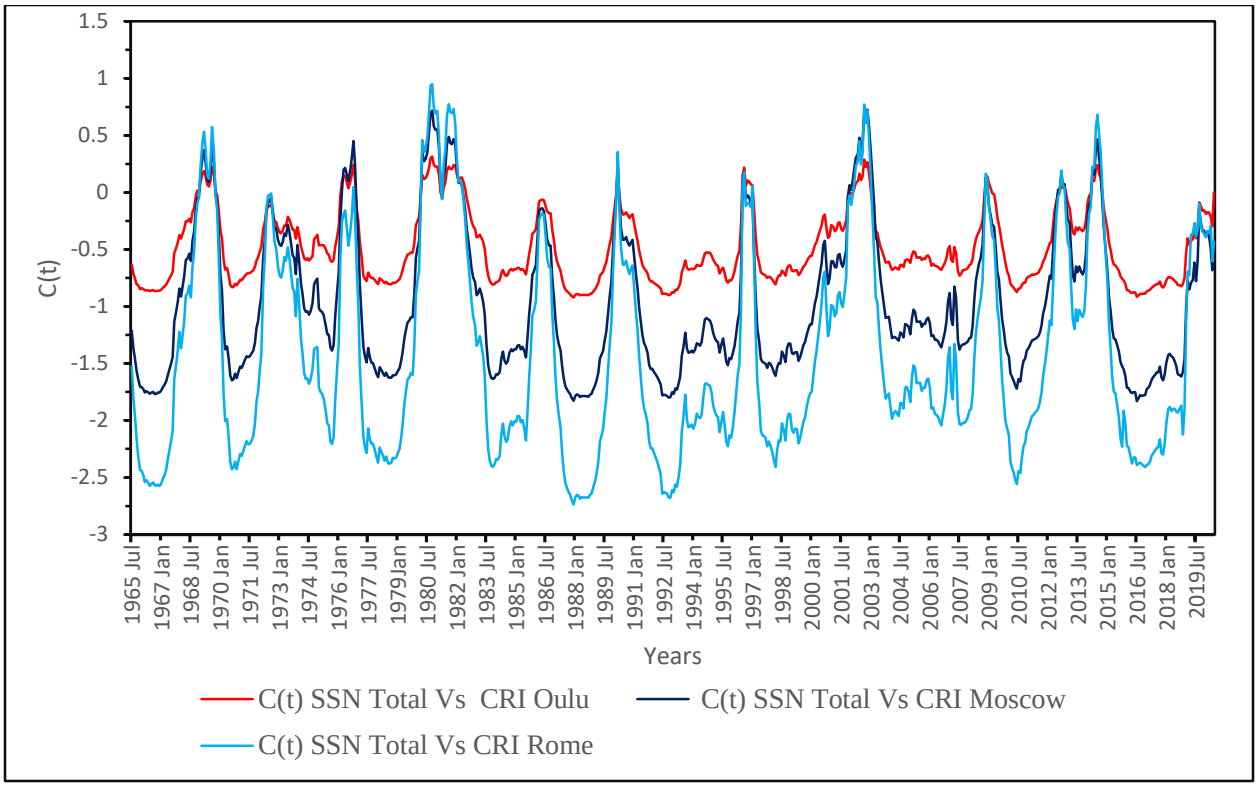


**Fig. 6** Graph Correlation Coefficient C(t) SSN Total (SIDC-SILSO) Vs CRI (Oulu, Moscow & Rome) with years during July 1965 to April 2020.

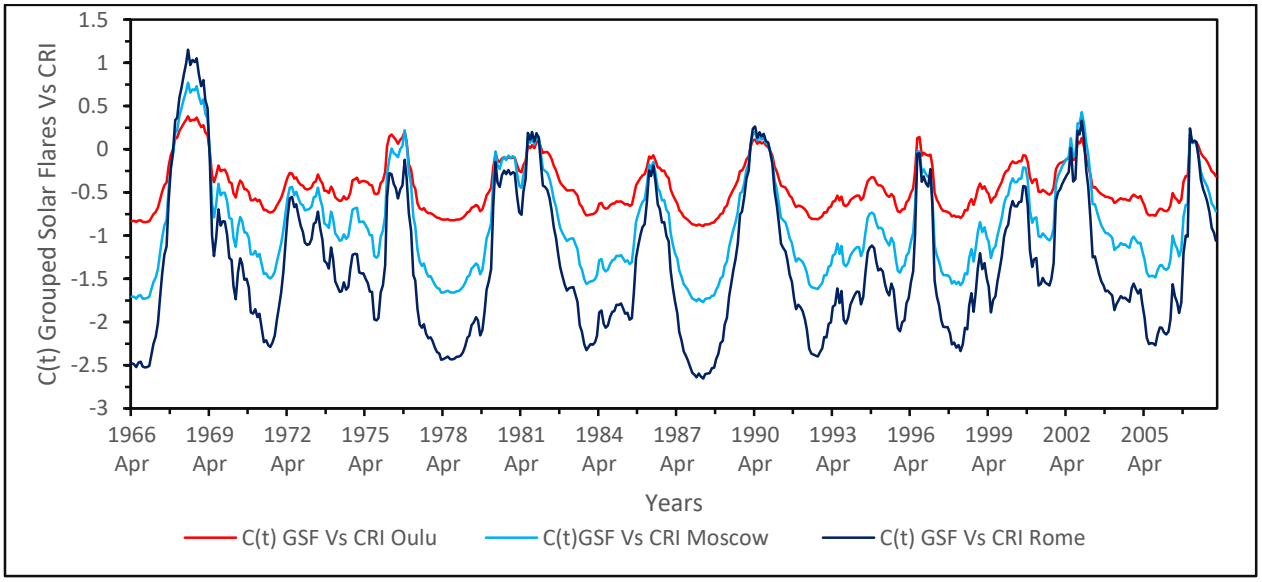


**Fig.7** Graph between cross correlation coefficient C(t) GSF Vs CRI (Oulu, Moscow & Rome) with years during April 1966 to January 2008.

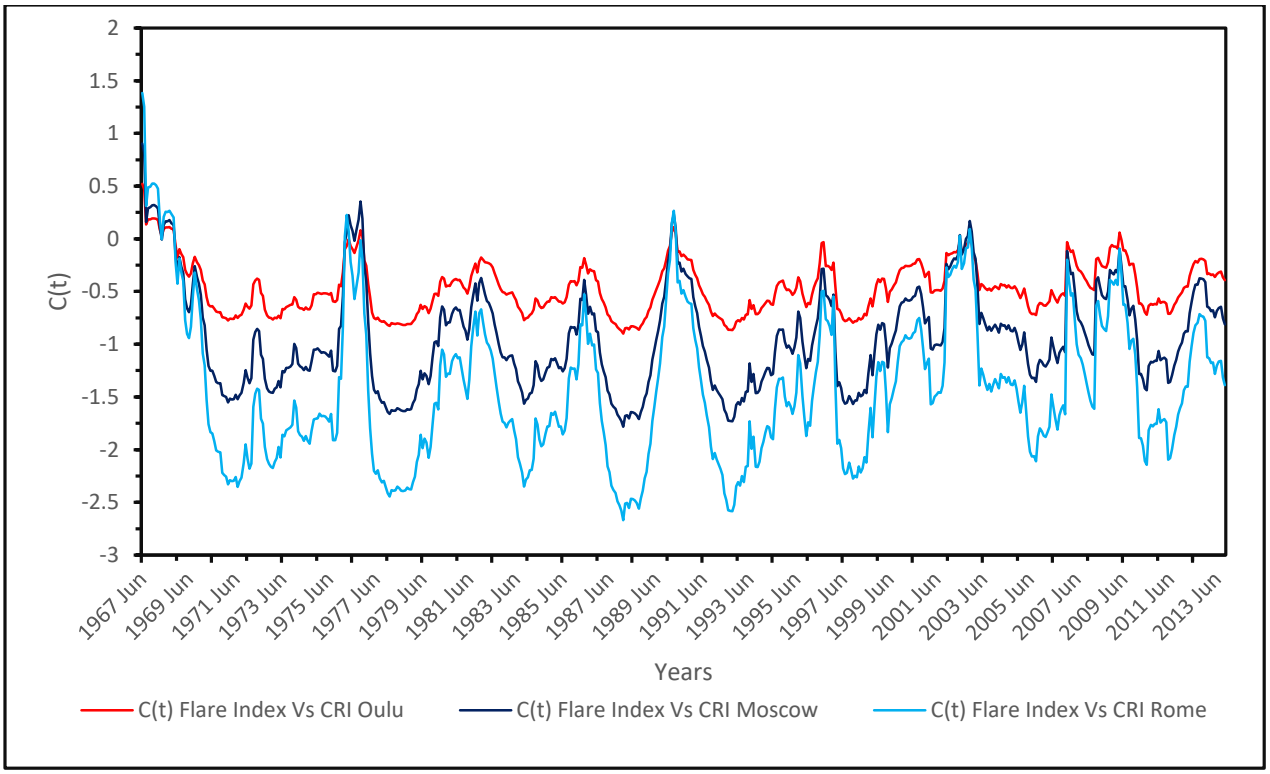


**Fig.8** Cross correlation between SFI and CRI (Oulu, Moscow &Rome) neutron monitor count rates from June 1967 to October 2013.

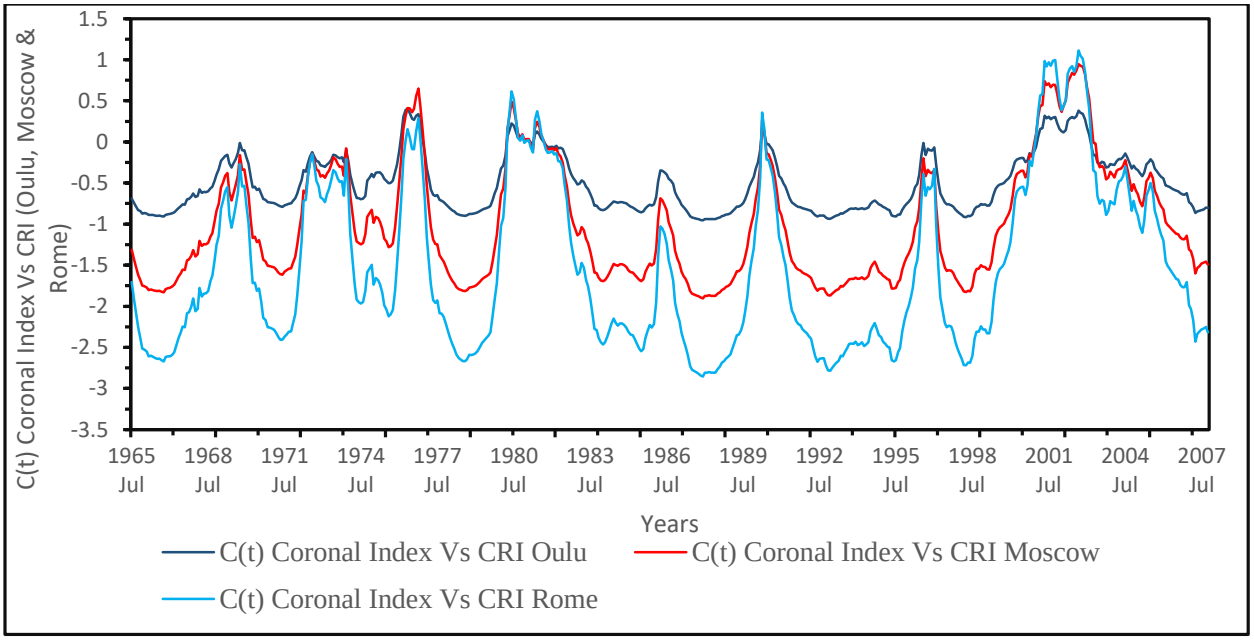


**Fig.9** Cross CC between CI and CRI of Oulu, Moscow and Rome NM count rates from July 1965 to October 2007.

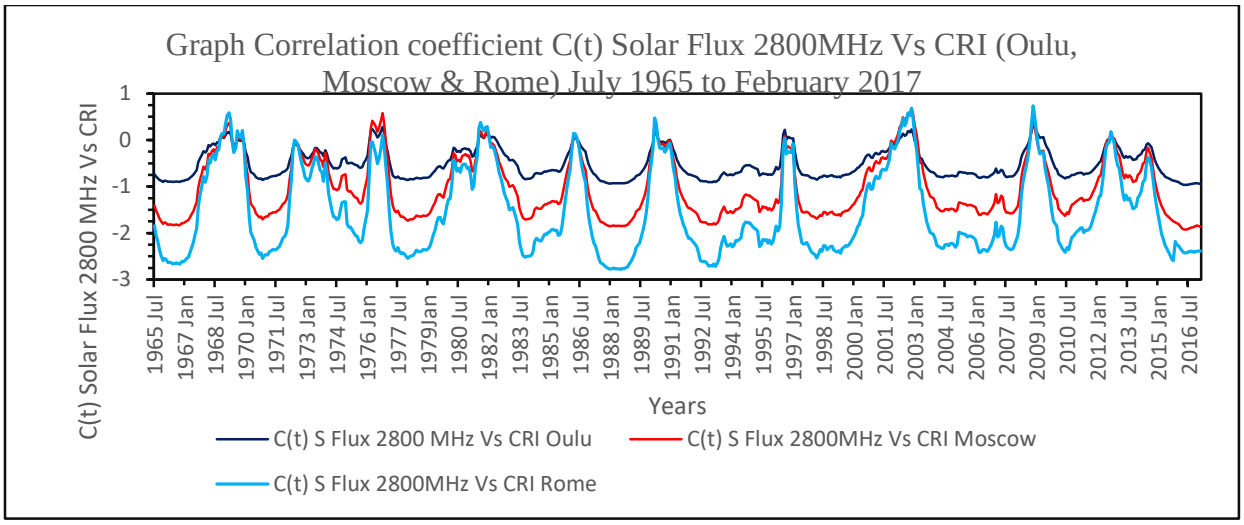


**Fig.10** Graph Cross-Correlation C(t) between Solar Flux 2800 MHz Vs CRI (Oulu, Moscow & Rome) with years from July 1965 to February 2017.

**Table-1 Correlation Coefficient between Cosmic Ray Intensity (Oulu, Moscow, and Rome) with Solar and Geomagnetic Parameters (Period from April 1954 to July 2021)**

| S. No. | Solar and Geomagnetic Parameters Vs CRI | Correlation coefficient C(t) | | |
|---|---|---|---|---|
| | | Oulu | Moscow | Rome |
| 1. | SSN Total (SILSO)- CRI | -0.807 | -0.805 | -0.430 |
| 2. | CI Slovakia- CRI | -0.831 | -0.822 | -0.825 |
| 3. | Flare Index-CRI | -0.684 | -0.693 | -0.710 |
| 4. | Solar Flux 10.7 cm (Penticton /Ottawa) – CRI | -0.824 | -0.822 | -0.413 |
| 5. | GSF- CRI | -0.582 | -0.542 | -0.583 |
| 6. | Solar Flux 2800MHz-CRI | -0.814 | -0.814 | -0.428 |
| 7. | AA Index- CRI | -0.606 | -0.582 | -0.603 |
| 8. | Ap Index- CRI | -0.586 | -0.604 | -0.360 |
| 9. | Kp Index – CRI | -0.577 | -0.596 | -0.340 |
| 10. | Cp Index – CRI | -0.586 | -0.606 | -0.343 |
| 11. | C9 Index – CRI | -0.583 | -0.602 | -0.347 |
| 12. | IMF (OMNI Web) – CRI | -0.755 | -0.7375 | NA |
| 13. | F 10.7 (OMNI Web) –CRI | -0.7875 | -0.795 | -0.731 |

**Table-2 Maximum correlation coefficient between CRI (Oulu, Moscow & Rome) & different solar -activity parameters during solar cycle 19 to 24 and Pre-SC 25 (April 1954 to July 2021) with probable error (P.E.).**

| Parameters | Correlation coefficient (r) | | | Time-Lag | | |
|---|---|---|---|---|---|---|
| | Oulu | Moscow | Rome | Oulu | Moscow | Rome |
| CRI-SSN | -0.92117± 0.00398 | -0.9134± 0.00412 | -0.9096± 0.00428 | 4 Month | 0 Month | 4 Month |
| CRI-GSF | -0.88781± 0.00637 | -0.8869± 0.00641 | -0.8861± 0.00646 | 0Month | 3 Month | 0 Month |
| CRI-SFI | -0.8997± 0.00543 | -0.8832± 0.00628 | -0.8867± 0.00609 | 0 Month | 0 Month | 0 Month |
| CRI-CI | -0.95513± 0.00262 | -0.9477± 0.00278 | -0.9522± 0.00257 | 1 Month | 1 Month | 1 Month |
| CRI-Solar Flux 2800MHz | -0.9667± 0.00177(P.E.) | -0.9610± 0.00192(P.E.) | -0.9312± 0.00332(P.E.) | 1 Month | 1 Month | 3 Month |

**Table-3 Correlation coefficient between monthly mean SSN Total (SIDC-SILSO) with Solar and Geomagnetic Parameters during SC 19 to SC 24 (overall period).**

| Period April 1954 to December 2020 | SSN Total Vs GSF | SSN Total Vs Solar Flare Index | SSN Total Vs CI Slovakia | SSN Total Vs Abs SF 2800MHz | SSN Total Vs AA | SSN Total Vs $A_P$ | SSN Total Vs Kp | SSN Total Vs Cp | SSN Total Vs C9 |
|---|---|---|---|---|---|---|---|---|---|
| C(t) | 0.843 | 0.818 | 0.913 | 0.983 | 0.362 | 0.433 | 0.412 | 0.412 | 0.414 |

**Conclusions-**There is a strong inverse correlation between cosmic ray intensity with sunspot numbers. Cosmic rays are minimum during periods of high solar activity and maximum during periods of low solar activity. The correlation was generally stronger on a cycle-by-cycle basis. It has been found that solar activity indices SSN, GSF, CI, SFI, and Solar flux (2800 MHz) show anti-phase with Cosmic Ray Intensity (CRI). The average time lag observed between cosmic ray intensity and solar activity parameters is estimated to be approximately 0 to 4 months for Oulu, Moscow & Rome NM stations for the period 1954 to 2021. It is found that the most of solar activity parameters such as Sunspot number (Total), Solar flux 10.7 cm, GSF, Solar flare index, Coronal index, and solar flux 2800 MHz are highly anti-correlated ( ~ -0.8832 to -0.9667) with cosmic ray intensity for all these three stations. When the correlation coefficient between CRI and SSN for different solar cycles (19 to 24 ) is considered with time -lag, it is found that the time-lag is larger for odd solar cycles and it is smaller for even solar cycles for all the three NM stations (Oulu, Moscow & Rome), which supports the odd-even hypothesis of cosmic ray modulations. SSN Total shows a positive correlation with solar and geomagnetic parameters from SC 19 to SC 24. Solar Flux 2800 MHz shows a negative correlation with CRI for all three NM stations Oulu, Moscow, and Rome period April 1954 to December 2019.

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**References**-

[1] Aslam, O.P.M. and Badruddin. (2012). Solar modulation of Cosmic rays during the declining and minimum phases of solar cycle 23: comparison with past three solar cycles. Solar Physics. **279**, 269-288, DOI:10.1007/s11207-012-9970-3.

[2] Gupta, M., Mishra, V.K. and Mishra, A.P. (2006). Study of cosmic ray intensity variations in relation to solar activity for sunspot cycles 19 to 23. Indian Journal of Radio & Space Physics. **35**, 167-173.

[3] Gupta, M., Mishra, V.K. and Mishra, A.P. (2005). Correlative study of solar activity and cosmic ray intensity for solar cycles20 to 23. 29th International Cosmic Ray Conference Pune. **00**, 101-104.

[4] Gupta, M., Narang, S.R., Mishra, V.K., Mishra, A.P. (2016). Correlation of the cosmic ray intensity variations with sunspot numbers and tilt angle from solar cycle 21 to present solar cycle. **3**, 1.

[5] Gupta, M., Mishra, V.K. and Mishra, A.P. (2006). Correlation of the long–term cosmic ray intensity variations with sunspot numbers and tilt angle. Indian Journal of Radio and Space Physics. **35**, 387-395.

[6] Gupta, M., Rathod, M. and Shrivastava, A.K. (2017). Various solar activity parameters and their Interrelationship from solar cycles20 to 24. Int. Res. J. of Science & Engineering. **5**, 59-69.

[7] Gupta, M. (2018). The green coronal index is a better parameter for solar-terrestrial studies; International Journal of Environmental Technology and Management.

[8] Mishra, A.P., Mishra, B.N., Gupta, M. and Mishra, V.K. (2008). Heliospheric distribution of bright solar flares and association of Forbush Decreases with flares and coronal mass ejections, Indian Journal of Radio & Space Physics. **37**, 237-243.

[9] Mishra, V.K. and Mishra, A.P. (2016). Coronal index of solar activity and Long-term variation of cosmic rays; International Journal of Science, Engineering and Technology Research (IJSETR).

[10] Mishra, V.K., Gupta, M., Mishra, B.N., Nigam, S.K. and Mishra, A.P. (2008). Multi-Parametric-effect of solar activity on cosmic rays. J. Astrophysics Astronomy **29**, 257-262.

[11] Rathod, M., Gupta, M. and Shrivastava, A.K. (2017). Long-term variation of solar flare indices in relation to sunspot numbers from solar cycle 20 to 24. Journal of Pure Applied and Industrial Physics **7(9)**, 339-347

[12] Tripathi, R. and Mishra, A.P. (2006). Occurrence of severe geomagnetic storms and their association with solar-interplanetary features. ILWS workshop, Goa.

[13] Tiwari, C.M., Tiwari, D.P. and Srivastava, P.K. (2005). Anomalous behaviour of cosmic Ray diurnal anisotropy during descending phase of the solar cycle-22. Current Science **88(8)**, 25.