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STUDY OF LONG-TERM COSMIC RAY VARIABILITY DURING SOLAR CYCLE 22 TO 24

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ABSTRACT

In this paper we have studied the cosmic ray variability during solar cycle 22 to 24. For our study we have taken yearly average value of sunspot number (Rz) and cosmic ray intensity of two different latitude neutron monitor. We observed that trend of solar activity during period of solar cycle 22 to 24 have decreased and their consequence as well as the cosmic ray intensity have been increased during this time interval. We found that solar cycle 24 is the weakest solar cycle than previously occurred two solar cycles i.e. 22 and 23.

KEYWORDS: Solar Cycle, Sunspot Number, Cosmic Ray Intensity

Study of cosmic ray modulation with solar activity parameters is old and so on. Cosmic ray variation is based on the solar activity parameters. It has been known for a long time that intensity as well as the energy spectrum of galactic cosmic ray is modulated by solar activity. Among the various solar activity parameters, the sunspot number has been considered as a primary indicator to define the level of solar activity which generally follows 11-years periodicity. The sunspot numbers are used as solar index for study of cosmic ray modulation and solar terrestrial relationship (Dorman and Dorman, 1967; Pomerantz and Duggal, 1971; Rao, 1972; Webber and Lockwood, 1988; Ahluwalia, 1998). Similarly several solar indices (solar flares, solar flux, coronal index, etc.) have been used as proxy index to represent the solar activity (Kane, 2005; Gupta et al., 2005, 2006). Cosmic ray is anticorrelated with solar activity parameters (Ahluwalia and Wilson, 1996; Dorman et al., 2001; Usoskin et al., 1998). Galactic cosmic ray in the energy range from several hundred MeV to tens of GeV is subjected to heliospheric modulation, under the influence of solar output and its variation. The heliospheric modulation of cosmic ray intensity and spectrum are associated with 11-year solar activity cycle. The charge/ polarity dependence of drift mechanism is clearly observed in cosmic ray modulation in terms of 22-year solar magnetic cycle, showing different shape of cosmic ray maxima in the alternate solar cycles. Long- term cosmic ray modulation in the high energy range is studied using the monthly mean data of global network of cosmic ray neutron monitor stations having different cut-off rigidity. In September, 2014, new results with almost twice as much data were presented of cosmic rays, in talk at CERN and published in Physical Review Letters (Schirber and Michael, 2014).

Data Collection Sources

For this work we have taken yearly average value of sunspot number from National Oceanic Atmospheric Administration (NOAA), their website is www.ngdc.noaa.gov and cosmic ray by Moscow neutron monitor having magnetic cut- off rigidity (Rc = 2.42 GeV) which is located on Earth at latitude 55.47N as well as longitude 37.32E similarly, Oulu neutron monitor have Rc = 0.8 GeV and location on earth at latitude 65.05N and longitude 25.47E.

RESULTS AND DISCUSSION

The Neutron monitors are more sensitive to cosmic ray in the energy range 0.5-20 GeV, which coincides with maximum energy response for effective solar modulation. Though, the anti-correlation is found to vary during the different phases of solar cycles (Nagashima and Morishita, 1979; Dorman et al., 2001). The sunspot number is the main characteristics of solar cycle variation. Sunspots are temporarily phenomenon on the photosphere of the sun and it's appearing visibly as dark spot compared to surrounding regions (Schwabe, 1843). Solar cycle is also called solar activity magnetic cycle. The sunspots are most obvious features of photosphere and firstly observed by Galileo. Figure 1 shows time profile variation of sunspot number (Rz) and cosmic ray intensity and there relative trend of progression. The sunspots are composed of hot gases but they appear dark because the temperatures in the spots are a few thousand degree Kelvin cooler than that of surrounding photosphere. The Sunspot number varies from year to year with a certain regularity of increase and decrease. Cosmic ray flux comes from outward expansion of solar ejecta into interplanetary space. The cosmic ray flux inters solar system anti-correlated with the solar activity. This anti-correlation is detected at the Earth

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surface by measurement. The cosmic ray flux varies with solar cycle during the period of solar cycle 22 to 24 (Anath, 1975). The unit of cosmic ray intensity is (particle/ m^2. ster. sec. MeV). When cosmic rays flux inter solar system these flux modulated by the solar ejecta (Nagashima and morishita, 1979; Mavoromichalaki and Petropoulos, 1984; Nymmik and Suslov, 1995; Strorini et al., 1995). The cosmic rays are deflected by the magnetic field in interstellar space; they are also affected by the interplanetary magnetic field embedded in solar wind and therefore have difficulty reaching the inner solar system. As solar activity varies, over the 11- year solar cycle the intensity of cosmic rays at Earth also varies, in anti-correlation with the sunspot numbers. Figure 2 shows the linear correlation of sunspot number with cosmic ray intensity of Moscow neutron monitor much higher than cosmic ray intensity of Oulu neutron monitor. It means the both two neutron monitor have situated at different latitude and cut – off rigidity.

CONCLUSION

The graphical result obtained since a long period of time is showing that the activity of Sun has decreased during period of solar cycle 22 to 24. Therefore the solar phenomena i.e. solar temperature, proton flux, solar wind velocity, solar magnetic field and solar plasma should also decrease during the period of solar cycle 22 to 24 so as its consequence the disturbance in space weather should also decrease which may cause irregularity in Earth atmosphere during this period.

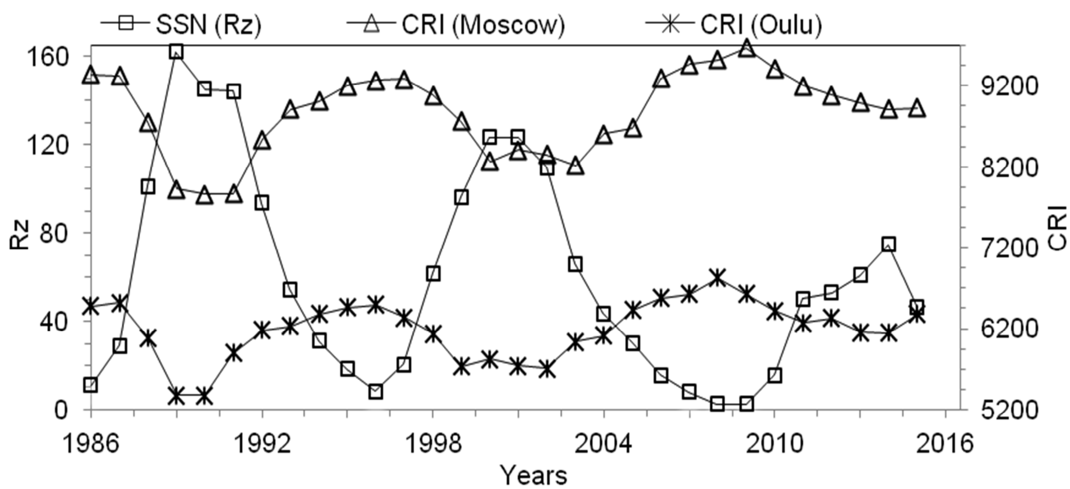

Figure 1: Shows the time profile of yearly average value of sunspot numbers (Rz) and cosmic ray intensity (Moscow and Oulu) during the time period from year 1986 to 2015.

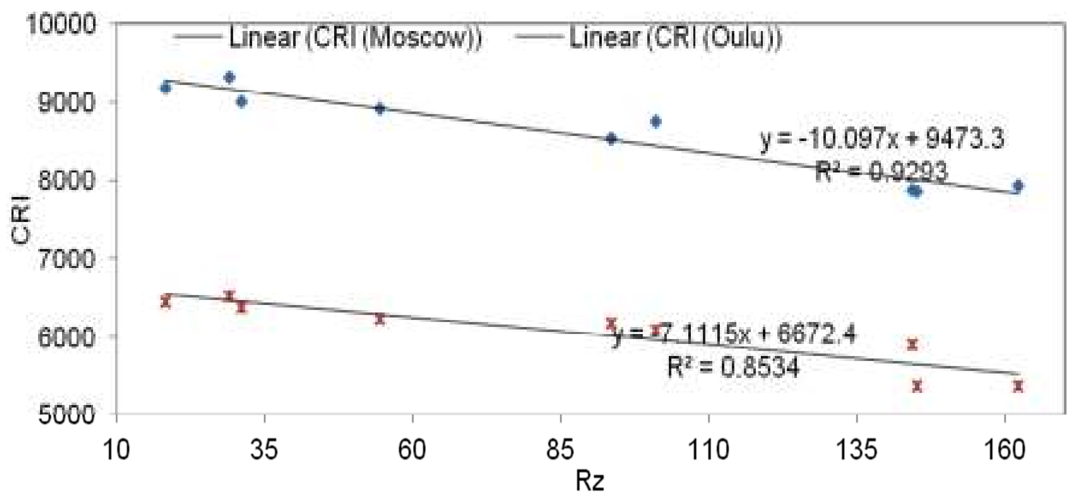

Figure 2: Cross plot of yearly average value of sunspot number with cosmic ray intensity (Moscow and Oulu NM) during the time period from year 1986 to 2015.

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