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Research Paper Physics

# Long-Term Variations of Geomagnetic Indices & Cosmic ray Intensities

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ABSTRACT

*The long-term variations of the 12-month running means of geomagnetic parameters during the sunspot cycles 22 & 23 (1986-2009), the geomagnetic index showed several peaks with in 3-5 years around the sunspot maxima, with some peaks during the declining phase of the sunspot cycles, whereas the sunspot numbers Rz showed smooth but broad maxima for 2-3 years in each cycle. The 11-year running means showed very good parallelism between Rz & geomagnetic indices cosmic ray neutron monitor intensity at Moscow (2.39 GV) were well anti-correlated with sunspot cycle & IMF (B), but poorly correlated with solar wind speed (V) & best correlated with the product V.B.*

Keywords : Geomagnetic index, Cosmic ray intensity, Interplanetary Magnetic Field (IMF).

**1. Introduction:-** The Sun-earth relationship is a very old topic & has evolved tremendously in the last few decades, notably after the advent of satellites which provide valuable interplanetary data. The important features of geomagnetic phenomena & Cosmic rays are described briefly as follows.

**1.1 Geomagnetic parameters:-** Whereas every abnormal interplanetary structure compresses the geomagnetic field further when the Earth enters the structure, not every structure, causes geomagnetic storms. It was noticed that storms occurred only when the interplanetary structure had a substantial Bz southward component. The reason for this condition was given by Bungey (1961) as follows. As the geomagnetic dipole field is stretched in magnetotail, a neutral sheet is formed with geomagnetic field away from the Earth above the neutral sheet & toward the earth below the neutral sheet. At the end, in a small region far away from the earth, the field is still north-south. If the field in the interplanetary shock has a component (negative Bz), which can neutralize the geomagnetic field, a neutral point is formed & solar wind gets an entry into the magnetosphere.

Geomagnetic activity is represented by several indices. The hourly Dst index (Sugiura 1964) is obtained from the superposition of data from magnetometer stations near the equator, but not so close that the E – region equatorial electro jet dominates the magnetic perturbations seen on the ground. The Ae index is an auroral electro jet index obtained from a number (usually greater than 10) of stations distributed in local time in the latitude region that is typical of the northern hemisphere auroral zone. (Davis et al 1966) for each of the stations the north-south magnetic perturbation H is recorded as a function of universal time.

**1.2 Cosmic rays: -** Cosmic rays (CR) are not a terrestrial phenomenon, through our information about them is obtained mainly from detectors (neutron monitors, ionization chambers, muon telescopes, studies of geological & biological specimens etc) placed on the earth, as also from satellites in deep space (Pioneers etc; Sarabhai et al 1953). There is some CR (Protons, alpha particles & heavier elements) originating in the Sun, but most of the others are of galactic & extragalactic origin. Outside the heliosphere, CR intensity (mostly isotropic) is almost constant, but a substantial CR modulation occurs during their transit through the heliosphere due to the plasma & magnetic field structure from about 0 to 100 AU.

**2. Data Analysis: -** Most of the data were obtained from the NOAA website;http//www.ngdc.noaa.gov/stp/ (SPIDR), but some were extracted from publications & some were obtained by private communications, since the purpose was to compare long-term changes, 12-months running means were evaluated & used. Geomagnetic data are also recorded at several places since long & using earlier data Mayaud (1973) constructed the longest series of geomagnetic index. In the present paper, the long-term evolutions of geomagnetic indices & CR variations are compared for cycles 22 & 23.

**3. Result & Discussions: -** Fig 1(a) shows the plots of the annual values of the sunspot number Rz, & geomagnetic index (B), B.V. & Cosmic ray intensity for 1986 to 2009 (Solar cycle 22 & 23). Vertical lines mark sunspot minima. Peaks are indicated by dots. Whereas Rz has mostly one but occasionally two nearby peaks, the B index shows several peaks spread over 3-5 years around the sunspot peaks. Fig 1(b) shows the correlation curve for Rz with B & R with V.B., data from the website (htt://tao.atmos.washington.edu/data.sets/global_sstanomts/sstglobalnom 18492003). The overall correlation are positive (Rz: B 0.4298, Rz: B.V. 0.4139), indicating that the long-term changes of these parameters have tracked each other. Fig 2(a) shows the plots of sunspot number Rz. Solar flux (2800 MHz) & Coronal Index (Ap) for 1986-2009 (12-months running means). Vertical straight lines mark sunspot minima. The successive peaks of the same parameters are joined by small approximately vertical lines oscillating structures are seen for Rz & Solar flux, but the coronal index shows a substantial rising tendency. Rybansky et al (2001) mentioned that coronal index increased during 1939-1998.

Fig 2(b) shows cross-correlation between Rz to solar flux & Rz to Ap. The overall correlations are positive (Rz: Solar flux 0.9730; Rz: Ap 0.6808).

From analysis following may be noted: -

(I) The open fluxes at low & high solar latitude have very different long-term evolutions.

(II) The high latitudes open fluxes had a long-term variation almost anti-parallel to that of sunspots with flux maxima occurring during sunspot minima.
(III) The sunspot number Rz is very highly correlated (0.9730) with the solar flux (2800 MHz) & to a slightly lesser extent (0.6808) with coronal index.
(IV) The Rz is highly correlated with cosmic rays (0.7783) with inverted (R plot). The solar flux & coronal index also have similar correlations with CR.
(V) The Rz had only moderate correlation (0.4139) with V.B.
(VI) The lags & hysteresis effects between CR & Solar activity are illustrated usually by plot CR versus Sunspot number Rz.

Fig 3(a) shows the plots of CR decreases versus sunspot number Rz for solar cycles 22 & 23. Fig 3(b) shows plots for CR versus the coronal index, here cycle 23 show broad hysteresis loops & in cycle 22 loop is not narrow. Fig 3(c) plot of CR versus solar flux, loops are same as fig 3(a). These hysteresis features have been earlier as due to drift mechanisms which give appositive effects with the changing sign of the solar magnetic field (Jokipii et al (1981); Kota et al (1983)), but there are other superposed effects due to a convection diffusion mechanism, which do not depend on the sign of the solar magnetic field (Dorman (2001), Dorman et al (2001), Dorman et al (2001)). Here, it seems that the hysteresis loops in the plots for CR versus solar indices could be different for different solar indices.

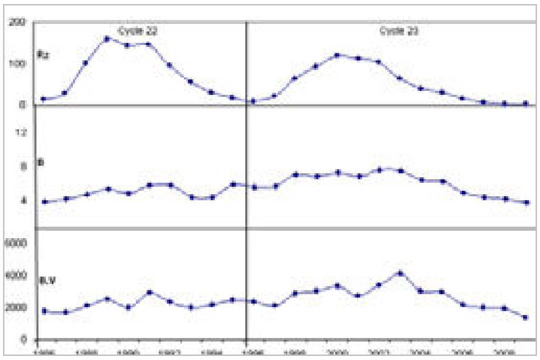


Fig 1(a)

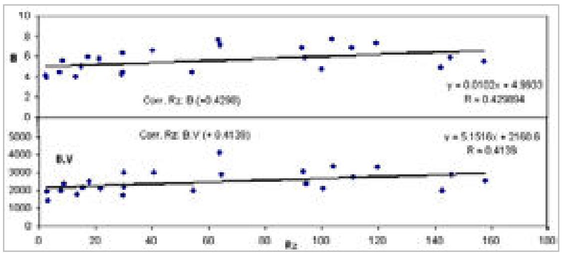


Fig 1 (b)

Fig 1(a): - Plots of the annual values of sunspot number Rz interplanetary magnetic field B & B.V for 1986-2009 (Solar cycle 22-23) & fig 1(b) Plots the cross-correlation running curve of the Rz: B & Rz: B.V. (vertical line mark sunspot minimum peaks are marked with dots).

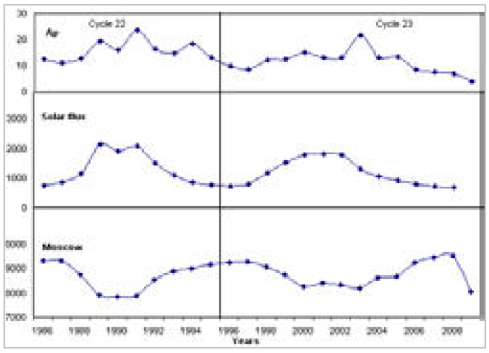


Fig-2 (a)

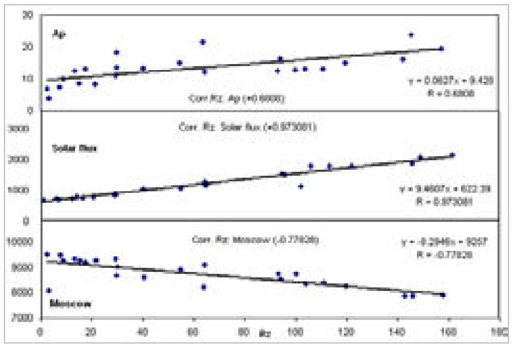


Fig-2 (b)

Fig 2(a): - Plots of the annual values of Ap, Solar flux & CRI (Moscow) for 1986-2009 (Solar cycle 22-23) & fig 2(b) Plots the cross-correlation running curve of the Rz: Ap & Rz: F10 & Rz: CRI.

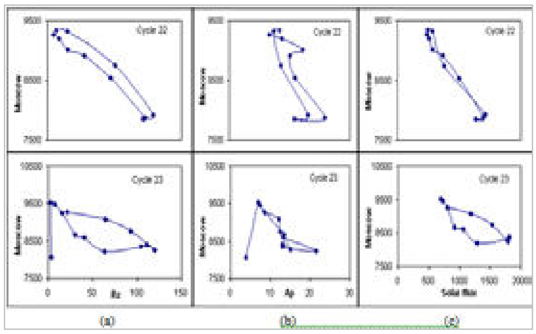


Fig. 3- Hysteresis loops for cycles 22, 23 of CR intensity versus (a) Rz (b) Coronal index (Ap) (c) Solar flux.

In a recent publication, Rybansky et al (2005) presented a re-examination of the previous data of solar coronal index where data errors were detected. When corrected, the new data set does not show the substantial long-term rising tendency of the coronal index reported earlier by Rybansky et al (2001), which was rather embarrassing & unexplained.

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