INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY EDUCATIONAL RESEARCH
ISSN : 2277-7881
VOLUME 1, ISSUE 3, AUG 2012

LONG TERM VARIATIONS OF SOLAR INDICES, GEOMAGNETIC INDICES & COSMIC RAY INTENSITIES

S.G. Singh
Department of Physics
A.P.S. University, Rewa, INDIA

A.K. Saxena
Department of Physics
A.P.S. University, Rewa, INDIA

Sangeet Kumar Tiwari
Department of Physics
Model Science Collage, Rewa, INDIA

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 solar geomagnetic phenomenon & cosmic rays are described briefly as here under.

Solar Phenomena: - The solar disc exhibits a variety of phenomenon, many of which have a direct influence on interplanetary & terrestrial environment. The earliest one observed & studied in the sunspot as an area seen as a dark spot on the solar surface. In 1849 R Wolf of Zurich formulated the general procedure for computing the sunspot number. A daily index of activity (R) is defined as $R = k (10g + s)$, where s is the number of individual spots, g is the number of sunspot groups & k is an observatory factor.

The solar atmosphere is full of plasma & entangled magnetic fields & hence is greatly dominated by magneto-hydrodynamics (MHD) processes. The fields are mostly transient with variable field strengths & closed field lines, but occasionally there are field mergings & formations of neutral points & plasma can escape outwards from the solar surface. Also, there are often open magnetic regions (Coronal holes) of the sun, which transmit magnetic fields to the interplanetary space[1, 2].

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 has a substantial Bz south ward component. The reason for this condition was given by Dungey as follows [3, 4].

As the geomagnetic dipole field is stretched in the monitorial, a neutral sheet is formed with geomagnetic field away from the earth above the neutral sheet &

toward the earth below the neutral sheet. Geomagnetic activity is represented by several indices. The hourly Dst index is obtained from the superposition of data from magnetometer stations near the equator, but so close that the E-region equatorial electrojet dominates the magnetic perturbations seen on the ground. The Dst index is a direct measure of the hourly average of this perturbation.

The Ae index is an auroral electrojet 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[5].

Cosmic rays: - Cosmic rays (CR) are not a terrestrial phenomenon, though our information about them is obtained mainly from detectors (neutron monitors ionization chambers, muon telescopes, studies of geological & biological specimens etc) place on the earth, as also satellites in deep space (Pioneer). There are some CR (Protons, alpha particles & to a much smaller degree element, heavier elements)[6, 7] 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 heliospehere due to the plasma & magnetic field structures from about 0 to 100 AU. There are several neutron monitors presently operative.

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-month running means were evaluated & used. In the present paper, the long-term evaluations of solar, geomagnetic indices & CR modulations are compared for cycles 22, 23 during period 1986 to 2009.

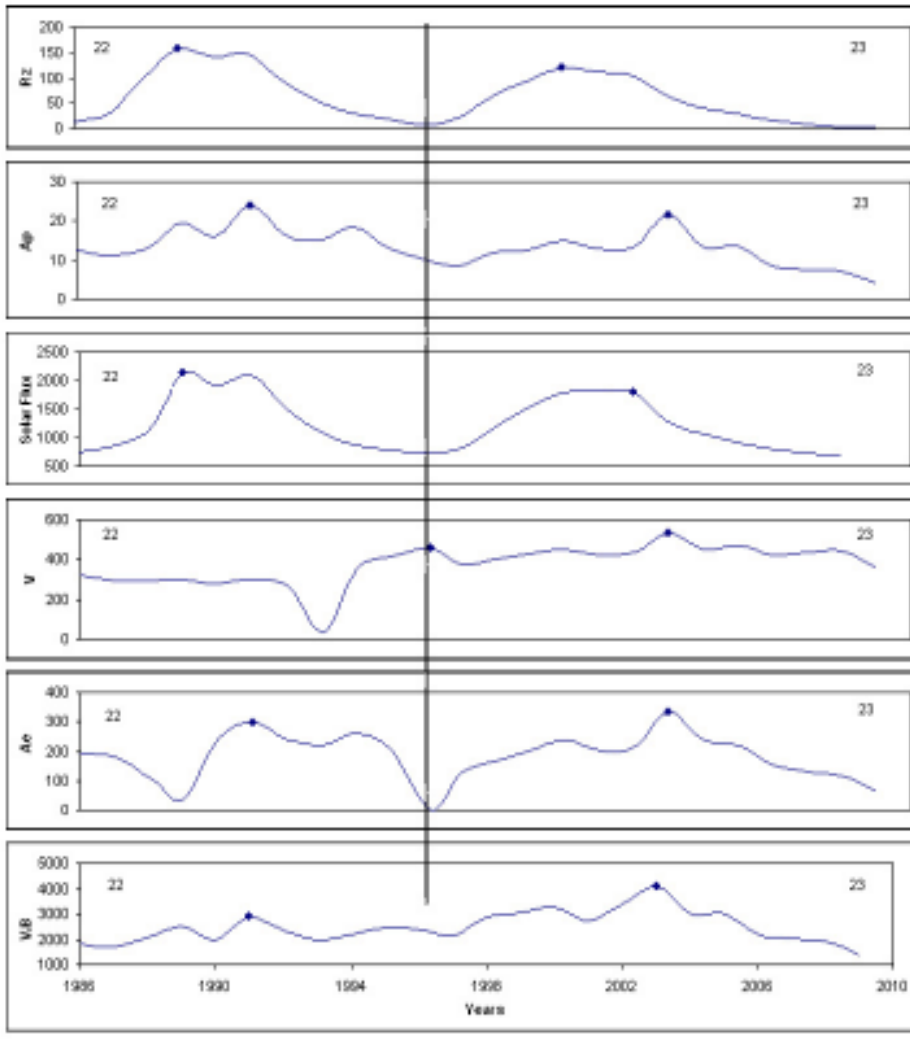

Fig 1 (a): *- Plot of the annual values of the sunspot number (Rz), the geomagnetic index (Ap), Solar flux (2800 MHz), Solar Wind Velocity (V), Electrojet index (Ae) & Electromagnetic field index (V.B) for solar cycle 22 & 23 during period 1986-2009.*

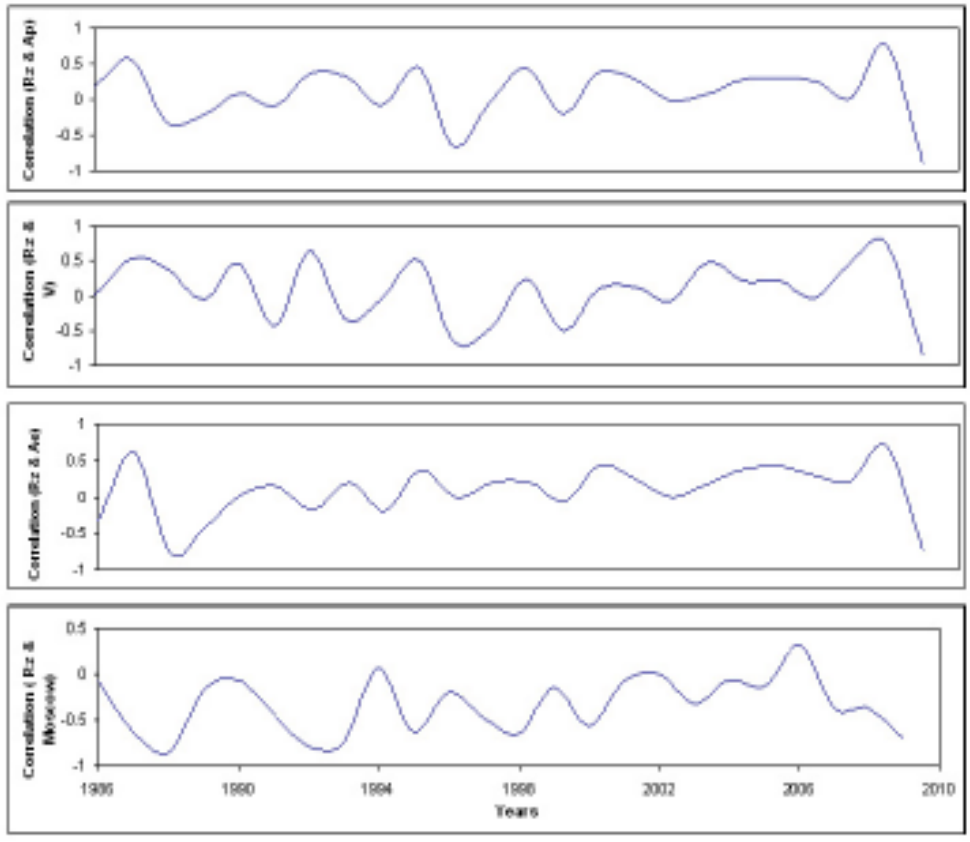

Fig 1 (b): *– 11-years running means of sunspot number (Rz: Ap), (Rz: V), (Rz: Ae) & (Rz: Moscow CI) correlation for solar cycle 22 & 23 during period 1986-2009.*

3. Graph plots: - Fig.1 (a) shows the plot of the annual values of the sunspot number (Rz), Solar wind speed (V = 450 Km/sec), geomagnetic disturbance index (Ap), electrojet index (Ae) & Solar Flux for solar cycle 22 & 23 during 1986 to 2009. Vertical lines mark sunspot minima peaks are indicated by dots. The Ap index shows several peaks spread over 3-5 years around the sunspot peaks. To eliminate the effects of the 11-year cycles & to bring out the long-term changes, 11-year running means where calculated. Fig 1 (b) shows the plots for Rz & V, V.B, Ap, Ae index, Solar Flux & Moscow index whose correlation coefficient is calculated, which found + ve, so direct correlation from between sunspot number to all geomagnetic & solar index. The overall correlations are high (Rz: Ap = 0.68, Rz: Solar Flux = 0.97, Rz: V = -0.24, Rz: V.B = 0.41, Rz: Ae = 0.28, Rz: Moscow = -0.78) indicating that the long-term

changes of these parameters have tracked each other.

Table 1, shows the inter correlations between all these parameters. The following may be noted in table 1.

Table 1: *Inter correlation between different solar & other parameters:*

	Rz	Ap	Ae	V	B.V	Solar flux	Moscow
Rz	1						
Ap	0.68	1					
Ae	0.28	0.62	1				
V	-0.24	-0.20	-0.001	1			
B.V	0.41	0.55	0.53	0.52	1		
Solar flux	0.97	0.65	0.66	-0.16	0.45	1	
Moscow	-0.78	-0.58	-0.29	0.09	-0.40	-0.916	1

Fig 1 (c) shows the reversals occurred several months after the anti-clockwise loop started. Thus, the role of the magnetic field reversals as initiators of the hysterisis loops seems to be dubious. This aspect needs further study.

1. Conclusions & Results: - The long-term variations of the 12 month running means of several solar & geomagnetic parameters during the last sunspot cycles 22 & 23 revealed the following:

(I) During the solar cycles 22, 23 (1986-2009) where as the sunspot numbers Rz, showed smooth but broad maxima for 2-3 years in cycle, the geomagnetic Ap index showed several peaks within 3-5 years around the sunspot maxima with some peaks during the declining phase of the sunspot cycles.

(II) The 11-year running averages showed very good parallelism between Rz & Ap index.

During about 1986-2009, Rz & f.10 (2800 MHz radio emission) showed similar 11-year fluctuations of varying amplitudes (Correlation Rz: f 10 very high + 0.97), but with solar wind velocity correlation Rz: V= -0.24.

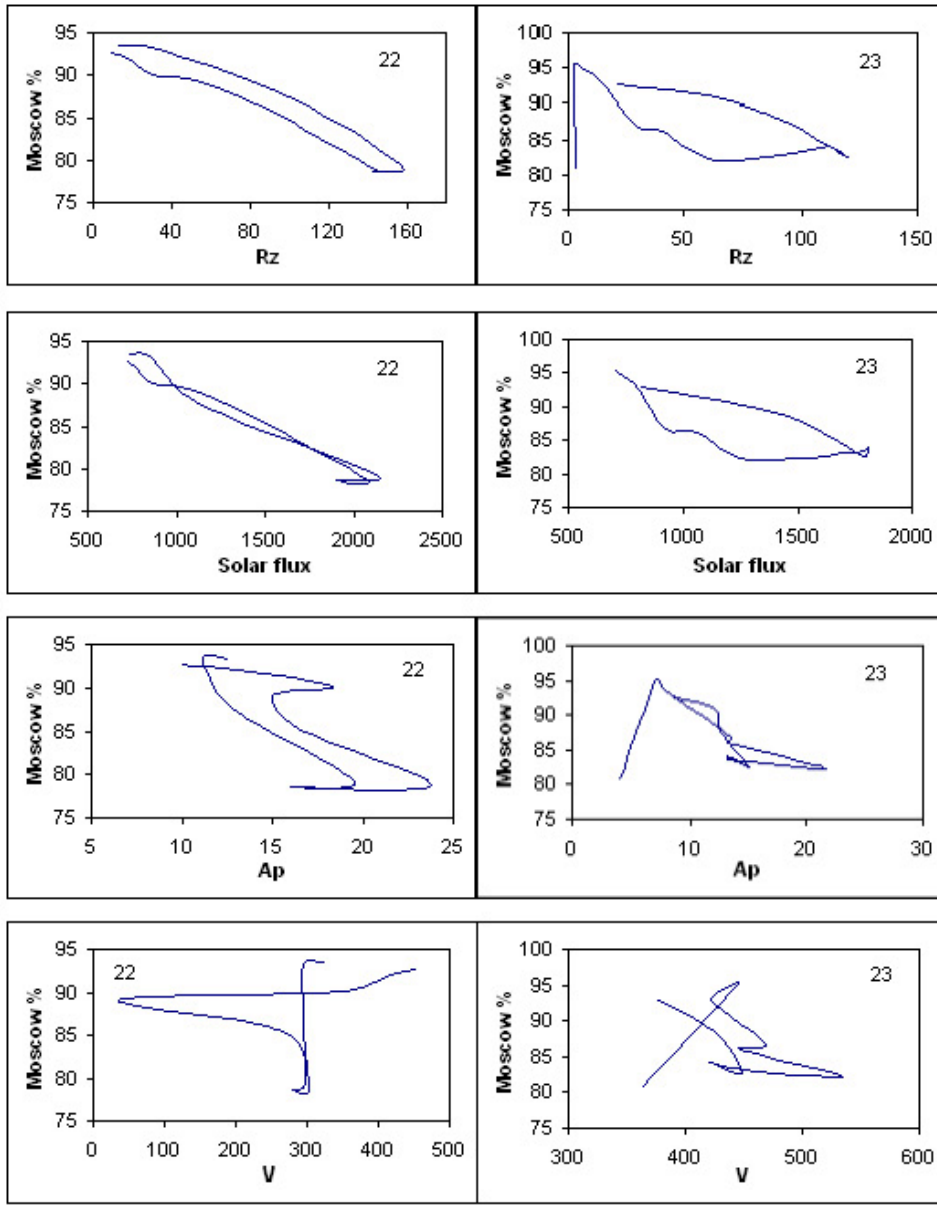

Fig 1 (c); - Hysteresis loops for cycle 22 & 23 of CR intensity (%) Versus Rz, Ap, Solar flux & V.

(I) Cosmic ray neutron monitor intensity at Moscow was well correlated with sunspots as well as f 10 & Ap index (-0.78, -0.91 & -0.58). The first peak tallied with the first sunspot peaks, but the second peak was delayed.

(II) Correlations of cosmic rays (R) with interplanetary electric field B.V were -0.41, which is poor negative. Thus, for long-term Cosmic ray modulation, interplanetary electric fields were the most important.

(III) The geomagnetic disturbance Ap index had a correlation + 0.68 with Rz, + 0.55 with V.B, + 0.62 with Ae, indicating that both high V.B & Ap were necessary for large long-term geomagnetic activity.

In a recent publication, Rybansky et al presented a re-examination of the previous data of geomagnetic disturbance Ap index, when data errors were detected when correlated, the new data set does not show the substantial long-term rising tendency of the Ap index reported earlier by Rybansky et al, which was rather embossing & unexplained.

Acknowledgement:-

Thanks are due to W.M.Wang for supplying data of open magnetic flux privately.

References:-

1. Davis T N & Sugiura M, Auroral electrojet activity index AE & its universal time variations, *J Geophys Res (USA),* 71 (1966) 785.
2. Dungey J W, Interplanetary magnetic field & the auroral zones, *Phys Rev Lett (USA)*, 6 (1961) 47.
3. Forbush S E, World-wide cosmic ray variations, 1937-1952, *J Geophys Res (USA),* 59 (1954) 525.
4. Rybansky M, Rusin V, Minarovjech M & Klocok L, Re-examination of the coronal index of solar activity, *J Geophys Res (USA),* 110 (2005), (A08/06) doi: 10.1029/2005JA011146.
5. Rybansky M, Rusin V & Minarovjech M, Coronal index of solar activity- Solar-terrestrial Research, *Space Sci Rev (USA),* 95 (2001) 227.
6. Sarabhi V & Kane R P, World-wide effects of continuous emission of cosmic rays from the Sun, Phys Rev (USA), 90 (1953) 204.
7. Simpson J A, Cosmic –Radiation Intensity- Time Variations & their orgin. III – The origin of 27-Day Variations. *Phys Rev (USA),* 94 (1954) 426.

8. Sugiura M, Hourly values of equatorial Dst for IGY, pp. 945-948, in *Annals of the International Geophysical Year*, Vol. 35 (Pergamon Press, Oxford), 1964.

9. Wang Y M, Lean l & Sheeley N R (Jr), The long-term variation of the Sun's open magnetic flux, *Geophys Res Lett (USA)*, 27 (2000) 505.

10. Wang Y M & Sheeley N R, Sunspot activity & the long-term variation of the Sun's open magnetic flux, *Geophys Res Lett (USA),* 107 (2002), (A10): 10.1029/2001JA005000.