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Seasonal Influence of Solar Activity on Cosmic Rays

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ABSTRACT

Cosmic ray intensity data and values of solar modulation potential ∅ (solar modulation parameter for cosmic rays) of ten (10) years, for the month of June (typical month in the rainy season) and December (typical month in the dry season) was obtained. The cosmic ray intensity of each year was compared with the same ten (10) years values of solar modulation potential ∅ using a statistical tool, for the two typical months. From the result, interpretation and understanding of the statistical behavior, shows the relationship of solar activities with cosmic rays. There is a forbush decrease, sudden decrease in cosmic ray intensity immediately the modulation of solar activity falls in the year 2009.This means that changes in the solar activity or solar modulation can cause changes in cosmic ray production in both rainy and dry season; and it gives impression that cosmic rays can come from extrasolar astrophysical sources and/or the sun.

INTRODUCTION

Cosmic Rays are high-energy subatomic particles from space that continuously bombared the earth's atmosphere. Cosmic rays can travel at nearly the speed of light and can carry enormous energy. Some lower particles come from the sun but most cosmic rays are thought to originate outside the solar system, with many coming from within our Milky Way Galaxy, and a few arriving from other galaxies, (James, 1998). This solar system is bathed by the sun's pulsar core, (Peter Toth, 1977; and V. A. Kotov, 1996). Cosmic rays are mainly positive ions (protons and atomic nuclei), and thus, a form of ionizing radiation.

The most energetic cosmic rays are thought to originate in the proccesses that spawn astrophysical neutrinos. Since cosmic rays are charged, they travel curved paths, shaped by magnectic fields, through the universe. This makes their origin difficult to trace. Studying neutrinos (which is one of the fundamental particles that make up the universe) is a way of understanding the origin of cosmic rays. Though, its origin is assumed to be a supernova from the corpse of a normal star, which is the neutron star. The neutron star is ultra dense, a bloated, dying star with a surprise in its core. This forms a long-sought cosmic oddity (Alexandra Witze, 2014).

Billions of cosmic rays strike atoms in Earth's atmosphere every year breaking the nuclei apart and creating showers of lower energy particles that can reach Earth's surface.When cosmic ray particles entre the Earth's atmosphere, they collide with molecules mainly oxygen and Nitrogen to produce a cascade of lighter particles, a so-called air shower.

Thus, cosmic ray shower are produced by a high energy proton of cosmic ray origin striking an atmospheric molecule. The number of particles created in an air shower event can reach in the billions, depending on the energy and chemical environment (i.e. atmospheric condition) of the incoming cosmic ray particles (Multhauf, 2002).

The galactic cosmic rays (CRs) are charged particles (comprising mostly protons, ~10% He nuclei and ~1% other elements; electrons comprise ~1%) with energies from about 1 MeV (1 MeV = 1.6 $X10^{-13}$ J) up to at least 5 $X10^{13}$ MeV (8 J) (Dorman, 2004). Low-energy particles are just absorbed in the atmosphere, but those with energies above some 1000 MeV generate new particles through interactions with atomic nuclei in air. Energetic cosmic rays initiate nuclear-electromagnetic cascades in the atmosphere, causing a maximum in cosmic ray intensity at the altitude of 15–26 km depending on latitude and solar activity level, the so-called Pfotzer maximum. The galactic CRs arrive at the Earth constantly but their intensity is modulated by the 11-year cycle of solar activity with the opposite phase i.e. the higher solar activity, the lower the intensity of galactic CRs. Solar CRs (also called solar energetic particles, SEP) are particles accelerated during the explosive energy release at the Sun and by acceleration processes in the interplanetary space (Lario and Simnett 2004).

Cosmic rays enter the atmosphere sporadically, with higher probability during periods of high solar activity. Due to their steep energy spectrum, only a small fraction of solar energetic particles (SEPs) with energy around several GeV generates cascades in the atmosphere sufficiently to allow neutron monitors to record a so-called ground-level enhancement, GLE. Another energetic particle population is that of magnetospheric electrons which can precipitate into the atmosphere. They are absorbed in the upper atmosphere, but the X-rays produced by these electrons can penetrate down to the altitude of about 20 km. Electron precipitation occurs more often during the declining phase of the 11-year solar cycle. The geomagnetic field determines which particles arrive at the Earth at different latitudes, i.e. the geomagnetic field acts as a charged particle discriminator (Miroshnichenko, 2004).

MATERAILS &METHODES:

The flow rate of cosmic rays incident on the earth's atmosphere is governed by the sun's solar wind. This solar wind is an expanding magnetized plasma generated by the sun, which has effect on the incoming particles. The amount of this wind is not constant due to changes in the solar activities. This work is limited to the use of cosmic ray data and values of solar modulation potential for a typical month in the rainy and dry season to investigate the rate of influence of solar activity on cosmic rays. Cosmic ray intensity counts for June (typical month in rainy season) and December (typical month in dry season) were downloaded from Mexico City Cosmic Ray Observatory. This CR data for June and December were downloaded for ten (10) years, i.e. from year 2000 to 2009. After noting the total in each year, the logarithm of each value was calculated and also recorded.

The cosmic ray intensity of each year was compared with the ten (10) years reconstructed values of solar modulation potential $\emptyset$ (solar modulation parameter for cosmic rays), using a statistical tool, for the two typical months (June for rainy season and December for dry season). The information was represented in a graph, so as to understand the behavior of the amplitudes of both cosmic ray intensity in each year and the ten (10) years reconstructed values of solar modulation potential $\emptyset$.

RESULT AND DISCUSSION

The tables and figures shown below describe the observations made and results during the course of the experiment.

Total of Solar Modulation Potential ∅ and Cosmic Ray Intensity Counts for the Typical Month in Rainy and Dry Season

Table 1: Total of Solar Modulation Potential ∅ and Cosmic Ray Intensity Counts for the Typical Month in Rainy and Dry Season.

Total of Solar Modulation Potential ∅					**Total of cosmic ray intensity counts**		
Year	Total in June	Total in December			Year	Total in June	Total in December
2000	1073	960			2000	19501184680000	18409385000000
2001	832	833			2001	56,683,834	61,039,151
2002	863	986			2002	60,437,517	19836977550000
2003	1067	930			2003	18295162690000	56,376,930
2004	636	615			2004	56,874,045	58,212,299
2005	610	540			2005	56,158,072	58,935,819
2006	423	467			2006	56,257,906	56,231,807
2007	354	340			2007	54,949,215	54,273,632
2008	367	309			2008	43,962,077	54,482,777
2009	270	255			2009	26,097,078	53,446,370

Logarithm of Solar Modulation Potential ∅ and Cosmic Ray Intensity Counts for the Typical Month in Rainy and Dry Season

For easy plotting and use of the ambiguous numbers recorded in table 1 above, logarithm of the values were taken, thus:

Table 2: Logarithm of Solar Modulation Potential ∅ and Cosmic Ray Intensity Counts for the Typical Month in Rainy and Dry Season

Logarithm of Solar Modulation Potential ∅					**Logarithm of cosmic ray intensity counts**		
Year	Log of solar modulation potential in June	Log of solar modulation potential in December			Year	Log of CR intensity in June	Log of CR intensity in December
2000	3.03	2.98			2000	13.29	13.27
2001	2.92	2.92			2001	7.75	7.79
2002	2.94	2.99			2002	7.78	13.30
2003	3.03	2.97			2003	13.26	7.75
2004	2.80	2.79			2004	7.75	7.77
2005	2.79	2.73			2005	7.75	7.77
2006	2.63	2.67			2006	7.75	7.75
2007	2.55	2.53			2007	7.74	7.73
2008	2.56	2.49			2008	7.64	7.74
2009	2.43	2.41			2009	7.42	7.73

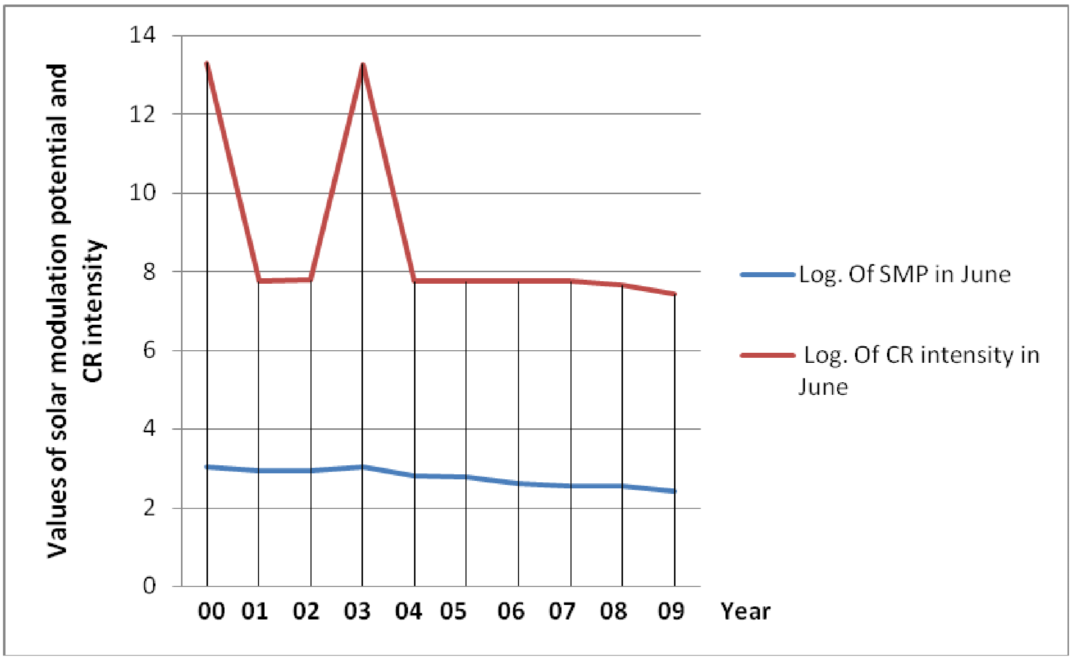

Figure 1: Graph of Logarithm of Solar Modulation Potential ∅ and Cosmic Ray Intensity Counts for a Typical Month in Rainy season (Month of June)

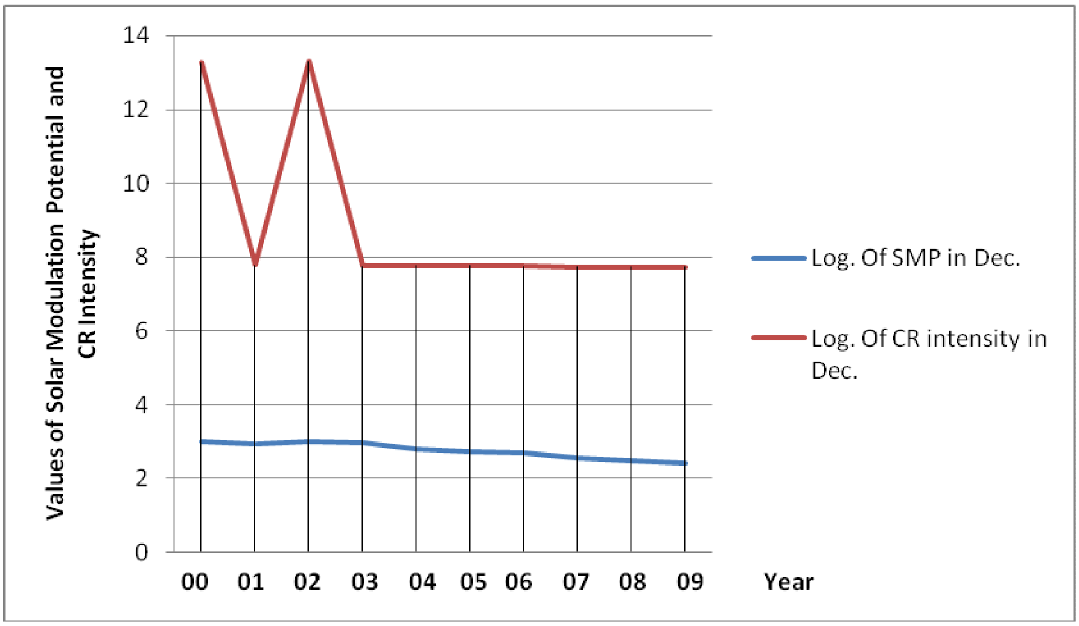

Figure 2: Graph of Logarithm of Solar Modulation Potential ∅ and Cosmic Ray Intensity Counts for a Typical Month in dry season (Month of December)

CONCLUSION

From the interpretation and understanding of the statistical behavior of the Cosmic ray intensity counts and the values of solar modulation potential $\emptyset$ of each year: a closer look into figure 1 and 2 entails that cosmic ray intensity tries to rise whenever solar activity is high. In the month of June, for the ten years observed (Figure 1), the amplitude of solar events peaked in the year 2000 which corresponded to the rise in cosmic ray intensity within that year. Peak value, 3.03 recorded in June 2000 as solar modulation potential corresponded to the peak value, 13.29 of cosmic ray intensity measured (Table 1).

In 2000, the peak value, 3.03 recorded in June as solar modulation potential corresponded to the peak value, 13.29 of cosmic ray intensity measured (Table 1). Also, In the month of December, for the ten years observed (Figure 2), the amplitude of solar events peaked in the year 2002 which corresponded to the rise in cosmic ray intensity within that year. Peak value, 2.99 recorded in December 2002 as solar modulation potential corresponded to the peak value, 13.30 of cosmic ray intensity measured (Table 2). There is a forbush decrease, (that is, sudden decrease in cosmic ray intensity) immediately the modulation of solar activity falls in the year 2009 (Figure 2). And something peculiar occurred for the ten (10) years observed, both solar modulation/events and cosmic ray intensity were noticed to be minimum in the month of June and December in 2009 compared to other years, (Table 2).

This observation shows that solar activity has the tendency of stimulating the occurrence of cosmic rays in both rainy and dry season, which might be traced as its core origin and source. This gives impression that cosmic rays can come from extrasolar astrophysical sources and/or the sun. This finding agreed with the work of Kumar R. M. *et al*. (1996), which their work revealed that the amplitude of the diurnal anisotropy of cosmic rays using the ground based Deep River neutron monitor data is well correlated with the solar cycle for the period 1981 to 1994.

In conclusion, the influence of solar modulation on cosmic rays in rainy and dry season reveals that, cosmic rays entering the atmophere are being affected by solar activity. Hence, they vary with the varying solar activity. This is in agreement with Henrik Svensmark and Nigel Calder, (2004), that the rate of cosmic ray reaching the earth varries based on electromagnectic flunctuation on the sun's surface, and earth's temperature. In a nutshell, this fact further revealed that, Cosmic rays might come from extrasolar astrophysical sources and/or the sun .

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