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Galactic and Solar Cosmic Rays on Ionization in the Atmosphere

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Abstract: A brief review of Galactic and Solar Cosmic Rays (GSCRs) in the Earth's atmosphere is presented. The results of the characterizations of the Galactic Cosmic Rays (GCRs) and Solar Cosmic Rays(SCRs) against time/days shows significant variations. Most of the variations in the months showed that high GCRs correspond to low SCRs. In the contrary, high GCRs and SCRs were recorded in the months of August and November, 2006. In addition, the anti-correlation coefficient, r between GCRs and SCRs, ranges from -0.001 to -0.400which shows that the events originates from different sources. The low level of these results indicates that other solar activities such as sunspot, coronal mass ejection and solar wind directly enter the Earth's atmosphere.

Key words: Cosmic Rays · Solar flare · Ionization and Solar Activity

INTRODUCTION

The role of Galactic and Solar Cosmic Rays (GSCRs) in the earth's atmosphere to bread ionization and nuclear-electromagnetic cascade which enhance hazard to astronauts, communication, human DNA and cells cannot be over emphasized.The main origin of these rays are from our solar system, which sun is the driving source were sporadic particlesare released into space during solar flares, which are known as Solar Cosmic Rays (SCRs), they are high energy protons and from outside our solar systemanother high energy proton and heavy ions originate, which are known as Galactic Cosmic Rays (GCRs).The composition of this GSCRs primariesare proton (~ 10%) and electrons (~1%). The contribution of this GSCRs is to generate ionizing radiation loses due to ionization and nuclear-electromagnetic cascade in theearth'satmospheric.The increase rate of ionization that takes place in the earth's atmosphere isthe most dangerous emissions from this radiations, including protons, x- Rays and ultraviolent radiations (UV). In spite of these, they continuous monitoring of the Earth's atmospheric ionization remains unlimited for the lives astronomers, astrophysics and space scientist globally [1].

The D-region of the Earth's atmosphere ranging from 50 to 80km above the sea level, create an independent galactic charged particles interaction [2, 3 and 4]. Then, the particles ionize the entire earth's atmosphere up to 100km. Furthermore, above 100km altitude, the contributions of the electromagnetic, x-rays and ultraviolent radiation dominates [4]. Based on these, the particles influences the ionization, chemical and electrical conditions in the atmosphere between 5 - 100km. Contrary, near Earth's surface (between 0 - 5km), an additional source of ionization occurs via natural radioactivity of the soil may introduce radon gas emission in some regions [5].

Moreover, great authors have investigated the atmospheric ionization by GSCRs [6, 7, 8, 9 and 4]. They also studied nuclear-electromagnetic cascade [11]. The other effects of GSCR sin the Earth's atmosphere are globally debated [12 and 13]. The effect of high energetic charged galactic particles has been investigated [14]. The high galactic cosmic rays and solar rays (such as solar flare) are combined and used in this work. This paper will be focused on the statistical review of GSCRs in the Earth's atmosphere as it mainly influences ionization.

Galactic Cosmic Rays: Galactic Cosmic Rays (GCRs) are high energetic charged particles originated from galaxies outside our solar system and interplanetary space [15]. The GCRs that enters the Earth's atmosphere are classified as primary cosmic rays [16]. The major dominated composition of these primary cosmic rays is proton (~ 10%) while the minor composition are electrons

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(~1%). The scientific community are interested in the effects of ionization and nuclear-electromagnetic cascade due to space radiation on the Earth's atmosphere.

The ionization due to galactic cosmic rays (GCRs) is always present in the atmosphere and it changes with the 11-year solar cycle due to the solar modulation. Primary cosmic rays initiate a nucleonic-electromagnetic cascade in the atmosphere, with the main energy losses at altitudes below 30 km resulting in ionization, dissociation and excitation of molecules [11].

In addition, the impact of cosmic rays on the ozone layer and formation of clouds in the troposphere becomes a new interested area for study. It is important to know precisely that the cosmic ray induced ionization (CRII) and its variations with the location, time, solar and geomagnetic activity. They also affect the ozone creation and depletion which the chemical process in the Earth's stratosphere [17].

Galactic Solar Radiation: In the same way, sporadic solar flare particles have been reported to have a direct effect on the Earth's atmosphere [18]. The intensity of the solar flare radiation does travel in 8 – 10minutes interval to the Earth's surface. They are the most sudden, rapid, intense variation in brightness and energetic explosions in the solar system. A solar flare occurs when magnetic energy ranging from 10^{27}ergs/s to 10^{32} erg/s that has built up in the solar atmosphere is suddenly released from the corona of the sun [14]. The radiation is emitted virtually across the entire electromagnetic spectrum from radio wave (at long wavelength end) through optical emission to x-rays and gamma-rays (at the short wavelength end). The amount of energy released is the equivalent of millions of hundred megaton hydrogen bombs exploding at the same time. The first solar flare recorded in astronomical literatures was on September 1, 1859. Two scientists, Richard C. Carrington and Richard Hodgson, were independently observing sunspot when they viewed a large flare in white light. The compositions of solar flare are protons, electron and heavy nuclei. When they penetrate the Earth's atmosphere, they can cause ionization and expand the Earth's upper atmosphere. Solar flares occur at solar minimum and at solar maximum every day. The number of solar flare in the Earth's atmosphere increases with decreasing intensity to the limit of the sensitivity of the instrument that has been used to detect them. The statistics of flares that were detected from 1980 - 1989 with the Hard x- rays Burst Spectrometer on the Solar Maximum Mission show that flares occurred at an average rate of ~1 per day at solar minimum. At solar maximum, the average rate was as high as 20 per day (average over a 6 months interval). So the rate at solar maximum is roughly a factor of 10 greater than solar minimum. It is important to realize, however, that the solar rate is very irregular. They can be long period of time at solar minimum when no detectable flare occur. Then, a large active region can form and produce many flares in just a few days [14].

Modeling of Atmospheric Ionization: Balloons [19, 20, 21, 22 and 23], Rockets [24] and Spacecrafts [25], are initially used in observing the ionization rates and level in the Earth's atmosphere at different latitude. Currently, numerous ground base observatory centers/networks and teams of astrophysics have been empowered to observe and measure the atmospheric mechanism and ionization process [26]. Many countries are observing and collecting data from activities in the atmosphere due to GCRs and SCRs. Most of these data are available for use to study the earth's atmosphere from observatory centers.

Various methods have been applied to interpret these observations and measurements of ionization and nuclear-electromagnetic cascades effects in the Earth's atmosphere. These methods are as follows: the empirical profiles of the ionization effects until 100 km, the quantitative model of the atmospheric ionization [27, 28 and 29], the analytical approximation model of the cosmic ray ionization losses [30, 31 and 32], the Monte Carlo CORSIKA (COsmic Ray Simulations for KAscade) for modeling the atmospheric nucleonic-electromagnetic cascade, ionization and electrical parameters in the planetary atmosphere [33, 34, 35, 36 and 4].

Further, convincing works of COST-724 action (2003–2007) gave their interpretation as follows: the numerical GCRs ionization models, Sofia model of analytical approximation of the direct ionization, CORSIKA Monte-Carlo package extended by FLUKA package to simulate the low-energy nuclear interactions [32, 38, 39], Oulu CRAC (Cosmic Ray Atmospheric Cascade) model for direct ionization of GCR particles [40 and 41), Bern model (ATMOCOSMICS/ PLANETOCOSMICS code) using the GEANT-4 Monte-Carlo simulation package [42, 43 and 44], CORSIKA and GEANT-4 code for the cascade evolution in the atmosphere, simulating the interactions and decays of various nuclei, hadrons, muons, electrons and photons [45].

Data and Result Analysis: The data for GCRs and SCRs were from Solar Soft Data Centre (SSDC) and Space Physics Interactive Data Resources (SPIDR) of 2006.

These measurements were grouped in three months of a minimum of 720 hours interval to cover the 12- months of events and they are arranged in a tabular form on excel spread sheet. On the sheet, the data were treated with threshold values for GCR and SCR measurements in each event. The variations in each of the group of GCRs and SCRs (measured in counts) against time (measured in hours) are shown in a graphical form in figs. 1 to 4.

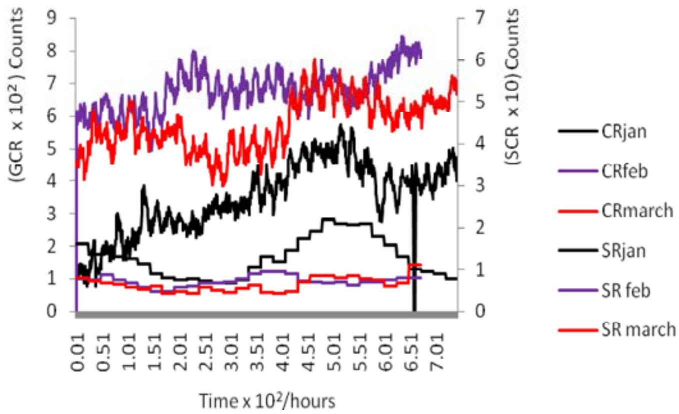

Fig. 1: Variations of Galactic Cosmic Rays (GCRs) and Solar Cosmic Rays (SCRs) against Time/hours. The colour keys for GCRs and SCRs: the month of January is black; the month of February is blue and the month of Marchred.

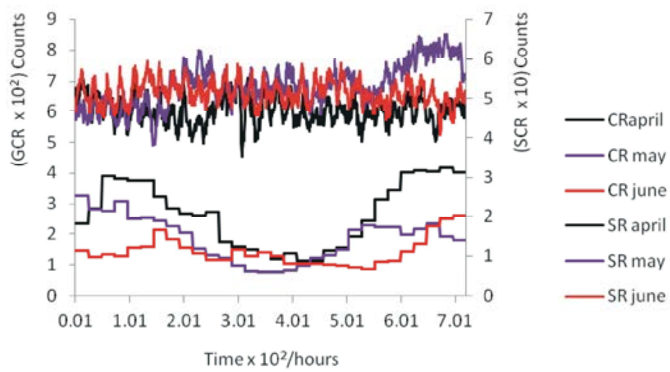

Fig. 2: Variations of Galactic Cosmic Rays (GCRs) and Solar Cosmic Rays (SCRs) against Time/hours. The colour keys for GCRs and SCRs: the month ofApril is black;the month ofMay is blue andthe month of June is red.

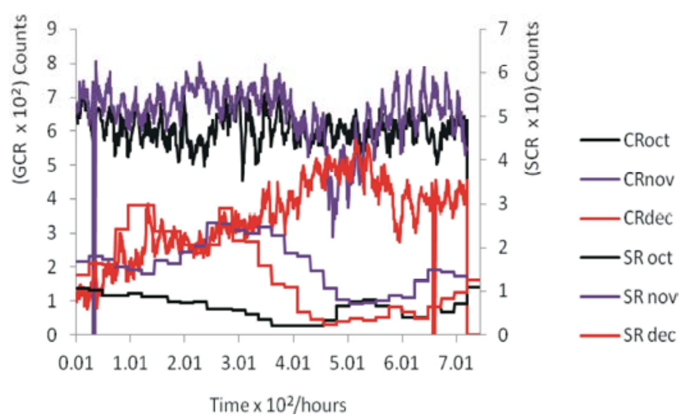

Fig. 3: Variations of Galactic Cosmic Rays (GCRs) and Solar Cosmic Rays (SCRs) against Time/hours. The colour keys for GCRs and SCRs: the month of July is black; the month of August is blue and the month of September is red.

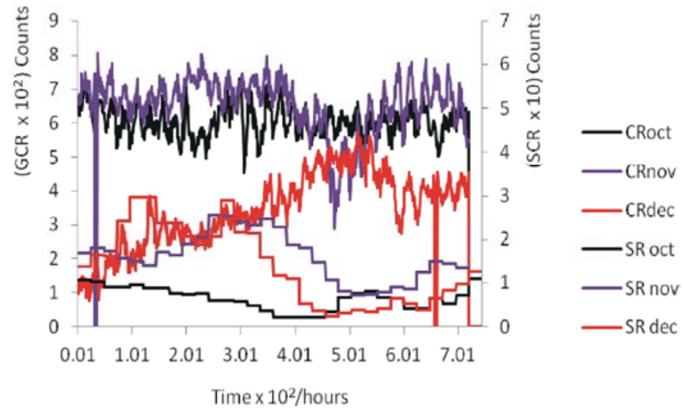

Fig. 4: Variations of Galactic Cosmic Rays (GCRs) and Solar Cosmic Rays (SCRs) against Time/hours. The colour keys for GCRs and SCRs: the month of October is black; the month of November is blue and the month of December is red.

In addition to the above variations, a correlation analysis of excel program were carried out in order to ascertain the level of relationship between GCRs and SCRs. The results of the correlation coefficient, r, ranges from -0.001 to -0.400.

DISCUSSION

The results of the statistical study of the two events (i.e. GCRs and SCRs) showed significant characterization. The GCRs showed a continuous variation with time while the SCR showed a slight block variation with time in all the 8,808 hourly events in 2006. These variations are in agreement with some authors [34 and 23]. In the result no GCRs detection was observed in some months. On the other side of the events, solar flare showed high significant variations in all the months. In comparism on the variation between GCRs and SCRs, fig.1 showed that the event of GCRs is high while the SCRs is low in the month of February; fig.2 showed that the GCRs is high while the SCRs is low in the month of May; fig.3 and fig.4 showed that the GCRs and SCRs are high in the months of August and November respectively. The correlation coefficients, r between GCRs and SCRs are anti-correlation, ranging from -0.001 to -0.400. The anti-correlation coefficient is in agreement with other authors [1 and 14].

In conclusions, the observatory stations exploring the earth's atmosphere records measurements of GCRs and SCRs on hourly events for the year, 2006. The interpretation of these measurements is being investigated. The graphical analysis showed that they are presents of GCRs and SCRs in the earth's atmosphere. The hourly variation of GCRs indicates a continuous arrival of events with variation in amplitude, except when arrivals are not recorded. This may be attributed to the instrumental rigidity (GV). But, the hourly variation of SCRs is constantly continuous for some seconds, their amplitude also varies. Finally, the anti-correlation coefficient found in these results shows that the events originate from different sources.

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