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Investigation of the Relationship between Cosmic Rays and Cloud Cover

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Abstract: *This study investigates the relationship between cosmic rays and cloud cover; in order to ascertain the interdependence of each on other. Global cloud cover data for high, middle and low clouds from 1983 – 2009 were obtained from the International Satellite Cloud Climatology Project (ISCCP)-D2 dataset. Pressure corrected hourly cosmic rays data from 1983 – 2009 was obtained from Thule Neutron Monitor Station (76.5^0 N, 68.5^o W, 26.0 m with geomagnetic cut-off rigidity of 1.0 GV). Descriptive analysis was employed in analyzing the data. These analyses were employed using MATLAB. Results reveal that, low cloud covers have good correlation with cosmic rays from 1983 – 1995; however, this relationship weakened after 1995 until 2009. On the other hand, middle and high clouds were poorly correlated with cosmic rays from 1983 – 2001, but the relationship were very significant from 2002 – 2009. This depicts that, the quiet period in recent solar cycles accompanied by high level of cosmic rays was associated with decrease in low cloud. On the contrary, middle and high clouds have been on the increase in this quiet period of recent solar cycles. This result contradicts the previous findings by many researchers who reported that cosmic rays were highly correlated with low cloud covers in contrast to middle and high clouds. We hereby suggested that further works need to be carried out on the relationship of cosmic rays with cloud cover; since cosmic rays could provide the link whereby solar activity affects the global climate.*

Keywords: *Cosmic rays, cloud cover, correlation, climate, relationship, solar activity*.

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I. Introduction

It is a well known fact that both the flux and the energy spectrum of cosmic rays are modulated by the interplanetary magnetic field, which in turn is strongly influenced by the magnetic field of the Sun. According to [1], it is feasible that galactic cosmic rays (GCRs) could provide the link whereby solar activity affects the global climate.

It has been proposed in the GCR-cloud hypothesis that cosmic rays influences cloud formation. The “ion-aerosol clear-air” hypothesis suggests that increase in cosmic rays cause increase in new-particle formation, cloud condensation nuclei concentration and cloud cover [2]. However, poor understanding of the physical mechanisms relating cosmic rays to clouds have been the major challenge in establishing the relationship between cosmic rays and clouds [2].

Over the years, there has been controversy about the relationship between cosmic rays and cloud formation and their possible link to climate change. Some researchers noted that cosmic rays could affect the Earth’s climate system through cloud formation or otherwise. [3], first reported the relationship between galactic cosmic rays (GCRs) and satellite-observed total global cloud cover. Since then, there has been growing interest in the possible importance of this relationship in the science of climate change. According to [4], there are two potential galactic-cloud-climate pathways: (i) galactic cosmic rays enhance aerosol nucleation rates and cloud condensation nuclei concentrations through ionization of gases. These changes modify cloud formation, cloud amount, and subsequently, the shortwave radiation reaching the surface. (ii) galactic cosmic rays impact precipitation through the modification of near-cloud electrification with subsequent impact on the freezing of super cooled liquid droplets.

[3], noted that cosmic rays promote the formation of terrestrial clouds through ionization of particles in the troposphere, but they were unable to give the actual microphysical explanation of such observation. [5], was able to provide the physical processes involved in the GCR-cloud hypothesis and also the observation that GCR greatly influence low altitude clouds than high altitude clouds. In line with these observations; [6] and [5], separately obtained a high correlation between GCR and low clouds based on infrared (IR) measurements of the International Satellite Cloud Climatology Project (ISCCP)-D2 dataset, in contrast to middle and high clouds.

[7], noted that variations of cosmic rays corresponds very well with variations of cloudiness. When cosmic rays decrease, planetary cloudiness decreases leading to increase in solar energy input in the lower atmosphere and increase in planetary surface temperature. He concluded that low altitude clouds have high positive correlation with cosmic rays than high and middle altitude clouds.

Recently, it has been observed that there exist controversy on the relationship between cosmic rays and cloudiness as the previous findings are contrasting with the current findings. For example; [8], reported from the re-evaluation of the hypothesis of coupling between GCRs, clouds and climate that the correlation between IR-low cloud cover and cosmic rays were well correlated between 1983 and 1993, but became poorer after 1993 as the cosmic ray flux continues to increase and then flatten out from 1997 – 1998, while the IR-low cloud cover gradually decreases after 1993 until 1998. They therefore concluded that due to a falling correlation between IR-low cloud cover and cosmic rays after 1993, the statistical significance of the correlation was low.

Similarly, using IR-low cloud cover from ISCCP –D2 dataset, [1] reported that despise the previous finding that total cloud cover and cosmic ray fluxes were correlated, their result shows that only low-level cloud follows solar activity over the full period, 1983 – 1994. They concluded that after 1994, the correlation did not confirm to the previous finding.

[9], observed that the recent extended quiet period between solar cycles 23 and 24 has led to a record of high level of GCRs, which in turn has been accompanied by a record of low level of lower-troposphere global cloudiness. This disagrees with the previous findings. They therefore suggested that further research on the GCR-cloud hypothesis and its possible role in the science of climate change should be carried out. Based on this controversy, there is need for further research works to be carried out so as to settle this controversy which this work hopes to proffer solution to.

II. Sources Of Data

The monthly mean global cloud cover data for high, middle and low clouds based on infrared radiation (IR) measurement were obtained from the International Satellite Cloud Climatology Project (ISCCP)-D2 datasets, available at isccp.giss.nasa.gov/pub/data/D2CLOUDTYPES. The data spanned for 27 years (1983 – 2009). The pressure corrected hourly cosmic ray neutron monitor data were obtained from Thule (76.5^0 N, 68.5^o W, 26.0 m) with geomagnetic cut-off rigidity of 1.0 GV. The data is available at http://www.bartol.udel.edu/~neutron. The Count rates are in units of hundreds of counts per hour. The data span for 27 years (1983 – 2009).

III. Method Of Data Analysis

Descriptive analysis was employed in analyzing the cloud covers and cosmic rays data; this was carried out using MATLAB. The procedure involved is as follows:

i. The average of the monthly mean global cloud cover ($\overline{M_{cc}}$) for high, middle and low cloud cover from 1983 – 2009 were computed from the monthly values (M_{cc}) using the equations [10]:

$$\overline{M_{cc}} = \frac{1}{n}\sum_{i=1}^{n} M_{cc\,i} \qquad (1)$$

Where n is the number of days in a month.

ii. The annual mean global cloud cover ($\bar{A}$) for high, middle and low cloud cover from 1983 – 2009 were calculated from equation 2.

$$\bar{A} = \frac{1}{12}\sum_{i=1}^{12} \overline{M_{cc\,i}} \qquad (2)$$

iii. The daily pressure corrected cosmic rays ($\mathrm{CR_D}$) was computed from the hourly values (CR_{H}) using equations 3.

$$\mathrm{CR_D} = \frac{1}{24}\sum_{\mathrm{i=1}}^{24} CR_{\mathrm{H_i}} \qquad (3)$$

iv. Monthly mean pressure corrected cosmic rays ($\mathrm{CR_M}$) was calculated using the expression:

$$\mathrm{CR_M} = \frac{1}{\mathrm{n}}\sum_{\mathrm{i=1}}^{\mathrm{n}} CR_{\mathrm{D_i}} \qquad (4)$$

Where n is the number of days in a month

v. Finally, the annual mean pressure corrected cosmic rays ($\mathrm{CR_A}$) was computed from equation 5.

$$\mathrm{CR_A} = \frac{1}{12}\sum_{\mathrm{i=1}}^{12} CR_{\mathrm{M_i}} \qquad (5)$$

IV. Results And DISCUSION

The variation trends of annual mean galactic cosmic rays (GCR) with global high cloud cover (HI), middle cloud cover (MI) and low cloud cover (LO) from 1983 – 2009 are presented in Figures 1 – 3 respectively.

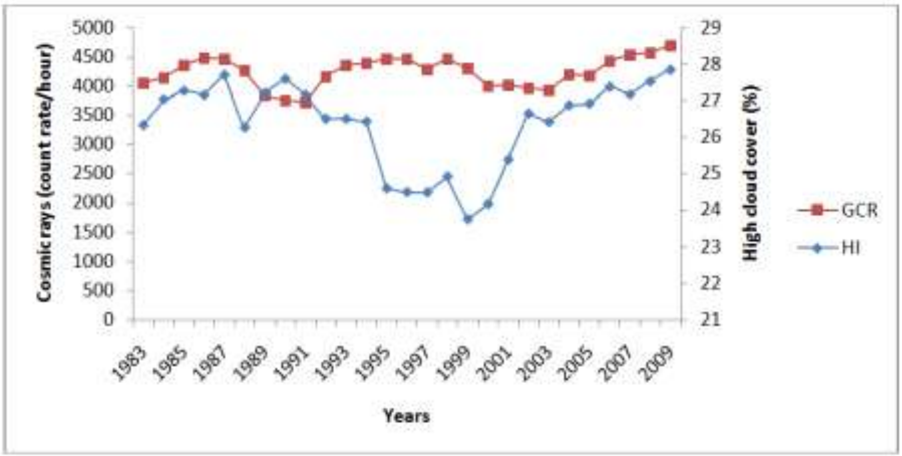

Figure 1: Variation trends of cosmic rays with high cloud cover from 1983 – 2009

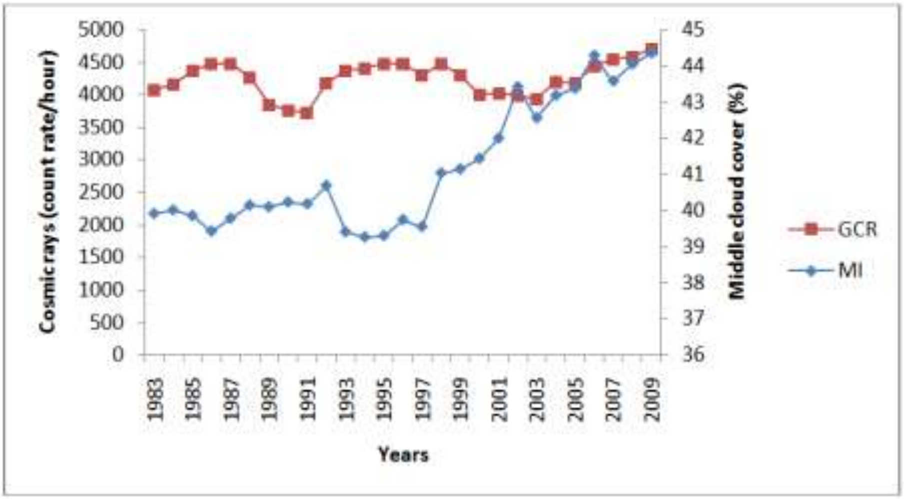

Figure 2: Variation trends of cosmic rays with middle cloud cover from 1983 – 2009

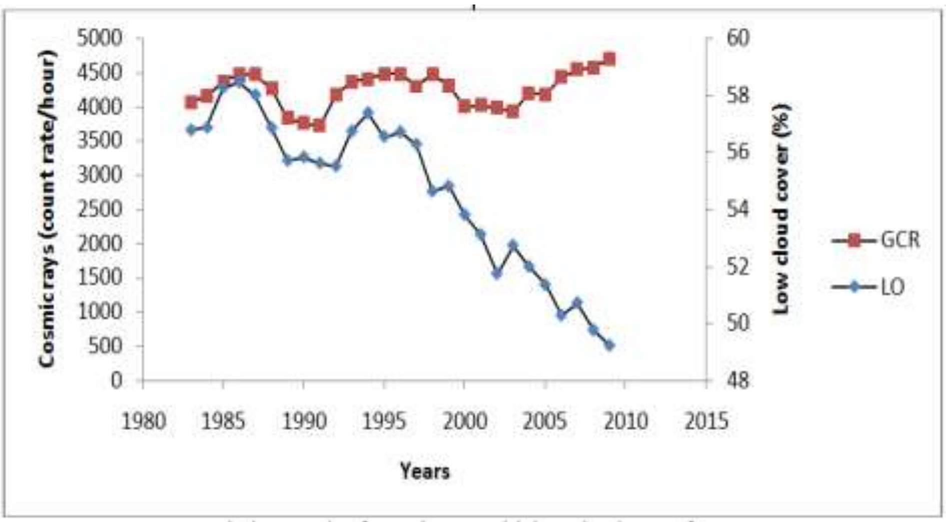

Figure 3: Variation trends of cosmic rays with low cloud cover from 1983 – 2009

Figure 1 depicts the variation trends of cosmic rays with infrared (IR) high cloud cover. It could be observed that cosmic rays and high cloud cover varies in the same direction from 1983 to 1989 but varies in opposite direction from 1989 to 1991. They also vary in opposite direction from 1991 to 2002, and then increases in the same direction until 2009. The variation of cosmic rays with IR middle cloud cover is presented in Figure 2. It could be observed that the middle cloud cover varies in opposite direction with the GCRs from 1983 to 2002, while both increases in the same direction until 2009. From the variation of cosmic rays with IR low cloud cover (Figure 3), it could be seen that low cloud cover has the same pattern of variations with cosmic rays from 1983 to 1995, but diverged after 1995 and decrease until 2009. This may probably be attributed to the irregular variability in the recent solar cycles.

From the above observations, it shows that there was good correlation between cosmic rays and low cloud cover between 1983 and 1995. This is in agreement with the observation of [6], [5] and [7]. However, the relationship became poorer after 1995 as low cloud cover continue to decrease gradually until 2009 while middle and high cloud cover increases with cosmic rays from 2002 to 2009. This is in line with the report of [1], [8] and [9]. This implies that the quiet period in recent solar cycles accompanied by high level of cosmic rays (due to modulation of cosmic rays by solar activity) should have led to high record of low cloud cover if cosmic rays greatly influence the formation of low cloud as reported by many researchers (e.g [7]). On the contrary, middle and high clouds have been on the increase in this quiet period of recent solar cycles accompanying with the high level of cosmic rays.

This recent observation shows that middle and high clouds cover have good correlations with cosmic rays while the relationship between cosmic rays and low cloud cover was significantly poor. This contradicts the earlier finding by [6], [5] and [7], who separately obtained high correlation between GCR and low clouds using ISCCP-D2 dataset, in contrast to middle and high clouds. From this observation, we can infer that cosmic rays have much influence on high and middle clouds in these recent solar cycles in contrast to low clouds. We hereby suggested that further works need to be done on the connection of cosmic rays and cloud covers; since cosmic rays could provide the link whereby solar activity affects the global climate.

V. Conclusion

Low cloud covers have good correlation with cosmic rays from 1983 – 1995, however, this relationship became poorer after 1995 until 2009. On the other hand, middle and high clouds were poorly correlated with cosmic rays from 1983 – 2001, but the relationship were significantly good from 2002 – 2009. This result contradicts the previous findings by many researchers who reported that cosmic rays were highly correlated with low cloud covers in contrast to middle and high clouds. We hereby suggested that further works need to be carried out, since cosmic rays could provide the link whereby solar activity affects the global climate.

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