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CORRELATION BETWEEN SUNSPOT NUMBER AND GEOMAGNETIC STORM

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ABSTRACT

Among the space weather subjects of research, geomagnetic storm and its effects on space and ground-based technologies has been of great interest to space scientists. For ages, geomagnetic storm has been observed after sunspot appearance, this in turn implies that there is a connection between the two. This study is aimed at finding the correlation between sunspot and geomagnetic storm over three solar cycles (i.e. solar cycle 21, 22, and 23). Our result shows a positive correlation between the two parameters with a correlation coefficient (r) of about 0.6. It was observed that severe geomagnetic storm is most likely around the solar maximum (The period when the sunspot numbers are most likely to be at the peak or high) and during declining years of sunspot cycle, it tends to halt at the sunspot minimum (Period when sunspot number is at its minimum). These findings are indicative of the interdependence of geomagnetic storms on the number of sunspot.

Keywords: Sunspot number; Geomagnetic storm, Dst, CME, Solar cycle

1.0 INTRODUCTION

Sunspots are dark flecks seen on the sun as a result of thermal deficiency. [1], observed that, no one fully understand the underlying physics of the sunspot cycle. However, it has been found to have a link with the sun magnetic field and also related to some solar activity such as; solar flares and corona mass ejection CME's [2]. Geomagnetic storms occur when there is a period of rapid magnetic field variation [3], caused by coronal mass ejections directed at the Earth from the sun. The arrival of CMEs into the Earth's magnetosphere can produce an increase in the ram pressure characterized by sudden increases in solar wind velocity, temperature and density as well as large changes in the North to South orientation of the interplanetary magnetic field IMF Bz [3]. It has been shown that the main parameter that determines the occurrence of geomagnetic storms is the interplanetary magnetic field Bz [4], as the input of energy into the magnetosphere depends on the orientation and magnitude of the IMF Bz [5, 6, 7 and 8]. The intensity of a geomagnetic storm can be defined by the minimum Dst value [9]. The Dst is a magnetic index that describes the depression in the Horizontal component of the magnetic field (H-field), which usually occurs as a result of the ring current that surrounds the earth during a geomagnetic storm event. [7, 10], has shown that the vital characteristic of a storm is the substantial increase of the ring current and its subsequent decay.

On January 19, 1926, an enormous group of spots came over the north-eastern edge of the sun and was brought into view by the sun's rotation; few days later (January 26, 192), after the spot had crossed the central meridian, the most intense magnetic storm that had been experienced in five years took place. This was considered as one of the worst magnetic storm experience leading to radio blackout. Activities associated with the sunspot must have been responsible for the storm, therefore, the correlation has been said to be more than mere coincidence [10]. It has been reported that sunspot appearance precedes geomagnetic storm [11], this happens 2 to 3 days interval [12]. This research aims at investigating the correlation between sunspot appearance and geomagnetic storm. The study is important because; aside the reliance of human on artificial satellite which geomagnetic storm affects, it also possesses danger on our ground system like the transformers, communication system and activities like transportation and geophysical exploration.

2.0 DATA and Method

The data used are for solar cycle 21, 22 and 23. The parameters used are the values of the Dst index and yearly averages of the sunspot number for the period under consideration. The data was downloaded from the website of Space Physics Interactive Data Resource (SPIDR) which is managed by National Geophysical Data Centre (http://spidr.ngdc.noaa.gov/spidr/dataset.do), and that of the World Data Center for Geomagnetism (WDC) Kyoto, Japan. The storm days were identified as days for which the Dst ≤ – 50 nT. The storm statistics for each year were obtained for all the years within the period of study. The results of the annual geomagnetic storm number and the annual sunspot number were then compared.

In order to investigate the degree of relationship between the two variables, i.e. sunspot number and geomagnetic storm, the coefficient of correlation (r), was computed using the relation in equation 1:

$$r = \frac{N\sum XY - [(\sum Y)(\sum X)]}{\sqrt{[N\sum X.X - (\sum X)2] \times [N\sum Y.Y - (\sum Y)2]}} \quad (1)$$

Where: X and Y are the parameters to be compared. Equation 1 is often called Pearson product moment [3]. This equation gives an exact quantification of the relationship between two variables. It should be noted that the Pearson product moment formula (Equation 1), requires the use of the sums;

$$\sum XY, (\sum Y), (\sum X), \sum X.X, \sum Y.Y \quad (2)$$

Correlation coefficient can also be calculated using the under root of the product of b and b′, the regression coefficient of Y on X and of X on Y, respectively.

$$r^2 = \frac{N\sum XY - [(\sum Y)(\sum X)]}{[N\sum X.X - (\sum X)2]} \times \frac{N\sum XY - [(\sum Y)(\sum X)]}{[N\sum Y.Y - (\sum Y)2]} \quad (3)$$

$$r = \sqrt{bb'} \quad (4)$$

Using equation (1), the coefficient of correlation was computed with the aid of Microsoft excel spread sheet as shown in Figure 2.1, where the annual geomagnetic storm was taken to be X and the sunspot number was taken to be Y.

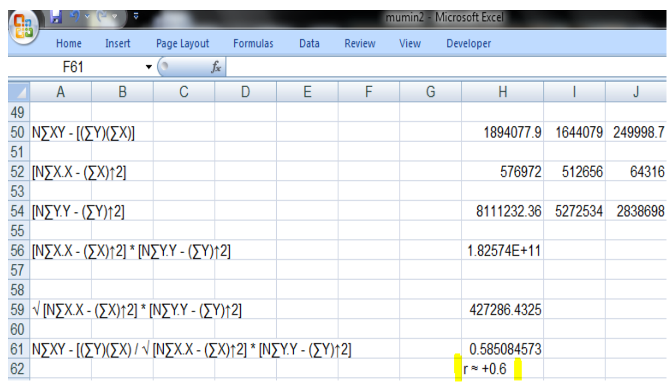

Figure 2.1: Excel worksheet showing the result of the correlation

3.0 RESULTS AND DISCUSSION

Figure 3.1 shows the result of the correlation between the sunspot number and geomagnetic storms. The plot spans three solar cycles (1976-2008). Observations from the Figure shows that more geomagnetic storm events were recorded during cycle 21 – 22, this cannot be unconnected to the higher values of sunspot number recorded during these periods. However, the variation in the annual average number of geomagnetic storms and sunspot number is not simultaneous across the years and do not follow a specific pattern. In cycle

21, the maximum number of geomagnetic storms was recorded in 1978, while the maximum sunspot number was observed in the year 1979. Similar observations were made in cycle 22, with maximum number of geomagnetic storms occurring at the declining stage of the solar cycle (year 1992), when the maximum sunspot number occurred in 1989. The observation in the solar cycle 23 shows the maximum number of geomagnetic storm and sunspot number occurring in the same year (year 2000).

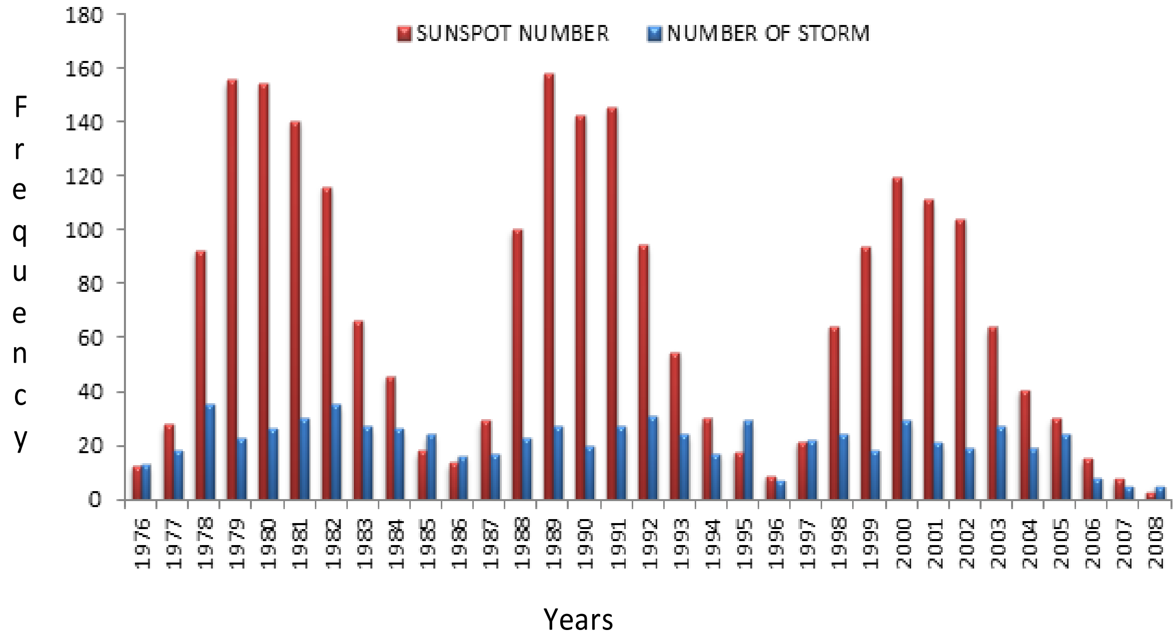

Figure 3.1: correlation between sunspot and geomagnetic storm

In other to further investigate the relationship between the two parameters, the correlation coefficient was calculated using equation (1). The result gives an approximate degree of correlation of 0.6 (Figure 3.1), which implies that the two phenomena are positively and fairly correlated. Equation (2) through (3) agrees with this value.

Further analysis of Figure 3.1 reveals that 1979 and 1990 suffered the highest deviation, the ratio of sunspot to geomagnetic storm was high, it was approximately 6: 1 which means, at an average, 6 appearance of sunspot group will just create a geomagnetic storm. On a contrary, the year 1976, 1985, 1986, 1995, 1996 and 1997 have a ratio of sunspot to geomagnetic storm to be almost 1: 1. This implies that for every sunspot appearance there is a geomagnetic storm occurrence, these years showed a very great connections between sunspot and geomagnetic storm that is more than just a matter of chance. 1997 has the best individual correlation while 1990 has the worst in the entire solar cycle 21 to 23.

It has been shown that in reality the solar cycle is not exactly 11 years [13], it varies, but when series of solar cycle is considered, the average tend to 11 years. For these solar cycles; solar cycle 21 is 10.3 years (1976 – 1986), solar cycle 22 is 9.7 years (1986 – 1996) while solar cycle 23 is 12.6 years (1996 – 2008) [14]. This implies that the length of data used also affect the result of the correlation in addition to time scale (daily, weekly, monthly, or yearly average) as stated by [10], hence a yearly average was choosen with the aim of having a better result.

Severe geomagnetic storm intervals can occur at almost any time during the solar cycle, for example, the most severe geomagnetic storm on record occurred on 17 September 1941 [15]. That was 53 months after the solar maximum. This storm occurred during a time when the sun was closer to the solar minimum than the solar maximum. Severe geomagnetic storms have also occurred within just a few months of the sun's actual solar minimum as well; an example is that which occurred on February 8, 1986. This indicates that significant space weather activity can occur at any time during the solar cycle. Nevertheless, there seems to be a slightly heavier preference for the years around solar maximum and during the declining years of the solar cycles. In cycle 21, the highest number of severe geomagnetic storm occurrence was in year 1982, followed by 1981 as seen in Table 3.1. These years lies at the decline of the sunspot cycle. It halts at 1983 and 1985 as we go down to the solar minimum.

During solar cycle 22, we had the highest frequency of severe geomagnetic storm occurrence at the sunspot maximum-year 1989; the frequency of occurrence reduces as it declines from 1989 to 1992, as shown in Table 3.1. At the sunspot minimum of the cycle (year 1996), there was no severe storms. However, the frequency of occurrence of severe storms was highest in the year 2000 and 2001. The solar cycle was at its peak in year 2000 which suggests high sunspot number; the frequent occurrence of severe geomagnetic storm at this point suggests a reasonable correlation between geomagnetic storm and sunspot number. Around cycle 23 sunspot maximum, we had the year 2003, which shows the same trend of severe geomagnetic occurrence. As the cycle declines, we had a total of 3 severe storms between year 2004 and 2005. These confirm that the occurrence of severe geomagnetic storm is more probable around the solar maximum and declining years of the solar cycle. Sunspots are more probable around this period which implies that there is a correlation between them and geomagnetic storm occurrence.

Table 3.1: Severe geomagnetic storm occurrence per year.

Year	Frequency of severe geomagnetic storm occurrence
1976	2
1977	-
1978	2
1979	-
1980	1
1981	3
1982	4
1983	-
1984	-
1985	-
1986	1
1987	-
1988	-
1989	4
1990	1
1991	3
1992	2
1993	-
1994	1
1995	-
1996	-
1997	-
1998	2
1999	1
2000	4
2001	4
2002	-
2003	2
2004	1
2005	2
2006	-
2007	-
2008	-

4.0 CONCLUSIONS

In conclusion, this study reveals:

- A significant relationship between geomagnetic storm and sunspot number.
- Frequent occurrence of severe geomagnetic storm was found to have a preference to the sunspot maximum and the declining year in the solar cycle, they tend to halt at the sunspot

minimum (the period when the sunspot numbers are most likely to be minimal). However, severe geomagnetic storm can occur at any time in the solar cycle.

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