Study of realtionship between solar activity and geomagnetic activity

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Abstract

This paper presents a study between solar activity and geomagnetic activity for the period 1996-2009. For this, will be used annual temporal series of phenomena related to solar activity (like Sunspot, Coronal Mass Ejection (CME) and Flares), and of the geomagnetic index Aa. Through statistical analysis of correlation, between this temporal series, find the existence of a relationship between the studied phenomena.

Introduction

The solar and geomagnetic activities are disturbances caused by changes in the magnetic fields of the Sun and Earth, respectively. These activities are linked through the interplanetary medium, that is defined as the region extending from the Sun to the interstellar medium, and in it lies the solar wind and magnetic field associated with it. (SUESS e TSURUTANI, 1998; GOSLING, 1993).

The geomagnetic activity is a set of disturbances in Earth's magnetic field caused by current systems existing in the Magnetosphere and Ionosphere. The origin of these disturbances is due to the interaction of charged particles from the solar wind and the interplanetary magnetic field, with the Earth's magnetic field. (KIVELSON e RUSSEL, 1995). Disturbances that generate a large decrease in the horizontal component of Earth's field are called geomagnetic storms. (KAMIDE ET AL., 1998).

Solar activity is responsible for various disturbances in the geomagnetic field that may be recurrent or transient. (SUESS e TSURUTANI, 1998). The lighter features of solar variability are changes over time in the number of sunspots seen on the visible half of the Sun (STUIVER e QUAY, 1980), These sunspots are cooler and darker than the photosphere due to it's strong magnetic fields, and have a cycle around 11 years, setting the solar activity cycle. (EDDY, 1976; SCHOVE, 1983).

Other characteristic phenomena of solar activity are: 1) Flares, bright regions of intense energy, that represent violent instability of part of the field of the active region, resulting in the release and emission of large amounts of energy, radiation and high-energy charged particles (PRIEST, 1987); 2) Coronal Mass Ejections (CME) which are one of biggest cause of intense geomagnetic storms (GOSLING et al., 1990,1991). These ejections release large quantities of matter in the solar corona to the interplanetary medium (HUNDHAUSEN et al., 1997). The CMEs of Halo type are those that expand in all directions of the interplanetary medium, thus reaching the Earth (WEBB, 2000).

Instruments called magnetometers perform measurements of the Earth's magnetic field. Magnetic measurements in various locations distributed over the globe as the geomagnetic activity varies, are complex and bulky to be handled easily. Geomagnetic indices were developed to replace this data (KIVELSON e RUSSEL, 1995).

This paper studies the relationship between solar and geomagnetic phenomena to a better understanding of the Sun-Earth relationship. For this, the linear correlation between the annual temporal series of phenomena related to solar activity (like Sunspot, Coronal Mass Ejection (CME) and Flares), and of the geomagnetic index Aa, were studied.

Methods

The temporal series were obtained by collecting data from NASA databases. For the CMEs was used SOHO CATALOG, for the Sunspots, NOAA (National Geophysical Data Center), for the Flares, Flare Index and for the geomagnetic index aa, that Will be used in this paper, was used aa index. Some of these databases directly provide the annual series, which is what matters in this paper, however there are other, like in case of SOHO CATALOG that provides only the daily values, it was necessary to reduce this data to find the annual temporal series. In this case, first the average value was carried out every month and finally, the average each year.

The study of the linear correlation between two temporal series with the same size shows if the changes in one temporal series are followed by the other (Figueiredo, 2007). The values of the two variables were plotted on a cartesian diagram called "dispersion diagram". The linear correlation coeficient (r) is determined by:

$$r_{xy} = \frac{S_{xy}}{(S_{xx}S_{yy})^{\frac{1}{2}}} \quad (1)$$

Where,

n= number of observations

$$S_{xy} = \frac{\sum xy - \frac{\sum x \cdot \sum y}{n}}{}$$

$$S_{xx} = \sum x^2 - \frac{(\sum x^2)^2}{n}$$

$$S_{yy} = \sum y^2 - \frac{(\sum y^2)^2}{n}$$

The linear coeficient of the correlation varies from -1 to $+1$ and it's interpretation depends on the numerical value of the signal, as follows (Figueiredo,2007):

$r = -1$ perfect negative correlation

$r = 1$ perfect positive correlation

$0,7 < r < 1$ strong correlation

$-1 < r < 0$ negative correlation

$0,2 < r < 0,4$ weak correlation

$r = 0$ zero correlation

$0,4 < r < 0,7$ moderate correlation

Results

Figure 1 shows the grafical representation of the Sunspots (green) series with Aa index (blue) as a function of time (years). The Aa index determinates the magnitude of the global magnetic activity.

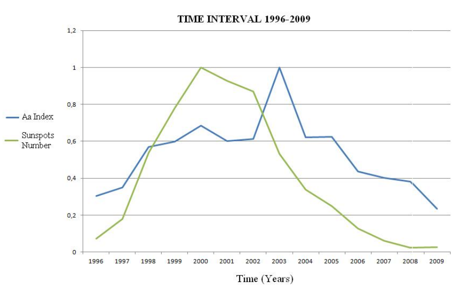

Figure 1: Normalized Aa index (blue) and sunspots number (green) as a function of time (years).

In figure 1 are observerd that both phenomena have a common feature, in the begining their values are growing, reaching a peak; after their values decline, however they are lagged, one related to the other. The sunspots show a fast growing and slow decline profile, while the Earth's magnetic field magnitude shows a proportional rate between its growing and decreasing period.

Figure 2 shows a dispersion diagram and the linear correlation coeficient between the two phenomena.

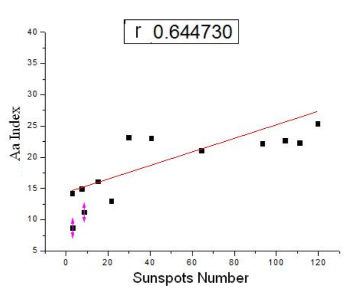

Figure 2: Dispersion diagram between Aa índex and Sunspots number for annual values.

The numerical value of the correlation coeficient was about 0,64, what shows the existence of a moderate correlation between the ocurrence of sunspots and the magnetospheric disturbance.

Figure 3 shows the ocurrence of Flares (green) and the Aa index variation (blue) as a function of time (years) between the studied period.

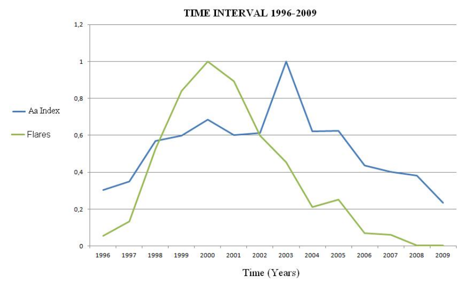

Figure 3: Normalized aa index (Blue) and the flares (Green) as a functions of time.

Similarly for the sunspots, a lag behind the two phenomena can be verified, but clearly both pass through a growing process, followed by a decreasing period. Notices that the initial and final period behave in a very similar way.

Figure 4 is the dispersion diagram of the flares with respect to the Aa index.

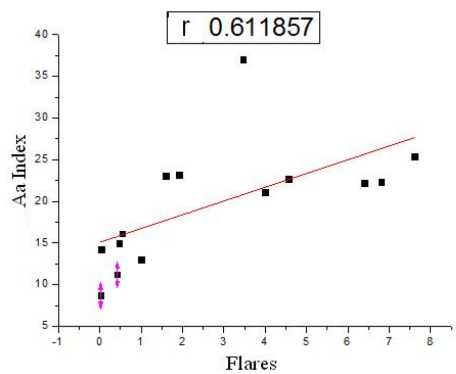

Figure 4: Dispersion Diagram between the aa index and the flares, for annual values.

The value obtained for the correlation coeficient was 0,61, too a moderate coeficient, and near to the sunspots coeficient. It shows the existence of a relation.

Figure 5 shows the CMEs (green) and the Aa index (blue). The behavior of the CMEs with respect to the Aa index is different from the previous cases. At the beggining both phenomena stated to grow proportionaly, however, from 2000, approximately, the behaviors change. The behavior is similar untill 2003, and just return to agree in 2008.This fact is due to the CMEs different behavior between 2004 and 2008, decreasing period of the solar activity - as observed in the previous cases. Again a lag (as in the sunspots and flares) in time, with the Aa geomagnetic index is observed.

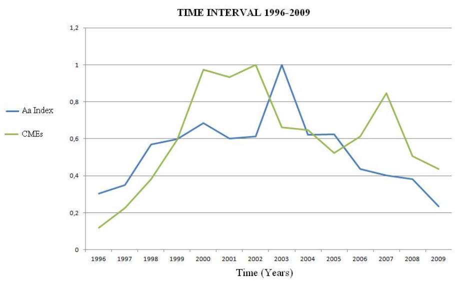

Figure 5: Normalized aa index (Blue) and Halo CME (Green) as a functions of time.

Figure 6 is the dispersion diagram of the CMEs with respect to the Aa índex. The value of the correlation coefficient was 0,50; showing a moderated correlation between the disturbances in geomagnetic field. This occours, probably because of period 2004-2008. In this present study was considered the activity solar, however, should be noted in the correlation between EMCs and Aa index that not all ejections are in the direction Sun-Earth, this fact may cause the variation in the correlation value.

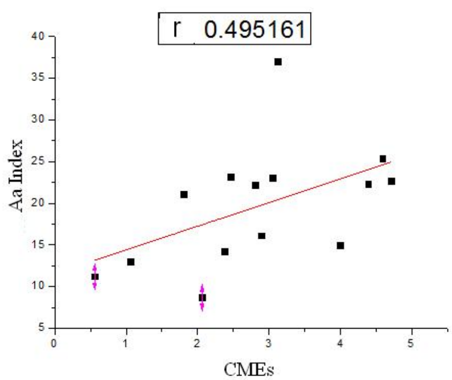

Figure 6: Dispersion Diagram between the aa index and the CME, for annual values.

Figure 7 is a graph of the CMEs (Green) and aa index (Blue) as a function of time. Again it is observed that the behavior, especially during the period of increase, is similar in both phenomena, which also has a function of time discrepancy between the two phenomena.

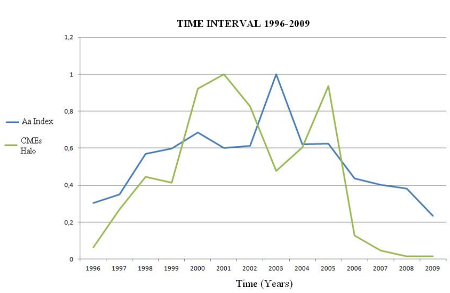

Figure 7: Normalized aa index (Blue) and Halo CME (Green) as a functions of time.

Figure 8 is the dispersion diagram for the case of the Halo CMEs and the aa index. The correlations coefficient obtained for that case was 0,65, being the largest found in this study, nonetheless still is a moderate correlation value. The fact of this value be grater than the other can be related with known phenomena that Halo CMS's always will hit the Earth Magnetic Field, causing thus, variations in the aa index.

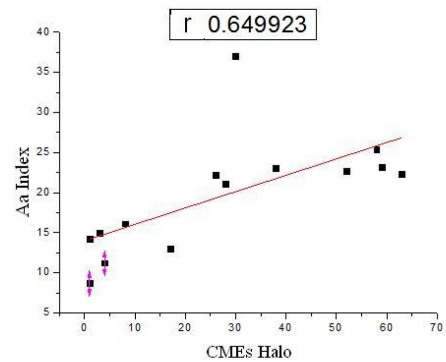

Figure 8: Dispersion Diagram between the aa index and the Halo CMEs, for annual values.

Conclusions

In this work was developed a study of the relationship between the solar and geomagnetic activity. For this, we used the annual series of the number of sunspots - which are the strongest feature of the variability of solar activity - flares, coronal mass ejections and ejections like Halo and aa geomagnetic index for the period 1996-2009 .

Due the statistical analysis of linear correlation was shown that there is a moderate relationship between solar and geomagnetic activity and that this relationship has a lag in time.

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