Analysis of geomagnetic storms in South Atlantic Magnetic Anomaly (SAMA)

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Abstract

Geomagnetic storm is a major disturbance of Earth's magnetosphere resulted from the interaction of solar wind and the Earth's magnetic field. This disturbance depends of the Earth magnetic field geometry, and varies in terms of intensity from the Poles to the Equator. This disturbance is quantified through geomagnetic indices, such as the Dst and the AE indices. AE measure the disturbance on auroral zone while Dst measure the disturbance on mid-latitude regions. As Dst and AE indices vary according to the geomagnetic field geometry, in this framework, fluctuations in the geomagnetic field can occur under the influence of the South Atlantic Magnetic Anomaly (SAMA). In this ongoing study proposes to investigate the geomagnetic storms at the region of SAMA influence. For this we will use a database of the Vassouras´Magnetic Observatory and AE and Dst indices. Our first impressions and perspectives will be discussed.

. Introduction

Geomagnetic storm is a major disturbance of Earth's magnetosphere resulted from the interaction of solar wind and the Earth's magnetic field. This perturbation can be quantified through geomagnetic indices as the Dst and the AE (https:// www.swpc.noaa.gov/phenomena/geomagnetic-storms).

The Dst index measures the magnitude of the current associated to the symmetry disturbance in the geomagnetic field (MANDEA; KORTE, 2011).

The AE index represents the overall activity of the electrojets (MANDEA; KORTE, 2011) through geomagnetic variations in the horizontal component *H* observed at 12 selected observatories along the auroral zone in the northern hemisphere.

Dst and AE indices allows the classification of geomagnetic storm as sporadic and recurrent. Sporadic geomagnetic storms present a chain of substorms with a sharp start and shorter duration whilst recurrent storms display a high level of background perturbations (SHADRINA, 2017).

Moreover, Dst and AE indices may vary according to the geomagnetic field geometry, such as polar to intermediate latitudinal field variations. In this framework, fluctuations in the geomagnetic field can occur under the influence of the South Atlantic Magnetic Anomaly (SAMA). The SAMA is a region of minimum geomagnetic field intensity values at the Earth's surface (Figure 1), and its dipole intensity is decreasing along the past 1000 years (Terra-Nova et. al., 2017).

In this study we will compare the behavior of the types of geomagnetic storms basis on AE and Dst indices.

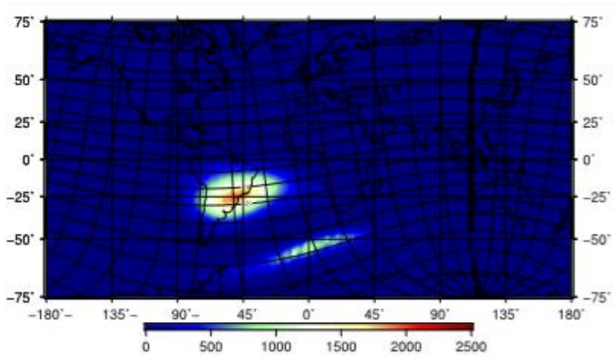

Figure 1 – Map of the geomagnetic field with eccentric dipole grid representation overlaid (DOMIMGOS, et. al., 2017).

Method

The Dst and AE indices magnetospheric data were obtained from the International Service of Geomagnetic Indices (http://isgi.unistra.fr/data_download.php). The dates have the format of IAGA – 2002, soured of data WDC for geomagnetism, Kyoto, Japan with interval of 1 hour and unit 1 nT.

In this study, we applied the parameter k to differ both types of storms (sporadic and recurrent) defined as k= (∆ Dst)/ (∑AE). ∆ Dst is the low latitude Dst-index amplitude, and ∑AE is the sum of high latitude index AE for the main phase of the storm. k values below 0.010 refer to sporadic storms, and k values above 0.015 refer to recurrent storms (SHADRINA, 2017).

Have been chosen two geomagnetic storms with different features between several to deepen the studies. The Table 1 show four different geomagnetic storms. Their parameter used were main phase duration (∆ t), low latitude Dst-index amplitude (∆ Dst), class of the stomr (S-small, M-moderate), sum of the high latitude index AE for the main phase of the storm (∑AE) and type (sporadic or recurrent) (SHADRINA, et al., 2014).

Table. 1– Dates and geomagnetic storm parameters

Date (dd.mm.yyyy)	Δ t	Δ Dst	Class	∑AE	Type
23.10.2003	12	48	S	3746	spor
30.10.2009	20	54	M	3610	spor
08.11.2009	12	39	S	3651	rec
11.03.2011	31	84	M	15153	rec

Posterior steps of this research will include the use of the cross-wavelet transform to identify similarities and/or differences between the geomagnetic field observed in both high and intermediate latitudes. This parameter is important to study because the geomagnetic storm can be feel in different intensity in different latitudes because of the geomagnetic field.

The wavelet transform can be expressed as (e.g. Torrence and Compo, 1998)

$$W(a,b) = \langle f(t), \psi_{a,b}(t) \rangle = \int_{-\infty}^{\infty} f(t)\psi^{*}_{a,b}(t)dt.$$

Where f(t) is a real function defined in time domain, $\psi(t)$ is the mother wavelet, $\psi_{a,b}(t)$ are the daughter wavelets. In this study we will use the Morlet wavelet because it is adequate to detect periodicities observed in geophysical signals.

Results

To evaluate the geomagnetic field variations during storms, we plotted the temporal evolution of Dst and AE indices during two different time episodes, centered on October 30th 2003 (Figure 2) and November 08th 2009 (Figure 3). To capture the behavior of the storms, we considered eight days before and after the storm day. Both indices are given in nT. Table 1 contains the parameters that define both storms detailed in Figures 2 and 3.

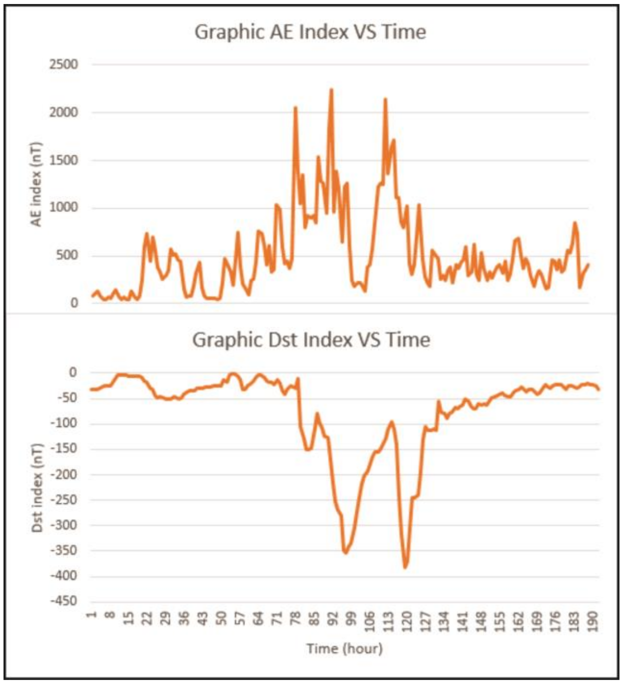

Figure 2 – shows how each index behaves before a sporadic geomagnetic storm occurred in Oct 30th 2003.

The geomagnetic storm observed in Figure 2 corresponds to the sporadic type as show in Table 1. Normally, the main phase has the period of 8 to 12 hours but in the graphic, we can interpret more than expect period. Probably this happing because the geomagnetic field delay to stabilize again.

At the graphic for AE index we can observe a chaotic system with several peaks and three stronger than other reference of main phase.

At the graphic for Dst index it is possible to interpret all the values are negative but we have a two peaks stronger reference of main phase.

The Figure 3 is based on the dates from geomagnetic storm recurrent, as show in Table 1.

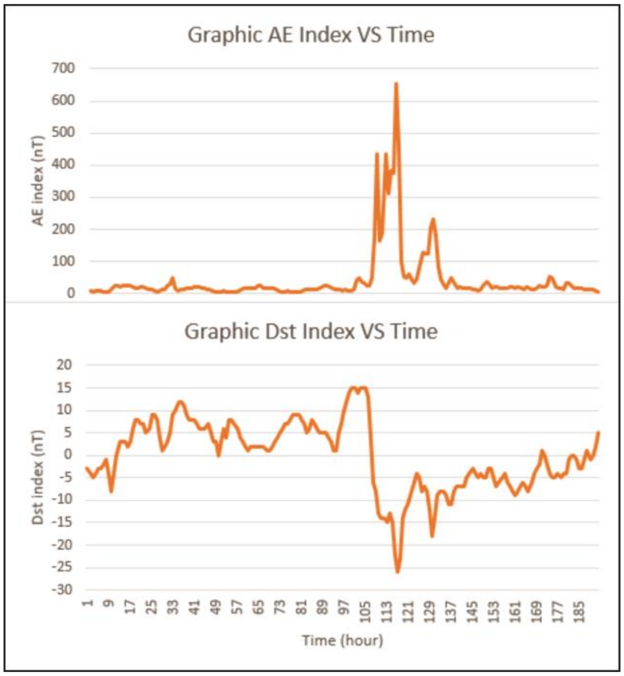

Figure 2 – shows how each index behaves before a geomagnetic storm occurred in Nov 08th 2009.

For this type of geomagnetic storm, recurrent storm, the main phase have period of 14 to 18 hours.

The measure for the AE index is very punctual, it is possible perceive that the values are linear, but in the middle have one anomaly.

The values from Dst index are symmetrical, visually we have the same number from values negatives and positives. The peak positive followed from one peak negative show the main phase.

Conclusions

Both indices, AE and Dst are not calculate basis in South America. They measure are fundamental in others regions for this reason it is expected a different behavior for this index in South America due to SAA.

The parameter k show to be effective being a numerical indicator of geomagnetic storm type. Between storm types, recurrent storms have a shorter main phase and more intense compared with sporadic storm.

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References

DOMINGOS, J. D., et. Al., The South Atlantic Anomaly throughout the solar cycle. Earth and Planetary Science Letters, 473 (2017) 154-163.

MANDEA, Mioara; KORTE, Monika. Geomagnetic Observations and Models, V. 5. Springer Science+Business Media B. V, 2011.

SHADRINA, Lyudmila P. Two Types os Geomagnetic Storms and Relationship Between Dst and AE Indexes, 2017.

SHADRINA, L.P.; SAMSONOV, S.N.; MANYKINA, V. I., Sporadic and Recurrent Geomagnetic Storm Responses in the Human Cardiogram, 2014.

TERRA-NOVA, Felipe; AMIT, Hagay; et al., Relating the South Atlantic Anomaly and geomagnetic flux patches 2017.

TORRENCE, c., Compo, G. P. A practical guide to wavelet analysis. Bulletin of the American Meteorological Society, 79(1), 1998.