Analysis of the Geomagnetic Storm Variations and the count-rate of Cosmic Ray Muons recorded at the Brazilian Southern Space Observatory

Everton Frigo[1,2], Jairo F. Savian[1,2], Marlos R. da Silva[3], Alisson Dal Lago[3], Nalin B. Trivedi[3], Nelson J. Schuch[2].

[1] Santa Maria Space Science Laboratory, UFSM, Santa Maria, Brazil,
[2] Southern Regional Space Research Center – INPE/MCT, Santa Maria, Brazil,
[3] National Institute for Space Research, Sao Jose dos Campos, Brazil.

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Abstract

An analysis of geomagnetic storm variations and the count rate of cosmic ray muons recorded at the Brazilian Southern Space Observatory -OES/CRSPE/INPE-MCT, in São Martinho da Serra, RS during the month of November 2004, is presented in this paper. The geomagnetic measurements are done by a three component low noise fluxgate magnetometer and the count rate of cosmic ray muons, are recorded by a multi-directional muon detector, both instruments installed at the Observatory. The fluxgate magnetometer measures variations in the three orthogonal component of Earth magnetic field, H (Nort-South), D (East-West) and Z (Vertical), with data sampling rate of 0.5 Hz. The muon detector records hourly count rates. The arrival of a solar disturbance can be identify observing the decrease in the muon count rate. The goal of this work is to describe the physical morphology and phenomenology observed during the geomagnetic storm of November 2004, using the H component of the geomagnetic field and vertical channel V (Sun-Earth) of the multi-directional muon detector in South of Brazil.

Introduction

One of the most important periods of solar cycles is the period of 11 years. During the phase of intense activity on the Sun, at the solar maximum, areas of instability can liberate high-speed solar wind and great amounts of matter and energy through solar plasma ejections. When the solar wind reaches the proximities of the Earth, it finds an obstacle in its propagation towards the surface of the Earth, due to the presence of the Earth's magnetic field. A portion of the incoming solar plasma may enter into the magnetosphere and the remaining flows along the lines of the magnetic field creating a bubble or cavity of the magnetosphere, (Figure 1). In the events of great disturbances in the Earth's magnetic field, the planet becomes vulnerable to precipitation of energetic particles of the solar wind and cosmic rays, this phenomenon is denominated geomagnetic storms (González et al., 1994). The geomagnetic storms can be classified through Dst index, based on the hourly measures of the component H of the geomagnetic field at selected low latitude stations. The geomagnetic storms are grouped in three characteristic groups, according to their intensity, : weak: -50 nT ≤ Dst ≤ -30 nT; moderate 100 nT ≤ Dst ≤ -50 nT and intense Dst < -100 nT (Gonzalez et al., 1994). The principal characteristic of a geomagnetic storms is the decrease of the H component of the geomagnetic field (Kamide et al., 1998). The decrease is attributed to the increase of the population of particles arrested in magnetosphere. The solar structures capable to cause geomagnetic storms move through the solar wind to high-speeds dragging the interplanetary magnetic field and causing disturbance in the interplanetary medium. This disturbance obstructed the passage of the cosmic rays causing a decrease in the count of the muons, the "Forbush decrease" (Cane 1993; Cane et al., 1994; 1996), Figure 2. In this work we analyzed the variations observed in the H component of the geomagnetic field and the decrease in the muons count during the geomagnetic storm of November of 2004 data observed at the Southern Space Observatory, in São Martinho da Serra, RS.

Data and Methodology of Analysis

The Brazilian Southern Space Observatory is located in the proximities of the center of South Atlantic Magnetic Anomaly - SAMA, that is, the area where the smallest intensity of the Earth's magnetic field is observed in the surface of the Earth (Trivedi et. al., 2003). Fluxgate magnetometer of low noise was used to conduct measurements of three ortoghonal components of the geomagnetic field and the data were recorded at a sampling rate of 2 seconds (0.5 Hz). We used the data of the variations observed in the H component during the 5 to November 15, 2004 to identify the geomagnetic storm. The muon detector located at the Observatory, in South of Brazil, is part of the International Muon Detector Network, with the one of Nagoya (Japan), and Hobart (Australia), recording hourly count rates of the muon precipitation on the surface of the Earth. As described previously, a relationship exists among the solar disturbances, the variations in the geomagnetic field and the decrease in the muons count rate.

Results

The Dst index is presented in Figure 3, obtained from Kyoto University (Japan), for November of 2004. It is observed on the 08/11/2004 a decrease in the Dst index corresponding at - 373 nT, indicating the occurrence of a intense geomagnetic storm. On the 10/11/2004 a decrease is observed of - 289 nT, indicating the occurrence of a second geomagnetic storm. Figure 4, display the variations observed in the H component of the geomagnetic field for the period of 5 to 15 of November 2004, detected by the fluxgate magnetometer. It the Southern Space Observatory displaies the counts for the same period, detected for the muons at the Observatory. The line 1 of the Figure 4 indicates an accentuated decrease of approximately 3,5% in the muons count rate, indicating that a Coronal Mass Ejection (CME) was driving in the direction of the Earth. The line 2 display a sudden increase in the intensity of the H component and a subsequent decrease, indicating that a solar structure was shocked with Earth magnetosphere. The line 3 display a new decrease in the muons count rate, approximately 4%, indicating that other solar structure goes the Earth. The line 4 shows a sudden increase in the intensity of the H component, and subsequent decrease, indicating that the second solar structure collided with the Earth's magnetophere.

Conclusions

Based on these results, it is noticed that the Muon Detector Network may detect the approach of solar structures about 12 hours before the shock of those structures may reach the Earth's magnetosphere. It is of highest importance for the Space Weather forecasts of the arrival of shocks and storms, made from detailed studies of these structures. It is essential to detect them with a larger antecedence, and avoiding eventual damages, such as: intensification of electric currents in the space and in the Earth surface, occurrence of polar auroras, acceleration of charged particles, and several damages in satellites, causing damages in the Global Positioning System (GPS), in telecommunications and even to the astronauts that are in spaceships.

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References

Campbell, W. H.; Introduction to Geomagnetic Fields. Cambridge University Press, New York, 1997.

Cane H. V.; Cosmic ray decreases and magnetic clouds, *J. Geophys. Res.*, 98, 3509–3512,1993.

Da Costa, A.M.; Mendes Junior, O.; Anomalia Magnética do atlântico sul e a radiação cósmica sobre a costa do Brasil. Revista Scientific American Brasil, São Paulo, Ano 2, n. 23, p. 20-29, Abril de 2004.

Da Silva, M. R., Contreira, D. B., Monteiro S., Trivedi N. B., Munakata K., Kuwabara T. and Schuch N. J.; Cosmic Ray Múon Observation at Southern Space Observatory – SSO (29°S, 53°W), Atrophysical and Space Science, 290: 398 – 397, 2004.

Dal Lago. A.; Estudo de nuvens magnéticas geoefetivas no meio interplanetário. 1999. 112 p. (INPE-7263-TDI/705. Dissertação (Mestrado em Geofísica Espacial) – Instituto Nacional de Pesquisas Espaciais, São José dos Campos, São Paulo, 1999.

Gonzalez, W. D.; Joselyn, J. A.; Kamide, Y.; Kroehl, H. W.; Rostoker, G.; Tsurutani, B. T. and Vasyliunas, V. M.; What is a magnetic storm?. J. Geophys. Res., v.99, n.A4, p.5771-5792, Apr. 1994.

Kamide, Y.; Yokoyama, N.; Gonzalez, W. D.; Tsurutani, B. T.; Daglis, I. A.; Brekke, A.; Masuda, S.; Two-Step development of geomagnetic storms. J. Geophys. Res., v.103, n.A4, p.6917-6921, Apr. 1998.

Munakata, K.; Bieber, J.W.; Yasue S.I; Kato C.; Koyama M.; Akahane, S.; Fujimoto, K.; Fujii, Z.; Humble, J.E. and Duldig, M. L.; Precursors of geomagnetic storms observed by the muon detector network, J. Geophys. Res., v. 105, n. 27, p. 457, 2000.

Russell, C. T.; Kivelson, M. G.; Introduction to Space Physics, 1. ed. Los Angeles: Cambridge University Press, 1995.

Trivedi, N. B.; Schuch, N. J.; Pathan, B. M.; Nishino, M.; Barreto, L. M.; Geomagnetic Phenomena in the South Atlantic Anomaly Region. Advances in Space Research, England, v.32, 2003.

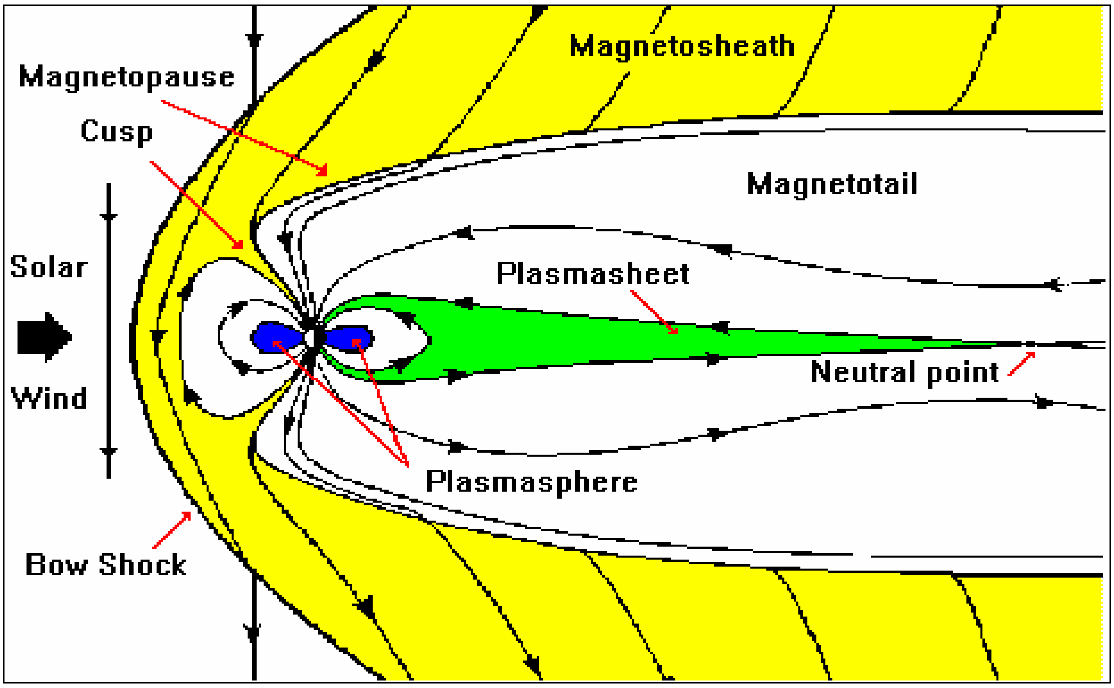

Figure 1 – Schematic of the forcing by the solar wind is able to modify this field, creating a cavity called the magnetosphere (Source: http://www.oulu.fi/~spaceweb/textbook/magnetosphere.html).

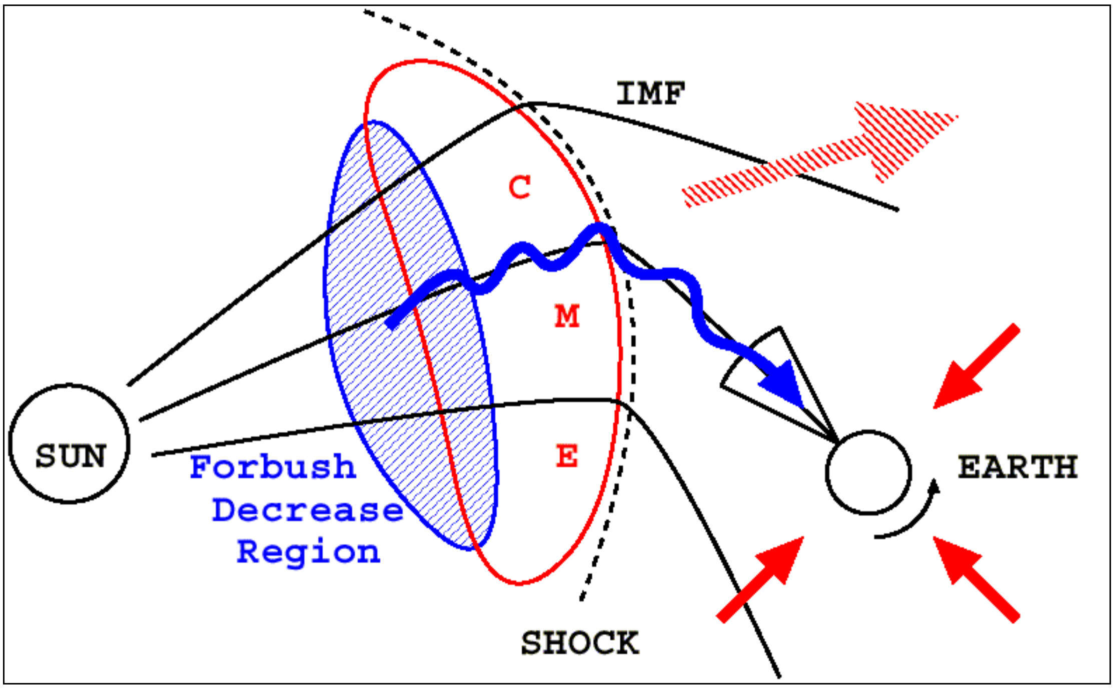

Figure 2 – Schematic figure the effect loss-cone precursor (Rufolo, 1999).

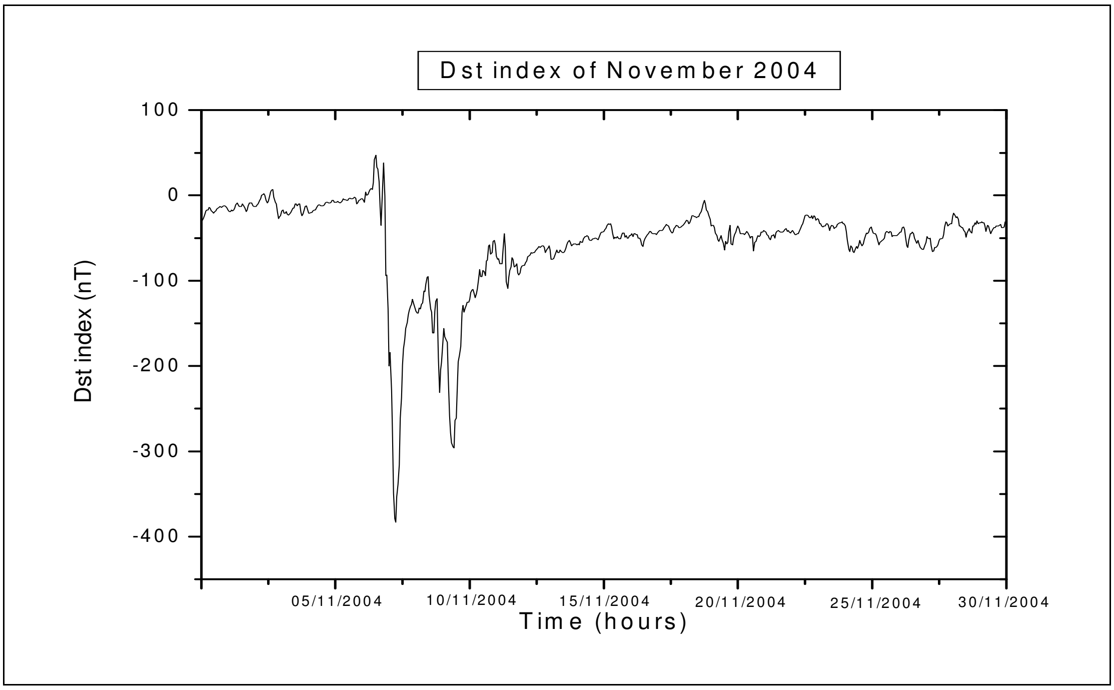

Figure 3 – Dst index of the month November 2004.

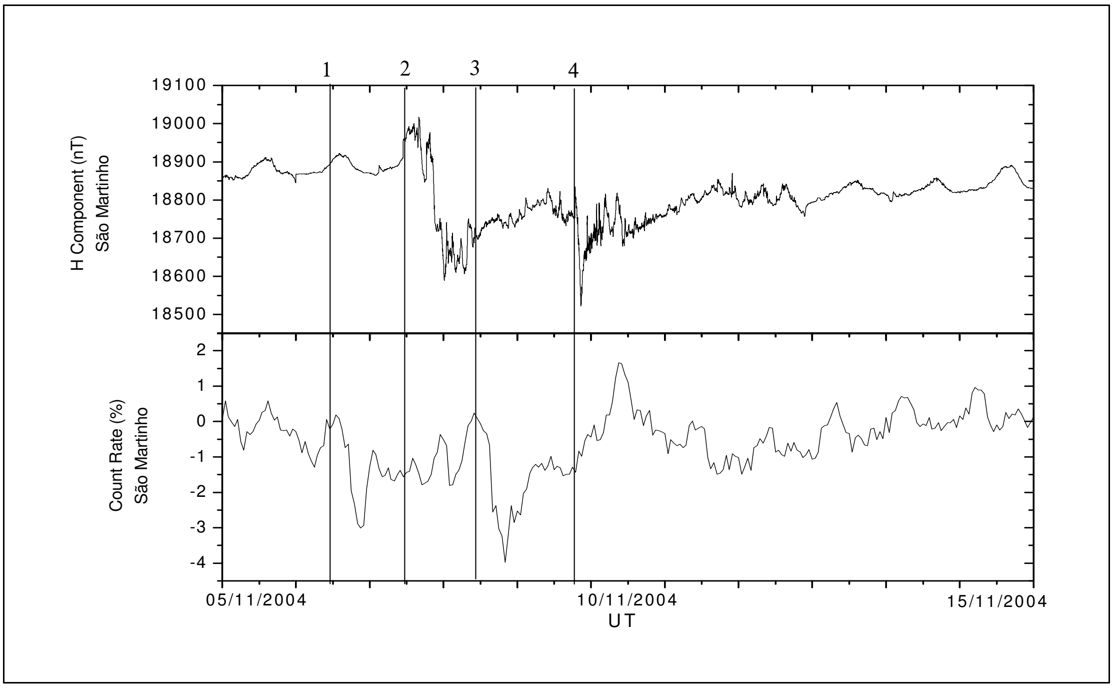

Figure 4 – Variations in H Component of Earth’s Magnetic Field and Count Rate of the muon detector for the period 5-15 November 2004.