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ANALYSIS OF GEOMAGNETIC STORM VARIATIONS AND COUNT-RATE OF COSMIC RAY MUONS RECORDED AT THE BRAZILIAN SOUTHERN SPACE OBSERVATORY

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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/CRS/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 rates of cosmic ray muons are recorded by a Muon Scintilator Telescope – MST, both instruments installed at the Observatory. The fluxgate magnetometer measures variations in the three orthogonal components of Earth magnetic field, H (North-South), D (East-West) and Z (Vertical), with data sampling rate of 0.5 Hz. The Muon Scintilator Telescope records hourly count rates. The arrival of a solar disturbance can be identified by 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 of the multi-directional muon detector in South of Brazil.

Keywords: geomagnetic storms, geomagnetic variations, cosmic rays, interactions Earth-Sun, space weather.

RESUMO. Neste trabalho apresentamos uma análise das variações geomagnéticas e contagem de raios cósmicos (muons) detectados no Observatório Espacial do Sul – OES/CRS/INPE – MCT (29.43°S, 53.80°W), em São Martinho da Serra, RS, durante o mês de Novembro de 2004. As medidas das variações geomagnéticas são realizadas através de um magnetômetro *fluxgate* de três componentes e baixo ruído, e as contagens de muons são obtidas através de um detector de muons multi-direcional, ambos instrumentos instalados no Observatório. O magnetômetro *fluxgate* detecta variações nas três componentes ortogonais do campo magnético Terrestre, H (Norte-Sul), D (Leste-Oeste) e Z (Vertical), com uma taxa de aquisição de 0.5 Hz. O Telescópio Cintilador de Muons realiza contagens horárias. A chegada de um distúrbio solar é identificada observando-se o decréscimo na contagem de muons. O objetivo deste trabalho é fazer uma descrição da morfologia e fenomenologia física observada durante a tempestade geomagnética de Novembro de 2004, usando a componente H do campo geomagnético e o canal vertical V do Telescópio Cintilador de Muons no Sul do Brasil.

Palavras-chave: tempestades, variações geomagnéticas, raios cósmicos, interações Terra-Sol, clima espacial.

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INTRODUCTION

Areas of instability in the Sun can release high-speed plasma structures, with great amounts of matter and energy, the so-called coronal mass ejections – CMEs (Hundhausen et al., 1984; Hundhausen, 1997) throughout the whole 11-year solar cycle. Although more frequent during maximum phase, these CMEs are also present during low activity periods of the solar cycle. Eventually these solar CMEs reach the Earth (Schwenn et al., 2005), interacting with the earth' magnetosphere. A portion of the incoming solar plasma may enter into the magnetosphere via a reconnection process (Dungey, 1961), causing great disturbances in the Earth's magnetic field denominated geomagnetic storms (Gonzalez et al., 1994), observed by ground magnetic observatories. These geomagnetic storms can be classified according to different Dst index levels: weak: -50 nT $\leq$ Dst ≤ -30 nT; moderate 100 nT $\leq$ Dst ≤ -50 nT and intense Dst < -100 nT (Gonzalez et al., 1994). This index is based on hourly measures of the H component of the geomagnetic field at selected low latitude stations. The principal characteristic of a geomagnetic storms is the decrease of the H component of the geomagnetic field (Kamide et al., 1998). This decrease is attributed to the increase of the population of particles trapped in magnetosphere. The solar structures capable of causing geomagnetic storms move through the solar wind shielding the passage of galactic cosmic rays, causing decreases in their count rates on the ground, also known as "Forbush decreases" (Cane, 1993; Cane et al., 1994, 1996). In this work we analyzed the variations observed in the H component of the geomagnetic field and the decrease in the high energy cosmic ray muon count rates during the geomagnetic storm of November 2004, both 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., 2005). A low noise fluxgate magnetometer was used to measure the three orthogonal 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 period from 5 to 15 November, 2004, in order to identify the geomagnetic storm. The Muon Scintilator Telescope located at the Observatory, in South of Brazil, is able to observe high energy cosmic rays (muons) in several directions (Da Silva et al., 2004), and it is part of the International Muon Detector Network, with other ones at Nagoya (Japan) and Hobart (Australia). It records 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 1, obtained from Kyoto University (Japan), for November 2004. On November 8th, 2004, a decrease is observed in the Dst index, reaching a negative peak of -373 nT, indicating the occurrence of an intense geomagnetic storm. On November 10th, 2004 another decrease is observed, reaching -289 nT, indicating the occurrence of a second geomagnetic storm. Figure 2, shows the variations observed in the H component of the geomagnetic field for the period of 5-15 November 2004, detected by the fluxgate magnetometer. Figure 2 also shows the counts for the same period, detected by the muonscintilator telescope at the Southern Space Observatory. The vertical line 1 of Figure 2 indicates an accentuated decrease of approximately 3,5% in the muon count rate, indicating that a Coronal Mass Ejection (CME) was driven towards the Earth, reaching the earth's magnetosphere. Line 2 display a sudden increase in the intensity of the H component and a subsequent decrease, indicating that a solar structure impact the Earth magnetosphere. Line 3 displays a second decrease in the muon count rate, of approximately 4%, indicating that another solar structure reached the Earth. Line 4 shows a sudden increase in the intensity of the H component, and subsequent decrease, indicating that the second solar structure impact the Earth's magnetosphere.

CONCLUSIONS

Based on these results, it is observed that the Muon Scintilator Telescope Network may detect the passage of solar structures (CMEs) by the Earth's magnetosphere. It is of high importance for Space Weather to detect the arrival of shocks and storms, from detailed studies of these structures. In the near future, cosmic ray data will be used to detect the arrival of CMEs before they reach the earth, using data from the whole high energy cosmic ray network. It is essential to detect them with a large antecedence, in order to avoid eventual damages, such as: intensification of electric currents in space and at the Earth surface, occurrence of polar auroras, acceleration of charged particles, and several damages in satellites, damages in the Global Positioning System (GPS), in telecommunications and even to the astronauts that are in spaceships.

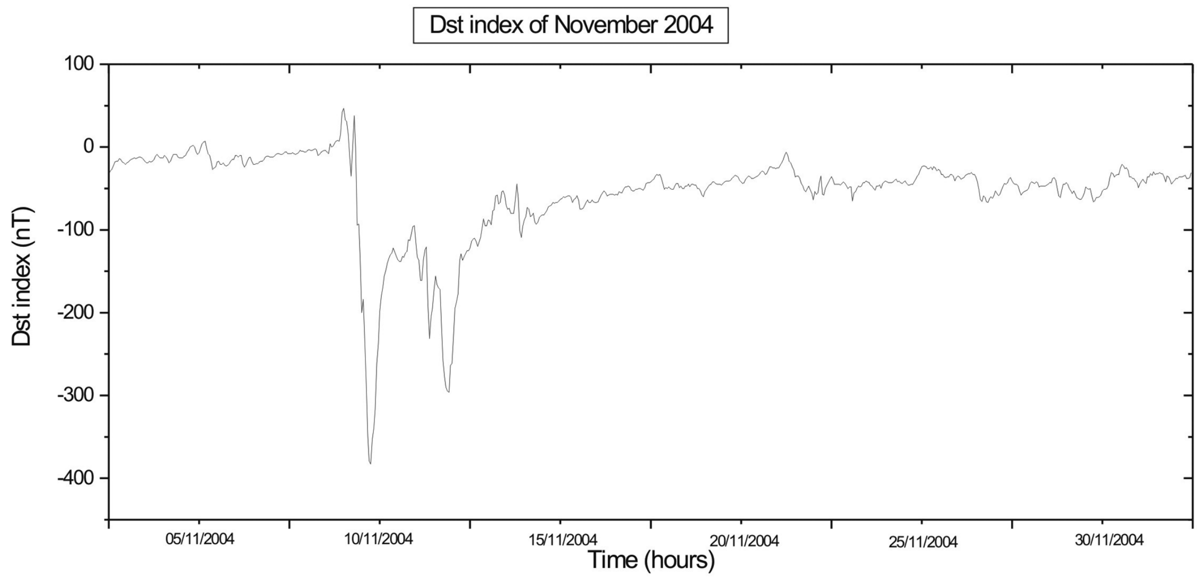

Figure 1 – Dst index of the month of November 2004.

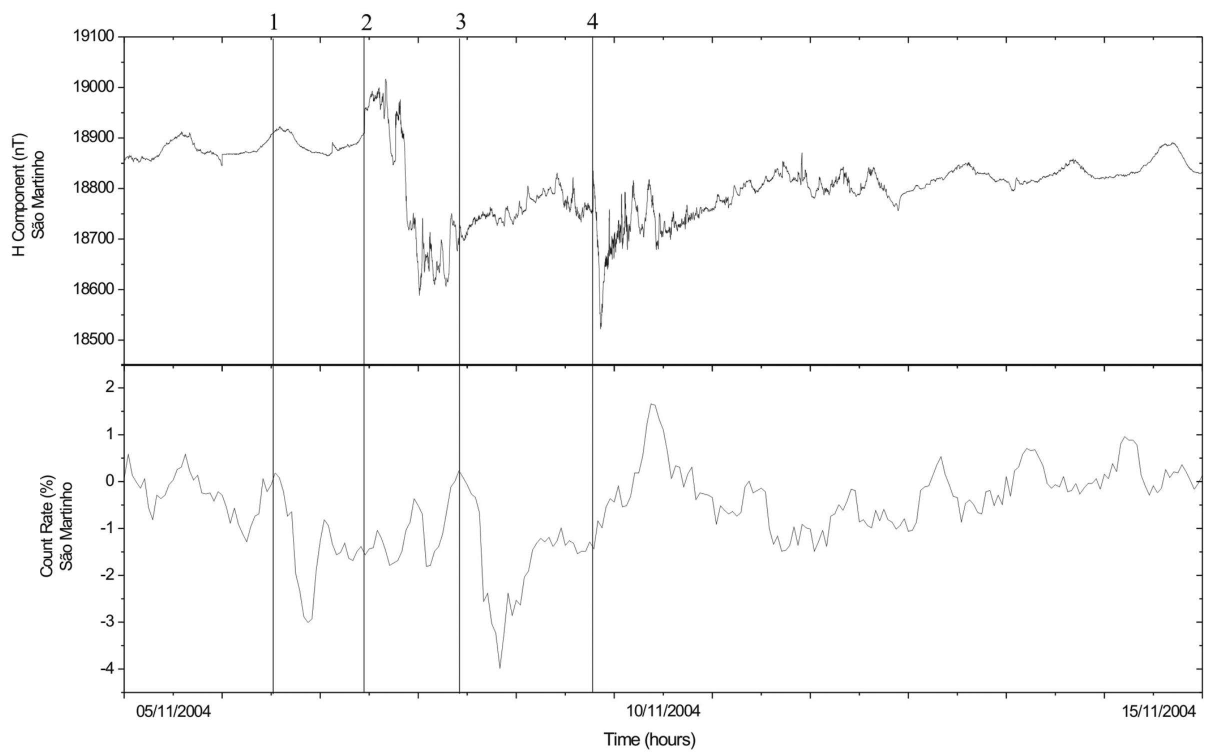

Figure 2 – Variations in H Component of Earth's Magnetic Field and Count Rate of the Muon Scintilator Telescope for the period of 5-15 November 2004.

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