A study of the cosmic noise absorption events in the south atlantic magnetic anomaly region associated with geomagnetic activity during corotating and transient streams

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A study of the cosmic noise absorption events in the south atlantic magnetic anomaly region associated with geomagnetic activity during corotating and transient streams

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Abstract. This work presents a study of the cosmic noise absorption events (CNAEs), recorded by the riometer in the South Atlantic Magnetic Anomaly region (22,55°S; 45,0°W) during a solar cycle (1984–1996). This study shows the CNAE occurrence and morphology behavior (occurrence rate and absorption intensity) during corotating and transient stream periods associated with geomagnetic activity and magnetic storm conditions. Results show that most of the CNAEs occur during transient streams instead of corotating stream periods. The CNAEs absorption intensity analysis (dB.h^{-1}) shows an increase tendency in transient stream periods, while for the corotating streams the absorption intensity remains stable. Thus, corotating streams periods show lower geoeffectiveness than transient stream periods in the induction of CNAE occurrences.

1. Introduction

The CNAEs are lower ionospheric disturbances strong enough to influence (change) the regular cosmic noise absorption in a short period (from 15 minutes to 6 hours). This phenomenon is associated with energetic electron precipitation events during magnetic disturbed periods (when the interplanetary magnetic field is southward directed for a long time and the solar wind shows high speed) and with the X-ray flux in the top of the atmosphere, for example.

The solar wind streams can be classified into two kinds, originated from two sources known as corotating flows and transient disturbances in the solar wind. The corotating are magnetically open, long-lasting, high-speed flows in quiescent solar wind, usually originated in coronal holes and exhibiting an apparent tendency to recur with the 27–day rotation period of the Sun. The transient disturbances can be low-speed flows that arise from the transient eruption of close-field solar regions and are mostly associated with coronal mass ejection.

The events originated by the solar energy particle injection and/or by the solar X-ray enhancement show a well known characteristic signature, analogous to most of the ionospheric disturbances produced during external interferences: a sudden response to the external disturb sources (a fast fall in the amplitude of the signal in the riometer data, for example) and, after its maximum absorption value, a slow and gradual recovery to the quiet conditions. A characteristic signature of the CNAEs is showed in Figure 1.

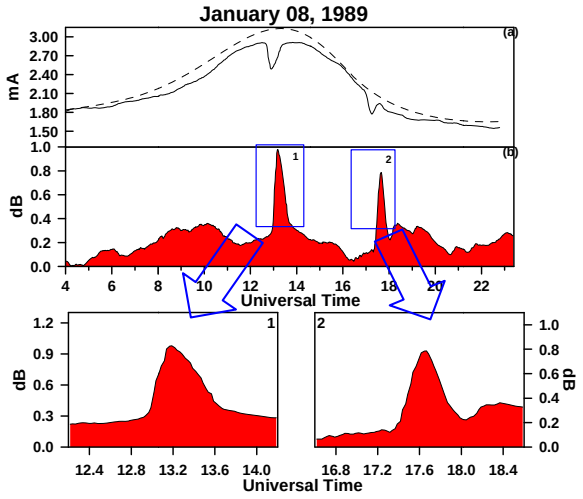

Figure 1. Events of energetic particle precipitation detected by the variation of the ionospheric cosmic noise absorption. (a) Data in units of current for the events (continuous lines) and for its respective curves at quiet conditions (dash line). (b) Curve of the ionospheric absorption intensity from the data presented in (a). Panels 1 and 2 present the events in detail.

This work studies the cosmic noise absorption events (CNAE) registered by the riometer at 30MHz from 1984 to 1996 located in Cachoeira Paulista (22.7°S, 45.0°W) in the lower ionosphere over the geomagnetic anomaly region. During this period, many CNAEs were detected. A parametric occurrence rate was computed and statistical analysis was carried out. The

analysis suggests a peculiar behavior of CNAEs in this site of observation (Figure 2).

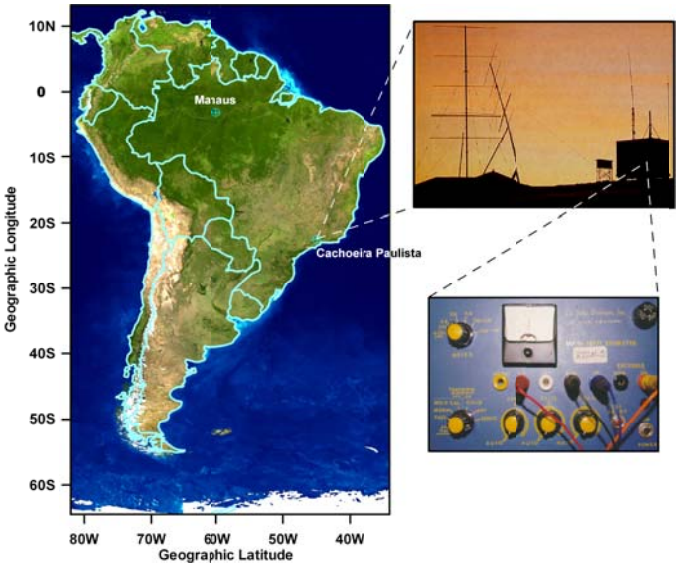

Figure 2. Geographic location of the riometer acquisition data system (Cachoeira Paulista - 22.7°S; 45.0°W).

2. Data reduction and analysis of the ionospheric absorption events.

In this work, it was performed 3749 days of riometer data analysis, in which there were 315 corotating stream (distributed in 1778 days) and 84 transient stream occurrences (distributed in 125 days), respectively. It was detected 354 CNAEs in these data and most of them occurring near 12:00 Local Time (~40 CNAE). In order to find out a relation between the CNAE occurrence rate with magnetic storm condition and geomagnetic activity associated with two kinds of solar streams, it was sorted a Dst and a Kp value in different ranges, which are presented in tables 1 and 2.

Table 1 – Magnetic storm condition ranges

Classification Period	Range
SW/SC - Shock Wave/Sudden Commencement	**Dst** > 0 nT
QC - Quiet Condition	0 nT ≥ **Dst** ≥ -30 nT
WS - Weak Storm	-30 nT > **Dst** ≥ -50 nT
MS - Moderate Storm	-50 nT > **Dst** ≥ -100 nT
IS - Intense Storm	-100 nT > **Dst** ≥ -250 nT
VIS - Very Intense Storm	**Dst**<-250 nT

Table 2 – Geomagnetic activity ranges

Classification Period	Range
VQ: Very Quiet	$0^{o} \leq$ **kp** $\leq 1^{o}$
Q: Quiet	$1^{o} <$ **Kp** $\leq 2^{-}$
N: Normal	$2^{-} <$ **Kp** $\leq 3^{+}$
D: Disturbed	$3^{+} <$ **kp** $\leq 4^{+}$
VD: Very Disturbed	**Kp** $> 4^{+}$

In Figure 3 the amount of data riometer data versus storm condition and geomagnetic activity ranges in daytime and nighttime periods are plotted. Most of the data are located in the quiet storm and normal geomagnetic condition ranges. The vertical antenna presents more hours of observation in the nighttime period. Unfortunately, we have few data in VIS and SW/SC storm periods for both daytime and nighttime.

Figure 4 shows the method used to compute the atmospheric absorption parameters. The ionospheric cosmic noise absorption for the riometer data was calculated using a reference curve (red line). This reference curve was defined as a fitting function between the initial and final times of the event analyzed and its respective registered values (in mA). Using this intersection as initial and final limits, a function of the quiet day curves was applied (using the sideral time as a temporal reference). Figure 4 presents an example of this method for 6 different events detected by the riometer at 13/01/1989 in the Brazilian Antarctic Station. The gray area means the total absorption (in dB) for a specific event. All the events detected by the vertical antenna in Cachoeira Paulista are showed overlapped on Figure 5. In Figure 5.a the reference curves that were used to calculate the relative ionospheric absorption to each event were also plotted (Figure 5.b).

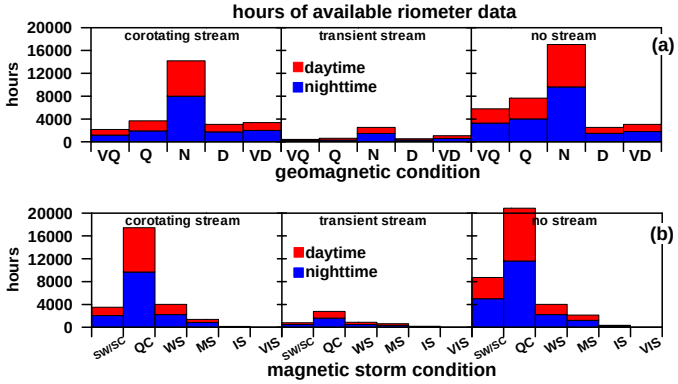

Figure 3 – Riometer data available (in hours) for different kinds of solar streams versus (a) geomagnetic activity and (b) magnetic storm intensity conditions.

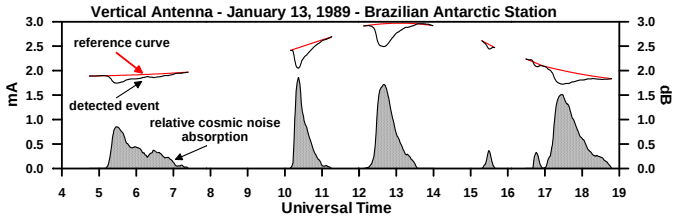

Figure 4. Example of cosmic noise absorption events (black line), reference curves (red line) and relative ionospheric absorption intensity (gray area).

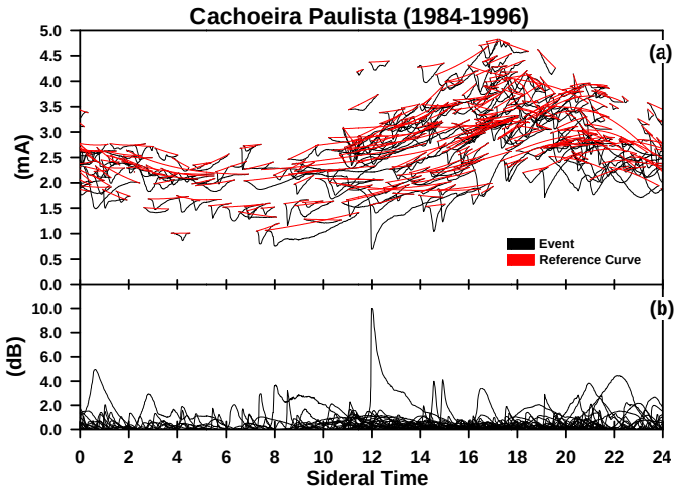

Figure 5. Events detected by the vertical antenna in Cachoeira Paulista. (a) Detected events (black line) and its reference curves (red line) versus sideral time. (b) Relative ionospheric cosmic noise absorption versus sideral time.

3. Results and Discussion

Histograms of CNAEs occurrence per hour for different types of stream (corotating and transient) are presented in Figure 5. In general, corotating stream periods showed a lower CNAE

occurrence rate than transient and no stream periods. However, the CNAE occurrence rate during corotating and transient stream periods increases with geomagnetic activity increasing. This tendency is not observed during any stream periods. There is a large CNAE occurrence rate in disturbed geomagnetic periods for both kinds of solar streams at nighttime. At daytime, the CNAE occurrence rate shows a large value in disturbed periods (D) in transient stream periods, but during corotating periods this do not occur. The CNAE occurrence rate in corotating and no stream periods do not show a clear tendency associated with geomagnetic activity in the daytime period.

Figure 6.c shows the absorption intensity ($dB.h^{-1}$) versus the geomagnetic activity. An enhancement of absorption intensity at daytime is clear in transient stream periods. In corotating streams, there is an almost constant intensity absorption in both periods (daytime and nighttime). It is noticed that the lowest values of absorption intensity are observed during corotating stream periods in daytime. During nighttime, this response is not observed. The highest value of absorption is registered during corotating streams. No stream periods show a decrease tendency with geomagnetic activity increase.

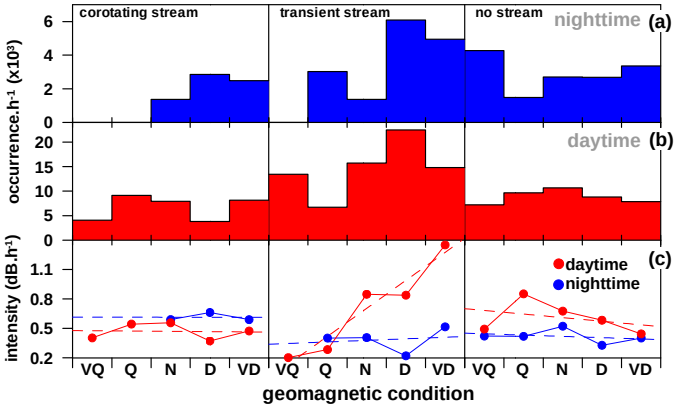

Figure 6. (a) CNAE occurrence per hour versus geomagnetic activity in nighttime and (b) in daytime. (c) Absorption intensity versus geomagnetic activity during corotating, transient and no solar stream periods.

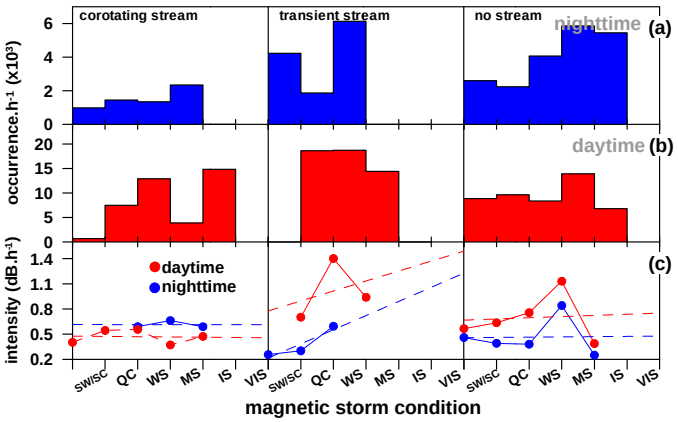

Figure 7 – (a) CNAE occurrence per hour versus magnetic storm conditions in nighttime and (b) in daytime. (c) Absorption intensity versus magnetic storm conditions during corotating, transient and no solar stream periods.

Under strong magnetic storm conditions (lower Dst), energetic particle precipitation occurs in the poles at local midnight. The geomagnetic field lines guide these particles until middle and low latitude regions. However, in the South Atlantic Anomaly Region, the precipitation altitude decreases to less than 100 km and the particle pitch angle increases, supporting a large particle precipitation and a large CNAE occurrence rate. However, this phenomenon takes place mainly after sunset and before midnight local time.

4. Conclusions

This study was carried out using data from 1984 to 1996 recorded by riometer in Cachoeira Paulista in the South Atlantic Magnetic Anomaly region. The main conclusions are:

- CNAE occurrence rate is larger in transient streams than in any other solar stream periods, independent of geomagnetic activity and magnetic storm conditions.
- Generally, the absorption intensity rate enlarges in transient stream periods with the increase of geomagnetic activity and magnetic storm conditions, while during corotating streams this intensity remains almost constant.
- Periods of the corotating streams are less geoeffective than transient stream periods to cause cosmic noise absorption events in the South Atlantic Geomagnetic Anomaly region.

Correlations between registered events of particle precipitations, geomagnetic conditions and characteristics of the interplanetary magnetic field (direction and intensity) have been made to contribute to this work. SUGGESTIONS AND COMMENTS ARE WELCOME.

Acknowledgments

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