Analysis of the Effects of the Thunderstorms in the Muon and Electromagnetic Component of the Cosmic Rays in Mexico City during 2004

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***Abstract*. We studied the effect of thunderstorms (TS) in the intensity variations of the electromagnetic (EM) and muon components of the Cosmic Rays during the year 2004. The results show variations of short period whose main periodicities are arranged in a distribution where the most important are the shortest. These may be associated to the electric fields of the TS. Significant long period variations were found too, these could be due to other processes linked to rainstorms. No systematic effect on the power of variations due to TS was found.**

***Keywords*: Thunderstorms, Cosmic Rays, Electric Field**

I. Introduction

In this study we used several methods in the search for signatures of TS over Mexico City in the secondary cosmic ray intensity records in the muon telescope located in the National University campus (1903' N, 9857'W). We considered 25 TS days (TSD) and 25 Quiet Days (QD) as control (for details see [1]).

II. Methodology

With the aim of reducing to a minimum the possible influence of solar activity, we selected the year 2004. Geomagnetic variations influence was reduced by choosing only quiet days where the Kp daily index was less than 20; furthermore the data were clear of periods when Forbush decreases; finally the data were corrected for atmospheric effects (pressure and temperature).

To find high frequency signals produced in the muon telescope due to variable electric fields we use a high pass filter to eliminate data trends [1]. A filtering process was done for each one of the 25 TS, using periods of 24 hours around the storm and for 25 QD that were also free from the influence of phenomena such as rain, and cumulonimbus clouds. These last conditions were imposed as the rain drags atmospheric radioactive radon that decays generating alpha, beta and gamma rays that may contribute mainly to the EM counting rates [2], [3].

The wavelet method was used to do a spectral analysis [4]. In the search for the periodicities present in the signals that could be due to the electrical storms we performed spectral analysis to four different sets of data: i) 24 hours of data centered on the TS. ii) Only the period of the TS was analyzed. iii) An equal number of QD were selected and the spectral analysis was performed for these 24 hour periods. iv) From 25 QD sets, a subset of a time length equivalent to those of the 25 TS used in ii) was selected.

III. Results

Filtered data show variations in the TSD from $\pm 0.5\%$ to over $\pm 1.1\%$ of the average counting rate for the EM component and from $\pm 0.5\%$ to $\pm 1\%$ for the muonic component. The maximum variation found is a $\pm 2\%$ corresponding to the EM component; and more than 80% of the variations for the QD lie in the range from $\pm 0.5\%$ to $\pm 1\%$. The maximum variation found for the QD is $\pm 1.4\%$ for the electromagnetic component.

The power spectral density (PSD) fluctuations were calculated with the wavelet method for the 25 TSD and for the QD filtered data. The data were normalized by the corresponding $1/\sigma^2$ in each case.

The calculated red noise [5] will be plotted as broken lines in the global power spectra shown in plots appearing in figures 1 to 4.

Case i) long and short period variations may be distinguished in the results for both components. One is of periodicity from 10 to 30 min., the other has a period of one hour or larger; these may be clearly appreciated in fig. 1. We may ascribe the short period directly to the TS as was the case with previous works in this field [3], [6]-[11] while the long period, that is present at times before and/or after the TS, could be due to the presence of rain as the falling water carries with it unstable particles that decay enhancing the electromagnetic flux variations [2], [3], [12].

ii) the high frequency variation with periodicities from 10 to 30 min is also found (see fig. 2). Due to the time resolution of our detector (5 min) it is not possible to see variations of a higher frequency as was done by other authors [13].

Case iii) the long and short period variations are also present; however the times when their significance

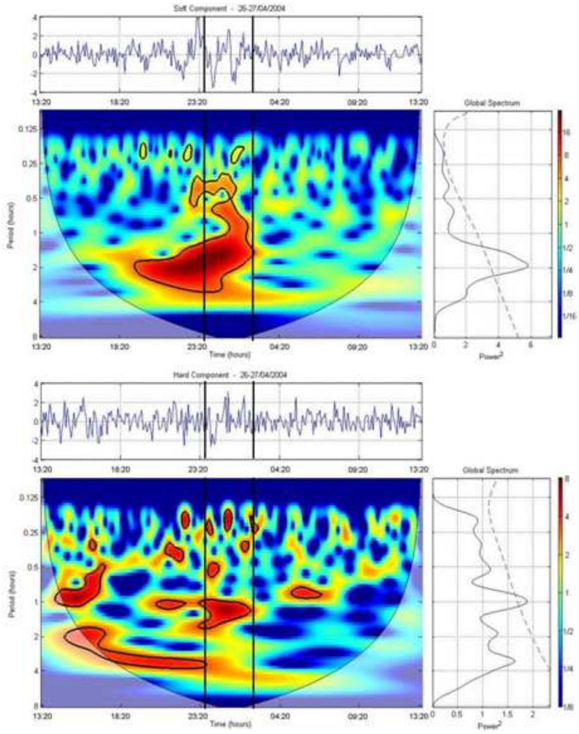

Fig. 1: Wavelet PSD showing short and long period variations on a TSD (26-27 April 2004) in the EM (top) and Muon components (down). The upper panel shows the high frequency variations normalized by the standard deviation. The storm period is indicated by the two vertical lines in the lower panel. The global spectrum is plotted in the right panel where the 95% significance level is indicated by the dashed line.

is of less importance than when thunderstorms are present. These variations could not be associated with atmospheric effects since the data were pressure and temperature corrected; we are also sure that any other perturbing phenomena such as intense rain or large clouds were absent during these days (see fig. 3).

Case iv) the soft component shows a very pale variation of around 10 min. The hard component global spectrum shows two peaks at around 10 and 20 min; they are all below the established confidence level (fig. 4).

To have a reference of the power dissipated during either TS or interval similar of a QD, the global spectra without normalisation were integrated. Then the total power of the TSD was normalized with the average total power of the QD. Results are shown in Figure 5. We have grouped the ratios obtained in class intervals to see if there is a systematic effect. In the case of the EM, there are 13 storms that show an integrated power that is smaller during TS than during QD, while 12 events show the opposite. It is to note that eight of the 12 TS show a level of variations that more than double

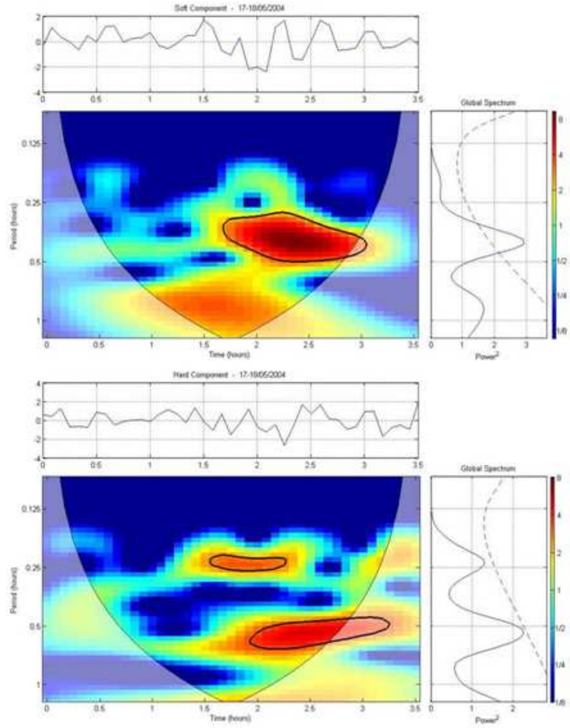

Fig. 2: Wavelet PSD for the TS on 17-18 May showing short period variations ($\sim$ 20 min) in the EM component (top) and Muon components (down). Panels are the same as figure 1.

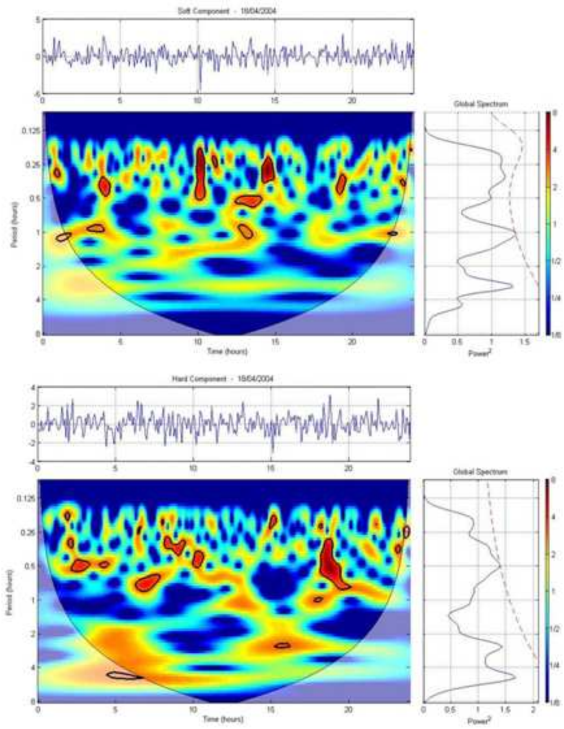

Fig. 3: Wavelet spectrum of the EM (top) and Muon components variations for the QD on 8 April 2004. Panels are presented in the same order as Figure 1.

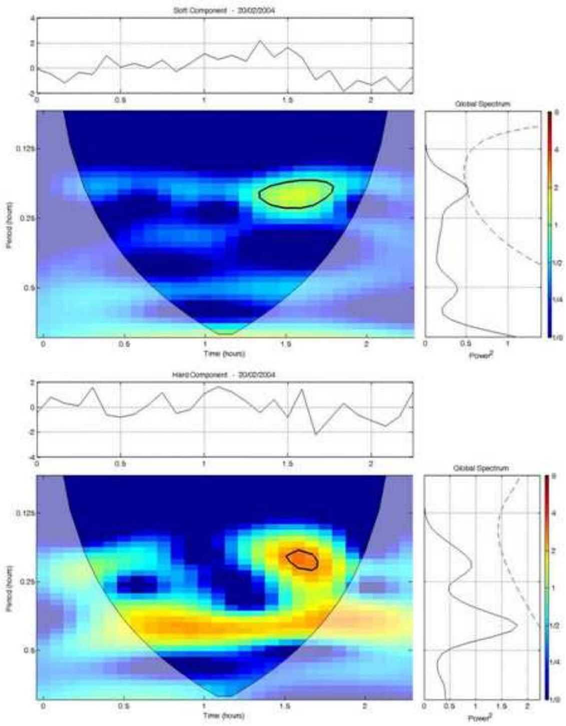

Fig. 4: Short duration variations in both components for QD (20 February 2004). Panels as in figure 1.

the fluctuation levels of QD times. The case of the muon component is similar: 11 TS have fluctuations smaller than the QD and 14 show the opposite.

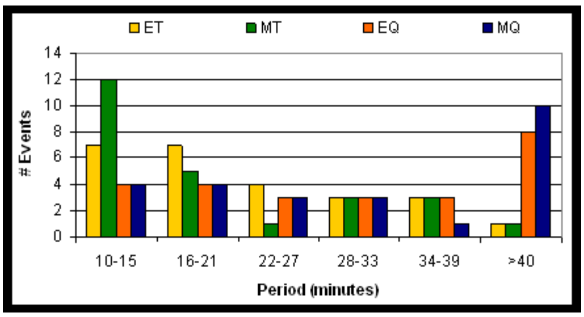

Fig. 5: Ratio of TS and QD for PSD integral of the EM and muon cosmic ray components.

IV. Discussion

The spectral calculations did show the presence of short term (10-30 min) and long term (few hours) periodicities in both components, in the analysis of the TSD calculations. As expected, the high frequency variations are also present when we take only the TS time intervals. This result is in accordance with the findings of [3], [6], [7]. The result of the low frequencies for the four cases is shown in fig. 6.

The results on the short term periodicities are presented in figure 7. There it is appreciated that during TS the highest frequencies dominate, in both components. In fact 72% of the events fall within this interval, as compared to only 44% for the QD. The effect is more pronounced in the muons and is probably due to the combination of two facts: i) shorter pathlenghts of electrons and positrons in the air, and ii) the production of beta and gamma radiation by enhanced radioactive elements during rainstorms. The observed tendency during TS is the opposite at QD, as there is a considerable amount of events where the highest power periodicity is larger than 40 min. This is a clear indication that the electric fields associated with the TS are enhancing the importance of the high frequency variations, to the best of our knowledge; no research group has reported an equivalent result previously.

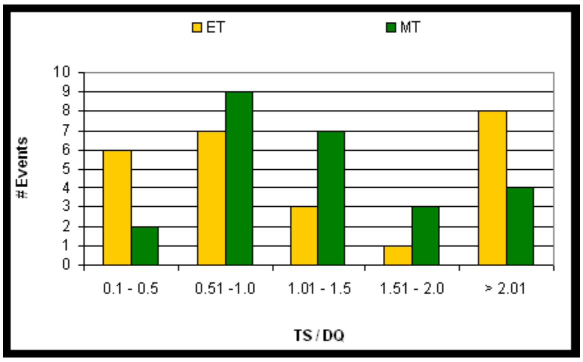

Fig. 6: Soft and Hard cosmic ray components most significant long duration periodicities during TS and QD. ET is the EM component and MT is the muon component for days with TS, whereas EQ is the EM component and MQ is the muon component for QD.

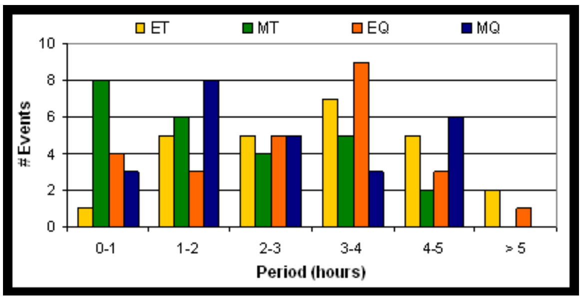

Fig. 7: Soft and Hard cosmic ray components most significant short duration periodicities during TSD and QD. Description as in figure 6.

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REFERENCES

[1] J. Alvarez-Castillo and J.F. Valdés-Galicia, Proc. 30th ICRC, México, 2007.
[2] M. Aglietta, B. Alessandro, P. Antonioli, F. Arneodo, L. Bergamasco, M. Bertaina, M. Brunetti, C. Castagnoli, A. Castellina, D. Cattani, S. Cecchini, A. Chiavassa, G. Cini, B. D'Ettorre Piazzoli, G. Di Sciascio, W. Fulgione, P. Galeotti, M. Galli, P.L. Ghia, G. Giovannini, M. Iacovacci, G. Mannocchi, C. Morello, G. Navarra, A. Pagliarin, O. Saavedra, G.C. Trinchero, P. Vallania, S. Vernetto and C. Vigorito,Proc. 26th ICRC, Salt Lake City, Vol. 7, 351-354, 1999.
[3] V.V. Alexeenko, N.S. Khaerdinov, A.S. Lidvansky and V.B. Petkov, Phys. Lett., A301, 299-306, 2002.
[4] C. Torrence and G.P. Compo, Bulletin of the American Meteorological Society, Vol. 79. No. 1, 61-78, 1998.
[5] D.L. Gilman, F.J. Fuglister and J.M.Jr. Mitchell, Journal of the Atmospheric Sciences, vol. 20, 1963.
[6] V.V. Alexeenko, A.E. Chudakov, V.G. Sborshikov and V.A. Tizengauzen, Proc. 19th ICRC, La Jolla, Vol. 5, 352-355, 1985.
[7] V.V. Alexeenko, A.B. Chernyaev, A.E. Chudakov, N.S. Khaerdinov, S.S. Ozrokov, and V.G. Sborshikov, Proc. 20th ICRC, Moscow, vol.4, 272, 1987.
[8] S. Vernetto for the EAS-TOP Collaboration, Proc. 27th ICRC, 4165-4168, 2001.
[9] N.S. Khaerdinov, A.S. Lidvansky, V.B. Petkov and Yu.P. Surovetsky, Proc. 28th ICRC, 4169-4172, 2003.
[10] N.S. Khaerdinov, A.S. Lidvansky and V.B. Petkov, Proc. 28th ICRC, 4173-4176, 2003.
[11] N.S. Khaerdinov, A.S. Lidvansky, V.B. Petkov, and Yu.P. Surovetsky, Proc. 28th ICRC, 4185-4188, 2003.
[12] V.V. Alekseenko, D.D. Djappuev, D.M. Gromushkin, A.U. Kudjaev, V.V. Kuzminov, O.I. Michailova, Yu.V. Stenkin and V.I. Stepanov, Proc. 30th ICRC, Mxico, 2007.
[13] Y. Muraki, W.I. Axford, Y. Matsubara, K. Masuda, Y. Miyamoto, H. Menjyou, S. Sakakibara, T. Sako, T. Takami and T. Yamada, Phys. Rev. D69, No 123010, 1-13, 2004.