30TH INTERNATIONAL COSMIC RAY CONFERENCE

Electric Storm Effects on the Soft and Hard Cosmic Ray Components Observed in Mexico City

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Abstract: The effects of thunderstorms on the electromagnetic and muon components of the cosmic ray secondary flux were studied during severe storms obtained in 2004, analyzing the variations of the counting rates shown in the upper and lower scintillators of the muon telescope installed in Mexico City and considering the data of storms report for the international airport of Mexico City.

Introduction

The acceleration of electrons by a charged thundercloud was first discussed for C.T.R. Wilson in 1925 [8]. Since then, many experiments were made to find the predicted beams of accelerated particles during thunderstorm.

In the early 1980s experiments with the air shower array at Baksan demonstrated correlations of variations of short duration in the intensity of secondary cosmic rays with the electric field of the atmosphere during thunderstorms [3], [1]; the new version of this experiment was published in 2002. Pre-lightning enhancements of the intensity of the soft component of secondary cosmic rays were observed in the experiment. It was also demonstrated that these enhancements apparently are of two different types [2]. One type has longer duration (several minutes) and is most frequent, while the other is shorter and very rare.

Khaerdinov et al. (2003) presented the results of a correlation between the hard and soft components of secondary cosmic rays and the atmospheric electric field during thunderstorm periods. They demonstrated that there is a quadratic effect changing the intensity of secondary cosmic rays in an electric field of any sign. They studied also the statistic effect of lightning on the intensity of cosmic rays [4], [5], [6]. At the 29th International Cosmic Ray Conference, Khaerdinov and Lidvansky studied the effect of thunderstorms electric field on the muon intensity observed at ground level. The resulting effect is predominantly negative (decrease intensity) and its amplitude increases with the decreasing energy threshold of muons [7].

Classification of Cosmic Rays Variations

Cosmic ray intensity variations may be expressed as due to three causes:

$$\frac{\delta N^i(R_c,x)}{N^i(R_c,x)} = -W^i_{R_c}(R,x)\,\delta R_c + \int_{R_c}^{\infty}\frac{\delta S^i(R,x)}{S^i(R,x)}W^i_{R_c}(R,x)\,dR + \int_{R_c}^{\infty}\frac{\delta I(R)}{I(R)}W^i_{R_c}(R,x)\,dR$$

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Where:

$$W^i_{R_c}(R,x) = \frac{S^i(R,x)\,I(R)}{N^i(R_c,x)}$$

I. Variations of the geomagnetic cut-off, that may occur as a result of any geomagnetic perturbation.

II. Variations in the integral multiplicity of generating secondary particles that may result from any type of variable conditions in the terrestrial atmosphere (Pressure, temperature, etc.).

III. Variations in the primary cosmic rays due to interplanetary variable conditions.

Data Selection

Muon counting rates were obtained from the upper and lower scintillators of the muon telescope installed in Mexico City. We use 5 minutes data of the vertical direction for the electromagnetic and muon component.

To obtain a proxy the electromagnetic component, we subtracted the counting rates of the lower scintillator to the upper scintillator, the upper scintillator counts all the secondary cosmic rays, the lower scintillator counts only the muon component. Figure 1 shows the scintillator array, each plastic has an effective area of 0.44 m^2. The energy cut-off of the detector is 8.2 GeV.

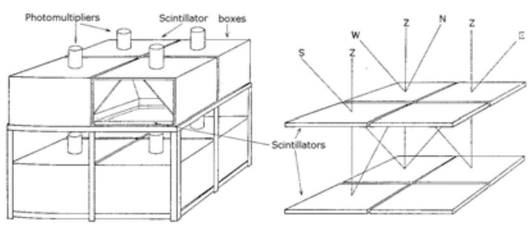


Figure 1: Scheme of the Muon Telescope.

Quiet time data periods were selected (i.e. Forbush Decreases wee omitted). Furthermore, to eliminate the possible influence of geomagnetic disturbances, we choose days with thunderstorms during which the daily sum of geomagnetic index $K_p < 20$. Finally the data were corrected for variations of atmospheric origin.

The thunderstorm data were obtained from the International Airport of Mexico City. The meteorological station is less than 10 km from the Muon telescope location. We search periods with thunderstorms of duration greater than two hours.

The total number of thunderstorms found is 107, disturbed free only 88 and we have 25 events greater than two hours.

Study Design

To find high frequency signals produced in the muon telescope due to variable electric fields we use a low filter to eliminate data trends (low frequency). Figures 2 and 3 shown the filtering process, to find variations in the hard and soft component we plot the 2σ level as horizontal lines in the lower panel.

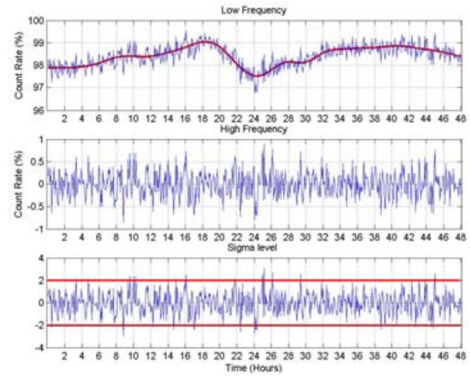


Figure 2: The filtering process of electromagnetic component for the 26-27 April, 2004. The top panel is the original electromagnetic data (blue), the resultant of the low pass filter is the red line. The middle panel it's the high frequency component of the cosmic ray data, the bottom panel it's the plot normalized with σ. The 2σ level is shown in red.

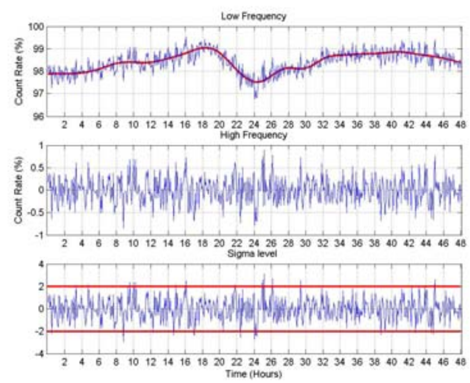
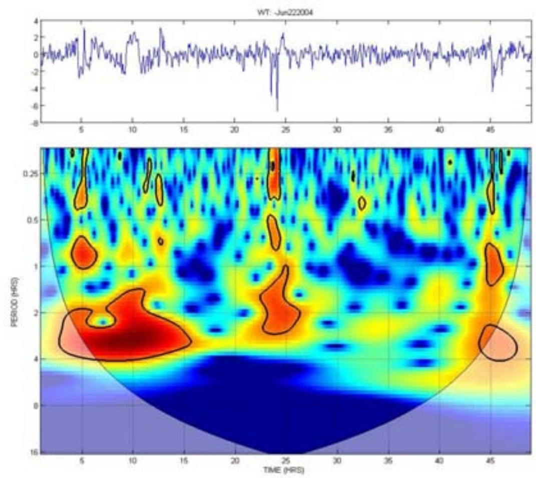
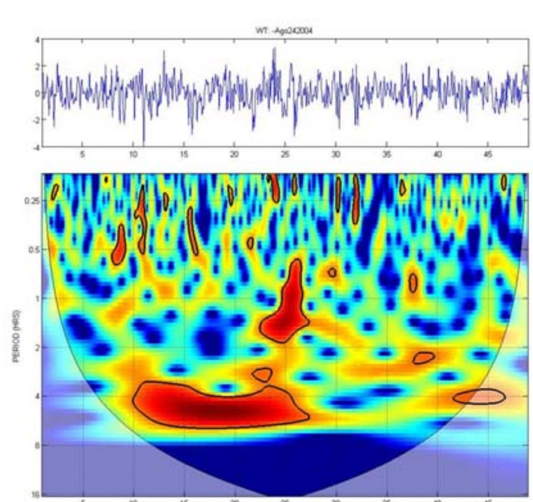


Figure 3: The filtering process of Muon component for the 26-27 April, 2004. The top panel is the original muon data (blue), the resultant of the low pass filter is the red line. The middle panel it's the high frequency component of the cosmic ray data, the bottom panel it's the plot normalized with σ. The 2σ level is shown in red.

The filtering was made for the 25 events. The series were analyzed with a wavelet transform. Results for two typical events (22 June and 24 August) are shown in figures 4 and 5.

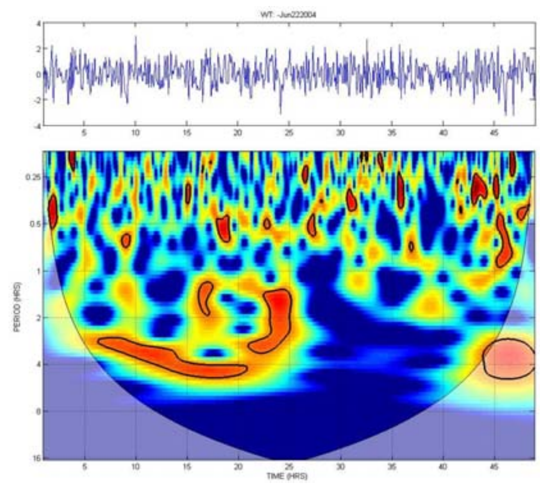


(a)

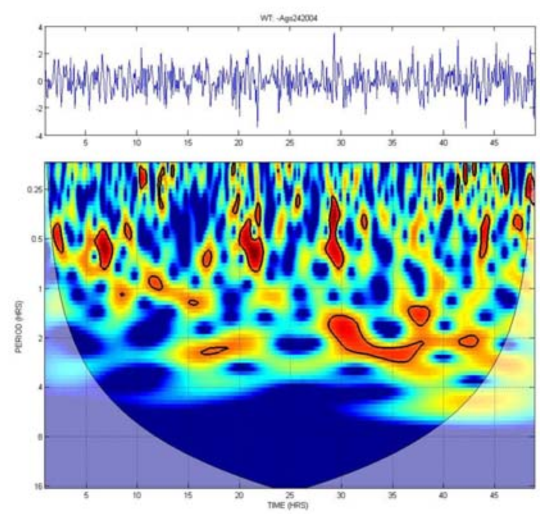


(b)

Figure 4: (a) is the electromagnetic component wavelet spectra of the 22-23 June, and (b) is the corresponding muon component spectra. The top panels are plots of the counting rates (%) cosmic ray data in units of standard deviation.



(a)



(b)

Figure 5: (a) is the electromagnetic component wavelet spectra of the 23-24 August, and (b) is the corresponding muon component spectra. The top panels are plots of the counting rates (%) cosmic ray data in units of standard deviation.

Results

The bottom panels of figure 2 show enhanced variations in the interval of 22-26 hours for the soft and hard cosmic ray components, during the thunderstorm of 26 April, 2004, whose duration was from 23:45 PM to 03:00 AM of the 27 April (2345-2700 hours in the plot). This could be an evidence of the electric field effect of thunderstorms on Secondary Cosmic Ray.

The two selected events show enhanced variations of the electromagnetic component in the range from 0.5 to 3 hours around the time of the thunderstorm (Figures 4a and 5a). In the case of the June 2004 event this enhancement extends to the lowest periodicities of the series (Figure 4a). Nearly 15 hours previous to the storm, there is a significant variation of around 4 hours period that could be speculated to be a precursor. Figures 4(b) and 5(b) are the muon component wavelet analyses. An enhanced periodicity of around 2 hours is present only in the thunderstorm in 4(b), this could be due to the fact that thunderstorms with weak electric field affect only the e-m component of secondary cosmic rays but not the muon component as this is more energetic and its transit times are faster.

Acknowledgments

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