Cosmic Rays Muon Flux and Precipitation

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Abstract—**Data from the muon telescope at BEO Moussala and data for the local precipitation for almost 2 years period were analyzed. Clear dependence between precipitations and cosmic rays variations was not established for the period analyzed.**

1. Introduction

THERE are many studies on the relation of climate changes with variations of the cosmic rays (CR) flux and their role as an amplifier of the solar variability effect. (See [1], [2] for detailed review.) One of the hypotheses is the CR - cloud cover connection through ionization [3], another is the influence of the solar wind on the global electric circuit and cloud formation [4]. The cloud cover obviously is connected with the rainfalls and CR - rainfall or solar cycle - rainfall relations for certain regions are established by many authors [5], [6], [7], [8].

The effect of the CR on different meteorological parameters is studied also during sporadic changes (Forbush decreases, Solar proton events) [9], [10].

On the other hand the atmosphere with its parameters influences the generation and propagation of the secondary CR particles, observed by ground-based detectors – the well known barometric effect for nucleon component and barometric and temperature effect for muon component. Another atmospheric effect is the acceleration of the charged particles in the electric field of the thunderclouds. [11], [12], [13], [14].

All mentioned above induced the presented study, in which we tried to find correlation between the intensity of the muon component of cosmic rays and the local precipitation at BEO-Moussala.

The Basic Environmental Observatory Moussala is located at peak Moussala, 2925 m a. s. l. (≈730 g/cm^2), 42°11'N , 23° 35'E. The rigidity cut off is Rc≈6.3 GV.

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2. The Data Set

The intensity of the muon component at the BEO site has been continuously measured since August 2006 with 1 m^2 muon telescope. The instrument has energy threshold for CR muons ~0.45 GeV and statistical error for vertical direction ~0.27% for hour time intervals [15]. The count rate is ~2400 min^{-1}, the counts are recorded every 15 seconds.

All of the used data are pressure corrected for 712 hPa, and the 0 % is the average of the counts during the whole period of observations. No data for the temperature profile of the atmosphere were available and no temperature corrections were applied.

The amount of precipitation is measured with the automatic weather station Vaisala, the rain gauge is type RG13H. The data is recorded every 10 min.

The analyzed period is from 2 August 2006 to 22 June 2008.

3. Data Analysis

A. Short Time Series.

We used 10 minutes averaged, pressure corrected muon count rates of the vertical direction to check if noticeable change during individual rain and snowfalls exist. The statistical error is ~0.65%. The data are high pass filtered, to avoid any possible trends due to modulation or due to geomagnetic disturbances.

Two typical plots are shown in Fig. 1 and Fig. 2. The variation of muon counts stays within 3σ limits (±1.95%) independently of the precipitation.

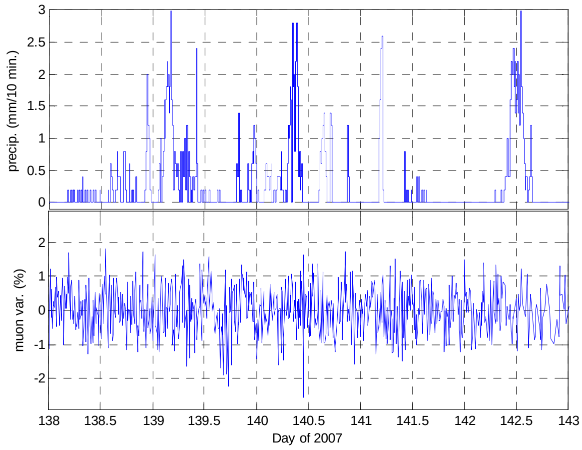

Fig. 1. Precipitation and muon flux variation during the time period 19.05.2007 – 24.05.2007 (rainfall)

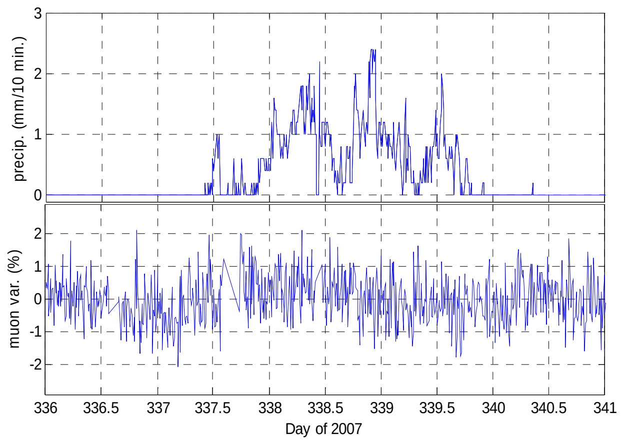

Fig. 2. Precipitation and muon flux variation during the time period 03.12.2007 – 08.12.2007 (snowfall)

B. *Daily Averaged Values.*

Daily variations for CR muons and daily precipitations for the considered period 02.08.2006-22.06.2008 are shown in Fig. 3. The correlation coefficient was r = -0.0143 (p=0.711).

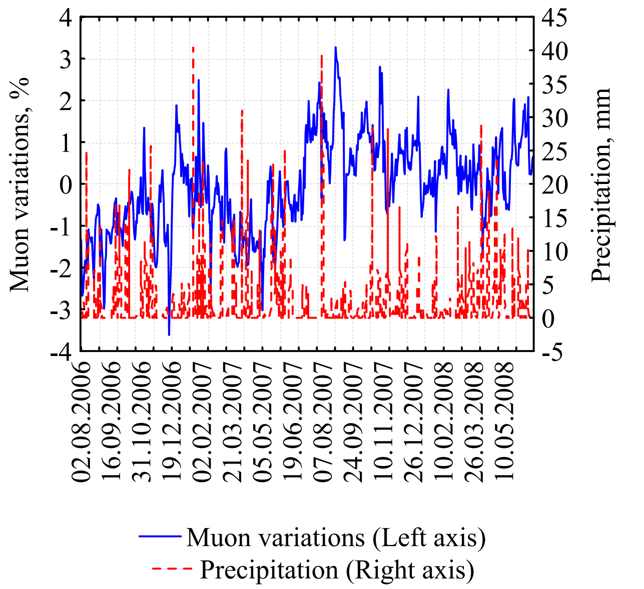

Fig. 3. Daily variations of precipitations and muon variations for the period under consideration 02.08.2006-22.06.2008.

Daily averaged data for 674 days were used to test the effect of CR muons on daily amount of precipitation by the statistical method *ANalysis Of VAriance* (ANOVA), statistical package STATISTICA, ver.6, StatSoft Inc., 2001. In general, the purpose of ANOVA is to test for statistical significance between means through comparing variances. In ANOVA a null hypothesis is considered when the studied factor A does not effect significantly the variation of the parameter X. This means when comparing the mean values of X at each A factor level there is no statistically significant difference between them. If such a difference is found, then the null hypothesis should be rejected [16].

It can be seen from Fig. 3 that the muon intensity varied in the range -3%-+3% during the period under consideration. The muon flux was divided into 7 levels with 1% variation each. Table 1 shows the number of the days for the time interval with the respective increases and decreases in the range.

TABLE 1
THE NUMBER OF DAYS WITH DIFFERENT MUON VARIATIONS

Muon variations	-3%	-2%	-1%	0%	1%	2%	3%
Number of days	2	17	123	408	105	17	2

ANOVA applied for the study of CR muon influence on the precipitations did not reveal statistically significant effect (p=0.5). Fig. 4 shows the mean amount of precipitations under different muon variations during the considered period. Vertical bars in the figure denote 95% confidence intervals (CI). It is seen that the precipitation amount decreased when CR muon intensity decreased with 2% and 3%. Unfortunately there were only 2 days during the period under consideration with muon variations -3% (Table 1) and because of that CI is large. However, there were 17 days with muon variations -2% and the precipitation amount was definitely low then in comparison to other CR muon levels (in fact muon increases).

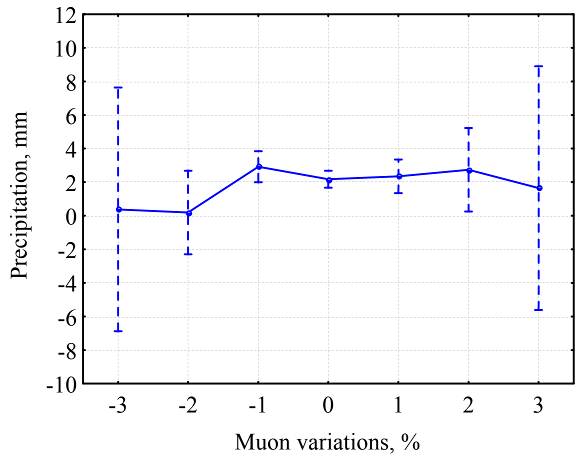

Fig. 4. Muon effect on precipitation (±95% CI).

The method of superimposed epochs and ANOVA were used to study muon influence up to 3 days before and 3 days after their variations on the precipitation amount. Significant effects were not established. Fig. 5 shows dynamic of precipitation for the different muon variations (on the days before (-), during (0) and after (+) different variations in muons. The amount of precipitation was almost one and the same on the days before, during and after muon variations with 0%. Precipitations decreased gradually from -3rd to +3rd day when muons varied with -1% and were larger from -1st to +2nd day of muons increase with 1%. There were peak increments on -1st day of muon variation with -2% and on +3rd day of muon variation with 2%. The minimal amount of precipitations was from -2nd to +3rd day of the largest muon decrease (muon variation with -3%). There were no precipitations on -3rd, -2nd, -1st, +2nd and +3rd day when muons increased with 3% but it should be noted that there were only 2 days in the examined period when muons increased with 3% (Table 1).

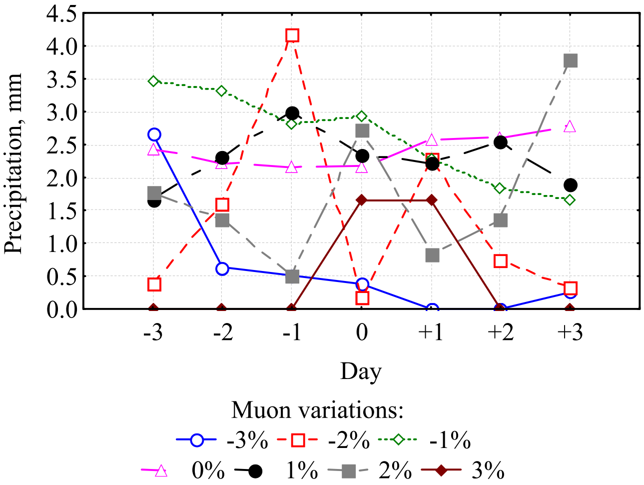

Fig. 5. Muon effect on precipitation before, during and after muon variations.

4. Discussion and Conlusion

For the short time series data we expected some relation, especially for the spring–summer months, since most of the rainfalls are accompanied by thunderstorms. The effect of the atmospheric electric field on muons with E>1 GeV measured by other groups [12], [13] is in the order of 1%, and probably the statistical error of our instrument is too high to register it. And yet, continuous monitoring of the intensity of the near Earth electric field at the Observatory will be useful.

For the analysis of the daily averaged values we expected to find a positive correlation, because of the connection of CR with the low cloud cover [17], hence precipitation. Moreover the observation site is with geographical coordinates at which the correlation coefficient CR - low cloud cover is comparatively high [18]. The correlation coefficient we obtained was negative and not significant, however ANOVA revealed a trend the amount of precipitations to increase with the CR muons increment.

The period analyzed was not long and it spanned only declining phase of solar activity, i.e. there were not many extreme solar events and Forbush decreases. Therefore general conclusions should not be drawn although the results support the hypothesis that at our latitudes precipitation increases with the muons increase.

Any effect of the CR variations (monitored by muon variations) on the rainfall at the Observatory could not be established mainly because of the short period for which the data are available, leading to poor statistics. Data gathering should continue and the study should be made for longer period.

Acknowledgment

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