The Effect of Lightning on the Intensity of the Soft Component of Cosmic Rays

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The pre-lightning enhancements of the soft component of cosmic rays were detected in the experiment with the Baksan air shower array. The pictures of two brightest events of this type were published, giving evidence of a big difference in duration of the enhancement depending on the lightning polarity. Now we study the lightning effect statistically. The variance of counting rate is calculated excluding time intervals around lightning from the analysis. This processing results in a decrease of the variance. The value of this decrease is studied in some detail for various selection criteria.

Introduction

The pre-lightning enhancements of the soft component of cosmic rays were detected in the experiment with the Baksan air shower array. The pictures of two brightest events of this type were published [1], giving evidence of a big difference in duration of the enhancement depending on the lightning polarity. There are, however, many events in which the enhancements are no so spectacular. It is not an easy matter to identify small events of this type and to determine their characteristics. In this paper we try to study the lightning effect statistically. The progressively increasing intervals around lightning events are excluded from the analysis successively and every time the remaining sample is analyzed.

Method

The active phase of thunderstorms is accompanied by lightning strokes of different type and height, which result in relatively fast variations of the electric field strength near ground level. The electric field meter records these variations, and for our analysis we need a strict definition of lightning. We define the 'lightning' as an event when the electric field changed its strength by a preset large value in preceding 10 s. Three criteria of this rate of change were used: more than 0.5, 1, and 2kV/m for 10 seconds. The period of time $\pm \Delta\tau$ symmetric around the instant of lightning was excluded from processing. The initial sample included the same 88 thunderstorm events selected from 108 events detected in three observation seasons as in [2] (in paper [2] the procedure of data selection and filtering is described). The value of $\Delta\tau$ was varied from zero to 2400 s with a gradually increasing step. The correlation analysis similar to that

Fig.1. The weighted mean ratio of the residual dispersion to its theoretical value versus the live time after exclusion of around-lightning intervals.

of [2] was performed for every thunderstorm event in every new sample. As a result of this correlation analysis we have two series of coefficients (linear and quadratic) and a series of ratios of residual dispersions to their expected values. The weighted mean values of these quantities are further analyzed as a function of $\Delta\tau$.

Results

Figure 1 presents the weighted mean value of the ratio of residual dispersion to the expected

Figs. 2 and 3. The linear (on the left) and quadratic (on the right) coefficients versus the time interval $\Delta\tau$ excluded around lightning events.

theoretical value versus the live time remaining in the sample. One can see that the dispersion at first quickly decreases approximately until $\Delta\tau$ = 540 s (hence, the characteristic time of lightning influence is within this limit), then its behavior depends on the criterion of lightning used. It is obvious that extreme cases are not suitable for the analysis. Too strong criterion 2 (kV/m)/10s leads to exclusion of regular field intervals, while small lightning events are retained. Therefore, the dispersion increases strongly after a minimum. Too liberal criterion 0.5 (kV/m)/10s is connected with significant loss of statistics. This means that not only disturbed intervals are excluded, but regular fluctuations as well. Therefore, the dispersion decreases monotonically in this case. Finally, we selected the intermediate value of 1 (kV/m)/10s, and further data are presented for this lightning criterion.

Fig. 4. The regression curve of the soft component intensity versus the electric field strength after the exclusion of all around-lightning intervals with $\Delta\tau$ = 540 s.

Figures 2 and 3 present the behavior of linear and quadratic coefficients, respectively, versus $\Delta\tau$. As is seen, the variation of the linear coefficient is small and monotone. The quadratic coefficient, on the contrary, changes rather strongly: after a sharp drop during 3 min, it slightly increases again and then remains approximately constant.

Figure 4 shows a plot similar to Figs. 2 and 3 in [2] for the value $\Delta\tau$ = 540 s, for which the minimum dispersion is achieved in Fig. 1. One can see that though the regular part of the soft component dependence on the electric field is not so good as in [2] (due to significant loss of statistics), the large fluctuations at the strong field disappeared, as well as the bump at positive field strengths. Figure 5 demonstrates pictorially how the method works by comparing the initial points (empty circles representing the same points as in Fig. 2 of [2]) with the final points (solid circles, the same points as in Fig. 4 above).

Conclusion

Thus, both linear and quadratic effects are present in the soft component variation with the electric field. Both are almost constant far from lightning instants, the linear effect, though slightly variable, is approximately constant even around lightning events. There must be a correlation between lightning instants and the existence of strong field high above, so the minimum in Fig. 3 can be ascribed to the contribution of muons, since they have a negative and energy-dependent quadratic effect [3] and are sensitive to the field over large distances. Pre-lightning enhancements have a typical time of several minutes. The weighted mean values of the linear and quadratic coefficients determined for $\Delta\tau$ = 540 s (far from lightning instants) are equal to (–0.0382 ± 0.0015) % per kV/m and (0.00340 ± 0.00032) % per $(kV/m)^2$, respectively.

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