Estimate of Distance to Lightning Events Associated with Cosmic Ray Enhancements during Thunderstorms

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1. Introduction

The pre-lightning enhancements of the intensity of soft cosmic rays (10-30 MeV) were observed by the Baksan air shower array [1] and interpreted as a direct confirmation of the theory of runaway electron breakdown [2]. In order to reconstruct a more detailed picture of the phenomenon under study we supplied our experiment with a simple microphone system, which allows us to derive some data about the distance to lightning channels. In the season of 2002 this system was in operation from August to November, and below we present some results of this experiment.

2. Experimental

Figure 1 presents a diagram illustrating the principles of distance measurements. The signal from a microphone M is divided and after passing through high-frequency and low-frequency filters feeds a coincidence circuit. The output signal of the coincidence circuit stops the counter of pulses CP that counts 50 Hz pulses from a generator G being started by the signal from an antenna A. Recording device R stores these data. The microphone M is put under a heavy metal plate in order to protect it against the sounds of noise produced by rain droplets. Unfortunately, this turned out to be possible within some limits, since extremely heavy rain results in the system malfunction (see Fig. 3 below for an example). The system of two filters is used in order to avoid the echo effect, which is especially important in a narrow mountain valley. The underlying idea is that the echoed signal contains mainly low frequencies, thus the necessary high-frequency component in the scheme of Fig. 1 essentially reduces reflected sound signals. Thus, the measurements of time delays of only direct sound signals should become possible.

3. Results

From August to November as many as 44 thunderstorm events were detected (we define a thunderstorm events as an event when the electric field strength exceeds 2 kV/m for at least 15 min, each event should be separated

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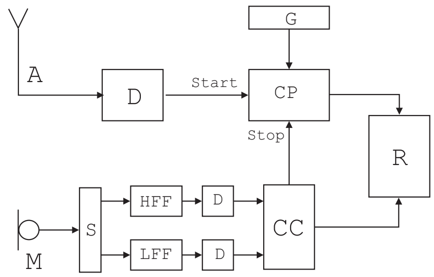

Fig. 1. A block diagram of measuring the distance to lightning. A and M are, respectively, an antenna and a microphone. D means discriminator, S is splitter, HFF and LFF represent HF and LF filters, CC is the coincidence circuit, G is generator, CP is the counter of pulses, and R is the recording system.

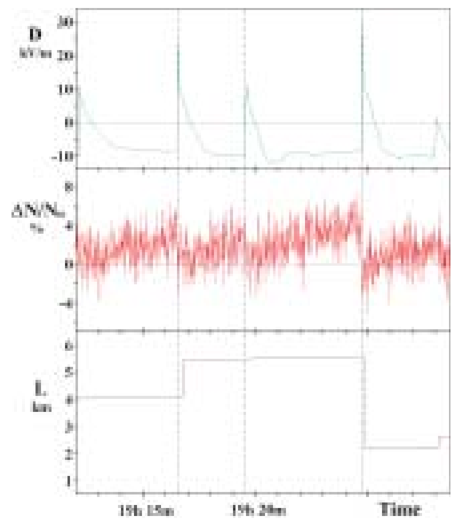

Fig. 2. A short interval of a thunderstorm on August 1, 2002.

from another one by at least one hour). Among these events only five can be considered as real thunderstorms with strong lightning activity. No pre-lightning enhancements so bright as examples presented in [1] were detected, though some modest events of the same type (increases of a few percent amplitude) are obviously present in the data. Figure 2 presents an example: a short episode of a thunderstorm on August 1, 2002. The data of the electric field meter (upper panel) show three well-pronounced lightning events in the center. There are increases of the soft component intensity before each lightning stroke; the largest (about 4%) is before the third lightning. The bottom panel of Fig. 2 presents the result of measurements according to the scheme of Fig. 1.

One should have in mind that the electronic circuits of Fig. 1 are not zeroed after each lightning. So, the distance to a previous lightning is conserved in the recording device until the next lightning (horizontal line segments in the bottom panel of Fig. 2). Note also that the plot presented possesses a property of self-checking: long delays of the first and second lightning strokes correspond to their large distance (5 km), while the smaller distance of the third lightning (2 km) is associated with a shorter delay. Thus, one can see from Fig. 2 that the simple scheme of Fig. 1 yields reasonable data. Figure 3 presents another example of a longer duration, a thunderstorm on September 5, 2002. This figure contains an additional plot where the data of measuring the electric current of rain are presented (bottom panel). It is clearly seen in this figure that, when at 23:07:30 rain is greatly intensified, the distance in the preceding plot goes to zero. This is, obviously, the effect of system's malfunction during heavy rain.

Figure 3 also illustrates other peculiar features of our system. One can

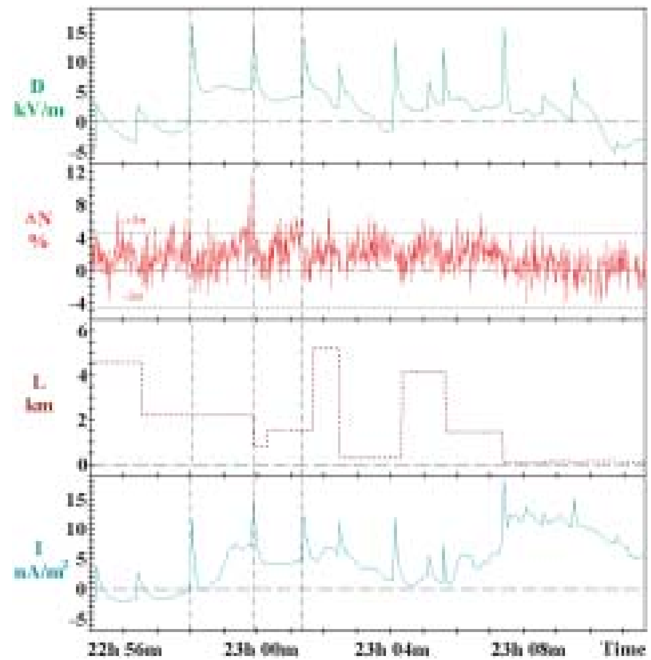

Fig. 3. Thunderstorm on September 5, 2002.

see that lightning effect in the field and current measurement systems does not directly correlate with probability of detection in the acoustic channel. For example, it does not 'hear' strong lightning at 22:58. On the contrary, very weak electric signal at 23:00:20 resulted in a measurable acoustic signal.The distance distribution of all detected events is given in Fig. 4. All individual events are represented in the same figure by the points whose ordinates correspond to percent amplitude of a pre-lightning increase (right scale). It is clearly seen that the interval 2-5.5 km includes the overwhelming majority of events. The amplitude of increase was determined as the difference of mean intensities over 20-s periods after and before lightning. The maximum effect thus determined is equal to 4%, while the average value for 37 events is 0.915 ± 0.056 %.

4. Discussion

Thus, we deal mainly with rather distant lightning events (Fig. 4). This is, perhaps, reasonable if we take into account that our air shower array is located in a rather narrow mountain valley at 1700 m a. s. l. Very close to the array a mountain slope begins with an angle of inclination of about 30°. The height of a nearby mountain peak is about 3900 a. s. l., i.e., more than 2 km above the level of observation (the approximate distance to this peak is shown in Fig. 4 by vertical dashed line.

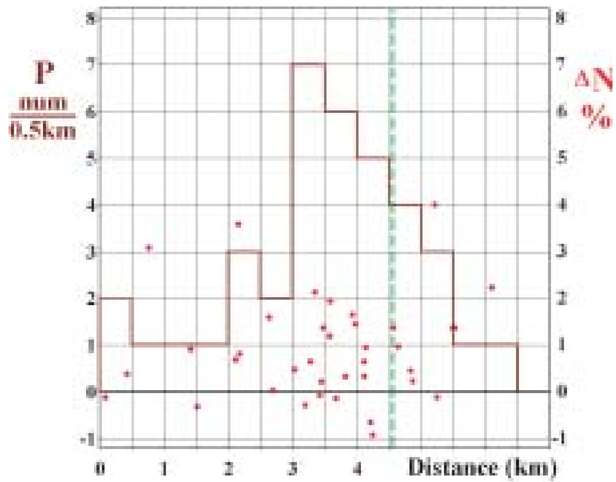

Fig. 4. Distribution of distances. Individual events are shown by points with their increases (right scale).

Under these conditions, the cloud-to-ground lightning is more probable to the mountain peak and slope. We can then hypothesize that we regularly observe the effects of strong field of a thundercloud, which is switched off by lightning. This situation is quite different from that taking place, for example, in the experiments where the immediate radiation of lightning (X-rays) are searched for in order to confirm the theory of runaway electron breakdown, either on balloons [3] or on the ground [4, 5]. We believe that our data are mainly concerned with the strong field effects, since the estimated minimum distance to lightning channel is rather large (Fig. 4).

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5. References

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