Analysis of thunder Generated by lightning cloud and ground flashes

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Abstract

A study of thunder generated by cloud and ground lightning flashes

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The sound of thunder has long been of interest to acousticians and atmospheric scientists. In this study it was attempted to contribute to the available knowledge of thunder by studying the audio frequency pressure oscillations generated by tropical thunderstorms. The experimental set-up for this study consisted of Bruel & Kjaer type 4198 free-field microphones, 2690 Nexus conditioning amplifier and NI 4472, 24 bits signal acquisition device. The data were collected at Hambantota (81^0 0'E, 6^0 10'N) close to the southern coast of Sri Lanka for three years (2005, 2006 and 2007).

The microphone output amplitude signifying the pressure perturbation of lightning, which varies considerably from sudden loud spikes to quieter more gradually varying parts. Features of thunder signals, their various sounds and frequency spectra have been studied for 90 cloud and ground lightning flashes separately. Above thunder signatures were compared between both types of lightning flashes. Moreover, a thunder source locating system and thunder channel reconstruction system have been unveiled and discussed.

Thunder duration statistics for all recorded flashes were studied. The properties of claps, peals, rolls and rumbles are studied further. The most significant sounds of thunder, clap, is analyzed briefly. According to this study a thunder is consisted of one or two claps in general, the number of claps per flash is varied from 1 to 5 in cloud flashes and from 1 to 3 in ground flashes. The pressure oscillations within these claps are being less than 300 Hz. The mean clap separation calculated in this study was 2.0 sec. Time taken to start the first clap was calculated and it is found that the claps of ground flashes started sooner than cloud flashes. The most probable thunder duration in this study was 10-15 sec. The channel length of the lightning flash is about 2-12 km. The minimum thunder duration recorded was 2.2 sec and the maximum duration was 33.7 sec. The mean thunder duration of cloud flashes was 14 sec and ground flashes was 12 sec. Pulses of ground flashes were preferred to accumulate in the initial portions of the thunder signal and highest amplitude pulses were seen at the very beginning of ground flashes. But in cloud flashes peak amplitude pulses were observed somewhat later in the thunder signal. Spectrograms of selected close and far thunder flashes were briefly analyzed to study the frequency distribution in time domain under different sound levels. The distribution of thunder frequencies at different sound levels was further studied. The contribution to the frequency spectrum, when thunder flash travels through the atmosphere was discussed. Frequency occurrence histograms are plotted for selected individual thunder flashes and also for all measured 90 cloud and ground flashes and their statistics were compared with past studies. The maximum occurred frequency range was 175-200 Hz for all collected successful thunder flashes. The mean frequency value is 227 Hz. The frequency spectrum was wider in cloud flashes than ground flashes and relatively higher frequencies were appeared in ground flashes than cloud flashes. In this study, a thunder source localization system is developed with three microphones and thunder channels of 8 flashes were reconstructed using the model. Reconstructed thunder path and locations were agreed with visual observations. Certain drawbacks arisen from three-microphone system can be overcome using sets of more microphones. As an example, two models were tested using four and seven microphones for numerically calculated data. A seven-microphone model could eliminate the arisen drawbacks and uniquely determine the location of the thunder. However, the model has to be further studied with the atmospheric effects taken into account.

The outcome of this study, as it was intended, is anticipated to be helpful to better understanding of the thunder phenomena.