Thunderstorm Ground Enhancements Abruptly Terminated by the Lightning Flash

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Abstract

Electrons giving rise to the Thunderstorm ground enhancements (TGEs, Chilingarian et al., 2010, 2011, Chilingarian 2014)) are accelerated by electric field formed by the main positively and negatively charged regions on the top and in the middle of the cloud and by the transient lower positively charged region (LPCR, Chilingarian and Mkrtchyan, 2012) in the bottom. LPCR charge is much less comparing with thundercloud main charged regions; however locally influence of LPCR can be essential, for instance LPCR prevents the lightning leader from reaching the ground and usually no –CG lightning occurs during mature LPCR when the particle flux is sizable (Nag and Rakov, 2009). Only after decaying of the LPCR the stepped leader makes its path to the ground.

TGEs and lightning are concurrent processes both discharging high potential difference in the cloud and switching off the electric field. Continuous attempts to start the stepped leader produces a large number of low- energy (few eV) electrons by ionizing the air. The low-energy electrons then drift in the thunderstorm electric field producing discharges and radiofrequency emissions. Weak bipolar radiofrequency pulses possibly originated from these discharges represent an early stage of formation of the conducting channel in the thundercloud (initial breakdown). Thus, both TGEs and TGFs precede the lightning activity and can be used for the research of poorly understood lightning initiation processes, providing a new research tool — the flux of elementary particles originated in the thunderclouds. Information acquired from the time series of TGEs and TGFs along with the widely used information on the temporal patterns of the radio emission waveforms will help to develop a reliable model of lightning initiation. Copiously measured on Aragats during thunderstorms TGE events comprising of the measurements of one-second and one-minute time series of the elementary particle count rates, gamma ray energy spectra, meteorological conditions, fast and slow disturbances of near-surface electric field allow us to investigate their causal relation to lightning initiation (Chilingarian et al., 2015).

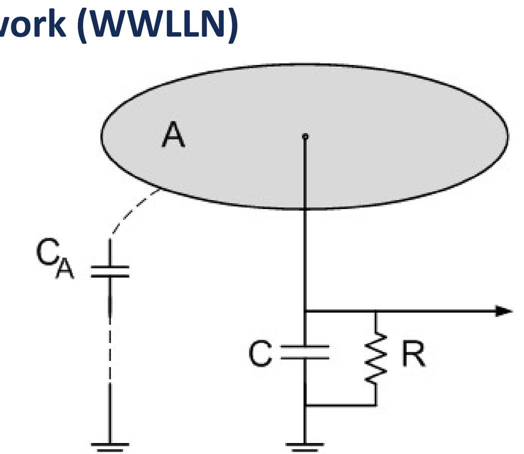
Instrumentation

Slow and fast electric field monitors

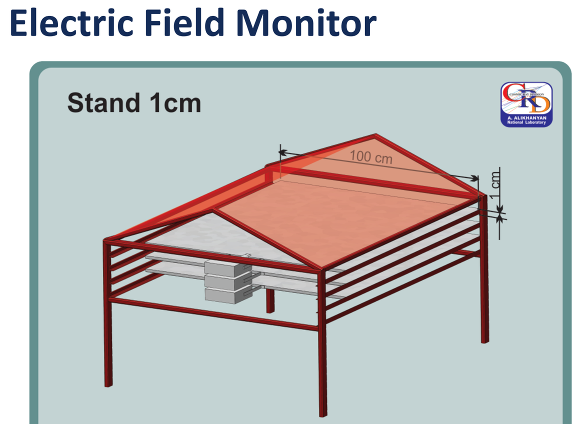
Particle flux detectors

World Wide Lightning Location Network (WWLLN)

Boltek EFM-100 Atmospheric Electric Field Monitor



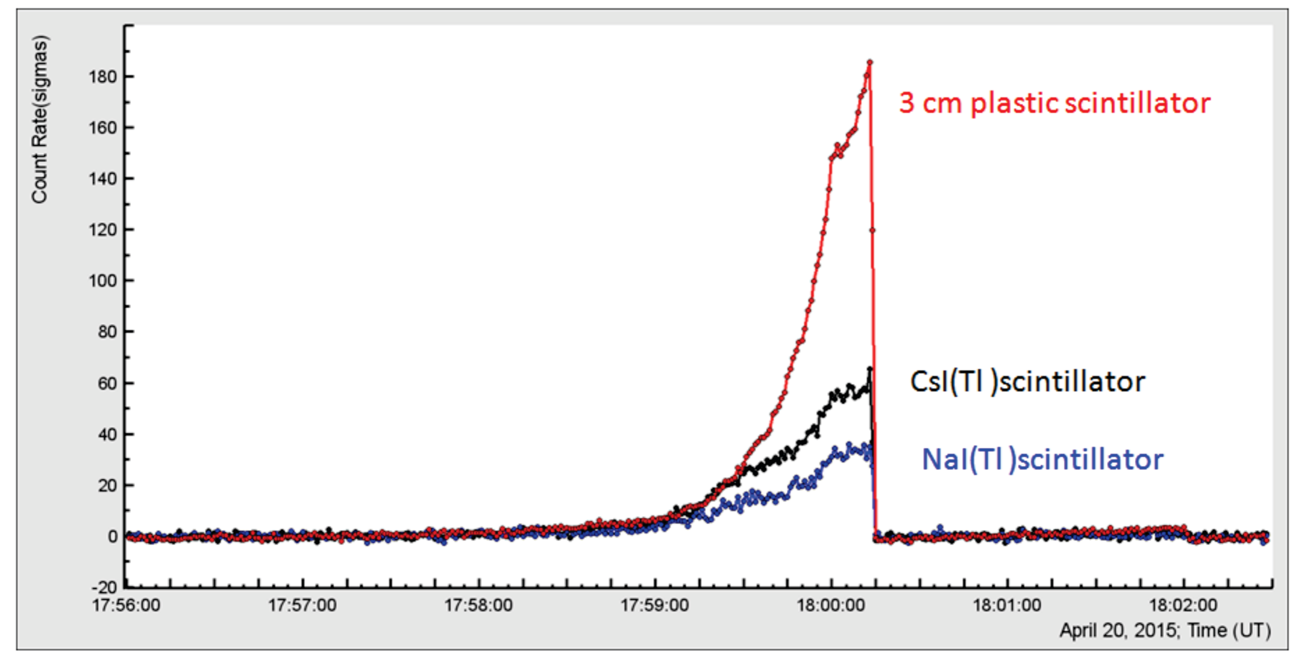
Flat plate antenna D=52cm, RC=10ms



Stack of three 1cm thick scintillators, sensitive area 1m²

3 cm thick scintillator, sensitive area 1m²

Observation data



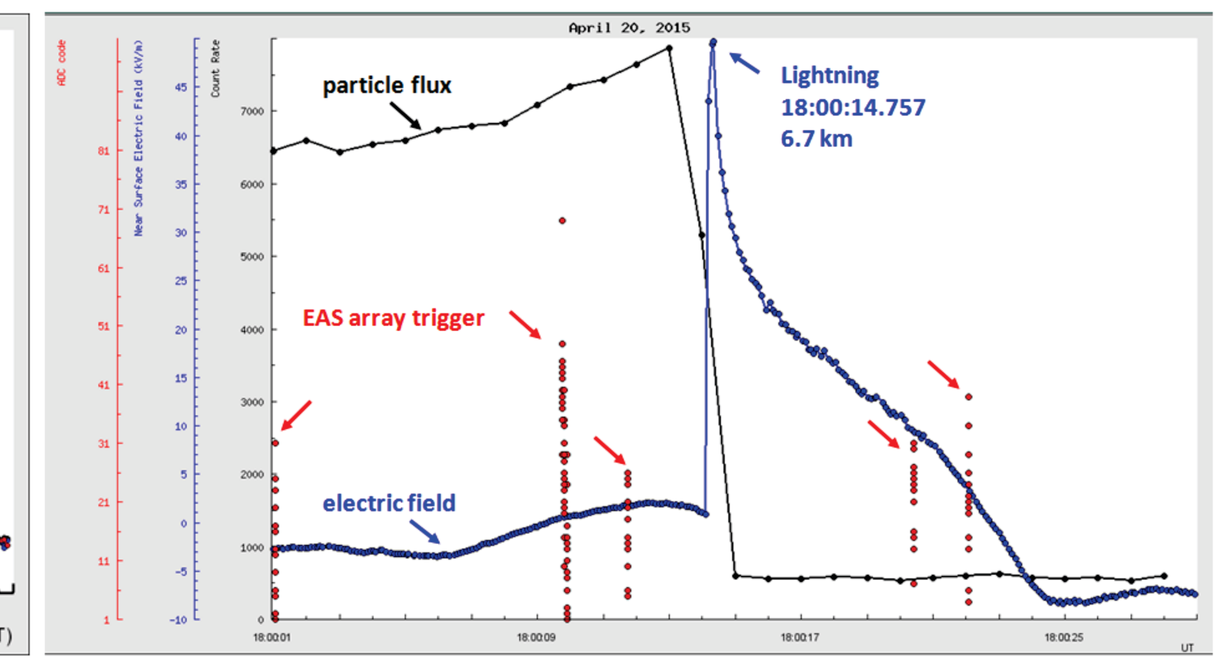
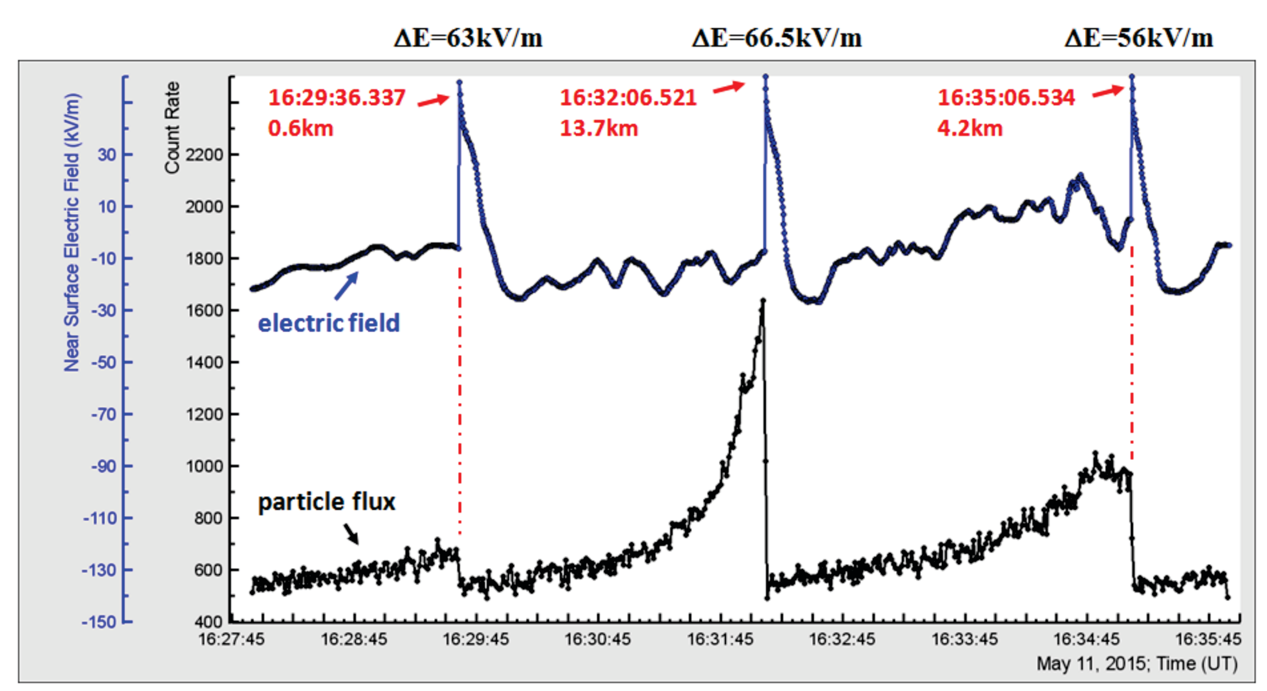


Fig.1. TGE initiated by Extensive Air Shower (EAS) and terminated by lightning (April 20, 2015). Left: count rate of particle flux in units of standard deviation detected by different detectors, right: 50ms time series of electric field, 1 sec time series of particle flux, and EAS trigger array.



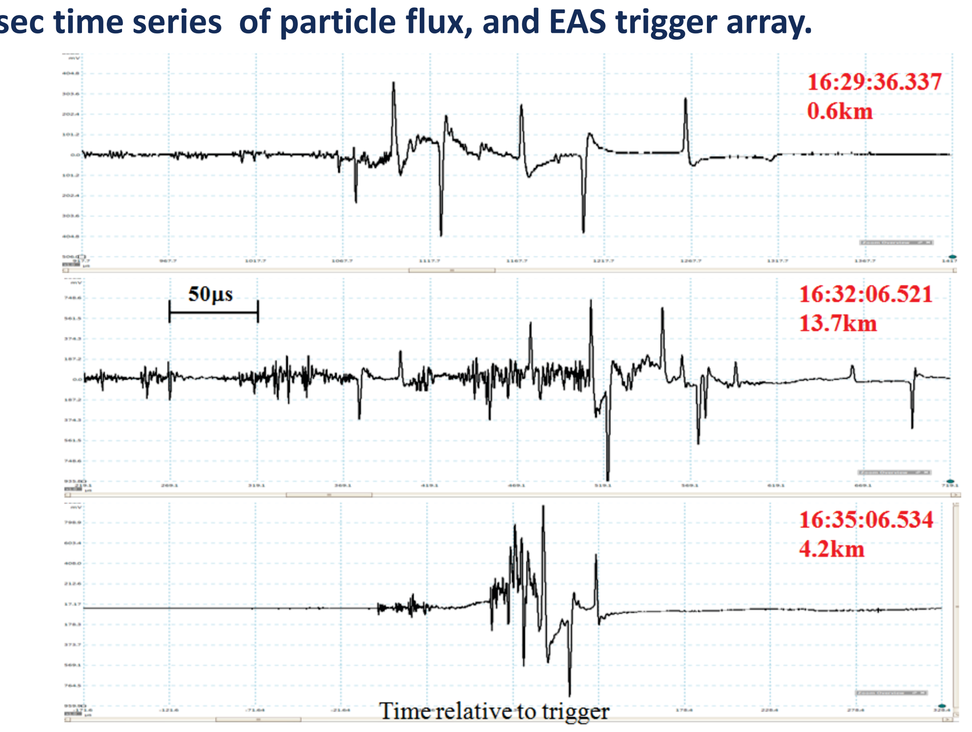
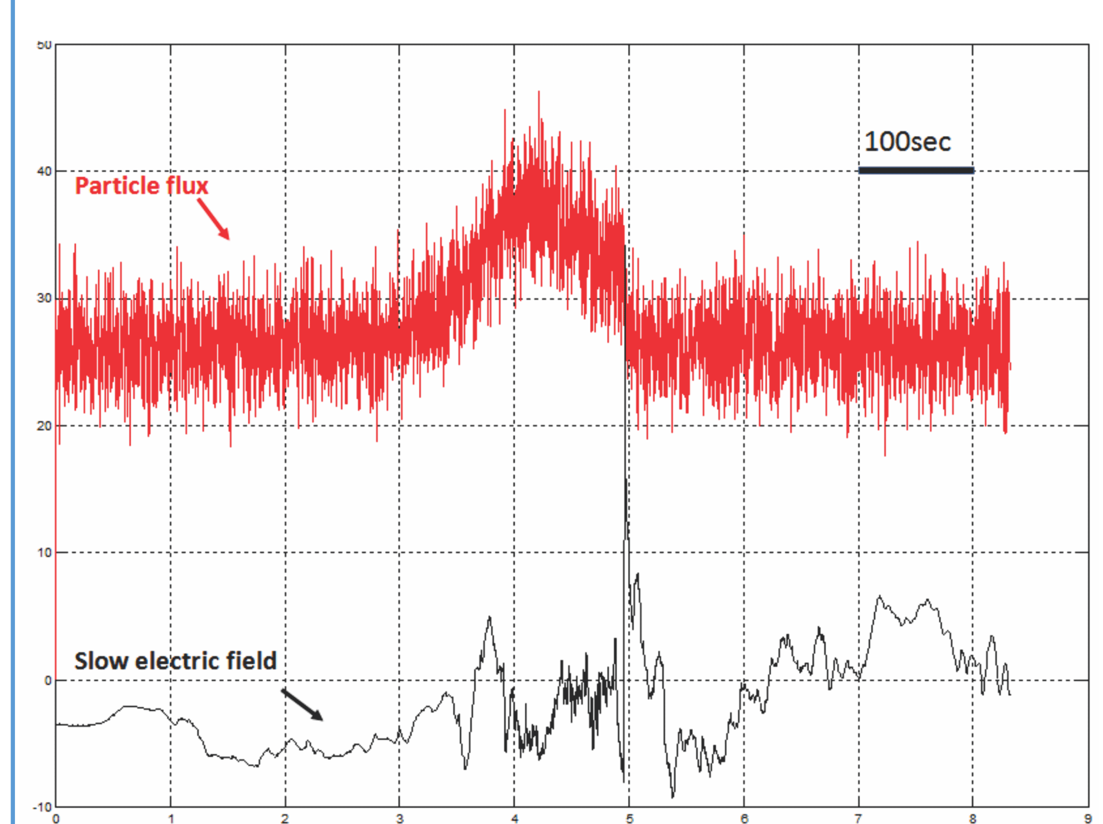


Fig.2. Sequence of three TGEs terminated by lightnings (May 11,2015) detected with 1sec time resolution of particle flux and 50ms resolution of slow electric field (left) , and corresponding fast electric field waveforms with 10ns resolution (right). Large positive change of electric field indicates occurrence of lightning which decreases a negative charge overhead. The electric field of the thundercloud that accelerates electrons downward is "switched off " by the lightning, and particle flux is terminated.



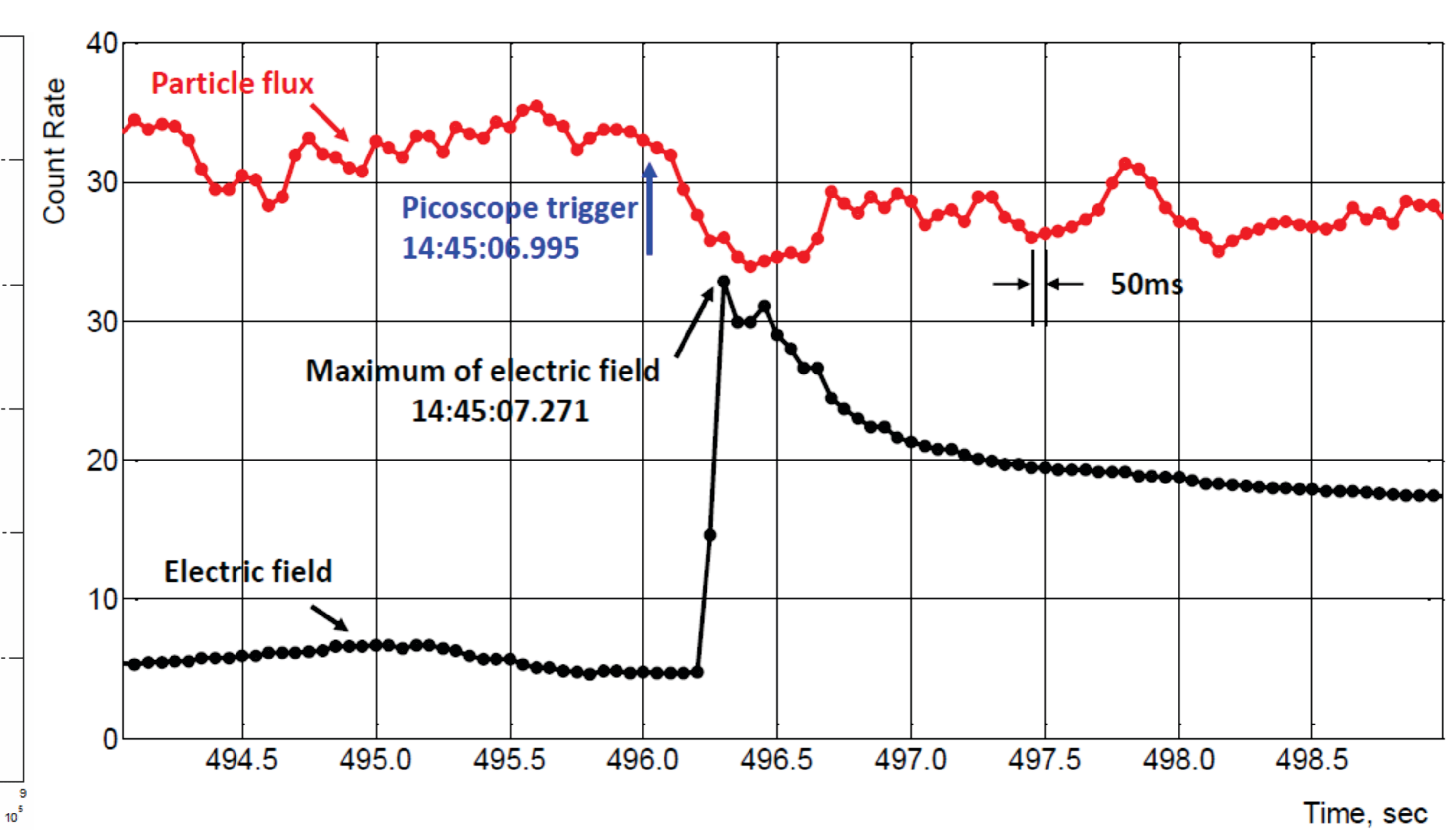


Fig.3. TGE terminated by lightning (October 7, 2015) detected with 50 ms time resolution of particle flux and slow electric field. Left: 12minute time frame, right: 4 sec zoom of time interval before and after sharp decline of particle flux. The Picoscope (fast waveform recorder) trigger at 14:45:06.995 and maximum of near surface electric field at 14:45:07.271 are denoted by arrows. The decay time of particle flux is about 500ms.

Key results

Recently installed at Aragats fast electronics provides synchronized measurements of particle fluxes, disturbances of near surface electric field and fast electric field waveforms on millisecond time scale. At 7 October 2015 All ASEC particle detectors recorded a large TGE event. One-minute time series of low-threshold detectors demonstrate huge enhancement equivalent to ~ 100 standard deviations. Differential energy spectrum of gamma rays extends till 30 MeV. Strong negative lightning seen as abrupt change of the near surface electric field with amplitude ~ 70 kV/m terminated particle flux. On the one-second time scale the termination looks like immediate decline. The more detailed analysis of the time series of fast and slow changes of the electric field and particle fluxes reveals that the TGE decay started with initial discharges, which triggered the detection of the fast waveforms. The particle flux gradually declined during about 500 ms. We conclude that the particle flux decline started simultaneously with the so- called preliminary breakdown (PB), which produced a sequence of characteristic electric field pulses (PB pulse train).

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