Lower positive charge region (LPCR) and its influence on initiation of Thunderstorm ground enhancements (TGEs) and cloud-to-ground (CG-) and intracloud (IC-) lightning occurrences

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Lower positive charge region (LPCR) and its influence on initiation of Thunderstorm ground enhancements (TGEs) and cloud-to-ground (CG-) and intracloud (IC-) lightning occurrences

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Abstract. We discuss role of the LPCR model in the initiation of intracloud and cloud-to-ground lightning as well as in accelerated electrons in positive field within the cloud. Our analysis is based on the thunderstorm data from the Aragats Mountain in Armenia, 3200 m a.s.l. The electrical mill and lightning detectors are monitoring the near surface electrical field, distance and type of lightning occurrences, particle detectors register fluxes of neutral and charged particles associated with thunderstorms. The relations of particle fluxes to electrical structure of thunderclouds and - to lightning occurrences of different types were established and discussed. Our analysis supports the transient character of emerging LPCR and confirms blocking of CG- lightning occurrences by the mature LPCR. High particle fluxes, associated with thunderstorms, so called Thunderstorm ground enhancements (TGEs) prove the existence of the LCPR and its transient character.

1. Introduction

During last 3 years of TGE research more near 300 significant enhancements of particle detectors count rates were detected at Aragats. After locating the field meters and lightning detectors in 2010-2011 we found that all TGEs were accompanied with disturbances of the near-surface electrical field and most of them – with lightning occurrences. Many researchers outline the dominant role lower positive charge region plays in initiating/triggering an intracloud and cloud-to-ground lightning discharge [1-3]. The influence of the LPCR on lightning leader propagation can be considered in the following steps:

- While negative charge accumulates at midlevel, it may not be energetically favorable to transfer negative charge to ground in -CG lightning. Starting to develop lower positive charge results in the enhancement of the electrical field strength within cloud, allows for negative charge transfer to ground in -CG lightning occurrence (Williams, 1989).
- When the magnitude of LPCR is becoming considerably large intracloud discharges IC- (attempted leader) are expected to occur. The "normal" IC+ intracloud lightning occurs between main negative and positive layers of the dipole; the electrical field is negative and electrons are accelerated upward. IC- lightning bridging the main negative and large lower

positive charge regions have been reported by (Qie et al., 2005); due to screening positive charge descending negative leader may change its direction of propagation to horizontal.

2. Particle fluxes, electrical fields and lightning occurrences

Electric field meters and lightning detectors installed at Aragats as well as multipurpose weather station allow correlate Thunderstorm Ground Enhancements (TGEs - fluxes of electrons, gamma rays and neutrons from thunderclouds [5-7]) with electric field disturbances, with occurrences of lightning of different types and with other meteorological conditions (rain, atmospheric pressure, temperature, humidity…). The TGE amplitude correlated with meteorological conditions was measured by the outside 5 and 3 cm thick, 1 m^2 area plastic scintillators. During the TGE event, see Figure 1, the near-surface positive electric field reaching strength of 40 kV/m after series of lightning occurrences (those types are usually equally distributed among intraclaud positive and negative lightning IC+ and IC- and cloud-to-ground negative lightning CG-, see Figure 3) started to reverse and simultaneously particle flux started to rise at 13:10. The evolution of the surface electrical field as in shown in Figure 1 suggests occurrence of the "special type thunderstorm", according to classification introduced in [3]. A special-type thunderstorm suggests the long period of negative surface electrical field. During this period large in dimension and high in charge magnitude LPCR exists at the base of the storm. 10 minutes of the negative surface electrical field coinciding with large particle flux, proves that the positive charge region at the base of thundercloud is large in dimension and charge magnitude. Electron acceleration downward is possible only if electrical field in the thundercloud is positive; i.e. if lower dipole is formed or under formation. Developed LPCR and large positive electrical field in the cloud enlarge particle flux downward, peaking at ~13:13 when the negative field approaching minimal strength of -35 kV/m. During several minutes of particle flux maximum IC+ and CG- lightning occurrences were highly suppressed and only IC- lightnings were observed, see Figure 4. Emerging large LPCR blocks the step leader propagation to the ground and turn it to intracloud IC- flash because the abundant lower positive charge made IC-discharges energetically preferable. At 13:20 both IC-flashes and electron flux neutralize the lower dipole; the LPCR contracted and correspondent particle flux stopped. Consequently diminished LPCR cannot block any more the lightning leader propagation to the ground and several CG- lightning occurred at 13:23 at fully stopped particle flux.

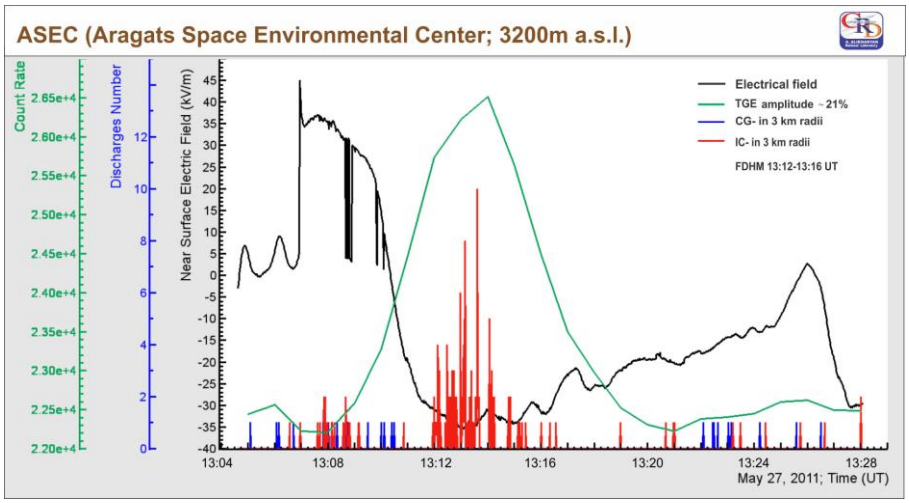

Figure 1. TGE of the first type according to pattern of the electric field disturbances; the black curve shows changing electric field; red lines - IC- lightning and blue CG- lightning occurrences within 3 km radii; the green curve shows the time series of the particle flux minutely counts. Particle flux peaked at 21% above CR background.

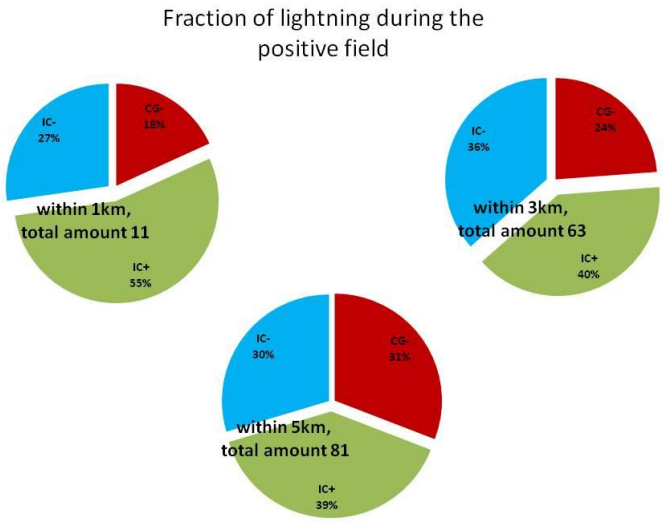

Figure 2 Fractions of lightning occurrences of different type during positive near-surface electric field (13:04-13:10 UT); positive field peaked 45.05kV/m at 13:06 UT.

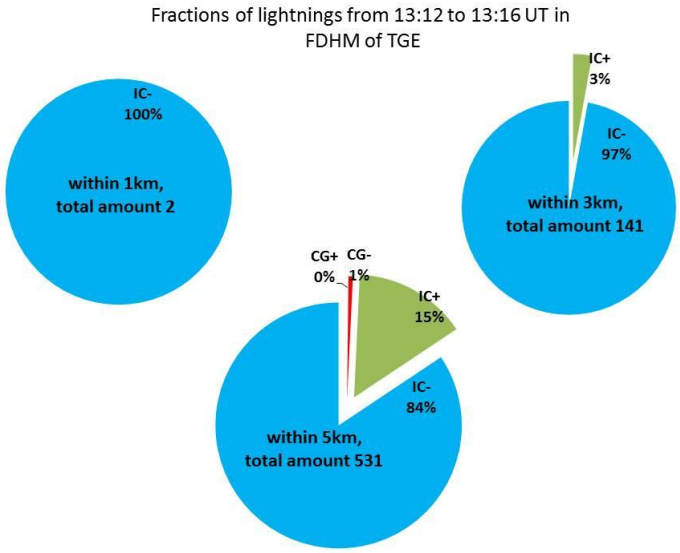

Figure 3. May 27 2011. Fractions of lightning occurrences of different type in FDHM of TGE (13:12-13:16 UT); negative field peaked -35.5 kV/m at 13:13 UT.

In the circular diagrams (Figure 2 and 3) we post the frequencies of lightning occurrences at positive and negative near-surface electrical field. The pattern of frequencies is drastically different. If at positive field the share of 3 types of lightning occurrences (intracloud positive and negative and cloud-to-ground negative) is approximately equal, at negative field we detect strong suppression of CG- and IC+ lightning occurrences (positive cloud-to-ground lightning IC+ is rather rare occasion).

3. Conclusions

The Aragats thunderstorms confirm the foundlings made on Tibet [3,4] that thunderstorm could be classified in 2 categories dependent on the polarity of the surface electrical field. If the polarity is negative at the mature stage of thunderstorm the LPCR prevents negative CG- flashes due to abundant lower positive charge making intraclaud IC- flashes preferable (see also [2]. The negative CG- discharges occurred in the late stage of the storm on degradation of the LPCR due to precipitation, downward electron flux in the cloud and intracloud inverse lightning occurrences. Therefore, scenarios a) and b) of section 3 are enabled successfully during one and the same thunderstorm. Aragats thunderstorm data also confirm founding from Tibetan thunderstorms that emerged LPCR did not cause positive CG+ flashes. Characteristic of maturing of LPCR is ~10 minutes coinciding with estimate from thunderstorms at Tibet plateau.

The technique of measuring particle fluxes during thunderstorms first used on Aragats allows following up the evolution of the electrical field strength within lower dipole. Maximal flux of gamma rays detected on the surface (and corresponding maximal flux of the electrons within lower dipole) pointed on the maximal positive electrical field in the cloud and, correspondingly on the maximal dimension and charge of the LPCR. The distance between the main negatively charged layer in the middle of cloud and LPCR should be significantly large to provide large potential drop necessary for the electron acceleration. Fading of the gamma ray flux evidences the degradation of the LPCR. Measured particle flux along with registered lightning occurrences of the different type allows researching the fine structure of the thunderstorm, including the time evolution of the LPCR and on-going processes of intracloud lightning initiation and electron avalanche propagation.

In several events the particle fluxes (TGEs) precede lightning occurrences, thus demonstrating that downward moving streamer can use the conductive channel opened by the downward electron-gamma ray avalanche, see [8]; however for some of TGEs the frequency of lightning occurrences at maximal particle flux is very low signalling that in some circumstances the particle acceleration and IC- lightning occurrences can compete.

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