Thunderstorm ground enhancements (TGEs) abruptly terminated by a lightning flash

Electron accelerators operated above our heads

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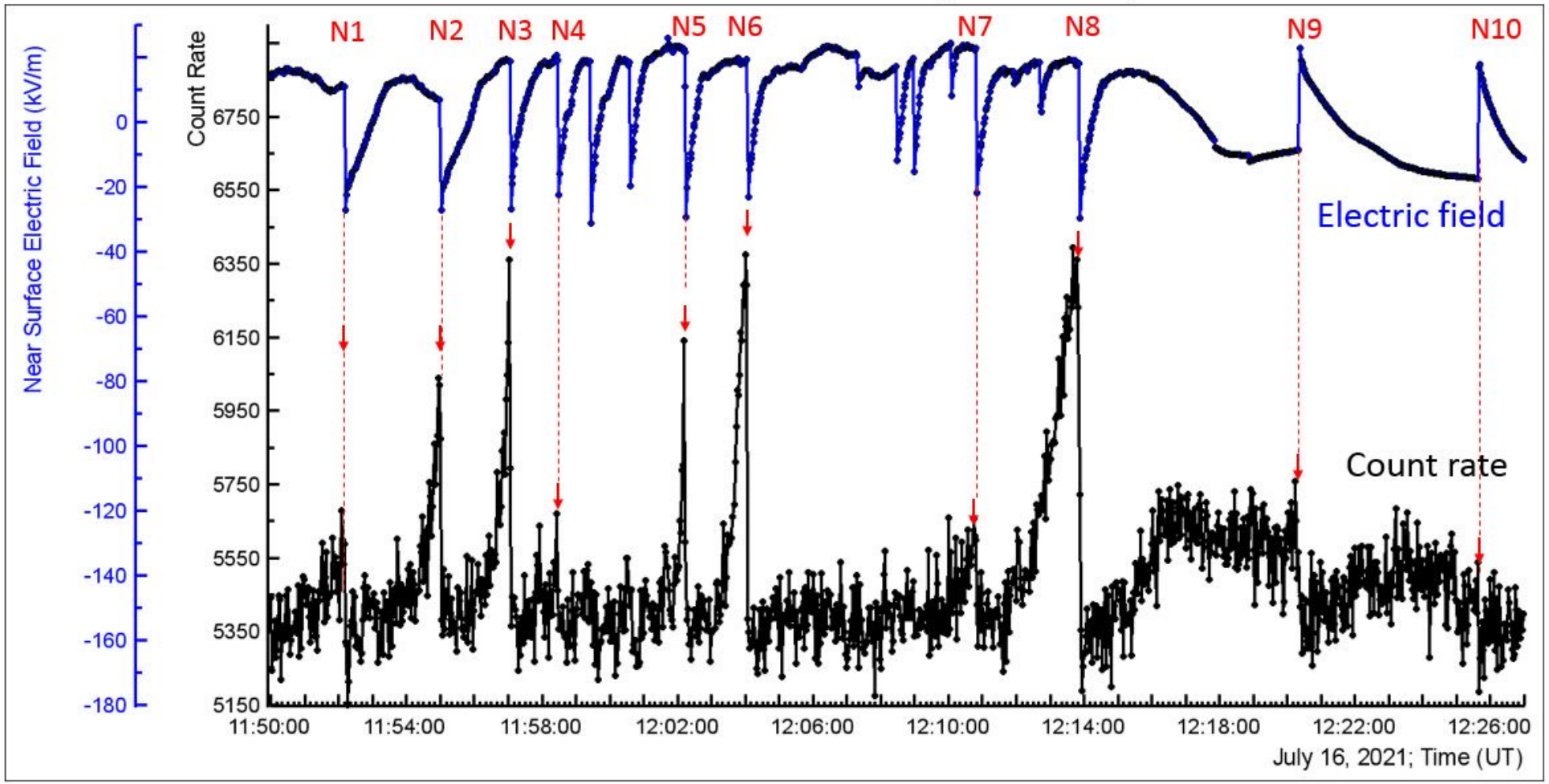
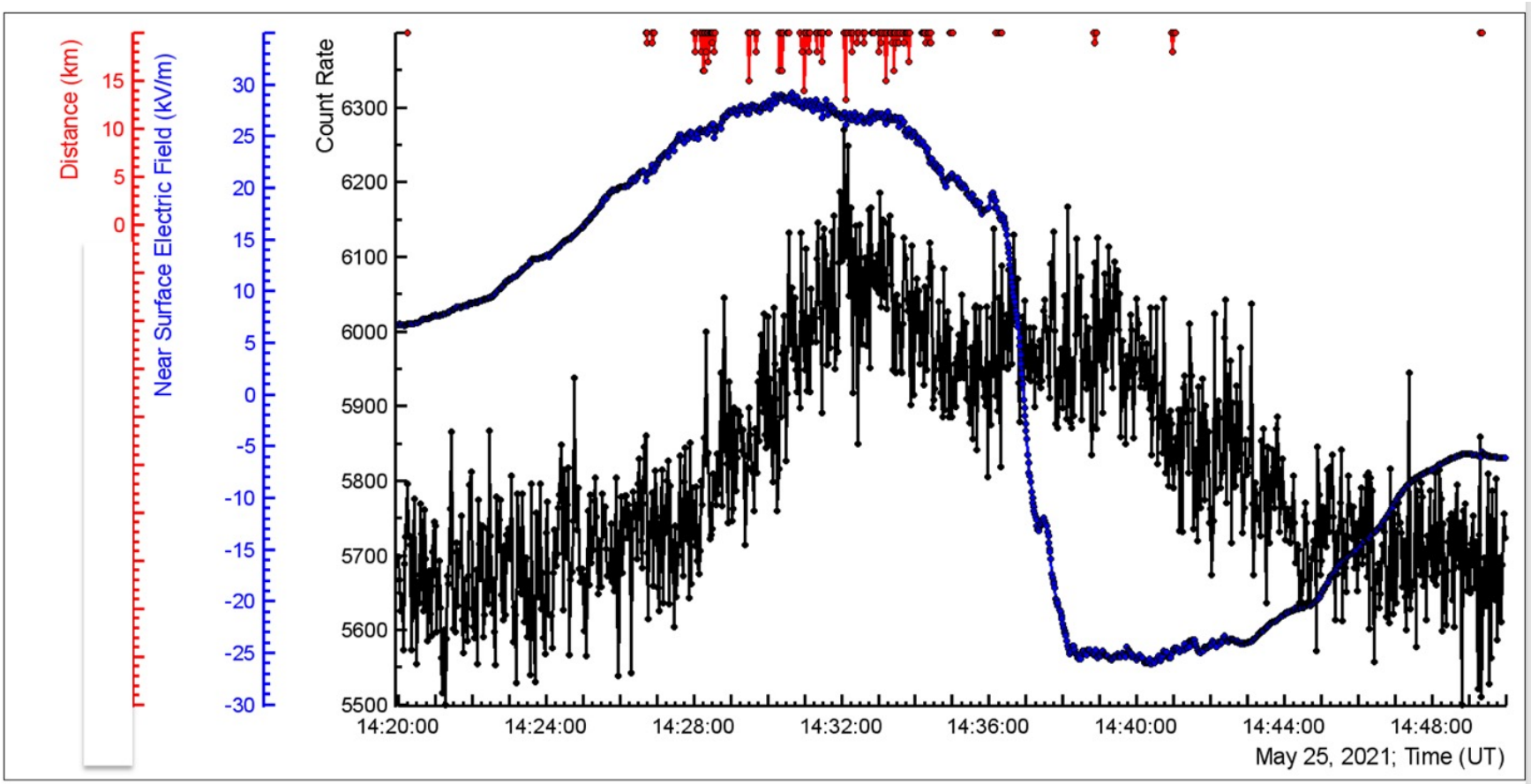
Aragats Cosmic Ray station. Year-round operation from 1943. 40.47N, 44.18E, 3200m

EGU General Assembly Vienna, Austria & Online 27 May from 13:34 to 13:41

Short TGEs: bursts of energetic radiation and particles registered by ground-based detectors during thunderstorms. Typical duration: tens of seconds, terminated by lightning discharges, storm active zone is above detectors.



Long duration TGE: on pherephery of storm active zone

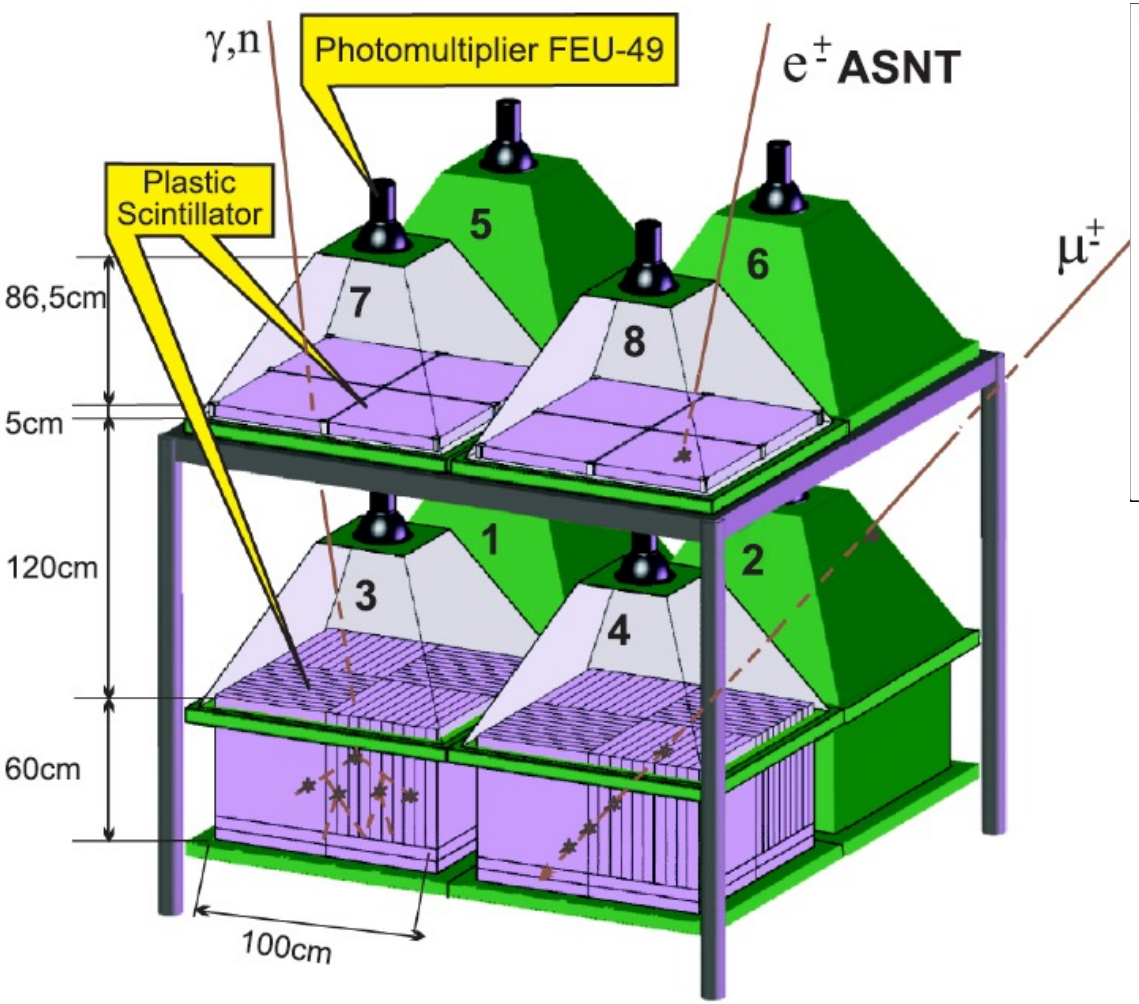


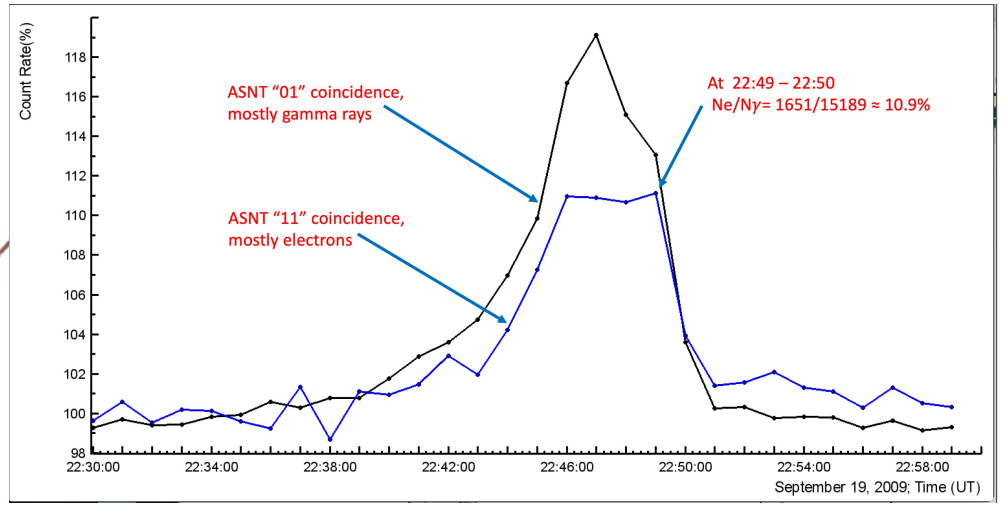
Disturbances of the near NS electric field (NSEF, blue), count rate of ASNT spectrometer (black), and distance to lightning (red lines). TGE duration was ≈18 minutes and particle flux continued both during positive (MN-LPCR) and negative NSEF (MN-MIRR), demonstrating that particle acceleration with emerged LPCR and after its decay can be smoothly continued.

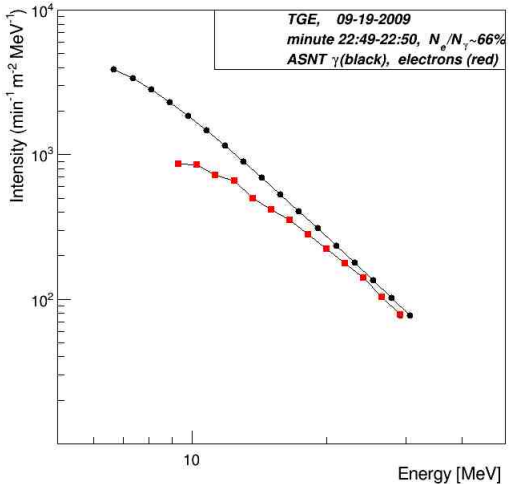
Particle detectors and Data sources

- Particle detectors and spectrometers, neutron monitors. Plastic scintillators and NaI crystals. Energy threshold ~ 0.3 - 7 Mev.
- Key instruments in the TGE study: Aragats Solar Neutron Telescope (ASNT) and SEVAN particle detector network (7 countries, 10 units).
- Network of electric field mills and lightning trackers for continuous monitoring of the near-surface electrostatic field, 20 Hz sampling frequency
- Wideband electric field measurement system (50 Hz-12 MHz) : electromagnetic emission from lightning, 1s capture length, 40 ns sample interval, interferometer
- Data of World Wide Lightning Location Network (WWLLN): VLF (3-30 kHz) emissions from lightning.
- Time series of particle fluxes measured by hundreds of particle detectors. Data on NSEF, geomagnetic field, weather conditions, shots of panoramic cameras. Data are available in numerical and graphical via ADEI multivariate visualization and statistical analysis platform: **http://adei.crd.yerphi.am/ and Mendeley datasets.**

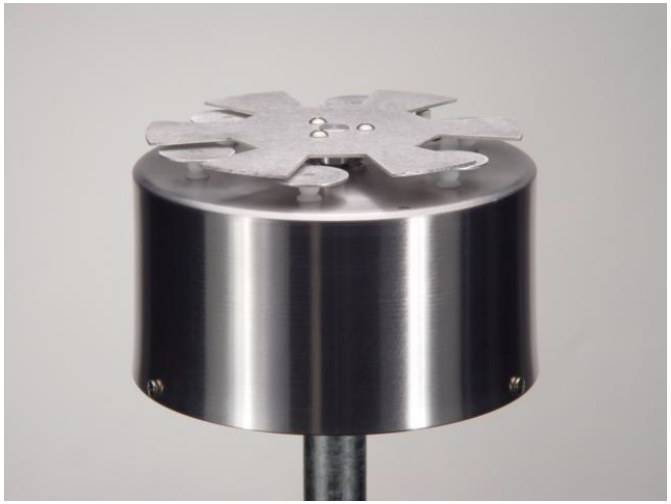
ASNT consists of 4 independent modules. Coincidences of signals from different modules are used to distinguish between charged and neutral particles, and angles of incidence





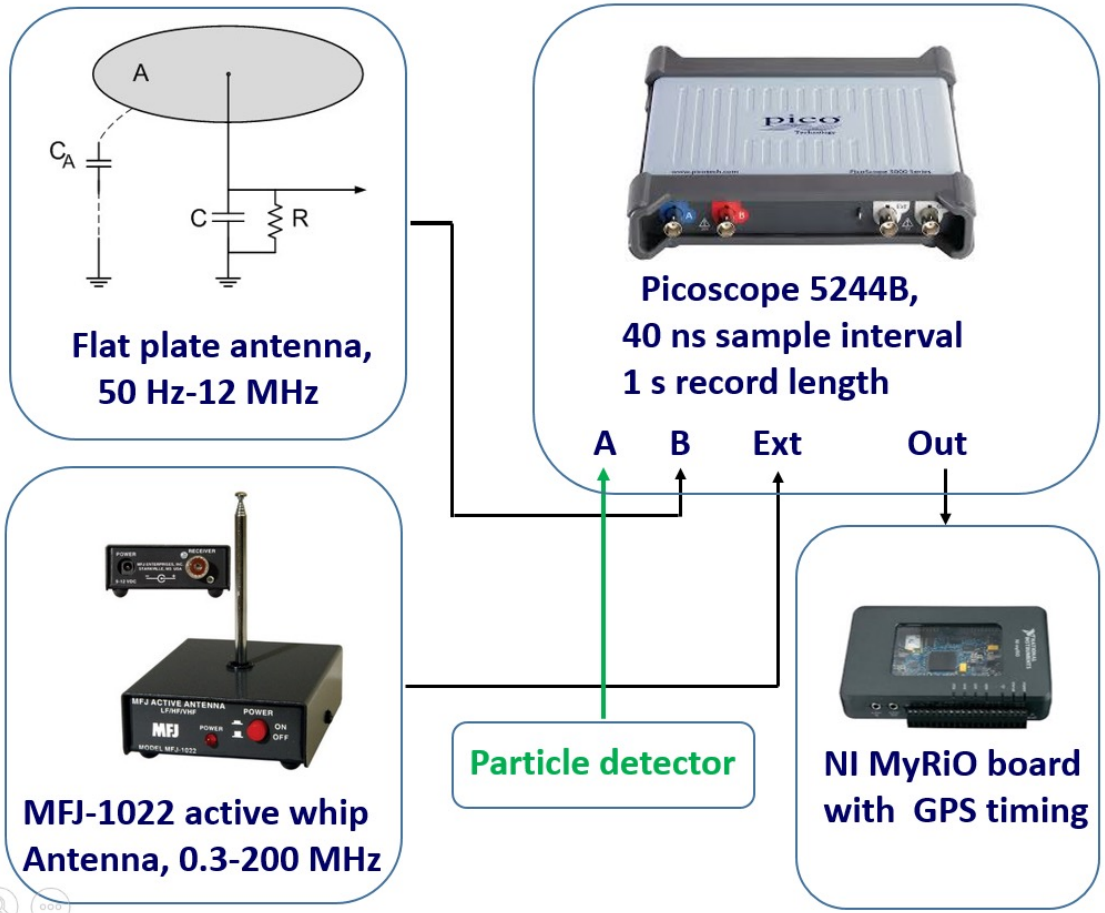


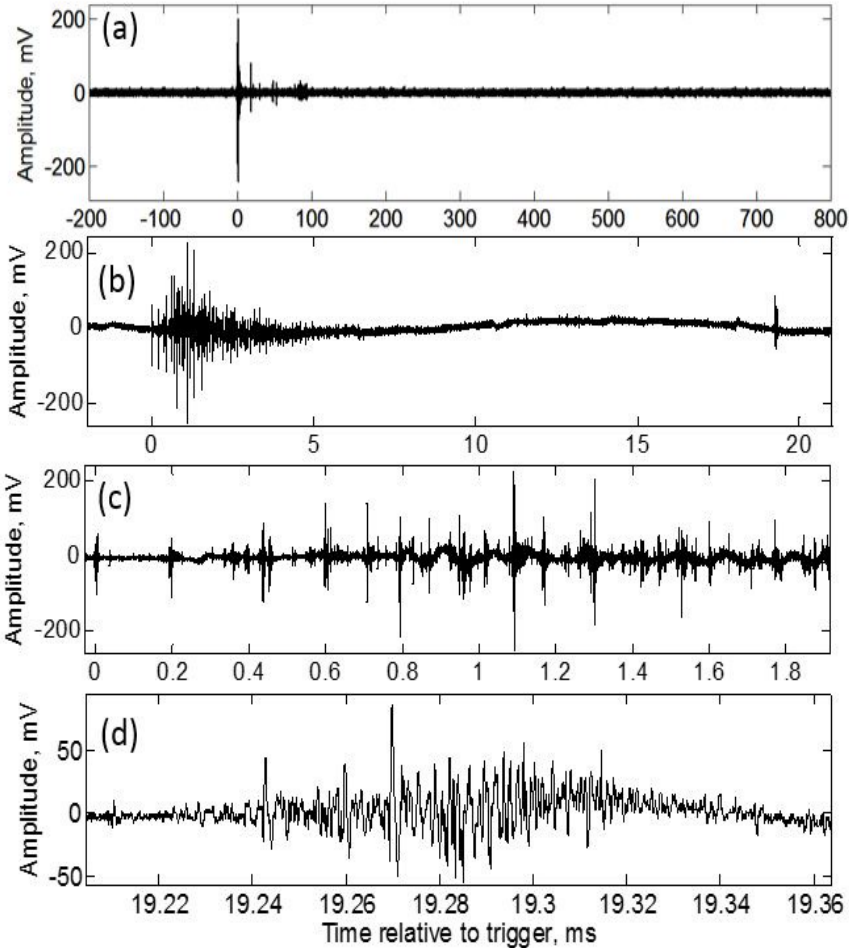
Network of electric field mills installed at Aragats, Nor Amberd, Byurakan, and Yerevan



Boltek EFM-100

Wideband electric field measurement system

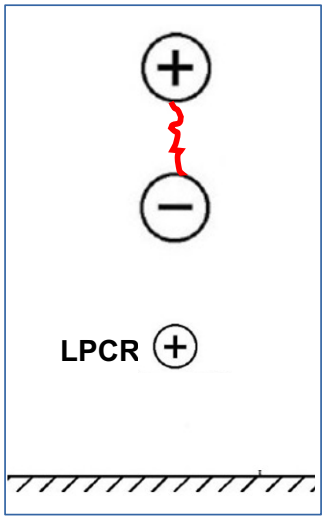




Left: measurement system. Right: electric field record (flash N8 in slide 2) has no pulses that could be attributed to return strokes of cloud-to-ground lightning. The lightning is identified as an inverted polarity intracloud flash (-IC).

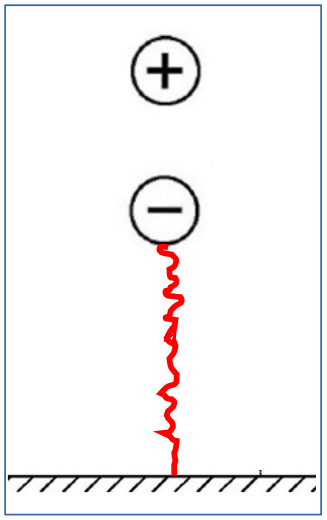
Criteria for lightning type identification based on behavior of change ΔE of the near-surface electric field

Normal IC



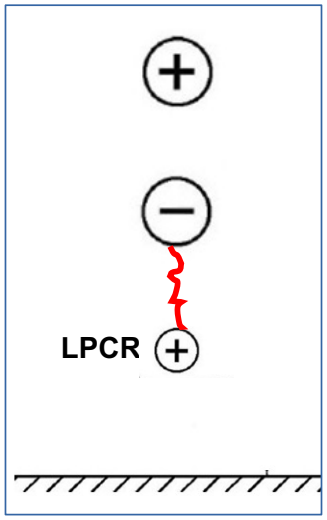
Close ΔE is positive, distant ΔE is negative.

-CG



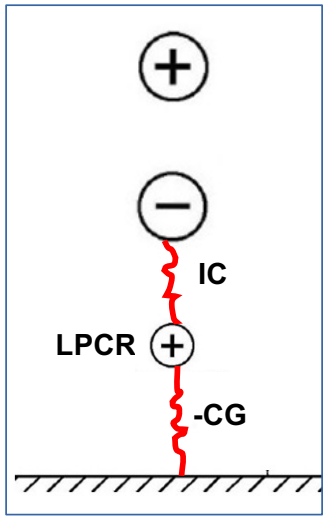
LPCR is small or absent. Both close ΔE and distant ΔE are positive.

Inverted IC



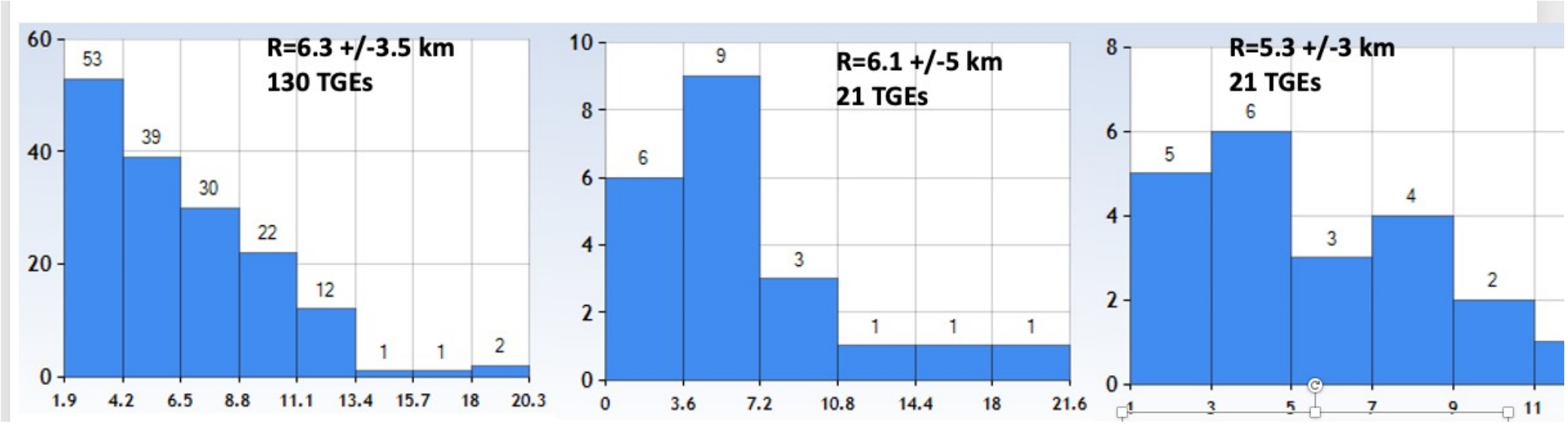
Close ΔE is negative, distant ΔE is positive.

Hybrid flash



Close ΔE is negative, distant ΔE is positive. ΔE polarity is determined by the inverted IC.

Distances to lightning flashes that terminated by a first type of TGEs



Distance to lightning measured by EFM-100 field mill (km)

Distance to lightning measured by WWLLN (km)

Distance to lightning measured by EFM-100 field mill for the events coinciding with those detected by WWLN (km)

Lightning active zone nearby particle detectors

Summary

- TGEs are terminated by four types of lightning flashes: normal ICs, negative CGs, inverted ICs, and hybrid flashes (an inverted IC followed by a -CG) if the storm active zone is above detectors.
- All four types neutralize some amount of charge in the mid-level negative charge region and thus reduce the electron accelerating electric field responsible for TGEs. Usually, the accelerating electric field is recovered and TGEs - restarted.
- Observation of TGEs terminated by inverted ICs and hybrid flashes indicates that the conditions for electron acceleration toward the ground needed for the production of TGEs can be created between the mid-level negative charge region and the lower positive charge region (NM-LPCR, lower dipole).
- TGEs are terminated by nearby lightning flashes, the typical distance to lightning is within ≈5 km.
- Our datasets [1] contain 165 TGEs interrupted mostly by the negative cloud-to-ground (-CG) discharges (-CGs : 50%, inverted intracloud (IC) flashes followed by –CGs: 21% , inverted ICs: 18%, normal ICs: 11%).
- If the storm active zone is >10 km from detectors, TGEs are extended for tens of minutes. TGEs each second send ≈10^{18} particles with energies >100 keV to the earth's surface.

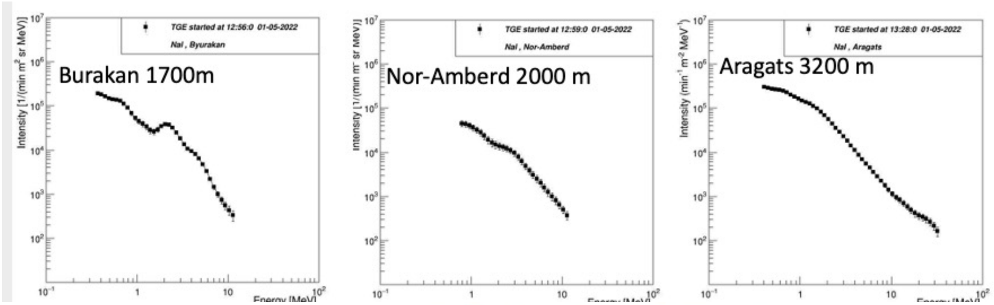
1. Soghomonyan, Suren; Chilingarian, Ashot ; Khanikyants, Yeghia (2021), "Dataset for Thunderstorm Ground Enhancements terminated by lightning discharges", Mendeley Data, V1, doi: 10.17632/p25bb7jrfp.1 https://data.mendeley.com/datasets/p25bb7jrfp/1

Ongoing research

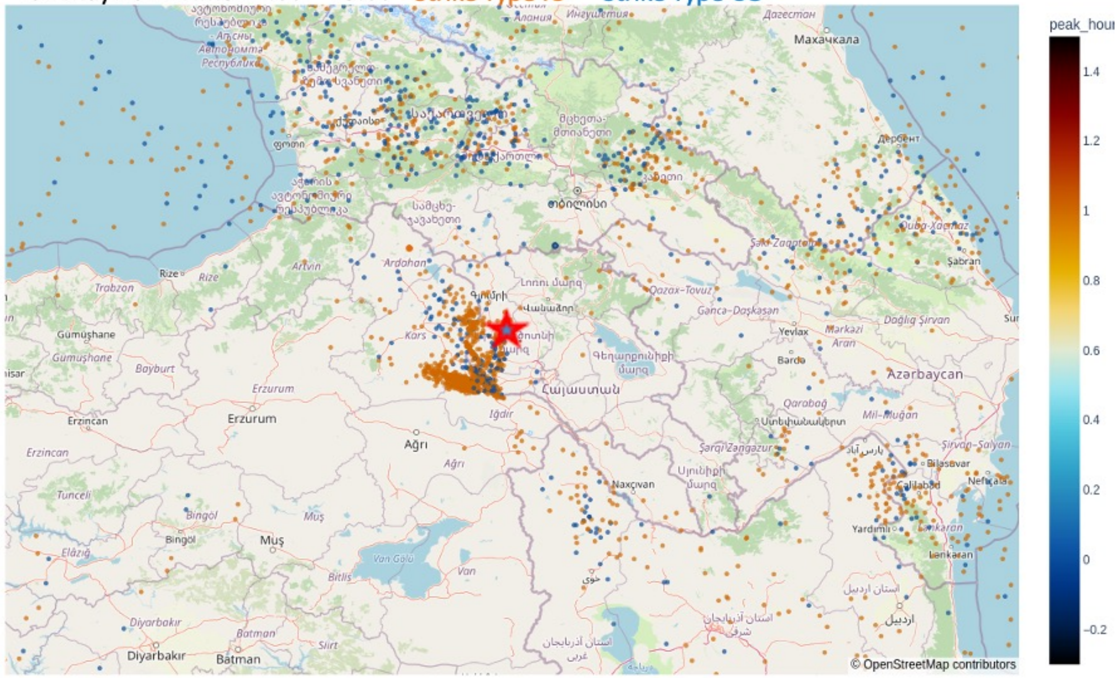
We know that TGEs have a duration of a few seconds to a few tens of minutes. However, very little is known about their space-temporal properties.

- What is the space-temporal pattern of the TGE?
- Is there any fine time structure on a microsecond or millisecond time scale?
- Horizontal profile of the atmospheric electric field, how far it can be extended from the lightning active zone?

Experiments on measuring TGEs with nanosecond time resolution and with several remote spectrometers are now in progress



01 May 2022 Time 11:00 – 15:00 Strike Type IC- Strike Type CG-


Махачкала
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Erzurum
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Tunceli
Bingöl
Muş
Van Gölü
Van
Bitlis
Elâzığ
Diyarbakır
Batman
Siirt
Naxçıvan
Yevlax
Bərdə
Azərbaycan
Şabran
Lənkəran
Yardımlı
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Neftçala
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Mil-Muğan
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