Lightning detection networks and Thunderstorm Ground Enhancements

H. Mkrtchyan, A. Reymers
Yerevan Physics Institute, Yerevan, Armenia

The Cosmic Ray Division (CRD) of the Yerevan Physics Institute operates a unique geophysical network of environmental monitors. This network is instrumented with electric field strength meters, lightning monitors, meteorological stations, and advanced cosmic ray particle detectors designed in Armenia, which are installed at 3 sites located on 1000, 2000 and 3200 m above sea level at slopes of Mt. Aragats and at Yerevan CRD headquarters. Boltek firm Lightning monitors determine location and types of the atmospheric discharges (intracloud or ground to cloud, negative or positive) around 1200 km from their location.

In the fall of 2013 CRD have joined the World Wide Lightning Location Network (WWLLN). This network detects very low frequency (VLF) radio waves emitted by lightning strikes.

1. Introduction

Cosmic Ray Division (CRD) of the Yerevan Physics Institute operates high mountain research station on slopes of Mt. Aragats and in Yerevan. Various particle detectors, electric field and lightning monitors, as well as automotive weather station are installed at 3 stations located on 1000, 2000 and 3200m above sea level. Main station is located on Mt. Aragats in higher point than other stations (latitude: 40°28'N; longitude: 44°10'E).

Starting from 2008 during very quiet 24-th solar activity cycle the CRD turns to investigations of the high-energy phenomena in the atmosphere. Existing and new designed particle detectors and unique geographical location of Aragats station allow to observe in 5 years more than 300 particle bursts, which were called TGEs— thunderstorm ground enhancements. TGEs observed on Aragats are not only gamma rays, but also sizable enhancements of electrons [1] and rarely also neutrons, usually lasting 10 min or more. Aragats physicists enlarge the possibilities for TGE research by coherent detection of the electrical and geomagnetic fields, atmospheric discharges, rain rate, temperature, relative humidity and other meteorological parameters. Adopted multivariate approach of investigations allows connecting different fluxes, fields and lightning occurrences and finally establishing comprehensive model of the TGE. TGE particle flux was often accompanied with disturbances of near surface electric field and intracloud lightning occurrences (IC-) and suppression of cloud-to-ground lightning occurrences (CG-). This temporal structure of lightning occurrences supports hypothesis of creation of developed lower positive charge region (LPCR) as a fundamental condition of TGE origination [2]. Large fluxes of electrons and gamma rays detected on the Earth's surface are only possible when LPCR is well developed and, consequently, electric field emerged between main negative charged layer in the middle of thundercloud and LPCR accelerates electrons downward. Lower dipole as well can initiate negative intraclaud lightning; however TGEs and lightning are not obligatory correlated. Simultaneous measurements of the particle fluxes, electrical field disturbances and lightning occurrences at Aragats in the seasons of 2011–2013 do not give any evidence on causative relation of lightning occurrences to TGEs. However, we notice that TGEs were accompanied usually by rain or high humidity. Consequently, we can deduce that charge is resided on the rain droplets. The positive and negative ions can be separated in the droplet under the action of the ambient electric field, thus forming two residual stretched charged clusters. Therefore, the upper part of droplet forms with main negative layer of the thundercloud the lower dipole accelerated electrons downward; and the negatively charged bottom of the droplet is responsible for the large negative near surface electric field. The TGE amplitude should be proportional to the total positive charge in LPCR; and, therefore—to the amount of rain droplets (water) in the bottom of cloud [3]. Stretched charged clusters residing on the rain droplets in the bottom of the thundercloud (LPCR) are also sources of atmospheric discharges and radio emission.

Therefore, detection of radio emissions from lightning discharge, from TGE and from LPCR can shed light on high energy processes in atmosphere and help to develop comprehensive model of lightning itself and of electron acceleration in thunderstorm atmosphere. We need broadband radio emission detection and plan to use for it existent

lightning detection networks and plan as well new sensitive devices for radio wave detection.

2. Networks detecting atmospheric discharges

Commercial lightning detecting networks are in operation in many regions of the world, using multiple stations to locate the source of lightning electromagnetic radiation pulses . Generally, multi-station lightning location systems consist of a number of spatially separated receiver stations positioned on the surface of the Earth. Only information collected from several sensors of stations enables to determine location of discharge. Moreover, multi-station networks could offer higher location accuracy and detection efficiency [4] than single-station techniques. World Wide Lightning Location Network (WWLLN; see http://wwlln.net/), managed by the Department of Earth and Space Sciences at the University of Washington in Seattle, Washington. [5] This network detects very low frequency (VLF) radio waves emitted by lightning strikes. WWLLN currently have over 50 sensors around the globe; least 5 sensors give lightning location data simultaneously. WWLLN stations registered very strong CG lightning.

Boltek firm Lightning monitors (StormTracker Lightning Detection System) was installed in three location on slopes of Mt. Aragats and in Yerevan. Boltek's StormTracker for each lightning stroke analyses a signal waveform in real time. The discrimination between IC and CG discharges is based on the shape and amplitude of the waveform, i.e., the rise and decline times. The direction is determined by looking at the magnetic field ratios for each stroke. The initial distance is determined by looking at the signal strength.

Comparison between Boltek and WWLLN networks has significant importance for our measurements.

3. Comparison between WWLLN and our stations.

We investigate relation between WWLLN and Boltek networks started from November 2013. WWLLN sensors give latitudes and longitudes of lightning and detection time with millisecond accuracy; also the sensors, which simultaneously detected the discharge, are stored. Much more detailed information from Boltek Network is available. The shape and amplitude of radio pulses with microsecond accuracy as well as decision made on distance and discharge type are stored for future analysis.

On January 30, 2014 huge thunderstorm has passed over our region and our stations simultaneously registered significant lightning activity.

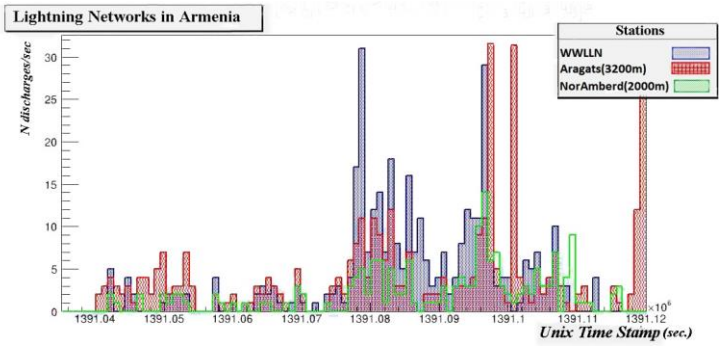

Figure 1. Lightning activity was registered by Aragats (3200m) and Nor Amberd (2000m) stations and by WWLLN, which data were depicted by red, green and blue accordingly.

4. Conclusion

We made first simultaneous measurements of atmospheric discharges by 2 lightning detection networks: worldwide WWLLN network and Armenian Boltek network. Broadband detection of radio emission emerging in thunderstorm atmosphere will allow development of comprehensive models of lightning initiation and high energy phenomena in atmosphere.

5. References

[1] Chilingarian, A., Daryan, A., Arakelyan, K., Hovhannisyan, A., Mailyan, B., Melk- umyan, L., Hovsepyan, G., Chilingaryan, S., Reymers, A., Vanyan, L., 2010. Ground-based observations of thunderstorm-correlated fluxes of high-energy electrons, gamma rays, and neutrons. Phys. Rev. D: Part. Fields 82 (4), 043009.

[2] A. Chilingarian and H. Mkrtchyan, Role of the Lower Positive Charge Region (LPCR) in initiation of the Thunderstorm Ground Enhancements (TGEs). Physical Review D 86, 072003 (2012).

[3] A. Chilingarian, Thunderstorm ground enhancements - model and relation to lightning flashes. Journal of Atmospheric and Solar-Terrestrial Physics 107 (2014) 68–76

[4] C. J. Rodger, S. Werner, J. B. Brundell, E. H. Lay, N. R. Thomson, R. H. Holzworth, and R. L. Dowden, Detection efficiency of the VLF World-Wide Lightning Location Network (WWLLN): initial case study. Ann. Geophys., 24, 3197–3214, 2006

[5] P. Orte´ga1 and T. Guignes, Lightning activity analyses with respect to the SPCZ location. Geophysical Research Letters, Vol.34, L11807, 2007