Thunderstorm Ground Enhancements (TGEs) – effects and physical model

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Space based gamma ray observatories, sensors on aircraft and balloons surface particle detectors detect fluxes of gamma rays and electrons, which are correlated with thunderstorms. In some, yet fully unknown circumstances electrons are accelerated upward in direction to space and downward in direction of earth and dramatically enhance usually rather stable cosmic ray background. This discovery attracts not only astrophysicists', but also meteorologist and atmospheric physicists' attention.

These very important and yet poorly understand phenomena are now intensively researched both from space and from mountain research stations. Aragats station has leading position in it. We present our results on correlated with thunderstorms fluxes of electrons, gamma rays and neutrons measured on Aragats. Along with energy spectra and physical model of Thunderstorm ground enhancements (TGEs) based on physical processes connected with propagation of cosmic rays within strong atmospheric electrical fields. In series of 3 papers (Chilingarian et al., 2010, 2011, 2012)Armenian physicists report new phenomena manifested by 6 physical effects:

- Large fluxes of the electrons and gamma rays;
- Neutron fluxes;
- Microsecond bursts of the electrons;
- Depletion of the high energy muon flux;
- Large negative near-surface electrical field;
- Depletion of the cloud-ground lightning occurrences and enhancement of the intracloud lightning occurrences.

Origin of TGE is a downward region in the bottom of the cloud (Torii et al., 2011) coincided with emerging Lower positive charge region (LCPR), which forms a lower dipole with the main negative charge region in the middle of the cloud. Intensive electrical field between these layers accelerates electrons downward and give birth to 2 processes:

- Relativistic runaway electron avalanches (RREA) process sustaining electron and gamma ray fluxes up to 10 times above cosmic ray (CR) background

(Wilson, 1925, Gurevich et. al., 1992);

- Modification of CR energy spectra (MOS) process, which is responsible for the gamma ray and electron flux enhancements and depletion of high-energy muon flux (Doerman, 2005).

Electrical fields in thunderclouds transfers field energy to electrons very effectively; electrons generate gamma rays and gamma rates by photonuclear reactions born neutrons detected on earth's surface;

RREA can generate particle bursts with duration less than 50 microseconds ; overall duration of TGE is ~ 10 minutes, during 10 minutes large amount of short bursts occurs;

Largest TGE events allows to estimate energy spectra: energy spectra of electrons and low energy gamma rays are exponential; energy spectra of gamma rays above 10 MeV are described by power law in overall agreement with GEANT4 simulation.

TGEs usually occurred on negative near surface electrical field varied from -10 to -30 kV/m;

During TGEs the fraction of IC- lightning occurrences is strictly increased, CG-lightnings are suppressed; observed behavior of lightning occurrences supports emergence of the LCPR and, consequently, lower dipole. The upper dipole accelerates electrons upward to the space where electrons, positrons and gamma rays are detected by space born gamma ray observatories.

These discoveries are very important for geophysics, atmospheric physics and climatology. Ongoing climate change can lead to significant increase of lightning occurrences mostly in globe dry regions. Monitoring lightnings by worldwide networks of antennas and by space born monitors, planned in coming decade will help to establish the forewarning services on disastrous weather conditions greatly enlarged recently. The increasing rate of lightnings and simultaneous increase of their height can alert on the upcoming huge thunderstorm with possible flooding. The increasing rate of positive cloud to ground lightnings is manifestation of possible hailing.

Numerous particle detectors and field maters located on the slopes of mountain Aragats and in Yerevan 24 hours 12 months are monitoring changing geophysical conditions. Planned geophysical station near Sevan lake with existing 3 stations on slopes of Mt. Aragats will monitor particle fluxes from sun, thunderclouds and Galaxy as we as magnetic and electrical fields, lightning occurrences, issue alerts and forewarnings on upcoming dangerous consequences of space and thunder-storms.

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