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The vertical profile of the atmospheric electric field during thunderstorms

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We introduce a novel method for remote sensing of atmospheric electric fields. Advanced particle spectrometers operated on the mountain altitudes on Aragats station are tuned for the measurement of energy spectra of charged and neutral particles separately. This gives the possibility to estimate the strength of the electric field in the lower atmosphere and estimate the particle flux incident on the earth's surface from the most powerful natural electron accelerators. Our measurements show that relativistic runaway electron avalanches (RREAs) can reach very low altitudes above the earth's surface. On the earth's surface RREAs are registered by the particle detectors as thunderstorm ground enhancements (TGEs) –large enhancements of electron and gamma ray fluxes, sometimes exceeding the fair-weather background fluxes up to a hundred times. Due to different mechanisms of the energy losses by comparing energy spectra of electrons and gamma rays it is possible to estimate the height above the ground where RREA terminates and avalanche particles exit the accelerating field. More than 2,000 thunderstorms are active throughout the world at a given moment, producing on the order of 100 flashes per second. The overall surface of the thunderous atmosphere each moment can be estimated as ≈ 200,000 km2, and according to our estimates, ≈ 1018 gamma rays are hitting the earth's surface each second.

The main results to be reported are as follows:

• Elaborated electric field remote sensing by monitoring particle fluxes provides several advantages over balloon-launched electric field meters;

• The strong accelerating electric field can extend very low above the mountain altitudes, reaching ≈2.0 kV/cm at altitudes ≈3-5 km, 50-150 m above the earth's surface. Such strong electric fields just above the arrays of particle detectors located at high altitudes (for instance LHAASO at 4410 m) will significantly enhance the size of showers introducing a large bias in the estimated energy of the primary particles.

• The most powerful electron accelerators operated in thunderclouds send ≈1018 gamma rays in direction to the earth's surface.

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