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Gamma-Ray Glow termination dilemma

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Long-lasting gamma-ray flux enhancements were observed in association with strong electric fields of thunderclouds. The enhancements are called gamma-ray glows when observed by airborne platforms, and Thundercloud Ground Enhancements (TGEs) when seen from the ground. The electric field accelerates charged particles from cosmic-ray background that results in generation of secondary particles which can again be accelerated. The precise glow's driving mechanism is still under debate with two leading hypothesis. The Relativistic Runaway Electron Avalanche (RREA) mechanism is proposed for relatively strong electric fields above a certain threshold, and Modification Of the energy Spectrum (MOS) is suggested for weaker electric fields.
The gamma-ray glows were observed to be abruptly terminated (tens to hundreds milliseconds) by a lightning discharge. It was suggested that the lightning neutralizes charge region that generates the required electric field. However, the actual glow-terminating process has never been studied in detail. Moreover, it has been recently suggested [1] that instead of being terminated by lightning, first the electric field starts to collapse, which leads to formation of a lightning flash later on. This created a causality dilemma, which started first: the flash or the termination? All previously reported observations did not have enough time resolution to solve the dilemma. An accurate observation of the glow-termination process with high time resolution are necessary to determine the causality between lightning flash and glow-termination moment.
The NASA ER-2 high-altitude aircraft was equipped with a set of gamma-ray detectors, electric field antenna, and high-end optical lightning mapper. When the aircraft was at 20 km altitude flying over an active thundercloud in Colorado, the gamma-ray count rate increased by 40%. The increase lasted for $\sim$80 seconds and was abruptly reduced after reaching its maximum. At the moment of the flux reduction the onboard antenna and optical instrument detected a lightning flash underneath and slightly ahead of the course. For the first time ever a ground based Lightning Mapping Array (LMA) recorded the glow-terminating lightning flash synchronously with the airborne gamma-ray measurements.
In this work we analysed the glow-termination moment with highest available time and spatial resolution. The analysis allowed us to unambiguously answer the question what is first, lightning or glow termination.

[1] Kochkin, P., et al. "In-flight observation of gamma ray glows by ILDAS." Journal of Geophysical Research: Atmospheres 122 (2017).