Contribution ID: **12** Type: **not specified**

Observations of the Origin of Downward Terrestrial Gamma-ray Flashes with the Telescope Array Surface Detector

Thursday, 14 July 2022 10:00 (30 minutes)

We present an overview and most recent observations of the lightning research program being conducted in conjunction with the Telescope Array cosmic ray observatory in Utah, U.S.A. This program focuses on understanding the initial breakdown stage of lightning through observations of downward Terrestrial Gamma-ray Flashes (TGFs).

Recent observations have demonstrated that Terrestrial Gamma-ray Flashes (TGFs) detected by satellites are associated with high-current energetic in-cloud pulses during ascending negative leaders. Meanwhile, a relatively small number of observations have been made of TGFs on the ground, owing to the greater atmospheric attenuation of gamma rays and the relatively rare occurrence of TGFs sufficiently close to detectors.

The Telescope Array Surface Detector (TASD) is a 700 square kilometer array of plastic scintillator detectors located in Utah's western desert. It consists of 507 three-square-meter detectors on a 1.2 km grid. The TASD was designed to detect particle showers generated by the interaction of ultra-high energy cosmic rays with the Earth's atmosphere.

Previously (Abbasi et al 2018, Belz et al 2020) we reported joint observations by TASD, Lightning Mapping Array (LMA), sferic sensor and broadband interferometer of particle showers coincident with lightning. These consisted of energetic showers of approximately 5 microsecond duration with footprints on the ground of order 10 square kilometers, originating in the first one to two milliseconds of downward lightning leaders and coincident with high-current processes within the leaders. Scintillator waveform and simulation studies confirmed that these showers must consist primarily of gamma radiation, thus the observations were identified as low-fluence TGFs near their initiation threshold. The TASD downward TGFs were in general of shorter duration and lower fluence than their satellite-detected upward counterparts.

Here, we report the new observation of several events of significantly longer duration and higher fluence, bridging the gap between the TASD and satellite based detections. These events further demonstrate the similarity between the upward and downward TGF varieties and the likelihood of a common origin for their production.

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Session Classification: Atmospheric Electricity