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Multi-Frequency Observation of Downward Terrestrial Gamma-ray Flashes in Winter Thunderstorms

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Terrestrial Gamma-ray Flash (TGF) is an instantaneous burst of high-energy photons associated with a lightning flash. Since the discovery by the Compton Gamma-Ray Observatory in 1994, TGFs have been mainly detected and investigated with space-borne instruments such as RHESSI, Fermi, AGILE, and ASIM. On the other hand, a limited number of TGFs have been detected on the ground, called downward TGFs. While satellite experiments are capable of detecting a large number of upward TGFs, ground-based ones can investigate limited samples of downward TGFs in detail.

Lightning Flashes in winter thunderstorms of Japan are known to trigger downward TGFs. Wada et al. (2022) reported seven downward TGFs in winter thunderstorms and classified them into two types based on broadband low-frequency waveforms. Since TGFs are coincident with lightning flashes, radio-frequency observations of TGFs are essential to understand the parent lightning discharges.

In 2020, we started a multi-frequency observation campaign of downward TGFs in winter thunderstorms. We developed a new instrument to record TGF photons without saturation. It has two scintillation crystals with different effective areas, and its analog outputs are recorded and saved by an oscilloscope. Also, the oscilloscope records very-high-frequency waveforms (VHF: 28-32 MHz) obtained by a flat-plate antenna, and VHF signals are used for triggering whole the detector system. On January and February 2021, a total of two downward TGF were detected by the instrument. One coincided with a lightning discharge, likely striking to a tall tower within 1 km, and completely saturated the instrument. This event was also recorded by a broadband low-frequency lightning detection network. The other occurred several kilometers away and individual photons were successfully recorded.

In 2022, we upgraded the observation campaign with VHF interferometers and an optical camera, aiming at lightning strikes to the tall tower. In December 2022, three downward TGFs were successfully detected. In this presentation, we will discuss the latest results of downward TGF observations in winter thunderstorms.

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