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Reassessing the BATSE Catalogue of Terrestrial Gamma-ray Flashes

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Abstract

Terrestrial gamma-ray flashes (TGFs) are bursts of gamma-ray flashes that last up to a millisecond and are observed by a spacecraft within a few hundred kilometers of the source of the gamma-ray. Since TGFs were discovered by the Burst and Transient Source Experiment (BATSE) on NASA's Compton Gamma-ray Observatory (CGRO) in the 1990s, other observations have increased our knowledge of TGFs (Fisherman et al., 1994). This improved understanding includes characteristics such as the distributions of geographic locations, pulse durations, pulse shapes, and pulse multiplicities. Using this post-BATSE knowledge, we reassessed the BATSE TGF catalogue (http://gammaray.nsstc.nasa.gov/batse/tgf/). Some BATSE triggers have features that can easily be identified as a TGF, while others display different features that are unusual for TGFs. The BATSE triggers of the TGF catalogue were classified into five categories: TGFs, Terrestrial Electron Beams (TEBs), unusual TGFs, uncertain due to insufficient data, and TEB candidates. The triggers with unusual features will be further investigated. A table of our classifications and comments will be added to the online catalogue.

Introduction

Terrestrial gamma-ray flashes (TGFs) originate from altitudes less than or equal to twelve kilometers in the atmosphere, putting the origin of the TGF inside a thunderstorm (Cummer et al., 2014). Electrons are accelerated by an electric field inside a thunderstorm. Terrestrial Electron Beams (TEBs) are a type of TGF that follows the geomagnetic field line in the inner magnetosphere and are observed differently than a TGF by not needing the spacecraft to be above the source. TEBs can also last up to tens of milliseconds in duration (Dwyer et al., 2008, 2012).

One main criteria used in this project was location compared to lightning activity. For this criteria, we used Optical Transient Detector (OTD) and Lightning Imaging Sensor (LIS) data from the public archive.

By returning to the BATSE TGF catalogue with this post-BATSE knowledge, we will gain a better understanding of the BATSE catalogue. The post-BATSE knowledge will allows us to categorize the triggers more efficiently and accurately.

Methodology

The spacecraft's geographic locations were plotted onto the lightning density map. OTD/LIS data maps from the public archive were used to help determine if a location was plausible to have lightning. This data, plotted on a continental world map, displayed in color the lightning density throughout the world. The spacecraft locations were plotted over-top of the lightning display.

Using the OTD/LIS data, two programs were created to plot a lightning density map with the overlaying spacecraft location data points. One program plotted a lightning density map with the spacecraft locations surrounded by 300 kilometer circles (Figure 1). The second program, plotted a lightning density map with the spacecraft locations of possible TEBs along with their corresponding northern and southern footprint locations (Figure 2). These two maps contributed to the geographic characteristic criteria by providing exact spacecraft locations to determine lightning plausibility in the area.

The two maps determine which BATSE triggers originate from areas with plausible lightning activity.

Characteristic criteria

Geographic location

Areas with greater lightning density have a higher probability of TGF occurrence. For long events that might be TEBs, the lightning activity at the footprint locations were examined. This was to evaluate if lightning was plausible at the northern or southern footprint locations.

Pulse duration

A key aspect in determining whether or not a trigger is a TGF or a TEB, is the trigger's pulse duration. If the pulse duration is a millisecond or shorter, the trigger is a TGF. If the pulse duration exceeds a millisecond, the trigger could possibly be a TEB. There is also a possibility of having longer TGFs due to unresolved multiple pulses.

Pulse shape

When looking at the trigger's pulse shape, the key feature to consider is if the rise time is less than the fall time. If the rise time is less than the fall time, that is characteristic of a TGF. Some events that have rise times slower than their fall times could be explained as consisting of two or more unresolved pulses.

Single or multiple pulse

The last piece of criteria observed was the trigger having a single or multiple pulse. If the trigger demonstrated a short single pulse, it was a TGF. If the pulse had a very long single pulse it could possibly be a TEB or possibly multiple pulses blended together. For short multiple pulses, each separated by about a millisecond, the trigger was likely a TGF.

Results and Conclusion

The BATSE triggers of the TGF catalogue were classified into five categories: TGFs, Terrestrial Electron Beams (TEBs), unusual TGF, uncertain due to insufficient data, and TEB candidate. 46 of the 76 trigger samples were categorized as TGFs. Two events were TEBs and six were considered to be TEB candidates. Six were unusual TGFs and 12 were recorded as uncertain due to insufficient data. A portion of the TGF triggers were found to have lasted a little longer than a millisecond. Other triggers displayed having a single long pulse that could potentially be multiple pulses.

With the post-BATSE knowledge we were able to categorize a more refined BATSE catalogue and gain a better understanding of the BATSE catalogue. A table of the trigger's classifications and comments will eventually be posted on the online catalogue.

References

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