Terrestrial Gamma-ray Flashes, Radio Atmospherics and Conjugate Sprites

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The observation of brief (<1 ms) bursts of intense γ-rays, the so-called Terrestrial Gamma-ray Flashes (TGFs), by the BATSE γ-ray experiment was one of the most unexpected discoveries by the Compton Gamma-Ray Observatory. Extensive modelling efforts following this observation interpreted the observations in the context of the runaway acceleration of energetic (>1 MeV) electrons by the intense quasi-static fields that temporarily exist at high altitudes above thunderclouds following positive cloud-to-ground lightning discharges. Association of individual TGFs, and positive cloud to ground (CG) lightning strikes have been demonstrated by means of the measurement of associated radio atmospherics, with at least some of the correlated sferics showing properties similar to those that cause sprites. However, simultaneous VLF data was only available for a few of the BATSE/CGRO events, so that a comprehensive study of this association was not feasible. New evidence from the RHESSI spacecraft now shows that TGFs occur much more commonly and that the photon energies typically extend to ~20 MeV. With the much larger number of TGFs now available from RHESSI, we undertake here a comprehensive study of the association between TGFs and sferics using VLF data collected at Palmer Station, Antarctica and other sites (e.g., in Alaska and the continental United States). Results indicate that by far the majority of observed TGFs are associated with an ELF/VLF radio atmospheric observed at Palmer Station, within ~1.5 ms of the expected time (when the sferic and the TGF propagation times are accounted for) and directionally determined to be arriving from an azimuth that is within 2 degrees of the RHESSI footprint. Compared with other sferics arriving from the same azimuth during a 30-min period around the time of the events, the sferics associated with the RHESSI TGF tend to be those with relatively large peak VLF intensities. The possibility has been suggested of 'conjugate sprites' as a result of the propagation of escaping runaway electrons along the Earth's magnetic field lines precipitating in the magnetically conjugate atmosphere, creating γ-rays, secondary ionization, and detectable optical emissions therein. In July and August 2003, an experiment was conducted in South Africa to attempt to measure these optical emissions, due to lightning in Western Europe, in order to verify and quantify the theoretical predictions. No optical emissions were detected from the ~1600 +CG's analyzed. However, the RHESSI spacecraft show that the region of Western Europe may indeed not be suitable for the creation of relativistic runaway electron beams, and that other locations such as the Caribbean Sea or Central Africa will be more suitable. Future experiments are now being designed to conduct optical measurements at these and other locations that are conjugate to regions of TGF observations by RHESSI.