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Understanding the Ratio between Terrestrial Gamma-ray Flashes and Lightning

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Project Summary

Terrestrial Gamma-ray Flashes (TGFs) were discovered in the early 1990's in Huntsville with the Burst and Transient Source Experiment (BATSE) on NASA's Compton Gamma-ray Observatory. TGFs are very brief (sub-ms) and extremely intense pulses of gamma-rays emitted by thunderstorms, closely associated with intra-cloud lightning. Electric fields in thunderstorms accelerate free electrons upward. Electrons that gain sufficient energy collide with atomic electrons and generate additional free electrons, which repeat the process, creating an upward cascade. The electrons also, when passing near nuclei, emit gamma-rays via bremsstrahlung, thereby producing TGFs.

Huntsville TGF research has continued with the Gamma-ray Burst Monitor (GBM) on NASA's Fermi Space Telescope. GBM has become the most prolific TGF instrument, detecting 850 per year (Briggs et al., 2013). We believe that TGFs are triggered by lightning. It is therefore a puzzle that the ratio between the rate of TGFs and the lightning rate is different in different parts of the world. For example, relative to lightning, TGFs occur at a 75% higher rate in Australia than in Central America and the Caribbean. Conversely, they occur half as often in Africa. There are also indications that TGFs that occur over Oceans are systematically shorter than those over land or close to coasts.

A recent paper summarizes geographic variations in lighting properties (Beirle et al., 2014). Some of these properties have geographic patterns similar to those of the TGF / lighting ratio. For example, radiance per flash is low in Africa and flash duration is high in Central America and the Caribbean and the portions of Australia observed by GBM. Large differences were found between land and ocean lightning. This suggests that the geographic variations in the TGF / lightning ratio might be related to geographic variations in lightning properties. The research project is to test this idea.

The key TGF properties are the ratio of TGF to lighting rate, TGF duration and TGF intensity. The student should read these quantities from our TGF database and average them by geographic region. Table 1 of Beirle et al. (2014) lists several lightning properties obtainable from the NASA public data of the Lighting Imaging Sensor (LIS). These quantities also need to be averaged by the same geographic regions. We already have a program that reads these LIS datafiles and extracts basic information. The student will need to augment that program to extract these additional lightning properties and accumulate by geographic region. Once the TGF and lightning properties have been averaged by geographic regions, the student can produce plots to see if there what correlations exist, if any.

Student Duties

The student will adapt existing programs to read the GBM and lightning data. The next step will be to average the data by large scale geographic features such as continents. The student will then plot the properties of the regions on graphs of TGF property versus lightning property. Examining the graphs, the student and mentor will judge which might show correlations. This exercise will also be done with the data grouped at finer geographic resolution. When likely correlations are found, statistical tests will be applied to test the significance of the correlations.

The student will learn exploratory data analysis and selected statistical tests. He or she will learn programming for data analysis, graphing data, and science of TGFs and lightning. Some knowledge of programming is desirable before starting this project.

The GBM TGF collaboration holds weekly or bi-weekly telecons; during the course of the project the student will have the opportunity to make several informal progress reports to these meetings. Other Huntsville GBM Team research scientists and graduate student working on TGFs will be available for assistance. The telecons and group discussion will expose the student to additional perspectives. The end result, due by the end of the 12 weeks, will be a summary report on geographic correlations between TGFs and lightning.

Office space for the student will be provided in Cramer Hall, near to the mentor and other GBM Team members.

Mentor Supervision and Interaction

The Mentor (Dr. Briggs) leads the GBM TGF research program, a collaboration of GBM Team members in Huntsville, and scientists at other US and international universities. During the first week of the project the student and mentor will work together approximately 3 hours per day to show the student how to access the data and to guide the student in the exploration of the data. When the project is past the initial setup, the student will work more independently, consulting with the mentor approximately one hour per day. More formal evaluations will take place weekly. If the mentor should be absent for several days or a week to attend a conference, other GBM scientists will be available as substitute mentors (Dr. Pete Jenke or Dr. Valerie Connaughton).

References

S. Beirle et al. (2014), *Nat. Hazards Earth Syst. Sci. Discuss.*, **2**, 2765, doi:10.5194/nhessd-2-2765-2014.

M. S. Briggs et al. (2013), *J. Geophys. Res. Space Physics*, **118**, 3805, doi:10.1002/jgra.50205.