

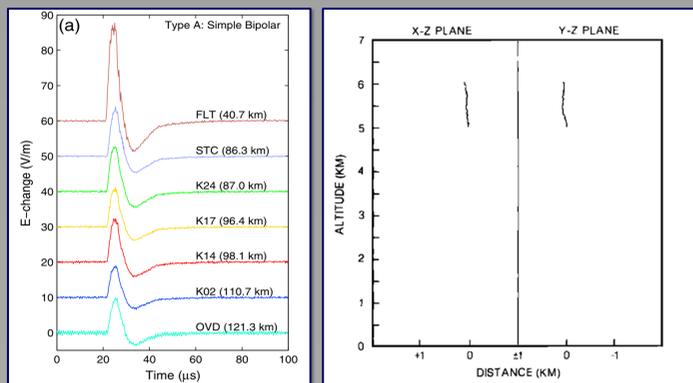


Narrow Bipolar Events

Abstract

Narrow Bipolar Events (NBEs) are high-energy in-cloud discharges associated with the initiation of lightning. NBEs named due to their narrow bipolar electromagnetic waveforms and short time duration. They are thought to be the brightest natural emitters of very high frequency (~10-100 MHz) radiation on Earth. In a 2016 field campaign at Kennedy Space Center in Florida, hundreds to potentially thousands of NBEs were measured with a *high-speed radio interferometer* (INTF) and a *lightning mapping array* (LMA). Here, we show that we can automate the identification of NBEs in the 2016 data set by exploiting their unique electromagnetic signatures. The NBE subset can then be investigated further to provide much-needed statistics.

The INTF is a broadband (20-80 MHz), three-antenna system, with a 180 MHz sample rate and 16-bit depth resolution, that maps lightning related radio sources with sub-microsecond resolution. A fast-electric field-change antenna, sensitive from 3 kHz to 3 MHz, is synchronously-digitized with the INTF. The LMA is a narrow-band 10-antenna system that maps radio sources in three spatial dimensions with 80-microsecond resolution. The LMA provides an associated least-squares error and estimated power output for each detected source.



Introduction

Narrow Bipolar Events (NBE's) are high-power in-cloud lightning phenomenon associated with the initiation of lightning events. They are characterized by distinct electric field waveform called a "Narrow Bipolar Pulse" (NBP) which can be seen in the surrounding figures. A NBP can be measured with a "Fast Antenna" (FA) that samples the change in electric field at ground level. Additionally, NBEs can be mapped in 3 spatial dimensions, with a lightning mapping array.

NBPs are named due to their very short duration, around 10 – 40 microseconds and their bipolar waveform shape. NBE's have the unique quality of being the strongest natural terrestrial emitters in the very high frequency (VHF) part of the electromagnetic spectrum, and because of this, they can be identified within the LMA data. They typically occur between 7-12 kilometers above sea level and can occur potentially hundreds of times in a single lightning storm. [Rison, E, et.al. 1999]

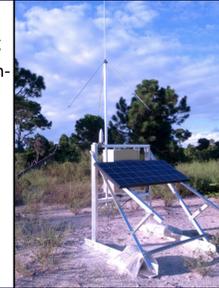
Data Collection

The *New Mexico Tech Broadband Interferometer* (INTF) pictured right, and *Kennedy Space Center Lightning Mapping Array* (LMA) were both operated at the Kennedy Space Center in Cape Canaveral Florida in the summer of 2016. Both instruments return raw data selections that can be imported into the sorting program for systematic testing. The INTF instrument returns the change in electric field waveform over time, store in digital units, and the LMA returns a 4-part space-time coordinate, with an associated chi-square and power value for each source.



Experimental Methodology

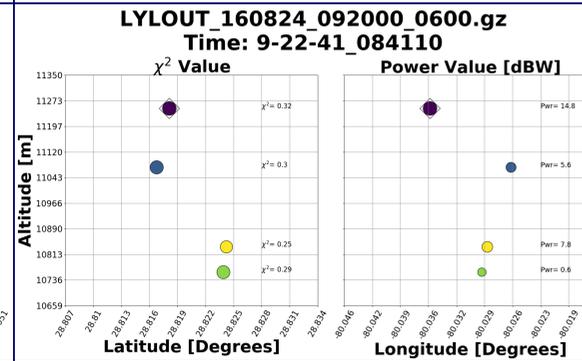
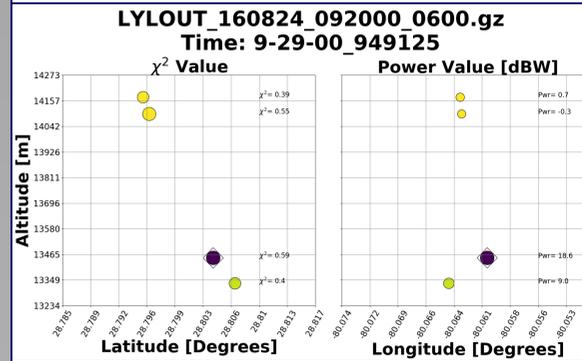
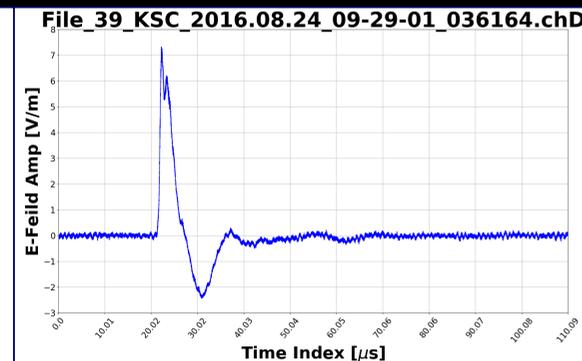
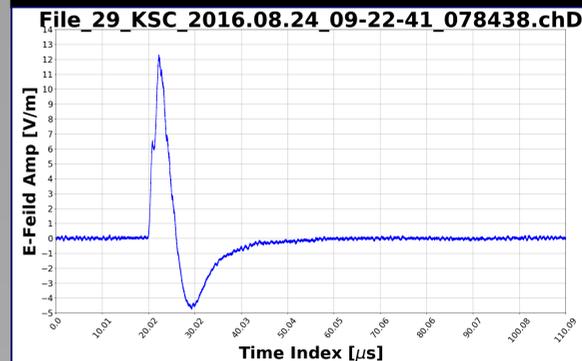
To identify Narrow Bipolar Pulses from this dataset, we designed two different searching algorithms from scratch, using Python, both programs accept user input parameters and sort through files as needed. The automated process can read, analyze, eliminate and identify characteristics far faster and more efficiently than any human could. By developing a series of mathematical parameters that describe NBPs based on documented cases, we can subject each raw data file or section of data to a series of these tests parameters. Files or events that failed to match these test criteria were noted and saved in a directory and files or events that matched all test criteria were marked to be NBP's and were saved in a different directory. Each file was stored in the form of a visualization, as seen in the surrounding figures, and a CSV file for future use. Detailed synopsis of this program can be found in the Algorithm Breakdown section.



Experimental Results

24 August 2016—09:22:41

24 August 2016—09:29:01



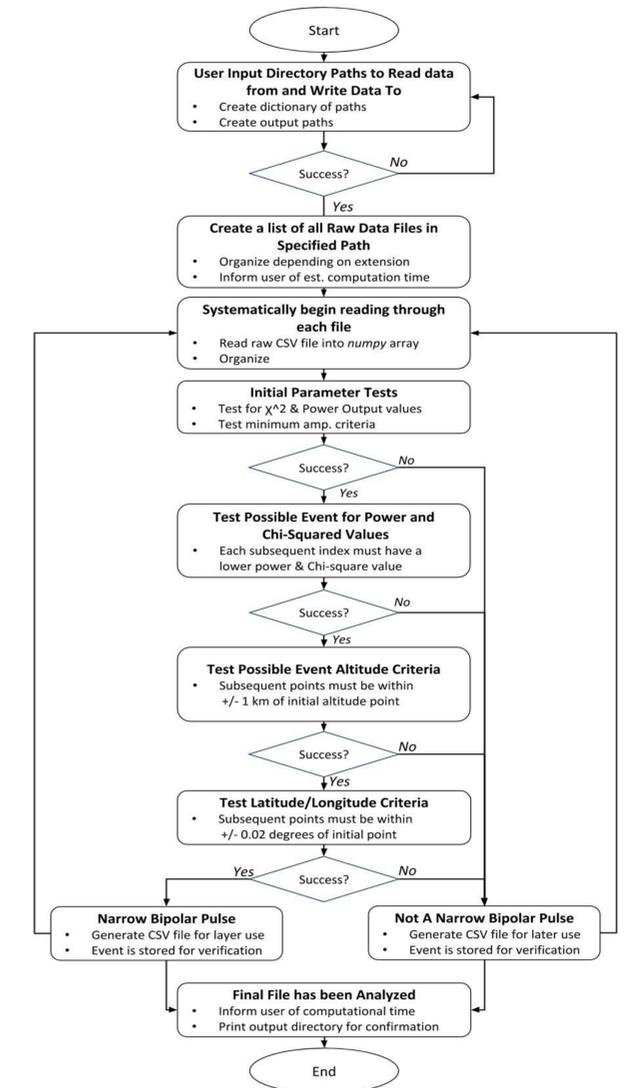
In the figures above, Potential NBPs are visualized using the two different data set characteristics. The Waveform plot is INTF data, and the Scatter plot is LMA data

Conclusions

With the test parameters applied to each raw data set, we were successfully able to sort and categorize each identified event based upon its electric field waveform or space-time characteristics. In the interferometer data, a set of 54 raw files were shown to contain 24 NBPs and a set of 5 LMA raw files, around 600 NBP-like patterns were found. Examples that were confirmed by human analysis can be used in further research to gain a deeper insight into the nature of these lightning-related phenomenon.

Additionally, events from both datasets contain timestamps that can be used to match the detections of the same event, measured in two different ways – one from the INTF, and one from the LMA. Two examples of this can be see in the figures above. By having these Narrow Bipolar Pulses measured and identified through multiple instruments, the sorting algorithms can be further refined to help identify NBEs.

Algorithm Breakdown (LMA)



References & Acknowledgements

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