Figure A

The Search for

Narrow Bipolar Pulses

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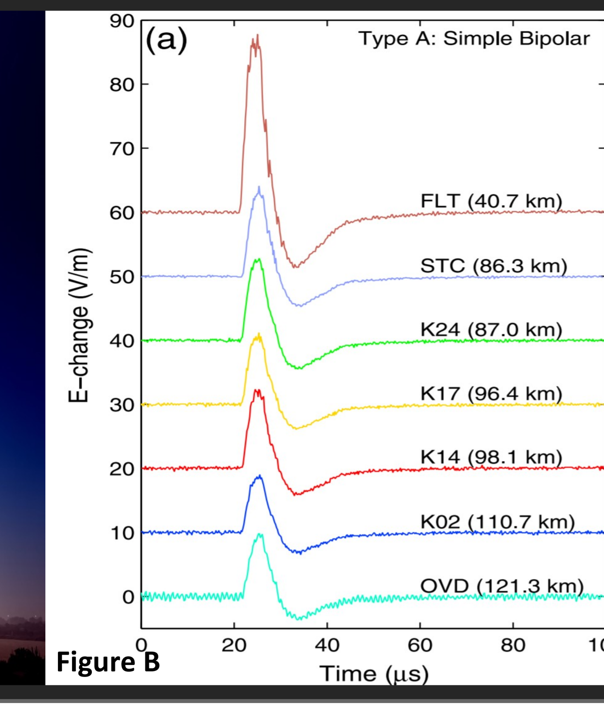

Figure B

Abstract

Narrow Bipolar Events (NBE's) are high-energy thunderstorm discharges that are associated with lightning initiation. NBEs are named due to a high-amplitude bipolar signal of short duration (tens of microseconds). During a 2016 field study at Kennedy Space Center, FL, hundreds to potentially thousands of NBEs were recorded by a high-speed radio interferometer and synchronized fast antenna with 100 microsecond decay time constant. The interferometer is used to map the development of radio-emitting sources, and is a triggered system, with many types of lightning processes recorded, not just NBEs. To gather and filter information, we require automated sorting of the interferometer data. Here we develop a Python code to isolate NBEs in the data based on identification of their fast antenna waveforms (NBPs). We find that by simply setting a lower-bound amplitude threshold on the fast antenna data, we can identify NBEs within a 100 km radius of the sensor, though we also find some events that are not Narrow Bipolar Pulses.

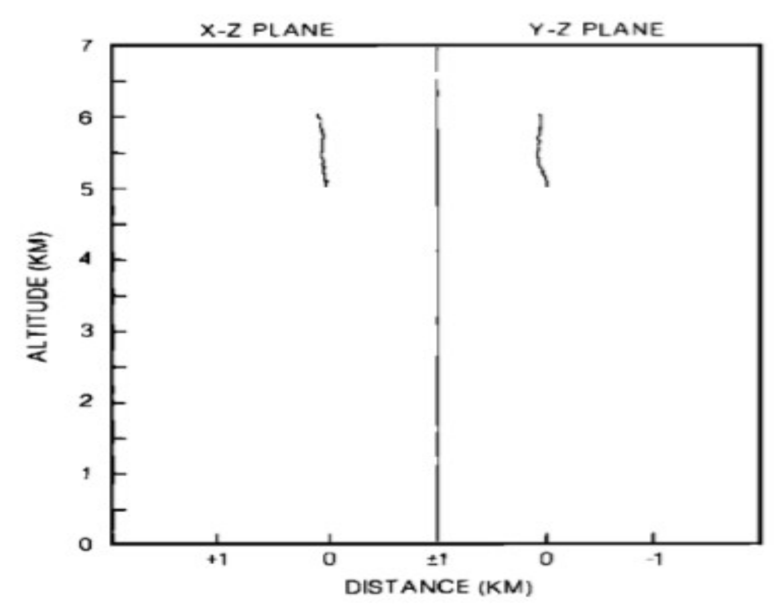

Figure I

Introduction

Narrow Bipolar Events (NBE's) are High-Energy, in- cloud lightning- associated events that are most commonly identified by a specific Electric-Field waveform, called a 'Narrow Bipolar Pulse' (NBP) which can be seen in **Figure B**. We can measure an NBP with a 'Fast Antenna' that samples the change in E-Field at ground level. NBE's are a possible mechanism for the initiation of lightning.

NBE's are the strongest natural terrestrial emitters in the Very- High- Frequency (VHF) portion of the Electro-Magnetic Spectrum, and their development can be mapped by Radio-Interferometers. A typical NBP will occur at an altitude of between 7 and 12 kilometers and last anywhere from 20 to up to 40 microseconds [Rison, W., et al.,1999].

Documented NBP's show that the E-Field will begin at a steady 'Zero-Point' amplitude and rise to a maximum in around 15 microseconds, followed by a jump to a minimum in 10 microseconds. Then, the E-Field will also decay back to its 'Zero-point' in another 25 microseconds. [Zhu, Baoyou, et al.,2010] This behavior can be seen in **Figure B.**

Our dataset consists of Electric-Field waveforms obtained at the Kennedy Space Center in Florida. The waveforms are measured by a Fast-Antenna, **(Figure A)** with a 100 microsecond decay time constant, and digitized at 180 MS/s in 16 bits. The resulting data is stored in as a digital unit in the form of a 'Channel-D' file. The fast antenna is synchronized with a three-element radio-interferometer that operates from 20 MHz to 80 MHz, which are channels A - C.

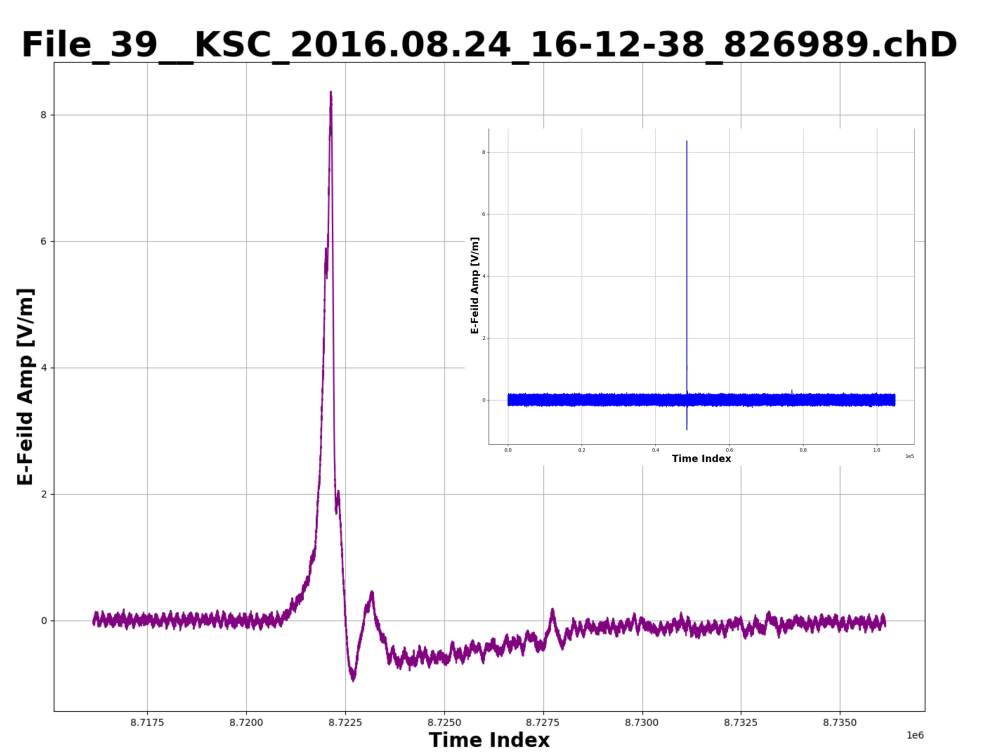

Figure C

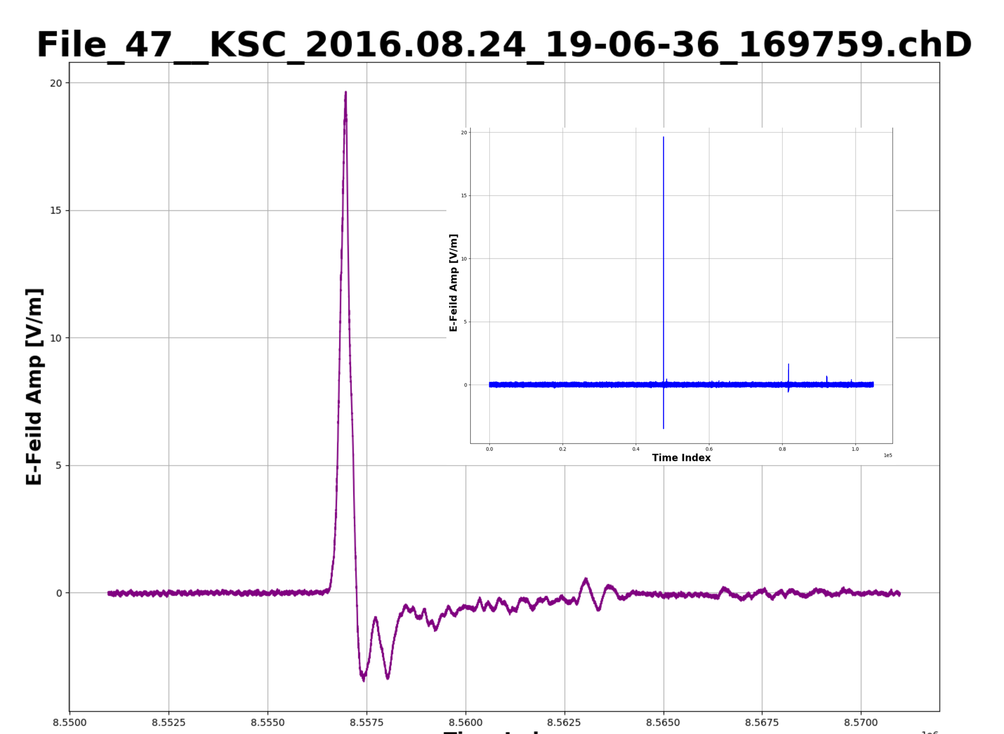

Figure D

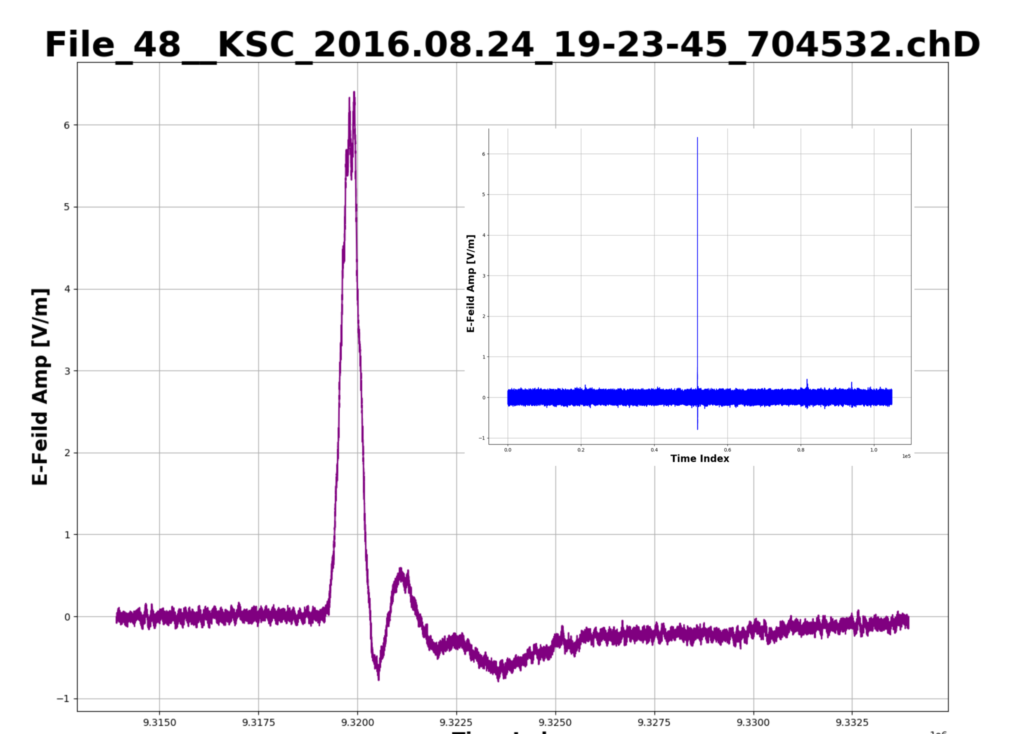

Figure E

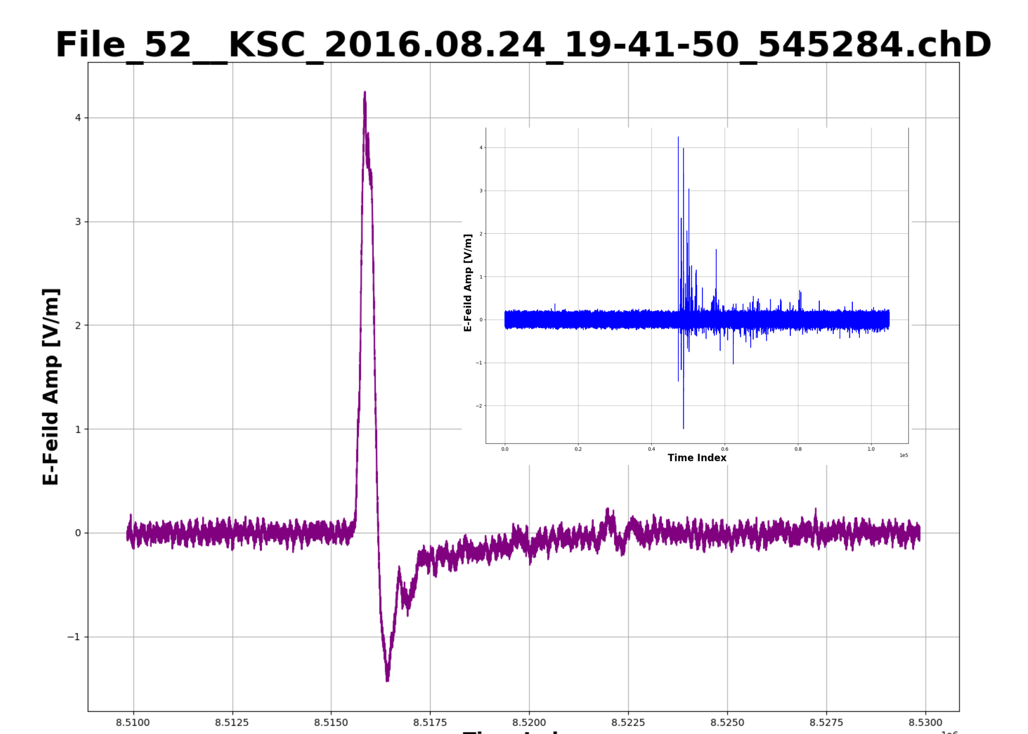

Figure F

Methodology

To Identify Narrow Bipolar Pulses, we produced a sorting algorithm to sift through the data and attempt to find them. Since NBP's produce a very specific E-Field wave form shape, it was the job of the program to produce plots of these data files so that we could identify them. The **Algorithm Breakdown** section provides a detailed synopsis of how the program reads, eliminates, plots and stores the channel D waveform files.

Figure G

INTF_1-200.txt - Notepad

File Edit Format View Help

```
Filename: INTF_1-200
Read From Directory:
        C:/Users/Landon/Documents/Lightning Research/data_rawINTF_1-200
It contains 56 Channel-D data file(s)
        24 were witten, 32 were omitted
-----------------------------------------------------------------
```

Filename	Number	Max Amp	Max Idx	Min Amp	Min Idx	Amp Diff	Idx Diff	Time Diff
KSC_2016.08.24_09-05-17_731781.chD	1	5.5388	11105195.0	-78.4211	11107069.0	83.96	1874.0	1.041944e-05
KSC_2016.08.24_09-34-11_631279.chD	2	4.3835	9431571.0	-3.3069	9433998.0	7.6904	2427.0	1.349412e-05
KSC_2016.08.24_09-50-12_890834.chD	5	5.2408	12894416.0	-4.4858	12897750.0	9.7266	3334.0	1.853704e-05
KSC_2016.08.24_09-59-55_096573.chD	7	4.7627	9273488.0	-9.3877	9268417.0	14.1504	-5071.0	-2.819476e-05
KSC_2016.08.24_10-01-19_903721.chD	8	10.4977	2528474.0	-7.8568	2527685.0	18.3545	-789.0	-4.38684e-06
KSC_2016.08.24_10-52-52_712626.chD	11	0.9602	6024639.0	-19.0642	6025572.0	20.0244	933.0	5.18748e-06
KSC_2016.08.24_12-32-21_818092.chD	13	6.6017	16112809.0	-2.5048	16117727.0	9.1064	4918.0	2.734408e-05
KSC_2016.08.24_12-32-36_381884.chD	14	4.4032	567103.0	-1.1925	572088.0	5.5957	4985.0	2.77166e-05
KSC_2016.08.24_14-31-44_630149.chD	15	-10.322	10113752.0	-160.5075	10099843.0	150.1855	-13909.0	-7.733404e-05
KSC_2016.08.24_15-45-23_511745.chD	23	13.2851	8841891.0	-4.2637	8843580.0	17.5488	1689.0	9.39084e-06
KSC_2016.08.24_15-45-26_348908.chD	24	13.8828	9120701.0	-3.7002	9123126.0	17.583	2425.0	1.3483e-05
KSC_2016.08.24_15-47-39_833042.chD	26	3.6352	10272875.0	-8.689	10259053.0	12.3242	-13822.0	-7.685032e-05
KSC_2016.08.24_15-49-43_206503.chD	27	7.2533	3300448.0	-0.901	3305617.0	8.1543	5169.0	2.873964e-05
KSC_2016.08.24_15-49-56_054788.chD	28	24.9367	9267632.0	-3.3885	9271110.0	28.3252	3478.0	1.933768e-05
KSC_2016.08.24_15-51-38_395387.chD	30	2.7248	1107497.0	-4.0037	1106534.0	6.7285	-963.0	-5.35428e-06
KSC_2016.08.24_16-03-27_461714.chD	34	11.7893	9435058.0	-3.5818	9435939.0	15.3711	881.0	4.89836e-06
KSC_2016.08.24_16-12-38_826989.chD	39	8.3611	8722139.0	-0.97	8722696.0	9.3311	557.0	3.09692e-06
KSC_2016.08.24_18-36-31_964203.chD	44	7.1952	475406.0	-1.8868	480377.0	9.082	4971.0	2.763876e-05
KSC_2016.08.24_19-06-36_169759.chD	47	19.6542	8556979.0	-3.4952	8557434.0	23.1494	455.0	2.5298e-06
KSC_2016.08.24_19-23-45_704532.chD	48	6.4057	9319922.0	-0.7964	9323563.0	7.2021	3641.0	2.024396e-05
KSC_2016.08.24_19-24-05_708763.chD	49	6.968	8490543.0	-0.6443	8496142.0	7.6123	5599.0	3.113044e-05
KSC_2016.08.24_19-41-50_545284.chD	52	4.2486	8515853.0	-1.435	8516402.0	5.6836	549.0	3.05244e-06
KSC_2016.08.24_20-53-48_222123.chD	55	13.0713	8753544.0	-41.9678	8741284.0	55.0391	-12260.0	-6.81656e-05
KSC_2016.08.24_21-03-20_448321.chD	56	12.4947	820154.0	-9.2045	825000.0	21.6992	4846.0	2.694376e-05

Algorithm Breakdown

1. A user will be prompted for a directory path to read data from and a directory path to output data to. Once both have been established, a list of all the 'Channel – D' files in that 'read directory' will be created. And used as a basis as to what files to read. The algorithm will move the 'read path' and the 'write path' directories for the duration of the program.

2. The 'Channel – D' files ('.chD') outputted by the Fast Antenna (FA) sensor range in size from 20 to 40 Megabytes, containing around 18,000,000 data points which makes each file around one-tenth of a second long (Graphed in Blue in Figures C-F)- These are the basis of the FA data.

3. Each wave form is stored in a Digital unit which must be converted into the SI unit Volts per Meter, and then flipped about the x-axis. Finally, the average of the data set will be computed and made into the 'zero-point' of the file. This means all values are measured in deviations from that average.

4. Once completing all of these steps, the algorithm will test the file to see if it meets the set minimum amplitude value threshold of +/- 4 V/m.

5. When a file passes the threshold condition, the program isolates the largest amplitude value in the dataset and creates a window of 111.21 microseconds around that value (Purple plots of **Figures C-F**). In this window, the maximum and minimum amplitudes, as well as their locations will be identified and stored in a data matrix.

6. Once each file in the specified directory path has been read through, analyzed, graphed and stored in the form of a '.png' file, a user will be prompted to enter a name to save a '.txt' file under.

7. This file will contain the printed-out matrix which displays the name of the file, the min & max amplitudes, their differences in terms of E-field and chronologically as well as other characteristic information which may assist in the further analysis of the data set (Figure G).

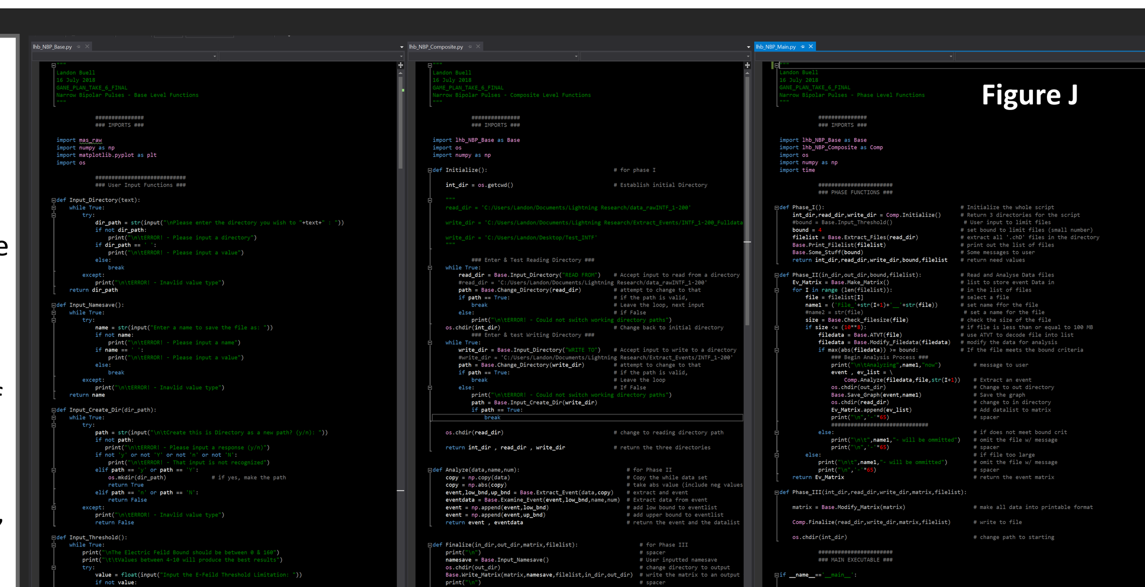

Figure J

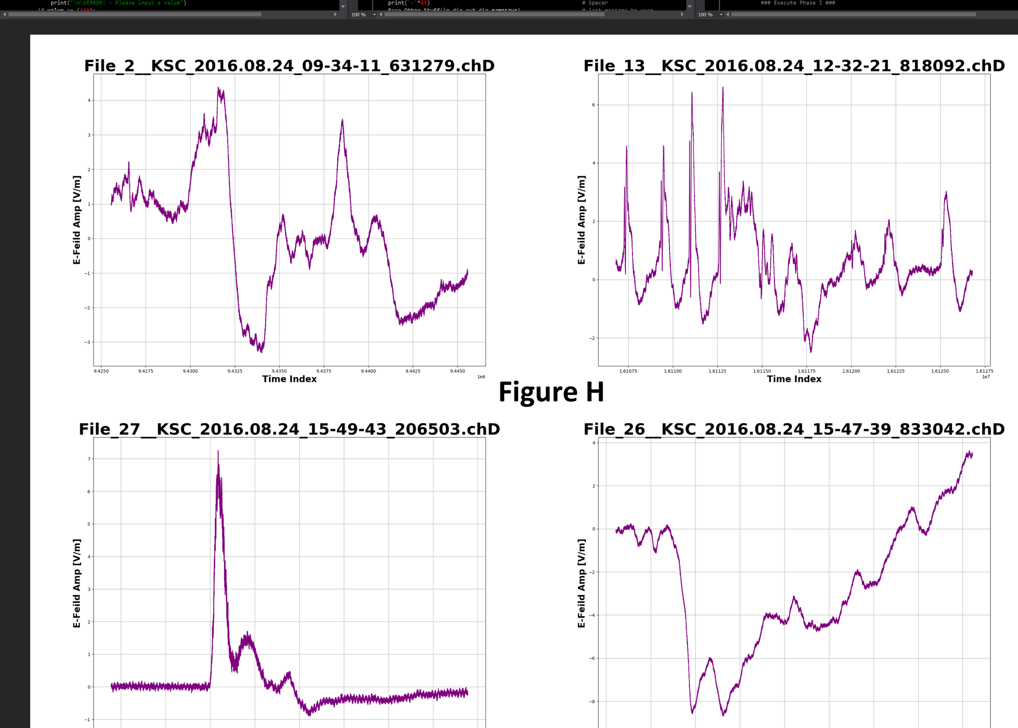

Figure H

Results

A sample of 24 'Channel- D' files was processed by our algorithm. Eight of the 24 files contain a waveform pattern that resembles documented Narrow Bipolar Pulses. The changes in Electric Field Amplitudes vary from around 4 V/m to up to 24 V/m. Based on the time stamps, these 8 NBP occurred within a time frame of about 12 hours- four of them are shown in Purple on **Figures C-F** . Other Non-NBP waveforms can be seen in **Figure H**

Conclusions

Narrow Bipolar Pulses can be identified by their resulting changes in Electric Field. Using the algorithm that we have developed, we have found 8 files that Narrow Bipolar Pulses from sample of 24 of them. The remaining files contain waveforms that do not specifically reflect NBP's. These could be the result of other events or ambient electromagnetic noise. Given the large quantity of data that we possess, the next step is to refine the searching process and include more specific parameters in our program.

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Sources

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