Automated Classification Of Narrow Bipolar Pulses

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Objective

- To autonomously identify and classify potential narrow bipolar events(NBEs)

Abstract

A narrow bipolar event (NBE) is a uniquely high-power, electrical discharge that takes places within thunderclouds [1]. "They are the most powerful terrestrial source of high-frequency (HF) and very high frequency (VHF) electromagnetic radiation in nature [2]", there is evidence that they can initiate other thunderstorm electrical discharges [2], and the polarity of their sferics (i.e., broadband electromagnetic signals) may correlate with the physical intensity of the storm [1]. These unique properties incentivize the identification and categorizing of NBEs for use in further research. In this work, we develop a method to automatically identify NBEs and determine their breakdown polarity using the INTF dataset, which consists of measurements from three broadband VHF (20-80 MHz) radio receivers that are used for interferometry, and a single electric-field change antenna that is used to record sferics produced by lightning. The INTF array was deployed to Kennedy Space Center in 2016, and all four signals were synchronously-digitized at 180 MSps. In our approach, NBEs are identified based on their narrow (roughly 10 microsecond-wide) bipolar sferics, and then the corresponding VHF data is processed to determine the breakdown polarity of the event.

Results

- Of the 545 detected NBE candidates, 137 were true NBEs
- 65 events were classified as having a negative breakdown polarity and 71 as positive.

Conclusion

The ability to identify and classify NBEs with minimal human intervention is currently limited by the ability to accurately identify an NBE within a data set and by the sometimes lacking temporal resolution of the VHF source data. These areas need further refinement before bulk NBE identification and classification can be implemented on a large scale. For the purposes of generating a database to be used for further research.

General Methodology

1) First approximate the amplitude of the noise in the electric-field change (sferic) data. Data that has a max amplitude greater then 120% of the noise level, in the first 10% of the time interval should be ignored

2) Search for the detection time, i.e., the first time the measured change in electric field goes above 120% of the noise amplitude (vertical green line in each figure).

3)Verify the selected interval is an NBE by looking at various perimeters like, the width of the wave form, activity surrounding the event, and the general shape of the signal.

4) Define the time interval of the event as: 30 microseconds before and 100 microseconds after the detection time (the vertical blue and black lines, respectively).

5) The measurements from the three radio broadband receivers are then used to to generate the VHF source locations within the time interval of the NBE.

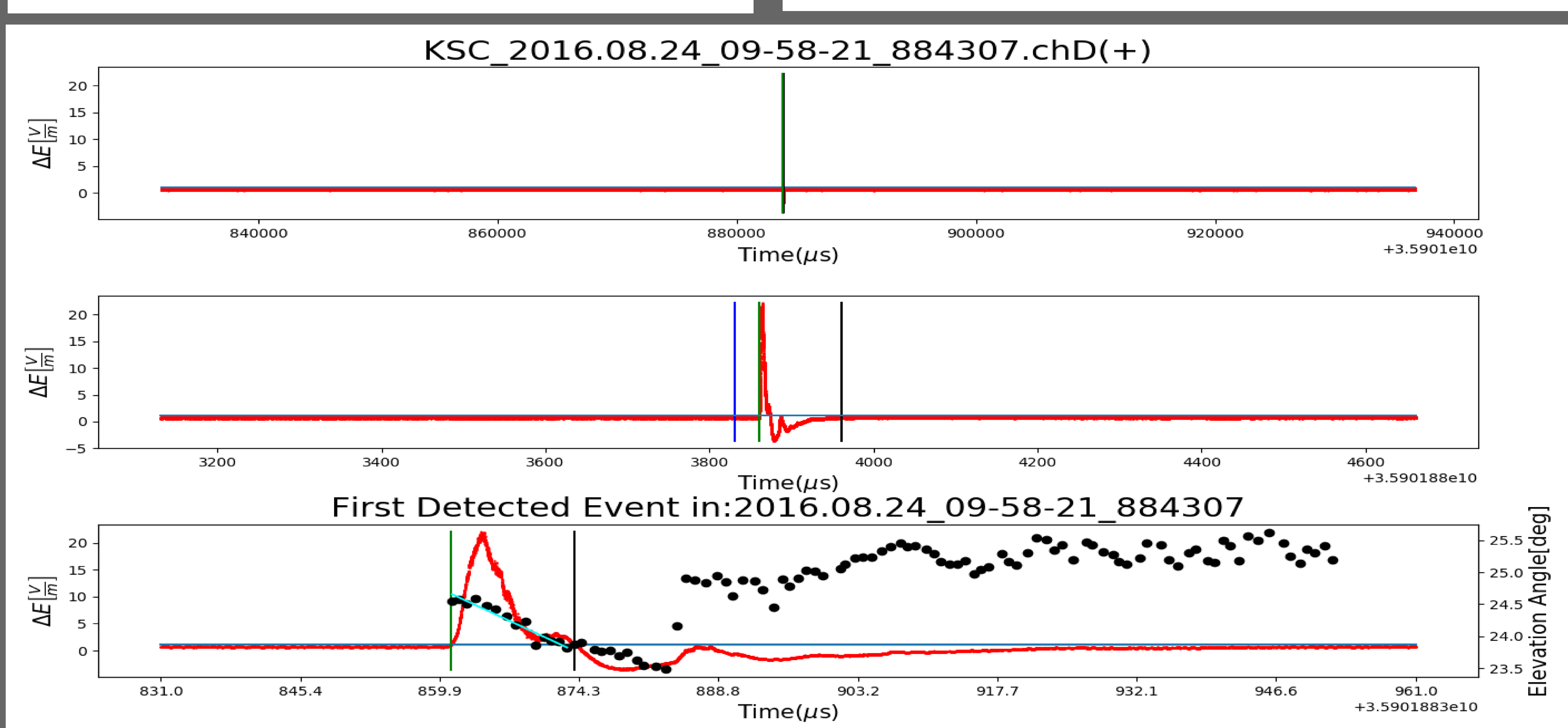
6) Determine the sferic polarity: We check if the electric field change signal has a positive maximum (with respect to the noise floor), then the signal has a positive polarity; otherwise, the sferic is of negative polarity.

7) Find the VHF source propagation direction by fitting a line to a elevation V.S time plot of the VHF source locations from the detection time to the next time the signal crosses below the same threshold step 2: 120% of the noise amplitude. The sign of the slope,ultimately, gives the direction of propagation.
- There should be no VHF sources more then approximately 5 micro seconds before the NBE detection time. If there are, question if the event is actually an NBE.

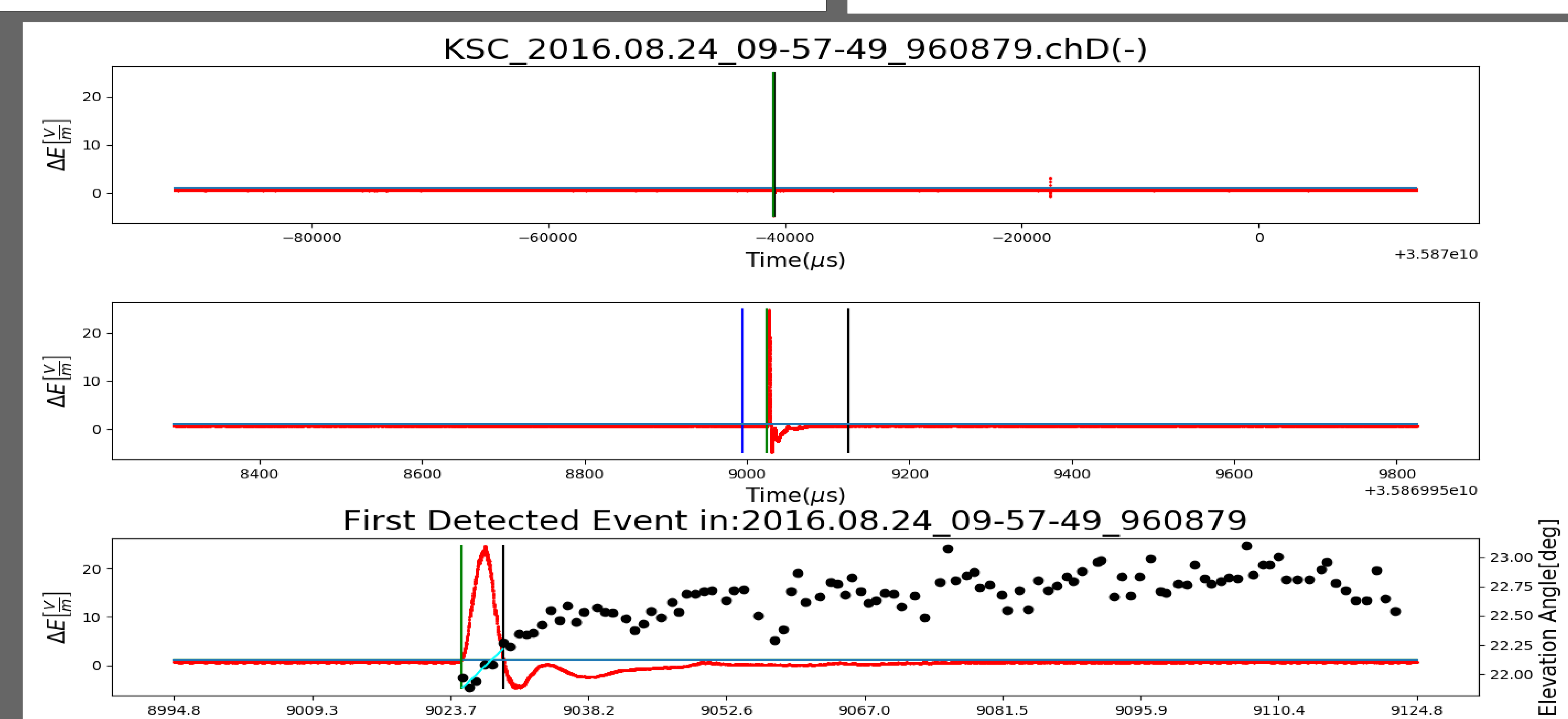
8) Determine the breakdown polarity – if both the sferic polarity and propagation direction have the same sign, then the breakdown is negative polarity; otherwise the breakdown polarity is positive.

References

- [1] Wu, T., Takayanagi, Y., Yoshida, S., Funaki, T., Ushio, T., and Kawasaki, Z. (2013), Spatial relationship between lightning narrow bipolar events and parent thunderstorms as revealed by phased array radar, Geophys. Res. Lett., 40, 618– 623.
- [2] Liu, N., Dwyer, J. R., Tilles, J., Stanley, M. A., Krehbiel, P. R., Rison, W., et al. (2019). Understanding the radio spectrum of thunderstorm narrow bipolar events. Journal of Geophysical Research: Atmospheres, 124, 10134– 10153.



Positive breakdown polarity



Negative breakdown polarity

Next Steps

- Improve the accuracy of of the scripts ability to identify an NBE from a data set
- Verify the accuracy of the script, in regards to classifying events, by running it through larger known data sets.