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Near-field, low frequency interferometric imaging of lightning

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1. Introduction

In the past, lightning interferometric mapping systems assumed that a source is very far from the measurement location. The assumption greatly simplifies the mathematics needed to locate the source, but the resulting source positions are limited to two spatial dimensions (azimuth and elevation). For short baseline systems, this assumption is very good because the source is almost always much farther away than the diameter of the array, making three-dimensional location all but impossible. Location in 3 spatial dimensions was primarily achieved by solving the time-difference of arrival equations [e.g. 1]. Even [2] used interferometry techniques only to determine the time-difference of arrival, and then solved the standard set of equations. However, using it is possible to adapt the interferometry imaging techniques described in [3] into the near-field case, allowing interferometry techniques to be used to locate sources in 3-D.

The purely interferometric method is quite different from the more typical time-of-arrival method. Instead of measuring arrival times or time differences of the radiation arriving at each station, a volume is imaged over some integration period and then searched for a source. It is not necessary to know that a source exists in the integration period for the interferometric imaging technique to produce a well-defined solution. Interferometric imaging can locate sources buried in noise, can locate both continuous and impulsive emission, and is capable of locating multiple simultaneously radiating sources. If the waveforms are corrected for propagation delay to the search volume, the integration period can be made arbitrarily small (limited only by the frequencies being observed), allowing the progression of lightning to be examined in detail. When applied to arrays with moderate spacing (less than 50 km between sensors), the technique can produce very high quality, 3-D maps of lightning. Further, the same technique can be applied to networks with much larger spacing (100+ km between sensors) to produce high quality 2-D maps of lightning.

Here we present the application of near-field interferometric imaging to data taken by the Broadband Observation network for Lightning and Thunderstorms (BOLT). The BOLT network uses 11 low frequency (5-500 kHz) electric field change sensors to detect and locate lightning. We then we extend the techniques to be useful by the Earth Networks Total Lightning sensors. The Earth Networks sensors are also low frequency electric field change networks, but in much larger numbers and spacing, and whose data have undergone lossy compression.

4. References

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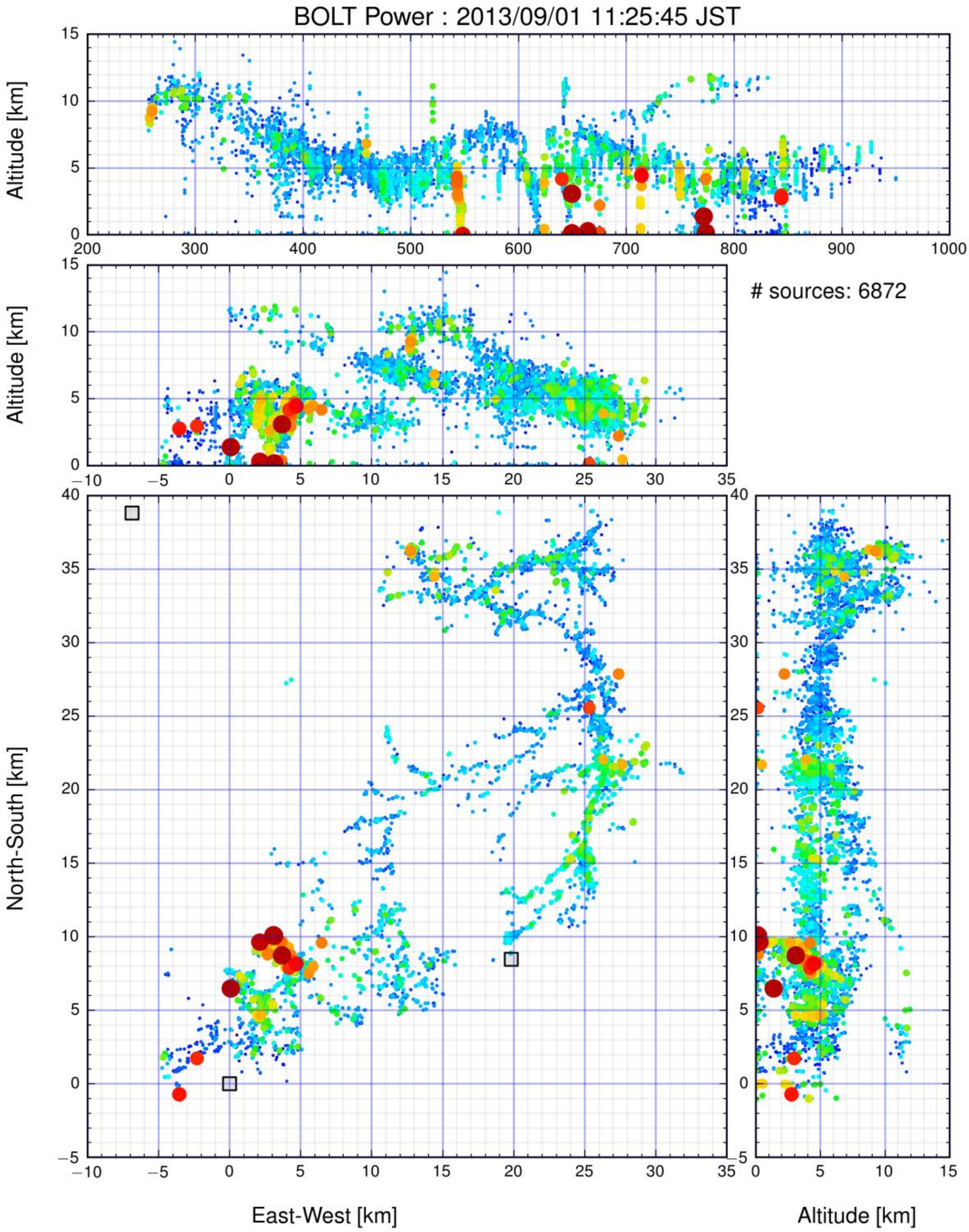

Figure 1. An example of a cloud-to-ground lightning flash as observed by BOLT and located using near-field interferometric imaging. Top panel shows altitude vs. time. Lower panels show the plan maps of the flash along with it's vertical projections. Color in all panels shows the amplitude of LF sources. The return strokes of the flash are easily identified as large red dots due to their high amplitude.