Simulated Source and Flash Detection EfficienciesUsing a New Interactive Tool

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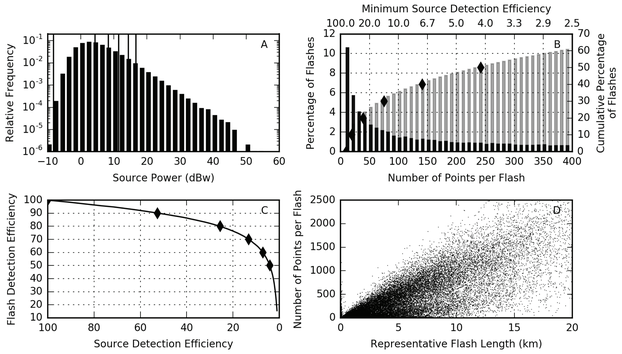
Goal

Develop a tool to better understand the variable performance of any Lightning Mapping Array (LMA) by simulating solutions given the noise floor at each station.

Methods

- Emitting sources placed on grid with 5 km horizontal, 0.5 km vertical spacing.
- **Each source was randomly assigned the maximum of 2000 samples (from assuming a 80 µs timing window and 25 MHz digitizer) of a P^{-1} distribution** to approximate the power distribution in Thomas et al., 2001. Far field propagation and free space loss were assumed.
- Propagated source from each location to all receivers.
- Gaussian timing error (σ=23 ns from WTLMA analysis) added to each retrieval.
- Set threshold for each station using observed noise floor, **each station only contributed if the received power was larger than the station threshold.**
- Variable number of stations required to retrieve a signal for the source to be considered.
- Used 17 months (29,899 flashes) of WTLMA observations over the network to find **the percentage of flashes with a given number of points and therefore minimum source detection efficiency needed for a given flash detection efficiency.**



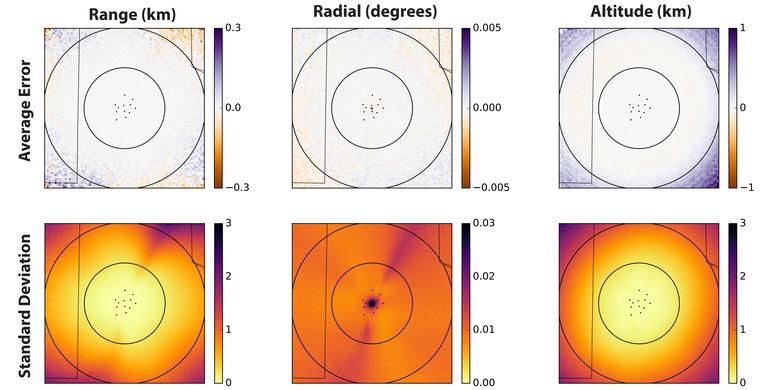
istribution used in model: A) Relative frequency of simulated powers (in dBW) assigned to source points, as described in text. B) Percentage of the 29,899 analyzed flashes within 20 km of the WTLMA from January 2012-May 2013 by the number of points m grouped into a flash. C) Percentage of observed flashes of at least ten points (y-axis) which would be detected at a given source detection efficiency (x-axis). D) The number of points m grouped into a flash and the square root of the area of each flash.

Improvements since publication

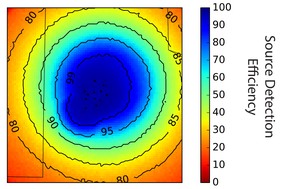
- Detection efficiency calculated by power above station threshold - Much faster!
- Confidence interval ellipse visualization - More intuitive display of errors and distortion of solutions

General Results

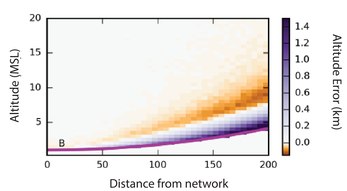
- Largest errors and variability are in the vertical. Sources at heights along the plane of the network have a large positive bias in solution location. Sources above have a smaller, negative bias.
- Variability of solution locations increases more rapidly with distance than location bias.
- Source detection efficiency decreases quickly with range while flash detection efficiency decreases at a slower rate.
- **The station thresholds determine the performance of a network on any given day.** Best performance can be offset from the center of the network based on the individual receiver thresholds.



Above: WTLMA example column averaged errors (biases) and standard deviations from the Monte Carlo model at 5-15 km MSL. Station locations are shown in black. Rings are ranges of 100 and 200 km from the center of the network. State lines are shown in grey.



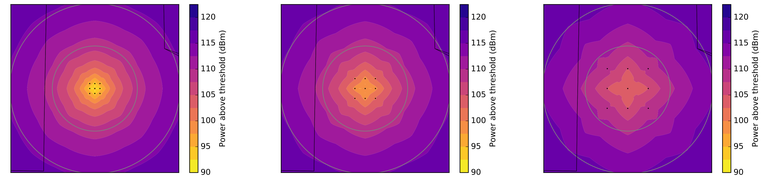
Estimated detection efficiency of the WTLMA example shown above. Fill is the *source* detection efficiency, contours are the *flash* detection efficiency. Note the the asymmetry and the more gradual decrease in flash detection efficiency as compared to the source detection efficiency.



Radially averaged altitude error at given height levels above MSL for the WTLMA example. Purple line shows the line of sight of the network. Note the increasing upward bias in solutions of sources near the line of sight.

Network Testing

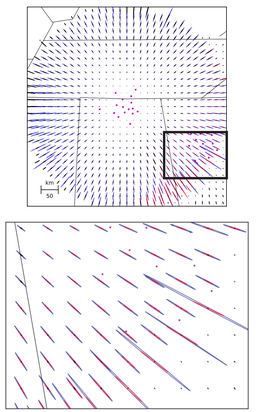
Station Spacing



Souce emission power over station thresholds needed for a six station solution using a uniform network with grid spacings of 12, 24 and 48 km respectively. Note the decrease in needed source power (more sensitivity) near the network in the small spacing example

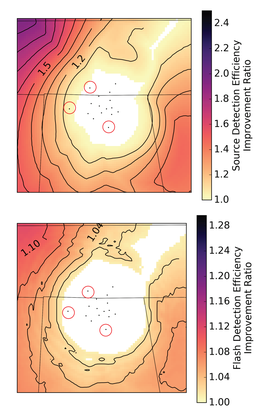
Additional Stations

Error Shape



Confidence ellipse for errors within 3 standard deviations. Blue: Only NALMA stations during VSE. Red: NALMA + additional 3 stations during VSE. Black: All previous + NGLMA stations as during VSE. Below: Zoomed in view of boxed area.

Detection Efficiency

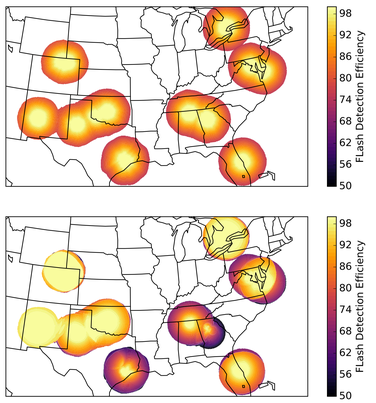


Ratio of estimated source (above) and flash (below) detection efficiencies over NALMA network domain with the addition of three extra stations during VSE (circled).

GLM Validation Applications

Above: Estimated flash detection efficiency using a uniform -78 dBm threshold at all stations

Below: Estimated flash detection efficiency of all LMAs for GLM validation using thresholds as of 16 January 2017. Adjoining networks treated as if processed together, not individually. Note that many network changes are still in progress.



References

Koshak, W. J., R. J. Solakiewicz, R. J. Blakeslee, S. J. Goodman, H. J. Christian, J. M. Hall, J. C. Bailey, E. P Krider, M. G. Bateman, D. J. Boccippio, D. M. Mach, E. W. McCaul, M. F. Stewart, D. E. Buechler, W. A. Petersen, and D. J. Cecil (2004), North Alabama Lightning Mapping Array (LMA): VHF source retrieval algorithm and error analyses, *J. Atmos. Ocean. Tech.*, 21(4), 543-558.

Thomas, R. J., P. R. Krehbiel, W. Rison, T. Hamlin, J. Harlin, and D. Shown (2001), Observations of VHF Source Powers Radiated by Lightning, *Geophys. Res. Let.*, 28(1), 143-146.

Thomas, R. J., P. R. Krehbiel, W. Rison, S. J. Hunyady, W. P. Winn, T. Hamlin, and J. Harlin (2004), Accuracy of the Lightning Mapping Array, *J. Geophys. Res.*, 109, D14207, doi:10.1029/2004JD004549.

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Program available at https://github.com/vbalderdash/LMAsimulation