1. OVERVIEW
This presentation examines in detail the standard retrieval method: that of retrieving the \((x, y, z, t)\) parameters of a lightning VHF point source from multiple ground-based Lightning Mapping Array (LMA) observations. The solution is found by minimizing a chi-squared function via the Levenberg-Marquardt algorithm. The associated forward problem is examined to illustrate the importance of signal-to-noise ratio (SNR). Monte Carlo simulated retrievals are used to assess the benefits of changing various LMA network properties. A generalized retrieval method is also introduced that, in addition to TOA data, uses LMA electric field amplitude measurements to retrieve a transient VHF dipole moment source.

2. FORWARD PROBLEM: SNR ANALYSES
Performing the forward problem illustrates how well the measurements (TOA, or difference in TOA) track changes in the VHF point source. The sensitivity of 1 sensor (or 2 sensor) systems to various source displacements is examined.

3. BASELINE MONTE CARLO SIMULATION
The baseline running the mean altitude retrieval error as a function of source altitude (given at the top of each plot) and horizontal source location relative to the fixed (3x3) Cartesian LMA network.

4. MORE SIMULATIONS: EFFECT OF ALTERING CERTAIN LMA NETWORK PARAMETERS
The SNR associated with a single sensor when a source a horizontal distance \(D_1\) away is displaced vertically (left plot), and horizontally (right plot).

The SNR of a two sensor system when a source is displaced in \(x\)-direction (top row), \(y\)-direction (middle row), and vertically (bottom row). Distance between sensors is: 50 km (left column), 100 km (right column).

Basic geometry (top), vertical displacement (middle), horizontal displacement (bottom).

The north east sensor.

Expanding the horizontal extent of the network.

Increasing the number of measurements.

Improving the measurement accuracy.

4. GENERALIZED RETRIEVAL METHOD
The vertical field \(E_z\) from He et al. (2000) due to a transient dipole source is generalized so that it expresses the field at the \(i^{th}\) LMA sensor. The amplitude measurement \(a_i\) and the associated model \(\hat{a}_i\) are identified, and the generalized chi-squared is minimized to obtain a solution [note: \(\beta\) is a function of the spatial variables \((r, \tau)\) and the orientation angles of the dipole source; \(\tau\) is the TOA observation at \(i^{th}\) sensor]:

\[
E_z(x, t) = \sum_{i=1}^{N} \left( a_i (x, t) \right) \frac{1}{\rho} \left( x - \hat{R}_i \right) \left( t - \hat{\tau}_i \right).
\]

The SNR associated with a single sensor when a source a horizontal distance \(D_2\) away is displaced vertically (left plot), and horizontally (right plot).

Improving the measurement accuracy.

5. REFERENCES
He, S., M. Popov, and V. Romanov, 2000: Explicit full identification of a transient dipole source in the atmosphere from measurements of the electromagnetic fields at several points at ground level, Radio Sci., 35, 7.07-7.17.