Two-dimensional analysis of intracloud lightning discharge utilizing time-dependent interior boundary conditions with LMA data

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Background

•A calculation of the electric potential and electric field of lightning discharge as a channel propagates through a cloud is made.

•Lightning model replicates the macroscopic propagation of discharges as a step-by-step process.

•Points are plotted on a uniform discretized grid, one at a time. After each point is plotted, the electric potential at that point is set to a constant value.

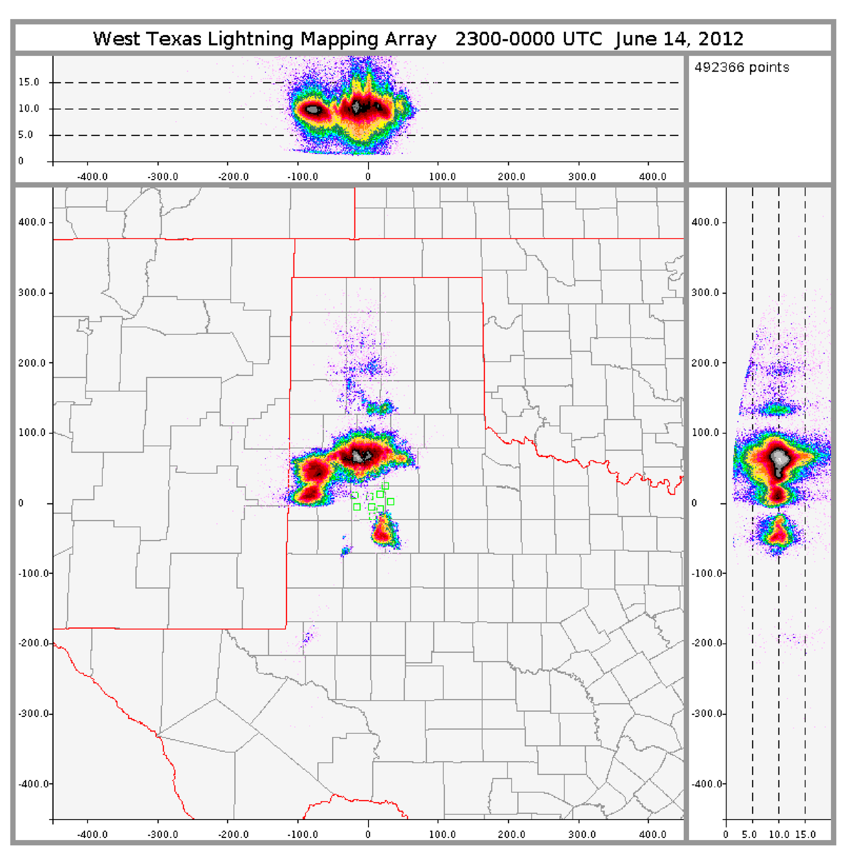
•The electric potential and electric fields are then calculated for every point on the grid via the Laplace's equation utilizing the successive over relaxation (SOR) method with time-dependent interior boundary conditions.

•With these calculations, one expects to be able to determine if the lightning track follows a statistically probable path.

This research follows a similar approach to Mansell (2002), Riousset (2007), and Petrov and Petrova (1993). However, as their approaches are probabilistic simulations with comparisons to observations from real lightning data, this research attempts to determine the physical structures of the cloud starting with the real lightning data and then judging whether or not these calculated physical structures are convincing.

Lightning Mapping Array

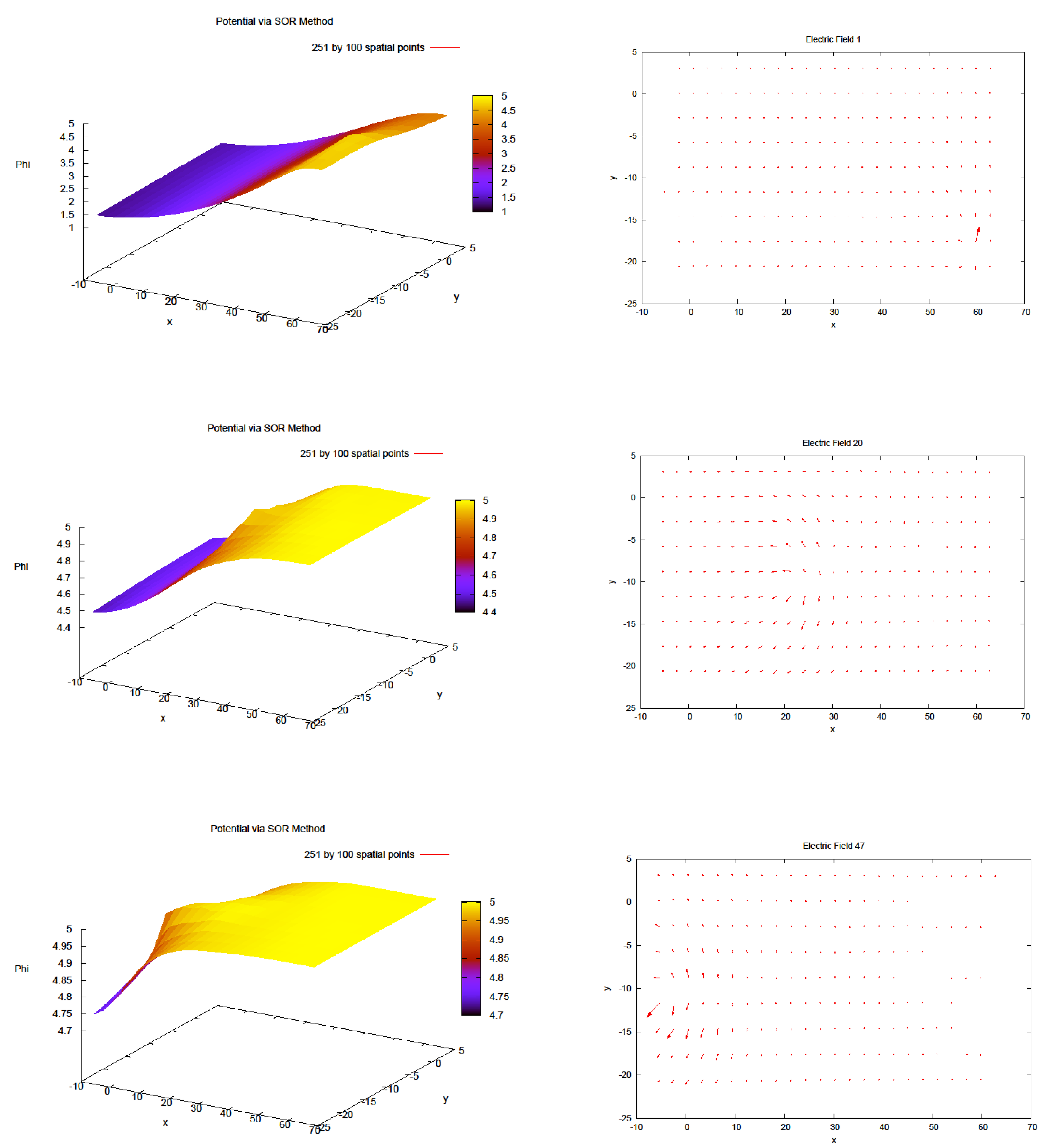
A Lightning Mapping Array (LMA) is an array of scientific instruments used to detect lighting across an area which allows the detailed study of thunderstorm electrification.



An array will show the three-dimensional shape, extent and the development of branched lightning channels. Data collected is an essential tool for cutting-edge lightning physics studies and forecast applications.

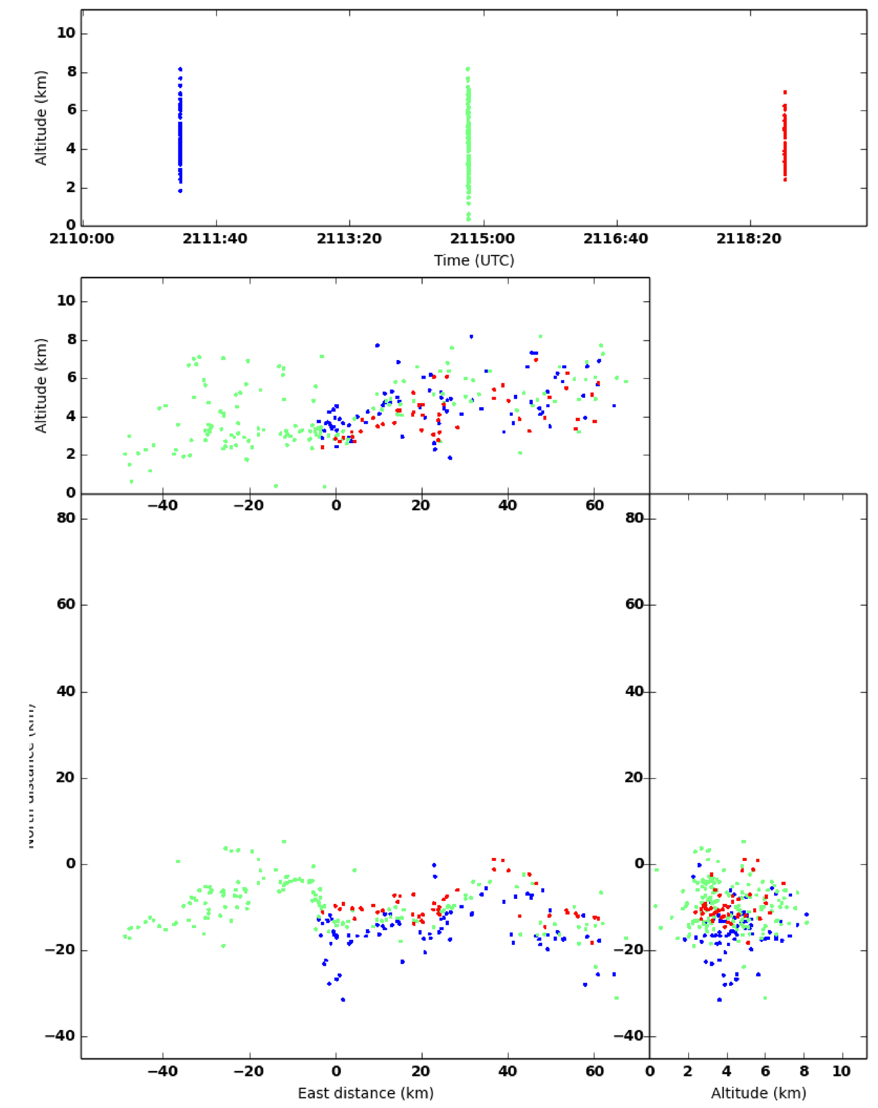
Plotting and Analysis Method

To analyze the data, we first assign a grid where the origin is in the same geographical location as the DCLMA. We first find the maximum and minimum values of the data. We allow for a region of 10 km outside of the maximum and minimum values to act as a buffer region. The entire grid is initially set to $\Phi = 0$. For the boundaries, we say that $\nabla\Phi \cdot \hat{n} = 0$. We then plot the raw east-west data points to the grid one at a time. To do this, we adjust the data set such that an integer value has 10 meters of precision. This is well within the physical accuracy of the LMA. When a point is plotted we assign the value of the potential, Φ, at that point to be non-zero. The values of the potential at every point on the grid is then solved using Laplace's equation through a method of successive over-relaxation. After the potential is known, the values for the electric field are then calculated. This process is repeated for each data point in the lightning channel.



Data

The data comes from the 26th of January 2011 and was detected by the Washington DC LMA (DCLMA). The data shows three distinct lightning flashes with similar path. Each of these flashes occurred in the same storm and approximately 3 minutes after one another. This data is of interest because the three flashes follow a similar path with several minutes between flashes.



Results and Extension

Calculating the SOR potential and electric field for every point in a discretized grid is shown to be feasible and is consistent with the lightning track data. Further analysis is required to determine if the electric field vector favors propagation toward the following data point and if the electric field magnitude between two points exceeds a critical value. Once this is known, we will be able to conclusively state that this model is representative of the physical process occurring in the January 26th, 2011 storm.

This work could be extended to include charge distribution in the cloud. A further, more ambitious, refinement would include extending this same analysis process to a three-dimensional data set.

References

[1] Mansell et al. (2002) *JGR* **107**, D9.
[2] Riousset et al. (2007) *JGR* **112**, D15203.
[3] Petrov and Petrova (1993) *Techn. Phys., 38*(4), 287-290.
[4] Petrov and Petrova (1999) *Techn. Phys., 44*, 472-475.