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Observations of The Spontaneous Nature of Lightning Initiation in VHF

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Using interferometric beamforming on data collected from the Low Frequency Array of Antennas (LOFAR), we have imaged the very first initiating event of a lightning flash. Recent observations of narrow bipolar events (NBEs) have provided hints to the physical mechanisms of initiation, however LOFAR is the first group to identify the initiation sources. Our observations and results provide evidence for the theory that cascades of streamers increasing in number produce VHF sources in the initiation region, as indicated by the ramp-up from background to near lightning leader source intensities. The first impulsive sources are observed to initiate at the location of the streamer inception point in two separate flashes, substantiating the original initiation method hypothesized by Griffiths and Phelps in 1976 [1]. Interferometric beamforming locates these sources, showing this motion on meter scale, and the overall increase in power of the streamer avalanche as it forms. This process provides a detailed 3D representation of the trajectory, and here we report an e-folding length that is consistent with previously published observations of fast breakdown in NBEs.

Application of 3D interferometric beamforming to VHF sources observed in lightning flashes improves and enhances accuracy of imaging and data analysis. Beamforming techniques combined with the myriad antennas and long baselines of LOFAR enable the identification of meter-scale motion of lightning sources and the observation of source intensity growth. In time of arrival (TOA) imaging applied to locating impulsive sources, LOFAR achieves 1 nanosecond timing accuracy and meter-scale spatial precision in lightning imaging on pulses observed in the 30-80 MHz band via the 38 Dutch-based stations. This project complements and enhances the previous work of the LOFAR lightning group of Groningen [2], and [3] improves image details in regions with weak sources. These sources are believed to be caused by a streamer-cascade-like initiation event leading to the formation of the first leader in two separate lightning flashes. The initiation starts from essentially background and within tens of microseconds ramps up a few orders of magnitude before the first impulsive sources connected with lightning leaders are observed. Specifically, for a flash recorded in 2018 we observe a velocity of about 4.8 x 106 m/s and a ramp up from background rates of about 10 orders of galactic background (GB) to 300 GB within a time period of 13.0 μs, or an e-folding time of about 2.8 μs. The first impulsive source is observed about 10 μs later and forms within 5 m of the start of the initiation region. The observed initiation events are likely an analog of fast breakdown in NBEs.

References

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