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Simulating the energetic impacts of lightning

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Abstract

A lightning flash deposits anywhere from millions to billions of Joules to its striking point and the surrounding environment. This energy is emitted in the form of electromagnetic waves measured by lightning-location systems, but that may also cause disruption in electronic systems. This energy is transferred to man-made structures in the form of electrical surges, heat, and mechanical stress. Additionally, this energy deposition also drives the synthesis of pollutant chemical compounds in the atmosphere. The problem of quantifying the impacts of lightning essentially can be boiled down to estimating its energy deposition. In simplified terms, the lightning return stroke can be represented by a lumped RLC circuit. The leader channels can be interpreted as representing a charged capacitor that is shorted to ground. The energy initially stored in this equivalent capacitor is dissipated in a resistor that symbolizes the channel attached to ground. The plasma nature of lightning channels ensures the complex behavior of its nonlinear resistance, which complicates an accurate account of the power dissipated during the return stroke process. In this work, we use a minimal numerical model capable of qualitatively capturing the temporal dynamics of the key plasma properties in a lightning channel, including its electric field, temperature, plasma density, radius, and the resulting nonlinear resistance. A series of novel parameterizations show that the problem can be reduced to the solution of six ordinary differential equations [see: da Silva et al., JGR, 124, 9442-9463, 2019]. We present a range of simulation results regarding energy deposition in a lightning flash derived from this theoretical model, and compare it with experimental data from triggered lightning and laboratory sparks.

Topic Areas

Lightning Physics, Characteristics and Measurements, Tower-Initiated and Rocket
Triggered Lightning

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