No longer a dot product: evidence of thunderstorm fluid dynamics in modern lightning measurements

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Lightning flash size and rate is controlled by the distribution of electrical potential in the thundercloud. This distribution results from microphysical charge separation followed by differential sedimentation and advective transport of charged hydrometeors.

Advancements in lightning instrumentation in the past twenty years have resulted in a new generation of lightning datasets which map the extent of lightning flashes in the cloud. These measurements enable construction of radar-like three-dimensional lightning grids of flash rate and size at one minute resolution. When combined with a simple electrostatic model of the lightning discharge the flash size data may be used to estimate lightning energy spectra. These spectra look like a thunderstorm's turbulence kinetic energy spectrum. In storm updrafts, there are many more small flashes than in anvil regions, suggesting that turbulence is helping to control the electrical energy distribution.

A recent measurement campaign conducted by Texas Tech University with two Ka-band mobile radars and VHF Lightning Mapping Array was designed to test the relationship between the turbulent properties of thunderstorms and lightning flash energy spectra. The radar data, which have 9-15 m range gates, resolve the outer length scale of the inertial range as well as turbulence statistics. We are using these data to study the association of flash size with more and less turbulent regions.

Our work with lightning and kinetic energy spectra in thunderstorms has led to interest in theoretical approaches to the study of the spectral content of the electrostatic and non-hydrostatic pressure fields, both of which are described by Poisson problems. An electrified cloud model may be used to study the spectral content of these fields, though to the author's knowledge analytic tools are lacking which might be used to guide the study of the observed multi-scale coupling of the electrostatics and kinematics.

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Thursday, 25 May 2017, 3:30 PM
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