Correspondence, or lack thereof, between microphysical and electrical boundaries in thunderstorms

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INTRODUCTION

A commonly accepted paradigm is that the dominant mechanism separating electric charge in convective clouds is the non-inductive separation that occurs when ice particles collide and separate. If the separating particles are different in size, one will sediment relative to the other. If small particles on average end up with charge of one sign, and large particles with the opposite, net charge separation will occur over time in the storm. The sign of charge retained by the smaller and larger separating particles varies with cloud liquid water concentration, temperature, cloud water trace solutes, and perhaps other parameters. Another mechanism that is hypothesized to lead to charge separation is melting of aggregates. Tiny fragments released from the outer branches on average carry charge of one sign and remain near the melting level, while the main body of the aggregate carries the other charge as it falls further.

If charge separates in this way, one would expect to find microphysical differences between regions of cloud with net charge of one sign compared to regions of cloud with net charge of the opposite sign. For instance, lower concentrations of predominantly larger particles in regions dominated by charge of one sign and higher concentrations of predominantly smaller particles in regions dominated by the opposite sign.

Here are two examples of airborne electric field measurements. In the first, the instrumented aircraft finds itself alternately above and below a thin undulating layer of positive charge near the melting level. Microphysical properties in the cloud are uniform across the horizontal sheet of positive charge. In the second, the instrumented aircraft crosses the path of a long looping horizontal lightning discharge. The lightning propagates along an apparent gradient in microphysical properties that can be discerned with a combination of airborne in situ and polarimetric meteorological radar observations.

Unfortunately, reliable particle size and charge observations are not available for either of these cases.

An instrument capable of imaging, and determining charge, for the same hydrometeor is needed for further progress in microphysical-electrical studies.

A long looping horizontal discharge through lower downshear anvil region of a Kansas supercell, at -10°C level appears to move along a microphysical gradient between predominantly graupel and predominantly aggregates.

These plots, and other data, suggest this lightning discharge propagated along a microphysical boundary between a region of positively-charged graupel forming around the updraft in the main storm and falling out to the east, and flanking cells to the north and south containing little precipitation or charge, and a region of snow/aggregates to the west.

References:

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