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Pre-thunderstorm Electrification Measured at the Surface

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The first cloud to ground lightning strike of a thunderstorm can often be the most hazardous, but is typically the most difficult to predict. Lightning detection networks by their nature require the presence of strikes to provide warnings, and lightning forecast models poorly represent thunderstorms physically and overestimate the spread and intensity of lightning strikes. There is therefore a need for better understanding of the electrical processes present in clouds before the first lightning strike occurs to improve prediction capabilities. Here, a novel combination of instruments is used to develop an understanding of how pre-thunderstorm cumuliform clouds develop both electrically and convectively.

One years' worth of measurements from an electric field mill and electrostatic thunderstorm detector (BTD) manufactured by Biral were compared with measurements from a 35 GHz Copernicus dopplerised vertical radar, all situated at Chilbolton Observatory, UK. A superimposed epoch analysis of the potential gradient (PG) during charged rain and corona events measured by the BTD showed a strong correlation between both electrostatic instruments. Charged rain and corona perturbed the PG on average by 1.5 and -5.5 kV/m respectively. This suggests that the presence of charged rain and corona can be used as early warning indicators of cloud electrification preceding lightning.

To investigate the electrification of clouds prior to lightning, a charged cloud classification was developed to evaluate common charging methods between clouds, depending on radar reflectivity the PG range and the presence of charged rain or corona. Each of the 187 clouds were classified into one of three categories depending on the extent of cloud electrification, and several physical parameters that are key to thunderstorm electrification theories studied. These include the presence of both ice and supercooled liquid droplets and for turbulence to exist within the ice phase of the cloud. For the 104 moderately charged clouds (PG >75 V/m and no charged rain or corona present) all clouds contained an ice phase, with 65 and 84 % of stratiform and cumuliform clouds, respectively, also containing supercooled droplets. This suggests that the dominant electrification process in pre-thunderstorm clouds occur within the ice phase of the cloud. The presence of supercooled droplets can enhance the charge separation by maintaining a sufficient relative humidity for diffusion or riming to occur. The relationship between maximum cloud reflectivity and PG range was also analysed to investigate the influence of the size and number density of hydrometeors on charging processes. A significant positive relationship between the two was found suggesting that successful convective development coincides with sustained charge separation. Understanding the electrical conditions of pre-thunderstorms is paramount to predicting the probability of lightning occurrence; this probability can be used to improve lightning forecast models using data assimilation.