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A laboratory study of charging processes in electrified clouds

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Lightning is a consequence of electrical charging processes within clouds leading to the development of regions within the cloud carrying net charge of opposite polarity. The conventional thunderstorm dipole typically is associated with regions of negative charge between the -10 and -20 C levels with an upper positive region at lower temperatures. A region of positive charge at lower altitude has also been identified. Electric field changes measured at the ground show that the negatively charged region remains at fairly constant altitude and is the source of negative lightning strokes, while the upper positive region moves up with the updraught. Lightning takes place between the charge layers or to ground and usually brings negative charge to ground. Field studies with radar, and aircraft penetrations of developing thunderstorms, have shown that the development of the electric field within the cloud is associated with the presence of ice particles growing by the accretion of supercooled water droplets to form small riming graupel pellets. Theories of charging have involved the convection of regions of charge into and around the cloud to become trapped on cloud particles, or the collision and separations of cloud particles in the pre-existing electric field to strengthen the field. These convective and inductive theories have not been shown to be able to account for the first lightning stroke in the time available for field growth.

In UMIST, Manchester, many experiments have been performed to study the non-inductive charging process in which ice crystals rebound from riming graupel pellets and separate electric charge during the brief contact period. The results show that substantial charge is transferred and that the sign of the charge transfer is dependent on many variables controlled by the microphysics of the cloud itself. In particular it has been found that graupel can charge negatively and will then fall to form the negative charge region while the ice crystals carry the equal and opposite positive charge to the upper regions of the cloud in the updraught. This gravitational separation process has been shown in numerical models to account for the observed growth rate of the electric field. A particular result of the laboratory studies, that reversed charge transfer can occur under certain

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cloud conditions, can be used to account for the observation of the lower positive region. Ongoing studies are identifying the driving forces of the charge transfer and a particular mechanism of charge transfer involving the growth rates of the interacting particles has been identified as being a likely candidate for the development of storm electrification.