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Importance of realistic ice crystal radii for charge generation according to the Relative Diffusional Growth Rate theory

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Collisional charge transfer between graupel and ice crystals in the presence of liquid water droplets is considered the dominant mechanism for charge generation in thunderclouds. The physical process of charge transfer and the sign of net charge generated on graupel and ice crystals under different cloud conditions are not yet understood. The Relative Diffusional Growth Rate (RDGR) theory suggests that the particle with the faster diffusional radius growth is charged positively. In this work, we calculate signs of charge according to the RDGR theory based on realistic parameter combinations that are generated by simulations of idealized thunderclouds with warm and cold two-moment cloud microphysics. Our analysis identifies the ice crystal radius as the most important parameter for the RDGR sign-of-charge calculations. In the simulated cloud, the average ice crystal size varies with altitude due to ice multiplication and the heterogeneous freezing of droplets and thus is correlated with temperature and liquid water content. As a consequence, missing or unrealistic variability of crystal radius with cloud temperature and effective water content in laboratory studies may limit the applicability of experimental results to thunderstorms. Due to the strong crystal-size sensitivity of the RDGR theory, we furthermore observe that the diffusional growth from the riming-related local vapor field as a key component of the RDGR theory is less important than variations of crystal size. Cloud microphysical processes and ice crystal radii vary with the abundance of ice-forming aerosol. Based on simulated profiles of crystal radii for different concentrations of ice-forming aerosol, we study aerosol effects on charge generation and discuss possible implications of cloud microphysics and aerosols for the charge structure in thunderclouds.