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Analysis of the Signatures Related to the Upper Charge Regions in an Isolated Thunderstorm Observed by Dual-Polarized Phased Array Weather Radar

Shuo Wang
Osaka University, Graduate School of Engineering, Suita, Japan (wang@se.eei.eng.osaka-u.ac.jp)

The evolution of charge structure plays a crucial role in thunderstorm electrification. In this paper, the signatures related to the upper charge regions consisting of charged ice crystals are analyzed in an isolated thunderstorm, observed by an X-band dual-polarized phased array weather radar (DP-PAWR), which operates in its normal operational mode which performs a volume scan with 110 elevations at a temporal resolution of 30 seconds. The radar data quality control is applied to polarized parameters of DP-PAWR, including the horizontal reflectivity Z_H, differential propagation phase shift, and specific differential phase. The lightning data was obtained by a lightning detection system called LIDEN (LIghtning DEtection Network system) operated by the JMA. A flash group algorithm is employed to group lightning discharges into flash branches according to a spatial range, azimuth interval, and time criterion.

To explore the mean structure of upper charge regions in the convective part of the thunderstorms, an expanded quasi-vertical profile method is applied to examine the temporal evolution of microphysical processes of upper charge regions. The convective part in the isolated thunderstorm is defined as one separated from nearby storms by an area of composite Z_H larger than 40 dBZ at and above -10□ layer, and a criterion of correlation coefficient ρ_{HV} greater than 0.8 is used to remove poor quality radar data. Meanwhile, only the lightning flashes within the given volume are used to calculate the IC lighting flash rate and explore the signatures with the upper charge regions.

The results indicate that during the different stages from the early developing stage of isolated thunderstorms to the end of the mature stage, the upper charge regions above the -10 □ layer experienced an evolution process from initiation to development accompanied by the rise of the charge region in the updraft and the enhancement of charge concentration. In the mature stage of thunderstorm, the upper charge regions extended from the -30□ layer to the cloud top, followed by a decay process in the upper charge region at the end of the mature stage, in which the IC lightning flash rate is larger than 60 flashes/min. At the same time, the mean structure evolution of the upper charge regions exhibited a good relationship with the in-cloud lightning flash rate.