A dual-polarization radar observation of the thunderstorm dominated by positive cloud to ground lightning flash

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A thunderstorm dominated by positive lightning flashes occurred in the Kanto Plain of Japan on May 10, 2018. Although this thunderstorm was accompanied by strong cloud to ground lightning (CG) activity, it was the thunderstorm whose radar echo intensity was weak and its echo top height was low. The characteristics of this thunderstorm were analyzed from dual-polarization radar observation and lightning observation.

The data used for this study are the observation data of the dual-polarization doppler radar for airport weather (DP-DRAW) installed at the Tokyo International Airport and the lightning detection network (LIDEN) by the Japan Meteorological Agency. DP-DRAW takes 5 minutes for volume scanning with 16 elevation observations. The spec of the radar is 5.3 GHz (C-band), the beam width is 0.7 degree, the range resolution is 150 m, and the observation range is about 120 km. LIDEN mainly uses the LF band and observes the two-dimensional location of lightning flashes across Japan in real time with an error of several kilometers using the time of arrival method. Umehara et al. [2017] was developed a Hydrometeor Classification Algorithm (HCA) based on dual-polarization radar observation. In this method, the observed polarization parameters are classified into 17 types of hydrometers.

The lifetime of the target thunderstorm was about 3 hours. The CG was observed 90 times during the lifetime, and 51 of them were positive discharge (CG+). The intra-cloud lightning (IC) was observed 203 times. In the first half of the lifetime, lightning activity was strong, however, no strong radar echo intensity exceeding 40 dBZ was observed, and the echo top height was also around 6 km, the same as the -20 ˚C height. As a traditional lightning prediction index, it is the threshold of CG that 40 dBZ is observed at -10 ˚C height (e.g., Gremillion and Orville, 1999), but in this case it is a difficult case to predict CG because the radar echo is less than 40 dBZ. Statistically, the ratio of lightning discharge category is about 10% for CG+ flashes and about 5 times for CG and IC in spring thunderstorms in the Kanto Plain (Ishii et al. 2014). These value are equivalent to the thunderstorms worldwide. In this study, CG+ is 57% of all CG, and the ratio of CG to IC is only doubled, which are different value from typical thunderstorms.

In this study, we analyzed the categorized volume which is also used by Deierling et al., 2008, and Sakurai et al. 2015. As a result, volumes exceeding 40 dBZ hardly appear in the first half of the lifetime, and appear frequently in the second half of the lifetime at altitudes near 0 ˚C. This indicates that the traditional lightning index was inappropriate for this thunderstorm. The graupel volume by HCA appears near -10 ˚C from the first half of the lifetime, and shows the largest value at the time when lightning activity is strong. The correlation coefficient between the graupel volume of the thunderstorm and the lightning activity was 0.62. Looking at the correlation between the graupel volume and the lightning activity at each height, it showed a maximum of 0.61 at -10 ˚C height. This result is consistent with the charge separation mechanism Takahashi [1978]. The graupel volume by HCA is a better lightning indicator than the radar echo intensity volume. The correlation coefficient between the graupel volume and the lightning discharge was 0.62 for CG, 0.83 for IC, and 0.44 for CG+, respectively. Graupel volume and IC activity showed the best correlation among all. CG+ showed lower correlation than CG at any particle and at any altitude, and the characteristics of thunderclouds giving CG+ were not clear. When

time lag correlation was taken as a prediction index, most particle volumes decreased with in time, but only ice crystals volume improved with in time. The cause was not clear in this study. As it is a study of only one case, it is necessary to study more cases in the future, clarify the mechanism of lightning, and obtain a better lightning prediction index.

Keywords: thunderstorm, dual-polarization radar, positive lightning discharge