# P9.82 TIME SERIES OF MICROPHYSICAL STRUCTURE OF A THUNDERCLOUD EXAMINED WITH HYDROMETEOR CLASSIFICATION METHOD FOR X-BAND POLARIMETRIC RADAR

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## 1. Introduction

It is important to examine the time series of microphysical structure of thundercloud in order to understand the mechanisms of severe weather phenomena, such as hail-fall, tornado, lightning and heavy rain. Polarimetric radars are useful instrument to obtain microphysical information and, therefore, they have been used for hydrometeor classification (hereafter, HC) in many researches (e.g. Liu and Chandrasekar, 2000). The authors have modified HC method for S-band polarimetric radar (S-pol) described in Liu and Chandrasekar (2000) to adapt to X-band polarimetric radars (X-pols) and tried HC with X-pols of Nagoya University (Kouketsu and Uyeda, 2010).

To evaluate the HC method, thunderclouds are useful target because several kinds of hydrometeor are included and their relative locations in the cloud are closely related to the polarity of lightning. And a single thundercloud is easy to examine its internal structure for its entire life cycle. Because of these reasons, we targeted a single thundercloud of which we observed entire life cycle in this study. We conducted HC in a single thundercloud around Nagoya, central Japan area, observed with an X-pol of Nagoya University and examined time series of microphysical structure of the thundercloud.

## 2. Data

### 2.1 X-pol data

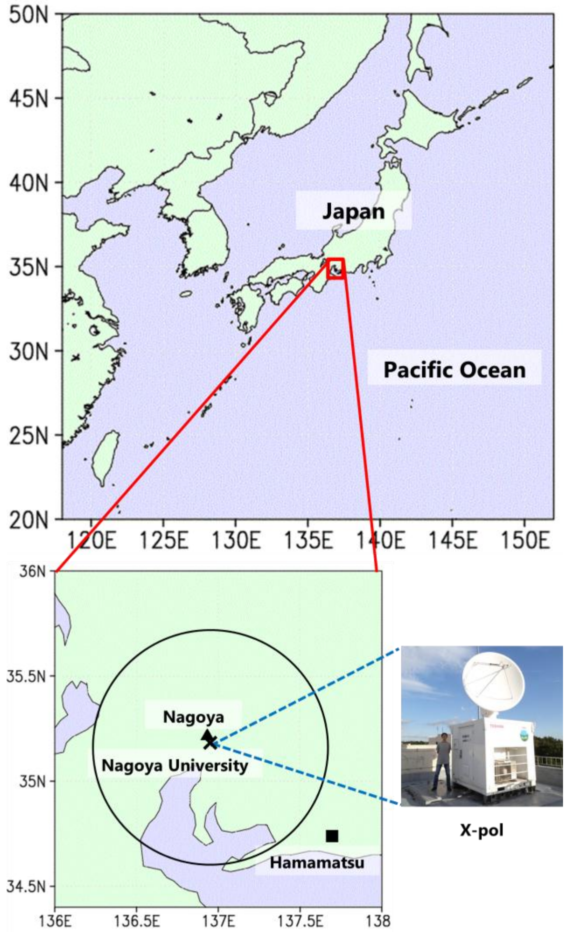


Fig. 1. The locations of the X-pol of Nagoya University (the mark of X), Nagoya local meteorological observatory (closed triangle) and Hamamatsu, the balloon sounding station (closed square). Black circle shows the range of radar analysis (60 km).

In this study, we used an X-pol of Nagoya University (Fig.1) to observe the thundercloud. The characteristics of the X-pol are shown in Table 1. The volume scan interval of the X-pol was 6 minutes with 15 elevations from 0.5° to 33.5°. When we conducted RHI scans, volume scans every 6 minutes were conducted with 12 or 13 elevations. We can obtain four polarimetric variables with the

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Table 1. Characteristics of the X-pol.

| | | |
|---|---|---|
| Frequency | | 9375 MHz |
| Antenna size | | 2.0 m |
| Beam width | | 1.2º |
| Transmitter | Type | Solid state component |
| | Peak power | 200 W |
| Max range | | 61.8 km |
| Pulse width | | 1 μs (within 5 km)<br>32 μs (beyond 5 km, pulse compression) |
| PRF | | 2000 Hz / 1600 Hz (dual PRF) |
| Transmission | | 45º or H only or V only |
| Rotation rate | | 3.0 rpm (PPI) ,<br>1.2 rpm (RHI) |
| Resolution | | 150 m |
| Nyquist velocity | | 16.0 $ms^{-1}$ / 12.8 $ms^{-1}$ |

X-pol: radar reflectivity with horizontal polarization ($Z_h$), differential reflectivity ($Z_{dr}$), specific differential phase ($K_{dp}$) and correlation coefficient of horizontally and vertically polarized signals ($\rho_{hv}$). Each variable is obtained up to 61.8 km from the X-pol with 150 m range resolution and 1.2° beam width, and interpolated into Cartesian coordinates with 0.5 km horizontal and vertical resolutions using weighting function (Cressman, 1959) .

### 2.2 Other data

As supplementary information for HC, we used temperature data of ground observation at Nagoya local meteorological observatory and balloon sounding at Hamamatsu (Fig. 1). In this study, we conducted HC in a thundercloud. The polarity of lightning is important information for HC because it suggests the presence of graupel and/or ice crystal and, therefore, it is a useful barometer of validity of HC. To obtain the information of polarity and frequency of CG from the thundercloud, we used the data of Lightning Location System (LLS) performed by Chubu Electric Power Company.

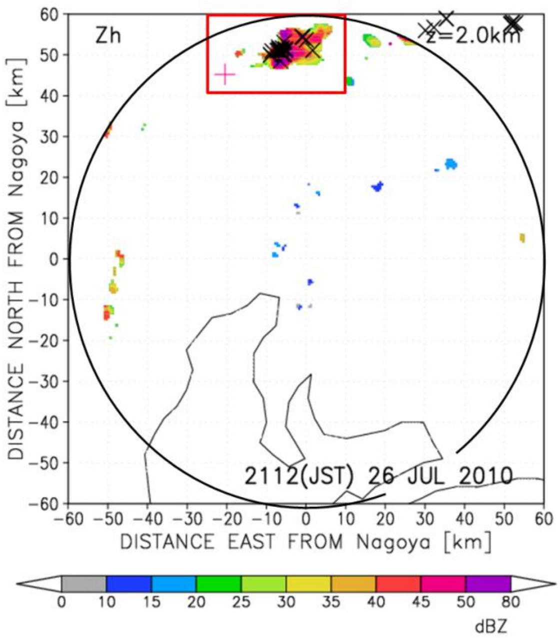


Fig. 2. The 2-km height $Z_h$ at 2112 JST on 26 July 2010. Black circle shows radar analysis range and the target thundercloud is indicated by red rectangle. The symbols of pink (+)-mark and black (x)-mark represent the locations of positive and negative CGs, respectively.

## 3. HC Method

In this study, we used HC method for X-pol described in Kouketsu and Uyeda (2010). We used four polarimetric valuables ($Z_h$, $Z_{dr}$, $K_{dp}$ and $\rho_{hv}$) and classified hydrometeor types into 10 categories: 1) drizzle, 2) rain, 3) wet snow, 4) dry snow, 5) ice crystal, 6) dry graupel, 7) wet graupel, 8) small hail, 9) large hail and 10) rain and hail. This HC method is based on that for S-pol (Liu and Chandrasekar, 2000) with some modifications. We tuned membership functions (MBFs) of $K_{dp}$ in order to adapt to X-pol because the value of $K_{dp}$ depends on wavelength (Bringi and Chandrasekar, 2001). We also made MBFs of temperature and for a part of HC categories (drizzle, rain, wet snow, dry snow, ice crystal and dry graupel), we take account for relative humidity (RH) at surface because the temperature that solid hydrometeors melt depends on RH (Matsuo and Sasyo, 1981a, 1981b).

With this method, we conducted HC for every grid point with 0.5-km horizontal and vertical resolutions, and calculated the volume of the region where the hydrometeor type was classified as

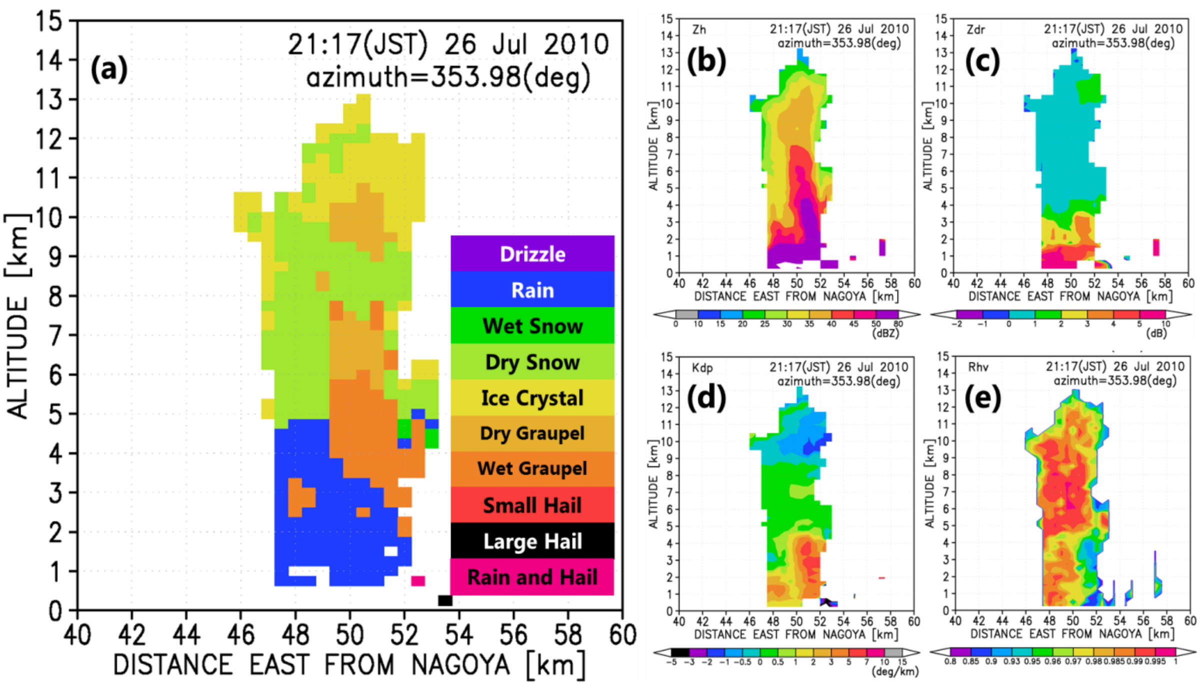


Fig. 3. Vertical profile of (a) HC result, (b) $Z_h$, (c) $Z_{dr}$, (d) $K_{dp}$ and (e) $\rho_{hv}$ obtained by RHI scan at 2117 JST on 26 July 2010.

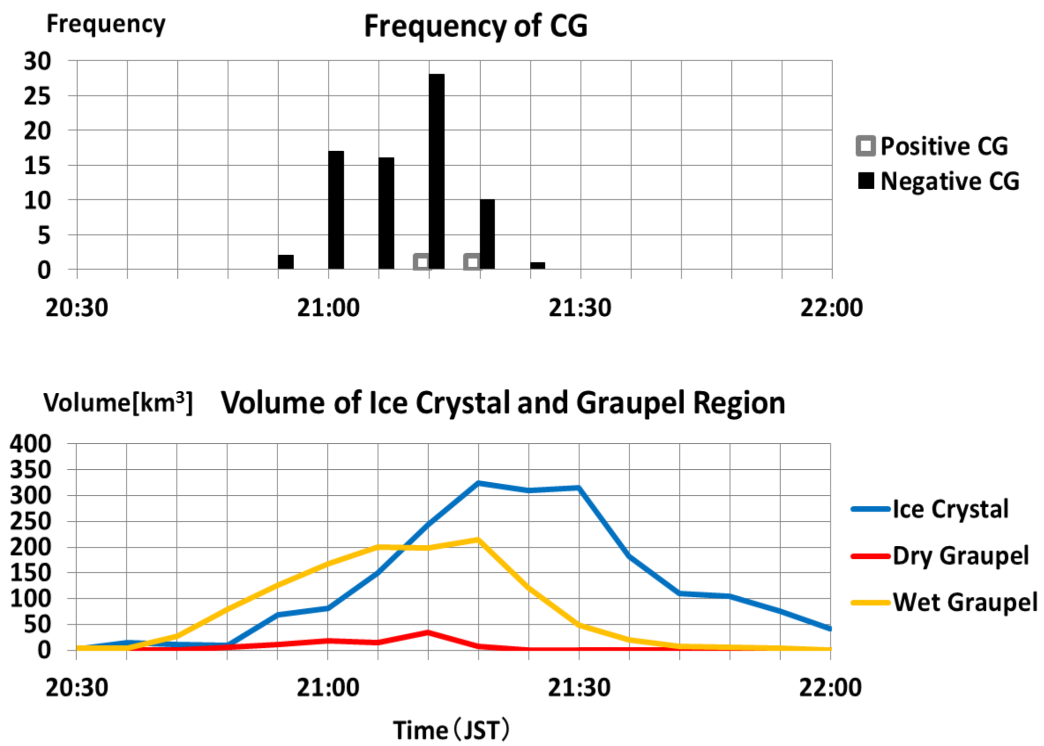


Fig. 4. The time series of frequency of positive and negative CGs (upper panel) and volume of regions where ice crystal, dry graupel or wet graupel was identified (lower panel) on 26 July 2010.

graupel (wet or dry graupel) or ice crystal by summating volumes of 0.5-km grid points.

## 4. Case Overview

Around 2030 JST (Japan Standard Time; JST = UTC + 9) on 26 July 2010, a thundercloud was

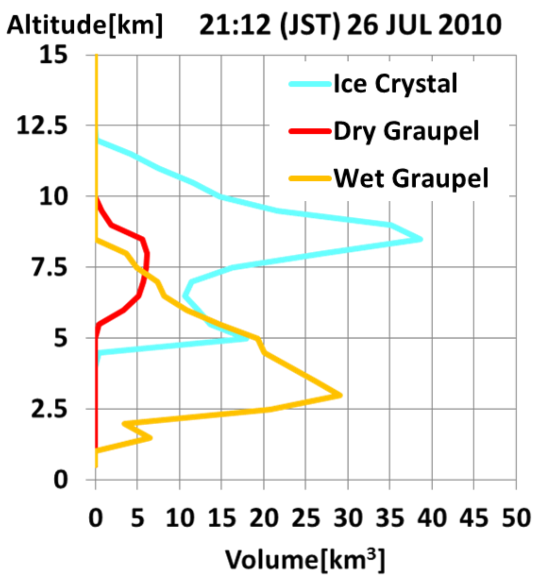


Fig.5. Vertical distribution of volume of regions where ice crystal, dry graupel or wet graupel was identified by the volume scan at 2112 JST on 26 July 2010.

generated at the point about 50 km north of Nagoya, and from 2054 JST, cloud-to-ground (CG) lightning was observed. The place where the thundercloud was generated is the north edge of the plain and wet southerly wind from the Pacific Ocean blows. According to the balloon sounding at 21 JST at Hamamatsu, the nearest balloon sounding point from the thundercloud, the air of low and middle level, up to 600 hPa height, was wet with RH exceeding 80 %, and there was cold air in the upper level. And the CAPE was very high (more than 2000 J/kg).

Around 2112 JST, the thundercloud was in mature stage and many negative CGs were observed (Fig.2). Then, the thundercloud declined gradually and the final CG was observed at 2124 JST. After that, the thundercloud dissipated by 2200 JST.

## 5. Result

The images of RHI scan of the thundercloud at 2117 JST, when the lightning activity was at its peak, are shown in Fig. 3. Both wet and dry graupels are identified corresponding to the region where the $Z_h$ value is high (≥ 40 dBZ for wet graupel and ≥ 35 dBZ for dry graupel).

Then, we examined the time series of microphysical structure of the thunder cloud by calculating volume of region where the hydrometeor type was classified as graupel (wet or dry graupel) or ice crystal. When the thundercloud was generated, there were a few cubic kilometers regions classified as graupel (wet and dry graupel) and ice crystal, and no CG was observed (Fig. 4). Then, graupel region increased and when the volume of wet graupel region exceeded 120 $km^3$ (2054 JST), negative CGs began to be observed. From 2100 JST to 2118 JST, the volume of wet graupel region reached the peak (about 200 $km^3$) and the frequency of negative CGs also reached the peak. From 2112 JST to 2118 JST, when the volume of ice crystal region increased rapidly and reached the peak, few positive CGs were observed. After that, the volume of wet graupel region decreased and the last (negative) CG was observed at 2124 JST, when the volume of wet graupel became below 120 $km^3$.

## 6. Discussion

As described above, negative CGs were observed only when there was large volume of wet graupel region. According to HC of RHI scan at 2117 JST, the peak of the frequency of negative CGs, the graupel region existed up to 11 km height and the temperature of the main graupel region was below -10 °C. And the vertical distribution of the volume of graupel (wet and dry graupel) and ice crystal regions (Fig. 5) shows there was main dry graupel region around the height where the temperature was -10 °C (6.5 km height). These facts are consistent with the polarity of CG expected from the riming electrification process (Takahashi,1978).

To confirm the validity of the HC method, we examined another case, a single thundercloud generated at the point about 30 km north of Nagoya around 1530 JST on 25 August 2010. From Fig 6, we can find that negative CGs were observed while the volume of graupel region exceeded 100 $km^3$. The frequency of negative CG was at its peak when the volume of wet graupel region was large (≥ 200 $km^3$). From 1612 JST to 1700 JST, when the volume of ice crystal region increased rapidly and reached i t s

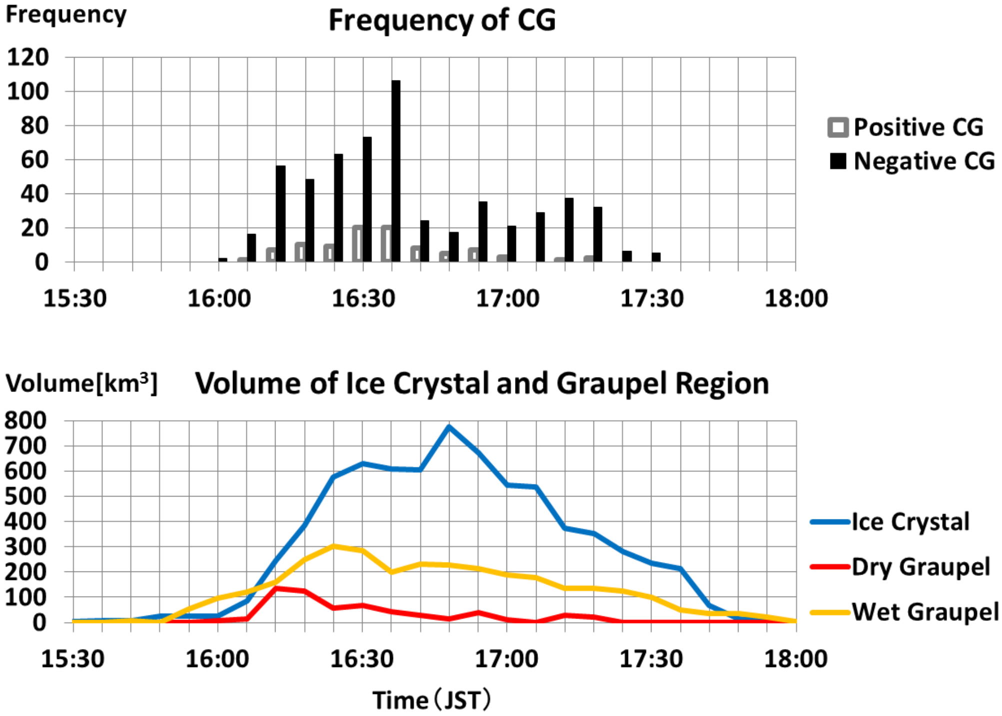


Fig. 6. Same as Fig. 4, but on 25 August 2010.

the peak, positive CGs were observed. The relation between the volume of graupel (ice crystal) regions and frequency of negative (positive) CGs is similar to that of the case on 26 July 2010. Therefore, it can be considered that our HC method for X-pol is reasonable for HC for single thundercloud.

## 7. Sammary

We conducted HC for a single thundercloud generated at the point about 50 km north of Nagoya around 2030 JST on 26 July 2010. We used the HC method tuned for X-pol and examined the microphysical structure of the thundercloud by calculating the volume of regions where graupel or ice crystal was identified from polarimetric variables.

A large volume of graupel region existed when many negative CGs were observed. At that time, there was dry graupel region around the height where the temperature was -10 °C. And the volume of ice crystal region increased rapidly or reached its peak when positive CGs were observed. This relation is consistent with the polarity of CG expected from the riming electrification process. In another case, the same relation was shown. Therefore, our HC method can be considered to be reasonable for HC of single thunderclouds.

*Acknowledgments.* This study was supported by Research Fellow of the Japan Society for the Promotion of Science. The authors are grateful to Chubu electric Power Company and Mr. Atsushi Sakakibara (Chuden CTI Co. Ltd.) for providing Lightning Location System (LLS) data. And this study was partly supported by a Grant-in-Aid for Scientific Research of the Japan Society for the Promotion of Science.

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