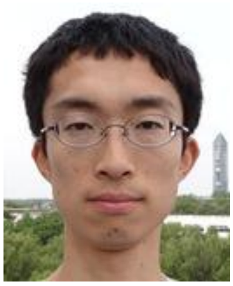
Validation of Hydrometeor Classification Method for X-band Polarimetric Radars using In Situ Observational Data of Hydrometeor Videosonde



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1. Introduction

Polarimetric radars are useful instrument to obtain microphysical information of precipitation systems and there have been many researches of hydrometeor classification (hereafter, HC) using polarimetric radars. For X-band polarimetric radars (X-pols), there have been a few researches of HC (for example, Dolan and Rutledge, 2009) but few HC methods were validated with in situ observational data. On the other hand, there have been some researches of HC method for S- or C-band polarimetric radars validated with aircraft and/or ground observational data (for example, Liu and Chandrasekar, 2000), targeting heavy solid precipitation: graupel or hail. X-pols are sensitive to weak solid precipitation with low reflectivity (snowflake and ice crystal). In moist environmental area, for example East Asia, non-hail-producing precipitations are dominant and X-pols are suitable to observation in such environmental area. Therefore, development and validation of HC method for X-pols in East Asia are needed.

The authors have tried hydrometeor classification with X-band polarimetric radars (X-pols) of Nagoya University (Kouketsu and Uyeda, 2010; Kouketsu et al., 2011) to identify solid precipitation types; snowflake and graupel. In Kouketsu and Uyeda (2010), we conducted HC for snow and groupel-falling cases and successfully identified snowflake and graupel near the surface. In Kouketsu et al. (2011), we conducted HC for a thundercloud in summer and graupel region was identified around -10 °C height corresponding to negative cloud-to-ground lightning (CG). This result was consistent with the polarity of CG expected from the riming electrification process proposed by Takahashi (1978). The remaining problem is distinguishing between snowflake and ice crystal by HC and its validation using in situ observational data.

In this study, we conducted HC for stratiform precipitation systems and an anvil region, in which the existence of snowflake and ice crystal is expected, and validated our HC method using data of balloon-borne instrument:Hydrometeor Videosonde (HYVIS). We used observational data of an X-pol of Nagoya University and HYVISs for precipitations under humid environment during rainy season so-called “Baiu” period, which is caused by stationary front in pre-summer season in Japan, around Okinawa, southwest part of Japan, from May to June in 2011. We conducted HC for RHI scans in the directions of HYVISs launched from Aguni Island, Okinawa and compared the hydrometeor types identified by HC using the X-pol and those observed by HYVISs.

2. Data

We used the data of an X-pol of Nagoya University located at Aguni Island, Okinawa (Fig. 1). The characteristics of the X-pol are shown in Table 1 and they also can be found in Kouketsu and Uyeda (2010). The parameters we can obtain are radar reflectivity (Z_h), differential reflectivity (Z_{dr}), correlation coefficient between signals of horizontal and vertical polarization (ρ_{hv}) and specific differential phase (K_{dp}). We observed precipitation with the X-pol from May 23 to July 13 in 2011.

To validate our HC method, we used the data of HYVISs launched from Aguni Island during the observation with X-pol. A HYVIS can obtain images of hydrometeors from 7 μm to 2 cm in size (Murakami and Matsuo, 1990). Each HYVIS was launched with a GPS radio sonde (RS-06G by Meisei Electric Co., Ltd.) and we obtained the data of temperature at the location of the HYVIS. We launched 6 HYVISs targeting 6 precipitation events (Table 2). For each event, we conducted volume scans with 15 elevations for every 6 minutes and RHI scans in the direction to the HYVIS arbitrarily with the X-pol.

3. Method

We conducted HC for four RHI scans that radar beam passed nearby HYVISs (Table 3), using data of four polarimetric parameters obtained with the X-pol (Z_h, Z_{dr}, ρ_{hv} and K_{dp}) and temperature obtained with GPS radio sonde. After that, we compared the hydrometeor types identified with our HC method (Kouketsu and Uyeda, 2010) to those observed with HYVIS in order to validate our HC method. In this study, we identified the hydrometeor type which is visually dominant in the image of hydrometeors obtained with HYVIS as the hydrometeor type observed with HYVIS. For comparison of hydrometeor types, we conducted HC with averaged data for every range bin within horizontally oblate spheroid, which has 500 m in horizontal

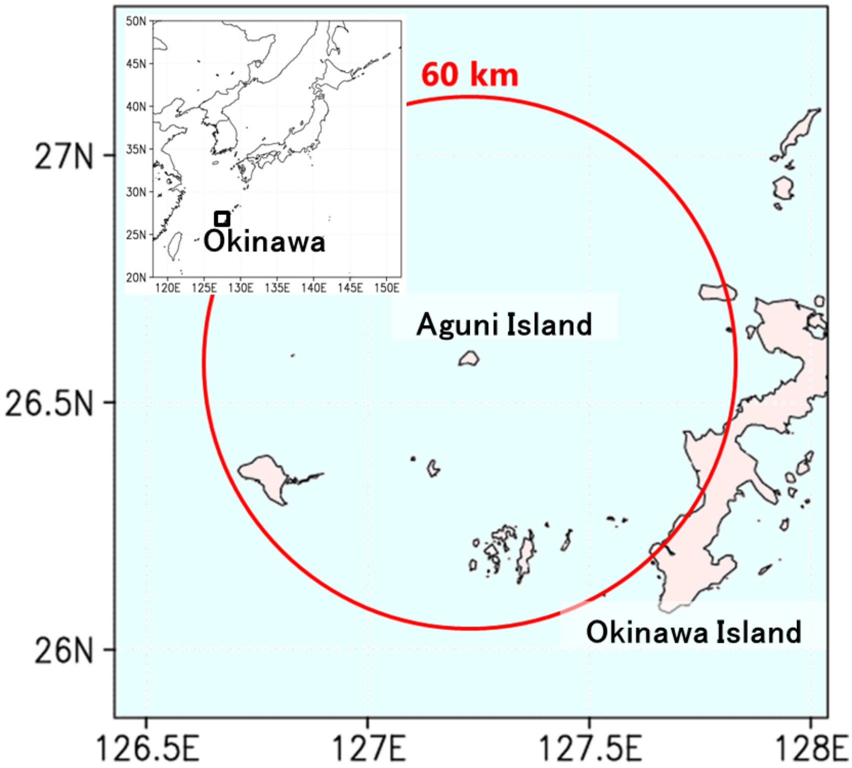

Fig. 1 Observational range of the X-pol of Nagoya University.

Table 1 Characteristics of the X-pol of Nagoya University.

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

Table 2 List of HYVISs launched from Aguni Island during the observation period.

Number	Time of launch (JST = UTC + 9hours)	Target
1	1739 May 27, 2011	Precipitation accompanied by typhoon
2	1540 June 1, 2011	**Stratiform** precipitation accompanied by Baiu front
3	2106 June 2, 2011	**Stratiform** precipitation accompanied by Baiu front
4	2025 June 13, 2011	**Convective** precipitation
5	0224 June 14, 2011	**Anvil** leeward of convective precipitation
6	1727 June 14, 2011	**Cirrus**

and 100 m in vertical radii, centered at the location of HYVIS.

4. Result and Discussion

The results of comparisons between hydrometeor types identified by HC and observed by HYVIS for four RHI scans listed in Table 3 are shown in Table 4 and the images of hydrometeors observed with HYVISs are shown in Fig. 2. The first and second RHI scans were conducted on June 1 targeting stratiform precipitation, which had obvious bright band (not shown). The third RHI scan was conducted on June 2 targeting stratiform precipitation. The fourth RHI scan was conducted on June 14 targeting anvil leeward of convective precipitation.

Table 3 List of RHI scans.

HYVIS Number	Time of RHI scan (JST)	Height of HYVIS
#2	1559 June 1, 2011	4.5 km
#2	1605 Junw1, 2011	5.8 km
#3	2135 June 2, 2011	9.4 km
#5	0247 June 14, 2011	9.4 km

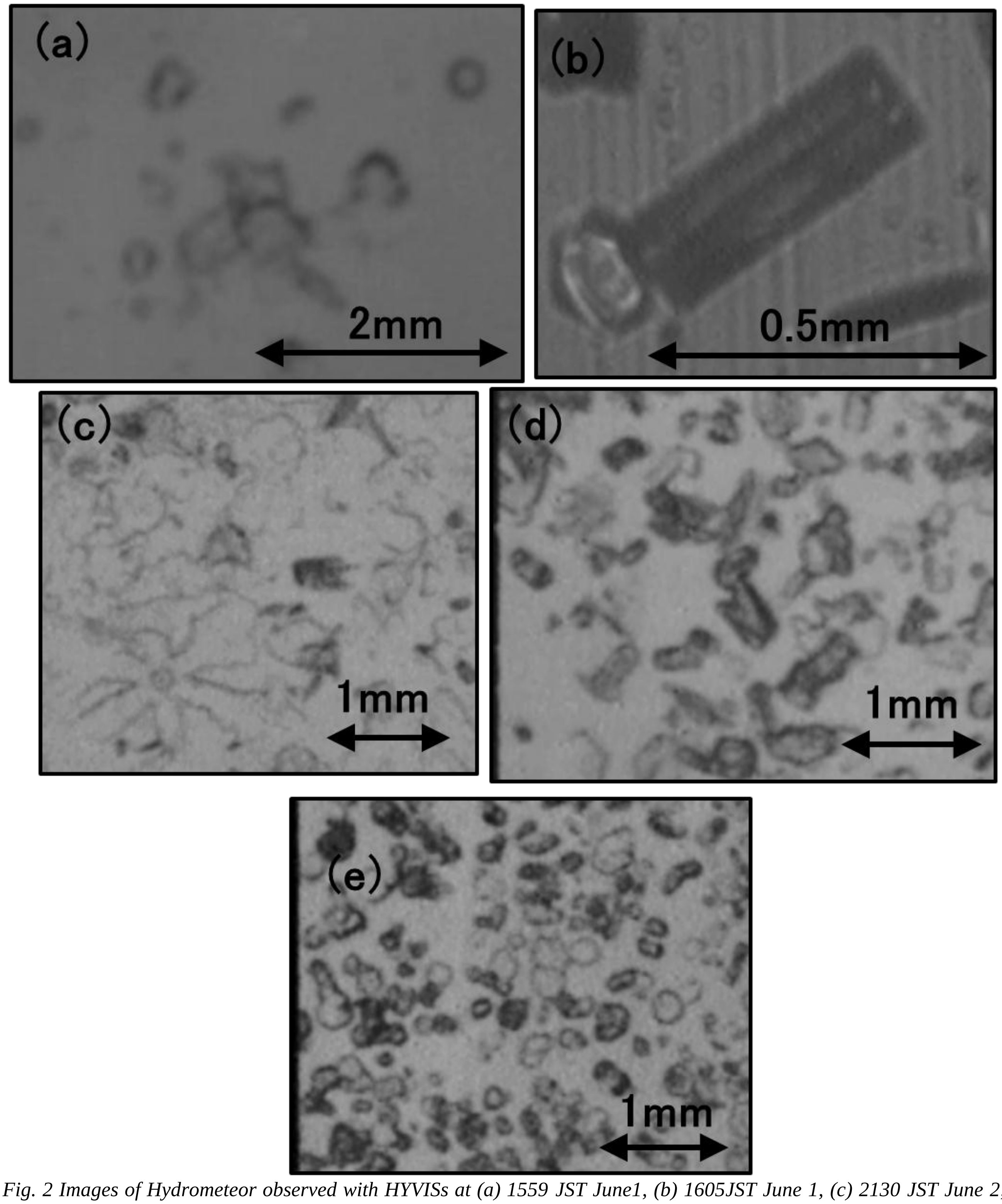

Fig. 2 Images of Hydrometeor observed with HYVISs at (a) 1559 JST June1, (b) 1605JST June 1, (c) 2130 JST June 2, (d) 2133 JST June 2 and (e) 0247 JST June 14. See Table 4 and text for additional information.

Table 4 Comparison between HC and HYVIS.

Time (JST)	height	temperature	HYVIS	HC
1559 June 1, 2011	4.5 km	-0.1 °C	Wet Snow	Wet Snow
1605 June 1, 2011	5.8 km	-5.4 °C	Ice Crystal (Column)	Dry Snow (Snowflake)
2130 June 2, 2011	7.6 km	-15.0 °C	Ice Crystal (Dendrite)	Ice Crystal
2133 June 2, 2011	8.6 km	-21.5 °C	Ice Crystal (Column)	Ice Crystal
0247 June 14, 2011	9.4 km	-25.5 °C	Ice Crystal (Column and Plate Mixture)	Ice Crystal

For the first RHI scan, HYVIS was located about 4.5 km in height and temperature was -0.1 °C and around the location of the HYVIS, clear bright band was observed with X-pol (now shown). Wet melting snowflake about 2 mm in size was observed with the HYVIS (Fig. 2a) and the result of HC was “wet snow”. Because the HYVIS was nearly at the 0°C height, the result of HC is reasonable. For the second RHI scan, the location of the HYVIS was about 5.8 km in height and temperature was -5.4 °C. Column particle was observed with the HYVIS (Fig. 2b) and “dry snow” (snowflake) was identified with HC. Because the value of Z_h around the location of the HYVIS was relatively large (~25 dBZ), it is expected that snowflake existed. Actually, snowflakes were observed with the HYVIS several hundred meters above and below the location of the HYVIS at the time of RHI. Therefore, the result of HC may reflect the existence of snowflake near the HYVIS.

For the third RHI scan, HYVIS was located almost upper edge of precipitation (about 9.4 km in height). A few minutes before the time of the RHI scan, dendritic particles (Fig. 2c, about 7.6 km in height and -15.0 °C in temperature) and column (Fig. 2d, about 8.6 km in height and -21.5 °C in temperature) about 1 to 2 mm in size were observed by the HYVIS. The results of HC at these points were “ice crystal” with below 15 dBZ in radar reflectivity. Assuming the stationarity of the precipitation system for a few minutes, the result of HC is reasonable.

For the fourth RHI scan, HYVIS was located about 9.4 km in height and temperature was -25.5 °C. Column and plate particles about a few tenths of a millimeter in size were observed with the HYVIS (Fig. 2e) and the result of HC was “ice crystal” with about 10 dBZ in radar reflectivity. Because no snowflake was observed by the HYVIS, the result of HC is reasonable.

From the results of comparisons shown above, it can be said that our HC method is reasonable for distinguishing between snowflake and ice crystal though there are some difficulties to distinguishing them with the X-pol when the radar reflectivity is relatively large for existence of ice crystal (~25 dBZ).

5. Summary

We validated our HC method by comparing the result of HC using X-pol of Nagoya University and the hydrometeor type observed with HYVIS for stratiform precipitation and anvil leeward of convective region under humid environment during rainy season so-called “Baiu” period around Okinawa from May to June in 2011. We conducted HC for four RHI scans that radar beam passed nearby HYVISs using data of four polarimetric parameters obtained with the X-pol (Z_h, Z_{dr}, ρ_{hv} and K_{dp}) and temperature obtained with GPS radio sonde attached to HYVIS..

For the stratiform precipitation on June 1 (the first and second RHI scans), wet (melting) snow was correctly identified and column particle observed with HYVIS was identified as “dry snow” (snowflake) with HC. Because the value of Z_h around the location of the HYVIS was relatively large (~25 dBZ) and indeed snowflake was observed near the location of the HYVIS at the time of RHI, the result of HC may reflect the existence of snowflake near the HYVIS. For the stratiform precipitation on June 2 (the third RHI scan), ice crystal was identified with HC. On the other hand, column and dendritic particles were observed with HYVIS a few minutes before the RHI scan. Assuming the stationarity of the precipitation system for a few minutes, the result of HC is reasonable. For the anvil on June 14 (the fourth RHI scan), ice crystal was correctly identified with HC.

From the results of comparisons, it can be said that our HC method is reasonable for distinguishing between snowflake and ice crystal though there are some difficulties to distinguishing them with the X-pol when the radar reflectivity is relatively large for existence of ice crystal (~25 dBZ).

Acknowledgment

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References

Dolan. B., and S. A. Rutledge, 2009: A Theory-Based Hydrometeor Identification Algorithm for X-Band Polarimetric Radars. *J. Atmos. Oceanic Technol.*, **26**, 2071- 2088.

Kouketsu, T. and H. Uyeda, 2010: Validation of Hydrometeor Classification Method for X-band Polarimetric Radar

Comparison with Ground Observation of Solid Hydrometeor. *Proc. Sixth European Conference on Radar in Meteorology and Hydrology (ERAD2010), Advances in Radar Technology*,Sibiu, Romania, 195- 201. [Available online at http://www.erad2010.org/pdf/POSTER/Thursday/02_Xband/09_ERAD2010_0261_Extended.pdf.]

Kouketsu, T., H. Uyead and H. Ohigashi, 2011: Time series of microphysical structure of a thundercloud examined with hydrometeor classification method for X-band polarimetric radar. *Proc.31st Conf. on Radar Meteor.* [Available online at http://ams.confex.com/ams/35Radar/webprogram/Paper191499.html.]

Liu, H. and V. Chandrasekar, 2000: Classification of Hydrometeors Based on Polarimetric Radar Measurements: Development of Fuzzy Logic and Neuro-Fuzzy Systems, and In Situ Verification. *J. Atmos. Oceanic Technol.*, **17**, 140-164.

Murakami, M., and T. Matsuo, 1990: Development of the Hydrometeor Videosonde. *J. Atmos. Oceanic Technol.*, **7**, 613-620.

Takahashi, T., 1978: Riming Electrification as a Charge Generation Mechanism in Thunderstorms. *J. Atmos. Sci.*, **35**, 1536-1548.