An introduction to the ULTIMATE project in Japan

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EGU 2021
26th Apr. 2021

An analysis was done by the NEC SX supercomputer at Center for Global Environmental Research of National Institute for Environmental Studies.

Introduction

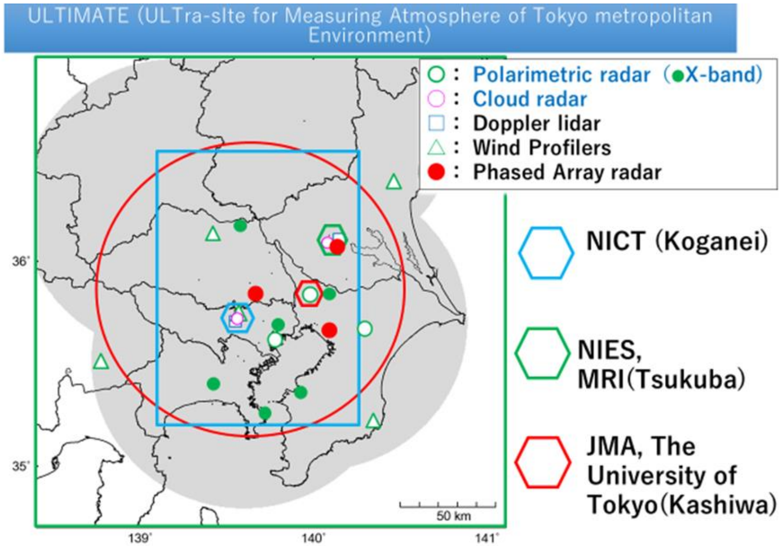
- It is important to evaluate and improve the cloud properties in global non-hydrostatic models like a Nonhydrostatic ICosahedral Atmospheric Model (NICAM, Satoh et al. 2014) using observation data. One of the methods is a radiance-based evaluation using satellite data and a satellite simulator (here Joint simulator, Hashino et al. 2013), which avoids making different settings of the microphysics between retrieval algorithms and NICAM.

- The satellite data with active sensors has a limitation to observe the specific case of cloud and precipitation systems. And it is needed to validate satellite observations using in-situ observation. There are intensive observation stations over the Kanto region.

- The ULTIMATE (ULTra sIte for Measuring Atmosphere of Tokyo metropolitan Environment) started to verify and improve high resolution numerical simulations based on these observation data this fiscal year.

- In this study, we introduce the available observation data for the ULTIMATE project.
- We introduce the evaluation results of NICAM using 94 GHz radar and 5.3 GHz polarimetric radar.

ULTIMATE (ULTra sIte for Measuring Atmosphere of Tokyo metropolitan Environment) project



We collected several observation data over Kanto area.
- The available observation data are like CPR, HSRL, wind profiler, C-band polarimetric radar, X-band phased array polarimetric radar, Ka polarimetric radar.
- We are testing and investigating the results about C-band polarimetric radar using POLArimetric Radar Retrieval and Instrument Simulator (POLARRIS, Matsui et al. 2019) in Joint simulator.

- We selected several cases for the ULTIMATE project

Evaluation and improvement of microphysics in NICAM

- 2019.09.08-09, 09.15-17, 09.19-21 for intensive observations using NICT CPR, HSRL

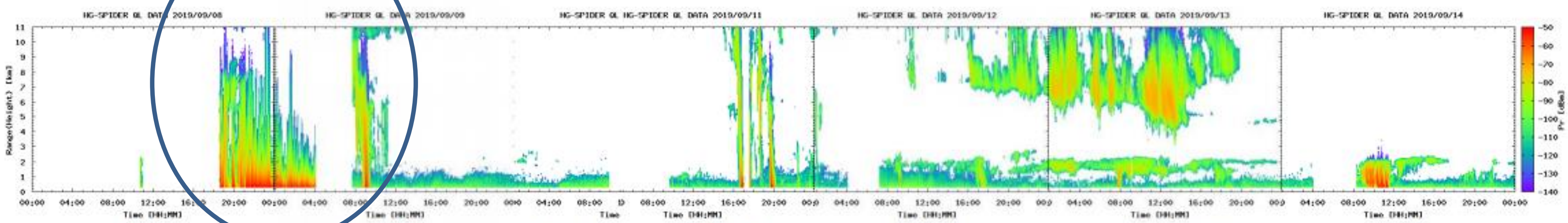
Intercomparisons and evaluations of three models (Kuba-san, Matsugishi-san)

- 2020.04.17-18 for intercomparisons among NICAM, ASUKA, SCALE

- Horizontal resolutions of the stretched NICAM using NCEP FNL data

- GL8: minimum 3.5 km (done)
- GL9: minimum 1.7 km (done)
- GL10: minimum 870 m (done)

CPR observation in Sep. 2019
(From NICT Ohno-san's slides)



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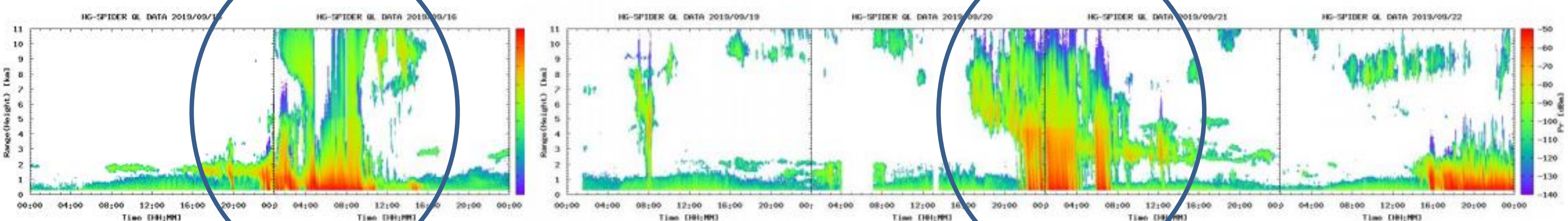

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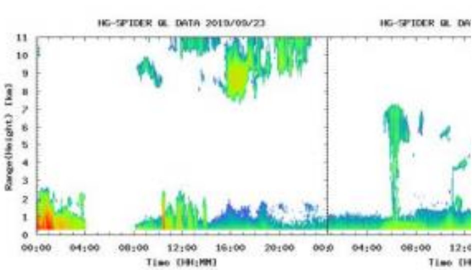

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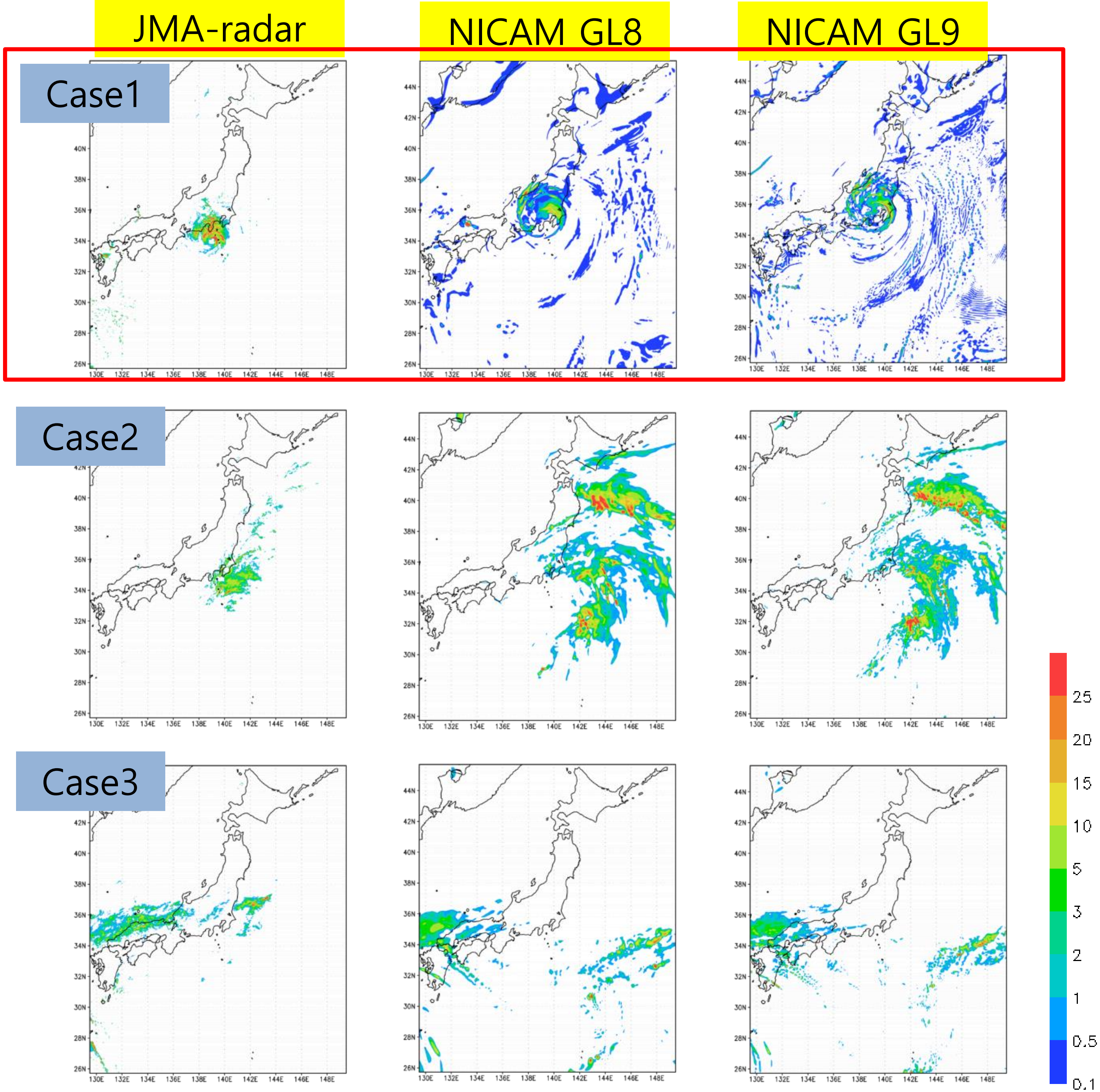
Available observation data for 2019.09 cases

- NICT 94 GHz CPR
- 5.3 GHz polarimetric radars in Narita and Haneda airport
- 9.4 GHz polarimetric phased array radar (MP-PAWR) in Saitama university
- NIED Ka/X band polarimetric radar
- NIED Skytree observation
- JMA Wind profiler data (WINDAS) in three stations like Kawaguchiko, Kumagaya, and Mito
- NICT 355 nm multiple-field-of-view multiple-scattering polarization Lidar (MFMSPL, ongoing)

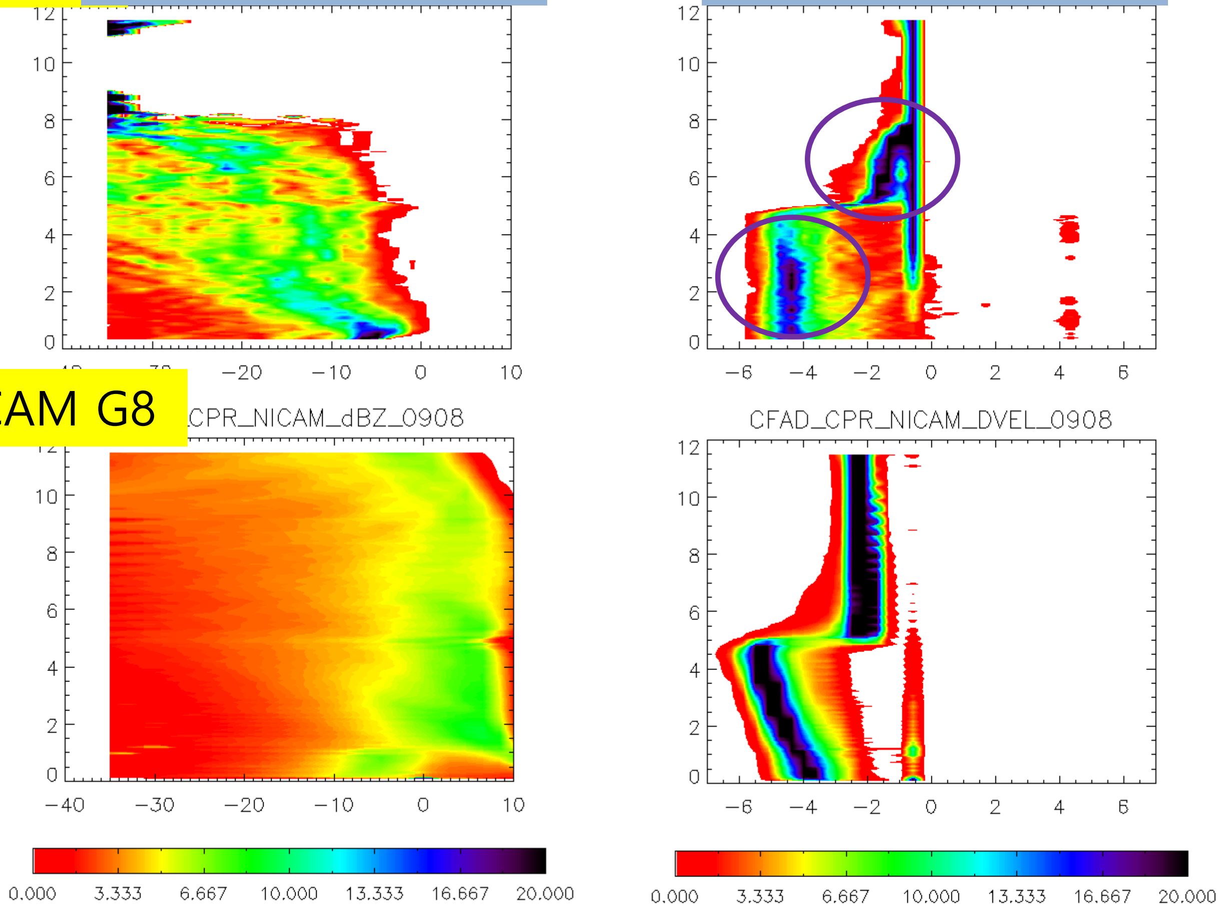
Precipitation distribution for three cases



Evaluation using NICT 94 GHz CPR

NICT | Radar Reflectivity | Doppler velocity

NICAM G8

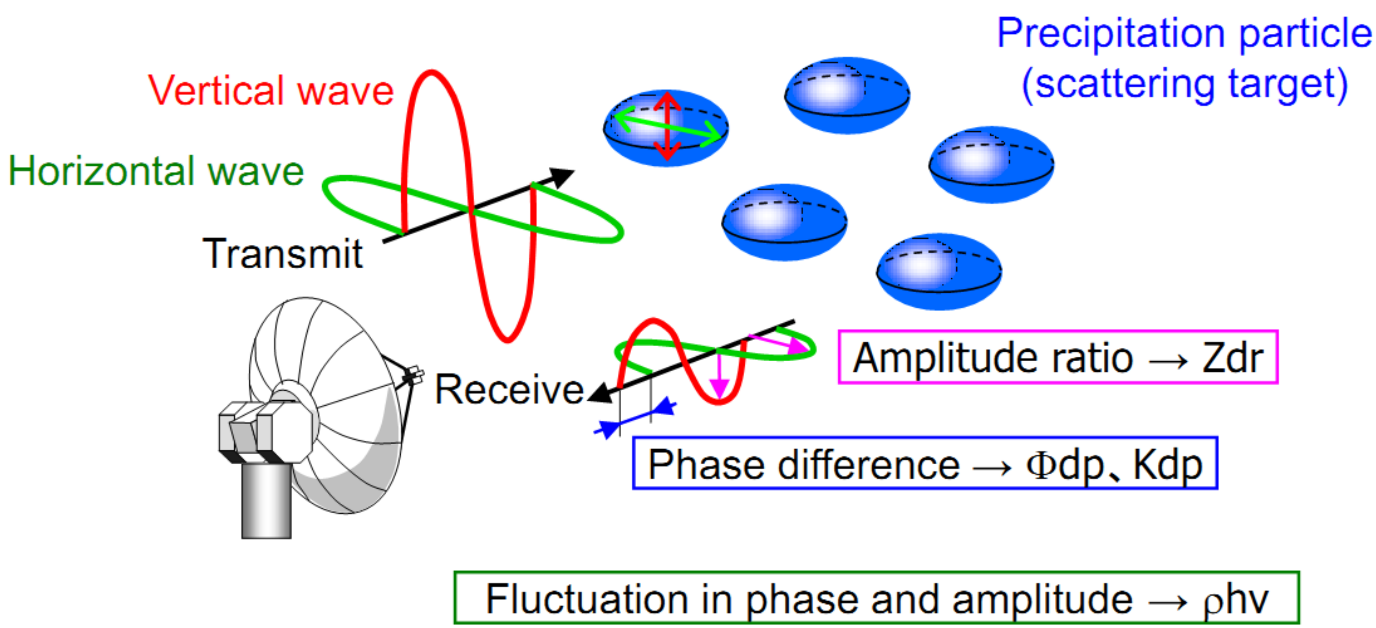


The data is provided in courtesy by NICT Ohno-san and Horie-san.

- Underestimation of radar reflectivity because of attenuation of CPR observation
- NICAM Doppler velocity shows the similar patten of observation for rain and ice hydrometeors.
- We will improve the riming process from 5 km to 8 km altitude.

Polarimetric radar?

- A radar capable of measuring any or all of the polarization-dependent attributes of a target or backscattering medium. (from AMS dictionary)

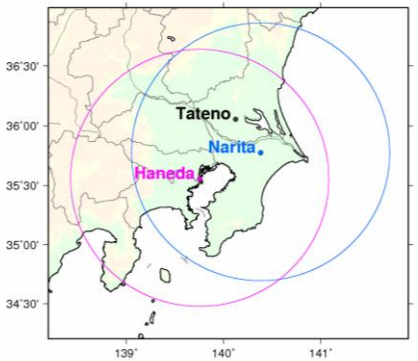


Yamauchi 2018

1. Size (Z_h)
2. Shape (Z_{DR} Differential reflectivity, K_{dp} Specific differential phase shift)
3. Variety (ρ_{hv} Co-polar cross-correlation coefficient)
4. Doppler velocity

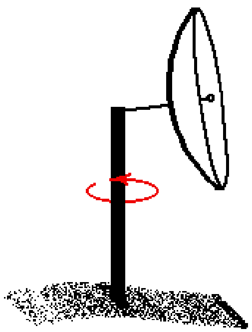
5.3 GHz Doppler Radar for Airport Weather

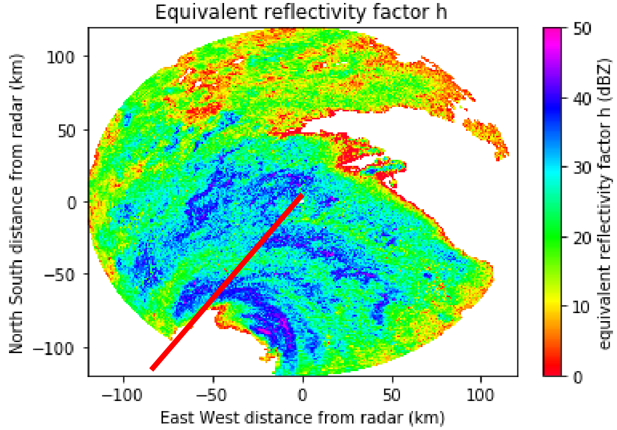
(DRAW, Uehara et al. 2020)

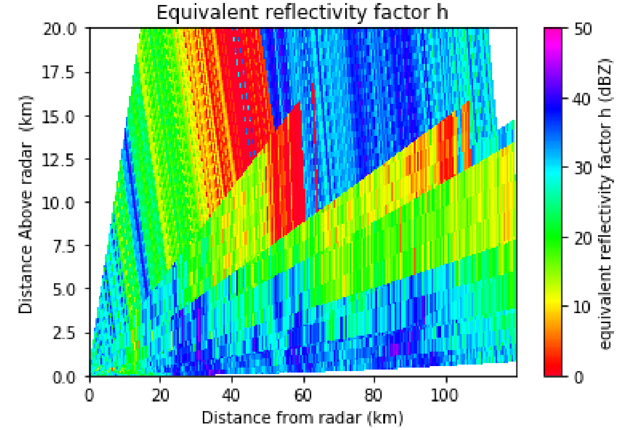


Frequency: 5.3 GHz
Time resolution: 5 min.
The range: 800 (120 km)
The resolution of range: 150 m
Angles: 11 (0 to 17 degree)

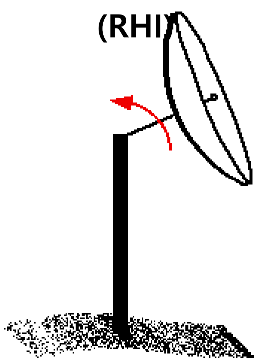
Plan Position Indicator (PPI)

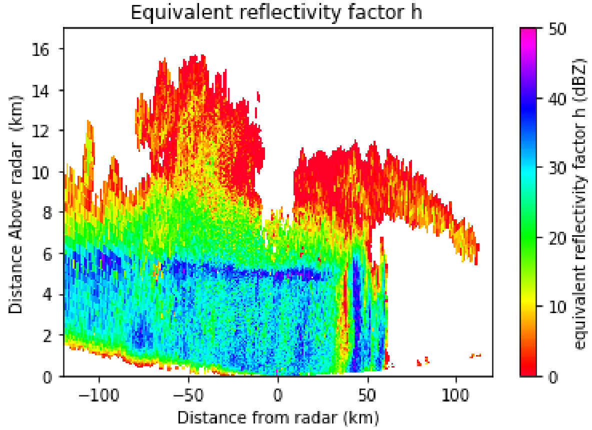






Range Height Indicator (RHI)





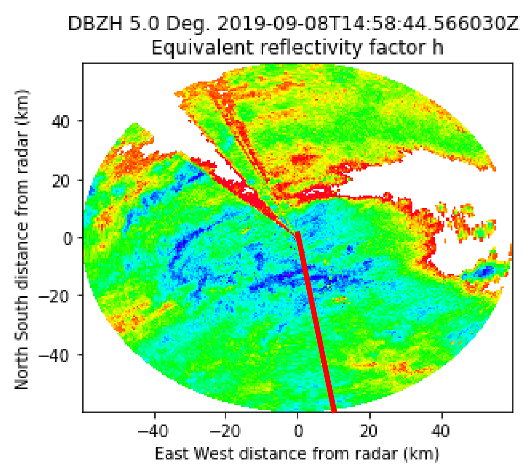
PPI mode has course vertical resolution for the upper cloud and precipitation.
RHI mode has the single angle data like 239.8 degree.

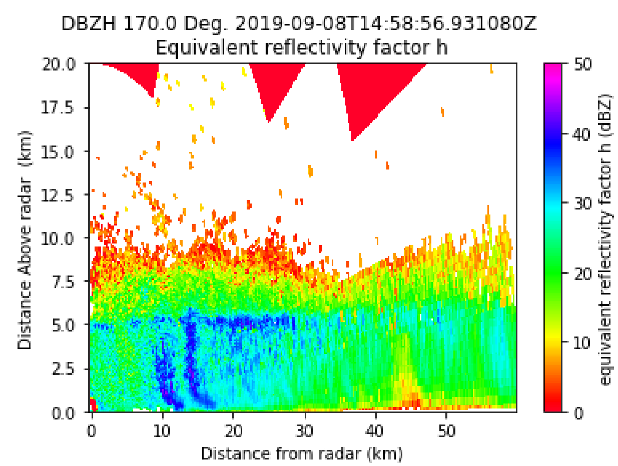
Multi-Parameter Phased Array Weather Radar (MP-PAWR, Takahashi et al 2019)

Fig. 4. MP-PAWR antenna (left) and the radome of MP-PAWR installed at Saitama University (right).

Spec.	XRAIN	MP-PAWR	
		XRAIN mode	Research mode
Obs. range	range：80km azimuth：360° elevation：0-30°(12 elev. angles, 90°for calibration)	range：80km azimuth：360° elevation：-2-60°(90°for calibration)	range：60km azimuth：360° elevation：0-90°
Temporal resolution	surface PPI：1 min. 3D：5 min.	3D: 1 min.	3D: 30 sec.
range resolution	150m	150m	
Beam width	H：<1.2° V：<1.2°	H：<1.2° V：<1.2°	
Products	Pr (H): power, Pr (V): power, V : Doppler, W: width of Doppler φDP: Phase difference between H and V pol. ρHV : Correlation coefficient between H and V pol.		
Radome	φ< 4.5m	φ< 4.5m	

Frequency: 9.4 GHz
Time resolution: 30 sec.
The range: 800 (60 km)
The resolution of range: 75 m
The sector: 301
Angles: 114 (0 to 90 degree)



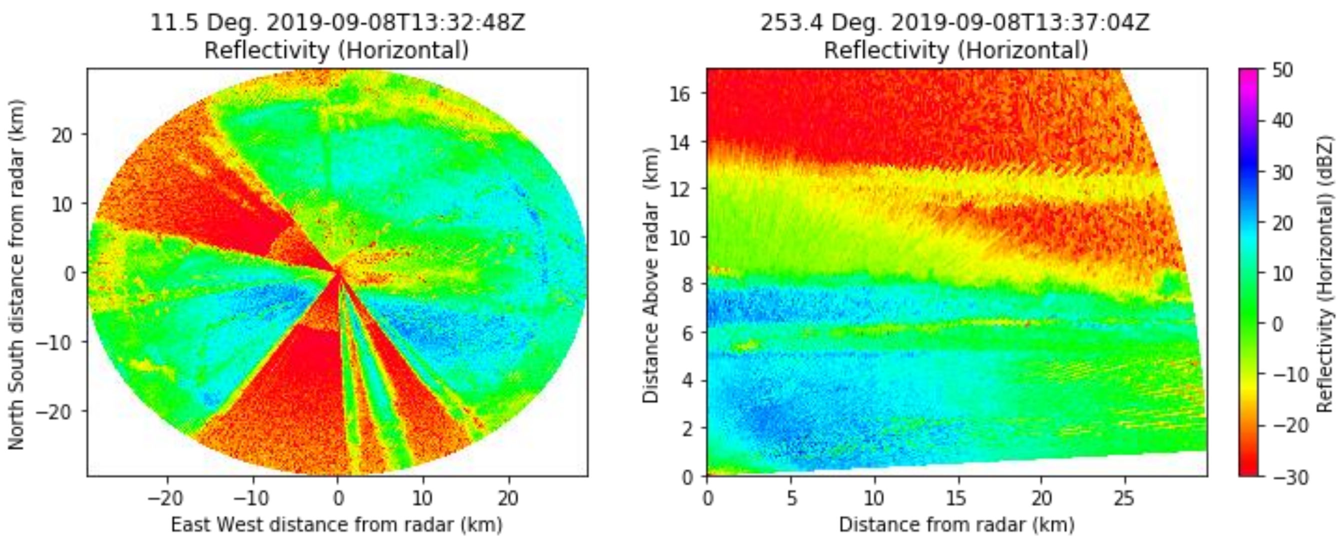


The data is provided in courtesy by NICT Satoh-san.

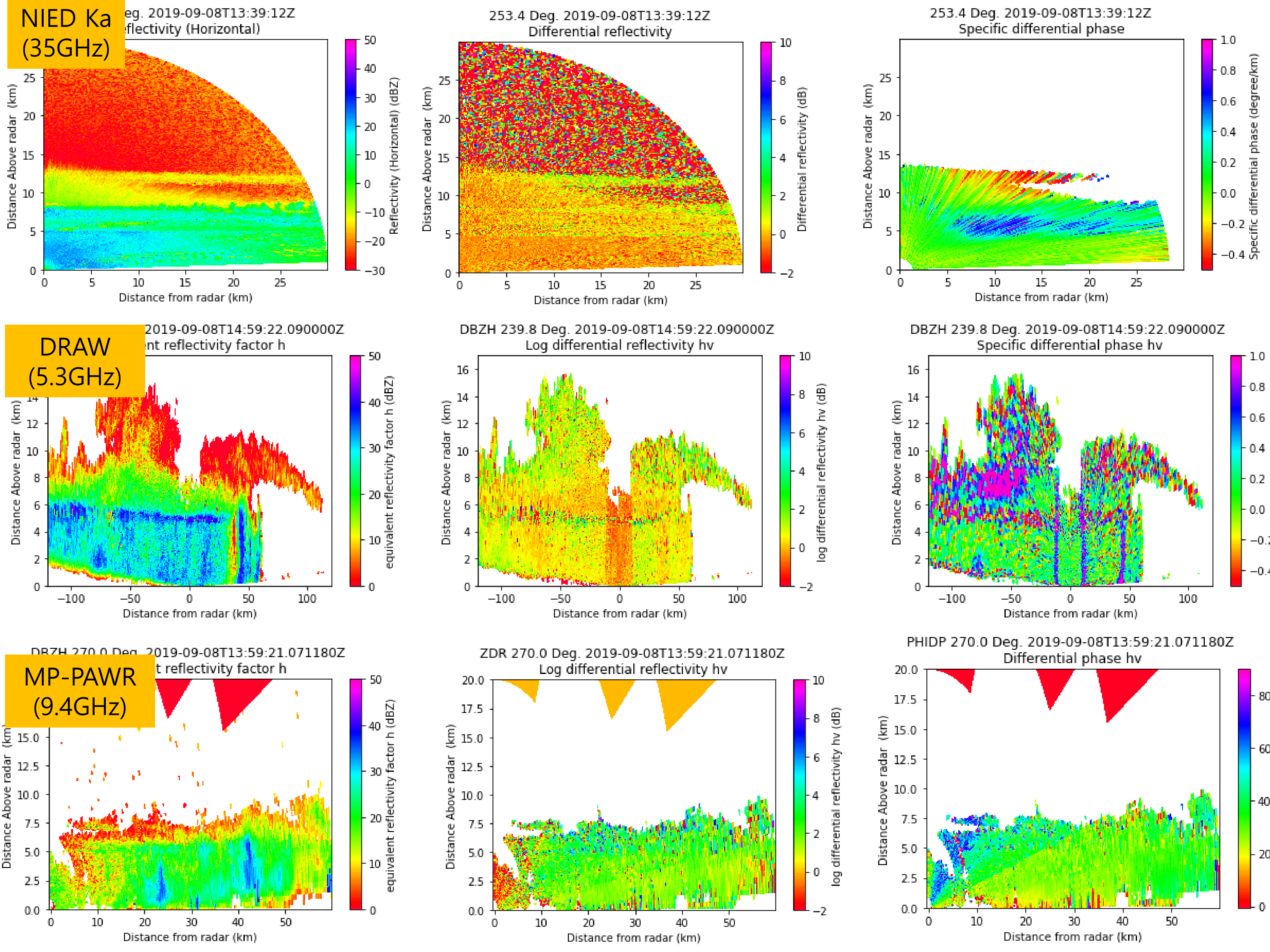
NIED Ka-band polarimetric radar

- The frequency of radar: 35 ~ 36 GHz, nonprecipitating clouds
- The number of radar observation stations: 5
- Polarimetric radar: Tsukuba(PPI+RHI), Oota, Hanno
- Radar: Nishi-Tokyo, Matsudo
- the range of radar: 30km
- the resolution of range: 150m
- Every 3 minutes
- The resolution of the azimuthal direction: 0.35 degree
- The number of elevation angles of PPI: 6

2 RHI (AZ: 253.4 up, 253.4 down), 2 sector PPI (EL: 5.2 8), and 4 PPI (EL: 11.5 15.7 20.8 27.2)



The data is provided in courtesy by NIED Misumi-san and Ohigashi-san.


NIED Ka (35GHz)
DRAW (5.3GHz)
MP-PAWR (9.4GHz)
253.4 Deg. 2019-09-08T13:39:12Z
Differential reflectivity
253.4 Deg. 2019-09-08T13:39:12Z
Specific differential phase
DBZH 239.8 Deg. 2019-09-08T14:59:22.090000Z
Log differential reflectivity hv
DBZH 239.8 Deg. 2019-09-08T14:59:22.090000Z
Specific differential phase hv
ZDR 270.0 Deg. 2019-09-08T13:59:21.071180Z
Log differential reflectivity hv
PHIDP 270.0 Deg. 2019-09-08T13:59:21.071180Z
Differential phase hv
Distance from radar (km)
Distance Above radar (km)
Reflectivity (Horizontal) (dBZ)
Differential reflectivity (dB)
Specific differential phase (degree/km)
equivalent reflectivity factor h (dBZ)
log differential reflectivity hv (dB)

POLARRIS
(POLArimetric Radar Retrieval and Instrument Simulator)

Matsui et al. (2019), JGR

POLARRIS-f (in courtesy by Hashino-san)

- T-matrix and Mueller-matrix modules added to GSDSU
  - ☀T-matrix calculates single-scattering of axis-symmetric oblate hydrometeors
  - ☀Muller matrix take into account the change of intensity and polarization after scattering.
- calculate Z_h Z_{dr} K_{dp} ρ_{hv} V_{rad}
- currently does not take into account attenuation (Consideration of MRI Ikuta-san's simulator)

iPOLARRIS, CSU-radar tools

- fuzzy-logic HID (hydrometeor identification)
- requires temperature, polarimetric data, and radar wavelength
- drizzle, rain, ice crystals, dry snow, wet snow, vertical ice, low-density graupel, high-density graupel, hail, and big drops.
- written in python2

From Hashino-san's ppt

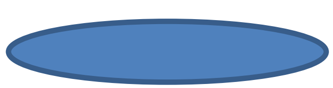
Handling about microphysics in POLARRIS

Table 1
Differing Assumptions Used for Particle Axis Ratio and Orientation Angle Distributions From Ryzhkov et al. (2011, RY11), Putnam et al. (2017, PU17), and This Study (MA18)

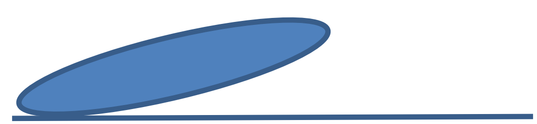
	RY11	PU17	MA18
Liquid (cloud and rain)	$A_{xis} = 0.9951 + 0.0251{*}D{-}0.03644{*}D^2 + 0.005303{*}D^3{-}0.0002492{*}D^4$ (Brandes et al., 2011) Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 1°$)		
Ice (column)	$A_{xis} = 2.0$ Type: random		
Ice (plate)	$A_{xis} = 0.35$ Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 10°$)		
Ice (dendrite)	$A_{xis} = 0.125$ Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 10°$)		
Snow aggregate	$A_{xis} = 0.8$ Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 40°$)	$A_{xis} = 0.75$ Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 20°$)	$A_{xis} = 0.7{-}0.05D + 0.003D^2$ Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 20°$)
Graupel	$A_{xis} = \max(0.8, 1.{-}0.2{*}D)$ Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 40°$)	$A_{xis} = 0.75$ Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 10°$)	$A_{xis} = 0.814$ Type: quasi-Gaussian ($\Theta_{mean} = 20°$, $\sigma = 42°$)
Hail	A_{xis} $\max(0.8, 1.{-}0.2{*}D)$ Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 40°$)	$A_{xis} = 0.75$ Type: quasi-Gaussian ($\Theta_{mean} = 0°$, $\sigma = 10°$)	$A_{xis} = \max(0.725, 0.897{-}0.0008D - 0.0002D^2)$ Type: quasi-Gaussian ($\Theta_{mean} = 90°$, $\sigma = 40°$)

Matsui et al. (2019), JGR

1. Aspect ratio



2. Distribution of orientations

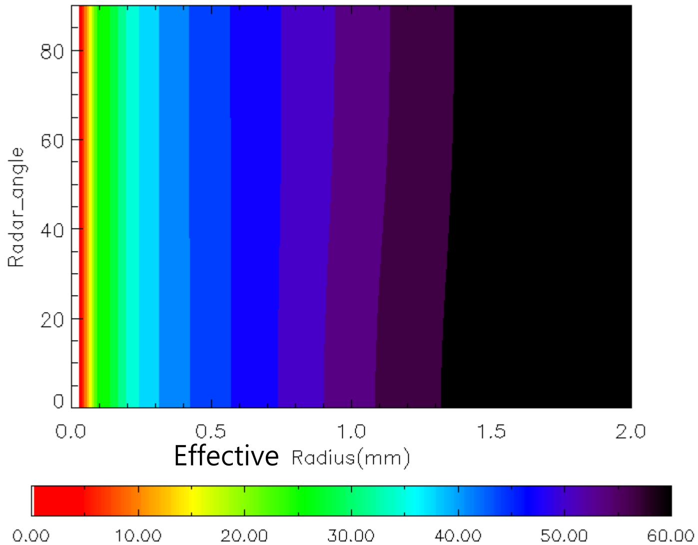


3. Radar angle

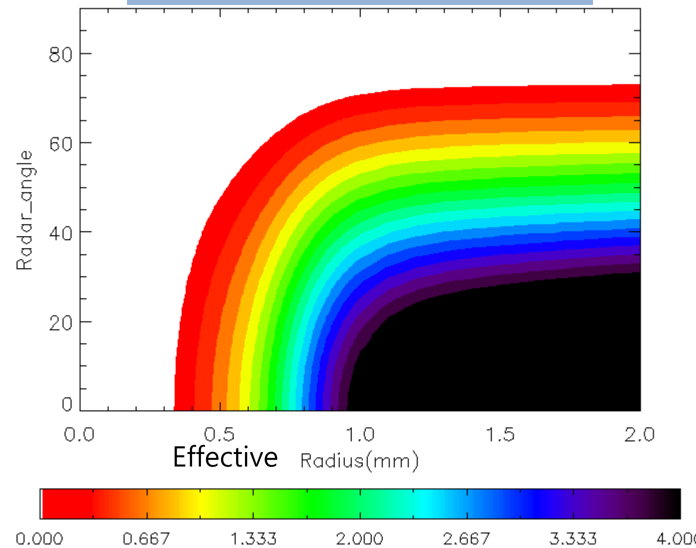
Examples of Lookup tables of POLARRIS for rain

300K, 1g/m^3

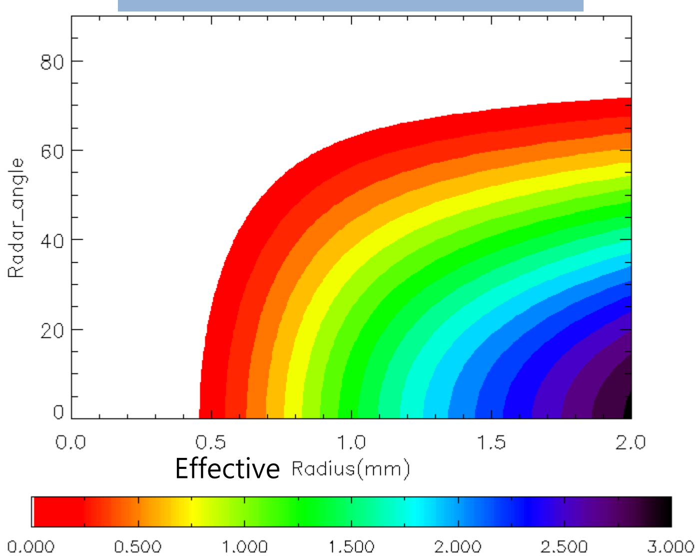
dBZ

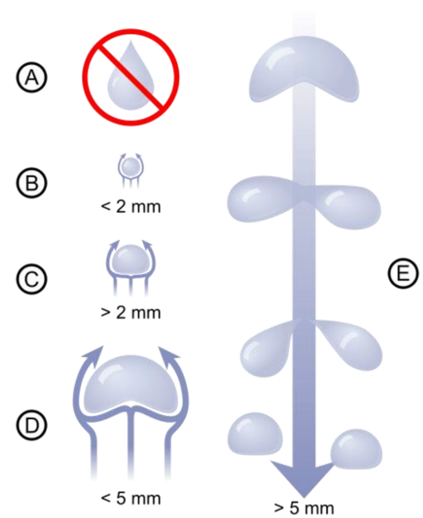


ZDR



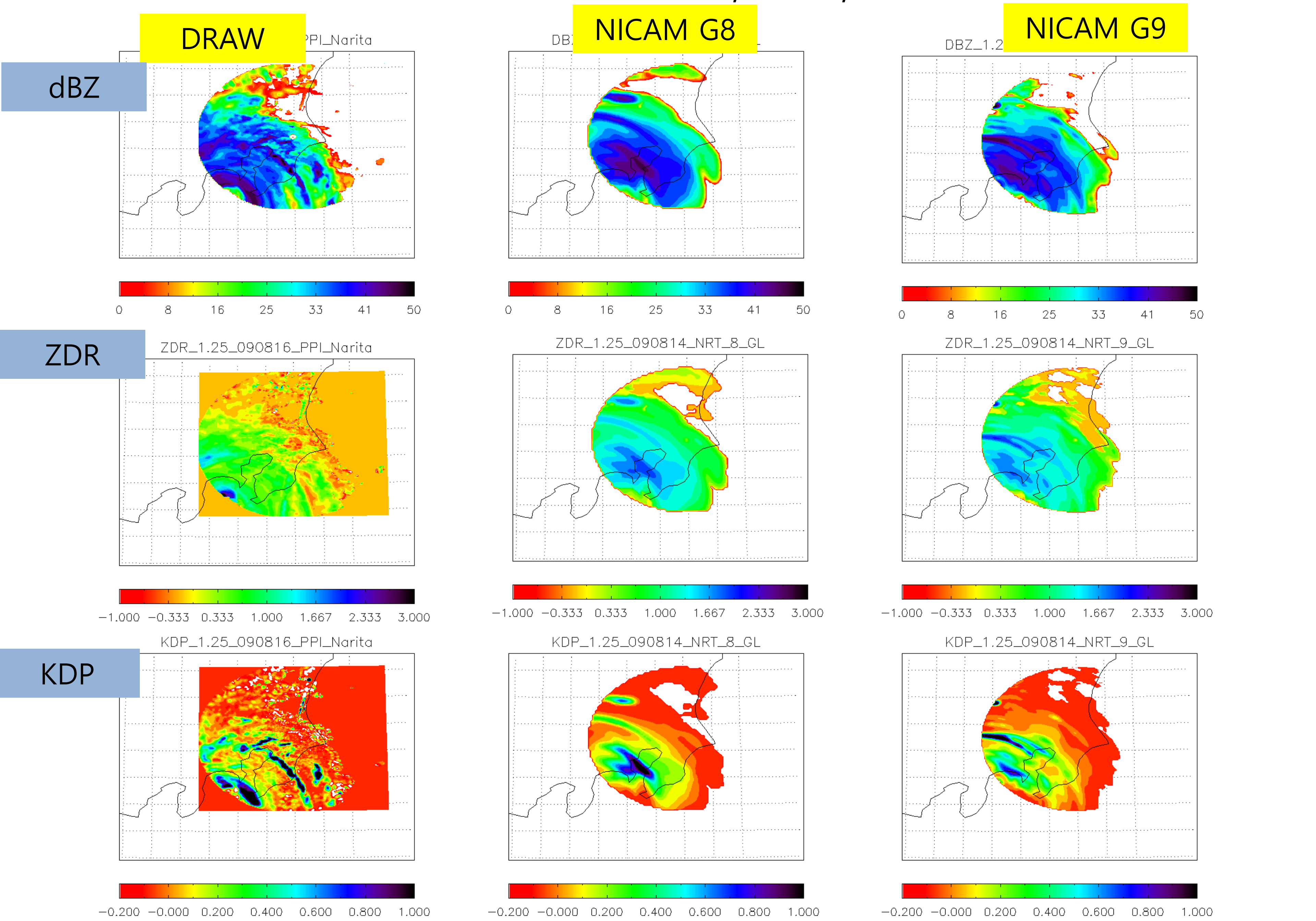
KDP



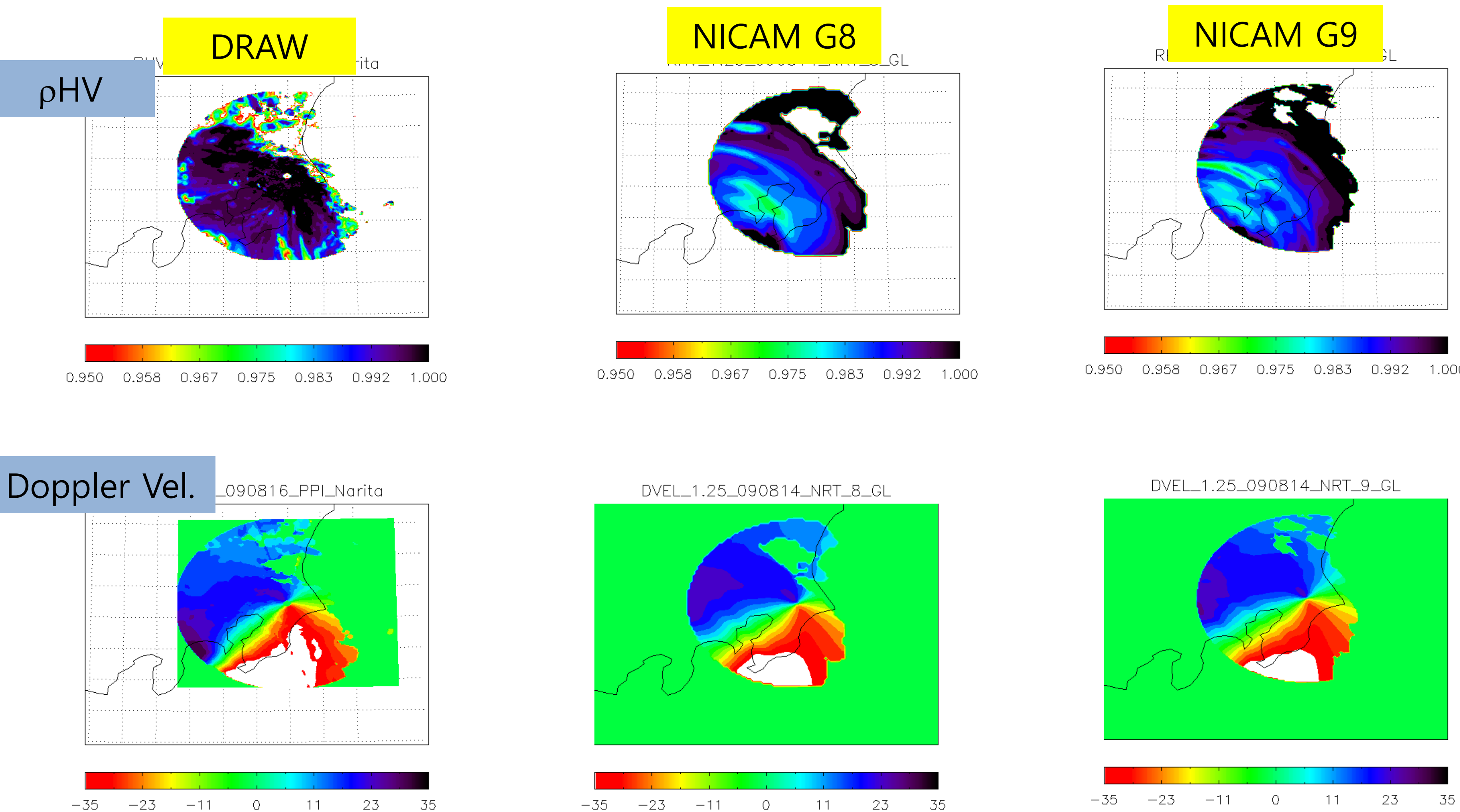


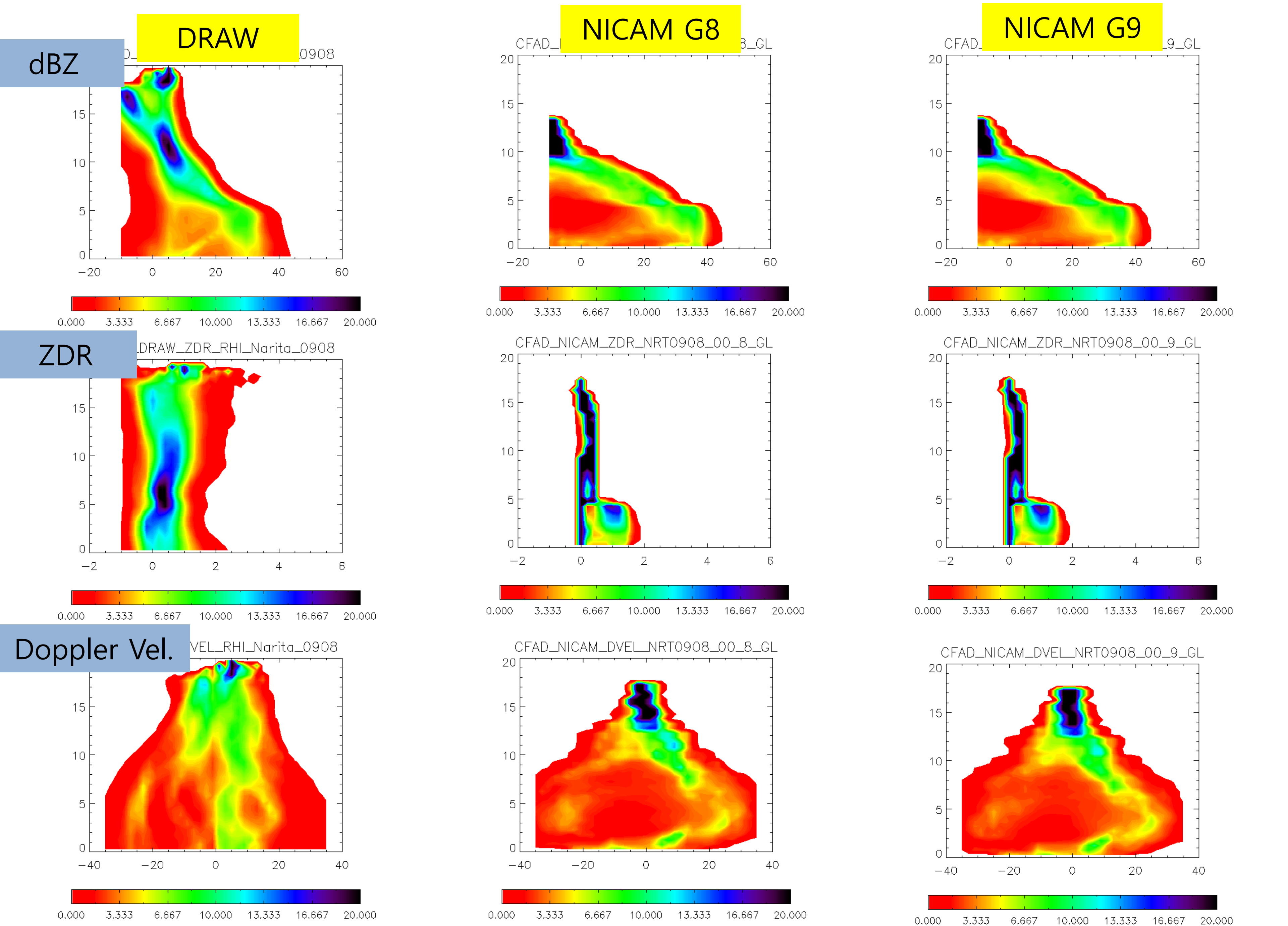
https://www.baranidesign.com/faq-articles/2020/1/19/rain-drop-size-and-speed-of-a-falling-rain-drop

Horizontal distributions of dBZ, ZDR, KDP for TC Faxai



Horizontal distributions of ρHV and Doppler veolocty for TC Faxai




DRAW
NICAM G8
NICAM G9
dBZ
ZDR
Doppler Vel.
DRAW_ZDR_RHI_Narita_0908
CFAD_NICAM_ZDR_NRT0908_00_8_GL
CFAD_NICAM_ZDR_NRT0908_00_9_GL
VEL_RHI_Narita_0908
CFAD_NICAM_DVEL_NRT0908_00_8_GL
CFAD_NICAM_DVEL_NRT0908_00_9_GL
0.000 3.333 6.667 10.000 13.333 16.667 20.000

Summary

- The ULTIMATE project started this fiscal year.
- We collected the several observation data for cases September 2019.

 - NICT CPR, JMA C-band polarimetric radar (DRAW), NICT 94 GHz CPR, X-band polarimetric phased array radar, JMA wind profilers, NIED Ka/X band radar, NIED Skytree observations.

- We implemented and tested POLARRIS for polarimetric radars in Joint simulator.
- We have done several simulations using the stretched NICAM for 2019.09 and 2020.04 cases.
- We evaluated NICAM using NICT 94 GHz CPR. The Doppler velocity from CPR shows a similar pattern like NICAM simulations, but NICAM overestimates the Doppler velocity from ice hydrometeors.
- We compared the DRAW and NICAM using POLARRIS in the Joint simulator.

- We will investigate the rain microphysics (e.g., breakup, coalescence) using NICT CPR and polarimetric radars.
- We will investigate the riming process using the NICT CPR and the relationship between KDP and ZDR
- We will evaluate NICAM using MP-PAWR and Ka radars.