Lessons learned from cal/val activity for GPM/DPR

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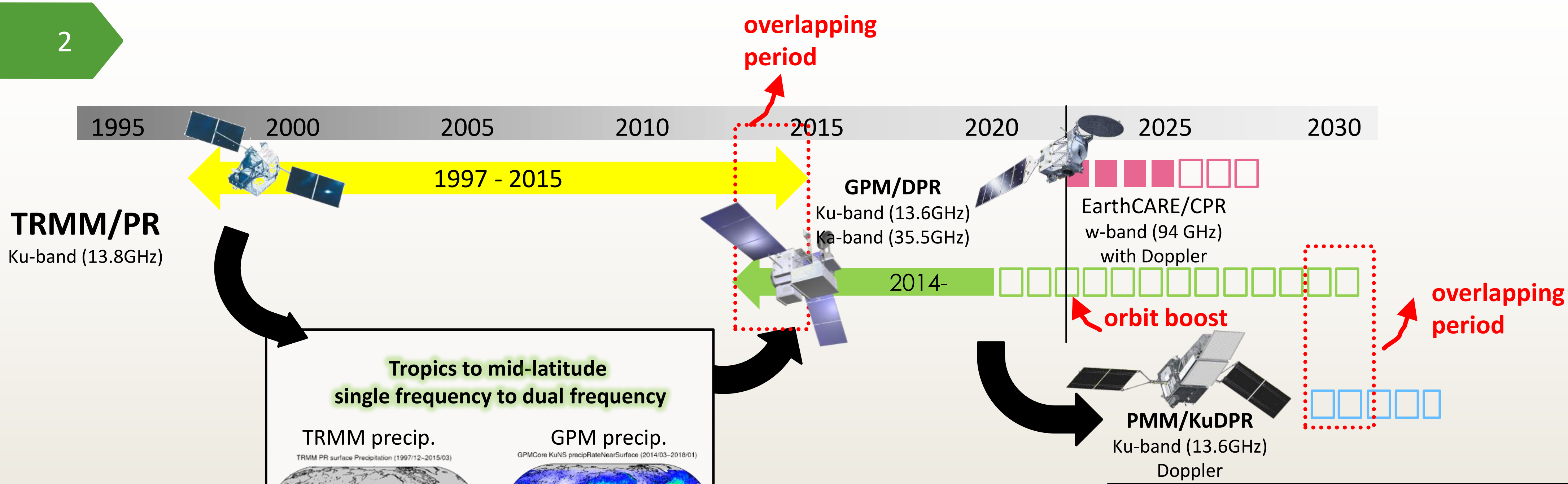
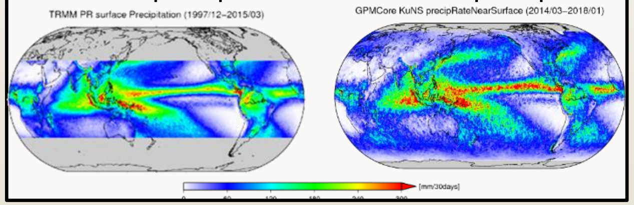
Pre-launch EarthCARE science and validation WS,

13-17, November 2023

Japanese spaceborne precipitation radars and cloud profiling radar



Tropics to mid-latitude
single frequency to dual frequency



Development of multi-satellite precipitation map
GSMaP (0.1 x 0.1 deg., hourly)

Better sensitivity & Doppler

1. Understanding cloud-precipitation processes
2. Collaboration with numerical models
3. Monitoring extreme phenomena

Technological heritage and Challenges

1. Phased array technology from TRMM/PR, GPM/DPR
2. Doppler velocity measurement technology from EarthCARE/CPR
3. Challenges to DPCA technology

GPM/DPR

- GPM core observatory launched Feb. 28, 2014
  - It will be in operation beyond 2030 because of orbit boost (400 to 443 km) in November 2023
- KuPR
  - 13.6 GHz
  - footprint 5 km
  - swath 245 km
  - sensitivity: 17 dBZ
- KaPR
  - 35.5 GHz
  - footprint 5 km
  - swath 120 km (245 km after May 2018)
  - sensitivity: 12 dBZ (high sensitivity mode)
- First introduction of variable PRF
  - EarthCARE/CPR introduces same approach
- Matched beam between Ku- and Ka-band radars

Calibration and validation of DPR

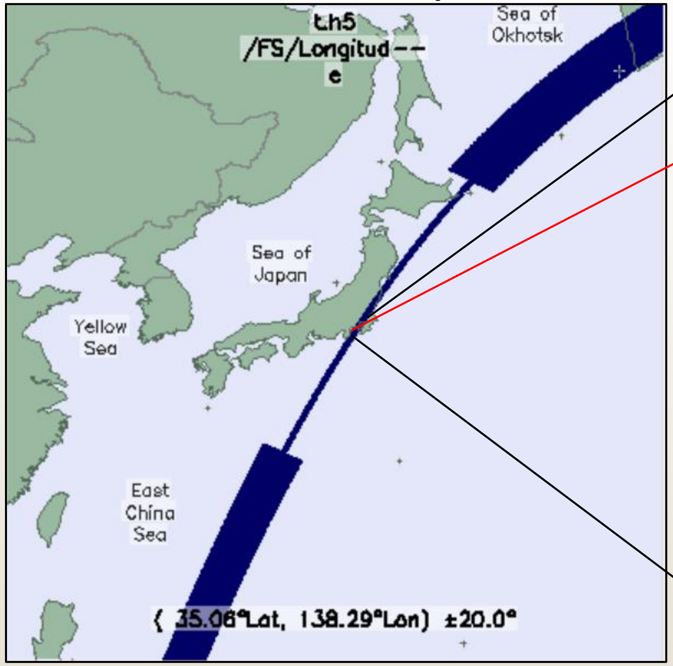
- Calibration
  - Internal calibration for Receiver system
  - External calibration using ARC for overall performance of the radar
    - target: 1 dB accuracy
  - Long term monitoring σ^0 (normalized surface backscattering cross section)
    - target: 0.1 dB accuracy
- Validation
  - Rainfall
    - gauge (simultaneous data for statistical comparison)
    - operational radar (simultaneous data for statistical comparison)
    - phased array radars (simultaneous 3D comparison)
  - Snowfall
    - radar (simultaneous data for statistical comparison)
    - in-situ (particle measurements at ground/balloon)

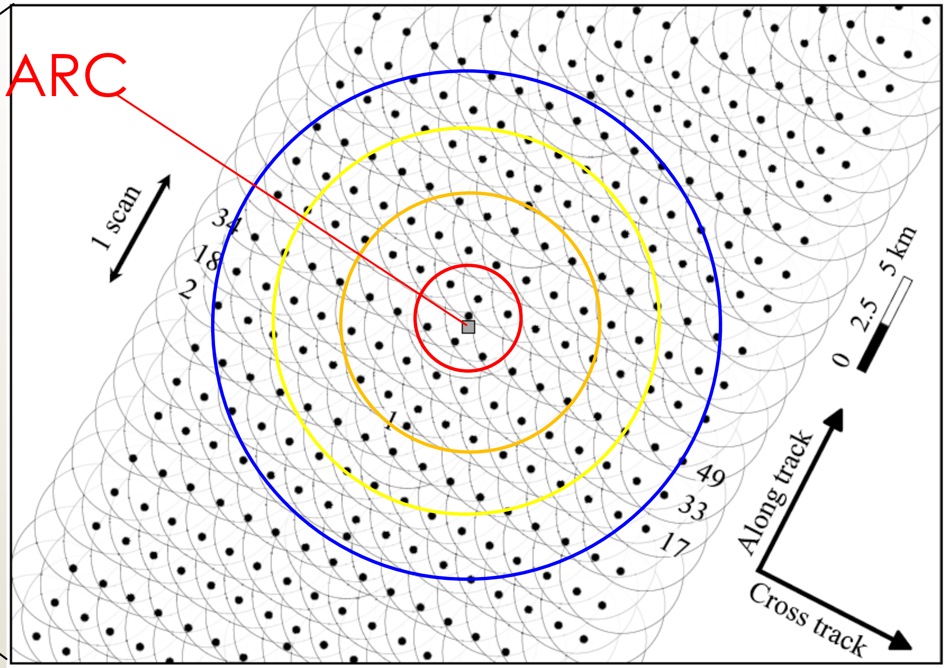
Calibration of GPM/DPR

Active Radar Calibrator (ARC)

Scan pattern during external calibration
DPR operates 3-times dense sampling

Masaki et al. (2020)
Add description

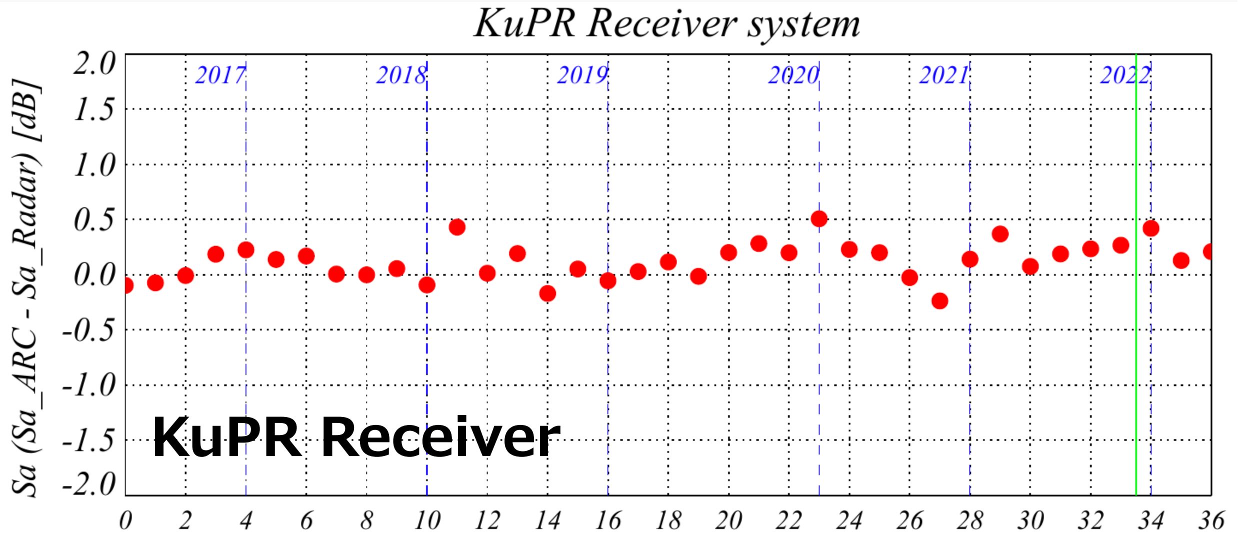


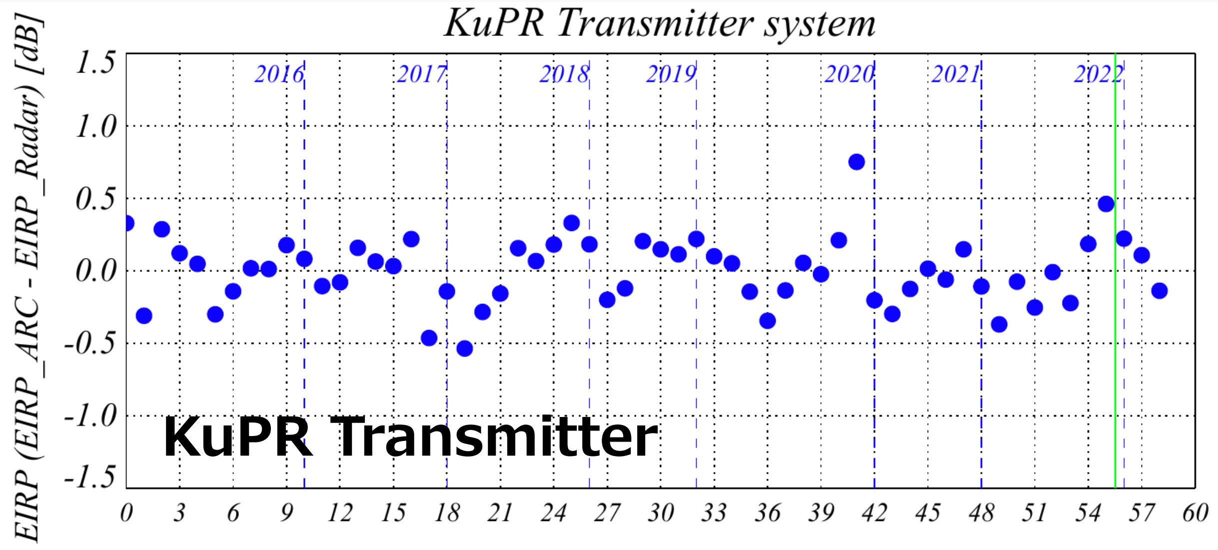


- **External calibration** using Active Radar Calibrator (ARC) to calibrate overall performance of the radar (echo power, not for Doppler)
  - 10 times a year (Masaki et al. 2020)
  - Antenna pattern is also estimated
- **Internal calibration** to see the relationship between received power and output digital count.
- These ideas are common both GPM/DPR and EarthCARE/CPR

External calibration result (Ku-band)

- both radar show the accuracy within 0.5 dB
- No increasing/decreasing trend cannot be seen with this accuracy





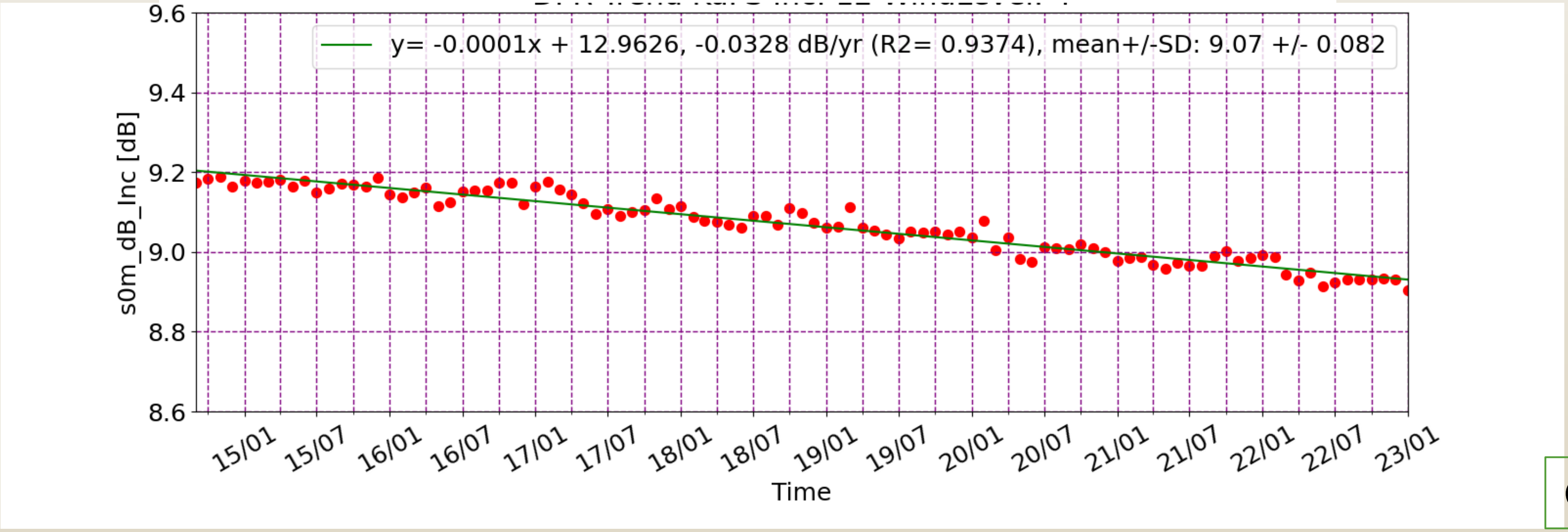
Courtesy of T. Masaki (RESTEC)

- More precise trend of radar performance is evaluated by using normalized surface backscattering cross section (σ^0) statistically

σ^0 trend

- using the 9-degree incident angle data
  - almost independent from sea surface wind.
- Statistical analysis shows a slight trend (-0.03dB/yr).
  - This change affects the global precipitation trend.
- Statistics of σ^0 will be available for EarthCARE/CPR . Careful treatment is needed to remove the effect of sea surface wind, because CPR is nadir looking radar.
- From this viewpoint, roll maneuver is important for CPR calibration.

Monthly averaged σ^0

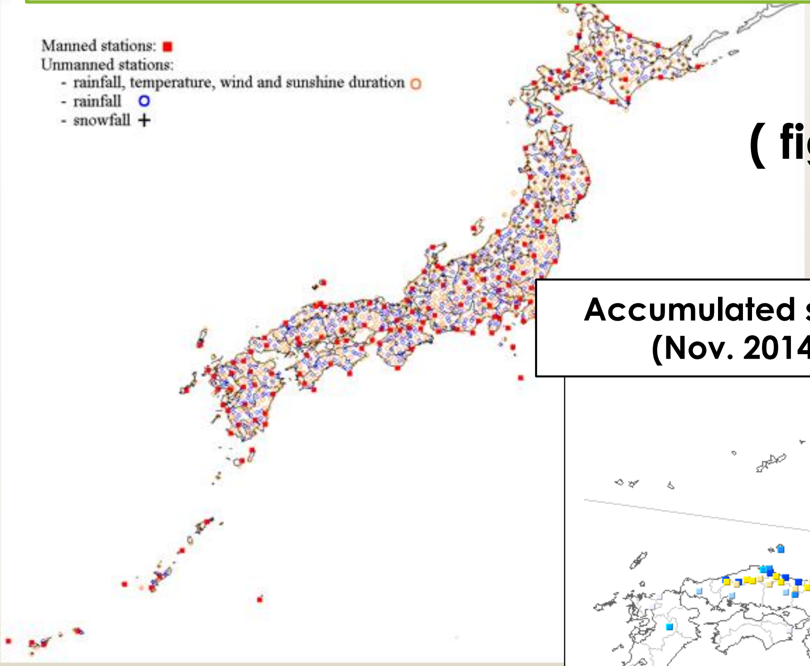


Courtesy of T. Masaki (RESTEC)

Validation in the GPM/DPR (rainfall)

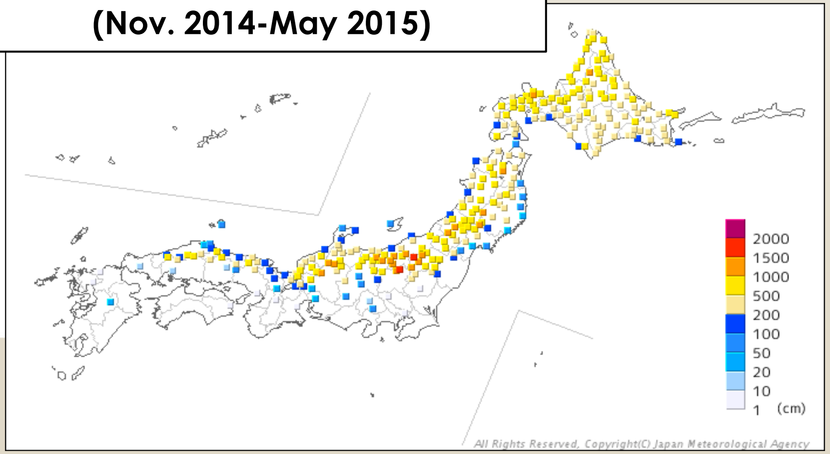
- **statistical approach using ground instrument network by Japan Meteorological Agency (JMA)**

JMA rain gauge stations
About 1,300 stations (average intervals of 17 km throughout Japan)

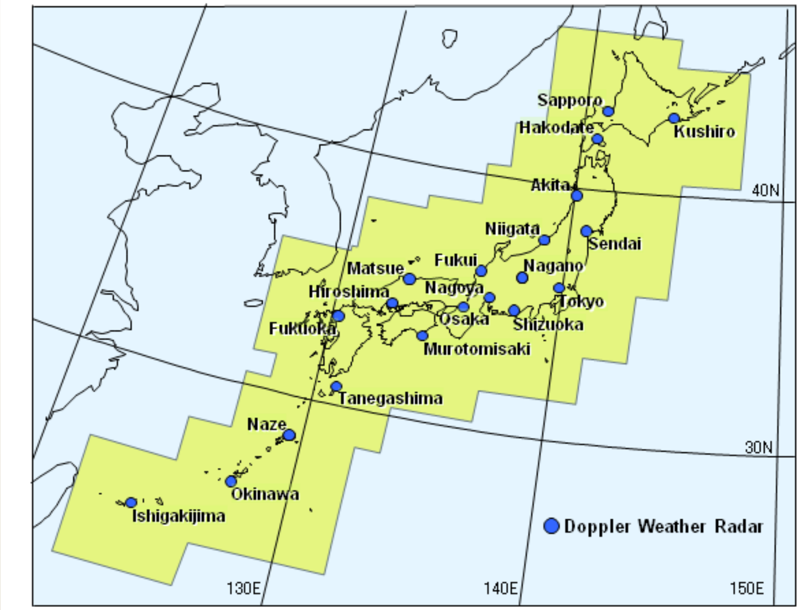


(figures provided by JMA)

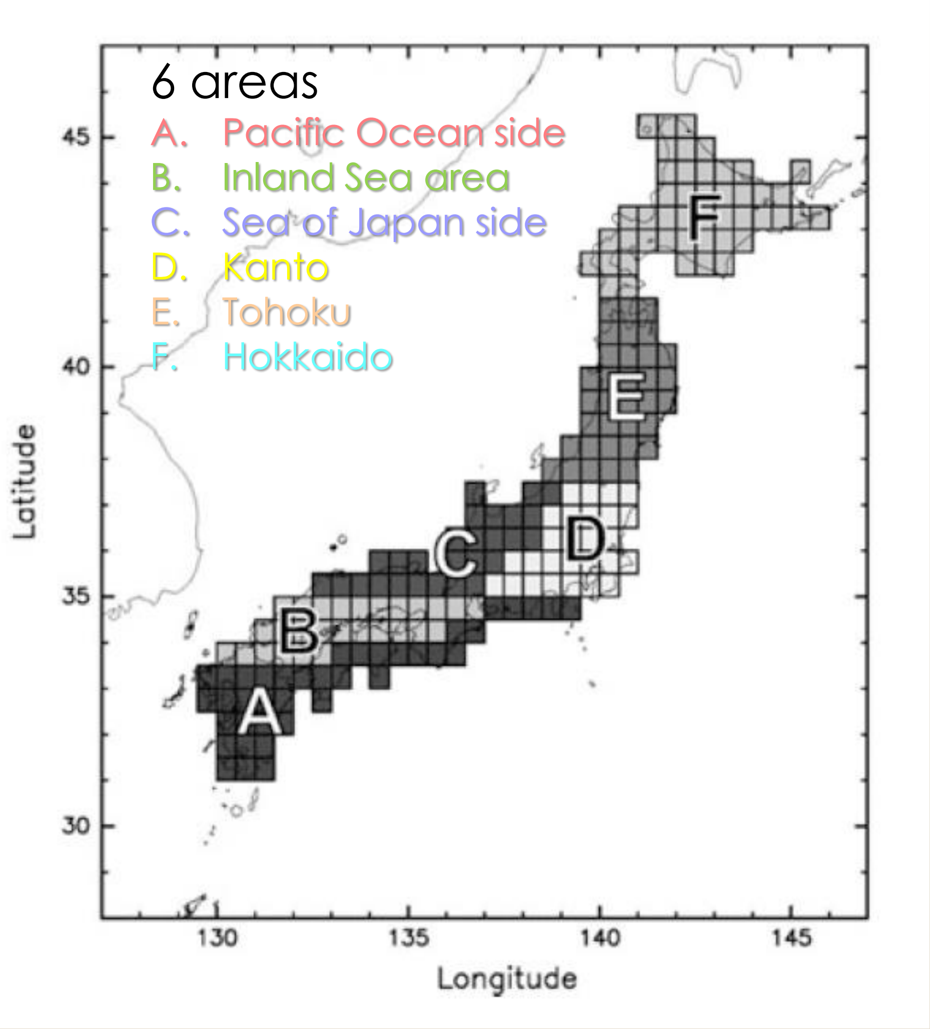
Accumulated snowfall amount (Nov. 2014-May 2015)



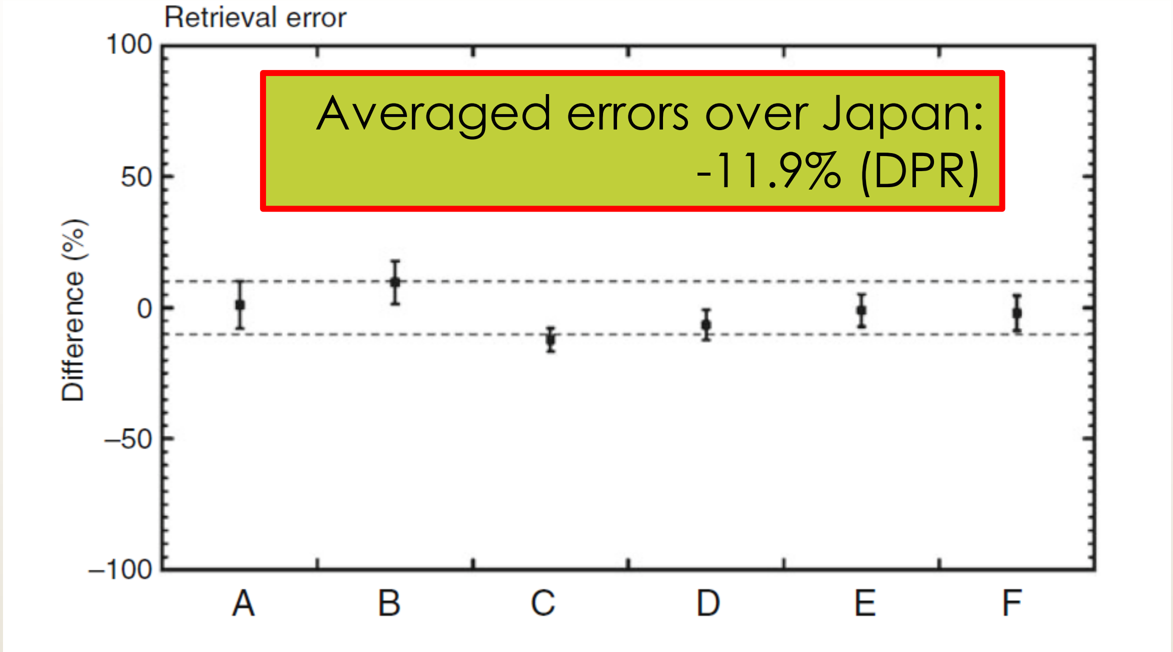
JMA radar network
JMA operates a network of 20 C-band Doppler weather radars across Japan



Validations with JMA rain gauge data



Error = (DPR – Gauge)/Gauge (%)

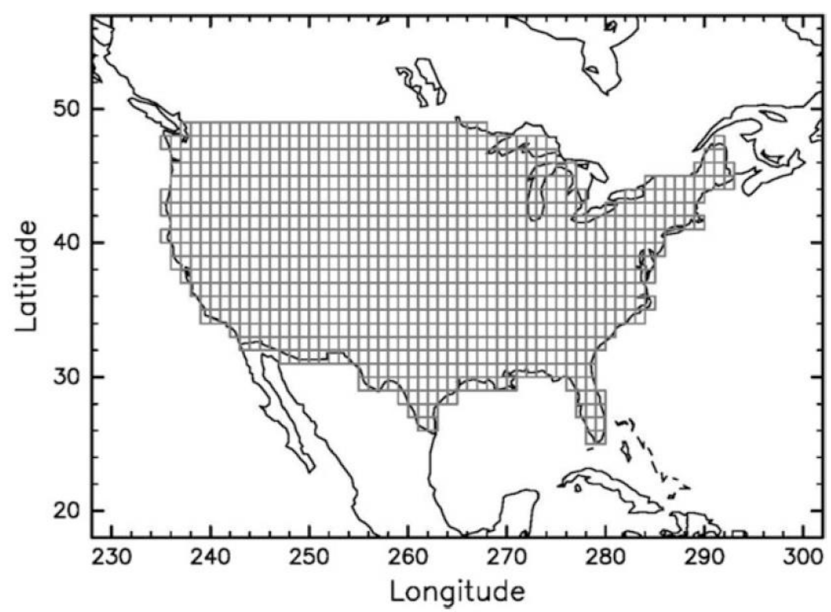


- Two years of data from April 2014 to March 2016
- AMeDAS data at overpasses only
- Gauge data are 10 min data immediately after the overpasses
- Rain total is estimated at each 0.5×0.5 deg. box, and means and standard deviations of 6 colored areas are calculated.
- To exclude snow fall data, if the surface temperature is below 6 degrees, data in that box are not used.

Oki et al. (2020, https://doi.org/10.1007/978-3-030-35798-6_3)

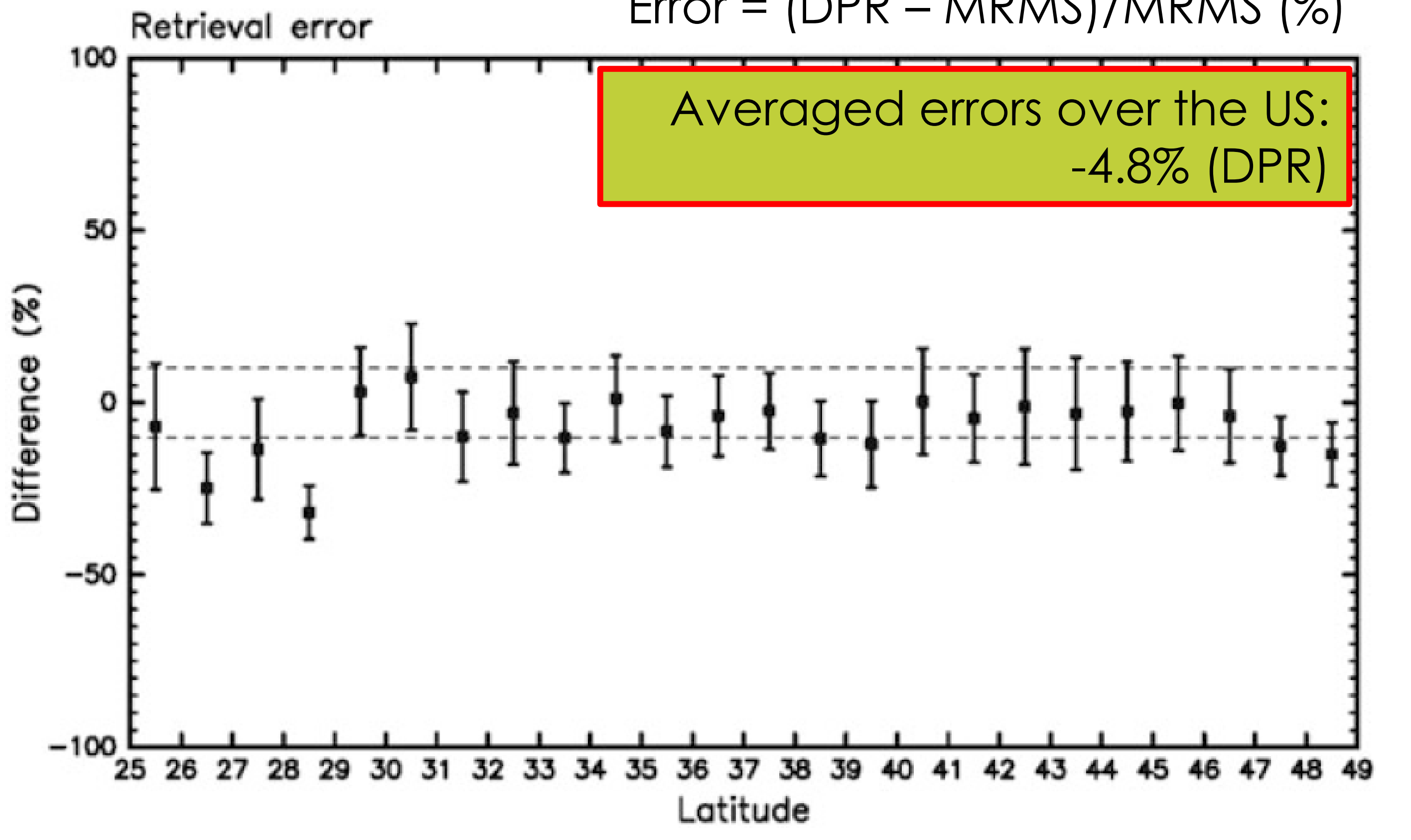
Validations with the US MRMS

- US Multi-Radar Multi-Sensor (MRMS) Dataset (provided by NASA GV team)
- June 2014 – May 2015 without winter season (Dec. Jan. Feb)
  - DPR overpass time only



$$\frac{\text{DPR - MRMS}}{\text{MRMS}}$$

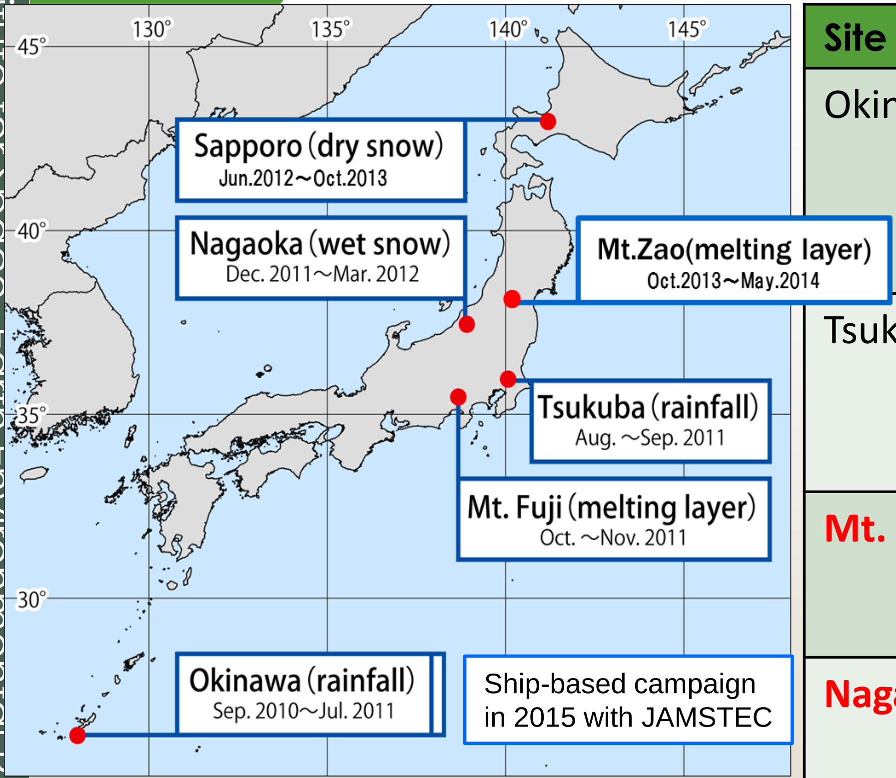
Error = (DPR – MRMS)/MRMS (%)



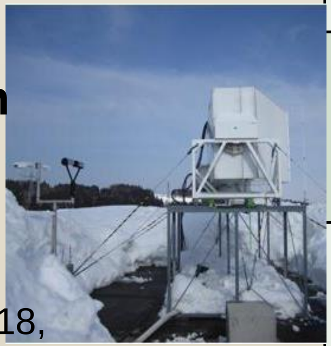
Oki et al. (2020, https://doi.org/10.1007/978-3-030-35798-6_3)

GPM GV field campaigns in Japan

Focusing mainly on solid precipitation and melting snow to validate because DPR is expected for better estimation of snow.



Site	Targets	Period	PI	Parameters	Instruments
Okinawa	Rain(Subtropics)	-- July 2011	Nagoya Univ. /NICT/JAXA	Rain Rate, Attenuation characteristics (Ka), DSD (profile, ground), Melting layer depth,	Ka-band GV radar x2, COBRA 400MHz WPR, 2DVD, Disdrometer, Micro Rain Radar (MRR), ORG
Tsukuba	Rain(the Temperate Zone)/Melting layer	Summer 2011	NIED, Nagoya Univ. /NICT/JAXA	Rain Rate, DSD (profile, ground), Attenuation profile through melting layer	Ka-band GV radar x2, KaW-band radar, 400MHz WPR, 2DVD, Disdrometer, Micro Rain Radar (MRR), ORG
Mt. Fuji	**Melting layer**	Autumn 2011	Nagoya Univ. /NICT/JAXA	Attenuation profile through melting layer, DSD (profile, ground)	Ka-band GV radar x2, 2DVD, Disdrometer, Micro Rain Radar (MRR), ORG
Nagaoka	**Wet snow**	Winter 2012	NIED, Nagoya Univ. /NICT/JAXA	DSD (profile), Rain rate (snow), Attenuation characteristics, (Ka) Snow particle parameters (density, particle size, falling speed etc.,)	Ka-band GV radar x2, X-band Radar, Lidar, 2DVD, Snow Particle Obs. system
Sapporo	**Snow(dry/ wet)** Rain	Sprinter 2012 – winter 2013	Hokkaido Univ., Nagoya Univ. /NICT/JAXA	Rain profile, Rain rate (rain, snow), Attenuation characteristics, Snow particle parameters (density, particle size, falling speed etc.,)	Ka-band GV radar x2, X-band radar, 2DVD, Lidar, Micro Rain Radar (MRR), Snow Particle Obs. system
Mt. Zao	**Melting layer**	Autumn 2013 -May 2015	Nagoya Univ. /NICT/JAXA	Attenuation profile through melting layer, DSD (profile, ground)	Ka-band GV radar x2, 2DVD, ORG, Disdrometer, Micro Rain Radar (MRR)



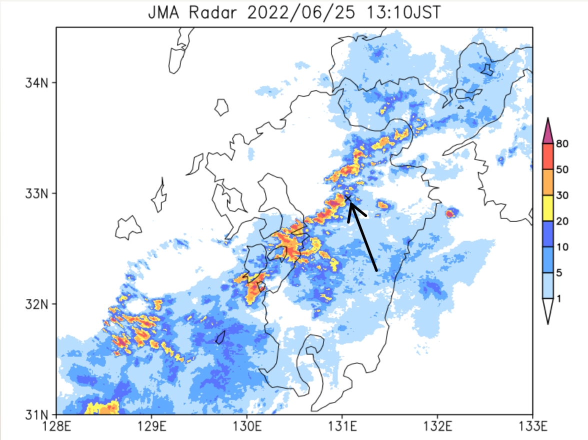
Dual Ka radar system facing each other for precise attenuation measurement
(Nakamura et al. 2011, 2018, 2021)

Particle fall velocity measurement by a newly-developed particle imaging radiosonde "Rainscope"

By K. Suzuki
(Yamaguchi Univ.)

Rainscope is a balloon-borne **particle imaging** radiosonde. It can capture clear images of precipitation particles, and is equipped with two infrared sensors, so it is possible to measure **the fall velocity** of particles in clouds by measuring the passing time.

Convective case
on June 25, 2022



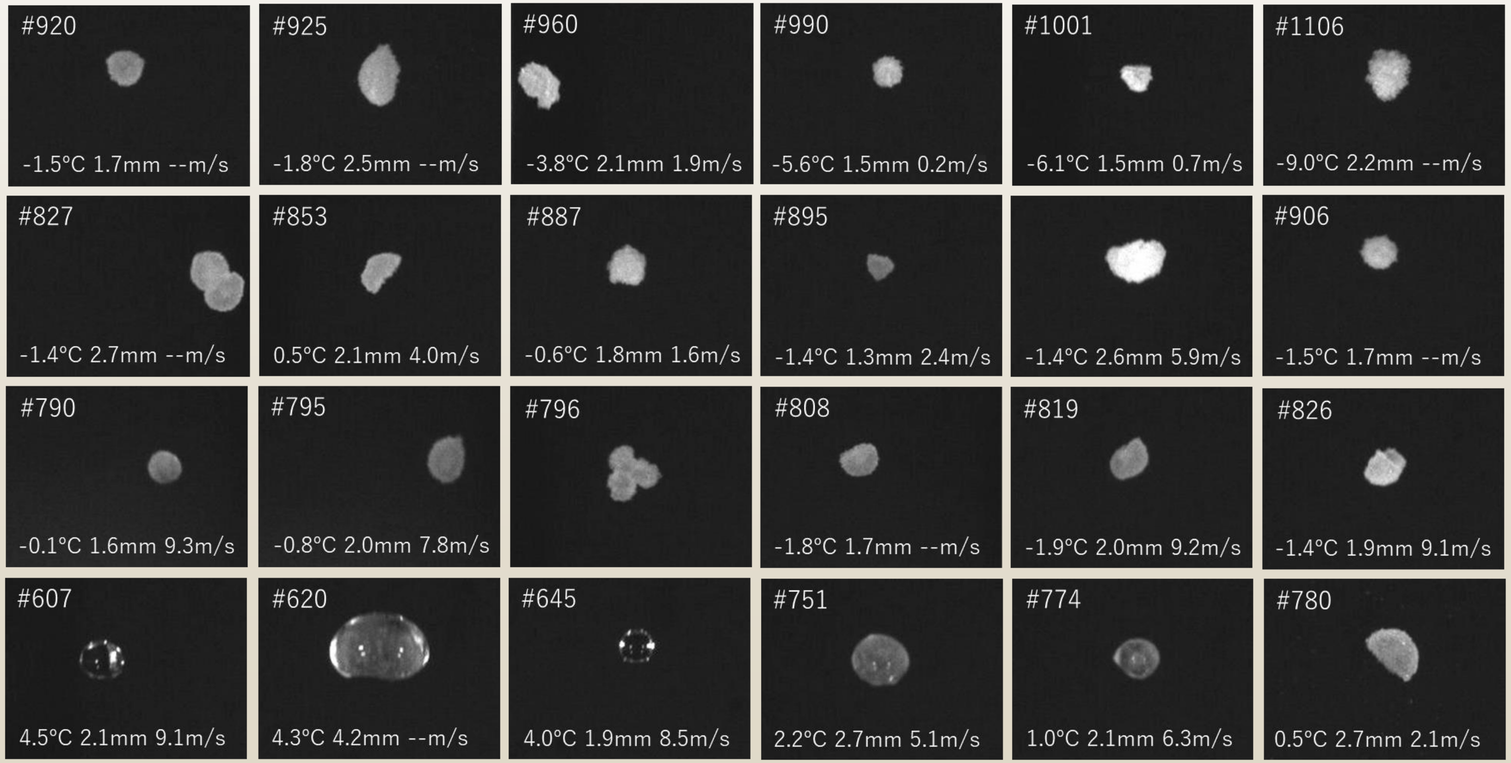
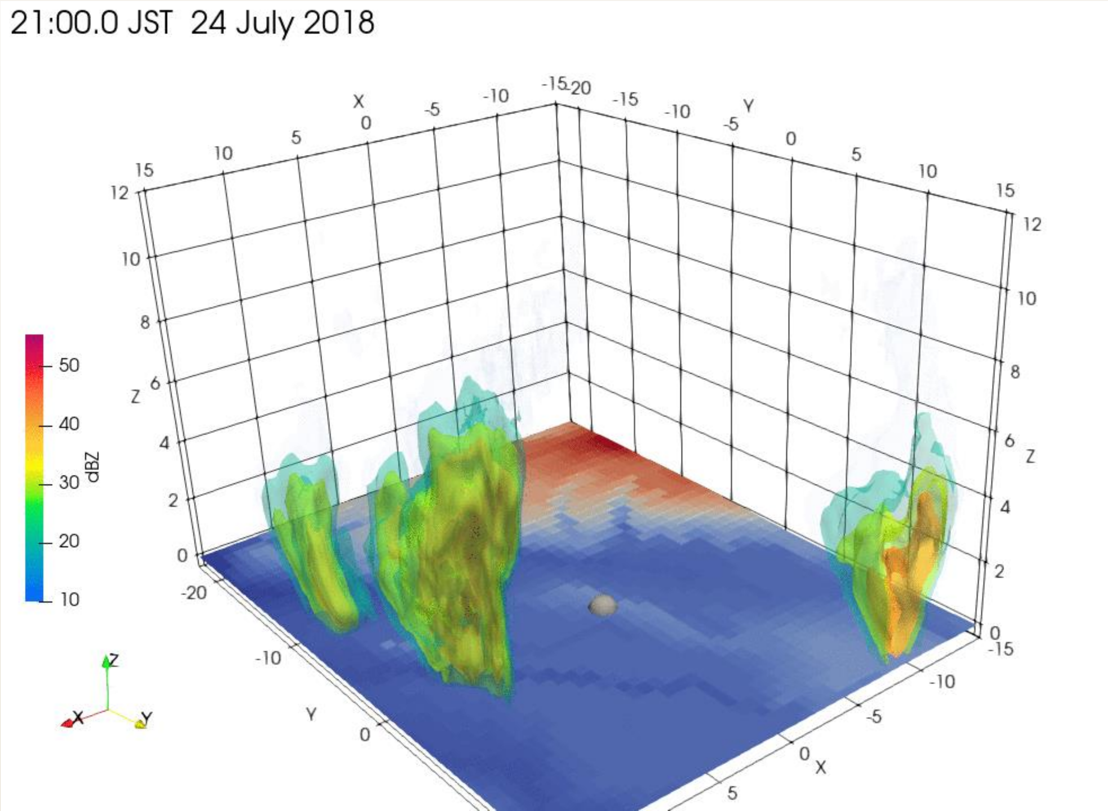


Fig. Particle images obtained from Rainscope launched into convective thunderstorm cloud. Values indicate temperature, diameter, and terminal velocity, respectively.

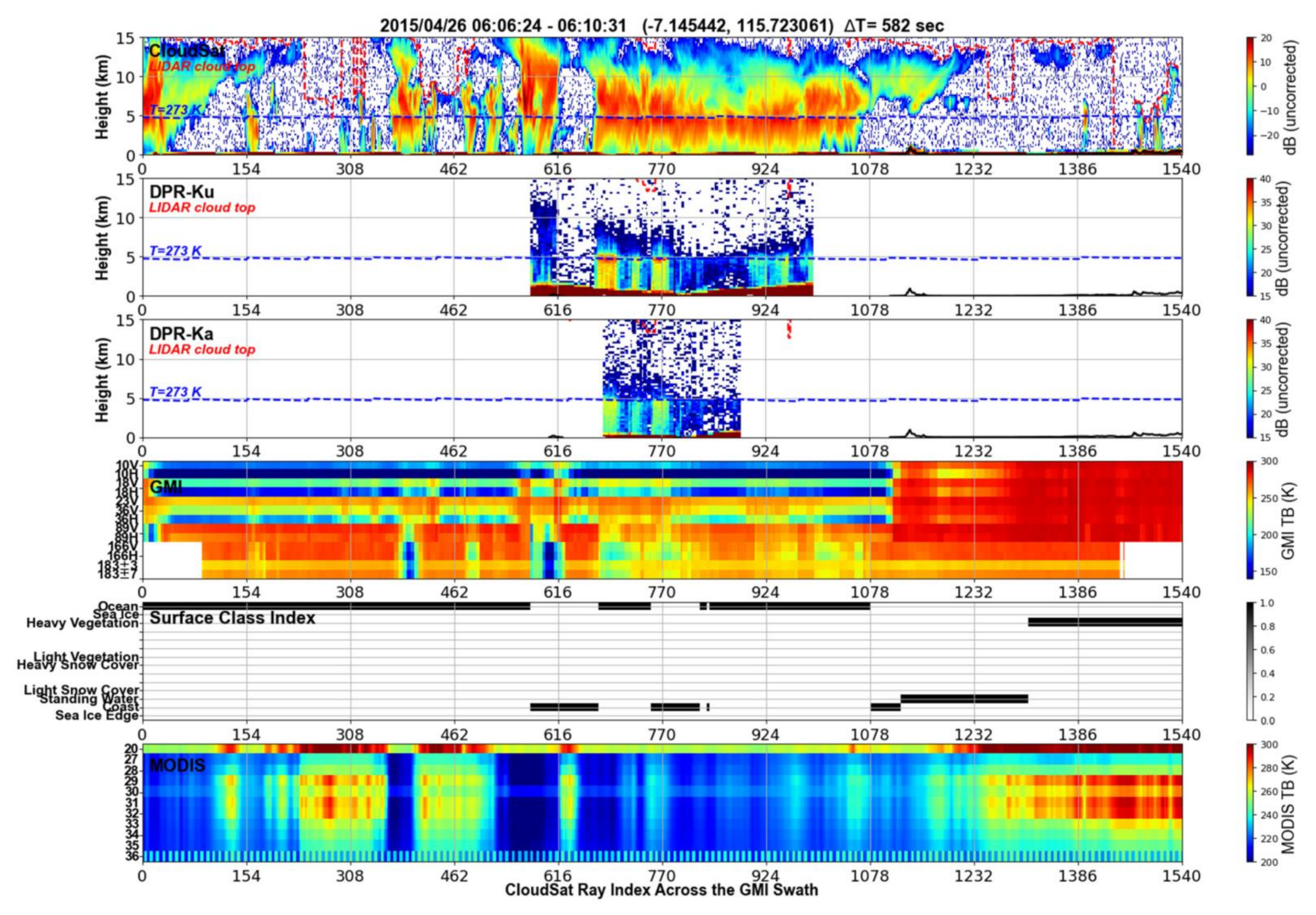
Phased Array Weather Radar (PAWR) and MP-PAWR

- Full 3D scan in 30 sec
- It is possible to compare simultaneous comparison of 3D structure
- Detail of this radar is shown in poster



validation using GPM-CloudSat matchup data

A-Train – GPM collocated dataset (Turk et al. 2021)



- GPM-CloudSat matchup data set (Turk et al., 2021) is used to compare DPR profile with CloudSat/CPR.
- It helps for better understand of precipitation system.
- JAXA is preparing to create synergetic dataset collocated GPM-EarthCARE data.

Summary: comparison of cal/val between GPM/DPR and EarthCARE/CPR

	GPM/DPR • **scanning radar** • **power only**	**EarthCARE/CPR** • **nadir looking** • **power and Doppler**
[CAL]Echo power	ARC + σ^0	ARC + σ^0 + roll maneuver
[CAL/VAL]Doppler velocity	N/A	ARC (for pointing of CPR) sea surface Doppler velocity
[VAL]Geophysical value (method)	**rain** (rain gauge, radar) **snow** (in-situ, polarimetric radar)	**cloud** (radar, in-situ) **ice** (cloud radar, polarimetric radar and in-situ) **velocity** (WINDAS, vertical pointing radar)

- For GPM/DPR, statistical approach is needed for precise calibration and validation that is reflected to cal/val plan for EarthCARE/CPR.
- Validation of solid precipitation needs comprehensive observation including in-situ ground-based observation, remote sensing, balloon observation and so on.

Thank you for your attention

Particle fall velocity measurement by a newly-developed particle imaging radiosonde "**Rainscope**"

By K. Suzuki (Yamaguchi Unv.)

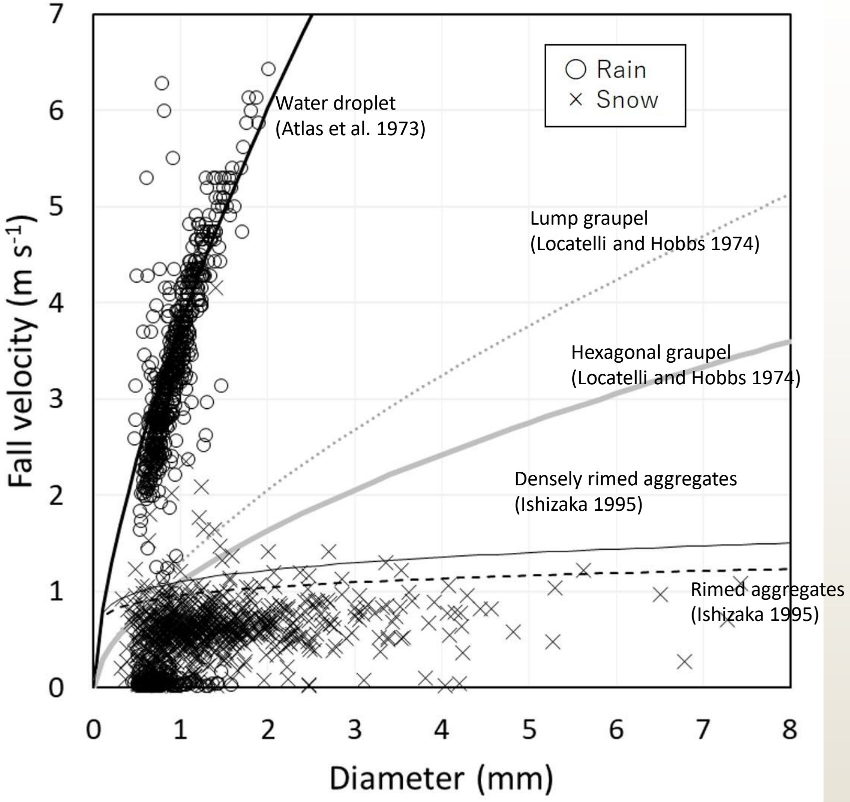


Fig. Relationship between particle diameter and fall velocity in rain (circle) and snow (cross) during Rainscope ground tests in December 2021.

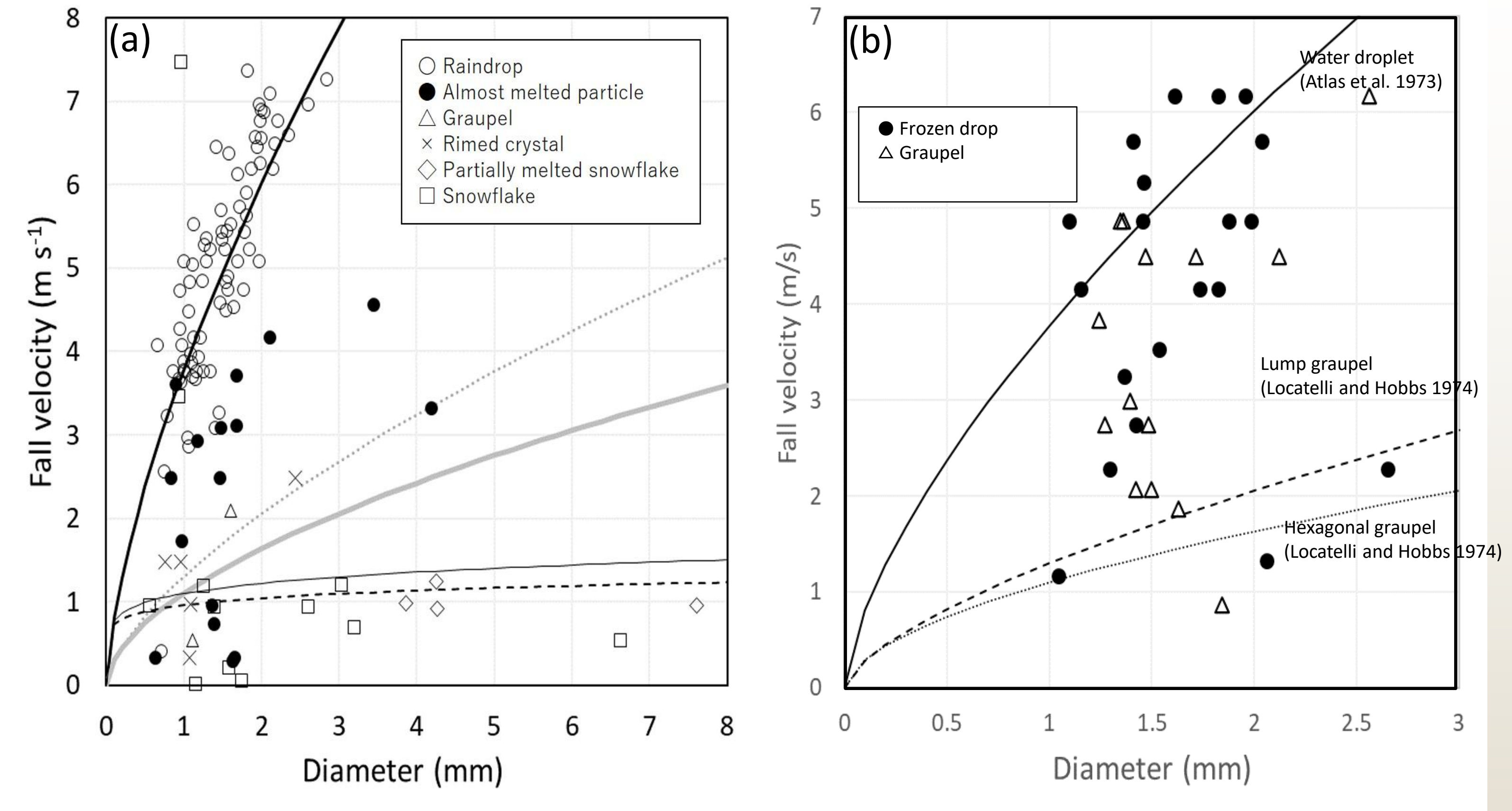


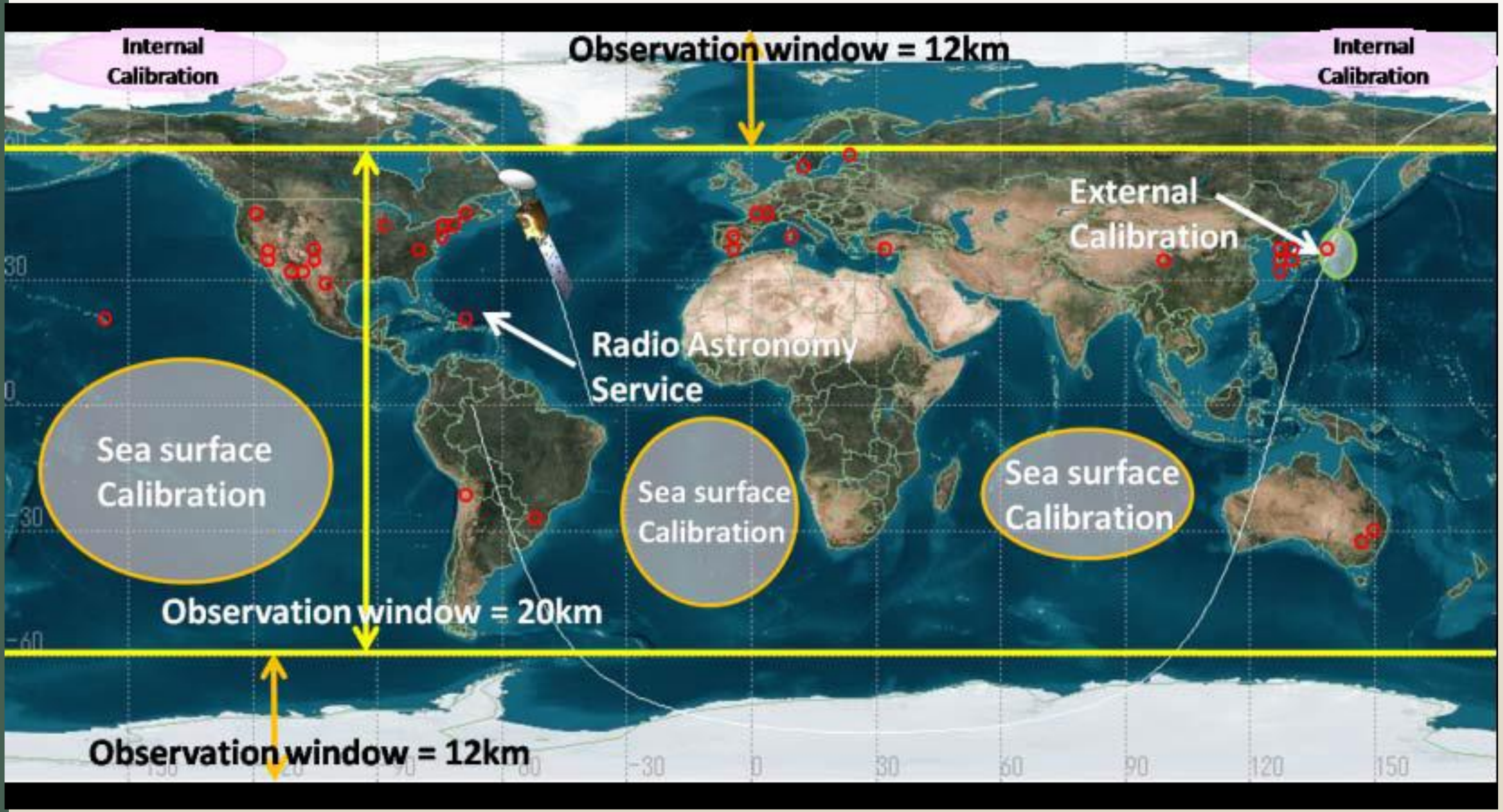
Fig. Relationship between diameter and fall velocity of precipitation particle obtained from Rainscope launchings. (a) stratiform cloud on February 20, 2021 (b) only graupel and frozen particle observed below the -10^{o}C level convective cloud on June 25, 2022. *Note that the axis scales and symbols are different in the two figures..

Particle fall velocity measurements in clouds:

- Raindrop's related to diameter (well known, e.g. Altas et al. 1973) → Potential for possible validation of updraft in clouds
- Solid particle's depend on density → better understanding of cloud microphysics, especially solid hydrometeor formation

Calibration of EarthCARE/CPR

- The external calibration study for EarthCARE/CPR was described in Horie et al. (2010, https://doi.org/10.1109/IGARSS.2010.5650733)
- Okada et al. (2009) showed CPR Operation Image.



There are three calibrations considered for the CPR.

1. The internal calibration for signal processing unit which will be processed electrically and this calibration need to stop the observation.
2. The sea surface calibration which will be performed to calibrate RF performance and to get normalized radar cross section.
3. The external calibration which will be performed using ground based radar calibrator (ARC).

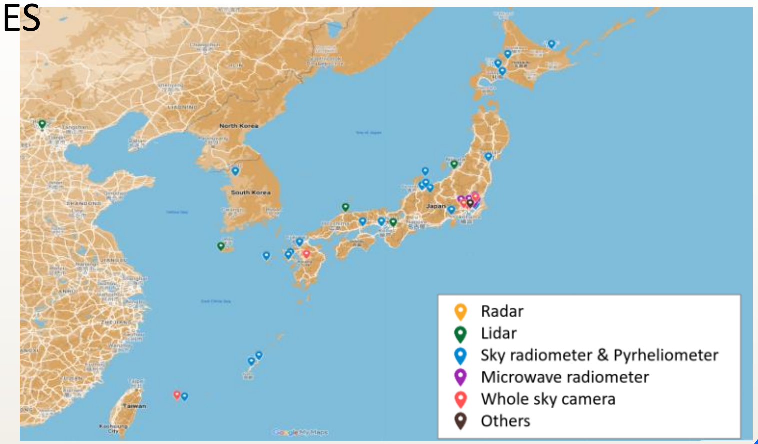
JAXA/EarthCARE validation activities

Long-term observation network

- Lidar network (AD-Net) by NIES
- SKYNET observation stations
- Wind Profilers by JMA

etc.

Location of ground-based instruments



→which can provide detailed validations of the JAXA EarthCARE products

Campaign observation

- Ground-based doppler CPR developed by NICT
- Multiple-field-of-view multiple-scattering polarization lidar (MFMSPL), High spectral resolution lidar, Direct Detection Doppler lidar (355nm) by Prof. Okamoto's kakenhi kiban S 17H06139

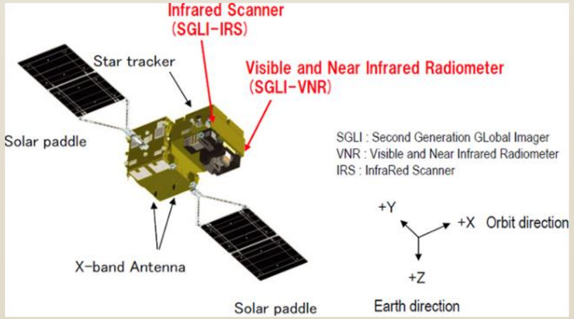
They are located in NICT Tokyo with other ground instruments.

Comparison with other satellite data

(CloudSat, CALIPSO, GCOM-C/SGLI, MODIS, VIIRS, CERES, etc.)

→which can provide global evaluations of the JAXA EarthCARE products

JAXA' GCOM-C satellite (carrying **SGLI sensor**)



Validation of the CPR in the NICT Tokyo

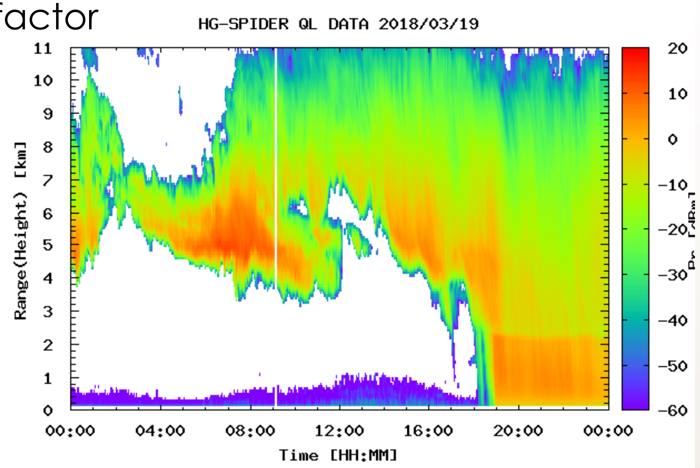
HG-SPIDER (NICT's Ground-based validation CPR)

HG-SPIDER: High sensitivity Ground-based SPIDER (CPR)

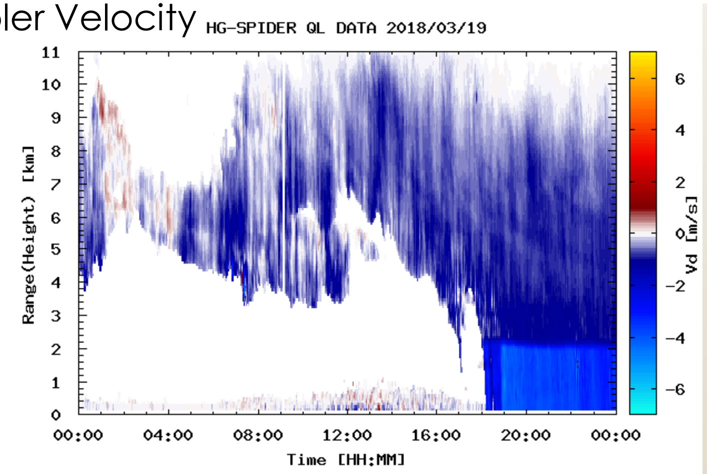
Item	Specification
Frequency	94.090GHz
Tx Power	1500W at EIK (peak)
Antenna Gain	55.9 dBi
Beam Width	0.3 degrees
Polarization	Linear Polarization
Pulse Width	0.5/1.0/2.0μs
PRF	3,000 - 10,000 Hz
Sensitivity	-40dBZ@15km (Integ. 1sec.)
Antenna Scanning	Fixed (zenith pointing)
Range	150m - 20km
Doppler Function	Pulse-Pair Processing

Better sensitivity than EarthCARE/CPR

Z factor



Doppler Velocity



NICT will operate several ground instruments including the ground cloud radar (HG-SPIDER).

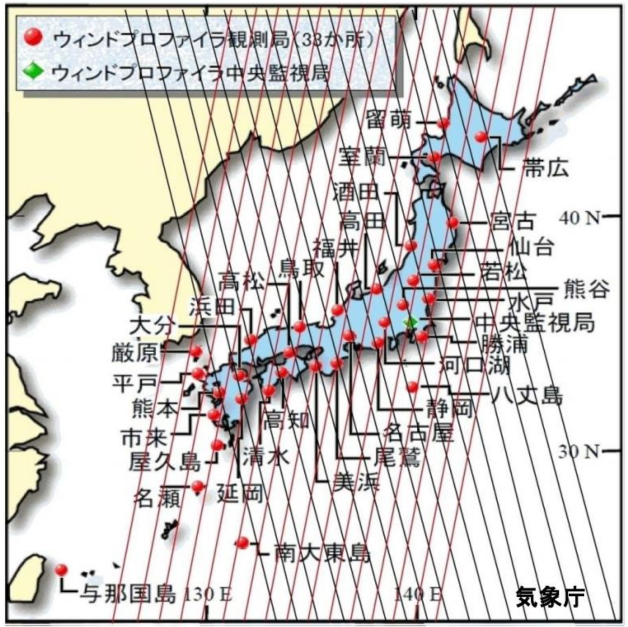
MFMSPL, HSRL, Direct Detection Doppler lidar (355nm) were developed by Prof. Okamoto (Kyusyu Univ.)'s Kakenhi.

・The HG-SPIDER is located in NICT Koganei (Validation Site) with other Instruments;
lidars by Prof. Okamoto's kakenhi, wind profiler, microwave radiometer, all-sky camera, etc...

JAXA/EarthCARE validation activities

- The JMA operates 33 wind profile network (WINDAS：WInd profiler Network and Data Acquisition System).
- The NICT is studying a validation of the CPR Doppler velocity using the WINDAS.

JMA wind profiler network（WINDAS）



WINDAS:1.357GHz Wind profiler

Main target: atmospheric turbulence

Horizontal wind profile with good height and time resolution

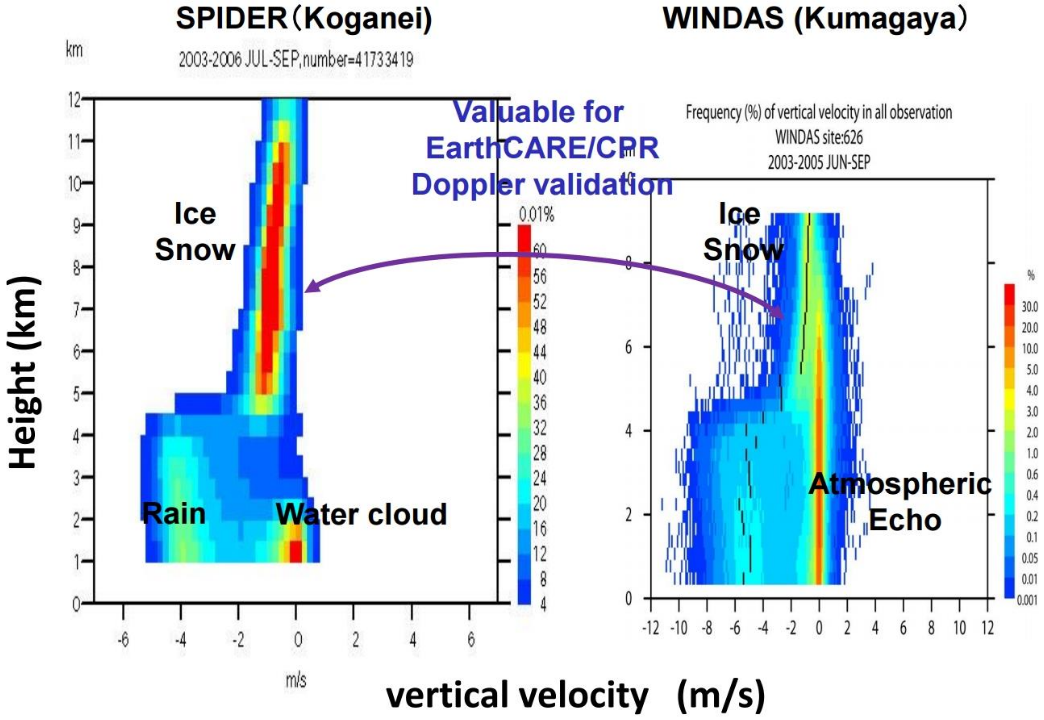
Sub target: Ice cloud and rain

Vertical velocity of cloud & rain particle

EarthCARE Doppler validation

JMA WINDAS

Echo appearances（SPIDER & WINDAS）



Slides provided by Yuichi Ohno (NICT)