CPR External Calibration by Active Radar Calibrator and CPR Level 1/Level 2 Product Validation

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NICT (National Institute of Information and Communications Technology)

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CPR Overview

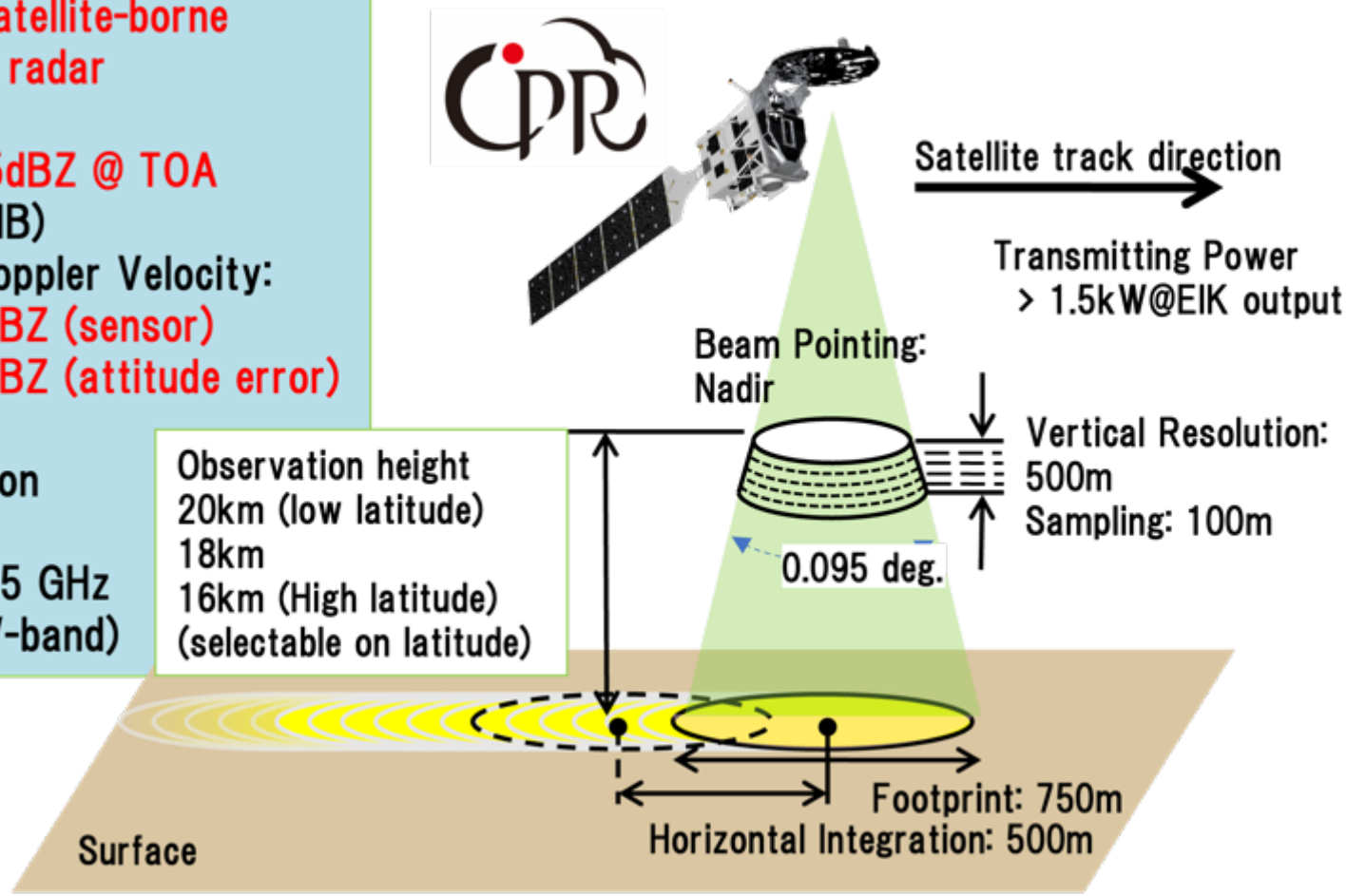
CPR: The first satellite-borne Doppler weather radar

Specification*:

- Sensitivity: -35dBZ @ TOA (Calibration: 1dB)
- Accuracy of Doppler Velocity:
  <1.0m/s @-19dBZ (sensor)
  <1.3m/s @-19dBZ (attitude error)

* Uniform cloud, 10km integration

Frequency: 94.05 GHz (W-band)



CPR L1b Product (Major Items):
Reflectivity Factor (Z factor)
Doppler Velocity (Vd)
Surface related product

CPR L2a (CPR ECO) Product:
Integrated Z factor (1/10km)
Integrated Vd (1/10km)
PIA: Path Integrated Attenuation
Mirror Flag/Clutter Echo
Vd folding/NUBF cprrection

Major Calibration/Validaion Items
Z factor
Doppler Velocity

CPR Calibration Concept

Basic Calibration Methodogy (On-board Calibration)

- CCDB (Calibration Characterization DataBase) is established by system test before launch.
- During level 1 processing, obtained data is corrected using CCDB as a function of temperature telemetry.
- On board equipments (ex. Power monitor & Doppler Reference Signal for transmitting power, noise diode & normal load for receiver gain) are used to compare level 1 processing result.
- Health check by Interncal Calibration Mode operation

External Calibration Objective

- CPR Radar Parameters (ex. Transmitting Power, Receiver Gain, etc) are measured for helth check of hardware.
- CPR Radar Parameters are checked from trend of measured data for long period.

ARC External Calibration

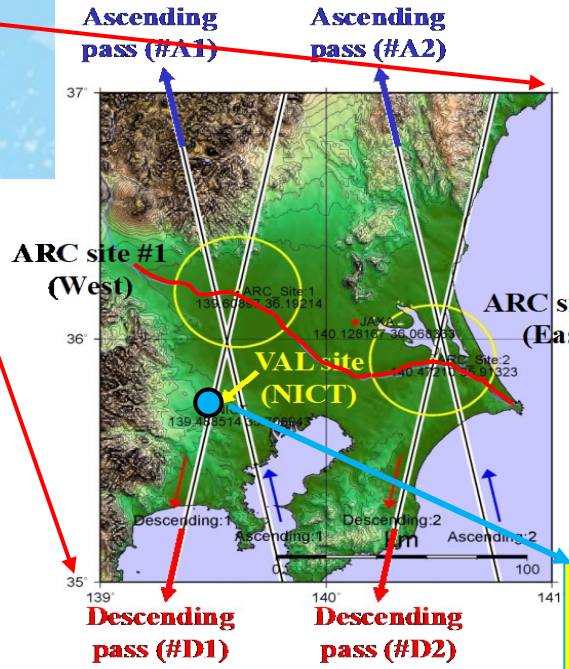
- CPR antenna beam pointing measurement (enough for cloudy day)
- CPR transmitter and receiver measurement indevendly (need sunny day)
  and then defined **Calibration Factor**

CPR ARC External Calibration

CPR Calibration Area

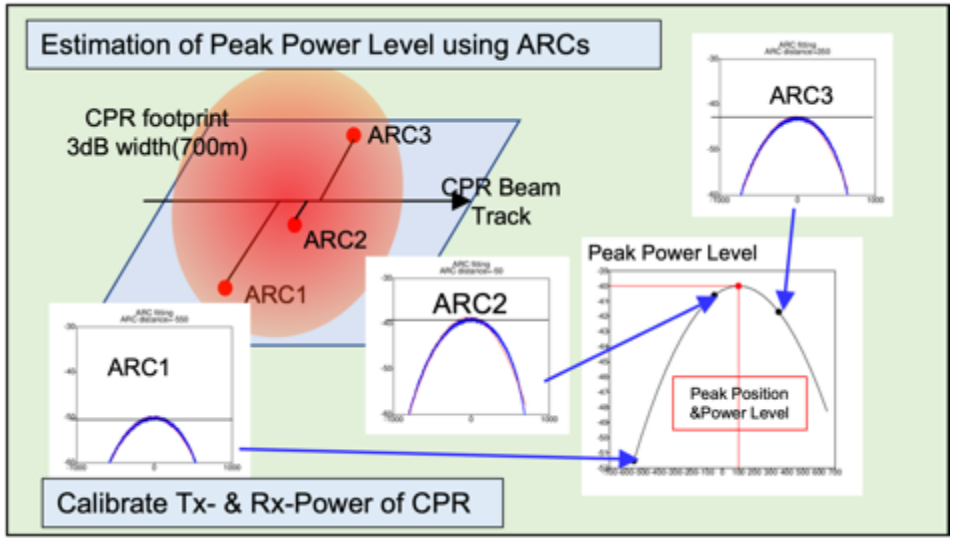
External Calibration using ARC is one of most impordant tasks for CPR Products.

Kanto Area

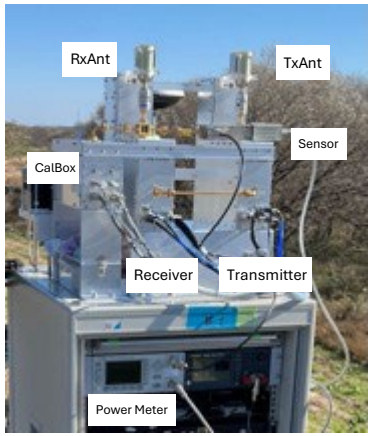


ANXLongitude:0.60 degrees
ARC experiment: 2 times / one repeat cycle (25days, 389 orbits)

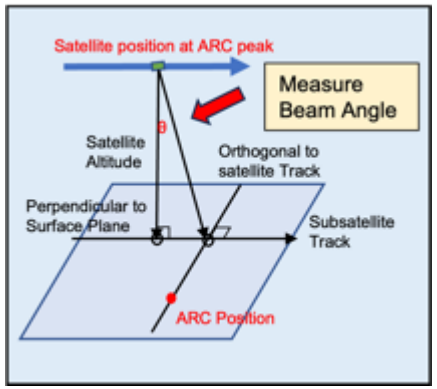
Peak Level Estimation using ARC



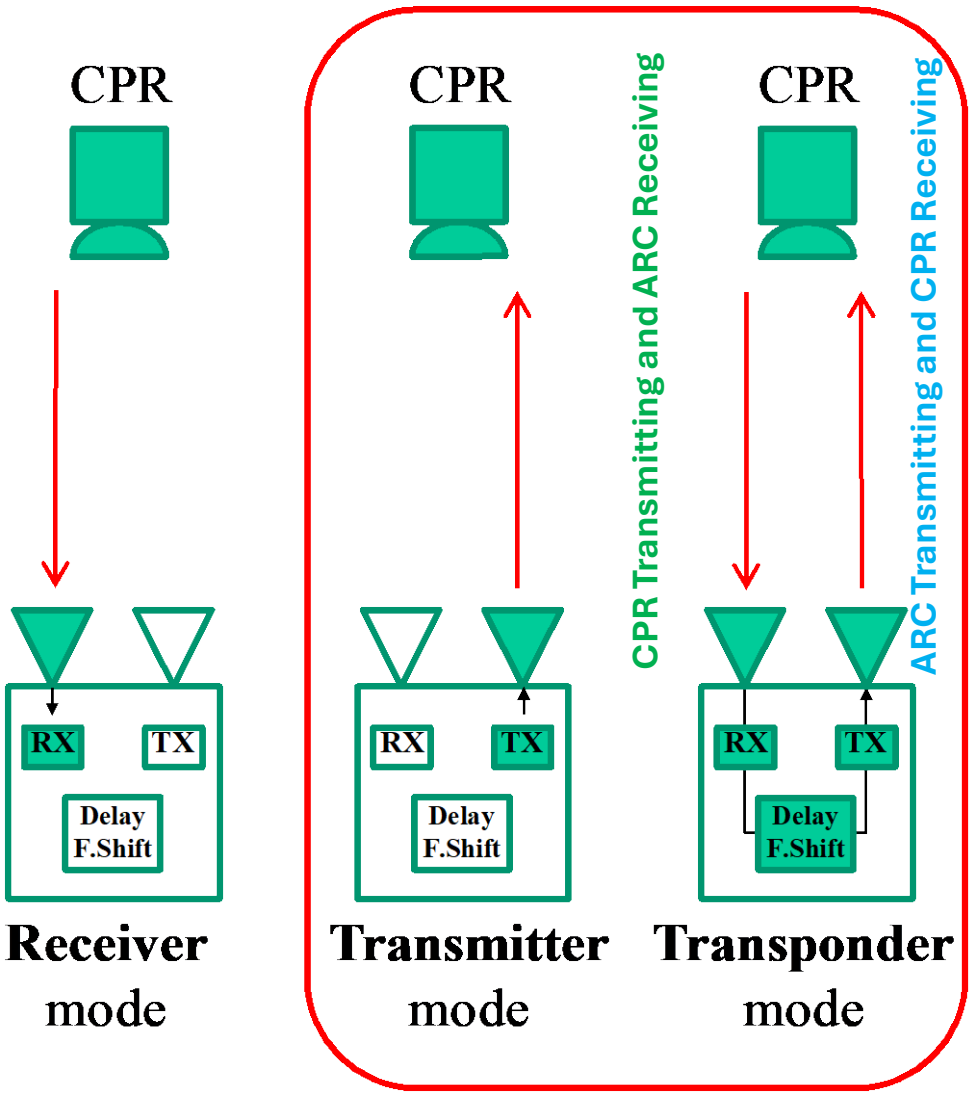
ARC: Active Radar Calibrator

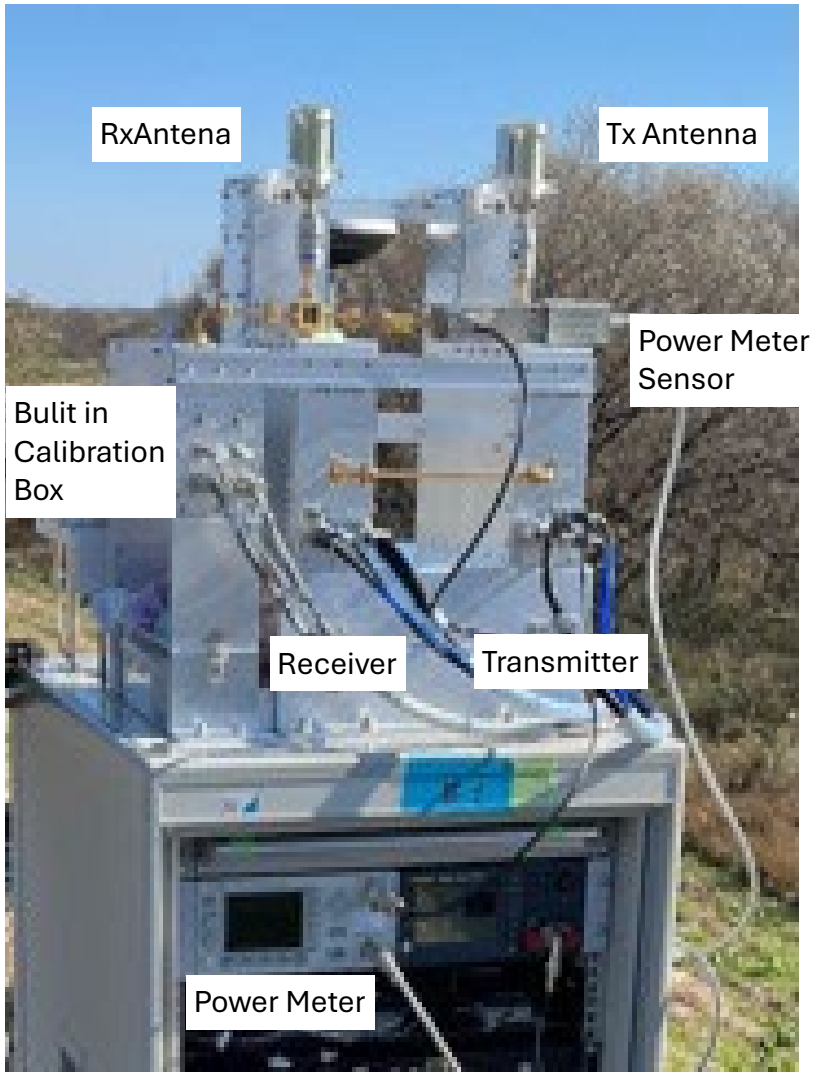


Beam Position Estimation



Active Radar Calibrator





External Calibration Activity

NICT conducts the external calibration using ARC (Active Radar Calibrator) for CPR at Tone-river area, which is needed to decide the exact values for CPR measurement.

The 7 ARC experiments had been performed.
Last 5 experiments data are available for CPR calibraion. Currently under evaluation for these data.


8/9


9/5


11/3


7/18


10/25


11/19


3/8


2/27


2/11


1/17


12/14

Nominal Orbit 1

Nominal Orbit 2

External Calibration Activity

ARC Experiment History

- N/A 2024/07/05 *Canselled due to HPT OFF*
- #00 2024/07/18 Not used to obtain radio station license
- #01 2024/08/09 *Failed due to wrong polarization*
- N/A 2024/08/29 *Canselled due to satellite track shifted*
- #02 2024/09/05 Succeed (Linear polarization)
- #03 2024/10/25 Succeed (doubtful due to Power Sensor failed**)
- #04 2024/11/03 Succeed (ARC#3 Power Sensor failed*)
- #05 2024/11/19 Succeed
- #06 2024/11/28 *Canselled due to HPT OFF*
- #07 2024/12/14 Succeed
- #08 2024/12/23 *Canselled due to HPT OFF*
- #09 2025/01/17 Succeed
- #10 2025/02/02 *Canselled due to bad weather*
- #11 2025/02/11 Succeed
- #12 2025/02/27 Succeed (ARC#1 Time Code was wrong)
- #13 2025/03/08 Succeed (Cloudy)
- #13 2025/03/24 Planned

no more valid

CPR-Tx, ARC-Rx Result

No	Date	Difference
#02	2024/09/05	-2.19dB
#03	2024/10/25**	-3.68dB
#04	2024/11/03*	-3.11dB
#05	2024/11/19	-2.60dB
#07	*2024/12/14*	*-2.30dB*

From this result until #05, Calibration Factor -2.4dB is proposed for CPR-Tx and measurement accuracy is 0.5dB.

Current Version of L1b (vCa) is used this Calibration Factor.

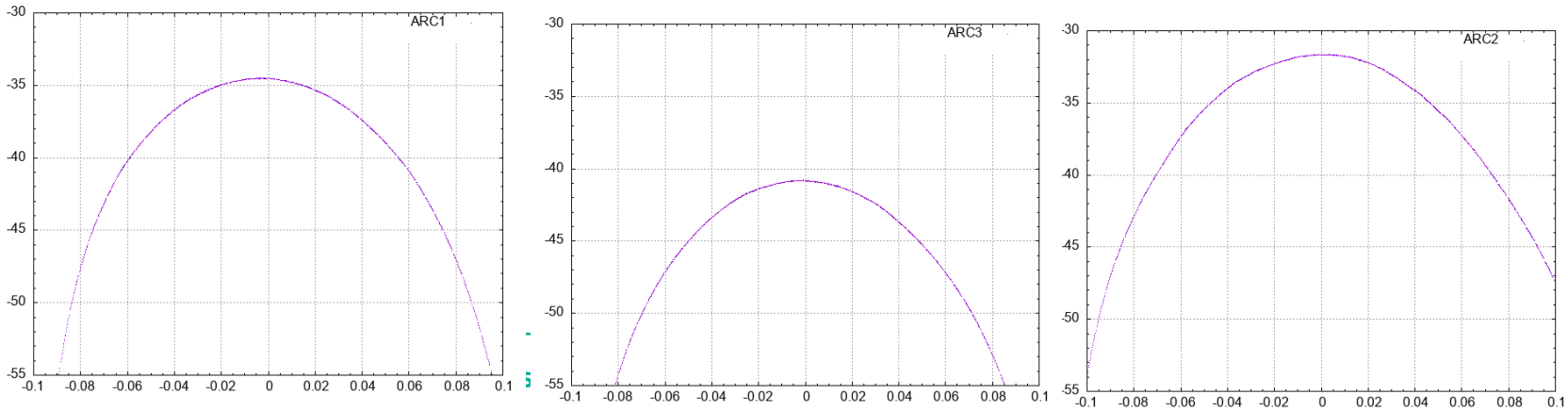
Methodlogy of ARC Calibration Activity

Estimation method for the system of CPR Transmitting and ARC Receiving

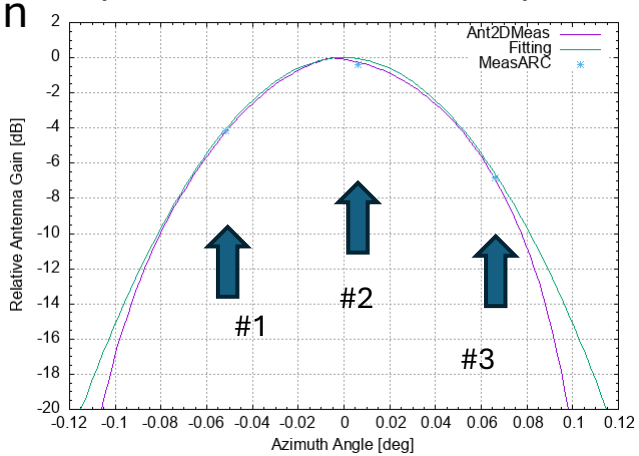
1. Each ARCs measure the time series of measured power, which is along track direction of satellite.
2. Convert to the along track angles from satellite altitude and velocity information, then peak powers are estimated for each ARCs (see figures below)
3. Each ARCs measure the exact location by GPS with correction (accuracy < 0.1m) then, cross-track angles from satellite are calcurated using restituted orbit data.
4. The peak received power at the ground is estimated the fitting antenna pattern for the cross-track direction. (see figure bottom-right)
5. Expected received power by ARC is calcurated by Friis transmission equation
6. Compare measured peak power and expected received power, and the correction factor is defined.

Friis transmission equation

$$P_r = \left(\frac{\lambda}{4\pi r}\right)^2 G_t G_r P_t L$$



Antenna pattern fitting (cross-track direcion)

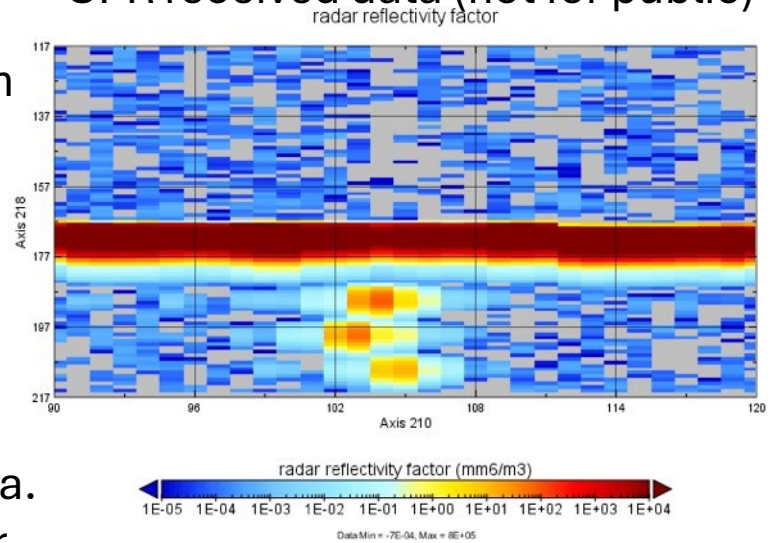


Methodlogy of ARC Calibration Activity

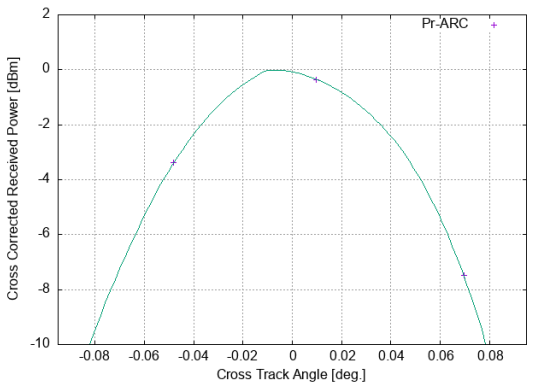
Estimation method for the system of ARC Transmitting and CPR Receiving

- Each ARCs transmit signal with the different delay time, so it can be distinguish each ARC signals from CPR Level 1 received signal data (see figure right).
- The peak power from each ARCs is estimated by the renge profile. (see figure bottom-right)
- The peak power corrected for the integrateion effect at the CPR on-board.
- Each ARCs measure the exact location by accurate GPS receiver (accuracy < 0.1m)
  then, cross-track angles from satellite are calcurated using restituted orbit data.
- The peak received power at the CPR is estimated the fitting antenna pattern for the cross-track direction. (see figure below)
- Expected received power by CPR is calcurated by Friis transmission equation
- Compare measured peak power and expected received power, and the correction factor is defined.

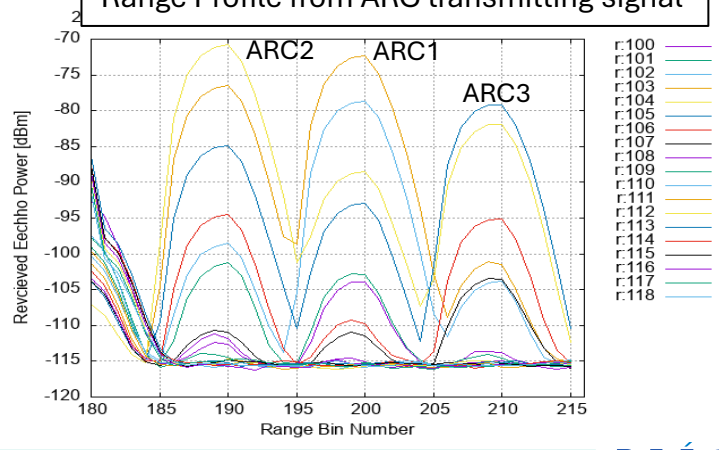
CPR received data (not for public)



Antenna pattern fitting
(cross-track direcion)



Range Profile from ARC transmitting signal



Result of ARC External Calibration

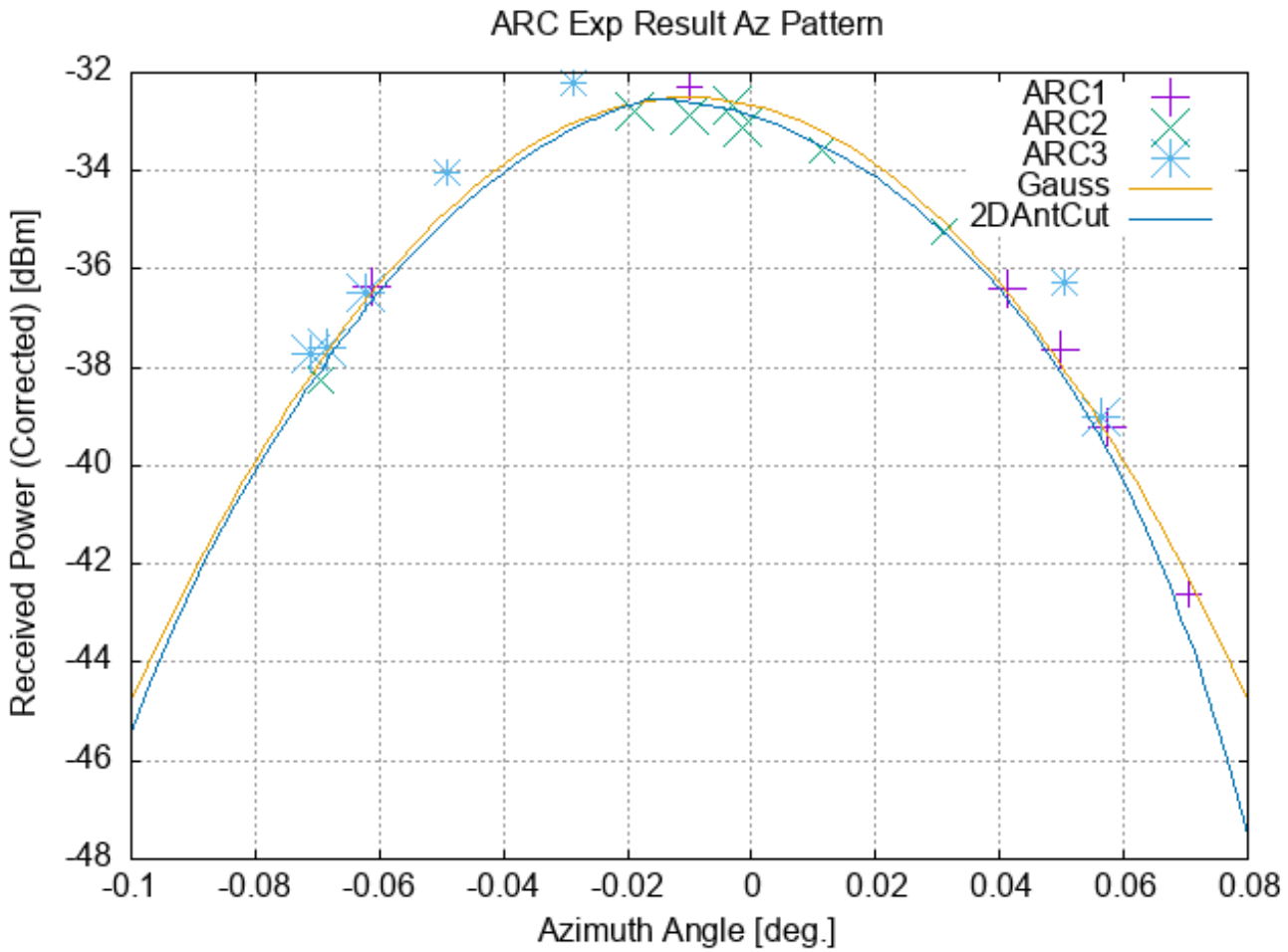
The difference between measured and expected value for the system of CPR transmission and ARC reception

The difference value for the system of ARC transmitting and CPR reception

CPR Tx → ARC Rx
Factor: **-1.94 dB**

ARC Tx → CPR Rx
Factor: **-2.06 dB**

CPR Transmitting Antenna Pattern Reconstruction



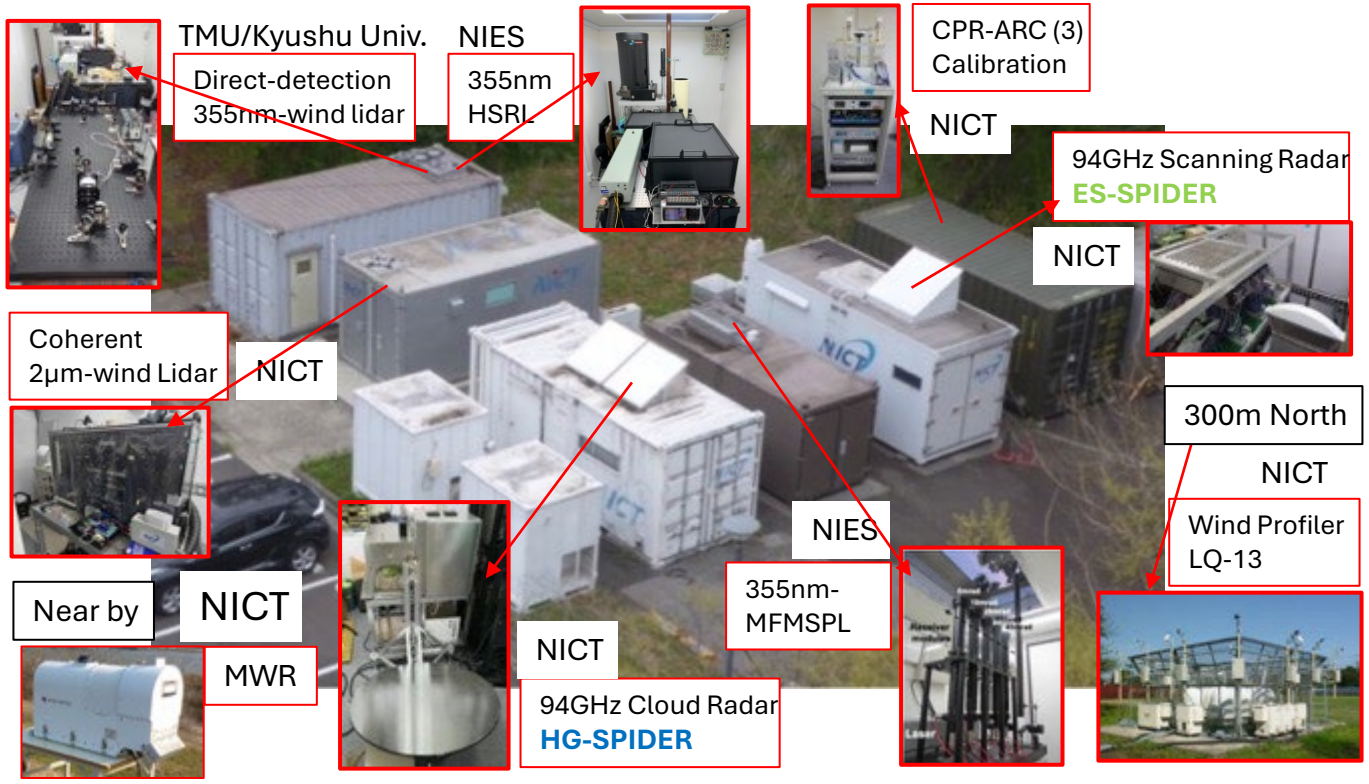
All measurement data is plotted from Sep. 2024 to the antenna pattern obtained by system test

Gauss pattern: same as beam width

Only 3 data are out from antenna pattern due to ARC calibration error due to failed power sensor.

NICT Koganei (Validation Super Site in Japan)

NICT W-band Cloud Radar for Validation at Koganei Super Site

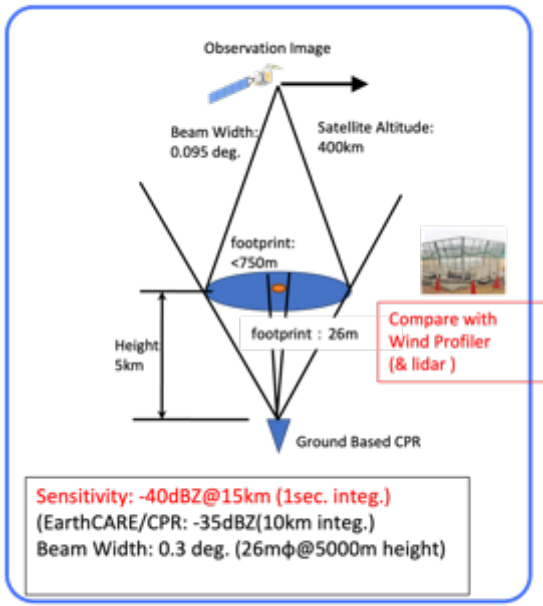


In addition, many Lidars (NICT, NIES, TMU and Kyushu-U) and oether instruments* are operated here.
* MicroWave Radiometer, Wind Profilier, Sky-Camera, etc.

Compare using ground-based radar for Z factor and Doppler Velocity.

Evaluate NUBF for Doppler Velocity measurement.

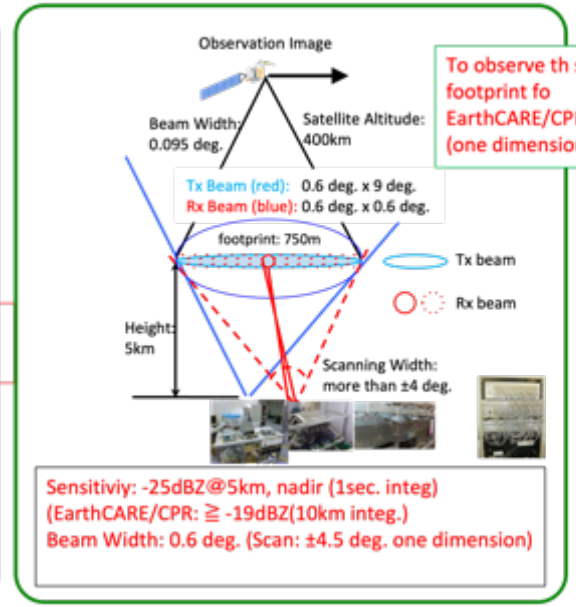
High-sensitivity Ground-based CPR (HG-SPIDER)



To Validate Reflectivity(Z) and Doppler Velocity

Sensitivity -40dBZ @ 15km height
for integration 1 seconds

Electronic-Scanning CPR (ES-SPIDER)



To Evaluate non-uniformity with antenna footpring

One Dimentional Scanning
750m @ 5 km height
Sensitivity: -26dBZ @ zenith
-20dBZ @ scan edge

CPR L1b Validation

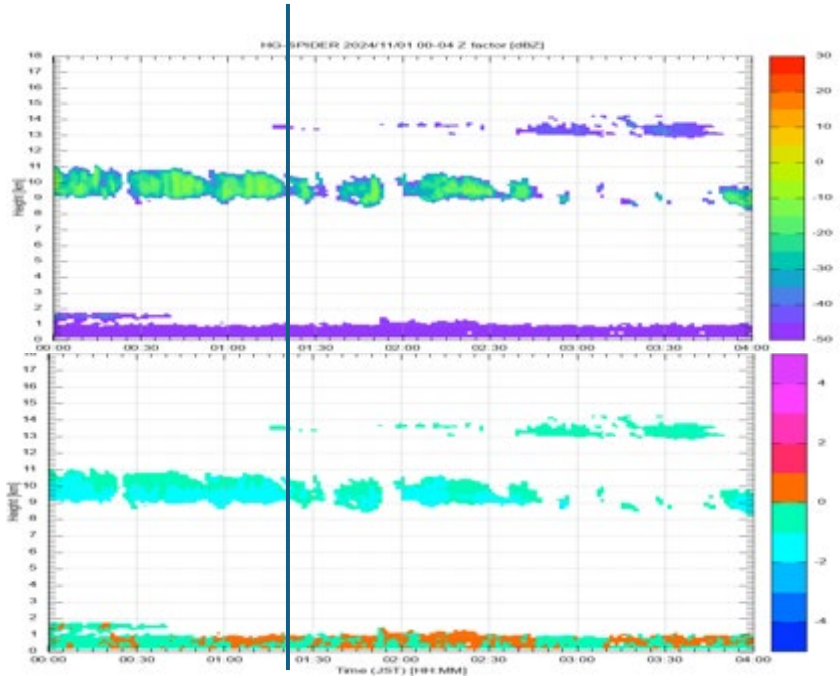
10/25 distance: 6.4km

◯ Machup with HG-SPIDER at NICT Koganei (direct comparison)

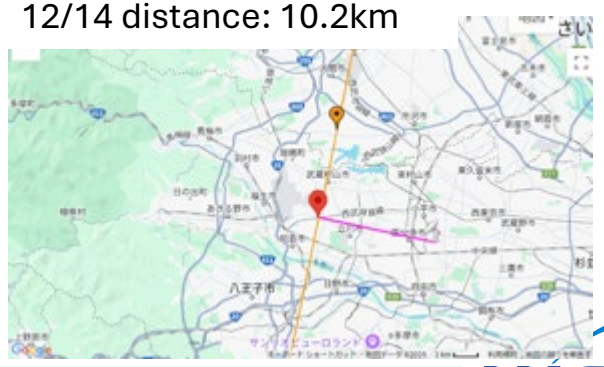
- 10/06 Ascending (no cloud echo)
- 10/25 Descending (cloud echo exist, distance: 6.4km)
- 11/01 Ascending (not enough cloud echo, distance: 8.1km)
- 12/14 Descending (not enough cloud echo, distance: 10.4km)

11/01 distance: 8.1km

CPR L1b 11/01 HG-SPIDER



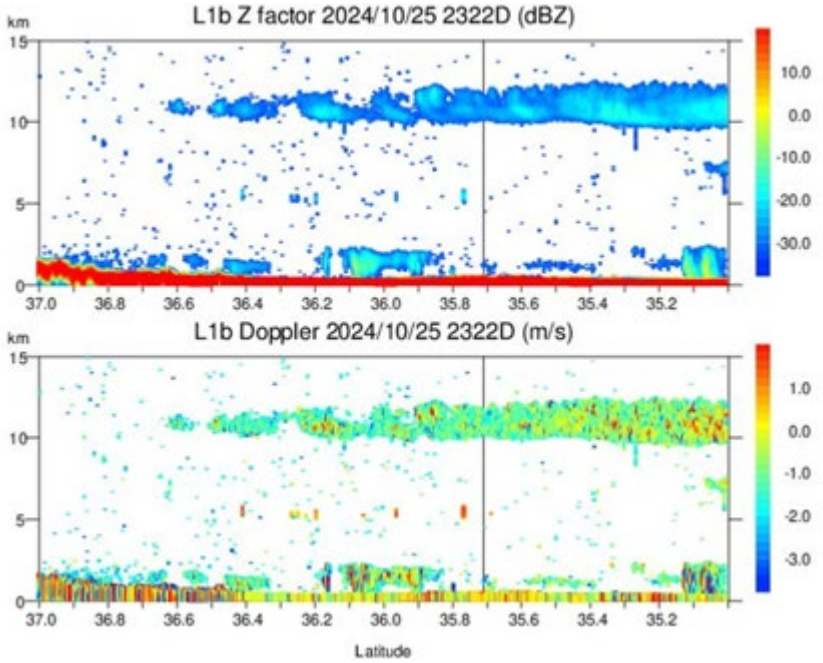
12/14 distance: 10.2km



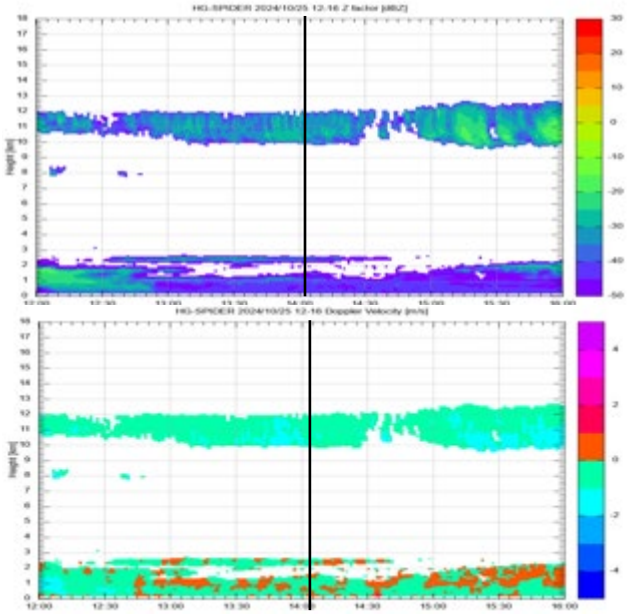
CPR L1b Validation (HG-SPIDER)

2024/10/25 Distance: 6.4km

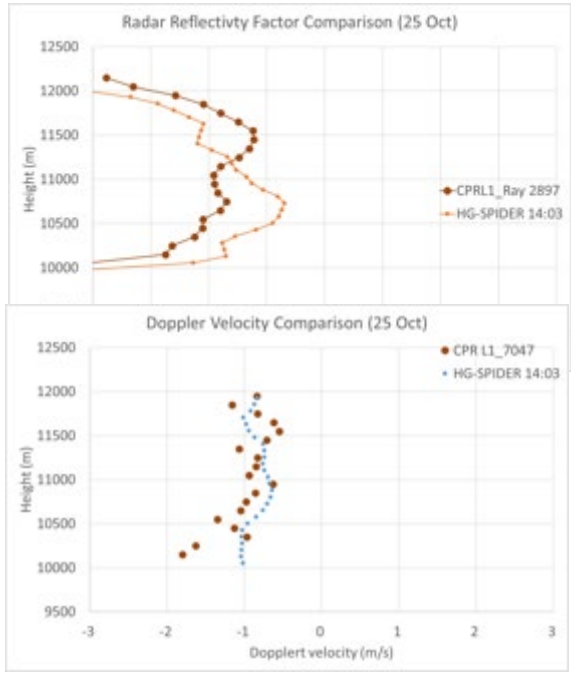
CPR L1b Before Correction



HG-SPIDER



Vertical Profile



Zfactor

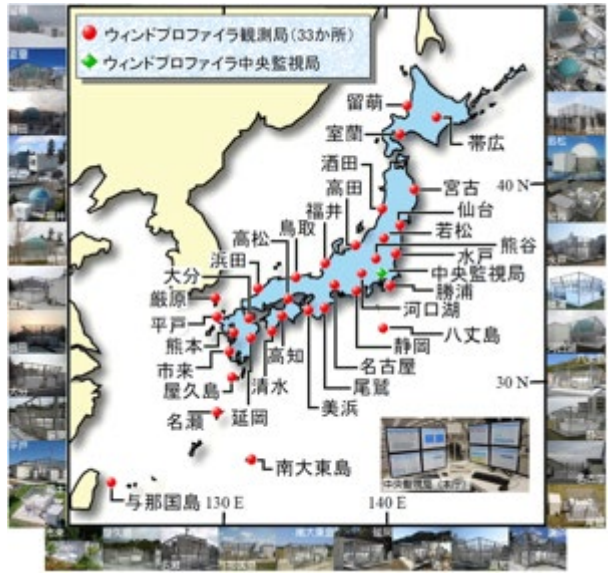
Vd

For direct comparison, the distance is slightly large for considering as the same cloud systems.
Statistics comparing is also cosidered.

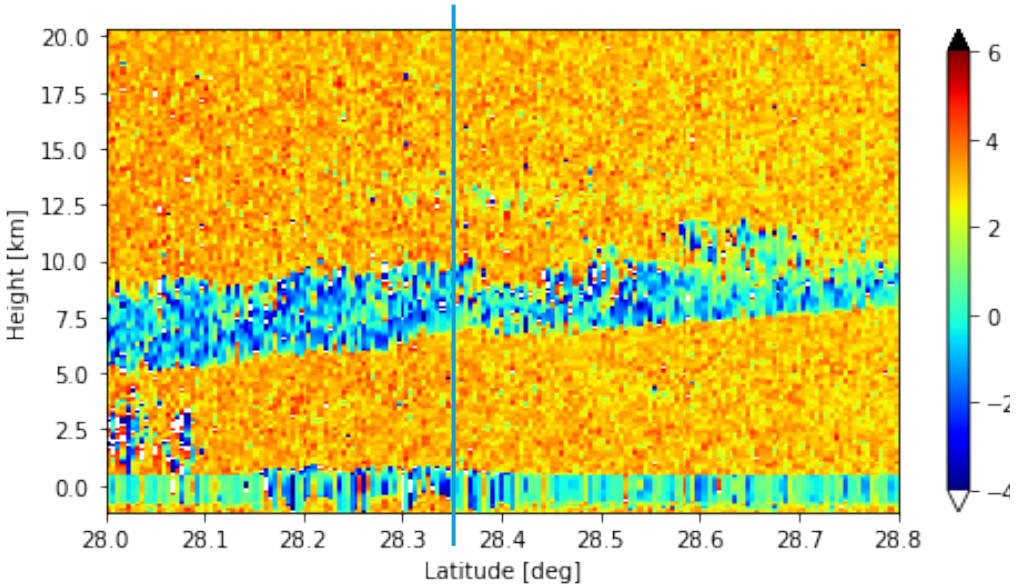
CPR L1b Validation (WINDAS)

- WINDAS（WInd profiler Network and Data Acquisition System） are pperated by JMA (Japan meterological agency) for 33 locations in Japan (Right figure). The observation period is 10 minutes.
- Matchup scene with WINDAS is only one times for July to September showed below, but it is 5 times for Octorbar.

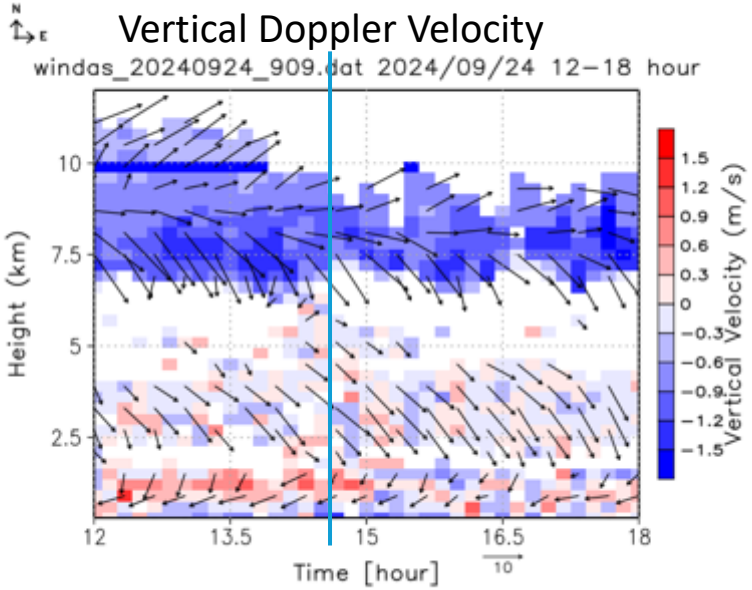
WINDAS Location



CPR Doppler Velocity



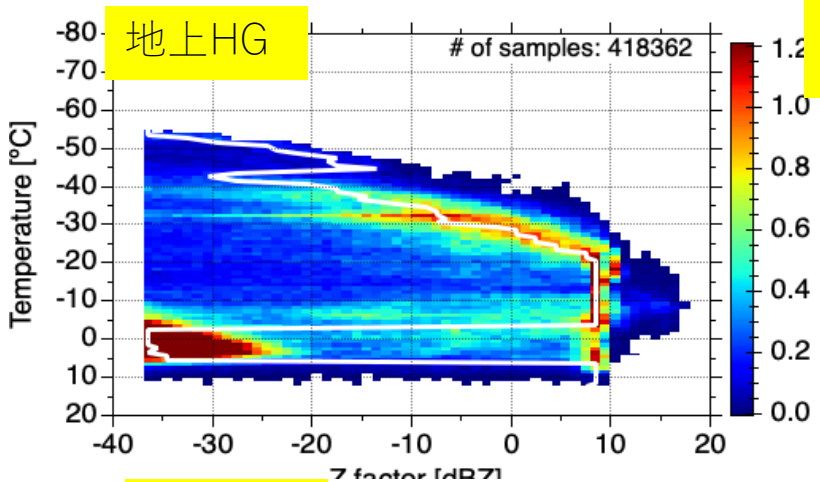
WINDAS Naze Site
Vertical Doppler Velocity

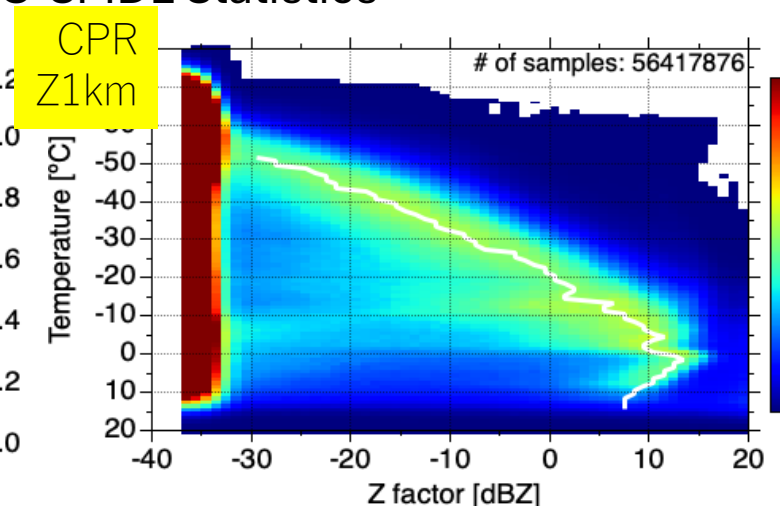


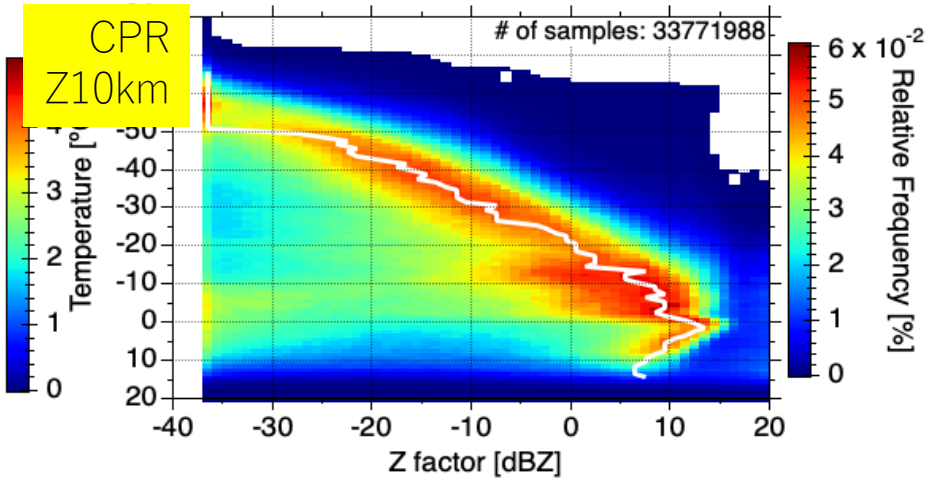
L2 Validation (Z factor & Doppler Velocity Statistics)

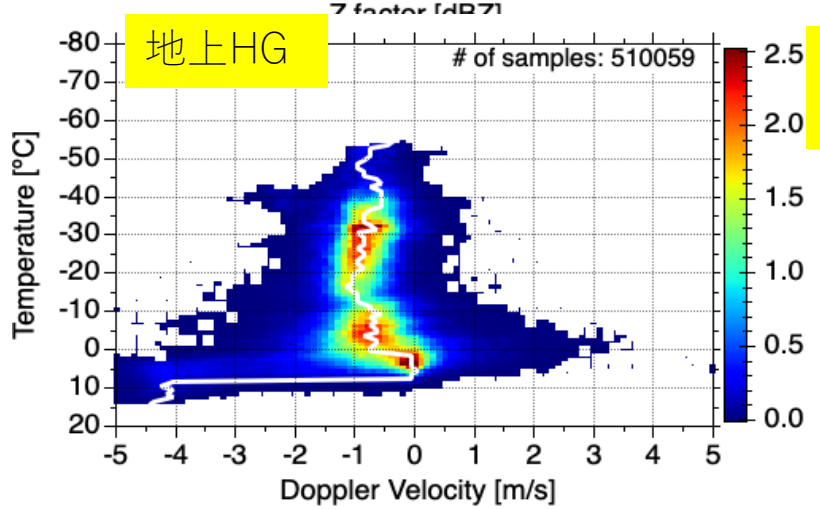
Comparison CPR Statistics and HG-SPIDE Statistics

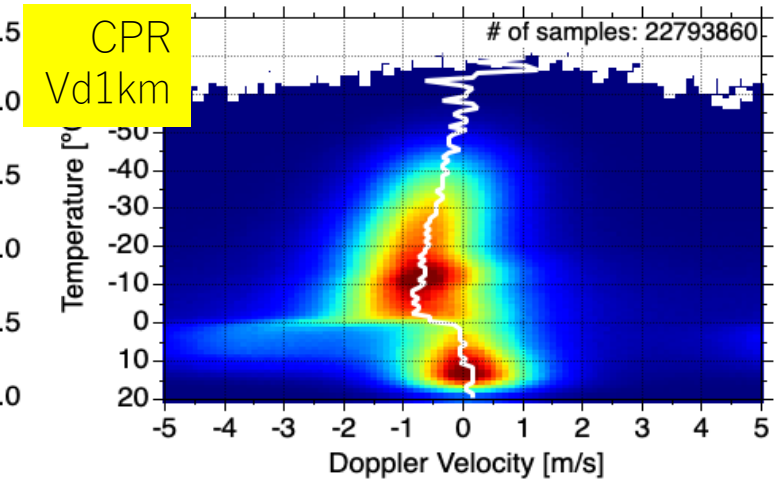
2025/01 L2a (equiv. vCa)

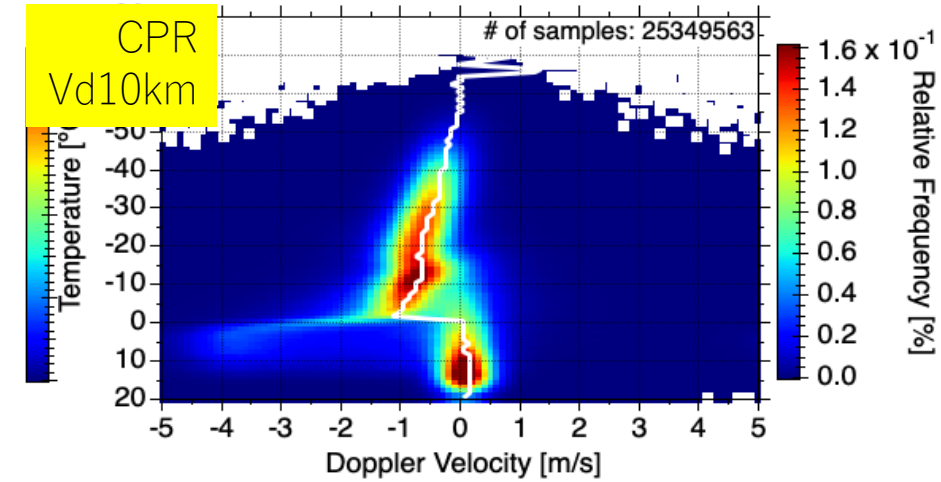








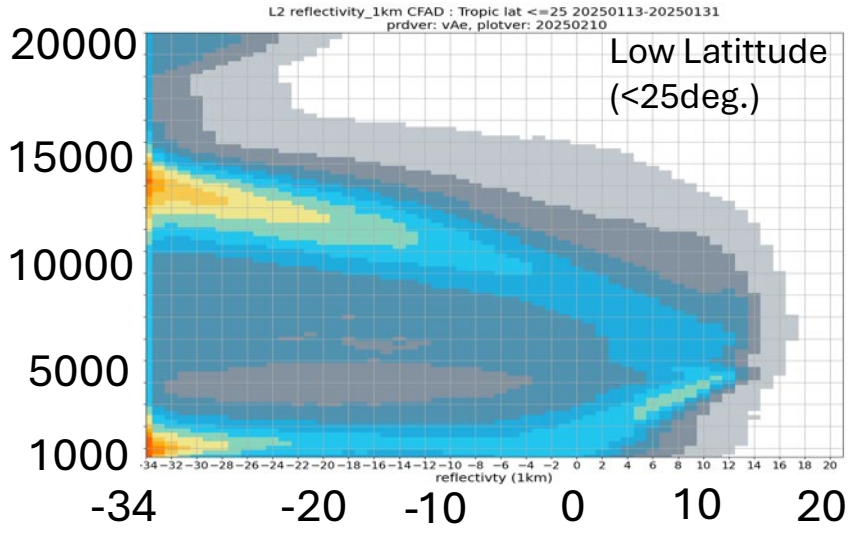


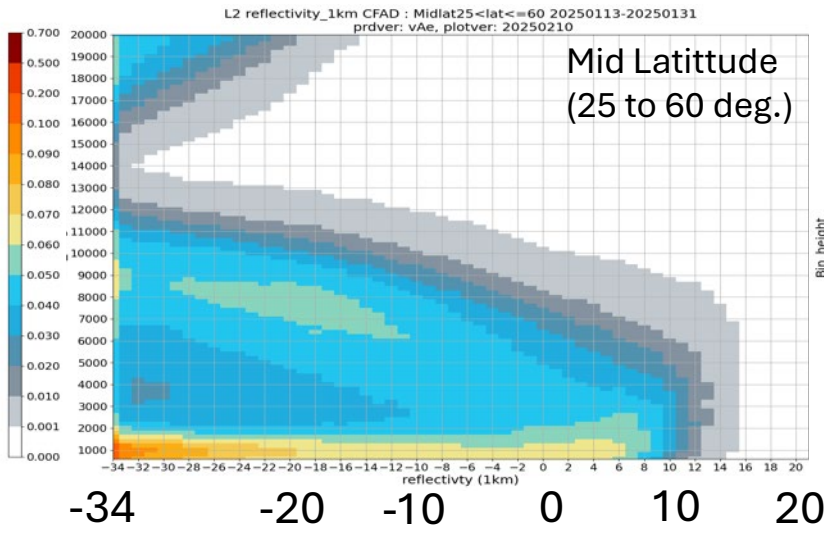


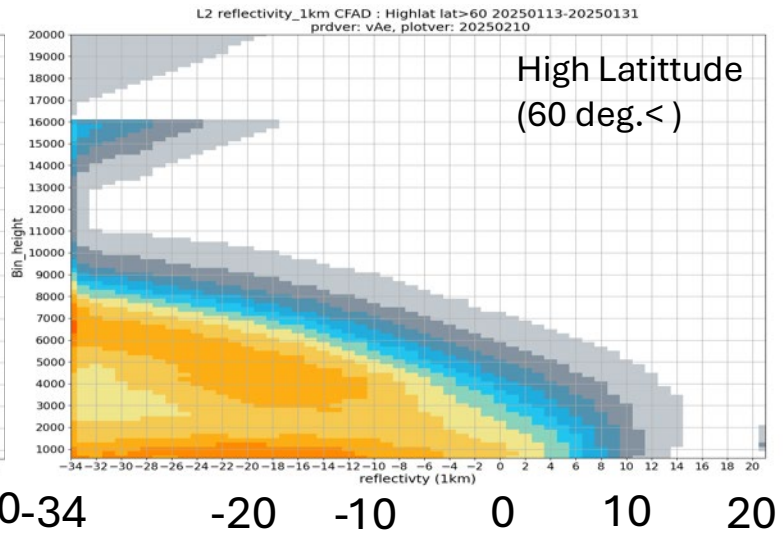
See Y. Hagihara's Presentation

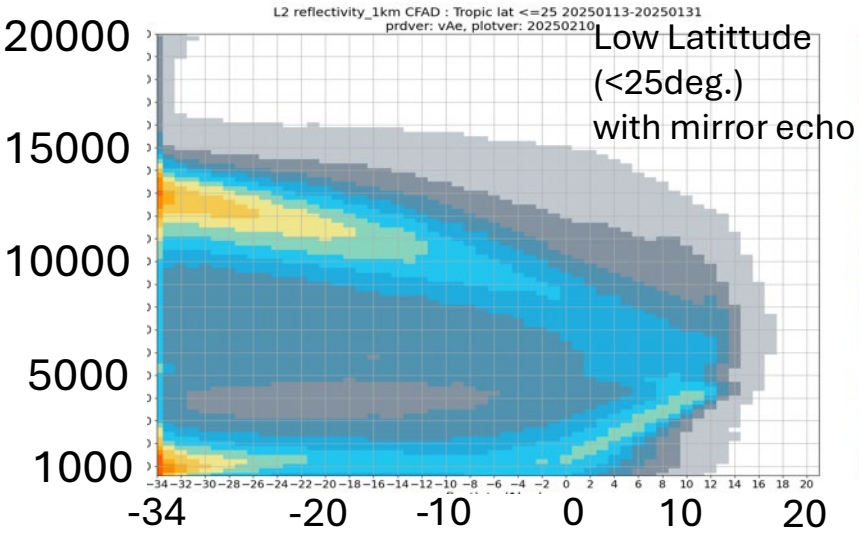
L2 Validation (mirror echo flag)

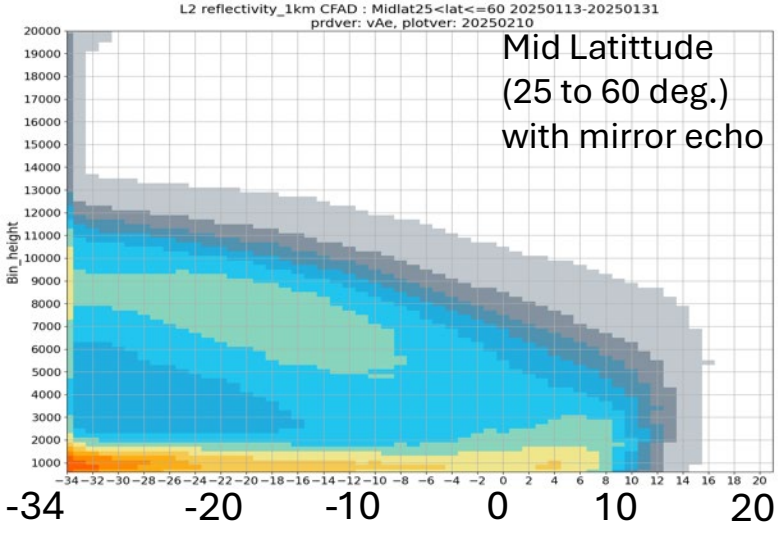
1km integration

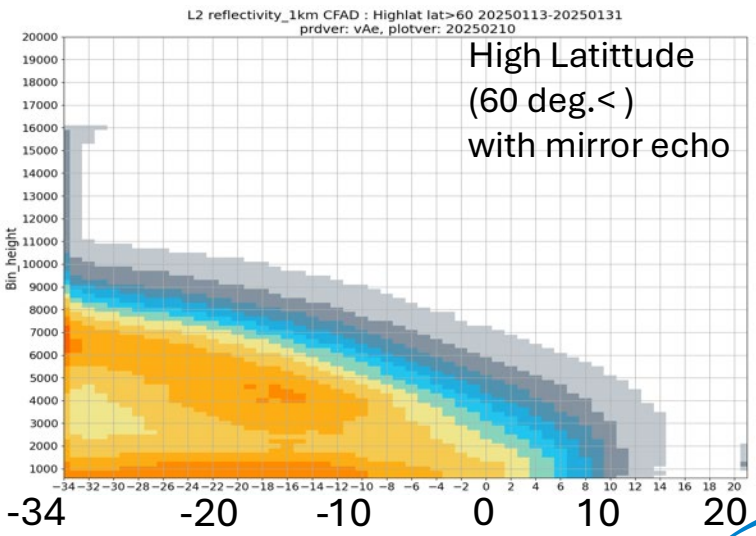








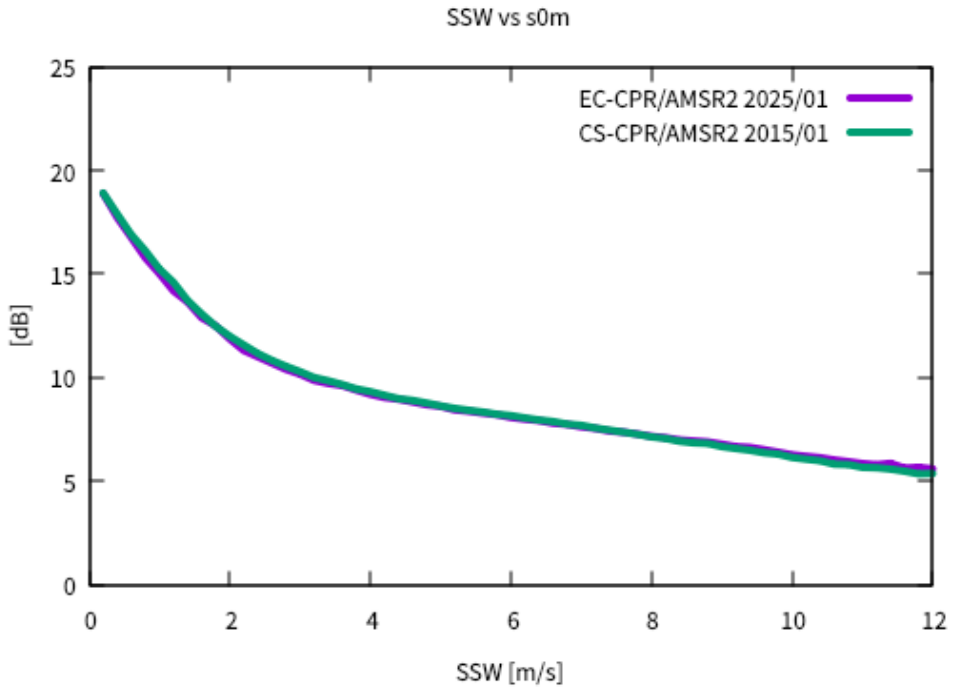




See S. Aoki's Presentation

L2 Validation (NRCS)

Sea Surface NRCS on wind speed 7-8m/s



CloudSat 2015/01
EarthCARE/CPR 2025/01
Equivalent to vBa (Calibration factor is implemented)

Cloud/Precipitation Echo data are excluded
Not corrected Gas attenuation

Almost same values (difference ～ 0.2-0.3dB)

See K. Kanemaru's Presentation

Summary

- Explained CPR calibration concept
- The result of CPR ARC externcal calibration is implemented current L1b data (vCb)

  CPR Tx: -1.94dB, CPR Rx: -2.04dB
- Introduced CPR L1b/L2a Zfactor and Vd Validation with HG-SPIDER (direct comparison)
- Introduced CPR L2a NRCS data comparison with that of cloudsat
- Introduced CPR L1b Vd Validation with WINDAS

Acknowledgment

This work was supported by the 'Promotion of observation and analysis of radio wave propagation' fund of the Ministry of Internal Affairs and Communications, Japan.