CPR Calibration

H. Horie, Y. Ohno, K. Kanemaru,
Y. Hagihara and H. Hanado
NICT

1st ESA-JAXA EarthCARE In-Orbit Validation Workshop
14 – 17 January 2025 | VIRTUAL EVENT

CPR Overview

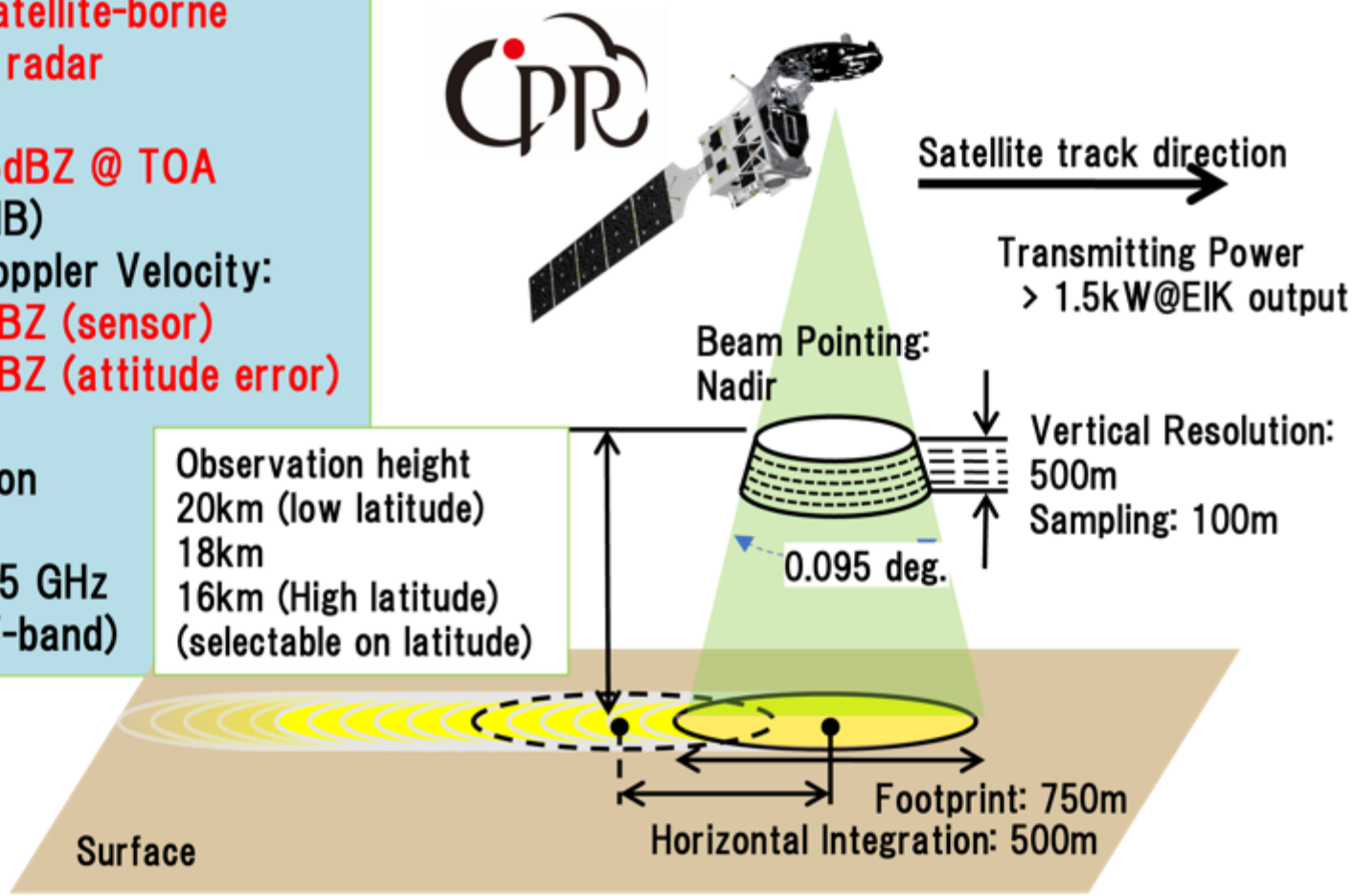
CPR: The first satellite-borne Doppler weather radar

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 Theory (On-board Calibration)

- Before launch, CCDB (Calibration Characterization DataBase) is established form system test.
- During level 1 processing, obtained data is converted by temperature telemetry and CCDB.
- 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 Calibration

- CPR antenna beam pointing measurement (enough for cloudy day)
- CPR transmitter and receiver measurement individually (need sunny day)

Sea Surface Calibration

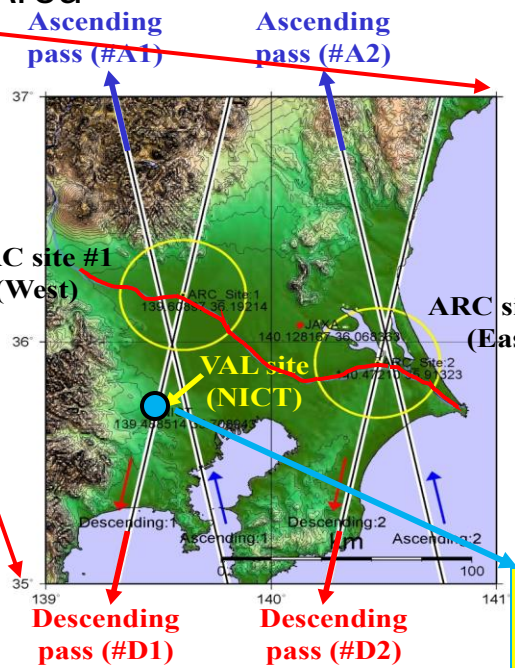
- CPR Overall Sensitivity measurement

CPR ARC Calibration

CPR Calibration Area

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

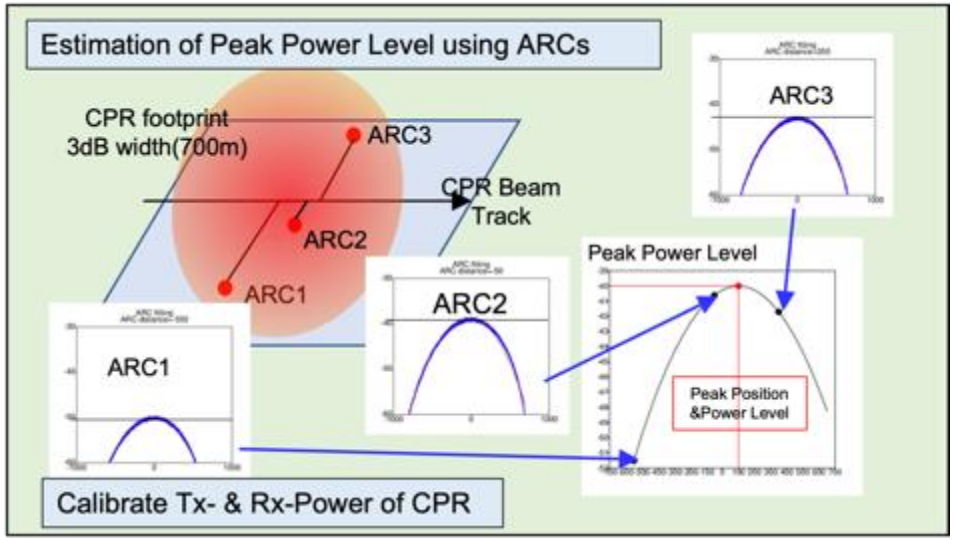
Kanto Area



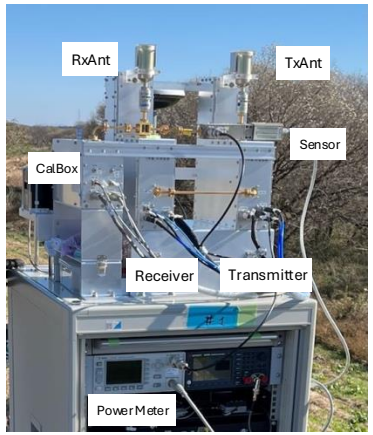
ANXLongitude:0.60 degrees
ARC experiment: 2 times / one repeat cycle (25days, 389 orbits)

In addition, SEA SURFACE CALIBRATION is perforemed.

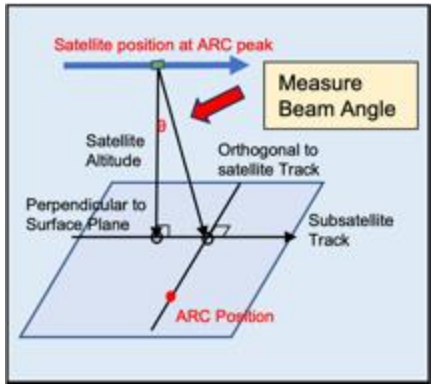
Peak Level Estimation using ARC



ARC: Active Radar Calibrator

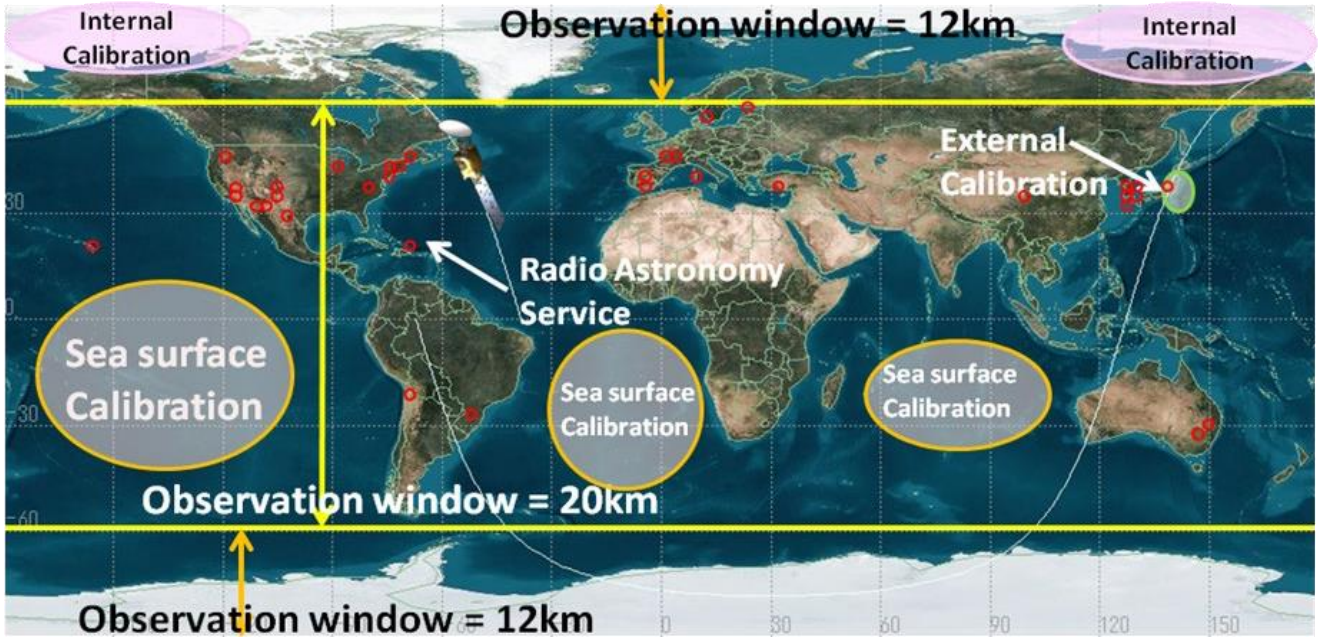


Beam Position Estimation



CPR Sea Surface Calibration using Roll manouevar operation

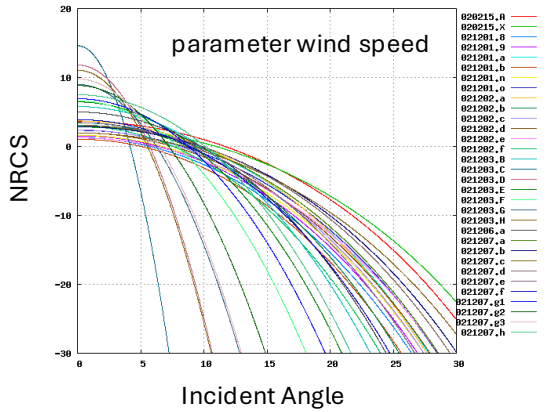
Sea Surface Calibration Area (far from RAS site)



Spacecraft operates roll manouevar operation which is that its roll angle changing constant angular velocity from 0 to 10 dregree.

Sea Surface Calibration

- Using Sea Surface Scattering mode, S^2 and $|R(0)|^2$ are function of wind speed, and created empirical formula using SPIDER data.



Sea Surface Scattering Model

$$\sigma^0 = \frac{|R(0)|^2}{s^2} \times \frac{1}{\cos^4 \theta} \exp\left(-\frac{\tan^2 \theta}{s^2}\right)$$

σ^0: Normarized Radar Cross Section
θ: incident angle to sea surface
s^2: Mean Square Slope (as function of surface wind speed)
R(0): Fresnel Coefficeint (as function of suface wind and temperature) (Valenzuela, 1978)

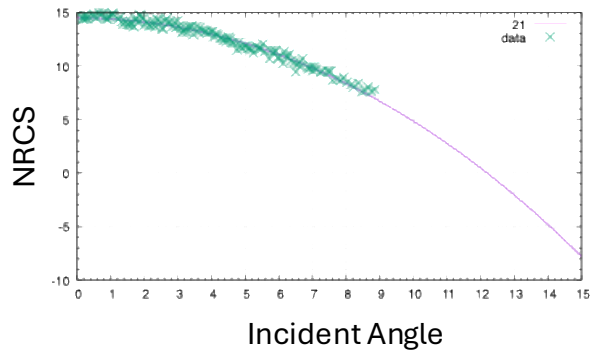
CPR Sea Surface Calibration using Roll manouevar operation

Sea Surface Calibration Method

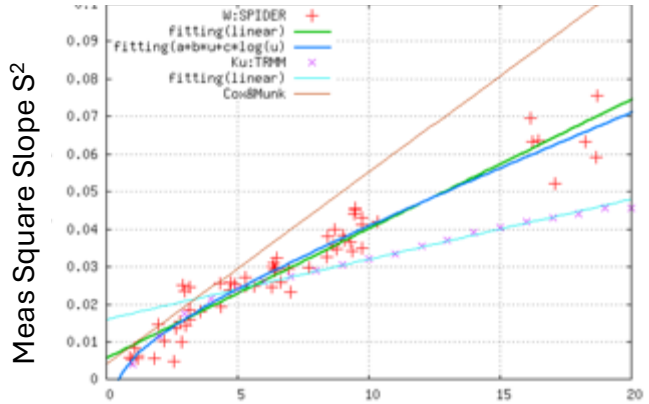
- From meaurment result, S2 is calculated with fitting.
- From S2, wind speed is esitmated from empirical model.
- From wind speed, R(0) and NRCS is calculated from emprirical model.
- Compare estimated NRCS and measurde NRCS, the result is to be calibration factor.

(For L1b data, atmospheric attenuation is not corrected.)

Example of measurement data



Emprical Model form SPIDER (attenuation is corrected.)

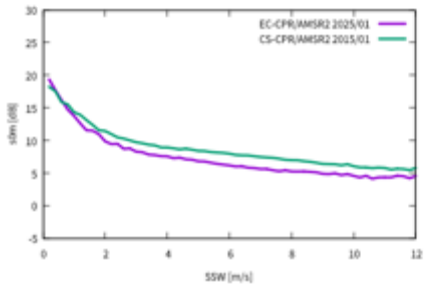


Sea Surface Scattering Model

$$s^0 = \frac{|R(0)|^2}{s^2} \times \frac{1}{\cos^4 q} \exp\left(-\frac{\tan^2 q}{s^2}\right)$$

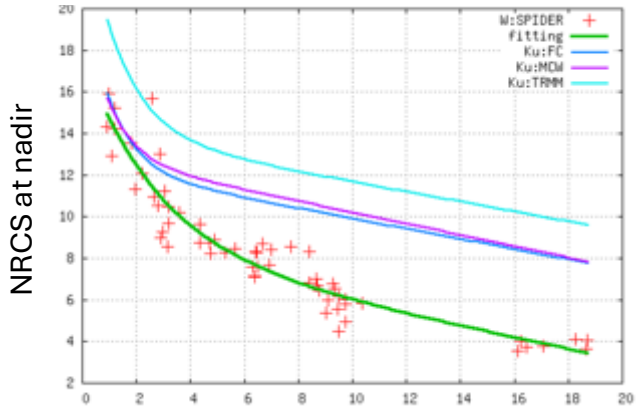
σ^0: Normarized Radar Cross Section
θ: incident angle to sea surface
s^2: Mean Square Slope (as function of surface wind speed)
R(0): Fresnel Coefficeint (as function of suface wind and temperature)
(Valenzuela, 1978)

NRCS (CPR & CloudSat)



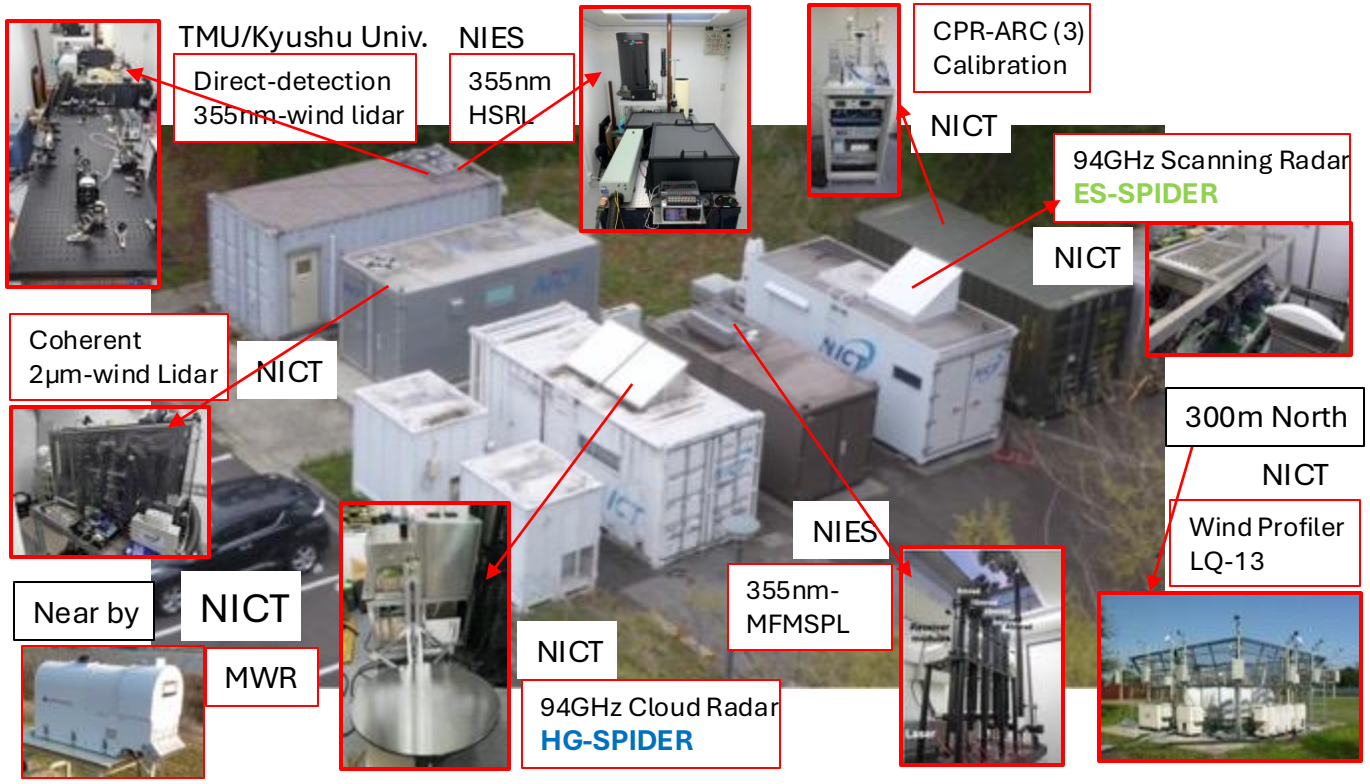
Comparison with cloudat
-> Kanemaru presentaion

Emprical Model form SPIDER (attenuation is corrected.)



NICT Koganei (Validation Super Site in Japan)

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

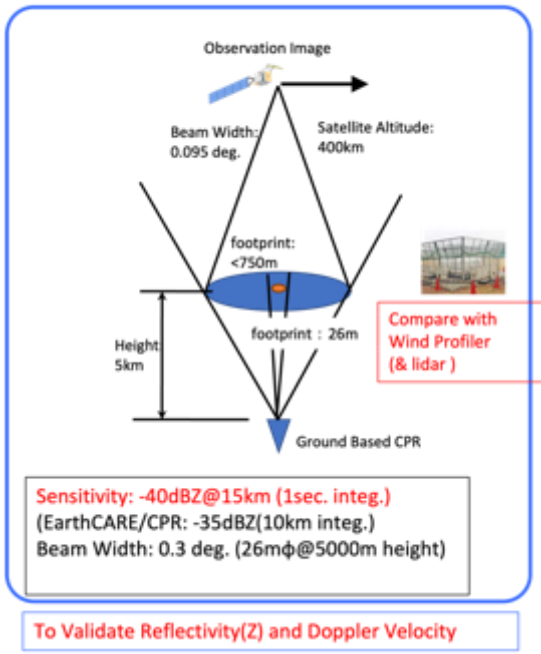


In addition, many Lidars (NICT, NIES, TMU and Kyushu-U) and oether instruments* are operated here.
* MicroWave Radiometer, Wind Profilier, Sky-Camera, etc.

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

Evaluate NUBF for Doppler Velocity measurement.

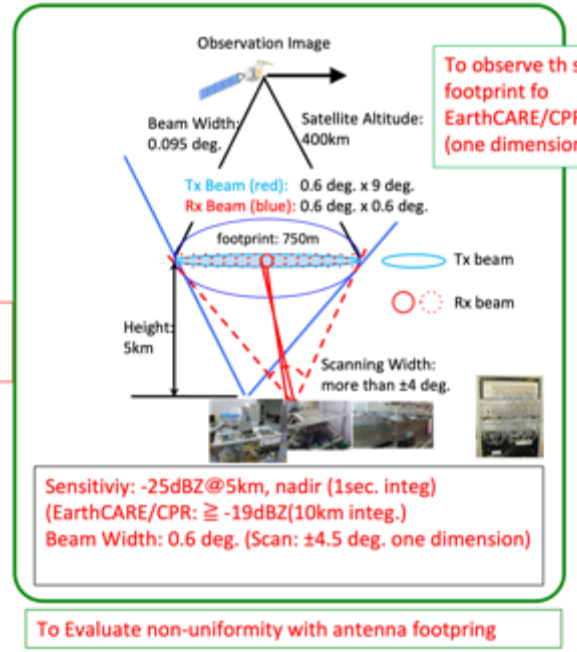
High-sensitivity Ground-based CPR (HG-SPIDER)



To Validate Reflectivity(Z) and Doppler Velocity

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

Electronic-Scanning CPR (ES-SPIDER)

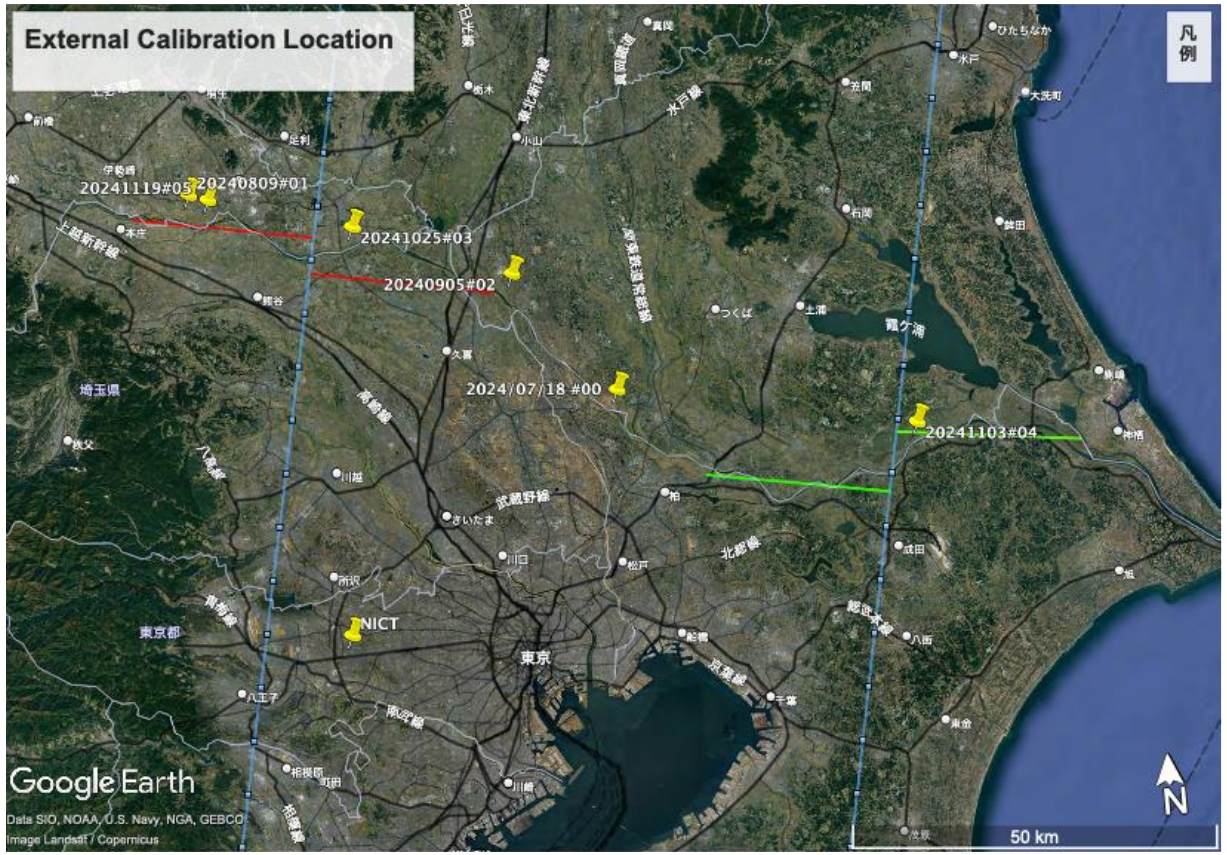


To Evaluate non-uniformity with antenna footpring

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

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.



Nominal Orbit 1

Nominal Orbit 2

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

12/14

11/19

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 Planned
- #10 2025/02/02 Planned

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*

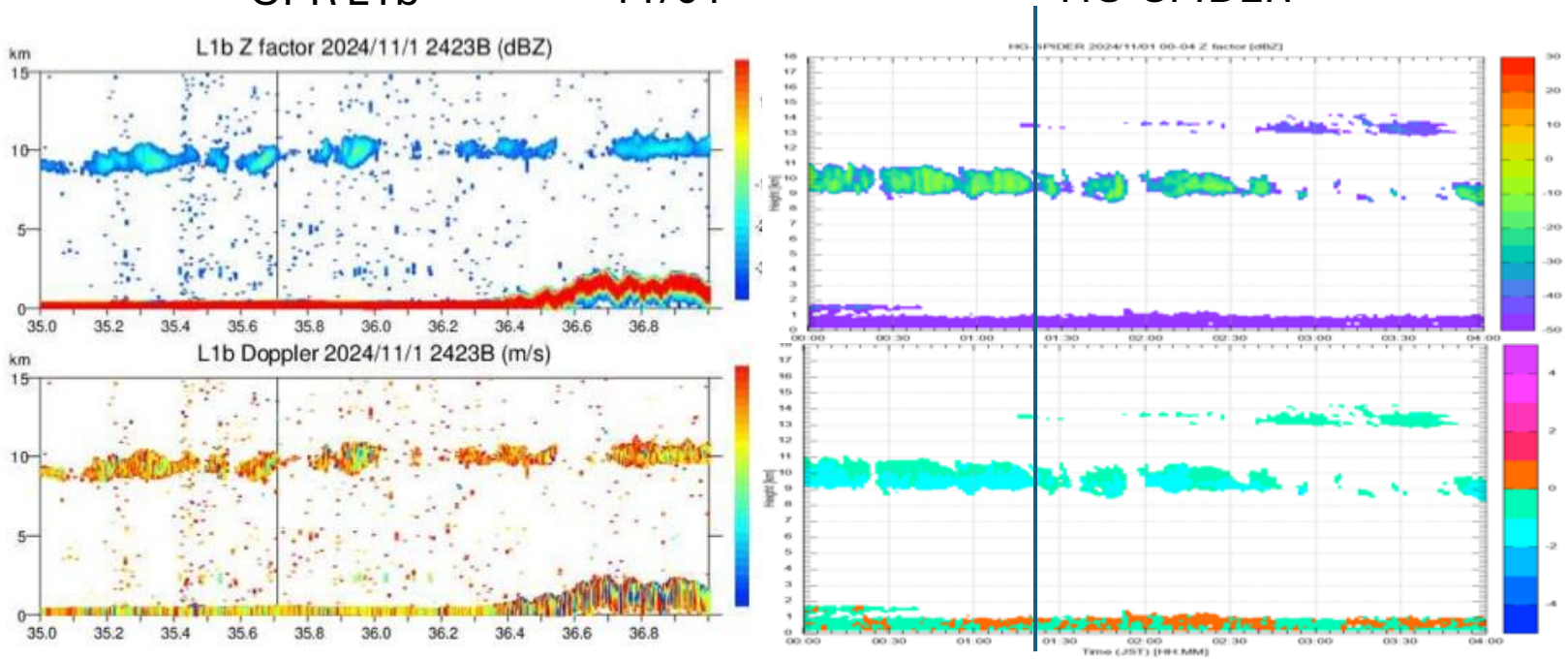
From this result until #05, Calbration Factor -2.4dB is proposed for CPR-Tx and measurement accuracy is 0.5dB.

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

CPR L1b Validation

◯ 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)

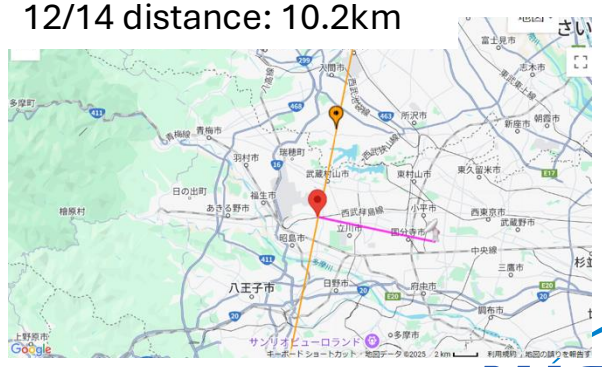
CPR L1b 11/01 HG-SPIDER



10/25 distance: 6.4km

11/01 distance: 8.1km

12/14 distance: 10.2km

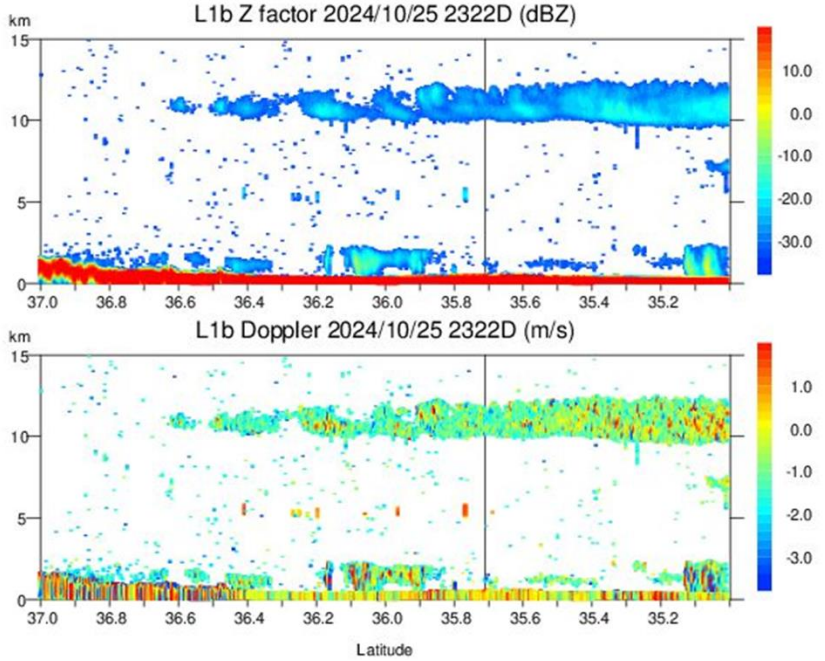


CPR L1b Validation (HG-SPIDER)

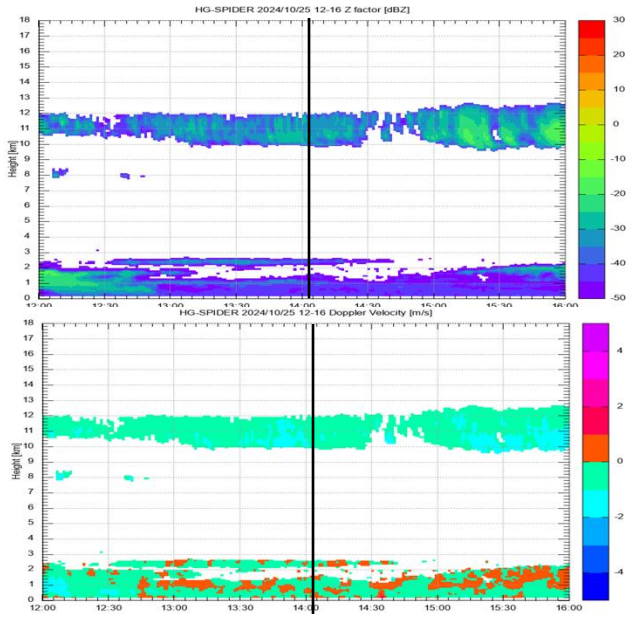
2024/10/25 Distance: 6.4km

CPR L1b

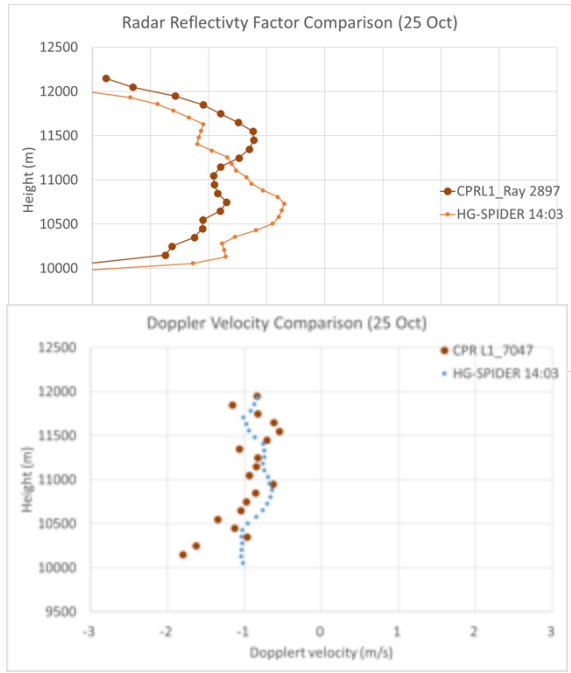
Before Correction



HG-SPIDER



Vertical Profile



Zfactor

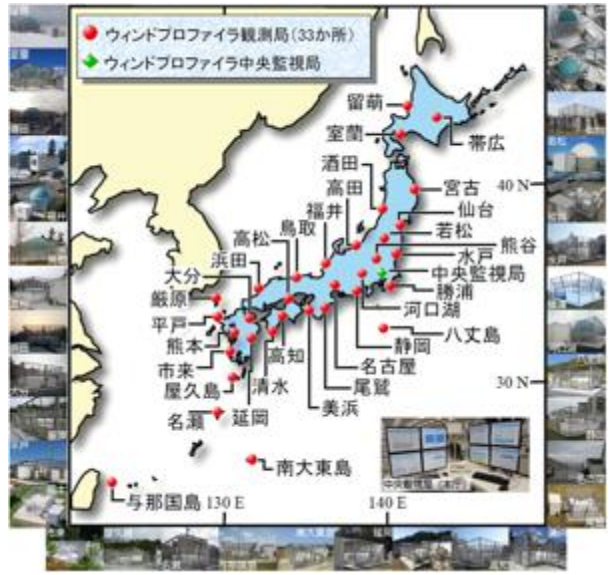
Vd

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

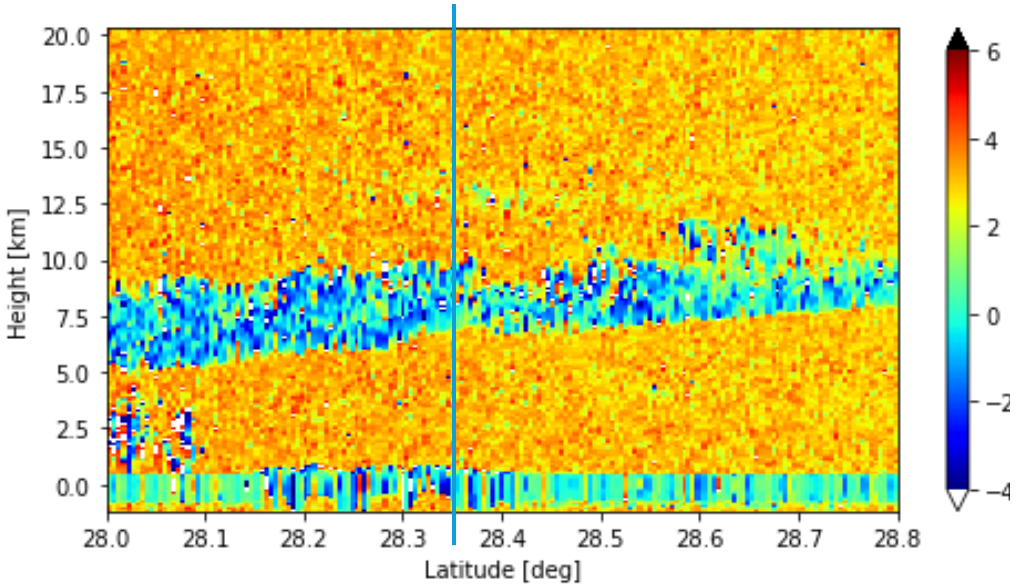
CPR L1b Validation (WINDAS)

- 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.

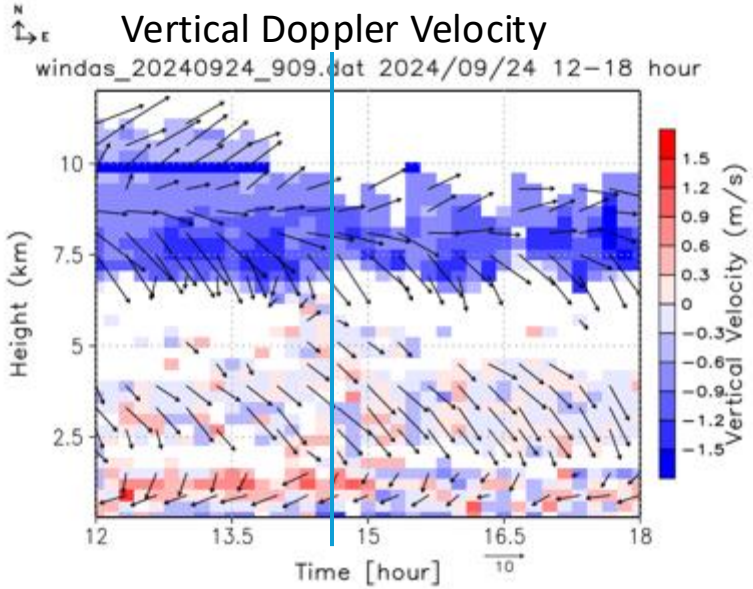
WINDAS Location



CPR Doppler Velocity



WINDAS Naze Site
Vertical Doppler Velocity



(by. Ohno) → Ohno-san's talk

Summary

- Explained CPR calibration concept
- Explained ARC externcal calibration concept and results
- Explained Sea surface calibration concept
- Introduced CPR L1b Zfactor and Vd Validation with HG-SPIDER (direct comparison)
- Introduced CPR NRCS data comparison with that of cloudsat
- Introduced CPR L1b Vd Validation with WINDAS