DPR algorithm status

- Current Status of the Dual-frequency Precipitation Radar (DPR) Algorithm Development -

Toshio Iguchi (NICT)

PMM meeting, Annapolis

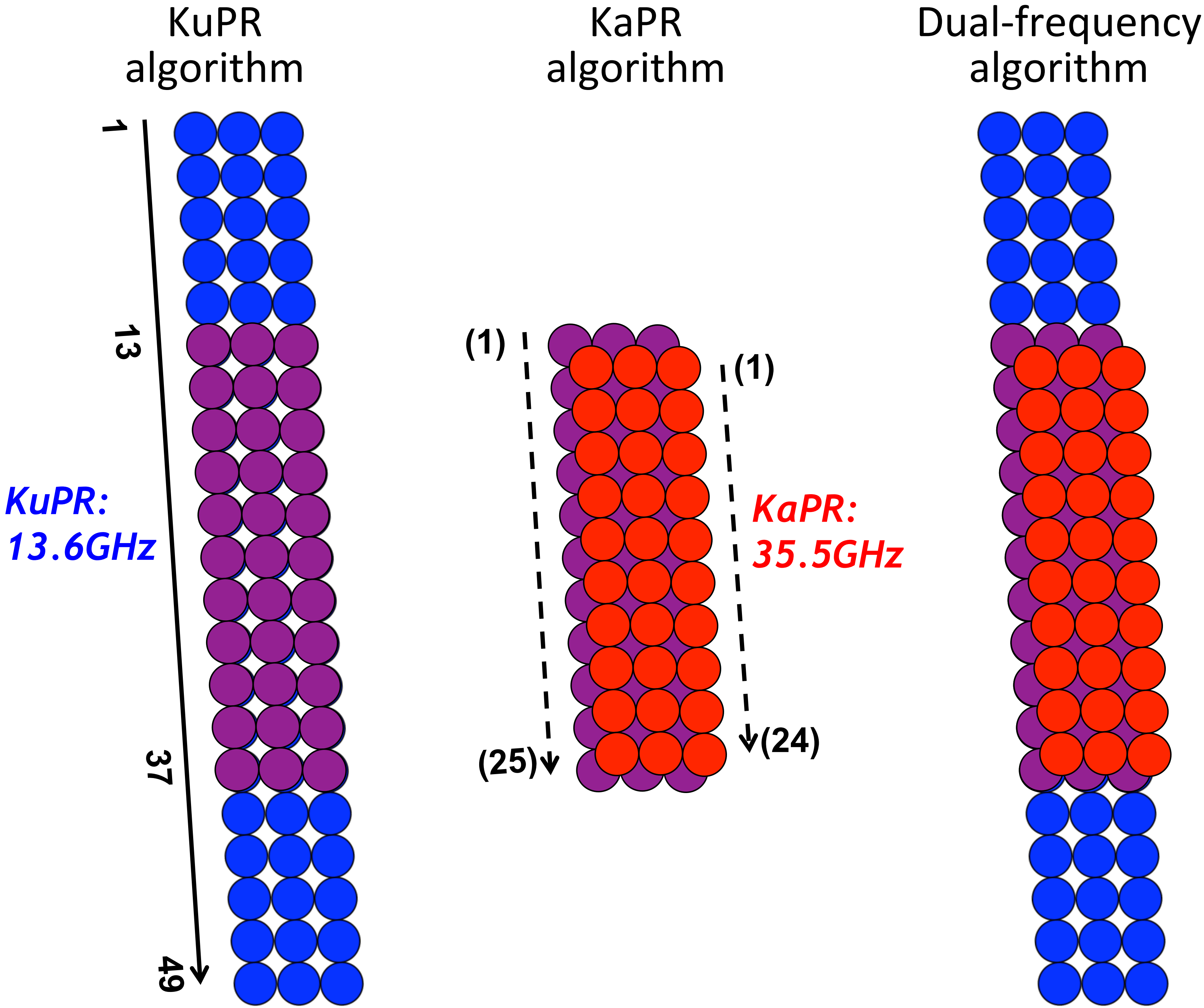
18 March 2013

DPR Standard Algorithm

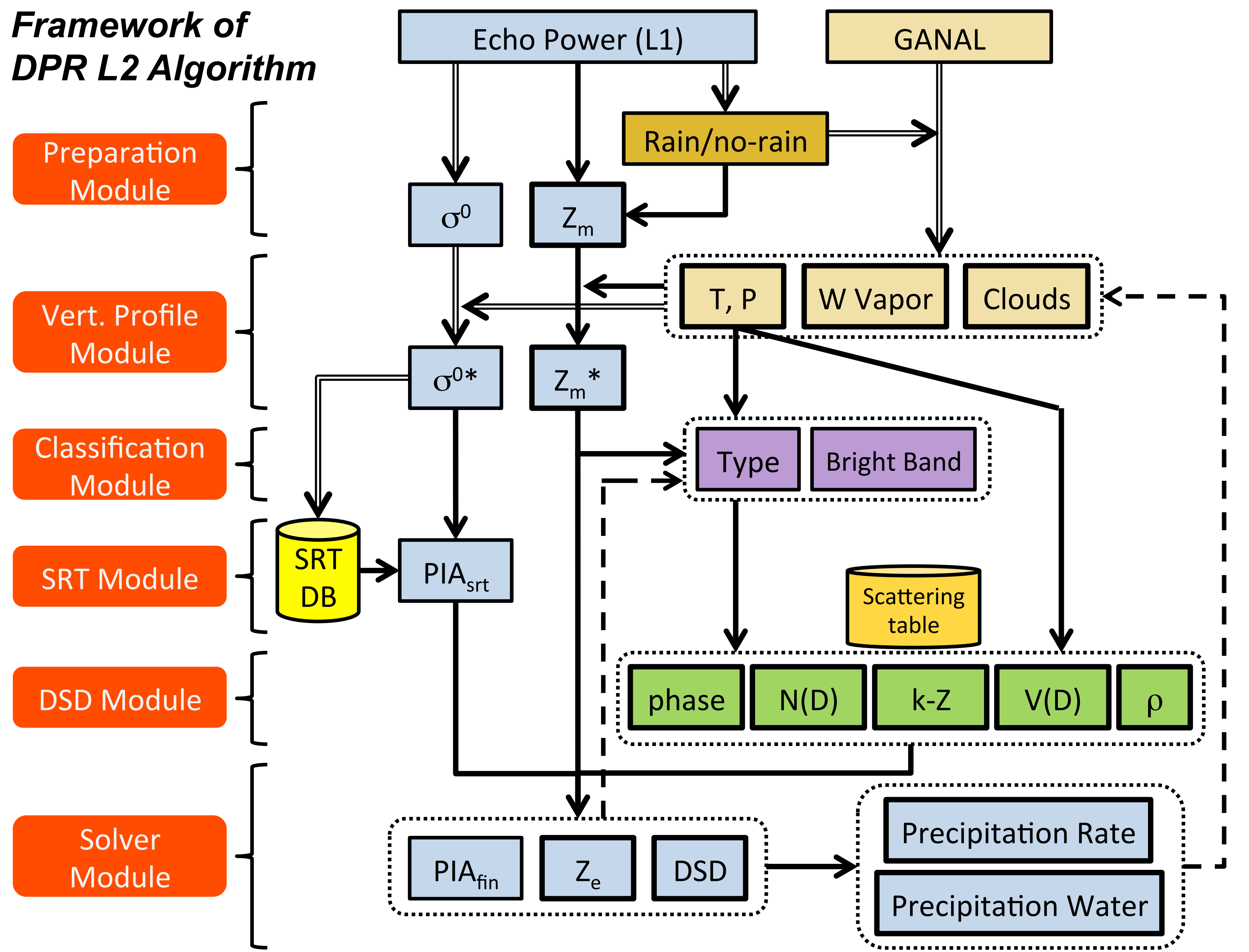
- Level-1 Radar echo power and measurement conditions/parameters are derived for each pixel
  - KuPR algorithm
  - KaPR algorithm

- Level-2 precipitation rates and precipitation-related variables (DSD, bright band, type, phase…) are retrieved for each pixel
  - KuPR algorithm (← KuPR L1)
  - KaPR algorithm (← KaPR L1)
  - Dual-frequency algorithm (← KuPR L1 and KaPR L1)

- Level-3 daily and monthly statistics of major outputs of L2



KuPR
algorithm
KaPR
algorithm
Dual-frequency
algorithm
1
13
37
49
KuPR:
13.6GHz
(1)
(25)
(1)
(24)
KaPR:
35.5GHz


Framework of
DPR L2 Algorithm
Preparation Module
Vert. Profile Module
Classification Module
SRT Module
DSD Module
Solver Module
Echo Power (L1)
GANAL
Rain/no-rain
σ0
Zm
T, P
W Vapor
Clouds
σ0*
Zm*
Type
Bright Band
SRT DB
PIAsrt
Scattering table
phase
N(D)
k-Z
V(D)
ρ
PIAfin
Ze
DSD
Precipitation Rate
Precipitation Water

People involved

- L 2 DPR algorithm (at-launch version) consists of the main module and 6 sub-modules.
  - Main module: Seto, Iguchi
    - controls the overall flow of data processing among the other 7 modules.
  - Preparation module: Yoshida, Kubota, Hanado
  - Vertical module: Kubota, Awaka
  - Classification module: Awaka, Chandra, Le
  - SRT module: Meneghini, Seto, Liao, Tanelli, Durden
  - DSD module: Seto, Kozu, Meneghini, Liao
  - Solver module: Seto, Meneghini

DPR L2 Development activities

- International DPR L2 telecons or meetings were held once per 2 months since Apr. 2012.
  - Apr. 2012, Jun. 2012, Aug. 2012, Oct. 2012, Nov. 2012, Jan. 2013
- Domestic DPR L2 meetings were held once a month.
  - Jan. 2012, Feb. 2012, Mar. 2012, Apr. 2012, May 2012, Jun. 2012, Aug. 2012, Sep. 2012, Oct. 2012, Dec. 2012, Jan. 2013, Feb. 2013
- Code submission to NASA PPS/JAXA MOSS
  - "Baseline code" (Version 2) was submitted in Jan. 2012
  - "At-launch code" (Version 3) was submitted in Dec. 2012.
  - "Updated at-launch code" (Version 4) will be submitted by the end of Mar. 2013.
  - "Final at-launch code" (Version 4) will be submitted by the end of Sep. 2013.

Major differences of DPR algo. from TRMM/PR

- SRT (Surface Reference Technique)
  - PIA is supposed to be more accurately estimated from the difference between σ^0 at the two frequencies than from each frequency.
- Precipitation type classification
  - Dual-frequency ratio (DFR) of Z_m is used to detect a melting layer, to classify rain types, and to identify particle types.
- DSD Retrieval
  - Two DSD parameters are retrieved from dual-frequency Z_m's.
  - A new retrieval method consistent with the TRMM/PR algorithm is developed.

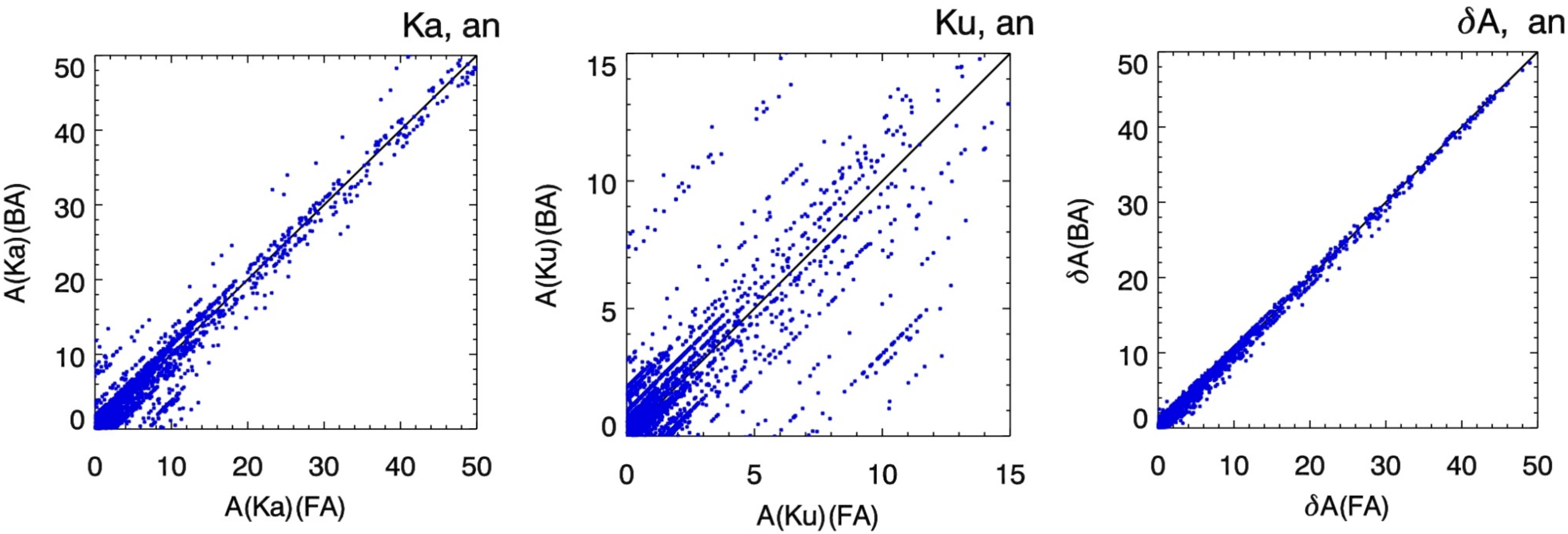
Dual-Frequency SRT

R. Meneghini, L. Liao, S. Tanelli, S. L. Durden

- δ *PIA* is more robust to surface variations

$$PIA = A(f) = \sigma^0_{NR}(f) - \sigma^0_R(f);\ f = \text{Ku} \quad \text{or} \quad \text{Ka}$$

$$\delta PIA = \delta A = [\sigma^0_{NR}(\text{Ka}) - \sigma^0_R(\text{Ka})] - [\sigma^0_{NR}(\text{Ku}) - \sigma^0_R(\text{Ku})]$$

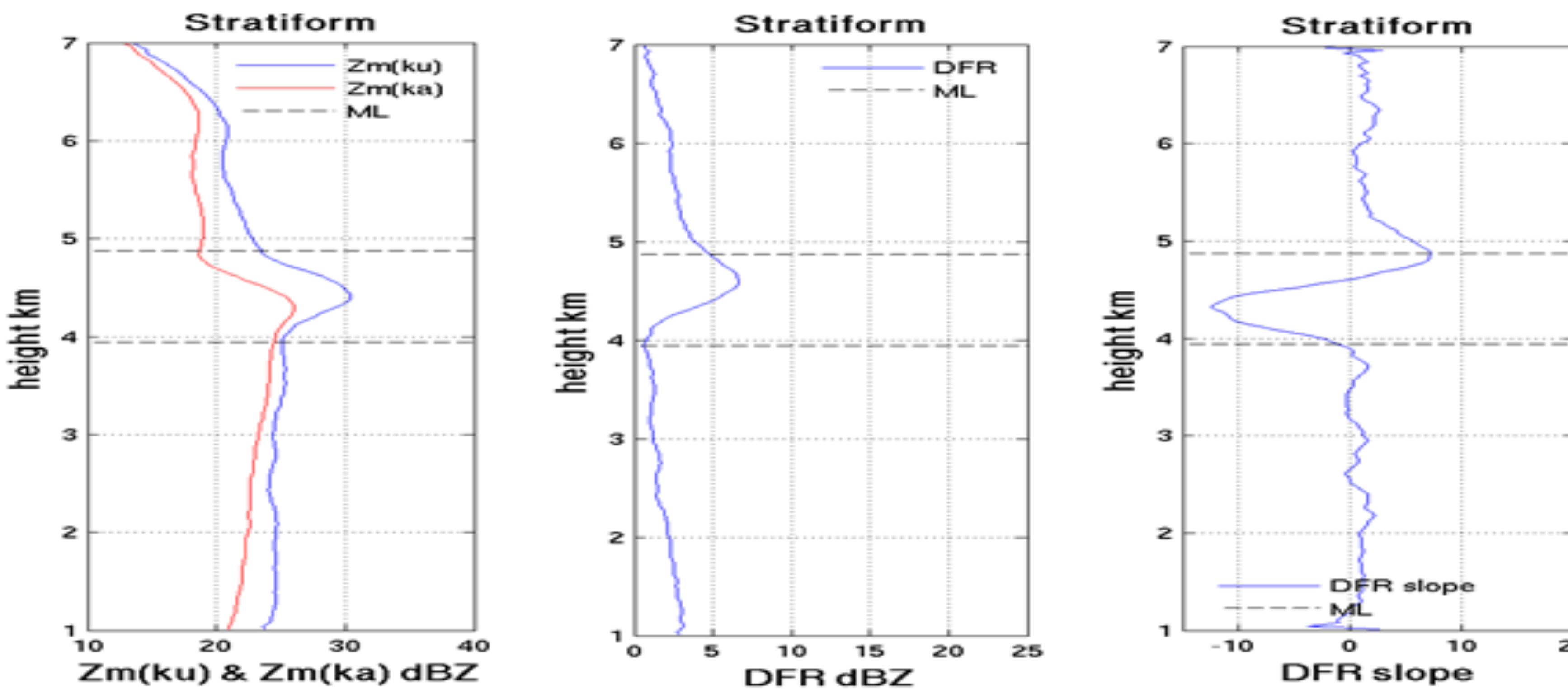


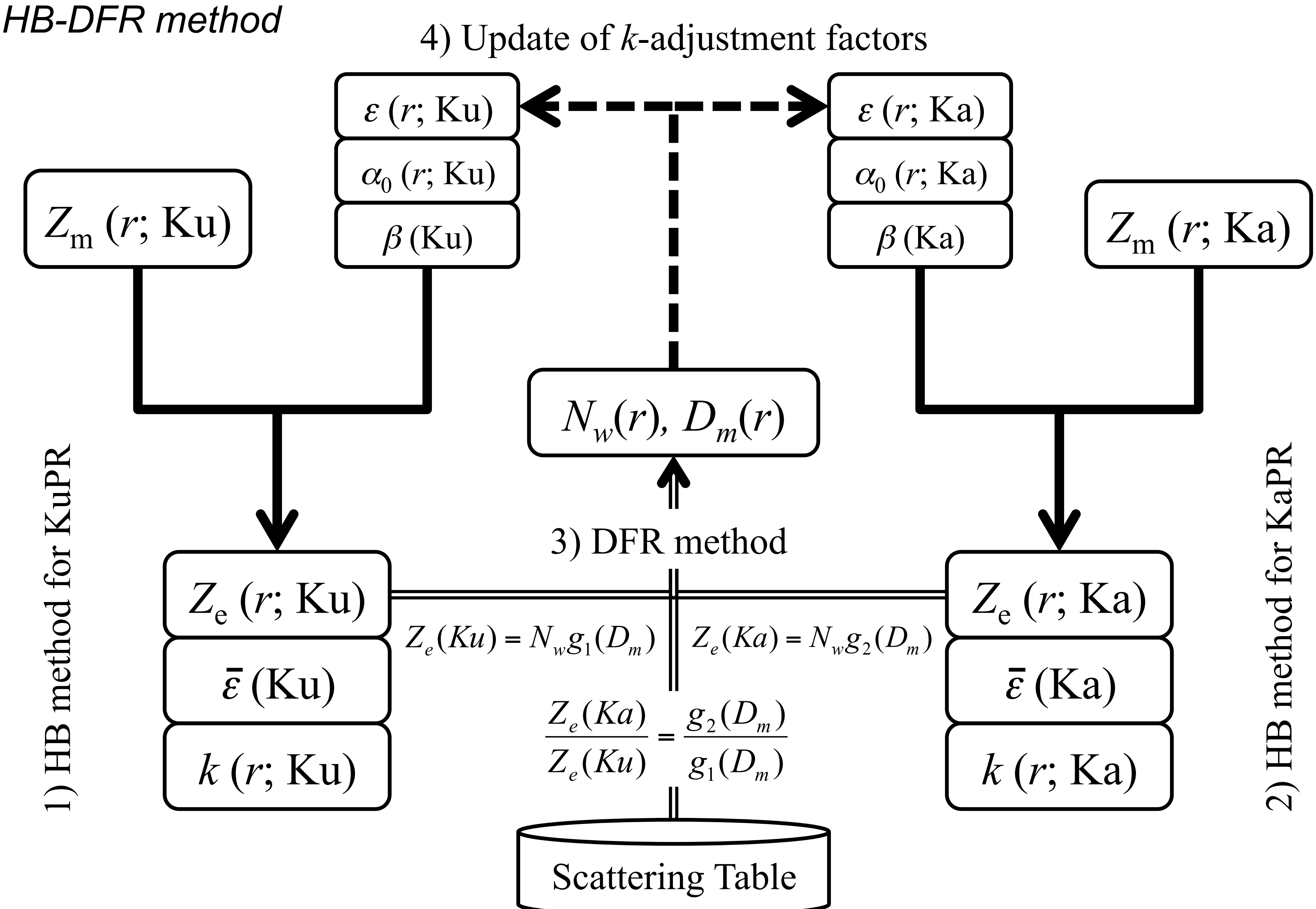
Incidence angle = 8.7 deg

Profile classification method using DFR

CSU: Le and Chandra

- Dual Frequency Ratio (DFRm) and its range variability are used to detect the hydrometer phase transition.
  -- Melting layer top: *DFRm* gradient has a maximum value.
  -- Melting layer bottom: *DFRm* has a local minimum value.



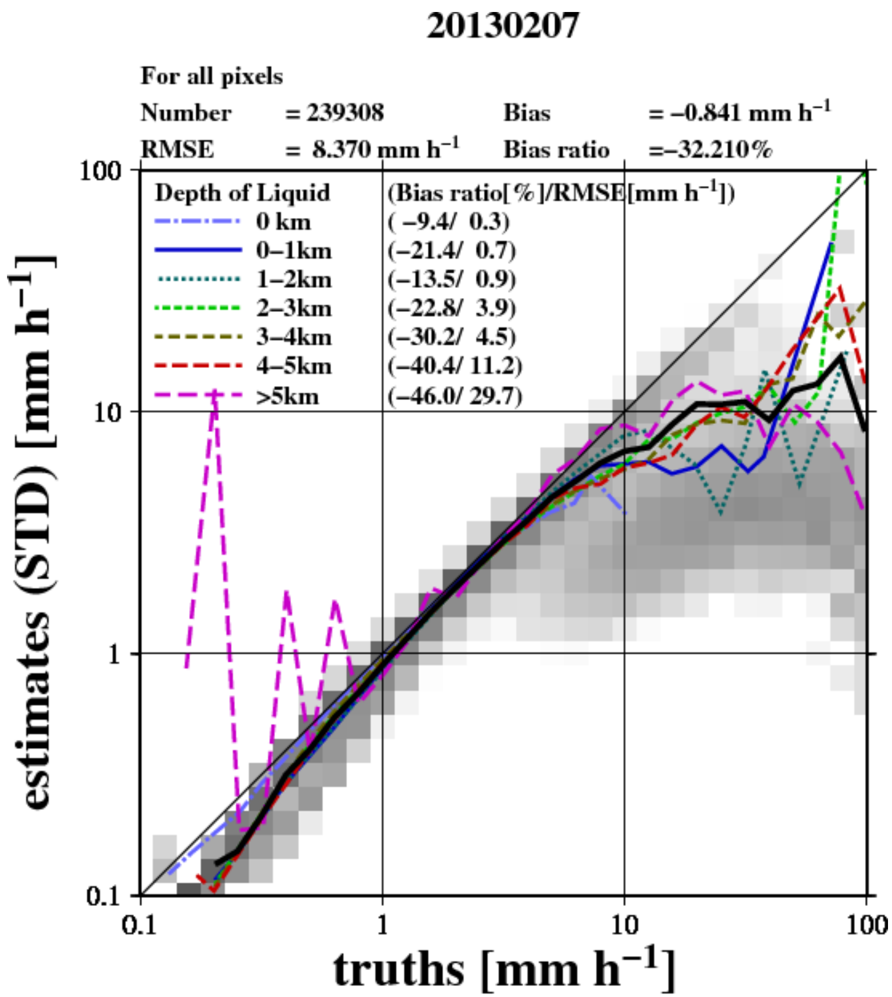


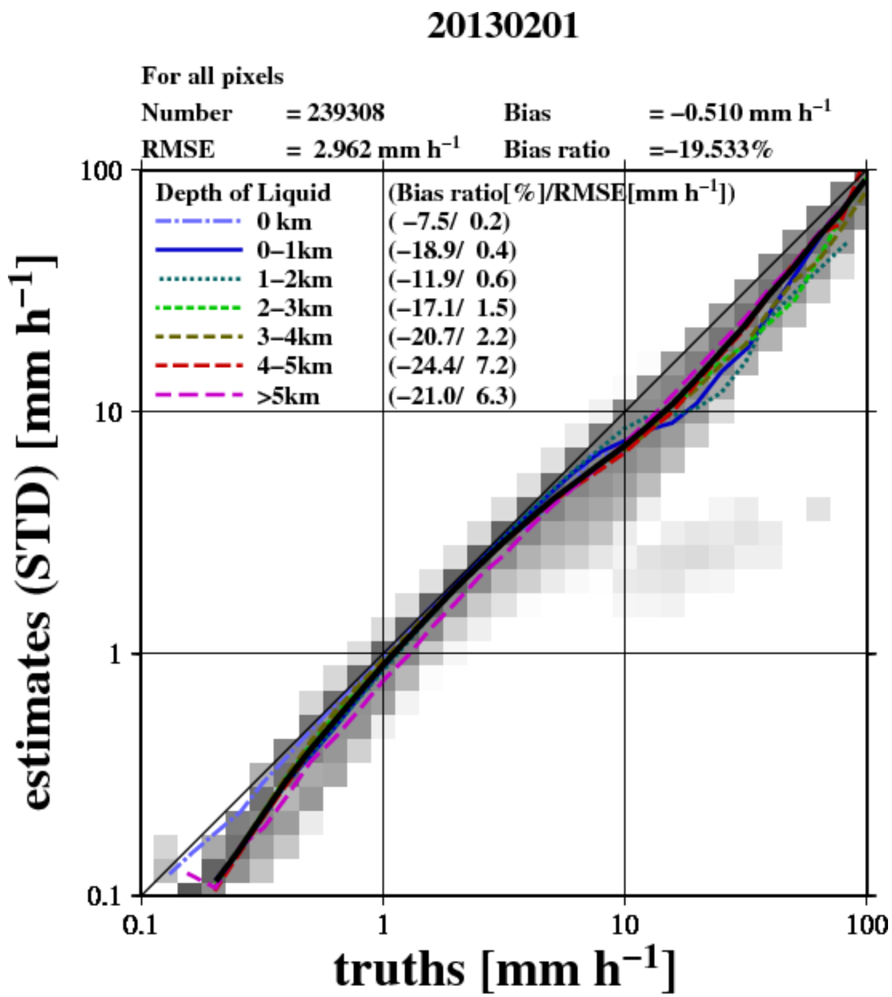
HB-DFR method
4) Update of k-adjustment factors
ε (r; Ku)
α0 (r; Ku)
β (Ku)
ε (r; Ka)
α0 (r; Ka)
β (Ka)
Zm (r; Ku)
Zm (r; Ka)
Nw(r), Dm(r)
3) DFR method
Ze (r; Ku)
ε̄ (Ku)
k (r; Ku)
Ze (r; Ka)
ε̄ (Ka)
k (r; Ka)
Ze(Ku) = Nw g1(Dm)
Ze(Ka) = Nw g2(Dm)
Ze(Ka) / Ze(Ku) = g2(Dm) / g1(Dm)
Scattering Table
1) HB method for KuPR
2) HB method for KaPR

Tests under ideal conditions

HB-DFR method
Underestimation for heavy precipitation

HB-DFR method + SRT
Improved by using SRT





Synthetic simulation data

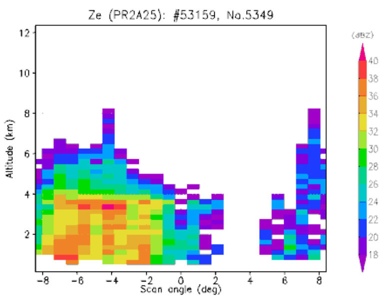
- JAXA has created 3 kinds of synthetic L1B data in DPR format.
  - Synthetic data with simple assumptions
    1. Purely simple synthetic data
  - Synthetic data under complicated assumption
    2. Synthetic data from TRMM/PR
    3. Synthetic data from numerical simulation
- US team has also made synthetic data
  - Airborne data based (JPL, GSFC)
  - TRMM/PR (CSU)
  - Numerical model (GSFC)
  - etc.

Kubota et al. (2011, 2013, *Proc. IGARSS*)

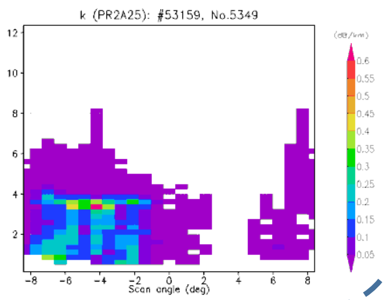
An example of the DPR L1 synthetic data at vertical cross sections

PR 2A25 Product

Attenuation-corrected effective Z-factor: Z_e

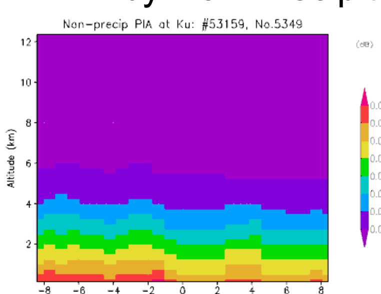


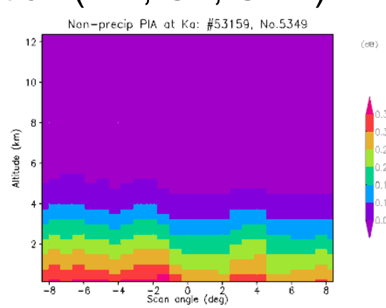
Specific attenuation: k (*"k" as in $k=\alpha Z_e^{\beta}$*)



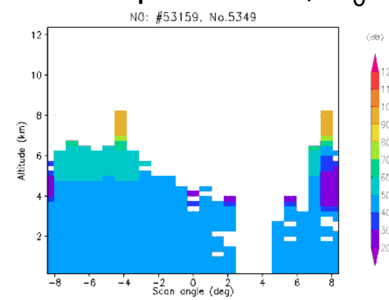
Ancillary data & CLW Database

PIA by Non-Precipitation (WV, O2, CLW)

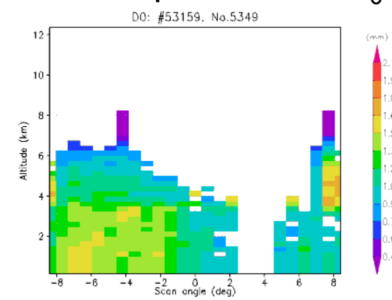




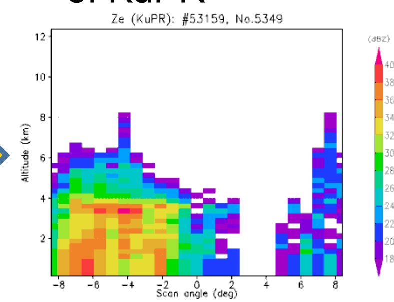
DSD parameter, N_0



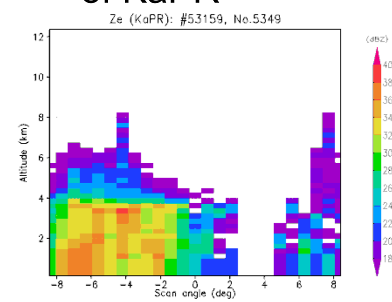
DSD parameter, D_0



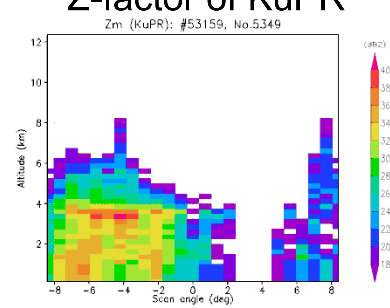
Effective Z-factor of KuPR



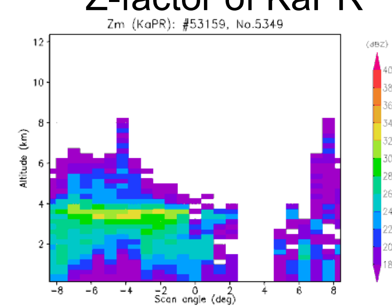
Effective Z-factor of KaPR



Attenuated effective Z-factor of KuPR

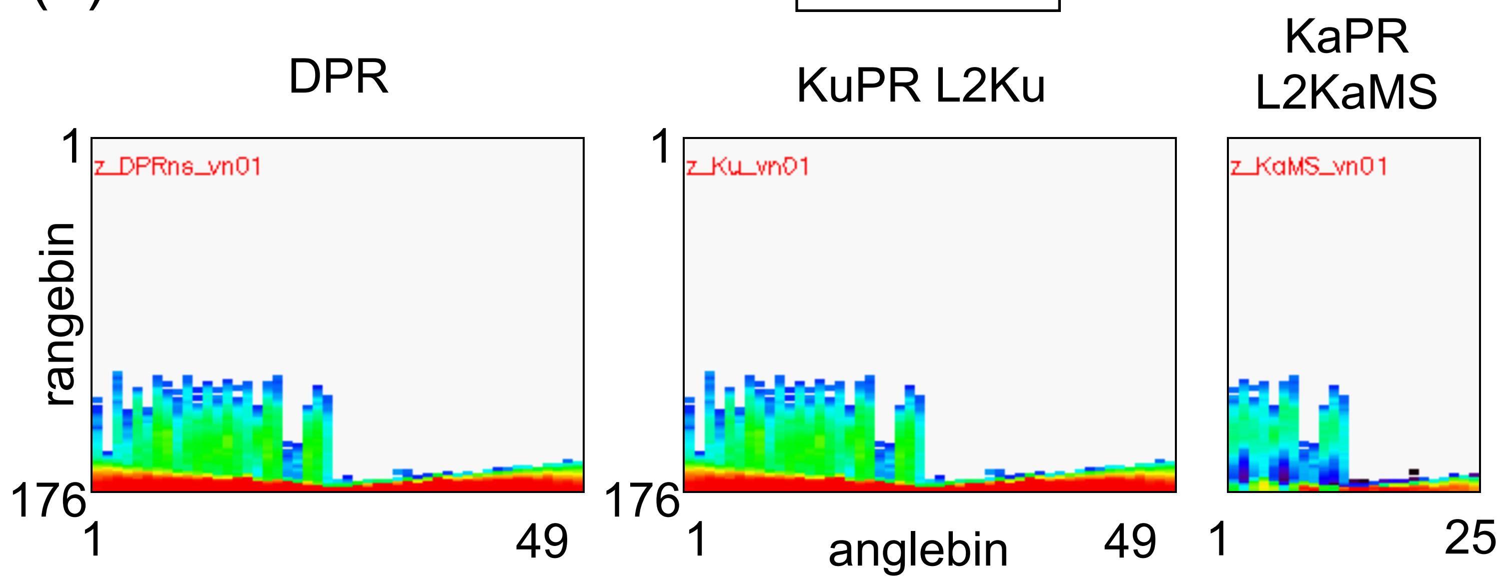


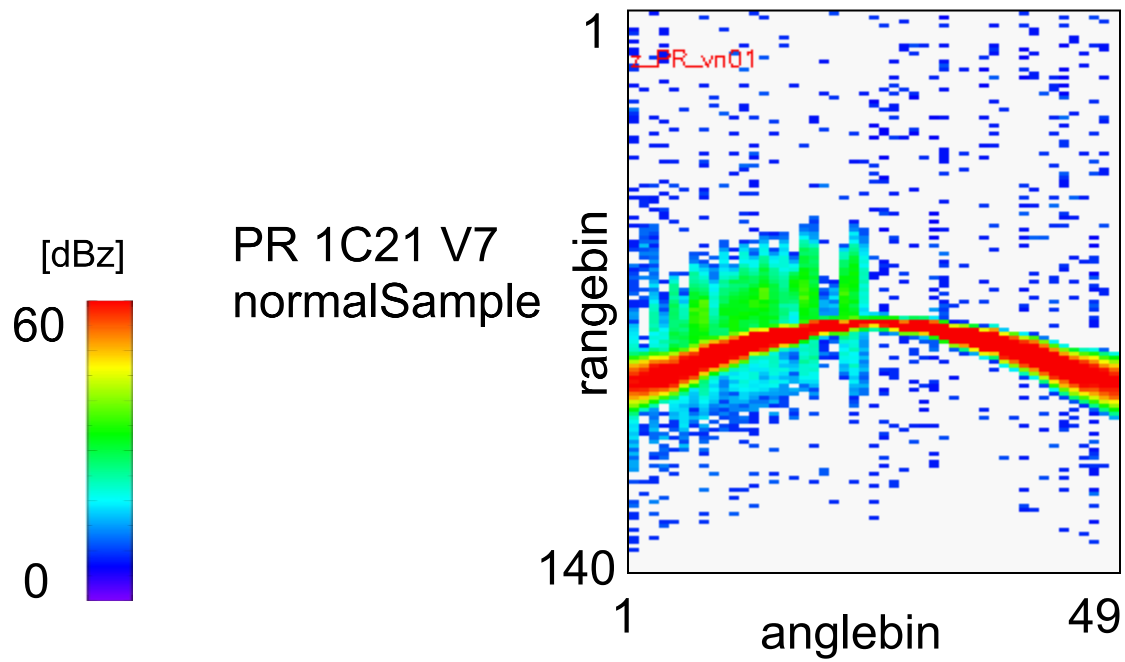
Attenuated effective Z-factor of KaPR



(3) zFactorMeasured

1766 scan

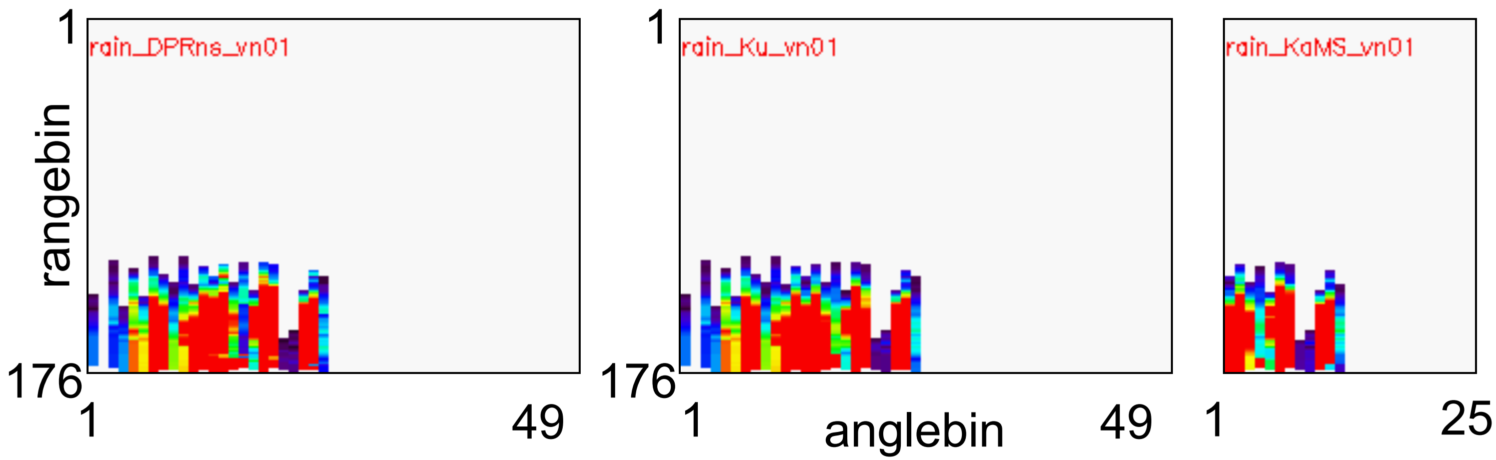


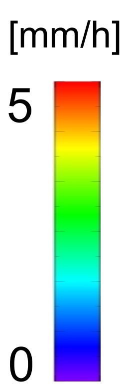


(8) precipRate

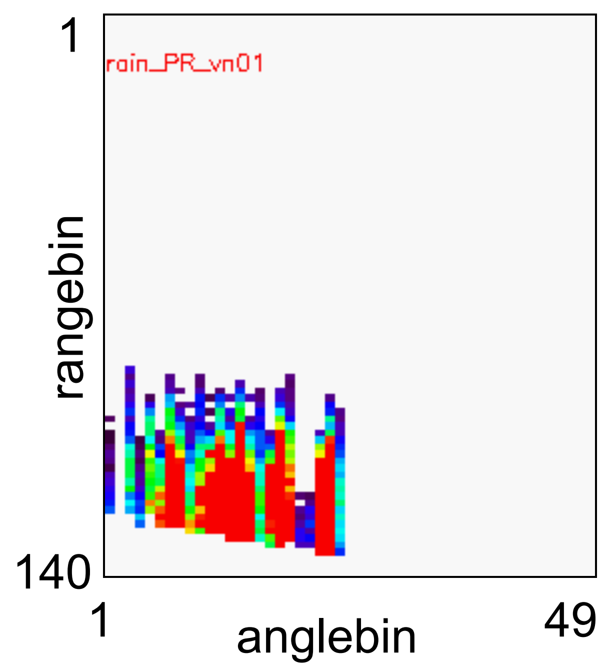
1766 scan

DPR | KuPR L2Ku | KaPR L2KaMS



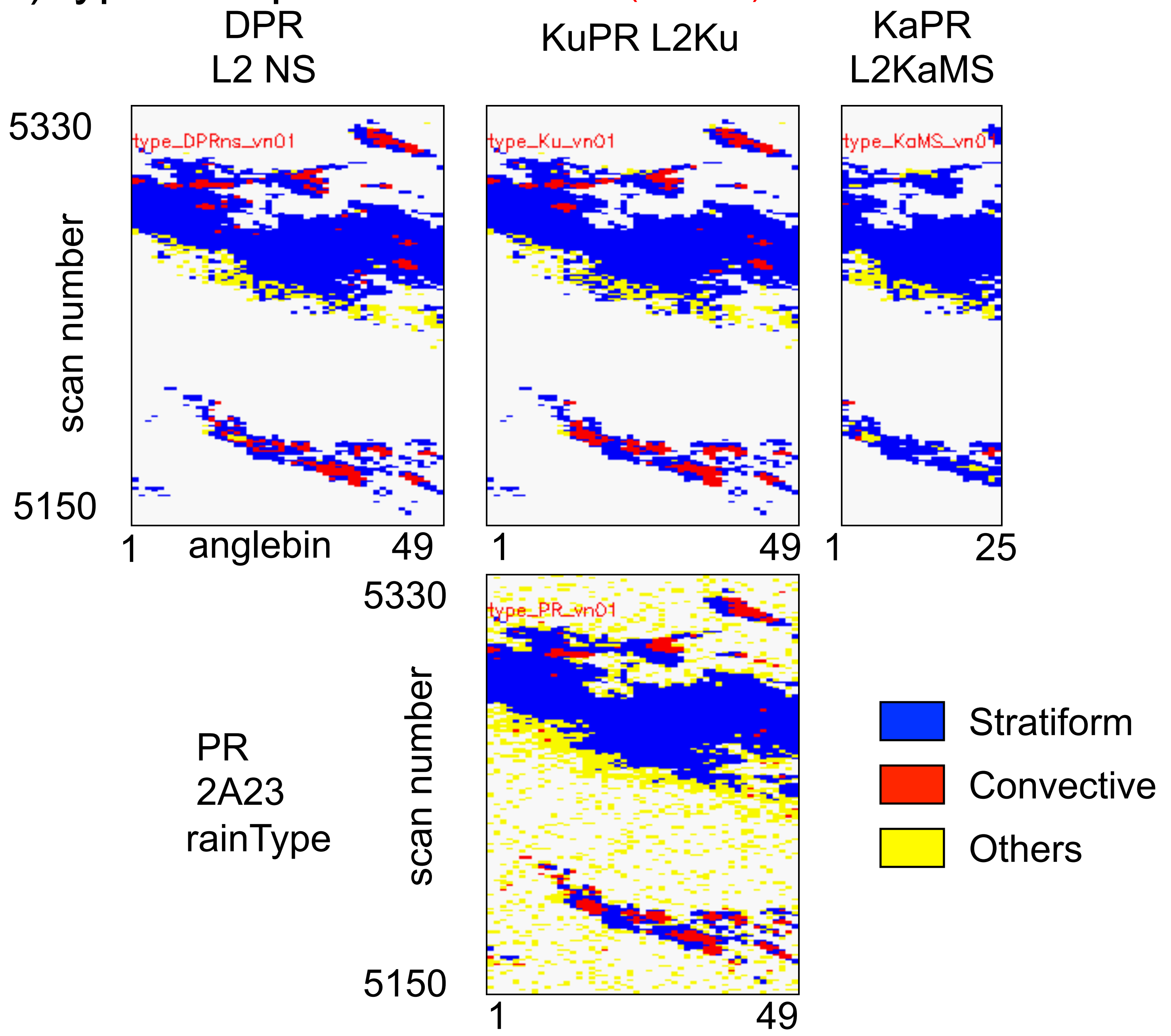


PR 2A25 V7
rain



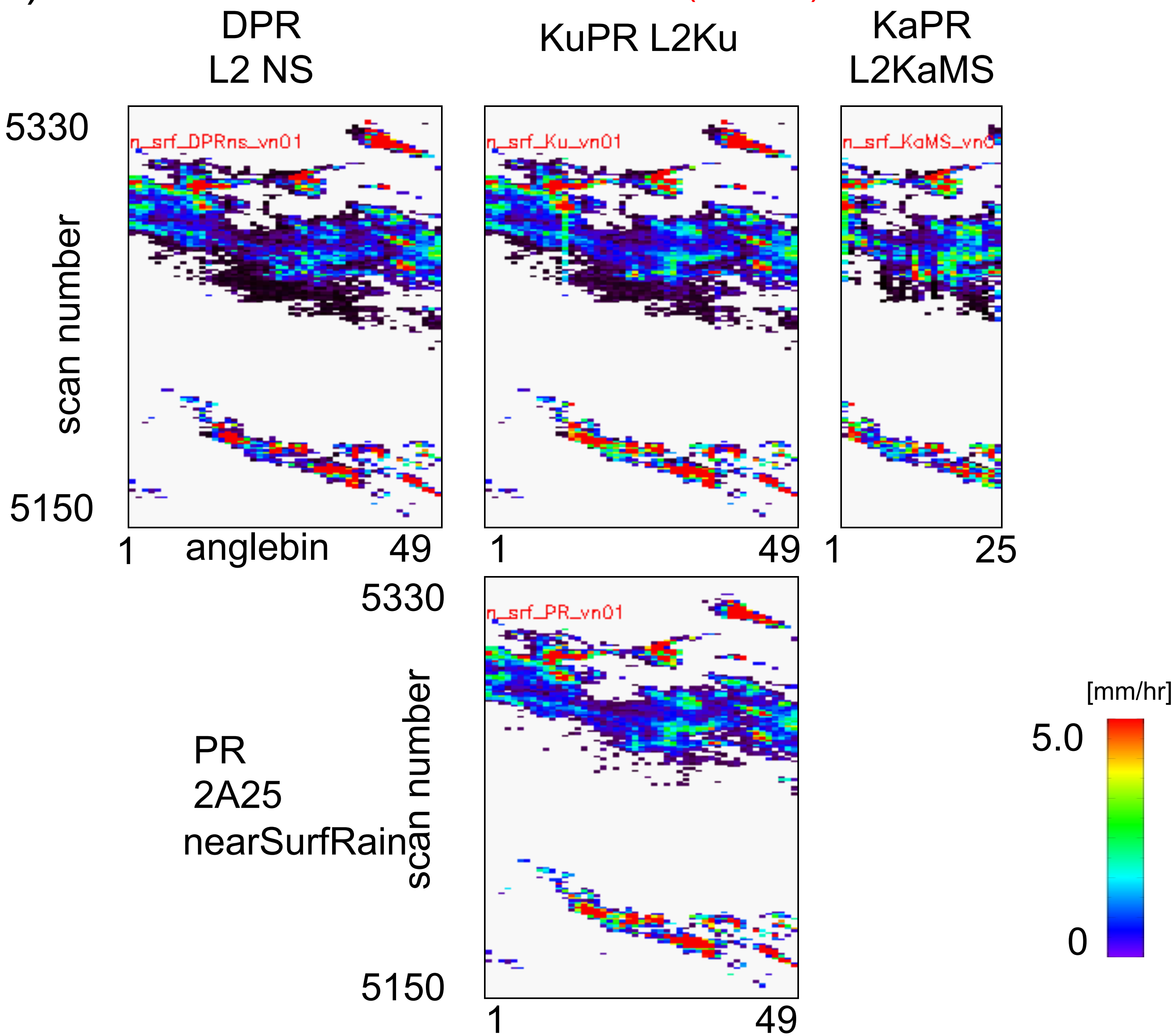
vn01

(24) typePrecip scan 5150 – 5330 (Ocean)



vn01

(25) nearSurfRain scan 5150 – 5330 (Ocean)



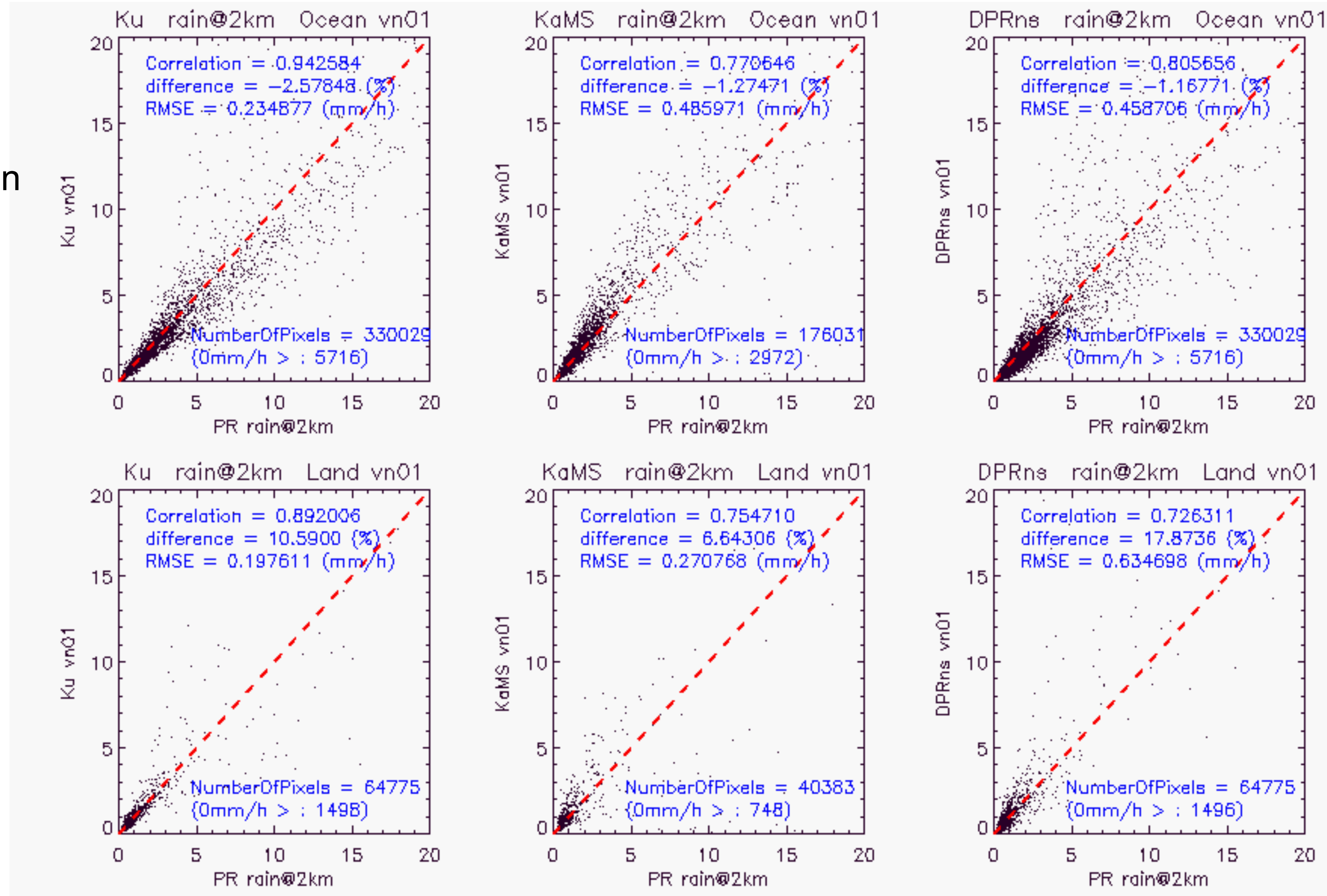
vn01

(10) precipRate 2km Scatter Plot

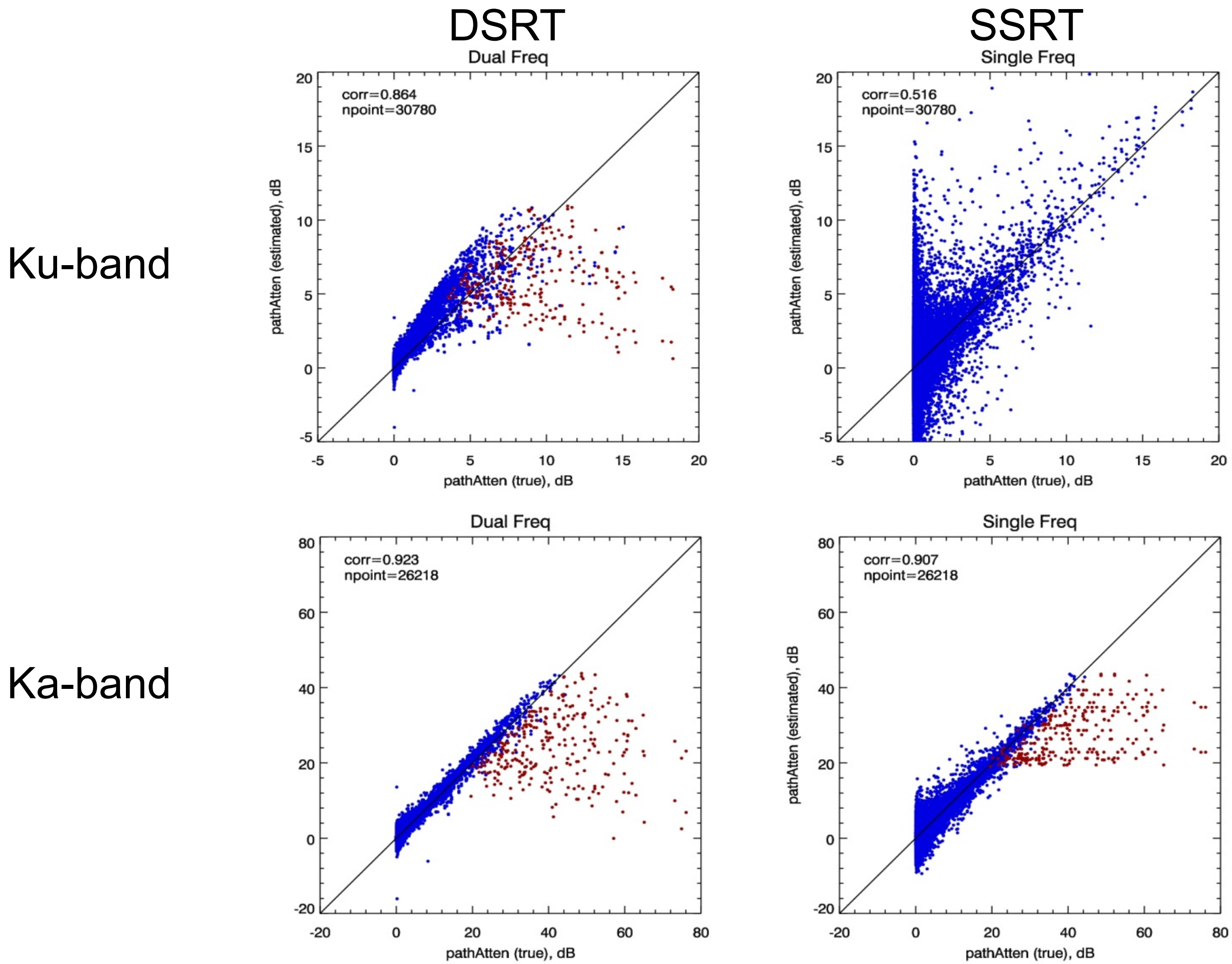
KuPR L2Ku | KaPR L2KaMS | DPR L2NS

Ocean

Land



Comparison of PIA estimates from the DSRT and SSRT



Comparison of PIA estimates from the DSRT and SSRT for a highly correlated surface for all incidence angles in the inner swath (Ocean and Land). Red data points indicate estimates in which the SNR at either Ku or Ka-band is small.

Issues

- DPR is expected to provide more accurate and reliable precipitation estimates than TRMM/PR. However, we have not verified expected significant improvement with simulated data yet, mainly because there are some inconsistent assumptions in the simulated data and the retrieval algorithm.
- More examination is necessary to adjust parameters in order to remove biases.
    - How to estimate better PIAs and their uncertainties by using Ku and Ka-band surface echoes.
    - How to classify precipitation types and identify particle types.

Future activities

- Tuning of parameters
- Defining a good model of vertical profiles of rain near surface.
- Uncertainty and error analysis
- Implementation of proposed and advanced functions
  - Wet surface SRT
  - Texture module that corrects for the effect of non-uniform beam filling.
    - Evaluation of NUBF effect and development of compensation algorithm
  - Creation of scientifically reliable models and tables:
    - scattering tables, BB model, ice particle models, etc
- Interface with other teams
- Revision of the ATBD

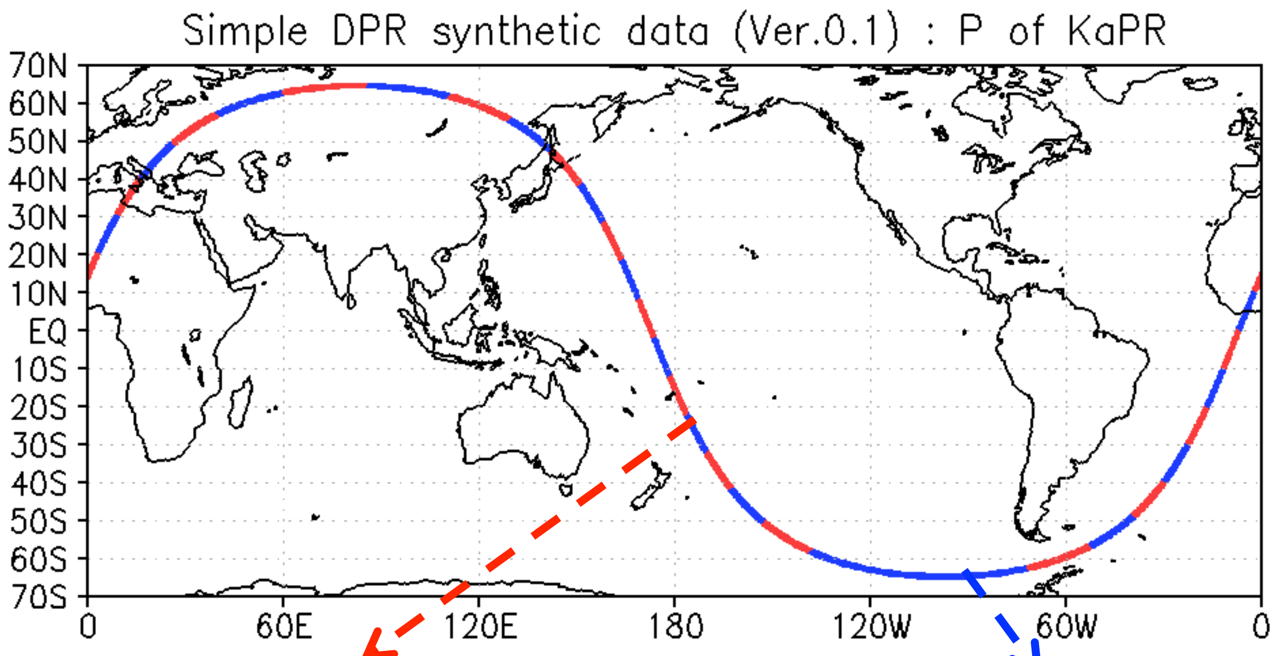
Summary

- At-launch version of the DPR algorithm was submitted to JAXA and NAXA.
- The code is currently under test with simulated data sets.
  - Early test results show that the retrieved estimates are comparable to PR estimates. (Look at the poster by T. Kubota, et al.)

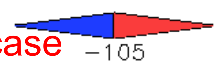
Progress since last PMM meeting

- Review of internal and external variables and format
- Implementation of proposed and advanced functions
  - DFR SRT, DFR classification
  - Creation of scientifically reliable models and tables:
    - scattering tables, BB model, ice particle models, etc
  - Iteration in the main module
  - Outer swath, Ku-PR, Ka-PR algorithms
- tests with synthetic data

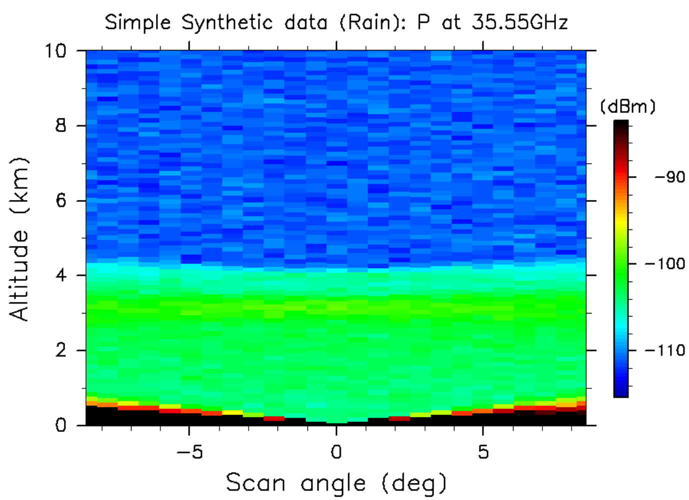
Example: Received Power of KaPR



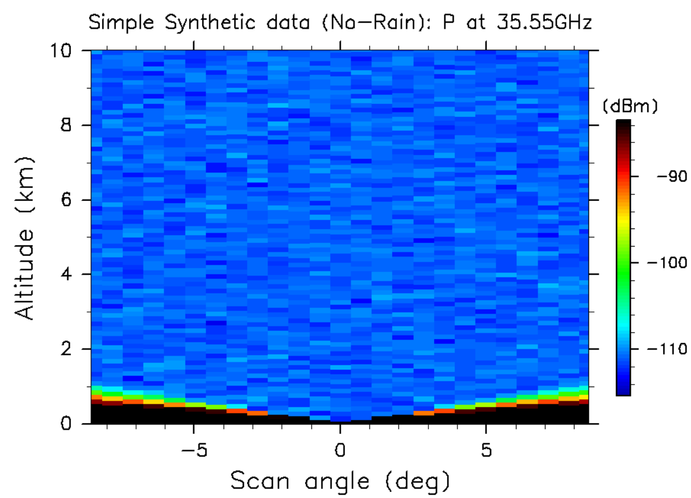
- Fixed echoPower profiles for precipitation or non-precipitation pixels
- Rectangular precipitation area
  - (Rain condition)
  - Qr = 0.2(g/kg) below 4km, and Qr=0 above 4km
- Ocean surface
- Random noises

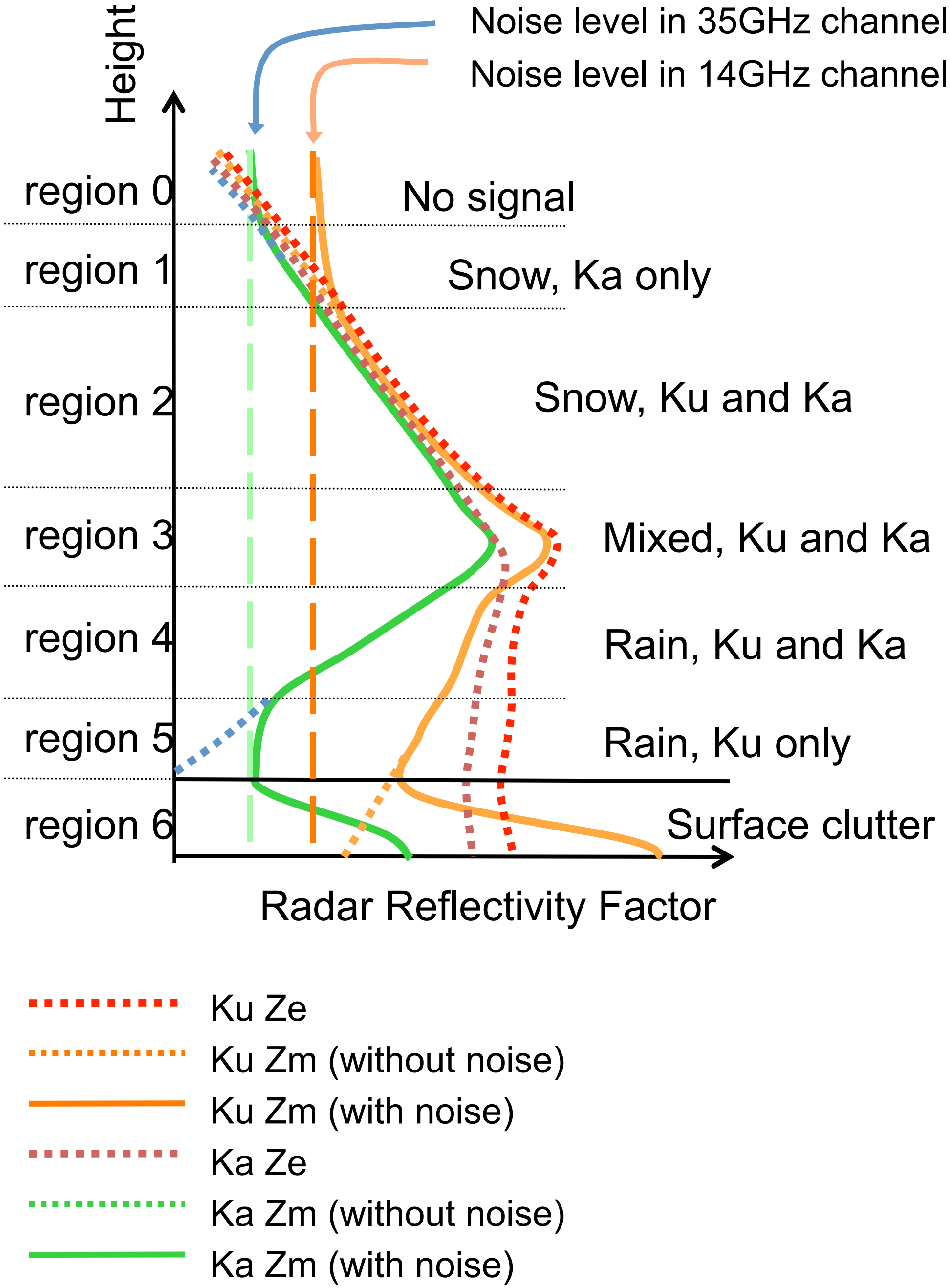


Vertical cross section in Rain case



Vertical cross section in No-rain case





DF algorithm applicable
in regions 2, 3, and 4.

Region 0: Nothing can be done.

Region 1: Use *Z*(Ka)-*R* relationship.
No attn. correction needed.
Region 2: Use DF algo. for snow.
Attn. by WV, CW.
Region 3: Use DF algo for mixed rain
Needs init. value at r3b or r3
Region 4: Use DF algo for rain.
Needs init. value at r4b or r4
Region 5: Use Ku SF algo for rain.
Needs init. value at r5b or r5
Region 6: Use a model profile

SRT gives attn. at r6b.

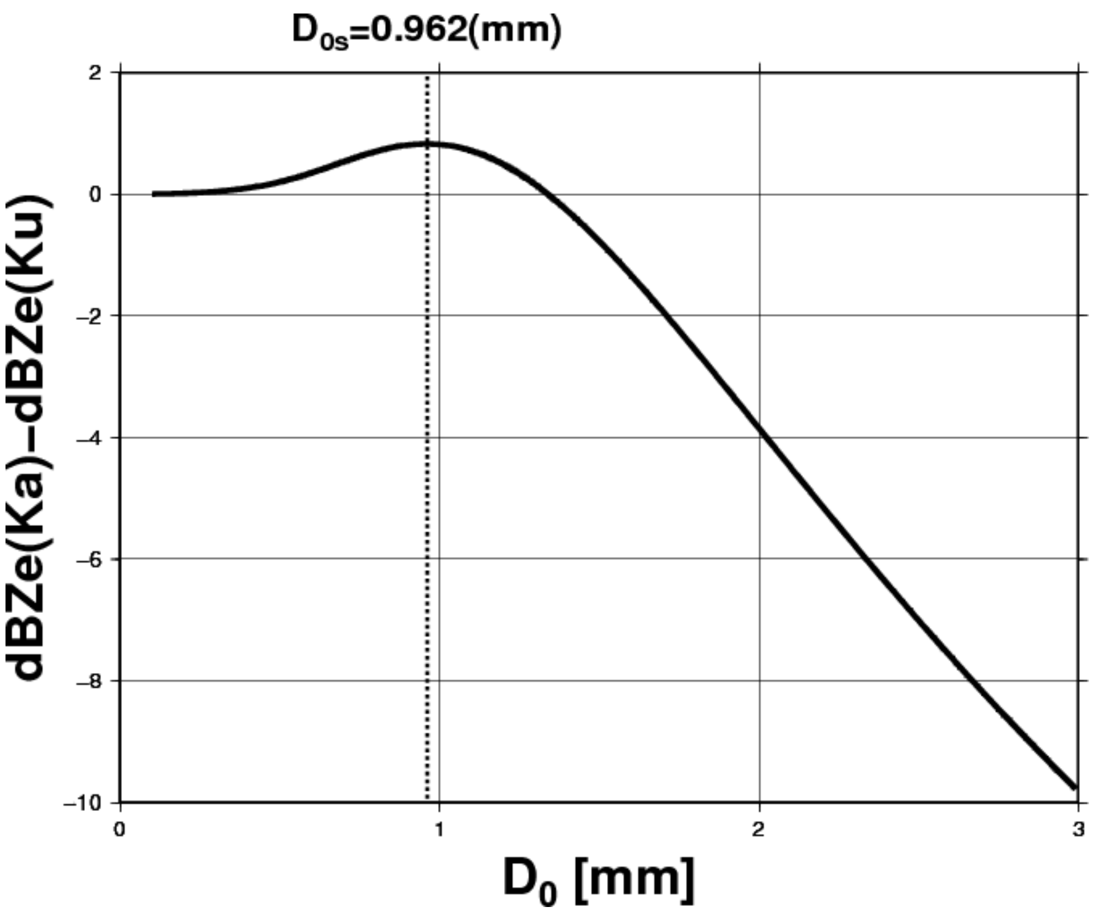
Region 5 appears only when
Ka attn. is large.

Special Concerns in Rain Profiling Algorithms for Spaceborne Radar

- Attenuation correction is essential
  - Attenuation by precipitation is not negligible.
    - In particular, Ka-band radar
    - *k-Z* relation for rain attenuation (H-B solution)
  - Attenuation by CLW and WV is not negligible.
    - **Cloud liquid water: Att(Ka) = 10 * Att(Ku), up to 5 dB**
    - **Water vapor: Att(Ka) = 5 * Att(Ku), up to 1.5 dB near surface**
    - **Oxygen: Att(ka) = 5 * Att(Ku), 0.4 dB near surface**
  - Use of surface reference technique (SRT) helps.
    - But, SR is not always available or reliable
- Type of particles (rain, snow, graupel, etc.) and their physical and electromagnetic properties need to be known (or assumed).
- Inhomogeneity of rain within IFOV
  - Entangled with apparent attenuation, etc.

DFR (Dual-frequency ratio) for DSD

DFR is the ratio of Z_e or the difference of Z_e in decibels
$DFR=dBZ_e(Ka)-dBZ_e(Ku)$
(dBZ_e indicates Z_e in decibles)



Assume DSD of 0 degree C rainfall follows a Gamma distribution with μ=3 and parameterized with D_0 and N_0. DFR is not dependent on N_0, and the relation between DFR and D_0 is given as shown left.

When DFR is positive, D_0 has multiple solutions.

D_0 is constrained to be larger than D_{0s}, where DFR takes the maximum.