DPR algorithm status

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

Toshio Iguchi (NICT)

PMM meeting, Denver

7 November 2011

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DPR L2 Development activities

- Domestic DPR L2 meetings were held 10 times since the last PMM meeting.
  - Dec. 9, 2010 (PI workshop), Jan. 14, March 2, April 14 (with GV team), May 17, June 13, July 15 (Telecon with US team), Aug. 22, Sept. 15, Nov. 1, 2011.
- Interface variables defined.
- Skeleton code submitted in April.
- "Baseline code" developed (ready to submit).
  - 6 basic sub-modules were developed and submitted
  - EORC/RESTEC compiled all (but SRT) modules successfully.
    - SRT module was combined to the other modules last week in the US.
    - Scattering tables created by Liao will be combined in the DSD module.
  - Simulation data (ver. 1) with HDF/DPRL1B format was created.
  - Overall flow of data were tested with the simulation data.
  - "Baseline code" will be submitted by the end of November 2011.
- "At-launch code" will be developed by next autumn.

People involved

- L 2 DPR algorithm consists basically of 8 modules .
  - Main module: Seto, iguchi
    - controls the overall flow of data processing among the other 7 modules.
  - Preparation module: Yoshida, Kubota
  - Vertical module: Kubota, Awaka
  - Classification module: Awaka, (Chandra, Le)
  - SRT module: Meneghini, Seto, (Liao, Tanelli, Durden)
  - DSD module: Kozu, Meneghini, Seto, (Liao)
  - Solver module: Seto, Meneghini
  - Texture module: Seto

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

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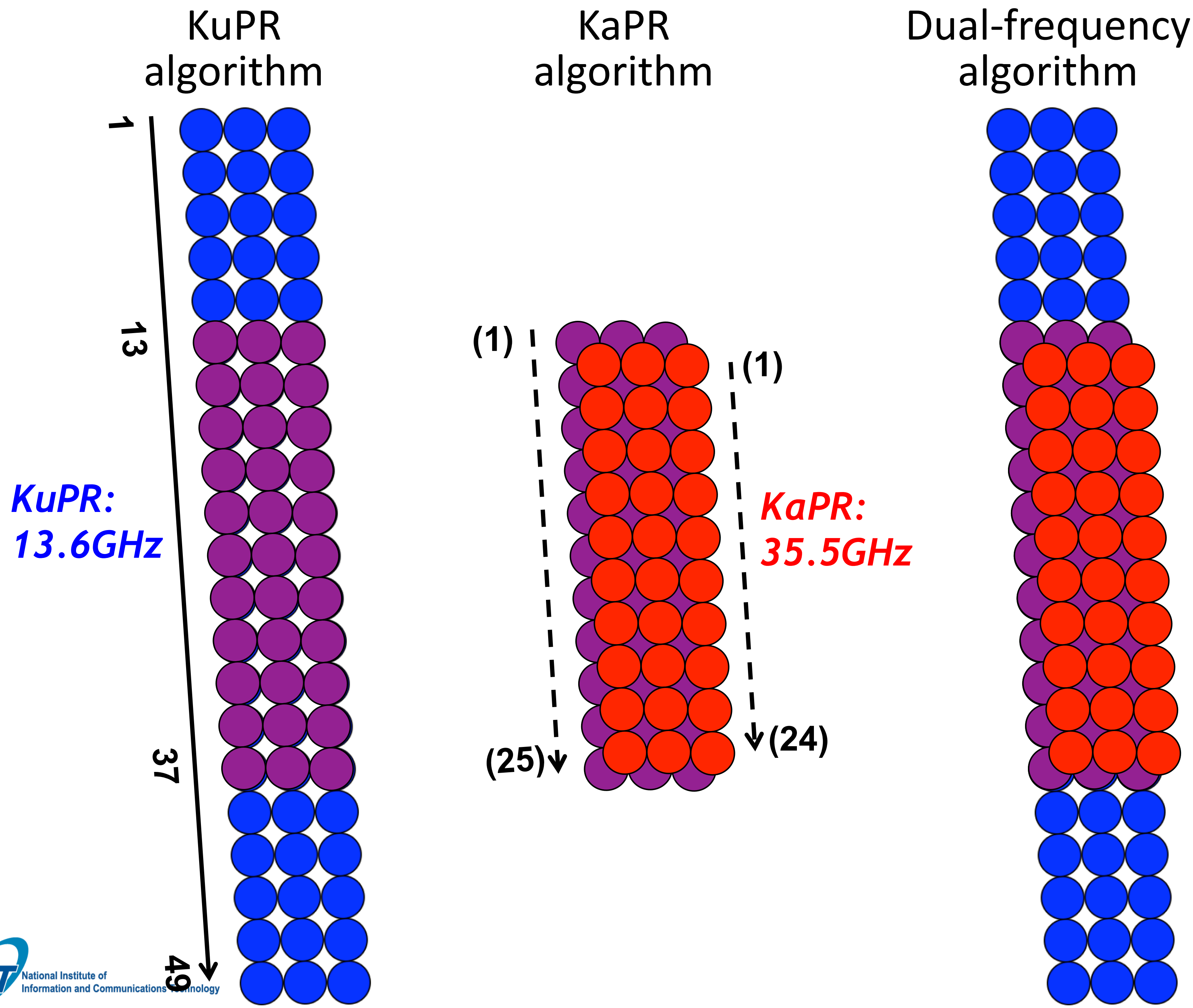
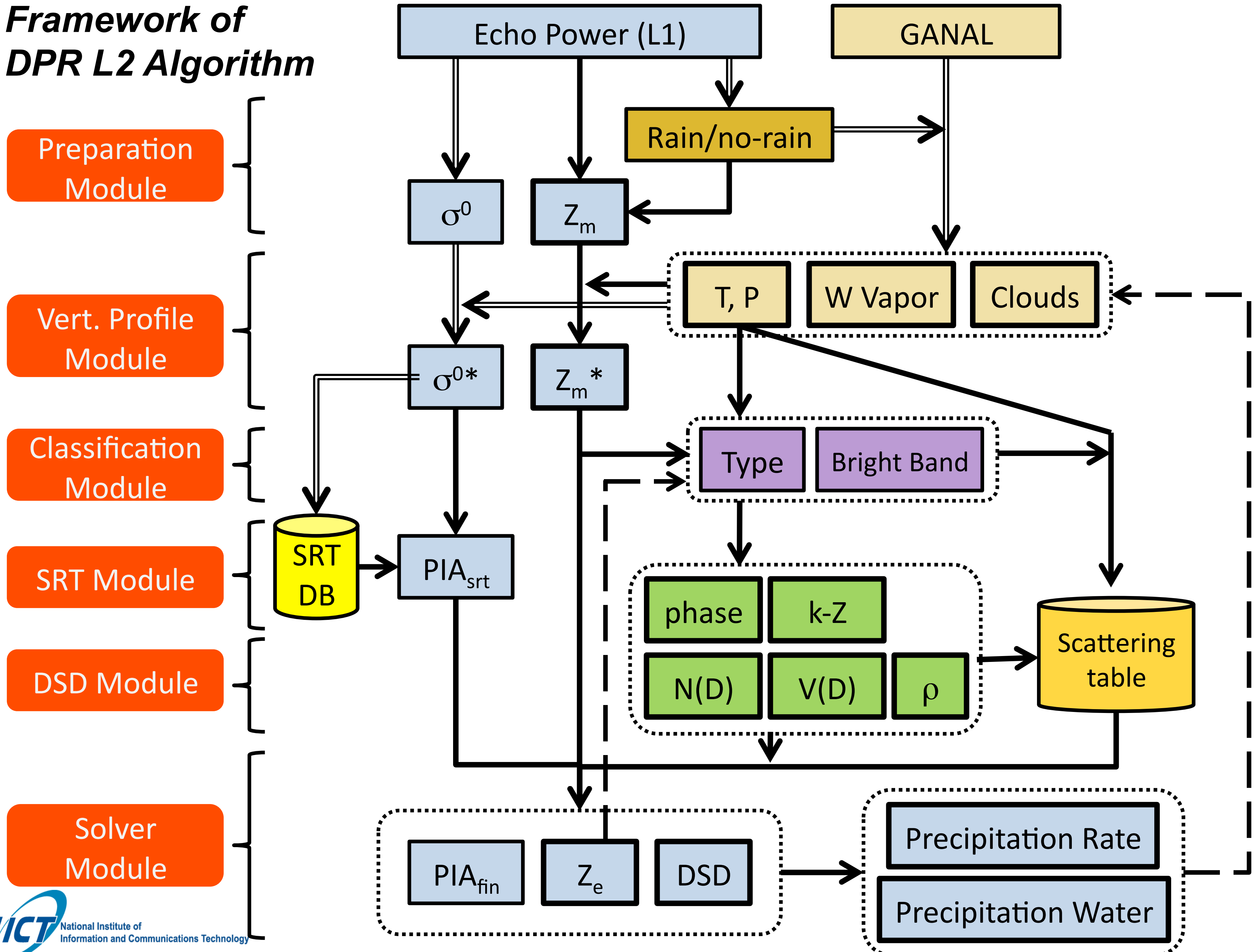

KuPR algorithm
KaPR algorithm
Dual-frequency algorithm
1
13
37
49
KuPR: 13.6GHz
(1)
(25)
(1)
(24)
KaPR: 35.5GHz

Framework of DPR L2 Algorithm



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New ideas with Dual-frequency techniques

- SRT (Surface Reference Technique)
  - PIA can be more accurately estimated from the difference between σ^0 at the two frequencies than from each frequency → Meneghini, Tanelli, Durden
- Precipitation type classification
  - The dual-frequency ratio (DFR) of Z_m is useful to detect a melting layer → e.g. Le and Chandra
- DSD Retrieval
  - Many previous studies exist to retrieve two DSD parameters from dual-frequency Z_m's
  - A new retrieval method consistent with the TRMM/PR algorithm is developed.

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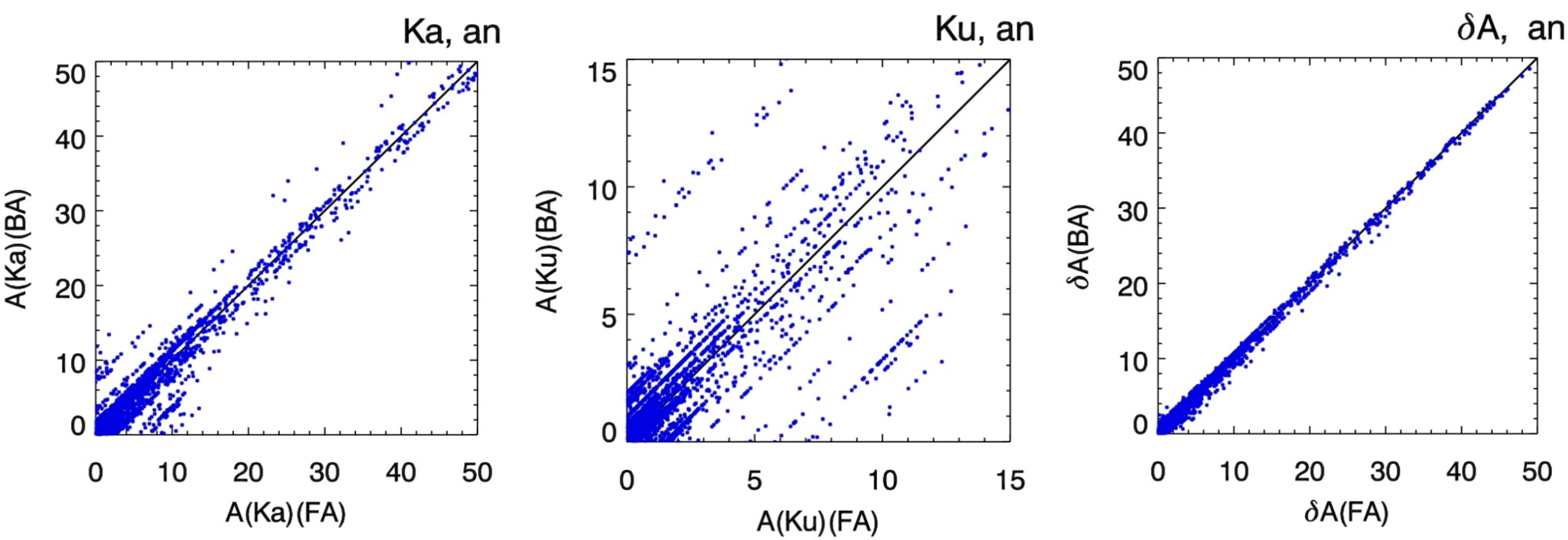
Dual-Frequency SRT

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

- δ *PIA* is more robust to surface variations

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

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



Incidence angle = 8.7 deg

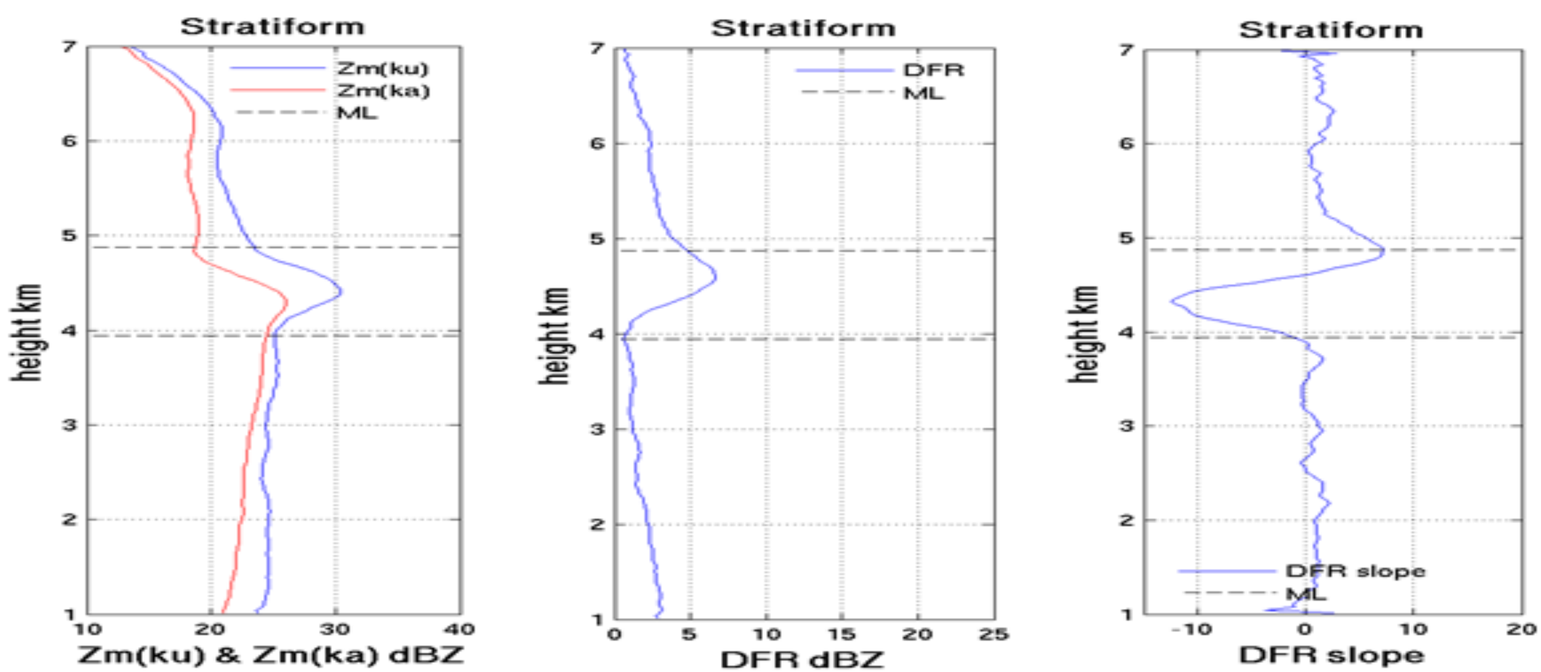
Profile classification method (CSU: Le and Chandra)

- Hydrometeor identification model *(HIM)* is the second model of the profile classification method.
- As discussed before, *DFRm* is useful parameter to detect the hydrometer phase transition.

The main parameter used in *HIM* is *DFRm* and its range variability.

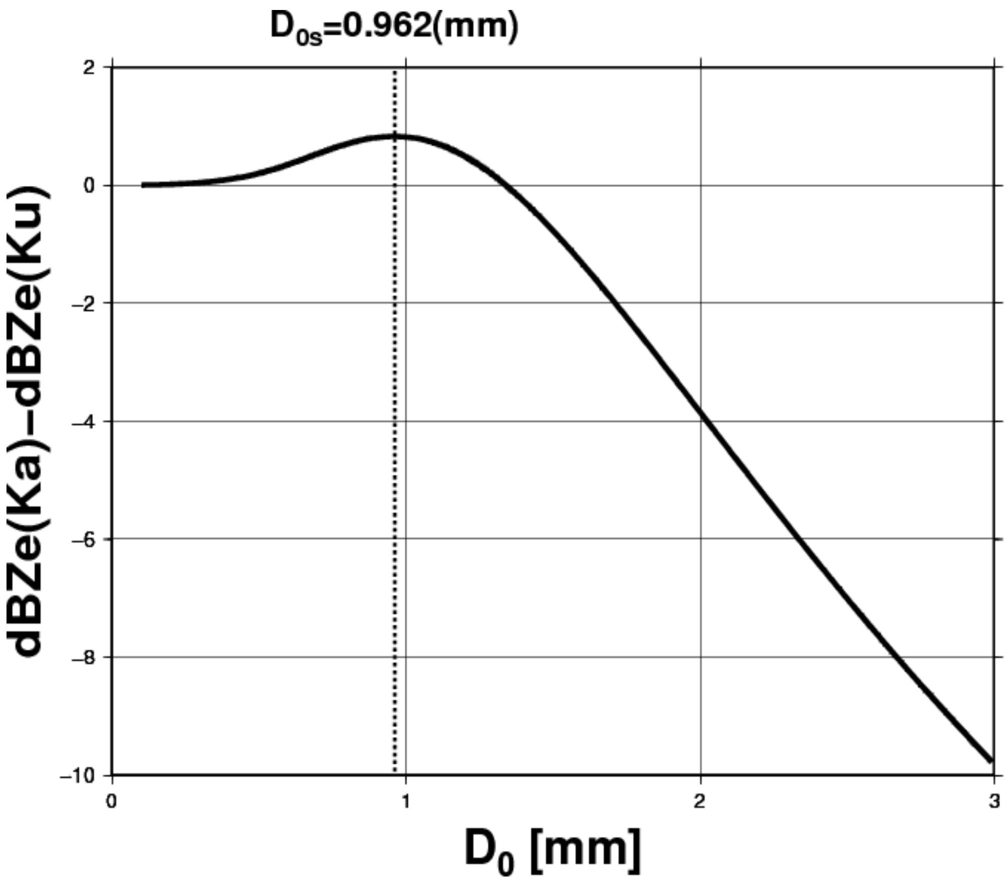
---- Melting layer top is the height at which *DFRm* gradient has maximum value.

----Melting layer bottom is the height at which *DFRm* has a local minimum value.



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.

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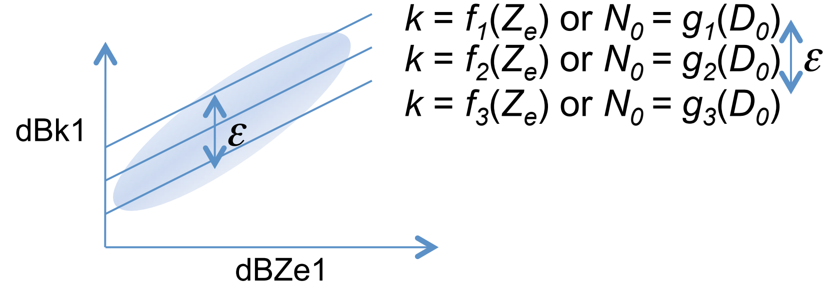
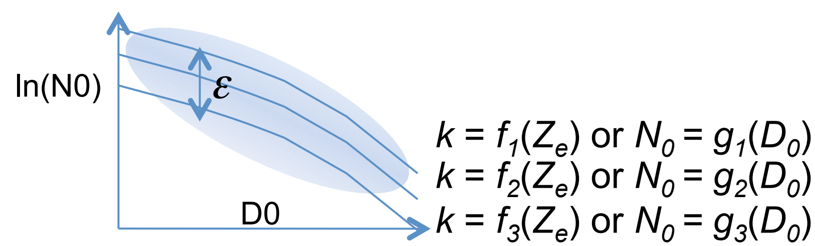
Equivalence of N_0-D_0 parameterization and k-Z_e-epsilon approach

- We assume that the PSD can be represented by two parameters.
  - We denote them by N_0 and D_0.
  - R, Z_e, k are all functions of N_0 and D_0:
    - $R(N_0, D_0)$, $Z_e(N_0, D_0)$, $k(N_0, D_0)$

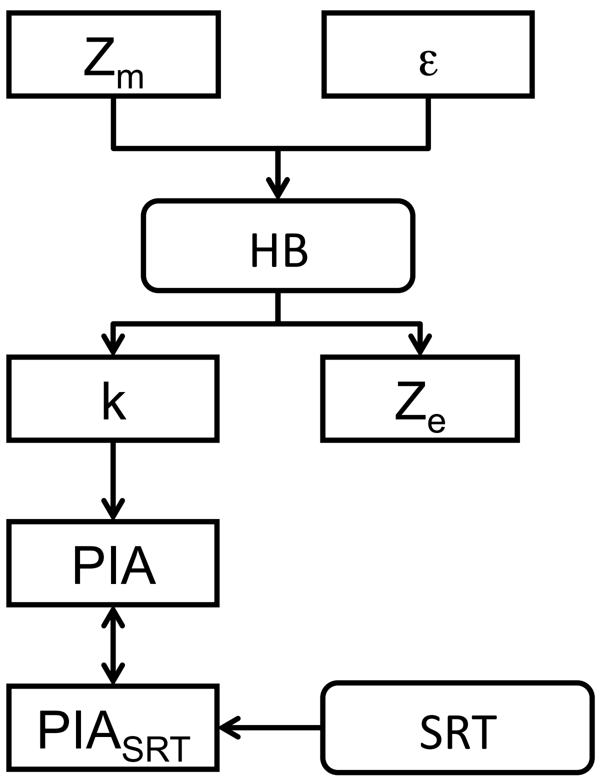


- Defining a k-Z_e relation gives a constraint on the N_0-D_0 relation: degree of freedom is 1.
  - $k(N_0, D_0) = f(Z_e(N_0, D_0))$ -> $N_0 = g(D_0)$



- Adding a parameter epsilon (ε) to the k-Z_e relation increases one degree of freedom to the N_0-D_0 relation. (degree of freedom is 2.)
  - $k(N_0, D_0) = f(Z_e(N_0, D_0), \varepsilon)$ -> $N_0 = g(D_0, \varepsilon)$
  - All realistic combination of (N_0, D_0) can be realized by Z_e and ε

The TRMM/PR standard algorithm (HB-SRT hybrid method)



Histchfeld-Bordan (HB) method corrects attenation with k-Z_e relations as

$k = \alpha Z_e^{\beta}$

where

$\alpha(r) = \varepsilon \alpha_0(r)$

ε is adjusted to maximize the likelihood;

$f(\varepsilon) g(\mathrm{PIA}_{\mathrm{SRT}}; \mathrm{PIA}(\varepsilon))$

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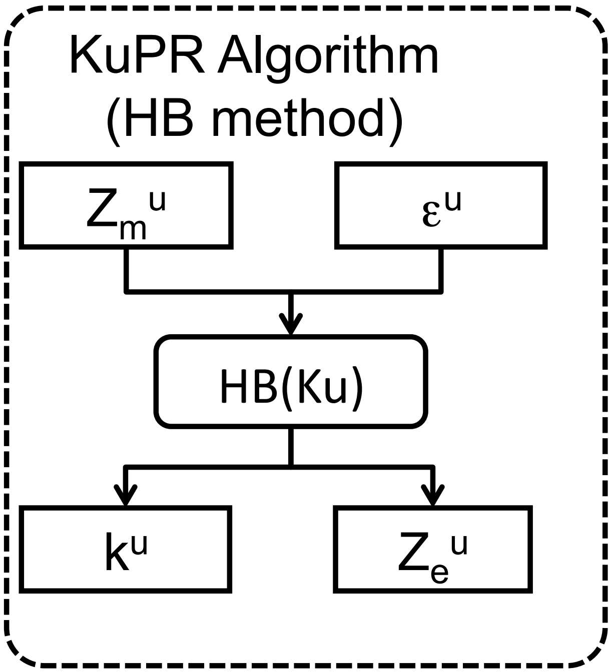
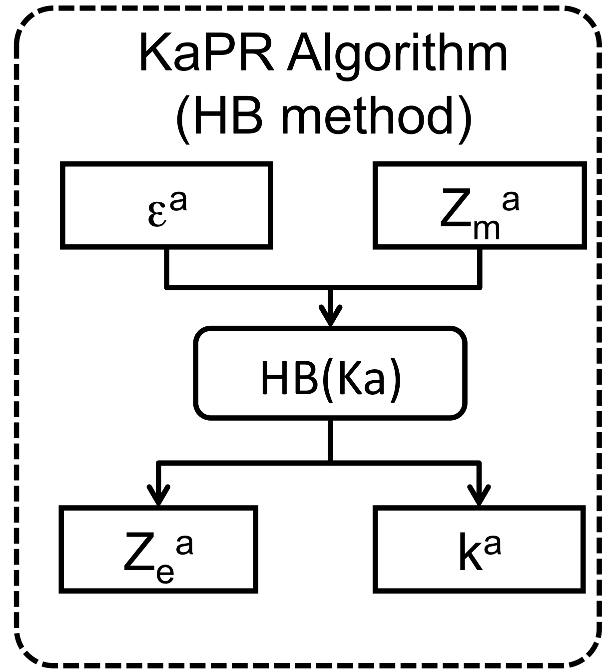
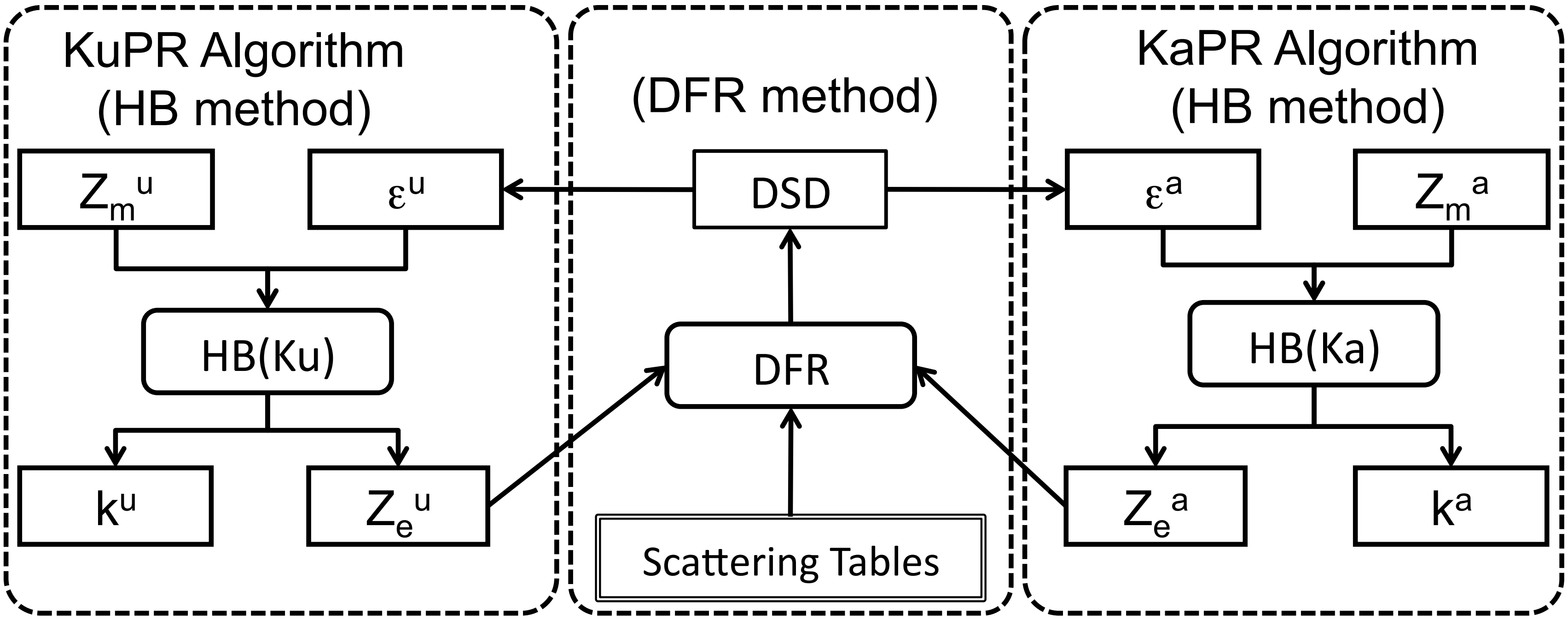
Baseline code for KuPR or KaPR algorithms (HB method)





Baseline code for Dual-frequency algorithm (HB-DFR method)



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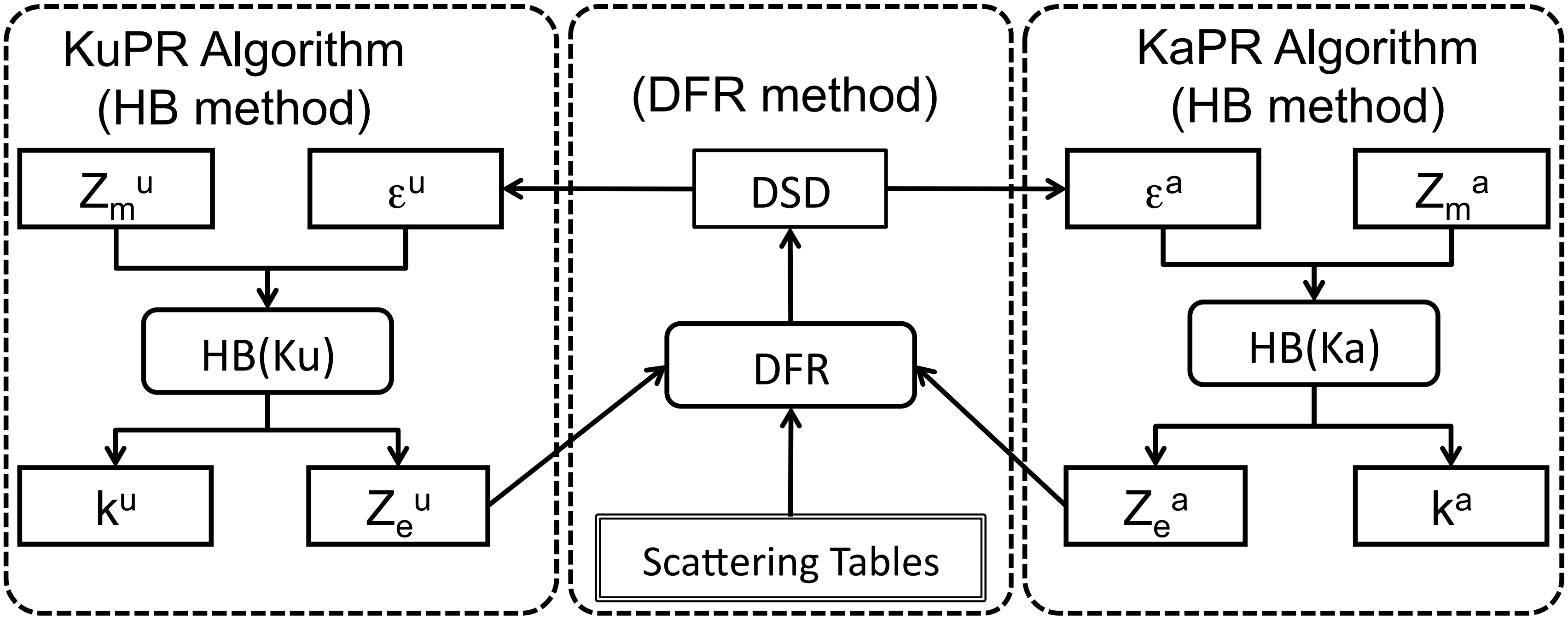
Baseline code for Dual-frequency algorithm (HB-DFR method)



Once DSD is estimated by DFR, k and Z_e are given as functions of N_0 and D_0.

For each range bin and frequency, ε is recalculated to satisfy $k=\varepsilon\alpha_0 Z_e^{\beta}$.

Iterations between HB and DFR may improve ε and DSD.

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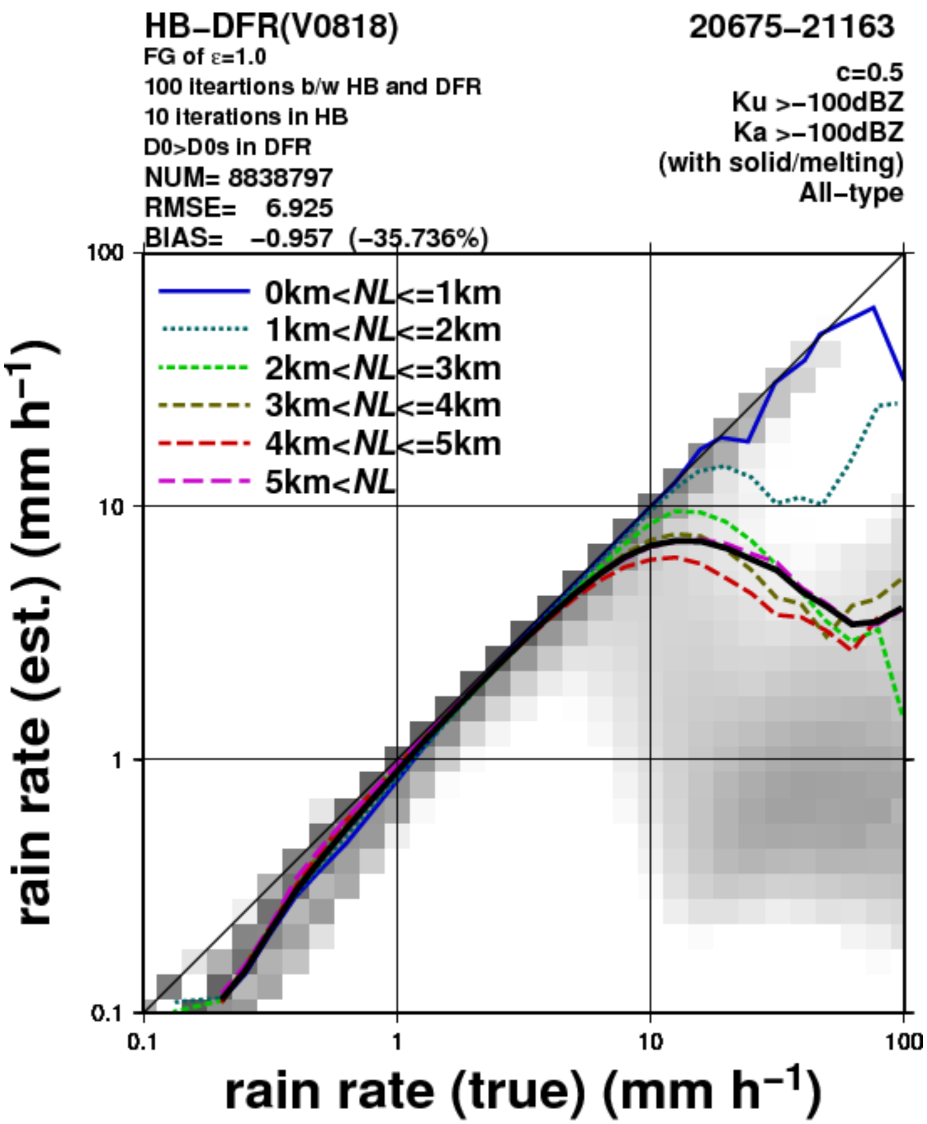
Testing of HB-DFR method

The simulation DPR dataset: DSD estimates by the TRMM/PR standard algorithm.
No measurement error, noise, clutter effects
One month (for July 2001)
# of iterations 100 (maximum)

Precipitation rate estimates at the lowest range bin (the closest to surface) are evaluated.

Light (0.1 – 1 mm/h)
Slight underestimation
Due to DFR (D_0>D_{0s})
Moderate (1 – 10 mm/h)
Satisfactory
Heavy (10 – 100 mm/h)
Severe underestimation
Due to multiple solutions
(*Seto and Iguchi 2011, IEEE TGRS pp. 1827-1838*)

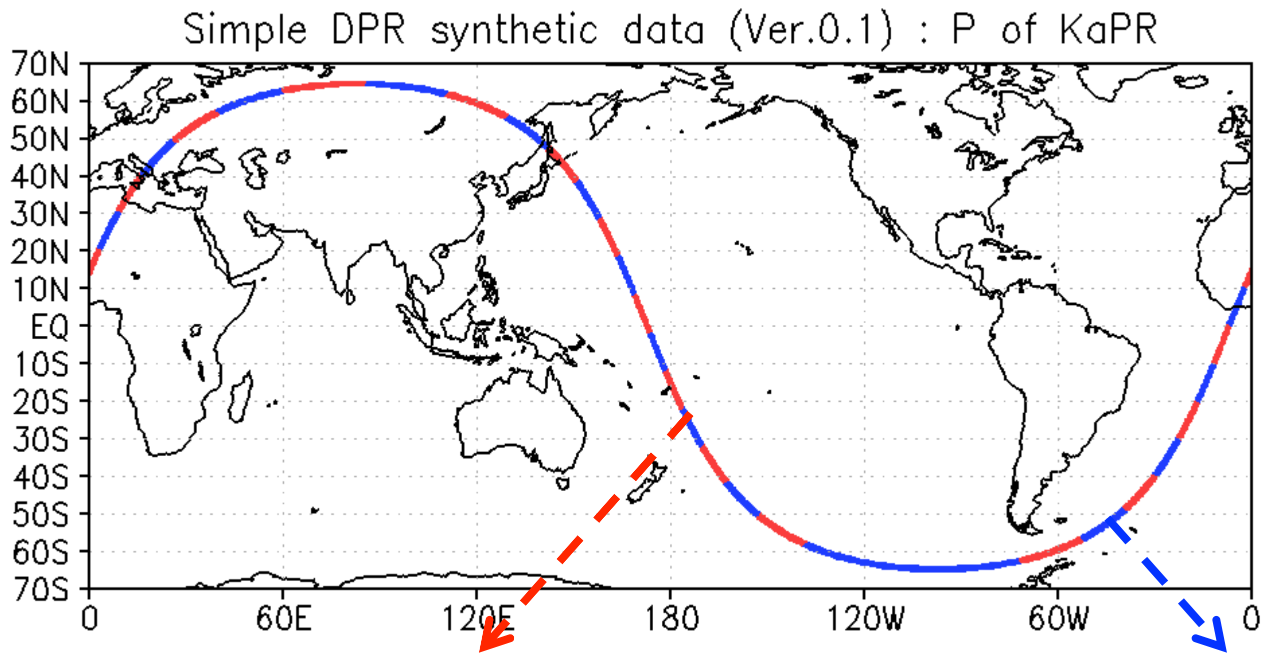


Synthetic simulation data

- JAXA is creating 3 kinds of synthetic L1B data in DPR format.
  - Synthetic data with simple assumptions
    1. Purely simple synthetic data (DPR format available)
  - Synthetic data under complicated assumption
    2. Empirical-based synthetic data (from TRMM/PR)
    3. Numerical simulation-based synthetic data

    (2 & 3: Now in binary-format, but DPR format available soon)
- US team members are also making synthetic data
  - Airborne data based (JPL, GSFC)
  - TRMM/PR (CSU)
  - Numerical model (GSFC)
  - etc.
- to be shared with other teams

Example: Received Power of KaPR



Fixed echoPower profiles for precipitation or non-precipitation pixels

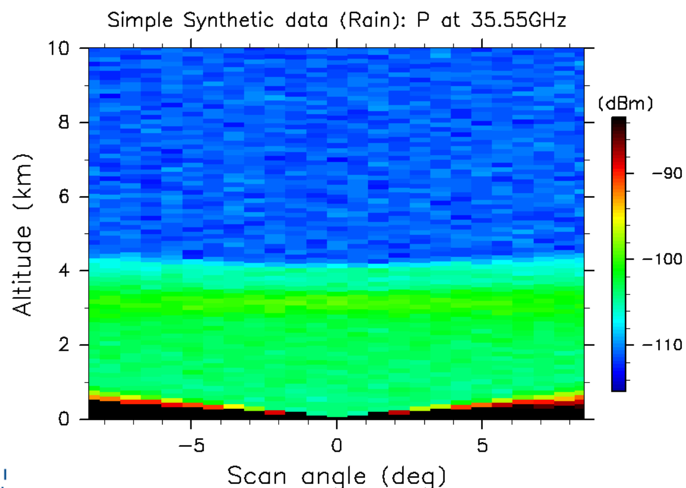
Rectangular precipitation area

(Rain condition)
Qr = 0.2(g/kg) below 4km, and Qr=0 above 4km

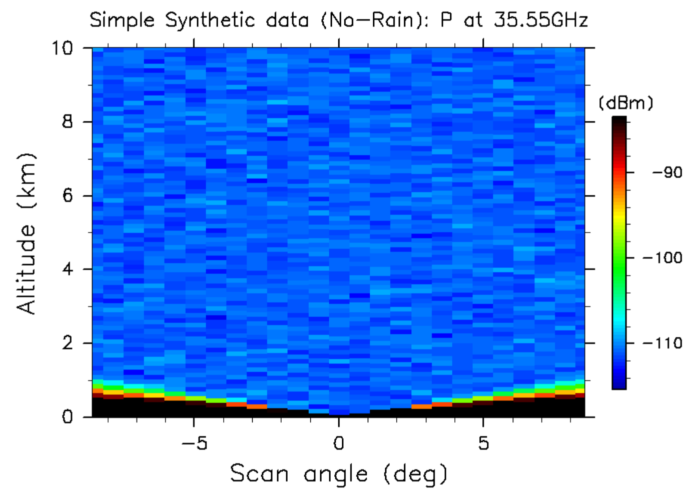
Ocean surface

Random noises

Vertical cross section in Rain case



Vertical cross section in No-rain case

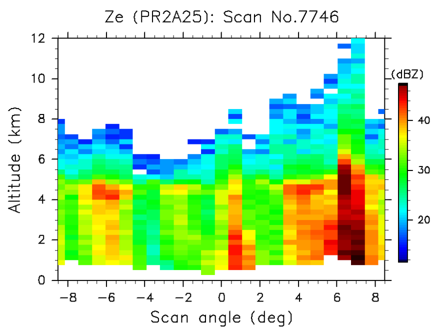


Kubota et al. (2011, *Proc. IGARSS*)

An example at vertical cross sections

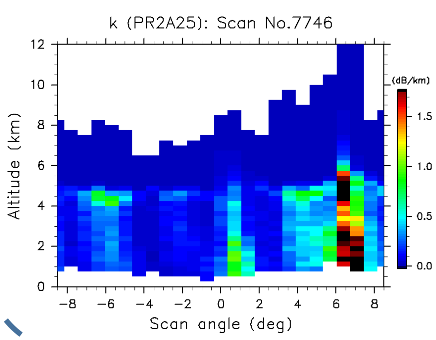
PR 2A25 Product

Attenuation-corrected effective Z-factor: Z_e



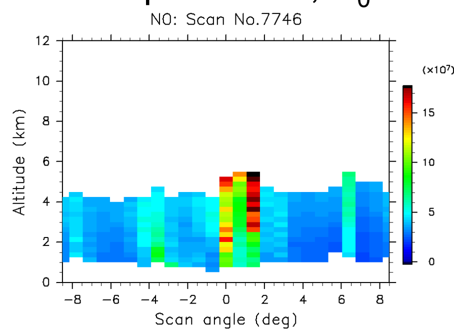
Specific attenuation: k

("k" as in $k=\alpha Z_e^{\beta}$)

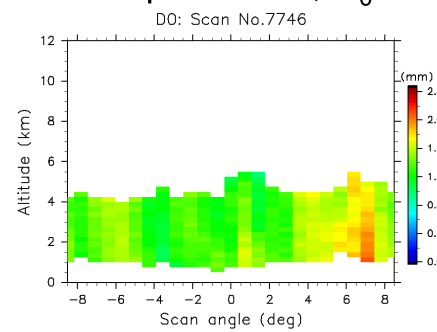


Rainfall signal only

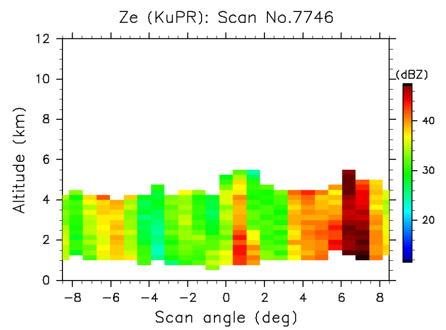
DSD parameter, N_0



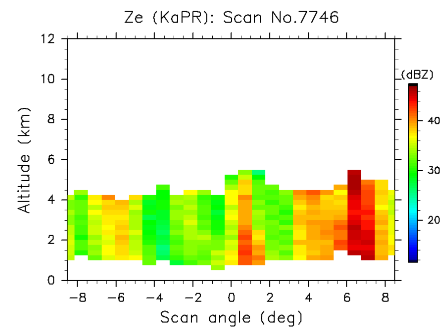
DSD parameter, D_0



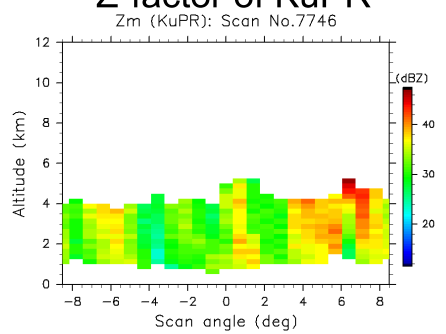
Effective Z-factor of KuPR



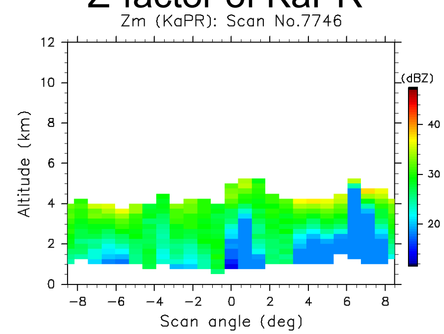
Effective Z-factor of KaPR



Attenuated effective Z-factor of KuPR



Attenuated effective Z-factor of KaPR



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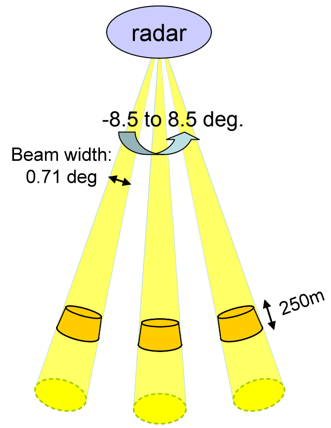
Kubota et al. (2010, *Proc. IGARSS*)

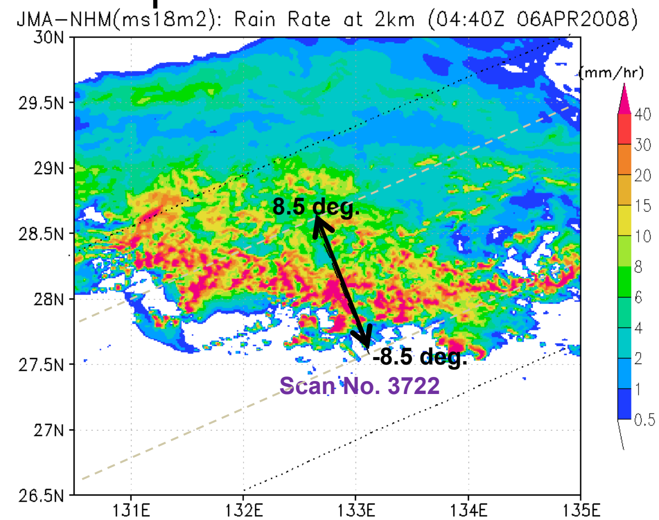
Examples of the GPM/DPR synthetic data

ISOSIM-Radar

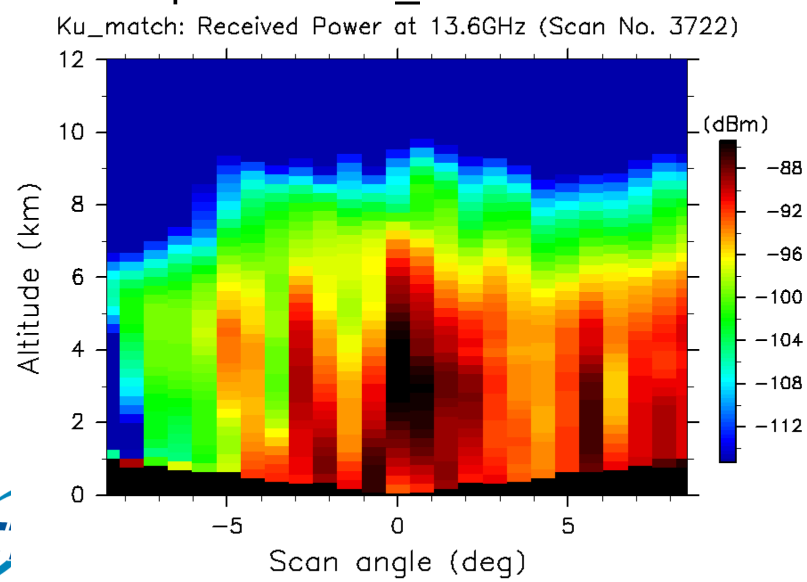


Sensor-related Parameters:
Height: 399.2km
Scan angle: -8.5 to 8.5 deg
25 angle bins (antenna beam directions)
Antenna gain: 47.4dBi
Sidelobe Level: -45dB
Pulse width : 500m
Antenna pattern : Gaussian
Sea Surface (spherical)

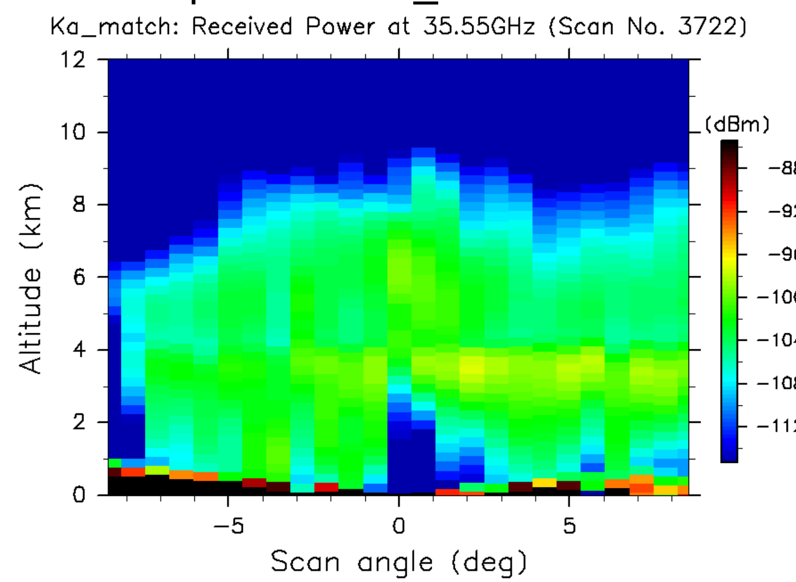
Scan position of ‘Scan No. 3722’



Received power of Ku_match at Scan No. 3722



Received power of Ka_match at Scan No. 3722



DPR Algorithm Schedule for 2011

Development Activities

Alg. Item	Up to 2010	Jan – Mar	Apr	May – Aug	Sep – Oct	Nov	Dec
Common	ATBD and A Table of variables	Framework of DPR-L2 Code (as Skelton Code)	Integration into Skelton Code	Testing of Skelton Code	Integration of sub modules into baseline code	Testing of Baseline Code	Deliver Baseline Code to JAXA and PPS
Preparation Module	Investigation of DPR-L1 data structure	Rain and clutter detection		Conversion to radar reflectivity factor	Conversion to surface backscattering cross section		
Vertical Profile Module	Investigation of GANAL data	Coordinate Conversion		Variable Conversion	attenuation correction for non-precipitation particles		
Classification Module	Investigation of TRMM/PR methods	Phase judgment method		Precipitation type judgment and bright band detection	A dual-frequency phase judgment method		
SRT Module	Investigation of TRMM/PR methods	A dual-frequency SRT method		Weak Rain Reference method	Preparation of preliminary database based on TRMM/PR products		
DSD Module	Preliminary Analysis	Look-up tables for liquid rainfall		Investigation of DSD in solid and melting layers	Look-up tables for solid and melting layers		
Solver Module	Improvement of IBRM methods	Testing of IBRM methods		Investigation of effective use of SRT in solver module	Testing of methods with SRT		
Misc.				Investigation of NUBF issues			
Simulation Dataset	Simple simulation data based on TRMM/PR products			L1B-format simulation data with simple assumptions			

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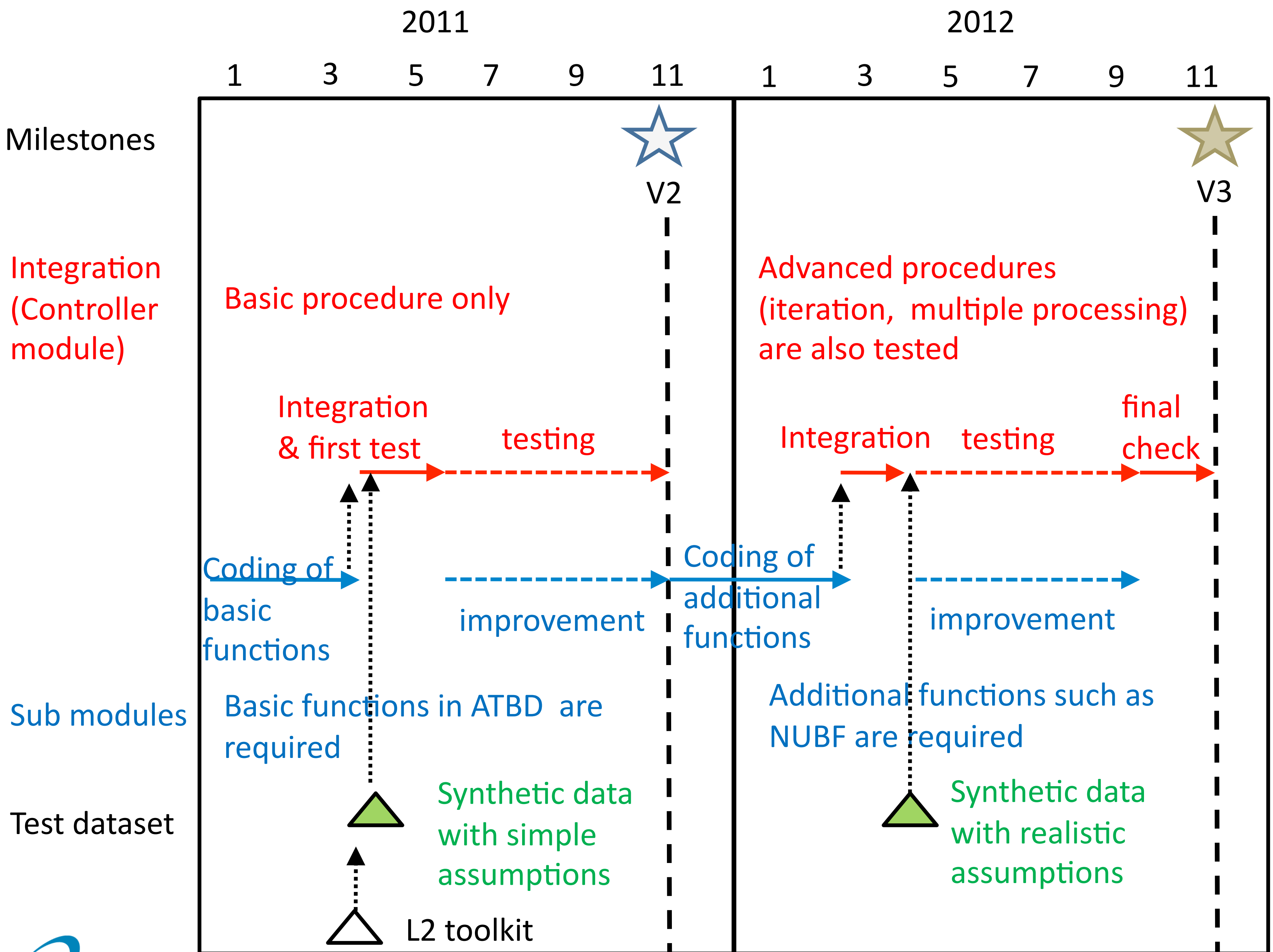
(Yellow boxes not implemented yet.)



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Summary and future activities

- DPR algorithm development nearly in accordance with the original schedule.
- Implementation of proposed and advanced functions
  - DFR SRT, wet surface 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
- Review of internal and external variables and format
  - Interface with other teams
- Uncertainty and error analysis
  - tests with synthetic data
- Evaluation of NUBF effect and development of compensation algorithm
- Revision of the ATBD

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Outline

- DPR algorithm
  - structure and modules
- Original schedule
- What we have done
- Changes
  - Solver,
- New implementation
  - Classification, SRT
- Simulation data
- Future activities
  - Error analysis, NUBF effect, L3 products, etc.
- Schedule

Radar Algorithm milestones in 2011

- October 2010: Define the input and output variables from each module
- March 2011: Submit a test version of modules
  - Scientific validity is not questioned in this version
  - Checking the overall flow of data is the main concern.
- March 2011: Synthetic data set for testing the algorithm.
- March 2011: Start testing each module and combined data flow with the synthetic test data.
- May 2011: Verify and summarize the performance of the test version.
  - summarize the issues and list the items to be improved or modified.
- October 2011: Submit code that satisfies the minimum functions described in the ATBD.
- November 2011: Submit the initial test version to PPS and EORC.
  - Comparison tests with GMI and combined algorithms.
  - Improve the algorithm
- November 2012: Submit the at-launch algorithm