Possible improvement of the Solver module for DPR standard algorithm Version 08

11th Workshop of
International Precipitation Working Group
July 15, 2024

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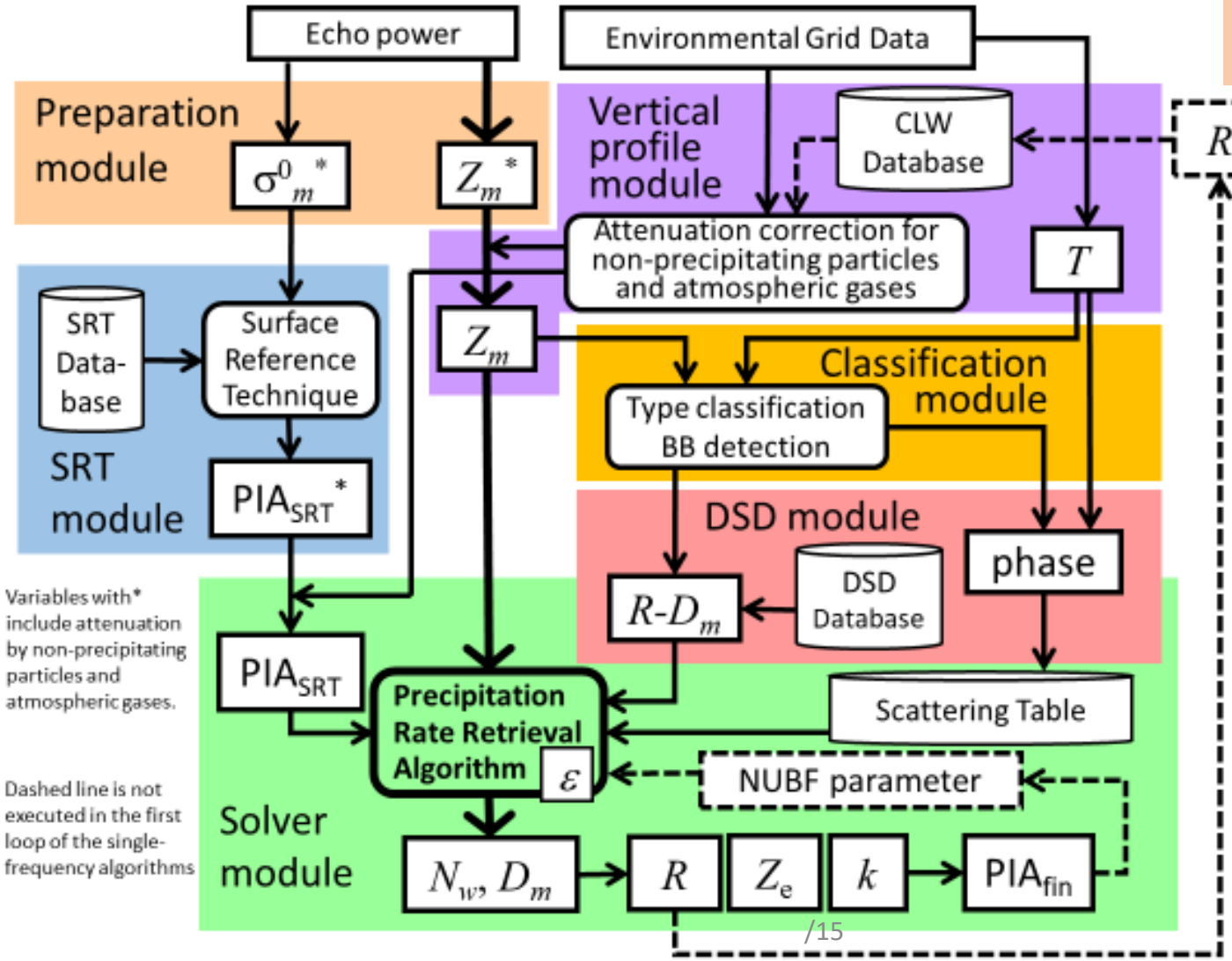
(Nagasaki University)

DPR standard algorithm Version 07

- **Version 08 is being developed and is planned to be released in 2026.**



Masaki et al. (2020)
IEEE Trans. Geosci. Rem. Sen.
10.1109/TGRS.2020.3039978

Kubota et al. (2020)
J. Atmos. Ocean. Technol.
10.1175/JTECH-D-20.0041.1

Awaka et al. (2021)
J. Meteorol. Soc. Japan
10.2151/jmsj.2021-061

Meneghini et al. (2021)
J. Meteorol. Soc. Japan
10.2151/jmsj.2021-010

Seto et al. (2021)
J. Meteorol. Soc. Japan
10.2151/jmsj.2021-011

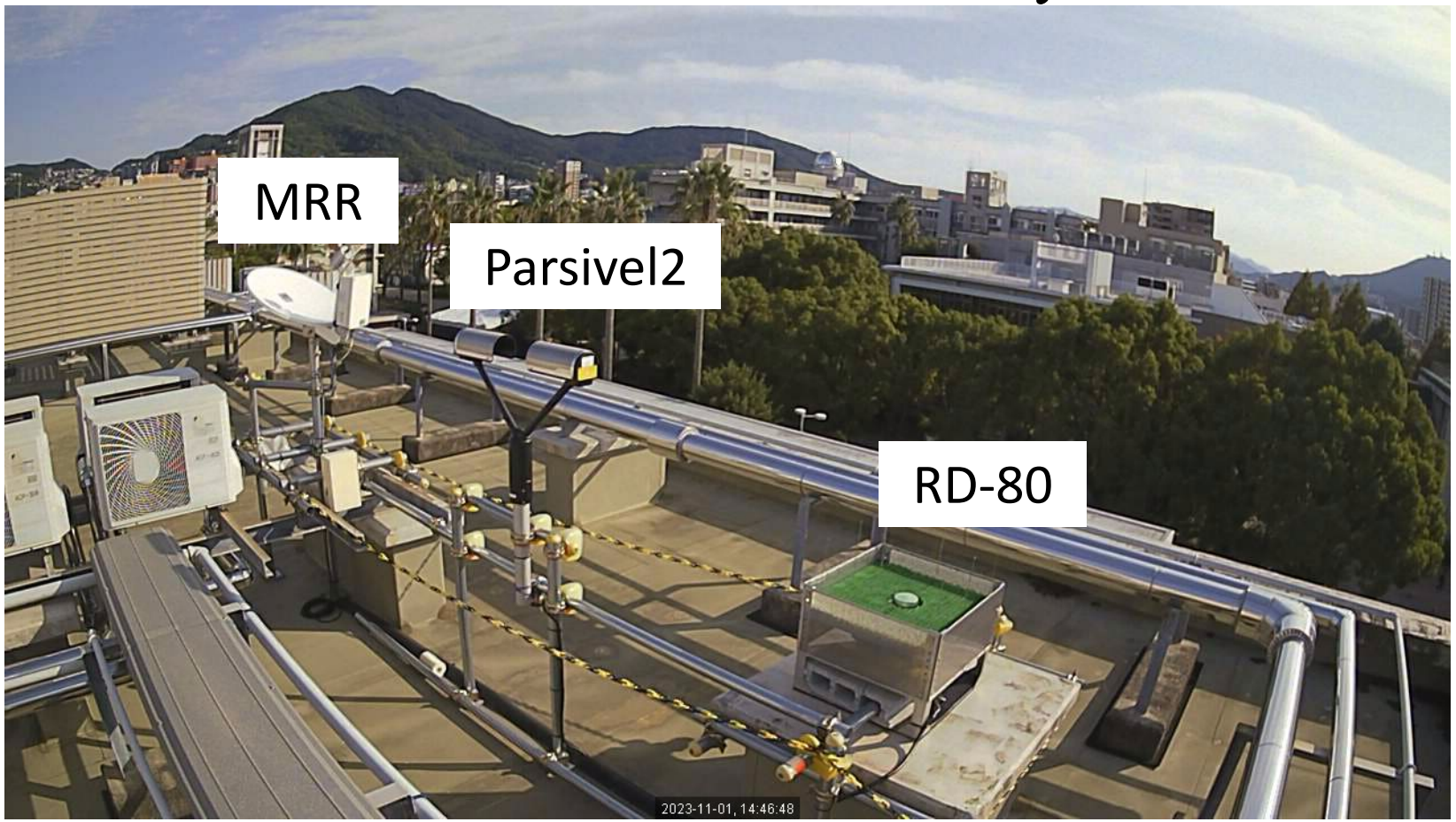
Seto (2024) New!
Advances in Weather Radar Volume 1, pp153-187.

Purpose

- Planned improvement of Solver module in Version 08
  - Extrapolation of *R* in main-lobe clutter region in all algorithms (in all algorithms)
  - Modification of the usage of SRT (in all algorithms, more important for KuPR algorithm)
  - New constraint on DFR (in dual-frequency algorithm)

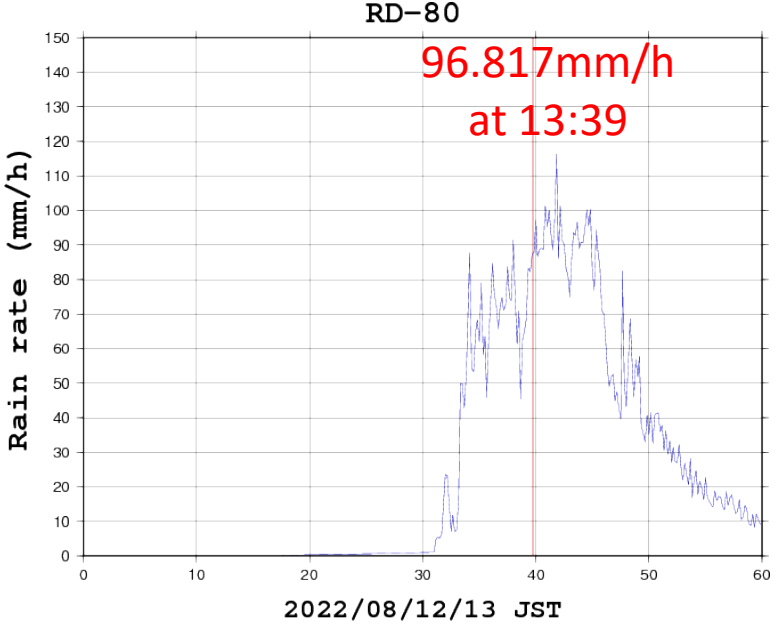
Observation at Nagasaki University

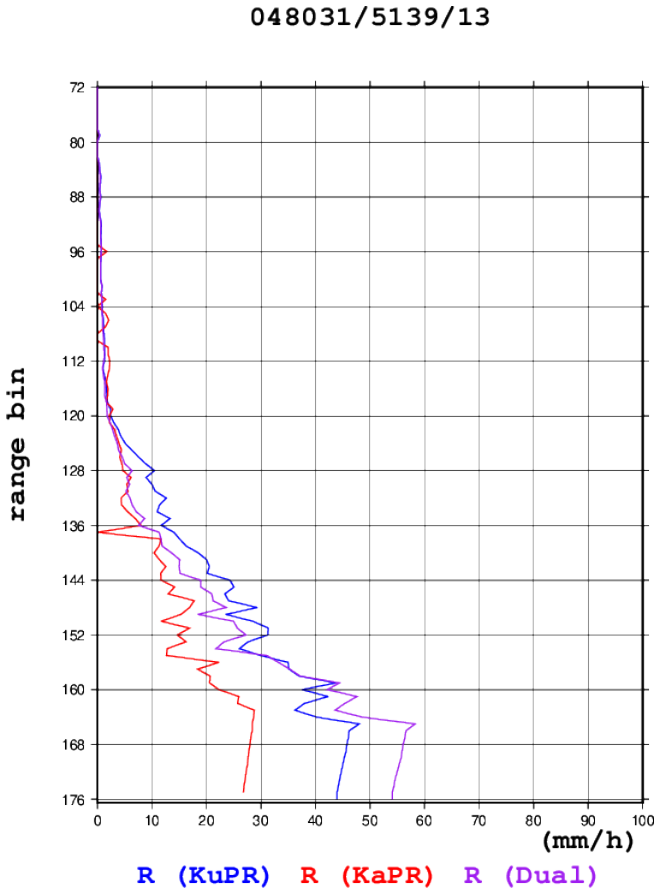
- Thanks to JAXA (and RESTEC), RD-80, Parsivel-2 and MRR have been installed at Nagasaki University.
- Observations continue for more than 2 years.

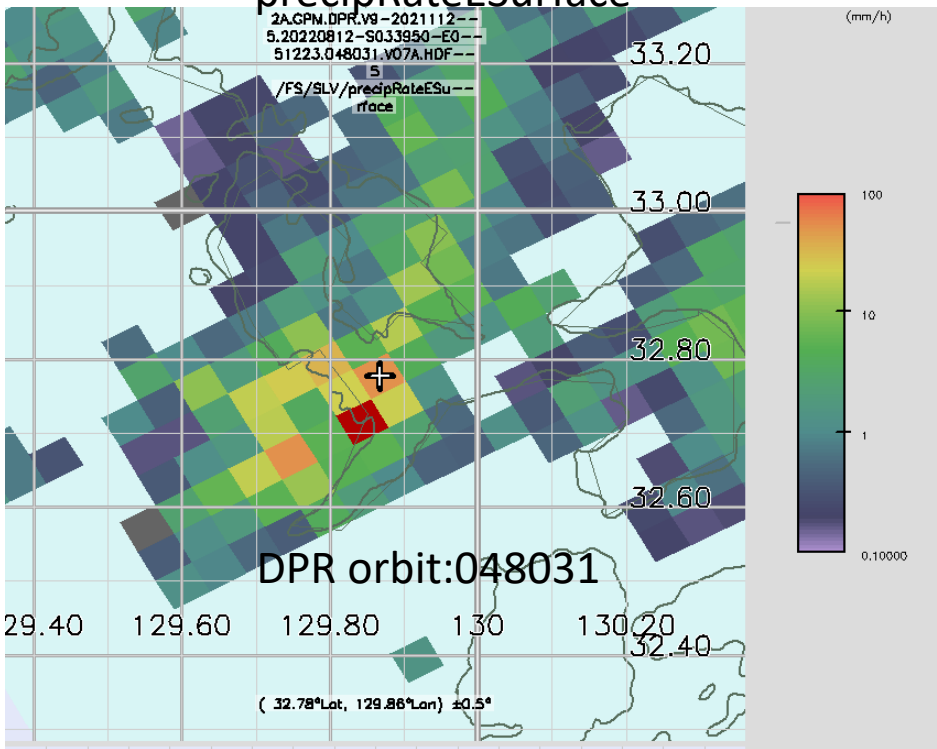


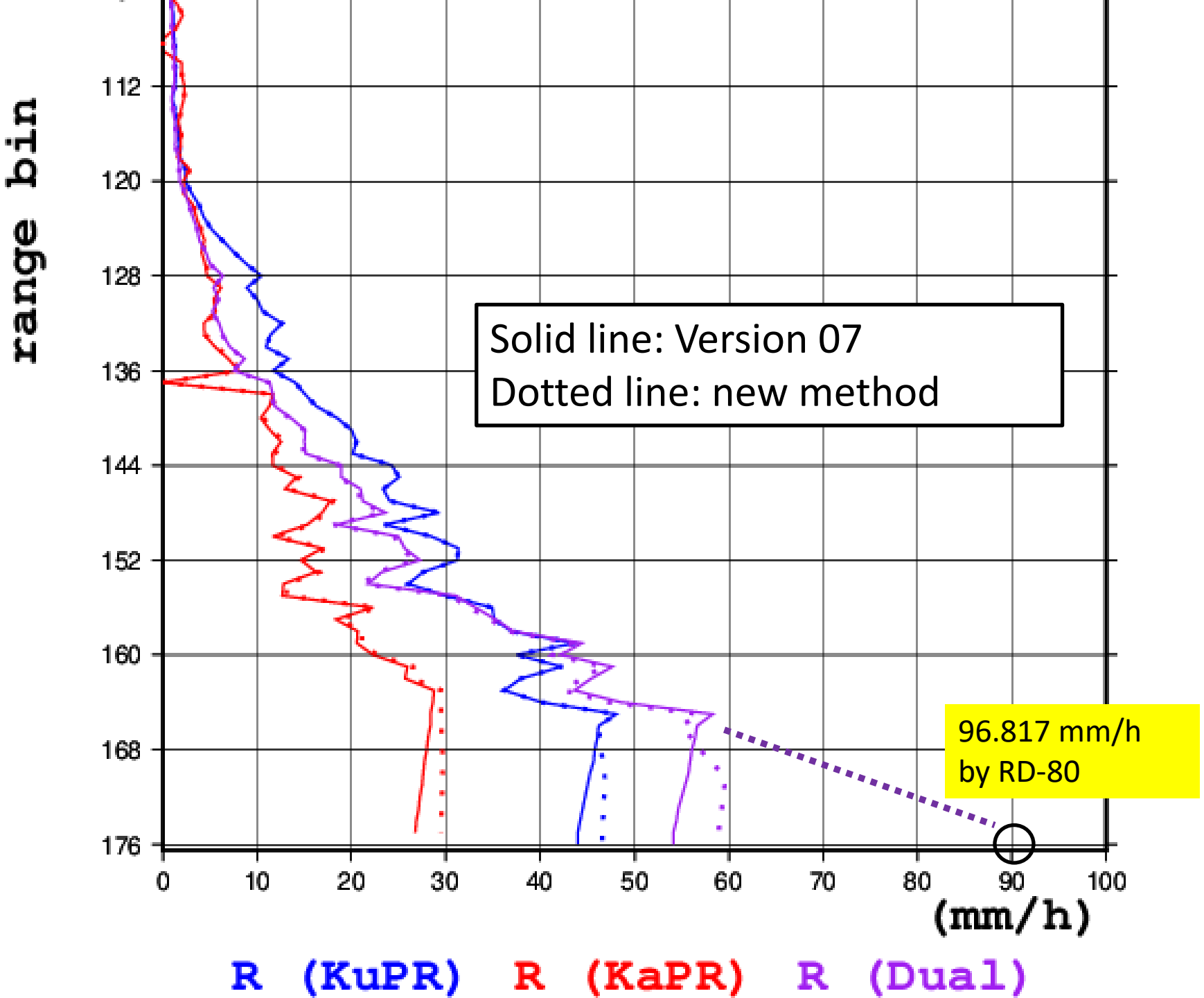
A heavy rainfall case

- Around 13:39, August 12, DPR observes heavy rainfall over Nagasaki University.








range bin
112
120
128
136
144
152
160
168
176
0
10
20
30
40
50
60
70
80
90
100
(mm/h)
Solid line: Version 07
Dotted line: new method
96.817 mm/h
by RD-80
R (KuPR)
R (KaPR)
R (Dual)

Extrapolation of R in main-lobe clutter region

- DPR algorithm V07 : Z_e is assumed to be vertically constant in the main-lobe clutter region.
- Hirose et al. (2021) : After the retrieval of R by the standard algorithm, R is extrapolated for the main-lobe clutter region using a database made by near-nadir observation.

→ Vertical profile becomes realistic, but the estimated precipRateESurface2 is not consistent with other products.

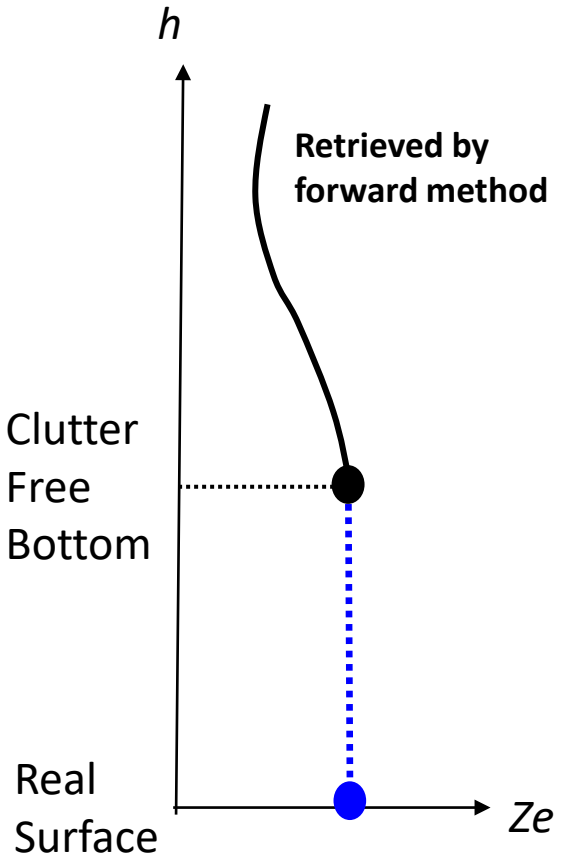
- Improvement plan : During the retrieval, for each candidate of ε, R is extrapolated based on the method of Hirose et al. (2021) or its updated method.
  - The best ε may be different by different extrapolation method.
  - Increase in computation resources may not be significant.

Extrapolation of R in main-lobe clutter region

In Version 07

- Forward retrieval with assumed ε
  - When Z_m is unavailable (main-lobe clutter region etc.), Z_e is set to be equal to that in one-level upper range bin

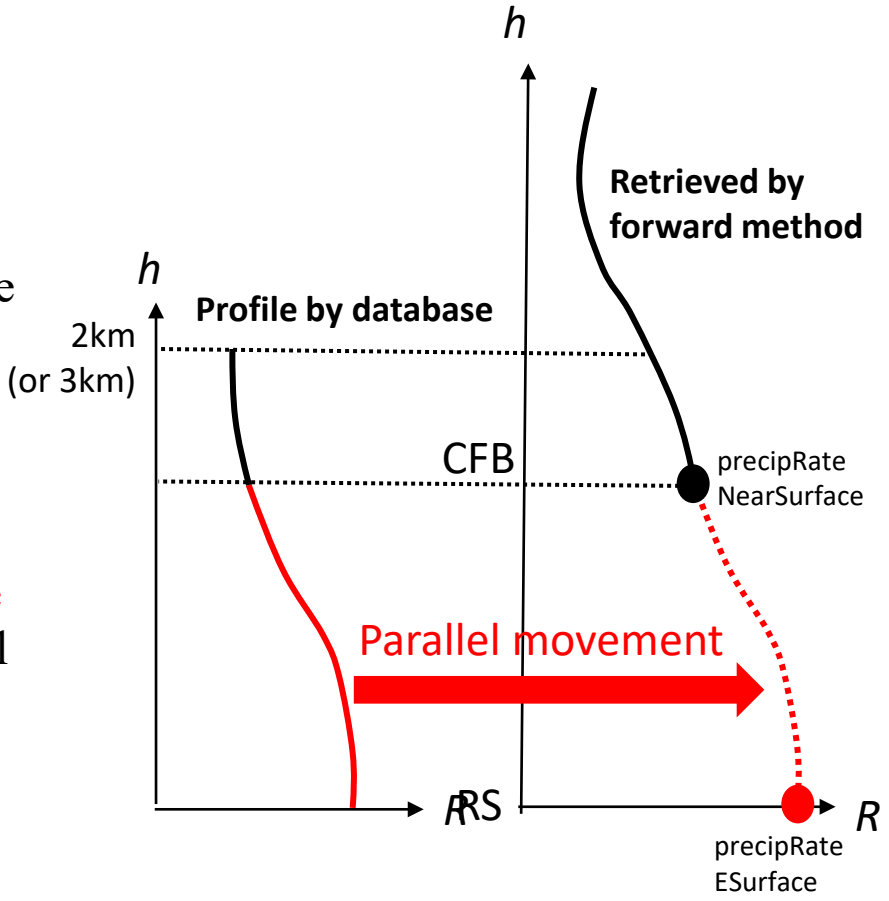
  → R is calculated from Z_e and ε
- The best ε is selected using SRT and a-priori pdf of ε



Extrapolation of R in main-lobe clutter region

New method

- A profile is selected from the database (Hirose et al. 2021) by referring output variables
  - In the second loop of single-freq. alg., the outputs of the first loop is referred.
  - In the dual-freq. alg., the outputs of the single-freq. alg. is referred.
- Forward retrieval with assumed ε
  - In the main-lobe clutter region, R is extrapolated by using the profile database
  - In the following cases, R is set to be equal to that in one-level upper range bin
    - Above CFB
    - In the first loop of single-freq. alg.
    - No profile database is selected
    - $R < 0$ if the database is used.
- The best ε is selected using SRT and a-priori pdf of ε



Conditions to select profile database

According to Hirose et al. (2021)

binStormTop

binZeroDeg

binClutterFreeBottom

binRealSurface

localZenithAngle

Storm Height

SH=(binRS-binST)*cosθ*125m

Freezing Height

FH=(binRS-binZD)*125m

Main-lobe bin number

MC=(binRS-binCFB)

SH (km)

SH<0 →No profile

0≦SH<3

3≦SH<6

6≦SH<9

9≦SH<12

12≦SH<15

15≦SH<20

20≦SH →No profile

SH 6 group

FH (km)

FH<-1

-1≦FH<0

0≦FH<1

1≦FH<2

2≦FH<3

3≦FH<4

4≦FH<5

5≦FH

FH 8 group

MC≦0 →No profile

1≦MC≦16 → 2kmDB

17≦MC≦24 → 3kmDB

25≦MC →No profile

2km DB 3km DB

20 28

19 27

18 26

17 25

16 24

15 23

14 22

1 1

0 0

ClutterFreeBottom

RealSurface

If all R>0 yes → Δ*R*/Δ*h*(mm/h/km)

no → Group-0

h

-5 -2 -0.5 +0.5 +2 +5

Slope 7 group

R

landSurfaceType

typePrecip

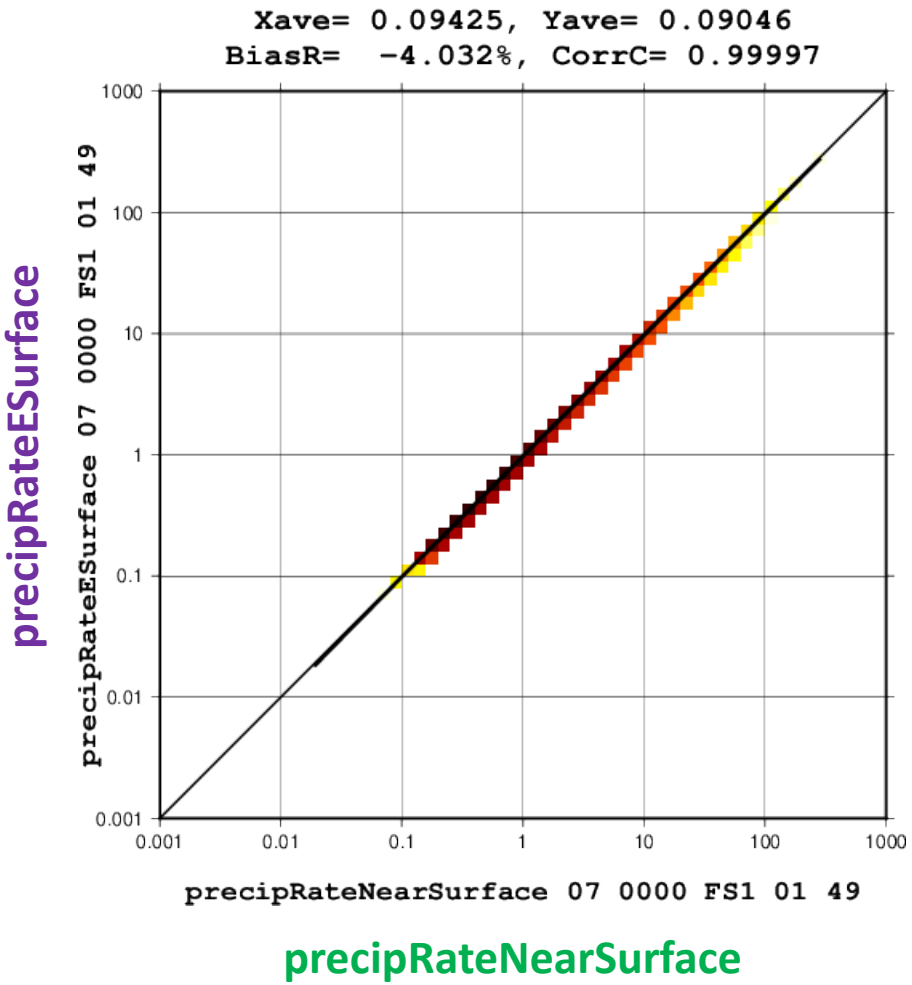
	Stratiform	Convective	Others
Ocean	Type 4 group		No profile
Others			No profile

Results (precipRateNearSurface & precipRateESurface)

KuPR algorithm

(Oribit #024182～024642 in June 2018)

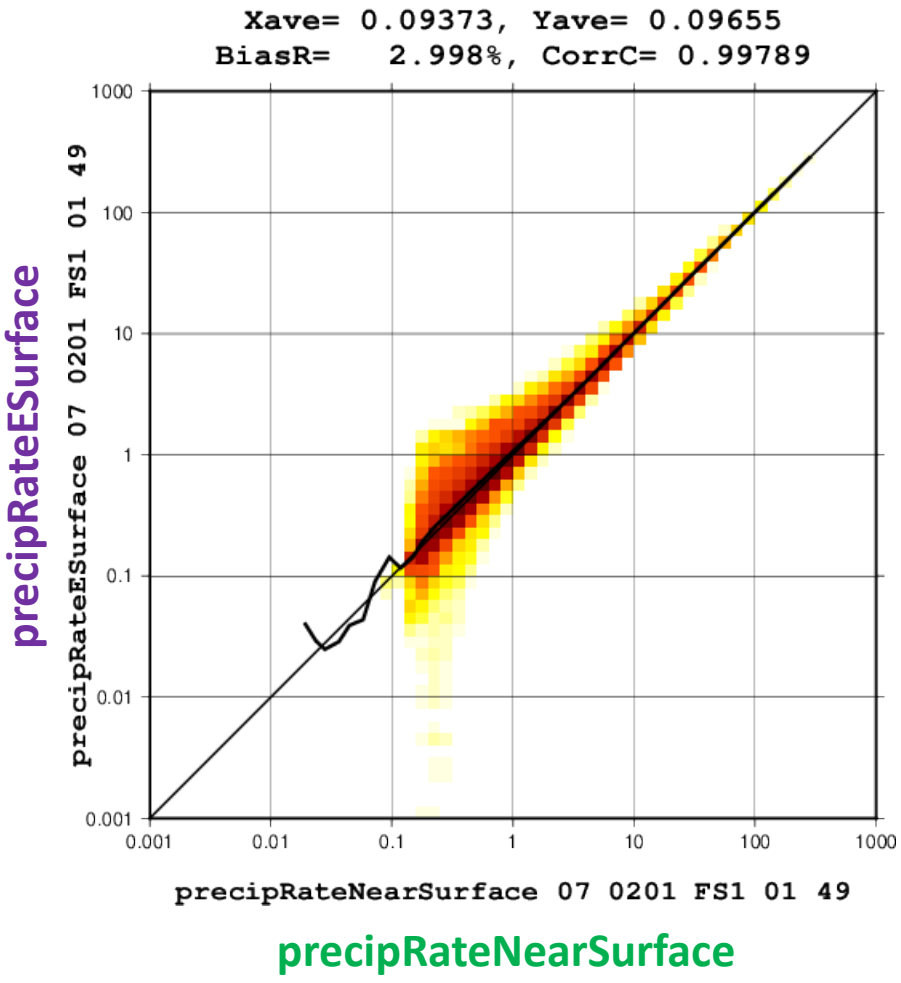
Version 07



precipRateESurface

precipRateNearSurface

New method



precipRateESurface

precipRateNearSurface

Results (precipRateNearSurface & precipRateESurface)

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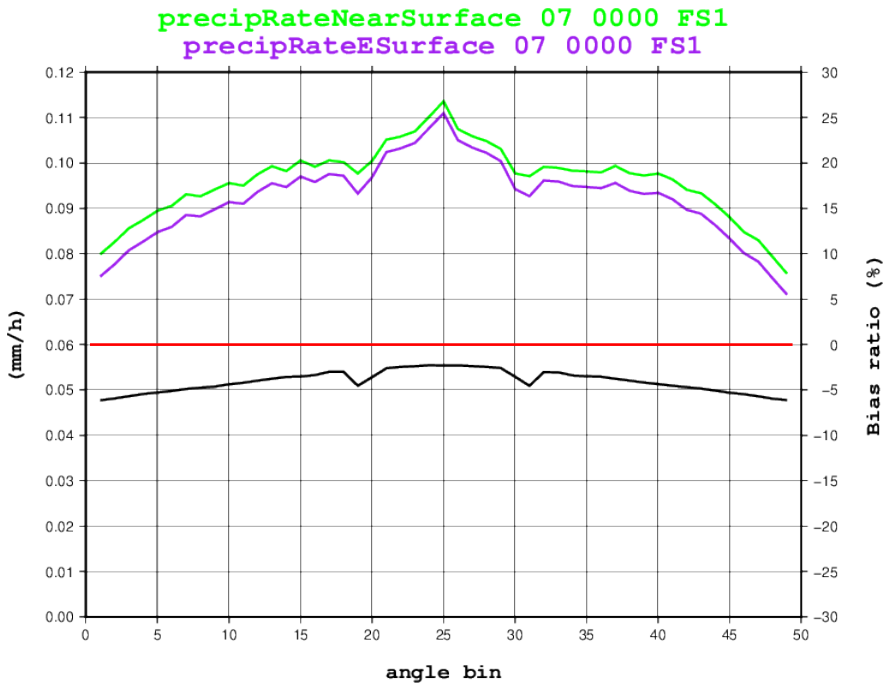
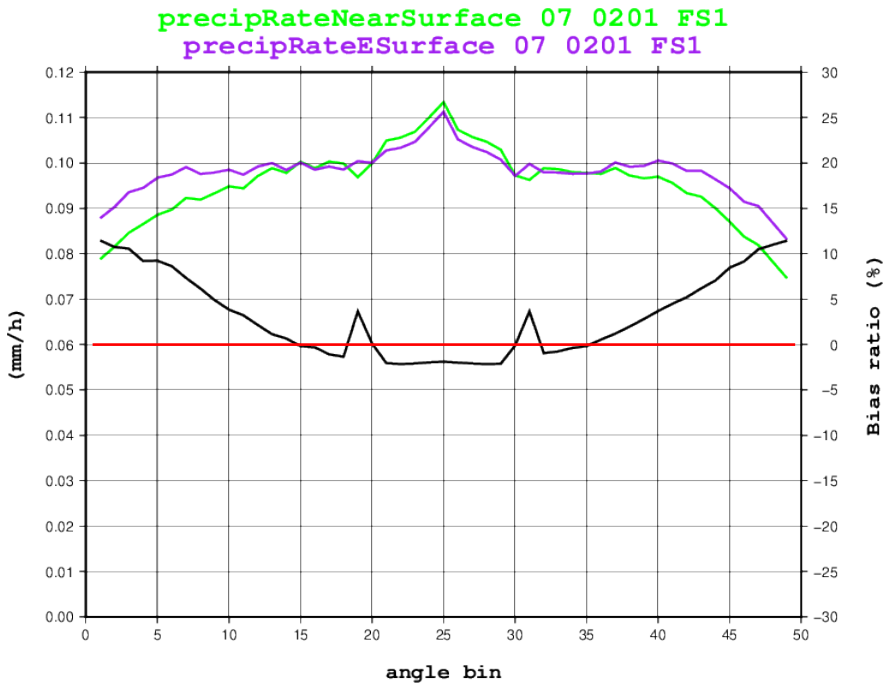


New method

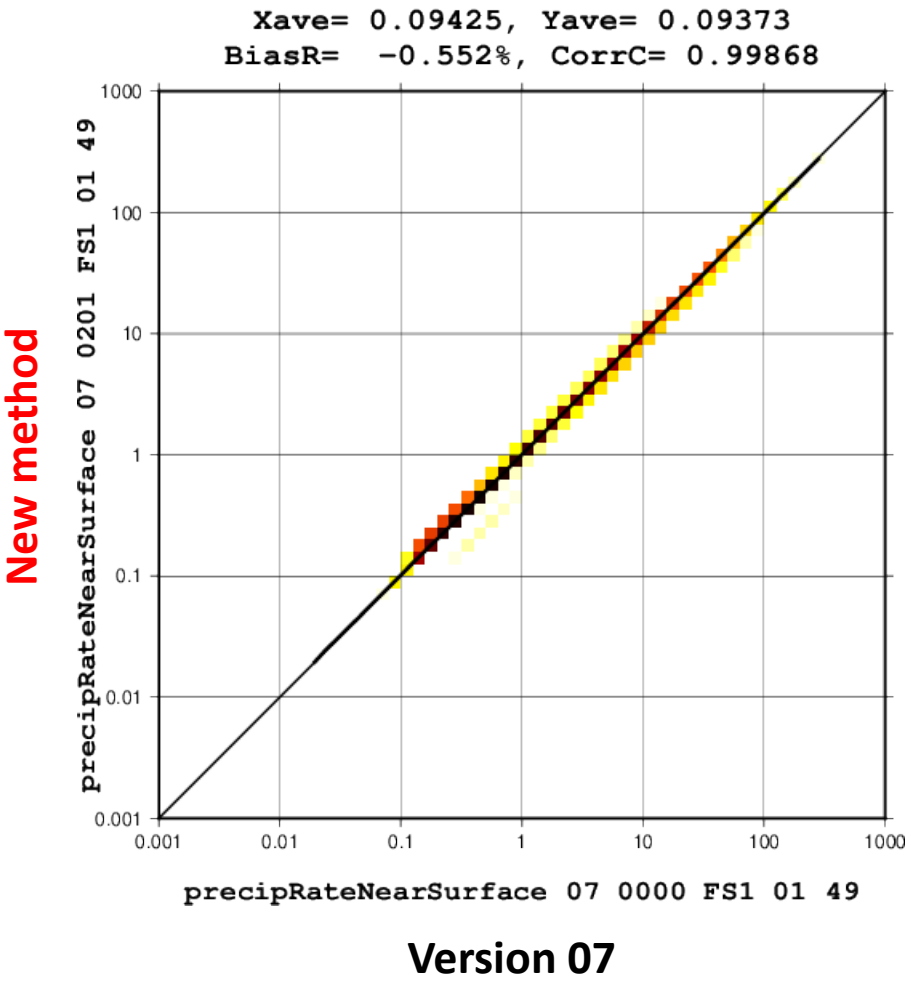


Results (Version07 → New method)

KuPR algorithm

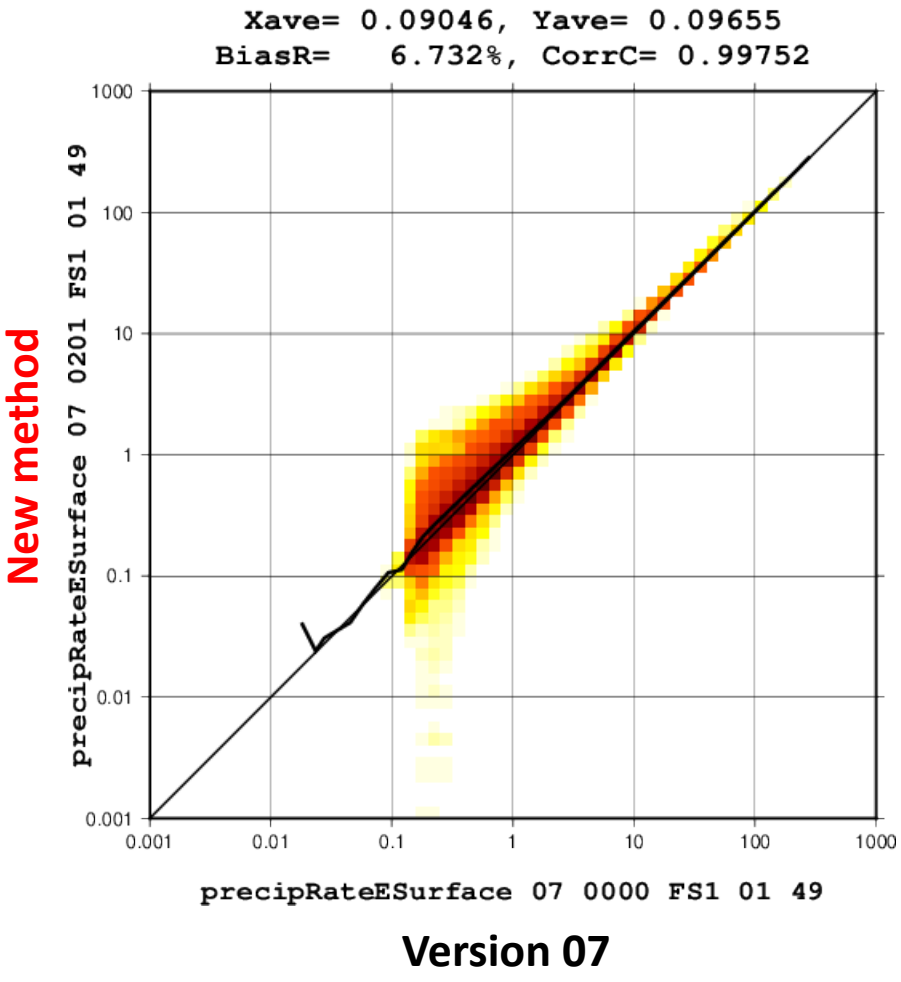
(Oribit #024182～024642 in June 2018)

precipRateNearSurface



Version 07

precipRateESurface

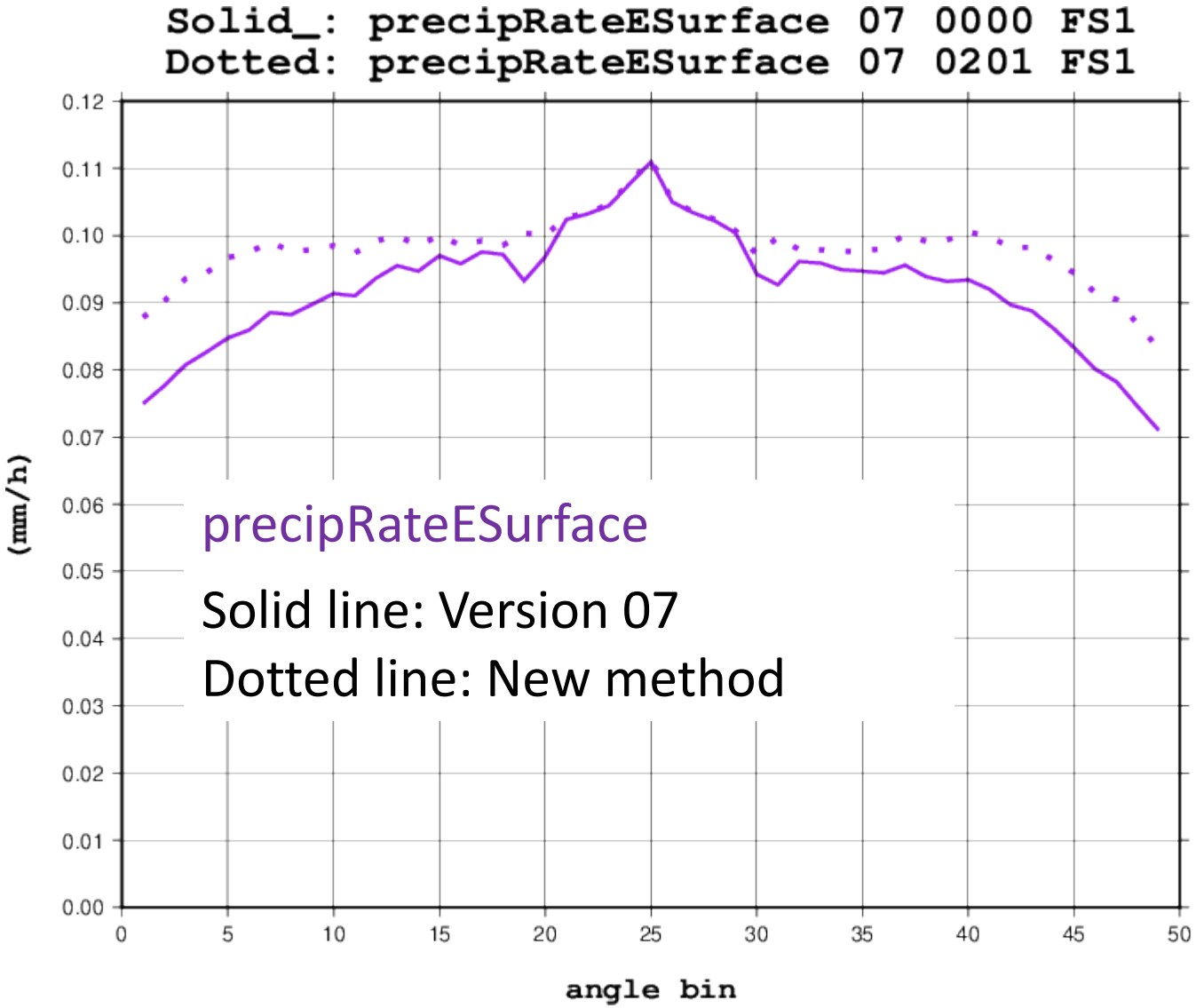


Version 07

Results (Version07 → New method)

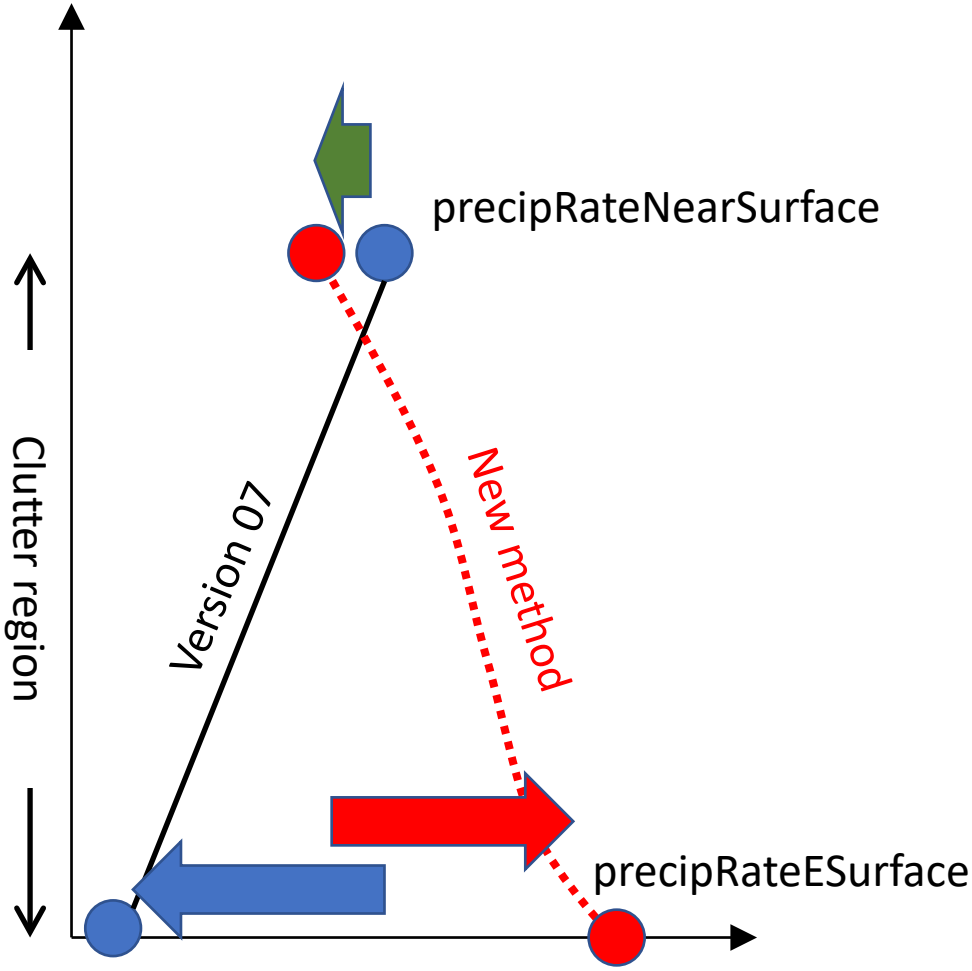
KuPR algorithm

(Oribit #024182～024642 in June 2018)



Results (summary)

- In Version 07, precipRate decreases in going downward
- In new method, precipRate generally increases in going downward
- *Due to the SRT constraints,* precipRateNearSurface (and precipRate above CFB) generally becomes smaller in new method.
- precipRateESurface generally becomes larger in new method.



Results (summary)

	KuPR Algorithm	KaPR algorithm	Dual-freq. algorithm
precipRateESurface(V07) ⇓ precipRateNearSurface(V07)	＋4.2%	＋7.3%	＋4.2%
precipRateNearSurface(V07) ⇓ precipRateNearSurface(new)	－0.6%	－0.5%	－0.9%
precipRateNearSurface(new) ⇓ precipRateESurface(new)	＋3.0%	＋1.4%	＋3.8%
precipRateESurface(V07) ⇓ precipRateESurface(new)	＋6.7%	＋8.2%	＋7.1%

Summary

- A new extrapolation of *R* in main-lobe clutter region is implemented according to Hirose et al. (2021).
  - Compared to Version 07, precipRateESurface increases by about 7 %.
  - The increase ratio is higher for larger incidence angle

  → Incidence angle dependence is partly mitigated.
  - For a heavy rainfall case, rapid increase in precipRate is not well shown by the new method.

Purpose

Version 07 products are evaluated to get an idea how to improve the algorithm in Version 08.

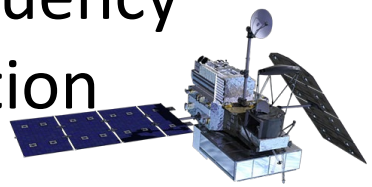
Data used in this study

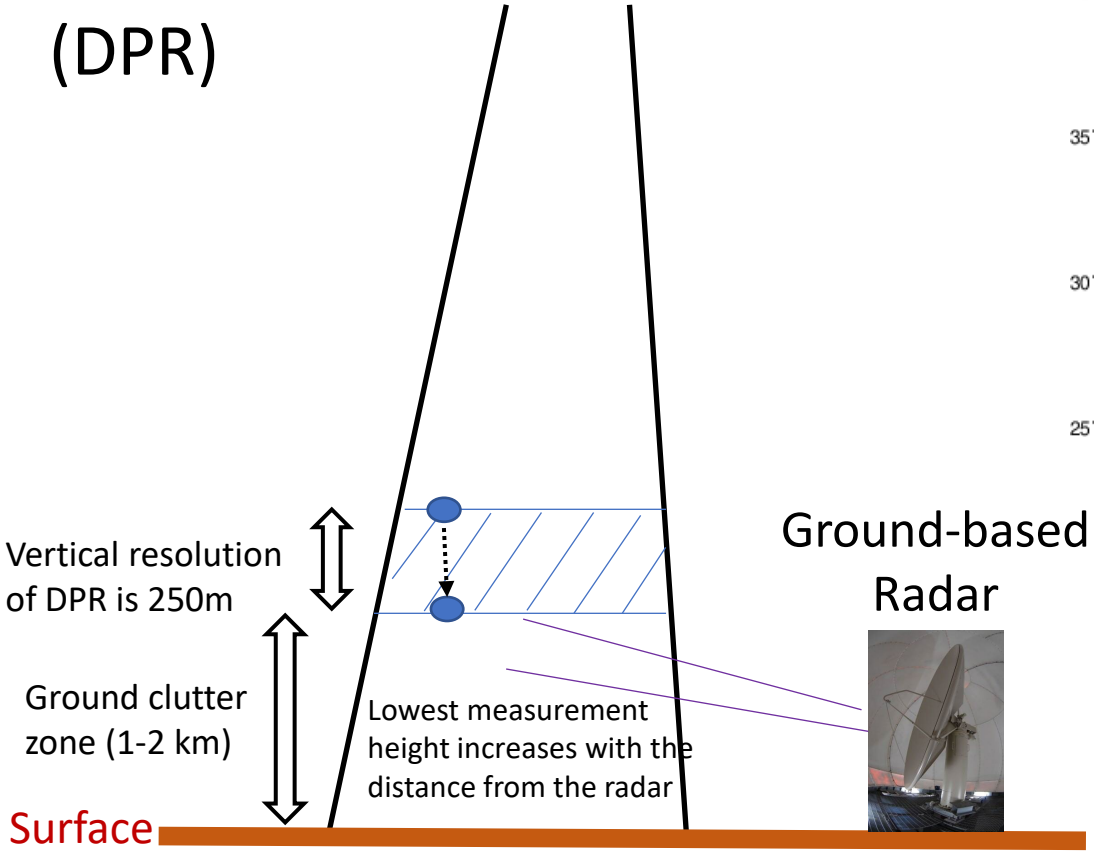
- DPR standard product Version 07
  - Orbit number from 024021 (after the scan pattern change on May 21, 2018) to 055066 (before the orbit boost on November 7, 2023)
  - KuPR product, KaPR product, and the dual-frequency product
  - precipRateESurface is the main variable to be analyzed

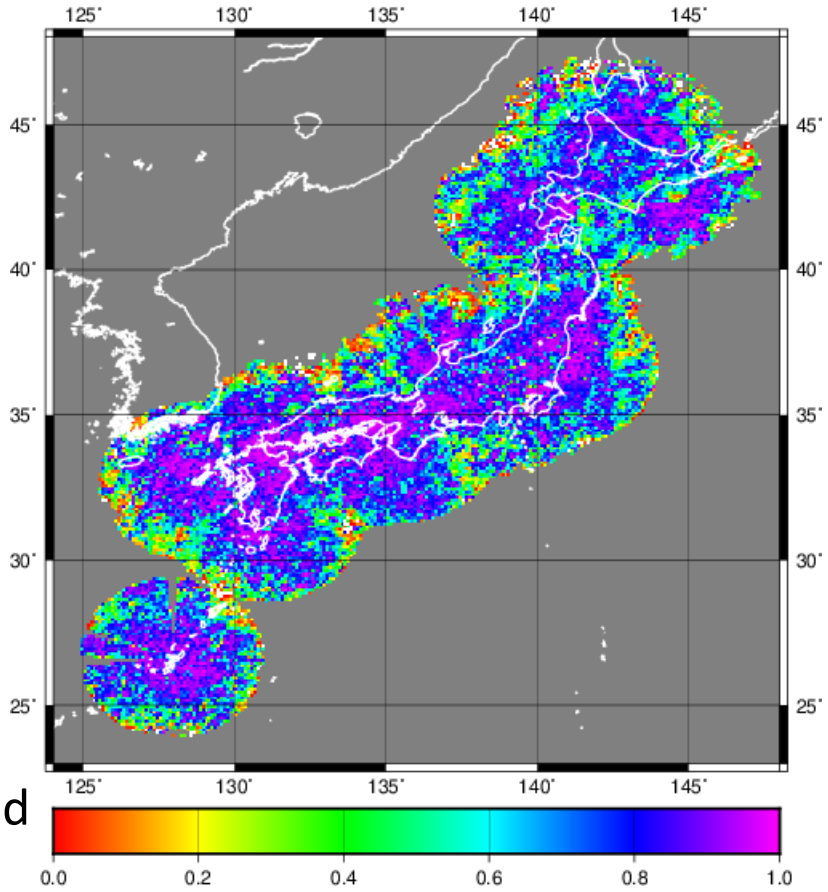
- XRAIN (composite of X-band and C-band ground-based rainfall radars)
  - Operated by MLIT, Japan and distributed by DIAS.
  - Available on and after April 5, 2018
  - 1-minute data
  - Spatial resolution is about 250m (1/320 deg. By 1/480 deg.)
  - Upscaled to 1km resolution (1/80 deg. by 1/120 deg.)

Preliminary analysis

Dual-frequency Precipitation Radar (DPR)







Correlation coefficient between DPR and XRAIN

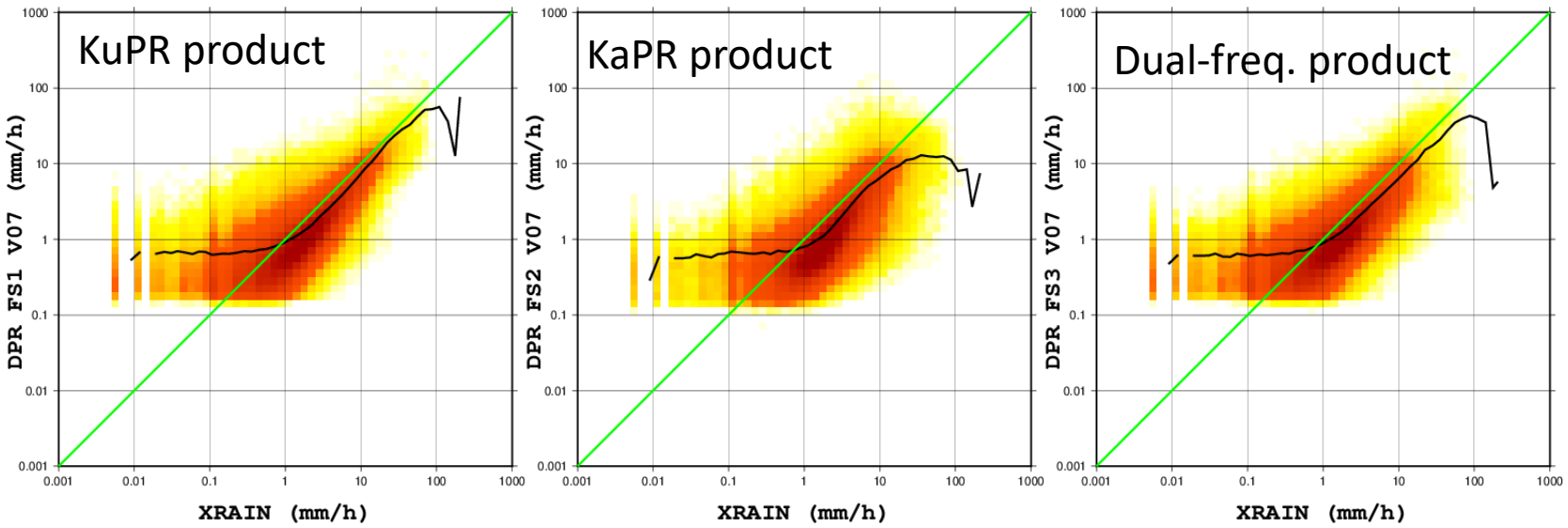
XRAIN data is degraded as the distance from the radar is longer

→ Matchup over ocean is excluded from this study

→ Time lag between DPR and Ground-based radar is NOT set in this study.

Evaluation results (1)

Abscissa: XRAIN
Ordinate: DPR
A black solid line is for the average value of DPR



	KuPR product	KaPR product	Dual-freq. product
Correlation Coefficient	0.594	0.465	0.553
RMSE (mm/h)	1.500	1.446	1.454
Bias ratio	-20.8%	-42.0%	-26.8%

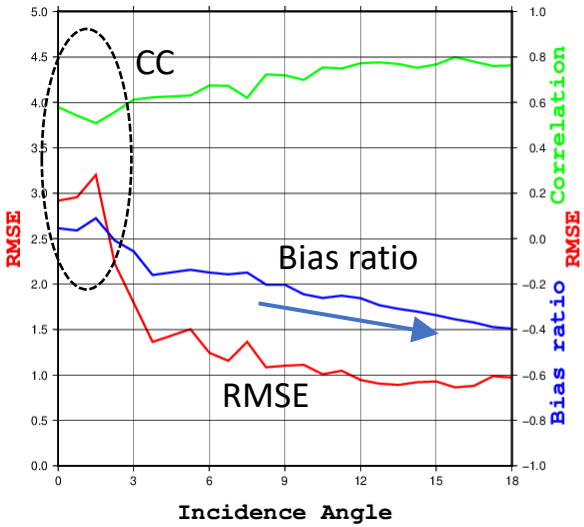
Bias ratio = (DPR-XRAIN)/XRAIN

Evaluation results (2)

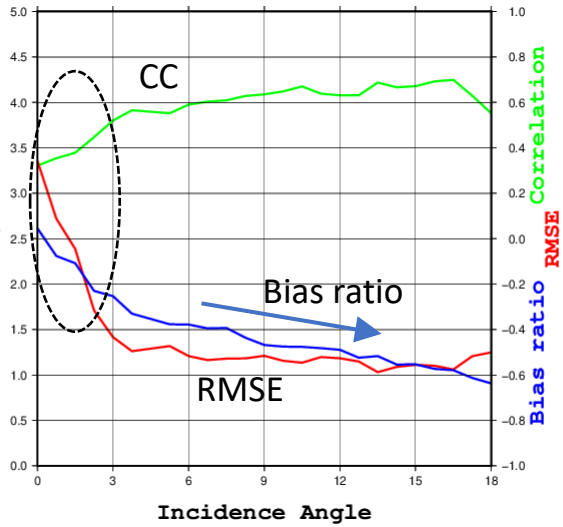
Abscissa: Incidence angle

Ordinate: Correlation coefficients(green)
RMSE(red) Bias ratio(blue)

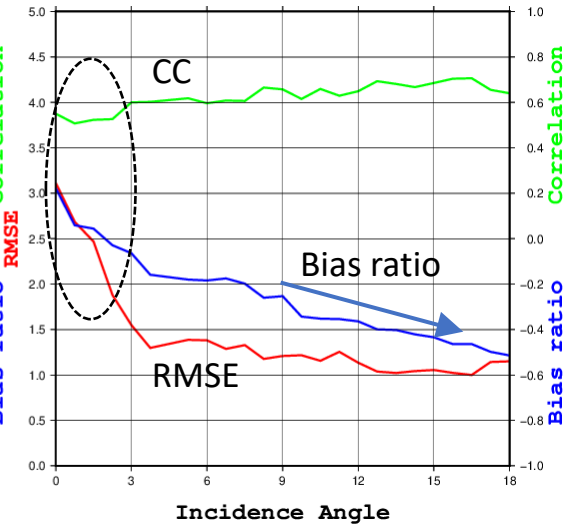
KuPR product



KaPR product



Dual-freq. product



- At larger incidence angle, the bias ratio is lower and negative.
  ←Because of the main lobe clutter, low storm is missed.

- At smaller incidence angle, RMSE increases and CC decreases
  ←Possibly because of Surface Reference Technique (SRT)

Modification of the Solver module to use SRT

- As the bias in precipRateESurface may be caused by SRT, the usage of SRT is modified in the Solver module of KuPR algorithm.
- Test products with different usage of SRT are produced, then they are evaluated with XRAIN.
  - For about 800 orbits which passed over Japan in 2022
- w (the weight of SRT to determine ε) is modified.

Test product 5	w=2.0
Standard product	w=1.0
Test product 1	w=0.5
Test product 2	w=0.2
Test product 3	w=0.1
Test product 4	No SRT is used

A new condition is added to prefer a profile where the vertical change of *R* is smaller. (restriction of vertical profile)

$x(=\log_{10}\varepsilon)$ is selected to maximize the following probability

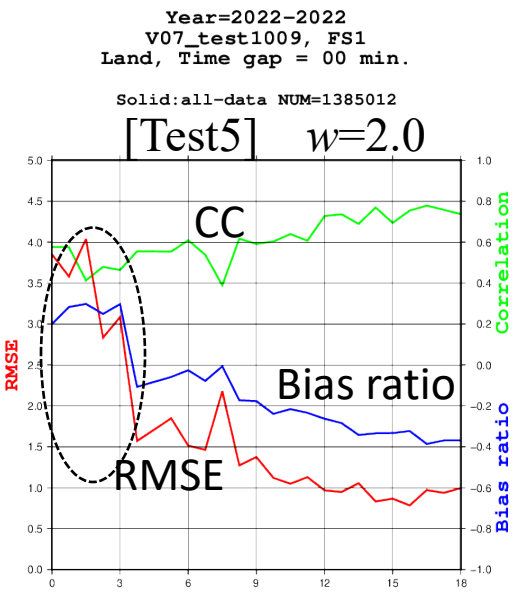
$$p_1(x)\,p_2(\mathrm{PIA_{SRT}}\,|\,\mathrm{PIA}_{g0}) = \frac{1}{2\pi\sigma_x\sigma_{\mathrm{SRT}}}\exp\left\{-\frac{1}{2}\left[\frac{(x-\mu_x)^2}{\sigma_x{}^2}+w\frac{(\mathrm{PIA_{SRT}}-\mathrm{PIA}_{g0})^2}{(\sigma_{\mathrm{SRT}})^2}\right]\right\}$$

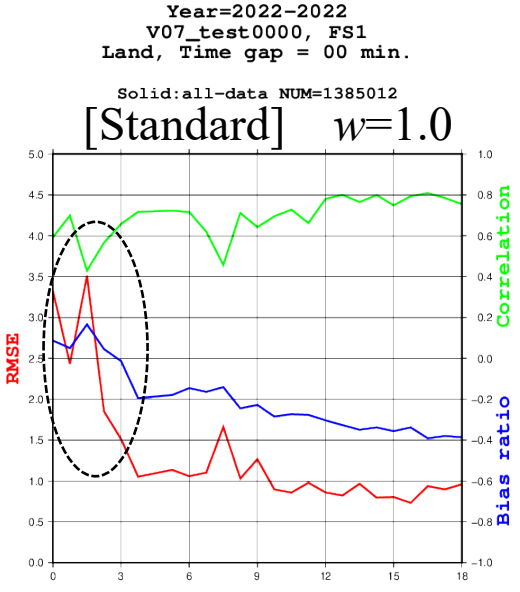
(PIA_{g0} depends on ε)

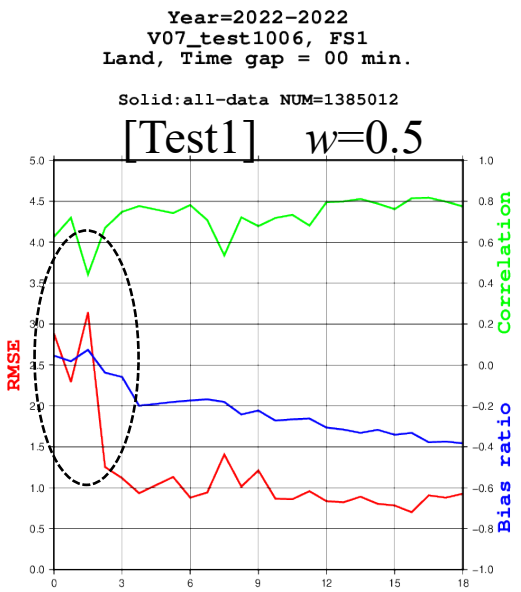
Evaluation of test products

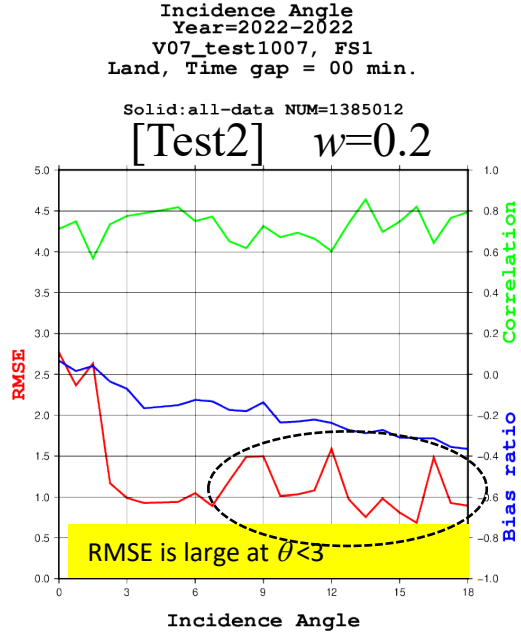
Abscissa: Incidence angle

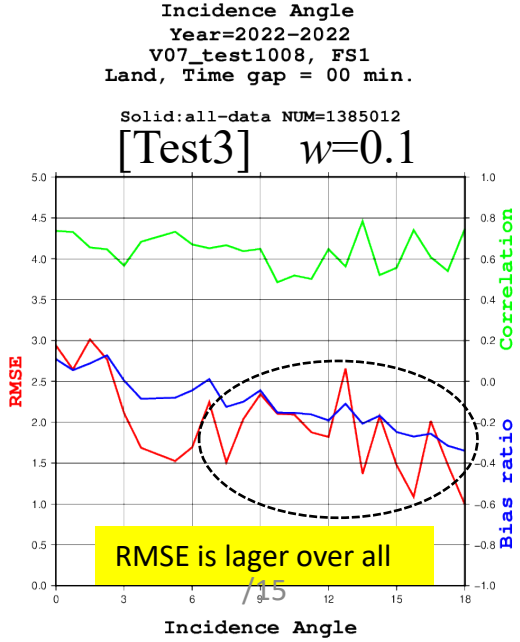
Ordinate: CC(green),RMSE(red),Bias ratio(blue)

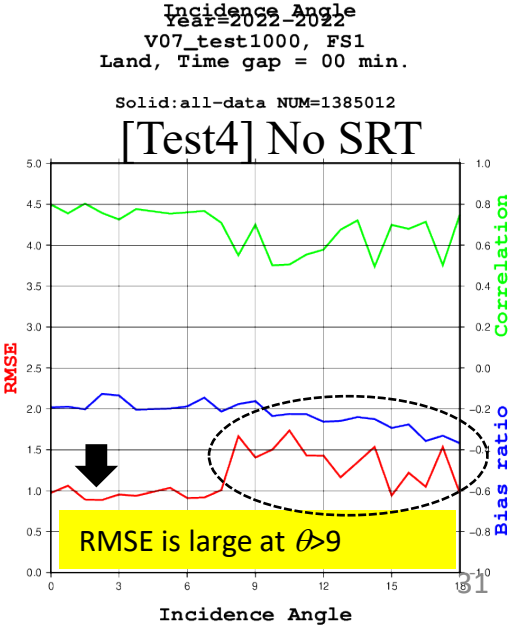












Summary

PrecipRateESurface of the DPR products are validated with XRAIN over land area in Japan.

At incidence angles at or smaller than 3 degrees, RMSE increases and Correlation coefficients decreases. This is seen at higher elevation.

→ It is partly because SRT is less accurate at smaller incidence angles and over mountainous area.

For the next version of DPR algorithms, it is considered to change the usage of SRT by incidence angles and surface conditions.

→ For example, no SRT is used at incidence angles at or smaller than 3 degrees. and the weight of SRT is set to be 0.5 at other incidence angles.