DPR Algorithm Status

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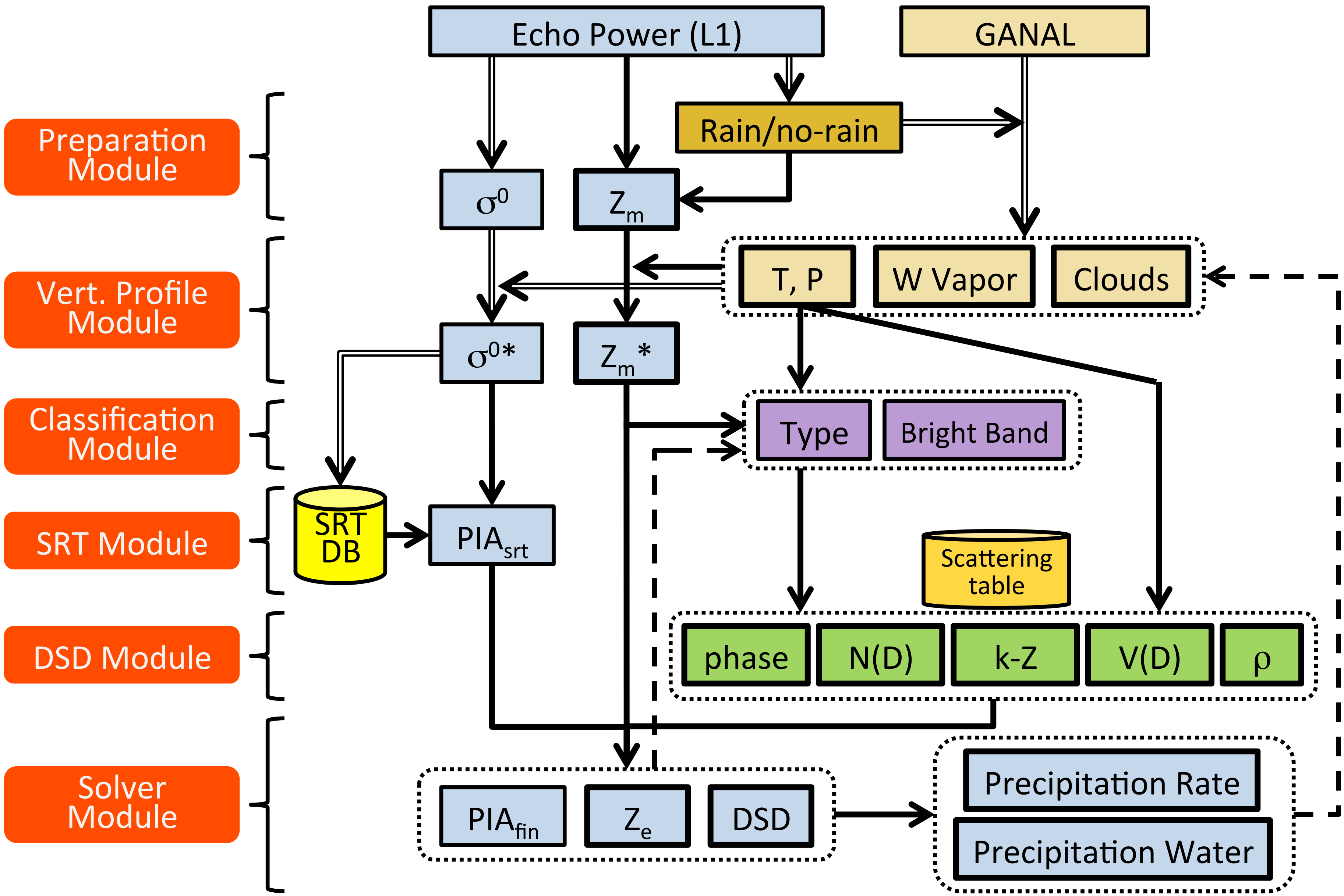
GPM/DPR rain profiling algorithm flow

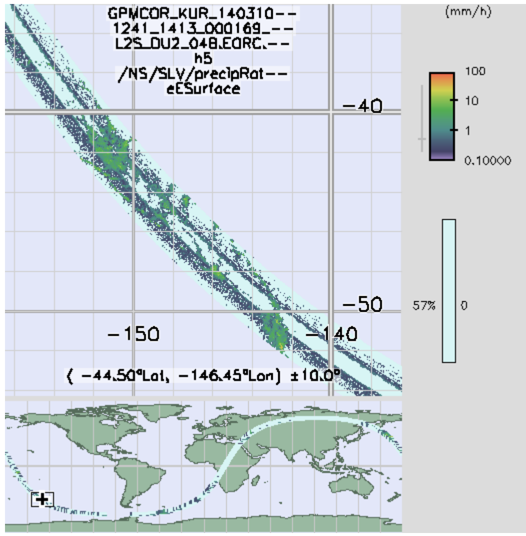


Improvement in preparation module

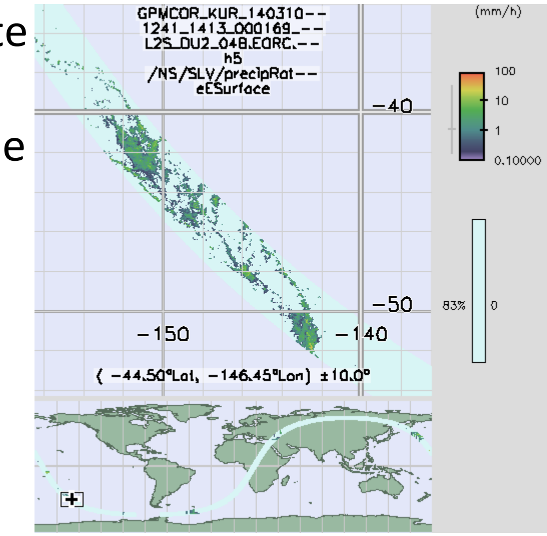
- Sidelobe clutter correction
- Range bin mismatch correction @ DPR_KaMS
  - Remove mismatch of rainge bin between Ku and Ka profiles for DPR algorithm
- Rain detection threshold in KaMS and KaHS
  - Increase rain detection especially in KaHS
- Introduction of sea ice concentration parameter
  - Issues remaining when precipitation over ice

Effects of the routine to reduce the sidelobe clutter in KuPR

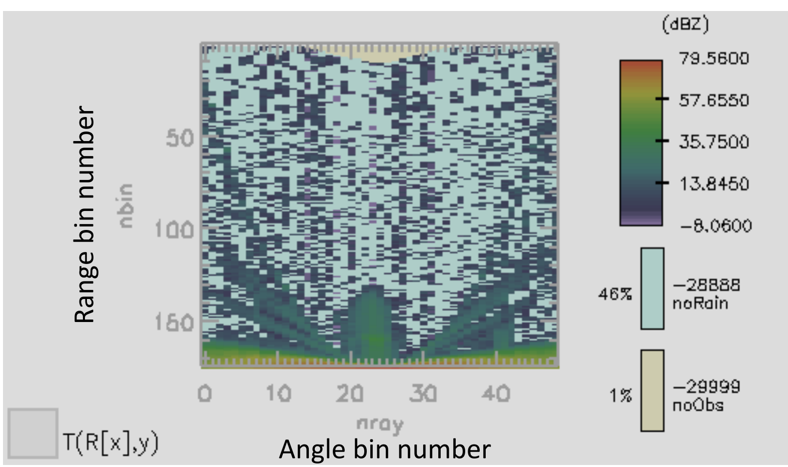
Precipitation rate at the surface without the sidelobe routine (OFF)



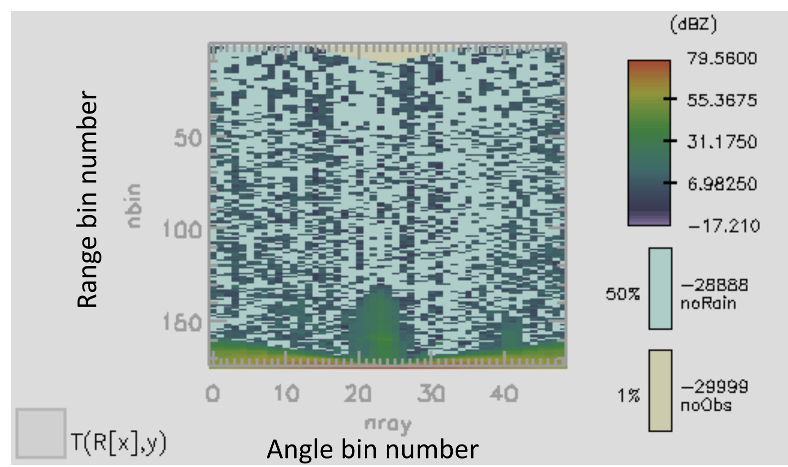
Precipitation rate at the surface with the sidelobe routine (ON)



Vertical cross section of Z_m (OFF)
Scan No. 6954, Orbit No. 169

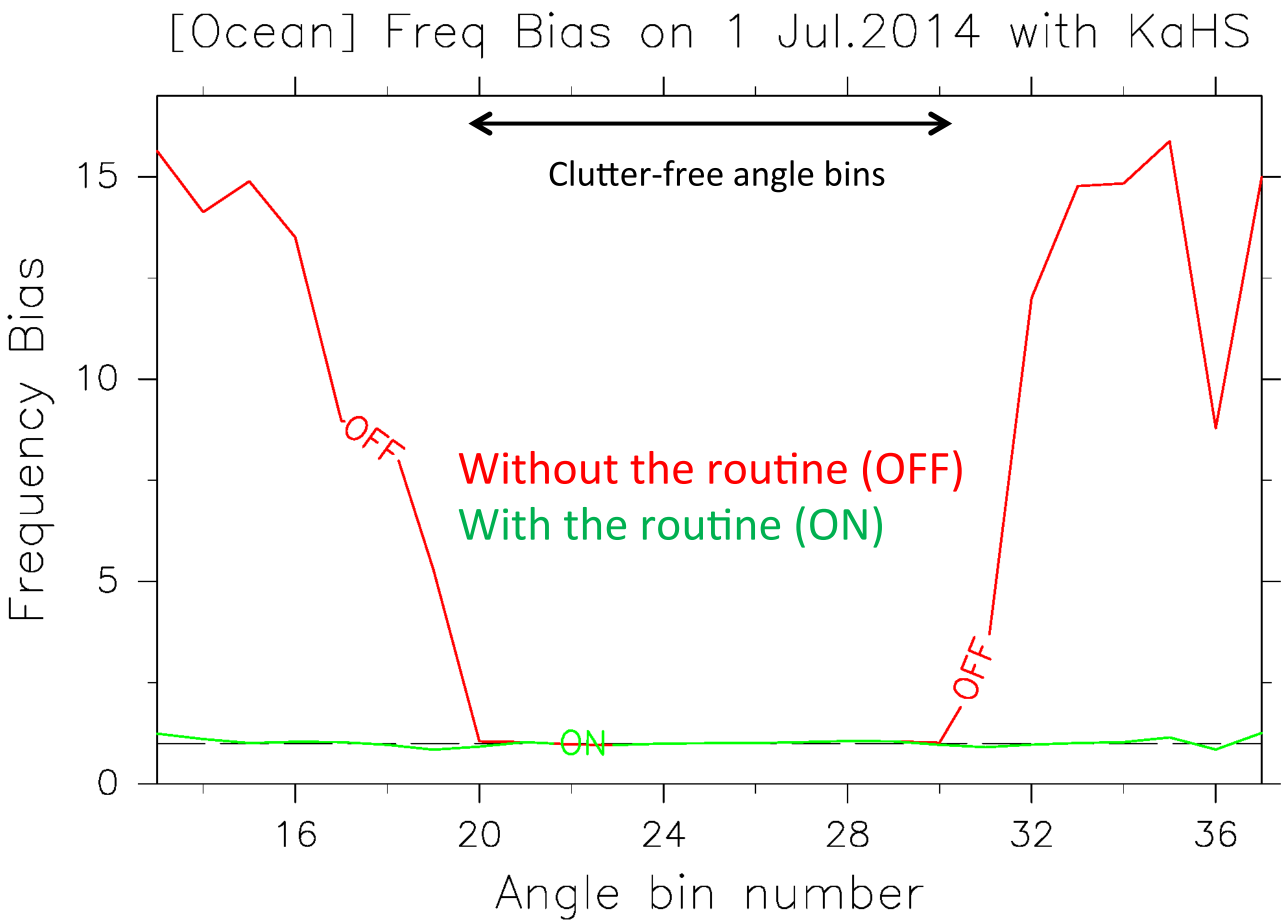


Vertical cross section of Z_m (ON)
Scan No. 6954, Orbit No. 169



Comparison of Frequency bias over the ocean

Frequency Bias (FB) =Ku precipitation frequency/KaHS precipitation frequency



15 orbits (#1920-1934)
Ocean-only

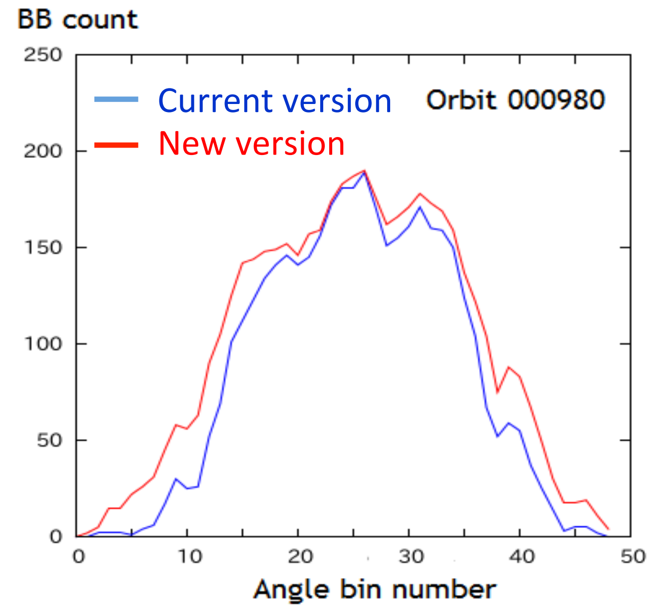
Name	FB
Inside clutter-free angle-bins	1.011
without the routine outside the clutter free angle-bin	10.28
FB with the routine outside the clutter free angle-bin	1.09

While the FB values are very high for the results with the routine (OFF) outside the clutter-free angle-bins, the FB values with the routine (ON) is quite similar to those inside clutter-free angle-bins.

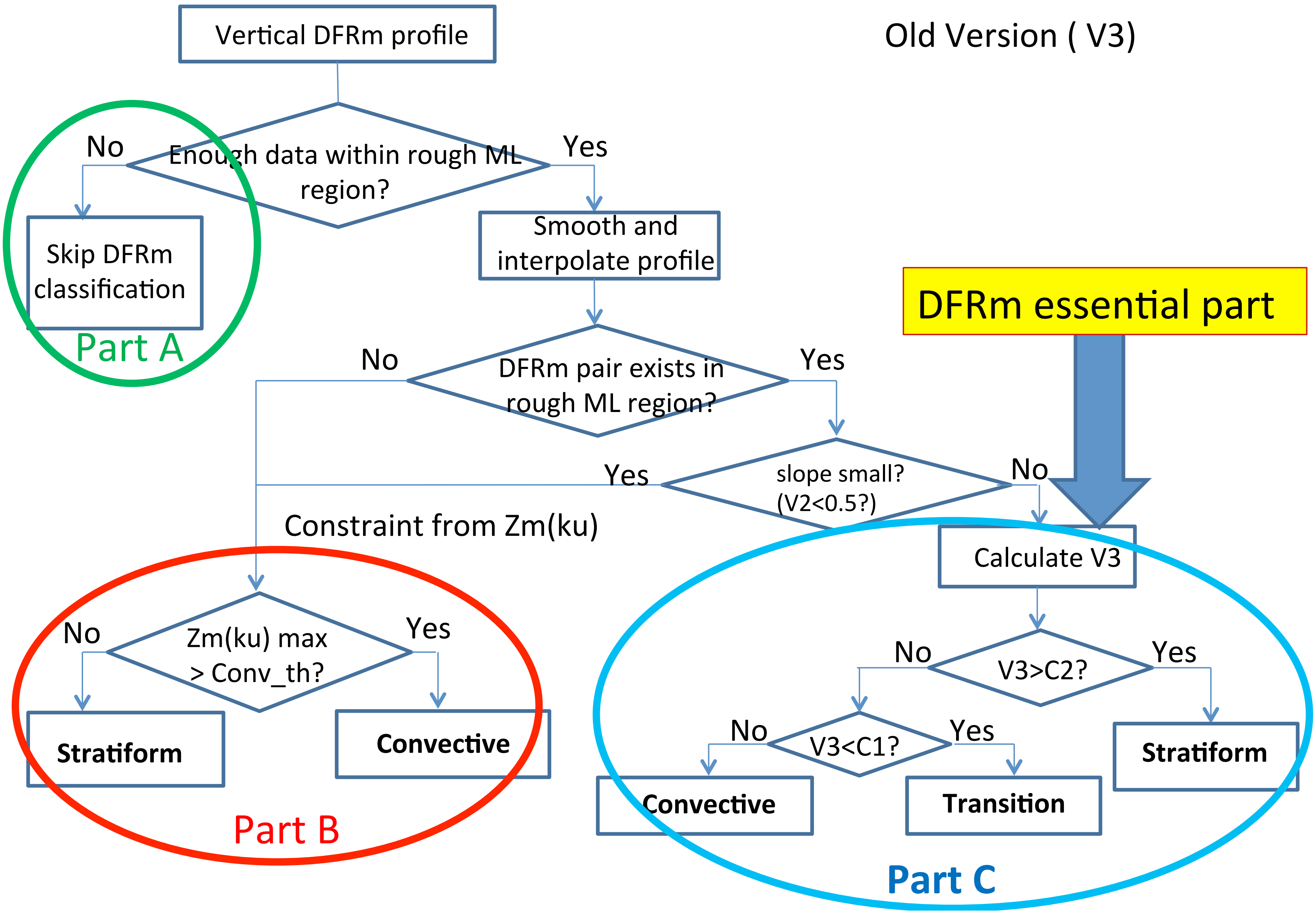
Classification (CSF) module

Objectives:

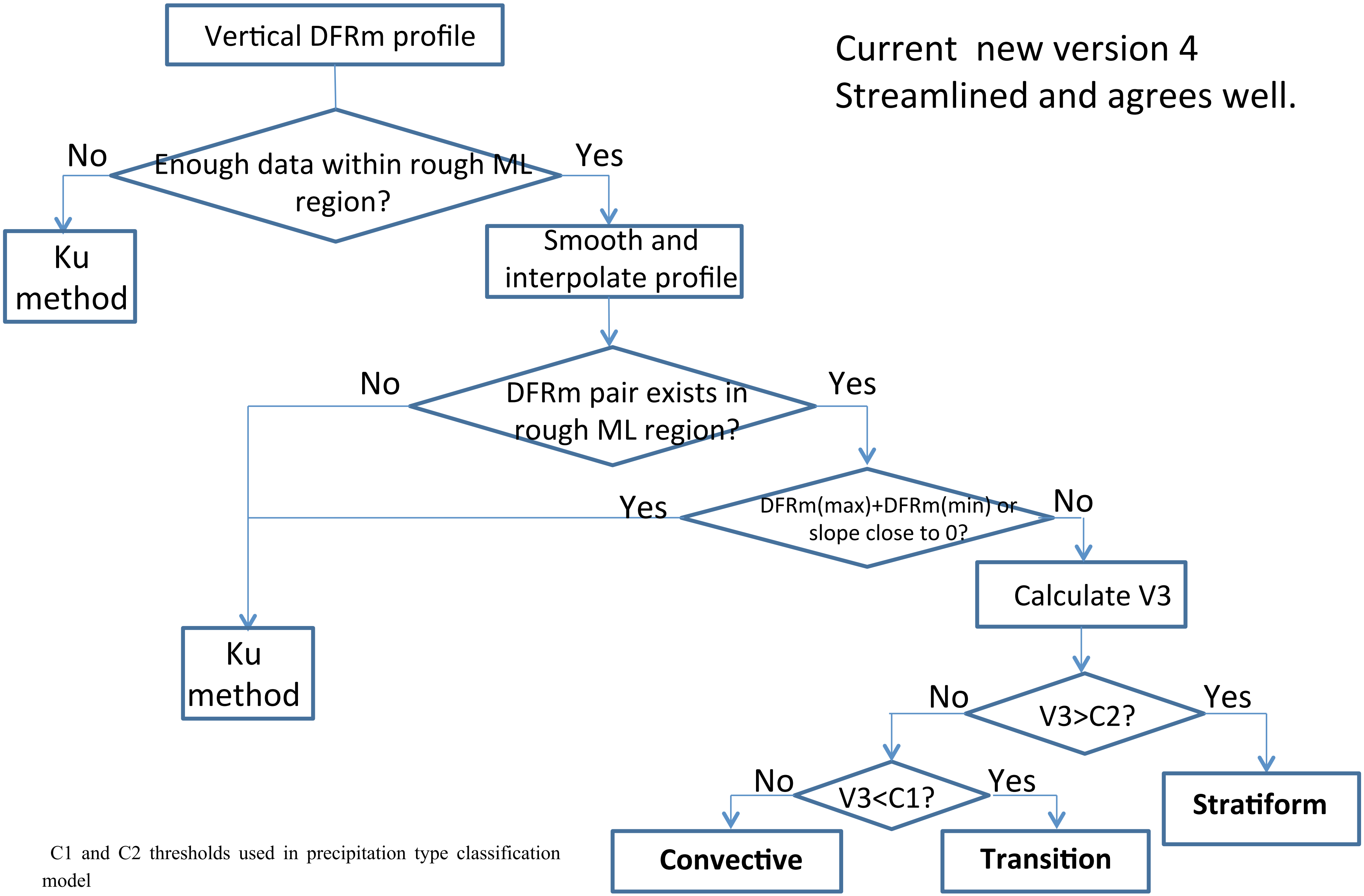
- Detection of BB
  - KuPR's algorithm improved
- Classification of rain type
  - Classify into three major rain types and many sub-types
  - Three kinds of CSF module
    - Ku-only CSF module: V + H-method
    - Ka-only CSF module: V + H-method
    - DPR CSF module: DFRm method parameter tuning
      - **DFRm** + H-method
      - **=> DFRm +** V + H-method



Flowchart of DFRm method

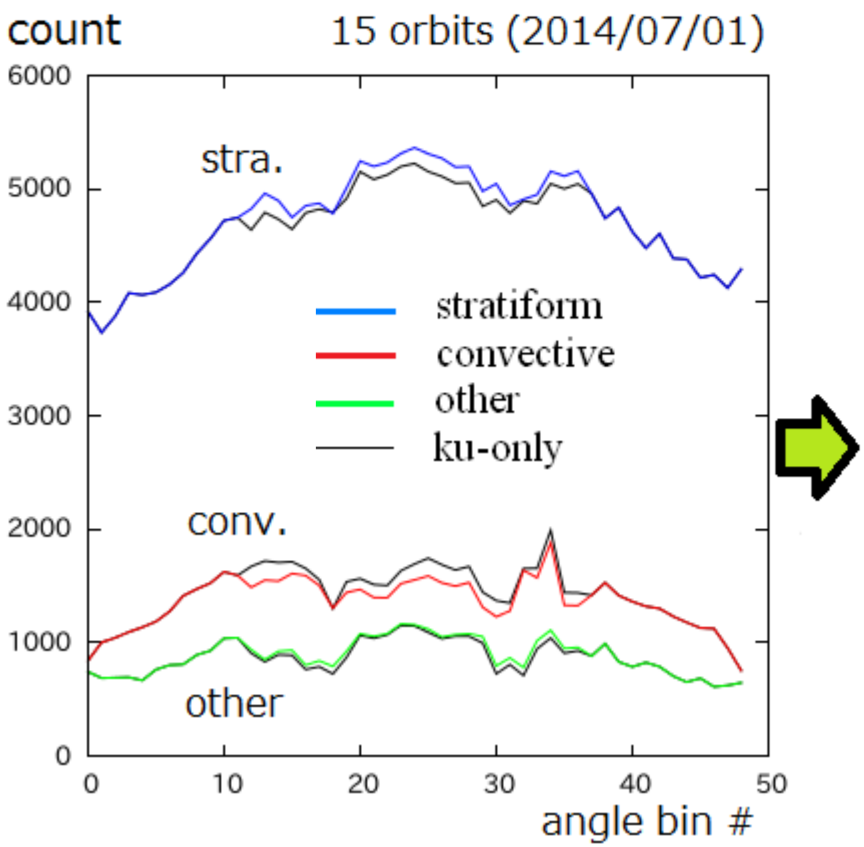


Flowchart of DFRm method

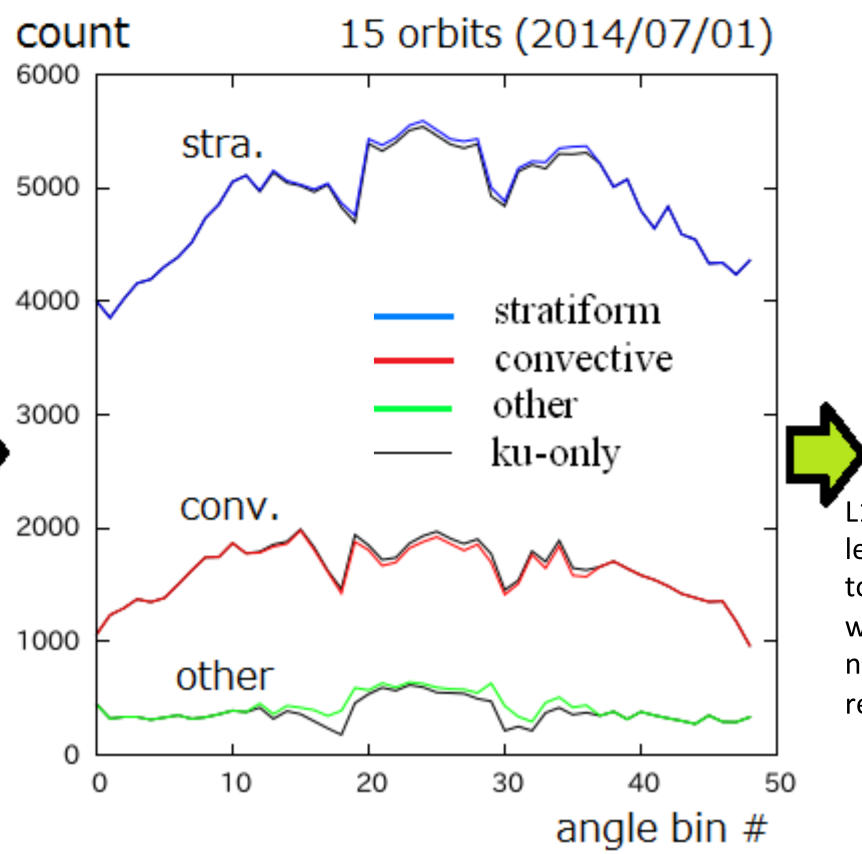


Current new version 4
Streamlined and agrees well.

C1 and C2 thresholds used in precipitation type classification model



(a) 03B (current public release data)



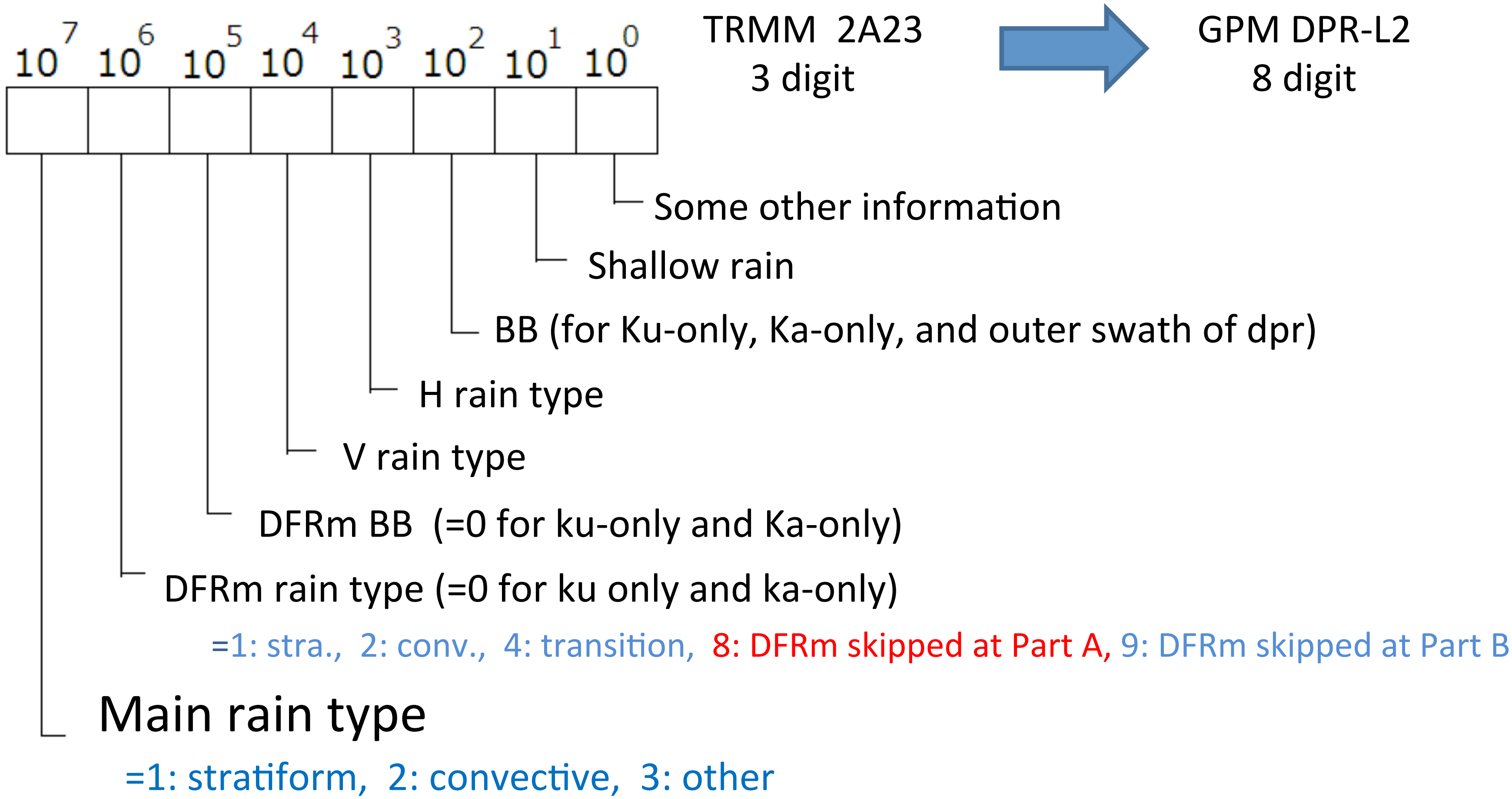
(b) New result using test L1 data (04B)

L1 data with levels similar to 03B L1 data will be used in next public release

Rain-type count by the dual-frequency CSF module

Appreciable difference between Ku-only rain-type count and the dual-frequency rain-type count observed in the current public data becomes smaller in a new test result which was obtained by using V6.20150516 algorithms. Fig. (b) includes the effect of not only CSF module but also other updated modules. Fig. (b) was generated using a test 04B L1 data.

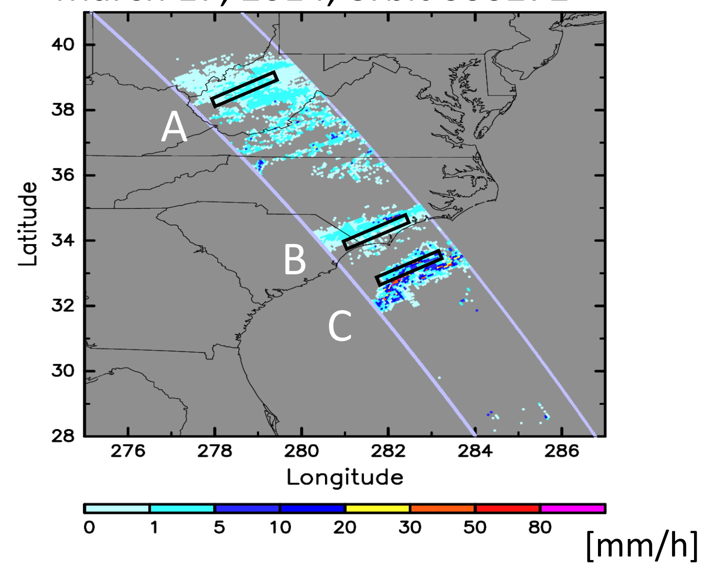
Rain type numbering (GPM DPR-L2)



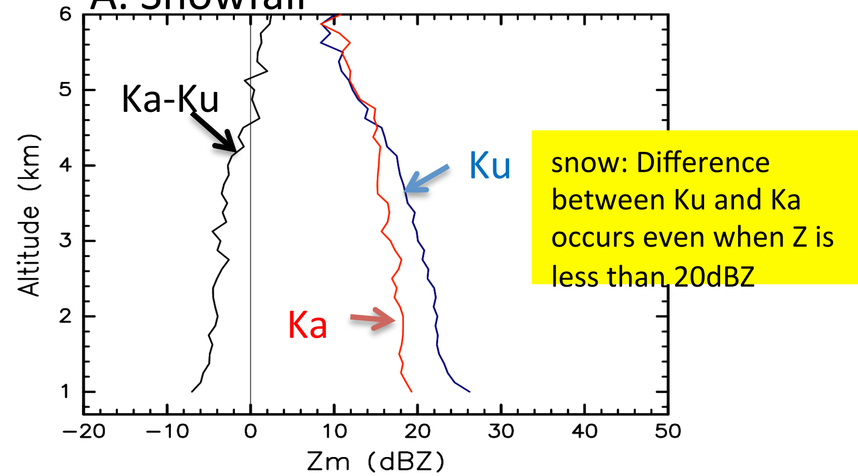
As shown in the previous DFRm flowchart, the essential part of DFRm decision is sometimes skipped at two different parts, i.e., Part A and Part B. To distinguish the DFRm skip at Part A and B, a new number '8' is introduced to the digit corresponding to DFRm rain type in the 8-digit typePrecip flag.

Plan to perform snow/rain separation from DFRm

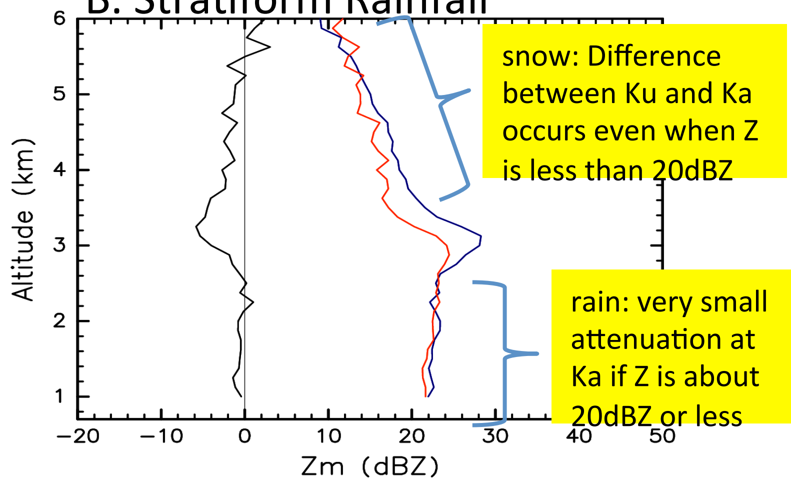
Rain rate from Ku on GPM/DPR
March 17, 2014, orbit 000272



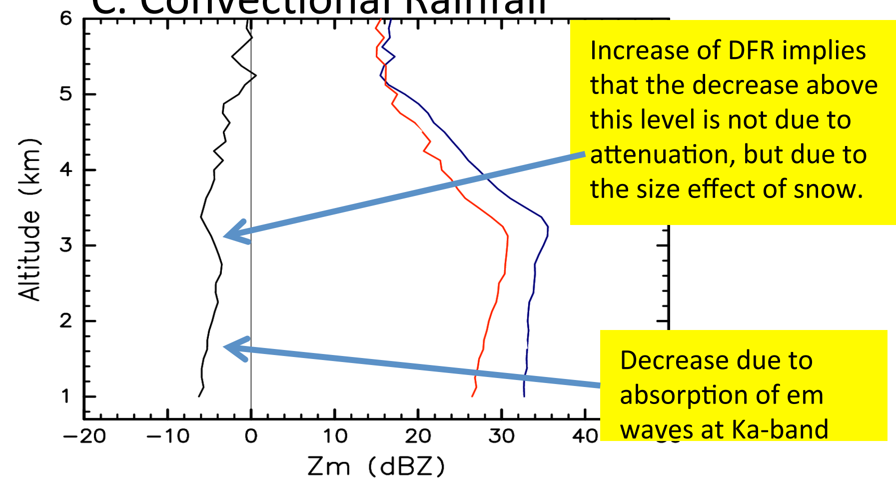
A. Snowfall



B. Stratiform Rainfall

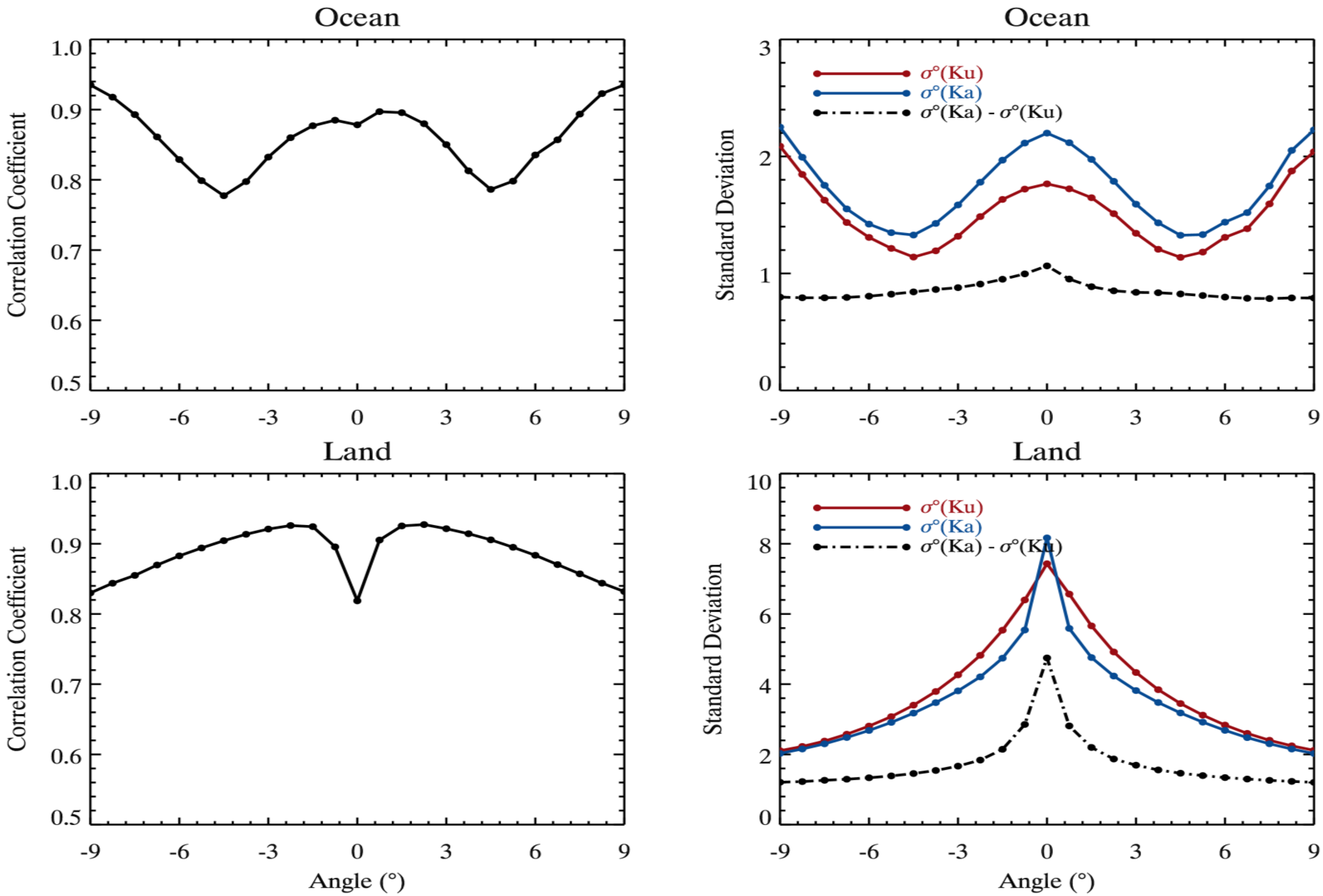


C. Convectional Rainfall

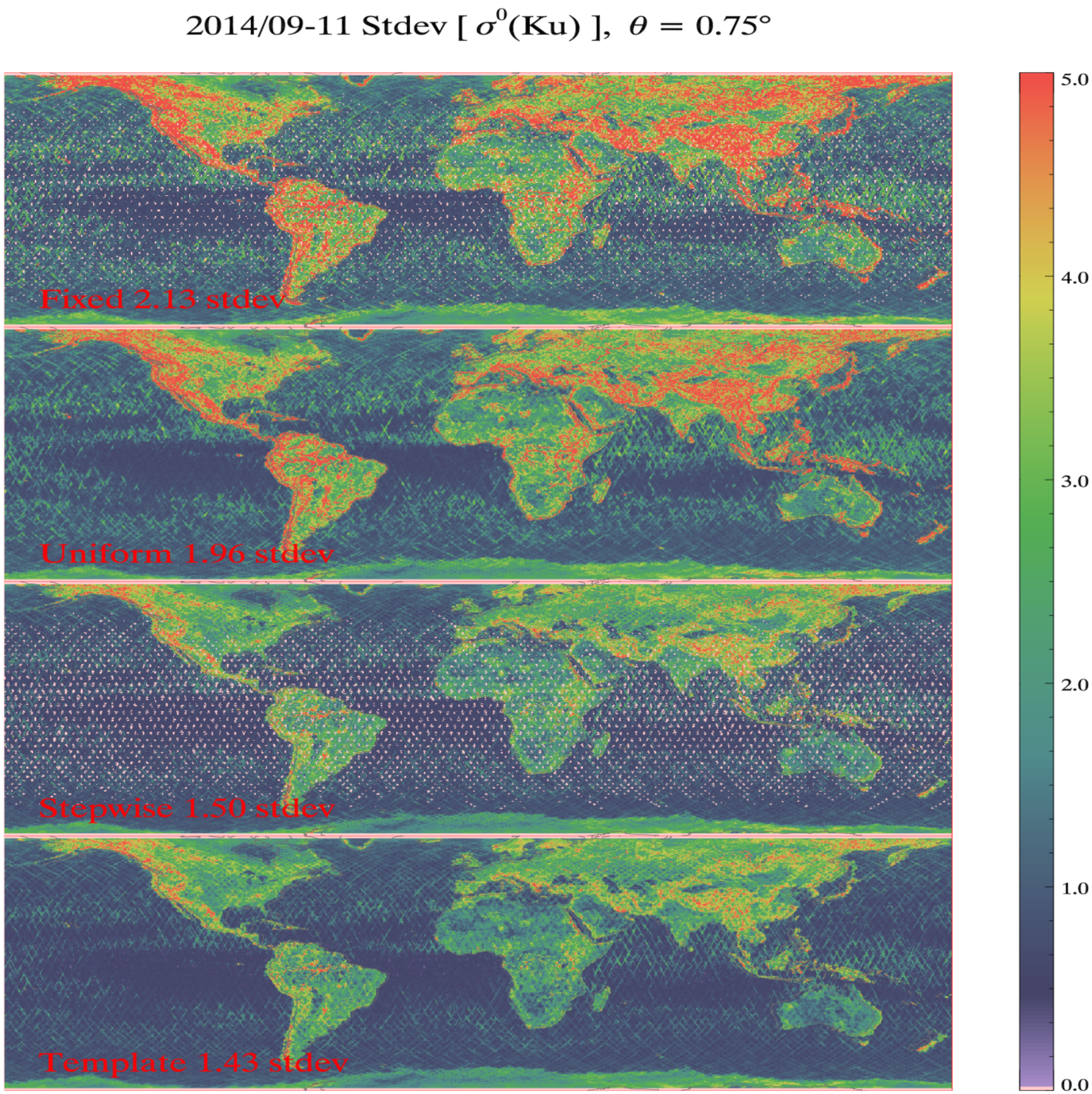


SRT module

- Dual-frequency SRT (DSRT)
  - Var[σ^0(Ka)- σ^0(Ku)] < var[σ^0(Ka)] and var[σ^0(Ku)]
  - Use of δA = A(Ka)-A(Ku) must be more reliable than use of A(Ku) or A(Ka) estimates
- Introduction of the temporal reference data in V4
- Issues with DSRT
  - Limited dynamic range (Loss of Ka-band surface echo):
    - Over ocean: 0.4% (nadir) to 0.8% (9^0) of data is missed
    - Over land: 0.75% (nadir) to 2% (9^0) of data is missed
  - Measurements are limited to the inner swath
    - Extending DSRT information to outer swath
  - The ratio A(Ka)/A(Ku) = p is needed to convert δA to A(Ku) and A(Ka)
  - Reduction in variance of sigma-zero
    - Defining optimal area in temporal reference data
    - Instantaneous estimates at near-nadir inc.
  - Implementation of wet-surface temp ref data
  - SRT over sea ice
  - Multi-beam & NUBF
  - Validation



SON Statistics

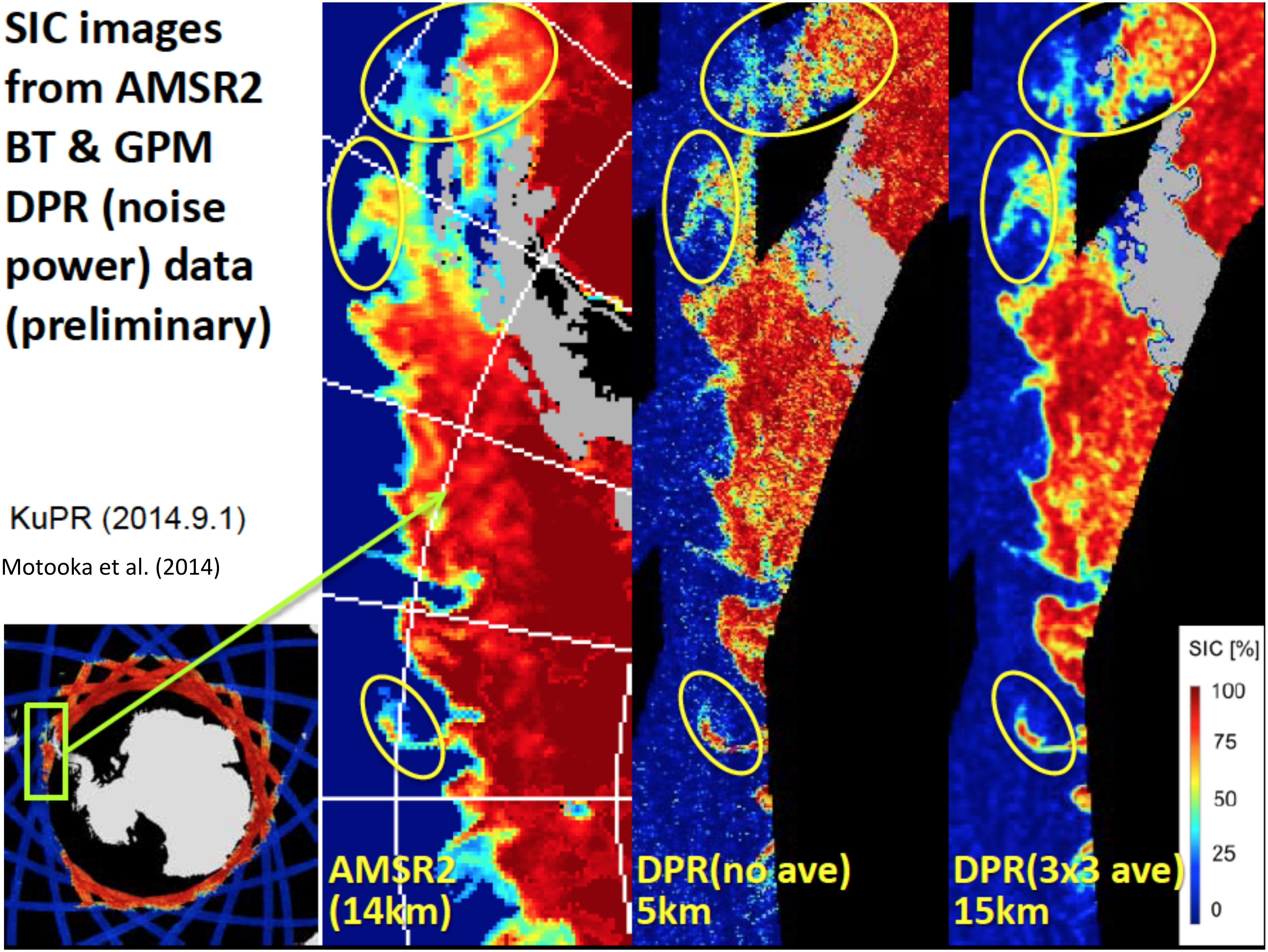


1-Std(temp)/Std(fix)
= 0.33

SIC images from AMSR2 BT & GPM DPR (noise power) data (preliminary)

KuPR (2014.9.1)

Motooka et al. (2014)



Problems in V03B

Common to DPR algorithms

No NUBF corrections.

KaPR algorithm

KaPR's k-Ze relations have not been examined well.

Rain and surface echoes are missed by heavy attenuation.

Heavy rainfall (R>10 mm/h) tends to be underestimated.

Dual-freq. algorithm

In HB-DFR, the range of estimated ε is limited.

A constant PIA ratio is assumed in DSRT and affects rain rates.

Precipitation type classification is not effectively used.

Actions for the next version

Common to DPR algorithms

[1] A new NUBF correction method is applied.

KaPR algorithm

[2] R-Dm relation is used as new DSD constraint

[3] Missing echoes are compensated.

[1-3]→Underestimation is partly mitigated.

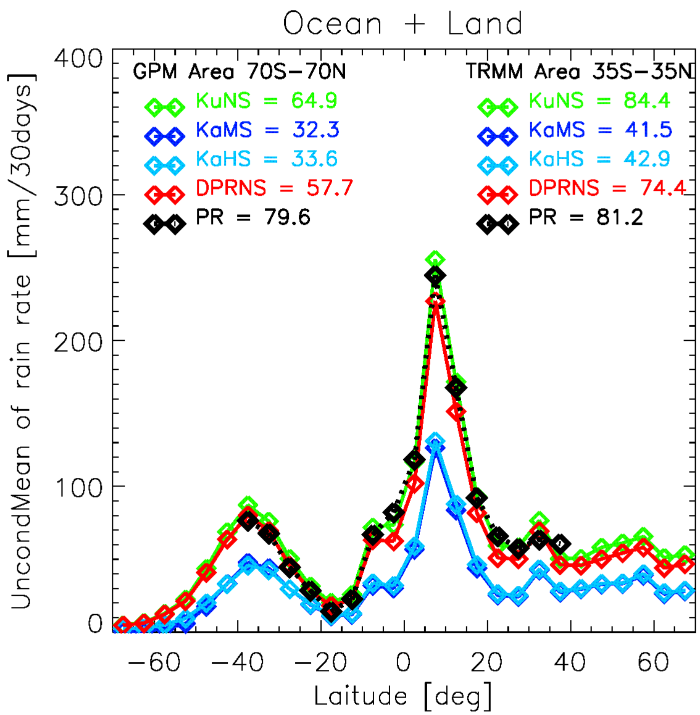
Dual-freq. algorithm

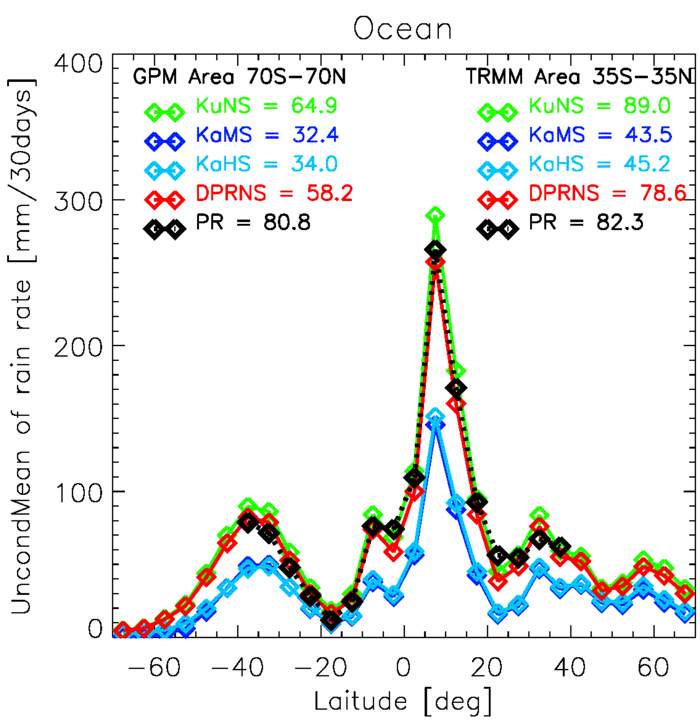
[4] ε is not estimated at each range bin

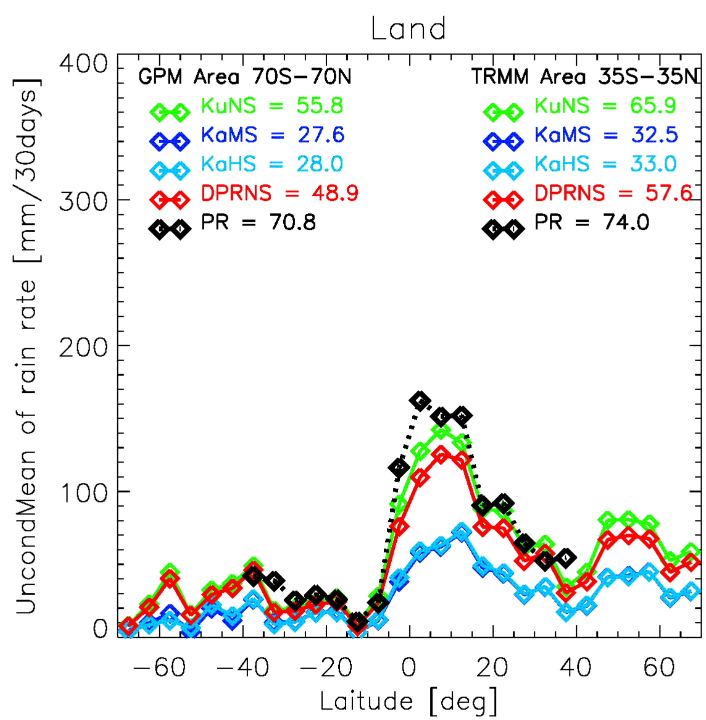
[5] δPIA by DSRT is directly used in SLV module

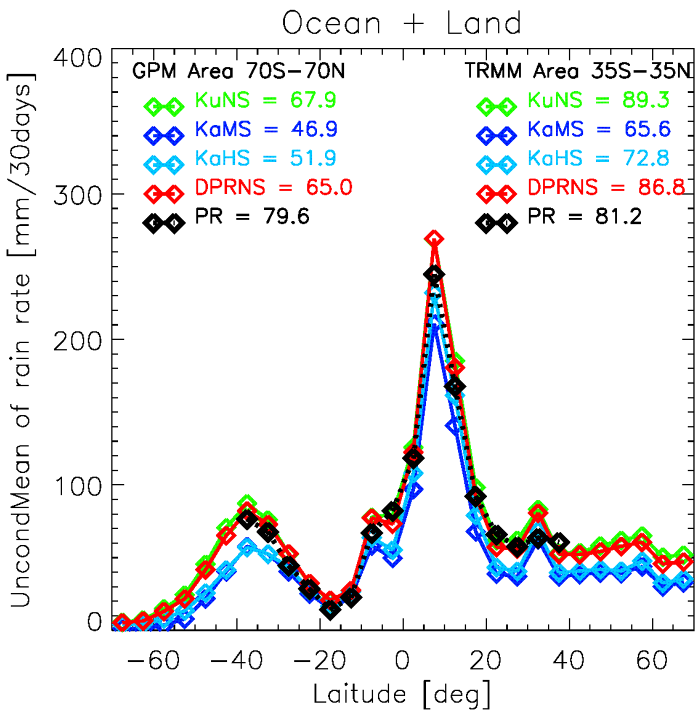
[4] →Precipitation type can affect rain rates.

V03B
current released version
rain @ 2km

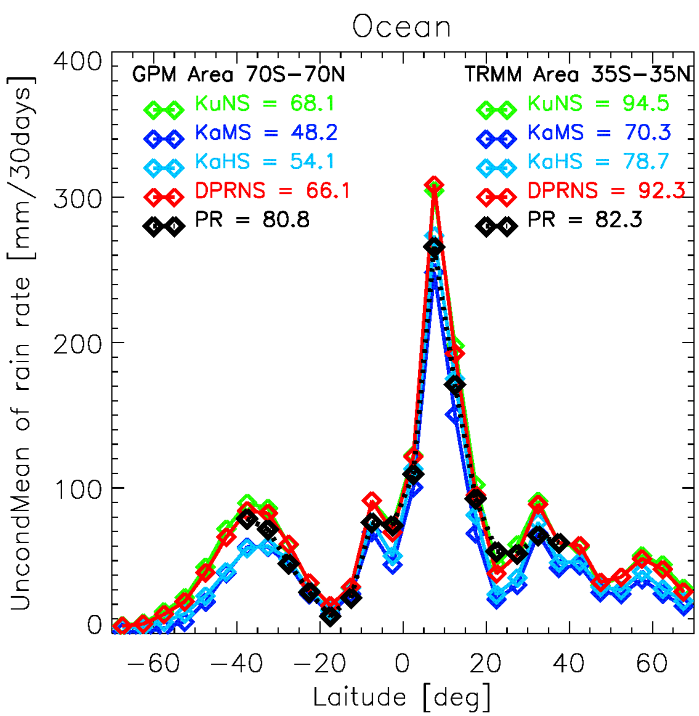


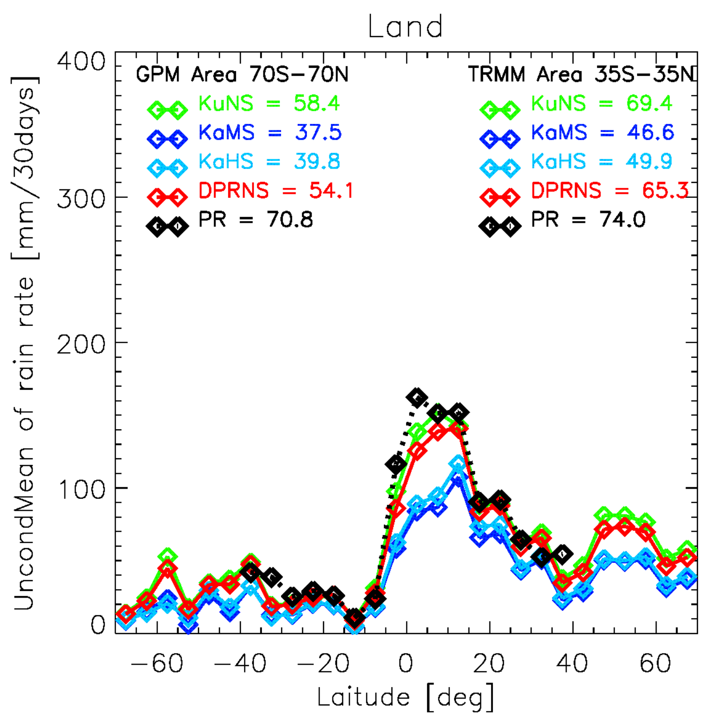






V04C
new (V6.20150706)
rain @ 2km





Summary

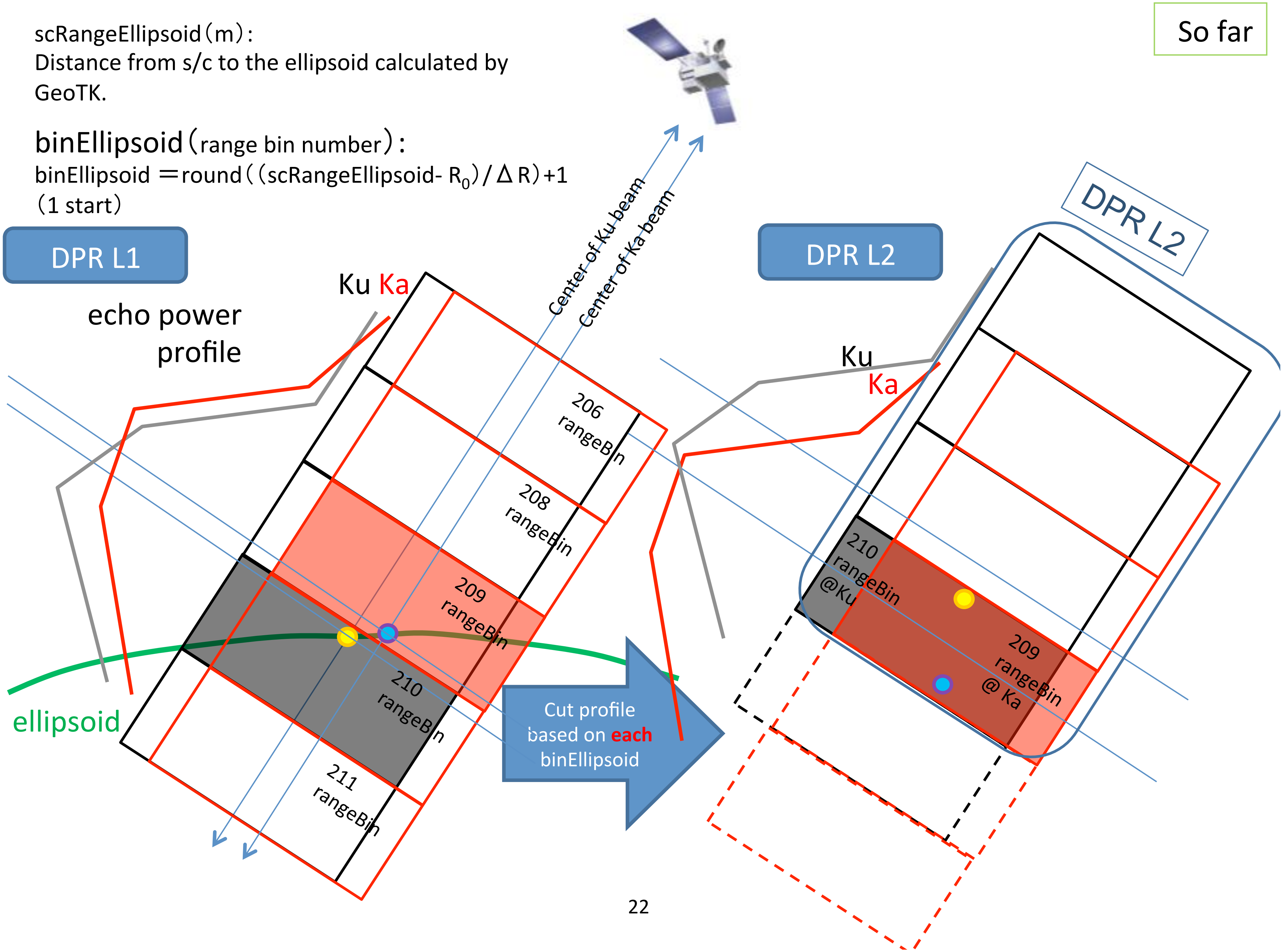
- Sidelobe clutter is now reasonably well removed.
- New classification module with DFRm method works well.
- DF Solver module adopts conservative method in V04.
- Rain estimates from KaPR have been improved substantially.
- Rain estimates in V04 are generally larger than those in V03B and PR. We have to clarify the reason of change.
- There are many future issues and possible improvements.
  - ✓ Effect of NUBF and multiple scattering
  - ✓ Regional and seasonal characteristics of the R-D_m relationship
  - ✓ Increase the reliability of PIA estimates with SRT
  - ✓ snow/rain separation using information from DFRm, Z(Ku) and other infomation (ex. storm depth)
    - DFRm and calibration are important components.

Back-up slides

So far

scRangeEllipsoid(m):
Distance from s/c to the ellipsoid calculated by GeoTK.

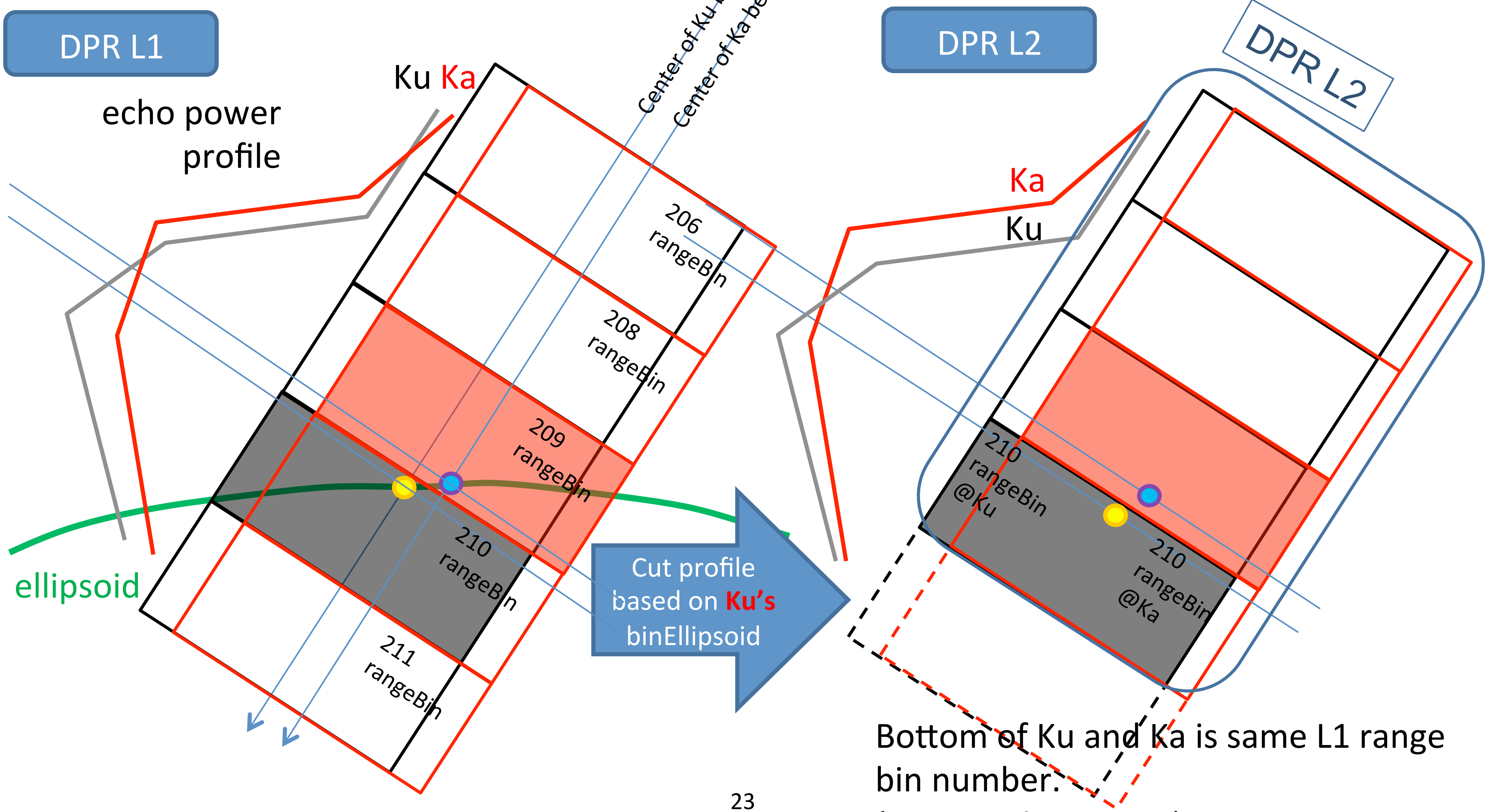
binEllipsoid (range bin number):
binEllipsoid =round((scRangeEllipsoid- R_0)/ΔR)+1
(1 start)



New
(V6.201506XX)

scRangeEllipsoid (m):
Distance from s/c to the ellipsoid calculated by GeoTK.

binEllipsoid (range bin number):
binEllipsoid = round((scRangeEllipsoid- R_0) / ΔR) +1
(1 start)

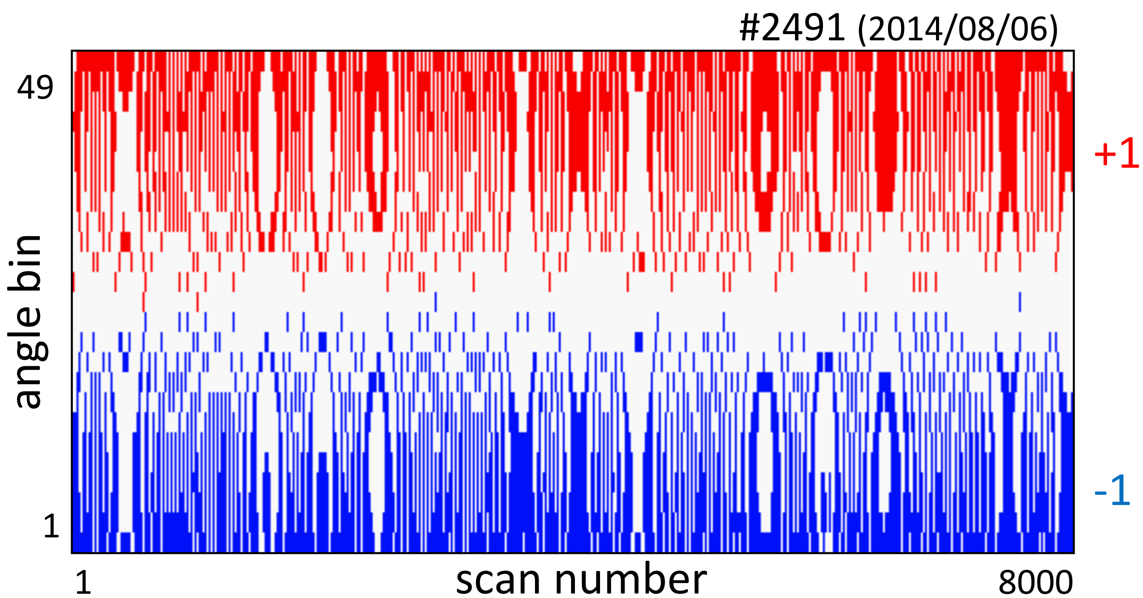


Bottom of Ku and Ka is same L1 range bin number.
(ex. 210 above case).

So far

2.2 current state

diff_binEllipsoid = binEllipsoid@Ka - binEllipsoid@Ku

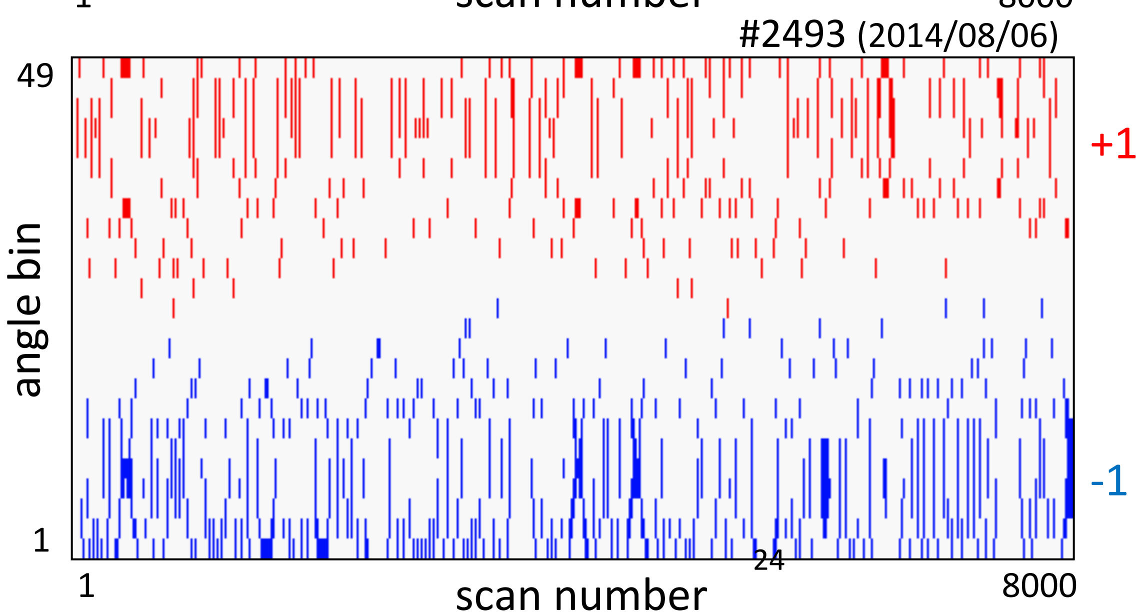


Maximum |diff_binE| is 1 during all period.

Diff ratio of binEllipsoid = 79603 (40.13 %)

Before #2491

After #2493



Diff ratio of binEllipsoid = 18315 (9.23 %)

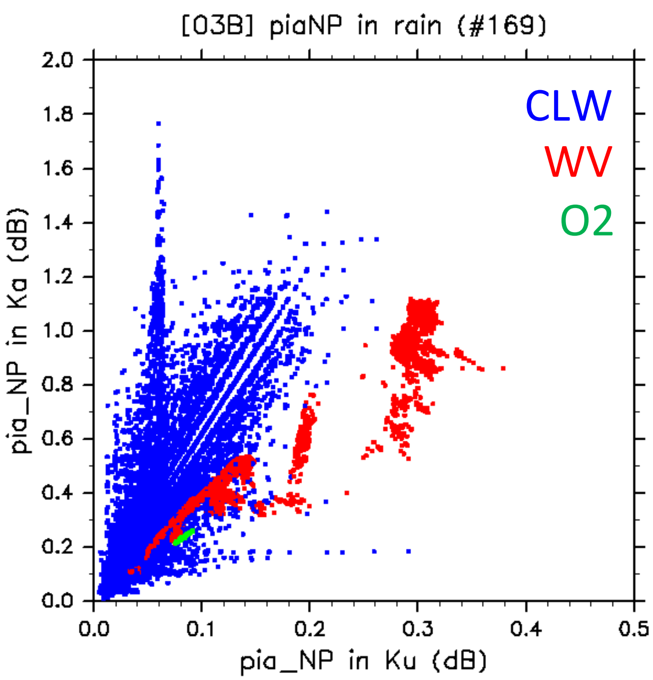
Vertical Profile module

KuPR and KaPR's independent estimates of precipitation rate and mismatch of footprint location

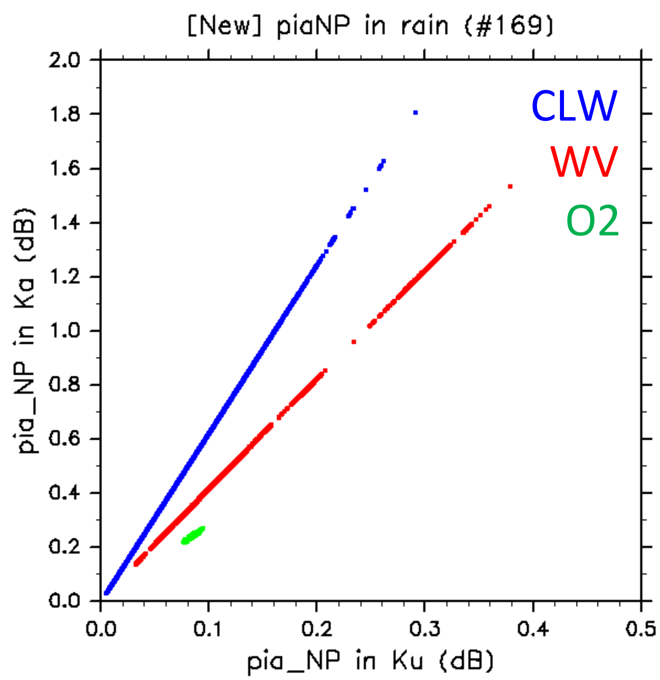
Different estimates of PIAs due to CLW, WV, and O2

Recalculate CLW, WV, and O2 in DFR algorithm using KuPR's output

piaNP in V03B



piaNP in next-version

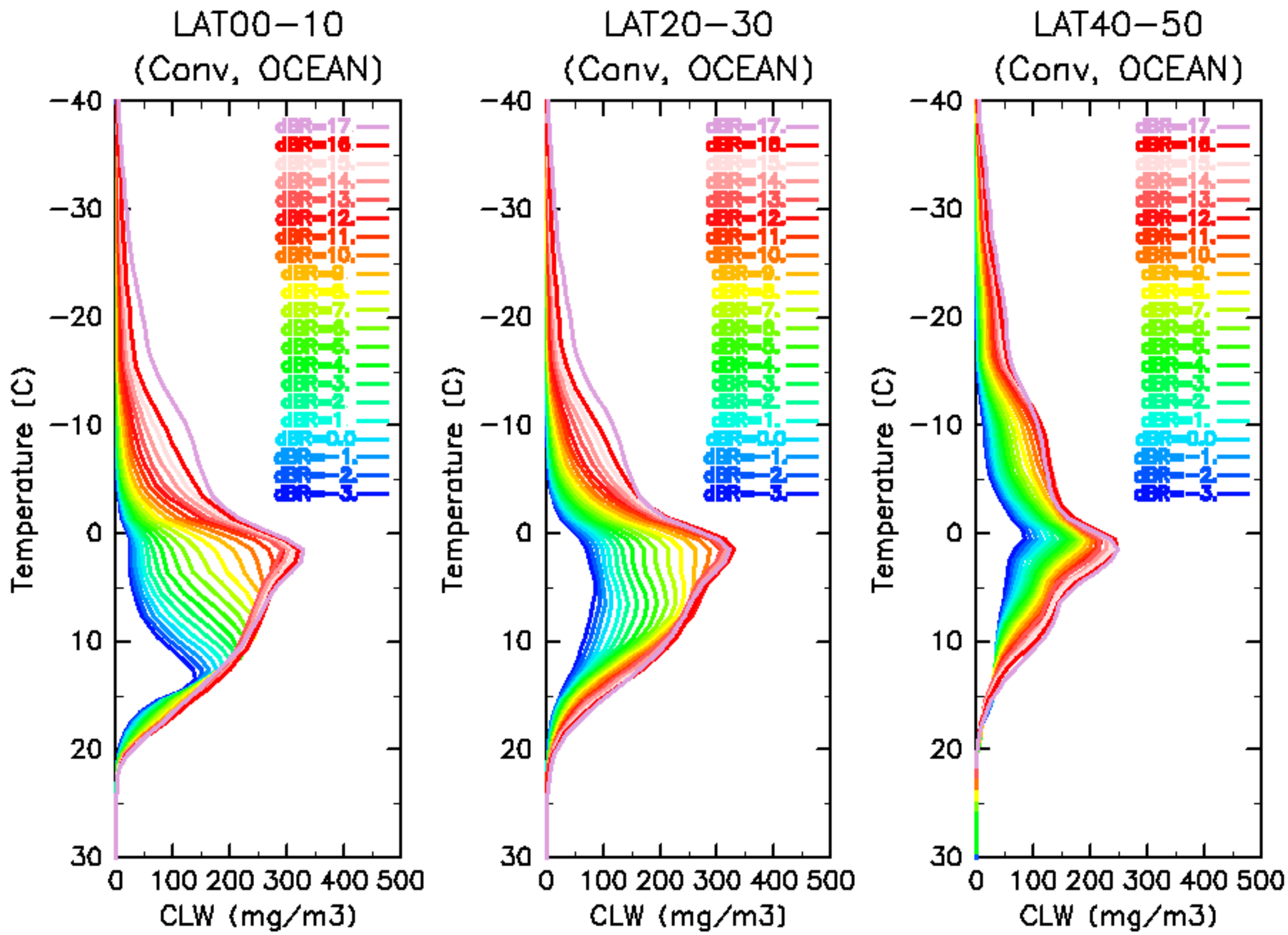


(Orbit Number 169, Rain case only)

Statistics for vertical CLW profiles

- The CLW profiles in the NICAM are classified by
  - surface rain rate (SRR)
    - collected according to a unit of dBR (10 x log10 (SRR))
  - convective/stratiform rain
  - temperature
    - CLW can highly depend upon temperature profiles including freezing level (FL)
  - surface type (land or ocean)
  - latitudes
    - 7 latitudinal zones without distinction of the hemisphere (EQ-10 deg., 10-20 deg. 20-30 deg., 30-40 deg., 40-50 deg., 50-60 deg., 60-90 deg.)

Profiles for Convective over ocean

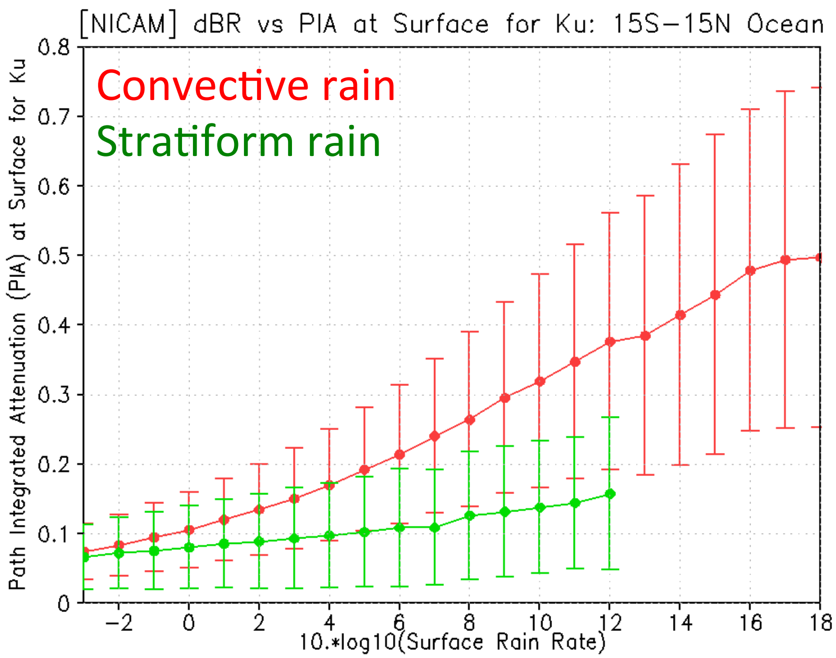


Profiles are quite different for latitudes.

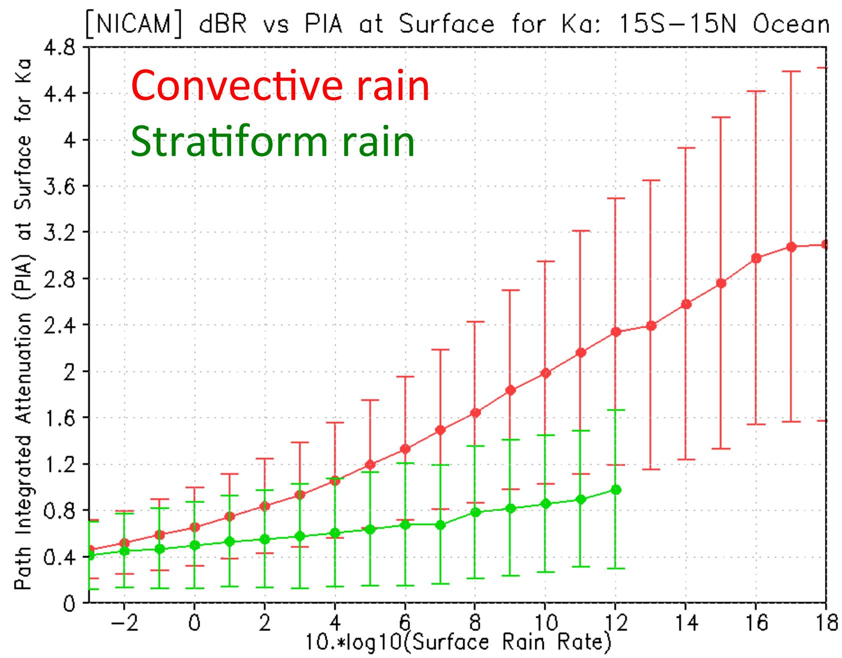
PIA by CLW from NICAM data: Ku vs Ka

Dependence of PIA_{CLW} at surface upon SRR over tropical (15S-15N) ocean averages with STD bars

Ku-band (13.6GHz)



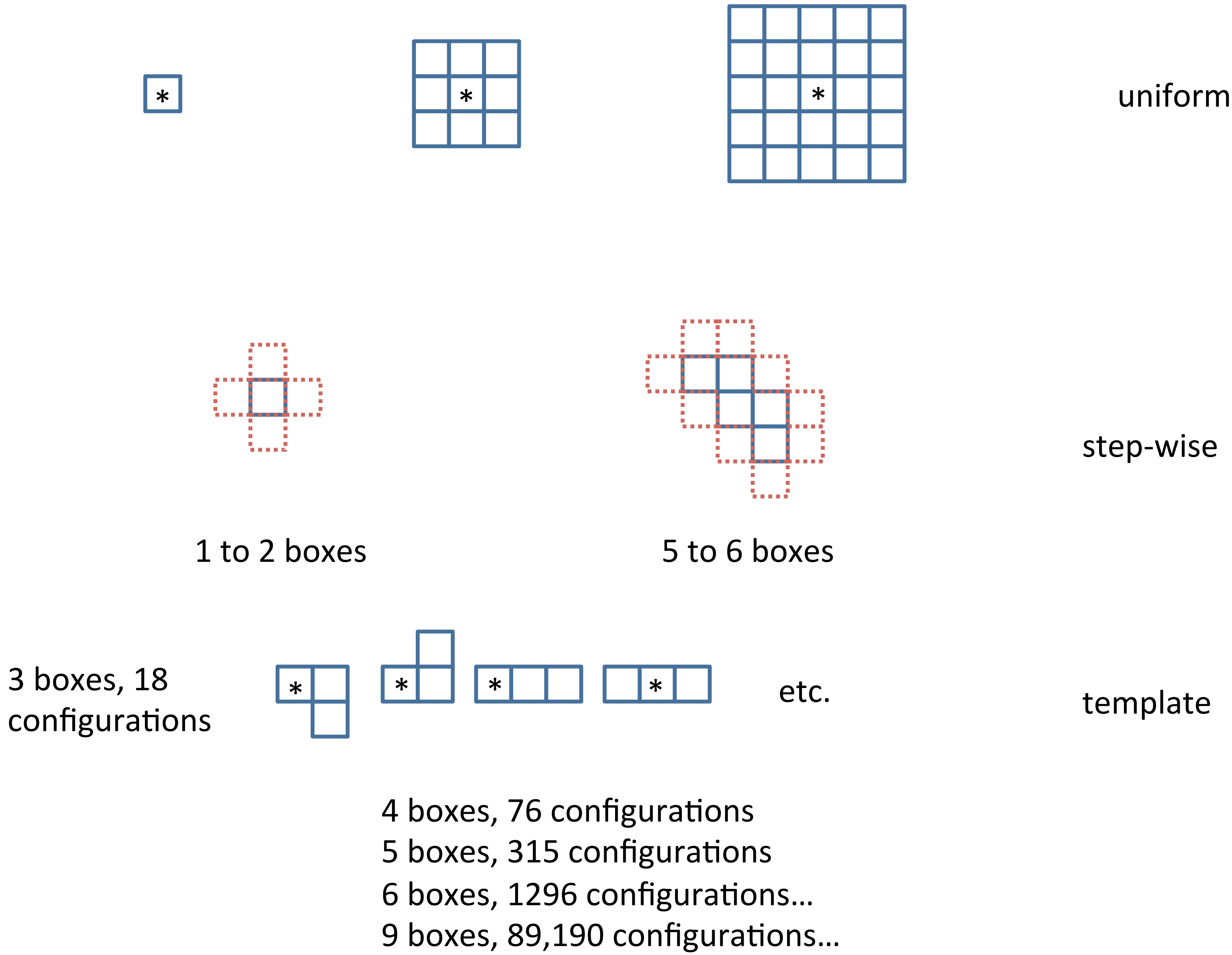
Ka-band (35.55GHz)



-3 in dBR = 0.5mm/hr, 0 in dBR = 1.0mm/hr, 10 in dBR = 10mm/hr, 20 in dBR = 100mm/hr

Types of assumptions

- Assumptions related to sensor characteristics
  - Satellite altitude, attitude, obs. time and location
  - Radar parameters
    - Gain, beam direction, beam pattern, sample volume
- Distribution of precipitation
  - Precipitation particle type as a function of temperature (height)
  - Homogeneity of precipitation in range direction within a scattering volume
- Scattering and absorption characteristics of precipitation particles
  - PSD, BB model, solid particle model, oblateness, temperature dependence, fall speed
- Scattering characteristics of surface
  - Incidence angle dependence, spatial homogeneity, temporal homogeneity
- Other kind of assumptions
  - Vertical profiles of cloud water, water vapor, oxygen molecules


*
*
*
uniform
step-wise
1 to 2 boxes
5 to 6 boxes
3 boxes, 18
configurations
*
*
*
*
etc.
template
4 boxes, 76 configurations
5 boxes, 315 configurations
6 boxes, 1296 configurations…
9 boxes, 89,190 configurations…

Variable Averaging/ Temporal Reference

- Appears that we can decrease average std dev assoc with the temporal reference by about 30-40% (going from fixed to template)
- Many questions to be answered
  - What is the impact on PIA estimates?
  - How do the weights on the temporal change relative to spatial reference?
  - Do we see any minima if we take the step-wise to much larger number of cells?
  - How do the results compare with other classification schemes?

Extending dual-freq solutions from the Inner to the Outer Swath

- As the dual-frequency estimate of A(Ku) is considered more accurate, can we use information from inner swath for the outer swath (OS) path attenuation estimates?
- Modify Ku-band surface reference data in the inner swath so that the average values of A_{SF}(Ku) and A_{DF}(Ku) agree
- This leads to a modified single-frequency Ku-band estimate in OS
  - This can be done in several ways
  - In each instance, the modification takes the form of an added term in the estimate that is a function of A_{DF}(Ku)

Extending dual-freq solutions to the Outer Swath

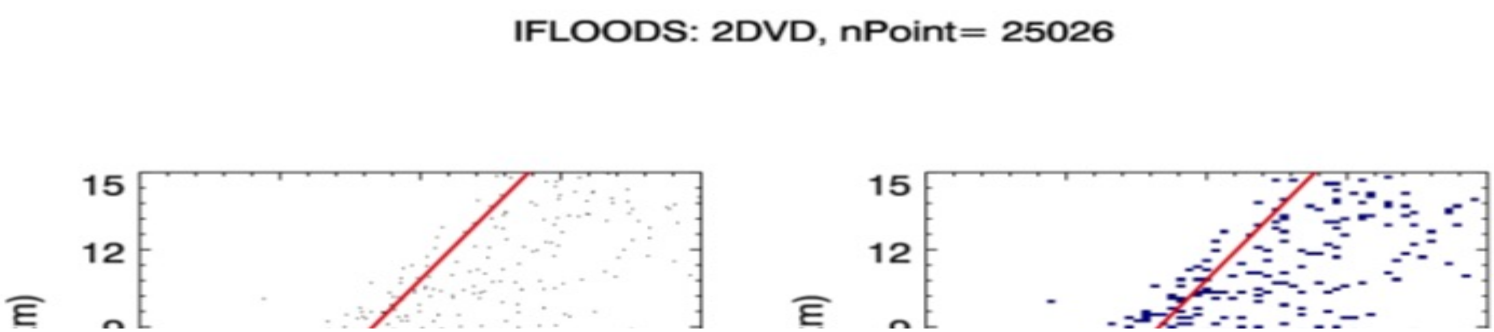
- Although the example shown is encouraging, the examples done to date show varying degrees of success
- The critical assumption is that the differences between the SSRT & DSRT seen in the inner swath can be used to modify the estimates in the outer swath – i.e., the biases are spatially correlated
- We need an independent assessment of the results to determine whether the approach is useful

Estimating the ratio A(Ka)/A(Ku)

- Analysis of raindrop size distribution data suggests that p=A(Ka)/A(Ku)=6 is a good approximation
- Also, as DSRT(Ka) depends on p but SSRT(Ka) does not, we can use 'good' data to choose p so that the RMS difference between DSRT & SSRT is minimized
  - This also yields $p \approx 6$
- Nevertheless, we would like something better that depends on the actual Z_m(Ku), Z_m(Ka) data

Iowa		Wallops			Swiss
APU	2DVD	APU	2DVD	Joss	Joss
N=70,186	N=25,026	N=52,521	N=49,898	N=15,273	N=14,978
p=4.84	p=5.41	p=5.90	p=6.68	p=6.44	p=6.34

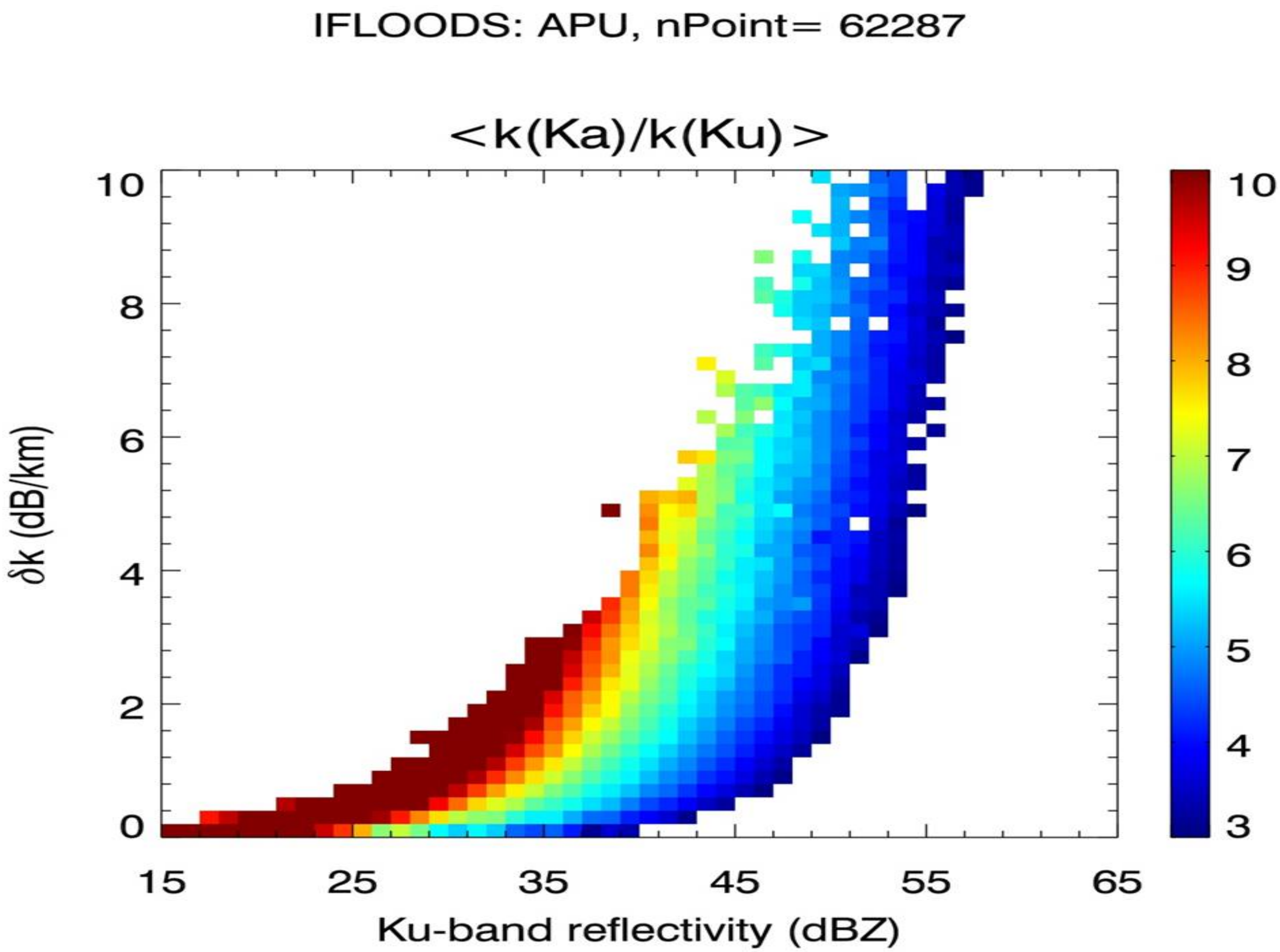
A(Ka)/A(Ku) Derived from Measured DSD



DSD data courtesy of Ali Tokay, Matthias Steiner

The plot below shows that from δk = k(Ka)-k(Ku) and Z(Ku), the ratio p can be estimated

However, what we estimate is δA (the path integral of δk) and Z_m(Ku), the measured rather than the actual Ku-band radar reflectivity

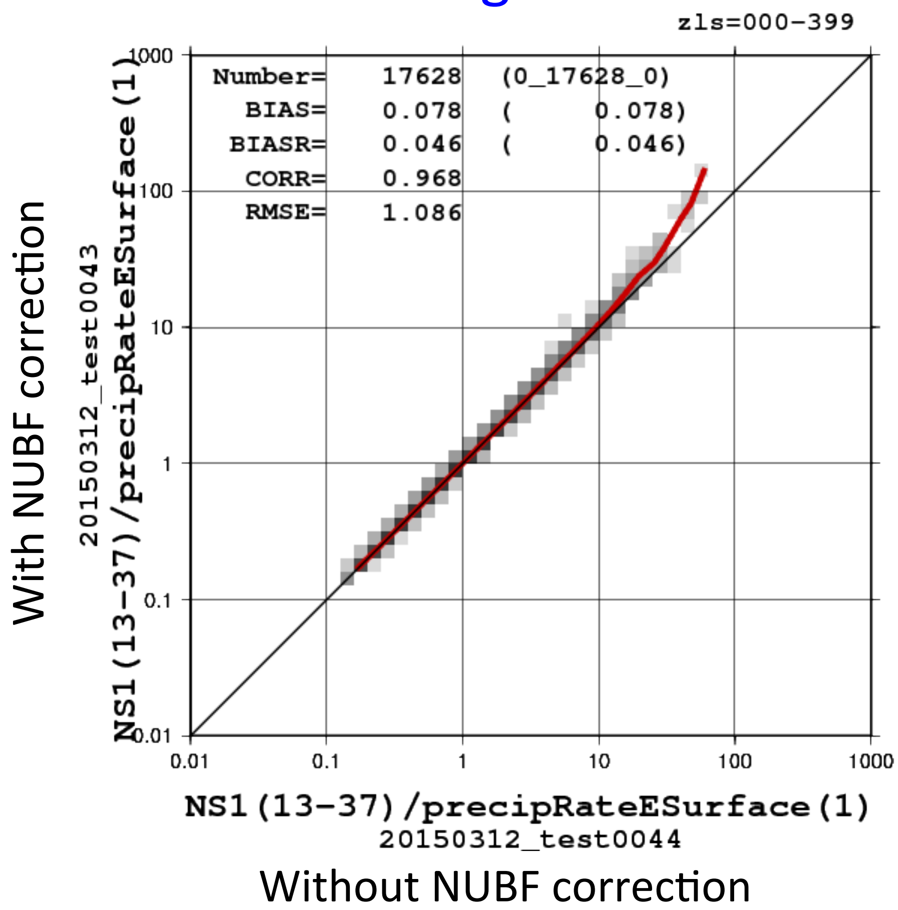


Modification for V04 [1]

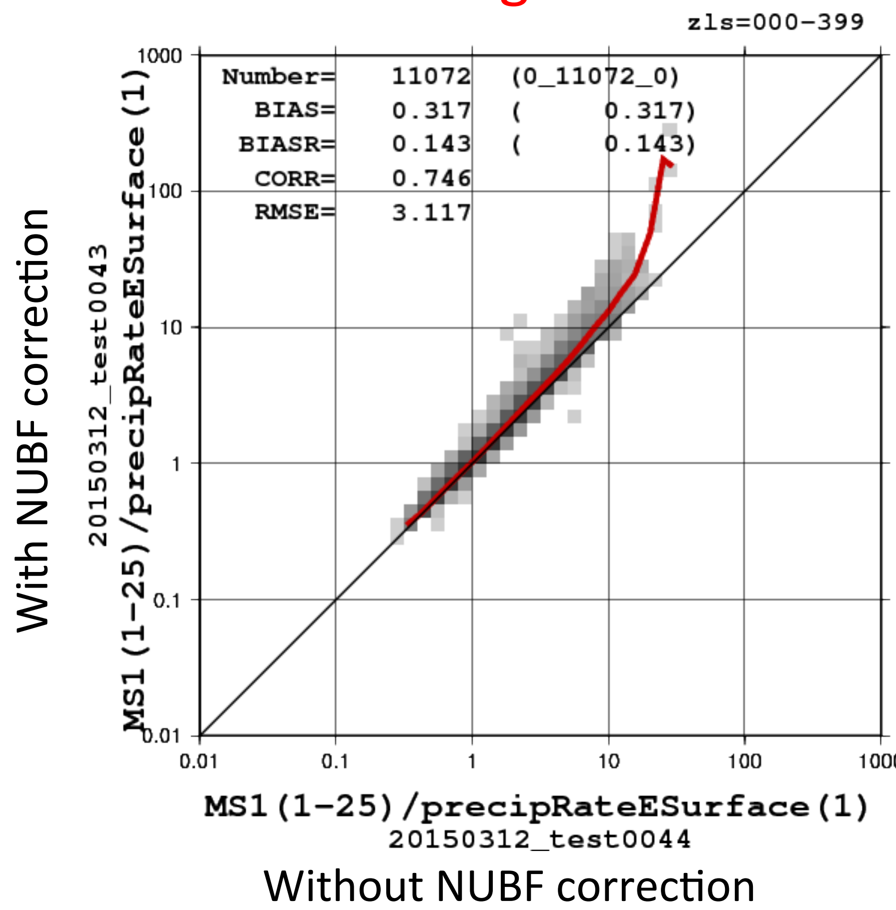
NUBF correction is incorporated

- NUBF correction incorporated in V04 is similar to that in TRMM/PR V7.
- NUBF correction increases rain rates particularly for heavy rainfall and in KaPR algorithm.

KuPR algorithm

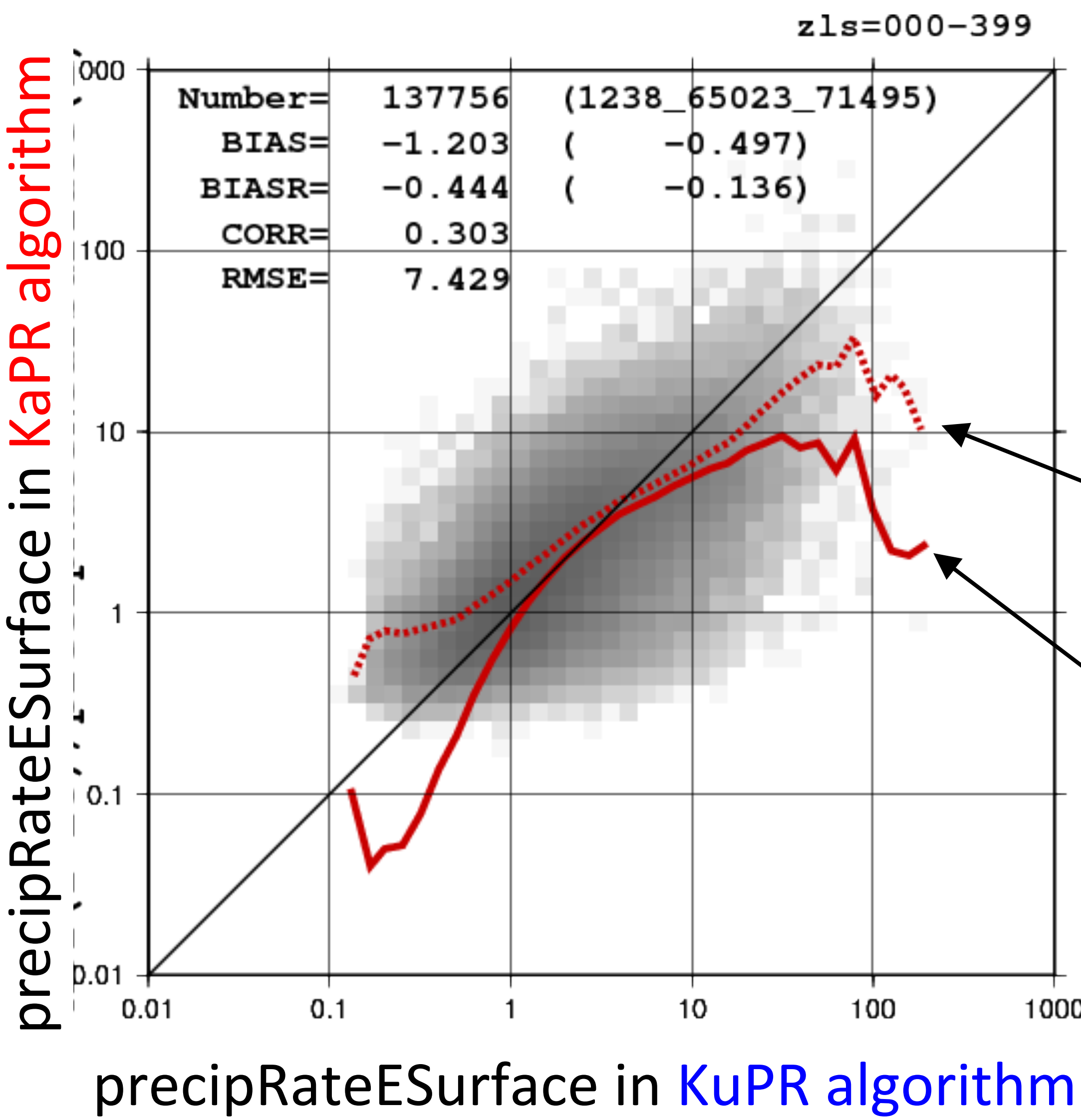


KaPR algorithm



Modification for V04 [3]

Missing echoes are compensated



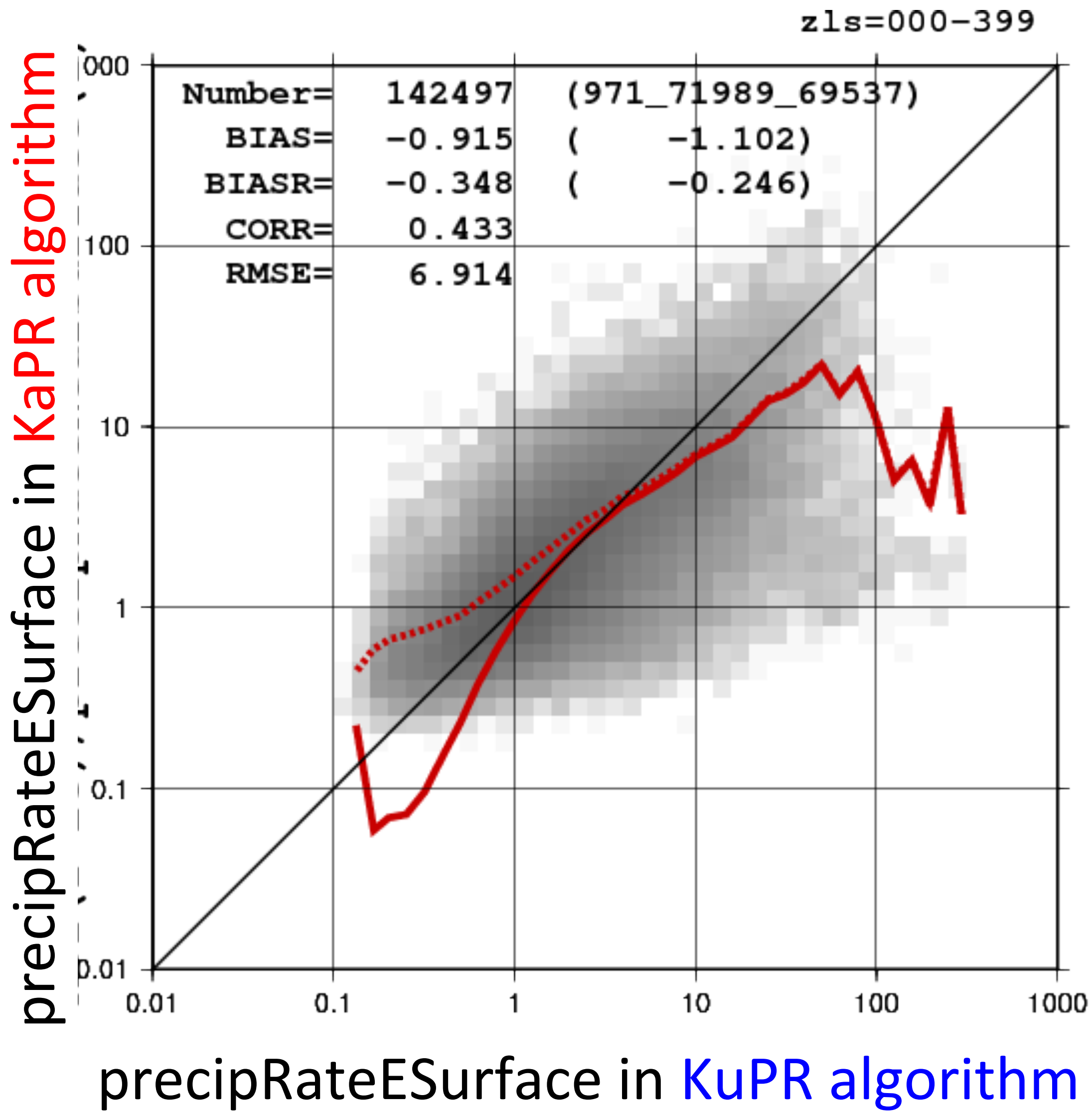
In an early test version for V04, KaPR misses some rain echoes which are caught by KuPR, not only for light precipitation but heavy precipitation (rain echoes are missed by attenuation)

(dotted line)
Average of KaPR algorithm
(KuPR>0 and KaPR>0)

(solid line)
Average of KaPR algorithm
(KuPR>0 and KaPR≧0)

Modification for V04 [3]

Missing echoes are compensated



In V04, missing echoes are compensated (Ze is extrapolated) under 24 or more range bins with rain echoes.

(dotted line)
Average of KaPR algorithm
(KuPR>0 and KaPR>0)

(solid line)
Average of KaPR algorithm
(KuPR>0 and KaPR≧0)

Modification for V04 [5]

δPIA is directly used.

- δPIA = KaPR's PIA – KuPR's PIA
- δPIA is more accurate than single-frequency PIAs as changes in σ^0 caused by land surface are cancelled by taking the difference of PIAs.
- However, in V03B, it was difficult to use δPIA directly in SLV module. Then, the ratio of KaPR's PIA to KuPR's PIA is assumed to be 6, and single-frequency PIAs are retrieved before SLV module.
- In V04, δPIA can be directly used in SLV module. No need to fix the ratio of KaPR's PIA to KuPR's PIA.