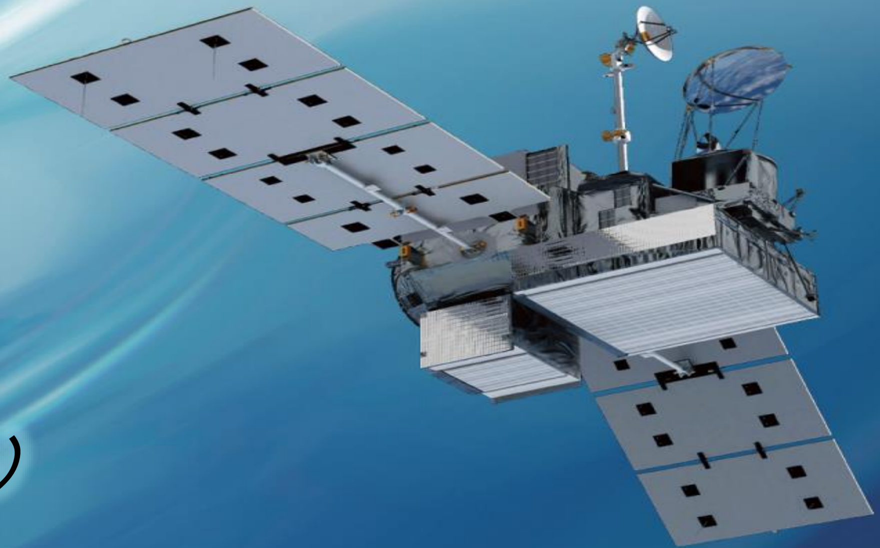
DPR Algorithm Status



Nobuhiro Takahashi （Nagoya University）

and

International DPR L2 team

NASA PMM 2020

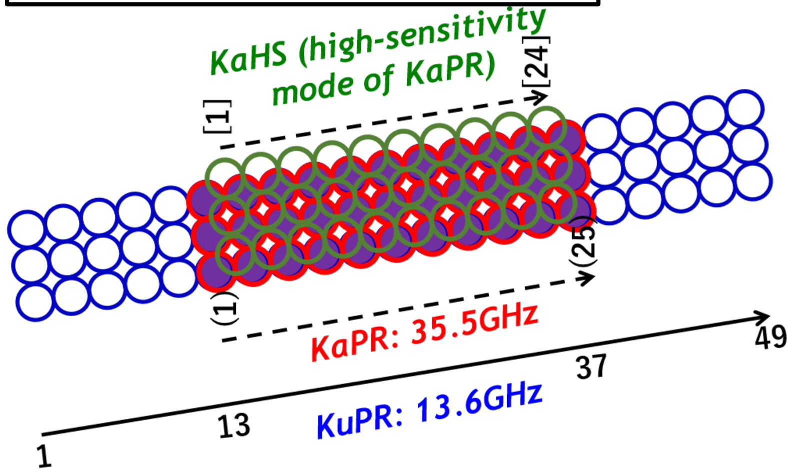
Online | October 20, 2020

Contents

- Overview of DPR algorithm status
  - V06X (Experimental)
  - V07 (next version up)
- DPR algorithm status (each module)
  - L1 status (Masaki, Kubota)
  - L2 PRE module (Masaki & Kubota, Kanemaru)
  - L2 VER module (Kubota)
  - L2 CSF module (Awaka, Chandra & Le)
  - L2 SRT module (Meneghini)
  - L2 SLV module (Seto)
  - L3 status (Meneghini)

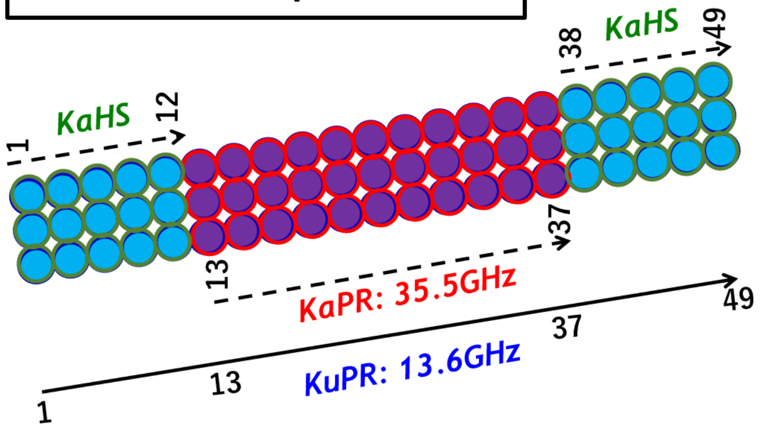
Before May 21, 2018

Original scan pattern



After May 21, 2018

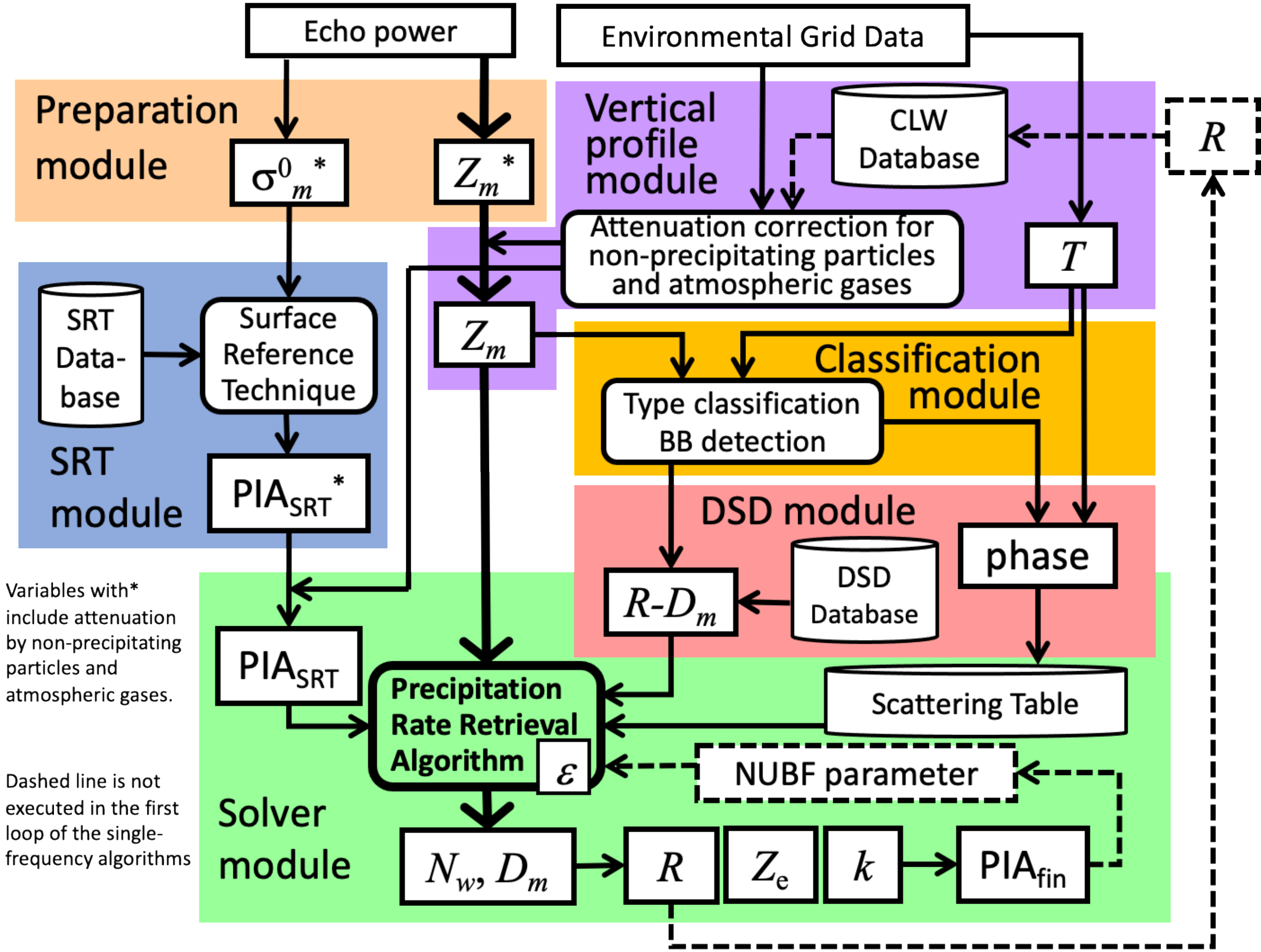
New scan pattern



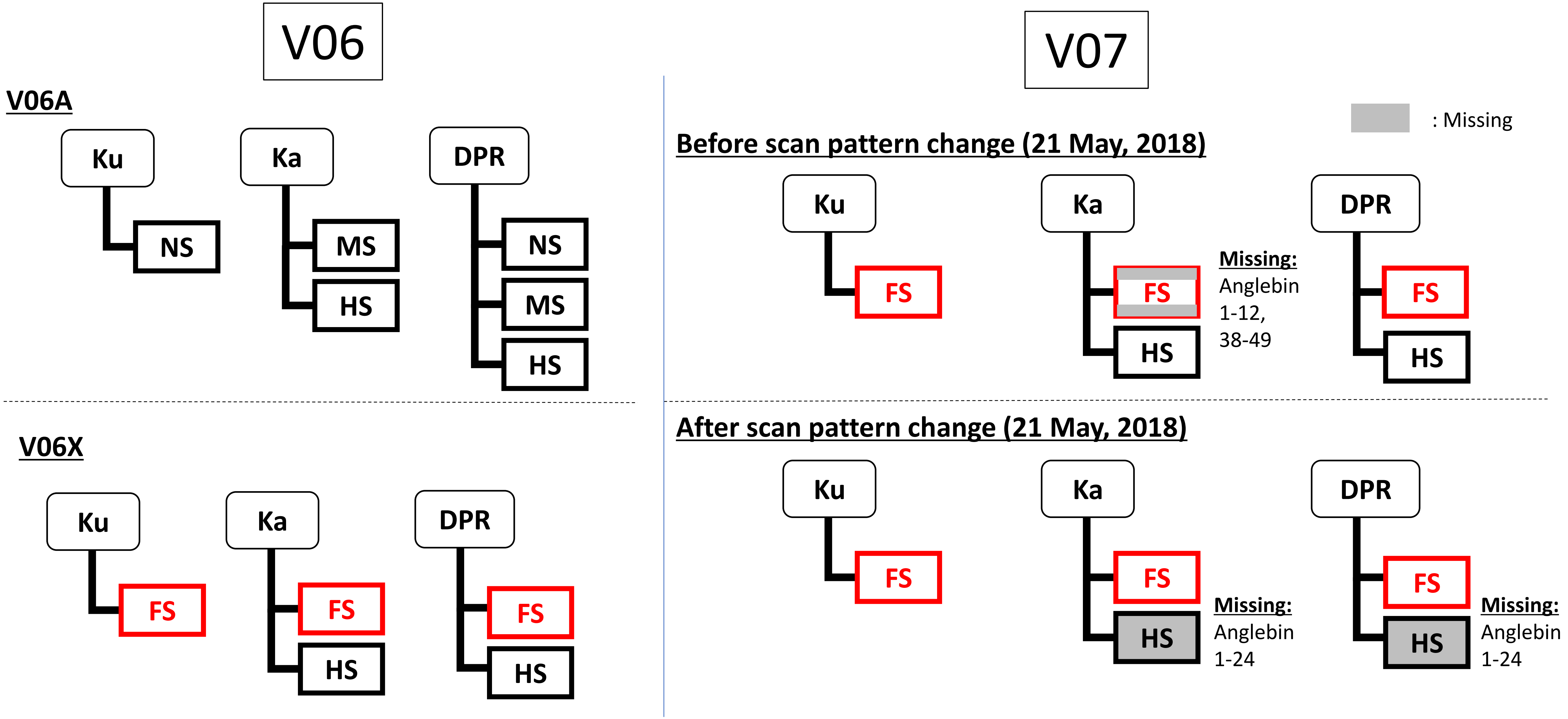
Dual-frequency measurement becomes available in outer swath

Overview of DPR algorithm status

- V06X (experimental product)
  - <u>Full swath</u> product after May 21, 2018
  - Modified V06 for full swath observation.
  - **Released June 2020**
  - Known issue: angle bin dependence of rain estimate over ocean by dual-frequency algorithm (common with V06 but prominent in V06X outer swath)
- V07 (next major version up)
  - Planed to be released in **mid-2021**
  - Major modifications will be
    - New rain/no-rain classification
    - Fixed ε in vertical -> variable in vertical
    - Common file structure before and after the scan change



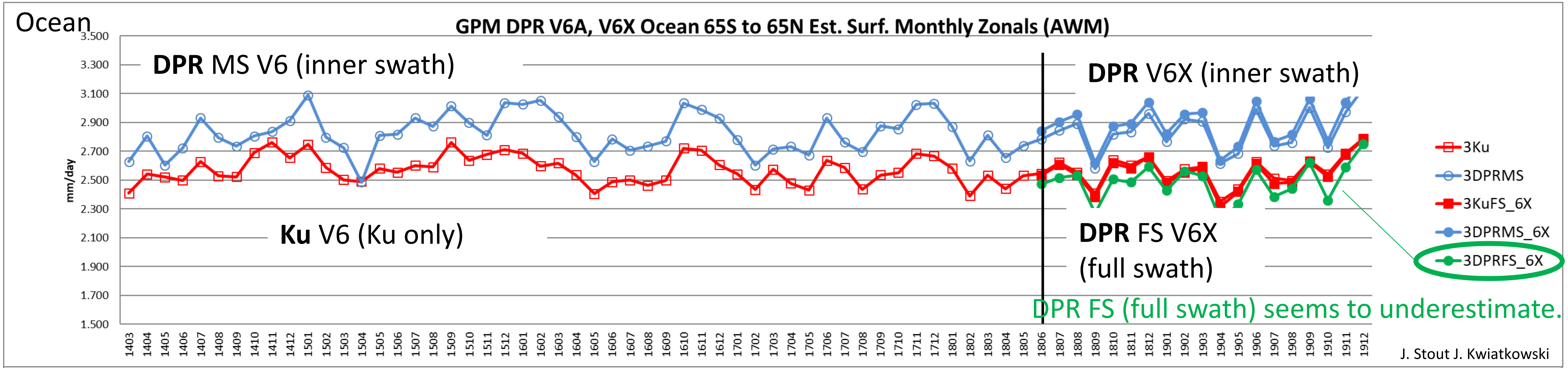
File structure (V06 to V07)

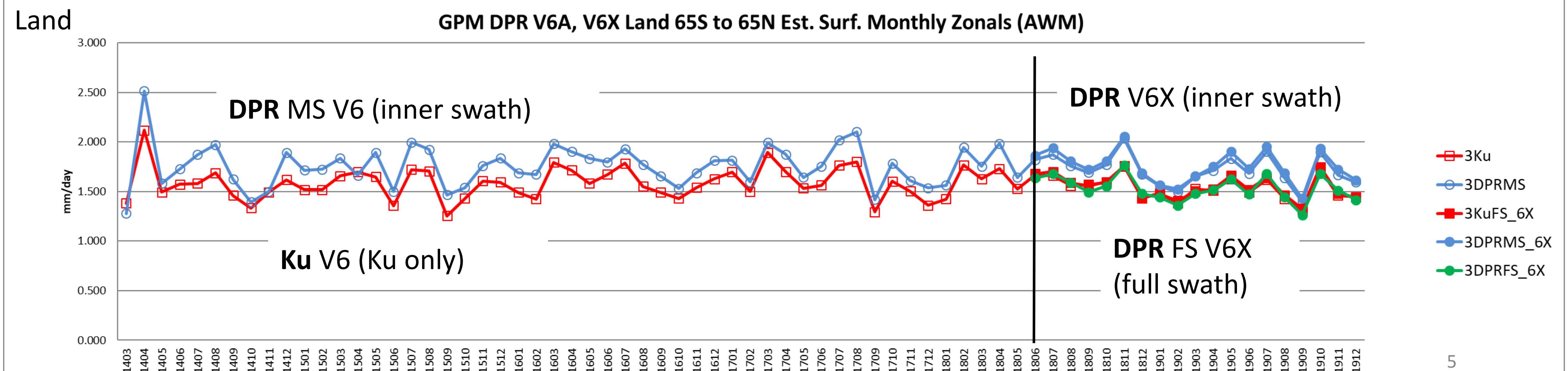


- Implementation of a new Group ‘FS’(Full Scan).
- ‘FS’ has 49 angle-bins and 176 range-bins for each scan.

Performance of V06X

J. Stout & J. Kwiatkowski

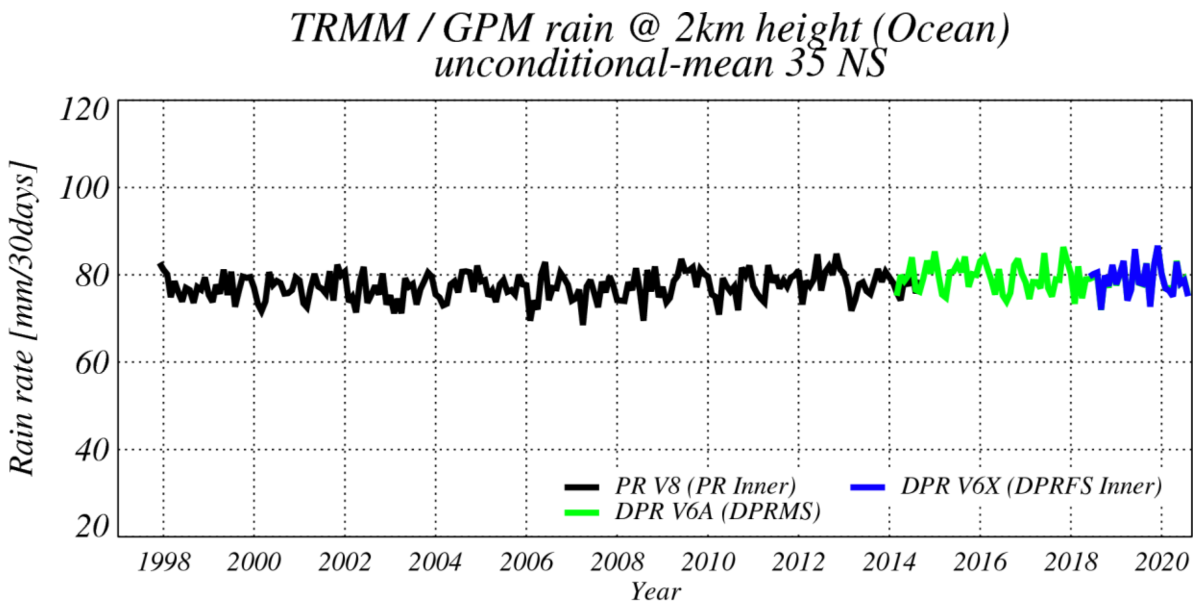




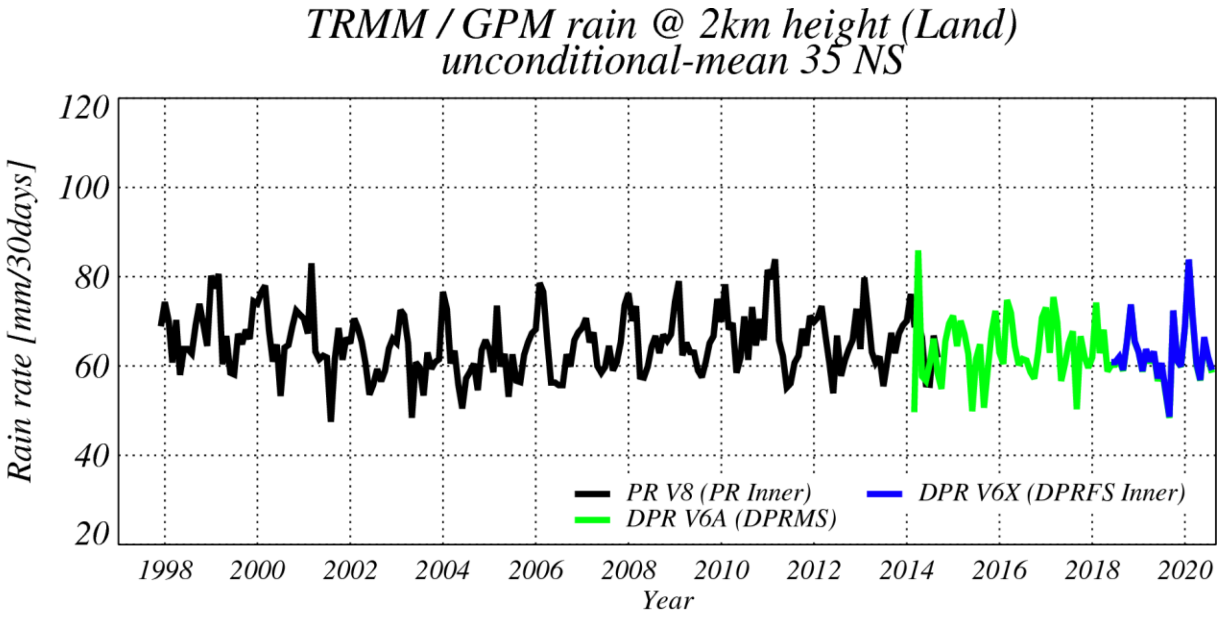
J. Stout J. Kwiatkowski

Long term performance (TRMM era to GPM era) (inner swath only)

Ocean



Land



(T. Masaki)

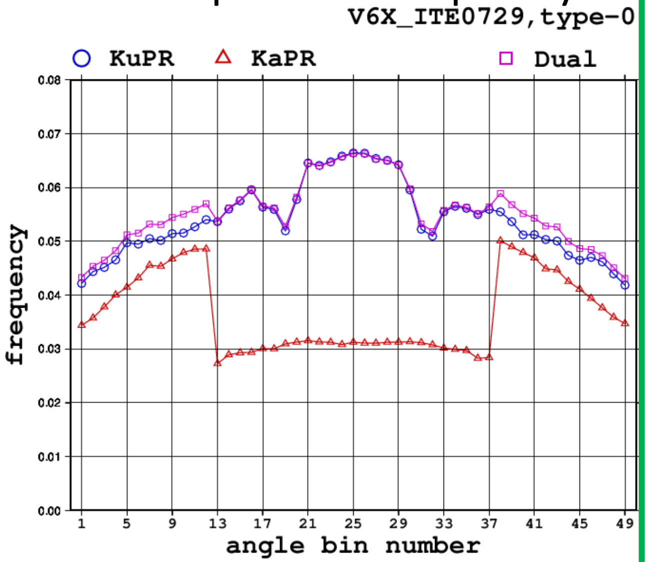
fnFigPdf=/josui_disk1/masaki/program/dpr_l2/ckZonal/fig/20201011/20201011_DPR_06A_ITE601_DPR06X_vs_DPR_06A_PR_06A_SAOC_L2_glb_trend.pdf

Angle bin dependency of DPR R (Solver module)

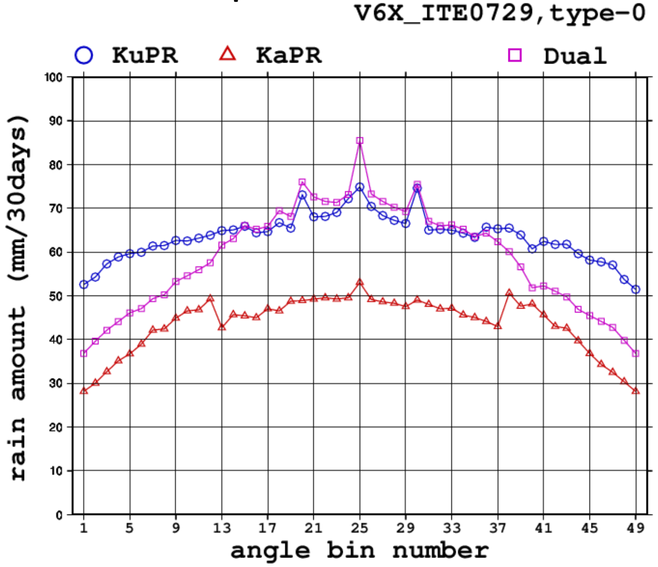
(S. Seto)

angle bin dependency of V06X

Precipitation Frequency

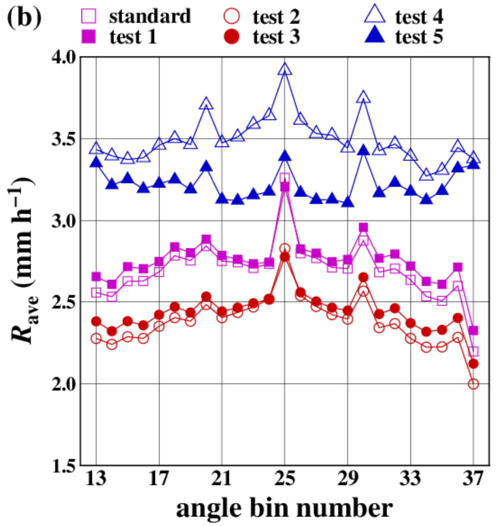


Precipitation Amount



The angle bin dependence problem is more severe in outer swath
➔ needs to be improved in V07

Investigation of angle bin dependency (Seto et al. *submitted to JMSJ*)



	ZfKa	SRT
standard (V06A)	Yes	DSRT
Test 1	No	DSRT
Test 2	Yes	SSRT(Ka)
Test 3	No	SSRT(Ka)
Test 4	Yes	SSRT(Ku)
Test 5	No	SSRT(Ku)

Both ZfKa method and Dual-frequency SRT (DSRT) cause angle bin dependence of average rain rate estimates.

(T. Masaki & T. Kubota)

Changes in V7 of **DPR L1** algorithm (see also appendix A-D)

- <u>Refine the scan angle table (KuPR).</u>
  - An asymmetry of some variables (e.g. StormTopHeight) will be improved.
  - There are not any changes DPR’s H/W setting.
- <u>Add a new flag for mirror image (KuPR and KaPR).</u>
  - A new quality flag which notifies an unusual precipitation at high altitude by the mirror image.
- <u>Change swath name (KuPR).</u>
  - A swath name in L1BKu product will be changed from ‘NS’ to ‘FS’.
- <u>Refine a gain of phase shifter.</u>
  - An angle bin dependency of the noise power will be improved.
- Other minor changes
  - Update for Geolocation toolkit etc.

Development has almost finished. A test processing is now on going with JAXA supercomputer.

Major changes in V7 of DPR L2 **PRE** module

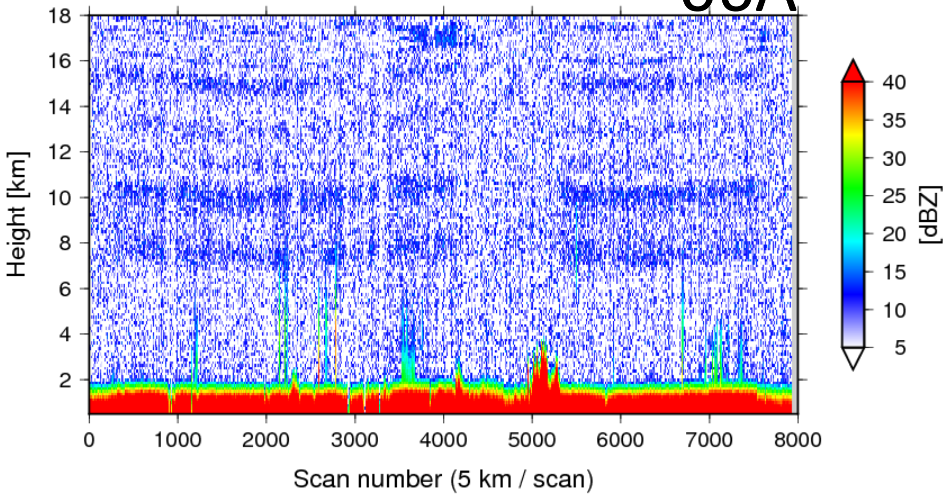
(T. Masaki , T. Kubota & K. Kanemaru)

- Introduce a new method for the rain/no-rain judgement.
  - Improvement of clutter rejection method before rain/no-rain judgement.
- Update adjustment factor which corrects Zm and sigma zero.
- Some minor updates.
  - Add a new flag for mirror image etc.

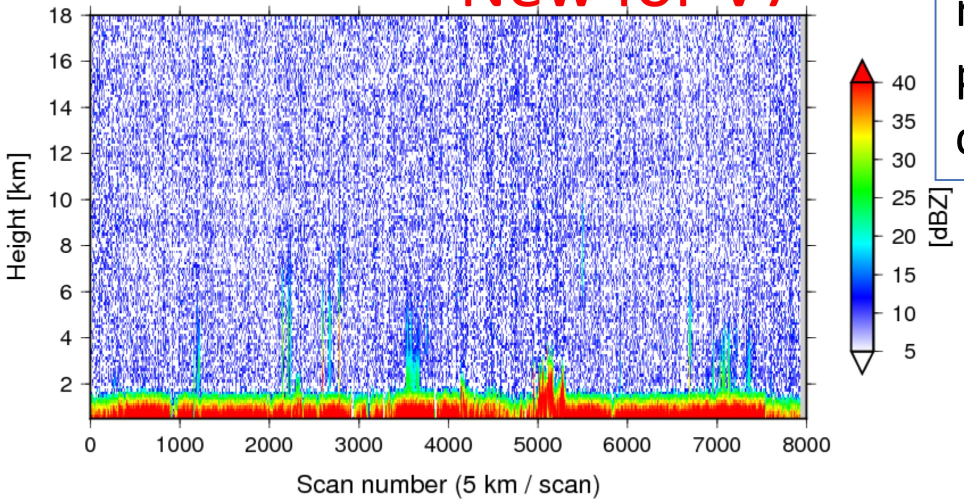
(K. Kanemaru)

Improvement of clutter removal method

06A



New for V7



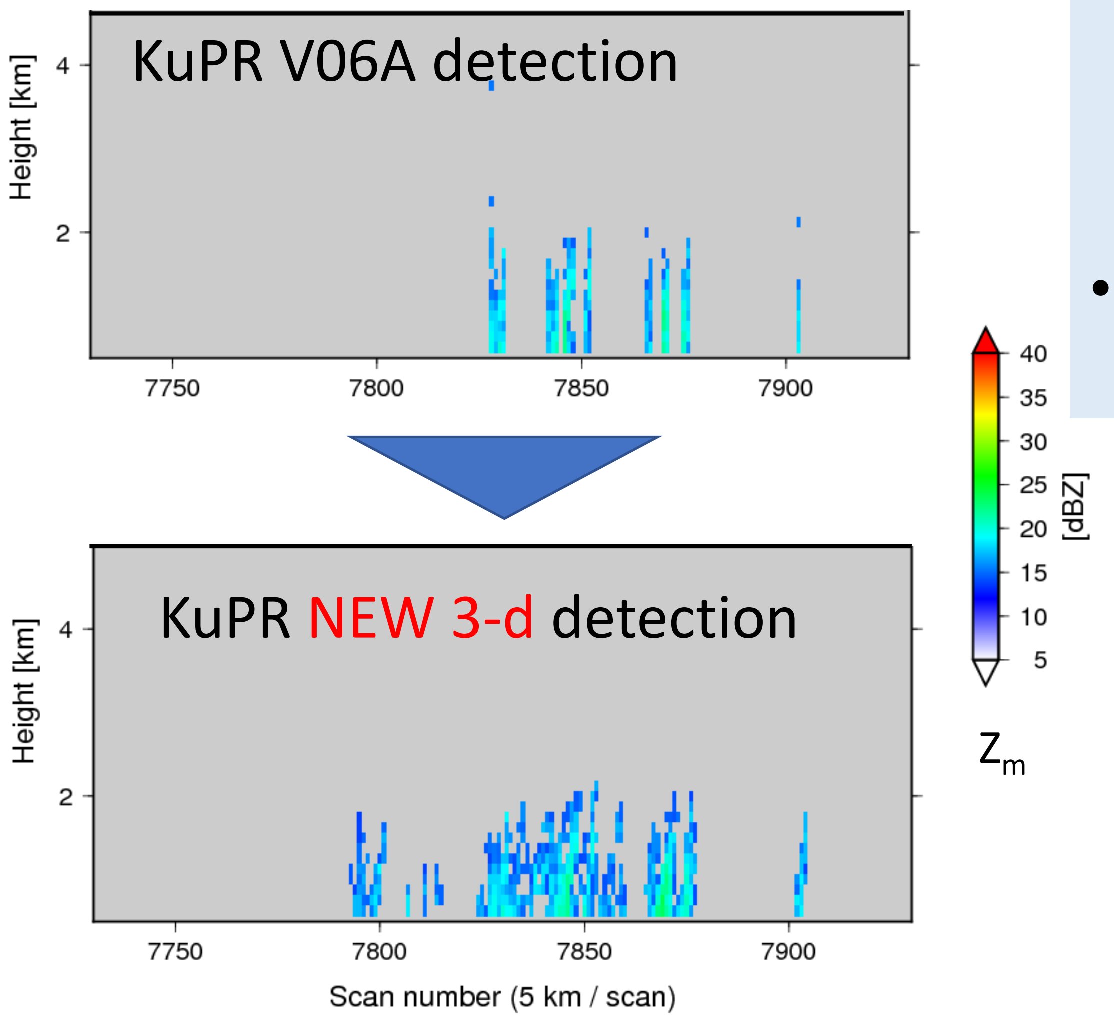
By improving the clutter removal routine, false precipitation caused by clutter are reduced.

19/09/04
orbit# 31343
KuPR vertical cross section (17.0 deg.)

(K. Kanemaru)

Improvement of precip. detection with 3-d information

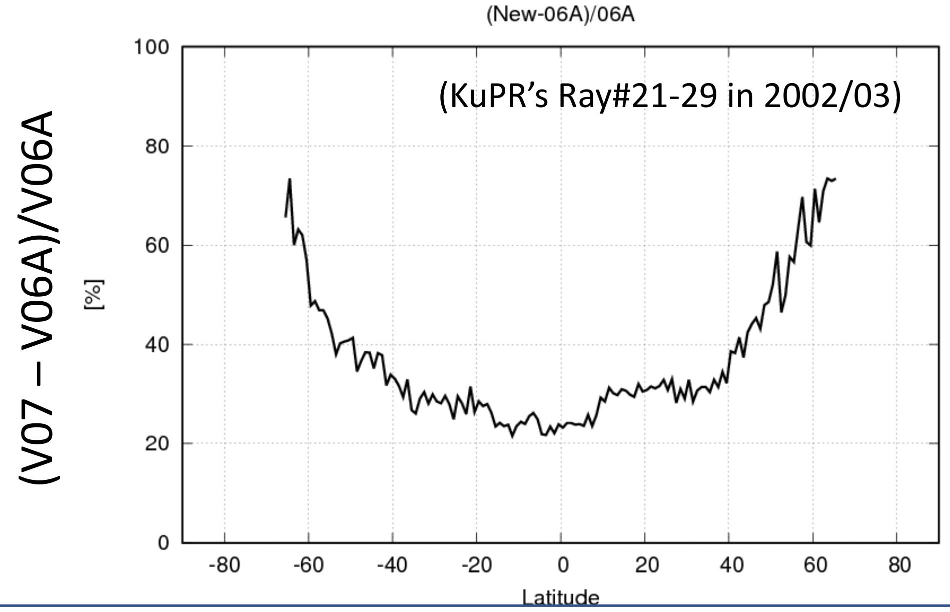
2019/09/04 orbit# 31343 GPM KuPR ray# 25 High latitude case



(Provided by Dr. Kanemaru, NICT)

- To fill in the sensitivity difference between cloud and precipitation radars, precipitation detection in the DPR algorithm in <u>V07 will be improved with 3d-information of precipitation echoes</u>.
- At high latitudes, <u>the new method increases frequency by ~60%</u> against the V06A products.

Relative change of rain detection in zonal mean



(T. Kubota)

Vertical Profile Module (VER) status

- The VER module computes the **path-integrated attenuation (PIA) due to non-precipitation (NP) particles (piaNP)** and generates a radar reflectivity factor corrected for the piaNP.
- Recently, a paper related to the VER appeared in JTECH.
  - T. Kubota, S. Seto, M. Satoh, T. Nasuno, T. Iguchi, T. Masaki, J. M. Kwiatkowski, and R. Oki, 2020: Cloud assumption of Precipitation Retrieval Algorithms for the Dual-frequency Precipitation Radar, *J. Atmos. Oceanic Technol.*, https://doi.org/10.1175/JTECH-D-20-0041.1
- Developments toward **V07**
  - A profile of air temperature will be output in the VER of V07 standard product (like V06X).
  - A "flag" with finding of an inversion layer of air temperature will be added.
  - Improvements of rain-free piaNP will be planned.

Classification module (CSF)

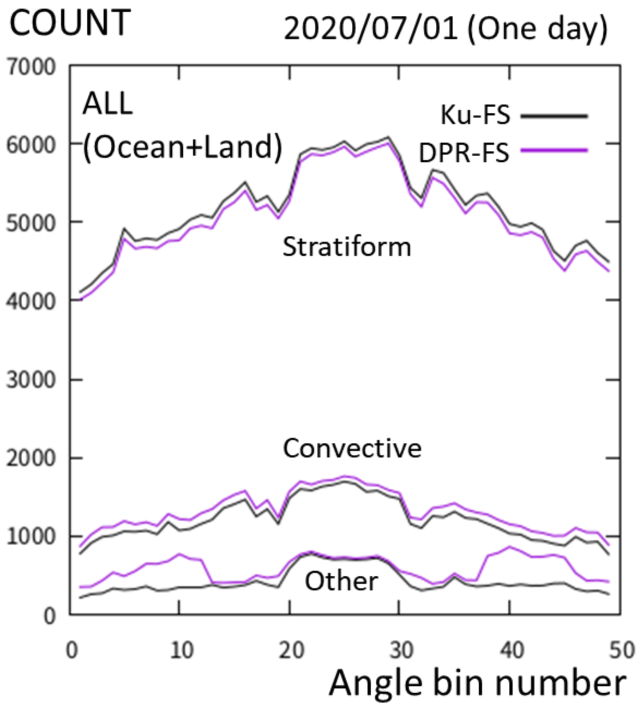
(J. Awaka)

V06X performance

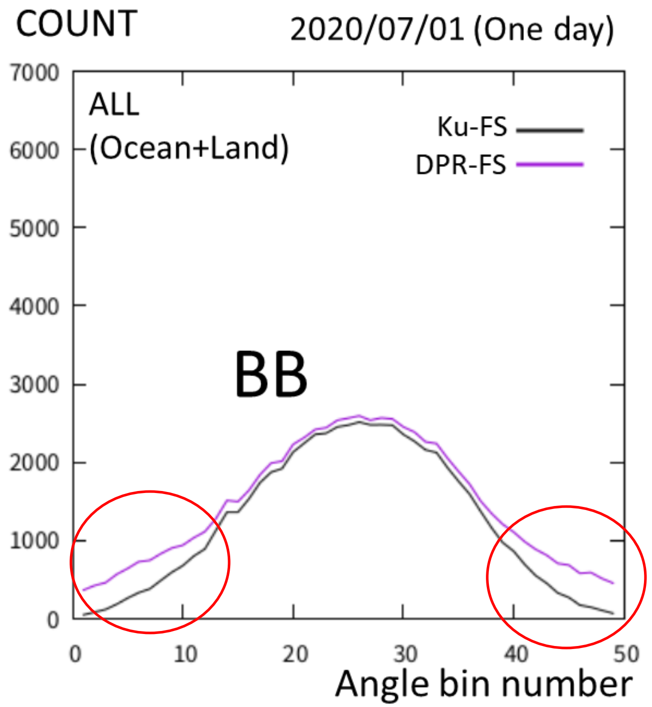
- Stratiform counts for Ku-FS and DPR-FS show almost parallel-shifting shapes in the full swath.
- Convective counts for Ku-FS and DPR-FS also show almost parallel-shifting shapes in the full swath.

In V06X, the dual frequency classification (CSF) module works well not only in the inner swath but also in the outer swath.

Bumps in DPR-FS other type count occurs due to the following data: No rain at Ku but rain at Ka. Probable reason: fluctuations of Ku are greater than those of Ka, making consecutive condition for rain echo violated in weak Ku data.



In V06X, a true **full swath dual frequency processing** becomes possible for the first time.



The BB counts reveals an advantage of dual frequency processing. Detection of BB improves greatly by the use of dual frequency processing.

V07 plan

(i) Improvement of BB detection. (Dr. Iguchi's method seems promising.)
(ii) Re-examination of stratiform rain when BB is not detected.

Performance of V06X and Plan for V07 for Dual-frequency Profile Classification

(Chandra & M. Le)

Performance of V06X

- Profile classification module includes 3 main functions:
  - Rain type classification/Melting layer detection.
  - Surface snowfall identification.
  - Graupel and Hail detection.
- All these algorithms have completed adjustments to the DPR full swath and illustrate good performance. Detection rate roughly doubles due to scan pattern change from inner to full swath.
- Rain type classification illustrates smooth transition from inner to outer and shows excellent agreement with Ku only algorithm. Melting layer top detection increase more than 20% after modification in V06X.
- Both Surface snowfall and Graupel Hail detection algorithm illustrate better comparisons with other sensors after processing with full swath data. Global scale analysis shows reasonable global distribution and seasonal variations.
- Global scale analysis on Graupel and hail detection algorithm is focusing on 5 major global regions with studies showing different features on regional and seasonal statistics.
- The flag from the graupel and hail identification algorithm is cross validated with Trigger module products and shows good comparisons.

Plan for V07

- As a step further of the graupel and hail detection algorithm, we plan to develop algorithm to detect large hail with the aid of precipitation type index and other information.
- Potential algorithm improvement for surface snowfall algorithm is planed to include storm top normalization.
- Potential algorithm improvement for graupel and hail detection to deal with shallow precipitation case.

(R. Meneghini)

SRT Status

- Purpose of algorithm is to provide estimates of path attenuation and their reliability for Ku-band, Ka-band & dual-freq estimation
  - Primary output is the SRT PIA which provides a constraint on rain retrievals
  - Hybrid PIA estimates are also provided as a more accurate estimate of PIA to mitigate deficiencies in SRT by combining it with HB and other methods
- Version V6X was submitted in Mar 2020 & is currently running in operational system
- Work on V7 is currently underway
  - V7 draft codes for Ku, Ka and DPR are working in latest environment
  - Several upgrades of codes are currently under test

(R. Meneghini)

Characteristics of V6X, V7

- V6X codes have given us the first opportunity to assess dual-freq DPR data in outer swath
  - Dual-freq SRT PIA is less noisy in outer swath than Ku-band single-freq SRT result
  - Large overestimates of path attenuation that are sometimes seen in single-freq estimates are largely missing in dual-frequency results
  - Hybrid dual-frequency estimates appear to be the most accurate but for large PIAs, we lose the Ka-band surface return & must use the single-freq Ku-band results

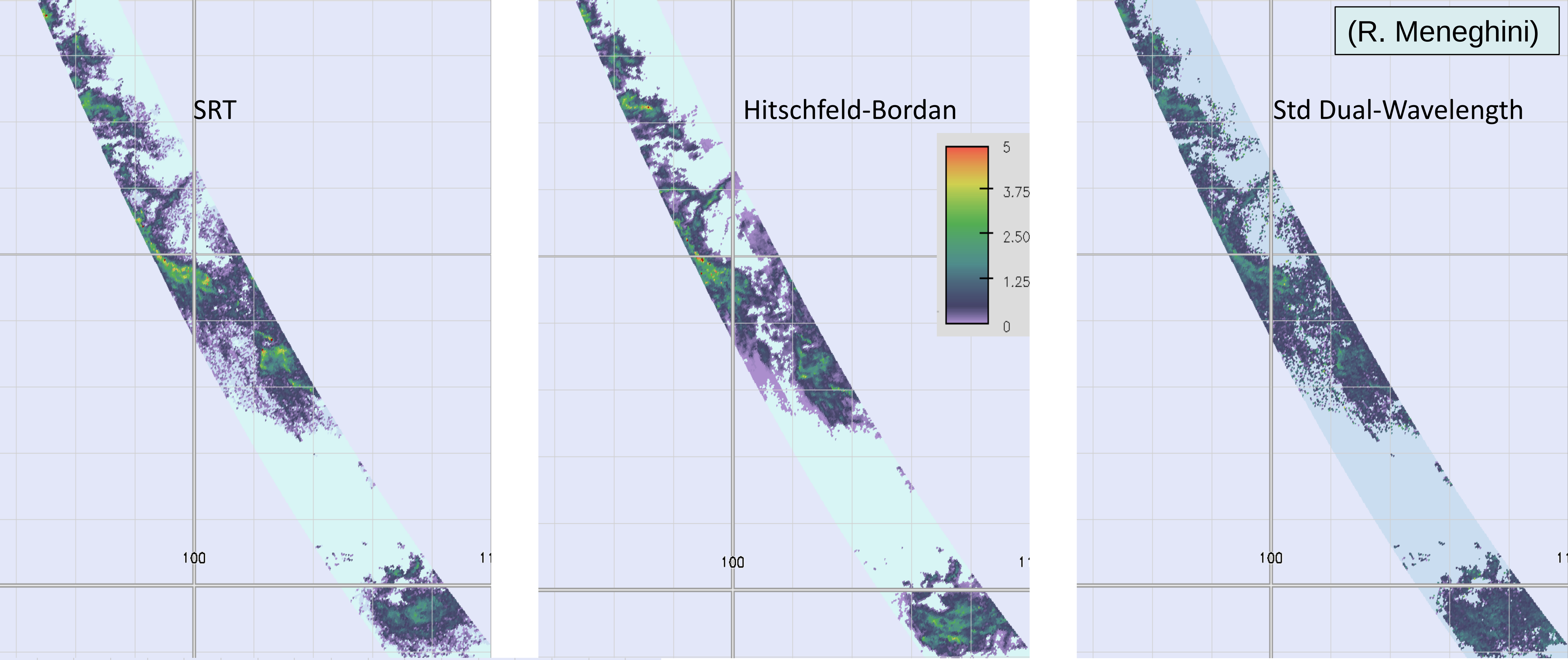
- V6X codes have been generalized to V7 to operate on data both before and after the scan change
  - Code changes are now underway to include sampling errors in the estimates (from finite number of samples)
  - Preliminary tests show changes, usually minor, to SRT and Hybrid results

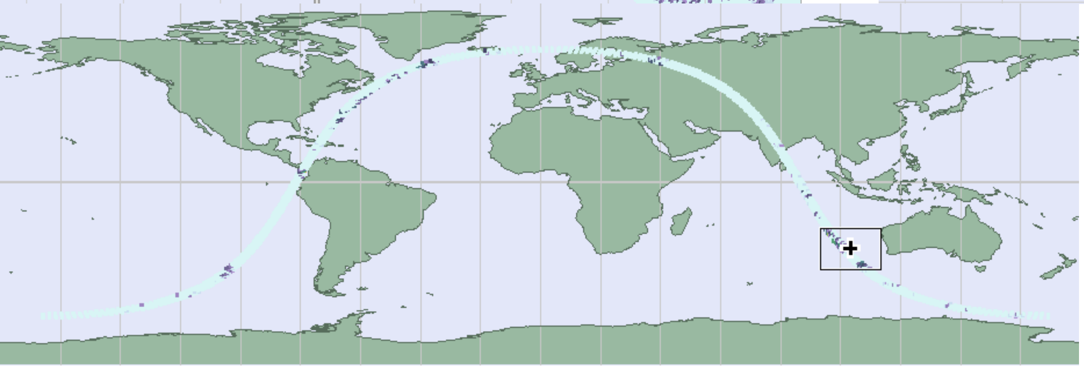
(R. Meneghini)

Example

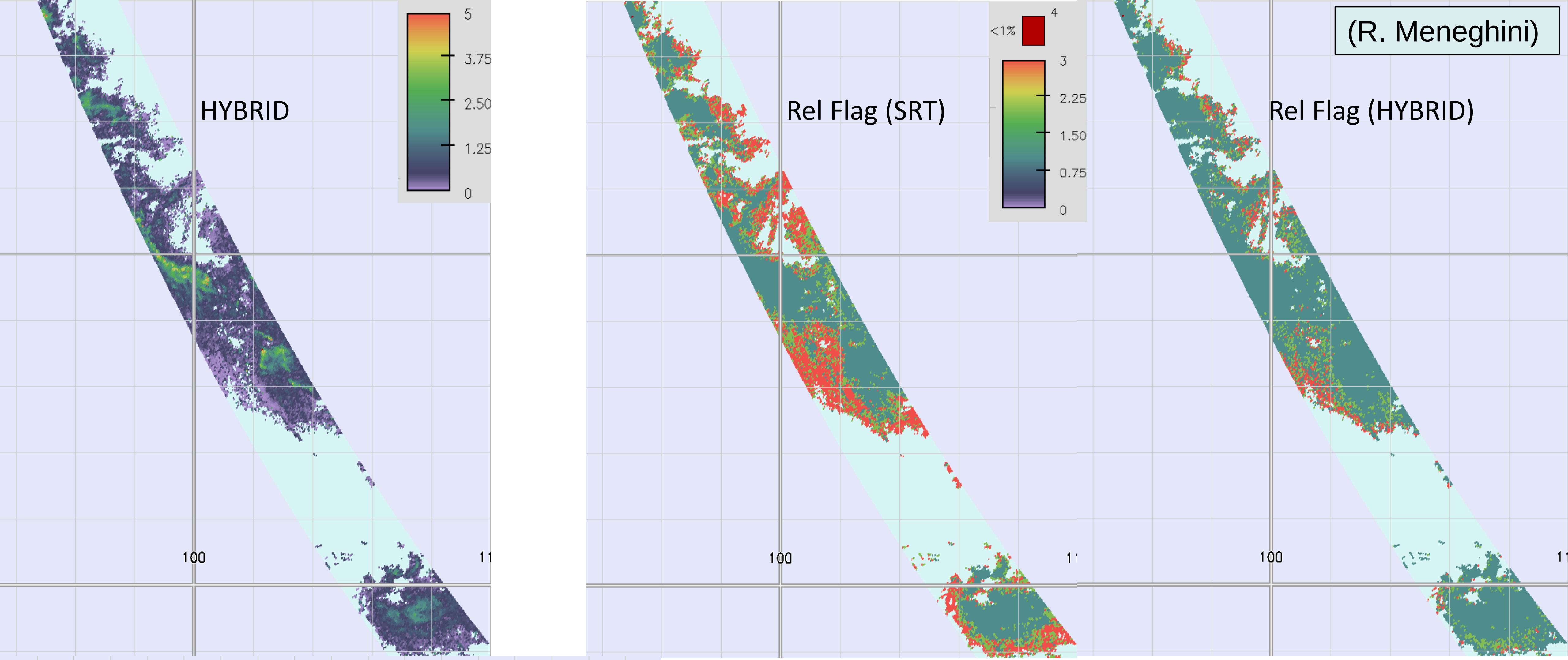
- The next two slides show how the hybrid is formed from a weighted combination of SRT, HB (Hitschfeld-Bordan), and DW (Standard dual-wavelength) methods
  - For single-frequency estimates only SRT and HB are used

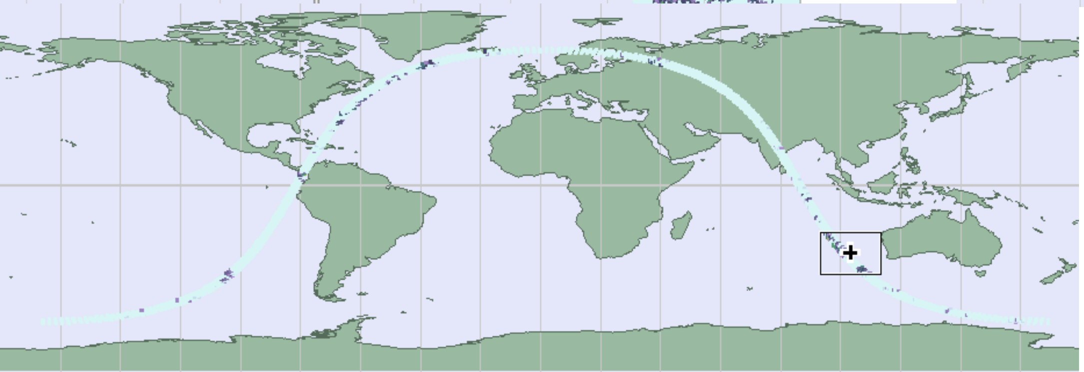
- The reliability flags in the second slide show that use of the hybrid generally improves the accuracy of the hybrid relative to the SRT
  - The main reason for this is that HB performs better at light rain rates than does the SRT so that combining the 2 results provides a more accurate estimate





- Orbit 24642, 30 Sep 2018
- DHybrid(Ku-band) estimate
- West of Australia
- Version V6X





RelFactor = E(A)/σ(A)

Rel Flag = 1 (reliable) if RelFactor > 3

Rel Flag = 2 (marginally reliable) if 1 <RelFactor < 3

Rel Flag = 3 (unreliable) if RelFactor < 1

Rel Flag = 4 (lower bound) if surface at Ka not detected

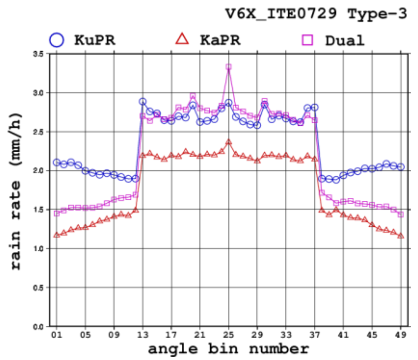
Improvement of DSD/SLV modules for Version 07 (tentative idea)

(S. Seto)

- The same parameters *p*,*q* and *r* in *R*-D_m relation ($R=\varepsilon^r p D_m^q$) or the same definition of ε is used for all precipitation types.
  - A-priori pdf of ε may be different by precipitation types.
  - ε can be directly compared between stratiform and convective precipitation.
- <u>ε is variable along the beam</u> and it is determined at each range bin.
  - DFR method is partly used if dual-frequency measurements are available.
  - Three conditions (a-priori pdf of ε, SRT and DFR) are considered to determine the vertical profile of ε.

- Angle bin dependence should be mitigated.

Conditional average of *R* in V06X (Jun 2018)



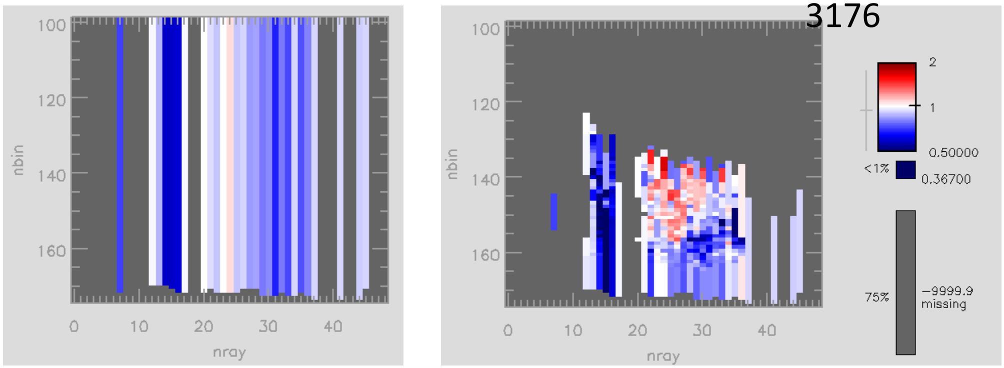
Distribution of ε (angle x range)

V06A

A test product

Orbit#12826

Scan# 3176



L3 Status

(R. Meneghini)

- The purpose of L3-DPR is to compile statistics of rain-related products from the L2 DPR data
  - Monthly outputs are generated at 5^0 and 0.25^0 resolutions
  - Outputs from Ku-band, Ka-band and DPR are included
  - Designed for end users as well as for diagnostic tests of L2 products
- Version V6X of the code was delivered in Mar 2020
  - A number of products were created/modified to accommodate changes in Ka-band scan pattern in May 2018
- Although L3-V6X can be extended to V7 with minimal changes, we are considering a change in structure to make products more easily accessible.

Data access and ATBD for V06X

- ftp site for V06X product
  - JAXA: ftp://gpm2:DPR-L2_early@hokusai.eorc.jaxa.jp/
    - User registration is required.
  - NASA: ftp://pps.gsfc.nasa.gov/gpmdata/<YYYY>/<MM>/<DD>/Xradar

- ATBD for V06X

  https://www.eorc.jaxa.jp/GPM/doc/algorithm/ATBD_DPR_202006_with_Appendix_a.pdf

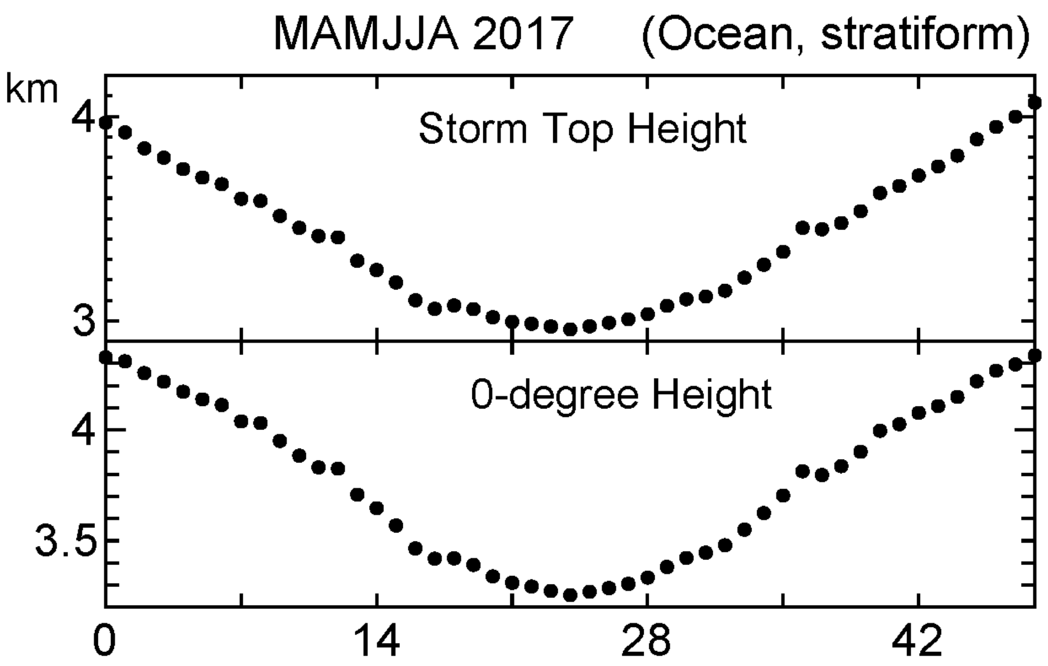
  or

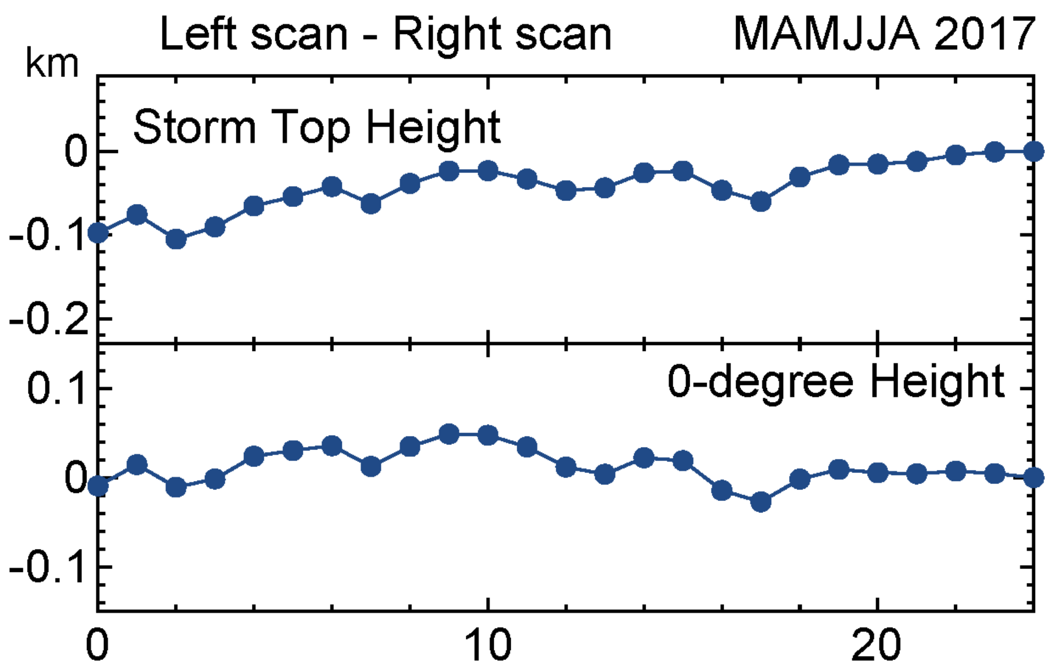
  https://pps.gsfc.nasa.gov/Documents/ATBD_DPR_202006_with_Appendix_a.pdf

Appendix A   Refine scan angle table

Refine scan angle table (1/3)

- An asymmetry of some variables (e.g. BB height, storm top height and sigma zero) in KuPR were found.
- According to the analysis, there is about 100 m bias between left side and right side of scan (e.g. StormTopHeight).





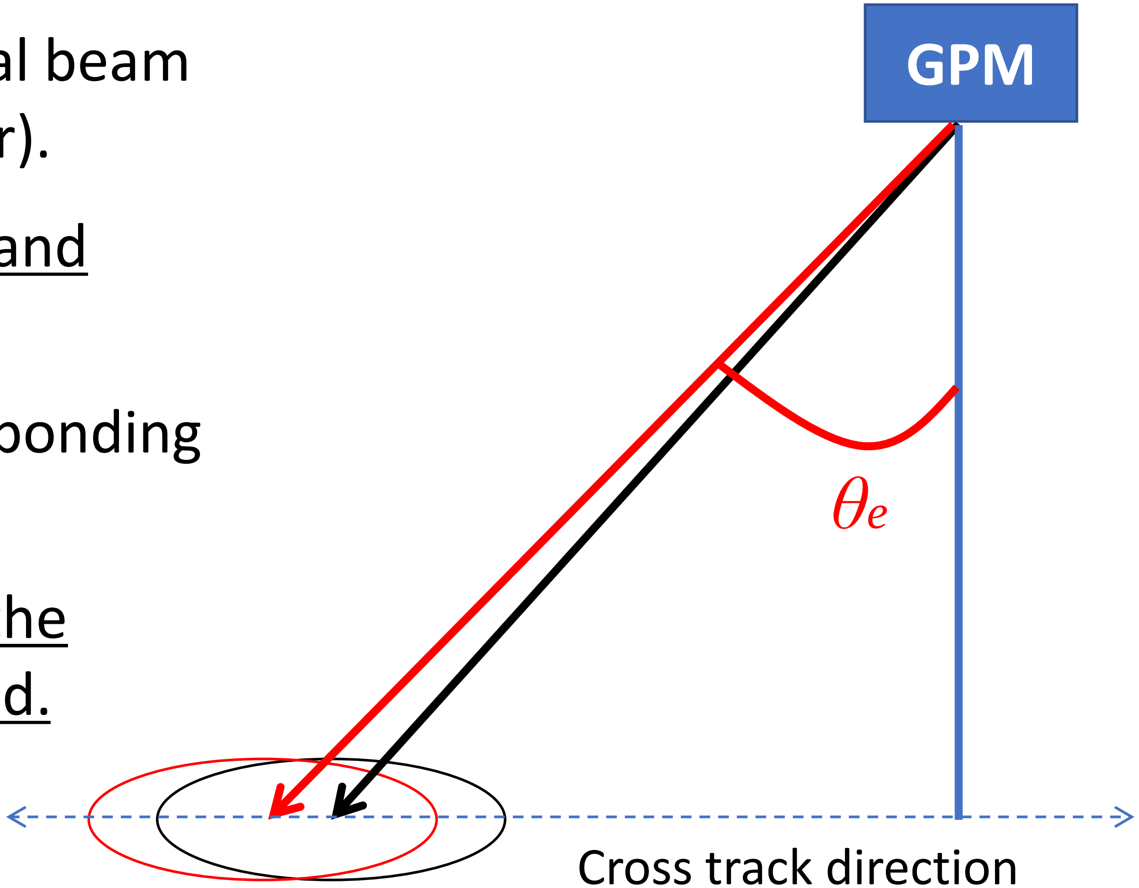
(N. Takahashi)

Refine scan angle table (2/3)

- Statistical results with a lot of observation data could reveal the angle bin dependency.
- Additional careful analysis by Dr. Kanemaru have detected that the bias was derived from DPR's pointing parameter.
- The magnitude of the bias is 0.024 deg (very small).
- It is too small to measure by ground test at pre-launch and it is difficult to detect where the bias was occurred.
- Therefore, based on the discussion with DPR L2 team in Japanese side and JAXA, we decided that
  - We don't change DPR's H/W setting (i.e. actual beam pointing doesn't change.)
  - We will adjust the bias as a refinement of scan angle table by updating DPR L1 algorithm (Only KuPR).

Refine scan angle table (3/3)

- Actual beam pointing (black) is determined by H/W setting (i.e. phase shifter).
- Scan angle table (red) is made by using the actual beam pointing parameters (i.e. a code for phase shifter).
- DPR L1 algorithm calculates the beam direction and geolocation with the scan angle table.
- In V7, the scan angle (θ_e) in the table and corresponding variables* will be changed.
- Our test with the new scan angle table showed the asymmetry of the storm top height was improved.



* Such as ray-vector and geolocation etc.

Appendix B   Refine a gain of phase shifter

Refine a gain of phase shifter (1/2)

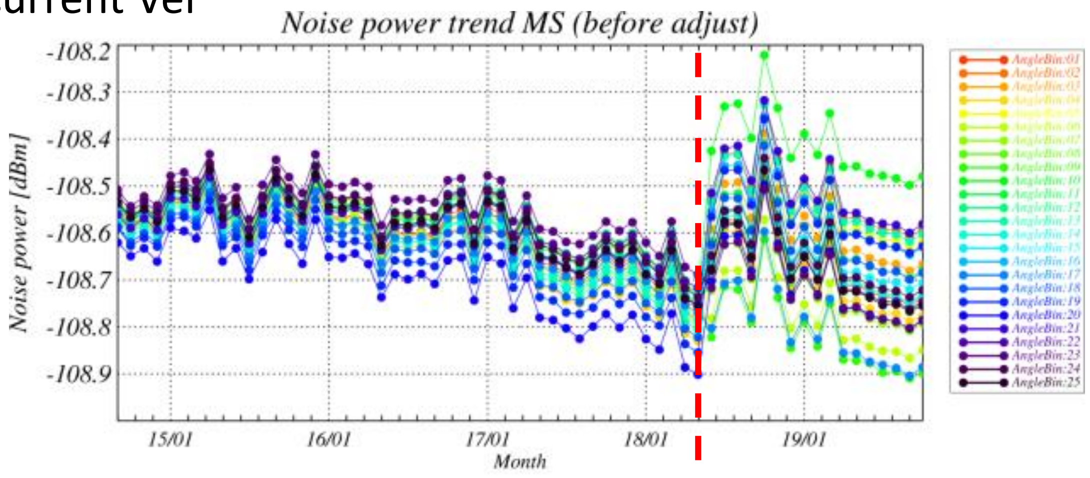
- DPR L1 algorithm provides the DPR’s received power by converting digital count to power with total gain of DPR receiver system.
- The total gain was measured at ground test before launch.
- A phase shifter is one of the component in the receiver system, and it is responsible for the DPR’s beam direction.
- The gain of the phase shifter depends on a code for the phase shifter, and the gain has an angle bin dependency (next page).
- We have mitigated the angle bin dependency by applying the correction factor to DPR L1 algorithm during before scan pattern (SP) change of KaPR.
- In May 2018, JAXA uploaded a new phase code to change the SP.
- Therefore, we need to adjust the gain after SP change as well.

Refine a gain of phase shifter (2/2)

Trends of noise power

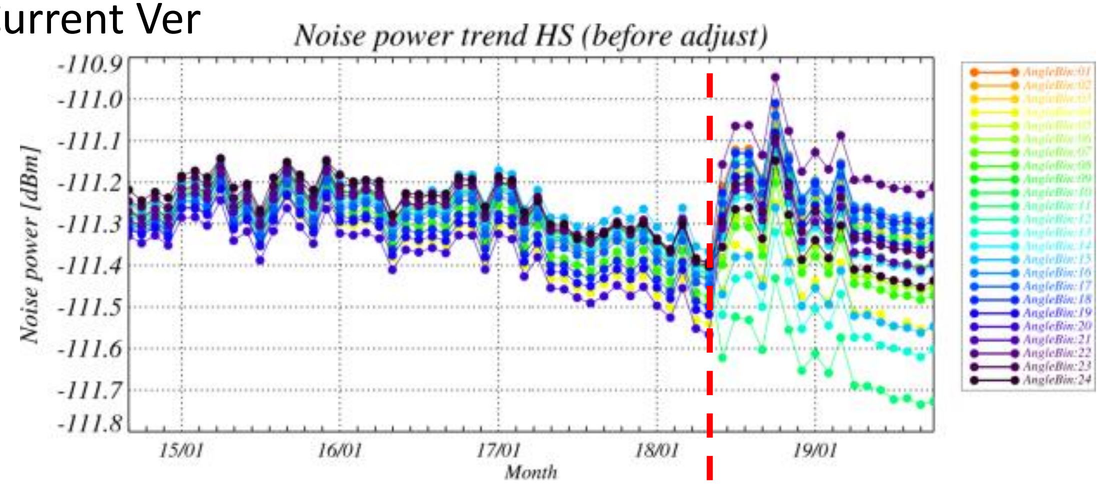
KaMS

Current Ver

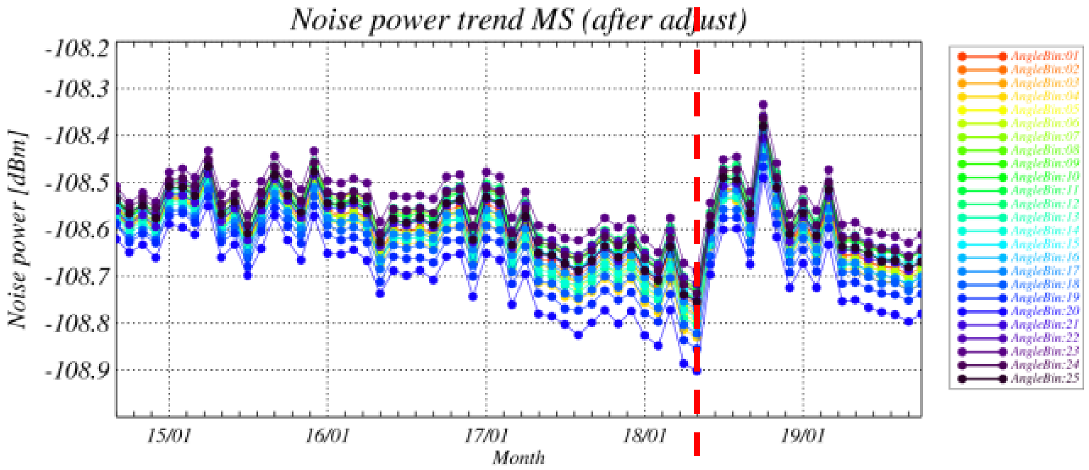


KaHS

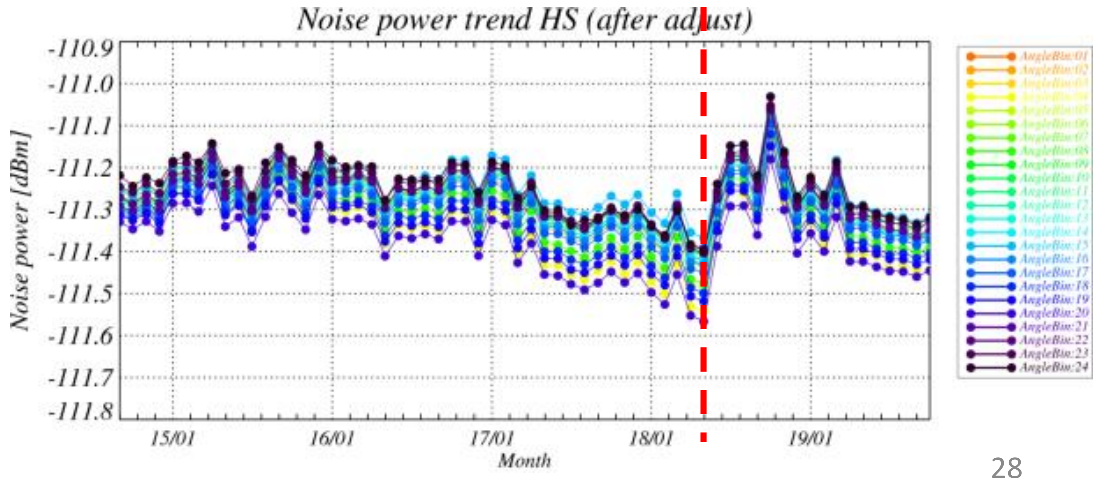
Current Ver



Test



Test



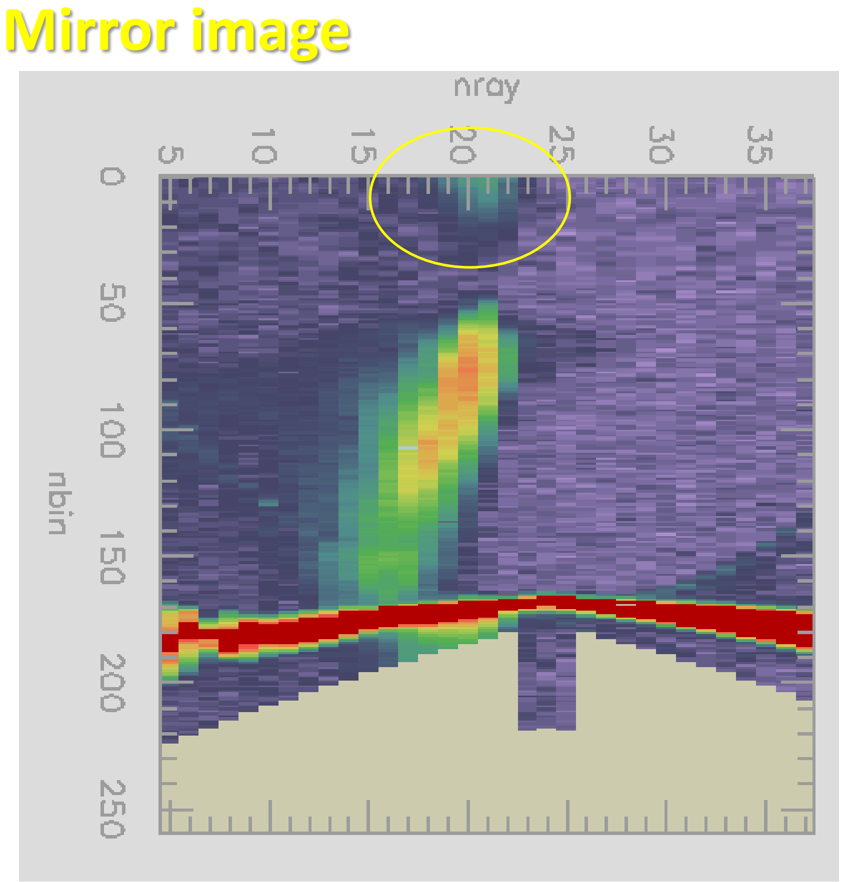
Scan pattern change

Scan pattern change

Appendix C   New flag for mirror image

Add a new flag for mirror image (1/2)

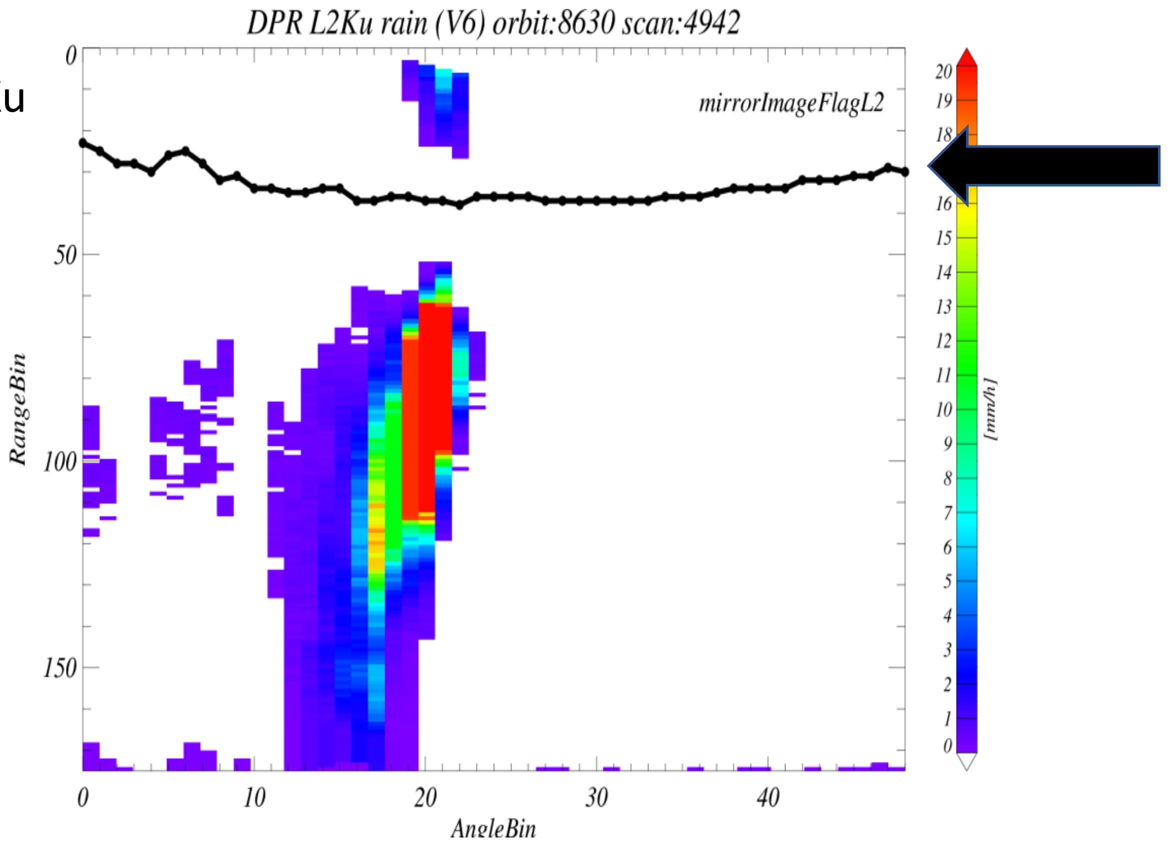
- Dr. Hirose (Meijo Univ) found a precipitation at an unusual altitude.
- Dr. Iguchi and we investigated and concluded that it was an effect of mirror images.
- The mirror image is a virtual image caused by the double reflection of echoes over the ocean.
- We can calculate where the mirror image appears with VPRF information in DPR L1 algorithm.
- In V7, a flag regarding the mirror image will be implemented in the DPR L1 algorithm.



KuPR's echo power:
Sep 5, 2015, at 07Z, over Naples

Add a new flag for mirror image (2/2)

Test
precipRate @ L2Ku



Name: binMirrorImageL2

Array: nscan x nray

Type: 2 byte integer

- DPR L2 algorithm will also add the new flag by using output of DPR L1 algorithm.
- The flag will inform users the range bin number which shows a bottom of possible mirror image.
- Users can know the possible mirror image above the range bin number.

Appendix D   Change swath name of KuPR

Change swath name of KuPR

- <u>We will change the swath name of DPR L1 KuPR product as well as DPR L2 KuPR product.</u> (John.K-san has suggested us. Thank you!)

- KaPR keeps current swath name as it is.

L1 05C (Current Ver.):	→	L1 07 (Next ver.):
Ku : NS		Ku : **FS**
Ka : MS, HS		Ka : MS, HS