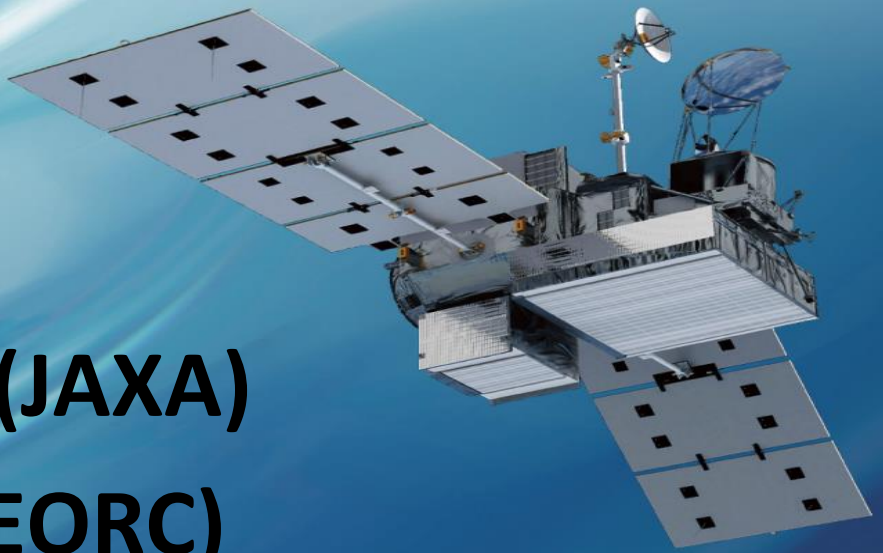
Dual-frequency Precipitation Radar

GPM/DPR Product Version 07



Japan Aerospace Exploration Agency (JAXA)

Earth Observation Research Center (EORC)

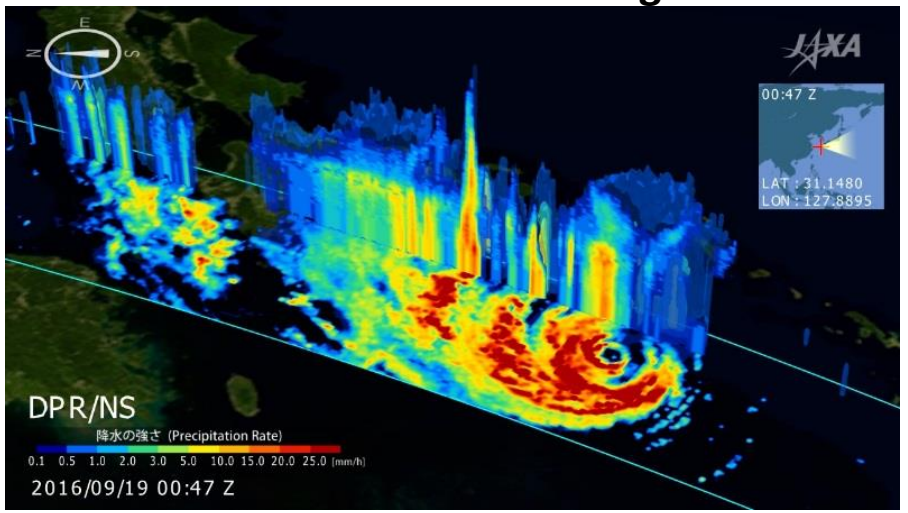
History GPM/DPR Product

- GPM/DPR Level 1 algorithm (JAXA)
  - V05 product released in May 2017.
  - V07A product released in December 2021.

- DPR Level 2 and 3 algorithm (Joint Japan-U.S.)
  - V06A product released in Oct. 2018.
  - V07A product released in December 2021.

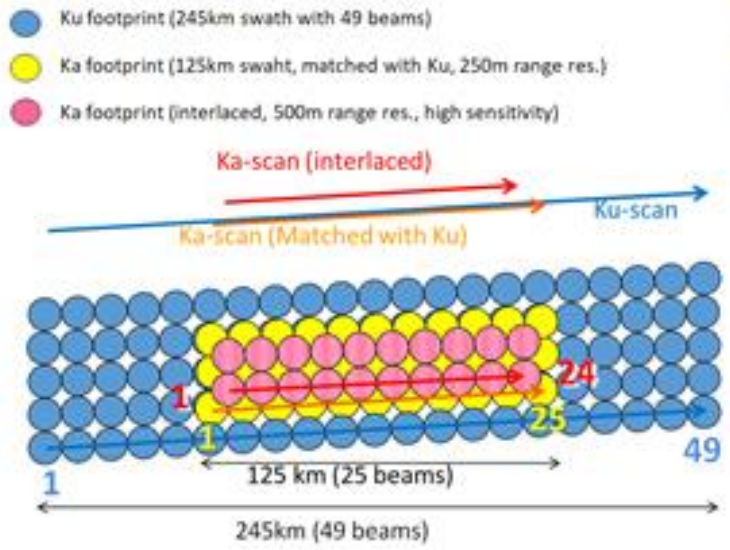
- DPR Spectral Latent Heating (SLH) algorithm (Japan-U.S.)
  - V06A product released in Oct. 2018,
    and V06B product released in Jul. 2020.
  - V07A product released in December 2021.

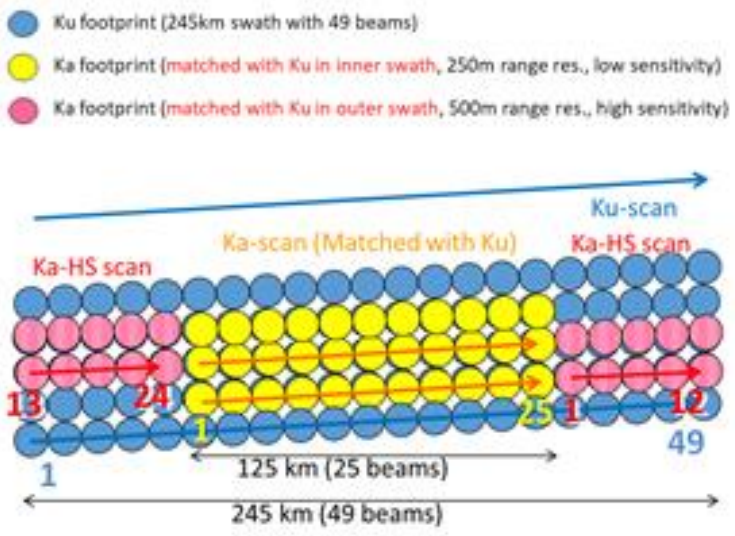
DPR 3D observation image

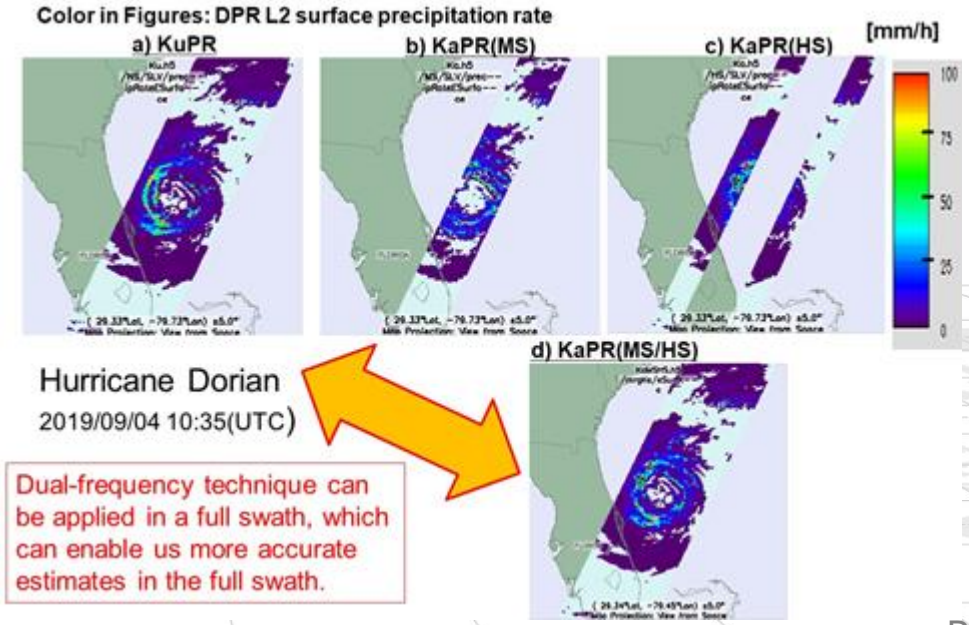


Major updates of DPR algorithm (1/3)

- Scan pattern of KaPR has been changed since May 2018.
  - https://www.eorc.jaxa.jp/en/news/2020/nw200604.html
  - The change has been made from the observation at 17:13UTC on May 21, 2018 (orbit number 24021).
- The GPM/DPR product version 7 is the first product responding to the KaPR scan pattern change.





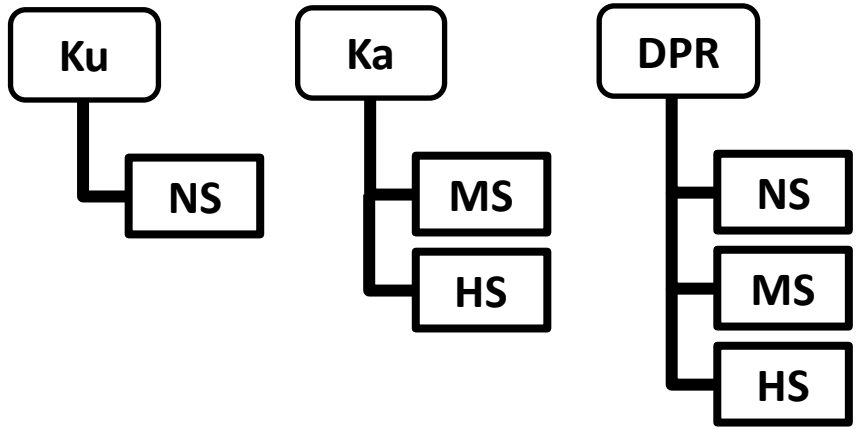


Major updates of DPR algorithm (2/3)

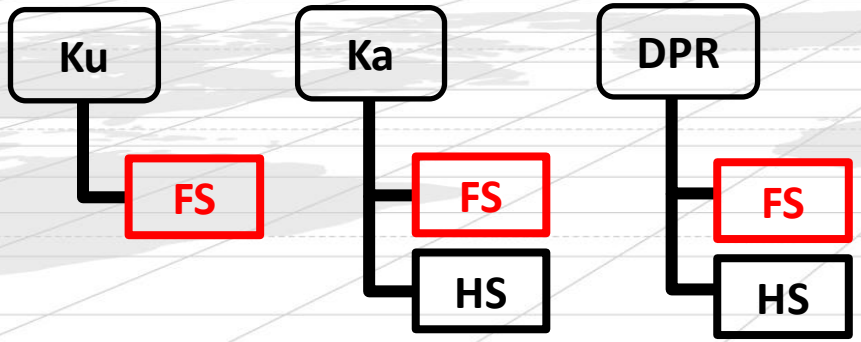
Format changes

V06

V06A



V06X

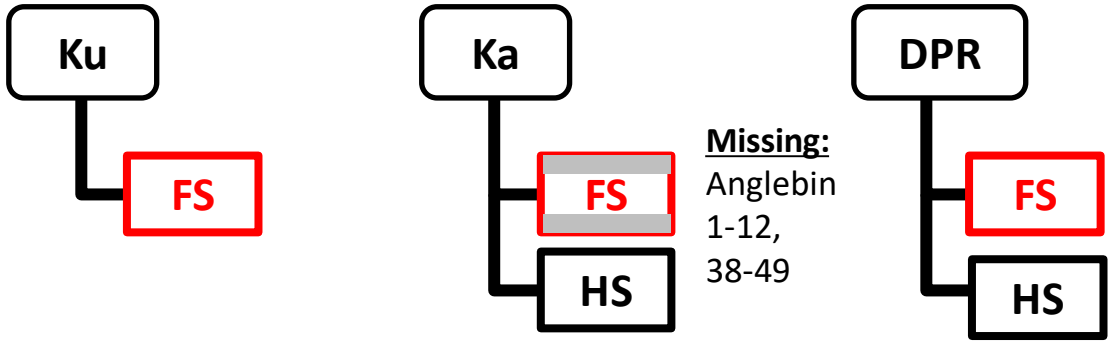


V07

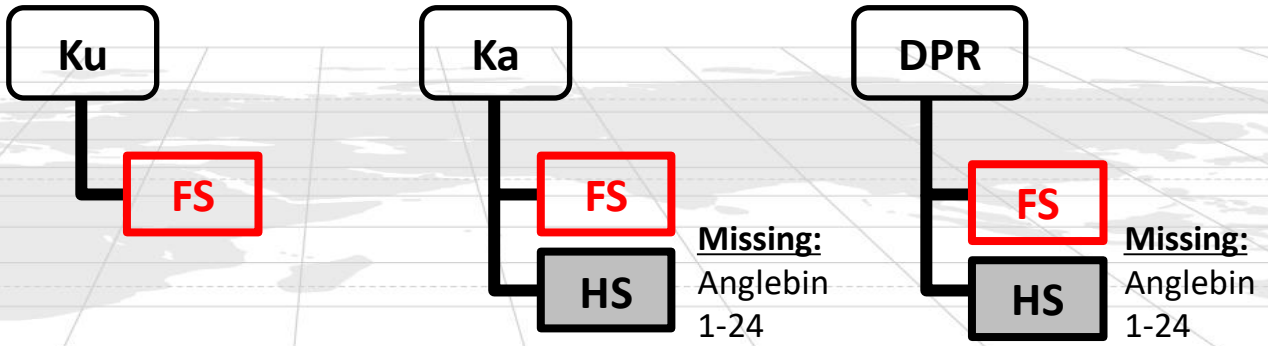
- Implementation of a new Group 'FS'(Full Scan).
- 'FS' has 49 angle-bins and 176 range-bins for each scan.

: Missing

Before scan pattern change (21 May, 2018)



After scan pattern change (21 May, 2018)



Major updates of DPR algorithm (3/3)

- **[PRE]** (Kanemaru, Masaki & Kubota)
  - New rain/no-rain classification
  - Improvement sidelobe clutter rejection

→ **Improvement of detection of shallow precipitation systems**
The method is more pronounced at mid and higher latitudes

- **[CSF]** (Awaka, Chandra & Le)
  - (new) flagHail
- **[SLV]** (seto)
  - Improvement of R-Dm relationship
  - Fixed ε in vertical -> variable in vertical
  - Add soil-moisture effect on σ0

→ **Precipitation rate over land estimated by single frequency algorithm increases (approximately 20%).**

- Common file structure before and after the scan change
- Several minor modification in Level 1 algorithm
  - Update on the DSD database

GPM/DPR L2 Algorithm Theoretical Basis Document (ATBD):
https://www.eorc.jaxa.jp/GPM/doc/algorithm/ATBD_DPR_V07A.pdf

Major updates of SLH algorithm

Spectral Latent Heating (SLH) Algorithm

- V04: Applying TRMM/PR V7 SLH algorithm to GPM/KuPR (only TRMM domain)
  V05: Extratropical module newly added
- V06: Input the improved KuPR data
- V07: Revision of tropical and extratropical module, and Highland module newly added (only LH)

Products

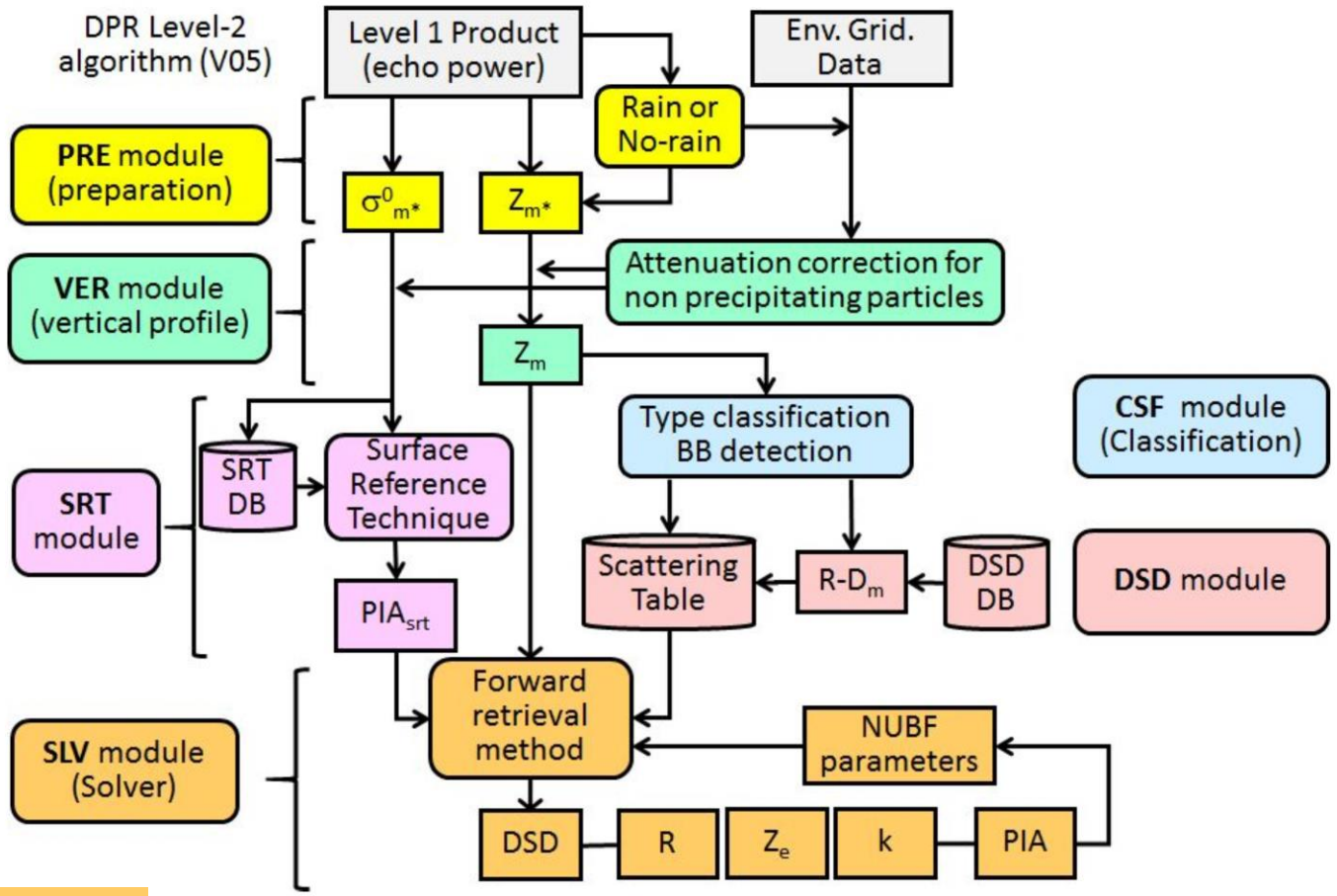
- L2 (SLP): SLH orbit data
- L3 (SLG): SLH orbit gridded data (0.5 degree)
- L3 (SLM): monthly gridded data (0.5 degree)

Takayabu and Tao, 2020: Latent heating retrievals from satellite observations.
https://doi.org/10.1007/978-3-030-35798-6_22

Algorithm Theoretical Basis Document (ATBD)
https://www.eorc.jaxa.jp/GPM/doc/algorithm/ATBD_DPR_V07A.pdf

Appendix : Major improvement in DPR-L2/L3

DPR L2 algorithm flow



Trigger module

Multiple scattering index
NUBF index

Experimental

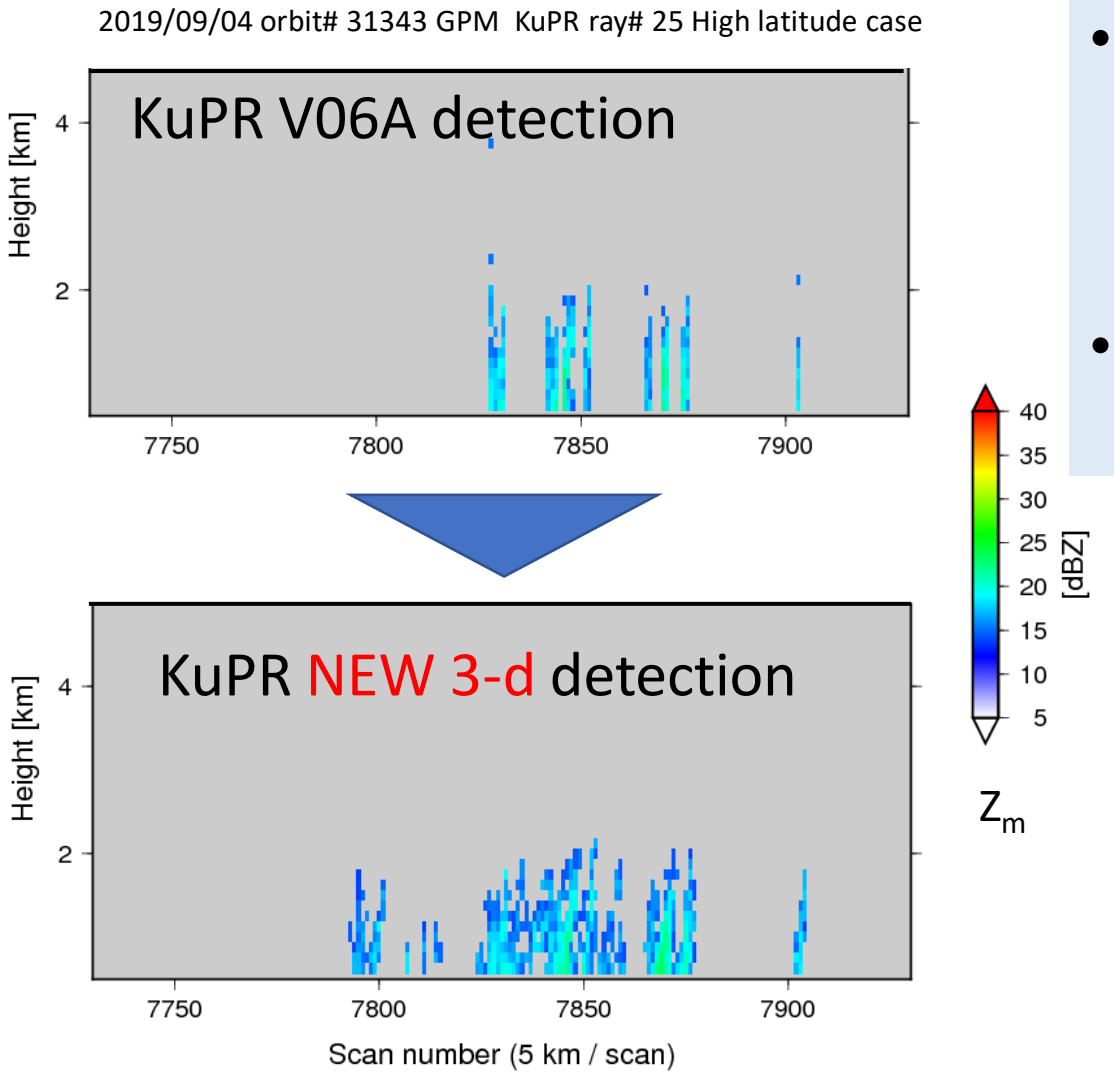
binMixedPhaseTop,
flagGraupelHail,
precipRateEsurface2, etc.

precipitation profile retrieval

Figure 3.1-1 DPR algorithm flow

(K. Kanemaru)

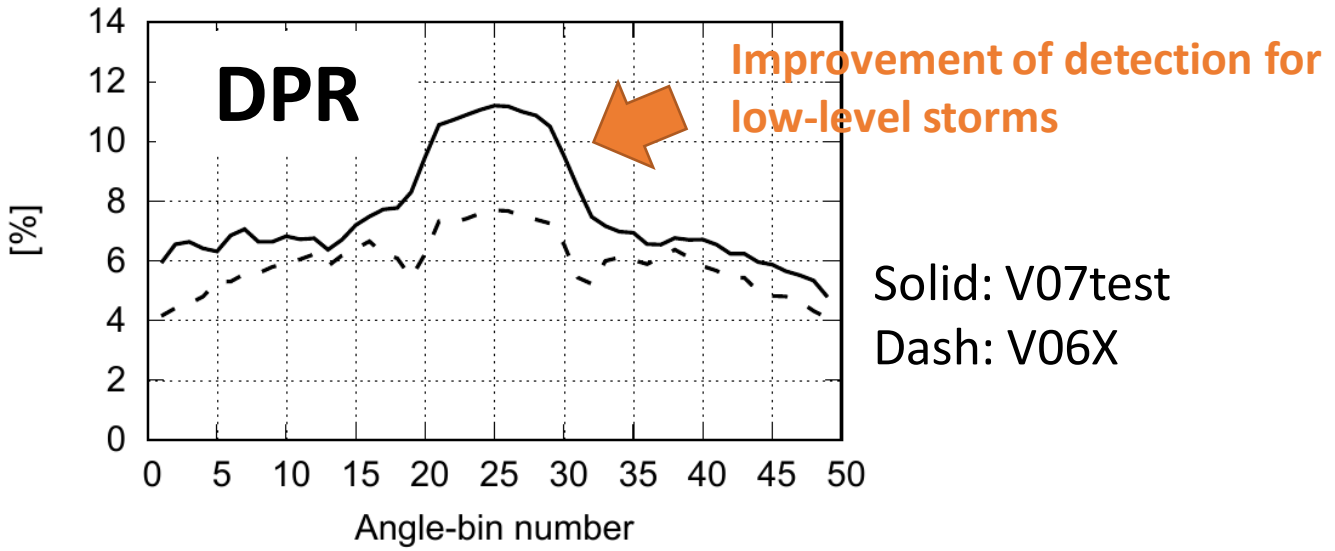
Improvement of precip. detection with 3-d information



(Provided by Dr. Kanemaru, NICT)

- To improve detection of low-level storms, precipitation detection of the DPR algorithm in V07 was developed with 3d-information of precipitation echoes.
- At mid latitudes, the new method increases frequency against the V06 products.

Precip. freq. over mid-lat ocean (35-65 N/S) 2018/06



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

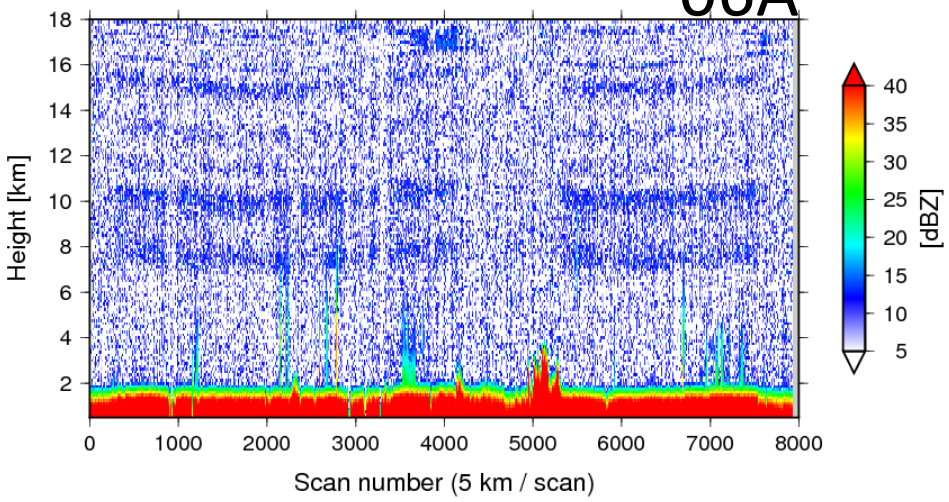
(T. Masaki , T. Kubota & K. Kanemaru)

- 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.
- Change code for new AutoSnow format
- Some minor updates.
  - Add a new flag for mirror image etc.

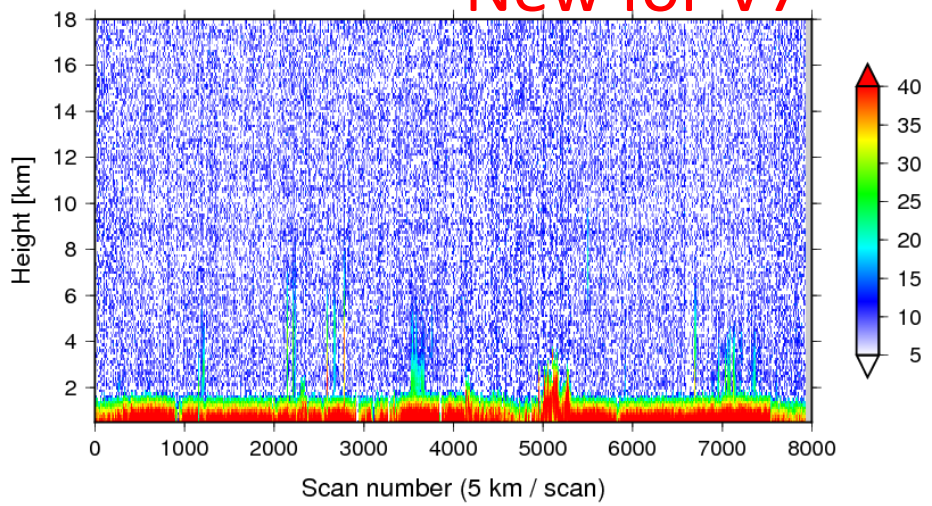
(K. Kanemaru)

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.)

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

(J. Awaka)

What's new in CSF V7

- **flagHail is introduced as STD output (Le & Chandra)**
- Type **counts** have **increased** because of **3D rain/no-rain decision** by Dr. Kanemaru.
  - Le, M. and V. Chandrasekar, 2021: Graupel and hail identification algorithm for the Dual-Frequency Precipitation Radar (DPR) on the GPM core satellite. *J. Meteor. Soc. Japan*, 99, 49-65. https://doi.org/10.2151/jmsj.2021-003

Changes of DSD/Solver module from V06 to V07

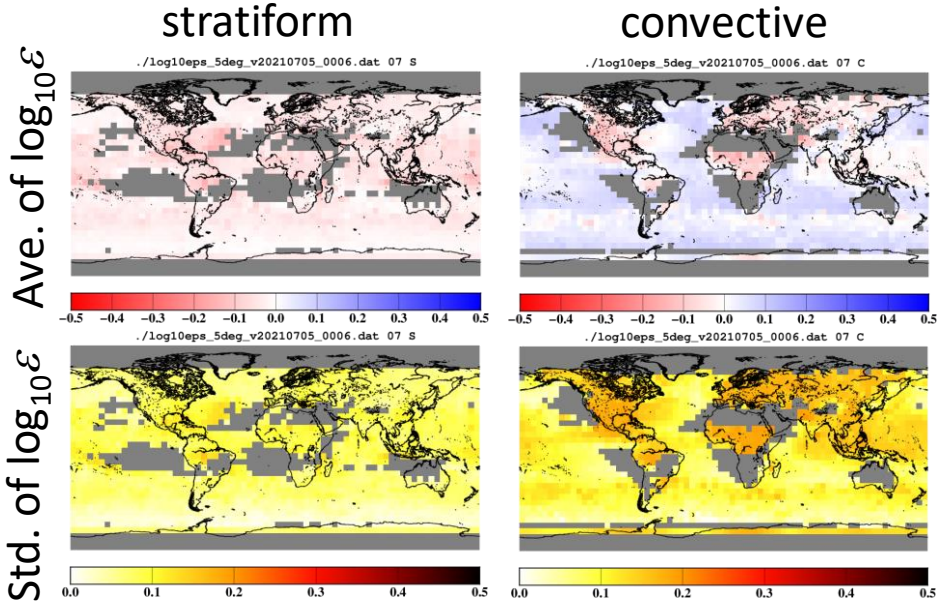
(S. Seto)

Revision of R-D_m relation ($R=\varepsilon^r p D_m^q$)

Conv. (V06) p=1.370, q=5.420, r=4.258
Strat. (V06) p=0.401, q=6.131, r=4.622

Conv. (V07) p=0.392, q=6.131, r=4.815
Strat. (V07) p=0.392, q=6.131, r=4.815
*In V07, the coefficients and the definition of ε is same for convective and stratiform

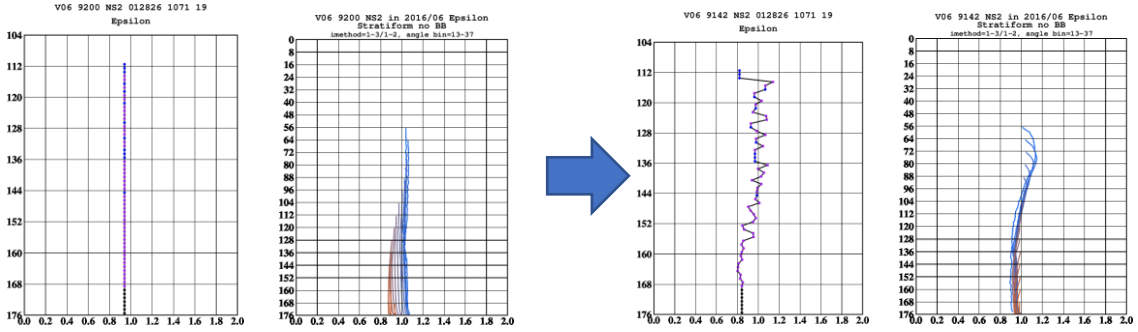
Revision of DSD database (used for single-frequency)



The vertical profile estimation of ε in dual-frequency algorithm

(V06) ε is vertically constant and depend on the storm top height.

(V07) ε is vertically variable and depend on the altitude.



Correction of PIA considering soil moisture effect (single-frequency algorithms, over land only)

See the next slide →

Soil moisture effect

(S. Seto)

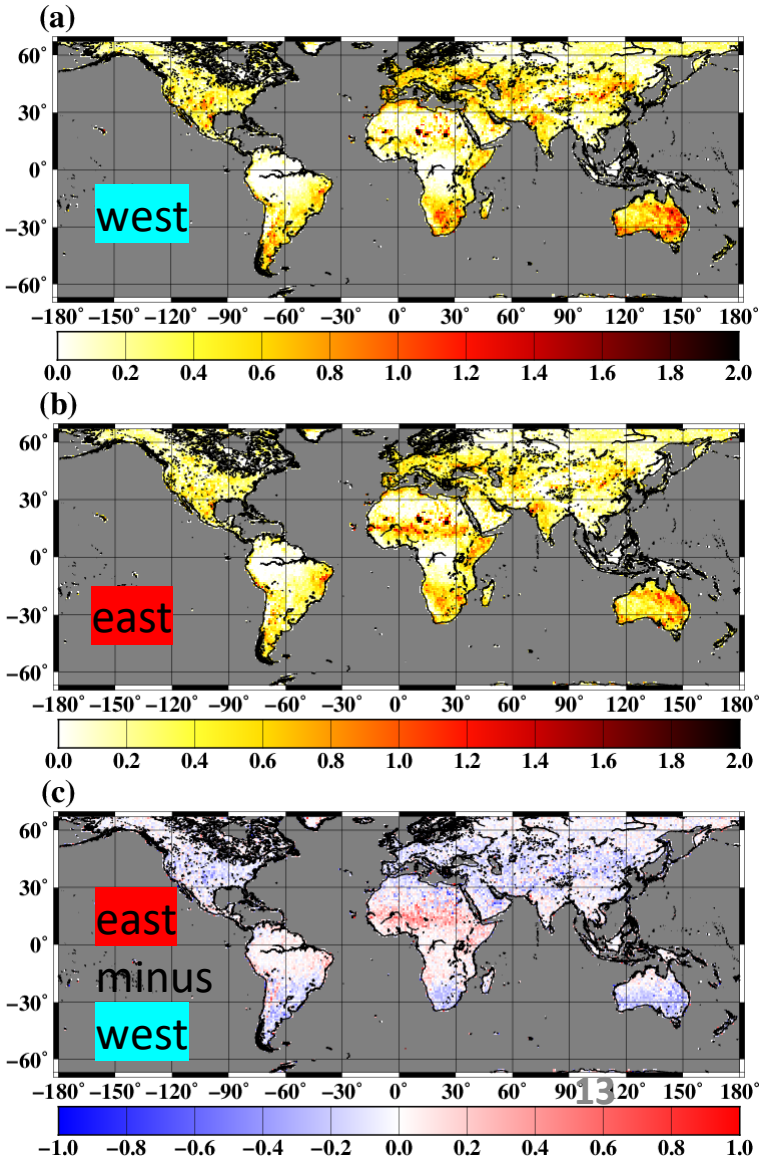


Fig. 1 The anomaly of σ^0 (KuPR) from its average at no-rain pixels.

- Over land, σ^0 measured near rain area is higher than the average of σ^0 at no-rain pixels (Fig. 1).
- This phenomena was found for TRMM/PR (Seto and Iguchi, 2007), and is called soil moisture effect. It is also seen for KuPR and KaPR.
- In the version 07 of DPR product (single-frequency algorithms, over land), soil moisture effect is considered and PIA by SRT is corrected. The offset of PIA depends on area, incidence angle and the first estimates of *R* (Fig. 2). This correction increases the final estimate of *R* by about 18% in KuPR (Fig. 3).

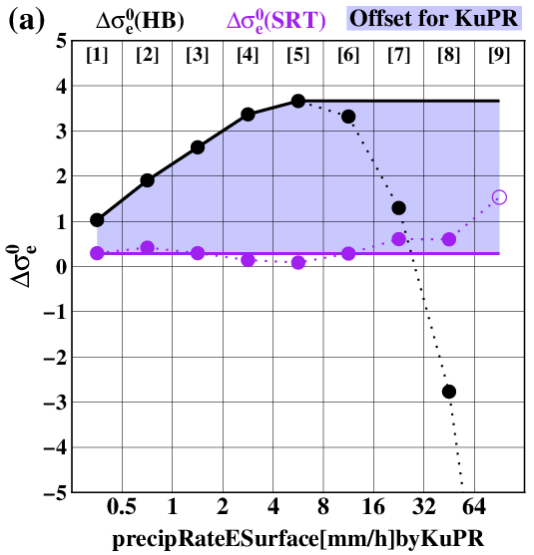


Fig. 2 The offset (height of blue area) of PIA is dependent on the first estimates of R. (KuPR, at 100-95W, 30-35N, θ=0-3°)

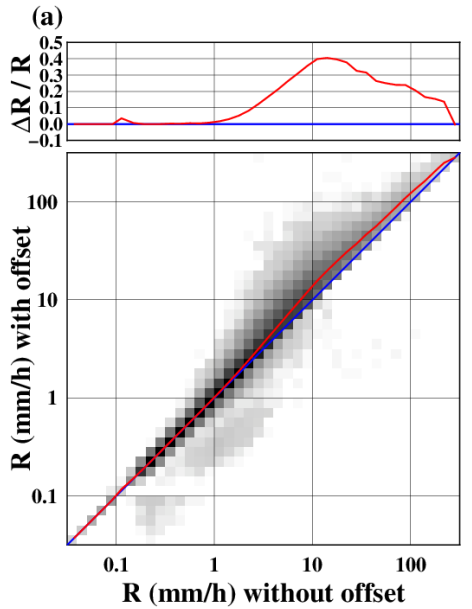


Fig. 3 The change of the final estimate of R without/with the offset of PIA (KuPR)

(M. Hirose)

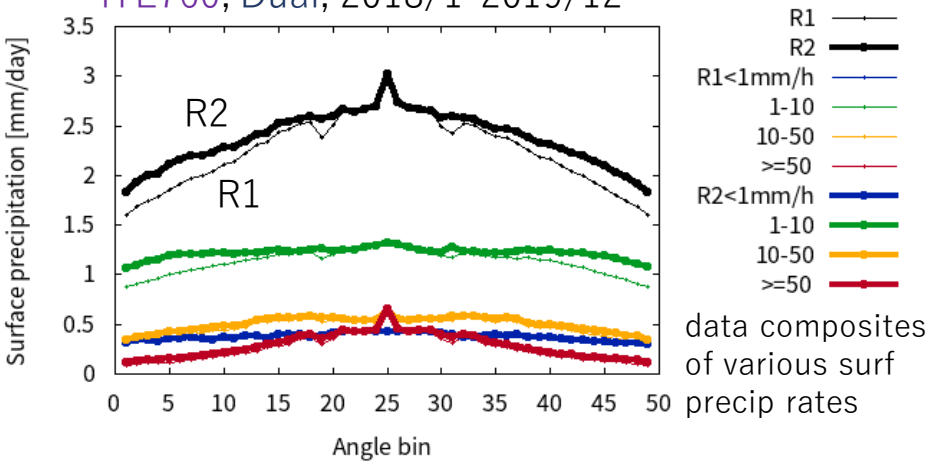
Experimental product: precipRateEsurface2

Surf precip estimate based on an a priori low-level precip profiles

precipRateEsurface (R1), **precipRateEsurface2** (R2)

R1 and R2 for each angle bin

ITE760, Dual, 2018/1-2019/12

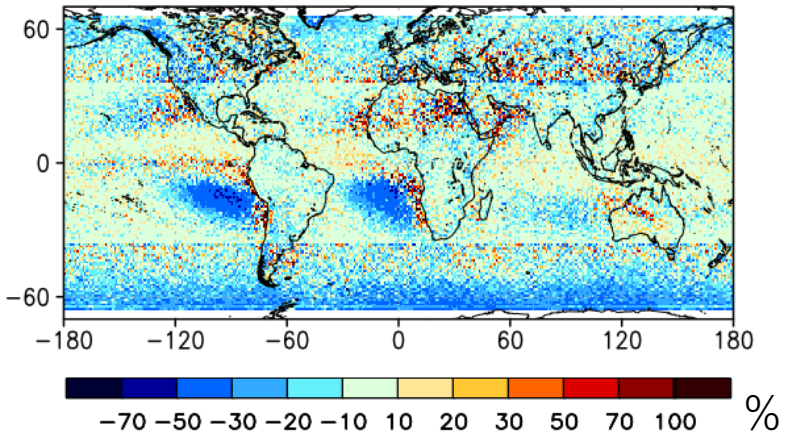


data composites of various surf precip rates

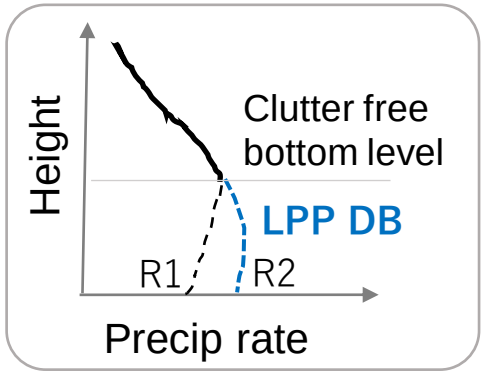
Incidence-angle differences in precipRateEsurface

PR v.8 & KuPR 06A 1998/1-2021/8

$$\mathbf{IAD}=100*(\mathbf{R_{All}}-\mathbf{R_{NN}})/\mathbf{R_{NN}}$$



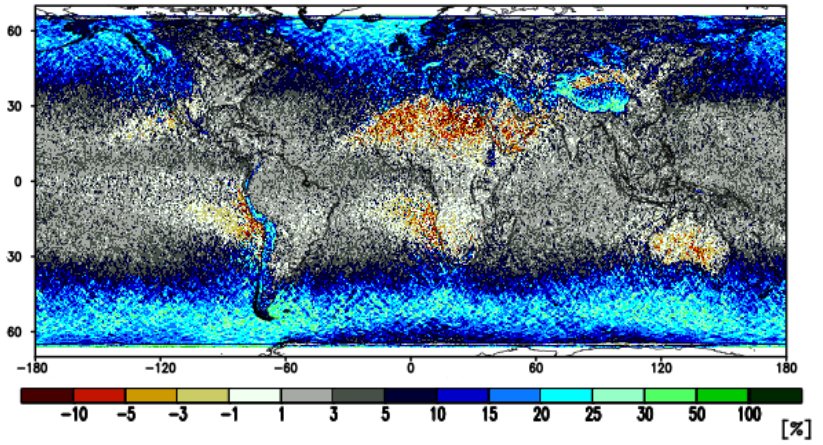
Low-level Precip Profile (LPP) correction



(Hirose et al. 2021, JMSJ)

100*(**R2**-**R1**)/**R1**

ITE760, Dual, 2yr



$\mathbf{R_{All}}$: precip at 1-49 bins,
$\mathbf{R_{NN}}$: precip at Near Nadir 21-23, 27-29 bins

ITE760, Dual, 2yr

	R1 [mm d^{-1}]	R2 [mm d^{-1}]	R1→R2 [%]	IAD_R1 [%]	IAD_R2 [%]
All	2.24	2.37	5.8	-15.5	-11.0
Ocean	2.43	2.58	6.0	-15.8	-11.0
Land	1.62	1.70	4.7	-14.2	-11.0

Validation results

precipRateESurface (July 2014)

2014/7
35N-35S

rain [mm/month]

	DPR	06A	07X_20210312	07X_20210415	07X_20210709
	Ku	06A	07X_20210312	07X_20210415	07X_20210709
	Ka	06A	07X_20210312	07X_20210415	07X_20210709
	PR	06A	N/A	N/A	N/A
rain @ eSurf					
Land+Ocean	DPRMS	97.03	93.32	86.77	98.17
	DPRHS	70.41	72.12	70.28	71.47
	DPRNS (or DPRFS)	88.93	84.71	79.50	88.45
	KuMS	86.03	82.27	78.31	85.85
	KuNS (or KuFS)	83.29	79.08	75.18	82.17
	KaMS	69.70	68.77	66.83	68.20
	KaHS	70.93	70.40	68.68	69.85
	KaFS	-9999.00	-9999.00	-9999.00	-9999.00
	PRMS	82.09	-9999.00	-9999.00	-9999.00
	PRNS (or PRFS)	80.04	-9999.00	-9999.00	-9999.00
Ocean	DPRMS	105.17	100.51	93.79	105.92
	DPRHS	78.97	77.55	75.83	77.25
	DPRNS (or DPRFS)	97.41	90.45	85.09	94.75
	KuMS	93.15	83.38	80.09	88.00
	KuNS (or KuFS)	91.25	81.71	78.10	85.61
	KaMS	77.27	73.53	71.62	73.18
	KaHS	79.12	75.48	73.86	75.25
	KaFS	-9999.00	-9999.00	-9999.00	-9999.00
	PRMS	90.14	-9999.00	-9999.00	-9999.00
	PRNS (or PRFS)	88.64	-9999.00	-9999.00	-9999.00
Land	DPRMS	66.33	65.81	60.21	68.85
	DPRHS	40.30	51.03	49.03	49.48
	DPRNS (or DPRFS)	58.89	62.62	58.22	64.65
	KuMS	59.34	72.21	66.90	72.80
	KuNS (or KuFS)	55.30	65.88	61.63	66.67
	KaMS	42.78	49.95	48.15	48.85
	KaHS	42.03	50.41	48.60	49.01
	KaFS	-9999.00	-9999.00	-9999.00	-9999.00
	PRMS	54.38	-9999.00	-9999.00	-9999.00
	PRNS (or PRFS)	51.28	-9999.00	-9999.00	-9999.00

Over ocean: (vs V06A)
-Decrease by about 5% (Single freq algorithm)
-Increase by about 1% (Dual freq algorithm: DPRMS)

Ratio= (V7X – 06A) / 06A * 100 [%]

ratio [%]

(07X – 06A)/06A

	DPR	06A	07X_20210312	07X_20210415	07X_20210709
	Ku	06A	07X_20210312	07X_20210415	07X_20210709
	Ka	06A	07X_20210312	07X_20210415	07X_20210709
	PR	06A	N/A	N/A	N/A
rain @ eSurf					
Land+Ocean	DPRMS	0%	-3.8%	-10.6%	1.2%
	DPRHS	0%	2.4%	-0.2%	1.5%
	DPRNS (or DPRFS)	0%	-4.7%	-10.6%	-0.5%
	KuMS	0%	-4.4%	-9.0%	-0.2%
	KuNS (or KuFS)	0%	-5.1%	-9.7%	-1.3%
	KaMS	0%	-1.3%	-4.1%	-2.2%
	KaHS	0%	-0.7%	-3.2%	-1.5%
	KaFS	0%	N/A	N/A	N/A
	PRMS	0%	N/A	N/A	N/A
	PRNS (or PRFS)	0%	N/A	N/A	N/A
Ocean	DPRMS	0%	-4.4%	-10.8%	0.7%
	DPRHS	0%	-1.8%	-4.0%	-2.2%
	DPRNS (or DPRFS)	0%	-7.1%	-12.6%	-2.7%
	KuMS	0%	-10.5%	-14.0%	-5.5%
	KuNS (or KuFS)	0%	-10.5%	-14.4%	-6.2%
	KaMS	0%	-4.8%	-7.3%	-5.3%
	KaHS	0%	-4.6%	-6.6%	-4.9%
	KaFS	0%	N/A	N/A	N/A
	PRMS	0%	N/A	N/A	N/A
	PRNS (or PRFS)	0%	N/A	N/A	N/A
Land	DPRMS	0%	-0.8%	-9.2%	3.8%
	DPRHS	0%	26.6%	21.7%	22.8%
	DPRNS (or DPRFS)	0%	6.3%	-1.1%	9.8%
	KuMS	0%	21.7%	12.8%	22.7%
	KuNS (or KuFS)	0%	19.1%	11.4%	20.5%
	KaMS	0%	16.7%	12.5%	14.2%
	KaHS	0%	20.0%	15.6%	16.6%
	KaFS	0%	N/A	N/A	N/A
	PRMS	0%	N/A	N/A	N/A
	PRNS (or PRFS)	0%	N/A	N/A	N/A

Over land: (vs V06A)
-Increase by about 14~23% (Single freq algorithm)
-Increase by about 4% (Dual freq algorithm: DPRMS)

DPR-related papers

- DPR Calibration
  - Masaki et al. (2020, *TGRS),* https://doi.org/10.1109/TGRS.2020.3039978
- PRE
  - Kubota et al. (2016, *JTECH*), https://doi.org/10.1175/JTECH-D-15-0202.1
- VER
  - Kubota et al. (2020, *JTECH*), https://doi.org/10.1175/JTECH-D-20-0041.1
- CSF
  - Awaka et al. (2016, JTECH) https://doi.org/10.1175/JTECH-D-16-0016.1
  - Awaka et al. (2021, JMSJ) https://doi.org/10.2151/jmsj.2021-061
- SRT
  - Meneghini et al. (2015, JTECH) https://doi.org/10.1175/JTECH-D-15-0044.1
  - Meneghini et al. (2021, JMSJ) https://doi.org/10.2151/jmsj.2021-010
- DSD/Solver
  - Seto et al. (2021, JMSJ), https://doi.org/10.2151/jmsj.2021-011
    - Seto et al. (2021) was awarded as “JMSJ Editor's Highlight” (Jan. 2021).