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Release Notes for the DPR Level-2 and Level-3 products

＜Major changes in the DPR Level-2 from Version 07A to Version 07B＞

In Version 07B, a new NOAA/NESDIS autosnow was introduced as the input to the DPR Level-2 algorithm. A comparison of precipitation estimates between old and new versions of the autosnow shows that there were differences in specific cases, but few in number. The monthly surface precipitation rate over areas where the snow cover indexes were changed in V07B was very close to that of V07A with the difference less than 1 %.

＜Major changes in the DPR Level-2 from Version 06A to Version 07A＞

Version 07A is the first standard product to account for the Ka-band Precipitation Radar (KaPR) scan pattern change implemented on May 21, 2018. This change in scan pattern allows for a more accurate precipitation estimation method for dual frequency radar, Ku-band and Ka-band Precipitation radar (KuPR and KaPR), to be applied to the entire observation swath.
On the other hand, this led to significant changes of DPR file specifications for common file structures before and after the scan change, in addition to algorithm evolutions. See full descriptions at the following websites:

https://arthurhou.pps.eosdis.nasa.gov/atbd.html

https://www.eorc.jaxa.jp/GPM/en/archives.html

1. Format change in the product

   In the V06X (experimental product), a new format was implemented including “FS” which is defined as the full swath dual-frequency product with 125 m range resolution. In the V07A, this FS format is applied to data taken both before and after the scan pattern change of the KaPR in May 2018 (Figure 1). Note that the DPR/FS has KuPR single frequency data in the outer swath before the scan pattern change, whereas it has DPR dual frequency data in the outer swath after the scan pattern change.

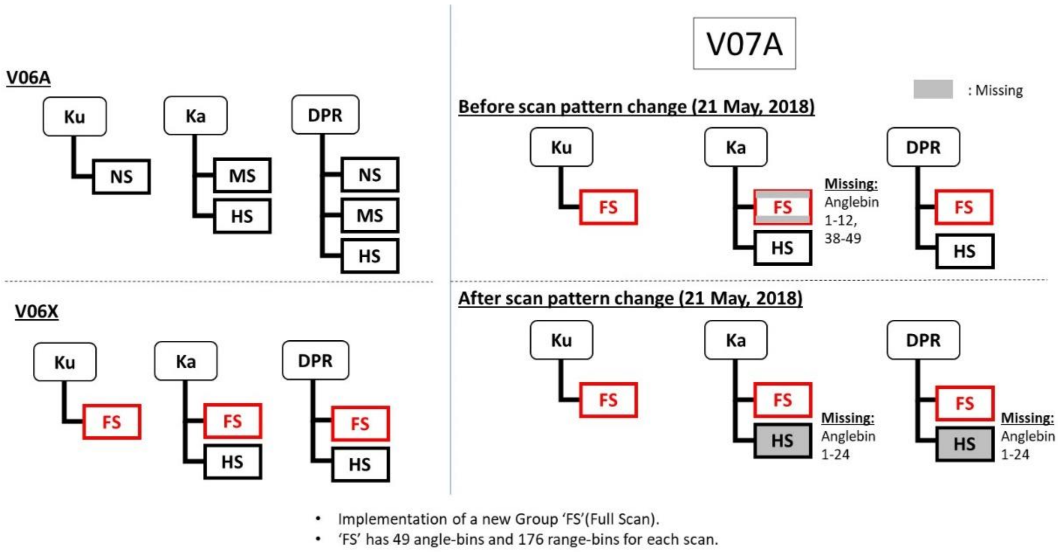

Figure 1. Changes of File structure from V06 to V07

2. In the version 07, the improved sidelobe clutter removal routine was implemented for the single frequency (KuPR, KaPR, and PR) Level-2 algorithms based on the results of Kanemaru et al. (2020, 2021). In addition, a new 3-D precipitation judgement method is implemented to improve the detectability of precipitation signals. This method uses signals not only in the vertical direction but also the in cross-track and along-track directions. This method is expected to improve the detection of weak, horizontally distributed precipitation that often occurs at high-latitudes. See the ATBD for full descriptions.
3. "flagHail" is newly implemented in the CSF. (Dual frequency only.)
4. The following new items are added to present information about flagHeavyIcePrecip in the CSF: binHeavyIcePrecipTop, binHeavyIcePrecipBottom, and nHeavyIcePrecip.
5. Variables of the Trigger module (TRG) are newly implemented in V07.
6. Changes in the DSD/Solver module from V06 to V07 are listed as follows.
   A) Revision of the relationship between precipitation rate R and volume-weighted mean drop size Dm (the so-called R-Dm relationship). In addition, the parameter ϵ in the R-Dm relationship, which is independent of range in V06, is allowed to vary with range in V07.
   B) Revision of DSD database (used for single-frequency).
   C) Soil moisture effect.

   Note that the soil moisture effect is expected to increase the precipitation amount over land as estimated by the single frequency algorithms by about 14-23%.
7. “precipRateEsurface2” is a surface precipitation estimate based on the *a priori* low-level precipitation profiles (Hirose et al., 2021,). This estimate is stored as an Experimental variable.
8. Other changes in DPR Level-2 algorithm:

- "binMirrorImageL2" is newly implemented in the Preparation module (PRE) to notify a false precipitation echo that appears at high altitude due to the mirror image.
- Adjustment factor for KaPR's σ^0 and Z-factor is updated in the Preparation module (PRE).
- The VER module includes new variables such as the profile of air temperature, a flag that indicates an inversion layer of air temperature, and the rain-free path-integrated attenuation estimate piaNP.
- Several variable names are changed.
  - zFactorCorrected → zFactorFinal
  - zFactorCorrectedESurface → zFactorFinalESurface
  - zFactorCorrectedNearSurface → zFactorFinalNearSurface
- Bugs are fixed in several modules. Details of the description for variables are described in Appendix or in the following websites:

https://www.eorc.jaxa.jp/GPM/en/archives.html

https://arthurhou.pps.eosdis.nasa.gov/GPMprelimdocs.html

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CAVEATS for DPR Level-2 V07A:

PRE module

1. In the DPR/FS and KaPR/FS, the following variables have unexpected values only in angle bins 1-12 of the first scan of the granule without any quality indications by the quality flags. This issue occurred only in orbits after the scan pattern change.
   - attenuationNP, piaNP, piaNPrainFree, sigmaZeroNPCorrected, and sigmaZeroCorrected.

CSF module

1. There are bugs on Heavy Ice Precipitation (HIP). The bugs appear only in the data before the antenna scan pattern change (viz., before May 21, 2018). Since the occurrence of HIP is not frequent, the effect of the bugs on the rainfall rate statistics would be small.
   A) flagHeavyIcePrecip in DPR FS does not reflect the Ka-band detection of HIP and the flag value is different from what is designed. The result is based on HIP detected by Ku-band and/or DFRm methods only. Nevertheless, a positive flag value indicates that HIP is detected.

      On the other hand, the additional HIP flags

      binHeavyIcePrecipTop
      binHeavyIcePrecipBottom
      nHeavyIcePrecip

      in the DPR FS structure contain correct values in the inner swath. These flags consist of two dimensional arrays in the DPR FS structure and the second array index distinguishes values obtained by the Ku, Ka, and DFRm methods. In the outer swath, however, binHeavyIcePrecipTop and binHeavyIcePrecipBottom for Ka-band should contain Missing values, but the bugs make them contain values copied from Ku-band. As for the DPR HIP data before May 21, 2018, our suggestion is that users should examine whether flagHeavyIcePrecip > 0 or not. Examination of nHeavyIcePrecip would be a good idea.

   B) In the HS mode data, the additional HIP flags, i.e.,
      binHeavyIcePrecipTop, binHeavyIcePrecipBottom, and nHeavyIcePrecip
      do not contain expected values. The values of those for the Ka-band single frequency HS data are always zero, and those items are even non-existent in the dual frequency DPR HS data structure, the latter of which might be a toolkit bug.

2. A bug on binBBTop: In the V07 DPR FS processing, binBBTop - binBBPeak in the outer swath is bounded by the same parameter value as that in the inner swath. Since the apparent width of BB increases in the outer swath because of the smearing of BB peak, a different parameter value should be used. This bug will be fixed in the next V08. Incidentally, there is not such a bug in the Ku-band single frequency FS processing. The bug was introduced when transplanting the Ku-band FS processing code to the DPR FS processing code. The effect of the bug on the rainfall rate statistics is estimated to be very small.

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＜Major changes in the DPR Level-3 from Version 06A to Version 07A＞

1. Format changes in Level-3 DPR Daily/Monthly Products

   For a full description of these changes see the Level-3 DPR V07 ATBD document. To accommodate the change in the FS/HS/MS swath structures in the Level-2 products, the Level-3 grids have been restructured as below.

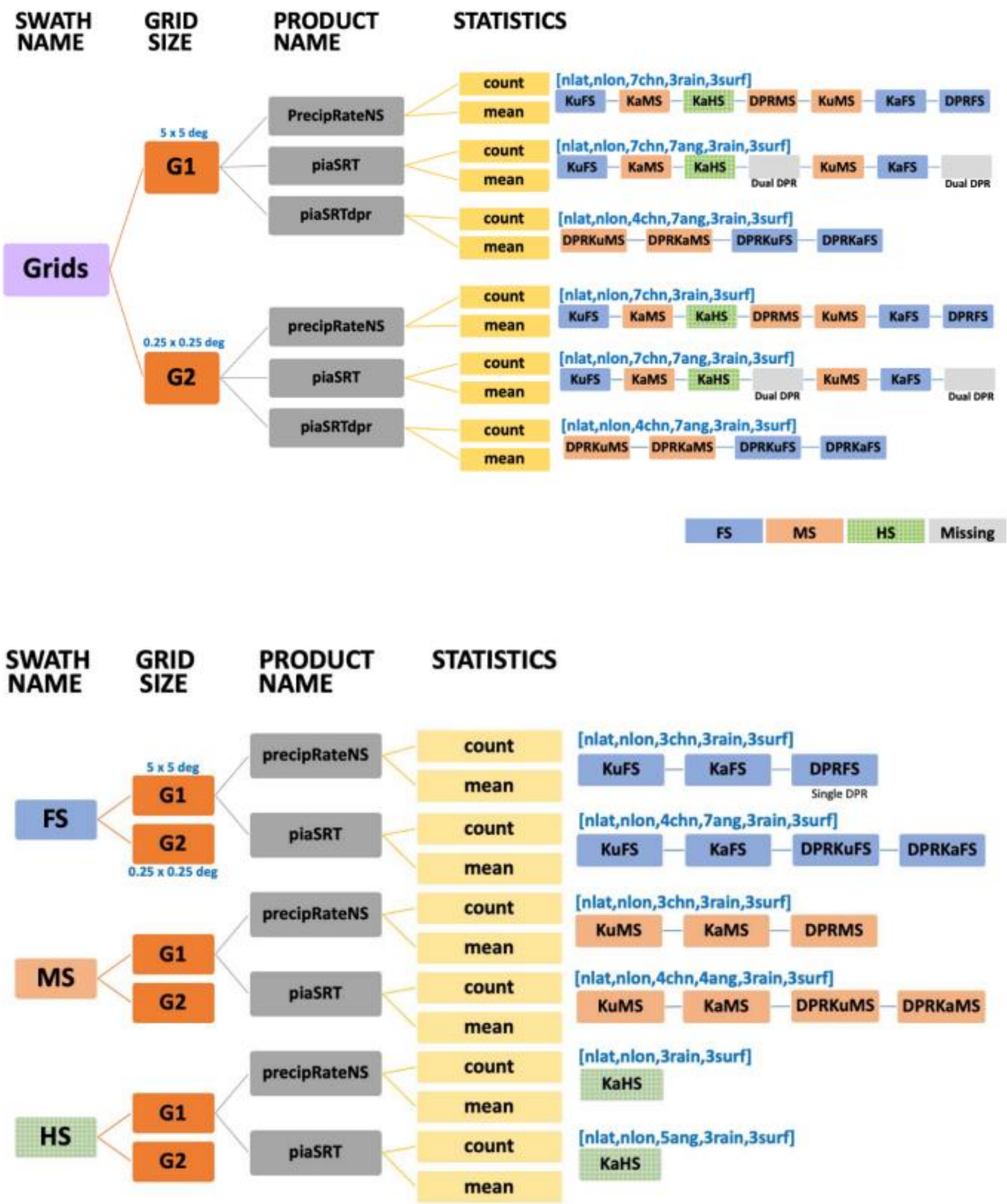

Figure 2. The organization for Level-3 in V06X (upper) and V07A (lower)

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CAVEAT for DPR Level-3 V07A:

The Version 07 Level-3 daily products 3DPR-ASC and 3DPR-DES do not accumulate FS statistics (full 49 ifov data) from 5/21/2018 to 5/28/2018 even though the Ka scanning pattern change occurred on 5/21/2018. This will be corrected in a later product version. Users should note that monthly statistics of the Ka and DPR FS/HS data do not cover the entire month of May, 2018.

CAVEAT for DPR Level-3 V06A:

The DPR Daily Product (3DPRD) of Version 06A includes a minor bug. In the array of KuPR channel for ascending path, stratPrecipRateNearSurfMean and stratPrecipRateESurfMean stores convective precipitation (they should have stored stratiform precipitation). This issue is fixed in Version 07A.

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＜Major changes in the DPR Level-2 from Version 05B to Version 06A＞

1. A new SRT code has been modified to include calculations of Hitschfeld-Bordan PIA as well as a hybrid PIA that combines HB and SRT results. As a result of applying the new PIA in SLV module, erroneously large estimates of high precipitation over ocean (near coast) are mitigated and both DPR (MS) and Ku rain estimates in V06A agree better with Ground Validation data over USA.
2. A new classification algorithm is introduced by the University of Washington (Stacy Brodzik & Robert Houze) to reclassify the stratiform rain type. The new algorithm improved an angle-bin dependence of rain classification and SLH profiles.

Minor changes in DPR Level-2 algorithm:

- Mitigated KaHS's sidelobe clutter and re-calculated the data base for KuPR's sidelobe clutter.
- New variables are introduced. They are flagScanPatten in PRE module, PIAhb, PIAhybrid, reliabFactorHY, reliabFlagHY, stddevEff, stddevHY and zeta in SRT module. For definitions of these variables, the reader is referred to the user manual.
- Modification of surface snow index for the winter temperature inversions.
- Applied the latest SRT data base.
- Bug fix of flagEcho in dual frequency data processing.

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<Major changes in the DPR Level-3 products from Version 05B to Version 06A>

1. New variables are introduced. They are zFactorMeasuredNearSurface, DFRNearSurface, DFRmNearSurface, piaHybrid, piaHybridDPR, piaHB, zeta, and flagHeavyIcePrecip. The definitions of these variables can be found in the user manual.

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＜Major changes in the DPR Level-2 products from Version 05A to Version 05B＞

Figure 3 shows DPR's scan patterns before May 21 2018 (left) and after May 21 2018 (right). KaHS beams scan in the inner swath before May 21 2018, but now they scan in the outer swath and match with KuPR's beams. Numbers in color indicate angle bin numbers for KuPR (blue), KaMS (yellow), and KaHS (red).

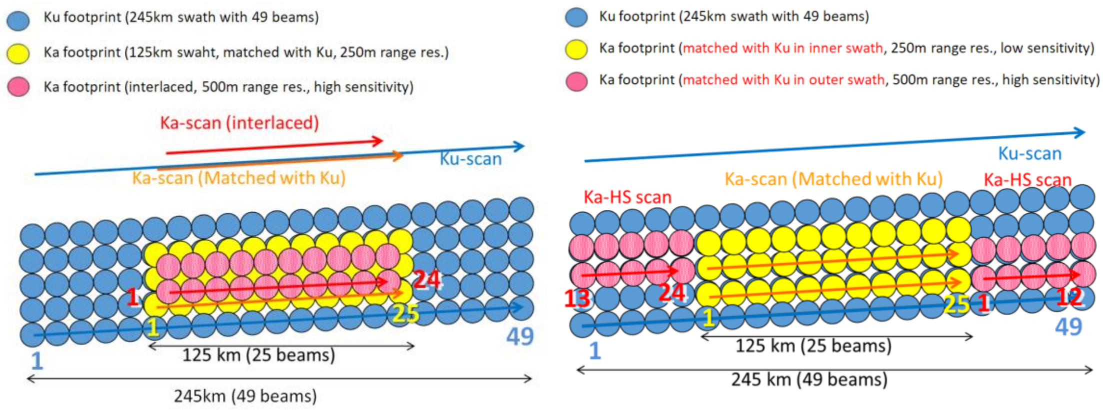

Figure 3. DPR's scan patterns before and after May 21 2018.

1. As of May 21, 2018, the scan pattern of KaHS beams was changed as shown in Figure 3. The KaHS beams scanned in the inner swath before May 21 2018, but now they scan in the outer swath and match with KuPR's beams. Please note that the range resolution of KaHS is 500m and differs from that of the KuPR or KaMS. One scan of KuPR over the full swath consists of 49 beams which are numbered from 1 to 49 in Figure **3** below. The array for one scan of KaMS data consists of 25 beams which correspond to KuPR's central beams from 13 to 37, whereas one scan of KaHS data array for 24 beams consists of two parts. The first 12 elements in the array correspond to KuPR's beams from 38 to 49, and the last 12 elements correspond to KuPR's beams from 1 to 12 of the following scan. All KaMS beams and the first 12 KaHS beams match well with KuPR's beams from 13 to 49. The magnitude of misalignment between these KuPR and KaPR beams is estimated to be less than 50 m after May 21. However, KaHS's beams from 13 to 24 are slightly shifted from the corresponding KuPR beams from 1 to 12 in the along-track direction. The magnitude of misalignment in these beams is about 400 m.

   The dual-frequency algorithm can be applied to the full swath of data after the change of scan pattern. However, because it takes time to develop a new algorithm applicable to the full swath and to adjust the necessary parameters to ensure the quality of the products, KaHS data are not processed in V05B Level-2 algorithm. Missing values are stored in the output variables that use KaHS data. KaHS's received power data are available only in Level-1 products in V05B.

2. All beam directions of KuPR and KaPR were adjusted to match better with the nominal footprint locations. The difference between KuPR and KaPR's footprint centers is now about 30 m at nadir. It was about 300 m before May 21, 2018. This improvement of beam matching is not considered to make a big difference in the Level-2 output products except for very heavy rain cases because the mismatch was small (300 m) from the beginning.

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<Major changes in the DPR Level-2 products from Version 04A to Version 05A>

All users of DPR Level-2 data should keep in mind the following changes in V5 products.

This document describes only the major changes in the Level-2 products. There are some changes in Level-1 that affect the Level-2 products. Please refer to "Release Notes for the DPR Level-1 products" for the details of the changes in Level-1 products.

Among several changes in Level-1 products, the important changes that affect Level-2 products substantially are the following points.

The DPR's system parameters were re-examined. Based on the new calibration results, the offset parameters for the transmitting powers, receiver's gains, the beam widths, and the pulse width of both KuPR and KaPR are redefined. As a result, Zm of KuPR has increased by about +1.3 dB, and Zm of KaPR by about +1.2 dB. The radar surface cross section (σ^0) of KuPR has increased by about +1.2 dB and that of KaPR by about +1.1 dB, although the changes in σ^0 depend slightly on the incidence angle due to the changes in the beam widths. Because of the introduction of the adjustment factors in Level-2 (see below) whose magnitudes vary with time, the numbers mentioned above are not fixed numbers but change with time, especially near the beginning of the GPM mission. In fact, for example, statistics show that an average (over angle) increase in σ^0 at Ku-band is about +1.0 dB, that at KaMS is about +0.6 dB and that at KaHS is about +0.9 dB on the first 5 days in June 2014.

- The FCIF-LUT for the KuPR near the saturation was improved so that the effect of saturation near the saturation level was mitigated.

Changes in Level-2 algorithm:

- In addition to the changes in the DPR Level-1 calibration, adjustment factors are introduced to remove small trends in the overall system gains in KuPR and KaPR. The adjustment factors change the measured received powers only by a small fraction of dB.
- Since the FCIF-LUT for the KuPR near the saturation level was modified to mitigate the effect of saturation, the statistics of σ^0 near the saturation level in the KuPR has changed. This change affects the SRT performance as well. The side-lobe echo cancellation parameters are adjusted to cope with this change as well.
- Measured radar reflectivity factor Zm and surface radar cross section σ^0 are calculated based on the new values of the pulse widths of both KuPR and KaPR. Accordingly, the angle bin dependence of σ^0 has changed slightly.
- A DSD database that depends on the month, region, surface type and rain type was created from the statistics of DSD parameters estimated with the dual-frequency algorithm. The R-

Dm relationship in the DSD database is used as the default R-Dm relationship in the single frequency (Ku-only and Ka-only) data processing before it is modified by other constraints such as the path-integrated attenuation. The introduction of the DSD database has modified the precipitation estimates substantially when they are light (less than about 3mm/h) in many cases. Rain estimates from the Ku-only and dual-frequency algorithms now agree very well.

- New flags are introduced:snowIceCover in the preparation module, flagHeavyIcePrecip and flagAnvil in the classification module, and flagSurfaceSnowfall and surfaceSnowfallIndex in the experimental module. The meanings of these flags should be referred to the user's manual.
- Winter convective storms that give large DFRm (measured Dual-Frequency Ratio) at the storm top are flagged and the corresponding pixels are classified as convective in V5. This category only appears in the inner swath since DFRm is available only there.

Reference

- Hirose, M., S. Shige, T. Kubota, F. A. Furuzawa, H. Minda, H. Masunaga, 2021: Refinement of surface precipitation estimates for the Dual-frequency Precipitation Radar on the GPM Core Observatory using near-nadir measurements. Journal of the Meteorological Society of Japan. Ser. II, 99(5), 1231-1252, https://doi.org/10.2151/jmsj.2021-060
- Kanemaru, K., T. Iguchi, T. Masaki, T. Kubota, 2020: Estimates of Spaceborne Precipitation Radar Pulsewidth and Beamwidth Using Sea Surface Echo Data, IEEE Trans. Geosci. Remote Sens., 58(8), 5291–5303, doi:10.1109/TGRS.2019.2963090
- Kanemaru, K., H. Hanado, K. Nakagawa, 2021: Improvement of the clutter removal method for the spaceborne precipitation radars, the IEEE Geoscience and Remote Sensing Society, the International Geoscience and Remote Sensing Symposium 2021, Virtual Symposium