Precipitation Processing System (PPS)

Introduction to PPS Data Products

Version 1.0

Prepared By:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
Code 610.2/PPS
Greenbelt, Maryland 20771

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Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

TABLE OF CONTENTS

Page

1. INTRODUCTION

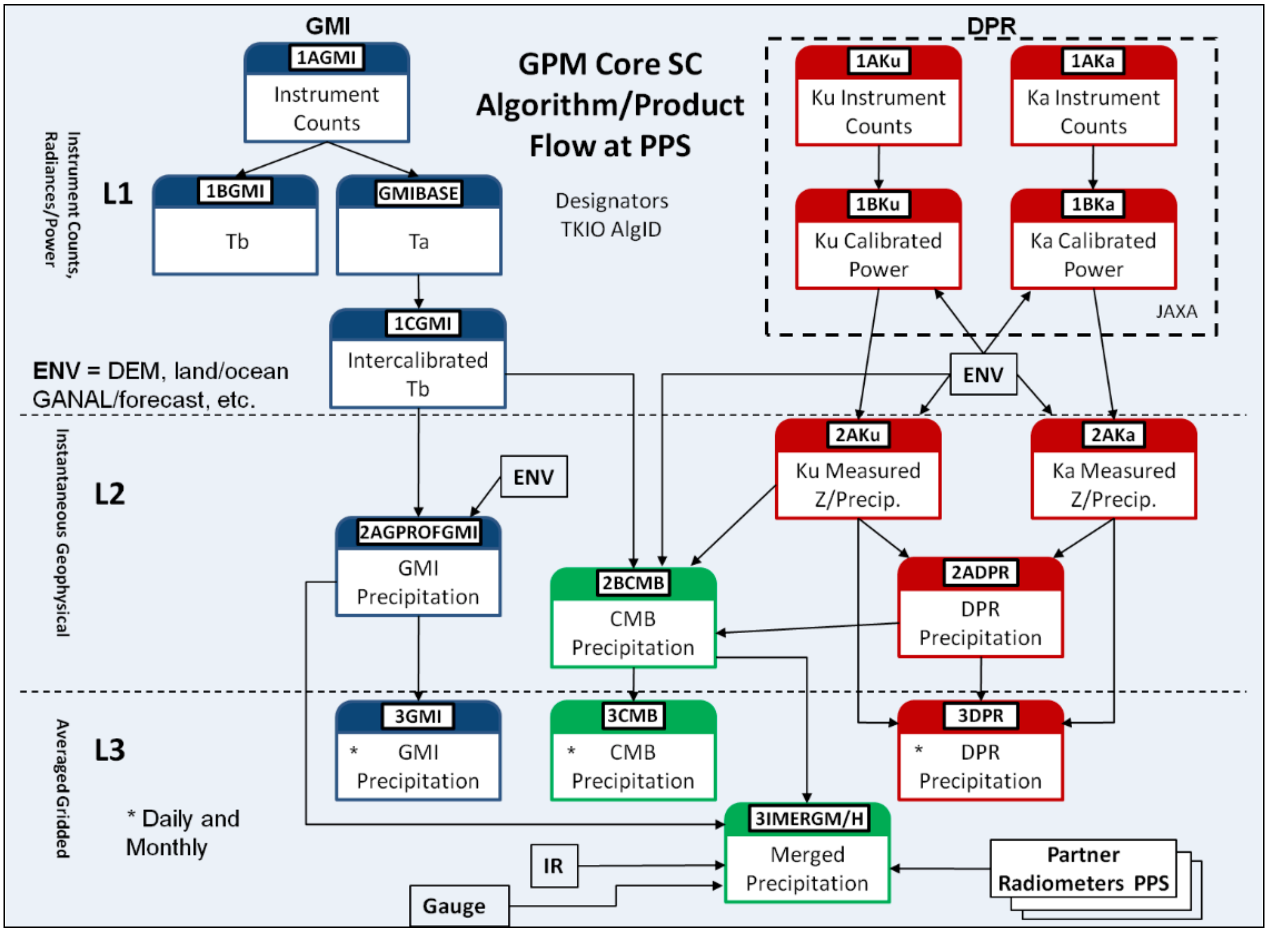
This guide is intended to enable graduate students and scientists who are not familiar with PPS data products to learn what is contained in the products; their purpose, major uses, parameters, and strengths; and suggestions about caveats and limitations. The goal of this document is to help new users to select products that would be of interest to them; the brief descriptions herein do not cover the level of detail that a file specification or an Algorithm Theoretical Basis Document (ATBD) provides, though these in-depth documents are referenced for each product. Documents posted on the PPS public Web site are hyperlinked in the MS Word version of this guide.

A diagram showing PPS algorithm dependency is on page 2; below is an explanation of the nomenclature regarding numeric levels and letters of the algorithms and data products:

The level of a product indicates the degree to which the data have been processed. Some Level 1 products contain instrument-independent physical variables such as radar reflectivity or brightness temperature in the original observation geometry of the instrument (i.e., the satellite's data swath). Other Level 1 products contain engineering variables, such as returned power, that are instrument dependent. Level 2 products have been further processed so that they contain geophysical variables such as rainfall rate. Generally, Level 2 products have the same observation geometry as the corresponding Level 1 product. Level 3 products contain time-averaged and space-averaged data, such as monthly average rainfall rate in a rectangular latitude/longitude grid.

At Level 1, A, B, and C mean that the products occur later in the chain at that level; e.g., 1AGMI, 1BGMI, and 1CGMI. At Level 2, the A means that the product contains data from one instrument and is at the first stage of Level 2 processing for that instrument; e.g., 2AKu, 2AKa, and 2ADPR. In 2BCMB, the B means that the product takes data from more than one instrument (DPR and GMI in this case), or that it is later in the product chain than the A's.

(**Note:** In the References section for each of the data product write-ups, citations in blue text are hyperlinked.)



Key:

CMB	Combined
DEM	Digital Elevation Model
DPR	Dual-Frequency Precipitation Radar
ENV	Environment
GANAL	Gridded Dataset of Global Analysis
GMI	GPM Microwave Imager
GPROF	Goddard Profiling Algorithm
IMERG	Integrated Multi-Satellite Retrievals for GPM
IR	Infrared
JAXA	Japan Aerospace Exploration Agency
KaPR/KuPR	Ka-band Precipitation Radar/Ku-band Precipitation Radar
L1A, L1B	Level 1A, Level 1B
PPS	Precipitation Processing System
SC	Spacecraft
Ta	Antenna Temperature
Tb	Brightness Temperature
TKIO	PPS Science Algorithm Input/Output Toolkit
Z	Reflectivity

2. 1AGMI

2.1 PURPOSE

The 1AGMI product has two purposes: To repackage the raw satellite data from binary Consultative Committee for Space Data Systems (CCSDS) packets to Hierarchical Data Format (HDF), and to geolocate the sample data. The counts in the 1AGMI product are the raw counts taken directly from the packets created by the GPM Microwave Imager (GMI) instrument. There is no calibration or interpretation performed at the 1AGMI level.

There are five swaths in the 1AGMI product:

1. Earth view, hot load, and cold sky samples for low-frequency channels.
2. Earth view, hot load, and cold sky samples for high-frequency channels.
3. Scan housekeeping data provided by instrument.
4. All samples for low-frequency channels.
5. All samples for high-frequency channels.

Swaths S1 and S2 are subsets of swaths S4 and S5, respectively. The samples to subset are noted in the 1AGMI product in the gmi1aHeader/sampleRangeFile table. This is a table determined during testing and the Launch and Early Orbit (L&EO) phase of the Global Precipitation Measurement (GPM) Mission. Geolocation is performed on the samples using the PPS Geolocation Toolkit. The details on GMI geolocation can be found in the GMI Calibration Data Book.

2.2 DATASET

The strength of the 1AGMI product is that it has unaltered data straight from the satellite. This product can be used to show exactly what was recorded by the GMI instrument.

The 1AGMI product also contains all of the data sent down by the satellite. If there is enough bandwidth, the entire circle of GMI samples will be sent down. The 1AGMI product's swaths 4 and 5 contain all of the samples that are sent down. Later products only use the subset of these data that contains the Earth view, hot load, and cold sky samples.

2.3 CAVEATS/LIMITATIONS

The data in the 1AGMI file are not calibrated at all. Do not use these data unless they can be correctly calibrated and interpreted.

2.4 REFERENCES

1. GPM Geolocation Toolkit Algorithm Theoretical Basis Document (ATBD).
2. GPM/PPS File Specification 1AGMI.
3. PPS Geolocation Toolkit.
4. GMI Calibration Data Book (Export Controlled).

3. 1BGMI

3.1 PURPOSE

The 1BGMI algorithm and software transform Level 0 counts into geolocated and calibrated brightness temperatures (Tb) for 13 GMI channels.

3.2 DATASET

The 1BGMI algorithm uses a non-linear three-point in-flight calibration to derive antenna temperature (Ta) and convert Ta to Tb using GMI antenna pattern corrections. The four-point calibration, which utilizes noise diode measurements, is used to monitor the sensor non-linearty. The noise diode measurements also provide a hot load back-up calibration in case hot load measurements are lost. Details are in the GMI ATBD.

3.3 CAVEATS/LIMITATIONS

The Tb calibration error is normally < 0.5 K. The NEDT results, with worst-case on-orbit corrections, are given in the following table:

			Receiver Temperature				Low Gain				Nominal Gain				High Gain			
Frequency (GHz)	pol	Blanking	Cold	Nom	Hot	Gain Setting	Cold	Nom	Hot	Gain Setting	Cold	Nom	Hot	Gain Setting	Cold	Nom	Hot	REQUIREMENT
10.65	vpol	Off	2.7	20.4	39.2	6	0.79	0.83	0.85	4	0.79	0.81	0.85	2	0.78	0.83	0.84	0.96
10.65	hpol	Off	2.7	20.4	39.2	6	0.80	0.82	0.85	4	0.79	0.81	0.86	2	0.78	0.82	0.84	0.96
18.7	vpol	Off	1.6	25.3	43.8	6	0.65	0.68	0.70	4	0.64	0.68	0.72	2	0.65	0.67	0.70	0.84
18.7	hpol	Off	1.6	25.3	43.8	6	0.62	0.64	0.68	4	0.61	0.64	0.66	2	0.61	0.64	0.67	0.84
23.8	vpol	Off	1.0	24.8	43.3	6	0.53	0.57	0.62	4	0.52	0.56	0.60	2	0.53	0.55	0.58	1.05
36.64	vpol	Off	-0.4	24.4	42.7	6	0.43	0.45	0.47	4	0.43	0.46	0.47	2	0.43	0.45	0.47	0.65
36.64	vpol	Dur=8	-0.4	24.4	42.7	6	0.60	0.77	0.95	4	0.45	0.53	0.64	2	0.44	0.45	0.50	N/A
36.64	vpol	Dur=20	-0.4	24.4	42.7	6	1.11	1.63	2.20	4	0.56	0.83	1.19	2	0.49	0.47	0.56	N/A
36.64	vpol	Dur=32	-0.4	24.4	42.7	6	1.73	2.54	3.41	4	0.68	1.19	1.83	2	0.55	0.48	0.67	N/A
36.64	hpol	Off	-0.4	24.4	42.7	6	0.45	0.46	0.50	4	0.45	0.46	0.48	2	0.45	0.47	0.49	0.65
36.64	hpol	Dur=8	-0.4	24.4	42.7	6	0.68	0.81	1.06	4	0.49	0.55	0.68	2	0.46	0.47	0.50	N/A
36.64	hpol	Dur=20	-0.4	24.4	42.7	6	1.42	1.75	2.42	4	0.67	0.87	1.34	2	0.48	0.48	0.60	N/A
36.64	hpol	Dur=32	-0.4	24.4	42.7	6	2.19	2.71	3.90	4	0.91	1.28	2.01	2	0.52	0.49	0.74	N/A
89	vpol	Off	3.6	27.0	45.6	6	0.34	0.36	0.38	4	0.33	0.35	0.37	2	0.33	0.35	0.38	0.57
89	hpol	Off	3.6	27.0	45.6	6	0.31	0.33	0.34	4	0.30	0.33	0.34	2	0.31	0.32	0.34	0.57
166	vpol	Off	2.0	14.1	35.0	4	0.69	0.71	0.74	2	0.69	0.70	0.74	1	0.70	0.71	0.74	1.50
166	hpol	Off	-0.1	13.7	34.5	4	0.64	0.65	0.69	2	0.64	0.67	0.69	1	0.64	0.67	0.69	1.50
183.31±3	vpol	Off	2.3	15.3	36.2	5	0.55	0.57	0.63	4	0.55	0.57	0.62	3	0.55	0.57	0.62	1.50
183.31±7	vpol	Off	2.3	15.3	36.2	5	0.48	0.50	0.53	4	0.48	0.49	0.53	3	0.48	0.50	0.52	1.50

3.4 REFERENCES

1. GPM Microwave Imager (GMI) Level 1B (L1B) Algorithm Theoretical Basis Document (ATBD).
2. GPM/PPS File Specification 1BGMI.
3. Wentz, F. J., and M. Thomas, 2008: GMI Calibration ATBD.

4. 1C PRODUCTS

4.1 PURPOSE

The purpose of Level 1C algorithms is to provide common intercalibrated microwave brightness temperature (Tc) products for GPM core and constellation satellites using the GPM Microwave Imager (GMI) as the reference standard to ensure the consistency among global precipitation retrieval and climate studies. Current available L1C products are listed in the following table:

Product ID	Radiometer	Satellite
1CAMSR2	AMSR2	GCOM-W1
1CATMS	ATMS	NPP
1CGMI	GMI	GPM
1CMHS	MHS	NOAA-18 NOAA-19 METOP-A METOP-B
1CSAPHIR	SAPHIR	MT1
1CSSMIS	SSMIS	F16 F17 F18
1CTMI	TMI	TRMM

4.2 DATASET

All 1C products have a common L1C data structure, simple and generic. Each L1C swath includes scan time, latitude and longitude, scan status, quality, incidence angle, Sun glint angle, and the intercalibrated brightness temperature (Tc). One or more swaths are included in a product. The radiometer data are recalibrated to a common basis so that precipitation products derived from them are consistent.

4.3 CAVEATS/LIMITATIONS

The L1C products contain brightness temperatures that have been intercalibrated to a common basis and are no longer the original instrument brightness temperatures. Channels not relevant to precipitation retrievals are not included.

The recalibration for most radiometers is a simple 2-point, linear adjustment. For the water vapor sounding channels, this is a simple offset. In the case of AMSR2, the adjustments are piecewise linear with more than two points to approximate the non-linear nature of the calibration of that instrument.

The goal is to make the brightness temperatures consistent to 0.1K. That is not to say the calibration is accurate to this level; there are no suitable standards to assure absolute accuracy. The 0.1K level of consistency has been achieved in most cases, but in the case of the channels near 90 GHz, the uncertainty is somewhat greater. Also, some radiometers are not stable enough to permit this level of consistency.

4.4 REFERENCES

1. GPM Level 1C Algorithms (L1C) Algorithm Theoretical Basis Document (ATBD).
2. GPM/PPS File Specification 1CAMSR2.
3. GPM/PPS File Specification 1CATMS.
4. GPM/PPS File Specification 1CGMI.
5. GPM/PPS File Specification 1CMHS.
6. GPM/PPS File Specification 1CSAPHIR.
7. GPM/PPS File Specification 1CSSMIS.
8. GPM/PPS File Specification 1CTMI.
9. Biswas, S. K., S. Farrar, K. Gopalan, A. Santos-Garcia, W. L. Jones, and S. Bilanow, 2013: Intercalibration of Microwave Radiometer Brightness Temperatures for the Global Precipitation Measurement Mission. IEEE, Trans. on Geoscience and Remote Sensing, Vol. 51, No. 3, March 2013, 1465-1477.
10. M. R. P. Sapiano, Berg, W. K., McKague, D. S., and Kummerow, C. D, 2013: Toward an Intercalibrated Fundamental Climate Data Record of the SSM/I Sensors. IEEE, Trans. on Geoscience and Remote Sensing, Vol. 51, No. 3, March 2013, 1492-1503.
11. T. T. Wilheit, 2013: Comparing Calibrations of Similar Conically Scanning Window-Channel Microwave Radiometers. IEEE, Trans. on Geoscience and Remote Sensing, Vol. 51, No. 3, March 2013, 1453-1464.

5. 2ADPR

5.1 PURPOSE

2ADPR provides single- and dual-frequency-derived precipitation estimates from the Ku and Ka radars of the Dual-Frequency Precipitation Radar (DPR) on the core GPM spacecraft. The output consists of three main classes of precipitation products: those derived from the Ku-band frequency over a wide swath (245 km), those derived from the Ka-band frequency over a narrow swath (125 km), and those derived from the dual-frequency data over the narrow swath. The Ka-band results are further divided into the standard and high-sensitivity estimates. In the standard sensitivity mode, the fields of view within the inner swath are matched to those of the Ku-band. Data from these matched-beam Ku- and Ka-band fields of view are used to derive the dual-frequency precipitation products. The retrievals are performed at each radar range bin along the slant path of the radar instrument field of view (IFOV).

5.2 DATASET

The dual-frequency retrieval benefits from having co-aligned measurements at Ku- and Ka-bands. Data from these measurements are used to infer properties of the particle size distribution, which are expected to lead to improved estimates of rainfall rate and equivalent liquid water content. Dual-frequency data are expected to improve the capability to discriminate among water, ice, and mixed-phase hydrometeors as a function of height. This capability is particularly important in convective storms where a bright-band signature, associated with mixed-phase hydrometeors, is usually not detectable. In addition, the different attenuation rates of the Ku- and Ka-bands allow differential attenuation techniques to be used to estimate the path integrated attenuation. The high-sensitivity Ka-band channel is expected to have 6 dB greater sensitivity than the Ku- and standard Ka-band channels and to provide enhanced detection capabilities at the light rainfall rates.

5.3 CAVEATS/LIMITATIONS

The presence of changing topography (ex.: mountains) presents challenges to the ability of the algorithm to distinguish between precipitation echo and surface clutter. The Ka frequency undergoes larger extinction through precipitation, and the dual-frequency retrieval may be limited to lower-moderate rain rates. As the DPR will be the first dual-frequency weather radar flown in space, dual-frequency retrieval methods will need extensive testing and validation.

Major sources of error that have an impact on estimates of surface precipitation include clutter contamination of near-surface echoes, incorrect identification of precipitation type (convective/stratiform), and severe attenuation of the Ka-band data in heavy precipitation.

5.4 REFERENCES

1. GPM/DPR Level 2 Algorithm Theoretical Basis Document.
2. GPM/PPS File Specification 2ADPR.
3. DPR Level 2 Variables.

6. 2AGPROF

6.1 PURPOSE

The 2AGPROF algorithm retrieves consistent precipitation and related science fields from the following GMI and partner passive microwave sensors:

GMI, SSMI (DMSP F15), SSMIS (DMSP F16, F17, F18)
AMSR2 (GCOM-W1), TMI
MHS (NOAA 18&19, METOP A&B), ATMS (NPP), SAPHIR (MT1)

This provides the bulk of the 3-hour coverage achieved by GPM. For each sensor, there are near-realtime (NRT) products, standard products, and climate products. These differ only in the amount of data that are available within 3 hours, 48 hours, and 3 months of collection, as well as the ancillary data used. The NRT product uses GANAL forecast fields. Standard products use the GANAL analysis product, while the climate product uses ECMWF reanalysis in order to allow for consistent data records with earlier missions. These earlier data may be archived separately. The main strength of the product is the large sampling provided.

6.2 DATASET

The GPM radiometer algorithms are Bayesian-type algorithms. These algorithms search an a-priori database of potential rain profiles and retrieve a weighted average of these entries based upon the proximity of the observed brightness temperature (Tb) to the simulated Tb corresponding to each rain profile. By using the same a-priori database of rain profiles, with appropriate simulated Tb for each constellation sensor, the Bayesian method is completely parametric and thus well suited for GPM's constellation approach. The a-priori information will be supplied by the combined algorithm supplied by GPM's core satellite as soon after launch as feasible. Databases for V0 of the algorithm had to be constructed from various sources as described in the ATBD. The solution provides a mean rain rate as well as the vertical structure of cloud and precipitation hydrometeors and their uncertainty.

6.3 CAVEATS/LIMITATIONS

The major sources of systematic errors in these algorithms are the quality of the a-priori database, and the estimate of the model uncertainties that are needed to construct a Bayesian algorithm. Some error can also be introduced by the ancillary information (surface type, surface temperature, and total precipitable water) used to subset the a-priori database in the algorithm.

Because passive microwave signatures at the pixel level represent primarily integrated quantities, neither the vertical structure nor the near-surface precipitation from radiometers are typically as good as their radar counterparts. Solutions are also smoothed by the Bayesian scheme, leading to fewer extremes relative to a radar.

6.4 REFERENCES

1. GPM GPROF (Level 2) Algorithm Theoretical Basis Document.
2. GPM/PPS File Specification 2AGPROFGMI.
3. GPM/PPS File Specification 2AGPROFSSMIS.
4. GPM/PPS File Specification 2AGPROFAMSR2.
5. GPM/PPS File Specification 2AGPROFMHS.
6. GPM/PPS File Specification 2AGPROFATMS.
7. GPM/PPS File Specification 2AGPROFSAPHIR.
8. GPM/PPS File Specification 2AGPROFTMI.
9. Kummerow, C., W. S. Olson, and L. Giglio, 1996: A Simplified Scheme for Obtaining Precipitation and Vertical Hydrometeor Profiles from Passive Microwave Sensors. IEEE, Trans. on Geoscience and Remote Sensing, 34, 1213-1232, doi: 10.1109/36.536538.
10. Algorithm Theoretical Basis Document, GPM Passive Microwave Algorithm Team.

7. 2AKa

7.1 PURPOSE

The 2AKa algorithm provides precipitation estimates from the Ka radar of the Dual-Frequency Precipitation Radar on the core GPM spacecraft. The product contains two swaths of data corresponding to the scans of the Ka radar. The first swath contains matched scans (MS), which are intended to be co-aligned with the Ku-band instantaneous fields of view (IFOV). The second swath contains the high-sensitivity scans (HS), which are interleaved between the Ku/Ka-MS swaths. Both swaths are narrow and centered within the interior of the Ku swath. This is a single-frequency retrieval of precipitation; no information from the Ku radar is used. The retrievals are performed at each radar range bin along the slant path of the radar IFOV for each swath.

7.2 DATASET

This is a single-frequency retrieval that relies on Ka-band data only. While the 2ADPR dual-frequency retrieval should give better overall estimates, that algorithm requires co-aligned Ku-band data. This 2AKa product will be produced independently and would not be impacted by any operational issues with the Ku-band radar. The high sensitivity to smaller hydrometeors should result in precipitation estimates in lighter precipitation then the Ku-only data.

7.3 CAVEATS/LIMITATIONS

Major sources of error that have an impact on estimates of surface precipitation include clutter contamination of near-surface echoes, incorrect identification of precipitation type (convective/stratiform), and severe attenuation of the Ka-band data in heavy precipitation.

The Ka-only retrieval has limitations of a single-frequency retrieval with reduced ability to detect water phase changes with height. This is partially mitigated by the use of external atmospheric state data from observations and models. The presence of changing topography (ex.: mountains) presents challenges to the ability of the algorithm to distinguish between precipitation echo and surface clutter. The Ka frequency undergoes larger extinction through precipitation, and the dual-frequency retrieval may be limited to lower-moderate rain rates.

7.4 REFERENCES

1. GPM/PPS File Specification 2AKa.

8. 2AKu

8.1 PURPOSE

The 2AKu algorithm provides precipitation estimates from the Ku radar of the Dual-Frequency Precipitation Radar on the core GPM spacecraft. The product contains one swath of data corresponding to the scans of the Ku radar. This is a single-frequency retrieval of precipitation; no information from the Ka radar is used. The retrievals are performed at each radar range bin along the slant path of the radar IFOV.

8.2 DATASET

This is a single-frequency retrieval that relies on Ku-band data only. While the 2ADPR dual-frequency retrieval should give better overall estimates, that algorithm requires co-aligned Ka-band data. This 2AKu product will be produced independently and would not be impacted by any operational issues with the Ka-band radar.

8.3 CAVEATS/LIMITATIONS

Major sources of error that have an impact on estimates of surface precipitation include clutter contamination of near-surface echoes, incorrect identification of precipitation type (convective/stratiform), and severe attenuation of the Ka-band data in heavy precipitation.

The Ku-only retrieval has limitations of a single-frequency retrieval with reduced ability to detect water phase changes with height. This is partially mitigated by the use of external atmospheric state data from observations and models. The presence of changing topography (ex: mountains) presents challenges to the ability of the algorithm to distinguish between precipitation echo and surface clutter. The Ku frequency undergoes larger extinction through precipitation, and the dual-frequency retrieval may be limited to lower-moderate rain rates.

8.4 REFERENCES

1. GPM/PPS File Specification 2AKu.

9. <u>2BCMB</u>

9.1 PURPOSE

The 2BCMB product uses data from the Dual-Frequency Precipitation Radars and GMI, determining the precipitation structure that best fits the combined data from these instruments. It is the Level 2 DPR and GMI Combined precipitation product that contains the data acquired by the GPM instruments in one orbit, or granule. It is written as a two-swath structure. The first swath, NS (normal scan), contains 49 rays per scan that match the KuPR rays. It is calculated from the KuPR and GMI data. The second swath, MS (matched scan), contains 25 rays per scan that match the 25 KaPR rays. It is calculated from the KuPR, KaPR, and GMI data.

The NS and MS swaths contain the following physical measurements of general interest, among others:

- surfaceAirPressure in hectopascals (hPa), (1013.25 hPa = 1 standard atmosphere, 14.7 PSI).
- surfaceAirTemperature in degrees Kelvin (K), (273 K = 0 Celsius).
- surfaceVaporDensity in g/m3.
- skinTemperature: Earth's surface temperature.
- airPressure in hPa at 10 vertical levels.
- airTemperature in K at 10 vertical levels.
- vaporDensity in g/m3 at 10 vertical levels.
- cloudLiqWaterCont: Cloud liquid water content in g/m3 at 88 vertical levels.
- cloudIceWaterCont: Cloud ice water content in g/m3 at 88 vertical levels (for future implementation).
- precipTotWaterCont: Total precipitation liquid water content in g/m3 at 88 vertical levels.
- precipTotRate: Total precipitation rate in mm/h at 88 vertical levels.
- liqMassFracTrans: Liquid precipitation mass fraction in phase transition region at 10 vertical levels.
- liqRateFracTrans: Liquid precipitation rate fraction in phase transition region at 10 vertical levels.
- surfPrecipTotRate: Surface rain rate in mm/h.
- surfPrecipTotRateSigma: Uncertainty of surface rain rate in mm/h.
- surfLiqRateFrac: Surface liquid precipitation rate fraction.
- tenMeterWindSpeed: Ten-meter altitude wind speed magnitude in m/s.

9.2 DATASET

There are uncertainties in the interpretation of data from any one of the instruments (KuPR, KaPR, and GMI). By using data from multiple instruments, further constraints on the solution of precipitation structure improve the final product.

9.3 REFERENCES

1. File Specification for GPM Products, Version 1.01, TKIO 3.60.0, March 11, 2014.
2. Olson, W. S., H. Masunaga, and the GPM Combined Radar-Radiometer Algorithm Team: GPM Combined Radar-Radiometer Precipitation ATBD (Version 2).

10. 3CMB

10.1 PURPOSE

The purpose of 3CMB is to give a daily and monthly accumulation of the 2BCMB precipitation product. The 3CMB product is a daily and monthly accumulation of the 2BCMB orbital combined product at two grid sizes, 5 x 5 degrees (G1) and 0.25 x 0.25 degrees (G2). Grid G1 contains the following physical measurements of general interest, among others. Grid G2 contains the same groups, but it is on the ltH x lnH grid and does not have the surface type (st) dimension or the histograms (see dimension definitions below). Below, conditional products represent means based upon precipitating areas only; unconditional products represent means for raining and non-raining areas combined. Probabilities represent the number of raining observations divided by the total number of raining and non-raining observations.

precipTotRate (Group in G1) – Conditional mean rate for all precipitation phases (ice, liquid, mixed-phase).

- count (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st): Count.
- mean (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Mean, mm/h.
- stdev (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Standard deviation for the monthly product. Mean of squares for the daily product, mm/h.
- hist (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st x bin): Histogram.

precipLiqRate (Group in G1) – Conditional mean rate for liquid precipitation.

- count (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st): Count.
- mean (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Mean, mm/h.
- stdev (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Standard deviation for the monthly product. Mean of squares for the daily product, mm/h.
- hist (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st x bin): Histogram.

precipTotWaterContent (Group in G1) – Conditional mean water content for all precipitation phases.

- count (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st): Count.
- mean (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Mean, g/m^3.
- stdev (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Standard deviation for the monthly product. Mean of squares for the daily product, g/m^3.
- hist (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st x bin): Histogram.

precipLiqWaterContent (Group in G1) – Conditional mean liquid water content.

- count (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st): Count.
- mean (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Mean, g/m^3.
- stdev (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Standard deviation for the monthly product. Mean of squares for the daily product, g/m^3.
- hist (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st x bin): Histogram.

precipTotDm (Group in G1) – Conditional mass-weighted mean particle diameter.

- count (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st): Count.
- mean (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Mean, mm.
- stdev (4-byte float, array size: ltL x lnL x ns x hgt x rt x st): Standard deviation for the monthly product. Mean of squares for the daily product, mm.
- hist (4-byte integer, array size: ltL x lnL x ns x hgt x rt x st x bin): Histogram.

precipTotRateDiurnal (Group in G1) – Conditional mean total surface precipitation rate indexed by local time.

- count (4-byte integer, array size: ltL x lnL x ns x st x tim): Count.
- mean (4-byte float, array size: ltL x lnL x ns x st x tim): Mean, mm/h.
- stdev (4-byte float, array size: ltL x lnL x ns x st x tim): Standard deviation for the monthly product. Mean of squares for the daily product, mm/h.

surfPrecipTotRateDiurnalAllObs (4-byte integer, array size: ltL x lnL x ns x st x tim): Number of total observations, whether precipitating or not, indexed by local time.

surfPrecipTotRateUn (4-byte float, array size: ltL x lnL x ns): Unconditional surface total precipitation rate (all phases). To obtain rate conditioned on precipitation, divide by the probability, mm/h.

surfPrecipLiqRateUn (4-byte float, array size: ltL x lnL x ns): Unconditional surface liquid precipitation rate. To obtain rate conditioned on precipitation, divide by the probability, mm/h.

surfPrecipTotRateProb (4-byte float, array size: ltL x lnL x ns): Probability of total surface precipitation (all phases), mm/h.

surfPrecipLiqRateProb (4-byte float, array size: ltL x lnL x ns): Probability of liquid surface precipitation, mm/h.

Dimension definitions:

- ltL – 28 – Number of low-resolution 5-degree grid intervals of latitude from 70 degrees S to 70 degrees N.
- lnL – 72 – Number of low-resolution 5-degree grid intervals of longitude from 180 degrees W to 180 degrees E.
- ltH – 536 – Number of high-resolution 0.25-degree grid intervals of latitude from 67 degrees S to 67 degrees N.
- lnH – 1440 – Number of high-resolution 0.25-degree grid intervals of longitude from 180 degrees W to 180 degrees E.
- ns – 2 – Number of swaths: NS (Ku+microwave), MS (Ku+Ka+microwave).
- hgt – 1 – Number of level heights 0-15: 0: near surface, 1-10: height = 1.0 km * index, 11-15: height = 10.0 km + 2.0 km * (index-10).
- tim – 24 – Number of hourly local time bins.
- rt – 3 – Number of rain types: stratiform, convective, all.
- st – 3 – Number of surface types: ocean, land, all.
- bin – 30 – Number of bins in histogram. TBD.

10.2 DATASET

There are uncertainties in the interpretation of data from any one of the instruments (KuPR, KaPR, and GMI). By using data from multiple instruments, further constraints on the solution of precipitation structure improve the final product.

10.3 REFERENCES

1. File Specification for GPM Products, Version 1.01, TKIO 3.60.0, March 11, 2014.
2. Olson, W. S., H. Masunaga, and the GPM Combined Radar-Radiometer Algorithm Team: GPM Combined Radar-Radiometer Precipitation ATBD (Version 2).

11. 3DPR

11.1 PURPOSE

The Level 3 DPR algorithm accumulates instantaneous precipitation estimates from the Level 2 retrieval algorithms into grids over a day and month time span. There are two grid resolutions: 5.0 degrees and 0.25 degrees. For each grid box, the core statistics are the number of measurements, mean, and standard deviation. Most variables are also conditioned on surface type and precipitation type with other three-dimensional fields adding the height above the ellipsoid. Unless otherwise specified, the means are conditioned on precipitation being present (rain rate > 0). For the daily product, the mean square statistic is saved rather than the standard deviation. In addition to the daily and monthly products is a simplified joint daily product that contains a subset of the fields from the full daily product.

11.2 DATASET

The Level 3 DPR products present the user with summary information over daily and monthly time periods. These gridded products are in a convenient gridded form and can be used easily in comparisons with other satellite and ground data.

11.3 CAVEATS/LIMITATIONS

The results presented in the Level 3 product are simple conditioned statistics of the Level 2 retrievals. Any errors/limitations are inherent to the Level 2 retrieval issues already presented.

Issues with sampling must be considered when using these data. For the daily products, the number of measurements in each 0.25-degree box is very limited. While this is a convenient resolution that can be used to create larger grids, the values at the 0.25-degree resolution should be used with caution. The standard deviation is not computed at the daily level for this very reason.

11.4 REFERENCES

1. GPM/PPS File Specification 3DPR.

12. 3DPRD

12.1 PURPOSE

The Level 3 DPR joint algorithm subsets precipitation estimates from the Level 3 daily products. In addition, it adds time information from Level 2 instantaneous data to give a date/time for the last measurement in each grid box. The product contains one 0.25 x 0.25 degree grid with separate indices for the ascending and descending parts of the GPM orbit.

12.2 DATASET

The precipitation estimates in the 3DPRD product are a subset of those in the full daily 3DPR product; the retrieval estimates are the same. Since this is a subset, the product is smaller, and Level 3 DPR products present the user with summary information over daily and monthly time periods. These gridded products are in a convenient gridded form and can be used easily in comparisons with other satellite and ground data.

12.3 CAVEATS/LIMITATIONS

Issues with sampling must be considered when using these data. For the daily products, the number of measurements in each 0.25-degree box is very limited. While this is a convenient resolution that can be used to create larger grids, the values at the 0.25-degree resolution should be used with caution. The standard deviation is not computed at the daily level for this very reason.

This is a subset product, and retrieval estimates are identical to those presented in the full daily 3DPR product. Any errors/limitations are inherent to the Level 2 retrieval issues already presented.

12.4 REFERENCES

1. File Specification for GPM Products, Version 1.01, TKIO 3.60.0, March 11, 2014.

3GPROF

12.5 PURPOSE

The purpose of the 3GPROF algorithm is to provide monthly and daily mean precipitation and related retrieved parameters from the Level 2 GPROF precipitation profiling algorithm for the GPM core and constellation satellites. Each 3GPROF product contains global 0.25 degree x 0.25 degree gridded monthly/daily means. Because this product is an accumulation of the Level 2 retrieval products, much more information is available via the GPROF Level 2 documentation. Current available 3GPROF products are listed in the following table:

Product ID	Radiometer	Satellite
3GPROF	AMSR2	GCOM-W1
3GPROF	ATMS	NPP
3GPROF	GMI	GPM
3GPROF	MHS	NOAA-18 NOAA-19 METOP-A METOP-B
3GPROF	SAPHIR	MT1
3GPROF	SSMIS	F16 F17 F18
3GPROF	TMI	TRMM

12.6 DATASET

3GPROF products provide global gridded monthly/daily precipitation averages from multiple satellites that can be used for climate studies. The 3GPROF products are based on retrievals from high-quality microwave sensors, which are sensitive to liquid and ice-phase precipitation hydrometeors in the atmosphere.

12.7 CAVEATS/LIMITATIONS

The primary limitation of the 3GPROF product is the reliance on a single sensor for each output file, thus limiting the available sampling to two times a day or less, except at high latitudes. In addition, with the exception of the GMI, TMI, and SAPHIR sensors, all of the other sensors are in Sun-synchronous orbits, meaning that they observe a given point on the Earth's surface at the same local times each day. Over land regions in particular, this can lead to large sampling errors associated with the diurnal cycle.

Errors due to the limited sampling and differences in the sampling times between Sun-synchronous satellites (e.g., F16, F17, F18, NOAA-18, NOAA-19, NPP, METOP-A, METOP-B, and GCOM-W1) can lead to significant differences in the monthly mean values between satellites/sensors. The sampling errors are largest over land regions with large diurnal cycles in precipitation.

Other sources of error that can significantly impact the 3GPROF products include difficulties over certain surface types such as sea ice, snow, frozen ground, and deserts, and limited sensitivity of the sounder instruments (in particular to light precipitation and/or shallow warm rain systems). The sounders include the ATMS, MHS, and SAPHIR sensors, which do not have channels with sensitivity to the surface and/or lower atmosphere.

12.8 REFERENCES

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13. IMERG PRODUCTS

13.1 PURPOSE

The Integrated Multi-Satellite Retrievals for GPM (IMERG) algorithm is designed to leverage the international constellation of precipitation-relevant satellites to create a long record of uniformly time/space gridded precipitation estimates for the globe. The algorithm is focused on creating the best estimate at each time step, meaning that it is not a Climate Data Record, although the ideal is as homogenous a record as possible.

13.2 DATASET

The uniform, relatively fine-scale gridding provided by IMERG makes its products well suited to a range of scientific and application studies that need to use precipitation estimates over areas without necessarily delving into specific details of precipitation sensor and algorithm performance. In general, this is the first product that non-expert users should consider out of the GPM suite of products, unless they have specific need for three-dimensional structure, Level 2 (swath/footprint) detail, or other specialized needs.

13.3 CAVEATS/LIMITATIONS

Some cautions are the result of IMERG's structure:

- IMERG will initially provide data for the latitude belt 60°N-60°S; complete global coverage depends on some additional development work in future releases.
- Calibrations tend to be monthly (or longer) to ensure stability, but fast-changing weather patterns might introduce variations that such calibrations cannot represent well.
- The morphing scheme used to time-interpolate between microwave sensor overpasses essentially uses linear interpolation. Particularly as the time between overpasses becomes more than about 2 hours, the morphed and actual evolution of precipitation can diverge significantly.
- The IR-based displacement vectors used in morphing are not guaranteed to reproduce the actual motions of precipitation systems. This is certainly true at scales below about 2.5° of latitude/longitude and when the motions of IR-sensed cloud tops are not well-coupled to the motions of lower-altitude precipitation features.
- Morphing will propagate the error in a microwave retrieval along with the good precipitation signal, creating correlated error at nearby times.
- When infrared estimates are used (due to a lack of microwave estimates within about ±90 min. of the analysis time), the quality will suffer due to the low quality of the snapshot infrared estimator.

Other cautions arise from the input data used:

- Current-generation microwave algorithms work best over tropical ocean and progressively less well over mid-latitude ocean, tropical land, mid-latitude land, regions of complex topography, and regions with frozen surface.

- Over land, the liquid-sensing capabilities of the emission signal in the lower-frequency channels cannot be used in current-generation algorithms, reducing the potential ability of algorithms.
- Frozen surfaces knock out the scattering signal in the higher-frequency channels, so microwave algorithms largely fail to retrieve precipitation there at all.
- In regions of complex terrain the scattering channels can be used, but a variable amount of precipitation enhancement and suppression takes place in the liquid phase. Such variations cannot be detected by the high-frequency channels.
- Looking more broadly, each sensor has its own viewing geometry and channel characteristics, and retrieval algorithms that represent compromises between precision, completeness, and practicality. To a limited extent it is attempted to emphasize strengths and compensate for weaknesses in the input data, but in many cases the errors contained in the input data are passed through to the IMERG output fields.

The error estimates contained in the IMERG Day-1 datasets are a first approximation and should be used with caution. Development work being done by the GPM Science Team and elsewhere holds promise for upgrades to error estimation in later releases. In common with all fine-scale precipitation datasets, the validation statistics for IMERG are relatively modest at full resolution. Averaging to progressively larger time/space data cubes results in improved error characteristics. Relatively uncertain estimates at these fine scales are released to allow the users to craft averages appropriate to their particular studies. This can include, for example, streamflows in sufficiently large basins, which implicitly average the data.

13.4 REFERENCES

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ACRONYMS AND ABBREVIATIONS

AMSR	Advanced Microwave Scanning Radiometer
ATBD	Algorithm Theoretical Basis Document
ATMS	Advanced Technology Microwave Sounder
CCSDS	Consultative Committee for Space Data Systems
CMB	Combined
DEM	Digital Elevation Model
DMSP	Defense Meteorological Satellite Program
DPR	Dual-Frequency Precipitation Radar
ECMWF	European Centre for Medium-Range Weather Forecasts
ENV	Environment
GANAL	Gridded Dataset of Global Analysis
GCOM	Global Change Observation Mission
GMI	GPM Microwave Imager
GPM	Global Precipitation Measurement
GPROF	Goddard Profiling Algorithm
HDF	Hierarchical Data Format
HS	High-Sensitivity Scan
IFOV	Instantaneous Field of View
IMERG	Integrated Multi-Satellite Retrievals for GPM
IR	Infrared
JAXA	Japan Aerospace Exploration Agency
KaPR/KuPR	Ka-band Precipitation Radar/Ku-band Precipitation Radar
L&EO	Launch and Early Orbit
L1A, L1B	Level 1A, Level 1B
METOP	(European) Meteorological Operational (Spacecraft)
MHS	Microwave Humidity Sounder
MS	Matched Scan
NEDT	Noise Equivalent Delta Temperature/Noise-Equivalent Differential Temperature
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-Orbiting Operational Environment Satellite
NPP	NPOESS Preparatory Project
NRT	Near-Realtime
NS	Normal Scan
PPS	Precipitation Processing System
SAPHIR	Sondeur Atmospherique du Profil d'Humidite Intertropicale par Radiometrie
SC	Spacecraft
SSMIS	Special Sensor Microwave Imager/Sounder
Ta	Antenna Temperature
Tb	Brightness Temperature
Tc	Intercalibrated Brightness Temperature
TKIO	PPS Science Algorithm Input/Output Toolkit
TMI	TRMM Microwave Imager
TRMM	Tropical Rainfall Measuring Mission
Z	Reflectivity