Global Hydrology Resource Center

Data User Guide

GPM Ground Validation Airborne Precipitation Radar 3rd Generation (APR-3) OLYMPEX

Introduction

The GPM Ground Validation Airborne Precipitation Radar 3rd Generation (APR-3) OLYMPEX dataset was collected from November 12, 2015 to December 19, 2015 during the GPM Ground Validation Olympic Mountains Experiment (OLYMPEX) field campaign held in the Pacific Northwest. APR-3 is the APR-2 used in previous field campaigns with the addition of W-band measurement capability. APR-3 beams scan cross-track from +/- 25° to the right and left of nadir. Ku-band, Ka-band and W-band frequency doppler measurements are made from the DC-8 aircraft at 10km altitude during OLYMPEX. The APR-3 dataset files are in HDF-4 format with PNG format browse images. This L1 APR-3 dataset provides radar reflectivity, doppler velocity for all bands, linear depolarization ratio at Ku-band, and normalized radar cross section measurements at Ka and Ku-bands.

Notice: This dataset is intended for research and users should contact the APR-3 team regarding data use, especially before publication or public presentation. This dataset is still undergoing validation and quality control. Users are invited to address questions and provide feedback to the Data Provider.

Citation

Durden, Stephen L. and Simone Tanelli. 2017. GPM Ground Validation Airborne Precipitation Radar 3rd Generation (APR-3) OLYMPEX [indicate subset used]. Dataset available online from the NASA EOSDIS Global Hydrology Resource Center Distributed Active Archive Center, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/GPMGV/OLYMPEX/APR3/DATA101

Keywords:

NASA, GHRC, OLYMPEX, Washington, APR-3, DC-8, precipitation, radar, radar reflectivity, doppler velocity, NRCS, LDR, airborne

Campaign

The Global Precipitation Measurement (GPM) mission Ground Validation campaign used a variety of methods for validation of GPM satellite constellation measurements prior to and after launch of the GPM Core Satellite, which launched on February 27, 2014. The instrument validation effort included numerous GPM-specific and joint agency/international external field campaigns, using state of the art cloud and precipitation observational infrastructure (polarimetric radars, profilers, rain gauges, and disdrometers). Surface rainfall was measured by very dense rain gauge and disdrometer networks at various field campaign sites. These field campaigns accounted for the majority of the effort and resources expended by GPM GV. More information about the GPM mission is available at https://pmm.nasa.gov/GPM/.

One of the GPM Ground Validation field campaigns was the Olympic Mountains Experiment (OLYMPEX) which was held in the Pacific Northwest. The goal of OLYMPEX was to validate rain and snow measurements in midlatitude frontal systems as they move from ocean to coast to mountains and to determine how remotely sensed measurements of precipitation by GPM can be applied to a range of hydrologic, weather forecasting, and climate data. The campaign consisted of a wide variety of ground instrumentation, several radars, and airborne instrumentation monitoring oceanic storm systems as they approached and traversed the Peninsula and the Olympic Mountains. The OLYMPEX campaign was part of the development, evaluation, and improvement of GPM remote sensing precipitation algorithms. More information is available from the NASA GPM Ground Validation web site https://pmm.nasa.gov/olympex and the University of Washington OLYMPEX web site http://olympex.atmos.washington.edu/.

Figure 1: OLYMPEX Domain
(Image Source: https://pmm.nasa.gov/OLYMPEX)

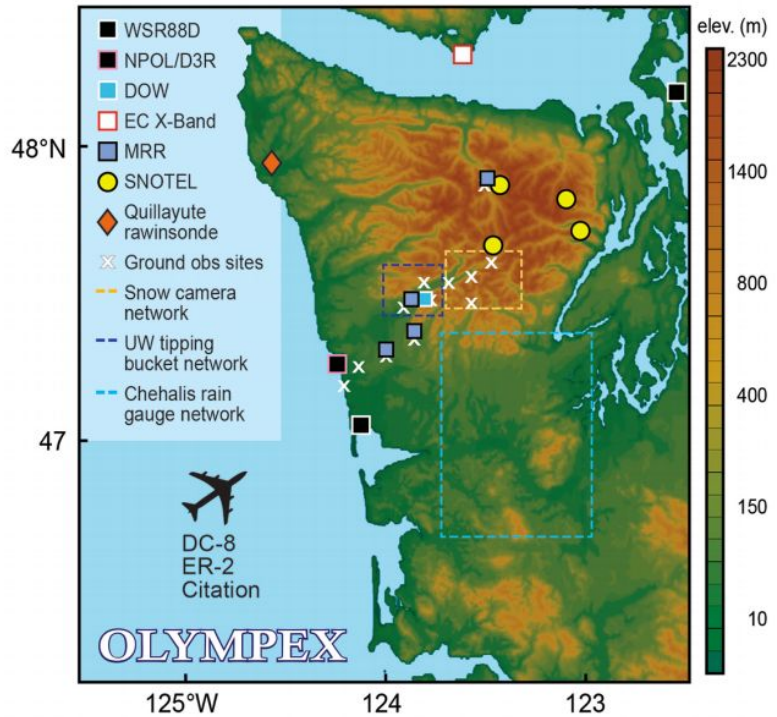

Figure 2: OLYMPEX Field Locations
(Image Source: https://pmm.nasa.gov/OLYMPEX)

Instrument Description

The Airborne Precipitation Radar 3rd Generation (APR-3) instrument is an enhanced version of the Airborne Precipitation Radar 2nd Generation (APR2) instrument, which was successfully used in a number of previous GPM-GC field campaigns. The APR-3 performs simultaneous radar measurements of both like- and cross-polarized signals at 13.4 GHz (Ka-band) and 35.6 GHz (Ku-band) and , for OLYMPEX, W-band measurements. The APR-3 instrument was flown onboard the NASA DC-8 aircraft. As shown in Figure 3, the instrument was positioned to look downward and scan from side-to-side across the flight track from 25° to the left and right of nadir. The W-band data are collected with the same cross-track scanning geometry as used for Ku- and Ka-bands. This was accomplished by modifying the existing Ku and Ka feed to allow for operation at W-band. A second W-band antenna was installed to provide the higher sensitivity needed for cloud sensing. This second W-band antenna has a larger aperture and only looked nadir (no side-to-side scanning) which allowed for more pulses to be integrated. For OLYMPEX, the data were acquired using one of the W-band antennas or the other, or sometimes both(simultaneous scanning and nadir). A flag is used to notify which antenna operated at any time. Radar sensitivity was not constant (mainly dependent on the pulse length). Users not familiar with the weather radar equation and APR-3 data should contact the APR-3 team to support data interpretation.

Users should refer to more detailed information about the APR-3 instrument operation in the Data provider documentation.

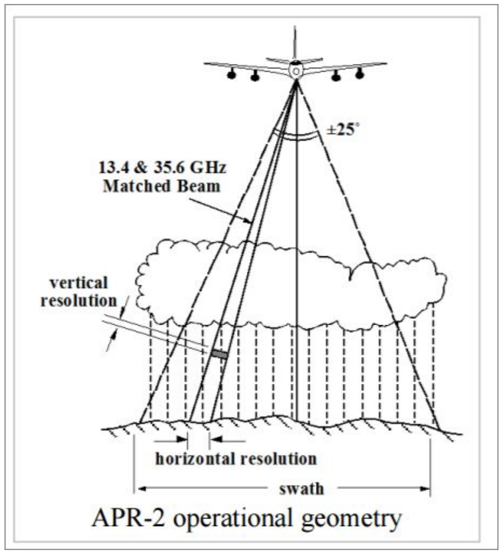

Figure 3. APR-2 (predecessor to the APR-3) operational geometry

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File Naming Convention

The GPM Ground Validation Airborne Precipitation Radar 3rd Generation (APR-3) OLYMPEX dataset has the naming conventions shown below. The data files are available in HDF-4 format and the browse images are in PNG format. The 23 or v23 in the data filename structures signify the algorithm version of 2.3. See the Data Provider documentation for description of the history of dataset versions. The browse images do not correlate to just one data file, but rather cover a specific time period that may encompass multiple data files.

Data files: OLYMPEX_APR3_YYYYMMDD_hhmmss_23.HDF
Browse files: OLYMPEX_APR3_YYYYMMDD_<starttime>-<endtime>_v23_Y_0m_h_1000m_Ch_1_2_3_4_8.png

Table 1: File naming convention variables

Variable	Description
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
hh	Two-digit hour in Z
mm	Two-digit minute in Z
ss	Two-digit second in Z
.HDF	HDF-4 format
<starttime> or <endtime>	Start time or end time of measurements in hhmm, where hh = two-digit hour in Z, mm = two-digit minute in Z
.png	Portable Network Graphics format

Data Format Description

The GPM Ground Validation Airborne Precipitation Radar 3rd Generation (APR-3) OLYMPEX data are available in HDF-4 format for the data processing level 1B. The browse images are available in PNG format and contain plots over a specific flight time.

Table 2: Data Characteristics

Characteristic	Description
Platform	Douglas DC-8 (DC-8)
Instrument	Airborne Precipitation Radar 3rd Generation (APR-3)
Projection	N/A
Spatial Coverage	N: 49.33 , S: 45.963, E:122.134, W: -129.048 (Washington)
Spatial Resolution	800 m horizontal resolution at 10 km altitude, 60 m range resolution
Temporal Coverage	November 12, 2015 - December 19, 2016
Temporal Resolution	Varies: typically less than 15 minutes
Sampling Frequency	1.8 seconds
Parameter	Radar reflectivity, doppler velocity, linear depolarization ratio
Version	2.3
Processing Level	1B

Data Parameters

The GPM Ground Validation Airborne Precipitation Radar 3rd Generation (APR-3) OLYMPEX dataset consists of radar reflectivity, linear depolarization ratio, and doppler velocity measurements in HDF-4 format. There are also browse images available in PNG format. The variables contained in the GPM Ground Validation Airborne Precipitation Radar 3rd Generation (APR-3) OLYMPEX files are shown in Table 3. The presence or absence of zhh95 and zvv95 are specified by the Wband Port value in the fileheader. Note that variable 23 of the fileheader was not used for OLYMPEX.

Table 3: Data Fields

Field Name	Description	Data Type	Size	Unit
fileheader	Contains APR-3 parameters that are constant over the entire file. Table 4 shows the information contained within the fileheader	int32	38	-
scantime	Beginning of scan in seconds since January 1, 1970 NOTE: To obtain the time of each ray, parameters 1 and 7 from the fileheader are necessary	int32	nscan* x nray*	s
roll	From aircraft or MMS navigation files	float	nscan x nray	°
pitch	From aircraft of MMS navigation files	float	nscan x nray	°
drift	From aircraft of MMS navigation files	float	nscan x nray	°
alt_nav	From aircraft of MMS navigation files (recommended). Calculated relying on the aircraft navigation information	float	nscan x nray	m
alt_radar	From APR-3 surface echo (alternate). Calculated relying on the observed surface return in Ku and Ka data. This is only reliable when flying over the ocean and provides a more accurate geolocation	float	nscan x nray	m
lat	Latitude of scan	float	nscan x nray	°
lon	Longitude of scan	float	nscan x nray	°
look_vector	From navigation files (recommended). Calculated relying on the aircraft navigation information	double	nscan x nray x 3	-
look_vector_radar	From APR-3 surface echo (alternate). Calculated relying on the observed surface return in Ku and Ka data. This is only reliable when flying over the ocean and provides a more accurate geolocation	double	nscan x nray x 3	-
range0	Distance of the first radar range bin from aircraft	float	nscan x nray	km
isurf	Index of radar range bin intersecting surface (starting from 0)	int32	nscan x nray	-
sequence	Ray number within the file	int32	nscan x nray	-
v_surfdc8	Apparent surface Doppler velocity as estimated from DC-8 navigation	float	nscan x nray	m/s
v_surf	APR-3 measurement surface Doppler velocity. Corrected for occasional aliasing and was used to correct Doppler	float	nscan x nray	m/s

	measurements of precipitation for the bias introduced by aircraft motion			
beamnum	Ray number within a scan	float	nscan x nray	-
surface_index	Preliminary surface classification index. Estimated by analysing Ku/Ka surface returns (roughness, angle dependence of the surface normalized radar cross section, apparent surface inclination and LDR at nadir). Table 5 describes the 6 values for surface_index	float	nscan x nray	-
sigma_zero	Surface NRCS (Ku and Ka band)	float	nscan x nray x 2	dB
zhh14	Radar reflectivity at Ku band (scaled dBZ)	int16	nscan x nray x nbin	dBZ
zhh35	Radar reflectivity at Ka band (scaled dBZ) nadir point	int16	nscan x nray x nbin	dBZ
ldr14	Linear depolarization ratio (scaled dB)	int16	nscan x nray nbin	dB
vel14	Doppler velocity at Ku band (scaled m/s)	int16	nscan x nray x nbin	m/s
zhh95	Radar reflectivity at W band (scaled dBZ), HH scanning channel	int16	nscan x nray x nbin	dBZ
zvv95	Radar reflectivity at W band (scaled dBZ), VV nadir channel (placed in 3D array to match lat3D, etc.)	int16	nscan x nray x nbin	dBZ
lat3D	Latitude of each resolution bin	int16	nscan x nray x nbin	°
lon3D	Longitude of each resolution bin	int16	nscan x nray x nbin	°
alt3D	Altitude of each resolution bin	int16	nscan x nray x nbin	m
lat3D_scale	-	double	1	-
lon3D_scale	-	double	1	-
alt3D_scale	-	double	1	-
lat3D_offset	-	double	1	°
lon3D_offset	-	double	1	°
alt3D_offset	-	double	1	m

*nscan is the number of scans in a file
*nray is the number of rays (beams, looks) within a scan
*nbin is the number of range bins within a ray
*missing data are replaced by -9999.

Table 4: Fileheader description

	Name	Src	Unit	Default	Description
1	PRF	Raw	Hz	5000	Pulse repetition frequency
2	Pulse Length	Raw	mus	3-20	Radar pulse length
3	Antenna Left	Raw	°	-25 or 0	Antenna scan left-limit
4	Antenna Right	Raw	°	+25 or 0	Antenna scan right-limit
5	Scan Duration	Raw	ms	1200	Scan time for antenna
6	Return Duration	Raw	ms	600	Antenna retrace time
7	Ncycle	Raw	-	250	Number of pulse averaged by Wildstar board
8	AZ Average	Raw	-	1	Number of blocks averaged in a beam or ray
9	Range Average	Raw	-	1	Number of 30 m range cells averaged in a bin
10	Scan Average	Raw	-	1	Number of scans averaged
11	Number of Bins	Raw	-	600	Number of range bins in the ray
12	Number of Beams	Raw	-	24	Number of rays in each scan
13	Range Bin Size	2HDF	m	30	The vertical resolution of range bin
14	Z scale factor	Raw	-	100	Factor multiplying reflectivity
15	V scale factor	Raw	-	100	Factor multiplying Doppler
16	Not used	write	-	-	Always the number 1
17	# of scans	L1A	-	-	Number of scans
18	CalVersion	write	-	-	obsolete
19	Radar Mode	L1A	-	-	Spare 1: mode (71 = dump, 87 = operate)
20	Rx Atten	L1A	-	-	Internal Cal parameter
21	Tx Atten	L1A	-	-	Internal Cal parameter
22	DR	Env	m	-	A priori range sampling (redundant)
23	Ka band Port *	Env	-	-	0 ⟶ Ka (2) = CxPol 1 ⟶ Ka (2) = Ka Zenith
24	Fixed Ka Pt	L1A	-	-	-
25	W band Port	-	-	-	flag_Wvv*10 + flag_Whh, where flag_Wzz is 0 absent, 1 present, but less than half scans, 2 else
26-38	Not used	-	-	-	-

* zenith-looking Ka-band not used for OLYMPEX APR-3 operation

Table 5: Values assumes for surface index

Value	Description
0	Rough land
1	Ocean (level flight)
2	Ocean (roll maneuver)
3	Flat land (level flight)
4	Flat land (roll maneuver)
5	Antenna not scanning (unknown surface)

Browse images show data from various channels and the ground track of the DC-8 for the data displayed in the plots. To understand the plots, see the Data provider documentation.

Algorithm

The Altitude and Look Vector are provided in two estimates: alt_nav and look_vector. These are calculated relying on DC-8 navigation information. Alt_radar and look_vector_radar are calculated relying on the observed surface return in Ku and Ka data. The alt_radar and look_vector_radar pair is reliable only when flying over the ocean, and, in this case, provides a more accurate geolocation than the navigation-based pair. The best resources for the algorithms used to process APR-3 data is Sadowy et al., 2003, and Tanelli et al., 2006.

Quality Assessment

External calibration was used for all products. Reflectivity measurements should be considered reliable to within ±3 sigma.

The alt_radar and look_vector_radar pair is reliable only when flying over the ocean, and for OLYMPEX, provides a more accurate geolocation than the navigation-based pair.

The surface Doppler velocity (v_surf) was corrected for occasional aliasing and, in turn, was used to correct the Doppler measurements of precipitation for the bias introduced by the aircraft motion. This correction can be undone by adding the value of v_surf from vel14 at all range bins of every ray. This alternate correction may be of interest for the minority of data collected over land where the v_surf estimate is more prone to errors, or for data collected during sharp maneuvers by the DC-8.

The surface index is estimated by analyzing Ku and Ka surface returns, such as roughness, angle dependence of the surface normalized radar cross section, apparent surface inclination, and LDR at nadir. This is estimated on a scan-by-scan basis. The most frequent misclassification is ocean being classified as flat land.

Occasionally, high lateral winds may cause the Doppler measurements to be aliased. Doppler measurements should be corrected to account for a maximum unambiguous velocity of ±27.5 m/s. Also, correction for aircraft motion is less reliable when the aircraft was maneuvering or was affected by turbulence or was over land.

The term 'beams' and 'rays' are considered to be the same. No data values can appear as -99.99, as well as -9999, due to scaling by 100. The 'Zhh35' field has -32768 as missing data instead of -9999. For the 'surface_index', a values of 7 indicates no surface echo, as typically found in bean 24, which is noise-only. Finally, the W-band Port value in the file header, which serves as the flag indicating the absence or presence of the W-band reflectivity arrays 'zhh95' and 'zvv95', has a description of "flag_Wvv*10 + flag_Whh", where 'flag_Wxx' is 0 if absent or 1 if present, but less than half of the scans, or 2 which implies Whh is present in a majority of the scans and Wvv is absent in all of the scans. If Wvv were also present in most of the scans, the value would be around 22.

More information about the quality assessment for this dataset can be found in the Data provider Documentation.

Software

No software is required to view the GPM Ground Validation Airborne Precipitation Radar 3rd Generation (APR-3) OLYMPEX HDF-4 self-describing data files. Panoply can be used to easily view the data.

Known Issues or Missing Data

If there are missing data within a file, it is replaced by -9999. The radar sensitivity was not constant and was mainly dependent on the pulse length. The report value of reflectivity for the first 5 bins after the blanked transmit window is underestimated. This region should only be used for detection purposes, and not quantitative estimation. Also, there is no correction for path attenuation included in this dataset.

No data are available from the 24th ray of each scan (beamnum = 1) at Ku/Ka. This ray was used for noise measurements (no pulse transmitted). The 24th ray was included in this dataset solely for compatibility with APR2 datasets from previous field campaigns. Users are cautioned when interpreting very low LDR values (e.g., less than -20 dB), which are characterized by larger overall uncertainty.

Doppler velocity is only reported at Ku-band and only when Zhh14 is above a certain threshold. The threshold was set high to be conservative.

On December 5, 2015, there were severe W-band timing problems including loss of pulses. Due to this, data for Dec 5 were not included. No W-band data were acquired on November 14, 2015 due to water damage of the W-band computer.

A file for December 1, 2015 starting at 21:14 Z contained all zero values for latitude and longitude. The file has been removed from this V2.3 dataset and will likely be replaced for a future version.

More information about known issues and missing data for this dataset can be found in the PI Documentation.

References

Sadowy, G. A., Berkun, A. C., Chun, W., Im, E., & Durden, S. L. (2003): Development of an advanced airborne precipitation radar.(Technical Feature). Microwave Journal, 46(1), 84-93.

Tanelli, S., S. L. Durden, and E. Im, (2006): Simultaneous Measurements of Ku- and Ka-band Sea Surface Cross-Sections by an Airborne Radar. IEEE Geoscience and Remote Sensing Letters, 3(3), 359-363. doi: https://doi.org/10.1109/LGRS.2006.872929

Related Data

All data collected during the OLYMPEX field campaign should be considered related data sets. To locate other OLYMPEX data, use the GHRC search tool HyDRO 2.0 with the search term OLYMPEX. The APR-3 is related to the APR-2 instrument flown on experiments such as GRIP and NAMMA. To locate previous APR-2 data, use the GHRC search tool HyDRO 2.0 with the search term APR-2.

Contact Information

To order these data or for further information, please contact:

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Created: June 19, 2017