Data User Guide

GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) OLYMPEX

Introduction

The GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) OLYMPEX dataset contains radar reflectivity, velocity, differential reflectivity, differential phase, spectrum width, and co-polar correlation products collected during the Global Precipitation Measurement mission (GPM) Ground Validation (GV) Olympic Mountains Experiment (OLYMPEX). The OLYMPEX field campaign took place between November 2015 and January 2016, with additional ground sampling continuing through February 2016, on the Olympic Peninsula in the Pacific Northwest of the United States. The purpose of the campaign was to provide ground-validation data for the measurements taken by instrumentation aboard the GPM Core Observatory satellite. The Dual-frequency Dual-polarized Doppler Radar (D3R) was developed by a government-industry-academic consortium with funding from NASA's GPM mission and was used in several ground validation projects. D3R operates at the Ku-band (13.91 GHz ± 25 MHz) and Ka-band (35.56 GHz ± 25 MHz) frequencies, similar to the frequencies used for the GPM satellite instruments, and covers a fixed range from 450 m to 40 km. For OLYMPEX, the D3R was co-located with the NASA S-band Dual Polarimetric (NPOL) Doppler Radar at a coastal Washington state location on the Olympic Peninsula. Due to blockage caused by NPOL, the D3R measurement area is limited to a 220 degree to 120 degree sector. The GPM GV D3R OLYMPEX dataset files are available from November 8, 2015 through January 15, 2016 in netCDF-4 format along with browse imagery of reflectivity in PNG format.

Citation

Chandrasekar, V. and Manuel Vega. 2017. GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) OLYMPEX [indicate subset used]. Dataset available online

from the NASA Global Hydrometeorology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/GPMGV/OLYMPEX/D3R/DATA101.

Keywords:
NASA, GHRC, OLYMPEX, GPM GV, reflectivity, differential reflectivity, co-polar correlation coefficient, differential phase, velocity, spectrum width, Dual-frequency Dual-polarized Doppler Radar, D3R, Washington, Olympic Peninsula

Campaign
The Global Precipitation Measurement mission (GPM) Ground Validation (GV) 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 from the NASA PMM GPM webpage.

The Olympic Mountains Experiment (OLYMPEX) was a GPM GV field campaign held in the Pacific Northwest (Figure 1) during 2015 and 2016 with an intensive observing period from November 1, 2015 to March 1, 2016. The goal of OLYMPEX was to validate rain and snow measurements in mid-latitude frontal systems as they moved 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 Olympic Peninsula and the Olympic Mountains (Figure 2). The OLYMPEX campaign was part of the development, evaluation, and improvement of GPM remote sensing precipitation algorithms. More information about OLYMPEX is available from the NASA GPM OLYMPEX Field Campaign webpage, the University of Washington OLYMPEX website, the GHRC OLYMPEX Field Campaign homepage, and the GHRC OLYMPEX Field Campaign Micro Article.

Figure 1: OLYMPEX Domain
(Image Source: [NASA PMM OLYMPEX webpage]())

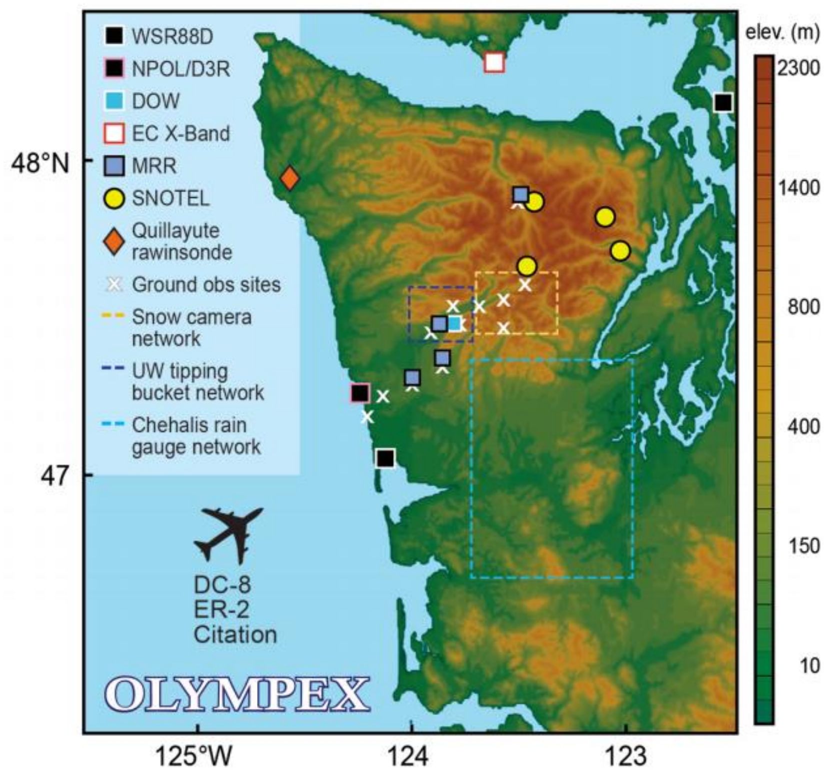

Figure 2: OLYMPEX Field Locations
(Image Source: [NASA PMM OLYMPEX webpage]())

Instrument Description

The Dual-frequency Dual-polarized Doppler Radar (D3R), developed with funding from NASA GPM, is a fully polarimetric, scanning weather radar system which provides estimations of hydrometeor classification and drop size distribution retrievals. The D3R design consists of two separate co-aligned single-frequency antennas mounted on a common, portable, pedestal with a dual-frequency dual-polarized solid-state transmitter (Figure 3). The D3R operates at the Ku-band (13.91 GHz ± 25 MHz) and Ka-band (35.56 GHz ± 25 MHz) frequencies covering a fixed range from 450 m to 39.75 km. These frequencies were selected for close compatibility with the GPM Dual-frequency Precipitation Radar (DPR) instrument onboard the GPM Core Observatory satellite. Though the instrument can scan a full 360 degree circle, placement near the NASA S-band Dual Polarimetric (NPOL) Doppler Radar resulted in blockage of the scan sector. The D3R observations are only available from 220 degrees to 120 degrees, as shown in Figure 4. Notable precipitation was observed on 38 of the 53 days of instrument operation with over 180,000 individual scans performed during operation time. More detailed information on the D3R can be found from the sources listed below:

- NASA PMM D3R Documentation
- Chandrasekar et al. (2016)
- Chandrasekar et al. (2010)
- Vega et al. (2010)
- GPM GV L3 Requirements for a Mobile Ka-/Ku-band Radar (2008)

Figure 3: The D3R on its portable trailer during the OLYMPEX field campaign. The smaller (28 inch) antenna is for the Ka-band and the larger (6 ft) antenna is for the Ku-band. (Image source: UW OLYMPEX website)

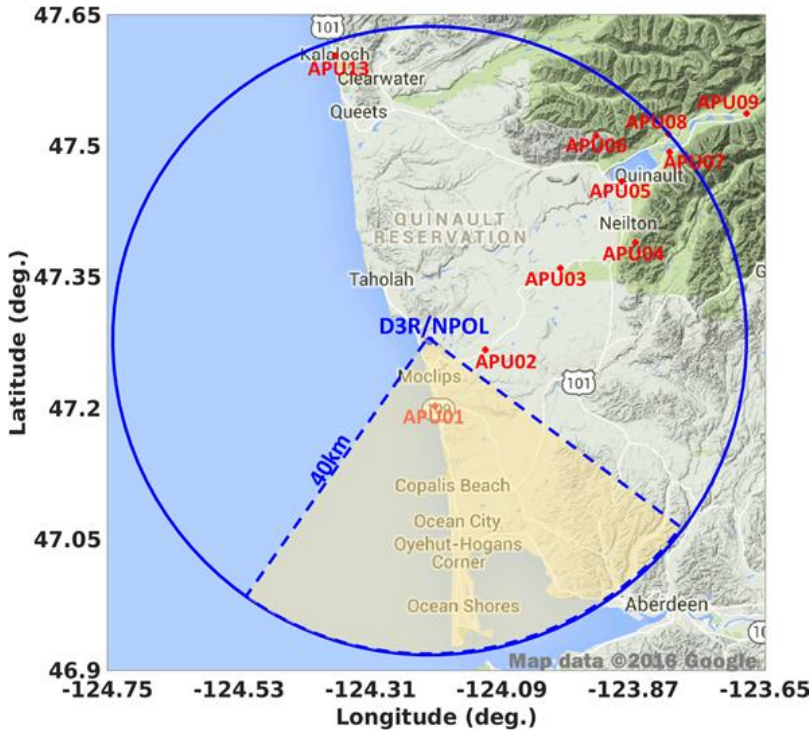

Figure 4: Region of measurement for the OLYMPEX D3R consisted of a sector from 220 degrees to 120 degrees and out to 40 km from the radar location. The Automated Parsival Units (APU) locations are noted in red.
(Image source: Chandrasekar et al., 2016)

Investigators

V. Chandrasekar
Colorado State University
Fort Collins, CO

Manuel Vega
NASA Goddard Space Flight Center
Greenbelt, MD

Data Characteristics

The GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) OLYMPEX dataset consists of radar reflectivity, velocity, differential reflectivity, differential phase, spectrum width, and co-polar correlation data products collected during the OLYMPEX field campaign. For these OLYMPEX D3R dataset files, the ground clutter filter was not enabled therefore, ground clutter will be present in the results. These data are available at a Level 1B processing level in netCDF-4 format along with browse imagery of reflectivity measurements in PNG format. More information about the NASA data processing levels are available on the EOSDIS Data Processing Levels webpage. The characteristics of this dataset are listed in Table 1 below.

Table 1: Data Characteristics

Characteristic	Description
Platform	Ground-based
Instrument	Dual-frequency Dual-Polarized Doppler Radar (D3R)
Spatial Coverage	N: 47.635 , S: 46.920, E: -123.685, W: -124.741 (Olympic Peninsula, Washington)
Spatial Resolution	Measures from 450 m to 39.75 km out from radar location, and -0.5 to 90.0 degrees elevation. Range gates are 150 m starting at 0 m.
Temporal Coverage	November 8, 2015 - January 15, 2016
Temporal Resolution	1 scan per file (each scan takes less than 2 minutes to complete)
Sampling Frequency	1 second
Parameter	Reflectivity, differential reflectivity, copolar correlation coefficient, differential propagation phase, radial velocity, spectrum width
Version	1
Processing Level	1B

File Naming Convention

The GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) OLYMPEX dataset files are named with the following naming convention:

Data files: olympex_d3r_[ku|ka]_YYYYMMDD_hhmmss_<##>.nc
Browse files:
olympex_d3r_[ku|ka]_YYYYMMDD_hhmmss_<##>_[rhi|ppi]_<angle>_<Pol/PRT Mode>_zdb.png

Table 2: File naming convention variables

Variable	Description
[ku|ka]	Frequency setting: Ku (13.91 GHz ± 25 MHz) or Ka (35.56 GHz ± 25 MHz)
YYYY	Four-digit year in UTC
MM	Two-digit month in UTC
DD	Two-digit day in UTC
hh	Two-digit hour in UTC
mm	Two-digit minute in UTC
ss	Two-digit second in UTC
##	Scan number within a volume
[rhi|ppi]	Scan type: “rhi’” for Range Height Indicator scan or “ppi” for Plan Position Indicator scan
angle	Fixed angle of the scan followed by two-letter abbreviation for angle type (az: azimuth for RHI, el: elevation for PPI)

Pol/PRT Mode	Two-digit number where the first number is the polarization mode and the second number is the PRT mode (see Tables 4 and 5)
.nc	netCDF-4 format
.png	Portable Network Graphics format

Data Format and Parameters

The GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) OLYMPEX dataset consists of netCDF-4 data files with each individual file consisting of 1 radar scan. The D3R uses two frequency diverse pulses: a “short” and “medium” pulse. The short pulse is used for the first 23 range gates (up to 3.3 km) while the medium pulse is used for the remaining data. These pulses are denoted by the text “Short” and “Medium” in data variable names. The pulse orientation is indicated by an “H” for horizontal and “V” for vertical. The *RawPower_** variables are the received power without any noise subtraction or manipulation . The *SignalPower_** variables are the power used to estimate reflectivity (without compensation for range or the radar constant). Table 3 lists the primary data fields within each file. Tables 4 through 6 list the values for the “Polarization Mode”, “PRTMode”, and “GcfState” data fields, describing the state of the data. Table 4 describes each value if the polarization mode was passive, horizontal, vertical, alternated, both, or if there was an error. Table 5 describes if the Pulse Repetition Time (PRT) was uniform or staggered. Table 6 described if the ground clutter filter was on or off. More information is available in the CSU D3R OLYMPEX documentation.

Table 3: OLYMPEX D3R netCDF-4 Data Fields

Field Name	Description	Data Type	Unit
Azimuth	Azimuth angle	Double	degrees
Elevation	Elevation angle	Double	degrees
Azimuth_Ray_Start	Azimuth ray starting position	Double	degrees
Azimuth_Ray_End	Azimuth ray ending position	Double	degrees
Elevation_Ray_Start	Elevation ray starting position	Double	degrees
Elevation_Ray_End	Elevation ray ending position	Double	degrees
GateWidth	Gate width	Integer	mm
StartRange	Start range	Double	mm
StartGate	Start gate	Integer	-
Time	Time	Integer	seconds
TxFrequency_Short	Transmitter frequency (short pulse)	Double	Hz
TxFrequency_Medium	Transmitter frequency (medium pulse)	Double	Hz
TxLength_Short	Transmitter pulse length (short pulse)	Double	seconds
TxLength_Medium	Transmitter pulse length (medium pulse)	Double	seconds
TxPowerH_Short	Transmitter horizontal power (short pulse)	Double	dBm

TxPowerH_Medium	Transmitter horizontal power (medium pulse)	Double	dBm
TxPowerV_Short	Transmitter vertical power (short pulse)	Double	dBm
TxPowerV_Medium	Transmitter vertical power (medium pulse)	Double	dBm
NoiseSourcePowerH_Short	Noise source horizontal power (short pulse)	Double	dBu
NoiseSourcePowerV_Short	Noise source vertical power (short pulse)	Double	dBu
StartGate_Short	Start gate (short pulse)	Integer	-
StartGate_Medium	Start gate (medium pulse)	Integer	-
GcfState	Ground clutter filter flag (see Table 6)	Integer	-
PolarizationMode	Polarization mode (see Table 4)	Integer	-
PRTMode	Pulse repetition time mode (see Table 5)	Integer	-
Reflectivity	Reflectivity	Float	dBZ
ReflectivityV	Reflectivity (vertical)	Float	dBZ
ReflectivityHV	Reflectivity (horizontal & vertical)	Float	dBZ
Velocity	Velocity	Float	m/s
SpectralWidth	Spectrum width	Float	m/s
DifferentialReflectivity	Differential reflectivity	Float	dB
DifferentialPhase	Differential phase	Float	degrees
CopolarCorrelation	Co-polar correlation coefficient	Float	-
NormalizedCoherentPower	Normalized coherent power	Float	-
SignalPower_H	Signal power (horizontal)	Float	dBu
SignalPower_V	Signal power (vertical)	Float	dBu
SignalPower_HV	Signal power (horizontal & vertical)	Float	dBu
RawPower_H	Raw power (horizontal)	Float	dBu
RawPower_V	Raw power (vertical)	Float	dBu
RawPower_HV	Raw power (horizontal & vertical)	Float	dBu
Signal+Clutter_to_Noise_H	Signal and clutter-to-noise (horizontal)	Float	dB
ClutterPowerH	Clutter power (horizontal)	Float	dBu
ClutterPowerV	Clutter power (vertical)	Float	dBu

Table 4: "Polarization Mode" states

Value	Description
0	Passive (no transmitter fired)
1	Horizontal only
2	Vertical only

3	Alternate
4	Simultaneous
99	Error

Table 5: “PRTMode” states

Value	Description
0	Uniform PRT
1	Staggered 2/3 PRT

Table 6: “GcfState” states (ground clutter filtering)

Value	Description
0	Off No ground clutter filter used
1	On GMAPTD ground clutter filtering enabled

Note: The ground clutter filter was not applied for this dataset

Algorithm

One of the purposes of D3R in the GPM GV program was to provide validation for spaceborne radar precipitation measurements. Due to hardware limitations on space-based platforms, spaceborne radars have to operate at higher transmission frequencies. Therefore, the ka- and ku-band frequencies used by D3R provide valuable validation measurements for satellite retrieval algorithms. The use of these high frequencies requires additional modifications to standard retrieval methods. For example, D3R provides ground-based statistics for raindrip size distribution (DSD) to help improve satellite DSD retrievals. However, the DSD retrieval algorithms using differential phase shift had to be adjusted for D3R because the instrument’s ka- and ku- bands observe different precipitation signatures and are more affected by attenuation than the more common S- and C- band radars. More information about these algorithm adjustments can be found in Chandrasekar et al. (2010).

Quality Assessment

Co-alignment verification of the D3R from solar observations was performed at 19:27 UTC on November 04, 2015. The solar observations verify that the D3R’s azimuth and elevation are co-aligned to within 0.06 degree in azimuth and 0.03 degrees in elevation. The data need to be corrected for signal attenuation. The latest attenuation correction method is described in Bechini and Chandrasekar (2015). The ground clutter filter was not enabled for these data therefore, ground clutter will be present in the results. Radar reflectivity calibration is expected to be within 1 dB. Additional information on OLYMPEX D3R data quality control is available in the CSU D3R OLYMPEX documentation.

Software

No special software is required to view the netCDF-4 data files; however, NASA's Panoply Data Viewer can be used to easily examine the data.

Known Issues or Missing Data

For these D3R OLYMPEX dataset files, the ground clutter filter was not enabled therefore, ground clutter will be present in the results. If ground clutter filtering is required, it must be requested from the instrument PI.

References

Bechini, R., & Chandrasekar, V. (2015). A semi-supervised robust hydrometeor classification method for dual-polarization radar applications. *Journal of Atmospheric and Oceanic Technology*, *32*, 22-47. https://doi.org/10.1175/JTECH-D-14-00097.1

Chandrasekar, V., Baldini, L., Bharadwaj, N., & Smith, P. (2015). Calibration Procedures for Global Precipitation-Measurement Ground-Validation Radars. *The Radio Science Bulletin*, *355*, 45-73. https://ieeexplore.ieee.org/abstract/document/7909473

Chandrasekar, V., Beauchamp, R. M., Chen, H., Vega, M., Schwaller, M., Willie, D., Dabrowski, A., Kumar, M., Petersen, W., & Wolff, D. (2016). Deployment and performance of the NASA D3R during the GPM OLYMPEx field campaign. *Proceedings of the 36th annual IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*. https://doi.org/10.1109/IGARSS.2016.7729553

Chandrasekar, V., Schwaller, M. R., Vega, M., Carswell, J. R., Mishra, K. V., Meneghini, R. & Nguyen, C. (2010). Scientific and engineering overview of the NASA Dual-Frequency Dual-Polarized Doppler Radar (D3R) system for GPM Ground Validation. *Proceedings of the 30th annual IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*. IEEE. https://doi.org/10.1109/IGARSS.2010.5649440

Colorado State University. (2016). D3R Data Processing for the OLYMPEx Campaign. GHRC. https://ghrc.nsstc.nasa.gov/pub/fieldCampaigns/gpmValidation/olympex/D3R/doc/OLYMPEx_D3R_data_description.pdf

Houze Jr., R. A., McMurdie, L. A., Petersen, W. A., Schwaller, M. R., Baccus, W., Lundquist, J. D., Mass, C. F., Nijssen, B., Rutledge, S. A., Hudak, D. R., Tanelli, S., Mace, G. G., Poellot, M. R., Lettenmaier, D. P., Zagrodnik, J. P., Rowe, A. K., DeHart, J. C., Madaus, L. E., Barnes, H. C., & Chandrasekar, V. (2017). The Olympic Mountains Experiment (OLYMPEX). *Bulletin of the American Meteorological Society*, *98(10)*, 2167-2188. https://doi.org/10.1175/BAMS-D-16-0182.1

Vega, M., Carswell, J. R., Chandrasekar, V., Schwaller, M. R. & Mishra, K. V. (2010). Realization of the NASA Dual-Frequency Dual-Polarized Doppler Radar (D3R). *Proceedings* *of the 30th annual IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*. IEEE. https://doi.org/10.1109/IGARSS.2010.5653929

Related Data

All data collected during the OLYMPEX field campaign should be considered related data sets. Those data can be located using the GHRC Hydro 2.0 search tool and searching the term "OLYMPEX". In addition, the D3R was used in other GPM GV field campaigns. These GPM GV D3R datasets are listed below:

GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) ICE POP dataset (http://dx.doi.org/10.5067/GPMGV/ICEPOP/D3R/DATA101)

GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) IPHEx dataset (http://dx.doi.org/10.5067/GPMGV/IPHEX/D3R/DATA101)

GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) IFloodS dataset (http://dx.doi.org/10.5067/GPMGV/IFLOODS/D3R/DATA101)

GPM Ground Validation Dual-frequency Dual-polarized Doppler Radar (D3R) GCPEx and IFloodS data sets (http://dx.doi.org/10.5067/GPMGV/GCPEX/D3R/DATA101)

Contact Information

To obtain these data, visit the GHRC web site. For further information, please contact:

NASA Global Hydrometeorology Resource Center DAAC
User Services
320 Sparkman Drive
Huntsville, AL 35805
Phone: 256-961-7932
E-mail: support-ghrc@earthdata.nasa.gov
Web: https://ghrc.nsstc.nasa.gov/

Created: 03/30/17
Updated: 07/19/21