Data User Guide

GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX Radar Data

Introduction

The GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX dataset was obtained by a dual-polarization and dual-frequency X-band mobile radar operated by the Center for Severe Weather Research (CSWR) during the Olympic Mountain Experiment (OLYMPEX) campaign. The DOW was deployed in the Chehalis Valley for the OLYMPEX field campaign with the goal of obtaining radar reflectivity observations of precipitation in order to better understand the orographic enhancement of precipitation during frontal passages over mountain ranges. The DOW radar uses two 250 kW transmitters with a measurement range of roughly 60 km. CF-Radial data files are available from 06 November 2015 to 15 January 2016 in the netCDF-4 file format. There is 1 radar volume per file representing 10 minutes of data.

Notice:
Due to a discrepancy between DOW and the NASA S-Band Dual Polarimetric doppler radar (NPOL), which was also used in the OLYMPEX campaign, an investigation to determine the appropriate calibration method is underway and a new version will be released at a later date. For more information, refer to the Known Issues or Mission Data section at the end of this user guide.

Citation

Houze, Robert A., Joshua Wurman, Stacy Brodzik, and Andrew Frambach. 2017. GPM Ground Validation Doppler on Wheels[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/DOW/DATA101

Keywords:

NASA, GPM, OLYMPEX, radar, radar reflectivity, precipitation, radar return power, doppler velocity, RHI, PPI, differential reflectivity, X-band

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)

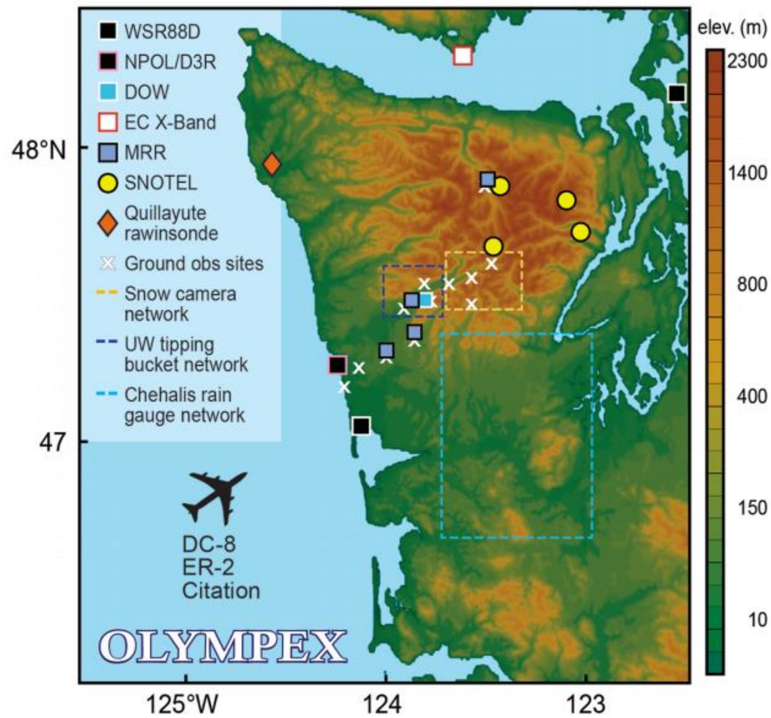

Figure 2: OLYMPEX Field Locations
(Image Source: https://pmm.nasa.gov/OLYMPEX)

Instrument Description

The Doppler on Wheels (DOW) consists of a dual-frequency X-band doppler radar mounted on a 7500 series International Workstar truck. The truck can be moved and positioned to study locations. For OLYMPEX, it was placed at 47.48 N, 123.86W, in the Chehalis valley (see Figure 2) on the shore of Lake Quinault, Washington. The DOW6 radar was used for OLYMPEX. DOW is operated by the Center for Severe Weather Research (CSWR). The DOW radar reflectivity and doppler velocity is used to study 3D wind and precipitation characteristics of storms. The rapidly deployable mobile radar has dual-250 kW transmitters for high sensitivity to clear radar returns and can be set in place for long term monitoring of storm systems. In addition, the X-band, 3 cm, 9 GHz transmissions are able to penetrate through intense precipitation conditions and return moderately high resolution differential reflectivity at an operational range of nearly 60 km. Table 1 contains additional information regarding the instrument characteristics.

These Cfradial-type data files were produced in netCDF-4 file format from dorade (sweep) files (using NCAR's RadxConvert program) that were produced from the raw I&Q time series data files collected during OLYMPEX. Upon request, the I&Q raw data can be made available from the PIs. The DOW6 used in OLYMPEX uses two independent transmitters with “high” (9.55 GHz) and “low” (9.40 GHz) frequencies; files are segregated/named accordingly. Either frequency can be used for analysis. After November 12, 2015, only the “low” frequency measurements are available. RHI volume scans contain scans at 22 azimuths, between 50.4 and 71.4 degrees. Sector PPI volume scans contain scans at six elevations between 2.8 and 11.0 degrees with azimuths ranging from 39.2 to 83.6 degrees.

General information about DOW is at http://www.cswr.org/contents/aboutdows.php. More information about the DOW radar can be found at the CSWR site (https://www.eol.ucar.edu/observing_facilities/dow) and https://www.eol.ucar.edu/system/files/brochures/observing_facility/DOW/DOW_LAOF_brochure_2013_web.pdf
Additional information about the DOW involvement in OLYMPEX is at the National Center for Atmospheric Researcher's Earth Observation Laboratory site (https://www.eol.ucar.edu/field_projects/olympex) as well as from Houze et al. 2017.

Table 1: Instrument Characteristics

Characteristic	Value
Pulse Repetition Frequency	1666/2500 stagger
Nyquist Frequency	39.87 m/s
Range	59.96 km
Gate Length	75 m
Pulse Length	500 ns
Beam Width	0.93 degrees
Beam Indexing	0.25 degrees

Figure 3: Doppler on Wheels (DOW) Mobile Radar Instrument in the field during OLYMPEX. Image Source: (http://olympex.atmos.washington.edu/Photos.html)

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Data Characteristics

The GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX radar data are available in netCDF-4 file format at a Level 2 processing level. For more information regarding NASA data processing levels, refer to this link. Table 2 outlines some key characteristics about these DOW data files.

Table 2: Data Characteristics

Characteristic	Description
Platform	Ground-based radar on a 7500 series International Workstar Truck
Instrument	DOW6 Dual-Frequency (2 x 250 kW), dual-polarization, X-band mobile radar
Projection	N/A
Spatial Coverage	DOW6 is positioned at N: 47.488456; W123.869193 (Lake Quinault, Washington) The instrument measures a region of: N: 48.0270599149; S: 46.9498535372 E: -123.330590842; W: -124.40779722
Spatial Resolution	59.96 km
Temporal Coverage	November 6, 2015 - January 15, 2016
Temporal Resolution	Full 360-degree scans were collected every 10 minutes. Two RHI volumes files and one PPI sector volume file recorded.
Sampling Frequency	Varies: Less than 5 miliseconds
Parameter	Radar reflectivity, doppler velocity
Version	Version 1
Processing Level	Level 2

File Naming Convention

The GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX dataset contains radar reflectivity data and associated calibration information for the DOW6 instrument. Vertical radar height indicator (RHI) and horizontal plan position indicator (PPI) volume scans are also segregated in separate folders named accordingly. Files are organized as one radar volume per file. A radar volume is 10 minutes of data. Table 2 shows the file naming convention for DOW data.

Data files:
olympex_dow6_cfrad.<start date>_<start time>_to_<end date>_<end time>_<radar>_v<volume number>_<scan type>.nc

Table 2: File naming convention variables for data files

Variable	Description
<start date> <end date>	Start/End date in YYYYMMDD where, YYYY: Four-digit year MM: Four-digit month DD: Four-digit day
<start time> <end time>	Start/End time of measurement in UTC in hhmmss.*** where, hh: two-digit hour mm: two-digit minute ss: two-digit second ***: three-digit millisecond
<radar>	hi: high frequency data lo: low frequency data
<volume number>	Four-digit sequential volume number for the during OLYMPEX
<scan type>	rhi=Radar Height Indicator (RHI): Vertical volume scan ppi = Plan Position Indicator (PPI): Horizontal volume scan
.nc	netCDF-4 file extension

Data Format and Parameters

The GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX radar dataset contains cfradial radar data in netCDF-4 file format and contains both volume radar reflectivity data and instrument calibration information. Several measured parameters received an adaptive clutter filtering and are named accordingly in the dataset. The measured differential reflectivity (ZDRM) is the directly measured parameter but has been corrected with an expected offset by the data provider and a new data field created called "corrected differential reflectivity" (ZDRC). This correction process is described in more detail in the Quality Assessment section of this user guide. Table 3 below outlines the parameters and associated scaling factors found in the OLYMPEX DOW6 dataset.

RHI volume scans contain scans at 22 azimuths, one for every degree between starting at 50.4 and ending at 71.4 degrees, with elevations ranging from 0 degrees to 71 degrees. PPI sector volume scans contain scans at six elevations: 2.8, 3.0, 5.0, 7.0, 9.0, and 11.0 degree. PPI sector volume scans are taken at a with azimuths ranging from approximately 39.2 to 83.6 degrees.

Table 3: Data Fields

Field Name	Description	Unit
altitude	Altitude	meters
altitude_agl	Altitude Above Ground Level	meters
altitude_correction	Altitude Correction	meters
antenna_transition	Antenna is in transition between sweeps	N/A
azimuth	Ray Azimuth Angle	degrees
azimuth_correction	Azimuth Angle Correction	degrees
DBMHC	Received power horizontal channel	dBm
DBMVC	Received power vertical channel	dBm
DBZHC	Equivalent reflectivity factor horizontal channel	dBZ
DBZHC_F	Equivalent reflectivity factor horizontal channel clutter filter	dBZ
DBZVC	Equivalent reflectivity factor vertical channel	dBZ
DBZVC_F	Equivalent reflectivity factor vertical channel clutter filter	dBZ
drift_correction	Platform drift angle correction	dBZ
eastward_velocity_correction	Platform eastward velocity correction	m/s
elevation	Ray elevation angle	Degrees
elevation_correction	Ray elevation angle correction	Degrees
fixed_angle	Ray target fixed angle	Degrees
follow_mode	Follow mode for scan strategy (none, sun, vehicle, aircraft, target, manual)	-
frequency	Transmission frequency	s-1
georef_time	Georeference time in seconds since volume start	seconds
georefs_applied	Georeference corrections have been applied to ray	seconds
grid_mapping	Grid mapping radar/lidar radial scan	-
heading	Platform heading angle	degrees
heading_correction	Platform heading angle correction	degrees
instrument_type	Type of instrument (radar/lidar)	-
KDP	Specific differential phase	Deg/km
KDP_F	Specific differential phase clutter filtered	Deg/km
latitude	Latitude	Degrees north
latitude_correction	Latitude correction	Degrees
longitude	Longitude	Degrees_ east
longitude_correction	Longitude correction	Degrees
measured_transmit_power_h	Measured radar transmit power of horizontal (h) channel	dBm
measured_transmit_power_v	Measured radar transmit power of vertical (v) channel	dBm
n_samples	Number of samples used to compute moments	N/A
NCP	Normalized coherent power	N/A
northward_velocity_correction	Platform northward velocity correction	m/s
nyquist_velocity	Unambiguous doppler velocity	m/s
PHIDP	Differential phase shift	Degrees
PHIDP_F	Differential phase shift clutter filtered	Degrees
pitch_correction	Platform pitch angle correction	Degrees
platform_type	Platform Type (vehicle)	N/A

polarization_mode	Polarization mode for sweep (horizontal, vertical, hv_alt, hv_sim, circular)	N/A
pressure_altitude_correction	Pressure altitude correction	Meters
primary_axis	Primary axis of rotation (axis_z, axis_y, axis_x, axis_z_prime, axis_y_prime, axis_x_prime)	N/A
prt	Pulse repetition time	Seconds
prt_mode	Transmit pulse mode (fixed, staggered, dual)	N/A
prt_ratio	Pulse repetition frequency ratio	Seconds
pulse_width	Transmitter pulse width	Seconds
r_calib_antenna_gain_h	Calibrated radar antenna gain horizontal (h) channel	db
r_calib_antenna_gain_v	Calibrated radar antenna gain vertical (v) channel	db
r_calib_base_dbz_1km_hc	Radar reflectivity at 1km at zero snr horizontal co polar channel	dBZ
r_calib_base_dbz_1km_hx	Radar reflectivity at 1km at zero snr horizontal (h) cross polar channel	dBZ
r_calib_base_dbz_1km_vc	Radar reflectivity at 1km at zero snr vertical (v) co polar channel	dBZ
r_calib_base_dbz_1km_vx	Radar reflectivity at 1km at zero snr vertical (v) cross polar channel	dBZ
r_calib_coupler_forward_loss_h	Radar calibration coupler forward loss horizontal (h) channel	dBZ
r_calib_coupler_forward_loss_v	Radar calibration coupler forward loss vertical (v) channel	db
r_calib_dbz_correction	Calibrated radar dbz correction	db
r_calib_index	Calibration data array index per ray. Note: “This is the index for the calibration which applies to this ray.”	N/A
r_calib_ldr_correction_h	Calibrated radar ldr correction horizontal (h) channel	db
r_calib_ldr_correction_v	Calibrated radar ldr correction vertical (v) channel	db
r_calib_noise_hc	Calibrated radar receiver noise horizontal (h) co polar channel	dBm
r_calib_noise_hx	Calibrated radar receiver noise horizontal (h) cross polar channel	dBm
r_calib_noise_source_power_h	Radar calibration noise source power horizontal (h) channel	dBm
r_calib_noise_source_power_v	Radar calibration noise source power vertical (v) channel	dBm
r_calib_noise_vc	Calibrated radar receiver noise vertical (v) co polar channel	dBm
r_calib_noise_vx	Calibrated radar receiver noise vertical (v) co polar channel	dBm
r_calib_power_measure_loss_h	Radar calibration power measurement loss horizontal (h) channel	db
r_calib_power_measure_loss_v	Radar calibration power measurement loss vertical (v) channel	db
r_calib_pulse_width	Radar calibration pulse width	seconds
r_calib_radar_constant_h	Calibrated radar constant horizontal (h) channel	db
r_calib_radar_constant_v	Calibrated radar constant vertical (v) channel	db
r_calib_receiver_gain_hc	Calibrated radar receiver gain horizontal (h) co polar channel	db
r_calib_receiver_gain_hx	Calibrated radar receiver gain horizontal (h) cross polar channel	db
r_calib_receiver_gain_vc	Calibrated radar receiver gain vertical (v) co polar channel	db
r_calib_receiver_gain_vx	Calibrated radar receiver gain vertical (v) cross polar channel	db
r_calib_receiver_mismatch_loss	Radar calibration receiver mismatch loss	db
r_calib_receiver_slope_hc	Calibrated radar receiver slope horizontal (h) co polar channel	N/A
r_calib_receiver_slope_hx	Calibrated radar receiver slope horizontal (h) cross polar channel	N/A
r_calib_receiver_slope_vc	Calibrated radar receiver slope vertical (v) co polar channel	N/A
r_calib_receiver_slope_vx	Calibrated radar receiver slope vertical (v) cross polar channel	N/A
r_calib_sun_power_hc	Calibrated radar sun power horizontal (h) co polar channel	dBm
r_calib_sun_power_hx	Calibrated radar sun power horizontal (h) cross polar channel	dBm
r_calib_sun_power_vc	Calibrated radar sun power vertical (v) co polar channel	dBm
r_calib_sun_power_vx	Calibrated radar sun power vertical (v) cross polar channel	dBm
r_calib_system_phidp	Radar system Differential Phase Calibration (PhiDP)	Degrees
r_calib_test_power_h	Radar calibration test power horizontal (h) channel	dBm
r_calib_test_power_v	Radar calibration test power vertical (v) channel	dBm
r_calib_time	Radar calibration time (UTC)	N/A
r_calib_two_way radome_loss_h	Radar calibration two way radome loss horizontal (h) channel	db
r_calib_two_way radome_loss_v	Radar calibration two way radome loss vertical (v) channel	db
r_calib_two_way_waveguide_loss_h	Radar calibration two way waveguide loss horizontal (h) channel	db

r_calib_two_way_waveguide_loss_v	Radar calibration two way waveguide loss vertical (v) channel	db
r_calib_xmit_h	Calibrated radar transmit (XMIT) power horizontal (h) channel	dBm
r_calib_xmit_v	Calibrated radar transmit (XMIT) power vertical (v) channel	dBm
r_calib_zdr_correction	Calibrated radar differential reflectivity (ZDR) correction	dBm
radar_antenna_gain_h	Nominal radar antenna gain horizontal (h) channel	db
radar_antenna_gain_v	Nominal radar antenna gain vertical (v) channel	db
radar_beam_width_h	Half power radar beam width horizontal (h) channel	Degrees
radar_beam_width_v	Half power radar beam width vertical (v) channel	Degrees
radar_rx_bandwidth	Radar receiver bandwidth	1/s
range	Range from instrument to center of gate. For this instrument, meters to center of first range gate ~37.474 meters. Meters between subsequent gates ~74.947 meters.	Meters
range_correction	Range to center of measurement volume correction	Meters
ray_angle_res	Angular resolution between rays	Degrees
ray_gate_spacing	Gate spacing for ray	Meters
ray_start_range	Start range for ray	Meters
rays_are_indexed	Flag for indexed rays	N/A
RHOHV	Correlation coefficient (Rho). This is a statistical correlation between the reflected horizontal and vertical power returns. It is a good indicator of regions where there is a mixture of precipitation types, such as rain and snow (https://www.nssl.noaa.gov/projects/q2/tutorial/dualpol.php)	N/A
RHOHV_F	Correlation coefficient (Rho) clutter filtered.	N/A
roll_correction	Platform roll angle correction	Degrees
rotation_correction	Ray rotation angle relative to platform correction	Degrees
scan_rate	Antenna angle scan rate	Degrees per second
SNRHC	Signal to noise ratio horizontal (h) channel	dB
SNRVC	Signal to noise ratio vertical (v) channel	dB
status_xml	Status of instrument	N/A
sweep_end_ray_index	Index of last ray in sweep	N/A
sweep_mode	Scan mode for sweep (sector, coplane, rhi, vertical_pointing, idle, azimuth_surveillance, elevation_surveillance, sunscan, pointing, calibration, manual_ppi, manual_rhi, sunscan_rhi)	N/A
sweep_number	Sweep index number (0 based)	N/A
sweep_start_ray_index	Index of first ray in sweep	N/A
target_scan_rate	Target scan rate for sweep	Degrees per second
tilt_correction	Ray tilt angle relative to platform correction	Degrees
time	Time in seconds since volume start. Note: Times are relative to the volume start time)	Seconds since 2015-11-06T13:48:17Z
time_coverage_end	Data volume end time (UTC)	N/A
time_coverage_start	Data volume start time (UTC). Note: Ray times are relative to start time in seconds	N/A
TRIP_FLA	Second trip detection	Time range
unambiguous_range	Unambiguous range between sweep echos (instrument parameter)	Meters
VEL	Doppler velocity	m/s
VEL_F	Doppler velocity clutter filtered	m/s

vertical_velocity_correction	Platform vertical velocity correction	m/s
VL	Doppler velocity long pulse	m/s
volume_number	Data volume index number	N/A
VS	Doppler velocity short pulse	m/s
WIDTH	Spectrum width	m/s
WIDTH_F	Spectrum width clutter filtered	m/s
WIDTH_LO	Spectrum width long pulse	m/s
WIDTH_LO_F	Spectrum width long pulse clutter filtered	m/s
WIDTH_SH	Spectrum width short pulse	m/s
WIDTH_SH_F	Spectrum width short pulse clutter filtered	m/s
ZDRC	Offset correction differential reflectivity	dB
ZDRM	Measured differential reflectivity	dB
ZDRF	Measured differential reflectivity clutter filtered	dB

Algorithm and Quality Assessment

In light to moderate rainfall, the measured differential reflectivity (ZDRM) distribution should be 0 dB, since falling drops will appear circular to a radar pointing vertically. However, an offset from 0 dB exists in the dataset due to some inconsistencies in the transmitters. The negative of the offset was added to the ZDRM values, and a new field was created containing the offset corrected differential reflectivity (ZDRC) and is expected to be used for any scientific analysis rather than the directly measured values. The offset values were determined by creating histograms of the ZDRM for each scan omitting values based on known inconsistencies in the transmitters. For instance: no ZDRM values with an equivalent reflectivity factor from the horizontal channel (DBZHC) lower than 10 dBZ were included; no ZDRM values with a correlation coefficient between the horizontal and vertical channels (RHOHV) less than 0.97 or greater than 1.0 were included; no ZDRM values were included that fell within the 1.2-2.2 km of the DOW range. The peak of the normal distribution of the ZDRM histograms were used as the offset for that scan, e.g. all ten minutes. Abnormally high or low values were omitted from the dataset and where no offset could be determined, a default offset of 0 dB was used. Refer to the PI readme.txt file located in the "doc" folder in the [GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX radar dataset directory]for further information regarding the offset correction process.

Software

This dataset is in netCDF-4 format and does not require any specific software to read. However, the data is easily readable and viewed in [Panoply].

Known Issues or Missing Data

Latitude and longitude values were taken with GPS at the beginning of the campaign, while altitude (plus three meters to accommodate ground to antenna height) was determined using Google Earth elevation layers. Instrument heading were obtained from a solar alignment conducted on November 3, 2015. However, on December 8, 2015 the truck and instrument heading was changed and a new heading was determined. GPS position and altitude information is included in the header file of the Cfradial files. More information can be found in the readme.txt file located in the dataset directory.

There is a consistent discrepancy between the reflectivity data observed by DOW and the NASA S-Band Dual Polarimetric (NPOL) Doppler Radar also deployed during the OLYMPEX campaign. The reflectivity bias is on the order of -4.5 dB. Therefore, the reflectivity values in this dataset are to be used with caution and will be updated with a new version of the dataset once the investigation into the calibration is complete. Refer to the PI readme.txt file located in the "doc" folder in the GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX radar dataset directory for further information regarding the reflectivity bias.

References

About the DOWs Center for Severe Weather Research. Retrieved from http://www.cswr.org/contents/aboutdows.php

Doppler On Wheels (DOW) Earth Observing Laboratory. Retrieved from https://www.eol.ucar.edu/observing_facilities/dow

DOW Center for Severe Weather Research. Retrieved from http://www.cswr.org/contents/dow6specs.php#schematics

Houze, R., L. McMurdie, W. Petersen, et al. (2017): The Olympic Mountains Experiment (OLYMPEX). American Meteorological Society, Bulletin of the American Meteorological Society. doi:https://dx.doi.org/10.1175/BAMS-D-16-0182.1

Related Data

All data from other instruments collected during the OLYMPEX field campaign are related to this dataset. Other OLYMPEX campaign data can be located using the GHRC HyDRO 2.0 search tool.

In particular, the GPM Ground Validation NASA S-Band Dual Polarimetric (NPOL) Doppler Radar OLYMPEX V2 dataset used during the OLYMPEX campaign that was also a doppler radar (http://dx.doi.org/10.5067/GPMGV/OLYMPEX/NPOL/DATA301).

Other field campaigns that deployed mobile radar can also serve as related data. For instance the Convection and Moisture Experiment (CAMEX-4) Mobile X-band Polarimetric Radar dataset (http://dx.doi.org/10.5067/CAMEX-4/XBAND/DATA101)

Contact Information

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

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