Global Hydrology Resource Center

Data User Guide

GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX V2

Introduction

The GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX V2 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 and Doppler velocity observations 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. These data are available in CFradial netCDF-4 format from November 6, 2015 through January 15, 2016.

Notice: This new version of DOW OLYMPEX data was created due to a discrepancy between DOW and the NASA S-Band Dual Polarimetric Doppler radar (NPOL), which was also used in the OLYMPEX field campaign. A new and more appropriate calibration method was determined and the data were reprocessed.

Citation

Houze, Jr., Robert A., Joshua Wurman, Stacy Brodzik, and Andrew Frambach. 2018. GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX V2 [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/DATA201

Keywords

NASA, GPM, OLYMPEX, Washington, radar, precipitation, radar return power, RHI, PPI, differential reflectivity, X-band, DOW, Doppler on Wheels, radar reflectivity, Doppler velocity, differential phase, correlation coefficient

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 mid-latitude 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, http://dx.doi.org/10.5067/GPMGV/OLYMPEX/DATA101, and the University of Washington OLYMPEX web site http://olympex.atmos.washington.edu/.

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

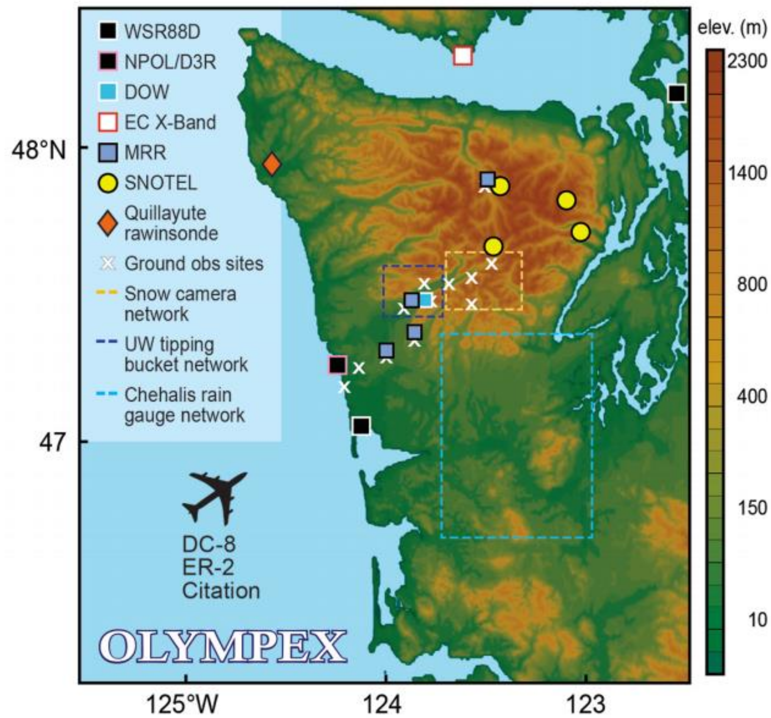

Figure 2: OLYMPEX Field Locations
(Image Source: https://pmm.nasa.gov/OLYMPEX)

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 measurements are 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 in netCDF-4 file format were produced 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. Vertical Radar Height Indicator (RHI) volume scans contain scans at 22 azimuths, between 50.4 and 71.4 degrees. Horizontal Plan Position Indicator (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 on the Center for Severe Weather Website. More information about the DOW radar can be found at the CSWR website. Additional information about the DOW involvement in OLYMPEX is at the National Center for Atmospheric Researcher's Earth Observation Laboratory website and 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 V2 radar data are available in CFradial netCDF-4 file format at a Level 2 processing level from November 6, 2015 through January 15, 2016. More information about the NASA data processing levels are available on the NASA Data Processing Levels website. Table 2 shows the characteristics of the data file.

Table 2: Data Characteristics

Characteristic	Description
Platform	Ground-based radar on a 7500 series International Workstar Truck
Instrument	Doppler on Wheels (DOW) Dual-Frequency (2 x 250 kW), dual-polarization, X-band mobile radar
Projection	Azimuthal equidistant
Spatial Coverage	N: 48.027, S: 46.950, E: -123.331, W: -124.408 (Washington)
Spatial Resolution	59.96 km
Temporal Coverage	November 6, 2015 - January 15, 2016
Temporal Resolution	<10 minutes
Sampling Frequency	<5 milliseconds
Parameter	Radar reflectivity, Doppler velocity, differential phase, correlation coefficient
Version	2
Processing Level	2

File Naming Convention

The GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX V2 dataset has the file naming convention shown below. These data are available in CFradial netCDF-4 file format.

Data files: olympex_dow6_cfrad_<start>_to_<end>_v####_<scan>_[lo|hi].nc

Table 3: File naming convention variables

Variable	Description
<start>	Start date and time of data collection YYYYMMDD_hhmmss.*** YYYY: Four-digit year MM: Two-digit month DD: Two-digit day hh: Two-digit hour in UTC mm: Two-digit minute in UTC ss: Two-digit second in UTC ***: Three-digit milliseconds
<end>	End date and time of data collection YYYYMMDD_hhmmss.***
v####	Four-digit sequential volume number
<scan>	rhi: Radar Height Indicator (RHI) vertical volume scan ppi: Plan Position Indicator (PPI) horizontal volume scan
[lo|hi]	lo: low frequency data hi: high frequency data
.nc	CFradial netCDF-4 data format

Data Format and Parameters

The GPM Ground Validation Doppler on Wheels (DOW) OLYMPEX V2 dataset contains radar reflectivity data, Doppler velocity data, and associated calibration information for the DOW instrument. RHI and PPI volume scans are also segregated in separate folders named accordingly. Files are organized as one radar volume per file and are available in CFradial netCDF-4 format. Table 4 lists and describes the parameters and associated scaling factors for this dataset.

The RHI files contains scans at 22 azimuths, one for every degree between 50.4 degrees and 71.4 degrees, with elevations ranging from 0 degrees through 71 degrees. PPI files contain scans at 6 different elevations: 2.8, 3.0, 5.0, 7.0, 9.0, and 11.0 degrees. These PPI files are taken at azimuths ranging from 39.2 to 93.6 degrees.

Table 4: Data Fields

Field Name	Description	Data Type	Unit
altitude	Altitude	double	m
altitude_agl	Altitude above ground level	double	m
altitude_correction	Altitude correction	float	m
antenna_transition	Antenna is in transition between sweeps 1: antenna is in transition	byte	-

	0: otherwise		
azimuth	Ray azimuth angle	float	degrees
azimuth_correction	Azimuth angle correction	float	degrees
DBMHC	Received power horizontal channel	short	dBm
DBMVC	Received power vertical channel	short	dBm
DBZHC	Equivalent reflectivity factor horizontal channel	short	dBZ
DBZHC_F	Equivalent reflectivity factor horizontal channel clutter filtered	short	dBZ
DBZHCC	Equivalent reflectivity factor horizontal channel with calibration offset	short	dBZ
DBZHCC_F	Equivalent reflectivity factor horizontal channel with calibration offset clutter filtered	short	dBZ
DBZVC	Equivalent reflectivity factor vertical channel	short	dBZ
DBZVC_F	Equivalent reflectivity factor vertical channel clutter filtered	short	dBZ
drift_correction	Platform drift angle correction	float	degrees
eastward_velocity_correction	Platform eastward velocity correction	float	m/s
elevation	Ray elevation angle	float	degrees
elevation_correction	Ray elevation angle correction	float	degrees
fixed_angle	Ray target fixed angle	float	degrees
follow_mode	Follow mode for scan strategy: none, sun, vehicle, aircraft, target, manual	char	-
frequency	Transmission frequency	float	s^{-1}
georef_time	Georeferenced time in seconds since volume start	double	s
georefs_applied	1: georefs have been applied 0: otherwise	byte	-
grid_mapping	Projection. azimuthal_equidistant	int	-
heading	Platform heading angle	float	degrees
heading_correction	Platform heading angle correction	float	degrees
instrument_type	Type of instrument: radar, lidar	char	-
KDP	Specific differential phase	short	deg/km
KDP_F	Specific differential phase clutter filtered	short	deg/km
latitude	Latitude	double	Degrees North
latitude_correction	Latitude correction	float	degrees
longitude	Longitude	double	Degrees East
longitude_correction	Longitude correction	float	degrees

measured_transmit_power_h	Measured radar transmit power horizontal channel	float	dBm
measured_transmit_power_v	Measured radar transmit power vertical channel	float	dBm
n_sample	Number of sampled used to compute moments	int	-
NCP	Normalized coherent power	short	-
northward_velocity_correction	Platform northward velocity correction	float	m/s
nyquist_velocity	Unambiguous Doppler velocity	float	m/s
PHIDP	Differential phase shift	short	degrees
PHIDP_F	Differential phase shift clutter filtered	short	degrees
pitch_correction	Platform pitch angle correction	float	degrees
platform_type	Platform type: fixed, vehicle, ship, aircraft_fore, aircraft_aft, aircraft_tail, aircraft_belly, aircraft_roof, aircraft_nose, satellite_orbit, satellite_geostat	char	-
polarization_mode	Polarization mode for sweep: horizontal, vertical, hv_alt, hv_sim, circular	char	-
pressure_altitude_correction	Pressure altitude correction	float	m
primary_axis	Primary axis of rotation: axis_z, axis_y, axis_x, axis_z_prime, axis_y_prime, axis_x_prime	char	-
prt	Pulse repetition time	float	s
prt_mode	Transmit pulse mode: fixed, staggered, dual	char	-
prt_ratio	Pulse repetition frequency ratio	float	s
pulse_width	Transmitter pulse width	float	s
r_calib_antenna_gain_h	Calibrated radar antenna gain horizontal channel	float	db
r_calib_antenna_gain_v	Calibrated radar antenna gain vertical channel	float	db
r_calib_base_dbz_1km_hc	Radar calibration. Radar reflectivity at 1km at zero signal-to-noise ratio horizontal co-polar channel	float	dBZ
r_calib_base_dbz_1km_hx	Radar calibration. Radar reflectivity at 1 km at zero signal-to-noise ratio horizontal cross-polar channel	float	dBZ
r_calib_base_dbz_1km_vc	Radar calibration. Radar reflectivity at 1km at zero signal-to-noise ratio vertical co-polar channel	float	dBZ
r_calib_base_dbz_1km_vx	Radar calibration. Radar reflectivity	float	dBZ

	at 1km at zero signal-to-noise ratio vertical cross-polar channel		
r_calib_coupler_forward_loss_h	Radar calibration coupler forward loss horizontal channel	float	db
r_calib_coupler_forward_loss_v	Radar calibration coupler forward loss vertical channel	float	db
r_calib_dbz_correction	Calibrated radar dBZ correction	float	db
r_calib_index	This is the index for the calibration which applies to this ray	int	-
r_calib_ldr_correction_h	Calibrated radar LDR correction horizontal channel	float	db
r_calib_ldr_correction_v	Calibrated radar LDR correction vertical channel	float	db
r_calib_noise_hc	Calibrated radar receiver noise horizontal co-polar channel	float	dBm
r_calib_noise_hx	Calibrated radar receiver noise horizontal cross-polar channel	float	dBm
r_calib_noise_source_power_h	Radar calibration noise source power horizontal channel	float	dBm
r_calib_noise_source_power_v	Radar calibration noise source power vertical channel	float	dBm
r_calib_noise_vc	Calibrated radar receiver noise vertical co-polar channel	float	dBm
r_calib_noise_vx	Calibrated radar receiver noise vertical cross-polar channel	float	dBm
r_calib_power_measure_loss_h	Radar calibration power measurement loss horizontal channel	float	db
r_calib_power_measure_loss_v	Radar calibration power measurement loss vertical channel	float	db
r_calib_pulse_width	Radar calibration pulse width	float	s
r_calib_radar_constant_h	Calibrated radar constant horizontal channel	float	db
r_calib_radar_constant_v	Calibrated radar constant vertical channel	float	db
r_calib_receiver_gain_hc	Calibrated radar receiver gain horizontal co-polar channel	float	db
r_calib_receiver_gain_hx	Calibrated radar receiver gain horizontal cross-polar channel	float	db
r_calib_receiver_gain_vc	Calibrated radar receiver gain vertical co-polar channel	float	db
r_calib_receiver_gain_vx	Calibrated radar receiver gain vertical cross-polar channel	float	db
r_calib_receiver_mismatch_loss	Radar calibration receiver mismatch loss	float	db

r_calib_receiver_slope_hc	Calibrated radar receiver slope horizontal co-polar channel	float	-
r_calib_receiver_slope_hx	Calibrated radar receiver slope horizontal cross-polar channel	float	-
r_calib_receiver_slope_vc	Calibrated radar receiver slope vertical co-polar channel	float	-
r_calib_receiver_slope_vx	Calibrated radar receiver slope vertical cross-polar channel	float	-
r_calib_sun_power_hc	Calibrated radar sun power horizontal co-polar channel	float	dBm
r_calib_sun_power_hx	Calibrated radar sun power horizontal cross-polar channel	float	dBm
r_calib_sun_power_vc	Calibrated radar sun power vertical co-polar channel	float	dBm
r_calib_sun_power_vx	Calibrated radar sun power vertical cross-polar channel	float	dBm
r_calib_system_phidp	Calibrated radar system PHIDP	float	degrees
r_calib_test_power_h	Radar calibration test power horizontal channel	float	dBm
r_calib_test_power_v	Radar calibration test power vertical channel	float	dBm
r_calib_time	Radar calibration time UTC	char	-
r_calib_two_way_radome_loss_h	Radar calibration two way radome loss horizontal channel	float	db
r_calib_two_way_radome_loss_v	Radar calibration two way radome loss vertical channel	float	db
r_calib_two_way_waveguide_loss_h	Radar calibration two way waveguide loss horizontal channel	float	db
r_calib_two_way_waveguide_loss_v	Radar calibration two way waveguide loss vertical channel	float	db
r_calib_xmit_power_h	Calibrated radar xmit power horizontal channel	float	dBm
r_calib_xmit_power_v	Calibrated radar xmit power vertical channel	float	dBm
r_calib_zdr_correction	Calibrated radar ZDR correction	float	db
radar_antenna_gain_h	Nominal radar antenna gain horizontal channel	float	db
radar_antenna_gain_v	Nominal radar antenna gain vertical channel	float	db
radar_beam_width_h	Half power radar beam width horizontal channel	float	degrees
radar_beam_width_v	Half power radar beam width vertical channel	float	degrees
radar_rx_bandwidth	Radar receiver bandwidth	float	s^{-1}
range	Range from instrument to center of	float	m

	gate		
range_correction	Range to center of measurement volume correction	float	m
ray_angle_res	Angular resolution between rays	float	degrees
ray_gate_spacing	Gate spacing for ray	float	m
ray_start_range	Start range for ray	float	m
rays_are_indexed	Flag for indexed rays	char	-
RHOHV	Correlation coefficient	short	-
RHOHV_F	Correlation coefficient clutter filtered	short	-
roll_correction	Platform roll angle correction	float	degrees
rotation_correction	Ray rotation angle relative to platform correction	float	degrees
scan_rate	Antenna angle scan rate	float	deg/s
SNRHC	Signal-to-Noise Ratio horizontal channel	short	dB
SNRVC	Signal-to-Noise Ratio vertical channel	short	dB
status_xml	Status of instrument	char	-
sweep_end_ray_index	Index of last ray in sweep	int	-
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	char	-
sweep_number	Sweep index number 0 based	int	-
sweep_start_ray_index	Index of first ray in sweep	int	-
target_scan_rate	Target scan rate for sweep	float	deg/s
tilt_correction	Ray tilt angle relative to platform correction	float	degrees
time	Time in seconds since volume start	double	Seconds since time in file name UTC
time_coverage_end	Data volume end time UTC	char	-
time_coverage_start	Data volume start time UTC	char	-
TRIP_FLA	Second trip detection	short	-
unambiguous_range	Unambiguous range	float	m
VEL	Doppler velocity	short	m/s
VEL_F	Doppler velocity clutter filtered	short	m/s
vertical_velocity_correction	Platform vertical velocity correction	float	m/s
VL	Doppler velocity long pulse	short	m/s
volume_number	Data volume index number	int	-
VS	Doppler velocity short pulse	short	m/s

WIDTH	Spectrum width	short	m/s
WIDTH_F	Spectrum width clutter filtered	short	m/s
WIDTH_LO	Spectrum width long pulse	short	m/s
WIDTH_LO_F	Spectrum width long pulse clutter filtered	short	m/s
WIDTH_SH	Spectrum width short pulse	short	m/s
WIDTH_SH_F	Spectrum width short pulse clutter filtered	short	m/s
ZDRC	Offset corrected differential reflectivity	short	dB
ZDRM	Measured differential reflectivity	short	dB
ZDRM_F	Measured differential reflectivity clutter filtered	short	dB

Algorithm/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 inconsistencies in the transmitters. The negative of the offset was added to the ZDRM parameter, and a new field was created containing the offset corrected differential reflectivity (ZDRC). The ZDRC parameter is expected to be used for any scientific analysis rather than the directly measured values, ZDRM. The offset values were determined by creating histograms of the ZDRM measurements 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, and 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 the scan. Abnormally high or low values were omitted from the dataset. When no offset could be determined, a default offset of 0 dB was used.

Based on a discrepancy discovered between DOW reflectivity data and NPOL/NEXRAD reflectivity data, a comparison between DOW and WSR-88D using OLYMPEX and Seeded Natural and Orographic Wintertime clouds - the Idaho Experiment (SNOWIE) data, as well as data collected locally near Denver with matched scans between radars, revealed an offset estimate of 3.2 (±1) dB, with the DOW being too low. This offset of +3.2 dB has been added to this version 2 dataset. In the error estimate, variations between receiver calibrations were also considered (varying up to 1 dB, but typically less). The caveat to this offset is that is does not necessarily hold in melting levels, where Mie scattering becomes an issue, or values over ~35 dBZ. The offset was still applied in these scenarios, but these caveats should be kept in mind when analyzing the data.

More information about these correction methods are available in the DOW V2 readme text file.

Software

This dataset is in CFradial 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

Data from 21:52:10 UTC on December 2, 2015 through 17:21:06 UTC on December 3, 2015 were reprocessed to correct a 2-gate offset. ZDR offsets were recalculated during this time period, which are reflected in the variable ZDRC. These changes are reflected in this version 2 dataset.

References

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

Earth Observing Laboratory: Doppler on Wheels. https://www.eol.ucar.edu/observing_facilities/dow

Houze, Jr. Robert, Lynn A. McMurdie, Walter A. Petersen, Mathew R. Schwaller, William Baccus, et al. (2017): The Olympic Mountains Experiment. *American Meteorological Society BAMS*, October 2017, 2167-2188. doi: https://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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