Data User Guide

GPM Ground Validation High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) OLYMPEX

Introduction

The GPM Ground Validation High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) OLYMPEX dataset consists of Doppler velocity and reflectivity profiles collected by the High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) onboard the NASA ER-2 high-altitude research aircraft during the Global Precipitation Measurement mission (GPM) Ground Validation 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. HIWRAP is a Doppler radar that combines conical scan mode measurements at two different frequency bands (Ka- and Ku-band) and two different incidence angles (30 and 40 degrees) to obtain profiles of wind and rain. These Level 1B HIWRAP data files are available from November 10 through December 12, 2015 in netCDF-3 format.

Note: HIWRAP was flown on the ER-2 aircraft as part of the Radar Definition Experiment (RADEX), a coordinated field campaign performed in conjunction with GPM GV OLYMPEX. HIWRAP data files have RADEX in the filename instead of OLYMPEX.

Citation

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Huntsville, Alabama, U.S.A. doi:
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Keywords:

GHRC, NASA, OLYMPEX, Washington, Olympic Peninsula, HIWRAP, ER-2, Doppler radar, Doppler velocity, radar reflectivity, radial velocity, radar backscatter, radar cross-section, return power, sensor counts

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])

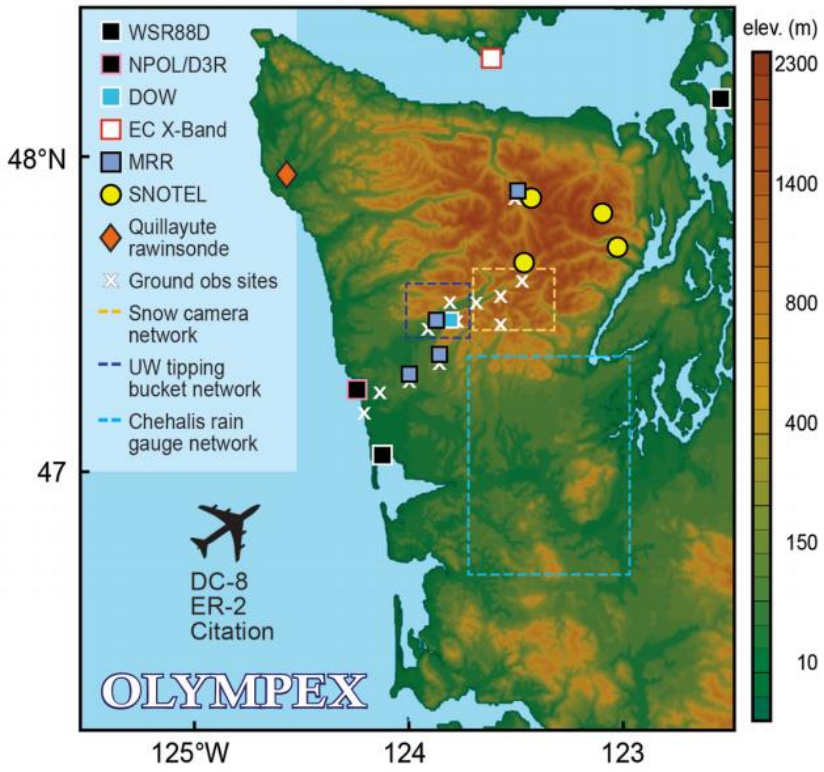

Figure 2: OLYMPEX Field Locations
(Image Source: [OLYMPEX Field Locations])

Instrument Description

The High Altitude Wind and Rain Airborne Profiler (HIWRAP) is a Doppler radar designed to measure tropospheric winds through deriving Doppler profiles from cloud and precipitation volume backscatter (Li et al., 2016). The winds are generated by combining conical scan mode measurements at two different frequency bands (Ka- and Ku-band) and two different incidence angles (30 and 40 degrees). HIWRAP utilizes solid state transmitters along with a novel pulse compression scheme resulting in a system that is considerably more compact and requires less power than typical radars used for precipitation and wind measurements (Figure 3). HIWRAP was originally designed to fly on the NASA Global Hawk with a scanning configuration, but was since modified to fly on the NASA ER-2 high-altitude research aircraft (Figure 4) with a fixed nadir pointing configuration as part of RADEX, a field campaign coordinated with OLYMPEX designed to develop algorithms for the ACE Decadal Mission Ka-/W-band Doppler radar. The specifications for HIWRAP are listed in Table 1 below. A more detailed description of the HIWRAP system and system parameters can be found in Li et al. (2016).

Table 1: HIWRAP Specifications adapted from Li et al. (2016)

Parameters	Specifications			
	Inner beam		Outer beam	
Frequency (GHz)	13.91	35.56	13.47	33.72
Tx Peak Power (W)*	25.0	8.0	25.0	8.0
Antenna Gain (dBi)	35.4	42.2	35.2	42.6
AZ 3 dB Beamwidth (°)	2.9	1.2	3.1	1.3
EL 3 dB Beamwidth (°)	3.0	1.2	2.9	1.2
Antenna Beams (°)	30.0		39.6	
Polarization	H		V	
Antenna Sidelobe (dB)	<-26.4	-27.2	<-23.2	-26.6
PRF (Hz)	5000/4000 Dual PRF			
Pulsewidth (μs)	0-60			
Rx Bandwidth (MHz)	0-4, programmable			
Chirp Bandwidth (MHz)	0-4, programmable			
Dynamic Range (dB)	> 65			
Min, Detect. Reflectivity (dBZe, 150 m range res., 10 km range, 20 μs/1 MHz chirp, 16 RPM scanning rate.)	7.8	1.5	7.8	1.5
Doppler Velocity (m/s)	0-110 (accuracy 1.5 m/s for SNR > 10)			
Scanning	Conical, 10-30 RPM			

*Note: The Ka-band was upgraded with a 45 W (peak power) SSPA after 2013.

Figure 3: The High Altitude Wind and Rain Airborne Profiler (HIWRAP)
(Image source: NASA Airborne Science HIWRAP webpage)

Figure 4: The NASA ER-2 high-altitude research aircraft
(Image source: NASA Armstrong ER-2 Fact Sheet)

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Data Characteristics

The GPM Ground Validation High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) OLYMPEX dataset contains calibrated reflectivity and Doppler velocity profiles along with aircraft attitude and other information. These data are available at a Level 1B processing level in netCDF-3 format. More information about the NASA data processing levels are available on the EOSDIS Data Processing Levels webpage. No wind information is available in these files. Winds are derived from the calibrated doppler velocities and released in a higher level product. The characteristics of this dataset are listed in Table 2 below.

Table 2: HIWRAP Data Characteristics

Characteristic	Description
Platform	NASA Earth Resources 2 (ER-2) aircraft
Instrument	High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)
Spatial Coverage	N: 48.8322, S:34.15762 , W: -130.0448, E: -117.7745 (Olympic Mountains/Washington state region)
Spatial Resolution	Vertical: 150 m, Horizontal: 6 km
Temporal Coverage	November 10, 2015 - December 12, 2015
Temporal Resolution	Each file contains 30 to 60 minutes with some overlap
Sampling Frequency	0.05 seconds
Parameter	Radar reflectivity, Doppler velocity
Version	1a
Processing Level	1B

File Naming Convention

The GPM Ground Validation High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) OLYMPEX dataset files are stored in netCDF-3 format and have the following naming convention:

Data files: RADEX_HIWRAP_L1B_<start date>_<start time>-<end date>_<end time>_H<XX>_dist_v01a.nc

Note: The files list "RADEX" as the field campaign instead of "OLYMPEX" as HIWRAP was flown on the ER-2 as part of the coordinated RADEX project for development of algorithms for ACE Decadal Mission Ka-/W-band Doppler radar.

Table 3: File naming convention variables

Variable	Description
<start date>	Start date in *YYYYMMDD* where YYYY: Four-digit year MM: Two-digit month DD: Two-digit day
<start time>	Start time in *hhmmss* where hh: Two-digit hour in UTC mm: Two-digit minute in UTC ss: Two-digit second in UTC
<end date>	End date in *YYYYMMDD* where YYYY: Four-digit year MM: Two-digit month DD: Two-digit day
<end time>	End time in *hhmmss* where hh: Two-digit hour in UTC mm: Two-digit minute in UTC ss: Two-digit second in UTC
XX	Frequency: 'Ka' for the Ka-band and 'Ku' for the Ku-band
.nc	netCDF-3 file format

Data Format and Parameters

The GPM Ground Validation High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) OLYMPEX dataset consists of radar reflectivity and Doppler velocity measurements along with aircraft attitude and other information. Table 4 gives a description, data type, and unit for each parameter provided in the data files.

Table 4: Data fields in the HIWRAP netCDF-3 data files

Field Name	Description	Data Type	Unit
altitude	Aircraft altitude	float	m
dopcorr	ka/ku Doppler velocity after correct for aircraft motion and folding	float	$m\ s^{-1}$
evel	East aircraft ground speed	float	$m\ s^{-1}$
gatesp	Radar range gate	float	m
gspeed	Aircraft ground speed	float	$m\ s^{-1}$
head	Aircraft heading	float	degrees
incid	Incidence Angle from nadir	float	degrees
lat	GPS aircraft latitude Note: minus sign = South	float	degrees
ldr	ka Linear Depolarization Ratio	float	dB
lon	GPS aircraft longitude Note: minus sign = West	float	degrees
missing	Missing value (Value: -999.0)	float	-
noise_db	Noise estimate for each profile	float	dB
nvel	North aircraft ground speed	float	$m\ s^{-1}$

pitch	Aircraft pitch angle	float	degrees
pku	Power	float	$mm^6\ m^{-3}$
range	Range from radar	float	m
roll	Aircraft roll angle	float	degrees
rot	Antenna rotation angle	float	degrees
sigm0	Surface sigma0	float	dB
surfvel	Surface Doppler Velocity	float	$m\ s^{-1}$
tilt	Nominal tilt angle	float	degrees
timed	UTC time	float	hour
track	Aircraft track angle	float	degrees
vacft	Estimate of aircraft Doppler component	float	$m\ s^{-1}$
wlku	Wavelength length of radar	float	m
wvel	Aircraft vertical speed	float	$m\ s^{-1}$
year	Year the data was collected	short	-
zku	ka/ku Radar Reflectivity	float	dBZ

Algorithm

The HIWRAP instrument uses Doppler radar backscatter from clouds and precipitation to derive tropospheric winds. Measuring backscatter at two different frequencies and incidence angles allows for 3D winds to be derived. Additional information on how the HIWRAP instrument obtains its measurements is detailed in Li et al. (2016).

Quality Assessment

The HIWRAP instrument is calibrated in three steps: using parameters of individual components to calibrate the system, using the return of the ocean surface as an external reference, and calibrating the system internally using a pulse-by-pulse calibration while processing post-flight data. To maintain high temporal and spatial resolutions, the transceiver supports simultaneous operation at the two center frequencies for each band so that they align with one of the two incident angles. HIWRAP is externally calibrated at Ku-band to TRMM 10 degree incidence angle values. Ka-band data are then tied to Ku-band.
More information is available in Li et al. (2016).

Software

No special software is needed to view these netCDF-3 dataset files; however, the NASA Panoply Data Viewer can be used to easily open and view the data.

Known Issues or Missing Data

During OLYMPEX, HIWRAP Ku-band linear depolarization ratio data experienced radio frequency interference from the ground-based D3R radar much of the time. The ER-2

aircraft did not operate during the entire campaign, therefore HIWRAP data are only available for aircraft flight days.

References

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Related Data

All data from other instruments collected during the OLYMPEX field campaign are related to this HIWRAP dataset. Other OLYMPEX campaign data can be located by searching the term 'OLYMPEX' in the GHRC HyDRO 2.0 search tool. In addition, the HIWRAP instrument was flown in other field campaigns and these HIWRAP datasets can be located by searching the term 'HIWRAP' in HyDRO 2.0. These datasets are listed below:

High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) IMPACTS dataset (http://dx.doi.org/10.5067/IMPACTS/HIWRAP/DATA101)

GPM Ground Validation High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) IPHEx dataset
(http://dx.doi.org/10.5067/GPMGV/IPHEX/HIWRAP/DATA101)

GPM Ground Validation High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) MC3E dataset
(http://dx.doi.org/10.5067/GPMGV/MC3E/HIWRAP/DATA101)

Hurricane and Severe Storm Sentinel (HS3) High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) dataset
(http://dx.doi.org/10.5067/HS3/HIWRAP/DATA101)

GRIP High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) dataset
(http://dx.doi.org/10.5067/GRIP/HIWRAP/DATA101)

Contact Information

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

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