Data User Guide

High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) IMPACTS

Introduction

The High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) IMPACTS dataset consists of Equivalent reflectivity factor, Doppler velocity, Doppler velocity spectrum width, Linear Depolarization Ratio (LDR), Ocean normalized radar cross section, Co-polarization signal-to-noise mask estimates collected by the HIWRAP onboard the NASA ER-2 aircraft during the Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) field campaign. IMPACTS was a three-year sequence of winter season deployments conducted to study snowstorms over the U.S. Atlantic coast. IMPACTS aimed to (1) Provide observations critical to understanding the mechanisms of snowband formation, organization, and evolution; (2) Examine how the microphysical characteristics and likely growth mechanisms of snow particles vary across snowbands; and (3) Improve snowfall remote sensing interpretation and modeling to significantly advance prediction capabilities. These data are available from January 25 through February 27, 2020 in HDF-5 format.

Notice:
This dataset is not continuous as flights did not occur every day.

Citation

Li, Lihua, Matthew McLinden, and Gerald Heymsfield. 2020. High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) IMPACTS [indicate subset used]. Dataset available online from the NASA Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/IMPACTS/HIWRAP/DATA101

Keywords:

NASA, GHRC, IMPACTS, HIWRAP, ER-2, Equivalent reflectivity factor, Doppler velocity, Doppler velocity spectrum width, Linear Depolarization Ratio (LDR), Ocean normalized radar cross section, Co-polarization signal-to-noise mask

Campaign

The Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS), funded by NASA's Earth Venture program, is the first comprehensive study of East Coast snowstorms in 30 years. IMPACTS will fly a complementary suite of remote sensing and in-situ instruments for three 6-week deployments (2020-2022) on NASA's ER-2 high-altitude aircraft and P-3 cloud-sampling aircraft. The first deployment began on January 17, 2020 and ended on March 1, 2020. IMPACTS samples U.S. East Coast winter storms using advanced radar, LiDAR, and microwave radiometer remote sensing instruments on the ER-2 and state-of-the-art microphysics probes and dropsonde capabilities on the P-3, augmented by ground-based radar and rawinsonde data, multiple NASA and NOAA satellites (including GPM, GOES-16, and other polar orbiting satellite systems), and computer simulations. IMPACTS addressed three specific objectives: (1) Provide observations critical to understanding the mechanisms of snowband formation, organization, and evolution; (2) Examine how the microphysical characteristics and likely growth mechanisms of snow particles vary across snowbands; and (3) Improve snowfall remote sensing interpretation and modeling to significantly advance prediction capabilities. More information is available from [NASA's Earth Science Project Office's IMPACTS field campaign webpage](#).

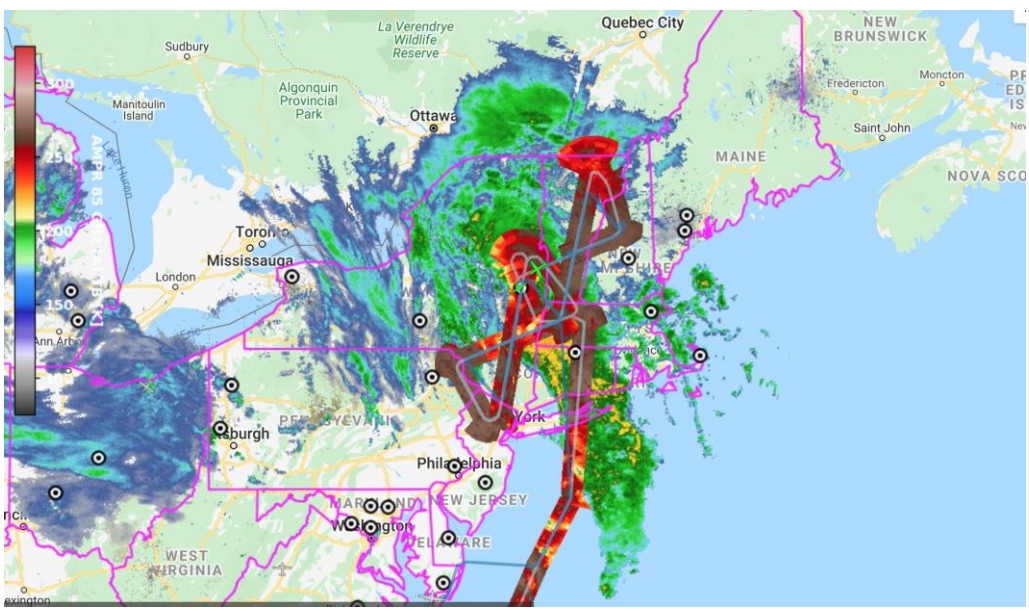

Figure 1: IMPACTS field campaign operations on January 25, 2020 with plots of ER-2 and P-3 flight tracks in addition to ground radar sites and radar reflectivity over the region (Image source: Dr. Timothy Lang, NASA MSFC)

Instrument Description

The High Altitude Wind and Rain Airborne Profiler (HIWRAP) instrument 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. A more detailed description of the HIWRAP system and system parameters can be found in Li et al., 2016. More information about HIWRAP can be found at the Goddard Space Flight Center High Altitude Radar Group: High-altitude Radar: HIWRAP.

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 (^{0})	2.9	1.2	3.1	1.3
EL 3 dB Beamwidth (^{0})	3.0	1.2	2.9	1.2
Antenna Beams (^{0})	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, 150m 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			

*: The Ka-band was upgraded with a 45 W (peak power) SSPA after 2013. Upgrade on the Ku-band with an 80 W (peak power) SSPA is under way.

Figure 3: HIWRAP Specifications
(Image Source: Lihua Li et al., 2016)

Investigators

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Data Characteristics

The High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) IMPACTS data are available in HDF-5 format at a Level 1B data processing level. 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	NASA Earth Resources 2 (ER-2) aircraft
Instrument	High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)
Spatial Coverage	N: 44.760, S: 33.095, E: -71.691, W: -90.774 (United States of America)
Spatial Resolution	150 meter in vertical, 6 kilometers in horizontal, 1 km footprint
Temporal Coverage	January 25, 2020 - February 27, 2020
Temporal Resolution	1 file per flight
Sampling Frequency	0.05 seconds
Parameter	Equivalent reflectivity factor, Doppler velocity, Doppler velocity spectrum width, Linear Depolarization Ratio (LDR), Ocean normalized radar cross section, Co-polarization signal-to-noise mask
Version	1
Processing Level	1B

File Naming Convention

The High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) IMPACTS dataset files are available in HDF-5 format and are named using the following convention:

Data files: IMPACTS_HIWRAP_L1B_RevA_<start time>_to_<end time>.h5

Table 2: File naming convention variables

Variable	Description
<start time>	Time when data collection started in YYYYMMDDThhmmss format where 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
<end time>	Time when data collection ended in YYYYMMDDThhmmss format where 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
.h5	HDF-5 format

Data Format and Parameters

The HIWRAP IMPACTS data files are in HDF-5 format. There are 15 data fields, including vector components of electric fields and aircraft parameters, in each data file (Table 3).

Table 3: Data Fields for HIWRAP HDF-5 files

Field Name	Description	Unit
/Information - General Information		
Aircraft	Aircraft: NASA ER-2	-
DataContact	Data Contact: Matthew L. Walker McLinden ('matthew.l.mclinden@nasa.gov')	-
ExperimentName	Experiment name: IMPACTS2020	-
FlightDate	Flight date	-
InstrumentPI	Instrument PI: Lihua Li, NASA/GSFC	-
L1A_ProcessDate	L1A File Process Date	-
L1B_ProcessDate	L1B File Process Date	-
L1B_Revision	L1B Revision	-
MissionPI	Mission PI: Lynn McMurdie, University of Washington	-
RadarName	Radar Name: HIWRAP	-
/Time/Data - Time Data		
TimeUTC	UTC profile time in Unix Epoch format (seconds since 1970). Obtained from aircraft NTP. Note that HIWRAP produces a profile every 0.5 seconds, but profiles are overlapping. See the ResolutionHorizontal16dB field for horizontal resolution.	seconds
TimeUTC_01Jan2020	Time of 0 UTC, January 1, 2020, for reference if the user does not have an easy Linux time converter.	seconds
/Products/Data - Radar Product Data		
dBZe	Equivalent reflectivity factor in dB with 1-sigma noise threshold applied for individual channels and -sigma noise threshold for the combined channel data. $\|K\|^2$ = 0.92. Use /Products/Information/MaskCoPol for thresholding greater than the default.	10*log10 (mm^6/m^3)
Velocity	Doppler velocity with aircraft motion correction default thresholding. Positive velocity is upward. Use /Products/Information/MaskCoPol for thresholding greater than the default. Possible intrusion of horizontal winds into the Doppler measurement due to slight off-nadir pointing. Check Navigation data	m/s

	(roll/pitch) to estimate possible impact or contact radar team.	
SpectrumWidth	Doppler velocity spectrum width estimate including aircraft motion and beamwidth. Default noise threshold applied. Use /Products/Information/MaskCoPol for thresholding greater than the default.	m/s
LDR (combined channel only)	Linear Depolarization Ratio (LDR) with 3-sigma noise threshold applied.The LDR uses the chirp for cross-polarization data and the high-resolution pulse for co-polarization data. The resolution is well matched, but has slight differences that can cause small artifacts at the edge of the surface return.	dB
sigma0	Ocean Normalized Radar Cross Section. Only valid over the ocean.	10*log10 (m^2/m^2)
/Products/Information - Radar Product Information		
AircraftMotion	Estimated aircraft motion in the direction of the beam that has been subtracted from the Doppler estimate.	m/s
AntennaSize	Antenna Diameter (0.5 meters)	meters
GateSpacing	Range gate spacing (26.25 meters)	meters
PRI	Description of the pulse repetition interval: 224 µs/280 µs staggered	-
Range	Range in meters from the aircraft of each range gate	meters
/Products/Ka|Ku/Information - Radar Product Information (Ka/Ku specific)		
Frequency	Radar frequency (35.56 GHz Ka, 13.91GHz Ku)	Hz
ResolutionHorizontal 6dB	Approximate horizontal resolution defined as the -6 dB width of spatial weighting as a function of range based on the antenna pattern and horizontal averaging.	meters
/Products/Ka|Ku/Chirp|Combined|HighResPulse|LowResPulse/Information - Radar Product Information (Pulse-type specific)		
MaskCoPol (not for combined data)	Co-polarization signal-to-noise mask. (Mask >= N) corresponds with (SNR > N-sigma) noise thresholding.	-
ChannelMask (combined data only)	Mask indicating which channel each range/time is using. 1: low resolution pulse 2: high resolution pulse 3: chirp This field can be used to investigate/detect any potential image artifacts associated with the combining algorithm.	-
/Navigation/Data - Navigation Data		
Drift	Difference between track and heading	degrees
EastVelocity	Eastward portion of velocity	m/s

Heading	Aircraft heading in degrees from north. 90 degrees is Eastward.	degrees
Height	Aircraft height above sea level	meters
Latitude	Latitude	degrees
Longitude	Longitude	degrees
NominalDistance	Nominal total along-track distance calculated by integrating instantaneous velocity. Used for simple plotting.	meters
NorthVelocity	Northward portion of velocity	m/s
Pitch	Pitch	degrees
Roll	Roll	degrees
Track	Direction of motion in degrees from north. 90 degrees is Eastward motion.	degrees
UpVelocity	Upward velocity	m/s
dxdr	Data cross-track distance from aircraft per radar range. Positive is in the starboard direction.	m/m
dydr	Data along-track distance from aircraft per radar range. Positive is in the forward direction.	m/m
dzdr	Data vertical distance from the aircraft per radar range. Positive is in the upward direction.	m/m

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 they align with one of the two incident angles.

Software

No software is needed to view this dataset; however, Panoply can be used to easily view the data.

Known Issues or Missing Data

This dataset is not continuous as flights did not occur every day.

References

Heymsfield G.M., L. Tian, A. Heymsfield, L. Li, and S. Guimond, 2010, Characteristics of Deep Tropical and Subtropical Convection from Nadir-viewing High-altitude Airborne Doppler Radar, J. Atmos. Sc, 67(2), 285-308, https://doi.org/10.1175/2009JAS3132.1

Li, L. et al., 2016, The NASA High-Altitude Imaging Wind and Rain Airborne Profiler, IEEE

Transactions on Geoscience and Remote Sensing, 54(1), 298-310, https://doi.org/10.1109/TGRS.2015.2456501

Li, L., G.M. Heymsfield, J. Carswell, D. Schaubert, M. McLinden, M. Vega, M. Perrine, 2011, Development of the NASA High-Altitude Imaging Wind and Rain Airborne Profiler, presented at IEEE Aerospace Conference, https://doi.org/10.1109/AERO.2011.5747415

Related Data

All other datasets collected as part of the IMPACTS campaign are considered related and can be located by searching the term "IMPACTS" in the GHRC HyDRO2.0 search tool. Listed below are datasets from other field campaigns and studies that used the HIWRAP instrument:

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

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

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

HURRICANE AND SEVERE STORM SENTINEL (HS3) HIGH-ALTITUDE IMAGING WIND AND RAIN AIRBORNE PROFILER (HIWRAP) (http://dx.doi.org/10.5067/HS3/HIWRAP/DATA101)

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

GRIP Global Hawk Navigation and Housekeeping data (http://dx.doi.org/10.5067/GRIP/NAV/DATA102)

Contact Information

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

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