Data User Guide

Cloud Radar System (CRS) IMPACTS

Introduction

The Cloud Radar System (CRS) IMPACTS dataset consists of calibrated radar reflectivity, Doppler velocity, linear depolarization ratio, and normalized radar cross-section estimates collected by the Cloud Radar System (CRS) onboard the NASA ER-2 high-altitude research aircraft. These data were gathered 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 (2020-2023). The campaign 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. The CRS IMPACTS dataset files are available from January 25, 2020, through February 28, 2023, in HDF-5 format.

Notice:
The ER-2 aircraft did not operate each day of the campaign, therefore CRS data are only available for aircraft flight days.

Citation

McLinden, Matthew, Lihua Li, and Gerald Heymsfield. 2020. Cloud Radar System (CRS) IMPACTS [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/IMPACTS/CRS/DATA101

Keywords:

NASA, GHRC, IMPACTS, CRS, W-band Doppler radar, polarimetric, reflectivity, doppler velocity, linear depolarization ratio, normalized radar cross-section, clouds, precipitation

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 (2020-2023) 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](#).

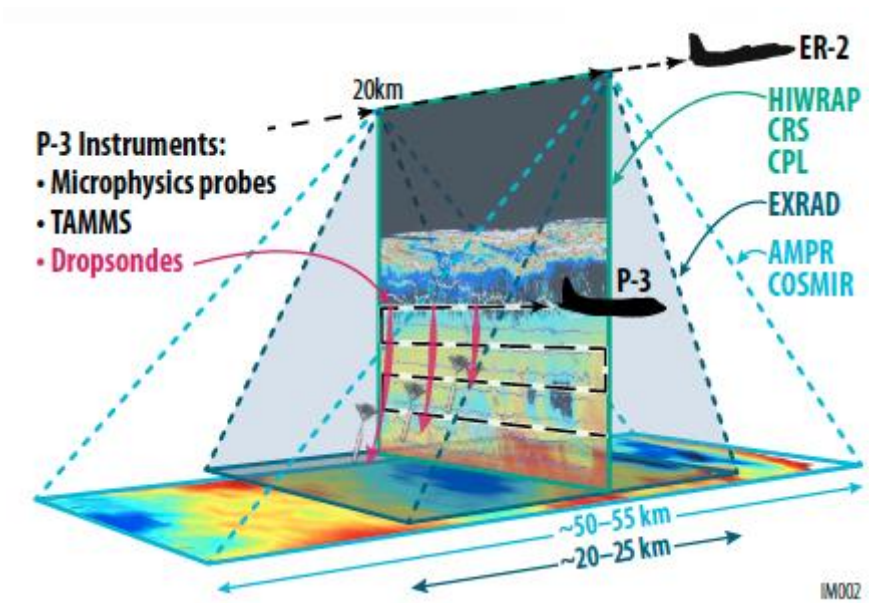

Figure 1: IMPACTS airborne instrument suite
(Image source: NASA IMPACTS ESPO)

Instrument Description

The Cloud Radar System (CRS) is a 94 GHz, W-band polarimetric Doppler radar at a 3-millimeter wavelength that was developed to operate without pilot assistance aboard the NASA ER-2 high-altitude science aircraft. CRS provides high-resolution profiles of reflectivity and Doppler velocity in clouds in addition to measurements for other important atmospheric properties. The CRS resides in the tail cone of the ER-2 superpod (Figure 3)

and its radar beam points downward toward the earth's surface. Due to the instrument's high-frequency transmissions, the CRS is highly sensitive and can therefore be used to study cirrus clouds. The ER-2 aircraft generally flies at an altitude of about 20 km, in the lower stratosphere, and can detect clouds and precipitation from the aircraft level down to the surface. Specifications of CRS are outlined in Table 1 below.

Table 1: CRS Instrument Characteristics

Characteristic	Value
Frequency	94.155 GHz
Instrument	Cloud Radar System utilizing a 94.155 GHz W-band 3mm airborne polarimetric Doppler radar
Transmitter Type	30 W Solid State Power Amplifier (SSPA)
Peak Power	30 W
Beamwidth	0.46 degrees
Pulse Repetition Frequency	High: 4464.29 Hz, Low: 3571.43 Hz
Range Resolution	161 meters (horizontal resolution at surface) at 20km range
Gate Spacing	75 meters

For more information about the NASA ER-2 CRS, refer to the NASA Airborne Science Program CRS webpage, NASA GSFC CRS webpage, and Li, Heymsfield, Racette, Tian, and Zenker (2004), describing the radar system in detail.

Figure 2: CRS setup in the laboratory with the airborne antenna configuration (Image source: Li et al. (2004))

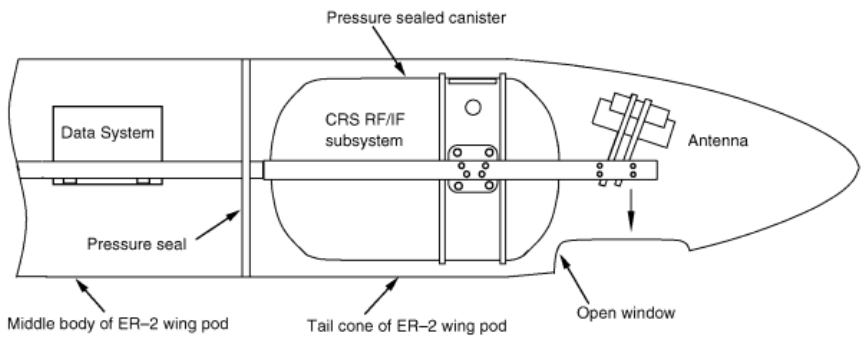

Figure 3: CRS configuration with the airborne antenna in the tailcone of the ER-2 superpod. (Image source: Li et al. (2004))

Investigators

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Data Characteristics

The Cloud Radar System (CRS) IMPACTS dataset consists of calibrated radar products stored in nested HDF-5 files. These data are available at a Level 1B processing level. More information about the NASA data processing levels is available on the EOSDIS Data Processing Levels webpage. The characteristics of this dataset are listed in Table 2 below.

Table 2: Data Characteristics

Characteristic	Description
Platform	NASA Earth Resources 2 (ER-2) research aircraft
Instrument	Cloud Radar System (CRS)
Spatial Coverage	N: 48.658, S: 31.073, E: -64.894, W: -95.460 (Eastern United States of America)
Spatial Resolution	161 m (horizontal resolution at surface) at 20km range
Temporal Coverage	January 25, 2020 - February 28, 2023
Temporal Resolution	Hourly -< Daily
Sampling Frequency	0.25 seconds
Parameter	Reflectivity, Doppler velocity

Version	1
Processing Level	1B

File Naming Convention

The Cloud Radar System (CRS) IMPACTS dataset files are stored in HDF-5 format and named using the following convention:

Data files: IMPACTS_CRS_L1B_RevB_YYYYMMDD..h5

Table 3: File naming convention variables

Variable	Description
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
.h5	HDF-5 format

Data Format and Parameters

The Cloud Radar System (CRS) IMPACTS dataset is stored in nested HDF-5 files.The top-level groups of the HDF-5 files are Information (general information), Time (time stamps), Products (radar data products), and Navigation (radar position and pointing information). More details about the CRS HDF-5 data format are available in the CRS IMPACTS Level1B Data Description document. The CRS HDF-5 data field descriptions are listed in Table 4 below. The top-level groups and subgroups heading each section are listed in bold.

Table 4: CRS HDF-5 File Data Fields

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: Matthew Walker McLinden, NASA/GSFC	-
L1A_ProcessDate	L1A File Process Date	-
L1B_ProcessDate	L1B File Process Date	-
L1B_Revision	L1B Revision	-
L1B_Revision_Note	L1B Revision Note	-
MissionPI	Mission PI: Lynn McMurdie, University of Washington	-
RadarName	Radar Name: CRS	-
/Time/Data		

TimeUTC	UTC profile time in Unix Epoch format (seconds since 1970). Obtained from aircraft NTP. Note that CRS produces a profile every 0.25 seconds, however profiles are overlapping.	seconds
/Time/Information		
TimeUTC_01Jan2020	UTC profile time	seconds
TimeUTC_01Jan2020_description	UTC profile time description	-
TimeUTC_description	Time UTC description	-
TimeUTC_units	Units for TimeUTC	-
/Products/Data		
dBZe	Equivalent reflectivity factor in dB with 1-sigma noise threshold applied. $\|K\|^2 = 0.75$ rather than 0.93 for consistency with CloudSat. Use /Products/Information/MaskCoPol or /Products/Information/SNR for thresholding other than 1-sigma	10*log10 (mm^6/m^3)
Velocity_corrected	Corrected Doppler velocity with aircraft motion correction and 1-sigma noise threshold applied. Positive velocity is upward. Use /Products/Information/MaskCoPol for thresholding other than 1-sigma. Possible intrusion of horizontal winds into doppler measurement due to slight off-nadir pointing. Check Navigation data (roll/pitch) to estimate impact or contact radar team.	m/s
Velocity_uncorrected	Uncorrected Doppler velocity with aircraft motion correction and 1-sigma noise threshold applied. Positive velocity is upward. Use /Products/Information/MaskCoPol for thresholding other than 1-sigma. Possible intrusion of horizontal winds into doppler measurement due to slight off-nadir pointing. Check Navigation data (roll/pitch) to estimate impact or contact radar team.	m/s
SpectrumWidth	Doppler velocity spectrum width estimate including aircraft motion and beamwidth. 1-sigma noise threshold applied. Use /Products/Information/MaskCoPol or /Products/Information/SNR for thresholding other than 1-sigma.	m/s
LDR	Linear Depolarization Ratio with 2-sigma co- and cross-polarization noise thresholding applied. Use /Products/Information/MaskCrPol for thresholding other than 2-sigma.	dB
sigma0	Ocean Normalized Radar Cross Section. Only valid over the ocean.	10*log10

		(m^2/m^2)
/Products/Information		
AircraftMotion	Estimated aircraft motion in the direction of the beam that has been subtracted from the Doppler estimate.	m/s
AircraftMotion_description	Description for aircraft motion parameter	-
AircraftMotion_units	Units for aircraft motion parameter	-
AntennaBeamwidth	Antenna beam width	m
AntennaBeamwidth_description	Description for antenna beam width parameter	-
AntennaBeamwidth_units	Units for antenna beam width parameter	-
AntennaSize	Antenna Diameter (0.5 meters)	meters
AntennaSize_description	Description for antenna size	-
AntennaSize_units	Units for antenna size	-
AveragedPulses	Number of averaged pulses per profile. Note that profiles are not independent, and are overlapping.	#
AveragedPulses_description	Description for averaged pulses parameter	-
AveragedPulses_units	Units for averaged pulses parameter	-
dBZe_description	Description for dBZe parameter	-
dBZe_units	Units for dBZe parameter	-
Frequency	Radar frequency (94 GHz)	Hz
Frequency_description	Description for frequency parameter	-
Frequency_units	Units for frequency parameter	-
GateSpacing	Range gate spacing (26.25 meters)	meters
GateSpacing_description	Description for gate spacing parameter	-
GateSpacing_units	Units for gate spacing parameter	-
HRRR_AlongWind	HRRR Along Wind	-
HRRR_AlongWind_description	Description for HRRR Along Wind parameter	-
HRRR_AlongWind_units	Units for HRRR Along Wind parameter	-
HRRR_CrossWind	HRRR Cross Wind	-
HRRR_CrossWind_description	Description for HRRR Cross Wind parameter	-
HRRR_CrossWind_units	Units for HRRR Cross Wind parameter	-
LDR_description	Description for LDR parameter	-

LDR_units	Units for LDR parameter	-
MaskCoPol	Co-polarization signal-to-noise mask. (Mask >= N) corresponds with (SNR > N-sigma) noise thresholding.	Special
MaskCoPol_description	Description for MaskCoPol parameter	-
MaskCrPol	Cross-polarization signal-to-noise mask. (Mask >= N) corresponds with (SNR > N-sigma) noise thresholding.	Special
MaskCrPol_description	Description for MaskCrPol parameter	-
NominalAntennaPointing	Nominal antenna pointing	-
PRI	Description of the pulse repetition interval: 224 µs/280 µs staggered	-
Range	Range in meters from the aircraft of each range gate	meters
Range_description	Description for Range parameter	-
Range_units	Units for Range parameter	-
ResolutionHorizontal6dB	Approximate horizontal resolution defined as the -6 dB width of spatial weighting as a function of the antenna pattern, horizontal averaging, and range	meters
ResolutionHorizontal6dB_description	Description for ResolutionHorizontal6dB parameter	-
ResolutionHorizontal6dB_units	Units for ResolutionHorizontal6dB parameter	-
ResolutionVertical6dB	Approximate vertical resolution defined as the -6 dB width of the range weighting function	meters
ResolutionVertical6dB_description	Description for ResolutionVertical6dB parameter	-
ResolutionVertical6dB_units	Units for ResolutionVertical6dB parameter	-
sigma0_description	Description for sigma0 parameter	-
sigma0_units	Units for sigma0 parameter	-
SNR	Estimated Signal-to-Noise Ratio	W/W
SNR_description	Description for SNR parameter	-
SNR_units	Units for SNR parameter	-
Spectrum/Width_description	Description for Spectrum/Width parameter	-
Spectrum/Width_units	Units for Spectrum/Width parameter	-
Velocity_corrected_description	Description for corrected velocity parameter	-
Velocity_corrected_units	Units for corrected velocity parameter	-

Velocity_horizwind_offset	Offset for horizontal wind velocity	-
Velocity_horizwind_offset_description	Description for horizontal wind velocity offset	-
Velocity_horizwind_offset_units	Units for horizontal wind velocity offset	-
Velocity_uncorrected_description	Description for uncorrected velocity parameter	-
Velocity_uncorrected_units	Units for uncorrected velocity parameter	-
Wavelength	wavelength	u
Wavelength_description	Description for wavelength parameter	-
Wavelength_units	Units for wavelength parameter	-
/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
/Navigation/Information		
Drift_description	Description for drift parameter	-
Drift_units	Units for drift parameter	-
EastVelocity_description	Description for EastVelocity parameter	-
EastVelocity_units	Units for EastVelocity parameter	-
Heading_description	Description for Heading parameter	-

Heading_units	Units for Heading parameter	-
HeadingCorrection	Heading correction	-
HeadingCorrection_description	Description for heading correction	-
HeadingCorrection_units	Units for heading correction	-
Height_description	Description for height parameter	-
Height_units	Units for height parameter	-
Latitude_description	Description for latitude parameter	-
Latitude_units	Units for latitude parameter	-
Longitude_description	Description for longitude parameter	-
Longitude_units	Units for longitude parameter	-
NavigationSource	Navigation source	-
NominalDistance_description	Description for nominal distance parameter	-
NominalDistance_units	Units for nominal distance parameter	-
NorthVelocity_description	Description for North Velocity parameter	-
NorthVelocity_units	Units for North Velocity parameter	-
Pitch_description	Description for pitch parameter	-
Pitch_units	Units for pitch parameter	-
Roll_description	Description for roll parameter	-
Roll_units	Units for roll parameter	-
RollCorrection	Correction for roll	-
RollCorrection_description	Description for roll correction	-
RollCorrection_units	Units for roll correction	-
Track_description	Description for track parameter	-
Track_units	Units for track parameter	-
UpVelocity_description	Description for UpVelocity parameter	-
UpVelocity_units	Units for UpVelocity parameter	-
dxdr_description	Description for dxdr parameter	-
dxdr_units	Units for dxdr parameter	-
dydr_description	Description for dydr parameter	-
dydr_units	Units for dydr parameter	-
dzdr_description	Description for dzdr parameter	-
dzdr_units	Units for dzdr parameter	-

Algorithm

The CRS data processing system uses dual pulse repetition frequencies to obtain clear, definitive Doppler velocity measurements. The Doppler processing was done using the

pulse pair estimation method, which requires less computation than other methods. This method is often used in pulse Doppler radar signal processing. The mean Doppler and spectrum width are calculated in post-processing. More detail on how the CRS data were obtained can be found in Li et al. (2004).

Quality Assessment

Both internal and external calibration methods are used on CRS. Radar calibration helps to minimize erroneous reflectivity measurements. Internal calibration of CRS included monitoring receiver performance and transmitter stability. External calibration was done using target calibration methods and intercomparing CRS measurements with those of other radars. Also, CRS Doppler velocity values have been corrected for the motion and orientation of the aircraft. More information about the ER-2 CRS calibration methods can be found in Li et al. (2004).

Software

No special software is required to read these data. Panoply is an easy-to-use free tool for reading and visualizing the data within the CRS HDF-5 files.

Known Issues or Missing Data

The ER-2 aircraft did not operate each day of the campaign, therefore CRS data are only available for aircraft flight days.

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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 Earthdata Search Portal search tool. Other datasets collected by CRS can be located by searching "CRS" in the GHRC Earthdata Search Portal and are listed below.

GOES-R PLT Cloud Radar System (CRS)
(http://dx.doi.org/10.5067/GOESRPLT/CRS/DATA101)

GPM Ground Validation Cloud Radar System (CRS) OLYMPEX
(http://dx.doi.org/10.5067/GPMGV/OLYMPEX/CRS/DATA101)

GPM Ground Validation Cloud Radar System (CRS) IPHEx
(http://dx.doi.org/10.5067/GPMGV/IPHEX/CRS/DATA101)

TCSP Cloud Radar System (CRS)
(http://dx.doi.org/10.5067/TCSP/CRS/DATA101)

Contact Information

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

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