Data User Guide

NCAR Particle Probes IMPACTS

Introduction

The NCAR Particle Probes IMPACTS dataset consists of data collected from six instruments on the NASA P-3 aircraft, the SPEC Hawkeye Cloud Particle Imager (CPI), the Hawkeye Fast Cloud Droplet Probe (FastCDP), the Hawkeye Two-Dimensional Stereo Probe (Hawkeye2D-S), the SPEC Two-Dimensional Stereo probe (2D-S), and two SPEC High Volume Precipitation Spectrometers (HVPS3). The 2D-S and HVPS3 are two-dimensional optical array probes that record images of particles that travel through their sampling area. The recorded images are then analyzed to produce particle size distributions from 20 microns to 3 centimeters in diameter. The FastCDP is a forward scattering instrument designed to measure the size and concentration of cloud droplets between 2 and 50 microns in diameter. The CPI is a high-resolution imager with a 256-level color depth. No particle concentration estimates have been attempted with the CPI. These data were collected during the Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) field campaign, 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 advance prediction capabilities significantly. Data files are available in netCDF-4 format, as well as browse imagery available in PNG format, from January 18, 2020, through February 26, 2020, and January 14, 2022 through February 28, 2023.

Citation

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Keywords:

NASA, GHRC, IMPACTS, P-3, Particle Probes, 2DS, 2DC, Cloud Probe, HVPS, cloud liquid water, ice water content, cloud droplet concentration, cloud droplet size, particle size distribution

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. The second deployment was from January through March 2022. 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 advance prediction capabilities significantly. More information is available from NASA's Earth Science Project Office's IMPACTS field campaign webpage.

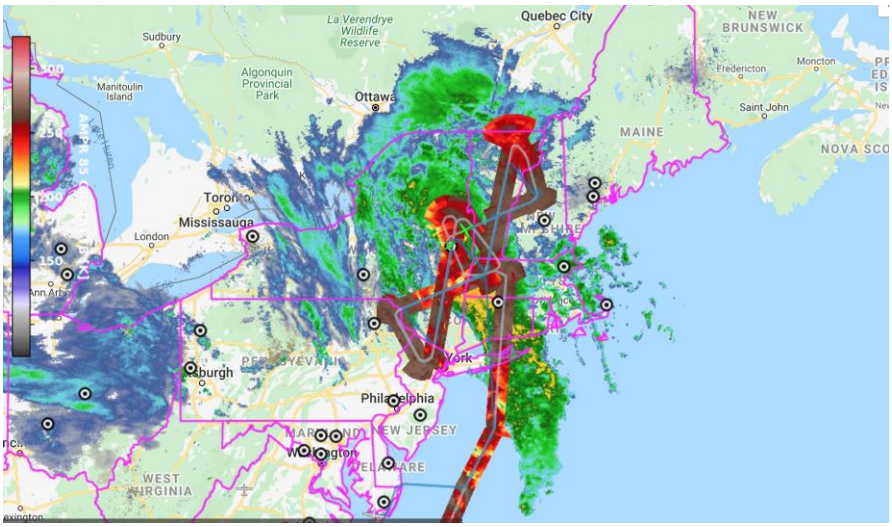

Figure 1: IMPACTS field campaign operations on January 25, 2020, with plots of ER-2 and P-3 flight tracks in addition to ground radar sites and radar reflectivity over the region (Image source: Dr. Timothy Lang, NASA MSFC)

Instrument Description

This NCAR particle probe dataset consists of data collected from a suite of instruments onboard the NASA P-3 Aircraft: the Hawkeye Cloud Particle Imager (CPI), the Hawkeye Fast Cloud Droplet Probe (FastCDP), the Hawkeye 2D-S, the 2D-S, and two HVPS-3 instruments.

The NASA P-3B Orion aircraft is a former U.S. Navy patrol aircraft that has been extensively modified by NASA for use as an airborne science laboratory. It is owned by NASA and operated by the NASA Goddard Space Flight Center's Wallops Flight Facility Aircraft Office at Wallops Island, Virginia. The P-3 is considered a "core" platform for the NASA Airborne Science Program. The aircraft can carry instrument payloads consisting of one to several at once while supporting scientific studies all over the globe.

The 2D-S instrument on the NASA P-3 Aircraft is a cloud particle imaging optical array probe that consists of two 128-element diode arrays with 10 microns per pixel that record particles in both vertical (imaging the top view) and horizontal (imaging the side view) orientation. The vertical and horizontal orientation data are considered to be two separate instruments in this dataset.

Figure 2: Image of the 2D-S instrument
(Image source: Michael Poellot)

The HPVS-3 instrument is a newer version of the HPVS-2 particle probe used in previous field campaigns. The HVPS-3 uses a 128-element array with a resolution of 150 microns per pixel. The sample volume of the HVPS-3 is 400 L s-1 at 100 m s-1. Two HVPS-3s were installed for IMPACTS, one in the horizontal orientation and one in the vertical orientation.

Figure 3: Image of HVPS-3 Instrument
(Image source: Michael Poellot)

The 2D-S and the two HVPS-3 make an excellent pair of probes that completely image particles from 10 microns to 1.92 cm. The Hawkeye CPI is a 1280 x 1024-element array with 2.3 microns per pixel, while the Hawkeye FastCDP is a forward scattering instrument.

The Hawkeye is a combination instrument containing three separate probes (CPI, Fast-CDP, and 2D-S) that measure particles passing through a sample tube. The CPI is a high-resolution imager at 2.3 microns per pixel. The Fast-CDP measures droplet size and concentration with a forward light scattering technique. The Hawkeye 2D-S is an optical array probe that works on the same principle as the 2D-S.

Figure 4: Image of Hawkeye instrument
(Image source: Michael Poellot)

More information about the NASA P-3 aircraft can be found on the NASA P-3B Airborne Science Laboratory Fact Sheet. More information about the instruments used to collect

these data can be found at the following link: IMPACTS Cloud Microphysics ReadMe, HVPS, 2D-S, and Hawkeye | IMPACTS.

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Data Characteristics

The NCAR Particle Probes IMPACTS data are available in netCDF-4 format at a Level 2 data processing level, with associated browse imagery available in PNG format. 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 P-3 aircraft
Instrument	HVPS-3, 2D-S, Hawkeye CPI, Hawkeye FastCDP, Hawkeye 2D-S
Spatial Coverage	N: 48.237, S: 33.261, E: -64.987, W: -95.243 (Eastern United States)
Spatial Resolution	2D-S: Two 128-element diode arrays, 10 microns per pixel, at Vertical orientation (V) and Horizontal orientation (H) Hawkeye 2D-S: Two 128-element diode arrays, 10 microns per pixel at Vertical orientation (V), 50 microns per pixel at Horizontal orientation (H) HVPS-3: 128-element diode array, 150 microns per pixel, two on aircraft, one with vertical (A) and one with horizontal (B) orientation Hawkeye CPI: 1280x1024 element, 2.3 microns
Temporal Coverage	January 18, 2020 - February 28, 2023
Temporal Resolution	File per flight
Sampling Frequency	1 second
Parameter	Ice water content, particle concentration normalized by bin width, and total particle number concentration
Version	1
Processing Level	2

File Naming Convention

The NCAR Particle Probes IMPACTS dataset files are available in netCDF-4 format, as well as browse imagery available in PNG format. The dataset files are named using the following convention:

Data Files: IMPACT_<inst>_YYYYMMDD_sizedistributions_v01.nc
Tarred Browse Imagery: IMPACTS_<inst>_YYYYMMDD_images_v01.tar
Untarred Browse Imagery: IMPACTS_<inst>_YYYYMMDD-hhmmss_images_v01.png

Table 3: File naming convention variables

Variable	Description
<inst>	2DSH-P3: Horizontal measurements from 2DS instrument on the NASA P-3 aircraft

	2DSV-P3: Vertical measurements from 2DS instrument on the NASA P-3 aircraft Hawkeye2DSH-P3: Horizontal measurements from Hawkeye 2DS instrument on the NASA P-3 aircraft Hawkeye2DSV-P3: Vertical measurements from Hawkeye 2DS instrument on the NASA P-3 aircraft FastCDP-P3: Measurements from the Fast Cloud Droplet Probe on the NASA P-3 aircraft HVPS3A-P3: Measurements from the High Volume Precipitation Spectrometer on the NASA P-3 aircraft, Probe A with horizontal orientation HVPS3B-P3: Measurements from the High Volume Precipitation Spectrometer on the NASA P-3 aircraft, Probe B with vertical orientation MergedHorizontal-P3: All horizontal measurements from the P-3 aircraft merged MergedVertical-P3: All vertical measurements from the P-3 aircraft merged
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
.nc	netCDF-4 format
hh	Two-digit hour in UTC
mm	Two-digit minute in UTC
ss	Two-digit second in UTC
.tar	Compressed files
.png	Portable Graphics Format

Data Format and Parameters

The NCAR Particle Probes IMPACTS dataset consists of netCDF-4 data files, as well as browse imagery available in PNG format. Table 4 describes the data fields within the netCDF-4 files.

Table 4: netCDF-4 Data Fields

Field Name	Description	Unit
CONCENTRATION	Particle concentration per bin, normalized by bin width	$\#/m^4$
COUNTS	Particle count per bin	#
GALT	GPS/Geopotential altitude	m
IWC	Ice Water Content for particles larger than 100um in diameter	g/m^3
LAT	Latitude	Degrees North
LON	Longitude	Degrees East
LWC	Liquid water content	g/m^3
MEAN_AREARATIO	Mean area ratio per size bin	-
MEAN_ASPECTRATIO	Mean aspect ratio per size bin	um
MMD	Median mass-weighted diameter for particles larger than 100um in diameter	um
MND	Mean diameter for particles larger than 100um in diameter	um
MVD	Median volume diameter for particles larger than 100um in diameter	um
NT	Total number concentration for particle larger than 100um in diameter	$\#/m^3$
PROBE_QC	Probe quality: 'quality_good', 'quality_medium','quality_bad'	-
time	UTC time	Seconds from midnight of start date

Particle size distributions are given in terms of particle maximum dimension, which is defined as the diameter of the smallest circle that can completely enclose the particle image. Images that touch a side of the array are counted if the center of the particle is deemed to be within the array. The technique described in Field et al. (2006) has been applied to mitigate shattering artifacts on the 2D-S and Hawkeye 2D-S. The 2D-S and HVPS-3 had probe tips designed to minimize the amount of shattering. Optical depth of field for the 2D-S, Hawkeye 2D-S, and HVPS-3 follows Lawson et al. (2006).

"MergedHorizontal" and "MergedVertical" files have been produced for each flight, which are a combination of the 2D-S for particles smaller than 1mm in diameter, and the HVPS3 for particles larger than 1mm in diameter. Merged files are only available when both the 2D-S and HVPS3 are available at the specified orientation (horizontal or vertical). Starting in 2022, the Hawkeye 2D-S is used for particles smaller than 1mm in diameter when the regular 2D-S is not available.

Bulk ice water content (IWC) is available in the size distribution files for the convenience of data users. Other derived parameters are available in the files, including total number concentration (Nt), mean diameter (MND), median mass-weighted diameter (MMD), and median volume diameter (MVD). All derived parameters are computed using particles larger than 100 microns in diameter to avoid uncertainties with very small particles.

More information can be found in the IMPACTS Cloud Microphysics ReadMe.

Algorithm

Condensed water content measurements were computed using mass = 0.0061 * (D^2.05) from Heymsfield et al., 2004. Particle shape information is available in mean area ratio distributions and mean aspect ratio distributions. The area ratio is defined as the area of the particle divided by the area of a circle with the particle's maximum dimension. The aspect ratio uses the method described by Korolev and Isaac (2003).

Droplet size distributions from the FastCDP were processed using software provided by the manufacturer. Particle images and shape information are not available from this instrument, all measured particles are assumed to be liquid in the derived variables.

Quality Assessment

Concentrations from particles smaller than 100 microns may contain large errors due to uncertainties in the probe's sample area; therefore, particles smaller than 100 microns are not included in measurements. Also, images that touch a side of the array are allowed. The technique described by Field et al., 2006 has been applied to mitigate shattering artifacts on the 2D-C and 2D-S instruments. These instruments also had modified probe tips to minimize the amount of shattering.

The ice water content algorithm has been indiscriminately applied, and will not be valid in cases of rain, graupel, or ice habits that are not well represented by this mass-size parameterization.

Ice particle shattering can be expected on the Hawkeye inlet tube. Concentrations of small ice may be significantly overestimated in Hawkeye 2D-S size distributions, especially for particle sizes smaller than 300 microns. These overestimates will carry over to the MergedHorizontal and MergedVertical data when the Hawkeye 2D-S is used in place of the regular 2D-S. Shattered ice fragments will be present in CPI images. Hawkeye Fast-CDP data may also contain artifacts from small shattered ice.

Software

Software is not required to read these data; however, Panoply can be used to easily view the netCDF-4 data files.

Known Issues or Missing Data

Periods of missing or poor data have been marked with a value of -999 in all variables. A probe quality flag is available to indicate where difficult probe conditions existed, such as low end-diode voltages, significant probe dead time, probe malfunction, or a high proportion of rejected particles.

Missing data for the 2020 campaign:
2D-S: Feb 25
HVPS3B: Jan 18, Jan 25, Feb 01, Feb 05

Missing data for the 2022 campaign:
2D-S: Jan 14, Jan 17, Jan 19, Jan 29, Feb 03, Feb04
HVPS3A: Jan 17, Jan19
HVPS3B: Jan 14

References

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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 Search Portal. Listed below are datasets from other field campaigns and studies that used the NCAR Particle Probes instrument:

GPM Ground Validation NCAR Particle Probes IPHEx
(http://doi.org/10.5067/GPMGV/IPHEX/MUTIPLE/DATA201)

GPM Ground Validation NCAR Particle Probes OLYMPEX
(http://dx.doi.org/10.5067/GPMGV/OLYMPEX/PROBES/DATA201)

Contact Information

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

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