Data User Guide

Water Isotope System for Precipitation and Entrainment Research (WISPER) IMPACTS

Introduction

The Water Isotope System for Precipitation and Entrainment Research (WISPER) IMPACTS dataset consists of condensed water contents, water vapor measurements, and isotope ratios in support of 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 dataset files are available in ASCII format from January 18, 2020, through February 28, 2023.

Citation

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Keywords:

NASA, GHRC, IMPACTS, WISPER, Precipitation, condensed water contents, water vapor, isotope, isotopologue

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.

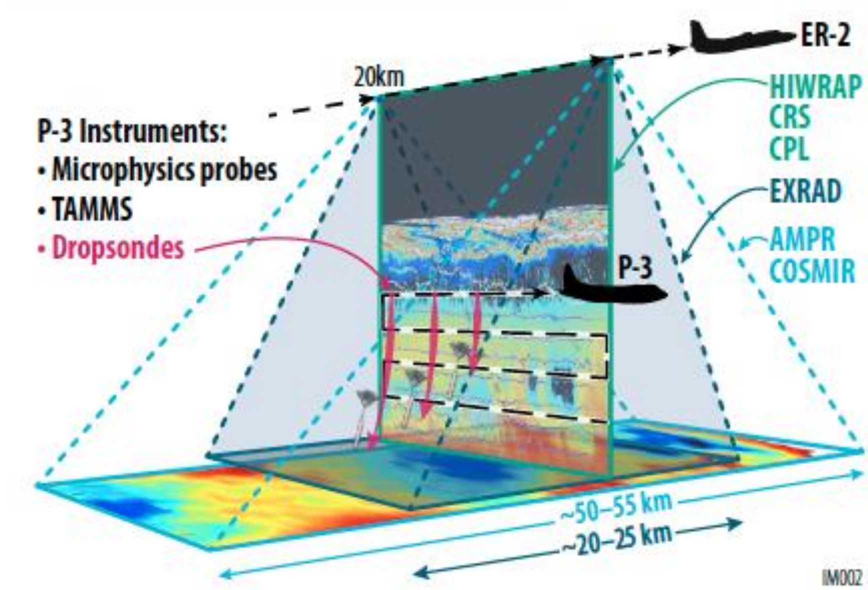

Figure 1: IMPACTS airborne instrument suite
(Image source: NASA IMPACTS ESPO)

Instrument Description

Water Isotope System for Precipitation and Entrainment Research (WISPER) primarily obtains in situ measurements of condensed water contents and the isotope ratios D/H and 18O/16O. For IMPACTS, WISPER uses two inlets. The primary inlet is a counterflow virtual impactor (CVI) of similar design to that described in Noone et al. (1988) and Twohy et al. (1997) and that has been deployed frequently on the NCAR G-V and C-130 aircraft for cloud-related studies (e.g., Twohy et al. 2021). To ensure that air is sampled from the free stream, the inlet is mounted on an extension similar to the one used on the NCAR C-130 aircraft. The inlet as flown on the NASA P-3 in January and February of 2020 is pictured in Figure 2.

Figure 2: Photo of CVI inlet as deployed on the NASA P-3 for IMPACTS 2020. The front of the NASA P-3 aircraft is to the left in the photo. The CVI inlet faces forward, above which is a backward-facing tube that was used for attempting to measure water vapor in and out of clouds. See text for additional details of both inlets.

(Image source: Darin Toohey)

A second inlet, facing backward, was intended to measure water vapor both in and out of clouds. Unfortunately, during IMPACTS 2020 there was insufficient heating of that inlet and too slow of the flow of air through the inlet to ensure that there was no contribution to that measurement by water condensing on surfaces near the tip of the inlet, and therefore those results are all considered suspect for the campaign (discussed later in the document). However, the measurements of condensed water contents are of high quality for most of the campaign.

Picarro cavity ringdown laser spectrometers (CRDS, models L-2120fxi and L-2120i) are used to measure condensed water and water vapor, respectively. The L-2120fxi operates at a fixed mass flow rate of 350 cm3 min-1, ensuring that the optical cavity is refreshed at a rate faster than the native measurement rate of 5 Hz. The L-2120i operates at a fixed flow rate of 25 cm3 min-1, which results in a much slower effective data rate. However, because the tip of the back-facing inlet was often contaminated by condensed water (as diagnosed by analyses of water isotopologues, which are a sensitive indicator of condensation and evaporation), this aspect of the measurements of water vapor for IMPACTS 2020 is unimportant.

The CVI inlet operates by continuously pulling air at a flow rate of ~3-18 liters per minute (LPM) down a sample line connected to the probe tip. A porous tube ~4 inches long and ~1/4" in diameter is inserted directly behind the tip, and dry air from a cylinder on the aircraft is pushed through the porous tube at a rate that is in slight excess of the sample rate. This excess (called the "excess counterflow") ensures that no ambient air or particles larger than about 5 microns in diameter penetrate into the air that is then sampled downstream of the probe tip. Particles (including hydrometeors) larger than 5 microns in diameter are then heated rapidly to ~45 °C (a process that takes less than 1 second under most conditions) in a ~12" long segment of tubing in the inlet, and this air then passes through a box that contains multiple heater controllers and flow controllers, a computer for operating a feedback control loop and recording signals necessary for calculating condensed water contents, and that air is finally exhausted out of the aircraft through a venturi mounted to the fuselage downstream of the inlet. A small fraction of the total sample flow is picked off by the Picarro L-2120fxi for measuring the water vapor mixing ratio and isotopic ratios D/H and 18O/16O produced by the evaporated hydrometeors. Under normal conditions, the response time of the measurements of condensed water is less than 1 second. However, in cold clouds (especially in the presence of supercooled water), there is some hysteresis due to icing and condensation and subsequent slow evaporation on inner surfaces of the inlet. This unavoidable situation is most noticeable as a slow dropoff of water vapor (hence, inferred condensed water contents) which can last tens of seconds and longer when exiting some clouds. Although there is no simple way to correct for these situations, it is estimated that the error in condensed water during these occasions is less than 15%, so this is the uncertainty quoted for the measurements reported here.

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Data Characteristics

The WISPER IMPACTS dataset consists of condensed water contents, water vapor measurements, and isotope measurements. These data are available at a Level 1A processing level and stored in ASCII 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	Water Isotope System for Precipitation and Entrainment Research (WISPER)
Spatial Coverage	N: 48.236, S: 33.261, E: -67.878, W: -95.243 (Eastern United States)
Temporal Coverage	January 18, 2020 - February 28, 2023
Temporal Resolution	Daily -< Weekly
Sampling Frequency	1 second
Parameter	Condensed Water Contents, Water Vapor measurements, isotope measurements
Version	1
Processing Level	1A

File Naming Convention

The WISPER IMPACTS dataset files are available in ASCII format and named using the following convention:

Data files: IMPACTS-WISPER-CWC_P3_YYYYMMDD_R0_SF##.ict

Table 3: File naming convention variables

Variable	Description
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
SF##	Flight number
.ict	ASCII file format

Data Format and Parameters

The WISPER IMPACTS dataset files are stored in ASCII format. The data fields included in each file are listed in Table 4 below.

Table 4: ASCII Data Fields

Column	Field Name	Description	Unit
1	Start_UTC	Seconds since start of day of record	s
2	CWC	Condensed water concentration (ice + liquid water)	g/m^3
3	H2O_VAP	Water vapor mixing ratio	ppm
4	DELTAD_C	HDO/H2(16)O ratio in condensed water	permil
5	DELTAO18_C	H2(18)O/H2(16)O ratio in condensed water	permil
6	DELTAD_V	HDO/H2(16)O ratio in water vapor	permil
7	DELTA018_V	H2(18)O/H2(16)O ratio in water vapor	permil

Algorithm and Quality Assessment

Condensed Water Contents

Condensed water contents (or CWC) are calculated in units of grams H2O per meter3 of air at ambient temperature and pressure using a geometric ratio of the impact rate of hydrometeors onto the cross-sectional plane of the trip of the sample tube (or R2 x V, where R is the inner radius of the inlet and V is the forward velocity of the aircraft perpendicular to that cross section) to the mass flow rate of air sampled by the inlet. This ratio is often expressed as a product of an "enhancement factor" that accounts for the sub-isokinetic nature of the inlet and the amount of condensed water. Enhancement factors employed during IMPACTS 2020 ranged from ~10-30, resulting in observed water vapor mixing ratios typically less than to < 40,000 ppm in most situations, ensuring that there was no condensation in the sample lines for the temperatures at which the inlet and sample lines were heated. However, there were some occasions when heavy precipitation was encountered, resulting in temporary condensation within the sample lines. This condition was diagnosed with isotopologue ratios, which are sensitive indicators of condensation and evaporation. To the extent they are evident in the isotopologue data, these occasions have been removed from this data release, and the results are replaced with -9999.

As part of the normal operation of the CVI inlet, and usually only when outside of clouds, the counterflow of dry air can be turned off, allowing for measurements of water vapor in ambient air. If, on occasion, this mode of operation is employed while in clouds, the resulting measurement is called "enhanced total water", and the measurement represents a sum of the ambient water vapor and the product of the condensed water and the enhancement factor. This mode, although potentially useful under some conditions, was not used extensively during IMPACTS 2020, although it was used on occasion to diagnose performance issues that help with data QA/QC. In the Rev_0 release of data, these periods have not been flagged or removed, so investigators should proceed with caution when discovering periods when WISPER is reporting appreciable condensed water contents when clearly outside of clouds.

Water Vapor Measurements

Water vapor was detected by sampling from a backward-facing, unheated inlet near the CVI probe. Unfortunately, for most of the IMPACTS 2020 campaign, small amounts of water vapor condensed on the surface of the inlet, probably by impaction of hydrometeors on the tubing that extended into the airstream. This condensed water then acted as a source of saturated water in the air at the pressure and temperature conditions at the first point of contact of ambient air with the inlet. Consequently, water vapor appears supersaturated with respect to free stream conditions due to a reduction in pressure due to suction at the entrance of the back-facing inlet. Investigators who wish to use these data should proceed with extreme caution, and they should contact the PI for the latest knowledge regarding the quality of the measurements, which will be undergoing additional analysis to determine whether or not accurate values can be retrieved. At the time of this writing, however, it is felt that the accurate water vapor measurements from IMPACTS 2020 may be irretrievable from WISPER. New in-flight diagnostics will be performed during IMPACTS 2022 to determine what values, if any, from the 2020 field campaign may be useful for scientific investigations.

Water Isotopologue Measurements in Condensed Water
Water isotopologues are useful for diagnosing the performance of the instrument (e.g., as noted in the previous section when icing, condensation, or evaporation is occurring on the inlet or in the transfer lines). Scientifically, they are useful for examining the origins of air masses and elucidating important microphysical processes, entrainment and detrainment, and precipitation. As of the writing of this document, the Rev-0 data are believed to be accurate, and investigators are encouraged to use them in their analyses. However, it is highly recommended that the PI be contacted prior to extensive use of the isotopologue data because ongoing laboratory work and in-flight diagnostics planned for the IMPACTS 2022 field campaign will be used to refine the results, as needed. It is likely that some data will eventually be flagged as suspicious if instances of icing, condensation, or evaporation are suspected in the results.

Water Isotopologue Measurements in Water Vapor
At the time of this writing, it is believed that the water isotopologue measurements in water vapor are not accurate for scientific analyses, at least when flying in cloud and for at least 10-15 minutes after exiting clouds. These measurements are useful for CWC data QA/QC purposes, and therefore they are included in the R0 exchange files. In future releases, a flag will be incorporated to specify if and when these results are accurate for scientific analyses.

Software
No special software is required to read these data.

Known Issues or Missing Data
Missing or bad data are indicated by -9999.

References

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Twohy, C.H., P.J. DeMott, L.M. Russell, et al. (2021). Cloud-Nucleating Particles over the Southern Ocean in a Changing Climate, Earth's Future. doi: https://doi.org/10.1029/2020EF001673

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 Earthdata Search.

Contact Information

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

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