ICECHIP IBHS Dataset Documentation

HAIL IMPACT DISDROMETERS

Title: IBHS Hail Impact Disdrometers

Authors:

Ian M. Giammanco (Lead)
Managing Director of Atmospheric Science
ORCiD: 0000-0002-4664-4245
Insurance Institute for Business & Home Safety
5335 Richburg Rd, Richburg SC 29729
igiammanco@ibhs.org
ibhs.org

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1.0 Dataset Description

IBHS developed a rapidly deployable network of 24 impact disdrometer probes for use in in-situ data collection from hail producing thunderstorms. The impact plate follows that used by Lane et al. (2004) and relies on a piezoelectric disk to capture hailstone impacts on the 1 ft^2 shallow pyramid impact plate. Probes sample the raw piezoelectric disk voltage output at 2.5 kHz, raw data impact data is post processed to provide impact data at a 1 Hz resolution. Probes also provide temperature, humidity and pressure data, as well as a GPS chip for time/date sync and deployment latitude/longitude. Also included in the dataset are IOP summary files which provide summary information for the given IOP deployment.

Data version: Current data version is version 1.
Data version completed: 1/7/2026
Data status: Final (Processed data ready for publication, could be revised later)

Time period: Impact disdrometer data available for IOPs1-5, IOPs 7-9, IOPs 11-13, IOP 15, IOPs 18-21. For other ICECHIP IOPs, disdrometers were not deployed.

Physical location: Latitude, Longitude, date, data start time (UTC), data end time (UTC) are provided in the IOP summary files. Post-processed data contains time in UTC.

Data frequency: Post-processed data for each probe is 1 Hz

Data source: IBHS

Web address reference: None

Dataset restrictions: None

2.0 Instrument Description

The IBHS hail impact disdrometer uses a 1 ft^2 shallow pyramidal impact plate and a piezoelectric disk mounted underneath the plate to sense hail impacts. The impact plate is designed based on that described in Lane et al. (2006). Beneath the impact plate is an enclosure which houses the data acquisition controller, the probe's battery, battery charge controller, and voltage buck converter for powering the aspirated thermodynamic sensor package (Figure 1). When deployed, an aluminum tripod is bolted to a plate on the bottom of the enclosure, securing the top portion to the supporting tripod (Figure 2). The tripod legs are adjustable to enable leveling on uneven ground. The probe is controlled by a toggle switch to turn the unit on and a separate toggle switch to turn on data logging with an LED indicator that tells the user if data collection has begun. The third toggle switch shown in Figures 1 and 3, puts the probe into a battery charge configuration or normal operations mode.

Figure 1. Photograph of the impact disdrometer impact plate and data acquisition enclosure assembly. Also note on the right side of the plate frame is the aspirated thermodynamic sensor package, which is a modified and scaled down U-tube style assembly.

Figure 2. Photograph of an IBHS hail disdrometer deployed in the field in 2017.

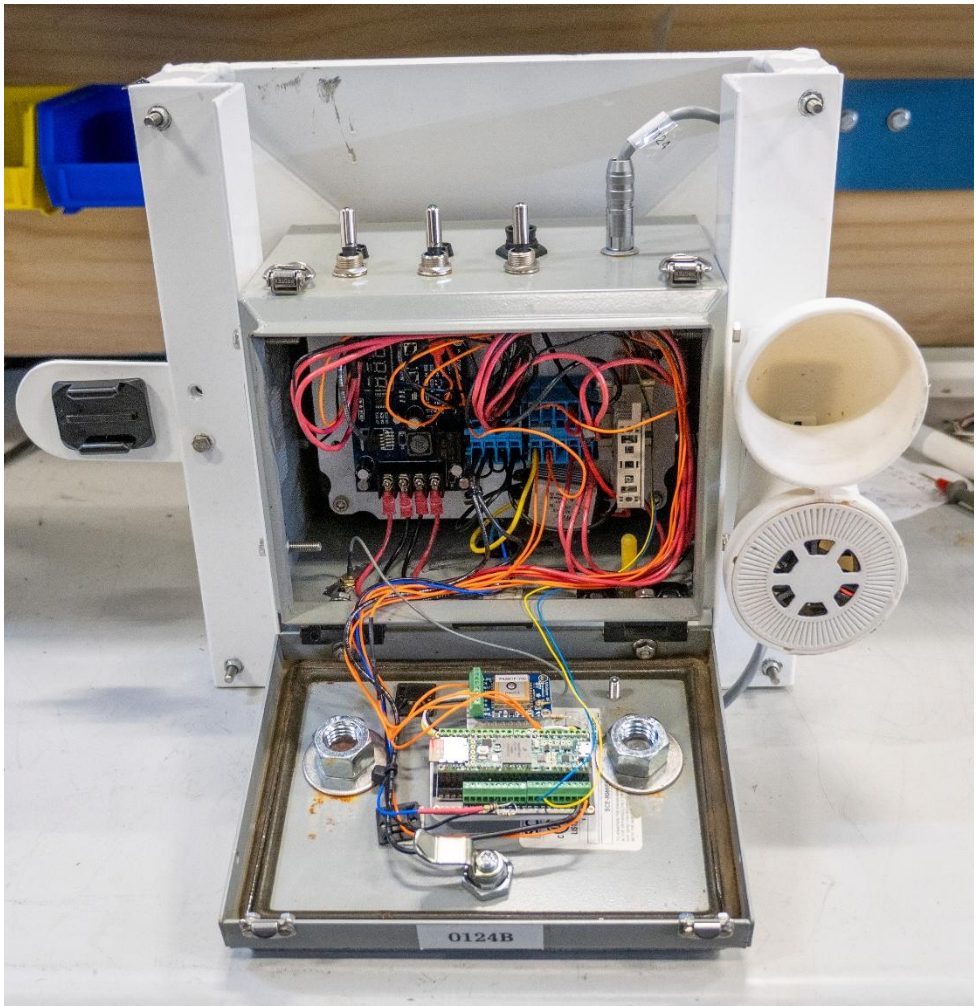

Figure 3. Photograph showing the inside of the data acquisition enclosure. Note the Teensy 2.0 and its GPS chip mounted on the inside of the enclosure lid. The battery charge controller, buck converter, and wire terminals are mounted on a back plane. The battery (not visible) is mounted under the back plane.

Its data acquisition system is driven by a Teensy 2.0 microcontroller, shown in Figure 3) which integrates a GPS chip (also shown in Figure 3) for date and time sync and position information. The onboard microSD card slot is used for data storage through a microSD card. The Teensy controller samples the raw piezoelectric disk output using an analog input at 2.5 kHz sampling. The output from the piezoelectric disk is in volts but converted by the Teensy 10-bit analog to digital converter to an integer (bits), which ranges from 0 to 1023, covering the full 0 – 5 V input range of the controller. For more information on the design, original prototype and an earlier version of the current operational probe see Giammanco et al. (2016).

Probes are calibrated at IBHS using laboratory manufactured hailstones (see Brown-Giammanco et al. 2021) propelled at kinetic energies based on Heymsfield et al. (2018) for their laboratory hailstone nominal size. of 1.0, 1.25, 1.5, 1.75, 2, 2.25

inches. Using 30 impacts per nominal size an integrated impact signal to kinetic energy curve is fitted for each probe and used to post-process raw datafiles to create a 1 Hz time history of hail impacts. The post-processed data for each probe includes a time history datafile, and a larger post-processed 1 Hz data file.

Table 1. IBHS Hail Impact Disdrometer Specifications

Variable	Sampling rate	Precision / resolution	Range	Error
Impact voltage signal	2.5 kHz	4.8 mV	0 – 5 V	N/A
Impact kinetic energy	500 Hz	0.01 J	0.01 – 500 J	RMSE =
Hail size estimate*	1 Hz	1 cm bin size	0.5 – ~10 cm	Dependent on Heymsfield et al. (2018) KE to Diameter relationships
Temperature (C)	1 Hz	0.001 C	-40 to 85 C	±1 C
Relative Humidity (%)	1 Hz	0.001%	0-100%	±3%
Pressure (hPa)	1 Hz	0.01 hPa	300 – 1100 hPa	±1 hPa

*derived

3.0 Data Collection and Processing

Raw impact time history processing

Raw impact data time histories are stored on the on-board microSD card. Each raw data file has a GPS header and footer for date, time, latitude, longitude and altitude. Prior to post processing, each raw file is visually inspected for issues, gap, incomplete records, radio frequency noise issues etc. Next, the full raw time history is filtered using a 5-sample moving average and a bias correction (using the first 1 second of data) to remove bit to bit signal noise.

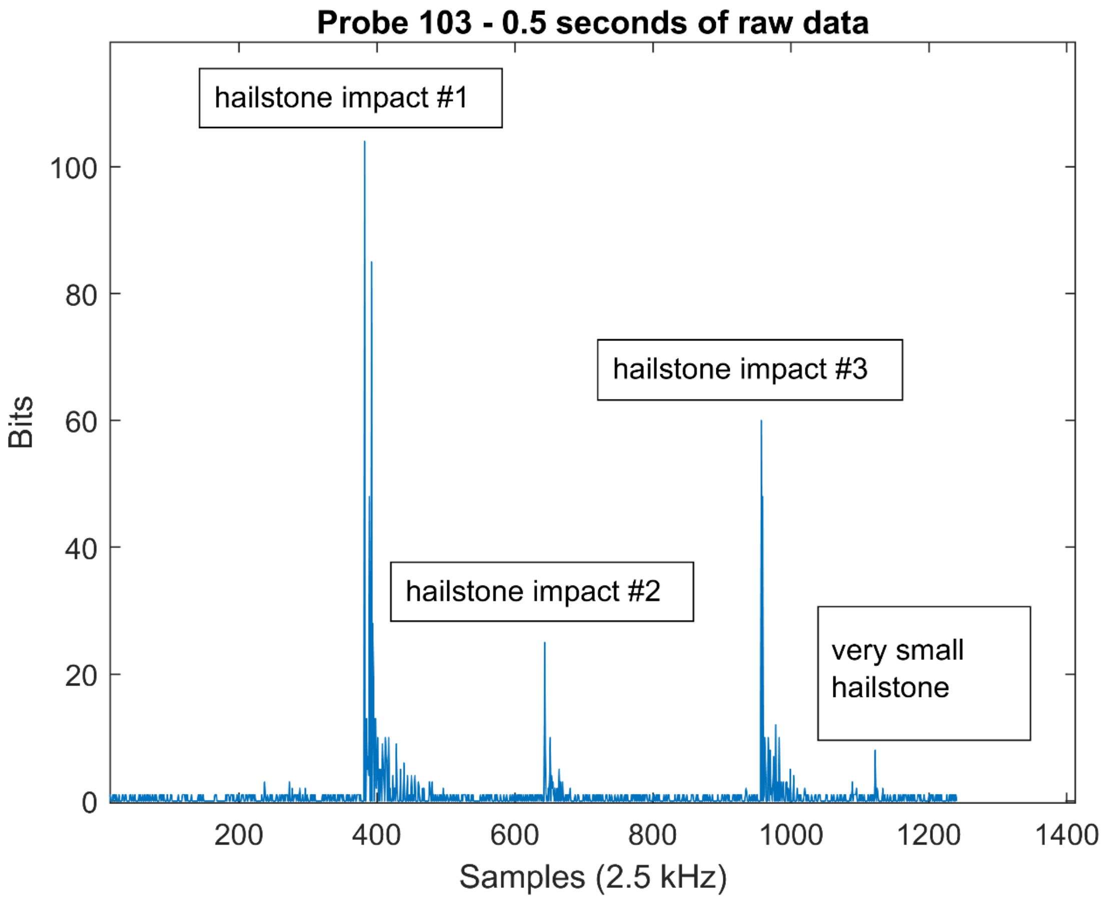

Figure 4. 0.5 seconds from a raw impact disdrometer record which had three impacts within that time window. Note the very small hail impact has a peak > 2 bits above the noise threshold.

Post-processed data

The raw time history is segmented into 1 second bins. Impacts are identified by the rising signal voltage indicated by a positive $\Delta V/\Delta t$ that are at least 2-bits above the signal-noise threshold (typically 1-2 bits) which is found using a centered difference approximation. Once the voltage change converges to zero for a time duration of 0.004 seconds (e.g. 10 observations at 2.5 kHz), the impact signal is truncated and then operated on. If an impact signal packet spans two 1-second bins, the impact is logged for the time bin in which the impact signal packet started. The method overall is similar to that used in acoustic raindrop detection by Joss and Waldvogel (1967). The technique assumes that the integral of the impact signal curve in time is proportional to the kinetic energy of the object impacting the plate. Repeated tests in heavy rainfall of the instrument co-located with a parsivel laser disdrometer showed that the probe does not resolve rain drops; however, hailstones < 0.5 cm can be resolved but are often filtered in post processing through the moving average filter.

For each 1-second bin, the kinetic energy of each impact is calculated and a size estimate generated using:

$$D_{max} = 2.311\ KE^{0.2433}$$

Additionally, the total number of identified impacts within the 1 second window is counted, a kinetic energy flux is calculated (summed kinetic energy over the 1 second time window), using the estimated hail size for each impact the number of impacts occurring in each 1 cm size bin (8 size bins total) is calculated along with an estimated volumetric concentration for each size bin (particles m^{-3} s^{-1}). The volumetric quantities assume a constant distribution in space and time over that 1 second interval and uses a terminal velocity assumption using the relationships specified in Heymsfield et al. (2018). Thermodynamic data are oversampled relative to the sensor response at the raw 2.5 kHz sampling rate and are block averaged over each 1 second window to produce the post-processed 1 Hz record.

Quality assurance and controls

Both raw and post-processed files are visually assessed for probe issues. Raw time histories with noted problems or abnormally high analog input noise (> 3 bits) are flagged for investigation. These records are not processed until issues can be identified. Those records with major problems are not post-processed and not useable for analysis. Post-processed data are also visually inspected for anomalously high hail concentrations relative to other nearby probes, this is often an indicator of RF interference and added noise over short time scales often caused by nearby lightning strikes. Post-processed data records are also compared with physical hail measurements and photographs of hail at deployment sites. When comparing with physical measurements, often hailstones are collected and measured over surface areas much larger than the 1 ft^2 surface of the impact plate. An example is shown in Figure 4.

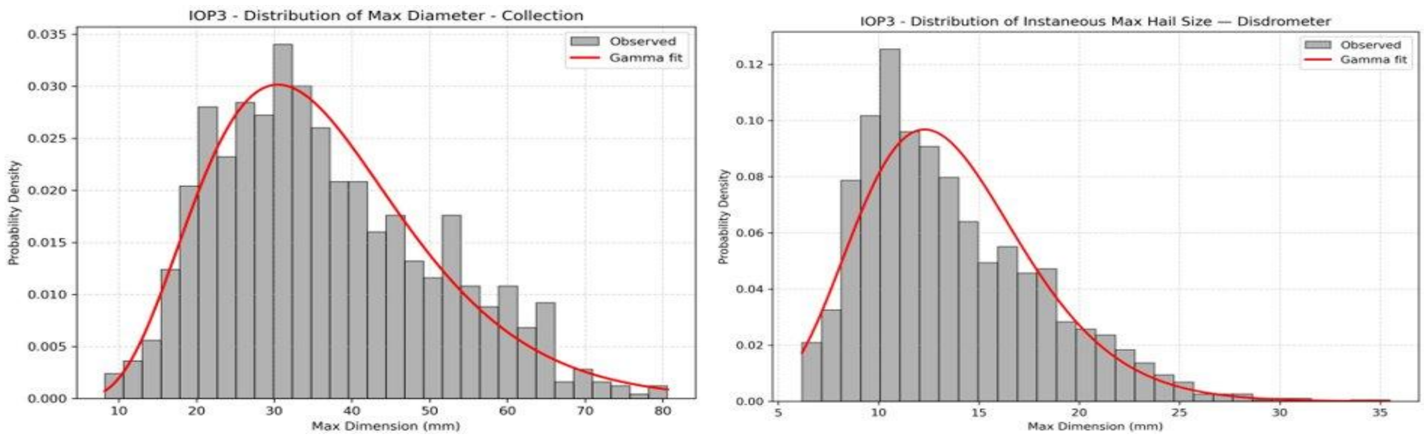

Figure 4. Probability distribution of (left) physical hailstone maximum diameter measurements and (right) disdrometer 1-second estimated maximum hail size for all deployed disdrometers and physical hailstone measurements collected during ICECHIP IOP.

Data intercomparisons

4.0 Data format

Post-processed data are contained within two .csv files.

1) Kinetic energy time history. Filename format: P1XX_IOPXX_KE.csv
2) Post-processed hail size and thermodynamic data. Filename format: P1XX_IOPXX_Processed.csv

P1XX corresponds to the disdrometer ID i.e. P101 – P125 IOPXX is the IOP number IOP1-IOP24.

Column headers and variables

- <u>Processed KE .csv files</u>

Filenaming: P1XX_IOPXX_KE.csv

KE files represent a time history of all impact kinetic energies detected during post-processing.

Column headers

1. Hour (UTC) - derived from entered start time
2. Minute (UTC) - derived from entered start time
3. Second (UTC) - derived from entered start time
4. Impact kinetic energy

- <u>Processed .csv files</u>

Filenaming: P1XX_IOPXX_Processed.csv

1 Hz data

Very small hail < 0.5 cm is filtered out in post-processing and considered not-detectable after time histories are processed to remove bias error and RF signal noise from electronics, lightning, power supply etc.

Column headers

1. Hour (UTC) - from entered start time (either from probe GPS or estimated from record, see summary for notes)
2. Minute (UTC) - from entered start time (either from probe GPS or estimated from record, see summary for notes)
3. Seconds (UTC) - from entered start time (either from probe GPS or estimated from record, see summary for notes)
4. Maximum detected size per second (cm)
5. Kinetic energy flux (J ft^{-2} s^{-1}) - Summed kinetic energy over 1 second time interval per square foot (impact plate surface area)
6. Total hail impacts per second per square foot
7. Number impacts Bin 1
8. Number impacts Bin 2
9. Number impacts Bin 3
10. Number impacts Bin 4
11. Number impacts Bin 5
12. Number impacts Bin 6
13. Number impacts Bin 7
14. Number impacts Bin 8
15. Volumetric concentration bin 1   (particles m^{-3} s^{-1}, estimated assuming constant distribution in space/time)
16. Volumetric concentration bin 2
17. Volumetric concentration bin 3
18. Volumetric concentration bin 4
19. Volumetric concentration bin 5
20. Volumetric concentration bin 6
21. Volumetric concentration bin 7
22. Volumetric concentration bin 8
23. 1 Hz mean BP (hPa)
24. 1 Hz mean T (C)
25. 1 Hz mean RH (%)

Bin particle sizes:
Bin 1: <1 cm

Bin 2: 1-2 cm
Bin 3: 2-3 cm
Bin 4: 3-4 cm
Bin 5: 4-5 cm
Bin 6: 5-6 cm
Bin 7: 6-7 cm
Bin 8: > 7

- Disdrometer IOP Summary files (.xls)
  IOP summary files provide basic information and summary statistics from the disdrometer deployments during the associated IOP. All dates/times in UTC

Column headers

1. Probe ID (i.e. 101, 102…125)
2. Deployment date (ddmmyy)
3. Probe deployment latitude (decimal degrees)
4. Probe deployment longitude (decimal degrees, i.e. -103.4089 '-' for western hemisphere)
5. Elevation (elevation of probe determined through probe GPS header or footer fix)
6. Start time (hhmmss - UTC, time the probe began data collection)
7. Stop time (hhmmss - UTC, time the probe ended data collection)
8. Impacts detected in the raw data (Yes or No: Y/N, determined from visual inspection of the raw disdrometer time history)
9. Impacts recorded in processed data (Yes or No: Y/N, determined from processed data)
10. Total impacts resolved in processed data
11. Maximum size detected in full record (cm)
12. Collection/measurement location ID (if measurement/collection was colocated)
13. Notes - Notes include qualtiative QA/QC descriptions, known instrument issues, known data file issues, GPS issues etc.

Example summary file.

Probe ID	Date (ddmm	Latitude	Longitude	Elevation (m)	Start Time UTC (hhmmss)	End Time UT	Impacts detected raw (Y/N)	Impacts record	Total impacts	Maximum size detected (cm)	Collection,Measu	Notes
101	250525						Y	Y	651	3.3		incomplete record, check GPS info and logs
102	250525	33.8342567	-100.84743	N/A	204759	234354	Y	Y	798	3.4		clean impact and thermo records
103	250525											raw_file only, possible corrupt raw file
104	250525	33.817923	-100.84745	816.6	205057	234829	Y	Y	1472	7.8		clean impact record, no thermo on probe
105	250525	33.809542	-100.84738	N/A	212922	000043	Y	Y	103	2.8		concatenated multiple files. Start time estimated from concatenated files. Likely not complete record
106	250525				205350	235456	Y	Y	314	3.5		GPS no position fix, need Lat/Long from logs. Clean impact and thermo records
107	250525	33.79467	-100.84738	N/A	204300	235708	Y	Y	109	1.9		Start time estimated from log. Clean impact and thermo records
108	250525	33.90508	-100.94943	N/A	203600	222150	Y	Y	11	1.4		Start time estimated from log. Clean impact and thermo records
109	250525	33.9082	-100.92272	842.1	204005	223325	Y	Y	119	2.5		Clean impact record. Thermo data with spikes/erroneous approx 4500 seconds
110	250525	33.90483	-100.96587	N/A	202700	221330	N	N	0	0		No GPS fix, start time and lat/lon from log. Clean impact and thermo records
111	250525	33.905183	-100.93386	N/A	202211	222901	Y	Y	223	5.5		clean impact and thermo records
112	250525	33.905045	-100.95846	N/A	202618	221939	Y	Y	221	2.6		qc flag: hail noted at end of record, possible incomplete record or other issue (erronous impacts late in record, check w/radar and truncate if needed)
113	250525	33.9038567	-100.85251	N/A	210209	215602	Y	Y	95	3.2	IBHSDisdro1 - L1	probe deployed at team shelter location w/NIU command, PurduePIPs. Clean impact and thermo records
114	250525	33.90664	-100.90246		201200	224228	Y	Y	126	2.5		No GPS fix, start time and lat/lon from log. Clean impact and thermo records
115	250525	33.904997	-100.97041	N/A	202822	221203	Y	Y	1	1.5		clean impact and thermo records
116	250525	33.90686	-100.89489	N/A	201143	224514	Y	Y	51	2.4		clean impact and thermo records
117	250525	33.906095	-100.9273	N/A	202058	223136	Y	Y	116	2		clean impact record. No thermo data, sensor pkg issue
118	250525	33.8914917	-100.84925	N/A	203251	233012	Y	Y	349	2.3		clean impact and thermo records
119	250525	33.870467	-100.85011	764	203615	233442	Y	Y	527	3		clean impact and thermo records
120	250525	33.856458	-100.85186	773.7	204031	233736	Y	Y	816	2.7		clean impact and thermo records

5.0 Data remarks

In general, most of the disdrometer fleet was available for each IOP. Data quality issues encountered in the field are described in the IOP summary files. The most common issue was quality GPS fix information especially in raw data headers. Also, for later IOPs thermodynamic sensor packages began to fail due to internal solder joint and circuit board issues as well as some cases of water intrusion on to the sensors themselves. Also in some instances, probes wrote multiple raw datafiles, in most cases these could be quickly concatenated to create a full record. These are noted in the disdrometer summary files for each IOP. Probes with QA/QC clean impact and thermodynamic records are noted in the IOP summary files. In some deployments and IOPs post-processing did not identify any impacts, however small impact above the noise threshold were identified in the raw time history. These impacts are likely hailstones less than 0.5 cm. These were counted from the raw files when present and are described in the IOP summary file. The disdrometers do not resolve rain drops.

Impact disdrometer data are not available for the following ICECHIP IOPs:
IOP6, IOP14, IOP16, IOP17, IOP22, IOP23, IOP24.

For those IOPs probes were not deployed.

IBHS Impact Disdrometer Contacts

Ian Giammanco
Igiammanco@ibhs.org

Lucas Faulkner
Lfaulkner@ibhs.org

Software compatibility

Matlab, Python, etc.

6.0 References

Brown-Giammanco, T.M., I.M. Giammanco, and H.E. Estes, 2021: A New asphalt shingle hail impact performance test protocol and damage assessment. *Natural Hazards Review,* https://ascelibrary.org/doi/full/10.1061/%28ASCE%29NH.1527-6996.0000509

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