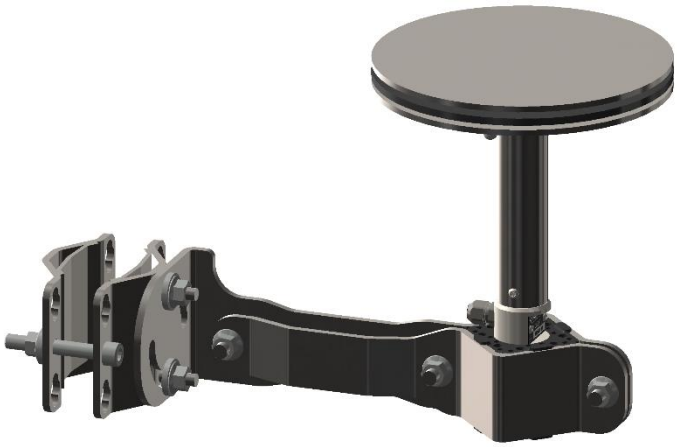
HailFlow HF4

Instrument for the counting and the
size classification of hailstones



Full documentation and User manual

Version 5.03

HailFlow™ HF4 is a Swiss made product of the ISAW line of meteorological sensing instruments by IAV Technologies SARL, a Swiss based company and original manufacturer of the product since 1997. The ISAW instruments are ultra robust, high performance, very low-power consumption and near zero-maintenance instruments, ideal for a wide range of gravity or aeolian transported liquid or solid precipitations applications. This manual provides the technical characteristics and all the information required to procure, configure and operate the HailFlow HF4 instrument and its accessories. The configuration of the instrument can be done through various direct or remote serial connection methods, as well as by means of the ISAW Toolbox software utility, which is available anytime on our website www.isaw-products.com, this without functional restrictions on use or duration. The articles, dimensions and other technical or informational details described in this document may be subject to minor changes, but any change that could impact the operation of the instrument will lead to a new version of the documentation.

Note about the firmware: This document applies to all instruments with firmware 3.55 onwards. If your instrument operates with an earlier firmware version, we advise you to update it with the latest firmware. However, even if you keep the older firmware, almost all of the information in this manual remains valid.

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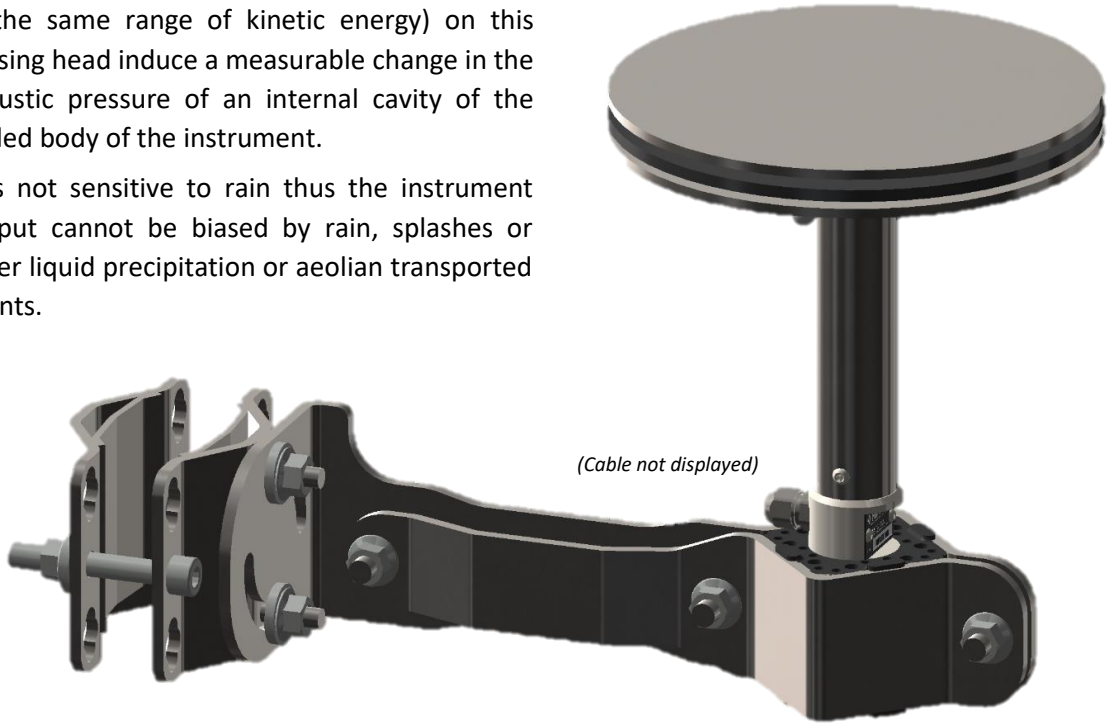
1. THE ESSENTIAL IN BRIEF

1.1. Introduction

HailFlow™ HF4 is an acoustic sensing instrument which operating principle is the detection of the kinetic energy of the hydrometeors impact on its sensing disk head, in particular the hailstones. It is an extremely robust and reliable instrument for the monitoring of hail and the characterization of hailstone sizes.

- It detects hailstones up to 7.5 cm diameter and will survive the most extreme environmental conditions, including off-shore and extreme wind situations.
- The universal fastening mounting kit is an unbreakable plain high grade stainless-steel arm with tiltable V-Brackets.
- The sensing element of this non-moving-part instrument is a plain high grade stainless-steel head.
- Impacts of hailstones (or any other lithometeors in the same range of kinetic energy) on this sensing head induce a measurable change in the acoustic pressure of an internal cavity of the sealed body of the instrument.
- It is not sensitive to rain thus the instrument output cannot be biased by rain, splashes or other liquid precipitation or aeolian transported events.



Typical applications:

- Meteorology (hail, solid precipitation, lithometeors)
- High resolution hail monitoring and warning
- Building and infrastructure surveillance and insurance
- Agriculture
- Maritime and offshore applications (wind turbines, buoys)
- Roadside, railway, airport protection
- Land management
- Applied scientific research

1.2. Operating principle and measurement range

Tip: For a quick start with the instrument, go directly to section Getting acquainted with your instrument.

The HailFlow HF4 instrument measures the impact of individual solid particles on a stainless-steel disc using an ultra-dedicated acoustic transducer, signal processing and calculation.

The instrument intercepts the falling hailstones (or other hydro- or lithometeors) and a high-resolution impulse detector converts the acoustic signal of each individual impact into a voltage that is proportional to the kinetic energy (KE) of the impact. In a most general manner, the KE transferred to the instrument mostly depends on the size of the hailstone, i.e. the higher the KE of an impact, the higher the detected signal and the bigger the size classification of the hailstone by the instrument.

The sensitivity and the internal processing of the instrument are set to nominally distinguish between **15 classes of hailstone diameters prognosis**, ranging **from 0.5 to 8 cm**, with a capability of counting up to **25 solid impacts per second (i.e. up to 795 impacts/m^2/sec.)**.

This function, that is comparable to the so-called disdrometry (DSD) function for characterizing the rain drops, provides a high-resolution output data frame that contains a counting of the total number of hailstones hits during a period of time (for example: 5 seconds), and for these counted hits, the percentage of them situated in each nominal hailstone size class, according to the following classification table:

Class #	Class Label	Hailstone Diameter D [mm]	Max. number of detectable impacts
1	10.0	$5.0 \leq D < 10.0$	25 impacts per second (i.e. 795 impacts/m^2/sec.)
2	15.0	$10.0 \leq D < 15.0$	
3	20.0	$15.0 \leq D < 20.0$	
4	25.0	$20.0 \leq D < 25.0$	
5	30.0	$25.0 \leq D < 30.0$	
6	35.0	$30.0 \leq D < 35.0$	
7	40.0	$35.0 \leq D < 40.0$	
8	45.0	$40.0 \leq D < 45.0$	
9	50.0	$45.0 \leq D < 50.0$	
10	55.0	$50.0 \leq D < 55.0$	
11	60.0	$55.0 \leq D < 60.0$	
12	65.0	$60.0 \leq D < 65.0$	
13	70.0	$65.0 \leq D < 70.0$	
14	75.0	$70.0 \leq D < 75.0$	
15	99	$D \geq 75.0$	

Note: The instrument is not sensitive to rain, thus it cannot be biased by a rain episode (even extreme).

The lower marker of the smallest class (1) is a diameter of **0.5 cm** that matches the detection threshold of the instrument. Except in very special conditions, smaller hailstones cannot be distinguished from the electronic self-noise of the instrument.

The upper marker of the largest class (99) is a diameter of **7.5 cm** which matches the saturation threshold of the instrument. Still, hailstones with a diameter larger than 7.5 cm may still be detected.

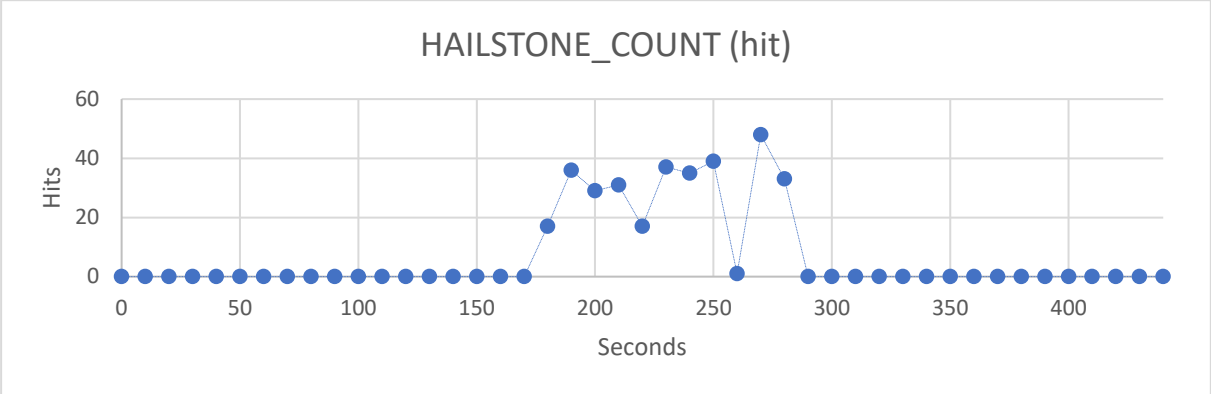
Note: For more information about hail physics, please refer to Appendix E

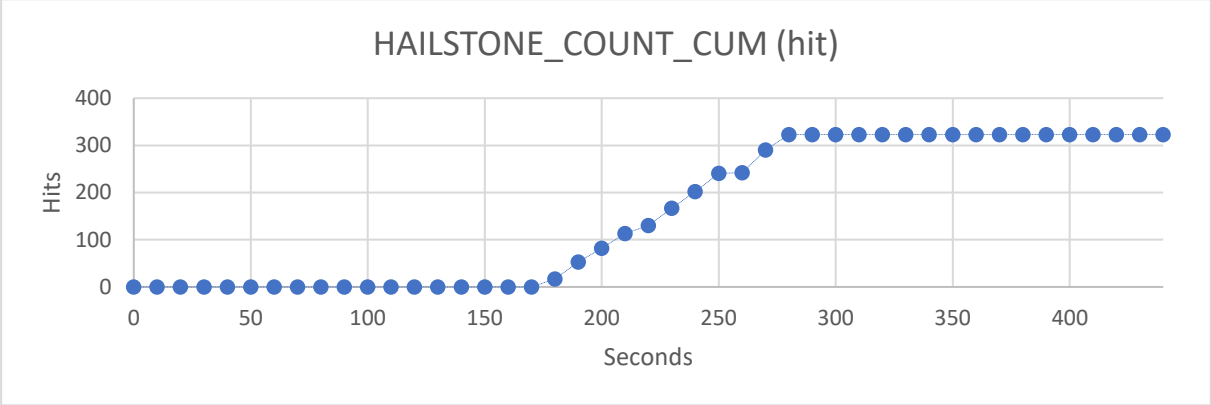
1.3. Data example

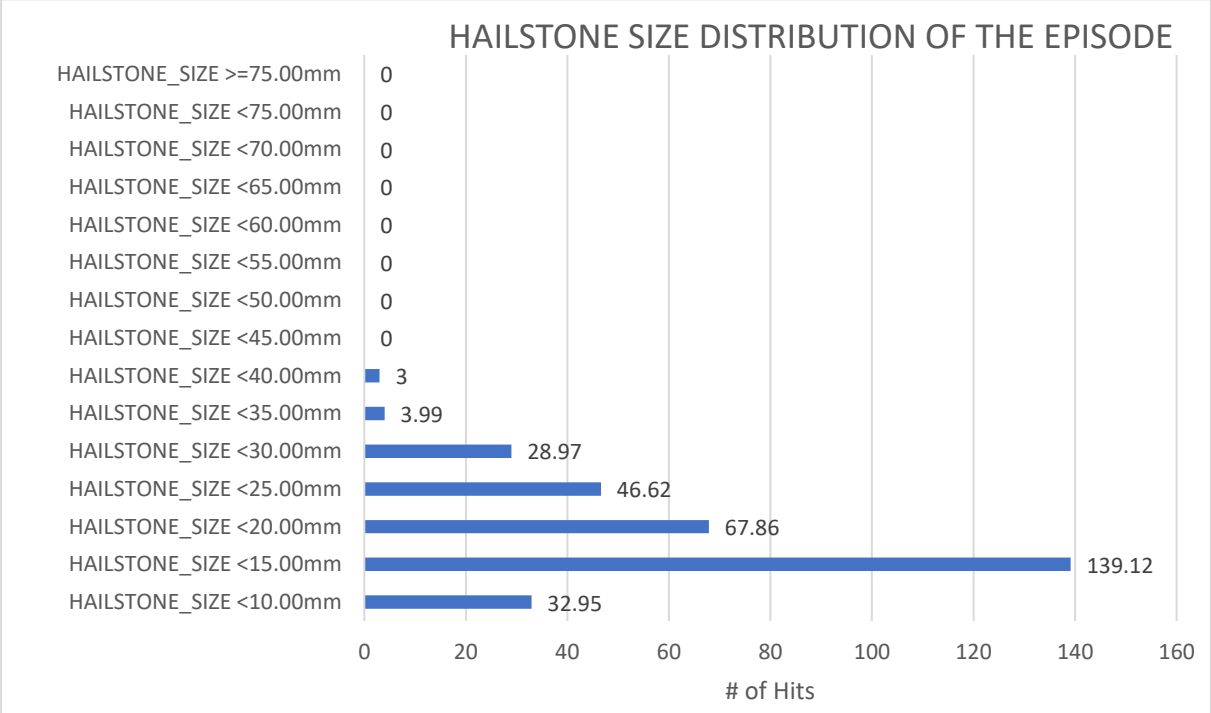
The following example is a raw data file of a HailFlow HF4 instrument that recorded a hail episode lasting 1 minute and 40 seconds with a 10 seconds averaging and writing resolution (i.e. the instrument did record continuously the full episode and produced a data frame every 10 seconds).

#	TIMESTAMP (s)	HAILSTONE_COUNT_MIN (hit/s)	HAILSTONE_COUNT_AVG (hit/s)	HAILSTONE_COUNT_MAX (hit/s)	HAILSTONE_COUNT_STD (hit/s)	HAILSTONE_COUNT_CUM (hit)	HAILSTONE_COUNT (hit)	HAILSTONE_SIZE <10.00mm	HAILSTONE_SIZE <15.00mm	HAILSTONE_SIZE <20.00mm	HAILSTONE_SIZE <25.00mm	HAILSTONE_SIZE <30.00mm	HAILSTONE_SIZE <35.00mm	HAILSTONE_SIZE <40.00mm	HAILSTONE_SIZE <45.00mm	HAILSTONE_SIZE <50.00mm	HAILSTONE_SIZE <55.00mm	HAILSTONE_SIZE <60.00mm	HAILSTONE_SIZE <65.00mm	HAILSTONE_SIZE <70.00mm	HAILSTONE_SIZE <75.00mm	HAILSTONE_SIZE >=75.00mm
1768	15:33:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1769	15:33:40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1770	15:33:50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1771	15:34:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1772	15:34:10	1.7	1.7	1.7	0	17	17	6	47	12	24	12	0	0	0	0	0	0	0	0	0	0
1773	15:34:20	3.6	3.6	3.6	0	53	36	11	42	22	19	3	3	0	0	0	0	0	0	0	0	0
1774	15:34:30	2.9	2.9	2.9	0	82	29	7	34	24	17	14	3	0	0	0	0	0	0	0	0	0
1775	15:34:40	3.1	3.1	3.1	0	113	31	3	42	16	23	13	0	3	0	0	0	0	0	0	0	0
1776	15:34:50	1.7	1.7	1.7	0	130	17	0	35	35	6	12	12	0	0	0	0	0	0	0	0	0
1777	15:35:00	3.7	3.7	3.7	0	167	37	8	49	27	8	5	0	3	0	0	0	0	0	0	0	0
1778	15:35:10	3.5	3.5	3.5	0	202	35	6	46	20	20	9	0	0	0	0	0	0	0	0	0	0
1779	15:35:20	3.9	3.9	3.9	0	241	39	15	56	13	10	5	0	0	0	0	0	0	0	0	0	0
1780	15:35:30	0.1	0.1	0.1	0	242	1	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0
1781	15:35:40	4.8	4.8	4.8	0	290	48	17	38	23	10	10	0	2	0	0	0	0	0	0	0	0
1782	15:35:50	3.3	3.3	3.3	0	323	33	18	39	21	12	9	0	0	0	0	0	0	0	0	0	0
1783	15:36:00	0	0	0	0	323	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1784	15:36:10	0	0	0	0	323	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1785	15:36:20	0	0	0	0	323	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1786	15:36:30	0	0	0	0	323	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1787	15:36:40	0	0	0	0	323	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The data record #1775 shows that **31 hailstone hits** were counted during the last 10 seconds, among them **23% in the size class 4** ($20.0 \leq D\ mm < 25.0$), these 31 counts adding from the last CUM value of 82 hits, i.e. a CUM sum actualizing to **113 hits counts**.

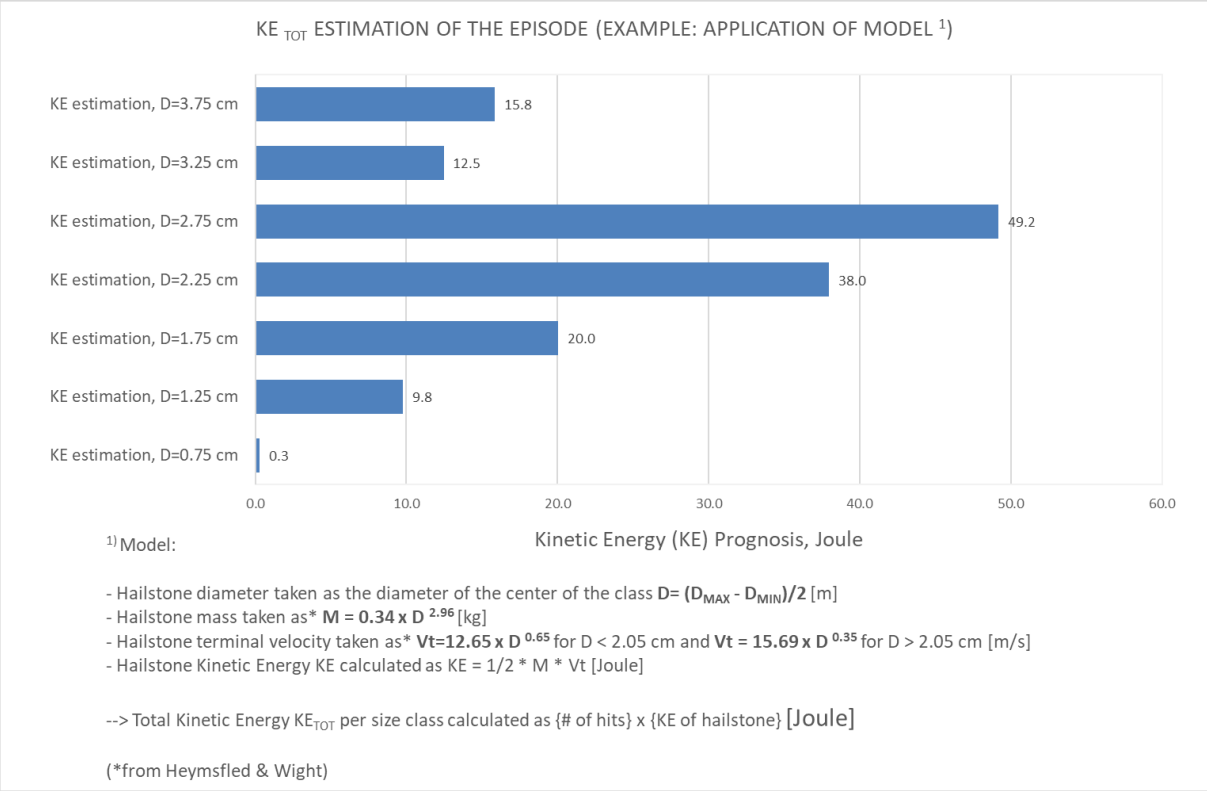






Note: On the last graph, numbers of hits are not integers. This is because the number of hits in each class is calculated from the raw data as a *rounded percentage of the total number of hits* (e.g., referring to the data example on previous page, data record #1775, between 15:34:30 and 15:35:00, the 23% in the size class 4 ($20.0 \leq D$ mm < 25.0), where 31 hits were counted, gives: $23\% \times 31 = 7.13$ hits in the class 4 size.

From the distribution presented in the previous example, data can be extrapolated in terms of Kinetic Energy (KE) of the hail episode, by applying a model of the kinetic energy of the hailstones expressed in terms of size. The example below shows such an extrapolation obtained by using the model described in appendix E.6.



1) Model:

- Hailstone diameter taken as the diameter of the center of the class **$D = (D_{MAX} - D_{MIN})/2$** [m]
- Hailstone mass taken as* **$M = 0.34 \times D^{2.96}$** [kg]
- Hailstone terminal velocity taken as* **$Vt = 12.65 \times D^{0.65}$** for D < 2.05 cm and **$Vt = 15.69 \times D^{0.35}$** for D > 2.05 cm [m/s]
- Hailstone Kinetic Energy KE calculated as KE = 1/2 * M * Vt [Joule]

--> Total Kinetic Energy KE_{TOT} per size class calculated as {# of hits} x {KE of hailstone} [Joule]

(*from Heymsfled & Wight)

1.4. Communication protocols

The following serial and bus communication protocols can be used with all ISAW instruments:

Protocol	Notes
MODBUS-RTU over RS-485 (with Modbus adapter)	Modbus RTU is recommended for network installations. The device can operate on a Modbus RTU network, or in a point-to-point configuration with the Modbus RTU protocol.
Continuous ASCII (native)	The device can be configured to output serial data every "M" seconds. Necessarily, in this mode the device must be in a point-to-point arrangement. The output format is configurable by the user.
SDI-12	The device is certified SDI-12 v1.3 compliant, a multi-drop serial data bus interface, compatible with long-distance cabling (typically up to 150 m) and with possibility to connect several instruments.

The instrument can also be used in **analog mode**, i.e. through the reading of DC voltage outputs (+0 to +2.5 V or +0 to +5 V analog voltage; continuous or pulse), or, when using the AD420 accessory, adapting to a **4-20 mA current loop mode**.

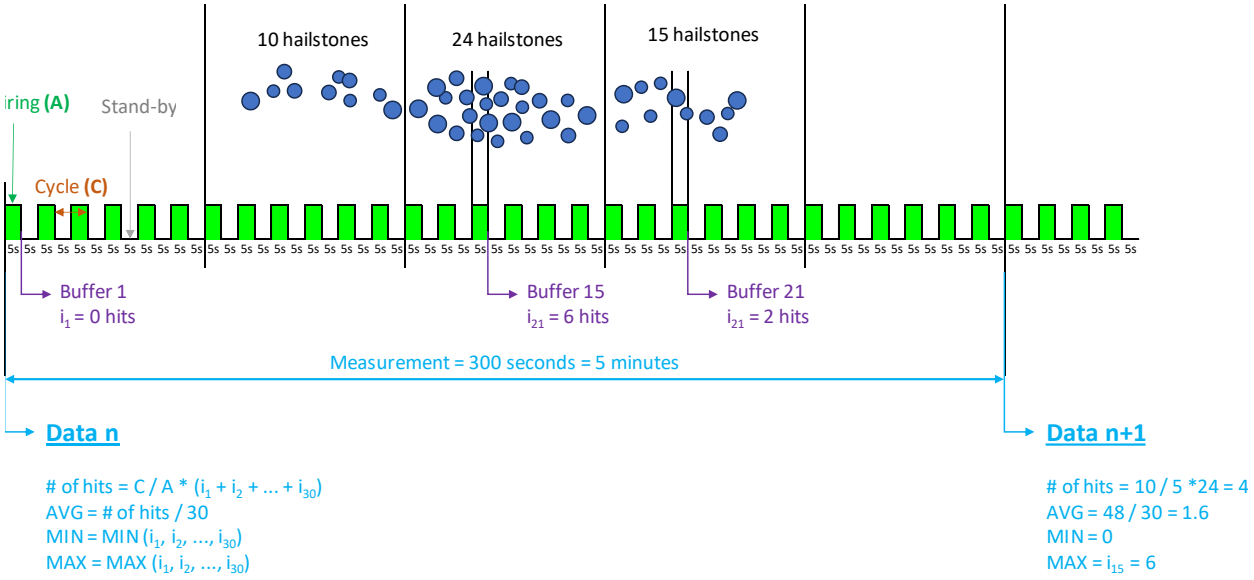
1.5. Main operating modes

1.5.1. Smart adjustability for all uses

While the instrument is capable of producing very high-resolution data down to a 1-second integration time, in meteorology applications the data services often process and display the data averaged on relatively longer periods of time, like typically intervals of 1 minute, 5 minutes, 10 minutes, 30 minutes, 1 hour, 4 hours. When using and manipulating time series of meteorological data, there is thus always some risk of making averaging miscalculations when displaying a data with a certain time interval granularity, while the data was recorded with another production interval (i.e. the output measurement or writing interval).

There are indeed most often different temporizations at play in a measure, because when we observe a physical phenomenon with a system, several durations come into consideration:

- The actual observation time of the phenomenon: **Acquisition "A"**.
- The Stand-by time which allows to optimize the energy consumption when necessary.
- The observation **Cycle "C"** includes one acquisition period and one stand-by period.
- The **Measurement "M"** time is the interval between two consecutive data writings. It usually covers several cycles.

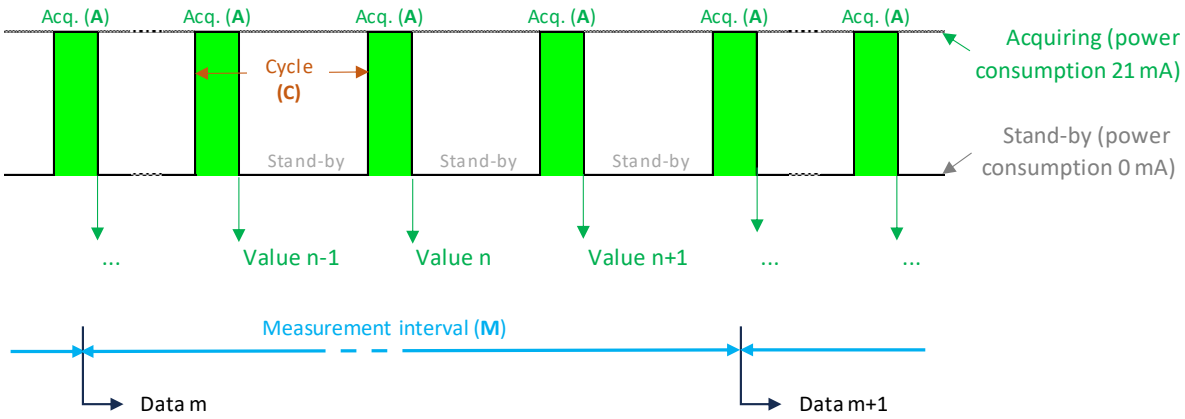


This is why it is necessary to make averages and it is over these periods that the statistical data must be calculated. For example, as per the scenario figure above, supposing we have an instrument operating as follows:

- With a duty-cycle of 50%, to cope with some power consumption limitations, and with a writing interval set to five minutes (so we will get a data frame every five minutes, which has to give the total number of hailstone hits of the last five minutes, whereas the instrument was acquiring and measuring only 50% of that duration).
- Or at the extreme, the same scenario still with a writing interval set to five minutes but measured with a duty-cycle of only 10% (so a data frame every five minutes that has to give the prognosis (supposedly the phenomenon was stationary over the period) of the total number of hailstones hits of these last five minute, while the instrument was acquiring and measuring only 10% of that duration, i.e. the phenomenon observed during one second every 10 seconds):
- As per the averaging calculation process described in the above example figure, and, again, with the assumption that the observed event (the hail fall) was stationary over the total period of a cycle (resp. 50% of 1 minute or 10% of 1 minute), the instrument will automatically process the averaging and the statistics accordingly.

The choice of the internal averaging and output writing and logging data rate of the instrument then depends on several contingencies, among them the memory capacity and/or the transmission baud rate of the receiving, storing and displaying infrastructures. Furthermore, in some cases, the total power consumption of the instrument can be an important concern, especially when operating in isolated remote locations.

To be able to cope very easily and smartly to every situation, the instrument can be adapted very largely to almost any desired averaging, data rate and total power consumption through **a very simple and immediate principle of operation that entirely relies on only three parameters of operation, and is called "the A,C,M setting" of the instrument**:



Measurement settings	Description	Default value
Measurement duration [M]	The measurement duration M is the period you would like to read a new measurement result, in other words, a data statistics of the period M. In other words, it is the time between the production by the instrument of two consecutive output data records. Depending on your need, it can vary from one second to several minutes, hours or even more. Whatever duration M you set, the instrument will internally aggregate and process all intermediate acquisitions and produce exactly the desired data.	10 minutes
Acquisition duration [A]	During the measurement period, the instrument will make some acquisitions and process them to produce the result. Acquisition can be continuous, or, in order to lower power consumption, it can also alternate with a certain percentage of stand-by periods where the instrument does not consume any current.	10 seconds
Cycle duration [C]	Sum of one acquisition duration A and one stand-by duration. If the instrument is set to operate continuously (i.e. no stand-by), we simply get A=C. When the stand-by duration A equals the measurement duration M, the instrument is continuously acquiring and there is no need for averaging (1 acquisition = 1 measurement). When the measurement duration M is greater than the acquisition duration A, the measurement result is produced as the MIN, AVG, MAX, and STD statistics of all the acquisitions produced during M.	10 seconds
Duty cycle	Ratio between acquisition duration A and cycle duration C, i.e. fraction of time in which the instrument is effectively active to the fraction of time it is in stand-by mode and drains no current. The greater the duty cycle, the more precise and accurate the data will be to the phenomenon being measured. For example, a duty-cycle of 10% means that over a period M (for example M=10 minutes) the instrument is 90% of the time in stand-by mode (54 seconds per minute) and the acquisition happens 6 seconds per minute.	100%

Numerical example of the figure page 11:

- In this example we have supposed that during a period of 5 minutes happened for 3 minutes (minutes 2, 3 and 4) a hail episode with respectively 10, 24 and 15 hailstones per the minute. This event has been recorded with the instrument configured to produce a data every 5 minutes, with acquisition cycles of 5 seconds and a duty-cycle of 50% (i.e. the instrument alternates cycles of 5 seconds of acquisition then 5 seconds of stand-by).
- The real hail was composed of 0+10+24+15+0 = 49 hailstones and the instrument produced a measurement of 48 hits (so, a “miss” of one hit), giving an averaging of 9.6 hits/minute, a MIN of 0 hits/minute and a MAX of 22 hits/minute.

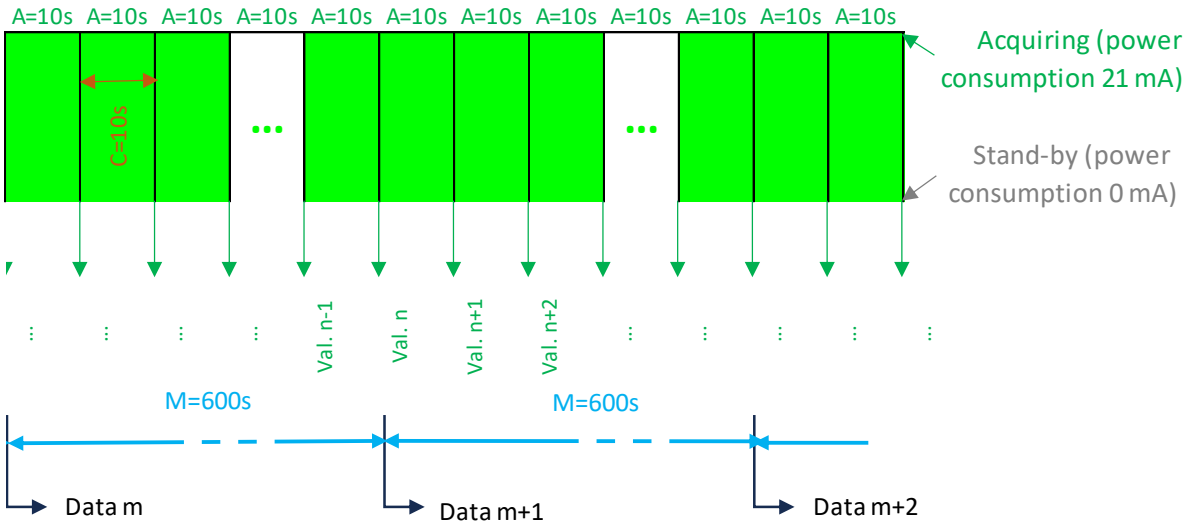
- In other words, the data has been automatically processed “as if measured” for a continuous operation of the instrument, so that one could always directly rely on the output data, without needing to re-consolidate the data by considering the different time-scales involved in the global setting.
- This means that if the duty-cycle had been 100% instead of 50%, the measurement result would have been exactly the same as the real hail.

Note: The higher the duty-cycle, the higher the accuracy of the instrument (i.e. maximal accuracy reached for a duty-cycle of 100%), so that, except for power limitation reasons, the duty-cycle of the instrument should always be left to 100%.

This particularity is extremely useful to avoid any miscalculation in the time averaging of the output data, and it allows the instrument to be used even under severe power consumption constraints, with an accuracy that depends on how much the phenomenon is stationary over the measurement cycle.

1.5.2. Standard continuous operation mode

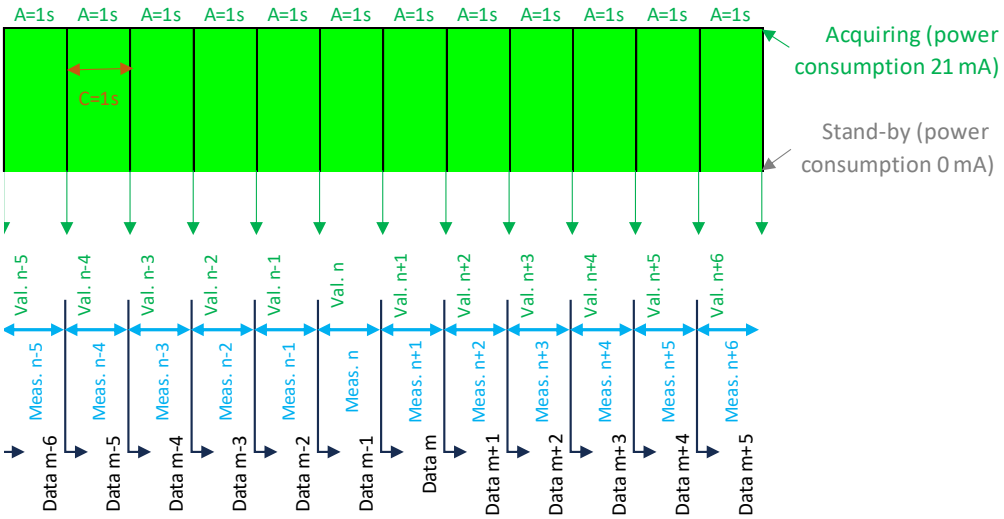
The most standard – and also default factory – configuration of the HailFlow HF4 instrument is a setting of A,C,M = 10,10,600 s, i.e. the instrument continuously acquires sequences of A=10 seconds and the data statistics is produced every 10 minutes on 60 consecutive samples:



"The sensor is contiuously acquiring (no stand-by periods). It produces a data frame every 10 minutes, which is a MIN, MAX, AVG and STD statistic on 60 consecutive values"

1.5.3. Maximum accuracy mode

To analyze the hail with the maximum time resolution of the instrument (1 second), set the instrument with the values A=C=M=1 second, which corresponds to the following processing:



"The sensor is continuously acquiring (no stand-by periods). It produces a data frame every second, which is a statistic with MIN=AVG=MAX=Value n, and STD=0."

According to this diagram:

- The instrument will be continuously powered and acquiring, i.e. a duty-cycle of A/C = 1 = 100%.
- There is no need for any averaging nor statistics, as each acquisition of A=1 second is directly written in a data frame.

In summary, this configuration allows to be in continuous acquisition with a data logging every 1 second.

Note: With a setting of A=C=M=10 seconds, we would also have a continuous measurement, but with a data logging every 10 seconds, and still with AVG=MIN-MAX and STD=0. In this configuration, the data granularity is less precise, but it **saves space on the datalogger**.

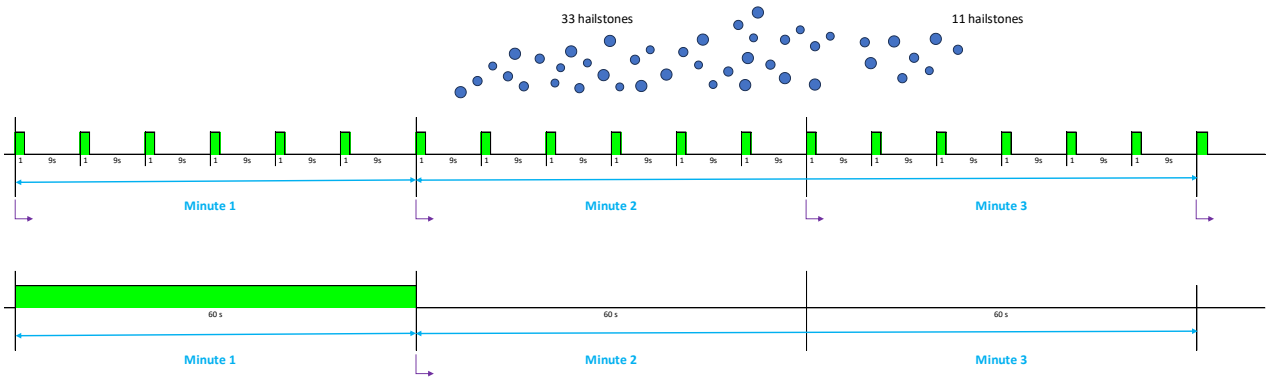
1.5.4. Ultra-low power mode

At the cost of a greater probability of reducing the good coverage of the observed phenomenon, the consumption of the instrument can be reduced as much as desired by reducing the duty-cycle. In plain terms, with a small duty-cycle, the longer and more stationary a hail phenomenon, the better the precision, because stationarity and duration mean that even if the phenomenon is observed only partially, the acquisition periods are faithful to the average intensity of the phenomenon.

In the example of page 11, the duty-cycle is 50%, i.e. the total consumption of the instrument is divided by a factor of 2. We have chosen to alternate acquisition and stand-by periods of 5 seconds. We could also have chosen periods of 1 seconds, but it seems unlikely that the hail intensity varies greatly from one 1-second period to the next.

To reduce the consumption of the instrument to a factor of 10, the duty cycle must be set to 10%. In this case, it seems wiser to establish this setting with the highest possible periodicity, i.e. better choose A = 1 second and C = 10 seconds than A = 1 minute and C = 10 minutes, because, as illustrated on the next diagram, in the first case we have a better chance to interpret correctly a short hail episode than

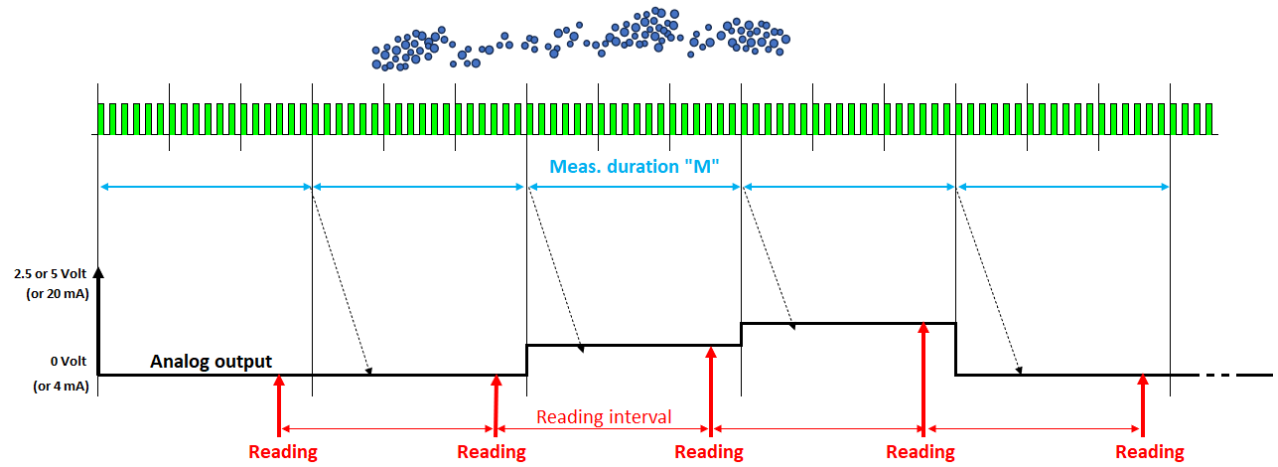
in the second case, where the instrument could misinterpret, or even completely miss an episode while in stand-by mode.



1.5.5. Analog output mode

In analog output mode, set the Measurement interval “M” according to your reading device: if your reading device is programmed to periodically read a voltage or current from the instrument, set the Measurement interval to the same period. Then you will always get the expected data, whatever the synchronization between the reading device and the instrument, because the analog outputs of the instrument are persistent on the wire until refreshed by the next measurement.

For example, if you have configured your instrument with a 1-minute Measurement duration, and your reading instrument is configured to take one reading of the voltage or the current every minute, then, except for the residual internal clock drifts of both instruments (which may rarely cause a loss of data), you will always get the live current value of the last minute on the reading side.



Also, in analog mode, note that the instrument is able to operate in **pulse mode**, i.e. a mode in which each time a certain amount of the physical phenomenon (hail) happens, a standardized pre-configured pulse is produced.

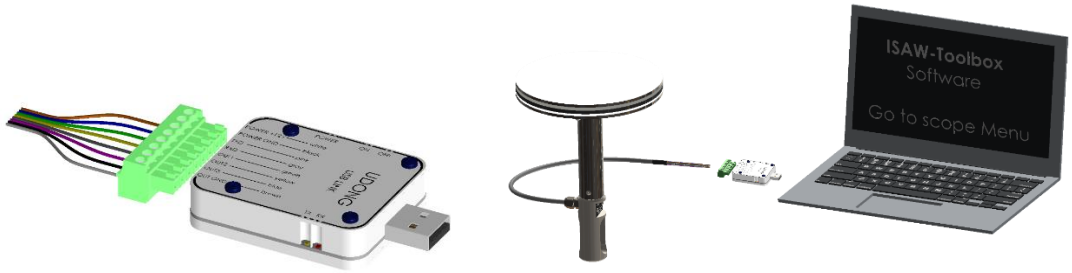
Notes: In these analog modes, the instrument cannot communicate the hailstone sizes to the reading device, but only the **average number of hailstones (HAILSTONE_COUNT_AVG [hit/s]).** Anyhow, this mode may be sufficient for some monitoring applications, and/or convenient with long-distance cabling requirements (typically up to 150 m).

1.6. The ISAW Toolbox software suite

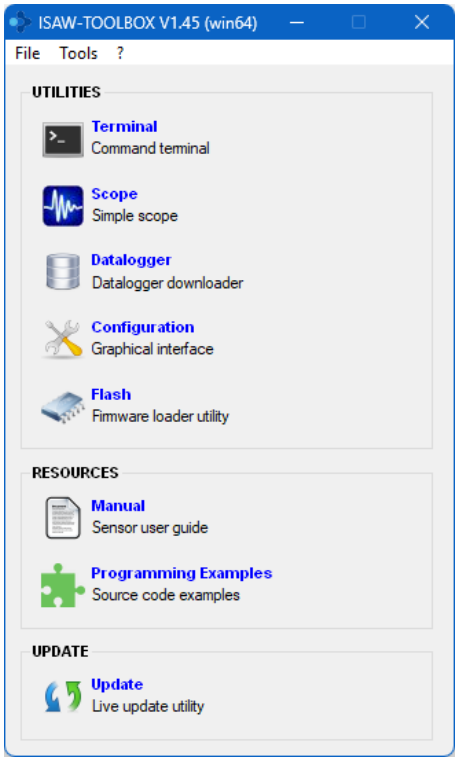
Download and install the free ISAW-Toolbox software suite from www.isaw-products.com. Add an ISAW icon on your Desktop to ensure a direct access to the ISAW-Toolbox utilities.

Plug the instrument to your computer using the USB Link accessory (UDONG). Wait for the device driver to be automatically installed and completed.

Note: If the driver is not properly installed, download it from https://ftdichip.com/drivers/vcp-drivers/ and install it manually: in the "Configuration panel" of your computer, open the "Device manager", and in the "Ports (COM & LPT)" section, you will find a new serial communication port (e.g. COM7).



The ISAW-Toolbox software suite includes a range of utilities and resources that you may need to configure, operate or maintain your ISAW instrument:



UTLITIES:

Terminal: Serial terminal emulator used for example to display the data produced by the instrument or to send a command to the instrument.

Scope: Simple scope tool allowing to check the live response of an instrument.

Datalogger: Download the data stored in the instrument's internal datalogger.

Configuration: Change the instrument's configuration parameters.

Flash: Update the instrument's firmware.

RESOURCES:

Manual: ISAW documentation (PDF files)

Programming Examples: Source code examples that you can use to interface your instrument with your acquisition equipment.

UPDATE: Check for new upgrades of the utilities or resources.

When opening one of the ISAW-Toolbox Utilities, select the **Serial port** the instrument is connected to, then press the **[Connect]** button. The connection procedure is completed when the [Connect] button is disabled and the [Disconnect] button is enabled.

Notes: If the instrument is plugged in after the start of the application and you can't find the serial port in the list, click on the reload button  to update the list, then select the right port.

When switching from one utility to another, first **[Disconnect]** the instrument from the first utility before connecting it to the other one.

IAV Technologies constantly improves its products and provides upgrades of the ISAW instruments firmware as well as for the ISAW Toolbox utilities. Each time you open the ISAW Toolbox, it automatically checks for new upgrades of tools and resources.

1.7. Getting acquainted with your instrument

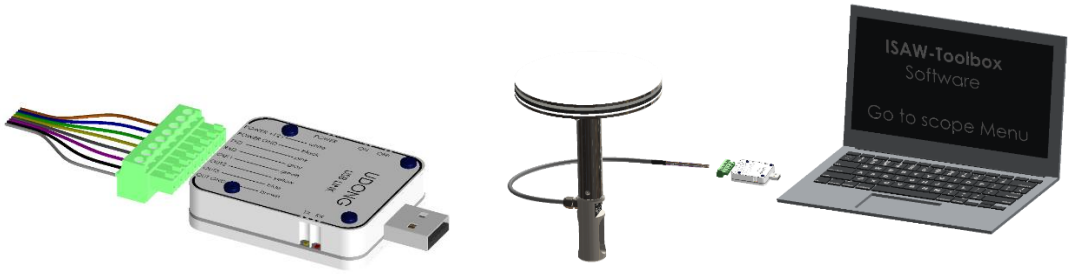
In this section we propose two ways to get acquainted with the instrument in a few minutes: either with a computer, or with a smartphone (or tablet).

1.7.1. Quick start using a computer

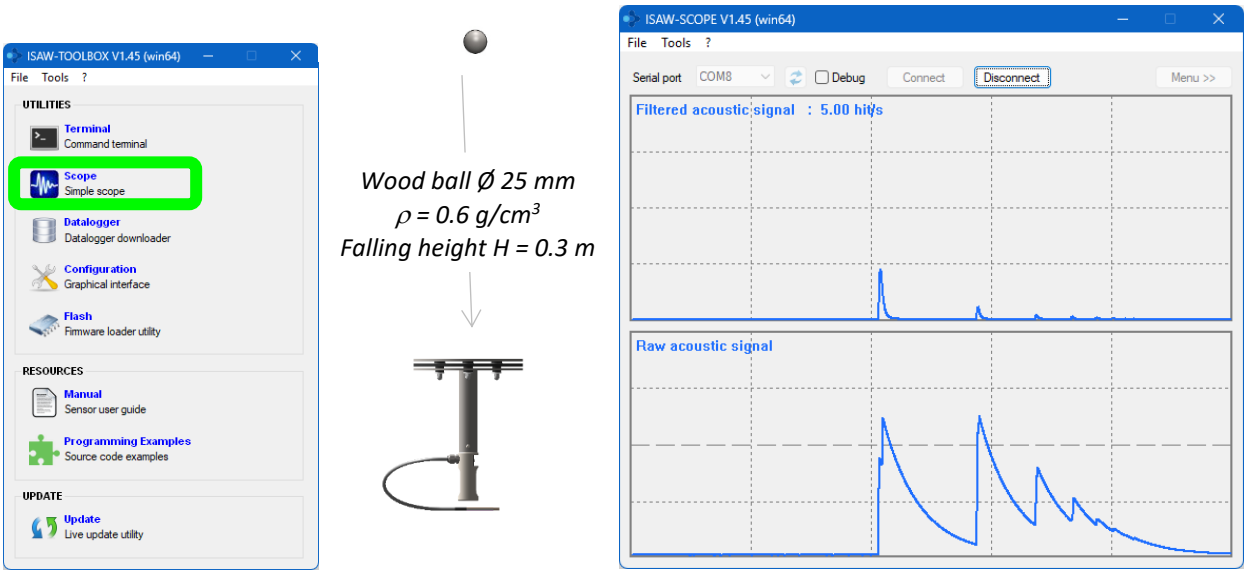
You will need:

- your HailFlow HF4 instrument,
- the USB link accessory (UDONG) provided with the instrument,
- the wood ball also provided with the instrument (optional),
- the ISAW-Toolbox software suite installed on your computer (PC or Mac with USB port).

Tip: To download and install the ISAW-Toolbox software suite and plug your instrument to your computer using the USB link accessory, see § 1.6.

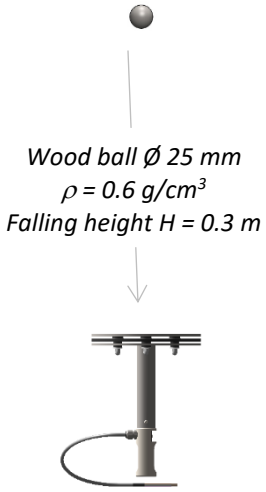


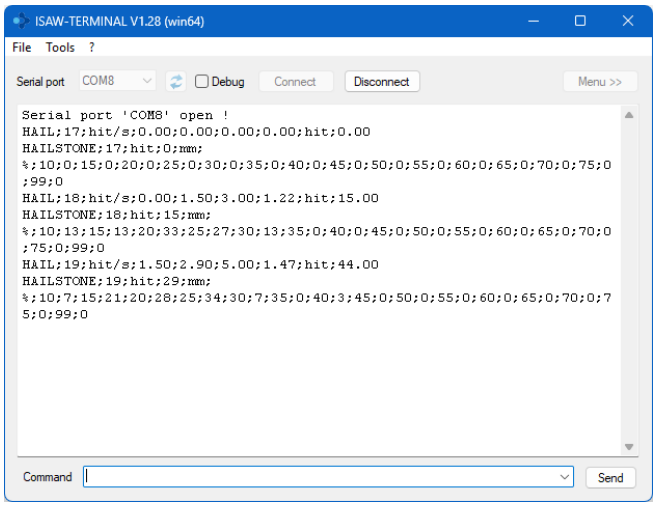
TO CHECK THE LIVE RESPONSE of your instrument, open the **Scope utility** of the ISAW Toolbox and connect your instrument. Drop the wood ball and let it rebound on the disk (you can also tap on the instrument with a pen or screwdriver). A live signal appears on the scope window (see example hereafter).



[Disconnect] your instrument when the test is over.

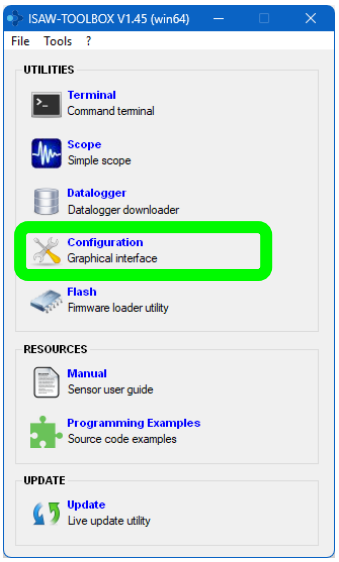
TO SEE THE DATA FRAMES produced by the instrument, open the **Terminal utility** of the ISAW Toolbox and connect your instrument. Drop the wood ball and let it rebound on the disk (you can also tap on the instrument with a pen or screwdriver). The values in the displayed frames should increase according to the number and intensity of the hits.

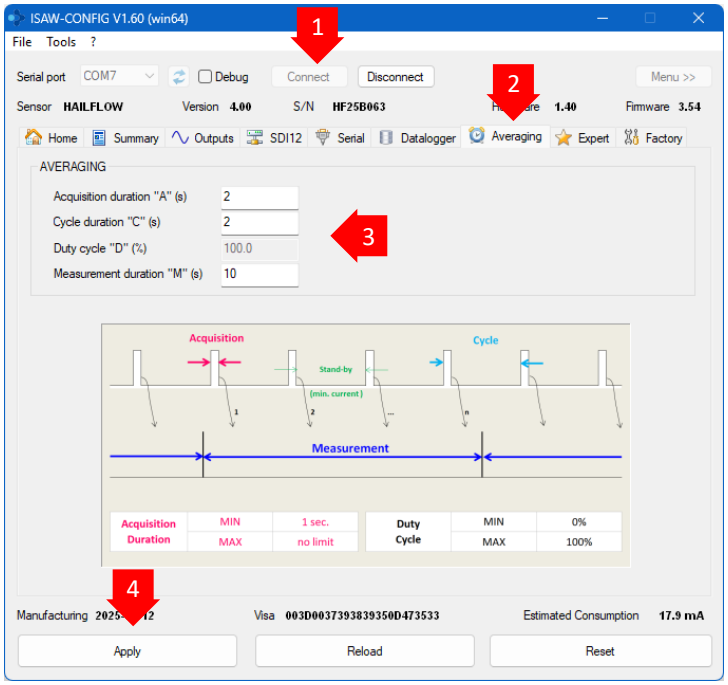




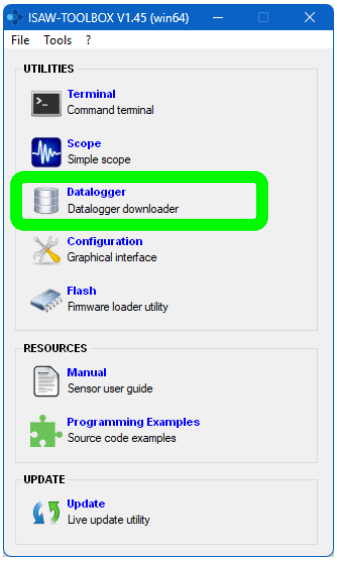
[Disconnect] your instrument when the test is over.

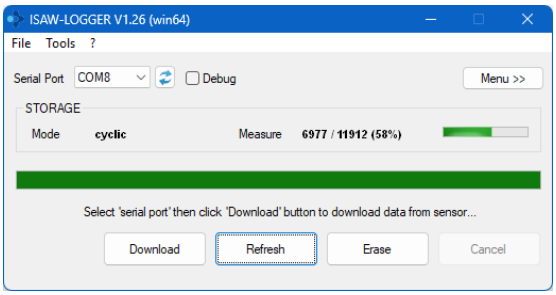
Note: In its default factory configuration, the instrument provides data **every 10 minutes**. To increase the data rate, adjust the averaging parameters of the instrument: in the **Configuration utility** of the ISAW Toolbox, go to the Averaging panel and set the values of parameters Acquisition (A), Cycle (C) and Measurement (M) respectively to 2 seconds, 2 seconds and 10 seconds (see screenshots below), then press [Apply], [Disconnect], and go back to the Terminal utility. With this new configuration, the instrument measures continuously and produces a data frame every 10 seconds, and the MIN, AVG and MAX values are statistics on the 5 consecutives acquisitions of 2 seconds each (more explanation about data and averaging rate in section 0).





TO RECORD AND DOWNLOAD THE DATA: By default, the instrument's internal datalogger is set to **Cyclic** so the instrument has already recorded your test data and you can retrieve it by using the **Datalogger utility**:



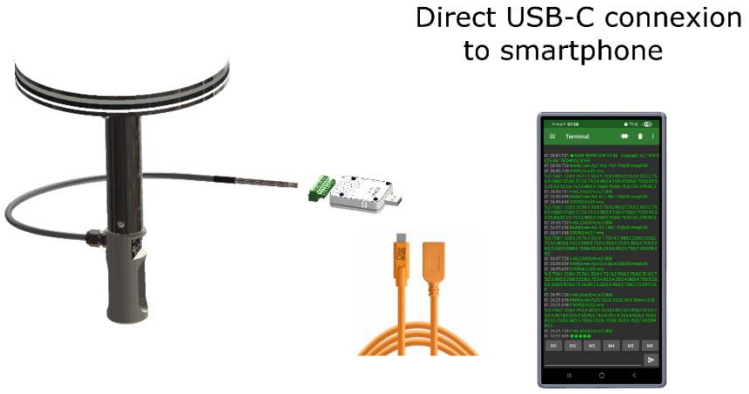


1.7.2. Quick start using a mobile device (smartphone, tablet)

You will need:

- your HailFlow HF4 instrument,
- the USB link accessory (UDONG) provided with the instrument, with USB-to-USB-C adapter,
- the wood ball also provided with the instrument (optional),
- a generic terminal / console app such as "Serial USB Terminal" installed on your mobile device (smartphone or tablet with USB-C interface).

Note: The instrument is directly powered by the USB-C connection.



Terminal app settings: Make sure to choose a baud rate of 115200. The HailFlow HF4 instrument is then immediately recognized and the data frames displayed in text mode. Frame example:

```
HAIL;9388;hit/s;11.00;11.00;11.00;0.00;hit;20283.00
HAILSTONE;9322;hit;7;mm;%;10;0;15;0;20;0;25;0;30;0;35;14;40;14;45;
29;50;29;55;14;60;0;65;0;70;0;75;0;99;0
```

The frame contains all the data for characterizing the total number of hits and their distribution by size classes. Its definition is provided in the § B.4.

Note: In its default factory configuration, the instrument provides data **every 10 minutes**. To increase the data rate, set the Acquisition, Cycle and Measurement parameters of the instrument to a shorter duration, for example every 10 seconds by typing the following commands:

```
set avg-a=2
set avg-c=2
set avg-m=10
```

With this new configuration, the instrument measures continuously and produces a data frame every 10 seconds, and the MIN, AVG and MAX values are a statistic on the 5 consecutives acquisitions of 2 seconds each (more explanation about data and averaging rate in section 0).

TO CHECK THE LIVE RESPONSE of your instrument, drop the wood ball and let it rebound on the disk (you can also tap on the instrument with a pen or screwdriver). The values in the next displayed frame will increase according to the number and intensity of the hits.

TO RECORD AND DOWNLOAD THE DATA: By default, the instrument's internal datalogger is set to **Cyclic** so the instrument has already recorded your test data and you can retrieve it by typing the following command:

```
datalogger download
```

A .CSV text file is produced, containing all recorded data frames.

1.7.3. Stand-alone use without any peripheral

In the simplest way of use, just power the instrument with a standard USB charger using the USB link accessory, and let the instrument operate in **standalone** mode on its internal datalogger.

Tip: Make sure that the datalogger is enabled, which is the case in the default factory configuration.

No software installation is required, and when you need to collect the recorded data, just connect your instrument to a laptop or mobile device and retrieve the data file from the internal datalogger. Note that the device is not equipped with an RTC, thus the appended data is not timestamped with absolute date and time. In case of temporary power shutdown of the instrument, when the instrument is powered again, the data continues to be appended after the last record.

You can also indefinitely log the data of the instrument on a computer by the means of the *livelogger utility* which is a programming executable example available with the ISAW-Toolbox software suite (see § 5.3). In this case, instead of connecting the USB link accessory to a USB charger, connect it to your computer and execute the *livelogger* program. This way the data will be timestamped and headed using with the computer clock.

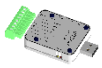
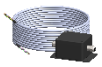
Note: Of course, in more integrated ways of use, the instrument can as well be connected to most of the existing datalogging, peripheral, network or all other kind of external units to get remote unlimited monitoring. All these ways of use are explained in details later in this document.

1.7.4. Direct USB Serial connection without UDONG

To connect the instrument to your computer without using the USB link accessory, you can do a custom connection as follows:

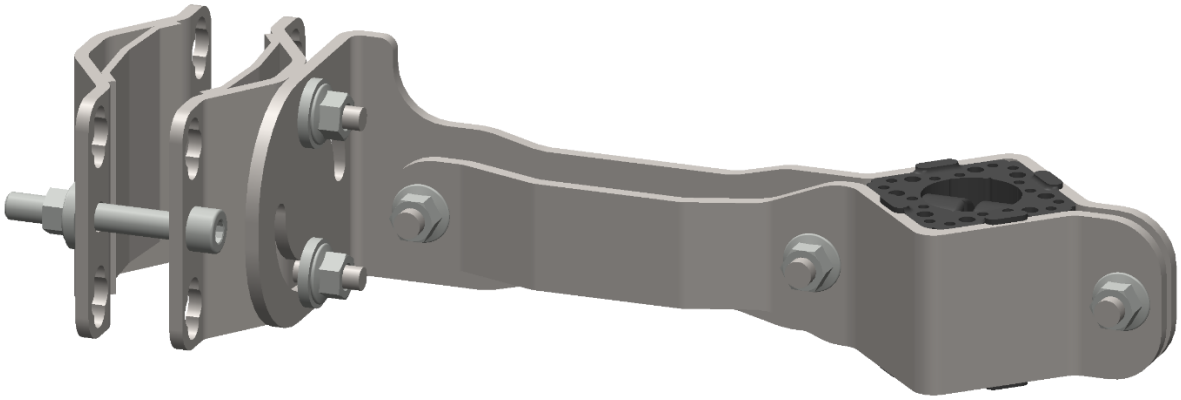
- Do not directly connect RX and TX wires to a serial RS232 connector (like a DB9).
- But use an **FTDI 3.3V serial USB converter/adapter** such as model https://ftdichip.com/products/ttl-232r-3v3-we/ (USB-to-TTL Serial Adapter Cable w/ Embedded Controller, 3.3V, Wire Ended), or equivalent (several other cable termination variants are available). Such an adapter is required to adapt the TTL 5V of the RS-232 to the 3.3V of the device.

2. HailFlow HF4 ACCESSORIES

Ref.		Description
AVARM		Complete **mounting kit** for fastening the instrument anywhere. This item is included in the HFBRA reference.
UDONG		**USB Link accessory** for connecting the instrument to a computer or a mobile device with USB-A or USB-C port. Provided with each HailFlow HF4 instrument.
EXT10		**Cable extension, 10 meters**, including junction box (Note: you can chain several items, or ask for a specific cable length, on request).
MOBUS		**Modbus RTU-485 adapter** for connecting the instrument to a Modbus RTU-485 environment.
AD420		**4-20 mA adapter** for converting the analog voltage output of the instrument in 4-20 mA current loop.
TMAST		Supporting structure: Tripod mast

AVARM – Fastening arm (mounting kit)

The **HailFlow HF4 standard mounting kit** is composed of a fastening arm with elastic coupler, equipped with V brackets adaptable to a mast or structure of outer diameter between 16 and 82 mm. The elastic coupler protects the instrument from the possible parasitic vibrations of the connected structure.



The arm is from 0° to 90° tiltable, i.e. compatible with all possible orientations of mast or structure. It can also be screwed directly onto a flat surface. See mounting examples on page 51.

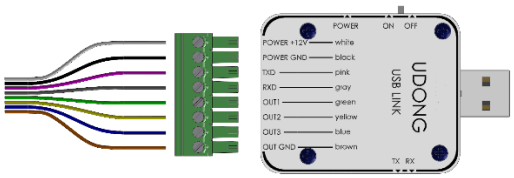
UDONG – USB link accessory

The UDONG is a **universal USB-to-serial TTL3V3 interface** for direct connection of any ISAW instrument to a PC, Mac, Linux, etc. It enables the instrument's power supply and the immediate use of all the software features of the ISAW-TOOLBOX freeware. The USB dongle is generic and can thus be used or interchanged with all ISAW instruments.

Main features:

- Immediate and standard consistent 8-pin connector and pinout
- Direct 12V (84 mA) power supply (from USB 5V 150 mA) of every ISAW instrument
- Genuine FTDI USB-Serial converter (FT232R). Reliable connection, drivers often already installed on Windows/Mac.
- USB port offering a solid and robust design. "Flex" micro-USB cables can be used. Reduces the risk of the USB connector breaking off the board.
- Bright LEDs for Power, RX, and TX.
  The **power LED** is on when the dongle is plugged into the computer's USB-port and switched on. The **TX LED** turns on when data is **T**ransmitted (sent out) through the USB port, while the **RX LED** turns on when data is **R**eceived from the USB port.

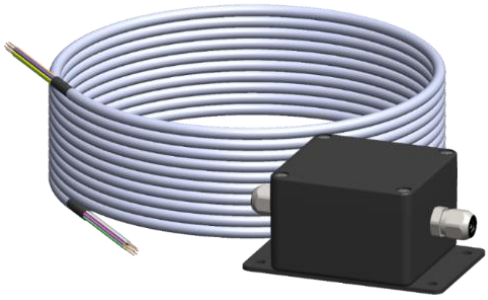
ISAW instrument cable



USB COM port

EXT10 – Cable extension, 10 meters

Each instrument is delivered with a 5-meter cable (see description and reference in § 4.1). Use one or several EXT10 cable extensions to extend this default length up to typically 200 m.



EXT10 is a **10 meters extension of the ISAW instrument cable**, equipped at one end with an IP68 aluminum enclosure **junction box**, which contains an 8-pin screw connector to connect any ISAW instrument or chaining several EXT10 extension cables.

Instrument cable

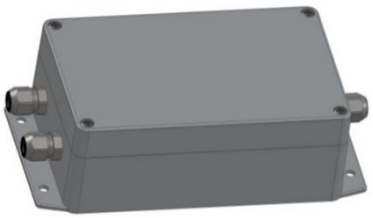
JUBOX (Junction box)

Plugging the cable extension:

Open the junction box (4 screws), disconnect the instrument wires from the terminal block plug, thread the instrument cable into the junction box through the cable gland, connect the instrument wires back into the terminal block plug, plug it into the junction box, tighten back the cable gland, tightly screw the lid back on the junction box.

MOBUS – Modbus adapter

The ISAW **Modbus RTU RS485 Adapter** (MOBUS) enables the power supply and connection of any ISAW instrument to a Modbus network.



MOBUS is the recommended accessory to interconnect the instrument through the open serial Modbus RTU (RS485) protocol based on a master/slave or client/server architecture. The fieldbus environment is the base level group of digital networks in the hierarchy of plant networks.

Complete description and instructions for use are given in Appendix D.

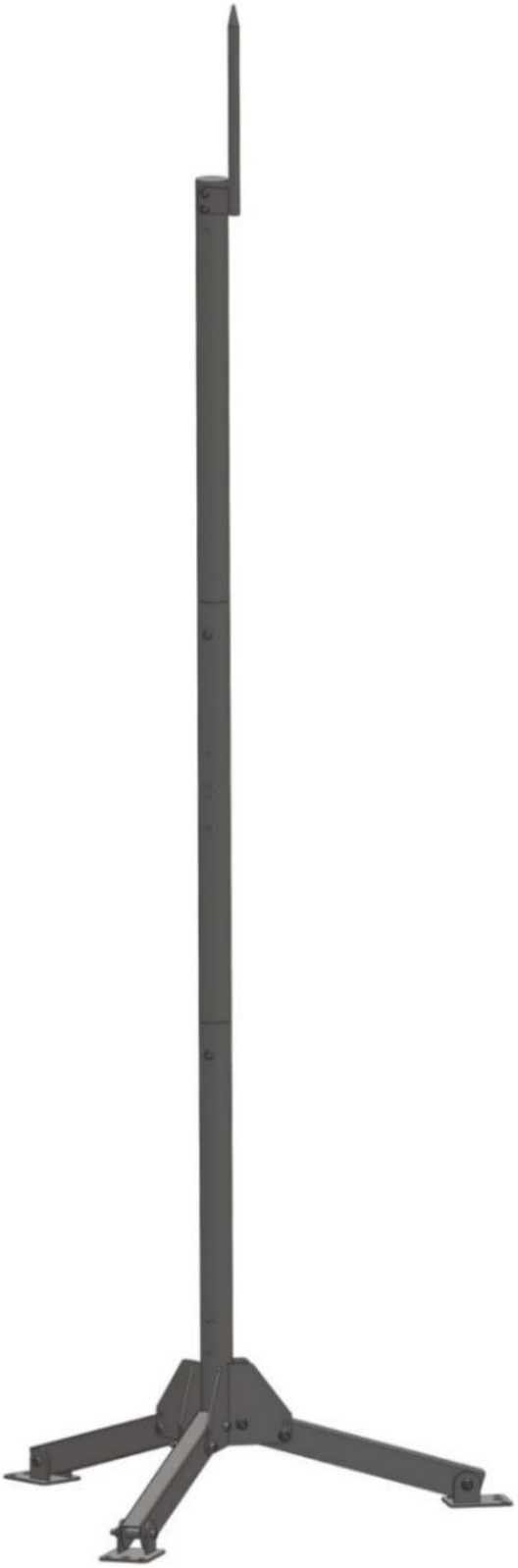
AD420 – 4-20 mA adapter

The ISAW **4-20 mA Adapter (AD420)** converts analog outputs voltages OUT1 and OUT2 of the HailFlow HF4 to a 4-20 mA current loop.

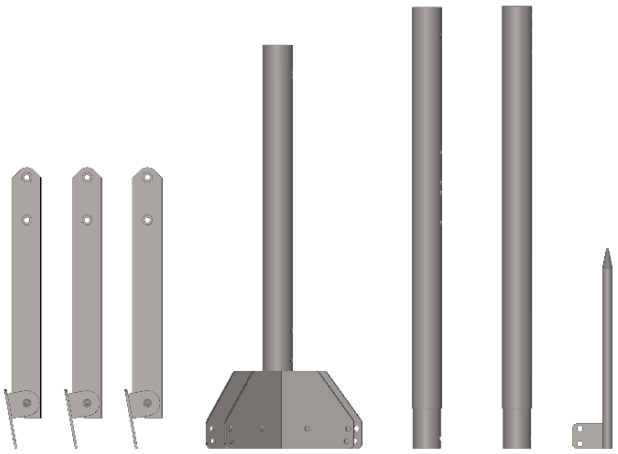
The enclosure is an IP68 aluminum box, with two cable glands, on one side with an 8-pin screw connector to connect your ISAW instrument, and on the other side a 4-pin screw connector to connect your power supply and your 4-20 mA current loop terminal.

HailFlow HF4		AD420 adapter	Your instrument	
Wire	Signal		Pin	Signal
White	Power		PWR+	Positive power supply
Brown	Signals GND			
Green	OUT1		PWR-	Negative/ground power supply
Yellow	OUT2			
Blue	SDI-12		LOOP-	4-20 mA output current loop -
Grey	RX			
Pink	TX		LOOP+	4-20 mA output current loop +
Black	Power GND (0V)			

TMAST – Tripod mast



TMAST is a heavy-duty, modular, cost-effective stainless steel tripod mast, lightweight and easy to transport. It allows all the usual ISAW instrument mountings, as well as supporting additional instruments and other accessories or auxiliary equipment. The H=2.89m (from ground to top of lightning rod) mast is dismountable (3 parts) and equipped with 3 tiltable legs and a lightning rod.



3. CONFIGURE THE HailFlow HF4

3.1. Introduction

Your HailFlow HF4 instrument is delivered **completely pre-configured** to **operate in continuous mode**. It is ready to be plugged into a power supply and into your reading peripheral (I/O module, data datalogger, automation server, controller, computer, etc.). See next page for an example of the full factory default configuration.

Configuration settings include:

- Measuring settings (e.g., acquisition and averaging / logging /writing durations)
- Power settings (e.g. automated duty-cycle of the instrument, in case of implementation with critical electrical consumption concerns)
- Communication and mapping settings (e.g., analog and/or digital outputs, voltage scales, duty-cycle, bus address, etc.).

Note: The default configuration, as well as any other customized configuration, is **non-volatile**, i.e. your instrument **remains in the desired operating configuration whatever the powering scenario**. Thus, even in case of repeated power failures, **the instrument will always restart automatically in the desired configuration mode**. When adding or replacing an ISAW instrument, it is possible to pre-configure it in order to achieve Plug and Play functionality without any on-site configuration.

You can change and adjust anytime the configuration settings, either by using the ISAW Toolbox Configuration utility (see § 3.3) or directly in terminal mode (see § 3.4),), or even using an extended SDI-12 command (see Appendix C.2).

3.2. Operating parameters

The complete configuration of a HailFlow HF4 instrument consists in the following parameters:

Default configuration of a HailFlow HF4 instrument

Parameter	Description	Type	Access[1]	Values / Format	Default value / *Example*
sens_type	Instrument type	string	ro	HAILFLOW	HAILFLOW
sens_version	Model version of the instrument	version	rw*	<major>.<minor> where major and minor cannot exceed 255	4.00
sens_date	Date of manufacturing/assembly of the full instrument	date	rw*	YYYY-MM-DD YYYY: Year, MM: Month, DD: Day	*2025-02-05*
sens_sn	Instrument serial number (matches instrument body engraving)	string	rw*	HFxxxxxxx	*HF25B063*
hw_version	Version of electronic hardware	version	rw*	<major>.<minor> where major and minor cannot exceed 255	*1.40*
hw_date	Date of electronic hardware manufacturing/assembly	date	rw*	YYYY-MM-DD YYYY: Year, MM: Month, DD: Day	*2025-03-12*
hw_sn	Electronic hardware serial number	string	ro	xxxxxxxxxxxxxxxxxxxxxxx	*003D0037393839350D473533*
hw_dev_id	Hardware device identifier	string	ro	0xXXXX (chipid)	*0x416 (STM32L151CBT6)*
hw_extflash	Internal Flash memory identifier	string	ro	0xxxxxxx(<model>) (0x000000 if no Flash memory is soldered to the instrument electronic board)	*0x202013 (M25P40)*
fw_version	Version of current firmware	version	ro	<major>.<minor> where major and minor cannot exceed 99	*3.54*
fw_build	Compilation information of current firmware	string	ro	Not specified	*Mar 18 2025 at 09:24:16 by GCC 10.3.1*
cfg_ident	Eeprom configuration map identifier	string	ro	_HF_	_HF_
cfg_version	Eeprom configuration map version	version	ro	<major>.<minor> where major and minor cannot exceed 255	*0.31*
range_hail	OUT1 and/or OUT2 range for full-scale hail intensity	string	rw	2V5 25 hit/s (HF4) full-scale 5V 25 hit/s (HF4) full-scale	5V
fscale_hail	OUT1 and/or OUT2 full-scale hail intensity, hit/s	string	ro	25	20.000000
thld_hail	Hail noise threshold [mV]	integer	rw	0 to 3300	3
out1_mode	OUT1 mode (green wire)	string	rw	off Disabled hail Hail intensity (Persistent, 0 to full-scale)	hail
out2_mode	OUT2 mode (yellow wire)	string	rw	off Disabled hail Hail intensity (Persistent, 0 to full-scale) raw Raw analog AC signal	off

[1] ro: read-only – rw: read/write – rw*: read/admin-write

Parameter	Description	Type	Access[1]	Values / Format	Default value / *Example*
sdi12_mode	SDI-12 mode (blue wire)	string	rw	off Disabled hail Hailstone count and hailstone disdrometry	hail
sdi12_addr	SDI-12 address	string	rw	ASCII character (standard SDI-12 characters are 0 to 9)	0
serial_mode	Serial mode (pink wire)	string	rw	off Disabled hail Hailstone count and hailstone disdrometry	hail
datalogger_mode	Datalogger mode	string	rw	off No recording on Data are recorded until memory is full. cyclic Data are recorded and the oldest data are constantly overwritten when memory is full.	cyclic
datalogger_cfg	Datalogger field configuration	integer	rw	The value is expressed in hexadecimal. Each bit matches a field. If the bit value is 1, the field is logged. Bit 15: reserved Bit 7: min. hail Bit 14: reserved Bit 6: avg hail Bit 13: reserved Bit 5: max. hail Bit 12: hailstone classes Bit 4: std hail Bit 11: hailstone count Bit 3: N.A. Bit 10: N.A. Bit 2: N.A. Bit 9: N.A. Bit 1: N.A. Bit 8: N.A. Bit 0: N.A.	0x181F
datalogger_usage	Datalogger record count usage	integer	ro	Number of recorded measurements.	0
datalogger_capa	Datalogger record count capacity	integer	ro	Maximum number of recordable measurements. Depends on the number of fields selected in datalogger_cfg.	11912
avg_a	Acquisition duration (s)	integer	rw	Must be > 0 (see Averaging duration rules below)	10
avg_c	Cycle duration (s)	integer	rw	Must be >= avg_a and avg_m/avg_c is integer (see Averaging duration rules below)	10
avg_m	Measurement duration (s)	integer	rw	Must be >= avg_c and avg_c must be modulo avg_m (see Averaging duration rules below)	600
pulse_thld	OUT1/OUT2 pulse threshold (hit)	float	rw	No limit	10.000000
pulse_to	OUT1/OUT2 pulse reset timeout (s)	integer	rw	Must be > avg_m	3600
pulse_ms	OUT1/OUT2 pulse duration (ms)	integer	rw	1 < pulse_ms < 500	50
pulse_lvl	OUT1/OUT2 pulse level	string	rw	2V5 Pulse level is 2.5 volts 5V Pulse level is 5 volts	5V
lin_xc1	Hail linearization coefficient XC1	float	rw	Default factory setting	5.100000
lin_xe1	Hail linearization exponent XE1	float	rw	Default factory setting	0.333333

Parameter	Description	Type	Access[1]	Values / Format	Default value / *Example*
calib_date	Date of instrument calibration	date	rw*	YYYY-MM-DD YYYY: Year, MM: Month, DD: Day	*2025-05-22*
calib_hail	Hailstone count calibration factor	float	rw*	Must be > 0	1.000000
cons_idle[2]	Timeout of console to return in idle mode	integer	rw	Seconds	10
sys_clk	System clock (It's not recommended to change this parameter)	string	rw	internal Use internal clock external Use external clock	external
sys_speed	System speed (It's not recommended to change this parameter)	string	rw	4MHz Run at 4 MHz 8MHz Run at 8 MHz 16MHz Run at 16 MHz 32MHz Run at 32 MHz	16MHz
sys_uptime	Time elapsed since power on	integer	ro	Seconds	*23*
sys_status	System status	string	ro	ok No error adc-overrun ADC Error	ok
sys_watchdog[3]	Hardware watchdog timer status	string	rw	on Watchdog is enabled off Watchdog is disabled	on
sys_reboot	Last system reboot type	string	ro	user Instrument has been rebooted manually by the user (power or software) watchdog Instrument has been rebooted by the watchdog	user
misc_pwrdly	Analog stage power delay: time to wait after power on amplifier and start acquisition	integer	rw	Milliseconds. Must be < 500	100
misc_dbg	Debug bit-field status	integer	ro	See "debug" command.	0x0000
misc_admin[4]	Current admin rights status	string	ro	yes User is admin, special parameters can be changed. no User is not admin, special parameters cannot be changed.	no
misc_scopeqry	Enable scope mode at next reboot, (automatically reset after startup)	integer	ro	yes or no, set by scopemode (see appendix B.2)	no
misc_scopemode	Scope mode currently enabled	integer	ro	yes or no, set by scopemode (see appendix B.2)	no

[2] When you enter this command, the console temporarily hides the measurement message (to clear the display), and then returns, after the selected timeout, to idle mode (stop hiding message).

[3] The **watchdog timer** is and independent hardware system which detects and recovers from instrument malfunctions due to software failure: if the instrument fails to reset the watchdog regularly (every 10 to 20 s) the timer will elapse, and the instrument will be restarted automatically.

[4] You can change the admin status using the "admin" command. Admin status is automatically reset to default ("no") after reboot.

3.3. Configuration using the ISAW Toolbox software suite

The configuration of the HailFlow HF4 instrument can be done either with the ISAW Toolbox software suite (see section 0.), and/or by direct or remote connection methods. This section describes how to configure your HailFlow HF4 instrument using the ISAW Toolbox Configuration Utility.

1. Open the ISAW-Toolbox by double-clicking on the ISAW icon on your desktop.
2. Start the Configuration utility by clicking on the corresponding item.
3. Select the Serial port the instrument is connected to and press the [Connect] button. Once the instrument is connected, the Configuration tabs appear and the control buttons are enabled.

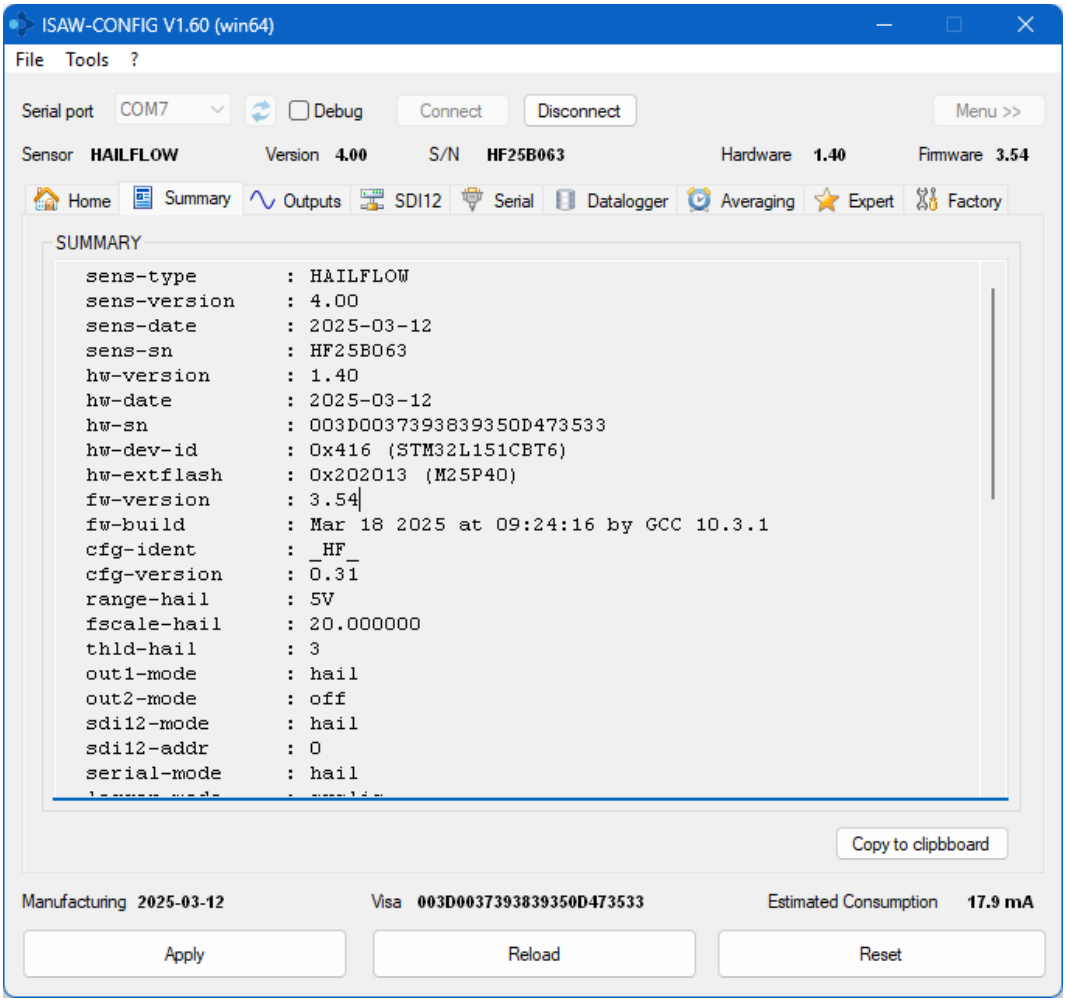
Configuration panels	
Summary	Current configuration.
Outputs	Setting analog outputs, voltage ranges, and pulse settings.
Sdi12	Setting SDI-12 settings.
Serial	Serial settings.
Datalogger	Internal data recorder.
Averaging	Setting acquisition duration, cycle duration, duty cycle and measurement duration.
Expert	Setting coefficients of the polynomial linearization functions, internal clock and timeout parameter.
Factory	Reading the instrument's factory information.

Control buttons	
[Apply]	Sends the complete configuration displayed in all tabs to the instrument. After receiving the configuration, the instrument restarts.
[Reload]	Reloads the instrument's configuration.
[Reset]	Resets the instrument with the default factory configuration. To confirm that the configuration has been properly installed, the application then reloads the configuration and displays it again. See the "reset confirm" command in appendix B.2 for more information.

3.3.1. Summary panel

To quickly check the full configuration of your instrument, the summary panel lists all the settings and instrument information.

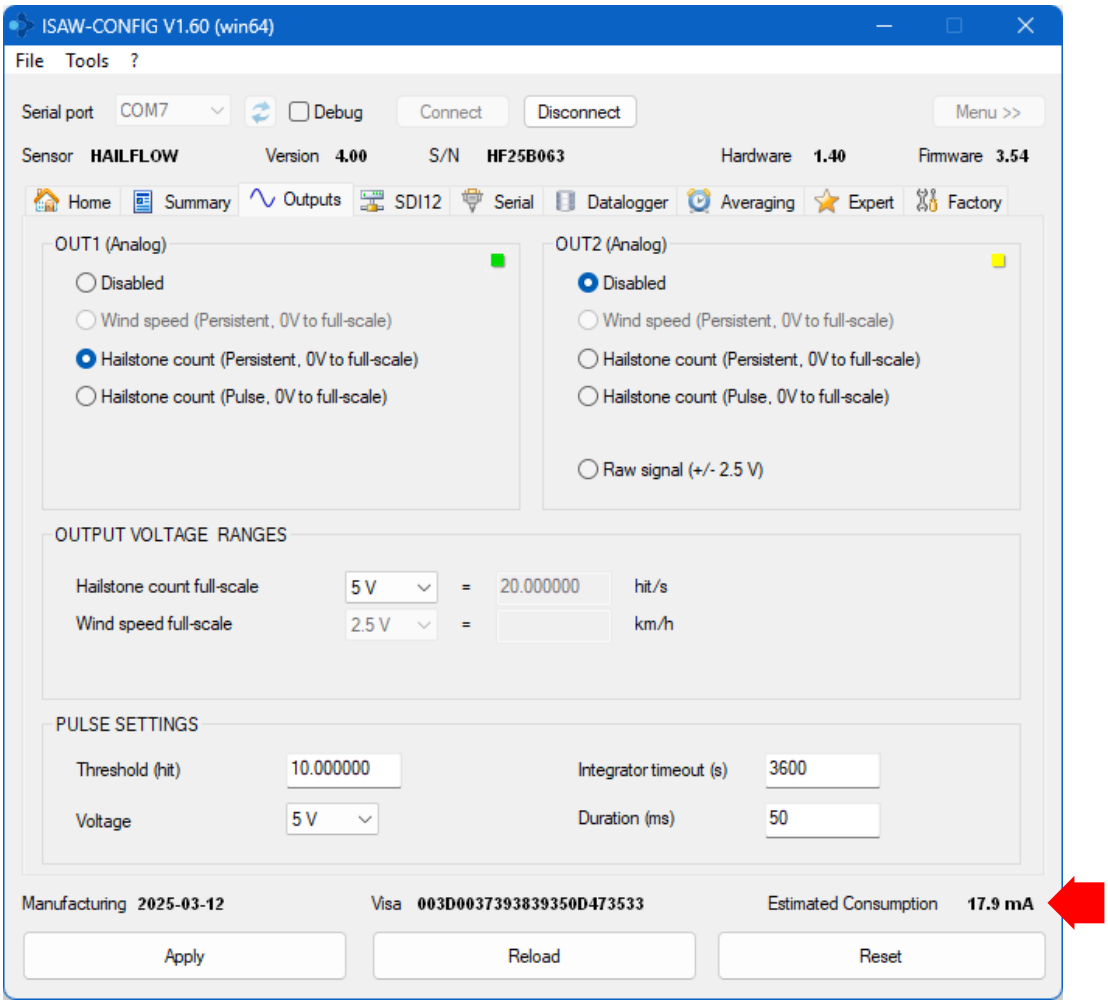
See § 3.2 for more details on the parameters.



The [Copy to clipboard] button allows you to copy the whole configuration and paste it in another destination for example in case of concurrently testing different settings, or for diagnostic, reporting or backup purposes.

3.3.2. Outputs panel

The outputs panel allows you to set the so-called OUT1 and OUT2 analog outputs, which mapping is user-selectable as explained in the next paragraph.



When choosing to connect your instrument to the analog input(s) of a reading device (so the reading device reads positive continuous voltage or counts pulses from either the green or the yellow wire of the instrument), you can decide which output signal you want to be physically present on each of the wires.

This functionality, called the *output mapping*, is a facility that allows the instrument to be adapted to almost any reading device.

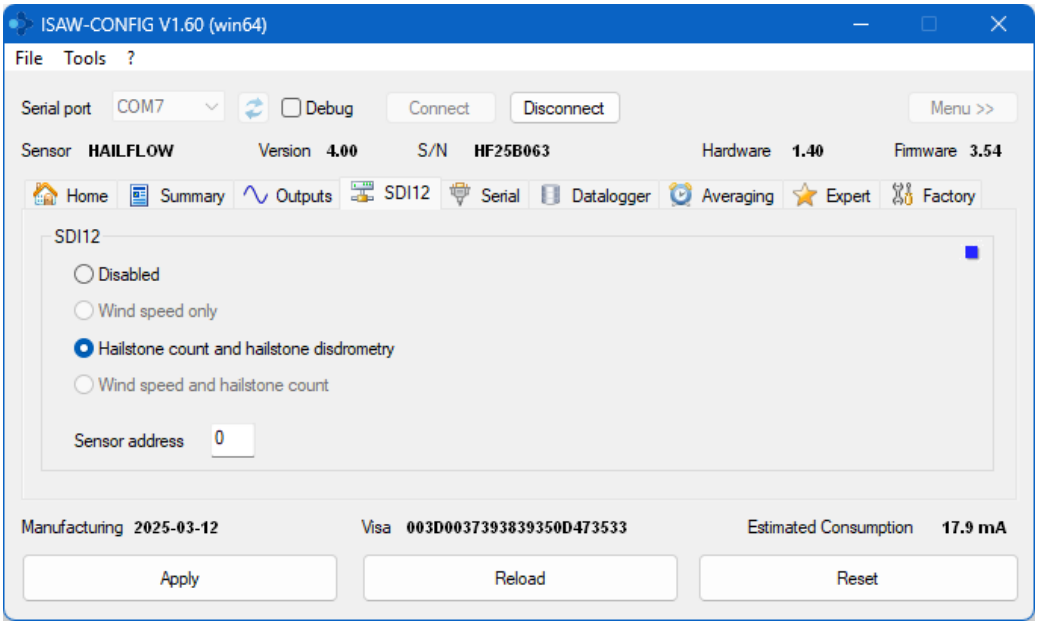
To understand the output mapping, the only thing to consider is that the instruments have two generic analog outputs, called OUT1 and OUT2. OUT1 is always carried by the green wire, OUT2 is always carried by the yellow wire. You decide which signal is attributed to OUT1 and OUT2 by selecting one of the options in this panel.

Further settings available in the output panel are the voltage ranges and the pulse settings, so that you can also adapt these to the characteristics of your reading device.

Tip: The **average power consumption** corresponding to your selected settings is displayed at the bottom right of the panel.

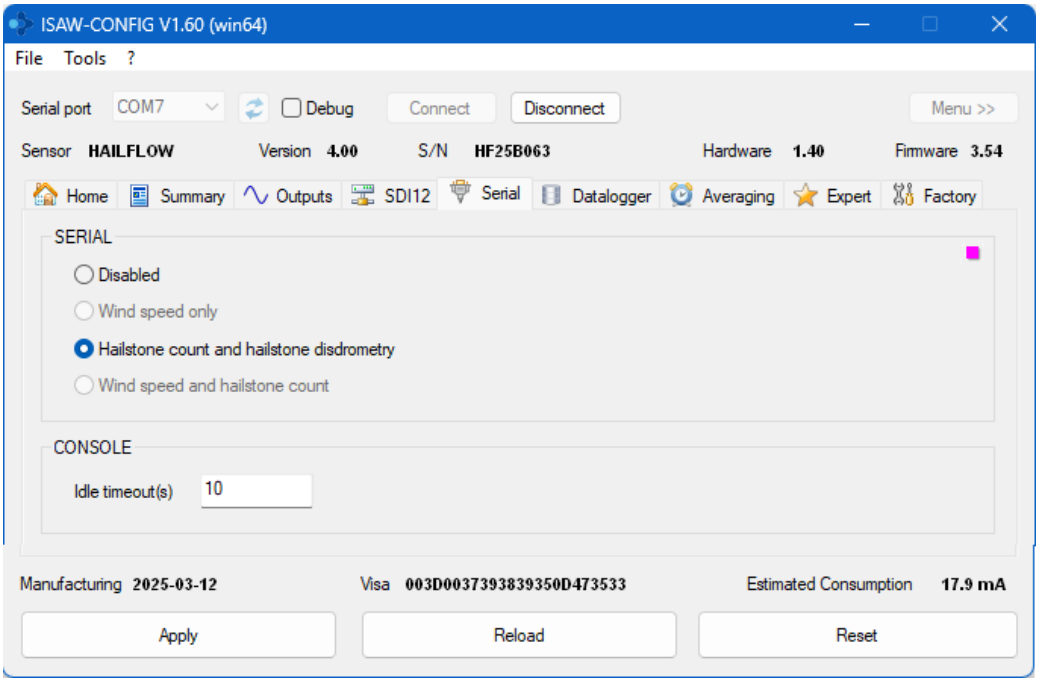
3.3.3. SDI-12 panel

When choosing an SDI-12 interface for your instrument, its positive voltage is always physically carried by the blue wire. You can select in the SDI-12 panel the data frame content you need and set the instrument address of your choice. For more instructions about the use of the SDI-12 interface, please refer to Appendix C.



3.3.4. Serial panel

Serial communication is always available and, unless disabled by the user, physically carried by the pink (TX) and grey (RX) wires in all ISAW instruments. You can select the data frame content you need in the Serial panel and set the idle timeout of your console.



For more instructions on the use of the serial communication, please refer to Appendix B.

3.3.5. Datalogger panel

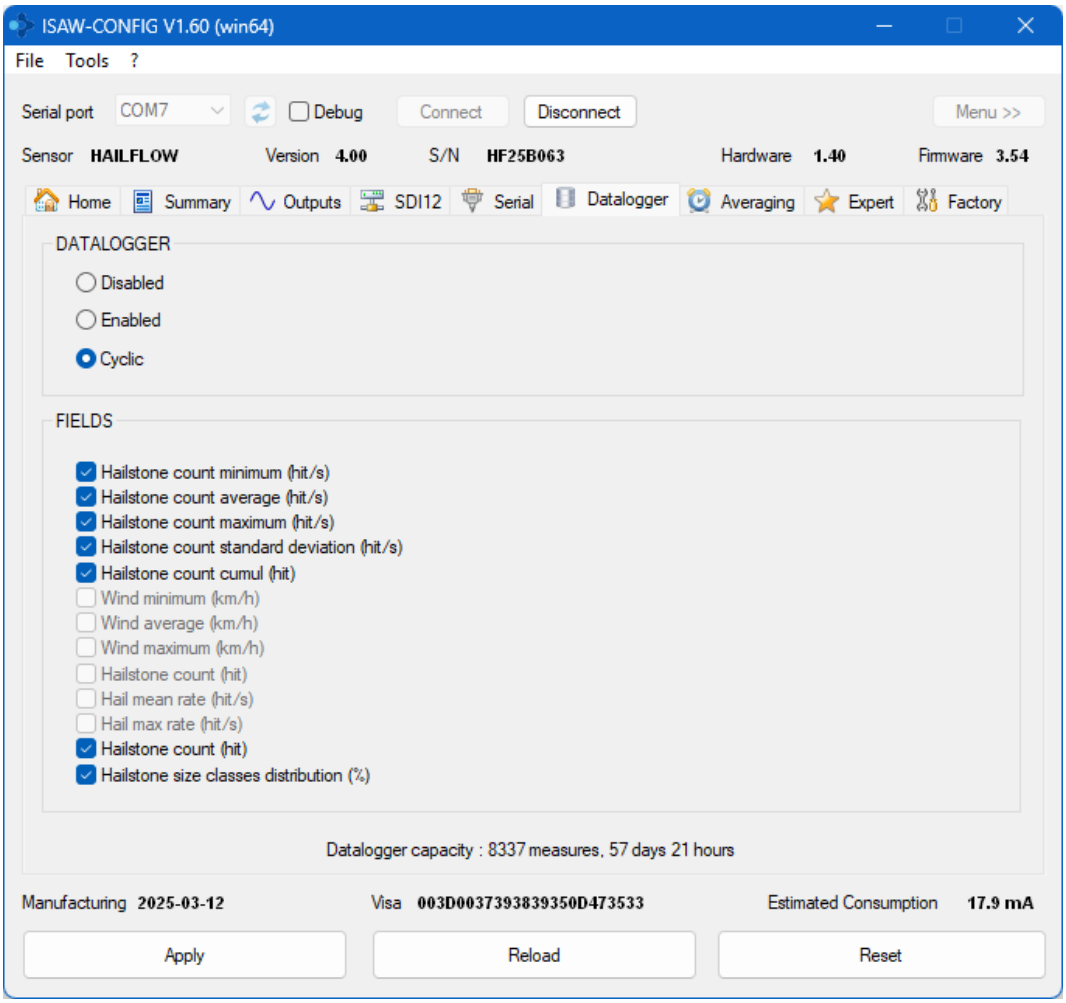
The internal datalogger can be configured as follows:

Disabled: No data is recorded.

Enabled: Data are recorded until the memory is full.

Cyclic: Data are recorded and the oldest data are constantly overwritten when the memory is full.

The logging frequency matches the measurement duration (see next section).



You can individually select the fields you want to record.

Note: The more fields you select, the fewer measurements you can record.

The datalogger capacity indicates the estimated number of measurements and the duration of the measurement session based on the measurement duration.

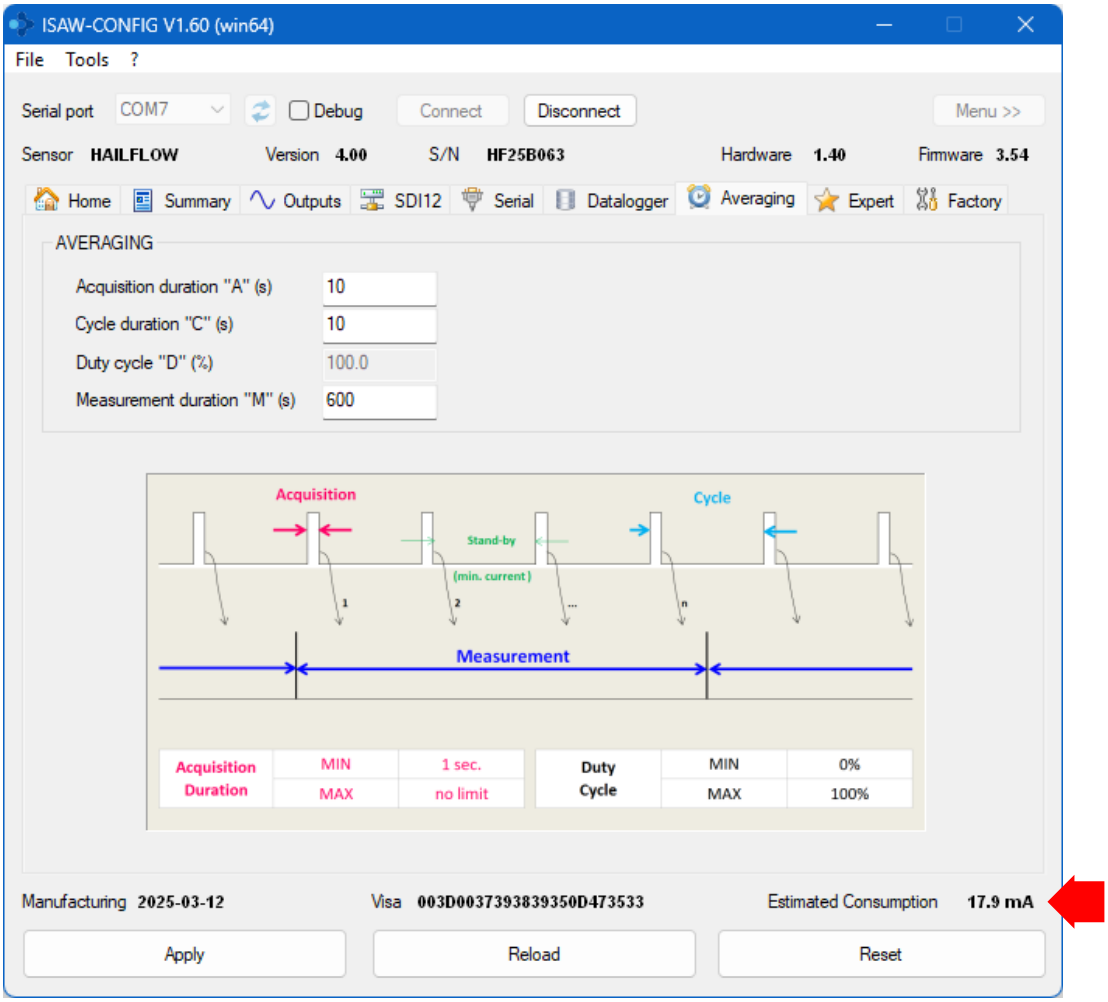
WARNING: The datalogger must be erased after changing the configuration fields (see § 5.1).

3.3.6. Averaging panel

The averaging panel allows you to set all the measurement settings, i.e.

- Acquisition duration (true observation time of the physical phenomena, also called *time integration window*),
- Cycle duration (the sum of the acquisition duration and a stand-by duration),
- Duty cycle (ratio between acquisition duration and cycle duration, the fraction of time in which the instrument is effectively active),
- Measurement duration or also called the *averaging duration* (the reading or writing data interval you want).

These parameters are explained in details in section 3.2.



Tip: The **average power consumption** corresponding to your selected settings is displayed at the bottom right of the panel.

Averaging duration rules:

The parameters "avg-a", "avg-c" and "avg-m" are interdependent and must satisfy the following rules:

`avg-a`, `avg-c` and `avg-m` are integers
$0 < \texttt{avg-a} \leq \texttt{avg-c} \leq \texttt{avg-m}$
`avg-m` / `avg-c` is an integer

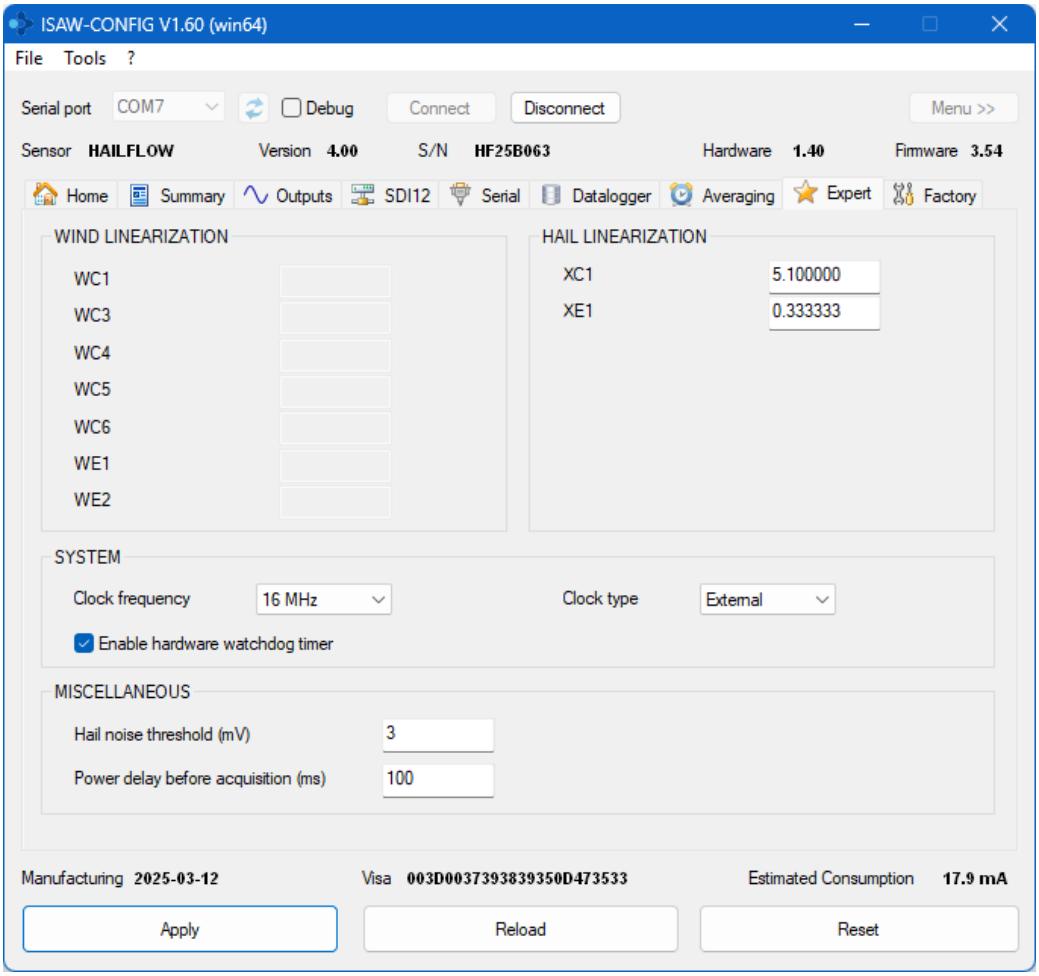
The rules are checked each time a parameter is changed. Therefore, in some cases, the user is unable to set the requested value.

In this case, set the requested averaging parameters in the following order:

1. Set the `avg-a` parameter to 1.
2. Set the `avg-c` parameter to 1.
3. Set the `avg-m` parameter to the requested value.
4. Set the `avg-c` parameter to the requested value.
5. Set the `avg-a` parameter to the requested value.

3.3.7. Expert panel

The Expert panel, reserved for scientific users or customized use of the instruments, allows you to set advanced linearization parameters, i.e. changing the internal calculation mode of the instrument.



For example, you can turn the instrument into pass-through mode, change the internal noise threshold (see “Hail noise threshold” in 0) or implement different coefficients to the internal calculation functions of the instrument.

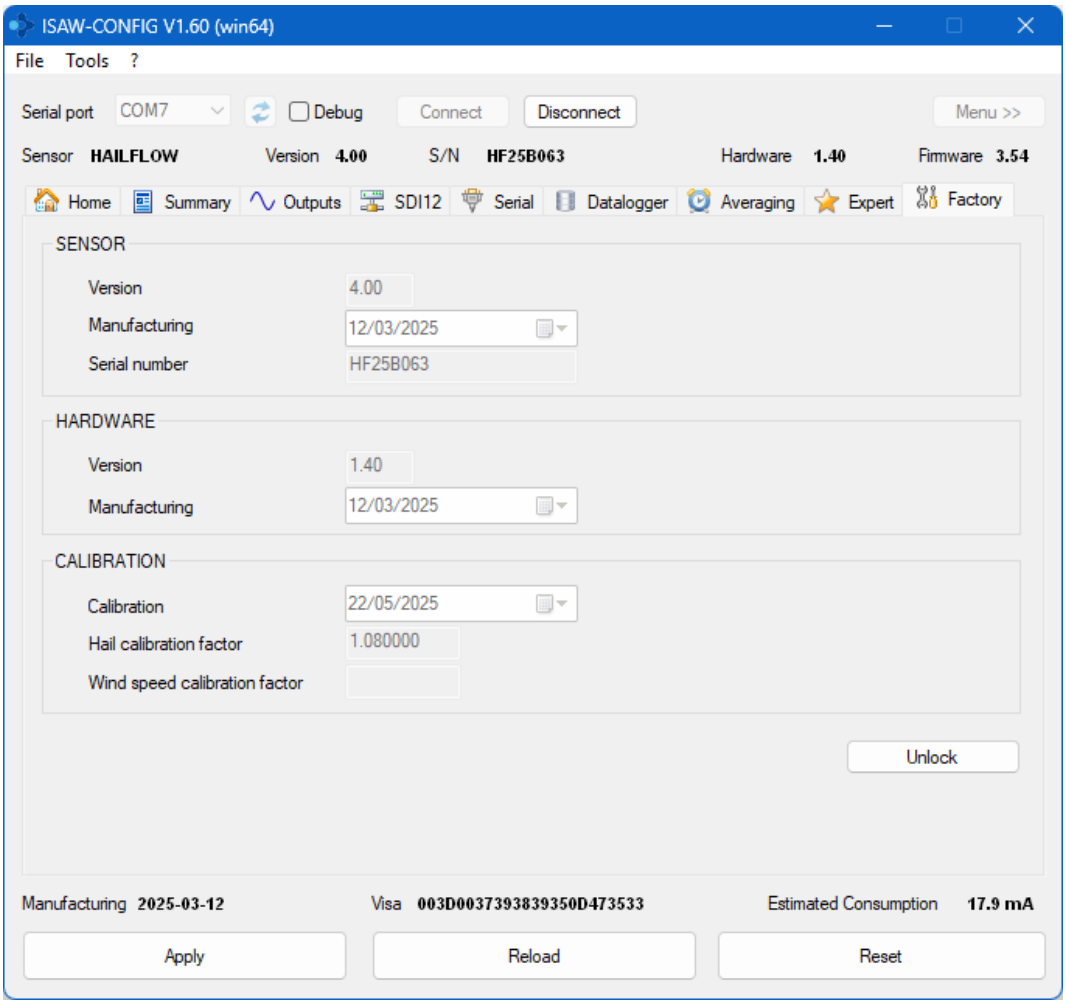
WARNING: Changing these parameters is not recommended.

The [Reset] button allows you to always return to the default factory settings.

3.3.8. Factory panel

The factory panel displays, in a read-only mode, the factory identifiers and calibration settings of your instrument.

Note: Only the manufacturer or the integrator can modify these parameters.



In case of failure of your instrument or when contacting the support, it is recommended to keep a copy of this information at hand to facilitate the identification of your instrument.

3.4. Configuration in Terminal mode (serial communication)

This section describes how to change a parameter of your HailFlow HF4 instrument using a serial terminal utility.

To use the ISAW Toolbox Configuration Utility, refer to section 3.3.

In the following explanations we use the terminal emulator provided with the free ISAW Toolbox software suite (available at www.isaw-products.com), but you can also use any serial terminal like Putty, TeraTerm, HyperTerminal, or other.

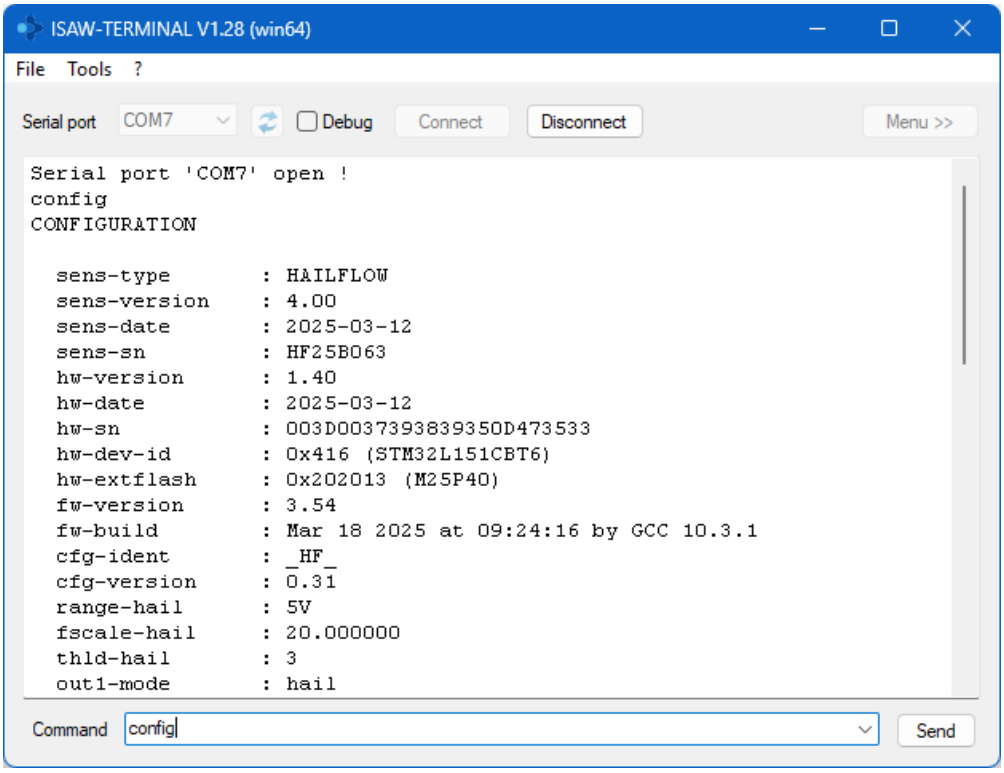
Open the ISAW-Toolbox by double-clicking on the ISAW icon on your desktop.

Start the Terminal utility by clicking on the corresponding item.

Select the Serial port the instrument is connected to and press the [Connect] button.

Optional: To check the current configuration, enter the `Config` command in the Command entry field and press the [Send] button.

The values of all parameters are displayed[5].



To change the required parameter, enter the command `set <parameter> <value>` in the Command entry field, then press the [Send] button.

Note: More serial commands are available in Appendix B

[5] All parameters are detailed in section 3.1.

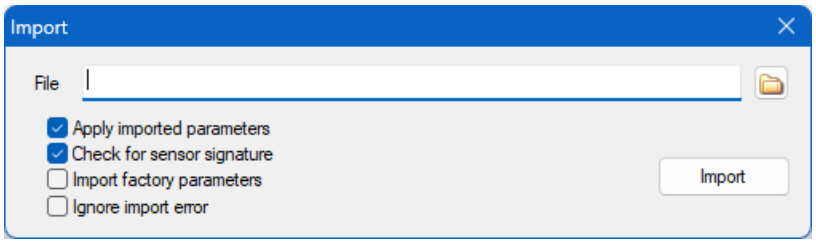
3.5. Import/export configuration

3.5.1. Import configuration

This function allows you to reload the previously exported configuration of an instrument.

Open the ISAW Toolbox Configuration Utility.

Open the Import window: select the "File > Import Configuration" menu. The Import window is displayed.



Select the file to import (*.isawcfg file): either enter the file name in the field, or click on the selection button, or drag and drop the file directly on the entry field.

Choose the import options. The default settings cover most of the situations, but you can change any of the following options:

Option	Description
Apply imported parameters	Send the imported configuration directly to the instrument when the import is completed.
Check for instrument signature	Check if the imported file has been exported from the same instrument (check the instrument's physical address).
Import factory parameters	Include the factory parameters in the import. This operation requires a password to unlock the factory parameters.
Ignore import error	Continue the import even if an import error occurs. If this option is not activated, the import stops at the first error.

Start importing by clicking on the [Import] button.

Note: If the option "Apply imported parameters" is unchecked, you will need to click on the [Apply] button once the import is completed to send the imported configuration to the instrument.

3.5.2. Export configuration

The export function operates the same way. It allows saving the instrument current configuration into a file.

Open the ISAW Toolbox Configuration Utility.

Open the Export window: select the "File > Export Configuration" menu. The Export window is displayed.

Enter the name of the export file. The default file name is the instrument's serial number with a .isawcfg extension.

Start the export by clicking on the [Save] button.

4. INSTALL THE HailFlow HF4

4.1. Conditions of use

Always remember that the HailFlow HF4 instrument is an acoustic instrument and could thus potentially be affected by structure-borne vibrations issuing from the supporting structure (for example, a steel cable impacting repetitively on a metal mast when subjected to wind); or to a lesser extent by parasitic low-frequency noise from the immediate environment (for example, excessive proximity to heavy traffic or machinery could lead to parasitic signals). It is recommended that you pay attention to avoiding possible parasitic noise when mounting the project.

4.2. Wiring & I/O Mapping

4.2.1. Instrument cable

Each instrument is delivered with a **5 m cable** prepared with bootlace ferrules at each of its 8 conducting wires, ready to be plugged into the 8-pin screw terminals of the ISAW accessories or any other terminal of your choice.

Cable reference:

LÜTZE SUPERFLEX ® TRONIC (C) PUR 7×0.25, ref. 117103with 7 conductors AWS 24 / 0.25 mm^2

The 8^{th} conductor (color: BLACK) is a 10 cm length termination welded on the shield.

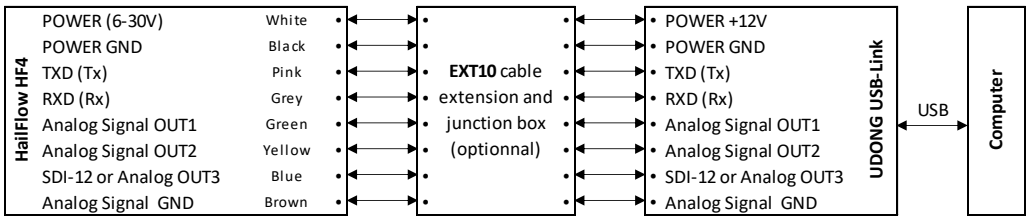
WARNING: It is strongly advised **not to shorten the factory cable**. Should you be obliged to, you must absolutely treat the shield as the BLACK (POWER GND) conductor, that is, protect the nude shield with a black thermal sleeve, crimp a terminal, and make sure to connect it to the GND of your connected device.

Wire	Signal	User selectable	Plug and play Default factory settings
White	Power	No	Positive power supply (6 to 30) VDC
Black	Power GND (0V)	No	Power GND (0V)
Pink	TX	■ Disabled ■ Hailstone count and hailstone disdrometry	RS-232 active, Hailstone count and hailstone disdrometry
Grey	RX		
Green	OUT1	■ Disabled ■ Hailstone count (Persistent, +0V to full-scale +2.5V or +5V) ■ Hailstone count (Pulse, +0V to full-scale +2.5V or +5V)	Hailstone count (Persistent, +0V to full-scale +2.5V or +5V)
Yellow	OUT2	■ Disabled ■ Hailstone count (Persistent, +0V to full-scale +2.5V or +5V) ■ Hailstone count (Pulse, +0V to full-scale +2.5V or +5V) ■ Raw signal (±2.5V) (Note: direct, unfiltered AC output of the instrument)	Hailstone count (Pulse, +0V to full-scale +2.5V or +5V)
Blue	SDI-12	■ Disabled ■ Hailstone count and hailstone disdrometry	SDI 12 bus active, address: 0, Hailstone count and hailstone disdrometry
Brown	Signals GND	No	OUT1 GND, OUT2 GND and SDI-12 GND

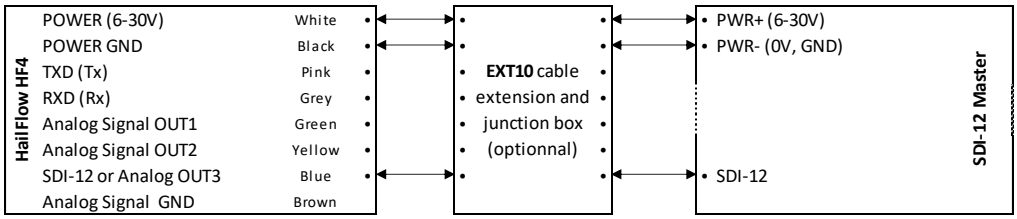
The instrument can simply be used by reading DC outputs (+0 to +2.5V or +0 to +5V continuous or pulse analog voltages available). Note that the continuous DC analog voltages are persistent on the outputs so that output voltages can be read at any time (the reading interval from your peripheral is independent from the duration of the time integration of the instrument).

4.2.2. Wiring diagrams

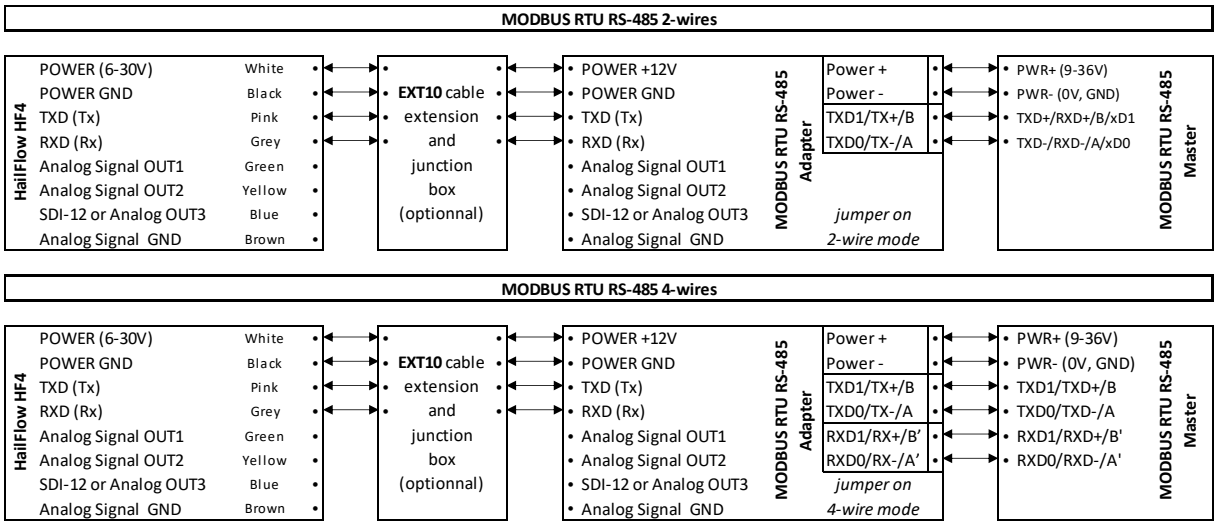
Direct USB-Link Serial connection to computer COM port



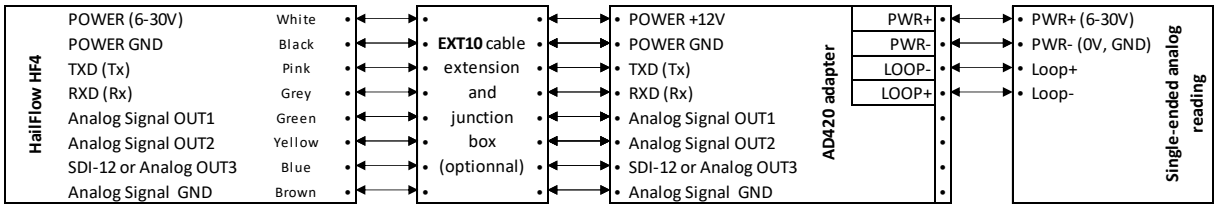
SDI-12 Data Logger (or other SDI-12 Interface)



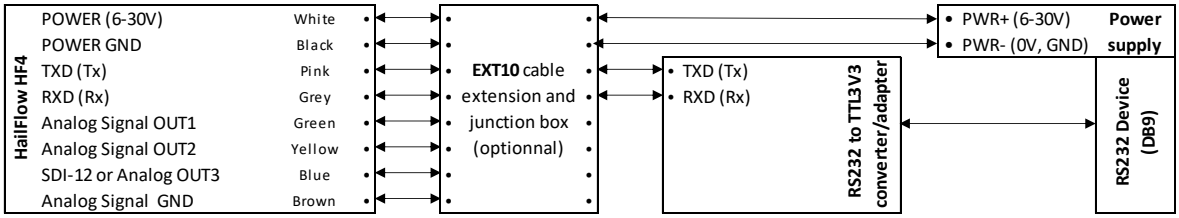
Modbus RTU RS-485



4-20 mA Current Loop



RS232 Serial (ex. DB9 on computer)

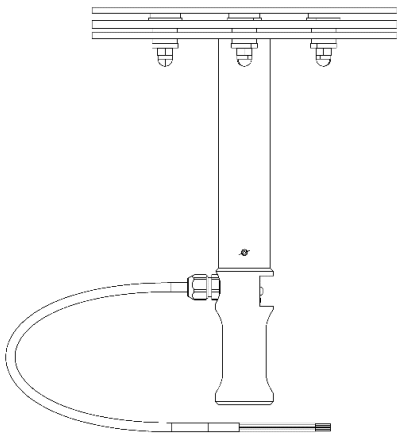


4.3. Mounting instructions

HFBRA Package content

Item ref.	Description	Quantity
HF4	HailFlow HF4 instrument	1
UDONG	USB dongle	1
REAFR	Anti-vibration arm front piece	1
REABK	Anti-vibration arm back piece	1
DAMPN	Dampener	2
BRARF	Front bracket	1
BRARB	Back bracket	1
BRASH	Reduction shim	2
BN 611 M10X70	M10 × 70 mm screw	2
BN 610 M10X40	M10 × 40 mm screw	2
BN 13289 M10x25x4	M10 washer 4 mm thick	10
BN 33010 M10	M10 securing nut	7

Instrument

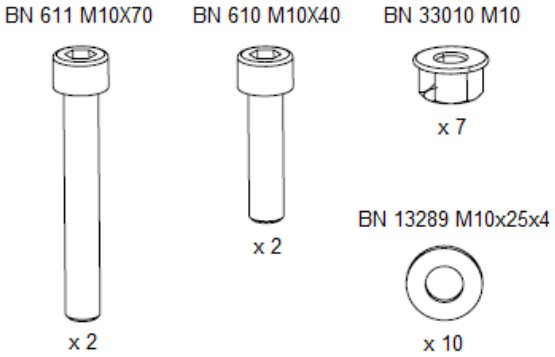


HF4

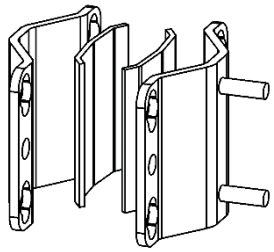
USB dongle

UDONG

Screw kit

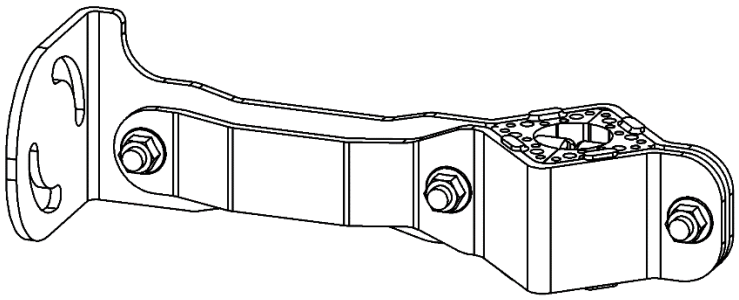


Bracket kit



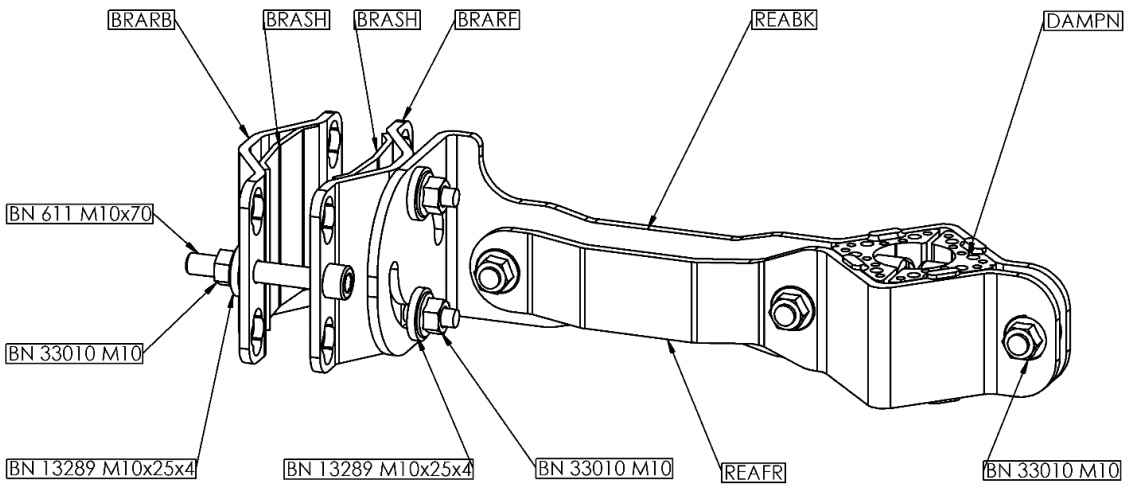
BRARB + 2xBRASH + BRARF

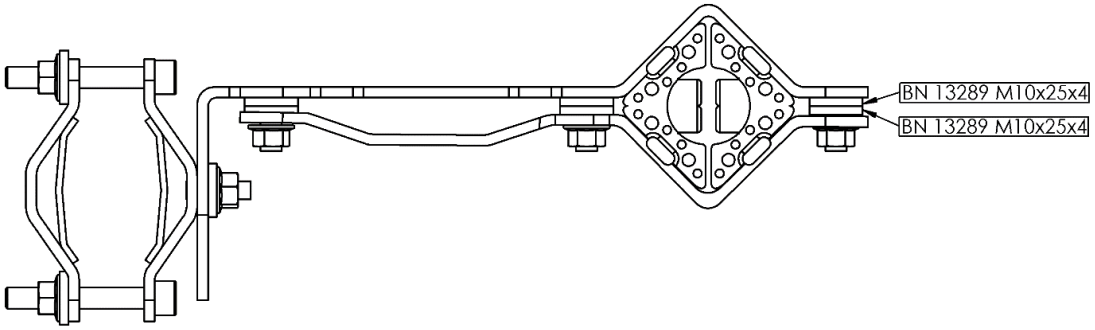
Anti-vibration arm



REARM

AVARM Mounting instructions



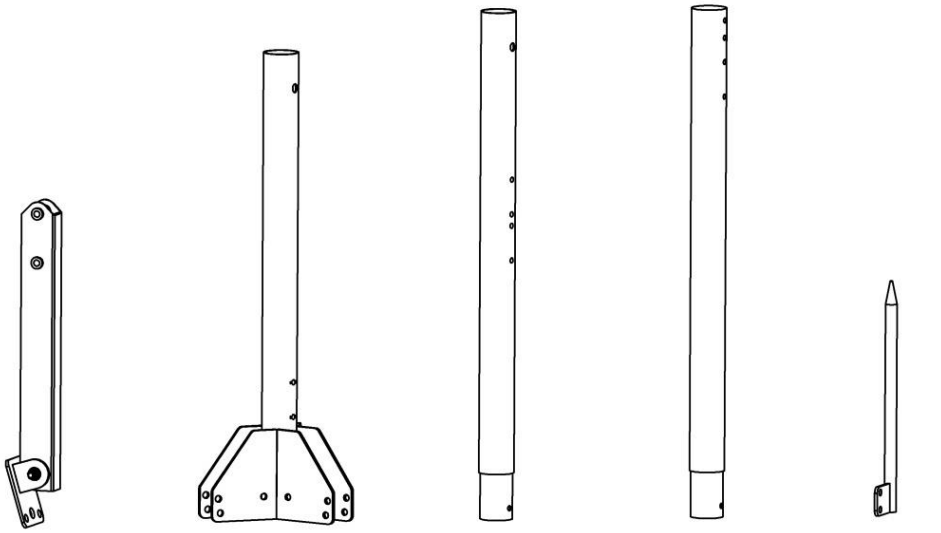


- For a **MAST OF OUTER DIAMETER < 60 mm**, replace the screws BN 611 M10X70 with provided BN 610 M10X40.
- For a **MAST OF OUTER DIAMETER ≥ 65 mm**, remove the reduction shims (BRASH).
- To fasten the instrument on a **FLAT SURFACE**, screw the front bracket (BRAFR) directly onto the surface.
- The instrument's cable must be **tightly secured** to the arm and mast using tie wraps.

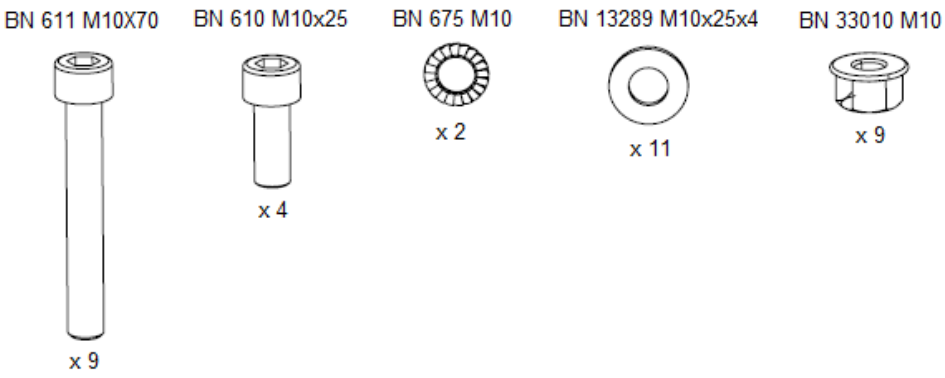
TMAST Package content

Ref.	Description	Quantity
TM01	Leg with inclinable foot	3
TM02	Base tube	1
TM03	Mid tube	1
TM04	Top tube	1
TM05	Lightning rod	1
BN 610 M10x25	M10 × 25 mm screw	4
BN 611 M10x70	M10 × 70 mm screw	9
BN 675 M10	M10 serrated lock washer	2
BN 13289 M10x25x4	M10 washer 4 mm thick	11
BN 33010 M10	M10 securing nut	9

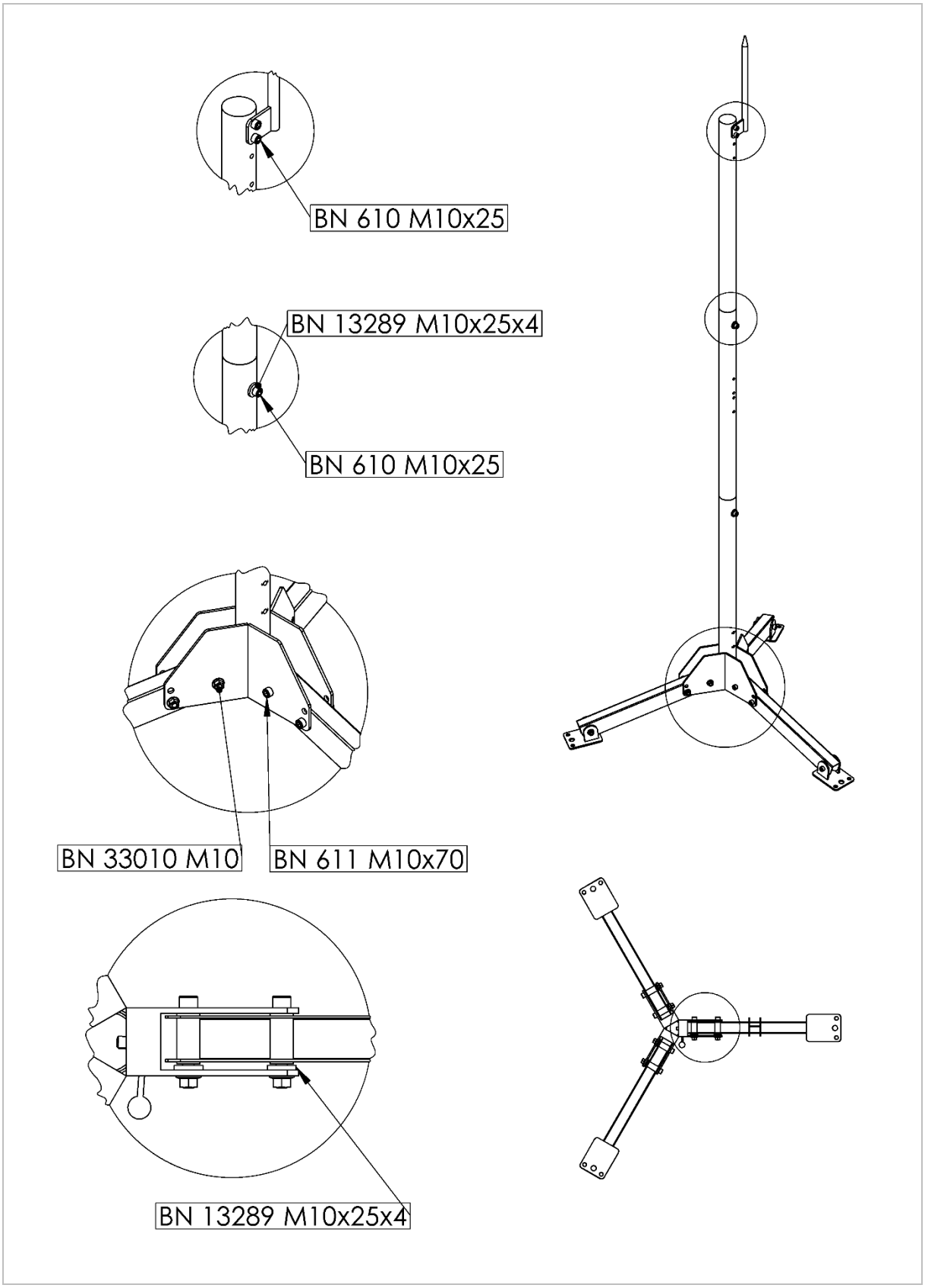
Mast kit



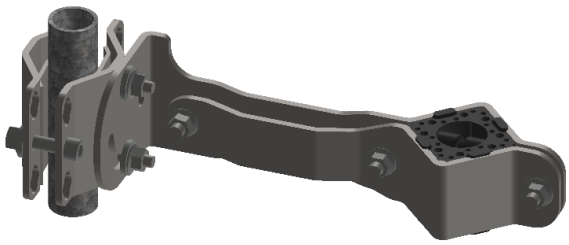
Screw kit



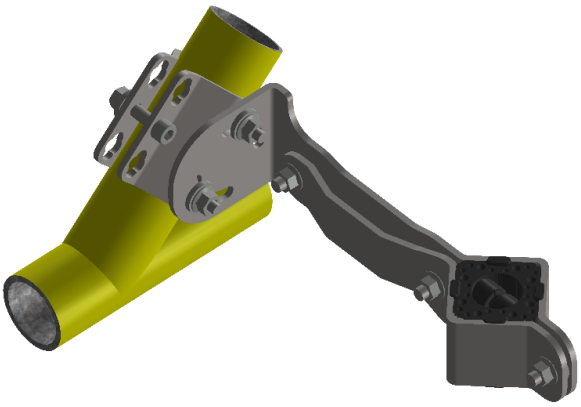
TMAST Mounting instructions



4.4. Mounting examples

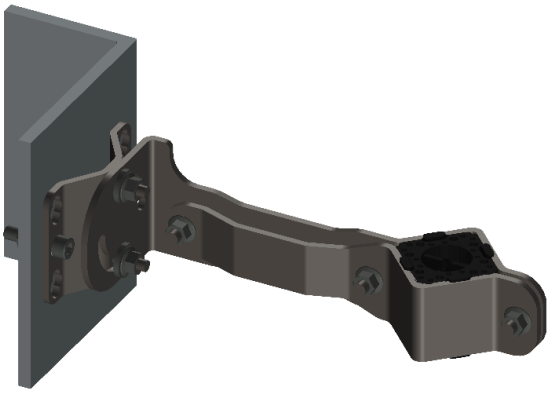


On a vertical, horizontal (or inclined) cylindrical mast with an outer diameter of **25 mm**, use the provided V brackets and **reduction shims**.

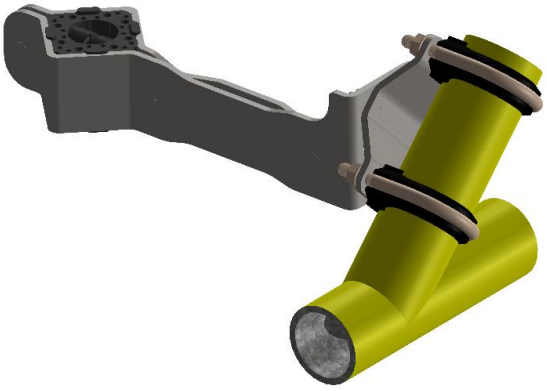


On an **inclined mast**, turn the arm to position the instrument vertically.

On a vertical, horizontal (or oblique) **cylindrical mast** with an outer diameter of **40 mm**, use the provided V brackets without the reduction shims.

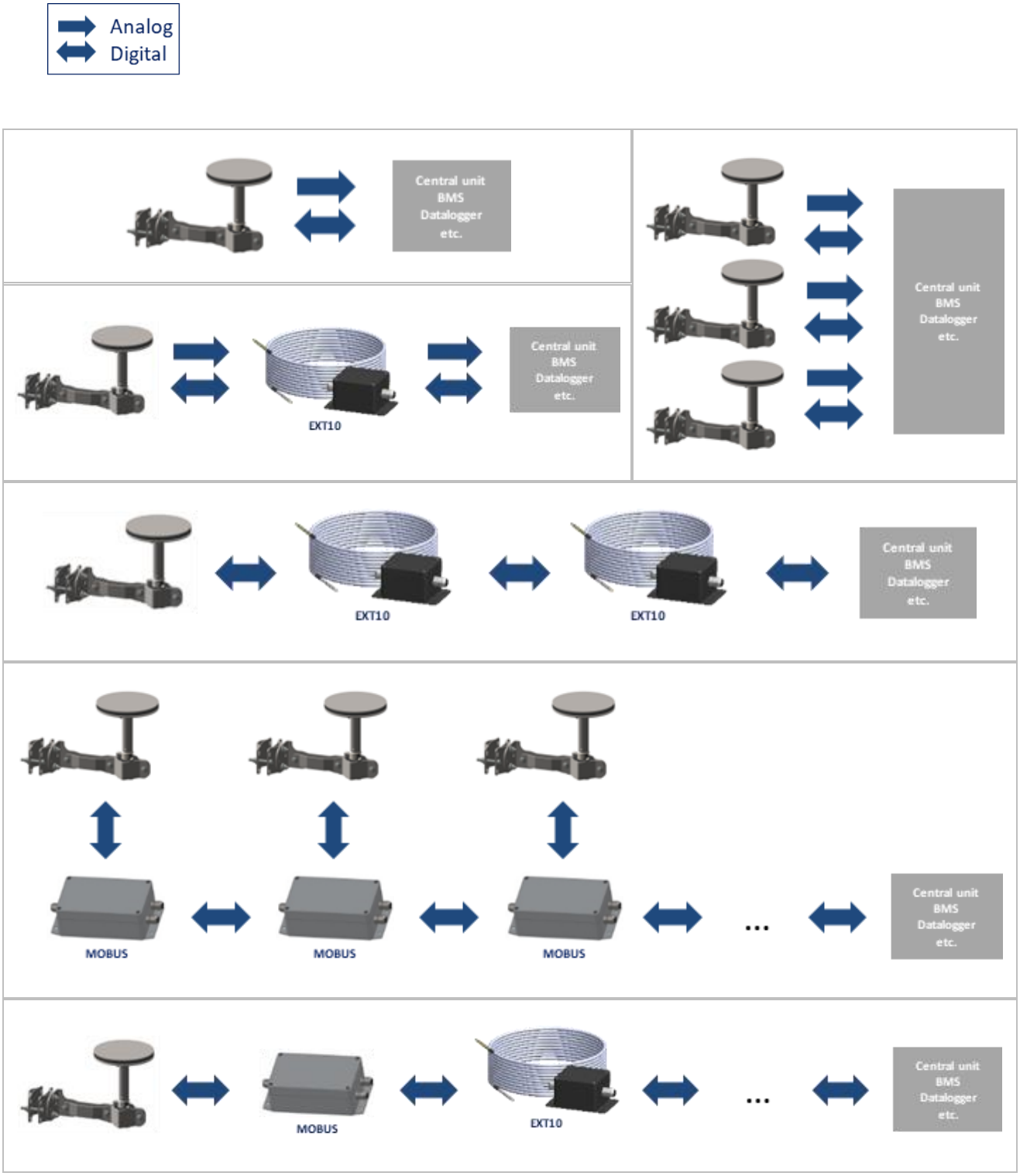


On a **flat surface**, screw the front bracket onto the surface.



Alternative mounting using standard **U-Bolt** fasteners (not provided).

4.5. Chaining examples



5. OPERATE THE HailFlow HF4

5.1. Disclaimer

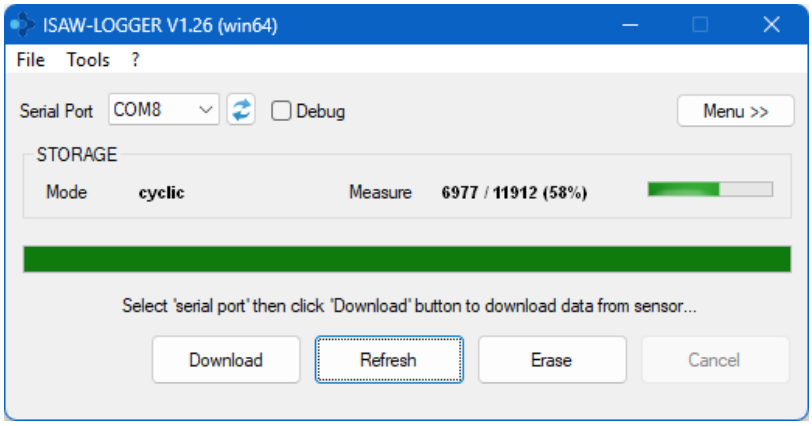
When using the HailFlow HF4 instrument, IAV Technologies SARL is not responsible for the choice, selection, relevance and usage appropriateness of the instrument installation site; nor for the usage, interpretation, and extrapolation of the information made available to the users. Any known system issues that may induce dysfunction or skew the measurements are reported to the users through documentation updates. To continually improve the system, the ISAW Products division of IAV Technologies SARL reserves the option to upgrade the instrument hardware, software, and user recommendations anytime.

5.2. Recording data using the internal datalogger

By default, the internal datalogger is activated in cyclic mode, i.e. the newest data constantly overwrites the oldest ones when the memory is full.

To change the recording mode or the content of the data frames, please refer to section 3.3.5.

To check the status of the datalogger, open the Datalogger utility of the ISAW-Toolbox (see § 1.6).



The mode can be: **Disabled** (no data is recorded), **Enabled** (data are recorded until the memory is full) or **Cyclic** (data are recorded and the oldest data are constantly overwritten when the memory is full).

Measure is the number of recorded measurements / Total number of recordable measurements.

The **gauge** shows the datalogger's memory status.

Press the [Refresh] button to update this information.

To download data from the datalogger, press the [Download] button. The content of the datalogger is saved into a .CSV file. This operation does not clear the datalogger.

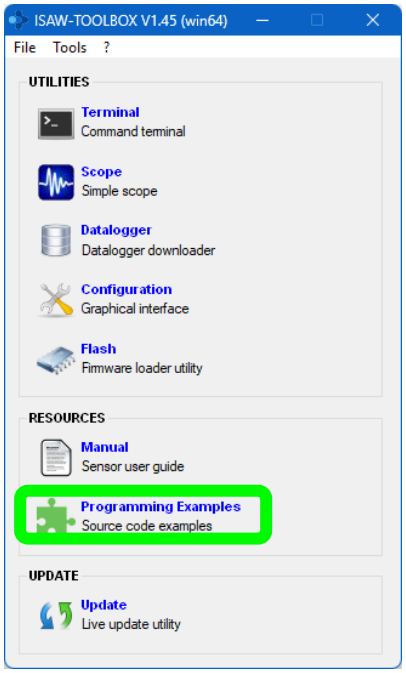
To clear the datalogger (i.e. delete all logged data), use the [Erase] button.

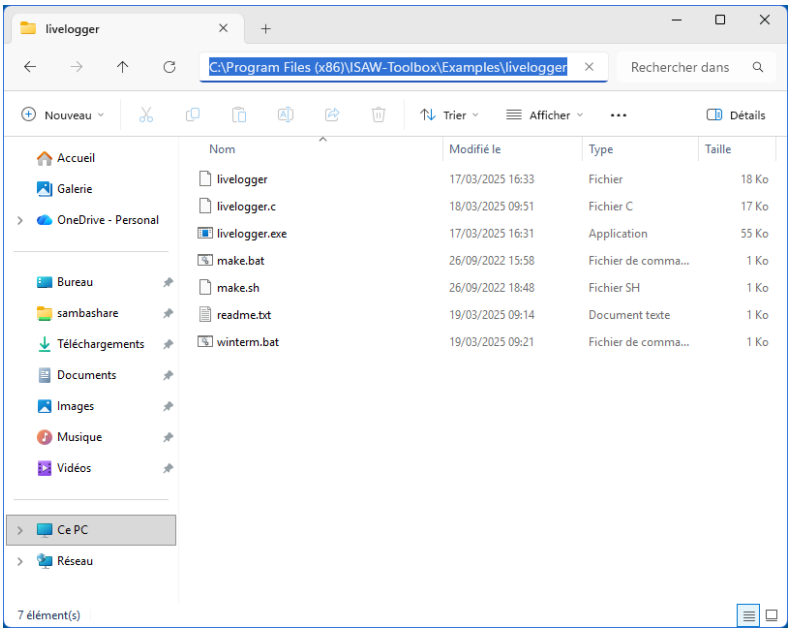
WARNING: This operation is irreversible: deleted data are definitely lost.

5.3. Recording data on a computer

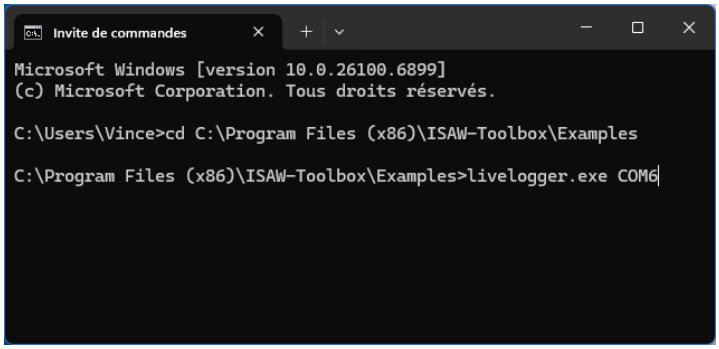
If connected to a computer with the USB link accessory, you can also log indefinitely the data produced by the instrument and without installing any software by means of the **livelogger utility** which is an executable program example available with the ISAW-Toolbox software suite.

Open the **Programming Examples** folder from the ISAW Toolbox to get the full pathname of the livelogger executable.

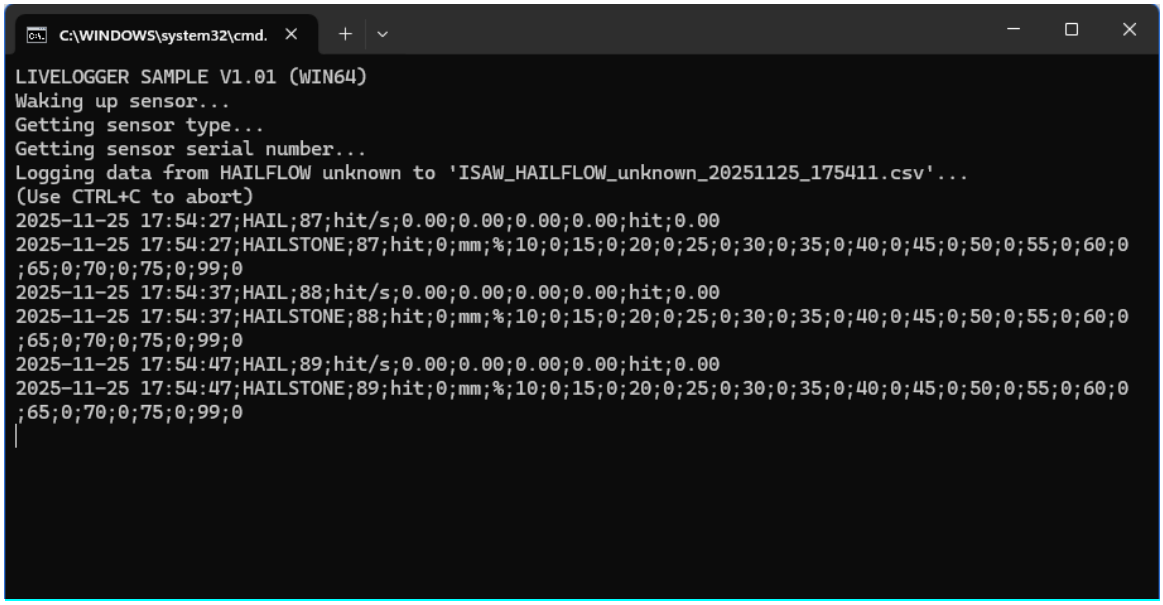




Open a command prompt, go to the right directory and execute livelogger.exe on the COM port the instrument is connected to.



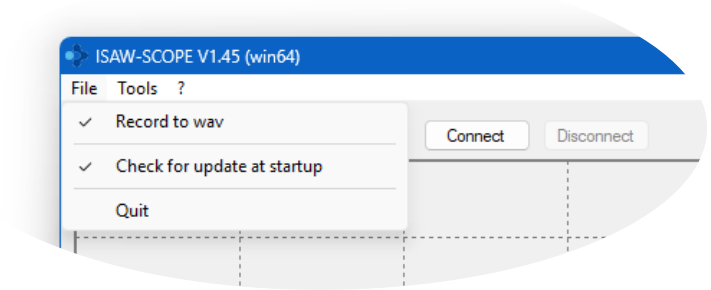
The data is displayed according to the specified A,C,M setting of the instrument (cf. § 1.5.1), and a .CSV file is also produced in the same directory. The data is timestamped according to the clock of your computer.



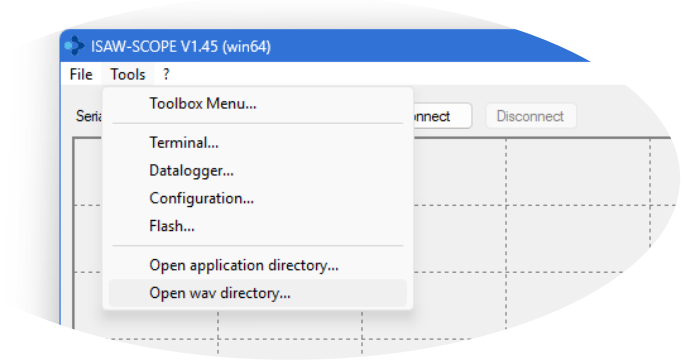
Note: If the internal datalogger of the instrument is activated, in case of unwanted interruption of the livelogger communication you will still be able to retrieve a backup of the data.

5.4. Getting a .WAV signal from the instrument

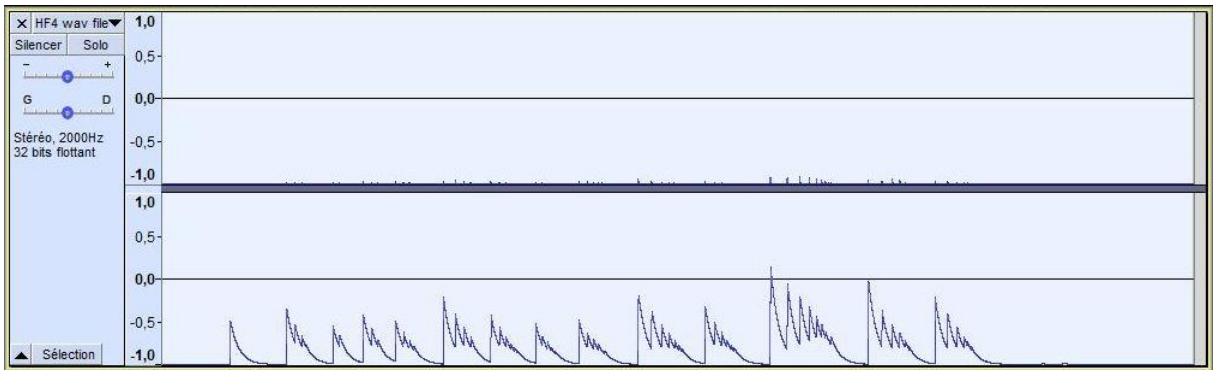
The instrument has a function that allows the direct recording of the raw measurement signal in the format of a .WAV sound file. To activate this function, open the **Scope utility** of the ISAW-Toolbox (see § 1.6) and check the "Record to wav" item in the "File" menu.



To open the .WAV file, use the “Tools > Open wav directory…” menu of the Scope utility.



The .WAV file is 16 bits, PCM, 2000 Hz sampling rate stereo file, which contains in the left channel the RMS, unfiltered envelop of the raw AC signal, and in the right channel the unfiltered raw AC signal. The following example shows a reading of such .WAV file in the Audacity® freeware, the capture showing a 17 seconds time history recording obtained while dropping several times the test woodball on the head of the instrument.



5.5. Update the instrument firmware

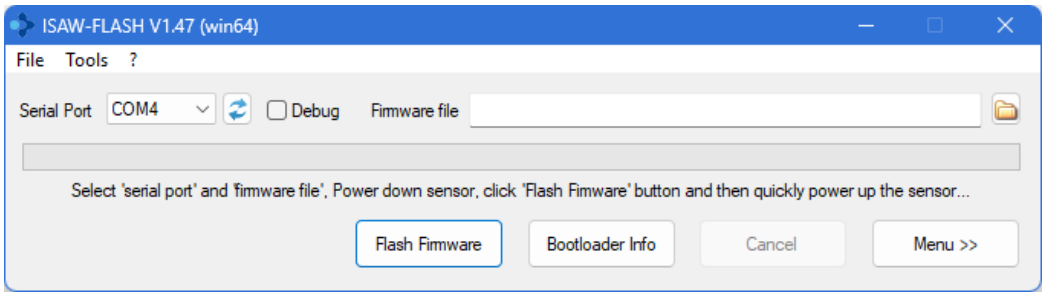
IAV Technologies constantly improves its products and provides upgrades of the ISAW firmware for all instruments. This section describes the procedure for upgrading the ISAW firmware.

Note: The instrument's configuration is not affected by the firmware update: existing parameters keep their value and new parameters, introduced with the new firmware's version, are set to their default value (see section 3.1).

Prerequisites:

- The ISAW-Toolbox is installed (see § 1.6).
- The last versions of the instrument firmware are installed (use the Update utility to check).
- The instrument is plugged to your computer using the USB Link accessory.

Open the ISAW Toolbox **Flash** Utility



Select the Serial Port the USB link is connected on.

Note: If you don't see the USB link serial port, it may be that another application is using it, so close all applications and restart ISAW-Flash.

Select the firmware file: Select the last version of the firmware corresponding to your instrument:

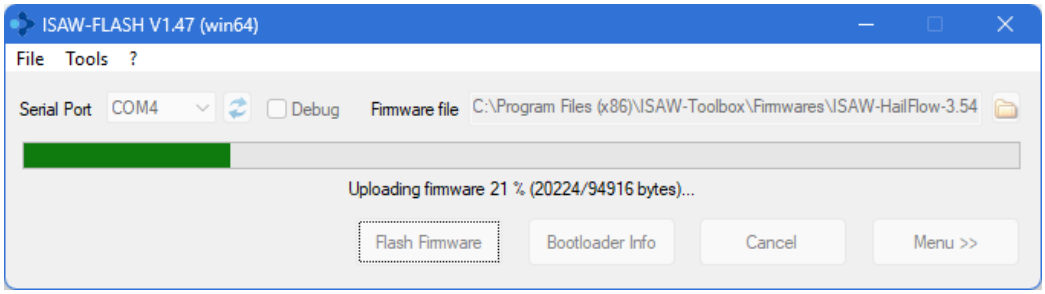
ISAW-HailFlow-x.xx.bin (where x.xx is the version number)

WARNING: The firmware folder contains all instruments firmware files. Make sure you select the one dedicated to your instrument!

Shut down the instrument power supply: set the USB Link power switch to OFF.

Press the [Flash Firmware] button. At this stage, ISAW-Flash will automatically search for a powered instrument during ten seconds.

Power-on the instrument: Switch the USB link power back to ON. As soon as ISAW-Flash has found the powered instrument, the firmware upload starts automatically.



Wait during the firmware upload. This may take a few minutes.

WARNING: Do not disconnect the power supply during firmware upload.

When the firmware upload is successfully completed, a confirmation message is displayed.

The instrument is now ready to use.

Note: The [Bootloader Info] command button retrieves the information of the bootloader installed on the instrument.

5.6. Troubleshooting

5.6.1. USB connection problem

Not or no longer recognizing the COM port when the UDONG is plugged to the computer. The port is not auto-selected, nor available in the pull-down menu.

- Power off the UDONG. Unplug the UDONG from the computer and unplug the instrument from the UDONG.
- Plug the UDONG alone back to the computer. The TX and RX (red and orange) LEDs on the UDONG should blink for a few milliseconds. Then, when powering “ON” the UDONG, the green led on the UDONG should switch on. If not, either the UDONG or the USB port is defective.
- If you have a multimeter, connect the instrument (or just the terminal block alone) to the UDONG and check on the terminal block screws if you really get 12 V between “POWER +12V (white)” and “POWER GND (black)”. If not, this means that the USB port of your computer is not providing the standard 12V, 500 mA USB powering.
- Double-check the wiring of the instrument to the terminal block pins (cut cable, untightened screw, cable(s) on the wrong terminal pin(s)).
- If the LEDs are working properly and the wiring is correct, it may happen that the COM port is preempted by another application, for example if another USB-to-serial device has been installed, which can cause driver conflict. In this case, try to choose an alternate driver in the “Device Manager”, or fully uninstall and reinstall the driver. In both cases, unplug and re-plug the device after to re-enumerate USB and/or reinstall the driver.

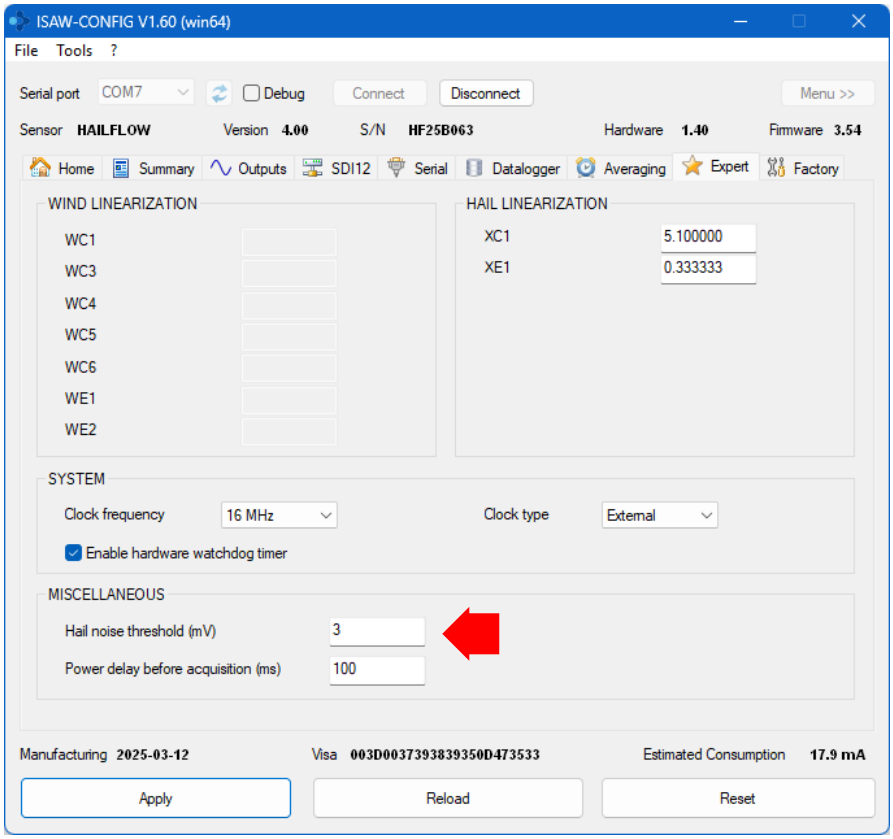
As another simple test of the full chain (UDONG and instrument), try to connect the instrument to another computer or smartphone (see introduction chapter). If the instrument is recognized, this means that the issue is most probably on the USB side of your computer.

Tip: While testing the USB connection, seize the opportunity to upgrade the ISAW-Toolbox software suite (just open it) as well as the instrument firmware (see § 5.5). This is not a requirement, but may help to solve the issue.

5.6.2. Remove false positives

In some use cases, the instrument may detect **false positives** in the smallest size classes, i.e. the data contains hits when no hail has occurred.

The factory default value of the detection threshold of the instrument (Hail noise threshold = 3 mV) must then be increased to a higher voltage value, in order to eliminate these "false detections". This is done on the “Expert panel” of the Configuration utility:



In most cases where false detections occur, they are parasitic shocks between the instrument and the structure to which it is attached, such as the knocking of a cable in the presence of wind, or, for example, a bird resting on the instrument.

In general, the higher the possible parasitic events, the higher the detection threshold shall be set. The higher the detection threshold is set, the better the rejection of the false hail events, but with the consequence of ignoring the lowest classes of hailstone diameter.

Note: This is NOT a change of scale (which would affect the sensitivity and calibration of the instrument) but simply a low-limit threshold, i.e. a “set to zero” of all the impact voltages that are below the threshold, to “ignore” the concerned events.

The following table shows the relationship between this voltage setting (X-axis), the corresponding theoretical diameter of the hailstones (Y-axis), for the five smallest classes (see the complete table in Appendix E.5).

Class #	Class Label	Hailstone diameter prognosis D [mm]	Lower marker diameter D [mm]	Lower marker Input Voltage U [mV]	Higher marker diameter D [mm]	Higher marker Input Voltage U [mV]
1	10	5.0 ≤ D < 10.0	5	0.94	10	7.54
2	15	10.0 ≤ D < 15.0	10	7.54	15	25.44
3	20	15.0 ≤ D < 20.0	15	25.44	20	60.31
4	25	20.0 ≤ D < 25.0	20	60.31	25	117.79
5	30	25.0 ≤ D < 30.0	25	117.79	30	203.54

For example, as per the above table, setting the **Hail noise threshold** to **7.5 mV** would automatically remove all the parasitic events that could be mistaken for an occurrence of class 1 hailstones.

A recommended field approach consists of first put the instrument in the field with the factory default setting of 3 mV, to get the maximum extension to the low limit of the scale, and then, after having analyzed the data, and only if necessary, increase the threshold value in order to eliminate what has been observed as “noise”.

Tip : In SDI-12 on a **distant location**, it may be easier to modify the threshold remotely by using the **SDI-12 extended command `aXS…!` on the parameter `thld-hail`**:

To read the value of the `thld-hail` parameter (here: 3), use the “Get” command `aXG…!`:

```
> 1XGthld-hail!
< OK3
```

To change the value of the `thld-hail` parameter to 7.5, use the “Set” command `aXS…!`:

```
> 1XSthld-hail=7.5!
< OK
```

Do not forget to **reboot the instrument** after changing the instrument configuration:

```
> 1XR!
< OK
```

5.7. Qualitative field-check of the response of the instrument

As hail is a rare event, the produced data is most of the time equal to zero, and may therefore be confused with an instrument failure. It may then be reassuring to check from time to time if the instrument reacts to an impact.

To quantitatively check the sensitivity of the instrument, and if you can temporarily reconnect the instrument to a laptop through the UDONG USB-Link accessory, you can reproduce the indicative but easy test of the getting started section 1.7.1 thanks to the woodball that is provided with the instrument.

6. ORDERING, MAINTENANCE & SUPPORT

Ordering references

The HailFlow HF4 instrument is available with its fastening arm, and a set of complementary accessories allows you to select the equipment that perfectly matches your operating situation:

Ref.	Description
HFBRA	HailFlow HF4 instrument with mounting kit (AVARM fastening arm)
AVARM	Fastening arm (included in HFBRA)
UDONG	USB Link accessory (provided HFBRA)
EXT10	Cable extension, 10 meters, including JUBOX junction box. (Note: You can chain several items, or ask for a specific cable length.)
MOBUS	Modbus RTU-485 adapter
AD420	4-20 mA adapter
TMAST	Supporting structure: tripod mast

Shipping

Eco-friendly packaging, worldwide shipping within 1-5 days a.r.o., URGENT BUSINESS shipping mode.

Safety and care

The full instrument and fastening elements is a heavy and plain device, it must always be fastened very cautiously and all the nuts tightened to avoid any possible looseness. The nuts are all with an integrated anti-unscrewing washer flange so apart from an improper assembly they cannot loosen themselves.

Cleaning and handling

There is no specific recommendation for cleaning or handling the instrument. The only soft material of the instrument are the cable and the elastomer damper of the mounting kit. They only require the standard state-of-art of protecting cables and connections, and visual check of the integrity of the material.

Product repair

In the event of an instrument breakdown or damage, IAV Technologies SARL provides all the support and spare parts necessary for a repair, either remotely or by returning the instrument to the factory, if the repair requires a recalibration of the instrument.

Warranty

The HailFlow HF4 instrument is a repairable products and benefits of a two-year warranty. The instrument, the USB dongle accessory and the mounting accessories are designed and produced with the highest standards. In case of failure, DO NOT TRY to open the instrument. Opening is destructive unless it is done at the factory for repair. None of the moving or user-serviceable parts requires routine maintenance. Opening the unit will void the warranty.

In the event of failure, before returning the unit, we recommend that you:

1. Check all cables and connectors for continuity, bad contacts, corrosion, etc.
2. Conduct a bench test e.g. using the Scope utility.
3. Contact us directly for advice.

Disposal

The instrument and mounting accessories are made of detachable and separable plain metals parts (stainless steel and aluminum), plastic or elastomer elements, a PUR cable and one electronic PCB circuit.

To recycle the instrument and its entire assembly kit, all screws must be disassembled, all the unit elements listed above must be recognized and separated, and placed in the appropriate recycling bins or circuits.

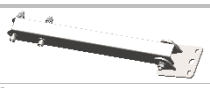
CE

Factory return address:
IAV TECHNOLOGIES SARL
ISAW Products Division
Chemin des Couleuvres 4A
1295 TANNAY
SWITZERLAND

Assistance:
isaw@iav.ch
+41 (0)22 960 11 04

www.isaw-products.com

Spare parts

Item ref.		Short name		Full description	Quantity		
					HFBRA	EXT10	TMAST
Instrument	HF4	HailFlow instrument		HailFlow HF4 instrument	1		
Mounting parts	REAFR	Fastening arm front piece		Fastening arm, front piece	1		
	REABK	Fastening arm back piece		Fastening arm, back piece	1		
	DAMPN	Dampener		Elastic coupler for fastening arm	2		
	BRARF	Front bracket		Front bracket for fastening arm	1		
	BRARB	Back bracket		Back bracket for fastening arm	1		
	BRASH	Reduction shim		Reduction shim	2		
Mast	TM01	Leg with inclinable foot		Leg with inclinable foot for supporting structure TMAST			3
	TM02	Base		Base for supporting structure TMAST			1
	TM03	Mid tube		Mid tube for supporting structure TMAST			1
	TM04	Top tube		Top tube for supporting structure TMAST			1
	TM05	Lightning rod		Lightning rod for supporting structure TMAST			1
Acc.	JUBOX	Junction box		Junction box for cable extension EXT10		1	
Standard	BN 610 M10x25	M10 × 25 mm screw		Hex socket head cap screws fully threaded (DIN 912, ISO 4762), stainless steel A2, M10x25 (e.g., Bossard BN 610 Art. No. 1233505)			4
	BN 610 M10X40	M10 × 40 mm screw		Hex socket head cap screws fully threaded (DIN 912, ISO 4762), stainless steel A2, M10x40 (e.g., Bossard BN 610 Art. No. 1032860)	2		
	BN 611 M10X70	M10 × 70 mm screw		Hex socket head cap screws partially threaded (DIN 912, ISO 4762), stainless steel A2, M10x70 (e.g., Bossard BN 611 Art. No. 1113356)	2		9
	BN 13289 M10x25x4	M10 washer 4 mm thick		Flat washers without chamfer, for bolts with heavy duty type spring pins (DIN 7349), A2, M10/10.5/25/4 (e.g., Bossard BN 13289 Art. No. 3062099)	10		11
	BN 33010 M10	M10 securing nut		Hex flange nuts (DIN 6923; EN 1661), stainless steel A2, M10 (e.g., Bossard BN 14476 Art. No. 1329359)	7		9

Item ref.	Short name		Full description	Quantity		
				HFBRA	EXT10	TMAST
TERM BLOCK PLUG 8POS STR 5.08MM	Terminal block plug		8 Position Terminal Block Plug, Male Pins 0.200" (5.08mm) 180° Free Hanging	1	2	
BALL	Calibrated wooden ball		Calibrated wooden ball - boxwood - 2.5 cm	1		

Appendix A: TECHNICAL DATA

Specifications

Measuring characteristics	
Measuring surface	200 mm outer diameter disc
Precipitation detected by the instrument	Solid only (hail). 15 classes, from 0.5 cm (minimal detectable diameter) to ≥ 7.5 cm (possible saturation of the instrument). Counting of the number of hailstones impacts up to 25 impacts per second.
Measurement accuracy	For a given controlled elastic momentum impact (such as spheres of equal diameter, density, Young modulus, falling speed and incidence angle), the response of the instrument varies typically by ± 10%, depending on the spatial position of the impact on the disc and on the instrument (± 10% variability between two instruments).
Particle velocity	Not measured.

Voltage ranges and measuring scales	
Voltage outputs	Continuous analog voltage or pulse analog voltage, user selectable +0 to +2.5V or +0 to +5V are available. Pulse threshold, integrator timeout and duration are also user selectable. The continuous analog voltage persists on the outputs so that output voltages can be read at any time.
Hail scaling	Sensitivity @voltage range +2.5V: [100 mV/(hits/s)] i.e. +2.5V corresponds to 25 hits/s
	Sensitivity @voltage range +5V: [200 mV/(hits/s)] i.e. +5V corresponds to 25 hits/s

Mechanical data	
Material	Stainless steel, plastic and anodized aluminum (breakdown voltage > 40 V/µm)
Installation	Universal mounting kit provided (ordering reference: HFBRA)
Weight	3.2 kg without mounting kit 5.4 kg with mounting kit
Dimensions (H×W×D)	260 mm × 450 mm × 200 mm with mounting kit

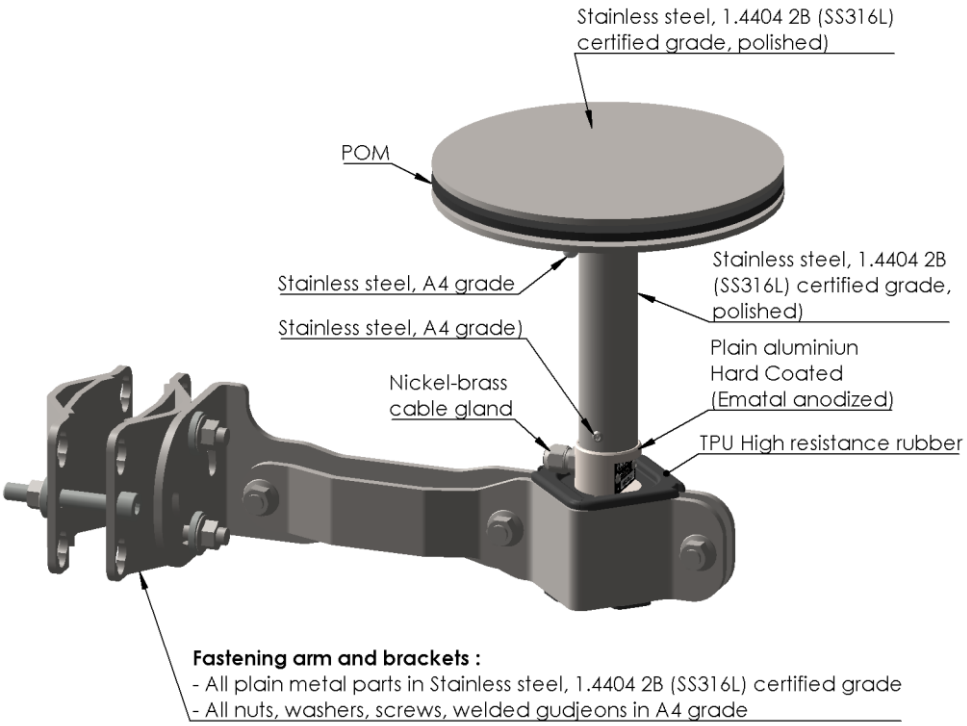
Supply	Ratings
Voltage	6 V to 30 V DC (9.6 V and 16 V DC in case of powering through the SDI-12 terminals)
Current	< 1 mA in stand-by mode and 20 mA max in acquisition mode. For a typical nominal duty-cycle of 10%: 2.1 mA (20 mA for duty-cycle of 100%).

Interfaces	
Analog	Pulse and continuous (and persistent) voltages, 0-2.5V or 0-5V
SDI-12	Yes, 1.3 certified (fully complies with the NR Systems SDI-12 Verifier)
Serial 3V3 TTL	Yes
Modbus RTU (RS485)	Yes, with the Modbus adapter accessory

Environmental conditions	
Temperature range	-40°C to +80°C. Can even operate over this range.
Relative humidity	0 to 100%
Protection	IP67, survive to 1 m temporary immersion in salt water
Standards	EN 61326-1: 2013, CE compliant 2014/30/EU, CE compliant

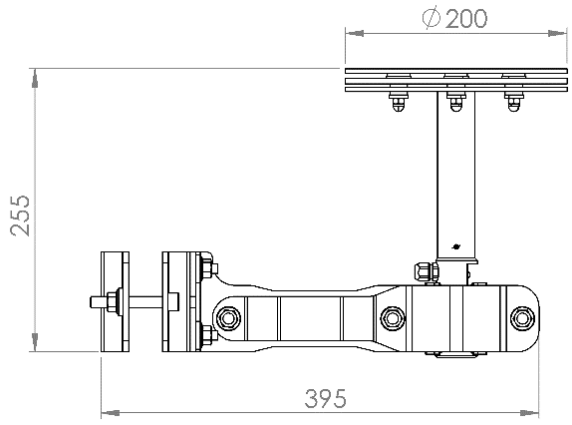
Materials

The sensing head is a 200 mm diameter metallic and plastic disk welded on top of a hollow pipe body containing the embedded electronics of the device, and mounted on a rigid foot that inserts into a heavy-duty high grade stainless-steel fastening arm trough a very long-life elastomer damper.

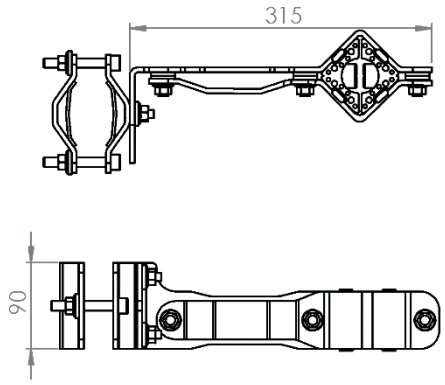


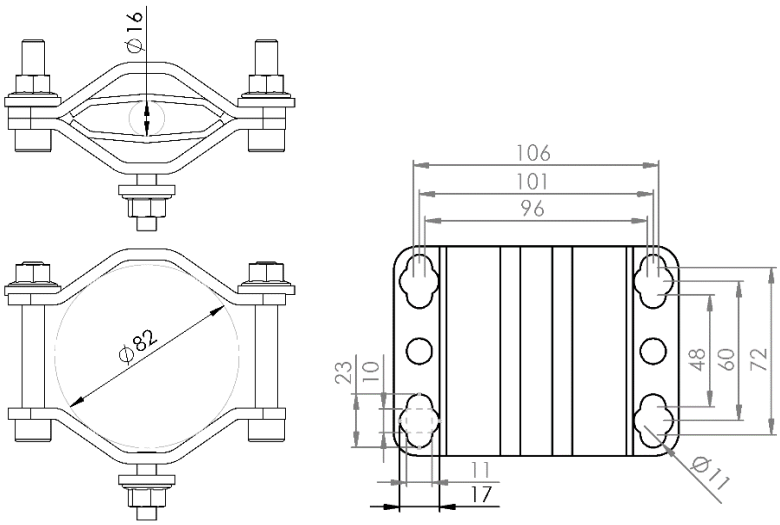
Dimensions

HFBRA

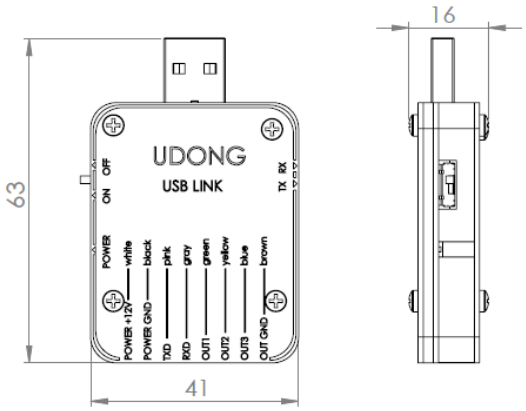


AVARM

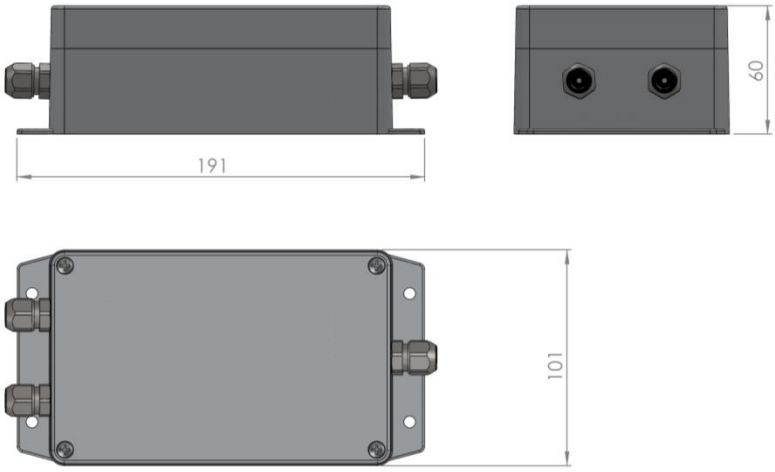




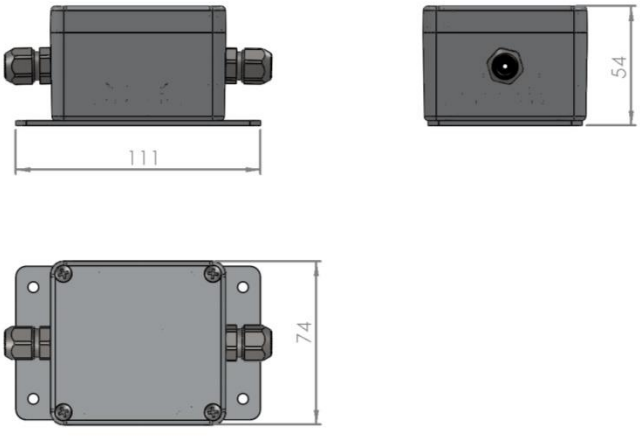
UDONG



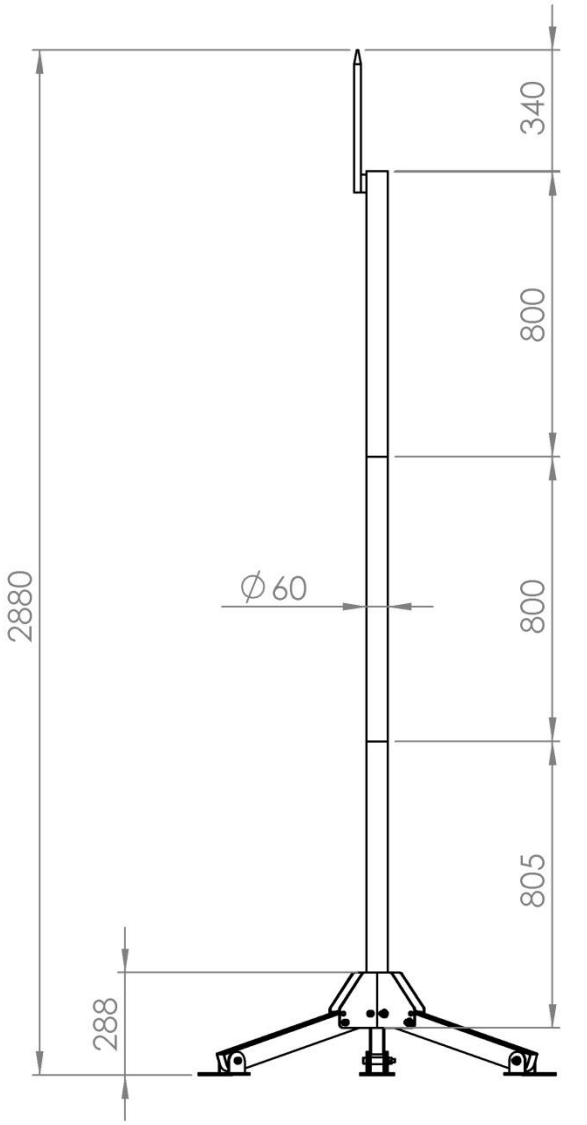
MOBUS

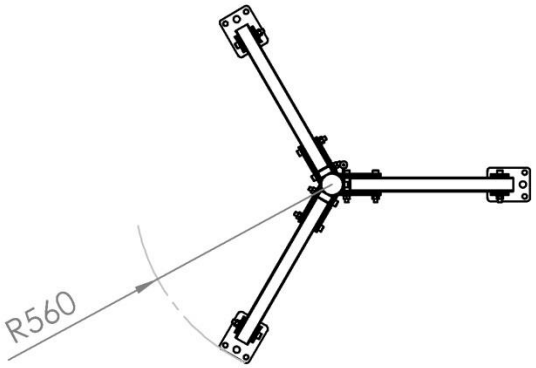


EXT10 / AD420



TMAST





Appendix B: SERIAL COMMUNICATION

ISAW provides a serial communication with the instrument with any serial terminal utility like Putty, TeraTerm, HyperTerminal, or other.

B.1. Connect in terminal or console mode

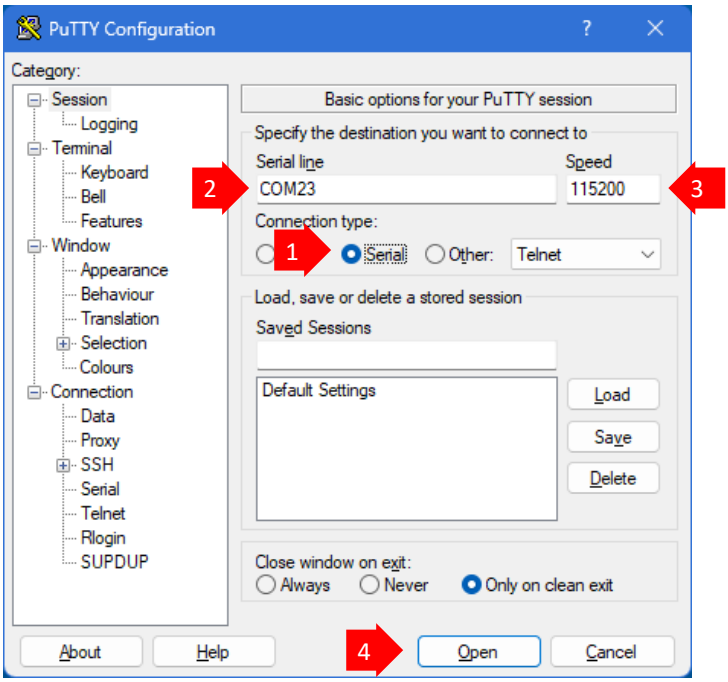
First you need to connect the instrument to a computer with the USB dongle accessory (or using a FTDI 3.3V serial USB converter/adapter).

WARNING: Do not connect the instrument directly to a non-TTL serial port like standard RS232 (DB9 connector). You must use a 3.3V serial adapter; otherwise, you may cause permanent damage to the instrument!

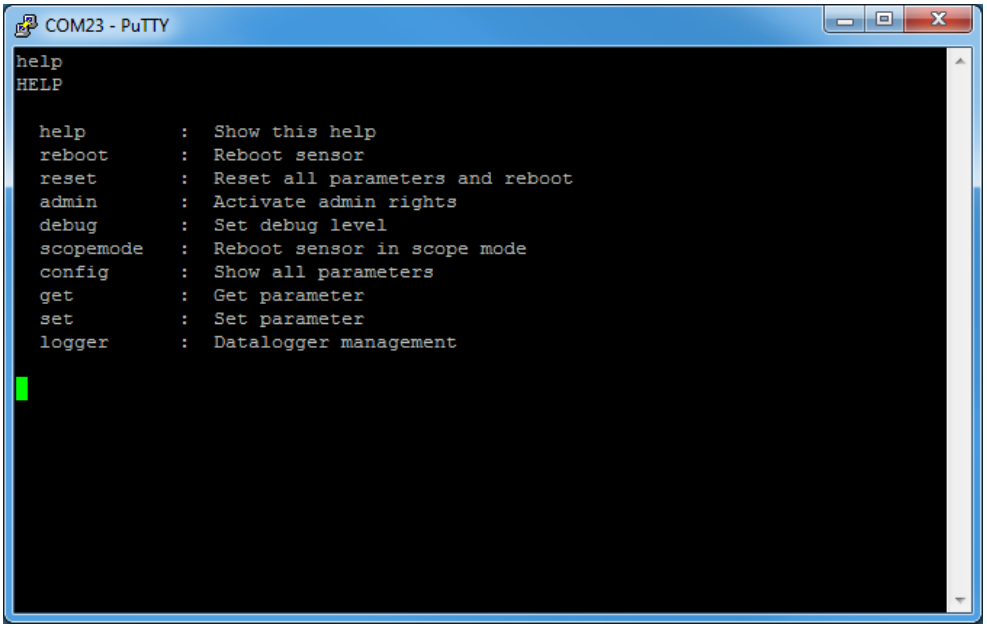
Connect your Terminal software

Open your favorite serial terminal on the serial port (*e.g.: COM23*) at 115200 bauds, 8 bits, 1 stop, no parity. Input terminator is <CR>, Output terminator is <CRLF>.

Example: You can use the lightweight and non-intrusive "putty.exe" freeware available at http://www.putty.org:



Type "help" and press [Enter] to display all available commands:



Execute ISAW command

Once connected, you can enter any one of the following commands.

B.2. Console commands

All command results share the same format:

`OK` : Successful command.

`OK=<value>` : Successful command with return value.

`ER=<message>` : Command error with error message.

Command	Result / Description
`help`	Displays the list of all available commands.
`reboot`	After changing the instrument configuration, you need to reboot the instrument by using the "reboot" command.
`reset confirm`	Recovers the default factory configuration and reboots the instrument. All parameters are reinitialized, except the following ones (internal factory parameters): sens-type, hw-version, fw-build, calib-hail sens-version, hw-date, cfg-ident, sys-uptime sens-date, hw-sn, cfg-version, sys-status sens-sn, fw-version, calib-date, misc-dbg
`config`	Displays the instrument current configuration (list of all parameters and corresponding values).
`admin <password>`	Activates the admin rights and allows changing special parameters. This command is reserved for factory parameters initialization and requires a password.

Command	Result / Description
`debug <module> <on|off>`	Activates / deactivates the debug mode for a given module. Debug messages are available on the serial console. **Note:** It is not recommended to activate the debug mode in production as it may result in ADC overrun. `<module>` can be: `all` Enable/disable all debug messages (very verbose). `console` Enable/disable console debug messages. `acq` Enable/disable acquisition buffer output. `measure` Enable/disable measurement calculation debug messages. `power` Enable/disable power status. `board` Enable/disable board debug messages. `sdi12` Enable/disable SDI-12 debug messages. Example: `debug sdi12 on` `OK`
`get <parameter>`	Allows getting a parameter value from the configuration. Example: `get sens-date` `OK=2025-02-05`
`set <parameter> <value>`	Allows changing a parameter value of the configuration. The list of all parameters and corresponding values is given in § 3.2. **Note:** Remember you need to reboot the instrument after changing the instrument configuration. Example: `set sdi12-addr 7` `OK`
`datalogger <command>`	Control the datalogger: `<command>` can be: `download` Download the data. `clear` Delete all logged data.
`datalogger <field> <on|off>`	Activates/deactivates the logging of a value: `<field>` can be: `hail_min` Minimum hailstone count (hit/s) `hail_avg` Average hailstone count (hit/s) `hail_max` Maximum hailstone count (hit/s) `hail_std` Standard hailstone count deviation (hit/s) `hail_cum` Cumulative hailstone count (hit) `hailstone_hit` Number of hailstones (hit) `hailstone_size` Percentage of hailstones within the class (%) **Note:** The datalogger must be cleared after changing the configuration fields (see p. 53). Example: `datalogger hail_min off`
`scopemode`	Reboots the instrument in scope mode. This command is used by the Scope Utility. It toggles the "misc_scopeqry" flag and reboots the instrument, which then restarts with the streams activated via the serial port. **Note:** Streams are transmitted in binary. If you execute this command in a text console, it may display strange characters or behave oddly.

B.3. Error messages

Error message	Description
Parameter is read-only	You cannot change this parameter.
Need admin permission	You need to use the "admin" command before executing the present command.
Busy	Command currently executed. Retry later.
Invalid unsigned integer value/argument	Value or argument is not a valid integer (only digits and <+> (plus) character are allowed).
Invalid integer value/argument	Value or argument is not a valid integer (only digits, <+> (plus) and <-> (minus) character are allowed).
Invalid float value/argument	Value or argument is not a float (only digits, <+> (plus), <-> (minus) and <.> (dot) characters are allowed).
Invalid value/argument size	Value or argument size is too long or empty.
Invalid value/argument	Value or argument is not valid.
Invalid dependent value/argument	Value or argument is not valid and depends on another parameter.
Value/argument out of range	Value or argument is out of range.
Invalid internal function	Internal error.
Invalid internal parameter type	Internal error.
Invalid internal limit type	Internal error.
Unknown command	Command is unknown.
Unknown parameter	Parameter is unknown.
Forbidden	Operation is forbidden with these parameters.
Invalid password	Password is not valid.

B.4. Serial measurement frame

Get a measurement result in a CSV formatted parameter after each "avg-m" on the serial port (TX: pink wire).

The serial result is computed and reset every [Measurement duration] interval.

HAIL

```
HAIL;<counter>;<unit>;<min>;<avg>;<max>;<std>;<unit>;<sum>
```

<counter>	is a frame counter incremented at each result
<unit>	is the unit of the following values in the frame: “hit/s”
<min>	is the minimum of the hailstone count measurement [hit/s]
<avg>	is the average of the hailstone count measurement [hit/s]
<max>	is the maximum of the hailstone count measurement [hit/s]
<std>	is the standard deviation of the hailstone count measurement [hit/s]
<unit>	is the unit of the following value in the frame: “hit”
<sum>	is the cumulative hailstone count [hit]

Example: `HAIL;9388;hit/s;11.00;11.00;11.00;0.00;hit;20283.00`

HAILSTONE

```
HAILSTONE;<counter>;<unit>;<hit_count>;<unit>;<unit>;<class>;
<distrib>;<class>;<distrib>;<class>;<distrib>;…;<class>;<distrib>
```

<counter>	is a frame counter incremented at each result
<unit>	is the unit of the following values in the frame: “hit”
<hit_count>	is the number of hailstones [hit]
<unit>;<unit>	are the units of the following pairs of values in the frame: “mm;%”
<class>	is the fixed hailstone size class in millimeters [mm] (see table p.7)
<distrib>	is the percentage of hailstones within the class [%]

Example: `HAILSTONE;9322;hit;7;mm;%;10;0;15;0;20;0;25;0;30;0;35;14;40;14;45;29;50;29;55;14;60;0;65;0;70;0;75;0;99;0`

Appendix C: SDI-12 – SERIAL DIGITAL INTERFACE

The ISAW firmware supports Serial Digital Interface (SDI-12) standard V1.3 (the SDI-12 V1.3 standard specification can be found at http://www.sdi-12.org).

SDI-12 stands for "serial data interface at 1200 baud" [Source: www.sdi-12.org]. It is recommended for applications of the ISAW instruments that you intend to interface with battery powered data recorders with minimal current drain and/or long-distance cabling (typically up to 150 m).

It is possible to connect more than one ISAW instrument (as well as other SDI instruments) to a single data recorder thanks to the fact that SDI-12 is a multi-drop interface that can communicate with multiple and multi-parameter instruments. The SDI-12 bus supports having ten or more connected instruments. “Multi-parameter” means that a single instrument may return more than one measurement.

This serial-digital interface is thus a logical choice for interfacing your ISAW instrument with a distant data recorder.

This has advantages for instruments and data recorders:

- Unique and complex self-calibration algorithms are executed in the microprocessor-based ISAW instrument.
- The instruments can be interchanged without reprogramming the data recorder with calibration or other information.
- Power is supplied to instruments through the interface.
- The use of a standard serial interface eliminates significant complexity in the design of data recorders.
- SDI-12 data recorders interface with a variety of instruments.
- SDI-12 instruments interface with a variety of data recorders.
- Personnel trained for SDI-12 will have skills to work with a variety of SDI-12 data recorders and SDI-12 instruments.

C.1. SDI-12 standard commands

Name	Command	Description/Response	
Acknowledge Active	a!		
Instrument Identification	aI!	13IAV-TECHAILFLO354	
Change Address	aAb!	*No need to reboot instrument*	
Address query	?!	a	
Start Measurement	aM!	*Always reset measure* a0005	
Start Measurement and request CRC	aMC!	*Always reset measure* a0005	
Send Data	aD0! … aD9!	aD0!	Min. hailstone count (hit/s)
		aD1!	Avg hailstone count (hit/s)
		aD2!	Max. hailstone count (hit/s)
		aD3!	Std hailstone count (hit/s)
		aD4!	Cumulative hailstone count (hit)
Additional Measurements	aM1! … aM9!	*No additional measurement* a0000	
Additional Measurements and request CRC	aMC1! … aMC9!	*No additional measurement* a0000	
Start Verification	aV!	*No verification* a0000	
Start Concurrent Measurement	aC!	*Always reset measure* a0005	
Start Concurrent Measurement and request CRC	aCC!	*Always reset measure* a0005	
Additional Concurrent Measurements	aC1! … aC9!	*No additional measurement* a00000	
Additional Concurrent Measurements and request CRC	aCC1! … aCC9!	*No additional measurement* a00000	
Continuous Measurements	aR0! … aR9! aRC0! … aRC9!	aR0!	Min. hailstone count (hit/s)
		aR1!	Avg hailstone count (hit/s)
		aR2!	Max. hailstone count (hit/s)
		aR3!	Std hailstone count (hit/s)
		aR4!	Cumulative hailstone count (hit)

Notes: Wildcard character "?" is supported.

Start Measurement (aM!) and Send Data (aD0!...aD9!) always send measurement since last request. So in this mode, measurement is reinitialized after each request.

Continuous Measurement (aR0!...aR9!) sends the current measurement. So in this mode, measurement is reinitialized after M duration.

The interval used for the calculation of the min, max and average statistical values starts either with each SDI-12 command, or after the avg-m parameter's duration, depending on which of these two conditions occurs first.

The behavior of the SDI depends on the sdi12-mode setting.

C.2. SDI-12 extended commands

ISAW firmware can handle an extended SDI-12 command that allows instrument configuration from SDI-12 bus.

All SDI-12 extended commands derivate from console commands.

All SDI-12 extended commands, in compliance with SDI-12 standard V1.3, have a generic format like:

```
aXcooo…!

a     : Instrument address
c     : Extended command identifier
ooo…  : Optional argument
!     : Command terminator
```

For each SDI-12 extended command, the instrument answers with a response formatted in the same way:

aOK	: Command success
aOK:vvvv…<CR><LF>	: Command success with value
aER:mmmm…<CR><LF>	: Command error with error message
a	: Instrument address
vvvv…	: Value
mmmm…	: Error message (see p. 73)
<CR><LF>	: Response terminator

Notes: Writing to eeprom to store a new parameter can take some time, which is why the "aXS!" command is delayed.

When the "aXS!" command is received, the instrument checks if the parameter and the value are correct and then sends the "aOK" response before the value is written on eeprom. Sending another "aXS!" while the instrument is currently writing a previous parameter value may result in a "Busy" error. Waiting at least 20 ms between two "aXS!" commands is recommended.

To be assured of the integrity of the parameter's writing in the memory read the parameter value (aXG!) after each "aXS!" command.

Remember that you need to reboot the instrument after changing instrument configuration.

Name	Description	Command	Response
reboot (aXR!)	After changing the instrument configuration, you need to reboot the instrument by using this command.	aXR! a : Instrument address ! : Command terminator	aOK<CR><LF> aER=mmmm…<CR><LF> a : Instrument address mmmm… : Error message (see p. 73) <CR><LF> : Response terminator
reset (aXZ…!)	Use this command if you want to recover the default factory configuration and reboot the instrument. All parameters are reinitialized, except internal factory parameters.	aXZccccccc! a : Instrument address ccccccc : Reset confirmation "confirm" ! : Command terminator	aOK<CR><LF> aER=mmmm…<CR><LF> a : Instrument address mmmm… : Error message (see p. 73) <CR><LF> : Response terminator
admin (aXA…!)	This command activates the admin rights and allows changing special parameters. This command is reserved for the initialization of factory parameters.	aXAwwwwwwww! a : Instrument address wwwwwwww : Admin password ! : Command terminator	aOK<CR><LF> aER=mmmm…<CR><LF> a : Instrument address mmmm… : Error message (see p. 73) <CR><LF> : Response terminator
get (aXG…!)	The get command allows getting a parameter value from configuration.	aXGpppppp…! a : Instrument address pppppp… : Parameter name (see § 3.1) ! : Command terminator	aOK=vvvv…<CR><LF> aER=mmmm…<CR><LF> a : Instrument address vvvv… : Parameter value (see § 3.1) <CR><LF> : Response terminator
set (aXS…!)	This command allows changing parameter values of the configuration.	aXSpppp…=vvvv…! a : Instrument address pppppp… : Parameter name (see § 3.1) vvvv… : Parameter value (see § 3.1) ! : Command terminator	aOK<CR><LF> aER=mmmm…<CR><LF> a : Instrument address mmmm… : Error message (see p. 73) <CR><LF> : Response terminator
disdrometer (aXD!)	This command allows getting disdrometry results	aXD! a : Instrument address ! : Command terminator	aOK=vvvv…<CR><LF> aER=mmmm…<CR><LF> a : Instrument address vvvv… : Disdrometry value mmmm… : Error message (see p. 73) <CR><LF> : Response terminator

Note: Due to the limited size of an SDI12 frame, the class sizes do not appear in the response of the `aXD!` command (unlike for the serial command). Only the total number of hailstones, followed by the distribution of 15 counters is mentioned as follows:

`aOK=<hit_count>;<distrib>;<distrib>;<distrib>;….`
`<hit_count>` is the number of hailstones [hit]
`<distrib>` is the percentage of hailstones within the class [%]

C.3. SDI-12 Synchronous vs. Asynchronous mode

Reminder about the instrument configuration:

[A] Acquisition duration
[C] Cycle duration
[M] Measurement refresh interval

Typical values: [A] = 6 s, [C] = 60 s, [M] = 600 s

The instrument acquires data for 6 seconds, then sleeps for 54 seconds, then wakes up for 6 seconds, etc. The **duty cycle** is 10% (= 6 / 60 seconds).

After 600 seconds, the measurement (min, max, avg, std, cum, etc.) is refreshed; the statistics are therefore calculated over 10 acquisitions of 6 seconds.

Note: Turning off the power of the instrument resets all measurements: cumulative values and counters are reset to zero.

Datalogger – SDI-12 Interrogation:

SDI-12 commands always wake up the instrument immediately and generate a response according to SDI-12 specification v.1.4, within 15 milliseconds.

The instrument can be interrogated in two ways: **asynchronous** mode or **synchronous** mode.

Asynchronous mode: "aM!/aDx!"

The data datalogger retrieves data at a customized, possibly variable frequency, which can be different from the one the instrument measures with (DATALOGGER is master).

Command:

aM! // Stores instrument measurements (min, max, avg, std, cum, etc.) for being retrieved by aDx! command, and resets measurements.

aDx! // Retrieves last measurements being stored by previous aM! Command.

Notes:

In this mode, the instrument parameter [M] is not taken into account.

In this mode, the instrument measurements are updated after each acquisition (at [C] interval rate).

Datalogger retrieve rate scenario (e.g., [C] = 60):

If the data datalogger retrieves data every 5 seconds, it receives 12 times the same value of the last cycle C (OVERSAMPLING).

If the data datalogger retrieves data every 60 seconds, it receives measurements integrated over the last 60 seconds, i.e., one cycle and one acquisition. So, all the values (min, max, avg, std, cum, etc.) are identical.

If the data datalogger retrieves data once a day, it receives measurements integrated over 86400 / 60 = 1440 cycles. All the statistical values (min, max, avg, std) are estimated over 1440 values; the cumulative result is integrated over the last 24 hours.

Synchronous mode: "aRx!"

The data datalogger should be programmed to send a "retrieve" command every [M] interval to acquire all instrument data.

Measurements (min, max, avg, std, cum, etc.) are automatically updated after [M] interval.

Command:

```
aRx! // Retrieves the last measurements available (min, max, avg,
        cum, etc.)
```

Datalogger retrieve rate scenario (e.g., [M] = 600):

- If the data datalogger retrieves data more frequently than every [M] seconds, for example every 60 seconds, the instrument will respond with 10 successive identical values (OVERSAMPLING).
- If the data datalogger retrieves data less frequently than every [M] seconds, for example every 6000 seconds, it will only receive 1 value in 10 (UNDERSAMPLING).

Notes:

- If the data datalogger command frequency is set to [M], the measurement retrieved in asynchronous mode "aM!/aDx!" will correspond to the measurement retrieved in synchronous mode "aRx!".
- The asynchronous mode is generally preferred when the user wants to update the sampling interval according to the previous measurement. For example, if the last average instrument intensity exceeds a certain threshold, the command frequency is increased.

Appendix D: MODBUS RTU 485 – INSTRUCTIONS FOR USE

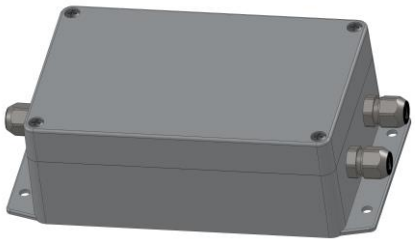
D.1. Introduction to using Modbus

Modbus is one of the most widely adopted industrial communication protocols for interfacing field instruments with supervisory control and data acquisition (**SCADA**) systems. Designed for simplicity, robustness, and interoperability, it provides a standardized method for exchanging real-time measurements, status information, and configuration data between instruments, controllers, and central monitoring platforms. When integrated into **SCADA** infrastructures, Modbus ensures deterministic polling, structured register mapping, and straightforward compatibility with **PLCs, RTUs, and industrial data loggers**.

In its **Modbus RTU** implementation – operating over **RS-485 twisted-pair cabling** – the protocol supports long-distance, multi-drop networks of up to 247 addressable devices, making it well suited for distributed environmental and industrial monitoring architectures.

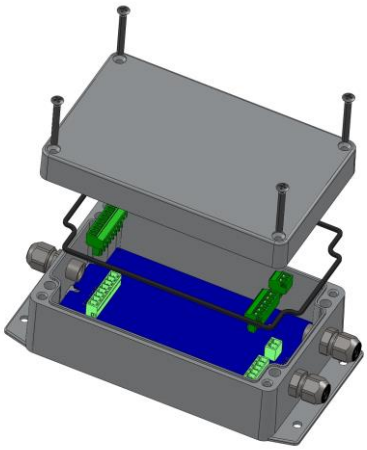
Modbus RTU is also widely used in **Building Management Systems (BMS)**. The ISAW Modbus adapter therefore enables direct integration of all ISAW instruments into auxiliary such as HVAC controllers, facility automation units, and centralized building monitoring infrastructures. This allows **ISAW instruments data and risk indicators** to be natively incorporated into building protection strategies, automated procedures, and alert systems.

D.2. The ISAW Modbus adapter



Because of its low overhead, minimal hardware requirements, and universal support in **SCADA software suites**, the **ISAW Modbus adapter** is often a preferred interface for transmitting instrument data into supervisory dashboards, alarm systems, and automated decision sequences. It provides access to measurement frames, configuration registers, and diagnostic functions through standardized Modbus function codes, ensuring consistent and reliable data acquisition.

The **ISAW Modbus adapter** is housed in a cast-aluminium enclosure, offering excellent mechanical robustness, strong electromagnetic shielding, and high resistance to outdoor exposure and sealing constraints. Its internal electronics are designed and assembled to demanding industrial standards, with reinforced isolation, comprehensive electrical protections, and high-quality components that ensure long-term reliability in harsh and mission-critical field deployments.

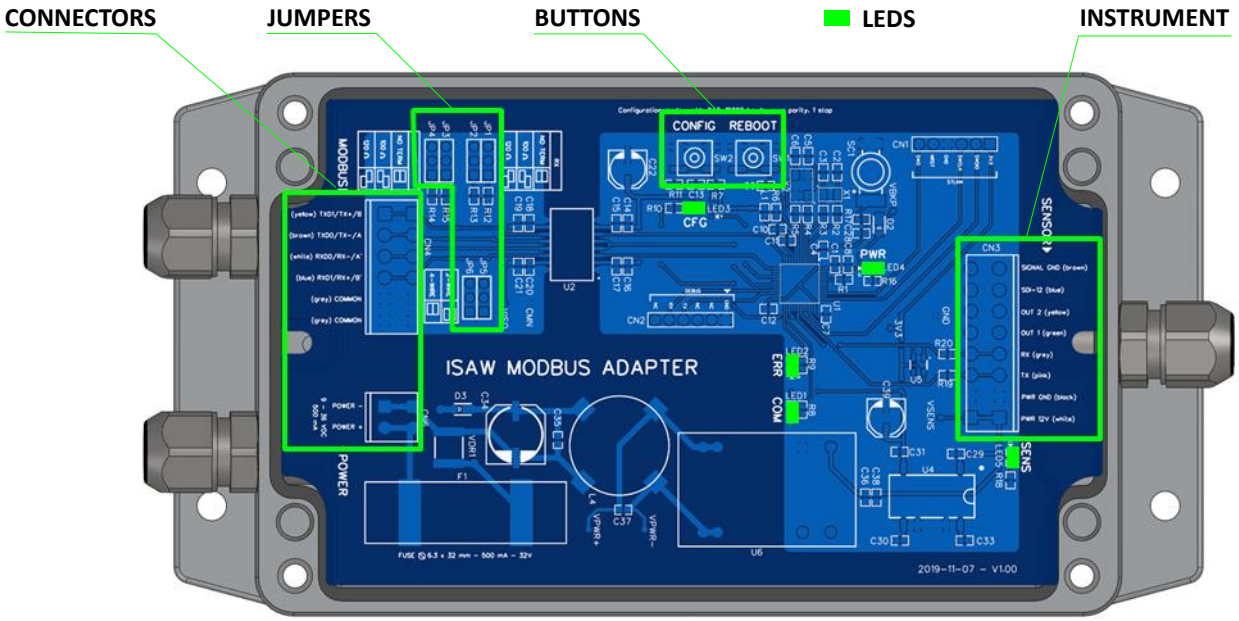


CHARACTERISTICS	
Protocol	MODBUS RTU (V1.1b3)
Physical Layer	EIA/TIA-485 (RS485) 2-wire and 4-wire
Galvanic isolation	Power 3kV RMS, Bus 5kV RMS
Unit load	1/8-unit load, up to 256 nodes on the bus
Startup time	1 s
Power supply	9 to 36 VDC (Typ. 100 mA, Max. 500 mA)
Implemented function codes	0x04 Read Input Registers 0x03 Read Holding Registers 0x06 Write Single Register 0x10 Write Multiple Registers 0x64 Pass-through 0x08 Diagnostic 0x17 Report Server ID
Configurable Baud rate	9600, 19200, 38400, 57600, 115200, 128000, 256000
Configurable Parity	No, Odd, Even
Configurable Stop Bit	1 or 2
Configurable Address	1 to 247

DEFAULT COMMUNICATION PARAMETERS	
Address	247
Baudrate	19200 bauds
Parity	Even
Stop bits	1 bit
Response timeout	1000 ms

MECHANICAL DATA	
Material	Aluminum box Nickel-plated brass cable glands
Protection	IP 68 (up to 10 bar) IP 69 for the cable glands
Dimensions (L×W×H)	160 mm × 100 mm × 60 mm Box thickness: 2.5 mm
Operating temperature	-40°C / +85°C (most sensitive electronic component)
Manufacturer references	Box: Bud Industries, product number AN-2866-AB Cable glands: AGRO, product number 1160.12.065

D.3. Description



BUTTONS

BUTTONS	
REBOOT	Restarts the Modbus adapter with the Holding register's parameters. **Note:** Switching the power OFF/ON also restarts the Modbus adapter.
CONFIG	Holding the CONFIG button pressed while starting (or restarting) the Modbus adapter starts (or restarts) the adapter with the default communication parameters (cf. previous page). **Note:** This operation does not change the parameters stored in the Holding register.

LEDS

LEDS	
COM	Flashing during a Modbus communication.
ERR	Flashing when a Modbus communication error occurs. Steady when a critical error occurs requiring a restart.
CFG	Flashing when the instrument is in CONFIG mode (started with the CONFIG button pressed).
PWR	Steady when input power OK.
SENS	Steady when output 12 V instrument power OK.

CONNECTORS

INSTRUMENT			
#	Name	Color	Description
1	PWR 12V	White	Power output 12VDC – 300 mA
2	PWR GND	Black	Power ground
3	TX	Pink	Serial input 3V3
4	RX	Grey	Serial output 3V3
5	OUT 1	Green	Not connected
6	OUT 2	Yellow	Not connected
7	SDI-12	Blue	Not connected
8	Signal GND	Brown	Not connected

POWER			
#	Name	Color	Description
1	PWR -	Black	Power ground
2	PWR +	Red	Power input 9…36VDC (500 mA)

MODBUS 4-WIRE			
#	Name	Color	Description
1	TXD1/TX+/B	Yellow	Output terminal 1, Vb voltage (Vb > Va for binary 1)
2	TXD0/TX-/A	Brown	Output terminal 0, Va voltage (Va > Vb for binary 0)
3	RXD0/RX-/A'	White	Input terminal 0, Va' voltage (Va' > Vb' for binary 0)
4	RXD1/RX+/B'	Blue	Input terminal 1, Vb' voltage (Vb' > Va' for binary 1)
5	COMMON	Grey	Signal ground
6	COMMON	Grey	Signal ground

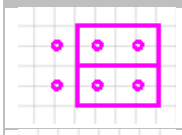
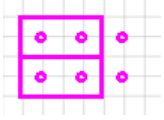
MODBUS 2-WIRE			
#	Name	Color	Description
1	TXD1/TX+/B	Yellow	Transceiver terminal 1, Vb voltage (Vb > Va for binary 1)
2	TXD0/TX-/A	Brown	Transceiver terminal 0, Va voltage (Va > Vb for binary 0)
3	RXD0/RX-/A'	White	Not connected
4	RXD1/RX+/B'	Blue	Not connected
5	COMMON	Grey	Signal ground
6	COMMON	Grey	Signal ground

Note: TXD0-RXD0 and TXD1-RXD1 are connected.

The polarity of the "A" and "B" wires can be reversed. Please check in the datasheet of your RS485/RS422 converter the polarity "+" or "-" ("1" or "0") affected to the "A" and "B" labels.

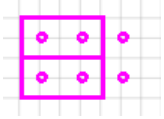
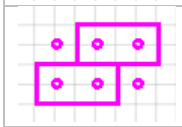
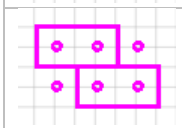
If you don't find this information in your converter documentation, try to plug "A" and "B" wires and if you get no communication, just invert the wiring.

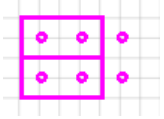
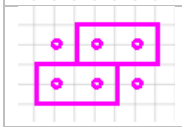
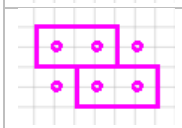
JUMPERS

MODE	
Jumper position	Description
	**2-WIRE MODE** [default] (TXD0-RXD0 et TXD1-RXD1 are connected)
	**4-WIRE MODE**

Notes:

1. If the ISAW Modbus adapter node is the last one of the bus, the jumper RX must be set to "100 Ω" or "120 Ω".
2. In 4 wire mode only, if the ISAW Modbus adapter node is the last one of the bus, the jumper TX must be set to "100 Ω" or "120 Ω".

TX TERMINATION	
Jumper position	Description
	**NO TERM.** *[default]* No termination resistor on TX pair
	120 **Ω** Standard 120 Ω termination resistor wired on TX pair
	100 **Ω** 100 Ω termination resistor wired on TX pair

RX TERMINATION	
Jumper position	Description
	**NO TERM.** *[default]* No termination resistor on RX pair
	**120 Ω** Standard 120 Ω termination resistor wired on RX pair
	**100 Ω** 100 Ω termination resistor wired on RX pair

D.4. Modbus function / Register definition

D.4.1. INPUT Registers

The Input registers contain measurements. The content of these registers is updated each time the instrument sends new measurements to the Modbus adapter.

Modbus function: READ INPUT REGISTER (0x04)

Address	Type*	Bytes	Offset	Alias	Comment
0x0000	UINT32	4	0	Counter	Hail measurement frame count
0x0002	STRING8	8	2	Unit	Hail measurement unit: "hit/h"
0x0006	FLOAT	4	6	Min	Hail measurement minimum
0x0008	FLOAT	4	8	Avg	Hail measurement average
0x000A	FLOAT	4	10	Max	Hail measurement maximum
0x000C	FLOAT	4	12	Std	Hail measurement stand. deviation
0x000E	STRING8	8	14	Unit	Cum. hail measurement unit: “hit”
0x0012	FLOAT	4	18	Sum	Cumulative hail measurement
0x0020	UINT32	4	32	Counter	Hailstone measurement frame count
0x0022	STRING8	8	34	Unit	Hailstone count unit: "hit"
0x0026	UINT32	4	38	Hit count	Hailstone count
0x0028	STRING8	8	40	Unit	Hailstone distribution unit: “%"
0x002C	UINT16	2	44	Classe 1	Hailstone distribution of the class 1
0x002D	UINT16	2	45	Classe 2	Hailstone distribution of the class 2
0x002E	UINT16	2	46	Classe 3	Hailstone distribution of the class 3
0x002F	UINT16	2	47	Classe 4	Hailstone distribution of the class 4
0x0030	UINT16	2	48	Classe 5	Hailstone distribution of the class 5
0x0031	UINT16	2	49	Classe 6	Hailstone distribution of the class 6
0x0032	UINT16	2	50	Classe 7	Hailstone distribution of the class 7
0x0033	UINT16	2	51	Classe 8	Hailstone distribution of the class 8
0x0034	UINT16	2	52	Classe 9	Hailstone distribution of the class 9
0x0035	UINT16	2	53	Classe 10	Hailstone distribution of the class 10
0x0036	UINT16	2	54	Classe 11	Hailstone distribution of the class 11
0x0037	UINT16	2	55	Classe 12	Hailstone distribution of the class 12
0x0038	UINT16	2	56	Classe 13	Hailstone distribution of the class 13
0x0039	UINT16	2	57	Classe 14	Hailstone distribution of the class 14
0x003A	UINT16	2	58	Classe 15	Hailstone distribution of the class 15
0x0057	UINT16	2	87	UINT16 Test	Fixed Value: 54321 (0xD431)
0x0058	UINT32	4	88	UNIT32 Test	Fixed value: 1234567890 (0x499602D2)
0x005A	FLOAT	4	90	FLOAT Test	Fixed value: 3,14159265 (0x40490FDB)
0x005C	UINT16	2	92	VERmaj	Major version of Modbus adapter firmware (since V1.19)**
0x005D	UINT16	2	93	VERmin	Minor version of Modbus adapter firmware (since V1.19)**

* Note: String are zero-padded.

** If not present, Modbus adapter firmware is V1.18

D.4.2. HOLDING Registers

Holding resisters are mainly used to configure the Modbus adapter communication.

Note: Restart the Modbus adapter after changing the configuration.

Modbus functions: READ HOLDING REGISTERS (0x03)
WRITE SINGLE REGISTER (0x06)
WRITE MULTIPLE REGISTERS (0x10)

Address	Type	Bytes	Offset	Name	Values
0x0000	UINT32	4	0	Serial speed	9600, 19200 [default], 38400, 57600, 115200, 128000, 256000
0x0002	UINT16	2	2	Parity	0: No parity, 1: Even [default], 2: Odd
0x0003	UINT16	2	3	Stop Bit	1 [default] or 2 (if no parity)
0x0004	UINT16	2	4	Device address	1 to 247 [default]
0x0005	UINT16	2	5	Response timeout (ms)	Default: 1000
	Total bytes:	12			
	Nb. REG:	6			

D.4.3. DATA TYPE Format

UINT16 (Big Endian)	High Byte	Low Byte		
UINT32 (Big Endian)	High Byte			Low Byte
FLOAT (IEEEE-754)	SEEEEEEE	EMMMMMMM	MMMMMMMM	MMMMMMMM
	(S: Sign, E: Exponent, M: Mantissa)			
RAW	Char 1	Char 2	Char 3	…

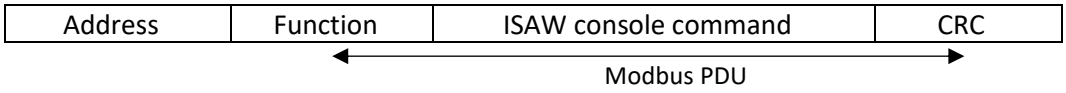
EXAMPLES:	**Decimal**	**Hexadecimal**	**Register N**	**Register N+1**
UINT16 (Big Endian)	54321	0xD431	0xD431	
UINT32 (Big Endian)	1234567890	0x499602D2	0x02D2	0x4996
FLOAT (IEEEE-754)	3.14159265	0x40490FDB	0x0FDB	0x4049
RAW	"hit"	0x68697400	0x6869	0x7400

D.5. Modbus function PASS-THROUGH (0x64)

This user-defined Modbus function, available for Modbus firmware version V1.19 and higher, allows to send an ISAW command through the Modbus (see Appendix B for more information about the ISAW console commands). For example, use this function with the “set” or “get” ISAW command to access the instrument’s configuration.

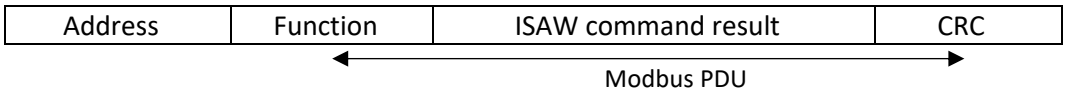
Note: The use of this function is limited by the request and answer lengths.

Request:



Field	Size (bytes)	Description
Address	1	Device address (target)
Function	1	0x64
ISAW Command	N	ISAW command as ASCII string
CRC	2	CRC16

Response:



Field	Size (bytes)	Description
Address	1	Device address (same as request)
Function	1	0x64
Result	N	ISAW command result as ASCII string
CRC	2	CRC16

Note: The response timeout of this command must be > 2 seconds to allow instrument wake-up.

D.6. Modbus frame examples

Raw examples of Modbus communication.

READ HOLDING REGISTER (all registers)

TX > 0xF7 0x03 0x00 0x00 0x00 0x06 0xD1 0x5E
RX > 0xF7 0x03 0x0C 0x4B 0x00 0x00 0x00 0x00 0x01 0x00 0x01 0x00 0xF7 0x03 0xE8 0x9D
RX > 0x9E

READ INPUT REGISTERS (All registers)

TX > 0xF7 0x04 0x00 0x00 0x00 0x5E 0x65 0x64
RX > 0xF7 0x04 0xBC 0x00 0x01 0x00 0x00 0x68 0x69 0x74 0x2F 0x73 0x00 0x00 0x00 0x00
RX > 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x68
RX > 0x69 0x74 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
RX > 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
RX > 0x00 0x00 0x00 0x00 0x01 0x00 0x00 0x68 0x69 0x74 0x00 0x00 0x00 0x00 0x00 0x00
RX > 0x00 0x00 0x00 0x25 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
RX > 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
RX > 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
RX > 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
RX > 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
RX > 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
RX > 0x00 0xD4 0x31 0x02 0xD2 0x49 0x96 0x0F 0xDB 0x40 0x49 0x00 0x01 0x00 0x13 0x14
RX > 0xC6

READ INPUT REGISTERS (read adapter version only)

Available on firmware version V1.19 or higher. If you receive a Modbus exception, firmware version is V1.18.

TX > 0xF7 0x04 0x00 0x5C 0x00 0x02 0xA5 0x4F
RX > 0xF7 0x04 0x04 0x00 0x01 0x00 0x13 0x7D 0x86

PASSTHROUGH (get avg-a)

TX > 0xF7 0x64 0x67 0x65 0x74 0x20 0x61 0x76 0x67 0x2D 0x61 0xEC 0x5D
RX > 0xF7 0x64 0x4F 0x4B 0x3D 0x31 0xD3 0x12

PASSTHROUGH (get avg-c)

TX > 0xF7 0x64 0x67 0x65 0x74 0x20 0x61 0x76 0x67 0x2D 0x63 0x6D 0x9C
RX > 0xF7 0x64 0x4F 0x4B 0x3D 0x32 0x93 0x13

PASSTHROUGH (get avg-m)

TX > 0xF7 0x64 0x67 0x65 0x74 0x20 0x61 0x76 0x67 0x2D 0x6D 0xEC 0x58
RX > 0xF7 0x64 0x4F 0x4B 0x3D 0x38 0x13 0x14

PASSTHROUGH (get hw-sn)

TX > 0xF7 0x64 0x67 0x65 0x74 0x20 0x68 0x77 0x2D 0x73 0x6E 0x68 0x12
RX > 0xF7 0x64 0x4F 0x4B 0x3D 0x30 0x30 0x32 0x45 0x30 0x30 0x34 0x30 0x33 0x36 0x33
RX > 0x32 0x33 0x30 0x33 0x36 0x30 0x43 0x34 0x37 0x33 0x34 0x33 0x31 0x1E 0xDF

PASSTHROUGH (get fw-build)

TX > 0xF7 0x64 0x67 0x65 0x74 0x20 0x66 0x77 0x2D 0x62 0x75 0x69 0x6C 0x64 0x0A 0xE0
RX > 0xF7 0x64 0x4F 0x4B 0x3D 0x4A 0x75 0x6C 0x20 0x32 0x32 0x20 0x32 0x30 0x32 0x30
RX > 0x20 0x61 0x74 0x20 0x31 0x36 0x3A 0x31 0x37 0x3A 0x30 0x36 0x20 0x62 0x79 0x20
RX > 0x47 0x43 0x43 0x20 0x37 0x2E 0x32 0x2E 0x31 0xF8 0x2C

PASSTHROUGH (set avg-m 8)

TX > 0xF7 0x64 0x73 0x65 0x74 0x20 0x61 0x76 0x67 0x2D 0x6D 0x20 0x38 0x14 0xD8
RX > 0xF7 0x64 0x4F 0x4B 0x07 0x88

PASSTHROUGH (reboot)

TX > 0xF7 0x64 0x72 0x65 0x62 0x6F 0x6F 0x74 0x6F 0xC7
RX > 0xF7 0x64 0x4F 0x4B 0x07 0x88

NOTES: Some useful tools to manually forge and decode your Modbus frames:

Compute CRC16 for Modbus online: https://crccalc.com/?method=CRC-16/MODBUS

Convert ASCII to HEX online: https://www.rapidtables.com/convert/number/ascii-to-hex.html

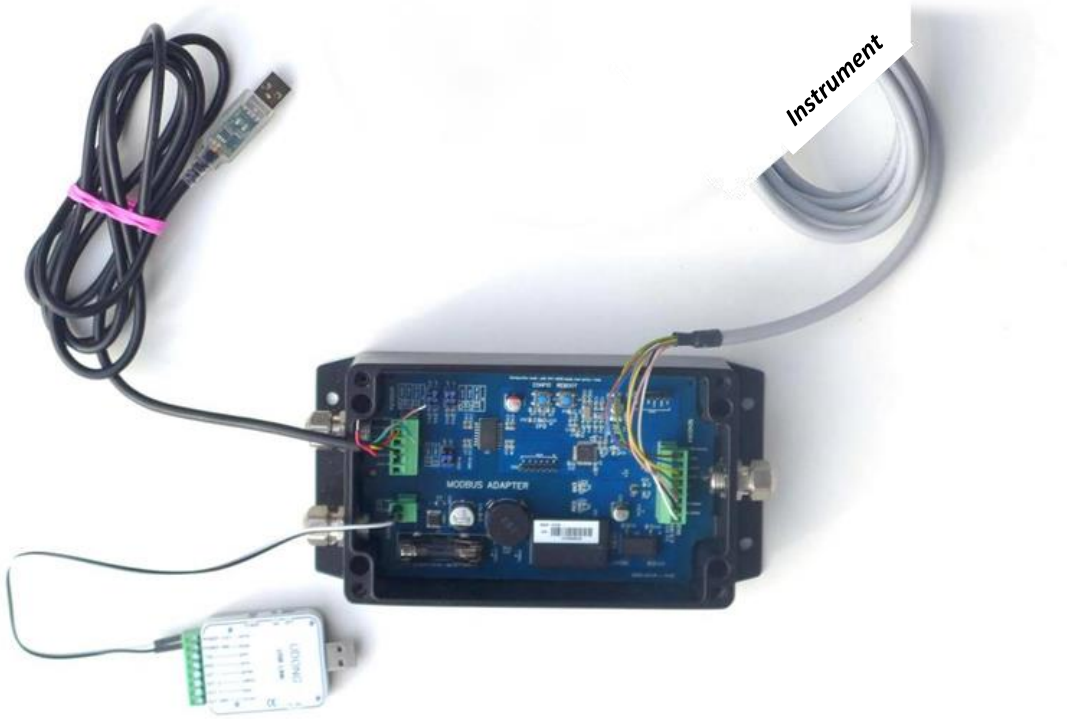
Convert HEX to ASCII online: https://www.rapidtables.com/convert/number/hex-to-ascii.html

Parse and decode MODBUS frame online (remove 0x prefix on the previous examples): https://rapidscada.net/modbus/

D.7. Test procedure

Communication example between an ISAW instrument and a PC using the Modbus Adapter.

D.7.1. Hardware setup



Picture 1: Hardware setup

The **instrument** is connected directly to the "INSTRUMENT" connector of the Modbus adapter as per Picture 2.

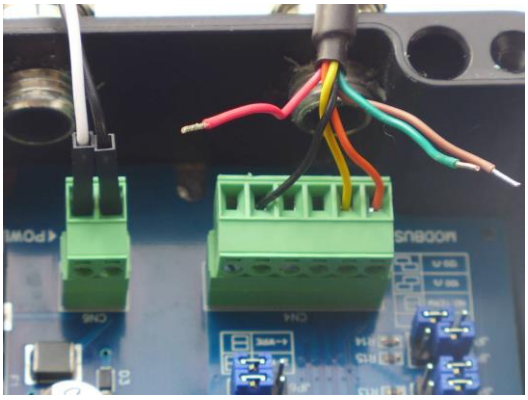
To **power** both the Modbus adapter and the instrument we simply use the white and black wires of the UDONG accessory, connected to the "POWER" connector of the Modbus adapter. The UDONG is plugged to the PC either directly or via a USB Hub (see Picture 2 and Picture 3).

To **communicate** between the MODBUS ADAPTER and the PC we use an RS485/422 adapter (e.g. FTDI USB-RS485-WE-1800-BT) connected to the "MODBUS" connector of the MODBUS adapter on one side, and to the USB hub (or directly to the PC) on the other side.

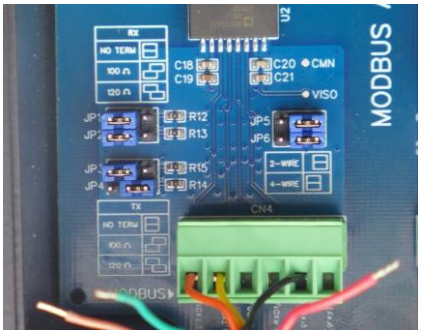
USB-to-RS485 Serial Converter Cable

Picture 2: Modbus adapter connectors. Left: MODBUS and POWER connectors. Right: INSTRUMENT connector.

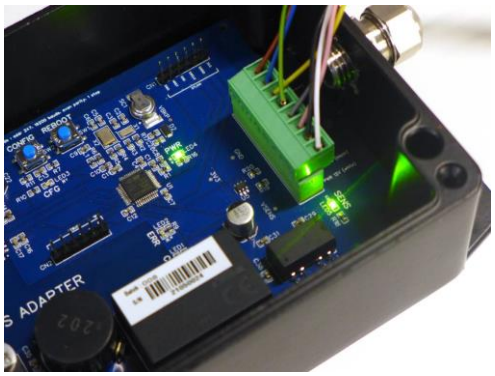
Picture 3: USB hub with UDONG on the left and RS485/422 adapter on the right



Picture 4: POWER connector (on the left), MODBUS connector (on the right)

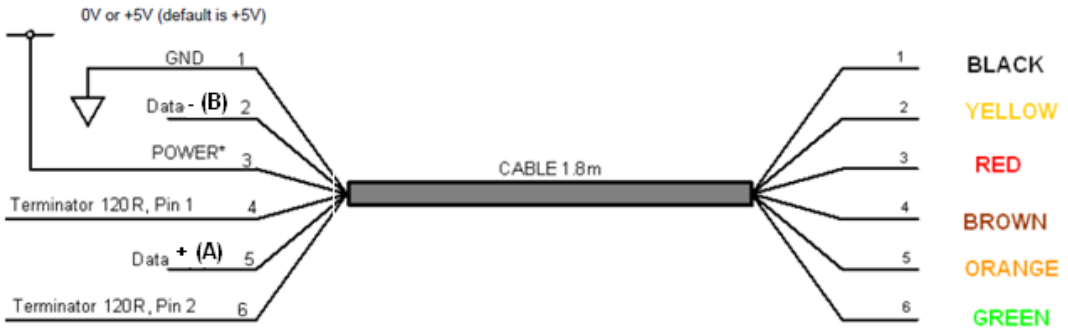


Picture 5: Jumpers



Picture 6: Modbus adapter LEDs

Cable signals and wire colors are detailed on the following figure:



(Source: https://www.ftdichip.com/Support/Documents/DataSheets/Cables/DS_USB_RS485_CABLES.pdf)

If needed, download the driver according to your operating system: https://ftdichip.com/drivers/vcp-drivers.

Then, on the Modbus adapter side, connect the USB-RS485 FTDI as per Picture 4, i.e. only black, yellow and orange wires (thus leaving the red, green and brown wires unused).

Set the jumpers of the Modbus adapter as per Picture 5.

Set the UDONG power switch to ON which activates the UDONG green led (see Picture 3) and also two green LEDs on the Modbus adapter (see Picture 6).

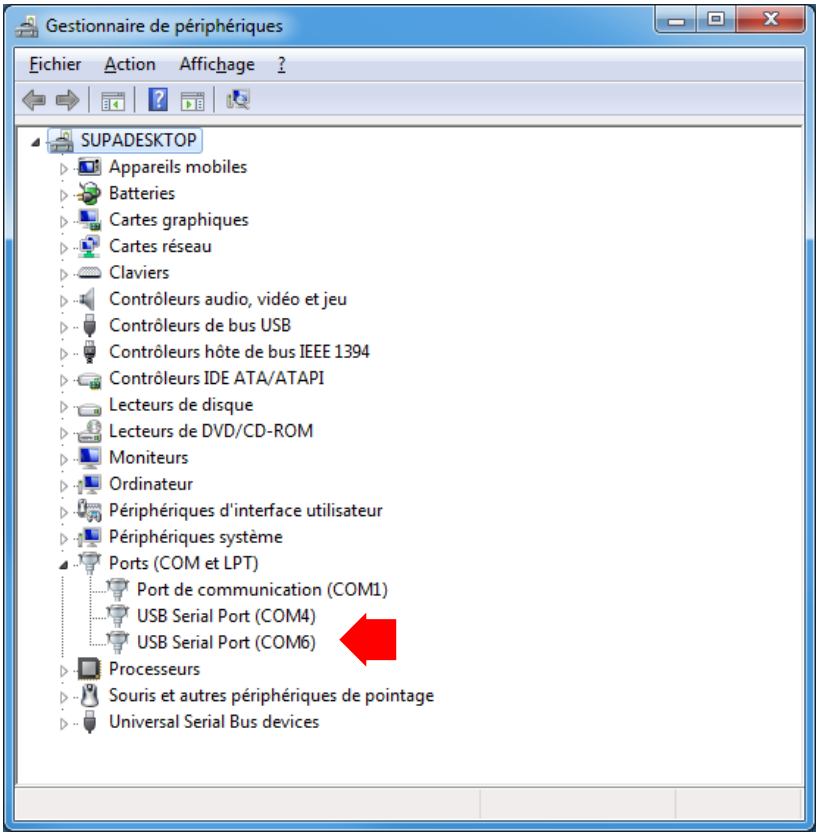
The hardware setup is complete. We can now communicate.

D.7.2. Communicating with the HailFlow HF4 instrument

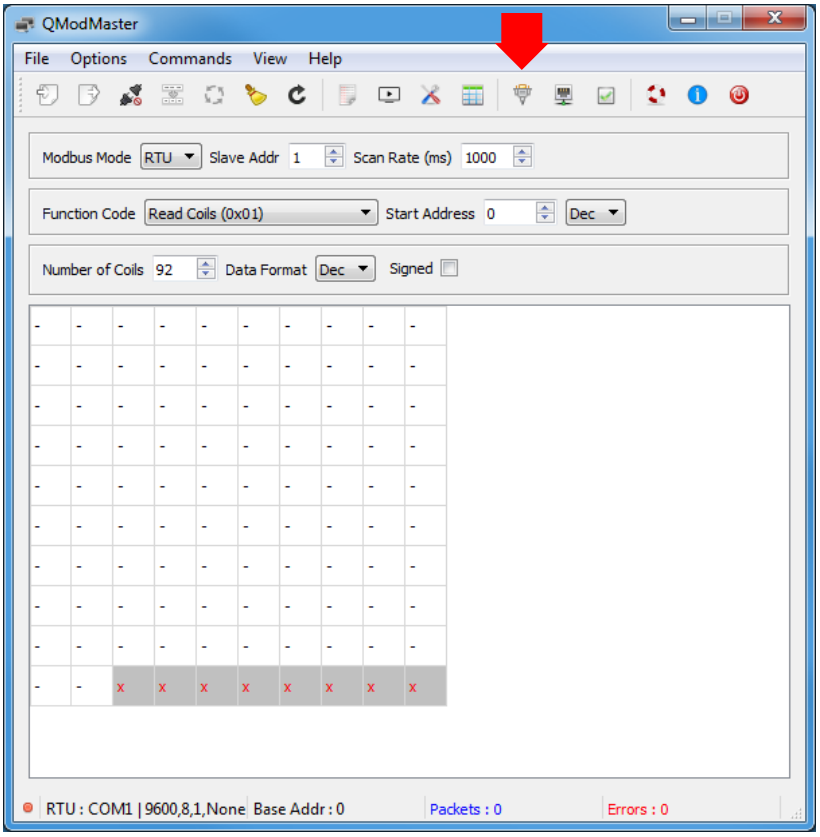
Download a communication software, for example QModMaster. QModMaster is a free Qt-based implementation of a Modbus master application. A graphical user interface allows easy communication with Modbus RTU and TCP slaves. QModMaster also includes a bus monitor for examining all traffic on the bus. See https://sourceforge.net/projects/qmodmaster/.

Open the « Device Manager » on your computer.

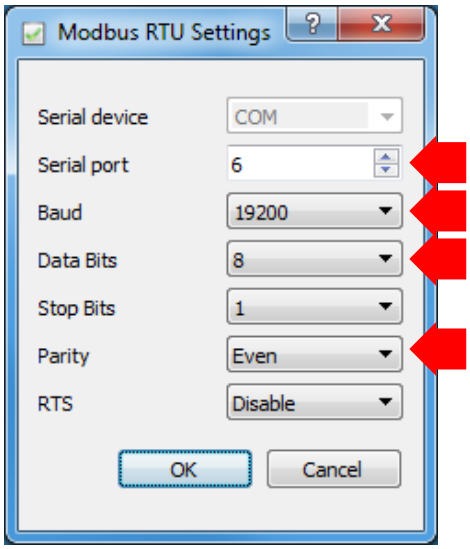
Plug the RS485/422 adapter USB connector to the USB hub or PC and install the required drivers. When the drivers are successfully installed, a new serial port appears (here: COM6).



Start QModMaster and open the Configuration Panel.

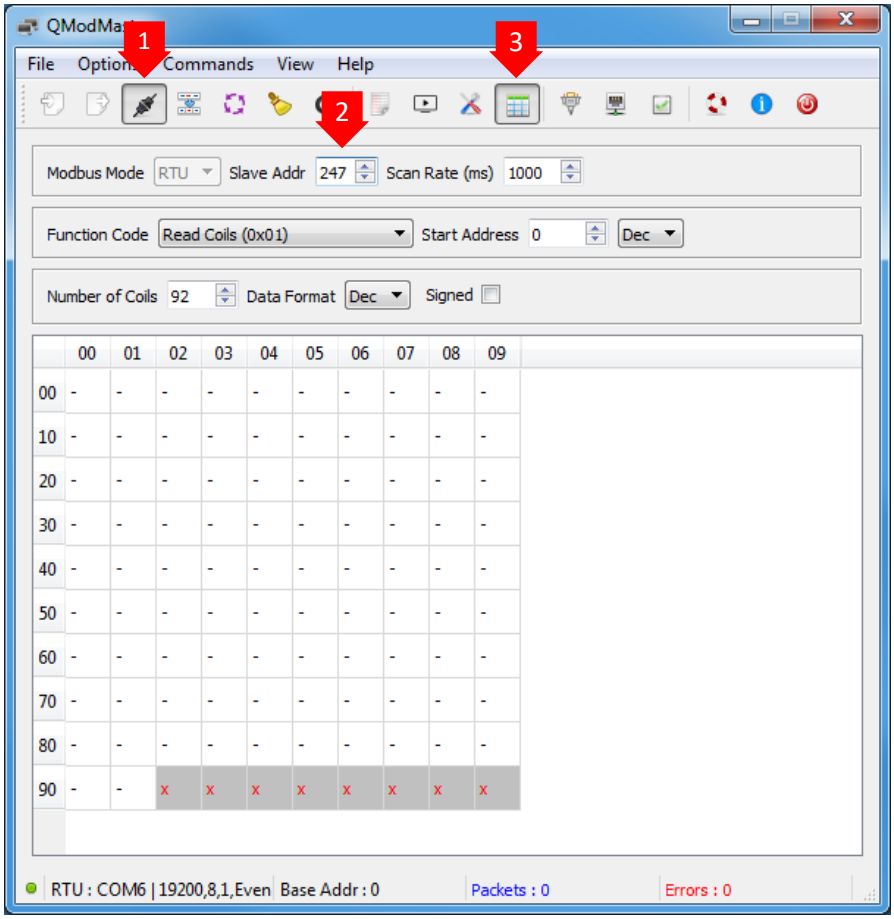


Set the serial communication parameters. Use the relevant serial port number (here: 6).



Connect the MODBUS adapter:

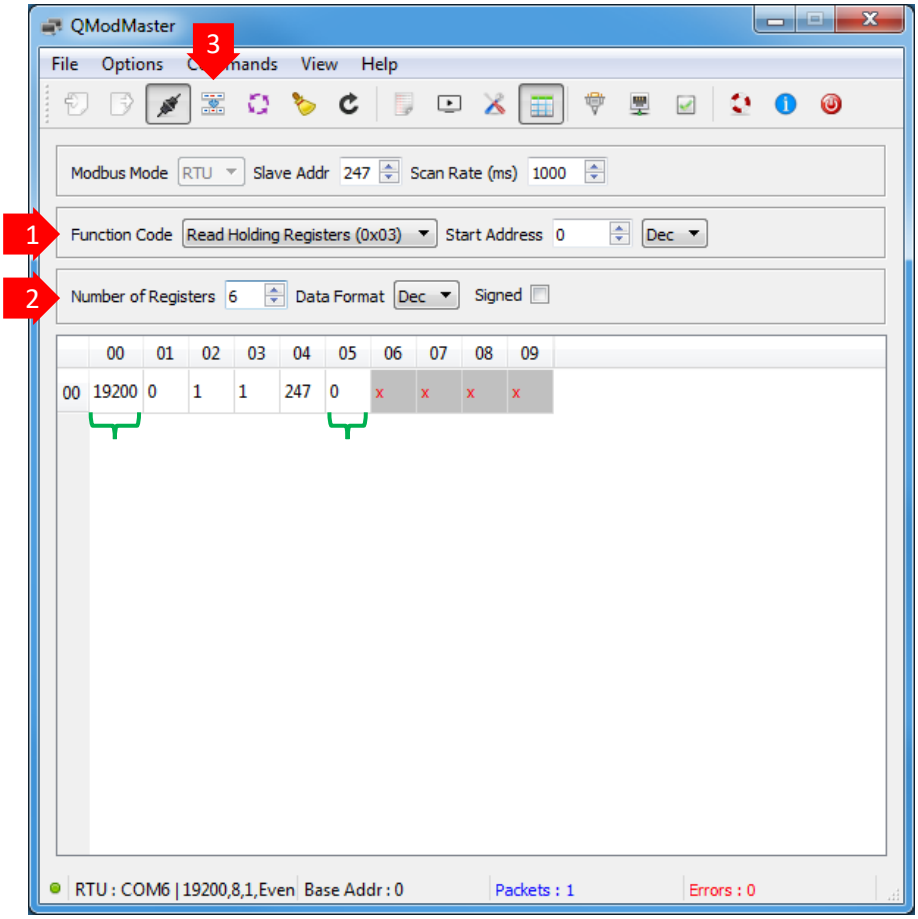
[1] Open the QModMaster serial port.
[2] Set the Modbus address (e.g. 247).
[3] Display grid header if needed.



Tip : If you receive the « Connection failed » message below, your serial port is probably already opened by another application. Stop the other application and retry.

To read the configuration:

[1] Select the function code « Read Holding Registers ».
[2] Set the number of registers (e.g., 6 for the whole configuration).
[3] Click on the [Read/Write] button.

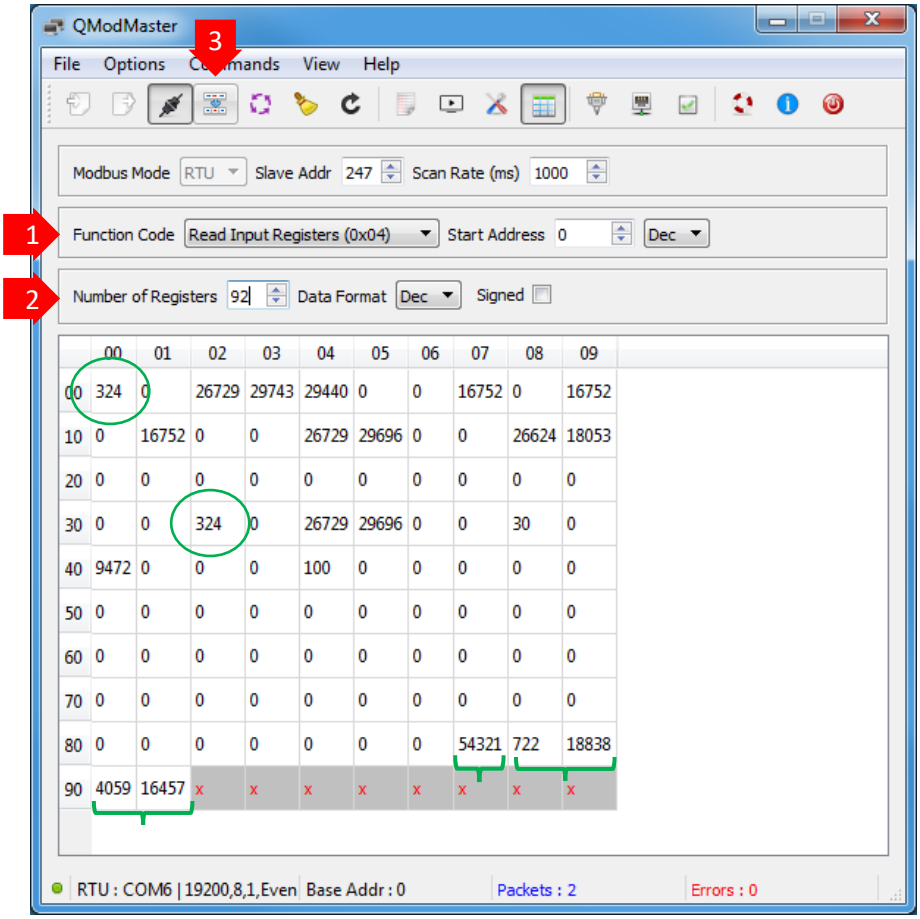


You can see for example the « Baudrate » (Register 0) and « Address » (Register 4). To understand the registers definitions, values and formats please refer to § D.4.

Tip : If you receive « Read data failed » message below (Timeout or CRC), please check your hardware wiring (especially data wire swapping), jumper position and QModMaster serial configuration (especially baud rate and parity).

To read the measurements:

[1] Select the function code « Read Input Registers ».
[2] Set the number of registers (e.g. 92 for the whole measurement).
[3] Click on the [Read/Write] button.



	00	01	02	03	04	05	06	07	08	09
00	324	0	26729	29743	29440	0	0	16752	0	16752
10	0	16752	0	0	26729	29696	0	0	26624	18053
20	0	0	0	0	0	0	0	0	0	0
30	0	0	324	0	26729	29696	0	0	30	0
40	9472	0	0	0	100	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	54321	722	18838
90	4059	16457	x	x	x	x	x	x	x	x

You can see for example « Frame counters » (Registers 0 & 32) and « Test fixed values » (Registers 87, 88 & 90).

To understand the registers definitions, values and formats please refer to § D.4.3.

Tip: The interval between two measurements of the instrument depends on the instrument's "Averaging" setting: by default, the instrument sends one measurement every 600 seconds, i.e. a refresh of the displayed data every 10 minutes. To get more frequent refresh of the displayed data, you can change the "Averaging" parameters "Acquisition (A)", "Cycle (C)" and "Measure (M)" of the instrument. To do so, connect the instrument to a PC using the UDONG accessory and refer to the "Averaging panel" section of the User Guide. Example for quick test: set A=1s, C=2s and M=4s. In this case, do not forget to re-set the "Averaging" configuration of your instrument according to your needs after this test.

D.8. Update the Modbus adapter firmware

IAV Technologies constantly improves its products and provides upgrades of the ISAW firmware for all instruments. This section describes the procedure for upgrading the ISAW firmware.

This chapter describes the procedure for upgrading the Modbus adapter's firmware.

D.8.1. Hardware setup

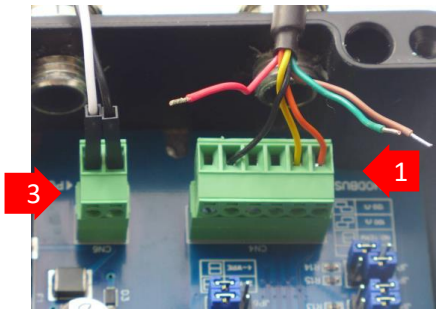
You will need

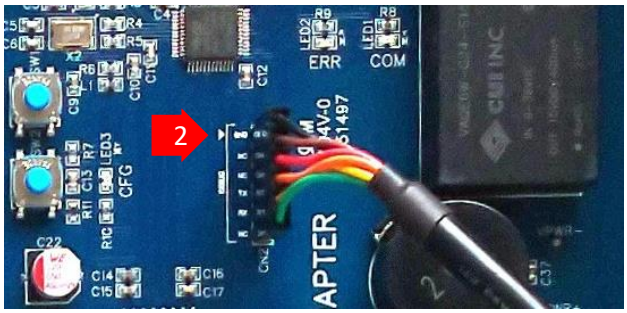
- a USB-to-RS485 Serial Converter Cable,
- the USB link accessory, which will be used as a 12V power supply,
- optional: an FTDI TTL-232 cable (if you want to know the Modbus adapter version before V1.19).

USB-to-RS485 Serial Converter Cable

FTDI TTL-232 Cable (optional)

4. **To communicate between the Modbus adapter and the PC**, use any RS485/422 adapter (e.g. FTDI USB-RS485-WE-1800-BT) connected to the "MODBUS" connector of the MODBUS ADAPTER.
5. **Optional:** Connect the Modbus adapter to the PC using the FTDI 232 cable with the black wire (ground) facing the GND mark ▶.
6. **To power the Modbus adapter**, use the white and black wires of the UDONG accessory connected to the "POWER" connector.





Hardware setup with USB hub and Modbus adapter

D.8.2. Update procedure

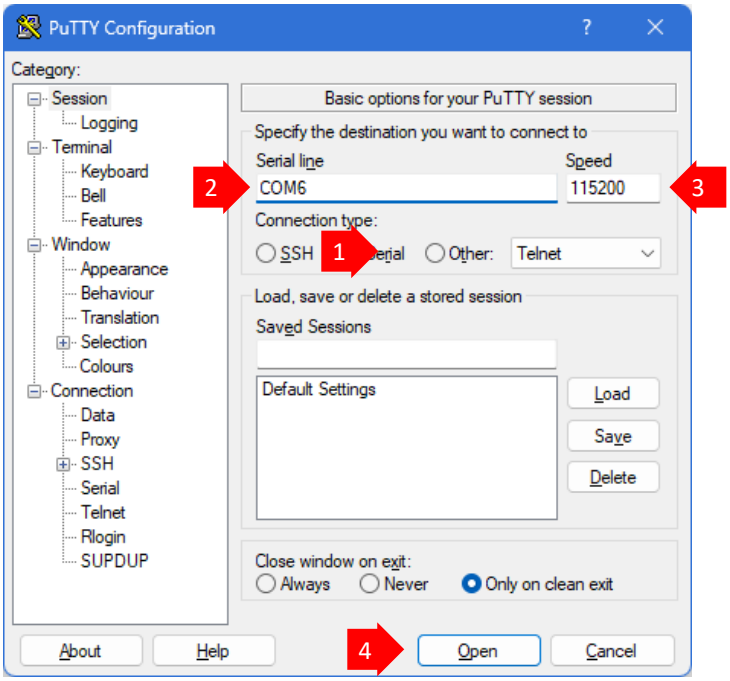
Prerequisites:

- The hardware setup is complete.
- The ISAW-Toolbox is installed (see § 0).
- The last versions of the firmwares are installed (use the Update utility to check).

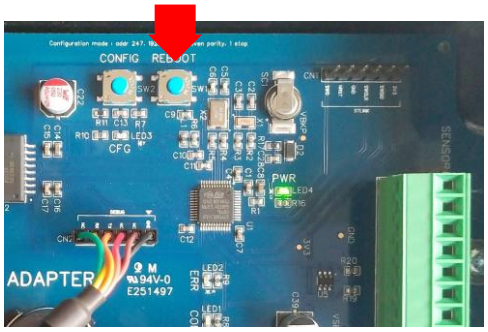
To display the current Modbus adapter configuration (optional), open your favorite serial terminal (e.g., Putty[6], TeraTerm, HyperTerminal) on the right serial port (here COM6) at 115200 bauds, 8 bits, 1 stop, no parity.

Tip:	To identify the serial port the FTDI 232 cable is connected to, open the Control Panel > Device Manager > Ports interface. Unplug then plug the FTDI USB end and check the activated USB serial port.

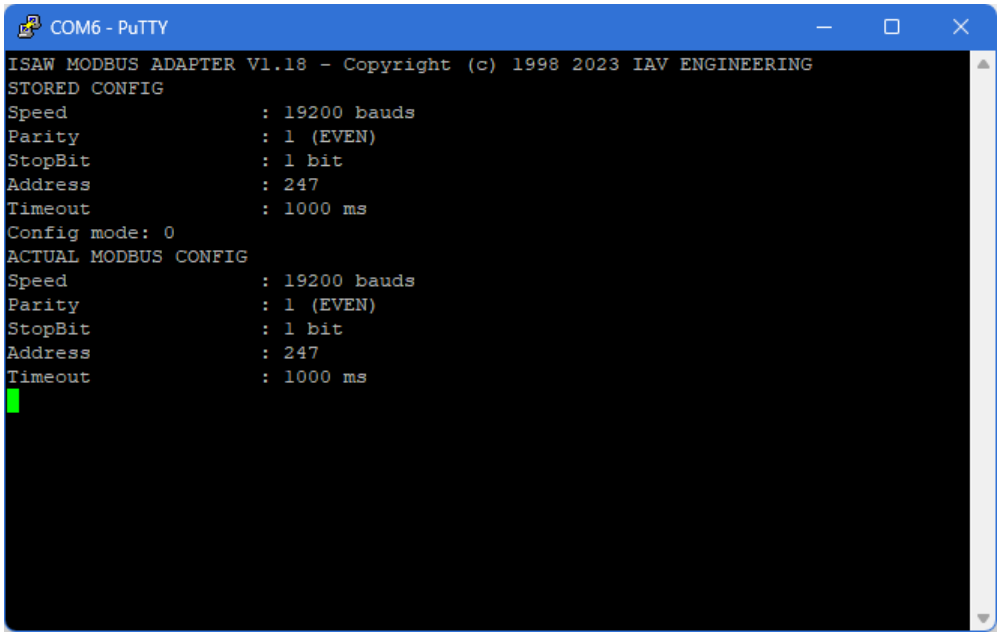
[6] Lightweight and non-intrusive "putty.exe" freeware available at http://www.putty.org.



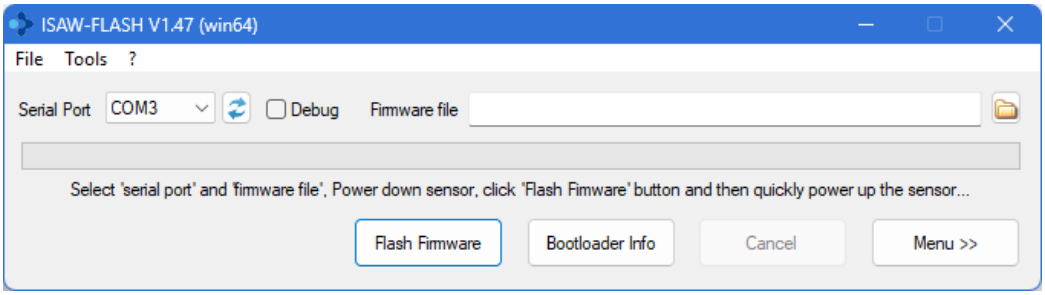
Press the REBOOT button on the Modbus adapter.



The current configuration of the Modbus adapter is displayed, starting with the firmware version:



Open the ISAW Toolbox **Flash** Utility.



Serial Port: Select the FTDI 485 serial port.

Tip:	To identify the serial port the FTDI 485 cable is connected to, open the Control Panel > Device Manager > Ports interface. Unplug then plug the FTDI USB end and check the activated USB serial port.

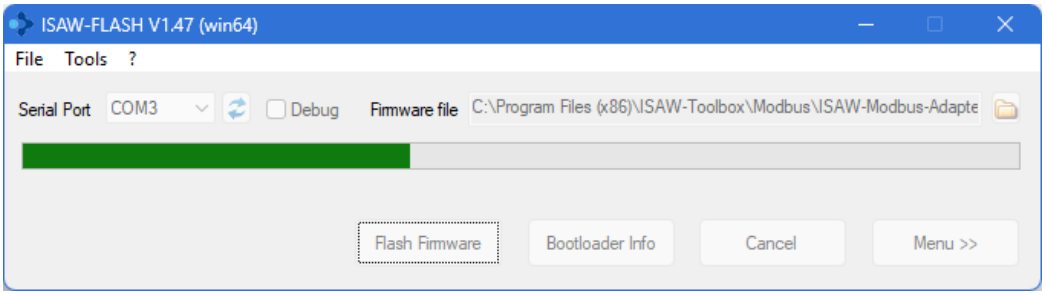
Select the firmware file: Select the last version of the Modbus firmware in the "ISAW-Toolbox\Modbus" directory:

ISAW-Modbus-Adapter-x.xx.bin (where x.xx is the version number)

Shut down the Modbus adapter power supply: set the USB link power switch to OFF.

Press the [Flash Firmware] button. At this stage, ISAW-Flash will automatically search for a powered device during ten seconds.

Power-on the Modbus adapter: Switch the USB link power back to ON. As soon as ISAW-Flash has found the powered Modbus adapter, the firmware upload starts automatically.



Wait during the firmware upload. This may take a few minutes.

WARNING:	Do not disconnect the power supply during the firmware upload.

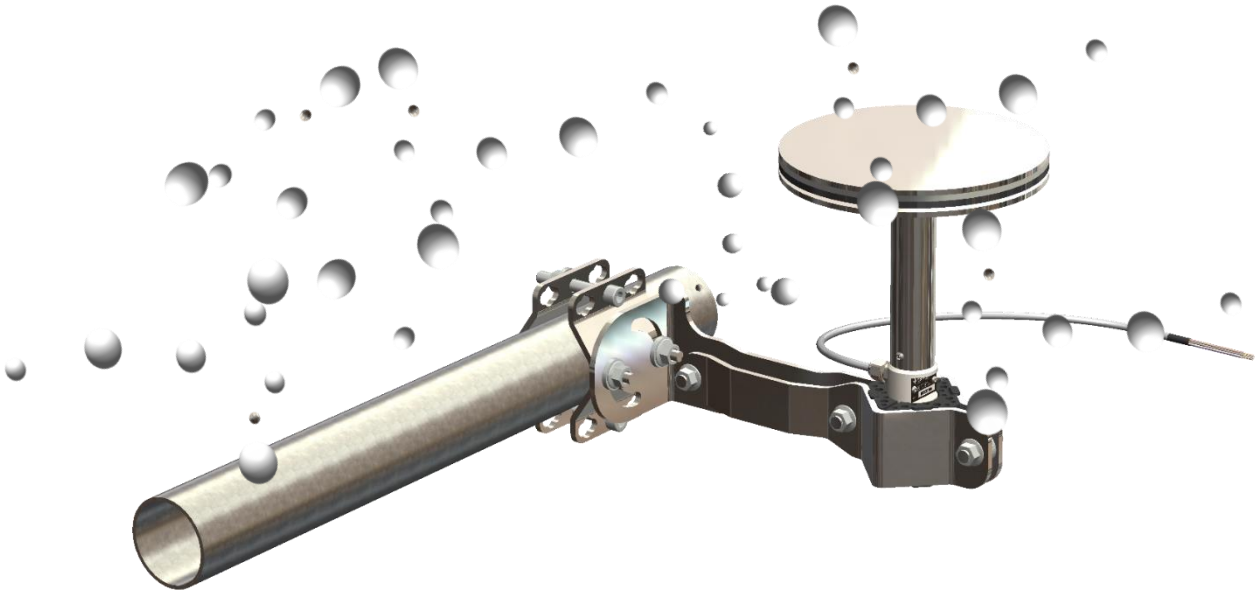
When the firmware upload is successfully completed, a confirmation message is displayed.

The Modbus adapter is now ready to use.

Optional: Use your serial terminal to check if the firmware version is properly updated (see first step).

Appendix E: More about hail physics, principle of detection and classification of hailstones

E.1. About hailstone size, terminal velocity & kinetic energy (KE)



The kinetic energy (KE) of a hailstone depends on the mass and the speed of the hailstone, i.e. two quantities that seem relatively easy to determine by calculations, laboratory experiments and/or field measurements. This introductory section reproduces a reference publication[7] presenting a state-of-art discussion in the knowledge of the impact kinetic energy of natural hailstones. There are many other publications available on this topic; this second reference[8] may also be used.

Tip: For a quicker read, the essential points in the context of this document have been highlighted.

"**Abstract** The physical properties of 2295 hailstones that developed in Great Plains (US) storms were measured, including their maximum dimension, mass, and cross-sectional area. Using these data, **size-dependent relationships for their terminal velocities and kinetic energies** are developed. These relationships **can be used in weather forecast modeling and hail damage prediction and assessment.** When hailstones are assumed to be spherical, their terminal velocities and kinetic energies are in agreement with what has been reported in previous studies. When non-sphericity is considered, which is the case for natural hail, the terminal velocities and kinetic energies are, on average, lower than those of spheres of the same maximum diameter, but can be larger.

Introduction […] An accurate estimate of the terminal velocity and kinetic energy of hail is important for assessing the factors that affect damage to building materials as well as for property risk assessment, loss estimation, and event characterization. However, the physical characteristics of hail

[7] [1] Heymsfield, A. J., I. M. Giammanco, and R. Wright (2014), Terminal velocities and kinetic energies of natural hailstones, *Geophys. Res. Lett.*, 41, 8666–8672, doi:10.1002/2014GL062324.

[8] [2] Betschart, M., Hering, A.: 2012, Automatic Hail Detection at MeteoSwiss – Verification of the radar-based hail detection algorithms POH, MESHS and HAIL, Arbeitsberichte der MeteoSchweiz, 238, 59 pp.

are not included or typically measured in local storm reports and/or hail-pad data. For example, in the US, storm reports are compiled by the National Weather Service in a severe weather climatological database, Storm Data. Fieldwork has shown that observed hail size in Storm Data and other sets is below that of what can be identified using high-resolution observations [Ortega et al., 2009; Blair and Leighton, 2012]. With the upgrade of all National Weather Service WSR-88D Doppler radars to dual-polarimetric capability, there is now the potential to characterize remotely the properties of hailstones, such as their shapes and sizes. Reliable information on their terminal velocities would help constrain parameters for horizontal reflectivity and dual polarimetric-based hail size-discrimination algorithms [Cintineo et al., 2012; Ryzhkov et al., 2013a, 2013b]. Proper detection of hail size could nowcast to mitigate damage to property (e.g., vehicles) and could offer early warning for potentially damaging storms. Relatively small changes in the terminal velocities of graupel and hail may have an appreciable effect on model simulations of precipitation developing from convection [Bryan and Morrison, 2012]. For example, using hail with a bulk density (ρb, the mass of the particle divided by the volume of a sphere of the same maximum diameter) of 0.9 g cm3 rather than graupel with a bulk density of 0.4 g cm^{-3} as the rimed ice species with appropriate adjustments to the terminal velocities, a hail-producing squall-line simulation resulted in a much narrower convective line and slightly smaller stratiform region. Other modeling studies have shown the sensitivity, the cold pool strength, and extent on graupel/hail properties [e.g., Gilmore et al., 2004]. **To date, accurate estimates of the terminal velocities Vt and kinetic energies KE of potentially damaging hail have been impeded by the lack of information on the masses m and cross-sectional areas A of these particles, since Vt is proportional to m/A, and KE is proportional to m^2/A.** In this study, detailed field observations of 2295 hailstones from 2012 to 2014 are compared to historical studies to evaluate hailstone diameter-mass relationships and to estimate Vt and KE. The main objectives of this study are to provide better estimates of graupel and hail terminal velocities and kinetic energies for use in weather forecast models remote sensing retrievals of hail properties, and estimates of hail damage." […]

Results We reference our results to those of Laurie [1960], who developed relationships between the terminal velocity or kinetic energy and diameter. These results are widely used within engineering applications to evaluate the performance of various materials through standardized test methodologies [UL 2218, Underwriters Laboratory, 2012; FM 4473, FM Approvals, 2005; ASTM F320, American Society for Testing of Materials, 2010]. Also, for reference, on the basis of the physical measurements of the actual particles in the laboratory at the National Center for Atmospheric Research, we note the physical properties of some of the largest stones ever collected in the United States: the Coffeyville, Kansas (1970), hailstone was about 13.7 cm in diameter and had an area of 107 cm^2 and an area ratio (Ar, the ratio of the area of the particle relative to the area of an equivalent diameter sphere) of 0.72; the Vivian, South Dakota (2010), hailstone had a diameter of about 17.8 cm, an area of 195 cm^2 , and an area ratio of 0.79. We also draw on photographs of hail from the Aurora (2003) and Potter, Nebraska (1928), hailstones. The relationships we develop are indicated in the figures and listed in Table 1.

Table 1. List of Relationships Used From *Heymsfield and Wright* [2014][a]

Variable	
Mass	$m = 0.34 D_{max}^{2.96}$
Area	$A = 0.66 D_{max}^{1.74}$
Area ratio	
Terminal velocity, 1000 hPa	$V_t = 12.65 D_{max}^{0.65}$, D < 2.05 cm
	$V_t = 15.69 D_{max}^{0.35}$, D > 2.05 cm
Kinetic energy, 1000 hPa	$KE = 0.0374 D_{max}^{3.67}$, D < 2.3 cm
	$KE = 13.5 D_{max}^{0.63}$, D > 2.3 cm

[a]At other pressure levels, V_t approx. V_t (1000) × $(1000/P)^{0.545}$, KE approx. KE(1000)$^{(1000/P)1.09}$.

[…] The terminal velocity is proportional to the square root of the mass divided by the product of the cross-sectional area and the drag coefficient. For the hailstones, this ratio, on average, falls below the values for solid ice spheres for sizes below about 2 cm and is close to it for sizes above 2 cm. Therefore, the terminal velocities of the hailstones should be someone lower than those for solid ice spheres at the smaller sizes, approaching those of spheres for the larger sizes. However, given the scatter in the ratio, scatter in the values of V t should be expected, but these exceed our expectations, but may be the result of the small sample size. Using the Reynolds number-Best number approach given in Heymsfield and Wright [2014], we have derived the terminal velocities of the stones

assuming their actual (maximum) and equivalent diameter dimensions, applied to a pressure level of 1000 hPa. For reference, we show the relationship developed by Laurie [1960]. Not surprisingly, the smaller hailstones have Vt, which are similar to those from the Laurie study, given the results we found for their masses and areas. The terminal velocities of the larger hailstones, however, depart from the Laurie [1960] curve, consistent with their departure from sphericity. The terminal velocities at a pressure level P should increase by about (1000/P) 0.545 relative to sea level [Heymsfield and Wright, 2014]. Note also that **at a given size, there is considerable variability in the terminal velocities, resulting from the variability in stone masses and cross-sectional areas,** which is a reflection of the underlying statistical variability in the growth processes. Note that hailstone tumbling and gyrations, which would influence the cross-sectional areas, are not considered in these calculations.

It is important to consider the variability of the kinetic energy at a given size, due to variability in their masses and areas. **At a particular size, it is hailstones with the highest kinetic energy that presumably produce the most severe damage for a given impact on any particular material (The true damage potential is also related to the concentration of hail on a given surface area and the size distribution). […] and it illustrates the importance of accounting for the shape of hailstones in any application that makes use of V t and KE**.

[…] It is clearly noted that there is a wide range of KE for sizes that fall both above and below the Laurie curve.

[…] Conclusions […]:

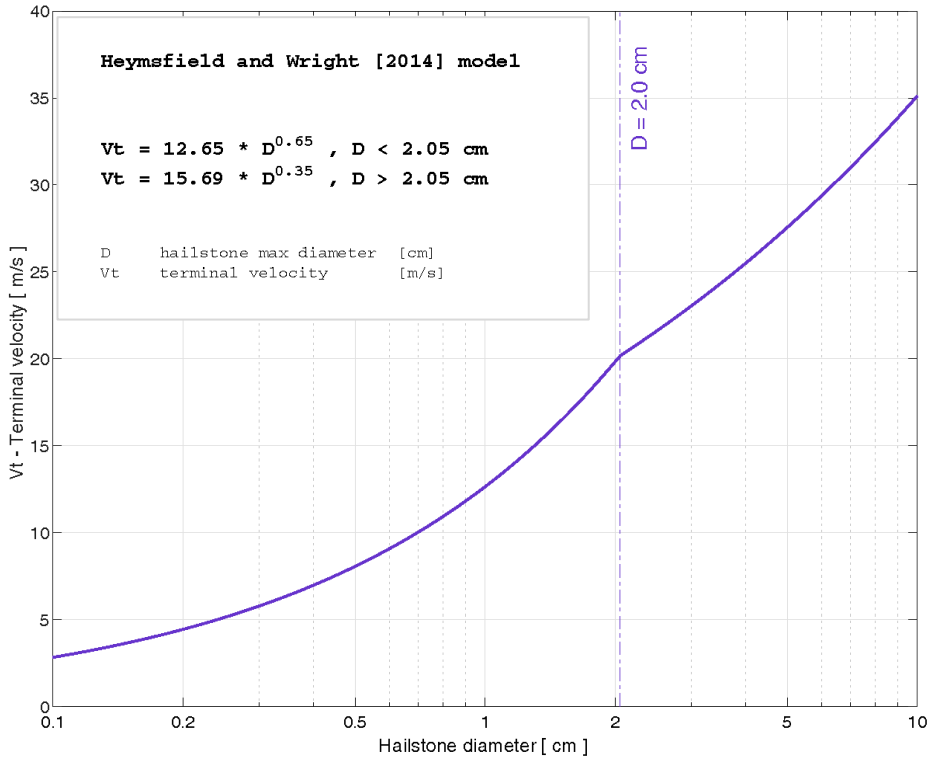
1. On average, hailstones smaller than 3 cm are found to have larger values of V t and KE relative to the "standard" relationships of Laurie [1960] that are widely used in the engineering and hail insurance areas. As hailstone sizes increase above this size, those hailstones that would likely produce more severe damage, relative values of V t and KE are, on average, lower than the Laurie curve, but there is still a wide range of KE that fall above that curve. **For any given hailstone maximum size, a range of KE values is found, the result of variations in the hail masses and areas among the stones. When an equivalent diameter is calculated, the estimates of V t and KE are in better agreement.** The terminal velocity should increase by about (1000/P) 0.545 at a given pressure level P relative to that at sea level of 1000 hPa and the kinetic energy by the square of this factor.

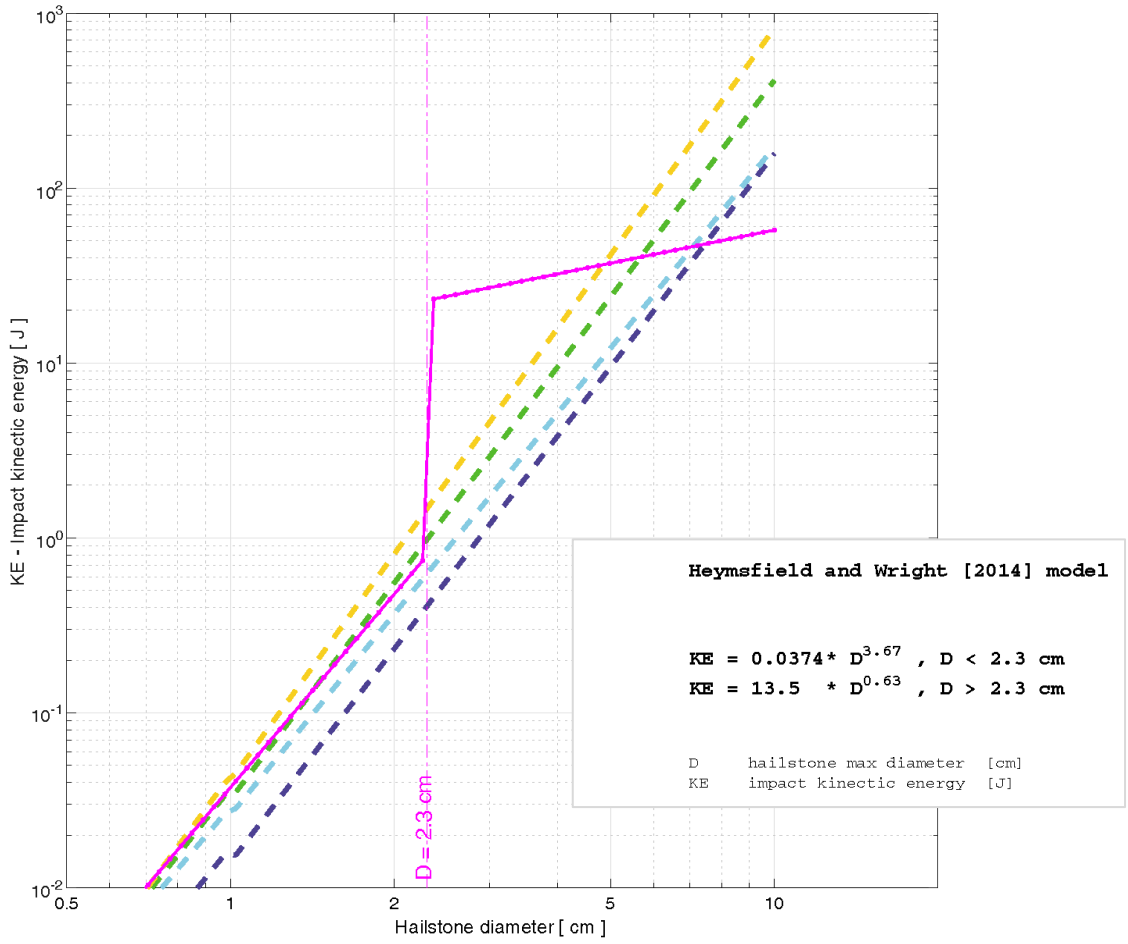
2. The departure from Laurie [1960] is a result of the **non-spherical shapes of hailstones at sizes above 3 cm. As size increases, hailstones become increasingly less spherical.**

3. We have examined the characteristics of relatively low-density graupel and small hail from earlier studies. In comparison to the small hail from our new data set, we suggest that as low-density graupel and small hail descend from near the freezing level to the ground, they fill with melted liquid and behave in a manner similar to the trends observed for larger hailstones.

Future studies can evaluate the impact of our results on storm dynamics and on hail damage functions. For example, using these new terminal velocities as a baseline, **sensitivity studies could change the velocities by +/- 50%**, and the resulting effect on storm dynamics could be investigated. **The kinetic energy curves presented here should provide a quality baseline for use in damage functions.** Future work should focus on assimilating information on the material properties of natural hailstones and the objects they impact to produce more accurate damage functions for risk modeling and event characterization applications.

In the two following figures, we have re-plotted the curves according to the formulas explained in the article.





E.2. Simplified classification for practical use: Size of hailstones expressed in nominal classes of diameter

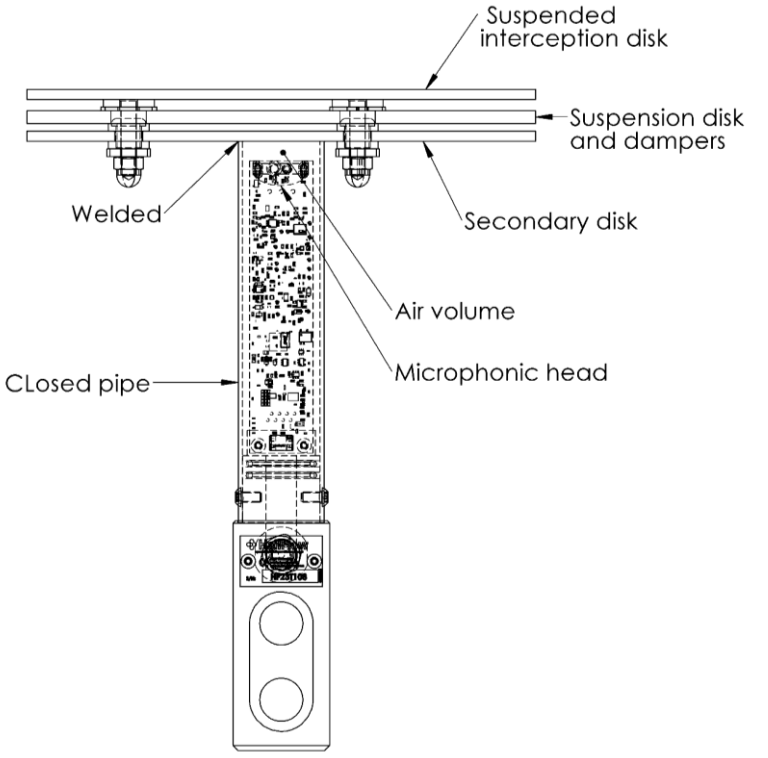
In the next table we represent a simplified spherical hailstone's geometry in steps of 5 mm increase in diameter from D = 7.5 mm to D = 72.5 mm and, to give a very simplified idea of the corresponding kinetic energy, we indicate the theoretical value obtained by the reference formula [1] when applied to this circular diameter D. From the refrence[1] we know that the variability of the kinetic energy can be extremely high around the values indicated in this table (by one or several factors of ten), this, especially for high diameters over 2-3 cm. **The kinetic energy values of column 4 are then only of a very rough correspondence with the said nominal diameter sizes of hailstones**. This point is discussed and illustrated in more details in the suite of the document.

Class #	Class Label (central diameter D) [mm]	Diameter range D [mm]	Estimated Kinetic Energy (KE) [J]
1	10.0	$5.0 \leq D < 10.0$	1.30E-02
2	15.0	$10.0 \leq D < 15.0$	8.48E-02
3	20.0	$15.0 \leq D < 20.0$	2.92E-01
4	25.0	$20.0 \leq D < 25.0$	7.33E-01
5	30.0	$25.0 \leq D < 30.0$	1.53E+00
6	35.0	$30.0 \leq D < 35.0$	2.83E+00
7	40.0	$35.0 \leq D < 40.0$	4.78E+00
8	45.0	$40.0 \leq D < 45.0$	7.57E+00
9	50.0	$45.0 \leq D < 50.0$	1.14E+01
10	55.0	$50.0 \leq D < 55.0$	1.64E+01
11	60.0	$55.0 \leq D < 60.0$	2.30E+01
12	65.0	$60.0 \leq D < 65.0$	3.12E+01
13	70.0	$65.0 \leq D < 70.0$	4.13E+01
14	75.0	$70.0 \leq D < 75.0$	5.37E+01
15	99	$D \geq 75.0$	> 6.86E-01

Hailstone size classes and corresponding estimated Kinetic Energy values

E.3. Operating principle and kinetic response of the HailFlow HF4 instrument

The operating principle of the HailFlow HF4 instrument consists in intercepting a falling hailstone (or more generally any kind of hydro- or lithometeor) with a plain stainless steel disk plate head and measuring the response of this impact with a microphone inside a cylindrical acoustic cavity structurally connected to the disk. The disk is suspended through dampers to a secondary disk that closes a pipe, the air column in the pipe forming a sealed acoustic volume in which a specific microphone arrangement records the acoustic signal of the vibrational response of the whole head. The closed pipe containing the electronics is a plain stainless steel cylindrical body supported by and sealed on a plain aluminum piece, that is the foot of the instrument that fastens to the external supporting structure through a heavy-duty damper*, bracket and arm, (*the damper integrated into the bracket and arm de-couples the instrument from possible parasitic structure-borne vibrations that could be issued/transmitted from the externally connected structures).



When the instrument is subject to an impact of sufficient kinetic energy, an impulse detector converts the identified transient acoustic signal of the impact into a voltage, processes the peak maximum amplitude of this acoustic signature of the impact, and interprets this peak maximum amplitude as an image of the kinetic energy of the impact.

Strictly speaking, the kinetic energy of the impact is not equal to the kinetic energy of the hailstone, and subsequently the kinetic energy of the impact is not a direct measurement of the kinetic energy (without impact) of the hailstone, because **the energy that is transferred to the instrument depends from many factors related to the impact itself, such as :** angle of incidence of the hailstone, shape of the hailstone (round or irregular), place of impact on the head of the instrument (partial impact at the edge), breaking of the Hailstone into multiple debris.

For example, if we consider two hailstones of the same KE, but of different geometries and ice structure (like for example one solid round and one fragile angular: at impact, the first may bounce back with a behavior close to a pure elastic shock (“sphere-plate punctual contact”), while the “parallelepipedal-shape” second one could break and explode in smaller pieces ejected in all directions.

Also concerning the instrument itself and as a whole, i.e. the instrument with its supporting elements (brackets, arm, connected structure or ground): for low KE energies, the instrument and its mechanical environment will behave as an “ideally rigid” structure, while the more KE will increase and especially when reaching extreme KE values, the forces will be able to induce some flexions and internal losses in the fastening elements and supporting structure, so evolving toward a more inelastic behavior, which will tend to cause an underestimation of the impact (a part of the energy is dissipated in the flexion of the supporting structure)..

To cope as better as possible with these magnitudes in terms of mechanical and acoustical impedance matching, and being able to rely over a reliable KE dynamic range of interest, the whole mechanical and acoustical design of the HailFlow HF4 instrument and supporting arm have been tuned in order to best homogeneously possible respond to hailstones of a kinetic energy ranging from about 0.01 to 100 Joules. The 0.01 to 100 Joules detection range of the instrument is a range including the bounds of the estimated kinetic energy values of the column 4 of the table on page 104, and these limits typically corresponds to respectively the detection and the saturation thresholds of the instrument, with a certain headroom of operation (i.e. hailstones with a diameter under 5 mm and over 80 mm may still be detected).

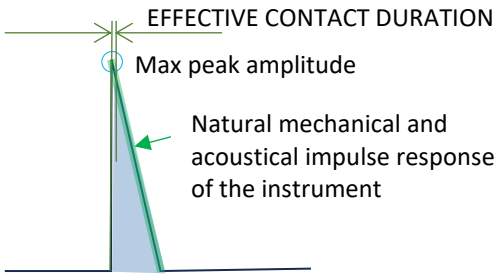
E.4. Time resolution limitations

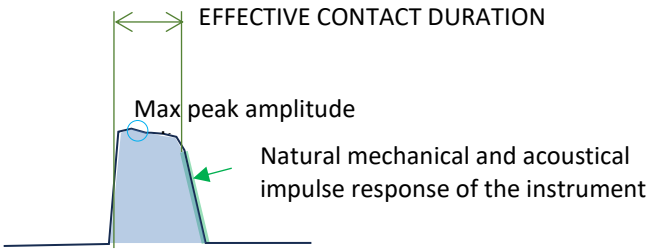
There is a physical limit to consider in terms of the number of impacts that can be separated and well individually discriminated because the flexural and viscoelastic response of the instrument (Note: and its supporting elements when considering the highest KE hailstones) has a certain response time, i.e., the said “mechanical and acoustical impulse response of the instrument”. With the actual design of the HailFlow HF4 instrument, this limit is a **capability of counting up to about at least 25 solid impacts per second**.

Also, in case of simultaneous impacts, the instrument **cannot discriminate between two (or more) impacts occurring too close**, in such case they will be counted has a single impact and their energy likely coherently or incoherently “added”, so causing an underestimation or an overestimation in that case.

Another important consideration for the interpretation of an operation principle based on a reading of impacts, is the fact that when computing the “peak amplitude” of the energy, the manner this maximum value is extremely sensitive to the effective duration of the shock (i.e. the effective duration the moving object exercises direct forces on the measuring instrument).

Schematically, as far as the kinetic energy of the impacting object is “low compared to the flexibility of the mechanical receiver” (and this includes the supporting structure of the target), and the shock is close to pure elastic, then **the duration of contact can be extremely short** (typically some microseconds in the case of small-to-medium-size hailstones on the head of the HailFlow HF4 instrument), in such case (note: here assuming adequate sample rate and bandwidth x time constant product) the time rise, and decay time sharpness of the peak amplitude of the shock is very well marked, and the reading is directly well proportional to the energy of the shock that has been transferred to the instrument. But, when the inertia of the impacting object is bigger enough to deform the reception instrument, and all the more if the shock makes the objects explode, then the duration of the shock can become by an order or so longer, thus showing a maximum peak amplitude rise that **can be much lower if considering the same very short-time integration**.

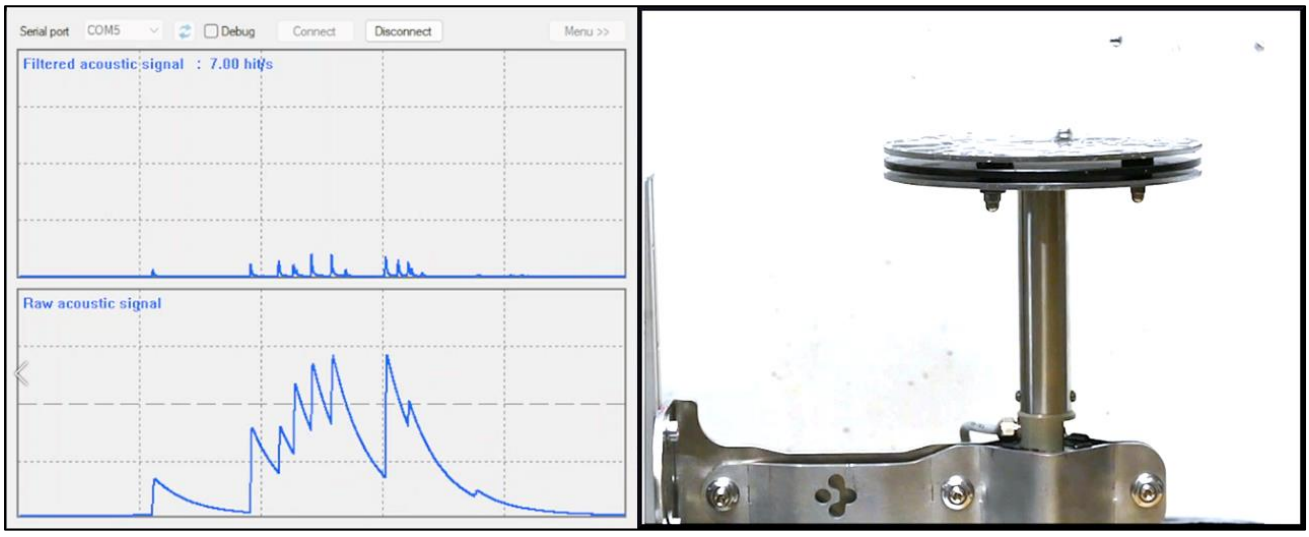




Ex. small rebounding round hailstone with KE=1
Quasi-pure elastic shock
Short duration and high peak amplitude
Surface S

Ex. heavy and exploding hailstone with KE=3
Inelastic shock
Long duration and low peak amplitude
Same surface (=S)

In other words, to cope with these phenomena and still keep a detection calculation that is the less possibly biased by all these factors, one must search for some very careful impedance matching over the KE range of interest and in the signal processing and linearization function calculations of the instrument: for these reasons, unless taking these considerations into account, the instrument shall only be used carefully for applications other than the one the linearization has been implemented for, i.e. in our case ice hailstones from a few millimeters to a dozen of centimeters in diameter, with terminal velocities of one to several dozens of m/s.



To illustrate this difference of behavior and phenomenology between elastic and inelastic response of a kinetic impact instrument, an experience can be reproduced by dropping for example a D=85 mm plain steel ball onto the instrument from a height of 1 m, which theoretically represents an impact energy equivalent to a giant hailstone. Proceeding so, one will observe that the result of this impact is a shock that is outside the flexural range adaptation of the instrument: the 85 mm ball almost doesn't bounce back, but touches, deforms, only few rebounds and then somehow almost rolls out on the surface of the instrument. In such a case the shock duration becomes orders of magnitude longer than if an elastic shock (like it could be on an ideally rigid surface). Slow motion video shows that a major part of the energy is dissipated into the viscoelastic response and deformation of the instrument and the associated structures (head, body, mounting brackets, supporting structure): the max amplitude voltage of the of this event is about 5 times lower than what the instrument delivers when a real giant hailstone of the same KE hits and explodes on the instrument.

E.5. Correspondence between output voltage and theoretical hailstone size class

The calculation model that is applied is called the **nominal linearization function of the HailFlow HF4 instrument** and is a function that, for every single individual impact detected, extrapolates a hailstone size diameter prognosis (hereafter D [cm]) from the measured (acoustic) U input voltage of the energy of impact, as follow:

$$Hailstone\ diameter\ prognosis\text{:}\quad \boldsymbol{D = XC1 \times U^{XE1}}$$

$\boldsymbol{D}$ *Hailstone diameter* $[cm]$

$\boldsymbol{U}$ *Input Voltage* $[mV]$

$\boldsymbol{XC1}$ *Model Coefficient* $= \mathbf{5.10}$ $(factory\ default\ value)$

$\boldsymbol{XE1}$ *Model Coefficient* $= \mathbf{0.33}(factory\ default\ value)$

This function is comparable to the so-called disdrometry (DSD) function for rain drops and produces a frame of 36 semicolon-separated values defined as follow:

```
HAILSTONE;<counter>;<unit>;<hit_count>;<unit>;<unit>;<class>;<distrib>;
<class>;<distrib>;<class>;<distrib>;…;<class>;<distrib>
```

where `<counter>` is a frame counter incremented at each result
`<unit>` is the unit of the following values in the frame: “hit”
`<hit_count>` is the number of hailstones [hit]
`<unit>;<unit>` are the units of the following pairs of values in the frame: “mm;%”
`<class>` is the fixed hailstone size class in millimeters [mm] (see table below)
`<distrib>` is the percentage of hailstones within the class [%]

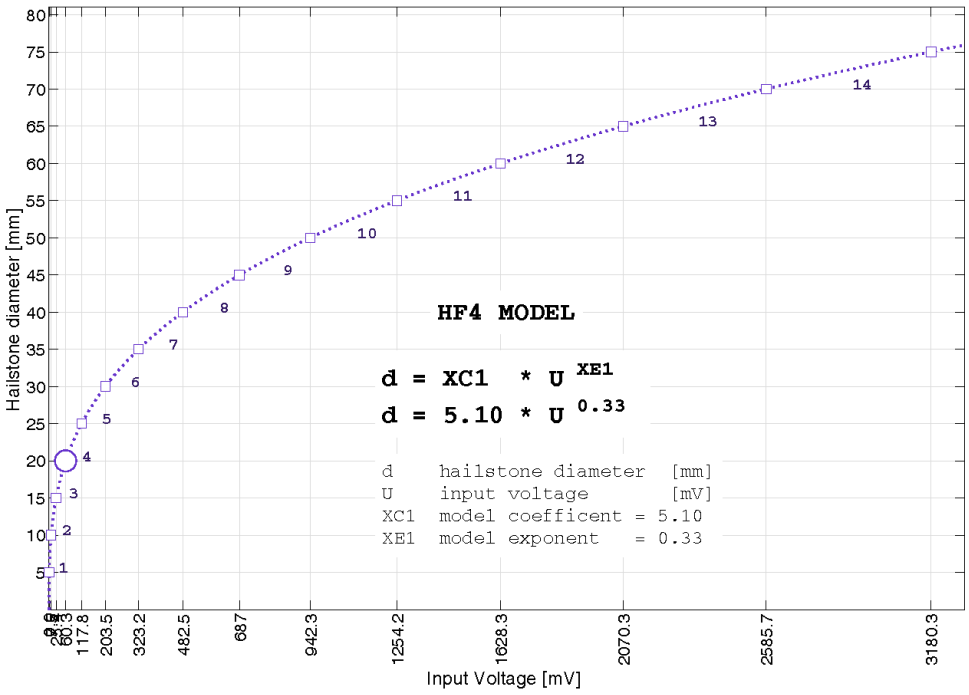
Example:

```
HAILSTONE;9322;hit;7;mm;%;10;0;15;0;20;0;25;0;30;0;35;14;40;14;45;29;50;
29;55;14;60;0;65;0;70;0;75;0;99;0
```

The next table gives the lower and upper markers values correspondence between voltage and diameter, with the factory default value (Note: for custom applications, the value of the coefficients can be modified in the Expert mode panel of the instrument's configuration utility).

Class #	Class Label	Hailstone Diameter prognosis D [mm]	Lower marker diameter D [mm]	Lower marker Input Voltage U [mV]	Higher marker diameter D [mm]	Higher marker Input Voltage U [mV]
1	10	5.0 ≤ D < 10.0	5	0.94	10	7.54
2	15	10.0 ≤ D < 15.0	10	7.54	15	25.44
3	20	15.0 ≤ D < 20.0	15	25.44	20	60.31
4	25	20.0 ≤ D < 25.0	20	60.31	25	117.79
5	30	25.0 ≤ D < 30.0	25	117.79	30	203.54
6	35	30.0 ≤ D < 35.0	30	203.54	35	323.22
7	40	35.0 ≤ D < 40.0	35	323.22	40	482.47
8	45	40.0 ≤ D < 45.0	40	482.47	45	686.95
9	50	45.0 ≤ D < 50.0	45	686.95	50	942.32
10	55	50.0 ≤ D < 55.0	50	942.32	55	1254.23
11	60	55.0 ≤ D < 60.0	55	1254.23	60	1628.33
12	65	60.0 ≤ D < 65.0	60	1628.33	65	2070.28
13	70	65.0 ≤ D < 70.0	65	2070.28	70	2585.73
14	75	70.0 ≤ D < 75.0	70	2585.73	75	3180.34
15	99	D ≥ 75.0	75	3180.34	n.c.	max. 3300

The next figure plots this linearization formula with the factory default value (Note: for custom applications, the value of the coefficients can be modified in the Expert panel of ISAW Toolbox software suite).



Considering the realty of the hailstone dynamics which is discussed in the other sections of this document and in reference [1], this linearization function must always be interpreted only as a nominal and theoretical classification, i.e. a classification corresponding to a-simplified and practically-oriented model.

E.6. Correspondence between output voltage and kinetic energy of an impact on the instrument

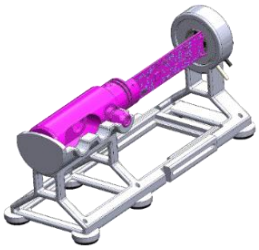
The table below proposes a summary of formulas to rely from the linearization function of the instrument with the kinetic energy relationships discussed in the first section from [1].

Peak amplitude voltage:	U *(as measured by HailFlow HF4)*	$[mV]$
Hailstone diam.prognosis:	$D = 0.1\ x\ 5.1 \times U^{0.33}$ *(as calc. by HailFlow HF4)*	$[cm]$
Hailstone diameter:	D_{max}	$[cm]$
Hailstone mass [1]:	$m = 0.34 \times {D_{max}}^{2.96}$	$[gram]$
Hailstone area [1]:	$A = 0.66 \times {D_{max}}^{1.74}$	$[cm2^2]$
Kinetic energy [1]:	$KE = 0.0374 \times {D_{max}}^{3.67}\ (for\ D < 2.3cm)$	$[J]$
Kinetic energy [1]:	$KE = 13.5 \times {D_{max}}^{0.63}\ \ (for\ D > 2.3cm)$	$[J]$
$Term.velocity, 1000\ HPa$ [1]:	$V\ t = 12.65 \times {D_{max}}^{0.65}\ \ (for\ D < 2.05\ cm)$	$[m/s]$
$Term.velocity, 1000\ HPa$ [1]:	$V\ t = 15.69 \times {D_{max}}^{0.35}\ \ (for\ D > 2.05\ cm)$	$[m/s]$
At other press. levels [1],	$V\ t\ approx. V\ t(1000) \times (1000/P)^{0.545}, KE\ approx. KE(1000)^{(1000/P)1.09}$	

Max. Amplitude Voltage Reading	HailFlow HF4 Lin. Function	Heymsfeld & Wright[1] Relationships																	
	D_{max} (cm) prognosis		Mass (grams)		Area (cm^2)		Term. vel V t, 1000 HPa				AVG KE, 1000 HPa				Distribution of KE Around median Values					
							for D_{max} < 2.05 cm		for D_{max} > 2.05 cm		for D_{max} < 2.3cm		for D_{max} > 2.3cm		KE Min.		KE Med.		KE Max.	
	XC1	XE1	XC2	XE2	XC3	XE3	XC4	XE4	XC5	XE5	XC6	XE6	XC7	XE7	XC8	XE8	XC9	XE9	XC10	XE10
	5.1	0.33	0.34	2.96	0.66	1.74	12.65	0.65	15.7	0.35	0.0374	3.67	13.5	0.63	0.0035	4.68	0.0189	4.43	0.0330	5.17
	$XCi*D_{max}^{XEi}$																			
6.4	0.9		2.49		0.6		12.2				0.03				0.00		0.01		0.02	
12.9	1.2		4.90		0.9		14.1				0.07				0.01		0.04		0.08	
25.8	1.5		9.64		1.3		16.4				0.16				0.02		0.11		0.26	
51.6	1.9		19.0		2.0		19.0				0.37				0.07		0.30		0.85	
103	2.4		37		2.9		21.2				23				0.19		0.84		2.76	
206	3.0		74		4.4		22.9				27				1		2.31		9.02	
413	3.7		145		6.5		24.9				31				2		6.38		29	
825	4.7		285		9.7		26.9				36				5		18		96	
1650	5.9		560		14.4		29.2				41				14		48		313	
3300	7.4		1103		21.4		31.6				48				41		133		1022	

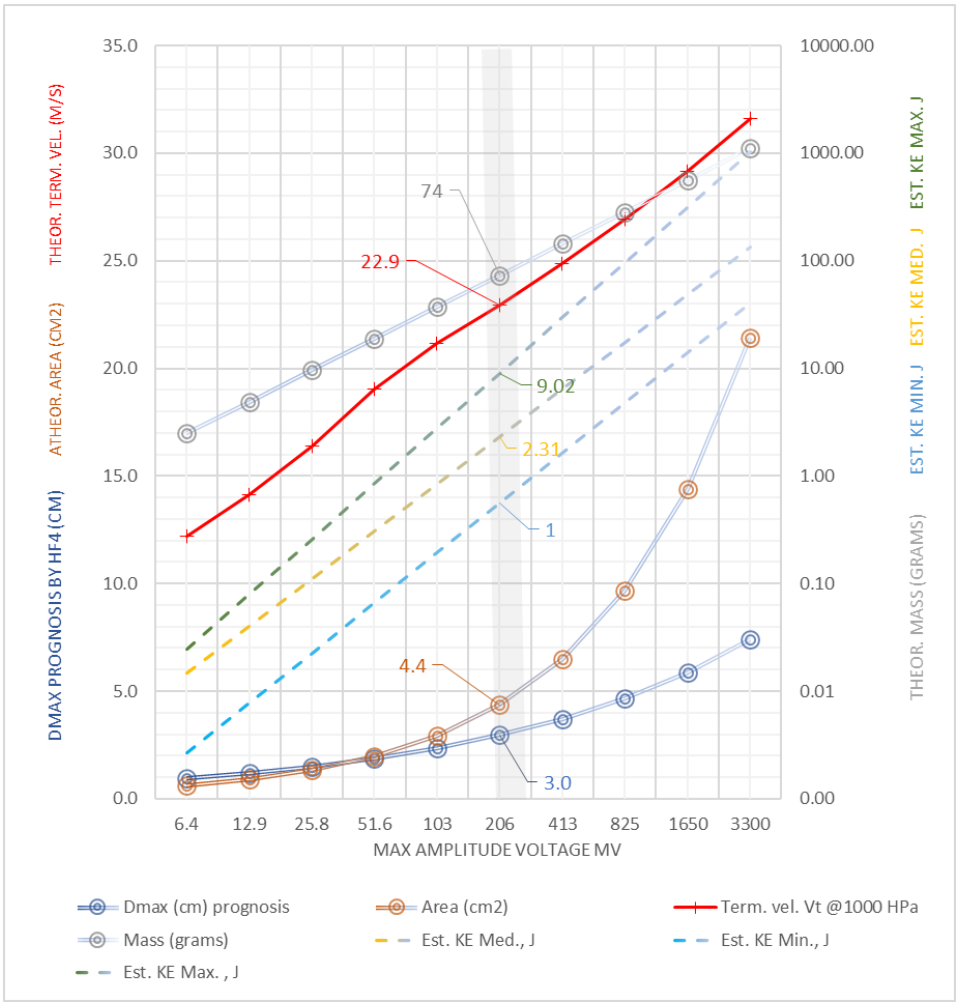
E.7. Calibration method of the instrument

The electronic and the mechanical response instrument is factory-calibrated individually and this for a lifetime duration so without requiring periodic recalibration.



This is performed trough a controlled vibroacoustic coupler and some artificial hailstone excitation of each instrument. The method produces the needed reference acoustics and vibration signals and the needed kinetic energy impacts excitations so that the whole sensitivity of the instrument can be set to the desired nominal reference sensitivity, with a precision and an accuracy of ±10 %.

As exposed in the previous sections, and as illustrated through the example graph below, extrapolated from the formulas and table of previous pages, even with a calibrated instrument, there are a considerable number of possibly high variability factors that are to be considered for a correct interpretation of hail data from a kinetic mode of operation instrument.



In particular, laboratory tests confirm that the larger-size and sharper shapes the hailstones, the more they break and explode during the impact on the instrument (Note: which is of a mechanical impedance similar to a wide range of usual construction materials concerned by hail damage). The transition typically occurs at about 20 to 30 mm size. In this “change of regime of shock”, i.e. when the hailstone doesn’t break the shock is more of a pure elastic nature, but when the hailstone breaks, the shock is more of an inelastic nature, in the breaking case a part of the kinetic energy of the shock is dissipated into the hailstone itself, and thus not transferred – so possibly underestimated – by the instrument.

This said, if in an optic of further relating the output data from the instrument to real effective damage (for instance for insurance or construction design matters), one may have to take into account that if the same happens with natural hailstones hitting a structure or construction of similar mechanical impedance, then the kinetic energy transferred to the structure or construction (and thus the effective damage) shall also reveal lower. So, in the end, **the measurement remains relatively precise and accurate with the potential for damage**.

Appendix F: DECLARATIONS

- EU DECLARATION OF CONFORMITY
- TREACABILITY AND CALIBRATION DECLARATION
- WMO APPLICABILITY

DECLARATION DE CONFORMITE UE
EU DECLARATION OF CONFORMITY

Nous | *We* **IAV Technologies SARL**
Chemin des Couleuvres 4A
CH-1295 TANNAY

ID: CHE-197.530.466

déclarons que les produits | *declare that the products*

Désignation *Name*	**Fabriqués depuis** *Manufactured since*	**Numéro de série S/N*** *Serial number S/N**
FlowCapt FC4	Jan. 2016	FC*YYBxxx*
SandFlow SF4	Jan. 2016	SF*YYBxxx*
RainFlow RF4	Jan. 2016	RF*YYBxxx*
HailFlow RF4	Jan. 2020	HF*YYBxxx*
WindFlow WF4	Jan. 2016	WF*YYBxxx*
USB Link Accessory (UDONG)	Jan. 2016	U*YYxxx*
Modbus Adapter (MOBUS)	Jan. 2020	MB*Bxxx*
4-20 mA Adapter (AD420)	Mar. 2024	A*YYxxx*
Extension Cable (EXT10)	Nov.2019	E*YYxxx*

* YY = Année de fabrication (2 chiffres) – *Year of manufacturing (2 digits)*
B = Numéro de batch (de A à Z) – *Batch number (from A to Z)*
xxx = Numéro de production dans le batch – *Production number in the batch*

auxquels se réfèrent cette déclaration, sont conformes aux prescriptions de la directive et des normes qualité suivantes | *to which this declaration relates, are in conformity with the requirements of the following directive and quality standards:*

2004/108/EU « Compatibilité électromagnétique », selon les standards suivants |***« Electromagnetic compatibility »****, using the following standards:*

EN 61326-1:2013 Matériels électriques de mesure, de commande et de laboratoire | *Electrical equipment for measurement, control and laboratory use.*

EN 55022:2010 Appareils de traitement de l'information - Caractéristiques des perturbations radioélectriques - Limites et méthodes de mesure |*Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement.*

2011/65/EU « Limitation de l'utilisation de certaines substances dangereuses dans les équipements électriques et électroniques », selon les standards suivants |***« Restriction of the use of certain hazardous substances in electrical and electronic equipment »****, using the following standards:*

EN 50581:2012 Documentation technique pour l'évaluation des produits électriques et électroniques par rapport à la restriction des substances dangereuses | *Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances.*

2006/42/CE « Machines », avec les qualités de composants électroniques et mécaniques suivantes | *« Machinery », with the following additional electrical/electronic and mechanical qualities:*

Parties électriques/électroniques : | *Electrical/electronic parts:*
- Production certifiée ISO9001 et ISO13485 (EN46001) |*ISO9001 and ISO13485 (EN46001) certified production*
- Assemblage conforme à RoHS |*RoHS compliant assembly*
- Contrôle final par échantillonnage AQL 0.65 pour les défauts majeurs et 1.00 pour les défauts mineurs |*Final control per sampling AQL 0.65 for major defects and 1.00 for minor defects*
- Référentiel qualité par défaut IPC-A-610, produits de classe II |*Default quality referential IPC-A-610, class II products.*

Parties mécaniques métal/plastiques | *Metal/plastic parts:*

- Production certifiée IQNet et SQS | *IQNet and SQS certified production*
- Acier certifié INOX 1.4301 2B / 316L 1.4404 1.4401 2B, soudures selon la norme ISO5817 Qualité D | *Certified stainless steel INOX 1.4301 2B / 316L 1.4404 1.4401 2B, welded process ISO5817 Quality D*
- Conformité plastique PET-C |*PET-C plastic conformity*: FDA 21 CFR 177.1630 2011/65/EU (RoHS2); 2015/863/EU (RoHS3); 1907/2006/EU (REACH)

Nous déclarons également que la personne autorisée à constituer le dossier technique est le chargé de projet de la société, basé au siège social de la société IAV Technologies SARL |*We also declare that the person authorized to produce the technical documentation is the project manager located at the IAV Technologies SARL Company.*

_____

Mis à jour à Tannay, le 1er avril 2024
Updated in Tannay on the 1st of April 2024

_____

Signatures autorisées et timbre :
Authorized signatures and stamp:

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ISAW PRODUCT
TRACEABILITY AND CALIBRATION DECLARATION

We, IAV Technologies SARL
Chemin des Couleuvres 4A
CH-1295 TANNAY

ID: CHE-197.530.466

hereby certify that all ISAW instruments: HailFlow HF4,
RainFlow RF4,
FlowCapt FC4,
SandFlow SF4
and WindFlow WF4

are delivered **factory calibrated** and accompanied by their individual calibration certificate.

The factory calibration is valid **for the entire lifetime of the instrument**. It consists of a calibration coefficient written in the internal memory of the instrument in a non-volatile and non-modifiable way. This calibration value is accessible anytime in the sensor parameters list.

This calibration is stored and remains valid even after a firmware update.

Should you wish to **check the instrument calibration**, IAV Technologies SARL has the exclusive right to perform this check. This operation requires the instrument to be returned to the factory, where it will be recalibrated and issued a new calibration value and a new individual calibration certificate.

Tannay, **May 16th, 2023,**

Vincent Chritin

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(Authorized signature)

WMO Applicability

The HailFlow HF4 kinetic-impact hail instrument (measuring solid precipitation, hail occurrence, hail intensity, or hailstone size) has been engineered in accordance with the key recommendations of the World Meteorological Organization (WMO) for the observation of solid precipitation, including hail occurrence, hail intensity and hailstone size. In particular,

- Its measurement principle, hailstone-size class reconstruction, impact-energy detection, and time-resolution performance comply with the guidance provided in WMO-No. 8 – Guide to Meteorological Instruments and Methods of Observation, particularly the sections addressing hail monitoring and impact-based detection methods.
- The HF4's factory calibration, lifetime-stable sensitivity coefficient and non-volatile configuration meet the requirements of WMO-No. 49 Technical Regulations for traceable, reliable, and well-documented meteorological instruments.
- Furthermore, the HF4 produces data fully compatible with WMO-No. 306 (BUFR) descriptors for hail occurrence and hailstone size, enabling integration into national and international observation networks.

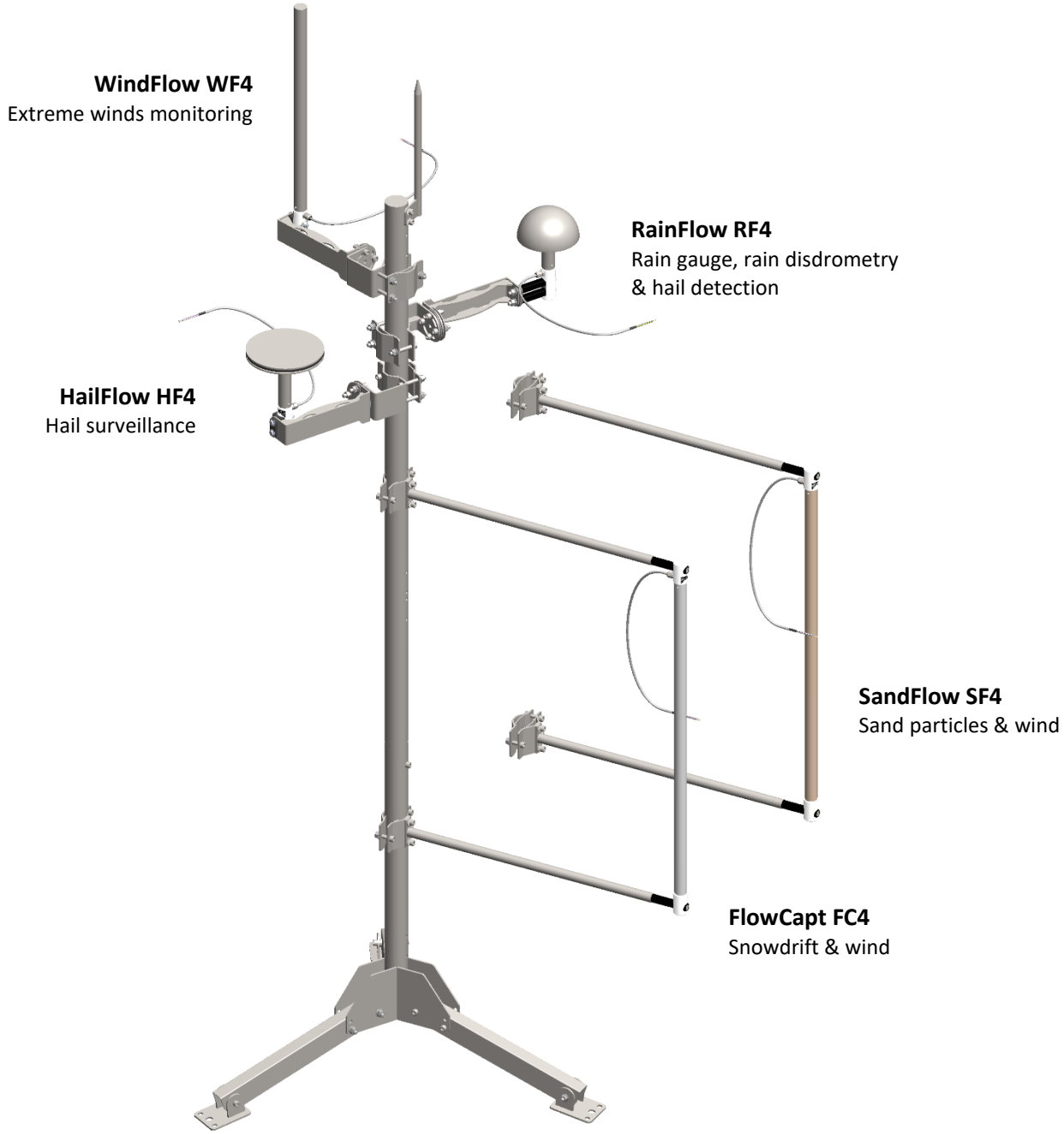
WMO Standard or Document	Applicability	Relevance to HailFlow HF4
WMO-No. 8	Primary	Hail detection, impact instruments, hailstone size estimation, siting, calibration
WMO-No. 49	High	Calibration traceability, technical requirements
WMO-No. 306 (BUFR/CREX)	Conditional	For networks transmitting HF4 hail data
WMO-No. 485	Medium	Hydrological use of hail observations
WMO SPICE & CIMO recommendations	High	Validation, comparison, hail impact physics
WMO QMF	Network-level	Data quality management

WMO Standards Applicable to HailFlow HF4

As such, the HailFlow HF4 satisfies WMO guidance for high-quality and scientifically robust hail monitoring applications.

Appendix G: ISAW INSTRUMENTS OVERVIEW

A total of five instruments is available as ISAW ultra-specialized instruments for the monitoring of solid and liquid precipitation, as well as aeolian blowing particles.



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