



# Instruction Manual

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## DustIQ • Soiling Measurement

Applicable to all models. **Please check regularly for updates.**

# 1. Important user information

Dear customer, thank you for purchasing a Kipp & Zonen instrument. It is essential that you read this manual completely for a full understanding of the proper and safe installation, use, maintenance and operation of your DustIQ.

We understand that no instruction manual is perfect, so should you have any comments regarding this manual we will be pleased to receive them at:

## **Kipp & Zonen B.V.**

Delftechpark 36, 2628 XH Delft, or  
P.O. Box 507, 2600 AM Delft  
The Netherlands  
Tel. +31 15 2755 210  
support@kippzonen.com  
www.kippzonen.com

## **Warranty and liability**

Kipp & Zonen guarantees that the product delivered has been thoroughly tested to ensure that it meets its published specifications. The warranty included in the conditions of delivery is valid only if the product has been installed and used according to the instructions supplied by Kipp & Zonen.

Kipp & Zonen shall in no event be liable for incidental or consequential damages, including without limitation, lost profits, loss of income, loss of business opportunities, loss of use and other related exposures, however incurred, rising from the faulty and incorrect use of the product.

Modifications made by the user may affect the instrument performance, void the warranty, or affect the validity of the CE declaration or other approvals and compliances to applicable International Standards.

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Kipp & Zonen reserves the right to make changes to this manual, brochures, specifications and other product documentation without prior notice.

Publication date: April 2019

## **Important changes:**

- Full Feature version with tilt sensor, PV panel temperature sensor and daisy-chain capabilities added.
- DustIQ height reduced from 40 to 35mm starting with serial number 180094
- Added status and calibration context flags and stored in Modbus® registers
- Increased minimum irradiation for local dust calibration to 800 W/m<sup>2</sup>
- Added remark that 5% transmission loss for local dust calibration equals 50 ‰ in Modbus register 21.



## Declaration of Conformity



**Kipp & Zonen B.V.**  
Delftechpark 36, 2628 XH Delft  
P.O. Box 507, 2600 AM Delft  
The Netherlands

declares under our sole responsibility that the product

**DustIQ**  
0386900

complies to  
[EMC - FCC] **Title 47CFR part 15**

Delft, 5 February 2018

A handwritten signature in blue ink, appearing to be "E. Valks", written over a horizontal line.

E. Valks - CEO  
Kipp & Zonen B.V.



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P.O. Box 507, 2600 AM Delft  
The Netherlands

declares under our sole responsibility that the product

### **DustIQ**

0386910 and 0386915

to which this declaration relates, is in conformity with European Harmonised Standards  
as published in the Official Journal of the EU, based on the following standard

[EMC - Emissions] **EN 61326-1:2013**

[EMC - Immunity] **EN 61326-1:2013**

[Environmental Affairs] **IEC 60529, IP65**

following the provisions

EMC-directive **2014/30/EU**

RoHS Directive **2011/65/EU**

also, complies to

[EMC - FCC] **Title 47CFR part 15**

Delft, November 2018

A handwritten signature in blue ink, appearing to be "E. Valks".

E. Valks - CEO

Kipp & Zonen B.V.

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## 2. Introduction

Reading this entire manual is recommended for a full understanding of this product..



The triangle with exclamation mark is intended to alert the user to the presence of important installation, operating and maintenance instructions in the literature accompanying the instrument.



This electrical equipment should only be serviced by authorized personnel, meaning people who have been trained and designated as “authorized” by their employers.

### Note

Useful information for the user

### 2.1. Safety precautions

Many hazards are associated with installing and maintaining instruments on towers or elevated structures. It is advised to use qualified personnel for installation and maintenance. The client is responsible for following the local safety regulations. The use of appropriate equipment and safety practices is mandatory. Check your company's safety procedure and protective equipment prior to performing any work. ) If the DustIQ is mounted at a high position, special care must be taken to secure both the person installing it and the instrument from falling during installation.



Since the DustIQ weighs 4kg, contains glass and is comparable to a regular PV panel it is advised to use the same safety precautions as the ones used for fitting regular PV panels.

While every attempt is made to get the highest degree of safety in our products, the client assumes all risk from injuries resulting from improper installation, use or maintenance of the DustIQ.

### 2.2. Waste disposal



The pictogram showing a waste bin with a cross means that the product is subject to European Union regulations covering segregated waste disposal. This applies both to the product itself and to any accessories marked with the same symbol. Disposal of any such item as unsorted domestic waste is not allowed.

### 2.3. Customer support

In case you need support, please contact:

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[support@kippzonen.com](mailto:support@kippzonen.com)

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### 2.4. Warranty and liability

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Kipp & Zonen shall in no event be liable for incidental or consequential damages, including without limitation, lost profits, loss of income, loss of business opportunities, loss of use and other related exposures, however incurred, arising from the incorrect use of the product. Modifications made by the user can affect the validity of the CE or FCC declaration.

### 3. Product overview

This manual, together with the updated Smart Explorer manual and instruction sheet, provides information related to the installation, maintenance, calibration, product specifications and applications of the DustIQ panel soiling monitor.

If any questions should remain, please contact your local Kipp & Zonen representative or e-mail the Kipp & Zonen customer and product support department at: [support@kippzonen.com](mailto:support@kippzonen.com)

Please go to [www.kippzonen.com](http://www.kippzonen.com) for information about other Kipp & Zonen products, or to check for any updates to this manual or software.

#### 3.1. The DustIQ soiling measurement instrument

The DustIQ instrument is a unique, high quality instrument designed for measuring the light loss resulting from the soiling of the panel. The measured light loss is an indication for the losses introduced by the soiling of the nearby PV panels too.

The DustIQ instrument features internal digital signal processing and interfaces optimised for industrial data acquisition and control systems. Kipp & Zonen has developed a smart interface that features RS-485 Modbus® data communication for connection to programmable logic controllers (PLC's), inverters, digital control equipment and digital data loggers.

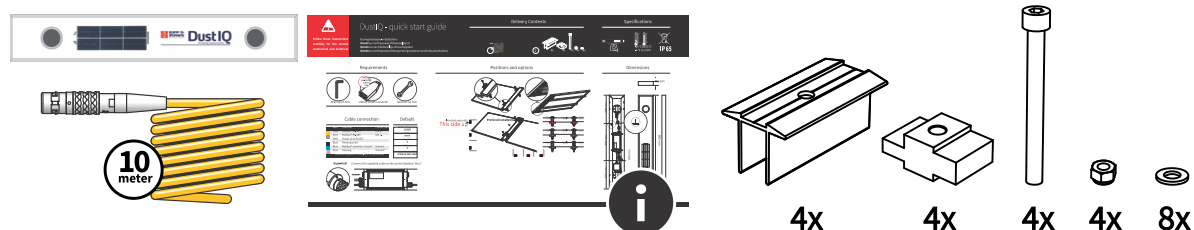
To achieve the required accuracy, the amount of reflected light is precisely measured and combined with the local dust calibration that has to be performed, the right light loss is calculated.

The DustIQ panel soiling monitors are normally delivered with a 10m UV resistant cable with an 8 pin plug on the instrument side and wire ends on the other side. Longer 25m and 50m cables will become available as well.

#### 3.2. Included with the product

Check the contents of the shipment for completeness (see below) and note whether any damage has occurred during transport. If there is damage, a claim should be filed with the carrier immediately. In the case of damage and/or the contents are incomplete, contact your local Kipp & Zonen representative or e-mail the Kipp & Zonen customer and product support department at: [support@kippzonen.com](mailto:support@kippzonen.com)

**Contents of part number 0386900 and 0386910: DustIQ panel, 4 mounting clamps with bolts, washers and nuts, instruction sheet, 10 m cable to the host or SCADA system.**



**The 0386915 model comes without standard cable and the cable (10, 25, 50, 100m to host or 5,10m daisy-chain) or the just the ODU connector must be ordered separately.**

Although all DustIQ instruments are weatherproof and suitable for use in harsh environmental conditions, they have some delicate mechanical parts. Please keep the original packaging for safe transport of the instrument to the measurement site, or for use when returning the instrument for possible repair or recalibration.

#### 3.3. Intended use

The DustIQ instrument is an instrument meant to measure and report the transmission loss (TL) and soiling ratio (SR) caused by light being blocked and reflected and subsequently not getting through the glass of the panel due to soiling of the panel.

The DustIQ is meant to be mounted next to and in the same plane as the PV panels in the solar park. The instrument is fully waterproof (IP65) and can be cleaned in the same way as the PV panels are cleaned, both wet and dry.

Communication is possible via Modbus® RTU using a RS485 2-wire connection and the power supply needed is 12 to 30 V and max 300 mA.



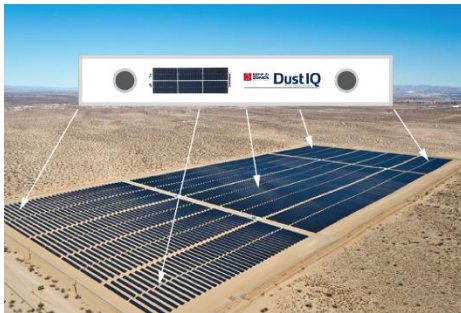
## 4. Planning the installation and use of the DustIQ

This chapter describes the best locations to place the DustIQ's and how to make the best of the acquired data.

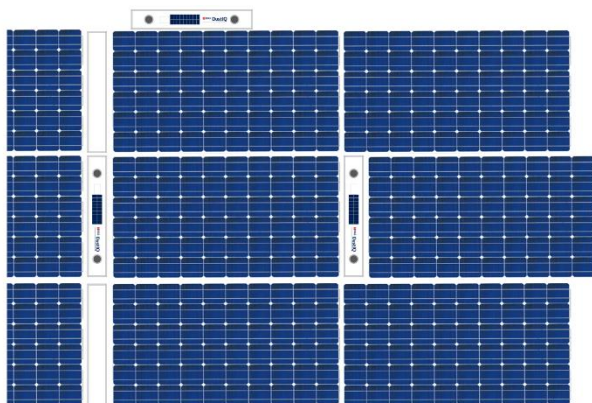
### 4.1. Where to place DustIQ in the PV plant

Measuring dust and soiling ratio is a new field of science. There are many opinions about it, but there is no large history of data and experience in measurements. Although the spot measurement of DustIQ is very precise, it is wise to do interpretation and use common sense when extrapolating the measurement value to the whole PV plant, or a part of it, for decision making. The measurement value thus is true, the only question is, whether this value is representative for the PV park.

For giving a good representation of soiling across the PV plant, one should place multiple DustIQ's across the plant. In fact, the IEC61724-1:2017 Standard for PV system performance (Monitoring) prescribes that one should have as many dust-sensors as irradiance sensors. This makes intuitive sense: it follows the same logic as irradiance that also is not constant across a solar plant, and one has to have sufficient measurements to make a valid interpretation. For the number of DustIQ's, one can thus follow the own policy for the number of pyranometers. Of course, every additional DustIQ adds up to a better overall measurement. For 1 MW plants, 1 DustIQ placed in the middle could do, whereas for larger plants – say 25 MW- one could imagine the one in the middle, and one near each corner could be a logical choice to understand the soiling pattern across the plant.



Soiling is a different phenomenon than irradiation, and also very site specific. Where you normally expect the same average irradiation value for all pyranometers at a solar plant, this is not necessarily true for DustIQ's: if the wind always blows from the east, one could expect more soiling (and thus another cleaning interval policy) at the east side of that solar plant. When wind direction changes over seasons, this pattern could shift during the year. Also, it is known that the very ends of an array, and the bottom row of an array (closest to the ground), typically suffer more from soiling than the rest of the PV modules. Therefore, better not place DustIQ's here for cleaning policy, unless your purpose is to learn and study soiling behaviour.



Again, soiling is a new scientific area, especially when applied to solar plants. Kipp & Zonen will build up the application data base along with the users, in order to set standards for best practices. When installing the DustIQ's, it makes sense to follow up the instrument readings over a period of weeks, and do visual inspection as to reassure yourself on representative values. DustIQ is designed in such a way, that you can easily dismount it, and put it at another location, where you trust it to give the most representative information for your purpose. DustIQ's can be placed at the side, and at the top of PV modules, in the middle of an array or at the sides. For a next release in 2018, Kipp & Zonen has scheduled to introduce DustIQ-array-fillers, in order to install the DustIQ in the middle of a row and in the middle of an array, without making gaps in the array.

## 5. How to value dust measurements

Measuring dust is a new area with new challenges. Below are a few of them explained.

### 5.1. Introduction

DustIQ is not an indicator of dust, but a real accurate measurement device, in line with all Kipp & Zonen instruments. The DustIQ measurement technology is unprecedented and new to the market. Therefore some extra words for the user of the measurement information.

One should understand that measuring physical quantities needs careful interpretation. Measuring voltage or velocity can be done very precise, and the answer is always very close to the truth. Influenced only by the accuracy of the used instrument. Much more difficult it gets for instance with precipitation or solar radiation measurements; there is an intrinsic limit as to how precise one can measure it and with which uncertainty.

Measuring dust / transmission loss /soiling ratio is a new field of science. There are many opinions about it, but there is no large history of data and experience in measurements. Although the spot measurement of DustIQ is very precise, it is wise to do interpretation and use common sense when extrapolating the measurement value to the whole PV plant, or a part of it, for decision-making. The coming years, Kipp & Zonen will build up this expertise together with you and our other customers and scientific users. Visual inspection seems the most logical validation for understanding and extrapolating the dust measurement information. Before decision making and taking cost intensive cleaning actions, it is recommended to do visual inspection: is the DustIQ device soiled in the same way as the average soiling on the PV modules? What helps in data validity, is the fact that the DustIQ is designed to handle local irregularities of soiling, and that the DustIQ has two measurement sensors, so one can compare the values.

For larger areas, it is wise to mount several DustIQ's, just like you now mount several pyranometers across a PV plant. Again: for DustIQ's, one can trust the measurement value to be correct, the only judgement you have to make, is, whether this value is representative for the whole PV park.

### 5.2. Solar angle dependency

The actual transmission loss and soiling ratio have a solar angle dependency. The DustIQ is not aware of the solar angle, but based on our initial test results and literature research we have two simple formulas to calculate the daily SR and TL averages.

$$SR_{DAILY\_AVERAGE} = 1.2 \times SR_{DUSTIQ} - 20 \quad \text{and} \quad TL_{DAILY\_AVERAGE} = 1.2 \times TL_{DUSTIQ}$$

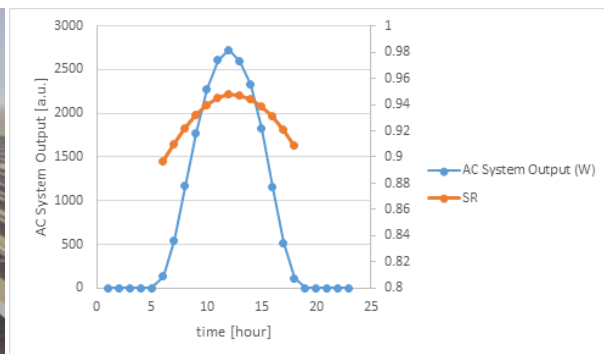
**Background:** For the customer a very useful value is to know the weighted average value for the Soiling Ratio over a day. Such a weighted average value is also prescribed by the IEC 61724-1 norm (page 30). We have chosen a weighting by PV power output over the course of the day.

For this calculation, we have chosen multiple locations:

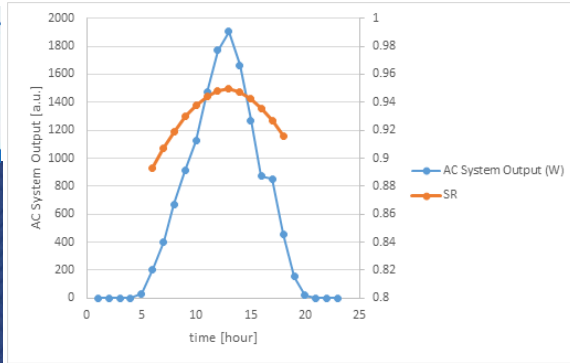
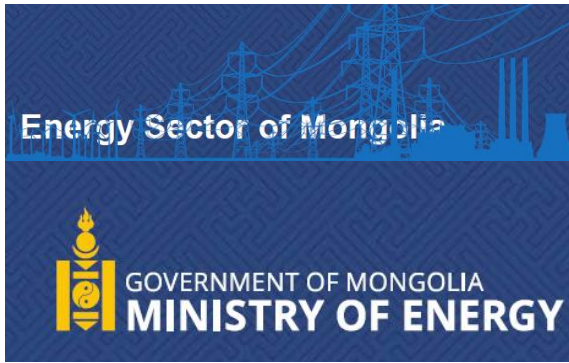
- 1) Close to the Dubai Mohammed bin Rashid Al Maktoum Solar Park in Dubai.
- 2) Close to planned new Solar Park in Baganuur near Ulaanbatur in Mongolia.



Dubai Mohammed bin Rashid Al Maktoum Solar Park  
We assumed the panels are mounted at 22° degrees in Dubai



Hypothetical PV AC output at the 8th of August 2017 in Dubai  
and soiling ratio (SR) over the day

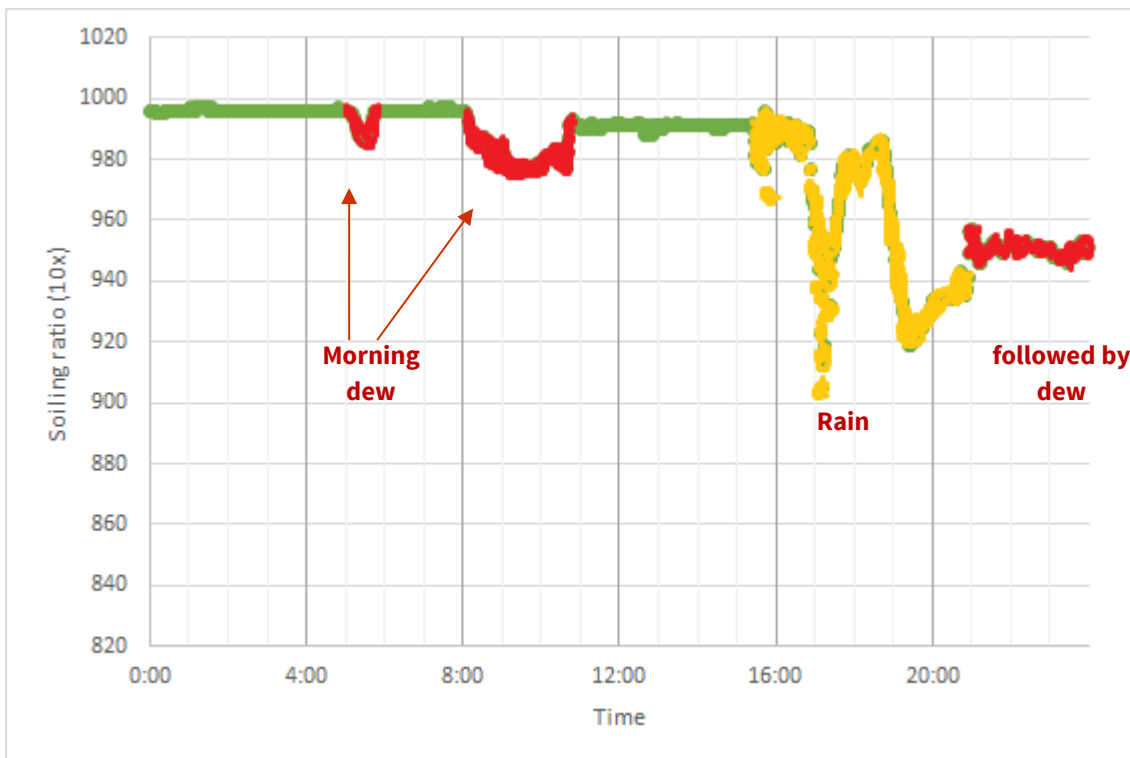


Hypothetical PV AC output at the 6th of august 2017 in Mongolia and SR over the day.

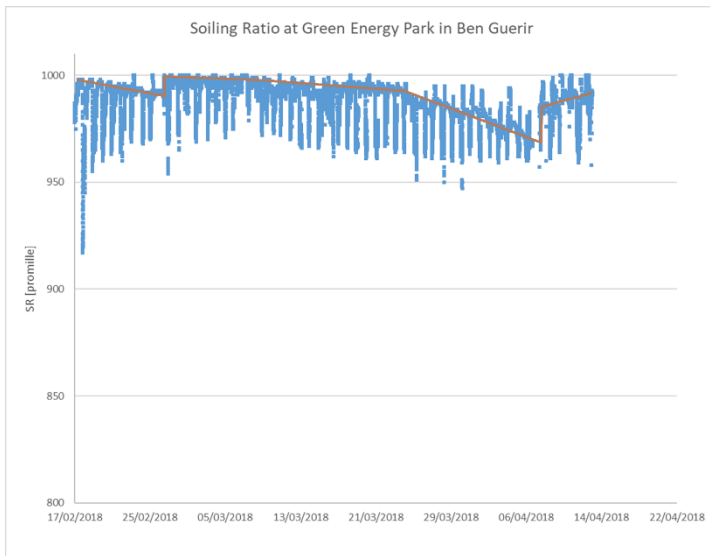
Combining the information from both graphs, we calculated the  $SR_{DAILY\_AVERAGE}$  weighted by the PV output for both locations and concluded that there is very little difference between Dubai (latitude= 24.4) and Mongolia (latitude = 47.9)

### 5.3. The influence of dew and rain

The DustIQ measurement are sensitive to dew and rain and measurements done during these conditions should better be ignored.

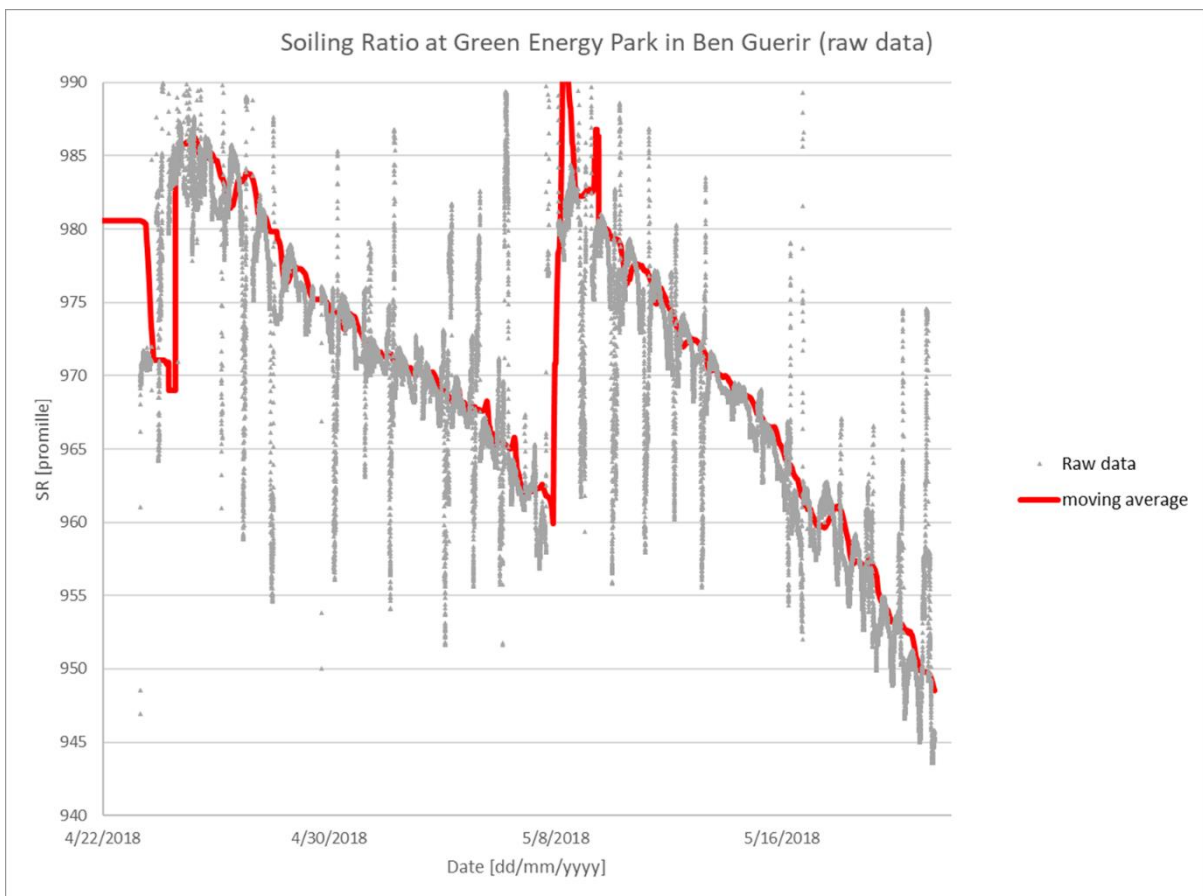


It's the trend line over a longer period of time that gives the best overview of the transmission loss.



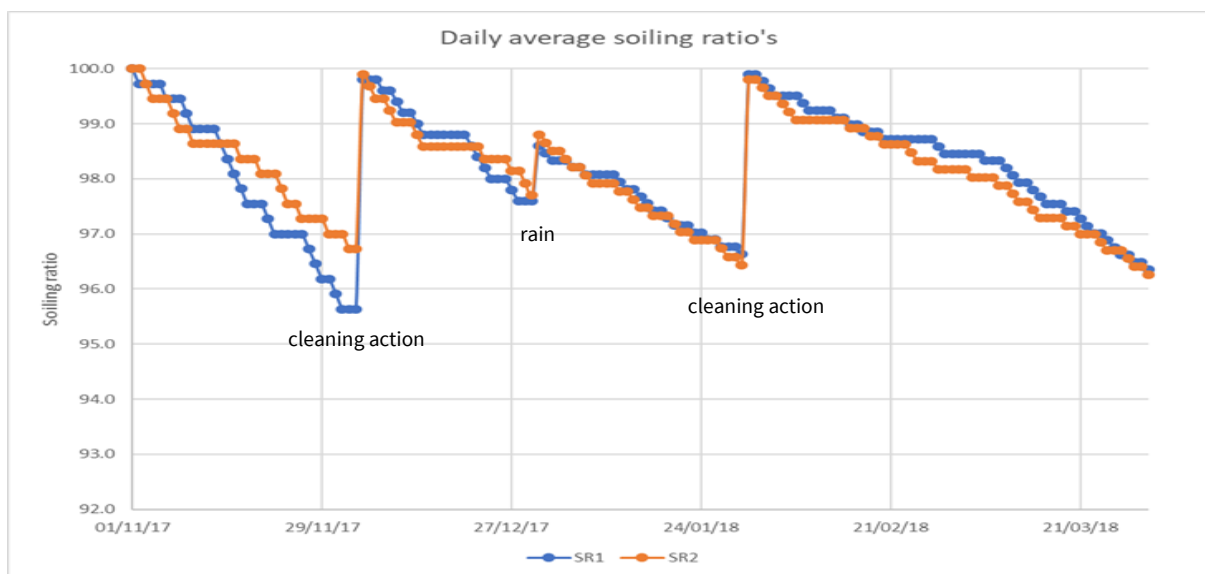
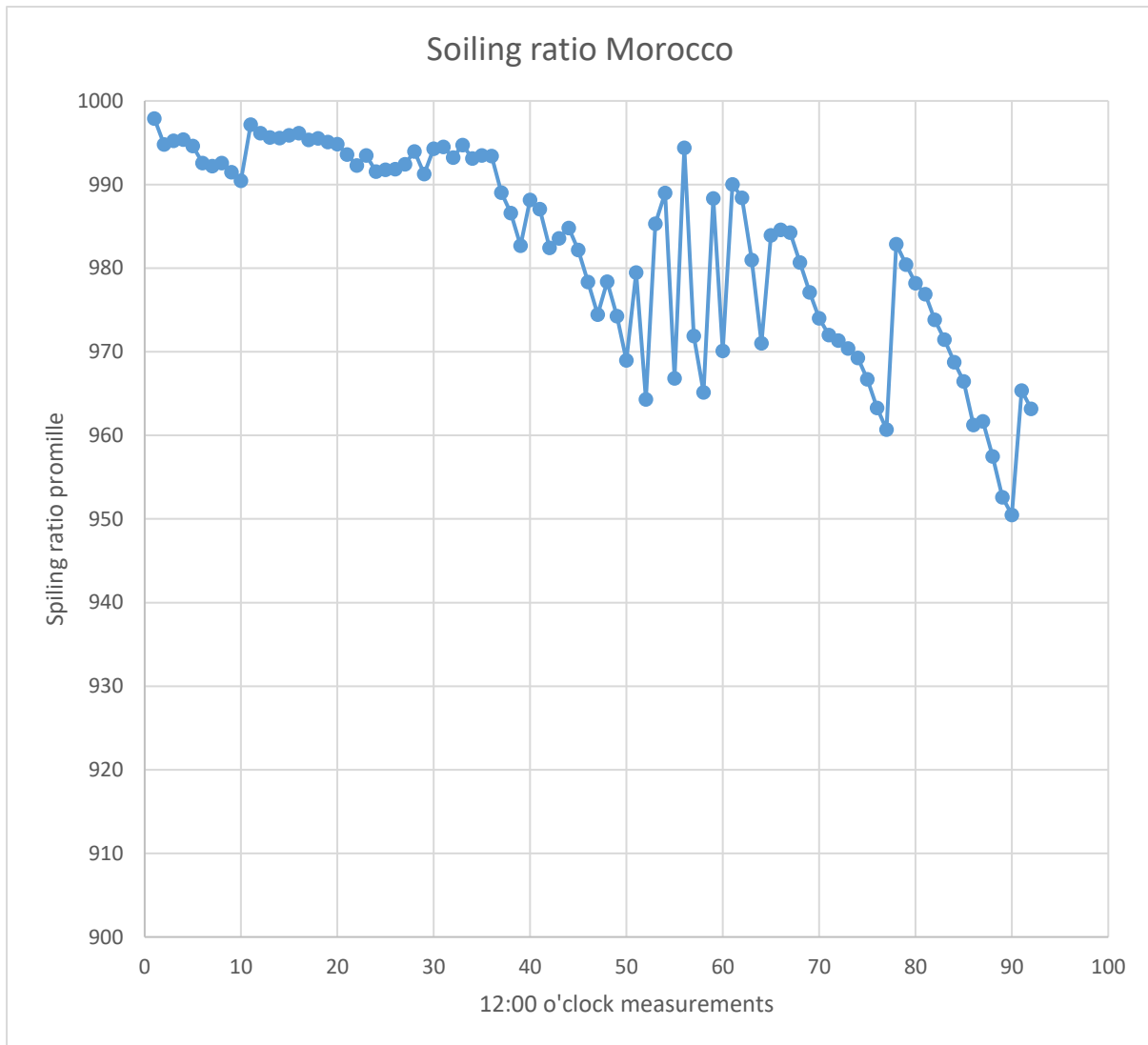
The spikes visible are due to morning and evening dew. The bigger, longer lasting changes are the result of rain cleaning the panel.

The DustIQ performs a measurement every minute but since the accumulation of dust is a slow process one doesn't need to read and record a measurement every minute and by using data from a weather station it is possible to select enough valuable measurements per day to show the soiling build up trend line.



The above sample data shows the data collected in Morocco with daily dew and occasional rain. Still the trendline in soiling build-up is clearly visible.

Taking only few measurements per day improves the readability of the chart.



## 6. Installation

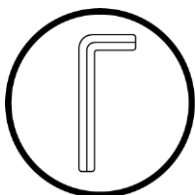
Please follow the instructions in this section carefully for the mechanical and electrical installation of the DustIQ.



Do not turn on power to the instrument,  
Do not connect the instrument to a computer,  
Do not turn on power to the operating computer until instructed to do so.

### 6.1. Tools required

The tools required to fit the DustIQ instrument to a PV panel are:



Allen key 6 mm



Spanner 13 mm

The tools required to change the default DustIQ settings are:



A type of USB-RS485 converter that supports half duplex 2-wire connections and preferably has optical isolation for increased safety and reliability.

DustExplorer software will be available from <http://www.kippzonen.com/download>

### 6.2. Pre-installation

If changing the settings from the factory default of is needed then it is advised to set the Modbus® address **prior** to visiting the site, otherwise a computer and RS-485 / USB converter may be required during installation. The Dust Explorer software needed for setting the Modbus address is available on the Kipp & Zonen website in the download section. Please perform the following steps without mounting the DustIQ and leaving it on your desk before moving the DustIQ outside.

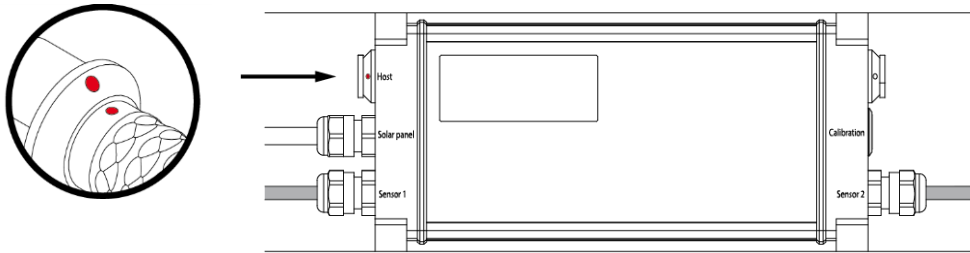
The DustIQ comes with the following **factory defaults**:

- Modbus baud rate: 19200
- Parity: even
- Data bits: 8
- Stop bits: 1
- Address: 1
- Local dust profile: Arizona test dust

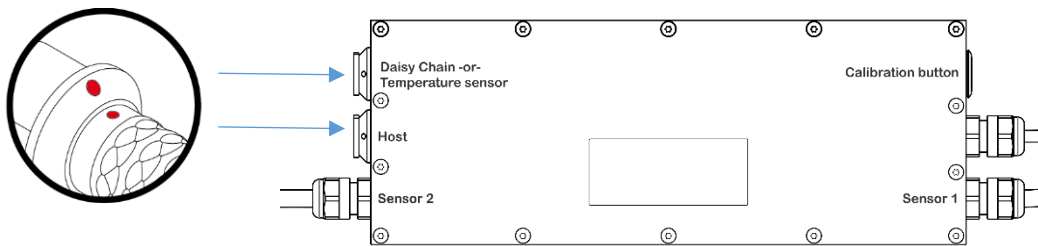
### 6.3. Connecting the cables to the DustIQ

Connect the supplied or locally made data cable to the socket labelled **Host**.

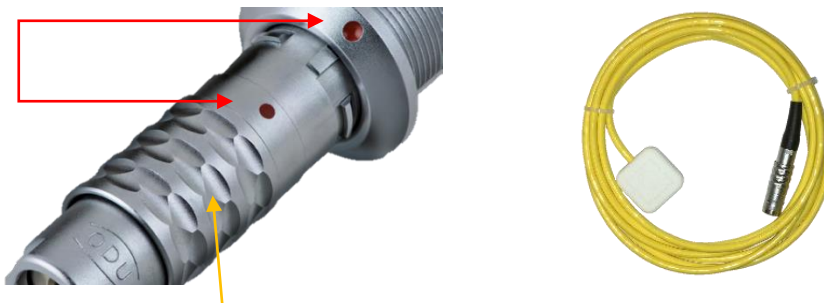
First released model Pn 0386900 that doesn't support daisy-chaining or PV panel temperature sensor.



Full feature models Pn 0386910 and 0386915.



Locate the 8 pin ODU plug correctly in the DustIQ socket, it only fits one way. The red dot on the plug should be opposite of the red dot on the chassis part. Push it in to secure whilst holding the plug by the end or by the grooved ring.

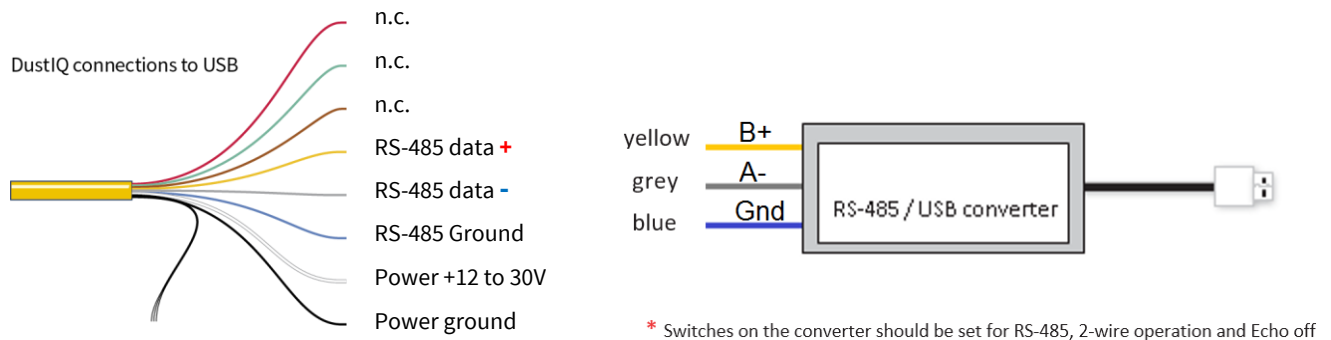


To unplug, pull the grooved ring back and then pull out the plug.

**Note** Do not remove the backing of the double sided tape of the sensor itself as it the sensor will stick extremely well and is very hard if not impossible to remove.

## 6.4. Connecting the cable to the USB converter and power supply

When using an industry standard USB-RS485 converter the following connections need to be made.



The minimum power supply voltage for the DustIQ instrument is 12 VDC. However, for reliable performance it is advised to use 16-24 VDC, especially when longer cables are used or if DustIQ's are daisy-chained.

**Note** It is advised to protect the output of the power supply with a fast blowing fuse of maximum 500 mA rating.

### Typical power consumption of the DustIQ instrument

12 VDC	60 mA LEDs off – 130 mA LEDs on, std duty cycle 5%
24 VDC	40 mA LEDs off – 70 mA LEDs on, std duty cycle 5%

Maximum average power consumption over a minute is 1,000 mW at 24V and 800 mW at 12 V.  
 Maximum input current is 150 mA at 12 V voltage.  
 Maximum inrush current is 10A for 50µs.

## 6.5. Connecting the cable to the UPM485 interface box

This dedicated USB & battery converter option will be available later.



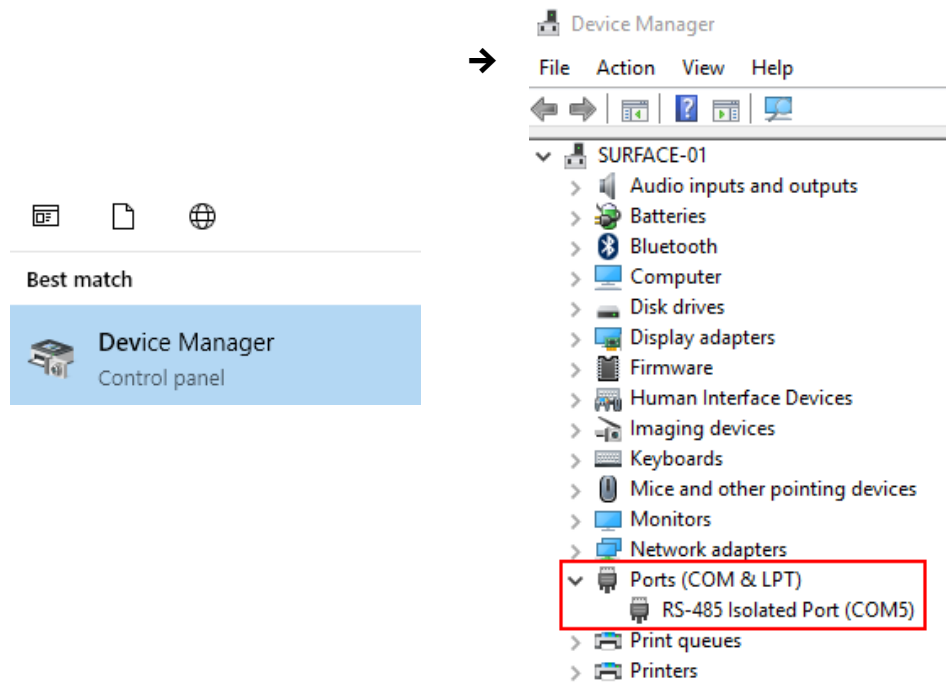
## 6.6. Changing the settings of the DustIQ

For changing the DustIQ settings the Smart DustIQ Explorer software is needed as well as one connected DustIQ.

### 6.6.1. Finding the COM port

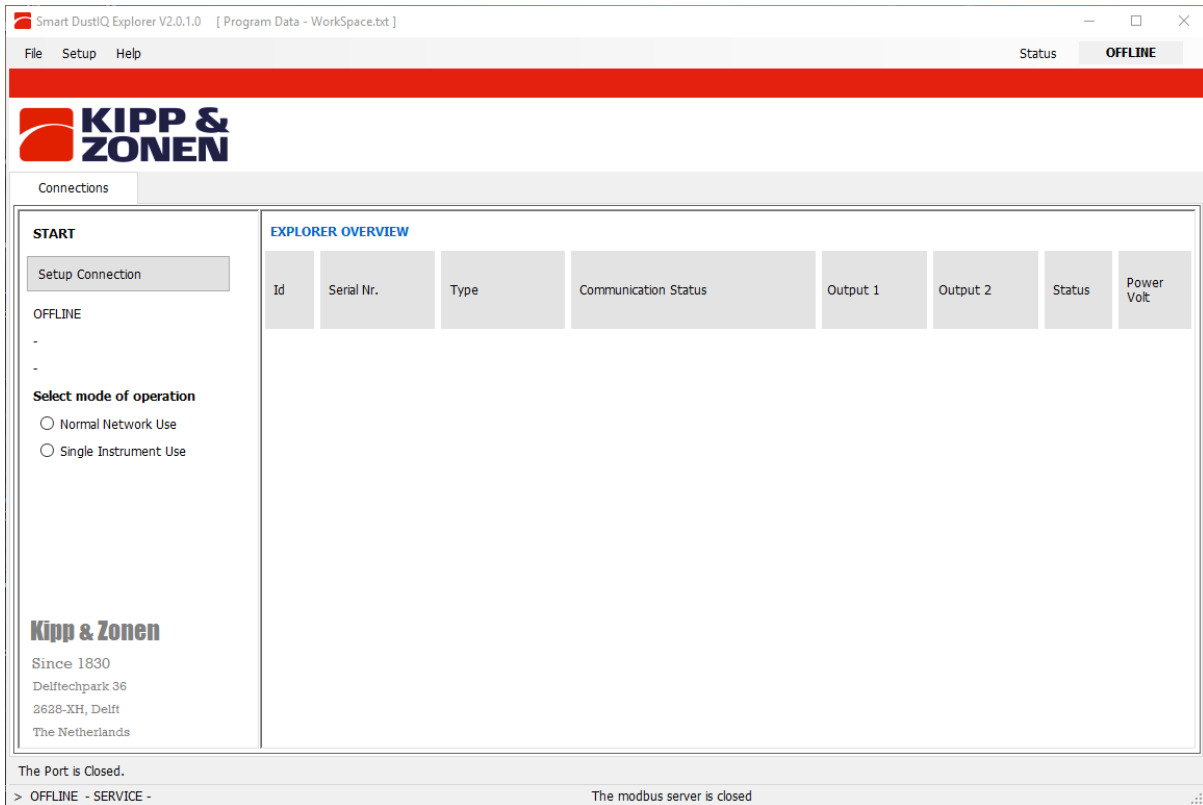
After starting the Dust Explorer software the user needs to select the right COM port on which your USB-RS-485 converter has been installed by the Windows® 7, 8 or 10 operating system.

One way of checking the COM port number is by using the standard Windows Device Manager via Control Panel



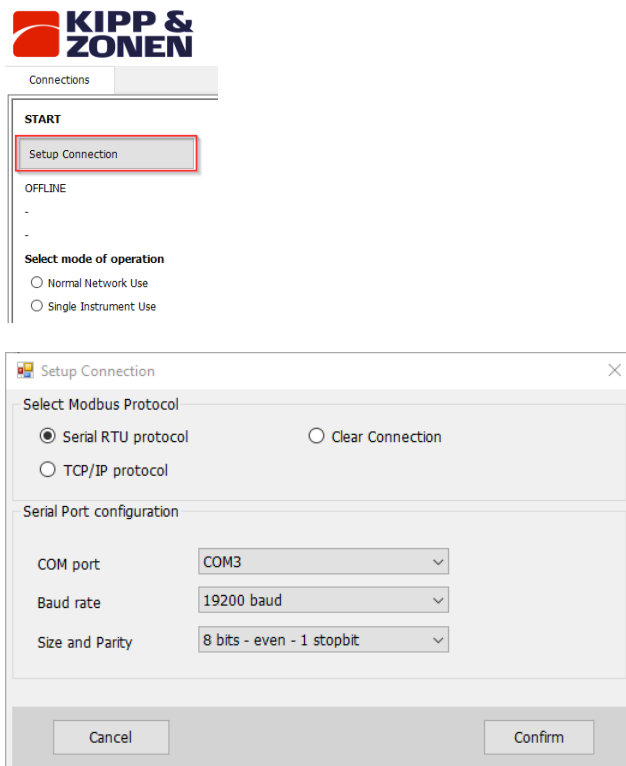
## 6.6.2. First start up

After the first start of the Smart DustIQ Explorer **V2.0.1.0** software the window below will appear:



## 6.6.3. Configuring the settings

In order to connect to the DustIQ: click on Setup Connection



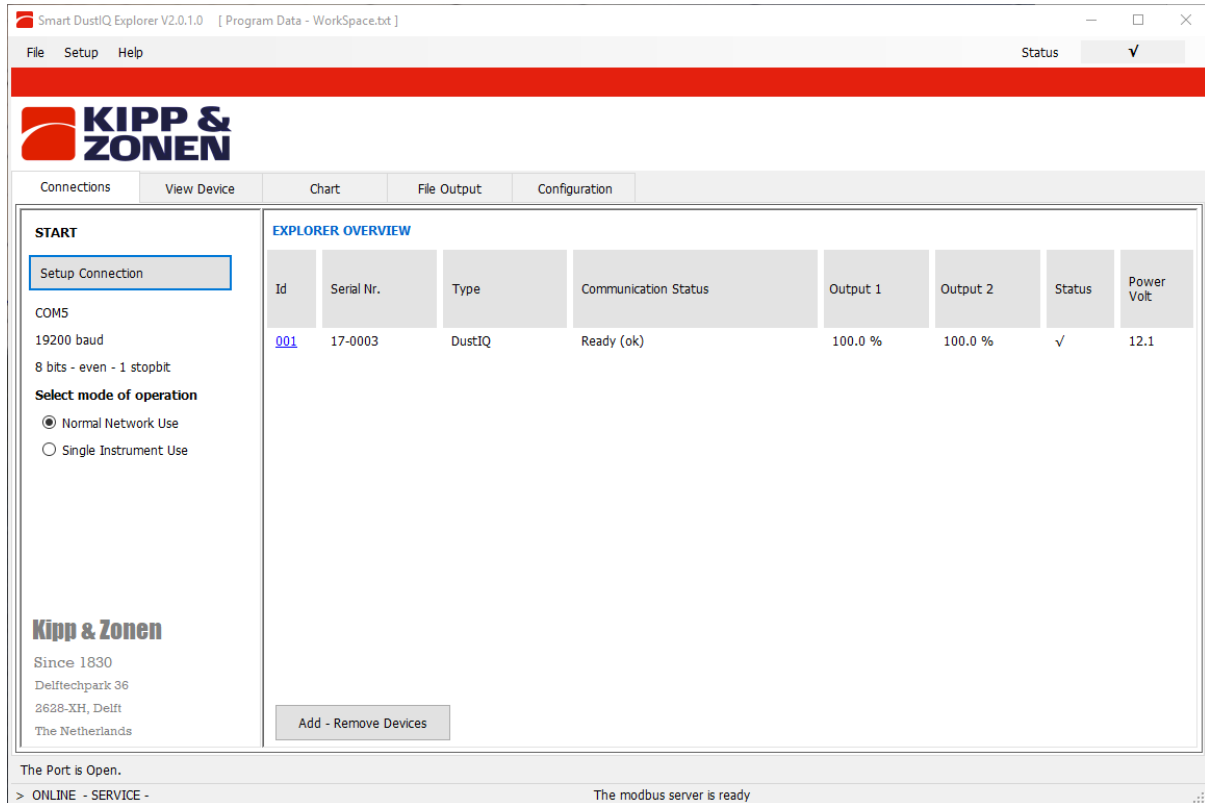
Select Serial RTU protocol for the direct RS485 connection that you're using.  
Select the COM port you found in the Windows Device Manager.  
Leave the other settings unchanged as these are the factory defaults for all Kipp & Zonen products.

If you have changed the settings and return to the Smart DustIQ Explorer you have to change the settings to the ones used by your instrument.

Click **Confirm** to save and use the settings.

#### 6.6.4. Main window - connections

Once the Dust Explorer software can communicate with the attached DustIQ, the following window appears:

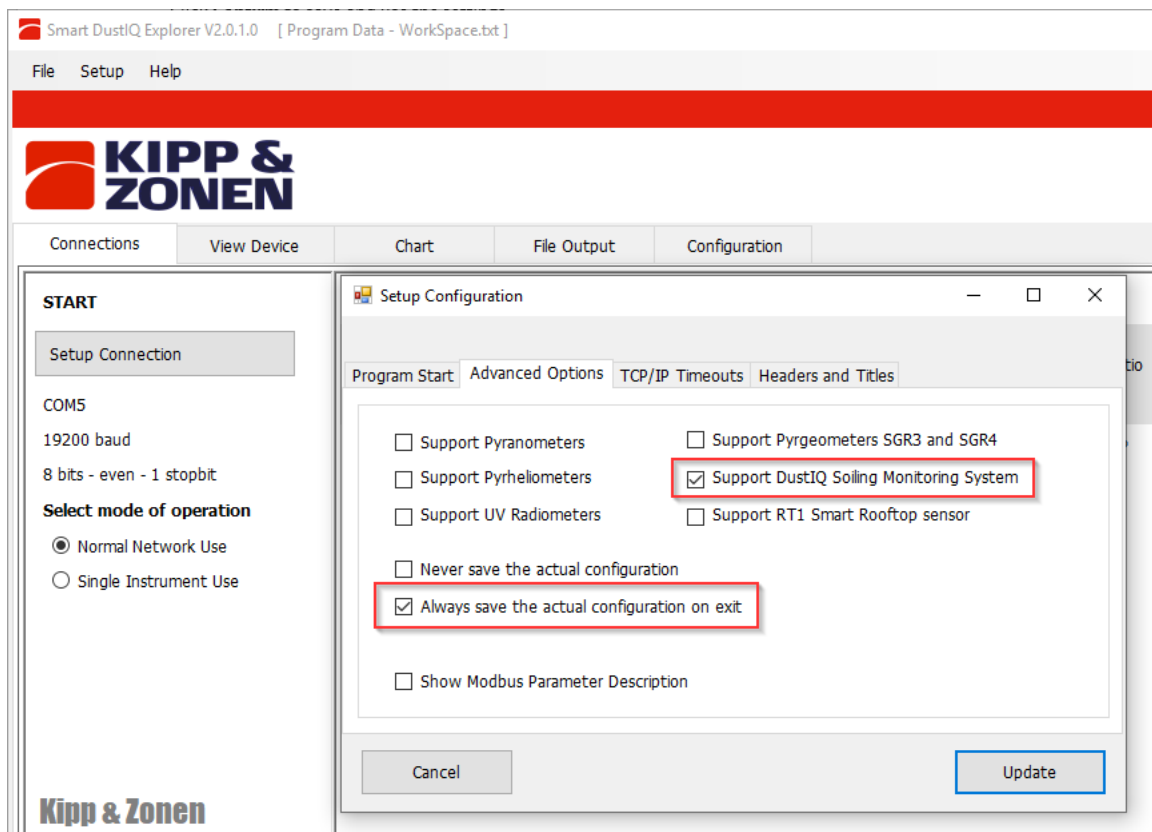
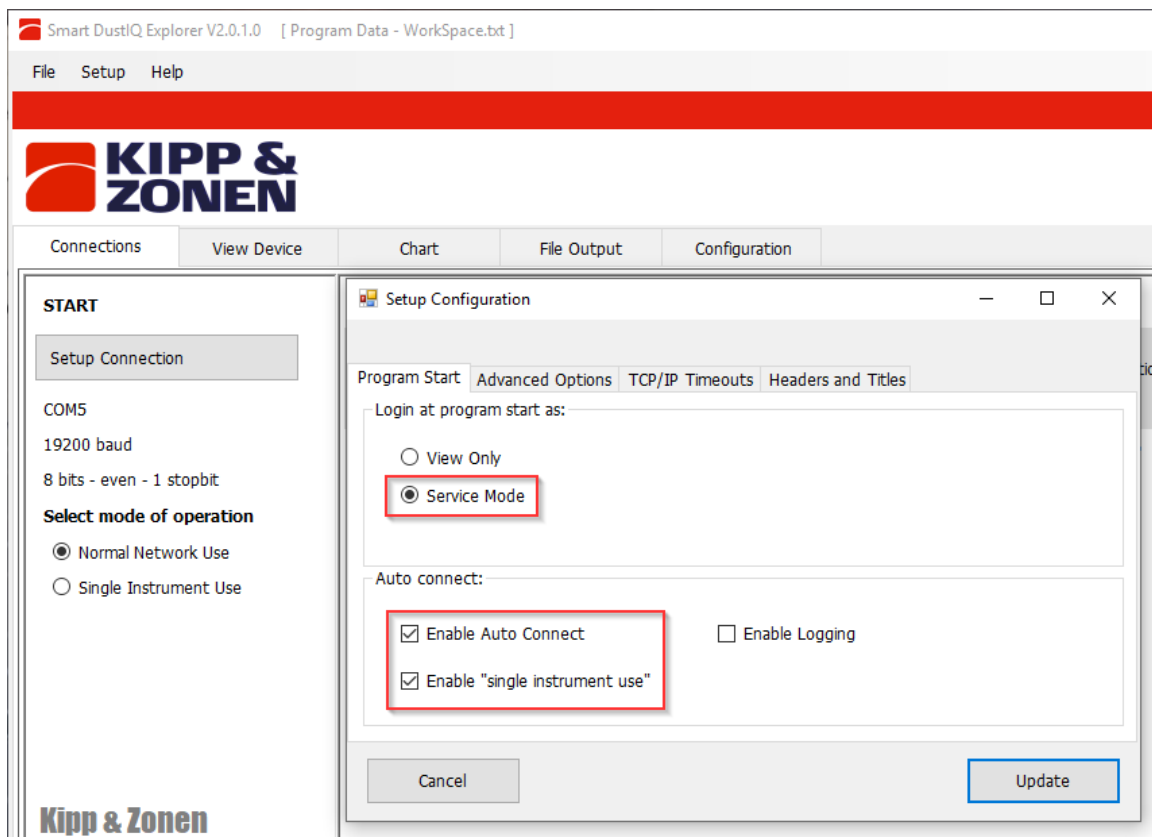


- The program starts in Normal Network Use, meaning you can have several instruments attached to monitor
- Changing setting is best done with only one instrument attached
- Finding an instrument with unknown communication settings is only possible with one instrument attached
- Allow 5 to 10 minutes for the instrument to stabilise before reading the measurements
- When started the first time and with a DustIQ straight out of the box: 19.200, 8E1 are the coms settings used and working.



*On the initial 0386900 model, Power Volt is not reported correctly and always 3.2V. Later models (0386910 & 15) report the actual supply voltage.*

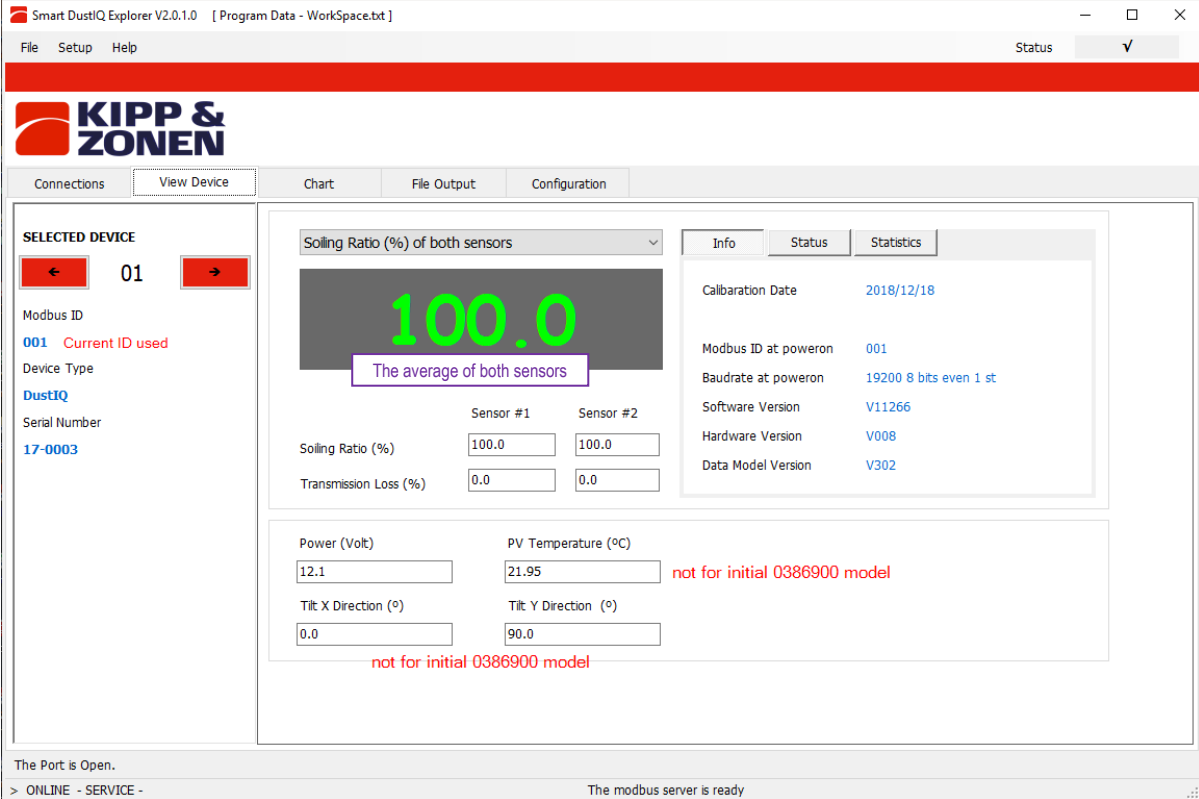
## 6.6.5. Main Window – Setup

After starting Smart DustIQ Explorer for the first time it is advised to check and set the following **Setup** selections:



### 6.6.6. Main Window – View Device

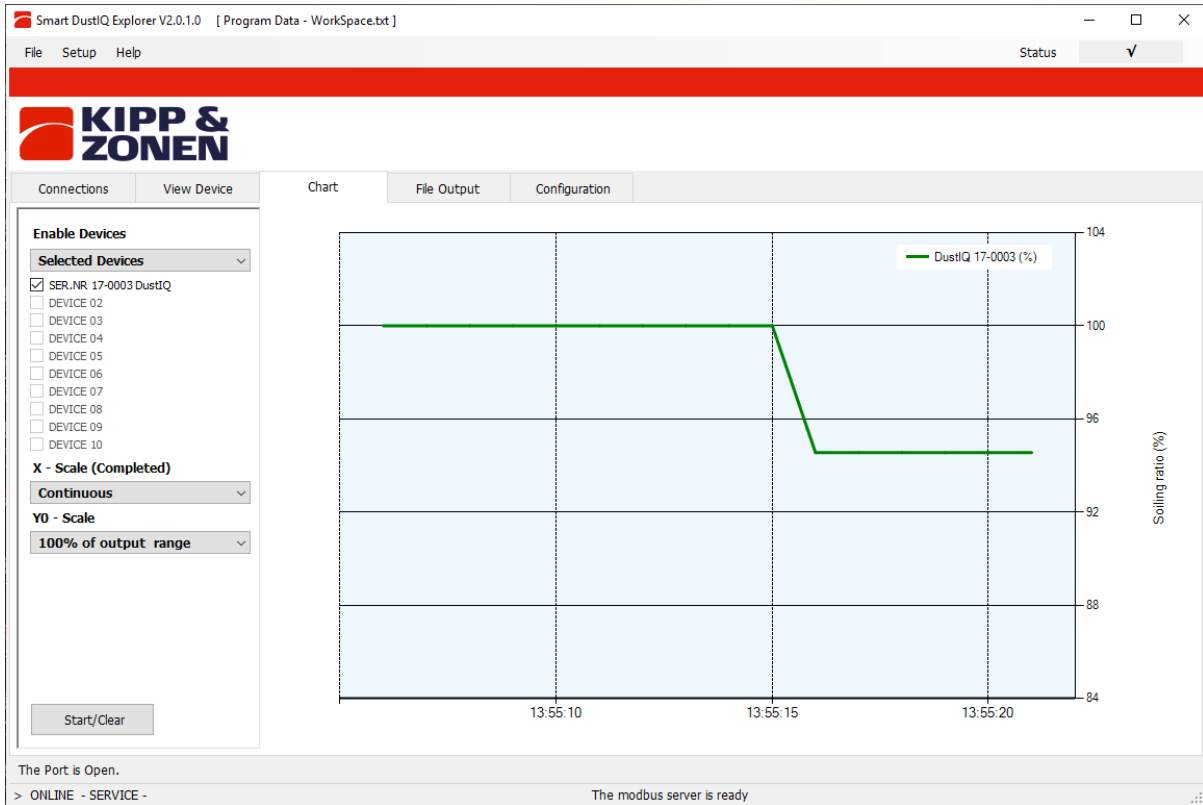
Clicking on View Device will bring up the information for the first device. If there are more instruments attached, then use the arrows  01  to select the right one.



The screenshot shows the 'Smart DustIQ Explorer V2.0.1.0' software interface. The main window is titled 'Smart DustIQ Explorer V2.0.1.0 [ Program Data - Workspace.txt ]'. The interface includes a menu bar (File, Setup, Help) and a status bar (Status, ✓). The KIPP & ZONEN logo is prominently displayed at the top left. Below the logo, there are tabs for 'Connections', 'View Device', 'Chart', 'File Output', and 'Configuration'. The 'View Device' tab is active, showing a 'SELECTED DEVICE' section on the left with navigation arrows and the device ID '01'. The main display area shows a large green '100.0' representing the 'Soiling Ratio (%) of both sensors', with a note 'The average of both sensors'. Below this, there are input fields for 'Sensor #1' and 'Sensor #2', both set to '100.0', and 'Transmission Loss (%)' fields set to '0.0'. A 'Power (Volt)' field shows '12.1' and a 'PV Temperature (°C)' field shows '21.95', with a red note 'not for initial 0386900 model'. 'Tilt X Direction (°)' is '0.0' and 'Tilt Y Direction (°)' is '90.0', also with a red note 'not for initial 0386900 model'. On the right, an 'Info' tab is active, displaying calibration and device information: Calibration Date (2018/12/18), Modbus ID at poweron (001), Baudrate at poweron (19200 8 bits even 1 st), Software Version (V11266), Hardware Version (V008), and Data Model Version (V302). The bottom status bar indicates 'The Port is Open.' and 'ONLINE - SERVICE -' on the left, and 'The modbus server is ready' on the right.

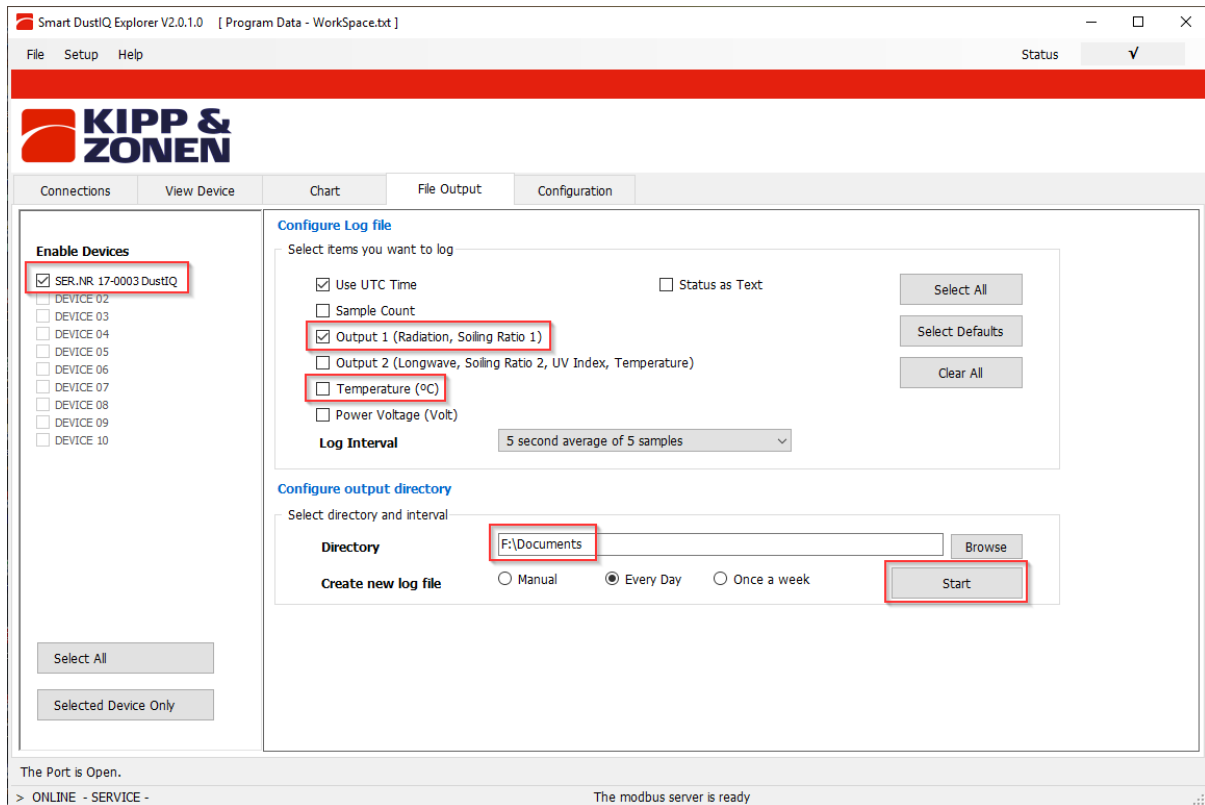
### 6.6.7. Main window – Chart


The chart window shows a simple rudimentary chart of the selected devices. The scale for the sensor 1&2 average soiling ratio is on the left-hand side.



### 6.6.8. Main window – File Output

For logging the data gathered from the devices the File Output tab is available. Depending on the attached instruments the proper selections are available.

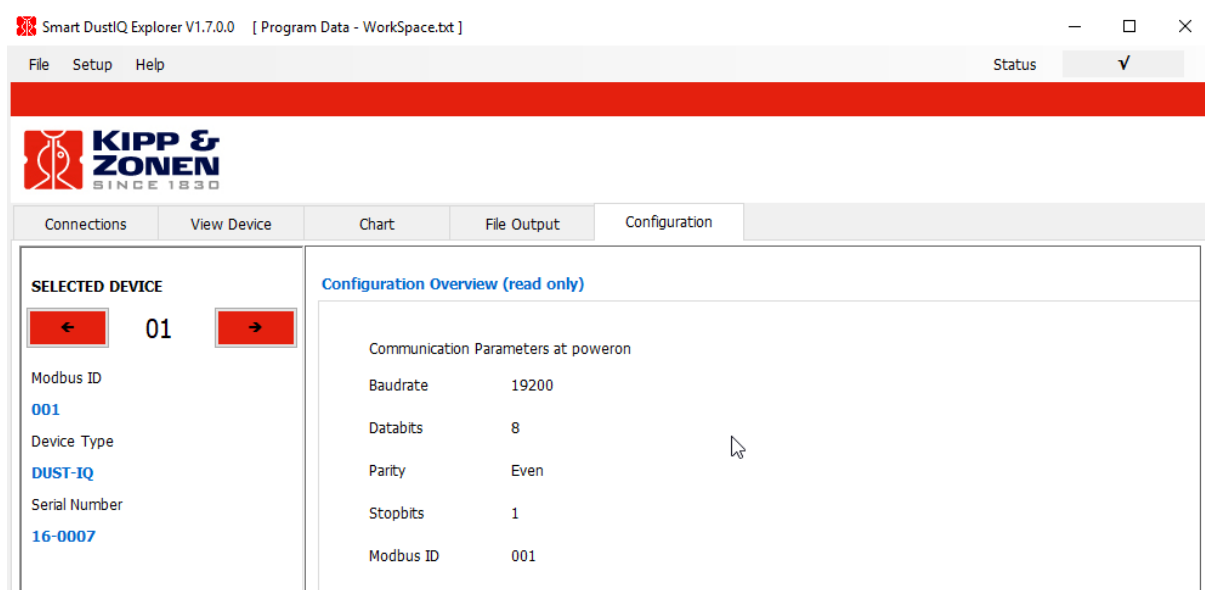


After clicking Start  will be visible on the right –hand bottom.


After clicking Stop a CSV file is available in the selected directory  named LOGyymmdd-hrmm.CSV

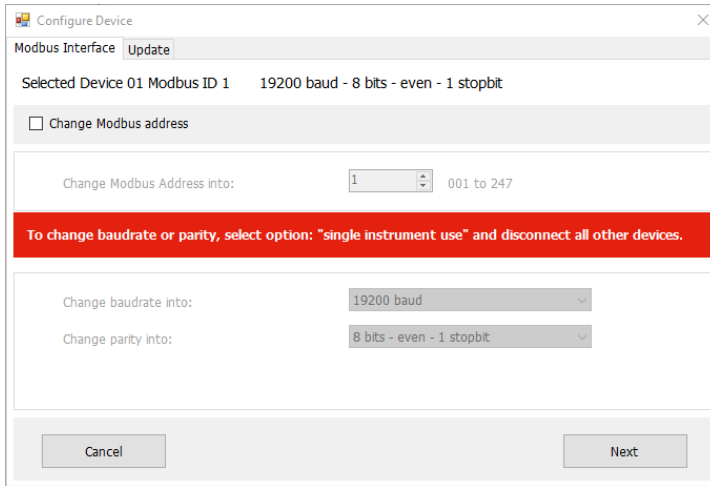
### 6.6.9. Main window – Configuration

Clicking the Configuration tab shows the current communications settings.



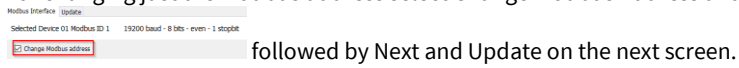
The place to change the DustIQ settings.

Click on  and a warning is shown. Read carefully.

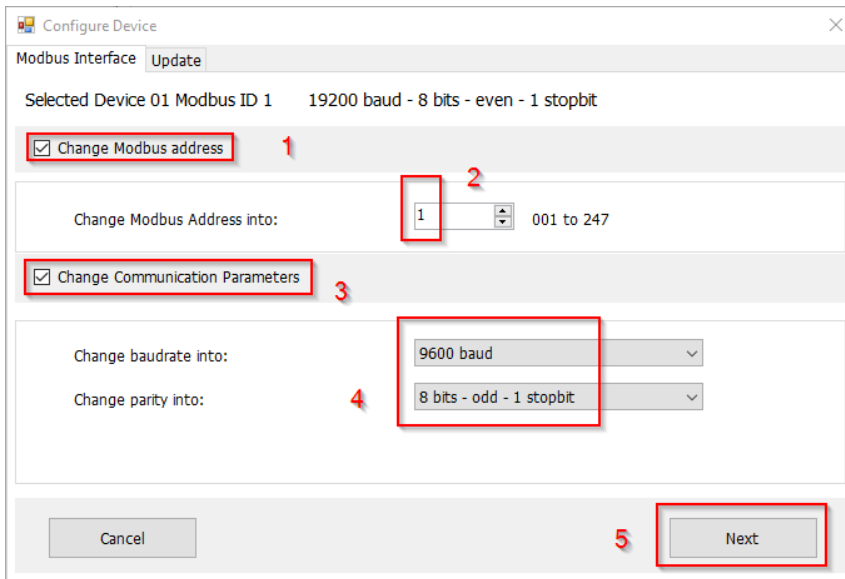


Go back to the first Connections tab to change to Single Instrument Use when the baud rate or parity needs to be changed too. Modbus address changes work also in Normal Network Use.

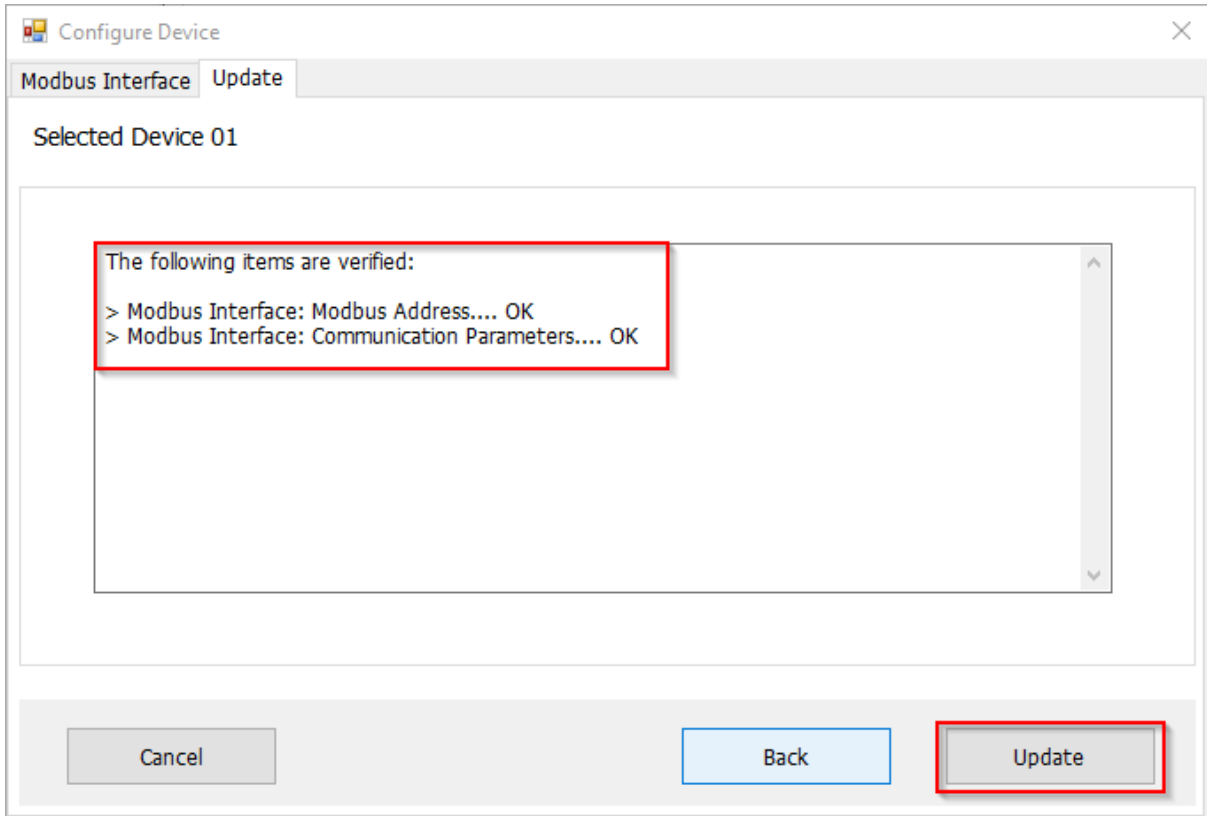
For changing just the Modbus address select Change Modbus Address and select the new Modbus address.



Otherwise select the changes needed followed by Next







If OK with the changes click Update.

After updating the DustIQ will be reset and take about a minute to be ready again. The communication parameters of the Smart DustIQ Explorer software have been changed accordingly and a working Connections tab should appear. When finished the program can be closed.

### 6.6.10. Finding a DustIQ with unknown communication parameters

When unsure of the current DustIQ settings and unable to connect there are two ways to try and find a single connected instrument.

First change to Single Instrument Use in the Connections tab.



When the communication parameters are known and properly setup and only the Modbus ID is unknown a Send Broadcast will find the attached DustIQ and show it.

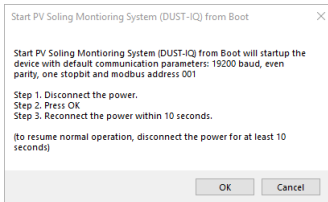
EXPLORER OVERVIEW

Id	Serial Nr.	Type	Communication Status
001	16-0001	DUST-IQ	Ready (ok)

If no instrument is found then mostlikely also one of the communication parameters is wrong or unknown.

To always find a DustIQ, there is the "Start From Boot" procedure that involves shortly removing the cable from the DustIQ to perform a Power Off – Power On or switch Off and On the power when possible.

Click on Start From Boot and the following window will appear:

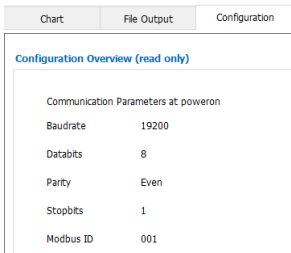


Follow the instructions given and the DustIQ will be found.

EXPLORER OVERVIEW

Id	Serial Nr.	Type	Communication Status
001	16-0009	DustIQ	Device started from boot

After about a minute the Connections tab will show reliable measurement results and the communication parameters setup of the DustIQ can be seen and changed on the Configuration tab.



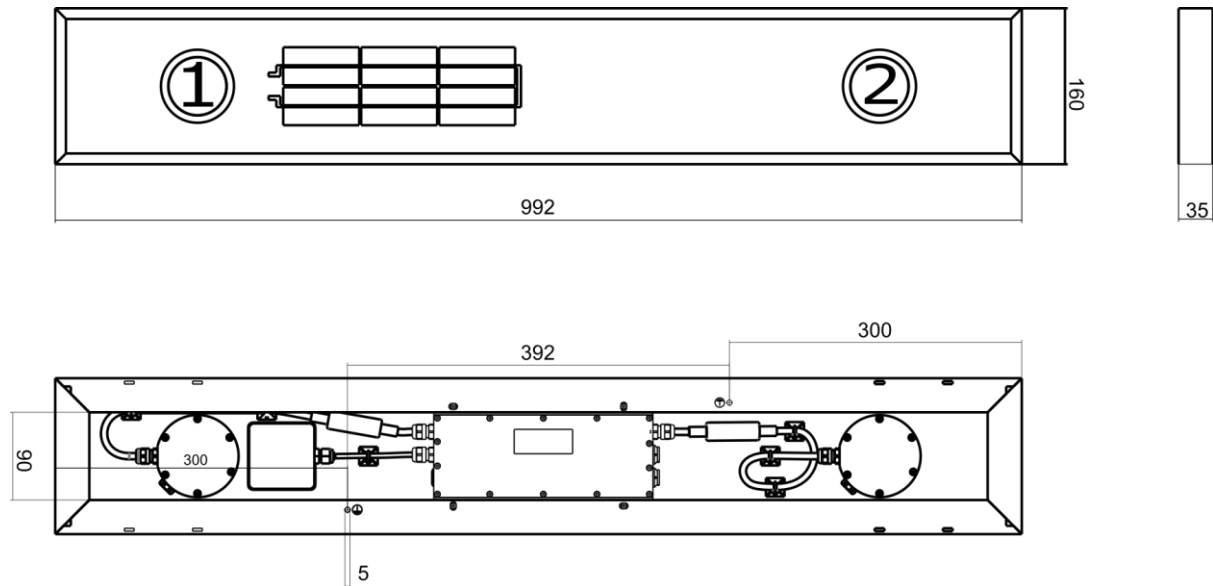
## 6.7. Mounting the DustIQ outside

The DustIQ – quick start guide contains all the outline information necessary for the correct installation of the DustIQ.

The DustIQ instrument is provided with 4 clamps for installation alongside a PV panel. The top of the DustIQ as indicated on the back of the panel should point towards the sky.

When mounted in between PV panels the 4 supplied clamps should be enough and these can take care of a possible 5mm difference in height.

Version 1 of the DustIQ has a height of 40 mm. Later models with serial number 180094 and higher will have a height of 35 mm.

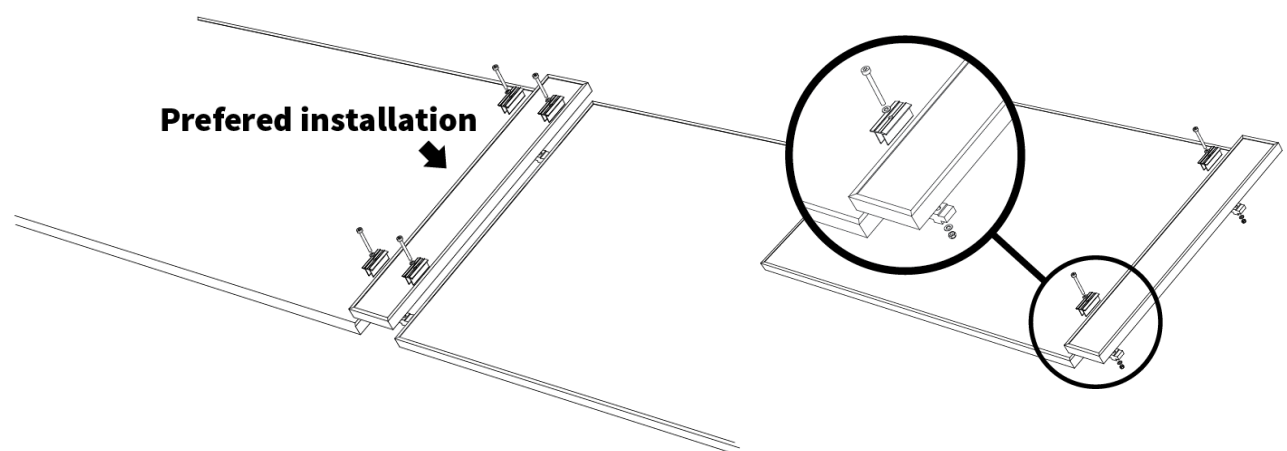


DustIQ weight is 4 kg.

## 6.8. DustIQ physical installation

The DustIQ comes with 4 clamps for mounting in between PV panels.

**For other setups, a locally made supporting structure is needed.**

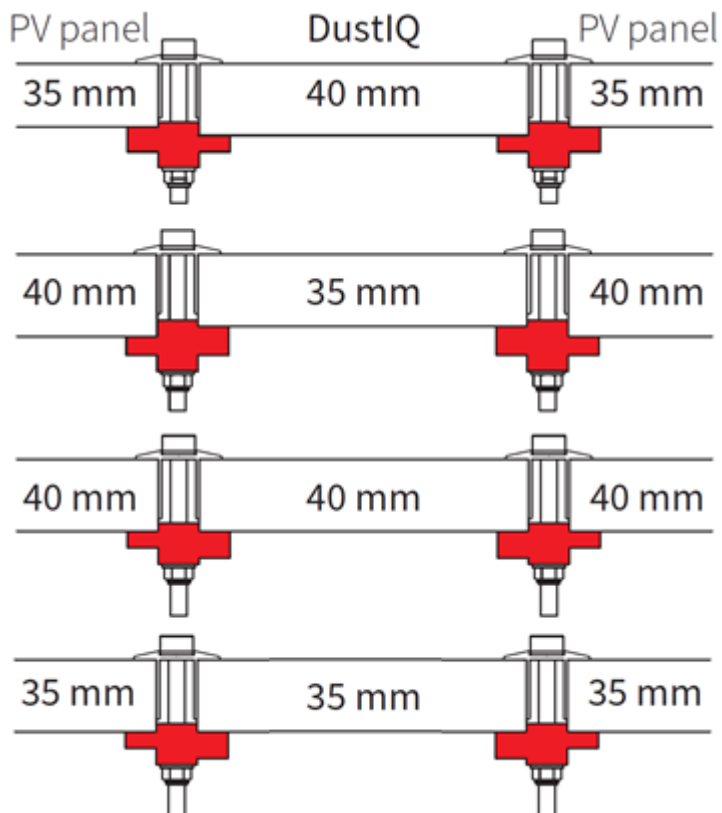


## 6.9. Use of the clamps for installation

Several scenario's with different PV panel and DustIQ heights can be dealt with using the supplied clamps.

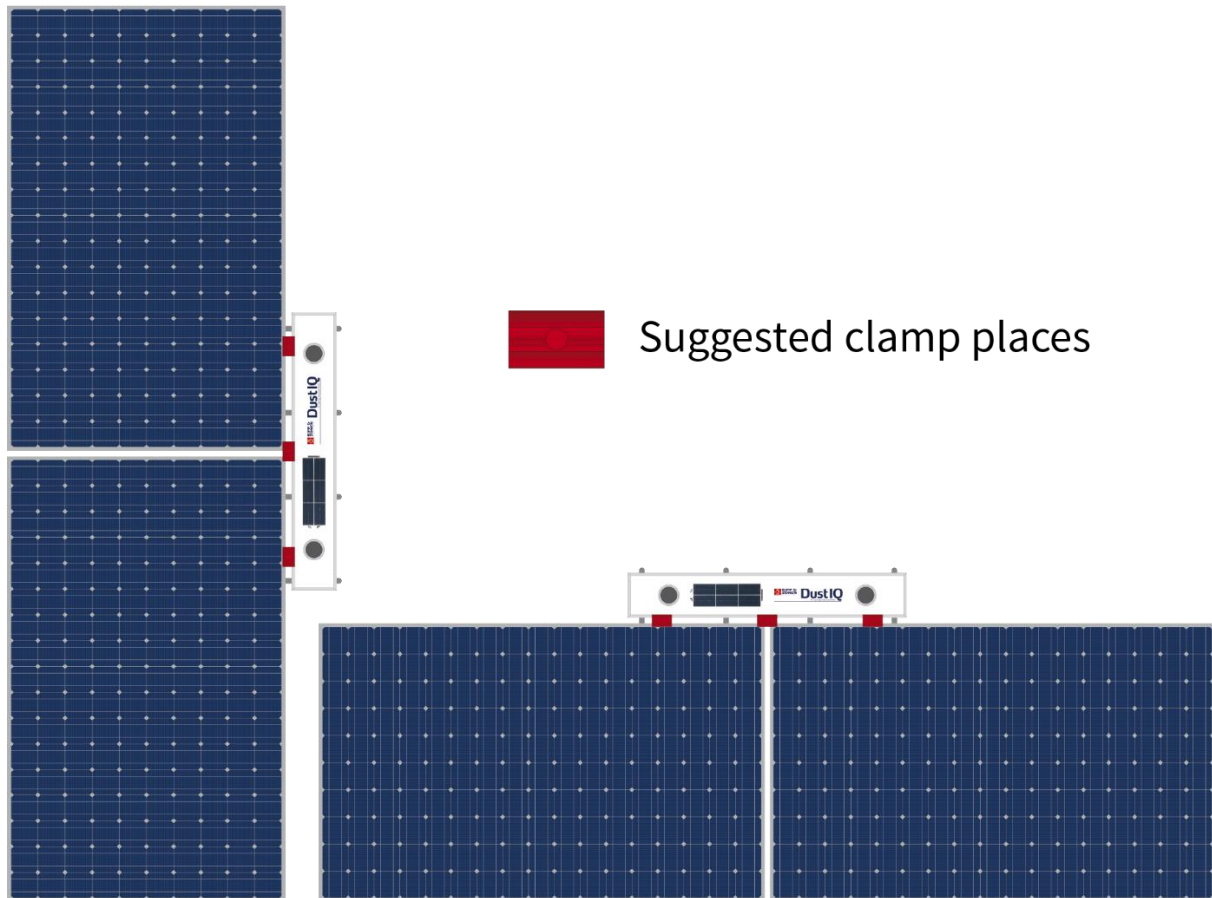
Rotating the bottom clamp around the Y-axis deals with height differences of plus or minus 5mm.  
(top drawings)

Rotating the clamps around the x-axis works for equal height panel and DustIQ.



As of serial number 180094 the height of the DustIQ changed from 40mm to a lower 35mm.

For **testing purposes in areas with limited chance of winds stronger than 6 Beaufort** it is possible to use the supplied clamps and install the DustIQ without supporting structure on a spot where two PV panels meet.



**Note** For other setups, a locally made supporting structure is needed.

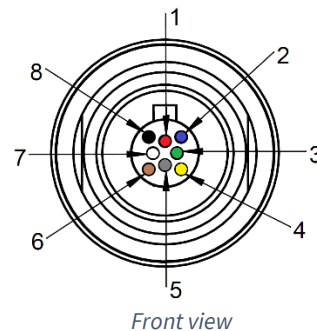
## 6.10. Fitting the host connector and cable outside:

Most DustIQ instruments are supplied with a 10m high quality yellow cable fixed to an 8 pin waterproof connector on one end and 8 wires and a shield covered with a black sleeve on the other end. Longer cables are available as an option.

The wire ends are to be connected to the data logger or SCADA system directly or to a junction box which in turn is connected to the host.

The colour code of the wires and the connector pin numbers are shown below and on the instruction sheet.

DustIQ connections		
Wire	Function	Connect to
1	Red	None
3	Green	None
6	Brown	None
4	Yellow	Modbus® RS-485 B+ B/B' / + on host or USB converter
5	Grey	Modbus® RS-485 A- A/A' / - on host or USB converter
2	Blue	Modbus® common / Ground
7	White	Power +12 to 30 VDC
	Black	Power ground / RS-485 Common
Shield	Housing	Ground



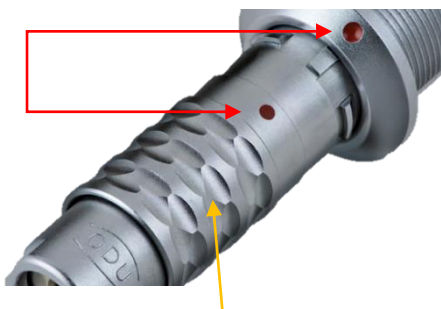
**Note** First connect all wires in your junction box, SCADA system or data logger before plugging into the DustIQ.

The shield of the cable is connected to the aluminium DustIQ housing through the connector body. Preferably, secure the DustIQ with a good connection to ground (e.g. by using a lightning conductor) and do not connect the cable shield at the junction box, SCADA system or data logger.

If there is no good ground connection at the DustIQ, the shield at the cable end should be connected to ground at the host or junction box.

**Note** Long cables may be used, but the baud rate of the RS-485 digital connection may affect the maximum length. Baud rate options are: 2400 , 4800 , 9600, 19200 (default), 38400

Locate the plug correctly in the DustIQ instrument socket labelled Host, it only fits one way, and push it in. Locking is done automatically.



To unplug, pull the grooved ring back and then pull out the plug.

It is advised to protect the output of the power supply with a fast blowing fuse of maximum 500 mA rating.

**Note** The cable should be arranged with a curve below the instrument so that water drips off, rather than running along the cable up to the connector.

If the cable needs to be extended it is advised to use high quality UV resistant CAT5 cable.

## 6.11. Fitting the daisy-chain cable

**Note** Below instructions are valid for DustIQ's with Pn 0386910 or Pn 0386915. The initial model DustIQ Pn 0386900 does **not** have this capability.

When installing several DustIQs in relative proximity they can be daisy-chained up to **3 instruments** in total and have only one data and power cable to the host, data logger or junction box.

Each unit needs to have a unique Modbus address setup before installation.

If this DustIQ is the only one or the last in a daisy-chain of max. 3 instruments one can fit the supplied PV panel temperature sensor.



The plug of the daisy-chain cable fits in the port labelled Daisy-chain / Temp sensor and leads to the Host port on the DustIQ next in line.

Both plugs of the daisy-chain cable are identical.

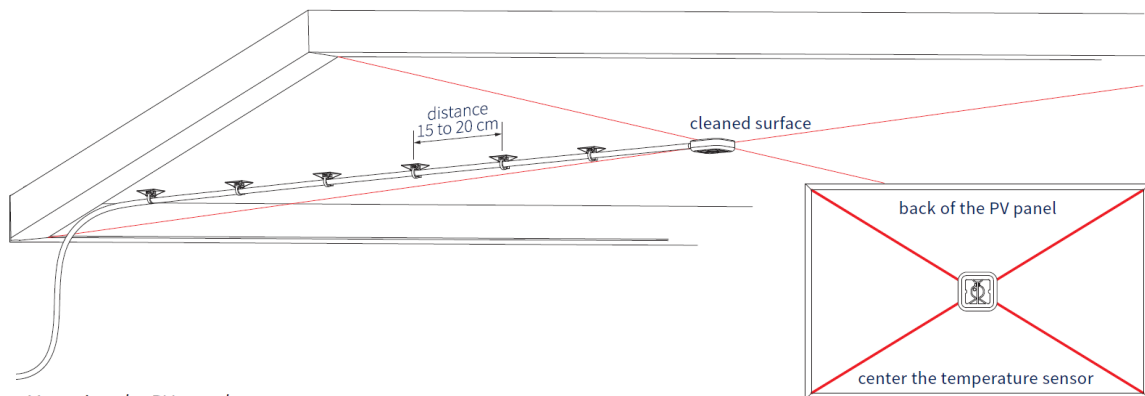
## 6.12. Installing the PV panel temperature sensor

**Note** Below instructions are valid for DustIQ's with Pn 0386910 or Pn 0386915. The initial model DustIQ Pn 0386900 does **not** have this capability.

When the daisy-chain port isn't used to connect a second instrument, then the port can be used to connect the supplied PV panel temperature sensor. The sensor comes with a 2.95m long cable and can be fitted on a nearby PV panel that represents the average PV panel temperature the best.

Install the PV panel temperature sensor by the following steps:

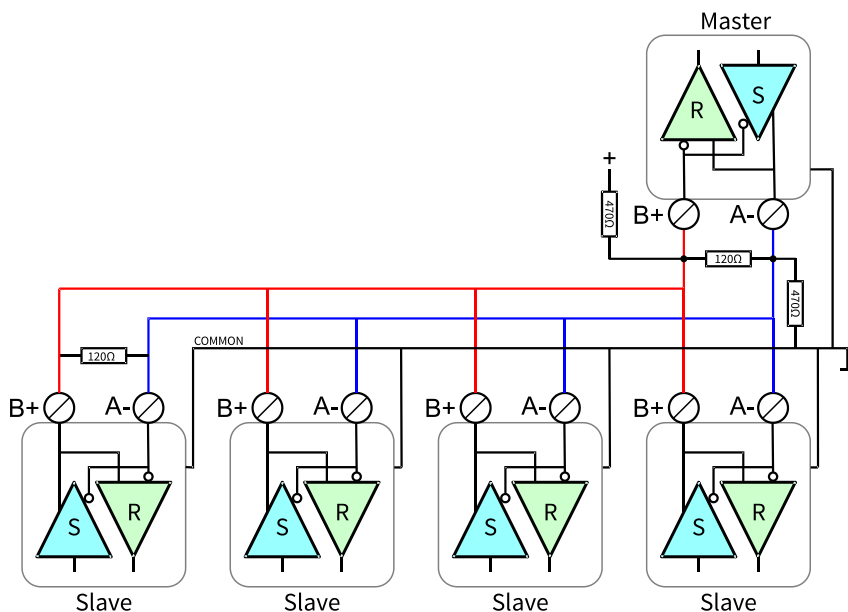
- From the DustIQ, remove the black dust cap of the daisy-chain connector
- Insert the plug in the connector of the DustIQ
- Clean the surfaces of the locations for the cable supports and for the PV panel temperature sensor(2) at the back of the PV panel
- The best location for the temperature sensor is the centre of the PV panel
- Stick the temperature sensor to the cleaned surface at back of the PV panel
- Place with care as the temperature sensor is hard, if not impossible to remove
- Stick the cable tie mounts to the cleaned surfaces at the back of the PV panel
- Secure the cable to the cable supports by using tie wraps



Mounting the PV panel temperature sensor

## 6.13. Connection to a RS-485 network

The digital interface must be connected as a slave to a 2-wire RS-485 network as shown below.



The slaves may be a DustIQ, an SMP pyranometer or other Modbus device. If this instrument is the last device on the network a line terminator (LT), consisting of a 120  $\Omega$  or 150  $\Omega$  resistor, must be connected between terminals A/A /Data- and B/B /Data+ right at the last device. It is also required to install the pull up and pull down resistors as shown. The value of these resistors must be between 470  $\Omega$  and 850  $\Omega$ .

## 6.14. Electrical details

The minimum power supply voltage for the DustIQ instrument is 12 VDC. However, for optimal performance it is advised to use 24 VDC when longer cables are used.

It is advised to protect the output of the power supply with a fast blowing fuse of 500 mA rating for one DustIQ. When daisy-chaining a bigger fuse is needed.

### Typical power consumption of the DustIQ instrument

12 VDC	60 mA LEDs off – 130 mA LEDs on, std duty cycle 5%
24 VDC	40 mA LEDs off – 70 mA LEDs on, std duty cycle 5%

Maximum average power consumption over a minute is 1.000 mW at 24V and 800 mW at 12V.

Maximum input current is 150 mA at 12V voltage.

Maximum inrush current is 10A for 50 $\mu$ s.

The DustIQ needs a good, stable power supply of 12-30V, 300mA peak and 200mA sustained. Preferably class II to IEC/EN 60536. A power supply with genuine and traceable CE, FCC, VDE, TUV or equivalent certification.

Some of the brands applicable: Traco, Omron, Mean Well, Cosel and others.



## 7. Operation and measurement

The DustIQ instrument only requires a suitable source of power to operate and make measurements. However, it is necessary to connect it to some sort of readout or data storage device in order to save the measurements, there is no internal data memory.

### 7.1. Data collection

An optimal setting for the data collection interval is to sample every minute. For setting up the combination of the DustIQ and data storage please refer to the manual of your data collection device. The data that can be collected is described in chapter 12.

### 7.2. Housing

The DustIQ housing accommodates all the key parts of a DustIQ instrument. The anodized aluminium parts are lightweight and give high mechanical and thermal stability to the instrument. The glass panel is equivalent to a real PV panel. The DustIQ has an ingress protection rating 65 (IP65) which means it is dust proof against harmful dust and can withstand waterjets from any direction.

## 8. Local Dust Calibration

The precise steps for a correct local dust calibration have been supplied as a laminated, double sided card that also has the DustIQ – instruction sheet on the back. The DustIQ calibration procedure is downloadable from [www.kippzonen.com/downloads](http://www.kippzonen.com/downloads) using DustIQ and Instruction sheet.

Only for the first local dust calibration of each DustIQ the customer needs to do a planned cleaning of the DustIQ. After this calibration the DustIQ can follow the cleaning pattern of the PV park.

**Note** The local dust calibration takes 10-15 minutes on average, needs a start transmission loss (TL) of minimum 5%, a clear, sunny sky around solar noon, **800 W/m<sup>2</sup>** solar irradiation and proper preparation.

The calibration procedure creates a step change in measured reflected light and the PV cells output and it's the step change that is processed, saved and used for future measurements.

The current firmware requires all DustIQs to individually follow this procedure.

### 8.1. The advantage of a local dust profile

The DustIQ leaves the factory calibrated for Arizona Test Dust (ATD) but it is very unlikely that the local dust composition matches this ATD and it is therefore advised to train each DustIQ for the local dust composition.

For the local dust calibration the DustIQ has a build-in PV cell. This PV cell allows the DustIQ to quantify the effect of the local soiling on an actual PV cell and subsequently correlate this to the DustIQ measurements of reflected light as produced by the soiling.

### 8.2. Correction of old DustIQ data after local dust calibration

#### 8.2.1. Introduction

For some customers with a DustIQ there is a need to know the Transmission Loss before they performed the local dust calibration. The local dust calibration changes the dust slope and therefore the old data is only considered qualitative data, not quantitative. In order to gain quantitative insight in the data before in field calibration it is possible to do a correction. In this section the method is described.

#### 8.2.2. Method

The new transmission loss after the correction can be calculated by:

$$TL_{new} = \frac{S_{new}}{S_{old}} TL_{old} \quad (1)$$

where  $TL_{new}$  is the new corrected transmission loss,  $TL_{old}$  is the old uncorrected transmission loss,  $S_{new}$  is the new Sensitivity after local dust calibration and  $S_{old}$  is the old Sensitivity before local dust calibration. The dimension of TL is [% Transmission loss], of S is [counts / % Transmission loss].

The new corrected Soiling Ratio ( $SR_{new}$ ) can be calculated from the old Soiling Ratio ( $SR_{old}$ ) by:

$$SR_{new} = 100 - \frac{S_{new}}{S_{old}} (100 - SR_{old}) \quad (2)$$

$S_{old}$  from certificate

The old sensitivity can be obtained from reading the Modbus register 36 (Sensitivity Sensor 1) before local dust calibration or it can be obtained from the calibration certificate that came with the DustIQ:

SENSITIVITY SENSOR 1	80 107 counts/ % Transmission loss ARIZ-TD
SENSITIVITY SENSOR 2	71 107 counts/ % Transmission loss ARIZ-TD

$S_{new}$  from DustIQ Modbus readout

The new sensitivity can be obtained by reading Modbus register 36 after the local dust calibration. It's a Long value in the range of 30-300 and fully instrument specific. Only the ratio between New and Old can be used.

After obtaining the  $S_{old}$  and  $S_{new}$  the old TL or SR data can be corrected using formula 1 and 2.

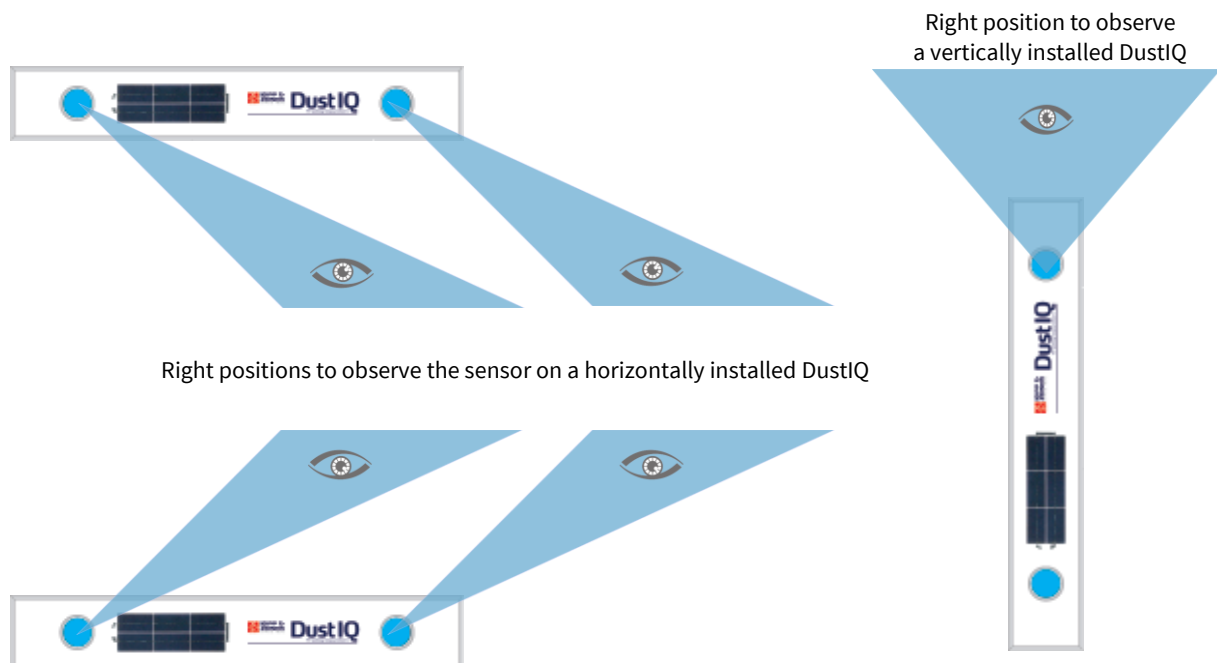
### 8.3. Making of a local dust profile

Before the actual local calibration will start the DustIQ firmware will check the following parameters:

1. Complete system status
2. A minimum of 5% transmission loss measured (Modbus register 21 holds 50 ‰)
3. A minimum of **800 W/m<sup>2</sup>** of sunlight

The training of the DustIQ and making the local dust profile (LDP) involves the following:

1. Wait for the DustIQ to get dirty as evenly as possible, this is very important
2. Let the reported transmission loss (TL) reach 5 - 10% or the soiling ratio (SR) 95 - 90%
3. Wait for a day with a clear sky and bright sun around solar noon
4. Perform the calibration somewhere in the period from 2 hrs before till 2 hrs after solar noon
5. Prepare well and have the calibration procedure, cleaning tools and local safety regulations at hand
6. Position an observer to watch the blinking of the blue sensors from the front of the DustIQ or the blue illuminated push button on the back, to follow the procedure



7. Initiate the calibration cycle by pressing the button on the bottom of the DustIQ and noticing the flashing LED
8. Move to the front and clean the first sensor, press the button, clean the solar cell and second following the sensor's blinking patterns and detailed instructions on the supplied Instruction Sheet.
9. Press the button again to Save the changes or to Cancel do nothing and wait 5 minutes.

When Saved, you have a clean, locally trained DustIQ, ready for action.

Otherwise you will have to clean the whole DustIQ thoroughly and wait for dust to build up before a next calibration can be initiated.

**Note**

If anywhere in the procedure a push of the button is required and nothing is done in 5 minutes the procedure will stop and the DustIQ will go back to normal operation using calibration settings from just before the procedure was started.

During the calibration the DustIQ will be reachable by the host but reported data will not be updated until after the procedure.

Detailed calibration status or issues can be retrieved from extra Modbus registers using paragraph 12.

## 9. Maintenance and re-calibration

The DustIQ instrument is simple to maintain and doesn't require any special tools or training. There are no service items requiring scheduled replacement.

### 9.1. Yearly maintenance

Check all the electrical connections.  
Check cables for damage caused by accident or by rodents.  
Check the instrument mounting.

### 9.2. Cleaning

As the DustIQ has been built using actual PV panel glass it is meant to withstand the cleaning cycles PV panels as found in commercial solar parks can withstand. Care must be taken not to scratch the panel's surface or use abrasive or etching compounds.

### 9.3. Calibration

A DustIQ instrument gives an output that is proportional to the light loss caused by the panel soiling. It uses internal correction for any unforeseen parameter drift and therefore needs no calibration apart from the local dust calibration to train the DustIQ for the locally deposited dust.

## 10. Specifications

Kipp & Zonen reserves the right to make changes to specifications and other product documentation without prior notice.

### 10.1. Optical and electrical

Transmission loss (TL) range Percentage of sunlight that is blocked or scattered in such a way that it does not reach the actual solar cells.	0 – 50 %
Soiling Ratio (SR) range	100 – 50 % (SR = 100 – TL)
Transmission loss measurement accuracy :	± 1 % and ± 0.1 of reading *
Tilt X and Y-axis **	-180 to 180° ±1°
PV panel temperature measurement **	-20 to +100 °C ±1°C
Ambient working temperature	-20 to +60 °C
Storage temperature	-20 to +80 °C
IP Class	IP65
Communication	Modbus® over 2-wire RS485
Maximum voltages on data lines	The maximum differential between either of the Modbus® RS-485 lines (yellow and grey) and the power ground / RS-485 common line (black) is 70 VDC.
Connection	One 8 pin ODU connector
Power	12 to 30 VDC, 200 to 70 mA a 24 V, 500 mA power supply is advised
Power consumption	< 2.5 Watt
Daisy-chain capability **	Three instruments max. in one chain. Only the last device can have the PV panel temperature sensor attached. Supply voltage needs to be 16V minimum for daisy-chaining.
In rush current	Maximum inrush current is 10A for 50µs.
Glass type	standard PV glass

\* After well performed local dust calibration

\*\* Is for Pn 0386910 and 0386915 only

**Note** It is advised to protect the output of the used power supply with a fast blowing fuse of maximum 500 mA rating.

### 10.2. Dimensions and weight

Dimensions packed	120 x 20 x 8 cm
Dimensions unpacked	99 x 16 x 3.5 cm
Weight packed with 10m cable	6 kg
Weight unpacked	DustIQ unit: 4 kg; Mounting clamps: 600 g; 10 m cable: 400 g

IP65 Protection against Dust	IP65 Protection against Water
First digit	Second digit
0 – no protection	0 – no protection
1 – protection against large foreign bodies	1 – protection against dripping water
2 – protection against medium foreign bodies	2 – protection against inclined dripping water
3 – protection against small foreign bodies	3 – protection against spray water
4 – protection against foreign bodies	4 – protection against splash water
5 – Dust protected	<b>5 – protection against water jets</b>
<b>6 – Dust tight</b>	6 – protection against powerful water jets
	7 – protection against immersion
	8 – protection against submersion

## 11. Trouble shooting

There are no user-serviceable parts within the DustIQ instrument and it must not be opened or taken apart without the agreement and instruction of Kipp & Zonen and only by qualified personnel.

### 11.1. Output signal not present or incorrect

The following contains a procedure for checking the instrument in case it appears that it does not function correctly:

1. Check the DustIQ instrument cable wires are properly connected to the readout equipment.
2. Check the power supply (12-24 VDC recommended).
3. Check that the instrument has a unique Modbus® address and the right communication parameters.
4. Check the instrument location.
5. Check the glass surface, it should be unbroken and unscratched.

Any malfunction or visible damage should be reported to your Kipp & Zonen representative, who will suggest the appropriate action.

### 11.2. Frequently Asked Questions

The most frequently asked questions are listed below. For an update or further information refer to our website at [www.kippzonen.com](http://www.kippzonen.com)

Q: Does the DustIQ work with snow?

A: No the current DustIQ will report a very high transmission loss, not related to the real transmission loss a PV panel with similarly snow cover would experience.

Q: The dust slopes in registers 36 and 38 didn't change after a local dust calibration.

A: Somewhere in the procedure a check failed. See paragraph 12 to help you interpreting the error codes.

## 12. Appendices

### 12.1. Modbus® commands

The commands are all according to the Modbus RTU protocols described in the document: ‘Modbus® over serial line V1.02’ and ‘MODBUS application protocol V1.1b’ available from the Modbus® organization ([www.modbus.org](http://www.modbus.org)). The commands can be tested using software tools, such as the program ‘Modbus Poll’ from [www.modbustools.com](http://www.modbustools.com).

The following commands are implemented:

Function	Sub function	Description
0x01	N/A	Read Coils
0x02	N/A	Read Discrete Inputs
0x03	N/A	Read Holding Registers
0x04	N/A	Read Input Register
0x05	N/A	Write Single Coil
0x06	N/A	Write Holding Register
0x10	N/A	Write multiple Registers

In the remainder of this chapter the DustIQ is referred to as a smart sensor. The smart sensor does not make a difference between a ‘coil’ and a discrete input. The only difference is that a discrete input is read only.

#### Note

The DustIQ makes a difference between a holding register and an input register. Only use 04 Read Input Registers to get data from the DustIQ.

### 12.2. DustIQ release 3.01 data model

The following section describes the data registers belonging to data model 3.01 as used at the time of introduction.

#### 12.2.1. Overview of the Modbus® registers

The base of the input register block is set to 1 (MODBUS PLC address [base 1]), or 0 (MODBUS Protocol Address [base 0]) and occupies max. 100 registers (0-99, [base 0]).

**The address field in the table below is the Protocol address with base 0 and not the PLC Address with base 1.**

COMMON DATA BLOCK DUSTIQ					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_DEVICE_TYPE	0	R	U	All	Device type of the DUST-IQ sensor 800 for DustIQ
IR_DATAMODEL_VERSION	1	R	U	All	Version of the data model (=301 for current version)
IR_SOFTWARE_VERSION	2	R	U	All	Software version of the firmware (= 110088 for current version)
IR_BATCH_NUMBER	3	R	U	All	Production year in yy format
IR_SERIAL_NUMBER	4	R	U	All	Production serial number for the above mentioned year from 0000 to 9999
IR_HARDWARE_VERSION	5	R	U	All	Hardware version (= 5 for current hardware)
IR_CALIBRATION_YEAR	6	R	U	All	Factory calibration year 2000 to 2099
IR_CALIBRATION_MONTH	7	R	U	All	Factory calibration month 1 to 12
IR_CALIBRATION_DAY	8	R	U	All	Factory calibration day 1 to 31
RESERVED	9-19				Reserved for future expansion

REAL-TIME DATA BLOCK, SOILING SENSOR 1 (SENSOR CLOSEST TO THE INTEGRATED SILICON CELL)					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_SOILING_RATIO_SENSOR1	20	R	U	N,S	Soiling ratio SENSOR 1 in 0.1% , 101 to 50% 9999 when not valid
IR_TR_LOSS_SENSOR1	21	R	S	N,S	Transmission Loss SENSOR 1 in 0.1% , -1 to+50% 9999 when not valid
RESERVED	22-23	R			Reserved for future expansion

REAL-TIME DATA BLOCK, SOILING SENSOR 2					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_SOILING_RATIO_SENSOR2	24	R	U	N,S	Soiling ratio SENSOR 2 in 0.1% , 101 to 50% 9999 when not valid
IR_TR_LOSS_SENSOR2	25	R	S	N,S	Transmission Loss SENSOR 2 in 0.1% , -1 to+50% 9999 when not valid
RESERVED	26-27				Reserved for future expansion

TILT SENSOR BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_TILT_X_DIRECTION	28	R	S	All	<b>Future enhancement</b>
IR_TILT_Y_DIRECTION	29	R	S	All	<b>Future enhancement</b>
RESERVED	30	R	S	All	Reserved for future expansion

TEMPERATURE SENSOR BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_BACKPANEL_TEMP	31	R	U	All	<b>Future enhancement in 0.1 degrees Kelvin</b>

DEVICE COMMON BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_DEVICE_VOLTAGE	32	R	U	All	<b>Internal Device voltage in mV = 3100 ±100</b>
IR_OPERATIONAL_MODE	33	R	U	All	<b>Operational mode: normal, service, calibration (1 = normal mode)</b>
IR_STATUS_FLAGS	34	R	U	All	Device Status flags (0 = status OK)
RESERVED	35 – 39	R	U	All	Reserved for future expansion

The following modus registers are used for calibration, identification and error handling. These registers can be asked for in order to facilitate remote problem solving.

DEVICE INTERNAL BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
INTERNAL_VALUES_FOR_ERROR_HANDLING	40 - 99	R			For identification and error handling

Legend: Parameter Unique name of the register  
Address Modbus PLC address  
note: the Modbus PLC address is the Modbus Protocol Address + 1  
R/W R= Read only / write ignore or R/W = read-write  
SZ Data type and size; the following data types are used:  
U 16 bit unsigned integer  
S 16 bit signed integer  
Level The following levels are used:  
N Available in the normal operational mode  
S Available in service/configuration level  
All Available in all modes except the terminal mode.  
Description Description of the parameter

**S** bold character and light grey background mean changed value from original communication.

Soiling ratio % = 100 – Transmission Loss %

All soiling and transmission loss values are stored in 1/10 of a % also known as ‰.

All measurement values need to be divided by ten. E.g. an internal device voltage reported as 156 at address 32 represents a voltage of 15.6 V and a soiling ratio reported as 985 represents 98.5%

Communication parameters are user selectable from the following range using the Smart DustIQ Explorer software

DEVICE COMMUNICATION BLOCK	
PARAMETER	VALUES
Baud rate	38400, 19200, 9600, 4800, 2400 and 1200
Data bits	8
Parity	None, even, odd
Stop bits	1, 2

The factory defaults are 19200 baud, 8 data bits, even parity and 1 stop bit (19200 – 8E1).



## 12.2.2. Status flags

DEVICE COMMON BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_STATUS_FLAGS	34	R	U	All	Device Status flags (0 = status OK)

BIT NR		STATUS WHEN 1	REMARKS
0	0000 0000 0000 000X	Hardware error detected	
1	0000 0000 0000 00X0	Soiling data error	Measurement out of range. Could happen after a bad local dust calibration or as a result of damaged glass.
2	0000 0000 0000 0X00	ADC error	
3	0000 0000 0000 X000	Flash error	Memory problem, potentially after a bad firmware upgrade
4	0000 0000 000X 0000	Tilt sensor error	Not used in the 0386900 model
5	0000 0000 00X0 0000	Not used	
6	0000 0000 0X00 0000	<b>Not used</b>	
7	0000 0000 X000 0000	Not used	
8	0000 000X 0000 0000	Not used	
9	0000 00X0 0000 0000	Not used	
10	0000 0X00 0000 0000	Not used	
11	0000 X000 0000 0000	Not used	
12	000X 0000 0000 0000	Watch dog error	A process timed out, try a power off / power on
13	00X0 0000 0000 0000	Not used	
14	0X00 0000 0000 0000	Not used	
15	X000 0000 0000 0000	Not used	

## 12.3. DustIQ release 3.02 data model (corrected)

The following section describes the data registers belonging to data model 3.02 as used at the time of the launch of the full feature model Pn 0386910 and 0386915.

### 12.3.1. Overview of the Modbus® registers

These registers are read-only and 16 bits wide unless otherwise specified.

The base of the input register block is set to 1 (MODBUS PLC address [base 1]), or 0 (MODBUS Protocol Address [base 0]) and occupies max. 100 registers (0-99, [base 0]).

**The address field in the table below is the Protocol address with base 0 and not the PLC Address with base 1.**

COMMON DATA BLOCK DUSTIQ					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_DEVICE_TYPE	0	R	U	All	Device type of the DUST-IQ sensor 800 for DustIQ
IR_DATAMODEL_VERSION	1	R	U	All	Version of the data model (=302 for current version)
IR_SOFTWARE_VERSION	2	R	U	All	Software version of the firmware (= 111238 or higher)
IR_BATCH_NUMBER	3	R	U	All	Production year in yy format
IR_SERIAL_NUMBER	4	R	U	All	Production serial number for the above mentioned year from 0000 to 9999
IR_HARDWARE_VERSION	5	R	U	All	Hardware version (= 5 for current hardware)
IR_CALIBRATION_YEAR	6	R	U	All	Factory calibration year 2000 to 2099
IR_CALIBRATION_MONTH	7	R	U	All	Factory calibration month 1 to 12
IR_CALIBRATION_DAY	8	R	U	All	Factory calibration day 1 to 31
RESERVED	9-16				Reserved for future expansion
CALIBRATION_COUNTER	17	R	U	All	Number of initiated local dust calibrations
CALIBRATION_SUCCESFULL_COUNT	18	R	U	All	Number of successful local dust calibrations
CALIBRATION_CONTEXT_FLAGS	19	R	U	All	Flags set during the calibration to indicate possible errors

REAL-TIME DATA BLOCK, SOILING SENSOR 1 (SENSOR CLOSEST TO THE INTEGRATED SILICON CELL)					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_SOILING_RATIO_SENSOR1	20	R	U	N,S	Soiling ratio SENSOR 1 in 0.1% , 101 to 50% 9999 when not valid
IR_TR_LOSS_SENSOR1	21	R	S	N,S	Transmission Loss SENSOR 1 in 0.1% , -1 to+50% 9999 when not valid
RESERVED	22	R	U	N,S	Reserved for future expansion
RESERVED	23	R	S	N,S	Reserved for future expansion

REAL-TIME DATA BLOCK, SOILING SENSOR 2					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_SOILING_RATIO_SENSOR2	24	R	U	N,S	Soiling ratio SENSOR 2 in 0.1% , 101 to 50% 9999 when not valid
IR_TR_LOSS_SENSOR2	25	R	S	N,S	Transmission Loss SENSOR 2 in 0.1% , -1 to+50% 9999 when not valid
RESERVED	26	R	U	N,S	Reserved for future expansion
RESERVED	27	R	S	N,S	Reserved for future expansion

TILT SENSOR BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_TILT_X_DIRECTION	28	R	S	All	<b>Tilt X direction (long axis) -179.9 to +180.0 in steps of 0.1 degree</b>
IR_TILT_Y_DIRECTION	29	R	S	All	<b>Tilt Y direction (short axis) -179.9 to +180.0 in steps of 0.1 degree</b>
RESERVED	30	R	S	All	Reserved for future expansion

TEMPERATURE SENSOR BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_BACKPANEL_TEMP	31	R	U	All	<b>Back panel temperature in 0.1 Kelvin</b>

DEVICE COMMON BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_DEVICE_VOLTAGE	32	R	U	All	<b>Device voltage in mV</b>
IR_OPERATIONAL_MODE	33	R	U	All	Operational mode: normal, service, calibration (1 = normal mode)
IR_STATUS_FLAGS	34	R	U	All	Device Status flags (0 = status OK)
RESERVED	35 – 39	R	U	All	Reserved for future expansion

The following modus registers are used for calibration, identification and error handling. These registers can be asked for in order to facilitate remote problem solving.

DEVICE INTERNAL BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
INTERNAL_VALUES_FOR_ERROR_HANDLING	40 - 99	R			For identification and error handling

Legend: Parameter Unique name of the register  
 Address Modbus PLC address  
 note: the Modbus PLC address is the Modbus Protocol Address + 1  
 R/W R= Read only / write ignore or R/W = read-write  
 SZ Data type and size; the following data types are used:  
     U 16 bit unsigned integer  
     S 16 bit signed integer  
 Level The following levels are used:  
     N Available in the normal operational mode  
     S Available in service/configuration level  
     All Available in all modes except the terminal mode.  
 Description Description of the parameter

S light grey background means changed value from original communication.

Soiling ratio % = 100 – Transmission Loss %

All soiling and transmission loss values are stored in 1/10 of a % also known as ‰.

All measurement values need to be divided by ten. E.g. the device voltage reported as 156 at address 32 represents a voltage of 15.6 V and a soiling ratio reported as 985 represents 98.5%

Communication parameters are user selectable from the following range using the Smart DustIQ Explorer software

DEVICE COMMUNICATION BLOCK	
PARAMETER	VALUES
Baud rate	38400, 19200, 9600, 4800, 2400 and 1200
Data bits	8
Parity	None, even, odd
Stop bits	1, 2

The factory defaults are 19200 baud, 8 data bits, even parity and 1 stop bit (19200 – 8E1).

## 12.4. Status flags

DEVICE COMMON BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_STATUS_FLAGS	34	R	U	All	Device Status flags (0 = status OK)

BIT NR		STATUS WHEN 1	REMARKS
0	0000 0000 0000 000X	Hardware error detected	
1	0000 0000 0000 00X0	Soiling data error	Measurement out of range. Could happen after a bad local dust calibration or as a result of damaged glass.
2	0000 0000 0000 0X00	ADC error	
3	0000 0000 0000 X000	Flash error	Memory problem, potentially after a bad firmware upgrade
4	0000 0000 000X 0000	Tilt sensor error	
5	0000 0000 00X0 0000	<b>Humidity error</b>	<b>Internal humidity sensor reports a level too high for proper operation</b>
6	0000 0000 0X00 0000	<b>Not used</b>	
7	0000 0000 X000 0000	Not used	
8	0000 000X 0000 0000	Not used	
9	0000 00X0 0000 0000	Not used	
10	0000 0X00 0000 0000	Not used	
11	0000 X000 0000 0000	Not used	
12	000X 0000 0000 0000	Watch dog error	A process timed out, try a power off / power on
13	00X0 0000 0000 0000	Not used	
14	0X00 0000 0000 0000	Not used	
15	X000 0000 0000 0000	Not used	

## 12.5. Calibration flags (added)

DEVICE COMMON BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_CALIBRATION_FLAGS	35	R	U	All	Calibration flags (0 = OK)

BIT NR		STATUS WHEN 1	REMARKS
0	0000 0000 0000 000X	Dust msrment started	Dust measurement started
1	0000 0000 0000 00X0	Clean msrment1 started	Clean measurement step 1 started (sensor 1 and silicon cell)
2	0000 0000 0000 0X00	Clean msrment2 started	Clean measurement step 2 started (sensor 2)
3	0000 0000 0000 X000	Calculation started	
4	0000 0000 000X 0000		
5	0000 0000 00X0 0000		
6	0000 0000 0X00 0000		
7	0000 0000 X000 0000		
8	0000 000X 0000 0000	Calc & Val error slopes	Calculation error in one of the slopes or validation of initial TL or sunlight not in range
9	0000 00X0 0000 0000	Leave button 2 early	Calibration button should be pressed a bit longer
10	0000 0X00 0000 0000	Error in DC ratio	Fluctuation in sunlight too big during calibration
11	0000 X000 0000 0000	Transmission loss too low	Procedure stopped after 1 <sup>st</sup> button press, TL of sensor 1 was <5% (<50 ‰ in register 21)
12	000X 0000 0000 0000	PV too low	Not enough sun or silicon cell extremely dirty
13	00X0 0000 0000 0000	Calibration btnn pressed	Calibration button pressed to start procedure
14	0X00 0000 0000 0000		
15	X000 0000 0000 0000		

Example: Decimal value of 2305 is binary 1001.0000.0001

- Dust measurement started
- Calc & Val error slopes
  - Transmission loss too low

Local dust calibration started when there was not enough soiling on sensor 1 (the sensor closest to the silicon cell).

## 12.6. Calibration context flags (address corrected)

DEVICE COMMON BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_CALIBRATION_CONTEXT_FLAGS	158	R	U	All	Calibration context flags (0 = status OK)

BIT NR		STATUS WHEN 1	REMARKS
0	0000 0000 0000 000X	Sensor error	Monitor signal sensor too low, critical error
1	0000 0000 0000 00X0	Not enough sun	Less than 800 W/m <sup>2</sup> measured
2	0000 0000 0000 0X00	Soiling error	Below 5% reported transmission loss (<50 ‰ in register 21)
3	0000 0000 0000 X000	Disturbed measurement	Sun was blocked by e.g. clouds or hands
4	0000 0000 000X 0000	Sensor 1 not cleaned	No difference measured before and after cleaning Sensor 1 not cleaned when it should have been cleaned
5	0000 0000 00X0 0000	PV cell not cleaned	No difference measured before and after the small PV cell should have been cleaned
6	0000 0000 0X00 0000	Sensor 2 cleaned	Sensor 2 cleaned when it should not have been cleaned yet
7	0000 0000 X000 0000	Sensor 2 not cleaned	Sensor 2 not cleaned when it should have been cleaned
8	0000 000X 0000 0000	Dust slope incorrect	Measurements have resulted in out of range calculations and are ignored
9	0000 00X0 0000 0000		
10	0000 0XX0 0000 0000		
11	0000 X000 0000 0000		
12	000X 0000 0000 0000		
13	00X0 0000 0000 0000		
14	0X00 0000 0000 0000		
15	X000 0000 0000 0000		

## 12.7. Sample ModbusPoll data for data model 3.01

Tx = 3; Err = 0; ID = 1; F = 04; SR = 1000ms

	Alias	00000	Alias	00010	Alias	00020	Alias	00030
0	Device type	800		60	SR1	1009		25158
1	Model	301		0	TL1	-9	PVtemp	0
2	Software	11088		0		0	mVolt	3182
3	Year	15		0		0	Status	1
4	Serial	1		0	SR2	1012	Flags	0
5	hardware	5		0	TL2	-12		0
6	Cal yr	2018		0		9955		78
7	Cal mnth	5		0		9984		0
8	Cal day	15		0	TiltX	0		73
9		0		0	TiltY	0		0

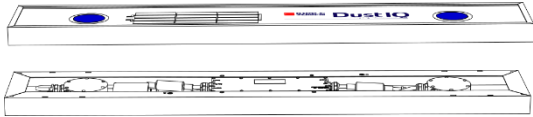
## 12.8. Tilt sensor output

Below are the Modbus registers and sample output depending on correct and incorrect mounting.

TILT SENSOR BLOCK					
PARAMETER	ADDRESS	R/W	SZ	LEVEL	DESCRIPTION
IR_TILT_X_DIRECTION	28	R	S	All	<b>Tilt X direction (long axis) -179.9 to +180.0 in steps of 0.1 degree</b>
IR_TILT_Y_DIRECTION	29	R	S	All	<b>Tilt Y direction (short axis) -179.9 to +180.0 in steps of 0.1 degree</b>
RESERVED	30	R	S	All	Reserved for future expansion

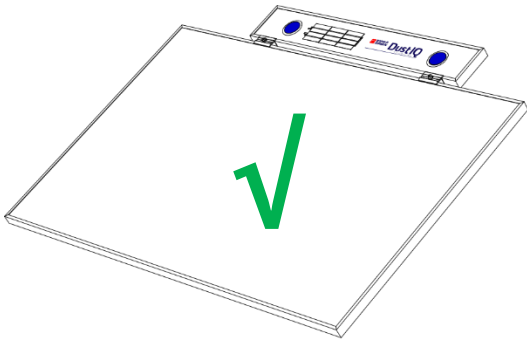
### 12.8.1. Tilt sensor readings in several positions

The tilt is reported in 0.1 degrees thus angle of e.g. 34.7 degrees is reported as 347.



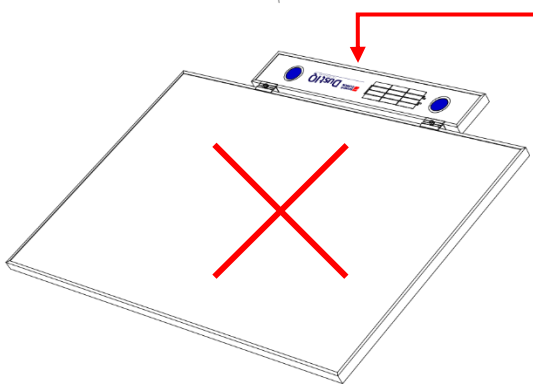
In the correct position. Tilt x and y are close to zero.

Upside down. Tilt x is zero and Tilt y is -1800

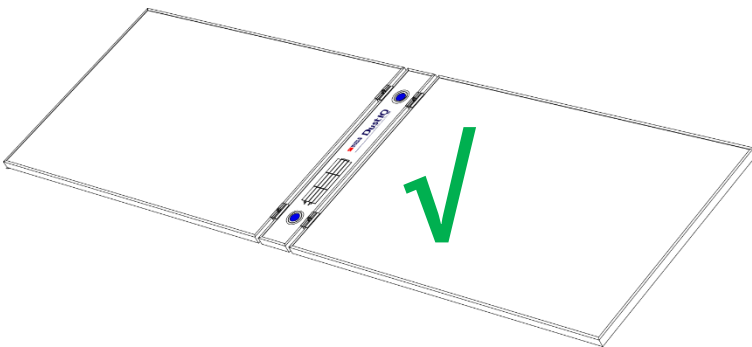


In the correct position on top. Tilt x  $\approx$  0 and Tilt y is between 0 and 900.

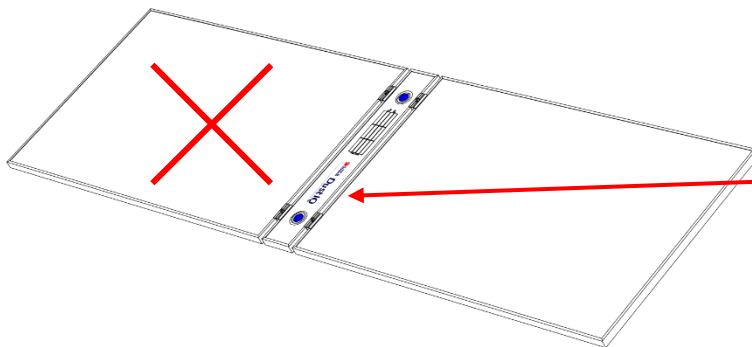
**This way the DustIQ must have a supporting structure.**



Upside down on top. Tilt x  $\approx$  0 and Tilt y is between -900 and 0.



In the correct position, in between or on the side, Tilt x is between 0 and 900 and Tilt y  $\approx$  0.



Upside down, in between or on the side, Tilt x is between -900 and 0 and Tilt y  $\approx$  0.

This way one **cannot** perform the local dust calibration properly.

## 12.9. Reset using Modbus Write coil commands

Depending on the firmware, the DustIQ offers one or two reset capabilities.

### 12.9.1. Full Factory reset valid for **all** firmware versions

This reset restores **all** settings to default, including resetting the communication parameters to 19.200 baud, 8 bit, 1 stop bit, even parity and the factory dust calibration with Arizona Test Dust. The reset works on all firmware versions.

**Note** The DustIQ will **not** go back to the previous dust calibration if one was made earlier but to the **factory** dust calibration.

If the SCADA system allows Modbus® commands to be programmed and send, then it can be done remotely without local intervention.

Otherwise connect the DustIQ to an RS485-USB interface and to a suitable 12-30V power supply, in-situ or in the office.

Start ModbusPoll or QModMaster or equivalent software

Example settings for a DustIQ at Modbus address 1

	Alias	00000
0		
1		
2		
3		0
4		0
5		0
6		0
7		
8		
9		

The coils 3 -7 are read as shown above:

Double click on the value of the desired register to switch the value to **On** and click Send.

Start with double clicking on register **5**.

Do this three times in the **5-3-6 order**:

- 1) Switch coil **5** to ON = Reset to factory config
- 2) Switch coil **3** to ON = Apply update
- 3) Switch coil **6** to ON = Reset instrument or you can perform Power Off and On

After the sequence the DustIQ gives a very short blink of the sensor LEDs. The switched coils will be reset.

## 12.9.2. Dust Calibration reset

This reset only restores the factory dust calibration with Arizona Test Dust and only works on firmware 11.148 and above.

**Note** The DustIQ will **not** go back to the previous dust calibration if one was made earlier but to the **factory** dust calibration.

If the SCADA system allows Modbus® commands to be programmed and send, then it can be done remotely without local intervention.

Otherwise connect the DustIQ to an RS485-USB interface and to a suitable 12-30V power supply, in-situ or in the office.

Start ModbusPoll or QModMaster or equivalent software

Example settings for a DustIQ at Modbus address 1

	Alias	Value
0		
1		
2		
3		0
4		0
5		0
6		0
7		0
8		0
9		

The coils 3 -8 are read as shown above:

Double click on the value of the desired register to switch the value to **On** and click **Send**.

Start with double clicking on register **8**.

Do this three times in the **8-3-6 order**:

- 4) Switch coil **8** to ON = Reset to factory config
- 5) Switch coil **3** to ON = Apply update
- 6) Switch coil **6** to ON = Reset instrument or you can perform Power Off and On

After the sequence the DustIQ gives a very short blink of the sensor LEDs. The switched coils will be reset.



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## 12.11. Example Campbell programs

The following programs are short examples of how to read and store data from a DustIQ connected to either a CR100X or CR6. Both of these have native RS-485 and Modbus support.

### CR6 example:

```
'For programming tips, copy this address to your browser
'https://www.campbellsci.com/videos/datalogger-programming

'CR6 Series Datalogger
'Date: 10-10-2018Program author:Donald van Velsen

'Declare Constants
'Example:
'CONST PI = 3.141592654 or Const PI = 4*ATN(1)

'Program to read the soiling and transmission loss registers of a DustIQ

'Result stores the outcome of the modbus communication. if succesfull the result is 0.
'If communications failed with the DustIQ result will increment with 1
Public Result

'Data array to store read out value
Public SRSensors(8) As Long
'Aliasing of the array to increase readability of the data table
Alias SRSensors(1) = Soiling_ratio_sensor_1
Alias SRSensors(2) = Transmission_loss_sensor_1
Alias SRSensors(3) = Reserved_sensor_1_1
Alias SRSensors(4) = Reserved_sensor_1_2
Alias SRSensors(5) = Soiling_ratio_sensor_2
Alias SRSensors(6) = Transmission_loss_sensor_2
Alias SRSensors(7) = Reserved_sensor_2_1
Alias SRSensors(8) = Reserved_sensor_2_2

'DustIQ modbuss address,
Public SensorMBAAddress(1)= {3} As INT 'the one on my desk had address 3

'Communication port to be used on datalogger
'ComC1 = data - is grey wire in Kipp cable
'ComC2 = data + is yellow wire in Kipp cable

Const SensorPort = ComC1 'DustIQ on a cr6 it is ComC1 or ComC3 see Campbell manual

'datatable to record the data
'in this case only the two soiling ratio's are stored
DataTable(DustIQ,True,-1)
    DataInterval(0,1,min,10)
    Sample(2,Soiling_ratio_sensor_1,Long,False) 'Soiling_Ratio_sensor 1
    Sample(2,Soiling_ratio_sensor_2,Long,False) 'Soiling_Ratio_sensor 2
EndTable

'Main Program
BeginProg
    'declare variable blnOpen, if true communication port is succesfully opened
    Public blnOpen As Boolean

    'Open the serial port, 8 bits, even parity, 19200 baud, optional param "4" at end for RS485 half-duplex
    on cr6
    blnOpen=SerialOpen(SensorPort,19200,2,0,200,4)    'even parity

    'scan the registers 20 and 21 for sensor 1, registers 24 and 25 for sensor 2.
    'note that they are incremented with 1.
    Scan (1,min,0,0)
        'ModbusMaster ( ResultCode, ComPort, BaudRate, ModbusAddr, Function, Variable, Start, Length,
Tries, Timeout, [ModbusOption] )
        ModbusMaster (Result,SensorPort,19200,SensorMBAAddress(1),4,SRSensors(1),21,2,3,10,1)
'Sensor1 Soiling Ratio & Transmission Loss read
    'register 21 & 22 read. register 22 & 23 are reseverd at this time
    ModbusMaster (Result,SensorPort,19200,SensorMBAAddress(1),4,SRSensors(5),25,2,3,10,1)
'Sensor2 Soiling Ratio & Transmission Loss read
    'register 25 & 26 read. register 27 & 28 are reseverd at this time
    'Store data to table
    CallTable DustIQ
    NextScan
EndProg
```

### CR1000X example:

```
'Program to read the soiling and transmission loss registers of a DustIQ

'Result stores the outcome of the modbus communication. if succesfull the result is 0.
'If communications failed with the DustIQ result will increment with 1
Public Result

'Data array to store read out value
Public SRSensors(8) As Long
'Aliasing of the array to increase readability of the data table
Alias SRSensors(1) = Soiling_ratio_sensor_1
Alias SRSensors(2) = Transmission_loss_sensor_1
Alias SRSensors(3) = Reserved_sensor_1_1
Alias SRSensors(4) = Reserved_sensor_1_2
Alias SRSensors(5) = Soiling_ratio_sensor_2
Alias SRSensors(6) = Transmission_loss_sensor_2
Alias SRSensors(7) = Reserved_sensor_2_1
Alias SRSensors(8) = Reserved_sensor_2_2

'DustIQ modbuss address,
Public SensorMBAAddress(1)= {1} As INT 'standard factory setting Modbus address

'Communication port to be used on datalogger
'ComC5 = data - is grey wire in Kipp cable
'Comc6 = data + is yellow wire in Kipp cable

Const SensorPort = comC5 'DustIQ on a cr1000x comC5 and comC6 canbe used, on a cr6 it is ComC1 or ComC2 see
Campbell manual

'datatable to record the data
'in this case only the two soiling ratio's are stored
DataTable(DustIQ,True,-1)
    DataInterval(0,1,min,10)
    Sample(2,Soiling_ratio_sensor_1,Long,False) 'Soiling_Ratio_sensor 1
    Sample(2,Soiling_ratio_sensor_2,Long,False) 'Soiling_Ratio_sensor 2
EndTable

'Main Program
BeginProg
    'declare variable blnOpen, if true communication port is succesfully opened
    Public blnOpen As Boolean

    'Open the serial port, 8 bits, even parity, 19200 baud, optional param at end for RS485 half-duplex
    blnOpen=SerialOpen(SensorPort,19200,2,0,200) 'even parity

    'scan the registers 20 and 21 for sensor 1, registers 24 and 25 for sensor 2.
    'note that they are incremented with 1.
    Scan (1,min,0,0)
        'ModbusMaster ( ResultCode, ComPort, BaudRate, ModbusAddr, Function, Variable, Start, Length, Tries,
    Timeout, [ModbusOption] )
        ModbusMaster (Result,SensorPort,19200,SensorMBAAddress(1),4,SRSensors(1),21,2,3,10,1) 'Sensor1
    Soiling Ratio & Transmission Loss read
        'register 21 & 22 read. register 22 & 23 are reseverd at this time
        ModbusMaster (Result,SensorPort,19200,SensorMBAAddress(1),4,SRSensors(5),25,2,3,10,1) 'Sensor2
    Soiling Ratio & Transmission Loss read
        'register 25 & 26 read. register 27 & 28 are reserverd at this time
    'Store data to table
    CallTable DustIQ
    NextScan
EndProg
```

## 13. Frequently asked questions

Q: My DustIQ doesn't flash every minute.

A: This is a serious condition and when you're sure that proper power (12-30V, 500mA) is supplied to the DustIQ and it doesn't change after a power off – power on sequence you will have to contact Kipp & Zonen or your local representative.

Q: My DustIQ flashes but I get no data.

A: Are your communication parameters setup correctly (factory standard is 19200, 8E1) and are Data + and Data- connected correctly? Does your data logger have the right native support for RS-485 Modbus RTU to Modbus slaves ?. Sometimes the RS-485 is for communication between data loggers only.

Q: Why is my PV panel temperature sensor giving strange readings?

A: Is the connector seated properly? Is the sensor itself installed properly and still on the back of the PV panel and in the right place? With the double sided tape used it's unlikely for the sensor to come lose unless the PV panel wasn't cleaned properly before installation.

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Our instruments have an impressively long operating life when properly maintained. We offer a variety of

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