METOS®
BY PESSL INSTRUMENTS

iMETOS SoilGuard

Portable Soil Moisture Meter

PRODUCT MANUAL

VERSION 1.0, 07-2021

Pessl INSTRUMENTS

General overview

Thank you for purchasing the iMETOS SoilGuard soil moisture meter. This manual describes the meter's general features and operation. The iMETOS SoilGuard solution is the perfect mobile tool for measuring soil moisture, electrical conductivity (EC) and soil surface temperature.

Its handling facility allows users - from agricultural to greenkeeping activities - to take multiple in-field measurements within one day. Data is displayed on the device screen or via data import. A USB stick should be connected to the SoilGuard uploader, while data can be visualized either on your smartphone or on the web portal (TurfClimate), while data will be available for both applications, once uploaded. SoilGuard uploader: **iOS** or **Android** versions; TurfClimate app: **iOS** and **Android**.

Together with the permanent readings and the mobile application and the spot readings from iMETOS SoilGuard you will get a complete picture of the golf course's moisture profile, the temperature readings on the various points of the green in the form of color-coded sample markers for easier understanding and further decision-making.

Key features:

- Easy to use, mobile and rapid measurements
- Easy-readable backlit display to see the values immediately
- Provides up to 50,000 measurements, all with their specific GPS coordinates
- Has an ergonomic design with a telescoping tubular frame
- Provides accurate measurements of:
  - soil moisture (Volumetric Water Content %)
  - electrical conductivity (salts)
  - soil surface temperature

Contents

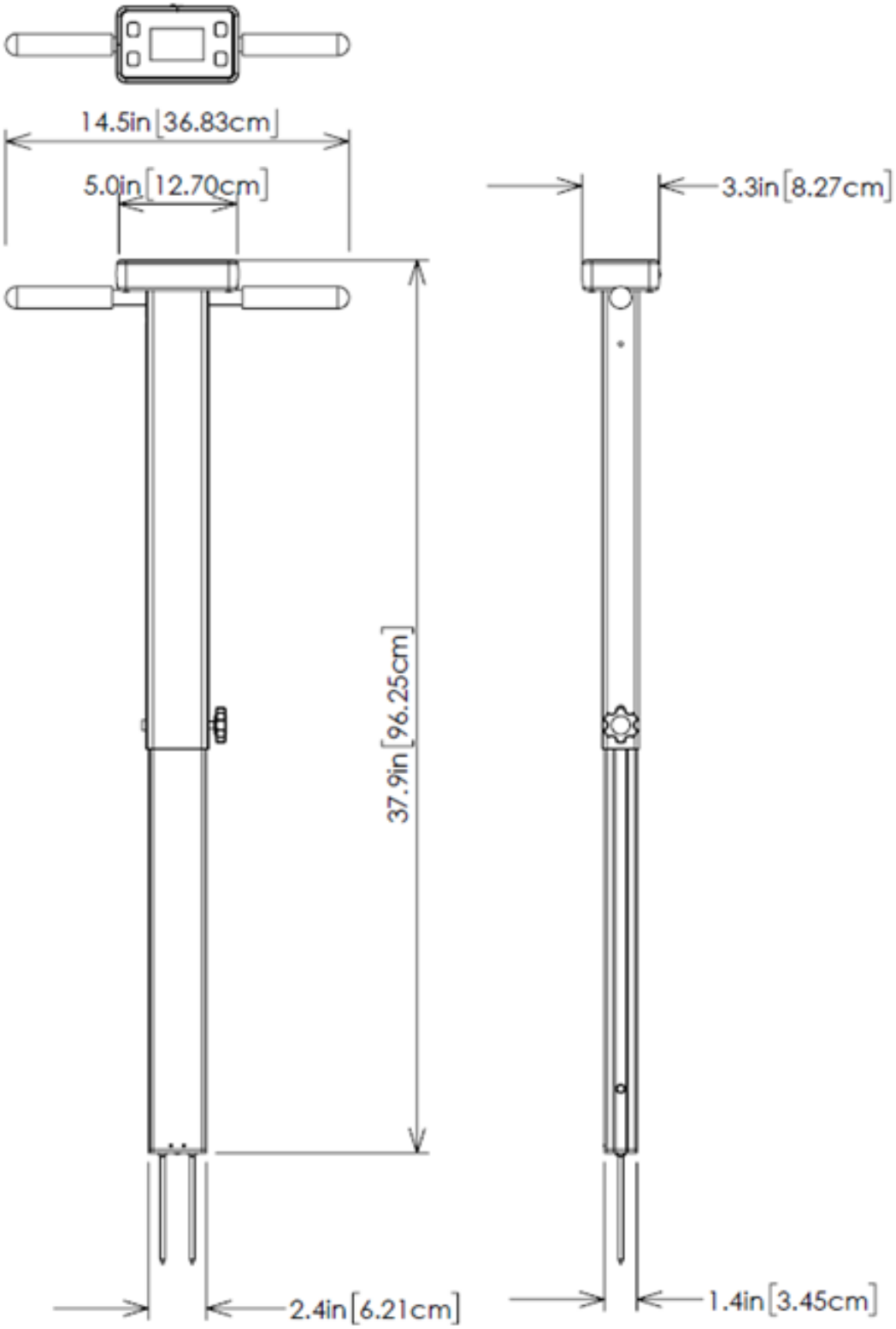
Includes the following components:

- iMETOS SoilGuard meter (in collapsed position)
- Carrying case
- 4 AA batteries already installed

Specifications

Measurement Units	Percent volumetric water content (VWC) Period (raw sensor reading)
Resolution, Accuracy and Range	VWC: 0.1% increment ±3.0% @ < 2 mS/cm 0% to Saturation (Saturation is typically around 50% volumetric water) EC: 0.01 increment ; ± 0.1 mS/cm; 0 - 5 range Temperature: 0.2 ˚F (0.1 ˚C) increment ; ± 1.8 ˚F (± 1 ˚C); -22 to 140 ˚F (-30 to 60 ˚C) Thermistor based; Infrared Optional
Connectivity	USB Type A, Bluetooth Low Energy
(GNSS)	Accuracy Galileo 1m; GPS 3.5 to 7.5m; GLONASS 2.8 to 10 m; QZSS 1 m (where available) WAAS, SBAS, and EGNOS enabled
Power	4 AA alkaline batteries
Log Capacity	50,000 measurements
Display	Backlit, high-contrast, graphic LCD
Weight	4.3 lbs. (1.9 kg)
IP Rating	Display: IP53, Probe: IP67
Available Rod Dimensions	Turf 1.5” (3.8cm) Short 3.0” (7.6cm) Medium 4.8” (12.2cm) Long 8.0” (20.32cm) Diameter: 0.2” (0.5cm) Spacing: 1.2” (3cm)

Product dimensions



Meter Care

The SoilGuard meter will function properly under normal conditions experienced in field use. The sensor block is sealed and will not be damaged by immersion in water. The display is not waterproof so it should not be used during heavy rainfall or left exposed during irrigation events. If the display does get wet, it should be dried out immediately.

Follow these tips to prolong the life of the device:

- Store in a cool and dry place when not in use.
- Keep the meter and probe rods clean and dry in between uses.
- Remove the batteries if not used for an extended period of time (ie: between seasons).

Battery life

If the battery level is low or a battery is inserted incorrectly, the low battery icon appears on the screen briefly then, the display will power off.

Battery life is affected by the enabled features, accessories connected, and the frequency of use. If not needed, the Bluetooth, GNSS Location and backlight features can be disabled individually. The backlight can be disabled or set to AUTO mode which allows enough time to see new measurements and then will power down the backlight to conserve the battery life.

Button functions

ON/OFF | BACK button

- Press briefly to power on.
- Press and hold to power on and stay on the startup screen.
- Press for 2 seconds to power off.
- Press briefly within a menu to return to the prior screen.

MENU | SELECT button

- Press to enter available menus.
- Press to select or confirm a menu selection.

DELETE | UP button

- Press to move up within the menu.
- Delete last measurement from the running average, counter, and its entry from the internal data log.

READ | DOWN button

- Press to move down within the menu.
- Press to make a reading from the Reading screen.
- Press and hold to reset the average and count.

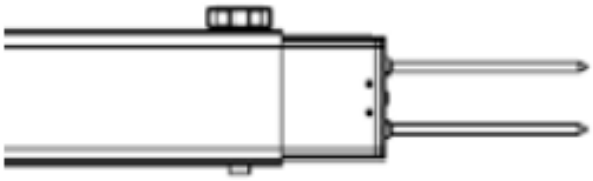
Meter operation

Setting up the meter

1. Pull the clear battery transport tab out of the display unit.
2. If desired, extend the collapsible shaft by removing the thumb screw (shown above) from the side, grip and extend the lower shaft to its new position, re-insert the thumb screw, and hand tighten.
3. Select a set of probe rods, screw in, and tighten them to the bottom of the probe block.
4. Set the desired user settings in the settings menu. See the Settings Menu.

Taking Readings

1. Grip the TDR handles to the left and right of the display.
2. Push down on the handles maintaining a steady downward pressure to drive the rods into the soil until the sensor base is in contact with the soil surface. Refrain from any back and forth or side to side movement which can introduce air pockets into the soil medium and alter the reading accuracy.
   Caution: Exercise care not to bend or damage the rods.
3. Press the READ button and observe the change in results on the top display.



Probe base, thumb screw, and probe rods

Display screens

The iMETOS SoilGuard has 3 main display screens:

- Startup
- Reading (shown below)
- Settings Menu

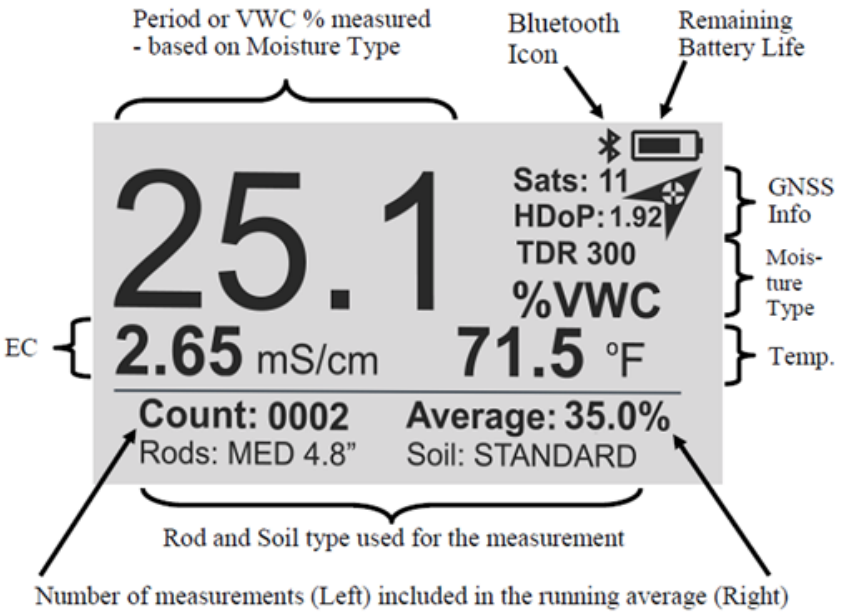
Startup Information screen

Initially displayed after first powered on.

- Displays model, serial number and firmware version.
- Press and hold ON/OFF|BACK button to remain on this screen.

Reading screen

Displays the last measurement, EC in milliSiemens per centimeter, temperature, selected rod type, selected soil type, and a reading count with running average. VWC=0% readings will be displayed but will not increment the counter or be included in the average.



Sample view from iMETOS SoilGuard

Settings Menu screen

Used for changing device features, setting rod length and working with log files.
Use the arrow buttons to move to the desired option. Use the MENU|SELECT button to toggle option choices.

Clear Average*: Clears the displayed average and count.
Note: Same as a press and hold of the **READ|Down** arrow button.

Rod Length: Select the Rod length. See page 4 for options.

Soil Type: Selects the soil type used in measurements:

- Standard: for most mineral soils.
- Hi-Clay: for soils with higher clay content (> 27%).
- Sand: for sand-based fields or turf greens.

Clear Logs*: Erases data logs from internal memory.

Save to USB*: Transfers data logs to a USB flash drive if attached.

Backlight: Sets the LCD backlight: ON, OFF, AUTO. In AUTO mode, the backlight will shut off 5 seconds after a button press

GNSS Location, GNSS Power Save, GNSS Use QZSS: Enable or disable features related to geo-location capability (see p. 12).

Bluetooth: Enable or disable Bluetooth connectivity to the SoilGuard ™ Mobile app (See p. 20).

Sound: Enable or disable beep for audible feedback.

Temp Source: Changes displayed temperature from the Soil Sensor to the IR Sensor (optional).

Temp Units: Fahrenheit or Celsius scale.

Moisture Type: Selects displayed moisture mode VWC%, Period, or TDR 300.
- VWC%: Volumetric Water Content with EC compensation.
- Period: Raw sensor reading in microseconds (us).
- TDR 300: VWC without EC compensation

EC Units: EC value (mS/cm) or Salinity Index (see p. 25).

Auto-Off: Power off delay: 15, 30, 45, 60 minutes.

Current Date, Current Time: Displays or changes current values. See p. 13 for details.

Timezone: Offset from Greenwich Mean Time. As the offset changes, the Time and Date will update.

Daylight Savings: ON or OFF.

Calibration*: Overrides factory calibration. See Appendix

Clear User Calibration: Clears the user applied calibration back to factory settings

Factory Defaults*: Resets menu settings and counter to the factory default value.

About: General information (Model and serial number, firmware versions for display and sensor).

Rod Length	None	**Temp Source**	Soil Sensor
Soil Type	Standard	**Moisture**	VWC
Backlight, GNSS, Bluetooth	Disabled	**EC units**	mS/cm
Sound	On	**Auto-Off**	15 minutes
Temperature	Fahrenheit	**Time Zone**	GMT

Setting Date/Time

By default, the iMETOS SoilGuard gets the date and time from the satellite signal. These values are displayed in the Settings Menu. The date and time can also be set manually. When the time and date are set manually, they will override the default value.
Note: When the batteries are removed, the date/time are reset and the meter resumes getting this information from the satel-lites.

Updating the Date and Time

1. Press the MENU|SELECT button to get to the Settings Menu.
2. Press the UP or DOWN arrows to navigate to either the Cur-rent Date or Current Time option.
3. Press the MENU|SELECT button to access the Time/Date up-date screen.
   There are 3 options:
   A. Press the READ|DOWN button to download an update from the GNSS satellites. Proceed to an area with a good view of the sky and press the Menu/Select button to initiate the process.
   B. Press the DELETE|UP button to set the date and time manu-ally. The current settings will be displayed. Use the UP and DOWN arrows to adjust the highlighted selection. Press the MENU|SELECT button to confirm and proceed to the next pa-rameter. After pressing the MENU|SELECT button to set the minutes, the display will return to the Reading screen.
   C. Press the ON/OFF|BACK button to return to the Settings Menu without making any change.

GNSS (location) Settings

GNSS Location adds the ability to log global position coordinates with measurements to aid in irrigation mapping of crops and turf greens. Location references are stored with the measurement in the data log and can be uploaded to the cloud through the SoilGuard Uploader mobile app option.
The following menu settings apply to and effect the GNSS location feature:

GNSS Location

Enabled: Measurements will include global position coordinates of the meter position in the data log and\or Turfclimate App.
Disabled: No location coordinates appear in the Data Log. The Turfclimate app measurements will include the global position of the mobile device running the app.

GNSS Power Save

Enabled: After periods of inactivity, the GNSS receiver will be placed in standby to improve battery life. The receiver resumes after the next read button press. A brief pause may be noticed as the receiver resumes operation.
Disabled: GNSS receiver will remain on for faster measurements. It is recommended to keep disabled during the first few days of use to im-prove accuracy and mapping.

GNSS Use QZSS

Enabled (Default): Improves location accuracy in Australia, Banga-lore, Guam, Hawaii, Japan, Singapore and surrounding areas.
Disabled: Can improve location referencing time when outside of the referenced regions.

GNSS Location: Features, Use and Optimization

When enabled, the GNSS Location feature provides active location referencing information to aid in measurement mapping.

HDoP: Actively transitions from a high to low value as the level of precision improves. It may increase in value if conditions degrade. Values typically range between 9.99 to as low as 0.2. The value will appear blank until satellites in range are received and precision is calculated.
Sats: Active number of satellites used for position and location measurements. The value will increase from 00 as more satellites are received and used.

Location Reference Arrow Icon:

Transitions with changes in conditions, available satellites, and higher levels of precision are reached.

Blank icon - GNSS feature is enabled and not ready for location referencing of measurements. Measurements made with this icon will not have a geo-referenced location.

Partially Shaded - HDoP level is high and the satellite count is low. Measurements will have geo-referenced coordinates with a low level of accuracy (< 10m typical).

Dark Shaded - High satellite count without supplemental aug-mentation. Measurement location accuracy will depend on HDoP and Sats count.

Dark Shaded with Blank Dot - Low Satellite count with supple-mental augmentation available to improve accuracy. Measure-ment location accuracy will depend on HDoP.

Dark Shaded with crosshair - High satellite count with supple-mental augmentation available to improve accuracy. Measure-ment location accuracy is optimal (< 2.5m) and will depend on HDoP.

Clock icon; HDoP: Z.zz - GNSS Power Save has placed the receiver in standby mode. Press READ|Down button to resume. Note: First reading will have a slight delay.

Initial Use:

During the first three days of use, the meter's GNSS receiver will build an internal satellite record used for tracking and accuracy. Accuracy during this time may appear low, will depend upon the accuracy of available satellite systems, and can vary to within 10 meters.

After the third use, the satellite record will be complete; the speed and accuracy of the location referencing will be at its best as the record is synchronized with the area the meter is being used.

Preparing for measurements:

Expect the first georeferenced location to take place within a minute or so of operation on a clear day.
A minimum of 4 received satellites are necessary for a location fix. Achieving 10 or more satellites will yield better position data.

For Best Results:

- Keep the meter active for more than 6 minutes per session.
- Avoid powering off the meter between measurement locations with-in a use session. The meter will acquire the most satellites and better position data when remaining on for longer periods of use.
- Position the meter upright (probes facing down) while moving between locations to allow continued satellite tracking.
- When positioning the meter for a measurement, observe the display for a dark arrow icon, low HDoP value, and high Sats number.
- If possible, keep the meter stationary in position for a moment before pressing the read button.
- For faster results, disable GNSS Power Save to keep the receiver active. When enabled and the meter has been inactive, GNSS receiver may take a few seconds to resume from standby.
- Avoid using close to structures and dense tree canopies which can block satellite signals.
- Adjust standing position to acquire best icon shading and satellite count prior to pressing the read button. Simply standing to the side of the meter may make satellites visible and change the count and precision.

Data Logs

Before downloading data to the USB, the USB-OTG adapter offered by Pessl Instruments has to be formatted before using it the first time for downloading data from your SoilGuard device.

- Simply connect it to your computer, go to the corresponding drive and format it. In Windows 10: right-click on the drive, click format.
- Select the FAT32 file system and press start.

Downloading Data Logs to a USB Flash Drive

1. Remove the protective dust cover from the USB port.
2. Connect the flash drive to the meter's USB port. Note: A USB cable is not required or recommended.
3. Press the MENU|SELECT button to open the Settings Menu.
4. Press the READ|Down arrow button to reach the Save to USB option.
5. Press the MENU|SELECT button to select the option.
6. When the download completes, "Logs Saved!" will appear on the LCD screen.
7. Remove the flash drive from the USB port and replace the dust cover.

The data will be saved to the flash drive as a comma-separated text file (.csv) named with the serial number as the filename. These files can be opened with common text-editing or spreadsheet software. If a previous data file exists on the flash drive with the same filename, it will be overwritten. Be sure to save any existing data logs on the flash drive prior to saving a new file.

Erasing the internal Data log

1. Press the MENU|SELECT button to open the Settings Menu.
2. Press the READ|Down arrow button to reach the Clear Logs option
3. Press the MENU|SELECT button to select the option.
4. Press MENU|SELECT button again to start the process or the ON/OFF|BACK button to return back to the menu.

Data Collected

The following information is logged with each reading:
Time, VWC%, Period, EC, Temp_Soil, Temp_Soil(F), Temp_IR, Temp_IR(F), Latitude, Longitude, Satellites, Fix, Rod Length, Soil Type, VWC Mode, HDoP

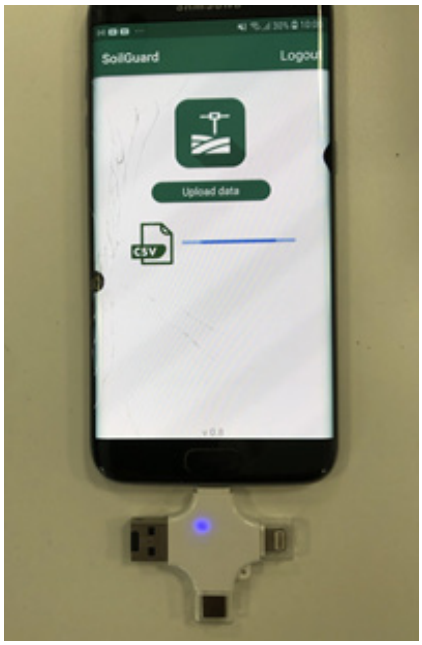
- **Time:** MM/DD/YYYY HH:MM:SS based on the GMT offset selected in the Timezone option, Data Logs
- **VWC%:** Volumetric Water Content based on the Moisture Type setting
- **Period:** Raw Period result (after any applied user calibration)
- **EC:** Electrical Conductivity in milliSiemens per centimeter
- **Temp_Soil:** Soil temperature sensor reading in degrees Celsius
- **Temp_Soil(F):** Soil temperature sensor reading in degrees Fahrenheit
- **Temp_IR:** InfraRed soil temperature sensor reading in degrees Celsius (if equipped)
- **Temp_IR(F):** InfraRed soil temperature sensor reading in degrees Fahr-enheit (if equipped)
- **Latitude, Longitude:** Geo-referenced coordinate acquired in decimal degrees format. Note: A negative sign may appear indicating South or West coordinates.
- **Satellites:** Number of satellites used in geo-referenced location
- **Fix:** GNSS location fix level; 0 - unreferenced, 1 - fixed reference, 2 - fix with additional accuracy correction (SBAS, WAAS, EGNOS)
- **Rod Length:** Depicted as L: Long (8"), M: Med (4.8"), S: Short (3"), T: Turf (1.5"), 1: 0.5" Spacer, and 2: 1.0" Spacer
- **Soil Type:** character depicted as S: Standard, H: Hi-Clay, and D: sand.
- **VWC Mode:** depicted as V for EC compensated or 3 for non-compensated (TDR-300).
- **HDoP:** Horizontal Dilution of Precision value achieved with the GNSS coordinates

Data Upload

There are 2 ways to import the data: either using SoilGuard uploader (mobile app) or TurfClimate (web platform).

Using the SoilGuard uploader

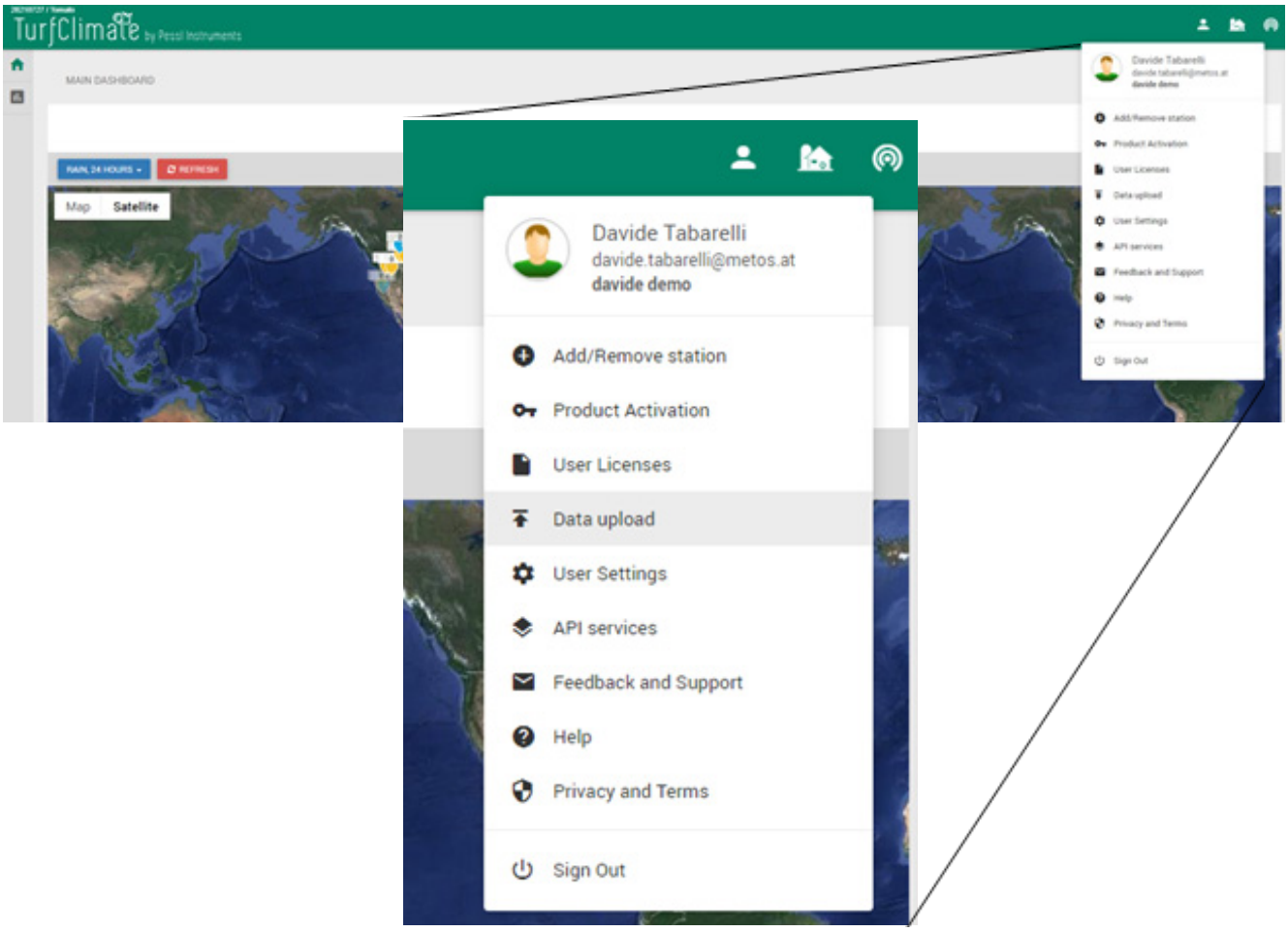
- For the data upload, a user account is required. You can register an account for free here: https://turfclimate.com/ or https://ng.fieldclimate.com/auth/login.
- Insert the USB sticker to the mobile phone
- For iOS phones, an Apple Lightning to USB camera cable is needed to connect the USB stick for the upload due to Apple security reasons.
- Open the SoilGuard uploader app and press ”Upload data”



Insert the USB sticker to the mobile phone.

Using the web platform

https://turfclimate.com or https://ng.fieldclimate.com/auth/login, data can be uploaded by clicking on the top-right corner **User menu -> Data upload**.



On TurfClimate select Data Upload and select the .csv file from the USB driver.

Data visualization

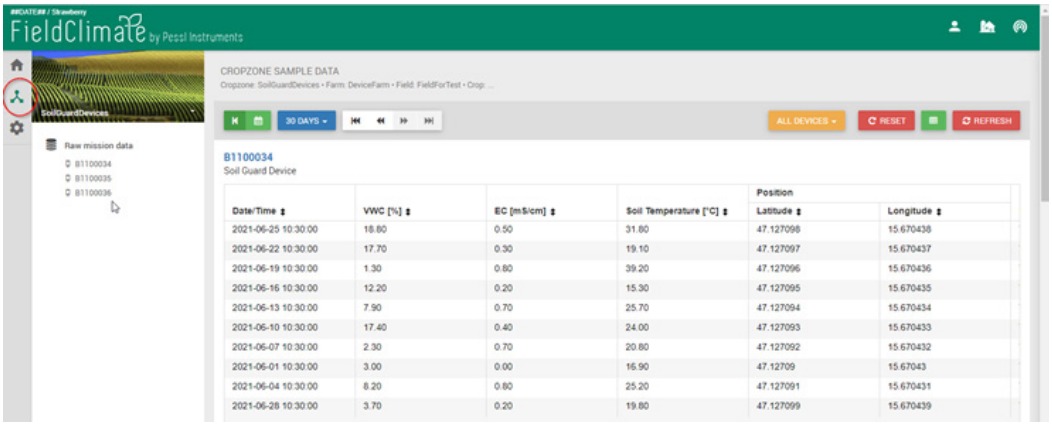
A **prerequisite for sample data** visualization on the TurfClimate App is the definition of a crop zone covering your samples using the web portal https://turfclimate.com/. To create a crop zone please follow the instructions on the tutorial https://www.youtube.com/watch?v=KGb5z6Ldu-g.
After data upload to the server, data can be visualized on the mobile app or the TurfClimate web portal. Both environments are dedicated for greenkeepers and farmers with iMETOS devices (SoilGuard, MobiLab, Dualex).

Web Portal data visualization

For the web portal application, SoilGuard data can be visualized on a raw-data table. There are two ways to check your SoilGuard data: (1) In Fieldclimate data is visualized by clicking on the station list (top-right icon). (2) additionally if you have a FarmView license data is visualized by clicking on the station or cropzone list (top-right icons).

Features are listed below:

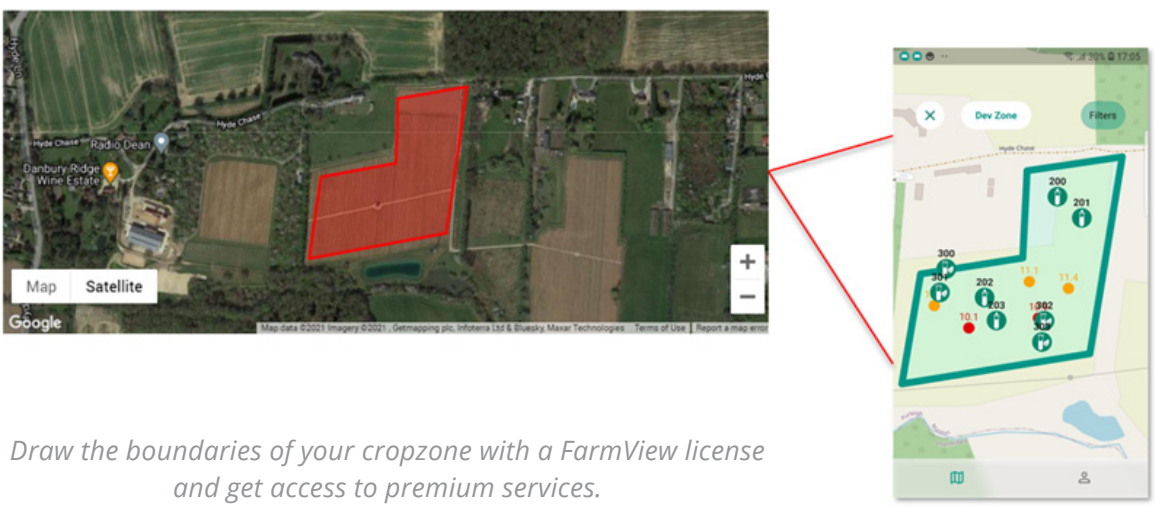
- Sort data per column
- Select devices on the station list (TurfClimate) or on the cropzone list (in case of FarmView license)
- Download data and export as Excel file
- Select data via customizable dates
- Filters to select the correct data



Date/Time	VWC [%]	EC [mS/cm]	Soil Temperature [°C]	Position	
				Latitude	Longitude
2021-06-25 10:30:00	18.80	0.50	31.80	47.127098	15.670438
2021-06-22 10:30:00	17.70	0.30	19.10	47.127097	15.670437
2021-06-19 10:30:00	1.30	0.80	39.20	47.127096	15.670436
2021-06-16 10:30:00	12.20	0.20	15.30	47.127095	15.670435
2021-06-13 10:30:00	7.90	0.70	25.70	47.127094	15.670434
2021-06-10 10:30:00	17.40	0.40	24.00	47.127093	15.670433
2021-06-07 10:30:00	2.30	0.70	20.80	47.127092	15.670432
2021-06-01 10:30:00	3.00	0.00	16.90	47.12709	15.67043
2021-06-04 10:30:00	8.20	0.80	25.20	47.127091	15.670431
2021-06-28 10:30:00	3.70	0.20	19.80	47.127099	15.670439

Users with a Fieldclimate account can see the data only in a table.

When having a **FarmView license**, SoilGuard users can also visualize its data within CropZone boundaries, to compare soil moisture conditions within different dates and locations, plus the right moment to irrigate, how much and Satellite imagery.

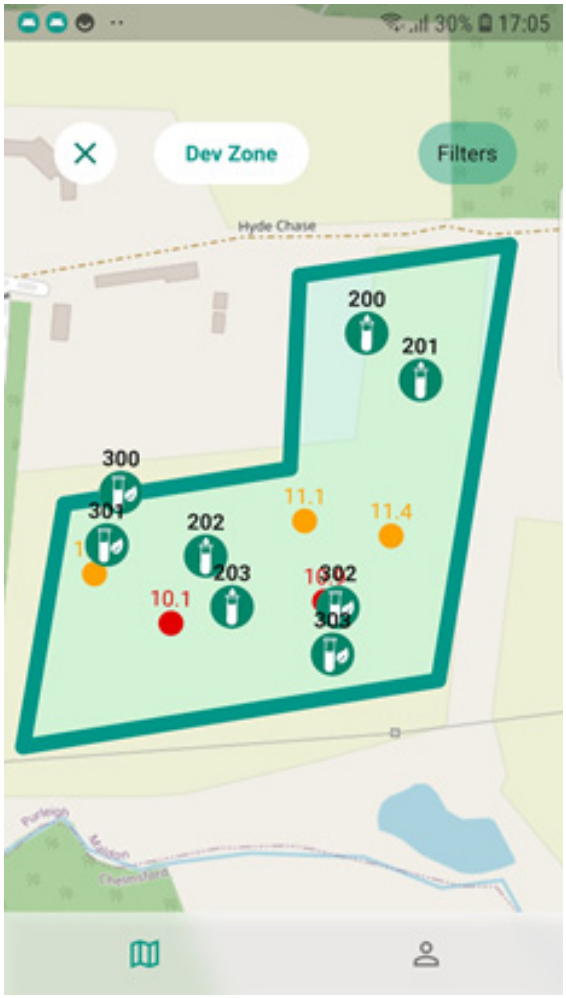


Draw the boundaries of your cropzone with a FarmView license and get access to premium services.

Mobile app data visualization

For the mobile app, SoilGuard data or other devices such as Dualex and MobiLab can be visualized in-field or remotely. Features are listed below:

- Color-coded data based on healthy conditions for each parameter
- Date and device filters
- Individual/clickable data samples for data visualization
- Data selection for SoilGuard moisture content, or MobiLab Soil sampling, Dualex nutrients, MobiLab Plant Sap, within other multiple options.
- In the case of FarmView license, users have access to cropzones (data monitor in space and time), device filters, and the possibility to choose a value of interest from each device.



Data visualization in TurfClimate mobile app.

Maintenance

Separating the Display and Sensor:

1. Remove the probe rods from the sensor base.
2. Flip the display so the backing plate is facing up.
3. Remove the 4 screws on the base using a Philips screwdriver.
4. Gently separate the display from the base plate. Note: The sensor cable connected in the center has limited cable length.

Battery Replacement:

1. Follow the steps in **Display and Sensor Removal** to access the batteries.
2. Install four new AA batteries observing correct polarity by referencing the (+) positive and (-) negative labels.
3. Follow the procedure on the next page to reinstall the display.

Display Removal:

1. Follow steps for **Display and Sensor Removal** to access the display and cable connections.
2. Remove the foam spacer and unplug the sensor cable connector from the jack (fig. 1). If an IR temperature sensor is connected, disconnect this plug as well. **Do not discard the foam spacer.**

Figure 1. Sensor connection to the display.

Display Installation:

1. Follow the procedures for **Display Removal** to access the display and cable connections.
2. Re-connect the sensor cable to the 3.5mm connector on the back of the display module.
3. Insert the foam spacer back into place behind the sensor cable. The split end fits around the sensor cable molding.
4. If equipped with the IR temperature sensor option, attach it to the smaller diameter connector.
5. Guide the excess cable length back down through the base plate.
6. Align the arrows on the base and display in the same direction. The USB port should face the same side as the serial number label.
7. Tighten the four mounting screws.

Sensor Block Removal / Replacement:

1. Follow steps for Display Removal to access the cable connections.
2. Remove the thumb screw lock bolt that joins the lower probe base to the upper shaft.
3. Separate the probe base from the shaft (fig. 2).
4. Feed the cable from the replacement probe base through the upper shaft. Attaching a string fed down from the top can aide in the process of cable reconnection.
5. Follow the procedure for Display Installation to complete the replacement.

Figure 2. Shaft interface

Volumetric Water Content (VWC)

The ratio of the volume of water in a given volume of soil to the total soil volume expressed as a decimal or a percentage. Three soil moisture levels of most importance can be defined as follows:

- **Saturation:** All soil pores are filled with water. The VWC will equal the percent pore space of the soil.
- **Field Capacity:** The condition that exists after a saturated soil is allowed to drain to a point where the pull of gravity is no longer able to remove any additional water.
- **Permanent Wilting Point:** The highest moisture content at which a plant can no longer extract water from the soil.

Additionally, we can define Plant Available Water as the amount of water between Permanent Wilting Point and Field Capacity. One rule of thumb is that irrigation should be initiated when half the Plant Available Water has been depleted.

Time Domain Reflectometry (TDR)

The speed of an electromagnetic wave along a waveguide in soil is dependent on the bulk dielectric permittivity (ε) of the soil matrix. The fact that water (ε = 80) has a much greater dielectric constant than air (ε = 1) or soil solids (ε = 3-7) is exploited to determine the VWC of the soil. The VWC measured by TDR is an average over the length of the waveguide.

The sampling volume is an elliptical cylinder that extends approximately 3 cm out from the rods. The high frequency signal information is then converted to volumetric water content. High amounts of clay or high electrical conductivity (EC>2 mS/cm) will attenuate the high-frequency signal and affect the reading displayed by the meter. Very high organic matter content will similarly affect the VWC reading.

Electrical Conductivity

The SoilGuard uses EC readings obtained from the same probes used to measure VWC. To improve the VWC measurement accuracy, EC is factored out of the VWC reading. This is a key advantage over its predecessor. The value measured is an average for the entire depth sampled. EC is expressed in units of mS/cm. The EC measured by an electrode is defined as the bulk EC.

The salinity level of soil is an important component of irrigation and nutrient management. The source of soil salts ranges from the original parent material, additions from natural sources, and management activity. High salt concentration in the soil has a negative effect as plant roots cannot bring in sufficient soil moisture. However, fertilizer exists as salt ions in that same soil solution. Low salt levels can result in plants not getting the nutrients needed.

Direct measurement of salt content can only be done by subjecting a field sample to laboratory analysis. Fortunately, the electrical conductivity (EC) is a function of the dissolved salts in the soil. This proxy measurement is possible because, as salts dissolve into the soil, they dissociate into ions which conduct electricity.

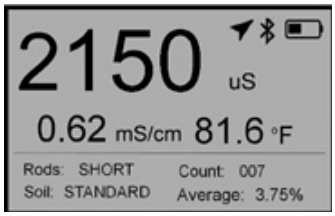
Salinity Index

The TDR also has the option to report EC in the form of the Salinity Index. The salinity index is defined as the ratio of the bulk EC to the volumetric water content (expressed as a decimal). For example, if the bulk EC is 0.25 mS/cm and the VWC is 22%, the Salinity Index would be reported as 1.14 (0.25 ÷ 0.22 = 1.14). Therefore, the Salinity Index combines VWC and EC (corrected for temperature) into a parameter that will be less dependent on the sub-saturated water content.

The TDR measures the bulk EC of soil that may or may not be saturated. As the soil dries, the remaining pore space solution becomes more concentrated which increases EC. However, reduced water in the pores leads to a longer and more tortuous path between the sensor electrodes, which decreases EC. The second mechanism dominates. Bulk EC will decrease as soil moisture decreases. EC measurements made at different times are comparable when the moisture content is the same. This is best observed if the readings are always taken when the site is at field capacity - when a saturated soil is allowed to drain to the point where the pull of gravity can no longer remove any additional water.

Appendix 1: Soil-Specific Reading Correlation

To improve accuracy, correlate TDR period readings with a soil-specific sample set. VWC data can be correlated by measuring the weight of a known volume of saturated soil as it is gradually dried, by gradually wetting a known volume soil with measured increments of water, or by using a neutron probe. In most cases, gravimetric sampling is performed. This procedure is briefly described below.



1. Establish a number of field sites to sample.
2. Wet each site with varying amounts of water.
3. Obtain SoilGuard period reading at each sample site.
4. Extract a known volume of soil at each sample site. Ideally, an undisturbed soil core. Reduce evaporation - store samples in a sealed plastic container.
5. Weigh the wet soil samples.
6. Dry the samples (105°C for 48 hours) and weigh again.
7. Plot sample measurements against SoilGuard readings.

Regression analysis is used to develop a formula to correlate TDR readings to the sample data.

Volumetric water content calculations:

$VWC = 100*(M_{wet} - M_{dry})/(\rho_w * V_{tot})$

Gravimetric water content calculations:

$VWC = GWC *(\rho_b/\rho_w)$
$GWC = 100*(M_{wet} - M_{dry})/M_{dry}$
$\rho_b = M_{dry}/V_{tot}$

Where:

M_{wet}, M_{dry} =	mass (g) of wet and dry soil respectively
V_{tot} =	total soil volume (ml)
ρ_w =	density of water (1g/ml)

Appendix 2: Troubleshooting

Sensor Function Verification:

Test readings can be taken in three standard environments; air, distilled water, and sand saturated with distilled water. It is important that any troubleshooting be done with distilled water. Readings taken in tap water can differ greatly from the expected results observed in distilled water. Test readings are made in a container of distilled water or saturated sand. The container should have a diameter of at least 3 inches (7.5cm) and should be tall enough so the rods can be completely immersed or inserted.

Readings should be taken with the **Soil Type** to Standard and the correct **Rod Length** selected. The meter should read VWC=0% in air. In saturated sand, it should read between 35% and 45%. The table below shows the approximate ranges of volumetric water content that are expected for the different rod lengths in distilled water.

Rod Length	Water
8 inches (20 cm)	60 - 65%
4.8 inches (12 cm)	70 - 75%
3 inches (7.5 cm)	75 - 80%
1.5 inches (3.8 cm)	65 - 70%

Note: The meter does not read 100% in water as the reading is run through soil equations created to be most accurate in the volumetric water contents typically found in the selected soil type.

Unable to save data or load firmware from USB flash drive:

Confirm the drive is not full. Verify the drive has FAT or FAT32 format. Firmware should be in the root directory; outside of any folders.

“No Sensor” appears on the display:

The sensor cable may be dirty or unplugged. Clean the cable connection Check the cable connection to the display. Confirm that the probe block is securely plugged into the display.

Appendix 3: Updating Device Firmware

Firmware updates may be made available to add or improve the product features.
The firmware can be updated using a USB flash drive. Firmware update files can be found on the Pessl Instruments website https://metos.at/manuals/.

1. Copy the latest firmware update from your PC onto the root directory of the flash drive. The file will not be seen by the meter if it is renamed or stored within a folder on the drive.
2. Power off the meter.
3. Remove the protective cap from the meter's USB port.
4. Insert the flash drive into the meter's USB port.
5. While pressing the DELETE|Up arrow button, press and release the ON/OFF|BACK button. The meter will beep.
6. Release the buttons. Note: The display screen will remain blank during the update process. The meter will beep a second time once the process has completed and then reboot to the logo screen. The new firmware will now be displayed below the Pessl Instruments logo.
7. The display will alert the user if further updates are to be made and show a message when completed.
8. Remove the flash drive and replace the USB cover.

Appendix 4: Calibration

The SoilGuard is fully calibrated at the factory. **Further calibration is not required** nor recommended. The meter has internal calibrations for standard, sand, and high-clay soil types which will work for many soils. Each meter will have a small difference in how it responds to identical soil conditions. This can be due to air being introduced while measuring, bent probes, loose probes, sensor drift or component tolerances. The meter allows for adjustments to the calibration to account for these differences. Should the user prefer to perform the calibration; the following are required:

1. A clean glass or plastic container. The container must be at least 10cm (4”) wide and at least 5.08cm (2”) longer than the length of the TDR rods.
2. A sufficient volume of unused distilled or deionized water to fill the above container.
   Note: Tap water cannot be substituted.

Procedure:

1. Pour all of the distilled/deionized water into the container. The water level must be deeper than the rods currently installed. Note: The water and container **must** be free of minerals and salts to calibrate properly.
2. From the Settings Menu (p. 10), set the rod length to the correct length of the rods currently installed.
3. From the Settings Menu, choose the Calibration option.
4. Press the **Select** button to initiate the calibration process. Follow the display messages.
5. While keeping objects and personnel clear from the area; raise the meter so the rods are in the air. Press the **MENU|SELECT** button and wait until the meter indicates it is ready.
6. Immerse the rods completely in the deionized or distilled water until the sensor base is in contact with the liquid. Keep the sensor base and rods centered in the container.
7. Press the **MENU|SELECT** button and wait until the meter indicates it is ready.

The meter will then show that the calibration is complete for that specific rod length. If more than one rod size is being used, a calibration operation must be done for each rod length used.

Glossary

EC: Electrical Conductivity. A measure of how well the soil solution conducts electricity. The EC is influenced by the amount of salt and water in the soil.

EGNOS: European Geostationary Navigation Overlay Service. Pan-European satellite navigation system. It augments the US GPS satellite navigation system and makes it suitable for safety critical applications.

GNSS: Global Navigation Satellite System. Standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. This term includes GPS, GLONASS, Galileo, QZSS, Beidou and other regional systems

SBAS: Satellite Based Augmentation System—used to improve satellite ranging errors

TDR: Time Domain Reflectometry. A technique for measuring soil moisture content that uses the fact that water has a much higher dielectric permittivity than air, soil minerals, and organic matter.

VWC: Volumetric Water Content. The percent of the soil volume that is filled with water. At saturation, the VWC will equal the soil porosity.

WAAS: Wide Area Augmentation System. Air navigation aid developed by the Federal Aviation Administration to augment the Global Positioning System (GPS), with the goal of improving its accuracy, integrity, and availability.

Warranty

This product is warranted to be free from defects in material or workmanship for two years from the date of purchase. During the warranty period Pessl Instruments will, at its option, either repair or replace products that prove to be defective. This warranty does not cover damage due to improper installation or use, lightning, negligence, accident, or unauthorized modifications, or to incidental or consequential damages beyond the Pessl Instruments product. Before returning a failed unit, you must obtain a Returned Materials Authorization (RMA) from Pessl Instruments. Pessl Instruments is not responsible for any package that is returned without a valid RMA number or for the loss of the package by any shipping company.

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DECLARATION OF CONFORMITY

Pessl Instruments Technologies, Weiz, Austria

Model Numbers:	6435
Description:	Portable Soil Moisture\Conductivity\Temperature Probe
Type:	Electrical Equipment for Measurement, Control, and Laboratory Use
Directive:	2004/30/EU
Standards:	EN 61326-2:2012
	EN 61000-6-1:2007
	EN 61000-6-3:2007+A1:2010
	ICES-003:2016; ITE Emissions for Canada (ANSI C63.4:2014)
	FCC Part 15:2016: Emissions for Unintentional Radiators for USA (ANSI C63.4:2014)
	EN 55032:2015

Paul Martis, Hardware Engineering Manager — February 6, 2017

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