# Frequently Asked Questions about Soil Moisture Sensors

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From this point forward, all soil moisture sensors will be referred to as $ECH_2O$ probes.

Onset adds smart sensor adapters to the $ECH_2O$ probes so that they are plug-and-play compatible with HOBO® U30 stations and HOBO Micro Stations. The S-SMC-M005 incorporates the EC-5 and the S-SMD-M005 incorporates the 10HS. Onset also offers the W-SMC HOBOnode wireless soil moisture sensor, which uses the $ECH_2O$ EC-5 and provides data in the same format as the S-SMC-M005.

## General

***1. How does the $ECH_2O$ probe measure volumetric water content (VWC)?***

The $ECH_2O$ probes use capacitance to measure the dielectric permittivity of the surrounding medium. The volume of water in the total volume of soil most heavily influences the dielectric permittivity of the soil because the dielectric of water (80) is much greater than the other constituents of the soil (mineral soil, 4; organic matter, 4; air, 1). Thus, when the amount of water changes in the soil, the $ECH_2O$ probe will measure a change in capacitance (from the change in dielectric permittivity) that can be directly correlated with a change in water content. Circuitry inside the $ECH_2O$ probe changes the capacitance measurement into a proportional millivolt output.

***2. What is the difference between volumetric water content (VWC) and gravimetric water content (GWC)?***

Gravimetric water content is the weight of soil water per unit weight of dry soil. Volumetric water content is the volume of soil water per unit of total volume. Volumetric and gravimetric water content are related by the bulk density of the soil. Gravimetric water content is the most easily measured, requiring only a glass jar with a lid, an accurate scale, and an oven. Indeed, while GWC may be more easily obtained and more intuitive, the output of most soil water content sensors (including $ECH_2O$ probes) is correlated with VWC. One common calibration error is to relate probe output with GWC.

***3. Does the probe read water content at a certain point on the sensor, or does it average over the entire length?***

The probe averages the volumetric water content over the entire length of the probe. The volume of influence depends on which sensor that you are using; the EC-5has a volume of influence of 0.3 L while the 10HS sensor has a volume of influence of 1 L.

***4. Where is the probe the most sensitive?***

The electromagnetic field produced by the probe decreases with distance from the probe surface.

***5. How long will the $ECH_2O$ probes last in the field?***

$ECH_2O$ probes should last at least 3 years in the field. In fact, they likely will last much longer than that. The sensors utilize a chemical on the circuit board that creates a physical bond between two plastics to decrease the chance of water entering the sensor circuitry. The sensor also utilizes a rodent-repellant cable additive to prevent rodent damage. Ongoing testing has shown these new probes to be exceptionally robust, even in extreme conditions.

***6. What is the difference between the different sensor models?***

All of the $ECH_2O$ sensors measure water content using a dielectric measurement; the EC-5 and 10HS use a measurement frequency at 70 MHz, compared to the EC-10 and EC-20 sensors at about 10 MHz. Because of this increased measurement frequency, the 70 MHz sensors have low sensitivity to differences in electrical conductivity (EC, tested to 8 dS/m) and soil texture. The EC-5 has prongs with a length of 5cm. The 10HS has prongs of 10cm length.

***7. In what case would I choose the EC-5 over the 10HS?***

Any time where large sampling volume is not essential.

***8. Is the ECH$_2$O sensor itself exposed to the soil?***

No. The copper traces used to measure water content are sealed between two pieces of epoxy-impregnated fiberglass (circuit board material). The EM field generated by the traces travels through the fiberglass and into the soil surrounding the probe.

## Measurement and Applications

***1. Can I measure the moisture content of grain using the ECH$_2$O probe?***

No studies have been conducted on this application. There may be limits on the accuracy of the ECH$_2$O because of the air gaps between the probe and the grain. It may be useful to use an evaluation ECH$_2$O unit to determine whether the ECH$_2$O probe could be used in your application.

***2. How would the ECH$_2$O probe function in a low-density medium like Perlite?***

We recommend using an EC-5 in low density media like Perlite. From testing so far, these probes perform very well in low density media. See the *Calibration Equations for the S-SMC-M005 and W-SMC Moisture Sensors Application Note* on www.onsetcomp.com for a calibration information for perlite and other media.

***3. Can the ECH$_2$O probe measure the water content of organic matter and compost?***

We would also recommend the EC-5 in these applications. Because it has a forked design instead of a blade, it can measure over a much larger range of water contents (all the way up to 100% volumetric water content (VWC) with the right calibration. The maximum temperature that the soils can function is 60 degrees C so compost measurements are only possible below this temperature.

***4. How does the probe respond to high soil moisture content?***

The EC-5 is a good option to measure soils or soilless substrates with high VWC because its output does not fall off when soil reaches saturation. The 10HS is accurate at high soil moisture contents, but not at high soilless substrate moisture contents (>56%).

***5. Can the ECH$_2$O probe be used in soils at a depth between 0 - 5 cm?***

ECH$_2$O probes can be used effectively at shallow depths, but temperature fluctuations are a consideration. Inherent in ECH$_2$O measurements, as with TDR and other capacitance probes, is a temperature dependence of 0.003 m 3 m -3 per degree C maximum, with typical of ~0.001 $m^3$ $m^{-3}$ °C -1. Obviously, temperature fluctuations near the surface would be an issue in these measurements and should be approached with considerable caution.

***6. What is the effect of temperature variation on ECH$_2$O probe output?***

Recently, several studies have shown the temperature sensitivity of probes that measure the dielectric constant of soil. It is well known that the dielectric of water changes with temperature, but theories to explain temperature sensitivity of soil dielectric are relatively new. Tests show the ECH$_2$O probe has a maximum temperature sensitivity of ~0.003 $m^3$ $m^{-3}$ per °C, similar to other sensors tested and to data found in the literature. Details of this study can be found in the application note *Response of ECH$_2$O Soil Moisture Sensor on Temperature Variation* found at http://www.onsetcomp.com/support/faq/sensor-notes-soil-moisture-smart-sensor. (These results may be complicated by highly saline soil.) A method for correcting the effects of temperature on VWC can also be found at http://www.onsetcomp.com/support/faq/sensor-notes-soil-moisture-smart-sensor.

***7. Will the ECH$_2$O probe be damaged by high soil surface temperatures?***

Soil temperatures up to 50°C should not damage the ECH$_2$O probe. However, it is important to consider the temperature dependence of the probe output when determining whether the ECH$_2$O probe is appropriate for a given installation.

## Calibration

***1. Do $ECH_2O$ probes need to be calibrated?***

It depends on how much accuracy you would like from your results and what type of medium you are working in. The EC-5 and 10HS appear, after extensive testing, not to require calibration in the majority of mineral soils, even those with high EC values, with an accuracy of ± 3%. As with anything, there will be exceptions that will require individual calibration, so consider calibrating the probe yourself (you can find details on our recommended calibration procedure at http://www.onsetcomp.com/support/faq/sensor-notes-soil-moisture-smart-sensor.

***2. Can the $ECH_2O$ probe be calibrated to measure the water content of organic matter and compost?***

The EC-5 probe is well-suited for measuring organic matter and soil-less media. So far, in testing rockwool and potting soil, consistent calibration curves were obtained regardless of electrical conductivity. Field tests of the probes have also show excellent response to soil water content changes.

For calibration equations and information for the EC-5 probes, see the *Calibration Equations for the S-SMC-M005 and S-WMC Soil Moisture Sensors Application Note* on www.onsetcomp.com which can be downloaded at http://www.onsetcomp.com/support/faq/sensor-notes-soil-moisture-smart-sensor.

***3. How can I calibrate my $ECH_2O$ probes for a medium that has not been tested?***

Follow the calibration procedure described in the application note at http://www.onsetcomp.com/support/faq/sensor-notes-soil-moisture-smart-sensor.

***4. What is wrong with calibrating by adding a known weight of water to a known volume of soil and using the soil weight loss-over-time to correlate probe output with VWC?***

Although, fundamentally, the evaporative weight loss of a soil should determine the change in VWC, the amount of water lost from the system will not be uniform across the vertical profile of the soil. Thus, even if the overall soil VWC has changed 5%, the actual VWC of the soil nearest the probe may have changed very little. Essentially, it is a problem of different sampling volumes (See *Methods of Soil Analysis, Part 4-Physical Methods*, J. Dane and G.C. Topp). Because of the likelihood of non-uniform wetting and drying, it is recommended that you calibrate using the procedure defined in the application note referenced above.

***5. Does the factory calibration that was supplied with my $ECH_2O$ probe work for all soils?***

The EC-5 and the 10HS sensors showed consistent calibration across all soil types and salinites that were tested. However, if you are concerned about the accuracy of your water content measurement, you may calibrate your probe(s) using the calibration procedure in the application note referenced above.

***6. Although you show a linear calibration, my results show some nonlinearity at very low and very high water contents. Why is this?***

Generally, the $ECH_2O$ probe has a linear calibration. However, as it approaches oven-dry or saturated soil conditions, probe sensitivity changes somewhat. If you are concerned about the ends of the spectrum, consider using a quadratic calibration equation.

***7. Can I calibrate my $ECH_2O$ probe by submerging it to different depths in water?***

No. A calibration that relates the percentage of water covering the probe and the voltage output of the $ECH_2O$ probe will not give an adequate soil calibration.

## Installation and Operation

***1. How do I install the $ECH_2O$ probe?***

Inserting the ECH2O sensors into undisturbed soil will always result in the best accuracy. For shallow installations, we recommend that you dig a trench and insert the sensors into the undisturbed soil in the side or bottom of the trench. With the EC-5 sensor, the sensor can generally be inserted directly into the soil with no pilot hole. The 10HS sensors often need a pilot hole, which can be effectively made with a blade slightly thinner than the thickness of the sensor.

For deep installation you can use a probe-shaped knife blade, slide-hammer, and extension rods to allow deeper installations with minimal soil disturbance. The EC-5 can be pushed into an augered hole using a notched PVC pipe.

***2. Should I place the sensors flat side up or flat side vertically when installing the sensors?***

Pooling may occur if the flat side of the sensor is facing up (parallel planes with the soil surface) so we recommend installing the sensors flat side vertically.

***3. How "good" does the contact with the soil need to be? For example, would the ECH$_2$O probe function if it is in partial contact with the soil, like a coarse gravel material, where there might be small air voids between the instrument and the soil?***

Because the ECH$_2$O probe is most sensitive at the surface, even small air gaps that are not reflective of the overall soil water content would cause problems with the measurement. In this type of application, consider testing one sensor to determine if it could be calibrated for your particular setup.

***4. Can I measure water content at several locations by inserting an ECH$_2$O probe into the ground, taking a reading, and then removing it?***

The ECH$_2$O probes are designed to be installed in the ground and left in place for long term monitoring. Inserting the probes in the ground and taking a reading will give a value of water content at that location, but because water content varies considerably over small areas, changes in water content may be difficult to distinguish using this method. In addition, additional variability in probe water content readings could occur because of variable soil-to-probe contact. If you need to make “push in and read” type measurements, then the EC-5 would be the best probe to use.

***5. After installing the ECH$_2$O probes, I see some variability between readings, even though they are all buried at the same depth. Why?***

Soil water content is inherently variable. Studies have shown soil water content to vary as much as ± 3% over a small area. Therefore, installing water content sensors in close proximity to each other does not guarantee that they will read the same value. Installation mistakes can also lead to difference in reading. Soil-to-probe contact is critical for accurate results. Therefore, during installation, you should make sure that the probe surfaces are snug against the soil surface. If a probe does not appear to be reading right, try reinstalling it in the soil.

***6. The entire probe does not fit in my plant pot. Can I use just a portion of the probe to measure water content?***

For potted plants, we recommend using the EC-5, which is a smaller probe designed to fit in small pots.

***7. Why does my ECH$_2$O sensor not measure 100% when submerged in water?***

Tests on the EC-5 probe indicate that the response allows for measurements up to 100%. However, for good accuracy and ease of use, linear calibrations are used for mineral soils that reach maxima at ~65%. If you would like your sensor to read 100% VWC when submerged in water, you can apply a quadratic equation to the output.

For the 10HS, the optimal measurement range in soil is from oven dry to saturated water content, which is typically 40 to 50%. Above saturation, the change in probe output with increasing water content is near 0. The ECH$_2$O probe uses an electromagnetic (EM) field to sense the dielectric of the surrounding medium. As water content increases, the width of that EM field diminishes somewhat. As it approaches 100% VWC (water with no soil), the EM field diminishes to a fraction of its original size, and primarily senses the probe surface itself. Therefore, changes in water content above that level result in relatively little change in the millivolt output from the 10 HS sensor.