Simultaneous Sentek and ML3 calibration

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Abstract

Soil- and sensor specific calibration of Sentek EnviroSCAN and ML3 sensors for the Lonzée experimental site.

Citation: Sarah Garre,Stéphane Becquevort,Lolita D'Ortona,Yohann François,Jimmy Duhamel Simultaneous Sentek and ML3 calibration. **protocols.io**

dx.doi.org/10.17504/protocols.io.jm5ck86

Published: 02 Feb 2018

Protocol

Soil collection in the field

Step 1.

- Dig a soil profile pit to give you access to the different soil horizons you wish to calibrate your sensors for. In this case 25, 55 and 85 cm deep (Figure 1).
- Sample min. three Kopecky rings in each horizon to be used in order to determin the bulk density of the soil in that horizon.
- Then collect pi*(40/2)^2 * 25= 31416 cm^3 of soil per container needed for the calibration process (and this for each horizon, and for each replicate, if any). Collect an extra of 20% of soil (Figure 2).
  HINT: to check the volume of soil you are digging, you can make a hole, put a plastic sheet inside and measure the volume of water needed to fill the hole completely.
- Paste tags on boxes with the name of the different horizons (Figure 3).
- Keep the soil of different horizons seperated and close the boxes for transport.

Tools : spades, boxes and caps, Kopecky rings and caps, Kopecky rings extensions, knife, mallet, tags, markers, tape measure.

Time: Approximatively 25 minutes per horizon

Figure 1 Figure 2

Figure 3

Bulk density measurement in the lab

Step 2.

On the first, take a sample of soil with a ring of known volume (250 cm^3). Cut the added soil at the top and the bottom of ring.

In lab, weight the sample and put it in the oven at 105°C during +/- 48 hours.

After the oven, let it cool in dessiccator and after weight dry sample and bulk density measurement is the mass of the dry sample/ known volume.

Tools: Kopecky rings and caps, knife, oven, balance (Figure 4), dessicator.
Time: collect 1 hour per horizon+ +/- 48 hours to dry + time to let it cool + weighting.

(Norm NF EN ISO 11272)

Figure 4

Soil drying

Step 3.

Using step 2, you can now calculate the weight of soil of a specific horizon needed to obtain the volume of a cylindrical container.
$W_{soil} = V_{column} \times BD_{soil}$.

For the calibration of a single Sentek EnviroScan sensor, a waterproof cylinder with diameter of 0.35m and a height of 0.25m is required (Figures 5 and 6).

Cylinder used for the experiment : http://www.polieco.com/editorcms/FT_ECOBOX.pdf

For a specific horizon and replicate:

- Oven-dry W_{soil} (g) + 10% margin of soil during at 45 °C during 3 days. To make the drying faster, separe the soil in different boxes.
- Pound and creen the required mass through a 5 mm sieve (Figures 7 and 8).

Tools: boxes with their tags, oven, sieve (5mm), mortar, pestle.
Time: 3 days.

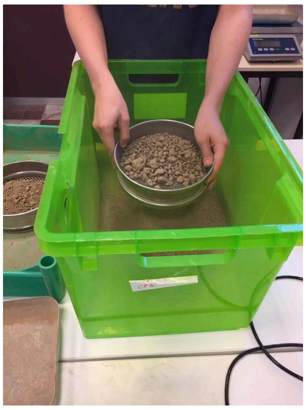


Figure 5 Figure 6 Figure 7
Figure 8

First column preparation

Step 4.

- Insert the cap to waterproof the Access Tube and the Sentek Sensor. (Figure 9)
- Measure the unfilled weight of the column container on a balance and the weight of the Sentek Sensor and the Access Tube.
- Make a stroke every 2cm on the Access Tube. (Figure 10)
- Put the Sentek Access Tube in the middle of the column and stabilize it during the filling. (Figure 11)
- Weigh out the mass of soil required for a 2 cm soil depth that will be packed to the chosen density using the same formula as given in step 3.
- Spread the soil uniformly in the container and pack down to a thickness of 2 cm. (Figure 12)

  HINT: Use a ring to uniformly pack down the soil near to the Sentek Access Tube. (Figure 13)

- Repeat until the container is full. (Figure 14)
- Measure the filled column weight on a balance.

Tools: balance, columns, Sentek Access Tube, wood mortar, ring
Time: Nearly 1h30 per column.

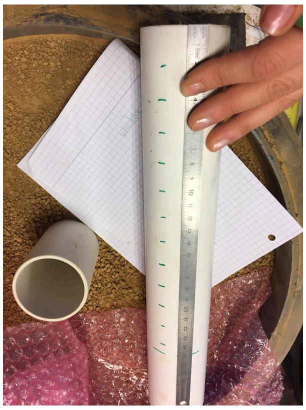



Figure 9 Figure 10 Figure 11
Figure 12


Figure 13 Figure 14

Data Logger Installation

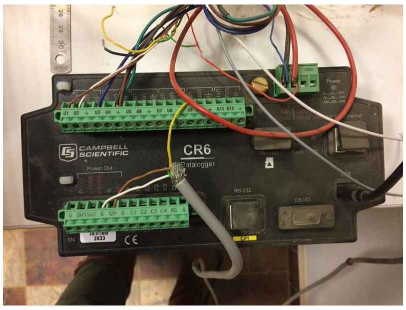
Step 5.

- Create a code.

  Code Link used for the experiment:

- Install on your computer “Probe Configuration Utility” and “LoggerNet 4.4.2”.
- Connect CR6 to an external 12V power, the computer to the CR6 in RJ45 using a router via LoggerNet. (Figures 15 and 16)
- Connect balances and ML3 probe to CR6Series.
- Program the interval of the data collection (every 15 minutes for the balance and every 20 secondes for the probe).

Tools: computer, external 12V power source, CR6Series, LoggerNet, Probe Configuration Utility, ML3 probe.
Time: 2 days for create a code and 1h for the connections.



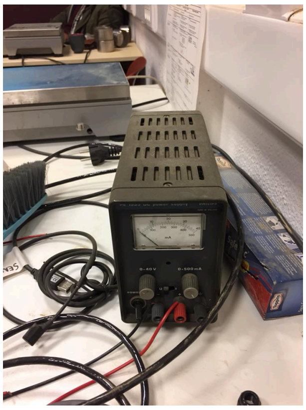


Figure 15

Figure 16

Normalization Procedure In The Air

Step 6.

- As for 'Normalization procedure in the water', insert Sentek Sensor into the Access Tube and connect the two parts together.
- Connect Probe programming cable to the TTL port on the probe interface and supply 12V power to the probe.
- Start the Probe Configuration Utility, Auto-Detect sensors and set appropriate sensors depths.
- Position the tube in the empty container and click the High/Air column header to normalize, one by one, all sensors. (Figure 17)
- Don't forget to transcribe the results on a sheet or in a computer document.

HINT: Pay attention to stay well away from cables and surrounds.

Tools: Sentek probe and its Access Tube, computer, empty container, external 12V power source, CR6Series, LoggerNet, Probe Configuration Utility .

Time: 1h

Figure 17

Normalization Procedure In The Water

Step 7.

- Take Sentek Sensor and identify each probe with a tag. (Figure 18)
- Insert Sentek Sensor into the Access Tube and connect the two parts together.
- Connect Probe programming cable to the TTL port on the probe interface and supply 12V power to the probe.
- Check that the column is waterproof and fill there with water. (Figures 19 , 20 and 21)
- Insert the probe into the water Normalization container. (Figures 22)
- Start the Probe Configuration Utility, Auto-Detect sensors and set appropriate sensors depths.

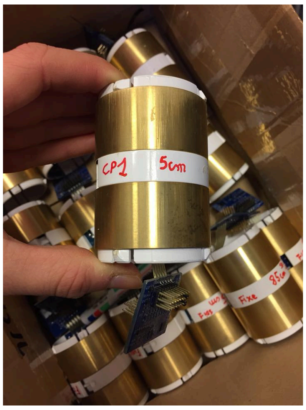
If the container supports all sensors at once click the Low/Water column header to normalize all sensors at once. If it only supports one sensor at time, position the sensor appropriately and click the Low/Water button at the appropriate sensor number. Repeat for all sensors.

- Don't forget to transcribe the results on a sheet or in a computer document. (Figure 23)

HINT: Ensuring the sensor to be normalized is positioned so the sphere-of-Influence is fully surrounded by water.

Tools: Sentek probe and its Access Tube, container of water, computer, external 12V power source, CR6Series, LoggerNet, Probe Configuration Utility .

Time: 2h



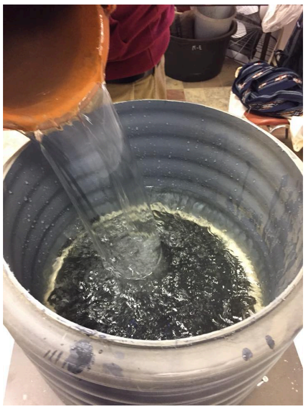


Figure 18 Figure 19 Figure 20
Figure 21

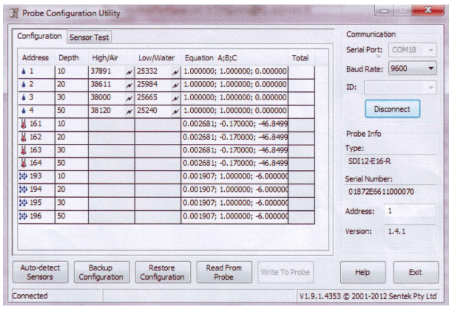


Figure 22 Figure 23

ML3 probe reading

Step 8.

The container for the sentek *probes is larger than the volume required for the ML3 probe calibration as indicated by the constructor (500 cm³), so they can be used to calibrate both ML3 and Sentek probes for each soil moisture level.*

- Insert the ML3 probe. (Figures 24 and 25)
- Read the voltage of the ML3 probe and the weight of the balance.
- Don't forget to transcribe the results on a sheet or in a computer document. (Figure 26)

Tools : ML3 probe, soil column, balance, computer, external 12V power source, CR6Series, LoggerNet, Probe Configuration Utility.

Time : 10 minutes for each measure.

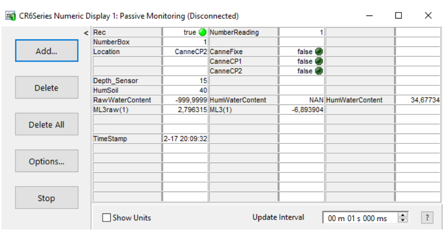


Figure 24 Figure 25 Figure 26

Sentek probe reading

Step 9.

- Insert the EnviroSCAN probe with sensors to 7.5 cm depth (middle of the column height) in the

Access Tube and connect the two parts together. (Figures 27 and 28)
- Fill all variable data: NumberBox, probe's provenance (wait until the trigger notice "false"), moisture content of the column, the original depth probe.
- For each EnviroSCAN, launches the program like for normalization. (steps 6 and 7)
- Record at least 3 readings (preferably more) for each sensor.
  This is conveniently done by setting the data collection time to 1 minute and leaving the probe in place for 10 minutes, giving 10 replicate readings. Note time of recording, ensuring that the logger, computer and stopwatch times are synchronized.

  For example: every 15 minutes for the weight of the balances and every 20 seconds for the voltage of the probes.

- Record the column weight using the balance for each sensor.
- Repeat this for all the EnviroSCAN sensors which need to be calibrated
- Don't forget to transcribe the results on a sheet or in a computer document.

Tools : Sentek probe and its Access Tube, soil column, balance, computer, empty container, external 12V power source, CR6Series, LoggerNet, Probe Configuration Utility.

Time : 10 minutes for each measure

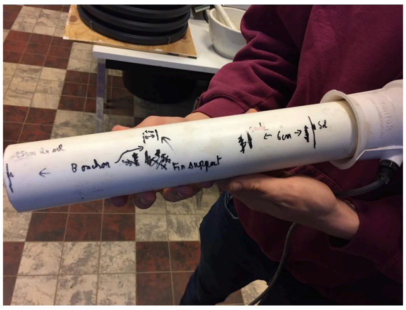


Figure 27

Figure 28

Gravimetric validation

Step 10.

- Use Kopecky rings to collect undisturbed soil cores by removing soil down to the required depth level in the same manner as described for the field calibration. (step 2) (Figure 27)
- Drive the ring in as close as possible to the access tube without touching it and stop driving when the centre of the ring matches the centre of the sphere of influence of the sensor field, which should be when the top of the sampling ring is level with the soil platform. Use a sampling ring tube extension when driving in the rings to avoid compacting the soil.
- Obtain wet and dry oven weights to determine volumetric water content and bulk density.

HINT: If you have a very different volumetric water, it is better to change your moisture content on the sheet or in a computer document.

Tools : Kopecky rings and caps, knife, oven, balance, dessicator.

Time : 20min per horizon + +/- 48h to dry + time to let it cool + weighting

Figure 29

Repetition for increasing soil moisture contents

Step 11.

- Remove the soil from the column (Figures 28 and 29)
- Spread the soil in a thin layer on the plastic sheet and mixed the soil with a measured volume of water.
- Mix the soil thoroughly and then apply further water and mix again. (Figures 30 , 31 , 32 , 33 and 34)
- Repeat steps 4-8-9-10 for at least 3 different soil moisture contents (5%, 15%, 25% and 40%).

Tools : Plastic sheet, water, soil, gloves, trowel.

Time : 50 minutes to disassemble, wet and reasemble the column.

Figure 30 Figure 31 Figure 31
Figure 32

Figure 33 Figure 34 Figure
35

Data tabulation and calibration relationship for EnviroSCAN probes

Step 12.

Tabulate the data as for the field calibration, and plot scaled frequency against volumetric water content to derive the calibration equation.

- Display the results in the following format
  Soil horizon, Sensor name, Depth of field installation, WCi,1, WCi,2, WCi,3, RCj,1, RCj,2, RCj,3
  With WC the volumetric water contents from the samples and RC the raw counts from the EnviroSCAN probes. i is the ID for a specific column at a specific soil moisture level. j is the ID of a specific probe.
- Convert raw counts obtained from the Sentek Soil Moisture Sensors at each particular depth level
  into Scaled Frequencies (SF), where:
  SF = (FA - FS) / (FA - FW)
  FA = raw count in the PVC access tube while suspended in air (Air Count);
  FW = raw count in the PVC access tube in a water bath or normalization container (Water Count);
  FS = raw count in the PVC access tube in the soil at each particular depth level (Field Count).
- Do not average the 3 Scaled Frequency readings per depth plane, but keep them separate as replicates.

- Plot Scaled Frequency data on the Y-axis and plot volumetric water content on the X-axis in replicate pairs per depth level using a spreadsheet or graphics software program.
- Fit the appropriate calibration curve to the data points. A similar graph to the default calibration equation shown in Figure 9 should be generated with corresponding A, B and C values.
- Perform a regression analysis on the data (this is readily done in some graphical spreadsheet programs by adding a Trend line). Note that if Microsoft Excel power-function is used then parameter C will be set to zero, so the trend may be insufficient. The closer the R-square value is to 1, the better the fit of the curve. If a strong relationship cannot be established between the Scaled Frequency and Volumetric Soil Water Content, then all or part of the calibration procedure may need to be repeated, or the soil profile may need to be split into different textural layers. Refer to Section 7 Common Calibration Errors for possible reasons why the calibration was not successful.
- From the calibration equation derived, assign A, B and C coefficients to enter into the Sentek EnviroSCAN or EasyAG Probes, IrriMAX software or Diviner 2000 display unit. These must match the equation format SF = AqB + C. If the derived calibration equation is linear, the B coefficient will be 1.

Note: *Calibration equations may not fit all points adequately on a single calibration for that profile. This is particularly relevant for soil profiles with different textural layers. In some cases you may need to*
generate separate calibration equations for individual soil layers at a particular depth level

Data tabulation and calibration relationship for ML3 probes

Step 13.

Soil moisture content is proportional to the refractive index of the soil as measured by the ML3. The goal of calibration is to generate two coefficients (a0, a1) which can be used in a linear equation to convert probe readings into soil moisture:$\sqrt{\varepsilon}=a_0 + a_1 \times WC$.

See p. 37 of the ML3 calibration manual for the formulas to apply.

LINK:
http://www.dynamax.com/images/uploads/papers/ML3_Manual.pdf