

Interactive comment on “Soil moisture sensor calibration for organic soil surface layers” by S. Bircher et al.

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Dear reviewer

We would like to thank you very much for having taken the time to thoroughly go through our manuscript and we would like to thank you for your constructive and useful feedback. Please find below our answers (point by point) how we plan to address your comments in the revised version of the manuscript:

REVIEWER COMMENT 1: ...large specific surface... ANSWER: This will be done as suggested (→ “specific” will be added wherever it is missing in the text)

REVIEWER COMMENT 2:...layer in close proximity (a few nano meters) to... ANSWER: This will be done as suggested

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REVIEWER COMMENT 3:... by the sensor manufacturer's. ANSWER: We will add “sensor” but omit the apostrophe as not appropriate here...

REVIEWER COMMENT 4: manufacturers' -> manufacturer's ANSWER: We won't do this, after our knowledge the apostrophe comes after the “s” in case of plurals ending in s (e.g. <http://www.grammarbook.com/punctuation/apostro.asp>, rule 2a)

REVIEWER COMMENT 5: Volumetric or gravimetric? Please specify. ANSWER: During the “loss on ignition” approach (commonly used for SOM determination) the soil sample's weight is determined before and after burning it at very high temperatures. Thus, the indicated percentage corresponds to a gravimetric measure. However, to our knowledge, the soil organic matter content is commonly provided in percent without this specification.

REVIEWER COMMENT 6: ... in the overlaying organic layer. ANSWER: This will be done as suggested

REVIEWER COMMENT 7: ... this function developed by Vaz... ANSWER: This will be done as suggested

REVIEWER COMMENT 8: delete “specified in” ANSWER: This will be done as suggested

REVIEWER COMMENT 9: Sentences difficult to understand: “To avoid this issue....” “5TE sensor was installed permanently 20 at the surface and in a horizontal fashion with the blade in vertical direction” ANSWER: These two sentences will be reformulated as follows and will hopefully be easier to understand that way: “To avoid this issue the material was initially saturated and the changing volume and bulk density during the subsequent dry down were automatically accounted for.” “In the center of each bucket one Decagon 5TE sensor was installed permanently at the surface. The sensors were always placed in horizontal position with the blades in vertical direction in order to avoid ponding of water.”

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REVIEWER COMMENT 10: I know that it is not an easy task to achieve a constant (in time and in depth) water-content in soils contained in a bucket. Can you please add comments on this experimental issue? ANSWER: Yes, we agree with this comment. As you state, this issue is mostly concerning different depths, that is, faster dry down at the surface compared to deeper zones. Therefore, it should not constitute a major problem in the chosen sampling protocol, since the measurements using the two sensor types as well as gravimetric samples were taken at the same depths.

REVIEWER COMMENT 11: To my knowledge, SM measurements performed with sensors installed very close to the surface can be affected by the air above the ground. So, I assume your ThetaProbes were installed deep enough to avoid this effect? Please comment here or even earlier in the manuscript. ANSWER: Yes, we agree, one has to be careful with such measurements. We took the measurements from the surface, as often practised with this sensor type. But as stated in the manuscript (being aware of the problem) we paid a lot of attention to pushing the probe into the soil firmly to assure good contact in order not to measure any air, and yet careful not to compress the material too much. Furthermore, we always took three measurements at a given time step in order to check the repeatability. As already mentioned above, this hand-held application where measurements are taken from the surface is common practice using this sensor type. Out of the five studies to which we compare our approach in Section 5.3, in four of them the ThetaProbe was applied by inserting the four rods vertically from the surface into the organic substrates as practised by us, in the laboratory (Nemali et al., 2007, Kargas and Kerkdis, 2008, and Vaz et al., 2013) as well as in the field (Kurum et al., 2012). As an illustrative example, please see Figure 2 in Vaz et al. (2013), attached to our response. In the fifth study (Yoshikawa et al., 2004) details on probe insertion were not specified. Given this consensus together with the above precautions in terms of sensor application, we concluded that our approach should be valid. Also, as a supplementary protective measure we clearly state in Sections 5 and 6 that we recommend the use of our calibration functions derived for the ThetaProbe only for measurements practised in the same way as in our study. In order to make

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this clearer in our manuscript, we plan on modifying this text passage as follows: “A lot of attention was paid to proper application of the ThetaProbes: the four rods of the instrument were inserted vertically and pushed firmly into the substrate in order to assure good contact and avoid air gaps, and yet careful not to compress the material too much. This is common practice with this sensor type, in case of organic material for example applied by Nemali et al. (2007), Kargas and Kerkdis (2008), and Vaz et al. (2013) in the laboratory as well as by Kurum et al. (2012) in the field. In our case, three readings were taken at a given time step in order to check the repeatability of the measurements, while the mean was recorded each time. Additionally, one reference sample was extracted per time step using steel rings of known volume.”

REVIEWER COMMENT 12: what do you mean with "points": points in time? Number of data? Please reformulate. ANSWER: We will adjust the text as follows which will hopefully make it clearer: “In case of continuously logged Decagon 5TE data, the two measurements closest to each ThetaProbe/sample timestamp were extracted and averaged. The thus resulting number of available data points per site and sensor type is indicated in Table 1.”

REVIEWER COMMENT 13: I assume with "data pairs" you mean (SM, raw-data)? If so, you may use a formulation along the proposed line? ANSWER: Yes, as already stated in the text, we mean pairs of apparent relative permittivity readings and volumetric moisture contents. We plan on removing the sentence “For Decagon 5TE data pairs of apparent relative permittivity readings and corresponding volumetric moisture contents this included 3rd order polynomial, power, natural logarithm, and square root functions. With respect to the ThetaProbe, fit functions were derived for both, output voltage-volumetric moisture and apparent relative permittivity-volumetric moisture pairs, (3rd and 1st order polynomial, respectively) as they are equally used in many studies.” from Section 4.3 to streamline the text as you say. Nevertheless, all this information is still given in Section 5.2 where we also discuss the different fit functions. Additionally, we will more clearly formulate what we mean by “data pairs”. The text at

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the beginning of Section 5.2. will then read as: "For the Decagon 5TE sensor data pairs of apparent relative permittivity readings and corresponding volumetric moisture contents (left column) different functions were tested: 3rd order polynomial (dark blue), power (light blue), natural logarithm (red), and square root (orange). With respect to the ThetaProbe (right column), fit functions (red) were derived for both, output voltage-volumetric moisture and apparent relative permittivity-volumetric moisture pairs, (3rd and 1st order polynomial in top and bottom row, respectively), as they are equally used in many studies."

REVIEWER COMMENT 14: Would it not make sense to provide explicitly the fit-functions at an adequate place? ANSWER: The fitted functions and corresponding manufacturer calibration curves are presented in the result section (section 5). Figure 3 shows our fits that are explicitly provided in Table 4, while respective statistics are given in Table 5. Regarding calibrations reported in literature, we indicate all proper references in Section 5.3, while the curves are illustrated graphically (applied to our dataset) in Figure 4 with corresponding statistics in Table 6. We do not believe that adding the explicit formulations of these functions would add any value to the manuscript.

REVIEWER COMMENT 15: Please try to find a better formulation: "exercise"??? "immediately adjacent ThetaProbe surface data"??? In my view the formulation "the mean of the two closest time steps" does not make any sense, although I can guess what you want to express. ANSWER: These sentences will be rephrased as follows: "At both sites, one of the three Decagon 5TE sensors at 5cm depth was chosen for this study together with the ThetaProbe surface data sampled in the immediate vicinity. The five ThetaProbe values available per day were averaged for our purpose. In case of the Decagon 5TE data the two time steps closest to the mean ThetaProbe acquisition time were averaged, resulting in maximum time shift between the two measurements of less than 30 minutes." We hope this will make it clearer.

REVIEWER COMMENT 16: 1) At some points the language could be improved (however, I am not native English speaking). ANSWER: We apologize for some mistakes

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and unclear formulations. Based on the reviewer comments and a thorough revision of the manuscript we will try to formulate better.

REVIEWER COMMENT 17: 2) At least for me it was sometime difficult to assign provided information to a specific reason (different sample types, different locations of sample origin, different labs,). Maybe, you could try to simplify/streamline information (what is essentially necessary to communicate to the reader; maybe some of the less relevant information could be moved to an appendix). It would simply be nice to come faster to the sections 5 "Results and Discussion" (especially for impatient readers). ANSWER: We totally agree with this comment. Accordingly, we will trim Section 2: we will integrate the third order subsections containing very detailed sample information into the respective FMI and HOBE data sections (2.1 and 2.2) and omit text parts not relevant to understand the work done. We considered the option of moving some information into an appendix, but then decided it won't be necessary as we believe it would not further improve the comprehensibility of the work presented.

REVIEWER COMMENT 18: Indicate different panels of Figure 2 with e.g. a), b), c), d), and make references in the text. ANSWER: We tried to be consistent in the style of figure captioning throughout the manuscript. If we introduce such a labelling in Figure 2, we would have to do it everywhere. But in our opinion this is not necessary for these type of figures since (1) they are of low complexity and (2) all necessary information is provided in the figures while the caption is not necessary to understand the figure content.

REVIEWER COMMENT 19: Say here in which direction the trend goes. ANSWER: We apologize, this sentence was not well placed. Therefore, we will move it down to the respective passages where the data measured in organic layers using Decagon 5TE (page 463, line 10 and following) and ThetaProbes (page 464, line 7 and following) are discussed.

REVIEWER COMMENT 20: "less" in comparison with what? ANSWER: We will

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rephrase the sentence to clarify our statement. It will then read as follows: "For both sensor types, the field measurements under less disturbed conditions (triangles) are in good agreement with the more disturbed laboratory data (dots)."

REVIEWER COMMENT 21: It would facilitate the reading if you would mention associated symbols and colors right in the text. E.g.: ...the field measurements (triangles) under less disturbed conditions are also in good agreement with the laboratory data (dots). ANSWER: Thanks for this suggestion. We will mention the symbols in the text to facilitate reading and understanding throughout Section 5.

REVIEWER COMMENT 22: ... specific surface area... ANSWER: This will be done as suggested

REVIEWER COMMENT 23: You may further elaborate this by providing more specific informations on e.g. what is meant with "first layers" -> of molecules, thickness is several Angström. Please have a look at e.g.: Or, D.; Wraith, J.M. Temperature effects on soil bulk dielectric permittivity measured by time domain reflectometry: A physical model. Water Resour Res 1999, 35, 371–383. ANSWER: Thank you for this suggestion with respective reference. We had a look into this very interesting study and will add the reference in the introduction section. However, we are not sure if adding further information to the discussion will substantially improve the manuscript since the scope of our study is not the quantitative investigation of the layer thickness of bound water (i.e. the fraction of water molecules that are rotationally hindered). But it would certainly be very interesting to study this issue in more detail in future work. For this, the specific surface areas of the different samples would have to be estimated additionally.

REVIEWER COMMENT 24: Exactly this mechanism is implemented in the dielectric mixing model described in Section "5.7.5 Dielectric properties of soil" (around Figure 5.23) of the book: Mätzler, C. Thermal microwave radiation: Applications for remote sensing. IEE Electromagnetic Waves Series No. 52, London, UK: 2006; Vol. 52. If you like you can download the Book from here:

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<https://www.dropbox.com/sh/npn4l231d93jxm1/AAAo1snPJGzQqlm8G2WT4mr5a?dl=0>

ANSWER: Thank you as well for the hint to this book section. We will also include this reference in the introduction section. And likewise we decided not to mention it in the discussion as dielectric mixing models are out of the scope of this manuscript. However, we are glad to be aware of this reference with respect to future work.

REVIEWER COMMENT 25: Just a possible further explanation: It is more critical to maintain a certain constant and well defined WC in organic soils (due to higher porosity) than in mineral soils (lower porosity)??? This would also impose a higher scatter for the measurements in organic soils. However, I am not sure about this.... ANSWER: When we talk about the "complex" nature of organic substrates compared to mineral soils, it is actually what we mean: high porosities/small bulk densities and large specific surface areas... this is addressed in section 1, page 451, lines 11-16. We will add "(i.e. very high porosities and large specific surface areas)" at the indicated text location to make this clearer.

REVIEWER COMMENT 26: indicate the associated line-colors used in Figure 3 ANSWER: This will be done as suggested

REVIEWER COMMENT 27: I can not identify a 1st order (linear) fit-function in Figure 3?? ANSWER: This will be indicated in the text to hopefully make it clearer

REVIEWER COMMENT 28: Indicate the respective curve plot-styles ANSWER: This will be done as suggested

REVIEWER COMMENT 29: use consistent naming Fig. or Figure throughout the manuscript. ANSWER: This format is predefined in the manuscript preparation guidelines: The abbreviation "Fig." should be used when it appears in running text and should be followed by a number unless it comes at the beginning of a sentence, e.g.: "The results are depicted in Fig. 5. Figure 9 reveals that...".

REVIEWER COMMENT 30: ... to the measurements performed on our organic sam-

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ples.... ANSWER: This will be done as suggested

REVIEWER COMMENT 31: These extremely high WC values seem not to be realistic for natural soils. Can you please comment on this? ANSWER: The extremely high water holding capacities of organic material are addressed in the introduction part (please see page 451, lines 11-16).

REVIEWER COMMENT 32: "when leaving" -> "beyond" ANSWER: This will be done as suggested

REVIEWER COMMENT 33: "clarify" -> "explain" ANSWER: This will be done as suggested

REVIEWER COMMENT 34: "displayed in the form of error bars" -> "shown as error bars" ANSWER: This will be done as suggested

REVIEWER COMMENT 35: "is detectable"-> "is observed" ANSWER: This will be done as suggested

REVIEWER COMMENT 36: ... and their dynamic range... ANSWER: This will be done as suggested

REVIEWER COMMENT 37: What is meant with "short range variabilities"? ANSWER: This formulation will be replaced by "small-scale variabilities"

REVIEWER COMMENT 38: "higher surface area fraction" -> "fraction of specific surface areas" ANSWER: We will adjust to "larger specific surface area" instead

REVIEWER COMMENT 39: "manufacturer's mineral and organic functions" does not make sense. Please reformulate in a more accurate way. ANSWER: Yes, we agree with you and will rephrase the sentence to: "In contrast, the ThetaProbe data acquired from the organic soil layers showed a closer match with the manufacturer's functions derived for mineral and organic substrates, though with more pronounced curvature."

REVIEWER COMMENT 40: "theory of increased bound water"??? Please reformulate.

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ANSWER: This will be rephrased to "In case of the Decagon 5TE sensor the reliability of the proposed calibration function is further underlined by the fact that it obeys basic physical principles (i.e. increased bound water fraction in case of organic material),..."

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., 5, 447, 2015.

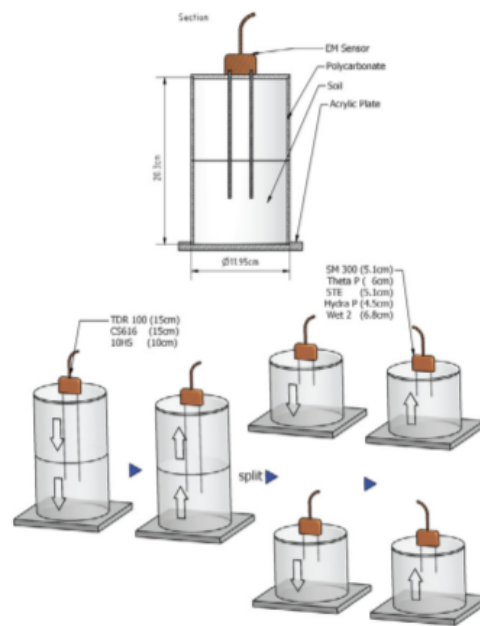


Fig. 2. Sketch illustrating the experimental procedure used to obtain a representative measurement for various electromagnetic (EM) sensors with different rod lengths.

Fig. 1.