Dear Editor(s) of the Earth System Science Data (ESSD) journal,

Dear Dr. Sibylle Hassler,

We would like to thank you for having considered our manuscript ‘Twelve years profile soil moisture and temperature measurements in Twente, The Netherlands’ (essd-2022-90) for publication in the well-established ESSD journal and offering the opportunity to revise and resubmit it. Included in this submission is a clean copy of the revised manuscript, a marked-up version of the manuscript showing the changes made and detailed point-by-point responses to the comments of Referees.
We have carefully considered the comments, questions, and suggestions for improvement made by the two referees and applied them where possible. The major changes can be summarized as follows:

- Textual improvements have been made throughout the manuscript based on suggestions of both Referees;
- Based on the suggestions by Referee 1 the structure and balance of the manuscript have been improved by:
    - Shortening descriptions, removing redundancies and paragraphs with less relevance in the context of the manuscript.
    - Refocusing section 5 on Data uncertainties, of which specifically the sensor calibration (section 5.1) and the spatial representativeness are addressed (section 5.2). The latter has been achieved through comparisons with the field campaign datasets.
    - Transforming the native section 6 ‘Time series’ into the revised section 6 with emphasis on ‘Research opportunities’ to provide readers examples on how to use the disclosed datasets.

The comments of the Referees, in particular Referee 1, have helped us to improve the usability of the disclosed datasets, the overall quality and the expected impact of the manuscript. Dr. MS. Salama and dr. P.C. Vermunt have helped substantially with the revision of the manuscript and have for their contribution been added to the list of authors with the consent of all authors.

Overall we trust that we have adequately addressed all the referee comments and improve the quality of the manuscript to the level that is expected from publications in the ESSD journal. We would like to thank you for taking the time to handle this contribution and look forward to hearing from you.

Yours truly,
Rogier van der Velde
On behalf of the authors.

Authors' response to Referee 1

In their manuscript "Twelve years profile soil moisture and temperature measurements in Twente, the Netherlands", R. van der Velde and colleagues present a corresponding dataset which is supplemented by several soil moisture measurement campaigns which add more points around the long-term measurements in terms of snapshots.

I congratulate the author team for a precious and useful dataset. The overall approach and design (a sparse network of profile probes) is not specifically innovative, yet it allows for interesting analyses and should be a useful asset for the scientific community. Most importantly, the author spent a lot of effort in the (re-)calibration of the soil moisture sensors by comparing the instrumental readings to gravimetric soil moisture measurements – an effort that is well-spent, and certainly nothing to be taken for granted.

The paper itself is mostly well-written, the accompanying dataset well-organised, complete, and contains both raw readings and processed data, conforming with various user requirements.

I still have some specific comments which you might classify as major, but which I am confident the authors will be able to consider in one way or the other. Most of them should be understood as suggestions to improve the manuscript.

Authors' response:
We thank the referee for the positive and detailed comments. The level of detail and provided suggestions are much appreciated and motivate us to critically reflect on the content of the submitted manuscript. In the text below, we provide our point-by-point response to the comments.

Most of the referee's suggestions have been implemented. Our response to the referee's comments is structured as follows:

- The native referee comment is labelled and written in black.
- The authors response is written in blue
- Text from the manuscript is written with the Times New Roman font whereby the native text is in black and the changes are in red with the number of lines referring to the revised manuscript.

General comments

R1GC1 (Referee 1 General Comment 1): Structure and balance of the manuscript

I think in the final parts of the manuscript, the structure should be adjusted to make it more straightforward. My suggestion is to drop section "5.1 Maintenance monitoring stations" (which is, in my opinion, not relevant in the context of this paper), and to combine section "5.2 Data processing and flagging" with the section "Data availability" (please note that the section numbering is wrong after section 5). Section "5.3 Known issues" deserves, in my view, a dedicated single subsection, but should be renamed to "Data uncertainty". Please use this section to provide a more comprehensive synthesis on the two most important sources of uncertainty: the sensor calibration (most importantly the relationship between permittivity and volumetric soil moisture, but maybe also some words on the relationship between the primary measurement variable, typically raw voltage, and permittivity, which is assumed to be set by the manufacturer), and the spatial representativeness (see comment below). The section title "Time series" is not really adequate. Still, I think it is an important section as it presents an opportunity to highlight the scientific potential of your dataset (see comment "Underlying research questions and prospective application of the data").

Apart from the structure, parts of the paper could be more concise. Please reconsider whether some details on the instruments' construction design and the calibration procedure could be removed for the sake of readability.

Authors' response:
Thank you for the suggestion for restructuring section 5. In the revision so far, we have dropped section 5.1, and renamed section 5 Data uncertainties with subsections 5.1 sensor calibration and 5.2 spatial representativeness. In the revised section 5.1 we discuss the sensor calibrations, the relationships between the raw measurements, relative electric permittivity and soil moisture. In section 5.2 we discuss spatial representativeness through comparisons between the station measurements and measurements collected during the field campaigns at different spatial scales. This will provide readers and prospective data users with ideas on how to best use the data.

Further, we have critically reviewed the text and presentations of the manuscript, by shortening descriptions and removing redundancies and paragraphs with less relevance to the context of the manuscript.

R1GC2 Underlying research questions and prospective application of the data
In ll. 44-49, you describe previous research that was based on the presented dataset, and which already started more than 10 years ago. While this exemplifies potential use cases of the dataset, it also leaves the reader with a feeling that this dataset was only published after it had already been comprehensively used.

Of course, that is not true! All the more, however, it is important for this paper to highlight and to exemplify open research questions and application cases related to this data. I think the section that is now entitled "Time series" is a good opportunity to highlight interesting properties of your dataset - as you already started to do. Still, I am wondering why you only show 3 out of 20 stations and 4 out of 12 years. Of course, this paper should not be about a scientific analysis, and of course you should not just show time series of all stations at all depths for all years. But maybe you could demonstrate the potential of your dataset along some exemplary research questions, maybe also at different time scales? This is just a thought, but I think this section could really increase the value and impact of your paper. The section "Summary" could then be extended to "Summary and outlook" and hence summarise the perspectives of prospective research based on this dataset, and maybe how it could be combined with other datasets.

Authors' response:
In the revised manuscript we have renamed the section 'time series' to 'research opportunities' in two main themes (please see the revised section 6 for more details):

- the validation of both satellite and model-based soil moisture products and questions related to:

  - how soil moisture varies in space and how this spatial variability differs throughout the growing season and is affected by weather (e.g. intensive rainfall, frozen soil, drought).
  - the temporal representativeness of station data with respect to the field data collected during the campaigns.
- Groundwater-Vadose zone-Atmosphere nexus and questions related to
  - the translation of surface to rootzone soil moisture and links with groundwater
  - factors controlling the development of heat waves and droughts.

As the referee suggests, the summary section of the revised manuscript is extended to a 'summary and outlook' to include also the perspectives on prospective research.

R1GC3 Horizontal and vertical representativeness

The supplemental campaigns are a great feature of this dataset, yet the importance of the campaign data is, in my opinion, not adequately represented. Only in ll. 364-367, you briefly address the issue of spatial representativeness of the permanent sensors, based on campaign data used by Benninga et al. (2020). However, that publication only looked into this issue for a small part of the fields, and also not in detail. I think it is worth providing a more comprehensive assessment of the uncertainty arising from a lack of horizontal representativeness, by using the campaign data. It does not need to be exhaustive, but at least I don't see why you cannot provide such an uncertainty estimate for all stations. It is a bit unfortunate, of course, that the campaigns were limited to the upper 5 cm. It is of course more tedious, but still feasible to carry out snapshot campaigns for vertical profiles by successively drilling to the next measurement depth. With the data limited to the surface, it is impossible to assess horizontal and vertical representativeness in a uniform framework. I assume that the limitation of the campaigns was partly justified by resource constraints, and partly by the motivation to use the data for ground-truthing remotely sensed soil moisture products. However, it should not be me speculating… so I would like to ask the authors to be more transparent about that study design and its justification, as well as about the resulting limitations and uncertainties with regard to soil hydrological applications.

Authors' response:

The reviewer is correct by assuming that the design of the field campaign data was motivated by the use of the data for the validation of remote sensing products. With this objective in mind, resources were focused on the sampling of a large spatial extent rather than collecting soil moisture profiles across fields. We have clarified this in the revised manuscript.

In the revised manuscript we also reported on comparisons between the field campaign measurements and the station data. In addition, we reported and discussed uncertainty levels on fields scale and the scale of the entire network, and investigated whether general conclusions can be drawn based on land cover.

R1GC4 Calibration

I appreciate the effort put into the calibration of the probes by using gravimetric measurements. Still, I am wondering whether the presentation of the corresponding procedures and the results could be more concise. Furthermore, I think that you usually calibrate the relationship between permittivity and soil moisture (which is non-linear), while you took the volumetric soil moisture reading and linearly "re-calibrated" them. Please elaborate briefly on possible implications, if this makes sense to you.

Authors' response:
During the revision process, we shortened the descriptions of both the applied procedure and results, and removed figures with redundant information.

In the new subsection 5.1 *Sensor calibration* of the section 5 *Data uncertainties* we have devoted the first two paragraphs to the possible implications of linearly calibrating the probe VSM against GVSM. The reason for linearly re-calibrating the native volumetric soil moisture content reading was to remain consistent with the earlier EC-TM calibration reported by Dente et al. (2011).

METER group has adopted third-order polynomials to describe the relationship between VSM and the ε_r for the 5TM (Topp et al. 1980) and EC-TM (equivalent to the Topp equation) probes. The ThetaProbe and HydraProbe use a linear relationship between the VSM and the refractive index ($\sqrt{\varepsilon_r}$), which can be rewritten as a second-order polynomial. When we use these equations and apply the calibration coefficients the manufacturers provide for mineral soil, the relationships of ε_r versus VSM are obtained as shown in Figure R1.

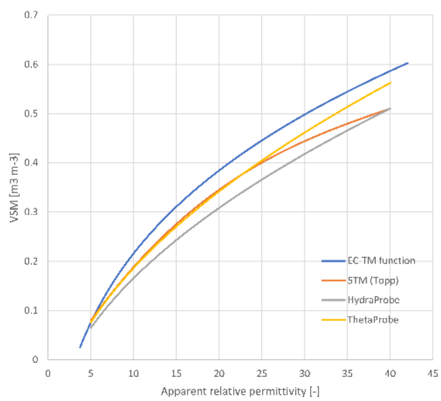

Figure R1: ε_r against VSM using the mineral soil calibrations provided for the EC-TM, 5TM, ThetaProbe and HydraProbe.

The relationships shown in Figure R1 have similar shapes. To explore this further, Figure R2 shows the EC-TM, ThetaProbe and HydraProbe VSM against the 5TM VSM. Indeed the relationships in Figure R2 are close to linear.

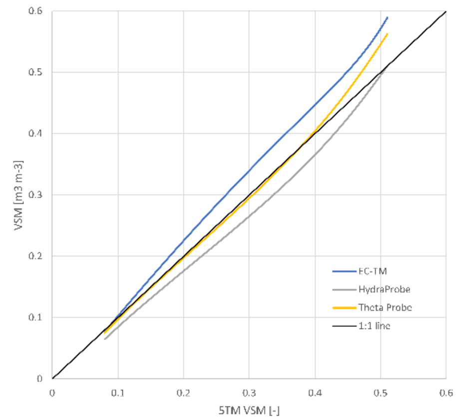

Figure R2: EC-TM, ThetaProbe and HydraProbe VSM against the 5TM VSM.

We fit linear equations through data points of probe (EC-TM, ThetaProbe and HydraProbe) VSM and 5TM VSM to mimic the VSM and GVSM calibration procedure reported in the manuscript. The VSM difference between the EC-TM, ThetaProbe and HydraProbe VSM and the 5TM VSM matched through the application of the established linear fits is shown in Figure R3.

Figure R3 shows that the differences are not negligible with maximum values up to 0.025 m^3 m^{-3} in the wet limit for the ThetaProbe and HydraProbe. This is the consequence of the difference between the second and third order polynomial. A summary of these results is included in section 5.1.

We expect, however, that the overall implications will be limited because in the limit with SM<=0.5 m^3 m^{-3} a linear relationship is well established between the VSM readings of the probe and the independently measured GVSM. Other sources of uncertainties, such as spatial scale mismatch and sampling errors, are apparently dominant over the ambiguity caused by the shape of the VSM and ε_r relationship. Further investigation of the form of the relationship between the VSM and ε_r goes beyond the scope of the manuscript and requires a different experimental setup.

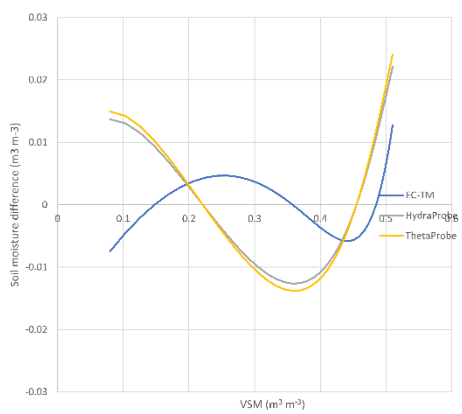

Figure R3: VSM difference between the EC-TM, ThetaProbe and HydraProbe VSM and the 5TM VSM matched through application of established linear fits.

R1GC5 Integration into ISMN

Why are these data not integrated into the ISMN? I would be interested in hearing your opinion on this. Many of the stations included in the ISMN are very similar types of profile measurements, and it should be helpful to put your data into an immediate context with these.

Authors' response:
The reason why this has not been done yet is the availability of time and the choice that our university has made to use DANS-easy as a trusted repository, which offers a guaranteed permanent DOI. We are planning on making an effort to integrate the data into the ISMN in the near future.

R1GC6 Homogeneity
You pointed out that some of the monitoring locations had to be changed during operations. Is there any way to assess the effect on data homogeneity? Are there periods of overlap for the new and the old locations for such an assessment?

Authors' response:
Unfortunately, the change of locations had to happen most of the time on an ad hoc basis. This has been the consequence of using privately owned land for monitoring purposes. In one case, (2017 change of ITC_SM03), we had the opportunity to have instrumentation operational at two locations along the field. However, the period of overlap was found too short (two months) for the data to be used to assess the data homogeneity.

R1GC7 Missing data
Please specify, maybe in a table, the percentage of missing data for each station.

Authors' response:
We have added the percentage missing data to Table S1 for each station. The missing data is on average 13.5%.

R1GC8 Data repository
I found the data repository (https://easy.dans.knaw.nl) very slow. Even for the small files, I sometimes had to wait for a long time for the download to start. I do not know the EASY repository, and it also does not offer much information. I assume it is ok, but maybe ESSD team members could check whether it meets the standards of ESSD? In the end, I could download the data, so it's fine for me.

Authors' response:
We apologize for this technical hiccup. We were informed by our data steward that at the time the referee downloaded the data the speed may have been slower due to the migration of the system.

To speed up the downloading, the 2022 version is reduced to 8 files with sizes varying from 1.6 MB up to 1.6 GB. Obviously, it takes more time to download a large file than a smaller one, but when the files are downloaded one at the time the retrieval of the data via DANS-easy is properly doable.

Specific comments:
R1SC1:

- Introduction: at the end of the introduction, could you briefly outline the structure of the manuscript, specifically since the sections are not related to a conventional manuscript structure?

Authors' response:
We added a paragraph to the end of the introduction that describes the structure of the manuscript (line 77-84), which reads "The manuscript is organized as follows …. and outlook in section 8"

R1SC2:
- Ll. 32: Gravimetric measurements are also unsuitable for monitoring purposes due to invasive and destructive nature of the measurement

Authors' response:
We have modified the text as follows (43-45):

Gravimetrically determined soil moisture measurements are, however, destructive in nature and labor intensive. The gravimetric approach is as such unsuitable for monitoring purpose due to inherent limitation in collecting repetitive measurements and has also become unfeasible for long-term monitoring as the cost of labor increased.

R1SC3:
- Ll. 36: why "relative electric permittivity" ?

Authors' response:
We assume that the referee would like see a motivation for why the relative electric permittivity measurements are an appropriate technique for *in-situ* soil moisture monitoring. We have modified the text as follows (lines 44-52):

Indirect estimation of the soil water content has therefore been widely investigated (e.g. Vereecken et al. 2008). The large contrast between the relative electric permittivity (ε_r) of dry soil (3-5) and water (80) as well as its relative insensitivity to variations in salinity and soil texture have made electromagnetic field sensors operating at frequencies below 1 GHz the standard non-destructive measurement technique used for regional-scale soil moisture monitoring networks (e.g. Martinez-Fernandez and Cebalos 2005, Calvet et al. 2007, Su et al. 2011, Bircher et al. 2012, Smith et al. 2012, Benninga et al. 2018, Bogena et al. 2018, Caldwell et al. 2019, Tetlock et al. 2019). Despite technological advances facilitated a substantial increase in the worldwide monitoring infrastructure, in situ monitoring networks providing long-term soil moisture data records are still very scarce (GCOS, 2016).

R1SC4:
- Ll. 73-80: Why is this required? I suggest removing this paragraph.

Authors' response:
We have removed the paragraph.

R1SC5:
- Comments on maps in Fig. 1-3: these should be made more clear and less redundant

R1SC6:
- In my view, Fig. 1 is not required as a standalone figure, it could be included as an inset map in the other maps

R1SC7:
- Fig. 2: Why are specific land cover types removed from the DEM? Apart from that, the topography map could be combined with Fig. 3 (soil map), e.g. by using contour lines and/or hillshading

R1SC8
- Fig. 3: Please use hollow markers so the reader can better see the land use behind a location marker; the colour for sand is unnecessarily dominant which makes the figure kind of fidgety.

R1SC9:
- Fig. 4: again, the choice of colours is quite glaring. More importantly, though, the choice is not suited for readers with color vision deficiency.

R1SC10:
- I would find it very helpful to have the monitoring sites and the precipitation gauges in one map. Precipitation is crucial to interpret the soil moisture observations, and it is unfortunate that there is not a closeby rain gauge for each profile probe. At least on the map, the reader should get an impression about the distance to the next rain gauge. Maybe that information could also be included in the location metadata?

Authors' response:

We agree with the above comments of the reviewer and replaced the Figs. 1 -4 with one single figure (Figure R4) based on the DEM showing the locations of the soil moisture stations, weather stations, precipitation stations and groundwater monitoring wells with different symbols. The land cover and soil map are excluded from the manuscript for the reason that the limited spatial variability shown in the maps is also described in the text.

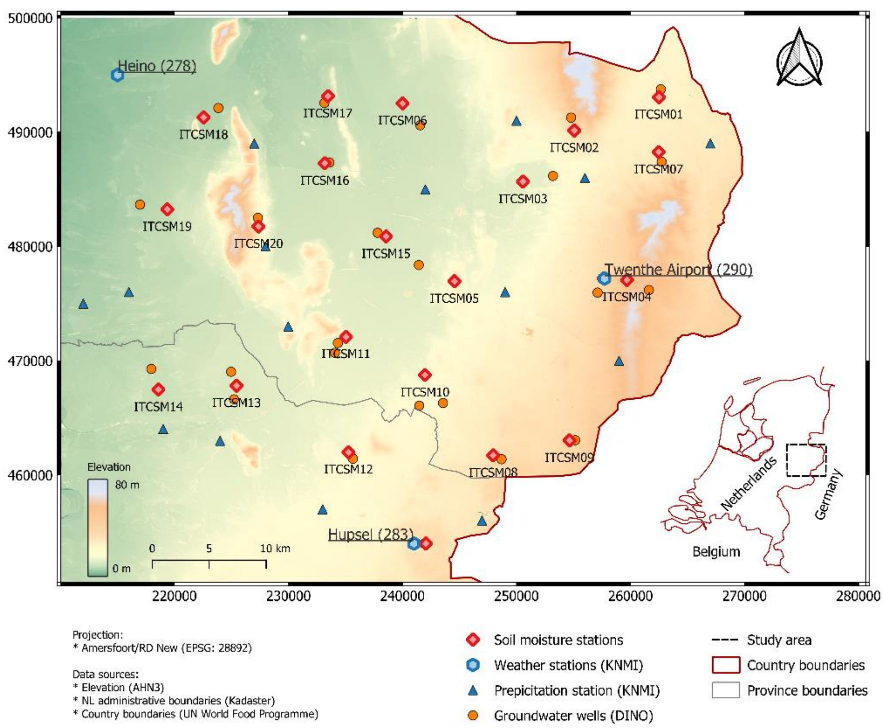

Figure R4.

R1SC11:
- You might also mention the open radar composite data. This data also has its issues, but it provides full coverage and hence provide useful information specifically in the case of convective rainfall in the summer season (https://dataplatform.knmi.nl/dataset/radar-corr-accum-03h-1-0, https://dataplatform.knmi.nl/dataset/nl-rdr-data-rtcor-5m-1-0).

Authors' response:
The following sentence has been added to the end of the first paragraph of section 2.4 (lines 135-136)

In addition, radar-derived precipitation is available as approximately 1 km gridded files for the Netherlands as gauge corrected accumulations for 5 min, 3 and 24 hours.

And a row has been added to Table 8 providing data access instructions.

R1SC12:
- Ll. 153-155: "The instrumentation is [...] typically placed at the border of fields and preferably several tens of metres away from disturbing features (i.e. trees, roads or watercourses) [...] to minimize disturbance from recurring farming practices and optimize its representativeness for the adjacent fields." How does the site selection, as described here, affect the representativeness for the agricultural fields? As pointed out above, it would be great if this issue was addressed in more detail in a dedicated section on uncertainty.

Authors' response:
This is indeed an important and interesting question. In the revised manuscript we will address the issue of the representativeness using the field campaign measurements as the referee suggests here and also in comment R1GC3. The sentence referred to in this comment has been modified as follows (line 162),

The instrumentation is, therefore, typically placed at the border of fields and preferably several tens of metres away from disturbing features (i.e. trees, roads or watercourses), as shown in Fig. 6, to minimize disturbance from recurring farming practices and optimize its representativeness for the adjacent fields, which is further addressed in section 5.2.

R1SC13:
- Ll. 157-159: Are the site properties (specifically soil!) only derived from the soil map or were they also specifically determined for the exact point (texture, SOM, horizons, …)?

Authors' response:
These properties are derived from the soil map and have not been determined in the soil laboratory. In the revised manuscript we have clarified this by modifying the text as follows (line 164-167),

Table S2 lists for each station the texture class derived from the soil map, land cover per year of the adjacent fields, percentage missing data, and changes made to the measurement setup. The location of the stations and their installation date are available as a list of geographic (datum: WGS84) and map projected (Amersfoort/RD New, EPSG: 28892) coordinates.

R1SC14:

- Table 1: I think that the table is useful, but in its current form, it might also go to the supplement, specifically since parts of the legend (asterisks) are also explained there. I think that the column "soil type class" should rather be "texture class".

Authors' response:

We have migrated the table to the supplement.

R1SC15

- Ll. 169-171: I think not all these details on sensor construction are required, please replace by adequate reference.

Authors' response:

In the revised manuscript we refer readers to the 5TM and EC-TM manuals for these details and added the following sentence to the end of the paragraph (lines 81-181),

'Readers are referred to the manuals for the details on the instrument design and its technical specifications (Decagon Devices 2008 and 2017)'

R1SC16

- L. 238: "The sampling strategy during campaigns aimed at characterizing the top 5 cm soil moisture content of fields." Stating the target variable (SM at 5 cm) is, in my view, not really a sampling strategy. Please also see my above comment on limiting the campaign to surface SM.

Authors' response:

We have modified the sentence to read (from lines 238 to 239),

The sampling strategy during campaigns was designed to validate soil moisture retrievals from satellite observations for which the top 5 cm soil moisture content was measured within fields.

R1SC17

- Section 4.1: How was the position of the sampling locations measured (GPS or DGPS / accuracy)?

Authors' response:

The accuracy of the position of the sampling points was not something that we recorded, but from our experience the GPS accuracy in our study area is and was 3 -4 m. The following sentence has been added at the end of the 1st paragraph (line 241-242).

Measurement locations have been determined using GPS with an accuracy better than 4 meters.

R1SC18

- Ll. 238-240: The criteria of selecting a sampling location remain unclear. Which role plays the distance between locations and the parcel size, as compared to a random placement?

Authors' response:

The sentence has been reformulated to read(line 239-241), A maximum of six measurement locations were selected per field about 50 m to 100 m apart, which was reduced to a minimum of three locations when the size of parcel was not big enough.

R1SC19

Fig. 8. does not really help me to understand the sampling design.

Authors' response:

We agree with the reviewer that the figure is of little added value in explaining the sampling design. We have, therefore, removed the figure from the manuscript.

R1SC20

- Ll. 242-245: Which design was used for locations that were neither grassland nor maize?

Authors' response:

We agree with the referee that the description is incomplete and modified the text as follows (lines 244-245):

At fields without crop rows, such as grass and wheat, soil moisture was measured with the impedance probe at four to nine points within a 1 m^2 plot and next to one of the probe readings a soil sample was taken for GVSM determination. In fields with crop rows, such as maize and potato, probe readings were taken along the transect perpendicular to the crop rows, approximately 0.75 m apart, with the soil sample taken in between two rows.

R1SC21

- L. 246: What do you mean by "The collection of soil samples for GVSM determination [...] stopped [...]"? Does that mean that after a specific campaign day, you decided that more gravimetric samples were not required?

Authors' response:

It is exactly that!

During field campaigns the collection of soil samples was the most time-consuming activity in the field, and also the 'post-processing', weighing and oven-drying of soil samples requires a lot of attention. Every season we have collected pairs of impedance probe recordings and soil samples. Throughout the campaigns, we monitored the impedance probe – GVSM relationship that was collected and ended the soil sampling when we were satisfied or when additional sampling would be of little added value due to similar soil moisture conditions. An exact number of independent samples is difficult to attach to this (but ideally > 25) because the cut-off would also depend on the dynamic soil moisture range covered up to that moment, and how many days the same conditions had been sampled.

We modify the sentence as follows (lines 248-250),

The collection of soil samples for GVSM determination was done each field campaign to calibrate the probe readings and stopped when the covered dynamic range and number of matchups, ideally greater than 25, were suitable to establish a calibration function.

R1SC22

- Fig. 9: I find the figure different to read because all the information is represented by the color code. Please consider a different approach: you could e.g represent the year by a colored circle and the gravimetric measurement by a marker inside the circle. I would also use a different marker for the maize stems.

Authors' response:

We have used these suggestions to replace the previous figure by the one below.

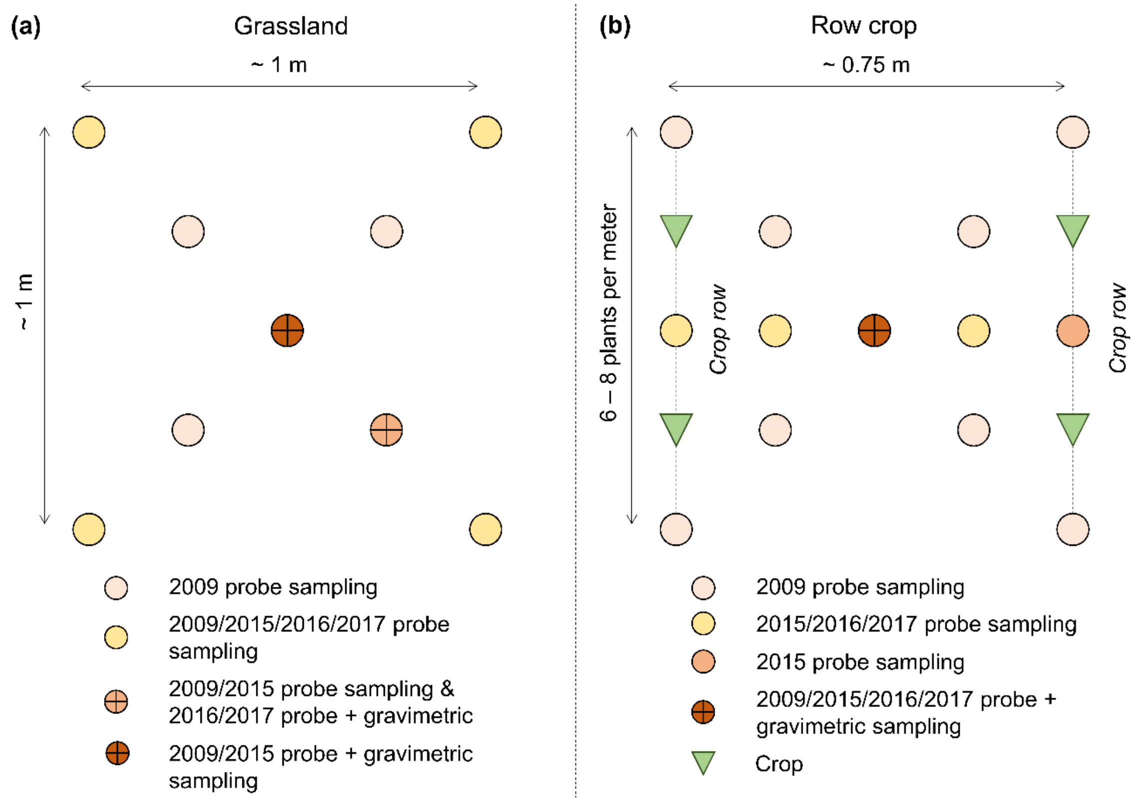

Figure R5

R1SC22

- Fig. 10: the labels are too small, the resolution insufficient.

Authors' response:

We have reproduced the figure (figure 9 in the revised manuscript) with a higher resolution. At the same time, we have taken the opportunity to improve its suitability for readers with colour vision deficiency by using different symbols and colour tones. Figures 7, 10 and 11 have also been reproduced in the same style for the revised manuscript.

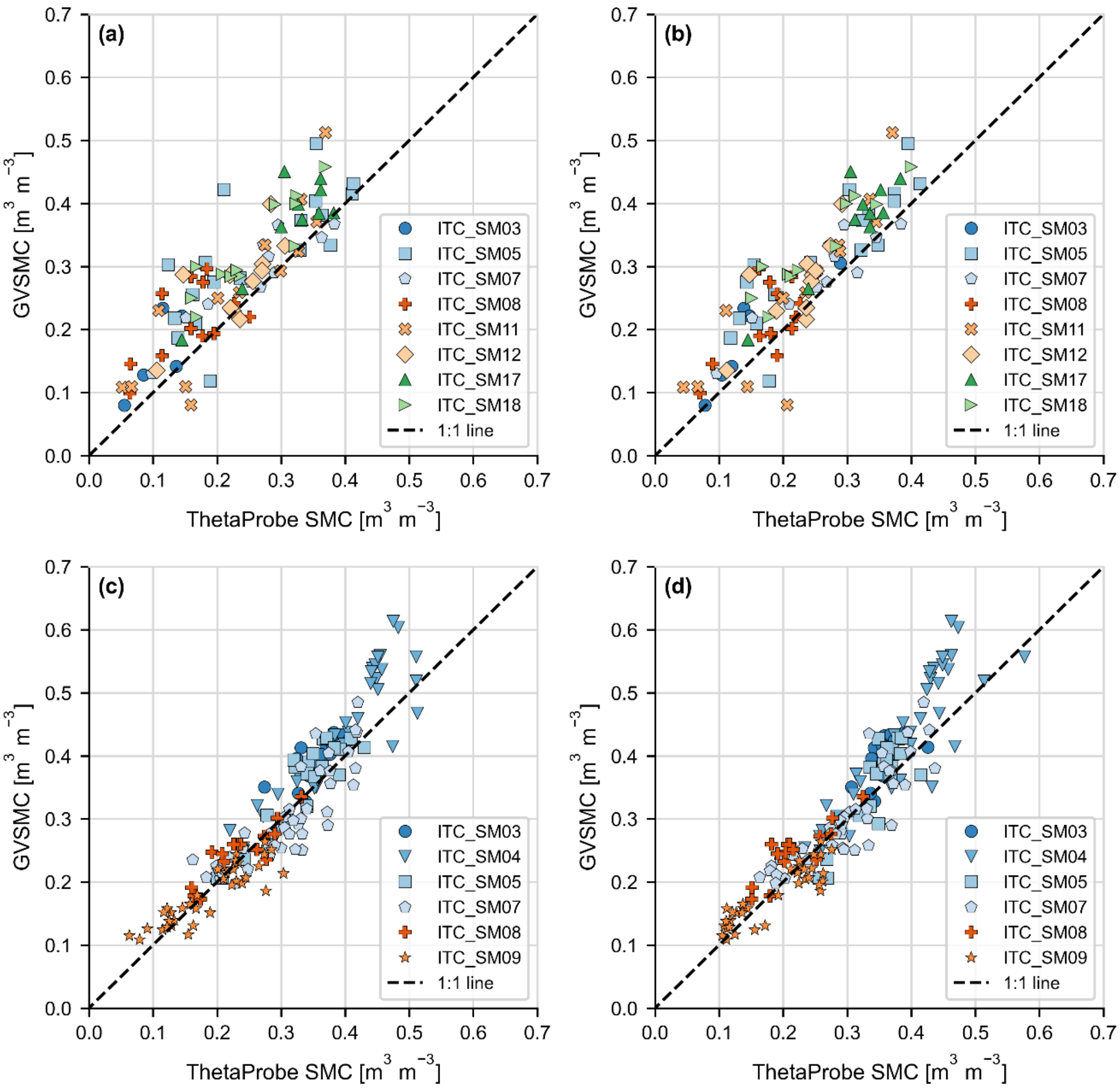

Figure R6

R1SC23

- L. 278: "[...] to develop the calibration functions for the ThetaProbe on a field campaign basis [...]" - please be more specific about what you mean here.

Authors' response:

We have modified this sentence as follows(lines 280-281),

Therefore, we have chosen to develop the ThetaProbe calibration functions for the 2009 and 2015 field campaigns separately and not for individual stations or specific soil types.

R1SC24

- Ll. 285-286: The agreement for Fig. 11 seems higher, but it should be noted that the points are mainly from a different set of stations: so is the better agreement due to the probe, or due to the different locations? Of course, that is difficult to say, but maybe the issue could be briefly mentioned?

Authors' response:

We have added to following two sentences to briefly address this issue (lines 289-292),

Factors that could have contributed to this agreement difference are the deployed instruments, the different sets of fields sampled, the number of matchups collected per field and the extent of the dynamic soil moisture range covered by the matchups. However, it is beyond the scope of this manuscript to quantify their relative contributions.

R1SC25

- L. 286: replace "little" by "small"

Authors' response:

done

R1SC26

- L. 287: "distributions" is not the adequate term here, I think. Isn't it the relationships between probe readings and GVSM that you mean?

Authors' response:

We have modified the sentence as follows (lines 292-294):

Also noticeable in Figs. 7 are the small differences among the relationships represented by the groups of the data points belonging to individual stations, which again may question the added value of station-specific calibration functions.

R1SC27

- Ll. 296-297: "The performance metrics presented in Tables 4 and 5 show that the matching probe ('site') and GVSM measurements generally led to better performance except for the 2009 field campaign [...]" - I don't agree entirely: in Tab. 5, the "mean" variant performs better for ITC_SM02.

Authors' response:

The referee is correct in the sense that RMSE of mean variant performs better for ITC_SM02, when comparing the R^2 in the tables the statement does hold. We have modified the sentence and add one sentence as given below(lines 301-303).

The performance metrics presented in Tables 4 and 5 show that the matching probe ('site') and GVSM measurements led to a better performance in terms of the R^2 except for the 2009 field campaign. The same holds when comparing the RMSEs with exception of the 2016-2017 results for ITC_SM02 in which case the mean of the probe readings leads to a better performance.

R1SC28

- Ll. 297-299: "Of the field campaign calibrations, the calibration developed for the HydraProbe (2016-2017) led to the best results with a RMSE of 0.032 m3 m-3 versus 0.041 m3 m-3 for 2015 and 0.048 m3 m-3 for 2009." This sentence is ambiguous, please change to: "Of the field campaign calibrations, the calibration developed for the HydraProbe (2016-2017) led to the best results with an RMSE of 0.032 m3 m-3 in comparison to RMSEs of 0.041 m3 m-3 for 2015 and 0.048 m3 m-3 for 2009, as obtained for the ThetaProbes."

Authors' response:

Thanks, we have modified the sentence as suggested.

R1SC29
- L. 325: readme file

Authors' response:
'file' has been added

R1SC30
- L. 347: "Long-term operation of in-situ monitoring networks goes hand in hand with measurement uncertainties." - please remove this sentence.

Authors' response:
Done

R1SC31
- Ll. 350-353: I understand this is too late, but you could also recalibrate the relation between the prime measurement variable (raw voltage) and permittivity yourself, by using pure air and water, for each sensor - correct?

Authors' response:
This is less straightforward than one would expect. The raw sensor output of the METER group probes are not voltages but digital numbers produced with the internal firmware from the prime observations. In the case of the 5TM probe, dividing by 50 returns the electric permittivity, but in the case of the EC-TM probe, this is not clear.

Further, a linear response between the voltage and the permittivity needs to be assumed. The range from 1 (air) up to 80 (water) is too large for this assumption and ideally several additional standards would be used to establish such relationship as is done at METER Group (formerly Decagon). Via personal communication (see copy of e-mail below) METER Group informed us that they use IPA with a permittivity of ~40 as the highest calibration standard for their sensor. This probably also links to the specified accuracy of the permittivity measurements +/- 1 below a permittivity of 40 and 15% above a permittivity of 40 (see link). This non-linearity is also described in a passage that we can across in the EC-TM manual (see link).

[redacted]@metergroup.com>
Aan: Velde, R. van der (ITC) Wo 21-4-2021 00:59
CC: [redacted]@metergroup.com **+2 anderen**

Hello,

The highest standard that we use is IPA, which has a dielectric just over 40, so I think it is a good idea to make that the upper limit.

Here are instructions to update your firmware. It does require a Procheck handheld unit and a laptop. I've cc'd our Europe support team that may be able to help if you do not have a Procheck. You can find the update file here.
Regards,

[redacted]

where θ is vol. water content and *Raw* is the output of the probe sensors (see appendix). It is worth noting here that this equation is linear. In fact, the linear fit provided as good a fit in the mineral soil range as did a higher order polynomial, with the added benefit that it is relatively easy to work with in data-logger programs, etc. However, one drawback with this

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ECH_2O-TE/EC-TM Probe Operator's Manual
4. Probe VWC Calibration

approach is that, immersed in water, this calibration gives a water content of ~80% VWC. This is because the calibration, although linear in the mineral soil water content range we tested (0 to ~35% VWC), actually is quadratic from 0 to 100% VWC. This fact is apparent when calibrating probes in rock-wool and other low-density material. If you want to develop your own quadratic equation, perform a medium-specific calibration, or use Decagon's calibration service, see **http://www.decagon.com/echo/calibration.html**.

Prior to the deployment of the instruments, we would indeed verify the functioning of the probes using air and water, and found for the 5TM that in air the reading would always be equivalent to a permittivity of 1, but in water reading would be less constant in time and also a sensor-to-sensor variability would be noticeable as was previously studied by Rosenbaum et al. (2010).

The above described detailed are included in the newly written section 5.1.

Rosenbaum, U., Huisman, J. A., Weuthen, A., Vereecken, H., and Bogena, H. R.: Sensor-to-Sensor Variability of the ECH2O EC-5, TE, and 5TE Sensors in Dielectric Liquids, Vadose Zo. J., 9, 181–186, https://doi.org/10.2136/vzj2009.0036, 2010.

R1SC32

- Table 8 should also contain, in a dedicated column, the main variable(s) represented by the corresponding third party datasets

Authors' response:
We will add such column to the table.

Technical comments

- Dataset: In the files in 0_measurement_campaigns/1_processed_calibrated, the combination of field IDs and location IDs are not unique. E.g. for file Twente_fieldwork_ITCSM03_pd_cd.csv, the first six rows show, for the field column, the values 1, 1, 1, 1, 1, 1 while the location column shows 1, 2, 3, 1, 2, 3 while I would have expected 1, 2, 3, 4, 5, 6. Could you elaborate?

Authors' response:
Yes the reviewer is correct. This is an artefact from the way in which we recorded the measurements during fieldwork. We have corrected this in the dataset submitted to DANS on 16 december, which doi 10.17026/dans-znj-wyg5.

- The header of your data repository is "Ten years profile soil moisture and temperature measurements in Twente (version 2022)" - that is inconsistent with the title of your paper.

Authors' response:
We have corrected this in the dataset submitted to DANS on 16 december, which doi 10.17026/dans-znj-wyg5.

- Ll. 22 ff.: "conversion of water into vapour via evapotranspiration at the expense of solar radiation" - I find that weirdly phrased

Authors' response:
We have changed this sentence to (lines 31-33),

Moreover, the availability of soil moisture for evapotranspiration controls heat and water exchanges between the land surface and atmosphere affecting weather and climate

- Punctuation requires revision throughout the paper.

Authors' response:
We have carefully checked the punctuation throughout the manuscript

- L. 114: Is heath actually cultivated in that context? I found it surprising to list it under agricultural land use.

Authors' response:
That is correct. We have removed 'heath' as well as 'forest'.

- L. 175: replace "circumstances" by "conditions"

Authors' response:
Done

- L. 175: replace "influence zone" by "footprint" or "spatial representativeness", if that is what is meant

Authors' response:
We have reformulated the sentence as given below because footprint may be confused with the footprint of remote sensing instruments and 'spatial representativeness' is straightforward to define in the soil moisture context (lines 197-180).

'Benninga et al. (2018) have shown under laboratory conditions that 5TM probe is sensitive to about 3 cm to 4 cm of soil layer around the prongs.'

- Fig. 8: the north arrow appears unnecessarily large

Authors' response:
We will reproduce the figure with a smaller north arrow.

- L. 283: I suggest to remove a) and b) from the text, this is included in the figure caption

Authors' response:
Done

- L. 405: measurements

Authors' response
Change to 'measurement locations'

Authors' response to Referee 2

This paper presents a dataset of ongoing in situ soil moisture measurements in a region in the eastern part of the Netherlands. The dataset covers the time period since 2009, 20 locations, and measurements at five different depths (in general). The paper presents also results from field campaigns that resulted in calibration functions for the soil moisture sensors.

Authors' response:
We would like to thank the referee for general positive feedback. In the text below, we provide our point-by-point response to the comments.

Most of the referee's suggestions have been implemented. Our response to the referee comments is structured as follows:

- The native referee comment is labelled and written in black.
- The authors response is written in blue
- Text from the manuscript is written with the Times New Roman font whereby the native text is in black and the changes are in red

R2GC1:
The paper is in general sound and I have only minor comments. However, a major concern is whether publication is warranted in a high impact journal like ESSD, for only 20 point soil moisture time series for a period of 13 years. Question is whether the dataset is unique enough for this journal. I have suggested "minor revision", but alternatively a recommendation could also be "rejection". I leave this decision to the editor.
Authors' response:
Our paper presents a unique dataset of in-situ soil moisture measurements in the Eastern part of the Netherlands. The uniqueness of this data set stems from its design as a network of fixed stations covering an area of 45 km by 40 km and measuring the soil moisture profile at nominal depths 5 cm, 10 cm, 20 cm, 40 cm and 80 cm for more than 10 years. Most of the current scientific articles reporting datasets based on in-situ measurements have generally a smaller temporal and spatial coverage in comparison to the presented work as will be further motivated in the following paragraph. Our paper also reports on complementary spatially distributed field measurements collected during campaigns organized in four different years, namely 2009, 2015, 2016 and 2017. Moreover, we have made an effort to describe in this paper an extensive collection of open third-party datasets (i.e. land cover/use, soil information, elevation, groundwater and meteorological observations) that can support the use of the Twente soil moisture and temperature datasets by other scientists and professional.

We have further investigated the suitability of our manuscript for the ESSD by searching in the title for the keyword 'soil moisture' and found 31 articles. From this collection of articles, we could identify at least eleven contributions of which the dataset relied on in-situ measurements. Those are listed below. The datasets reported in all articles cover a time span not significantly more 10 years and a similar spatial extent as the Twente region, with exception of Bogena et al. (2022) who report on an European network of cosmic ray probes. Three out of the eleven identified articles have a topic comparable to our manuscript, which are Benninga et al. (2018), Tetlock et al. (2019) and Zhang et al. (2021). We have looked up the number of citations in Web of Science for those three articles and found that they are cited 18, 23 and 15 times, respectively. All three have been cited more than the journals impact factor. This leads us to the conclusion that the impact of the topic of our manuscript is at the appropriate level for the ESSD journal.

Acticles on in situ soil moisture measurement dataset:

1. Bam, E. K. P., Brannen, R., Budhathoki, S., Ireson, A. M., Spence, C., and van der Kamp, G.: Meteorological, soil moisture, surface water, and groundwater data from the St. Denis National Wildlife Area, Saskatchewan, Canada, Earth Syst. Sci. Data, 11, 553–563, https://doi.org/10.5194/essd-11-553-2019, 2019.

2. Benninga, H.-J. F., Carranza, C. D. U., Pezij, M., van Santen, P., van der Ploeg, M. J., Augustijn, D. C. M., and van der Velde, R.: The Raam regional soil moisture monitoring network in the Netherlands, Earth Syst. Sci. Data, 10, 61–79, https://doi.org/10.5194/essd-10-61-2018, 2018. (Web of Science citations: 18)

3. Bogena, H. R., Schrön, M., Jakobi, J., Ney, P., Zacharias, S., Andreasen, M., Baatz, R., Boorman, D., Duygu, M. B., Eguibar-Galán, M. A., Fersch, B., Franke, T., Geris, J., González Sanchis, M., Kerr, Y., Korf, T., Mengistu, Z., Mialon, A., Nasta, P., Nitychoruk, J., Pisinaras, V., Rasche, D., Rosolem, R., Said, H., Schattan, P., Zreda, M., Achleitner, S., Albentosa-Hernández, E., Akyürek, Z., Blume, T., del Campo, A., Canone, D., Dimitrova-Petrova, K., Evans, J. G., Ferraris, S., Frances, F., Gisolo, D., Güntner, A., Herrmann, F., Iwema, J., Jensen, K. H., Kunstmann, H., Lidón, A., Looms, M. C., Oswald, S., Panagopoulos, A., Patil, A., Power, D., Rebmann, C., Romano, N., Scheiffele, L., Seneviratne, S., Weltin, G., and Vereecken, H.: COSMOS-Europe: a European network of cosmic-ray neutron soil moisture sensors, Earth Syst. Sci. Data, 14, 1125–1151, https://doi.org/10.5194/essd-14-1125-2022, 2022.

4. Fersch, B., Francke, T., Heistermann, M., Schrön, M., Döpper, V., Jakobi, J., Baroni, G., Blume, T., Bogena, H., Budach, C., Gränzig, T., Förster, M., Güntner, A., Hendricks Franssen, H.-J., Kasner, M., Köhli, M., Kleinschmit, B., Kunstmann, H., Patil, A., Rasche, D., Scheiffele, L., Schmidt, U., Szulc-Seyfried, S., Weimar, J., Zacharias, S., Zreda, M., Heber, B., Kiese, R., Mares, V., Mollenhauer, H., Völksch, I., and Oswald, S.: A dense network of cosmic-ray neutron sensors for soil moisture observation in a highly instrumented pre-Alpine headwater catchment in Germany, Earth Syst. Sci. Data, 12, 2289–2309, https://doi.org/10.5194/essd-12-2289-2020, 2020.

5. Godsey, S. E., Marks, D., Kormos, P. R., Seyfried, M. S., Enslin, C. L., Winstral, A. H., McNamara, J. P., and Link, T. E.: Eleven years of mountain weather, snow, soil moisture and streamflow data from the rain–snow transition zone – the Johnston Draw catchment, Reynolds Creek Experimental Watershed and Critical Zone Observatory, USA, Earth Syst. Sci. Data, 10, 1207–1216, https://doi.org/10.5194/essd-10-1207-2018, 2018.

6. Heistermann, M., Bogena, H., Francke, T., Güntner, A., Jakobi, J., Rasche, D., Schrön, M., Döpper, V., Fersch, B., Groh, J., Patil, A., Pütz, T., Reich, M., Zacharias, S., Zengerle, C., and Oswald, S.: Soil moisture observation in a forested headwater catchment: combining a dense cosmic-ray neutron sensor network with roving and hydrogravimetry at the TERENO site Wüstebach, Earth Syst. Sci. Data, 14, 2501–2519, https://doi.org/10.5194/essd-14-2501-2022, 2022.

7. Jackisch, C., Germer, K., Graeff, T., Andrä, I., Schulz, K., Schiedung, M., Haller-Jans, J., Schneider, J., Jaquemotte, J., Helmer, P., Lotz, L., Bauer, A., Hahn, I., Šanda, M., Kumpan, M., Dorner, J., de Rooij, G., Wessel-Bothe, S., Kottmann, L., Schittenhelm, S., and Durner, W.: Soil moisture and matric potential – an

open field comparison of sensor systems, Earth Syst. Sci. Data, 12, 683–697, https://doi.org/10.5194/essd-12-683-2020, 2020.

8. Roche, J. W., Rice, R., Meng, X., Cayan, D. R., Dettinger, M. D., Alden, D., Patel, S. C., Mason, M. A., Conklin, M. H., and Bales, R. C.: Climate, snow, and soil moisture data set for the Tuolumne and Merced river watersheds, California, USA, Earth Syst. Sci. Data, 11, 101–110, https://doi.org/10.5194/essd-11-101-2019, 2019.

9. Schaffitel, A., Schuetz, T., and Weiler, M.: A distributed soil moisture, temperature and infiltrometer dataset for permeable pavements and green spaces, Earth Syst. Sci. Data, 12, 501–517, https://doi.org/10.5194/essd-12-501-2020, 2020.

10 Tetlock, E., Toth, B., Berg, A., Rowlandson, T., and Ambadan, J. T.: An 11-year (2007–2017) soil moisture and precipitation dataset from the Kenaston Network in the Brightwater Creek basin, Saskatchewan, Canada, Earth Syst. Sci. Data, 11, 787–796, https://doi.org/10.5194/essd-11-787-2019, 2019. (Web of Science citations: 23)

11. Zhang, P., Zheng, D., van der Velde, R., Wen, J., Zeng, Y., Wang, X., Wang, Z., Chen, J., and Su, Z.: Status of the Tibetan Plateau observatory (Tibet-Obs) and a 10-year (2009–2019) surface soil moisture dataset, Earth Syst. Sci. Data, 13, 3075–3102, https://doi.org/10.5194/essd-13-3075-2021, 2021. (Web of Science citations: 15)

R2SC1:

L28. Instead of Mecklenburg et al., 2016 an earlier citation should be included.

Authors' response:

The citation Mecklenburg et al. (2016) has been replace to a citation to Kerr et al. (2010)

Kerr, Y.H., Waldteufel, P., Wigneron, J.-P., Delwart, S., Cabot, F., Boutin, J., Escorihuela, M.-J., Font, J., Reul, N., Gruhier, C., Juglea, S. E., Drinkwater, M.R., Hahne, A., Martin-Neira, M., and Mecklenburg, S.: The SMOS mission: New tool for monitoring key elements of the global water cycle, P. IEEE, 98, 666-687, doi: 10.1109/JPROC.2010.2043032, 2010.

R2SC2:

L114. What does "forest" mean here? Fruit trees? Please specify.

Authors' response:

The forest in the study area are a mixture of coniferous and deciduous trees. Forest should in the context of the study area not fall under agriculture. Also based on the suggestion by Referee 1, forest and heath are removed from the sentence. The first sentence of the paragraph has been modified to include this information.

From the 2015 land use map from Statistics Netherlands can be deduced that 70.2 % of the land is used for agricultural activities, 13 % is mixed coniferous and deciduous forests, 11.3 % is built-up and the remaining 5.5 % is classified as water, recreational, dry and wet nature.

R2SC3:

L116. Probably harvested in September and October.

Authors' response:

Only in the recent dry years farmers started with the harvest maize in September. In the past it was not unusual that the harvest would be postponed to November because the maize cobs needed more time to mature. The text is modified as follows:

Maize is planted in the months April/May and harvested in the period from September to November depending on the vehicle bearing capacity of the land and growing conditions.

R2SC4:
L185. What has happened in case of sensor failure? What if sensors had to be replaced? Was the same sensor type used? Was there a check for inhomogeneity in the measurement time series?

Authors' response:
In the case of sensor failure the sensor was replaced by a similar METER group sensor, type EC-TM or 5TM. Prior to installation, every sensor was tested for its functionality using measurements of air and water.

The sensor-to-sensor variability was accounted for by the manufacturer's sensor calibration against known dielectric standards as we wrote on l192-194. The installed sensor type is included in the data quality flags as explained on l333-337. This issue with the internal calibration of a specific batch of the 5TM sensors has been dealt with as reported in l354-359.

The following sentence has been added to the first paragraph of section 3.2.

The functionality of the probes were tested using measurements of water and air prior to deployment and the installed probe types are documented as a quality flag within the datasets, see section 6.

R2SC5:
L296-L303. Can you explain why these RMSE´s are so large? What is the RMSE for the average soil moisture content of a complete field or area?

Authors' response:
The RMSE values are not specifically large for field campaigns during which soil moisture is measured in multiple fields and over the full dynamic range. The uncertainty levels are generally lower under controlled laboratory conditions or for a single prepared field because under those conditions soil sampling is more reliable due to the absence of natural variabilities in, for instance, soil clods and plant roots. This explanation is provided in the context of the conducted field campaigns around l300-303.

For comparison, Cosh et al. (2005) report on RMSEs varying from 0.027 up to 0.041 m^3 m^{-3} and from 0.040 m^3 m^{-3} up to 0.054 m^3 m^{-3} for field specific and soil specific calibrations, respectively, see copied table below. We obtain for the 2009 campaign the highest RMSE value of 0.048 m^3 m^{-3}. This field campaign had the lowest number of sampling days in combination with the largest number fields sampled, which may have led to a larger uncertainty. This explanation is given in l271-274 of the manuscript. We obtain for the 2015 field campaign a measurements uncertainty of 0.041 m^3 m^{-3} with the ThetaProbe and for the 2016/17 campaign an overall RMSE of 0.032 m^3 m^{-3} is achieved with the HydraProbe. So all-in-all the RMSEs are in line with the reported state-of-art.

Table 2
Summary statistics for the SMEX02 impedance probe calibration methods

Data set	Generalized calibration	Soil specific calibration	Field specific calibration
WC region			
R^2	0.698	0.698	0.787
Bias (m^3/m^3)	0.022	0.001	0.000
rmse (m^3/m^3)	0.061	0.049	0.041
IA region			
R^2	0.744	0.742	0.803
Bias (m^3/m^3)	0.009	−0.014	0.000
rmse (m^3/m^3)	0.053	0.054	0.040
Little Washita (LW)			
R^2	0.367	0.370	0.612
Bias (m^3/m^3)	−0.010	−0.006	0.001
rmse (m^3/m^3)	0.057	0.051	0.039
OS region			
R^2	0.713	0.722	0.844
Bias (m^3/m^3)	0.013	0.014	0.000
rmse (m^3/m^3)	0.039	0.040	0.027
ON region			
R^2	0.571	0.571	0.760
Bias (m^3/m^3)	0.003	0.007	−0.001
rmse (m^3/m^3)	0.048	0.040	0.028
Total			
R^2	0.716	0.716	0.821
Bias (m^3/m^3)	0.001	−0.006	0.000
rmse (m^3/m^3)	0.053	0.050	0.037

Table copied from Cosh et al. (2005)

Cosh, M.H., Jackson, T.J., Bindlish, R., Famiglietti, J.S., Ryu, D.: Calibration of an impedance probe for estimation of surface soil water content over large regions, Journal of Hydrology, 311, 49-58, doi:10.1016/j.jhydrol.2005.01.003, 2005.

R2SC6:
L335. iv) instead of v)

Authors' response:
done

R2SC7:
L343: Change to: "a readme document"

Authors' response:
We have changed this to 'the readme document accompanying the dataset'.

R2SC8:
L366. Do you compare here individual measurement points with measurements?

Authors' response:
These error metrics are based on the comparisons of the stations with the field average soil moisture obtained from the campaigns. This issue will be clarified in the new section on spatial representativeness that was suggested by referee 1.

R2SC9:
L375. "lower groundwater levels" instead of "low groundwater levels"?

Authors' response:
Done.

R2SC10:
L391. How doe you explain this? Could it be related to preferential flow in the unsaturated zone?

Authors' response:
It is possible that preferential flow is an explanation. Another more likely explanation is that the shallow groundwater table causes a naturally fast response of the surrounding hydrology, especially in winters. This leads to the fact that groundwater table fluctuations match relatively well with temporal variations in soil moisture measured at 5 cm and 10 cm measured. The moisture content measured at 40 and 80 cm is under those conditions less responsive to rain events because the surrounding soil is already saturated. The following three sentences are added.
This can likely to be attributed to the shallow groundwater table in the study area that causes a naturally fast hydrological response. The groundwater table fluctuations match especially in winters well with the variations in soil moisture measured at 5 cm and 10 cm. The moisture contents measured at 40 and 80 cm is under those conditions less responsive to rain events because the surrounding soil is already saturated.

R2SC11:
L394. Or opposite? In situ groundwater levels (whose availability is more abundant than soil moisture measurements) provide information on soil moisture content.

Authors' response:
Indeed, in the western world in-situ groundwater measurements often (readily) available and soil moisture measurements not. In the majority world, however, in-situ groundwater monitoring networks are seldomly in place, while societies have a great demand for them. The text is modified as follows,

Hence, there lies also an opportunity to further investigate the connection between the water content in the unsaturated zone and the groundwater table. This knowledge may be used to provide soil moisture estimates in regions where groundwater monitoring wells are abundant or groundwater information based on surface soil moisture observed from space in countries where groundwater monitoring networks are absent.

R2SC12:
L423. Typo: “third-party”.

Authors’ response:
done

R2SC13:
Figure 8. Please explain the numbers in the figure (why twice “1”, “2”, “3” etc.)

Authors’ response:
These numbers stand for the measurement locations within a unique field. We have decided to remove this figure based on the suggestion by referee 1 and because we find it in retrospect of little added value to the text.