Hydrol. Earth Syst. Sci. Discuss., 10, C1534–C1536, 2013
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Hydrology and Earth System Sciences Discussions

Interactive comment on "Temporal stability of soil moisture patterns measured by proximal ground-penetrating radar" *by* J. Minet et al.

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Received and published: 8 May 2013

We thank the referee for its constructive comments, especially as he noticed that the two methods for determining time-stable areas could actually not be quantitatively compared. Most of the major points raised by Wei Hu were also pointed out by H Bogena. Please find below a quick response to the major comments of the paper. A detailled review will be prepared soon.

1) About the trade-off between GPR uncertainties and spatial resolution

We strongly concur with the comment of the referee stating that the opportunity of using GPR for soil moisture mapping depends on the trade-off between spatial resolution

and measurement accuracy. This trade-off is function of the relative importance of the measurement uncertainty w.r.t. the spatial variability, under the constraint of a maximal uncertainty that can be accepted. In our context, we think that the trade-off is mainly in favor of the GPR method w.r.t. to the reference method, as the uncertainties in soil moisture using GPR is much smaller than the observed soil moisture variability. We support that an indirect measurement method can be better suited for mapping if it provides much larger amount of data than an accurate but cumbersome method with a few measurement points. This is actually one of the principle of the digital soil mapping approach.

In the paper, we will emphasize this in 2.2 (Comparison with soil core sampling measurements) and the influence of soil moisture to depth characterization will be better discussed, because this is a large part of the uncertainties from the GPR that were underestimated.

2) About the uncommensurability of the two methods

H. Bogena made a similar remark on this point. We agree that the second method (intersection of time- stable areas) is poorly generic and could actually not be closely compared with the first method. Indeed, the tolerance of the second method highly depends on the number of acquisitions, while the tolerance of the first method not. The choice of the soil moisture threshold is also highly arbitrary, except if we keep in mind the opportunity to use this method to install permanent sensors. The first method should be preferred rather than the second one, although straight-forward and particularly suited for continuous mapping methods, which is bringing a new conclusion to the paper.

We will strongly clarify the description of the second method in he Materials and methods. The two methods were no more directly compared, as they are actually uncommensurable as you raised, except at the level of the geographical delineation they provide.

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3) About the wheel compaction

As written in the paper (3.2 Line effect), the repeated passes of the ATV have compacted the soil underthe wheel tracks, resulting in (1) a change in the volumetric soil moisture by the modification of the soil bulk density and (2) the possibility of deviation of flow paths. Nevertheless, it is worth noting that the spacing between ATV's wheels is about 1 m width so that the major part of the footprint below the GPR antenna was not directly affected by the compaction.

This important issue was already raised in the paper, but we will advance this reason in the paper to explain the larger errors in the last two acquisitions.

4) About the few number of acquisitions

The small number of acquisitions and the limited time frame on which the study was conducted is probably the weakest point of this study. That is why this is explicitly stated in the abstract and the conclusions. It is also closely linked with the lower applicability of the intersection method (second method) with a larger number of acquisitions.

We will insist on that in the revised version of the paper.

5) About the low penetration depth.

This is indeed a major concern with the radar remote sensing of soil moisture instruments. Note that the GPR is using lower frequencies (200-800 MHz) than the lowest frequency-satellites (L-band, $\sim$ 1300 MHz) and have thus a deeper characterization depth. Nevertheless, it is widely accepted in the remote sensing community that it is more valuable to use remotely-sensed data in a change detection approach, e.g., by investigating the time stability of a spatial pattern, rather than using remotely-sensed data as absolute measurements.

We will also insist on that in the revised version of the paper.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 4063, 2013.

Hydrol. Earth Syst. Sci. Discuss., 10, C1550–C1552, 2013
www.hydrol-earth-syst-sci-discuss.net/10/C1550/2013/

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We thank the referee for his constructive comments. We agree with most of the comments and it is worth noting that similar issues were raised by the other referee Wei Hu. In particular, the weaknesses of the intersection method were better underlined and this has to be better discussed in the paper. Please find below a quick response to the major comments of the paper. A detailed review will be prepared soon.

1. About the GPR data

I fully agree that the GPR method and data was presented with a lack of critical mind. In particular, the depth characterization issue and the line effect need to be more discussed. It will be done in the review, especially concerning the last two dates that

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showed larger discrepancies with reference soil moisture and a larger line effect.

2. About the gravimetric soil moisture determination method

This comment is to be related with the previous one, so we agree with it. Actually, it is worth noting that most of the discrepancies between the reference and GPR method can be explained by the different support scales, among other sources of uncertainties, even if these other sources may be also important.

This will be better balanced in 3.3 (Comparison with soil core sampling). In addition, the GPR method w.r.t. the reference method will be better presented as a digital soil mapping method, i.e., a method giving a large number of measurements that can be less accurate but that are better catching the spatial variability than an accurate but cumbersome method.

3. About the line effect and the compaction

The observed line effect is an important issue in this GPR dataset. As it is observed at the same locations at different dates, we could exclude a sensor drift. The soil compaction may be the main responsible of the line effect observed in volumetric soil moisture, either due to the passes of the ATV or previous agricultural machinery. Note that the compacted-trakcs due to the ATV are situated at the edge of the GPR antenna footprint and that the antenna is mostly sensitive to the backscattered signal from the center of the antenna. The effect of soil compaction on the GPR data was also raised by the other referee Wei Hu.

The soil compaction will be more strongly affirmed as the main cause of the line effect in the chapter 3.2 (Line effect) of the paper.

4. About the GPR data interpolation

The GPR-derived soil moisture data interpolation is an important issue as it smooths a lot of local variability. However, we don't fully understand the request of the referee here: - The soil moisture data were not aggregated before the kriging but the kriging

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equation were adapted by taking into account a rectangular neighboorhood window for computing the kriging weight to be assigned to each data point (instead of a circular in usual kriging algorithm). If I'm not making a mistake, this is not resulting in a aggregation. - The resolution of interpolated map is exactly 2 m and it will stated in the revised version. The spacing of the measurements in the field varies between 2 and 5 meters along an acquisition line. It should be 2 meters according to the GPS but communication issues between the instruments (i.e., the PC, the GPR and the GPS) could increase the spacing between points. The interpolation resolution (2 m) was chosen between the support scale (2 m^2) and the measurement spacing (min. 2 m, but more generally about 2.5 m along the line and 5 m between the lines). The mode of data acquisition using the GPS will be more detailed in the paper. - A map using a moving window aggregation will be tested as requested by the reviewer.

5. About the intersection method

The other referee, Wei Hu, also remarked that this method could not be used in all conditions and that it is also not quantitatively comparable with the first method (i.e., temporal stability indicators). As a result, the description (2.4) and the interpretation (4.2 and 4.4) of the intersection method will be drastically modified in the revised version. We will also better balance the choice between the two methods, probably by stating that the intersection method may be poorly generalizable.

6. About the copying from other papers The methodology for the paragraphs will be revised to avoid repetition from previous papers and we will focus on the particularities of the paper, namely, the data acquisition in the field at 5 different dates.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 4063, 2013.