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Hydrology and Earth System Sciences Discussions

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Interactive Comment

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

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OVERVIEW

This study investigated temporal stability of surface soil moisture collected using a proximal ground-penetrating radar (GPR) in an agricultural field. Time-stable areas rather than time-stable point were emphasized for field average moisture identification using two methods: (1) relative difference analysis and (2) spatial intersection of the field-average areas. The results showed that the relative size of the time-stable areas identified by the two methods highly depended on the number of soil moisture acquisitions. I appreciate the importance of time-stable areas where a probe can be installed for mean soil moisture observation. Using high spatial resolution data measured by

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GPR for temporal stability analysis is novel. The paper is well written and structured. It may deserve to be published in Hydrology and Earth System Sciences considering the wide interest in soil moisture observation at large scales for hydrological application. However, major revision is requested to address the following issues.

GENERAL COMMENTS

There is merit in the concept of time-stable areas over time-stable point, though Hu et al. (2010) mentioned the concept. The real novelty of this study was the combination of GPR measurements and temporal stability analysis which presented great potential in locating the time-stable locations quickly for future soil moisture observation. On one hand, the time-stable areas identified by the higher spatial resolution data collected by GPR may reduce the uncertainty of time-stable point identified with measurements from in-situ sensors (e.g., neutron probe and TDR). On the other hand, the relatively low accuracy of GPR as compared to the in-situ sensors and the dependence of detection depth on soil water conditions may also bring uncertainty in identification of time-stable areas. Therefore, the relative performance between GPR and in-situ sensors in terms of identification of time-stable areas should depend on the balance between spatial resolution and measurement accuracy.

This study compared the time-stable areas identified by the two methods. However, they are incommensurable due to the following two reasons: (1) the criteria of these two methods do not have the same units as the authors mentioned. The criterion for spatial intersection is a variable in m3 m-3, while mean relative difference is a variable without dimension ([ ]). Actually, the criterion for the relative difference method is a relative term to the mean soil water content. Therefore, for the same critical value, say 0.02, the tolerance of the spatial intersection method is ± 0.02 m3 m-3, while the tolerance of the relative difference method is the product of 0.02 and mean soil water content ($\pm 0.02 \times 0.228$ to $\pm 0.02 \times 0.298$ m3 m-3). From this aspect, the tolerance of the relative difference method is much stricter than that of the spatial intersection method. Previous studies suggested a critical value of 0.05 or 0.1for the relative difference method (Mohanty and Skaggs, 2001; Jacobs et al., 2004; Schneider et al., 2008). (2) the spatial intersection method requires that the difference between soil moisture of time-stable areas and spatial average for each time should fall into the tolerance range, while the relative difference method just requires that the mean difference between soil moisture of time-stable areas and spatial average for all time fall into the tolerance range. In another word, the criterion is not necessarily satisfied at each time for the relative difference method. From this point, the tolerance of the relative difference method is more relaxed than that of the spatial intersection method. Therefore, with increasing the number of acquisitions, the spatial intersection method becomes stricter while the relative difference method may be relatively stable. This is why the spatial intersection method indicated larger time-stable areas than the relative difference method when dry conditions and wet conditions were separately analyzed and opposite results were found when all acquisitions were considered.

The GPR system mounted on an all-terrain vehicle is a fast and appealing way to collect soil moisture, especially at large scales. However, the possible wheel compaction should be noticed and discussed. Soil bulk density and volumetric soil water content may change due to compaction. In addition, the wheel track, which may easily develop in the wet conditions, may change surface water flow path. This may have large influences on the temporal stability of soil moisture pattern.

The relative few number of soil moisture acquisitions is a weakness of this study. Study period of less than one month was considered, which is too short for temporal stability analysis. According to previous studies, at least about one year is needed to identify the time-stale location using temporal stability analysis (Martínez-Fernández and Ceballos, 2003; Hu et al., 2012). Therefore, the time-stable areas identified with data from a short time may not be really time-stable. This may result in large errors in terms of soil moisture measurement in other seasons. If GPR measurement could cover longer period, say at least one year, the results may be more affirmative.

In addition, the value of the surface (5cm) soil moisture measurement is debatable. Like

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most remote sensing products, this is inherently a roadblock to practical application of the acquired soil moisture values.

SPECIFIC COMMENTS

Page 4064, Line 11: No units for mean relative difference. Pay attention to it in the whole manuscript.

Page 4065, Line 19: What is "temporal stability of the continuous soil moisture pattern"? Why emphasize "continuous" here?

Page 4065, Lines 21-24: I do not understand this sentence. If the field-average is known, why do you need to determine the field-average with time-stable locations which show under- or over-estimates?

Page 4066, Line 8: It is normal to have a relative long-term soil moisture measurement for temporal stability analysis. Otherwise, the time-stable locations identified may have large uncertainty.

Page 4066, Line 24: "influencing" instead of "showing".

Page 4068, Line 8: Soil moisture was just collected in the spring, then how to extend the results to other seasons? At Line 23, you refer to "at the end of the winter". What should the sampling season be?

Page 4069, Line 27: The inconsistent detection depth by GPR is a weakness for temporal stability analysis.

Page 4070, Line 15: The soil core size should be given since in my opinion, the sampling support also affects temporal stability analysis.

Page 4073, Lines 8-11: If measurement periods extend over a relatively long period, the time-stable areas identified by the spatial intersection method may be very limited. This will greatly decrease the significance of this method in identifying time-stable areas.

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Page 4074, Lines 14: According to Table 2, larger range in wetter conditions was observed as compared to that in drier conditions. However, previous studies indicated both larger (De Lannoy et al., 2006) and shorter range (Western et al., 1998; Wang et al., 2001; Hu et al., 2011) in wetter conditions. Do you have any explanations on this point? In addition, I'm very surprised that the spatial variability of soil moisture at the support scale (2 m) can explain 20-50

Page 4074, Line 27: In the study of Famigliette et al. (2008), what they really showed was that the soil moisture standard deviation versus mean moisture content exhibited a convex upward relationship at the 800-m and 50-km scales, which is usually the case in the wet environment. According to Hu et al. (2011), the variability increased with increasing mean soil water content, which is usually observed in arid and semi-arid environment.

Page 4075, Lines 4: Is the strips in soil moisture pattern caused by compaction? I'm surprised that the spatial pattern between dry and wet conditions differed so much. Does this mean temporal stability do not exist between contrasting soil water conditions? Do you have any explanation for this? I suggest you use rank correlation coefficient to characterize the temporal stability of soil moisture pattern between different dates (Hu et al., 2009).

Page 4076, Lines 3: Actually, soil moisture of the first day was underestimated and that of the third day was overestimated as Figure 5 shows.

Page 4077, Lines 5-6: Here, "the standard deviation ranges from 0-0.27", but in the below at page 4079 Lines 6-7, you indicate "0-0.08".

Page 4078, Lines 6-7: Do you have any explanations on the layout of soil core sampling? In my opinion, the time-stable locations identified can be largely affected by the number of samples and the sampling layout.

Page 4079, Line 5: Comprehensive review on temporal stability was also given recently

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by Vanderlinden et al. (2012).

Page 4079, Lines 18-19: Better to show the elevation data together with soil moisture.

Page 4080, Line 8: Only 0.1 mm rainfall was received between the first and second measurement, why soil moisture increased (from 0.228 to 0.235)?

Page 4080, Lines 18-19: As mentioned in the General Comments, I do not understand how "these two methods were in accordance" since they are incommensurable to me.

Page 4081, Lines 18-20: The second method can be used in a short period, but I do not appreciate its applicability in a long period.

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