Interactive comment on “Electrical capacitance Volume tomography of soil water infiltration in vessel experiments”

The authors would like to thank of reviewers for their objective comments on our manuscript in order to improve our research contribution in this manuscript. The authors addressed all the reviewers comment hereafter and accordingly prepared the revised version of the manuscript. All the changes have been underline in the revised version of the manuscript.

Reviewer #2:

This paper presents an interesting method to image non-invasively water flow in soils. I am not familiar with this method and not aware of its aplications in soil science. Large parts of the section in which the method was presented were hard to understand for me and I assume that this will be similar for many readers of HESS. I think the authors should improve this. The readability of the paper could also be improved drastically by proof-reading by a native English speaker. The result of the inversion is an image of normalized dielectric permittivity. I have two main questions about normalized dielectric permittivity. The first is about the reference that is used to normalize the dielectric permittivity. As I understood it, the authors use the dielectric permittivity of water. But, since the dielectric permittivity of wet soil is considerable smaller than that of water, I do not understand how the authors come to a normalized dielectric permittivity of wet soil that is equal to 0.9. Therefore, I guess that the authors did not normalize to the dielectric permittivity of water but to the dielectric permittivity of water saturated soil. But, this is not as it is written in the text. The second question is related to the derivation of the normalized dielectric permittivity. As I understood it, the authors invert normalized measured capacitances. However, this must be related to a few assumptions and approximations. In general, inversion of a normalized measurement signal does not lead to a normalized output variable. I think the authors should make these assumptions explicit or explain why these assumptions hold true.

Reply:

1. The authors thank and agree with the reviewer comment. For normalized capacitance we used permittivity of air as a low-permittivity medium and permittivity of water as a high-permittivity medium for both of the experiment study (i.e., 1st experiment by supplying water to the empty vessel and 2nd experiment by filling the vessel with soil and then gradually filling the soil column with water). Therefore, the mean normalized capacitance of wet soil is smaller than pure water. Some modification has been added based on the reviewer comment (see pages 15).

2. The authors thank to the reviewer comment. In this study the normalized measured capacitances is not inverted, but we transpose the sensitivity matrix of the geometry

sensor (see Eq. 8). The derivation of normalized dielectric permittivity is shown in Eq. 8 showed that the normalized dielectric permittivity is equal the transpose of sensitivity matrix times the normalized capacitance. This explanation has been added on page 10 on 2nd paragraph.

Detailed comments:

In the introduction part, it is suggested that the listed techniques provide data with temporal resolution but do not provide 3-D spatial data. I think that this is not generally true. There are also a few examples where ERT tomography (Daily et al., 1992; LaBrecque and Yang, 2001; Zhou et al., 2002) was used to monitor 3-D infiltration.

Reply:

The authors thank to the reviewer comment. The manuscript has been revised based on reviewer comment (see pages 4 and 5).

Comment:

p1370: In Eq 2, Qi,j is defined and in the other equations, only Qj is used.

Reply:

P1370: The authors thank the reviewer for this comment. Eq. 2 has been changed as shown page 6.

Comment:

p1371 ln 13: 'because the relation between the interrogating field and the permittivity … are dependent on each other' I do not understand this sentence. If there is a relationship, then I would say that it is trivial that the interrogating field and the permittivity are dependent.

Reply:

P1371: In math, the "soft-field" term is used for two parameters which are dependent and highly nonlinear function. In this case, the value of electric field is depending with permittivity distribution.

In soft-field tomography, the interrogating field is a highly nonlinear function of the (physical) constitutive property (e.g. electric permittivity) distribution of interest (Marashdeh et al. 2006).

Comment:

p1371: I am not familiar with ‘soft fields’ and ‘soft tomography’. The authors could maybe explain this a little bit

Reply:

P1371: there are two main of image reconstruction technique in tomography i.e. soft-field and hard-field tomography. In this manuscript there is no term of ‘soft tomography’.

Comment:

p1371 ln 29: sensivity mode Æ sensitivity model?

Reply:

P1371L29: The manuscript has been revised “In this step, the sensitivity matrix was used to solve the inverse problem.” (see page 9)

Comment:

p1373, Eq. 9: The authors use a normalized capacitance. This normalized capacitance is then inverted to obtain normalized permittivities. In several tomographic methods, the measurement signal is inverted to an image and the image is subsequently normalized. I think there are some underlying assumptions or approximations here. I propose that the authors explain this.

Reply:

P1373 eq.9: predicting the unknown permittivity distribution from the measured capacitance makes the system suffering the ill-determined problem due to noise or unstable circuit. Therefore, to minimize the problem, we need the calibration process that constraining the capacitance data into two well-determined value. This effort will restricted the permittivity value in between two well-determined value.

Comment:

p1376: ‘When the soil is saturated, the permittivity will not be as high as the permittivity of pure water. Therefore the value of the mean normalized capacitance … will not reach the pure water value.’ I do not understand the reasoning and argumentation here. The dielectric permittivity of a wet soil is smaller than 90% of the permittivity of water. Dielectric mixing models have been developed to relate the dielectric permittivity of wet soil to the volumetric

water content and the dielectric permittivity of water and soil particles (Roth et al., 1990). Or has the permittivity been normalized to the permittivity of the wet soil?

Reply:

P1376: The authors thank and agree with the reviewer comment. In Figs. 7 and 9, we analyzed the mean normalized capacitance, where the correlation between the capacitance and permittivity value is nonlinear (see Eq. 4). Therefore we could not compare this calculation with permittivity analysis that proposed by Roth et al. (1990).

Comment:

p1376 and Figure 8: Except for the value of the relative permittivities, the results shown in figure 8 seem to be plausible. But, similar to other tomographic methods, I guess in this method there will also be some issues about smoothing or the introduction of artefacts. For instance, the pure water infiltration experiment in the empty column shows some of these artefacts. In this experiment, the water front should be flat and sharp and there shouldn't be increases in water content above the wetting front. Figure 6 illustrates that the inversion does not fully obey these criteria. Therefore, I think that some discussion about artefacts in Figure 8 would be useful. For instance, to what extent do the distributions represent real heterogeneities of the water distribution in the column and to what extent are artefacts displayed?

Reply:

P1376 and Fig.8: Same as other tomography modes, ECVT also still having problems in terms of accuracy of the reconstructed permittivity image with the actual permittivity distribution. Until now, scientists are constantly looking for ways to improve the quality and accuracy of the resulting image. An artefact is one of the negative effects arising from the weakness of this technique. However, when compared with other tomography techniques, the robust nature of ECVT use and capable of generating the data 4D makes this technique has the opportunity to study some more in the future.

References

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