

Review of manuscript HESS-2012-248, Three-dimensional monitoring of soil water content in a maize field using electrical resistivity tomography by L. Beff et al.

General comments

The manuscript HESS-2012-248 presents a study in which electrical resistivity tomography (ERT) was used in combination with time-domain reflectometry (TDR) to monitor the 3D soil water content (SWC) distribution under maize plants. The manuscript has two goals. Firstly, it is aimed to demonstrate the applicability and performance of a state-of-the-art 3D ERT setup for quantitative monitoring soil water redistribution under maize under field conditions. Secondly, the ERT image data were to be used to investigate soil water dynamics under maize plants under natural climatic and subsoil boundary conditions. Both goals are successfully tackled by the authors.

It is true that similar goals have already been topics in preceding studies, e.g. by Michot et al. 2003, Srayeddin et al. 2009 or Robinson et al. 2012 using surface-electrode ERT or by Garré et al. under semi-laboratory conditions. However, Beff et al. 2012 are to my knowledge the first ones who successfully apply an advanced modern 3D ERT measurement layout in combination with TDR in a field for vadose zone water content monitoring under natural boundary conditions. The quality of their results is consequently unprecedented and for the first time allows for a quantitative visualization of the 3D spatio-temporal water dynamics in cropped soils under field conditions. The manuscript is therefore highly relevant for a publication in HESS.

The scientific methods are valid and clearly outlined with the exception that the influence of ERT-image resolution is not discussed. Such a discussion is crucial and should be included in the manuscript. Provided that this is done the (possibly slightly modified) conclusions of the manuscript would be sufficiently supported by the results. The description of experiments and calculations are sufficiently complete and precise to allow their reproduction by fellow scientists. The number and quality of the references is appropriate and the authors give proper credit to related work, an exception being some citations of former ERT studies which are cited in a wrong context (see below). The title clearly reflects the contents of the paper and the abstract provide a concise and complete summary.

The manuscript is well structured and clear. However, the language should be improved since it still contains some grammatical flaws (e.g. wrong article use) and strange word choices and is not always very precise. The mathematical formulae appear correct to me. However, some of the units are not given (see below).

I recommend a major revision.

Specific comments

It should be worked out more clearly what the authors' new original contributions to research were. Quantitative interpretations of smoothness constraint ERT is never an easy task. Caveats should be given explaining why it was working well in this study and why no major mass balance errors (e.g. like in Singha, K., and S. M. Gorelick (2005), Saline tracer visualized with three-dimensional electrical resistivity

tomography: Field-scale spatial moment analysis, *Water Resour. Res.*, 41(5)) between ERT and alternatively derived water contents were observed. As the degree of regularization comprised within smoothness-constrained ERT images depends on the position of the image-voxel relative to the ERT electrodes, the electrode positions should be indicated in the ERT-images shown in the manuscript (see Friedel 2003; Day-Lewis, F. D., K. Singha, and A. M. Binley (2005), Applying petrophysical models to radar travel time and electrical resistivity tomograms: Resolution-dependent limitations, *Journal of Geophysical Research-Solid Earth*, 110(B8)). An overview of the amount of smoothness in the different regions of the ERT images should be given, e.g. in form of an ERT sensitivity distribution. Since it appears from figure 3 that the borehole electrodes are not symmetrically arranged in space, it would be helpful for the interpretation of the ERT images to know the ERT sensitivity shown from above on the soil surface and in 1 or two depths. Also an integral measure of sensitivity for the averaged vertical cross-sections would be helpful.

p8536, l6: “.. validate the sensitivity of ERT..”. It is misleading to use the term ‘sensitivity’ in this context because the ERT-sensitivity of a specific voxel normally refers to the hypothetical change in the measured transfer resistances associated with a change in bulk electrical resistivity of this voxel (see e.g. Kemna, A., J. Vanderborght, B. Kulesa, and H. Vereecken (2002), Imaging and characterisation of subsurface solute transport using electrical resistivity tomography (ERT) and equivalent transport models, *J. Hydrol.*, 267(3-4), 125-146.)

p8538, l19ff:

- a) “Binley, A., G. Cassiani, R. Middleton, and P. Winship (2002), Vadose zone flow model parameterisation using cross-borehole radar and resistivity imaging, *J. Hydrol.*, 267(3-4), 147-159.” did image water and solute transport in the deep vadose zone using borehole electrodes that extended more than 10 meters into the ground. A small uncropped soil column was used in the following study: “Binley, A., S. HenryPoulter, and B. Shaw (1996), Examination of solute transport in an undisturbed soil column using electrical resistance tomography, *Water Resour. Res.*, 32(4), 763-769.”
- b) The lysimeter in Garre et al. 2010 was not yet cropped.
- c) The study of Cassiani et al. 2006 may have been under a cropped field but aimed at detecting a tracer plume in the shallow and deeper groundwater, so it was not relevant for their experiment whether it was carried out under a cropped field or not
- d) Kemna et al. (2002) monitored a tracer plume in the groundwater under a meadow in a depth of 8 meters below the soil surface.
- e) Vanderborght et al. (2005) merely conducted a numerical experiment. The study only took place on their computers.

p8540: It would be worthwhile knowing how high the maize plants were in the beginning of the experiment and how much they grew during the monitoring period.

p8540, l.7: Do you mean “horizontal spacing”?

p8541, l8: “showed” would be more adequate than “proved”.

p8541, l9: Did you conduct the ERT and TDR measurements at the same time? Or did you disconnect the TDR multiplexers when carrying out the ERT measurements to prevent short circuits?

p8542, l6: it should be “normal and reciprocal mode”.

p8542, l9: “..contained 12664 measurements” Including or excluding reciprocals?

p8543, l11: “a constant value of 50 for lambda was chosen..”. Explain why you chose 50 and not another value.

p8544, eq. 5 and 6: Are both, the r_{rms} and the χ^2 needed here or is one of them sufficient? Furthermore, I do not understand how both, r_{rms} and χ^2 were “mostly close to the estimated error level” of 2.7% and 0.8 mV. Please explain this further.

p8544, eq.7: It should be stated explicitly that equation 7 requires that the solute electrical conductivity remains constant.

p8545, l13: Did you mean (Garré et al., 2010)?

p8465, section 2.6 (Validation of ERT soil water content): An approach for appraising the impact of the varying ERT image resolution with respect to the electrode positions should be included in this section, e.g. ERT-sensitivity distribution with respect to the row- and inter-row positions (see general comments).

p8546, l12-21: This passage is not concerned with the ERT validation at all. It would better fit under section 2.2 (experimental plot).

p8547, l3: Did you mean “ERT voxels corresponding to the TDR depths..”?

Figure 4: Please start the X-axis at 0. It took me several minutes to figure out how a reasonable parameterization of equation 7 could cut the y-axis (which it would not if the y-axis were at $x=0$).

p.8548, l17-20: It should also be mentioned in the caption of Figure 5 that the ERT measurements corresponding to the cyan line were taken from the depth of the TDR probes (by the way: were they taken in the vicinity of the TDR probes?)

Figure 5: The circles indicating the ERT measurements should be larger. Also the font size should be increased. Finally, I would find the time series shown in Figure 5 and in later figures much more intuitive if the months and days were shown instead of the DOYs.

p8549, l27: Please mention again how many TDR probes were installed per depth.

p8551, section 3.3.1: especially the spatial variability should be discussed also with respect with ERT sensitivity, as the spatial variability will appear to be smaller in regions with low ERT sensitivity (see e.g. Day-Lewis et al. (2005))

p8551, l11: better “topmost soil horizon”

p8552, l13: please explain in the material and methods what you mean by “root impact”

p8553, l7-8: is the discontinuity in the water depletion curve due to the use of two different Waxman-Smits-type law calibrations? This should be discussed.

p8553, l9-11: please explain in more detail what you mean by this statement. From looking at your figures I would rather say that it fits not too bad. (also see p8556, l12-14)

p8556, l15-23: “At the beginning..” these explanations should already be given in section 3.3.3. If I understood correctly they are probably the main reason for why you observed different water uptake patterns in your study differ from the ones reported by Michot et al. (2005).

Figure 6: a legend should be provided for this figure (the meaning of the different shades of grey should not only be explained in the caption.

Figure 8: The last two ERT measurements are the only ones which clearly underestimate the TDR values. Do you have any explanation for this?

Figure 9: The black lines should be explained in the caption

Figure 10: Instead of showing all CV profiles, one may be enough to support your point. Instead, a comparison to the ERT sensitivity distribution (or image resolution) should be given. Temporal development of the SWC-CV would be better illustrated by 1D time-series, maybe from different depth.

Figure 11: The difference in water content would become more obvious if colors would be used in this figure. It should be explained in the manuscript that the clear separation of the soil horizons stems from the use of three different pedophysical relationships (or, if this was not the case, this should be pointed out too).

Technical corrections

p8536: the abstract is started in the past tense and should remain in the past tense.

p8536, l17: it should be “short dry periods”

p8536: “At the opposite” is used several times in the manuscript. I am not an English native speaker so I may be wrong here, but it reads odd to me. I think that it is not an expression commonly used in English. “In contrast” may be more appropriate. There are similarly uncommon expressions throughout the manuscript which could easily be improved by letting an English native speaker read through the manuscript. Another example is “destroying variability” (p8437, l7). I will not list similar cases in the following.

p8537, l.9 “ the rain repartition ..., the drainage, the pollutant dispersion, ...” as the processes are addressed in a general way I think the articles should be skipped. Again I have to admit that I may be wrong since I am not a native English speaker. In contrast, on p8540, l18 an article is needed: “The TDR method was used..”

8538, l5: It should be “The advantage of these methods is their robustness..”

8538, l6: It should be “gravimetric measurements are ..”

8538, l9: “are limited to a few cm”

...

There are more similar mistakes throughout the manuscript which I will not explicitly state in the following.

p8539, l7: in the introduction, the two goals are enumerated with (1) and (2). In the conclusions, (i) and (ii) are used instead. One of the two different enumerations should be used consistently.

p8539, l.23: better “plough pan”

p8542, l16: the units of R and e should be given. Likewise on the next page for rho and epsilon, the variables in equation two as well as U. I have not checked whether the units for all the other variables are given. If not, it should be done.

p8543, l1: the sentence “Occam’s inversion finds the smoothest distribution of logarithmized resistivities..” implies that Occam’s inversion is necessarily connected with a smoothness constraint and with logarithmized resistivities. I am sure that the authors are aware that this is not necessary the case. The sentence should be reformulated.

p8554, l4ff: there is no reason to switch into present tense

p8554, l20: RWU is not defined

p8555, l12-18: this part can be skipped.

p8555, l23-25: “We observed..” this sentence should be moved to a later section as it has nothing to do with aim (i) i.e. the validation of ERT.

p8556, l26: I think “excellent” is a bit exaggerated since the spatial resolution of ERT is rather limited (albeit superior to any other contemporary method which is applicable in the field)