

Interactive comment on “Combining cross-hole geophysical and vadose zone monitoring systems for vadose zone characterization at industrial contaminated sites” by N. Fernández de Vera et al.

Anonymous Referee #1

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article The authors present a *Vadose Zone Monitoring Setup* at an industrial contaminated site motivated by the need to better understand hydrological and chemical processes. The monitoring system consists of four deep borehole ERT arrays and a TDR and suction cup array in a slanted borehole. In addition seven piezometers are reported. Based on one ERT tomography and the borehole logs the subsurface is characterised. Continuous monitoring of soil water content and sampled water analyses for dissolved ions and heavy metals are used for process interpretation.

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1 General comments

The overall study appears to be an excellent example of shallow geophysics for hydrological applications in combination with water chemistry and soil water dynamics. The authors also approach subsurface flow in matrix and macropores. As such the study is highly relevant and fits the scope of HESS. Unfortunately, the manuscript (MS) is not yet in a shape that really pinpoints the strengths and limitations of the approaches and corroborates the findings with data. I hence suggest the MS to be strongly revised along the following lines prior to publication in HESS. I hope the authors find these comments as constructive contribution to improve the presentation of their work.

1.1 Title and structure of the MS

From the title I have expected much more application of the installed ERT arrays as main part of the proposed vadose zone monitoring system. This mismatch of expectation and presentation somewhat remained through the MS. On the one hand, this is due to a lack of structure. On the other hand, the used terms and explanations deserve more precision. What is the experiment in contrast to the monitoring? Why do you distinguish between VZES and VMS? What is the theoretical concept of your study, what hypotheses do you approach and how does the setup contribute to the identified shortcomings? By what means are analyses done. What error margins have to be considered for the respective techniques? [...] In general the MS is not well structured. A thorough clarification of the research questions and a precise methods section could help understanding a lot and would leave more room for results and a more detailed discussion.

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1.2 ERT system and analysis

For my understanding this is intended as main focus of the manuscript. However, in the current version ERT is only used once for six cross-borehole profiles in order to characterise the already well-known lithology of the subsurface. I do not understand why there is no repeated or time-lapse data shown. Nor do I agree that the six profiles are already a tomography. Is the setup not suitable for much more electrode pairs than simple pairwise measurements? I also miss an interpretation of the data beyond the imaging of electrical resistivity. How does borehole-based ERT add precision and information in comparison to surface-based ERT? Using ERT as part of a vadose zone monitoring would also require to clarify the possible resolution in time and space and whether or not this is sufficient for the processes under study.

1.3 Soil moisture dynamics

One very interesting finding of the study is the quick reaction of soil moisture to events also in greater depth (mainly comprised in Figure 4). However, without a more detailed analysis of single events (e.g. concerning water balances, breakthrough timing, recessions) I find it very vaguely argued how this can step beyond a first formulation of process hypotheses. Especially as I do not see that the authors draw any connection beyond the process hypotheses between the used methods I find it a missed opportunity of the study.

1.4 Water chemistry

Water chemical signatures are classified as facies which sounds very interesting but is not described in the methods. From the MS I find it very difficult to bring together the bits and pieces without getting lost in minor details or broader expectations. The MS

lacks a combination of soil water dynamics and soil water chemistry. Especially with regard to preferential flow the frequency of sampling may be an issue to give attention to.

2 Specific comments

Abstract Streamline the abstract closer to the core findings which are really corroborated by data. In the current form it does not match well and sparks confusion.

Introduction This should be the place to frame the study. Leave technical details to the methods section and make sure to clarify the core questions of the study at hand. Be more precise about scales and language in general.

P3L9 what is the experiment?

P3L16 what kind of conventional methods? what scales do you consider (time and space)?

Sec2.1 It is very interesting to consider the history of the anthropogenically formed site. However, I cannot really get the overall behaviour from the brief information here.

P4L24 which geophysical method? why does it allow for structure detection? what scale? what sensitivity? what error margins?

P4L26 single campaign? is the borehole material also considered as data? ERT only in addition?

P5L10 which CTD sensors?

P5L14 what is meant by "Geophysical images". what data, what methods?

Fig3 i cannot judge the other ER pairs. revise figure.

P5L21 what tomographic model?

Sec4.1 one would expect that a well defined artificial deposit can be well-detected by ERT. where is the interesting part in this - especially since the results are not free from noise and ambiguity?

P6L6 where can i see fast rises? what is fast? are these the spikes? what event water balances can be calculated?

Fig4 where are the axes ticks of the magnified plots? what sensors are giving the coloured dots? label points properly. what are the many spikes in the chalk and silt layer sensors?

P6L10 from fig 4 it is very difficult to judge the event-scale.

P6L17 where are these profiles? i cannot really follow the argumentation - especially as for the given event i cannot see a strong reaction in greater depth

P7L3 is this matrix flow induced from percolation at the site or externally driven? i cannot distinguish this important point for the site under study.

P7L8 so far the VMS does record states from which dynamics can be inferred.

P7L12 isnt it rather a hypothesis than an identification?

P7L16 what else flow could it be? i dont get the point.

P7L18 low electrical resistivity. this can have different causes... be more precise.

Sec4.3 move to methods section. expand. it is really hard to guess what is intended from this step. i dont get the intention and the meaning of the data, nor the results from this.

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Fig6 this figure is very complex and deserves more guidance. how are the facies of water determined and how is the process inferred? what is the signal to noise ratio here? is it only based on monthly samples? is this appropriate to speak about preferential flow with this coarse resolution?

P7L29 continuous? what intervals? is the resolution sufficient?

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