Hydrol. Earth Syst. Sci. Discuss., 9, C1917–C1921, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C1917/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Hydraulic properties at the North Sea island Borkum derived from joint inversion of magnetic resonance and electrical resistivity soundings" *by* T. Günther and M. Müller-Petke

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Received and published: 30 May 2012

First of all, we like thank the reviewer for the critical review, instructive comments and the suggestions that will help to clarify the manuscript.

This paper combines a methodical development and an interesting case study. The authors developed a joint inversion algorithm for the magnetic resonance sounding (MRS) and vertical electric sounding (VES) data and applied this algorithm on MRS

and VES data observed on the North Sea island Borkum. In addition to the derived model parameters (water content, decay time, resistivity), they have predicted the porosity and hydraulic conductivity of the survey area by using pumping test data to calibrate petrophysical relationships.
On the whole, the paper is easy to follow and well organized. Unfortunately, some details of the developed joint inversion technique are not presented. This is due to the fact that the authors combine two different topics (joint inversion algorithm and derivation of petrophysical data) in the same paper.
In the following, I list some suggestions/ questions to improve the paper. They include mainly the modifications of some figures. Nevertheless, I request that the authors should explain the necessity of the joint inversion by comparing the result with the single inversion. The paper can be published after some minor corrections.

The focus of this manuscript is clearly on the hydraulic relevance of the new methodology. Therefore details of the inversion are not given, however the joint inversion scheme is quite simple. Actually we are already comparing single and joint inversion results on the last dataset (SKD).

1) The title is misleading. In general, without borehole information about the calibration factor which is used in Eq. 6, hydraulic properties cannot be derived from the joint inversion of MRS and VES data alone. This fact should be mentioned in the abstract and in the conclusion part.

The title intends to attract attention from hydrologists about using MRS and VES. Actually, the calibration is part of the analysis and data come from MRS/VES as well. The fact that we use a pumping test is not crucial for the technology and should therefore not be included in the title. Calibration could also be done on samples.

2) I am wondering why Mr. Liebau is not a co-author of this paper. He has measured the MRS data and also interpreted them in his thesis. I also miss a comparison of his inversion results with the results of this paper.

The measurements were actually conducted by one of our technicians. The analysis of Mr. Liebau did not include a QT type inversion and is therefore of minor importance for the subject hydraulic parameters. The data were completely reprocessed. Since he is not in Geophysics anymore, we think Acknowledgements for Mr. Liebau are appropriate and discussed with him.

3) The authors argue that the joint inversion significantly improves the reliability of the results. Again I miss a comparison with individual single inversions. Where is the improvement?

The comparison was done on the last sounding (SKD) with the best quality. See Figure 5 for independent inversion and Figure 6 for the joint inversion. The benefit of joint can be clearly seen in the layer models but also in the uncertainty values.

In addition, there is no information whether the authors use a weighting between the methods in their joint inversion. If they did, how? If they didn't, why? I would also suggest that the developed joint inversion algorithm should be applied first of all on synthetic data. I am sure that the authors did it, but they did not show it in this paper.

We did not use any weighting between the methods because all individual data are already weighted by their errors (eq. 2 and surrounding text). Doing so the inversion showed a chi2-fit for both methods individually (not shown). We will add a sentence about that and give an additional reference.

4) The difference between the joint inversion algorithm of Vouillamoz et al. (2007) and the algorithm presented in this paper should be more detailed.

Vouillamoz et al. (2007) did not jointly invert (therefore the title is Joint use) by coupling layer thickness. They fixed the aquifer thickness for the VES inversion (see their abstract). Furthermore their MRS data were not inverted with a QT scheme, which made reliable T2* time prediction difficult.

5) What is f in Eq. 1?

We will replace f by w to distinguish it from f in equation 2.

6) The amount of layers is relative clear by visual inspection of the VES curve. Why are you then starting with a homogenous halfspace?

We derived the number of layers from the VES curve as stated. Nevertheless we start from a homogeneous model in order to present a robust and general solution whose success does not rely on the starting model.

7) Fig. 1 should be improved. The location of the VES and HEM stations are not visible. Please write also the name of the MRS stations on the map.

All figures will be redrawn to enhance readability. The problem in Fig. 1 was a vector-bitmap conversion.

8) What is the vertical electrode chain? Is it a different name for the VES? Unfortunately, the reference about it is an extended abstract and I could not find it.

The vertical electrode chain is a buried tool with electrodes connected to a multi-electrode instrument for continuous electrical monitoring and does therefore represent ground truth of conductivity. We will add some more text on this and also a reference where the extended abstract can be downloaded.

9) Fig. 2: Write the name of the structure on the lithological map. It is not necessary to display so many curves showing the same information in Fig. 2c. At least HEM (L=19) and VEC can be deleted. Fig. 2b is interesting but not relevant for this paper.

We will add lithology text in Fig. 2a. Figure 2b supports the lithological interpretation, but also shows that the two aquifers are indeed different, which will be needed for the interpretation (which will be expanded). However, this must be discussed in more detail. The resistivity curves in Fig. 2c show how differently equivalent resistivity information can be. VEC represents ground truth and HEM (L=19) is used for deriving the initial kernel.

10) Please define error weighted misfit.

We will slightly expand equation (2) in order to define the error-weighted misfit clearer.

11) The conductive layer (clay) in 20 m depth is not resolved by the water content and the resistivity. As also demonstrated in Fig. 3, the error bounds are too large. There is also no indication of this layer on the apparent resistivity curve. Why did you choose a 5 layer model in Fig. 3 which is not visible on the apparent resistivity curve? The resolution of a thin conductive layer is also a well known phenomena of the resistivity method. I am wondering why this layer is displayed in the resistivity inversion model. Please write the units for Fig. 2, 3, 4, 5d.

Sounding CL2 was done to show the effectiveness of the method in comparison with the borehole. Therefore we chose 5 layers to represent the lithological units present in Fig. 2a/b. The data could be fitted using 4 layers almost equivalently and we will discuss this in more detail.

12) The authors state that the joint inversion improves the resolution and therefore decreases uncertainties (p. 2815). In order to prove this statement, I would expect a sensitivity analysis of the single inversion and a sensitivity analysis of the joint inversion and then you could compare the single and joint inversion's improvements of importances.

Separate and joint inversions are shown in Figs. 5 and 6 for sounding SKD. We will add the uncertainty measures also for Fig. 5. However, uncertainty of a three-layer case cannot easily be compared to a five-layer case.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 2797, 2012.