Hydrol. Earth Syst. Sci. Discuss., 11, C1474–C1479, 2014
www.hydrol-earth-syst-sci-discuss.net/11/C1474/2014/

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Large scale 3-D modeling by integration of resistivity models and borehole data through inversion" *by* N. Foged et al.

Anonymous Referee #2

Received and published: 20 May 2014

Referee N# Journal: HESS Title: Large scale 3D-modeling by integration of resistivity models and borehole data through inversion Author(s): N. Foged et al. MS No.: hess-2014-11 MS Type: Research Article

General comments The paper proposes an automatic method to parameterize a 3-D model, integrating lithological information from boreholes with resistivity models, with the objective to construct background hydro-geophysical (groundwater) models of the subsurface useful for further hydro-geological processes modelling. In general the topic and the content of the manuscript complies the aims of the journal. The topic is interesting in the research framework of the "construction and structural calibration" of hydro-geophysics models which is the new and future challenge in the research oriented to the modelling of hydro-geological processes.

The paper is well structured and the data support the results and with some efforts it could be suitable for publication in HESS. In my opinion some general and technical clarifications and integrations should be addressed to improve the manuscript. I advice the editor to accept the manuscript with major revisions. I encourage the authors to spend some effort to improve the paper for the publication.

Scientific questions and issues. In general I identify three general comments/questions on the scientific contents of the manuscript.

1)First question: Is the proposed method an inversion approach or an integrated interpretation approach based on a"geo-statistical approach" through an optimization approach? The proposed method in my opinion regard the integrated interpretation and structural calibration of the geophysical 3-D model obtained with the airborne EM method with borehole data, even though an inverse problem approach is used.

2)Second question: The authors should specify, for a better reader comprehension, the reason to select the "Clay-Fraction" (CF) as characteristic descriptive hydro-geophysical parameter of the model. As the authors claim (2.1 paragraph; with references Waxman and Smits 1968 and Shevnin et al 2007) that, , "It is a common assumption that a petrophysical relationship between resistivity and clay content can be establish. . .". Detail about this relationship should be given. In my opinion the selection of this parameter should be deeply explained. Is the CF a sensitive parameter for hydro-geological process description (in spatial and time scales)? In particular how the "CF", which is an integral descriptor parameter (as a consequence of its definition), could be used in the hydro-geological modelling, in which probably the fine-distribution of CF parameter of the stratigraphic units are requested for an accurate predictive modelling. Nevertheless I agree with authors that an approach in which we model the hydro-geophysical model is parameterised in terms of a set of parameters that characterize the "homogeneous hydro-geological units" but this should explained in detail, (ie: why only one parameter?), also in terms of the errors that this choice induces in the predictions in the hydro-geological modelling, when a such approach is used. Really

we are dealing with an hydro-geological conceptual model and, in this context, I advice to use the term “CF-conceptual model”, more than “CF-concept”. They should explain the basic “adopted conceptual model“. Conversely if you want perform a “calibrated” structural interpretation of the EM data with a geo-statistical approach considering one parameter we should say it explicitly, clarifying the proper use of the obtained model, as, it seems, the authors definitively claims in the conclusion “With the CF-concept and clustering we aim at building 3-D models suitable as structural input for groundwater models”. Finally connected to this point the CF vs Resistivity relationship is not a single values relationship, as pointed out also by the authors to justify the results. So, again, why they chose an integration procedure with a single parameter?

3 – The differences in spatial sampling between boreholes and airborne EM resistivity. The authors should spend more effort in describing the spatial parameter setup (spatial analysis of the data, mesh-grid selection, smoothing and interpolation parameters).

Technical issues - In the equation 1 should be used a notation 3D using the discrete indices, explicating also the rho meaning (even though is trivial). Also the figure 2 should be modified inserting the grid notation. The constraints in m_up and m_low should be explicated: what do you intend: a smoothing, limits and why you need to constrain these values, How do you set these constraints?

- From eq.1 I think that the translator function (probably better “CF profiler function”) is isotropic but really when I read the entire procedure, due to lateral smoothing operation seems to be anisotropic; please explain this aspect.

- Probably it will be interesting to show to the reader, integrating the figure 2, for a vertical profile: geo-stratigraphy with description about “clay contents” and the corresponding Psilog, and show the corresponding electro-stratigraphy, the corresponding ‘Translator function’ and the derived Psires. This also to demonstrate the basic assumption of the approach(eq. 1 and 2).

- In the equation 3 it should be explain the meaning of m (the parameter of the translator

function.

- What are the resistivity errors. What is the sensitivity in depth of resistivity inversion?

- A central technical issue of the application of the procedure is the spatial sampling and in particular the difference between the sampling in resistivity and boreholes. The first issue regards the vertical (z) sampling and resolution. The good geo-stratigraphic data (quality 1 and 2 following the author classification) probably are characterize by an oversampling with spatial wavelength of 1-2 m despite the inverted resistivity that has a higher sampling 4 or 8/10 m. In the horizontal direction we have the inverse situation with resistivity data sampled at about 15 m along the line and 50-100m between the line and the distance between borehole surely greater of 100 m but, I think , and comparable with about 1000 m which is the lateral grid used in the geo-statistical optimization with the proposed procedure. About this the authors should analyze and report some statistic parameter of spatial distribution of the borehole. Probably a statistical evaluation of the Voronoi area could be suitable to fix the minimum horizontal area including the min depth information in the whole data space (geo-stratigraphy+resistivity). Probably an areal pre-selection based on the areal distribution of the data could drive the optimization. If the studied area is about 156 kmˆ2, and we suppose an homogeneous spatial distribution of the deeper boreholes up to 90m which are 125 (100 of which up to 60m),we have about 0.8 boreholes/kmˆ2. This is quite in agreement with the horizontal grid used in the CF procedure (1 km), but if we see the figure 4b, 6c and 6d, the spatial boreholes distribution is highly variable. Furthermore the depth sampling of boreholes seems poor with respect the resistivity one. So the obtained results, as claimed by the authors, is mainly driven by the starting model for 6320 CF points over a total of 11520! This aspect should be emphasized.

- How is obtained the starting/reference model for m. “starting model and constrains setup are based on experience and the expected geologic variability and fine-tuned through a subsequent of test inversion”(3.3 paragraphs). It should spend some explanation about this; what is the type of information you intend as experience and degree

of geological expectation? It is possible to perform trials or numerical experiment and test to study the robustness of the procedure respect the starting model, procedure parameters and constrains? The strength of an automatic procedure of data interpretation is connected to her sensitivity to the initial setup (a priori information, starting model, procedural parameter setup). The author in 3.3 paragraph claim that to setup the inputs of procedure “fine tuned test inversion” were performed. Which tests was perfomed, which are the results of these test in order to drive the setup of the inputs of the procedure?

-Results. Can you give a measure of errors in the optimized parameters (even though difficult for non-linear inversion) or the reduction in residuals?

-Conclusions: the binomial behaviour should be expected due to the math feature of the “translator function”, i.e. an on-off or low-pass filter. What you think about? Could you present, if is available for the same area, examples of the application of other approaches as it is reported in the introduction paragraph and references?

- The figure 3 could be reported as an inset panel in figure 4.

- In figure 4b beside the quality could be interesting to insert a color or symbol size to represent the maximum boreholes depths.

- Figure 6 what the colour palette of borehole indicate the clay layer. Further in figure 6d it could be better to represent the CF obtained from boreholes using the palette of CF or representing the values in a CF vs Z profile, probably better in a inset zoom panel or another figure.

- What is the reason for CF mapping of the use of a colour palette with a different colour tunes? Why the authors didn’t use a standard 5 colour palette like those used in m values or resistivity?

- In figure 7 the size of grid point should be increased? In the text should be explained that reason of the smoothing of the imaged m values is due to the interpolation in

representation, if I well understand.

-The references are OK.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/11/C1474/2014/hessd-11-C1474-2014-supplement.pdf

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 1461, 2014.