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Interactive comment on "Electric resistivity and seismic refraction tomography, a challenging joint underwater survey at Äspö Hard Rock Laboratory" *by* Mathias Ronczka et al.

Anonymous Referee #2

Received and published: 6 February 2017

Dear Editor/Authors

This is a very interesting paper which uses an exemplary methodological approach for interpreting real data coming from different geophysical methods. The use of state-of-art interpretation software with custom forward modelling and combined inversions is certainly the way forward to increase the quality of geophysical interpretations in complex environments.

As I view it, the paper is very good but on the other hand it has some weak points that need to be addressed prior to its publication. I will present the most important suggestions below.

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Further, the paper needs a thorough checking by the authors as there are quite a few spelling mistakes and some not clearly written parts which are minor but still need correction or rewriting. I include more minor correction suggestions into the second part of the review.

Main points:

1. Add a paragraph in introduction giving some key references regarding the joined inversion methodologies.

2. Paragraph “3.1 Inversion” needs partial rewriting and clarification as it is not very informative. Both ERT and seismic data processing was made using same minimization scheme but the first paragraph of this section refers only to the geoelectrical parameters and ignores seismic. Further, the joined inversion approach is not clearly explained. It is understandable that part of joined inversion approach is published before but still the reader needs to get an idea of the procedure, esp. to know what approach and parameters were used in this work. Currently this occupies just 3 lines (p5,ln20-23).

3. The authors use the word “coverage” to describe the resolution of the inverted areas. Although I understand the purpose of using the word “coverage” I am not sure if this is the best term to describe the model resolution since I am not aware of the word “coverage” being used as a technical term (maybe is used in seismic imaging). Why not using the word resolution instead? If you decide to use the term “coverage” you need to make a clear definition of it prior to its use as it is different for the case of electrical images (sensitivity norm) and the seismic images (seismic ray density). No definition of it

4. In continuation to the above I consider that the use of the sensitivity matrix norm (not just a summation ! as mentioned in line 2 pg6) to get a metric of the resolution of the geoelectrical inversion cells is interesting however its direct use into the inverted geoelectrical results generates some problems:

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- Shading generates complicated figures that non-expert readers are not easy to follow. In particular, strictly speaking, the color scale in ERT images is not fully correct as the presented rainbow color scale does not incorporate the overlaid alpha shading. For example, the reader cannot easily distinguish between highly shaded light green and yellow parameters so cannot really appreciate the actual resistivities behind the highly shaded (almost colorless) areas. In any case I would think that the inverted images somehow need to be presented as any resolution metric related image could be an additional one.

- As said the authors choose to use a binary (0,1) masking for the seismic data but a shaded one for the ERT images. Apparently they could have used the same approach for both: why not using seismic ray density, or seismic model resolution for alpha shading also to the seismic data? Or conversely why not using a 0,1 approach for the geoelectrical images: use a threshold sensitivity norm value below which all inverted resistivity values are blanked.

- A further consideration is that I have doubts if the sensitivity matrix norm is an indicative proxy for deciding the reliability of the inversion result of a particular parameter. Sensitivity norm values are also dependent on the size of the parameters. In this work, parameters have uneven sizes (coinciding with triangular elements) so small sized parameters may exhibit small sensitivity norm values also because of their size and thus they may be appearing as partly shaded. However, the geoelectrical images are the product of an inversion procedure which is being subjected also to structural regularization (smoothness). This regularization is an important factor of the inversion and effectively it operates in a way that increases the reliability of smaller parameters. This fact is not taken into account into the alpha shading which is solely based on the parameter sensitivity matrix values. In this context, I would think that the diagonal of the model resolution matrix would be a more reliable indicator for accessing the reliability of the inversion as it also takes into account the inversion procedure.

Overall, I agree with your idea to include a metric for evaluating the inversion results but

this need to be done in a way that is more reliable and easier for potential readership (i.e. engineers) to follow. I have mentioned some possible suggestions of how this could be done, and I am sure that the authors can come with even better ways to address this issue in the revised manuscript.

5. Joined inversion Results: the geoelectrical joined inversion result are at parts difficult to justify. The joined inversion result clearly constrains the thickness of the sediments and also helps identify a fracture zone. The geoelectrical image however also depicts very high resistivity values with high “coverage” at the bottom parameters of the image esp. at the left bottom part of the image. This is very different compared to the independent inversion results. More importantly why now the bottom left part of the inverted space (e.g. see parameter at x=100m, z=-125) is more reliable? How this is justified given that the seismic image information is inexistent for this region and generally this part of the model is well established that it has an inherently low resolution in geoelectrical surveys? I believe that the high ‘coverage’ of this part of the model is due to the size of the parameters in combination of their extremely high resistivity values which however are not reliable. I believe that the points made in previous remark hold also for this case so again I feel that it strengthens that argument that authors need to reconsider the way they present the results.

Minor Comments

Page1-ln13-15: too much detail and new terms in abstract, please revise.

Page1-ln15: replace “separated” with individual

Abstract: consider writing a more concise abstract

Page1-ln17: replace “unusually” with “very”

Page1-ln18: replace “The results” with “The joined inversion results”

Page1-ln18: replace “imaging some geologic” with “the imaging of important geologic”

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Page1-ln18: add in “been not detected” “been either not”

Page2-ln5: maybe replace “dry” with “unsaturated”

Page2-ln10: “extreme points” not clear what you mean.

Page2-ln11-12: how is this statement on the finding fits in this part of the paper. Seems out of context

Page2-ln33: “field surveys” you mean “geophysical surveys”

Pag3-ln1: “numerical background”: what do you mean? Is it geophysical propery background?

Page3-ln4: replace “disposal” with “disposal site” or “disposal facility” (same in ln11)

Page3-ln24: replace “analysis” with “analyses”

Page4-ln14: how you decide “wrong GNNS position” add some more info about electrode positioning.

Page4-ln31: replace “submarine” with “sea bottom”

Page6-ln2: simple summation of sensitivities will result in an artificially low sum as geoelectrical sensitivities can be also negative. Did you actually use the “norm”?

Page6-ln7: change “conductivity” to “resistivity” as given value is in Ohm-m.

Page6-ln8: replace “pure water is as well constant 1440m/2” with “saline water is also constant 1400 m/s”

Page6-ln16: consider rephrasing “We follow a strict 2D scheme” You mean: “In this work data were processed using a 2D inversion scheme” ?

Page6-ln26: replace “anomalies” with “anomalous bodies” or “perturbing bodies”

Page6-ln28-29: replace “incorporated by a rectangular cube” with “simulated by a rectangular prism” and “water cube” with “water modelling body”

Page7-ln2-3: replace “nose” with “noise”. Not clear how you added noise. Is it both a noise on apparent resistivity and on the measured voltages? Please explain and justify.

Page8-ln11: explain somehow what you mean with “compensation artefacts” for non-inversion expert readers.

Page8-ln20: “alpha shading”: not sure that all readers are familiar with this term. Please explain.

Page8-ln24: replace “resistive” with “resistivity”

Fig 1: Add an Arrow in survey line. Replace “scheduled” with “measured” in caption

Fig 3: in Fig is “brown” but in caption “red”

Fig 4: Axes impossible to read in figure due to the dark colors. Also please add labels of exact material properties directly on the prisms as no exact color scale is provided.

Fig 5: Delete “pure” in caption

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