Reviewer 2

We have tried our best to follow the comments given by reviewer 2. It was quite difficult as the comments were not referred to specific places in the manuscript, which means that we had to guess in some cases what the particular comments were referring to.

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.

Well, we see this as an approach as the title says: "integrating lithological information from boreholes with resistivity models through an inverse optimization". It is therefore an integrated approach using an inverse formulation and in that sense it is not either or. Though, the inversion part is, in our opinion, what makes it unique.

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.

The Waxman and smiths relation is quite trivial (basically: sigma = sigma_water/F +sigma_clay) stating archies law plus a clay term. For the purpose here we find that it would make the introduction overly long if this (and similar) should be added in detail. Though, we have added more paragraphs on this both in the introduction and in the discussion part.

In my opinion the selection of this parameter should be deeply explained. Is the CF a sensitive parameter for hydro-geological process description (in spatialand time scales)? In particular how the "CF", which is an integral descriptor parameter (as a consequence of its definition), could be used in the hydrogeological modelling, in which probably the fine-distribution of CF parameter of the stratigraphic units are requested for an accurate predictive modelling.

We have added an extended paragraph in the introduction explaining and giving reasons for our choice of "clay-fraction" as the key parameter, and for the concept in general. The discussion part have also been extended with sections discussing related issues

Nevertheless I agree with authors that an approach in which we model the hydrogeophysical 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.

We have tried to include an elaborated discussion on this as well in the introduction

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".

We apologize, but we are not quite sure what is meant here. We are definitely NOT dealing with model building using geo-statistical approaches (whatever that precisely is). The model in the end could be called “CF conceptual model”, but we would like to refer to the overall procedure as the “CF concept”. Though, “Conceptual model” indicates in our opinion that it is a rough model based on limited background information. Here, we actually present an approach taking in all the borehole information AND all the structural information in the resistivity model to produce a clay-fraction model.

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?

Again, we are unfortunately not sure what is meant here. The CF is a single parameter being an output of a relationship that is a spatially distributed two-parameter function. We choose the single parameter in lack of good options. We hope that the extended paragraphs in the discussion section adds to the confusion addressed by the reviewer.

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).

Yes, this is pointed out also by the other reviewer and we have added an extended paragraph in the discussion.

Technical issues

Review remarks	***Authors response***
In the equation 1 should be used a notation 3D using the discrete indices,	Equation 1 is not intended as describing the 3D distribution of the translator function. Here it is merely a general description of the translator function without any dimensionality (i.e referring only to the inset of figure 2). For clarification we have introduced the translator function in its own figure without the 3D grid.
explicating also the rho meaning (even though is trivial).	Done
Also the figure 2 should be modified inserting the grid notation.	Fig. 2 is a principle sketch for the translator function grid and constraints. Adding i,j,k indexes for the three directions (if that what meant by “grid notation”) will just add unneeded complexity to the figure in our opinion.
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?	This is also partly addressed by the other reviewer and we have added more text to clarify these choices. Though, the purpose of the constraints is already explained: *“To migrate information of the translator function from regions with many boreholes to regions with few boreholes or with no boreholes, horizontal and vertical smoothness constraints are applied between the translator functions at each node point… The smoothness constraints furthermore act as regularization and stabilize the inversion scheme.”* The paragraph explaining the constraint setup for the case has been rephrased and extended: *“The regularization constraints between neighboring translator model nodes are set relatively loose to*

	promote a predominantly data driven inversion problem. In this case we uses horizontal constraint factors of 2 and vertical constraint factors of 3. This roughly corresponds to allowed translator parameter variations of a factor of 2 (horizontal) and a factor of 3 (vertical) relative to adjacent translator parameters."
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.	The translator function is NOT isotropic, and it will vary vertically and horizontally as dictated by the data. We have emphasized this in the beginning of the Methodology section.
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).	This is a good idea, and we have added this information to a new figure 2.
In the equation 3 it should be explain the meaning of m (the parameter of the translator function)	Minor update/explanation of m added.
What are the resistivity errors.	The paper already hold this paragraph: *"The resistivity models are also associated with an uncertainty and if the variance estimates of the resistivities and thicknesses for the geophysical models are available we take these into account. The propagation of the uncertainty from the resistivity models to the ρres values is described in detail in Christiansen et al., 2013."*
What is the sensitivity in depth of resistivity inversion?	Sensitivity/resolution for the Airborne EM results is a topic worth several papers in itself and hence out of the scope of this paper in our opinion. Though, it is an important issue when building models based on airborne EM resistivity models and we mention this now in the rewritten discussion section
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.	The lithological logs are generally not oversampled (on the contrary). Some boreholes have lithological samples for each 1 m some for each 5 m, while others only define when the lithology changes. The vertical discretization of the CF-models (thickness of the calculation layers) has been selected to some degree to reflect the vertical resolution in the resistivity models since it is the translation of the resistive model that gives the structure in the CF-model.
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	In our opinion it is probably a bit too detailed to describe in detail the distribution of boreholes as it would be difficult to make any real use of this information. However, we have updated two key figures to provide overview "statistical" information on the borehole distribution: Figure 4a has been updated to also show the drill

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 km^2, 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/km^2. 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.	depths, so the borehole distribution vs. depth can be examine and fig. 5 has been updated with boreholes/km2 information for the different depths intervals. Also, a paragraph elaborating the choice of horizontal discretization for the translator model vs. borehole and resistivity model density has been added to the Discussion section.
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.	We agree that this was not clear in the original manuscript. Paragraph updated: *"Translator functions in the 3D grid situated above terrain, below DOI of the resistivity models, and outside geophysical coverage does not contribute at all, and are only included to make the translator function grid regular for easier computation/bookkeeping. The effective number of translator functions, is therefore close to 5,200."* A discussion on selecting starting model has also been added to the discussion.
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?	Paragraph about this added to the Discussion section.
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?	Any inversion problem will be sensitive to the starting model and the setup of constraints. Normally, very little is written in papers about the fine-tuning of the inversions, but in this case the data density becomes very low for the deeper layers with few boreholes and obviously this increases the effect of the starting model. An extended discussion on starting model and constraints has been included in a discussion section.
-Results. Can you give a measure of errors in the optimized parameters (even though difficult for non-linear inversion) or the reduction in residuals?	We could give these estimates as we have everything ready at hand. However, the uncertainties are fairly difficult to use by themselves as we are really interested in the uncertainties of the resulting clay fraction model and not the translator model parameters. For the clay fraction model we have chosen not to show the uncertainties to avoid this complexity level as the uncertainties are by far dominated by the uncertainty in the kriging interpolation, which means that the uncertainty map is, to the first degree, a visualization of the data density, without much unique information.

	However, the text has been slightly updated to emphasize key issues about uncertainty and we have added key misfit numbers on the data side as these were missing in the first version.
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?	Not sure what is meant here? The statement as written here is correct and is also what we conclude in the paper looking at it from the lithology side: *"The majority of the voxels in the CF-model have values close to 0 or 1. This is expected since the lithological logs are described binary clay/non clay, and Ψ_{log} values not equal to 0 or 1 can only occur if both clay and non-clay lithologies are present in the calculation interval".*
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?	Very good idea, but no, not at present. For the Norsminde area a model comparison paper is under preparation comparing: 1) A traditional "cognitive" geological model 2) stochastical generated models using transition probability geostatistics and conditional Sequential Indicator Simulation". 3) The CF model of this paper.
- The figure 3 could be reported as an inset panel in figure 4.	Fig. 4 is already relatively compact. Not really room for fig. 3. as a panel.
- In figure 4b beside the quality could be interesting to insert a color or symbol size to represent the maximum boreholes depths.	Yes – good point. Figure updated with drill depth information.
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.	The figure text clearly explains the color code of the boreholes: "Black borehole colors mark the clay layers, while yellow colors mark sand and gravel layers". If we use the same color scale for the boreholes as for the CF-model (Red- brown) will it be very difficult to see the boreholes in figure 6d!.
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?	The color scale for the CF-model (red- brown) has been selected to have it stand out from the resistivity scales indicating that this is a totally different regime.