Does Accurate Processing of Airborne EM Data Have an Impact on Derived Hydrogeological Units?

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Summary

Airborne Electromagnetics is used in many countries as a major tool for groundwater management, and environmental management. In this paper we assess the effects that different levels of processing of Helicopter TEM data have on the resulting electrical models and then on the hydrogeological models. We use a SkyTEM dataset from in Denmark, acquired in 2008. We focus on different approaches in the processing of the raw data found in the industry, whilst inversion, which is necessary to show the effect in the model space, is undertaken in rather standard way. We show how the electrical models, and then the hydrogeology, change depending on the level of decoupling of artifacts, of lateral averaging, of late time noise assessment, and compare it with available borehole information. Each one of these processing steps alters the output, and therefore the derived models. With respect to e.g., under/overextimating the depth to bedrock by several tens of metres, or the absolute resistivities by hundreds of Ohm m, and therefore potentially assigning the wrong hydrogeological unit to a given electrical layer, the extra time, effort and monetary investment involved in accurate detailed processing is probably worthwhile.

Introduction

The increase in use of AEM data in hydrogeological investigations has lead to a demand for accurate resolution of the shape and the absolute resistivity of the conductivity depth structure of the ground. In order to achieve the desired outcomes, three main issues needed to be addressed: Acquisition of better raw data and monitoring of the system at all times during acquisition; appropriate processing of the raw data; and accurate inversions. This paper focuses on the second aspect, which hasn't been discussed systematically in literature before, approaching it from an end user point of view. We analyze in details the consequences in the model space, and then on some hydrogeological units, of different levels of inaccuracy in the EM data processing.

Theory and/or Method

For this study a smaller area flown with SkyTEM in 2008 in Denmark has been chosen. A large number of power lines and roads are present in this area. This survey was conducted with a focus on the deeper geological features while simultaneously mapping the near surface structures. More specifically the objectives were to map the top of the Palaeogene, sand and clay layers in the Miocene as well as buried valleys cutting the tertiary layers. Additionally there was a desire to map the thickness and extent of near surface clay layers, to be able to extract a measure of the aquifer vulnerability from surface pollutants. We have devised likely scenarios for doing a "wrong" or incomplete processing, each of them representing one experiment. They range from inspecting raw data directly without even inverting them, to a proper full processing and inversion, touching on many in-between variations. Main issues analyzed are improper decoupling of data from artifacts due to infrastructures, inadequate assessment of late time noise, excessive lateral averaging. Firstly the results are analyzed from a numerical and visual point of view in the data and model space, and then, where possible, we compare them with available borehole information. Finally, we highlight the effects of the different processing directly on hydrogeological parameters such as aquifer thickness. See Auken et al. (2009) for a thorough description of suggested standard complete processing workflow of SkyTEM data.

Examples

We need to invert the raw data to decouple the measured data from the (variable) system transfer function, and then inspect the conductivity depth structure we extract. Let us now start by inspecting the results of inversion of raw data at different depth intervals (Figure 1), without any processing or filtering prior to the inversion, apart from removal of negative data. The inversion is full non linear, based on exact forward solution, using no lateral constraints. We will always perform the same kind of inversion in all our experiments.

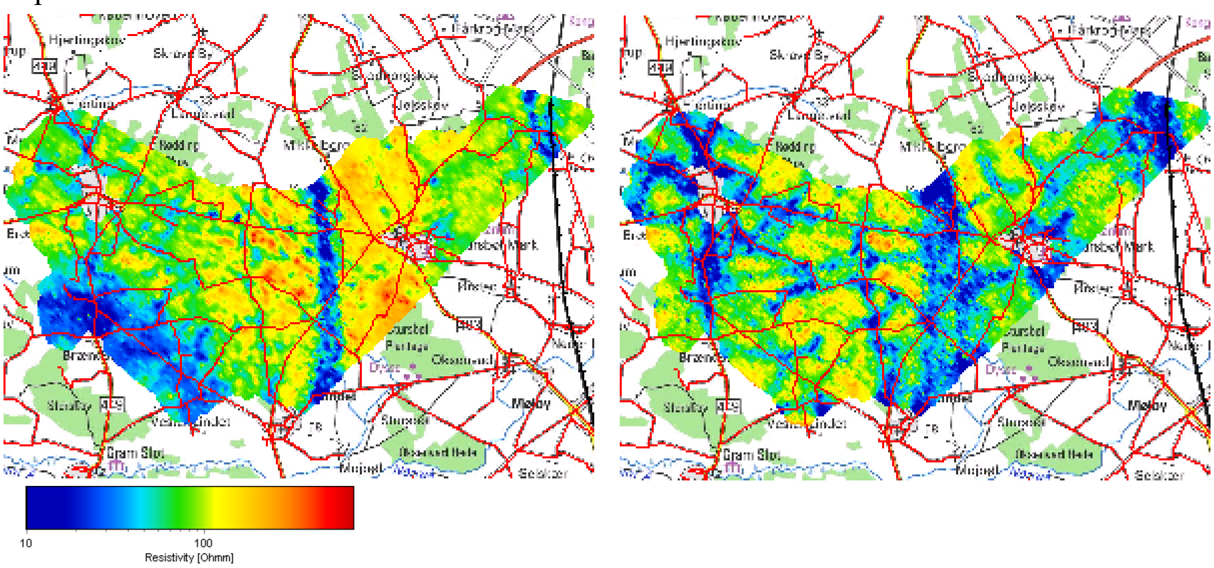

Figure 1: Inversion results obtained with completely unprocessed data., Depth intervals 60-80 m, and 120-140 m.

A conductive, north-south trending feature clearly visible in the shallower depth intervals is due to the coupling of the data with power lines. Other features that stand out are the correlation between roads and low resistivities in the depth interval 120-140m, also attributed to coupling, and a spotted appearance due to the lack of proper late time noise processing. In areas with a lot of culture present, failure to remove coupling or late time noise will produce artifacts in the inversions of the data. Coupling is not only a concern in Europe, but also elsewhere such as in the US and Canada, where irrigation devices can produce serious coupling effects in the data, even in rural areas with small roads and houses. These artifacts are less serious if the near surface is more conductive.

After combined automated and manual decoupling of the SkyTEM data from artifacts due to man made infrastructures, we ran the inversion again, with same settings as before. Figure 2 shows on the left the decoupled SkyTEM data for a flight line segment.

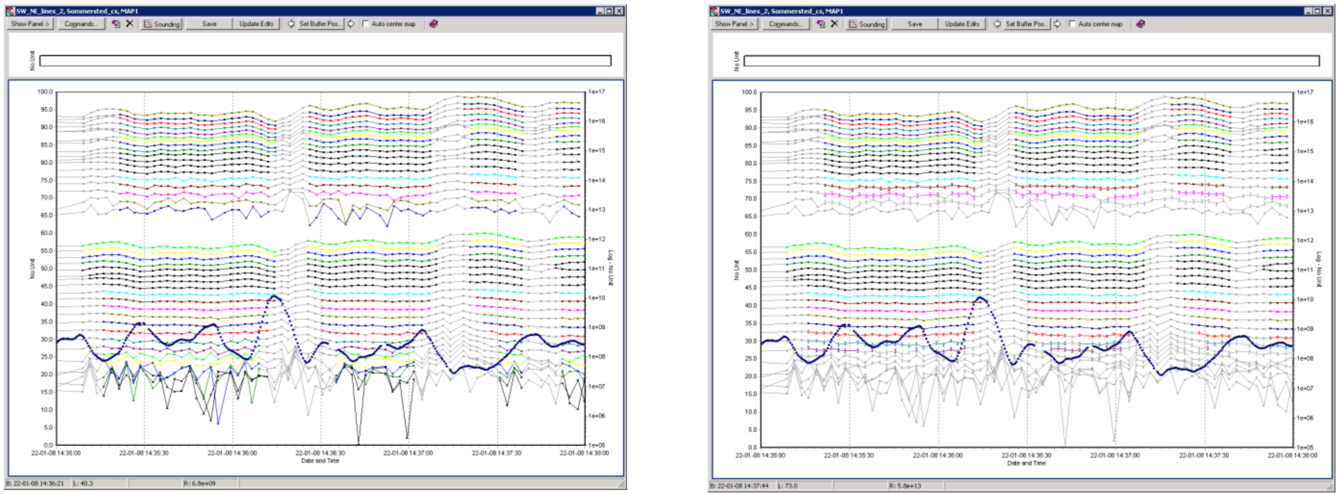

Figure 2. Left Panel) Raw data decoupling only (grey areas), Low (top panel) and High Moment (lower panel) data. Right Panel) Decoupling and late time noise removal (greyed channels) for Low and High Moment data, with no lateral averaging applied.

Some results of inversion of the decoupled dataset are shown in figure 3. The north-south trending feature has been removed and is therefore not likely to misinterpreted. The spotting at depth is still seen in the decoupled inversion results; this is expected as these features are expressions of data affected by ambient noise rather than coherent noise due to coupling with infrastructure.

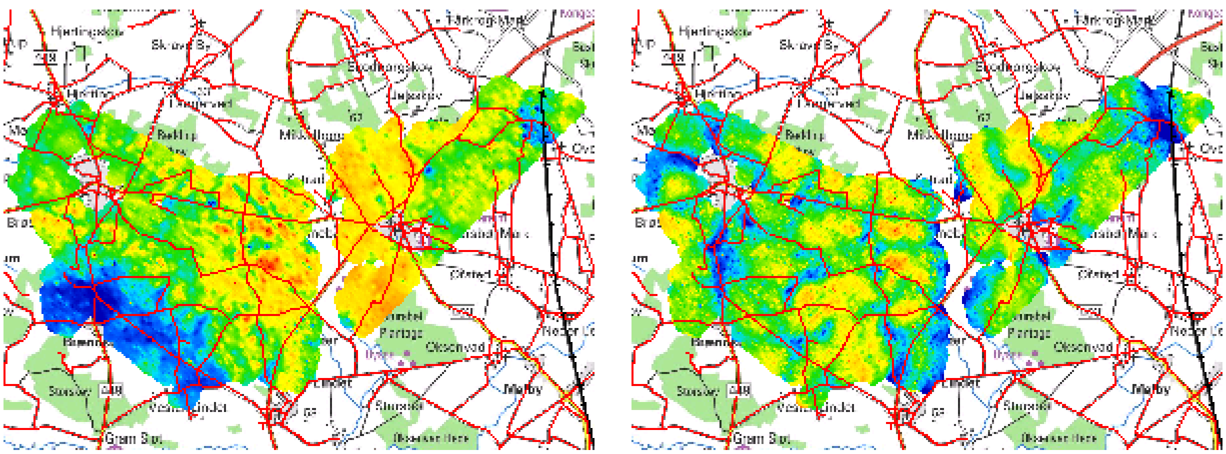

Figure 3. Resistivity-depth intervals derived from the full inversion of decoupled data. Depth Intervals 60-60 m, 120-140 m

As previously mentioned, removing the effects of infrastructure from the data is only the first step of data processing. Late time noise, representing the effect of random ambient noise becomes evident when the signal drops, i.e., at late times, has to be assessed and dealt with. The right panel of Figure 2 shows this procedure on small set of data. Inverting the dataset with the late time noise present, results in artifacts in the deeper parts of the inverted models, that can often be interpreted as conductors. Ignoring late time noise in multi layer (smooth) inversions, where vertical constraints are set between resistivities of layers, can affect also the intermediate part of the models, typically by decreasing its resistivity. In order to illustrate the effect of the late time noise removal on the recovery of relevant hydrogeological units, we extracted as example from the model space the depth to the good conductor, i.e., the Paleogene clays. Figure 4 shows the map of the depth to the good conductor/depth to base of aquifers, derived from the inversion of data that was only decoupled, and from data that was decoupled and had late time noise removed.

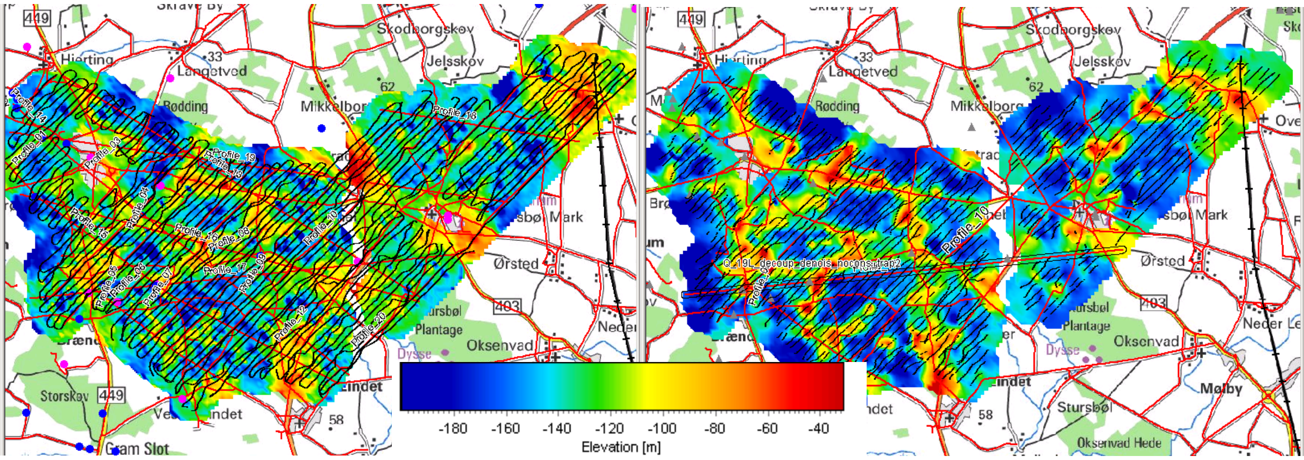

Figure 6. Elevation of the top of the good conductor (Paleogene clays), derived from decoupled data (left), and from data that was decoupled, averaged and denoised (right).

The differences in elevation are significant, with more accurate processing delivering, in general, larger vertical dynamicity, and therefore better defined morphology of the clay. This has obvious potential relevant consequences on the hydrogeological models of the area, as it contributes to determining the aquifers size, geometry and interactions. Other hydrogeological parameters that can be affected by improper processing (e.g., excessive lateral filtering of raw data to produce cleaner data) will be discussed at the oral presentation.

Conclusions

Deriving hydrogeological models from inversions of AEM data require an accurate data processing of navigation and EM data before the data is inverted. We have illustrated how different levels of accuracy in the data processing step affect the inversion results and the subsequent derived hydrogeological products. The main steps involved in ensuring an appropriate processing are; altitude processing to avoid e.g. canopy effects, removal of artifacts caused by infrastructure, late time noise assessment and applying a suitable lateral averaging filter to the data. The final inversion output is highly dependent on how these steps are performed. The examples in this paper were based on a SkyTEM dataset, but the conclusions hold for virtually any airborne EM system.

Acknowledgements

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