Inversion of HEM data from 3D conductivity distributions

Angelika Ullmann, Bernhard Siemon

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover

Project

Airborne electromagnetic data sets are able to reveal information about the spatial conductivity distribution in the subsurface of large survey areas. As the footprint of helicopter-borne electromagnetic (HEM) measurements is rather small (some hundred metres), many conductivity structures having small lateral variations only are close to 1D settings. Therefore, stitched together 1D inversion models are widely used to approximately display the 3D conductivity distribution. Laterally strongly varying conductivity structures (anomalies), however, require 3D modelling. An accurate 3D inversion of the HEM data of an entire survey area is often neither feasible nor necessary.

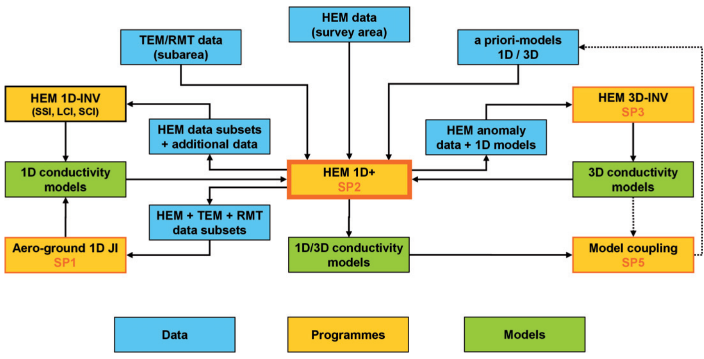


Fig. 1: Model coupling within AIDA

Within the framework of AIDA we are working on combining 1D/3D inversions. Thus, the programme (HEM1D+) to be developed will be linking the work of the project partners as shown in Fig. 1. The stitched together 1D inversion models are inspected for 3D effects and anomalies are selected. For straightforward geometries the electromagnetic field can be calculated from a simple forward model, e.g. sphere, cable, etc. This model is manually varied by trial and error to fit the modelled to the measured data. Data subsets of complex geometries are handed over to the 3D inversion algorithm being developed by a project partner (SP3: TU Bergakademie Freiberg). The resulting 3D models will then be re-integrated into a quasi 1D environment. Geophysical plausibility at the boundaries between the models obtained from 1D and 3D inversion has to be obeyed (Fig. 2). The combined 1D/3D conductivity models will be forwarded to the project partners (SP5: CAU Kiel, LU Hannover) for crosschecking with hydro-geological and geological models. Additional data obtained from different geophysical and geological methods are used to improve the HEM 1D inversion.

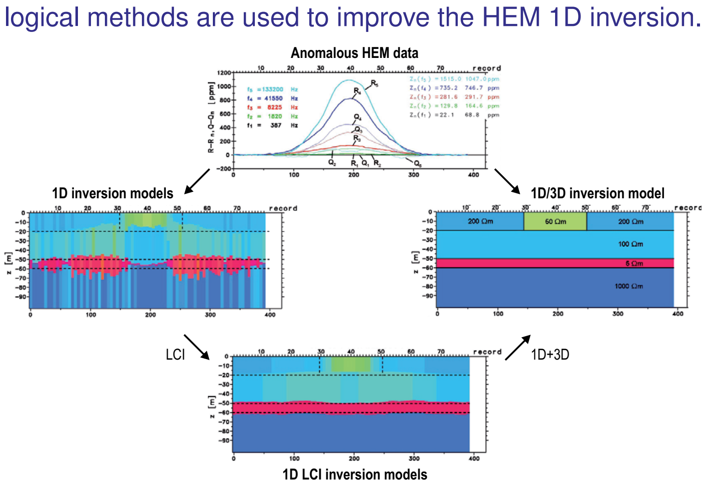


Fig. 2: Combined 1D/3D inversion of HEM data

Study area Cuxhaven

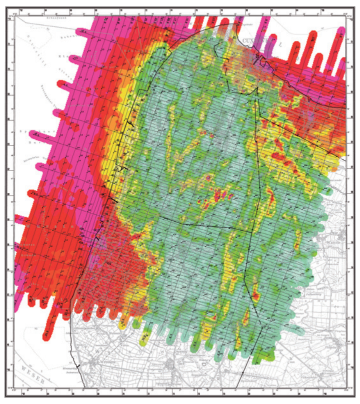


Fig. 3: Resistivity map at 20 m bsl

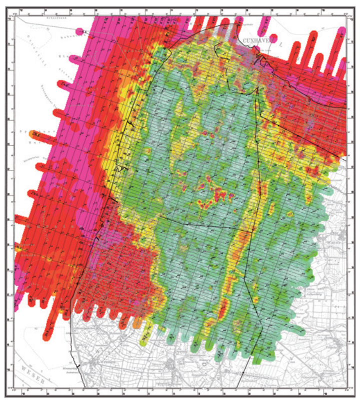


Fig. 4: Resistivity map at 40 m bsl

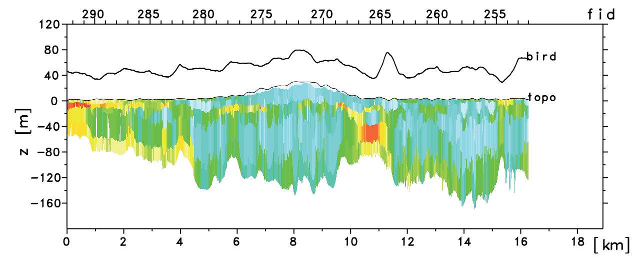


Fig. 5: Vertical resistivity section along L35.1

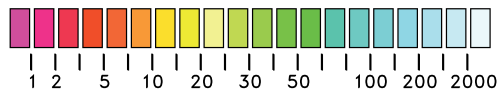
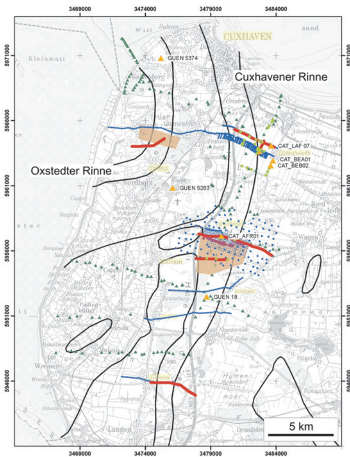


Fig. 6: Colour scale for the resistivity ρ (Ωm)

Fig. 7: Map of the study area Cuxhaven including: SkyTEM (■), TEM (●), gravity data (●), seismic surveys (–), vertical electric soundings (▲), cone penetration tests (●) and boreholes (▲). A HEM survey covers the whole area.



The Cuxhavener Rinne is chosen as a study area of this project as many data sets from different geophysical methods, e.g. airborne and ground based electromagnetics (HEM, SkyTEM, TEM), gravimetry, reflection seismics and borehole logging (Fig. 7), have been collected before and during the BurVal project (Rumpel et al., 2009). Here, some results of the HEM survey (Siemon et al., 2004) will be presented. Resistivity maps at selected depths and a vertical resistivity section derived from multi-layer inversion models are shown in Fig. 3-5. Due to the resistivity contrast between the top clay layer in the buried valley and the surrounding material the Cuxhavener Rinne can clearly be seen in the south-eastern part of the survey area (Fig. 4) as a SSW-NNE running structure.

To study how multi-dimensional conductivity structures are reproduced by the HEM 1D inversion a 3D model of the Cuxhavener Rinne is built. The conductivities are constant in y-direction close (<1 km) to the cross-section (Fig. 8). This model is based on the results of the different geophysical surveys of this area. For the forward modelling the following parameters are used:

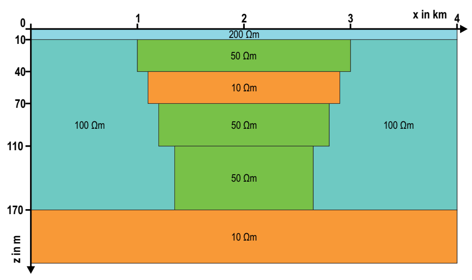


Fig. 8: Cross-section of 3D model of the Cuxhavener Rinne

- Programme: x3da code (Avdeev, Kuvshinov & Pankratov)
- Method: volume integral equation approach
- Discretisation in x-, y-direction: 25 m
- Discretisation in z-direction: increasing with depth

- Frequencies: 375, 1792, 8600, 41 000 and 195 000 Hz
- Coil configuration: HCP
- Coil separation: 6.7 m
- Sensor height: 40 m
- Sampling distance: 50 m

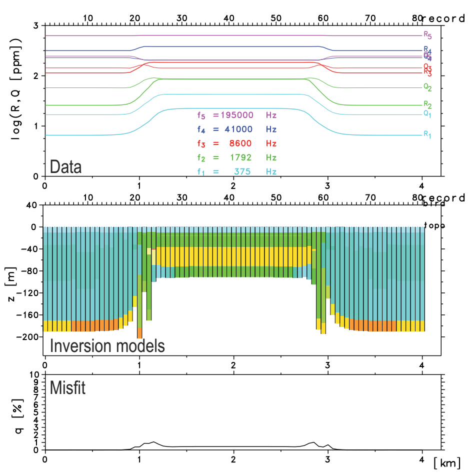


Fig. 9: HEM 1D inversion results

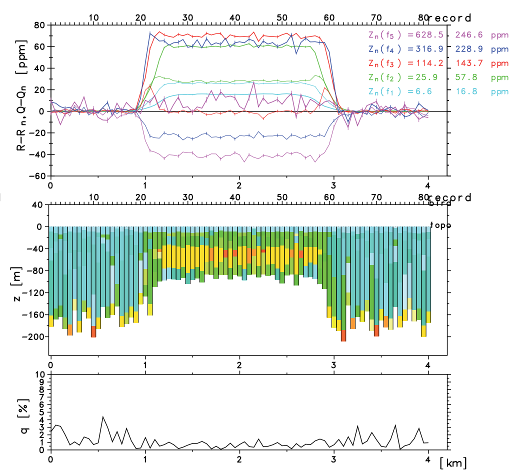


Fig. 10: HEM 1D inversion results, 1 % noise

Figures 9 and 10 show the results of the 1D inversion of HEM data obtained from a 3D conductivity distribution (Fig. 8). To give a more realistic picture 1 % noise is added to the synthetic data (Fig. 10). For this case, only the anomalous part of the data is displayed. It is obtained by subtracting the electromagnetic field values of the 1D background model (layered half-space, ρ = 200, 100, 10 Ωm, d = 10, 160 m) from the synthetic data.

The results of the 1D inversion of the noise free data fits the background model nearly perfect. The misfit is almost 0 %. In the centre part the resistivity, depth and thickness of the top clay layer are nicely reproduced and an indication of a resistive layer below is given. The edges of the Cuxhavener Rinne, however, prove to not be reproducible by 1D inversion (record 15-29 and 52-66). The results of inverting the noisy data are basically the same. Top and resistivity of the basement are hinted but not as clearly resolved as by inversion of the noise free data. The top edge and the resistivity of the clay layer are reproduced. The resistive body below is indicated only.

Contact:

Angelika Ullmann
Email: angelika.ullmann@bgr.de

References:

Rumpel, H.-M., Binot, F., Gabriel, G., Siemon, B., Steuer, A., & Wiederhold, H. (2009). The benefit of geophysical data for hydrogeological 3D modelling - an example using the Cuxhaven buried valley. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften*, *160*(3), 259–269.

Siemon, B., Eberle, D., & Binot, F. (2004). Helicopter-borne electromagnetic investigation of coastal aquifers in North-West Germany. *Zeitschrift für Geologische Wissenschaften*, *32*(5/6), 385–395.

Supported by:

Bundesministerium für Bildung und Forschung