Helicopter-borne electromagnetic surveys in Northern Germany

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ABSTRACT

For more than three decades BGR has conducted helicopter-borne geophysical surveys worldwide. Currently most of these surveys were flown in Northern Germany, where saltwater intrusion and clay mapping are the principal topics. Particularly airborne electromagnetics (AEM) is suitable for these mappings. Two helicopter-borne systems were used, a frequency-domain system (HEM) operated by BGR and a time-domain system (SkyTEM) developed at the university of Aarhus. The spatial conductivity distribution, which was derived from AEM data provides information on both lithology and water salinity.

INTRODUCTION

The airborne geophysical system operated by BGR for more than three decades enables simultaneous frequency-domain electromagnetic (HEM), magnetic and radiometric data acquisition. The project D-AERO, which is conducted by BGR in collaboration with State Geological Surveys of Germany and research institutes, merges existing airborne survey areas and appends new areas with respect to focusing on scientific and/or regional aspects. Several airborne geophysical surveys have been carried out by BGR in Northern Germany within the last two decades (Figure 1). In 2008-2009, LIAG supported these surveys by co-financing a number of BGR surveys and commissioning time-domain helicopter-borne electromagnetic surveys using the Danish SkyTEM system (Sørensen and Auken 2004). These systems were used to investigate the coastal areas of the North and Baltic Sea and some of the Frisian Islands (Wiederhold et al. 2010).

LIAG and BGR are building up a geophysics database (www.geophysics-database.de) which contains all airborne geophysical data sets. However, the more significant effort is to create a reference data set as basis for monitoring climate or man-made induced changes of the saltwater/freshwater interface at the German North Sea coast. The significance of problems for groundwater extraction and treatment caused by groundwater salinization is increasing and particularly coastal areas are affected by a latent risk for the sustainable usage of aquifers.

METHODS

The electromagnetic systems (DIGHEM, RESOLVE) operated by BGR are towed by a helicopter on parallel flight lines about 30–40 m above ground level. The processed HEM data are converted to half-space parameters, which are used to define individual multi-layer starting models at each data point for an iterative Marquardt-Levenberg inversion procedure (Steuer et al. 2014). The HEM inversion results are displayed as (apparent) resistivity maps and vertical resistivity sections (VRS) showing the 1D resistivity models along a survey profile with respect to the topographic relief (in m above mean sea level). As man-made effects caused by power lines, railway tracks, highways or urban areas are able to distort nearby HEM measurements, these data have to be corrected (Siemon et al. 2011). Similarly, the processed time-domain data are converted to resistivity models (Viezzoli et al. 2008). Both systems as well as processing and interpretation schemes are described in detail by Siemon et al. (2009) and Steuer et al. (2009).

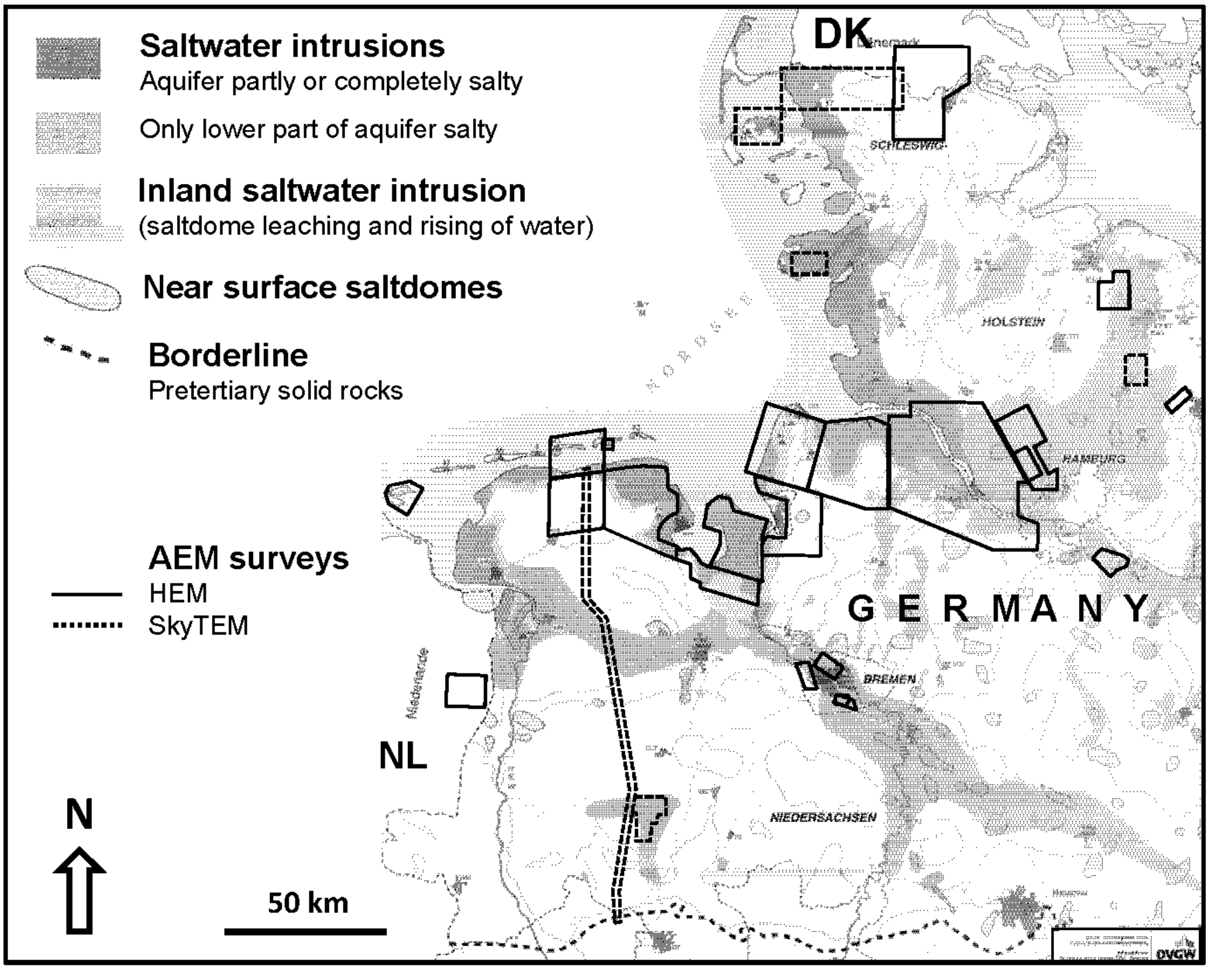

Figure 1. HEM surveys in Northern Germany. Background map: Groundwater salinization (modified after Grube et al., 2000).

RESULTS

Resistivities at a depth of 15 m bsl (below sea level) derived from 1D inversion are displayed on the map of Figure 2. Low resistivities ($\rho < 0.5\ \Omega$m or $\rho < 3\ \Omega$m) clearly outline areas of saltwater or saltwater intrusion, respectively. High resistivities $\rho > 50\ \Omega$m indicate freshwater saturated sandy sediments. The resistivities in-between are typical for clayey sediments. Due to the sensitivity to the lithology and water salinity, rather low resistivities (ρ = 3-10 Ωm) could also represent sandy sediments saturated with brackish water.

Comparison with Figure 1 demonstrates that the low resistivities derived from AEM data are suitable for mapping areas of the saltwater intrusion in great detail along the coast (Siemon et al. 2014) and inland (Klimke et al. 2013). Furthermore, AEM enables spatial mapping of freshwater lenses on islands (Burschil et al. 2012; Sulzbacher et al. 2012) and shallow submarine freshwater outlets (Rodemann et al. 2005). As AEM is also suitable for clay vs.

sand mapping (Siemon et al. 2014), buried tunnel valley can be outlined if the channel fill, e.g. clay, differs from the host material, e.g. sand (Eberle and Siemon 2006).

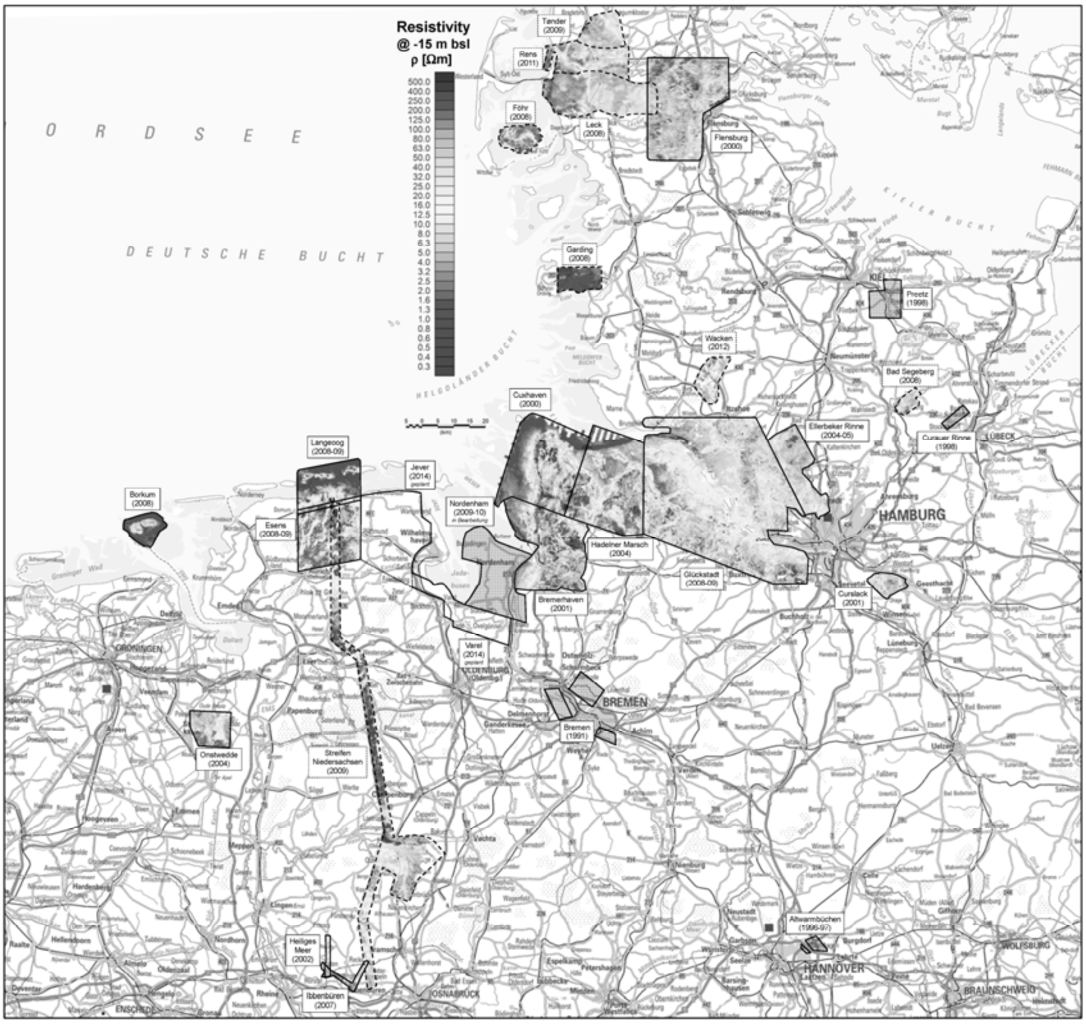

Figure 2. Resistivities at 15 m bsl derived from HEM (solid frames) and SkyTEM (dashed frames) data are plotted on a topographic map (BKG 2014).

DISCUSSION AND CONCLUSIONS

Airborne geophysical methods enable economic and ecological mapping of subsurface natural resources. Besides groundwater and mineral exploration the investigation of non-mineral resources is an important task. Electromagnetic methods are able to map lithological units if these are correlated with electrical conductivity. Particularly resistive sands and gravels can be distinguished from conductive clayey materials as well as freshwater from saltwater.

REFERENCES

BKG. 2014. Digitale Topographische Karte 1:1 000 000 (DTK1000): Geobasisdaten © BKG 2014. Map accessed at 20 February 2014 at http://www.bkg.bund.de/.

Burschil, T., W. Scheer, R. Kirsch, and H. Wiederhold. 2012. Hydrogeological characterisation of a glacially affected barrier island – the North Frisian Island of Föhr. Hydrology and Earth System Sciences 16: 3485-3498.

Eberle, D.G., and B. Siemon. 2006. Identification of buried valley using the BGR helicopter-borne geophysical system. Near Surface Geophysics 4, no. 2: 125-133.

Grube, A., K. Wichmann, L. Hahn, and K. H. Nachtigall. 2000. Geogene Grundwasserversalzung in den Poren-Grundwasserleitern Norddeutschlands und ihre Bedeutung für die Wasserwirtschaft: TZW (Technologiezentrum Wasser) Schriftenreihe 9.

Klimke, J., H. Wiederhold, J. Winsemann, G. Ertl, and J. Elbracht. 2013. Three-dimensional mapping of Quaternary sediments improved by airborne electromagnetics in the case of the Quakenbrück Basin, Northern Germany. Zeitschrift der Deutschen Gesellschaft für Geowissenschaften 164: 369-384.

Rodemann, H., E. Brost, J. Schünemann, U. Noell, B. Siemon, and F. Binot. 2005. Gleichstromgeoelektrische Untersuchungen eines mit aeroelektromagnetischen Messungen kartierten Süßwasservorkommens im Sahlenburger Watt unter Berücksichtigung von Äquivalenzfällen und 2D/3D-Modellrechnungen. Zeitschrift für angewandte Geologie 1/2005: 43-51.

Siemon, B., A.V. Christiansen, and E. Auken. 2009. A review of helicopter-borne electromagnetic methods for groundwater exploration. Near Surface Geophysics 7: 629-646.

Siemon, B., A. Steuer, A. Ullmann, M. Vasterling, and W. Voß. 2011. Application of frequency-domain helicopter-borne electromagnetics for groundwater exploration in urban areas. Journal of Physics and Chemistry of the Earth 36: 1373-1385.

Sørensen, K.I., and E. Auken. 2004. SkyTEM - a new high-resolution helicopter transient electromagnetic system: Exploration Geophysics 35: 191-199.

Steuer, A., B. Siemon, and E. Auken. 2009. A comparison of helicopter-borne electromagnetics in frequency and time-domain at the Cuxhaven valley in Northern Germany. Journal of Applied Geophysics 67: 194-205.

Siemon, B., W. Voß, J. Elbracht, N. Deus, and H. Wiederhold. 2014. Airborne clay mapping at the East Frsisian coast. In Proceedings of the 23rd Salt Water Intrusion Meeting, Husum, Germany.

Steuer, A., B. Siemon, U. Meyer, and H. Wiederhold. 2014. Helicopter-borne electromagnetics: A powerful tool for the mapping of coastal aquifers. In Proceedings of the 23rd Salt Water Intrusion Meeting, Husum, Germany.

Sulzbacher, H., H. Wiederhold, B. Siemon, M. Grinat, J. Igel, T. Burschil, T. Günther, and K. Hinsby. 2012. Numerical modelling of climate change impacts on freshwater lenses on the North Sea Island of Borkum using hydrological and geophysical methods. Hydrology and Earth System Sciences 16: 3621-3663.

Viezzoli, A., A.V. Christiansen, E. Auken, and K.I. Sørensen. 2008. Quasi-3D-modeling of airborne TEM data by Spatially Constrained Inversion: Geophysics 73: F105-F113.

Wiederhold, H., B. Siemon, A. Steuer, G. Schaumann, U. Meyer, F. Binot, and K. Kühne. 2010. Coastal aquifers and saltwater intrusions in focus of airborne electromagnetic surveys in Northern Germany. In Proceedings of the 21th Salt Water Intrusion Meeting, S. Miguel, Azores, Portugal.

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