Bundesanstalt für Geowissenschaften und Rohstoffe

GEOZENTRUM HANNOVER

AIRBORNE GEOPHYSICAL PEAT MAPPING CASE STUDY AHLEN-FALKENBERGER MOOR

Bernhard Siemon[1], Malte Ibs-von Seht[1], Stefan Frank[2]

[1]Federal Institute for Geosciences and Natural Resources (BGR), Hannover
[2]State Authority for Mining, Energy and Geology (LBEG), Hannover (now at: Thünen Institute, Braunschweig)

Introduction

Peatlands release greenhouse gases to the atmosphere, particularly if anthropogenic drainage and land use for agricultural, silvicultural or horticultural purposes take place. In Germany, 2.8 % (7.8 Mio. T CO_2-C-equivalents) of the total national greenhouse budget of 2006 came from peatlands (Höper 2007). Knowledge on peat volumes of peatlands (both bogs and fens) is essential to accurately estimate carbon stocks and to facilitate appropriate peatland management (Gatis et al. 2019).

Ground-based methods (e.g. ground penetrating radar, probing) are labour intensive and unfeasible to capture spatial information at landscape extents (Gatis et al. 2019). Remote sensing and airborne geophysical methods have not been investigated sufficiently for this purpose so far. From all the airborne geophysical methods successfully used for e.g. mineral or groundwater exploration, particularly airborne radiometric (Beamish 2014, 2015) and electromagnetic (Silvestri et al. 2019) surveys may help to estimate peat depth and extent. We propose a combination of both methods and demonstrate the feasibility by a case study at a bog in Germany.

Ahlen-Falkenberger Moor

This Atlantic peat bog complex is situated in NW Germany, ca. 20 km to the south of the coast. Part of the bog (39 km²) is covered by an airborne survey area (Figure 1). The peat is on average 2.9 ± 1.1 m thick and the base lies at -0.3 ± 1.3 m above mean sea level (amsl). The mean values are derived from 110 boreholes with peat thicknesses of 0.4–7.0 m (Figure 2). The groundwater table is at or, where drainage channels exist (Frank et al. 2014), close to the surface (<1 m depth).

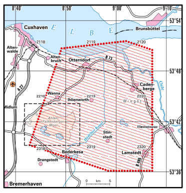

Figure 1. Airborne survey area and location of the study area of the Ahlen-Falkenberger Moor.

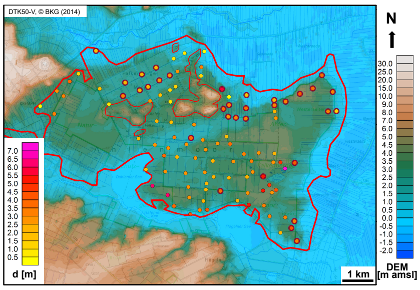

Figure 2. DEM map including peat thicknesses (d) found in 110 boreholes. Red lines outline the bog and circles show the location of boreholes. The coloured dots within the circles indicate peat thicknesses above sandy (black circles) or clayey (larger red circles) sediments.

Airborne Survey

The airborne survey area (700 km², 3000 line-km) is located to the south of the mouth of the river Elbe (Figure 1). BGR conducted this survey in spring 2004 using a digital 5-frequency (0.4–140 kHz) helicopter-borne electromagnetic system (Resolve) together with a Cs magnetometer and a 256-channel gamma-ray spectrometer (GR-820) with a 4×4 l NaI crystal pack (Figure 3).

The electromagnetic (HEM) and radiometric (HRD) data sets were recently reprocessed (Siemon et al. 2019a) using sophisticated software tools. That also enabled an evaluation of HEM and HRD data with respect to the investigation of the peat bog complex in Lower Saxony, Germany.

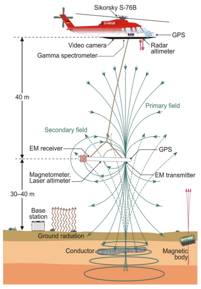

Figure 3. Sketch of BGR's helicopter-borne geophysical system with electromagnetic, magnetic and radiometric devices.

Lateral Extent of the Bog

A clear correlation between peat extent and resistivity maps derived from HEM data of 25 WNW–ESE flight lines crossing that area is not obvious, because – even at the highest frequency – the apparent resistivities relate more to the sediments below the peat than to the peat itself (Figure 4).

HRD data, however, correlate fairly well to the outlines of the bog (Figure 5, red lines) due to very low exposure rates. Only in the south, where the surface elevation is lower, similar low exposure rates occur due to wet peat of a fen. This fen partly underlies the bog, particularly close to its borders. Therefore, we combined two thresholds (exposure rate < 1 µR/h and DEM > 0.5 m amsl) to define a peat indicator estimating the bog extent from airborne data. This peat indicator is used to select and display the results.

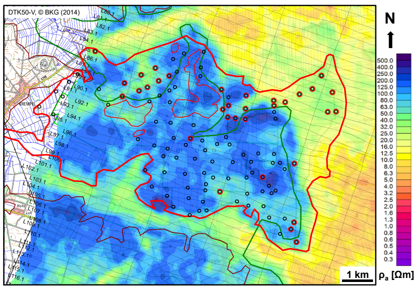

Figure 4. Apparent resistivity at the highest frequency (140 kHz). Blue/orange colours indicate sandy/clayey substrate. Red circles mark boreholes with clay at the base. Red/brown/green lines outline bog/fen/clay extent.

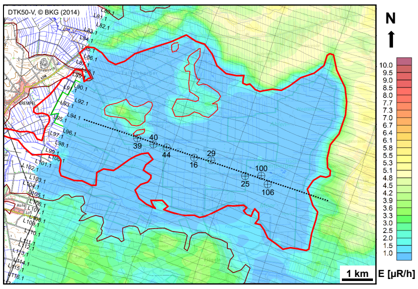

Figure 5. Low exposure rates correlate fairly well with the extent of the bog (red lines), except in the south where wet peat of a fen (brown lines) exists. Comparisons are shown along flight line L94.1 (dotted black line) where eight boreholes (⊕ and borehole ID) exist nearby.

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Vertical Extent of the Bog

Peat thicknesses were derived from smooth 20-layer HEM inversion models in combination with the steepest gradient approach (Siemon et al. 2019b). The results required smoothing along the flight lines by a non-linear filter (length: 200 m, tolerance: 2 m) as well as resistivity (<130 Ωm at interface) and elevation thresholds (at -5 m amsl) to exclude unrealistic values. Resulting gaps (Figure 6, red lines) are interpolated by minimum curvature gridding (dark red lines).

Assuming exponential absorption of the radiation passing through a homogenous material of thickness d: $E = E_0\, e^{-\mu d}$, E_0 = source radiation intensity (Davisson 1965), leads to $\mu = (\ln(E_0) - \ln(E))/d$. As $\ln(E_0)$ is unknown, it is set to zero. Using exposure rates for E and HEM peat thicknesses for d yields an average value of $\mu = 0.29\ m^{-1}$. This value was applied to derive HRD peat thicknesses (Figure 6, blue lines).

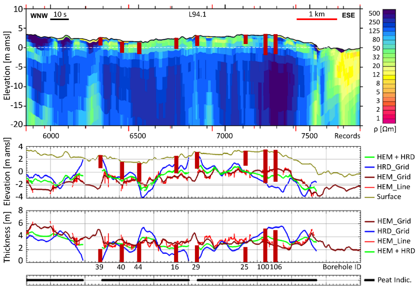

Figure 6. Vertical resistivity section derived from smooth HEM inversion (above) and peat elevations/thicknesses (below) derived from HEM or/and HRD data compared with peat ranges found in boreholes (brown columns).

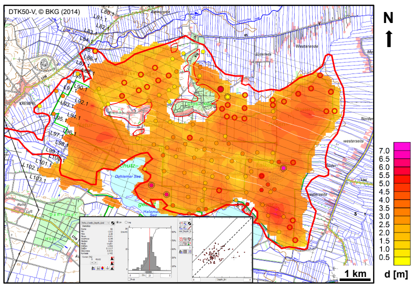

Figure 7. Peat thickness derived from HEM and HRD data (grid) and found in boreholes (dots). Differences are displayed as histograms and scatter plots (vertical red lines: no difference, black dashed and dotted lines: 1:1 line and ±2 m lines.

Combined HEM and HRD Results

Finally, we combined HEM and HRD results considering all depth values with differences less than ±2 m (Figure 6, green lines). The resulting gaps were interpolated using grid values regarding the peat indicator. The differences of the airborne mapping and the borehole results (Figure 7) are small on average: -0.01 ± 1.09 m (thickness), 0.03 ± 1.10 m amsl (peat base elevation), but locally some greater differences above ±2 m (dotted lines on the scatter plot) do occur.

Conclusions

An Atlantic peat bog complex situated in NW Germany was investigated by airborne geophysics in order to estimate its lateral and vertical extent. The results derived from helicopter-borne electromagnetic and radiometric data are very promising. Particularly the combination of both yielded results, which are (with a few exceptions) close to peat depths found in boreholes. These may result from the comparison of point values (borehole data) with grid values (airborne data), which are always smoother. This case study focused on a single bog – a more general investigation of numerous and diverse peatlands (bogs and fens) will be necessary to prove the approach presented here, which would enable large-scale peatland mapping.

Contact: Bernhard Siemon, Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2, D-30655 Hannover, Germany
Tel.: +49 (0)511-643 3488, Email: Bernhard.Siemon@bgr.de

Further information:
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