Helicopter-borne electromagnetic surveys for groundwater modelling in the North Sea region

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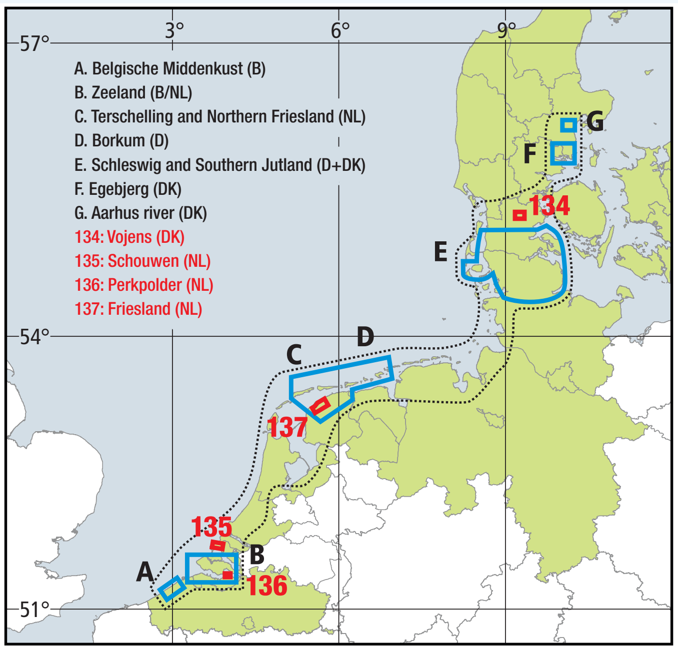


Fig. 1: CLIWAT pilot areas

Introduction

Climate change simulations indicate a sea-level rise and increasing rainfall in the North Sea region. This will lead to higher groundwater levels and a forced outwash of nutrients and pollutants from industrial areas, agriculture and landfills.

CLIWAT (climate & water) is a transnational Interreg project funded by the European Union with partners from four participating countries: Belgium (Ghent University), The Netherlands (Deltares, TNO, VITENS, Provincie Fryslan, Wetterskip Fryslan), Germany (LIAG, LLUR, SEECON, BGR) and Denmark (Region Midtjylland, GEUS, Region Syddanmark, Environment Centre Aarhus, Environment Centre Ribe, Aarhus University, Municipality of Horsens).

The goal of the project is to determine the affects of a possible climate change on groundwater systems, surface water and the fresh-saltwater boundary in the North Sea and Baltic Sea region. Therefore geological and geophysical measurements are carried out in seven pilot areas of the project (Fig. 1). In order to map the existing groundwater structures with airborne geophysical methods the German Federal Institute for Geosciences and Natural Resources (BGR) conducted four surveys in Zeeland, Friesland (both NL) and Vojens (DK).

BGR helicopter-borne geophysical system

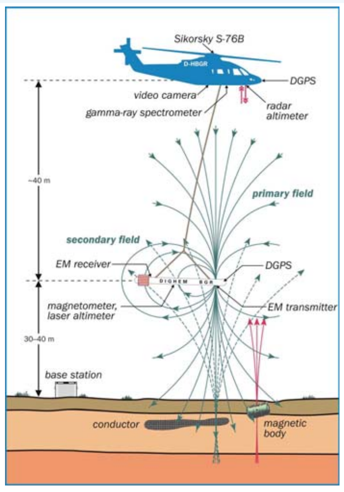


Fig. 2: Airborne geophysical system

Electromagnetics
RESOLVE
(Fugro Airborne Surveys)
Frequencies: f = 387, 1820, 5400, 8390, 41440, 133 300 Hz
Coil separations: ≈ 8 m
Coil orientations: 5 HCP, 1 VCX
Sampling rate: 10 Hz
Sampling distance: ≈ 4 m

Magnetics
Cs magnetometer

Radiometrics
256 ch. gamma-ray spectrometer

Navigation / Positioning
DGPS / radar and laser altimeter
Bird altitude: ≈ 30 m
Survey speed: ≈ 140 km/h

Methods

Electromagnetic (EM) surveys are able to reveal the electrical conductivity distribution of the subsurface. Due to the conductivity contrast between freshwater and saltwater and between clay and sand the EM results are used to investigate the existing groundwater structures. At each site, the multi-frequency HEM data were inverted to resistivity-depth models using a Marquardt-Levenberg 1D inversion technique (Siemon et al., 2009).

Resistivity maps at selected depths and vertical resistivity sections were derived from the inversion models. Freshwater-filled sediments are represented by resistivities greater than 10 Ωm. Highly conductive zones with resistivities less than 3 Ωm outline saltwater-filled sediments. The aquifer thickness was estimated by accumulating the thicknesses of the model layers with resistivities greater than 10 Ωm. The colour scales used for the presentation of the resistivity and the aquifer thickness are shown in Fig. 3 and Fig. 4, respectively.

Schouwen survey (Zeeland)

Size of survey area	60 km^2
Total profile length	340 km
Line spacing	lines: 200 m tie lines: 500 m
Survey period	August 25-26, 2009

Perkpolder survey (Zeeland)

Size of survey area	50 km^2
Total profile length	222 km
Line spacing	lines: 200 m tie lines: 500 m
Survey period	August 26-27, 2009

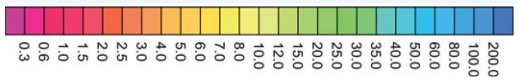


Fig. 3: Colour scale for the resistivity ρ (Ωm)

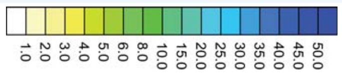
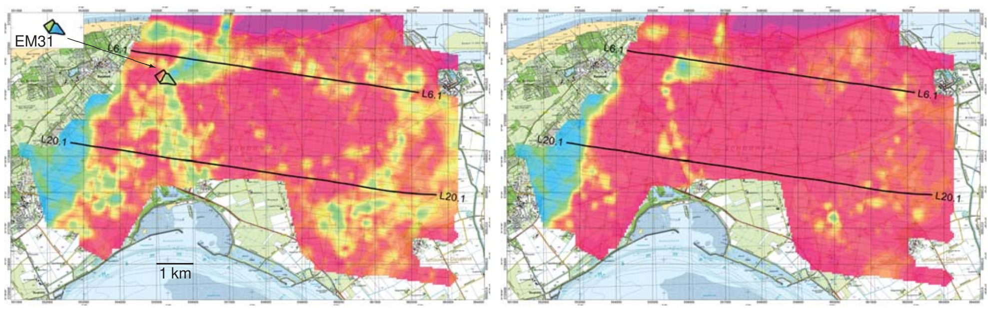


Fig. 4: Colour scale for the aquifer thickness (m)

Schouwen



(a) z = 3 m below sea level (b) z = 8 m below sea level

Fig. 5: Resistivity maps at 3 and 8 m below sea level

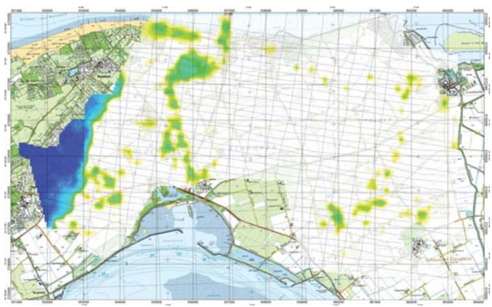
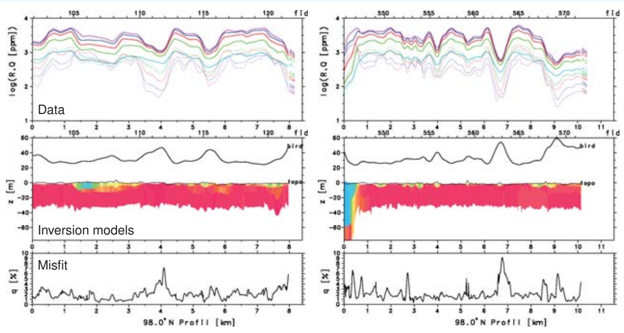


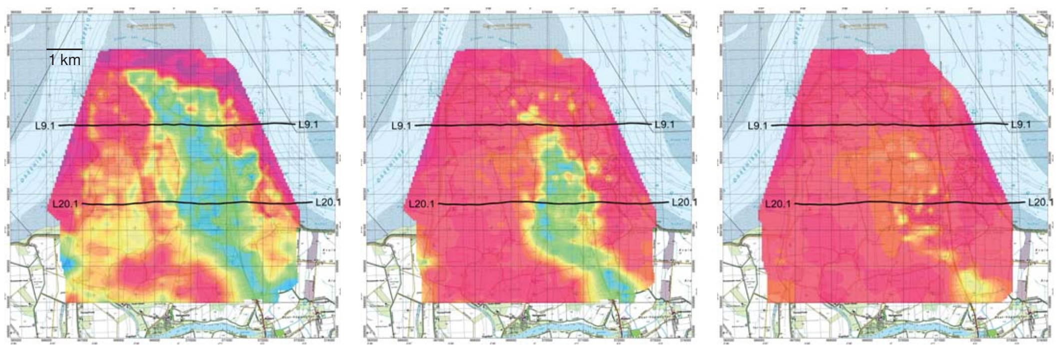
Fig. 6: Aquifer thickness in m, $\rho > 10$ Ωm



(a) L6.1 (b) L20.1

Fig. 7: Vertical resistivity sections along two flight lines

Perkpolder



(a) z = 2 m below sea level (b) z = 12 m below sea level (c) z = 20 m below sea level

Fig. 8: Resistivity maps at 2, 12 and 20 m below sea level

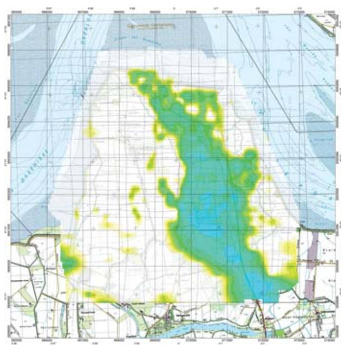
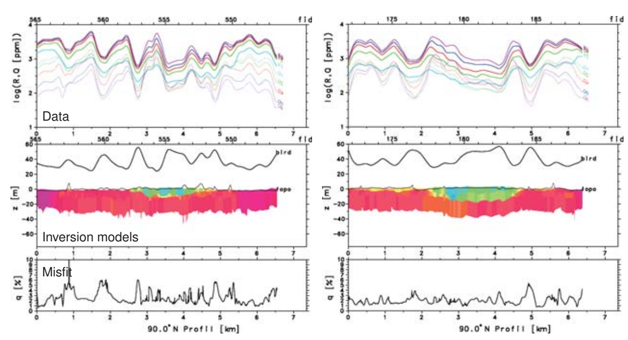


Fig. 9: Aquifer thickness in m, $\rho > 10$ Ωm



(a) L9.1 (b) L20.1

Fig. 10: Vertical resistivity sections along two flight lines

Results

In the dune areas of the survey area Schouwen, the freshwater-saltwater interface was detected at depths greater than 50 m below ground level. Otherwise, in the polder areas which are situated below sea level, the interface was found within 3 m depth (Fig. 5-7). The HEM data correspond well with other field data (EM31) which were collected in greater detail for a small area (Fig. 5(a)). A NW-SE striking channel structure was discovered in the survey area Perkpolder. There, the boundary between freshwater and saltwater was detected down to 30 m below ground level (Fig. 8-10). These data sets will be used as input for the hydrological modelling of the particular groundwater structures.

References

Siemon, B., Auken, E., & Christiansen, A. V. (2009). Laterally constrained inversion of helicopter-borne frequency-domain electromagnetic data. *Journal of Applied Geophysics*, *67*, 259–268.

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