Airborne Geophysics: a powerful tool to start up fresh groundwater management in the coastal zone

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Deltares Enabling Delta Life

The Interreg IVB North Sea Region Programme — Investing in the future by working together for a sustainable and competitive region

INTRODUCTION

Fresh groundwater in coastal areas throughout the world is a popular water resource for domestic, agricultural and industrial activities and for nature conservation due to its huge quantities and its high quality relative to surface water. For the future, the use of fresh groundwater in most areas is very likely to increase due to population rise, economic growth, intensified agricultural development, and the loss of surface water due to contamination (Fig. 3). These stresses probably lead to salinisation and reduces the availability of fresh groundwater. In addition, sea level rise, changes in recharge and evapotranspiration pattern and (indirectly) land subsidence will intensity the future pressure on coastal groundwaters even more. Therefore, we need tools to manage this fresh groundwater in a proper way, now and in the future. An essential first step in this management is to know the present spatial distribution of fresh, brackish and saline groundwater. Data scarcity often limits sustainable management of vulnerable groundwater systems worldwide (Fig. 3). Traditional monitoring is labor-intensive and is very time-consuming. As an alternative, Airborne Electromagnetic (AEM) geophysical methods are cheap ways of collecting data and can cover large areas in a short time span.

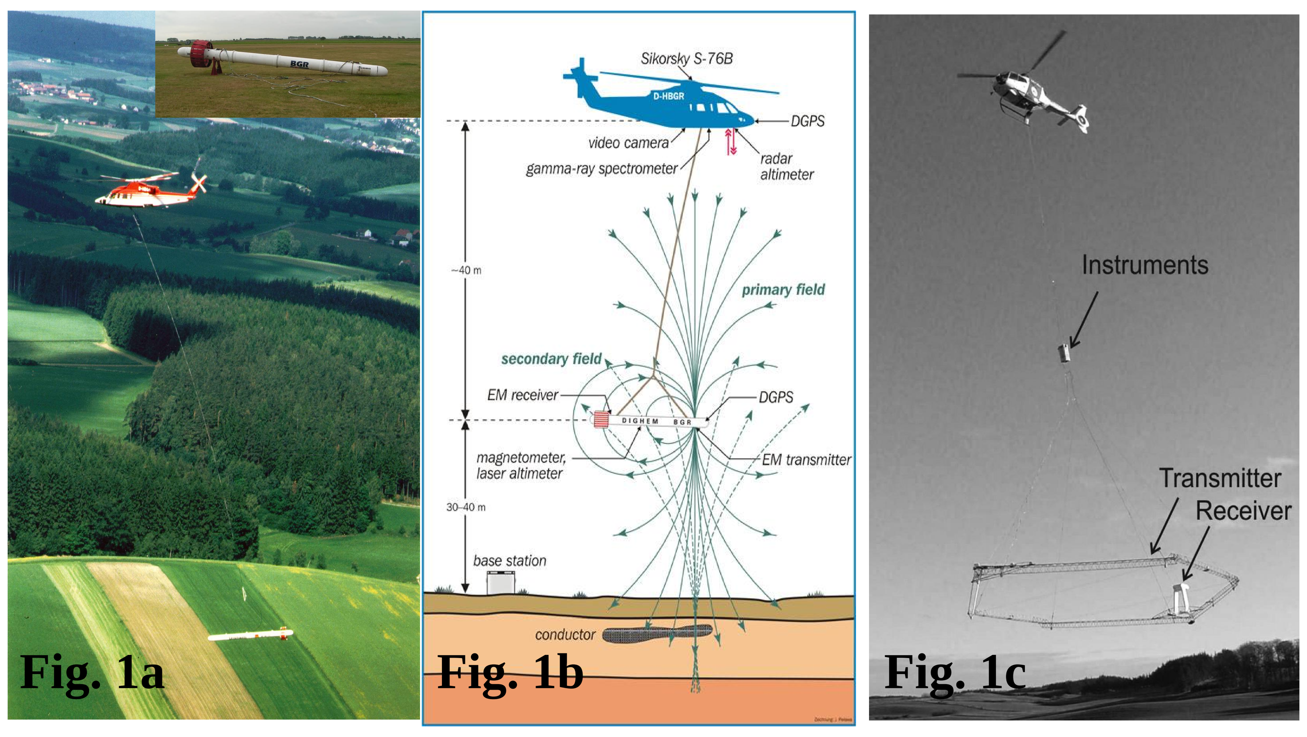


Figure 1. Helicopter-borne geophysical systems: a and b.: BGR system recording simultaneously frequency-domain electromagnetic, magnetic and radiometric data ('the HEM bird of BGR' retrieves the resistivity of the subsoil), c: SkyTEM system recording time-domain electromagnetic data.

Airborne salinity and lithology detection

Airborne Electromagnetic (AEM) geophysical methods are used to detect the salinity of groundwater due to the impact of salinity on the conductivity for electrical currents used in EM (Fig. 1). Complicating factors such as man-made infrastructure that transports electrical currents (e.g. powerlines, railways) and underlying geological structure are dealt with. As both salinity and lithology influence the response of the EM system, the combined effect of these two factors have to be unravelled. AEM is combined with 3D geological models to get a much better insight in the spatial distribution of fresh, brackish and saline groundwater than only based on 0D, 1D and 2D measurements, such as sampling, borelogs, CVES, TEC, CVES and EM31.

Dutch case studies

Within Interreg IV-B project CliWat, Deltares works together with TNO, BGR, University Aarhus in three pilot studies in The Netherlands (Fig. 2): Northwest Friesland, Schouwen-Duiveland and Perkpolder.

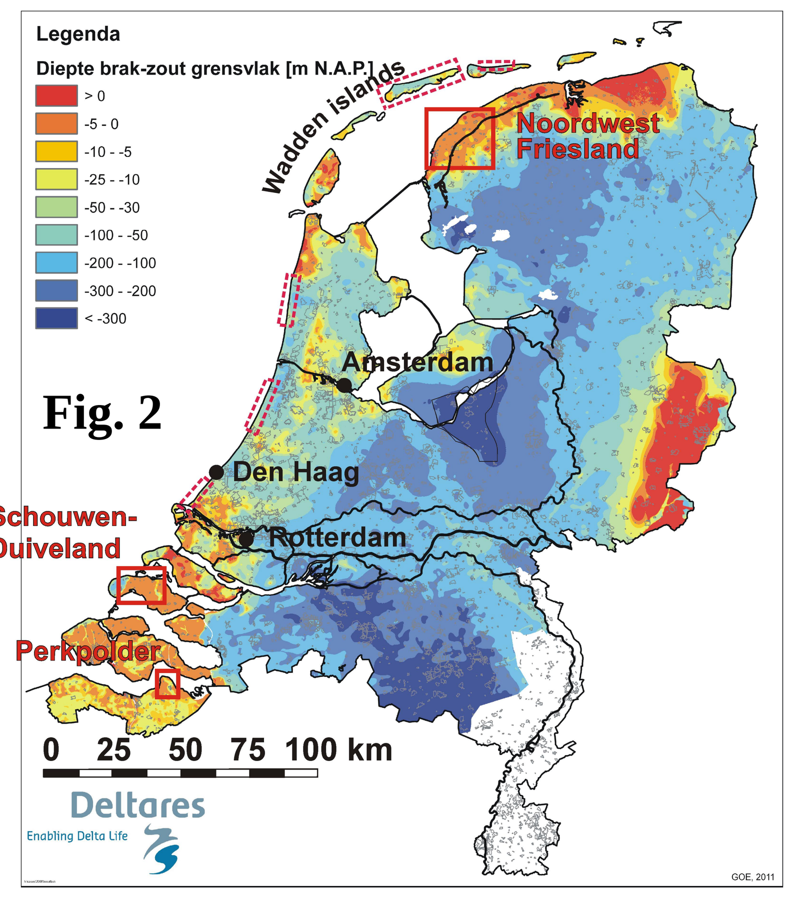


Figure 2: The three investigated pilot areas. Additional AEM-activities have been taking place along the coast of Ameland, Terschelling and drinkwater companies (PWN, Waternet and Dunea (The Sand Engine)).

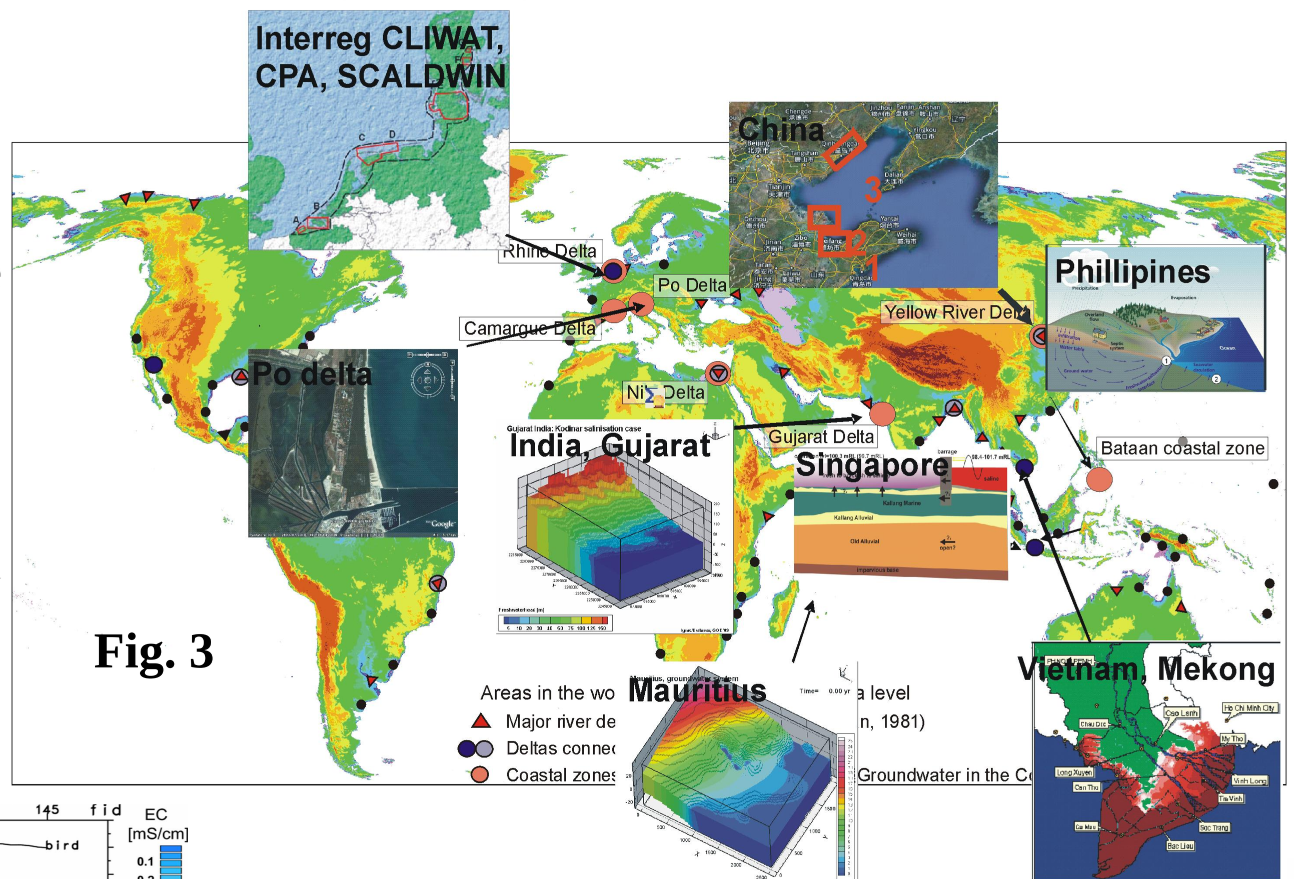
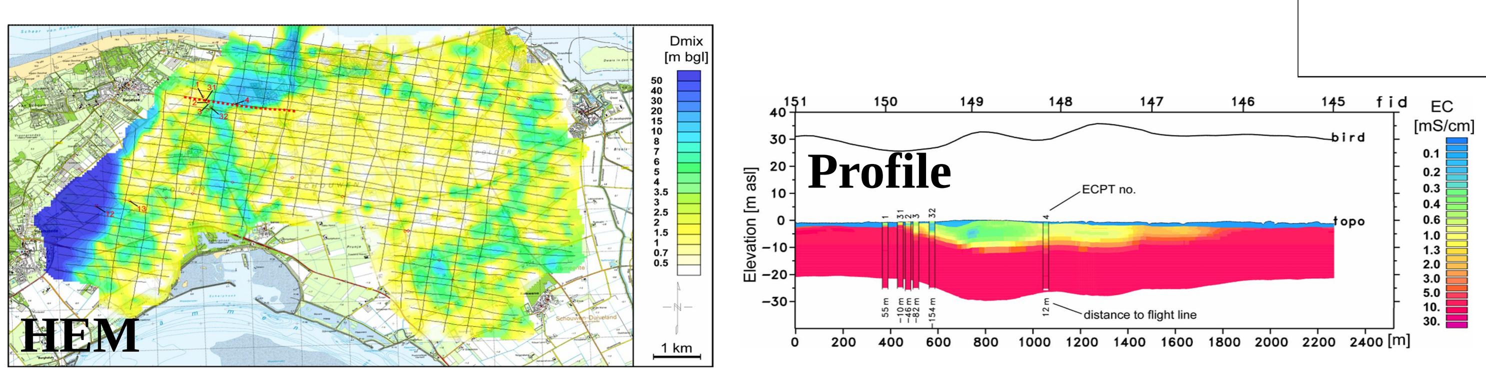
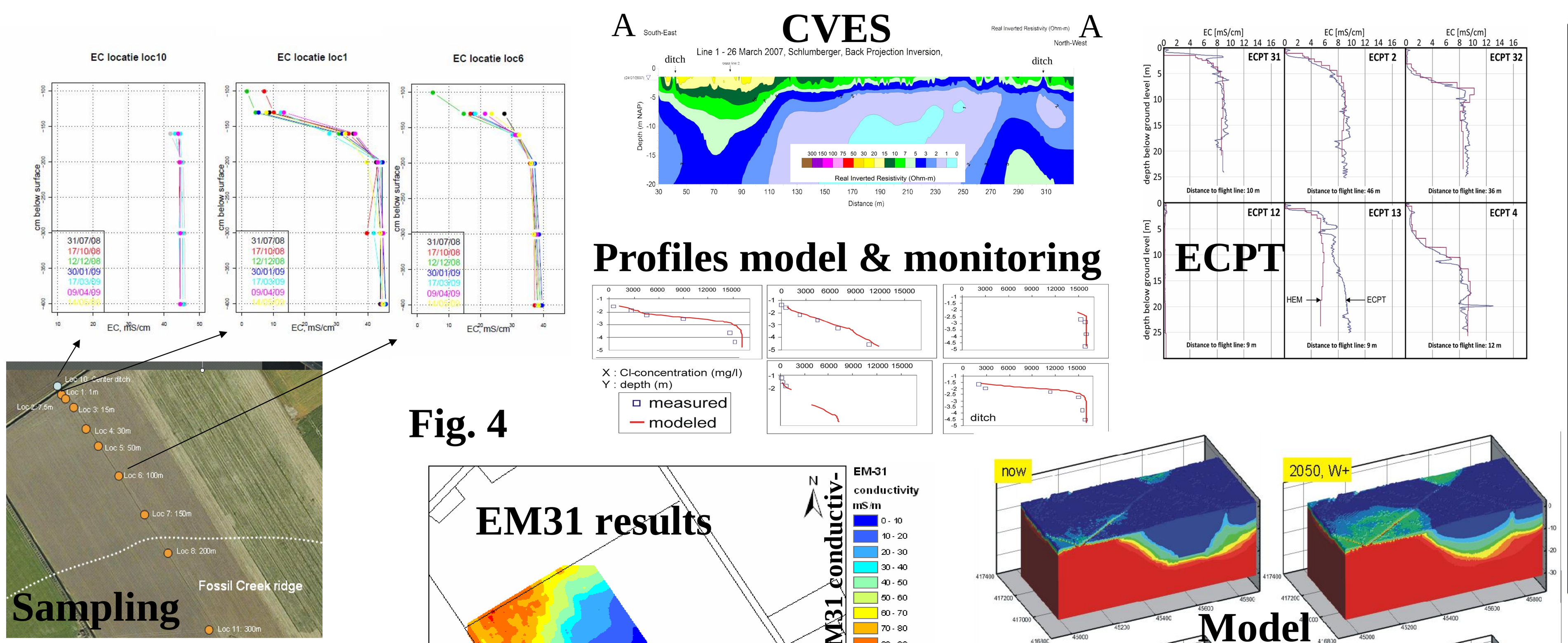


Figure 3: The shortage of fresh (ground)water resources is a worldwide problem, especially in the coastal zone with saline groundwater close by.

Case Schouwen-Duiveland: verification

Various techniques are combined on Schouwen-Duiveland in the Province of Zeeland (Fig. 2) to determine the fresh-brackish-saline groundwater distributions. It is very suspicious but here we think we have a beautiful fit between different types of geophysical techniques (TEC, CVES, EM31, electrical CPT), samples groundwater, Helicopter EM (conductivity at 4 m below sea level) and a 3D numerical model. We see that the thickness of a thin fresh water lens largely varies over small distances (Fig. 4).





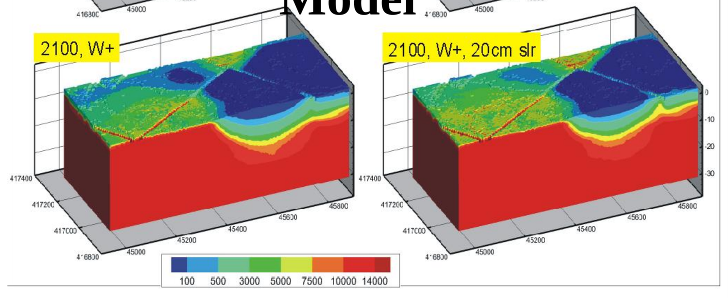


Figure 4: Many techniques the depth of the fresh–saline interface at a local scale in Zeeland.

Case Northwest Friesland

Both HEM and Sky-TEM is used in the Friesland case (Fig. 2). The flying lines are shown in Figure 5. Figures 6 and 7 show the spatial distribution of fresh, brackish and saline groundwater. This distribution is used in the variable-density modelling. The impact of sea level rise on fresh groundwater resources is simulated, using the code MOCDENS3D (Faneca *et al.*, 2012).

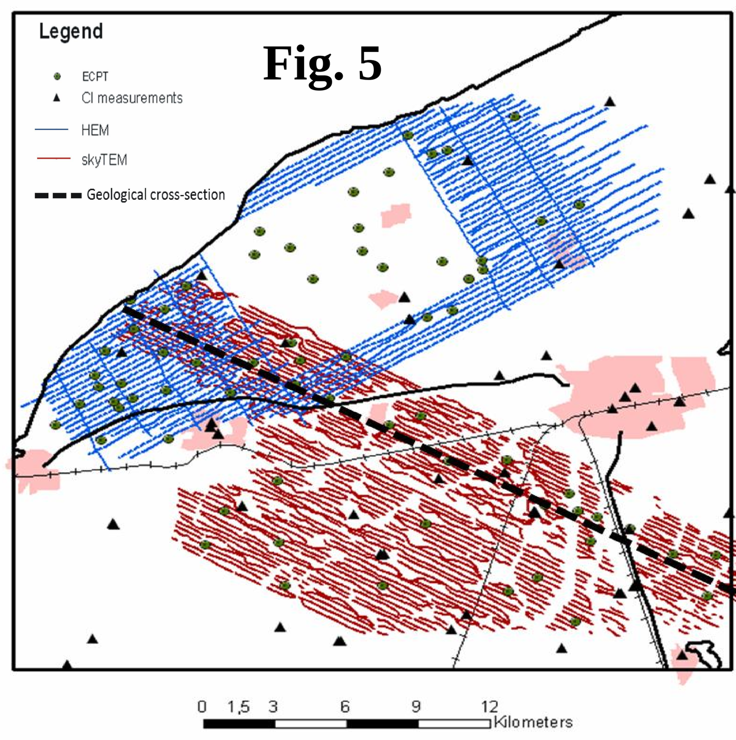


Figure 5: Flying lines of both the HEM and SkyTEM method in North-westFriesland.

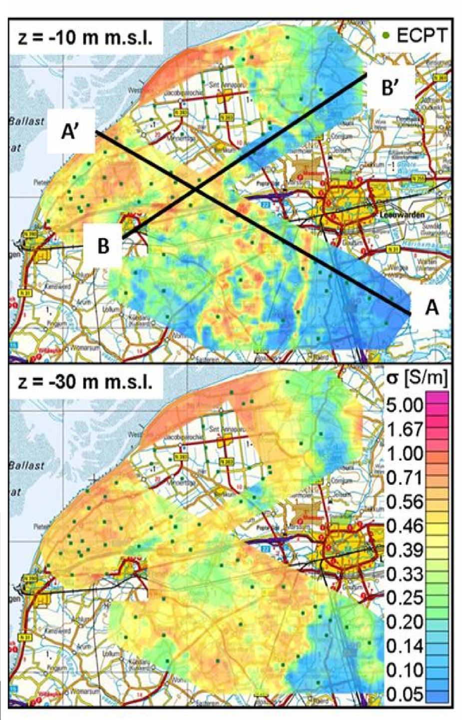
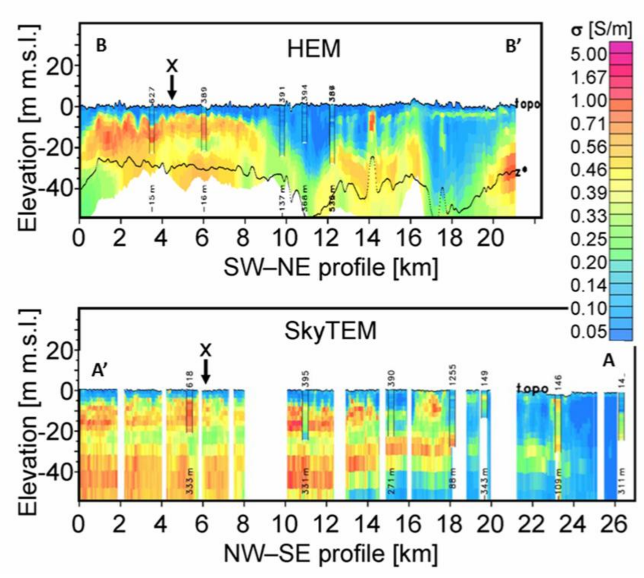


Figure 6: Depth slices and cross-sections of EC (total) from the AEM models.



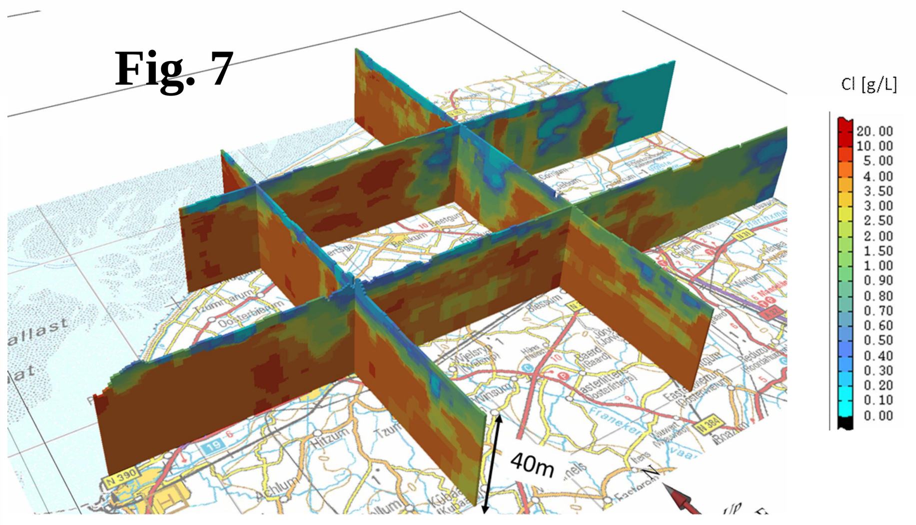


Figure 7: 3D chloride distribution field in the study area obtained after the interpolation of the measurements.

Detailed modelling: the next step

3D variable-density groundwater and salt transport models predict the possible effects of climate change, sea level rise and human activities such as adaptive strategies on the availability of fresh groundwater resources. Incorporating all these different (innovative) techniques will, in the end, lead to a more sustainable fresh groundwater management.

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