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

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. 1). 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. 1). Traditional monitoring is labor-intensive and is very time-consuming. As an alternative, airborne geophysical methods are cheap ways of collecting data and can cover large areas in a short time span.

Airborne salinity and lithology detection

Airborne Electromagnetic (AEM) 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. 3). 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 an 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 groundwater sampling, borelogs, CVES, TEC, CVES and EM31.

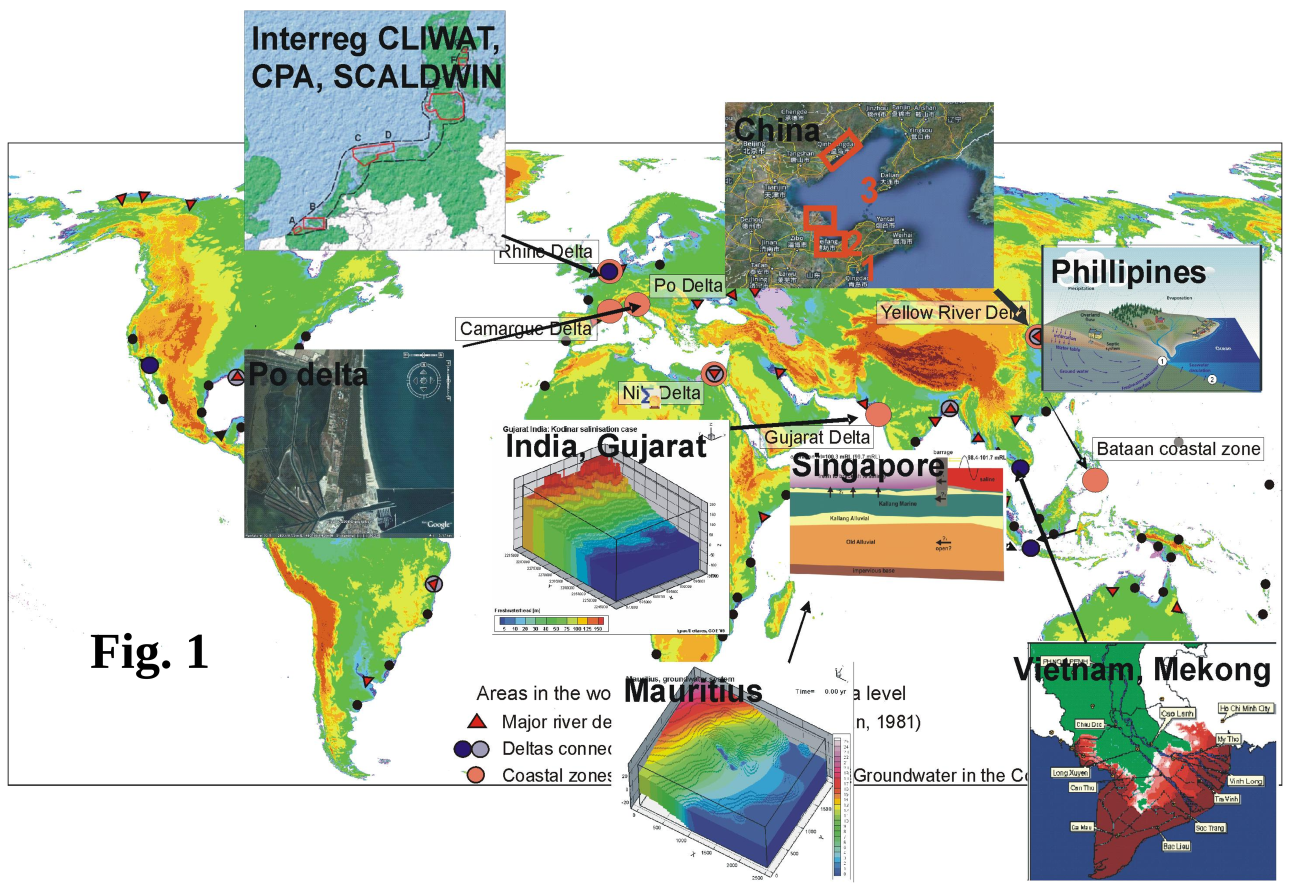


Figure 3: The shortage of fresh (ground)water resources is a worldwide problem, especially in the coastal zone with saline groundwater close by.

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 Fryslân, Schouwen-Duiveland and Perkpolder.

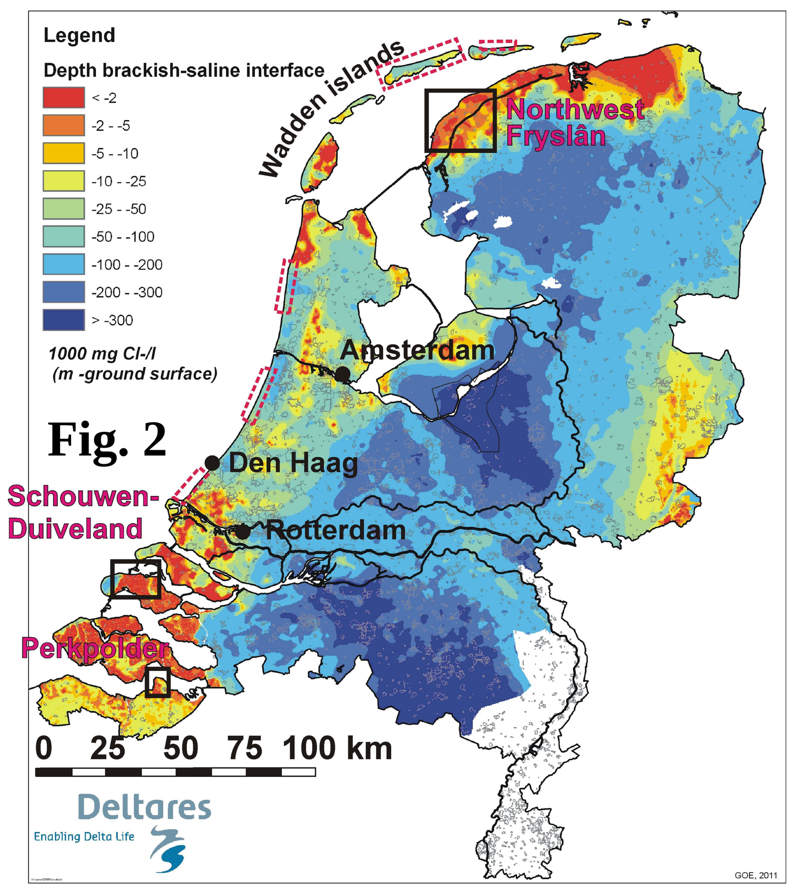


Figure 2: The three investigated pilot areas. Additional AEM-activities are taking place along the coast of Ameland, Terschelling and drinkwater companies (PWN, Waternet and Dunea).

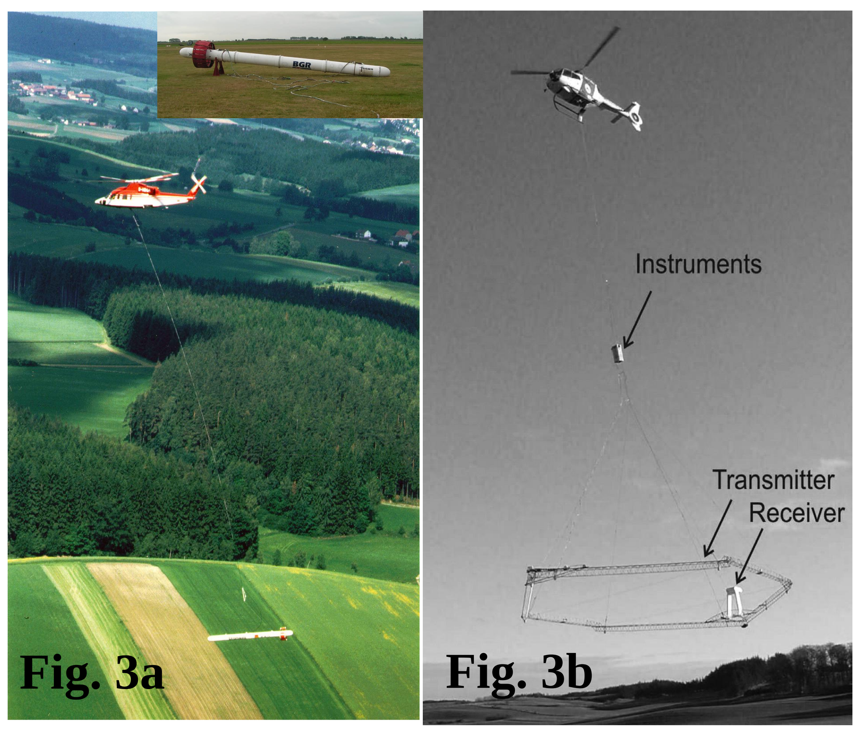


Figure 3. Helicopter-borne geophysical systems: a: BGR system recording simultaneously frequency-domain electromagnetic, magnetic and radiometric data , b: SkyTEM system recording time-domain electromagnetic data.

Case Northwest Fryslân

Both HEM and Sky-TEM is used in the Fryslân (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).

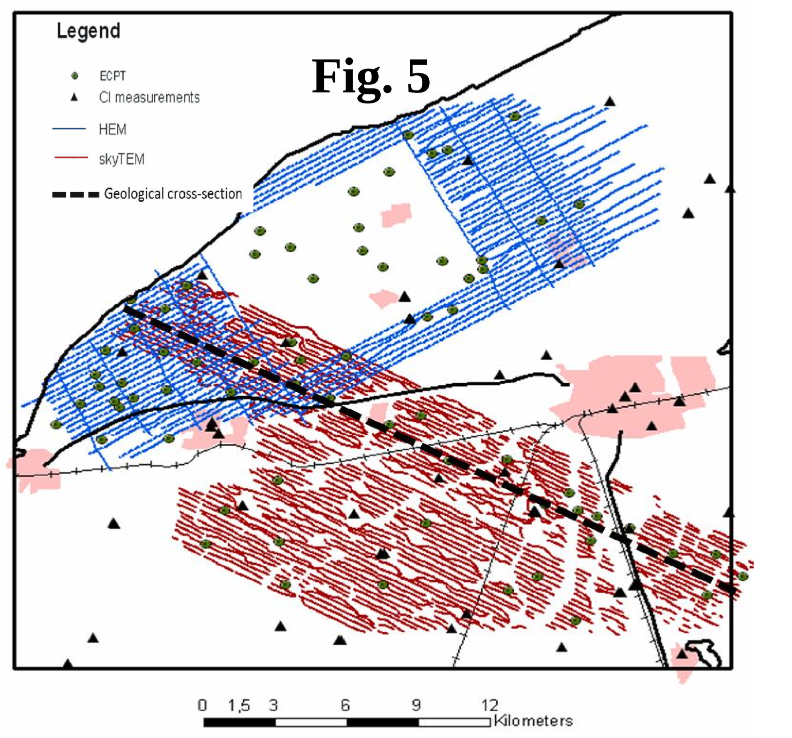
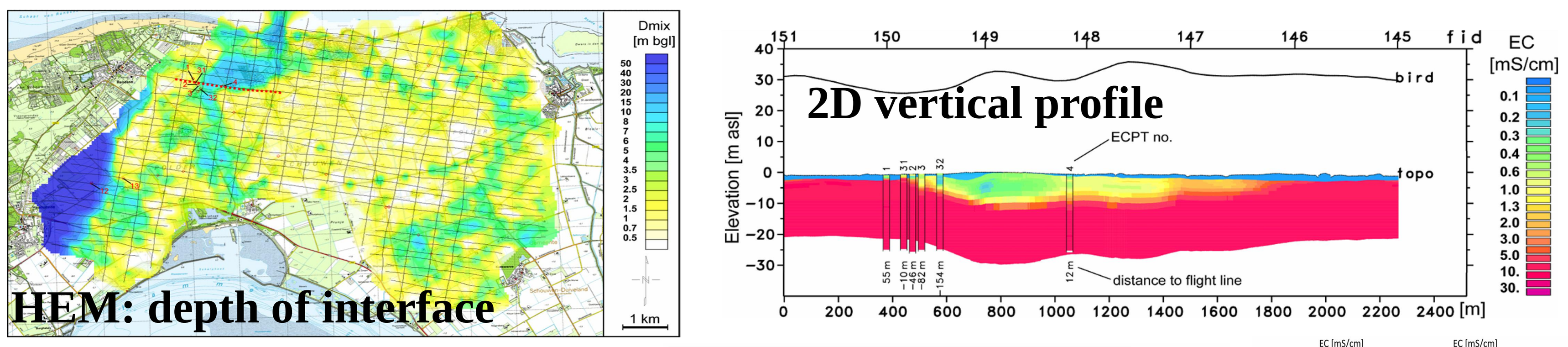


Figure 5: Flying lines of both the HEM and SkyTEM method in Northwest Fryslân.

Case Schouwen-Duiveland, Zeeland

Various techniques are combined (Fig. 2) to determine the fresh-brackish-saline groundwater distributions. It is very 'suspicious' but we think we have a beautiful fit between different types of geophysical techniques (TEC, CVES, EM31, ECPT), groundwater samples, Helicopter EM (depth of the interface) and a 3D numerical fresh-salt model. We see that the thickness of a thin fresh water lens largely varies over small distances (Fig. 4).



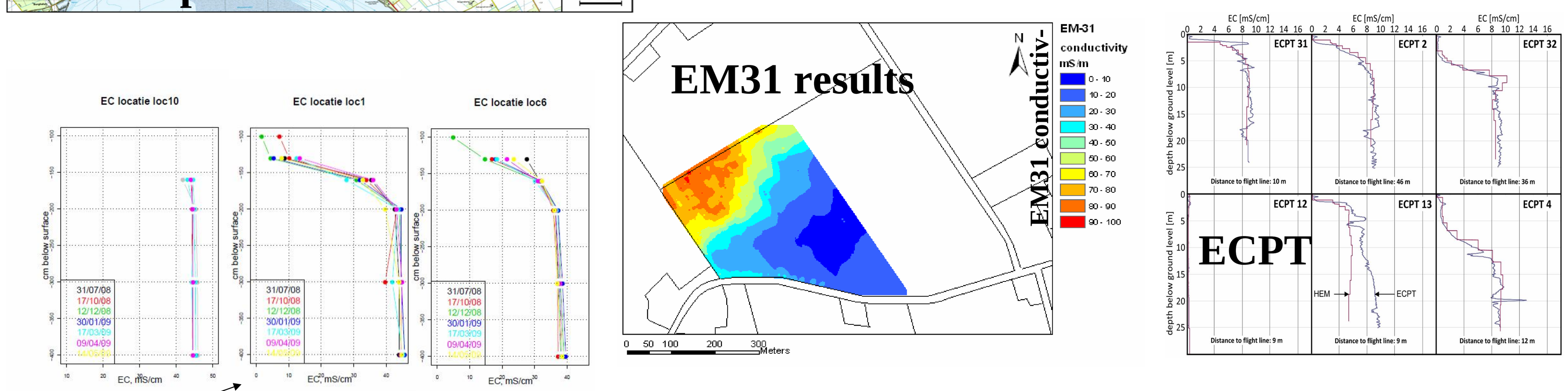
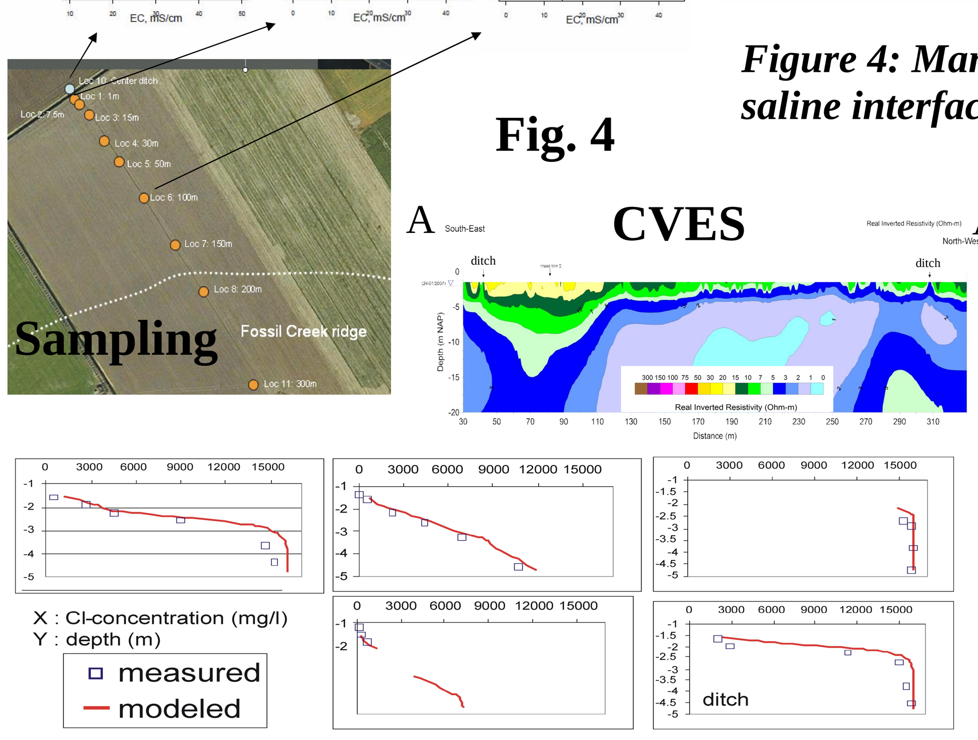
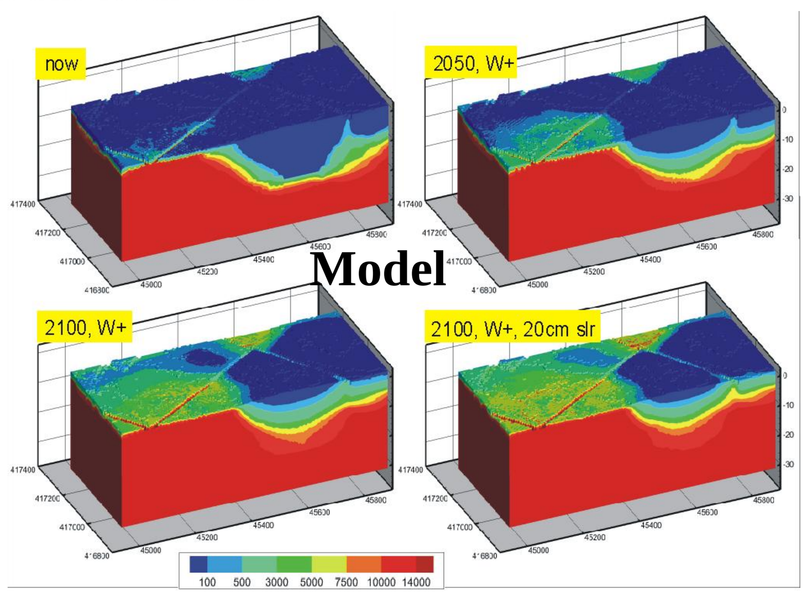
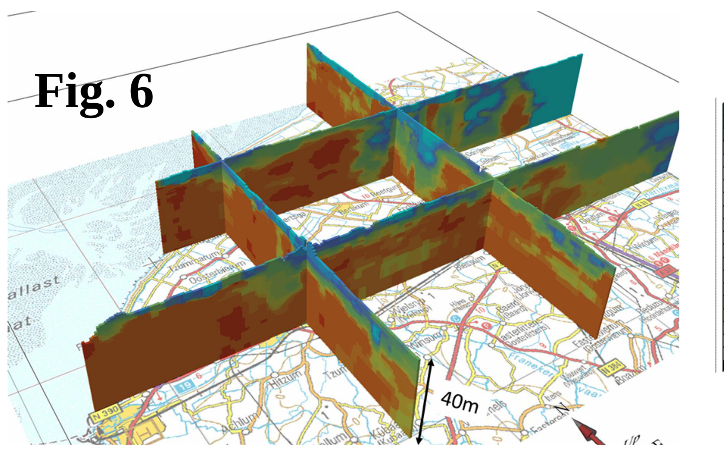


Figure 4: Many techniques determine the depth of the fresh–saline interface at this local scale.





Profiles model & monitoring



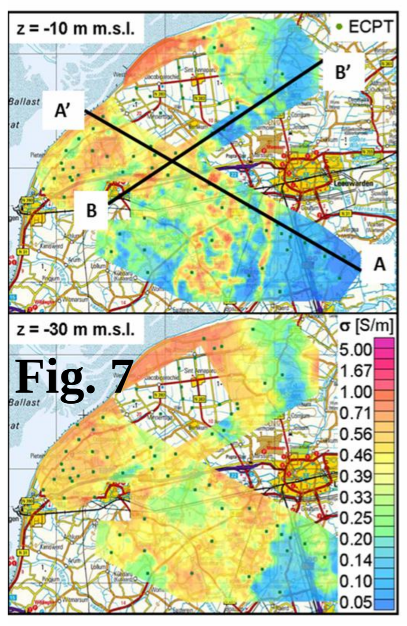
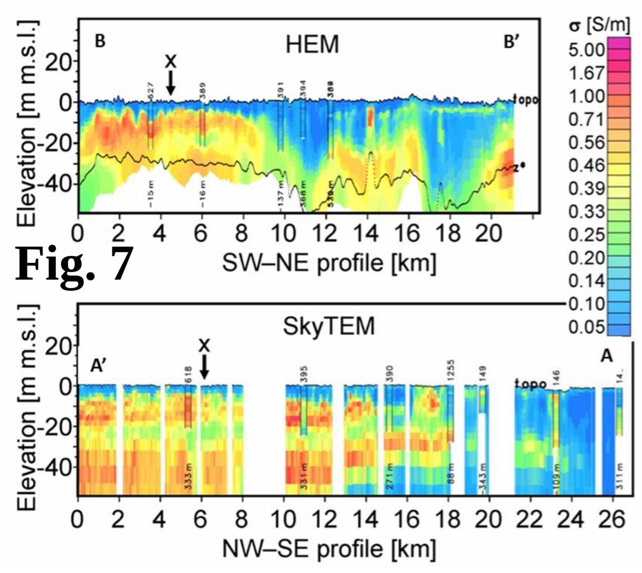


Figure 6: 3D chloride distribution field in the study area obtained after the interpolation of the measurements.

Figure 7: Depth slices and cross-sections of the Electrical Conductivity from the AEM models.



Water management strategies: the next step

The models will predict the effects of climate and global change. The next step is to develop water management strategies to assure the availability of fresh groundwater resources for the future. Right now, different innovative methods are implemented in pilot studies that will, in the end, lead via upscaling to a more sustainable fresh groundwater management for entire regions.

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References:

- Faneca Sànchez, M., Gunnink, J., van Baaren, E.S., Oude Essink, G.H.P., Elderhorst, W., de Louw, P.G.B., Simon, B., Auken, E. Modelling climate change effects on a Dutch coastal groundwater system using airborne Electro Magnetic measurements, submitted to Hydrol. Earth Syst. Sci. Discuss.
- Pauw, P., Louw, P.G.B., de, Oude Essink, G.H.P. 2012 Groundwater salinization in the Wadden Sea area of the Netherlands; quantifying the effects of climate change, sea level rise and anthropogenic interferences, accepted in Netherlands Journal of Geosciences.
- Louw, P.G.B., de, Eeman, S., Siemon, B., Voortman, B.R., Gunnink, J., Baaren, E.S., van and G.H.P. Oude Essink, Shallow rainwater lenses in deltaic areas with saline seepage, Hydrol. Earth Syst. Sci. Discuss., 8, 7657-7707, 2011.
- Goes, B.J.M., Oude Essink, G.H.P., Vernes, R.W. and Sergi, F. 2009. Estimating the depth of fresh and brackish groundwater in a predominantly saline region using geophysical and hydrological methods, Zeeland, the Netherlands, Near Surface Geophysics 401-412.

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