www.cliwat.eu

CLIWAT

Transnational project about climate change and coastal groundwater in the North Sea Region

Bold=present at SWIM21

Esben Auken[10], Aleid Bosch[4], **Carolien Courtens**[3], Wilbert Elderhorst[5], Jan Gunnink[4], **Klaus Hinsby**[7], Joca Jansen[6], Rolf Johnsen[11], **Arjen Kok**[2]
Luc Lebbe[3], **Perry de Louw**[1], Rik Noorlandt[1], **Gualbert Oude Essink**[1], Jes Pedersen[11], Per Rasmussen[7], Wolfgang Scheer[12], Bernhard Siemon[9]
Torben Sonnenborg[7], **Hans Sulzbacher**[8], Angelika Ullmann[9], **Alexander Vandenbohede**[3], **Helga Wiederhold**[8]

1 Deltares, Subsurface and Groundwater Systems, Utrecht, The Netherlands
2 Vitens, Leeuwarden, The Netherlands
3 Ghent University, Geology and Soil Science, Belgium
4 TNO, Utrecht, The Netherlands
5 Province of Fryslan, Leeuwarden, The Netherlands
6 Wetterskip Fryslan, Leeuwarden, The Netherlands
7 GEUS, Copenhagen, Denmark
8 Leibniz Institute for Applied Geophysics, Hannover, Germany
9 Federal Institute for Geosciences and Natural Resources, Hanover, Germany
10 University Aarhus, Denmark
11 Region Midtjylland, Denmark
12 Landesamt für Landwirtschaft, Umwelt und ländliche Räume Schleswig-Holstein, Flintbek, Germany

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

INTRODUCTION

CLIWAT is a transnational project in the North Sea Region with the main objective to evaluate the physical and chemical impacts of climate change on (coastal) groundwater and surface water systems, and to provide a sound knowledge base for adaptive and sustainable water management and infrastructure. Seventeen institutes from Denmark, Germany, The Netherlands and Belgium work together in this project.

METHODS

For this SWIM, we focus on the topic of salt water intrusion. We merge common existing techniques with new innovative methods such as HEM and SkyTEM data (Fig. 2) (Siemon *et al.,* 2009). In the determination of the fresh-brackish-saline groundwater distributions, numerous techniques are combined (e.g. Goes *et al.*, 2009), such as groundwater sampling, geophysical borehole logging, electrical CPT, HEM, EM31, EM34, VES, CVES, GPR and TEC probe data (see Fig. 4 and 5). Furthermore, groundwater dating is applied to support the evaluation of flow velocities and flow dynamics in and around fresh–saline water mixing zones, and pumping- and slug tests are used to estimate the hydraulic parameters of the investigated systems, which is used as input for the groundwater flow models. In addition, variable-density groundwater flow and coupled salt transport at different sites in the area are modelled to assess future changes in the groundwater system (Fig. 3). Different variable density groundwater flow and coupled solute transport modelling tools are used (e.g. MOCDENS3D, SWI, SEAWAT and FEFLOW).

SOME PRELIMINARY RESULTS

In this poster we demonstrate preliminary results of several pilot areas in Germany, The Netherlands and Belgium.

Fig. 1

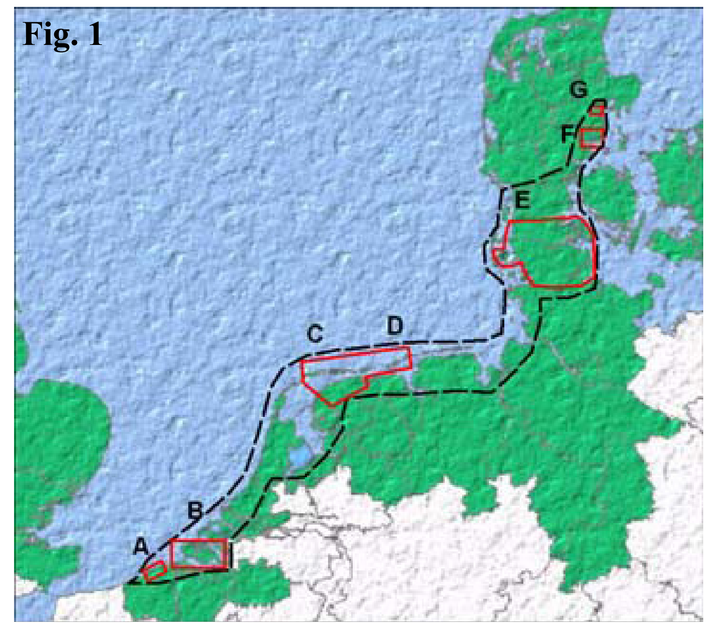

Figure 1: The investigated pilot areas of the CLIWAT project within the Interreg North Sea Region. Salt water intrusion is the main subject in the pilot areas A, B, C and D.

North Sea island, Germany (D, E)

Airborne electromagnetic measurements with HEM (North Sea island Borkum) or SkyTEM (North Sea island Föhr) give 3D ideas of the distribution of fresh, brackish and saline groundwater. This is locally verified by various ground-based measurements (geoelectrical methods, ground penetrating radar, magnetic resonance soundings, drillings, logging, etc). On Föhr, structural constraints are also achieved by reflection seismic surveys. On Borkum, two vertical electrode chains at a depth of 50 to 70 m monitor changes in the saltwater/freshwater transition zone. The integration of the data into 3D geological and variable-density groundwater flow and coupled solute transport models is still in progress...

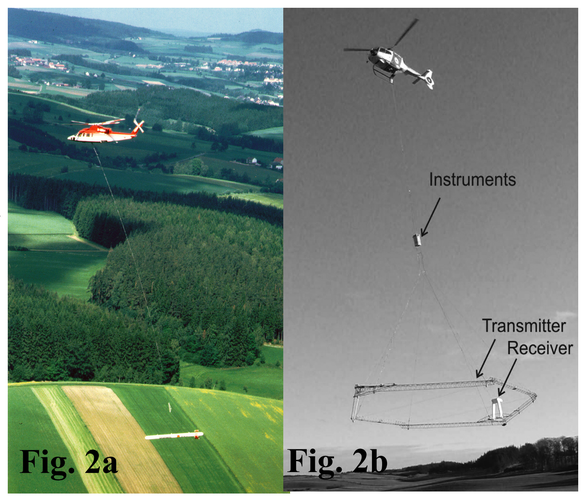

Figure 2. Helicopter-borne geophysical systems: Left: BGR system recording simultaneously frequency-domain electromagnetic, magnetic and radiometric data, Right: SkyTEM system recording time-domain electromagnetic data.

De Haan, Belgium (A)

The impact of sea level rise on fresh groundwater resources is simulated in the Belgian coastal plane, using codes as SWIFLEC3D and MOCDENS3D.

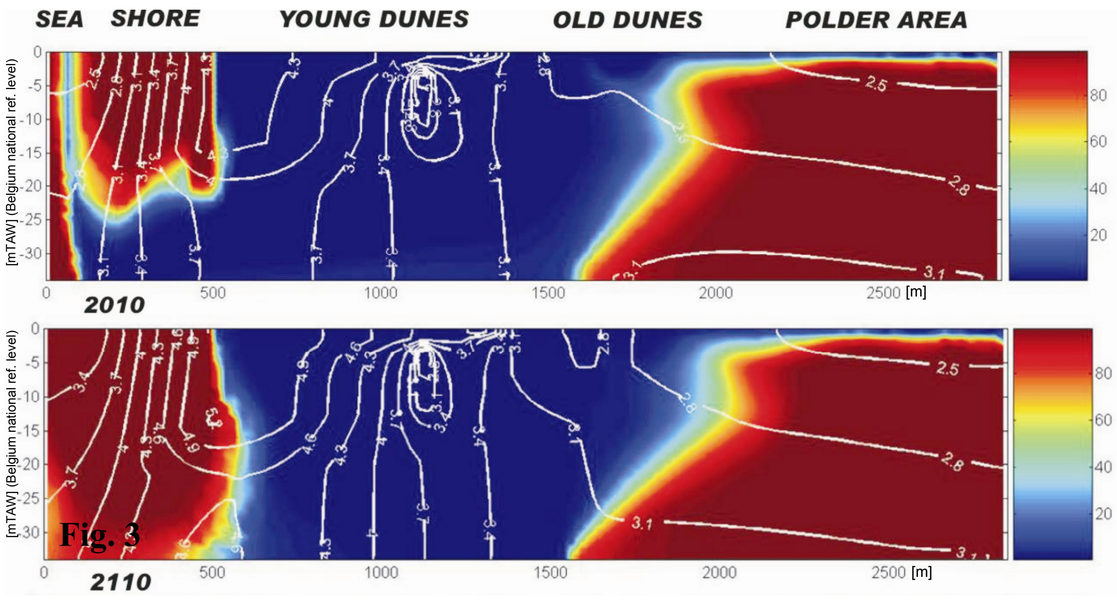

Figure 3: Simulated evolution of the fresh-salt water distribution in north-south cross-section near the village of De Haan. Colors represents the salt water percentage (0% is fresh water with TDS = 500 mg/l, 100% is salt water with TDS = 28 g/l). White contour lines are fresh water heads in mTAW (Belgium national reference level).

Zeeland, The Netherlands (B)

The results of a small-scale ground-geophysical EM31 survey in Zeeland are compared with a small portion of a larger-scale HEM survey (Fig. 4). The larger number of frequencies used the HEM data provide not only information on the lateral conductivity distribution but also on vertical conductivity changes such as the freshwater-saltwater interface.

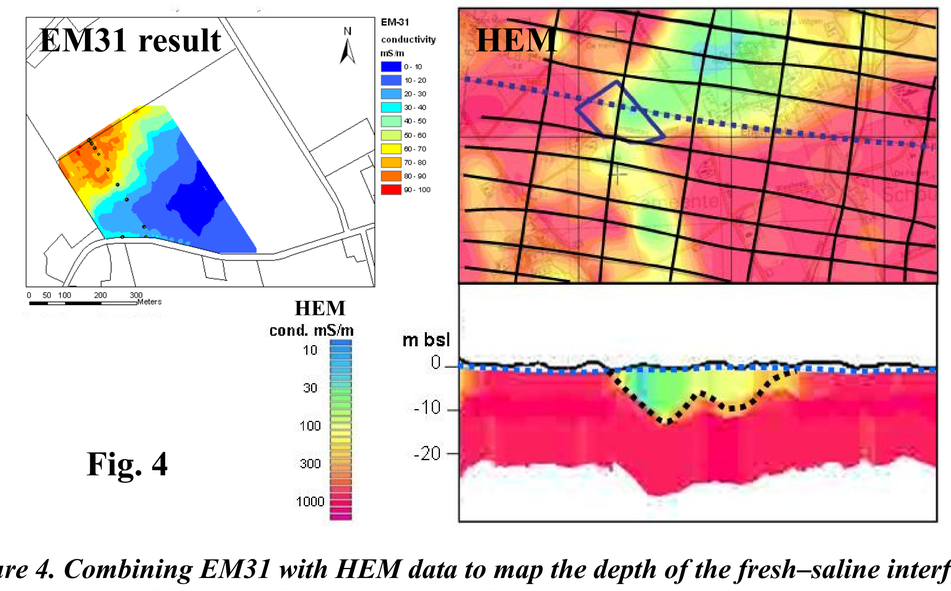

Fig. 4

The map to the left shows the EM31 results and the map to the right the HEM conductivity at 4 m below sea level and the flight-line net.

Figure 4. Combining EM31 with HEM data to map the depth of the fresh–saline interface at a local scale in the Province of Zeeland, The Netherlands. The dotted line marks the location of the HEM cross-section that clearly reveals the groundwater table (blue dots) and the freshwater-saltwater interface (black dots).

Terschelling, The Netherlands (C)

The result of a CVES survey on the island of Terschelling reveals the thickness of a freshwater layer on top of saltwater (Fig. 5). In addition, the island has also been mapped using the SkyTEM method (Fig. 2b). Not only the fresh-salt water boundary below the island is mapped but also clear evidence of fresh groundwater outflow ('*Submarine Groundwater Discharge*') to the North Sea is detected several hundreds of meters from the coast line.

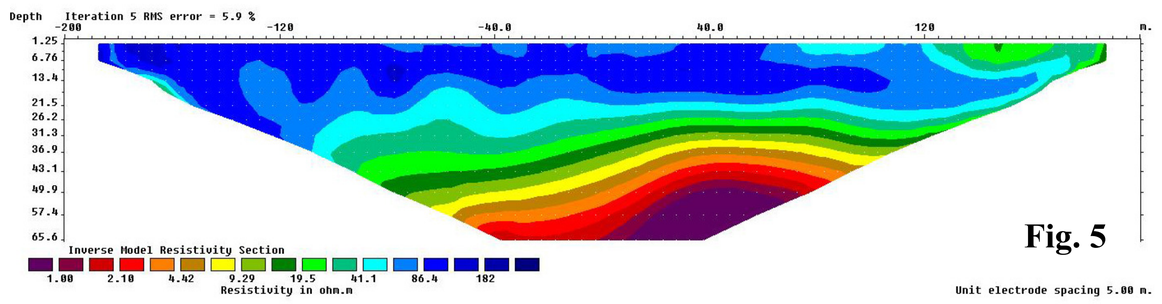

Fig. 5

Contact information:
Gualbert Oude Essink,
Deltares, Subsurface and Groundwater Systems
PO Box 85467
3508 AL Utrecht, The Netherlands
+31-6-30550408
gualbert.oudeessink@deltares.nl

References:

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