CLIWAT: a transnational project about climate change and coastal groundwater in the North Sea Region.

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ABSTRACT

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 groundwater and surface water systems, and to provide data for adaptive and sustainable water management and infrastructure. Seventeen institutes from Denmark, Germany, The Netherlands and Belgium work together in this project. For this SWIM, we focus on salt water intrusion and upconing of saline groundwater from old marine deposits. We will present tools and methods which are used to increase our knowledge of the present physical system and to assess future changes in coastal groundwater systems.

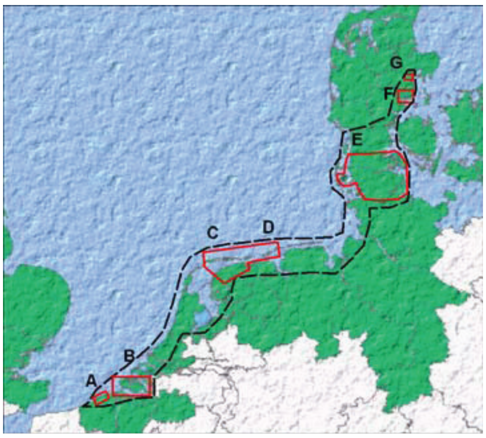

Figure 1. The investigated pilot areas of the CLIWAT project (www.cliwat.eu) within the Interreg North Sea Region. Salt water intrusion is the main subject in the pilot areas A, B, C and D.

INTRODUCTION

Within CLIWAT, different kinds of monitoring methods are combined to better understand the relevant subsurface processes in the coastal zone and to map the present status of the coastal (ground) water systems. In addition, sophisticated numerical modelling tools are used to assess impacts of future climate change and sea level rise.

METHODS

The CLIWAT project merges common existing techniques with new innovative methods such as HEM (Figure 2) and SkyTEM data (Siemon *et al.,* 2009). Especially in the determination of the fresh-brackish-saline distributions in the groundwater system, numerous techniques are combined (e.g. Goes *et al.*, 2009), such as groundwater sampling and analysis, geophysical borehole logging, electrical CPT, HEM, EM31, EM34, VES, CVES, GPR and TEC probe data (see Figures 3 and 4). Furthermore, groundwater dating is applied to support the evaluation of flow velocities and flow dynamics especially in and around fresh – saline water mixing zones, and pumping and slug tests are used in a few cases 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 is modelled to assess future changes in the groundwater system (Figure 5). Different modelling tools such as MOCDENS3D, SWI, SEAWAT and FEFLOW are used.

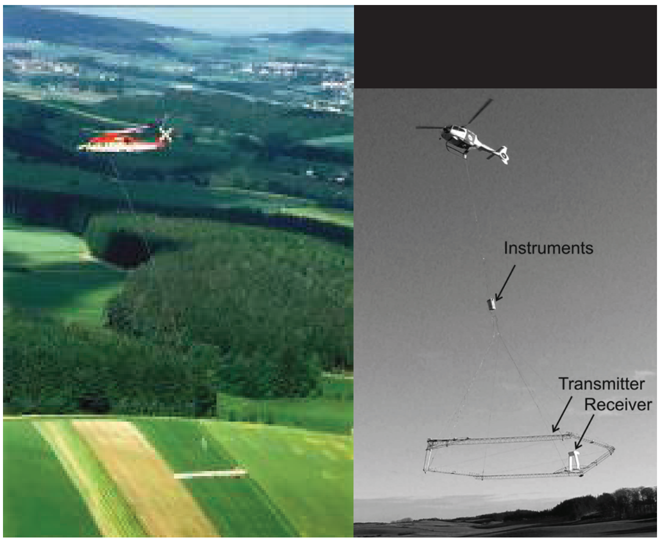

Figure 2. Helicopter-borne geophysical systems: Left: BGR system recording simultaneously frequency-domain electromagnetic, magnetic and radiometric data, Right: SkyTEM system recording time-domain electromagnetic data.

SOME PRILIMINARY RESULTS

The pilot areas in The Netherlands are located in Friesland and Zeeland. An example for a CVES survey on the island of Terschelling is shown in Fig. 3 revealing the thickness of a freshwater layer on top of saltwater. In addition, the island of Terschelling has also been mapped using the SkyTEM method. Not only the fresh-salt water boundary below the island is mapped but also clear evidence of fresh water outflow (‘*Submarine Groundwater Discharge*’) to the North Sea is detected several hundred meters from the coast line.

In Fig. 4 the results of a small-scale ground-geophysical EM31 survey in Zeeland are compared with a small portion of a larger-scale HEM survey. Due to 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.

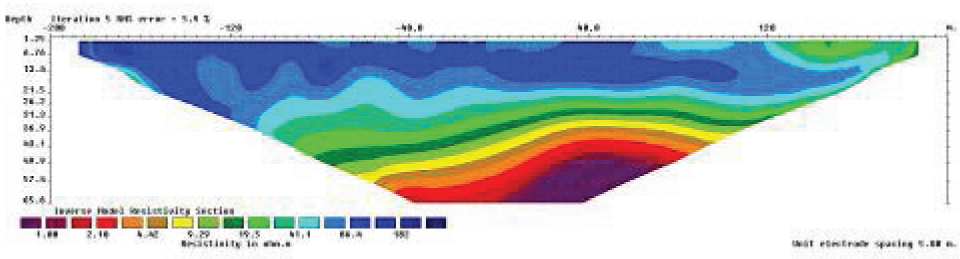

Figure 3. CVES measurements at Terschelling, The Netherlands.

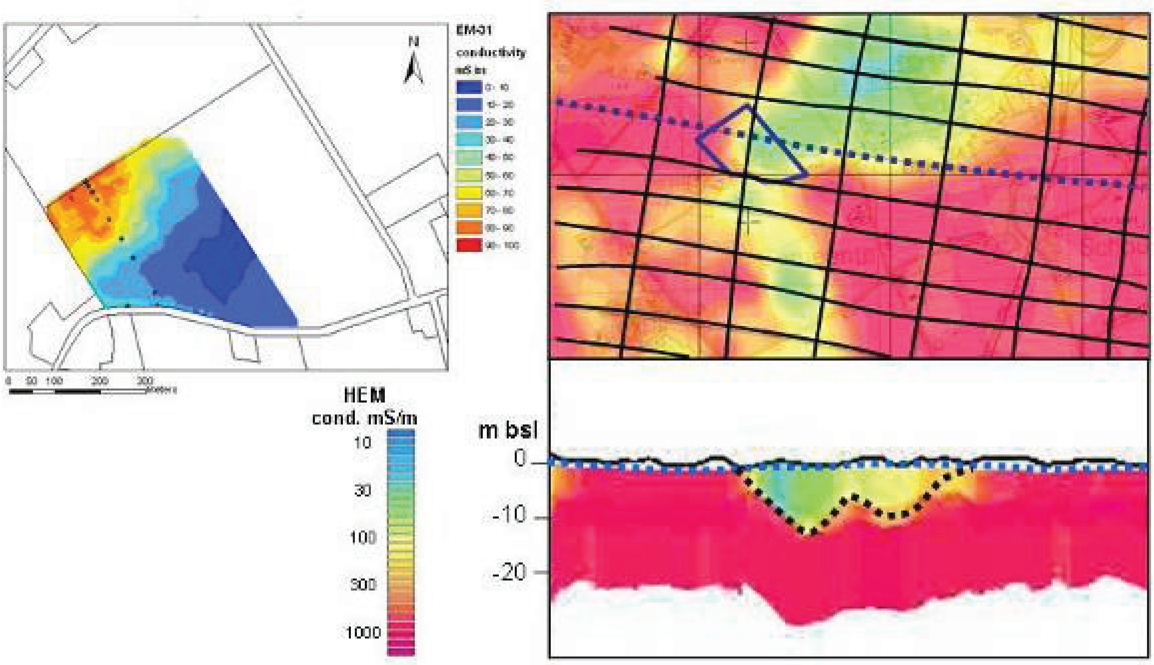

Figure 4. Combining EM31 with HEM data to map the depth of the fresh – saline interface at a local scale in the Province of Zeeland, The Netherlands. The left-hand map shows the EM31 results and the right-hand map the HEM conductivity at 4 m below sea level and the flight-line net. The dotted line marks the location of the HEM cross-section that clearly reveals the groundwater table (blue dots) and the freshwater-saltwater interface (black dots).

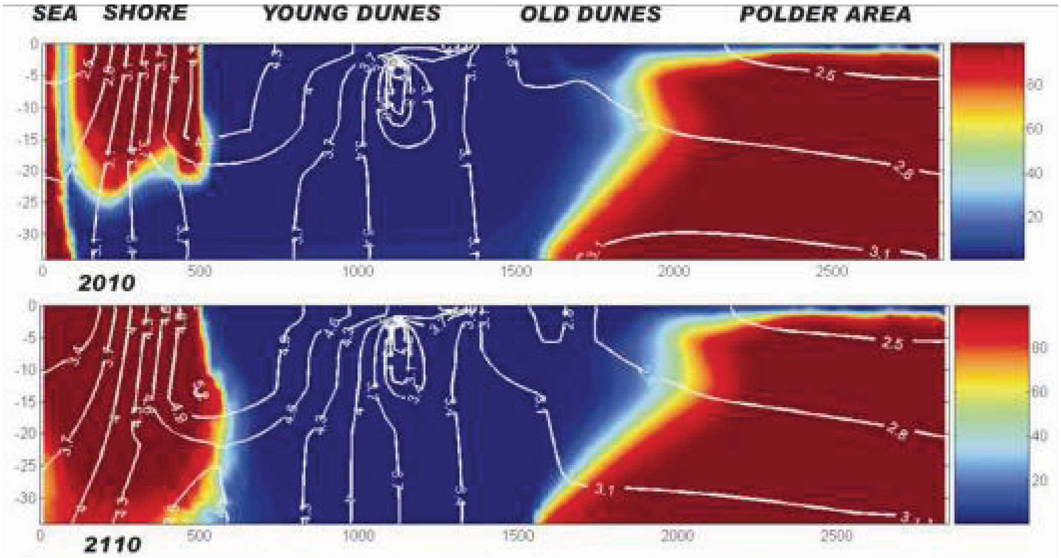

Figure 5: Simulated evolution of the fresh-salt water distribution in north-south cross-section near the village of De Haan, at the coast of Belgium. Colors represents the salt water percentage (0% is fresh water with TDS = 500 mg/l, 100% is salt water with TDS = 28 g/l). White contour lines are fresh water heads in mTAW (Belgium national reference level). On vertical axis level in mTAW and horizontal axis is distance in m.

In Germany, the North Sea islands Borkum and Föhr are in the focus of investigation. Airborne electromagnetic measurements with HEM (Borkum) or SkyTEM (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 in about 50 m to 70 m depth 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.

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This project is co-financed by the European Union

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