

Saltwater intrusion under climate change in North-Western Germany - mapping, modelling and management approaches in the projects TOPSOIL and go-CAM

Helga Wiederhold¹, Wolfgang Scheer², Reinhard Kirsch³, M. Azizur Rahman¹ and Mathias Ronczka¹

¹Leibniz Institute for Applied Geophysics (LIAG), Hannover, Germany

²State Agency for Agriculture, Environment and Rural Areas Schleswig-Holstein (LLUR), Flintbek, Germany

³Institut of Geosciences, University of Kiel, Germany

ABSTRACT

Climate change will result in rising sea level and, at least for the North Sea region, in rising groundwater table. This leads to a new balance at the fresh–saline groundwater boundary and a new distribution of saltwater intrusions with strong regional differentiations. These effects are investigated in several research projects funded by the European Union and the German Federal Ministry of Education and Research (BMBF). Objectives and some results from the projects TOPSOIL and go-CAM are presented in this poster.

INTRODUCTION

Predicted results of climate change in the North Sea region (DK, GE, NL, BE, UK) are warmer and dryer summers and increased precipitation in the colder seasons leading to enhanced groundwater recharge and rising groundwater table (CLIWAT Working Group 2011). Additionally, a rise of sea level up to 1 m is predicted. At the coastline, this will lead to a new balance between seawater and freshwater with consequences for the saltwater intrusions. Rise in sea level will also extend the reach of saltwater in the River Elbe towards the inland. Hence, the area of influence of saltwater intrusion from the river will also extend. Size and sign of this effect can have strong regional variation and must be quantified to enable action plans to ensure sufficient freshwater for the human population, agriculture and industry.

Investigations of future development of saltwater intrusions in the North Sea regions started 2008 with the EU INTERREG IVB North Sea project CLIWAT and 2013 with the German government funded project NAWAK. Focus areas were the coastal region of Lower Saxony and the North Sea islands of Föhr and Borkum. Results were, e.g., enhanced demand for drainage and a new saltwater intrusion pattern (Burschil et al. 2012, Sulzbacher et al. 2012). Based on these results, two new projects TOPSOIL and go-CAM started in 2015 and 2017 respectively.

The TOPSOIL Project

Focus of the INTERREG VB North Sea project TOPSOIL (www.topsoil.eu) is the interaction of soil and groundwater under climate change. The TOPSOIL project considers 16 pilot areas that are located in Belgium (2 pilot areas), Denmark (4 pilot areas), Germany (5 pilot areas), the Netherlands (3 pilot areas) and the UK (2 pilot areas). In Northern Germany, aspects of seawater intrusion are investigated in 2 corresponding pilot areas in Schleswig-Holstein (GE-1: Störmarsch) and Lower Saxony (GE-2: Elbe-Weser region)

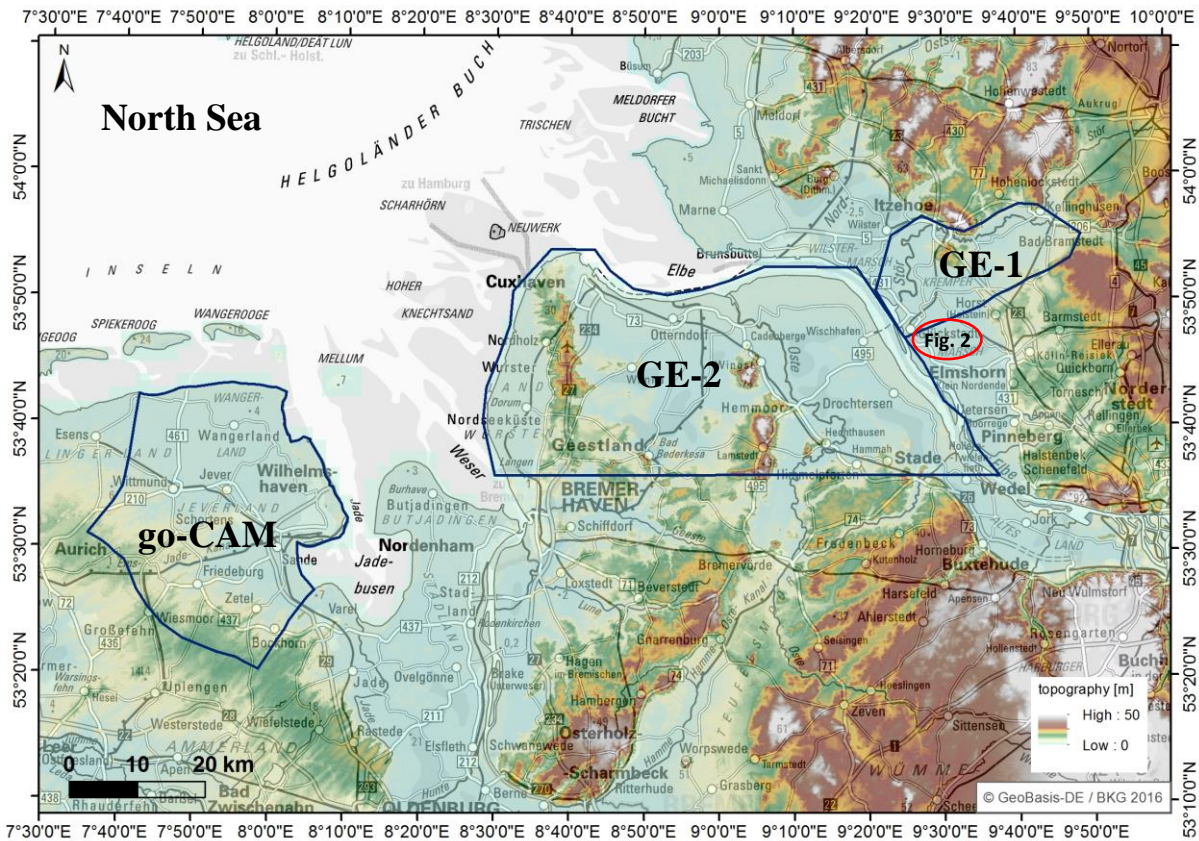


Figure 1. Location map of pilot areas GE-1 and GE-2 concerning the TOPSOIL project and the go-CAM project area. For nearly all areas HEM data are available from BGR (Siemon et al. 2014).

situated on both sides of the River Elbe (Figure 1). At these regions, saline water intrusion from the sea and from the River Elbe has been considered as the main impact on the groundwater catchment due to climate change. The drainage and irrigation channels might also play a vital role on the fresh–saline groundwater boundary development and possible upconing of saltwater into the drainage channels due to change in rainfall, groundwater recharge and groundwater gradients. These phenomena will be investigated at two different scales: local and regional. These impacts will be investigated by developing density driven groundwater models for both pilot areas. A local scale (ca. 300 km²) groundwater model has been considered for GE-1 where the process of saltwater upconing to the drainage channels will be investigated. Additionally, the intrusion of brackish water from the River Elbe due to sea level rise and river bed deepening will be analyzed. Earlier observations indicate that the deepening of the River Elbe was followed by an increased salt load of the river water. As a consequence, the groundwater in the region near the river is already brackish and might increase further towards the inland. To support the modeling activity and to monitor river-aquifer interaction, installation of a monitoring station using the vertical electrode chain SAMOS is planned (Grinat et al. 2018). The monitoring station will be installed near the River Elbe in Glückstadt to observe the fluctuation in resistivity in the subsurface due to change in salt content of the water and water level at the river. The groundwater model will be developed by Leibniz institute for Applied Geophysics (LIAG) with support from the Geological Survey of Schleswig-Holstein (LLUR).

A regional scale (ca. 1700 km²) groundwater model has been planned for GE-2 to investigate the following: (i) saltwater intrusion from the sea due to sea level rise, (ii) saltwater intrusion

from the River Elbe due to sea level rise and river bed deepening, (iii) possibility of managed aquifer recharge to store and transport water at the Geest area (near the western coast), (iv) role of drainage and irrigation channel on the development of or change in fresh-saline groundwater boundary. The geological and hydrogeological condition of this is complex and salinity distribution in vertical and horizontal direction is non-uniform. Groundwater quality is also heterogeneous (Rahman et al. 2018). Therefore, a development of a density driven groundwater flow and transport model is a big challenge here. The groundwater model will be developed by LIAG in collaboration with the Geological Survey of Lower Saxony (LBEG).

In these regions, helicopter-borne electromagnetic (HEM) surveys were performed by the Federal Institute for Geosciences and Natural Resources (BGR) (Siemon et al. 2014). HEM data provide useful information about the subsurface properties (such as presence of clay) and salinity. Due to high data coverage and high resolution of horizontal and vertical information, HEM data is considered as one of the main source of salinity information for the groundwater model. But it is a big challenge to transform the resistivity (Ωm) information to salinity (in mg/l), due to presence of clay and saltwater who both have the property of low resistivity. Therefore, a systematic analysis technique will be developed to transform the HEM data to salinity. Challenging is also the lateral heterogeneity of the near surface covering layers (Figure 2).

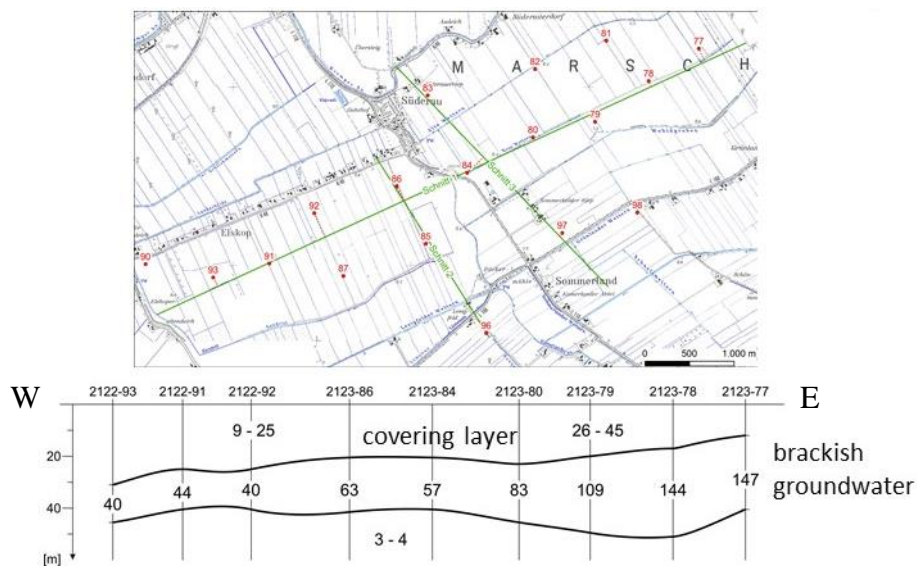


Figure 2. Vertical resistivity section (resistivity in Ωm) from vertical electrical soundings show the resistivity increase of the brackish groundwater (= decrease of salt content) with increasing distance to the river Elbe. Different electrical resistivities of the covering layer (Klei, clayey organic sediment) are caused by different clay contents with consequences for the hydraulic conductivities of this layer.

To develop the groundwater models, an integrated approach has been presented by Wiederhold et al. (2017) and a modified version is shown in Figure 3. An interdisciplinary approach, considering geological, geophysical and geochemical information has been formulated for groundwater catchment characterization (see details in Rahman et al. 2018). These information together with hydrological and meteorological information from several organizations (e.g., Germany's National Meteorological Service (DMD), Lower Saxony

department of water, coastal and nature conservation (NLWKN) etc.) facilitate to analyze and assess the coastal groundwater catchment. These information will be fed to the groundwater model that will be used afterwards to achieve the planned objectives mentioned before.

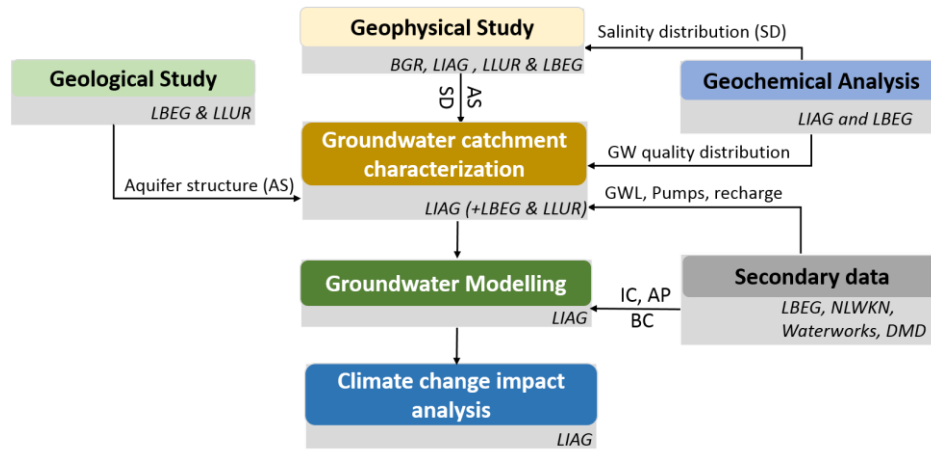


Figure 3. Integrated concept of coastal zone studies in the two pilot areas of the TOPSOIL project.

The GO-CAM project

Globally, integrated coastal zone water resources planning and management targets to develop and preserve the coastal zone as an ecologically intact and economically flourishing habitat for human taking environmental, ecological, economic, social and geo-political conditions into consideration. Active involvement of transdisciplinary actors to the planning and management of coastal zone makes the entire formal planning and decision making procedure complex. Since a few decades, the conflicts among the different actors became worse in the coastal region where climate change, sea level rise, and salinization play very vital role on the limited availability of fresh groundwater resources. Hence, proper decision making requires a contribution from transdisciplinary sciences and engineering areas (e.g., natural sciences, social science, economic analysis etc.). A multicriteria decision analysis (MCDA) tool has the ability to combine all these information and contribute to the intelligent and optimal planning for sustainable use of water resources at the coastal area.

Whereas the TOPSOIL project focuses on the development of approaches jointly to analyze the climate change impact due to sea level rise and increase in groundwater table by field investigation and model development, go-CAM project aims at the development and implementation of a multi-criteria steering instrument (coastal aquifer management, CAM) for the sustainable use of water resources in coastal areas (<https://www.tu-braunschweig.de/lwi/hywa/forschung-projekte/gocam>). This action can be considered as one step further to implementation of coastal zone groundwater management strategies.

In go-CAM partners from research and practice work together. The project is initiated by TU Braunschweig. The specific objectives of the project is: (i) development of groundwater model for some pilot area in Lower Saxony, (ii) development of MCDA tool for coastal zone water management, (iii) transfer of the dialog platform CAM developed for the project

region Northern Germany to international partner regions (such as Brazil, Turkey and South Africa).

LIAGs part are field investigations including mapping and monitoring of saltwater intrusions in the coastal region of Niedersachsen (Figure 1) in cooperation with TU Braunschweig and water supply companies (OOWV). Mapping of saltwater occurrence will be carried out with geophysical methods. As in the TOPSOIL region GE-1, monitoring of the fresh–saline groundwater boundary by the system SAMOS is planned at two locations. Density driven groundwater flow and transport modeling will be done by Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) (Schneider et al. 2018).

Acknowledgement

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REFERENCES

- Burschil T, W. Scheer, R. Kirsch, and H. Wiederhold. 2012. Compiling geophysical and geological information into a 3D model of the glacially affected island of Föhr. *Hydrol. Earth Syst. Sci.* 9(4), 5085-5119, DOI: 10.5194/hessd-9-5085-2012.
- CLIWAT WORKING GROUP (2011): Groundwater in a Future Climate - The CLIWAT Handbook. ISBN: 87-7788-265-2, Central Denmark Region, Aarhus.
http://cliwat.eu/xpdf/groundwater_in_a_future_climate.pdf
- Grinat, M., D. Epping and R. Meyer. 2018. Long-time resistivity monitoring of a freshwater/saltwater transition zone using the vertical electrode system SAMOS. 25th Saltwater Intrusion Meeting, Gdansk, this volume.
- Rahman, A.M., E. González, H. Wiederhold, N. Deus, J. Elbracht, and B. Siemon. 2018. Characterization of a regional coastal zone aquifer using interdisciplinary approach – an example from Weser-Elbe region, Lower Saxony, Germany. 25th Saltwater Intrusion Meeting, Gdansk, Poland, this volume.
- Schneider, A., H. Zhao, J. Wolf, D. Logashenko, s. Reiter, M. Howahr, M. Eley, M. Gelleszun and H. Wiederhold. 2018. Modeling saltwater intrusion scenarios for a coastal aquifer at the German North Sea. 25th Saltwater Intrusion Meeting, Gdansk, this volume.
- Siemon, B., H. Wiederhold, A. Steuer, M.P. Miensopust, W. Voß, M. Ibs-von Seht, and U. Meyer, 2014. Helicopter-borne electromagnetic surveys in Northern Germany. In Programme and Proceedings of SWIM 2014, ed Wiederhold, et al., 375-378, 23rd Salt Water Intrusion Meeting 2014, Husum, Germany.
- Sulzbacher H., H. Wiederhold, B. Siemon, M. Grinat, J. Igel J, T. Burschil, T. Günther, and K. Hinsby. 2012. Numerical modelling of climate change impacts on freshwater lenses on the North Sea Island of Borkum using hydrological and geophysical methods. *Hydrol. Earth Syst. Sci.*, 16, 3621-3643, DOI10.5194/hess-16-3621-2012.

Contact Information: Helga Wiederhold, Leibniz-Institut für Angewandte Geophysik (LIAG), Stilleweg 2, Hannover, Germany, Email: helga.wiederhold@leibniz-liag.de