Leibniz Institute for Applied Geophysics
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TOPSOIL Interreg North Sea Region

6 CLEAN WATER AND SANITATION

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


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## Motivation, concept, background

Predicted results of climate change in the North Sea region are warmer and dryer summers and increased precipitation in the colder seasons leading to enhanced groundwater recharge and rising groundwater table. 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 saltwater intrusion. 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.

In this context the projects TOPSOIL and go-CAM are initiated. To be able to manage climate consequences concerning coastal aquifers a better understanding of local and regional processes is needed wherefore numerical density driven groundwater flow models will be developed. The approach is integrated and interdisciplinary (Fig. 2; Rahman et al. 2018). A valuable database is the resistivity data from airborne electromagnetic surveys (AEM) acquired in the German coastal area since 2000 (Siemon et al. 2018a). The 3D data volume gives insight into the complex geologic structures of this glacially affected lowlands with buried valleys, glaciotectonics or saltwater intrusion. Especially the salinity distribution in horizontal and vertical direction is non-uniform and doesn't follow the coastline (Fig. 3). An example for the vertical fresh-saline groundwater boundary is given in Figure 4. For different approaches to derive the boundary from AEM data see Siemon et al. (2018b). A resistivity monitoring of this vertical zone could be a good warning system if salinity increases (see Grinat et al. 2018).

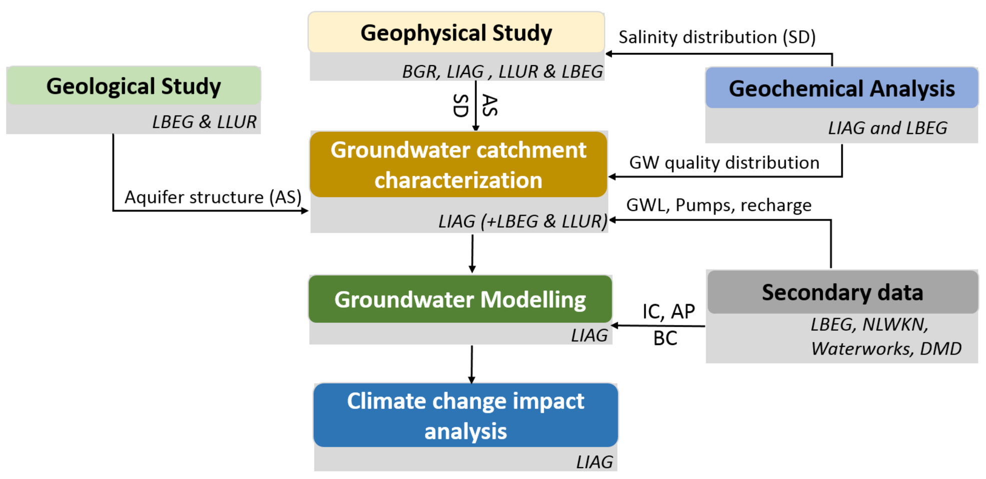



**Fig. 2** Integrated concept of coastal zone studies in the two pilot areas of the TOPSOIL project. Several organizations participate.

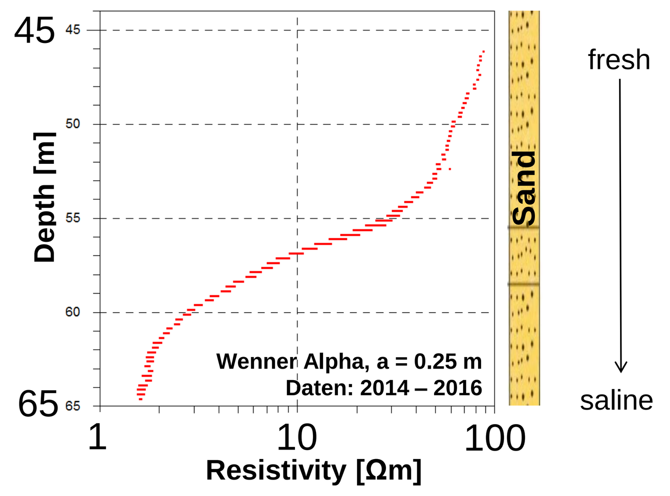



**Fig. 4** Resistivity characteristic of fresh-saline boundary in depth. Example from Borkum island (Grinat et al. 2018).

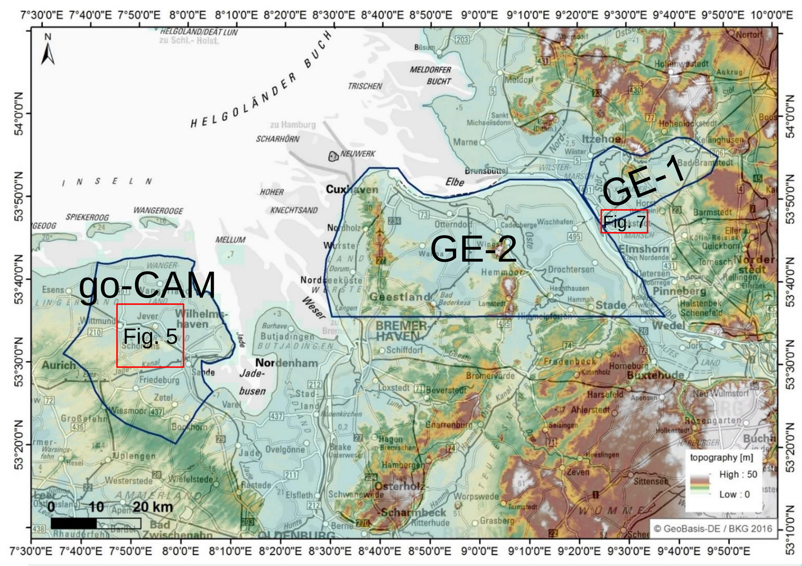
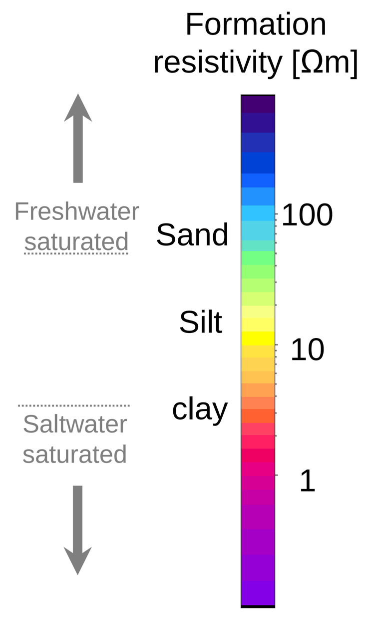



**Fig. 1** Location map of pilot areas GE-1 and GE-2 concerning the TOPSOIL project and the go-CAM project area.




Colour scale AEM data

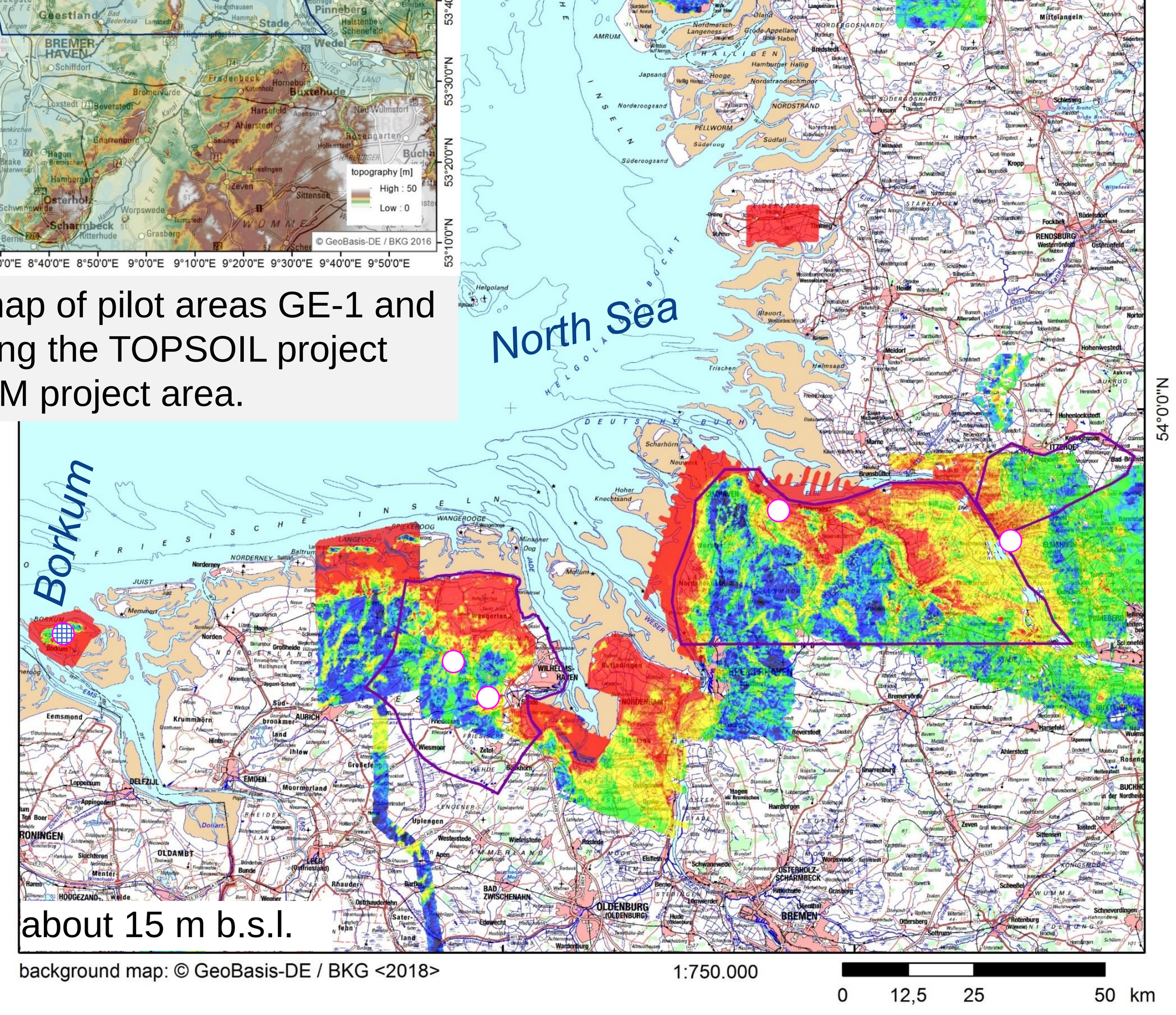



**Fig. 3** Resistivity map from **A**irborne **E**lectro**M**agnetic surveys (Siemon et al. 2018a). Very low values (red) correlate with salinization; high values (blue) with fresh-water aquifer. ○ monitoring locations under discussion; ● running monitoring.

## The go-CAM Project – current status

In the go-CAM project area a numerical density driven groundwater model is already set up (see Schneider et al. 2018). The initial condition for the salt concentration is based on the aeroelectromagnetic data. But beside the modelling with climate sensitive parameters and unknown uncertainties a monitoring of the fresh-saline groundwater boundary is desirable. Building on good experience with long-time resistivity monitoring at the island of Borkum with the vertical electrode system SAMOS (Grinat et al. 2018) we intent to install a similar system in the go-CAM area. The search for a representative location is in progress. The location should be of interest for the water supplier.

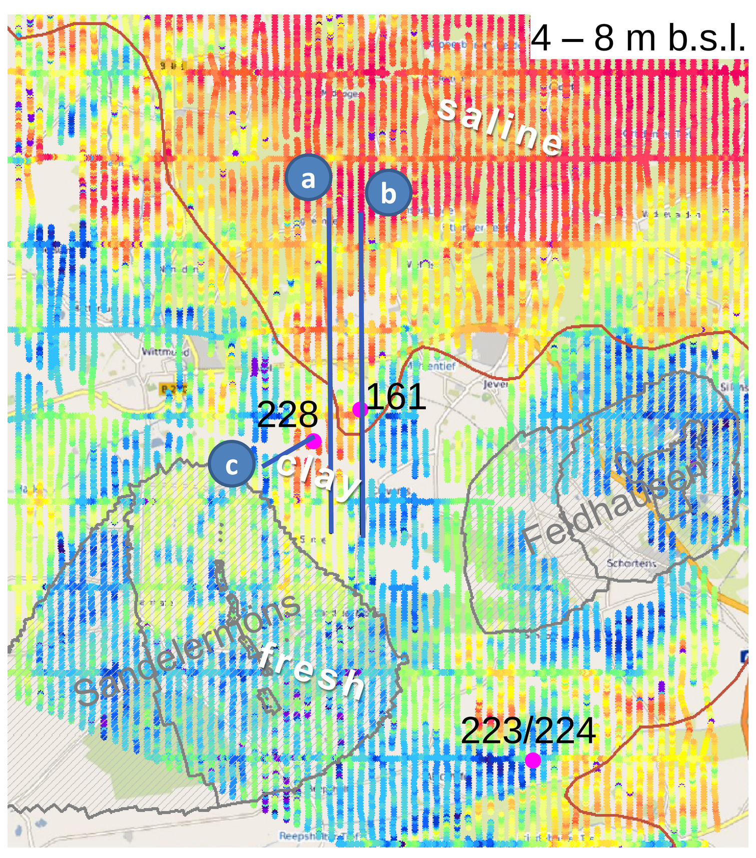



**Fig. 5** Location of interest close to catchment area ( ) of waterwork Sandelermöns: resistivity distribution obtained from AEM survey. • Groundwater observation well with increased chloride content. ~ fresh-saline groundwater boundary from 1987.

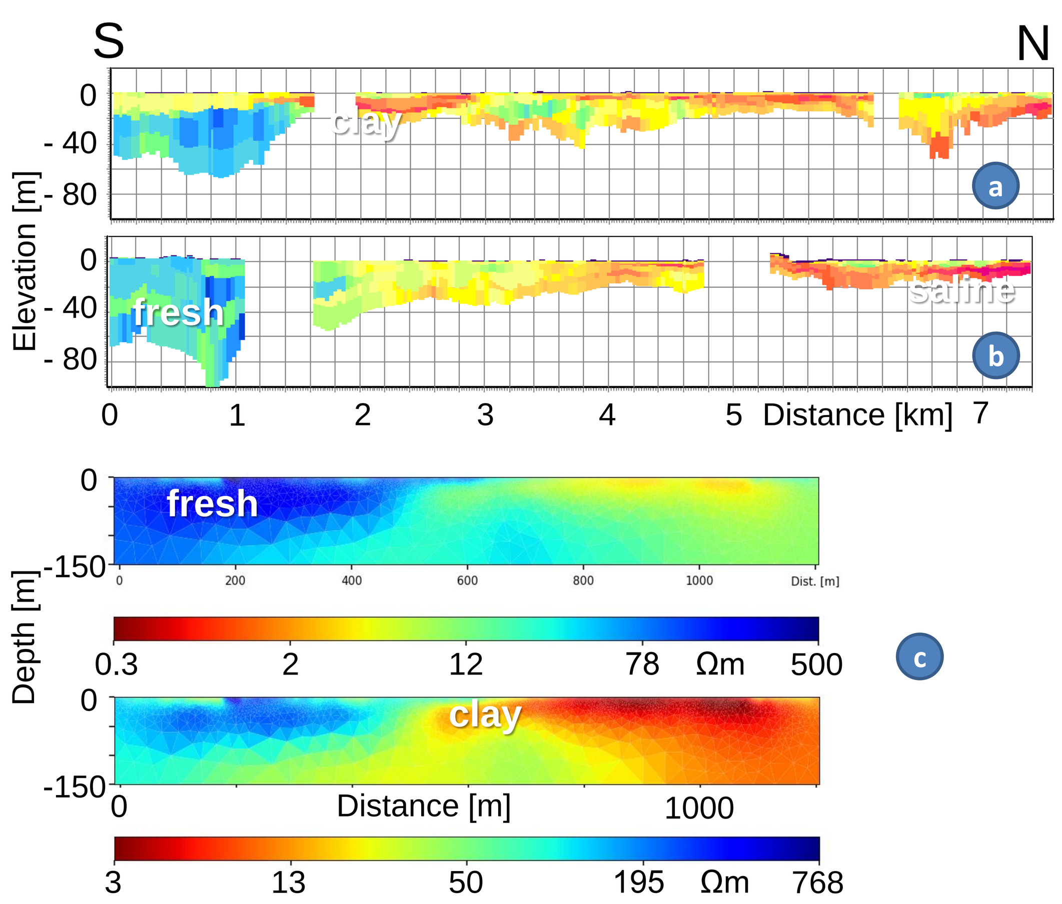



**Fig. 6** (a, b): Resistivity depth distribution obtained from AEM data. (c): resistivity depth section from a 2D Wenner measurement. The resistivity contrast supposed to represent the fresh-saline boundary is probably a clay layer or lens. (upper figure: colour scale corresponding AEM data, lower figure: colour scale adjusted to anomaly.

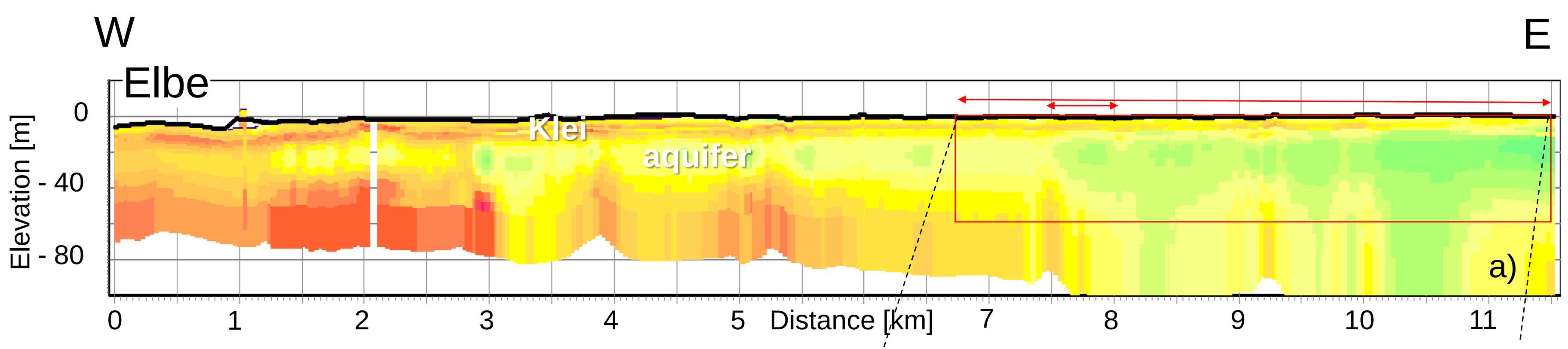
## The TOPSOIL Project – current status

Both german pilot areas of the INTERREG North Sea project TOPSOIL are situated on opposite sides of the river Elbe downstream Hamburg (Fig. 1). As a consequence of ongoing deepening of the Elbe, the salt content of the river water increases with the consequence of brackish water intrusions into the aquifers at the shoreline.

The Schleswig-Holstein part of the pilot areas (GE-1) is situated between the rivers Elbe and Stör and consists mainly of flat marsh land. The topsoil layers are built up by up to 30 m of silty marine sediments called Klei with low hydraulic conductivity, underlain by water bearing sands with more or less brackish groundwater.

Different resistivity surveys were carried out to delineate geological layering and groundwater salinity as data base for groundwater modelling (Fig. 7). Airborne EM as well as 1D and 2D geological soundings show a low resistive top layer (=Klei) underlain by a layer of higher resistivity (aquifer with different salinities). The profile combining 1D vertical electrical soundings (VES; Fig. 7b) shows an increase of specific electrical resistivities of the aquifer from 40 Ωm in the western part (closer to the river Elbe) up to 147 Ωm in the eastern part. Assuming a formation factor of 5 (middle to coarse sand) aquifer resistivity of 40 Ωm corresponds to a pore water resistivity of 8 Ωm leading to a salt concentration of about 0.3 g/l. The influence of brackish water declines with increasing distance to the river Elbe.

It is expected that brackish water intrusions will increase with further deepening of the river Elbe. Therefore a monitoring of water quality with the vertical electrode system SAMOS installed close to the Elbe is in discussion.



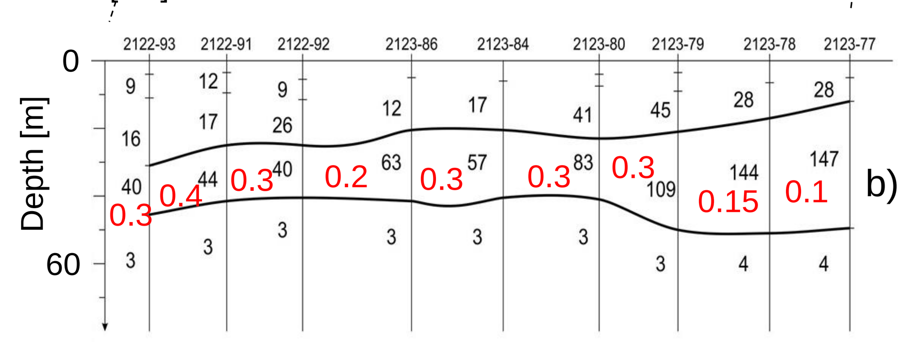




**Fig. 7** Resistivity depth sections north-east of the river Elbe (Elbe at the town of Glückstadt = km 0): a) AEM survey flown by BGR, b) reinterpretation of VES measured by Geological Survey Schleswig-Holstein. Black numbers = formation resistivity [Ωm], red numbers = chloride concentration of pore water [g/l].

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Poster SWIM25

Oral SWIM25

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