238533: A Quantitative Review of 1D Airborne Electromagnetic Inversion Methods: A Focus on Fresh-Saline Groundwater Mapping

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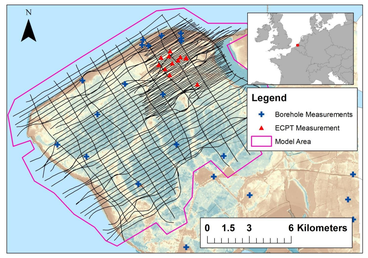
1. Introduction

Geophysical inversion translates measurements into physical properties. Using frequency domain airborne data (HEM), 1D inversions were tested for groundwater mapping using available airborne and ground data (figure 1).

HEM data were acquired by BGR for the project 'FRESHEM Zeeland over the Province of Zeeland, the Netherlands. Here a subset of this was used over an area called Walcheren.



	Type	Quantity
Airborne HEM	Airborne Geophysical	~1000 line km
Electrical cone penetration (ECPT)	Ground Geophysical	12 holes
Borehole	Ground Geophysical	16 holes

Figure 1. Location and data

2. Methods

Inversions types tested are listed in table 1, and were run using Aarhus Workbench and UBC GIF.

- Regularisation parameters were selected using best fit to ground-data over a single test-line.
- Parameters were tested for robustness using variance plots.
- From these results, inversions were run over all flightlines and interpolated into a 3D volume.

Name	Type	Reference
UBC Fixed Trade	Smooth 20 Layers	Farquharson et al., 2003
UBC GCV		
UBC LC		
UBC LS		
LCI Sharp	Laterally Constrained Smooth	Siemon et al., 2007; Vignoli et al., 2015
LCI Smooth		
LCI 5 Layer	Laterally Constrained Few Layered	
LCI 9 Layer		

Table 1. Inversion types tested

3. Results

4a: Conductivity Distributions

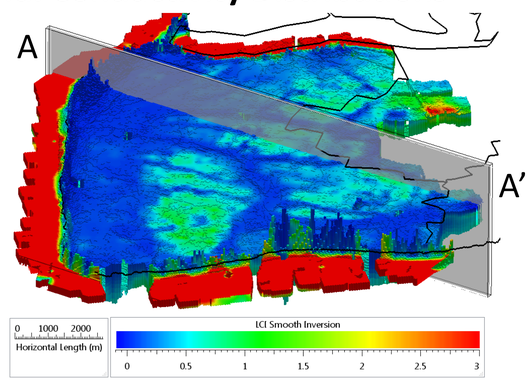


Figure 2. 3D volume of electrical conductivity

- All inversions consistently visually matched ground data (figure 3).
- Major conductivity contrasts successfully mapped between smooth and few layered results.
- XY plots of ECPT data vs. conductivity show preference to smooth results (figure 4).

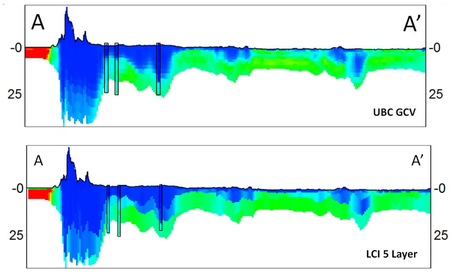


Figure 3. Inversion section examples and ECPT data

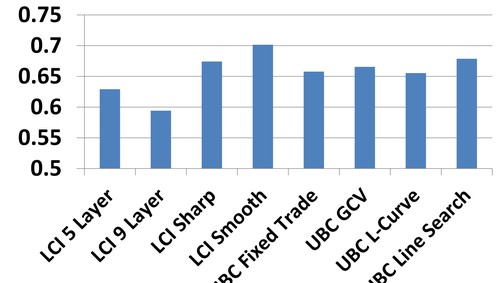


Figure 4. XY plot, inversions vs. ECPT

4b: Salinity Volume Estimates

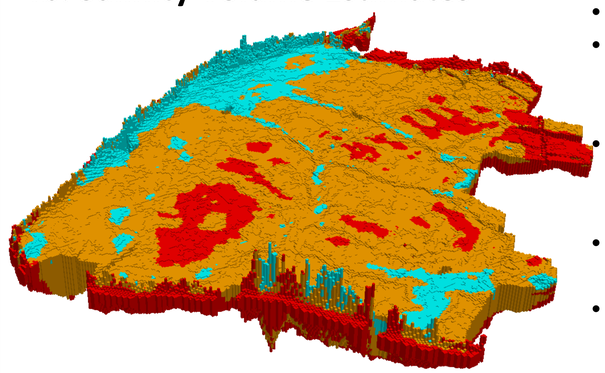


Figure 5. 3D volume of fresh-brackish-saline regions

- Estimates consistent across all inversions.
- 'Sharper' inversions resulted in bigger freshwater estimates, e.g. LCI Smooth & few layered.
- Out of 2,8 billion m3 total volume, freshwater estimate differs by 7%, or 195 million m3 between LCI 5 layer and LCI smooth.
- Brackish estimates differ by maximum of 4%, or 82 million m3.
- Little variation noticed between UBC methods.

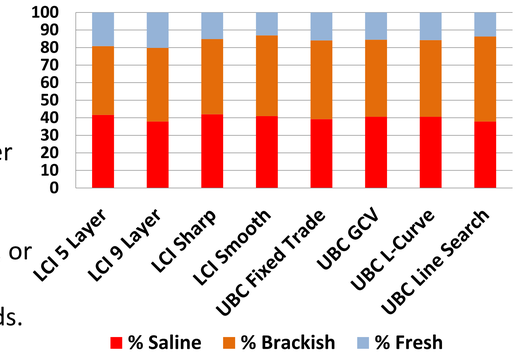


Figure 6. Volume estimates of fresh-brackish-saline regions

4c: Interface Mapping

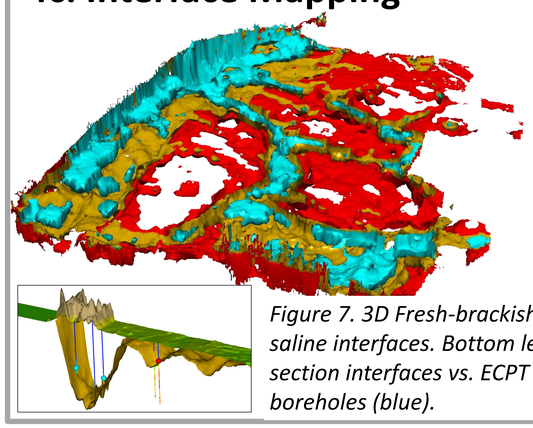


Figure 7. 3D Fresh-brackish saline interfaces. Bottom left: section interfaces vs. ECPT (red), boreholes (blue).

- Interfaces all mapped with a consistency of ~3m.
- Brackish interfaces resolved better than others.
- Shallower ECPT data show LCI 5 & 9 layer mapped fresh interface better, contrary to borehole data.
- Deeper borehole data show LCI 5 & 9 mapped brackish interface well, but smoother methods resolved fresh better.

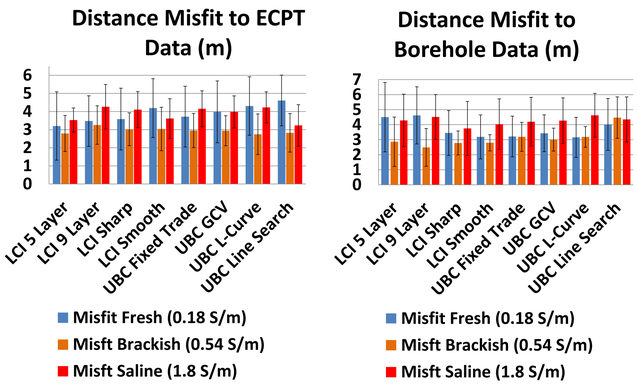


Figure 8. Distance from interface to ground constraints (ECPT left, boreholes right)

4. Conclusions

- Generally all inversions are consistent, honouring major conductivity distributions. Largest differences are observed between few layered and smooth inversions.
- Predictably, for mapping a smooth volume of groundwater salinity smooth techniques are favourable (e.g. UBC GCV, LCI Smooth). Choice of smooth inversion should reflect prior knowledge (e.g. brackish thickness).
- Few layer inversions are successful at mapping fresh interface in shallower areas.
- For mapping deeper interfaces, LCI few layered is best in the presence of a strong conductivity contrast.

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References: Colin G. Farquharson, Douglas W. Oldenburg, and Partha S. Routh*z. 2003.* Simultaneous 1D inversion of loop–loop electromagnetic data for magnetic susceptibility and electrical conductivity. *GEOPHYSICS, VOL. 68, NO. 6 (NOVEMBER-DECEMBER 2003); P. 1857–1869;* Giulio Vignoli, Gianluca Fiandaca, Anders Vest Christiansen, Casper Kirkegaard and Esben Auken. Sharp spatially constrained inversion with applications to transient electromagnetic data. *Geophysical Prospecting,* 2015, 63, 243–255. Siemon, B., Auken, E. & Christiansen, A.V., 2007. Laterally constrained inversion of frequency-domain helicopter-borne electromagnetic data. Journal of Applied Geophysics, doi: 10.1016/j.jappgeo.2007.11.003.