



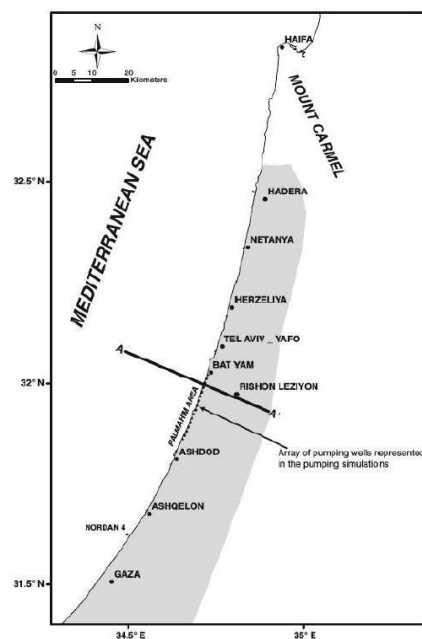
Joint Inversion of marine LOTEM and DED data from the Bat Yam coastal aquifer, offshore Israel

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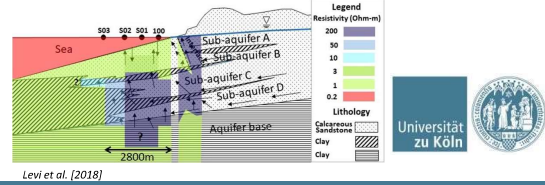
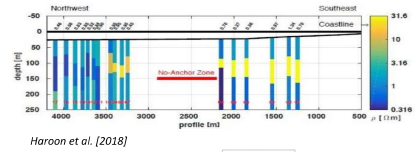
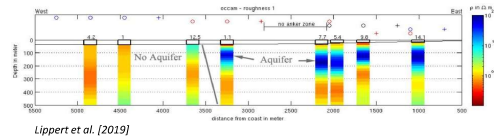
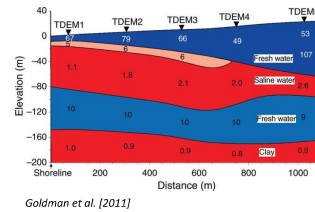
Introduction

- Groundwater aquifers are important for the fresh-water supply, especially in dry and highly urbanized regions
 - Onshore aquifer is exploited
- CSEM methods have proven to be applicable in groundwater exploration
- Prior studies agree that the aquifer extends offshore for some kilometers
 - Kafri & Goldman [2006]
 - Goldman et al. [2011]
 - Lippert (et al.) [2011, 2015, 2019]
 - Tezkan et al. [2012]
 - Haroon (et al.) [2016, 2018]
 - Levi et al. [2018]
- No proper 2D inversion software existed at that time



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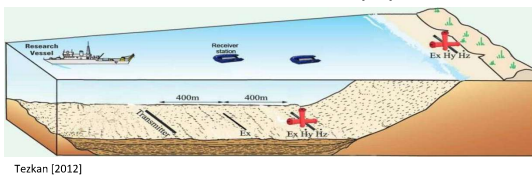
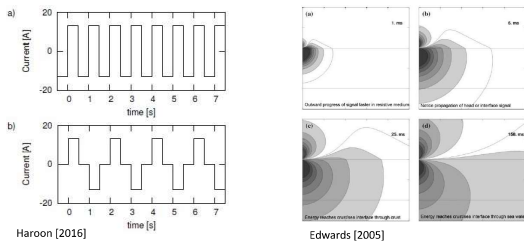
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Introduction

LOTEM

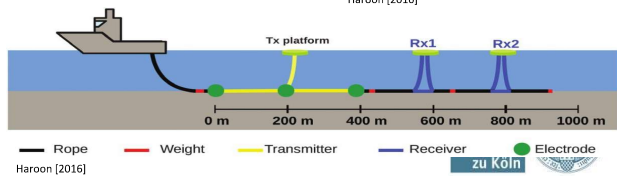
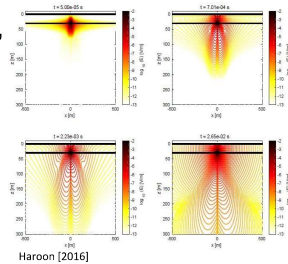
- Dipol transmitter of 400m length at the seafloor + broadside receiver dipoles at 400-800m offset
- Rectangular current signal



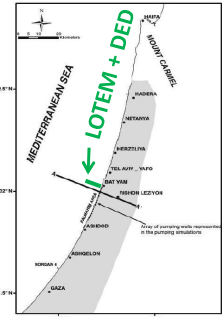
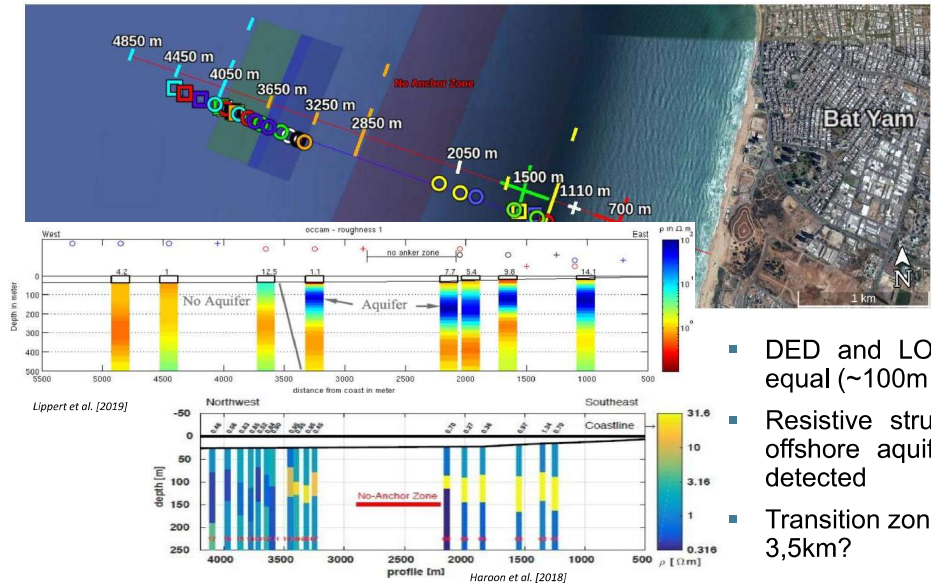
DED

- Two opposite dipol transmitters each of 200m length towed behind a vessel + 2 inline receiver dipoles at 370 and 580m offset.
- Compared to LOTEM, the electric field of a DED is more focused beneath the source

Lateral resolution is increased



Introduction

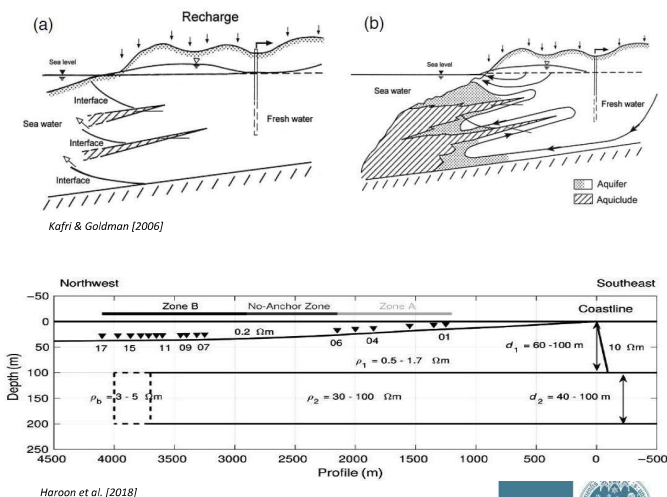


- DED and LOTEM profiles approx. equal (~100m offset)
- Resistive structures relating to an offshore aquifer extent have been detected
- Transition zone at 3,5km?



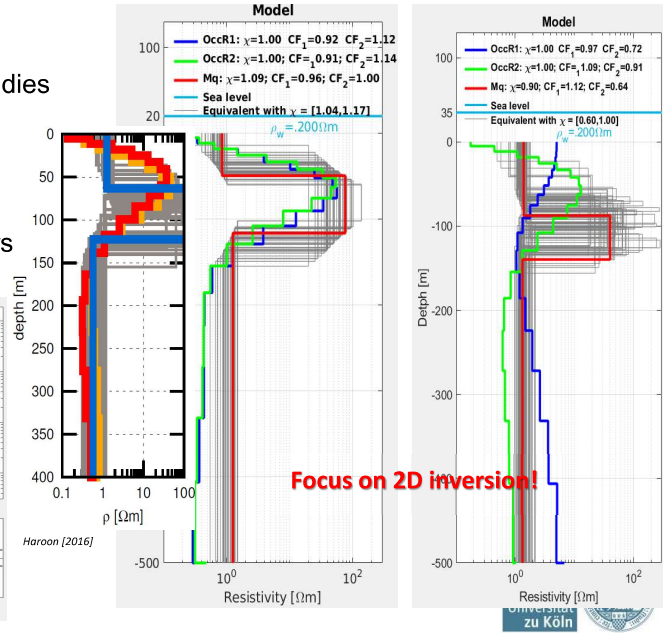
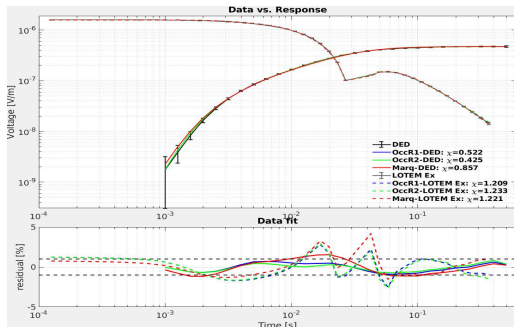
Motivation

- The shape of the sea-water to fresh-water interface remained unclear
 - Important due to onshore exploitation
 - Depending on the scenario the aquifer might deteriorate
- A 2D inversion of the LOTEM and DED data of Lippert and Haroon remained unprocessed
 - 2D effects expected, thus 1D inversion might be improper for some data sets
- A joint inversion might improve the resolution of the aquifer, which is interesting especially around the lateral boundary
 - Brackish? → Salinization possible
 - Pumping rates? Sea level rise?



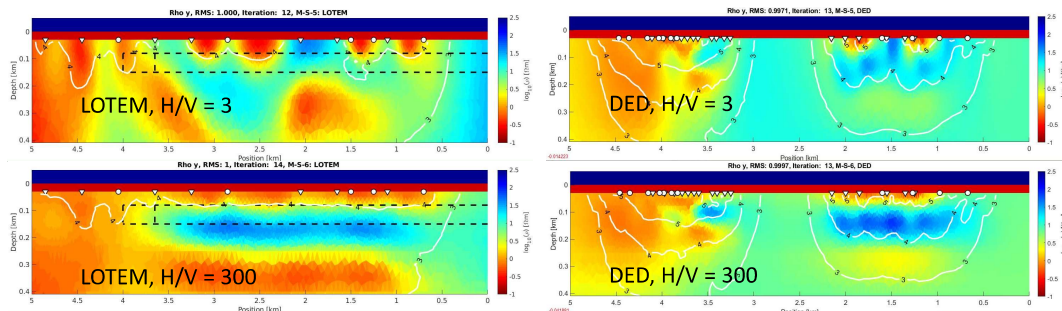
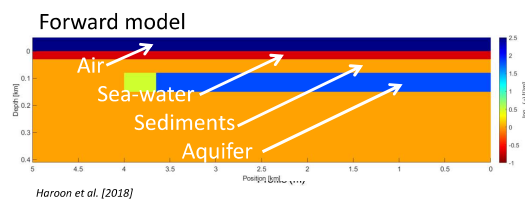
1D - Inversion

- Using MARTIN, 1D joint synthetic studies predicted:
 - Significant increased Eigen parameters
 - Visibly less scattered equivalent models
 - Better agreement of Occam and Marquardt
- Calibration factors as additional parameters
 - Serve as pre-2D-inversion shift factors



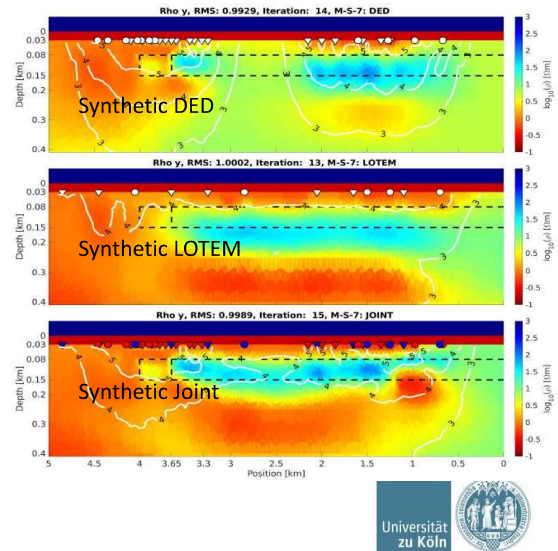
2D – Synthetic modeling

- Using MARE2DEM
- Error model: $\Delta = \frac{1}{\sqrt{t}} \Delta_{abs} + \Delta_{rel} + \Delta_{sgn}$
- Most important inversion parameter turns out to be the ratio between horizontal and vertical smoothing (≥ 300)



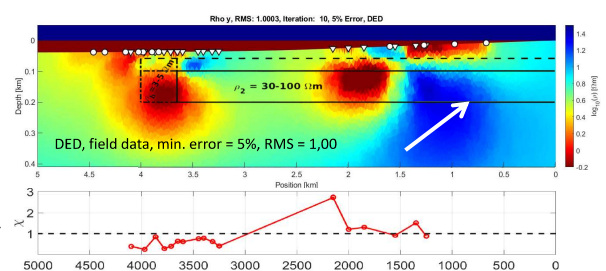
2D – Synthetic modeling

- As expected DED reproduces the lateral boundary
 - Resolves the resistivity contrast between saline-, brackish- and fresh-water
- LOTEM resolves the sediment layer beneath the resistor and shows a continuous aquifer across the data gap
- The Joint inversion combines the advantages of both methods
 - Sensitivity isolines underline that most of the information in the shallow to intermediate depth come from DED, while LOTEM covers the deeper structures



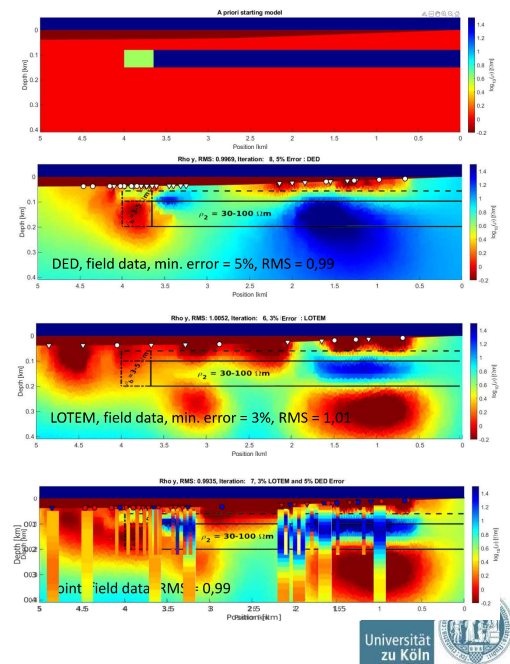
2D – Inversion

- Prior to a 2D inversion the LOTEM data was shifted by the 1D inversion CFs
- The LOTEM data was given a minimum relative error of 3%, DED was given 5% to fit the data.
- DED inversion with 1Ωm homogenous seafloor
 - Shore side aquifer might be resolved, but not its lower boundary
 - Lateral sea-water to fresh-water interaction might be interpreted as brackish transition zone
 - Highly conductive structure at 2km prohibits reasonable interpretation
 - Chi value is appreciable increased here



2D – Inversion

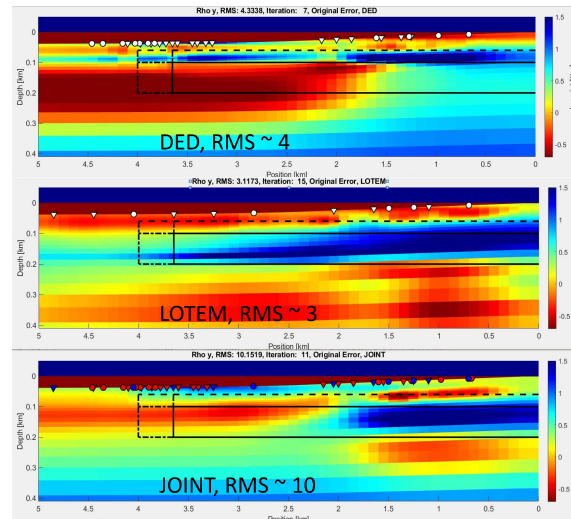
- Additional information was given into the inversion process
 - The starting model contains an expected aquifer scenario
- The conductive region at 2km vanishes in the DED inversion
 - Compared to the 2D forward modeling results of Haroon [2018] (black lines) the prior made interpretation approach seems more reasonable
- LOTEM inversion resolves the shore side aquifer and its lower boundary, but seems not reliable beyond the data gap (~2,5km)
- The joint inversion provides the best representation and comparability to the 2D forward modeling results of Haroon [2018]
 - Data gap region between 2-3km remains unclear
 - Results are also consistent with 1D inversion results of Haroon [2018] and Lippert et al. [2019]



Conclusions & Outlook

- Modeling clearly shows the advantages of applying a joint inversion of both methods for the prevalent hydrogeology.
- LOTEM and DED 2D inversions both can resolve the expected aquifer extent at some locations of good data coverage, ...
 - ...although for 2D inversion a priori information seems essential
- The inversion results are in good correlation with prior results
 - Compared to the 2D forward model of Haroon [2018], the most shallow predicted scenario seems to be prevalent
 - The transition zone between sea-water and fresh-water might be brackish
 - Important information for the water supply due to possible deterioration
- We know a resistor exists at certain depth, to clarify if the lateral boundary is still reproduced in the inversion, we should include a 1D shaped resistor in the starting model
- Use quadrilateral grid for further studies
 - Should be more reliable to represent lateral structures for our bad data coverage

Outlook – Quadrilateral Mesh



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Thank you!

