Poster Session - GQ2016-103

Groundwater Quality Conference 2016

Quantitative characterization and calibration of salt water intrusion models with electrical resistivity tomography

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1. Introduction

Groundwater quality and coastal ecosystems in coastal areas are among the most vulnerable as they are threatened by excessive groundwater withdrawals, sea level rise and storm events potentially leading to salt water intrusions into fresh water aquifers. Electrical resistivity tomography (ERT) can provide spatio-temporally distributed data for hydrogeological modeling at relatively limited costs. ERT is very sensitive to the conductivity of pore water which is directly linked to the total dissolved solid content (TDS) of groundwater.

2. Improved inversion of ERT data

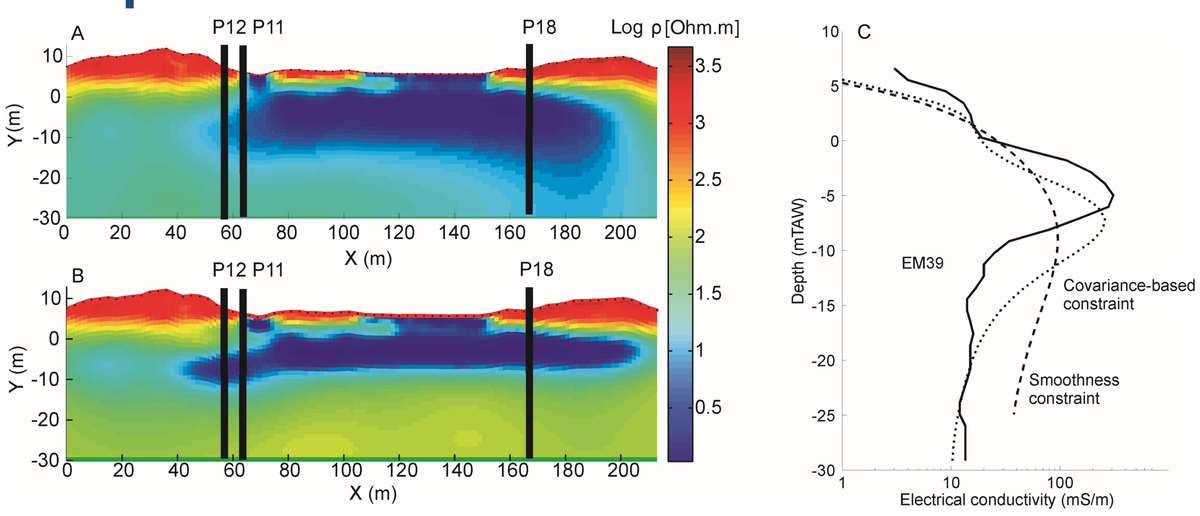


Fig 1. Smoothness (A), covariance (B) constraint inversions and EM comparison (C)

Standard geophysical inversion can be improved by incorporation of prior information [1]. Here we use the vertical correlation length obtained through borehole data to constraint the inversion. The resulting resistivity distribution from sea water intrusion is much more realistic and closer to the truth than the standard smoothness constraint inversion, as can be seen in the comparison with electromagnetic borehole measurements (EM39)

3. TDS content from ERT

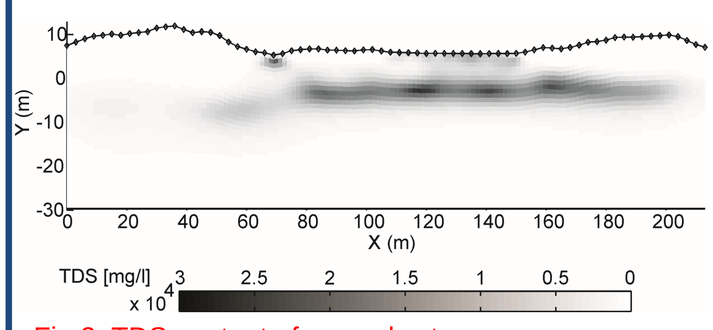
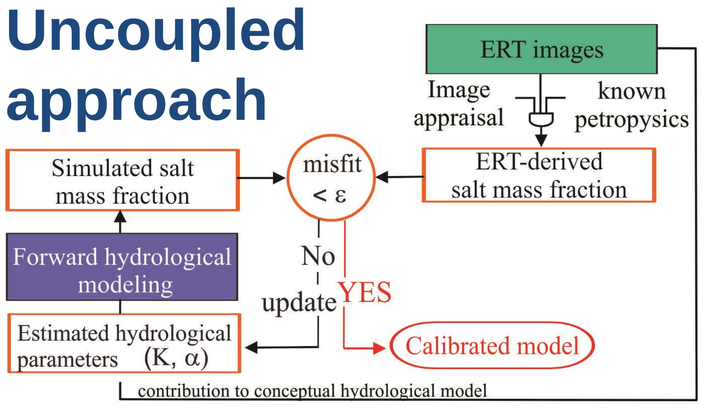
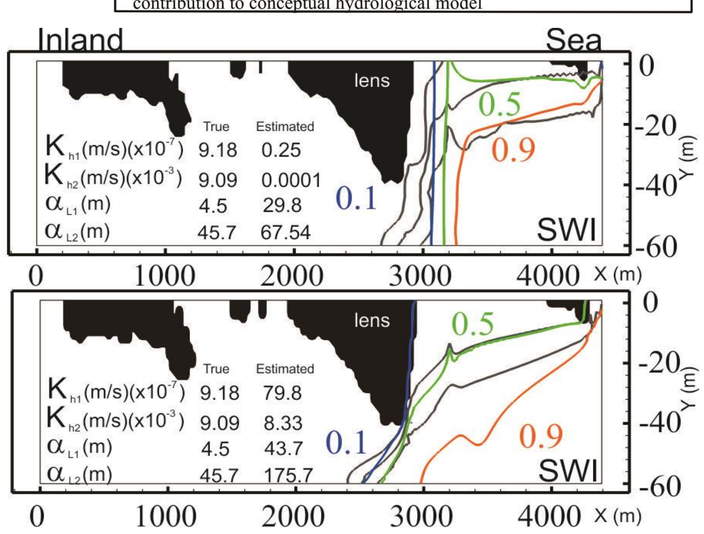


Fig 2. TDS content of groundwater

Using a site-specific petrophysical relationship [2], it is possible to derive the TDS content from the resistivity distribution. The maximum value (27000 mg/l) corresponds to the salinity of the North Sea. This can be used as additional data for the calibration of a hydrogeological model

4. Model Calibration with ERT data Uncoupled approach





A SWI hydrogeological model can be calibrated using ERT-derived hydrological data (i.e. the TDS content or salt mass fraction). The hydrogeophysical inversion methodology consists of two separate steps (so-called uncoupled approach) [3]:

1. ERT inversion to determine the bulk electrical conductivity distribution which is filtered using an image appraisal tool,

2. Inverse parameter estimation (calibration loop) is performed to estimate the SWI model parameters using the ERT-derived hydrologic data.

ERT images can be used to refine the hydrologic conceptual model such as **a model error** exists (<u>middle</u> Fig 3.) or **not** (<u>down</u> Fig 3.).

Fig 3. Uncoupled approach (flowchart). Calibration results for a heterogeneous SWI model.

5. Filtering - Image appraisal tool

Filtering an ERT image consists in calibrating an appraisal sensitivity indicator to retrieve high quality ERT-derived hydrologic data (low error on recovered hydrologic data).

Estimating the error model may be performed either on the basis of groundtruth information or with the creation of a synthetic model based on the field ERT image (forward of the field ERT image, inversion of the ERT data and petrophysical relationship to retrieve the hydrologic data). The filtered ERT-derived hydrological data (TDS or SMF) can then be used as additional data for the calibration process of the hydrologic model.

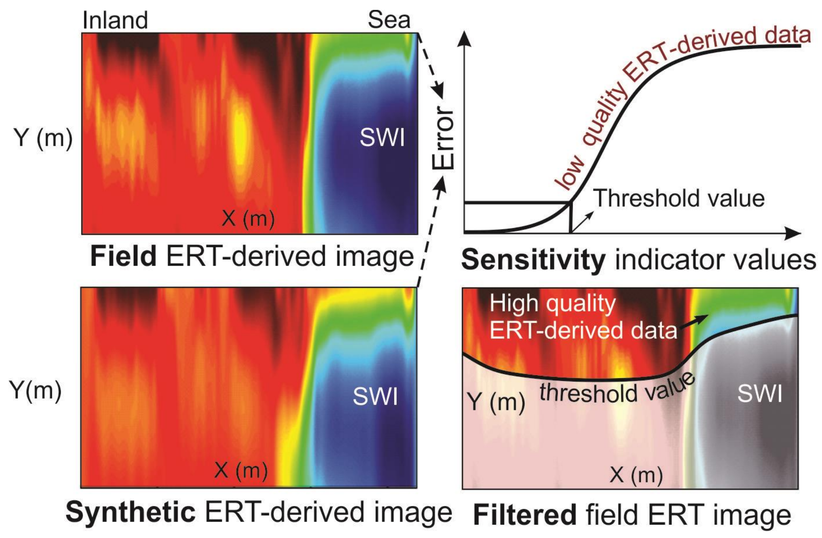
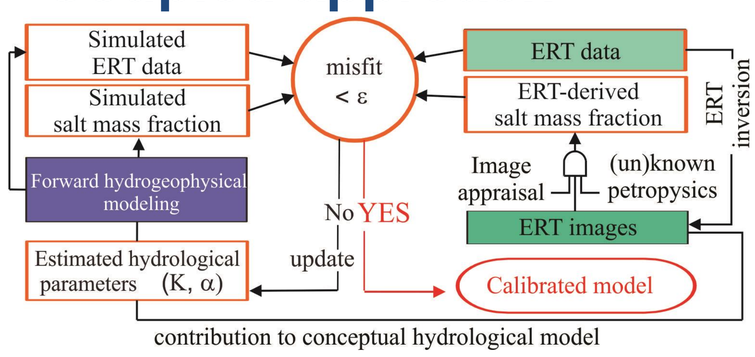


Fig 4. in-situ validation-dependent methodology can be used in order to quantitatively appraise an ERT image using the sensitivity indicator (example with a wedge shaped SWI in coastal area).

6. Model Calibration with ERT data – Coupled approach



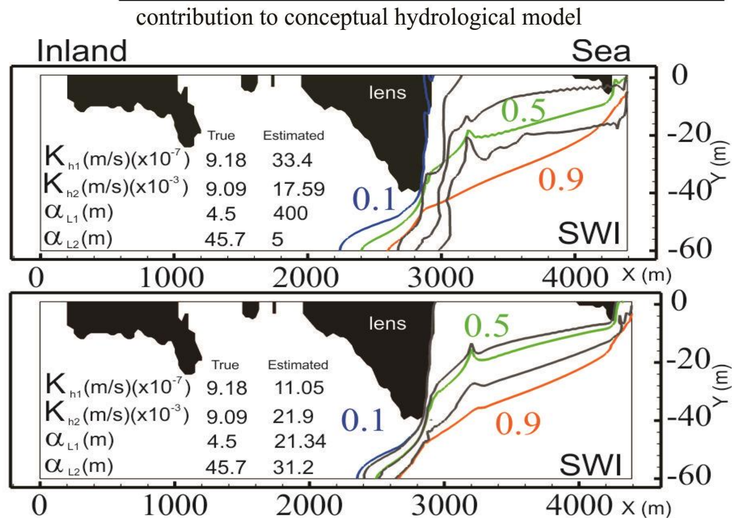


Fig 5. Coupled approach (within a more general flowchart of a combined uncoupled-coupled approach)

A SWI hydrogeological model can be calibrated using ERT data (i.e. the resistances) and a petrophysical relationship The hydrogeophysical inversion methodology consists of two separate steps [4]:

1. Forward hydrogeo modelling to determine the TDS content, the corresponding bulk electrical conductivity and the resistance values,

2. Inverse parameter estimation is performed to estimate the SWI model parameters using the ERT data.

Independent geophysical inversions (ERT images can be used to refine the hydrologic conceptual model (<u>as for</u> Fig.3) .

6. Conclusion and perspectives

- ERT is a valuable tool to qualitatively monitor saltwater intrusions
- Careful processing of ERT data can help to assess quantitatively seawater intrusions through the estimation of TDS content
- ERT-derived quantities (TDS) or ERT data themselves can be used to calibrate hydrogeological model through uncoupled or coupled approaches respectively
- Filtering schemes improve the calibration through reduced weight given to low-resolution geophysical data, the coupled approach avoids the thresholding approach
- A combined uncoupled-coupled approach could extent the beneficial effect of filtering scheme to coupled approaches – this will be investigated in the future (Fig. 5)

References

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[3] Beaujean J., Nguyen F., Kemna A., Antonsson A., Engesgaard P. 2014. Calibration of seawater intrusion models: Inverse parameter estimation using surface electrical resistivity tomography and borehole data. Water Resources Research, 50, 6828-6849.

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