WARMINGUP

PhD Project: Joint inversion of EM and seismic data to monitor geothermal reservoirs

Investigating frequency domain electromagnetic methods for monitoring geothermal activities in shallow subsurface

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TU Delft

Agenda

- Motivation
- Background
  - Frequency domain EM induction
- Methodology and Results
  - Forward modelling and Synthetic data analysis
  - Field work data acquisition
- Outlook

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Motivation

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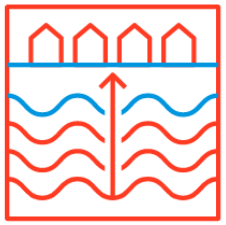
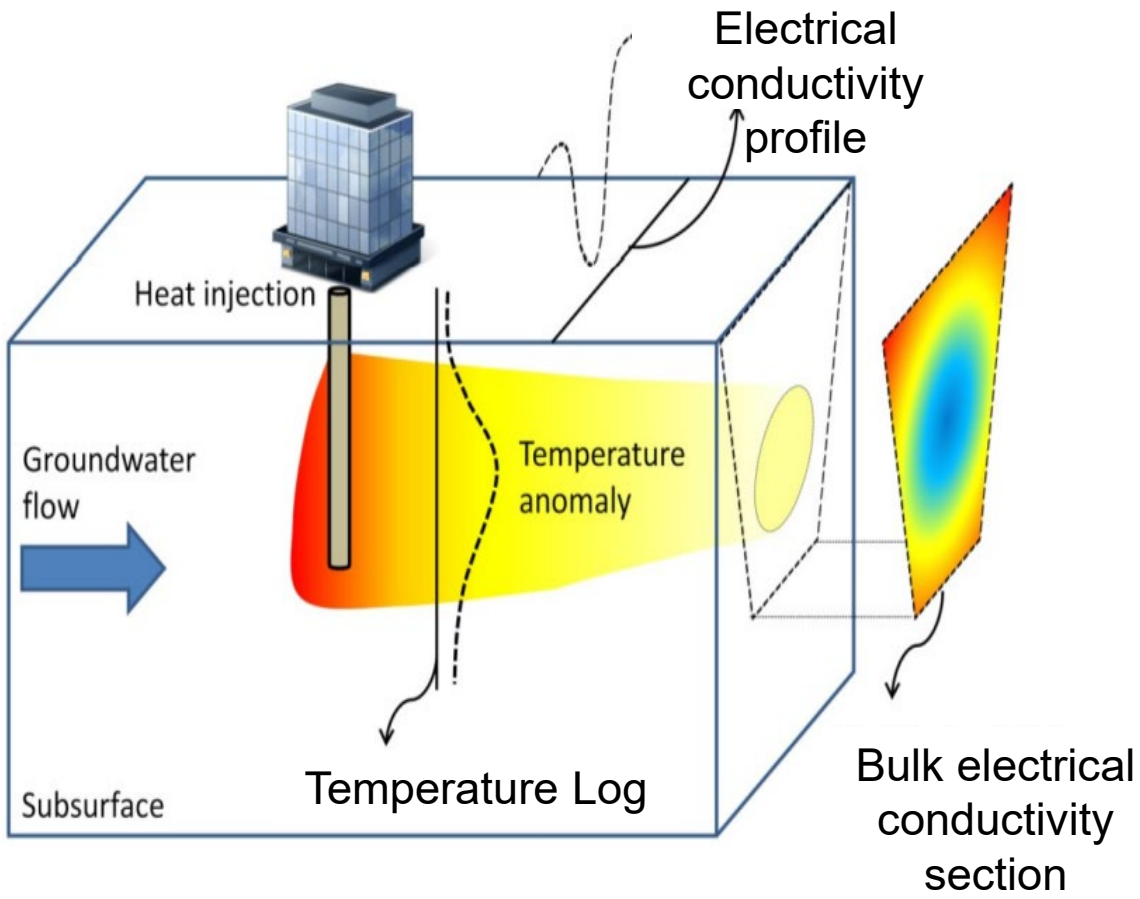
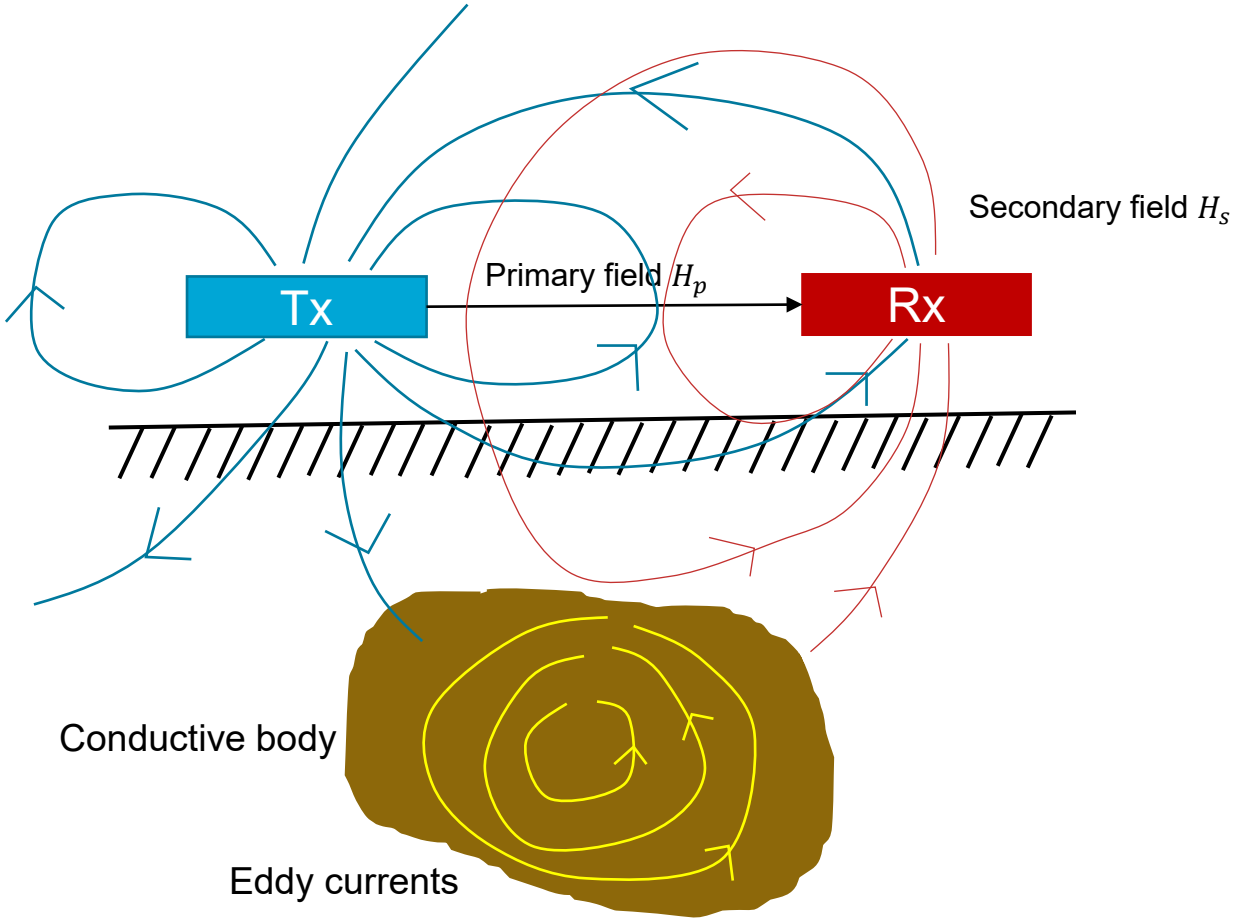
PhD Project setting and motivation

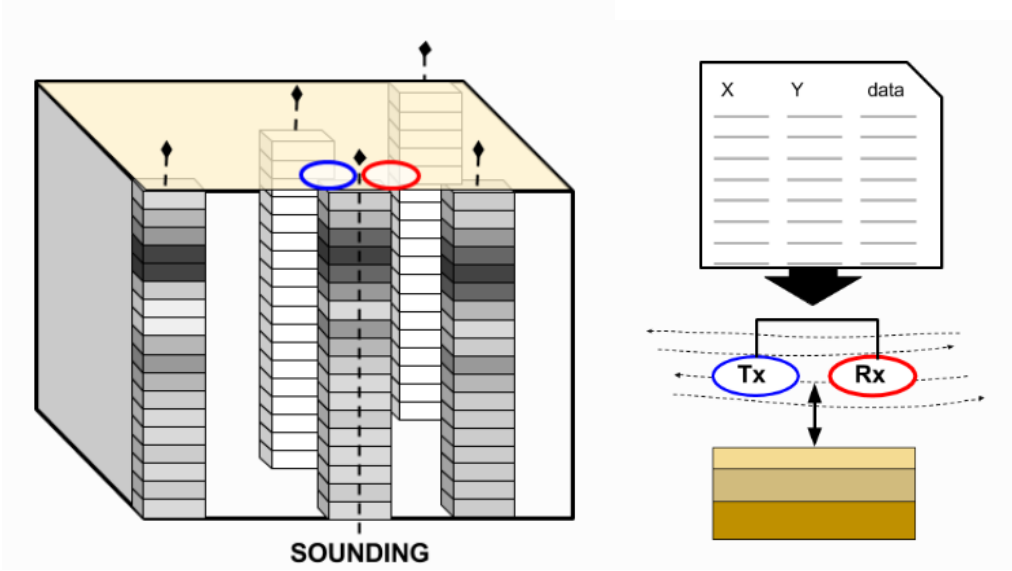


- **Setting:** WarmingUP – Geothermie
- **Project goal:**
  - Aims to develop methodologies for monitoring temperature variations in the shallow subsurface through the combination of seismic and electromagnetic induction data
- **Why:**
  - Evaluate the behaviour of temperature changes of shallow subsurface
  - Possible hydrochemical / microbiological changes related to temperature variation may affect groundwater quality



Frequency domain electromagnetic induction (FDEM)





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Methodology and Results

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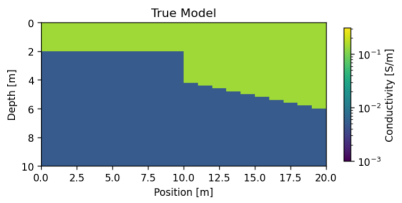
Methodology: Analysis of FDEM measurements to estimate Electrical conductivity values

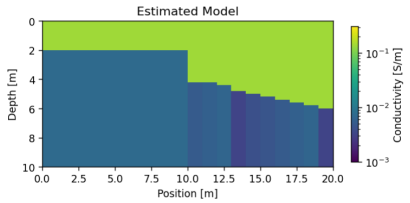
Forward modelling of FDEM measurements

Synthetic 1D layered Earth Model

Synthetic Data

Inverse estimation of the Earth model





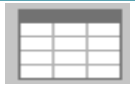
Global search inversion

Forward calculation of lookup table

Sample model parameters (Ns =51)

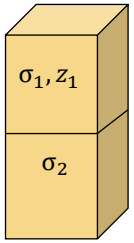
σ_1 [0.1 mS/m - 100 mS/m]
σ_2 [0.1 mS/m - 100 mS/m]
z_1 [0.1 m - 9 m]

→ Calculate for each model $\boldsymbol{Z = Q + IP}$ → Lookup table



Global search of closest 1D model

1D model



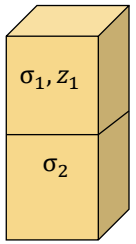
→ Calculate Z_{data} → Search in Lookup table for index of smallest error

$$indx\left(\min\left(\log\sqrt{\sum\left(Z_{lookup} - Z_{data}\right)^2}\right)\right)$$

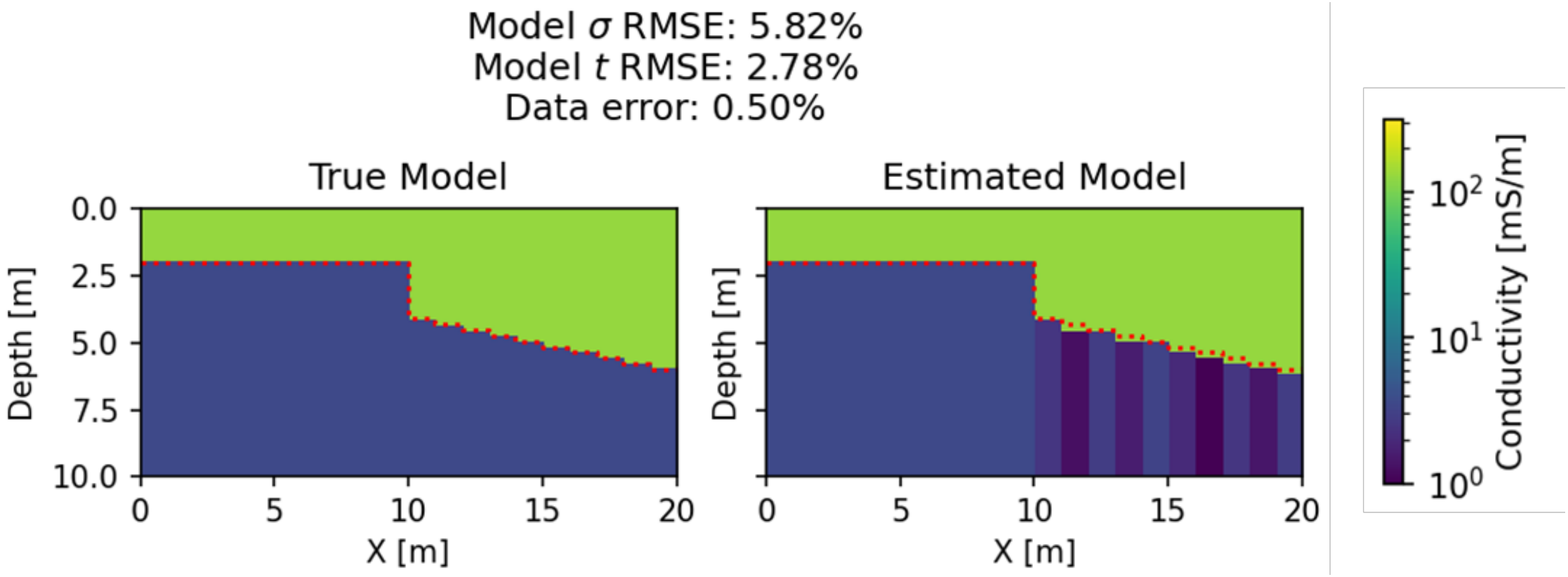
→ Index of smallest error = index of estimated model

$$indx(error) = indx(model)$$

→ 1D estimated model

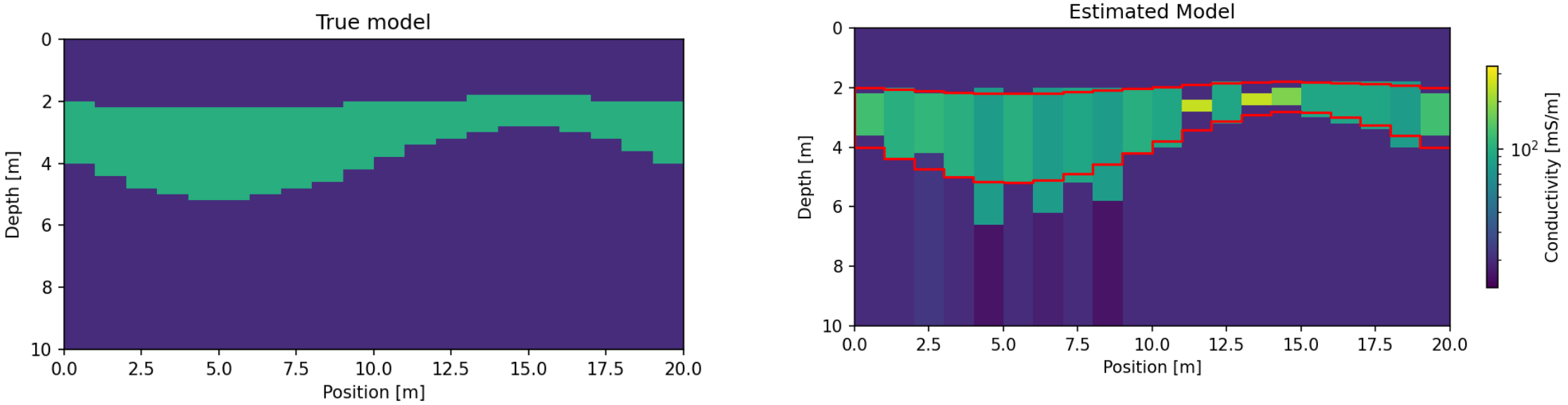


Global search inversion – Results 2 layers earth model

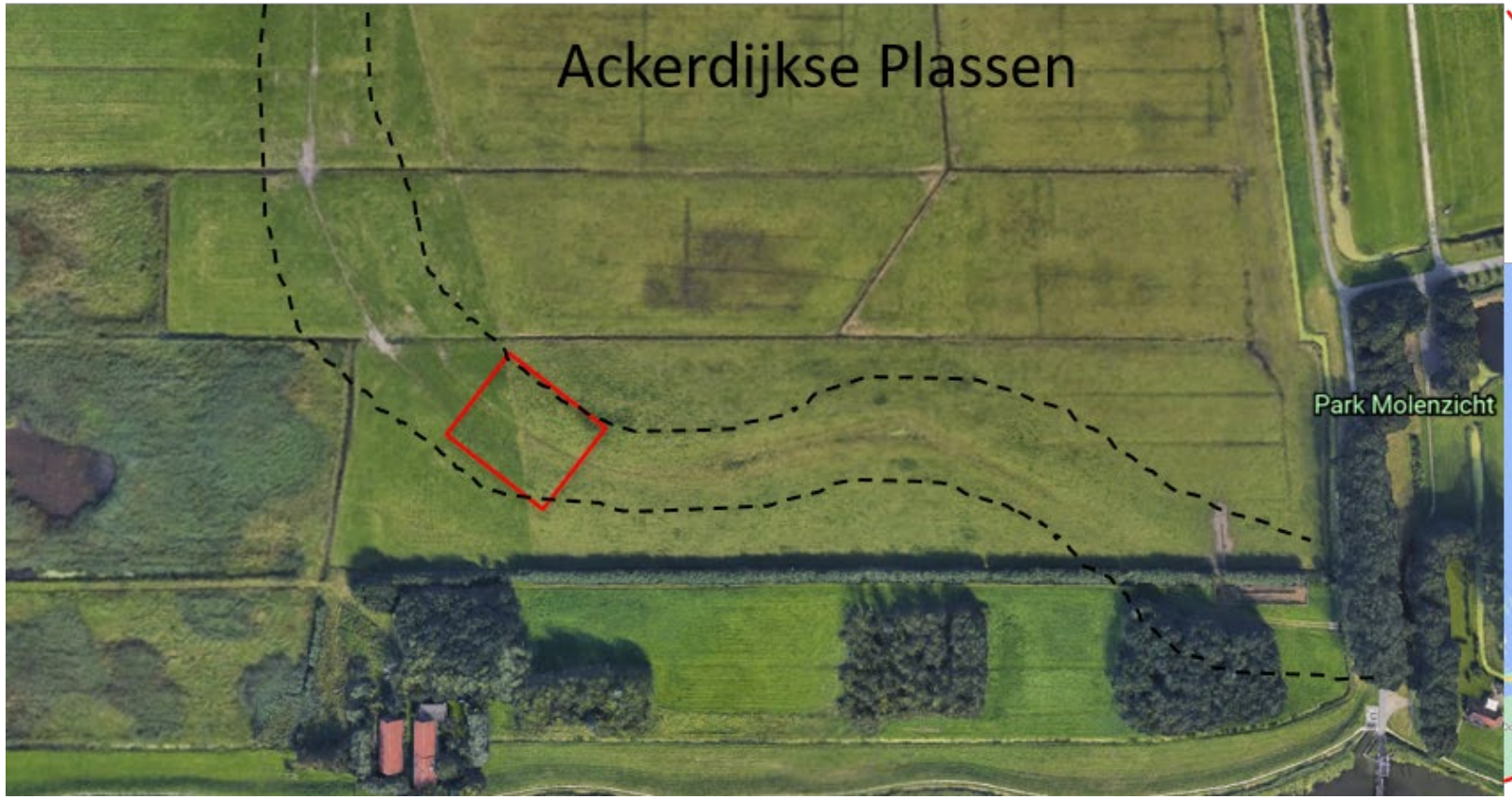


Global search inversion – Results 3 layers earth model

Model σ error: 10.53%
Model t error: 29.91%
Data error: 0.51%



Field work data acquisition



Field work data acquisition

February 2021:

- FDEM: VCP coil orientation
- Electric resistive tomography
- Surface Wave Tomography (seismic)

February 2023:

- FDEM: VCP, HCP, PRP coil orientation
- Electric resistive tomography
- Lithology sampling

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Conclusions

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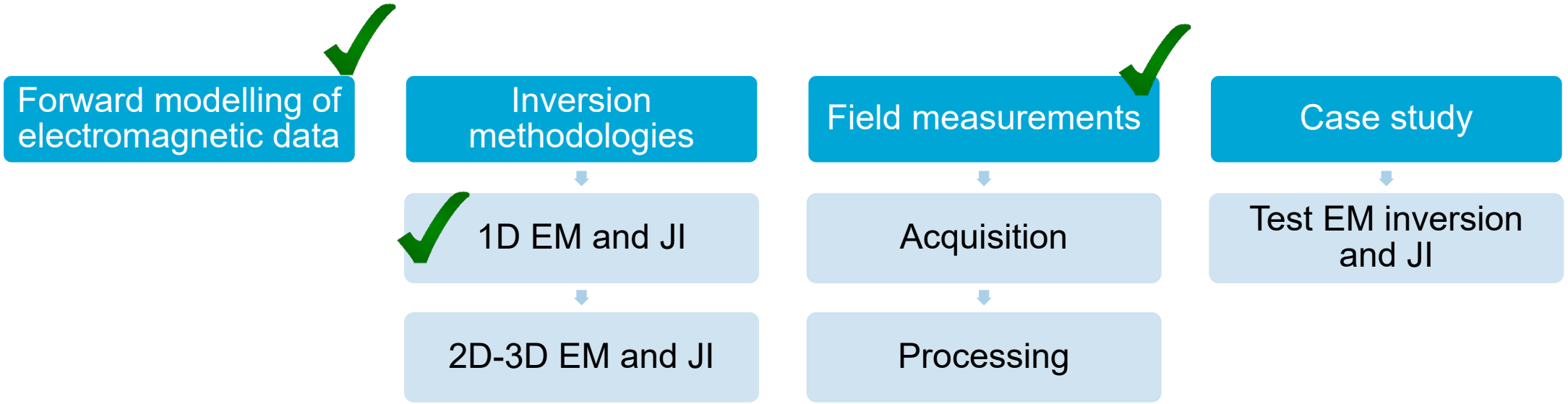
Conclusions

- FDEM measurements are useful to estimate apparent electrical conductivity in the shallow subsurface. These measurements can be used to estimate variations in groundwater temperature.
- Estimations of 1D layered models of the earth's electrical conductivity have been possible using global search inversion
- To obtain the solution for a 1D layered model of the earth's electrical conductivity with more than two layers using global inversion search might present equivalent earth models that also explain the data (more than one global minima in the solution space)
- Additional data from other geophysical measurements (electrical resistive tomography, seismic) might help reduce the uncertainty of the estimation and reach the global minima

Outlook



Conference Paper: **Exploiting the full information of the coupling ratio measurements in frequency domain electromagnetic induction instruments.** Maria Carrizo, Evert Slob, Dieter Werthmüller. EGU 2023

Thank you!

Questions and comments