pyGIMLi – Geophysical Inversion and Modelling Library

pyGIMLi
Geophysical Inversion & Modelling Library

Introduction

Nino Menzel

September 09, 2022

Institute for Applied Geophysics 1: Computational Geoscience,

Geothermics and Reservoir Geophysics (CGGR)

nino.menzel@rwth-aachen.de

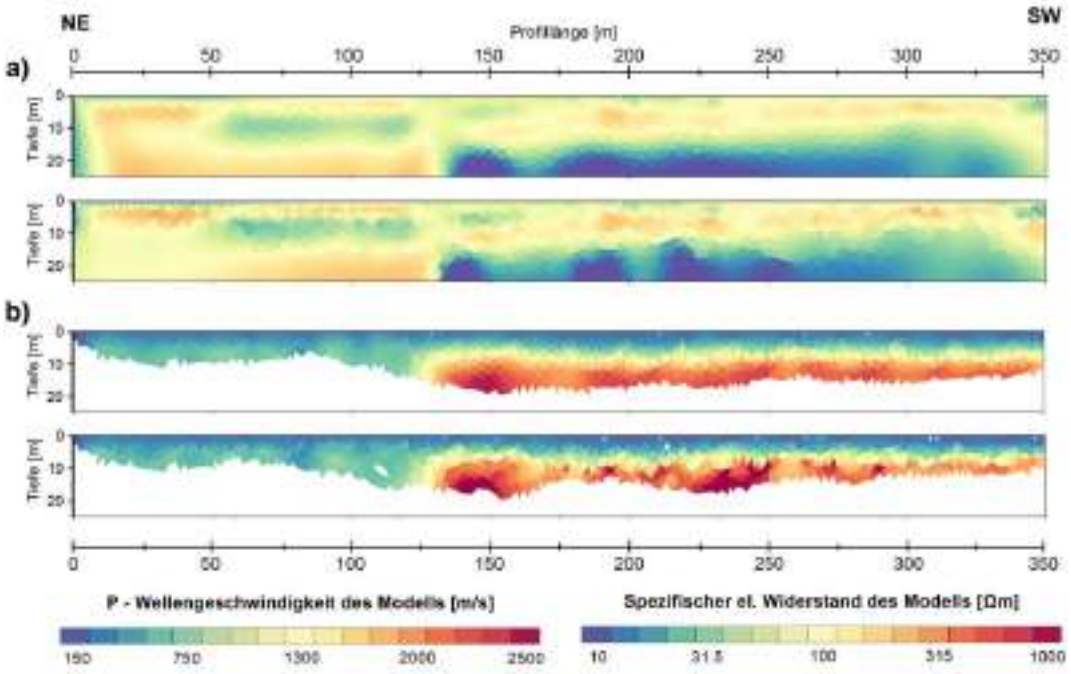
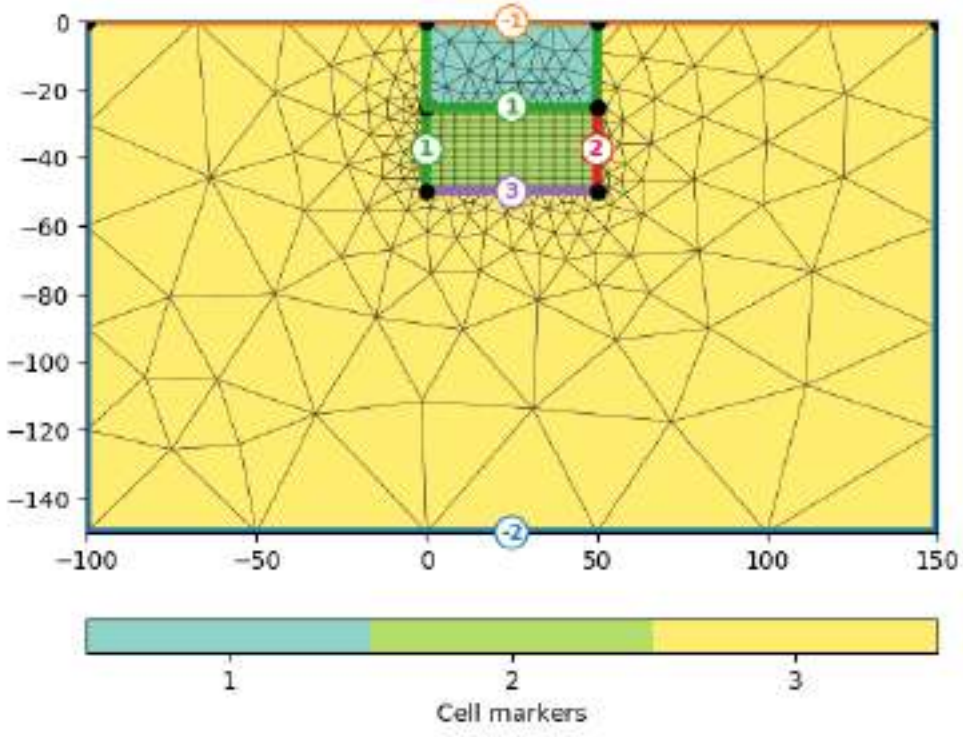


Table of Contents

What is pyGIMLi?

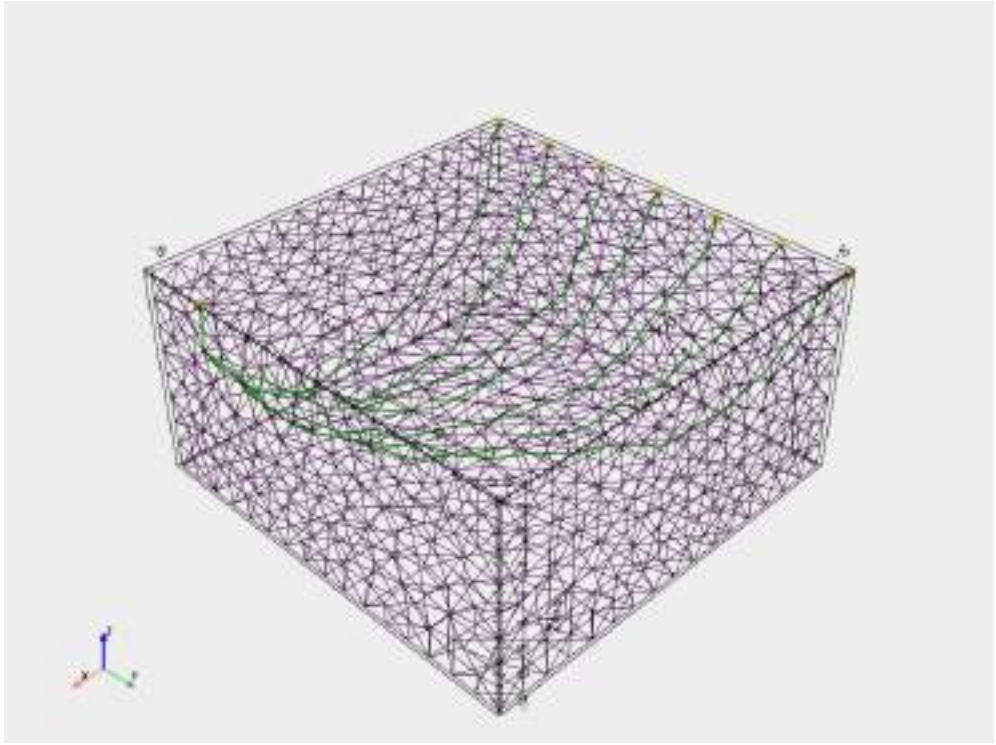
- Geophysical modeling and inversion library (**open-source**)
- Management of **structured and unstructured meshes**
- Useage of **finite-element and finite-volume solvers**
- software provides several **geophysical forward operators** for user
  - ERT, IP, Traveltime…
- General **Gauss-Newton type inversions**, also applicable to more complex problems
- opportunity for **interdisciplinary geoscientific analysis**



Rücker et al., 2017

What is pyGIMLi?

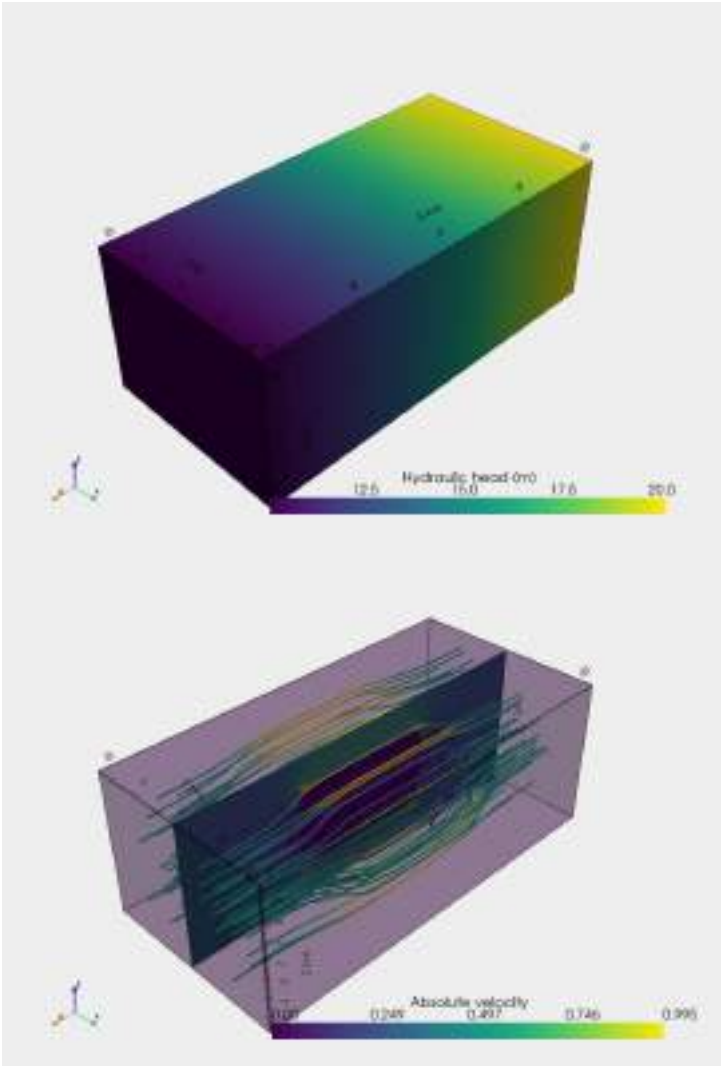
- Geophysical modeling and inversion library (**open-source**)
- Management of **structured and unstructured meshes**
- Useage of **finite-element and finite-volume solvers**
- software provides several **geophysical forward operators** for user
  - ERT, IP, Traveltime…
- General **Gauss-Newton type inversions**, also applicable to more complex problems
- opportunity for **interdisciplinary geoscientific analysis**



Rücker et al., 2017

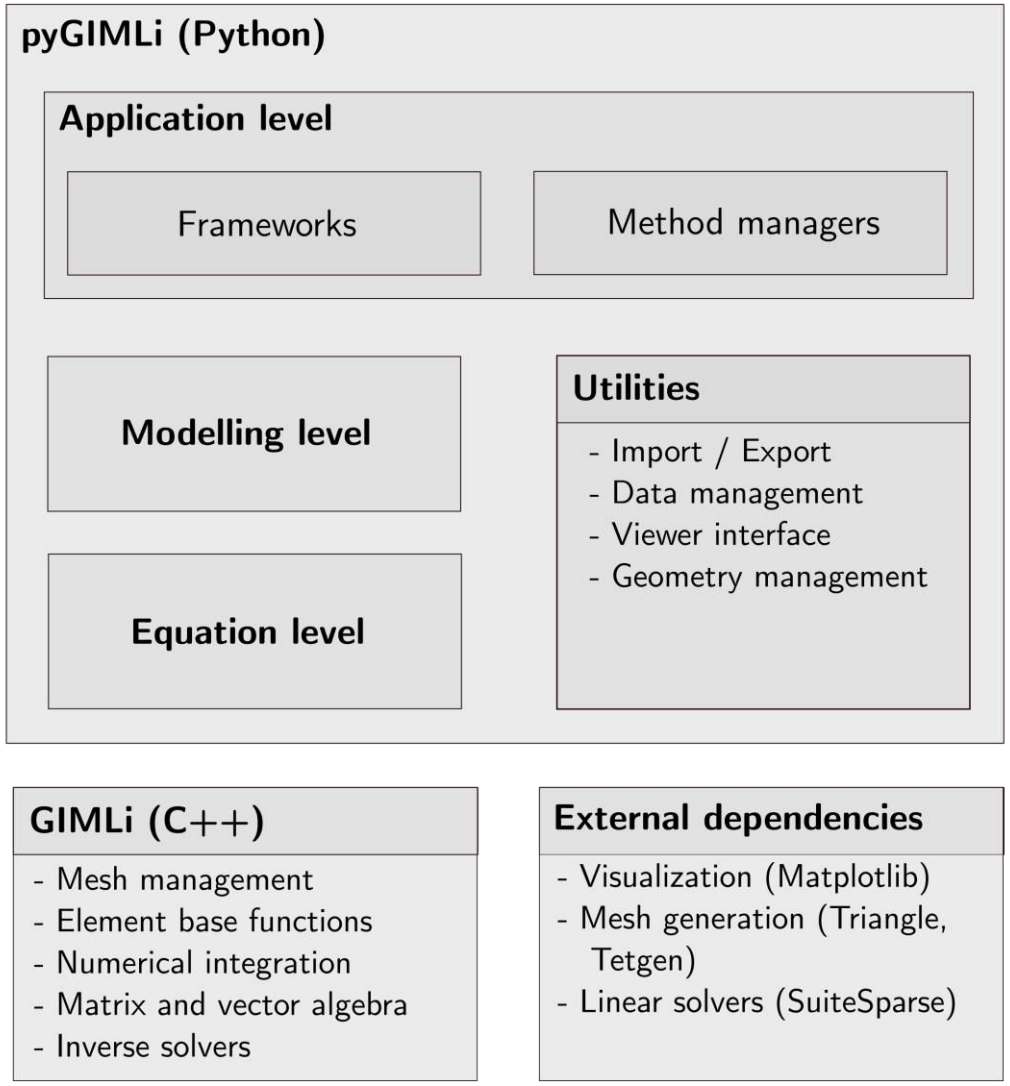
What is pyGIMLi?

- Geophysical modeling and inversion library (**open-source**)
- Management of **structured and unstructured meshes**
- Useage of **finite-element and finite-volume solvers**
- software provides several **geophysical forward operators** for user
  - ERT, IP, Traveltime…
- General **Gauss-Newton type inversions**, also applicable to more complex problems
- opportunity for **interdisciplinary geoscientific analysis**



Rücker et al., 2017

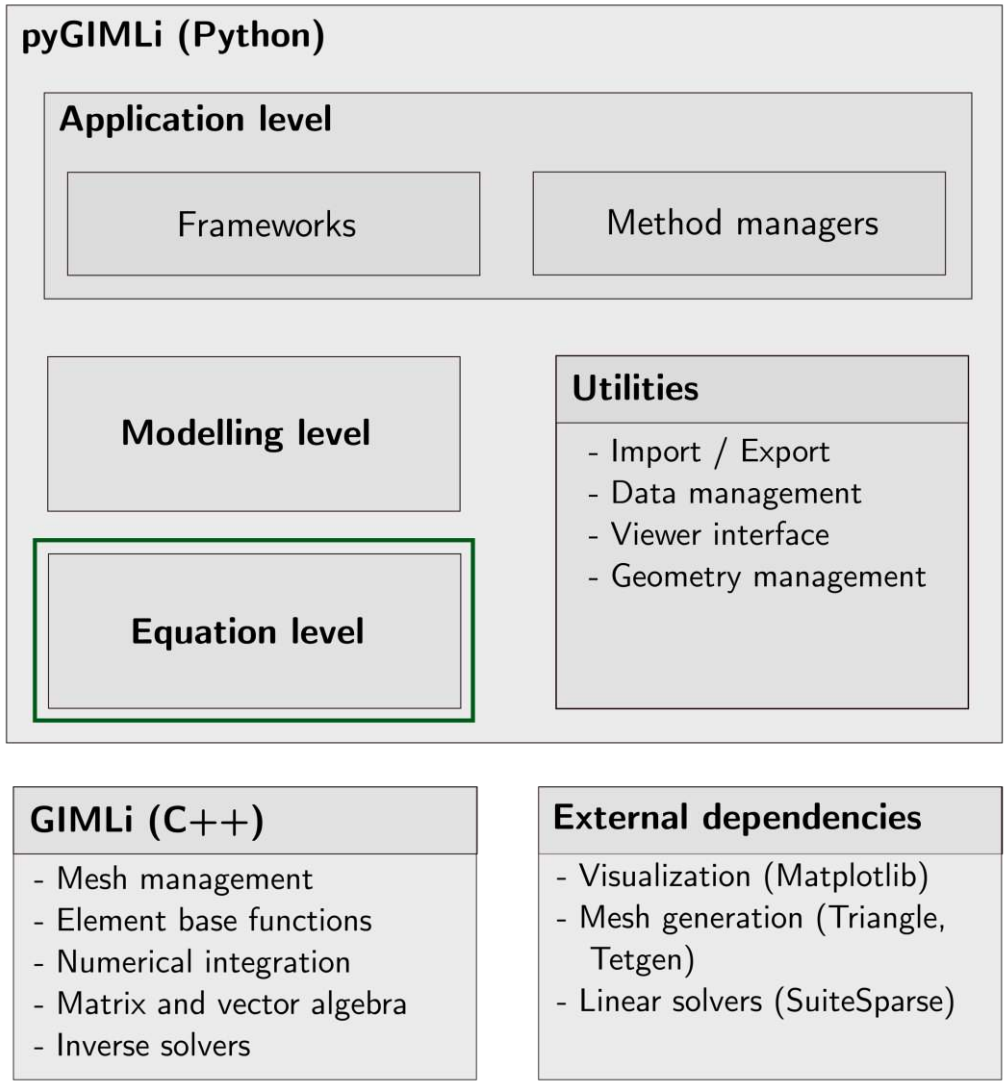
Software architecture – Overview



Following Wagner and Uhlemann, 2021

- Very powerful **external dependencies**
- Additional **C++** library
- Features of software itself divided into **three levels**
- **Additional utilities** for different purposes included

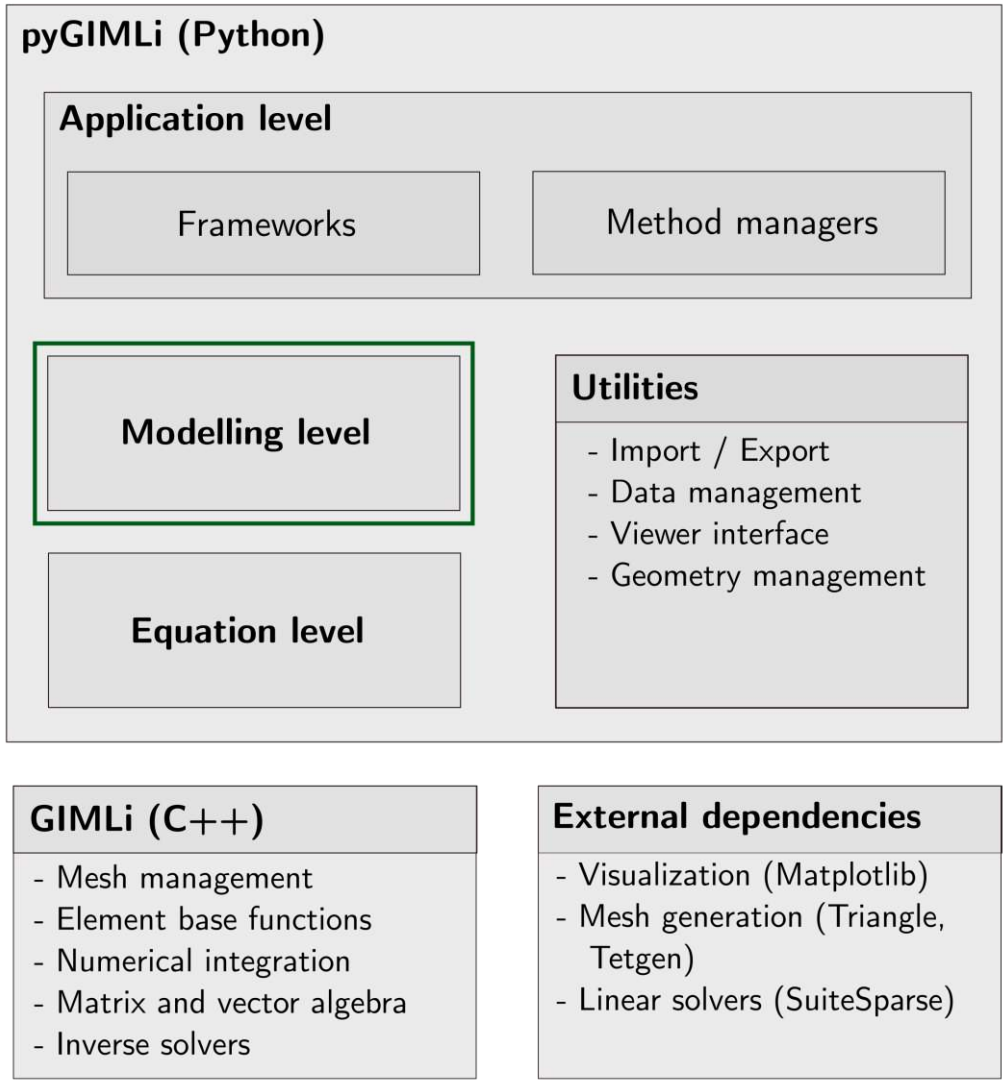
Software architecture – Equation level



Following Wagner and Uhlemann, 2021

- **Finite-Element** and **Finite-Volume** calculations on user-defined mesh
  - **2D meshes**: triangles, quadrangles
  - **3D meshes**: tetrahedra, hex, prisms
  - Possible to create **mixed meshes**

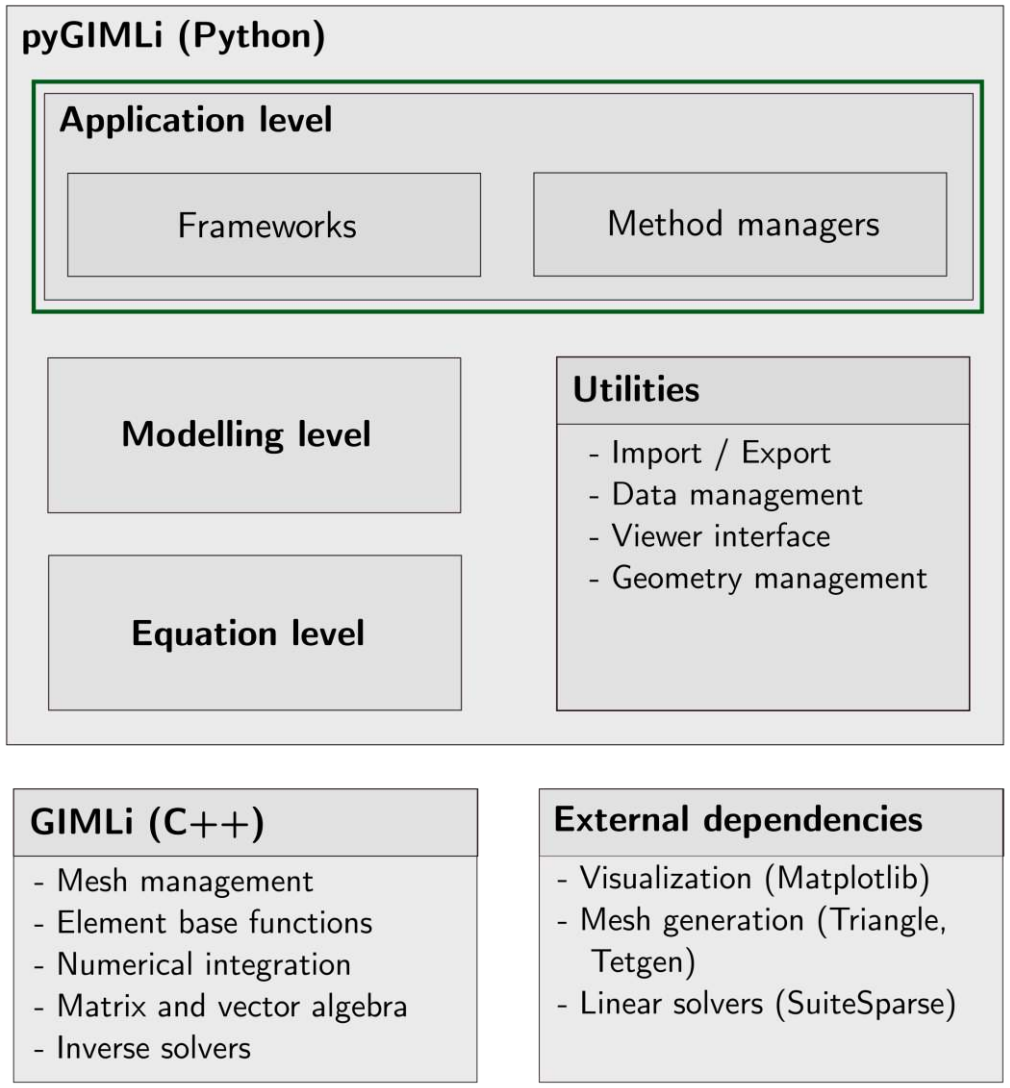
Software architecture – Modelling level



Following Wagner and Uhlemann, 2021

- Modelling level **is based on** on Equation level
- **Forward operators** for specific geophysical problems
- **Ready-to-use** 2D and 1D method managers
  - **2D**: ERT/IP, Traveltime, Graviemtry, MRS
  - **1D**: MT, FDEM, TDEM

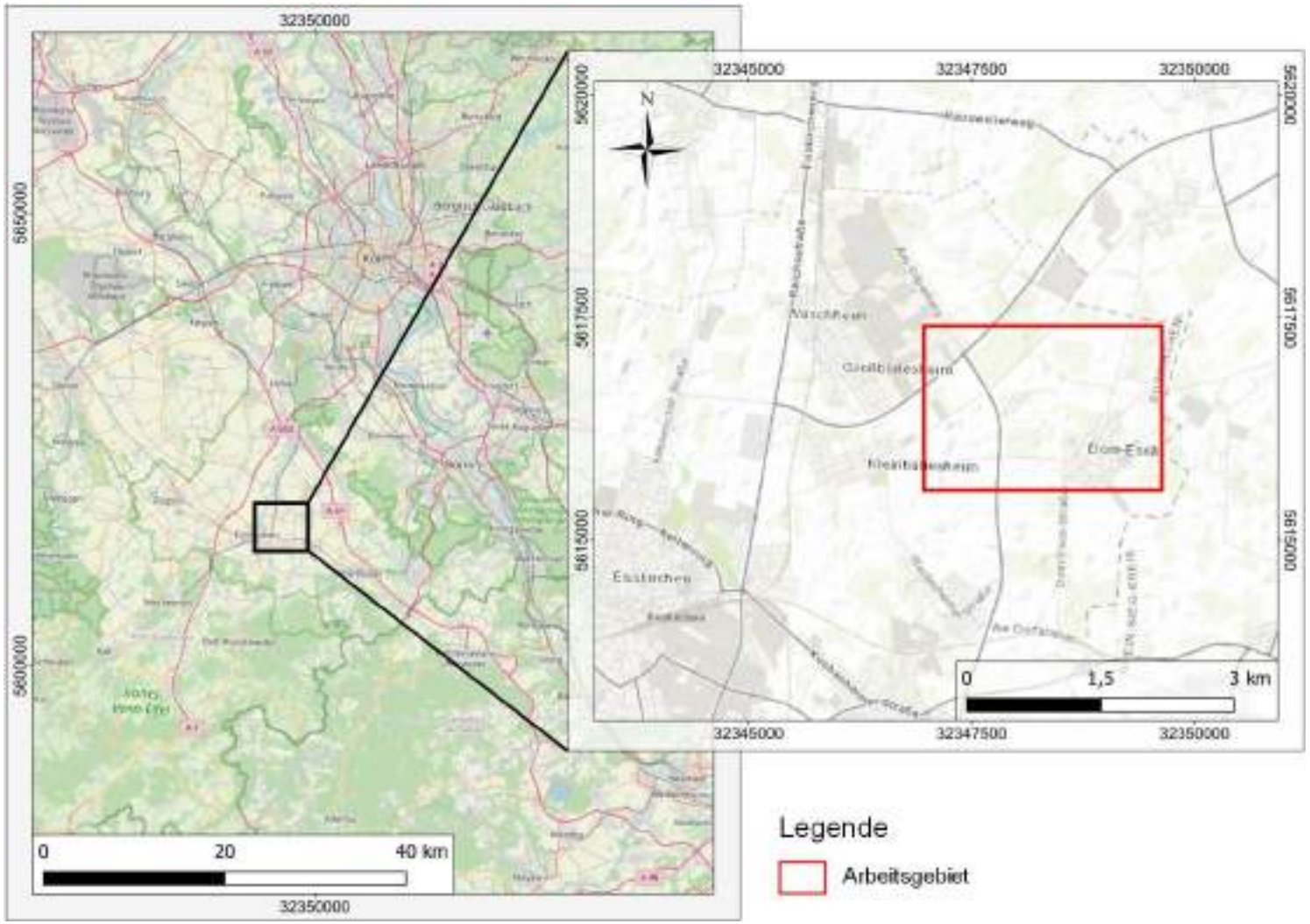
Software architecture – Application level



Following Wagner and Uhlemann, 2021

- Possibility to **visualize**, **pre-process** and **invert** data
  - **Data** and **misfit visualization** possible
- **Ready-to-use** method managers allow problem-specific data management
- Method managers integrated into **frameworks** for…
  - **Process-based** inversion
  - **Joint** inversions
  - …

Case study – Prospection of fault system

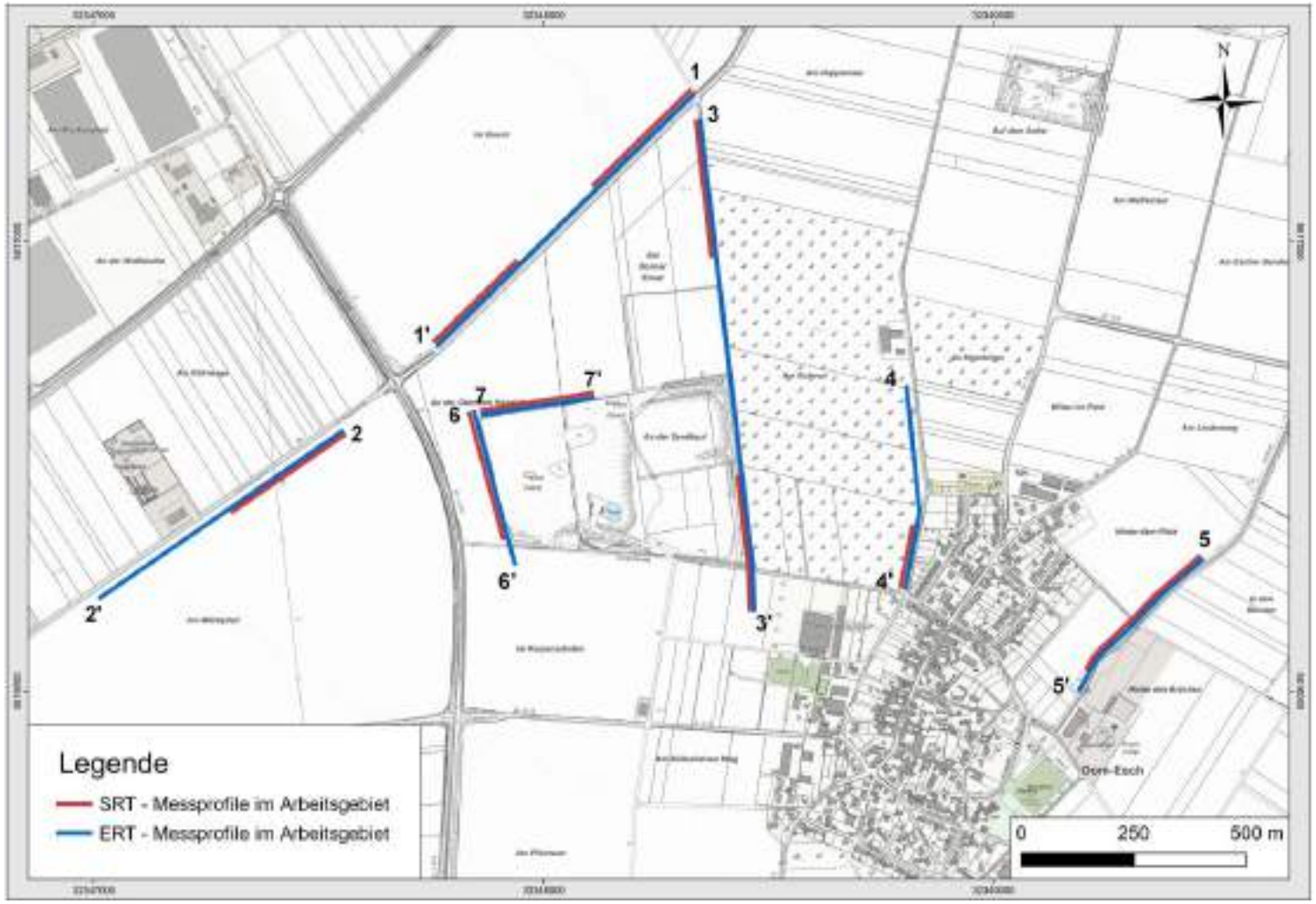


- Area of interest near Euskirchen

Case study – Prospection of fault system

- Area of interest near Euskirchen
- Very **complex** (small-scale) **tectonic structures**
  - Part of **NRB**
- Strong influence on **groundwater table**

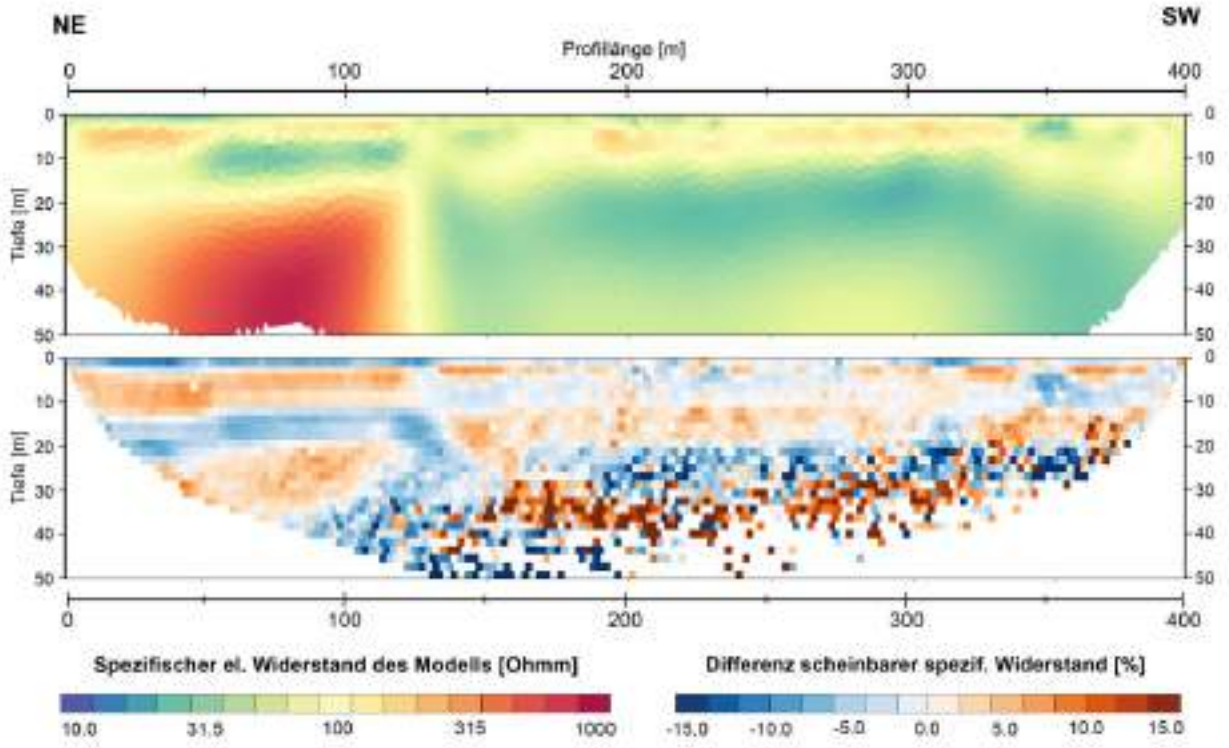
Case study – Prospection of fault system



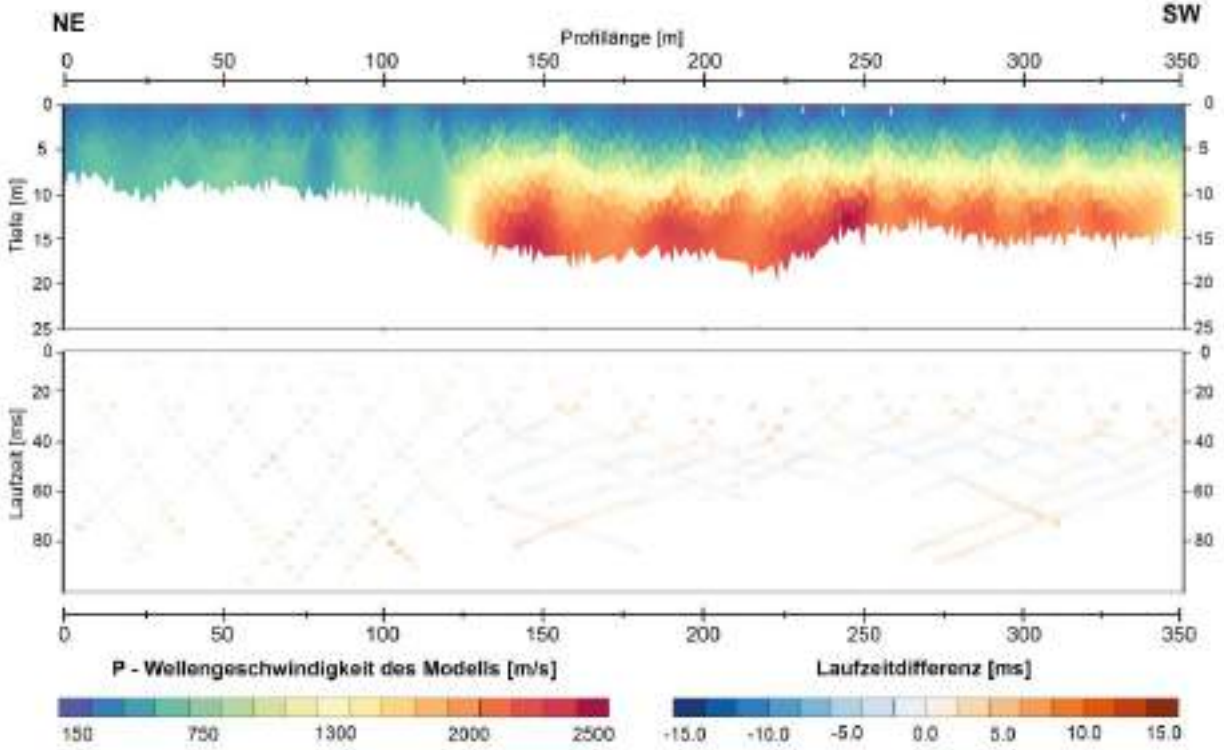
- Area of interest near Euskirchen
- Very **complex** (small-scale) **tectonic structures**
  - Part of **NRB**
- Strong influence on **groundwater table**
- **ERT-** and **SRT-measurements** performed
- Data acquisition on **seven profiles**
- Data pre-processed and inverted with **pyGIMLi**
  - **Single inversions**
  - **Joint inversion** of ERT- and SRT-data

Case study – Prospection of fault system

- **Single inversions** of Profile P5

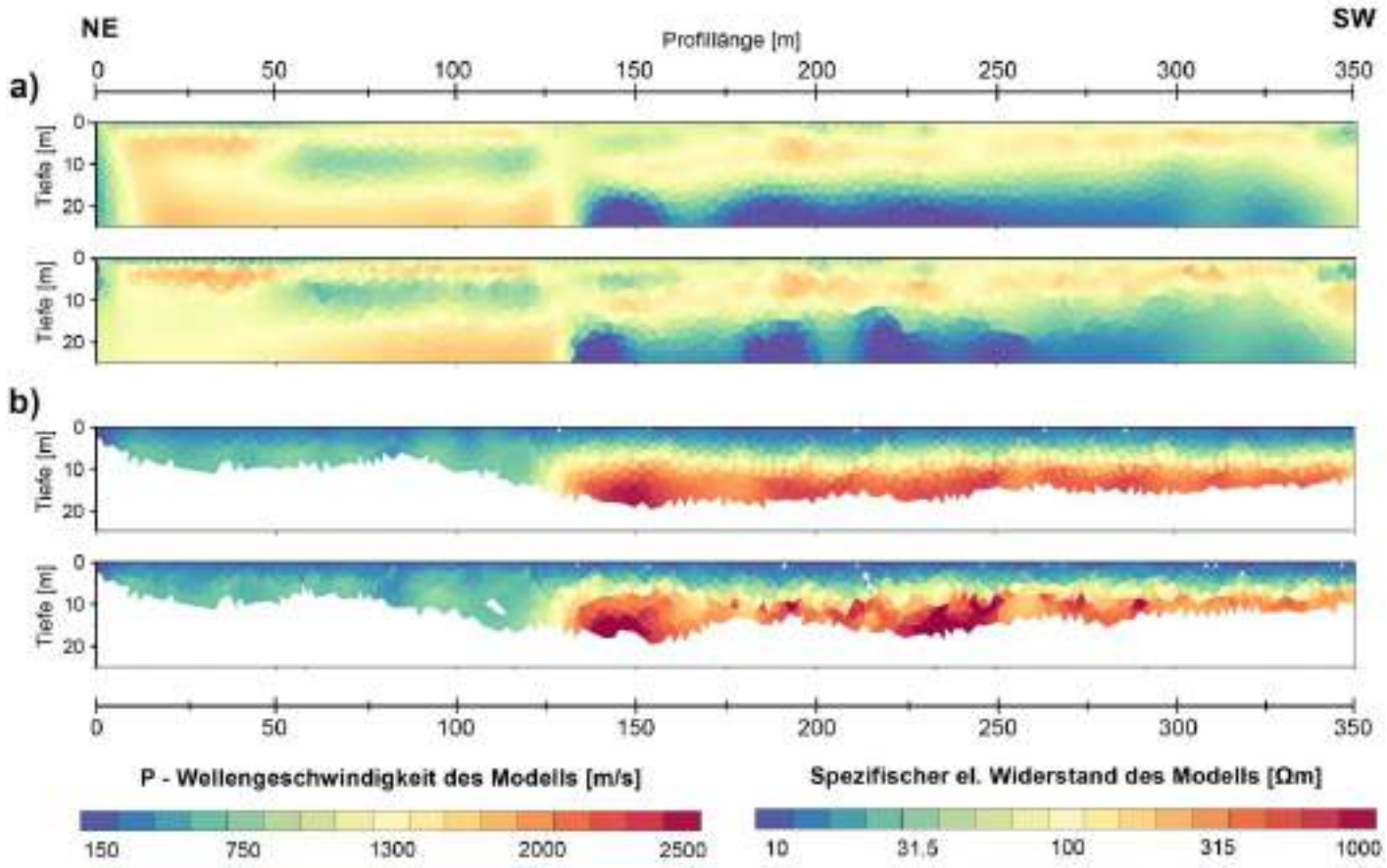


ERT-inversion result



SRT-inversion result

Case study – Prospection of fault system



Joint-inversion result

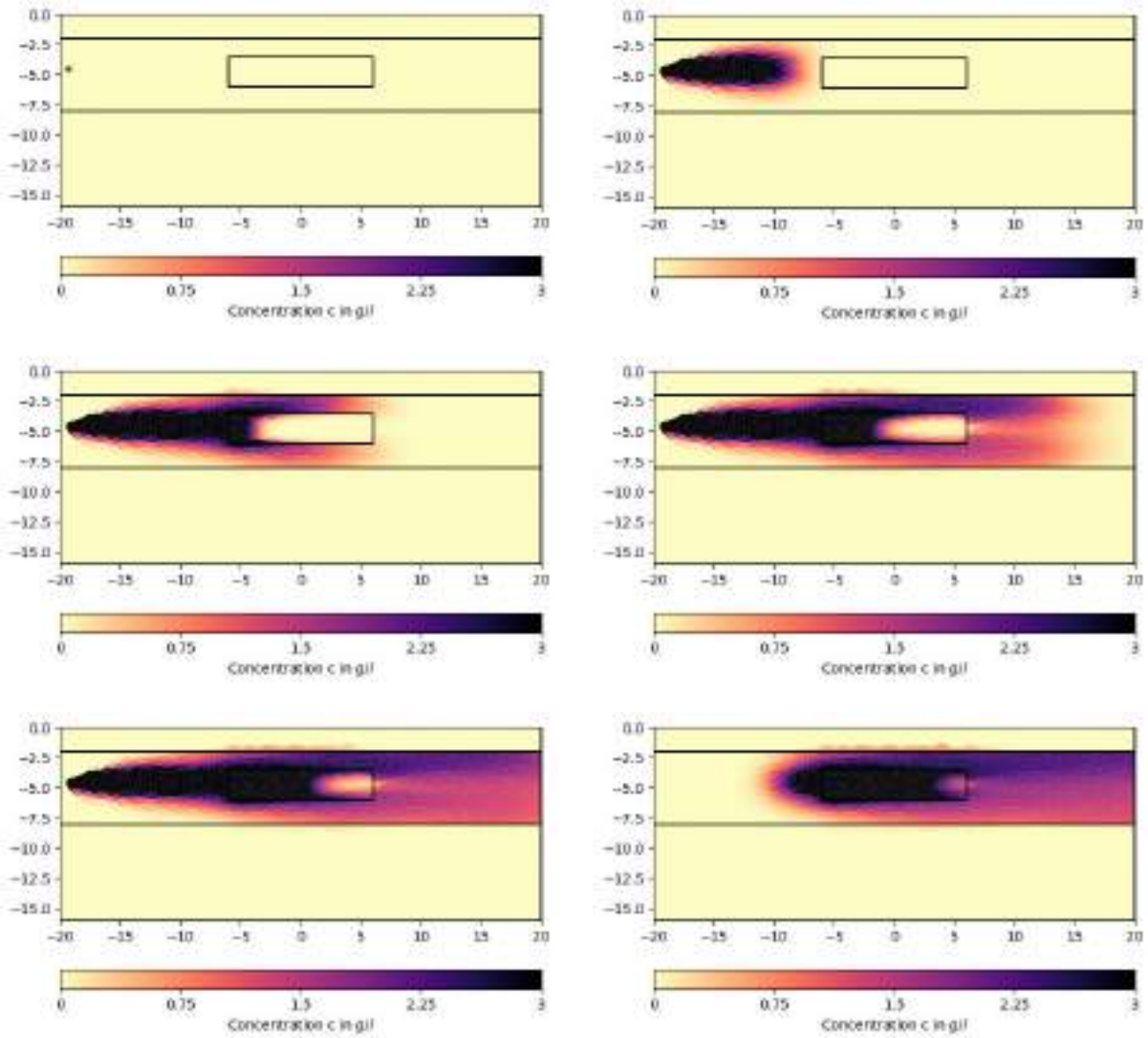
- **Joint inversion** of ERT- and SRT-data on profile P5
- Algorithm based on **cross-products** of model gradients of single methods used:

$$\underset{t}{\rightarrow}(\mathbf{x},\mathbf{y},\mathbf{z}) = \boldsymbol{\nabla m}_{f}(\mathbf{x},\mathbf{y},\mathbf{z}) \times \boldsymbol{\nabla m}_{s}(\mathbf{x},\mathbf{y},\mathbf{z})$$

- Structural similarities are underlined by **reducing local smoothness constraint**

Application in context of repository monitoring

- Can be utilized as **framework** for any kind of **geophyiscal inversion**
- Realization of **2D**- as well as **3D-geometries** for modelling
- **Multi-parameter inversions**
- Useful for **survey optimization**



Rücker et al., 2017

Thanks for your attention!

pyGIMLi
Geophysical Inversion & Modelling Library

Questions?

Constales, D., Yablonsky, G., D'hooge, D. R., Thybaut, J. W., & Marin, G. B. (2016). *Advanced data analysis and modelling in chemical engineering*. Elsevier.

Rücker, C., Günther, T. & Wagner, F.M. (2017). pyGIMLi: An open-source library for modelling and inversion in geophysics. *Computers and Geosciences*, 109, 106-123.

Wagner, F.M. & Uhlemann, S. (2021). An overview of multimethod imaging approaches in environmental geophysics. *Advances in Geophysics*, 62, 1-72.