Karlsruhe Institute of Technology

AI-based monitoring of geothermal Seismicity (AIS)

KIT, BRGM, SEMEX-ENGCON, *ES-Géothermie*

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DLR Projektträger

Motivation

- Induced seismicity: A solved problem?
- AI approaches have become a powerful tool in forecasting

Aims of AIS

- Develop a more efficient chain of AI based algorithms to detect and locate induced seismicity.
- Develop AI-based seismicity catalogue analysis and forecasting tools.
- Develop cost-effective sensors for seismic networks to monitor induced seismicity to significantly increase the amount of data, a prerequisite for AI based approaches
- Apply these methods to a real case in Soultz-sous-Forêts, Rittershoffen.

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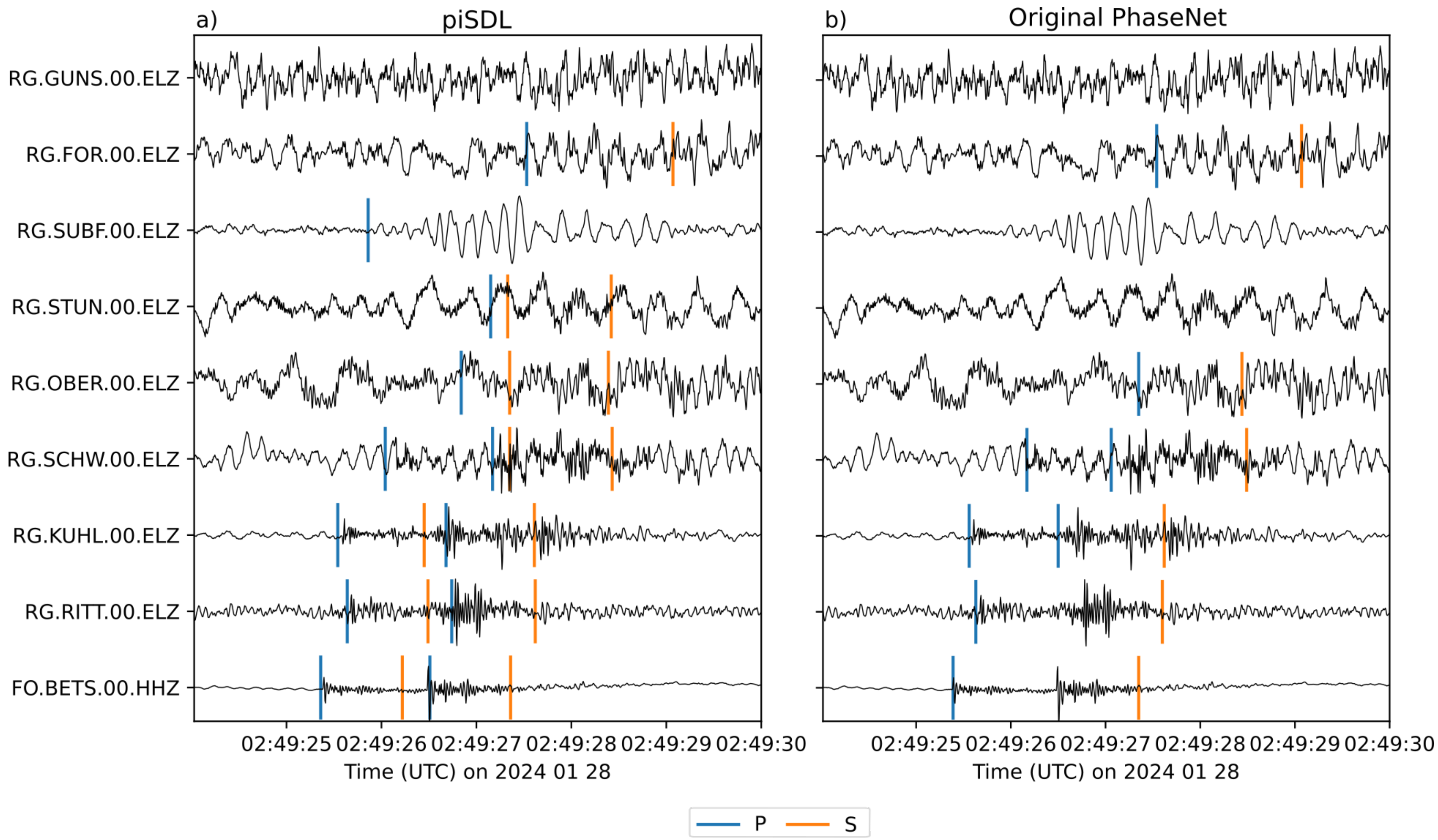
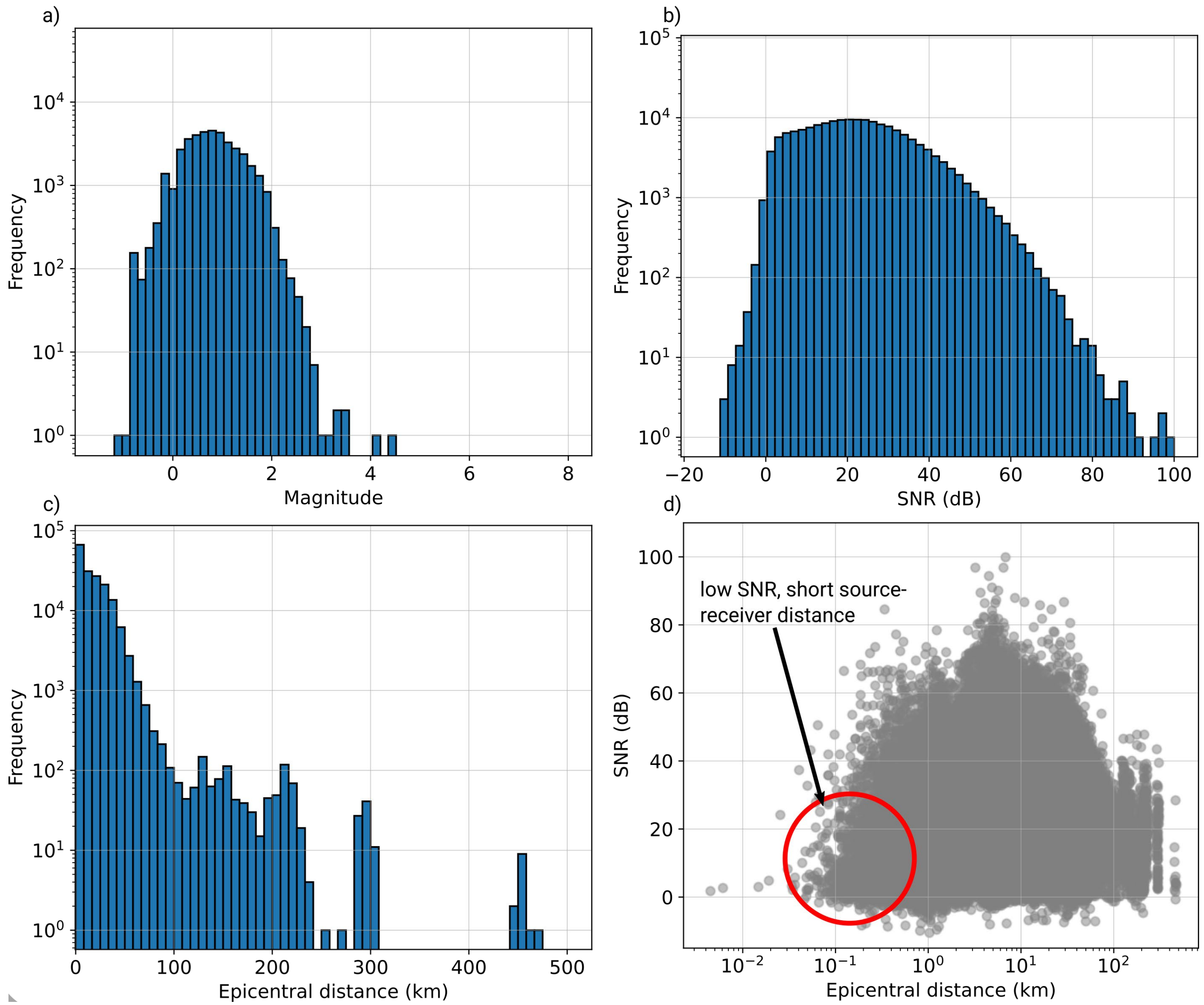
piSDL: PhaseNet for induced Seismicity



A new dataset for AI in Seismology (induced seismicity)



- low magnitude events
- short distances between source and receiver (e.g. shallow earthquakes)
- low signal-to-noise ratios
- 170,000 three-component waveforms with P- and S-arrival in each window
- 40,228 different seismic events
- 455 seismological stations

- seismic events are from
  - geothermal sites
  - wastewater disposal
  - coal mine flooding
  - low-magnitude events from SED

Talk by Janis Heul on Friday

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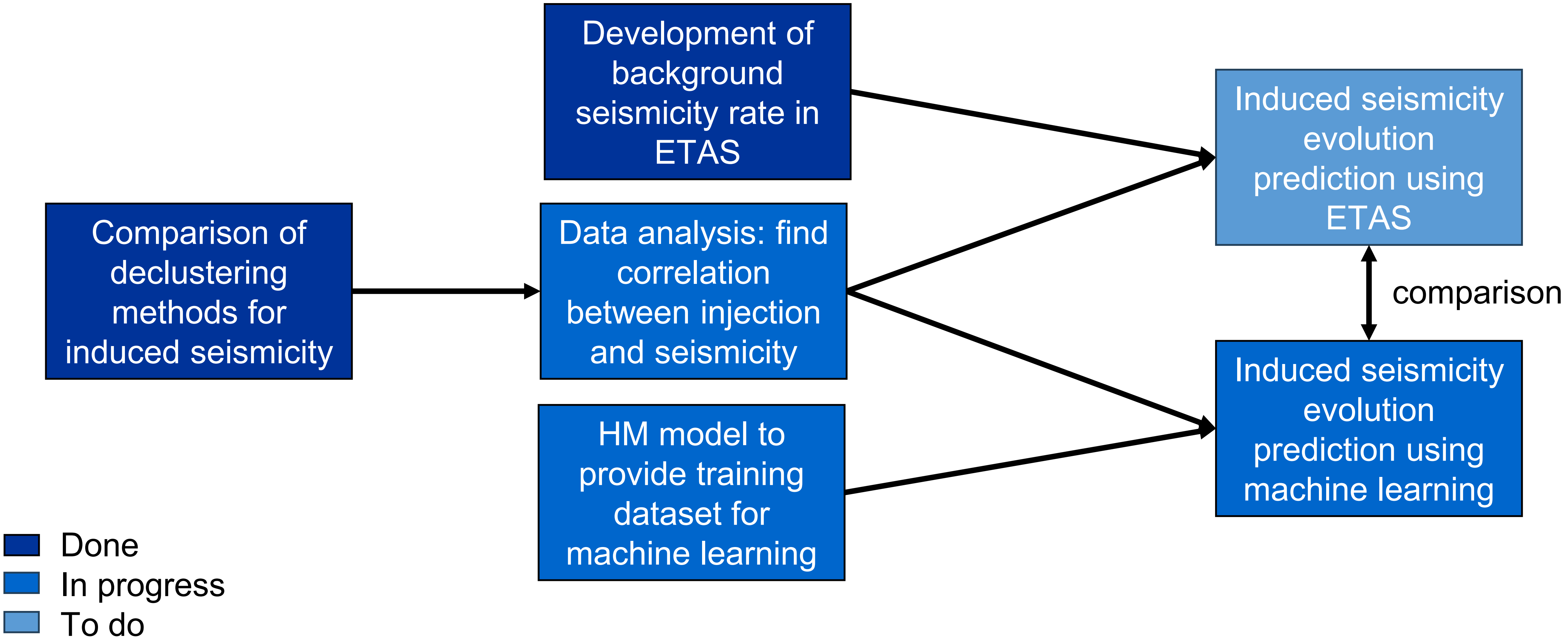
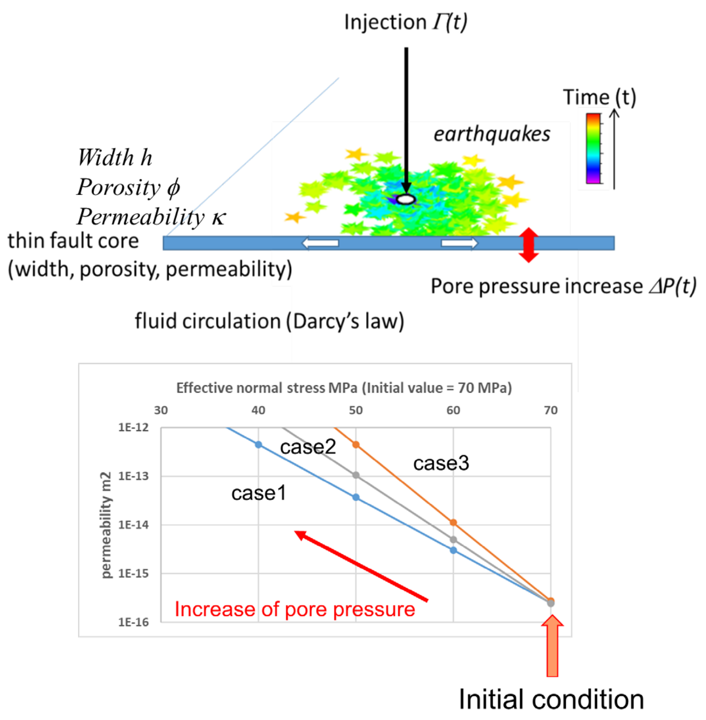
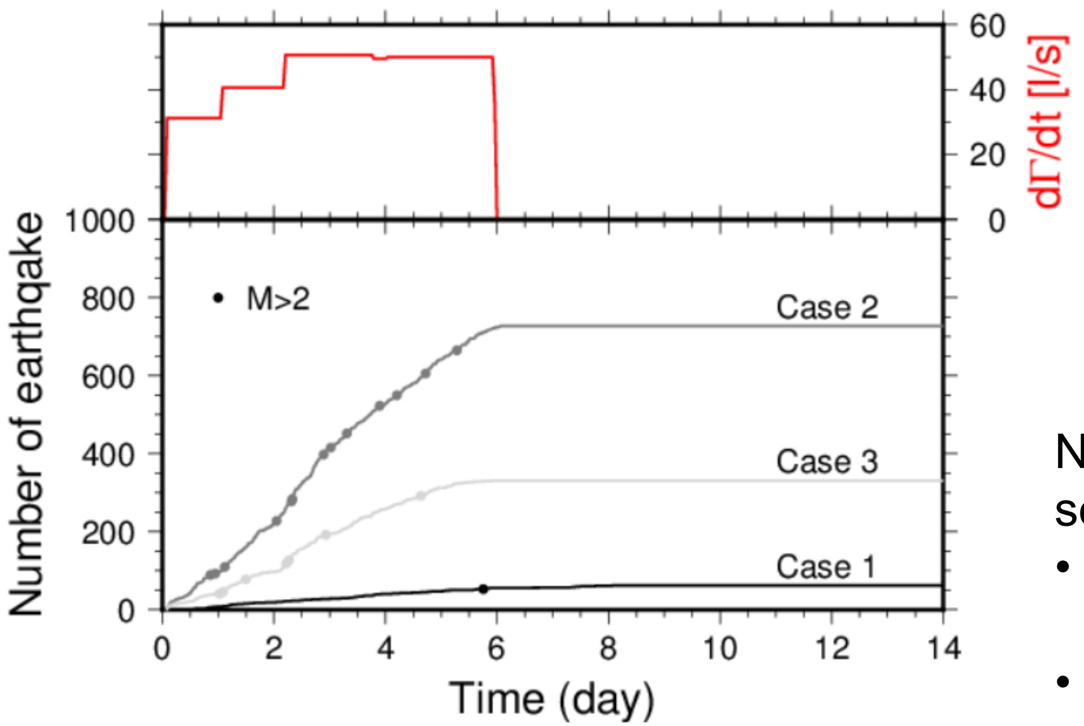
AI-based seismicity catalogue analysis and forecasting



Importance of hydraulic process in induced seismicity modeling





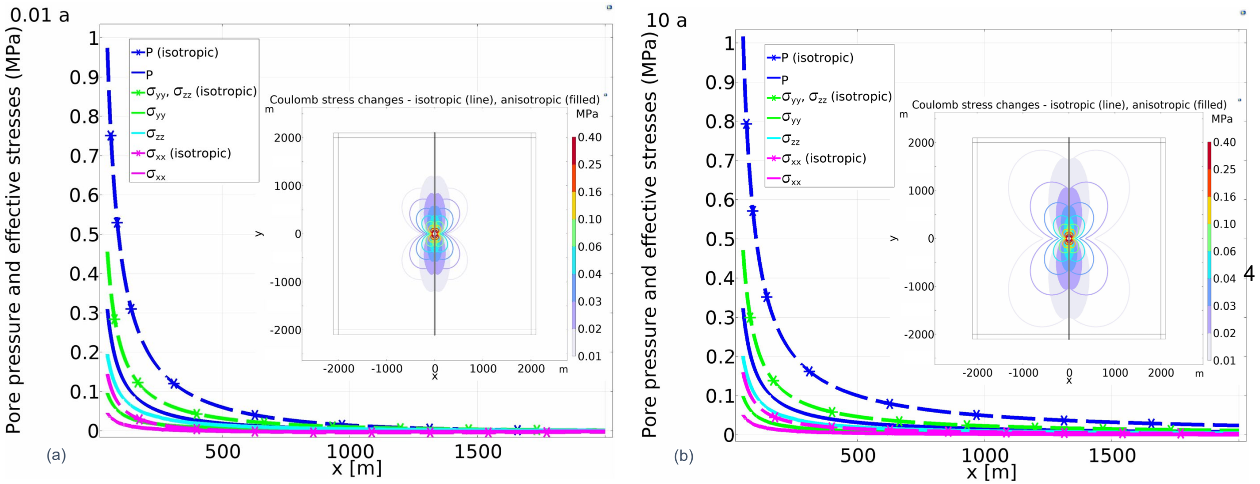
Numerical modeling of induced seismicity for:

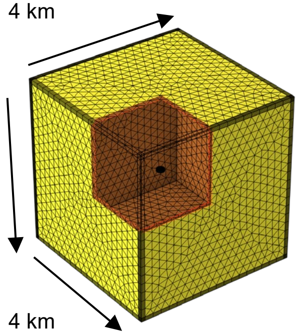
- Understanding the physical background
- Providing synthetic data sets for machine-learning

Poster P7 by Hideo Aochi in Modelling and physics of induced seismicity

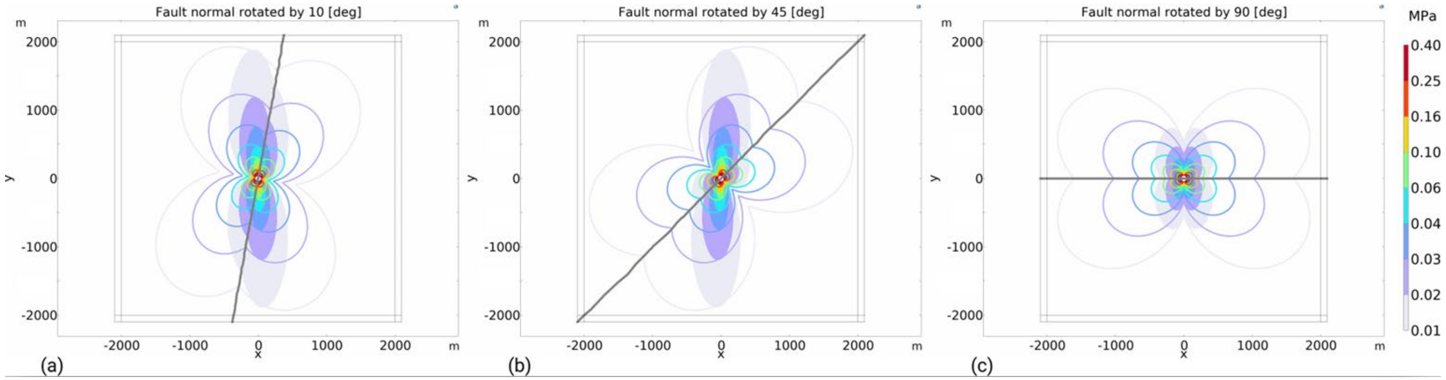
Poroelastic stresses and pore pressure in media with anisotropic permeability

Comparison of effective stress and pressure distributions after about 3.5 days (left) and 10 years (right) for isotropic and anisotropic media with corresponding Coulomb stress changes (inlay).





Comparison of distribution of Coulomb stress changes for vertical faults oriented at 10°, 45° and 90° relative to high permeability direction.



Poster P15 by Tatia Sharia: Modelling and physics of induced seismicity

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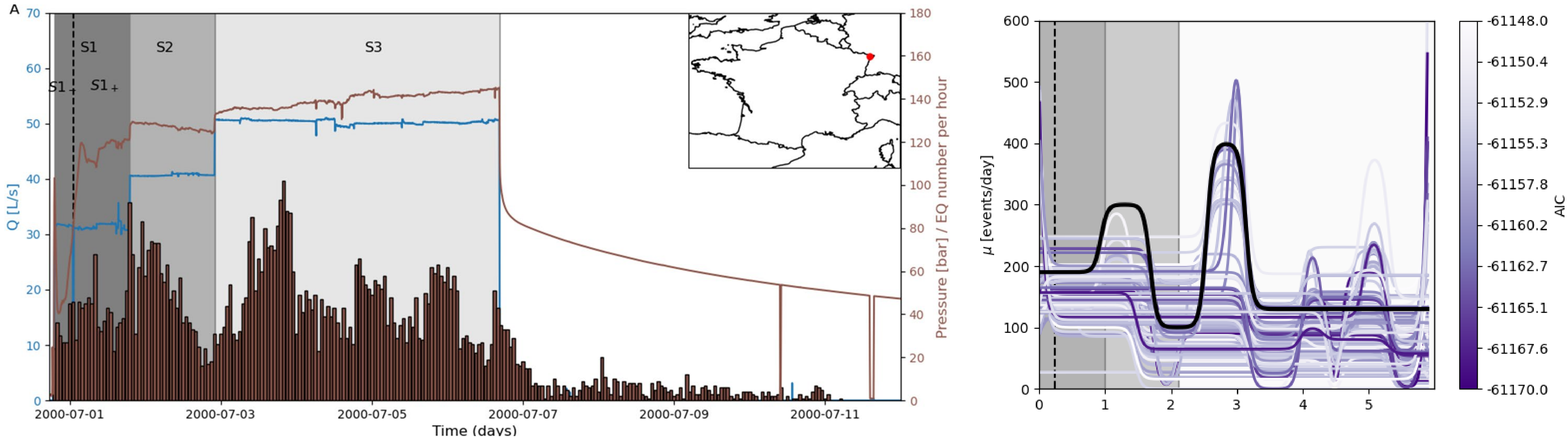
Inferring the evolution of seismicity rate using ETAS model

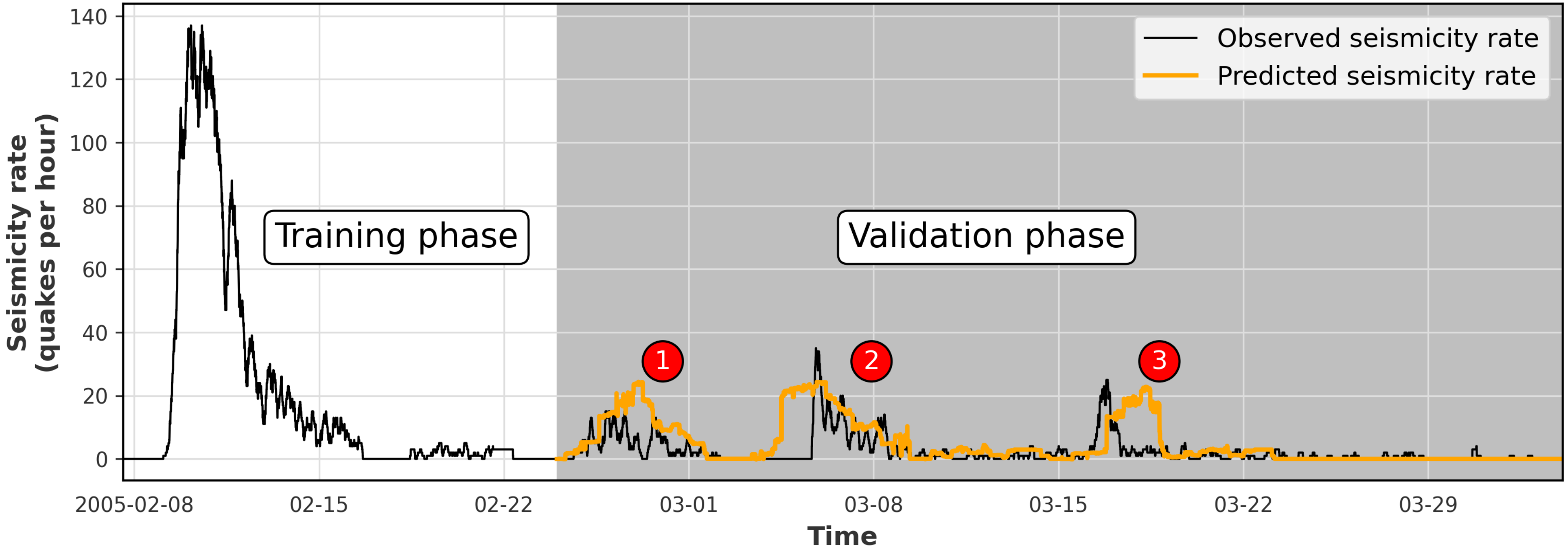


Using time dependent background seismicity rate to analyse induced seismicity: infer a link to injection parameters

Poster P18 by Julie Maury in Modelling and physics of induced seismicity

Prediction of induced seismicity: a machine learning approach

Application to Soultz-sous-Forêts 2005 stimulation phase



Using only injection parameters (flow rate and wellhead pressure) infer seismicity rate evolution with a few weeks of training phase

Poster P21 by Arthur Cuvier in Case Studies session

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Develop cost effective sensors

- Low investment costs
- Easy to install by anybody
- Easy configuration of a sensor network, which can be monitored through the cloud (self organised networks)
- Low power consumption (no mains necessary)
- High sensitivity
- Online Communication including state of health information
- AI enhanced

Pilot instrumentation already running: piSDL implemeted

7 additional stations integrating piSDL for event detection will be deployed in 2025

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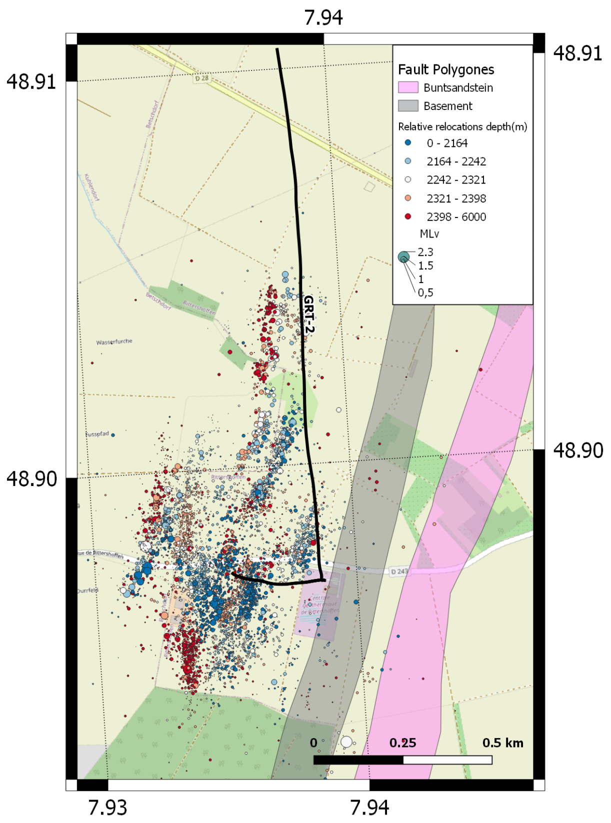
Adaptation of geothermal seismicity monitoring

Task 5.1 - Preparation for dataset from the existing observation network



- More than 10,000 events from Rittershoffen dataset were added to an existing dataset to built piSDL dedicated to the detection of induced seismicity (Heuel et al., 2025)
- 85 seismic sequences were identified (at least 10 events in less than 10 hours according to Bakkum et al., 2014)
- These sequences will be used to test the performance of piSDL and compare it to the actual automatic and manual catalogue

Talk by Vincent Maurer in the afternoon

See also *:* Lengliné O., Maurer V., Yorillo A. (2025). Intermittent induced seismicity during the multi-year operation of a geothermal reservoir, submitted to *Geophys. J. Int.*
Heuel J., Maurer V., Frietsch M., Rietbrock A. (2025). Seismic Phase Picking for Induced Seismicity with Deep Learning, submitted to *Seismica*

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Thank You

Stay tuned for the next 18 months