MODERN 2020

Development and Demonstration of monitoring strategies and technologies for geological disposal

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safe solutions for radioactive waste

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Geophysical Monitoring Of High-Level Radioactive Waste Repositories

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This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement n° 662177

Introduction

Why Geophysics?

- Allows testing from **outside** the repository
- Provides **volumetric** information
- Suitable for **monitoring** subtle changes of the physical properties

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Introduction

Suitable geophysical techniques

- **Seismics**
  - Full waveform inversion (FWI)
  - Differential tomography
  - Anomaly detection
- **Geoelectrics (ERT) and induced polarization (IP)**
  - Tomographic imaging
  - Laboratory measurements

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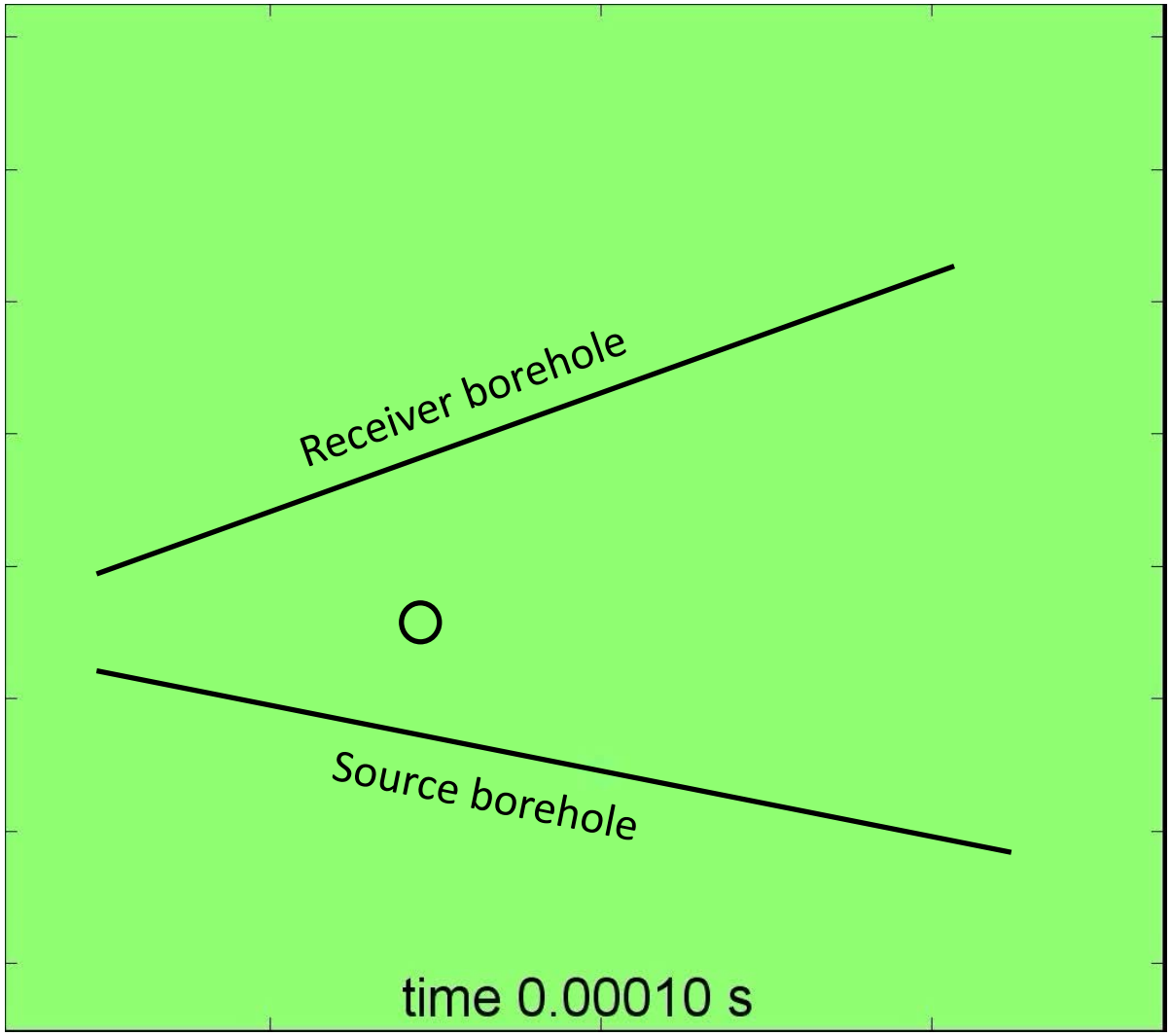
Seismic Full Waveform Inversion



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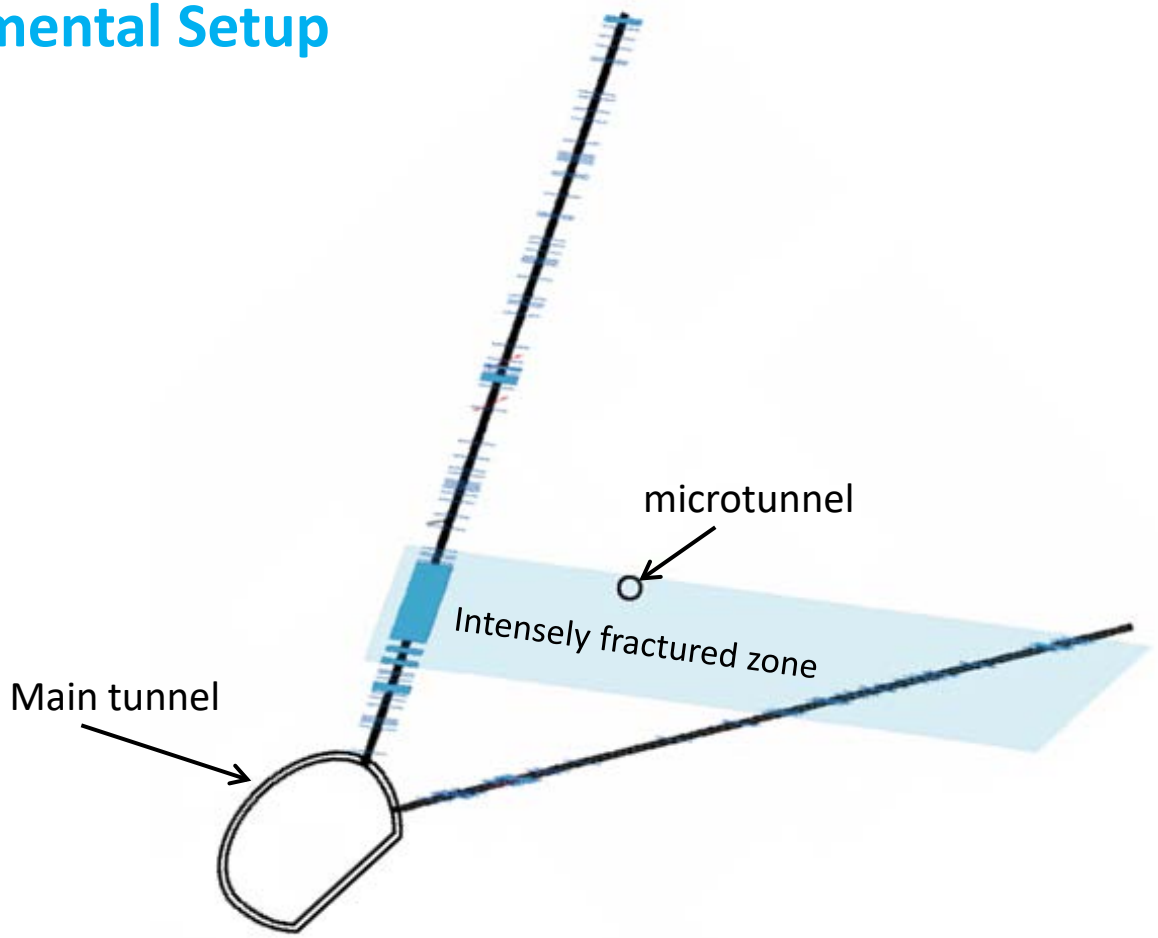
Seismic Full Waveform Inversion

Experimental Setup



modified after Badertscher, 2005

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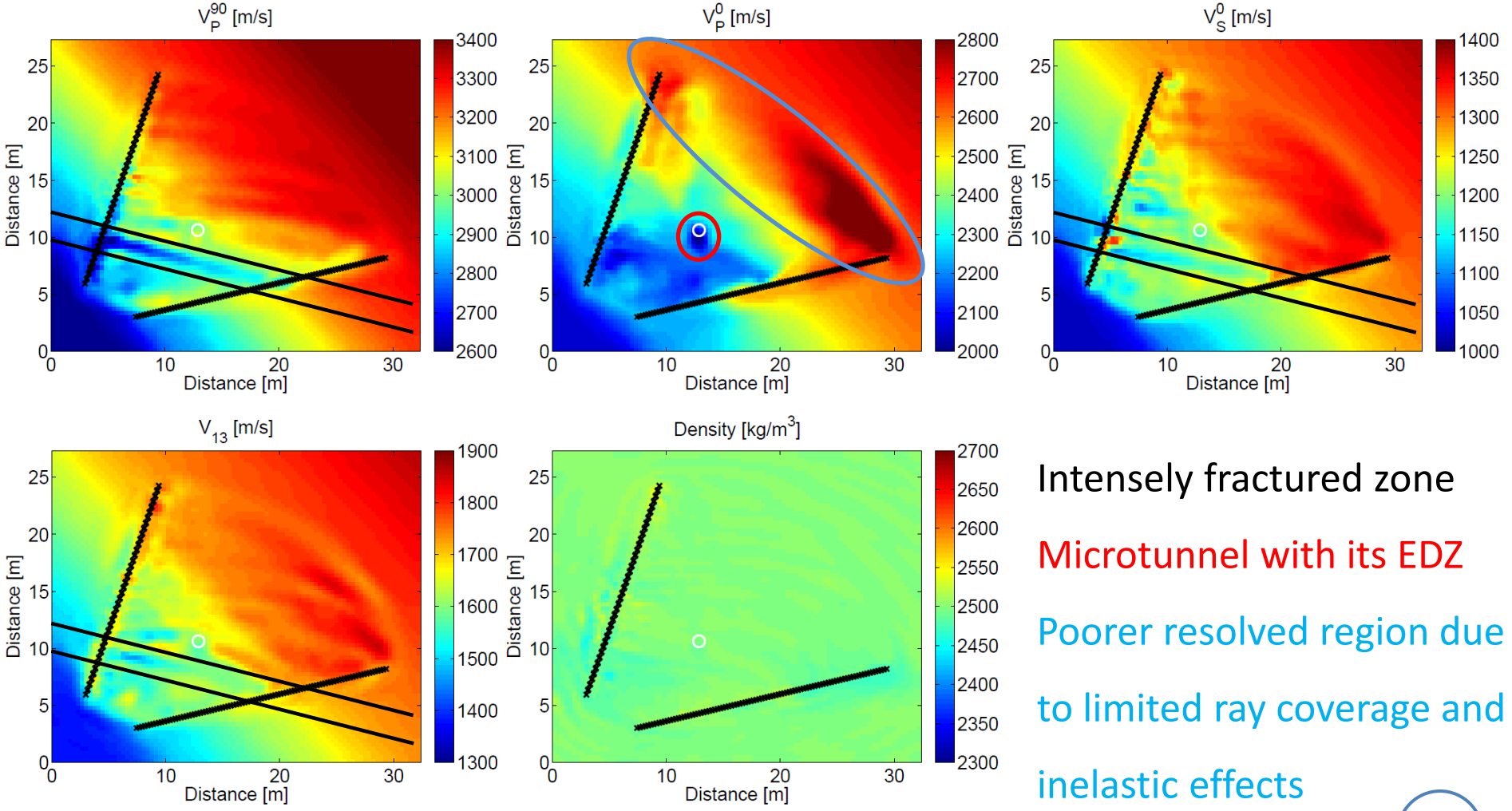
Seismic Full Waveform Inversion

Inversion results



Intensely fractured zone

Microtunnel with its EDZ

Poorer resolved region due to limited ray coverage and inelastic effects

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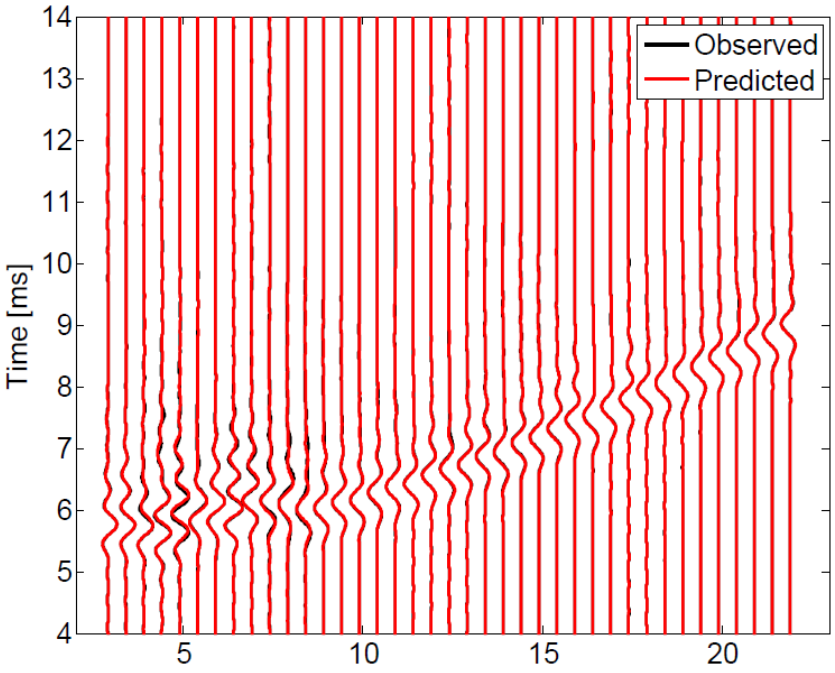
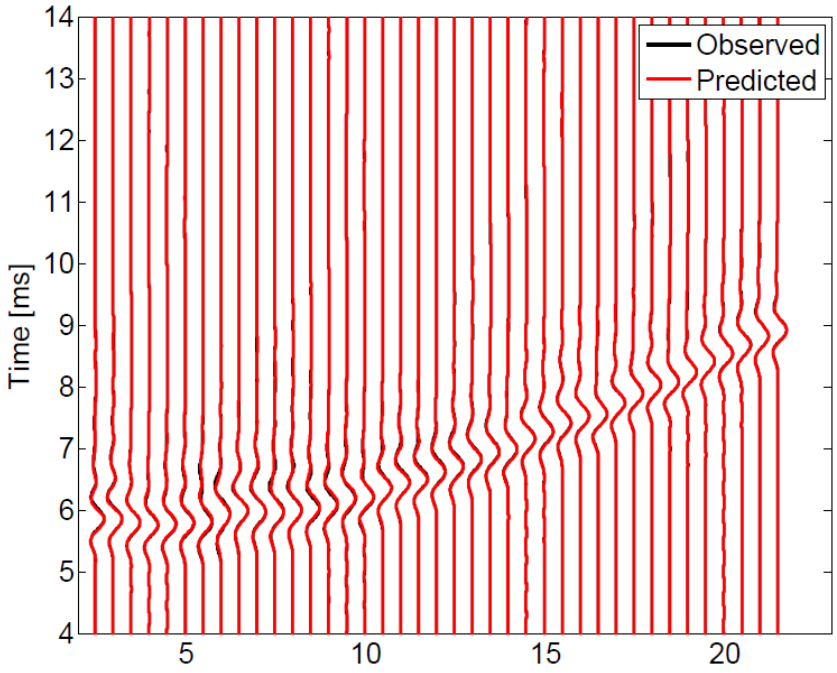
Seismic Full Waveform Inversion

Displacement parallel to the borehole



Displacement perpendicular to the borehole



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Differential Tomography

- Ground-penetrating-radar (GPR) travel time data instead of seismic full waveform data were considered
  (results can be transferred to seismic measurements)
- Intrusive experiment
  (results can be transferred to non-intrusive monitoring)
- GPR data are primarily sensitive to temperature and moisture content
- Differential tomography allows subtle temporal changes to be monitored.

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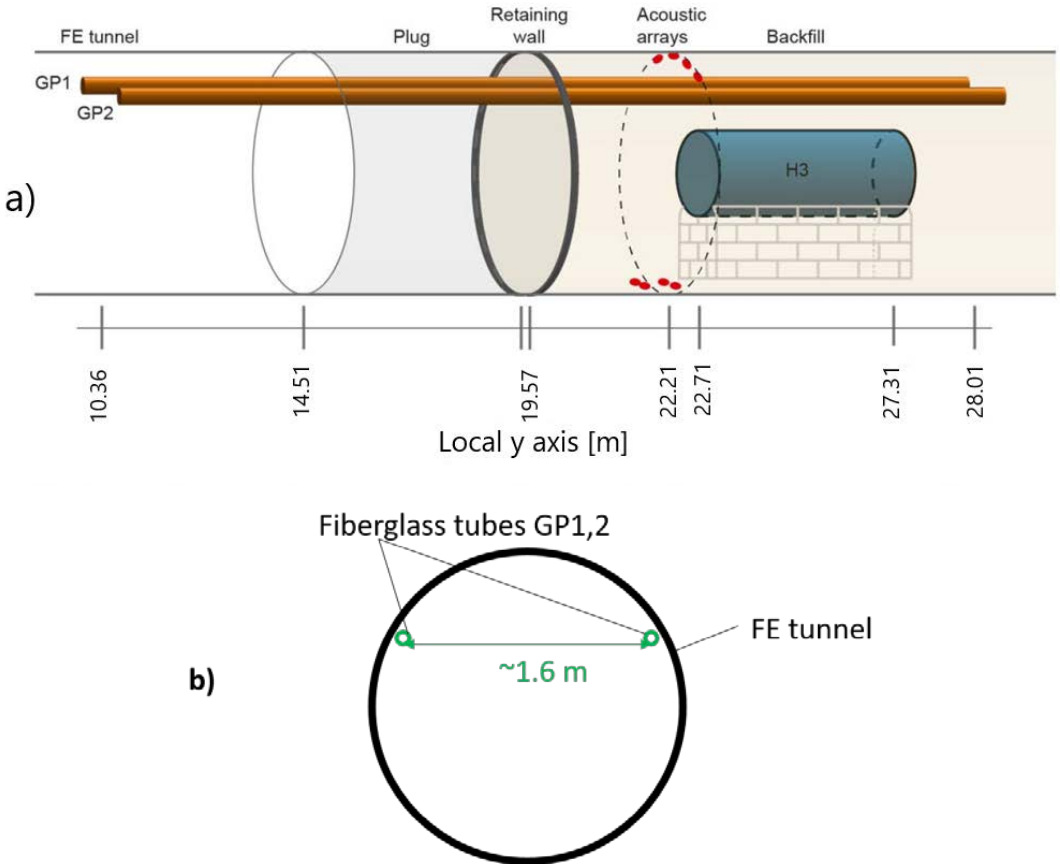
Differential Tomography



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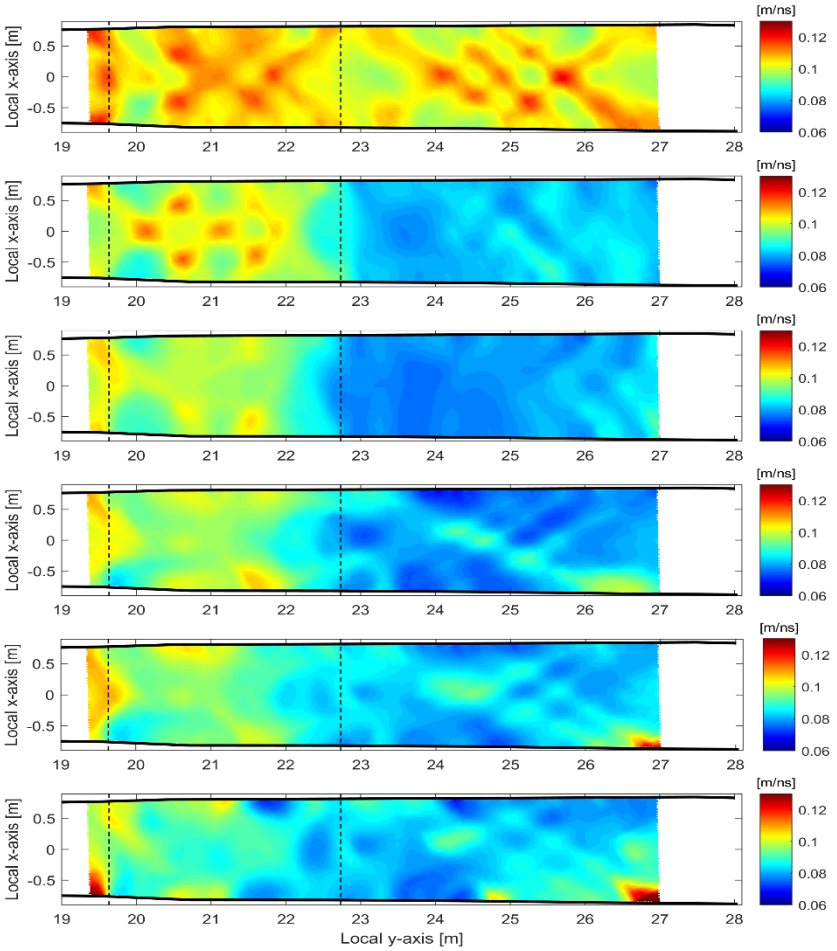
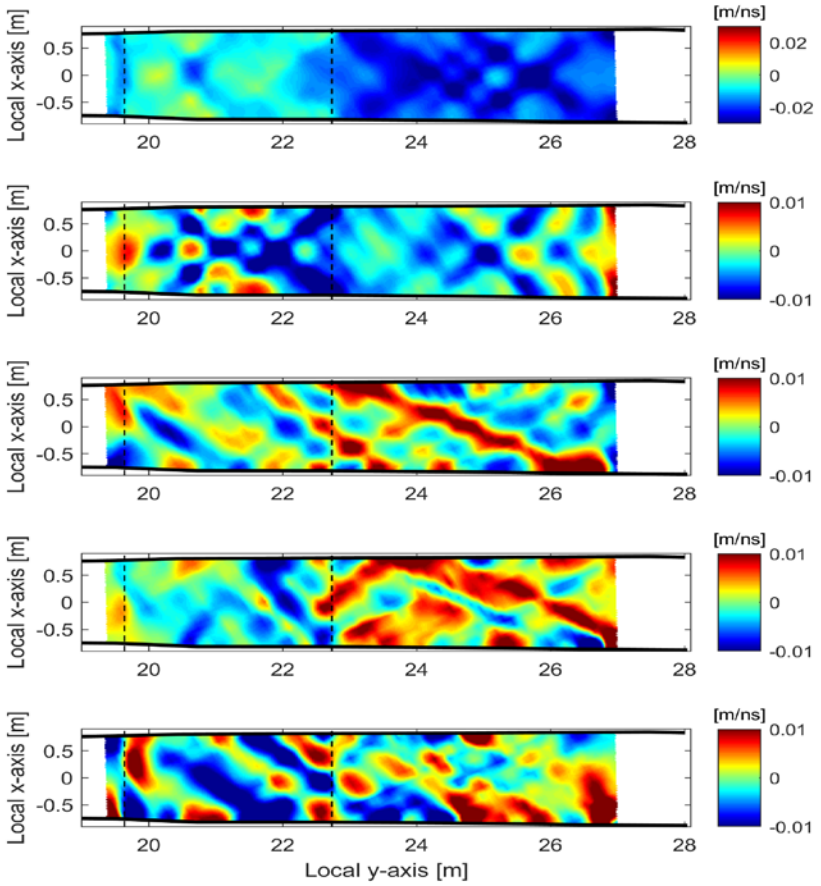
Differential Tomography

GPR tomograms



Differential tomograms

Tomogram differences



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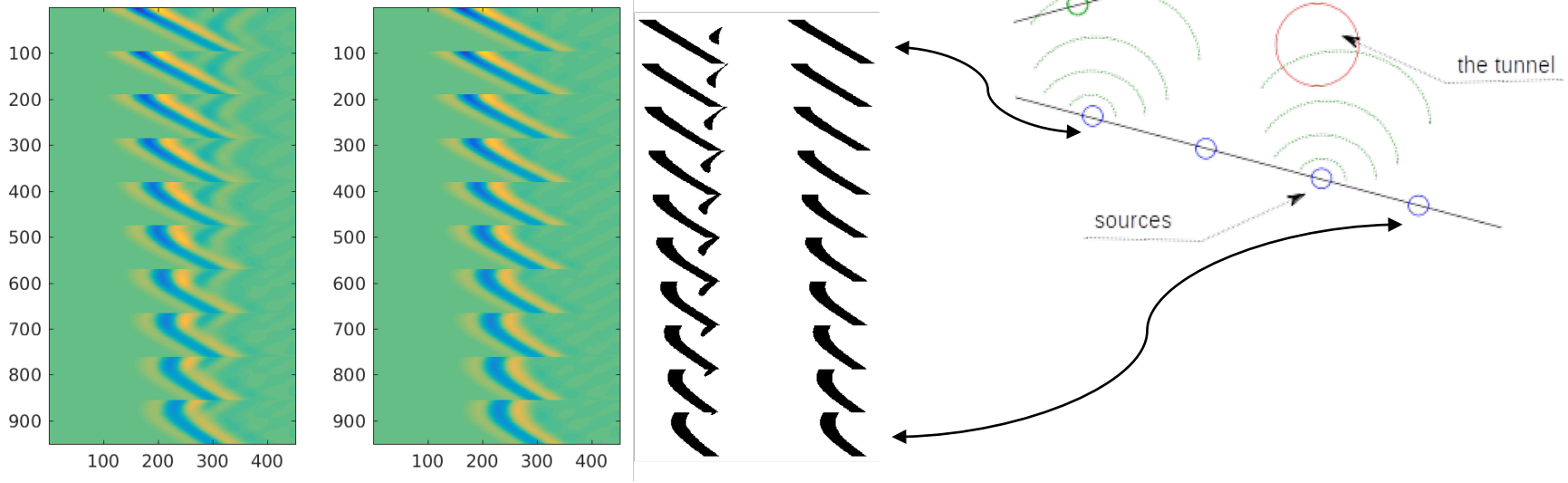
Outlook:
Anomaly detection using machine learning and seismic data



ERT/IP Tomography

- ERT/IP tomography:
  Determination of electrical subsurface parameters by injecting electrical currents and measuring the resulting voltages
- Electrical subsurface parameters are sensitive to moisture content and temperature
- Key developments required
  - ✓ Establishing suitable tomography algorithm
  - ✓ Testing the procedures in the laboratory at various scales
  - ✓ Establishing constitutive relationships between electrical parameters and moisture content and temperature

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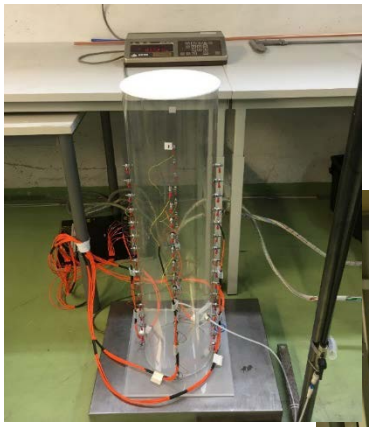
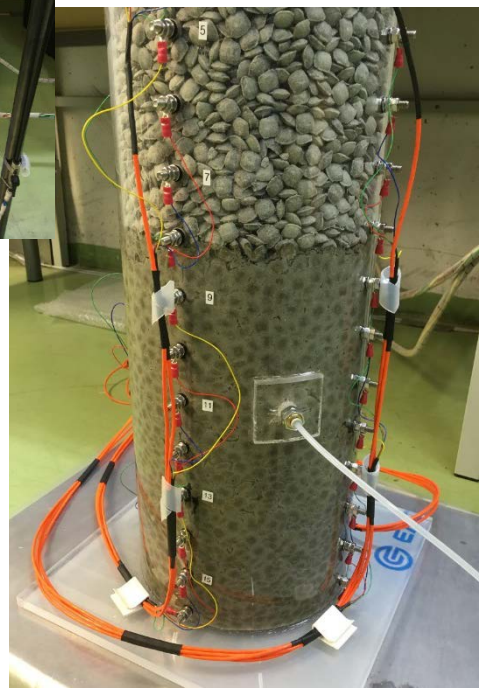
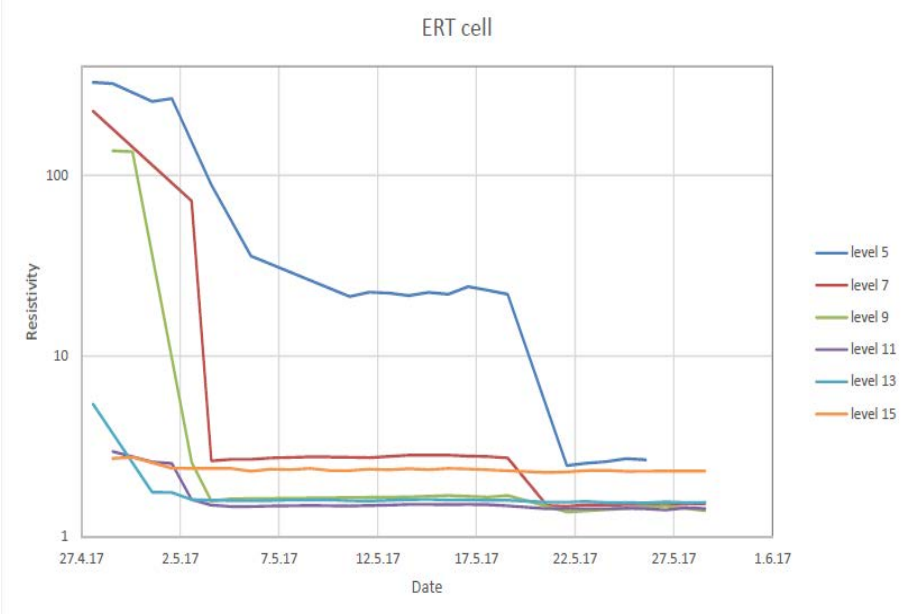
Column experiment for testing the developed 3/4D ERT/IPT algorithms

- **Repeated measurement of the time domain spectral full waveform recordings during the ontime current injections in a column experiment (lab-scale)**







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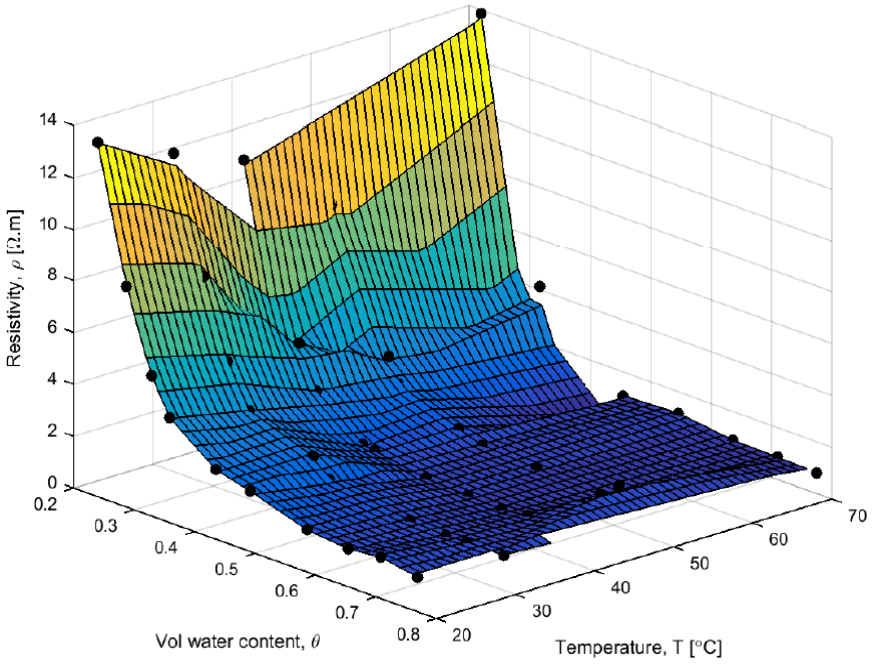
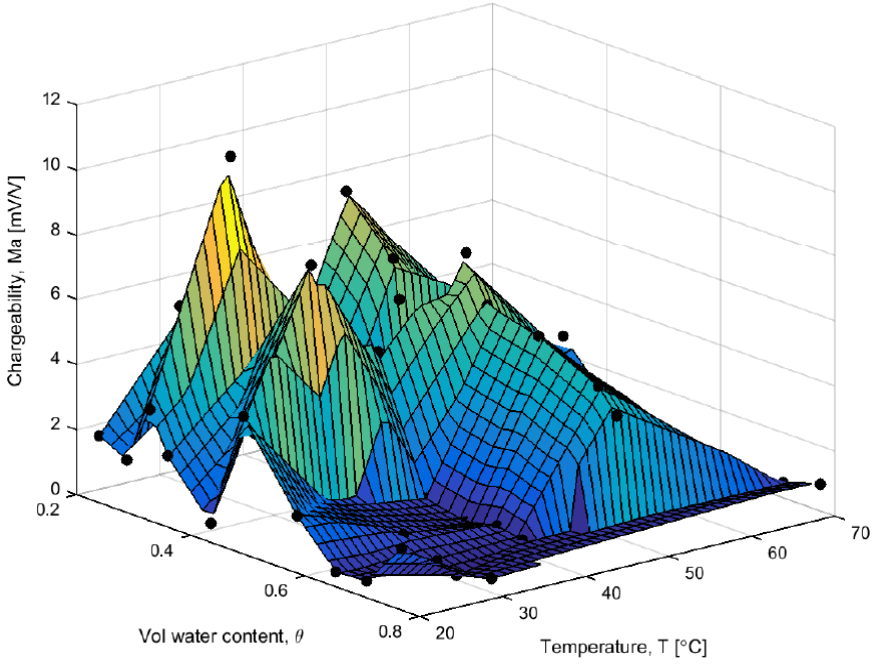
Constitutive relationships

ERT calibration results



IP calibration results



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Bentonite characterisation using ERT/IP measurements

See presentation

Session 7b: New Developments in Repository Monitoring Technologies (Chair: José Luis García-Siñeriz)

14:40	Non-intrusive Geo-electrical ERT Monitoring of High-Level Radioactive Waste Experiments in Tournemire URL	Bruna De Carvalho, University of Strathclyde (UK)

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Conclusions Seismics

- Seismics (GPR)
  - ✓ Anisotropic FWI algorithm established and tested on synthetic and field data
    → Technology is ready for applications
  - ✓ Differential tomography algorithms developed that are applicable to waveform data (seismics and GPR)
    → Technology is ready for applications
  - ✓ Establishing constitutive relationships for elastic parameters
    → To be done
  - ✓ Anomaly detection algorithm implemented
    → proof of concept with field data still pending

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Conclusions Geoelectrics

- ERT/IP
  - ✓ ERT/IP inversion algorithms developed and tested with laboratory experiments
    → Technology is ready for applications
  - ✓ Calibration of ERT/IP response as a function of moisture content and temperature performed
    → Technology is ready for applications
  - ✓ Application of novel tools in the Tournemire demonstrator experiment
    → Work is still ongoing

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