Seismic monitoring of geothermal reservoirs using DAS on dark fibers

The RUBADO project

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HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

EGU26
GENERAL ASSEMBLY

Motivations

Fiber networks: widely installed, spanning multiple scales

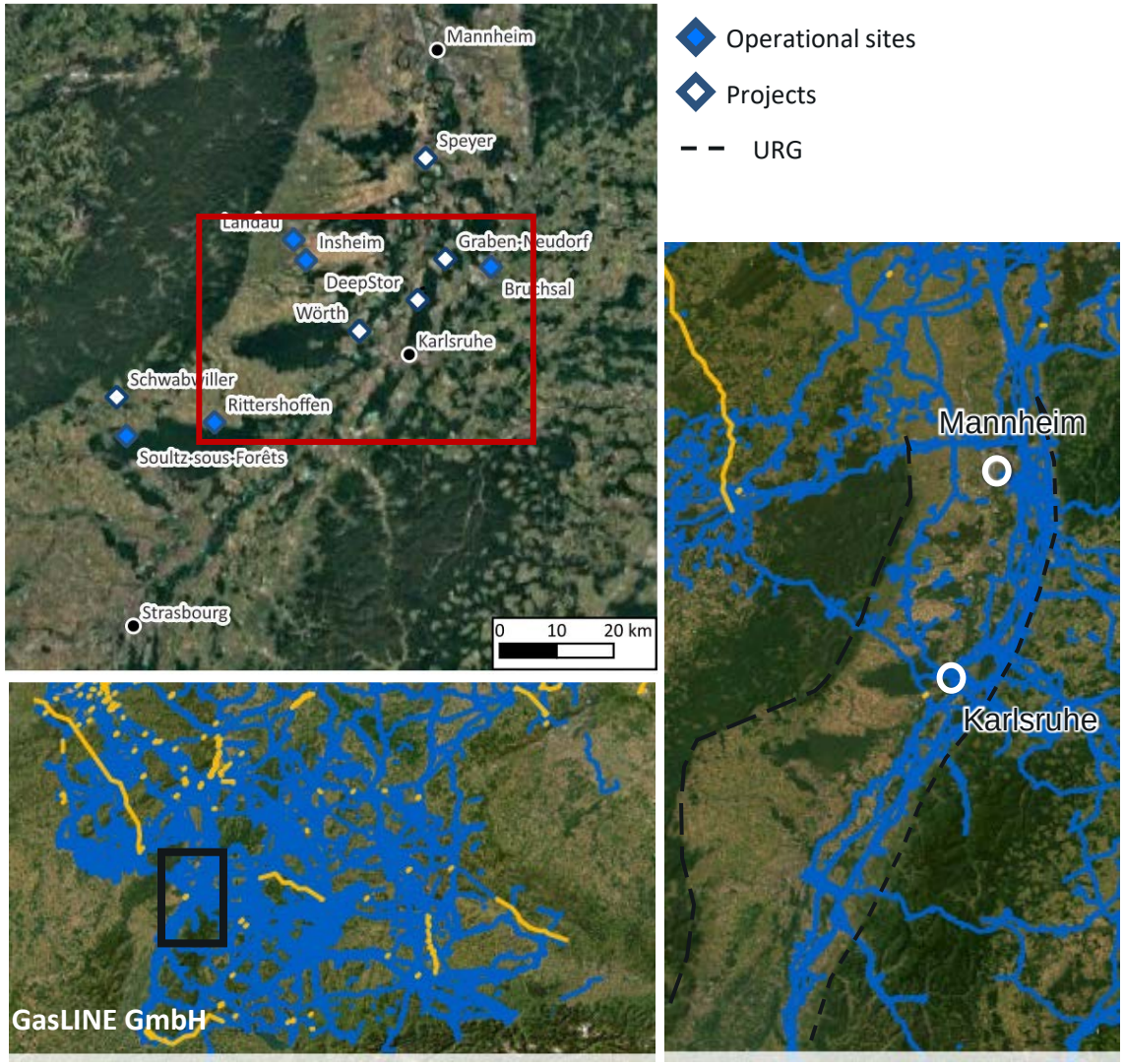
- DAS on dark-fibers to achieve vast, dense seismic arrays
- But not designed for seismology… Opportunity for seismic monitoring?

Focus on the Upper Rhine Graben

- Key region for deep geothermal energy, several active sites/planned projects
- Operations can induce seismicity
- Seismic networks at scale of individual site, with limited interoperability

RUBADO project:

- Leverage dark-fibers for seismic monitoring of geothermal sites
- Local dense recordings + regional coverage
- Connect observations across different geothermal sites



RUBADO

Supported by:
Federal Ministry for Economic Affairs and Energy
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geotomographie

UHH

KIT Karlsruhe Institute of Technology

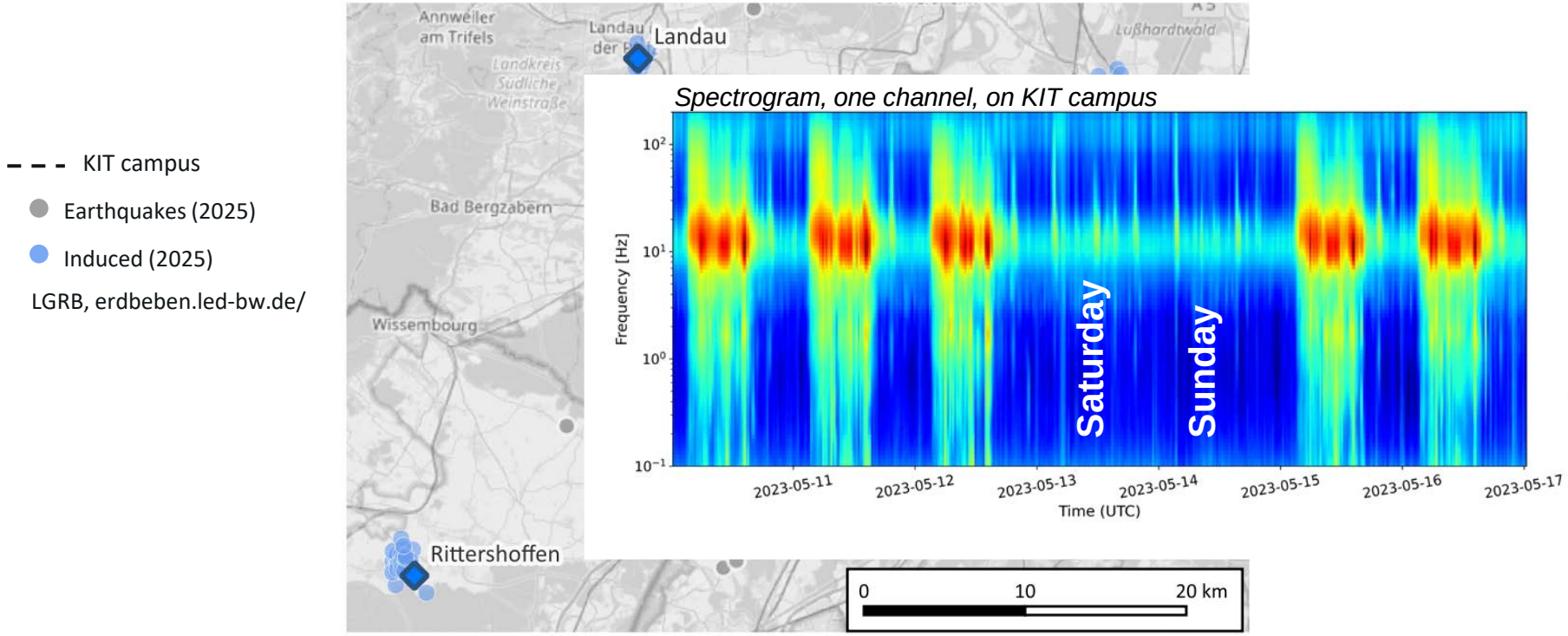
Research Context

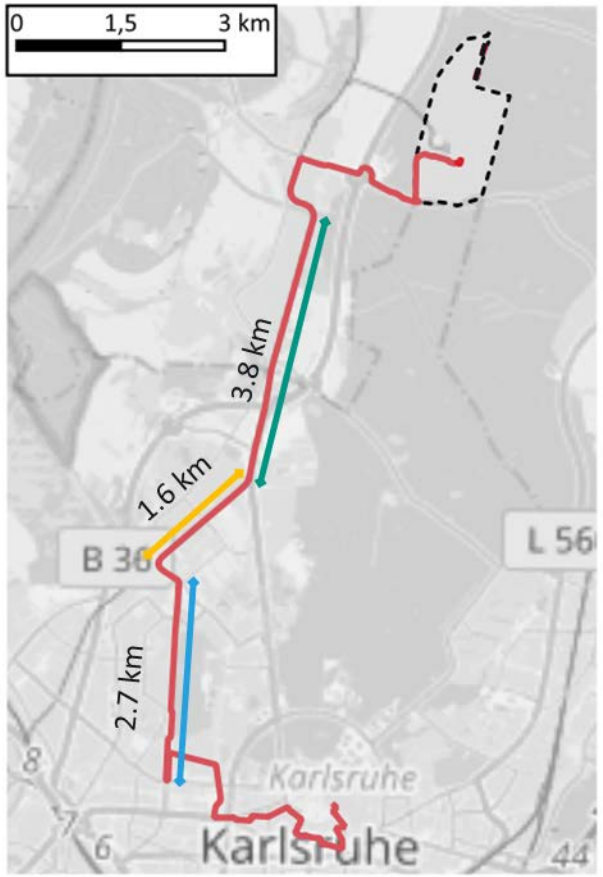
Region of Karlsruhe

- Natural and induced seismicity during operation of geothermal sites is reported

DAS recording on dark-fiber

- Geometry: 22 km, between KIT campuses, along main transportation corridors (road, railways)
- Segmented in km-scale, rectilinear sections
- Strong anthropogenic noise, with imprint in freq. range of interest





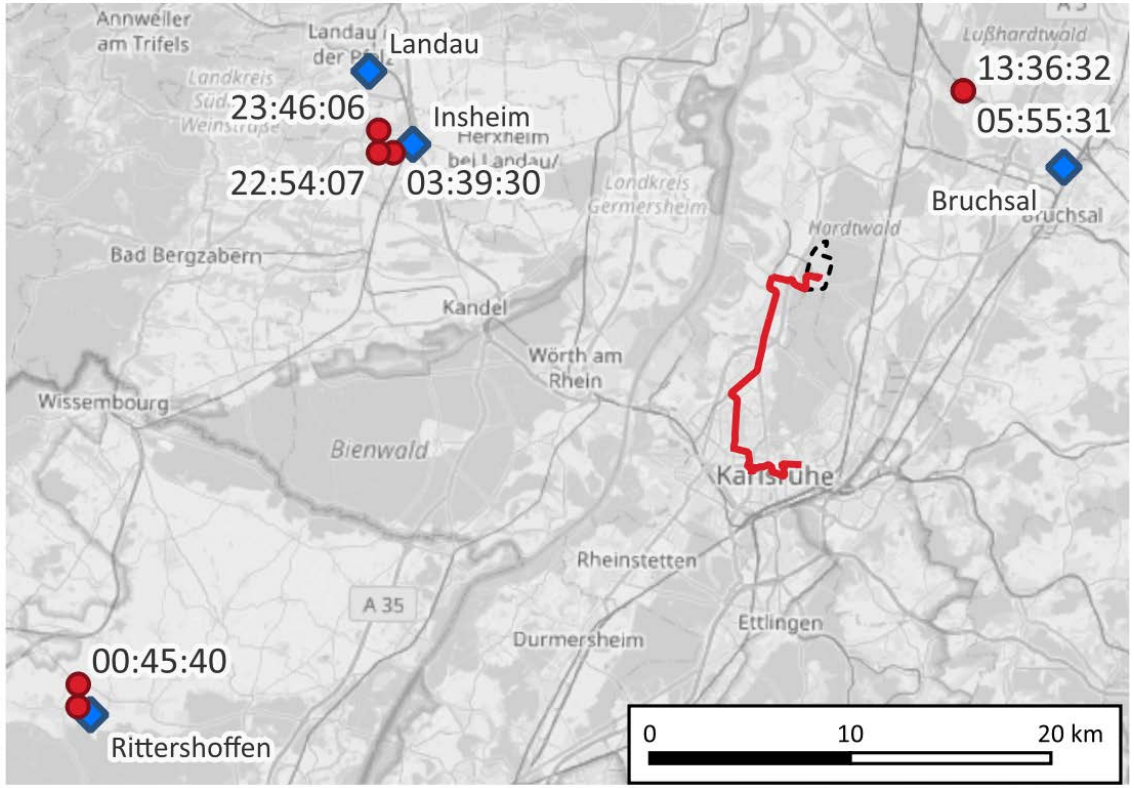
Observations

Provides valuable observations of induced seismicity in the region

- Induced micro-seismic events identified in DAS data after catalogue scanning
- From 3 geothermal sites: Bruchsal, Insheim, and Rittershoffen
- Mostly observed during periods of lower anthropogenic activity

Observed events

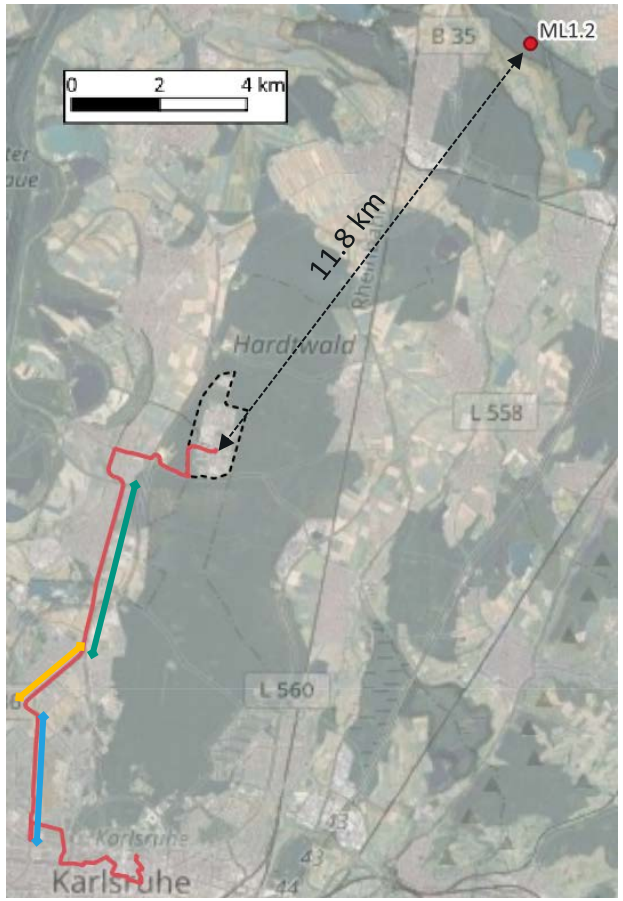
LGRB, erdbeben.led-bw.de/

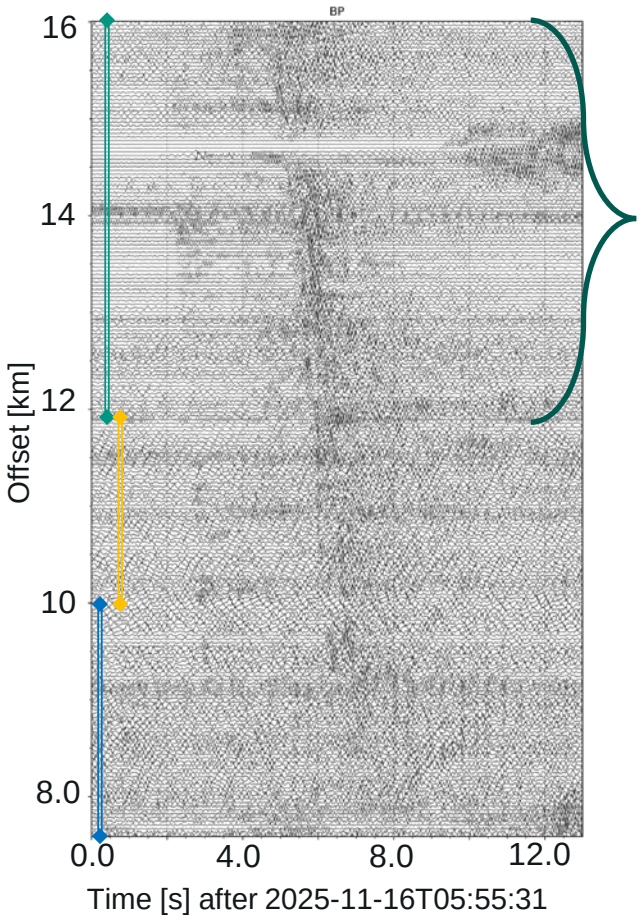


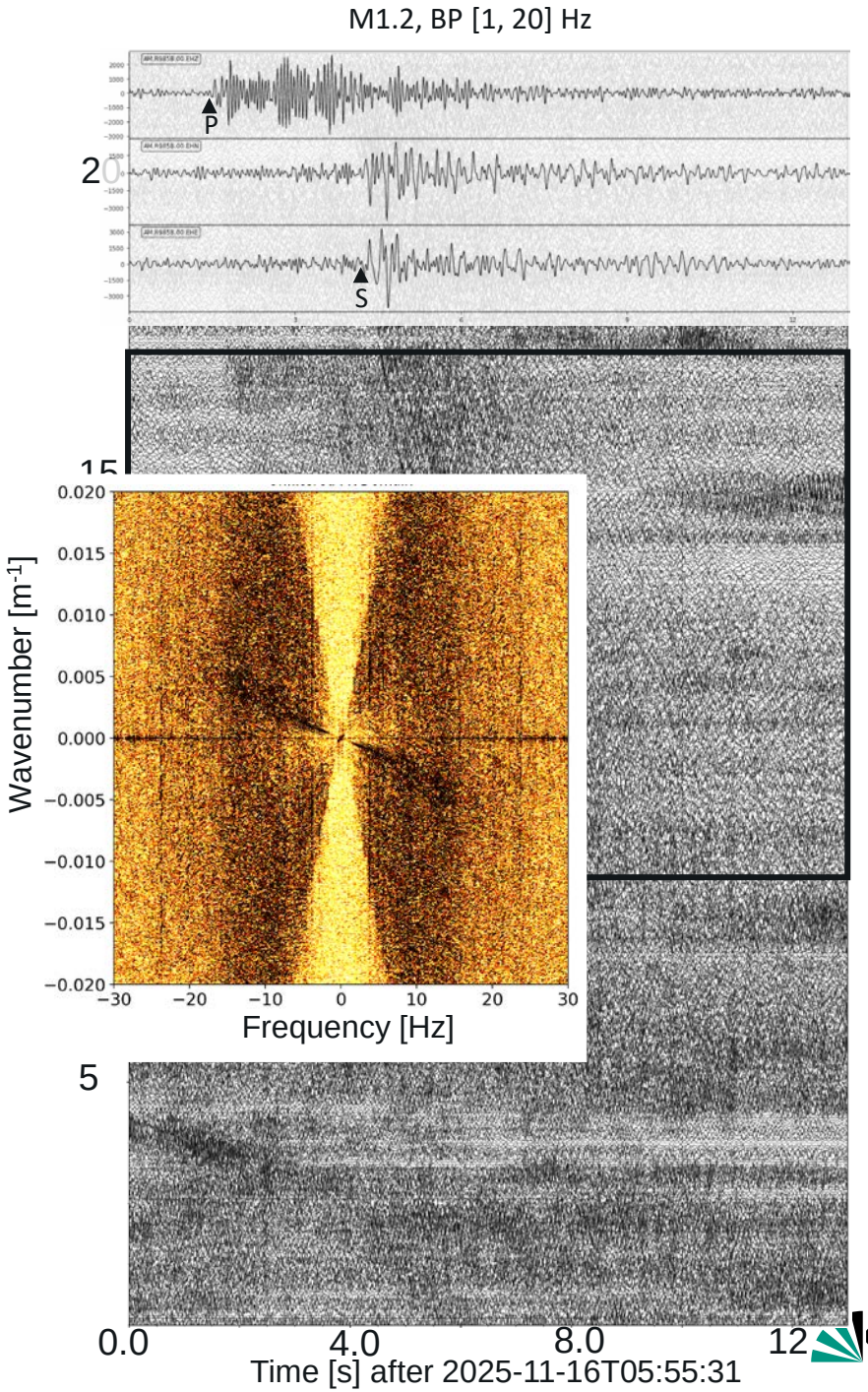
Observations

DAS array provides observations of seismicity in the region

- Collects multiple seismic phases (comparison with data from RS3D)
- Visible propagation of a coherent wavefield
- Data from rectilinear section in *fk* domain shows characteristic pattern



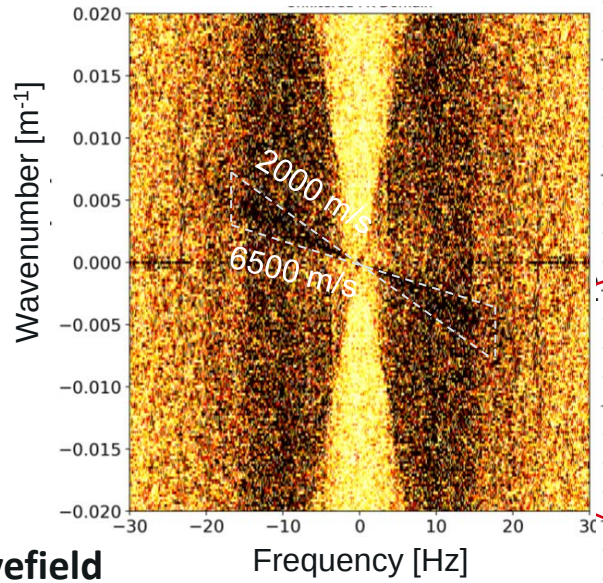




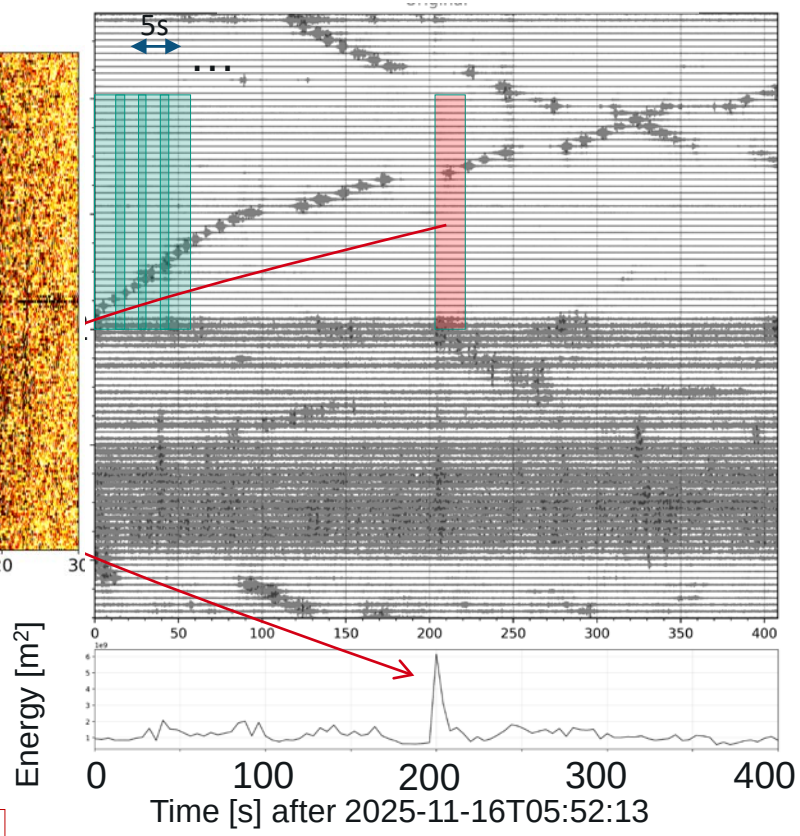
Signal detection/classification

fk energy detector to identify characteristic propagation signatures

- Data analyzed in successive time/space windows, focus on the rectilinear segments
- Define region in the *fk* domain based on the expected apparent propagation parameters
- Energy estimation in *fk* sub-domain over time
- Peak energy → target wavefield detected; noise rejected



Bruchsal, 2025-11-06T05:55 M1.2

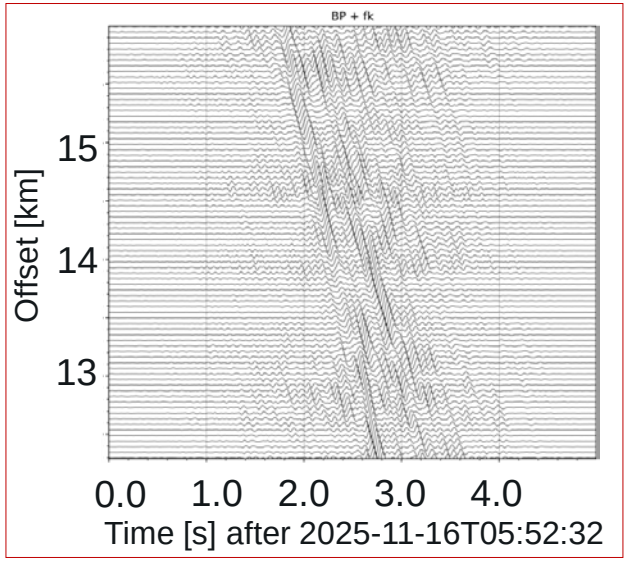


Current direction, from *fk* detection to learning the signature of wavefield

- Separation of signal types via unsupervised/ supervised clustering of patterns

Side product

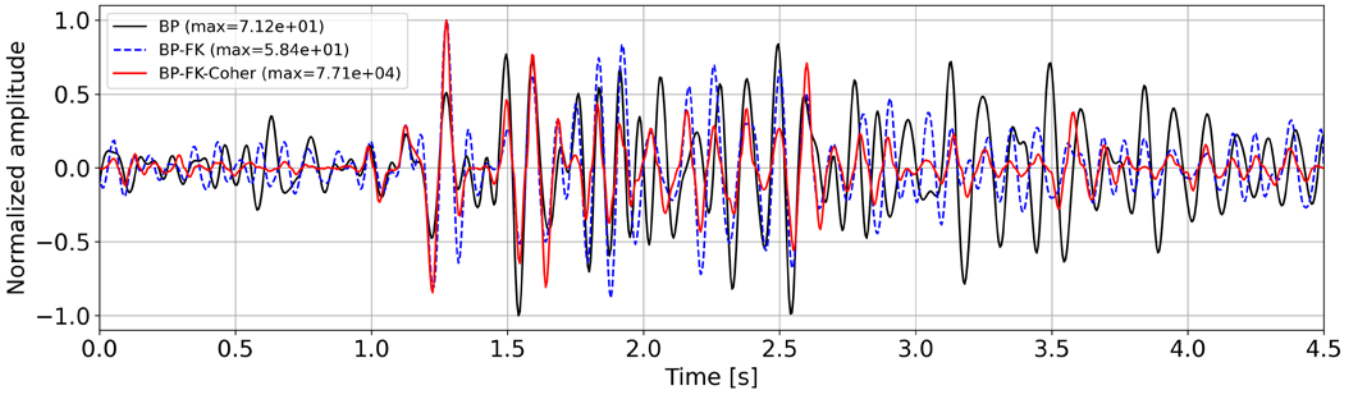
- Identification of patterns also interesting for data filtering

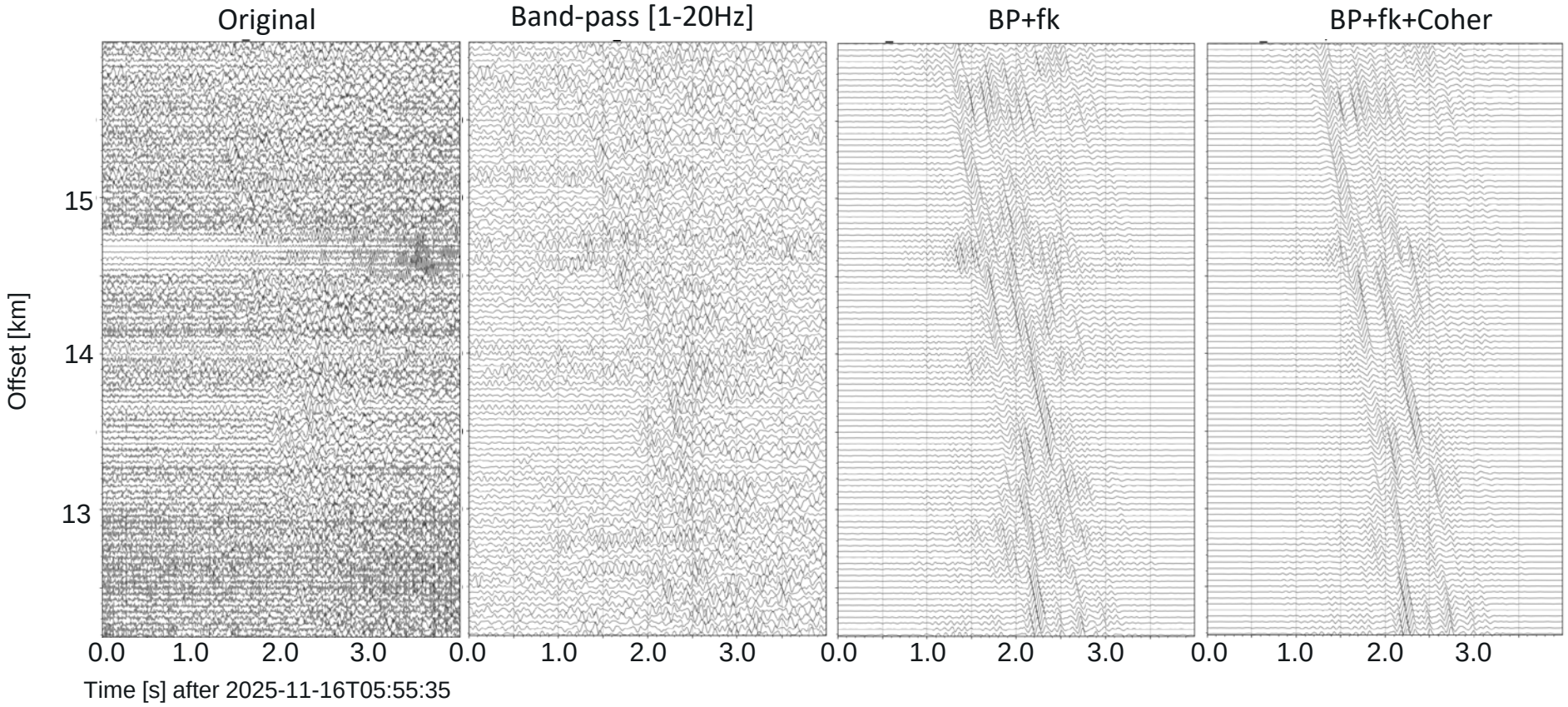


Signal filtering

Extract coherent wavefield information

- Enhance signals that are consistent across the array
- Band-pass + *f-k* filtering + coherence weighting
- Increase SNR in single channel measurements
- Consistent phase information





Upscaling the concept to the URG

Implementation

- Simultaneous use of multiple long-distance fiber links
- Multiple fiber branches configuration to
  - Improve spatial coverage,
  - Vary cable orientations,
  - Cover multiple sites with single monitoring framework

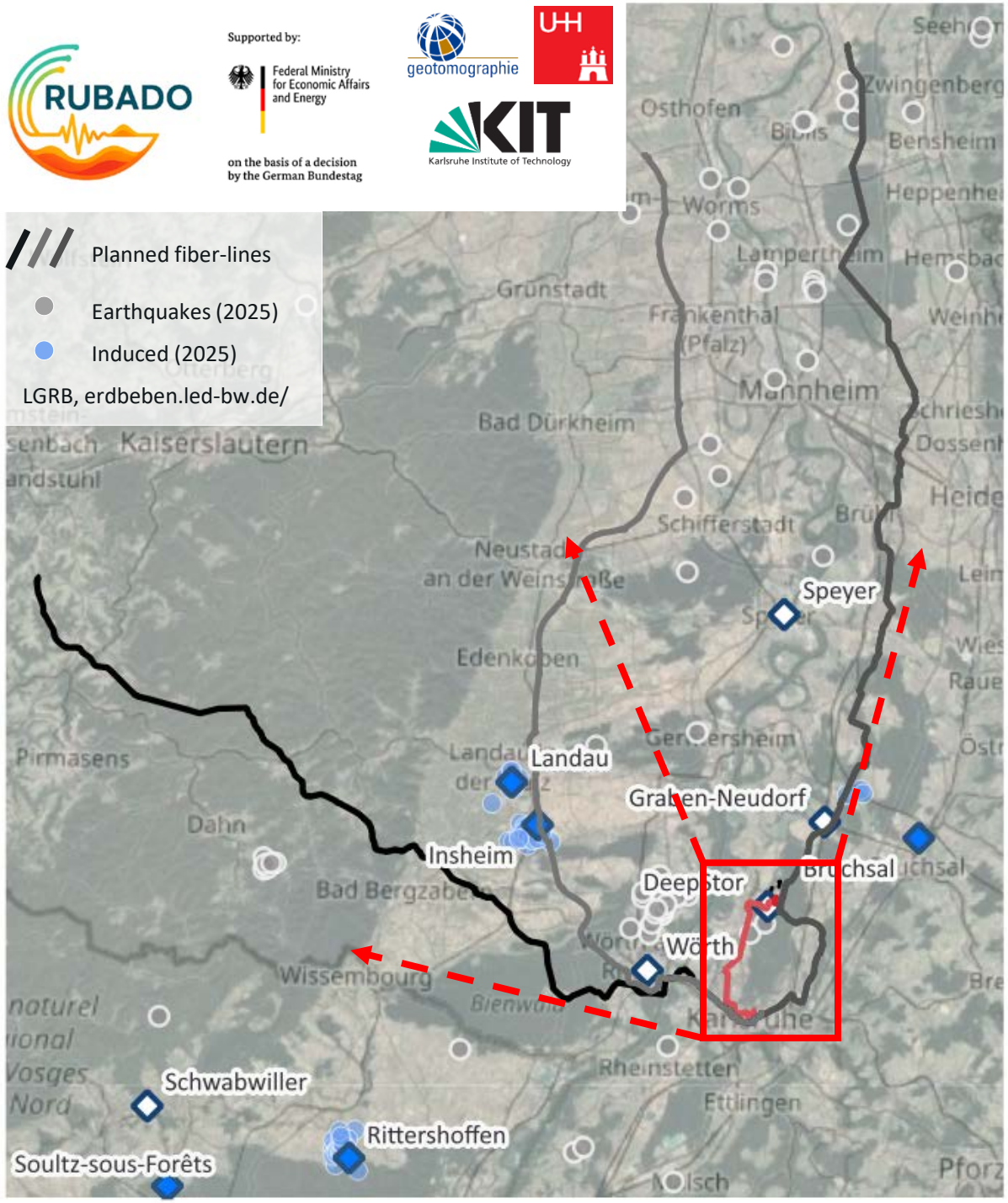
Project focus

- Seismic monitoring and passive seismic imaging
- Systematic characterization of sensing points (location, response), results validation (with 3C nodes/seismometers)

Open (PhD) positions

UHH
Passive seismic imaging

KIT
ML supervised signal clustering



Take-home messages

DAS on dark fiber for scalable seismic monitoring

- Leveraging existing telecom infrastructure from local to regional scale

Monitoring of induced microseismic events

- Events down to ML 1.2 could be observed in a 40 km range on dark-fibers
- Coherent wavefield analysis is proposed for
  - Detection in challenging environments
  - Extraction of coherent wavefield information

Towards regional, multi-site monitoring (RUBADO)

- Connecting geothermal sites across the Upper Rhine Graben
- Vision: A distributed, scalable seismic observatory based on telecom networks

Thank you for your attention

RUBADO

Grand number: 03EE4076A

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Federal Ministry for Economic Affairs and Energy

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ptj projektträger jülich

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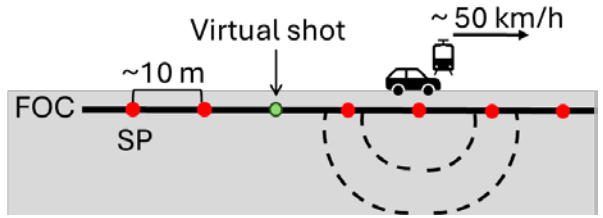
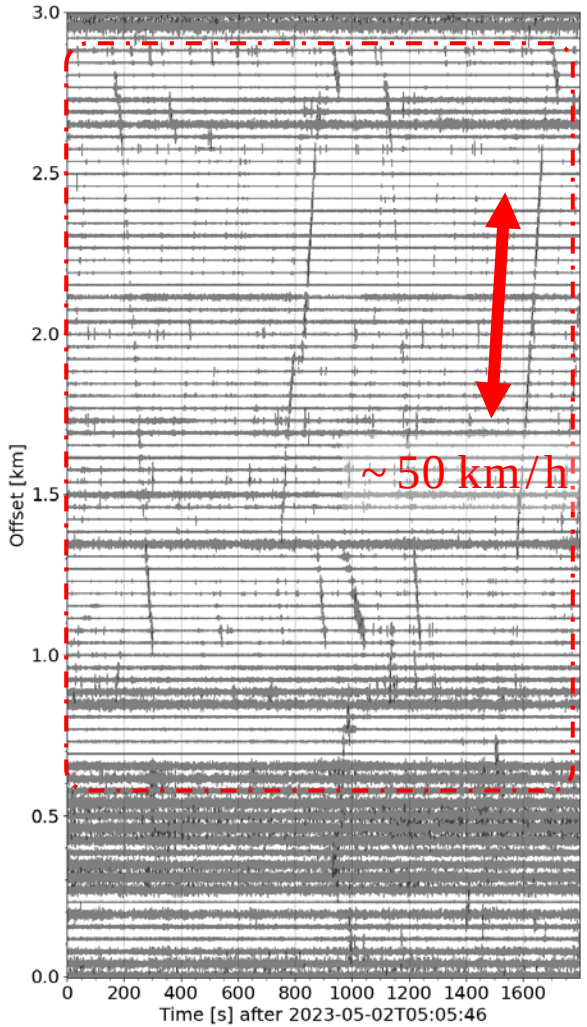
Multi-channel Analysis of Surface Waves (MASW)

Instead of treating vehicles as challenge…

using signals as a moving source of surface waves for MASW

Poster EGU26-5539, SM5.1
Friday, 8 May 2026, 14:00-18:00



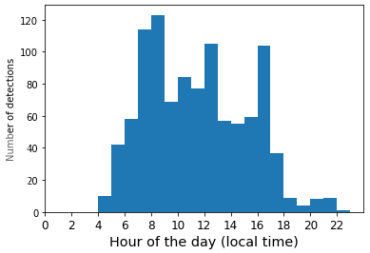


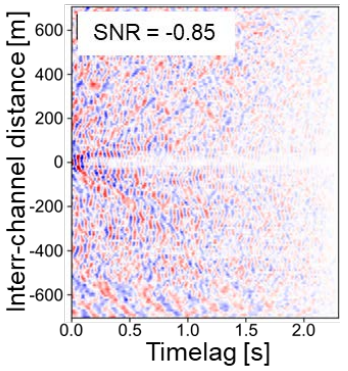
Detection/ Tracking

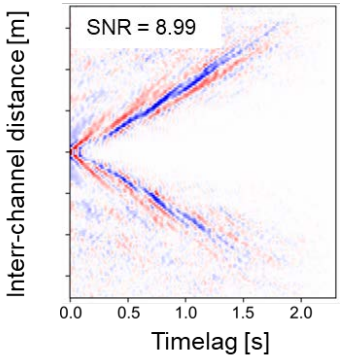
Correlation

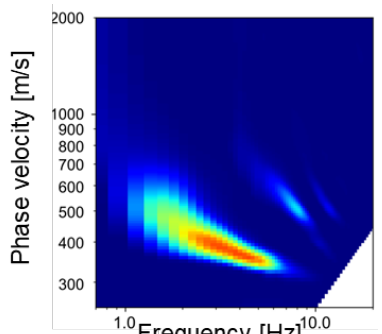
Stacking Post-processing

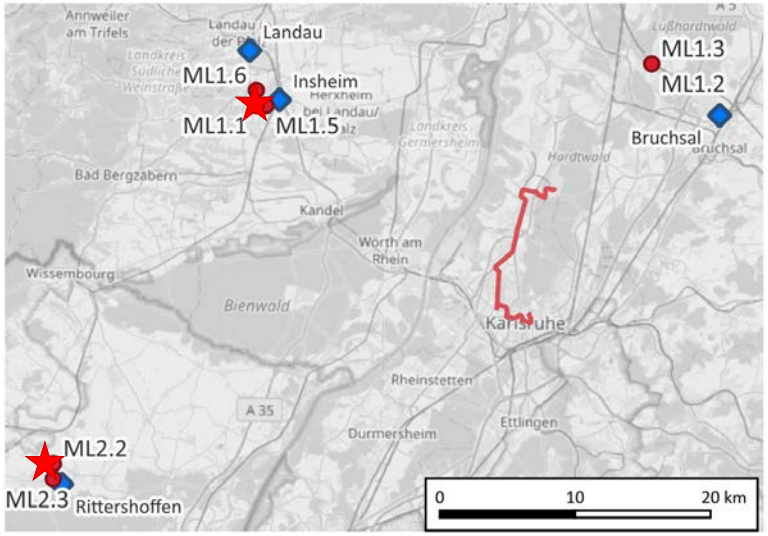
Dispersion analysis

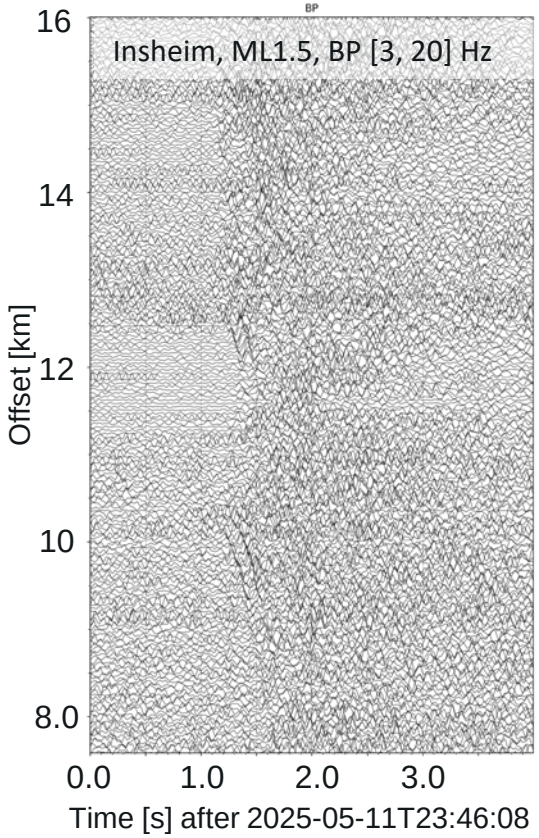


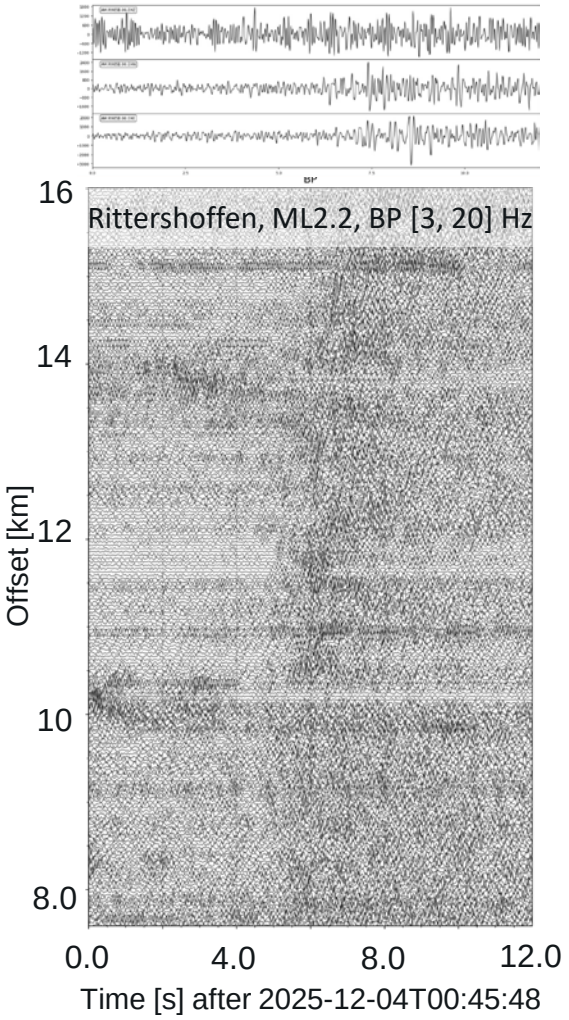


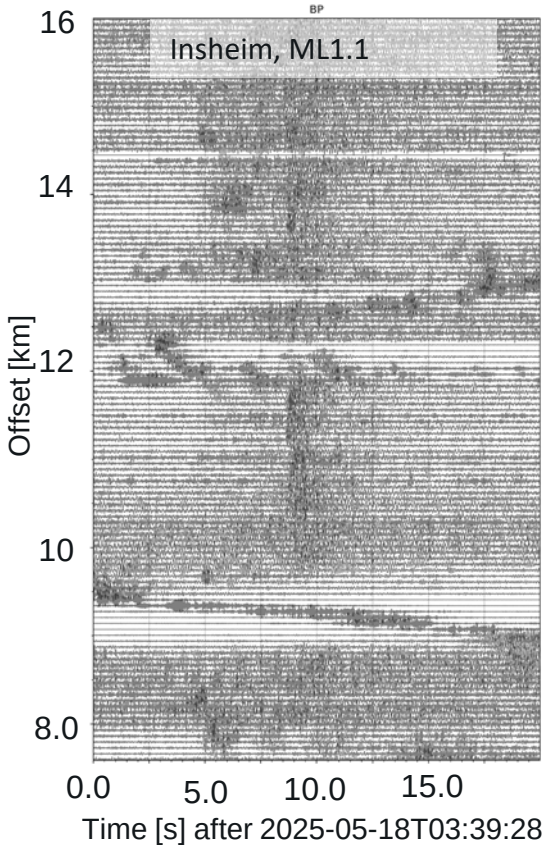





Landau
ML1.6
Insheim
ML1.1
ML1.5
ML1.3
ML1.2
Bruchsal
Bad Bergzabern
Kandel
Wörth am Rhein
Wissembourg
Bienwald
Karlsruhe
Rheinstetten
A 35
Durmersheim
Ettlingen
ML2.2
ML2.3
Rittershoffen
0
10
20 km


Insheim, ML1.5, BP [3, 20] Hz
Offset [km]
16
14
12
10
8.0
0.0
1.0
2.0
3.0
Time [s] after 2025-05-11T23:46:08

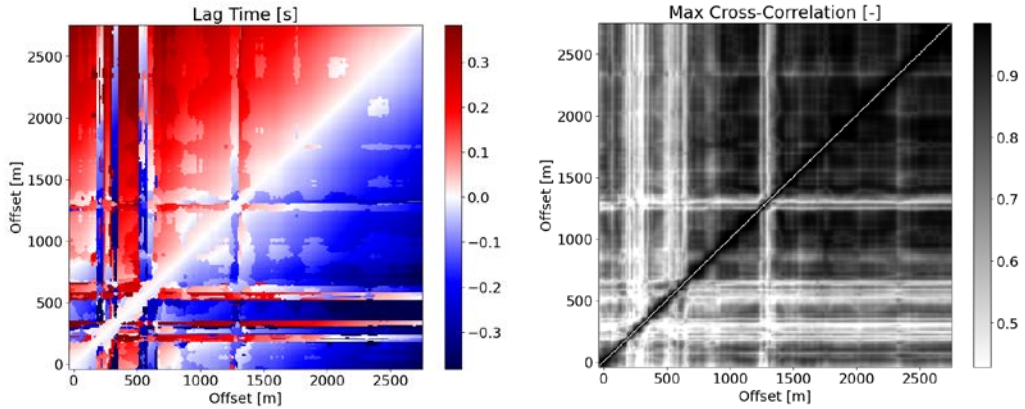

Rittershoffen, ML2.2, BP [3, 20] Hz
Offset [km]
16
14
12
10
8.0
0.0
4.0
8.0
12.0
Time [s] after 2025-12-04T00:45:48


Insheim, ML1.1
Offset [km]
16
14
12
10
8.0
0.0
5.0
10.0
15.0
Time [s] after 2025-05-18T03:39:28

Natural EQ, ML 1.0, 12 km depth (April 15, 2023)

- Signal-processing for robust estimation of inter-channel delays
- Beamforming (shift-and-sum)
  - Using linear part of the array
  - BAZ=251°, v=3013m/s at maximum beamformed trace energy
  - matches range of BAZ
  - Poor resolution due to array geometry

Lag-time and Max.correlation matrix after signal processing



Wavefront before/after shifting, and beamformed energy in fct of BAZ/v