Implementation and evaluation of Distributed Acoustic Sensing (DAS) for continuous seismic monitoring of geothermal fields in the Munich area (Germany)

Karlsruhe Institute of Technology

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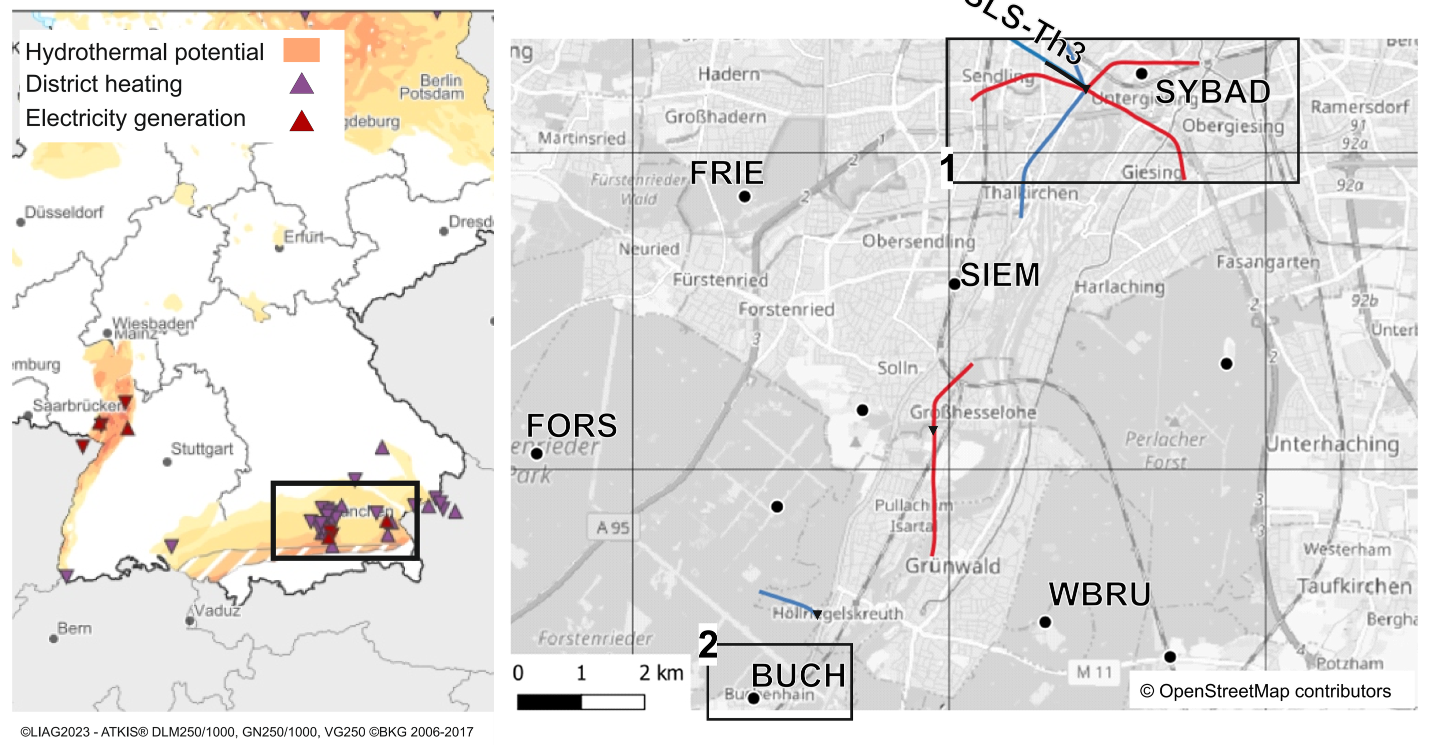
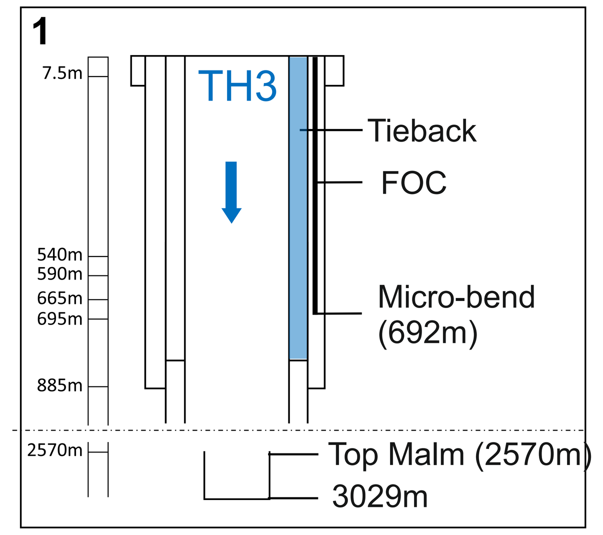
INSIDE

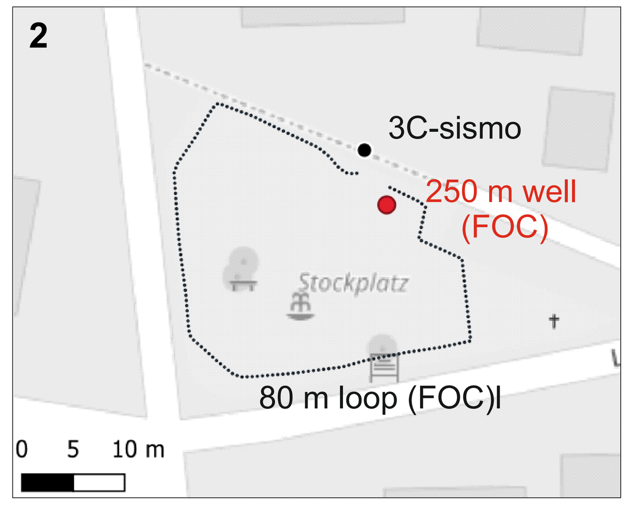
Summary

- Local geothermal energy operators of the Munich area (Germany) are interested in the capabilities of the Distributed Fiber Optic Sensing (DFOS) for routine monitoring of the production and of the operated hydrothermal system – the porous Malm reservoir
- We present DAS measurements conducted over two years on dedicated infrastructures in Munich, with the prime objective of monitoring locally induced seismicity within a 10 km radius
- The analysis encompasses a range of monitoring tasks
  - → the handling of the substantial data flow using a dedicated data management system
  - → the effective implementation of a DAS monitoring system as one additional component of the monitoring of the operational activity of the plant
  - → processing capabilities covering the detection of seismic events to the description of seismic sources, particularly in terms of location, moment magnitude, and stress drop
- We evaluate the capabilities of DAS monitoring compared to different monitoring set-ups for detecting (micro-)seismic events within the study area

0 - The case study







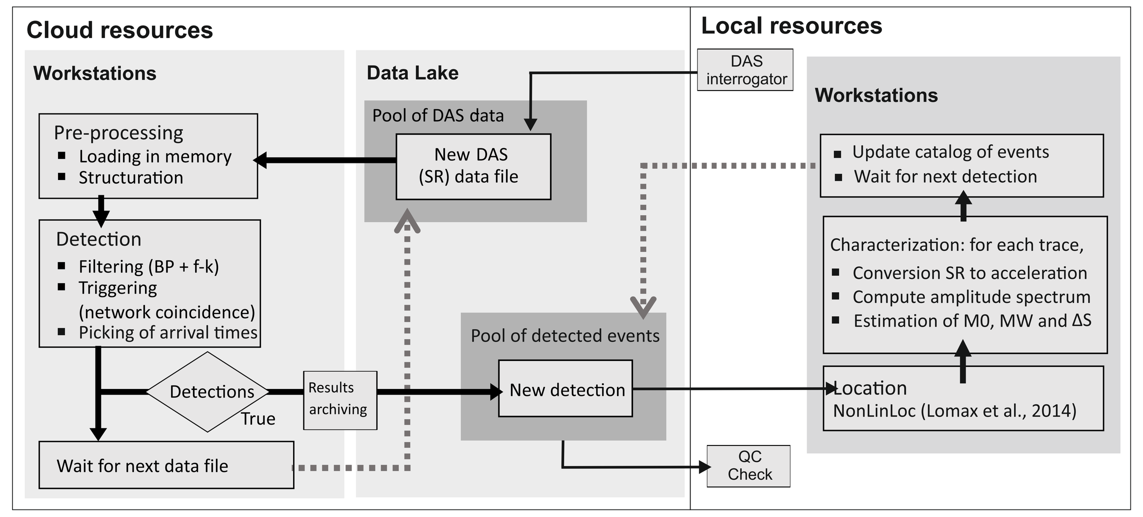
Industrial partners: SWM and IEP, two geothermal operators of the Munich region

Two study sites:

- **SLS:** implementation of a DAS monitoring system at the Schäftlarnstraße (SLS) geothermal plant. Based on ~700m long FOC in injection well Th3.
- **BUCH:** DAS measurement station in the municipality of Buchenhain. A 80-meter FOC section (near-surface, deployed in loop configuration) + 250m dedicated monitoring well + 3C broadband seismometer.

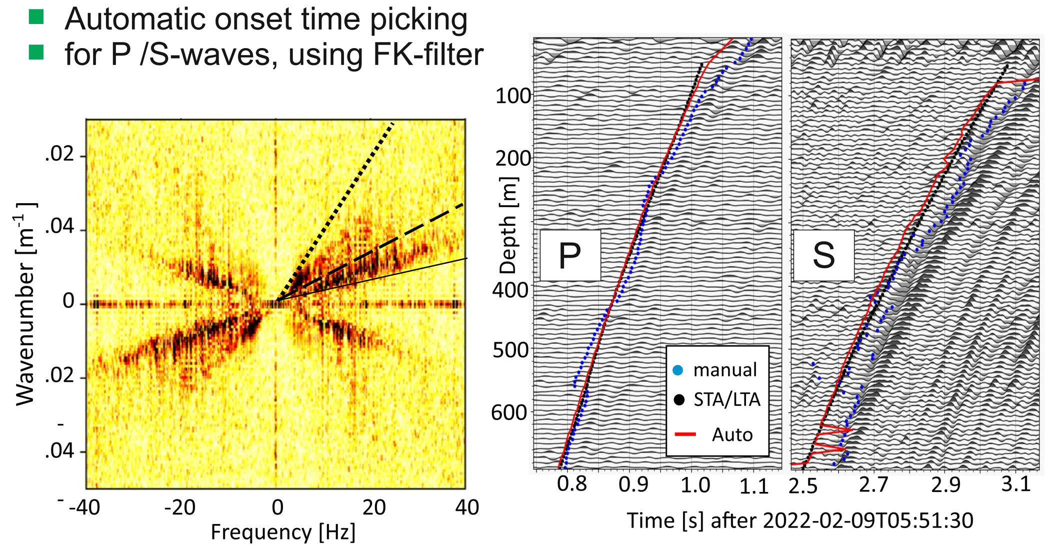
1 - Continuous DAS-monitoring at the SLS site

- An integrated DAS-monitoring system based on a cloud Internet-of-Things (IoT) platform for data management (saving + processing)
- Tested over six months,
  → demonstrated efficiency in acquiring and processing continuous DAS data
  → successfully detected seismic events, also in noisy urban/operational conditions,
  → complemented the local seismometer-based monitoring network.
- Multiple processing capabilities are demonstrated here for a specific seismic event: 2022-02-09 - ML 1.5 ; distance ~10 km



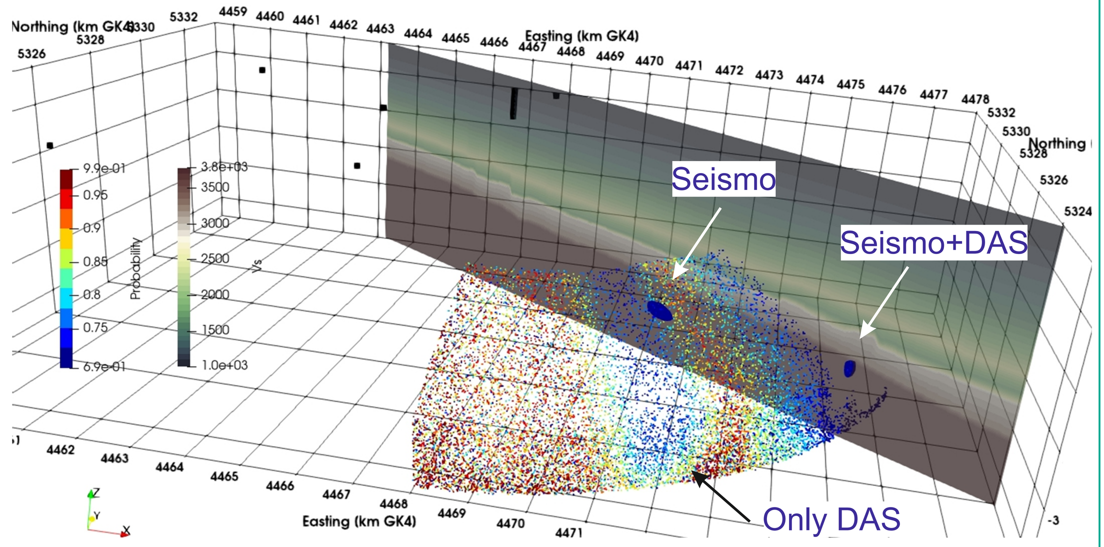
Detection and onset-time measurement

- Automatic onset time picking
- for P /S-waves, using FK-filter



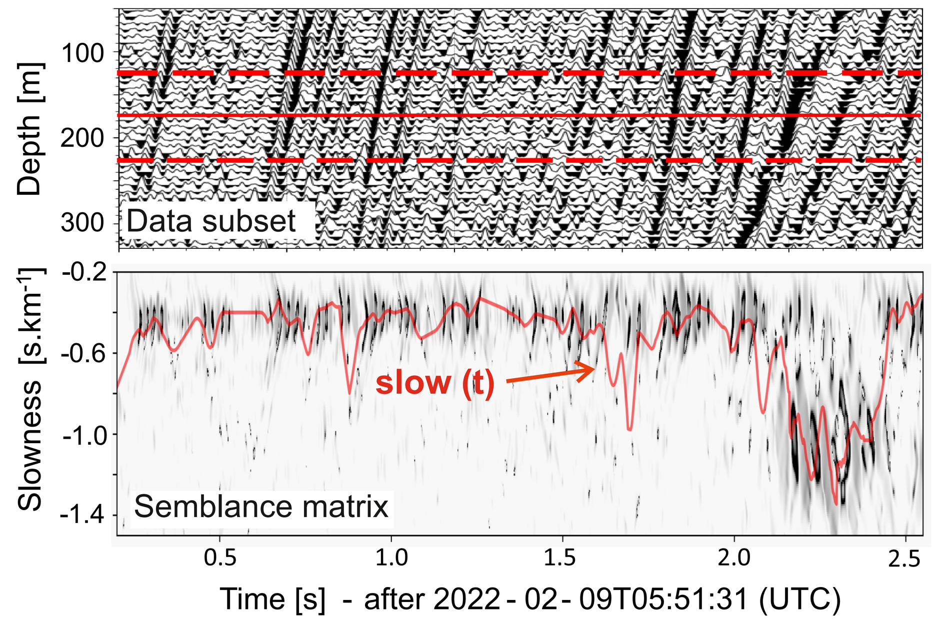
Event location

- Location on ellipsoid possible from single DAS-array in Th3
- Estimation of source-receiver distance

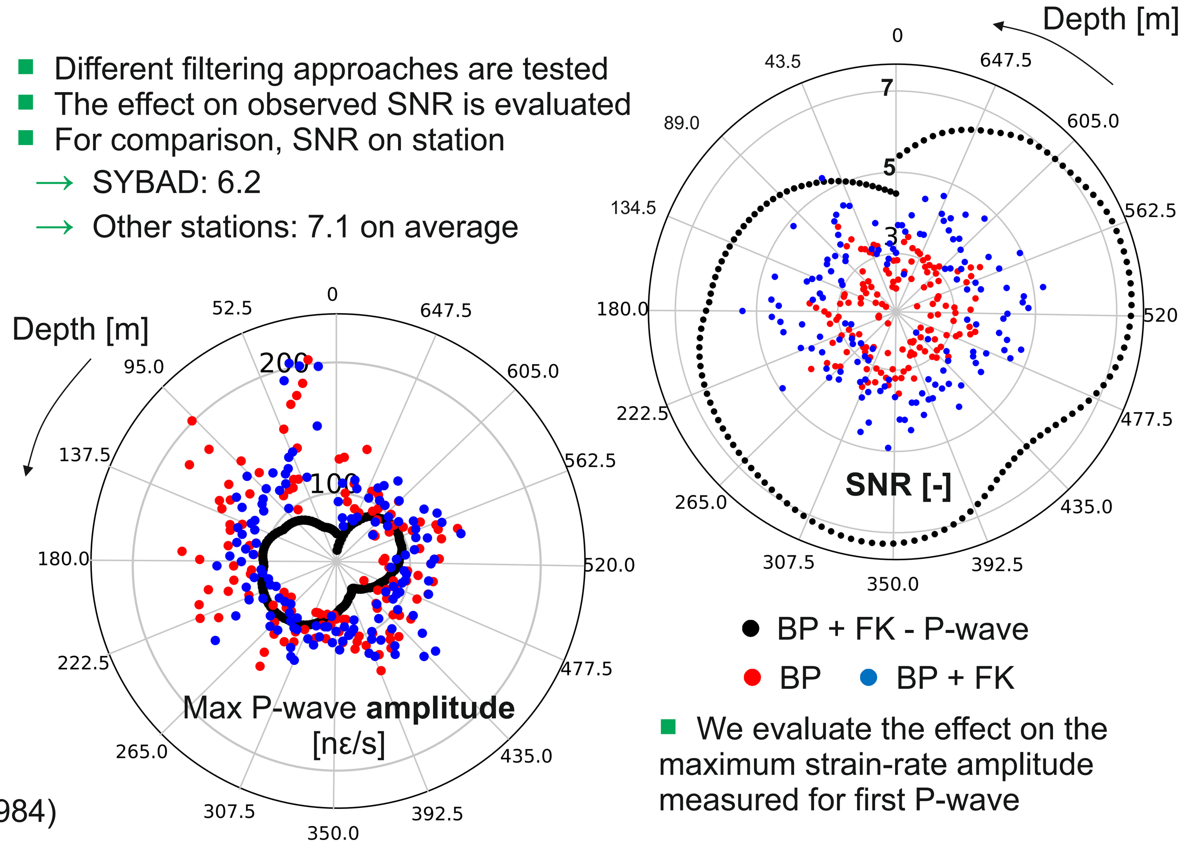


Analysis of strain rate

- SR to ground motion conversion: ACC (t) = SR (t) / slow (t)
- Based on temporarily varying slowness

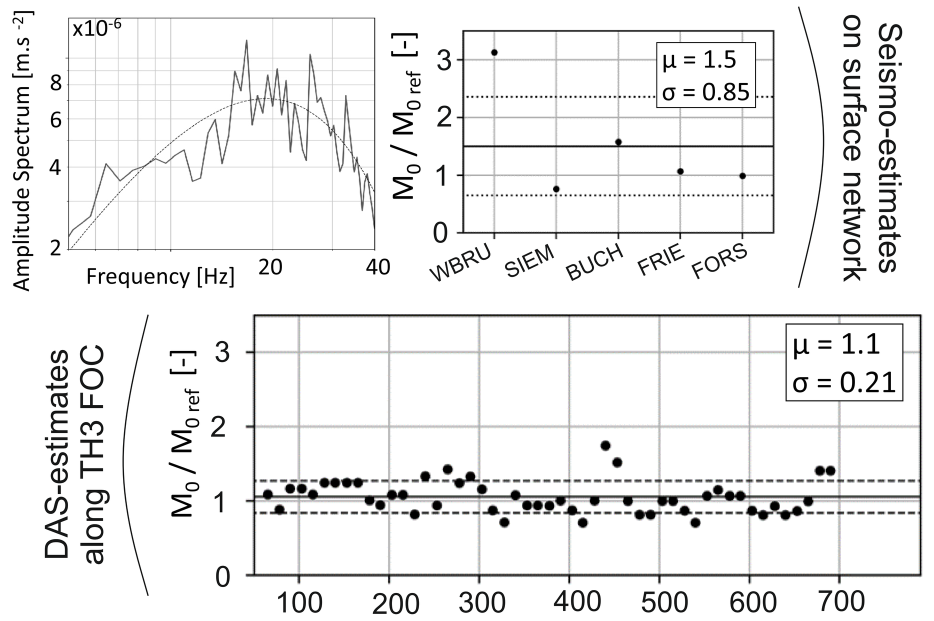


- Different filtering approaches are tested
- The effect on observed SNR is evaluated
- For comparison, SNR on station
  → SYBAD: 6.2
  → Other stations: 7.1 on average



- We evaluate the effect on the maximum strain-rate amplitude measured for first P-wave

- Inversion of moment magnitude based on model by Anderson et al. (1984)
- Results comparison with the SYBAD seismometer ($M_{0,ref}$)



+ Advantages +

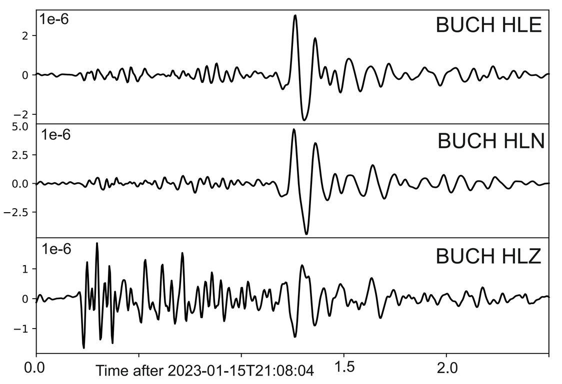
- Proximity of sensors with monitoring target and detection sensitivity
- One FOC, multiple sensing capabilities
- Future-proof and evolutivity
  → Offers new prospects for integrated reservoir monitoring
  → Possiblity to combine multiple wells/FOC for increased monitoring capabilities
- Consistent P- and S- wave picking over channels
- Dense „seismic string"

- Limitations -

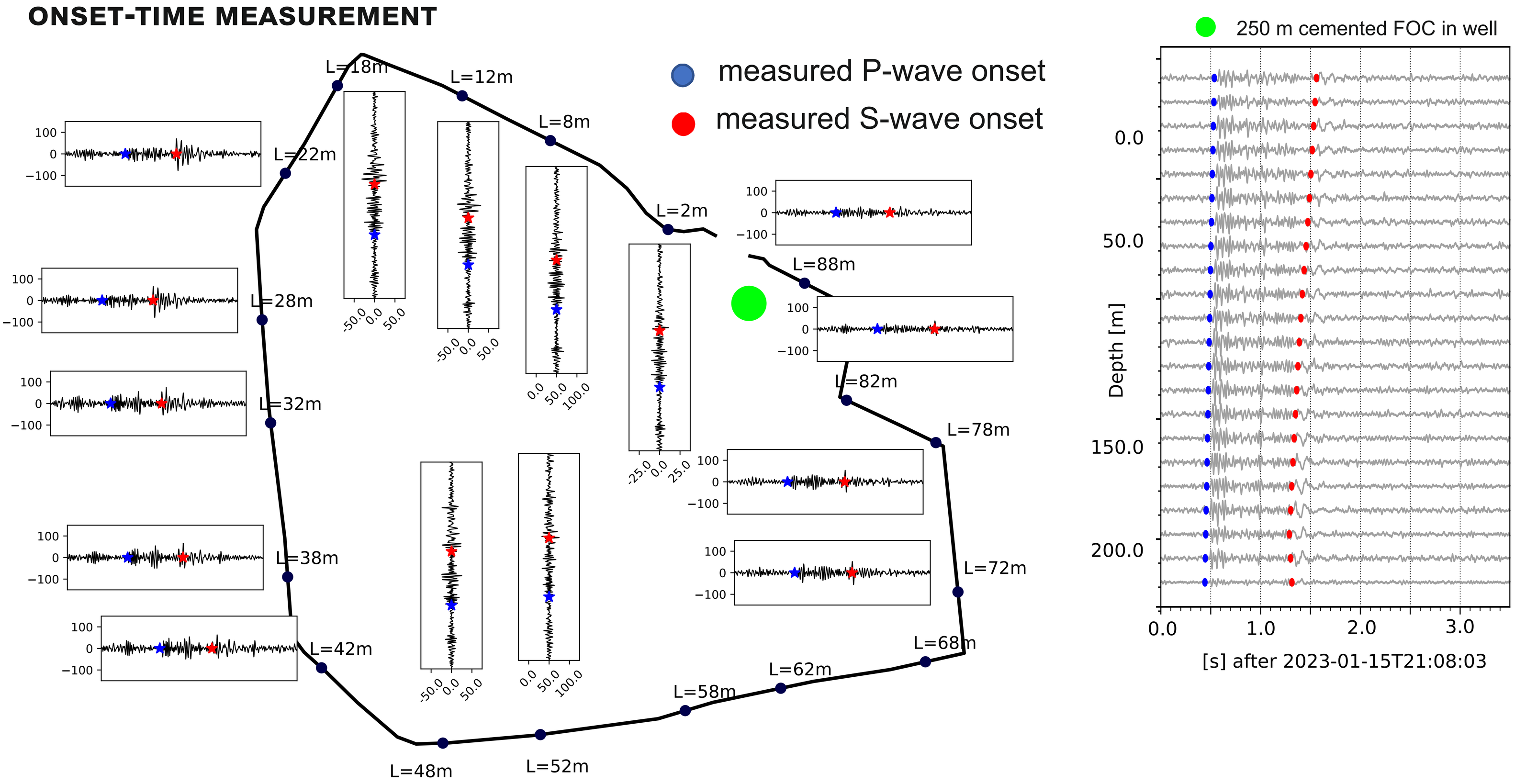
- Necessary storage / processing infrastructure and associated costs
- Limited signal-to-noise ratio
- Monocomponent „seismic string"

2 - DAS-array station vs. 3-C at Buchenhain

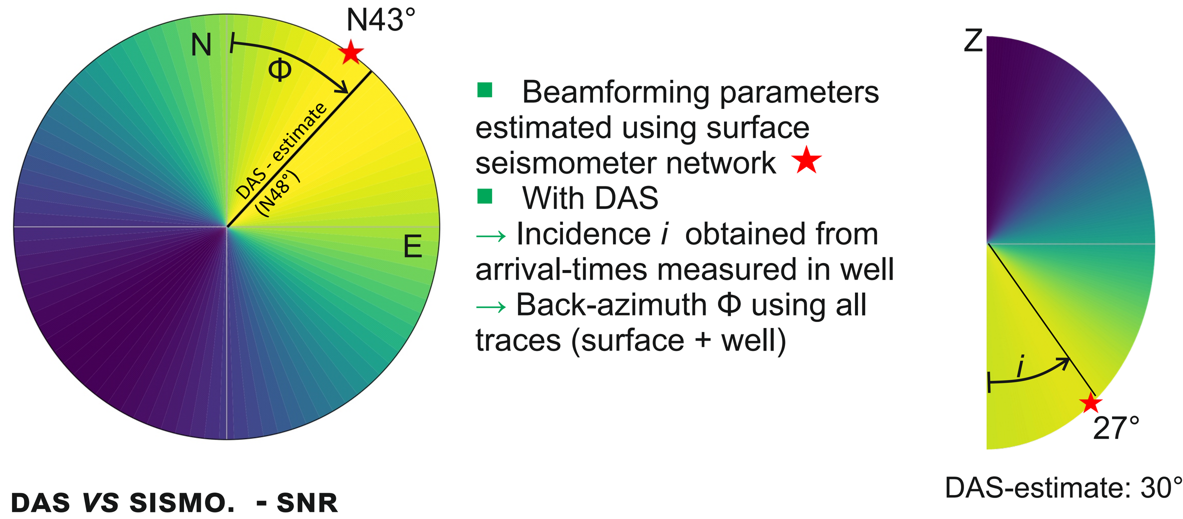
- DAS + Distributed Strain Sensing (DSS) + 20-s seismometer recording continuously in a parc in village (Buchenhain)
- Processing capabilities discussed for event from 2023-01-15



Onset-time measurement



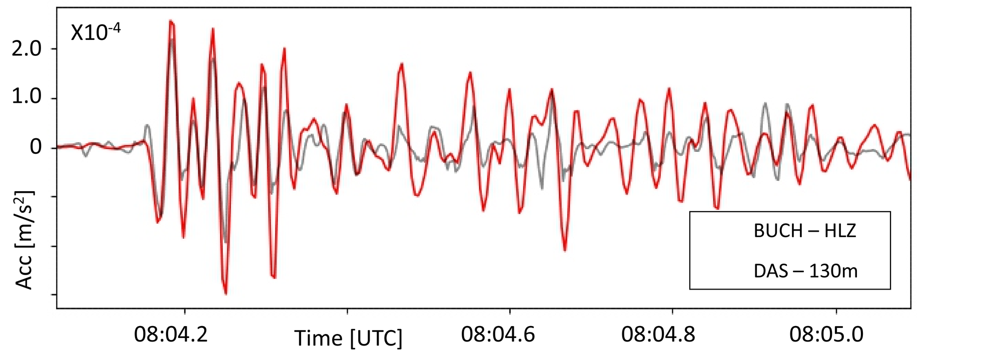
Event location using DAS-array



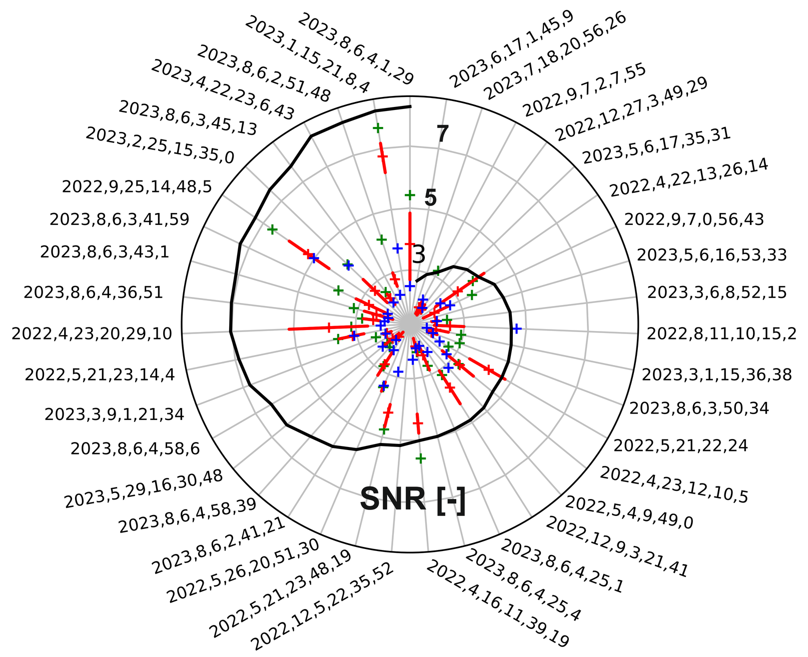
- Beamforming parameters estimated using surface seismometer network ★
- With DAS
  → Incidence *i* obtained from arrival-times measured in well
  → Back-azimuth Φ using all traces (surface + well)

DAS *vs* Sismo. - Amplitudes

- SR to Acc. applied to borehole data, comparison with BUCH - HLZ
- Comparison shows consistency in phase and amplitude



DAS *vs* Sismo. - SNR



- Events detectability on DAS is limited, from the well or surface
- Comparison of SNR using
  → DAS in well and surface seismometer
  → different filtering approaches on DAS

Seismo
— BUCH HL* - AVG
DAS in well
+ after BP - AVG
+ after BP+FK - AVG and range
+ after BP+FK - STACK

+ Advantages +

- All-in-one station, providing monitoring capabilities from a single sensing element for:
  → Event detection
  → Event location (incidence and backazimuth)
  → Source characterization (moment magnitude estimation)
- Multiple monitoring capabilities from a single FOC

- Limitations -

- Installation costs (especially for well)
- Limited sensitivity in detecting seismic events
- Limited aperture of the DAS-based array

3 - Take home messages

- Contribution of DAS to the monitoring network varies according to the location of the observed seismicity
- Measurements show that DAS can complement the surface network:
  → by providing increased sensitivity for low-magnitude events close to downhole measurement points
  → by offering advanced processing capabilities
  → by providing access to applications beyond seismic monitoring

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