Karlsruhe Institute of Technology

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Bundesministerium für Wirtschaft und Energie

INSIDE

Institut für Angewandte Geowissenschaften - Abteilung für Geothermie und Reservoir-Technologie

INSIDE: Investigating the impact of geothermal exploitation in the Munich area

The induced seismicity perspective

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3 IEP INNOVATIVE ENERGIE PULLACH 4 SWM 5 ERDWERK

INSIDE: Investigating the impact of geothermal exploitation in the Munich area

The induced seismicity perspective

Scientific research is carried out in the framework of the INSIDE project (supported by the German Federal Ministry for Economic Affairs and Energy, BMWi) to assess the impact of deep geothermal exploitation on induced seismicity in the Munich area (Germany, Molasse Basin). The project involves the research institute Karlsruhe Institute of Technology as well as two geothermal operators, Stadtwerke München (SWM) and Innovative Energie für Pullach (IEP). The research work focuses on three aspects: the monitoring, the modelling and the integration with operations.

With respect to the monitoring, the deployment of a measurement network going beyond the standard for seismological and geodetic observations is considered. Therefore, an extensive and plural monitoring network was designed to monitor high (seismicity) and low (subsidence, uplift) frequency deformation processes of the subsurface. Several types of technologies as well as several types of deployment configurations are involved. Their relative performances are intended to be compared in order to contribute to the development of suitable strategies for deformation monitoring and their data processing.

After presenting the aim and purpose of the project, we concentrate on the status of the seismic measurement network being implemented around the three geothermal sites of Baierbrunn, Pullach and Schäftlarnstrasse. In addition to "standard" monitoring stations installed in the area, we report on the deployment of various innovative technical solutions, among which a seismic mini-array and a monitoring borehole dedicated to Distributed Acoustic Sensing (DAS). We show how these stations complement the existing network in Munich and present their main characteristics, in particular the associated noise measurements. We additionally discuss the data-management system being developed to handle all these new data.

I. Project presentation
>> General aspects
>> WP1: Data recording

II. The seismic measurement network
>> Deployment of the seismic network
>> Different ways of acquisition

III. Performances assessment
>> Guidelines for geothermal monitoring
>> Assessment of detection / location capabilities

WHO, WHERE, WHEN?

Project ID	
Project duration	2019-09-01 – 2023-08-31
Partners	-Karlsruher Institut für Technologie -Stadwerke München (SWM) -Innovative Energie Pullach (IEP)
Funding authority	Bundesministerium für Wirtschaft und Energie (BMWi.IIC6)
Study area	Greater Munich area
Granted amount	4.7M €

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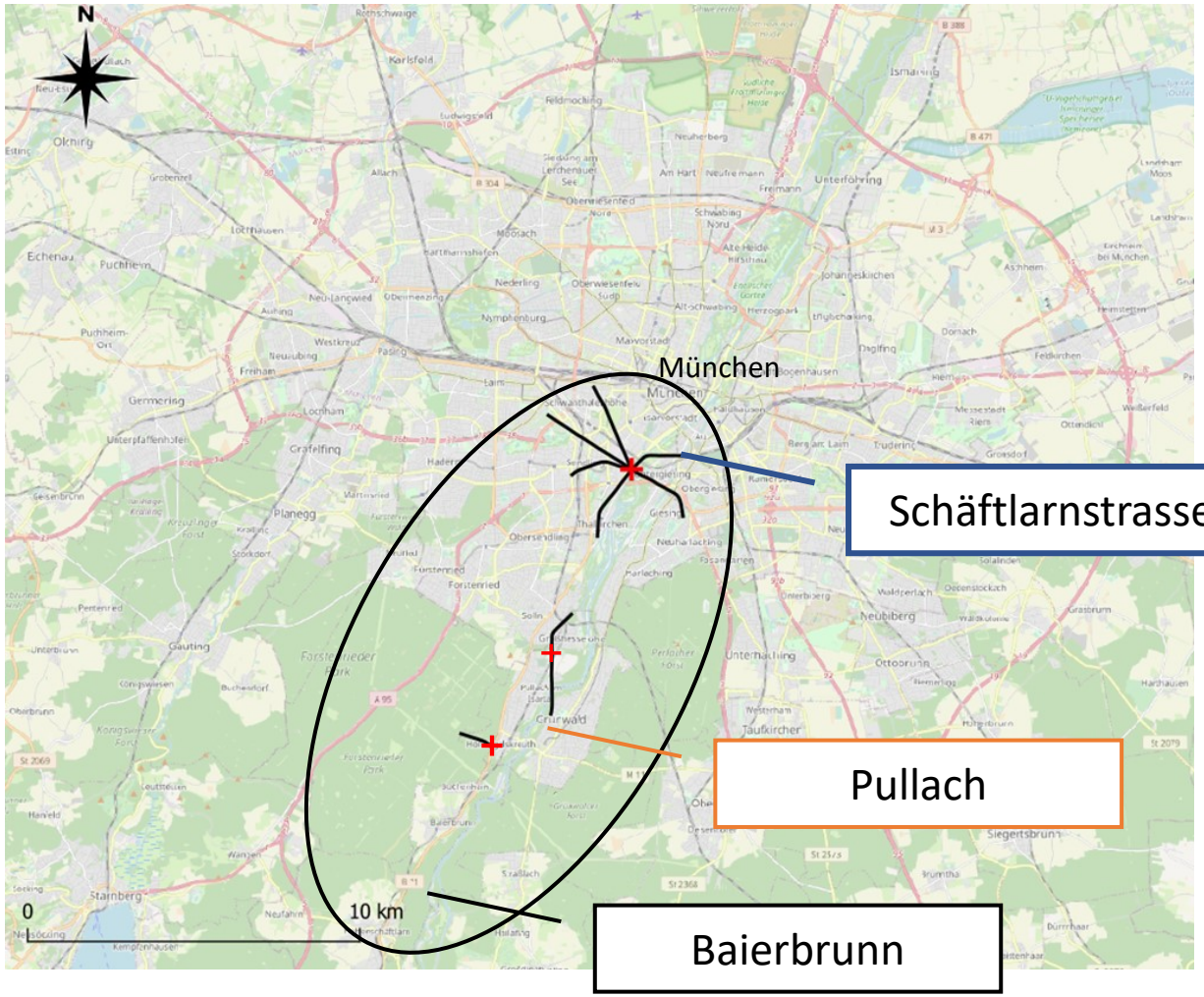


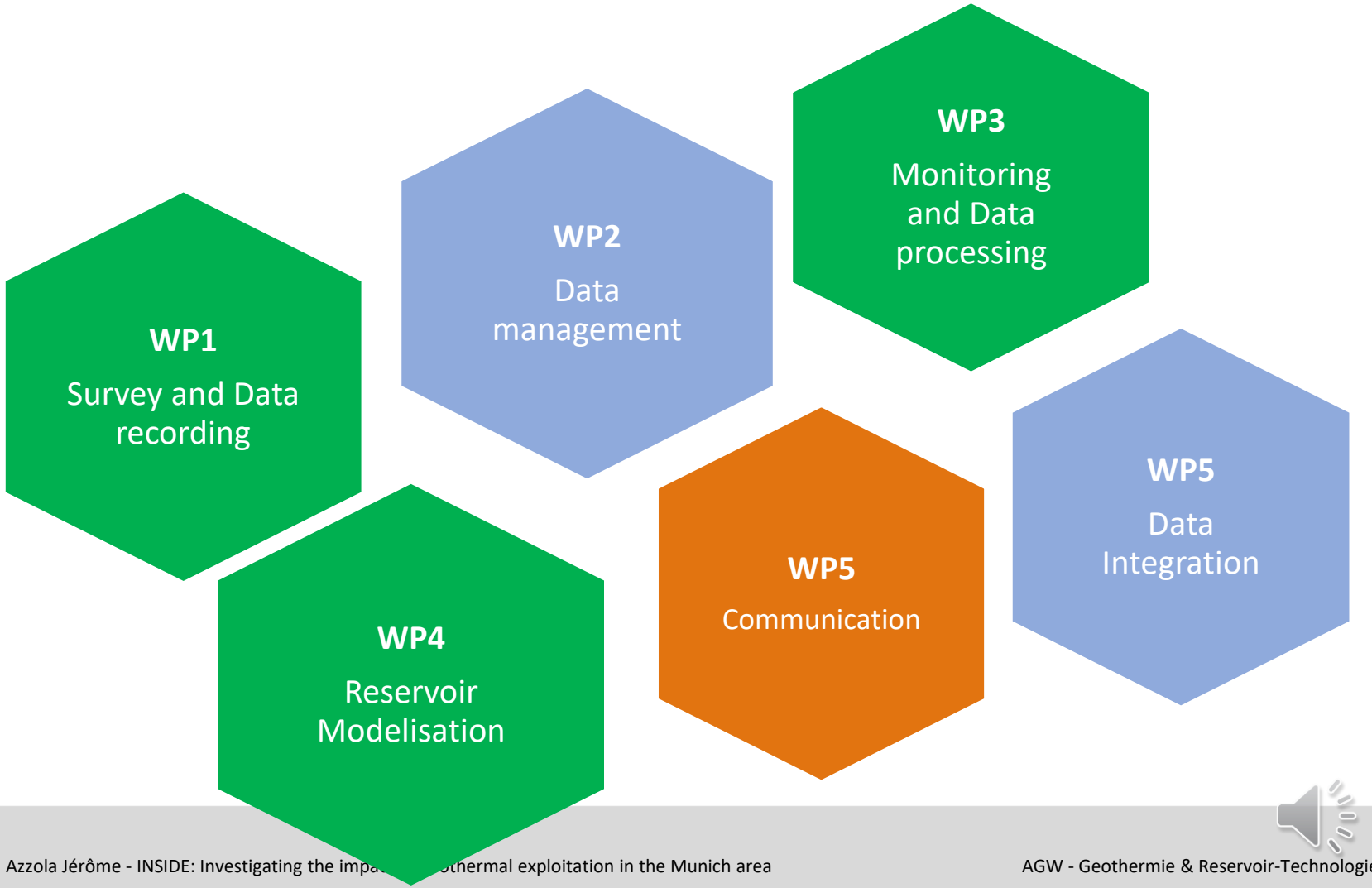
WHAT WE STRIVE FOR?

Background of the project: Seismicity can be induced **also in deep hydrothermal systems**

Site	First detection	Strongest event / Event number	Description
Unterhaching (UH)	10.02.2008	M_L 2.4 / 657	27 events $M_L \geq 1.0$, six events $M_L \geq 2.0$, near inj. well, decreasing magnitude
Taufkirchen (TK)	19.07.2012	M_L 0.3 /11	During circulation test at inj. well
Kirchstockach (KS)	23.08.2012	M_L 0.8 /33	30 microseismic events $M_L \leq 0.8$ near inj. well
Sauerlach (S)	19.06.2014	M_L 1.2 / 2	M_L 0.7 and M_L 1.2, big location error
Pullach (Pu)	21.02.2015	M_L -0.4 / 1	Near inj. well
Oberhaching (OH)	01.02.2016	M_L 0.5 / 3	Near inj. well
Duerrnhaar (DH)	31.07.2016	M_L 1.3 / 10	Big location error
Poing (PO)	19.11.2016	M_L 2.1 / 21	18 microseismic events, two events $M_L \sim 2.1$, near inj. well

Our motivations: Minimize risks associated with seismicity / deformation, strive for the development of a **"Reservoir Management System"**

WHAT WE DO?


WP1
Survey and Data recording
WP2
Data management
WP3
Monitoring and Data processing
WP4
Reservoir Modelisation
WP5
Communication
WP5
Data Integration

WHAT WE DO?

➢ **Expansion of a measurement network going beyond the standard**

WP1
Survey and Data recording

WP2
Data management

WP3
Monitoring and Data processing

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Reservoir Modelisation

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Communication

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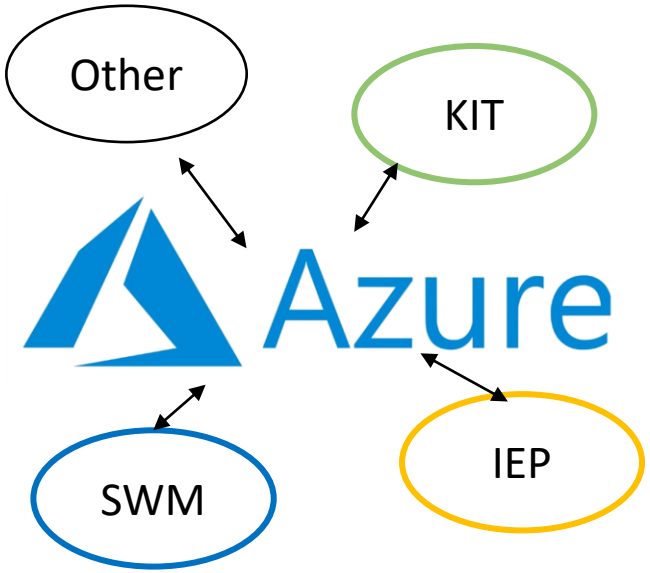
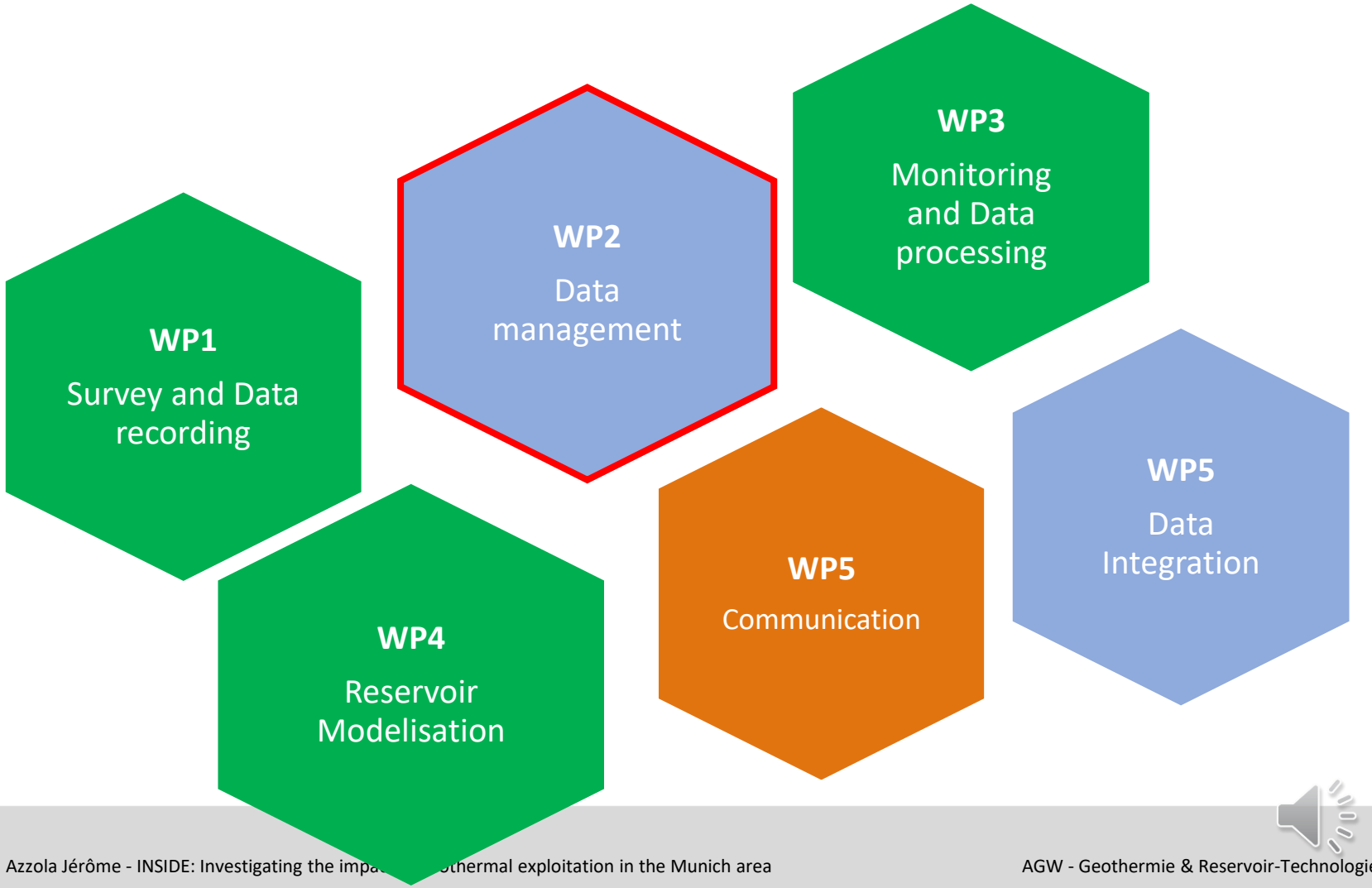
Data Integration

WHAT WE DO?

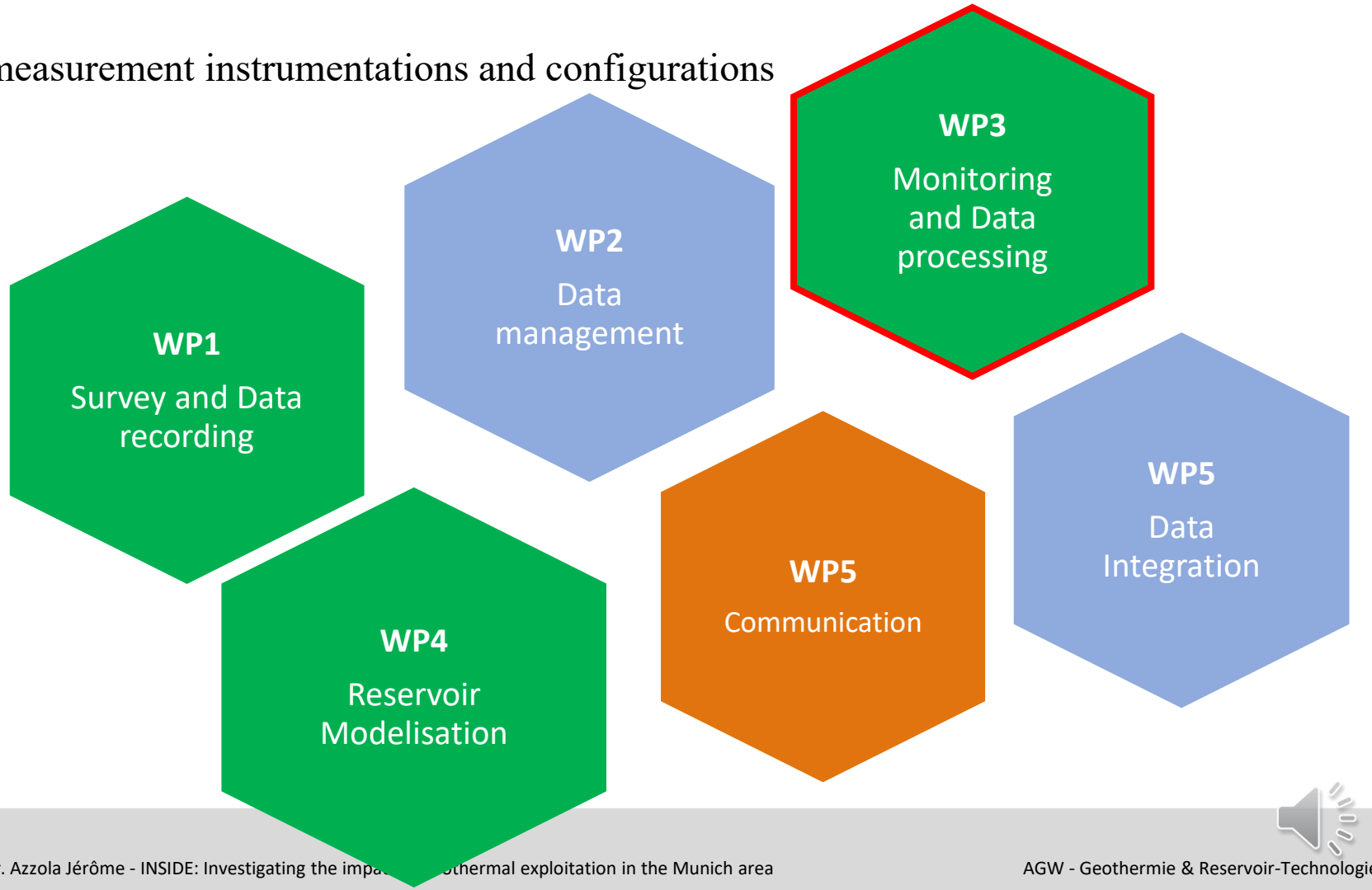
- Expansion of a measurement network going beyond the standard
- … **and related data management**





WHAT WE DO?

- Expansion of a measurement network going beyond the standard
- … and related data management
- **Self-performance comparison** of measurement instrumentations and configurations



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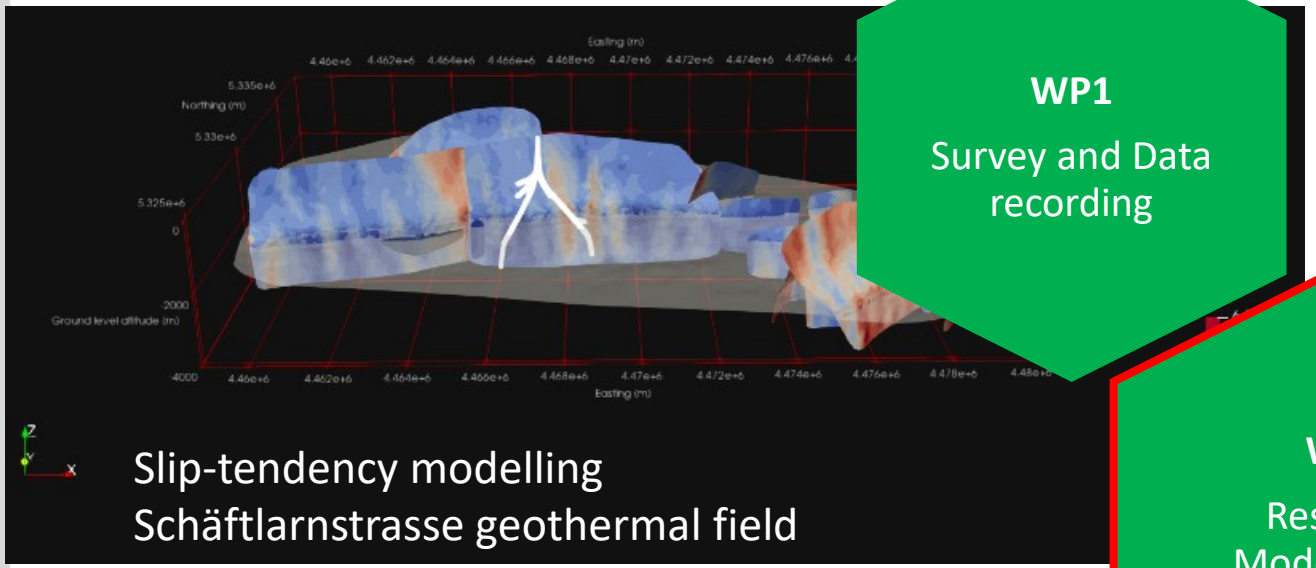
WHAT WE DO?

- Expansion of a measurement network going beyond the standard
- … and related data management
- Self-performance comparison of measurement instrumentations and configurations
- Integration of results in **dvlp. of innovative modelling approaches**
- **Towards a "Reservoir Management System"**



Slip-tendency modelling
Schäftlarnstrasse geothermal field

WP1
Survey and Data recording

WP2
Data management

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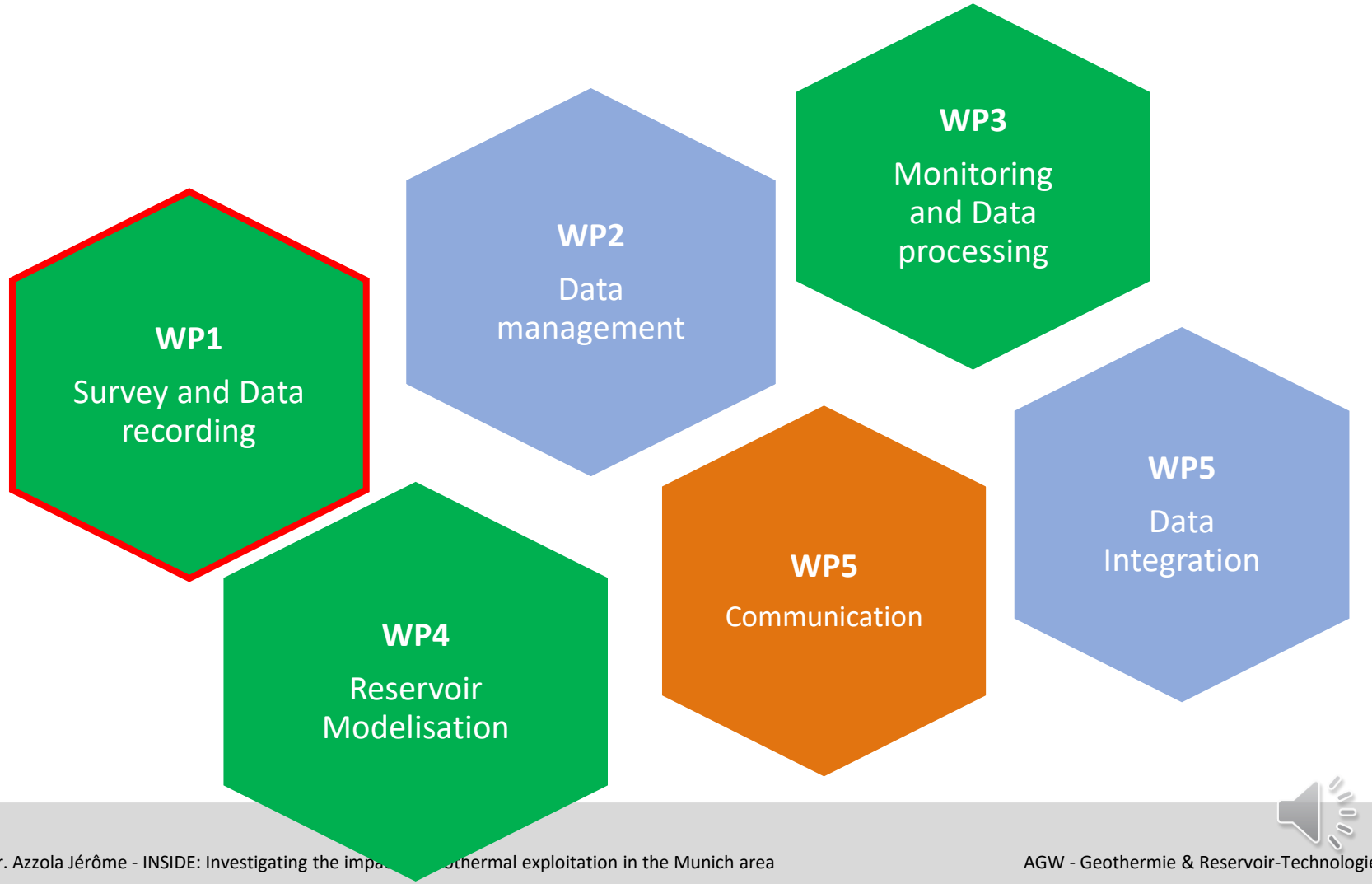
WP5
Data Integration

WHAT WE DO?

- **Expansion of a measurement network going beyond the standard**



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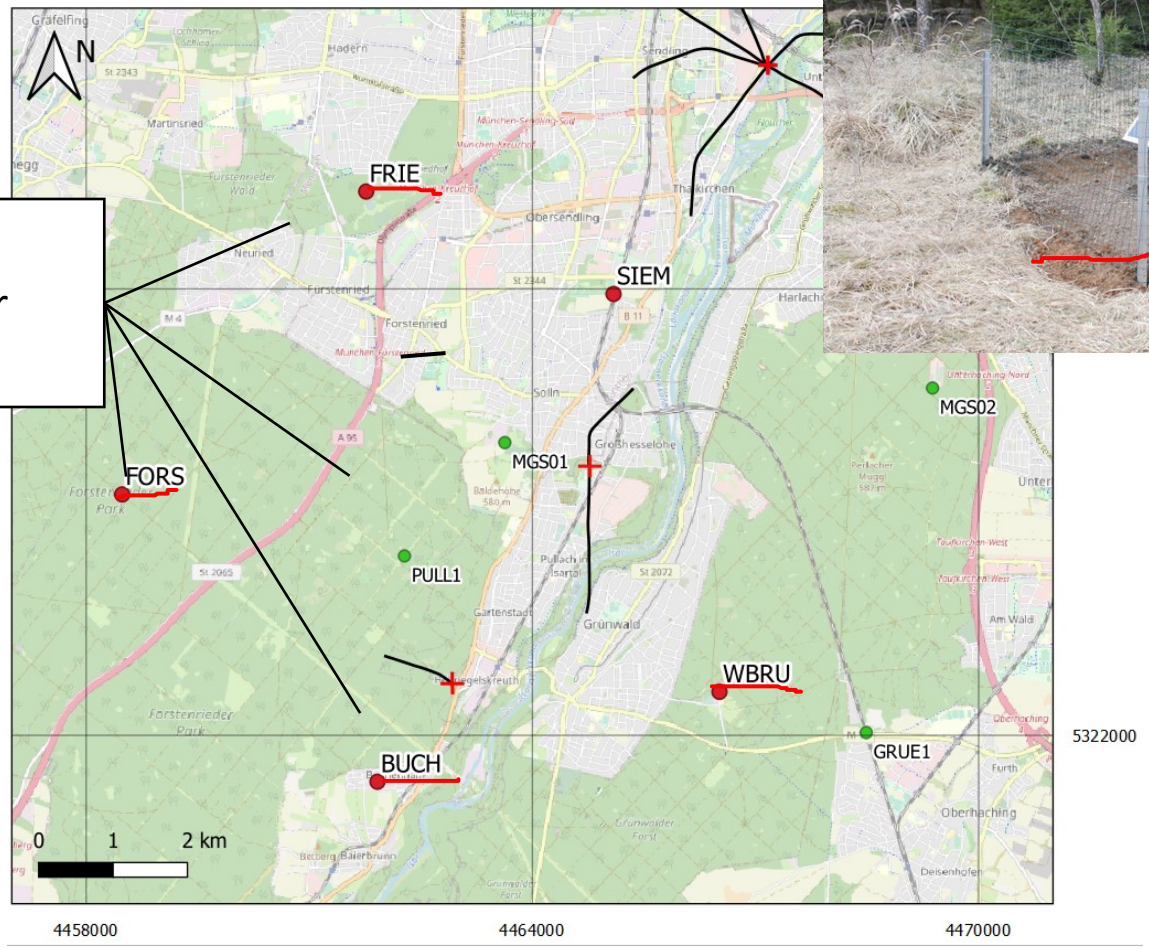
Surface station
3C-seismometer
TC-120s



- Well trajectories
- INSIDE seismic stations
- Seismic stations of « Operator Network » (LMU)

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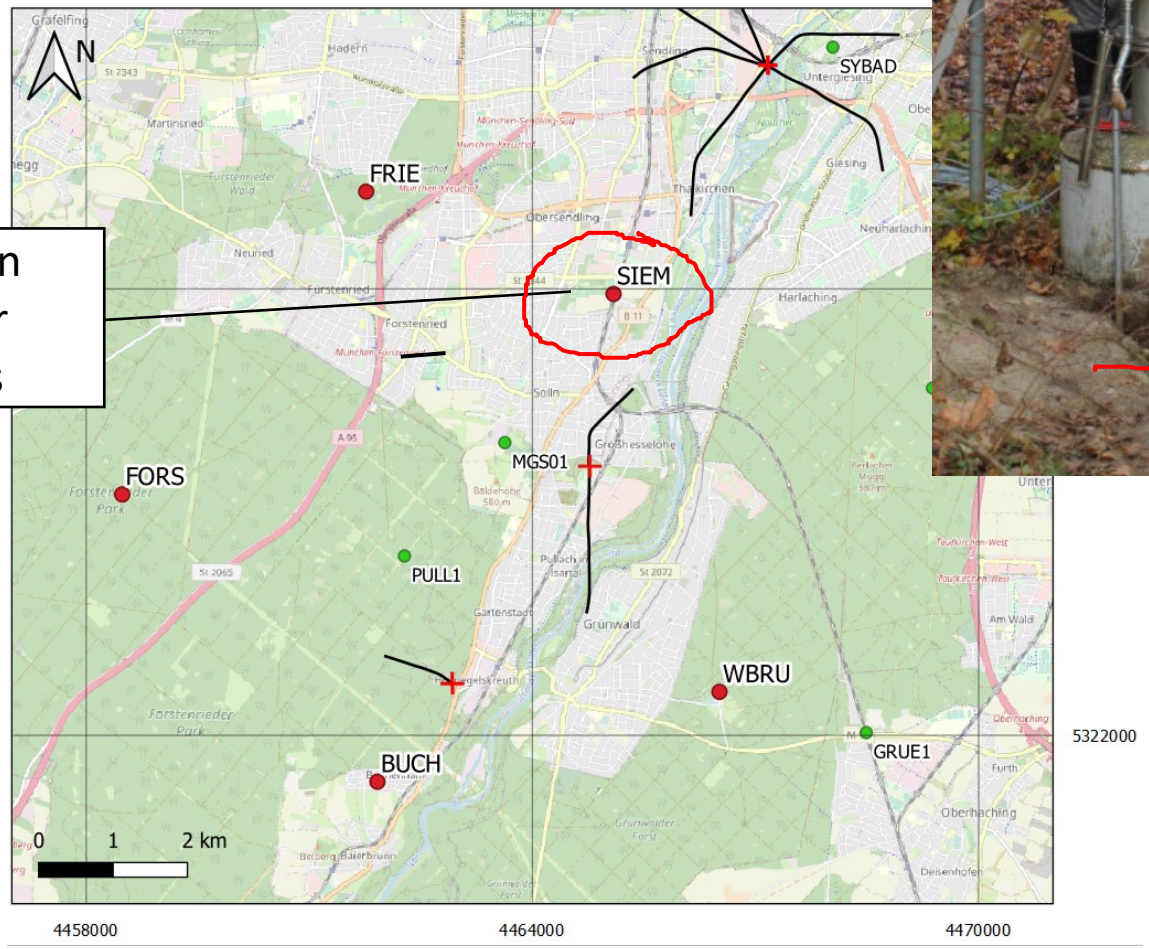
Downhole station
3C-seismometer
TC-Posthole 20s



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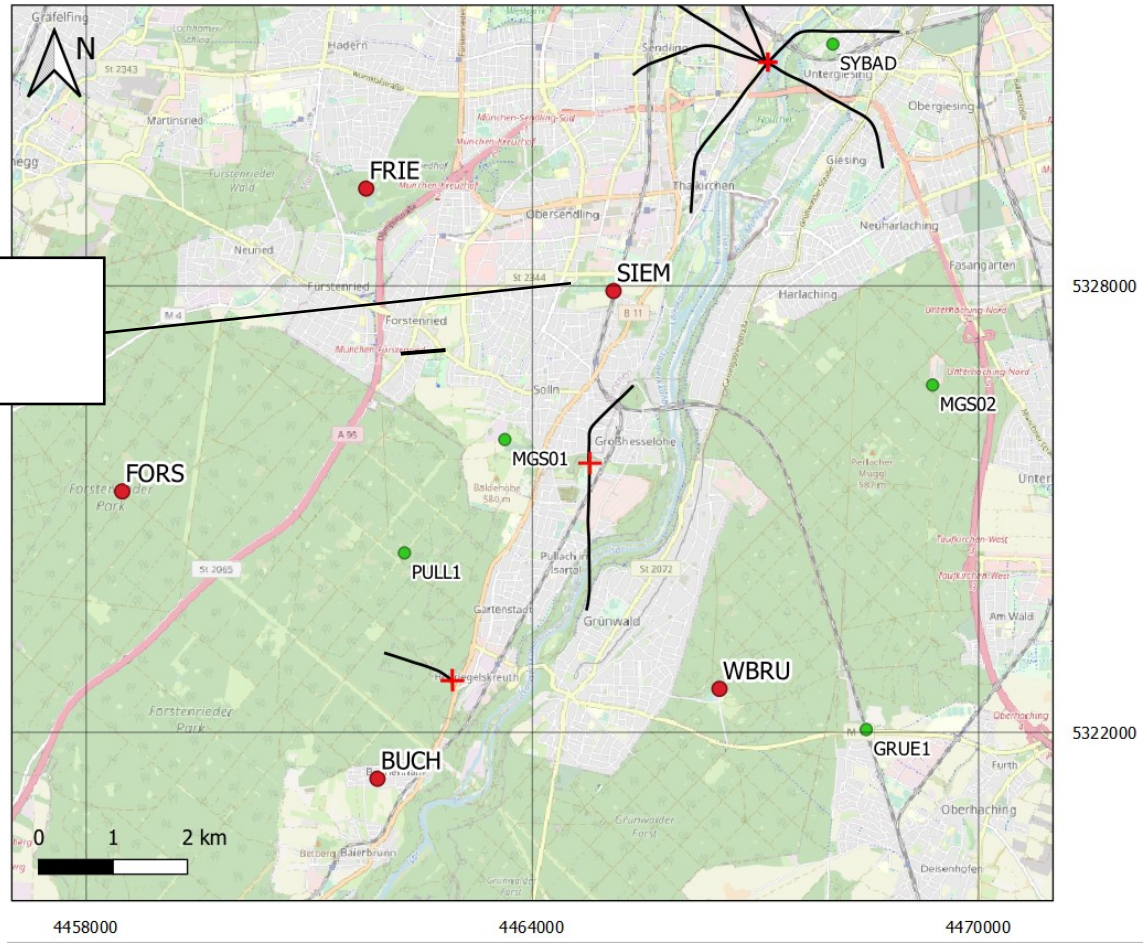
Mini-array



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Mini-array:

- 9 x 3-components seismometers
- Possibility to compare the results of various recording configurations at this location

- Not yet installed

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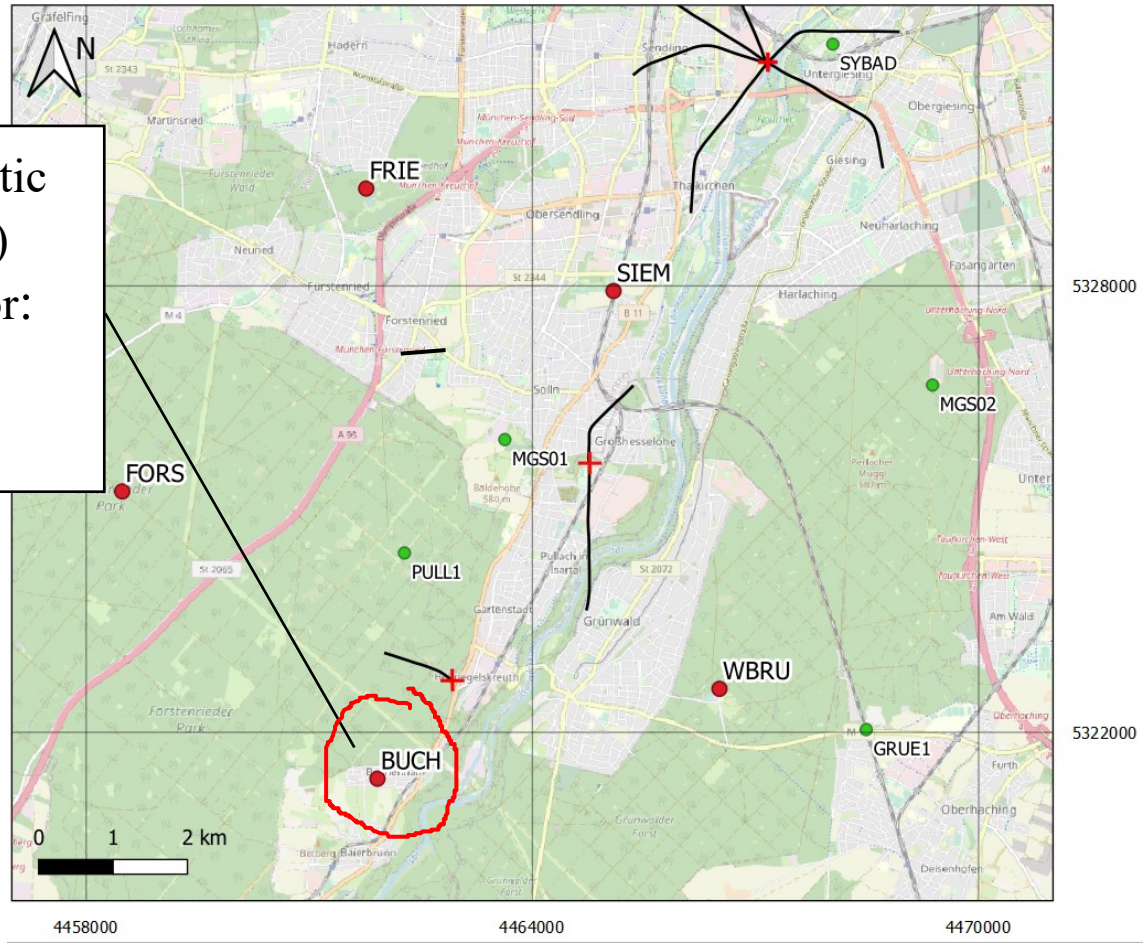
Distributed Fiber-Optic Sensing (**DFOTS**) measuring station for:

- DAS

- DTSS



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Distributed Fiber-Optic Sensing (**DFOTS**) measuring station for:

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Distributed Fiber-Optic Sensing (**DFOTS**) measuring station for:

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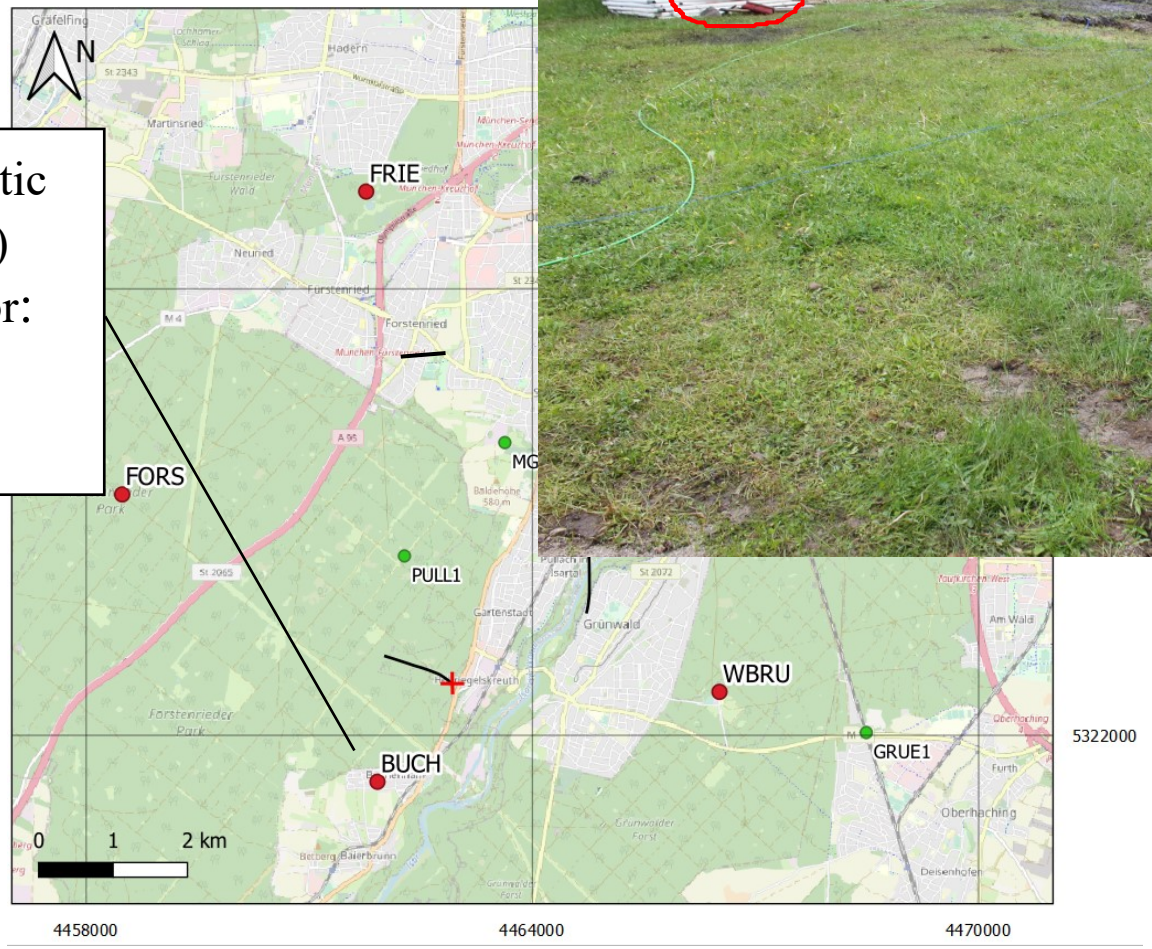

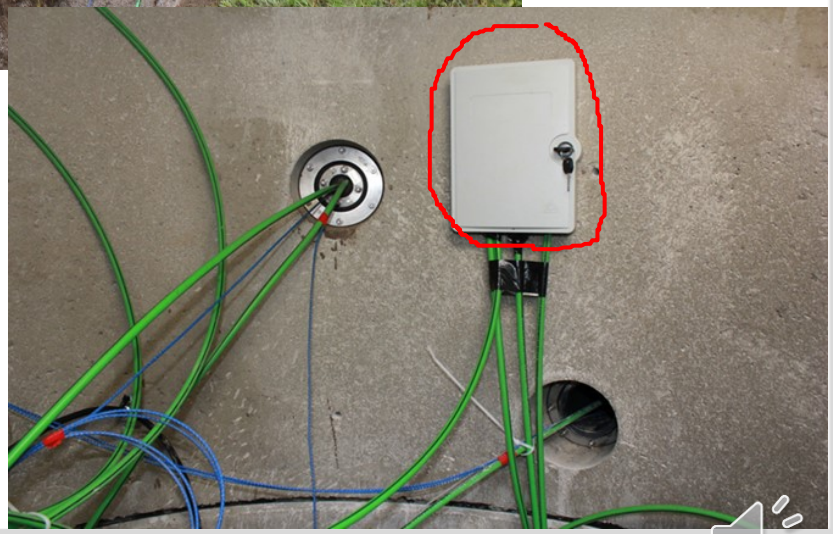

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Distributed Fiber-Optic Sensing (**DFOTS**) measuring station for:

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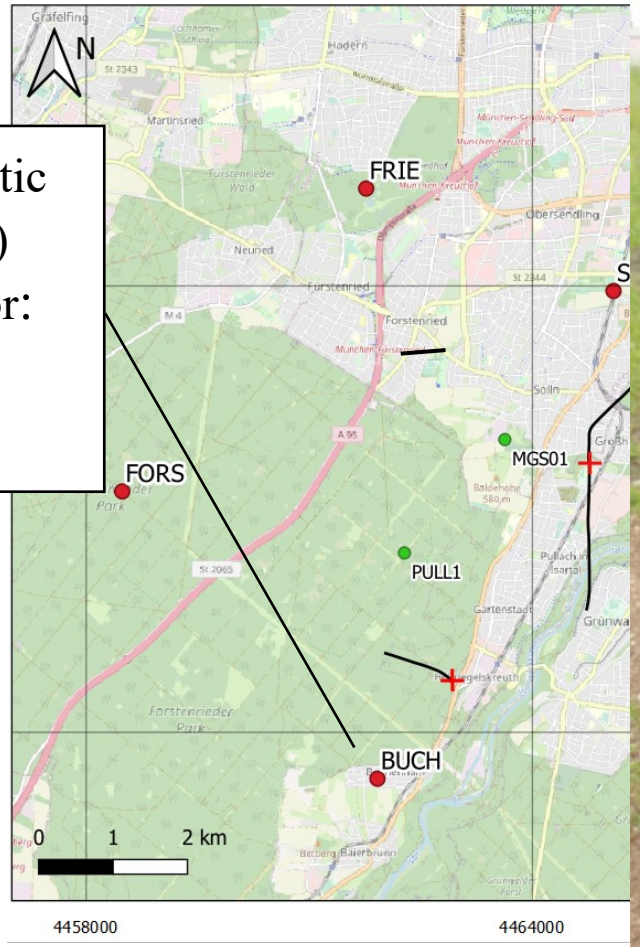

- Well trajectories
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DAS / DTSS interrogators

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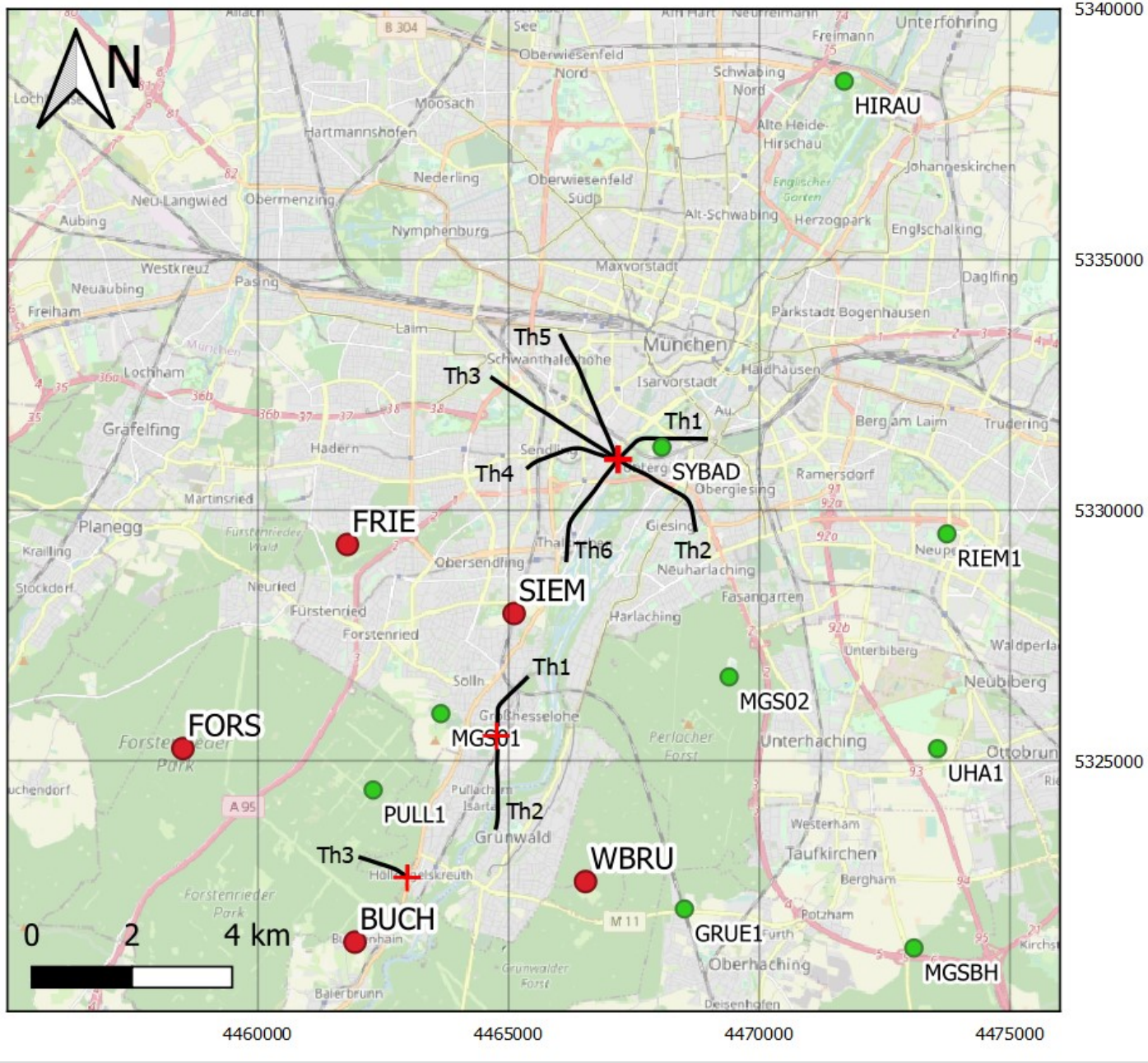

- Well trajectories
- INSIDE seismic stations
- Seismic stations of « Operator Network » (LMU)

EVALUATING THE PERFORMANCE OF THE SURFACE STATIONS

Working Group "Induced Seismicity" **Forschungskollegium Physik des Erdkörpers e. V. (FKPE e. V.),** et al., 2012; Groos and Ritter, 2009

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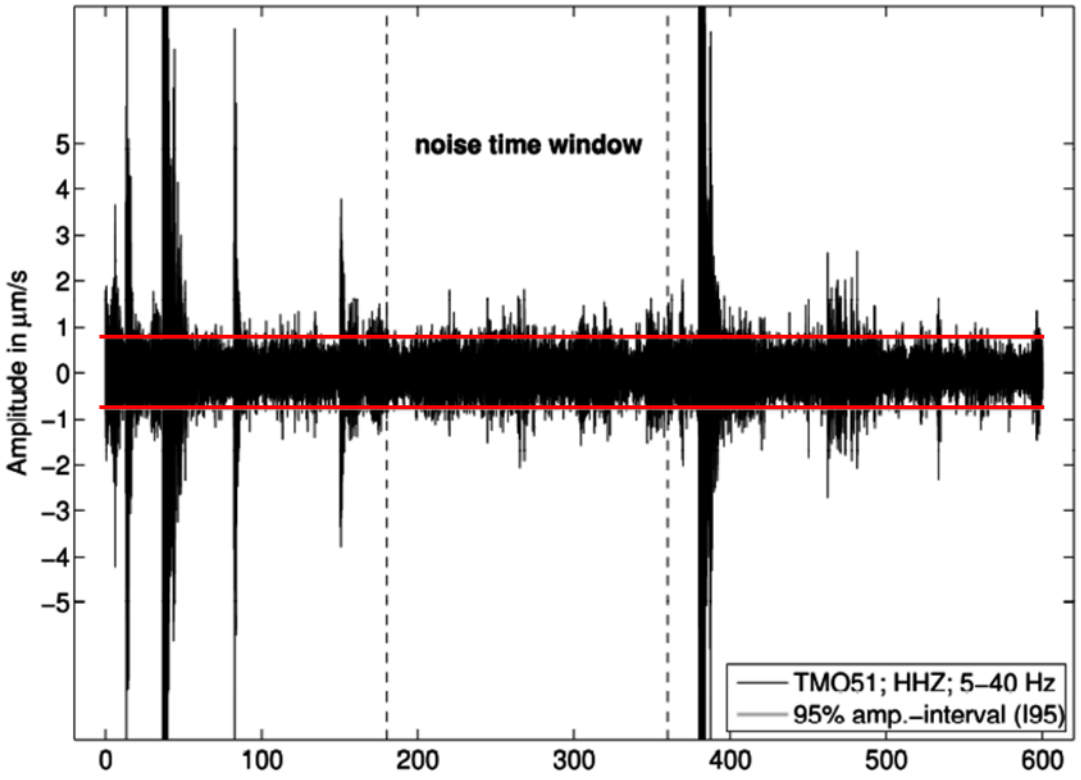
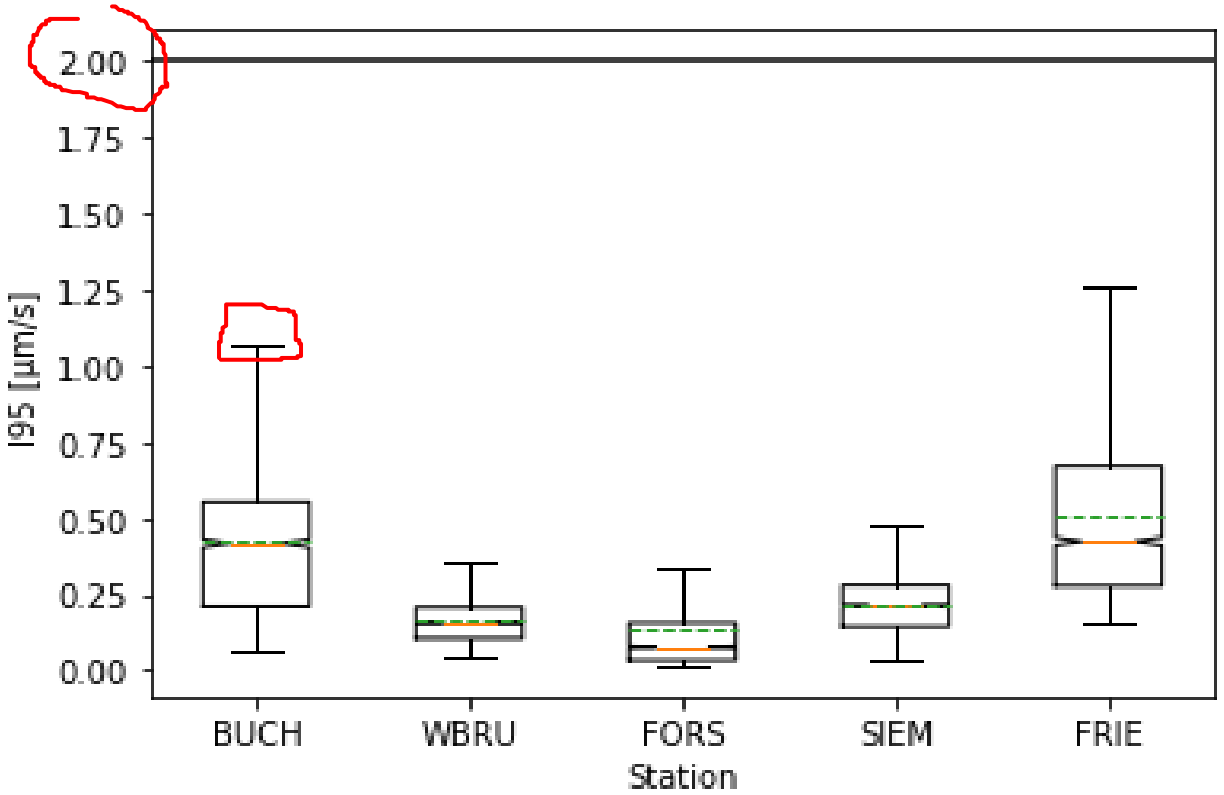


I95 values = a measure of soil turbulence
Source: BVG Guideline 1101.



Statistical distribution of I95 values estimated for the Z comp.

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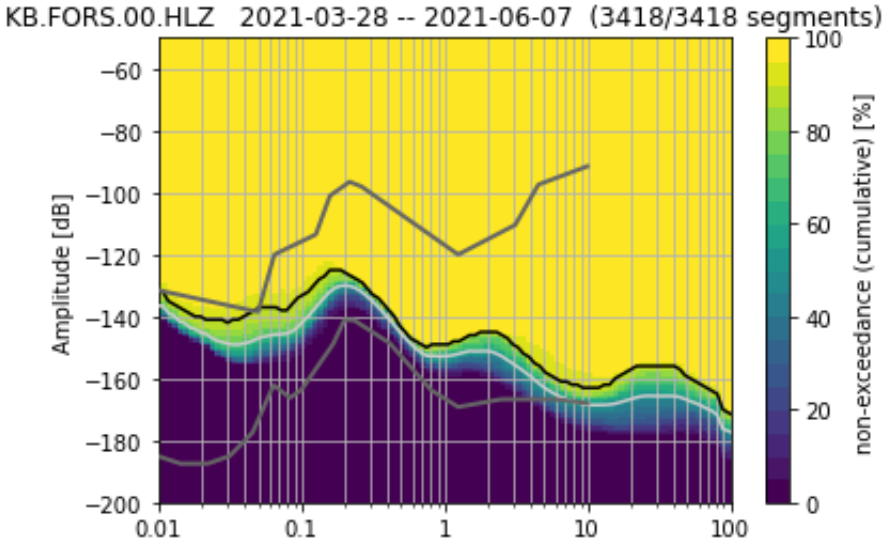
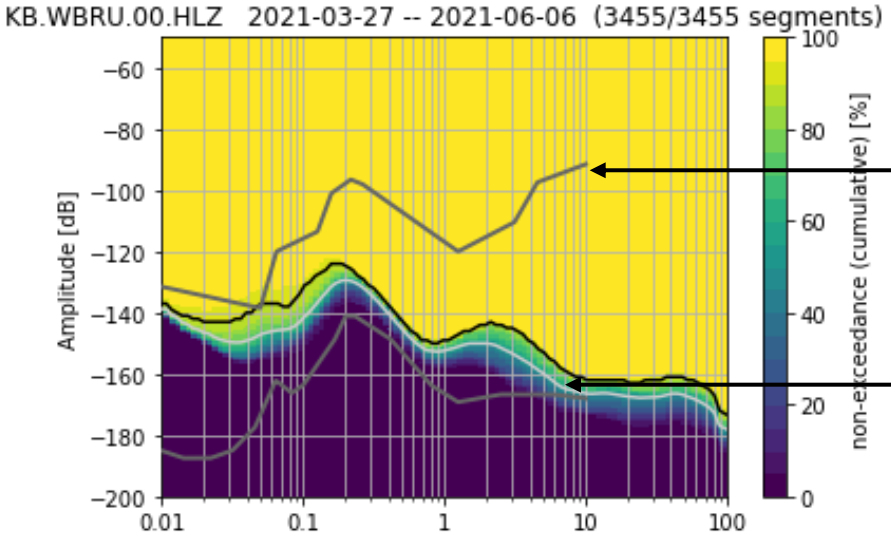
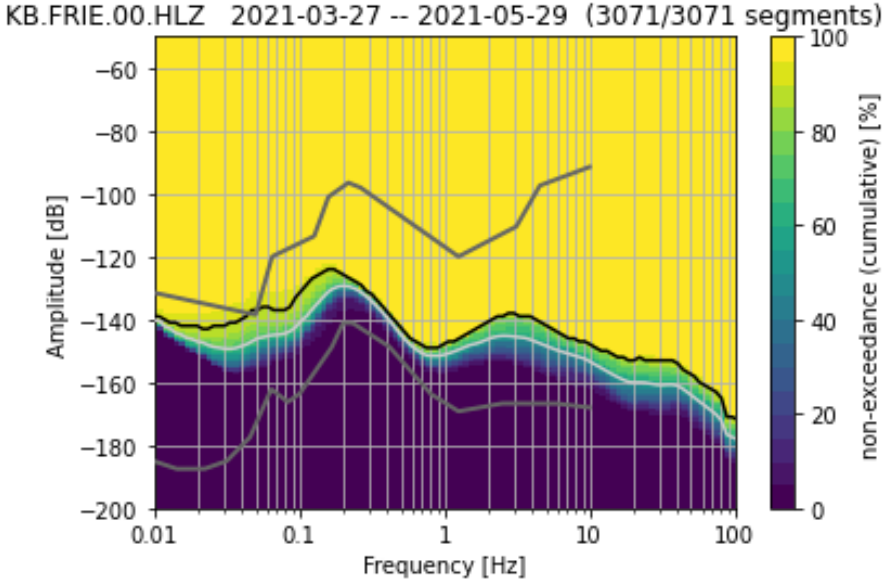


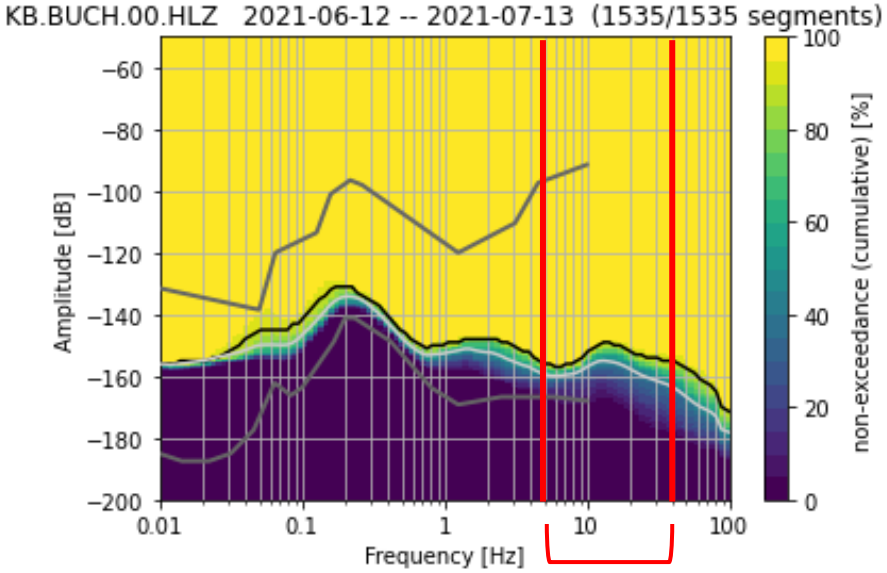


NHNM

(Peterson, 1993)

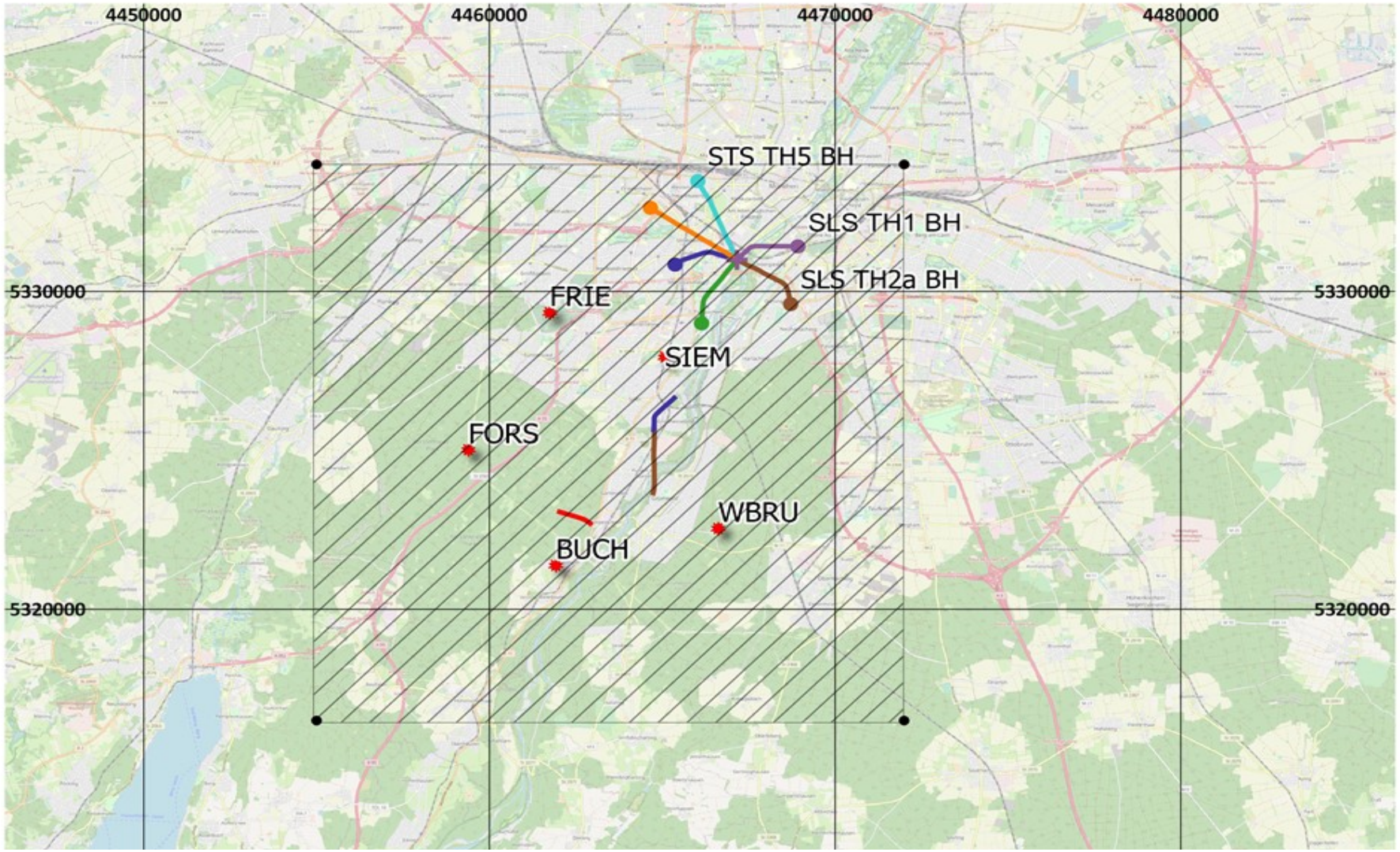
NLNM





PPSD on vertical component for each station

5-40Hz



Surface area where the detection capability has been assessed
In depth, targets the reservoir at a depth of 2250 (below MSL)

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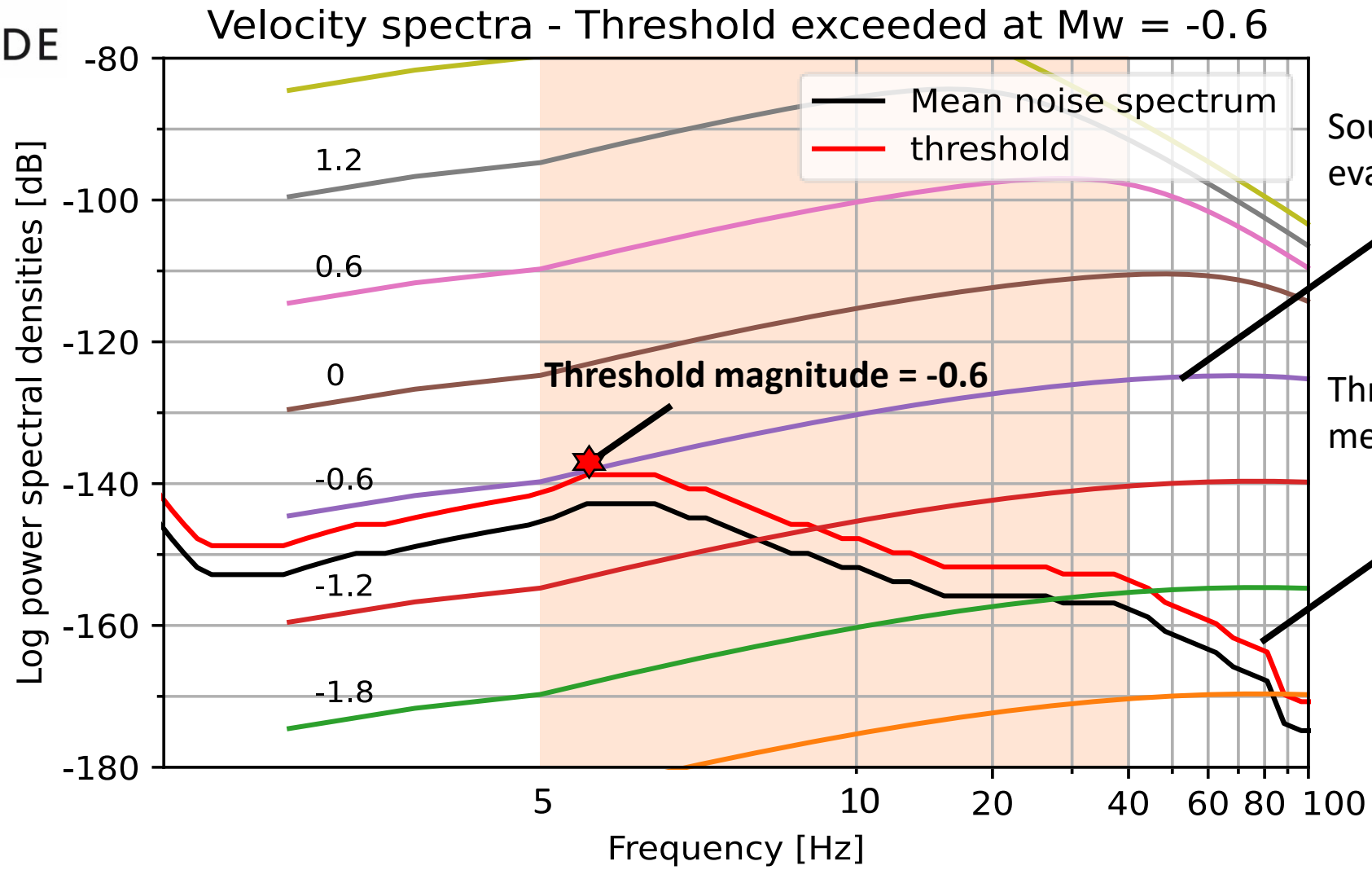

Source signal is theoretically evaluated (Boatwright et al., 1980)

Threshold signal from noise measurements at a given site

For 1 position, comparison between the theoretical spectrum for different Mw + cut-off spectrum from msts of station “FRIE”

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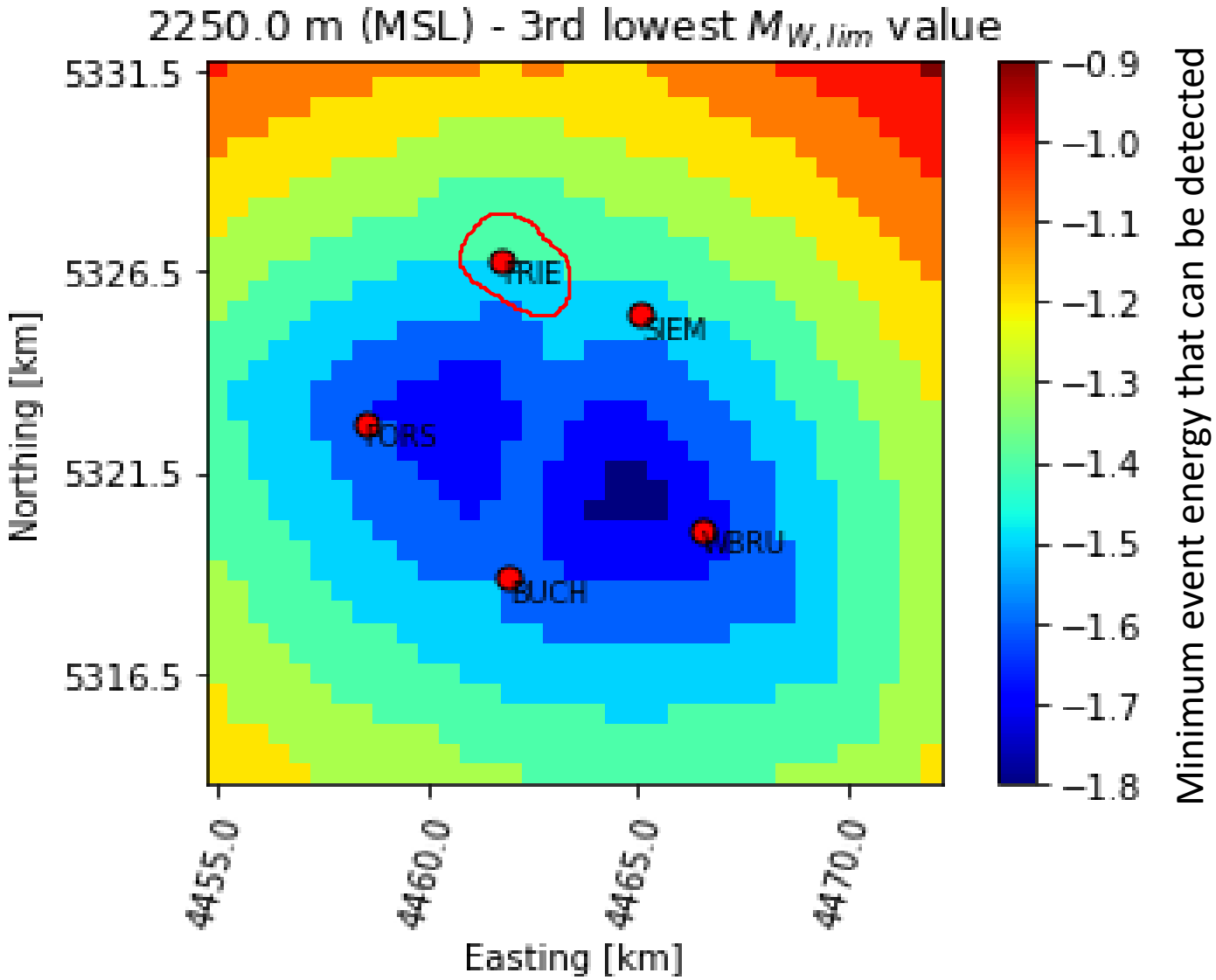
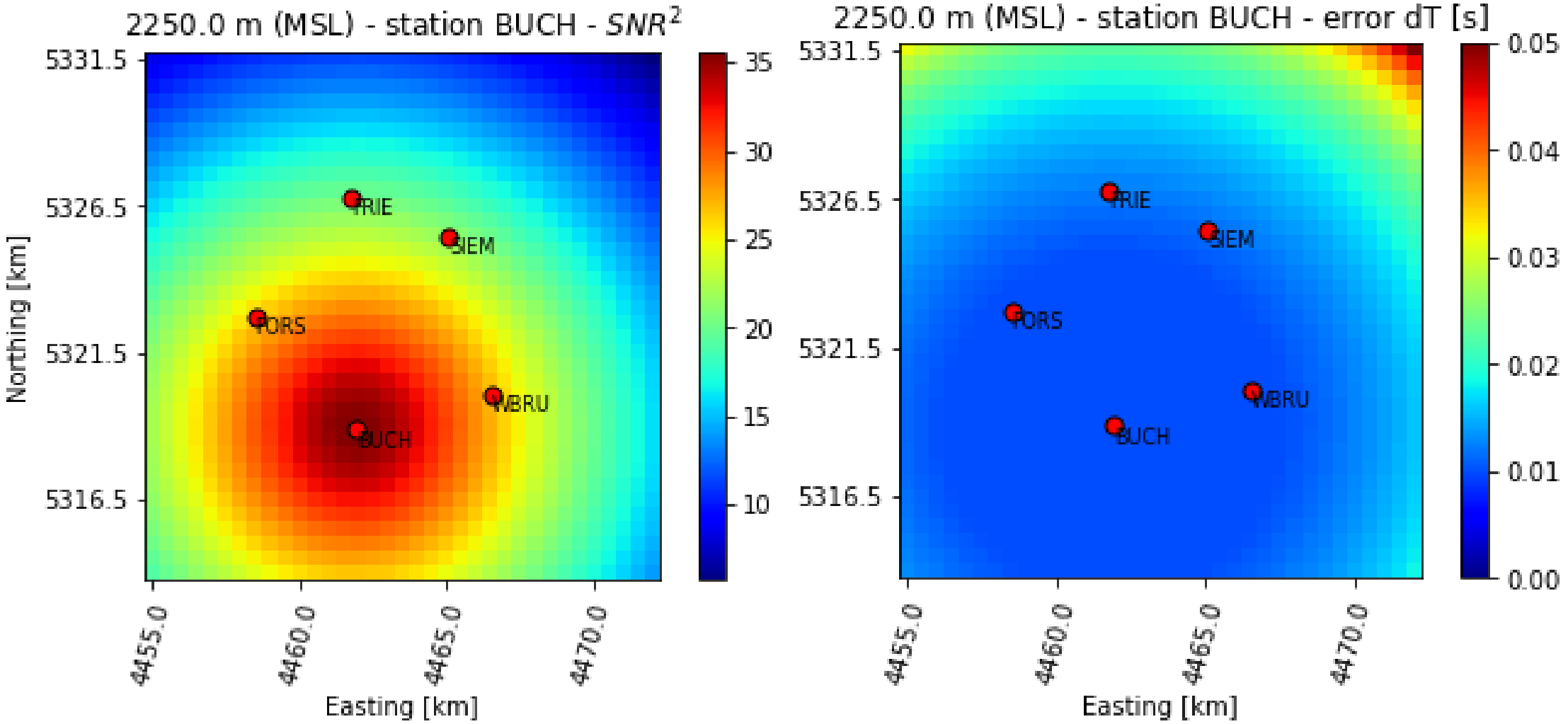


Map at a depth of 2250 m – spatial evolution of the minimum event energy that can be detected with three stations



From the noise msts. and source spectra, corresponding signal-to-noise ratio, converted in picking error dT

Take home messages

Several acquisition techniques are implemented in the INSIDE network, their suitability for monitoring seismicity will be compared

INSIDE surface and borehole stations meet the FKPE recommendations

-1.3 → minimum event energy that can be detected by three stations in the network

10 ms to 20 ms → error in picking the P-wave arrivals for an event of magnitude MW = -1

Outlook: how are these results comparable with real data, and what are the performances of the other implemented acquisition methodologies?

… more info on inside-geothermie.de