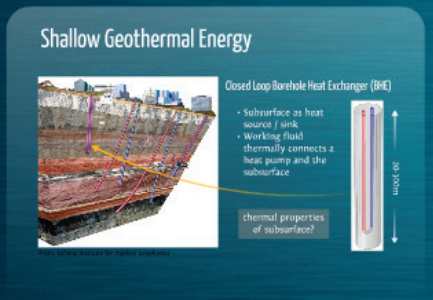
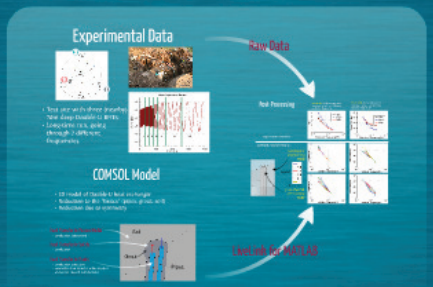
GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

COMSOL
CONFERENCE
ROTTERDAM2013

Scope of Work



COMSOL Application



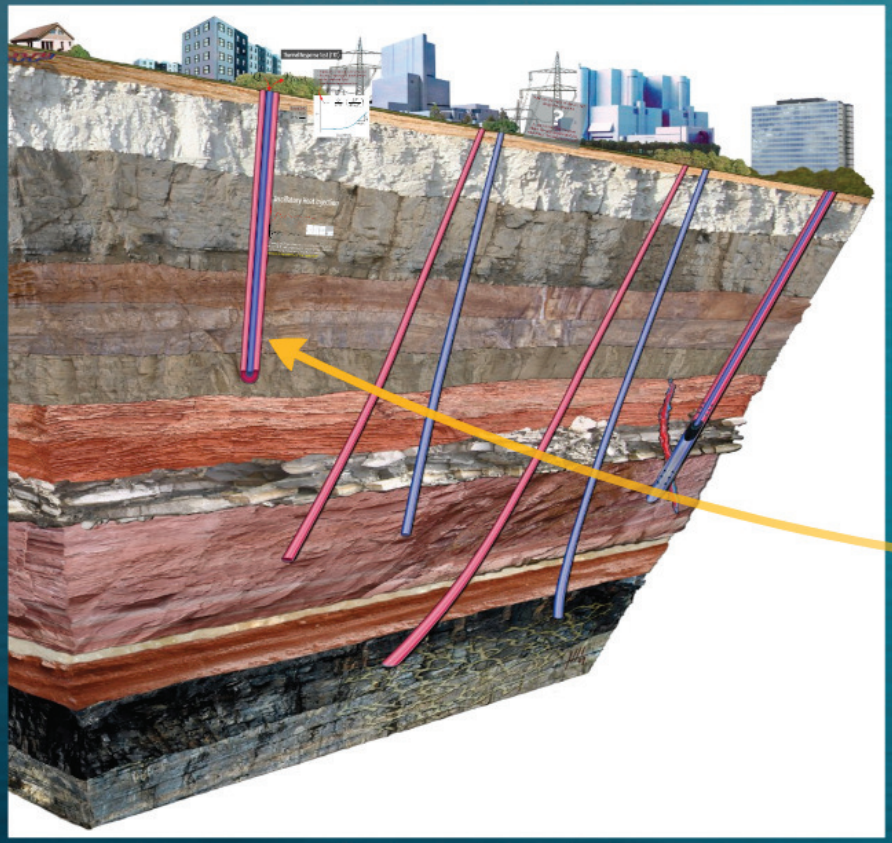
Conclusions

Oscillatory Thermal Response Tests

An advanced method for shallow geothermal applications, developed with COMSOL

Phillip Oberdorfer, Dipl.-Phys.

Shallow Geothermal Energy



From: Leibniz Institute for Applied Geophysics

Closed Loop Borehole Heat Exchanger (BHE)

- Subsurface as heat source / sink
- Working fluid thermally connects a heat pump and the subsurface

thermal properties of subsurface?

Thermal Response Test (TRT)

$\dot{Q}$

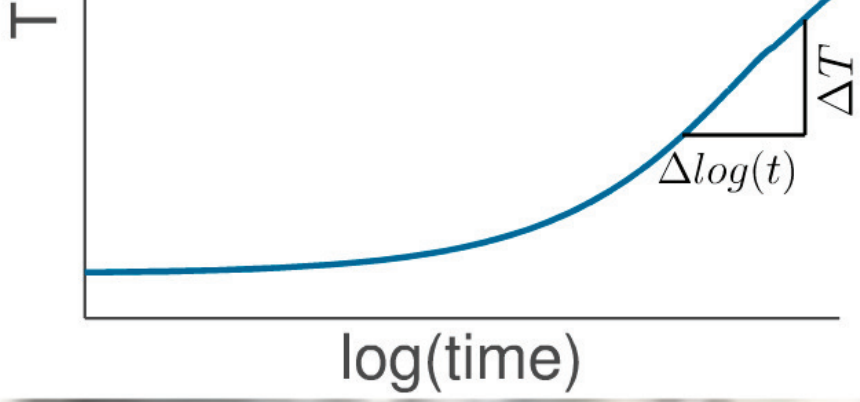
T_{fluid}

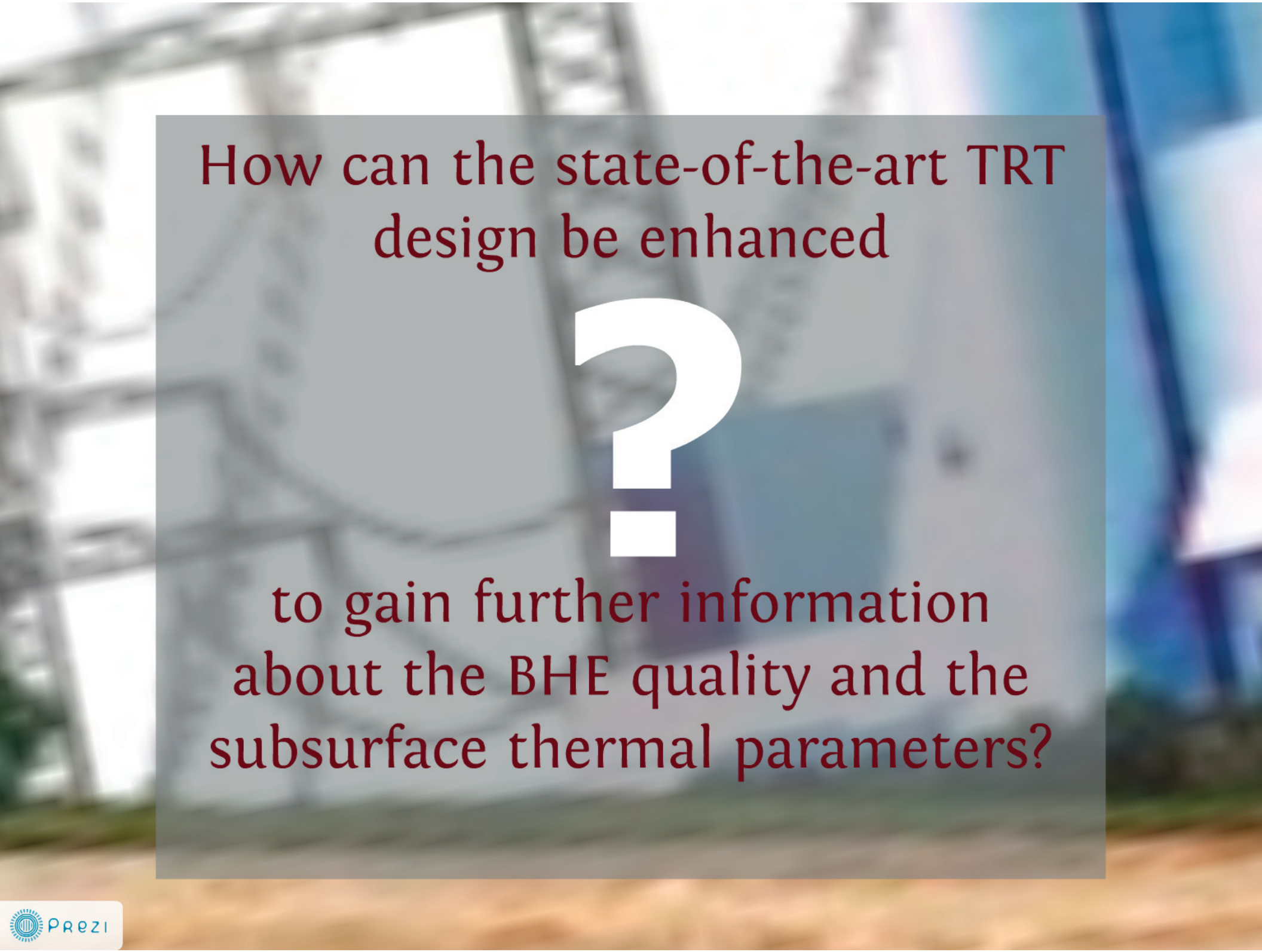
- Injection of heat at constant rate
- Record temperature development of the working fluid
- Line Source Approximation

Constraint:

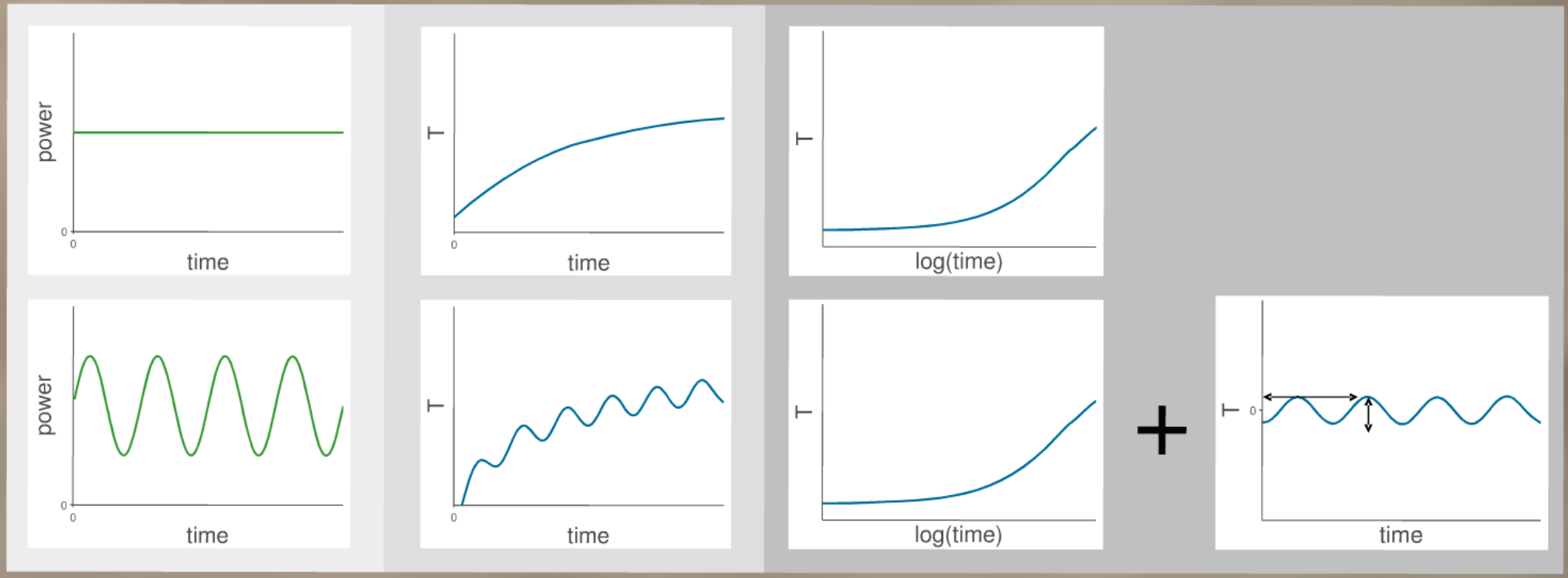
$$t > \frac{5r^2}{a}$$

$$\lambda_{eff} = \frac{\dot{Q}}{4\pi H} \cdot \left(\frac{\Delta T}{\Delta log(t)} \right)^{-1}$$




How can the state-of-the-art TRT design be enhanced
?
to gain further information about the BHE quality and the subsurface thermal parameters?

Adding an oscillatory part to the constant injection rate:



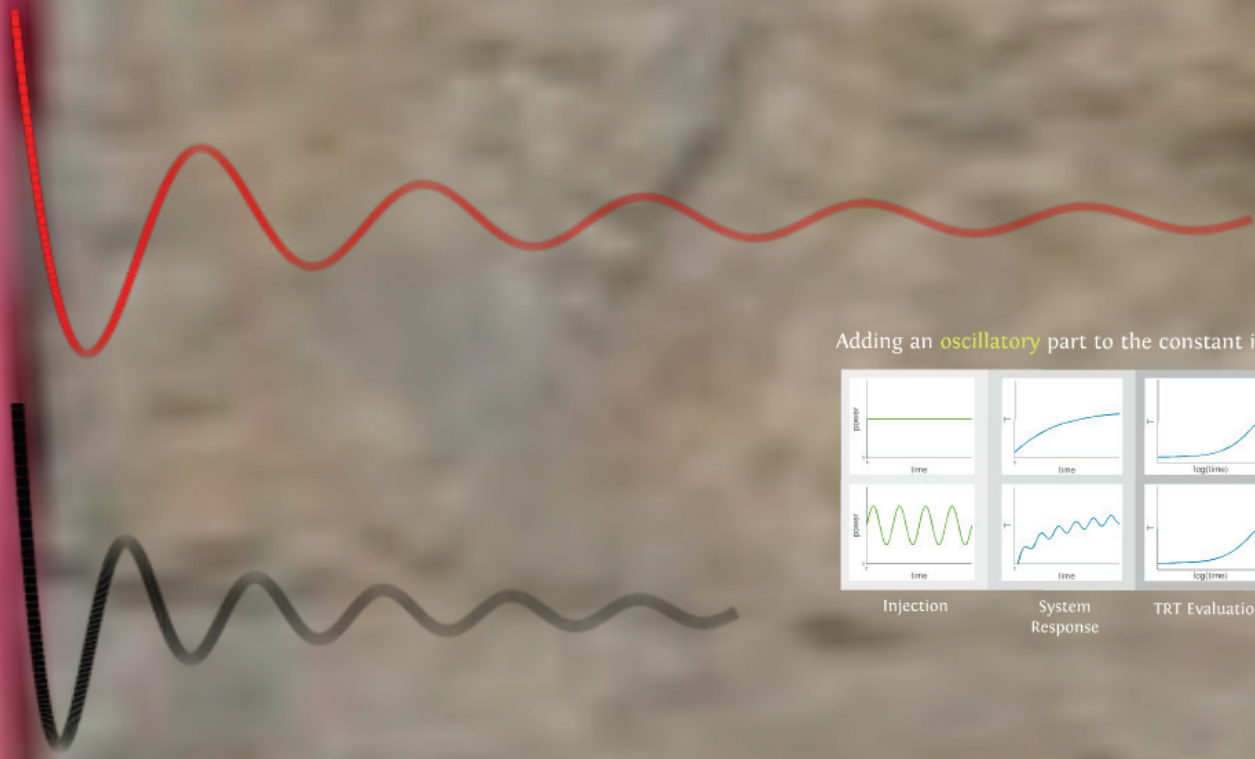
Injection

System Response

TRT Evaluation

Additional Oscillatory Information

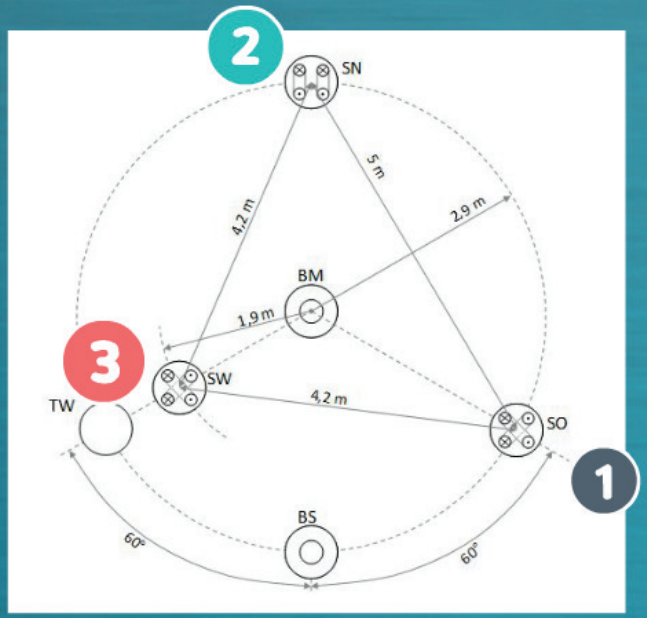
Oscillatory Heat Injection



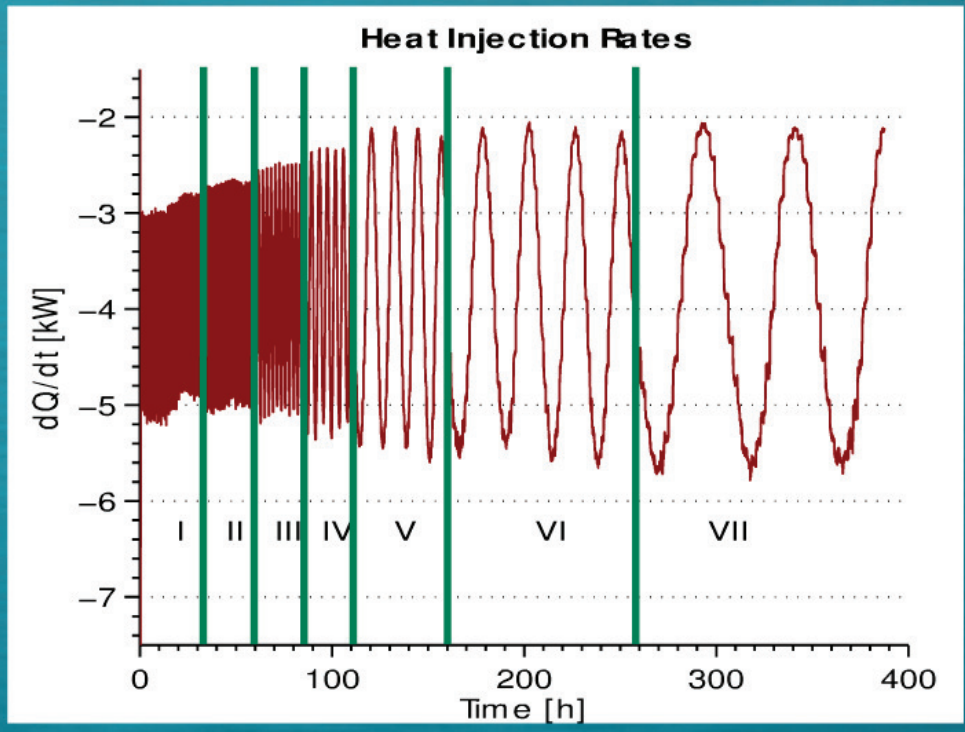
Adding an oscillatory part to the constant injection rate:

- Penetration depth depends on excitation frequency
- Phase shift and amplitude of response signal depend on thermal parameters of involved materials
- Analytical approximation not applicable!

Experimental Data



- Test site with three (nearby) 70m deep Double-U BHEs
- Long-time run, going through 7 different frequencies



COMSOL Model

- 3D model of Double-U heat exchanger
- Reduction to the "basics" (pipes, grout, soil)
- Reduction due to symmetry

Heat Transfer in Porous Media

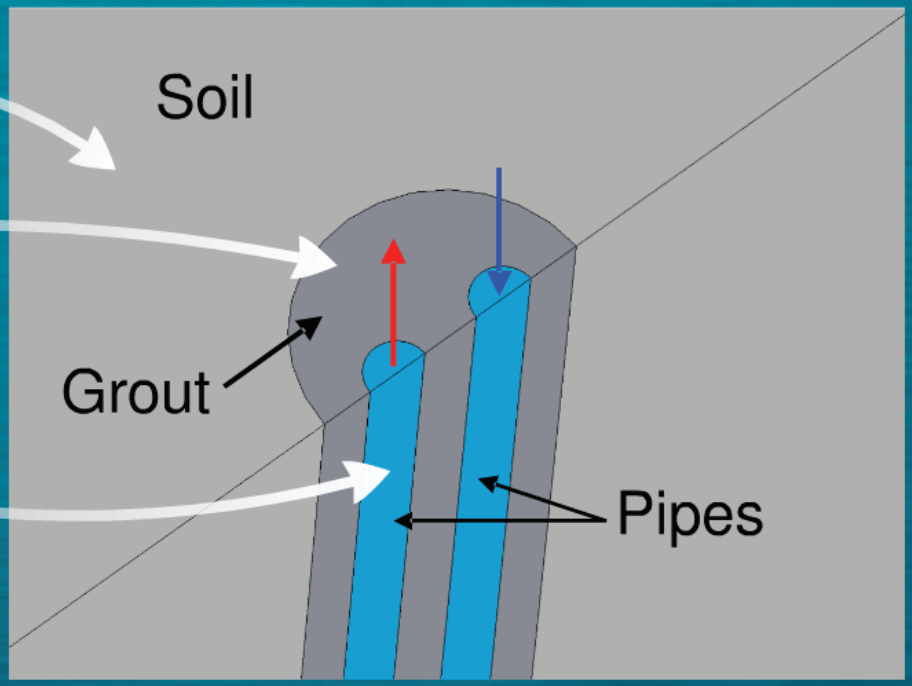
- conduction, (advection)

Heat Transfer in Solids

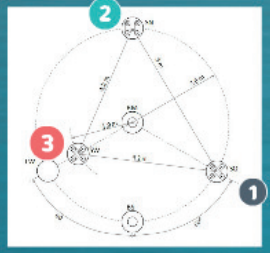
- conduction

Heat Transfer in Fluids

- conduction, advection
- convective heat transfer between pipes and grout (Nusselt Correlations)



Experimental Data



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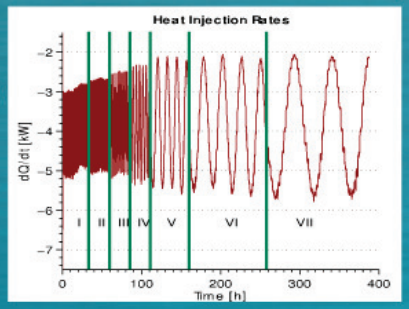

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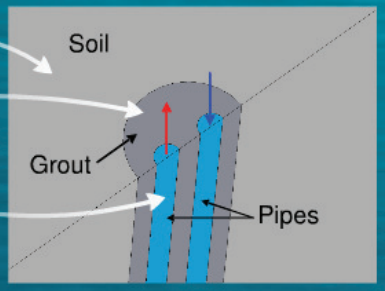
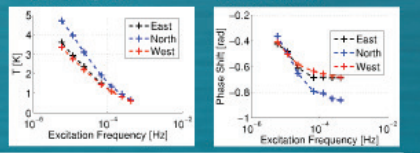


Raw Data

Post-Processing

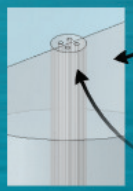
Amplitude of the temperature response signal at different excitation frequencies

Phase Shift of the temperature response signal at different excitation frequencies



Experimental Results

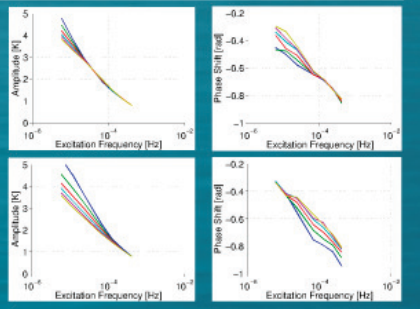
COMSOL Model Results



soil thermal conductivity study

Legend
1
1.4
1.8
2.2
2.6
3

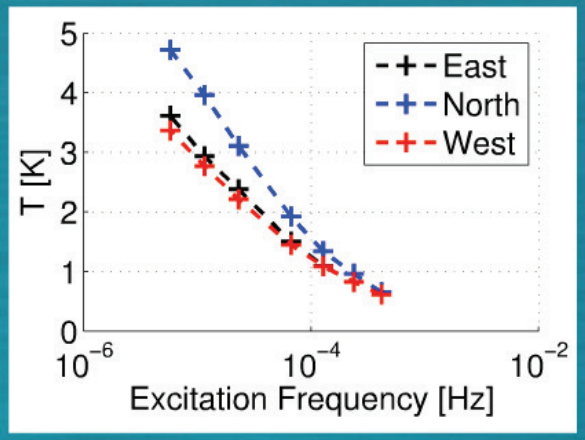
grout thermal conductivity study



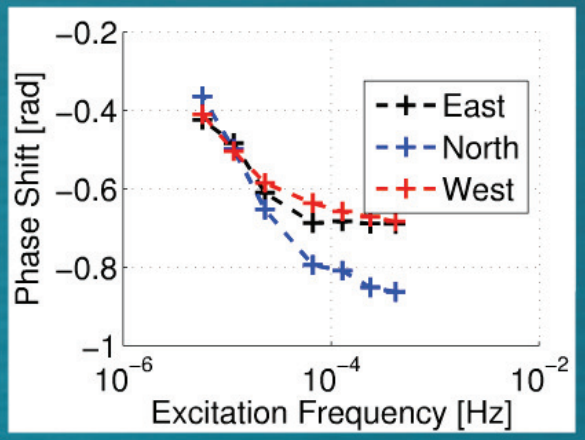
LiveLink for MATLAB

Post-Processing

Amplitude of the temperature response signal at different excitation frequencies



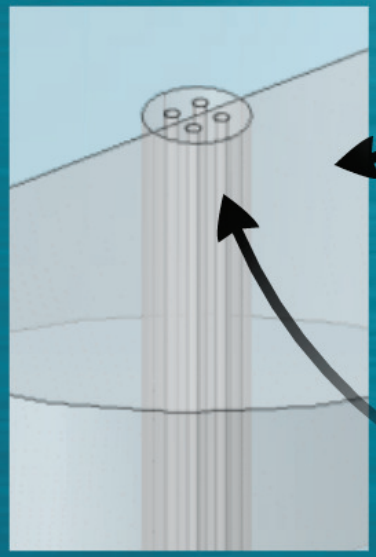
Phase Shift of the temperature response signal at different excitation frequencies



Experimental Results

COMSOL Model Results

soil thermal conductivity study

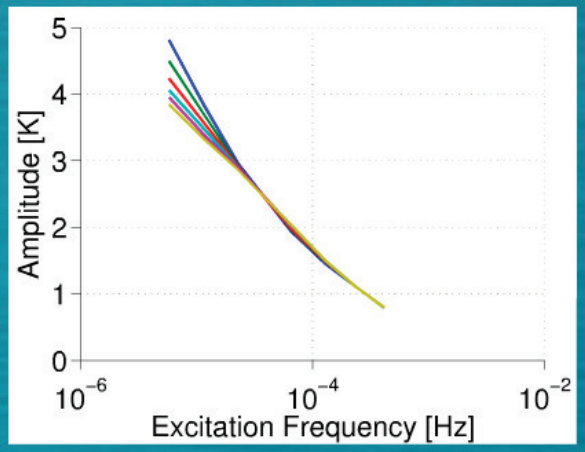


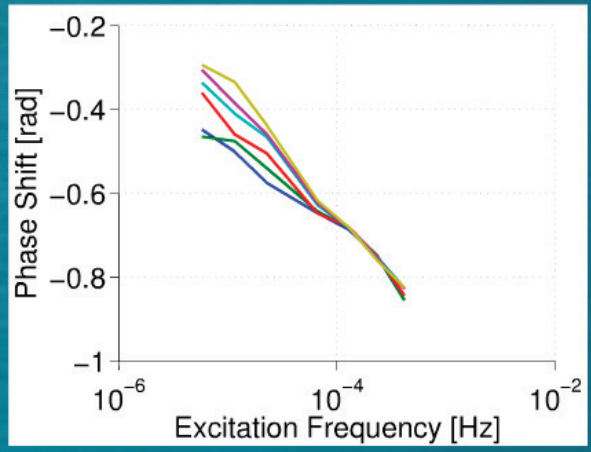
Legend

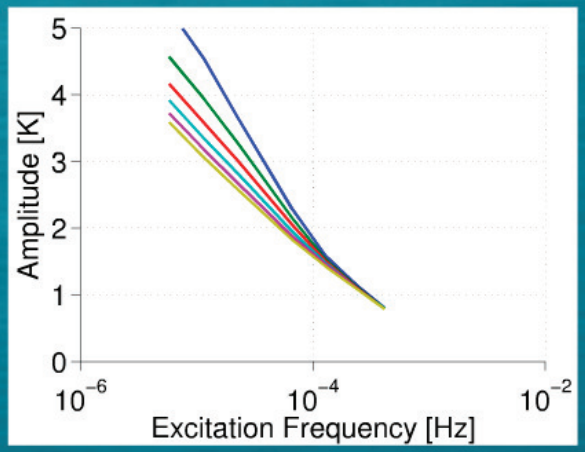
1
1.4
1.8
2.2
2.6
3

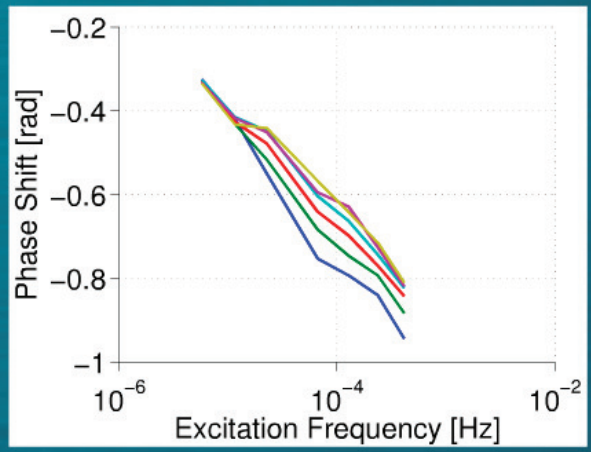
$\lambda[W/(m \cdot K)]$

grout thermal conductivity study









Conclusions

- Oscillatory heat injection bears additional information about thermal properties of the BHE and the subsurface
- Evaluation and interpretation of the thermal response requires numerical simulation

- O-TRTs may be a useful add-on to state-of-the-art TRTs
- This new method requires further numerical analysis

Thank you for your attention!

Dieses Projekt wird mit Mitteln des Europäischen Fonds für regionale Entwicklung gefördert.

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Europäischer Fonds für regionale Entwicklung

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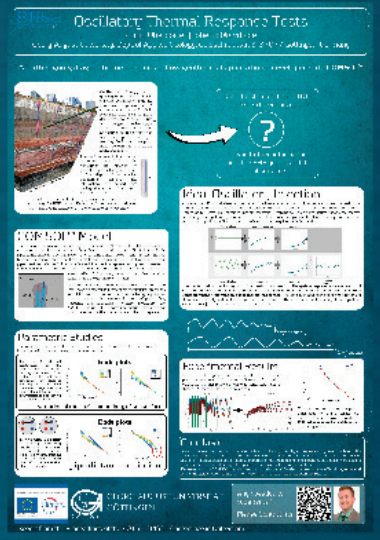

@ my poster (#113)

meet me

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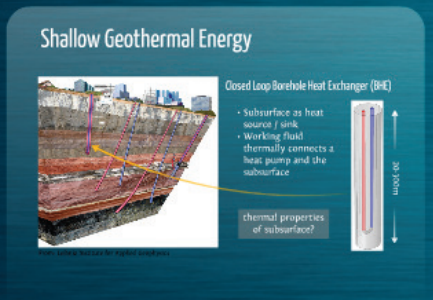
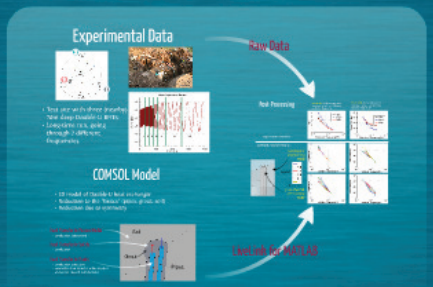


COMSOL Application



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