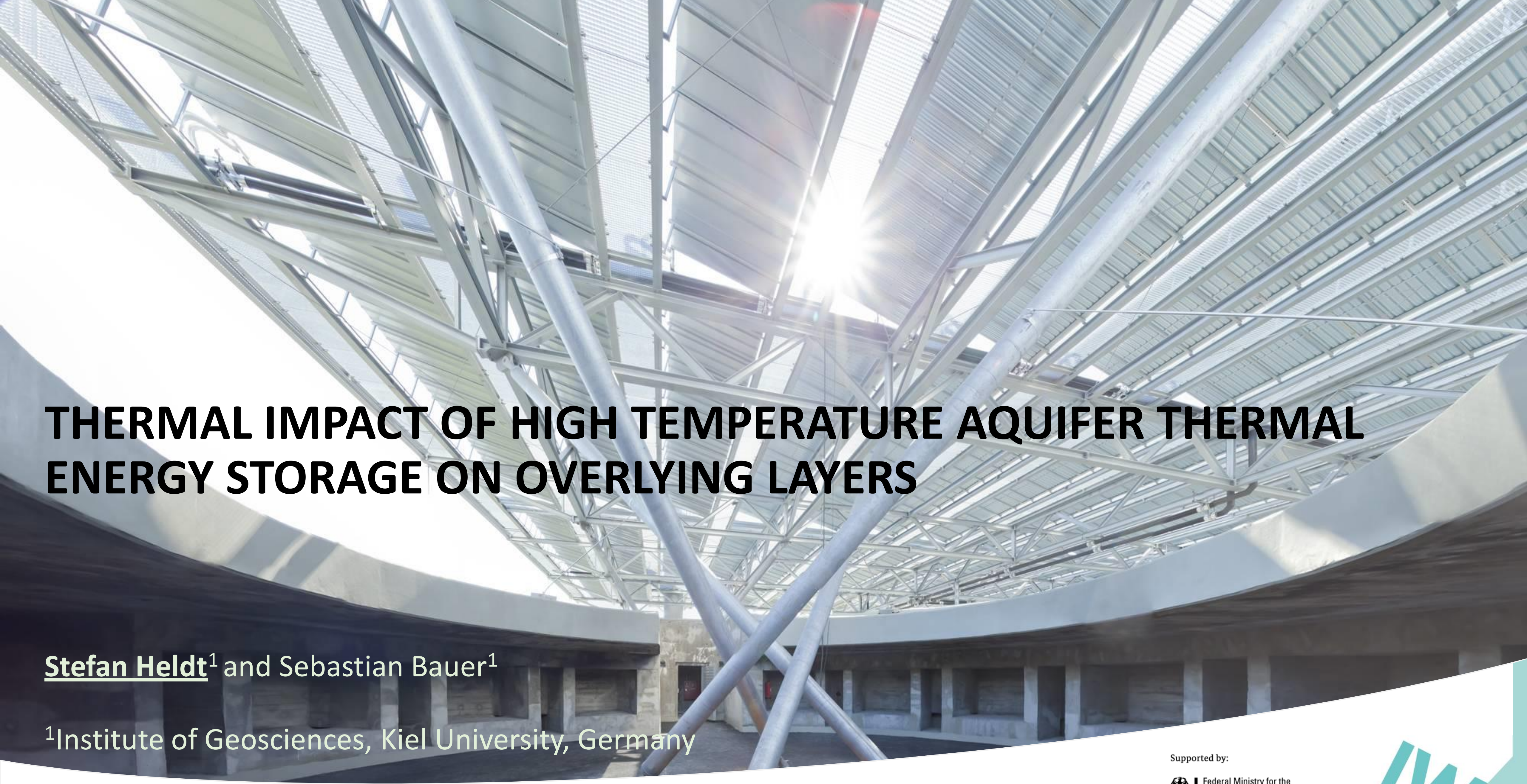


THERMAL IMPACT OF HIGH TEMPERATURE AQUIFER THERMAL ENERGY STORAGE ON OVERLYING LAYERS

Stefan Heldt[1] and Sebastian Bauer[1]

[1]Institute of Geosciences, Kiel University, Germany

Supported by:

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

based on a decision of the German Bundestag

C A U
Kiel University
Christian-Albrechts-Universität zu Kiel

IW3 Integrierte WärmeWende Wilhelmsburg

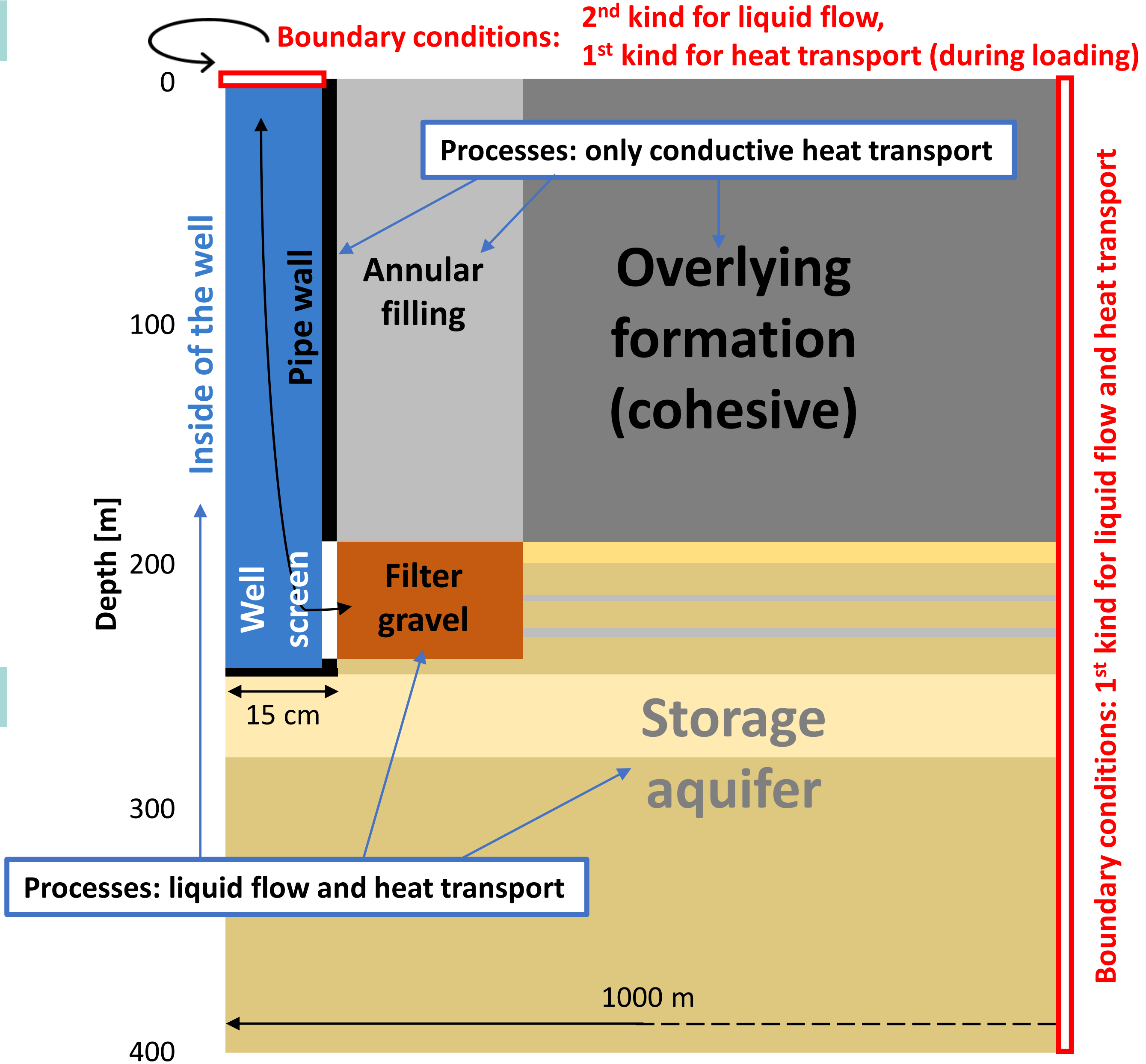
Stefan Heldt (stefan.heldt@ifg.uni-kiel.de)

Introduction

- High Temperature Aquifer Thermal Energy Storage (HT-ATES) is a promising technology in a renewable-dominated heating sector
- The thermal impact of HT-ATES on overlying layers, which is caused by conductive heat loss from the borehole, was mostly disregarded in previous studies
- Therefore: radially symmetric model, which includes the discretized geometry of a HT-ATES well

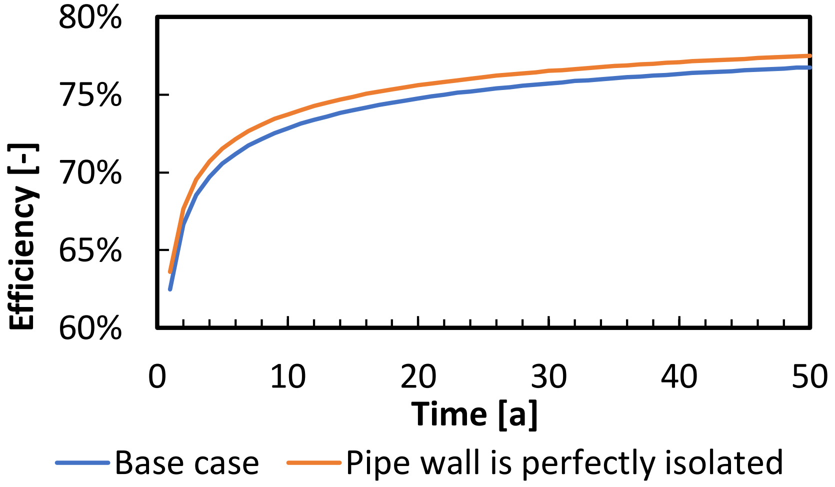
Model setup

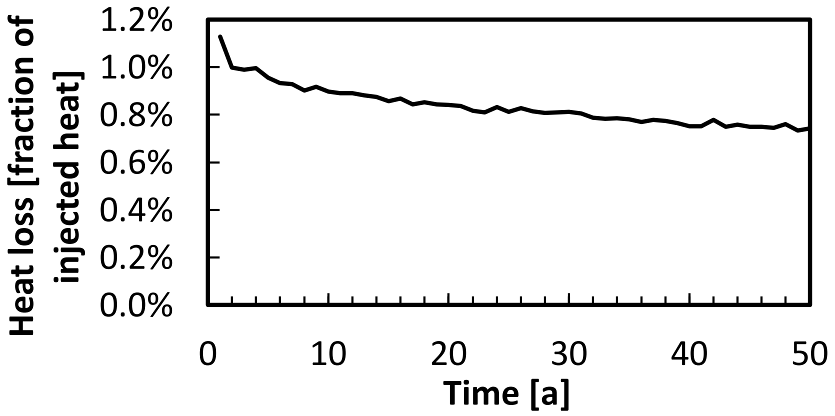
- Numerical simulation of the coupled thermo-hydraulic processes using OpenGeoSys (OGS)
- 50 years of HT-ATES operation
- 0.5 year loading, 0.5 year unloading
- Injection temperature = 85 °C
- Pumping rate = 30 m^3/h



Efficiency

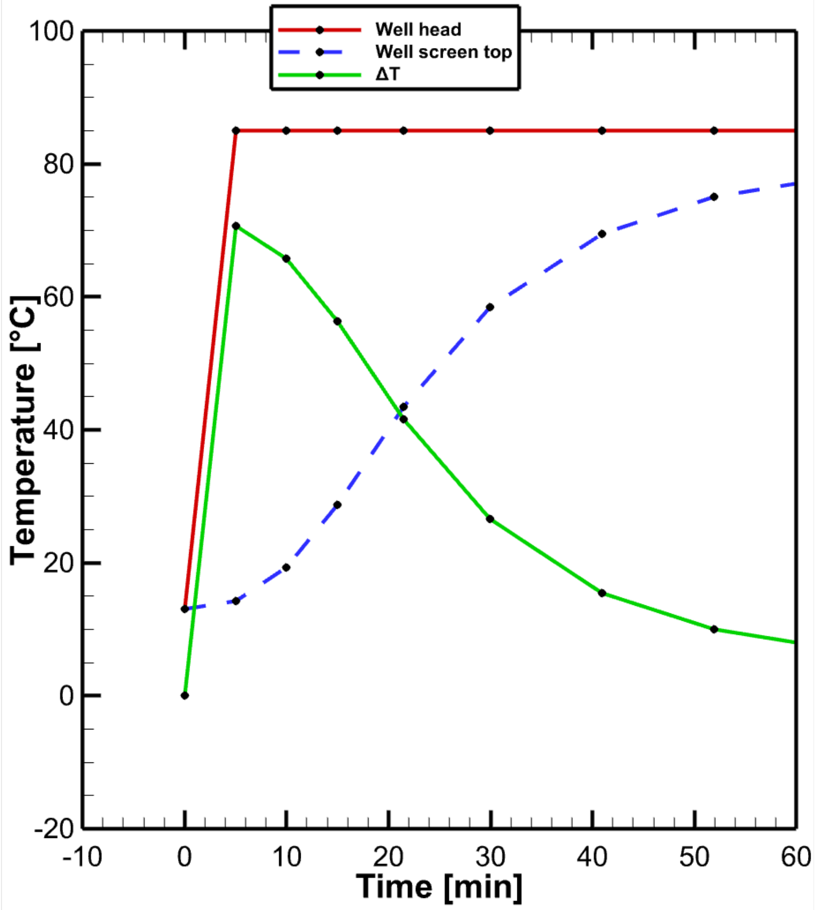
- The comparison of the base case to a scenario with a perfectly isolated pipe wall shows:
  0.7 – 1.1 % of injected heat is lost through the pipe wall

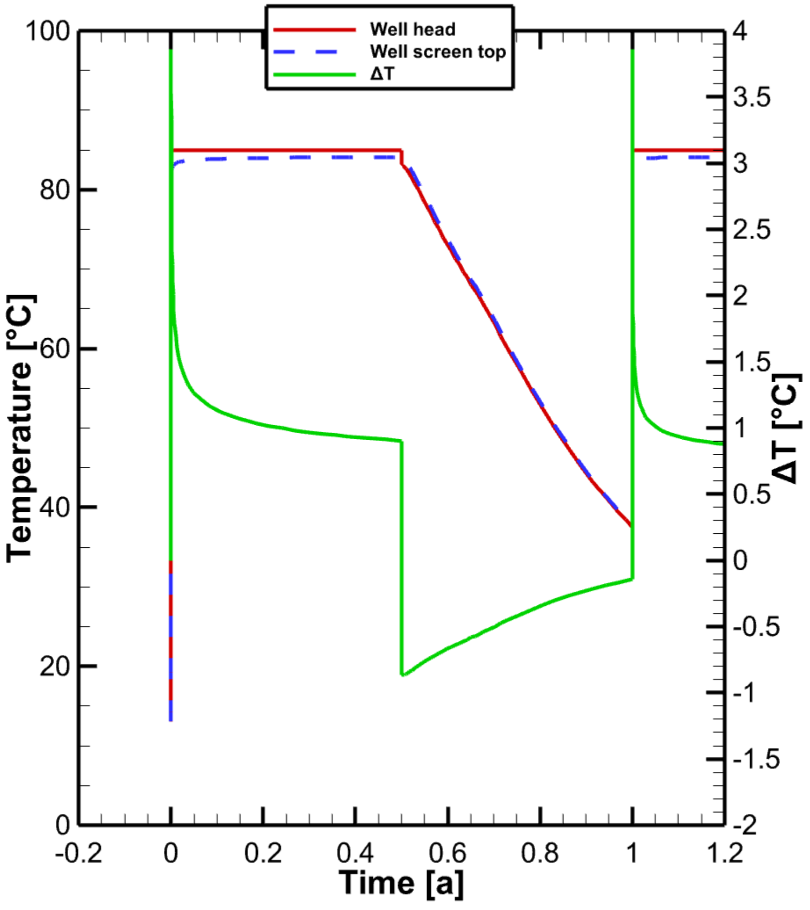




Temperature difference

- The temperature difference between the well head and the well screen top is…
  - … Initially 72 °C → difference between injection temperature and ambient temperature
  - … Over most of the first loading phase: ≈1 °C
  - … Over the first unloading phase: 0.1 – 0.9 °C

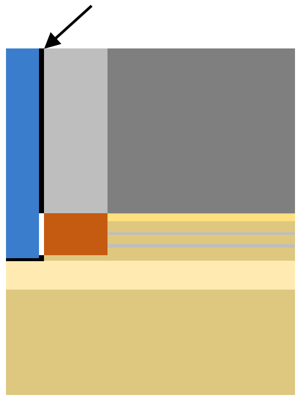


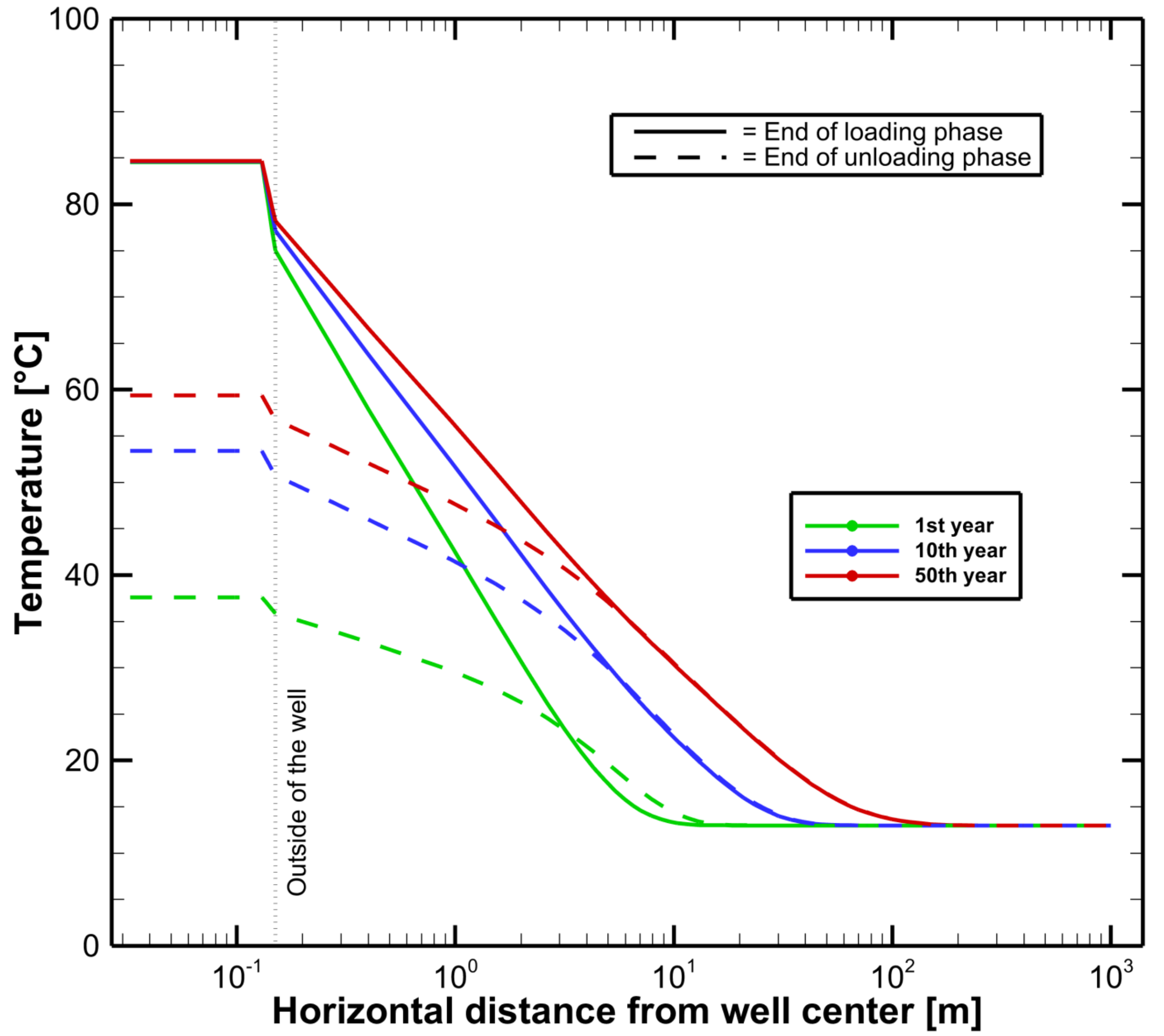


Temperature profiles in 95 m depth

- At the end of loading phases: largely linear temperature decrease in the semilogarithmic plot (outside of the well)
- At the end of unloading phases: temperature is lower near the well, due to the lower extraction temperature
- Temperatures rise from year to year → a temperature increase of 5 °C is found in…
  - 6 m distance after 1 year
  - 16 m distance after 10 years
  - 40 m distance after 50 years
- The pipe wall, which is parameterized as fibre-reinforced plastic, induces a temperature decrease due to it‘s isolating effect

Pipe wall material: **Fibre-reinforced plastic**



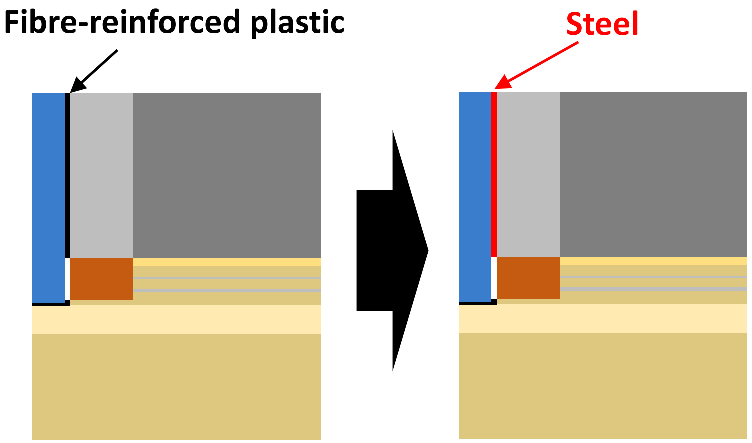


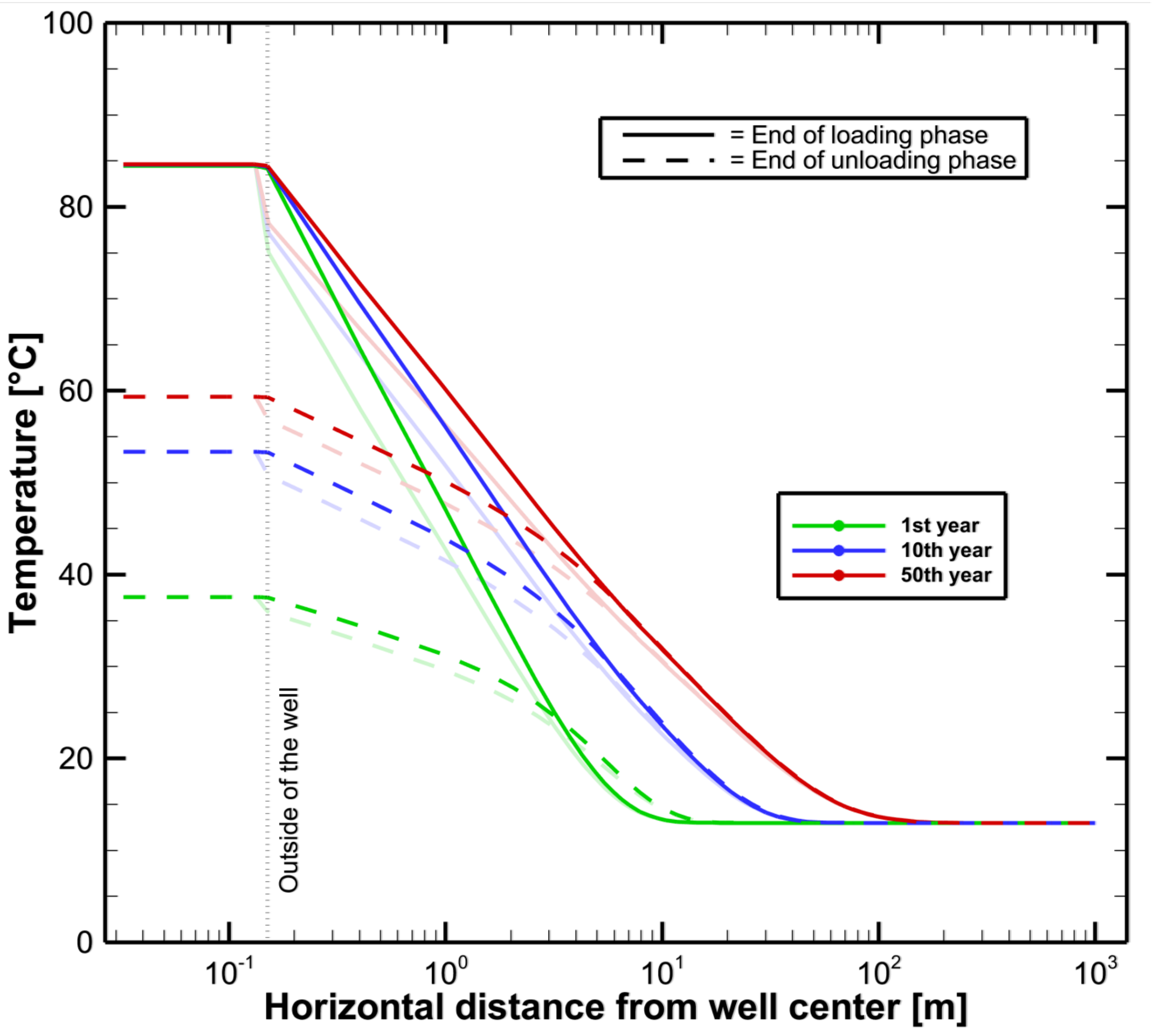
Temperature profiles in 95 m depth

- If steel is used instead of fibre-reinforced plastic as pipe wall material, the well temperature is reached outside of the well

		Fibre-reinforced plastic	Steel	
λ	Thermal conductivity	0.4	15	W/(m·K)
c	Heat Capacity	1000	502	J/(kg·K)
ρ	Density	2000	7800	kg/m³
D_{th}	Thermal diffusivity	2.00E-07	3.83E-06	m²/s

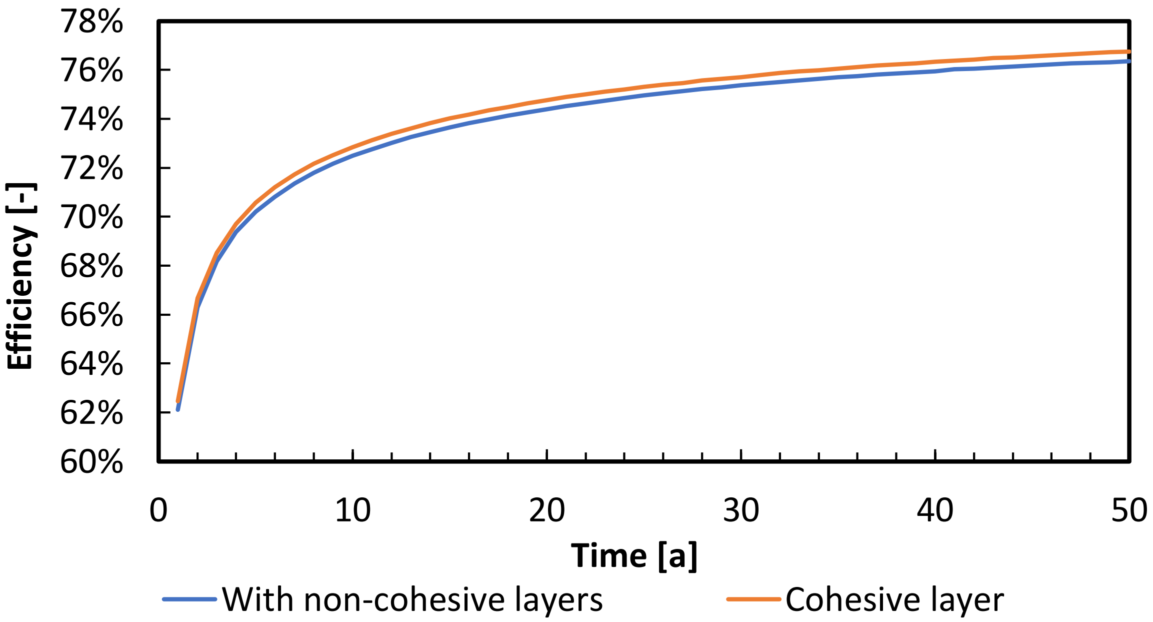
Pipe wall material:

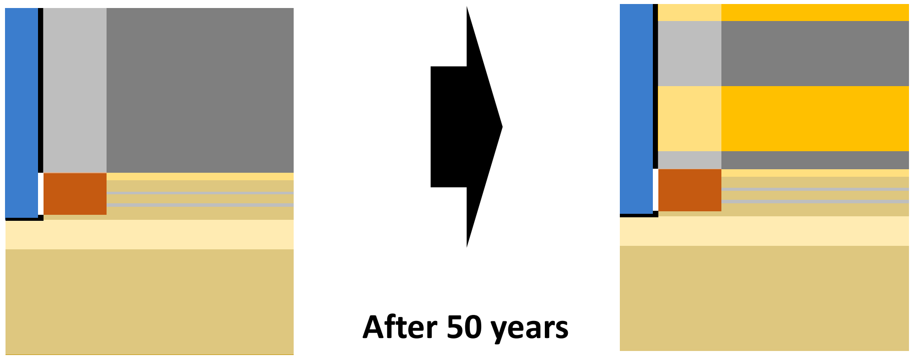


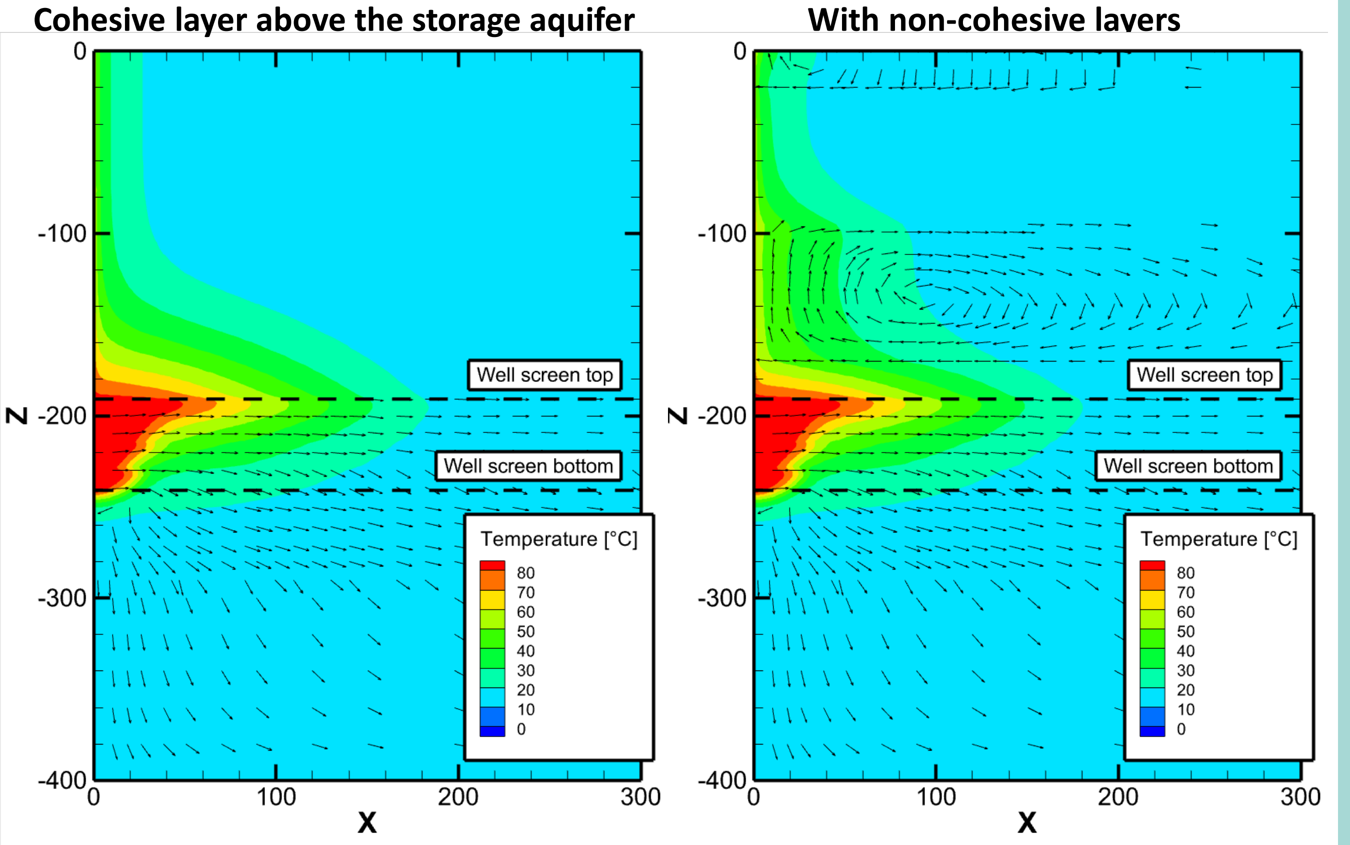


Thermal impacts and convection

- Thermal convection is induced in the non-cohesive formation in 95 – 170 m depth
- The thermal impacts are therefore larger in the upper layers than with non-cohesive layers
- Efficiency is reduced by 0.4 % on average by the convection
- This approach is conservative for non-cohesive layers, since ambient groundwater flow is neglected, which would advectively transport heat away from the wellbore





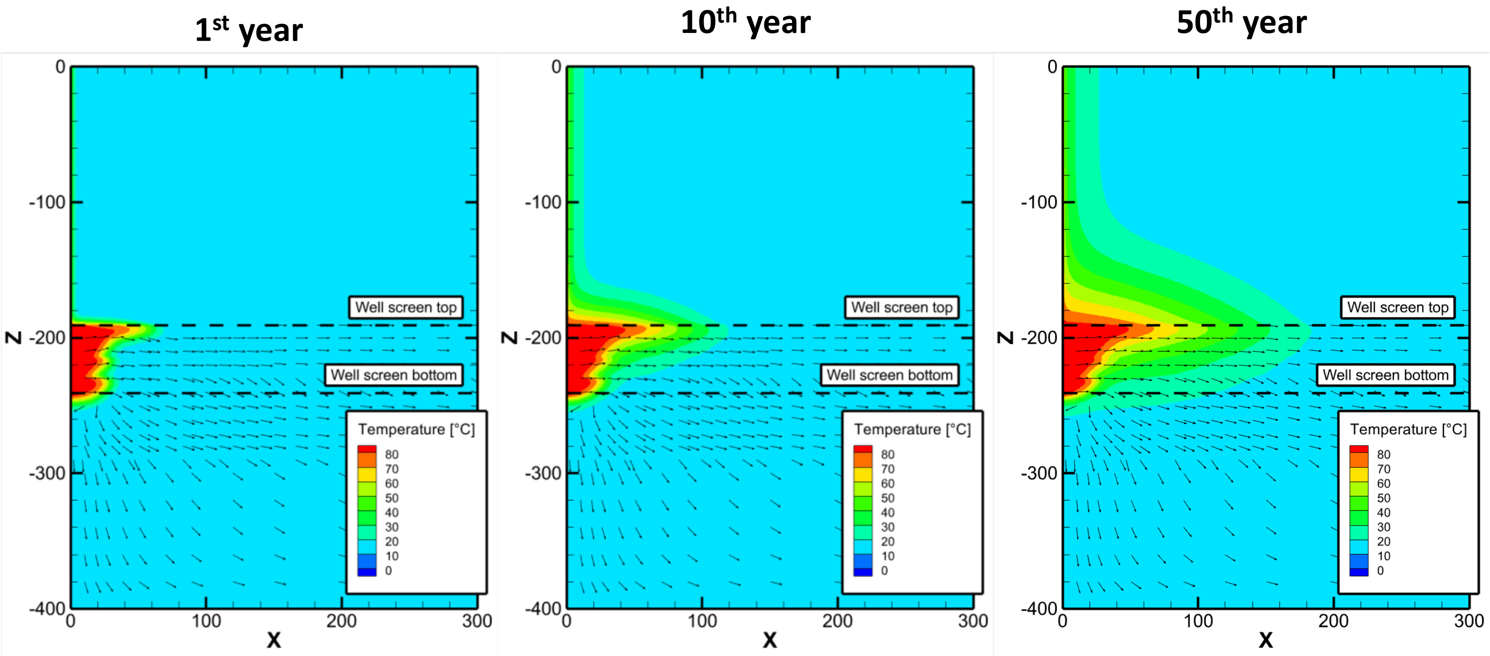


Stefan Heldt (stefan.heldt@ifg.uni-kiel.de)

Supported by:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
based on a decision of the German Bundestag

Conclusions

- The consideration of heat loss through the well pipe in the numerical HT-ATES model…
  - … has a relatively small influence on thermal recovery (≈1% of injected heat lost)
  - … induces thermal impacts, which can be relevant in HT-ATES applications (e.g., 5 °C temperature increase in 40 m distance after 50 years)
  - … can result in thermal convection, which slightly reduces efficiency (by 0.4 %) and increases the thermal impacts, although not drastically compared to the thermal impacts without convection



Thank you for your attention!

Supported by:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
based on a decision of the German Bundestag