Statistical analyses on the relevance of thermal data for the safety-related assessment of repository systems

first results from the project ThermoBase

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Project

The ThermoBase project aims to investigate the thermal field in sedimentary areas in Germany. It was initiated by the Federal Company for Radioactive Waste Disposal (BGE) and motivated by design calculations and safety analyses that are to be carried out as part of the site selection process for a high-level radioactive waste repository. This research project is carried out jointly by the GFZ German Research Centre for Geosciences and the Federal Institute for Geosciences and Natural Resources (BGR).

Focus

This contribution addresses stochastic FE computations from the BGR on the influence of parameters on the transient temperature field in the underground. Based on research previously completed by the BGR [1, 2], comparative numerical analyses of the temperature distribution for typical geological situations in Germany are conducted. The focus is on the configuration of thermal material parameters, boundary conditions, and the uncertainty in these parameters.

Method

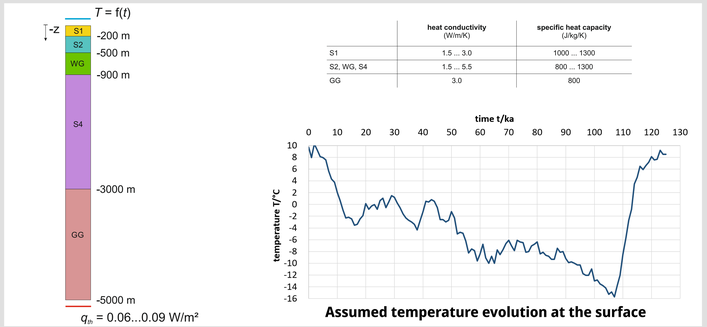
Statistical methods, such as the Monte Carlo method and stochastic collocation, will be used to make quantitative statements on the impact of changes in the parameters. Methods for the quantification of uncertainties in geological formations related to heat-generating waste repositories [3, 4], which have recently been developed at the BGR and in the joint project MeQur/URS [5], are used here.

Models

Different generic FE models are used for this purpose: (1) a 1D column model in which wide parameter variations will be considered, covering a broad range of different rock types, (2) a 2D model, representing a case study of a repository system in the Lower Cretaceous claystone in northern Germany [1], and (3) a case study of a salt dome in northern Germany, represented by a 2D rotationally symmetric model.

1D column model

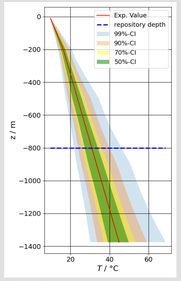
Setup

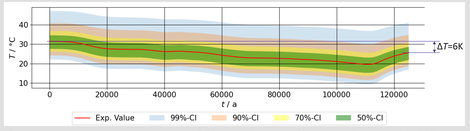


	heat conductivity (W/m/K)	specific heat capacity (J/kg/K)
S1	1.5 ... 3.0	1000 ... 1300
S2, WG, S4	1.5 ... 5.5	800 ... 1300
GG	3.0	800

Assumed temperature evolution at the surface

Results



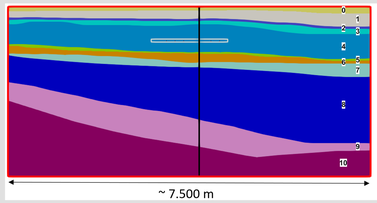


Calculated temperature at -800 m with confidence intervals (CI);
a potential glaciation may lead to 6 K temperature decrease.

Calculated stationary temperature profile with confidence intervals (CI);
in repository depth, a temperature between 25 and 40 °C can be expected (90 % certainty)

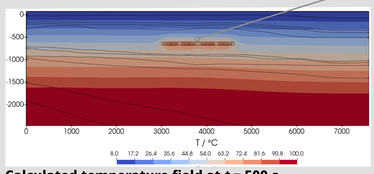
2D model: generic repository system in Lower Cretaceous

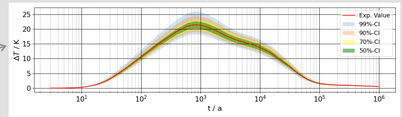
Setup



geology		HB	porosity ϕ	solid density ρ^s / (kg/m³)	solid heat conductivity λ^s / (W/m/K)	solid specific heat capacity c_s^s / (J/kg/K)	
Quartenary	q	0	0.3 ... 0.5	2350 ... 2700	2.4 ... 4.46	740 ... 974	fluid specific heat capacity c_s^f / (J/kg/K)
Cretaceous	krl	1	0.24 ... 0.4	2350 ... 2700	1.86 ... 3.46	740 ... 974	
	S3	2	0.08 ... 0.13	2350 ... 2650	1.97 ... 3.67	740 ... 974	3380 ... 4150
	krp	3	0.23 ... 0.38	2350 ... 2700	1.82 ... 3.38	740 ... 974	
	krb, krh	4, ewG	0.04 ... 0.28	2350 ... 2700	1.35 ... 2.51	740 ... 974	
	krv	5	0.16 ... 0.26	2350 ... 2700	1.66 ... 3.08	740 ... 974	fluid density ρ^f / (kg/m³)
	wd	6	0.1 ... 0.16	2350 ... 2650	1.55 ... 2.87	740 ... 974	1004 ... 1155
Jurassic	jo	7	0.11 ... 0.19	2700 ... 2950	1.99 ... 3.69	585 ... 820	
	jm, S2, ju	8	0.11 ... 0.19	2350 ... 2700	1.98 ... 3.68	740 ... 974	
Triassic	S1, k	9	0.05 ... 0.09	2350 ... 2860	1.86 ... 3.45	740 ... 974	
	so, m, su, sm, z	10	0.11 ... 0.19	2150 ... 2700	2.07 ... 3.84	740 ... 974	

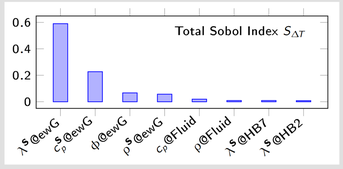
Results





Calculated temperature field at t = 500 a

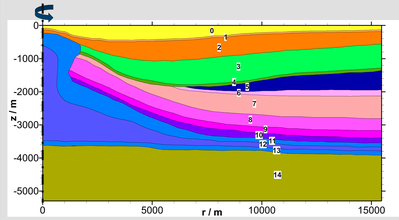
Calculated temperature increase with confidence intervalls (CI) at one point 10 m above the repository



The sobol indices represent the relevance of the parameter variation on the temperature increase. The variations in the thermal solid parameters of the host rock have the largest influence.

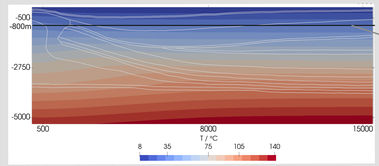
2D rotationally symmetric model: generic repository system in salt dome

Setup

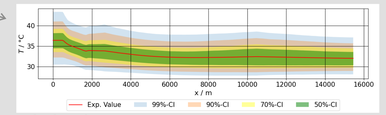


geology		HB	heat conductivity (W/m/K)
Quartenary and Tertiary	q-toloc	0	1.5 2.5
	tolR	1	1.5 2.1
	teo-lpa	2	1.5 2.5
Cretaceous	kro	3	1.9 2.5
	kru	4	1.9 2.5
Jurassic	ju	5	2 2.5
Triassic	ko	6	2.3 2.6
	ku	7	1.7 2.5
	m-so	8	1.7 2.7
	sm	9	1.7 2.7
	su	10	1.7 2.7
Permian	z2-z7	11	2.3 4.3
	z2	12	3.2 6
	z2-z1	13	2.3 4.3
bedrock	gg	14	2.3 3.4

Results



Calculated stationary temperature field



Calculated temperature at -800 m;
in the saltdome an increase of 9 K is expected

References

[1] Maßmann, J. & Ziefle, G. (2017): Integritätsnachweis geologische Barriere. (In: Jobmann, M. et al.: Systemanalyse für die Endlagerstandortmodelle - ANSICHT). Ber.-Nr.: TEC-29-2016-TB; Peine, Hannover, Braunschweig (DBE TECHNOLOGY, BGR, GRS).
[2] Mönig, et al. (2020): RESUS: Synthesebericht. GRS; 567; Köln.
[3] Maßmann, J. et al. (2022): ANSICHT-II – Methode und Berechnungen zur Integritätsanalyse der geologischen Barriere für ein generisches Endlagersystem im Tongestein. BGR, Hannover. DOI:10.25928/n8ac-y452.
[4] Bittens, M., & Gates, R. L. (2023): DistributedSparseGrids. Jl: A Julia library implementing an Adaptive Sparse Grid collocation method. Journal of Open Source Software, 8(83), 5003.
[5] Nagel, T, et. al. (2023): MeQur - Uncertainties in THM-coupled integrity calculations, Project web page; URL: https://urs.ifgt.tu-freiberg.de/en/topics/mequr, [Accessed 09-01-2024]

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