Do we have to consider temperature-dependent material properties in large-scale environmental impact assessments of UCG?

Christopher Otto, Thomas Kempka

GFZ German Research Centre for Geosciences, Section 5.3 - Hydrogeology, Potsdam, Germany

GFZ Helmholtz Centre Potsdam

Poster EGU2015-791

Helmholtz Centre Potsdam
GFZ German Research Centre for Geosciences

This poster participates in **OSP**

Outstanding Student Poster Contest

Introduction

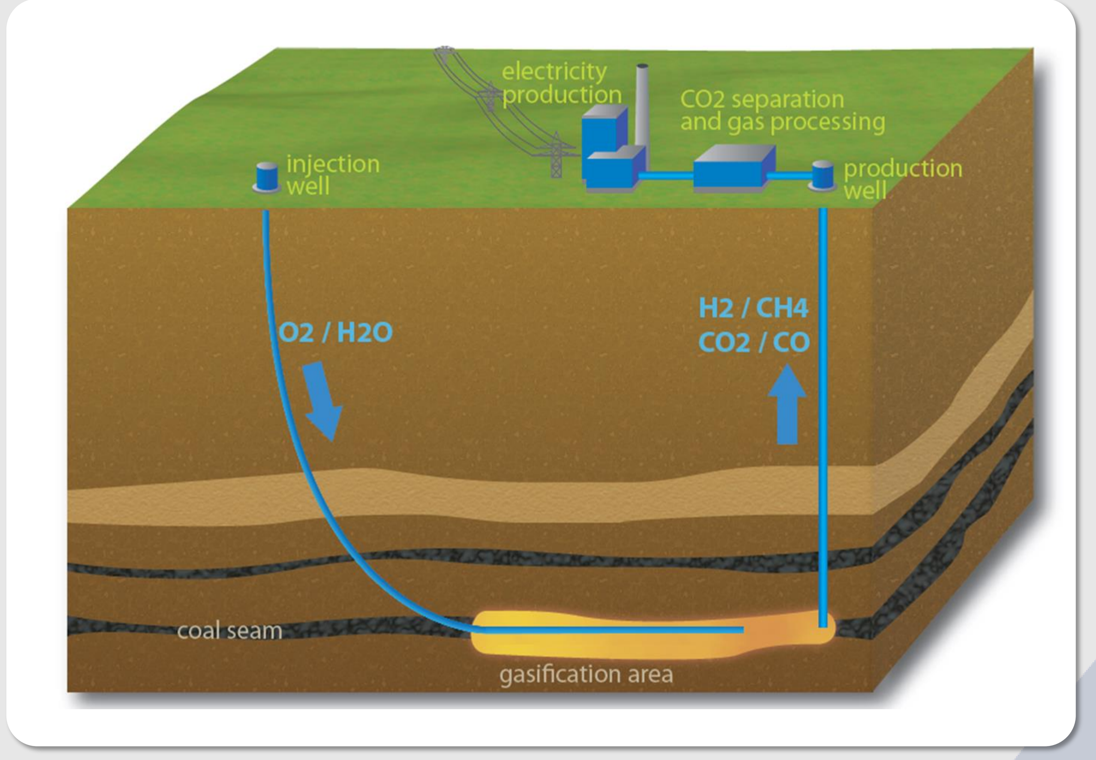
Underground coal gasification (UCG) can allow to **develop coal deposits not economically mineable** by conventional methods due to large depths or complex geology. Even though, economic potentials are generally expected to be high, **potential environmental impacts**, comprising ground surface subsidence and groundwater pollution, have to be assessed on a site-specific basis. Thereto, we developed a **coupled thermo-mechanical model** to calculate **permeability changes** in the vicinity of an UCG reactor. Our simulation results allow for an assessment of fluid flow into and out of a UCG reactor during operation and in the post-abandonment phase.

Summary and Conclusions

- Thermo-mechanical **rock behavior** of sandstone and bituminous coal is **mainly influenced** by **thermal expansion coefficient**, **tensile strength** and **elastic modulus**.
- **Permeability changes** derived from volumetric strain increments show **negligible differences** for temperature dependent and -independent parameters.
- **Near-field models** require temperature-dependent parameters, while **far-field** models can benefit from higher computational efficiency by neglecting temperature-dependence.

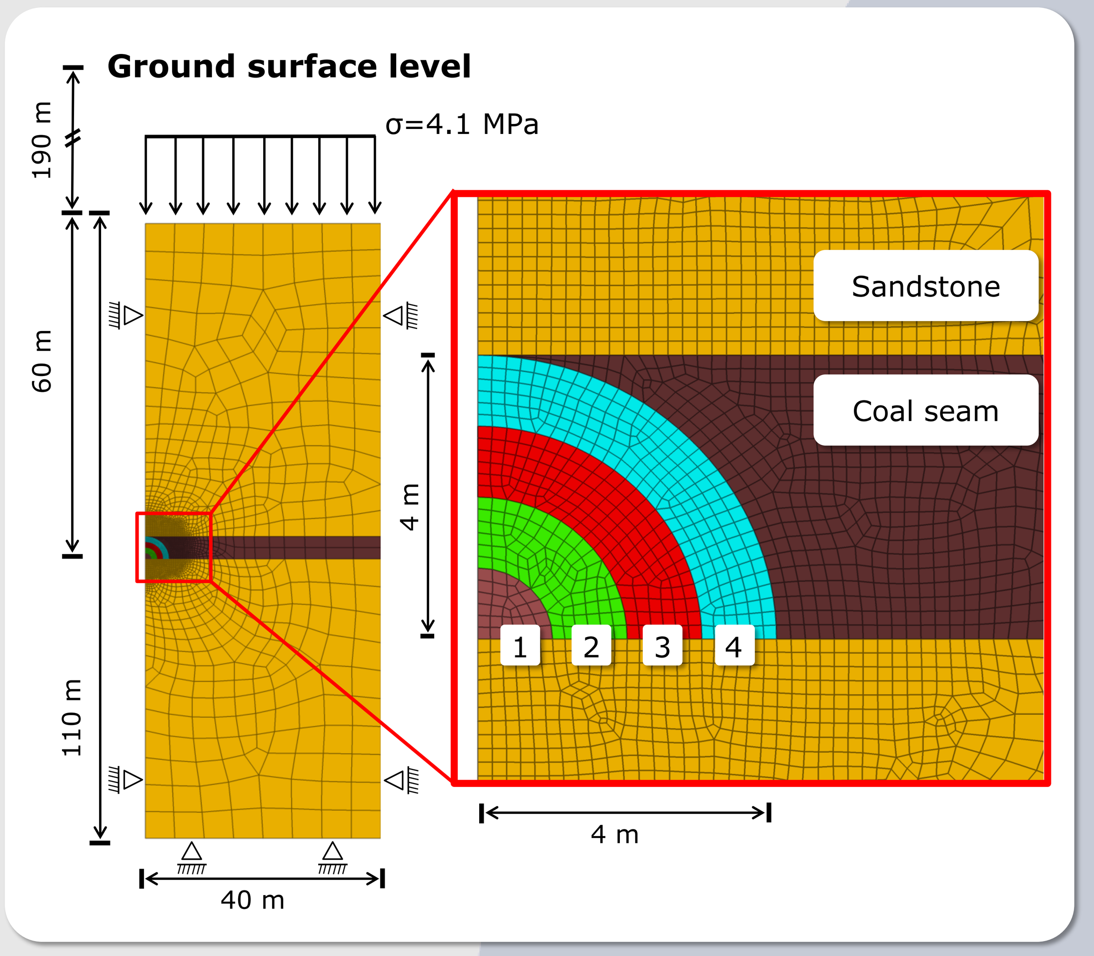
Underground coal gasification

- UCG has the potential to **increase world-wide coal reserves** by utilization of deposits not mineable by conventional methods [1].
- UCG produces a **high-calorific synthesis gas** for electricity generation and/or chemical feedstock production [2,3].
- **Ground subsidence** and **groundwater pollution** are potential environmental impacts [1].



Model domain and boundary conditions

- 2D model was discretized by about **3,000 elements** with unstructured mesh and **four reactor sizes** applied with **stepwise reactor excavation** (shapes 1-4 in right figure).
- **Stress boundary condition** at model top to represent overburden load and **fixed velocity boundary conditions** at lateral and bottom boundaries.

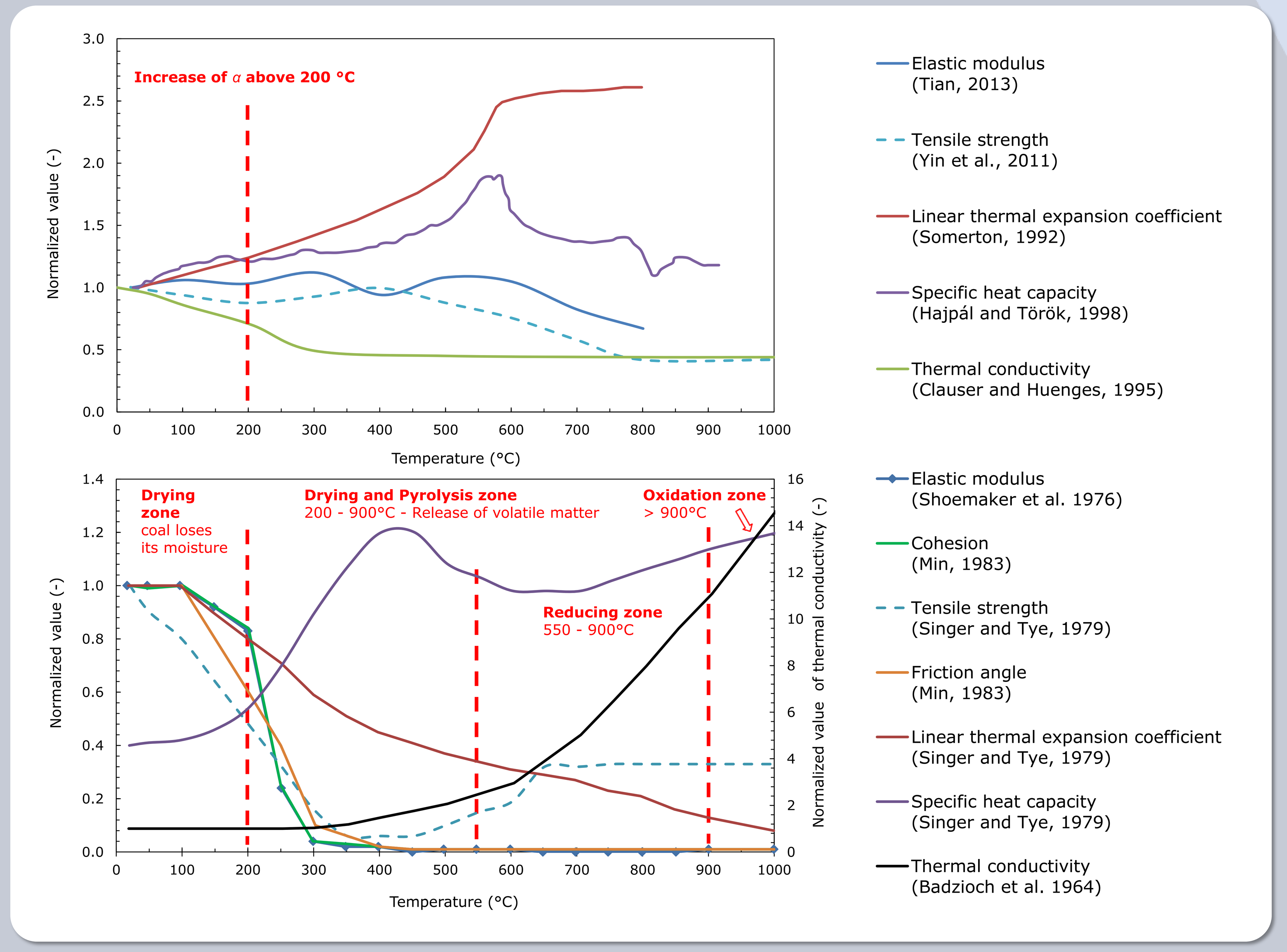


Model parameterization

Model parameterization based on available literature data [3-5].

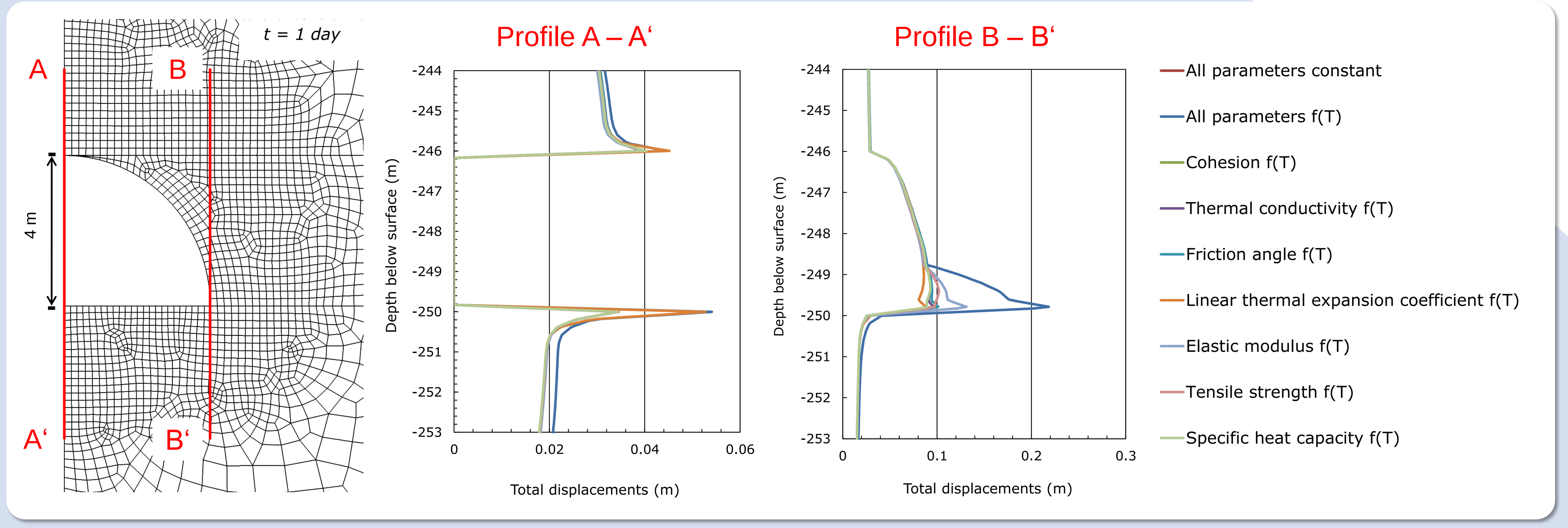
Input parameter		Unit	Sandstone	Coal
Mechanical parameters				
Elastic modulus (E)	f(T)	GPa	4	2
Tensile strength (σ_t)	f(T)	MPa	5	5
Friction angle (ϕ)	Constant for rock	°	32	20
Cohesion (c)	Constant for rock	MPa	5	1
Poisson ratio (ν)	Constant	-	0.35	0.44
Density (ρ)	Constant	kg/m³	2,200	1,300
Thermal parameters				
Linear thermal expansion coefficient (α)	f(T)	K^{-1}	1.6×10^{-5}	5.0×10^{-6}
Specific heat capacity (C_p)	f(T)	J/kg K	1,363	2,000
Thermal conductivity (λ)	f(T)	W/m/K	2.30	0.23

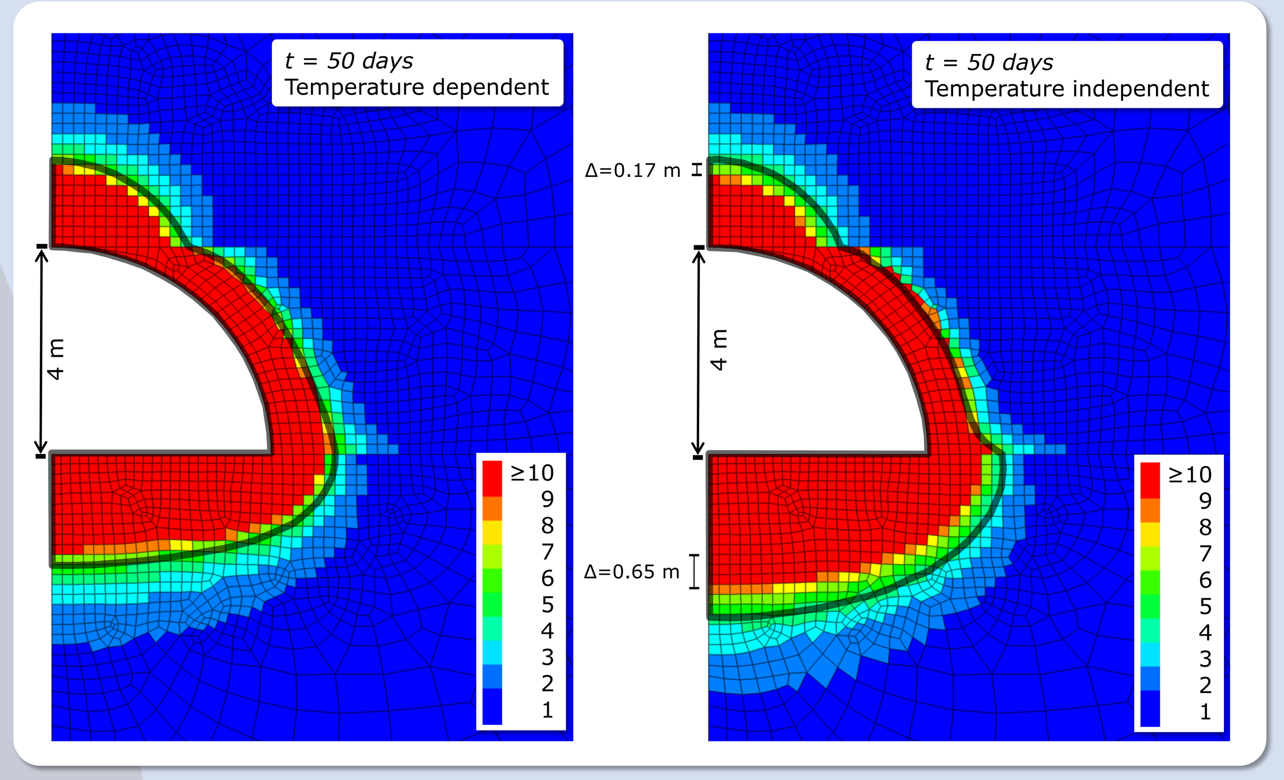
Trend of **thermo-mechanical** sandstone and coal property development as f(T) shows **high temperature dependency**.



Simulation results

Profiles of **total displacements** demonstrate thermo-mechanical **rock behavior** is mainly influenced by **thermal expansion coefficient**, **tensile strength** and **elastic modulus**.





- Permeability is expressed as function of **volumetric strain increment**.
- Regions of **high temperature** (black solid line: temperature ≥ 200 °C) experience positive **volumetric strain increments** in reactor vicinity.
- Permeability changes (normalized) show **negligible differences** for temperature-dependent and -independent parameters.

References

[1] Burton, E., Friedmann, J., Upadhye R. (2006) Best practice in underground coal gasification. Technical Report. LLNL, US Department of Energy, CA.
[2] Nakaten, N. C., Schlüter, R., Azzam, R., Kempka, T. (2014) Energy 66:779-790.
[3] Tian, H., Kempka, T., Xu, N.-X., Ziegler, M. (2012) Rock Mech Rock Eng, 45(6):1113-1117.
[4] Tian, H., Kempka, T., Yu, S., Ziegler, M. (2015) Rock Mech Rock Eng, 7 p. Article in Press. doi:10.1007/s00603-015-0724-z.
[5] Otto, C., Kempka, T. (2015) Submitted to Energies.

Acknowledgements

The authors gratefully acknowledge the funding received in the scope of the TOPS project (EU-FP7 grant 608517).

www.gfz-potsdam.de
contact: otto@gfz-potsdam.de

Helmholtz Association