

Integrity analysis under uncertainty



Preliminary results for generic clay rock site

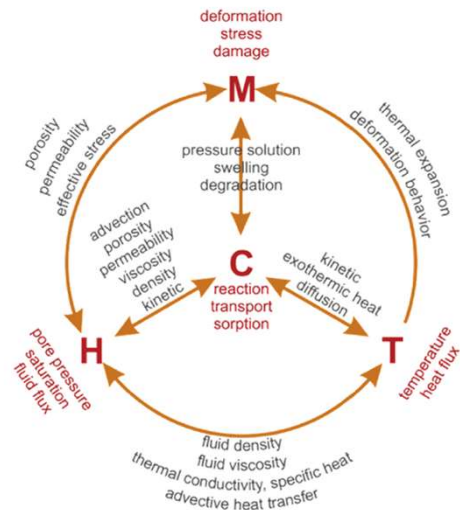
**URS Klausurtagung
Annweiler am Trifels**

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18.04.2023

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und Rohstoffe

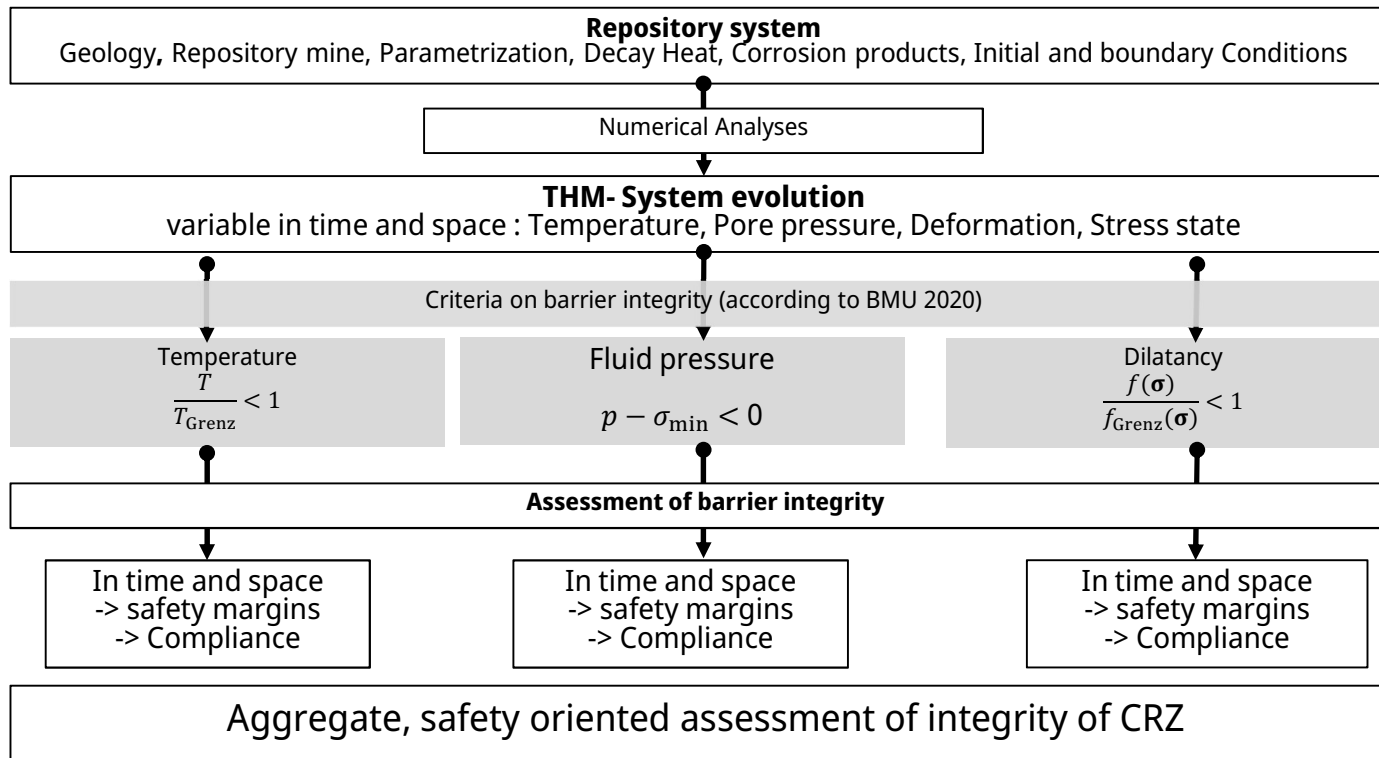


THM simulations for integrity assessment

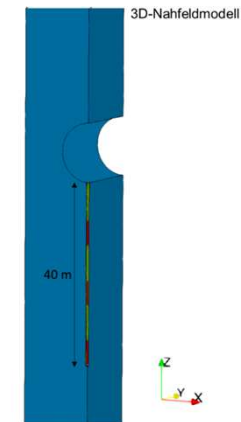
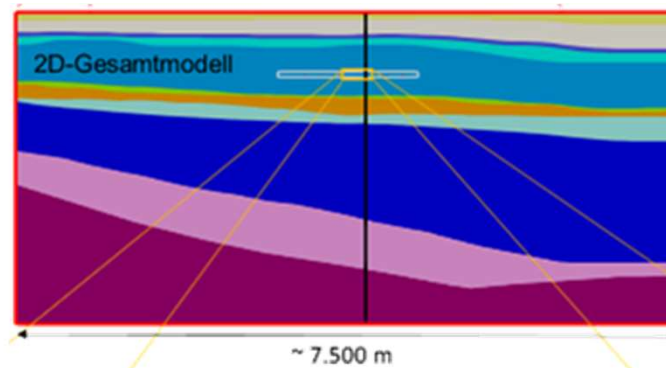
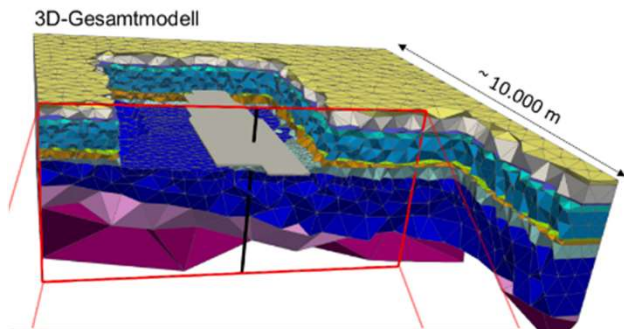
Generic clay rock site in Northern Germany

Integrity: preservation of the barrier properties relevant for safe confinement

Numerical integrity assessment



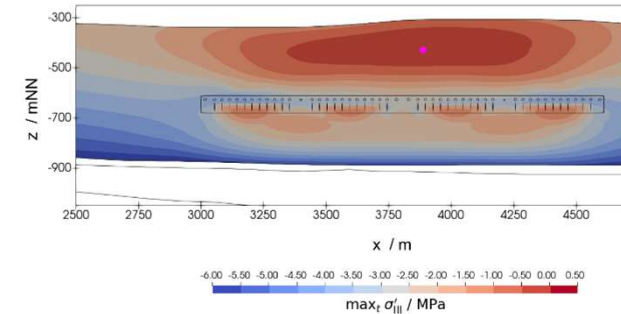
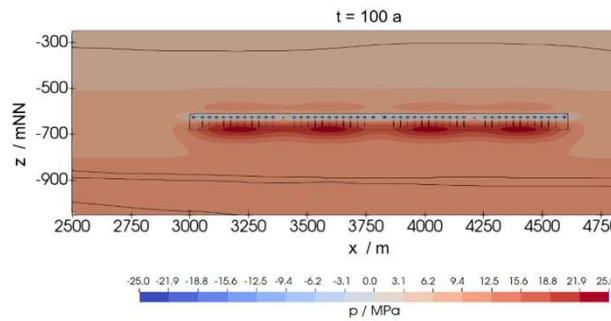
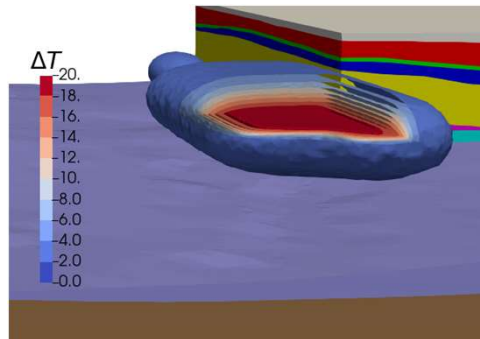
Numerical integrity assessment Modeling concept



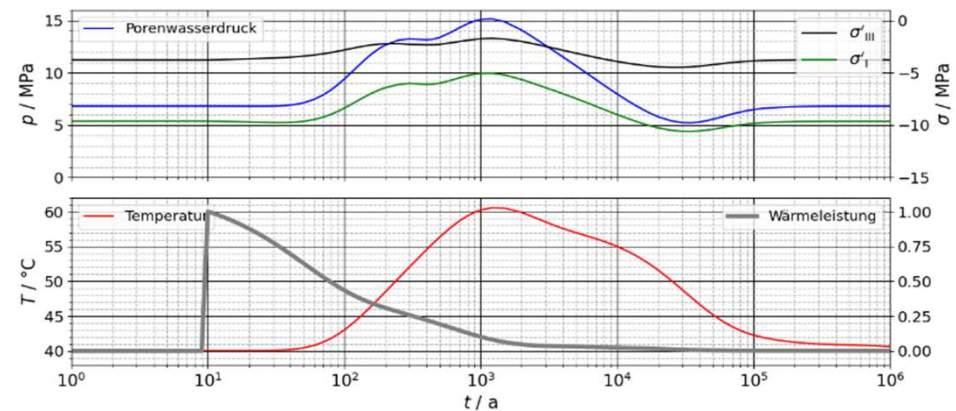
- Model hierarchy for efficient numerics
- Selected processes and couplings
- THM-simulations with OpenGeoSys v6

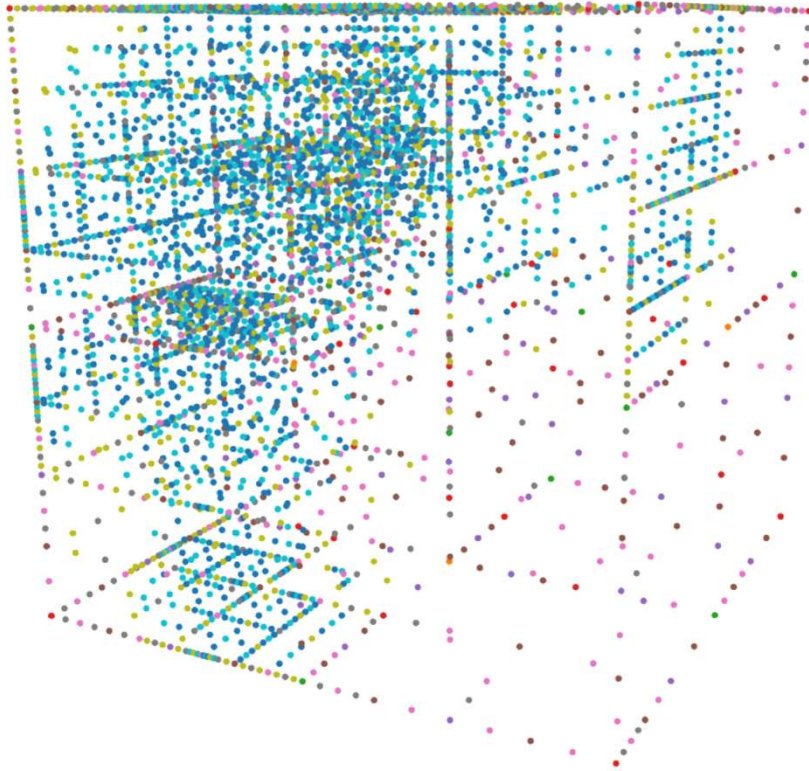
Maßmann et al 2022, ANSICHT-II –Methode und Berechnungen zur Integritätsanalyse der geologischen Barriere für ein generisches Endlagersystem im Tongestein
https://www.bgr.bund.de/DE/Themen/Endlagerung/Aktuelles/2023_04_18_integritaetsanalyse_barriere_tongestein.html

Numerical integrity assessment



- Temperature increase due to decay heat
- Thermal expansion
 - Thermal pressurization
- Decrease in effective compressive stresses
 - Fluid pressure criterion
 - No violation in reference case

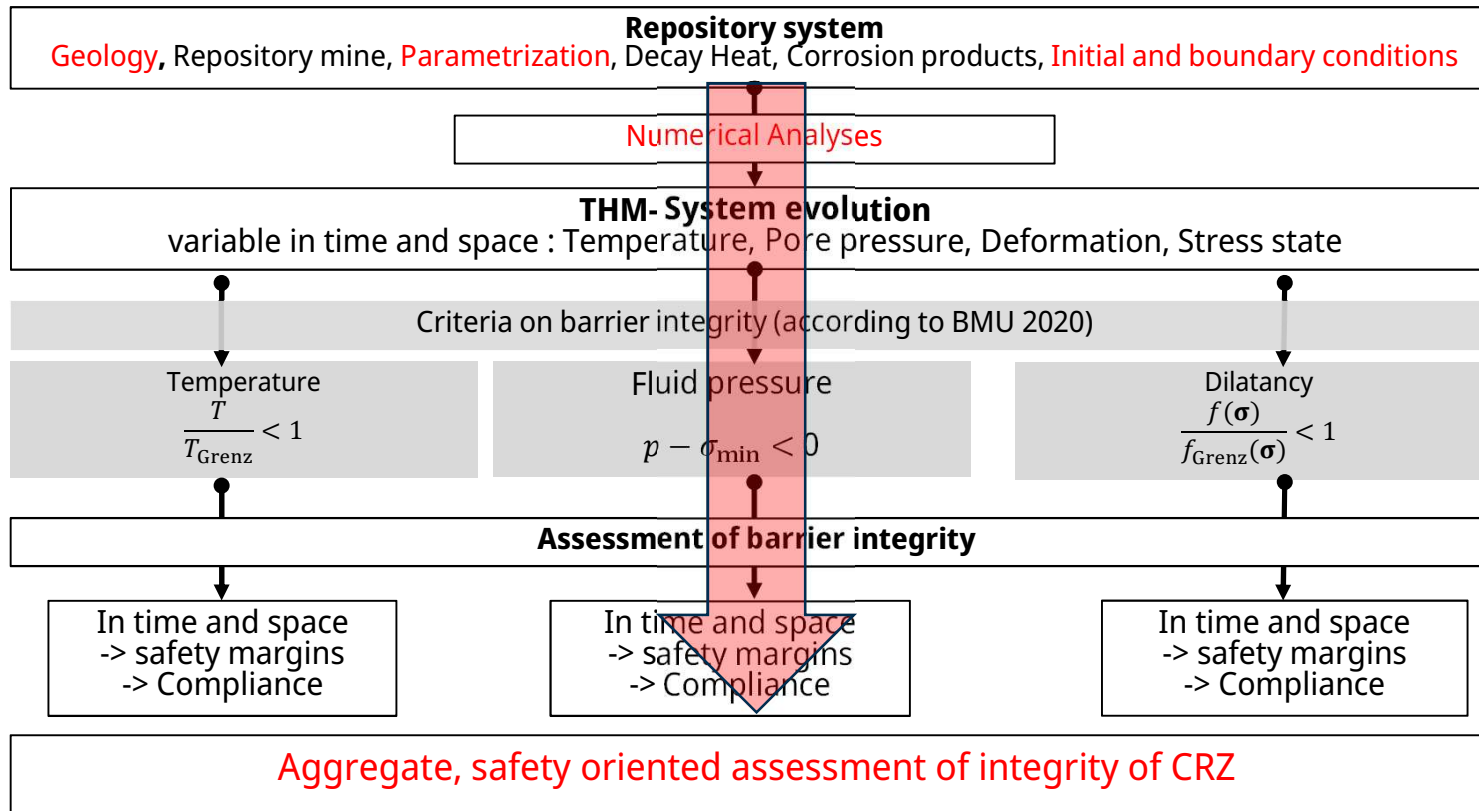




Integrity assessment under parameter uncertainties

Methods and preliminary results

Integrity assessment under uncertainties



Integrity assessment under uncertainties

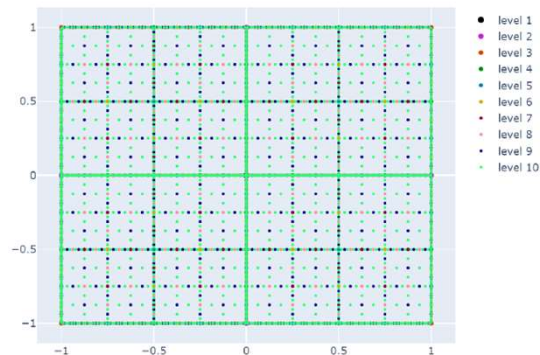
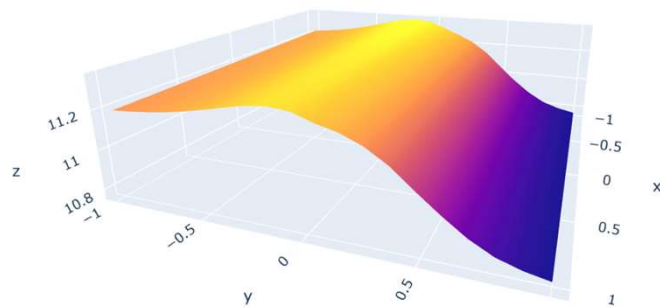
Parameter uncertainties



Variable	Parameter	Unit
X_1	horz. th. conductivity	$[\frac{W}{mK}]$
$X_1/1.4$	vert. th. conductivity	$[\frac{W}{mK}]$
X_2	horiz. permeability	$[m^2]$
$X_2/10$	vert. permeability	$[m^2]$
X_3	porosity	$[-]$
X_4	heat capacity	$[\frac{J}{kgK}]$
X_5	thermal exp.	$[\frac{1}{m}]$
X_6	biot	$[-]$
X_7	young's mod	$[\frac{N}{m^2}]$

-> 7 independently varied input parameters

Integrity assessment under uncertainties - THM surrogate model



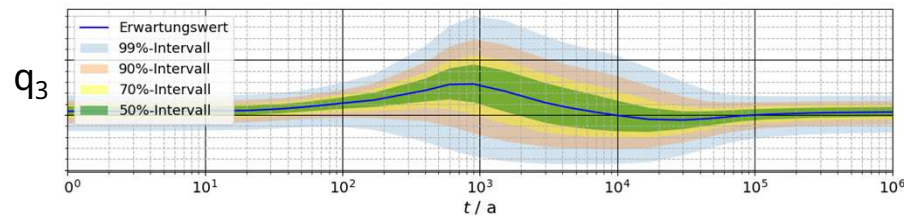
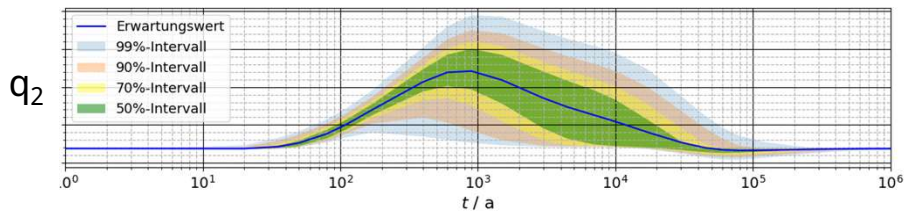
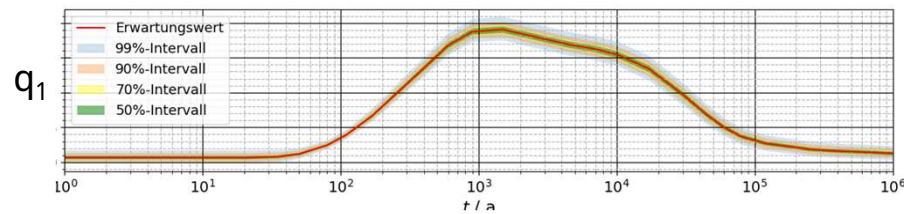
Multi-stage approach:

1) Building of proxy/surrogate model/response surface for THM-response on a simplified model

- Adaptive Sparse Grid
- Interpolation for THM quantities in space and time
- Hierarchical Basis
 - OVAT
 - Subset of varied parameters
- Open-source tool developed in **julia** (c) 2012-2022: Stefan Karpinski <stefan@karpinski.org>
- <https://doi.org/10.21105/joss.05003>
- High computational effort

Integrity assessment under uncertainties

Probabilistic evaluation



2) Evaluation of QOI

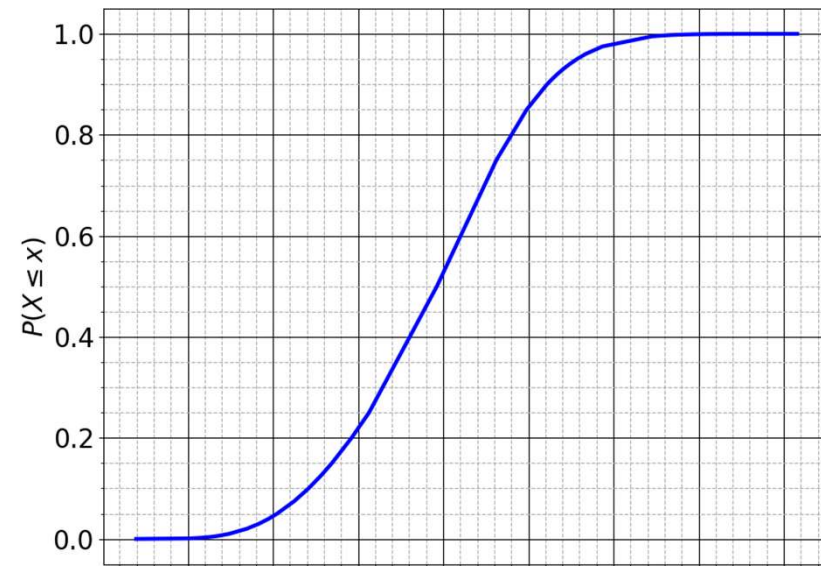
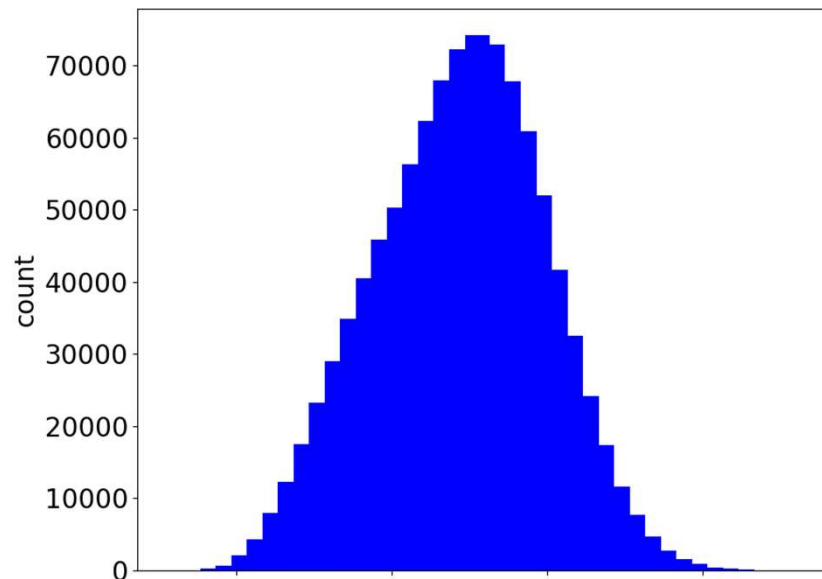
- Single points over time
- Maximal values over time
- ...

3) Probabilistic evaluation

- Monte Carlo on proxy
 - Incorporation of distributions
 - Computation of probabilities
 - Computation of quantiles
 - Computation of stochastic moments
 - Variance based sensitivities
 - ...

Integrity assessment under uncertainties

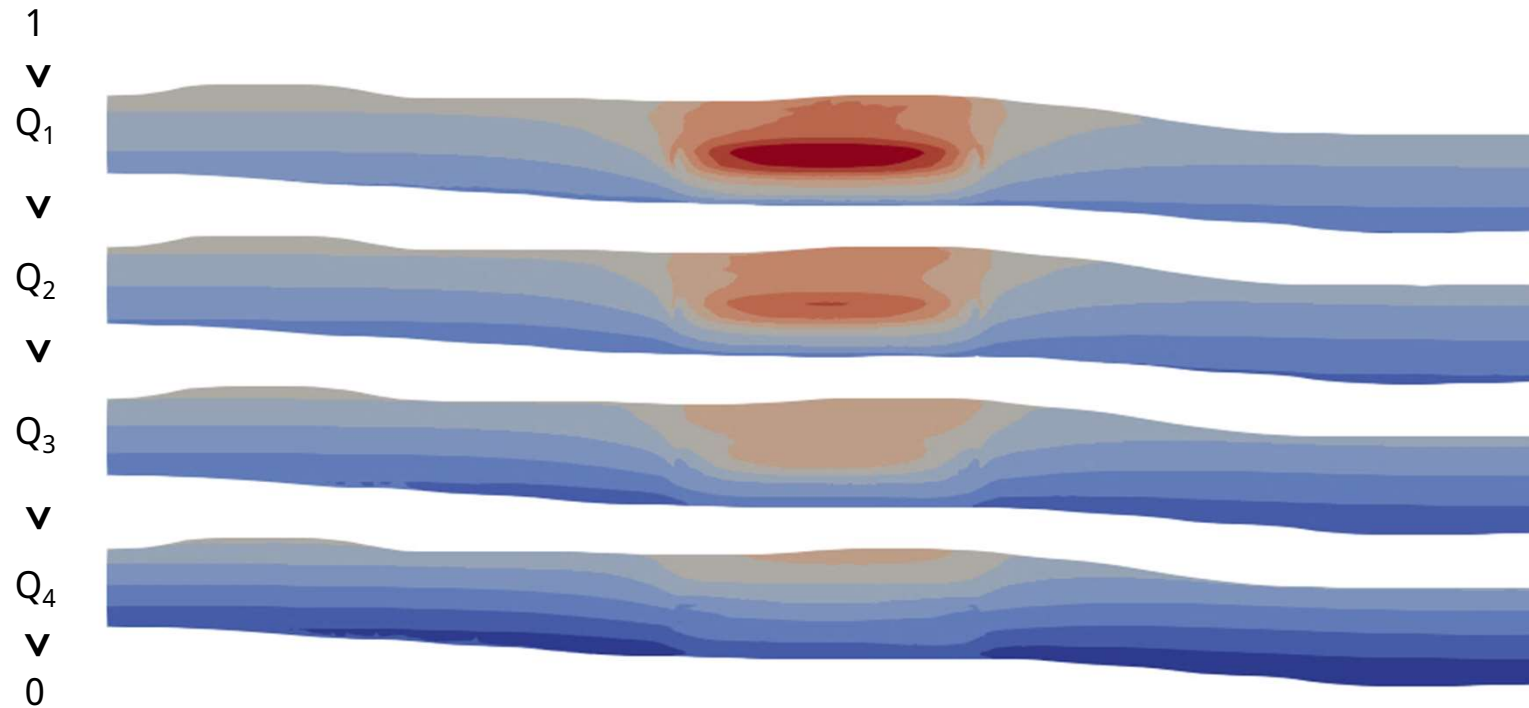
Probabilistic evaluation



emp. PDF / CDF

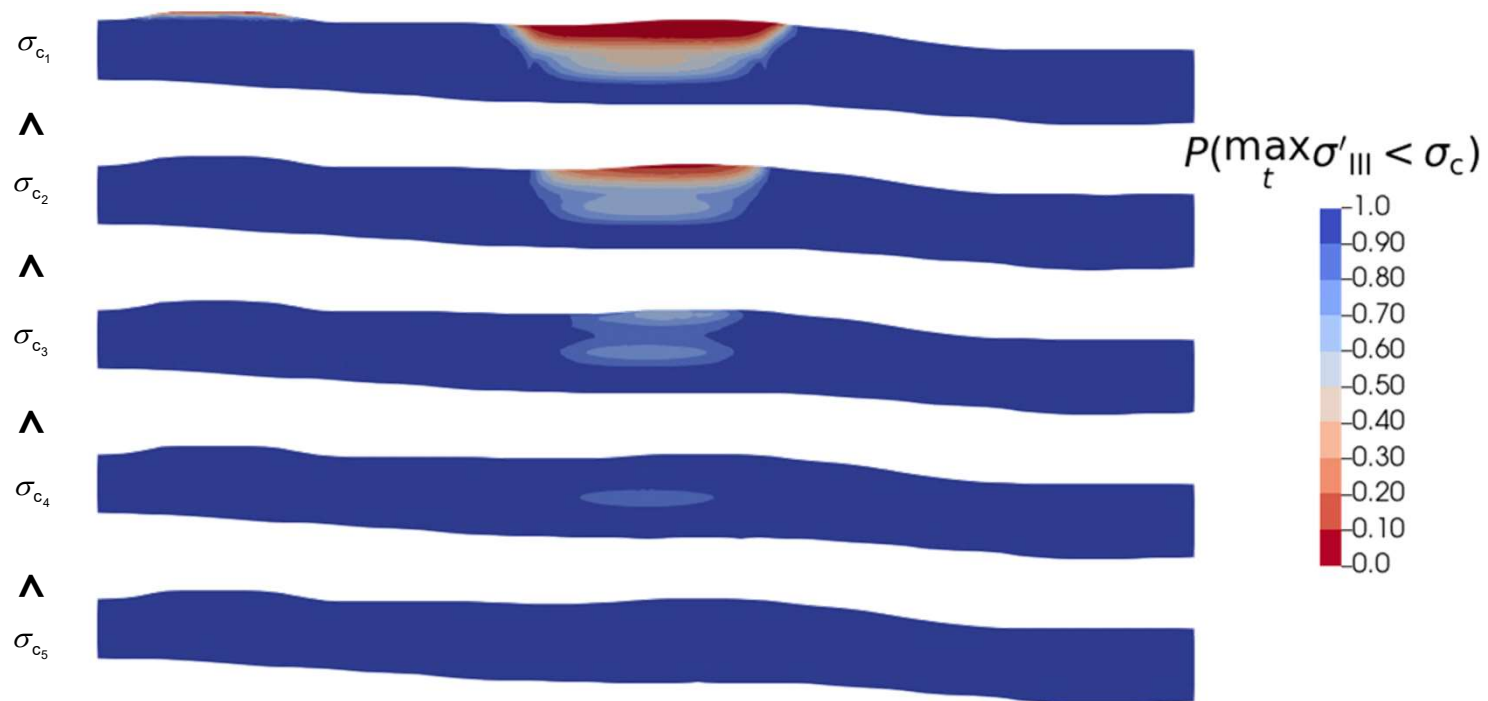
Integrity assessment under uncertainties

Selected quantiles on fluid pressure criterion



Integrity assessment under uncertainties

CDF-Evaluation of fluid pressure criterion



Outlook



- Evaluation of criteria
- Sensitivity analysis
 - Feedback to laboratory
- Model comparison
 - How much effort is needed to obtain accuracy and where?
 - Compare different surrogates
 - Compare to nested information
- Input distributions
 - Influence of improved information
- Address spatial heterogeneity
- ...



**Vielen Dank
für Ihre Aufmerksamkeit!**