Investigation of Different Sampling and Sensitivity Analysis Methods Applied to a Complex Model for a Final Repository for Radioactive Waste

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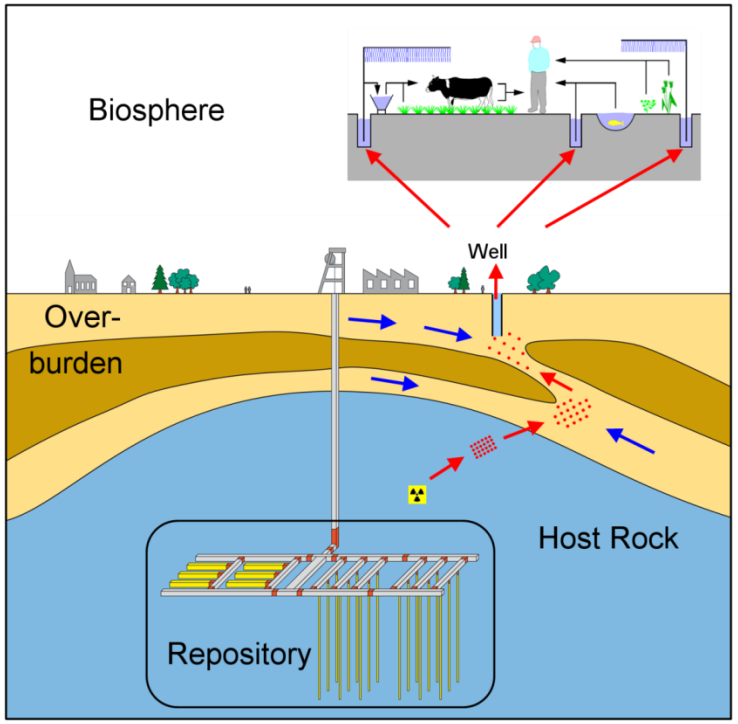
Introduction

Numerical long-term performance assessment for a deep underground repository for radioactive waste



- Brine intrusion cannot be excluded
- Canister corrosion and contaminant mobilization
- Pressure buildup by gas production
- Convergence of voids
- Fluid flow inside the underground facility
- Radionuclide transport
- Contamination of groundwater
- Chemical effects
- Radioactive decay
- Biosphere pathways
- Radioactive exposure of man

Coupled numerical model

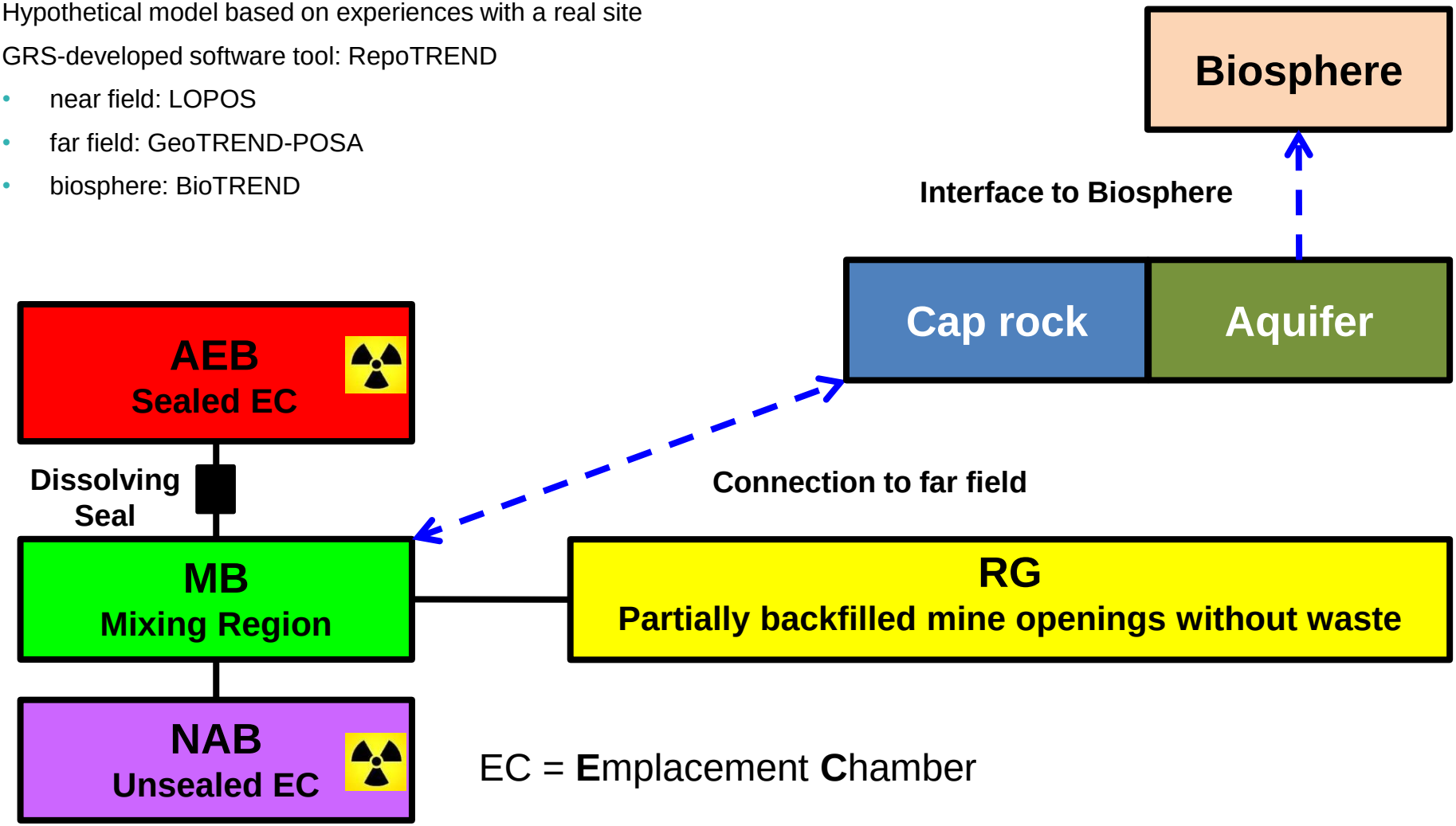
- Complex behavior
- Many uncertainties
- Non-linear
- Non-monotonic
- (Virtually) non-continuous

Test model: repository for low- and intermediate-level waste (LILW)

Hypothetical model based on experiences with a real site

GRS-developed software tool: RepoTREND

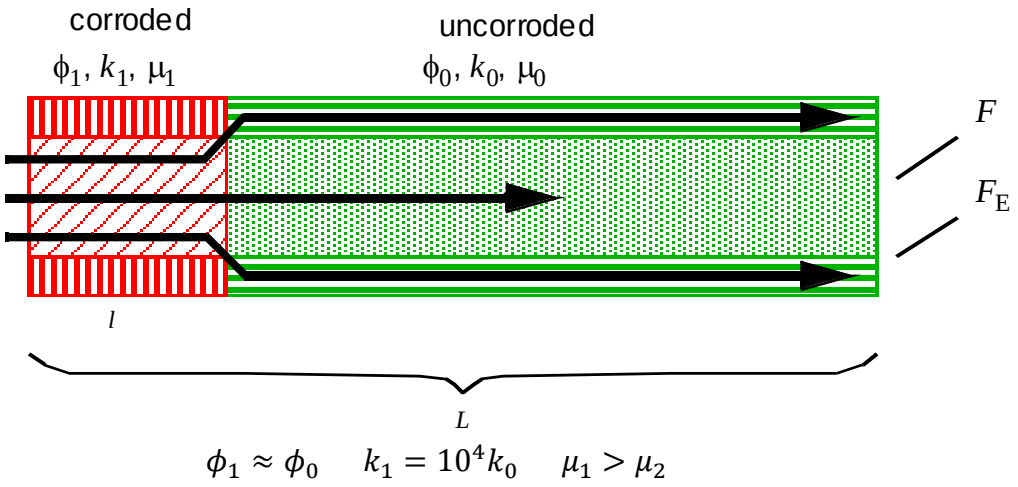
- near field: LOPOS
- far field: GeoTREND-POSA
- biosphere: BioTREND



Seal failure

Seal isolating the waste emplacement chamber from the mine

- Cementitious material
- Chemically corroded by magnesium containing brine
- Dissolution front travelling through the seal
- Flow resistance is determined by intact part
- Sealing effect lost almost instantly when the front reaches the end
  - sudden increase of output (dose) at some point in time
- Time of seal failure determined by
  - initial permeability of seal material
  - magnesium content of brine
  - pressure differences



Investigated methods of sampling and sensitivity analysis

Sampling

- Random sampling
  - pseudo-random sequence
  - typically shows gaps and clusters
- Quasi-random LP-Tau sequence
  - deterministic sequence
  - designed to prevent clusters and gaps (low-discrepancy sequence)
- Used samples:

Sampling Technique	Number of Samples	Sample Sizes (Number of Simulations)
Random	4	2048, 4096, 8192 and 16384
LpTau	1	

Sensitivity analysis

- Contribution to sample mean (CSM)
  - graphical method
- Standardized rank regression coefficients (SRRC)
  - well-established method
  - based on rank transformation
  - designed for monotonic models
- Effective algorithm for estimating first-order sensitivity indices (EASI)
  - variance-based method
  - applicable with all kinds of samples
  - fast algorithm

Time-dependent analysis

Model time: 1 million years

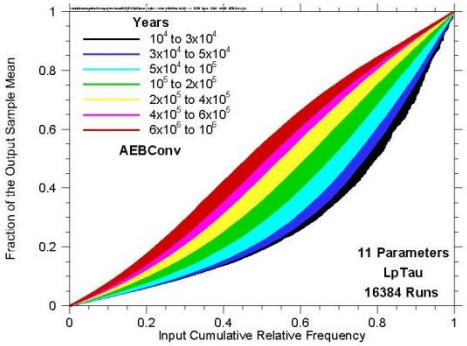
CSM

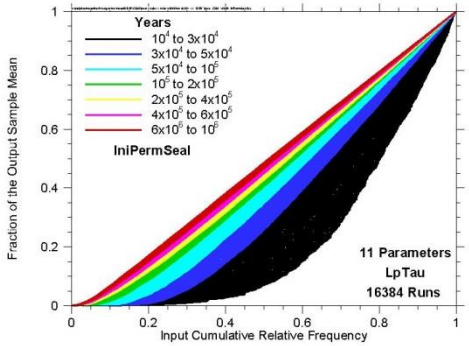
- CSM curves calculated for 201 points in time (not below 10^4 years)
- curves show total contribution to sample mean for ordered sample
- curvature represents direction of parameter influence:
  - positive
  - negative
  - zero
- presented in different colors to demonstrate time development

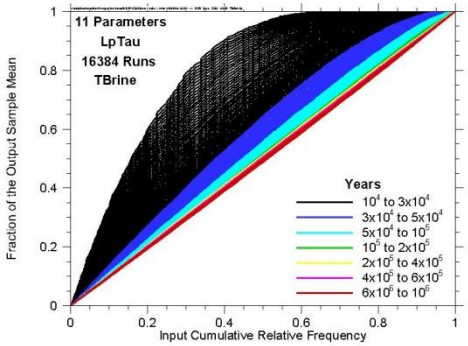
SRRC and EASI

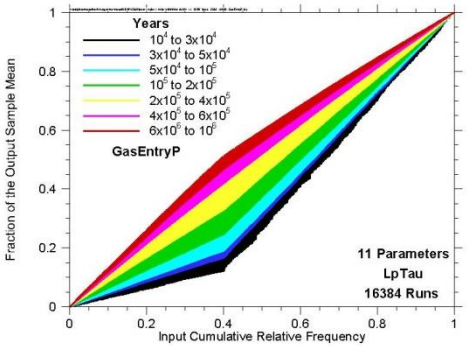
- calculated for 301 points in time
- presented as time curves
- SRRC:
  - values between -1 and 1
  - sign represents direction of parameter influence
- EASI:
  - values between 0 and 1
  - direction of parameter influence not represented

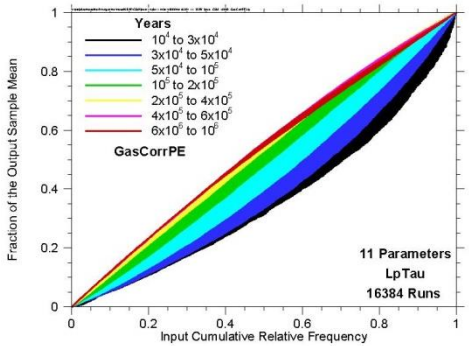
CSM plots: results

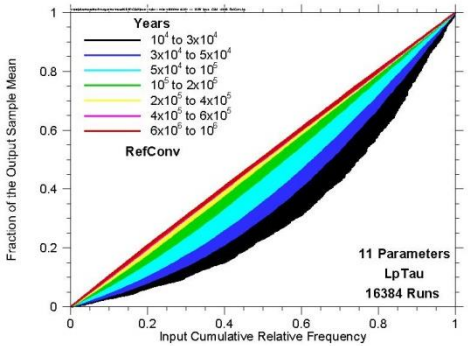


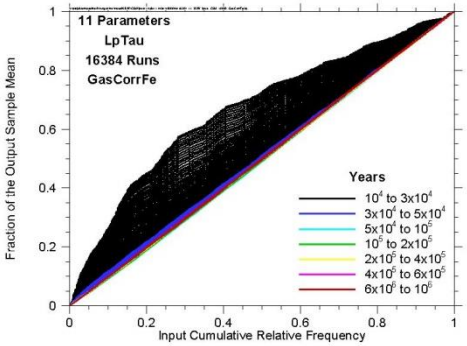


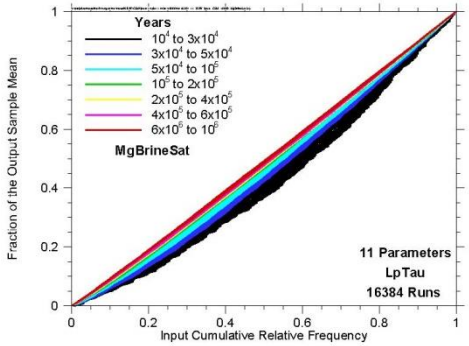


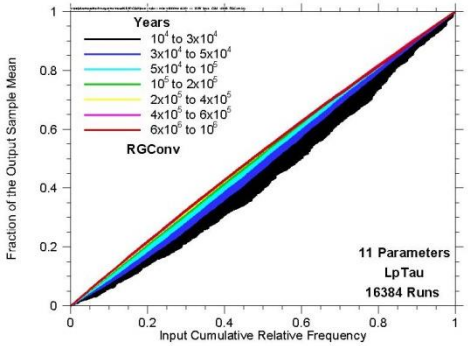




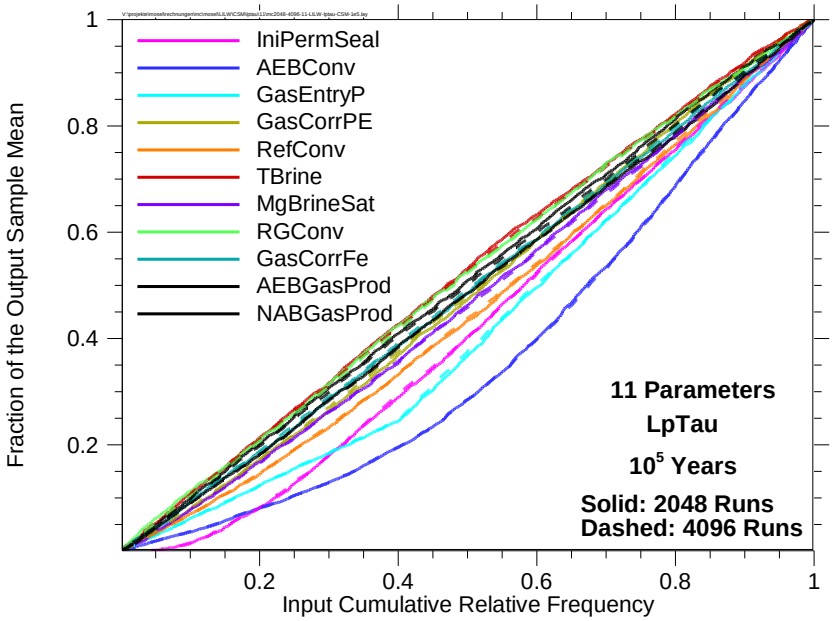


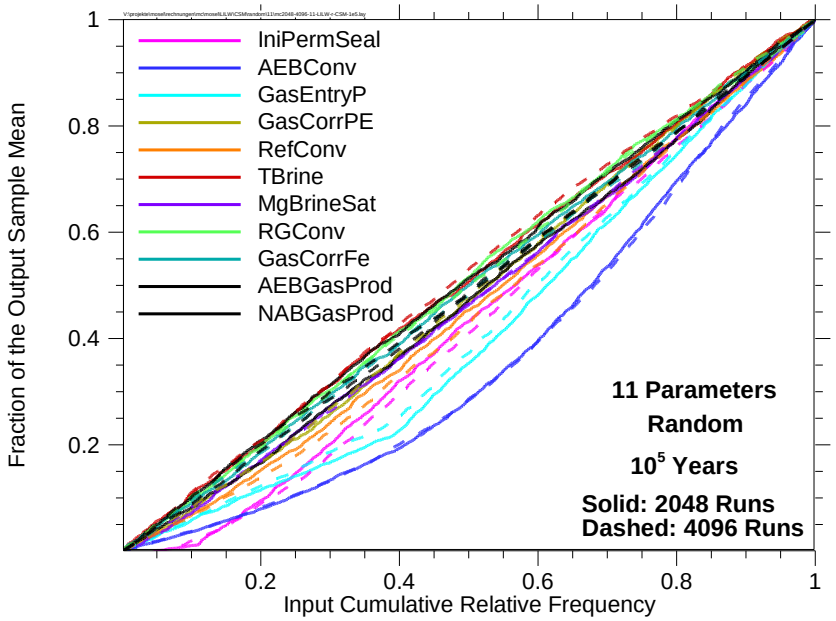






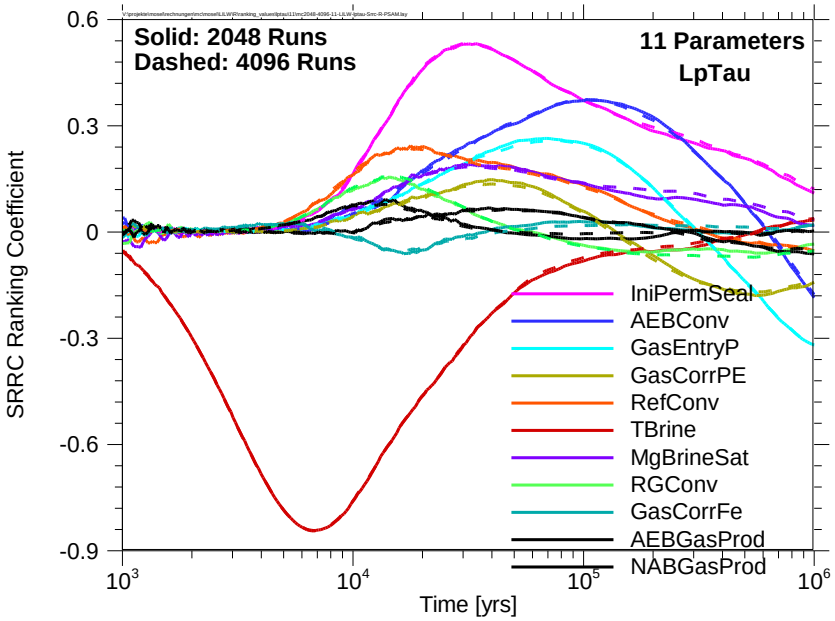
CSM plots: comparison of sampling techniques

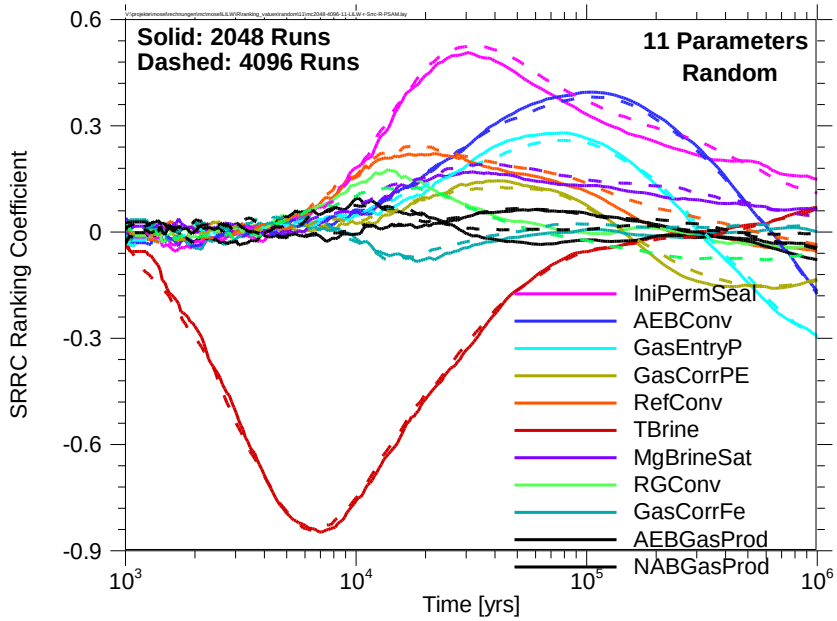




- *AEBConv, IniPermSeal* and *TBrine* seem to be most important parameters
- For later times, *IniPermSeal* seems only relevant in the lowest part of its range
- Nearly binary influence *GasEntryP*: sharp bend in the curve
- LpTau sampling shows clearly better convergence

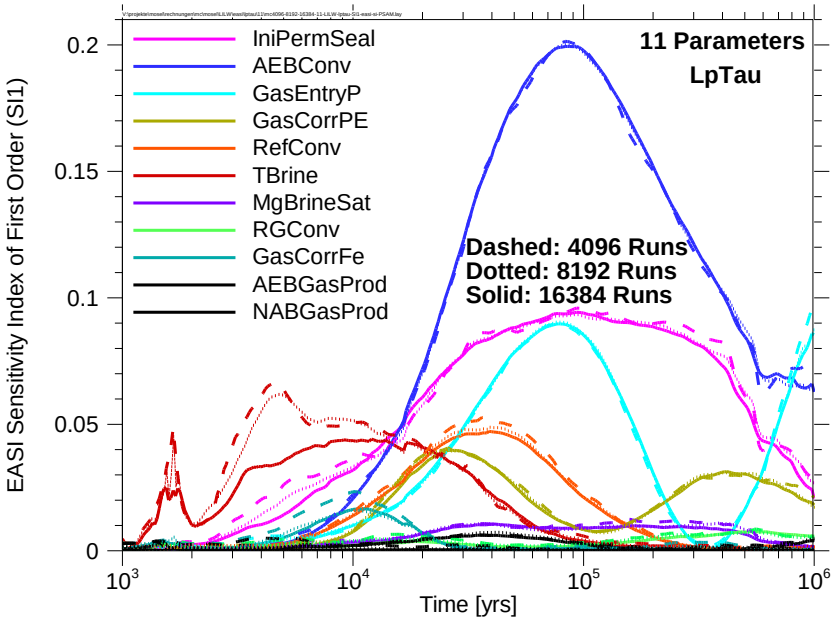
SRRC: results and comparison of sampling techniques

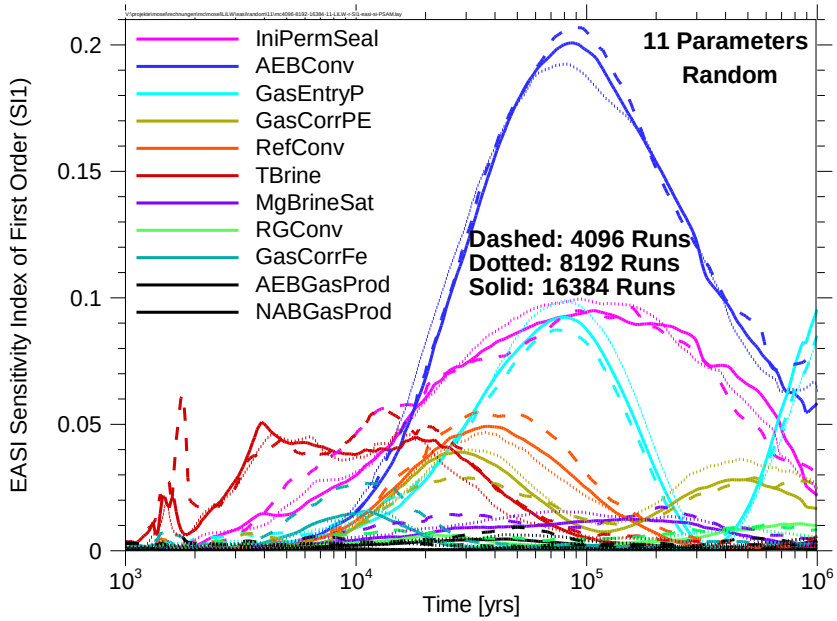




- Qualitative parameter rankings are quite similar to those of CSM
  - but: *IniPermSeal* seems more noticeable than *AEBConv*
- Dominance of *TBrine* in the early phase
- Again, LpTau sampling yields more stable results than random sampling

EASI: results and comparison of sampling techniques





- Results are not fully in line with those of SRRC
  - most conspicuous parameter is *AEBConv* instead of *TBrine* and *IniPermSeal*
- Unclear and unstable behavior in the early time phase (parameter *TBrine*)
  - possible solution approach: output transformation (see *Becker, paper 158*)
- Again, LpTau sampling yields more stable results than random sampling

Summary and conclusions

- Three sensitivity analysis methods were applied to a complex model
  - CSM, SRRC, EASI
- Two sampling techniques were compared
  - LpTau, random sampling
- CSM and SRRC yield comparable parameter importance rankings
- EASI rankings are not fully in line with CSM and SRRC
- EASI gives no information about direction of influence
- All methods provide their own specific information
- Interpreting sensitivity analysis results is not an easy task
- LpTau performs better than random sampling in all investigations

Project MOSEL

Subject:

- Identification and testing of modern numerical methods for sensitivity analysis with regard to final repository performance assessment

Organization:

- Gesellschaft fuer Anlagen- und Reaktorsicherheit (GRS) mbH, Braunschweig, Germany

Collaboration with

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Thank You for Your Attention!