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Sensitivity Analysis in Repository Safety Assessment: Findings from an International Exercise

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Introduction

- Sensitivity analysis in case studies involving geologic disposal of spent nuclear fuel or nuclear waste
- Comparison of of available mathematical methods
- Goal of the exercise
  - strengths and weaknesses of various SA methods, identify cost vs. performance tradeoffs
  - highlight best practices and lessons learned: provide guidelines

Informal international working group

- Sandia National Labs (USA),
- GRS, TU Clausthal (Germany),
- SCK*CEN (Belgium),
- Posiva/Fortum (Finland),
- IBRAE (Russia),
- observing partners from France, Switzerland, UK.

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Test Models: Four test models identified, for which sets of probabilistic calculations are available

Model name	Provided by	Description	Characteristics	Time-dependent?	No. of input params.	No. of runs sample type
Clay HLW/SF	GRS	Generic repository for HLW/SF in clay host rock	Smooth model behaviour	yes	6	4096 random 8192 random
Shale repository	SNL	Generic repository for commercial spent nuclear fuel in a shale host rock.	Smooth behaviour, 6 scalar model outputs	no	10	50 LHS 200 LHS
Dessel	SCK•CEN	Surface LILW repository at Dessel/Belgium	Non-monotonic, some inputs change at a given point in time	yes	22	256 QMC 1024 QMC
Groundwater flow	IBRAE	Single-phase fluid flow in the heterogeneous geological media of Nizhnekansky massif (Russia)	Smooth behaviour, hydraulic head at 37 local positions is calculated	yes	12	140 / 1400 / 14000 / 28000

Sensitivity analysis approaches

		FP	FF	TI	SD	RI	Number of model evaluations (M = number of input factors)
Graphical	Scatterplots	✓		✓		✓	>100
	Cumulative Sum of Normalized Reordered Output (CUSUNORO)	✓		✓	✓	✓	>100
Correlation & Regression analysis	Pearson correlation & Partial Correlation	✓		✓			>100
	Spearman Rank Correlation & Partial Rank Correlation	✓		✓			>100
	Regression coefficients (Linear, Rank, Stepwise)	✓		✓			>100
Variance-based	Sobol' indices	✓	✓		✓		>500xM
	Fourier Amplitude Sensitivity Test (FAST), extended FAST (eFAST)	✓	✓		✓		> 500xM
	Effective Algorithm for Sensitivity Indices, Cosine Sensitivity (EASI, COSI)	✓			✓		>500
	Random Balance Designs	✓			✓		>500
Moment-independent	Borgonovo's δ	✓	✓		✓	✓	>1000
	Pianosi and Wagener (PAWN)	✓	✓		✓	✓	>500(xM)

Sensitivity settings

Factor prioritization (FP)
Finding the most important input parameters.
Factor fixing (FF)
Finding the least important input parameters.
Trend identification (TI)
Identify monotonicity or convexity properties of the model.
Structure discovery (SD)
Uncover additivity, linearity, interactions.
Regionalized information (RI)
Finding active regions of input parameters.

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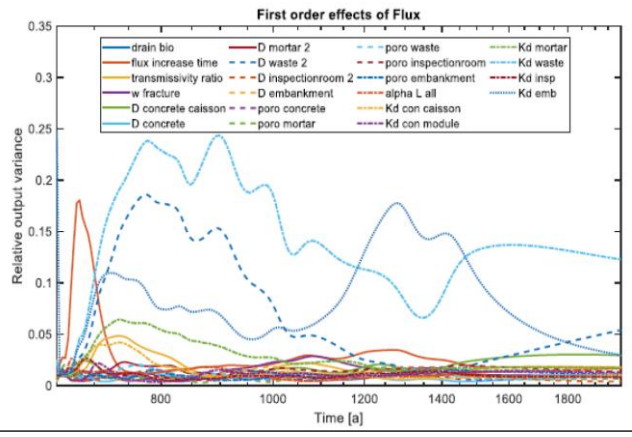
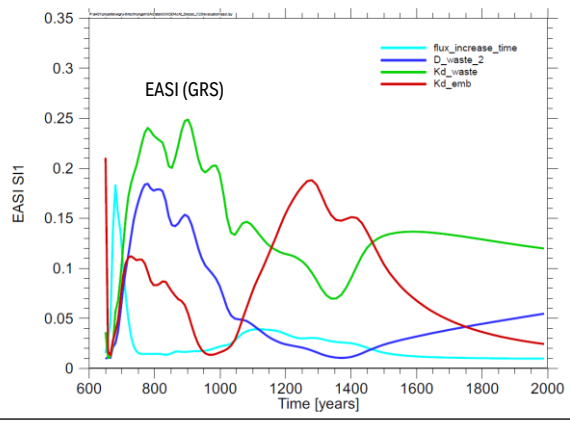
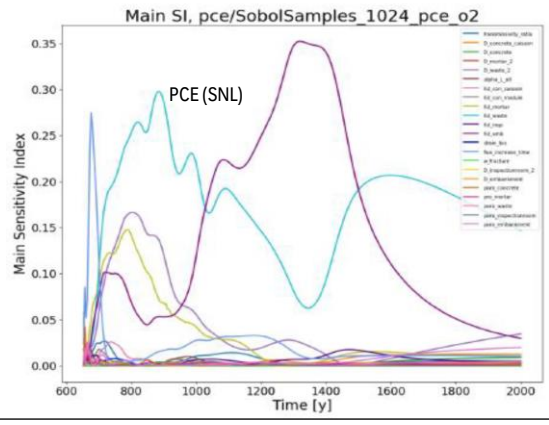
Dessel case: First-order SI







Findings

- First order variance-based index estimates are easily generated from observational data
  - no specific sampling schemes required
- Linear and rank correlation coefficients and regression approaches continue to be used
  - valuable information
  - consistency between the measures and with variance-based SA

parameters

- More advanced methods show results mostly consistent with simpler methods
- Data transformations can have an influence on parameter rankings
- Graphical methods such as CUSUNORO provide additional visualization
  - variation of influences over the range of a variable

Future plans

- More complex model systems
  - Sandia crystalline case
  - GRS LILW salt case
  - Further models?
- Investigation of the effects of data transformations
- Link to EURAD-DONUT/UMAN

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