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Sensitivity Analysis in Performance Assessment: Towards a Joint Approach

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Outline

- Context
  - IGSC co-operation on the treatment of uncertainties
  - Sensitivity analysis (SA) and the Safety Case

- Approach of an ongoing SA exercise

- Current work: The Dessel example

- Conclusions

IGSC co-operation: Treatment of uncertainties

- Since 2015, triggered by exchanges between IGD-TP and IGSC: Collaboration of several waste management, consultant and research organizations

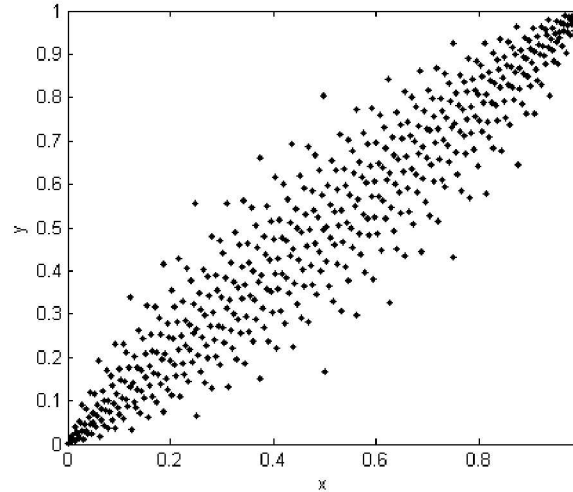# IGSC co-operation: Treatment of uncertainties

- Topics:
  - Parameter uncertainty quantification
  - Modelling aspects in the context of uncertainties
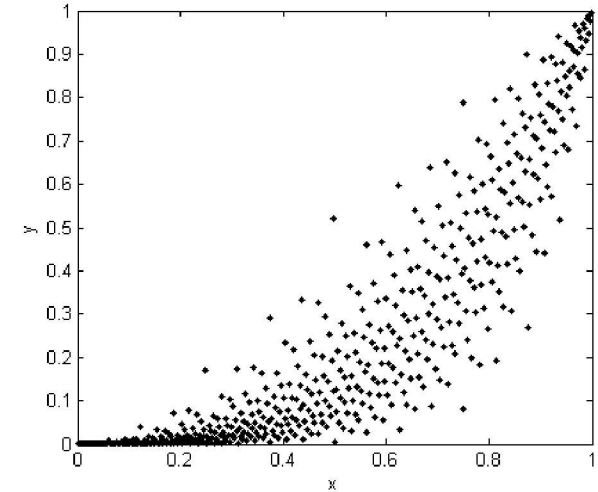 - Sensitivity Analysis (SA)

Why sensitivity analysis (SA)?

- Modelling under (input parameter) uncertainty
- Complex, non-linear processes, multiple interfaces in simulation
- Correlated and / or interacting inputs

➢ Need to know the importance (or lack thereof) of each input for the output uncertainty, about the joint impact of two or more inputs ("interactions") as well as about general model behaviour (linearity or lack thereof, monotonicity etc.)
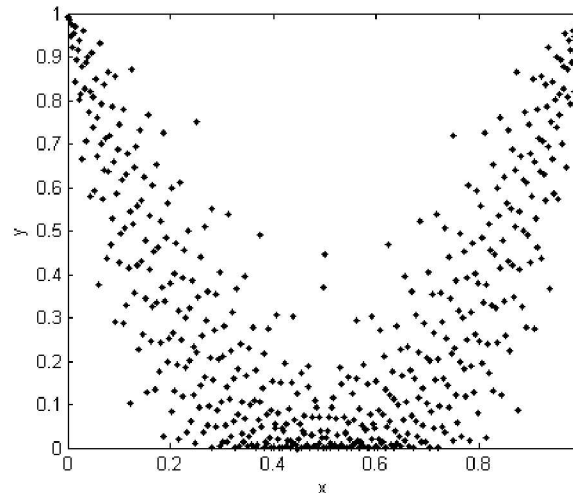
**Different types
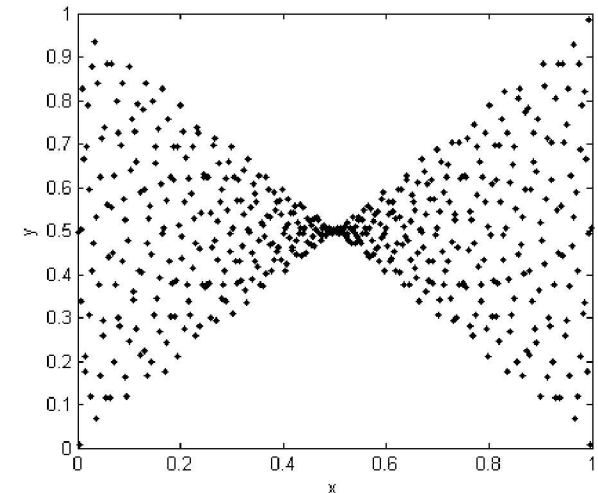of sensitivity
→ different
methods**

→ Linear methods

→ Rank-based methods

→ Variance-based methods

→ Density-based methods

Sensitivity analysis (SA) and the Safety Case (SC)

- In the past: Application of SA in SCs restricted to …
  - Local / deterministic methods
  - Global methods based on linear and rank regression / correlation
  - In some cases: Variance-based methods
- Recent research:
  - Better estimation methods for variance-based approaches (given data!)
  - Complementary numerical and graphical approaches

➢ **Whether, under which circumstances and to which extent are recent research results applicable and useful in the Safety Case context?**
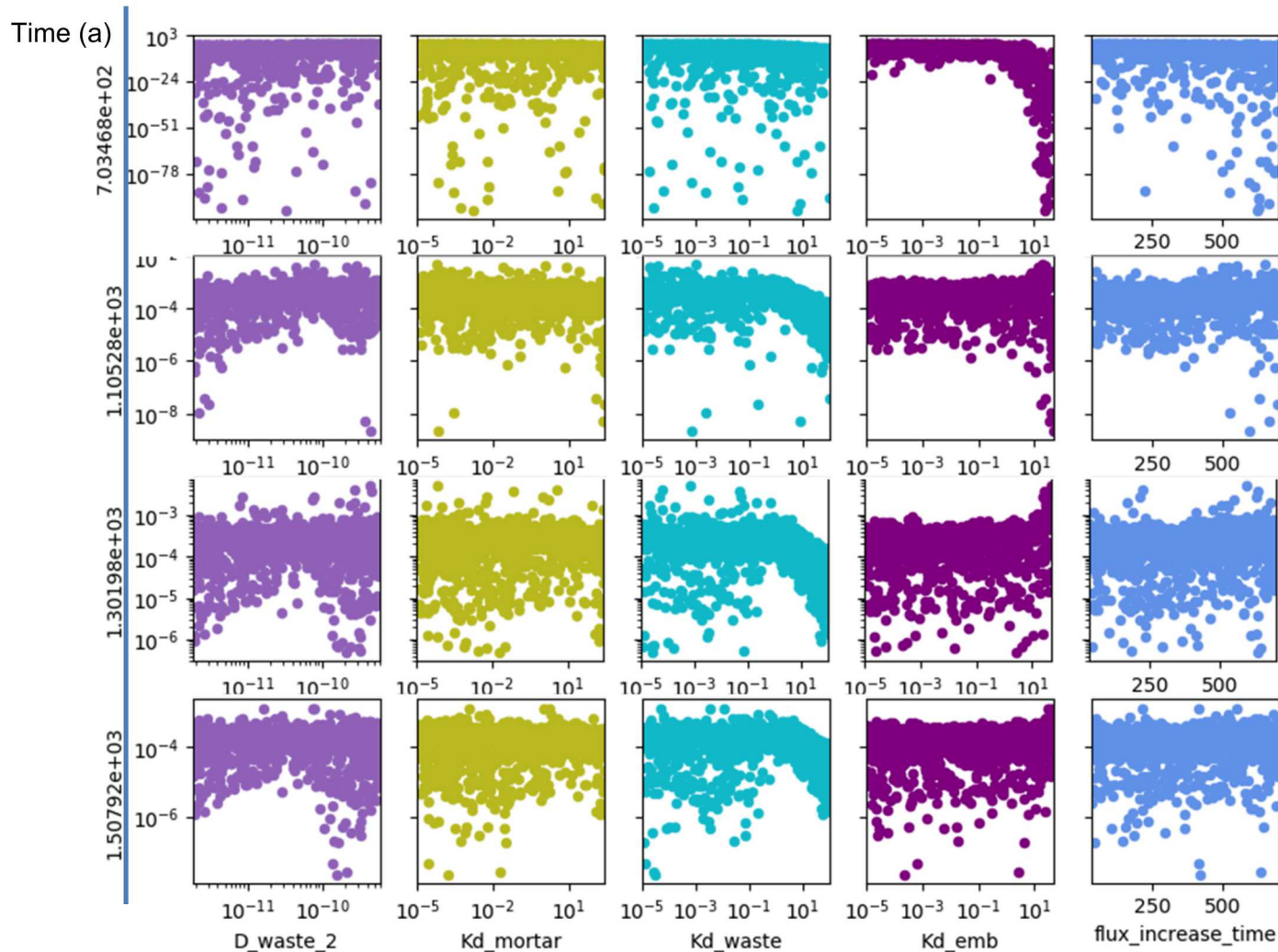
Exercise approach (1)

- Restricted to global methods based on input / output pdfs
- Participants have access to …
  - Various SA methods
  - PA and THMC test cases (existing input / output data!) with different degrees of complexity

➢ Questionnaire: features of each potential test case
  - Number of parameters
  - Sample size(s)
  - Linearity, monotonicity, continuity, or lack thereof
  - Interactions
  - …

Exercise approach (2)

- Series of cases with increasing complexity
  - SNF/HLW repository in clay (GRS)
  - Generic disposal facility in shale (SNL)
  - Surface repository at Dessel (Belgium)
  - Generic LILW repository in a salt mine (GRS)
  - Reactive transport model (SNL)
  - Generic disposal in crystalline rock (SNL)
  - PA model used in the 2014 WIPP CRA
- Mostly: Time-dependent outputs
- Differences: number / dependency of inputs, model behavior
- Participants address cases using their method(s) using only existing data

Time-Dependent SA of the Dessel Example

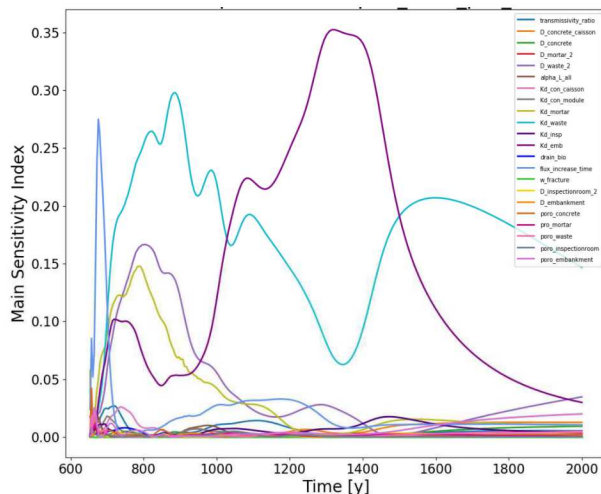# SA using „established" and „novel" approaches

- Linear and rank regression / correlation
- Variance-based (estimates for given data)
  - Effective Algorithm for Computing Global Sensitivity Indices (EASI): 1st order
  - Cumulative sum of the normalized reordered outputs (CUSUNORO) slope: 1st order
  - Polynomial chaos expansion (PCE): 1st order, totals
  - Harmonic regression: 2nd order (not reported here)
- CUSUNORO curves: graphical

- Performance tests for different sample sizes (not reported here)
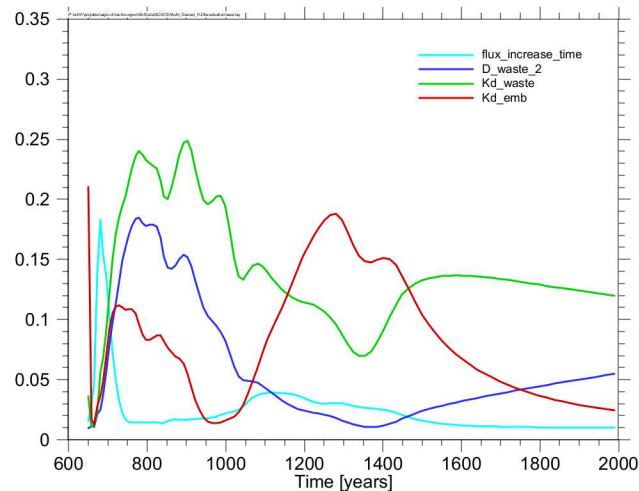
„Novel" methods

- PCE:

  - Surrogate model (meta-model, response surface) from which sensitivity indices can be analytically calculated

  - Approximation using polynomial chaos expansion

  - Possibility to construct the PCE from small samples

- CUSUNORO:

  - Graphically aggregating information otherwise available only from (too many?) scatterplots

  - Slope used to estimate 1st order effects

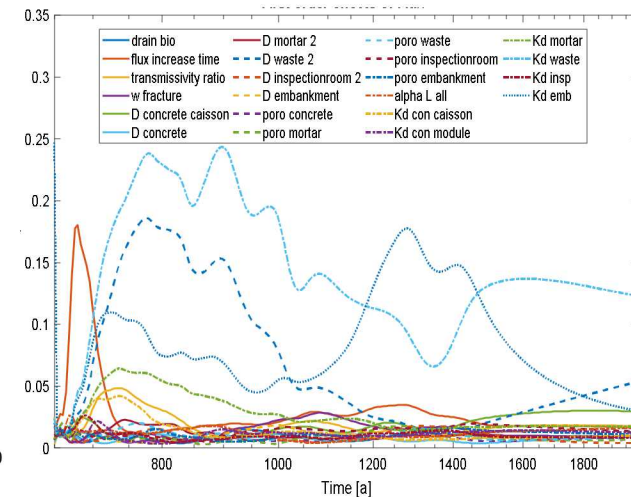# Comparison: 1st order effects calculated with different methods
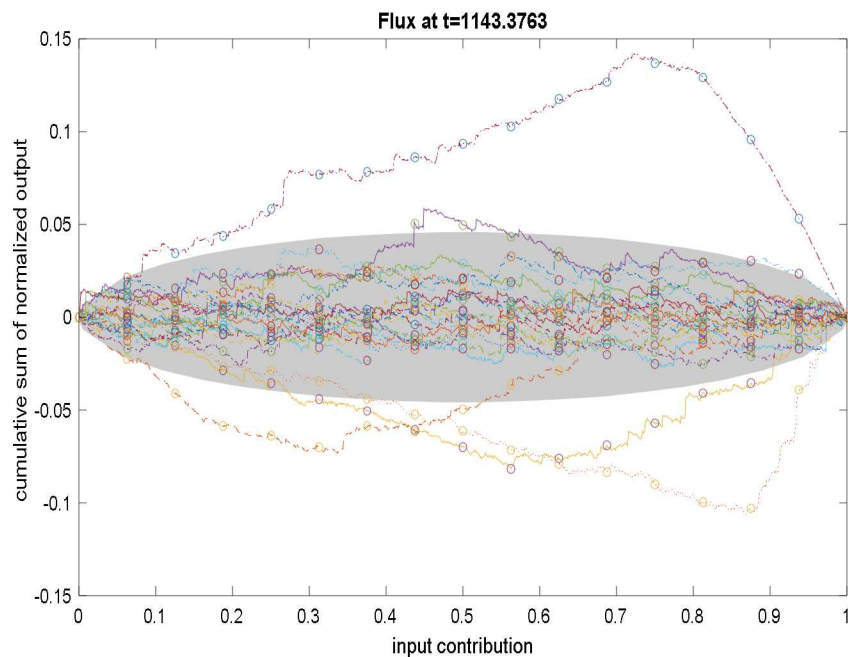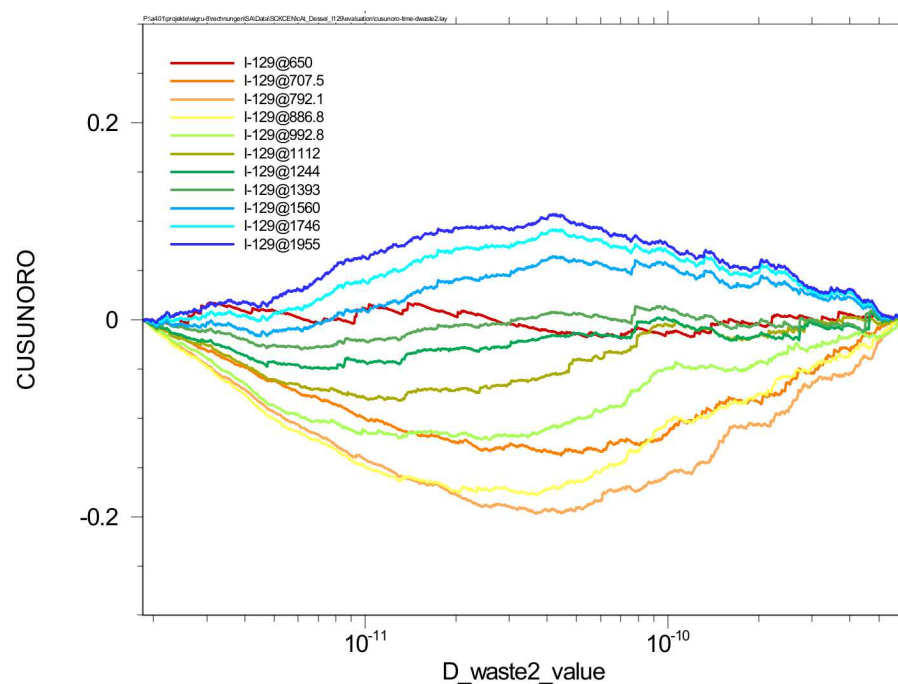
PCE (SNL)   EASI (GRS)   CUSUNORO (TUC)

- Similar qualitative behavior
- But considerable differences in detail
- Some differences might be resolved when using bigger samples (ongoing)
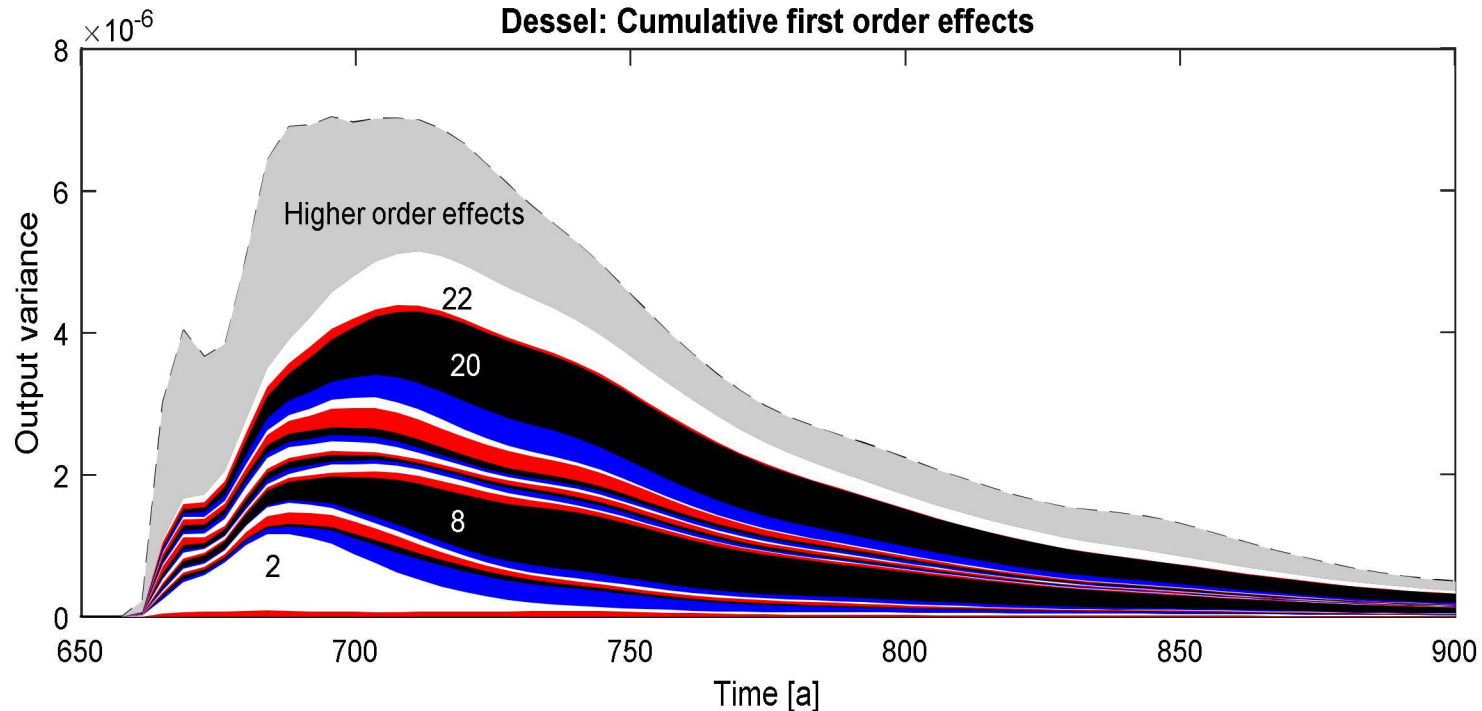
CUSUNORO Plots

Time fixed, all inputs
„ellipsoid of significance" (grey)

Different times, one input

There are interactions …

Dessel: Cumulative first order effects

- Note: Absolute rather than relative contributions to the variance are shown → additional information when considering sensitivities evolving over time

- "Missing" grey area: Fraction of variance not explained

➢ Interactions (to be further investigated)

Conclusions

- Dessel example: Standard set of SA methods does not sufficiently explain model behaviour

- Use goodness-of-fit measures to obtain information on explanatory power!

- Options to address issue:
  - Higher order effects
  - Output transformations
  - Moment-independent

- Future work:
  - Apply such methods
  - Investigate performance against sample size
  - Study further test cases

Acknowledgment