Uncertainty and sensitivity analysis methods used at Andra

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Uncertainty methods used at Andra

Scenarios Situations → **Deterministic treatment** (no probabilistic approch)

Principles (Safety Guide) :
- No probabilistic approach to choose the scenarios
- No probabilistic distribution for the impact

→ No risk analysis

Models → **Deterministic treatment** (no probabilistic approch)

Entry data
- Stochastic (natural variability, …)
- Epistemic uncertainty (lack of knowledge, …)

→ Different types of treatment :
- **deterministic mono /multi parametric**
- **probabilistic Monte-Carlo type** (linearity / monotonic indicators),
- **ANOVA methods** (variance analysis) (Kurtosis-skewness under developpement)
- **adjoint state** (automatic local differenciation)

Probabilistic Monte-Carlo/ANOVA methods
General methodology to undertake probabilistic work

Pre-processing

- Definition of uncertain parameters probabilities
  - types of laws = f(number of available data)
  - Law troncations
- Correlations / constrains between parameters
  - Statistical correlations
  - inequalities
- Choice of the sampling method
  - LHS (reference)
  - Random + importance (sensitivity)

Processing

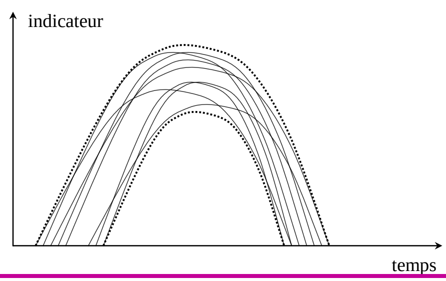
Implementation of tools **(Cassandra)**

Results

-Temporal

- maximas

- t(maximas)



Post-processing

- Uncertainty analysis
  - Quantiles
  - Moments
  - Distributions
- Sensitivity analysis
  - Scatter plots
  - linearity and monotony indicators, based on correlations and regressions

Probabilistic Monte-Carlo/ANOVA methods

Analysys of relations between results and entry data

Monte-Carlo

Linear relation ?

No → **Monotonic relation ?**

Yes ↓

Correlation coefficient (Pearson, PCC)

Standard Regression coefficient (SRC)

Monotonic relation ?

No → (ANOVA)

Yes ↓

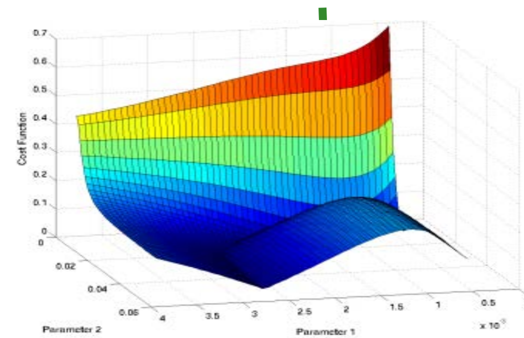
Rank Correlation Coefficients *(Spearman, PRCC)*

Regression Coefficients based on the ranking (SRRC)

ANOVA

Kurtosis/skewness analysis under developpement

Construction/validation of a response surface (meta-modèle)



Generation of several tens of thousands of results

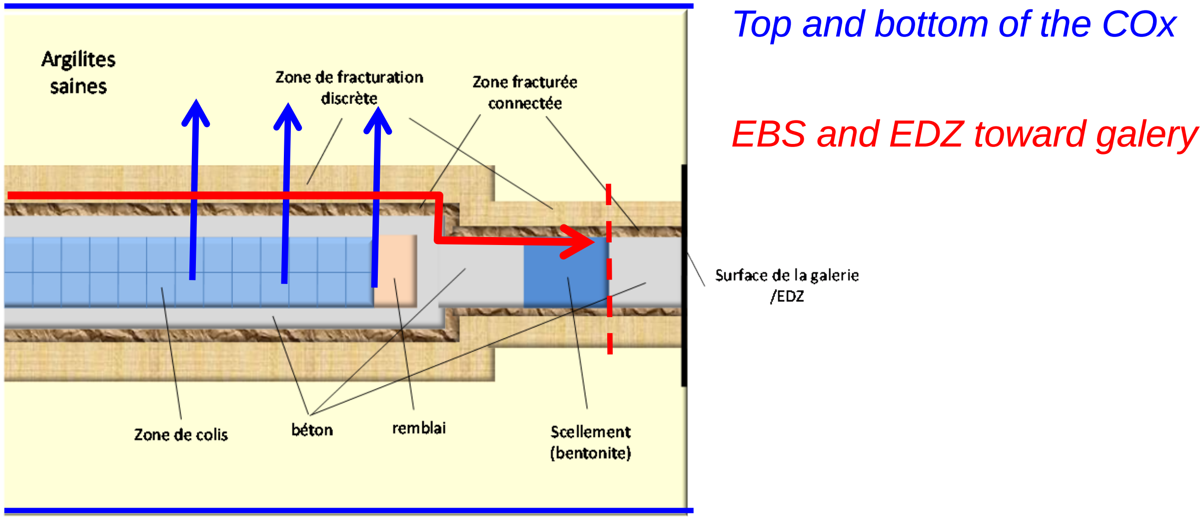
↓

Sobol indicators

Object : sensitivity and uncertainty analysis of 129 iodine transfert inside and around an ILLW vault

Physical indicators (quantification of the transfert paths)

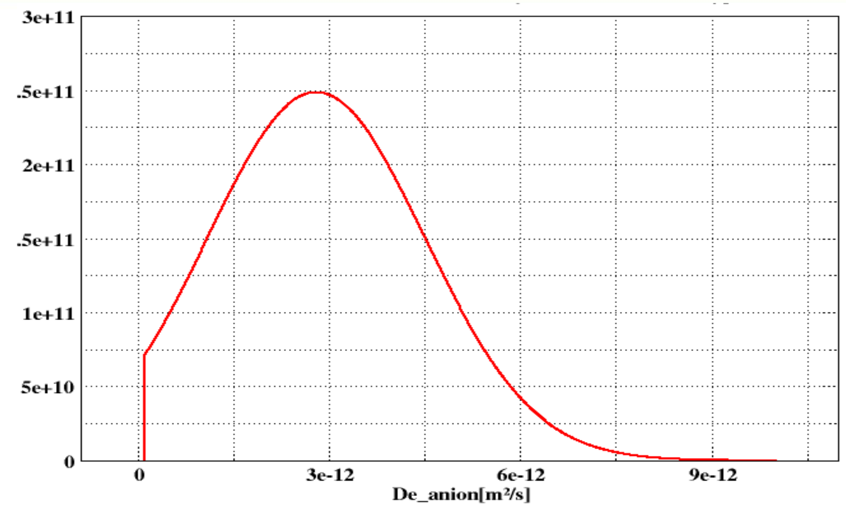
- Molar flux through geological barrier
- Molar flux through the EBS and the EDZ toward the access galery



Caracteristics

- Conceptualisation + parameters from Dossier 2009
- ~ 20 parameters uncertainties taken into account, 7 materials considered
- Correlations between parameters + inequalities
- 3D representation, 300.000 elements mesh

Example n°1 : 129 iodine transfert in a ILLW vault
Probabilistic distributions, correlations and constrains



- Probabilisitic distribution definition
  - Based on a high number of available data
  - Troncation if needed

Ex : Effective diffusion coefficient distribution
Normal law $m = 2{,}8 \cdot 10^{-12}$; $\sigma = 1{,}7 \cdot 10^{-12}$; $[10^{-13} ; 10^{-11}]$

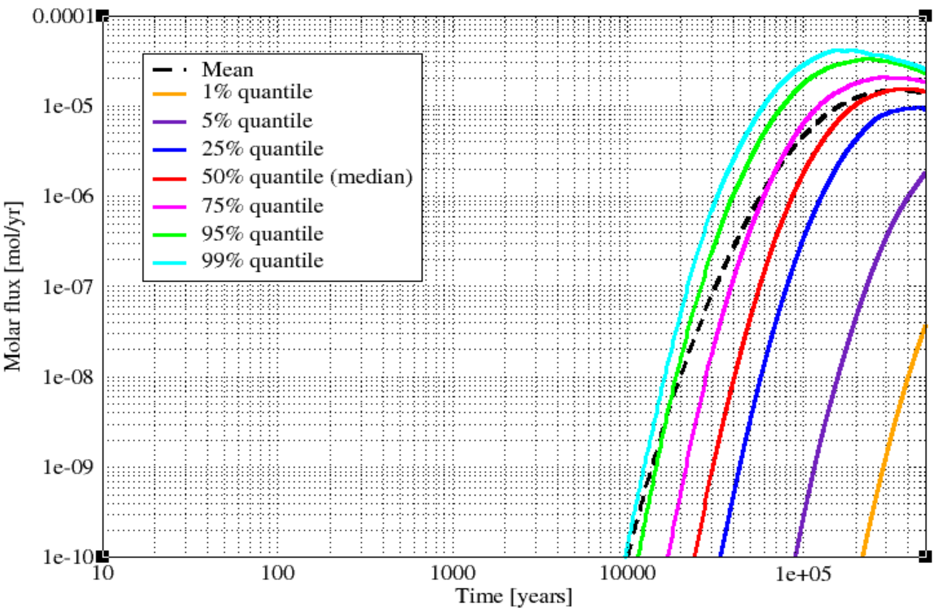
- Taking into account statistical correlations
  - Ex : correlations between permeability and effective diffusion coefficient

- Taking into account other contrains
  - Ex : Cox permeabilities

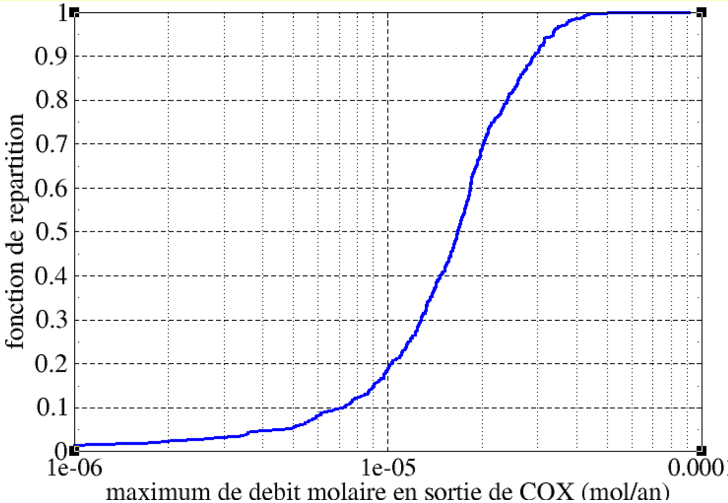
    Kv (COX) < Kh (COX) < K (« discrete EDZ ») < K (« connected EDZ »)

Example n°1 : 129 iodine transfert in a ILLW vault
Uncertainty analysy - Results

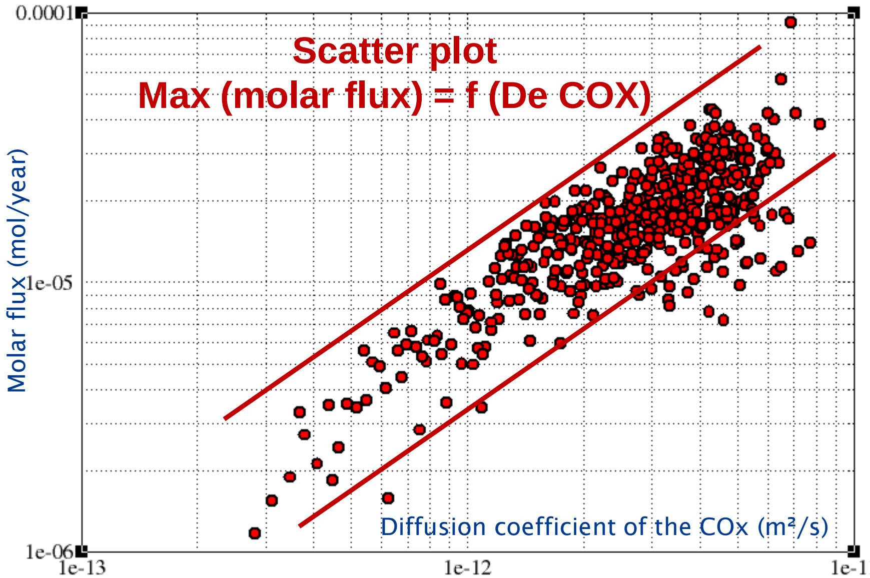
129 iodine molar flux evolution on top and bottom of the Cox - Quantiles



Repartition function of the 129 iodine molar flux on top and bottom of the Cox

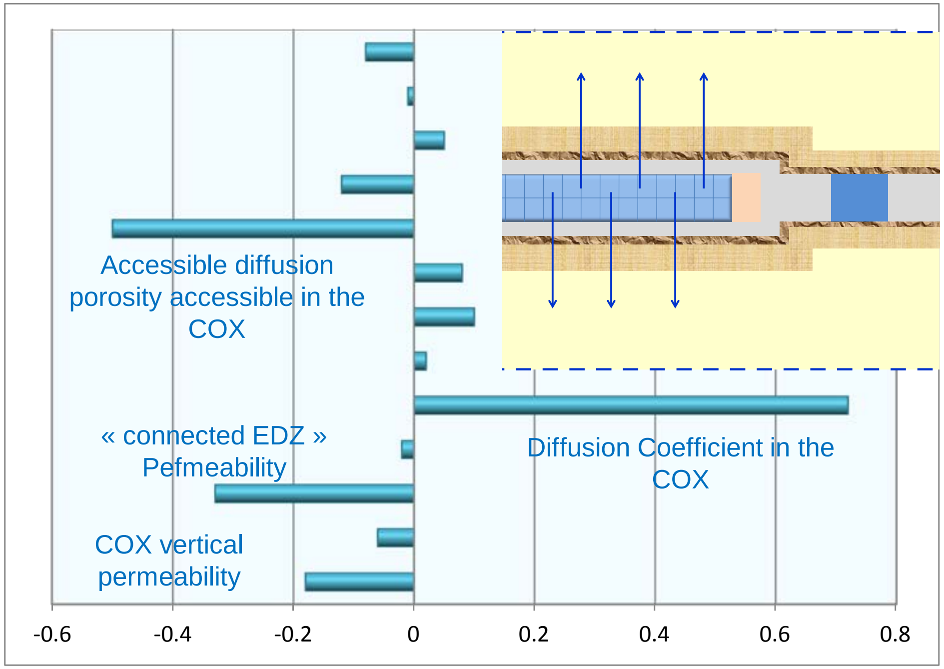


- Maximum molar flux on top and bottom of COx
  - Troncation of maximas at 1e6 years for 25% of the results
  - Factor 4 of variability for 75 % of the results
  - Max (median) ~ Max (mean)
  - High correlation between maximum of molar flux and diffusion coefficient of the COx



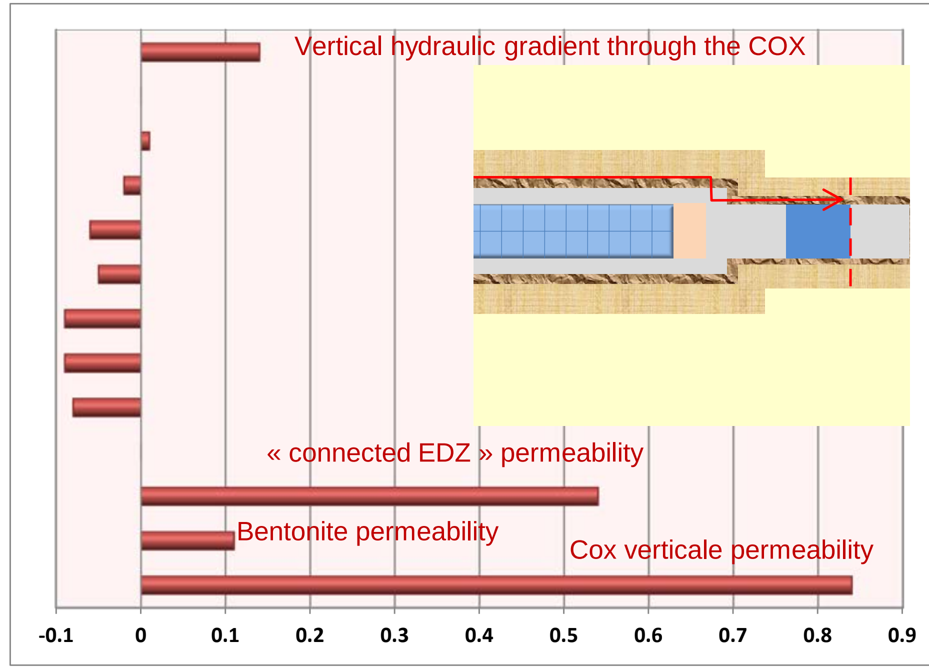
Example n°1 : 129 iodine transfert in a ILLW vault
Sensibility analysis- Results

Transfert path through the argilites



Rank correlation factors (PRCC)

Transfert path through the vault toward the galery



Rank correlation factors (PRCC)

Influential parameters ranking:

- COx Diffusion and porosity
- COx and EDZ permeability
- Other parameters are not influent

Influencial parameters ranking:

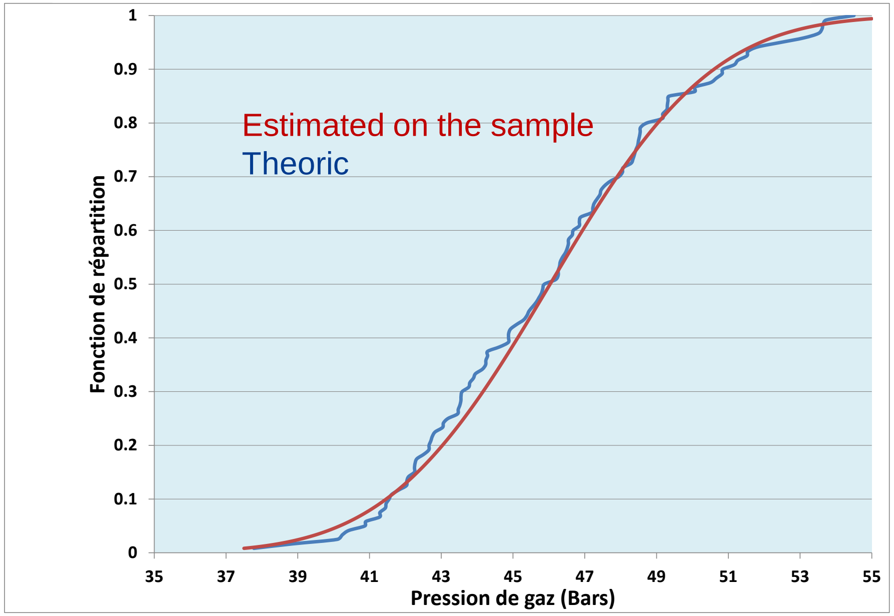
- Cox and EDZ permeability
- Vertical hydraulic gradient
- Bentonite permeability
- Other parameters are not influent

- Object : Uncertainty and sensitiviy analysis on the hydrauic-gas transient inside an ILLW vault

- Physical indicator:
  - Maximum gas pressure

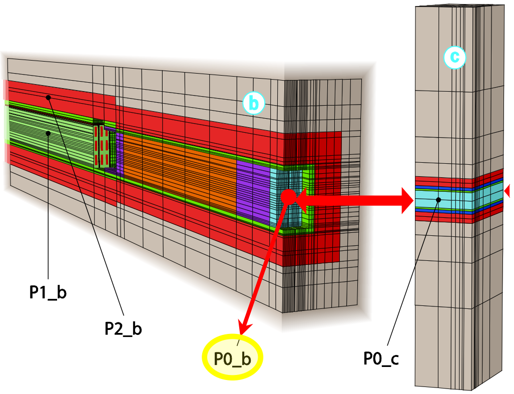
- Physical parameters
  - Corrosion rate
  - H2 diffusion coeffciient (dissolved, gas)
  - Porosities
  - Permeabilities
  - Van Genuchten parameters
  - …

Distribution of the maximum gas pressure in the vault



- Initial 120 numerical simulations (modèle 3D – Tough2_MP)
  - Correlation/regression analysis on values and ranks
    - *R^2 (values) = 0,74 and R^2(rank) = 0,7*
  - Non linear and non monotonic system

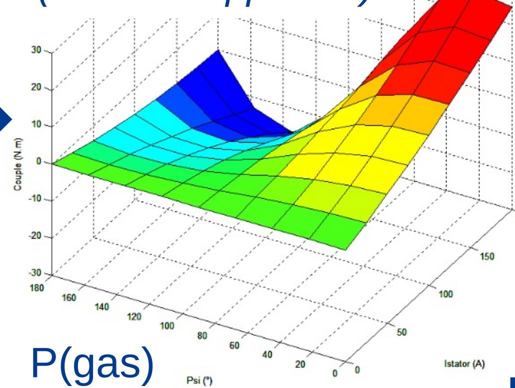
↳ Necessity to define a meta-model for the calculation of the SOBOL indices pour le



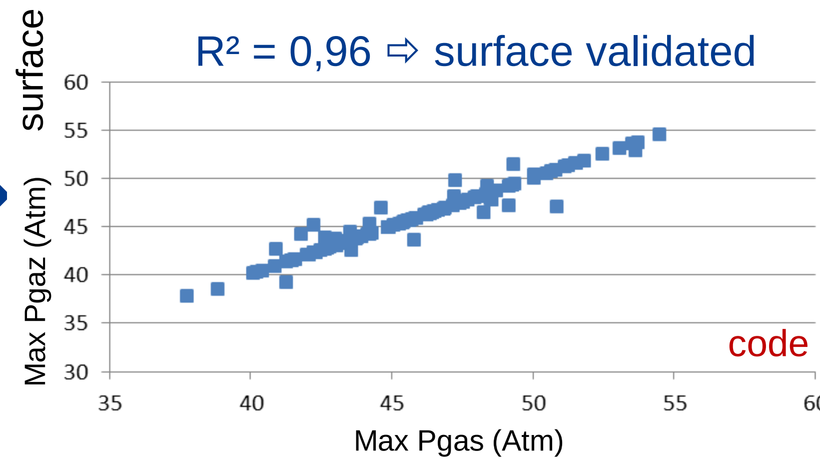
Construction of the meta-model and sensitivity analysis

120 simulations
(code Tough2_MP)

Response surface
(neuronal approach)

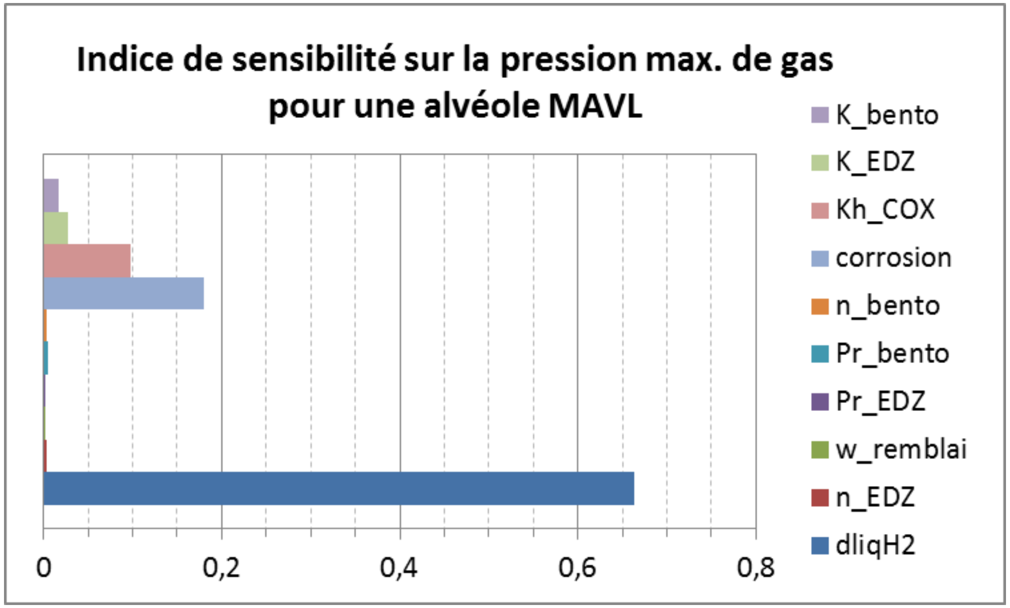


P(gas)



50.000 simulations

- First order Sobol indices (on variance)
- Influantial entry data ranking:
  1. *Dissolved H_2 diffusion coeffcient ,*
  2. *Corrosion rate,*
  3. *Horizontal Cox permeability.*
  4. *No or low influence of other parameters*



Conclusions

- Uncertainty methods at Andra
  - Definition of scenarios : deterministic treatment
  - Determination of phenomenological models : deterministic treatment
  - Determination of entry data : probabilistic approach

- Available probabilistic approach
  - Monte-Carlo type probabilistic approaches : used for linear or monotonic problems
  - ANOVA methods : used for highly non linear problems (highly coupled problems) in association with a response surface approach (neuronal network type)
    - + *Deterministic supplementary sensitivity analysis around operating points if needed*
  - Numerical tools : plate-forme Cassandra, ModeFrontier, Traces (état adjoint)

- R&D efforts
  - Decomposition of high orders moments (skewness, kurtosis)

→ Andra has all the needed tools (and skills) to fulfill uncertainty and sensitivity analysis in the context of phenomenological or safety evaluations