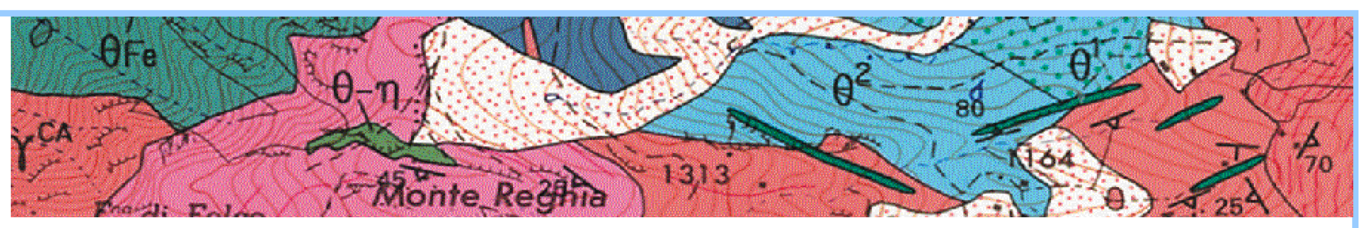


Ranking importance of **uncertainties** for the assessment of **residual and dissolution trapping** of CO_2 on a **large-scale** storage site

Motivation

> CO_2 plume migration and trapping after storage operations is often investigated through **numerical flow simulation**

> EU Directive on the geological storage of CO2: "**Multiple simulations** shall be undertaken to **identify the sensitivity** of the assessment to assumptions made about particular parameters"

What could be the challenges for such an importance ranking (sensitivity analysis) ?
and
How to face them ?

Variance-Based global Sensitivity Analysis

> **Basic idea**: Variance (model output) ~ measure of uncertainty

> **Tools**: Sobol' indices [Sobol', 1993; Saltelli et al., 2008].
- if one knew the true value of one input parameter
  ⇒ Expected reduction in Variance (model output) ~ measure of sensitivity
  = **Main effect of each input parameter**
- if one knew the true value of all input parameters but one
  ⇒ Expected variance (model output)
  = **Total effect of each input parameter**

> **Objectives**:
- **Main effect:** prioritizing the characterization effort to decrease the output uncertainty
- **Total effect:** shows the « **non-influential** » parameters

Challenges

> Best practices for global sensitivity analysis requires running models a **large number of times** (> 1,000-10,000)

> Relevant numerical models generally include **many processes, on a large scale**, and **long simulation times** to capture long term phenomena: **High computation time** (several hours- days)

⇒ Proper sensitivity analysis should be conducted combined with fast-running approximations (**reduced-order models** aka **metamodels**)

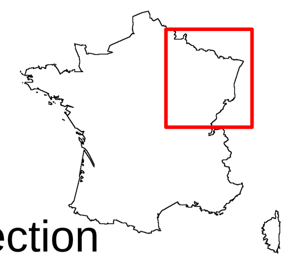
> Relevant numerical flow models generally require **numerous input data (~10)**, of **different types** and **with different levels of uncertainty**.

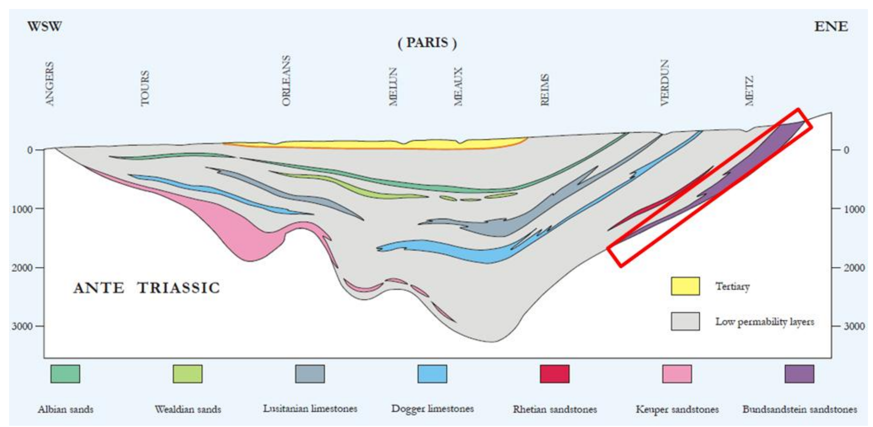
> Several ways to account for the related uncertainty:
- **Fixed value:**
  ex. structural geological model
- **Continuous probability distribution for parameter uncertainty:**
  ex. porosity / permeability distribution
- **Discrete variables (scenarios) for model uncertainty:**
  ex. flow model gridding
  ex. capillary pressure scenarios

⇒ Accounting for discrete variables in meta-models has been addressed recently [Storlie et al., 2013]

Case study: objective and hypothesis

[after Bonijoly et al., 2003]



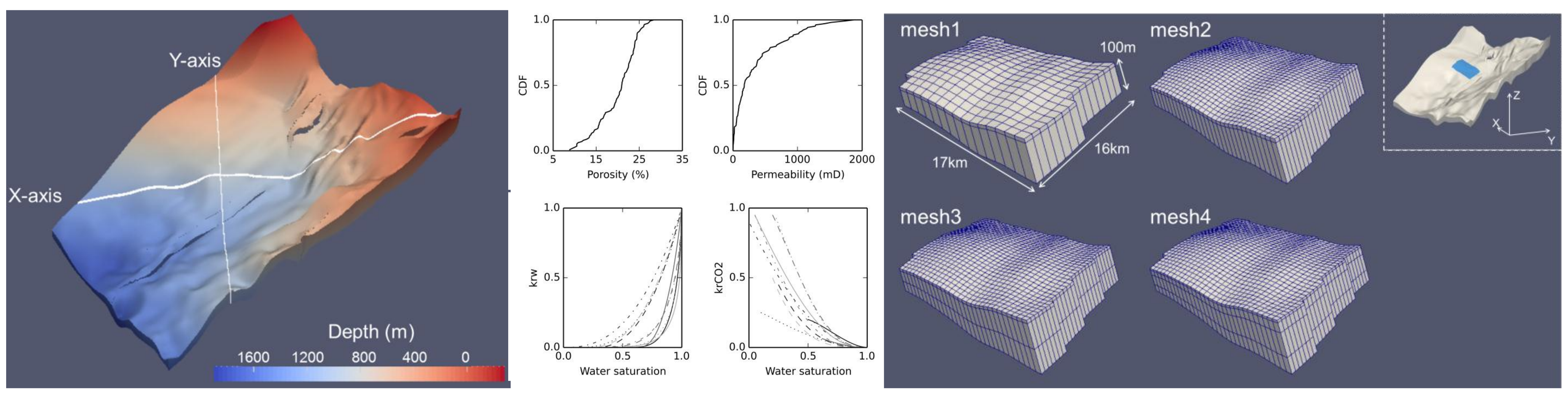


> **Injection of 30 Mt of CO2 during 30 years** in the lower Triassic sandstone formation in the Paris basin (France).

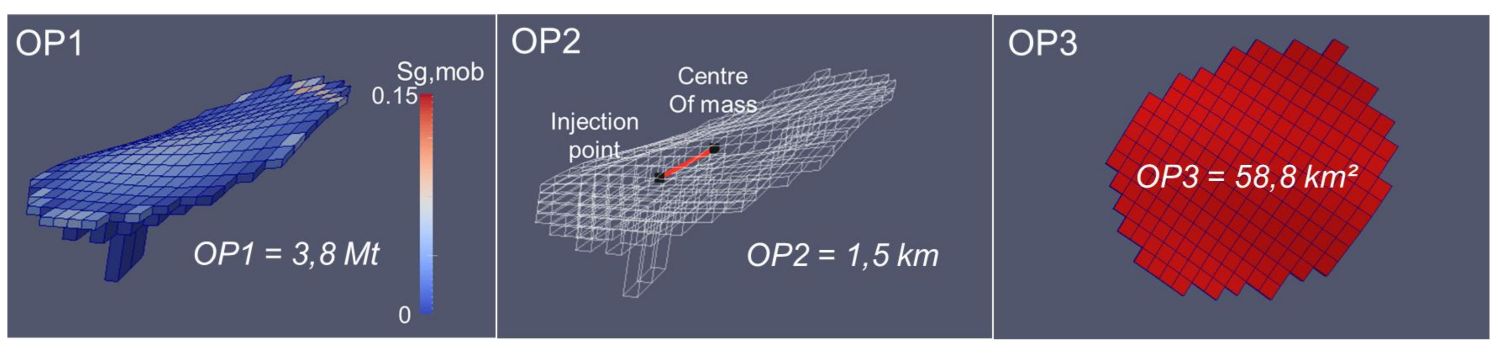
> **Objective**: assessing the **evolution of the mobile free-phase CO_2** plume up to 250 years after injection

> **Data / Inputs**:
- **Fixed value:**
  Geological model of the reservoir
  Temperature / salinity at injection point
- **Continuous probability distribution:**
  Porosity/permeability: distribution from well data
- **Discrete variables (scenarios):**
  Permeability anisotropy: 3 different scenarios
  Local pressure gradient: 2 extreme scenarios
  Capillary pressure: 2 extreme scenarios
  Relative permeability: 10 scenarios from literature dataset
  Gridding: 4 scenarios from 4 different refinements degree

[Manceau and Rohmer, 2014; Submitted]



> **Model and outputs**:
- Flow simulator: LBNL TOUGH2 (accounting for solubility and residual trapping)
- **3 outputs parameters (OPs) of interest:**
  OP1: Mass of mobile free-phase CO2
  OP2: Distance from the injection point
  OP3: Surface in contact with the caprock



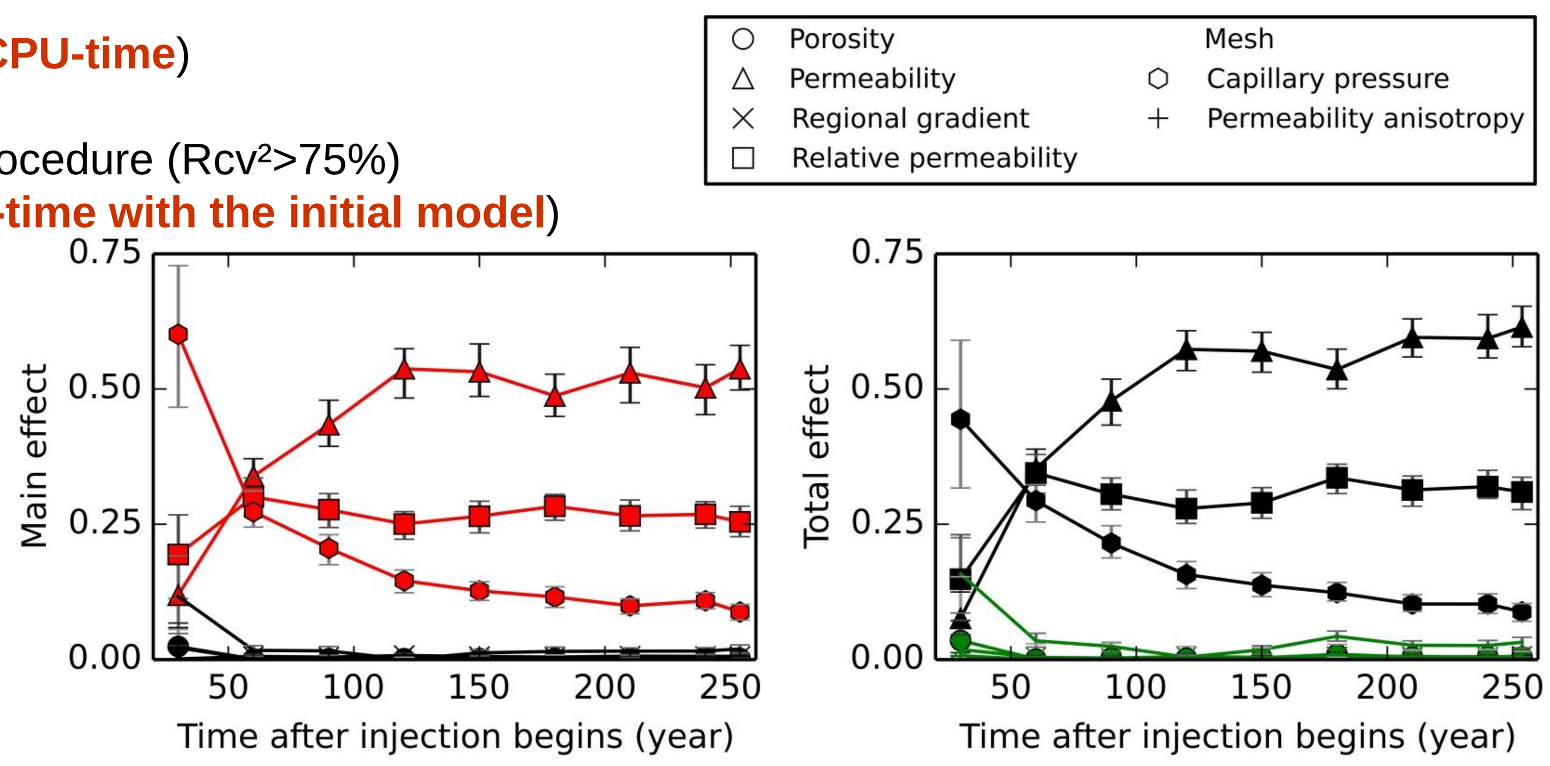
Case study: application of the methodology and results

> **Procedure**:
- **a -** 300 samples of the input parameters randomly generated
- **b -** Flow simulation for the 300 samples and assessment of the 3 OPs (ca. **1.25 m. CPU-time**)
- **c -** ACOSSO-type meta-model for each OP and for several simulation times
- **d -** Approximation quality (R^2>90%) / Predictive quality by 10-fold cross-validation procedure (R_{cv}^2>75%)
- **e -** 90,000 meta-model runs for computing the main and total effects (Ca. **30 y. CPU-time with the initial model**)

> **Results (example for OP1)**
- Most important parameters: **kabs, kr and Pc**
- Pc importance decrease vs. Kabs and kr increase: early trapping driven by Pc
- « Non-influential » parameters: **kh/kv, mesh, regional gradient, porosity**

> **Main outcomes on the methodological perspective**
- The method provides physically sound outcomes
- The method provides important elements to derive recommendations to reduce uncertainties with a limited time cost

[Manceau and Rohmer, 2014; Submitted]



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