EXAMIN

WP2

Numerical Modeling of Wave Propagation at Local and Regional Scales

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Validation of numerical models at low frequency

"Validation"

Quantitative comparison between the synthetic and observed earthquake ground-motions

Sites of interest

- Argostoli, Greece
- Grenoble, France

Origin of the 3D velocity structure models

- Data inversions from WP1 and previous studies/projects
- Assumption: 3D models derived from multiple 1D soil structures
  - Verification *a posteriori* in WP2.2

Validation of numerical models at low frequency

Validation's characteristics

- Frequency content below 1 Hz
- Small strain, linear elastic stress-strain relationship
- Set of well characterized earthquakes (location, magnitude, focal mechanism)

Wave propagation tools

- EFISPEC3D
- SPECFEM3D

Deliverable D2.1 (BRGM,ISTerre)

Report on the numerical models and their synthetic earthquake ground-motions compared with observed earthquake ground-motions

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Full numerical inversion exercice

Exercice

- Inversions of 1D velocity structures from synthetic ground-motions generated in 3D random media
- Comparison between input and inverted velocity structures

Deliverable D2.2 (ISTerre,BRGM)

Report on full inversion exercice

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Nonlinear 2D FEM analysis to assess basin amplification

Site of interest

- Grenoble, France

Origin of the 2D velocity structure model

- 2D cross-section (to be determined) extracted from the 3D model
- Constrain: get the nonlinear input curves G/G_{max}

Source

- Plane S-wave ?

Numerical tool

- Code_Aster (use of Iwan constitutive law)

Deliverable D2.3 (EDF,BRGM, ISTerre)

Report on the impact of nonlinear soil behavior on site amplification

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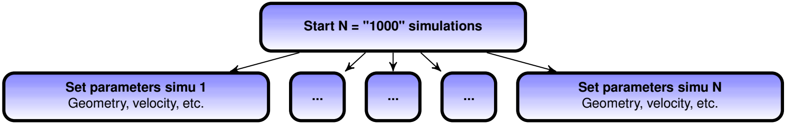
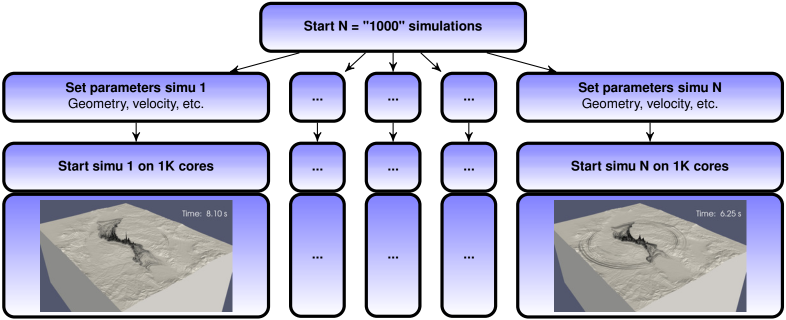
Start N = "1000" simulations

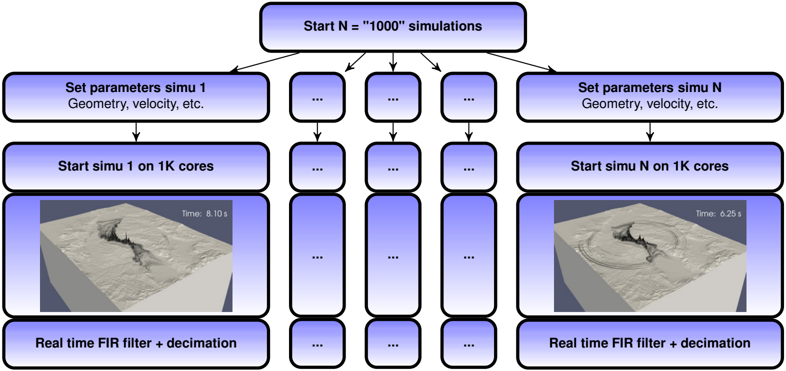
UQ in scenarios of earthquakes for Grenoble basin



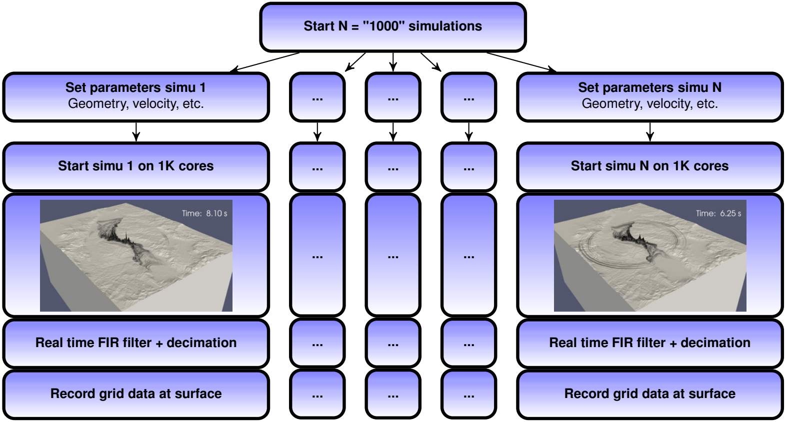
UQ in scenarios of earthquakes for Grenoble basin



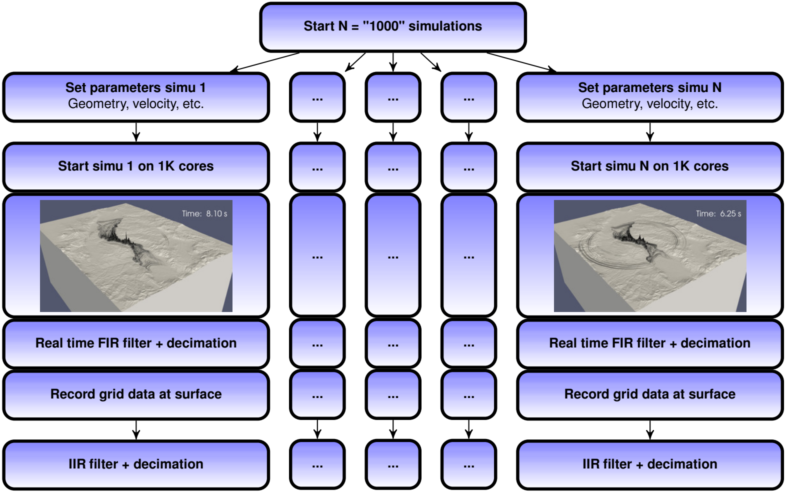
UQ in scenarios of earthquakes for Grenoble basin



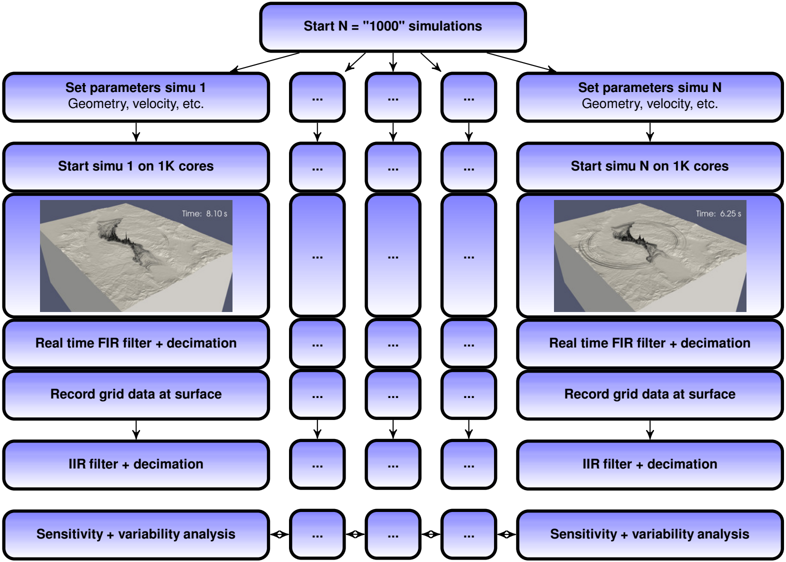
UQ in scenarios of earthquakes for Grenoble basin



UQ in scenarios of earthquakes for Grenoble basin



UQ in scenarios of earthquakes for Grenoble basin



UQ in scenarios of earthquakes for Grenoble basin

Site of interest

- Grenoble, France

Earthquakes characteristics

- Magnitude $M_w = 4, 5, 6$
- Stochastic kinematic rupture: Mai and Beroza (2002)
- Uncertain parameter: final slip distribution only ? (dependency with slip rate, etc.)

Soil random variability at local scale

- Implementation of Karman or Gaussian correlation models
- Correlation length and coeff. of variation from WP1 and literature

UQ methods

- Monte-Carlo
- Polynomials chaos expansion

Synthetic ground-motions used for

- Comparison with observed spatial correlation and coherency functions
- Insight on the impact of fault, epistemic uncertainties and local soil variability on 3D site response

UQ in scenarios of earthquakes for Grenoble basin

Deliverable D2.4a (BRGM, ISTerre, EDF)

Report on the comparison of coherency and correlation models available in the literature

Deliverable D2.4b (BRGM, ISTerre)

Waveforms for the structural analysis in WP3 and meta-models for major intensity measures (PSA, etc.) that will be used to generate the maps accounting for the uncertainties to be used in WP4

Deliverable D2.4c (BRGM, ISTerre, EDF)

Report on lessons learned from the 3D site response and sensitivity analysis

Thank you

References I

Cameron, R. H. and Martin, W. T. (1947). The orthogonal development of non-linear functionals in series of fourier-hermite functionals. Annals of Mathematics, pages 385–392.

Mai, P. M. and Beroza, G. C. (2002). A spatial random field model to characterize complexity in earthquake slip. Journal of Geophysical Research: Solid Earth, 107(B11).

Framework

- Non-linear model $\mathscr{M}$ with parametrics uncertainties
  Quantity of interest $\rightarrow$ function $u(x)$, $x \in \Omega = [a, b] \subset \mathbb{R}$

$$\mathscr{M}(\boldsymbol{\xi}, u) = 0$$

  $\boldsymbol{\xi} = (\xi_1, \cdots, \xi_n)$ vector of N independent random variables

- $u \in L_2(\Xi, p)$

$$\mathbb{E}[u(x, \cdot)^2] = \int_{\Xi} u(x, \boldsymbol{\xi})^2 p(\boldsymbol{\xi}) d\boldsymbol{\xi} < \infty, \forall x \in \Omega$$

  Ξ stochastic domain of $\boldsymbol{\xi}$ and p probability density function

- Inner product and norm $\forall (f, g) \in L_2(\Xi, p)^2$

$$\langle f, g \rangle = \int_{\Xi} f(\boldsymbol{\xi}) g(\boldsymbol{\xi}) p(\boldsymbol{\xi}) d\boldsymbol{\xi}, \quad \|f\| = \langle f, f \rangle^{1/2}$$

Polynomial Chaos Expansion

- $\Phi_{k>0}$ hilbertian basis

$$L_2(\Xi, p) = span\{\Phi_k, k \geq 0\}, \quad \langle \Phi_k, \Phi_l \rangle = \delta_{kl}, \quad (k, l) \in \mathbb{N}^2$$

- Expansion of $L_2(\Xi, p)$ random process (Cameron and Martin, 1947)

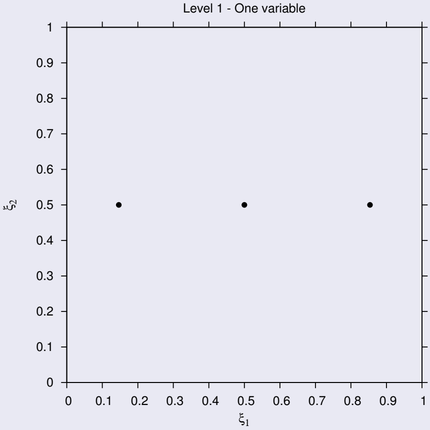
$$u(x, \xi) = \sum_{k \geq 0} u_k(x) \Phi_k(\xi)$$

$\{u_k\}_{k \geq 0}$ spectral modes $\rightarrow$ projection of $u(x, \xi)$

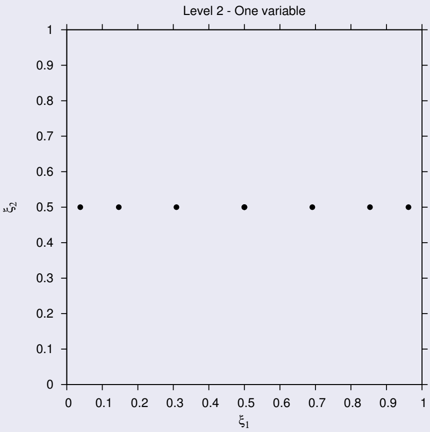
$$u_k(x) := \langle u(x, \xi), \Phi_k \rangle$$

- L_2 convergence of truncated series

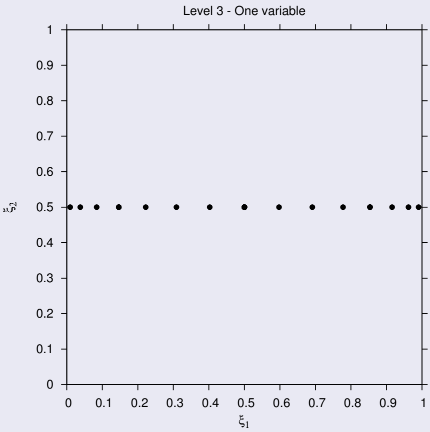
One variable ξ_1 ($\xi_2 = cst$) - Level 1



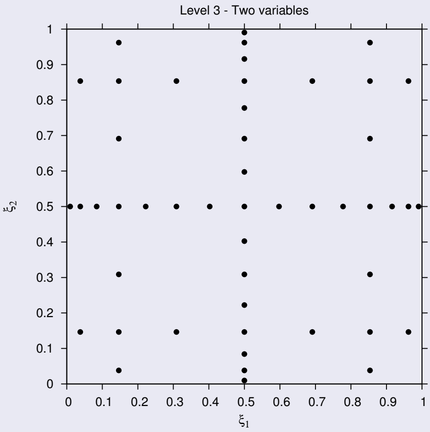
One variable ξ_1 ($\xi_2 = cst$) - Level 2



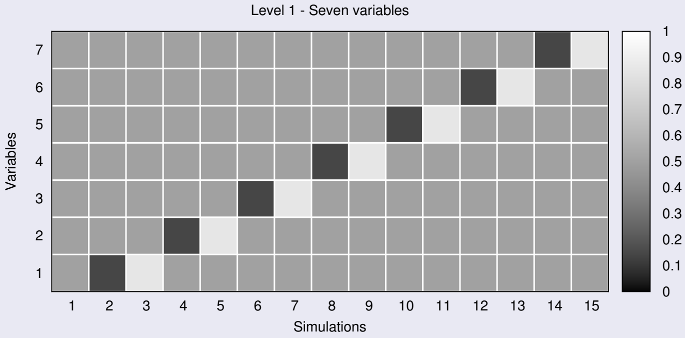
One variable ξ_1 ($\xi_2 = cst$) - Level 3



Two variables ξ_1, ξ_2 - Level 3



Seven variables - Level 1 → First order indices



Seven variables - Level 2 $\rightarrow$ First order indices + higher orders