Нумеричко моделирање интеракције конструкције и тла у земљотресном инжињерству: ЗЕМЉОТРЕС

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СУЗИ
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Outline

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Motivation

- Improve design and assessment of infrastructure objects
- Use of high fidelity numerical models to analyze behavior of earthquake, soil, structure interacting (ESSI) systems
- Control modeling uncertainty
- Propagate parametric uncertainty

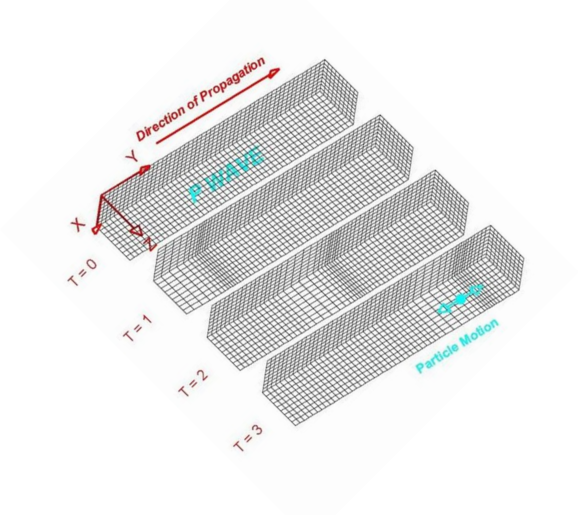
Outline

Earthquake Ground Motions

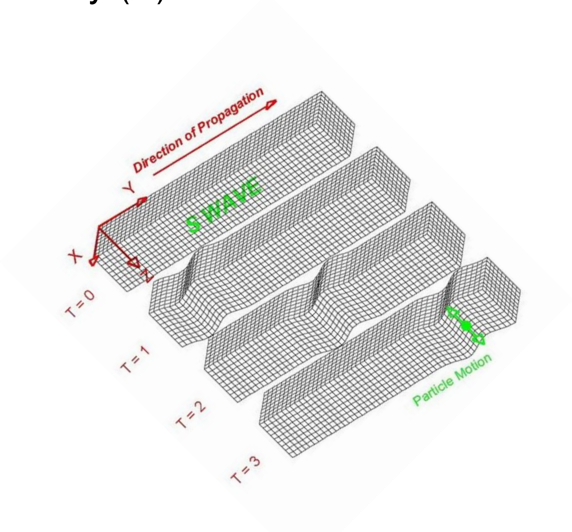
- Real earthquake ground motions
  - Body, P and S waves
  - Stoneley waves
  - Surface, Rayleigh and Love waves
  - Lack of correlation (incoherence)
  - Inclined waves
  - 3C. 6C waves
  - Uncertainty!

- What are the effects of these earthquake ground motion features on structures

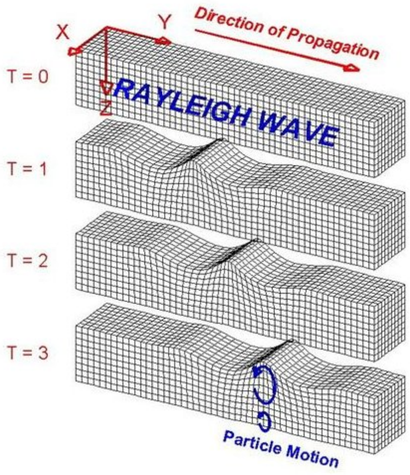
Body Primary (P) Waves



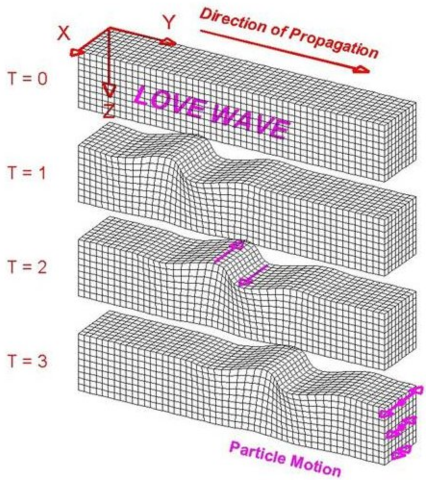
Body Secondary (S) Waves



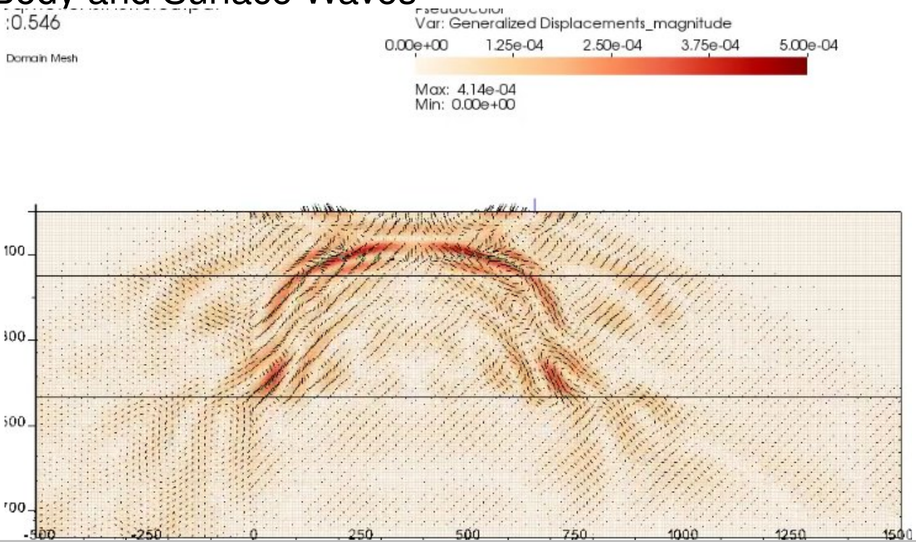
Surface Rayleigh Waves



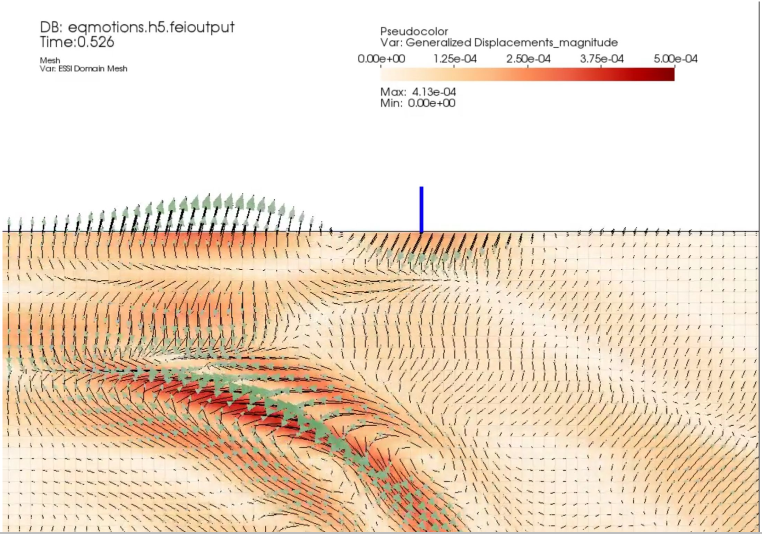
Surface Love Wave



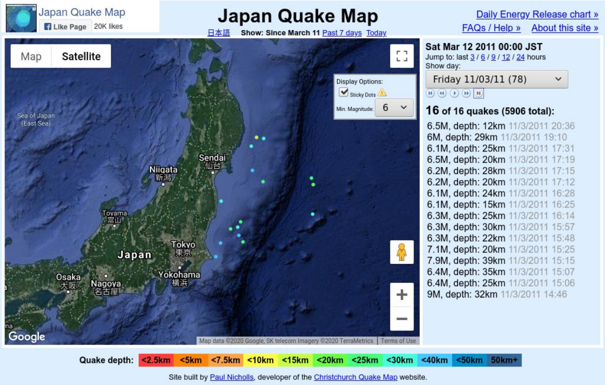
Body and Surface Waves



Zoom in on Motions



Tōhoku Earthquake Slip Sequence



http://www.japanquakemap.com/

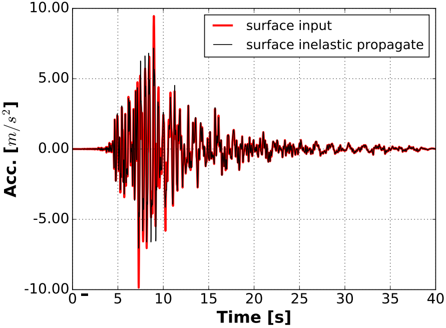
Spatial Variability, Incoherence, Lack of Correlation

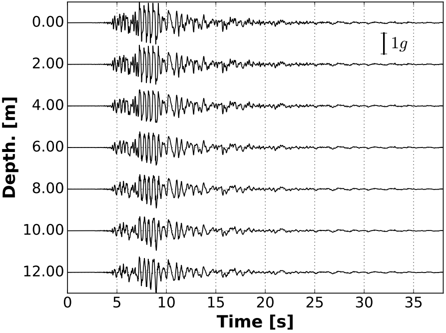
Incoherence $\rightarrow$ frequency domain

Lack of Correlation $\rightarrow$ time domain

- Attenuation effects
- Wave passage effects
- Extended source effects
- Scattering effects
- Variable seismic energy dissipation

1C, 1D Wave Propagation





Seismic Risk Analysis (SRA)

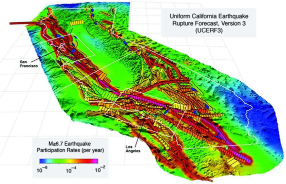
- Intensity measure (IM) selected as a proxy for ground motions, usually Spectral acceleration $Sa(T_0)$
- Ground Motion Prediction Equations (GMPEs) need development, ergodic or site specific
- Probabilistic seismic hazard analysis (PSHA)
- Fragility analysis $P(EDP > x | IM = z)$, deterministic time domain FEM, Monte Carlo (MC)

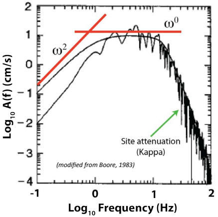
Seismic Risk Analysis Challenges

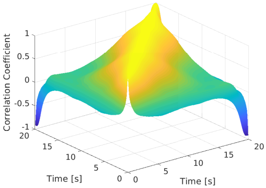
- Miscommunication between seismologists and structural engineers, $Sa(T_0)$ not compatible with nonlinear FEM
- IMs difficult to choose, Spectral Acc, PGA, PGV...
- Single IM does not contain all/most uncertainty
- Monte Carlo, not accurate enough for tails
- Monte Carlo, computationally expensive, CyberShake for LA, 20,000 cases, 100y runtime, (Maechling et al. 2007)

Stochastic Seismic Motion Development

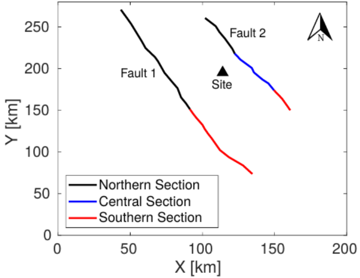
- UCERF3 (Field et al. 2014)
- Stochastic motions (Boore 2003)
- Polynomial Chaos Karhunen-Loève expansion
- Domain Reduction Method for P_{eff} (Bielak et al. 2003)



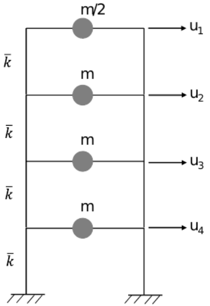




Uncertain Model Description



(a) Faults configuration



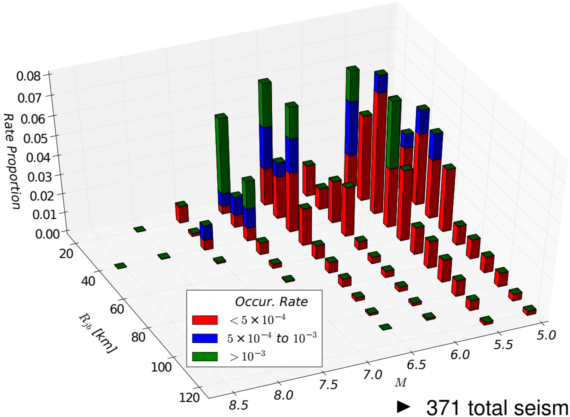
(b) Building structure

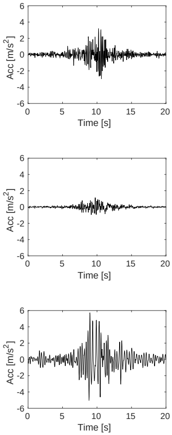
$$Cov_k = \begin{bmatrix} 1.0 & 0.6 & 0.3 & 0.2 \\ 0.6 & 1.0 & 0.5 & 0.2 \\ 0.3 & 0.5 & 1.0 & 0.7 \\ 0.2 & 0.2 & 0.7 & 1.0 \end{bmatrix}$$

- Fault 1: San Gregorio fault
- Fault 2: Calaveras fault
- Uncertainty: Segmentation, slip rate, rupture geometry, etc.

- $Vs_{30} = 620m/s$
- $m = 100kips/g$
- $\overline{k} = 168kip/in$

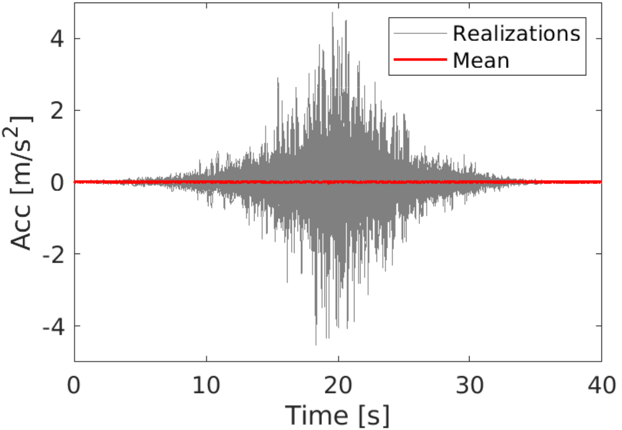
Seismic Source Characterization





- 371 total seismic scenarios
- M 5 $\sim$ 5.5 and 6.5 $\sim$ 7.0
- R_{jb} 20km $\sim$ 40km

Stochastic Ground Motion Realizations



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Summary

- Importance of using realistic seismic motions!

- Reduce modeling uncertainty

- Propagate parametric uncertainty