Numerical Simulation of the Impact of Regional Geology on the Structural Response

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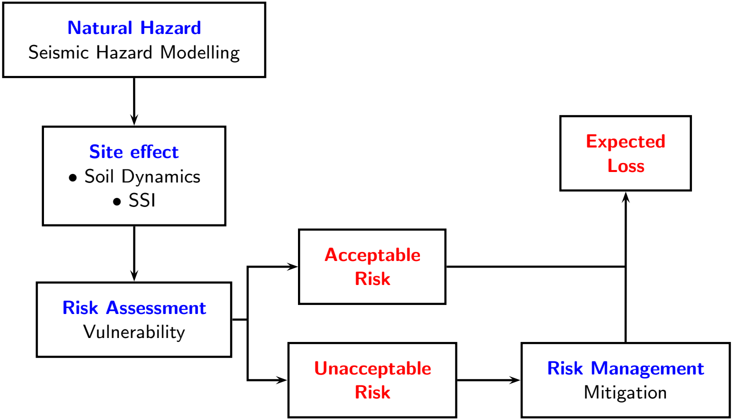
UMR 8579

Earthquake loss estimation



Holistic approach

- Need for understanding mechanisms controlling induced damage in earthquake loss estimation (e.g. soil foundation, structures, dams, . . .) ;
- Improve and validate traditional approaches and evaluation methods ;
- Take into account the non linear soil behaviour ;
- Use of numerical methods in order to facilitate the comprehension of the global problem via parametric analyses ;

- *Estimation of seismic safety of strategic facilities ;*
- *Various uncertainties on the material properties, loading parameters and scenarios will be considered ;*
- *Computer models can be computationally expensive $\rightarrow$ surrogate models, response surface models, meta-models, emulators . . . ;*

Points to develop

Physics-Based 3D ground motion simulation

3-D Simulation of NCOEQ2007 aftershocks

SSI coupling

Points to develop

Physics-Based 3D ground motion simulation

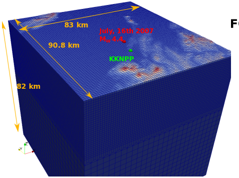
3-D Simulation of NCOEQ2007 aftershocks

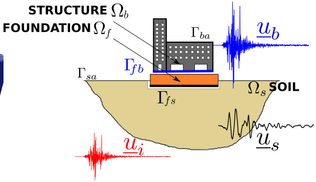
SSI coupling

Physics-Based 3D ground motion simulation

We want to simulate

- 3D - regional scale (10 - 100 km)
- Engineering frequencies (0.1 - 15 Hz)



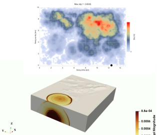


We need

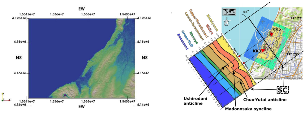
- Computational power
- Simulation code suited to massive parallel architectures
- Details on the seismological and geological scenarios.
- Coupling with a NL numerical code.

SINAPS@ project - SEM3D

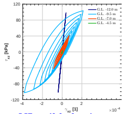
3D simulation of source to structure earthquake scenario



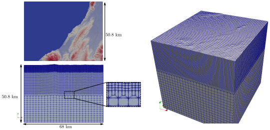
Seismic sources



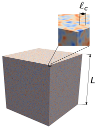
Topography, bathymetry and geology



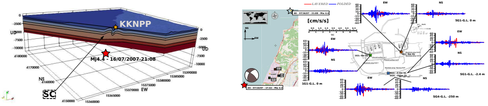
NL soil behaviour



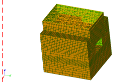
Meshing tool for large scale realistic media



Random field generation



Spectral Element Method for 3D elastodynamics



SSI
(SEM+BEM+FEM)

3D simulation of source-to-site earthquake scenario - SINAPS@ (ANR-11-RSNR-0022-04)

Points to develop

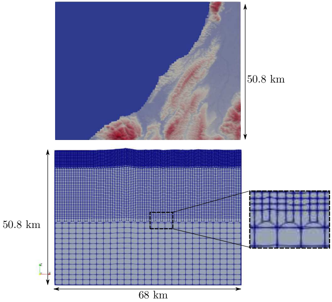
Physics-Based 3D ground motion simulation

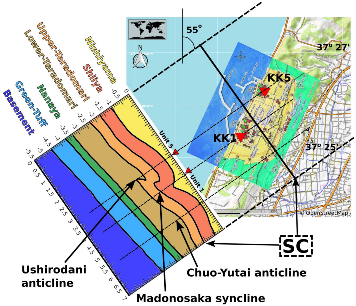
3-D Simulation of NCOEQ2007 aftershocks

SSI coupling

2007 Niigata earthquake

Coupling regional model with local geological structures (Gatti et al. 2018)



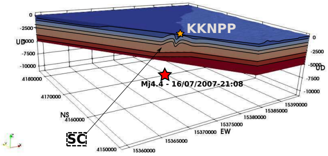


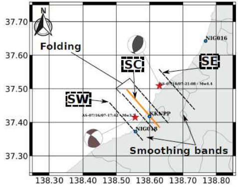
Mesh size : 48 km×48 km×22.5 km.
Min. Element size : 80 m×80 m×80 m
♯Elements : ≈4e6
♯DOFs : ≈1.5e9
$V_{S,min}$=700 m/s (Nishiyama)
f_{max} = 5 Hz

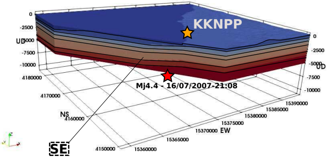
Tsuda et al. (2011) geological model

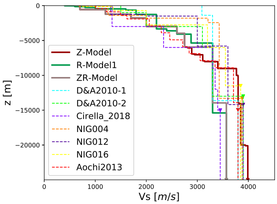
2007 Niigata earthquake

Improved geological model : from 1D to 3D structure (Gatti et al. 2018)



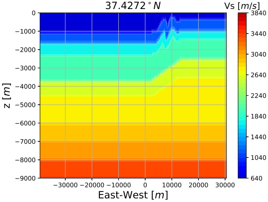


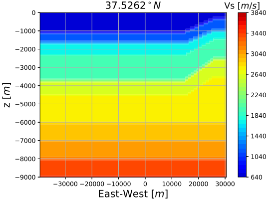


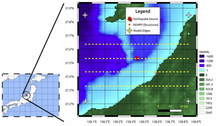


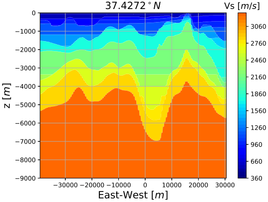
2007 Niigata earthquake

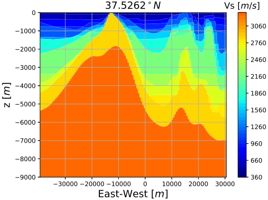
Improved geological model : from 3D structure (Castro-Cruz et al., 2021)











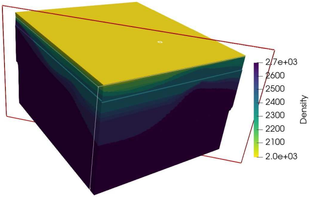
Watanabe et al. (2009)
Tsuda et al. (2011)
Z model

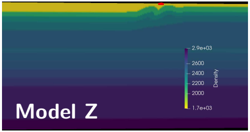
Sekiguchi et al. (2009)
Geological Survey of Japan
R model

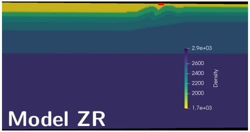
KKNPP Description

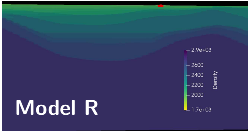
Regional Geology

- → Model Z - Folding
- → Model ZR - Intermediate
  - → Depth - Model R
  - → Surface - Model Z
- → Model R - GSJ



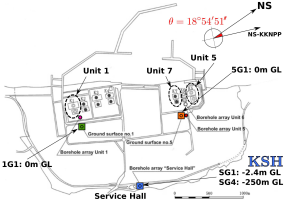


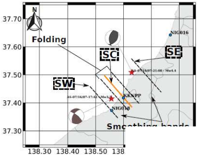


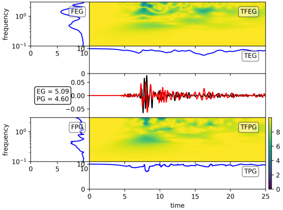


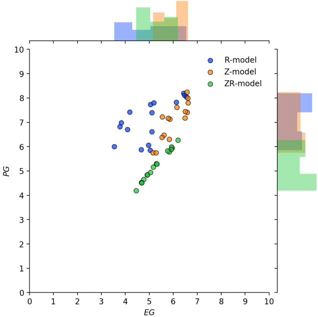
2007 Niigata earthquake

Model validation - Aftershock EQ1 M_w=4.4 - f_{max}=5 Hz









2007 Niigata earthquake

Model response - Aftershock EQ1 M_w=4.4 - f_{max}=7 Hz

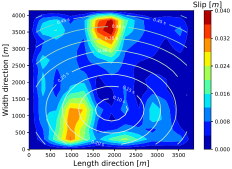
Kinematic source (RIK model)

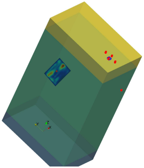
Ruiz et al. (2011) and Gallovic (2015)

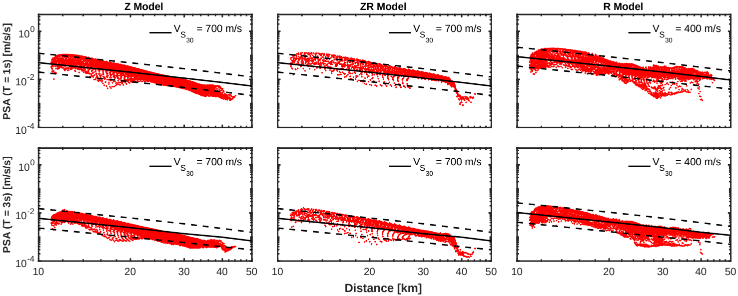
Depth = 11 km

Strike, Rake, Dip = 187°, 70°, 54°

$M_0^{max} = 46.3 \cdot 10^{14}$ **Nm**







Points to develop

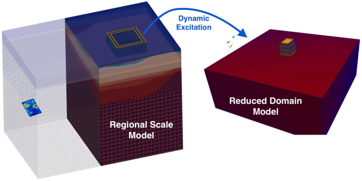
Physics-Based 3D ground motion simulation

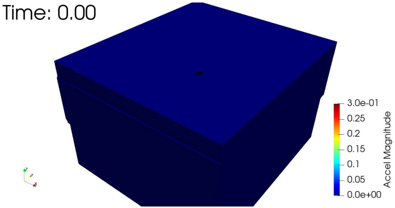
3-D Simulation of NCOEQ2007 aftershocks

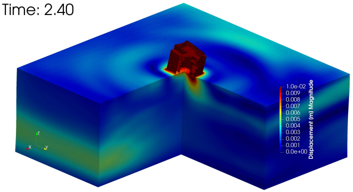
SSI coupling

2007 Niigata earthquake

Kashiwazaki-Kariwa NPP (Japan) - DRM coupling (SEM-FEM)







Korres et al. (2021)

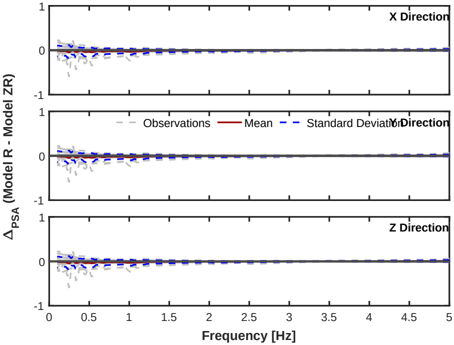
Impact of regional geology

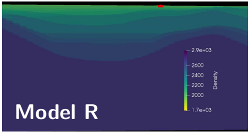
Model Response - Close to the fault

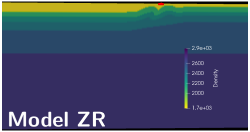
12 kinematic sources (RIK model)

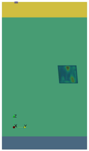
Frequency band : 0.1 - 7 Hz

$\Delta_{es} = \ln(IM_R) - \ln(IM_{ZR}),\ IM = PSA(f)$









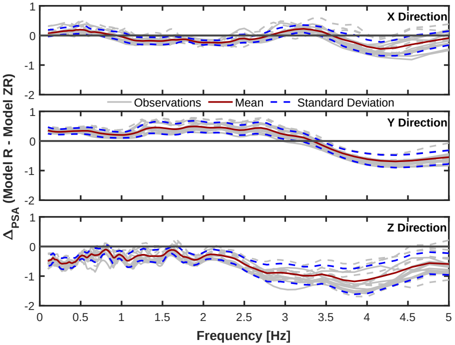
Impact of regional geology

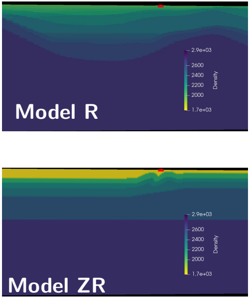
Model Response - Top of the structure

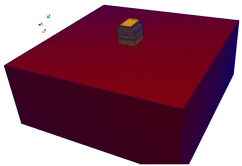
12 kinematic sources (RIK model)

Frequency band : 0.1 - 7 Hz

$\Delta_{es} = \ln(IM_R) - \ln(IM_{ZR}),\ IM = PSA(f)$







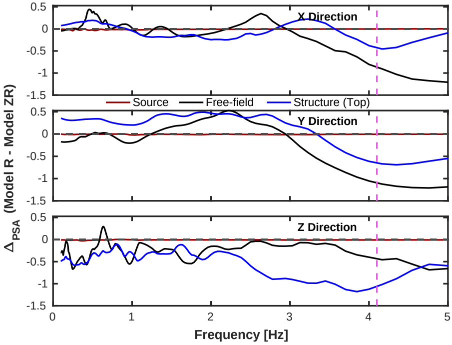
Impact of regional geology

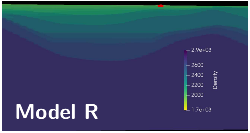
Model Response - Mean values

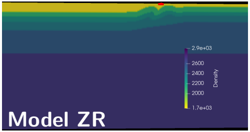
12 kinematic sources (RIK model)

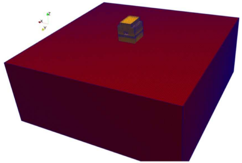
Frequency band : 0.1 - 7 Hz

$\Delta_{es} = \ln(IM_R) - \ln(IM_{ZR}), \; IM = PSA(f)$









Partial Conclusions

some key points :

- The sensitivity analyses showed that **regional complexity and folding (ZR model) have an impact after 2 or 3 Hz** ;
- For vertical component, the response seems to be controlled principally by **the regional complexity (R model)** ;
- The presence of building **reduces the effect of the folding (ZR model) on the obtained horizontal responses** at the top of the structure ;
- The presence of building **increases the effect of the folding (ZR model) on the obtained vertical responses** at the top of the structure.
- The next step is to assess the effect of different source positions and to increase the frequency range.

Thank you for your attention