



EARTHQUAKE AND NUCLEAR PLANT -  
IMPROVING AND SUSTAINING SAFETY

# Numerical simulations of ground motion performed on the Cephalonia test-site

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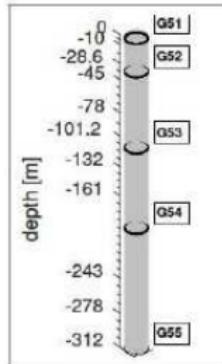


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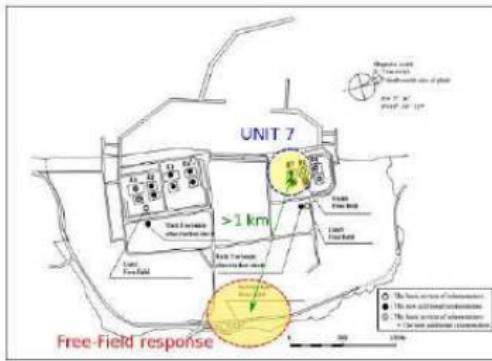


# Context

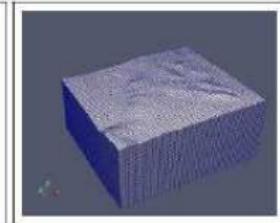
Goal : Numerical simulation of a seismic scenario at regional scale



1D analysis  
BOREHOLE  
 $\approx 100$  m



2D site analysis  
SITE  
 $\approx 1$  km



3D site analysis  
REGION  
 $\approx 10$  km

Issues : Predict ground motion for new scenarios

# Context

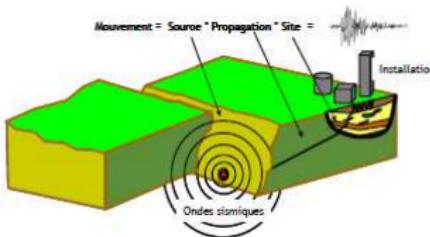
**Goal : Numerical simulation of a seismic scenario at regional scale**

**We need :**

Studied site

Geological model

Numerical tools : verified and validated  
computational resources

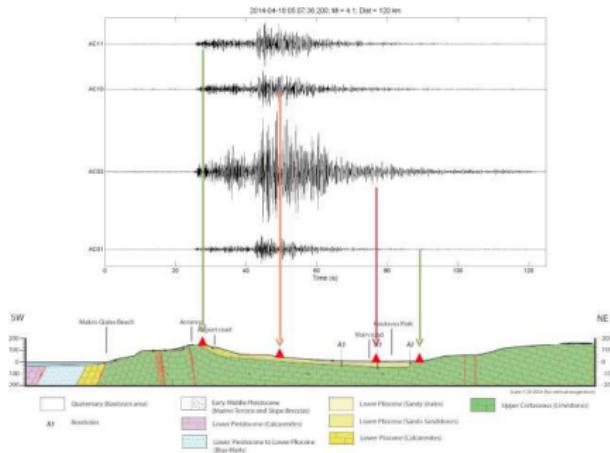
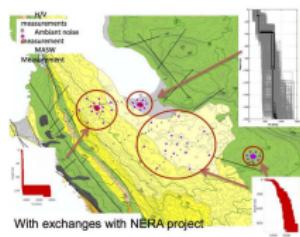


# Context

What is the effect of :

- ▶ Seismic source
- ▶ Non-linear behaviour
- ▶ Topography and bathymetry
- ▶ Material heterogeneities

on the ground motion prediction



# Outline

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- ▶ SEM3D code verification
- ▶ Sedimentary basin modelling
- ▶ Topography and Bathymetry effects
- ▶ Comparison with recorded data

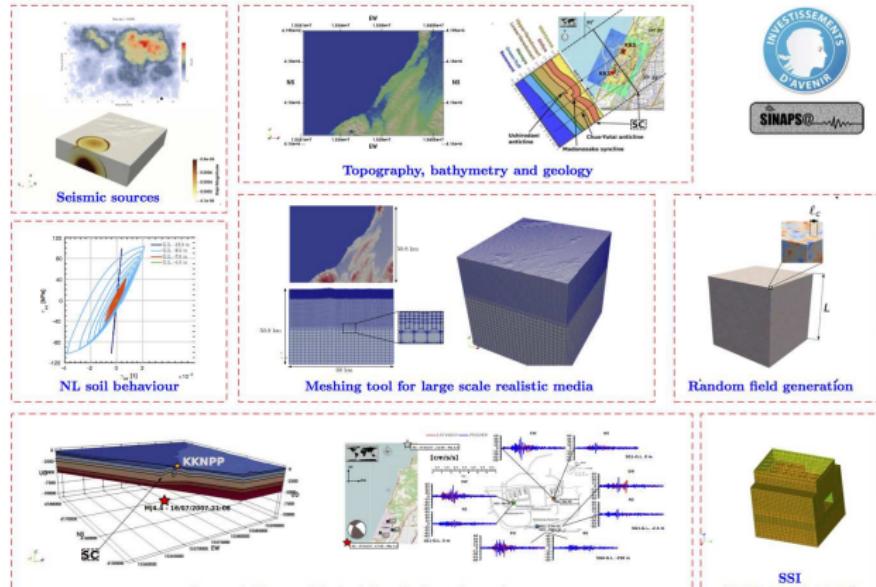
## Spectral Element Method for 3D elastodynamics

**SEM 3D** [Maday & Patera, 1988 ; Komatitsch et al., 2002 ; Cupillard et al., 2012]

Finite-Element method with high order (tensor) Lagrange polynomials with Gauss-Lobatto-Legendre (GLL) nodes

- ▶ Lagrange polynomials with GLL nodes  $\Rightarrow$  efficiency and low dispersion
  - ▶ Spectral convergence
  - ▶ Diagonal mass, explicit scheme
- ▶ 2D and 3D Solid or Fluid elastic linear medium
- ▶ Unstructured hexahedral mesh, Domain Decomposition
- ▶ Perfectly Matched Layers

# Model construction - Lego approach

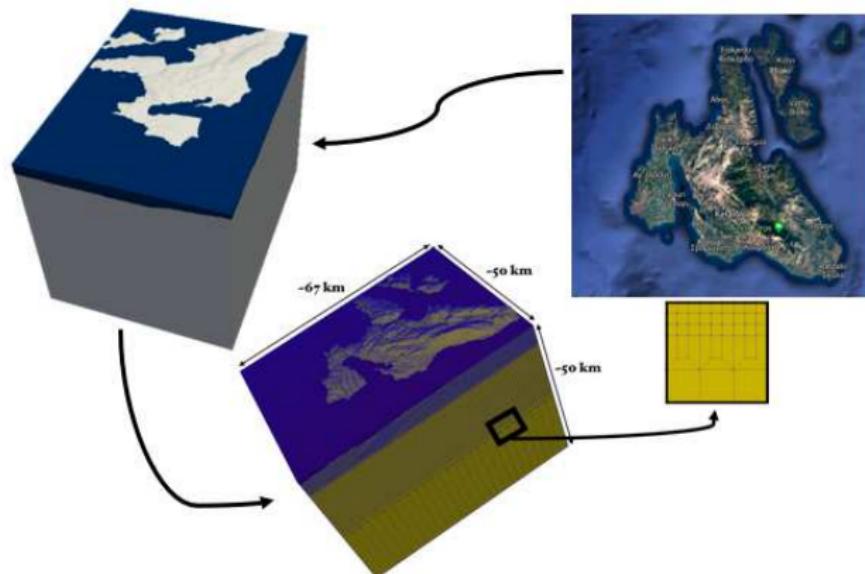


3D simulation of source-to-site earthquake scenario - SINAPS@ (ANR-11-RSNR-0022-04)

# Mesh construction

Extrude topography/bathymetry model

Zone selection (google maps)

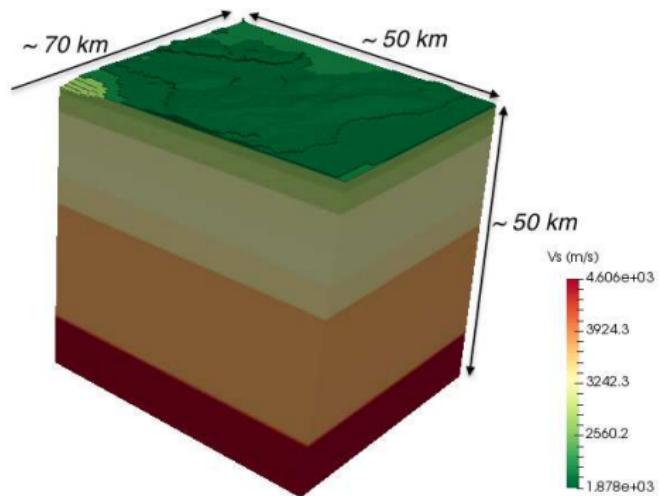
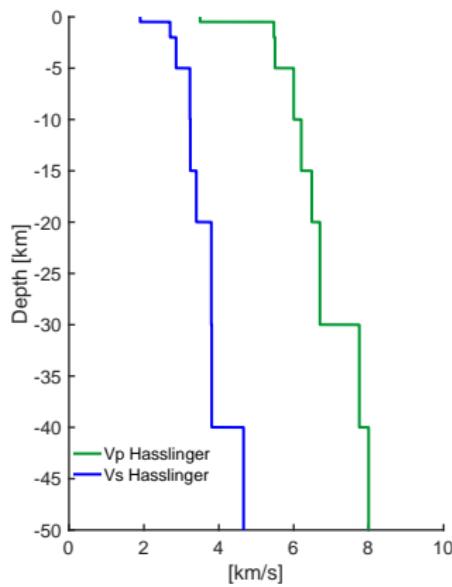


[L. De Abreu Correa]

Mesh more refined at top

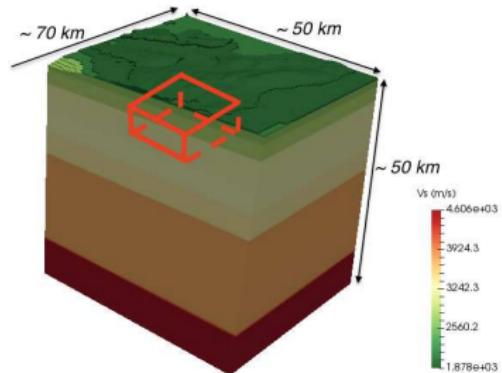
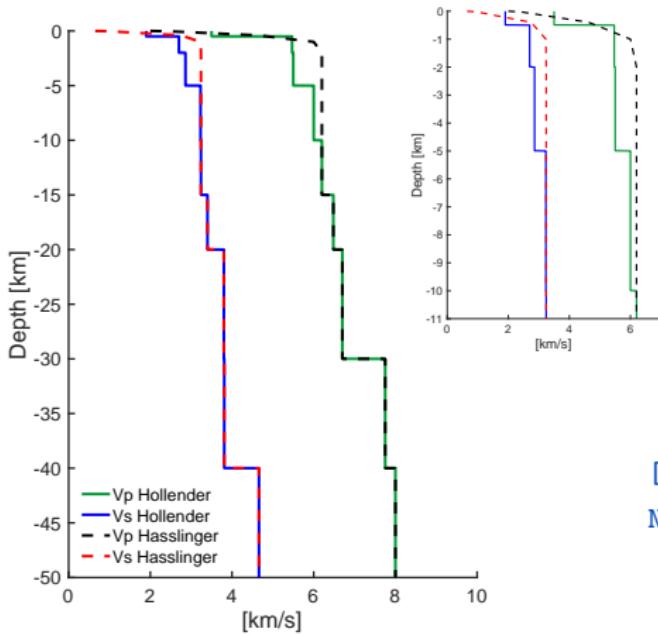
# Crustal model

Low frequencies  $\sim 1\text{Hz}$



[Haslinger et al. 1999]

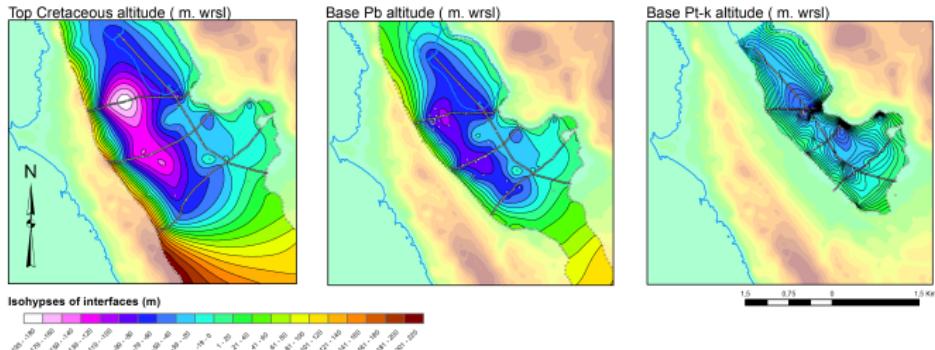
# Shallow and local model



[Hollender et al., 2015] SINAPS@ & NERA project

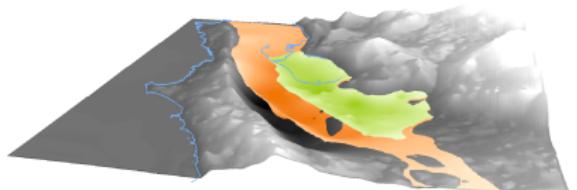
No local effects

# Refined geological model



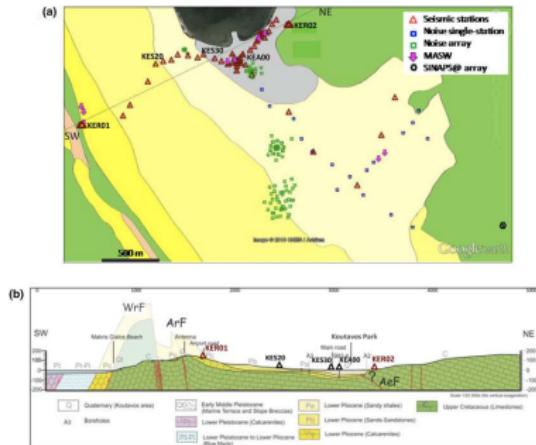
Taking into account the geological characteristics of the site : More refined model

[Cushing et al., in prep.]

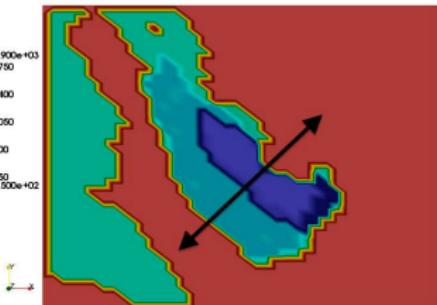


# Refined geological model

## Site model

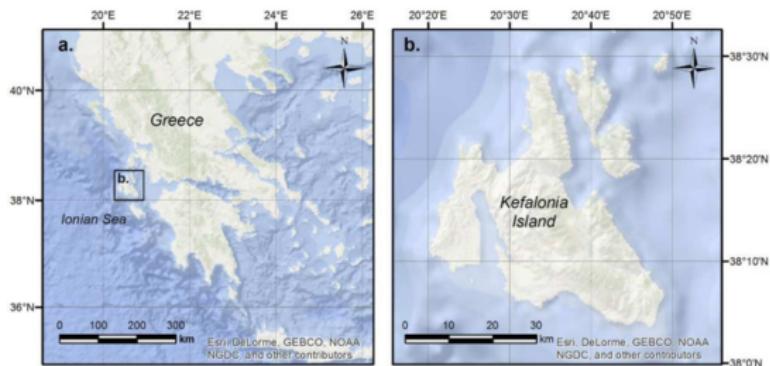


## Numerical model

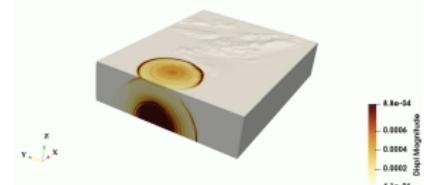


**no mesh compatible approach**

# Studied Earthquake Scenario

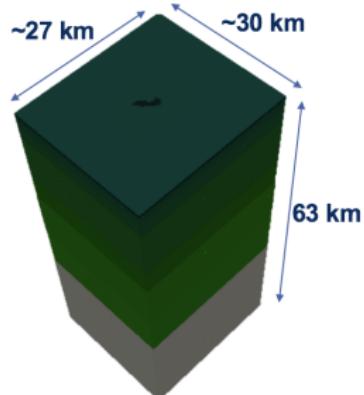
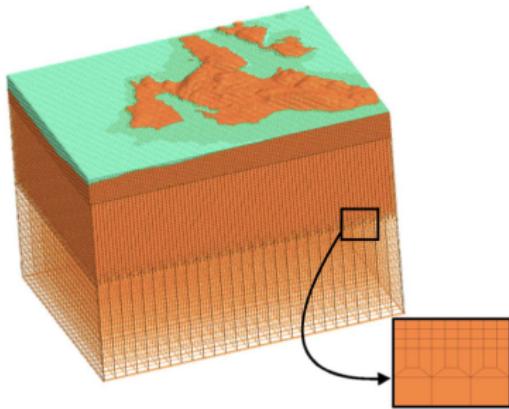


Magnitude : Mw4.6 with Strike=163°,  
 Dip=39°, Slip=92°  
 Point wise located at 14 km depth



<https://geofon.gfz-potsdam.de/data/alerts/2016/gfz2016kylx/mt.txt>

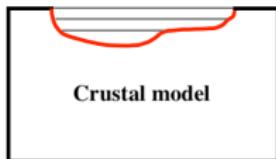
# Effect of local and global geology



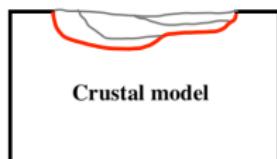
- ▶  $2.10^6$  Elements
- ▶ 216 proc
- ▶ 7 GLL
- ▶  $Vs_{min} : 1900$  m/s
- ▶  $Freq_{max} : 8$  Hz
- ▶  $9.10^5$  Elements
- ▶ 96 proc
- ▶ 7 GLL
- ▶  $Vs_{min} : 650$  m/s
- ▶  $Freq_{max} : 5$  Hz

# Effect of local geology

First parametric study - Importance of local basin geology



Basin V1

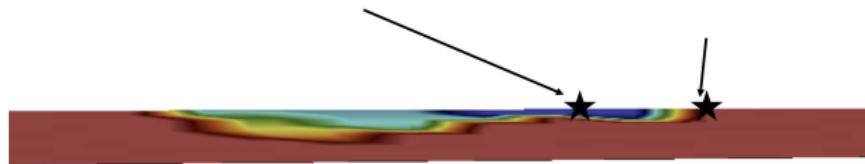
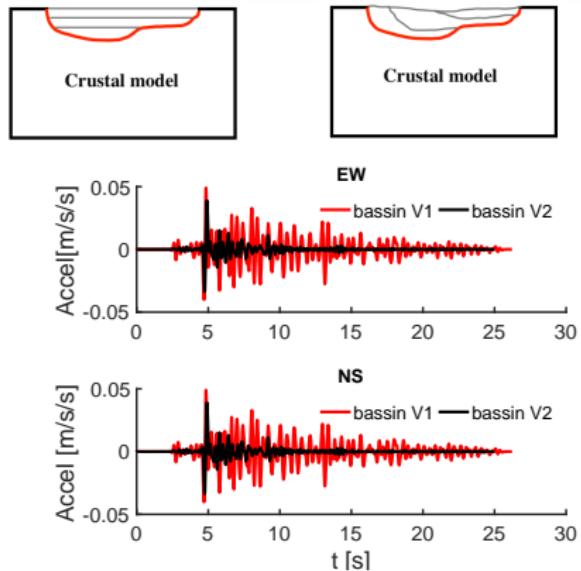
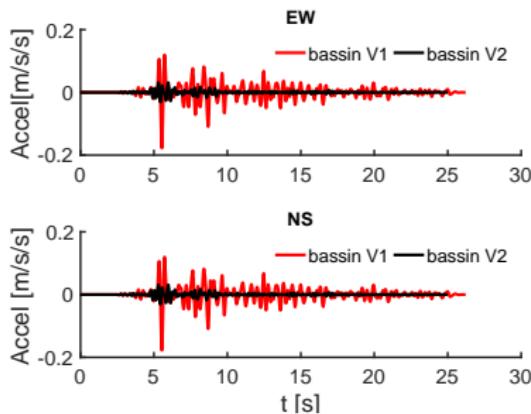


Basin V2

Pi|ar||ay

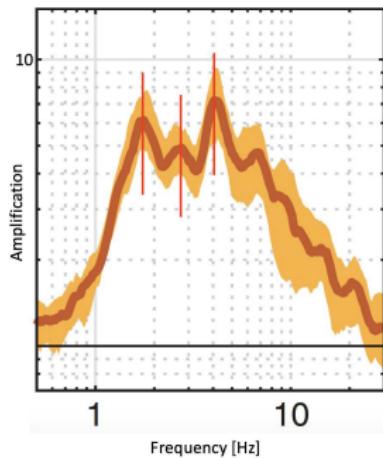
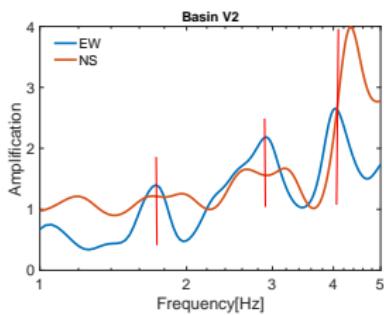
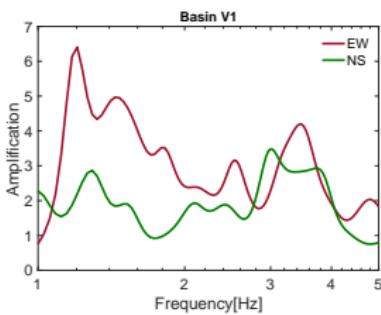
# Effect of local geology

## Acceleration

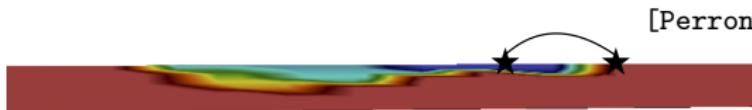


# Effect of local geology

## Amplification Function

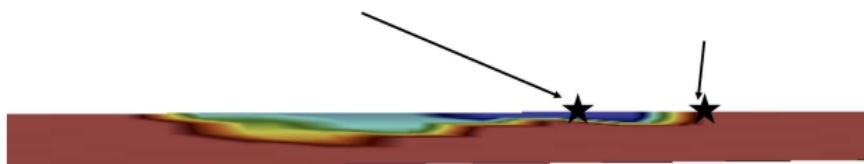
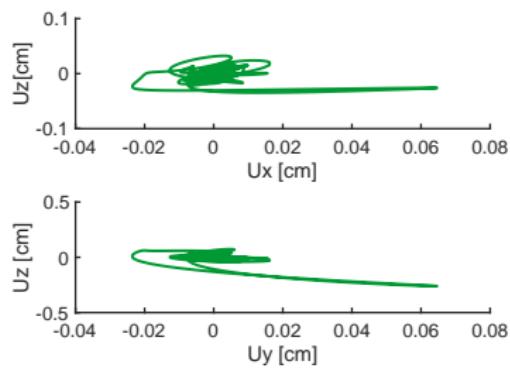
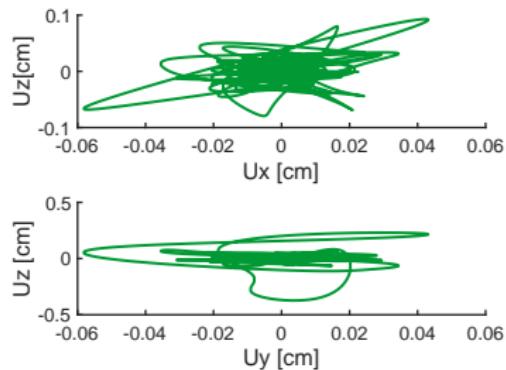


[Perron et al., 2018]



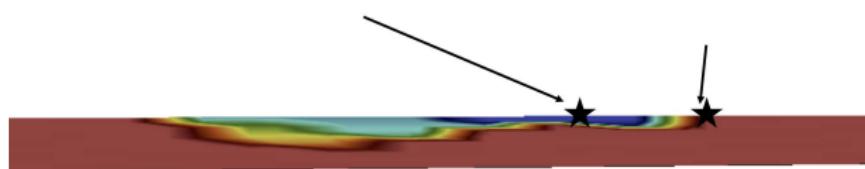
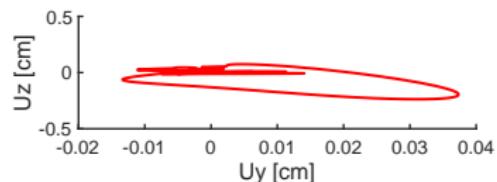
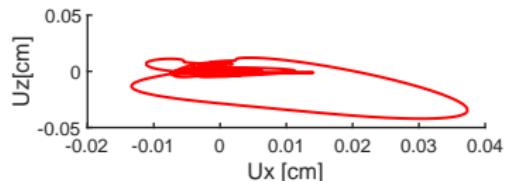
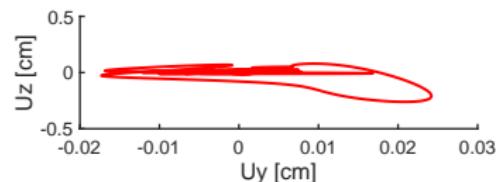
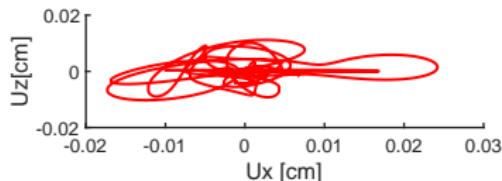
# Effect of local geology

## Point displacement - Bassin V1

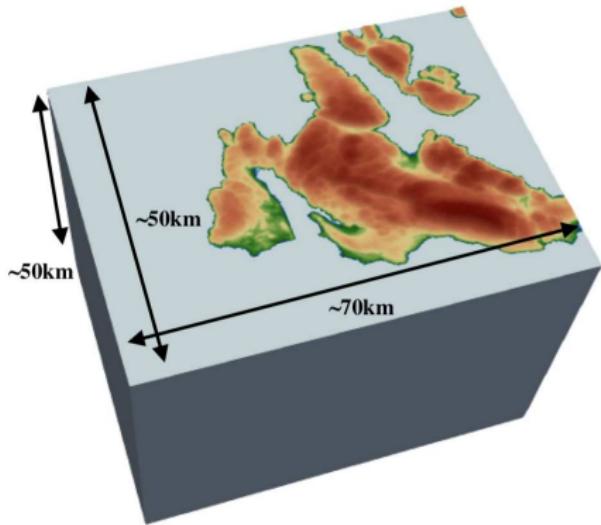


# Effect of local geology

## Point displacement - Bassin V2



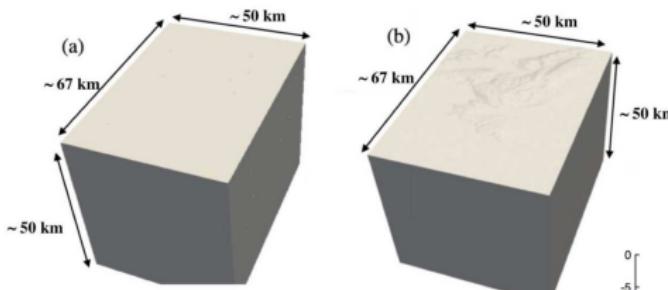
# Effect of Global geology



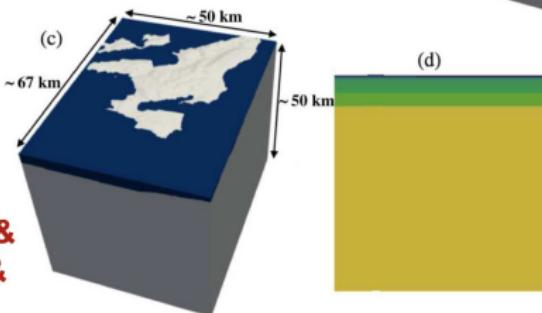
# Effect of Global geology

## Studied cases

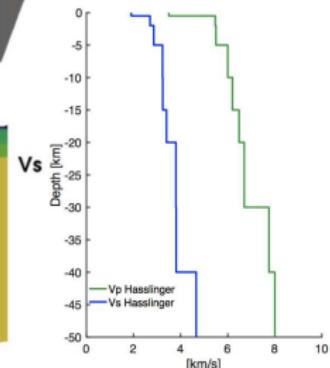
Flated model



Model including stratigraphy & topography & Bathymetry

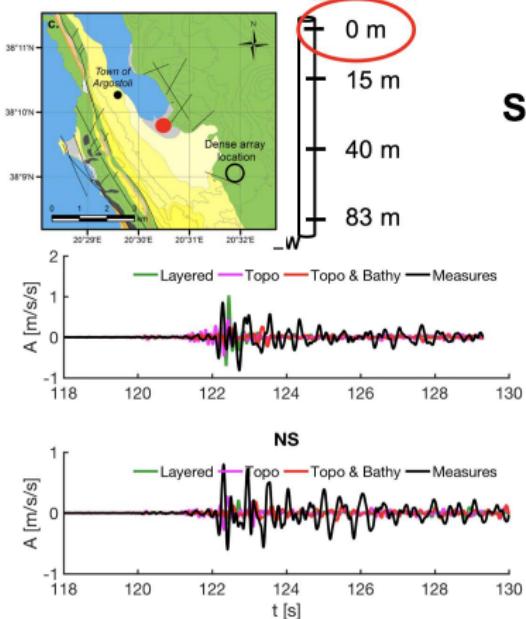


Model including stratigraphy & topography



# Effect of Global geology

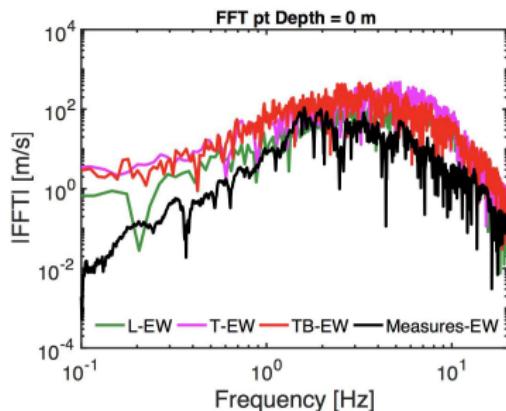
## Comparison with recorded data



Filtered at 8 Hz

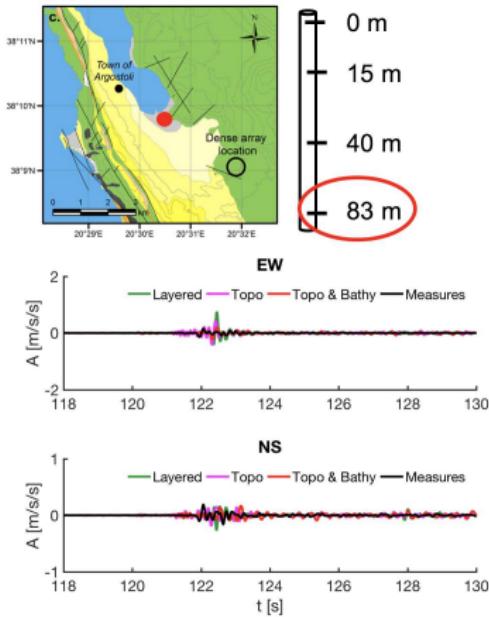
## Simulations vs Recorded Data

No basin effects



# Effect of Global geology

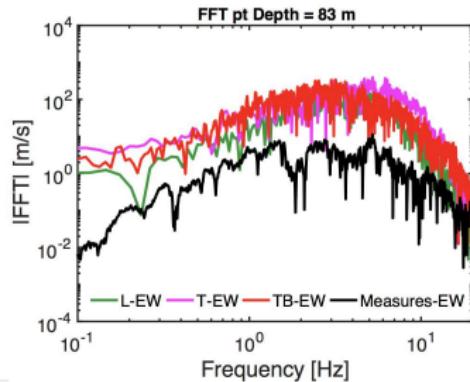
## Comparison with recorded data



Filtered at 8 Hz

## Simulations vs Recorded Data

No basin effects



# Conclusion and perspectives

- ▶ The study highlights the influence of the local geology and both topography and bathymetry.
- ▶ The presence of these structures in the studied site requires a specific analysis that takes into account both the 3D structure and the soil conditions in order to capture local effects that may be particularly disastrous.
- ▶ Next step :

