Evaluation of Ground Motion Numerical Simulation Relevance: Main Results of the EuroSeisTest Verification and Validation Project

HOLLENDER F.[1], ***CHALJUB E.***[2], ***MOCZO P.***[3], ***BARD P.-Y.***[2], ***MANAKOU M.***[4], ***BIELAK J.***[5], ***THEODULIDIS N.***[6], ***TSUNO S.***[2], ***PITILAKIS K.***[4], ***GELIS C.***[7], ***BONILLA F.***[7], ***et al. …***

[1] *CEA Cadarache, France,*
[2] *LGIT, Grenoble, France,*
[3] *Comenius University, Bratislava, Slovakia,*
[4] *AUTH, Thessaloniki, Greece,*
[5] *Carnegie Mellon University, Pittsburgh, USA,*
[6] *ITSAK, Thessaloniki, Greece,*
[7] *IRSN, Fontenay aux Roses, France,…*

E-2VP
EUROSEISTEST
VERIFICATION AND VALIDATION PROJECT

LGIT Grenoble

ARISTOTLE UNIVERSITY OF THESSALONIKI

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General framework and objectives

- Site effect evaluation = a major component of seismic hazard assessment

- Numerical simulation: "only" one of the several approaches to estimate site effects but it becomes important for:
  - low seismicity area (only few and weak earthquakes for a reasonable recording time)
  - non-linearity consideration

- Objective of the E2VP: to evaluate the reliability of ground motion numerical simulation in a real case, within the general framework of civil engineering design purposes

- E2VP: "natural" continuation of ESG2006 numerical benchmark (Grenoble basin simulation)

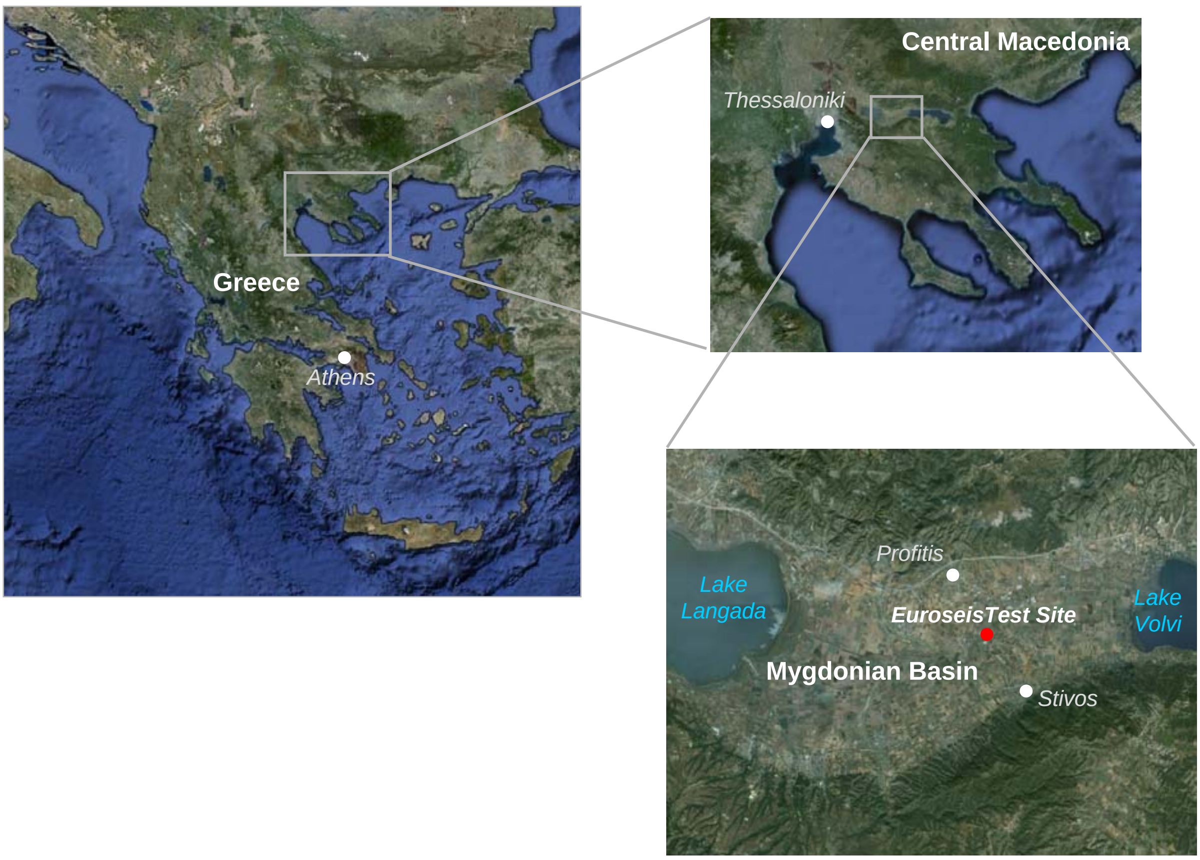
First step : to find the right site…

- The “ideal” site features:
  - a site where we could observe site effects (basin configuration)
  - good geological, geophysical, geotechnical knowledge of the site, if possible, a “3D geological model” already available
  - well instrumented site, where earthquakes (as strong as possible) were already recorded on a maximum of stations
  - ease to obtain, use and share the data (records, geological model…) within a broad collaborative project

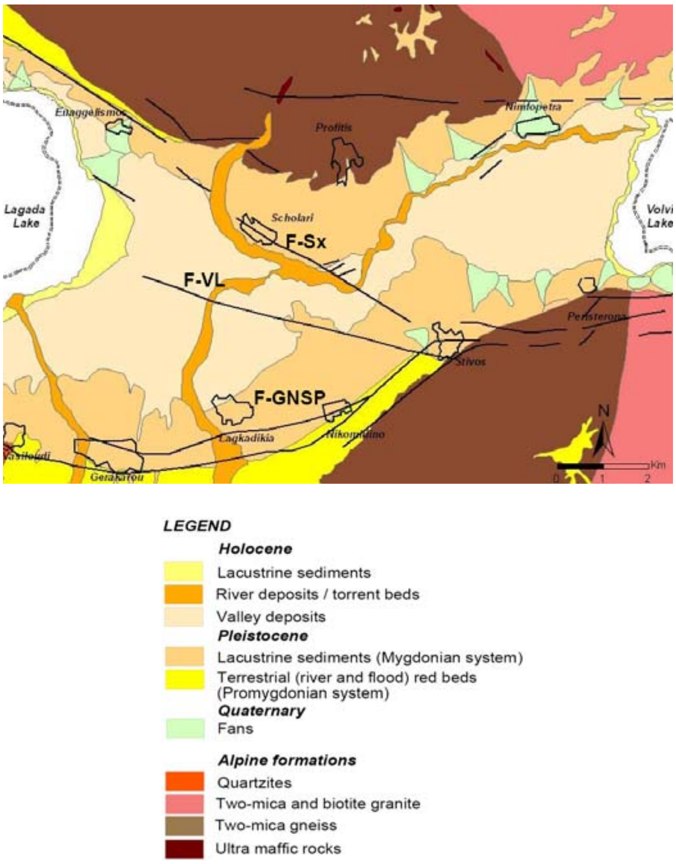
- How to find the best site:
  - an international “inquiry” (P.-Y. Bard):
    - a questionnaire send to almost 50 potential sites
    - ~ 20 responses
    - detailed comparison of 6 sites

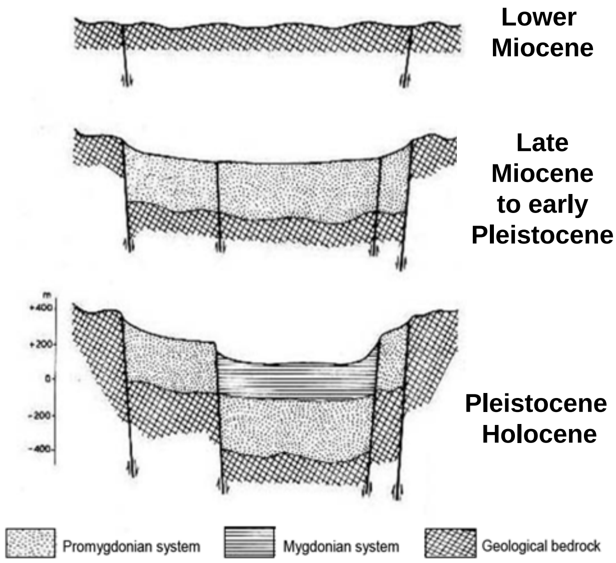
➔ ***selected site : EuroseisTest Site, near Thessaloniki, Greece***

The EuroseisTest Site



The EuroseisTest Site: geological context

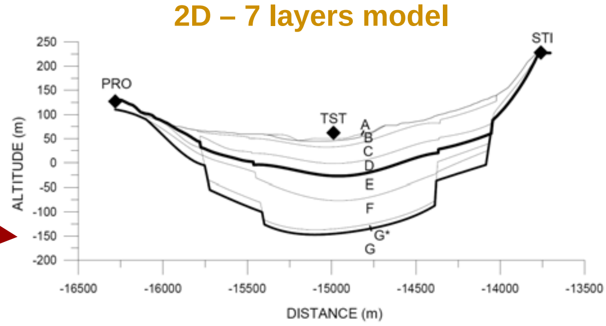




Geological, geophysical, geotechnical characterization

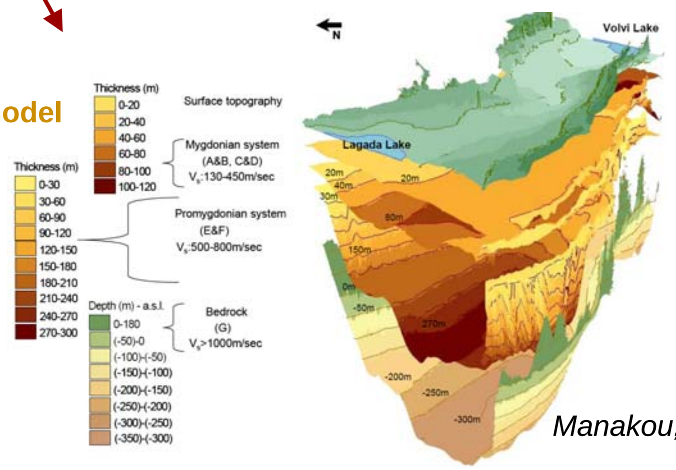
- A high characterisation effort:
  - boreholes
  - surface and boreholes seismic surveys
  - electric surveys
  - array microtremor measurements
  - H/V measurements
  - laboratory measurements on samples
  - etc.

2D – 7 layers model



Raptakis et al. 2000

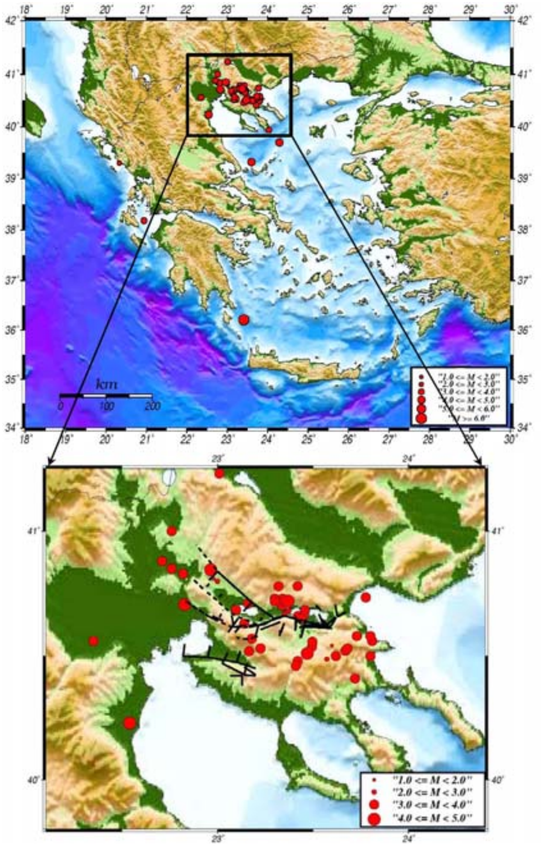
3D – 3 layers model



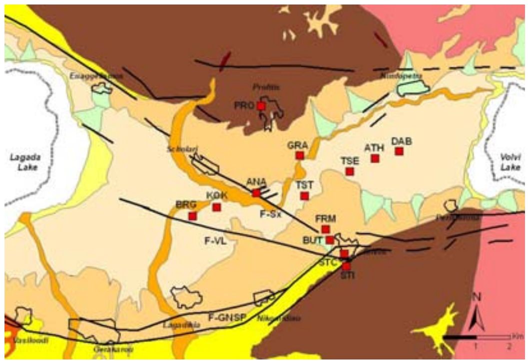
Manakou, 2007

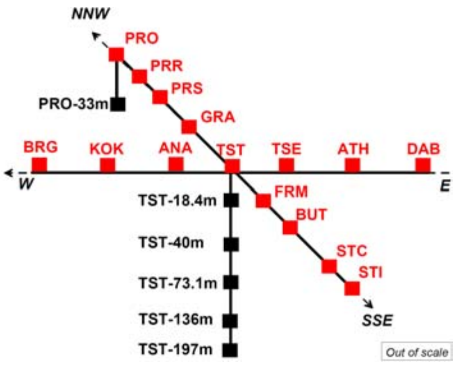
The EuroseisTest Site: instrumentation and records

~ 50 recorded earthquakes



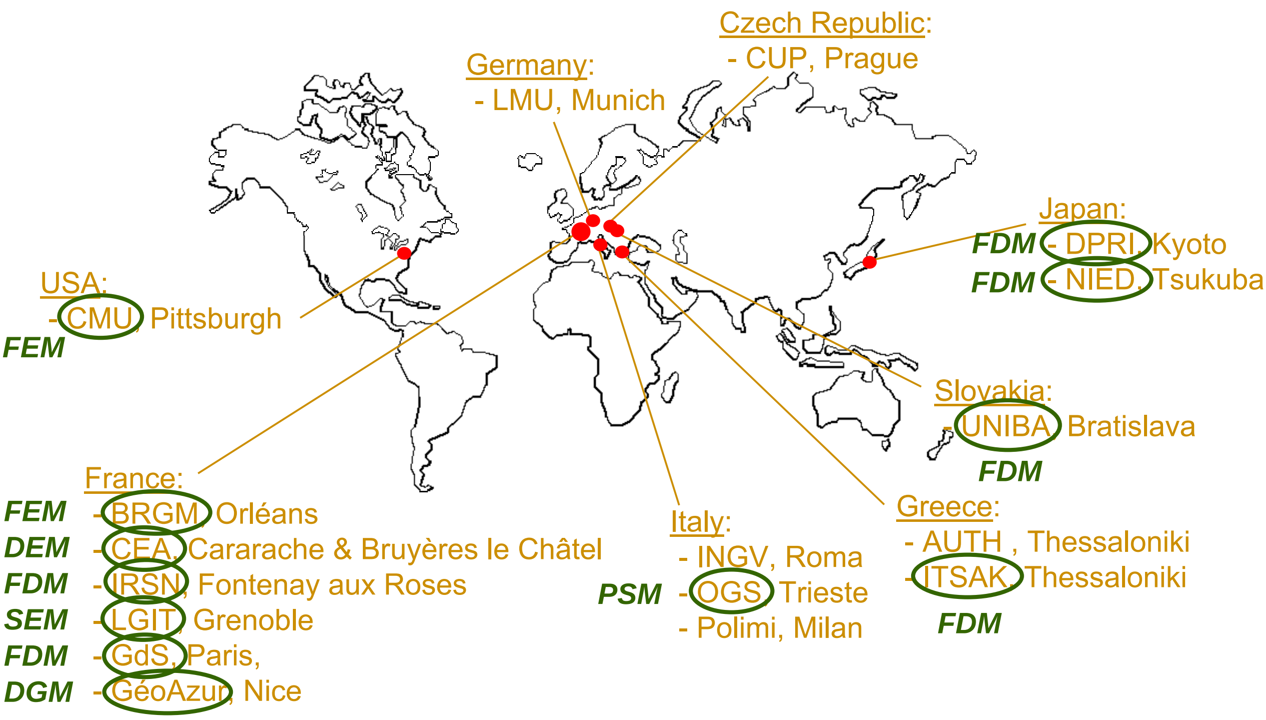
21 accelerometric stations





The "participating teams"

- Invitation were sent to most of known potentially interested teams.
  - 17 participating teams (Europe, USA, Japan)
  - 12 "modeling" team with 6 different numerical approaches



Organisation

- An “iterative” work with many interaction and discussion:
  - one “Kick-off Meeting” (may 2008)
  - 3 intermediate workshop (nov. 2008 – may 2009 – oct. 2009)
  - one final meeting (june 2010)
    - allow fruitful discussions
    - better iteration and convergence between results
    - a better definition of the needed computing cases of the following phase


« Kick-off », Cadarache (may 2008)


Workshop 3, Cadarache (oct. 2009)


Workshop 1, Grenoble (nov. 2008)


Workshop 2, Cadarache (may 2009)

Validation and Verification

- Verification: evaluating the accuracy of numerical methods when applied to realistic applications where no reference solution exists
  - compare the results of numerical simulation with each
  - allow the identification of implementation errors, meshing problems

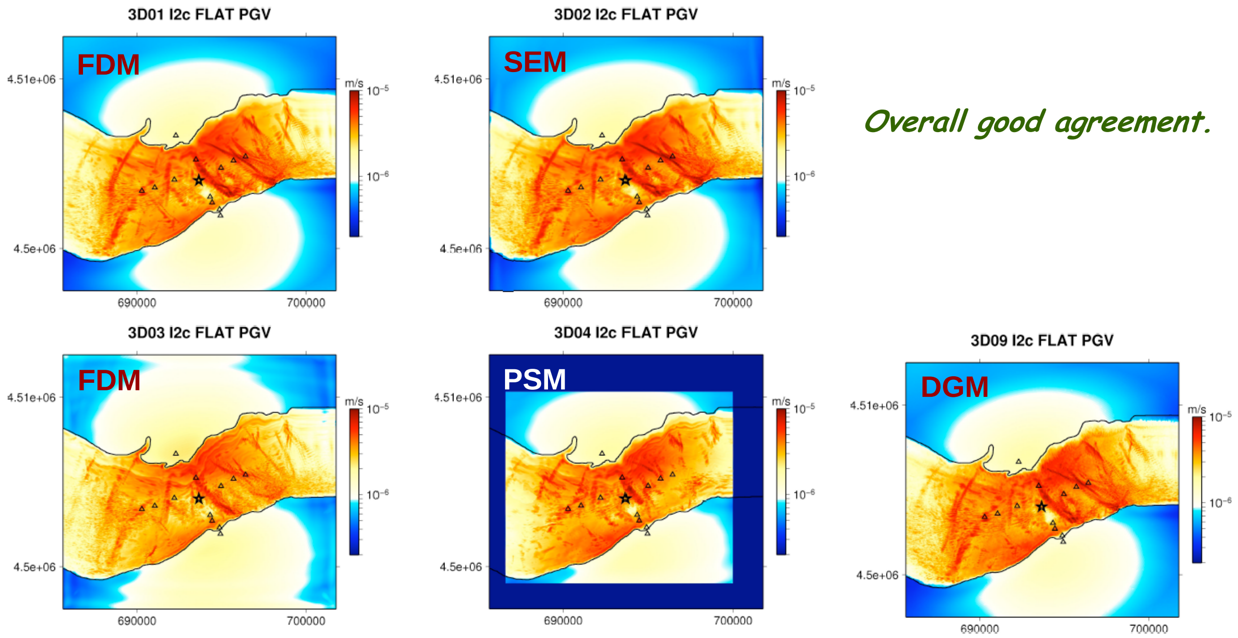
- Validation: quantifying the agreement between recorded and numerically simulated data
  - needs real field data
  - needs a site where the geological, geophysical, geotechnical characterization is good

Computing cases

- Verification:
  - 3D (up to 4 Hz):
    - pure elastic / visco-elastic (Q-factor)
    - 3 layers with homogenous properties / gradient based model
    - different excitation.
  - 2D (up to 10 Hz):
    - pure elastic / visco-elastic / "fully" non-linear,
    - 7 layers / 3 layers / gradient based model,
    - different excitation.
- Validation:
  - 3D (up to 4 Hz):
    - 6 different earthquakes (visco-elastic, 3 layers model).

Verification examples

3D – pure elastic computing, PGV maps

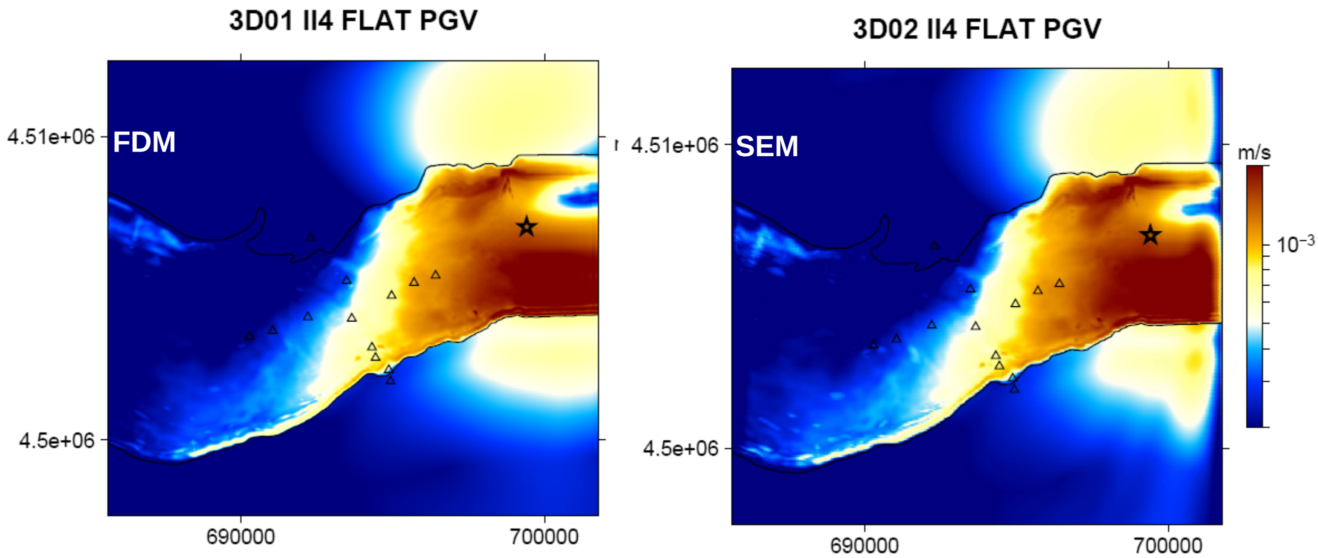


Overall good agreement.

➔ *For more information, see poster by Moczo et al.* ***(SH4/P26/ID33)***
Site Effects and Ground Motion in the Mygdonian Basin
Verification of the 3D Numerical Methods

Verification examples

- 3D – visco-elastic computing, PGV maps

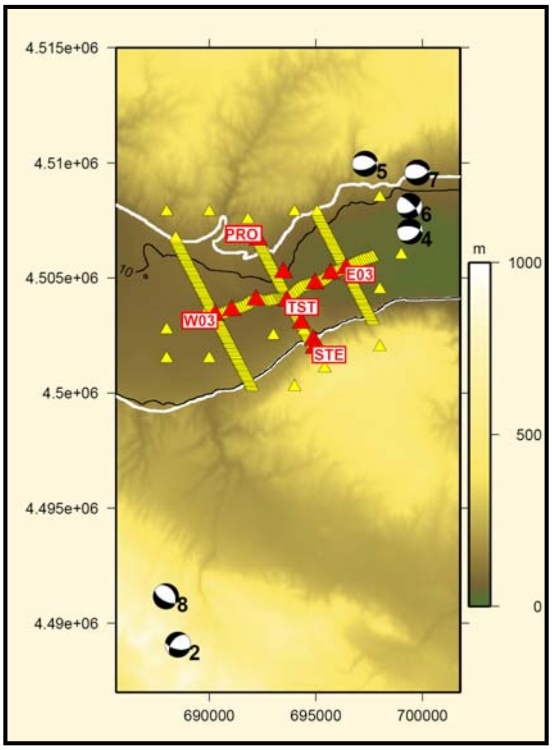


Very good agreement.

➔ *For more information, see poster by Moczo et al.* ***(SH4/P26/ID33)***
Site Effects and Ground Motion in the Mygdonian Basin
Verification of the 3D Numerical Methods

Validation : modelled earthquakes

- A selection of 6 earthquakes



Event #	Mag	Depth	Strike	Dip	Rake
2	2.8	6.9 km	100°	60°	-50°
4	4.4	5 km	53°	43°	-127°
5	3.1	6 km	72°	55°	-113°
6	3.9	6 km	61°	55°	-115°
7	3.4	5 km	72°	55°	-113°
8	3.8	10 km	329°	34°	-64°

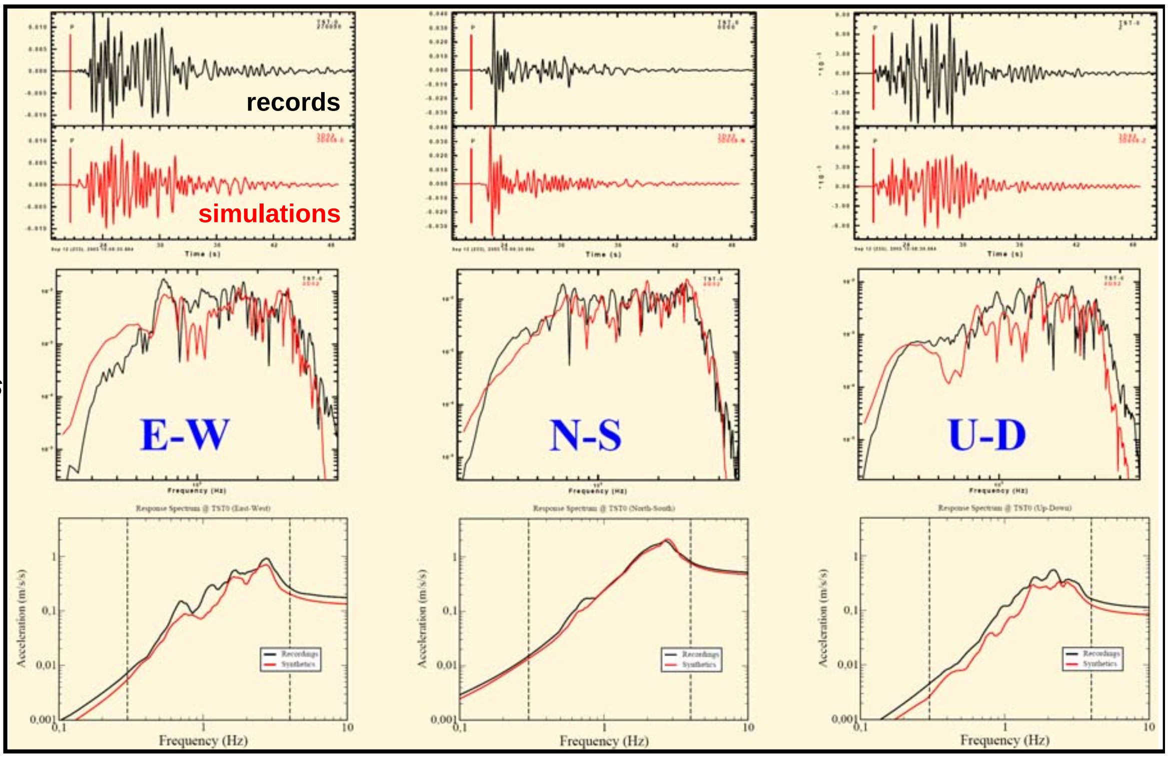
Validation : waveform and spectrum “visual” comparison

- Station TST – earthquake #4 (M = 4.4): a good agreement exemple

Time histories

Fourier transforms

Response spectra



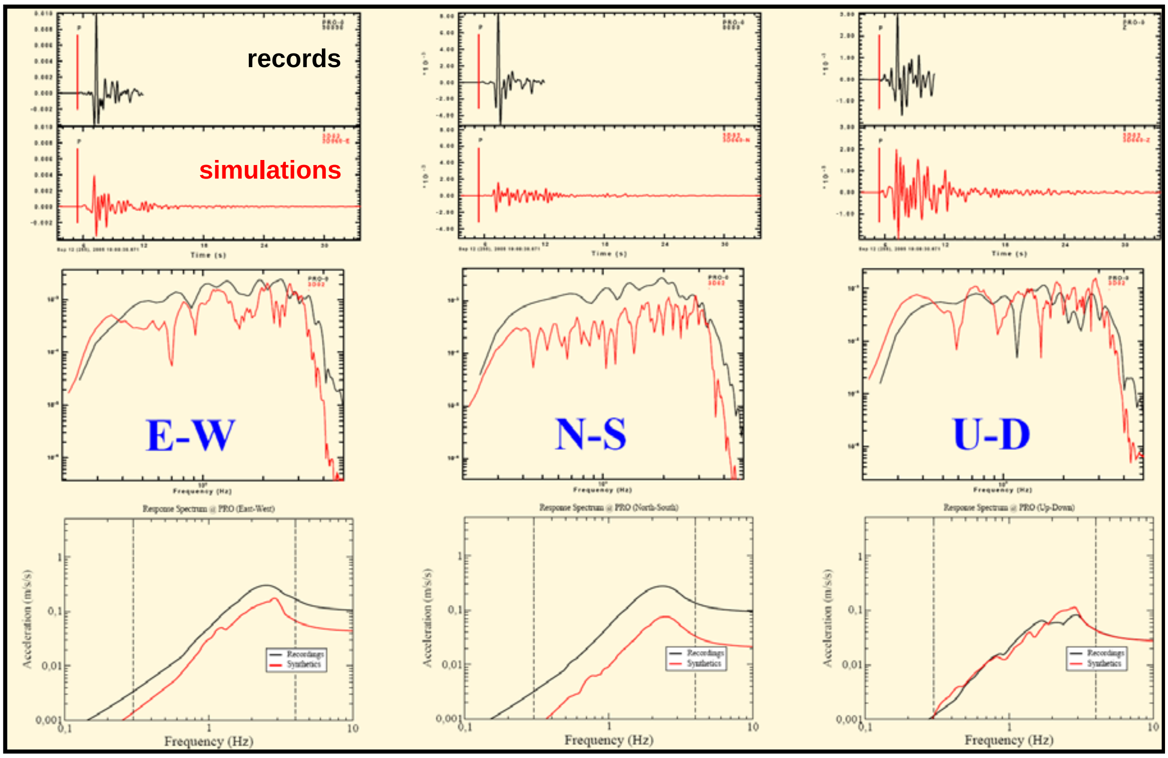
Validation : waveform and spectrum “visual” comparison

- Station PRO – earthquake #4 (M = 4.4): a perfectible agreement exemple

Time histories

Fourier transforms

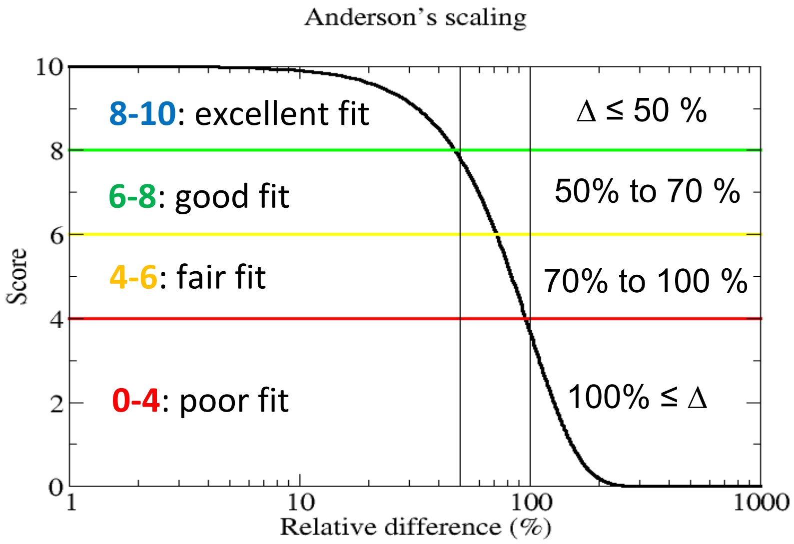
Response spectra



➔ *High amplitude differences on horizontal components.*

Anderson's goodness-of-fit criteria

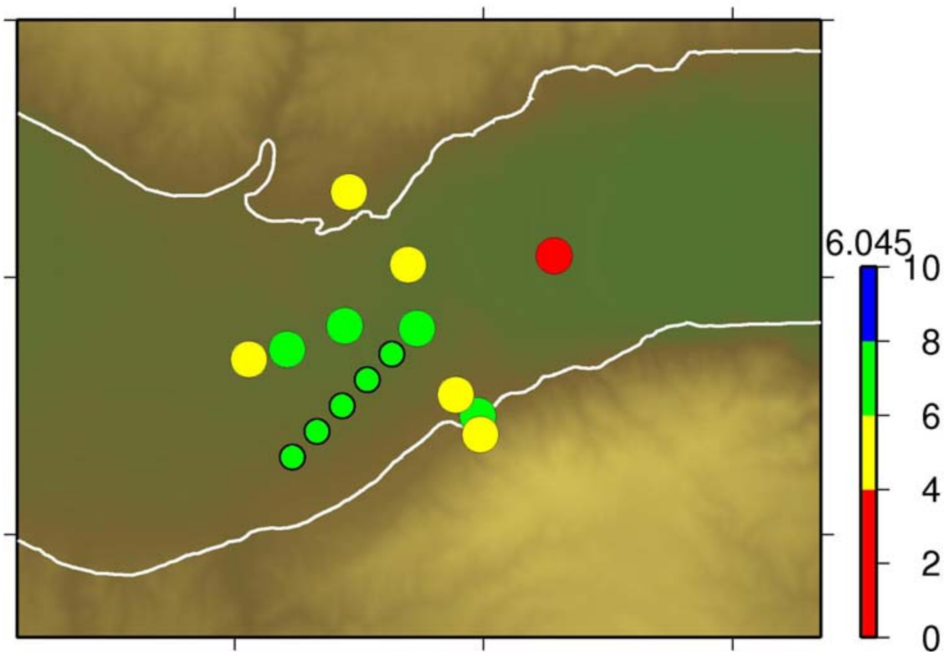
- Combinaison of 10 parameters (average of 3 components):
  - C1: Arias duration - Max(t)
  - C2: Energy duration - Max(t)
  - C3: Arias intensity
  - C4: Energy integral
  - C5: Peak acceleration
  - C6: Peak velocity
  - C7: Peak displacement
  - C8: Response spectra - Mean(f)
  - C9: Fourier spectra - Mean(f)
  - C10: Correlation coefficient



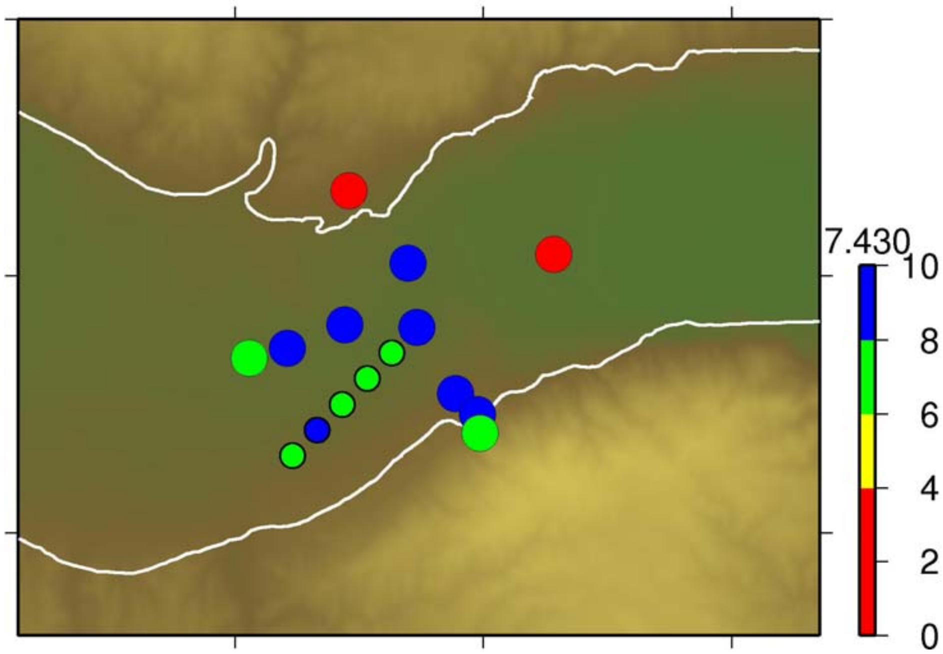
Each criterion is measured and scaled between 0 and 10:

Gof=10 Exp(-diff²)

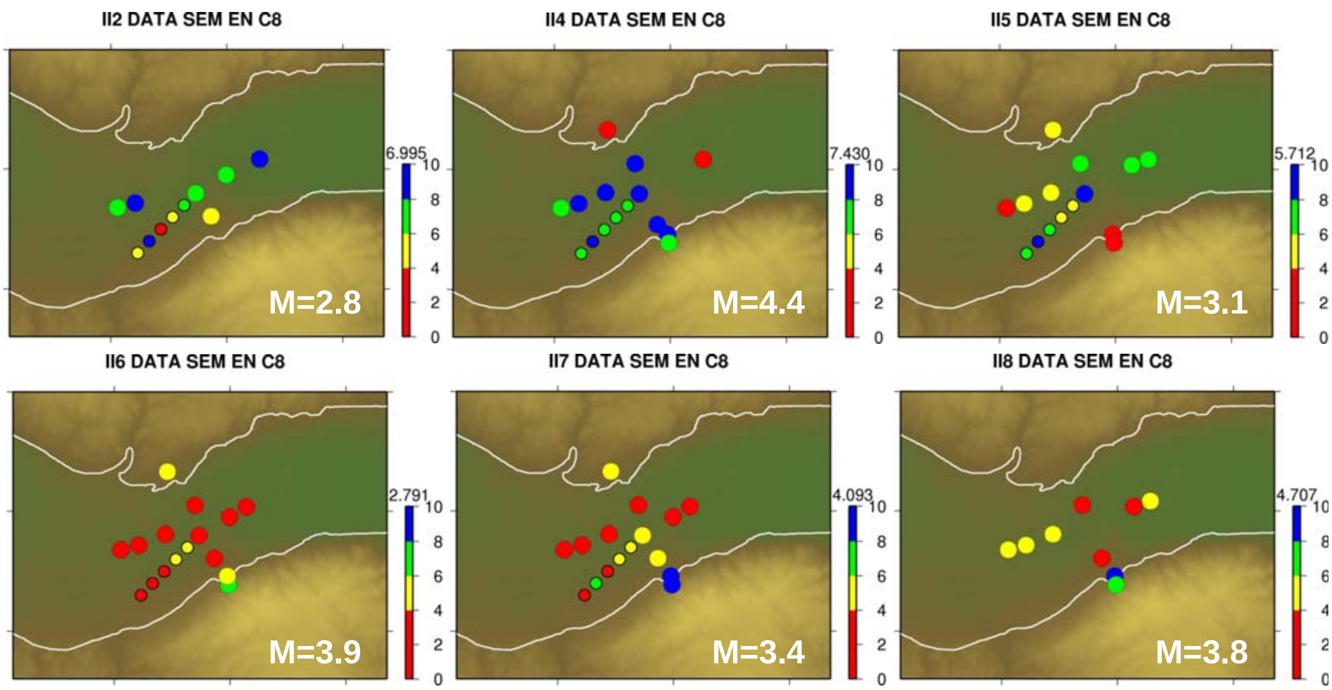
Event #4: Global "Goodness of fit" (all components)



Event #4: Response spectra (horizontal components)



All events: Response spectra (horizontal components)



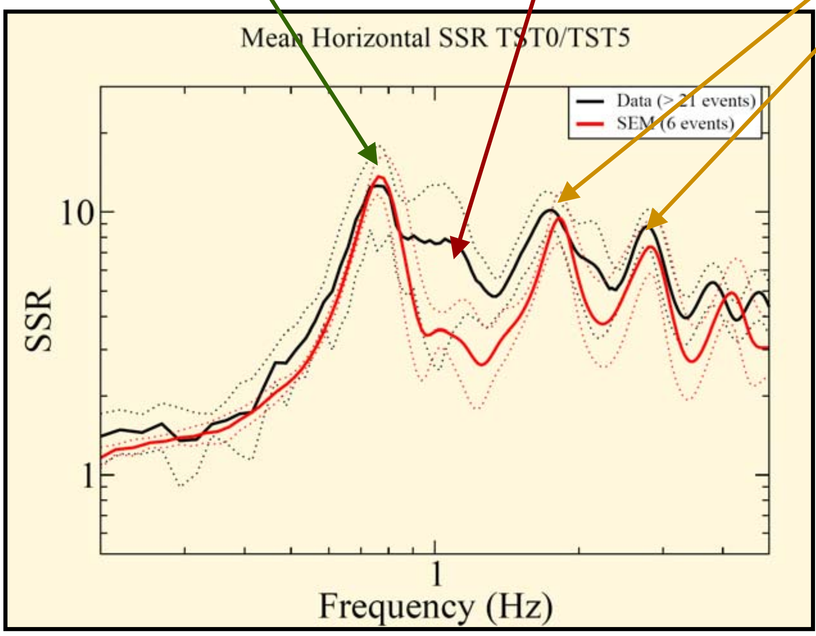
Mean amplification estimation at TST

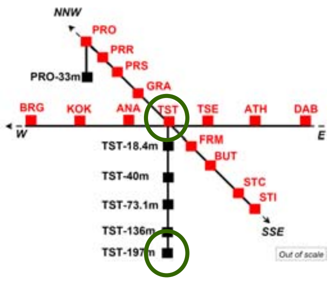
- Synthesis : spectral ratio

Still needs to be understood…

Very good agreement

Rather good agreement





Conclusions

- Verification:
  - We obtained a better (and "faster") agreement between simulations in comparison with the ESG2006 benchmark (Grenoble basin).
  - It remains discrepancies for late surface wave arrivals, especially for models with high velocity contrasts.
  - Non-linearity modelling : still need efforts to meet the same "verification" level than visco-elastic simulations.
- Validation:
  - The project shows surprisingly good agreement for the largest magnitude event, even at high frequencies (up to 4 Hz).
  - The remaining discrepancies could be due to different causes, not only numerical ones.

- From a civil engineering point of view, the overall reliability of numerical simulation had clearly been improved, but we still must continue the work…

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Perspectives

- Next research efforts: evaluate the influence of source parameters and geological knowledge uncertainty on numerical simulation uncertainty:
  - Until which frequency are the deterministic modelling approaches relevant?
  - Which geotechnical parameters are the more important (geometry of interfaces, velocity, attenuation)?

➔ *« E2VP – phase 2 »*

- The most E2VP interesting cases will be introduced within the SPICE Code Validation website *(http://www.nuquake.eu/SPICECVal/).*

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