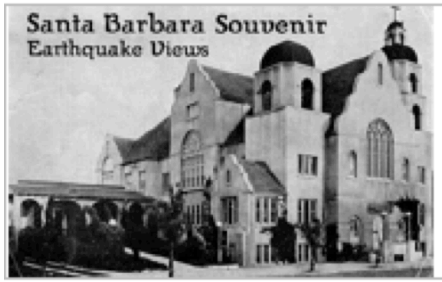

4th IASPEI / IAEE International Symposium:

Effects of Surface Geology on Seismic Motion

August 23–26, 2011 · University of California Santa Barbara

VERIFICATION AND VALIDATION OF NUMERICAL SIMULATION TECHNIQUES: LESSONS FROM THE E2VP PROJECT and ONGOING STUDIES IN EUROPE

(EUROSEISTEST VERIFICATION AND VALIDATION PROJECT)

Pierre-Yves BARD, Fabrice HOLLENDER, Emmanuel CHALJUB, Peter MOCZO, Jozef KRISTEK, Nikolaos THEODOULIDIS and Kyriazis PITILAKIS

+

many French, European, American and Japanese colleagues

ISTerre
Institut des Sciences de la Terre

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IFSTTAR

Outline

E2VP : framework and objectives

The site

Verification

- 2D, Non-linear
- 3D, linear

Validation

- 3D (weak motion only)

Concluding comments and ongoing studies

General framework and objectives

Numerical simulation: “only” one of the several possible approaches to estimate site effects, of special interest for

- low seismicity areas (only few and weak earthquakes over a "reasonable" recording time)
- consideration of non-linearity

Objective of the E2VP

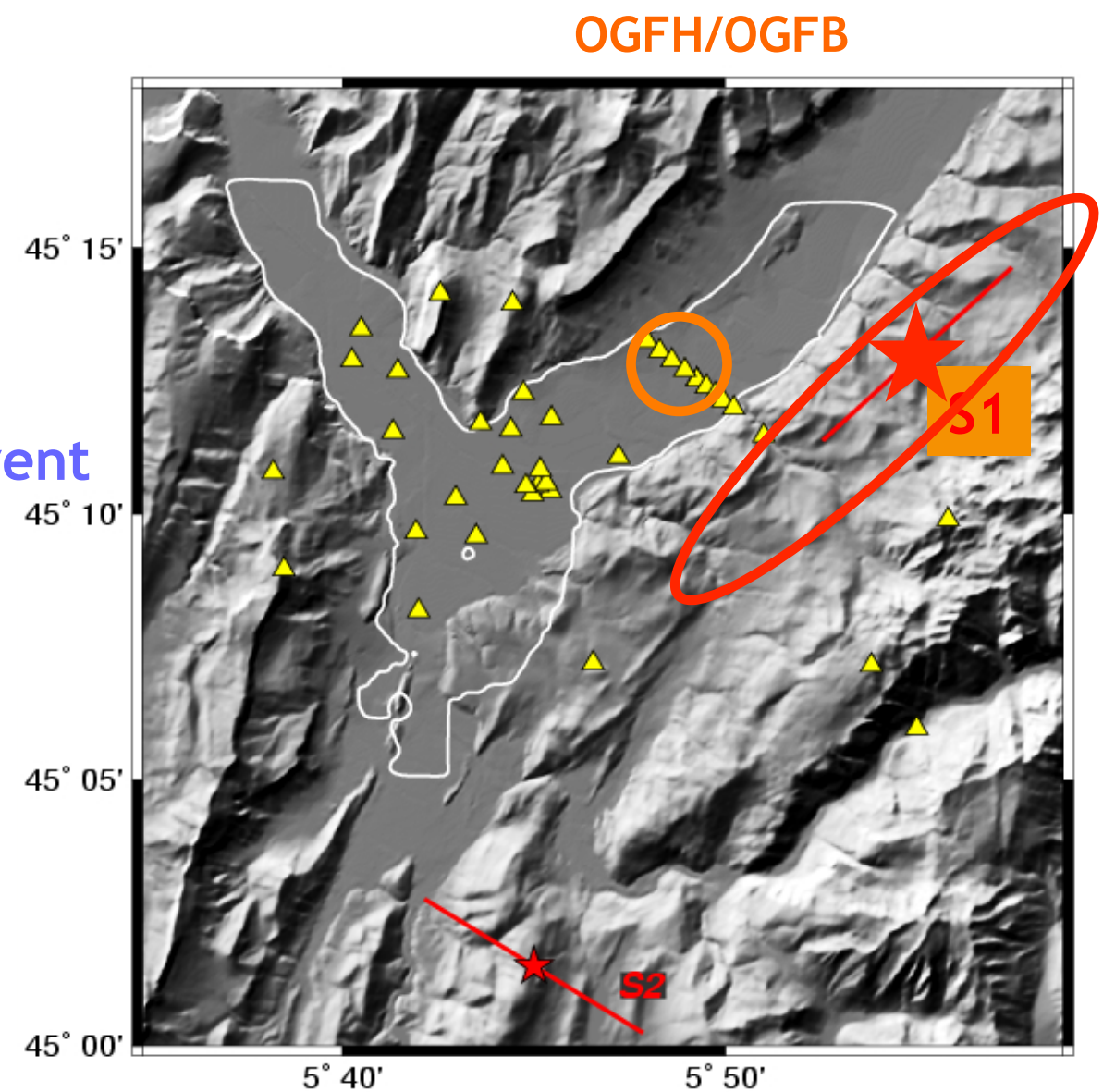
- to evaluate the reliability of ground motion numerical simulation in a real case, within the general framework of civil engineering design purposes

E2VP: “natural” continuation of ESG2006 numerical benchmark (Grenoble basin simulation)

3D benchmark (Grenoble) : Main prediction

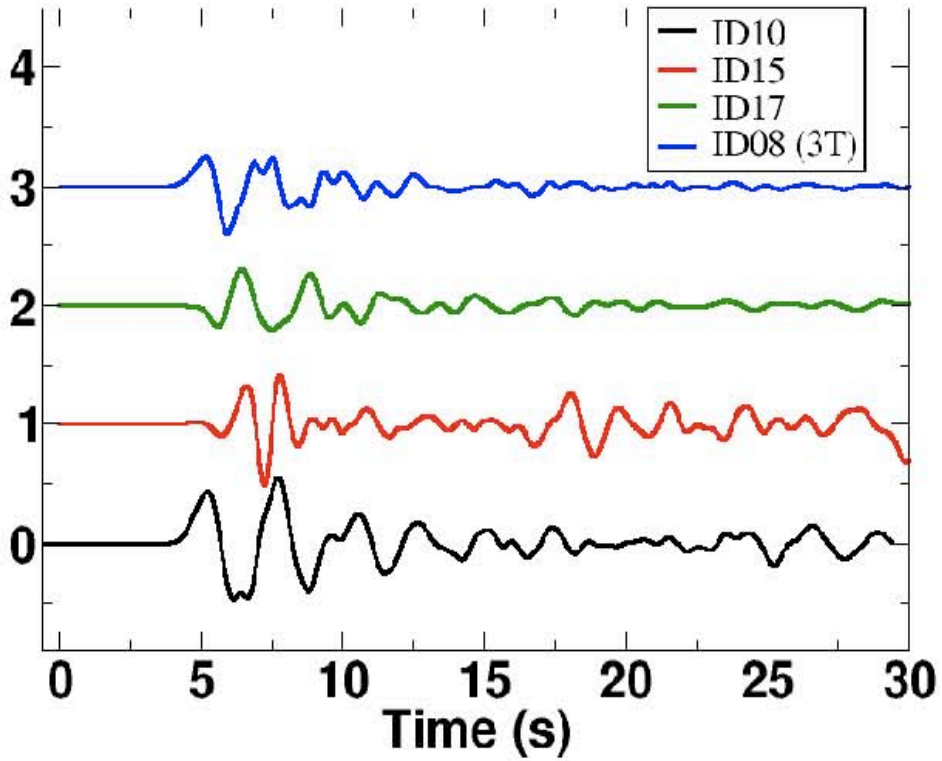
1 hypothetical strong event

- S1 (M=6)
- Extrapolation from weak event W1
- Source : imposed geometry and kinematics

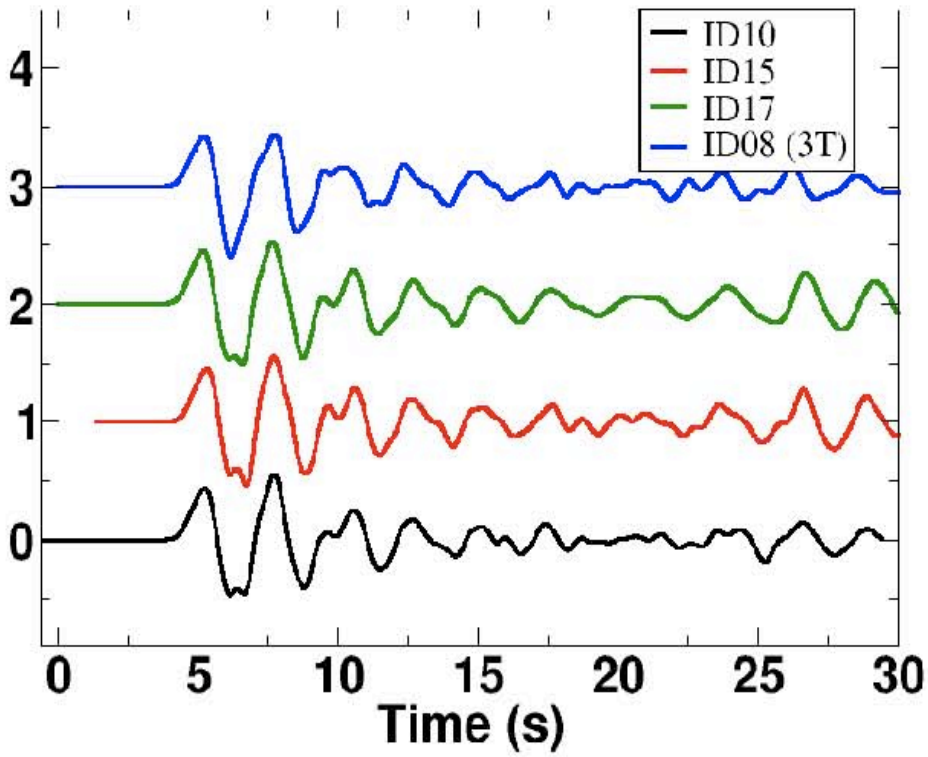


Iteration process : 3 teams (/6)

September 1, 2006



April 8, 2007

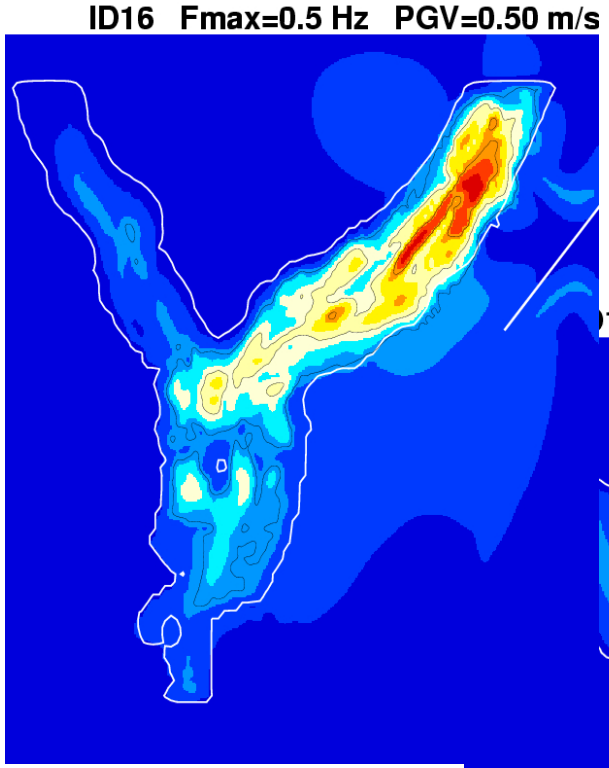


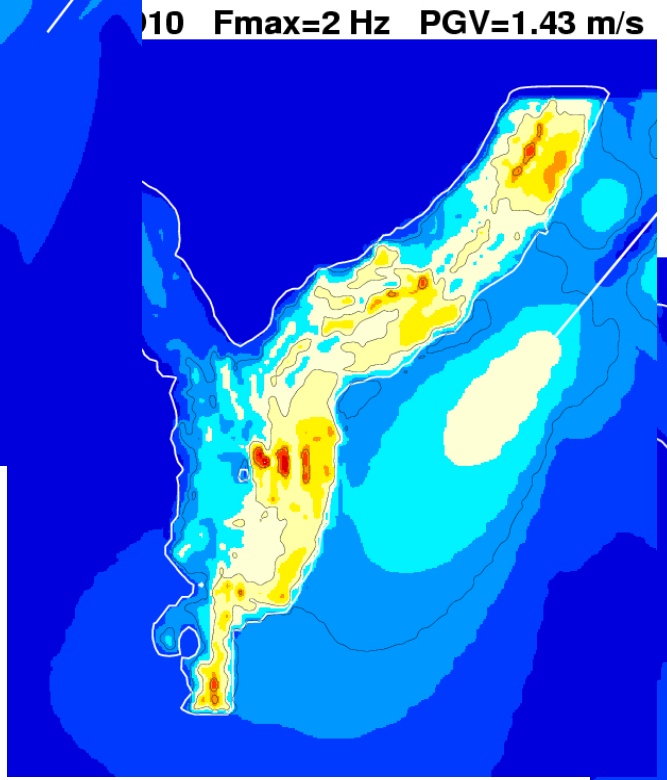
ID15 : bug in basin model definition

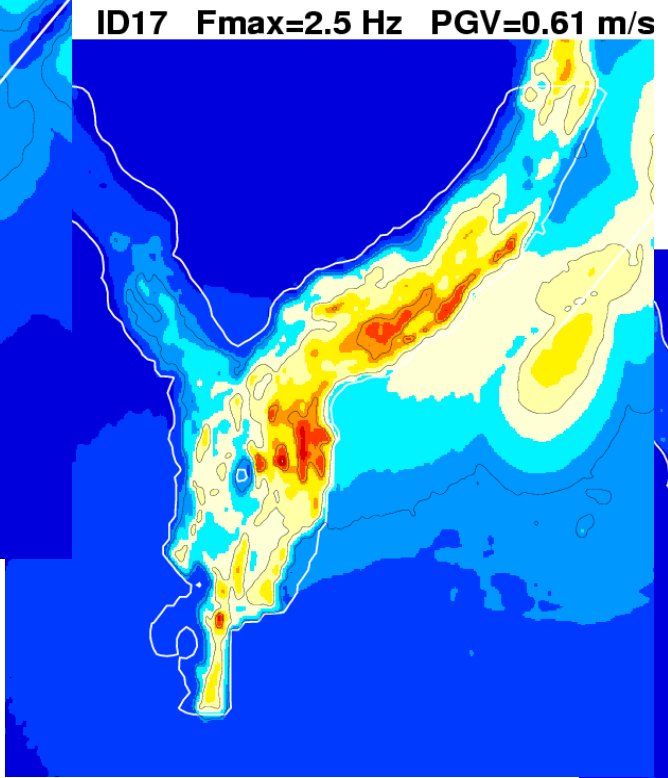
ID17 : bug in extended source definition

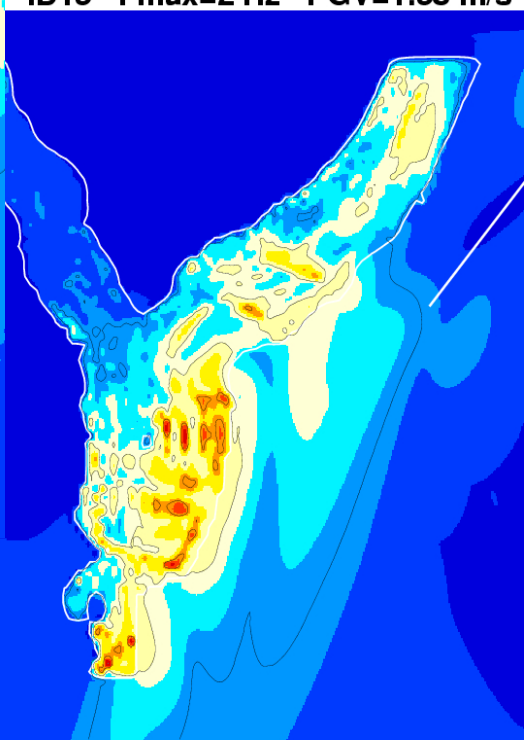
ID08 : bug in extended source definition

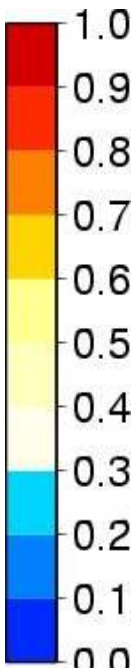
PGV maps, S1 case
Initial predictions (3D)





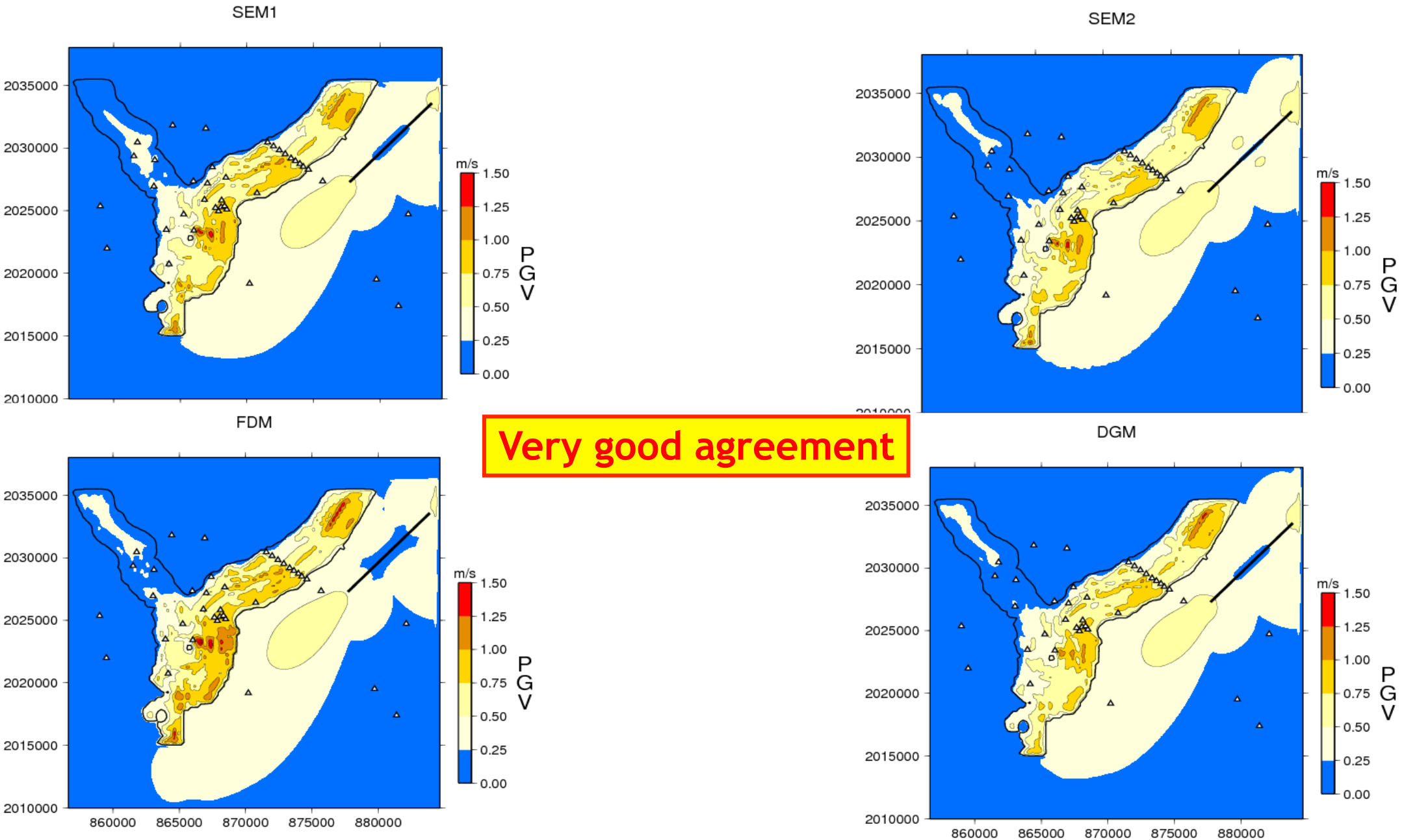






PGV maps from 3D predictions, flat case

After iteration



Very good agreement

EuroSeisTest Verification and Validation Project, 2007 - 2010 +…

Building on lessons from ESG

- new site with more data
- Careful scheduling with 3 phases for iteration; 1 kick-off meeting + 4 workshops (May 2008, Fall 2008, Spring 2009, Fall 2009, Spring 2010 = Final)

Verification

- 3D, Linear : Up to 4 Hz
- 2D, NL - Target = 8-10 Hz

Validation

- local, moderate magnitude events

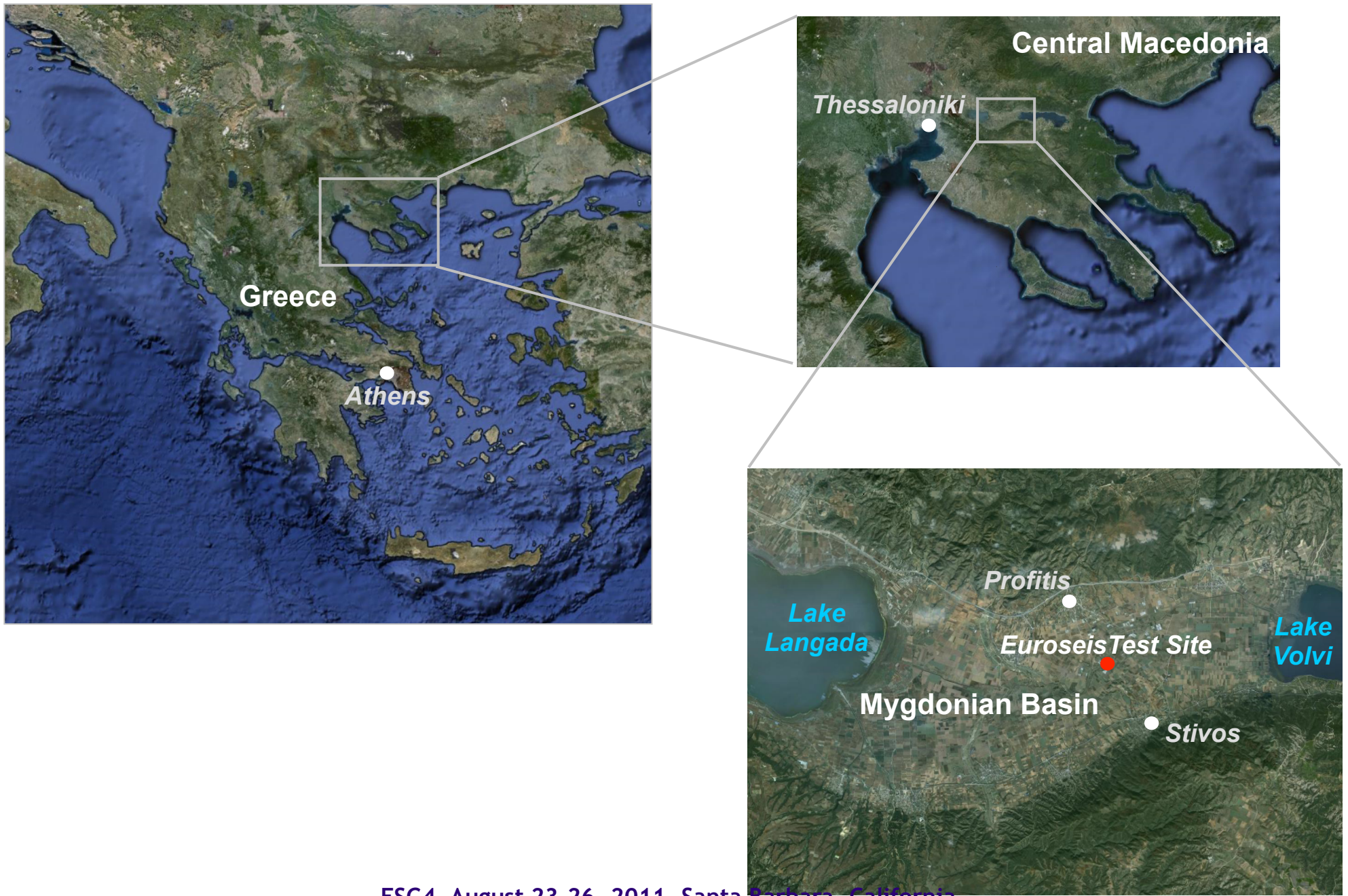
Partnership

CEA Cadarache, France
Laue-Langevin Institute, Grenoble, France
LGIT, Grenoble, France,
Comenius University, Bratislava, Slovakia
AUTH, Thessaloniki, Greece,
Carnegie Mellon University, Pittsburgh, USA
ITSAK, Thessaloniki, Greece
IRSN, Fontenay aux Roses, France,…

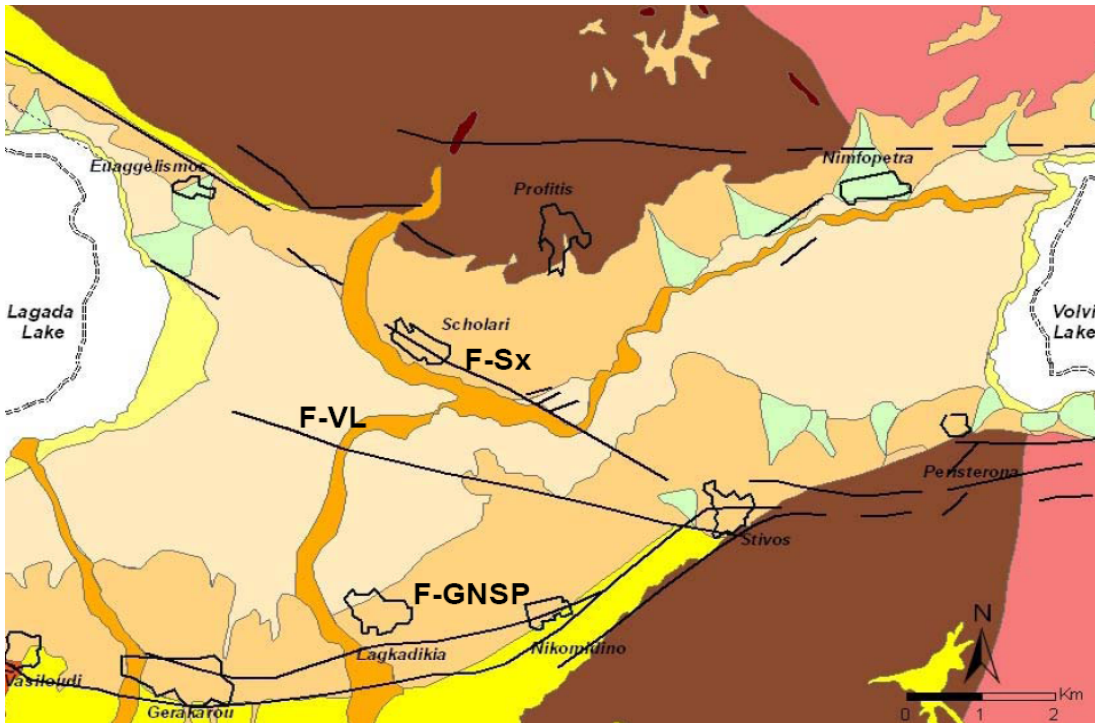
Verification: evaluating the accuracy of numerical methods when applied to realistic cases where no reference solution exists

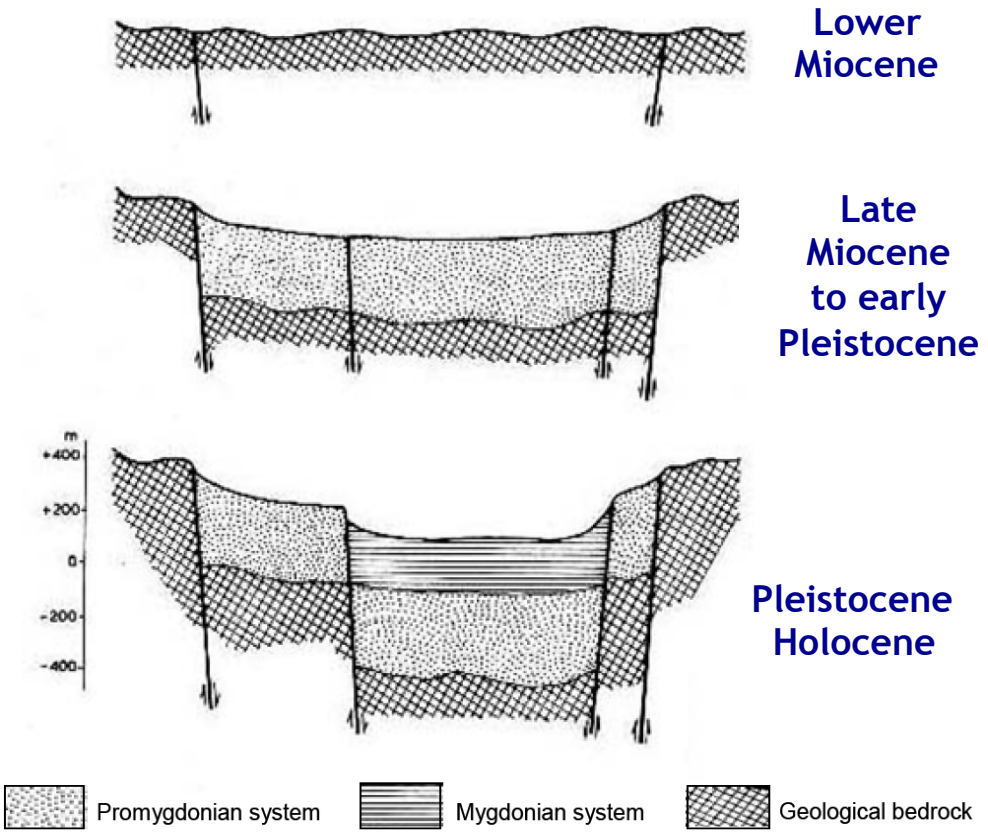
Validation: quantifying the agreement between actual recordings and numerically simulations

The EuroseisTest Site



The EuroseisTest Site: geological context





LEGEND

Holocene
- Lacustrine sediments
- River deposits / torrent beds
- Valley deposits

Pleistocene
- Lacustrine sediments (Mygdonian system)
- Terrestrial (river and flood) red beds (Promygdonian system)

Quaternary
- Fans

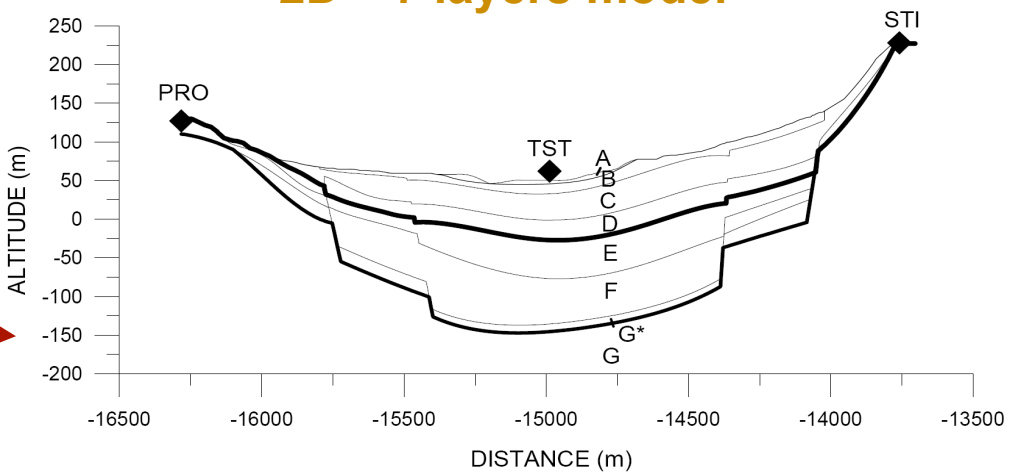
Alpine formations
- Quartzites
- Two-mica and biotite granite
- Two-mica gneiss
- Ultra maffic rocks

Geological, geophysical, geotechnical characterization

Multiple, in-depth investigations

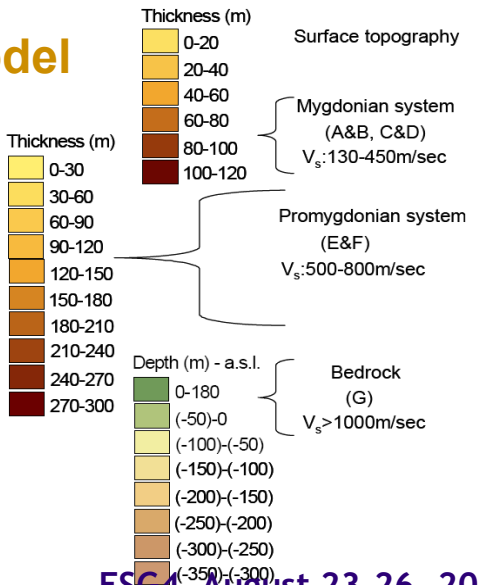
- boreholes
- surface and borehole seismic surveys
- electric surveys
- array microtremor measurements
- H/V measurements
- laboratory measurements on samples
- etc.

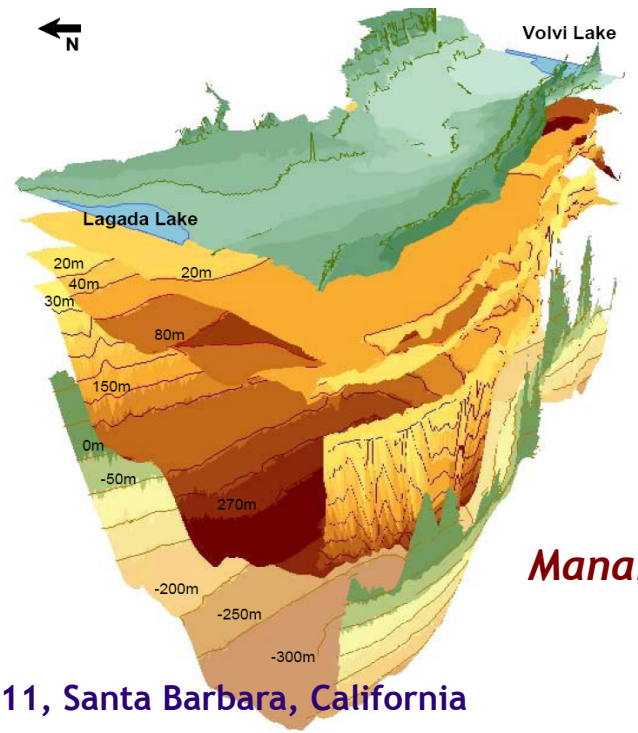
2D – 7 layers model



Raptakis et al. 2000

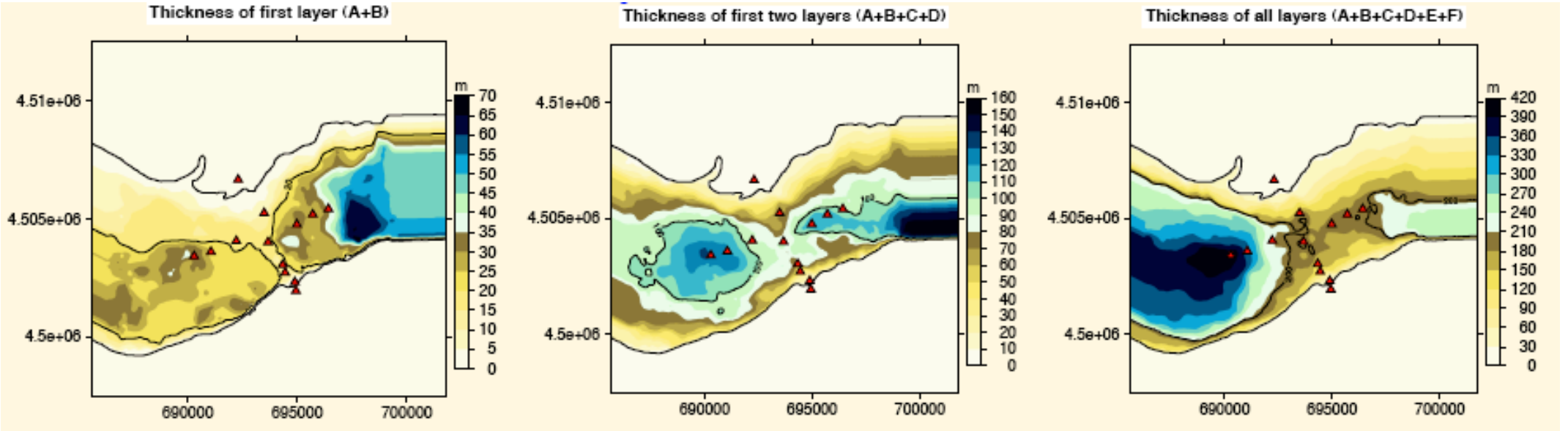
3D – 3 layers model





Manakou, 2007

Cashima - Euroseistest: basic 3-layer model

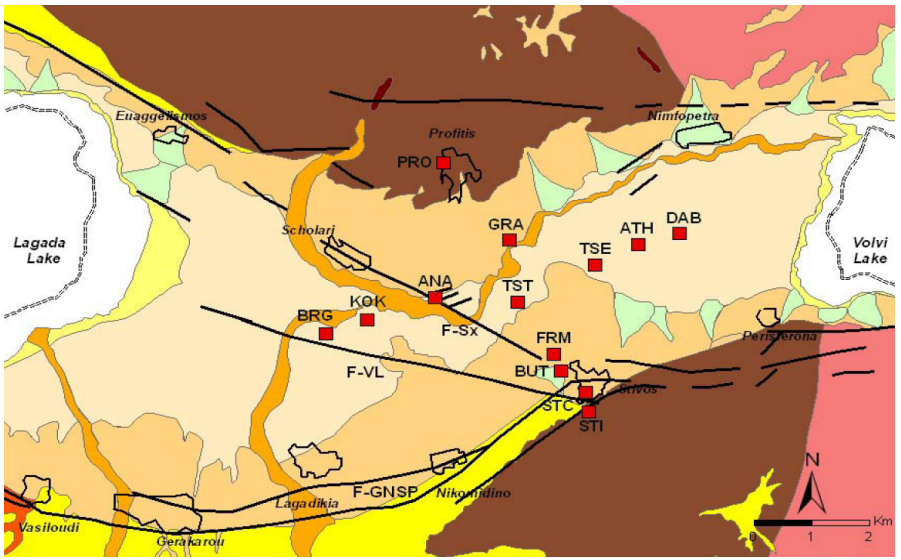


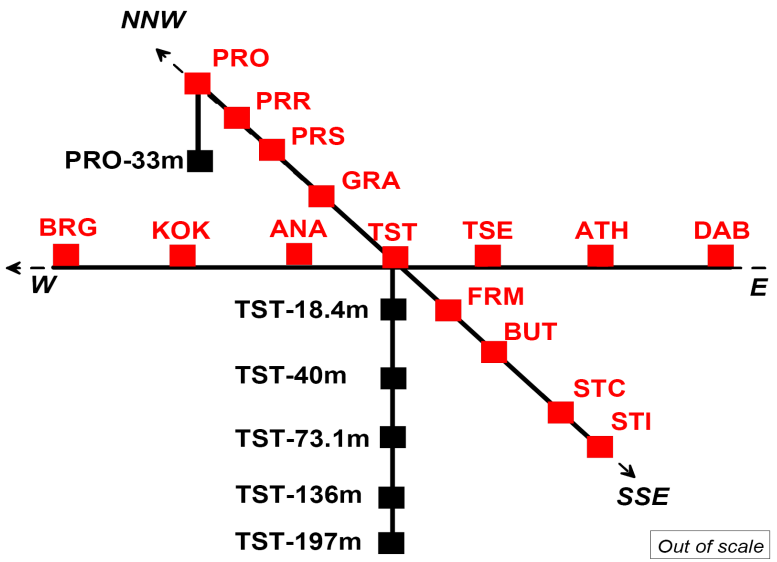
Layer	V_S (m/s)	V_P (m/s)	ρ (kg/m^3)	Q_S	Q_κ
A+B	200	1500	2100	20	∞
C+D	350	1800	2200	35	∞
E+F	650	2500	2200	65	∞
Bedrock	2600	4500	2600	260	∞

Low Vs
Large contrasts
High Poisson's ratio
Low Q_S

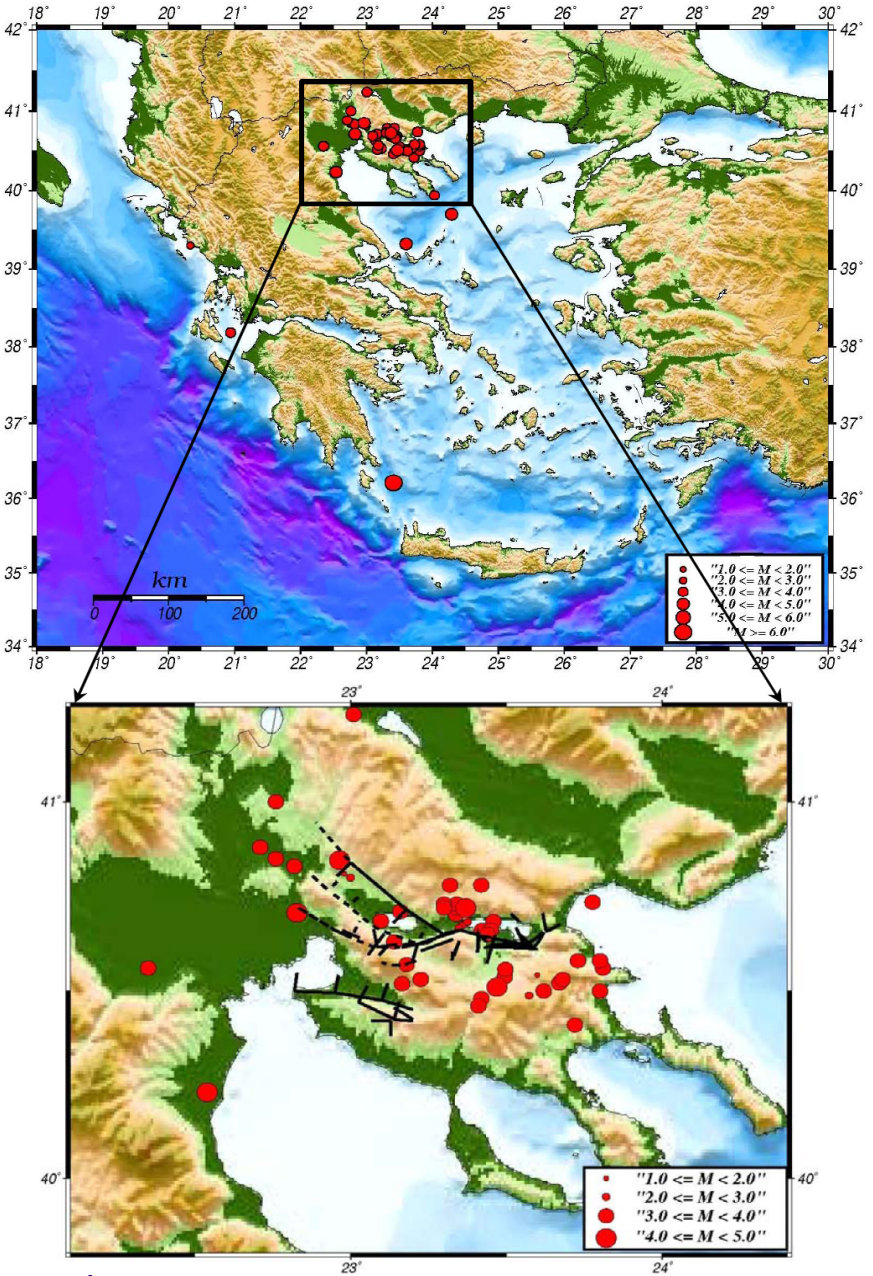
EuroseisTest Site: instrumentation and recordings

21 accelerometric stations





~ 50 recorded earthquakes



The “participating teams”

Invitations were sent to most of known potentially interested teams.

- 17 participating teams (Europe, USA, Japan)
- 12 “modeling” teams with 6 different numerical approaches

3D
2D

Czech Republic:
- CUP, Prague

Germany:
- LMU, Munich

Japan:
FDM - DPRI, Kyoto
FDM - NIED, Tsukuba

USA:
- CMU, Pittsburgh
FEM

Slovakia:
- UNIBA, Bratislava
FDM

France:
FEM - BRGM, Orléans
DEM - CEA, Cararache & Bruyères le Châtel
FDM - IRSN, Fontenay aux Roses
SEM - LGIT, Grenoble
FDM - GdS, Paris,
DGM - GéoAzur, Nice

Italy:
- INGV, Roma
PSM - OGS, Trieste
- Polimi, Milan

Greece:
- AUTH , Thessaloniki
- ITSAK, Thessaloniki
FDM

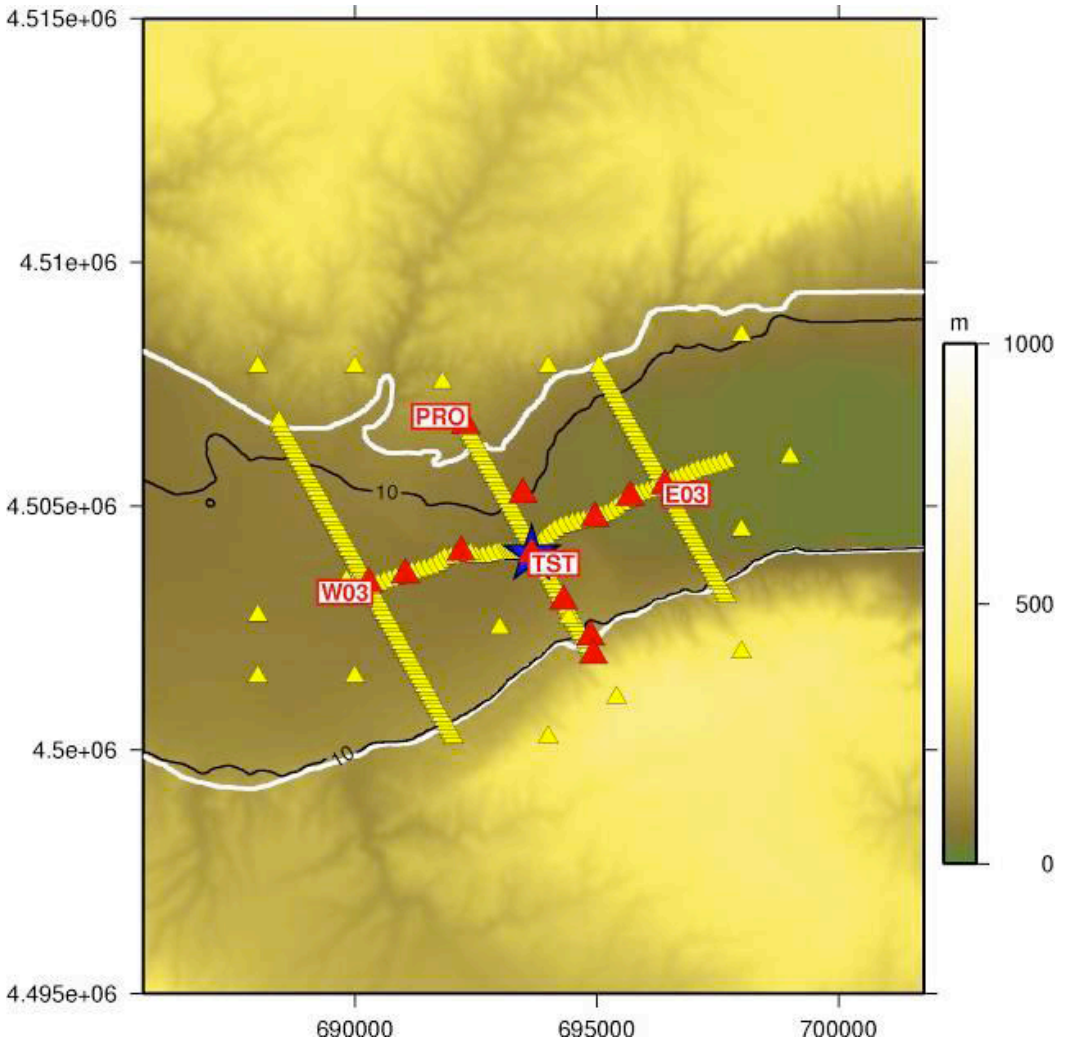
Required computations

3D

- point sources (virtual + real)
- 288 receivers
  - actual SM sites
  - 4 profiles
  - various rock sites
- 30 s long signal

2D

- vertically incident plane S waves
- 2D profile, Dx = 100 m
- + vertical arrays



Models and computations, 2D case

Non-linear cases

Cases

- Initial NL curves : 2 teams
- Modified NL curves : 3-4 teams hoped

Types of comparisons

- Time histories at various receivers
- Cross-sections
- pga (z) and stress-strain plots
- Response spectra

Linear case

Method to method comparison (7 teams)

- with and without damping
- reference case for NL computations
  - (internally, for each team)

Not yet completed

Partners and codes

Partner	Numerical method	Label	Technical aspects	Attenuation model	Nonlinear rheology
BRGM	Finite Elements	FEM1	Triangular mesh	Kelvin-Voigt	Hujeux (1985)
GdS		FEM2	Triangular mesh	No	Prevost and Keane (1990)
IRSN	Finite Differences	FDM_RG2	Rotated staggered Grid: order 2 in space and time	Day and Bradley (2001)	Iai et al. (1990) (combined with attenuation)
CUB		FDM_SG4	Staggered Grid: order 2 in time and 4 in space	Kristek and Moczo (2003)	No
AUTH		FDM_SG4			No
ISTerre	Spectral Elements	SEM	Quadrangular mesh	Moczo et al. (2007)	No
CEA	Discrete Elements	DEM		Mariotti (2010)	Johnson and Rasolofosaon (1996)

(Bonilla et al., 2010)

NL curves

Surface layers (A and B)

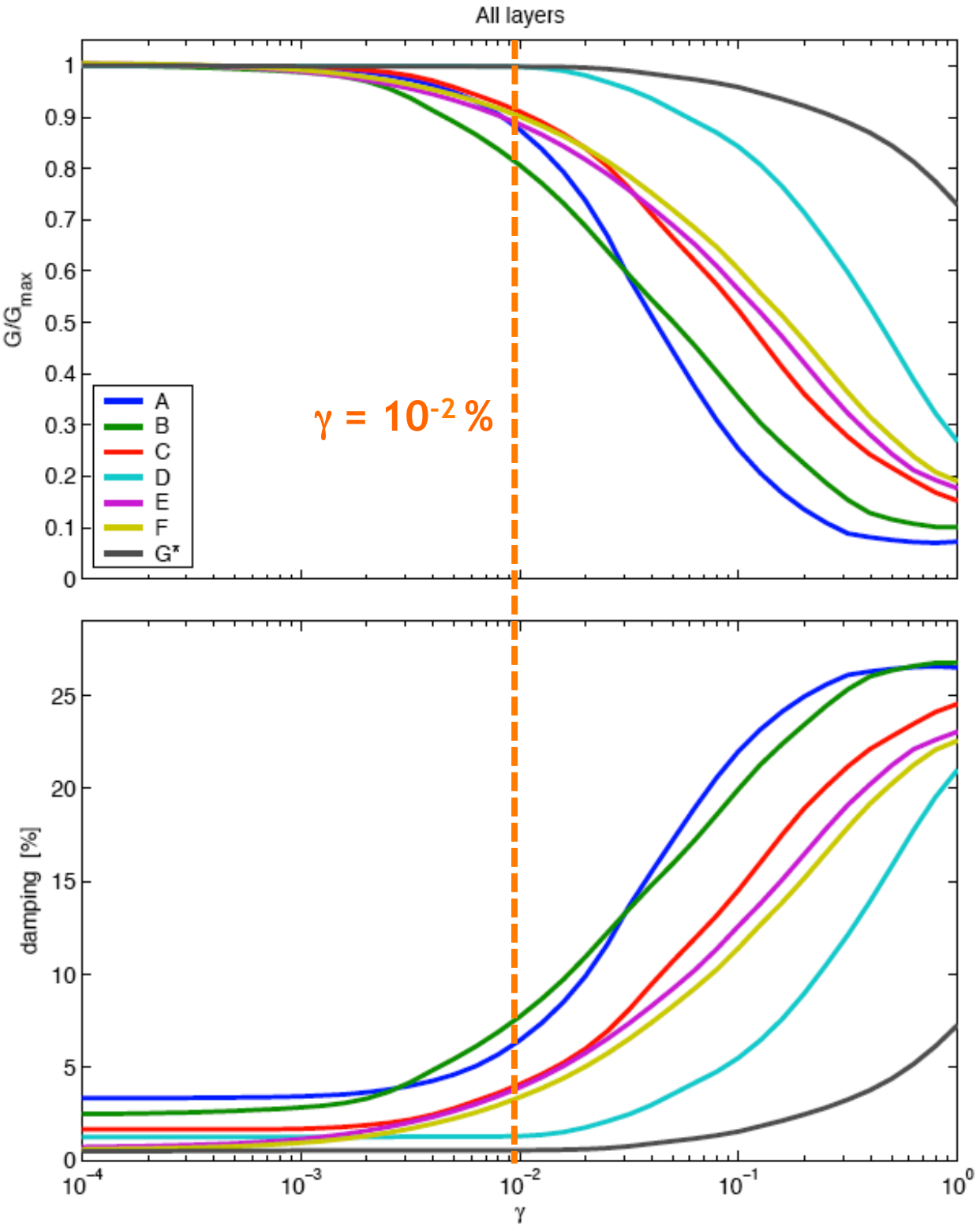
- 15-20% G reduction around 1-2 10^{-4} strain
- 6-8% damping around 1-2 10^{-4} strain

Less non-linear layers

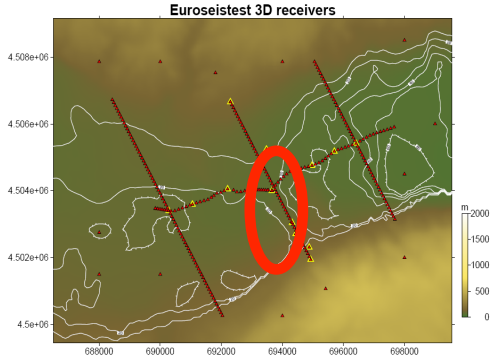
- G*
- D

Intermediate layers

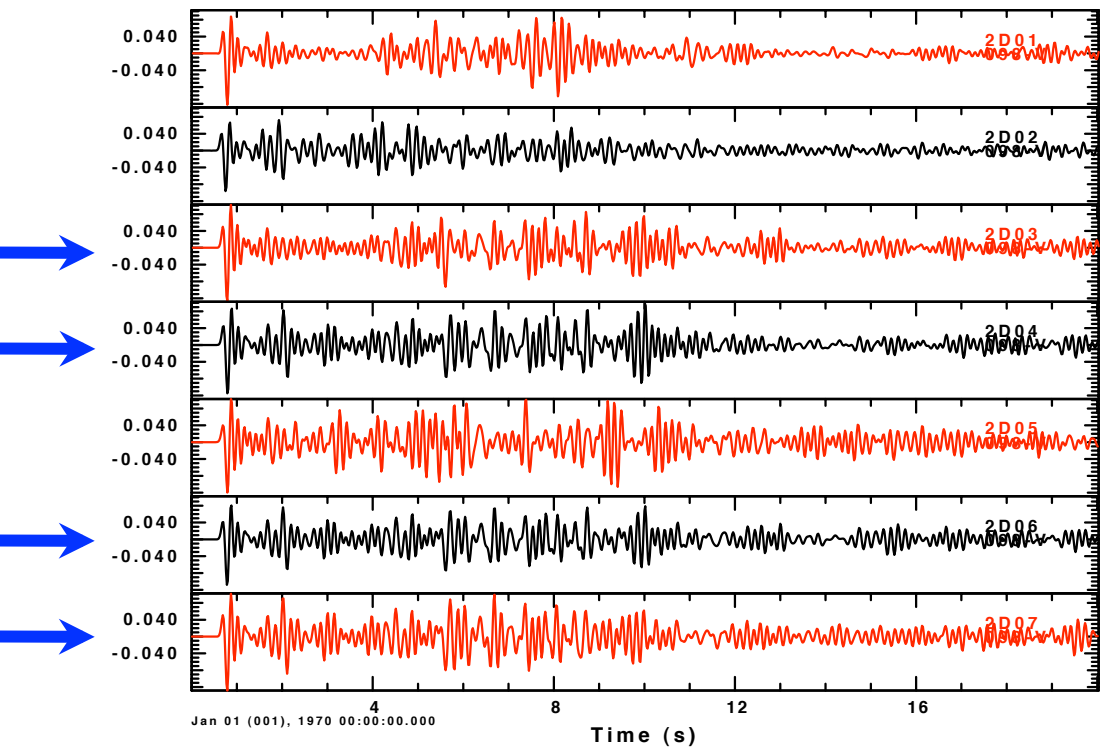
C,E,F



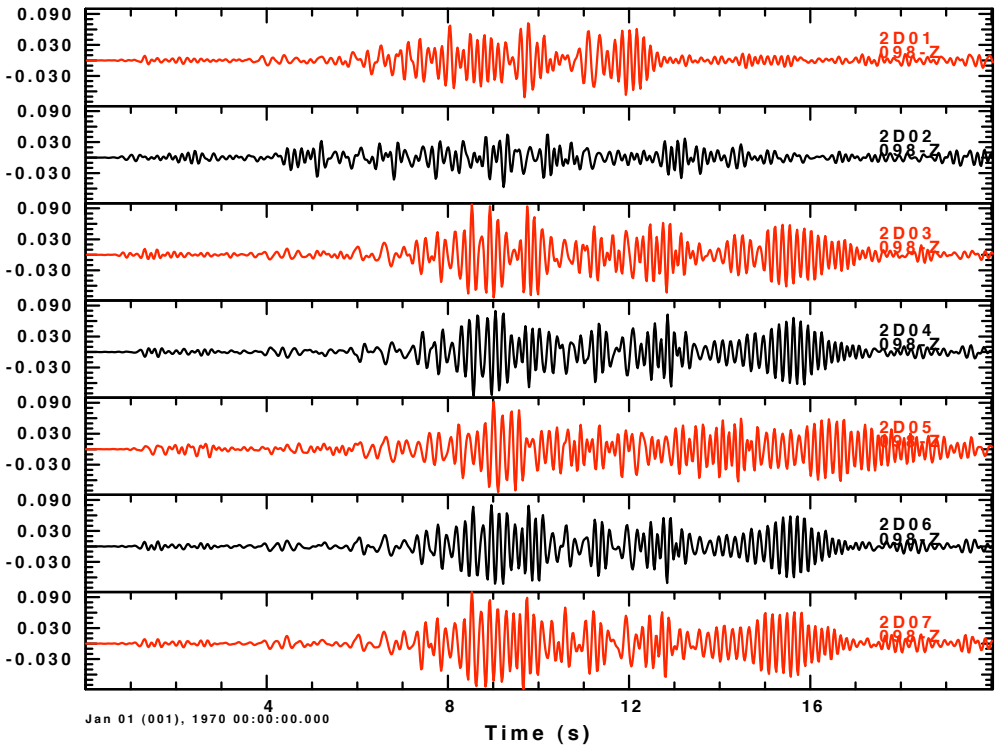
Results, 2DL, no Q - TST - 0-8 Hz



Radial component



Vertical component



Good fit : 2D03, 2D04, 2D06, 2D07