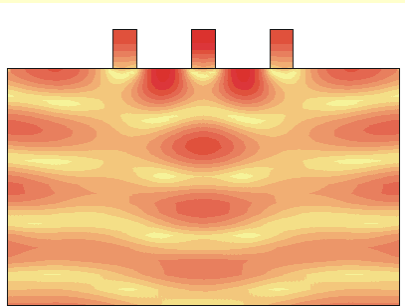
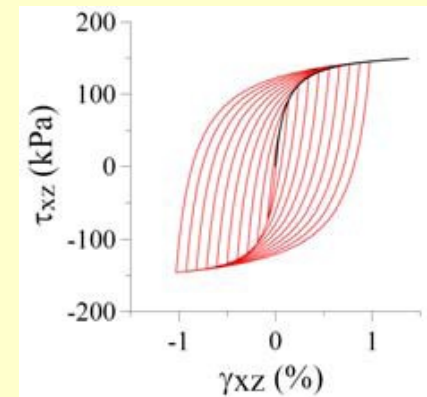


# Influence of soil nonlinearities on dynamic soil-structure interaction

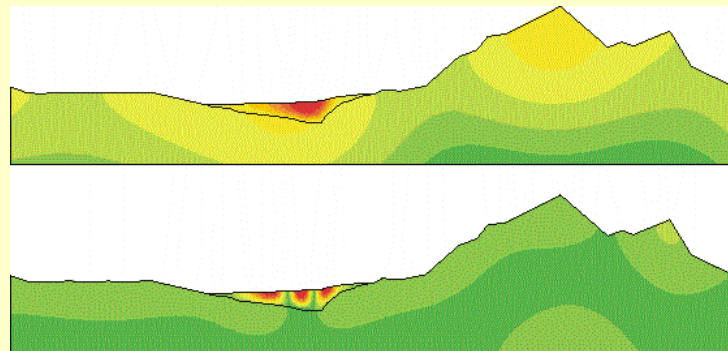


**A. Gandomzadeh<sup>1,2</sup>, J.F. Semblat<sup>1</sup>,  
L.Lenti<sup>1</sup>, M.P.Santisi<sup>1,2</sup>, F.Bonilla<sup>2</sup>  
([semblat@lcpc.fr](mailto:semblat@lcpc.fr))**

- (1) **LCPC, Paris, France (Univ. Paris-East)**  
*Dept of Geotechnics, Water and Risks*  
(2) **IRSN, Fontenay-aux-Roses, France**

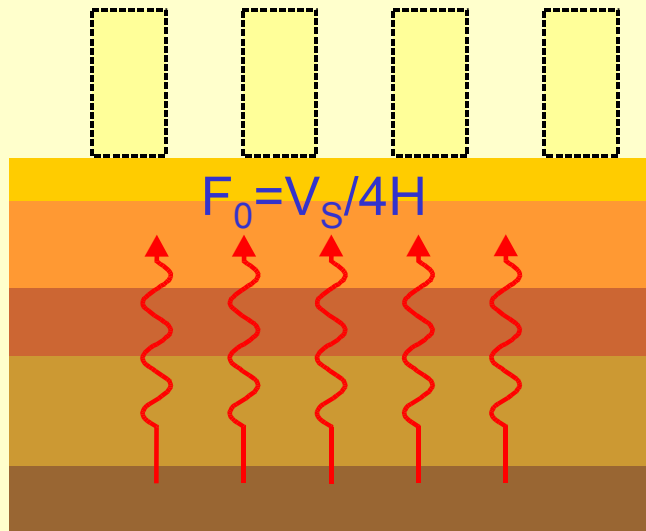


# SSI: what is the right scale?

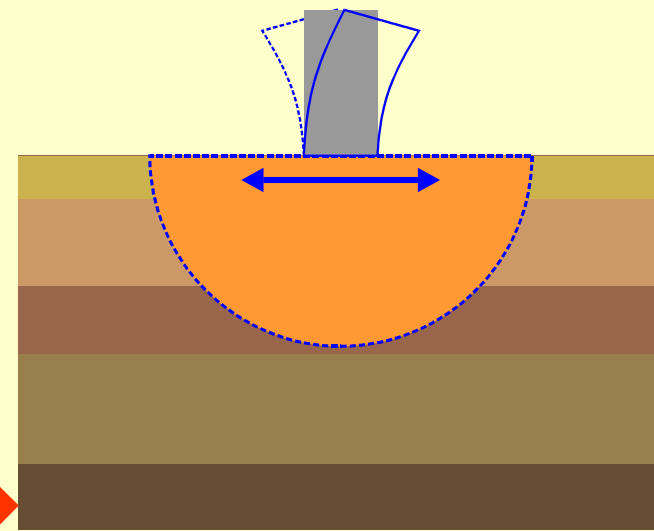


# Seismic waves vs SSI?

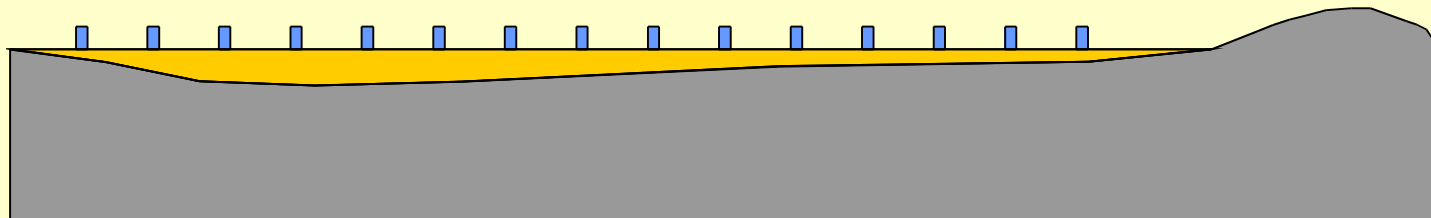
Ground motion



Soil-structure interaction

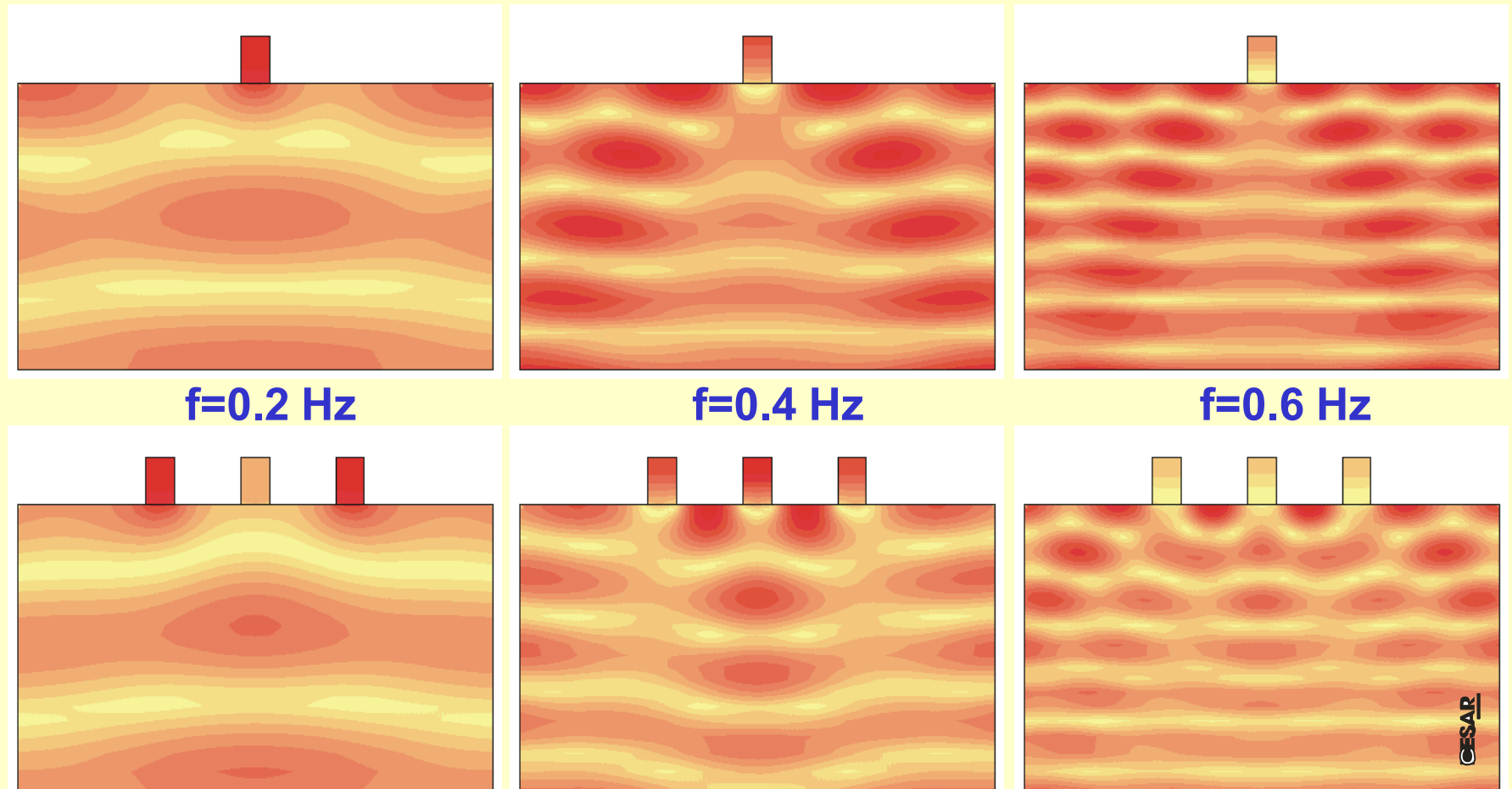


Large scale interactions



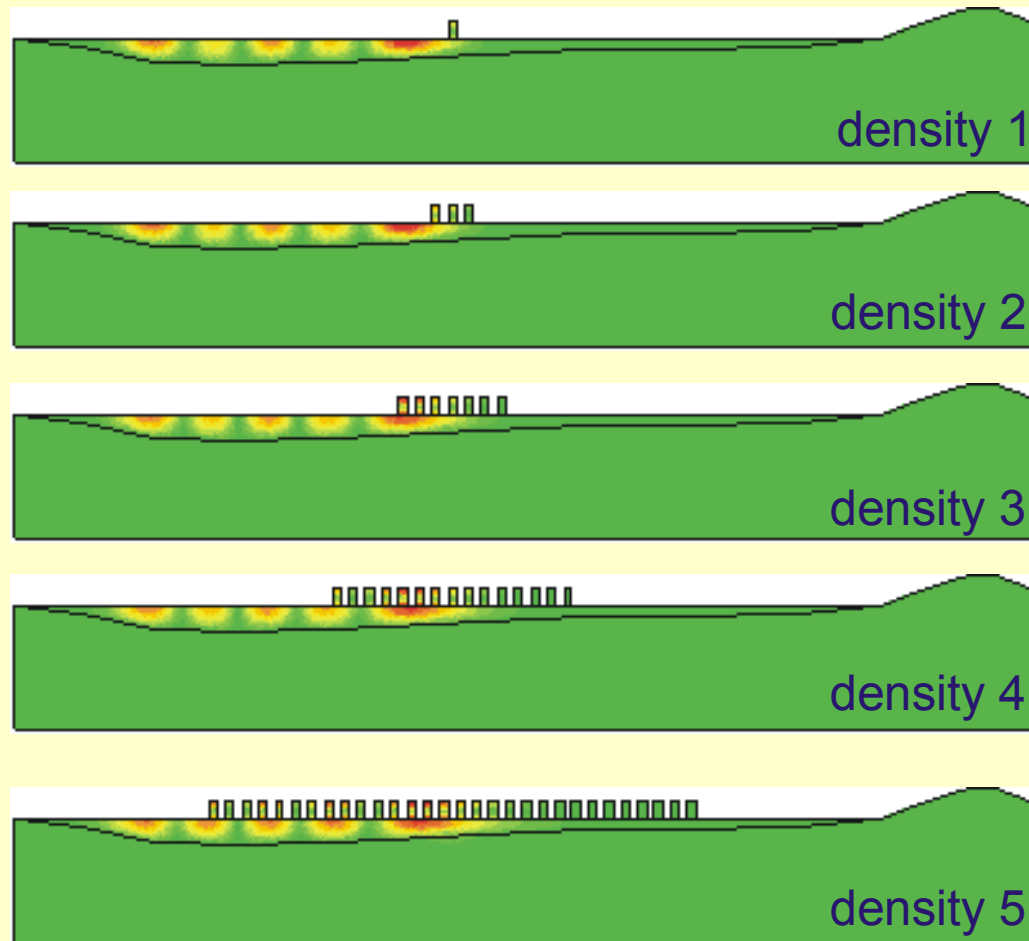
# Structure to structure interaction

- BEM simulations + centrifuge experiments



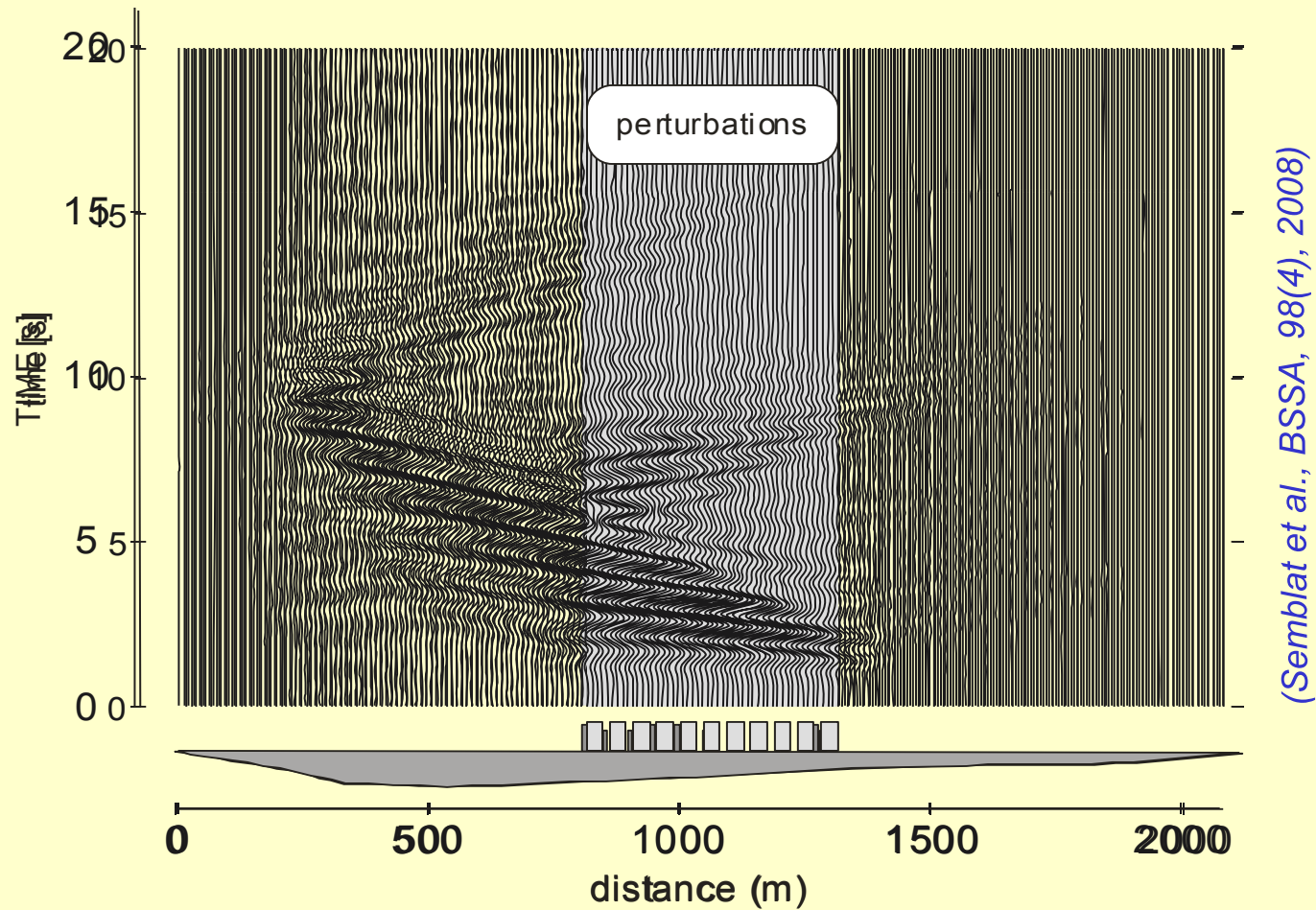
# Large scale interactions in basins

- BEM

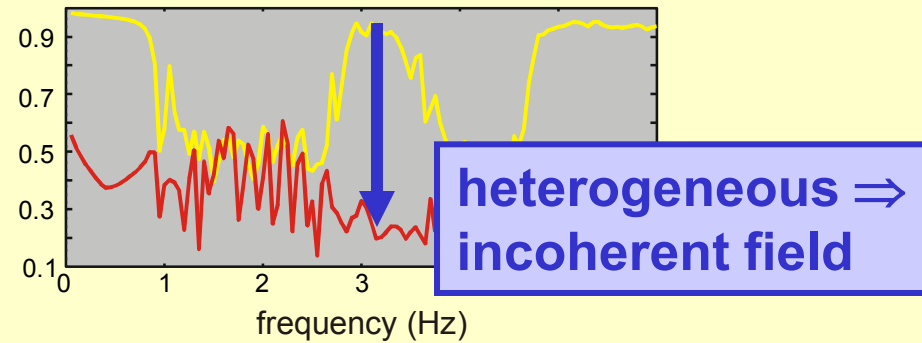
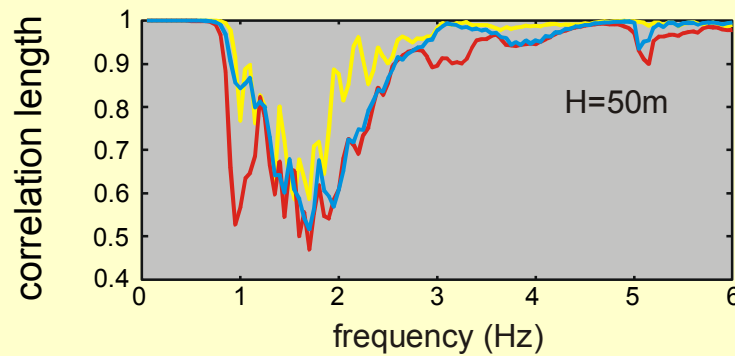
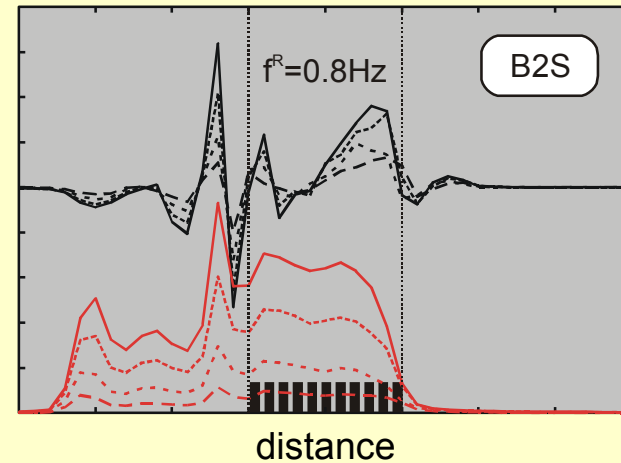
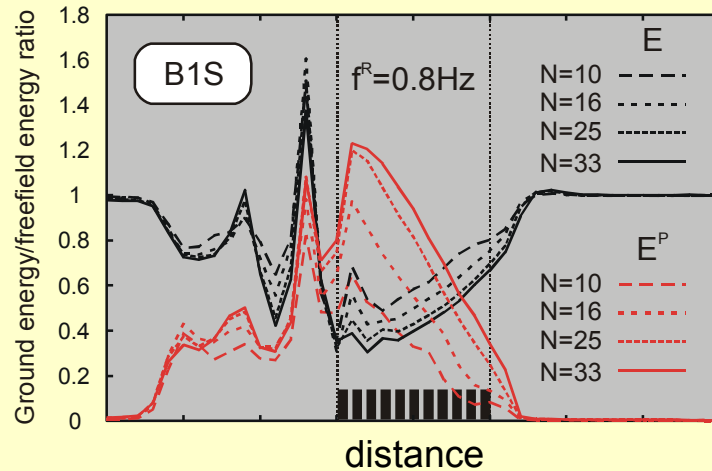


(Kham et al., BSSA, 96(5), 2006)  
 (Semblat et al., BSSA, 98(4), 2008)

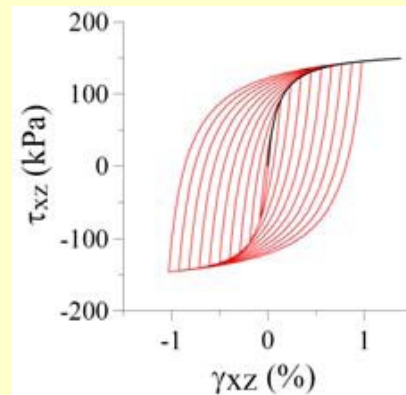
# Radiated wavefield



# Frequency match & coherency



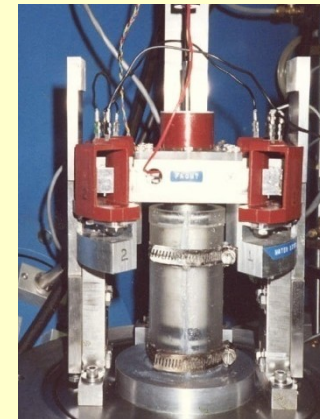
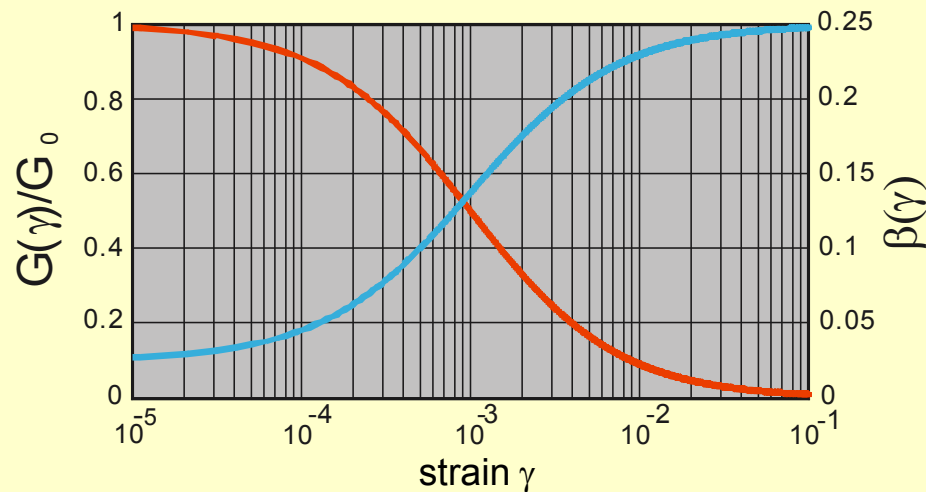
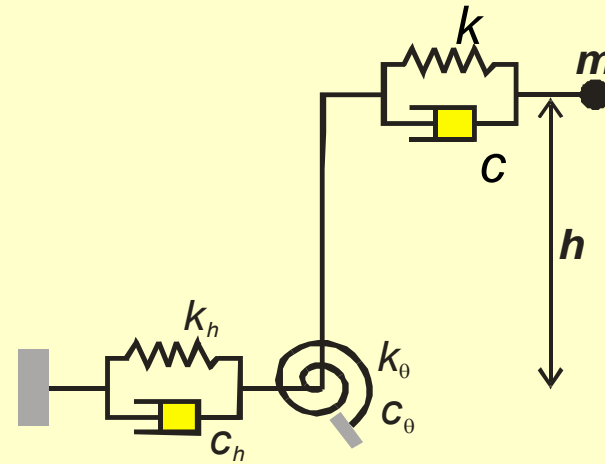
# SSI vs strong motion?





# Strong motion: influence of soil

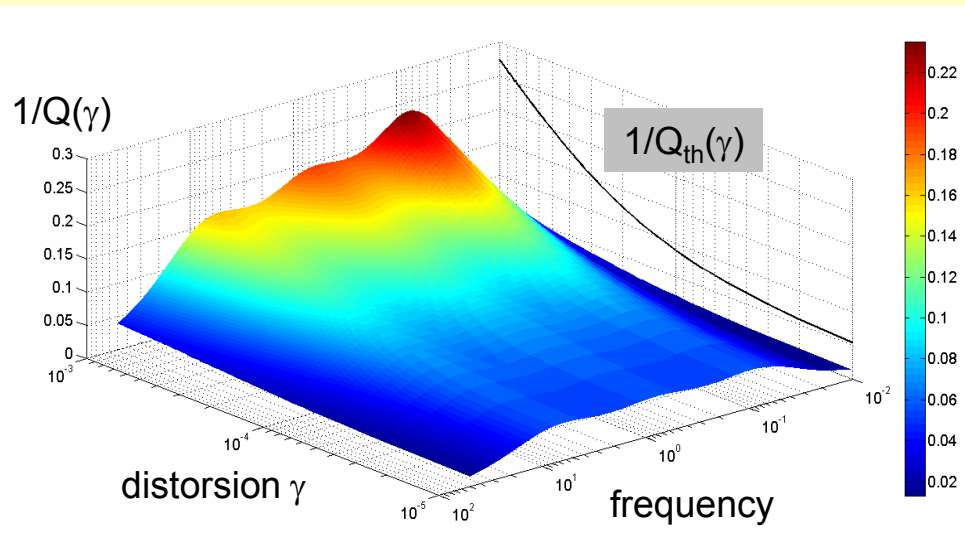
- SSI depends on:
  - Soil stiffness
  - Geometrical damping
- Strong motions lead to:
  - Stiffness reduction
  - Dissipation increase



# 'Nonlinear' soil models

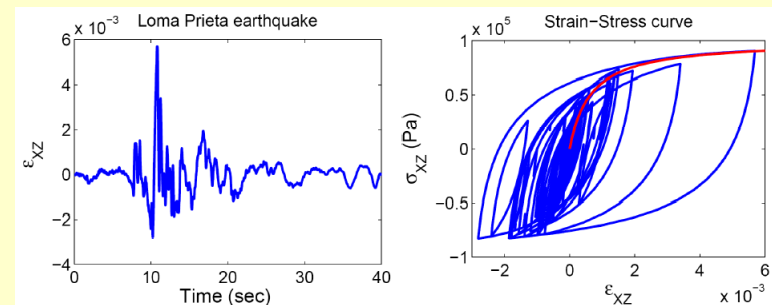
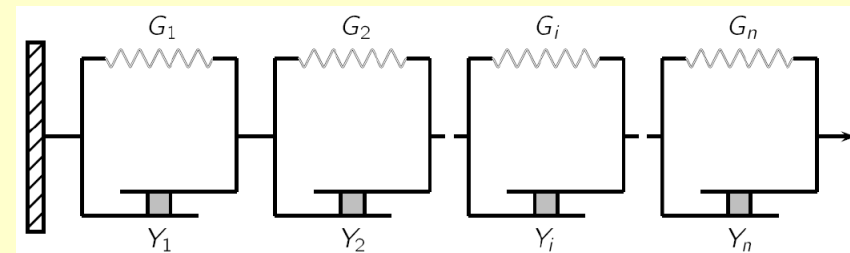
- Lin. equivalent: iterative, layer response,
- Intermediate: freq. dep. (Kausel, Assimaki), 'X-NCQ',
- Plasticity models, coupled models (pore pressure), etc.

## X-NCQ: nonlinear viscoelastic



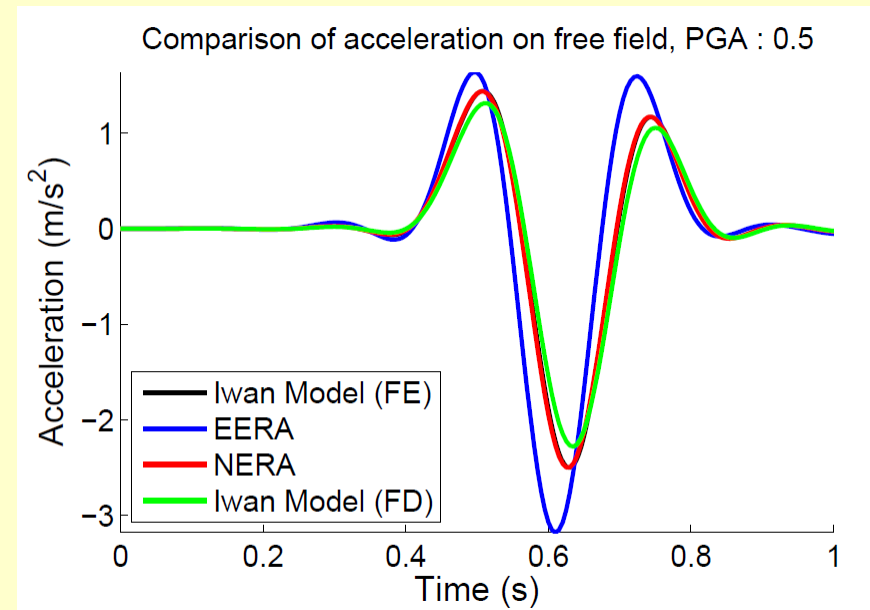
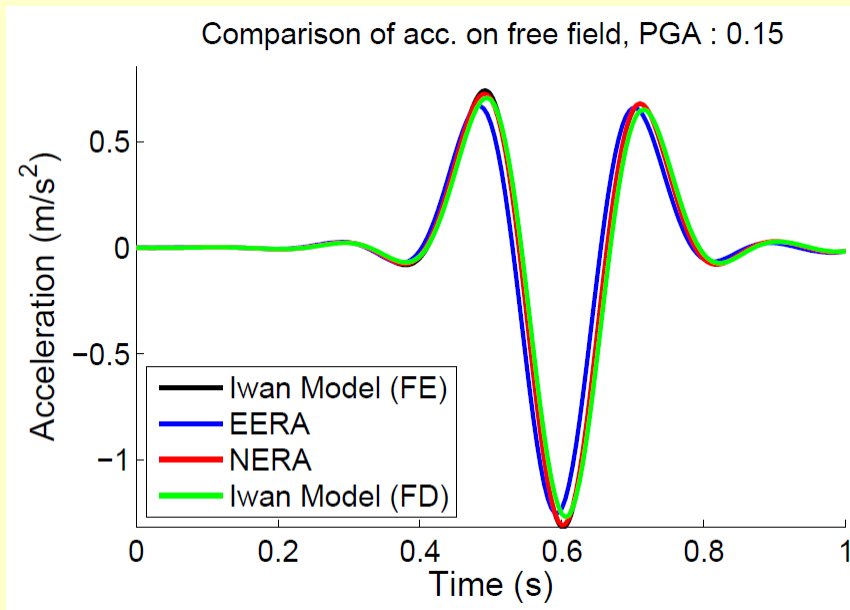
(*J.Eng.Mech., ASCE, 135(11), 2009*)

## Hysteretic model



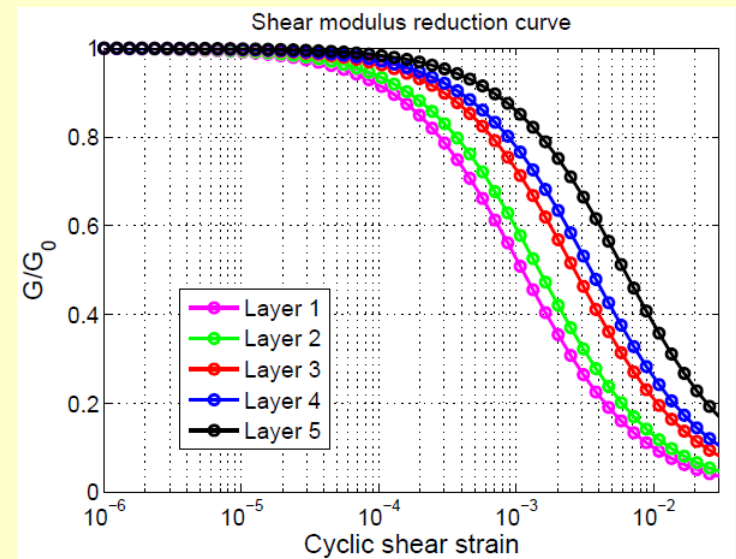
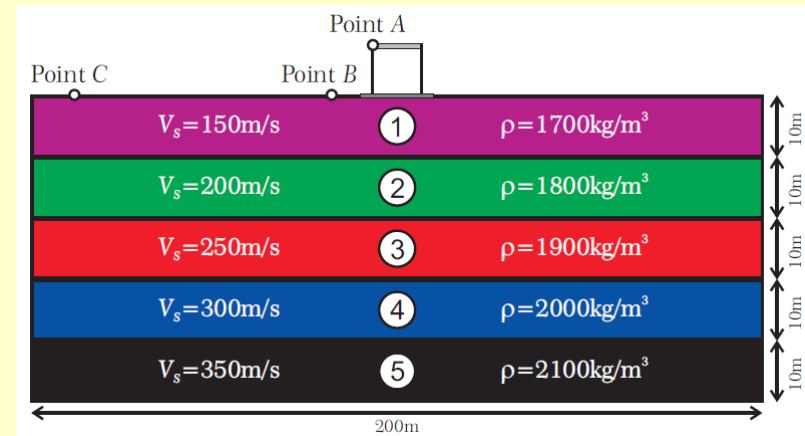
# Validation of the hysteretic model

- Homogeneous layer (50m)
- Various codes/approaches (EERA, NERA)
- Various excitation levels

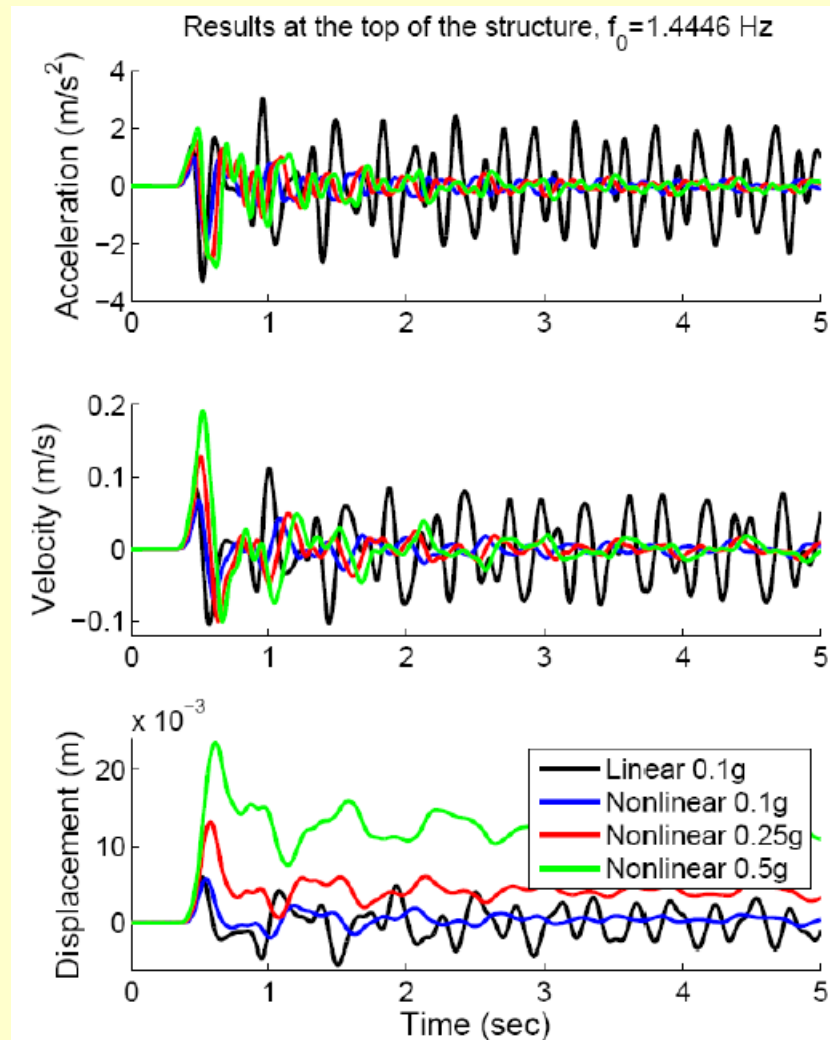


# SSI for strong quakes

- NL-SSI model:
  - Linear struct.
  - NL stratified soil (hyst.)
  - Initial stress state
  - Interface: slid./frict./uplift
  - Abs. layers ('CALM', IJNME, sept. 2010)
  
- Analyses:
  - Influence of the excitation level on the SSI
  - Amplitude (time, freq.)
  - Dissipation into the soil

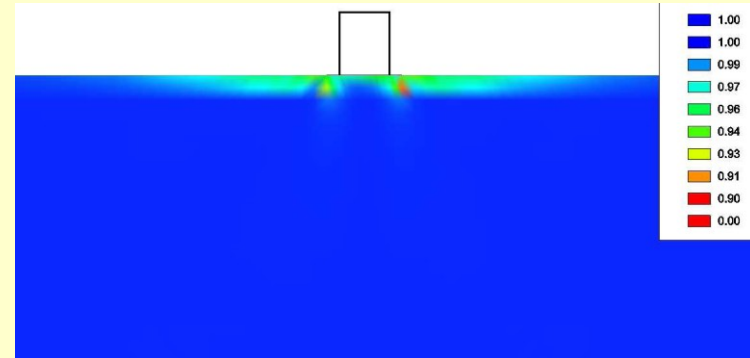


# Response of the structure

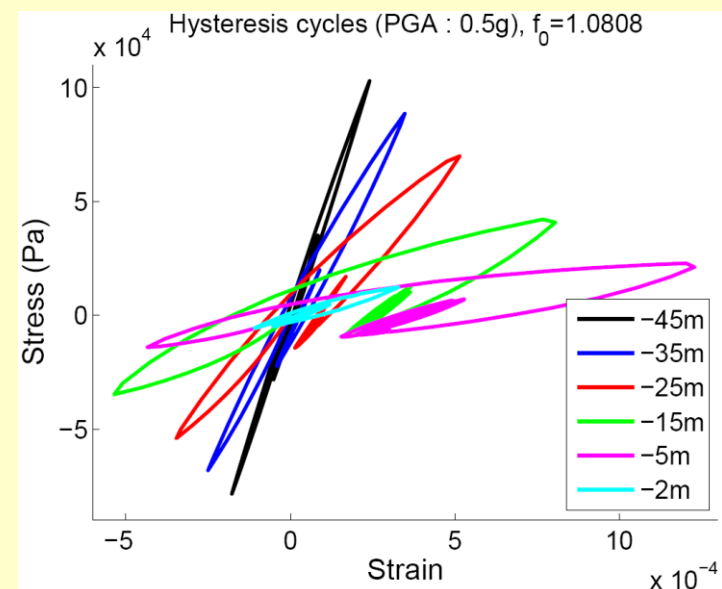
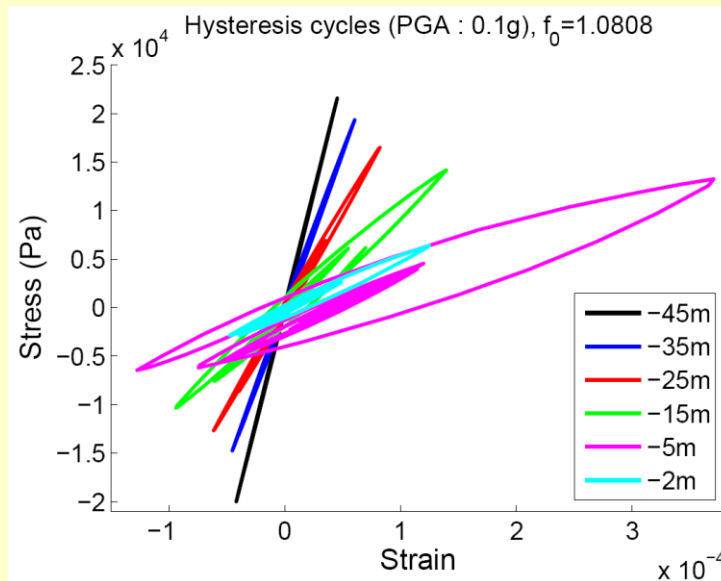


# NL response of the soil

- Energy dissipation (ratio shear/total)



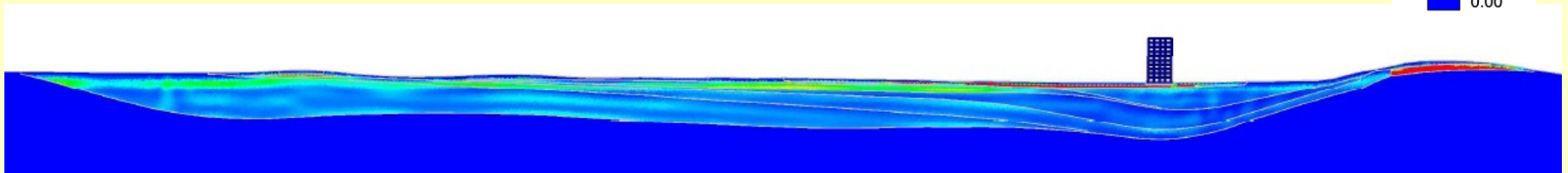
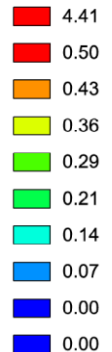
- Hysteretic loops for two excitation levels and different depths



# SSI for strong quakes in a basin

- Alluvial basin in the city of Nice
- Non horizontal soil layers
- NL soil response
- Seismic motion: PGA=0.25 g
- Dissipated energy (J/m<sup>3</sup>)

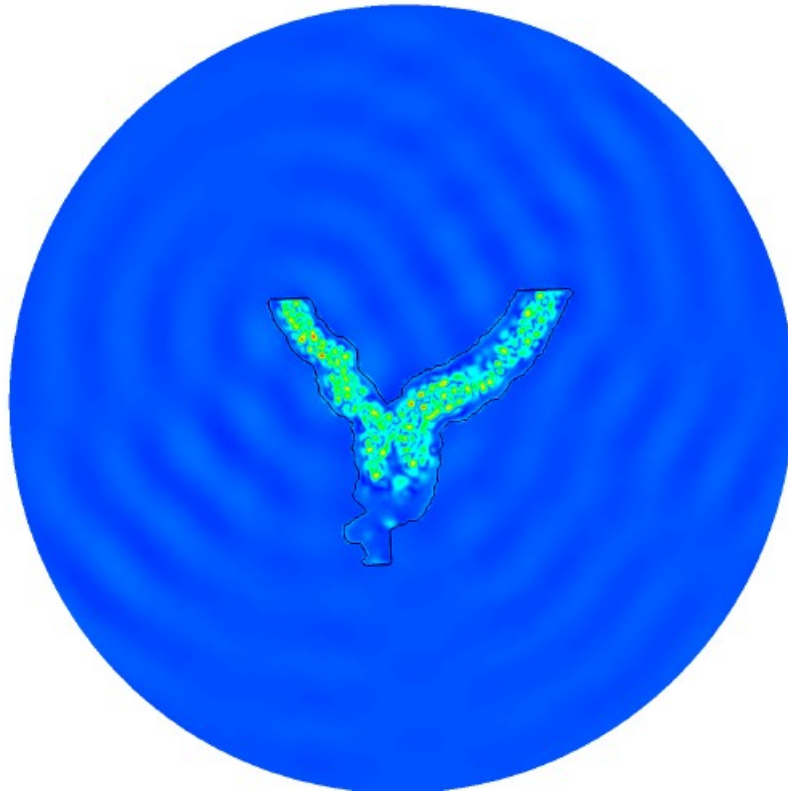
epyy [ ] / 1.E1



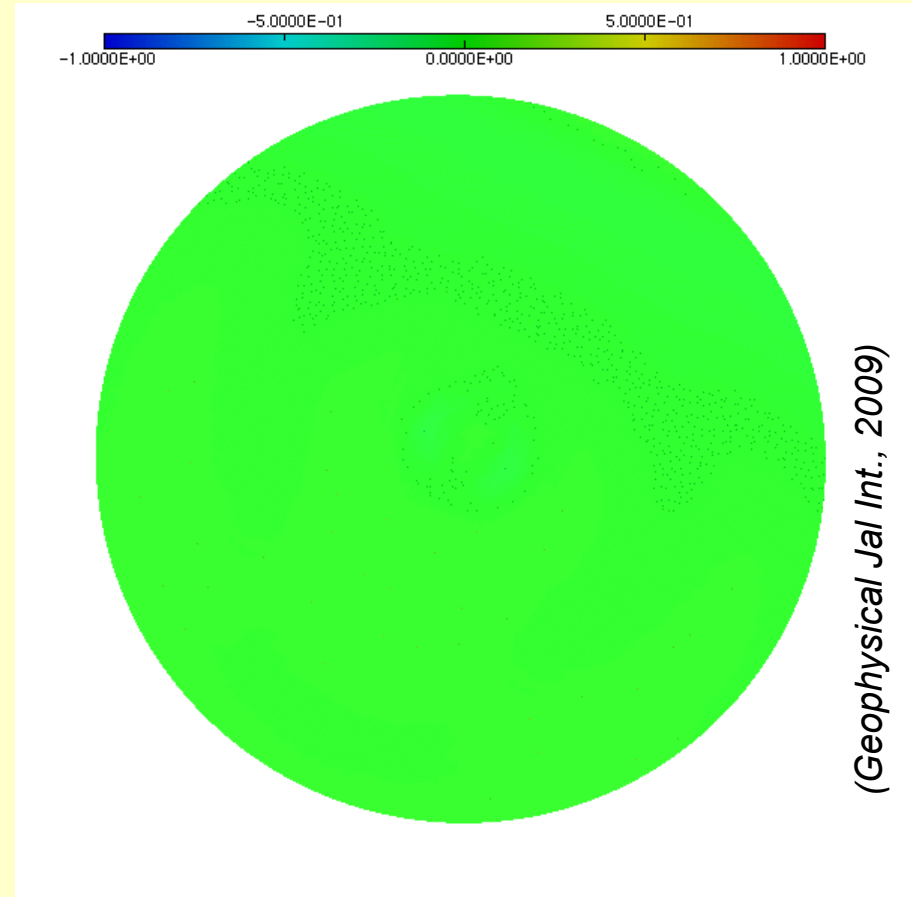
- Data needed!!! (in the nonlinear range!!)

# 3D effects? (or '1D-3C'!)

## Fast-BEM approach *Measurements in Grenoble*



(Chaillat, Semblat, Bonnet, CiCP, 2010)



(Geophysical Jnl Int., 2009)



# Thank you!

<http://perso.lcpc.fr/semblat.jean-francois>

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# Absorbing layer method

- ‘CALM’: Cauchy Absorbing Layer Method (IJNME, sept.2010)
- Absorbing layer with adequate Rayleigh/ Cauchy damping parameters

