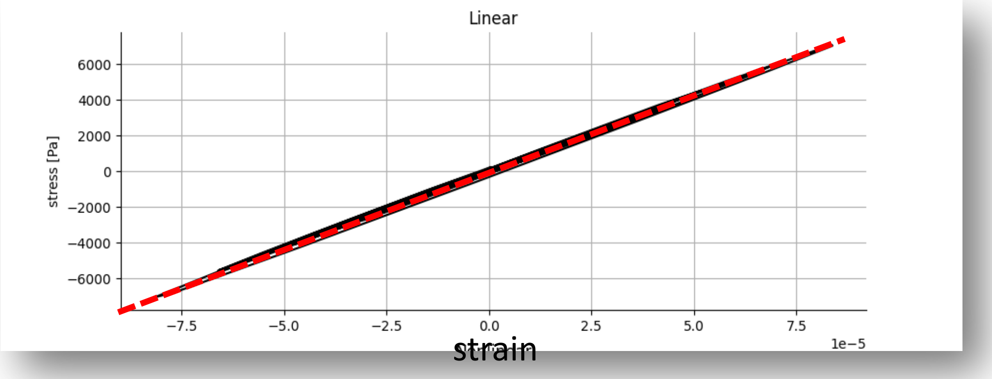
ANR E-City

Understanding the nonlinear behavior of shallow sediments

Case study: Iwate Prefecture, Japan

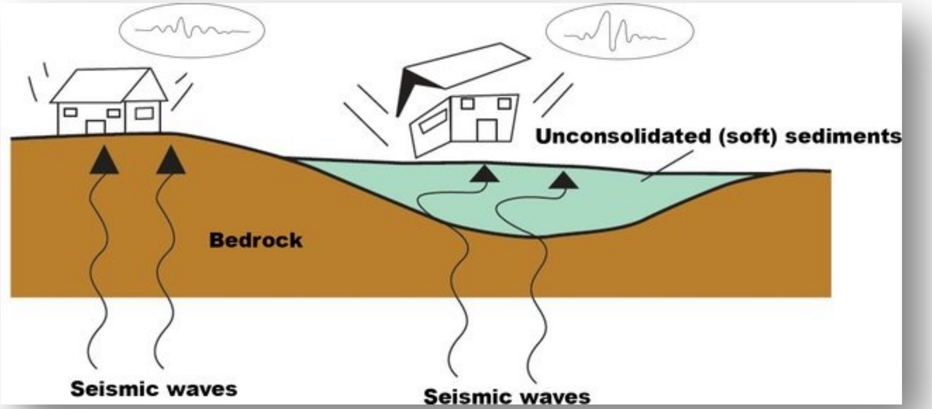
Ph.D. student Schibuola Alessandra
Email adress: alessandra.schibuola@univ-eiffel.fr
Supervisors: Luis Fabian Bonilla & Eléonore Stutzmann

Introduction: the linear world

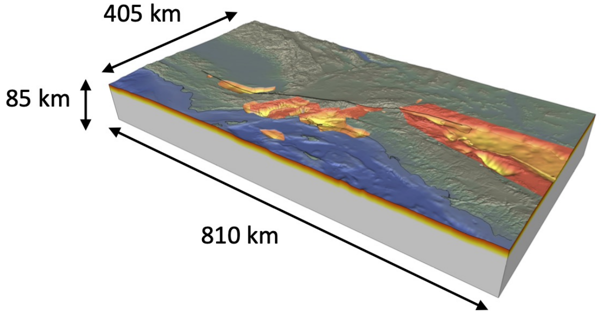


What is the effect of seismic ground motion on different soil types?

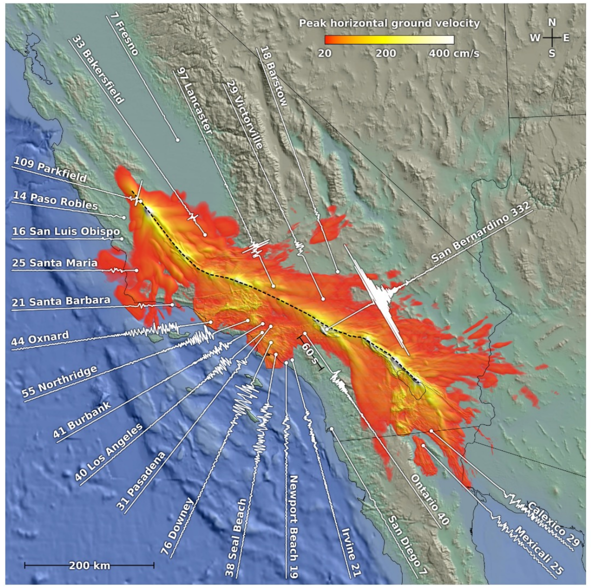
- **Sediments can amplify** earthquake ground motion relative to bedrock
- Weak motion earthquake **amplification** is well-explained in terms of **linear elasticity**, where the imposed stress is directly related to the associated strain



(Darvasi and Agnon, 2019)



- M8
- 360 s of ground motion
- spontaneous rupture
- **minimum Vs = 400 m/s**
- **frequency: 0 - 2 Hz**

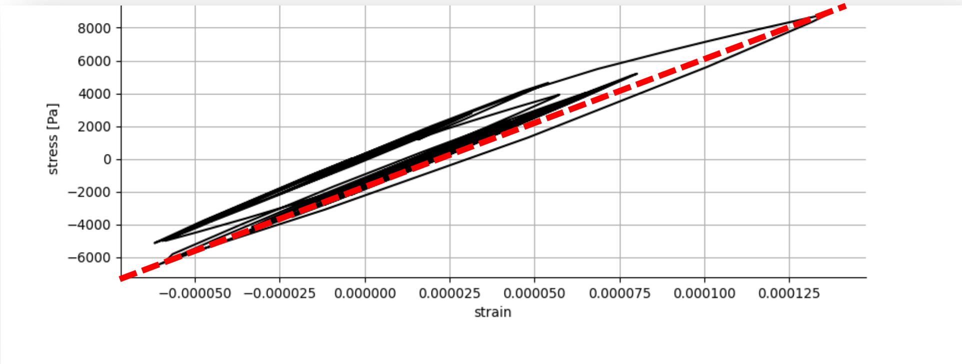


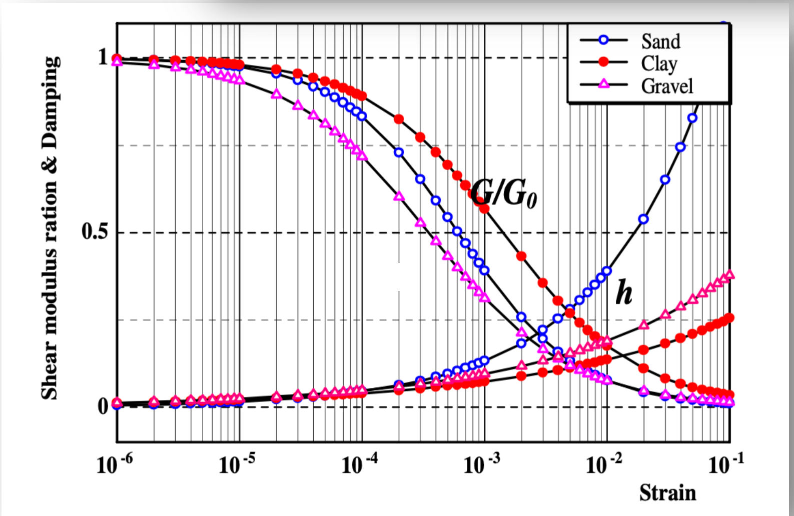
(Cui et al., 2010)

➢ Introduction:

What is nonlinearity and why is it important? what about strong ground motion produced by large earthquakes?

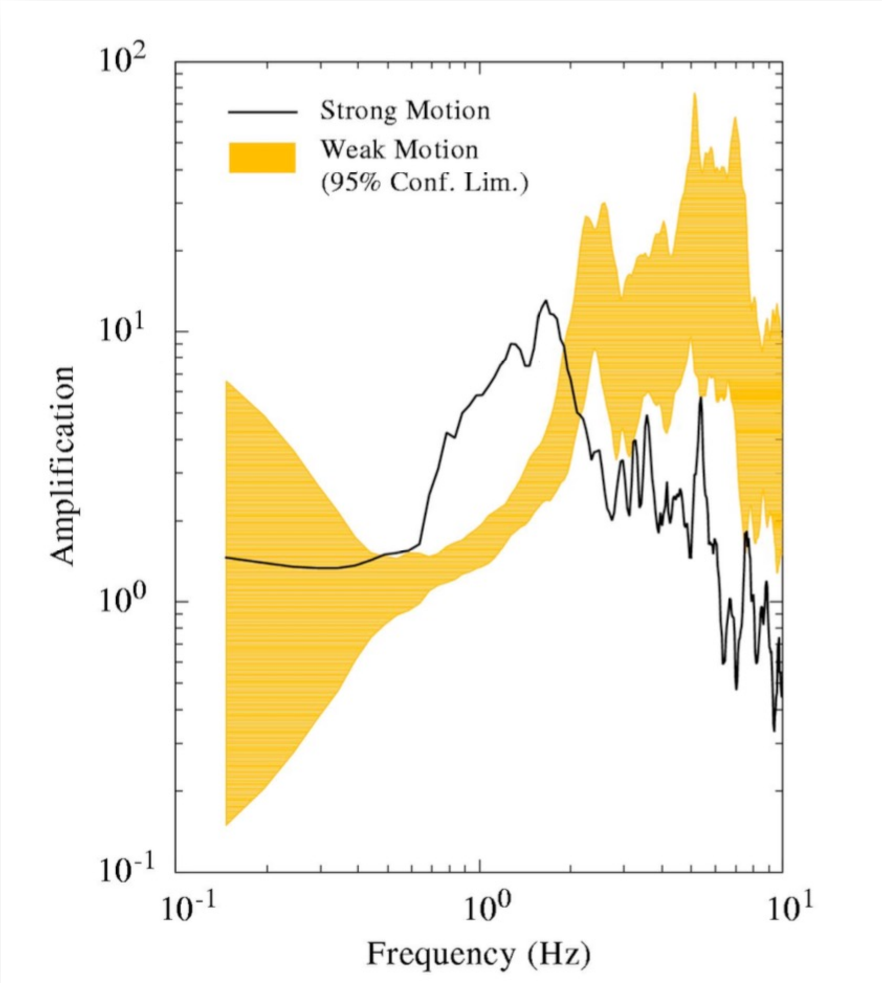
- The **linear relationship** between stress and strain **breaks down for large earthquake**





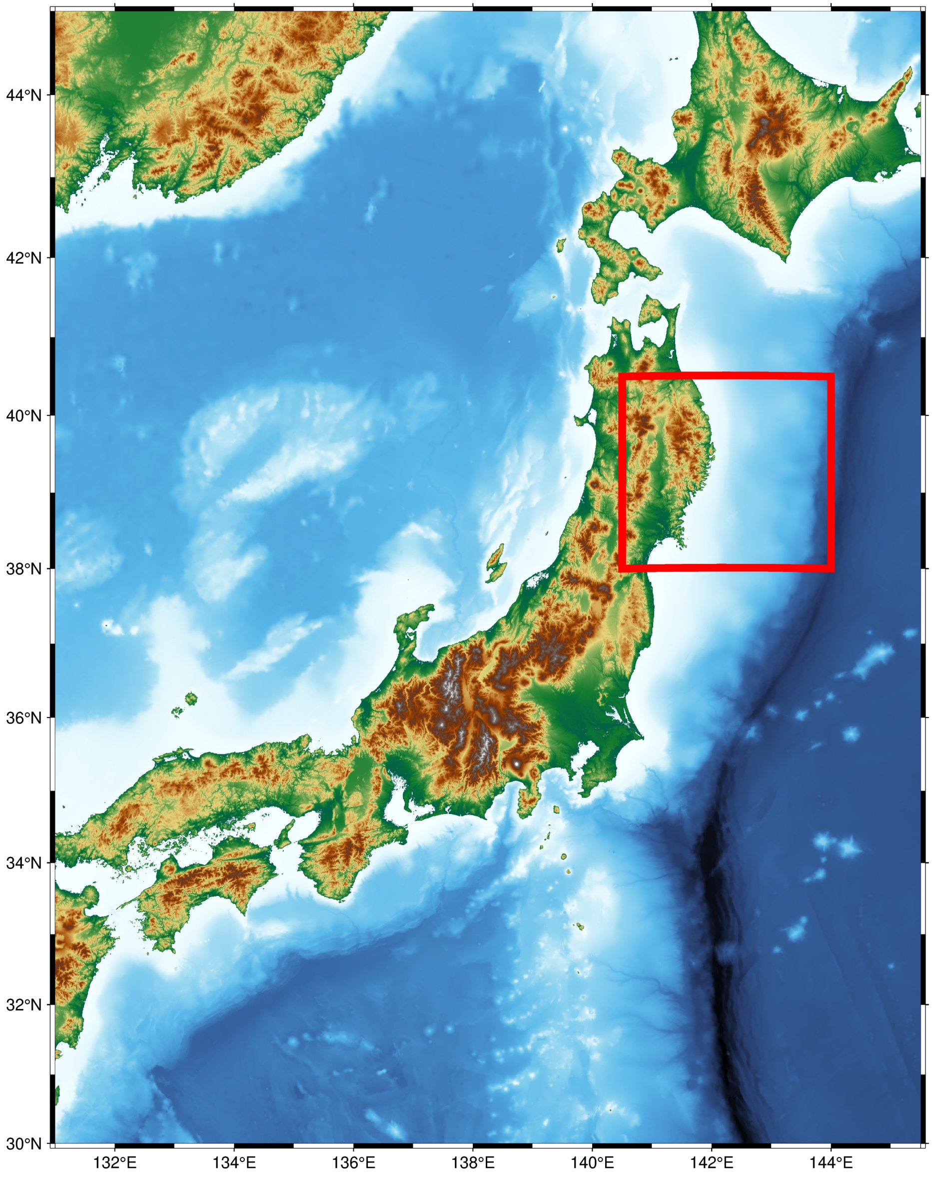
(Hayashikawa et al., 2004)

$$G_0 = \rho v_s^2$$

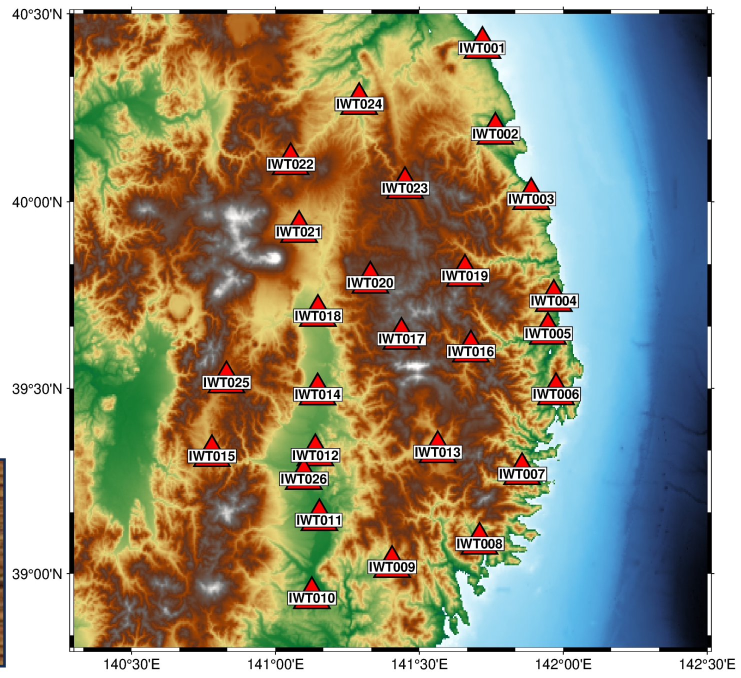


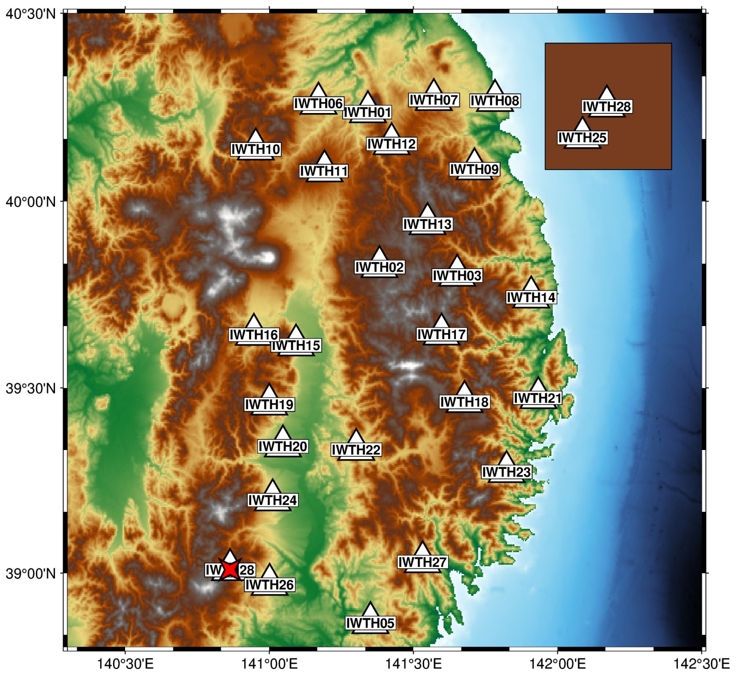
(Bonilla et al., 2018)

➢ Data: KiK-net & KNET records from Iwate Prefecture, Japan



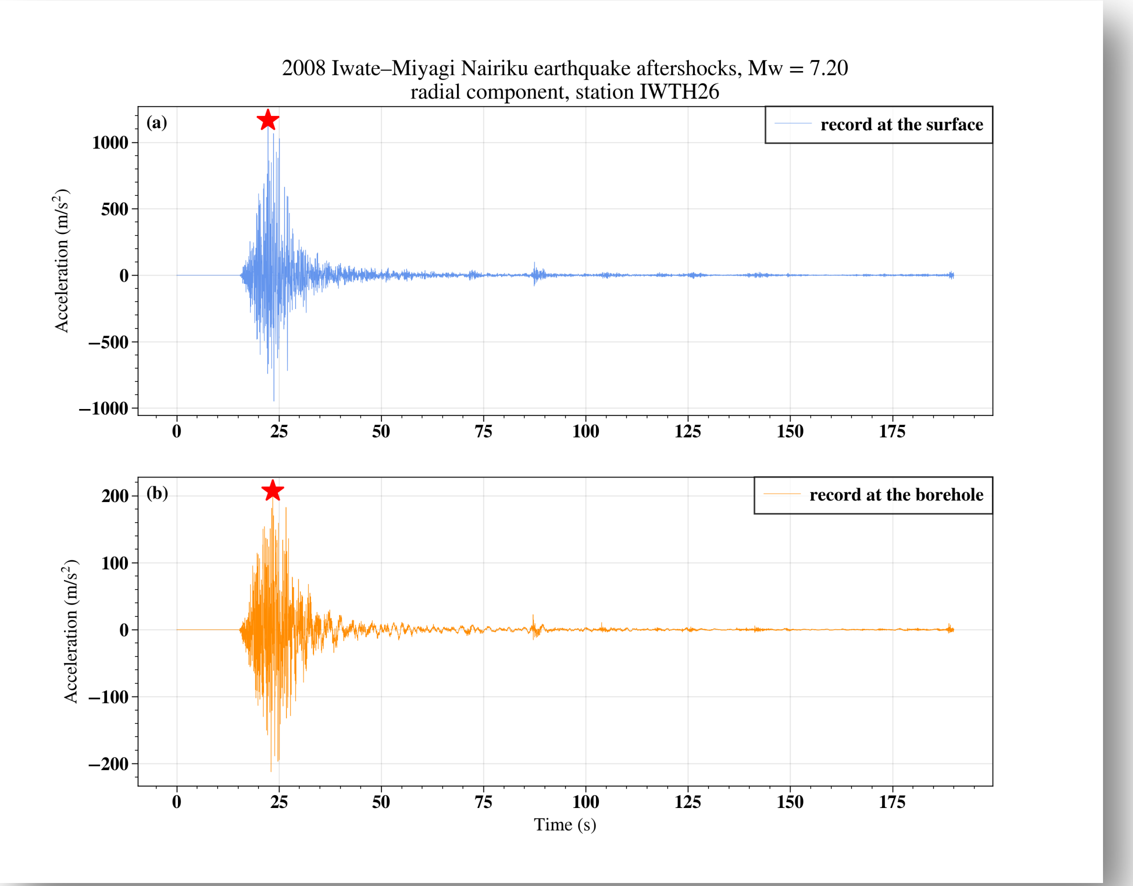
- Period: **1996-2022**
- Earthquake recorded from **Japanese seismic networks**





- Around **2000** earthquakes per station
- Magnitude ranging from **2** to **9**

➢ Data Processing: Ground motion classification



Peak Ground Acceleration (PGA) is the highest level of shaking experienced at a certain location during an earthquake

Earthquakes are **categorized based on PGA levels** (weak to strong)

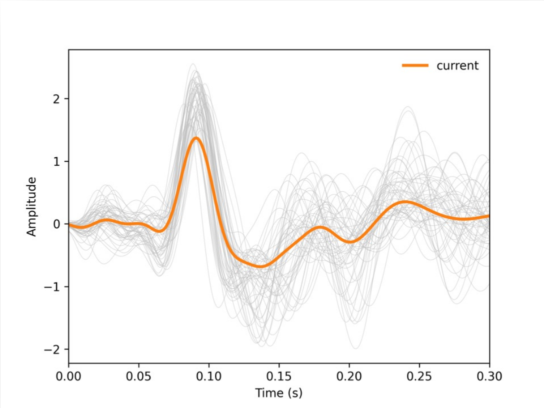
Linear reference established for **weak ground motion**

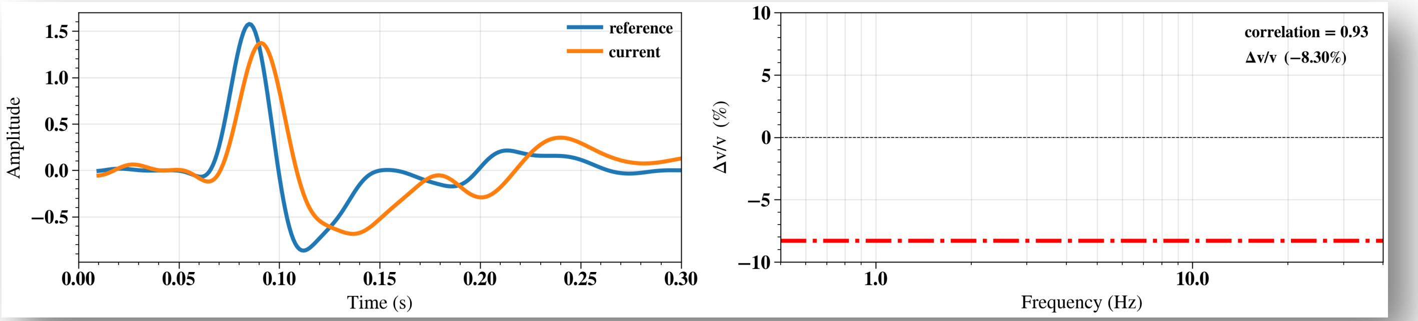
$1\ (cm/s^2) \le PGA \le 5\ (cm/s^2)$

Data Processing: Signal processing techniques

The results are obtained by applying seismic interferometry through deconvolution in IWTH21.
The data are **stacked** for each bin of PGA.
The stretching method is employed for comparison between the reference (from 1 to 5 cm/s^2) and the current (from 50 to 100 cm/s^2).

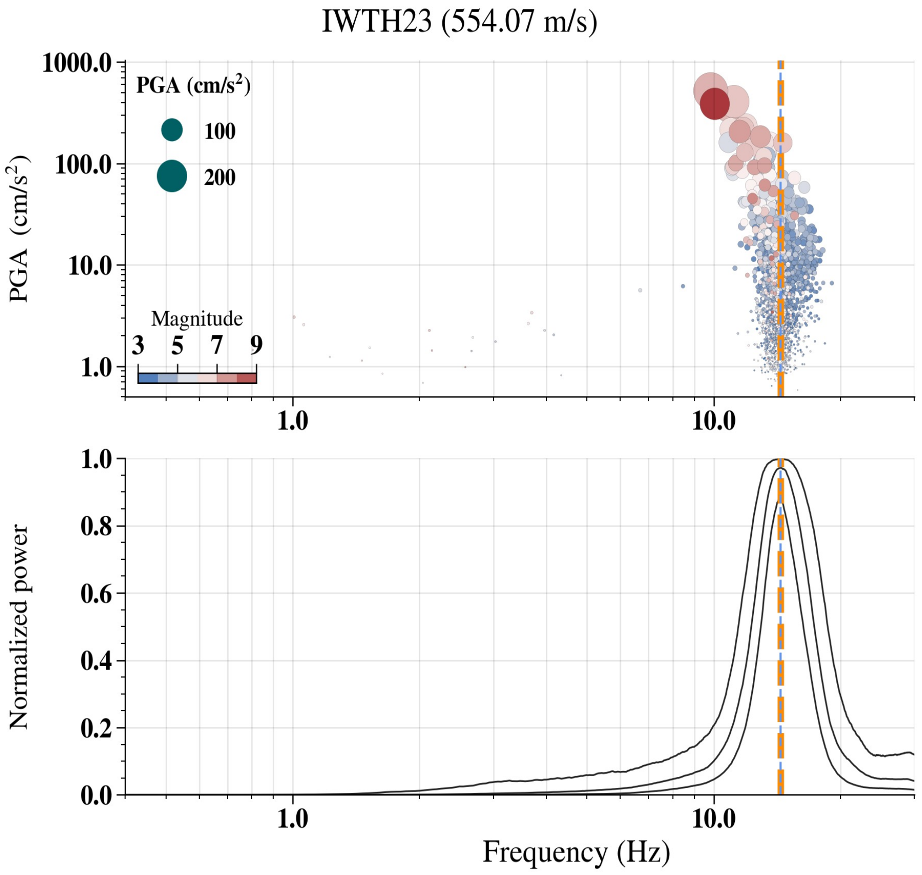
$$\varepsilon = \frac{\Delta v}{v} = -\frac{\Delta t}{t}$$



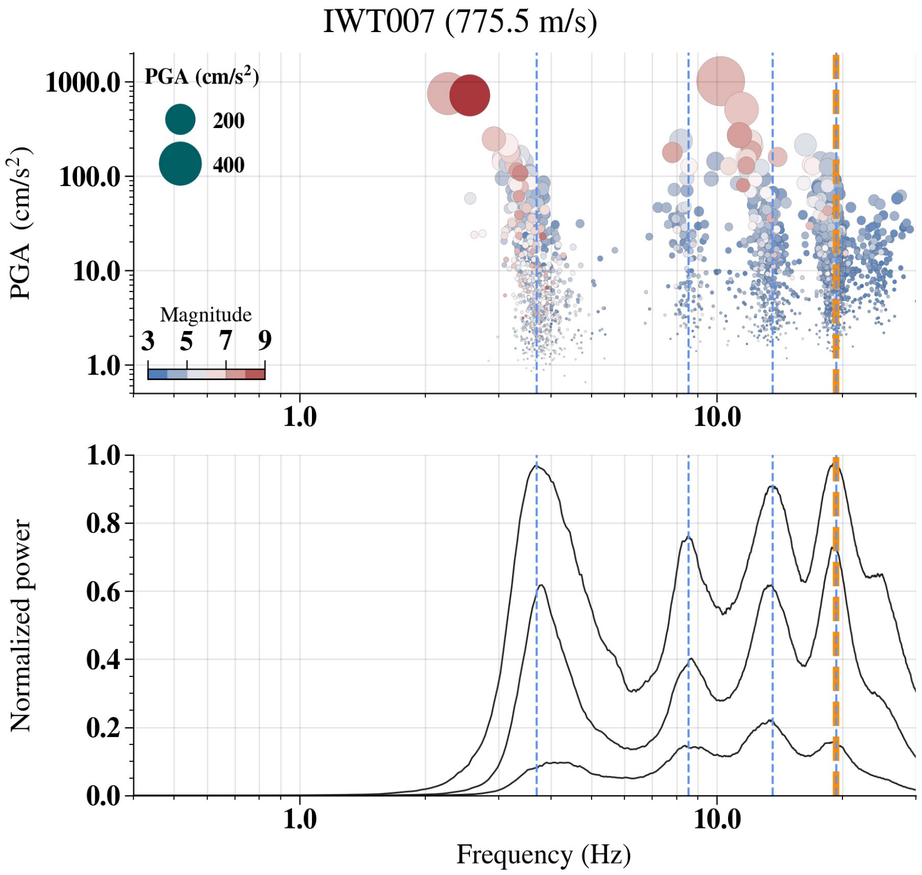


➢ Soil nonlinearity observations: frequency and velocity changes

Unimodal

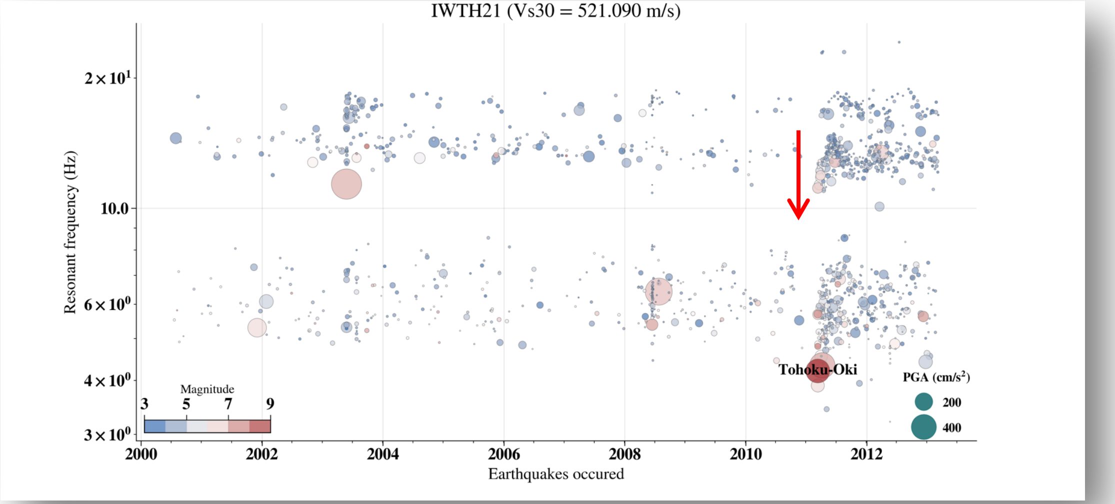


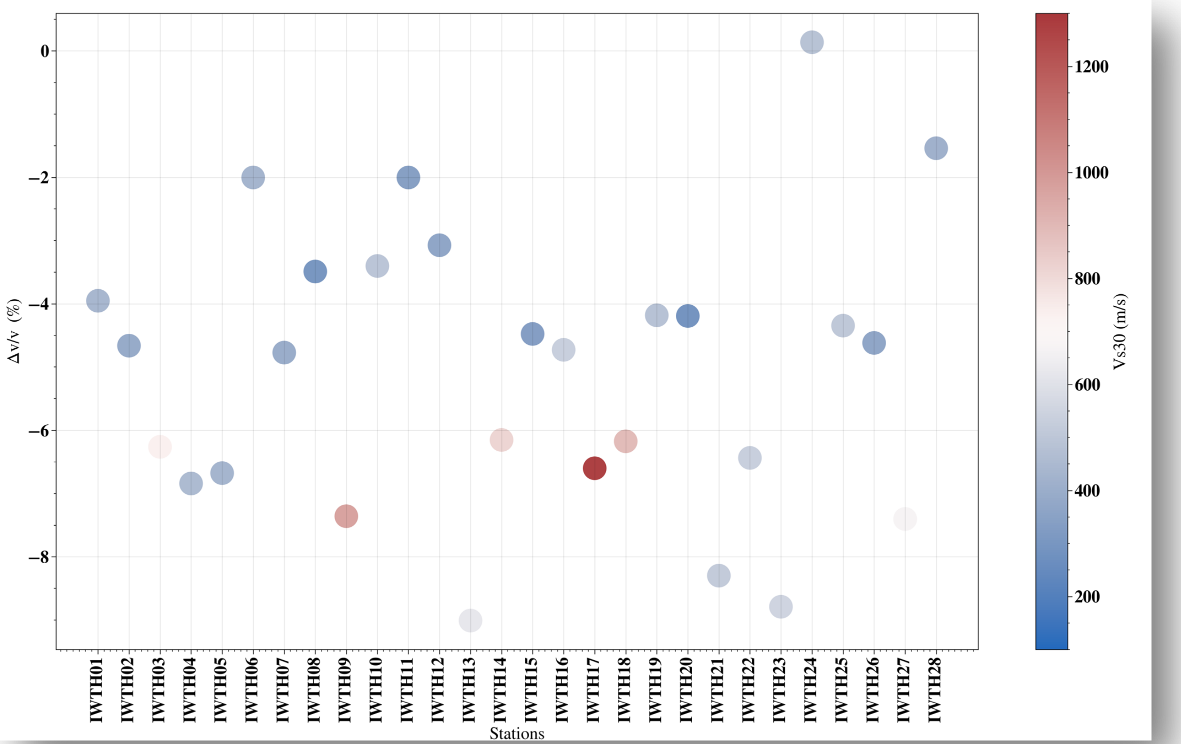
Multimodal



Soil nonlinearity observations: frequency and velocity changes

Some events can cause **strong decreases in frequency**,
and it may take months to years to fully recover from this effect





Conclusions

1. The station response can be either unimodal or multimodal behavior underlining the complexity behind soil-ground motion interactions

2. During strong ground motions, the materials in the shallow crust may drastically change causing the linear relationship between stress and strain to break down

3. There is a reduction in material stiffness and an increase in damping as strain increases

➢ References

- Darvasi, Y. & Agnon, A. (2019), Calibrating a new attenuation curve for the Dead Sea region using surface wave dispersion Surveys in site damaged by the 1927 Jericho earthquake. European Geosciences Union. SE, 10, 379-390.
- Cui, Y. *et al*. (2010), Scalable Earthquake Simulation on Petascale Supercomputers. *SC '10: Proceedings of the 2010 ACM/IEEE International Conference for High Performance Computing, Networking, Storage and Analysis*, New Orleans, LA, USA, pp. 1-20.
  keywords: {Mathematical model;Computational modeling;Equations;Earthquakes;Stress;Propagation;Numerical models},
- Bonilla, L.F., Gelis, C., & Régnier, J. (2018). Effects of Surface Geology on Seismic Motion THE CHALLENGE OF NONLINEAR SITE RESPONSE: FIELD DATA OBSERVATIONS AND NUMERICAL SIMULATIONS
- Hayashikawa, T., Abdel, R. S., & HASHIMOTO, I. (2004). NONLINEAR SEISMIC RESPONSE OF SOIL-FOUNDATION-STRUCTURE INTERACTION MODEL OF CABLE-STAYED BRIDGES TOWER

Thank you!

alessandra.schibuola@univ-eiffel.fr

E-City

ANR E-City

Université Gustave Eiffel

IPGP

Université Paris Cité