Variability of earthquake ground motion due to small scale heterogeneities: comparison of 2D and 1D probabilistic approaches

Presented by:

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16/11/2018

Influence of 2D heterogeneous elastic soil properties on surface ground motion spatial variability.

El Haber, E., Cornou, C., Jongmans, D., Abdelmassih, D. Y., Lopez-Caballero, F., & AL-Bittar, T. (2019).

Soil Dynamics and Earthquake Engineering, 123, 75-90.

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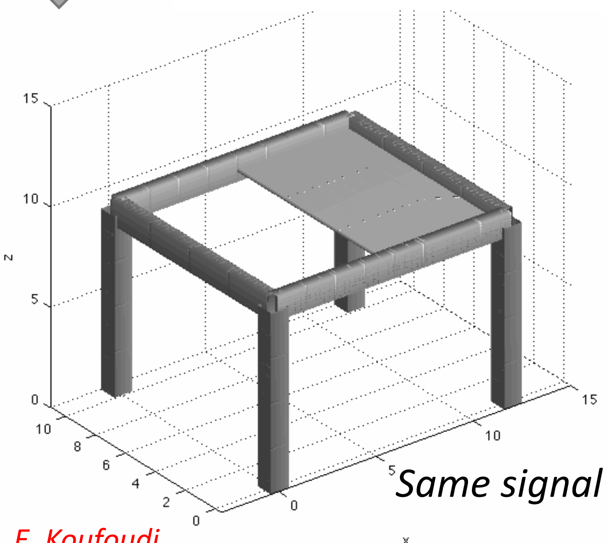
Definition and near surface causes

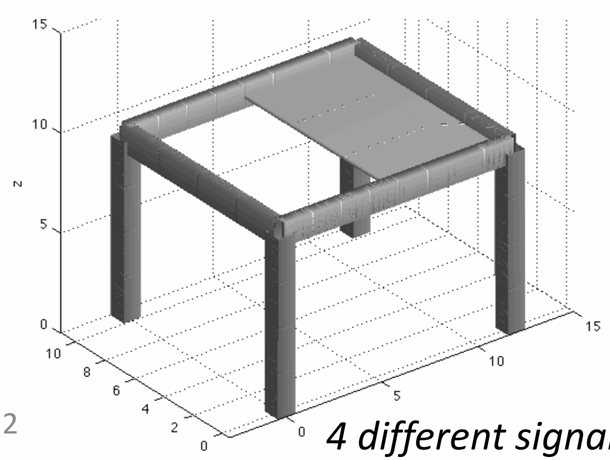
Spatial variability of earthquake ground motion (SVGM)

Difference in amplitude and phase between two recordings on surface



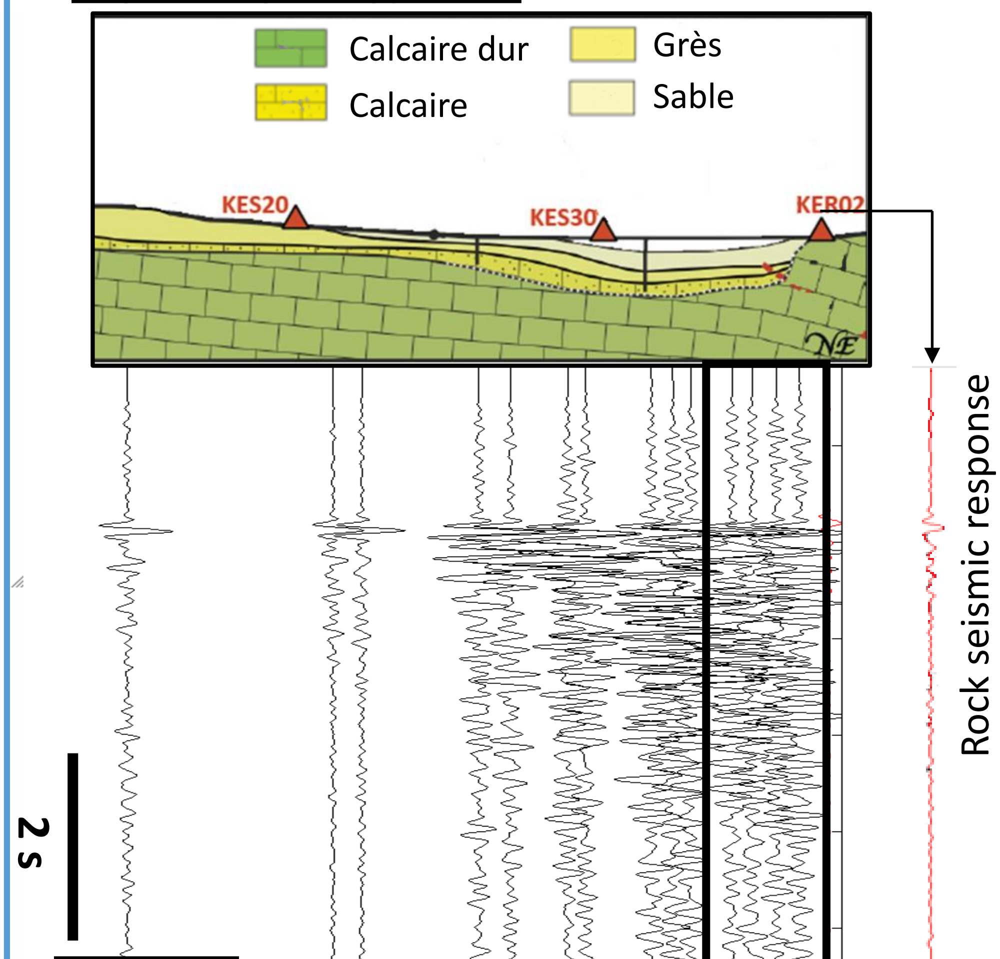
Same signal at supports

E. Koufoudi



4 different signals at supports

Argostoli geology basin



Theodulidis et al. 2018

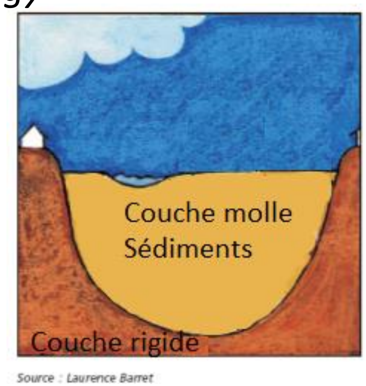
Definition and near surface causes

Spatial variability of earthquake ground motion (SVGM)

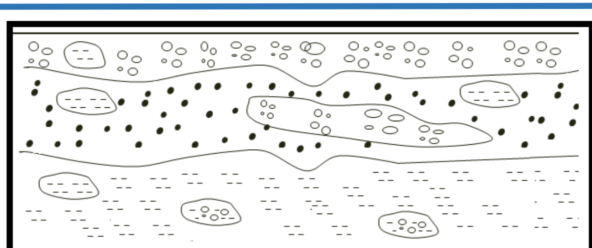
Difference in amplitude and phase between two recordings on surface

Large scale heterogeneities
[few hundred of m -> few kms]

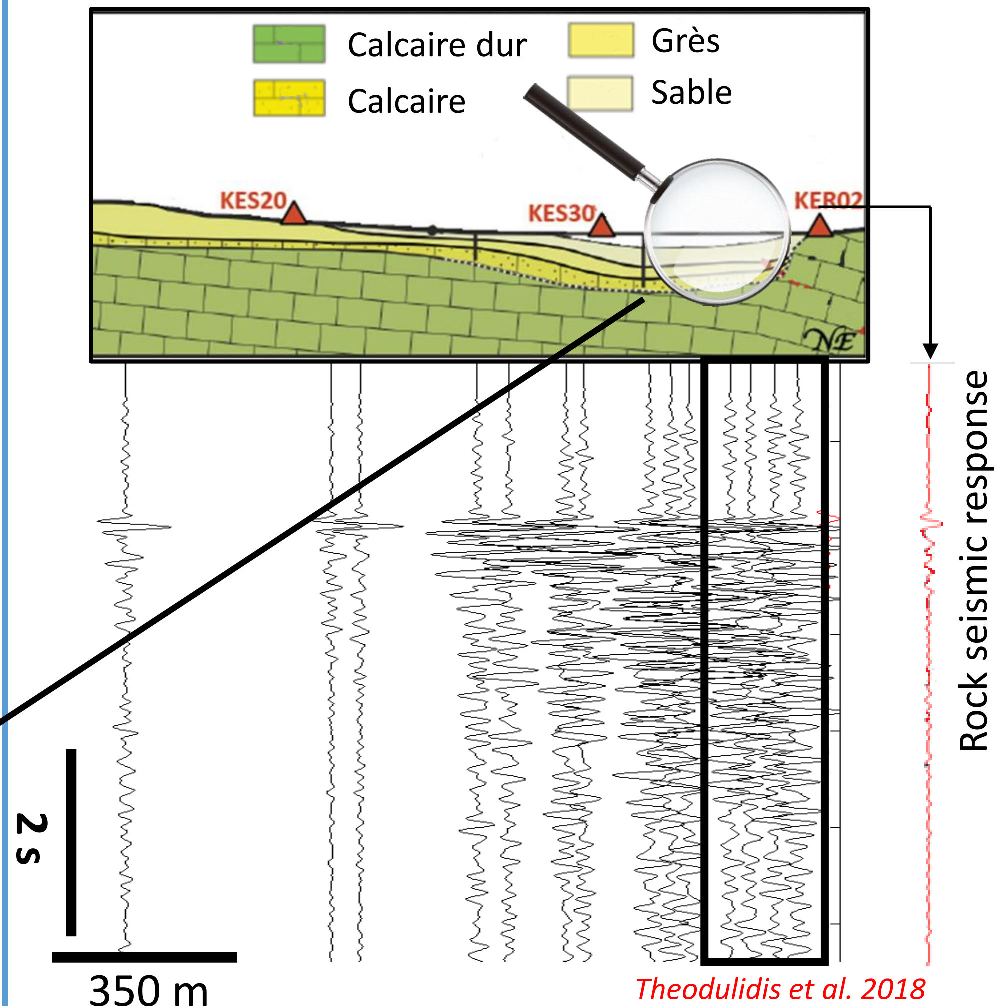
Lithology



Small scale heterogeneities
[few cms -> few hundred of m]



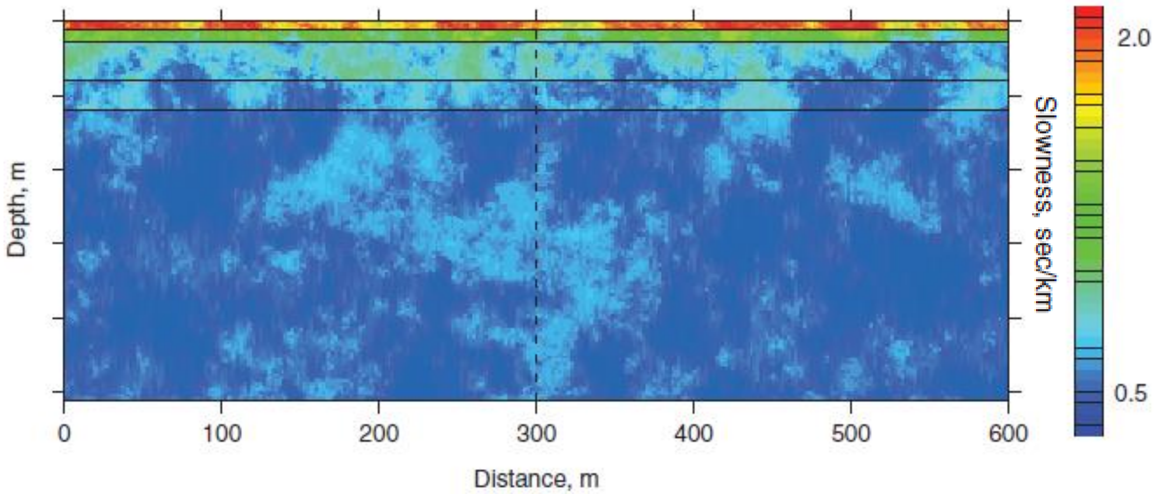
Argostoli geology basin

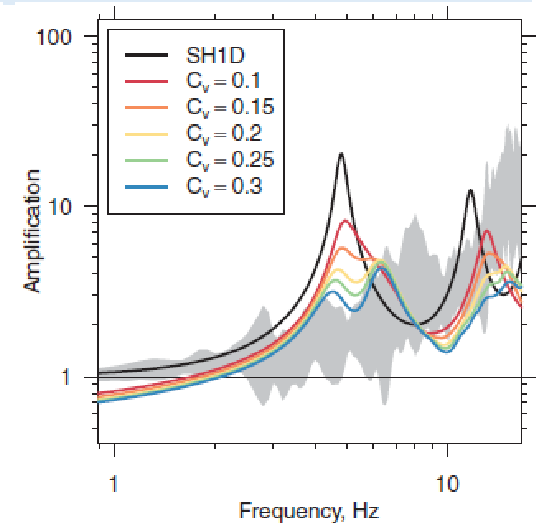


Theodulidis et al. 2018

Small scale heterogeneities and site response prediction – Example (1)

Thompson et al. (2009)



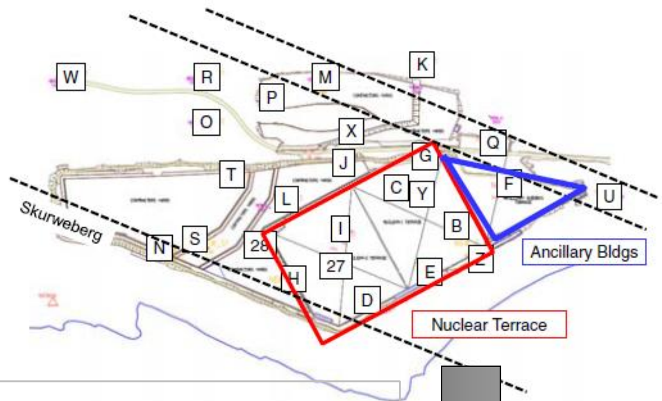


=> Importance of the small scale heterogeneities in the site response prediction

=> Not all the 1D profiles can predict the seismic response recorded on surface

Small scale heterogeneities and seismic response prediction – Example (2)

Rodriguez-Marek et al. (2014)

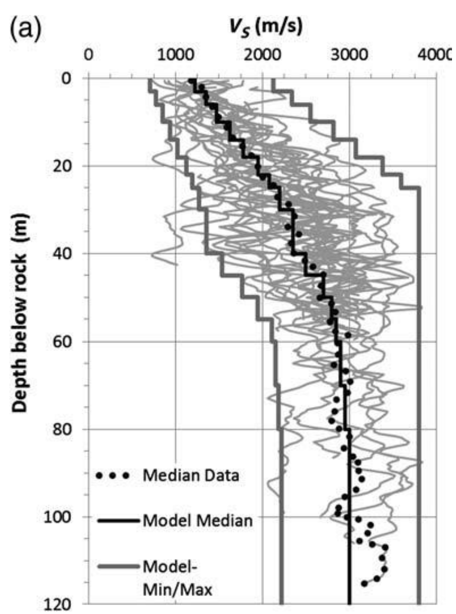


For a given site

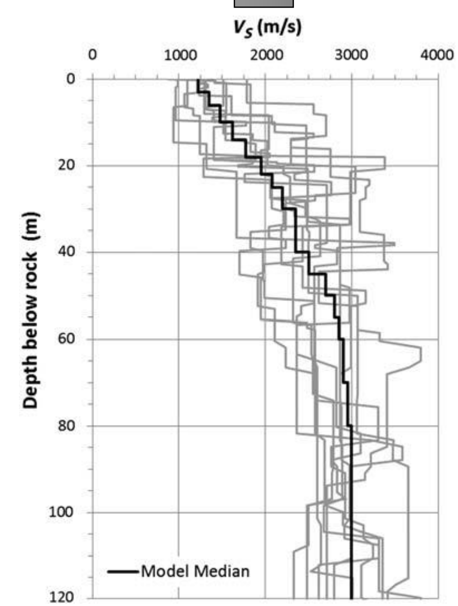
Seismic response prediction

Definition of a mean and std for the soil properties

1D calculations



Generation of 1D random soil profiles



Strategy and objectives

Evaluate the impact of small Scale Heterogeneities on SVGM

Compare 1D and 2D simulations

Simplified Parametric Study

- Sediment Layer over a Bedrock
- Only linear Analysis
- Variability anisotropic of V_s
- ~~Attenuation Non-Linearity~~

→ Single station ground motion indicators

Outline

- Small scale heterogeneities modeling and waves propagation simulation
- Effect of the 2D heterogeneities on single station ground motion indicators
- 2D and 1D comparison
- Conclusions and perspectives.

2D modeling of small scale heterogeneities

Probabilistic approaches

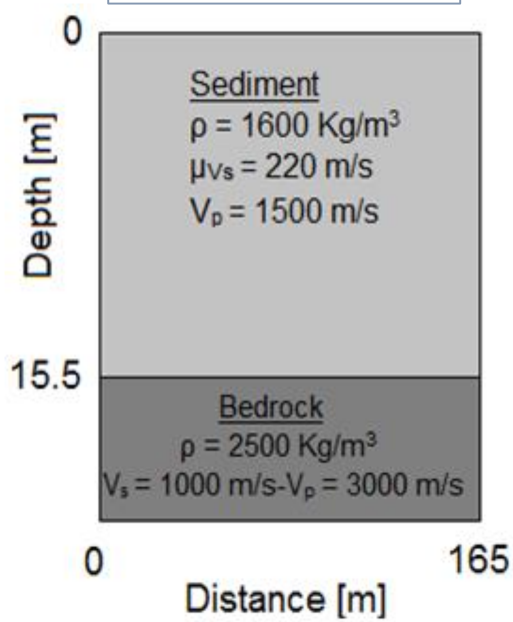
Soil structure with uncertainties → Multiple possible scenarios/probabilistic realizations

How to apply this method in our study?

Probabilistic approach - Definition

Definition of the deterministic model

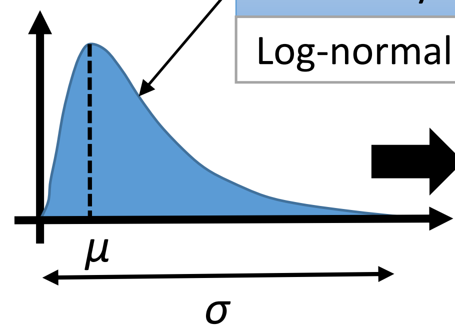
Variability = 0%



Salloum et al. 2014

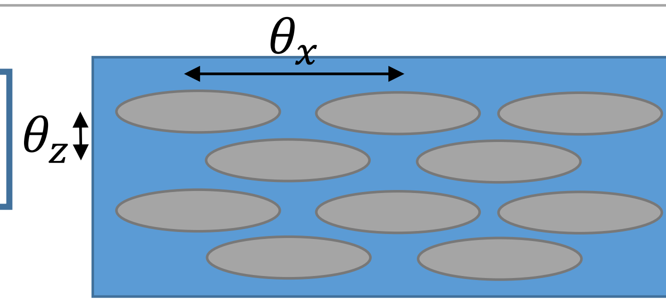
Modeling Vs as a random field

Probabilty distribution function
Log-normal (for soil properties)



$$COV = \frac{\sigma}{\mu}$$

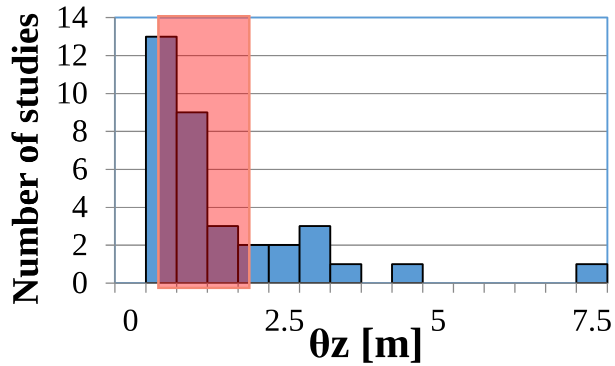
<u>Autocorrelation function</u>

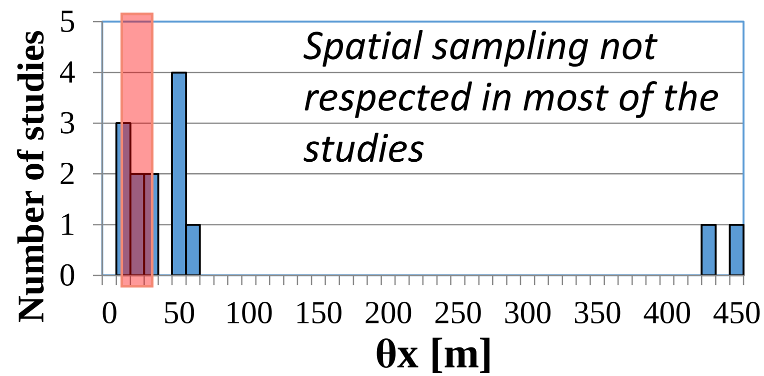


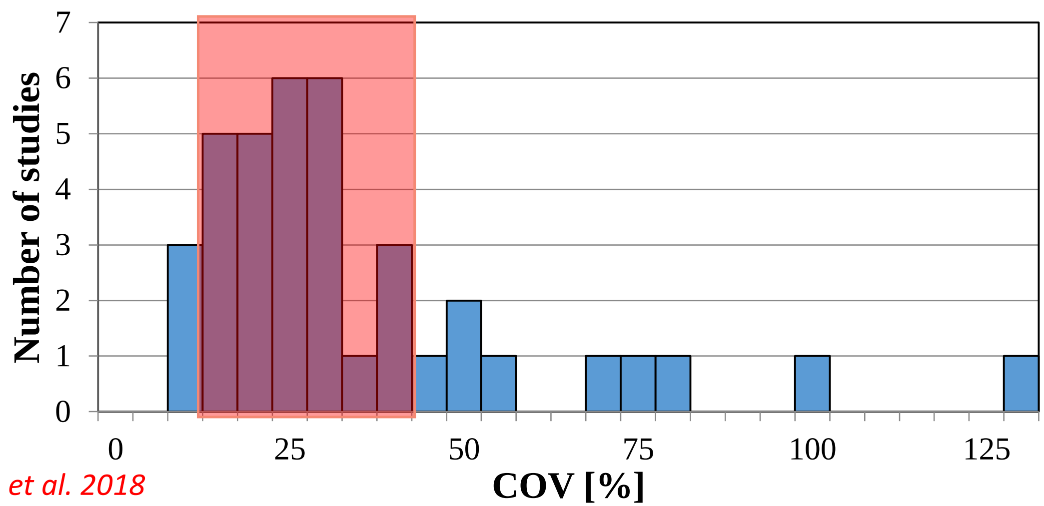
Statistical parameters: COV, θ_x et θ_z

Statistical parameters – range of values

Over 33 characterization studies of near surface soil properties

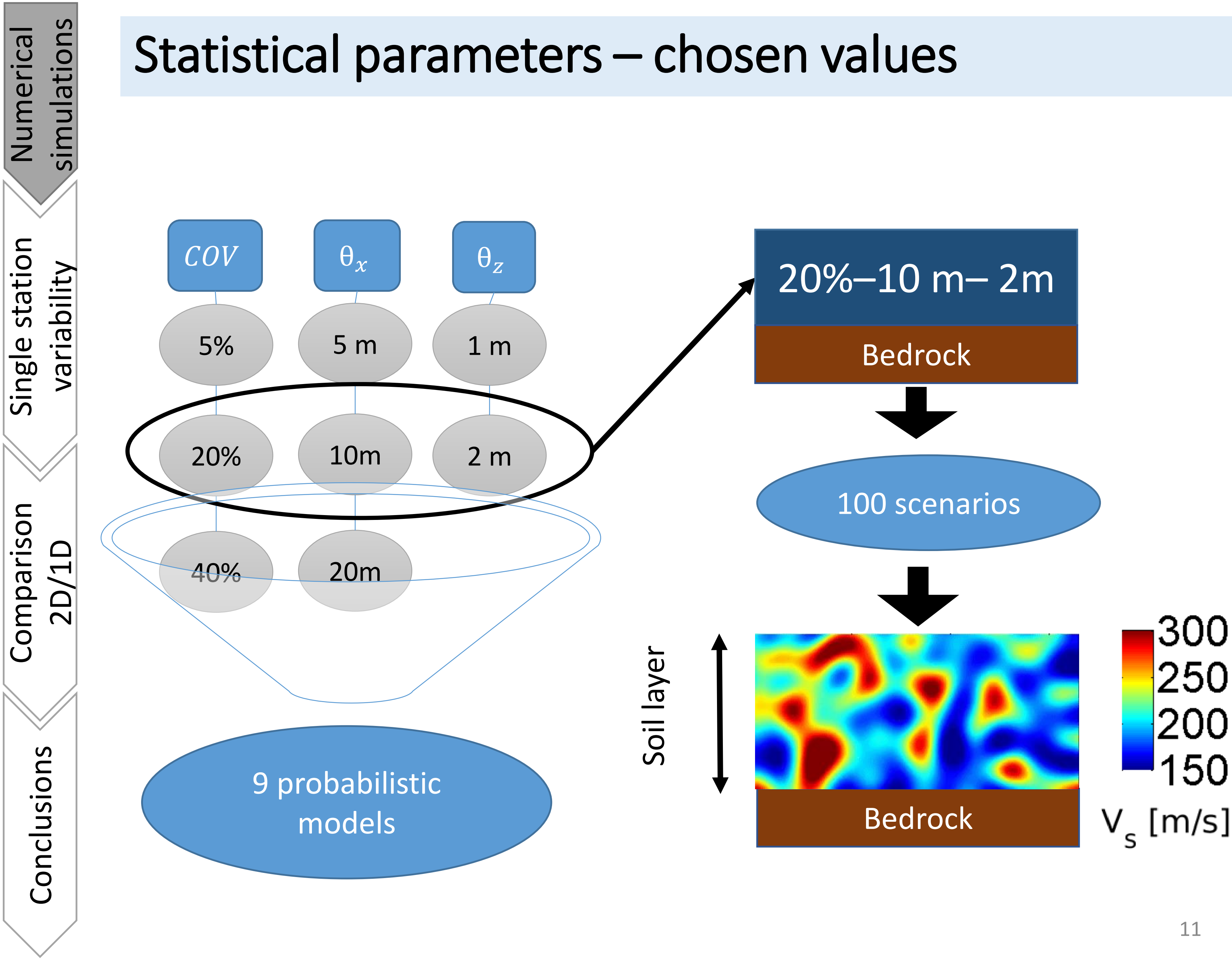






Youssef Abdel-Massih et al. 2018

Statistical parameters – chosen values



Random field discretization and waves propagation simulation

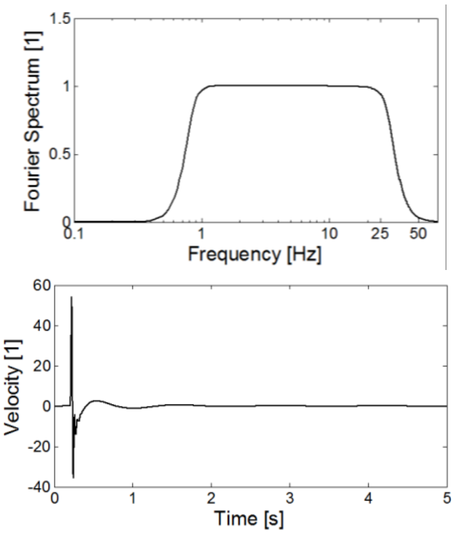
Expansion Optimal Linear Estimation (EOLE)

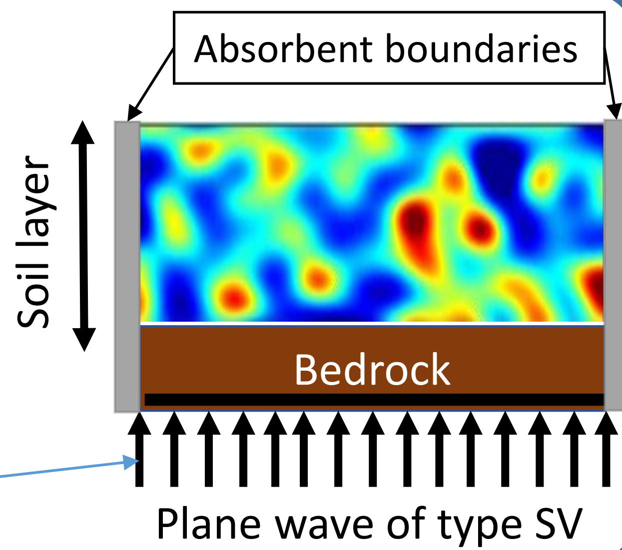
- Krigging method
- Account for the 2D spatial correlation in the soil

Li et Der Kiureghian, 1993

FLAC2D: Finite difference code

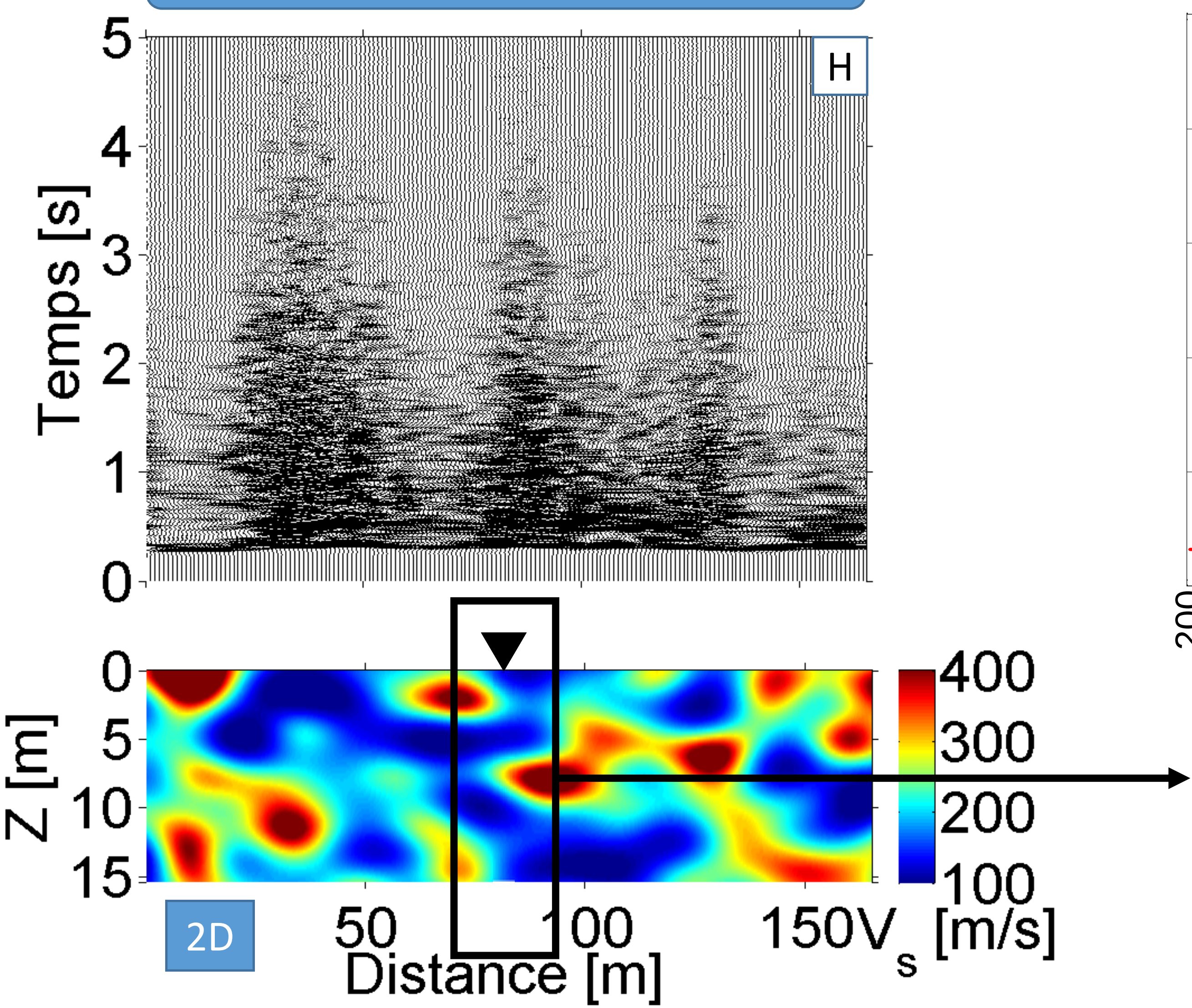
- Linear analysis
- No attenuation

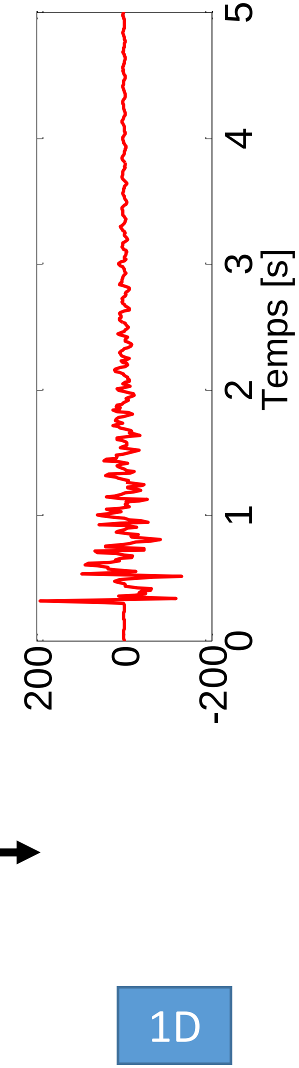




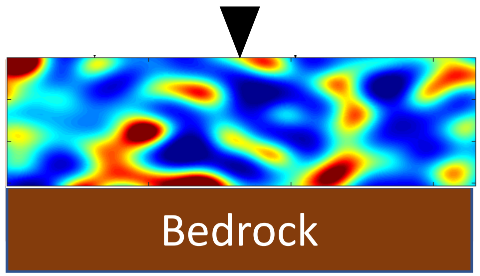
Synthetic simulation - Example

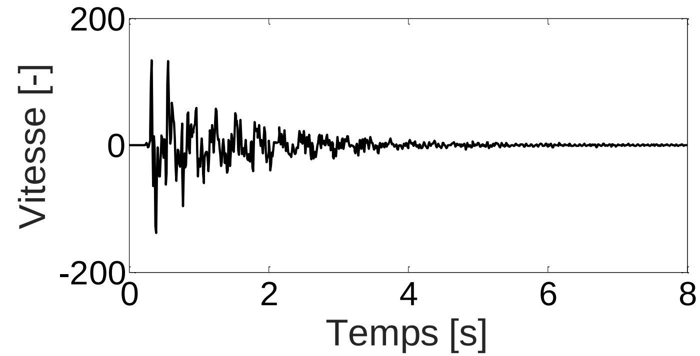
$COV = 40\%$, θ_x=10 m et θ_z= 2 m





Single station ground motion indicators – time and frequency domains





Time domain

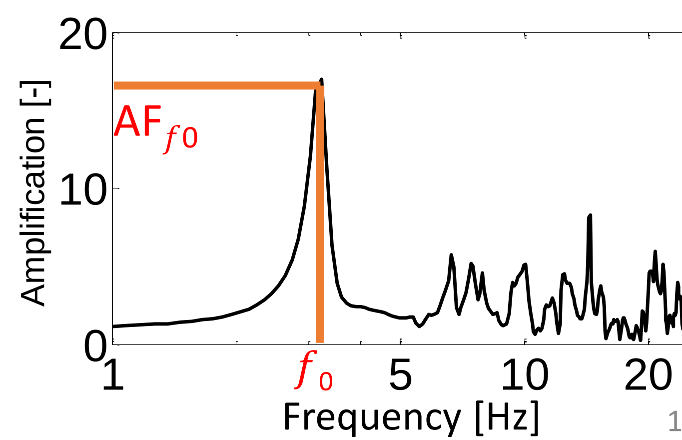
- Energie du signal (ou Intensité d'Arias):

$$A_bI = \int_0^\infty v(t)^2 dt$$

- Durée du Signal:

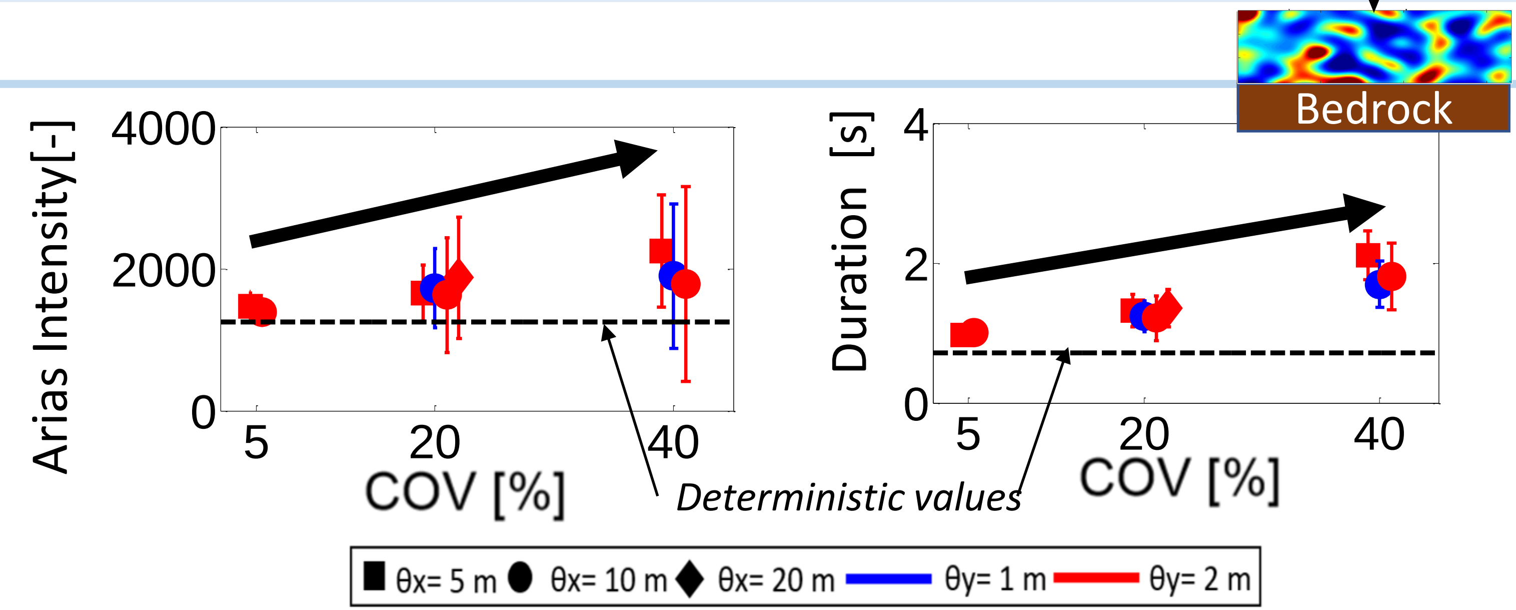
$$DA_bI = t_{E=0.95A_bI} - t_{E=0.05A_bI}$$

Frequency domain



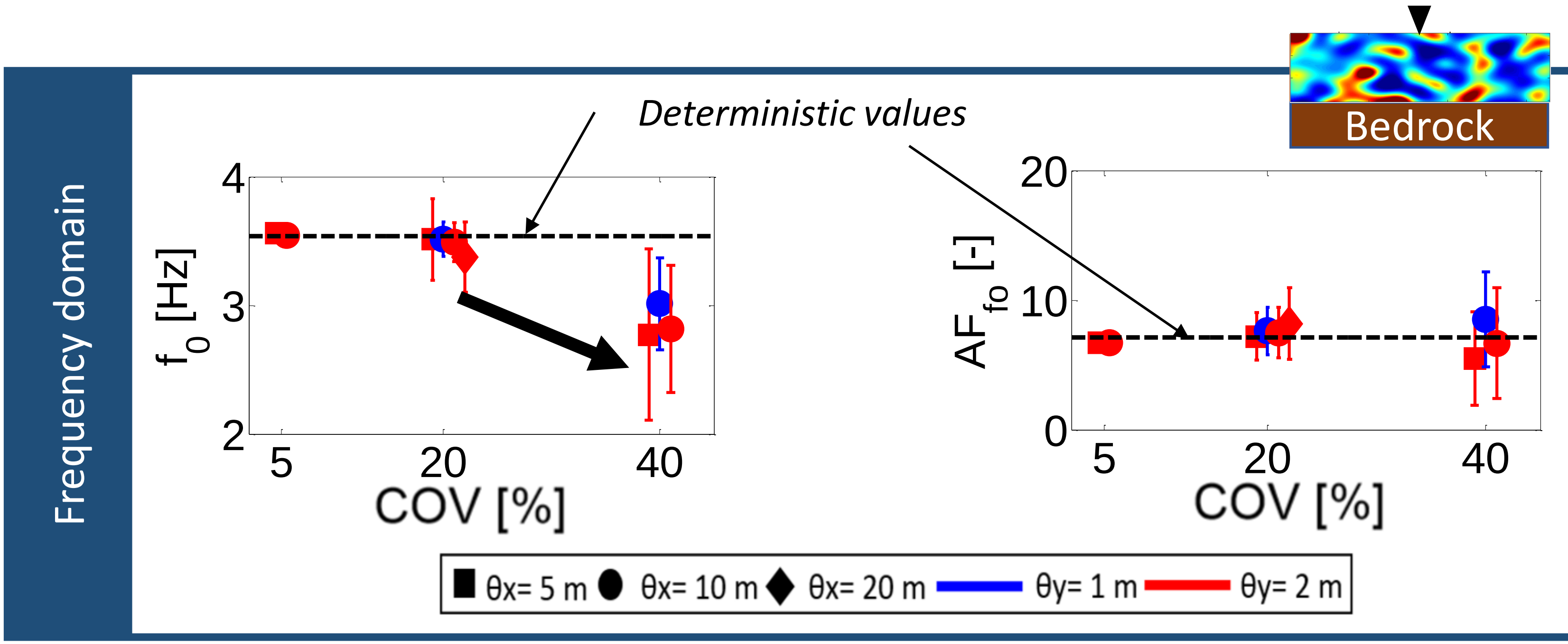
Average and standard deviation at single station (1)

Time domain



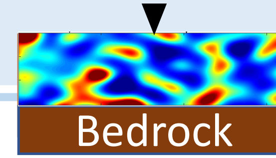
COV is controlling the ground motion variability on surface

Average and standard deviation at single station (2)

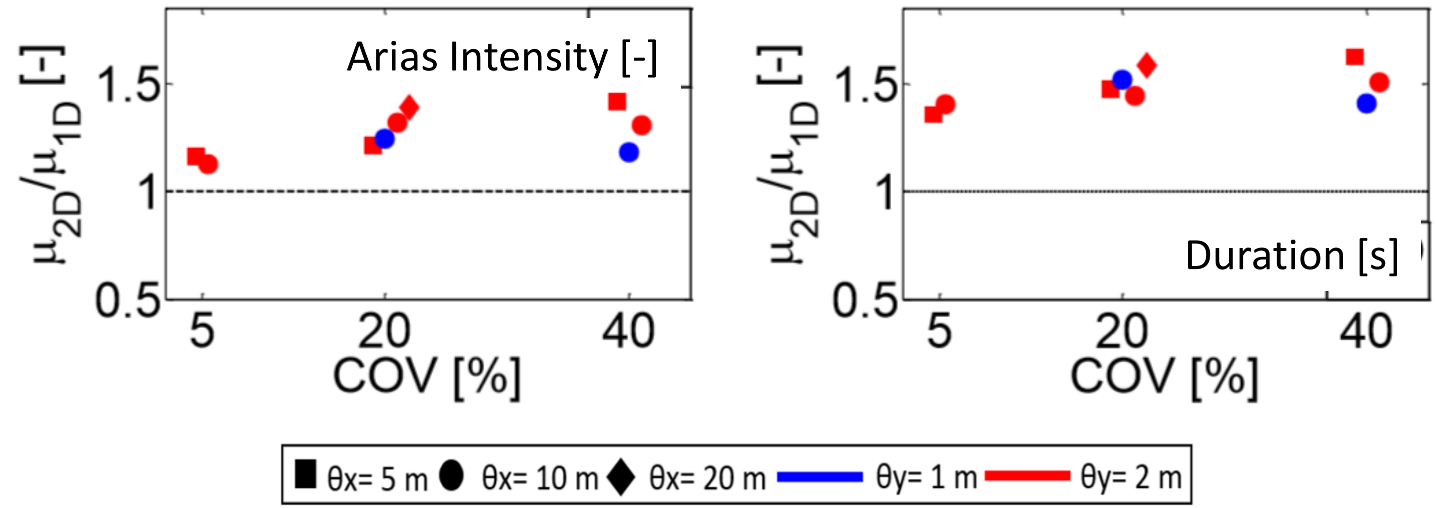


- For the average, no large difference between probabilistic and deterministic approaches.
- COV controls the ground motion variability.
- A shift in the fundamental frequency is observed for COV 40%.

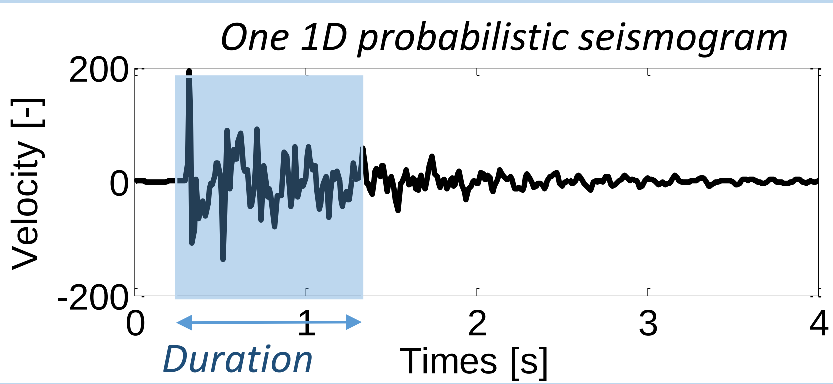
Comparison 2D/1D – Time domain

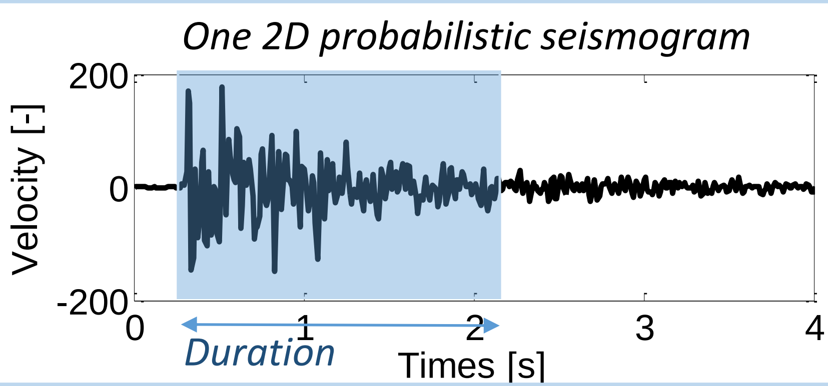


Time domain

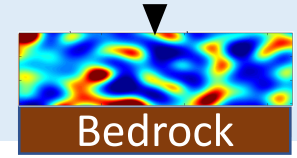


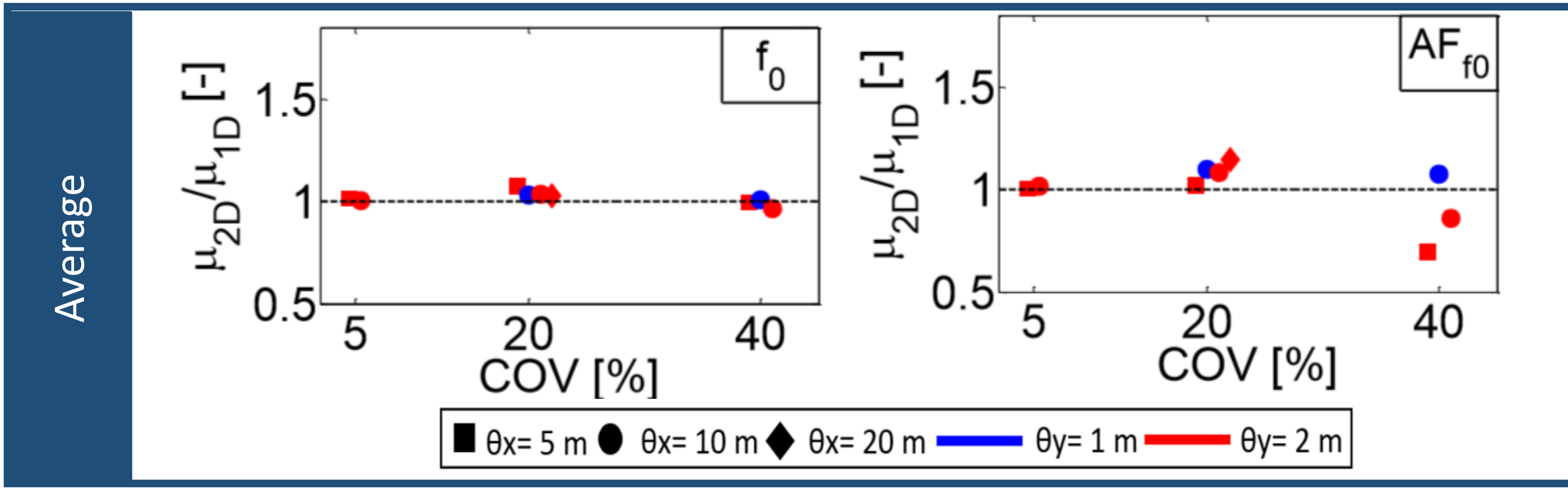
1D calculations clearly underestimate the energy and the duration of the ground motions recorded on surface

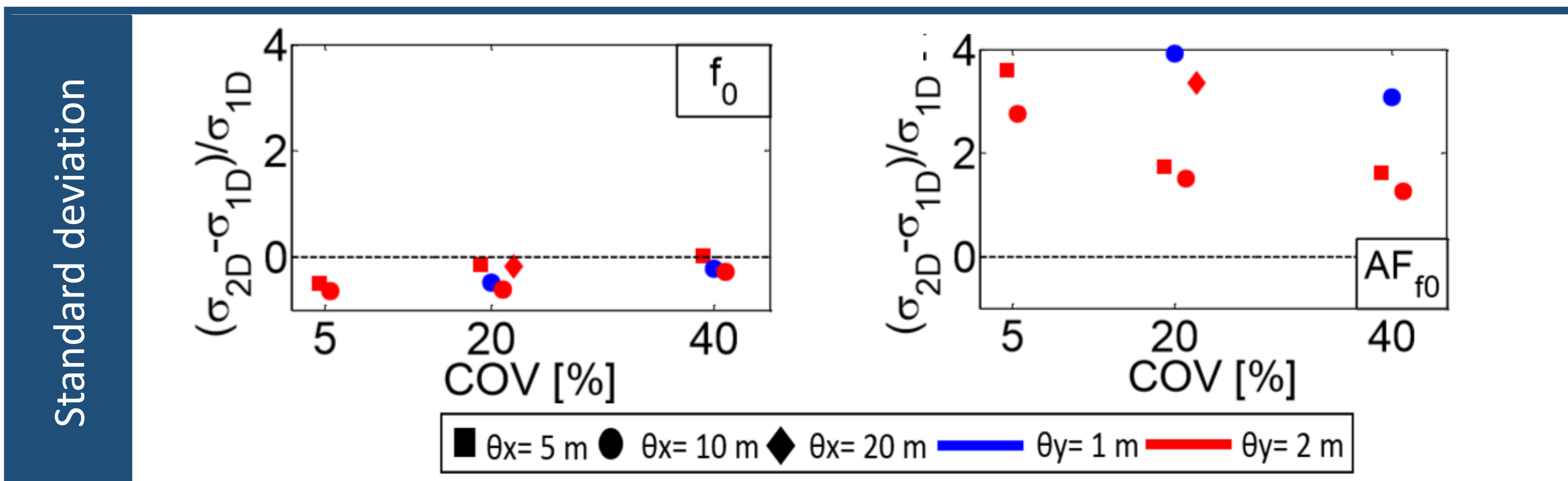




Comparison 2D/1D – Frequency domain







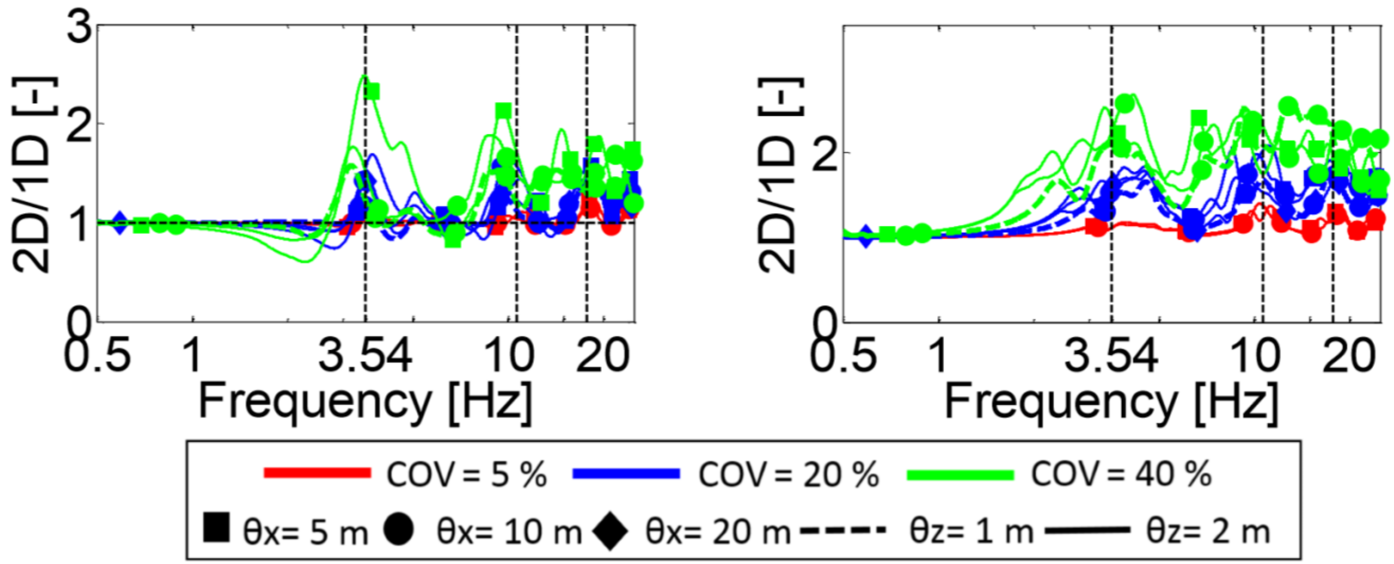
- The 1D approach can predict the f_0 and AF_{fo} average values.
- The 1D approach under estimate the variability of AF_{fo}

Comparison 2D/1D – Spectral amplification

AF_{2D} / AF_{1D}

Average

Standard deviation



The 1D approach underestimate the amplification variability especially at high frequencies.

Numerical simulations
Single station variability
Comparison 2D/1D
Conclusions Perspectives

Main conclusions

- **Small scale heterogeneities generate diffracted surface waves that increase the duration and energy of the seismograms on surface. Waves scattering is more highlighted in 2D approaches than the 1D analysis.**

- **COV is the statistical parameter mainly controlling the variability of the single station ground motion indicators.**

- **Even though 1D probabilistic approaches can predict the fundamental frequency and corresponding amplification, however, they under estimate the spectral amplification variability especially at high frequencies.**

- **1D approaches may not be appropriate to replace the 2D ones in the prediction of site response.**

Some perspectives

- **Account for attenuation and non-linearity behavior in the wave propagation simulation.**
- **More realistic Vs profiles.**
- **More complex soil structures (different geology layers, 3D modeling, …)**

Thank you for your attention

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