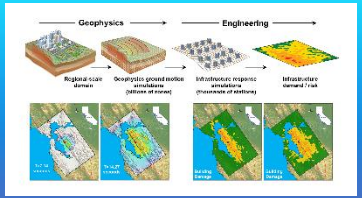
PEER International Pacific Rim Forum
June 16-17, 2021



Pushing the Simulation of Earthquake Ground Motion in the Grenoble Valley to Higher Frequencies.

Part I: Integrating Geotechnical, Geological and Geophysical Near-Surface Properties into a 3D Model

Cornou Cécile

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ISTerre, Grenoble, France

June 16, 2021

PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR

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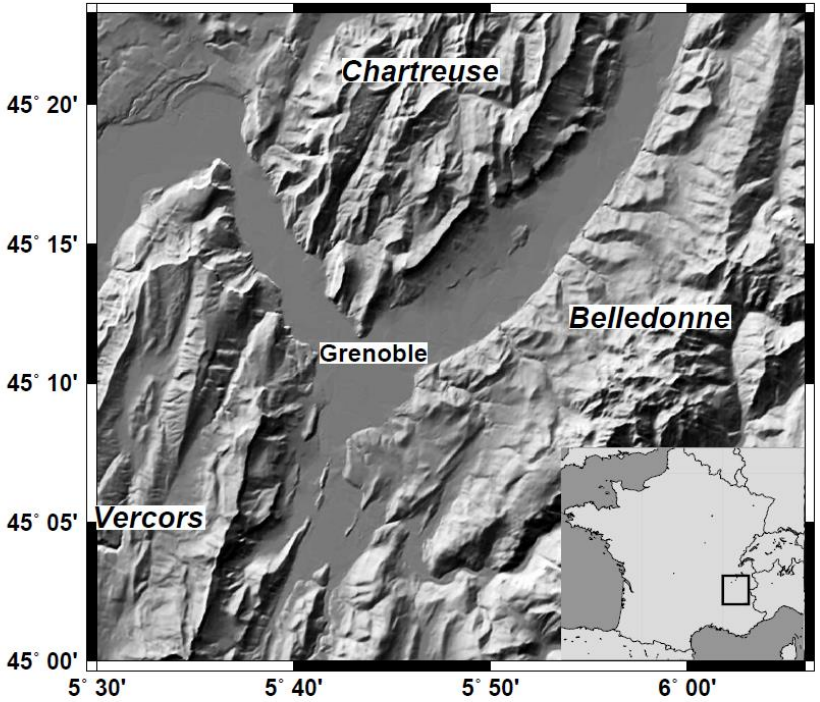
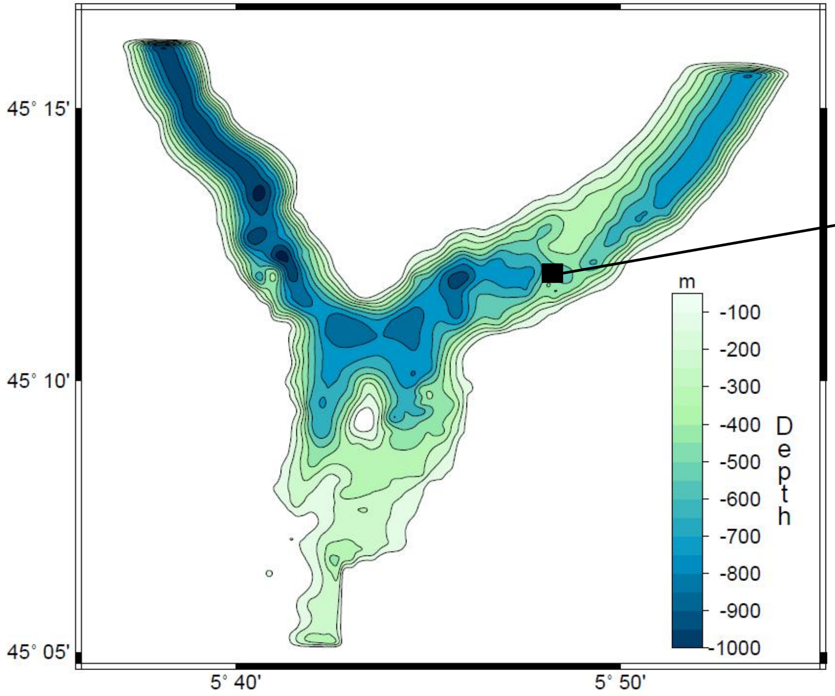
The Grenoble's basin model @ ESG2006

Surface topography



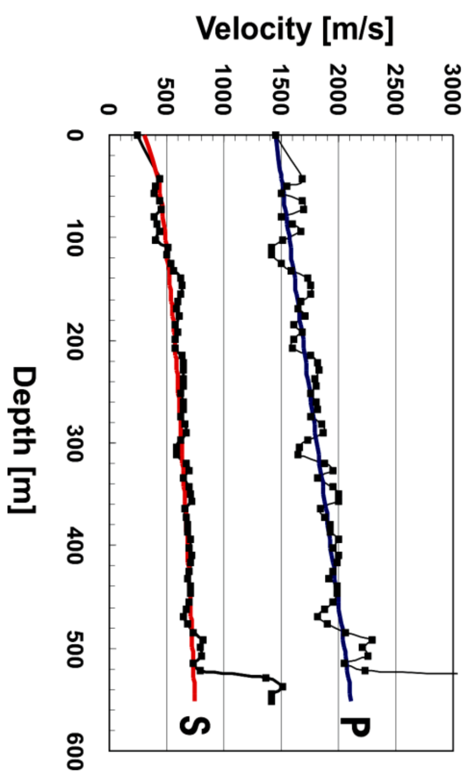
Chaljub et al., 2006

Bedrock topography



Gravimetry measurements (Vallon, 1999)

Vp, Vs & Qp, Qs

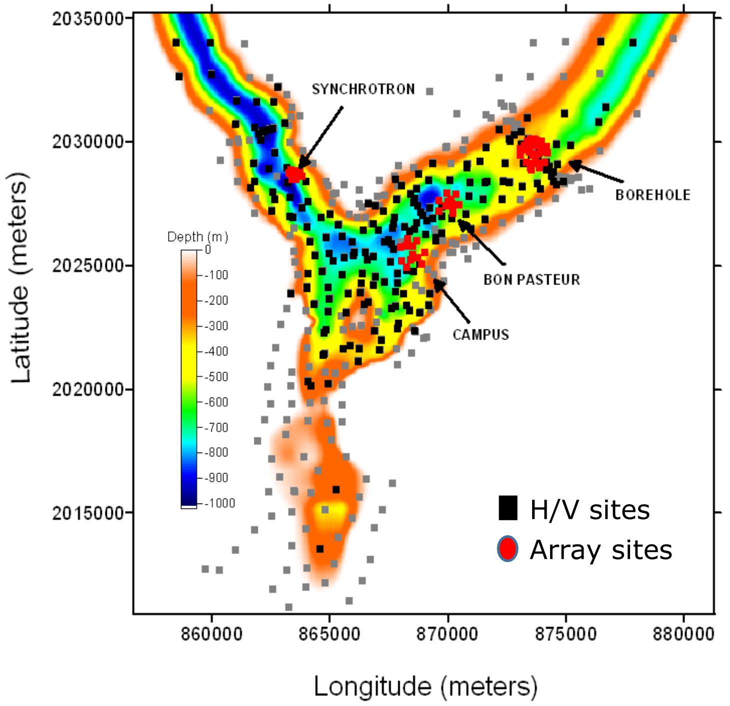


Qp=40
Qs=20

DH measurements (Cornou, 2002)

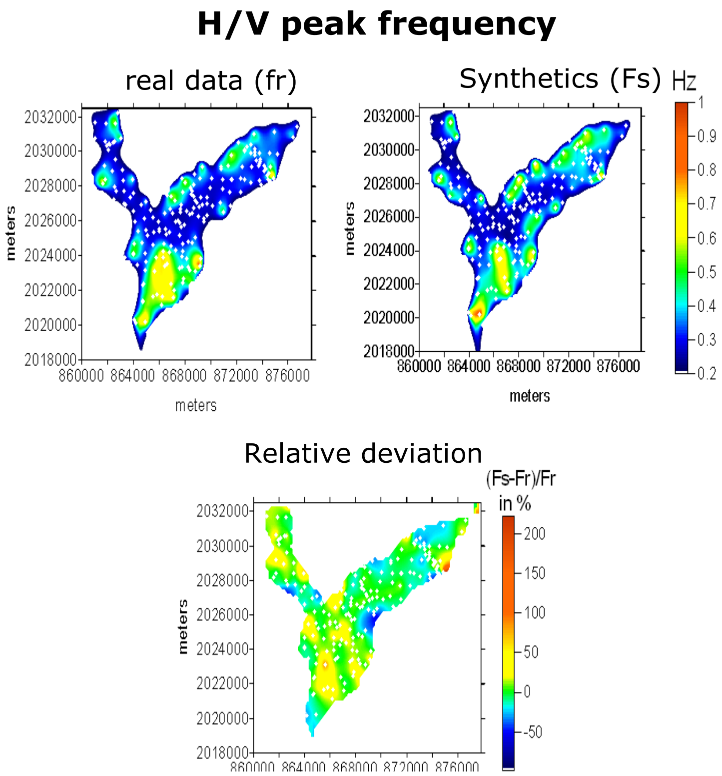
ESG2006 benchmark on ground motion simulation : Chaljub et al. (2010)

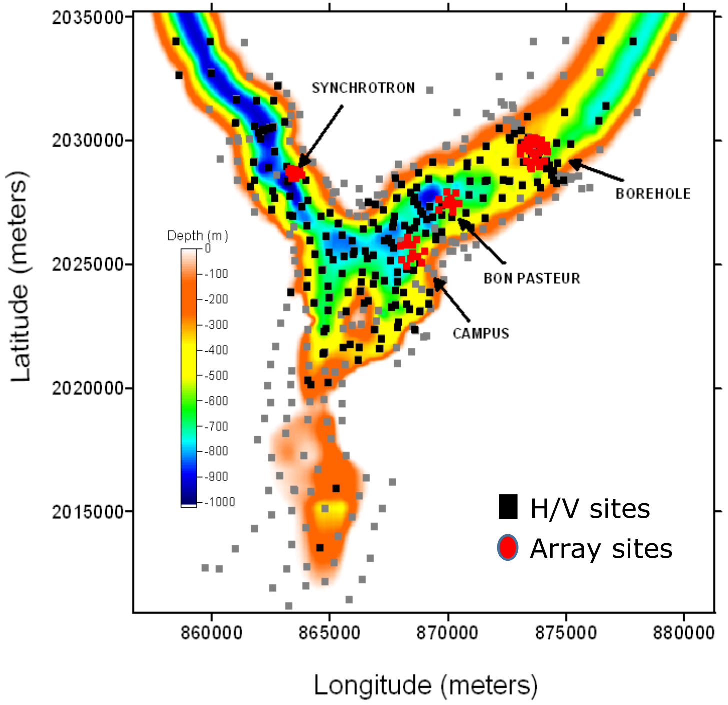
Does the Grenoble's model @ ESG2006 reproduce observations ? (1)



Simulation of seismic ambient noise between 0.2 and 1.1 Hz (Cornou et al., 2008)
FD scheme (Moczo and Kristek, 2002)

Does the Grenoble's model @ ESG2006 reproduce observations ? (1)

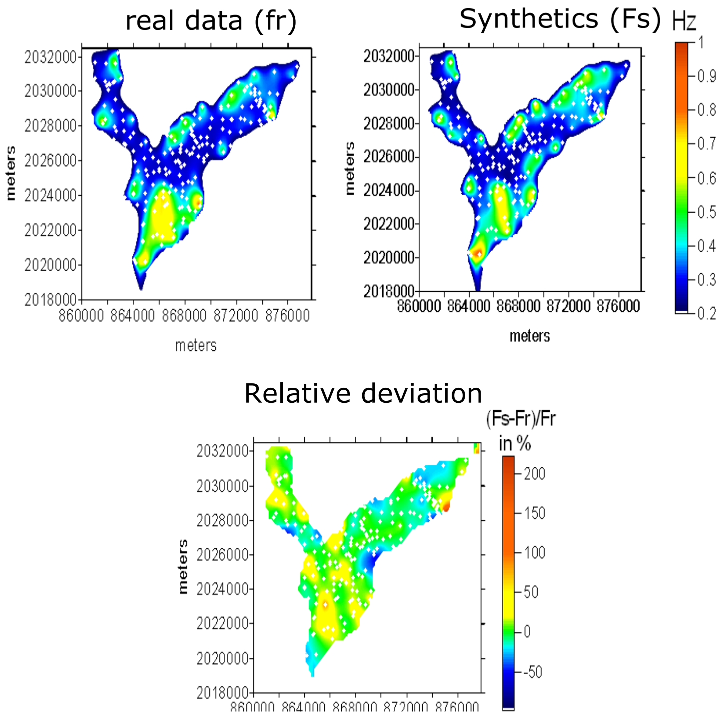


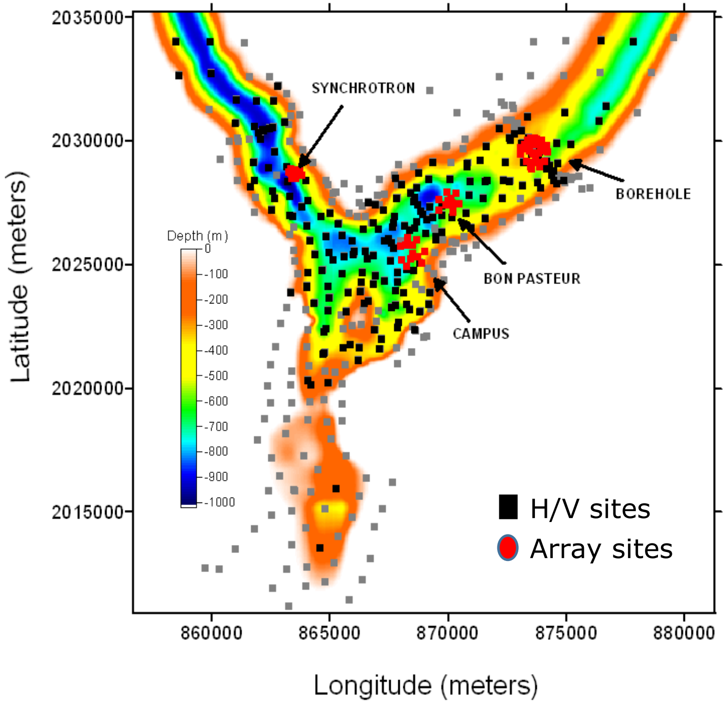


- Largest differences close to basin borders
- In basin center, slight overestimation of actual H/V peak frequencies for sites with fH/V > 0.6 Hz

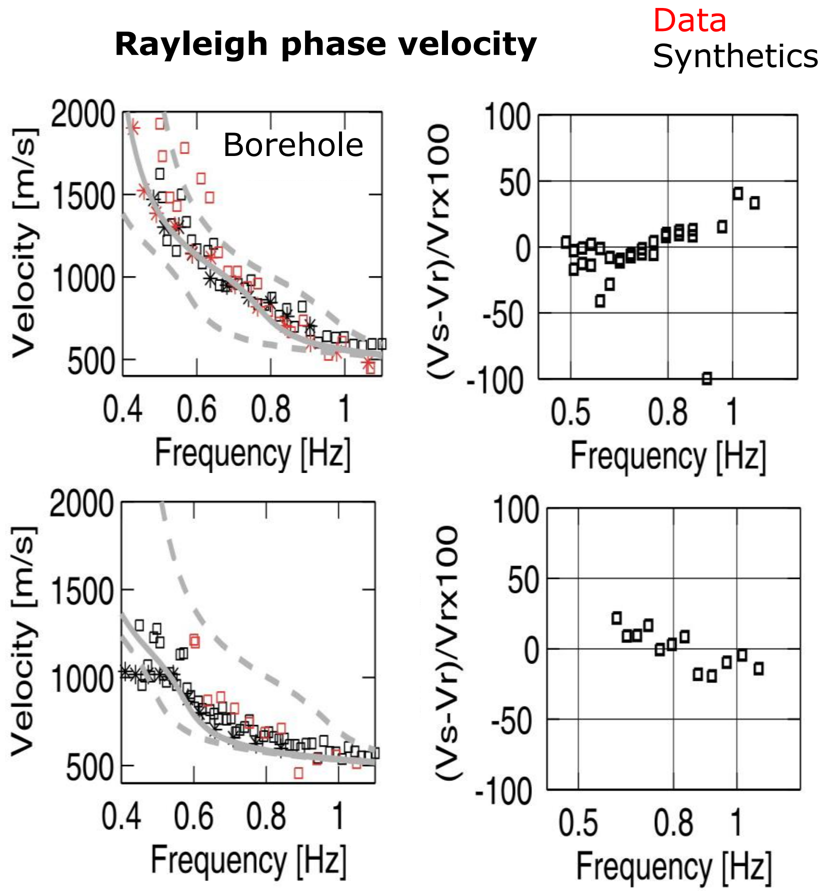
Does the Grenoble's model @ ESG2006 reproduce observations ? (1)

H/V peak frequency





Rayleigh phase velocity

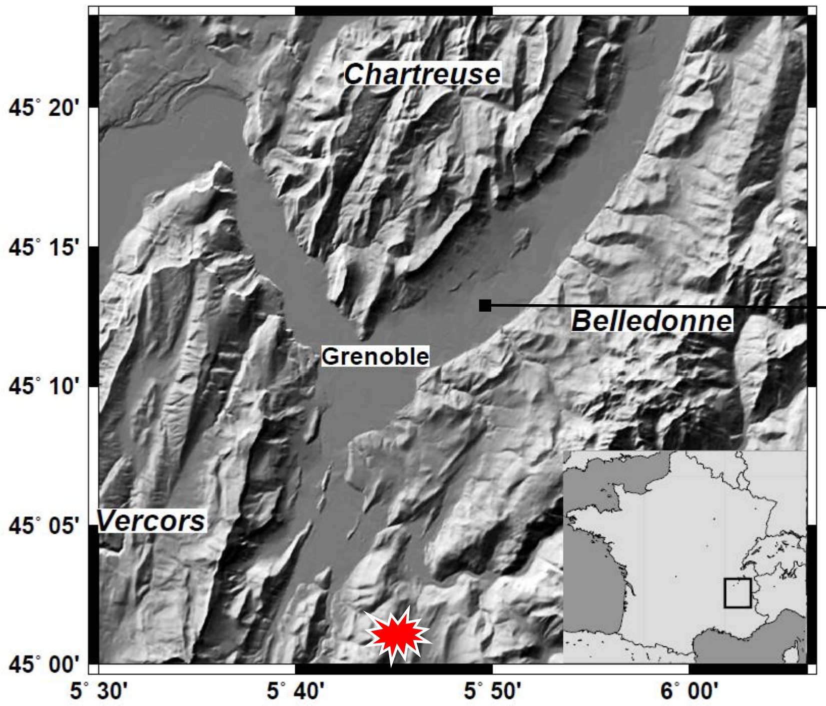


- Largest differences close to basin borders
- In basin center, slight overestimation of actual H/V peak frequencies for sites with fH/V > 0.6 Hz

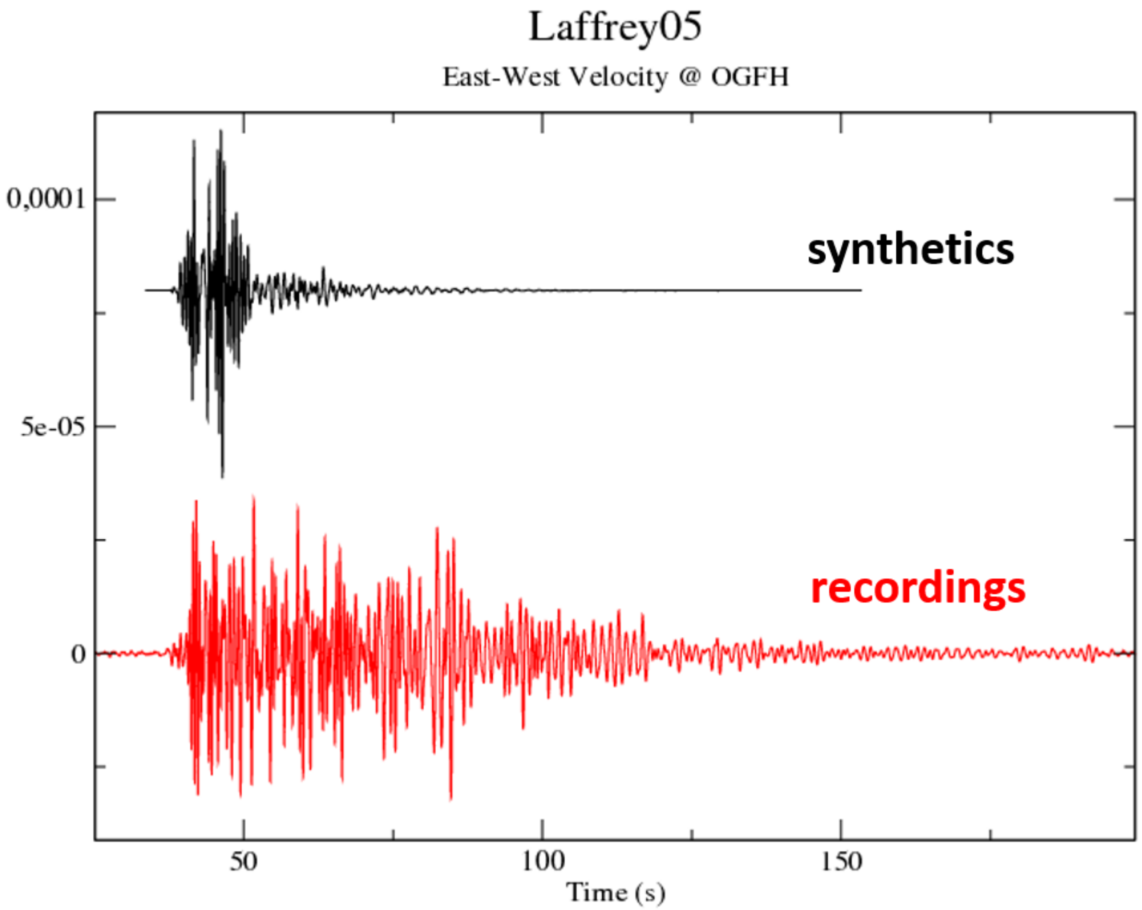
- Sligth under/over-estimation of phase velocity for f > 0.8 Hz

Grenoble's model @ ESG2006 suitable for reproducing H/V and dispersion estimates up to 1 Hz

Does the Grenoble's model @ ESG2006 reproduce observations ? (2)



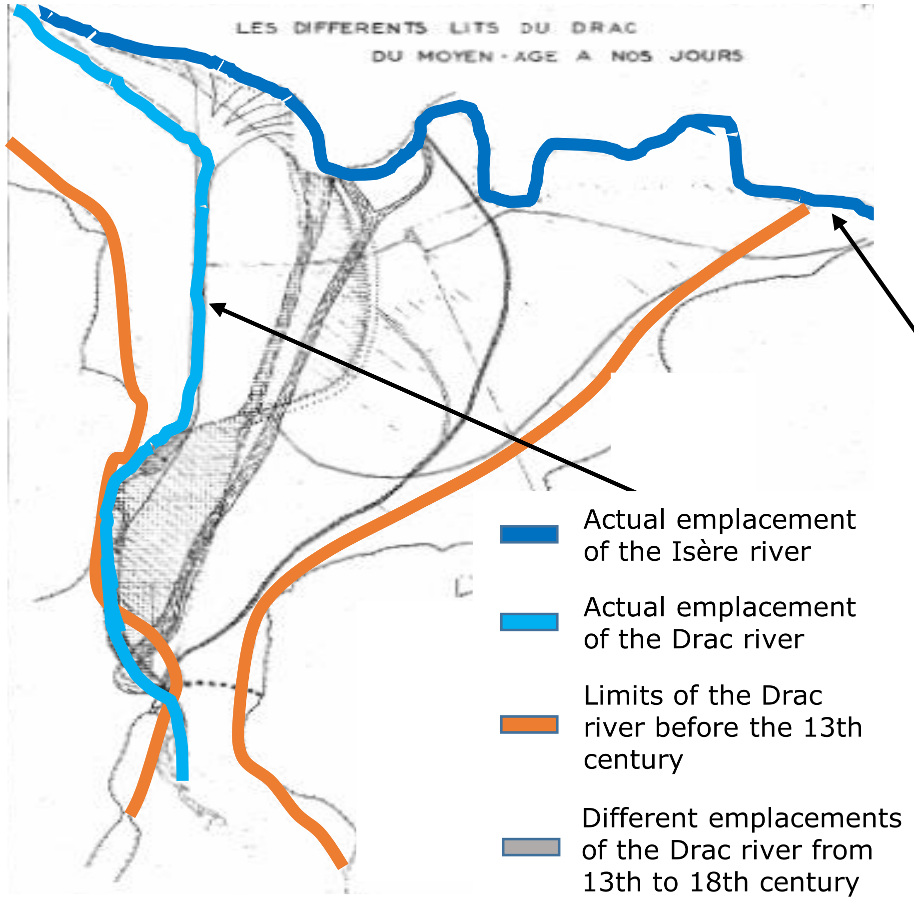
Laffrey05 earthquake (Ml 2.8; 10/01/2005)



Velocities band-pass filtered between 0.5 and 1.5 Hz

Improvement of the Grenoble's model: near-surface geology

Different beds of the drac from the Middle Age to nowadays



Adapted from Lacroix (1970)

Infilling of the valley :

- Two glacial-interglacial cycles (Riss-Würm and Holocene periods)
- Erosive phases followed by a lake infilled with fine homogeneous sediments (sandy or clayey silts).
- Lake deposits covered by heterogeneous alluviums coming from 2 rivers: the Drac river and the Isère river.

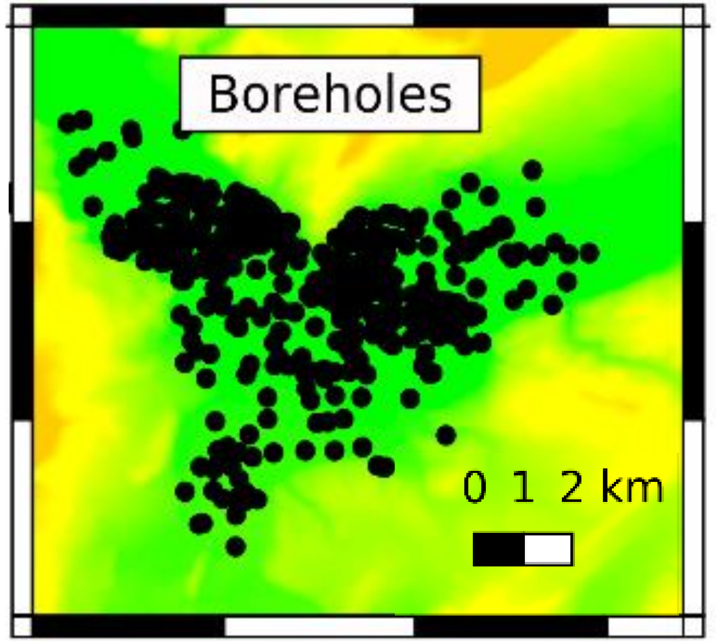
The Isère river: mainly fine deposits (clay, silt)

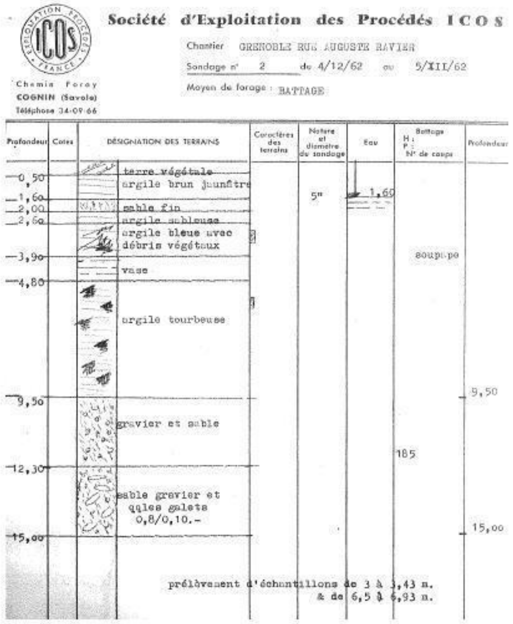
The Drac river : highly energetic river with several large floods in the past; mainly coarse materials (gravels, sand)

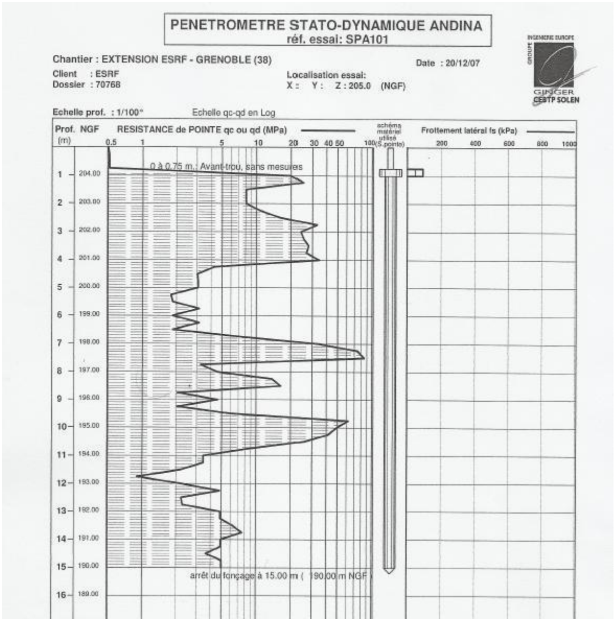
Improvement of the Grenoble's model in the near-surface: near-surface geology

Collection of 1350 geological or geotechnical logs (Cartier and Cornou, 2016; National borehole database, https://infoterre.brgm.fr)
Borehole depth > 10 m

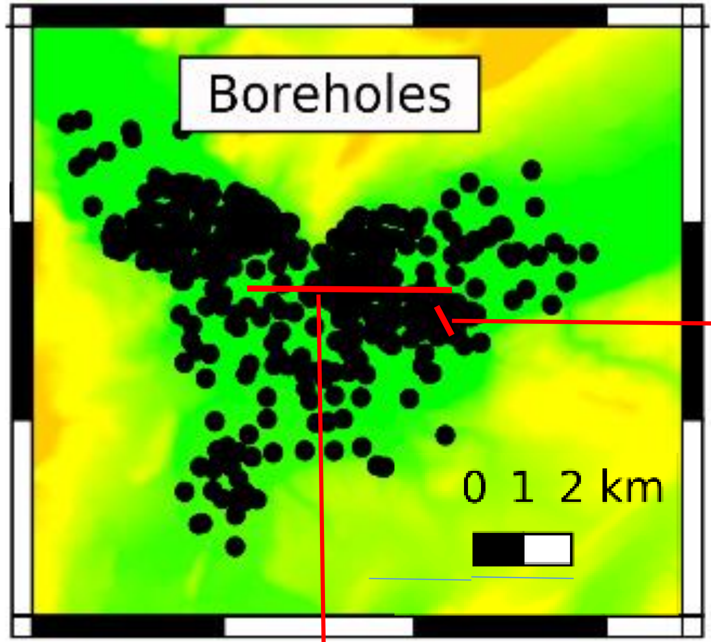
Types of information: Andina penetrometer test; Destructive drilling description log; Pressuremeter test with geological interpretation; resistivity

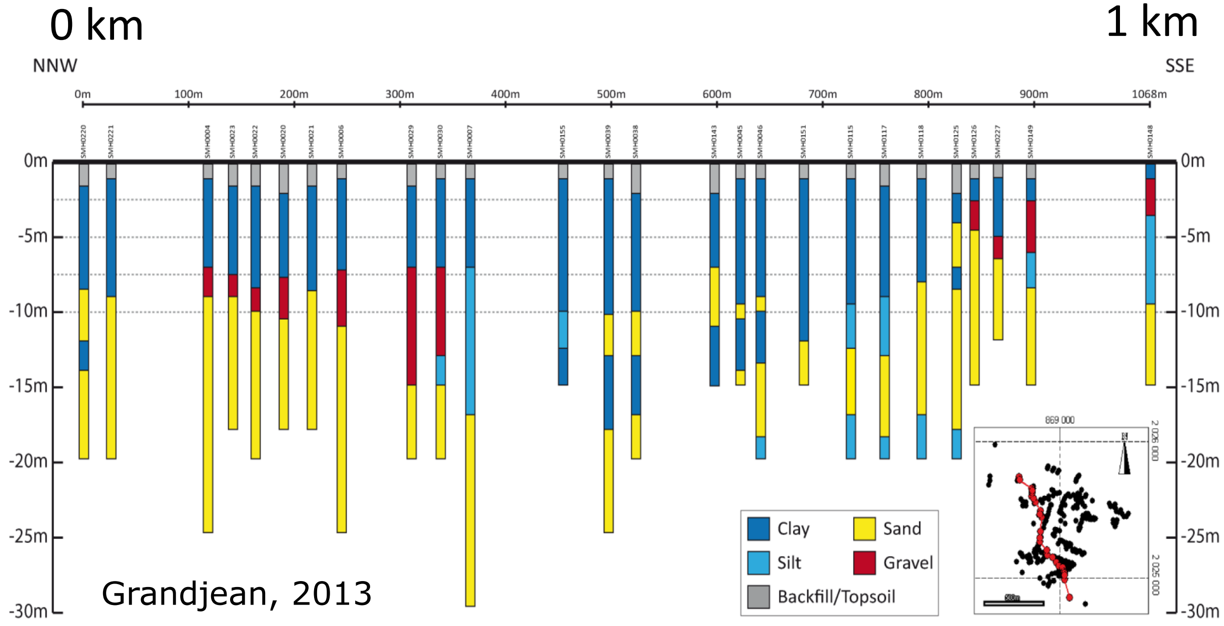


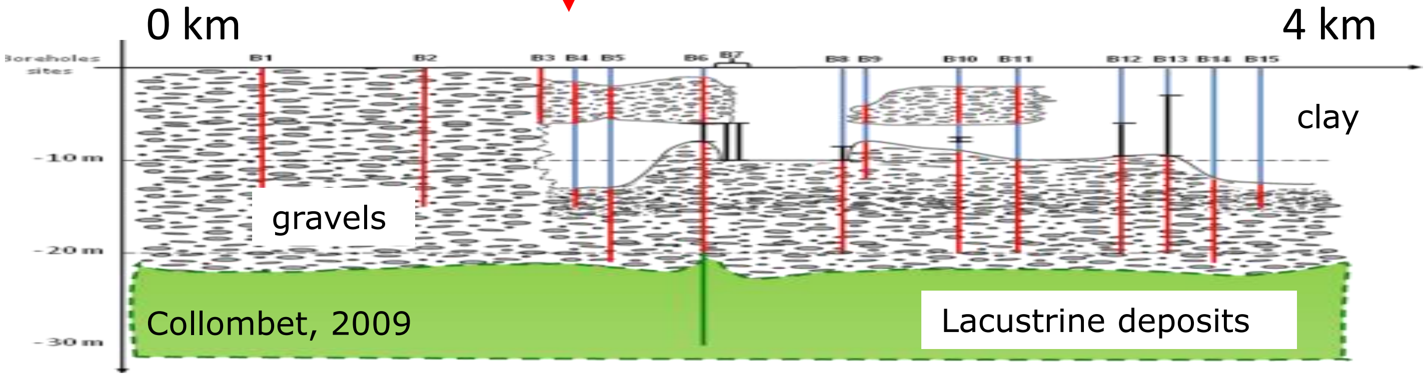




Improvement of the Grenoble's model in the near-surface: near-surface geology





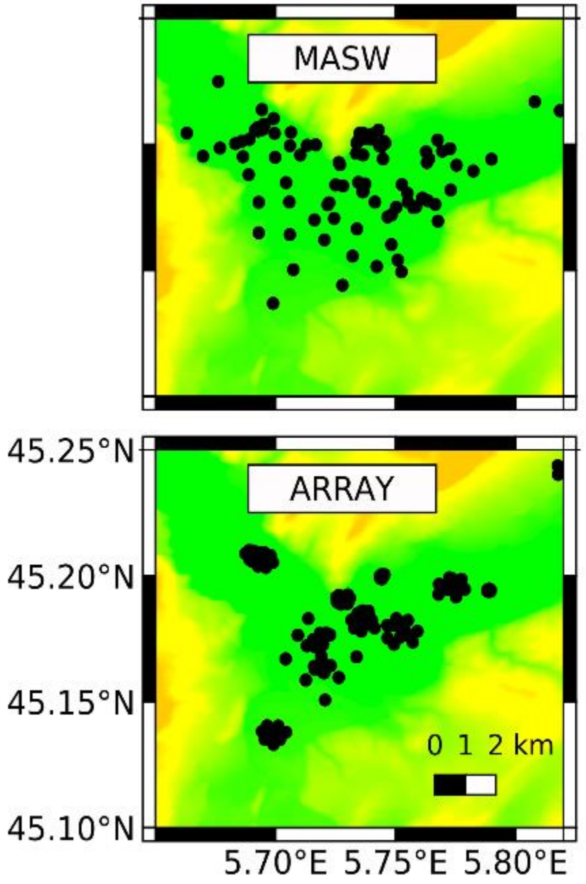


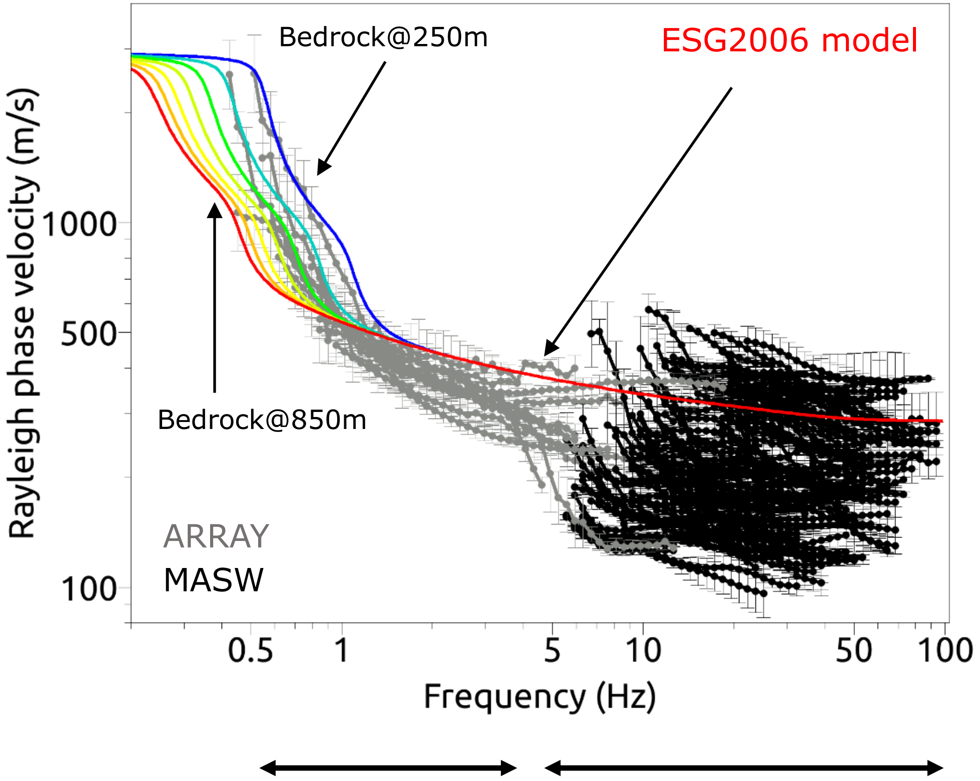
Main geological facies in the top 20 m:

- Gravel
- Sand
- clay/silt

Lateral variation at basin and local scales

Improvement of the Grenoble's model in the near-surface: geophysical data





Vs in intermediate to deep layers slightly lower than ESG2006 model

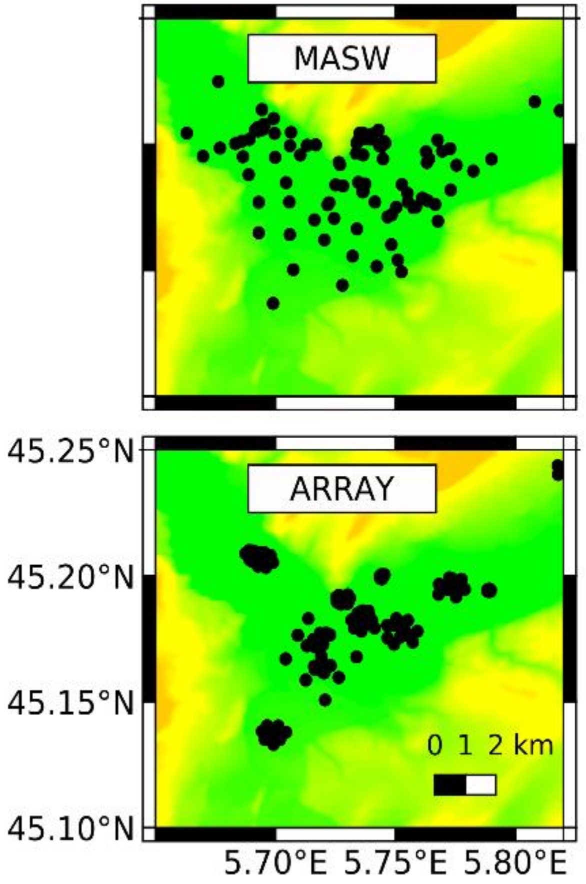
Large varialibity of near-surface velocities

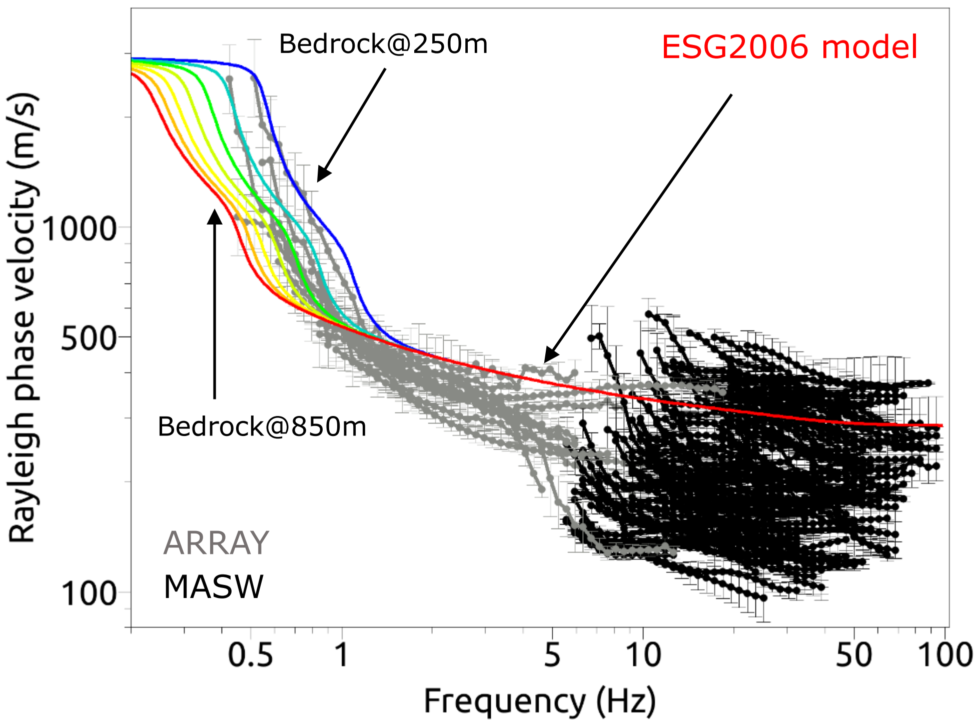
Collection over the last 15 years by various teams of active and passive surface waves (Bettig et al., 2001; Tsuno et al., 2008; Garofalo et al., 2016; Hollender et al., 2018; H. Kawase's team; etc.)

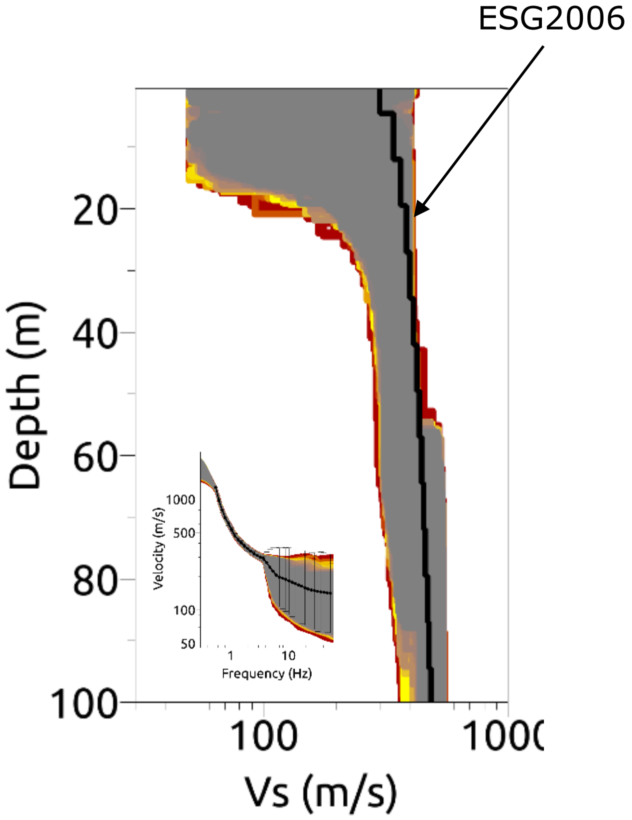
110 sites with active surface waves measurements (MASW)

15 sites with passive surface waves array measurements (ARRAY)

Improvement of the Grenoble's model in the near-surface: geophysical data





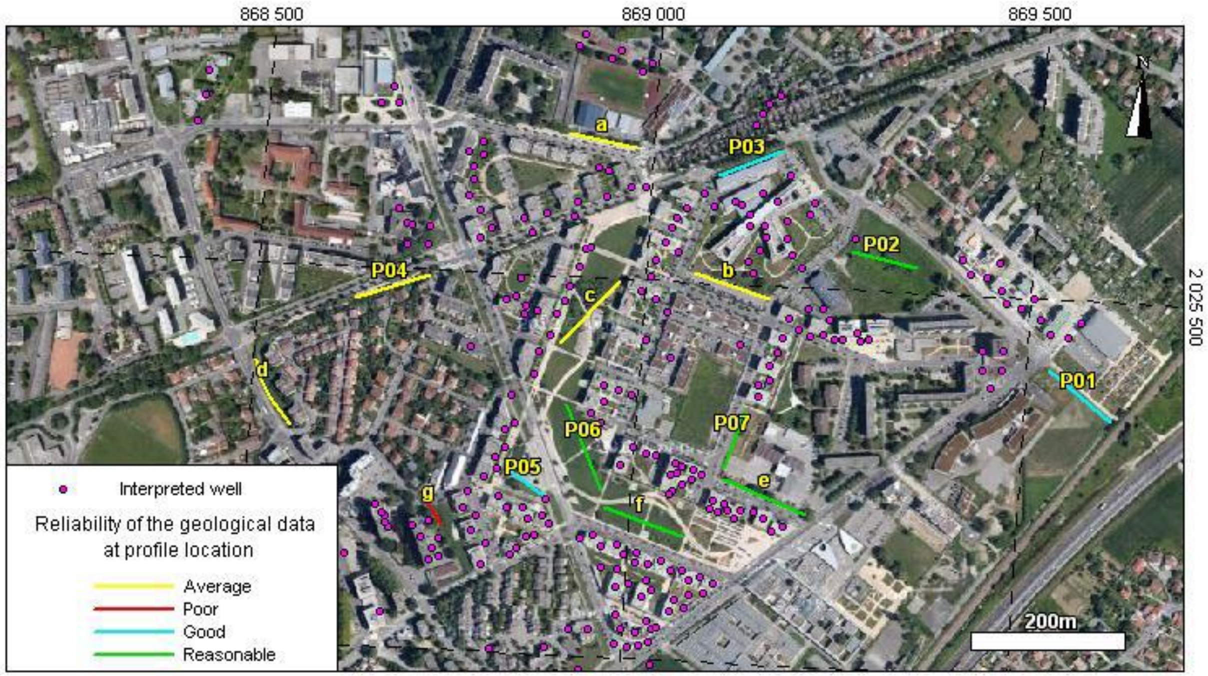


Vs in intermediate to deep layers slightly lower than ESG2006 model

Large variability of near-surface velocities …

… within the first 20-30 meters

Improvement of the Grenoble's model in the near-surface: correlation between geophysical and geological facies



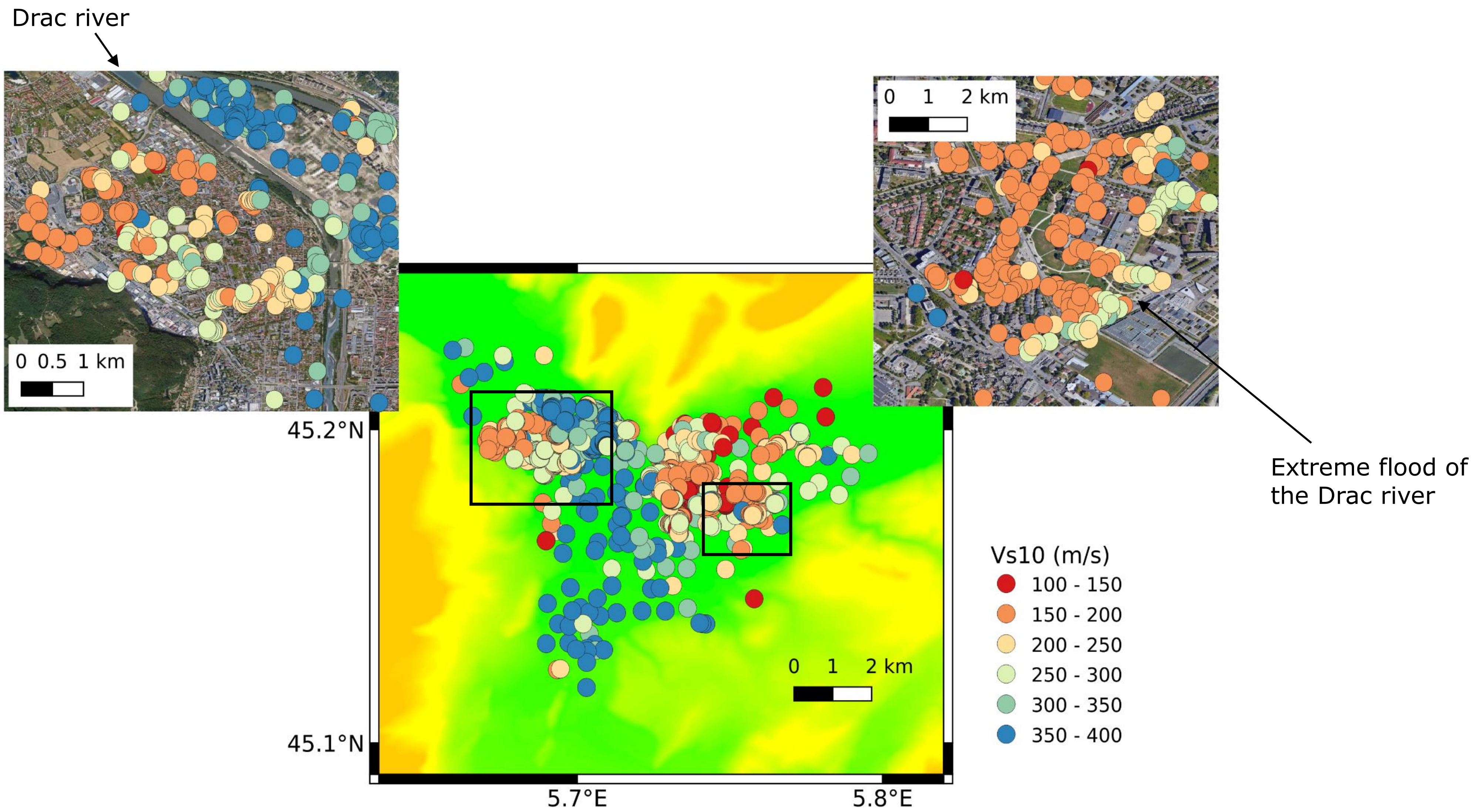
Main facies	Vs (m/s)	Uncertainty (%)
Backfill	250	20
Gravels	400	20
Peat	100	20
Clay	150 (z< 20m) 200 (z> 20m)	20
Sand	400	20

Specific MASW measurements at borehole locations

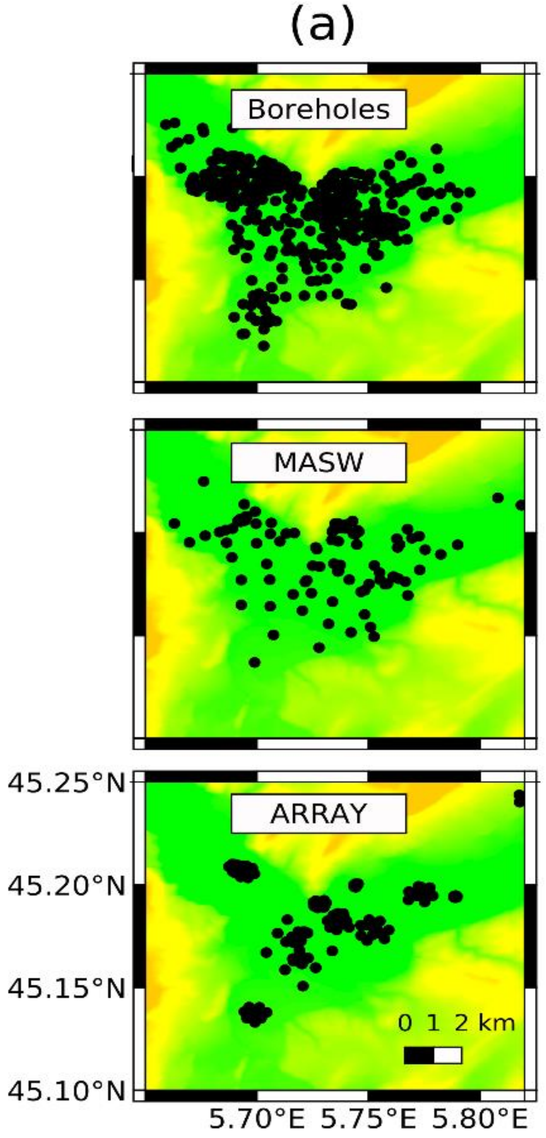
Surface waves inversion constrained with the geological layering information

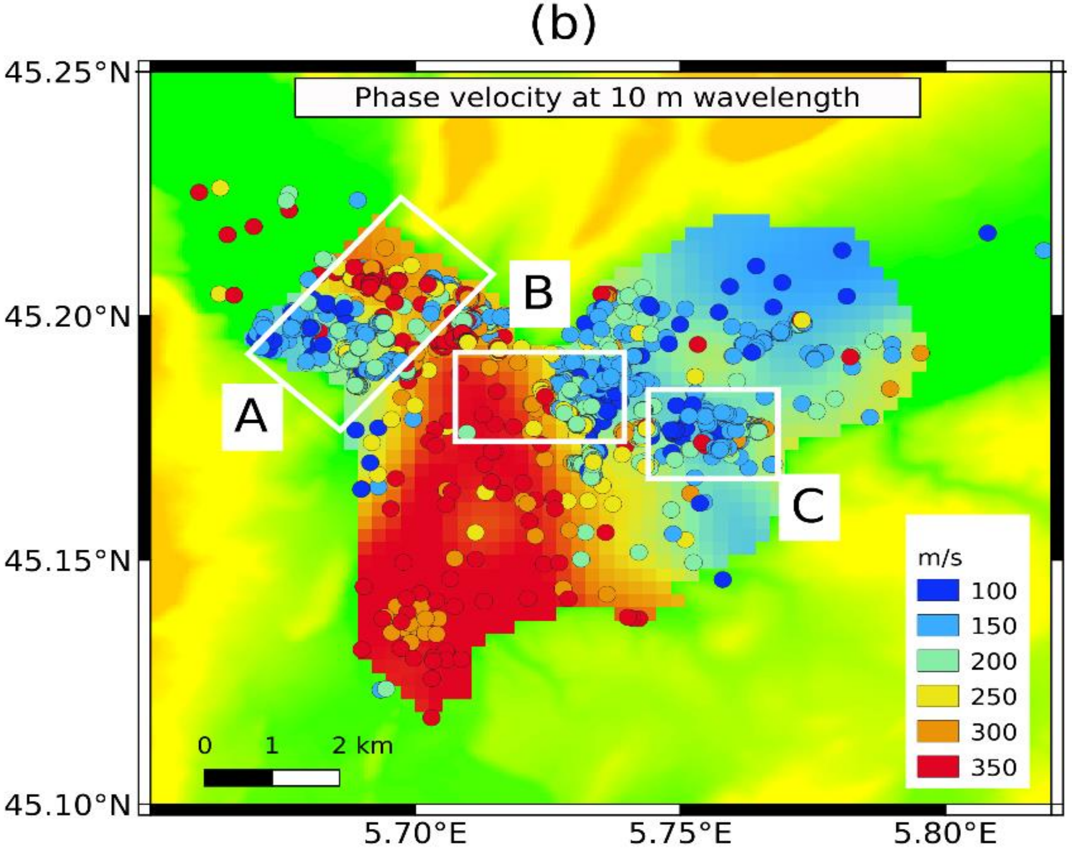
Correlation between geological facies and Vs => inferred Vs profiles at borehole sites

Improvement of the Grenoble's model in the near-surface: Vs10 distribution @ borehole sites



Spatial distribution of phase velocities

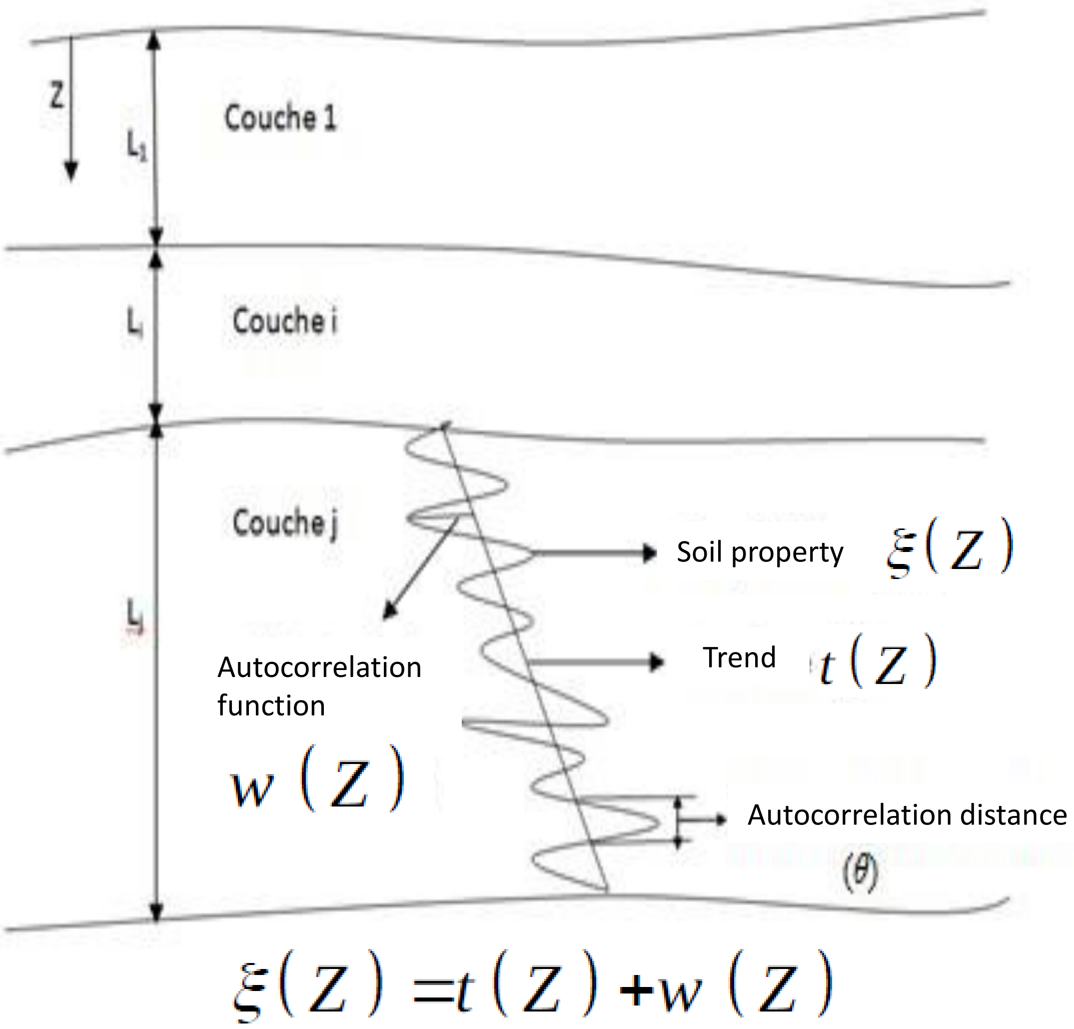


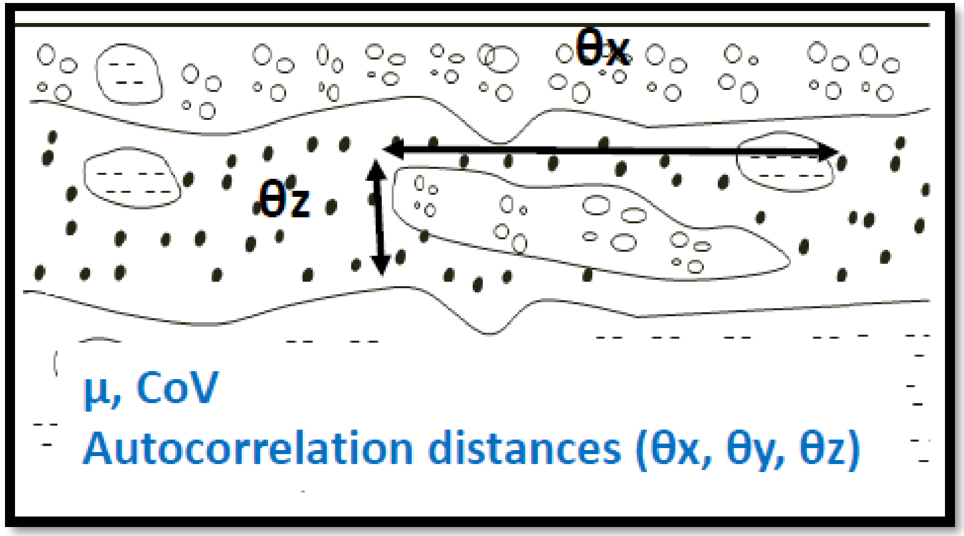


Consistent phase velocities distribution with all surface wave measurements

Lateral variation of velocity in relation with the near surface geological deposits

Quantification of spatially variable elastic properties: main principles

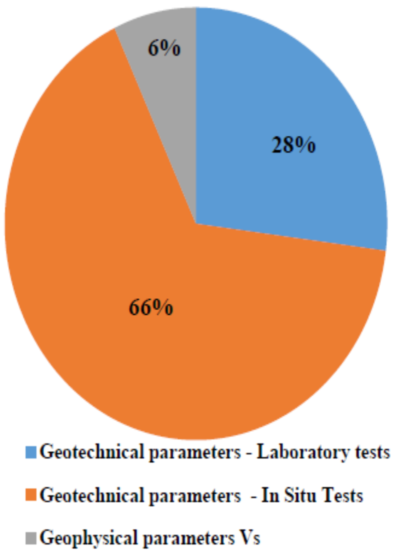


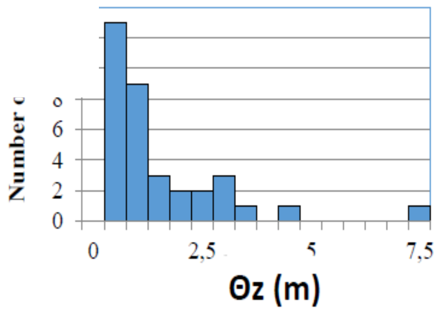


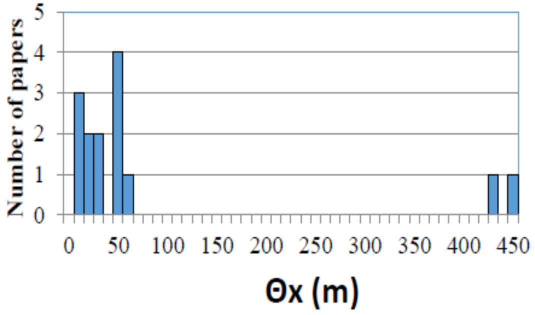
Quantification of spatially variable elastic properties : what do we know ?

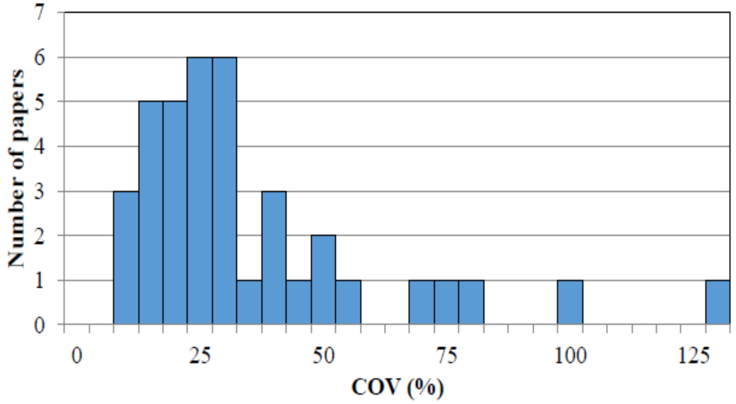
! Spatial sampling not always respected !

33 papers; 10-20 first top meters

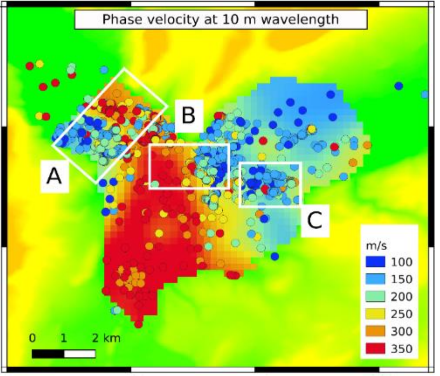




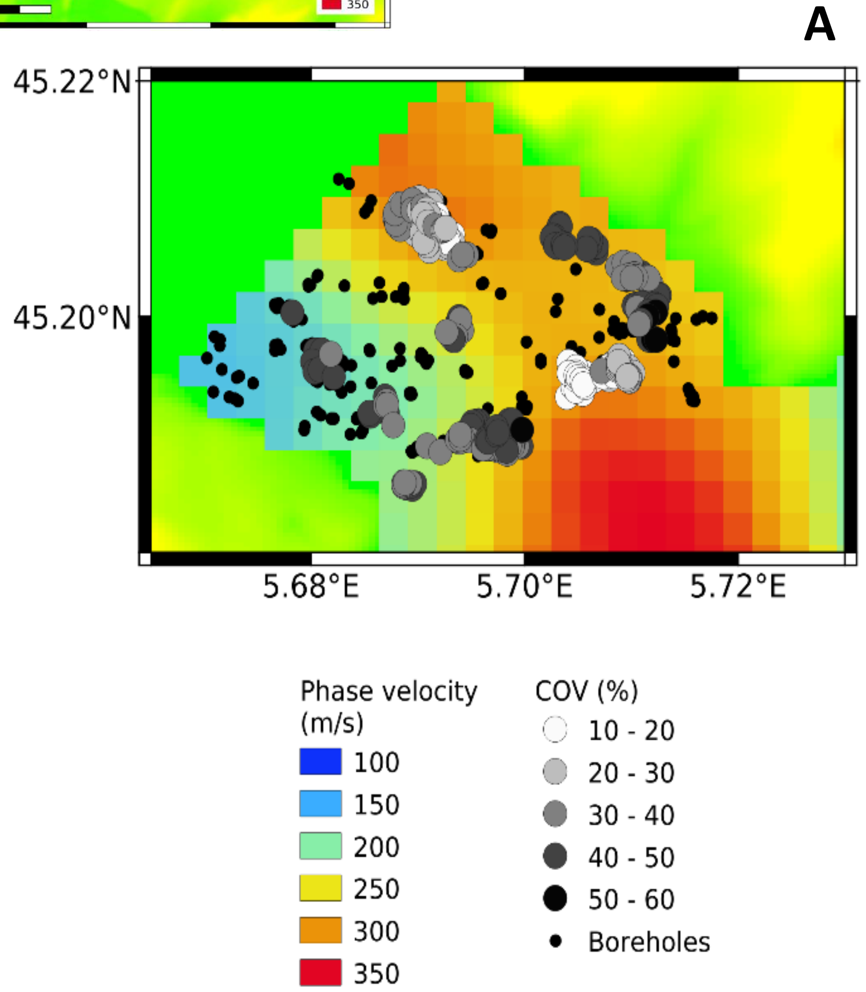




Salloum, 2015; courtesy of D. Youssef Abdel-Massih (2018)



Quantification of spatially variable elastic properties



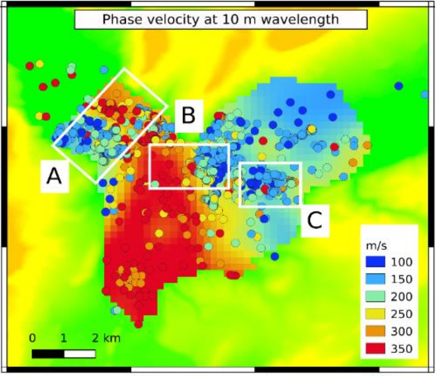
Vs from the surface to 20 m depth inferred from geological boreholes

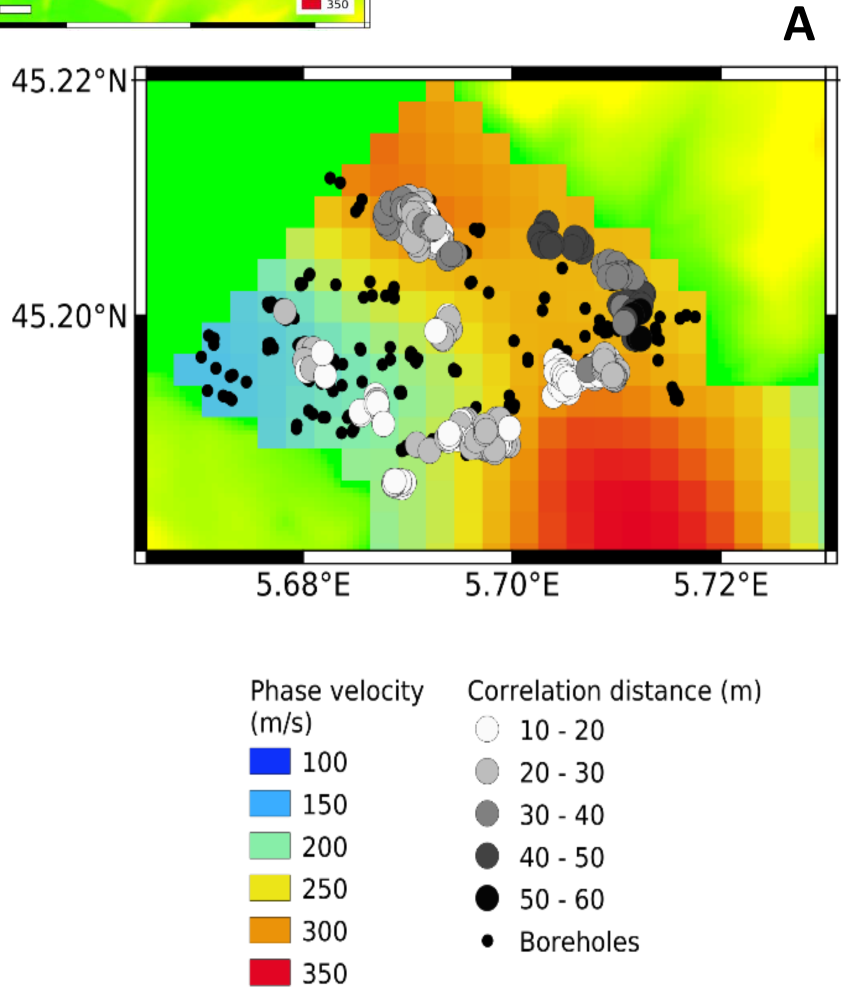
COV and θx estimated at each borehole location provided at least 10 boreholes located within 200 m from the target borehole.

Exponential decaying auto-correlation function

Clay formation (east zone) : mean COV of 30 +/- 11%
Gravel formation (west zone) : mean COV of 40 +/- 4%

Quantification of spatially variable elastic properties





Vs from the surface to 20 m depth inferred from geological boreholes

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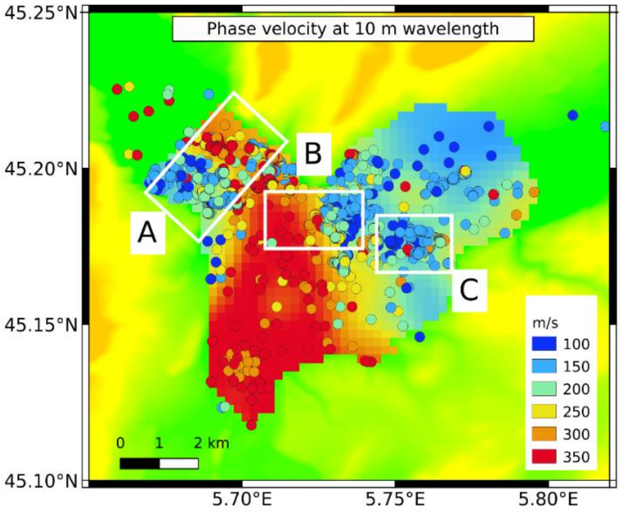
Exponential decaying auto-correlation function

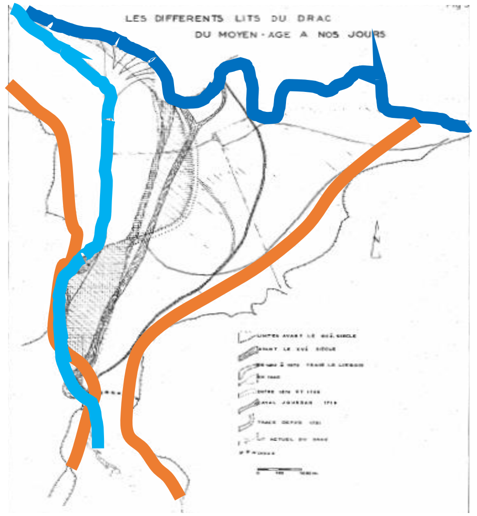
Clay formation (east zone) : mean COV of 30 +/- 11%
Gravel formation (west zone) : mean COV of 40 +/- 4%

ϴx exhibit slightly lower values in the western zone compared to the eastern one
Mean ϴx including both zones : 20 m +/- 5 m

Similar range of COV and ϴx values in B and C zones

Concluding remarks





Strong lateral variation of Vs within the first top 20 meters in relation with the deposits from the Drac (gravels, sand) and Isère (clay, silt) rivers

Vs model @ ESG2006 is definitely too «fast» in the first 20 to 30 m

Spatial variability of the near-surface elastic properties:

Clay dominated formation : mean COV of 30 +/- 11%
Gravel dominated formation : mean COV of 40 +/- 4%

Mean ϴx including both formation : 20 m +/- 5 m

Thank you for your attention