Sisprobe and Helsinki region ambient noise surface wave tomography

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Sisprobe overview

January 2017 :
- Sisprobe creation

September 2019 :
- 3 offices (Grenoble/FRA, Los Angeles/USA, Hobart/AUS)
- 10 people + scientific board

- 200 Smartsolo IGU-16HR 3C nodes

September 2021 :
- Egis buy Sisprobe
- 450 Smartsolo IGU-16HR 3C nodes

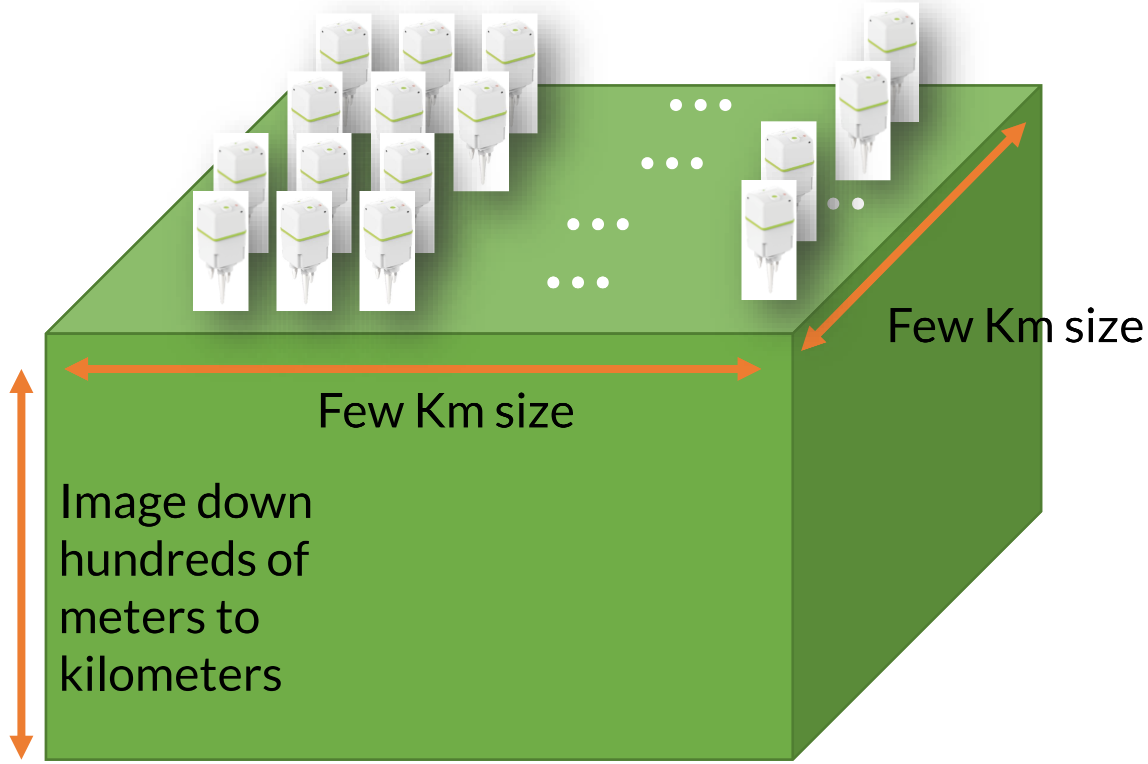
We are specialized in passive imaging and monitoring:
- Use ambient seismic noise to produce 3D Vs models and/or continuous seismic velocity monitoring.
- No use of active seismic sources as explosions or vibrating trucks.

- Allow us to work in city environments and protected areas
- Cost less
- Non-destructive
- Image with less resolution than active seismic

Sisprobe average project and applications

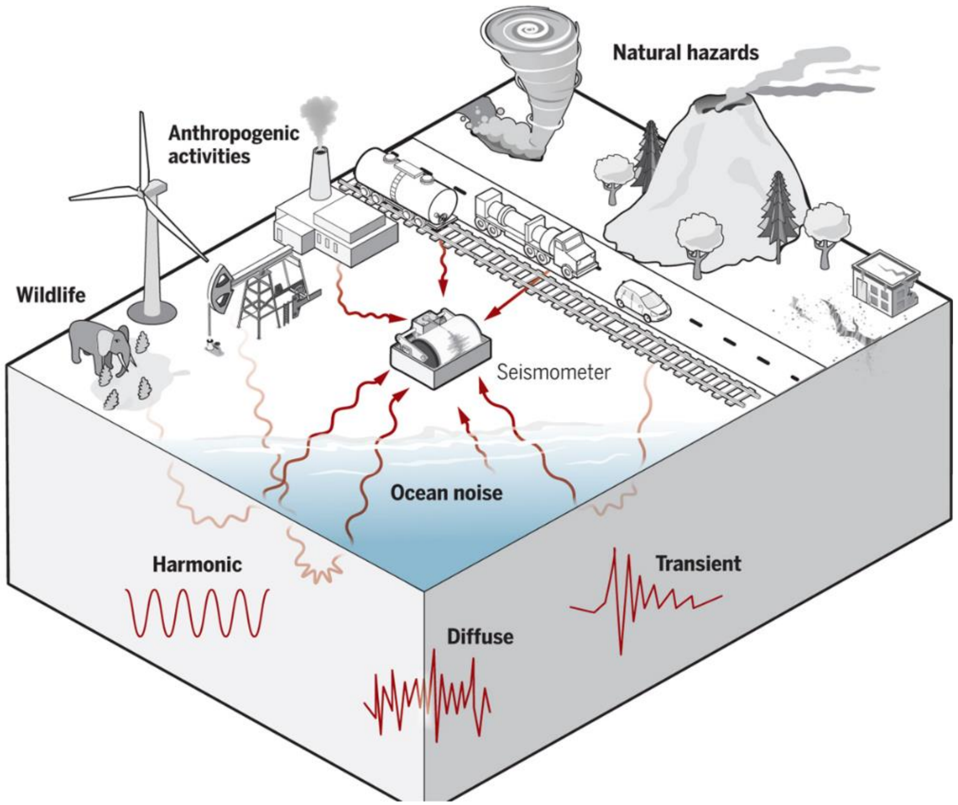
- Hundreds of nodes (1C or 3C)
- Array shape made by us to fit the objectives as much as possible
- 15 days – 1 month of recording

Applications :
- Exploration for mine or oil industry
- Seismic hazard assessment
- Monitoring of infrastructures or subsurface



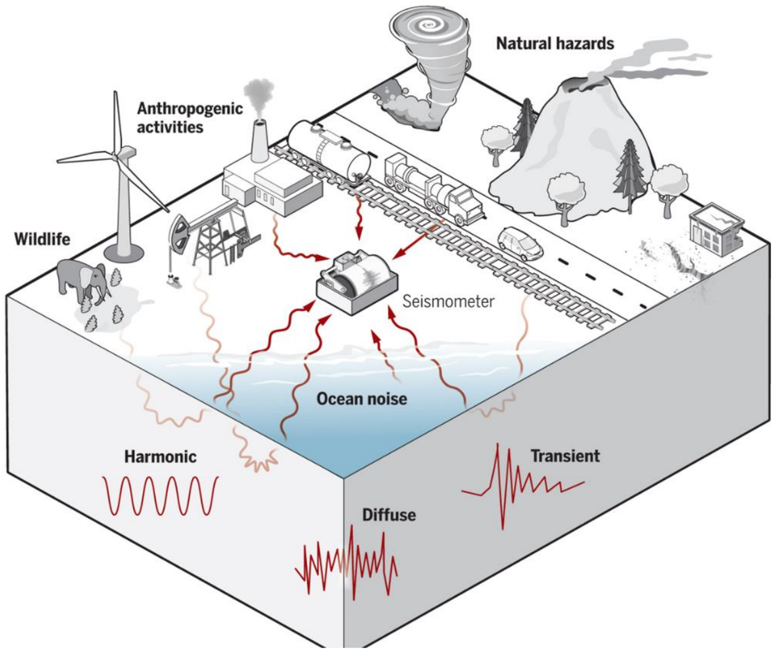
Node installation

Sources of ambient seismic noise

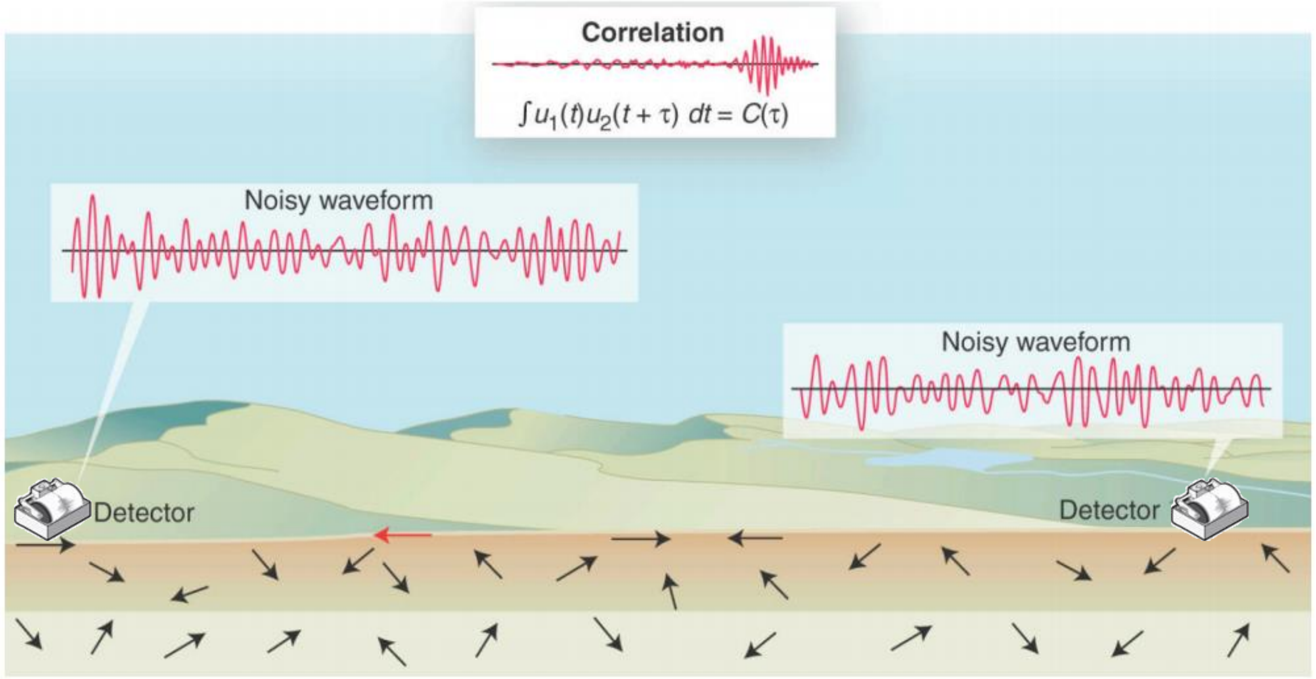


Ambient seismic noise to useful information about the subsurface:

The seismic interferometry



Sources of ambient seismic noise

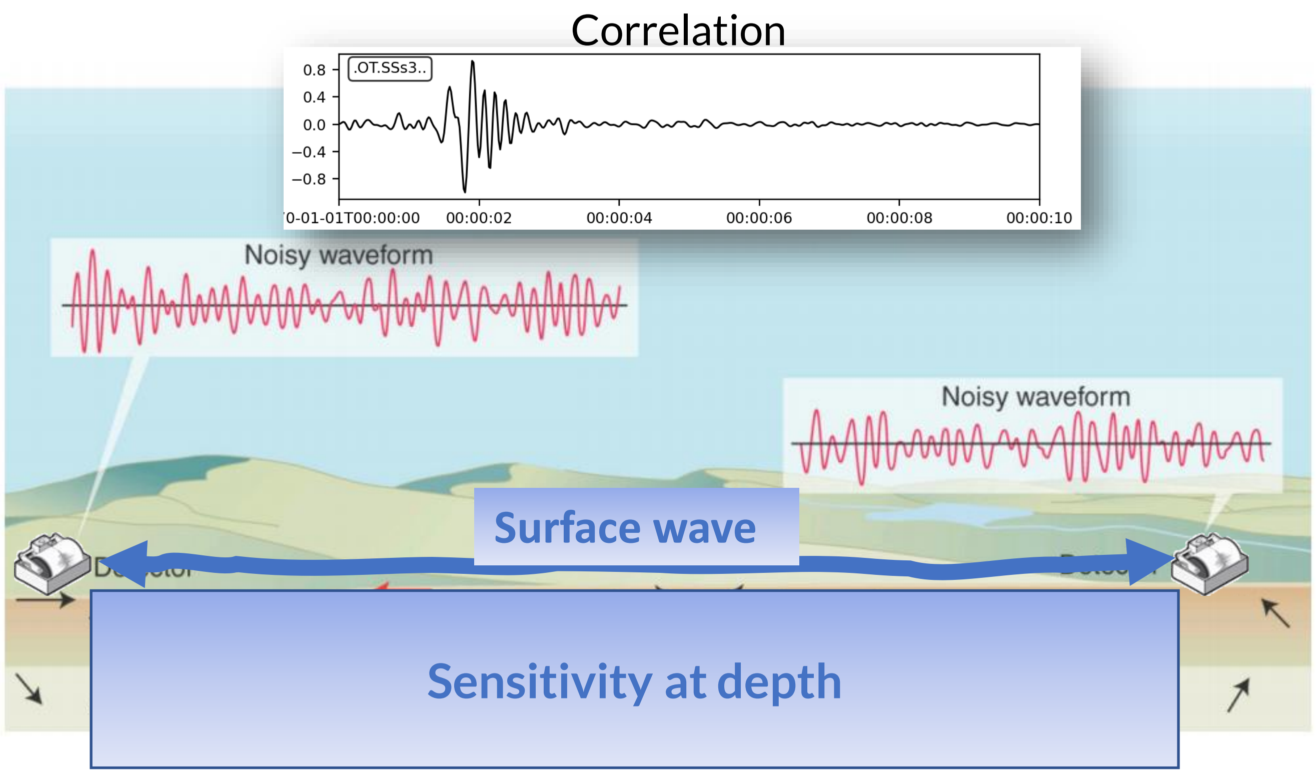


Ambient seismic noise to useful information about the subsurface:

The seismic interferometry in practice

Surface waves give:

- Information at depth;
- Average medium between the two stations



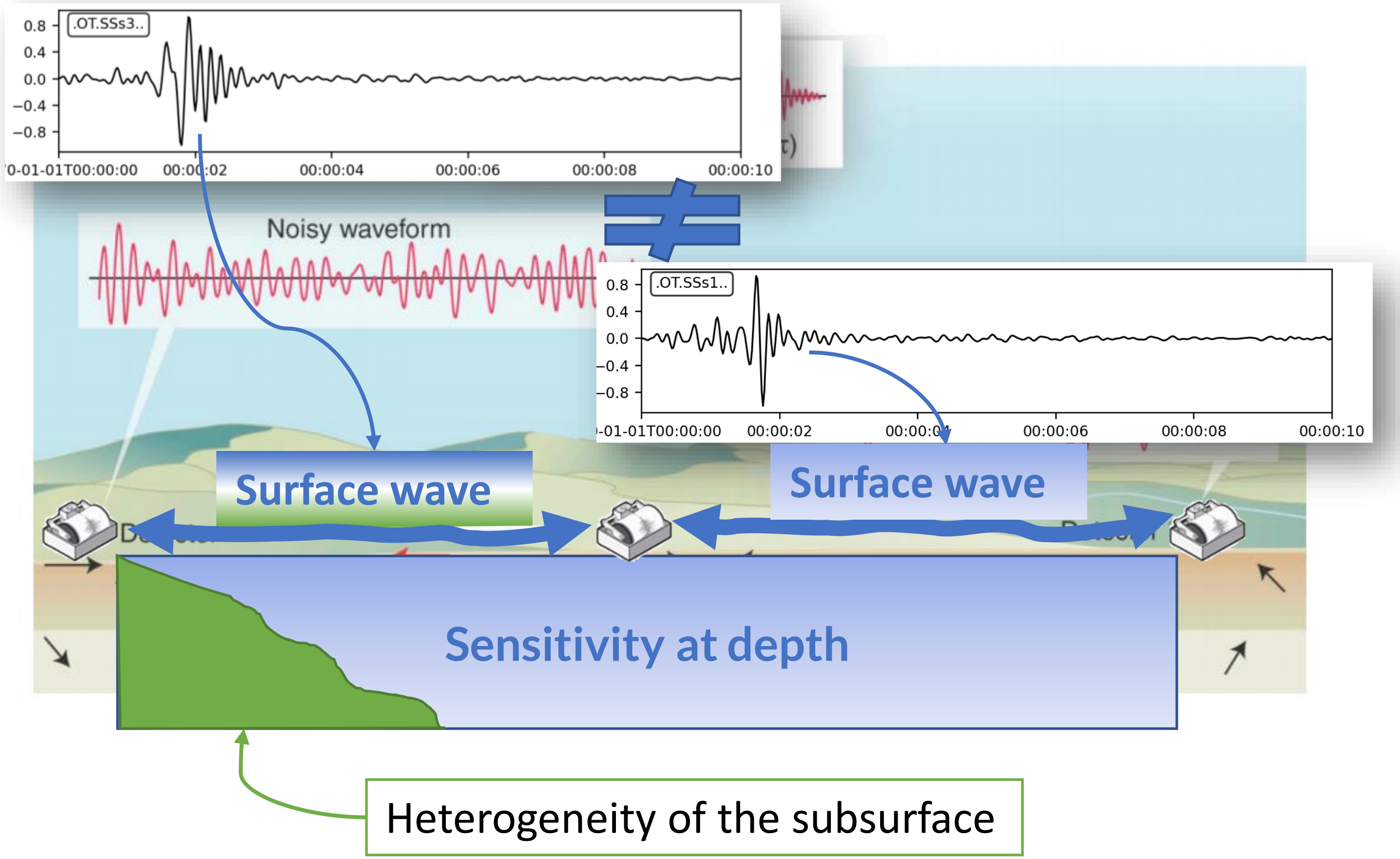
Ambient seismic noise to useful information about the subsurface:

The seismic interferometry in practice

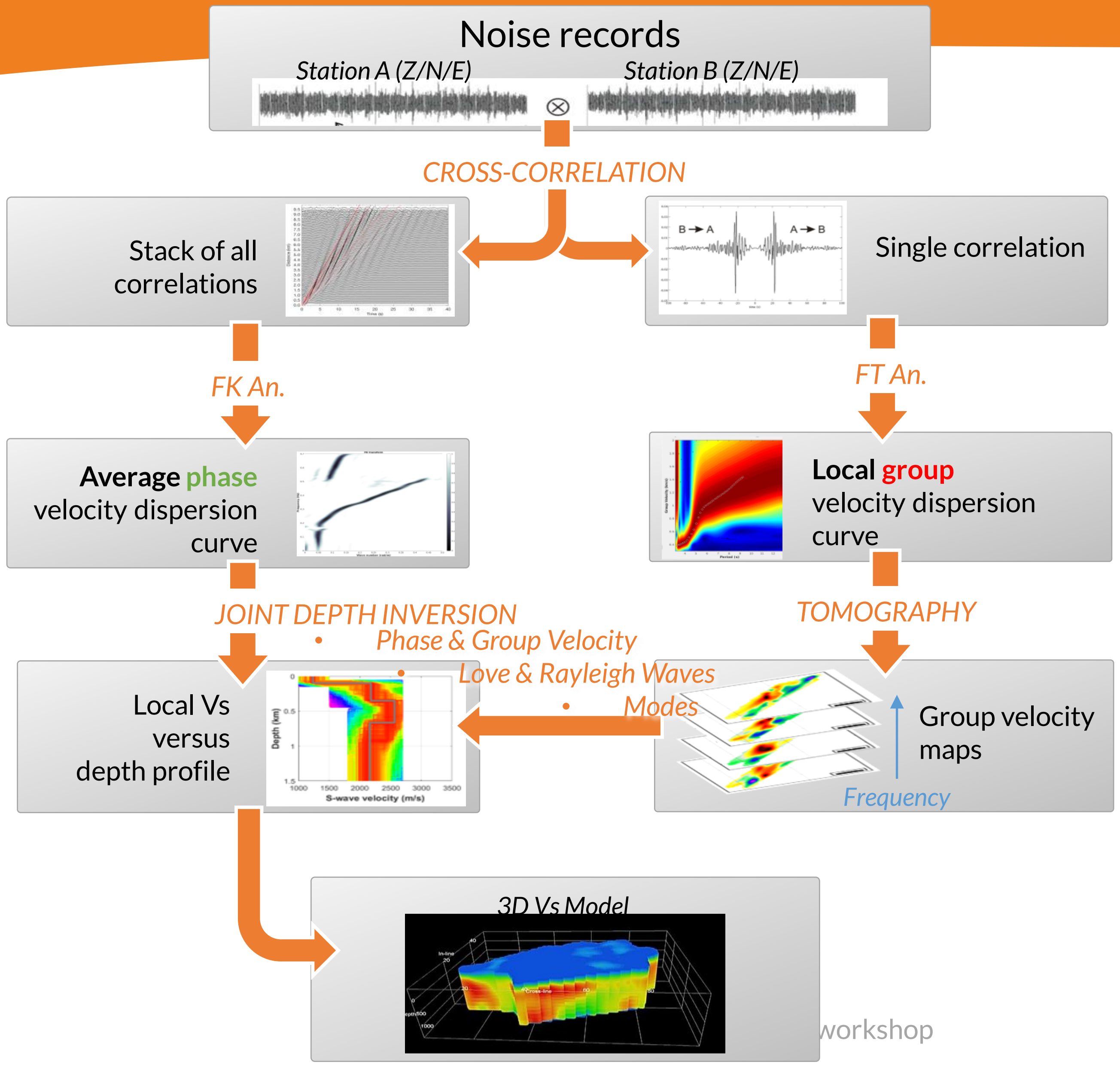
Surface waves give:

- Information at depth;
- Average medium between the two stations

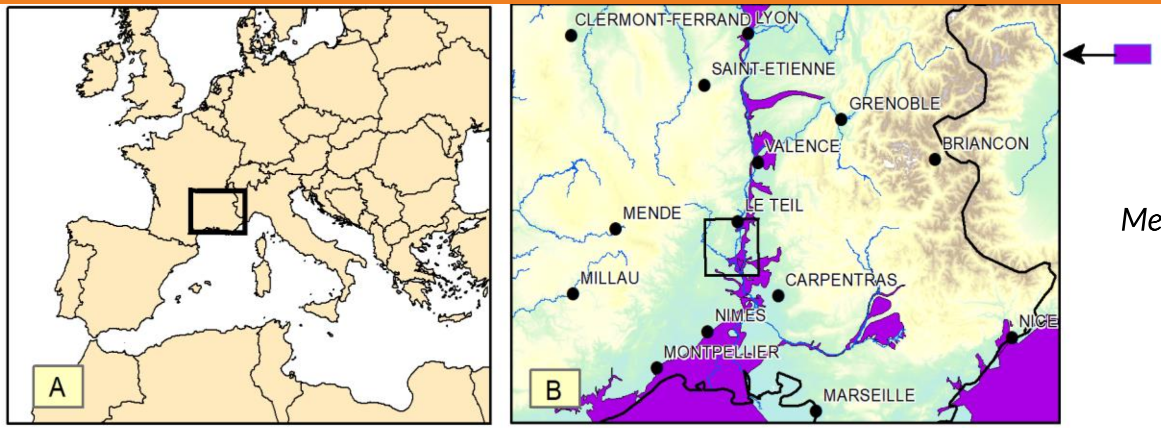
Add stations to
increase resolution.



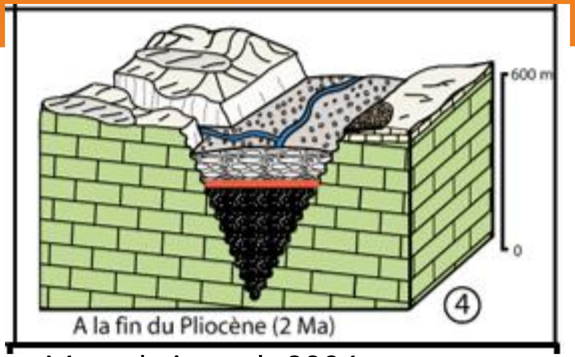
Ambient seismic noise to useful information about the subsurface:



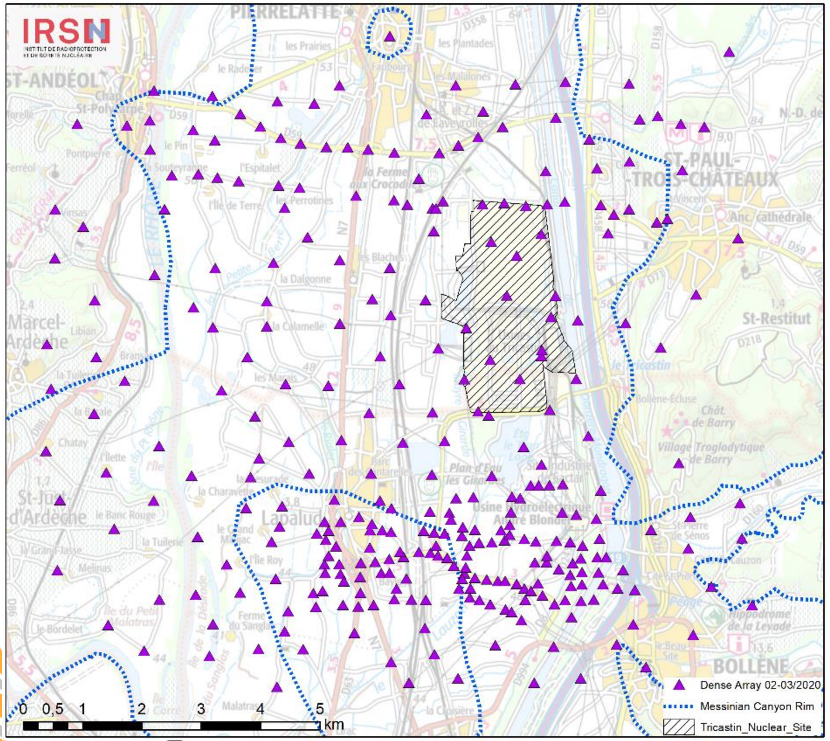
ANSWT of a Messinian paleo-canyon in Tricastin region, Rhône valley, France



Rhône paleo-canyon dug during Messinian crisis (-5.8Ma) and filled with sediments.



Mocochain et al., 2006



by egis

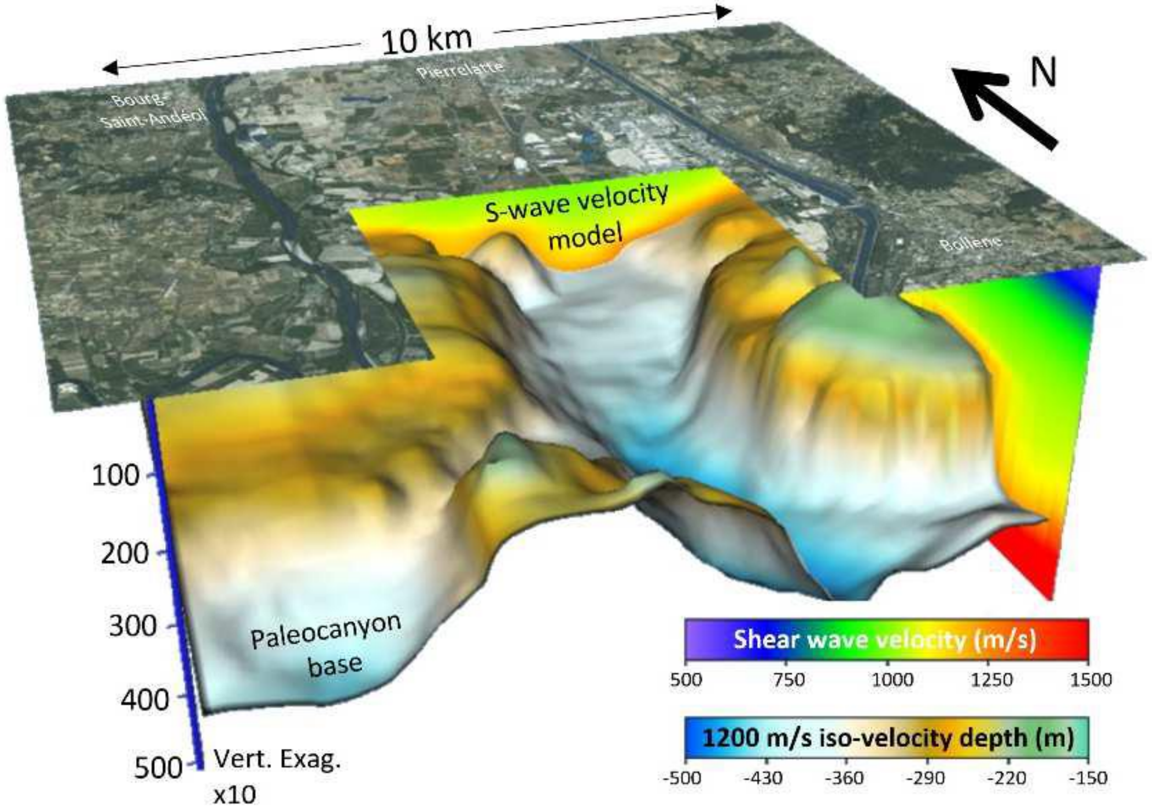
- → High velocity contrast between sediments (sand, clay) and base rock (limestone).
- → Geological context favorable to ground motion amplification: site effects.
- → Need to investigate those effect to evaluate seismic hazard in the region where we have critical installations such as nuclear plants.
- → For this, we used a 3D velocity model obtained by ANSWT to image the paleo-canyon.

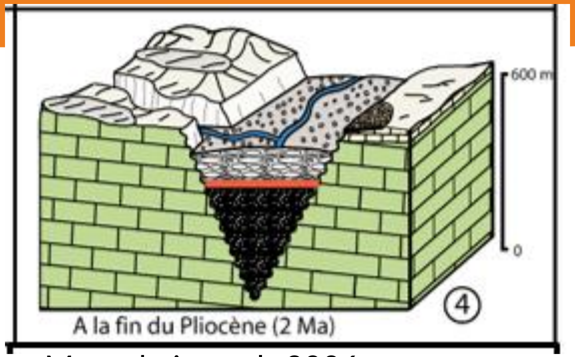
Experiment characteristics:
- → 400 nodes (3 components)
- → 1 month of recording (February-March 2020)

Credits:

IRSN INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

ANSWT of a Messinian paleo-canyon in Tricastin region, Rhône valley, France





Mocochain et al., 2006

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Monitoring of a stockpile at a mine facilities in Moanda, Gabon

Major Transportation Hub

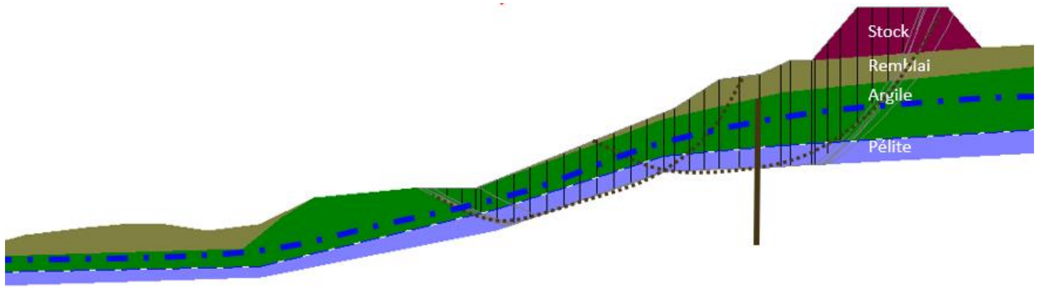
- Crucial for mine operations

Challenging geotechnical context

- Steep slopes, locally 40°
- Unfavorably dipping clay-rich layer
- Two slippage surfaces
- Water table in the pelites is very sensitive to rainfall

Reinforcement measures

- Construction of buttresses
- Pumping to lower the water table



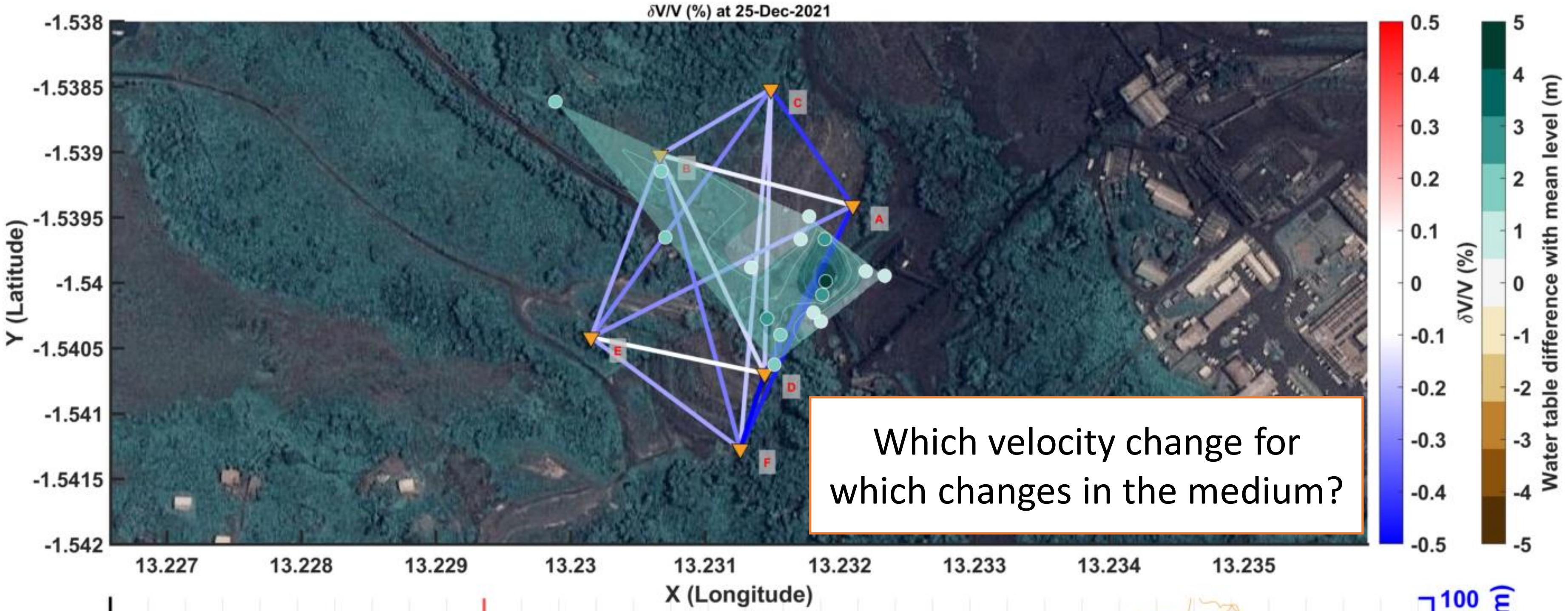
Objective of the project

- Use continuous recording to track seismic velocity change
- Create an automatic notification system when anomalous velocity change are detected.

Monitoring of a stockpile at a mine facilities in Moanda, Gabon

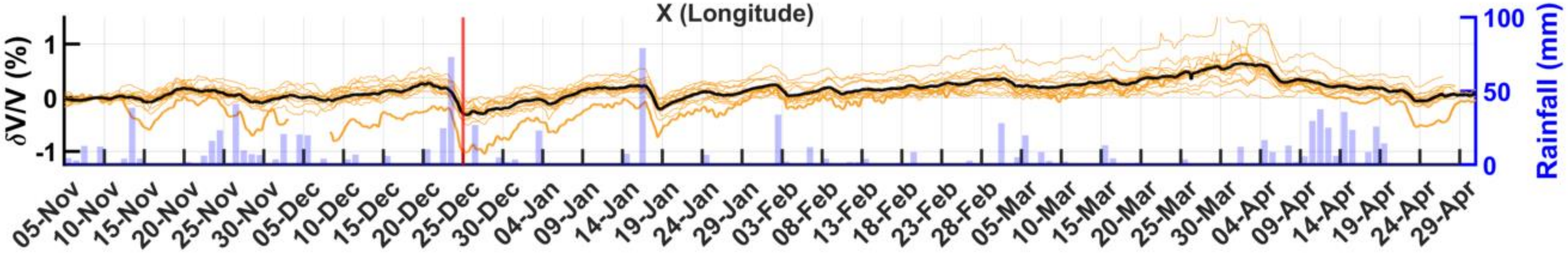
▽ : Seismic stations

● : Piezometers



Which velocity change for which changes in the medium?

Velocity changes between all pairs of stations



Tomography model of the Helsinki capital region

- Part of the Seismic Risk project:

Mitigation of induced seismic risk in urban environments

- Example in Strasbourg (France):
  following induced earthquakes in 2019 and 2021
  causing damages to infrastructures,
  no more authorization to continue.

⇒ Need to assess the seismic hazard!

- Sisprobe's job is to produce a 3D shear wave velocity model of the Helsinki capital region.
- Use of past deployments of seismic stations in 2016, 2018, and 2020.

Séismes à Strasbourg

Au sommaire du dossier

Vendenheim-Reichstett

Géothermie profonde : « Plus aucune autorisation sur le site »

Lors du comité de suivi, jeudi à Strasbourg, la préfète du Bas-Rhin a réaffirmé qu'il n'était pas question d'une reprise d'activité sur le site géothermique de Vendenheim-Reichstett.

Par **V.B.** - 05 mai 2022 à 20:51 | mis à jour le 06 mai 2022 à 23:00 - Temps de lecture : 2 min

| Vu 1859 fois

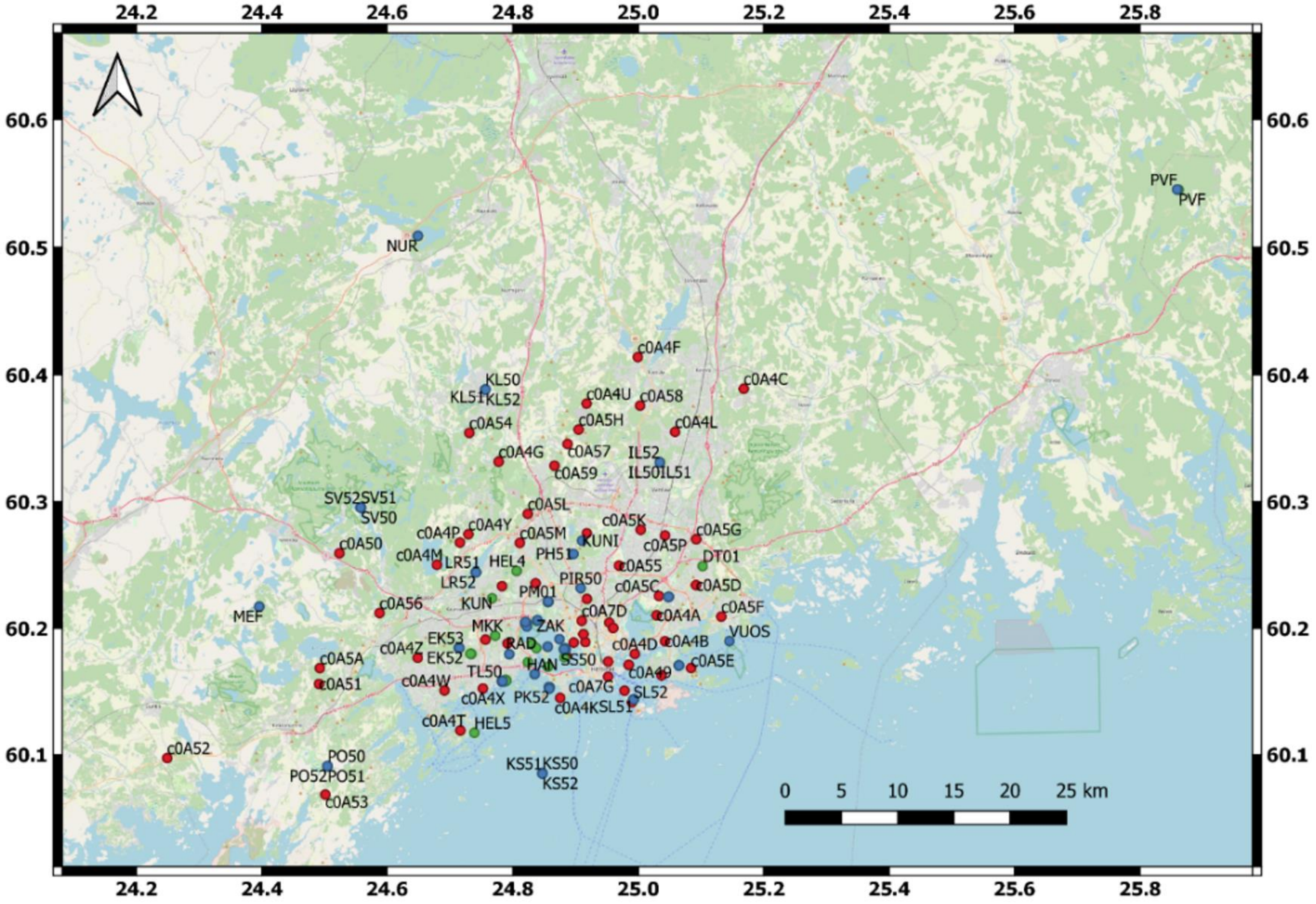
01 / 02 Suite aux séismes, la quasi-totalité des dossiers de sinistre ont été expertisés. La moyenne des indemnisations tourne autour de 2 500 euros. Photo Archives DNA /JEAN-CHRISTOPHE DORN

SEISMIC RISK

https://www2.helsinki.fi/en/projects/seismic-risk

Station map

Year	Number of stations	Number of components	Recording duration
2016	59	1	~32 days
2018	101	3	> 8 months
2020	90	3	> 8 months



Station map: area covered by the study

Year	Number of stations	Number of components	Recording duration
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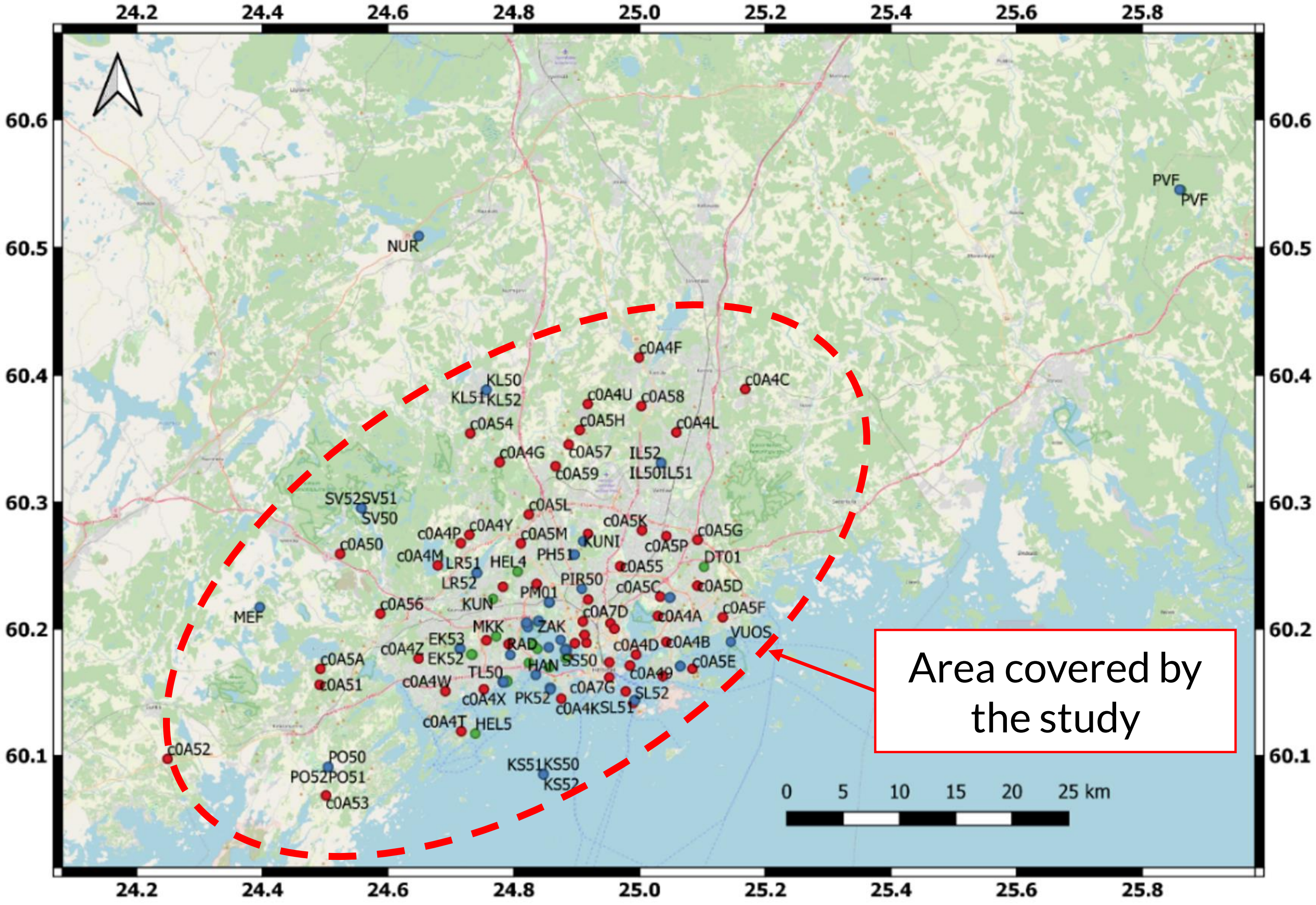
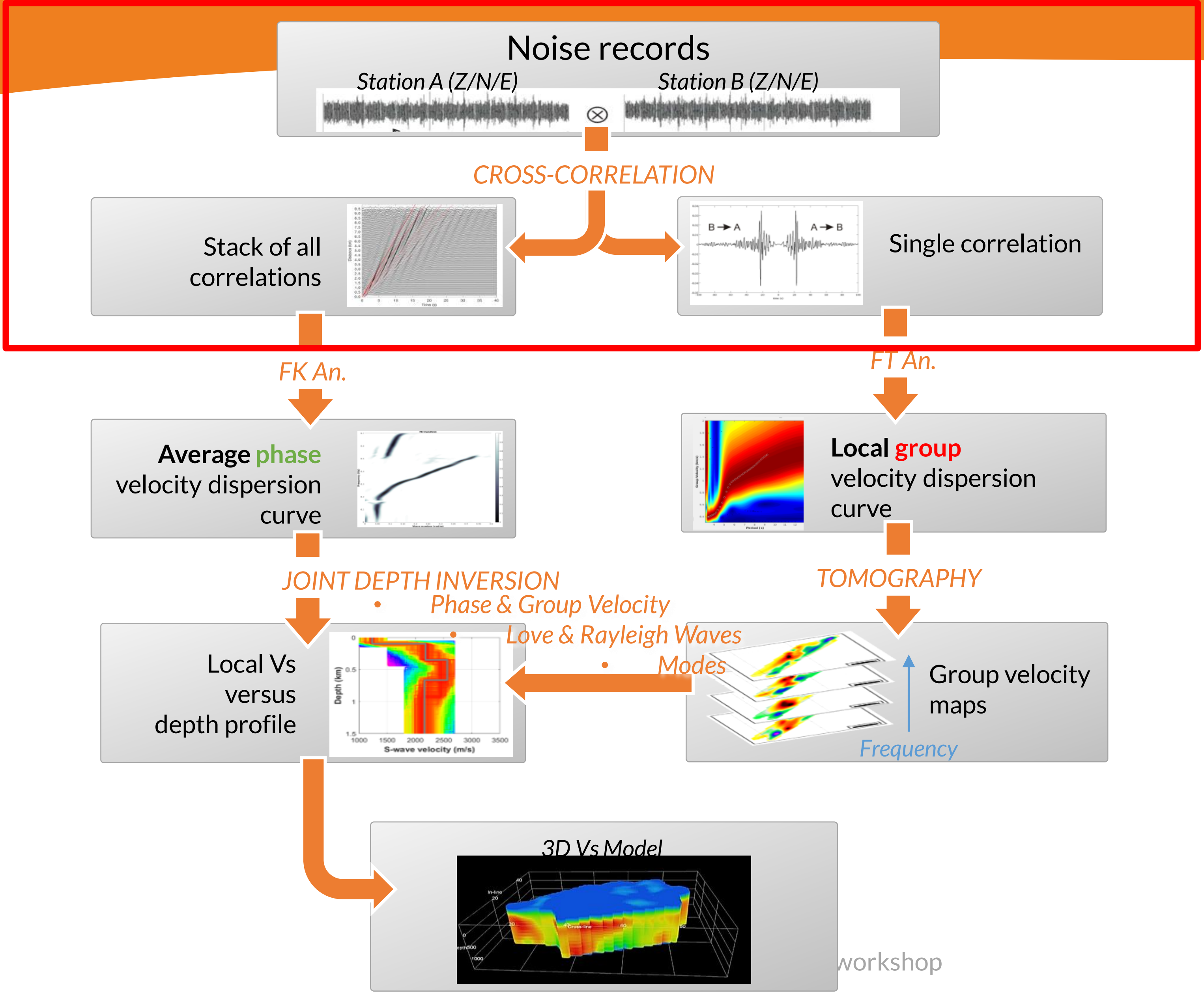
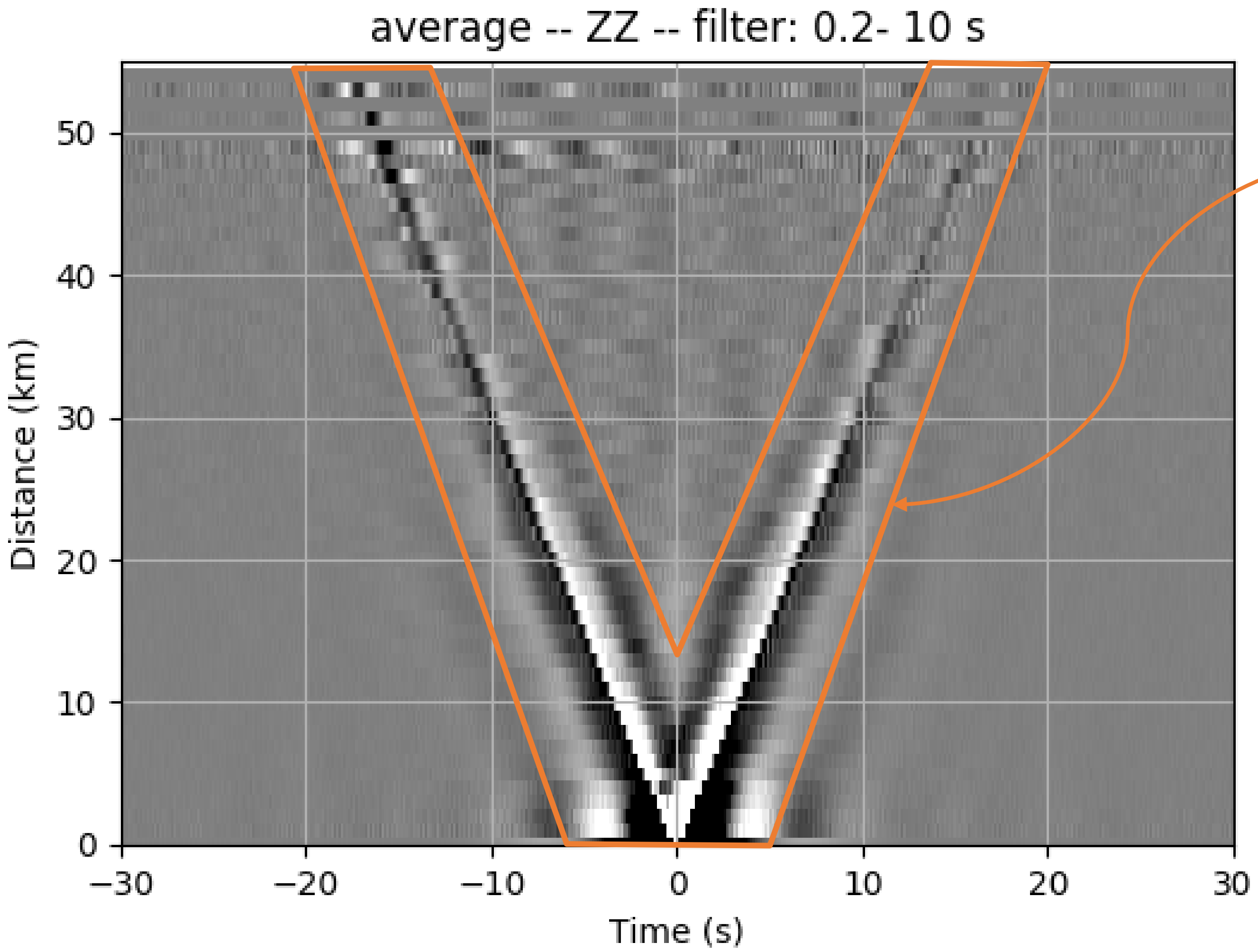


Ambient seismic noise to useful information about the subsurface:

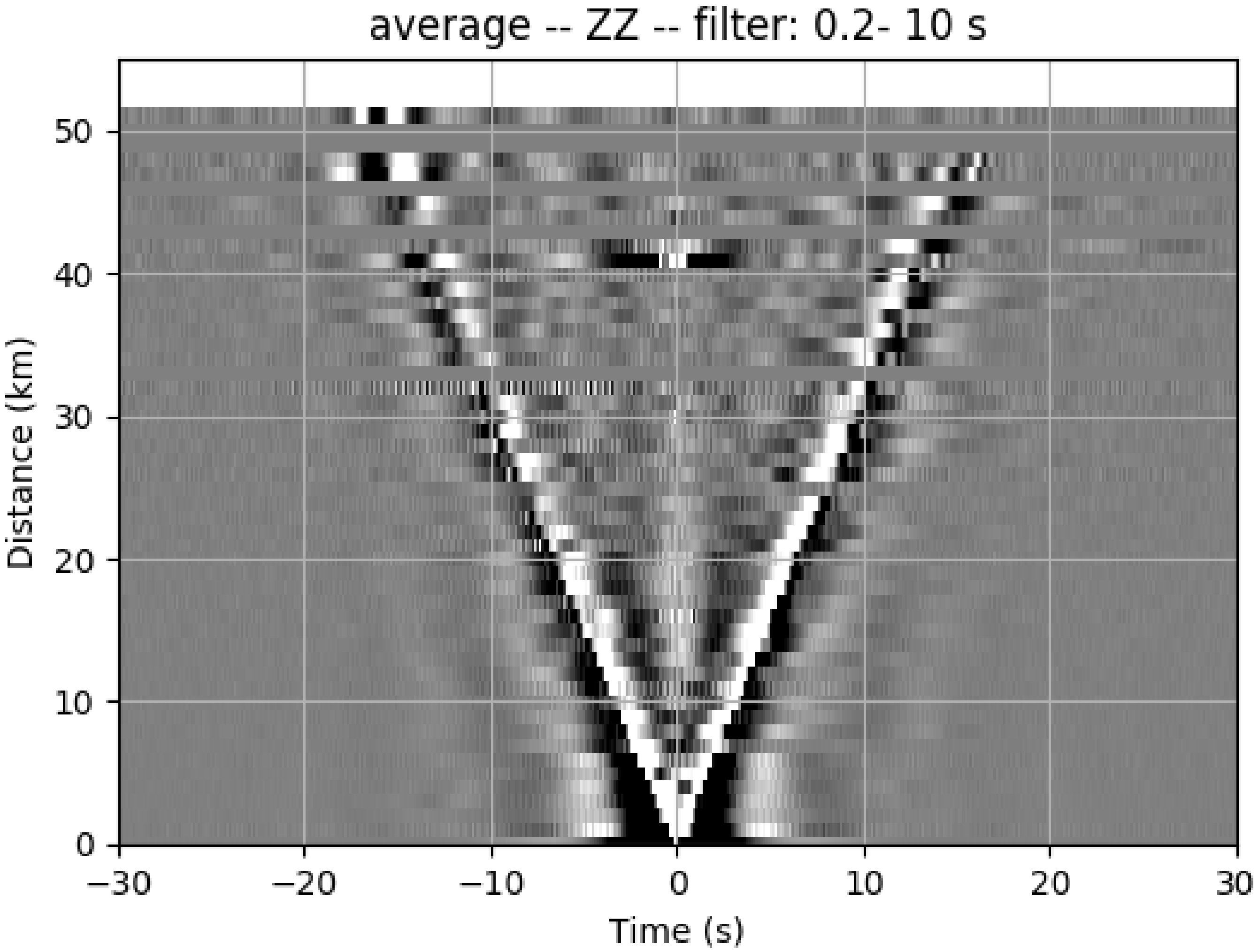


Application of the seismic interferometry



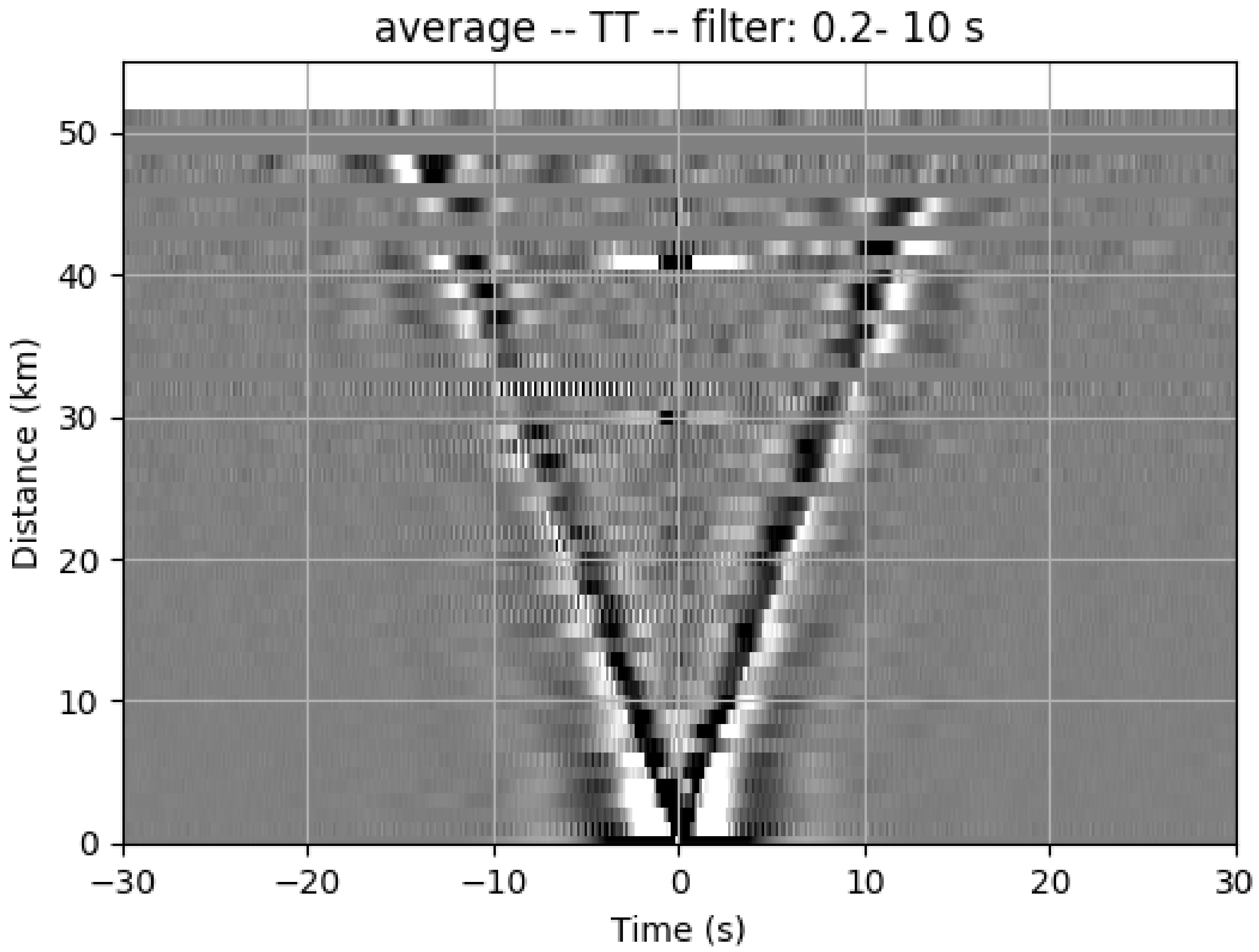
- 2016 dataset
- Clear arrival at around 3km/s
- No clear dispersion => Rayleigh wave in a homogeneous medium?

Application of the seismic interferometry



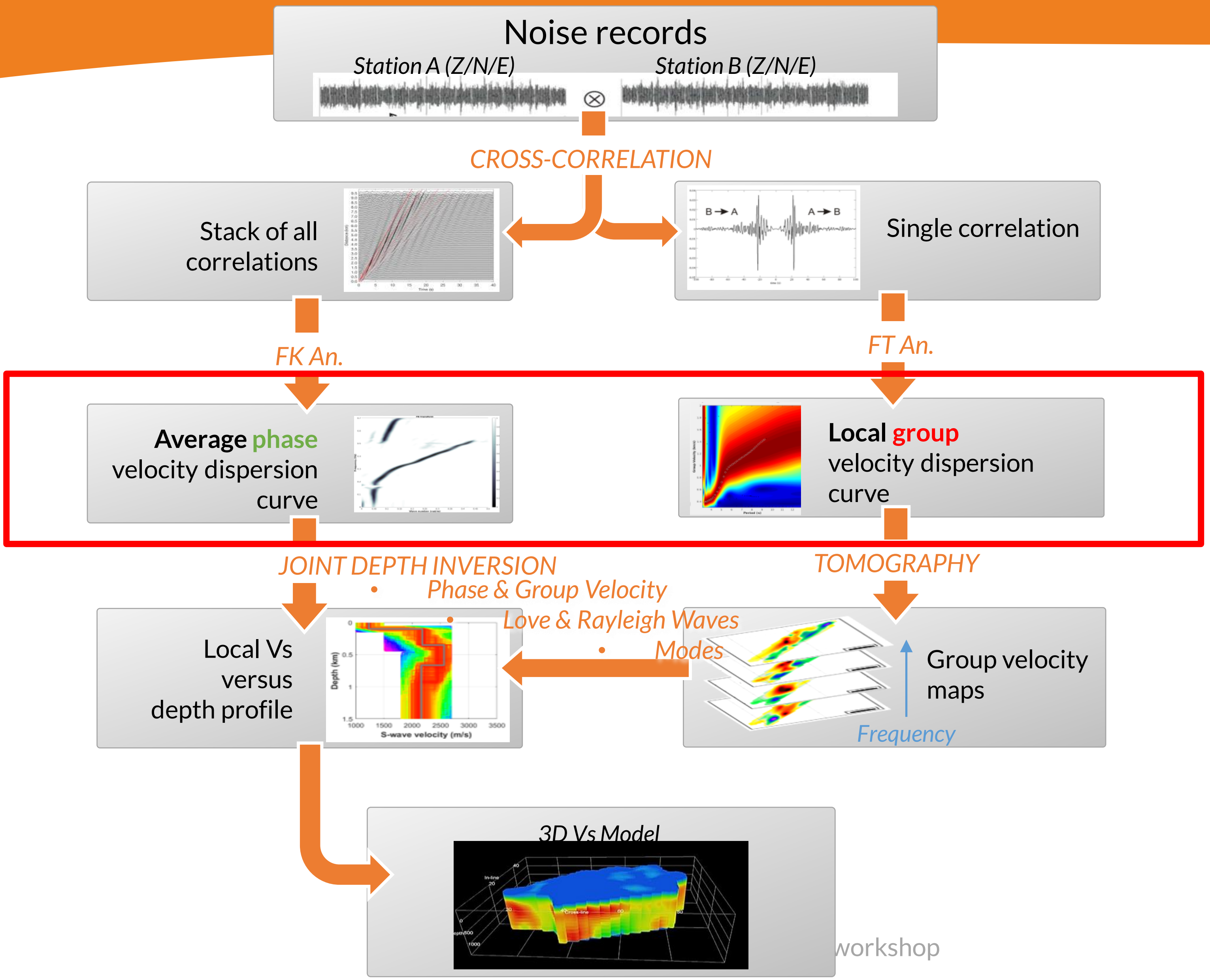
- 2020 dataset
- Clear arrival at around 3km/s
- No clear dispersion => Rayleigh wave in a homogeneous medium?

Application of the seismic interferometry

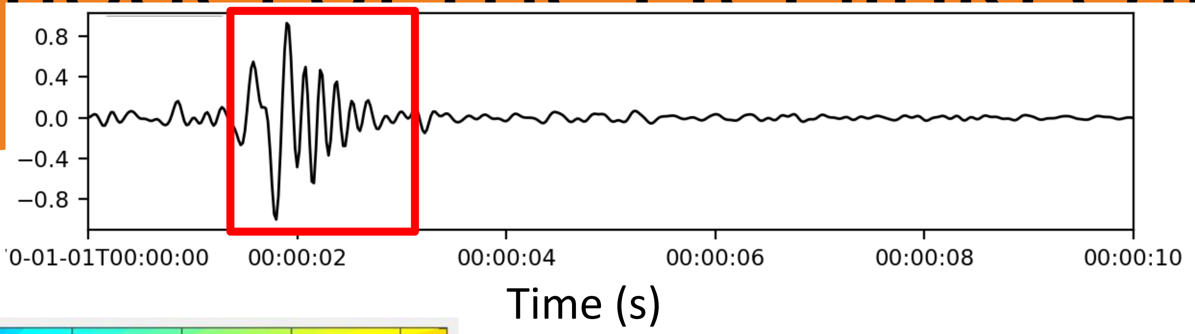


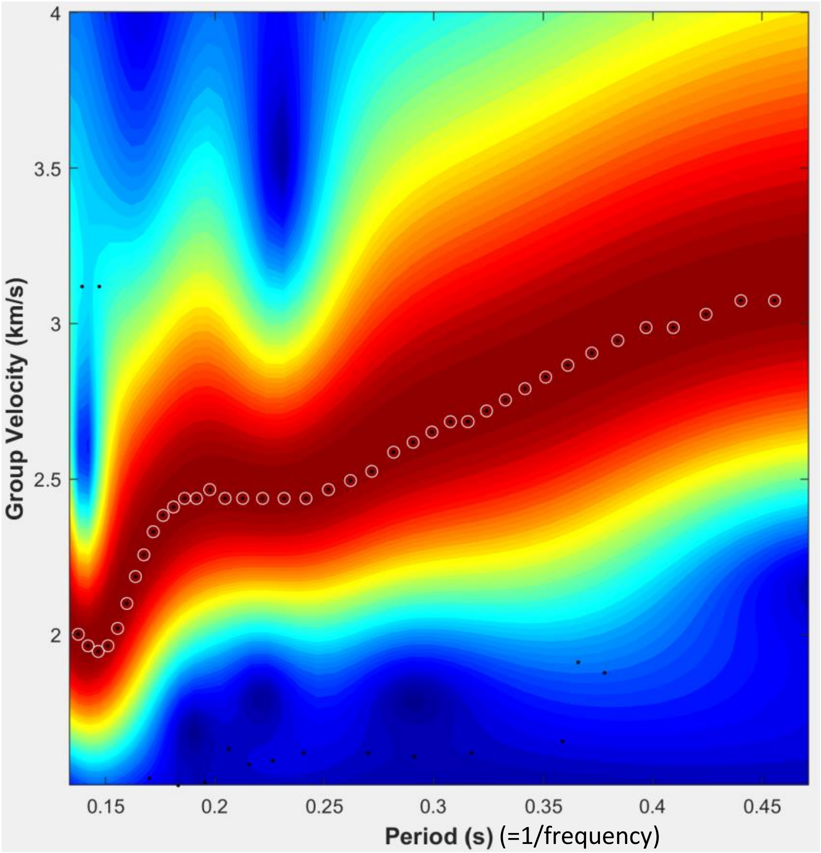
- 2020 dataset
- Clear arrival at around 3.5km/s
- No clear dispersion => Love wave in a homogeneous medium?

Ambient seismic noise to useful information about the subsurface:



Tomography model of the Helsinki capital region

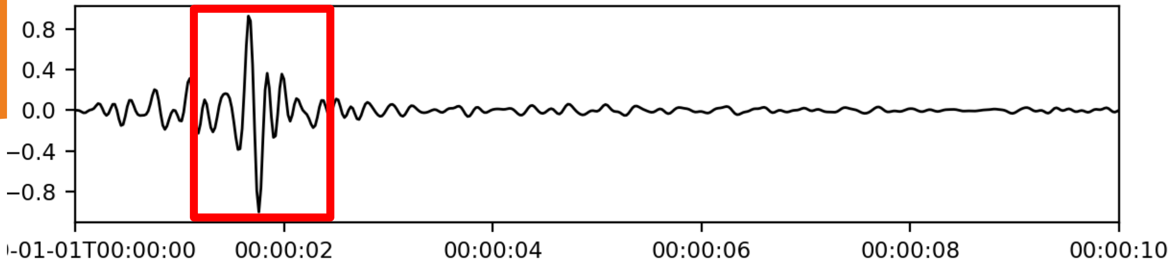




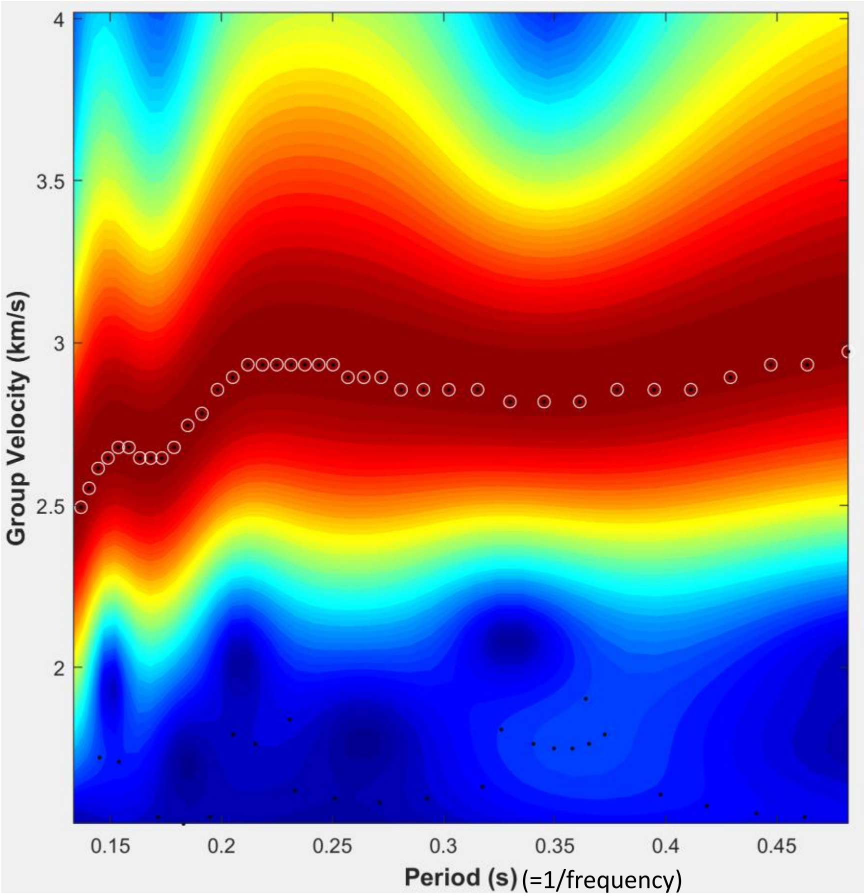
- Different velocity at different frequency are measured
  => multiple layer(s)
- Sensitive down to ~1000-1500m depth

Cross-correlation between: OT.EV(00|01|05|06) – OT.SS(03|04|09B)

Tomography model of the Helsinki capital region



Time (s)

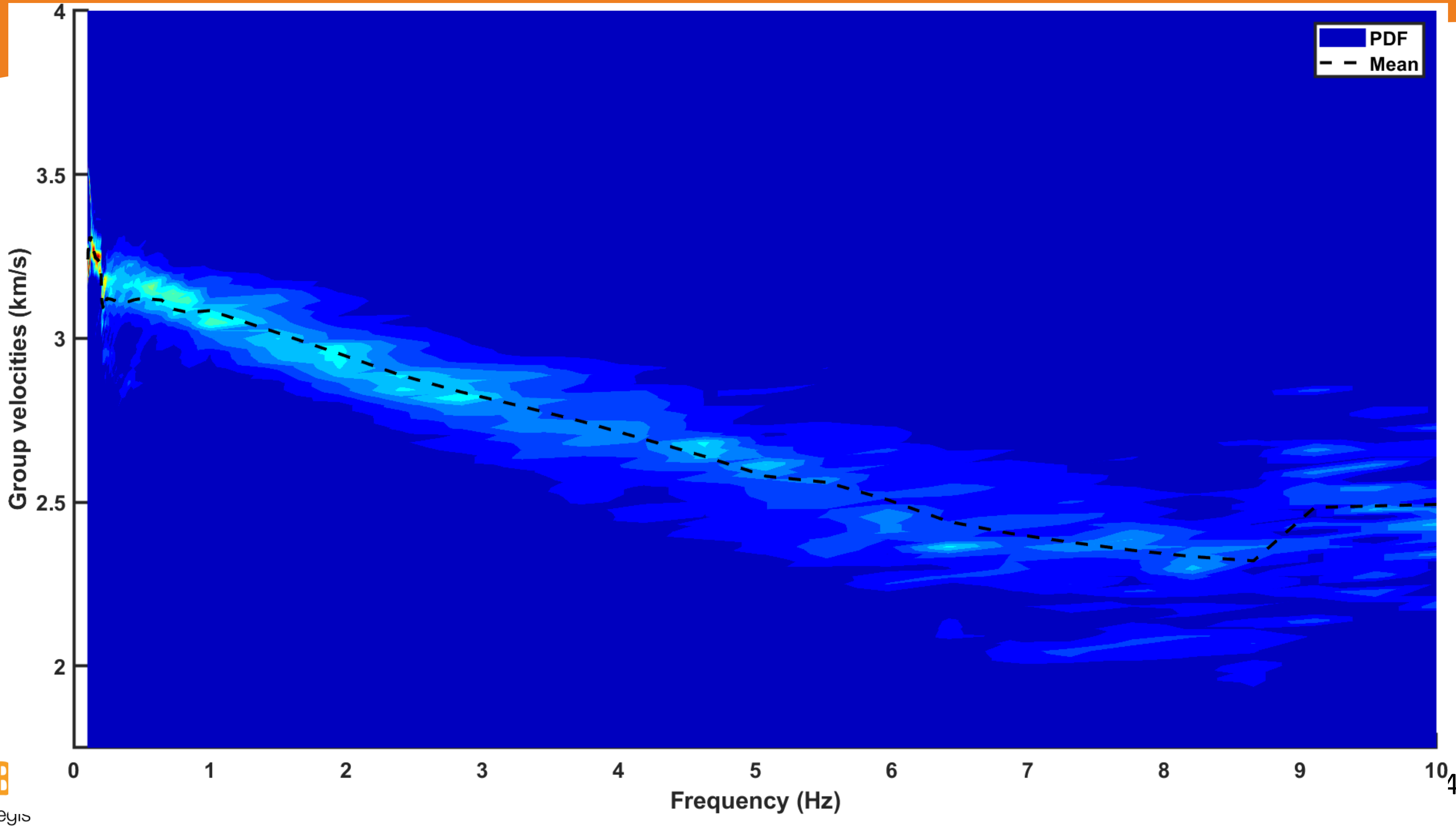


(=1/frequency)

- Velocity more or less equal at different frequency are measured
  => tend toward homogenous medium
- Sensitive down to ~1000-1500m depth

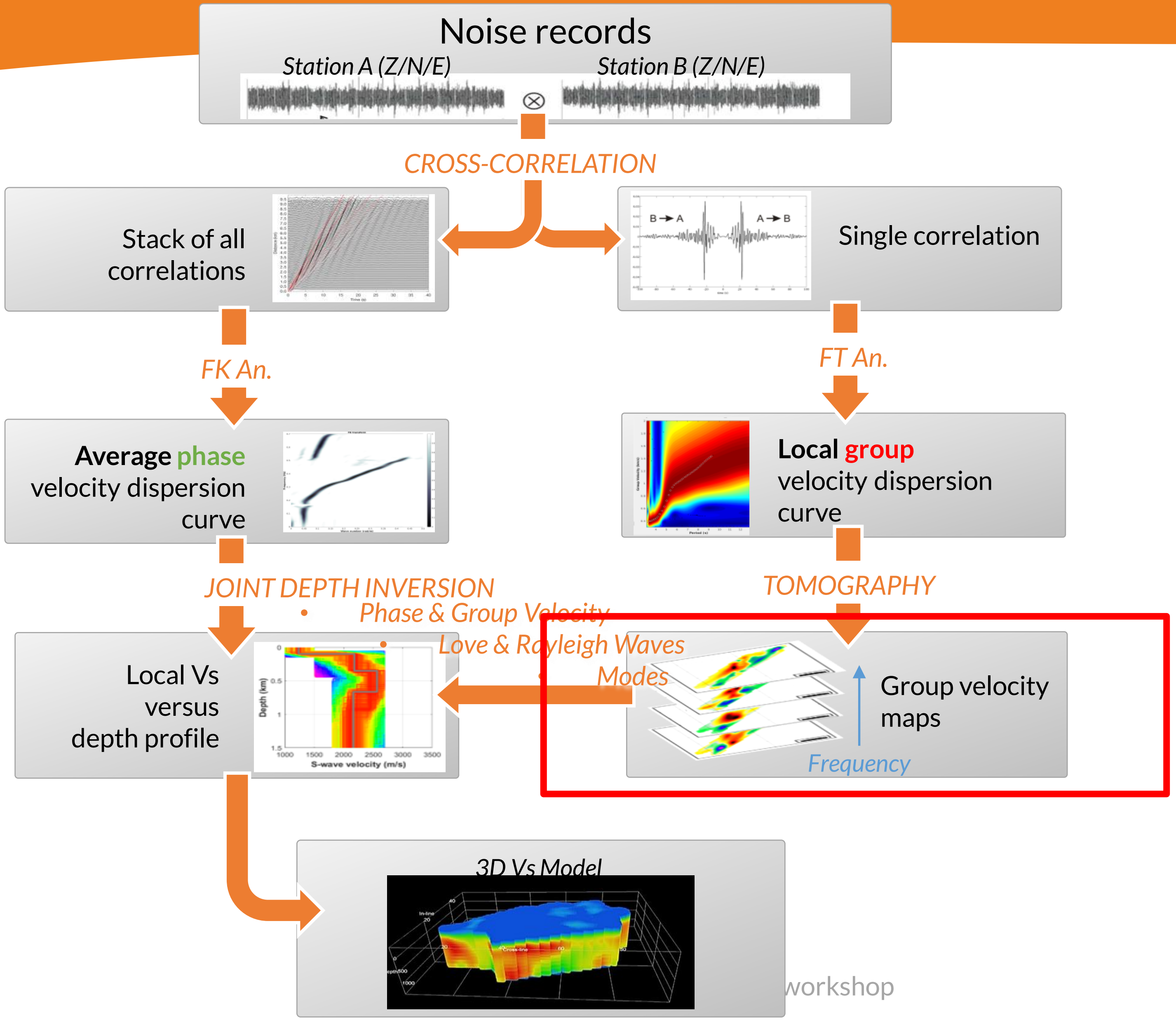
Cross-correlation between: OT.PM02 – OT.SS(00B|01|06)

Rayleigh wave dispersion curves



SISPROB by eqis

Ambient seismic noise to useful information about the subsurface:



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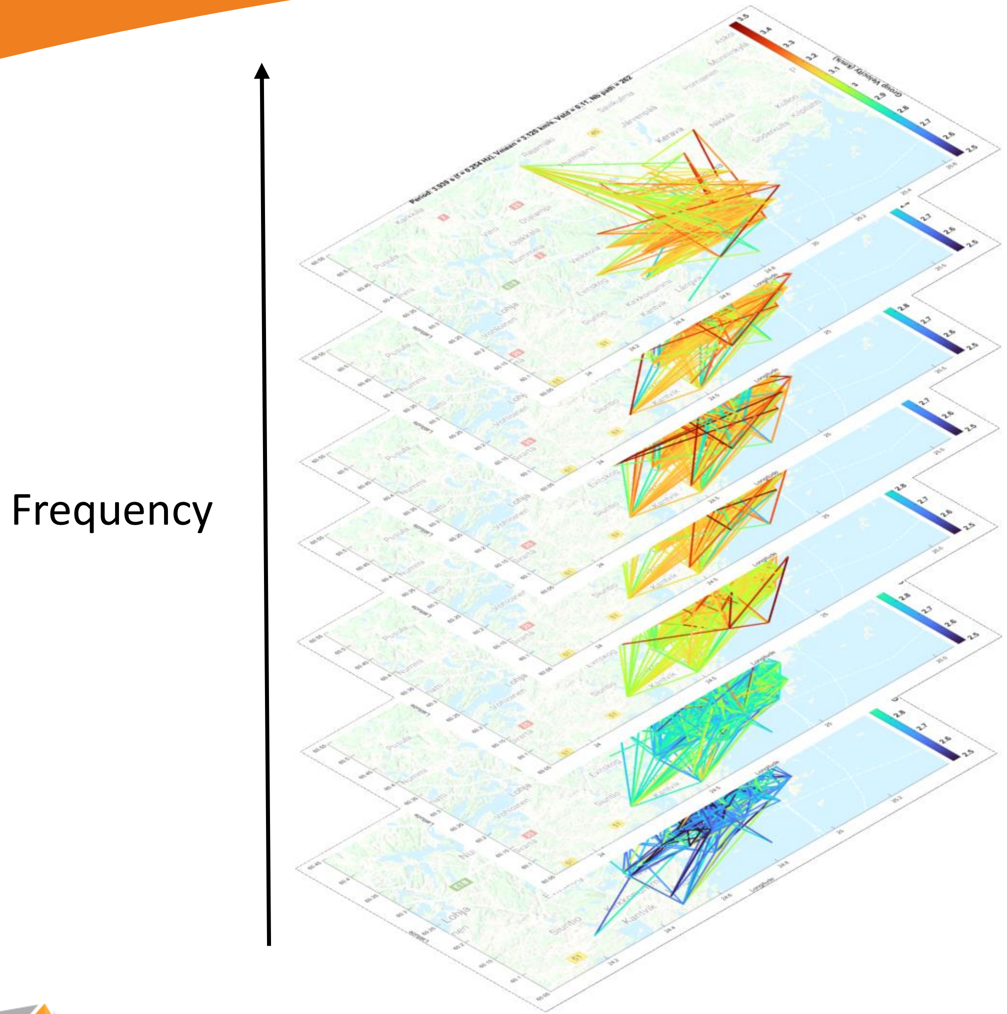
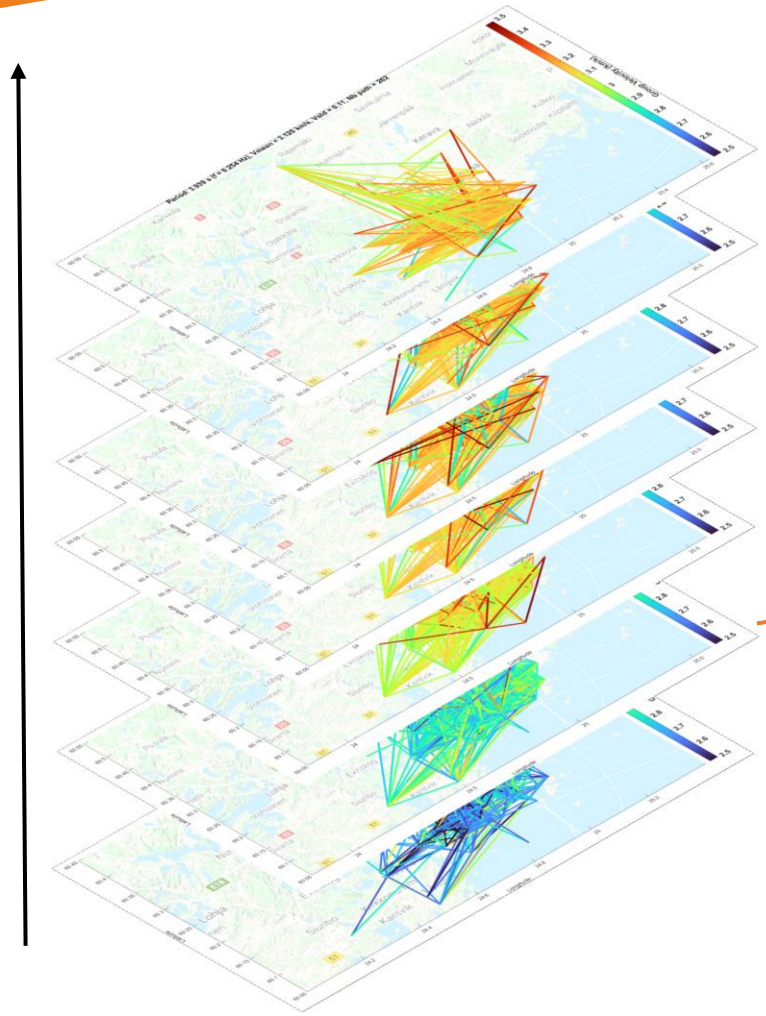
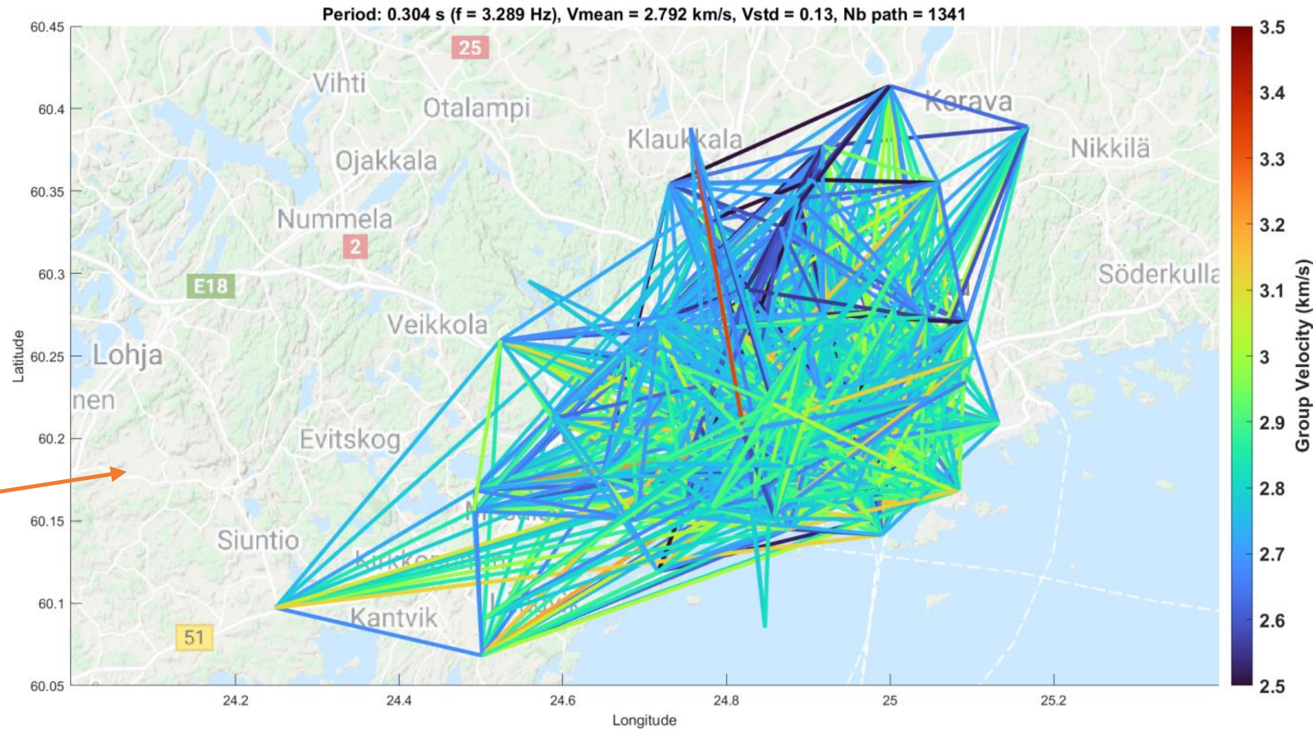


- One map per frequency
- Each map contains N-paths
- Each path = group velocity

Tomography model of the Helsinki capital region

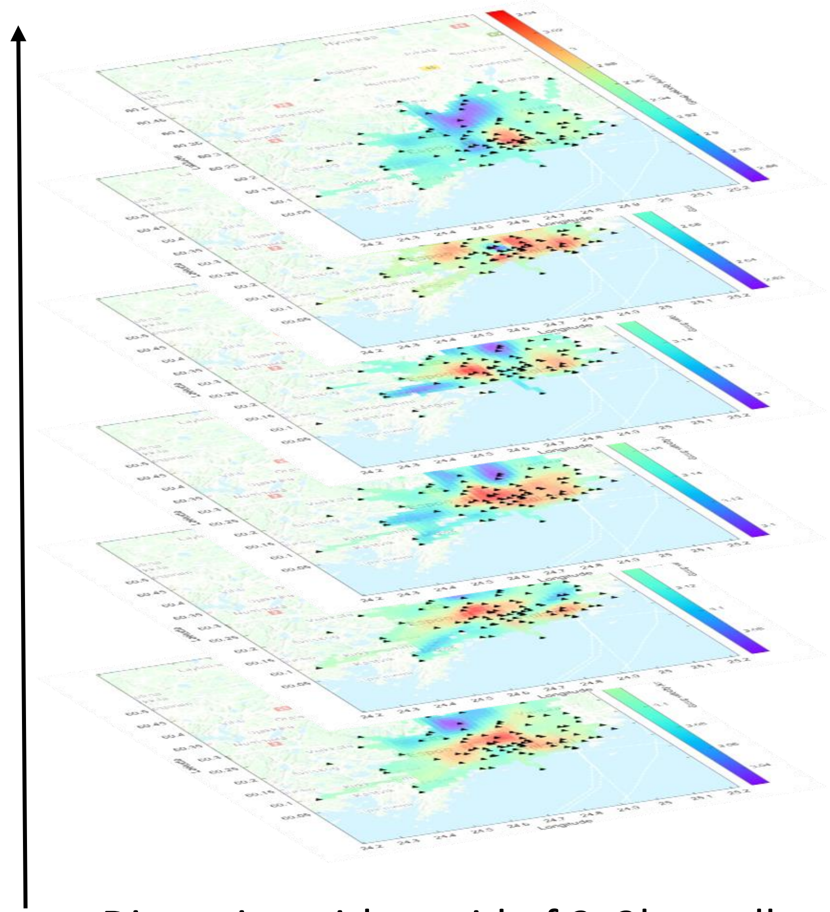
Frequency



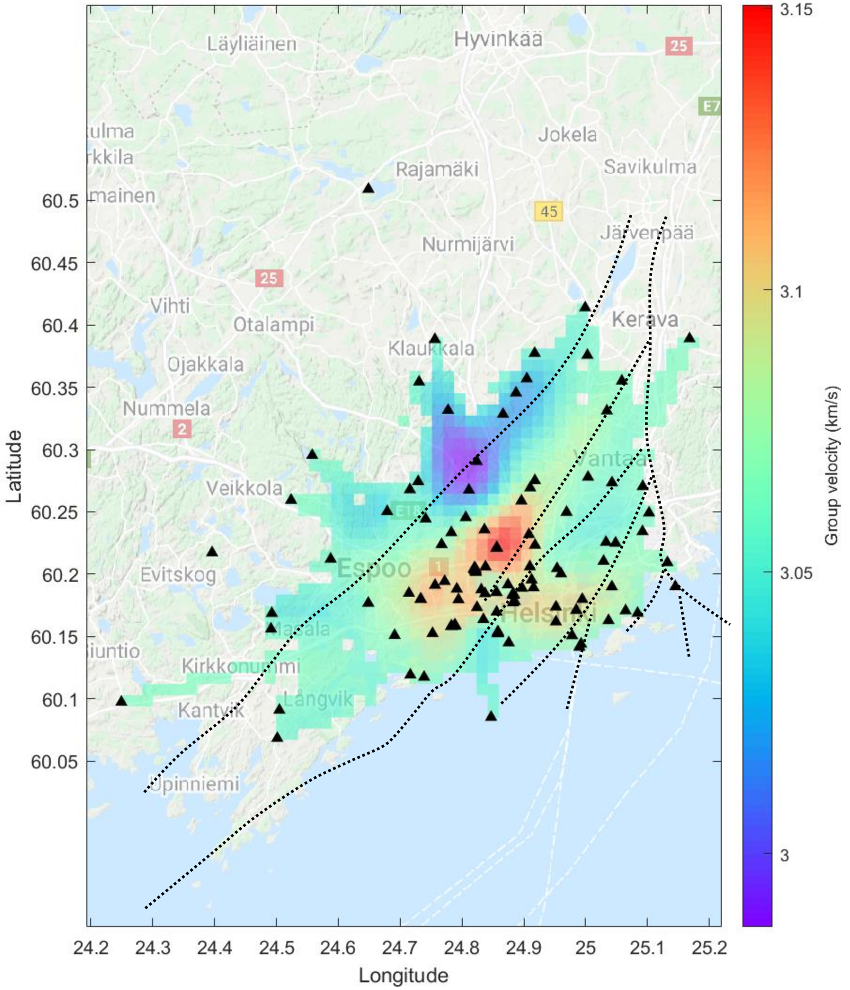


Tomography model of the Helsinki capital region

Frequency

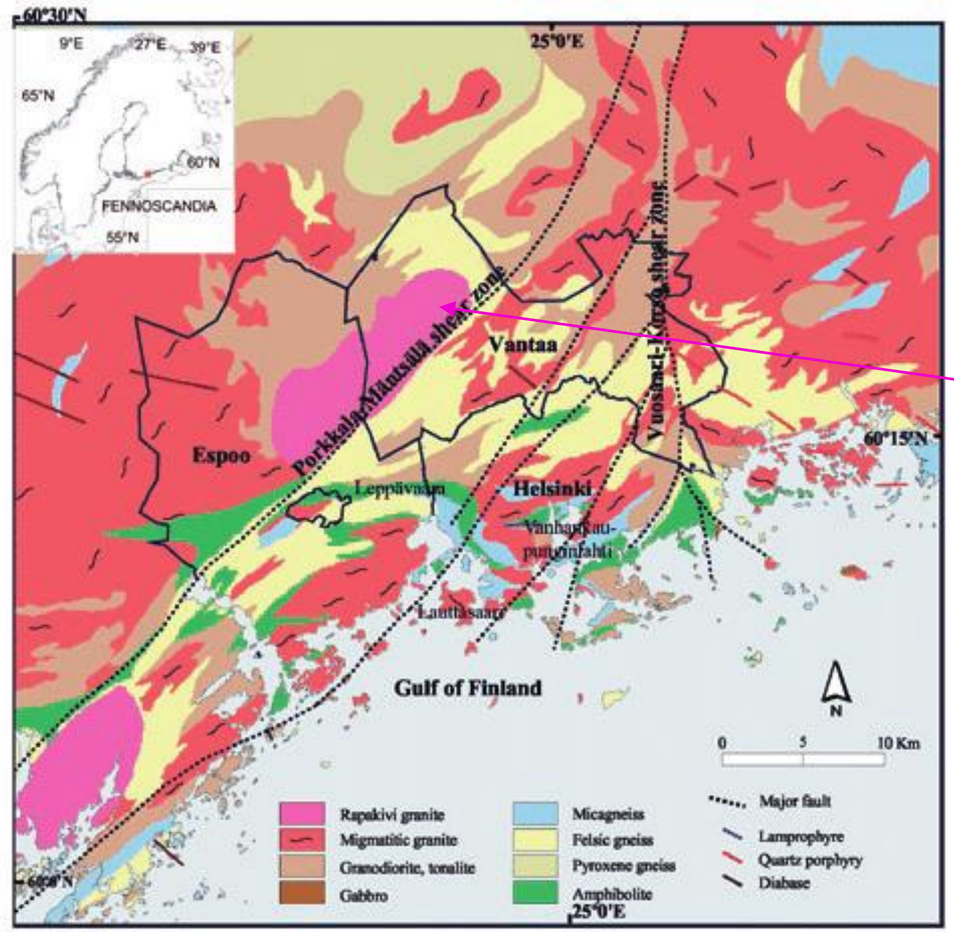


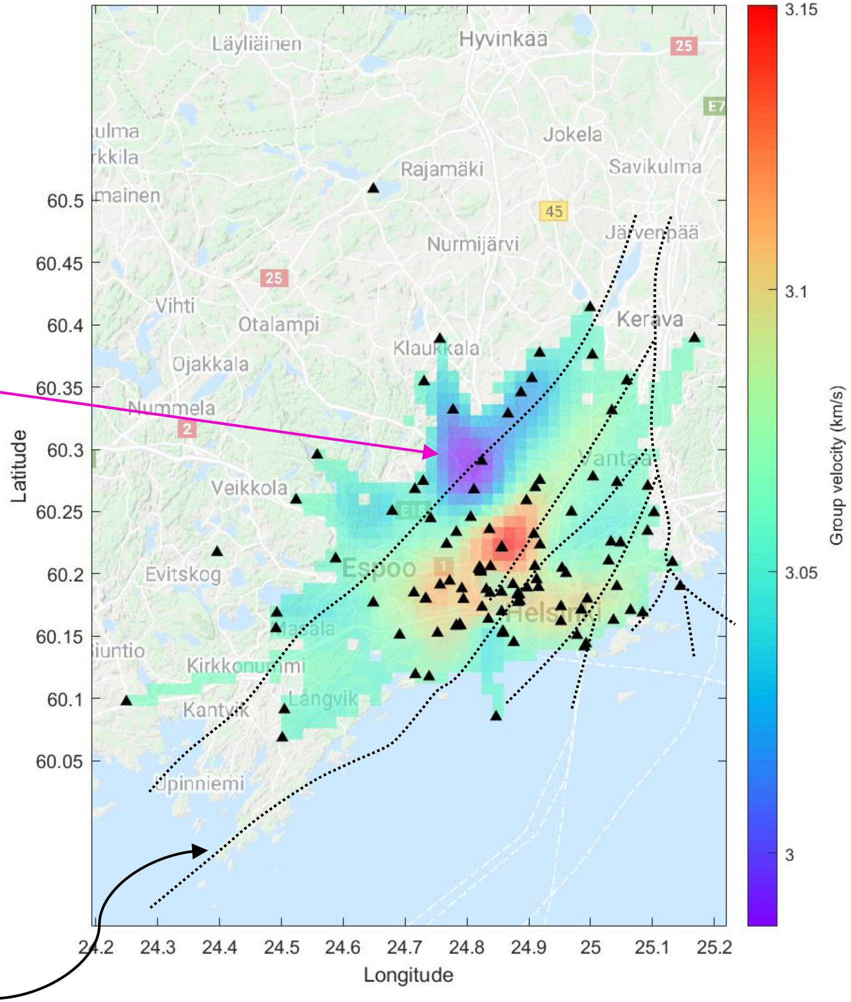
Discretize with a grid of 3x3km cells



Rayleigh wave group velocity map at 1s

Tomography model of the Helsinki capital region



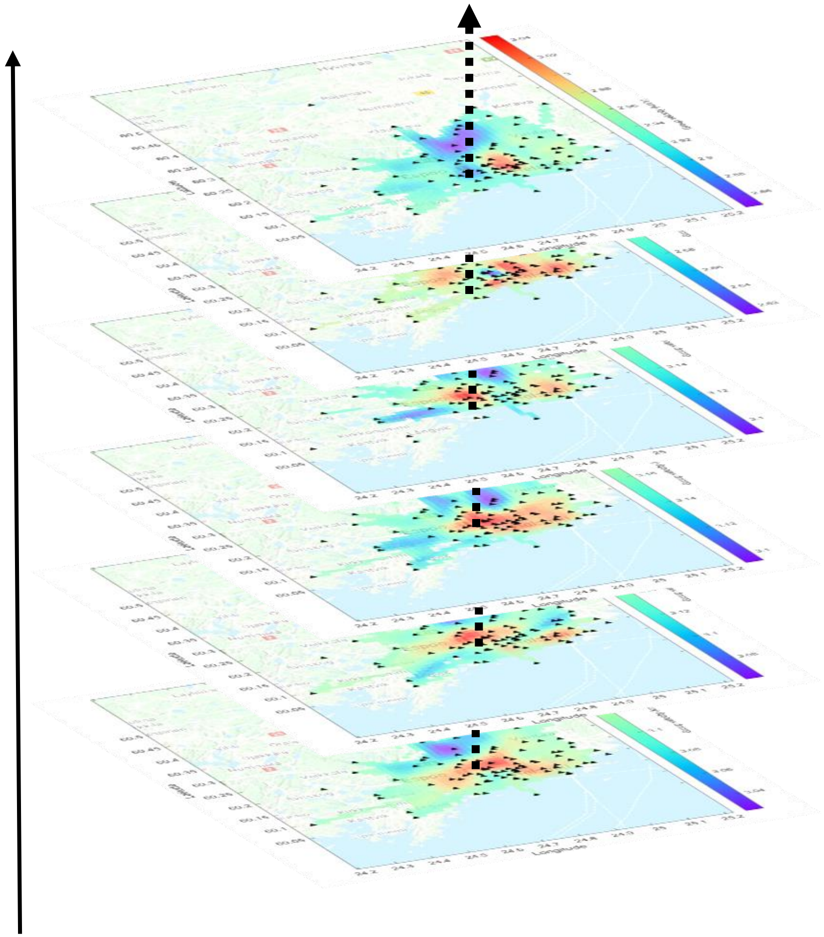


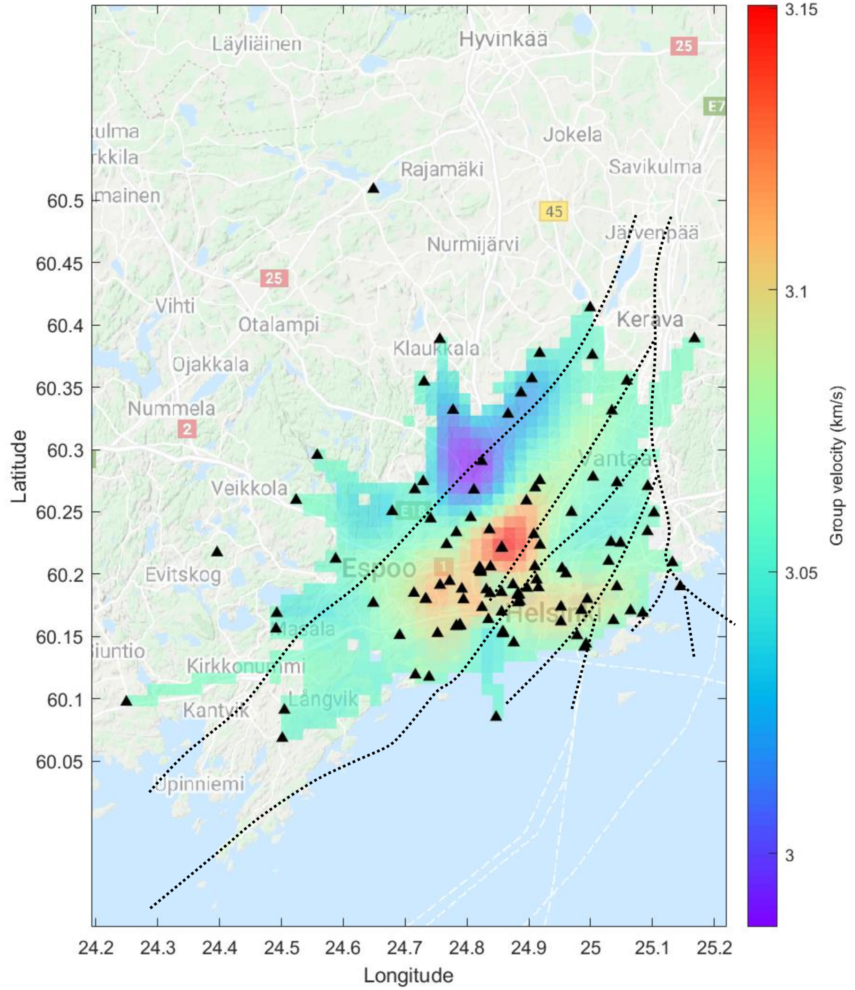
Major faults
(approximative position)

Rayleigh wave group velocity map at 1s

Group velocity maps to 3D Vs model

Frequency





Rayleigh wave group velocity map at 1s

Group velocity maps to 3D Vs model

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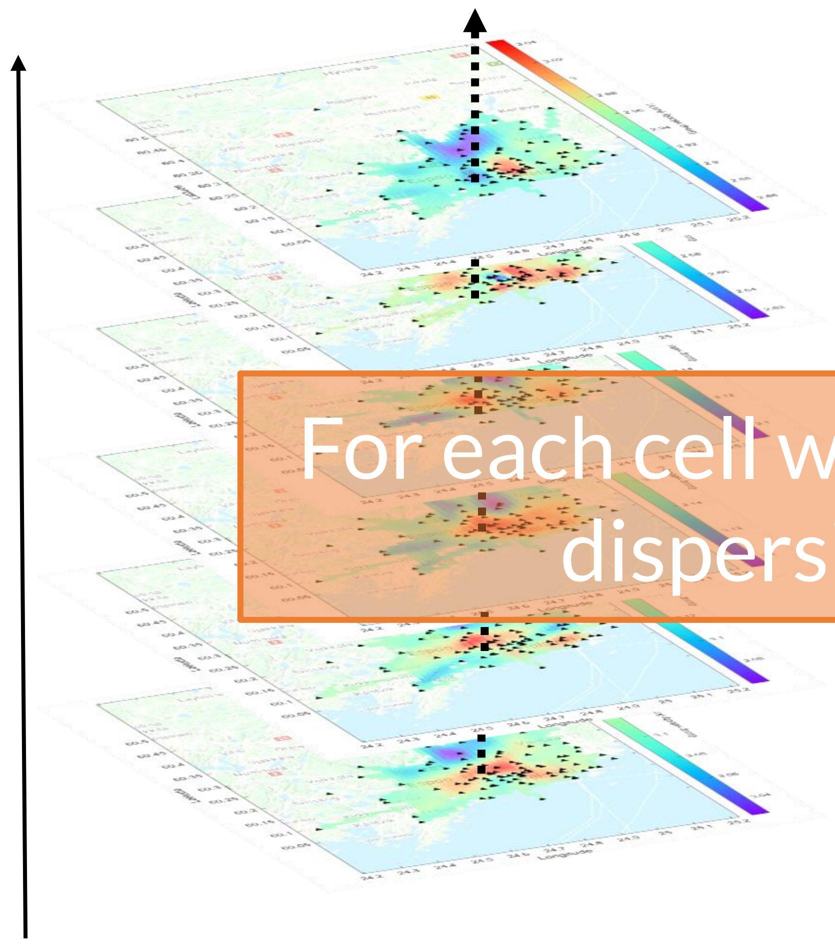
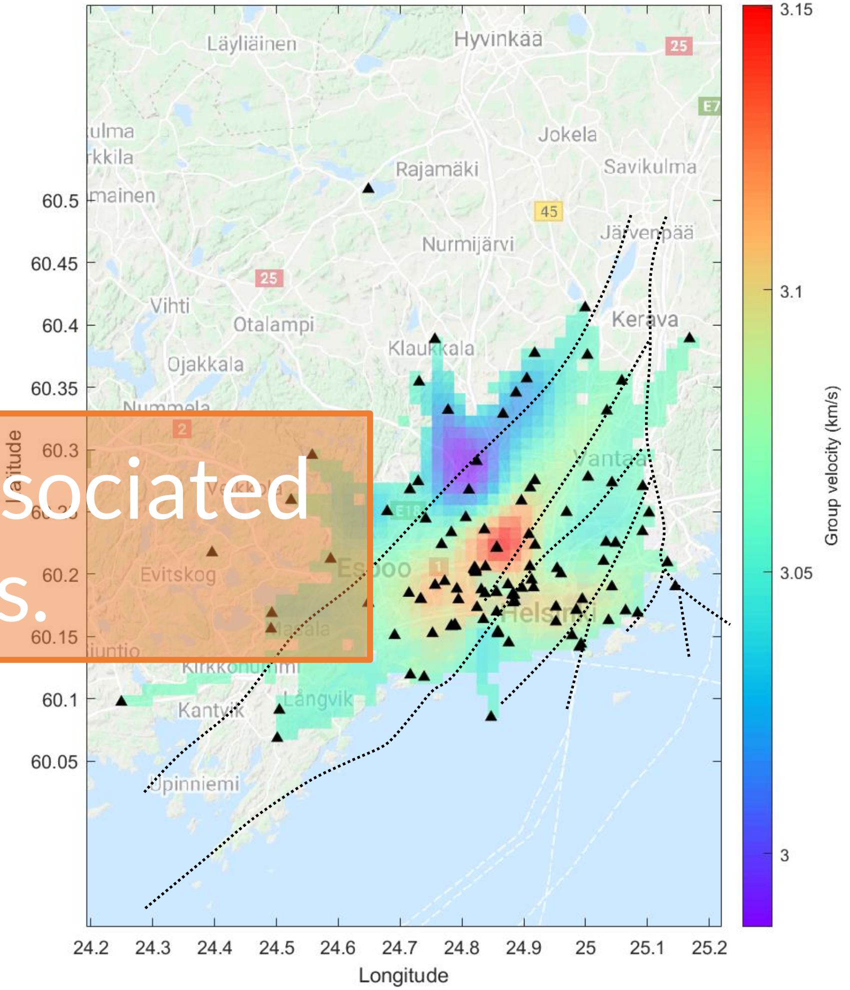
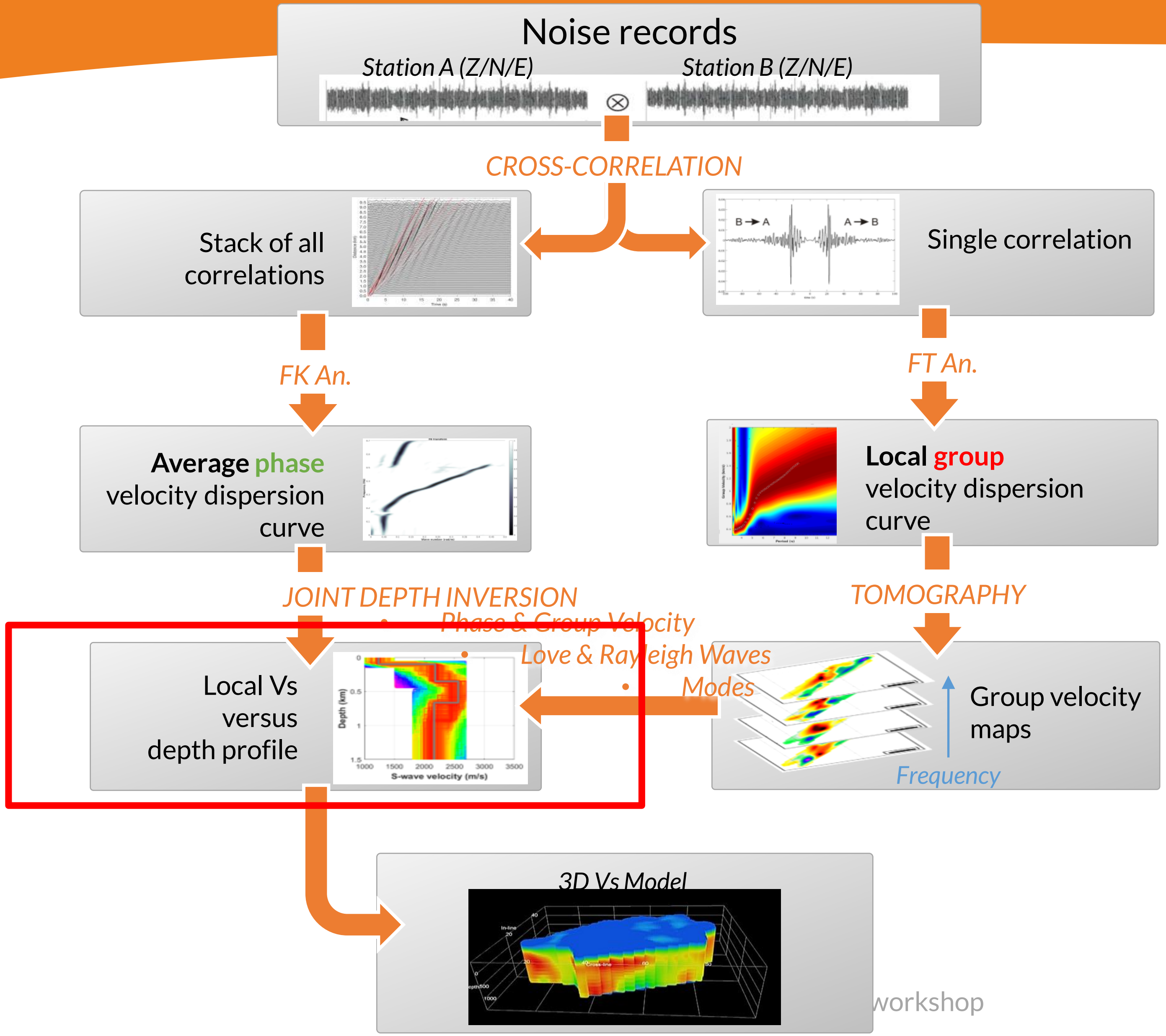


For each cell we have associated dispersion curves.

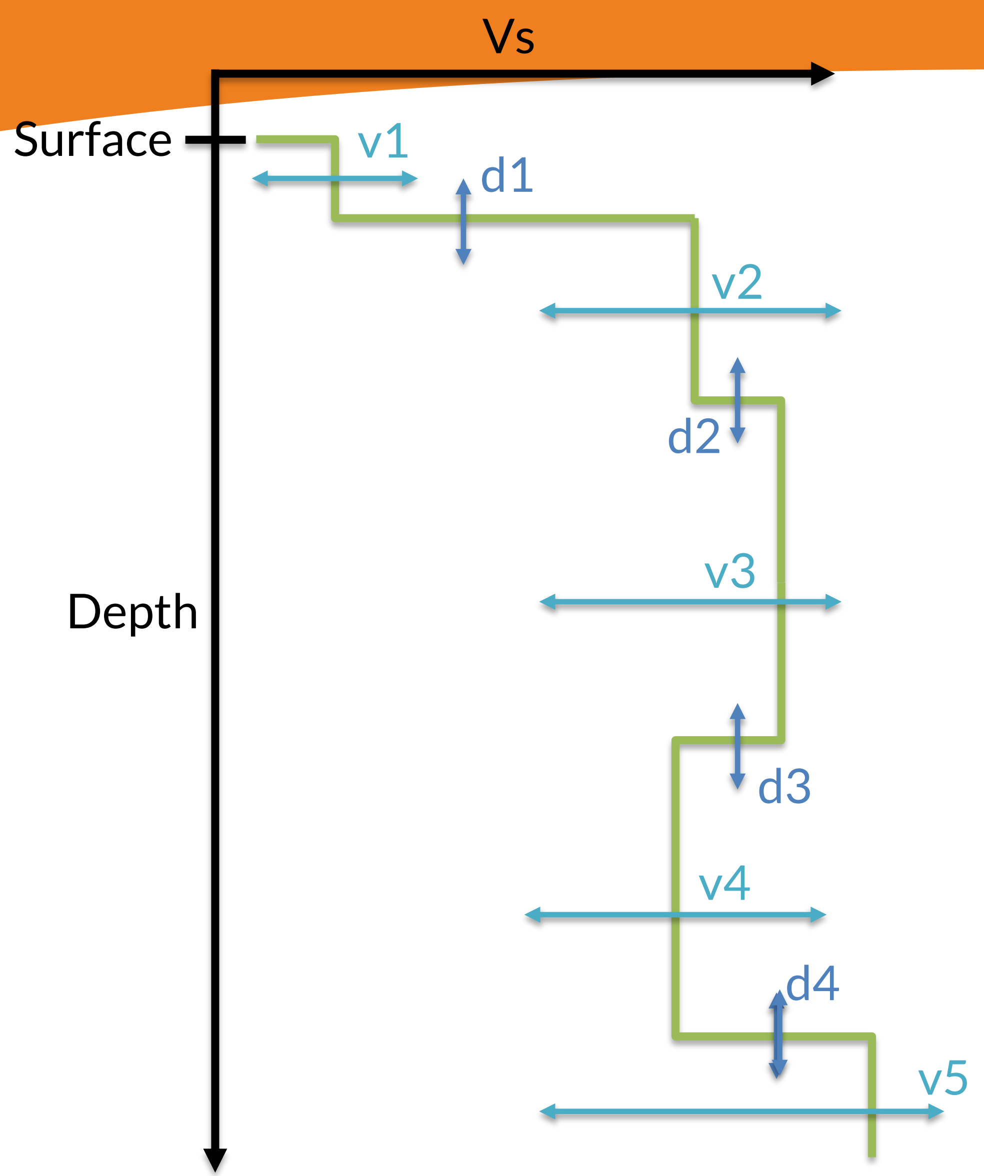


Rayleigh wave group velocity map at 1s

Ambient seismic noise to useful information about the subsurface:

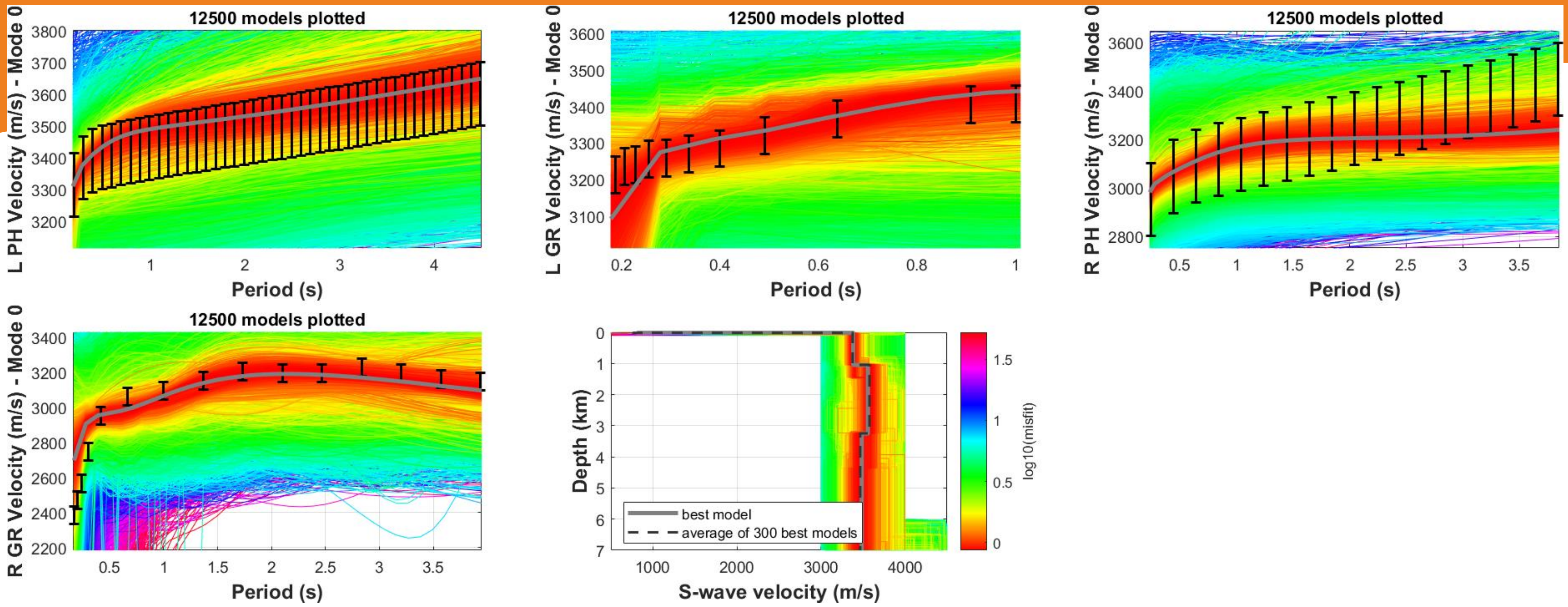


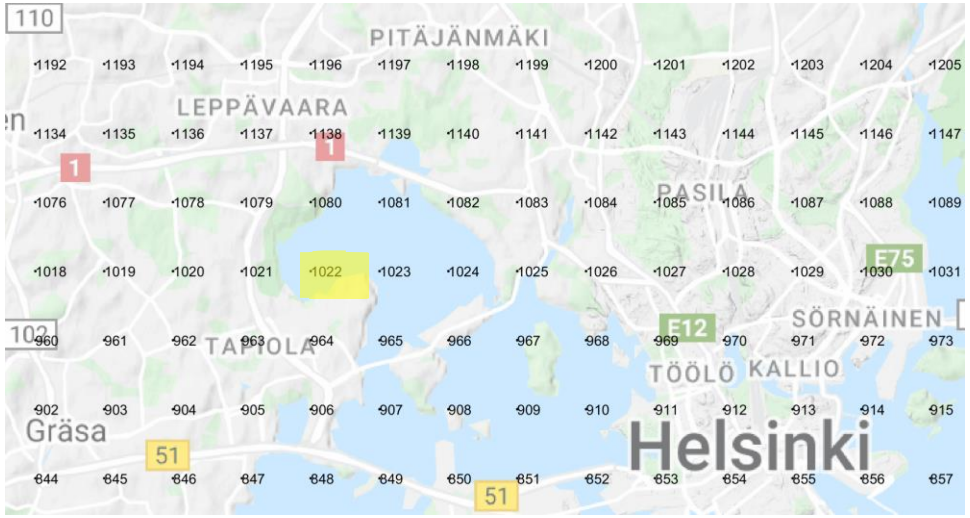
1D Vs model parameters explored by the inversion



Parameters	Min	Max
d1	5 m	100 m
d2	750 m	2,5 km
d3	3 km	4.5 km
d4	6 km	10 km
v1	500 m/s	4 km/s
v2	3 km/s	4 km/s
v3	3 km/s	4 km/s
v4	3 km/s	4 km/s
v5	3 km/s	4.5 km/s

Example of inverted 1D Vs model





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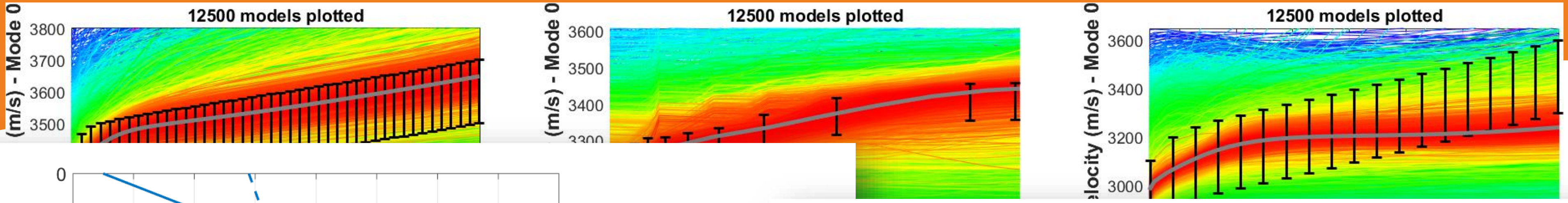


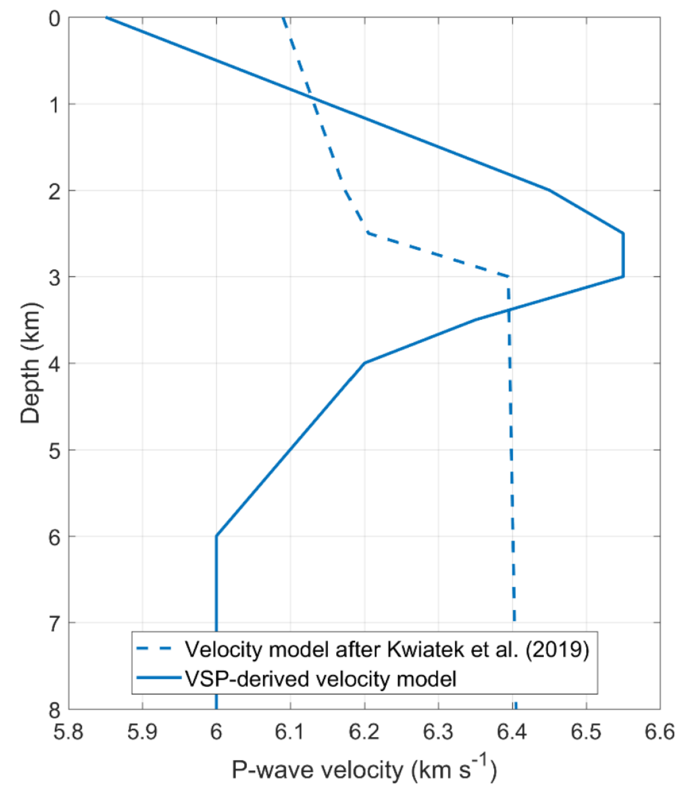
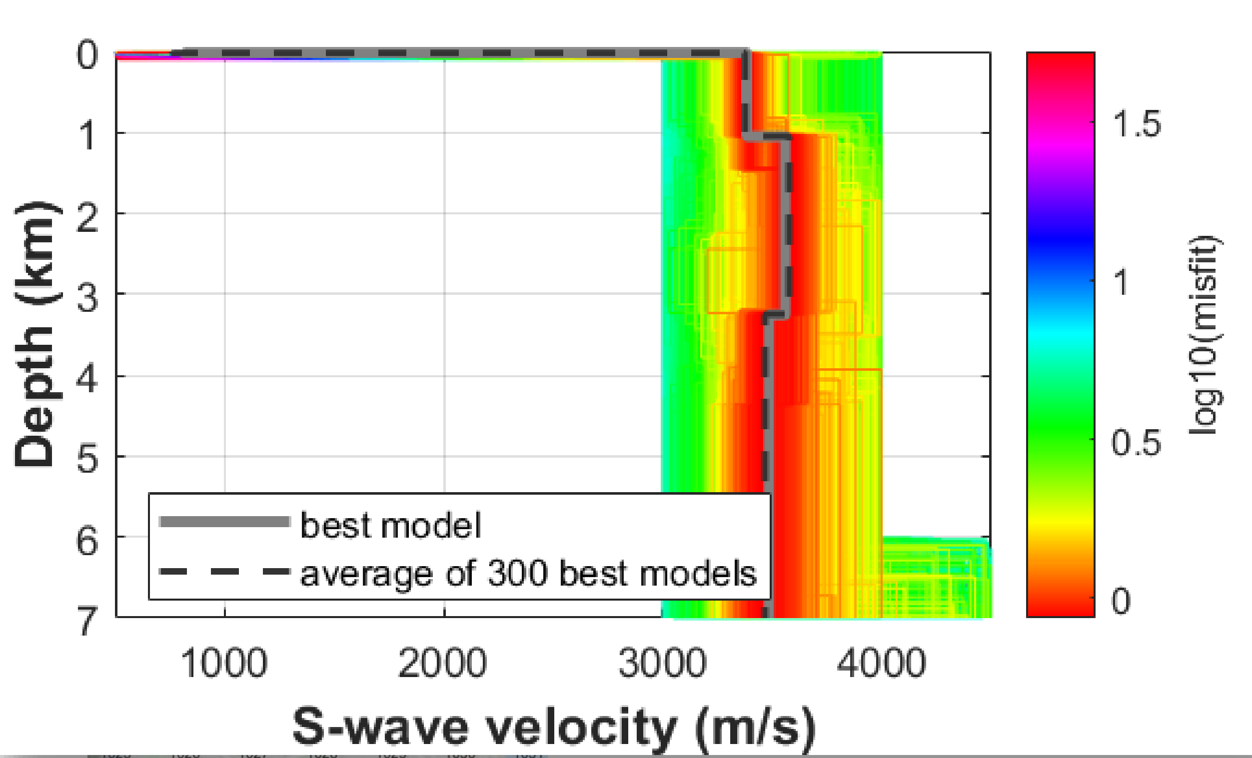
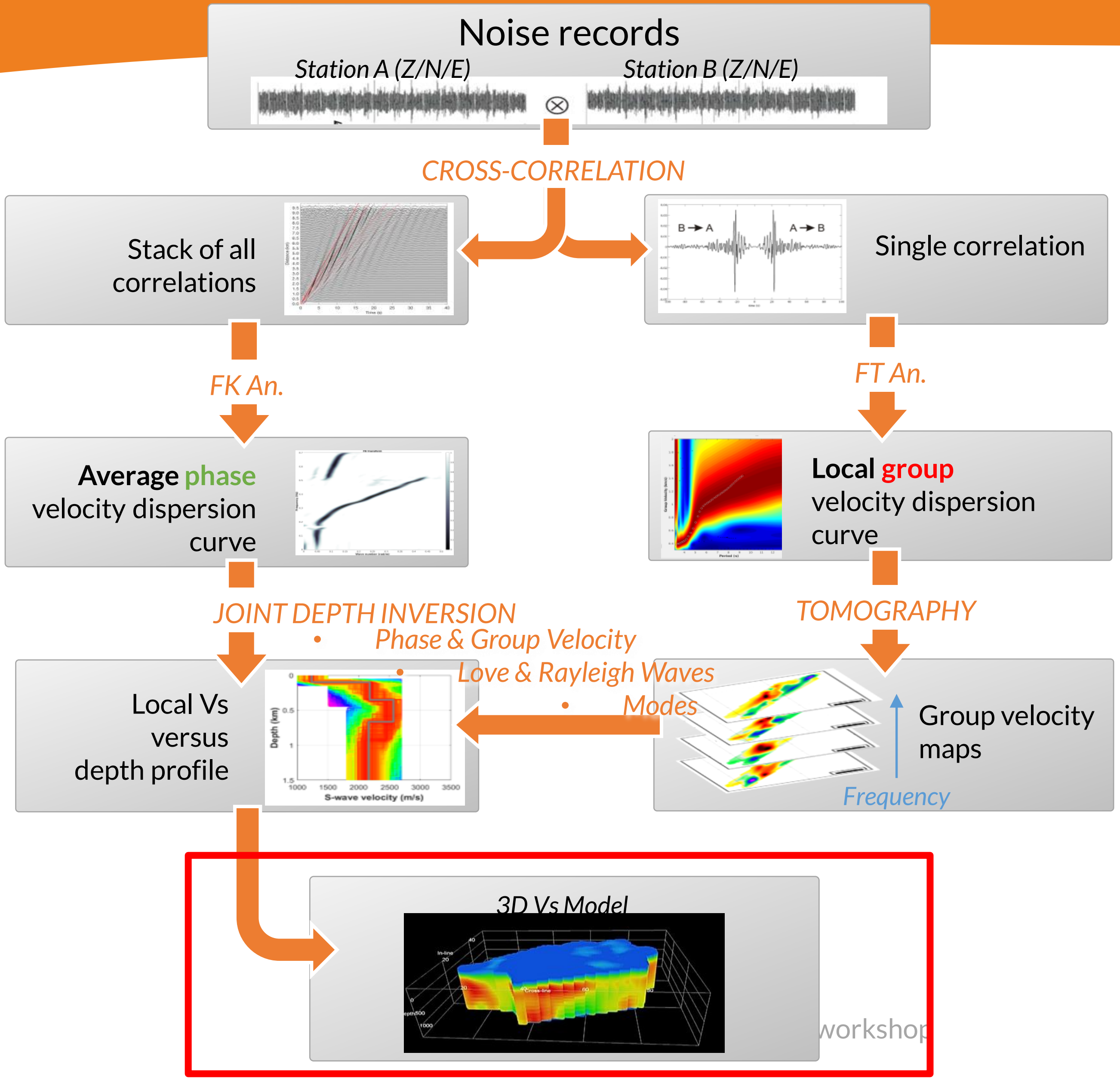


Figure 1. Comparison of the updated 1D layered velocity model derived from calibration shots of VSP campaign (solid line) with the 1D layered velocity model used in Kwiatek et al. (2019) (dashed line).

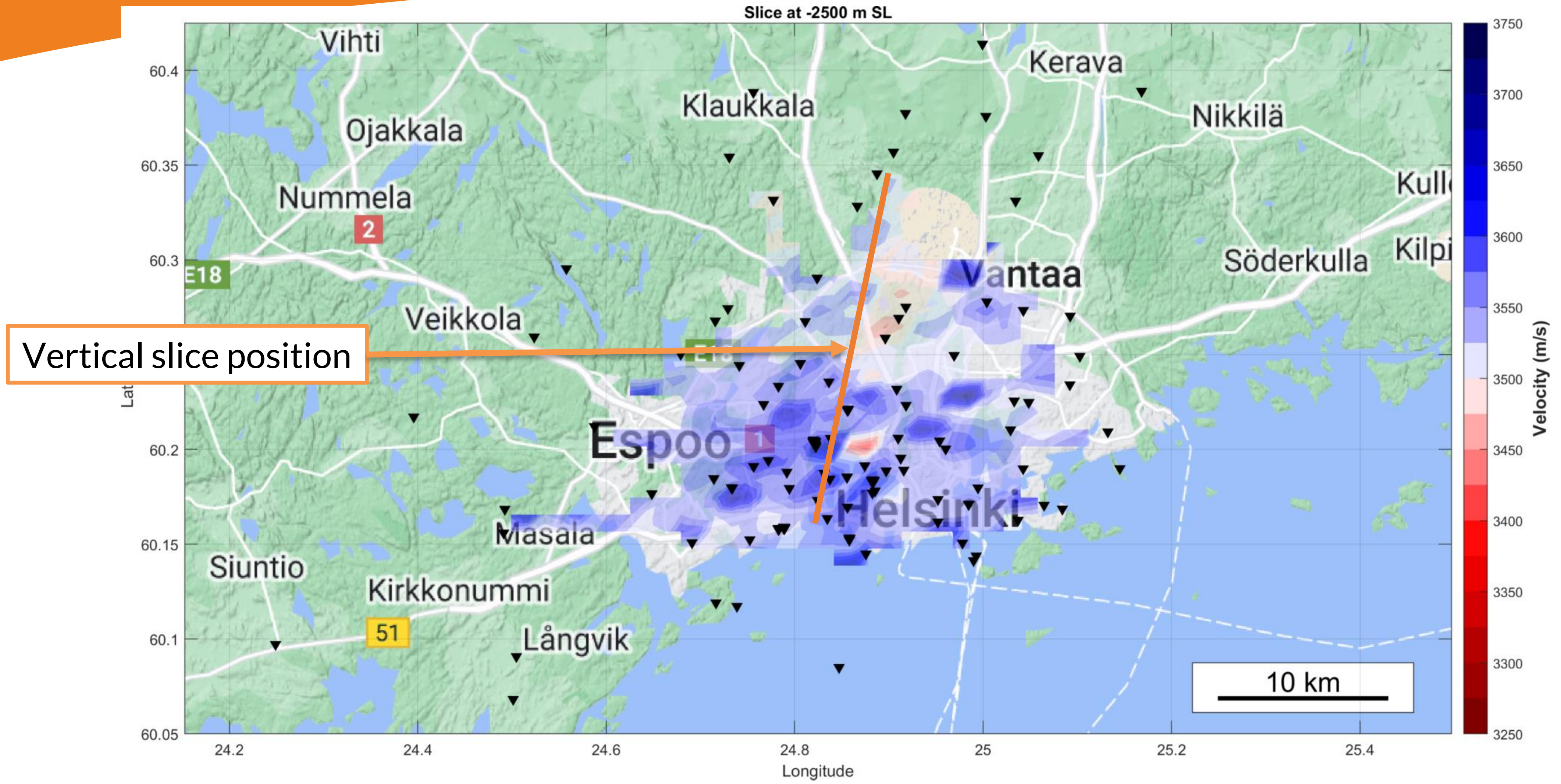


From Leonhardt & al., 2020

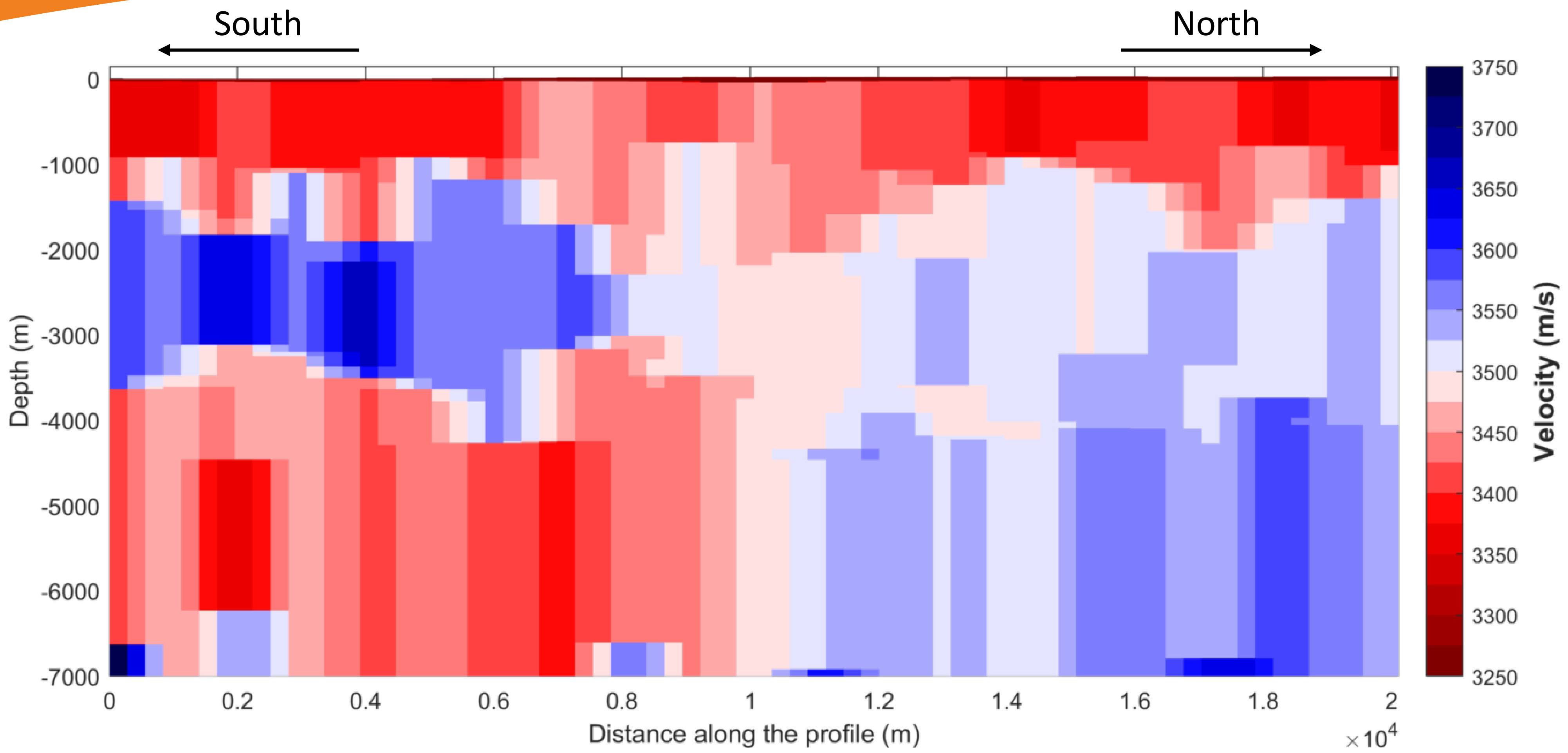
Ambient seismic noise to useful information about the subsurface:



Slice in the inverted 3D Vs model



Slice in the inverted 3D Vs model



Tomography model of the Helsinki capital region: Conclusion and future work

3D Vs model

Understand, compare and discover geological features

Predict ground motion in case of earthquake

Locate earthquakes