



MISS – Project

Minderung der Störwirkung von Windenergieanlagen auf seismologische Stationen

Gefördert durch:



EUROPÄISCHE UNION
Investition in unsere Zukunft
Europäischer Fonds
für regionale Entwicklung

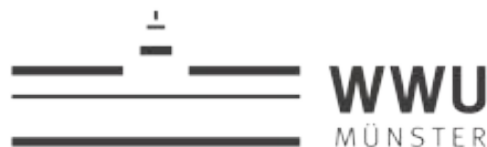
Teilprojekt WWU:

Mitigation of effects on the travel path – a theoretical approach

Rafael Abreu, Christine Thomas



BAUDYNAMIK
HEILAND & MISTLER GmbH

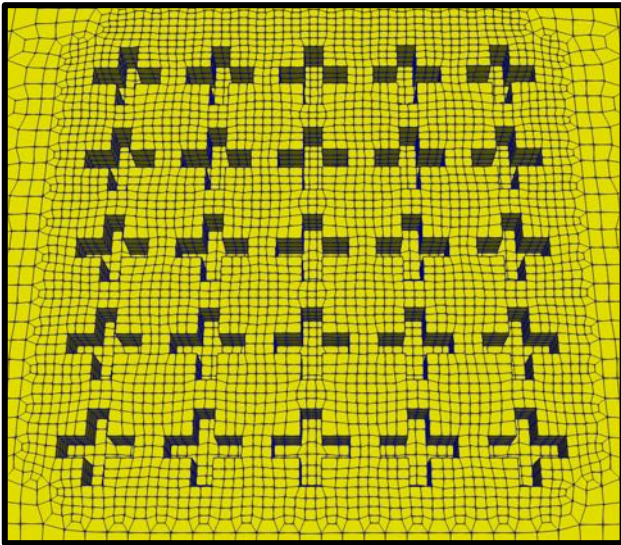


RUHR
UNIVERSITÄT
BOCHUM

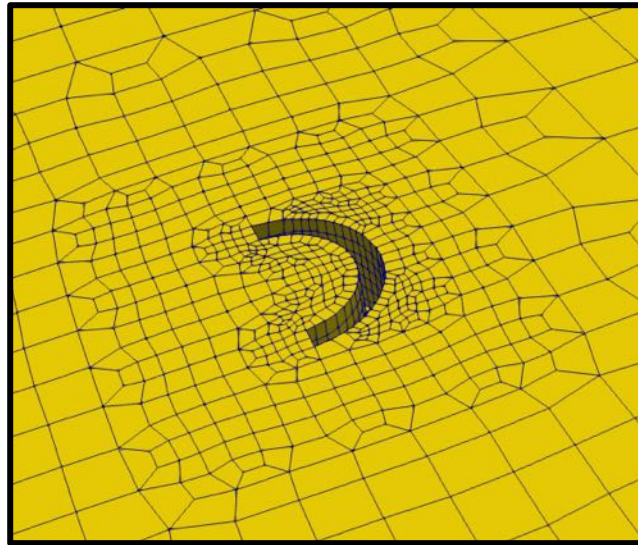


Mitigating wind-turbine noise

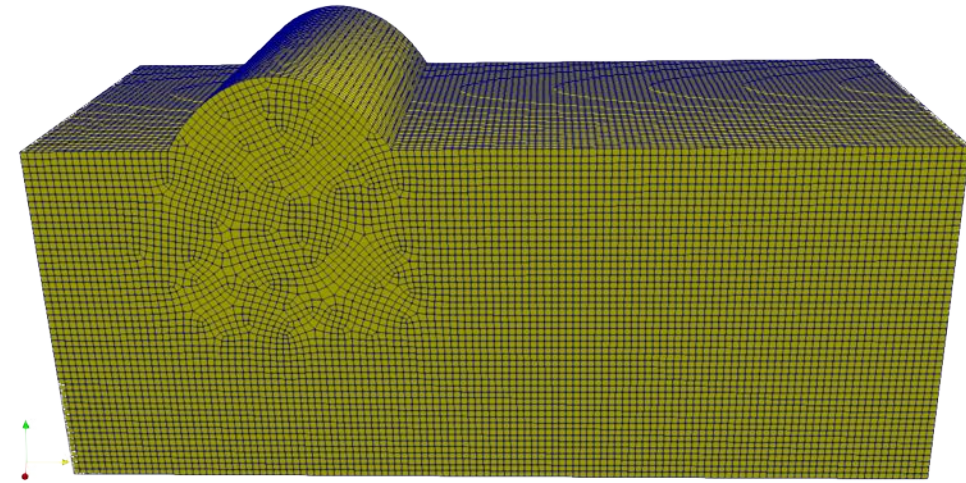
Cross shaped metamaterials



single trenches



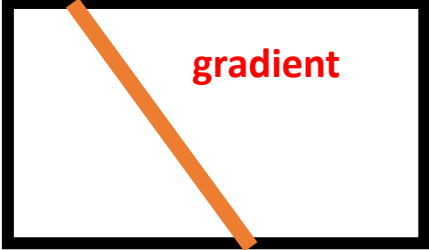
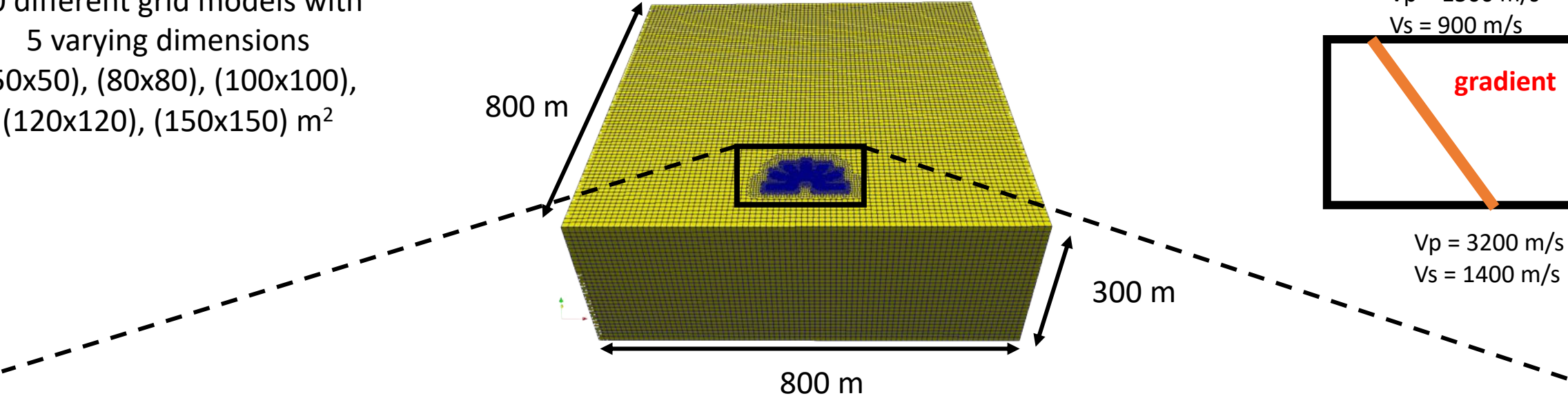
Topographic effects



Total cross-shaped meta models

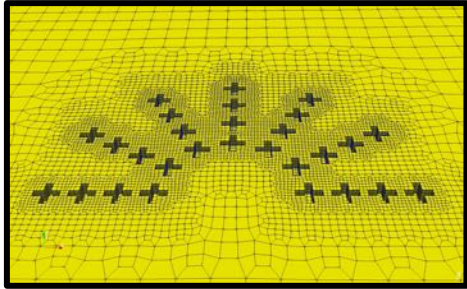
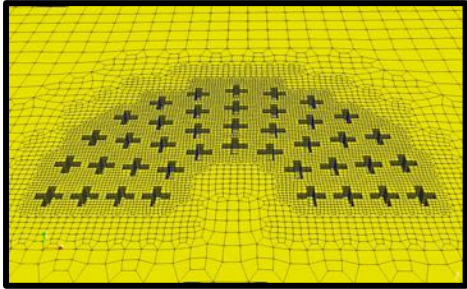
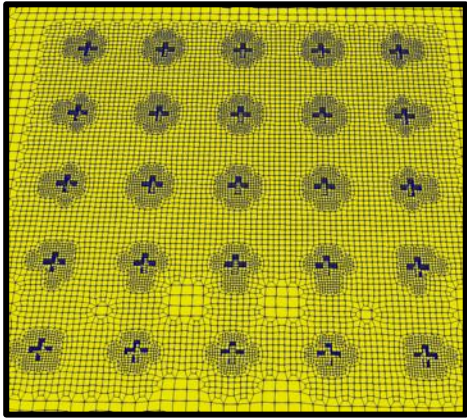
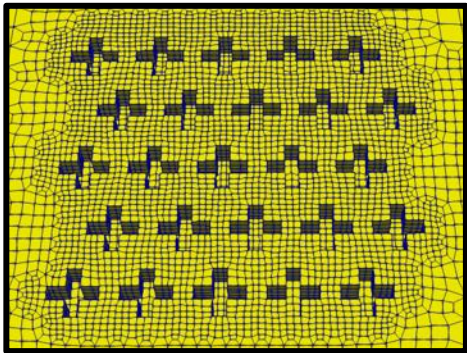
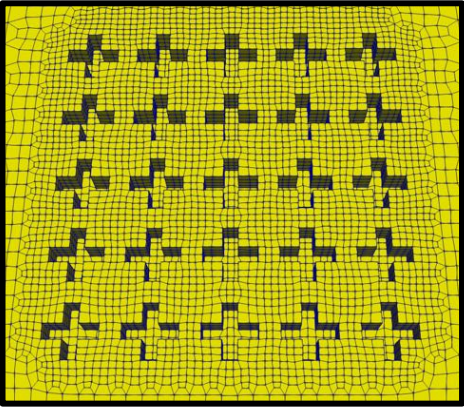
12 total models

10 different grid models with 5 varying dimensions (50x50), (80x80), (100x100), (120x120), (150x150) m²

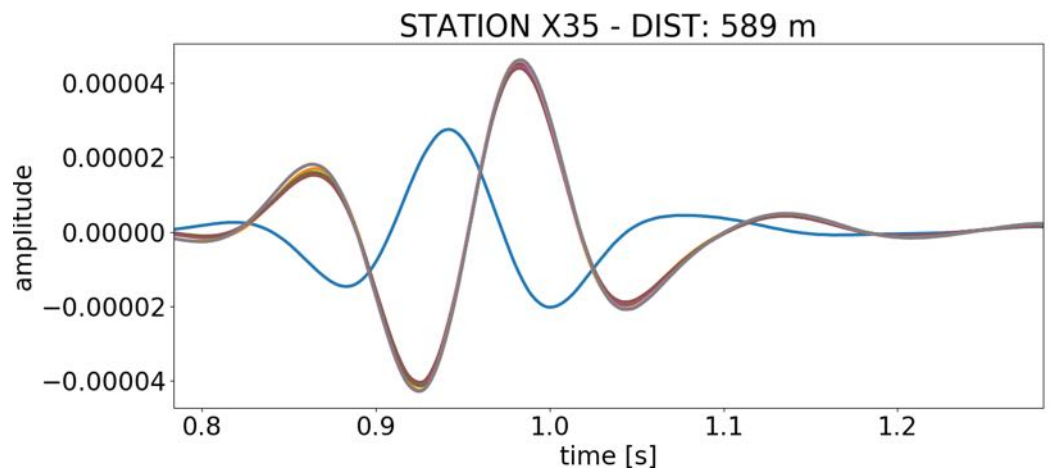
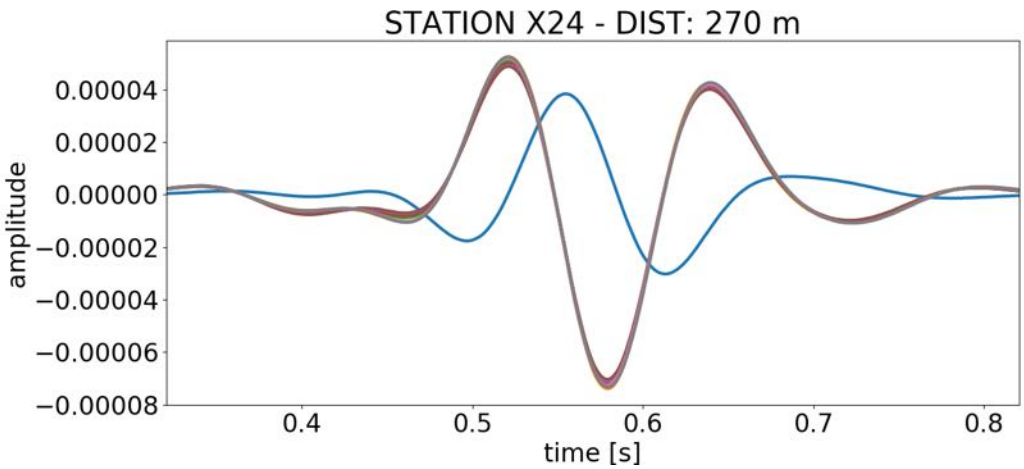


$V_p = 1500 \text{ m/s}$
 $V_s = 900 \text{ m/s}$

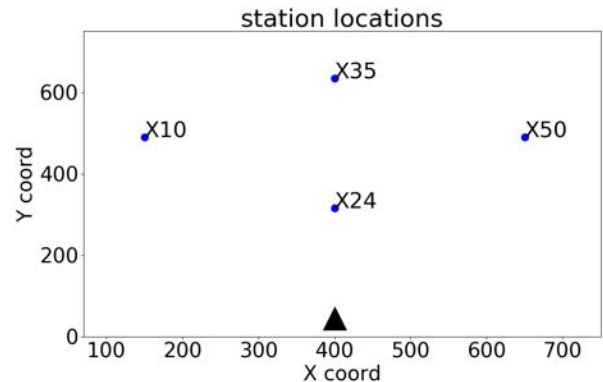
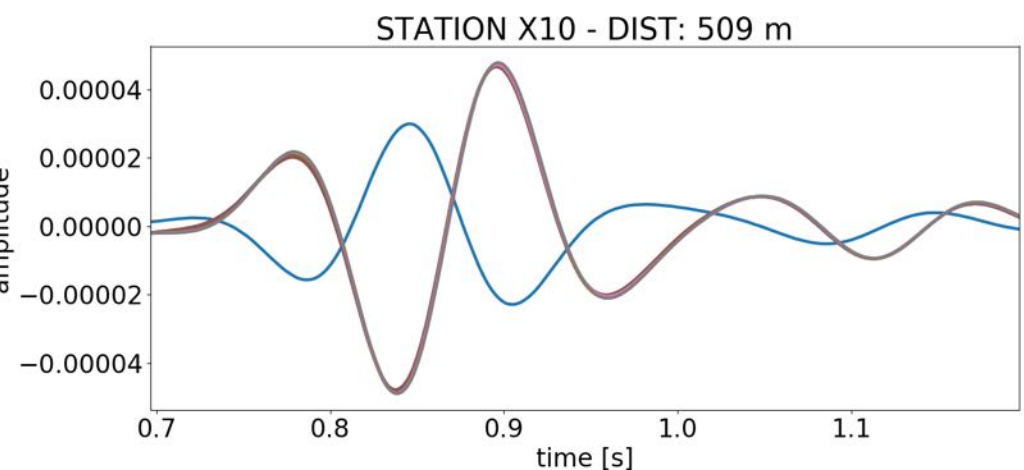
$V_p = 3200 \text{ m/s}$
 $V_s = 1400 \text{ m/s}$



Cross-shaped meta results (5 Hz)



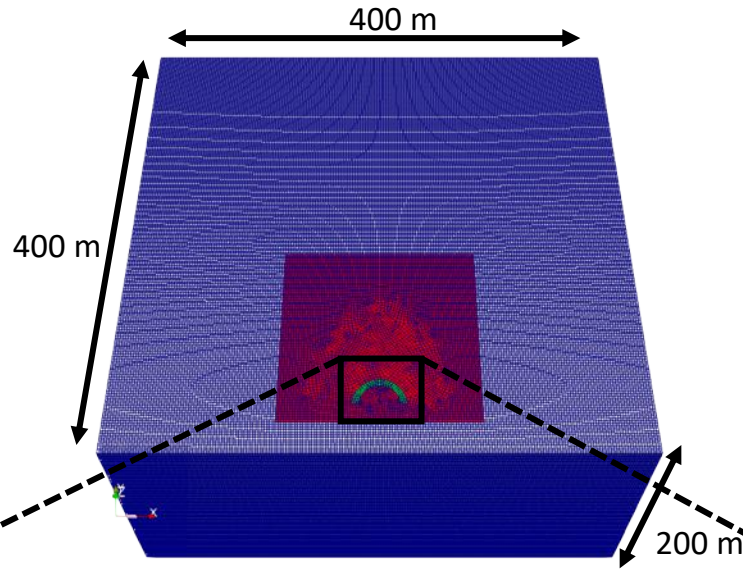
velocity – Z comp.



- no hole
- 50 m² - no shifted
- 80 m² - no shifted
- 100 m² - no shifted
- 120 m² - no shifted
- 150 m² - no shifted
- circular (a)
- circular (b)

No reduction of energy at 5 Hz

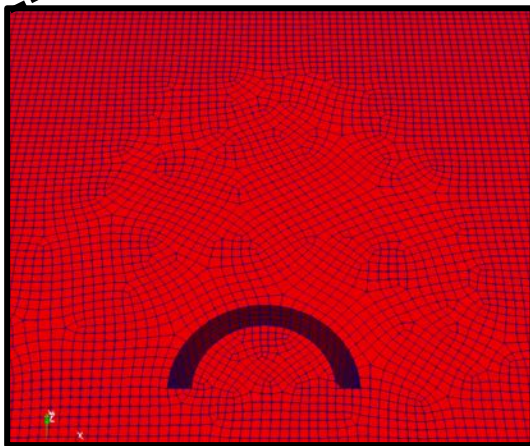
Trenches (empty and water filled)



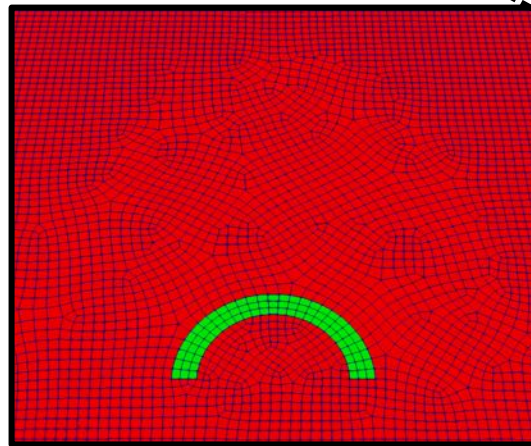
varying widths
5m and 3m
varying depths
20-15-10-5 m

Total of 16 different models

1) empty holes



2) filled with water

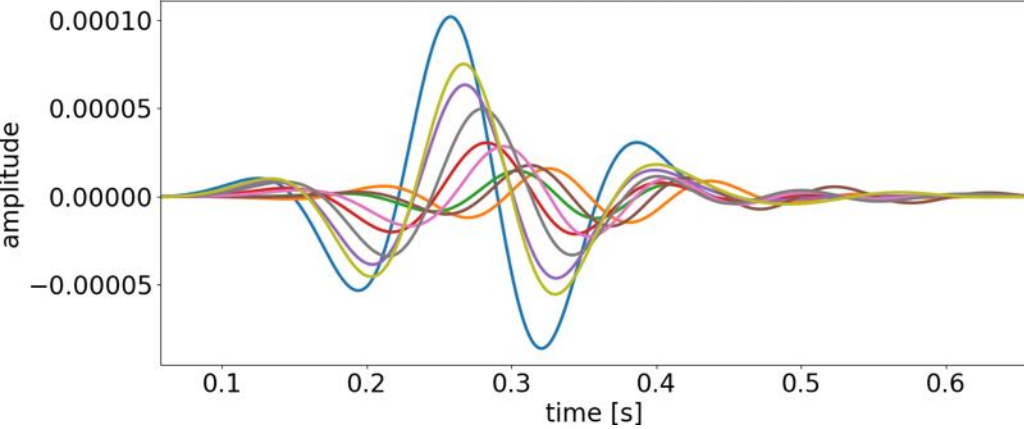


constant vel

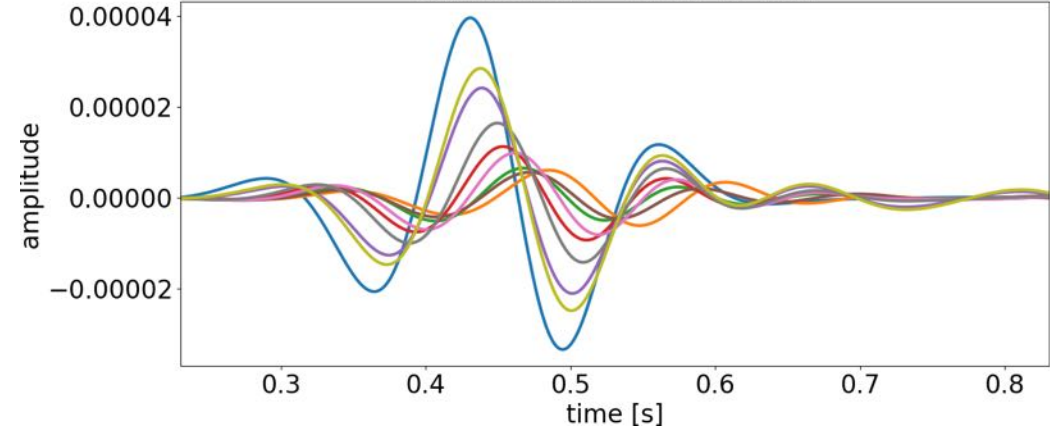
$V_p = 1500 \text{ m/s}$
 $V_s = 900 \text{ m/s}$

Results empty trenches (5 Hz)

STATION X16 - DIST: 28 m

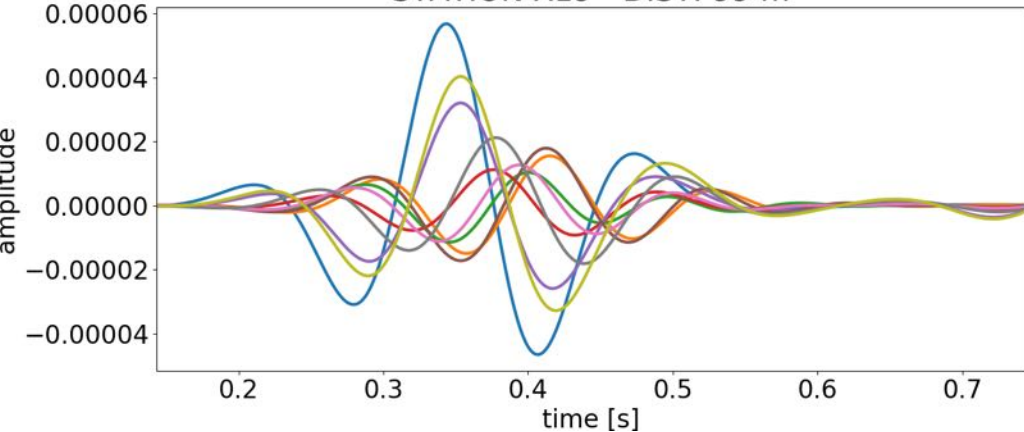


STATION X5 - DIST: 171 m

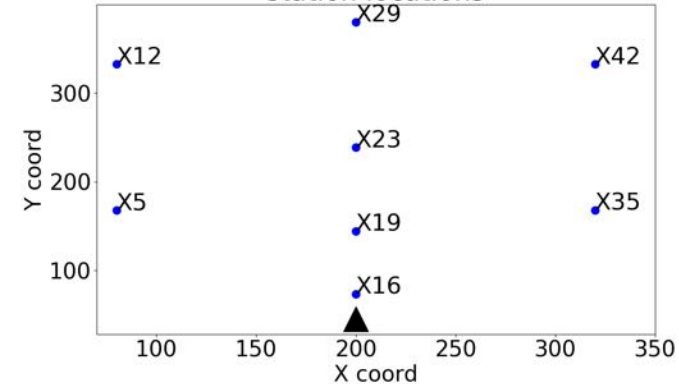


velocity – Z comp.

STATION X19 - DIST: 99 m



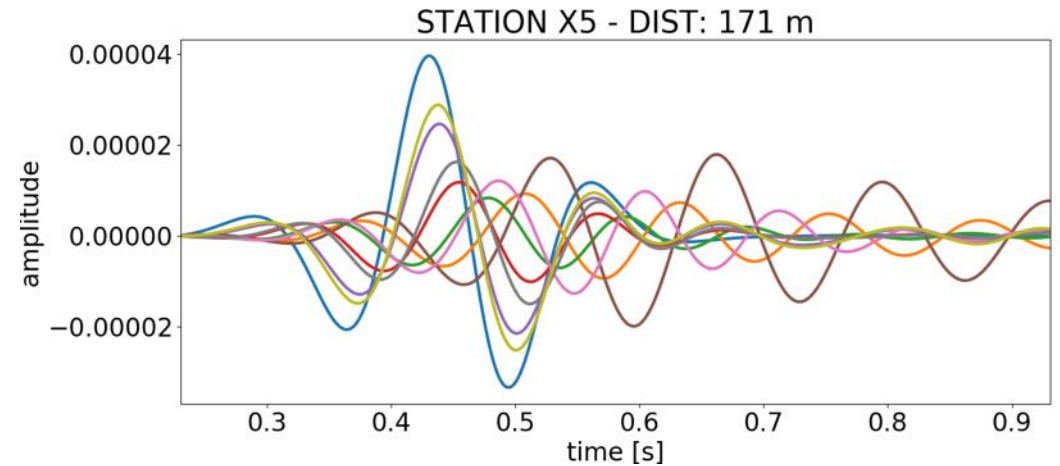
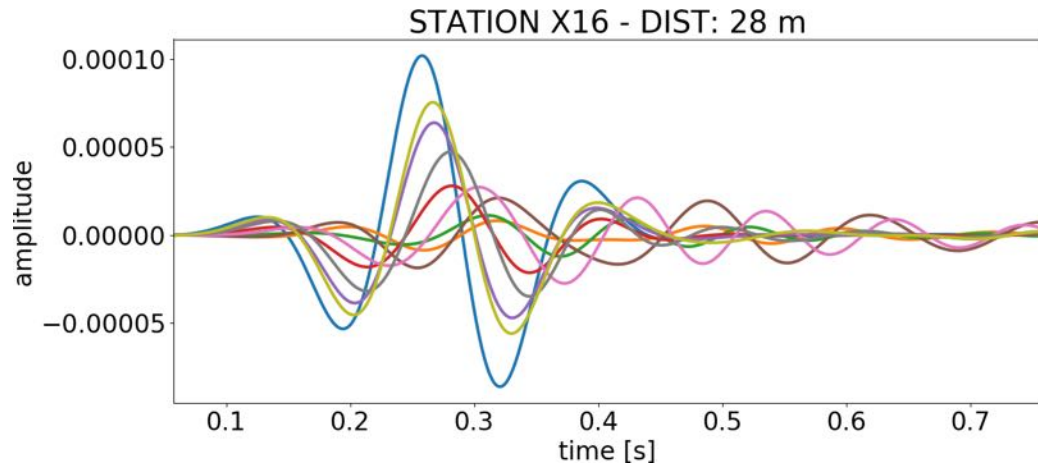
station locations



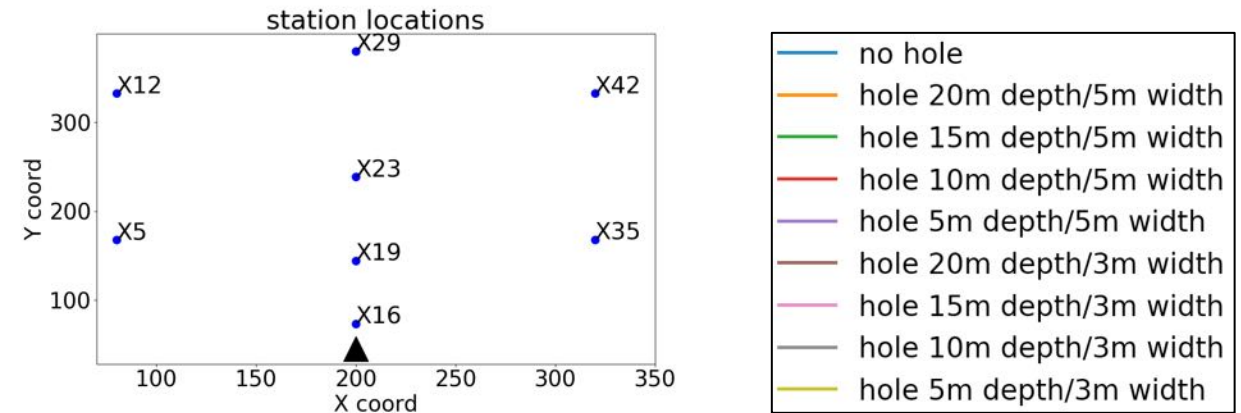
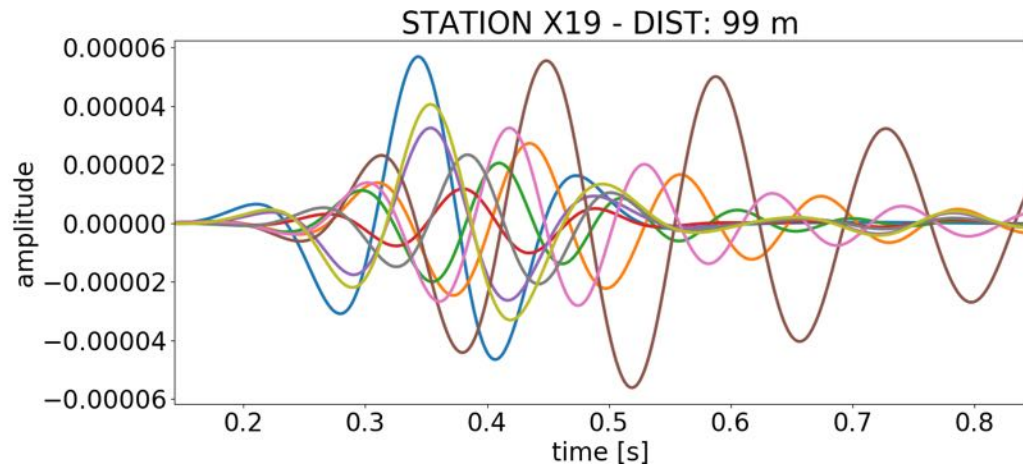
- no hole
- hole 20m depth/5m width
- hole 15m depth/5m width
- hole 10m depth/5m width
- hole 5m depth/5m width
- hole 20m depth/3m width
- hole 15m depth/3m width
- hole 10m depth/3m width
- hole 5m depth/3m width

All trenches mitigate the seismic energy

Results trenches filled with water (5 Hz)

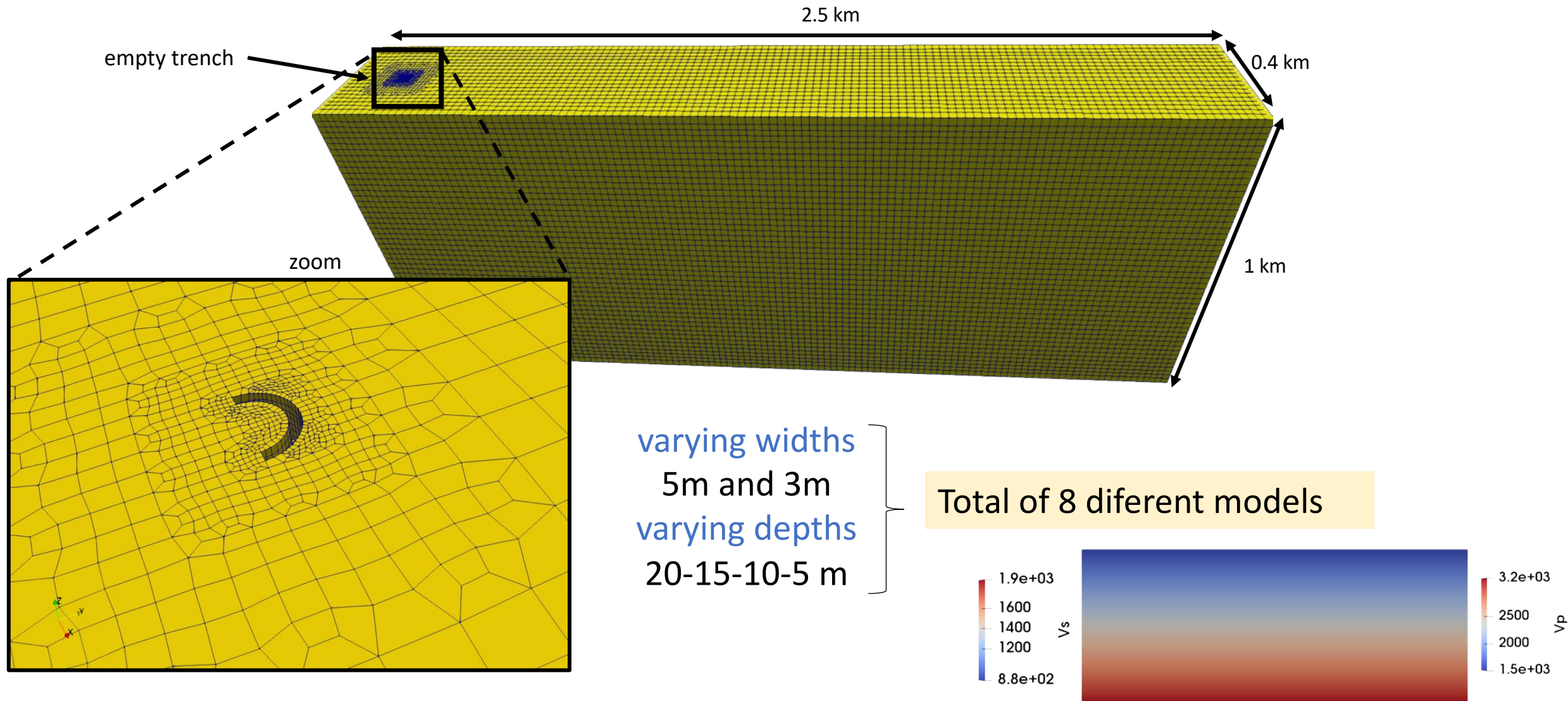


velocity – Z comp.

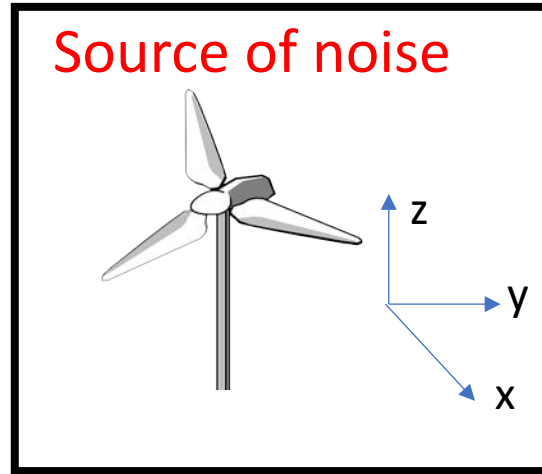
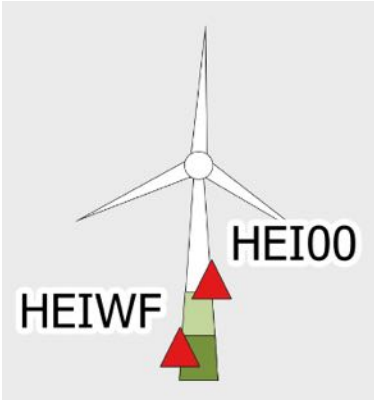


Effects of reberberations observed

Structural effects with realistic noise sources

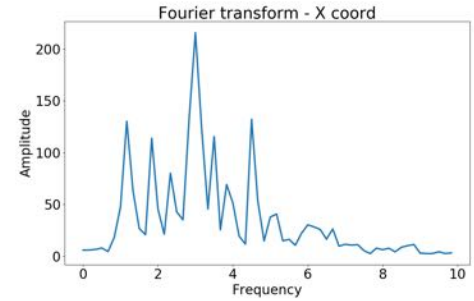


Noise sources from DMT

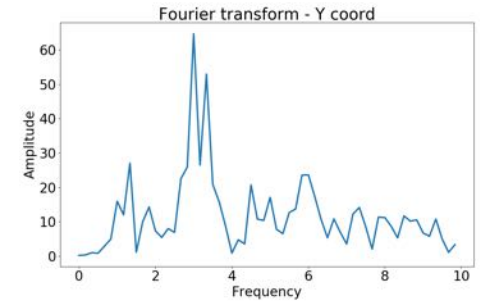


3 components measurements (X,Y,Z)

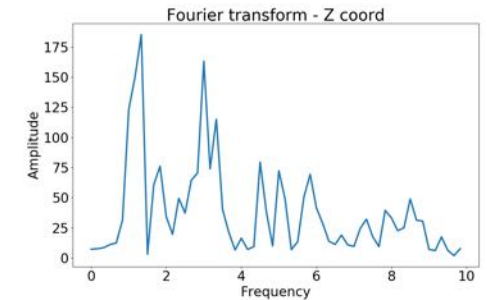
a) X component



b) Y component



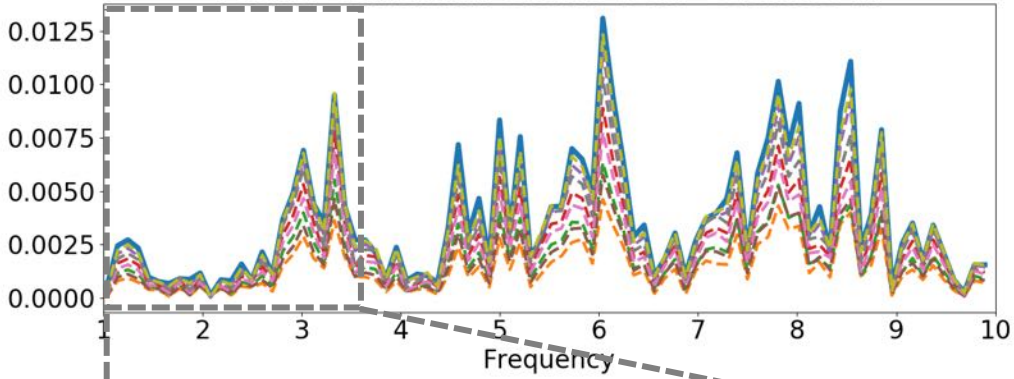
c) Z component



TOTAL of measurements: 3 (comp) x 1 (sta) = 3 source time functions

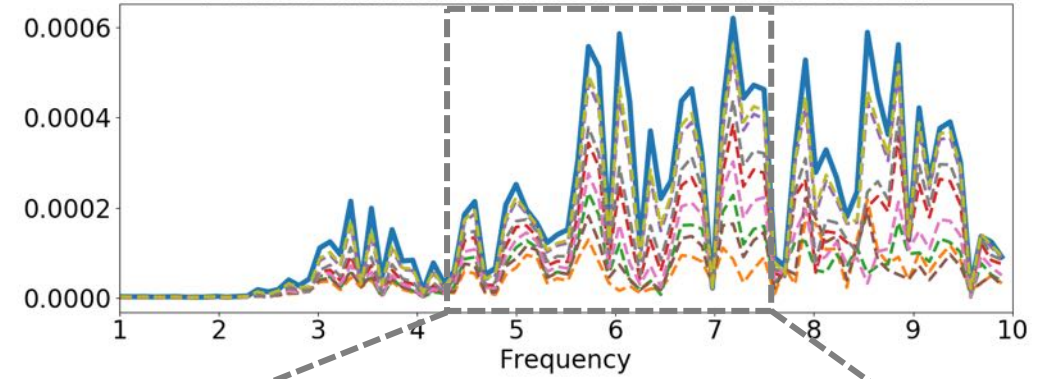
Results

Fourier transform: STATION X0 - DIST: 30 m

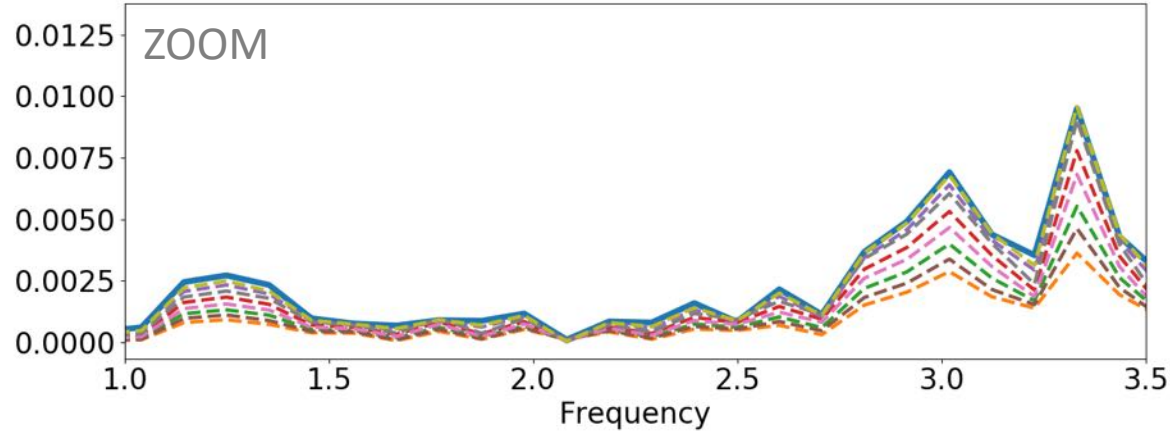


- no hole
- hole 20m depth/5m width
- hole 15m depth/5m width
- hole 10m depth/5m width
- hole 5m depth/5m width
- hole 20m depth/3m width
- hole 15m depth/3m width
- hole 10m depth/3m width
- hole 5m depth/3m width

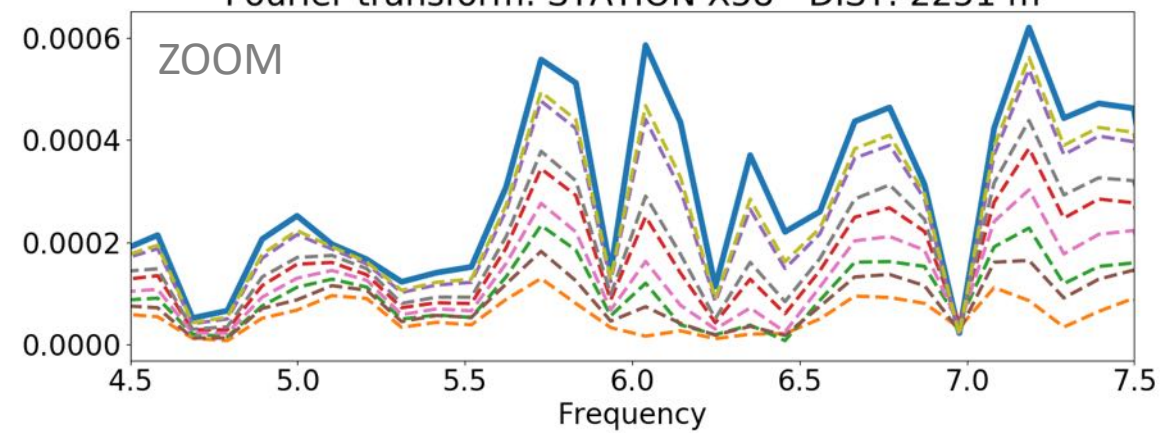
Fourier transform: STATION X58 - DIST: 2251 m



Fourier transform: STATION X0 - DIST: 30 m



Fourier transform: STATION X58 - DIST: 2251 m

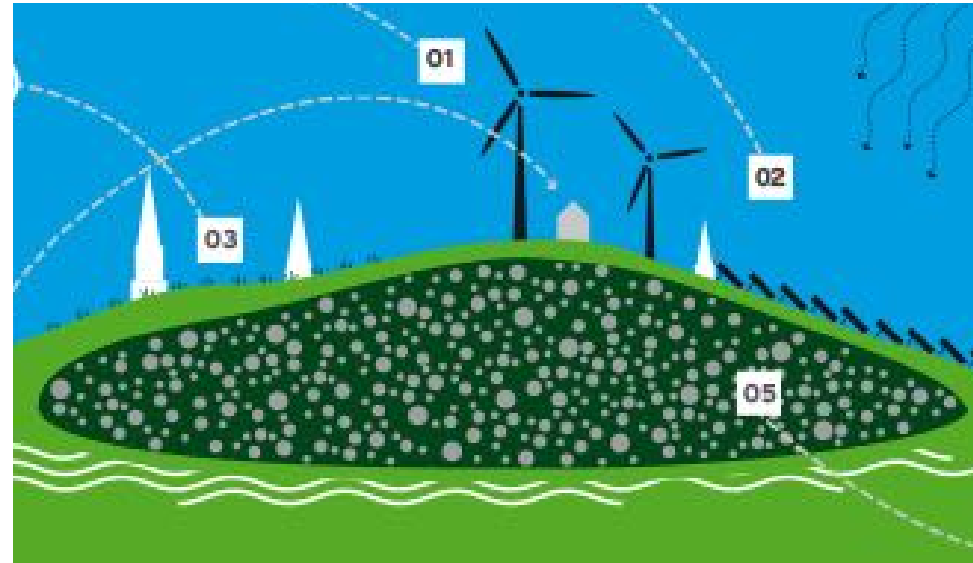


Die energieberg (mountain for energy production)



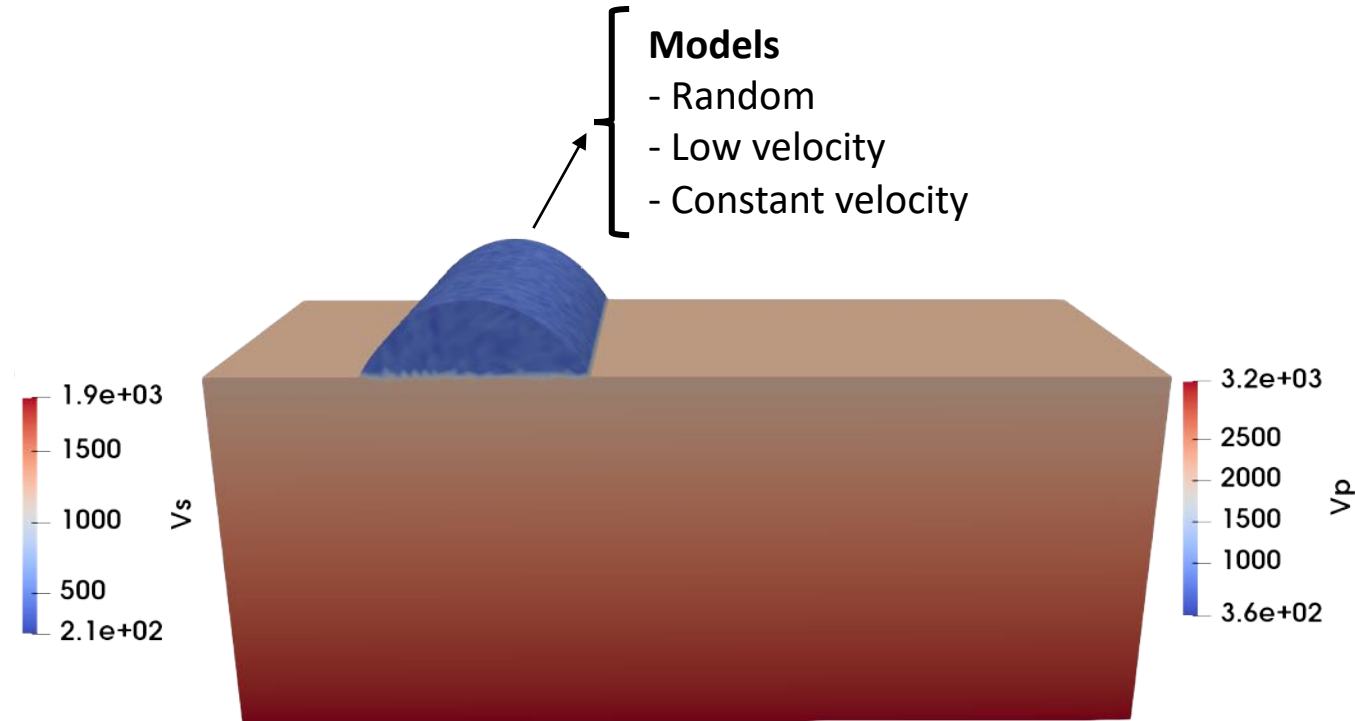
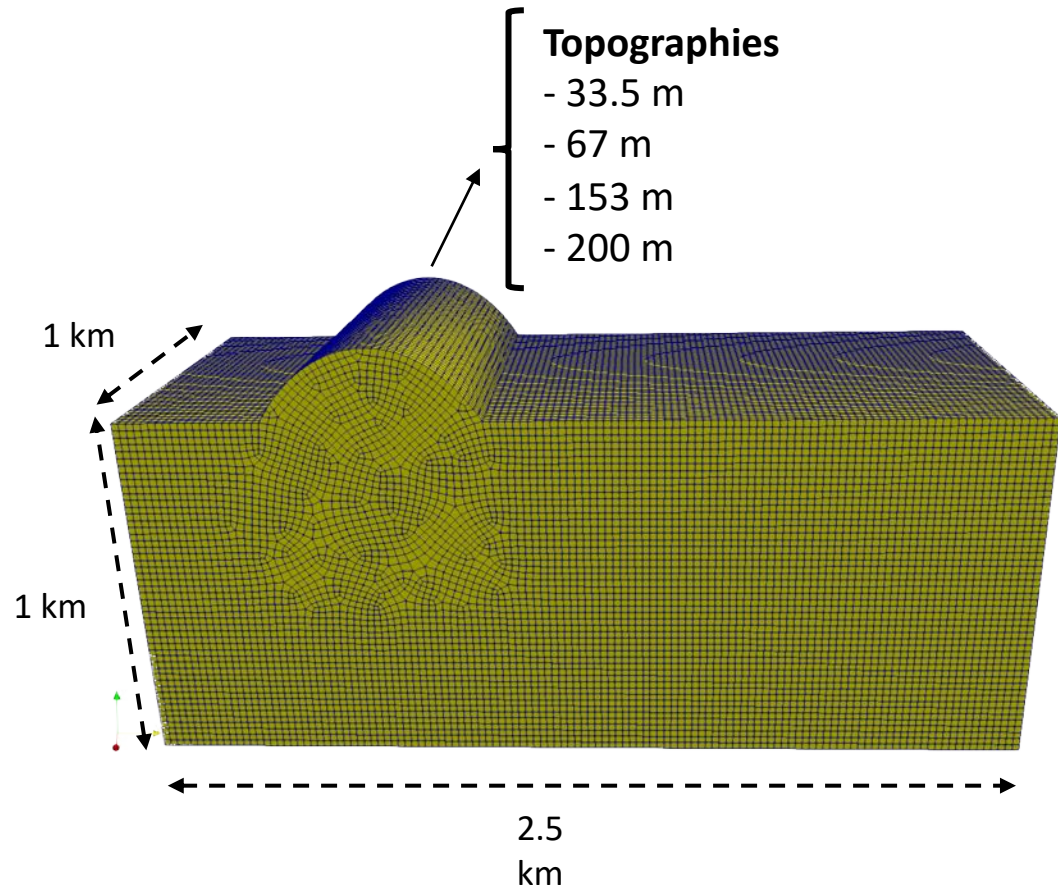
<https://www.geo.de/geolino/natur-und-umwelt/20896-bstr-diese-orte-hat-sich-die-natur-zurueckerobert/264332-img-heute-dasselbe-gruen>

- Located in Karlsruhe
- 60 m height of human waste disposals with three WTs and a photovoltaic system on top



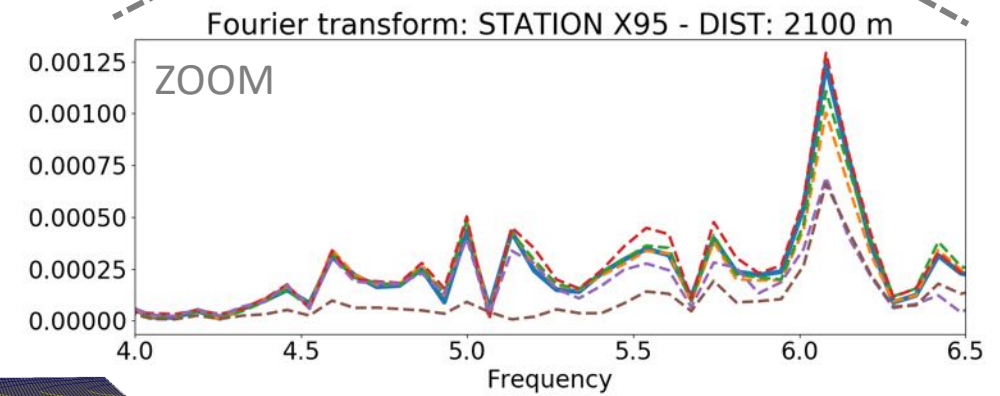
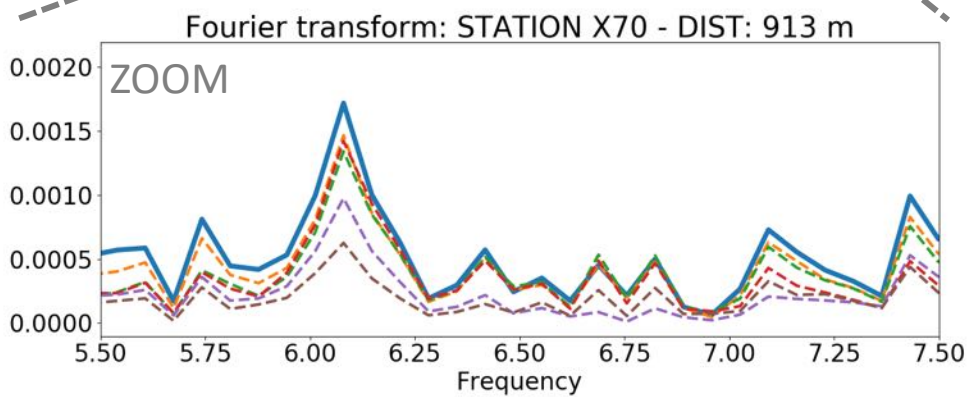
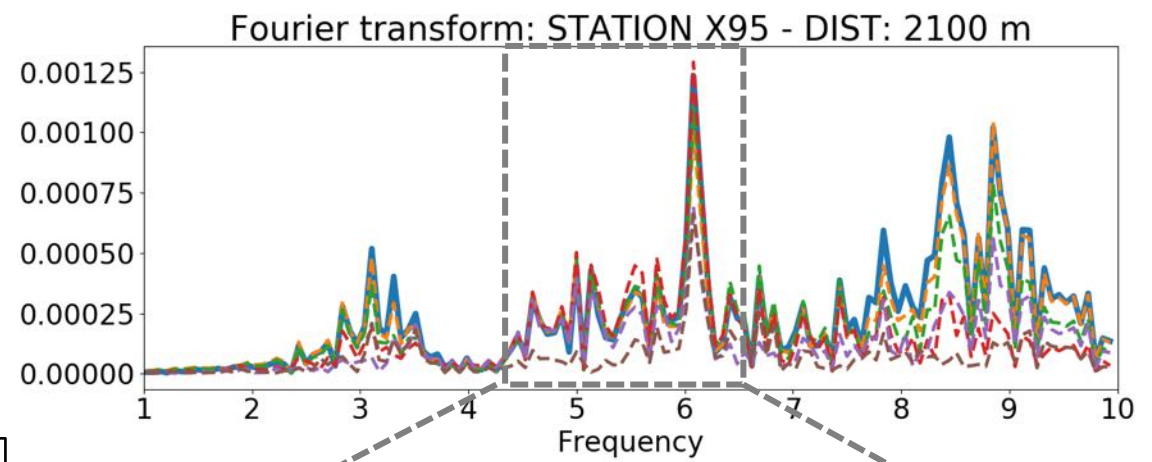
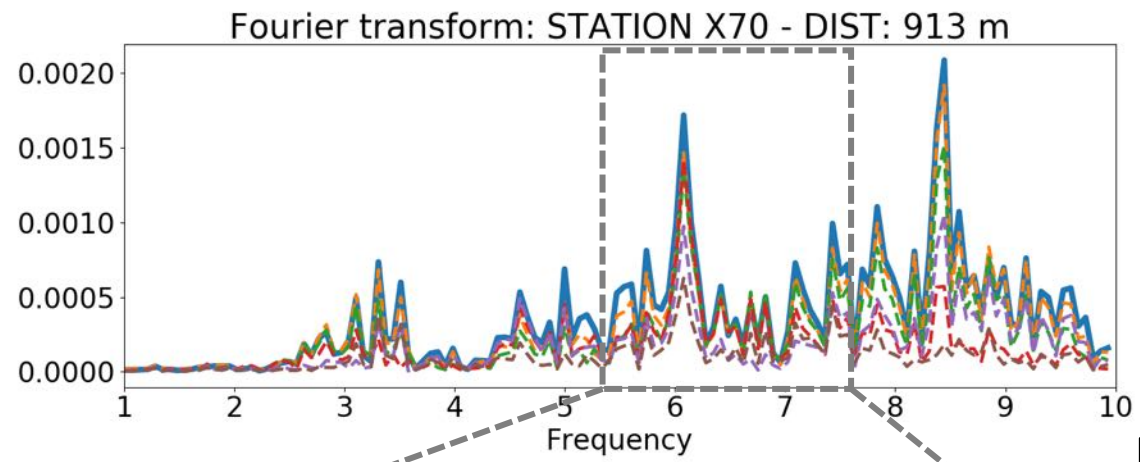
<https://www.internationale-bauausstellung-hamburg.de/en/projects/energieberg-georgswerder.html>

Topographic effects on waveforms

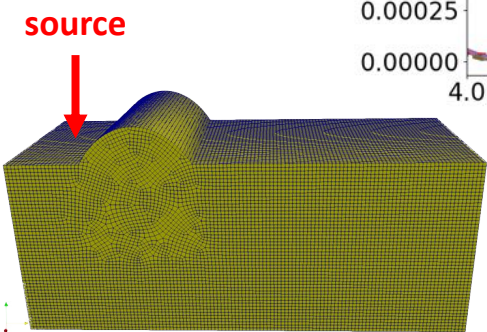


More than 20 models generated

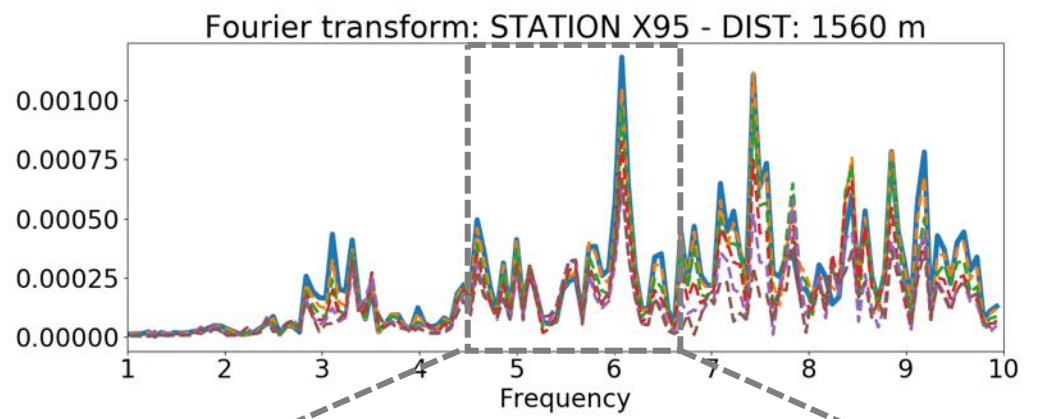
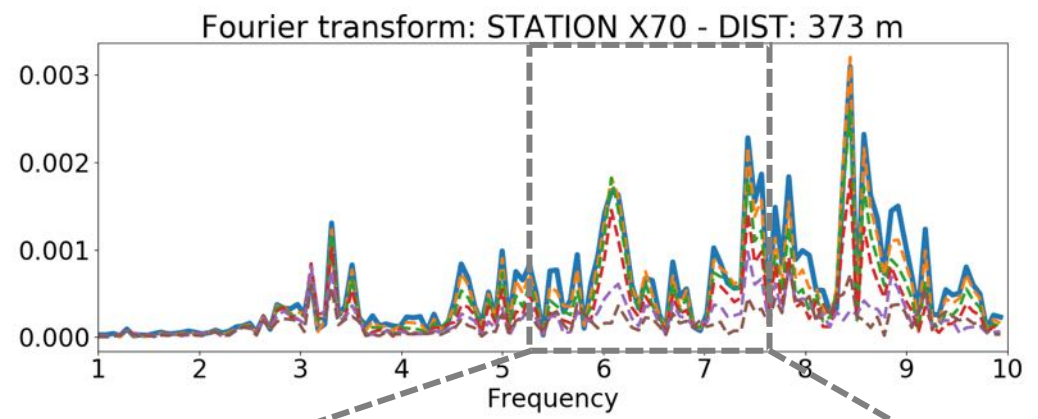
Results topography with constant velocity (same as surface)



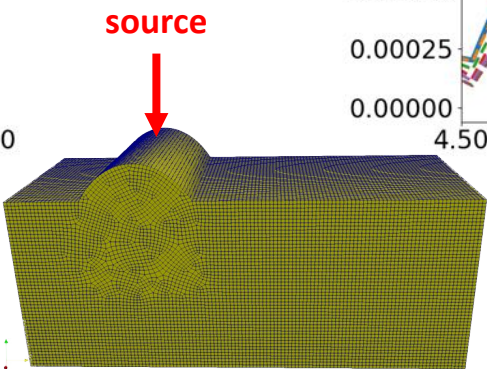
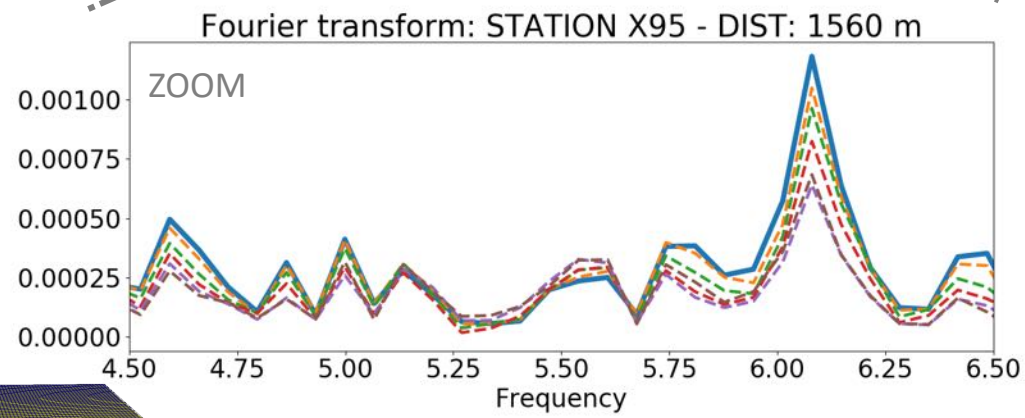
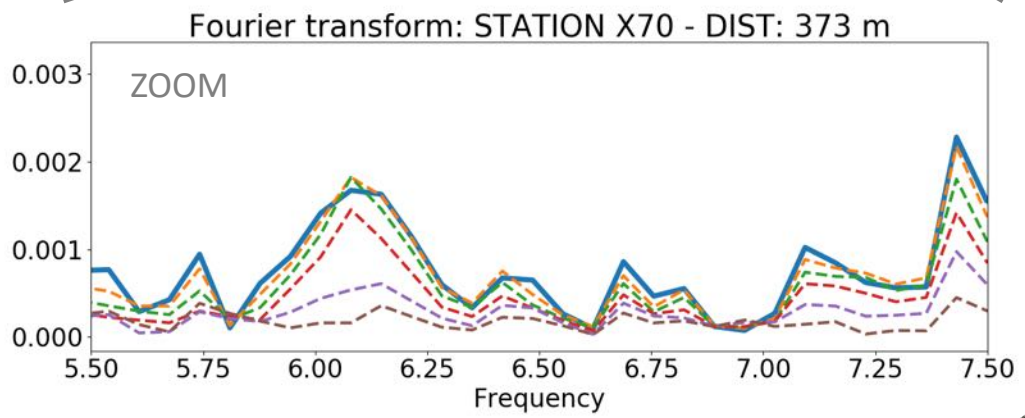
- flat
- - 33.5 m
- - 67 m
- - 100 m
- - 157 m
- - 200 m



Results topography with constant velocity (same as surface)

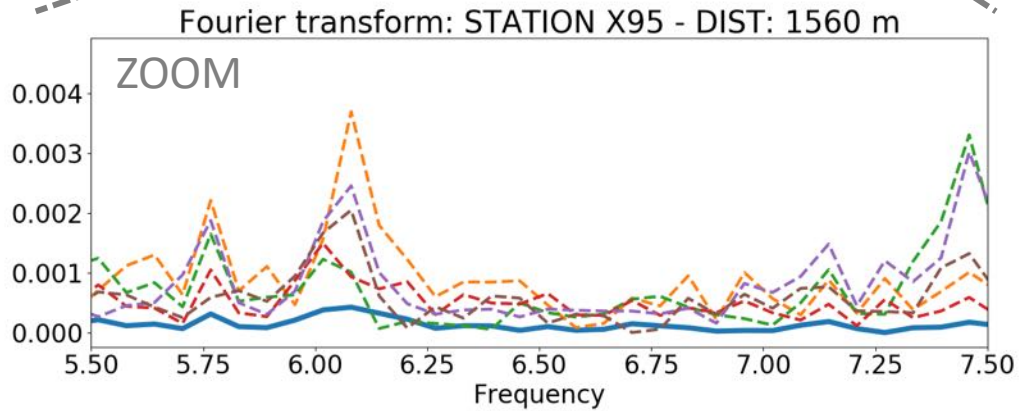
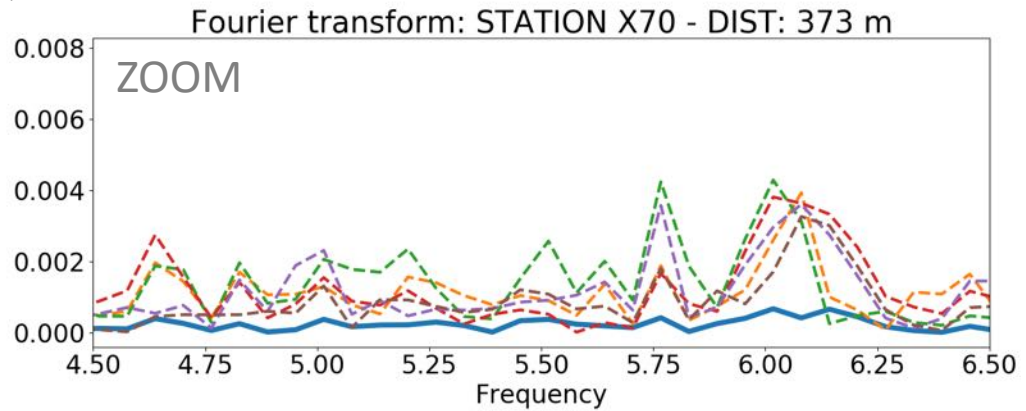
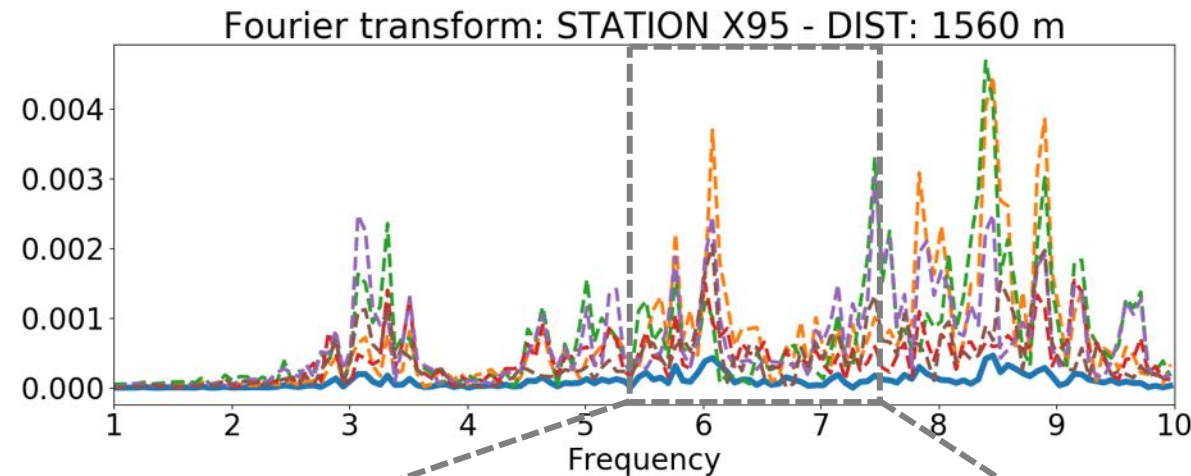
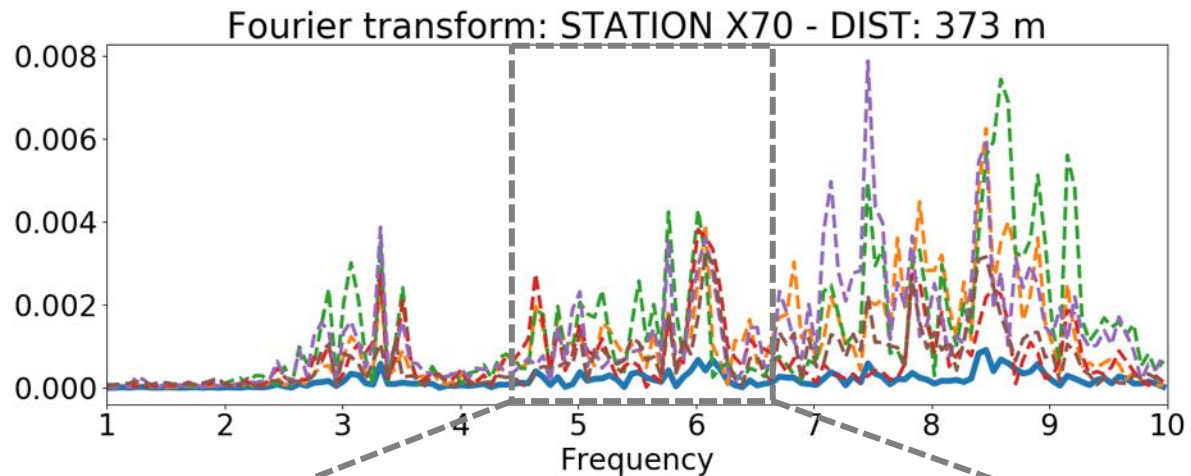


- flat
- - 33.5 m
- - 67 m
- - 100 m
- - 157 m
- - 200 m



No change in the spectrum.
Amplitude reduction only.

Results topography with low scattering velocity (700 RMS +/- 200 m/s and $\alpha=10$ m)

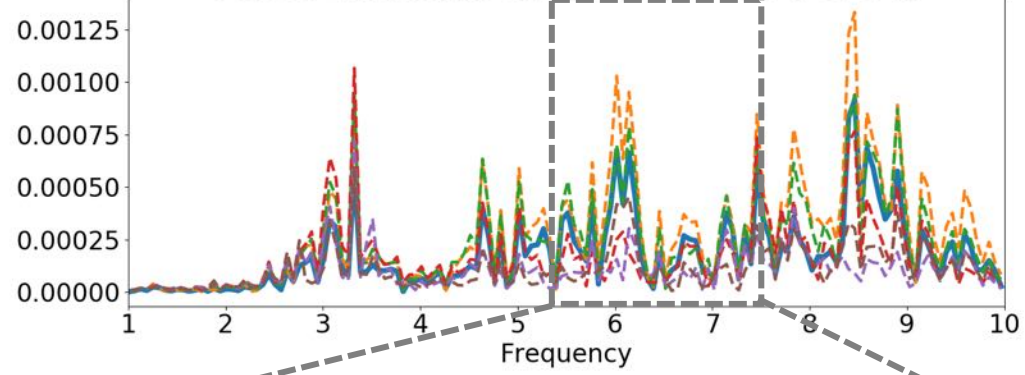


- flat
- - - 33.5 m
- - - 67 m
- - - 100 m
- - - 157 m
- - - 200 m

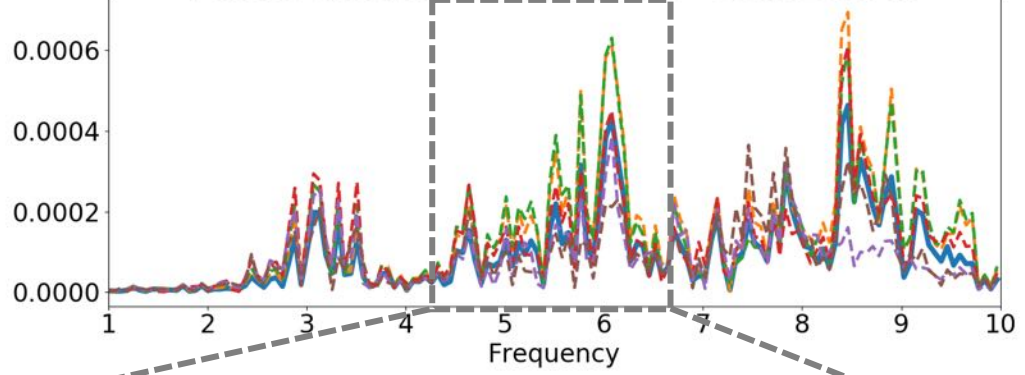
amplification possibly due to basin like effects?

Results topography with scattering velocity (0 RMS +/- 200 m/s and $\alpha=10$ m)

Fourier transform: STATION X70 - DIST: 373 m

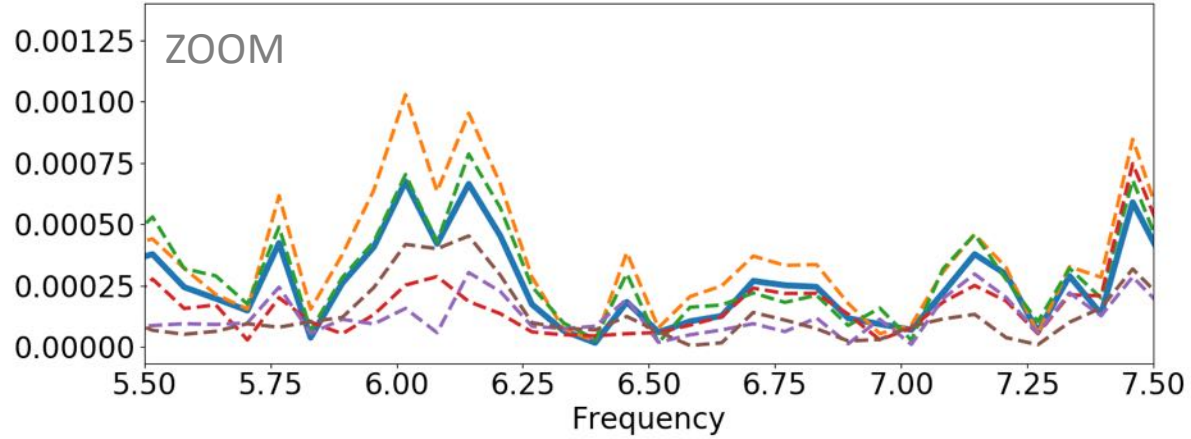


Fourier transform: STATION X95 - DIST: 1560 m

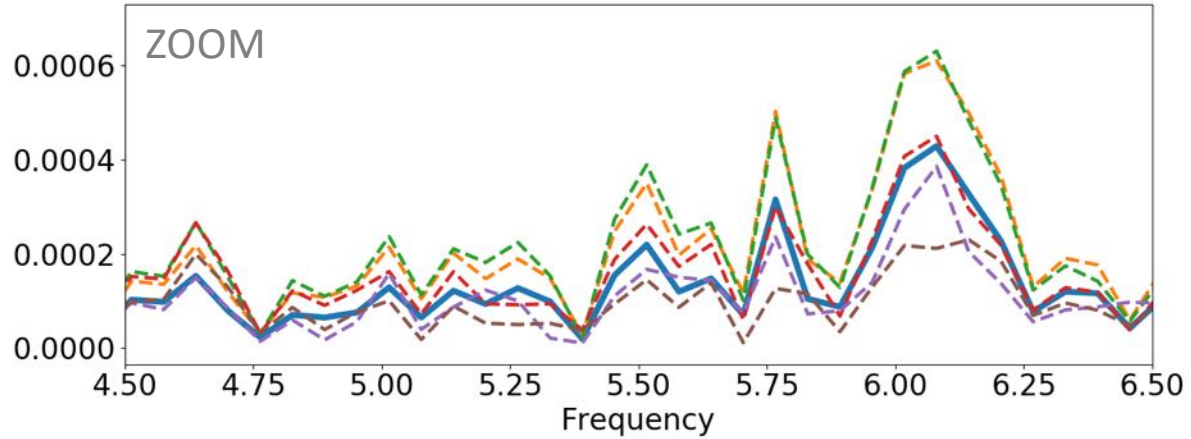


- flat
- - 33.5 m
- - 67 m
- - 100 m
- - 157 m
- - 200 m

Fourier transform: STATION X70 - DIST: 373 m

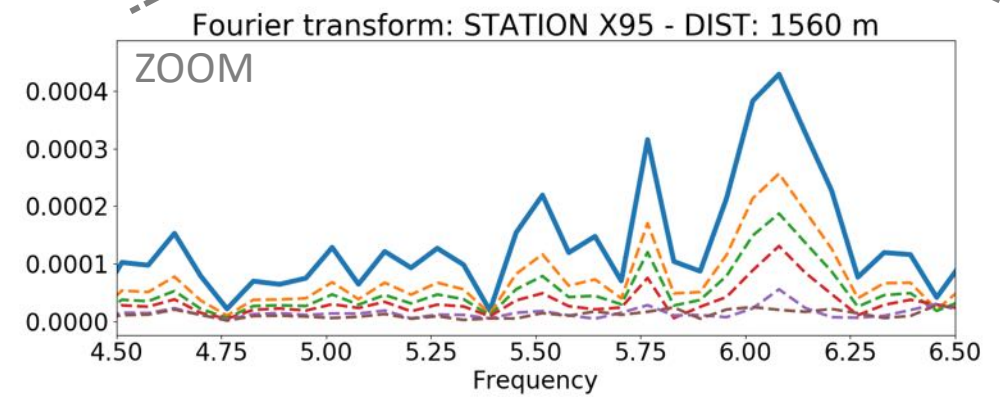
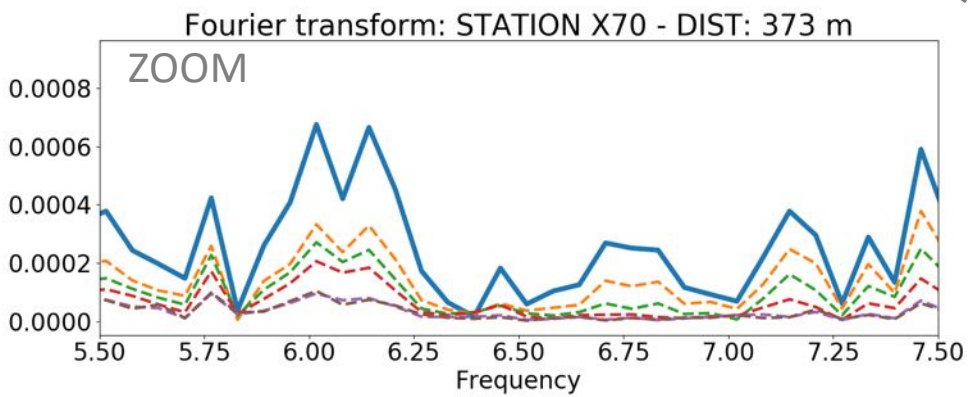
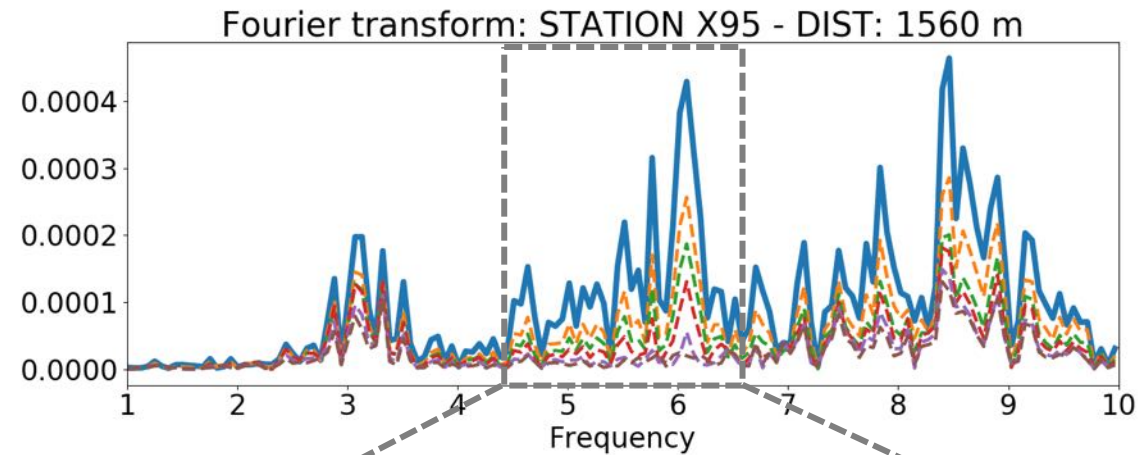
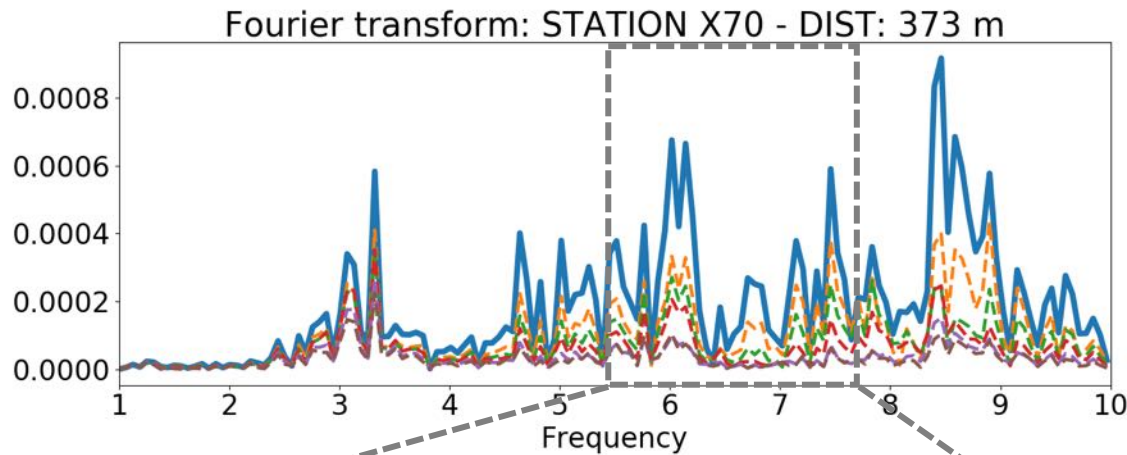


Fourier transform: STATION X95 - DIST: 1560 m



clear reduction of the seismic energy compared to the previous case

Results topography with high scattering velocity (2750 RMS +/- 250 m/s and $\alpha=10$ m)



- flat
- - 33.5 m
- - 67 m
- - 100 m
- - 157 m
- - 200 m

considerable reduction of the seismic energy compared to the previous cases

Concluding remarks

Model

- Cross shaped metamaterials
- Half circular holes filled with water
- Half circular empty holes
- Hills with low velocity (scattering)
- Hills with scattering
- Hills with high velocity (scattering)

Effect on the seismic energy

- Amplifies
- Amplifies
- Reduce the seismic energy (1-10 Hz)
- Considerable increase
- Increase/reduce
- Reduce the seismic energy (1-10 Hz)

Concluding remarks

- ✓ Filling the holes with volcanic material like pumice is beyond our numerical capabilities (poroelastic simulation with SpecFEM does not work).
- ✓ Another commercial packages like Salvus do not have this capability either.
- ✓ Including viscoelasticity in a single domain in one simulation is beyond actual numerical capabilities.



Outlook (activities last 3 months)

Finish and submit two papers:

- Reducing wind turbine noise recorded at seismological stations.
- Full 3D numerical modeling of wind turbine seismic noise (finish one simulation of WPs).