MISS – Project

Minderung der Störwirkung von Windenergieanlagen auf seismologische Stationen

Teilprojekt WWU:
Mitigation of effects on the travel path – a theoretical approach

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Investitionen in Wachstum und Beschäftigung

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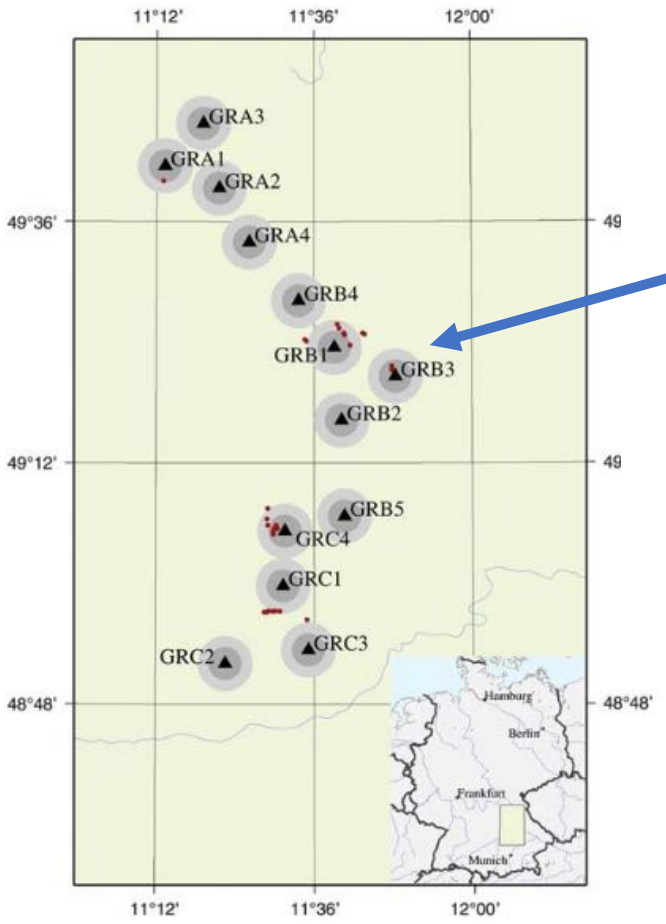
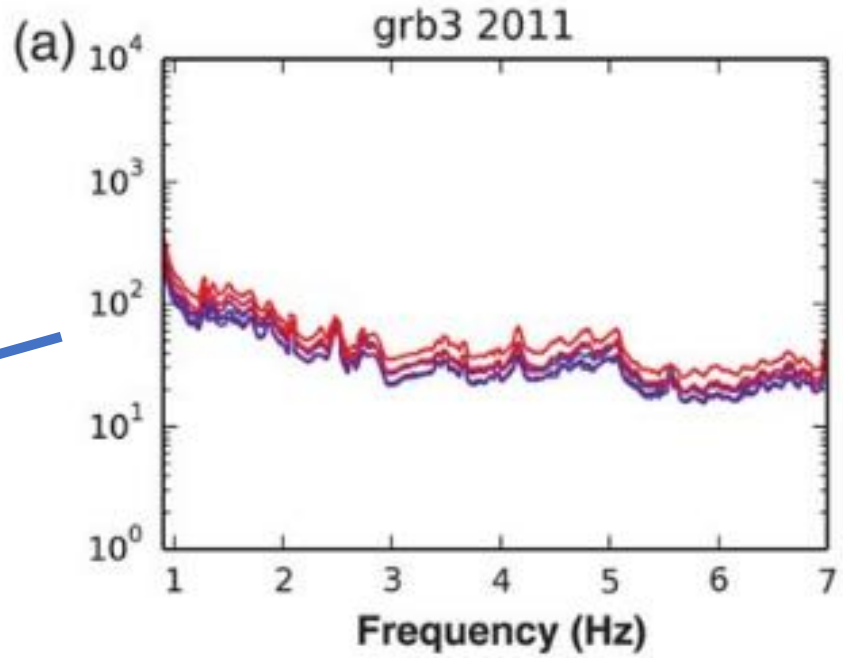
Windturbine noise in Germany

Gräfenberg
seismic array

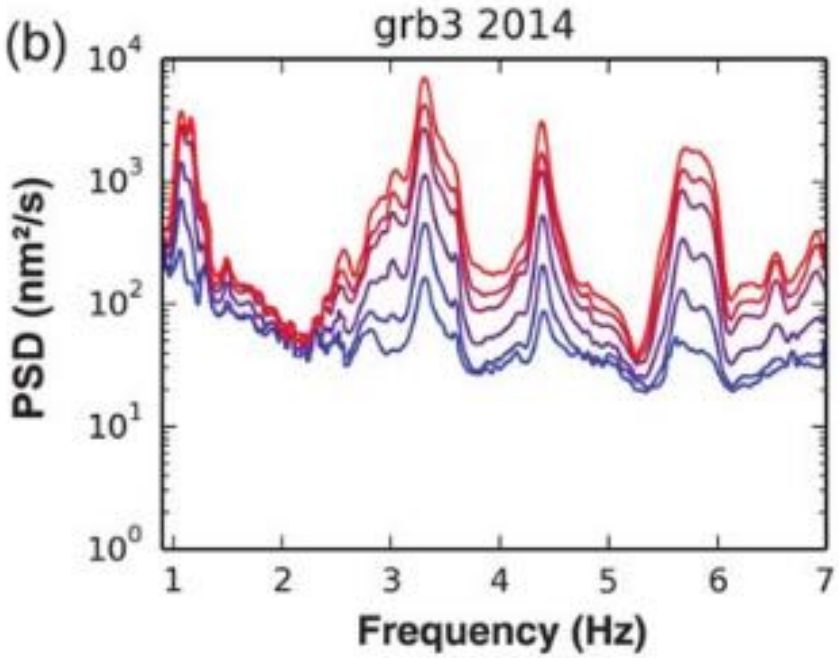


Stammler and Ceranna 2016

Before installation of WT



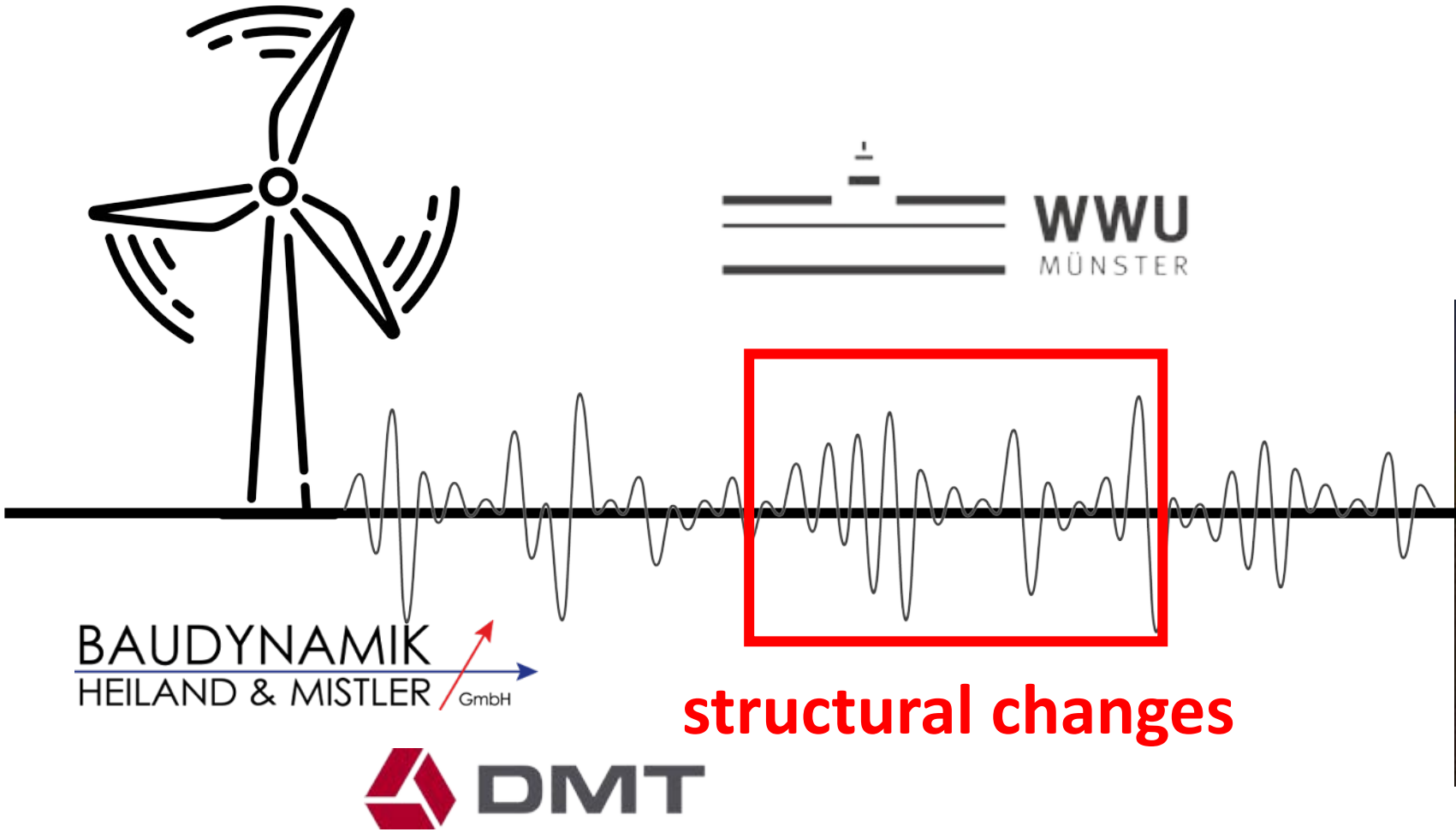
After installation of WT



Colors of the lines for different wind speeds.

Seismometers show strong noise dependence on wind strength

MISS: Mitigation of induced seismic signals



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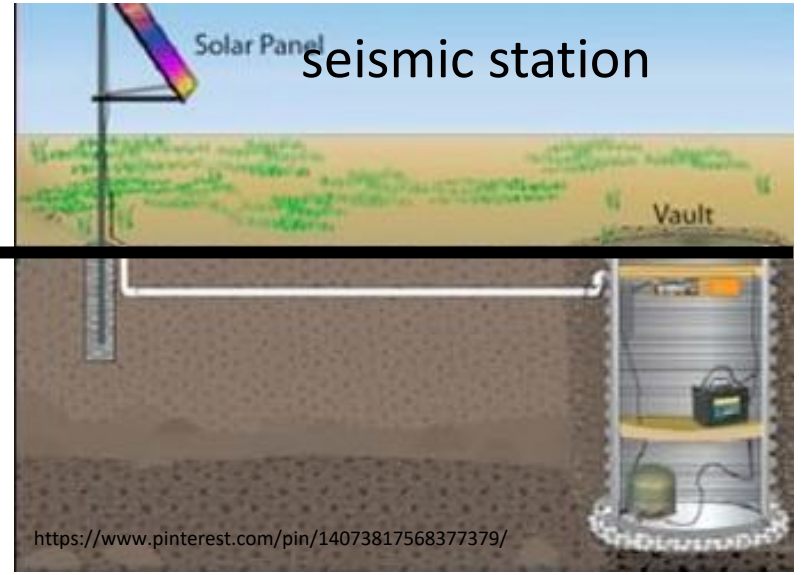
DMT

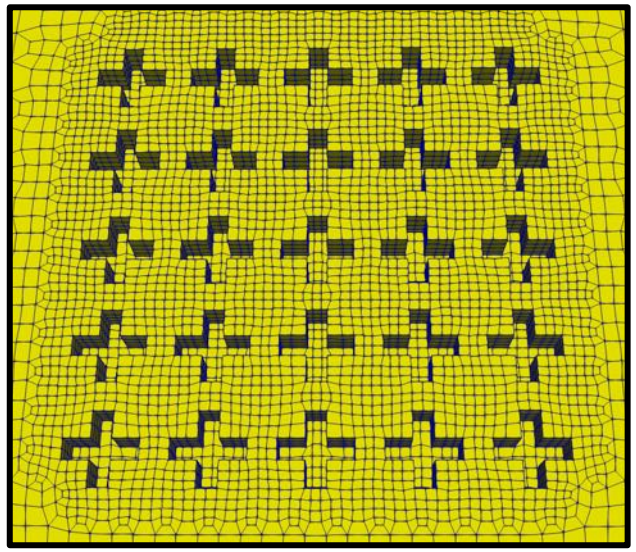
structural changes



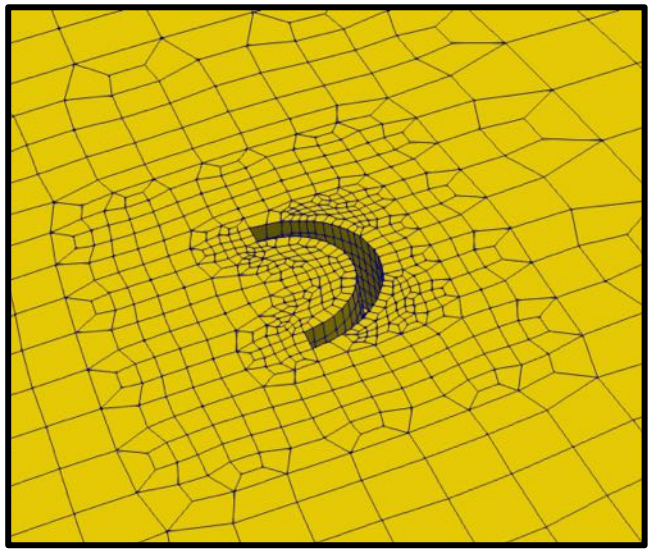
seismic station

Mitigating wind-turbine noise

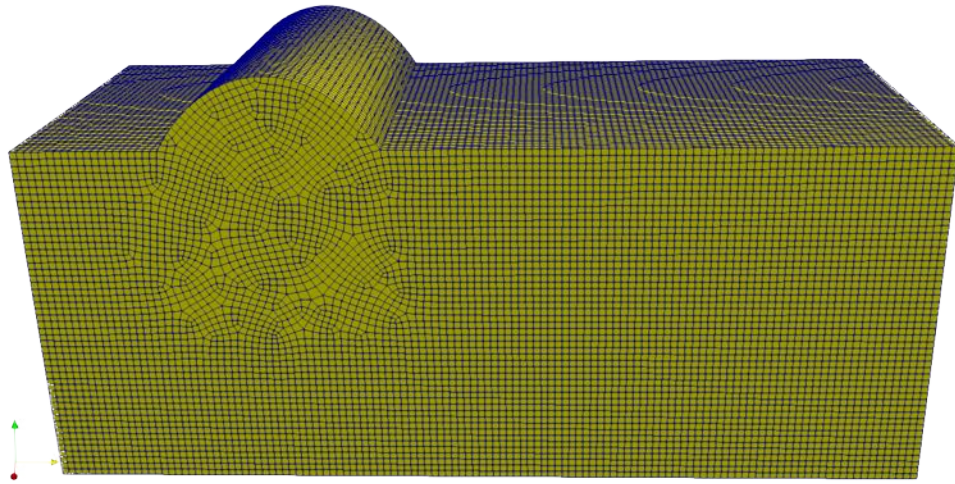
Cross shaped structural changes



single trenches

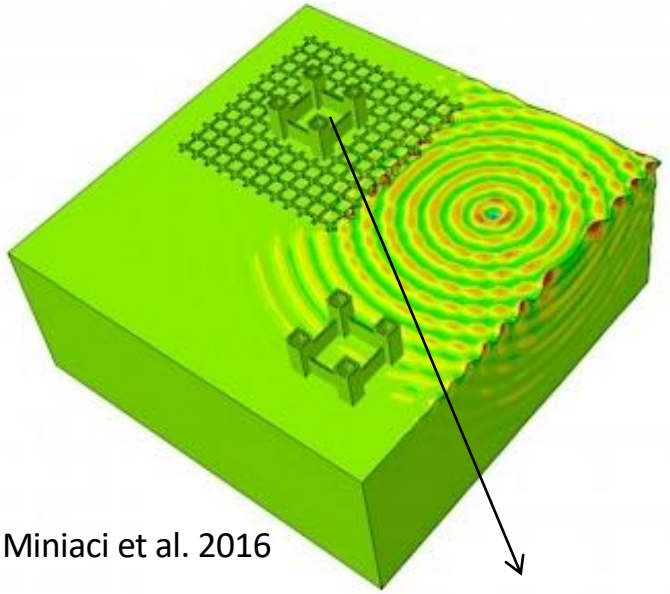


Topographic effects



Structural changes – metamaterials in the literature

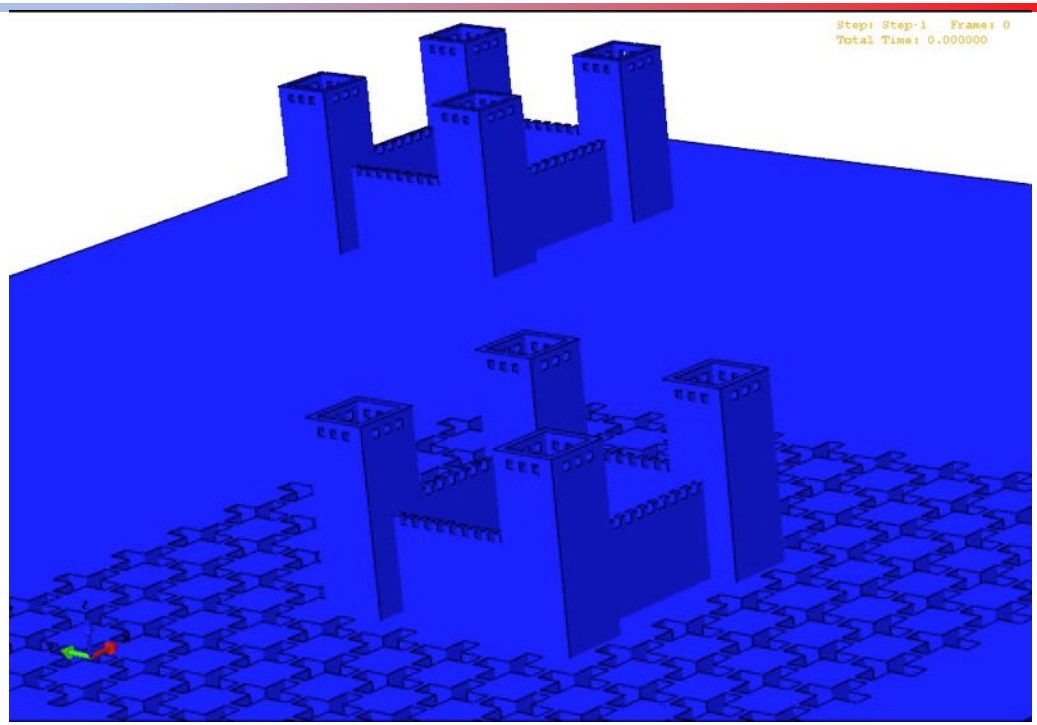
Finite element simulation at 5Hz



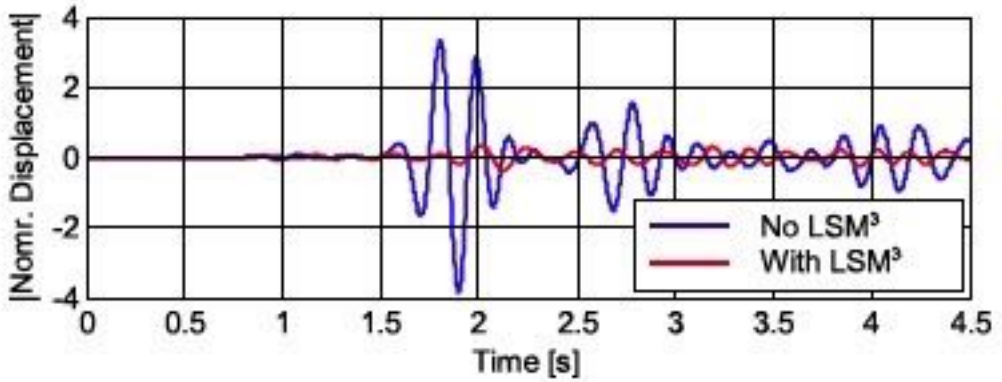
Miniaci et al. 2016

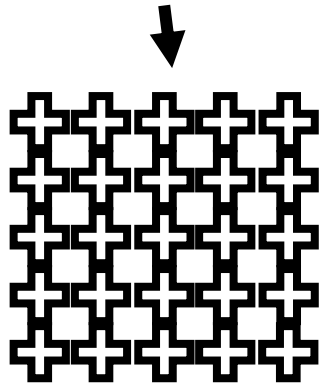
Miniaci et al. 2016

Metamaterials have been proposed to protect buildings so far. They reduce frequencies through scattering and attenuation



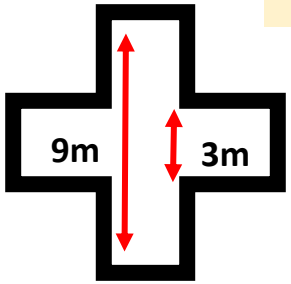
LSM- Large Scale Metamaterial





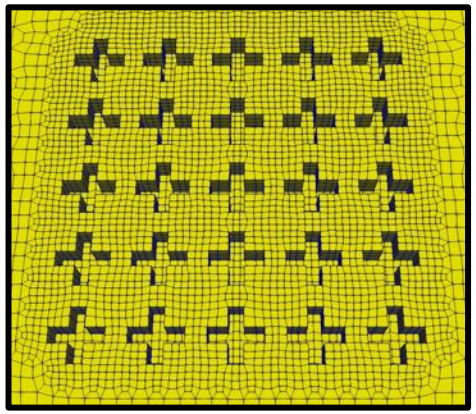
Total cross-shaped models

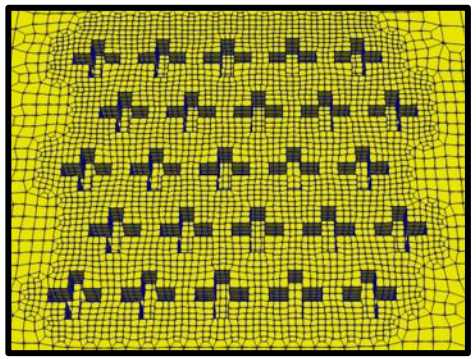
12 different grid models with 5 varying dimensions and setups

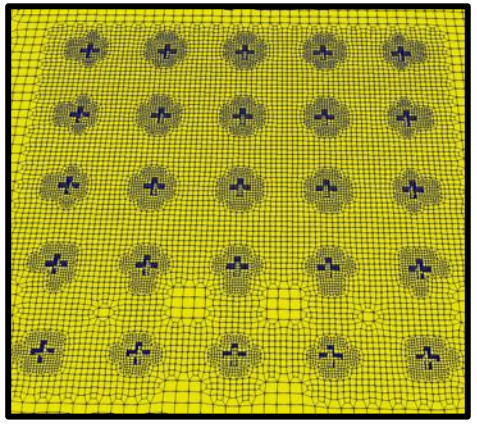


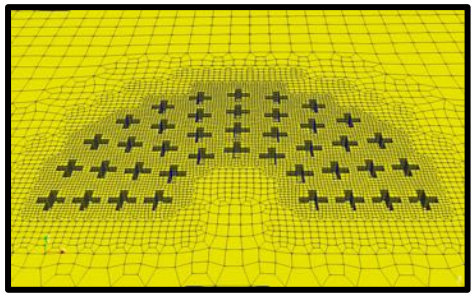
depth 10m

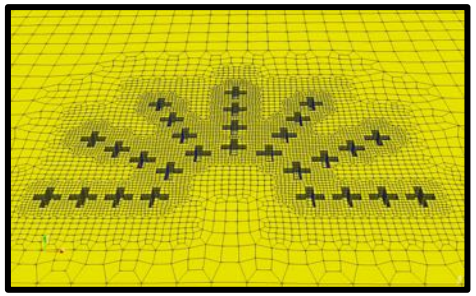
12 total models





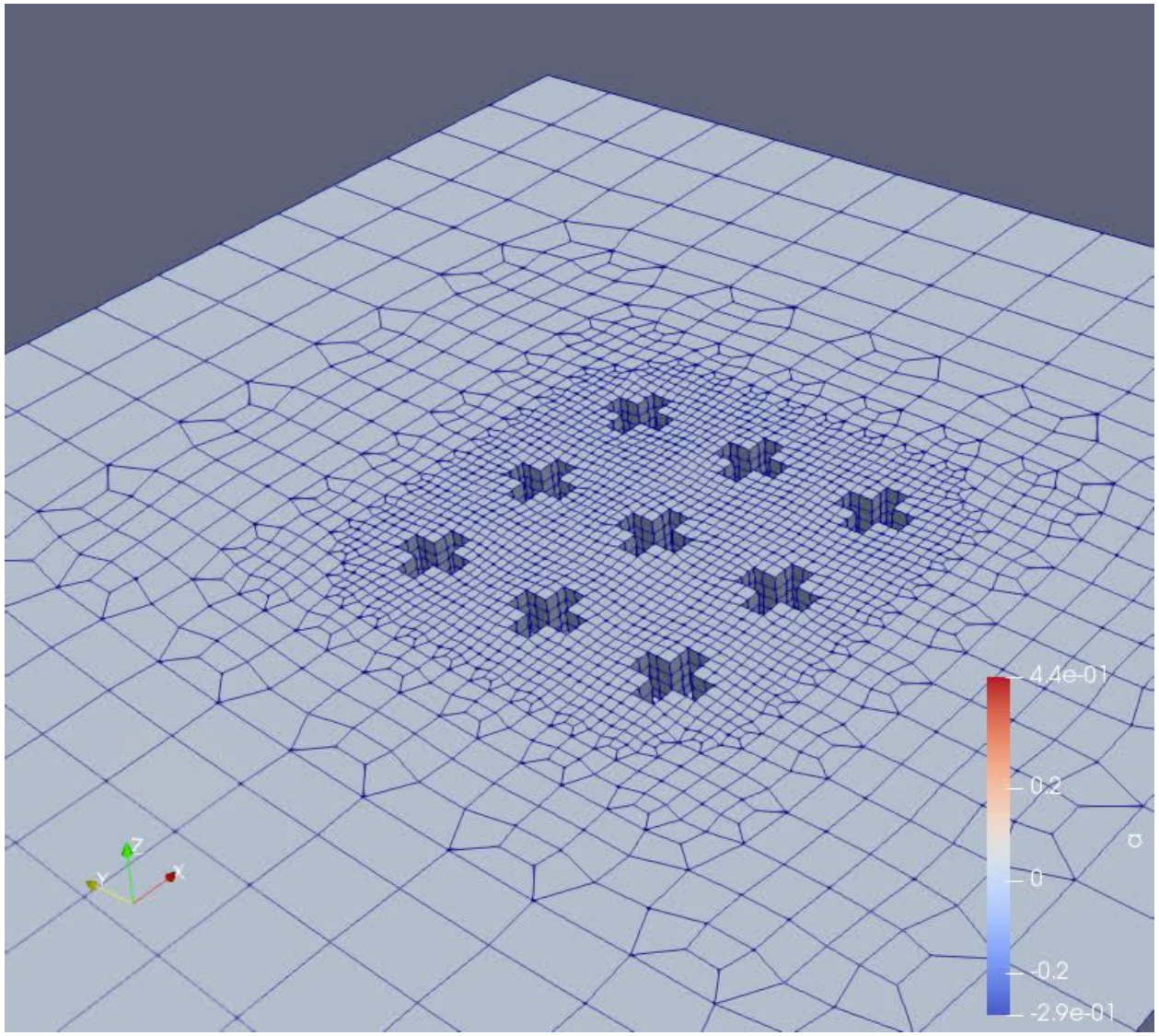




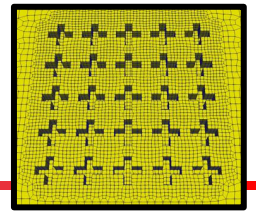


Example simulation

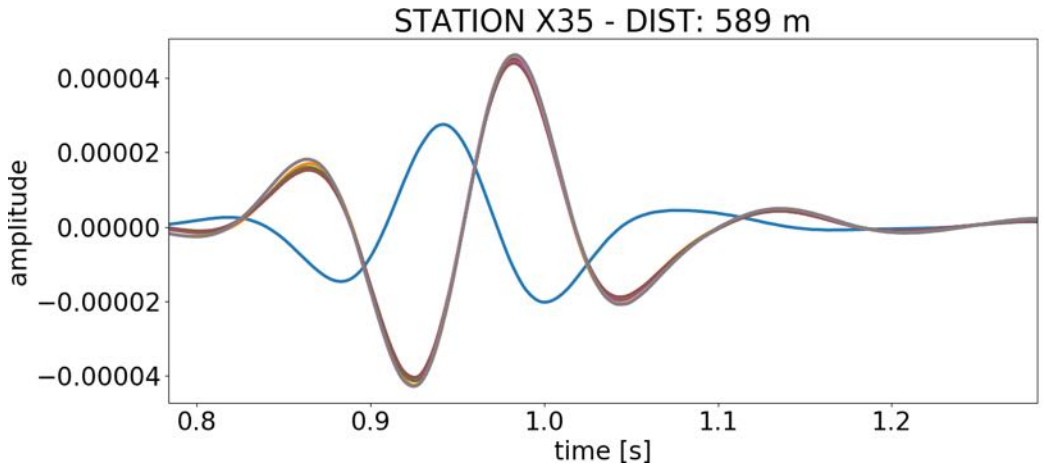
Wave propagation in an example mesh designed to test metamaterials' effects

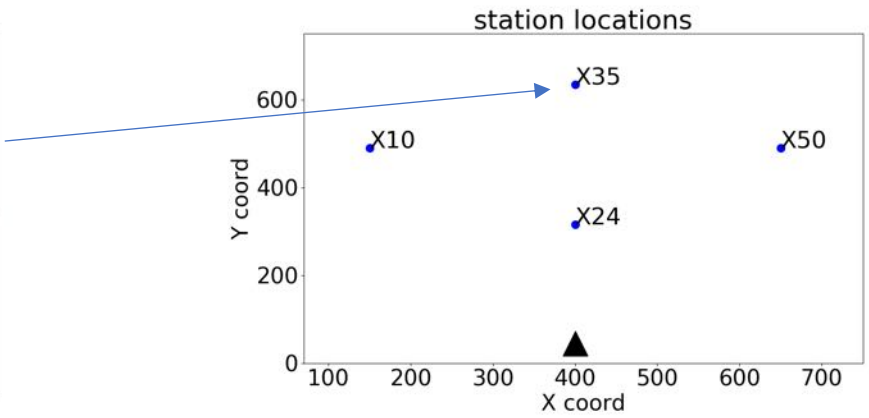


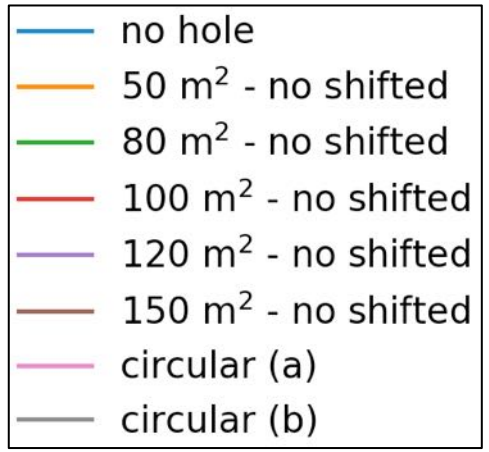
Cross-shaped results (5 Hz)

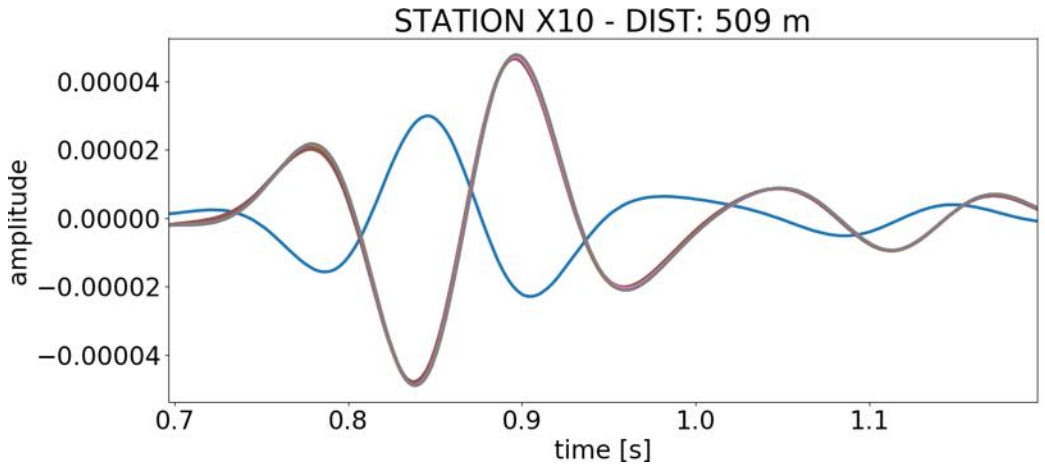


velocity – Z comp.









- ✓ Increase of seismic energy (5 Hz)
- ✓ The same effects happen for all cross shaped structural changes tested
- ✓ This setup is very frequency dependent and therefore not a good case for our purposes
- ✓ Our setup is different from previous work (Miniaci, 2016) in that cavities are not connected – may lead to waveform healing

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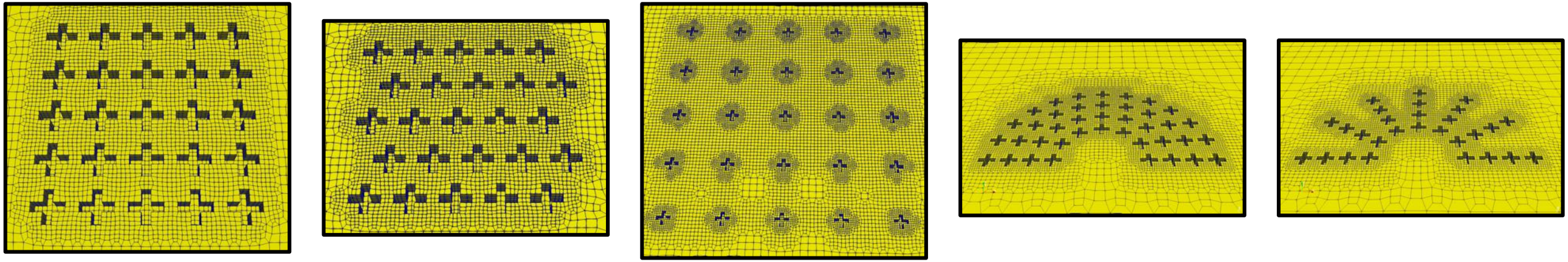
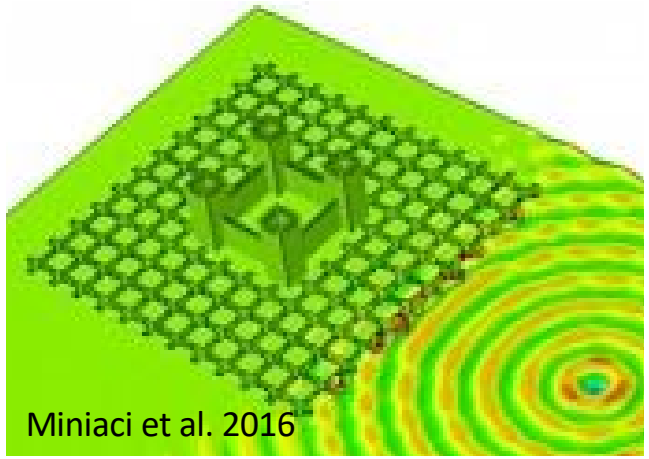
Take home message of cross shaped holes

12 total models



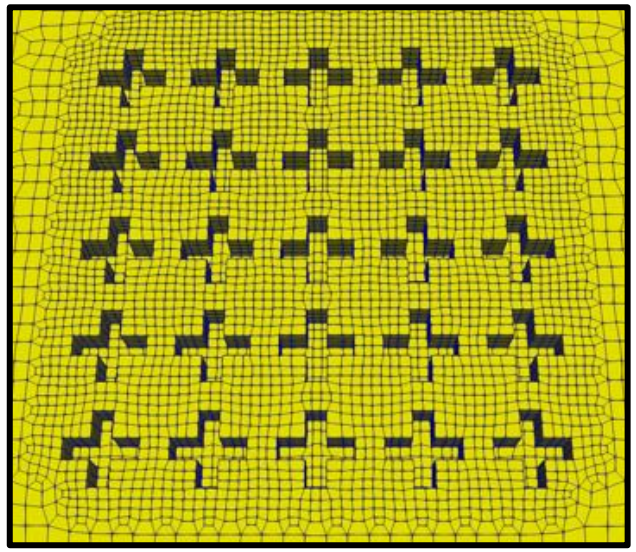


Miniaci et al. 2016

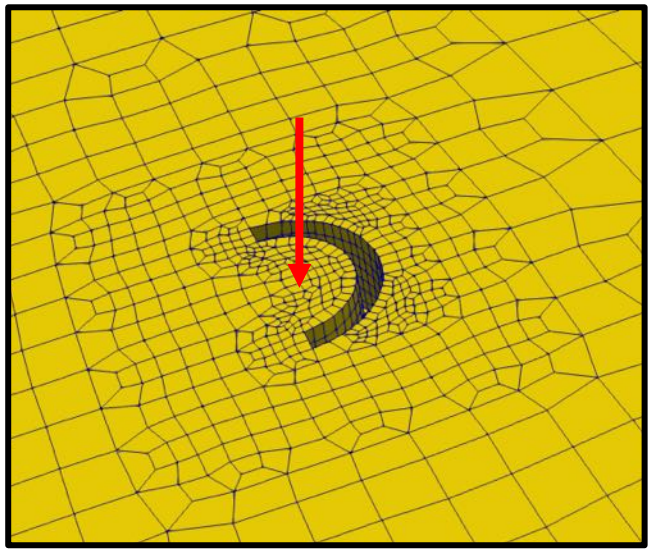
- No reduction of seismic energy at 5 Hz
- Not useful for our purposes

Mitigating wind-turbine noise

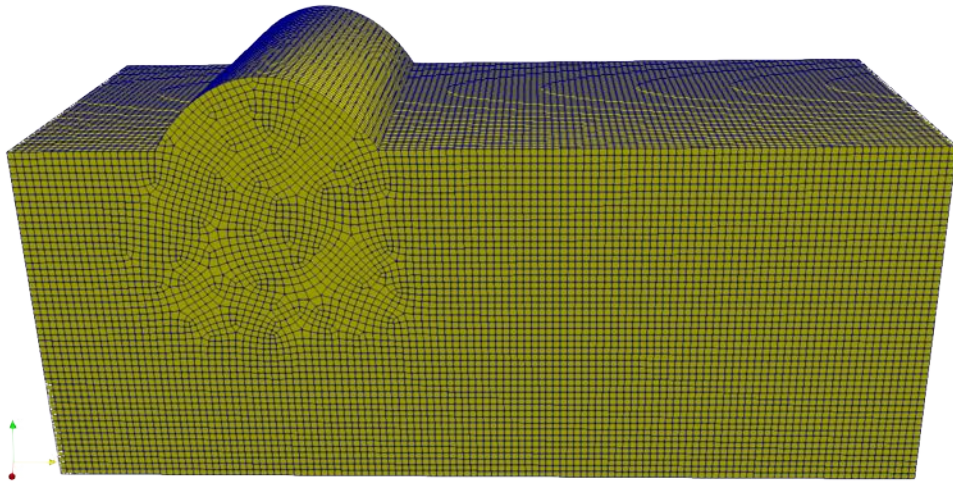
Cross shaped structural changes



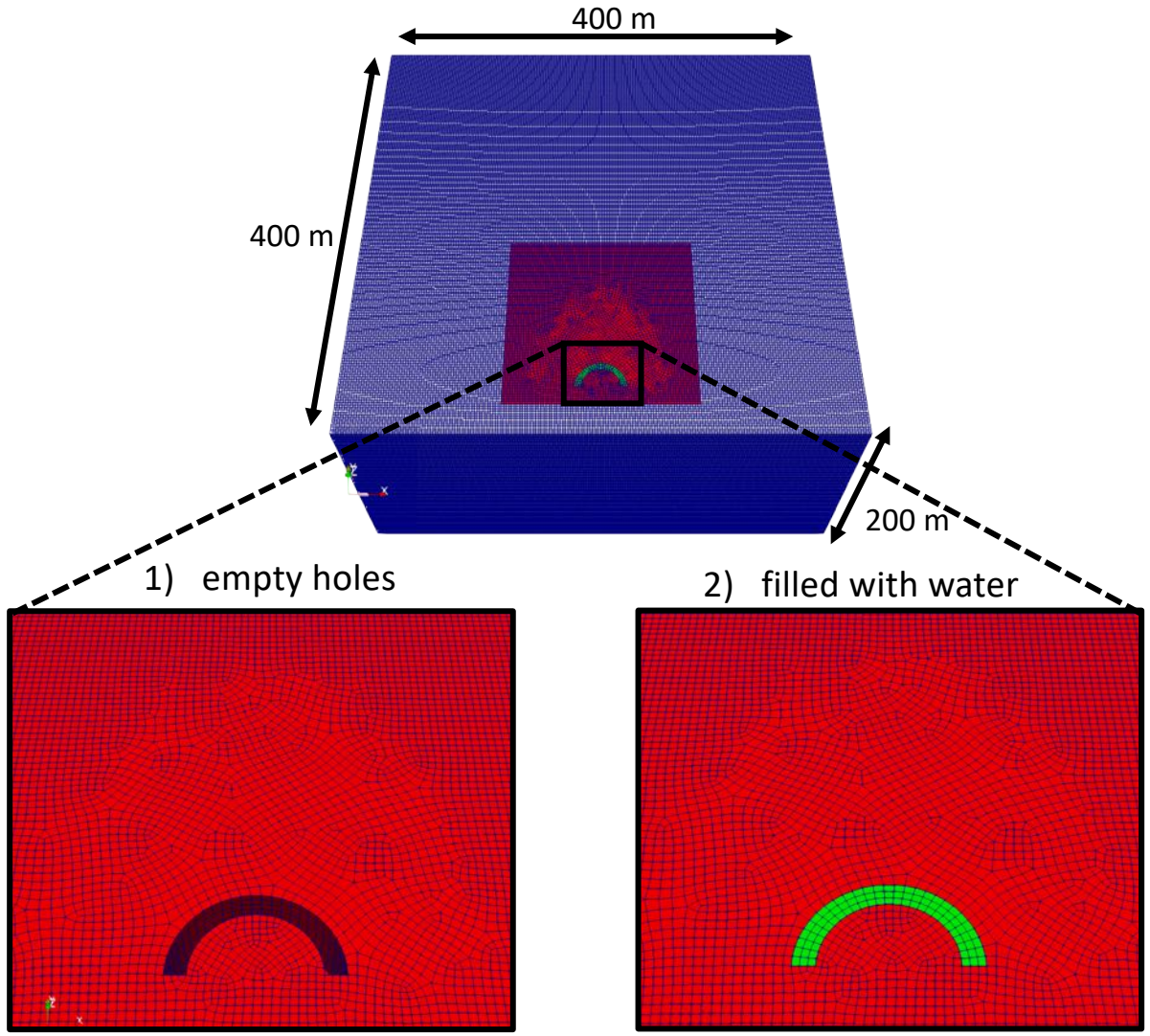
single trenches



Topographic effects

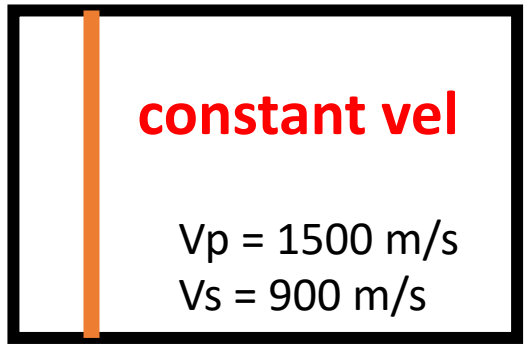


Trenches (empty and water filled)

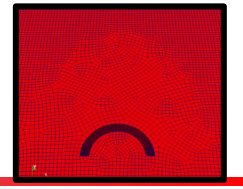


varying widths
5m and 3m
varying depths
20-15-10-5 m

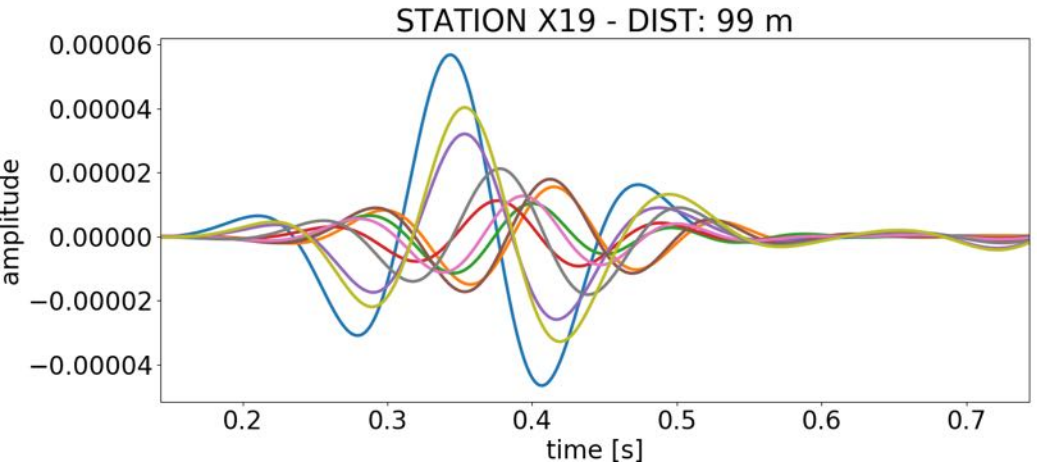
Total of 16 diferent models

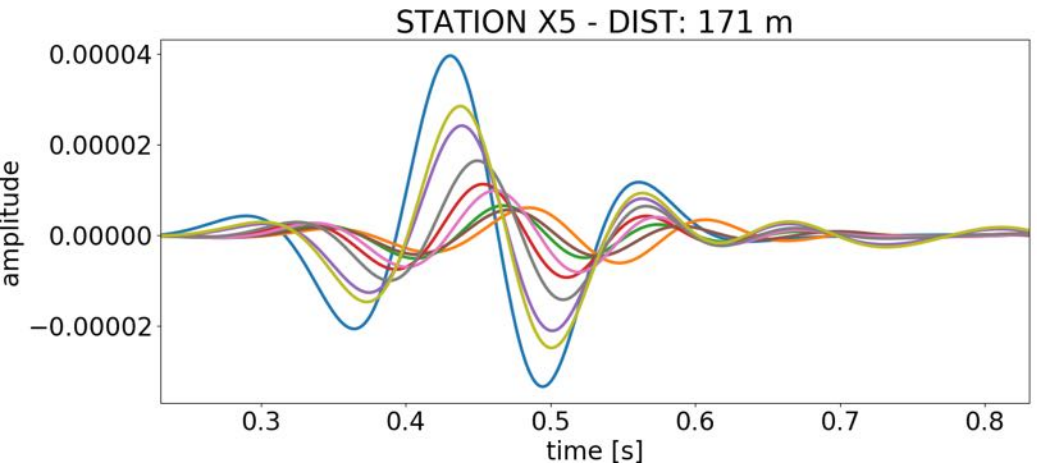


Results empty trenches (5 Hz)

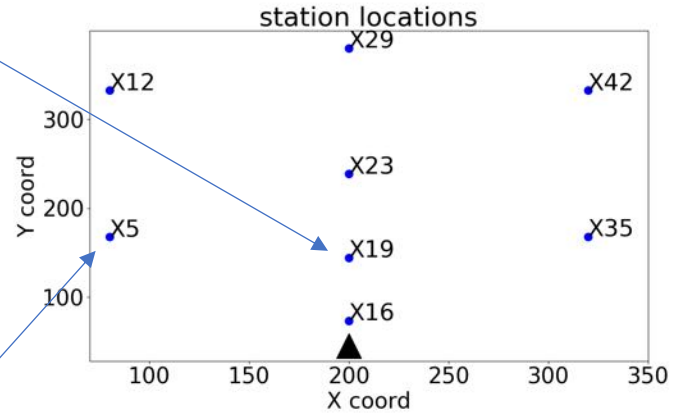


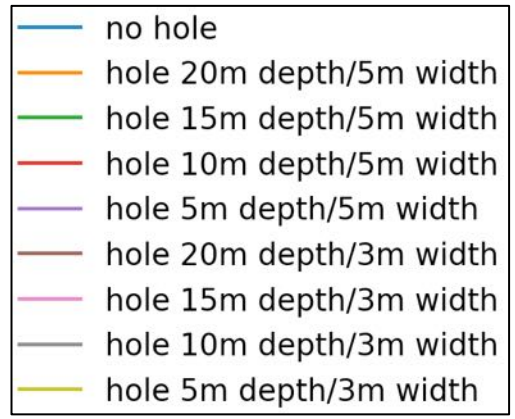
velocity – Z comp.





✓ All trenches mitigate the seismic energy



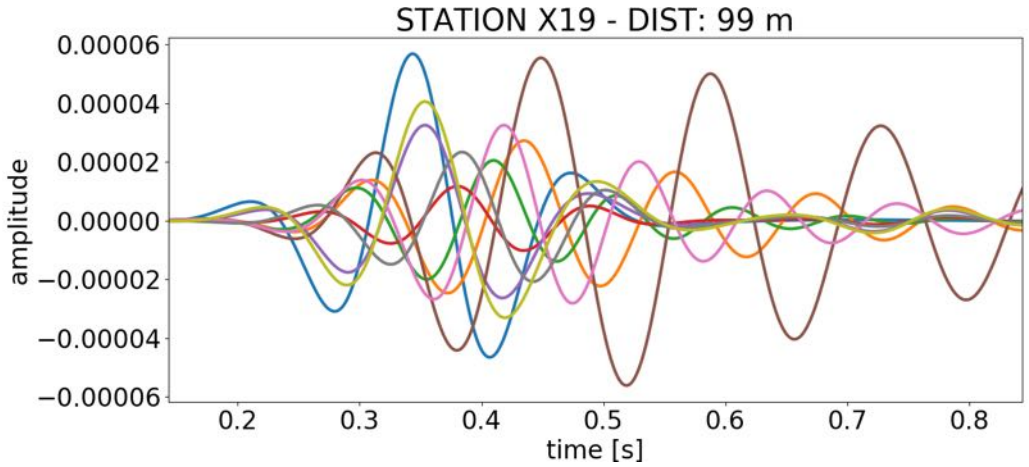


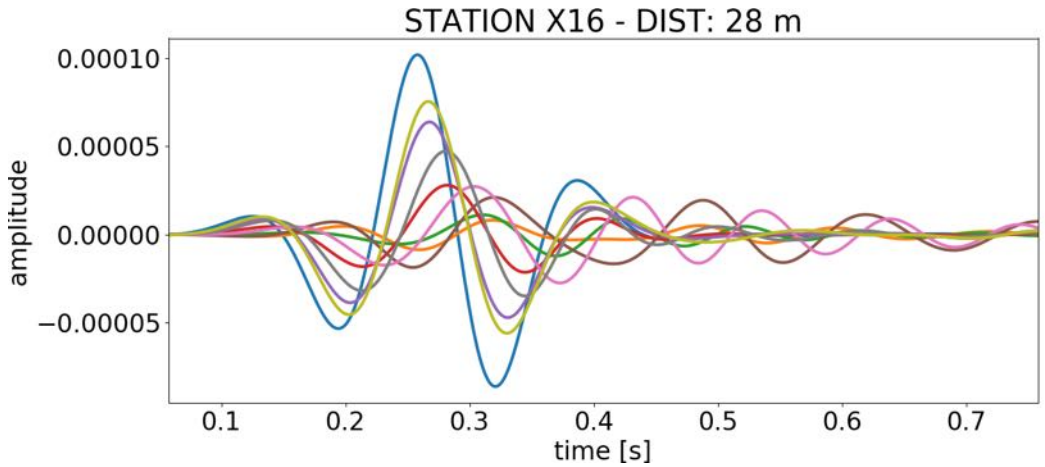
✓ Deeper trenches reduce the energy more than shallower trenches

✓ The trench acts as a barrier

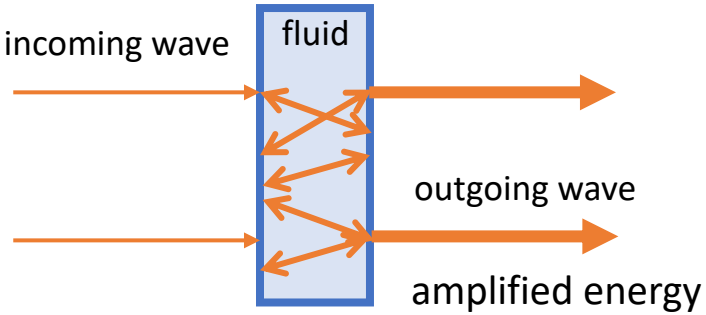
Results trenches filled with water (5 Hz)

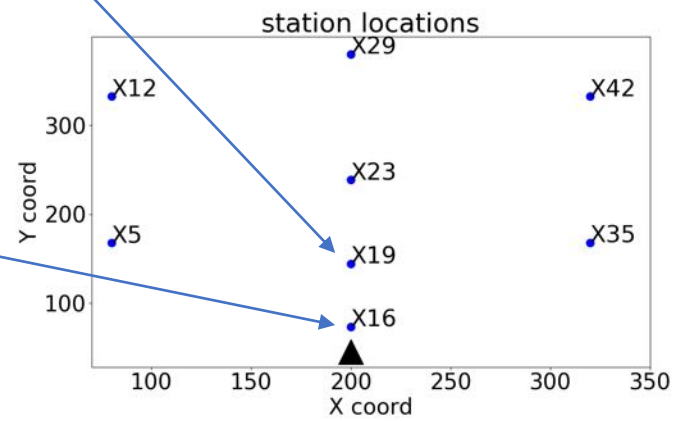
velocity – Z comp.

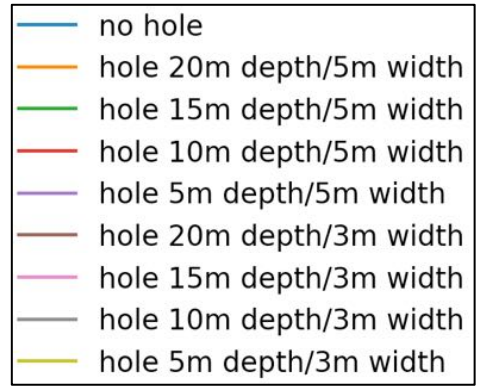




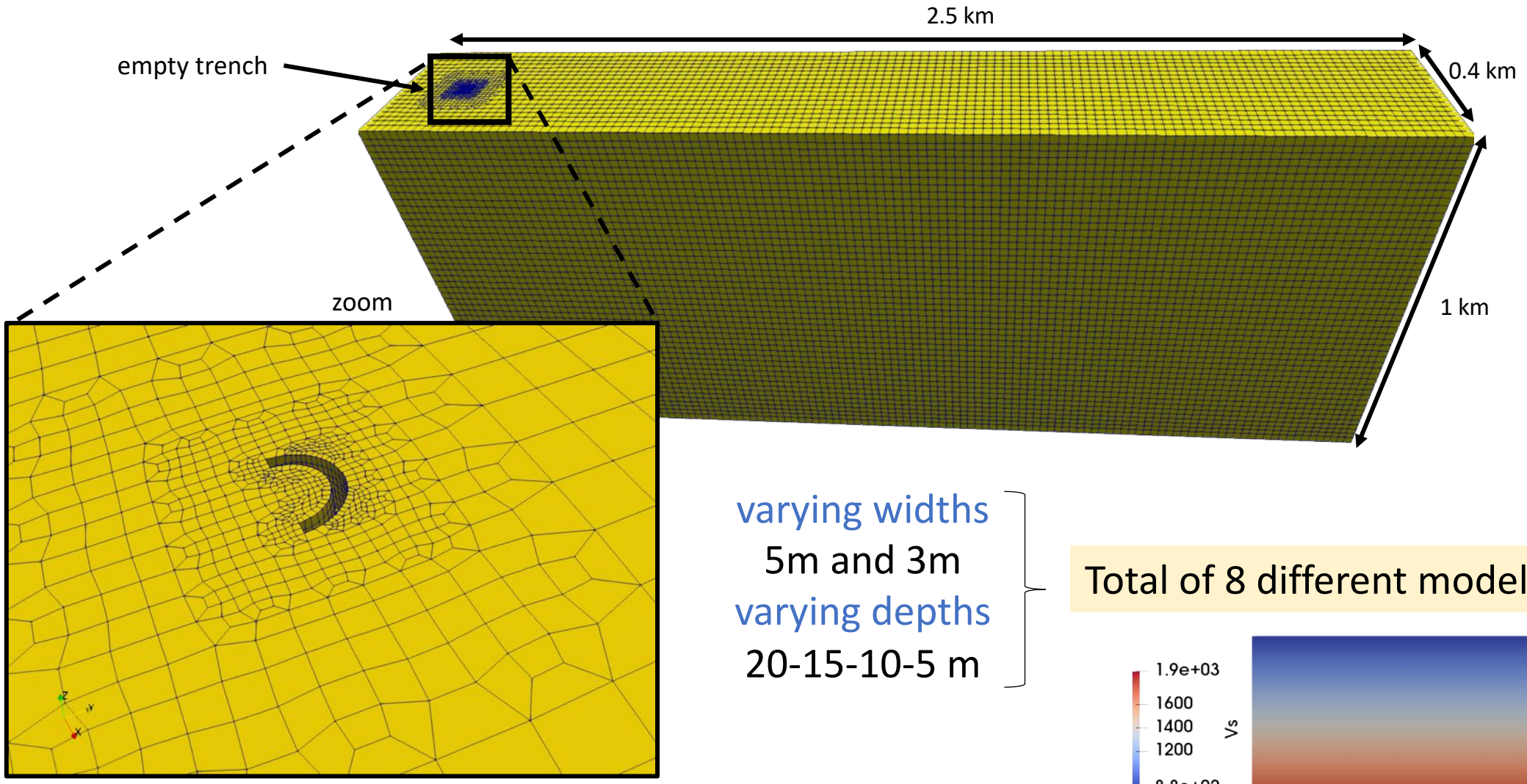
Effects of reberberations observed





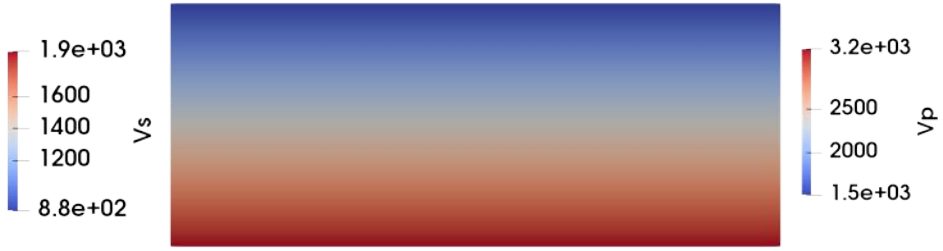


Structural effects with realistic noise sources



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

Total of 8 different models



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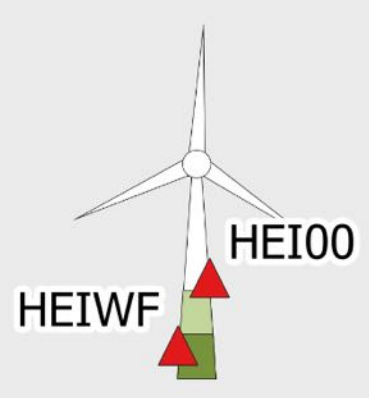
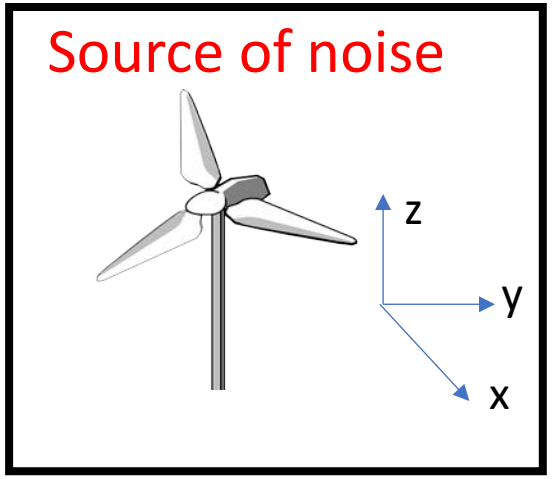
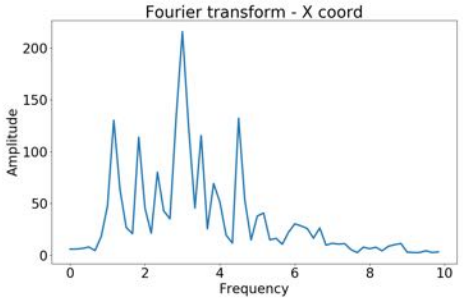
Noise sources from DMT

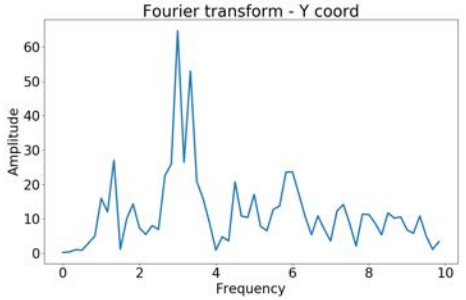




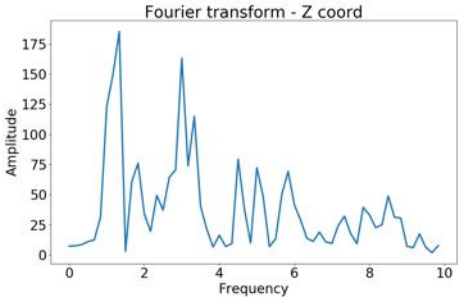
a) X component



b) Y component



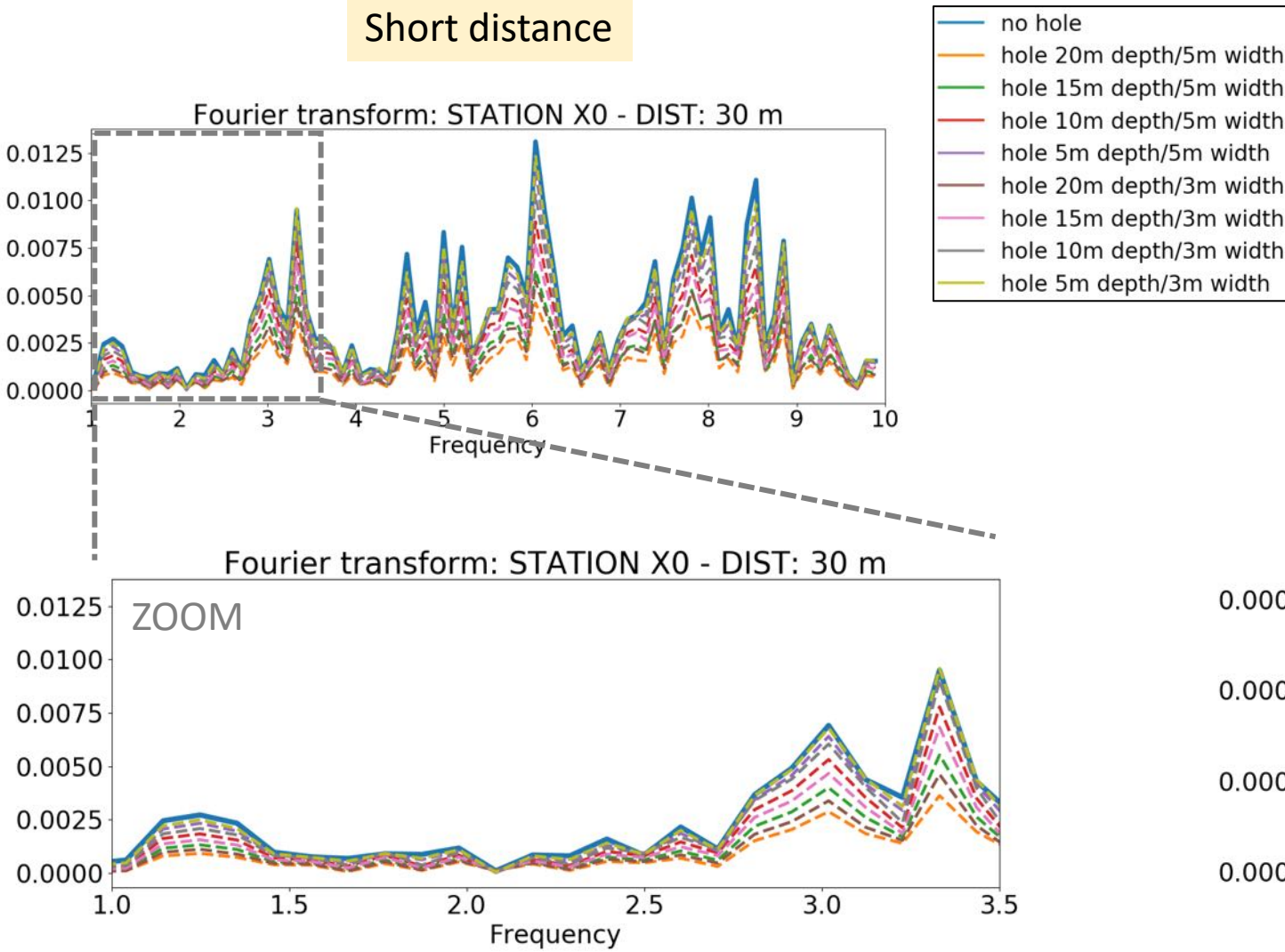
c) Z component



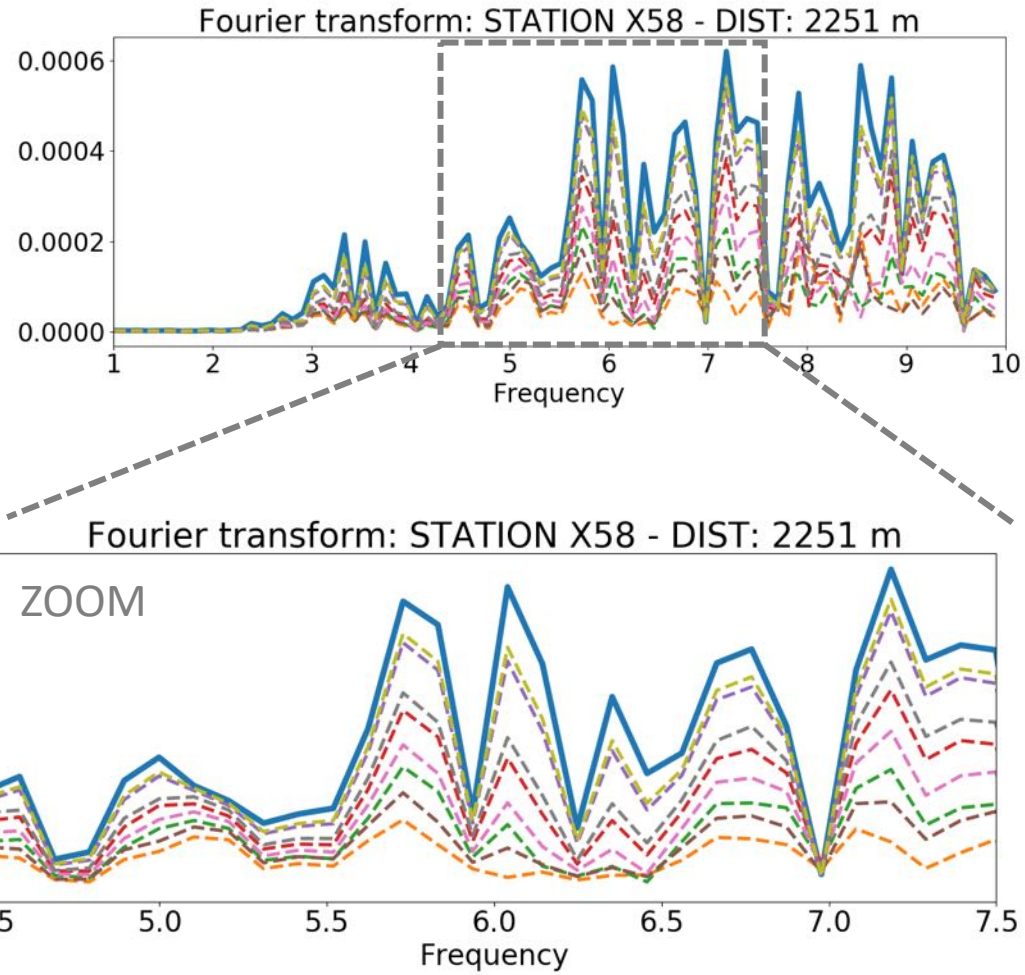
- ✓ Realistic source measured by DMT is used instead of a Ricker wavelet.
- ✓ Ricker wavelet limited in frequencies
- ✓ Real signal contains frequencies in the range [1-10] Hz with frequency peaks as send out by the WT

Results trenches (large models)

Short distance



Long distance



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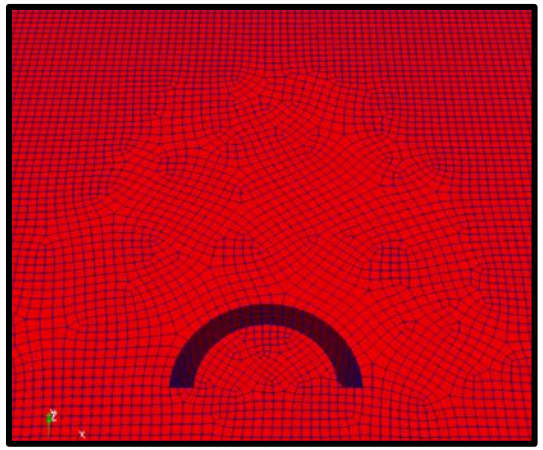
Take home message of empty and filled trenches

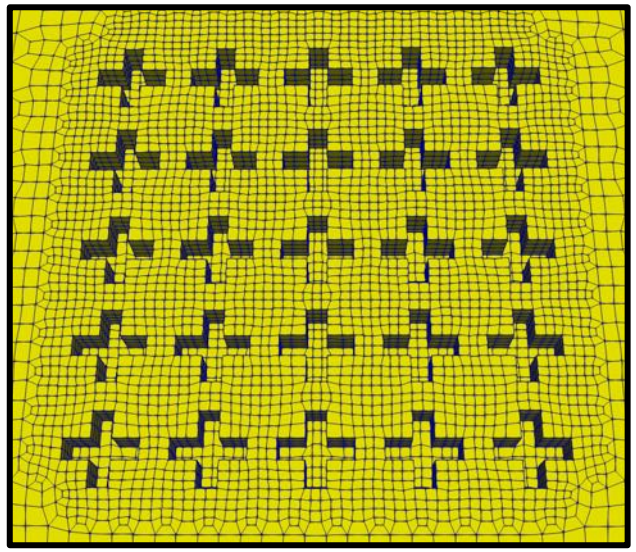


- ✓ Empty circular trenches help to mitigate the seismic energy at long and short distances
- ✓ The depth of the structure seems to be more important than the width
- ✓ Trench acts as barrier to surface waves

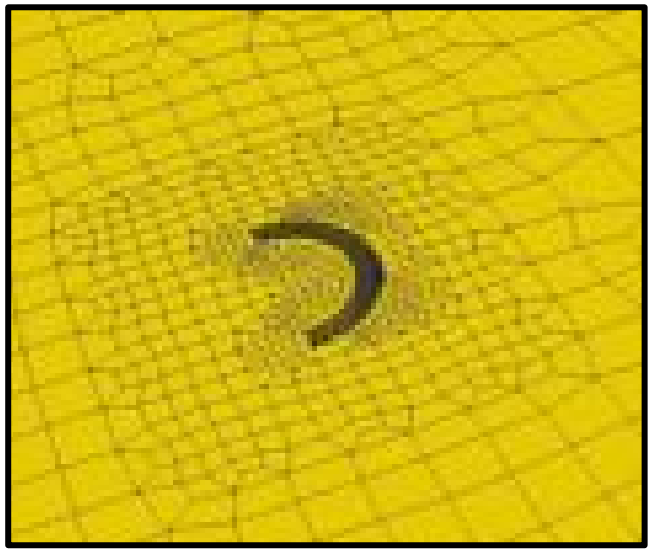
- ➢ Reverberation are observed in circular trenches filled with water – empty structures are preferred
- ➢ Porous materials as trench material did not have a large effect

Mitigating wind-turbine noise

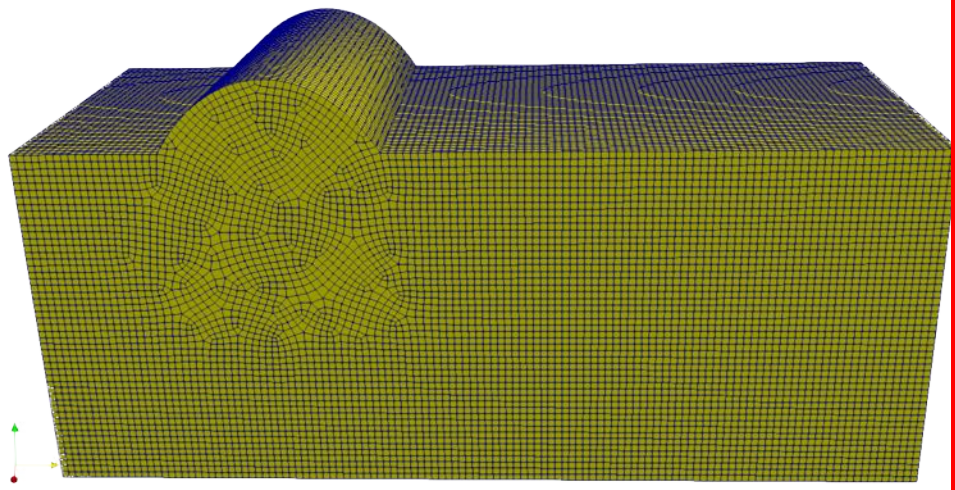
Cross shaped structural changes



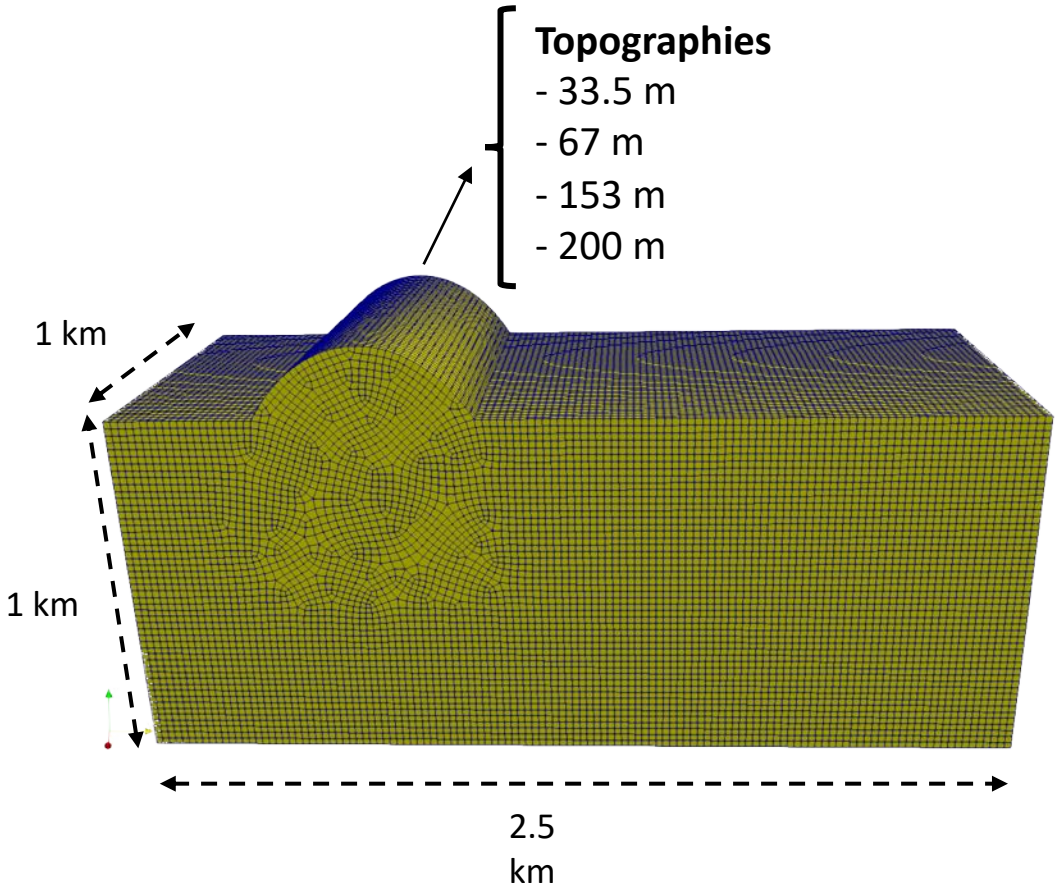
single trenches

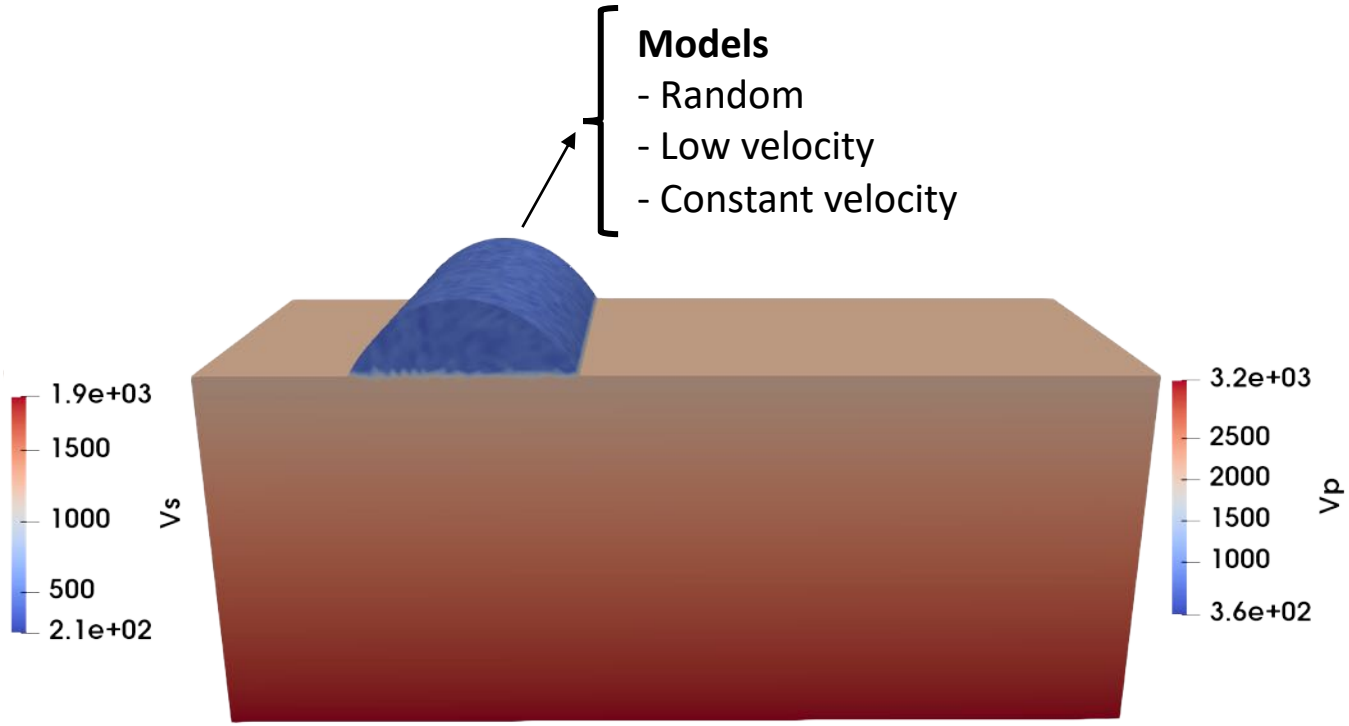


Topographic effects



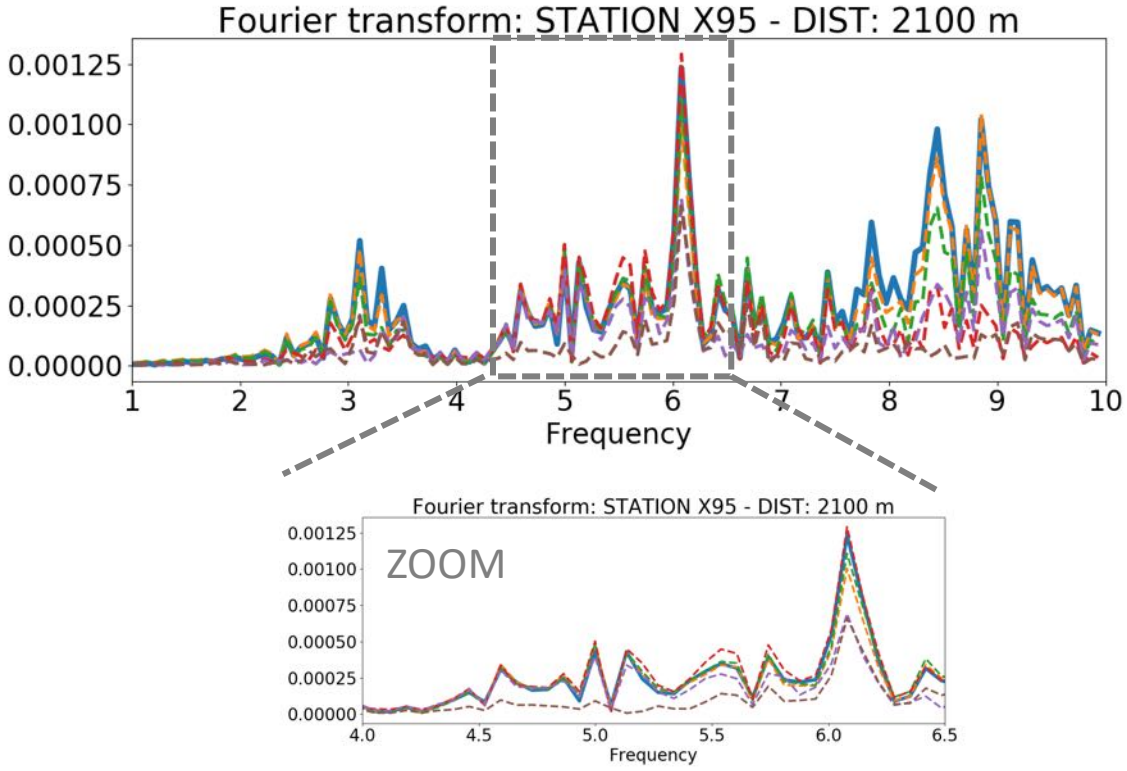
Topographic effects on waveforms

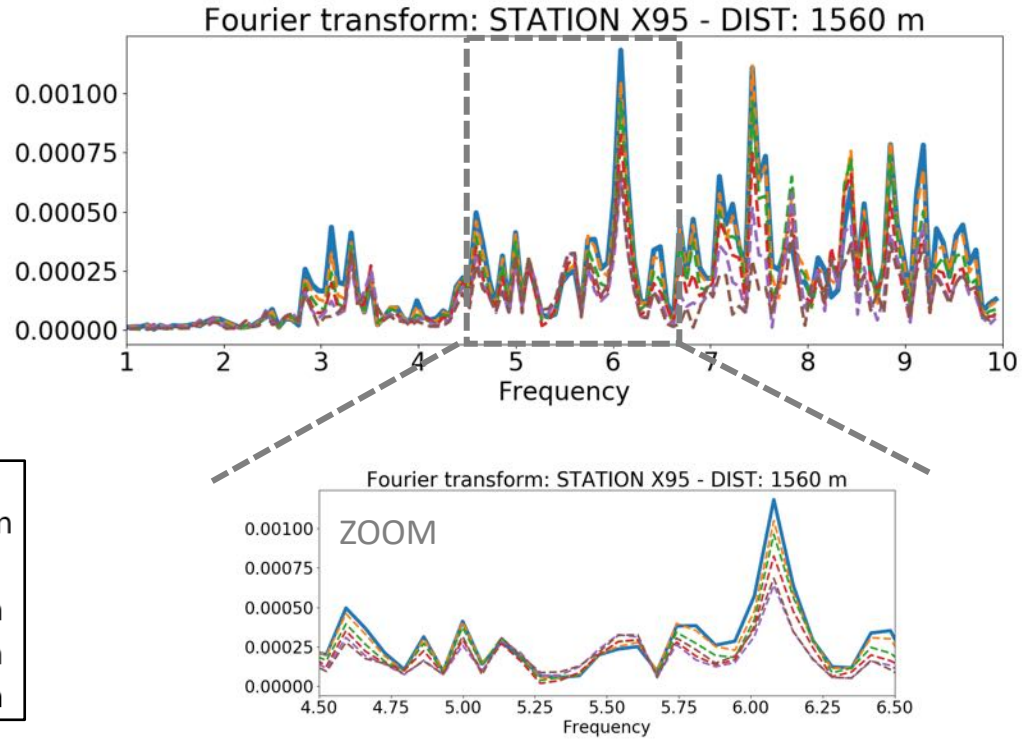


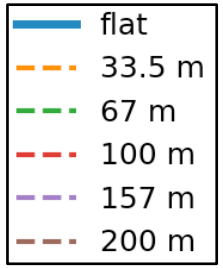


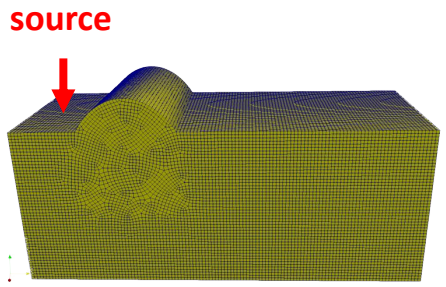
More than 20 models generated

Results topography with constant velocity *(same as surface)*

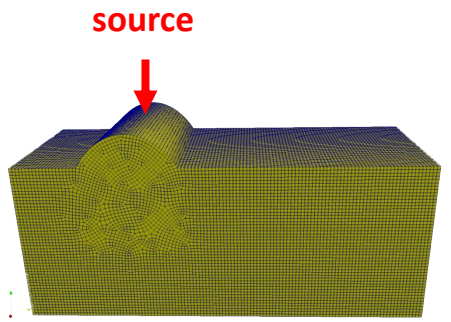




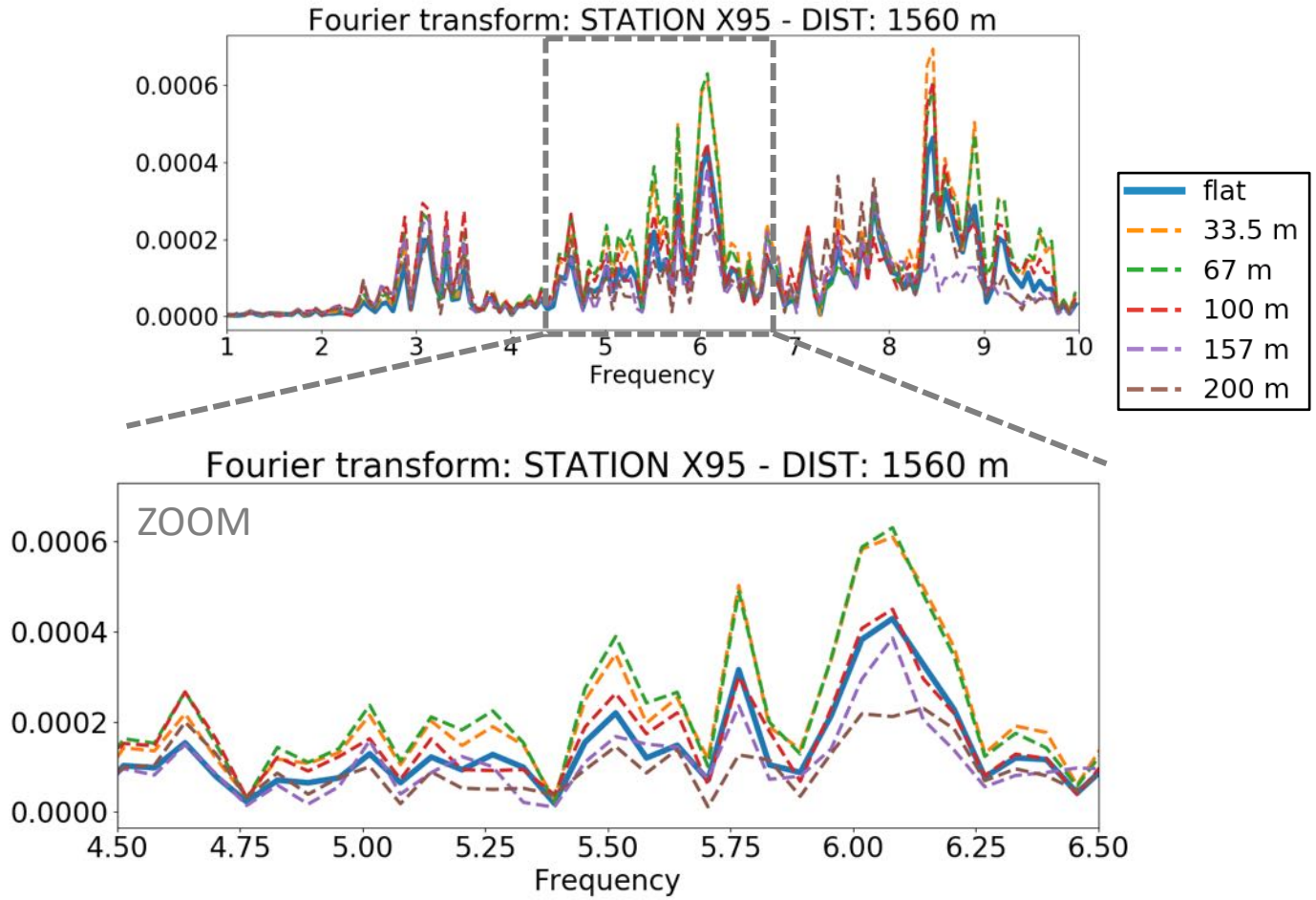




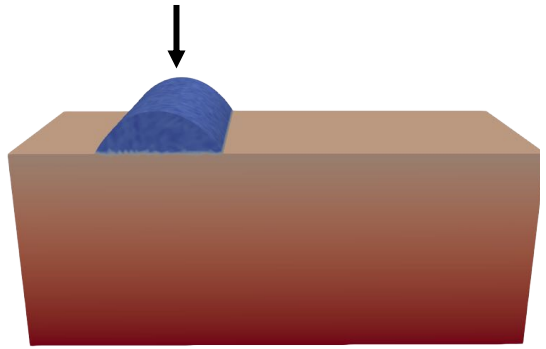
similar behavior observed in both cases



Results topography with scattering velocity *(0 RMS +/- 200 m/s and a=10 m)*



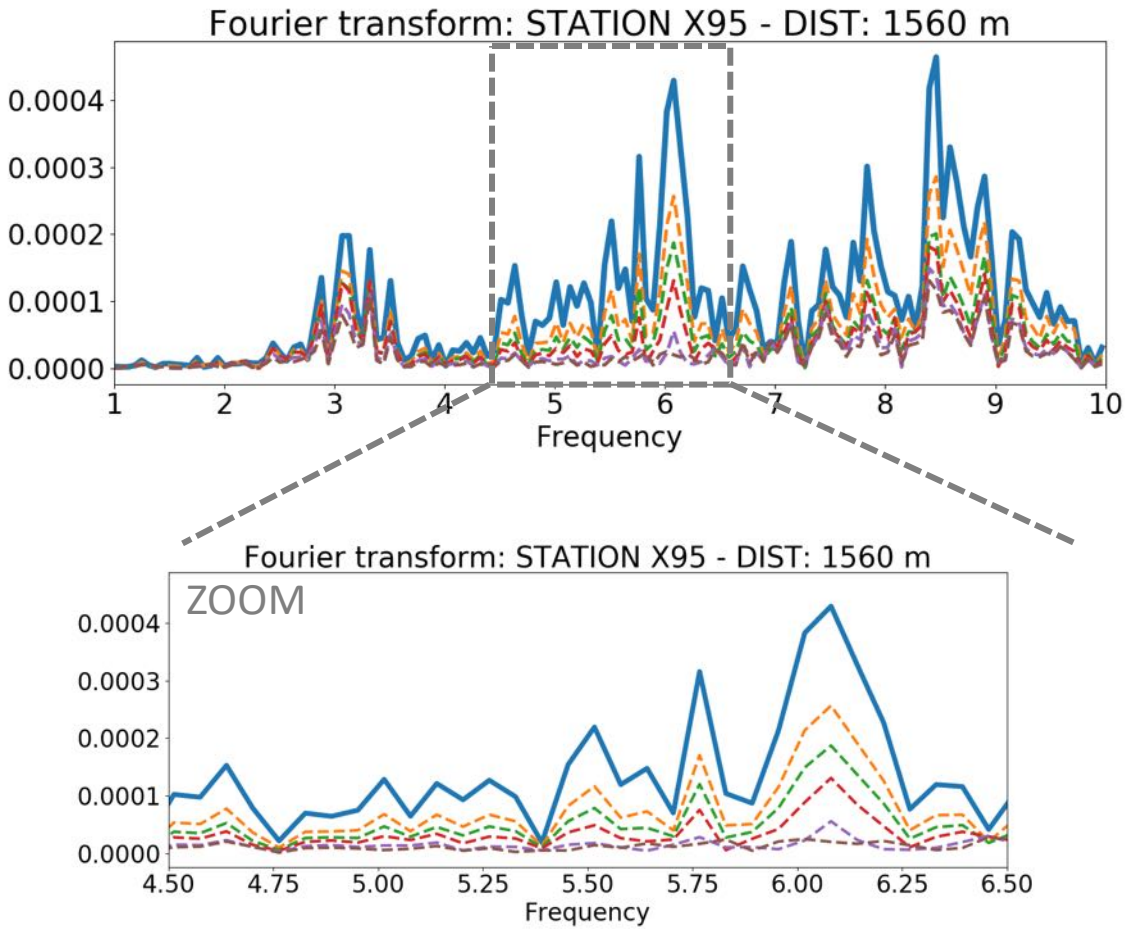
velocity variation at the topography of +/- 200 m/s with a correlation length of 10 m

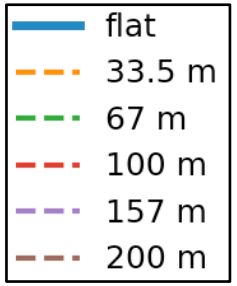


- ✓ Clear reduction of the seismic energy compared to the previous case depending on the topographic height
- ✓ For shallow topography the peaks are increased
- ✓ Topography has to be high enough

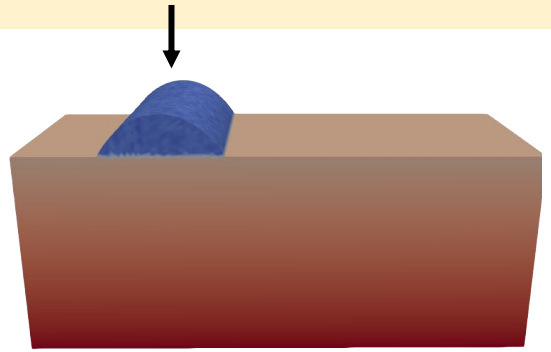
EFRE.NRW Investitionen in Wachstum und Beschäftigung
EUROPÄISCHE UNION Investition in unsere Zukunft Europäischer Fonds für regionale Entwicklung
WWU MÜNSTER
miss
GEOPHYSIK WWU MÜNSTER

Results topography with high scattering velocity *(2750 RMS +/- 250 m/s and a=10 m)*



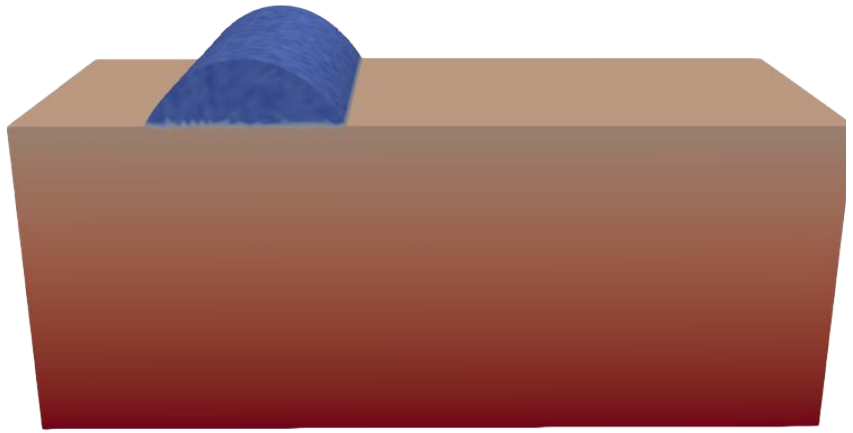


High velocity variation at the topography of +/- 250 m/s with a correlation length of 10 m



✓ Considerable reduction of the seismic energy compared to the previous cases for all topographies

Take home message of topographic effects



- ✓ Some topographies reduce the noise – size matters
- ✓ Topography with high velocity scatterers reduce the seismic energy – geology matters
- ✓ No important differenes observed when locating the WTs on top a of hill or in front of it (most WTs are on top of hills)
- ✓ Topography with low velocity scatterers amplify seismic energy

- ➢ Influence of geology needs to be tested
- ➢ More complex topography needs to be tested

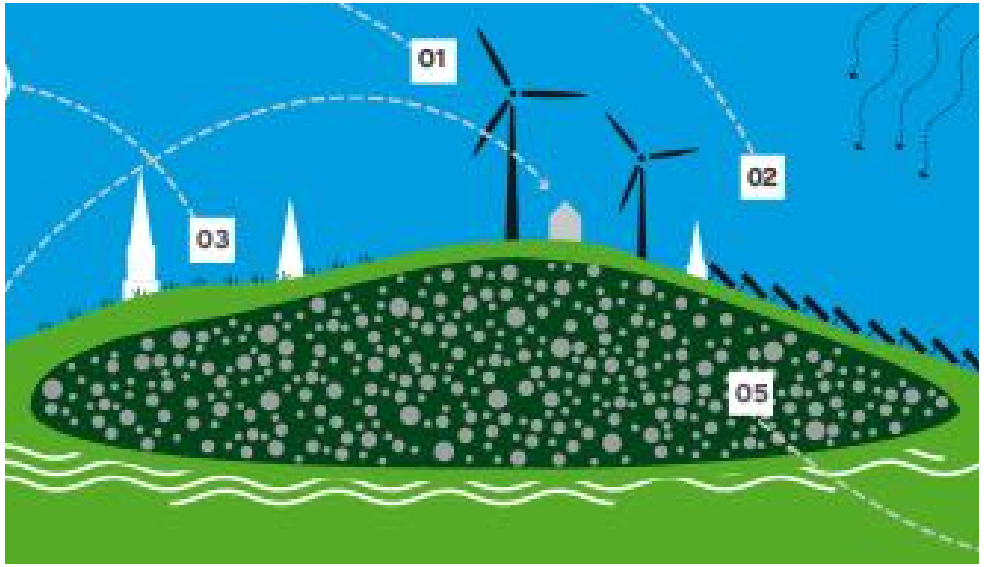
(limitations of the modelling methods used here)

Summary of results

Model	Effect on the seismic energy
▪ Cross shaped structural changes	➢ Amplifies
▪ Half circular holes filled with water	➢ Amplifies
▪ Half circular empty holes	➢ Reduce the seismic energy (1-10 Hz)
▪ Hills with low velocity (scattering)	➢ Amplifies
▪ Hills with scattering	➢ Increase/reduce
▪ Hills with high velocity (scattering)	➢ Reduce the seismic energy (1-10 Hz)

Die Energieberg (mountain for energy production)

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



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

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

Topography with metamaterial

Summary of results

Model	Effect on the seismic energy
▪ Cross shaped metamaterials	➢ Amplifies
▪ Half circular holes filled with water	➢ Amplifies
▪ Half circular empty holes	➢ Reduce the seismic energy (1-10 Hz)
▪ Hills with low velocity (scattering)	➢ Amplifies
▪ Hills with scattering	➢ Increase/reduce
▪ Hills with high velocity (scattering)	➢ Reduce the seismic energy (1-10 Hz)

Based on our results: the best model would be an air filled circular trench or topography filled with some high velocity scattering material