Seismic Microzonation using 6C Measurements

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Microzonation

- Subdividing region into areas with different hazard potential
- Estimating wave velocity of shallow subsurface

→Ground motion depends on regional geology

→Soft sediments amplify waves

Common Methods

1) Seismic Arrays

→ Frequency Wavenumber Analysis

→ Spatial Autocorrelation

+ Well established
+ Computation of dispersion curves
+ Complete 1D velocity profile
- Complex installation and maintanance

2) Single Station Approach

→ H/V Spectral Ratios

+ Easy installation
- Non-uniqueness of results
- Highly depends on quality of noise and velocity structure

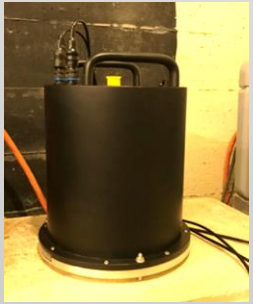
New Approach

6C Measurements

→3 translational components

→3 rotational components

+ Single station approach
+ Easy installation
+ Computation of dispersion curves
+ Complete 1D velocity profile



blueSeis-3A
(iXblue)

Trillium Compact
(Nanometrics)

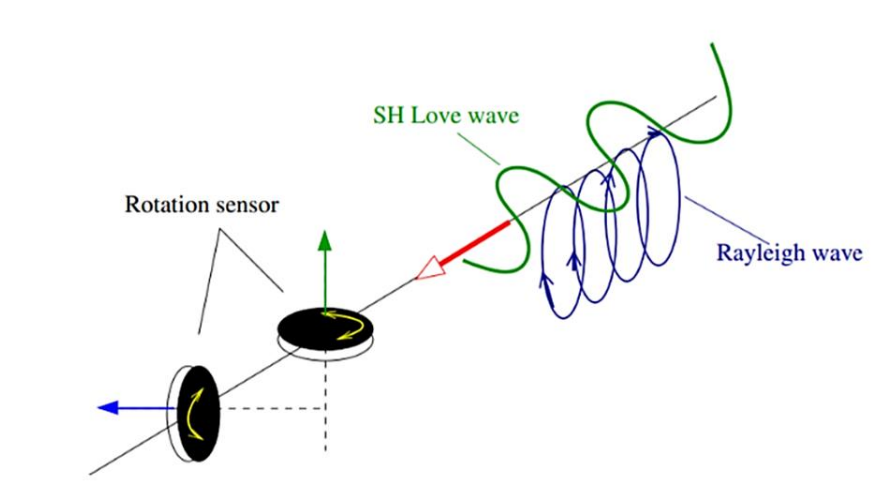
Theoretical Background

Love waves:

$$c(f) = -\frac{a_T(f)}{2\dot{\Omega}_Z(f)}$$

Rayleigh waves:

$$c(f) = \frac{a_Z(f)}{\dot{\Omega}_T(f)}$$



Suryanto (2006)

c Phase velocity

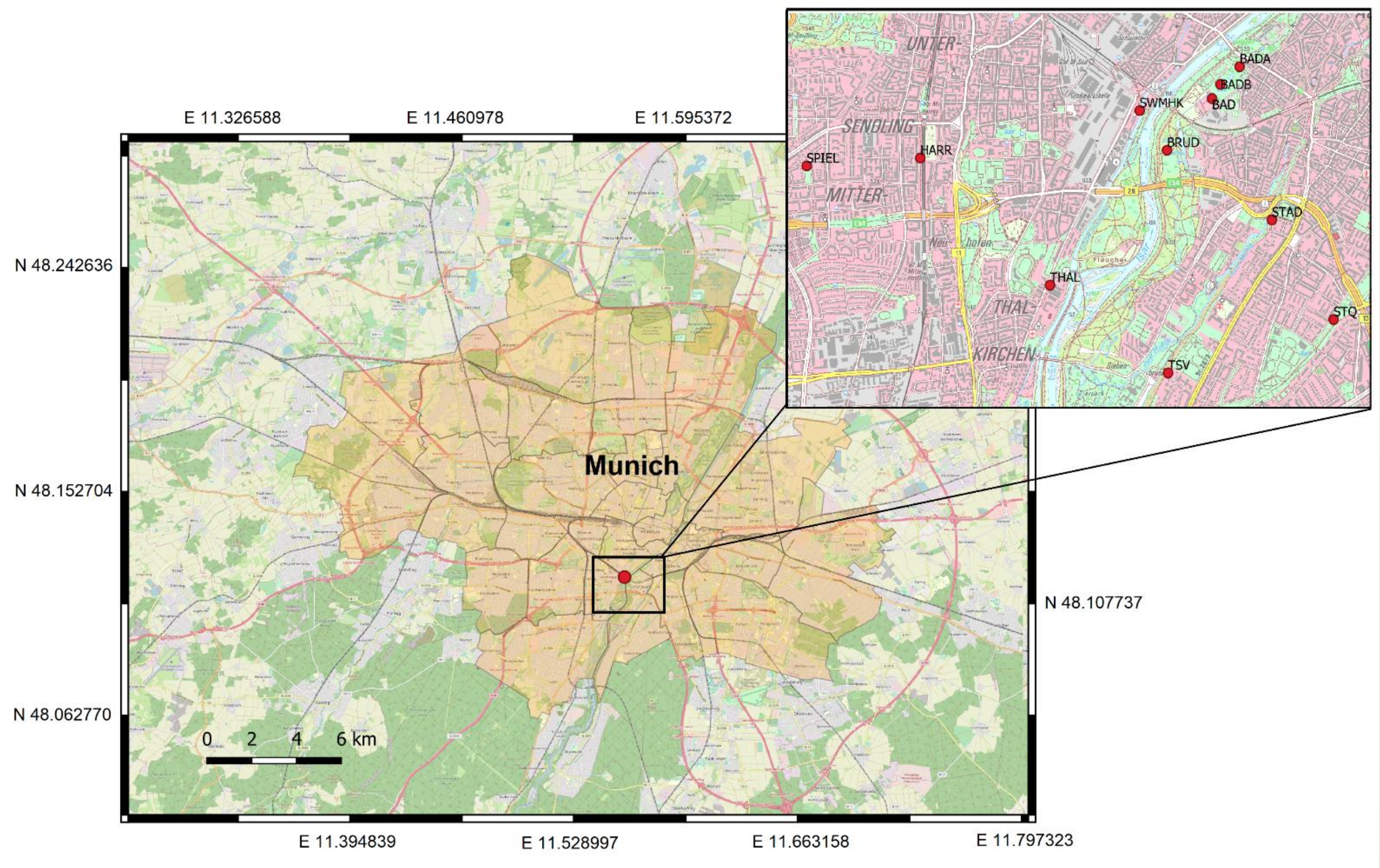
a_T Transversal acceleration

a_Z Vertical acceleration

$\dot{\Omega}_T$ Transversal rotation rate

$\dot{\Omega}_Z$ Vertical rotation rate

Study Area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Measurements

- Instruments:

  - Trillium Compact Seismometer

  - blueSeis-3A rotational Sensor

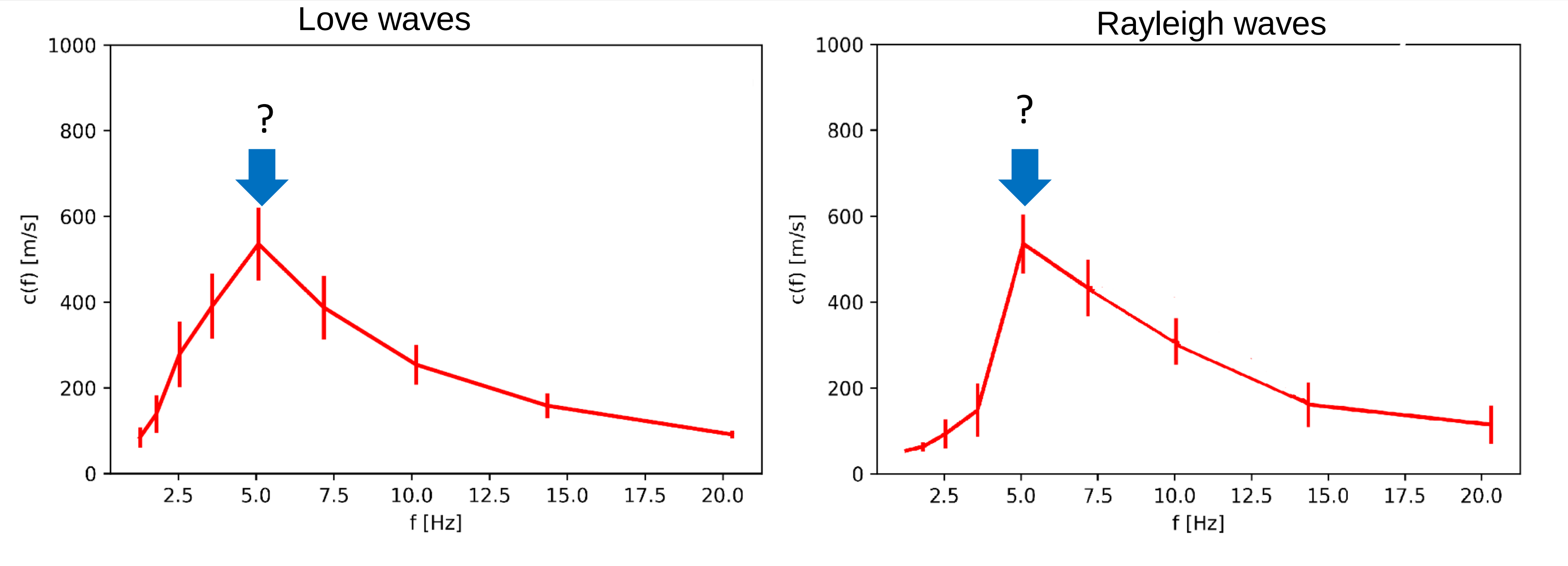
    (= Fiber Optic Gyroscope)

- Input: Noise (1-20Hz)
- Duration: 2 hours

Measurement set-up

Results – Dispersion curves

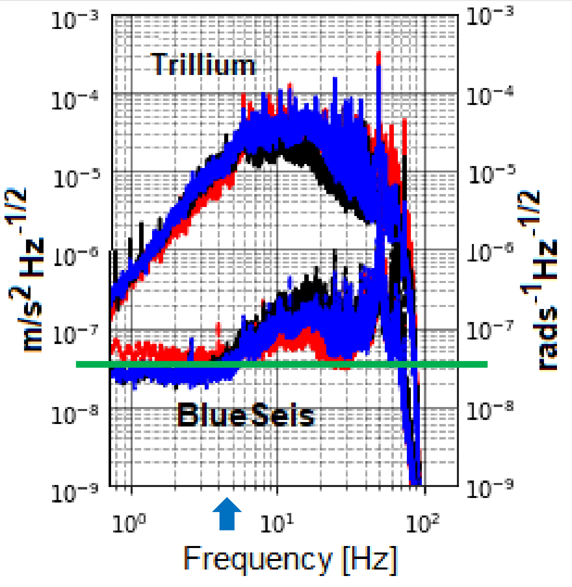
Station SWMHK

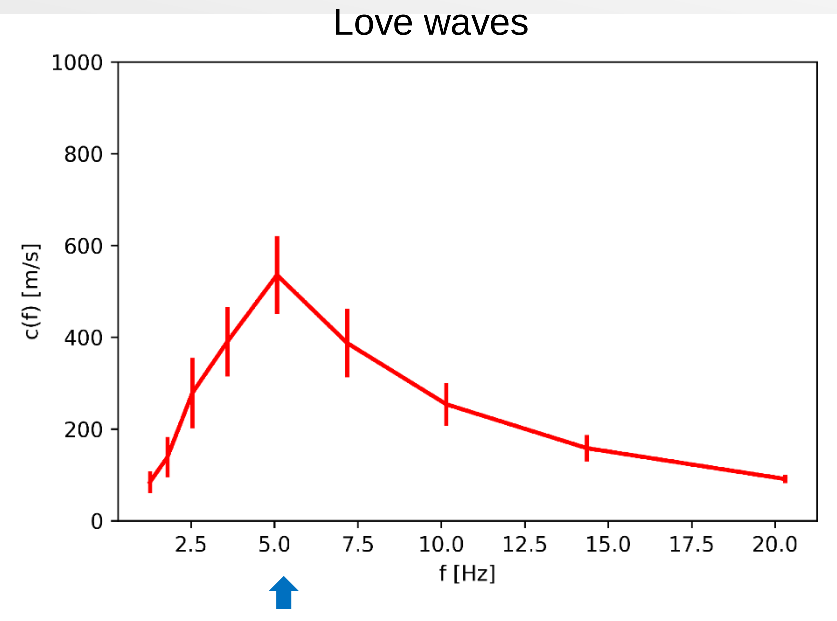


→ Phase velocities drop below 5Hz. Why?

Results – Dispersion curves

Power Spectral Density



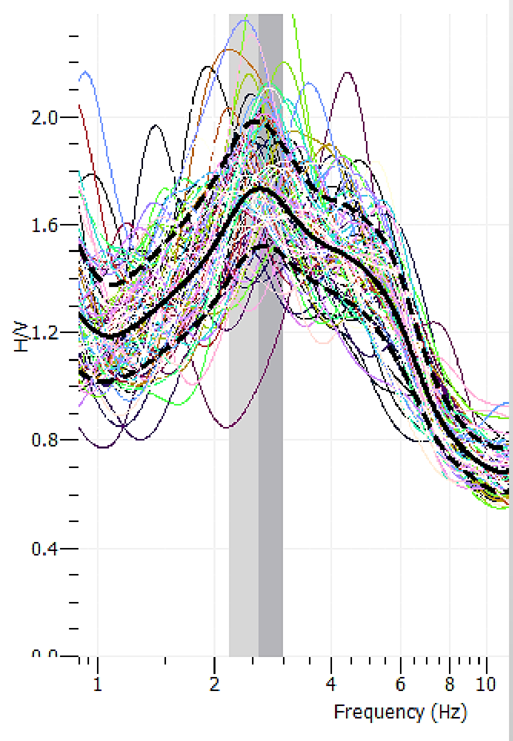


Self-noise level blueSeis ~ 30 nm/$s^2Hz^{-1/2}$

Below 5Hz the self-noise level of the rotational sensor is reached
→ rotation rates are too small to be recorded → dispersion curve drops

Results – H/V curve

Station SWMHK



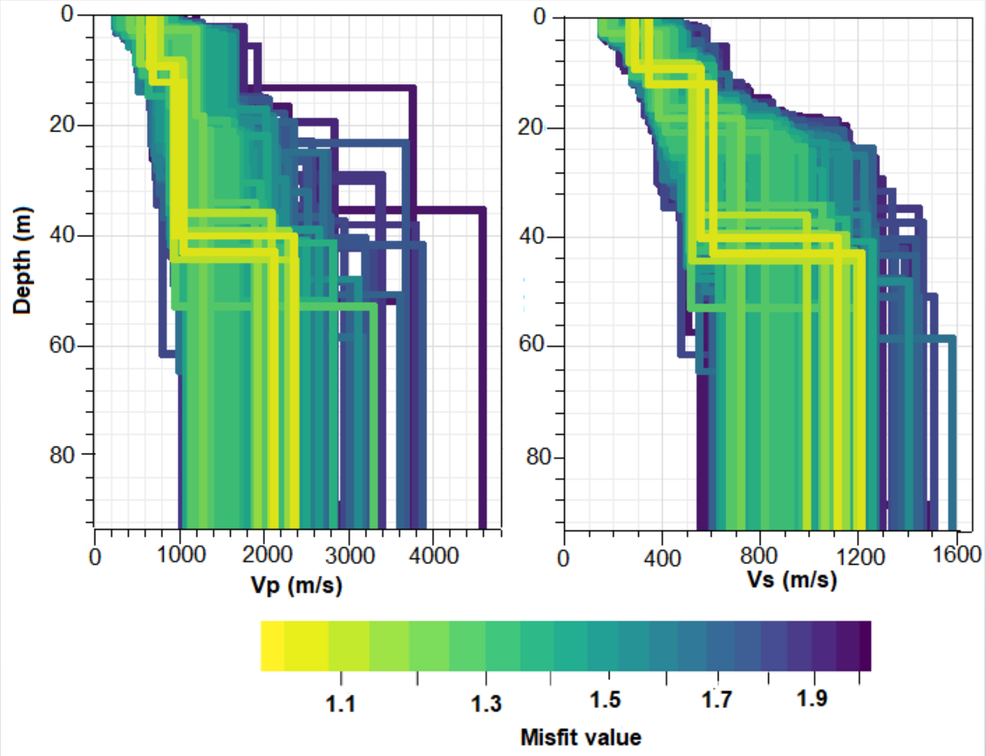
Compute H/V curve from the 3 translational components

→ Provides additional information in the lower frequency range

→ Inversion to greater depth possible

Results – Velocity profiles

Station SWMHK

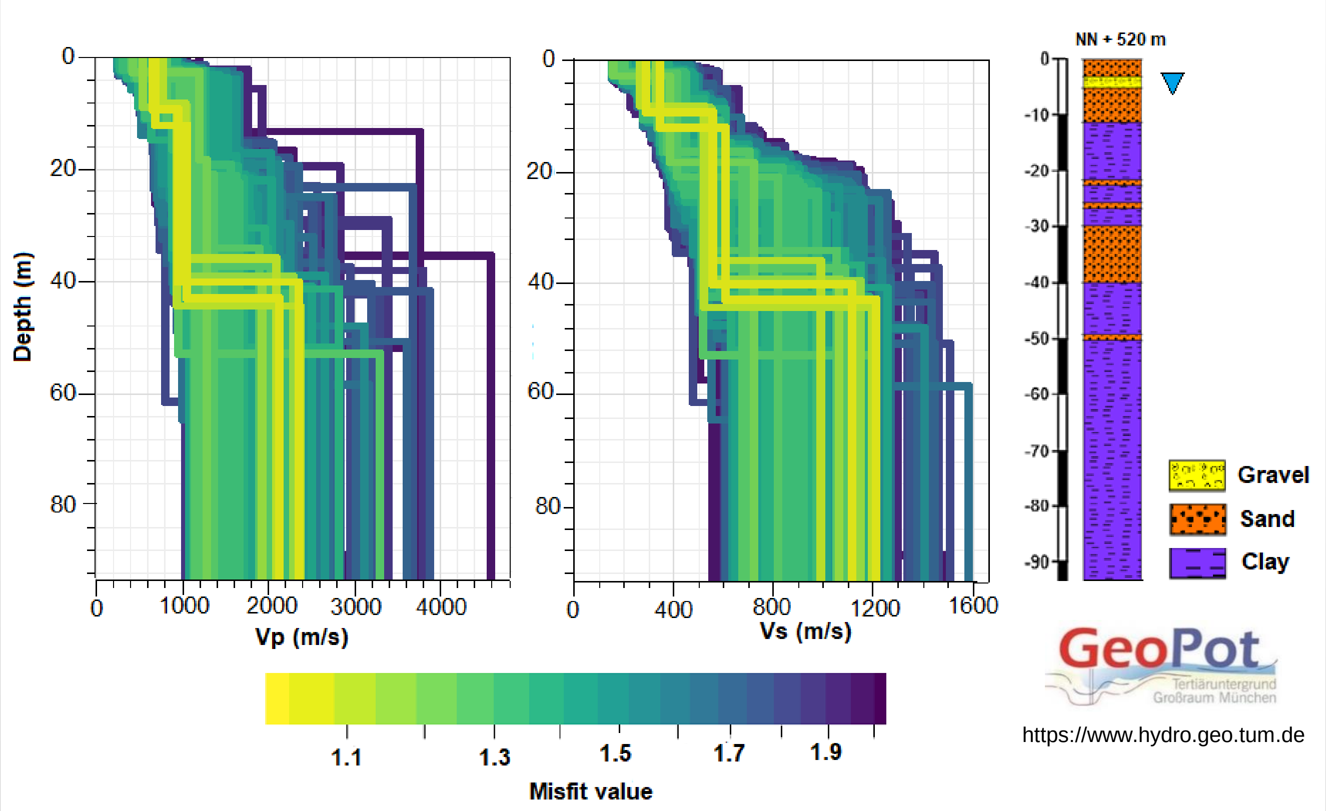


Inversion:

- Love + Rayleigh dispersion curve + H/V curve
- 3 layer model
- Vp linked to Vs
- GEOPSY software

→ Two velocity steps at ~ 10m and ~ 40m depth

Results – Comparison with Lithology



https://www.hydro.geo.tum.de

- Velocity jump at ~10m coincides with material change from sand to clay and groundwater table
- Velocity jump at ~ 40m coincides with material change from sand to clay
- Thin sandstone lenses cannot be resolved

Conclusions

- 6C measurements very convenient compared to array set-up
- Limitation in the lower frequency range connected to the noise source and/or the rotational sensor itself
- Complementation of the dispersion curves with H/V ratios allows inversion to greater depth
- Positive correlation between velocity profiles and lithology

References

Joachim Wassermann, Alexander Wietek, Celine Hadziioannou, Heiner Igel. (2016). Toward a Single-Station Approach for Microzonation: Using Vertical Rotation Rate to Estimate Love-Wave Dispersion Curves and Direction Finding. *Bulletin of the Seismological Society of America* ; 106.1316–1330.

Suryanto, Wiwit (2006). “Rotational Motions in Seismology, Theory and Application”. PhD thesis. Ludwig–Maximilians–Universität, München.

Sabrina Keil, Joachim Wassermann, Heiner Igel. (2020). Single-station Seismic Microzonation using 6C Measurements *(under Review)*