Study of Seismic Ambient Noise measured with Distributed Acoustic Sensing

on the KIT North Campus Telecommunication Network

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Karlsruhe Institute of Technology

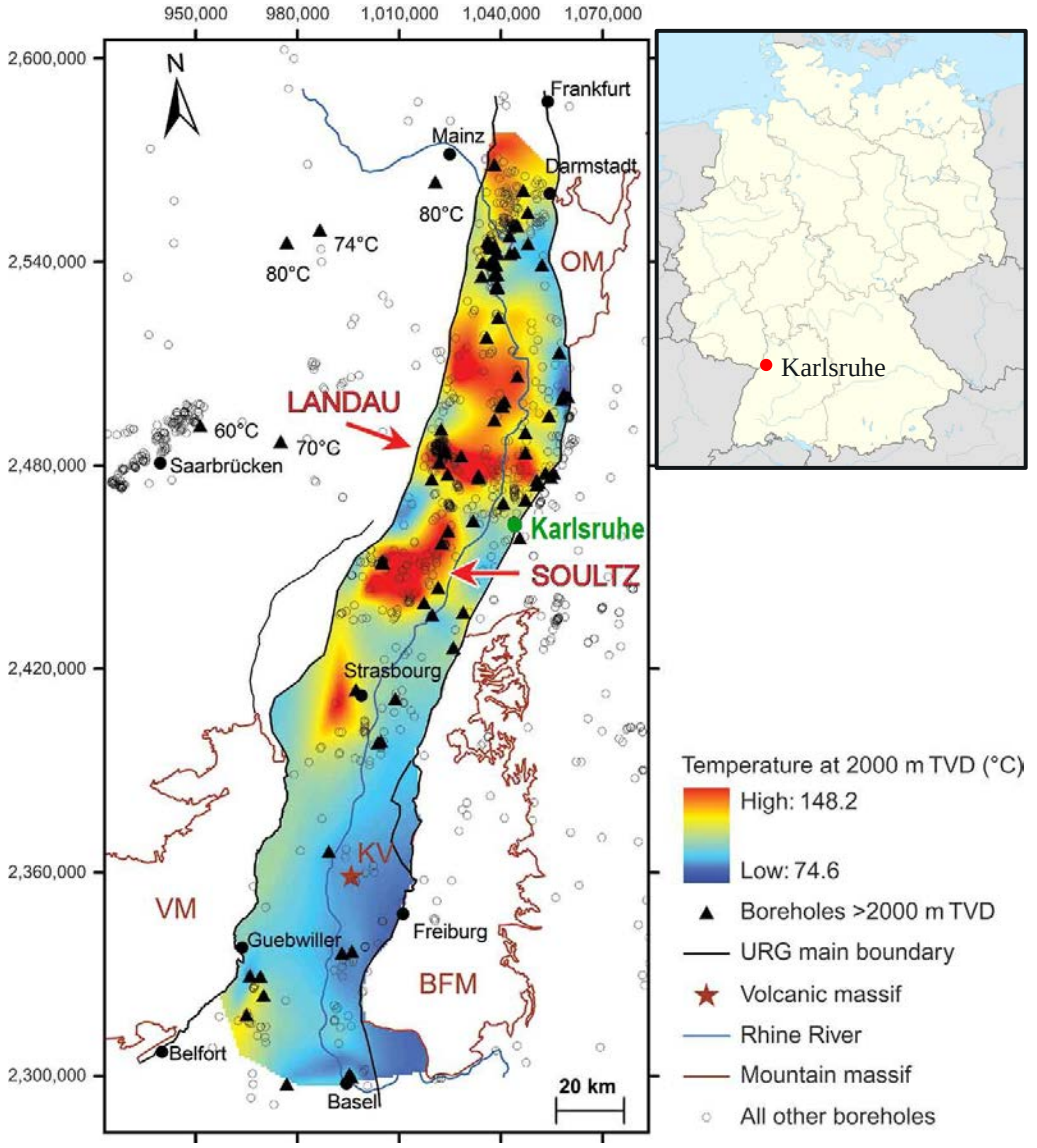
European Geosciences Union

Motivations and Objectives

DeepStor Research Infrastructure (KIT Campus North):

- High geothermal potential in Upper Rhine Graben
  - Major temperature anomalies
  - Ongoing geothermal plants
- Implement Aquifer Thermal Energy Storage on KIT CN
- Facilitate access to fiber optic network, operated by KIT
  - To apply fiber optic sensing technologies (DAS)
  - For monitoring seismic activity
  - For monitoring underground structures

What is achievable with ambient noise interferometry ?



Research Context

Access to a 3km fiber optic cable

Acquisition period:

- 8 months from March to October 2023
- 2 gaps: 12/08 to 23/08, and 20/10 to 23/10

DAS acquisition parameters:

- Channel spacing = 9.6 m
- Gauge length = 20 m
- Sampling rate = 500 Hz

Map of Karlsruhe with position of the fiber optic cable (orange) and planned DeepStor site (blue)

Zoom on KIT North campus

Passive Ambient Noise Interferometry

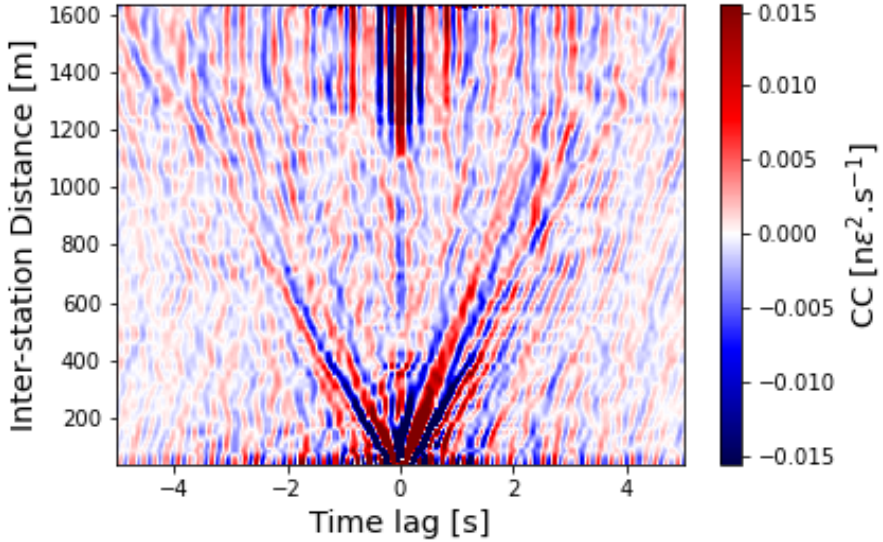
Multi-channel Analysis of Surface Waves (MASW)

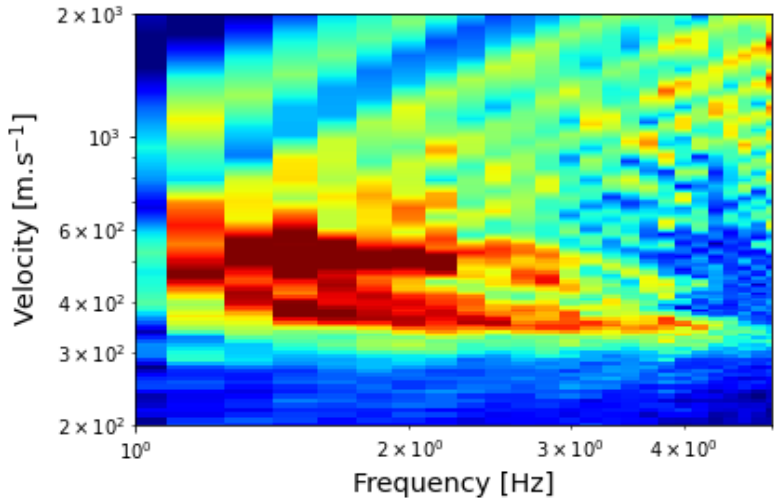
Data used for correlation:

- From 76 sensing points
  (around 1600m array aperture)
- 6 months of the study period
- Data selection to mitigate impact of anthropogenic sources on CN
  (before 6 am and after 8 pm local time)

Process using MSnoise (Lecocq et al. 2014):

- Standard preprocessing (Bensen et al. 2007)
  - Spectral whitening
  - One bit normalization
- Correlate 30mn long segments
- Filtering between 1 and 5 Hz





Virtual Shot Gather built with ambient noise correlations stacked over 6 months.

Dispersion spectrum computed in frequency-phase velocity domain.

Vehicles Detection and tracking

Preprocessing:

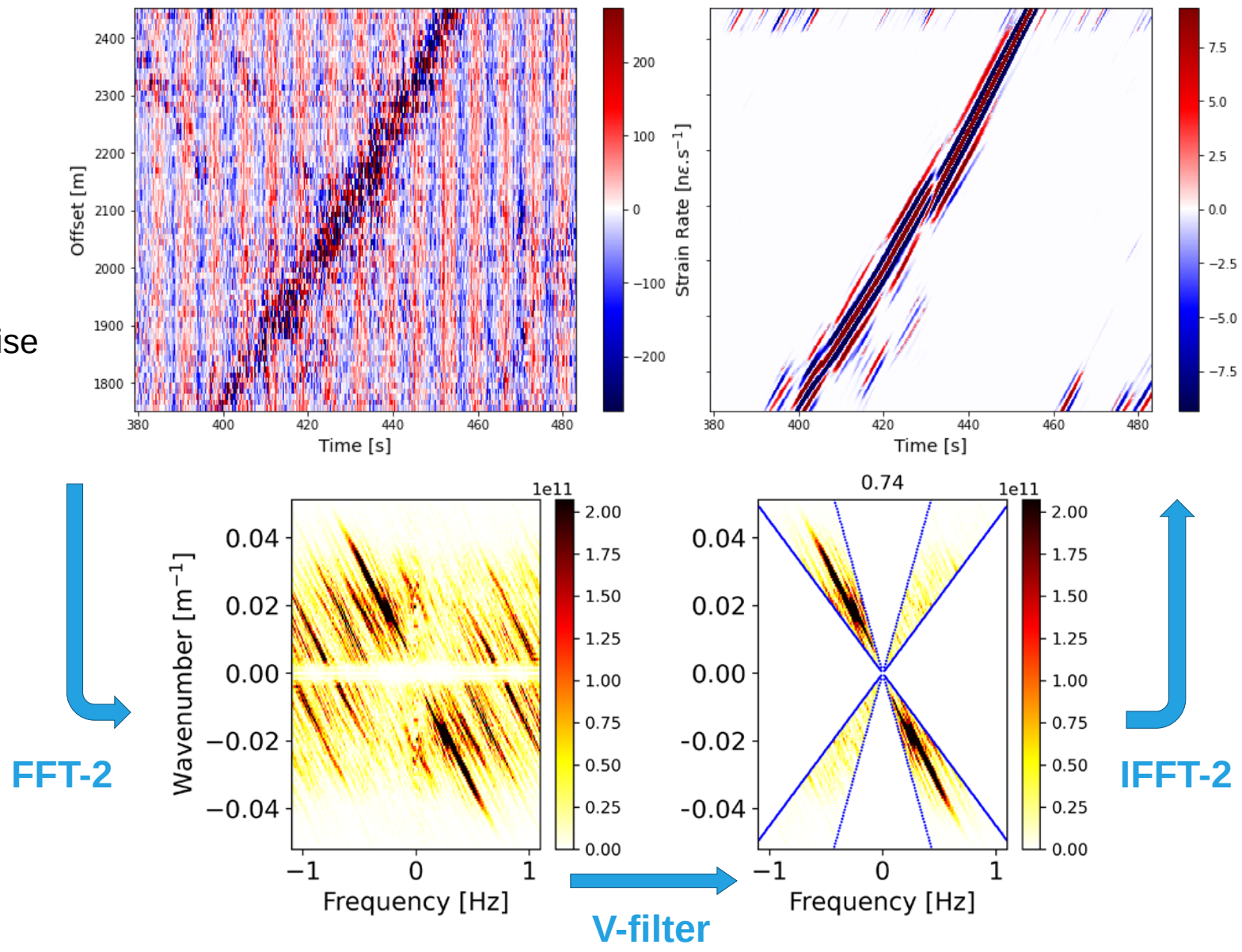
- Necessity of removing the common-mode noise
- Implementing a velocity filter in f-k domain

Detection and tracking algorithm:

- Adapted from (Yuan et al. 2024)
- Based on a Kalmann filter, allowing to track the trajectory

Results of detection:

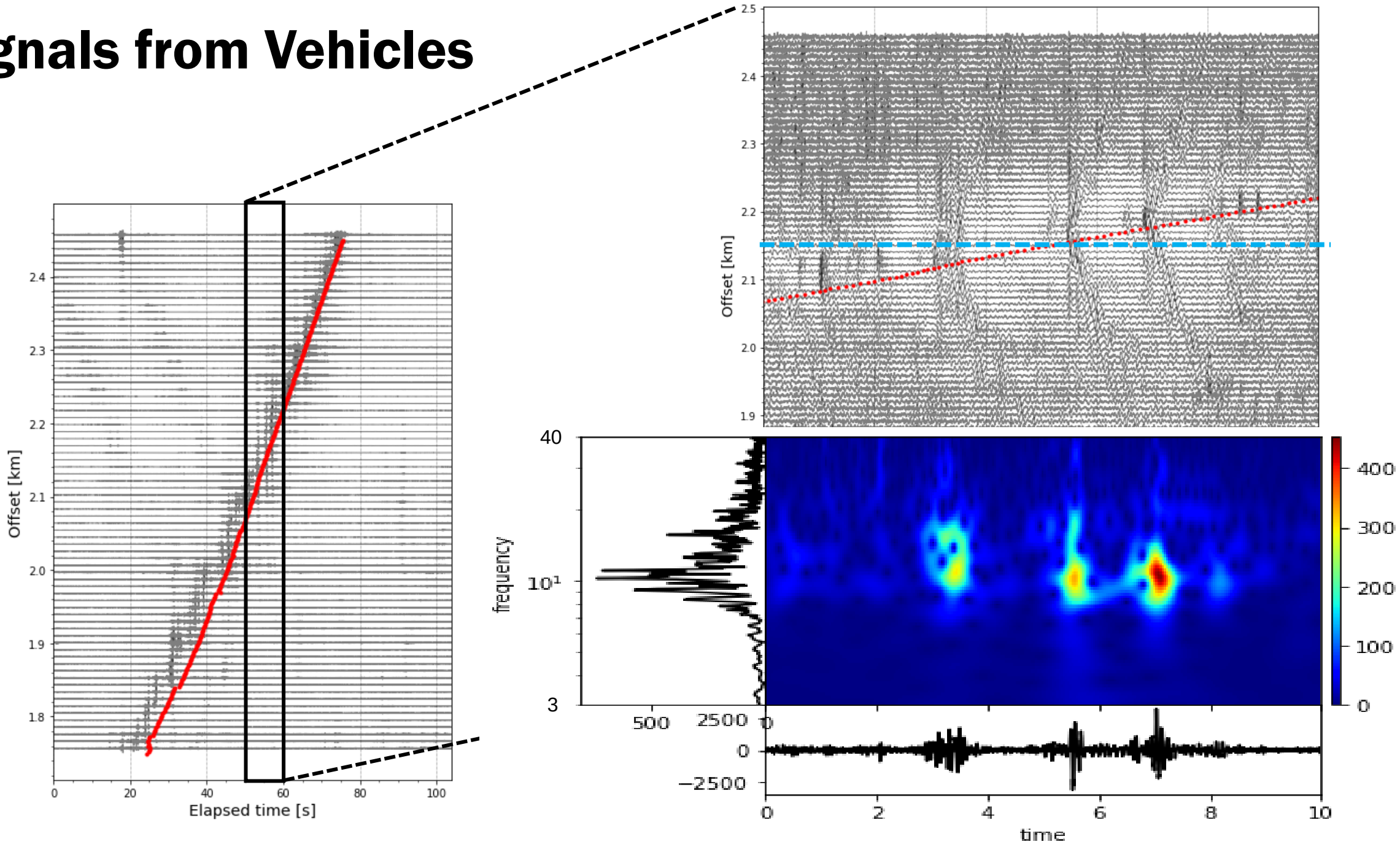
- Straight section along the main road
- 6126 detections for 3 months



Data window around a vehicle passage, before and after preprocess for tracking.

Same data window in (f-k) domain with illustration of the velocity filter.

Signals from Vehicles



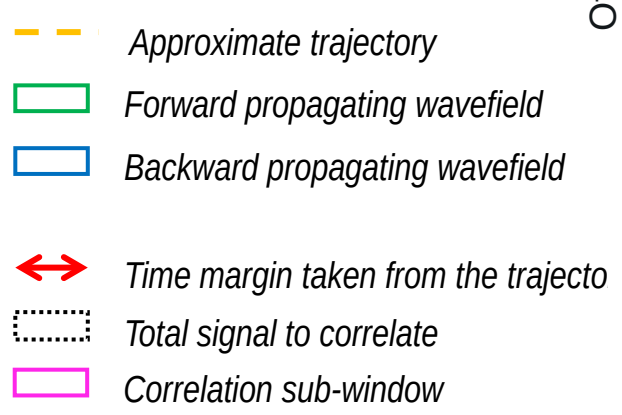
Vehicle Signals Correlation

Data window selection around estimated trajectory

Correlations calculated

- With respect to a pivot channel
- With segments defined from arrival time at pivot
- In 3 - 40 Hz frequency band with spectral whitening

Virtual Shot Gather (VSG) built from correlations



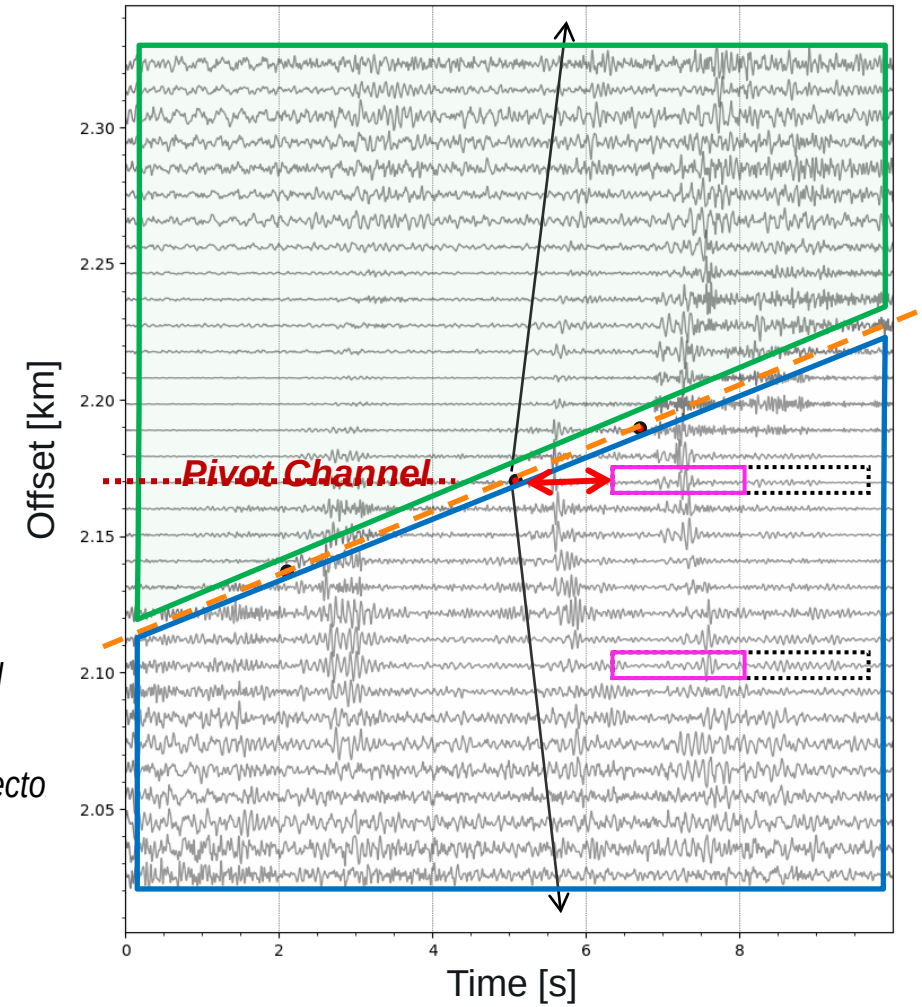
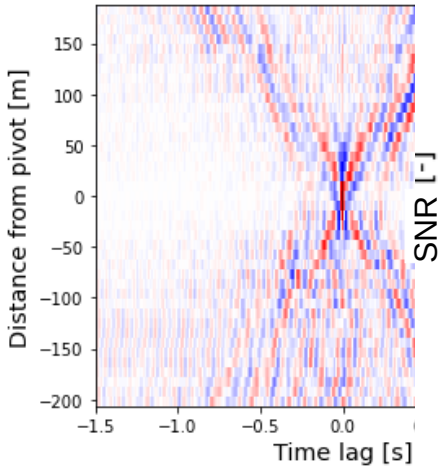


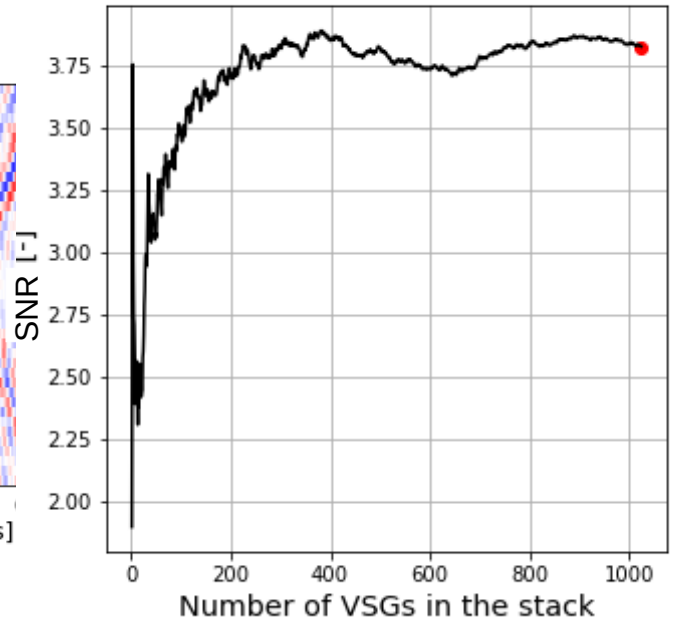
Illustration of the vehicle signal correlation process.

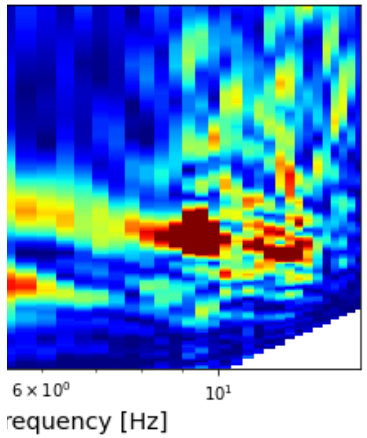
Active Approach using Vehicles

Postprocessing of VSG:

- Stacking
  - +1000 single VSGs used here
  - Signal for SNR between 200 and 1500 m/s

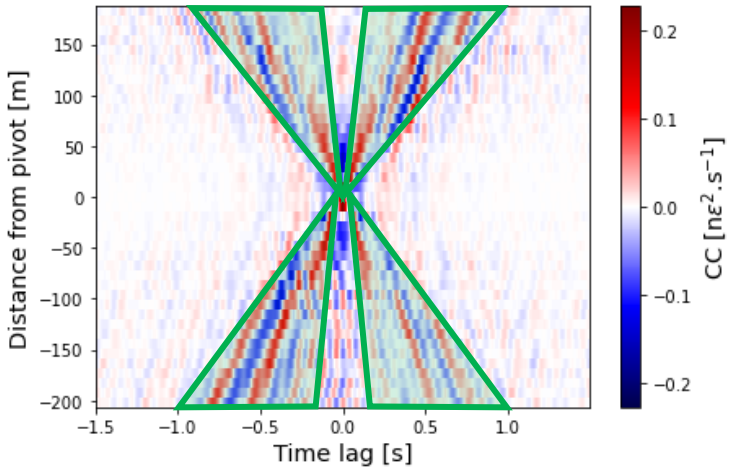


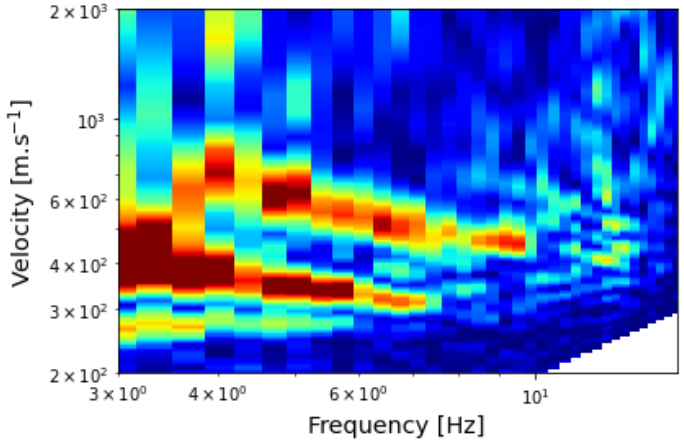




MASW for dispersion spectrum:

- Assessing the influence of processing steps
- Correlation of surface waves also possible in this case





VSG of vehicle signal correlations stacked for +1000 detections and corresponding dispersion spectra.

SNR curve of during the stacking process.

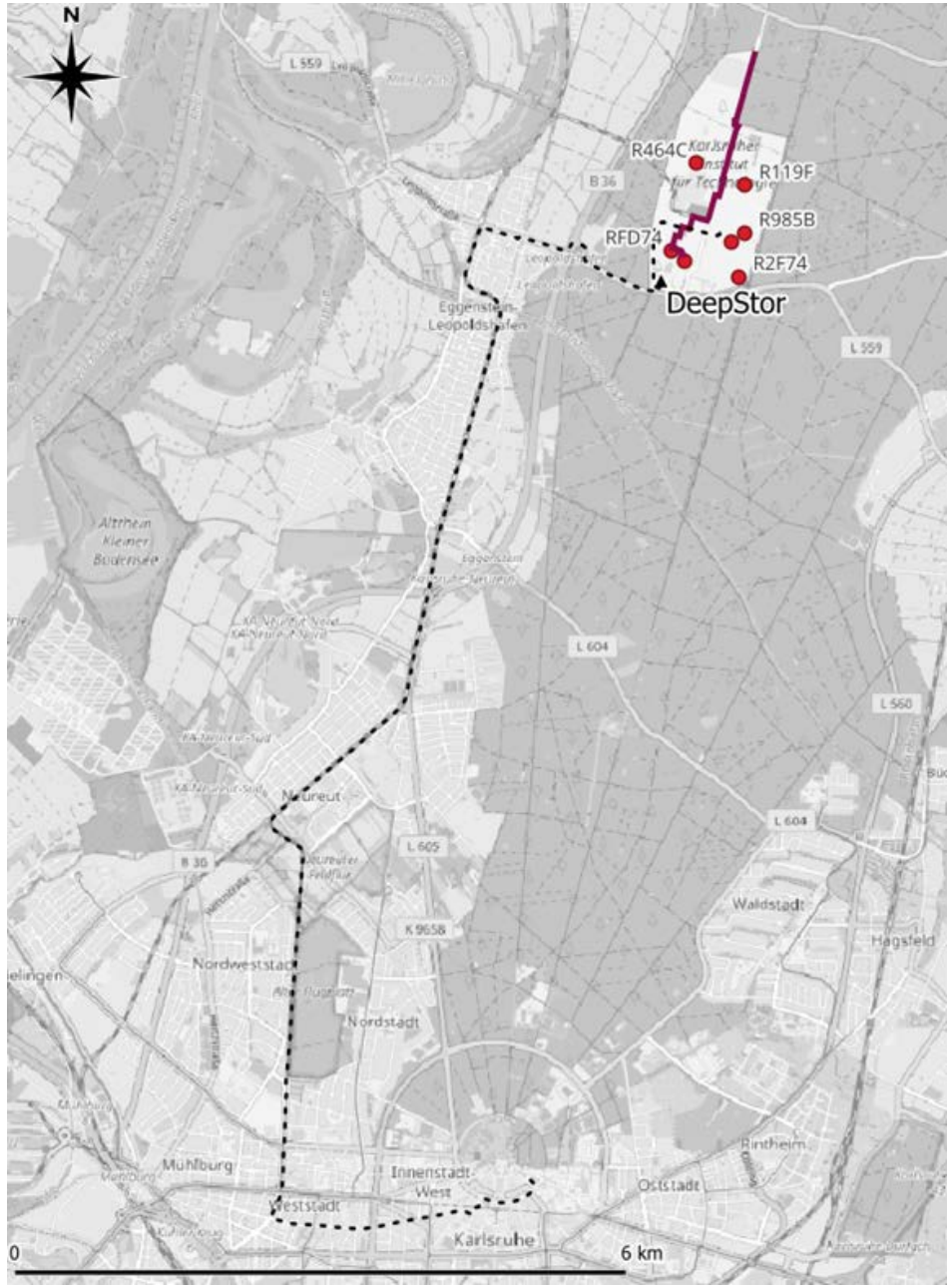
Conclusions and Perspectives

What could be done:

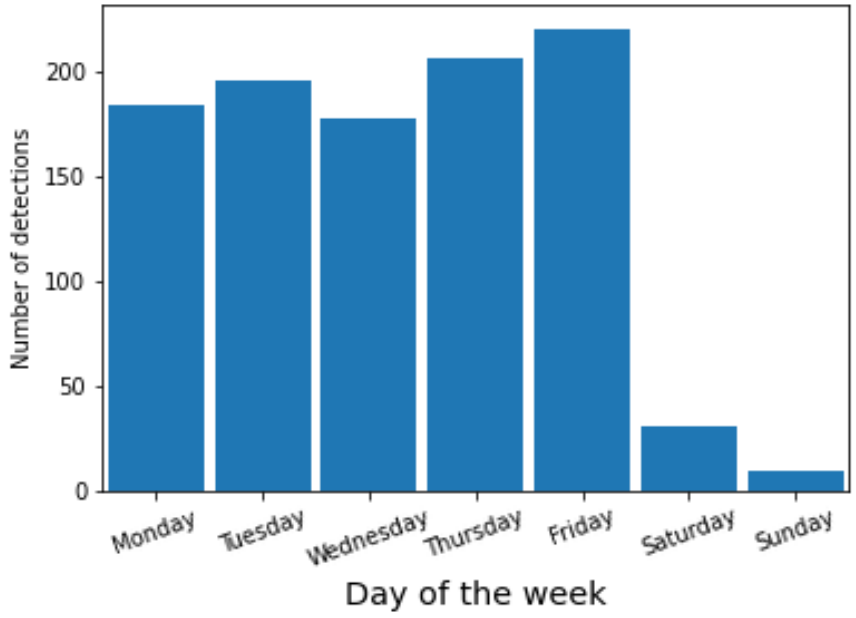
- Ambient Noise Interferometry on continuous DAS records
- Vehicles tracked and their signals correlated
- Both methods useful for MASW

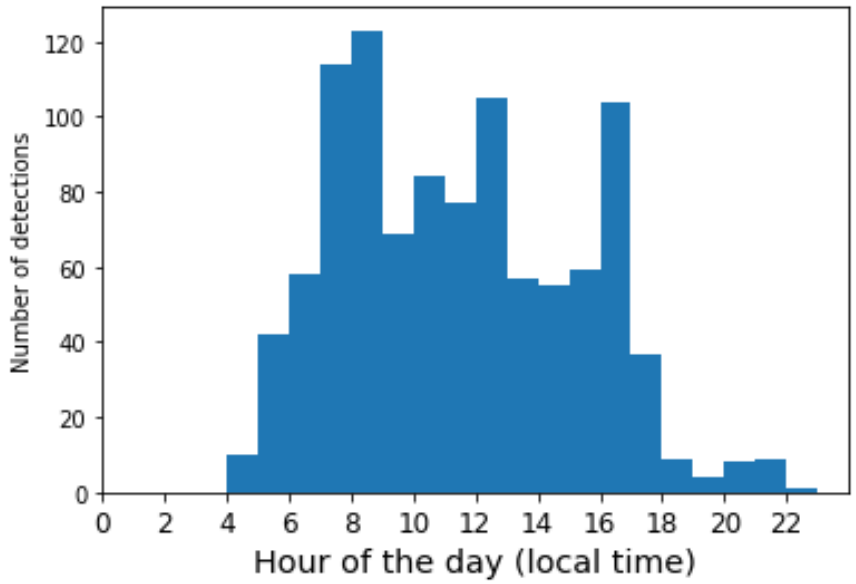
Follow-up work:

- Analysis of the spatio-temporal variations
  - Monitoring relative speed variations (Moving-Window Cross-Spectral analysis)
- Upscaling to longer Fiber Optic Cable
  - Possibility of tracking trains
  - Correlation of microseismic noise
- Inversion of shear wave velocity profiles



Map of Karlsruhe with new fiber optic cable location (dashed line)


Number of detections
200
150
100
50
0
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of the week


Number of detections
120
100
80
60
40
20
0
0
2
4
6
8
10
12
14
16
18
20
22
Hour of the day (local time)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