Exploiting vehicle-induced DAS signals on dark fiber for MASW and monitoring of temporal variations of near-surface ground properties

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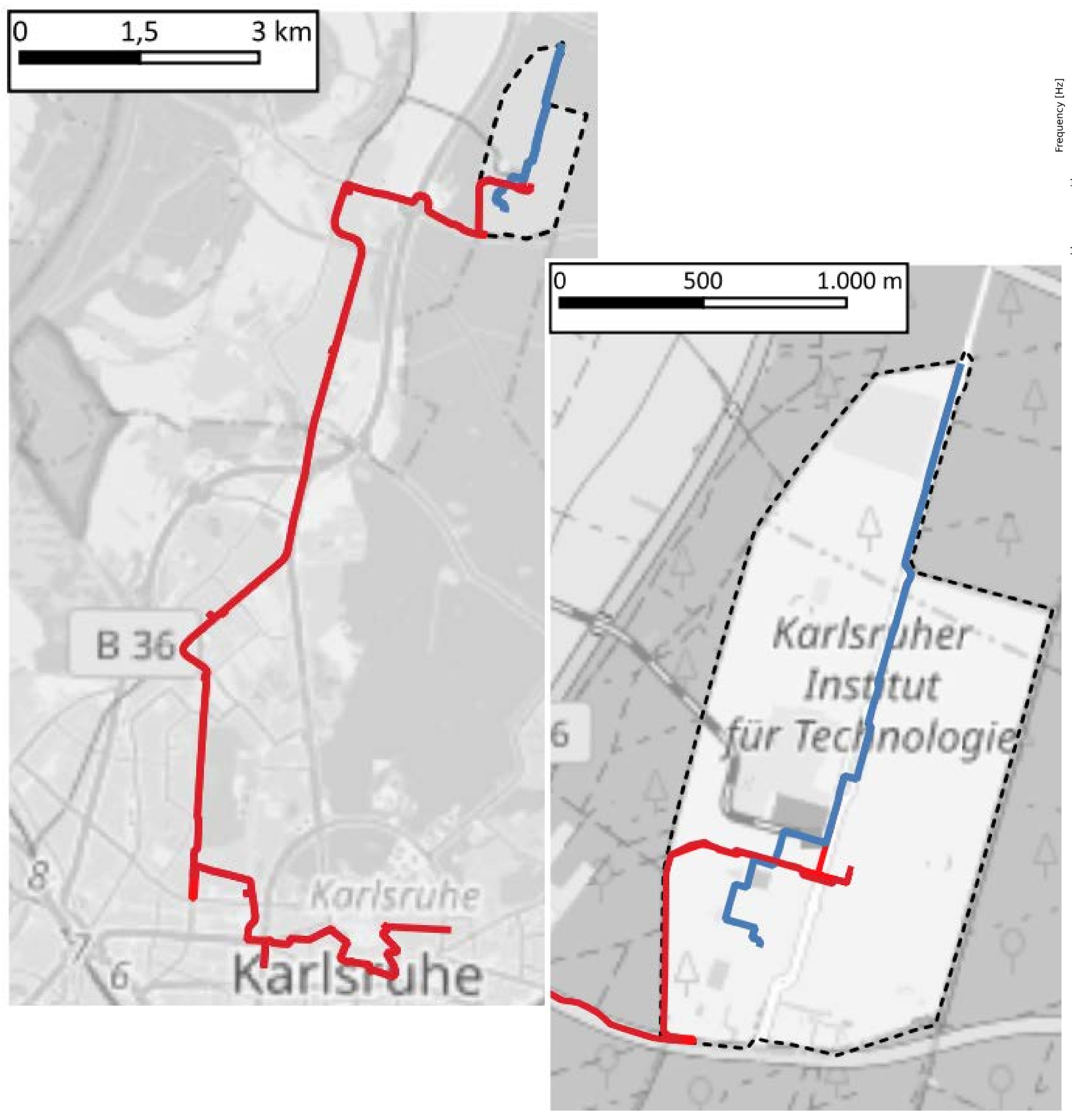
Sharing is encouraged

EGU26 GENERAL ASSEMBLY

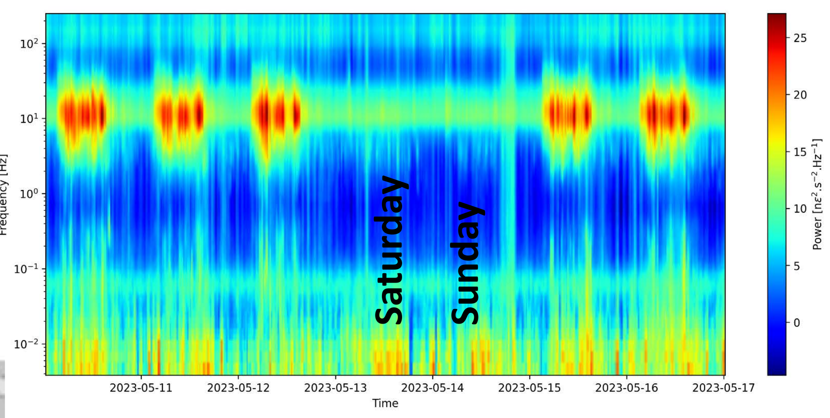
EGU26-5539

Research context and technical aspects

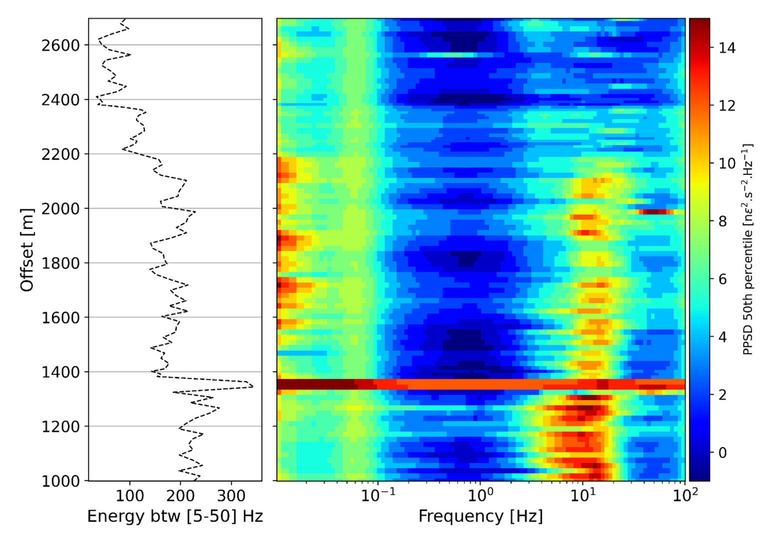
- 3 km FOC on campus → continuous from Feb. 23 → Nov. 23
- 22 km between campuses → from Nov. 24 → Jan. 26
- Follow major transport corridors



Spectrogram, one channel at 2000 m offset

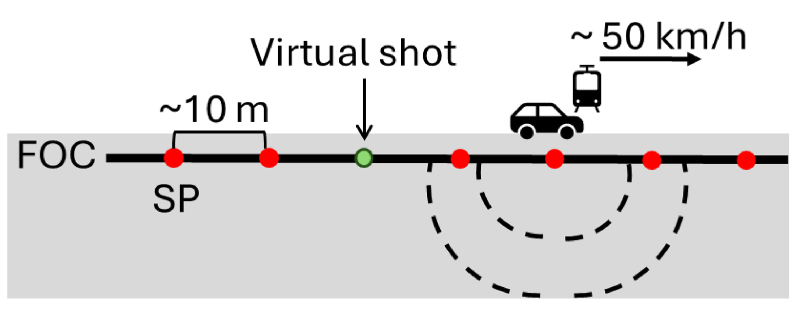


Median from PPSD on all channels of straight section and average energy

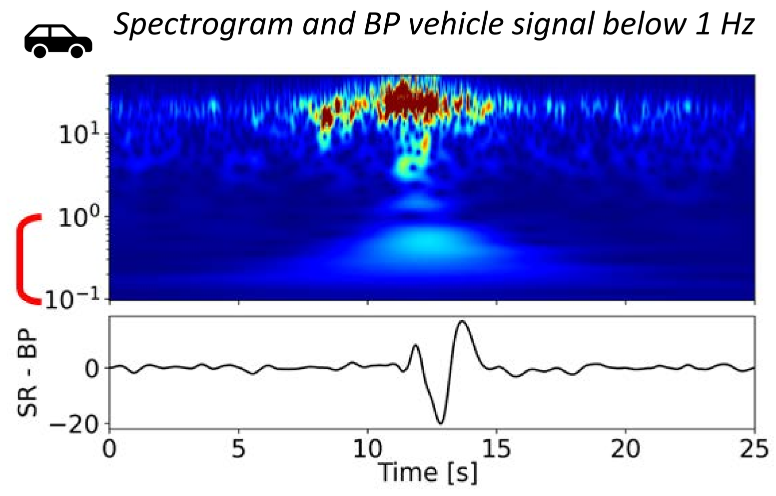


Observations

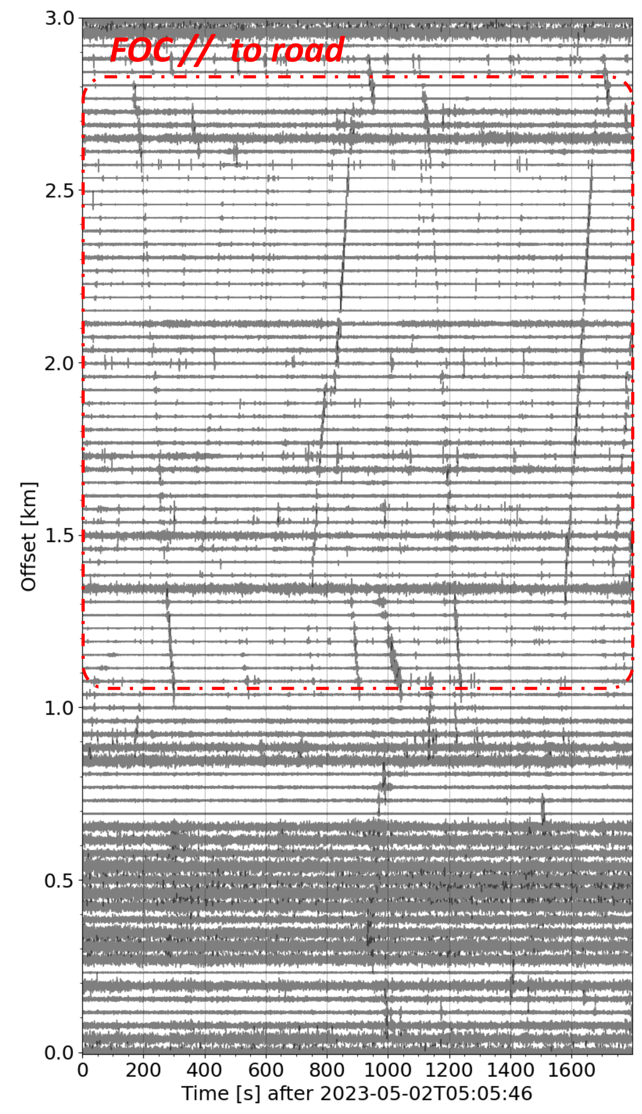
- Vehicles → "active" source of SW moving along the array
- Fiber optic cable is running parallel to transport corridors
- Clear and frequent patterns, useful for stacking



Spectrogram and BP vehicle signal below 1 Hz



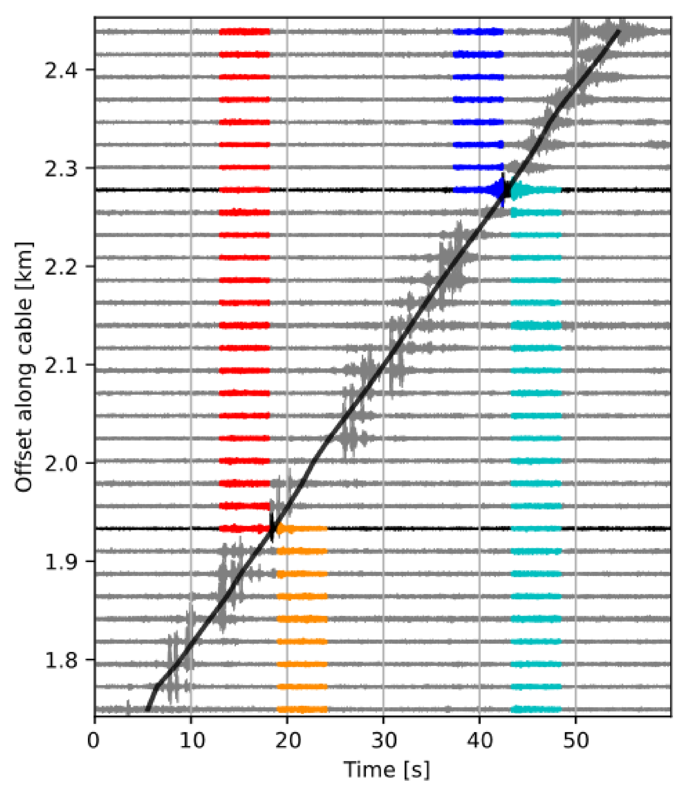
DAS Dataset from the KIT campus



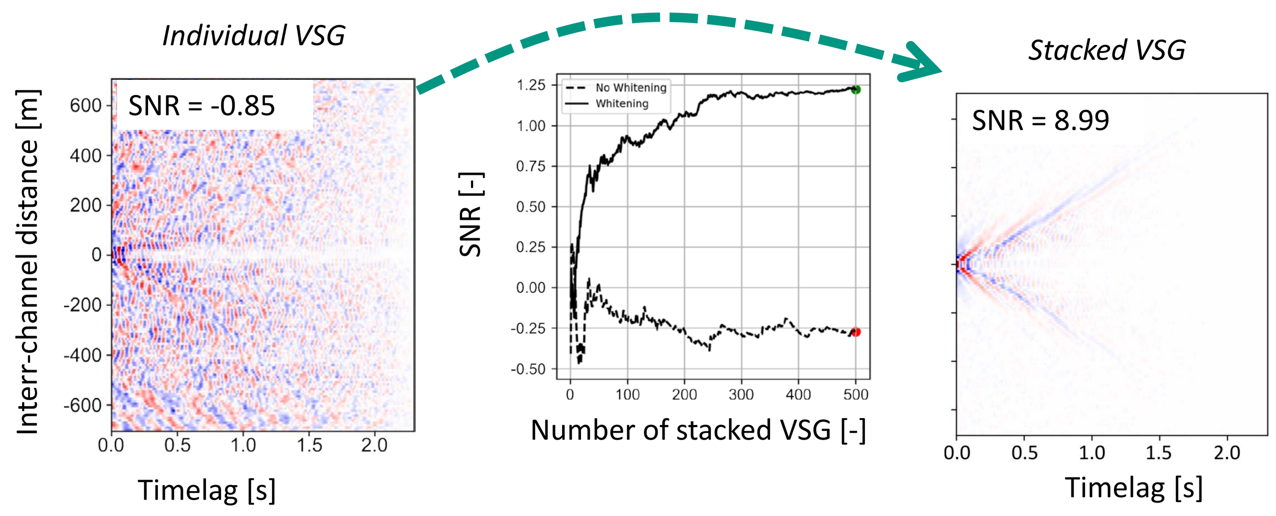
Workflow

- Detect, track, isolate vehicle signals (surface wave windows)

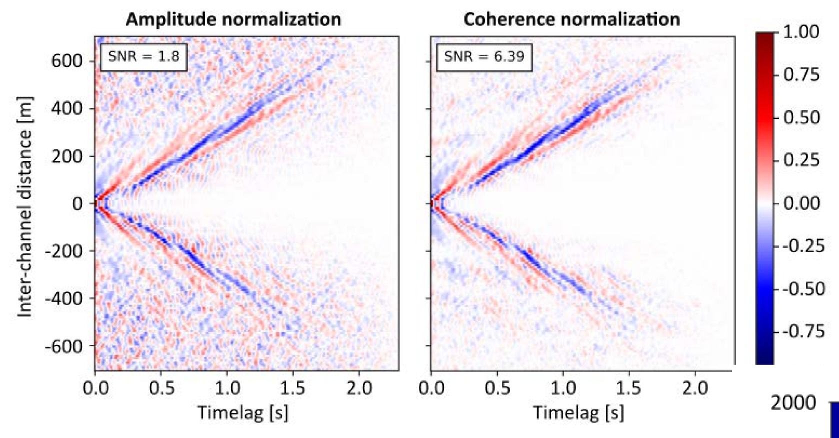
Tracked vehicle trajectory with correlation windows



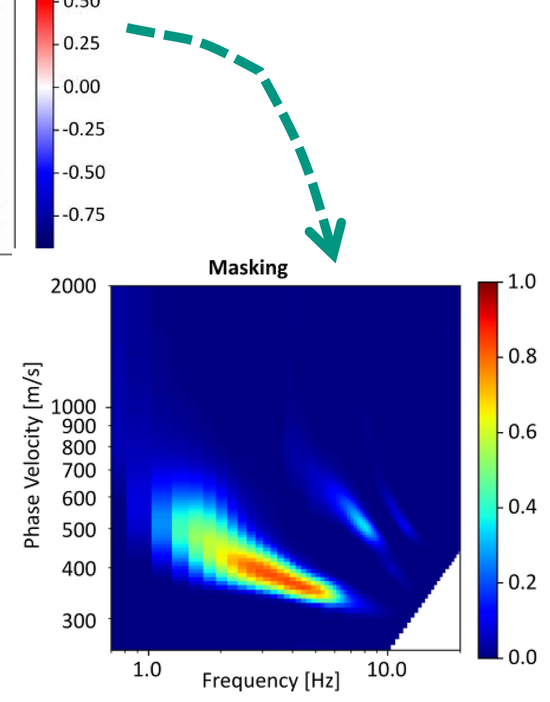
- SW windows processing, vehicle signal cross-correlation
- Virtual Shot Gather construction (1 VSG / vehicle passage)



- VSG post-processing (signal improvement, stacking)
- Dispersion spectrum computation



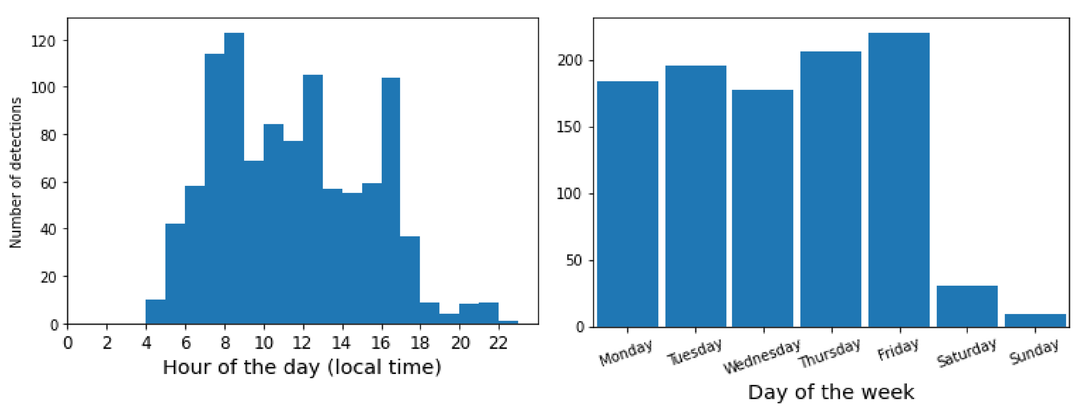
Coherence normalization: Reinforce coherent wavefield energy across the array by weighting data points by inter-channel coherence metrics.
Masking: Reinforces information in f-v spectra that is stable over varying array apertures.



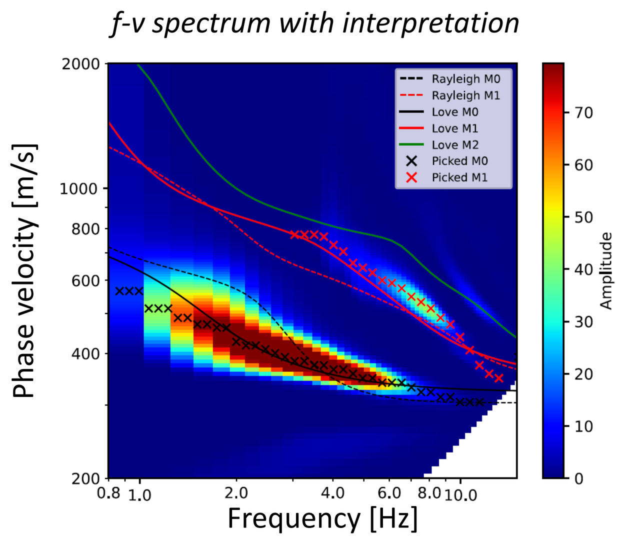
With car signals

- Detections / validated trajectories: temporal patterns are observed, with most detections occurring during weekdays, particularly around arrival/departure times and lunch breaks.
- Dispersion analysis: interpreted with forward modeling (*disba*), suggest predominant sensitivity to Love-wave dispersion?

Number of validated detections/trajectories over one week and one day



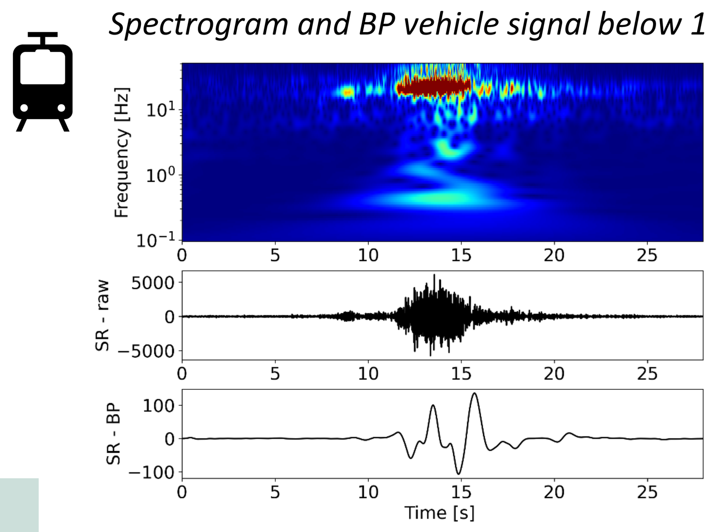
f-v spectrum with interpretation



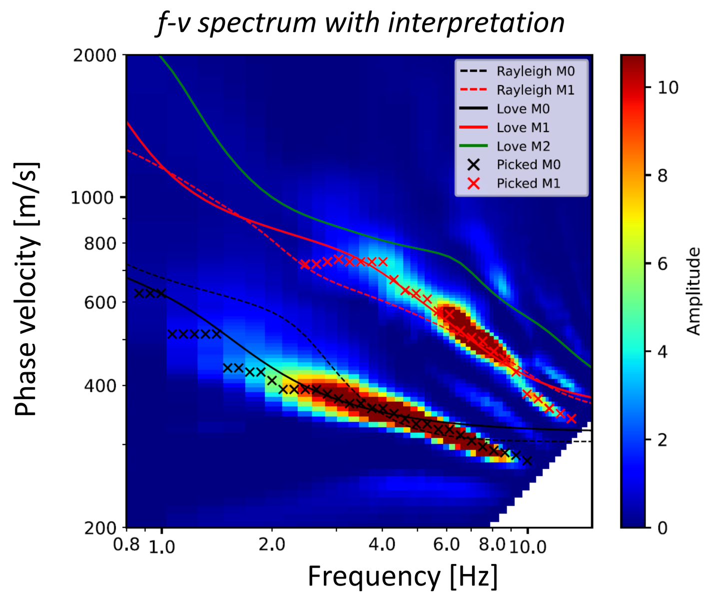
With railway signals

- Stronger signals: Higher energy levels, increased contributions at higher frequencies/higher modes.
- More complex wavefields: Contributions from multiple axles lead to overlapping wavefields and interference patterns.
- Adapted processing: Additional steps (e.g., masking) are applied to enhance the signal of interest and reduce artefacts arising from wavefield interference.

Spectrogram and BP vehicle signal below 1 Hz



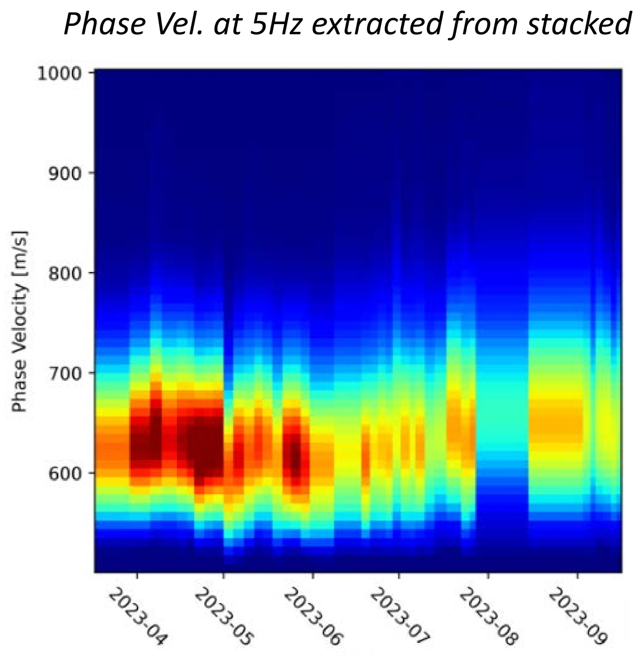
f-v spectrum with interpretation



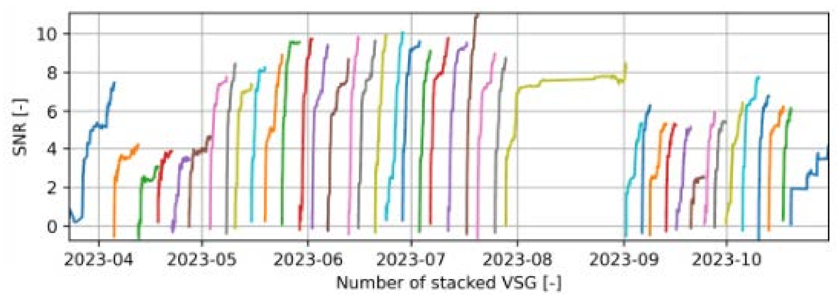
Temporal evolution of dispersion spectra (focus on car signals)

- Adaptive stacking: new stacks triggered by SNR increase to monitor temporal changes.
- Temporal trends: evolution of dispersion mode at fixed frequencies.
- Comparison with hydrological data to check possible environmental forcing

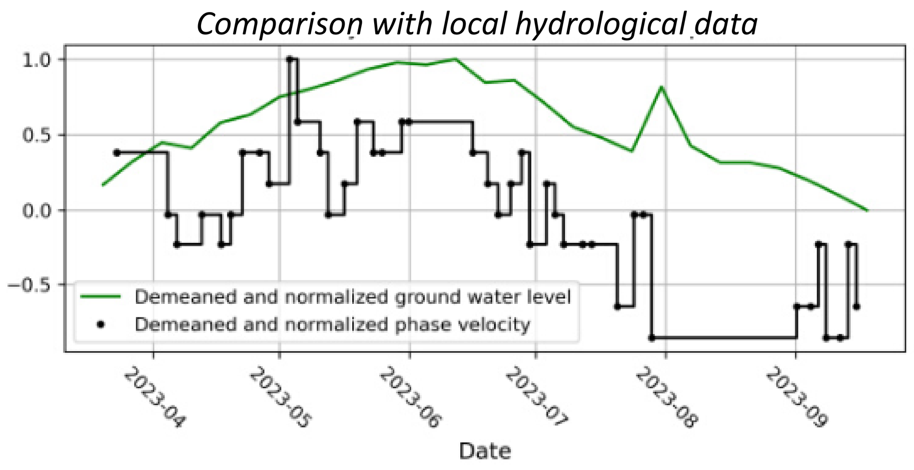
Phase Vel. at 5Hz extracted from stacked VSGs



42 stacks over 2023, 300 individual VSG each, gap in August



Comparison with local hydrological data



- MASW could be applied using vehicles as a source of SW recorded by DAS on dark-fibers
- Same formalism was tested on signals induced by road- and railway-traffic
- Temporal variations of dispersion trends at fixed frequencies and environmental forcing is explored
- **Interpretation**: Higher phase velocities are observed during periods of lower groundwater (GW) table, suggesting increased effective stiffness of the near-surface layers under drier conditions.
- **Perspectives**:
  - Upscaling the used fiber-link to regional coverage (10–100+ km).
  - Explore synergies with Ambient Noise Interferometry

This study is part of the subtopic "Geoenergy" in the program "MTET—Materials and Technologies for the Energy Transition" of the Helmholtz Association

Liu, J. et al.. (2025). Characterizing Vehicle-Induced Distributed Acoustic Sensing Signals for Accurate Urban Near-Surface Imaging. Seismological Research Letters, doi.org/10.1785/0220240344

Yuan, S.et al. (2024). Using Vehicle-Induced DAS Signals for Near-Surface Characterization With High Spatiotemporal Resolution. Journal of Geophysical Research: Solid Earth, doi.org/10.1029/2023JB028033