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# Fast near-surface imaging using Rayleigh wave ellipticities and velocities from three-component ambient noise beamforming

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Ambient seismic noise techniques are emerging as a complimentary tool to active seismic surveys for imaging subsurface velocities. However, questions about uncertainties and best practices of different processing schemes remain.

Most often beamforming or cross-correlation techniques are only applied to the vertical component. In studies of ambient-noise surface waves, it is assumed that only the Rayleigh wave is sampled since the Love wave is not polarized in the vertical direction. Recently, horizontal-to-vertical spectral ratios (HVSR) have been integrated into the analysis of surface wave dispersion curves to better constrain the depths and velocities of shallow structures. In this context, the HVSR curves are used to estimate the Rayleigh ellipticity.

Using three-component surface wave beamforming (3CFK) provides the advantage of obtaining the polarization, and hence the wave type, of recorded waves in addition to the wave velocity over a frequency range. Thus, Rayleigh and Love waves can be identified and distinguished from body waves resulting in more accurate dispersion curves. Furthermore, from the polarization parameters, the ellipticity of the Rayleigh wave may be recovered at the same frequency resolution as the Rayleigh wave phase velocities. Thus, the frequency at which the polarization of Rayleigh wave changes from vertical to horizontal can be directly determined. This frequency is related with the commonly observed phenomenon of intersecting Rayleigh modes in dispersion curves. Determination of this so-called osculation frequency helps distinguish the fundamental and higher-mode Rayleigh waves.

In this study, a synthetic three-component realistic ambient noise wavefield has been created and the application of HVSR and 3CFK has been investigated. Uncertainties of both methods are compared with the true velocities and depths. It can be shown that the depth of the first large impedance contrast can be calculated using the osculation frequency retrieved from Rayleigh ellipticity curves and Rayleigh velocities at frequencies smaller than the osculation frequency. This method has less deviations from the true depth than the typical relation using the peak frequency of HVSR curves and a quarter of the average shear velocity above the impedance contrast.

3CFK and HVSR are applied to field data from Weisweiler, Germany, to demonstrate the applicability of the method. In Weisweiler, 15 three-component stations were recording the ambient noise wavefield for 10 days in June 2021. The stations covered a total aperture of about 200 m.

The methodology presented here is especially suited for large three-component nodal networks. The depth of the first large impedance contrast, in dependence of the array geometry, may be mapped fast and efficiently without the need for costly inversion processes, a priori assumptions or additional information from wells.