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Singulated elastic Rayleigh wave modeling for ambient noise anisotropy studies

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The anisotropy of the subsurface can be theoretically derived by measuring the velocity of a seismic wave as a function of its propagation direction. To verify this an ambient seismic noise recording was simulated. We created synthetic seismograms consisting initially only of low-frequency Rayleigh waves to suppress superposition of other wave types and determined their direction and velocity.

The direction the wave comes from and the corresponding velocity give an idea about the anisotropy of the subsurface. In layered media the velocity of a Rayleigh wave depends on its frequency. Rayleigh waves with different frequencies penetrate the subsurface to varying depths depending on local material parameters and therefore vary in speed. Hence, using Rayleigh waves allows us to also investigate anisotropy as a function of frequency, or consequently depth.

Several forward elastic wave propagation simulations were performed using a finite difference scheme on a regular grid. Different source wavelets and simulation parameters were tested to produce low-frequency Rayleigh waves. The targeted frequency range was between 0.5 and 2 Hz. The aim of the forward simulations was to generate a clean Rayleigh wave without other disturbing wave types, multiples or boundary reflections. For this purpose a Rayleigh was cut out from a first simulation using two adjacent time steps and a spatial cosine filter. This Rayleigh wave can now be inserted in distinguished models to study the influence of heterogeneous structures on the seismograms. We estimated the accuracy of the approach by comparing it to analytically determined velocities. The overall goal is to model synthetic array data to systematically consider anisotropic structures with a three-component frequency-wavenumber analysis.

The method presented here allows the creation of an arbitrary singulated elastic Rayleigh wave. A multitude of anisotropic cases can be simulated with this wave by using different models and different directions for the incoming wave.