Geophysical Research Abstracts
Vol. 19, EGU2017-7529, 2017
EGU General Assembly 2017

The role of array design and noise source distribution in anisotropy monitoring with three-component frequency-wavenumber analysis

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We test the ability of an array technique called three-component frequency-wavenumber (fk) analysis to detect and monitor surface wave anisotropy within the ambient seismic noise wavefield. Our study focusses on the effect of an irregular network geometry and an anisotropic source distribution on the detected surface wave anisotropy.

Three-component fk analysis is an array technique closely related to beamforming and provides the propagation direction, the velocity at a given frequency, and the polarization of surface waves recorded at an array of seismic stations. Given that waves from different directions are detected, the method provides a direct measurement of azimuthal anisotropy of seismic velocities. As an example, we analyse an ambient noise data set recorded at a 36-station network in the Parkfield region, California (US), between November 2001 and April 2002, where we expect to see subsurface anisotropy associated with the San Andreas Fault and benefit from the Pacific Ocean as a strong and continuous, though directional, noise source.

Our results indicate significant and stable Love wave anisotropy in the frequency range between 0.2 and 0.4 Hz. However, testing the method on synthetic isotropic data, we show that the measured anisotropy can be affected by an apparent anisotropy: when plane waves coming from different directions are superimposed, both velocities and propagation azimuths recovered by fk analysis deviate slightly from the actual values. This effect is caused solely by the irregular geometry of the network and should be corrected. Further, for frequencies above and below the stable range, the noise source distribution seems to be more limited and subject to seasonal variations, which leads to apparent temporal variations in the detected anisotropy. We demonstrate the necessity of examining and understanding both effects for each array individually when deducing information about subsurface properties or processes from fk analysis.