Improving Estimates of the Empirical Green's Function Extracted from the Ambient Seismic Wavefield using an Eigenvalue Filter Based on Random Matrix Theory

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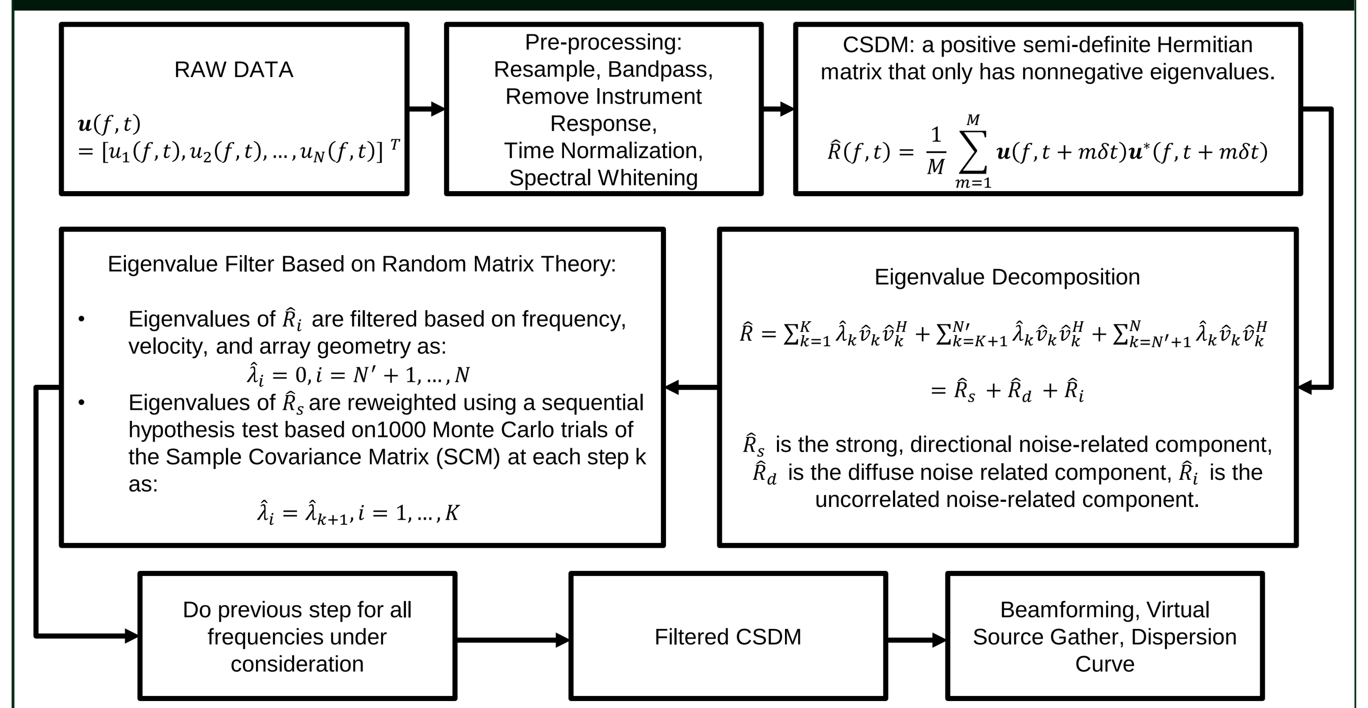
Introduction

- Retrieving reliable estimates of the empirical Green's function (EGF) using seismic interferometry (SI) requires a fully diffuse noise wavefield.
- The ambient seismic field in the real Earth does not typically satisfy this assumption, which interferes with the convergence of the EGF.
- We develop a practical, array-based, pre-processing technique to suppress strong, anisotropic signals, i.e., non-diffuse components of the ambient seismic wavefield.
- We then demonstrate the technique's application to datasets containing two different types of strong sources embedded in a background ambient seismic wavefield.

Methodology



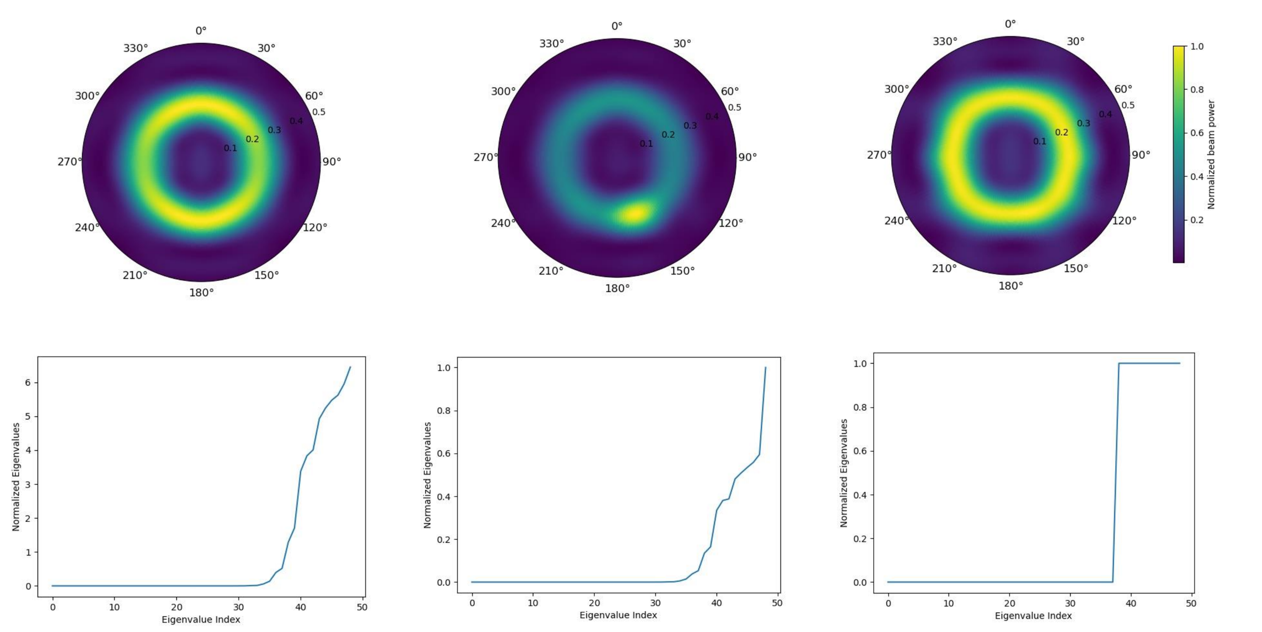


Figure 1. Eigenvalue filter applied to a synthetic source embedded in an idealistic 2-D isotropic seismic noise. We fixed the slowness s=0.25 s/km, and f=0.05 Hz. Lower panels show the covariance matrix eigenvalues and corresponding beamforming is presented in each case at the top.

Flexible Array Experiment and the M8.2 Earthquake ~ 93 km NW of Iquique, Chile

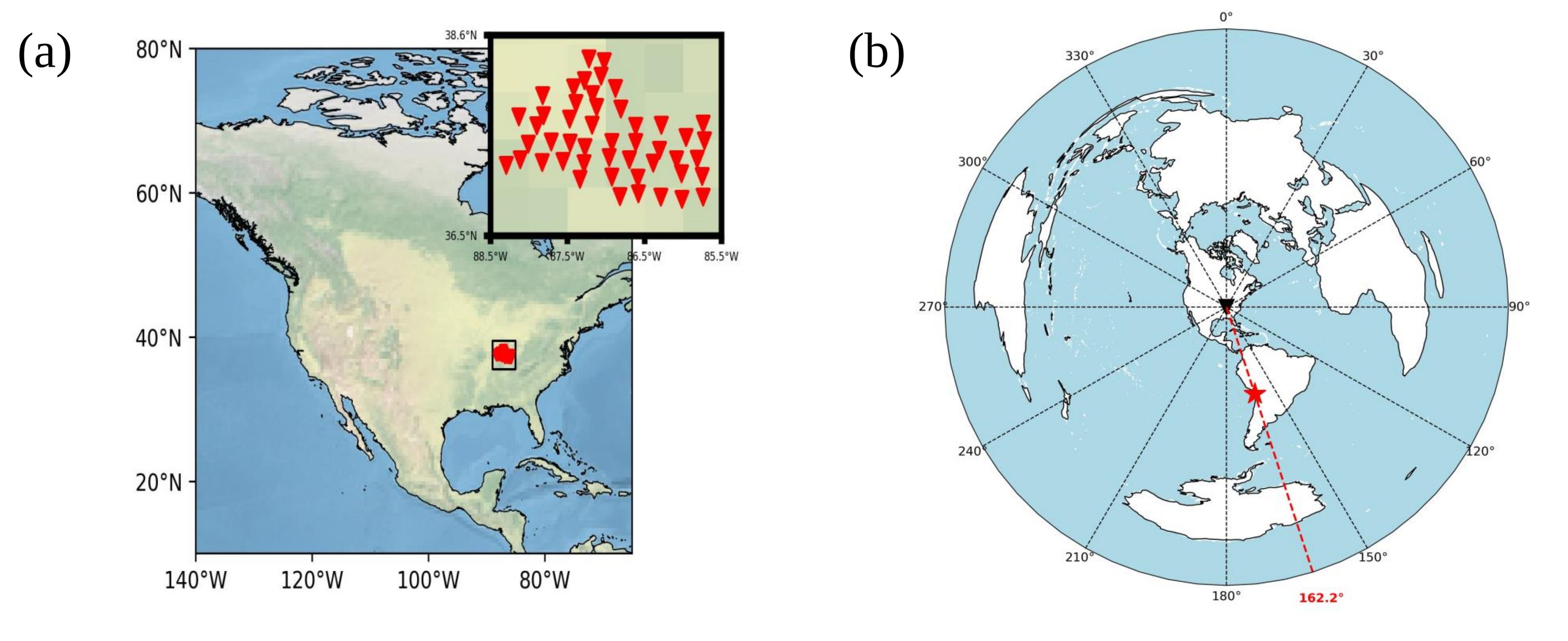


Figure 2. (a) 2011-2015 Ozark Illinois Indiana Kentucky (OIINK) Flexible Array experiment (Network Code: XO) centered on the Illinois Basin in the east-central United States. (b) Azimuthal global map centered on the XO array center (black triangle). The location of the M8.2 earthquake epicenter is shown with a red star at 162.2-degree azimuth from the XO array center. The M8.2 earthquake occurred on April 1, 2014, 93 km north-west of Iquique, Chile at 23:46:47 UTC (USGS Earthquake Search).

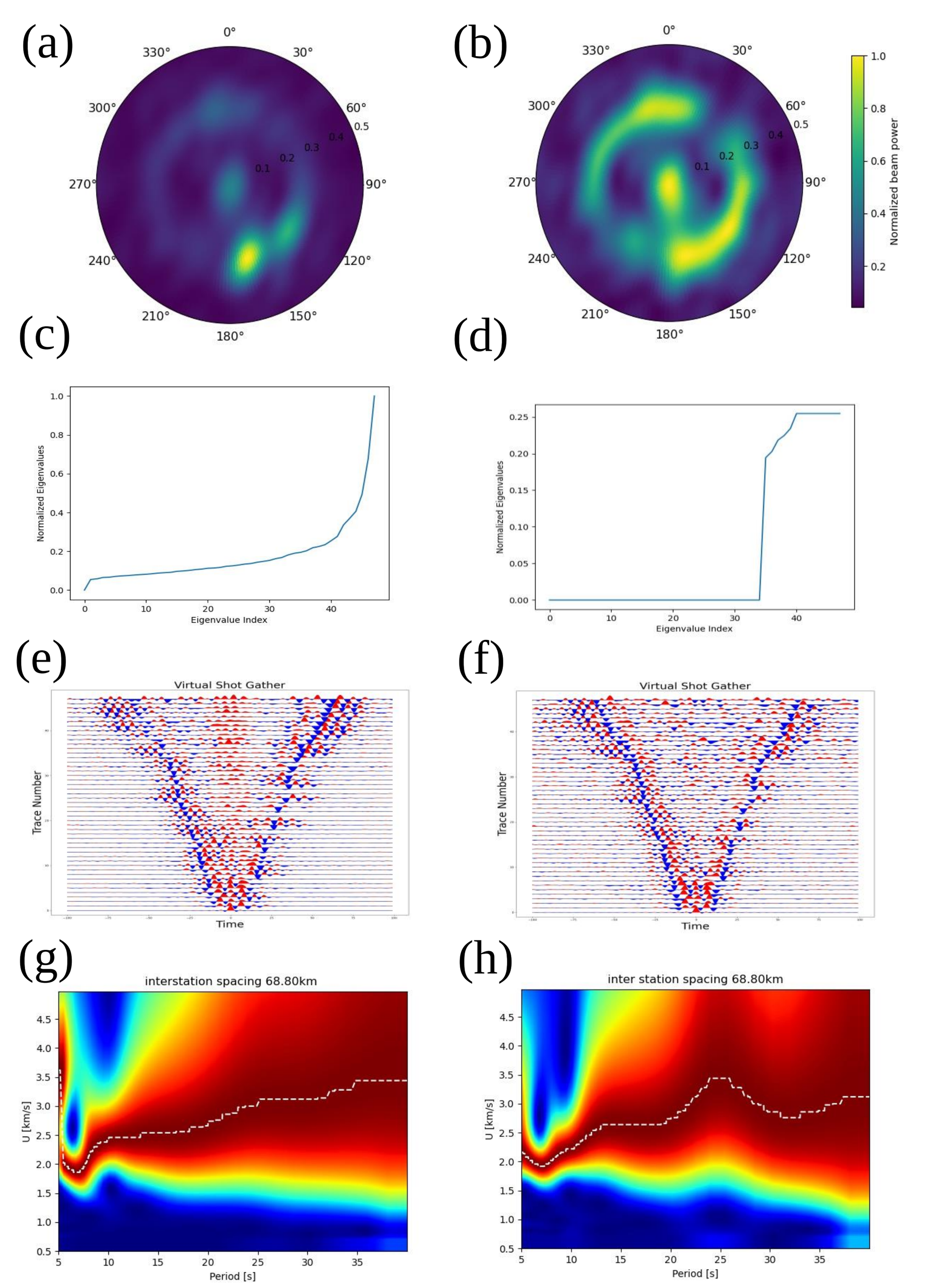
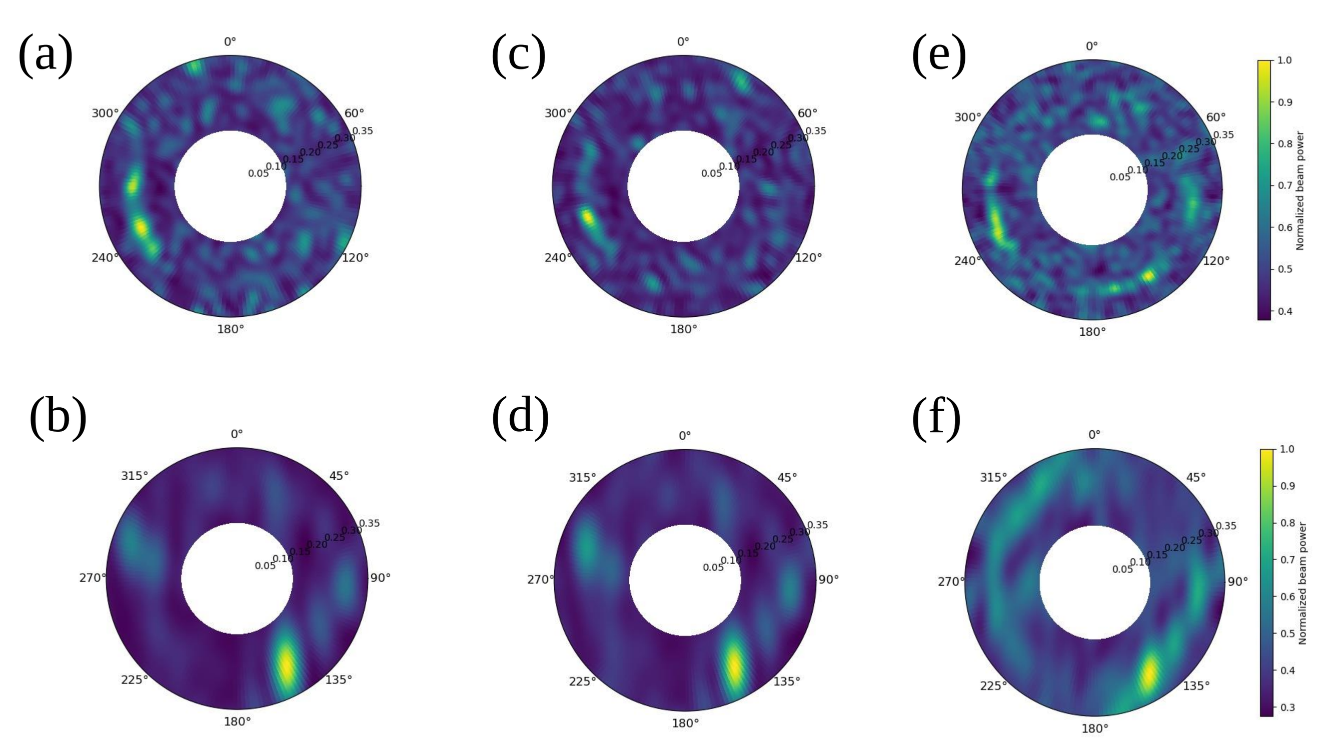


Figure 3. Eigenvalue filter applied to 2014 M8.2 earthquake. (a), (b) plane wave-based beamforming analysis before and after the application of filter. (c), (d) normalized eigenvalue distribution of before and after application of the filter. (e), (f) virtual shot gathers (VSG) band passed in frequency range 0.005 Hz to 0.2 Hz (before and after, respectively). (g), (h) surface wave group velocity dispersion curves obtained using a wavelet transform to trace the wave energy on multiple frequencies (before and after, respectively).

Enigmatic Microseismic Sources in the Gulf of Guinea and Application of Eigenvalue Filter to Primary Microseism Band



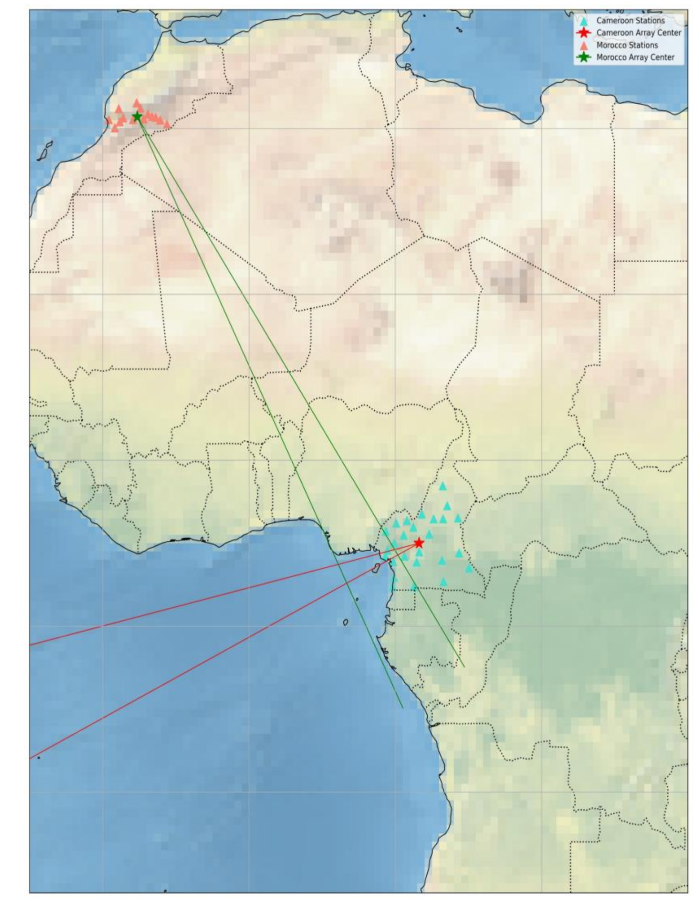


Figure 5. (left) Locations of seismic arrays in Cameroon and Morocco. The back-azimuth that corresponds to the maximum beam power from beamforming outputs of both arrays point towards Gulf of Guinea for the 26s microseism.

Figure 4. (up) Beamforming analysis of enigmatic sources including 28s microseism, 26s microseism, and gliding tremors associated with 26s microseism using data recorded by Cameroon array (CM) in 2006 and Morocco array (MM) in 2011. (a), (b) 28s microseism recorded by CM array and MM array, respectively. (c), (d) 26s microseism recorded by CR array and MM array, respectively. (e), (f) gliding tremors in frequency range 0.038 Hz to 0.05 Hz recorded by CR array and MM array, respectively.

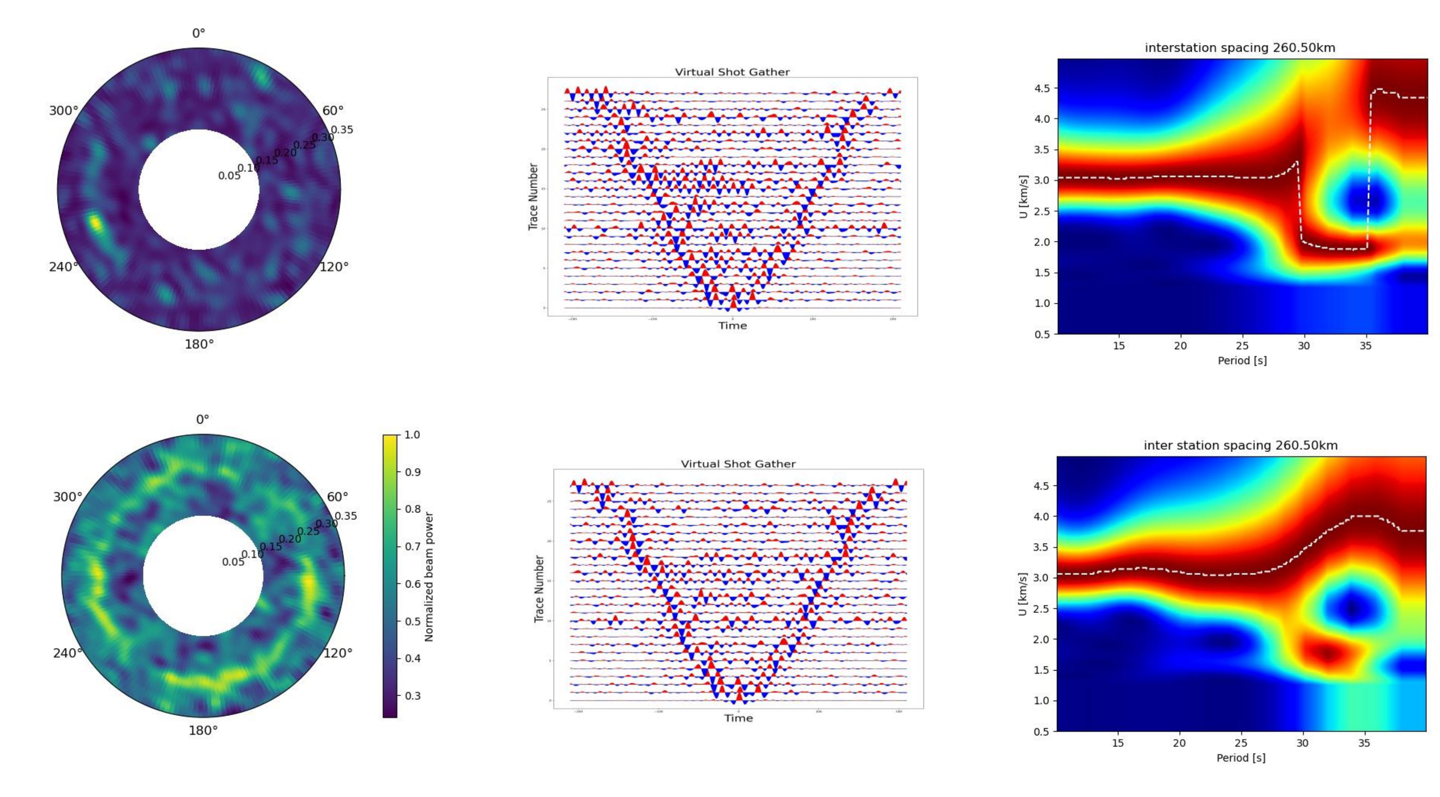


Figure 6. (right) Eigenvalue filter applied to primary microseism band using data recorded by Cameroon array in June 2006.

Conclusions

- We have developed a useful pre-processing approach that enhances the estimate of a Green's function from ambient seismic noise in the presence of strong seismic sources. Our approach efficiently suppresses the strong directional component of ambient seismic wavefield and reinforces the background diffused noise component of the wavefield.
- Applications of the filter demonstrate its ability to reduce both spurious coherent arrivals in the middle of the gather and the the asymmetry of the VSG.
- The filter increases the SNR of the VSGs, which further improves the measurement resolution of dispersion curves.
- Our method automatically defines the eigenvalue thresholds for the strong directional component and the non-propagating uncorrelated noise-related component based on the array geometry, frequency under consideration, approximate velocity structure beneath the array, and statistical properties of the 2D isotropic noise field.