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Source and processing effects on noise correlations

Andreas Fichtner
ETH Zurich, Department of Earth Sciences, Zurich, Switzerland (andreas.fichtner@erdw.ethz.ch)

We quantify the effects of spatially heterogeneous noise sources and seismic processing on noise correlation measurements and their sensitivity to Earth structure.

Our analysis is based on numerical wavefield simulations in heterogeneous media. This allows us to calculate inter-station correlations for arbitrarily distributed noise sources where – as in the real Earth – different frequencies are generated in different locations. Using adjoint methods, we compute the exact structural sensitivities for a given combination of source distribution, processing scheme, and measurement technique.

The key results of our study are as follows: (1) Heterogeneous noise sources and subjective processing, such as the application of spectral whitening, have profound effects on noise correlation wave forms. (2) Nevertheless, narrow-band traveltime measurements are only weakly affected by heterogeneous noise sources and processing. This result is in accord with previous analytical studies, and it explains the similarity of noise and earthquake tomographies that only exploit traveltime information. (3) Spatially heterogeneous noise sources can lead to structural sensitivities that deviate strongly from the classical cigar-shaped sensitivities. Furthermore, the frequency dependence of sensitivity kernels can go far beyond the well-know dependence of the Fresnel zone width on frequency.

Our results imply that a meaningful application of modern full waveform inversion methods to noise correlations is not possible unless both the noise source distribution and the processing scheme are properly taken into account. Failure to do so can lead to erroneous misfit quantifications, slow convergence of optimisation schemes, and to the appearance of tomographic artefacts that reflect the incorrect structural sensitivity. These aspects acquire special relevance in the monitoring of subtle changes of subsurface structure that may be polluted when the time dependence of heterogeneous noise sources is ignored.