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Generalised interferometry by correlation

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We develop a general theory for interferometry by correlation that (i) properly accounts for heterogeneously distributed sources of continuous or transient nature, (ii) fully incorporates any type of linear and nonlinear processing, (iii) applies to any type of medium with 3D heterogeneities and attenuation, (iv) enables the exploitation of complete correlation waveforms, including seemingly unphysical arrivals, and (v) unifies the earthquake-based two-station method and ambient noise correlations.

We demonstrate that processing transforms the actual wavefield sources and wave propagation into effective sources and wave propagation. The transformation is determined by the processing scheme, and can be easily computed. Forward modelling errors, induced by processing, describe the extent to which processed correlations can actually be interpreted as proper correlations, i.e. as resulting from some effective source and some effective wave propagation.

Using adjoint techniques, we derive sensitivity kernels for wavefield sources and Earth structure. The structure kernels depend on the sources of the wavefield and the processing scheme applied to the raw data. Therefore, both must be taken into account correctly in order to make accurate inferences on Earth structure.

Not making any restrictive assumptions on the nature of the wavefield sources, our theory applies to earthquake and ambient noise data, either separately or combined. This allows us (i) to unify the earthquake-based two-station method and noise correlations without excluding either of the two data types, and (ii) to eliminate the requirement to remove earthquake signals prior to the computation of noise correlation functions.

This work is intended to provide a comprehensive theoretical foundation of full-waveform interferometry by correlation, and to suggest improvements to current passive monitoring methods based on Green function retrieval.