Source-structure trade-offs in noise correlation functions in 3-D

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Noise correlation functions are shaped by both noise sources and Earth structure. The extraction of information is thus inevitably affected by source-structure trade-offs. Resorting to the principle of Green’s function retrieval deceptively renders the distribution of ambient noise sources unimportant and existing trade-offs are typically ignored. In our approach, we consider correlation functions as self-consistent observables. We account for arbitrary noise source distributions in both space and frequency, and for the complete seismic wave propagation physics in 3-D heterogeneous and attenuating media. We are therefore not only able to minimize the detrimental effect of a wrong (homogeneous) source distribution on 3D Earth structure by including it as an inversion parameter, but also to quantify underlying trade-offs.

The forward problem of modeling correlation functions and the computation of sensitivity kernels for noise sources and Earth structure are implemented based on the spectral-element solver Salvus. We extend the framework with the evaluation of second derivatives in terms of Hessian-vector products. In the context of probabilistic inverse problems, the inverse Hessian matrix in the vicinity of an optimal model with vanishing first derivatives and under the assumption of Gaussian statistics can be interpreted as an approximation of the posterior covariance matrix. The Hessian matrix therefore contains all the information on resolution and trade-offs that we are trying to retrieve. We investigate the geometry of trade-offs and the effect of the measurement type. In addition, since we only invert for sources at the surface of the Earth, we study how potential scatterers at depth are mapped into the inferred source distribution.

A profound understanding of the physics behind correlation functions and the quantification of trade-offs is essential for full waveform ambient noise inversion that aims to exploit waveform details for the benefit of improved resolution compared to traditional ambient noise tomography.