Seismic interferometry from correlated noise sources

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It is a well-established principle that cross-correlating seismic observations at different receiver locations yields new seismic responses that, under certain conditions, provide a useful estimate of the Green's function between the given receiver locations (that is, the medium response at one receiver location, had there been an impulsive source located at the other receiver). This principle, known as seismic interferometry, is a powerful technique that transforms previously discarded data such as seismic codas or background noise into useful signals that allow us to remotely illuminate subsurface Earth structures.

In practice it is often necessary and even desirable to rely on noise already present in the environment, since this type of seismic energy is freely and widely available in many regions around the globe. Across many applications of ambient noise interferometry there exists a persistent assumption that the noise sources in question are uncorrelated in space and time, and that energy arrives at the receiver array more-less equally from all directions. That this assumption is so tenaciously made comes as no surprise since the underlying theory unambiguously requires that the noise sources be uncorrelated for interferometry to work.

However, many real-world noise sources such as trains or highway traffic are inherently correlated both in space and time, in direct contradiction to these theoretical foundations. Violating the uncorrelatedness condition makes the Green's function and associated phases liable to estimation errors that so far have not been accounted for. We show that these errors are indeed significant for commonly used noise sources, in some cases completely obscuring the phase one wishes to retrieve. Furthermore, we perform analysis that explains why stacking has the potential to reduce these errors in the interferometric estimate, as well as some limitations of this approach. This analytical insight allowed us to develop a novel workflow that mitigates or even completely removes the spurious effects arising from the use of correlated noise sources. Our methodology can be used in conjunction with already existing approaches, and hence we expect it to be widely applicable in real life ambient noise studies.