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On the role of scattering and reverberation in seismic interferometry

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The ensemble-averaged ambient wave field observed on Earth is approximately diffuse, and it is precisely this property that makes ambient-noise interferometry valid within approximation. How close is ambient noise to being exactly diffuse? What features of the Earth (coupling between oceans and solid Earth, scattering by crustal heterogeneities...) contribute to its randomness and complexity? It is necessary to understand the roles of scattering and reverberation, to determine the range of applicability of seismic interferometry.

Studies of cross-correlation of late coda in earthquake data, conducted mostly by the Grenoble group, emphasize the contributions of scattering in the interferometric reconstruction of Green functions. Yet, other authors like R. Snieder and co-workers point to the limitations that the presence of a complex (scattering) structure introduces: they have noted, in particular, that although direct surface waves are accurately extracted by interferometry, examples of the reconstruction of scattered waves are still lacking.

We analyze the cross-correlations of diffuse flexural waves, generated by an air nozzle shooting compressed air on a 1-square-meter aluminum plate, and recorded by two accelerometers on the plate. Flexural waves are dispersive, thus reproducing one of the main characteristics of surface waves observed on Earth. The aluminum plate is pierced by 500 randomly distributed holes (6mm in diameter) that give rise to scattering. Seismic noise is known to be largely generated by the coupling between atmosphere and solid Earth, and the air-nozzle approach can be seen as a way to reproduce this phenomenon as realistically as possible in a laboratory.

We find ensemble-averaged cross-correlations of the so generated diffuse flexural wave field to be strongly symmetric with respect to (causal and anti-causal) time, beyond the direct flexural-wave arrivals; this indicates that the Green function is correctly reconstructed, including scattered and/or reverberated arrivals. We find that, for this particular source mechanism (air nozzle), the "ballistic" (i.e. source-azimuth-dependent) signature in cross-correlations is weak even before ensemble-averaging: we infer that, even in a single-source scenario, scattering or reverberations from the sides of the plate give rise to a diffuse wave field.

Through a suite of experiments and numerical simulations, we disentangle the role of scattering from those of reverberation and source mechanism and geometry. Our findings validate recent studies that identify phases other than the first surface-wave arrival (e.g., body waves reflected by seismic discontinuities) in cross- and auto-correlations of seismic ambient signal.