Empirical Green's function retrieval using ambient noise source-receiver interferometry

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Empirical Green's function (EGF) retrieval commonly relies on cross-correlating the long-term ambient seismic wavefield that is simultaneously recorded at multiple stations. Recent studies have demonstrated observationally that cross-correlating the coda of ambient noise cross-correlation functions enables reconstruction of the EGFs, regardless of the operating time of the stations. In this study, we examine the feasibility of using the non-diffuse energy (i.e., surface waves) of the ambient cross-correlation functions to retrieve EGFs between asynchronous stations. We show that source-receiver interferometry (SRI), which is conventionally applied to reconstruct virtual seismograms between earthquake-station pairs, provides an effective framework to retrieve EGFs between asynchronous stations. SRI exploits the non-diffuse wavefield rather than the scattered coda waves that may be contaminated by incoherent energy under non-ideal (e.g., sparse, noisy and short-duration) network configurations. We first demonstrate the robustness of SRI by retrieving asynchronous EGFs and performing seismic tomography between 1) nearby stations and 2) distant temporary arrays from southern Australia. The additional ray paths from asynchronous EGFs provide better illumination of small-scale crustal structures beneath the regional network. In the larger-scale example, involving two asynchronous arrays, SRI offers new constraints to the sparsely sampled region along the continental margin of southern Australia.

We then apply the proposed workflow to seismic imaging of the Australian continent. Our dataset consists of continuous seismic recordings from over 1400 stations deployed between 1994-2019. Among them, over 200 long operating stations are employed as virtual sources by SRI to tie temporary deployments with asynchronous operating periods. This provides over half million new cross-correlation functions in addition to those from synchronous stations using conventional ambient noise correlation. The group velocities between 5-35 sec are inverted from 12,0000 high-quality cross-correlation functions, including 90000 measurements from the asynchronous station pairs, which provide the most detailed continental-scale seismic model of Australia to date. Our model is highlighted by 1) highly consistent spatial distribution of low velocities and known sedimentary basins and 2) the illumination of small-scale basins (e.g., Perth basin) near the continental margins. This study demonstrates that SRI is a promising tool for integrating transportable arrays operated at different times and can greatly benefit the effort of improving data coverage and resolution in seismic imaging.