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Wiener filter seismic timeseries prediction - site response application and connections to array processing

Daniel Bowden (1), Michael Coughlin (2), Jan Harms (3), Andreas Fichtner (1), Victor Tsai (4), Vuk Mandic (5), Gary Pavlis (6), Pat Meyers (7), Ross Caton (6), and Tanner Prestegard (5)

(1) Eidgenössische Technische Hochschule Zürich, Institut für Geophysik, Departement Erdwissenschaften, Zürich, Switzerland (daniel.bowden@erdw.ethz.ch), (2) California Institute of Technology, Division of Physics, Mathematics and Astronomy, Pasadena, California, USA, (3) Gran Sasso Science Institute (GSSI), Astroparticle Physics, L'Aquila, Italy, (4) California Institute of Technology, Seismological Laboratory, Pasadena, California, USA, (5) University of Minnesota, School of Physics and Astronomy, Minneapolis, Minnesota, USA, (6) Indiana University, Department of Geological Sciences, Bloomington, Indiana, USA, (7) University of Melbourne, School of Physics, Parkville, Victoria, Australia

We describe the formulation of a Wiener filter as an array processing tool for seismic timeseries prediction and subsequently for site characterization. Generally speaking, numerous existing methods rely on the comparison or correlation between seismic timeseries, such as in ambient noise cross-correlation tomography, beamforming, site-amplification characterization (hard-rock to basin transfer function), etc. Many of these methods, however, start from one-station to one-station comparisons which then are later somehow combined or aggregated. In contrast, a Wiener filter arbitrarily relates any number of observed inputs to a desired output; in this case we may observe seismic signals at any number of stations in an array and try to predict the output signal at a target station of interest. We show how this approach is mathematically analogous to existing methods of ambient noise cross-correlation for a two-station case, but allows for a framework to instead simultaneously use all data in an array. Insofar as we are using all data from an array, we can also compare and contrast the Wiener filter framework to existing beamforming methods. Finally, we test the approach on two different arrays with the goal of characterizing the strength of shaking at a given station in an array, based on earthquake observations at other stations, and we compare this to standard site-characterization approaches in seismic hazard literature. We note that the method can be applied to any type of geophysical timeseries, and expands on work by Coughlin et al, 2014 and 2019 (in review), which ultimately seeks to reduce the impact of seismic noise on gravitational-wave detector instrumentation.