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Estimating temporal seismic velocity changes from large databases of ambient noise cross-correlation functions using a Markov Chain Monte Carlo approach

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Temporal changes in seismic velocity (dv/v) in the crust are interpreted to be the result of changes to the mechanical properties of the constituent rock. Such changes can be induced by a variety of tectonic, environmental and anthropogenic processes, for example, slip events, precipitation-related changes to pore fluid pressure, tidal forces, and fluid extraction or injection. The calculation of dv/v changes from ambient noise correlation functions usually involves the designation of some reference background velocity, most commonly derived from a time-averaged (stacked) cross correlation function for the entire recording period. This definition is arbitrary, and can be prone to significant bias when the individual cross correlation functions and the reference function are not similar. A more recent approach involves calculating the velocity change between every unique pair of (usually daily) cross correlation functions, and then performing an inversion for a continuous dv/v time series. Whilst eliminating the need for an arbitrary reference velocity, the computational costs of conventional least squares matrix inversion methods scale poorly with the amount of data involved, and thus add restrictions to both the temporal resolution that can be achieved using this approach, the total span of the time period that can be analysed, and the number of stations that can be used simultaneously. To address these problems, we implement a Bayesian Markov Chain Monte Carlo approach to calculate the dv/v time series. The inversion of a matrix is not required, and the corresponding reduced computational cost allows for the tractability of problems involving much larger data sets. Furthermore, drawing representative samples directly from the posterior distribution allows us to robustly analyse the uncertainties of the dv/v time series without imposing subjective constraints, such as the level of smoothing, upon the resulting models. This development is important for a wide range of applications in ambient seismic noise monitoring, particularly in the context of data sets collected from large-N seismometer networks.