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A new approach to measure time- and frequency-dependent seismic velocity evolution

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Temporal variations of relative seismic velocity (dv/v) provide information about the stress perturbations in the crust and can be measured from earthquake doublets or ambient noise cross-correlations. The traditional way of calculating dv/v, that is, the Moving-Window Cross-Spectrum Analysis (MWCSA), faces several challenges. First, in MWCSA the frequency bands and the moving-window must be sufficiently broad to allow reliable phase-shift regressions, limiting the frequency and lapse-time resolution, and thus the spatial resolution. Second, measuring dv/v in multiple frequency bands by MWCSA requires repeating the calculation multiple times, increasing the computational cost. Third, the MWCSA fails at large lapse-times when cycle skipping appears. Here we present a new approach to measure dv/v based on wavelet cross-spectrum analysis, which is computationally efficient and estimates travel-time shifts all over time and frequency domain with the best resolution under the uncertainty principle. Synthetic tests and real data applications demonstrate that this new method can more stably and accurately retrieve the time- and frequency-varying travel time shifts than the traditional method. It allows us to improve the spatial localization of the source of velocity change in the shallow crust.