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Model-Based Signal Processing: Correlation Detection With Synthetic Seismograms

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Recent applications of correlation methods to seismological problems illustrate the power of coherent signal processing applied to seismic waveforms. Examples of these applications include detection of low amplitude signals buried in ambient noise and cross-correlation of sets of waveforms to form event clusters and accurately measure delay times for event relocation and/or earth structure. These methods rely on the exploitation of the similarity of individual waveforms and have been successfully applied to large sets of empirical observations. However, in cases with little or no empirical event data, such as aseismic regions or exotic event types, correlation methods with observed seismograms will not be possible due to the lack of previously observed similar waveforms.

This study uses model-based signals computed for three-dimensional (3D) Earth models to form the basis for correlation detection. Synthetic seismograms are computed for fully 3D models estimated from the Markov Chain Monte-Carlo (MCMC) method. MCMC uses stochastic sampling to fit multiple seismological data sets. Rather than estimate a single “optimal” model, MCMC results in a suite of models that sample the model space and incorporates uncertainty through variability of the models. The variability reflects our ignorance of Earth structure, due to limited resolution, data and modeling errors, and produces variability in the seismic waveform response. Model-based signals are combined using a subspace method where the synthetic signals are decomposed into an orthogonal basis by singular-value decomposition (SVD) and the observed waveforms are represented with a linear combination of a sub-set of eigenvectors (signals) associated with the most significant eigenvalues. We have demonstrated the method by modeling long-period (80-10 seconds) regional seismograms for a moderate (M~5) earthquake near the China-North Korea border. Synthetic seismograms are computed with the Spectral Element Method for a suite of long-wavelength (2 degree) seismic velocity models based on the MCMC method. We are working on higher resolution (1 degree) models for the same region and methods to increase the frequency content of the synthetic seismograms.

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