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Probabilistic inversion of teleseismic P-wave coda autocorrelation for imaging crustal structure

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The autocorrelation of the seismic transmission response of a layered medium with a free surface corresponds to the reflection response beneath the receiver as if there was a virtual source collocated with the receiver (a zero-offset reflection). This seismic transmission response includes direct waves as well as multiple reverberations from seismic discontinuities beneath the receiver. In recent years, the autocorrelation of both the diffusive wave field (e.g., ambient noise energy) and teleseismic coda waves has become a popular approach to image the local crustal and upper mantle discontinuities e.g., Moho depth beneath seismic stations.

Despite the success of many studies on the processing and forward modelling of autocorrelation traces, so far there are no published studies on the inversion of autocorrelograms for imaging crustal structures. Here, we use teleseismic P-wave coda, recorded on the vertical components of more than 1200 permanent and temporary seismic stations across Australia to estimate the reflection response beneath all stations and investigate the feasibility of the Bayesian inversion of autocorrelograms for crustal imaging.

For each station, we construct the stacked autocorrelogram from seismic waveforms associated with distant earthquakes with magnitudes larger than 5.5 and epicentral distances between 30 and 90 degrees. We then use all stacked autocorrelograms as input to our Bayesian inversion framework, which utilises a Markov Chain Monte Carlo approach. The Earth beneath each seismic station is parameterized with four horizontal and isotropic crustal layers over an upper mantle layer (half-space). Each crustal layer is described by three main parameters: density, layer thickness variation, and Vp/Vs. The slowness is also treated as unknown and directly derived from the inversion.

Our synthetic tests show that we are able to recover the first-order estimate of the true crustal structure using these class of measurements in the presence of noise. Results of the inversion of the observed stacked autocorrelograms demonstrate the success of the method by producing patterns of Moho structure highly compatible with the current Moho model for Australia (Kennett et al. 2011). Also, the 3-D Vp structure, constructed from the mean of inverted Vp from individual stations shows patterns of features consistent with those in the AuSREM Vp model (Salmon et al. 2013). Some of the inverted low-velocity anomalies mark the locations of known thick sedimentary basins, which was previously imaged by the ambient seismic noise tomography, active source and receiver function studies. The consistency of our Moho estimates with the AusMoho model and the correlated patterns of Vp variations with those seen in the AuSREM Vp model suggest the robustness of this approach for imaging the Moho and crustal structure when the inversion of receiver functions and the deep reflection profiling may not be applicable.

References:

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