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Benchmarking passive seismic methods of estimating the depth of velocity interfaces down to ∼300 m

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In shallow passive seismology it is generally accepted that the spatial autocorrelation (SPAC) method is more robust than the horizontal-over-vertical spectral ratio (HVSR) method at resolving the depth to surface-wave velocity (Vs) interfaces. Here we present results of a field test of these two methods over ten drill sites in western Victoria, Australia. The target interface is the base of Cenozoic unconsolidated to semi-consolidated clastic and/or carbonate sediments of the Murray Basin, which overlie Paleozoic crystalline rocks. Depths of this interface intersected in drill holes are between ∼27 m and ∼300 m. Seismometers were deployed in a three-arm spiral array, with a radius of 250 m, consisting of 13 Trillium Compact 120 s broadband instruments. Data were acquired at each site for 7–21 hours. The Vs architecture beneath each site was determined through nonlinear inversion of HVSR and SPAC data using the neighbourhood algorithm, implemented in the geopsy modelling package (Wathelet, 2005, GRL v35). The HVSR technique yielded depth estimates of the target interface (Vs > 1000 m/s) generally within ±20% error. Successful estimates were even obtained at a site with an inverted velocity profile, where Quaternary basalts overlie Neogene sediments which in turn overlie the target basement. Half of the SPAC estimates showed significantly higher errors than were obtained using HVSR. Joint inversion provided the most reliable estimates but was unstable at three sites. We attribute the surprising success of HVSR over SPAC to a low content of transient signals within the seismic record caused by low levels of anthropogenic noise at the benchmark sites. At a few sites SPAC waveform curves showed clear overtones suggesting that more reliable SPAC estimates may be obtained utilizing a multi-modal inversion. Nevertheless, our study indicates that reliable basin thickness estimates in the Australian conditions tested can be obtained utilizing HVSR data from a single seismometer, without a priori knowledge of the surface-wave velocity of the basin material, thereby negating the need to deploy cumbersome arrays.