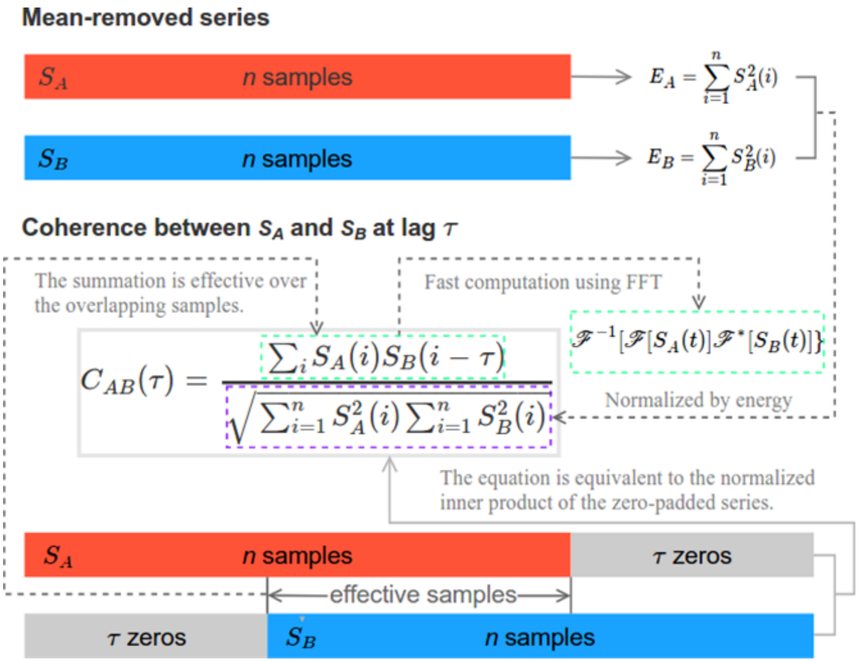

Figure S1: Schematic diagram explaining the computation of the correlation function between two mean-removed time series.

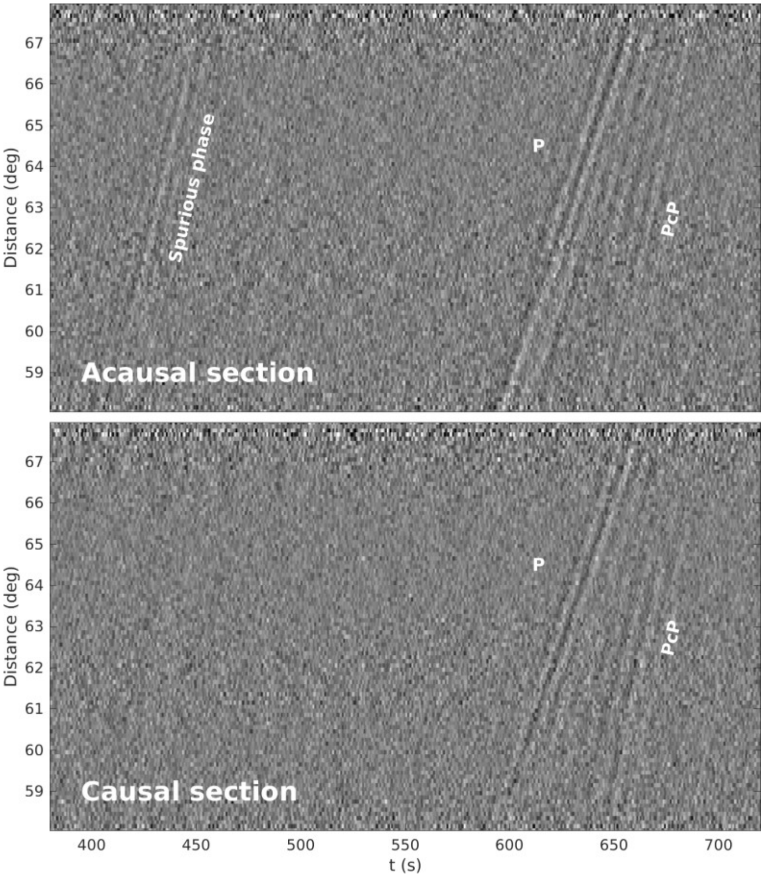

Figure S2: Broadband (1 to 100 s) sections of the acausal and causal parts of the vertical-vertical noise correlations stacked in 0.1° distance bins.

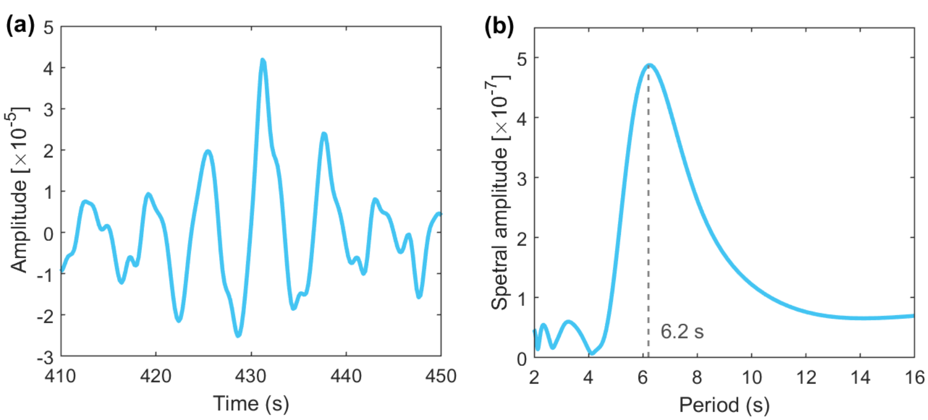

Figure S3: (a) Beamed waveform and (b) amplitude spectrum of the spurious phase in the broadband of 1 to 100 s.

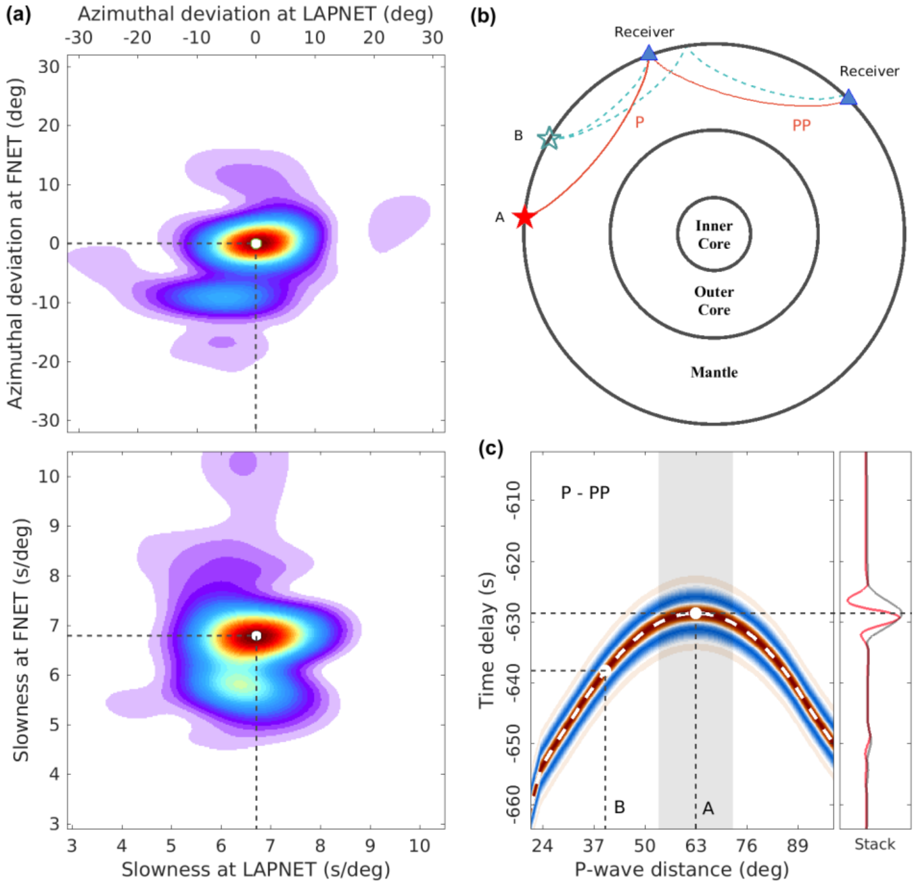

Figure S4: (a) Results of double-array slowness analysis for the acausal P wave. (b) Ray paths of the correlated P and PP waves from distributed sources. Source A is placed at the stationary location. The P wave to the first receiver and the PP wave to the second receiver have a common slowness and a common P path. The correlation operator cancels the common path and extracts the phase delay between two receivers. Label B denotes any noise source on the global surface outside the stationary-phase region. For simplicity, the correlations between higher-order multiples like PP-PPP that can also give rise to P waves are neglected. (c) Reconstruction of the inter-receiver P wave from the P-PP correlations by source averaging, which is explained by the traditional stationary-phase theory. The stationary location corresponds to the extreme point on the dashed time-delay curve. Amplitudes in the P-PP correlations for sources outside the shaded stationary-phase region cancel out by the averaging. The time delay at the maximum of the envelope of the stacked waveform matches exactly with the theoretical travel time of the inter-receiver P wave.