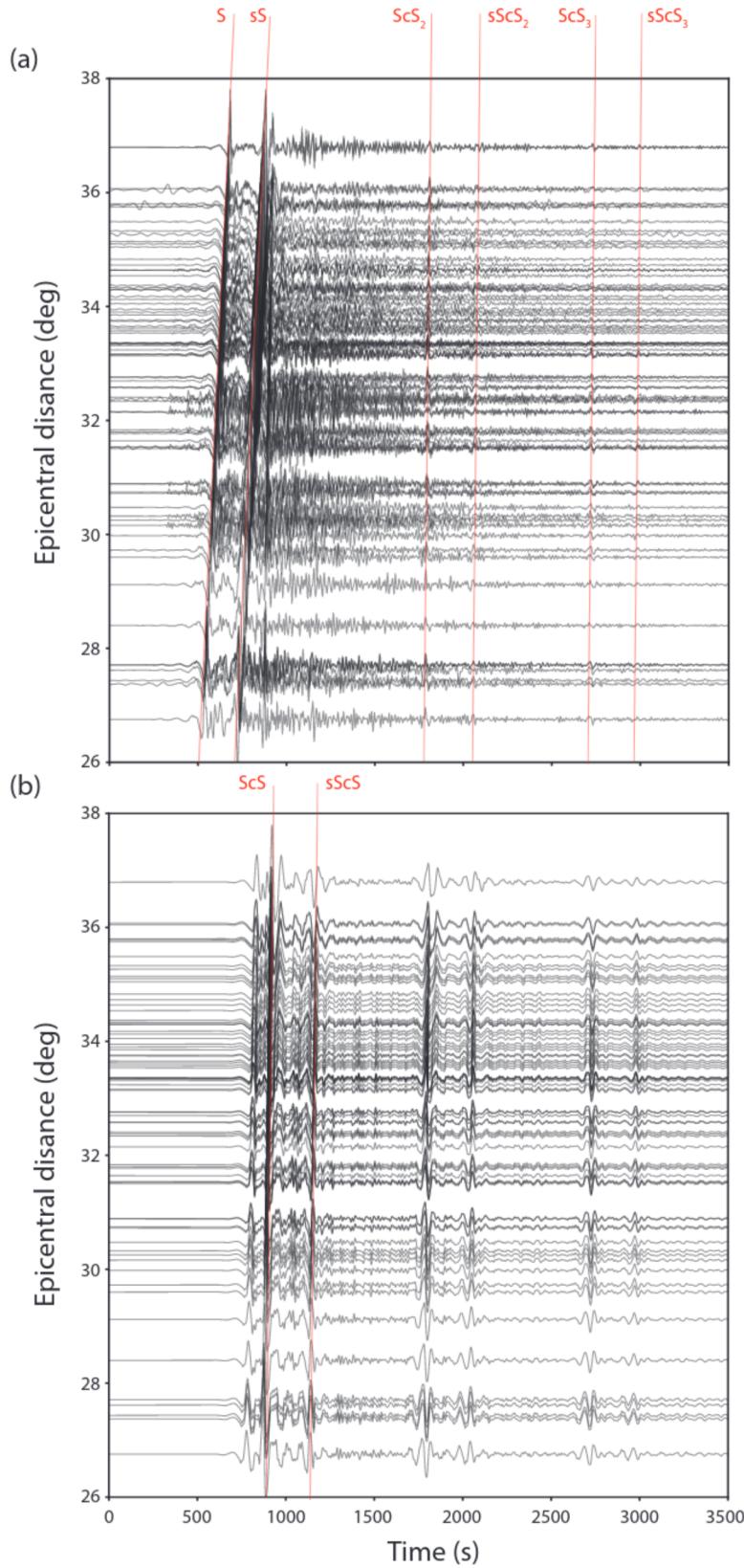
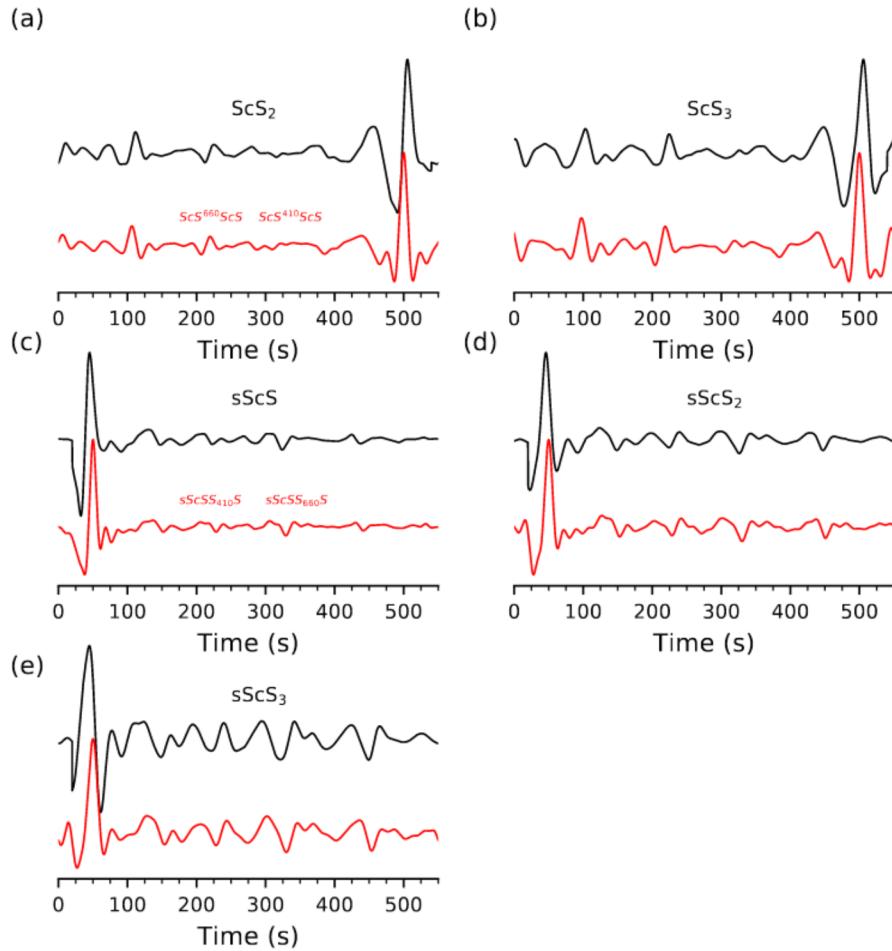


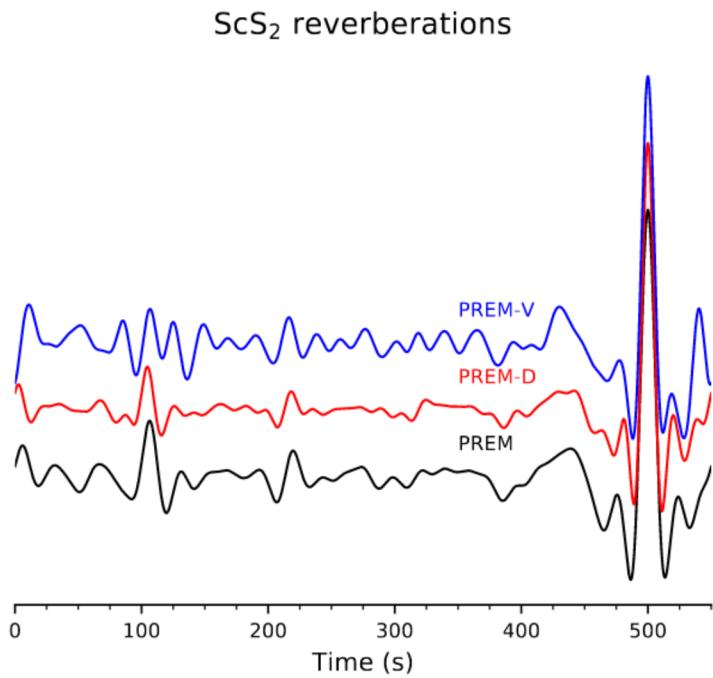
**Figure S1.** Illustration of the traveltime degeneracy between (a) the topside reflection at the 660,  $ScSS_{660}S$  and (b) the topside reflection at a discontinuity at depth  $x$ ,  $sS_xSScS$  for an earthquake at depth  $h$ . (c) indicates values for  $h$  and  $x$  when the traveltimes of  $sS_xSScS$  and  $ScSS_{660}S$  (blue) or  $ScSS_{410}S$  (orange) are the same. Panels (d) and (e) are cross sections of migrated PREM synthetics along transect A-A', as discussed in Section 4.1. Panels (d) and (e) are determined for waveforms from earthquakes with depths between 100–300 km and earthquakes deeper than 300 km, respectively. The orange ellipse in (d) indicates a migration artifact in the MTZ.



**Figure S2.** Transverse component record sections of Event 6 (a) before and (b) after radon transformation. Major expected ScS phases are indicated by red lines.



**Figure S3.** Synthetic reverberation windows for a station 20 degrees away from a 578 km deep earthquake. Each reverberation window is shown with the unprocessed trace in black and the deconvolved trace in red. Reverberation windows are: (a)  $ScS_2$ , (b)  $ScS_3$ , (c)  $sScS$ , (d)  $sScS_2$ , (e)  $sScS_3$ .  $ScS$  Reverberations from the 410 and 660 are labeled in (a) and (c).



**Figure S4.** Synthetic ScS<sub>2</sub> reverberation window for a station 20 degrees away from a 578 km deep earthquake shown for PREM (black), PREM-D (red), and PREM-V (blue). All windows are normalized on ScS<sub>2</sub>