Waveform modeling of seismic records from MERMAID (the ultimate emerging hardware and software)

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Thousands of seismograms have been reported by MERMAID (Mobile Earthquake Recording in Marine Areas by Independent Divers), an oceanic float that detects earthquakes in remote regions. MERMAID seismograms have been used for travel-time tomography, but modeling the entire waveform has remained elusive. What prevented the application of Full-Waveform Inversion (FWI) to MERMAID seismograms is that simulating wave propagation in a 3-D global domain with an ocean in which acoustic waves propagate is too computationally expensive at the frequencies 0.1–10 Hz, where MERMAIDsinstrument response is flat. Our solution is to split the simulation into a part that models the response of the solid Earth from the earthquake source to the ocean bottom, and another that models the wave propagation within the ocean layer. For the first part, we use Instaseis, with precomputed elastic Green's functions, to obtain displacement seismograms within a 1-D Earth model. For the second part, we first use SPECFEM-2D to solve the elastic and acoustic wave equations, taking into account bathymetry and pressure wave propagation within the water column. The simulations return time series of vertical displacement at the ocean bottom due to incoming plane waves, and acoustic pressure at the MERMAID depth. We de-convolve them to obtain a catalog of response functions between the displacement at the conversion point of plane waves from distant earthquake sources and the sound pressure, for a variety of environments and ray parameters. For any particular earthquake-receiver pair, we then convolve the vertical displacement from Instaseis with the appropriate response function to model hydroacoustic pressure waveforms observed by MERMAID. In this way can successfully model MERMAID records within the first few seconds following the first P-wave arrival, within a frequency band determined dynamically. The correlation between synthetics and observations in our vast collection is as high as 0.98, with a median of 0.72, and very coherent across the array, allowing for the determination of cross-correlation travel times and opening up MERMAID seismograms to conduct full-waveform tomography of Earth's mantle.

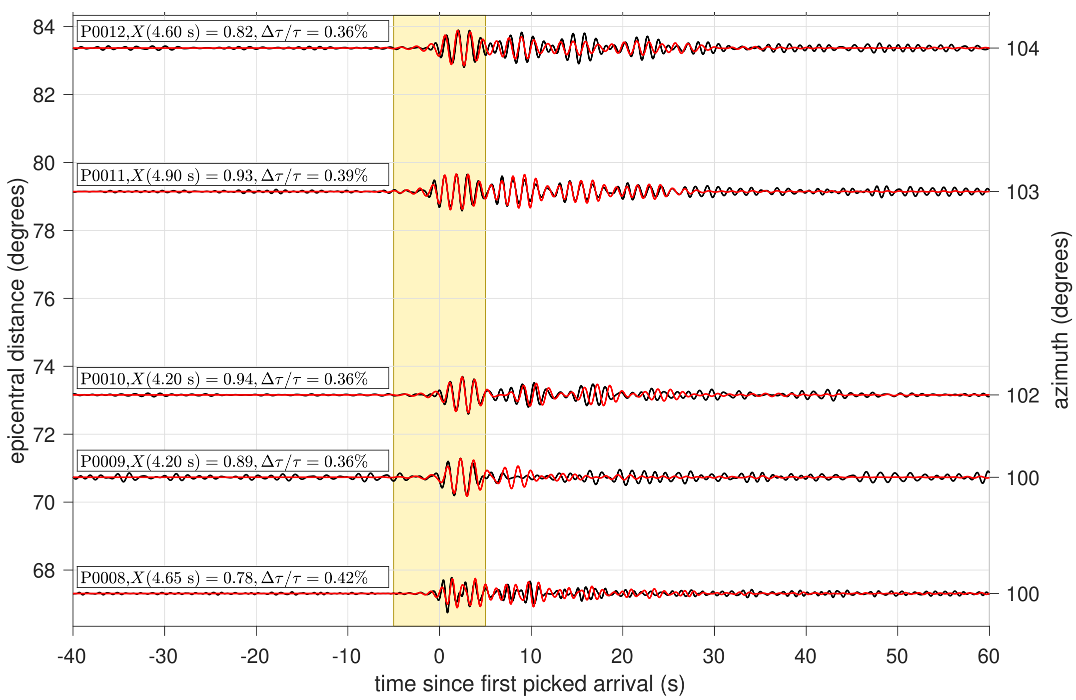

Figure 1: Waveform modeling of MERMAID records of CMT event C201808171535A, magnitude 6.50, depth 529.00 km. Indicated are MERMAID name and number, cross correlation argmax and value, and the relative travel-time anomaly (in per cent). MERMAID was designed capture high-frequency P-wave travel times, but its lower-frequency waveforms can be modeled with great accuracy and precision, allowing for detailed analysis.