Cross-validation of numerical modeling and laboratory experiments of seismic wave propagation in complex geological environments

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Numerical simulation of wave propagation is widely used for environmental and industrial applications for subsurface evaluation in seismic exploration. Simulation is also a core tool of seismic imaging and inversion. Consequently, it is important to trust the results provided by the numerical methods. However, it is a challenging task to compare these results to real seismic data as the subsurface is never exactly known. Since they can provide a valuable link between purely numerical and real seismic datasets, laboratory measurements on small-scale physical models have recently again been considered as a good alternative approach to point out the advantages and the limitations of numerical methods. In the same time, comparison between numerical and experimental results may emphasize the improvements of the experimental setup that must be made to increase the accuracy of the experiments. Here, we present a case study for such a comparison between ultrasonic data obtained for a complex model with topographic features and numerical results obtained with a spectral-element method and a finite-difference method. Reflection data were collected in a water tank with piezoelectric transducers using a conventional pulse-echo technique. We paid special attention to the implementation of the real source signal and radiation pattern in the numerical domain. It involved a laboratory calibration measurement followed by an inversion process. The model geometry was implemented using a non-structured mesh for the spectral-element simulations. The comparisons show a very good fit between synthetic and laboratory traces in general, the small discrepancies being assigned mostly to noise present in the laboratory data. Special attention is also paid to the impact of the strong surface curvatures of the model on both the numerical and experimental results.