Abstract

The shallow subsurface is interested by human activities and the properties of shallow geological formations have significant impact on them. Near-surface modelling, which can range from a few metres to a few hundred metres based on the field of application, is of great significance in different fields like civil engineering, seismic hazard, mining industry, climate change mitigation and adaptation, and hydrocarbon exploration. Seismic methods are widely applied to model subsurface property distribution. Surface waves (SW) are usually present in the seismic data and dominate seismic recordings.

SW are dispersive, meaning that in a vertically heterogeneous medium, the phase velocity is frequency dependent. Dispersion curves (DCs), which represent the phase velocity as a function of frequency, can be estimated from seismic recordings. Because SW are mainly sensitive to S-wave velocity (VS) distribution of the subsurface, the estimated DCs can be inverted to obtain VS models. There are different methods to analyse SW data. Surface wave tomography (SWT) is a well-established method in seismology which has recently attracted attention of researchers in near-surface studies. In SWT, the lateral variability of the subsurface can be considered in the forward modelling. This makes SWT a good candidate for near-surface studies since the shallow part of the subsurface is commonly known to have highly heterogeneous structures.

We investigate the performance of two SWT methods, straight-ray and curved-ray SWT, at the near-surface scale. We apply them to four 3D examples with high lateral velocity variation. In three examples, we optimise acquisition layouts to make sure that high coverage of DC data can be obtained. For the other example, we use a cross-spread acquisition scheme that is a typical exploration layout. The inversion results show that both straight-ray and curved-ray SWT methods provide high-resolution VS models. The results of straight-ray and curved-ray SWT are very similar in three examples. However, the curved-ray SWT produces considerably better results in case of the example in which the data had been acquired using a typical exploration layout. We compare the obtained results from the four examples in terms of accuracy and computational cost. This quantitative comparison reveals the significance of survey design optimisation. The results show that if the acquisition layout has been optimised for a SWT study, straight-ray method can provide almost same results as curved-ray SWT but with significantly lower computational cost. Otherwise, the use of curved-ray SWT considerably improves the results.

Joint inversion schemes are effective methods to reduce the limitation of individual inversions. We develop a novel joint inversion scheme to integrate SWT and body wave tomography (BWT) in 2D and 3D media. BWT based on first-arrival times data consists of inverting P-wave first-arrival times to build P-wave velocity (VP) models. In our joint inversion scheme, we use Poisson's ratio as the physical link between the obtained VS model from SWT and VP model from BWT. We apply the proposed joint inversion algorithm to three 2D examples. The results show that compared to individual inversions, both VS and VP models are improved and are more physically meaningful in the proposed joint inversion algorithm. We also show that the proposed joint inversion algorithm can be an effective tool to build 3D VS and VP models which are better than individual inversions.