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Joint inversion of apparent resistivity and seismic surface and body wave data

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A novel inversion algorithm has been implemented to jointly invert apparent resistivity curves from vertical electric soundings, surface wave dispersion curves, and P-wave travel times. The algorithm works in the case of laterally varying layered sites. Surface wave dispersion curves and P-wave travel times can be extracted from the same seismic dataset and apparent resistivity curves can be obtained from continuous vertical electric sounding acquisition. The inversion scheme is based on a series of local 1D layered models whose unknown parameters are thickness h, S-wave velocity Vs, P-wave velocity Vp, and Resistivity R of each layer. 1D models are linked to surface-wave dispersion curves and apparent resistivity curves through classical 1D forward modelling, while a 2D model is created by interpolating the 1D models and is linked to refracted P-wave hodograms. A priori information can be included in the inversion and a spatial regularization is introduced as a set of constraints between model parameters of adjacent models and layers. Both a priori information and regularization are weighted by covariance matrixes.
We show the comparison of individual inversions and joint inversion for a synthetic dataset that presents smooth lateral variations. Performing individual inversions, the poor sensitivity to some model parameters leads to estimation errors up to 62.5 %, whereas for joint inversion the cooperation of different techniques reduces most of the model estimation errors below 5% with few exceptions up to 39 %, with an overall improvement. Even though the final model retrieved by joint inversion is internally consistent and more reliable, the analysis of the results evidences unacceptable values of Vp/Vs ratio for some layers, thus providing negative Poisson's ratio values. To further improve the inversion performances, an additional constraint is added imposing Poisson's ratio in the range 0-0.5. The final results are globally improved by the introduction of this constraint further reducing the maximum error to 30 %.
The same test was performed on field data acquired in a landslide-prone area close by the town of Hvittingfoss, Norway. Seismic data were recorded on two 160-m long profiles in roll-along mode using a 5-kg sledgehammer as source and 24 4.5-Hz vertical geophones with 4-m separation. First-arrival travel times were picked at every shot locations and surface wave dispersion curves extracted at 8 locations for each profile. 2D resistivity measurements were carried out on the same profiles using Gradient and Dipole-Dipole arrays with 2-m electrode spacing. The apparent resistivity curves were extracted at the same location as for the dispersion curves. The data were subsequently jointly inverted and the resulting model compared to individual inversions. Although models from both, individual and joint inversions are consistent, the estimation error is smaller for joint inversion, and more especially for first-arrival travel times. The joint inversion exploits different sensitivities of the methods to model parameters and therefore mitigates solution nonuniqueness and the effects of intrinsic limitations of the different techniques. Moreover, it produces an internally consistent multi-parametric final model that can be profitably interpreted to provide a better understanding of subsurface properties.