Cross-gradient joint inversion and classification of crosswell seismic and GPR traveltimes at the Boise Hydrogeophysical Research Site

Joseph Doetsch[1], Niklas Linde[2], Michael B. Kowalsky[1]

[1]Earth Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA, jdoetsch@lbl.gov, mbkowalsky@lbl.gov
[2]Institute of Geophysics, University of Lausanne, Lausanne, Switzerland, niklas.linde@unil.ch

Geophysical imaging is a powerful tool for delineating aquifer properties at an appropriate scale and resolution, but it suffers from problems of ambiguity. One way to overcome such limitations is to adopt a simultaneous multitechnique inversion strategy. We use a previously developed methodology for aquifer characterization based on structural joint inversion of multiple geophysical data sets followed by clustering to form zones and subsequent inversion for zonal parameters. Joint inversions based on cross-gradient structural constraints require less restrictive assumptions than, say, applying predefined petrophysical relationships and generally yield superior results for field data. A classification scheme using maximum likelihood estimation is used to determine the parameters of a Gaussian mixture model that defines zonal geometries from joint-inversion tomograms. The resulting zones are used to estimate representative geophysical parameters of each zone, which give subsurface properties at the scale of the borehole spacing.

Here, we jointly invert seismic and GPR traveltimes that were picked from the publically available data sets recorded at the Boise Hydrogeophysical Research Site (BHRS). We decided to concentrate on the saturated zone, thus omitting any surface to borehole data or any air refractions in the GPR data. Our data set is comprised of 1869 seismic and 1926 GPR traveltimes, with 35 and 32 sources, and 108 and 129 receivers for the seismic and GPR case, respectively. The data is inverted individually and jointly, using stochastic regularization based on an exponential model with integral scales of 5 m in horizontal and 2.5 m in vertical direction. The data misfit is minimized using a L2 norm and for the model norm, we use both L2 and an iteratively reweighted L1 norm. All models fit the data to the same error level, which corresponds to 2% (0.07 – 0.16 ms) for the seismic and 1.2 % (1.3 – 2.4 ns) for the GPR data set.

The classification scheme is then applied to each of the seismic-GPR model pairs, giving the best result when assuming four different zones. The zone geometries are then used to invert for zonal parameters, yielding one seismic and radar velocity for each zone. The joint inversion results are laterally more continuous and structurally more similar than the individual inversions. For these models, the classification results are clearly more contiguous and the data misfit for the zonal inversions is lower than for the individual inversion results indicating an improved zonal model.