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Microseismic earthquake location and velocity inversion by eikonal tomography

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Real time monitoring of hydraulic fracturing entails fast computation of hypocenters of the induced micro-earthquakes. The micro-earthquakes during hydraulic fracturing are caused by changes in stress and pressure in pre-existing or newly induced fractures. Microseismic monitoring can potentially image the full fracture geometry and can also be useful to understand fracture complexity in the presence of fracture network. We present a joint inversion technique for source locations of microseismic events and P-wave velocity structure. The objective function is defined as the l2-norm of the difference between observed and theoretical first arrival traveltimes. The traveltimes are computed by solving the eikonal equation using the fast sweeping method. The gradient of the misfit function is computed using the adjoint-state method. The gradient can be found by backpropagating the residual traveltimes at the receiver locations. We then employ the l-BFGS algorithm to update the model parameters using the computed gradient and an approximate Hessian matrix. We demonstrate our algorithm on a synthetic velocity model with gaussian anomaly with multiple microseismic sources. With a constant velocity as our initial model, we perform inversion for source locations and the velocity model. The inverted source location and velocity correspond closely to the true source locations and the true velocity model, respectively.