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Abstract

Q tomography has been developed for estimating attenuation model for several years but is generally ray-based. It needs to compute the Fréchet derivatives in each iteration, which would lead to large computation time when input parameters are increasing. In this paper we propose a new gradient-based method using the adjoint-state technique to estimate the distribution of near surface attenuation without the need for introducing Fréchet derivatives.

In high-frequency approximation, if $q = Q^{-1} \ll 1$, raypaths remain unchanged as acoustic case. We assume $\delta q \cdot t = \delta t^*$ and $\tilde{c} = Qv$ is the combined effect of velocity and attenuation, while t^* is attenuated traveltime. We pick first arrivals in data and measure attenuated traveltime. Then we build the objective function minimizing the difference of calculated and observed attenuated traveltime in term of variable Q. Following the steps of the Lagrangian formulation, we can obtain the extended objective function from the adjoint technique. The fast sweeping method is used to compute the calculated attenuated traveltime and the adjoint state variable. The gradient descent method is employed to solve the attenuation distribution Q through a tomographic inversion.

We apply our adjoint-state Q tomography flow to a 2D Q model of Gaussian anomaly deployed within the low velocity zone for a given velocity model. The strongest value of Gaussian anomaly center is Q=100 with background Q=400 in other area. We generate synthetics with these models and pick the first arrivals, then compute the attenuated traveltimes of first arrival picks. The initial Q model is a constant Q value of 400 that means weak attenuation in the background medium. A low-pass filter is applied to the gradient of the objective function at each iteration. Through several iterations of the adjoint-state Q tomography, we obtain the inverted Q result, which is recovered quite well. We also further check the attenuated traveltimes for different locations on surface. The attenuated traveltimes from the inverted Q model are much closer to the ones from the true Q model. From these results, the proposed approach of the adjoint-state Q tomography is verified. Although we use first arrivals here, it could be easily extended to seismic reflection data.

The advantage of this method is that it depends only on the size of velocity and attenuation models, not the amount of input parameters. The algorithm can allow us to handle a data set of any size easily. The adjoint-state Q tomography can provide a good tool for estimating near surface Q model. It could be included in the Q compensation process to fully account for the attenuation effects, and therefore improve subsurface depth imaging.