On performance verification of seismic tomography using structural regularization

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We apply various structural regularization methods to seismic tomography and discuss their performance. The seismic tomography generally provides the structure of propagation velocities in the earth's crust, using arrival times of seismic waves recorded by seismic observation stations. In our study, we use 3-D grid points in the subsurface to model the velocity structure. In the field of the seismic tomography, the least-squares method (LS), the damped least-square method (DLS) which employs a penalty term consisting of square norm of model parameter change from the initial values, and the Laplacian regularization which smoothes the inter-grid velocity fluctuations via Laplacian operator and l2-norm, have been widely used.

Recently, some studies have represented characteristics of seismic velocity by introducing sparse regularization methods. The sparse regularization methods with l1-type penalties yield estimates with zero values, and work well in balancing the tradeoffs of mitigating overfitting and obtaining estimation accuracy when the estimand has sparse representation. It is also known to have an advantage of accurate estimation from a small amount of data. For example, a penalty term consisting of l1-norm for the velocity difference of adjacent grid points, and a term obtained by replacing l2-norm in the Laplacian regularization with l1-norm can be cited. The important effect of sparse regularization is to shrink small variations and emphasize the large ones. Furthermore, Yamanaka et al. (2022, under revision) developed a method to express sharp changes in velocity structure caused by such as Conrad discontinuities, by dividing the penalty term into the vertical and horizontal directions, and by employing the penalty term having a form of "l1-sum of l2-norm". In this presentation, we discuss the performance, advantages and disadvantages of these methods by conducting numerical experiments assuming various velocity structures.

Keywords: Seismic tomography, Velocity structure, Structured regularization