Sensitivity Analysis of Berryman regularizing matrices in refraction tomography

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Abstract

A common approach to stabilize the ill-posed inverse problem is the application of regularization, which in practice corresponds to restricting the possible solutions for the inversion. Thus, a regularization term is incorporated into the tomographic error function to solve the non-uniqueness of the inverse geophysical problem. This work aims to evaluate the effects of regularization on refraction tomography and the resulting seismic velocities. The study was methodologically based on a case study. The regularizations tested in this work were the Berryman. The definition of Berryman's regularization was created in 1991 explicitly for cases in which each element of the tomographic matrix represents the length of each ray in a cell of the model to be inverted. This regularization proposes to consider physical criteria in the choice of regularizing matrices. This study used the program based on Podvin ray tracing, finite difference by the eikonal equation referring to the first arrivals, tomographic matrix calculation, and regularization algorithm. The range of parameterization values is between -1 and 1. The values used were between 10^{-8} and 10^{-1}. The synthetic velocity model is based on a shallow seabed channel geology with channel structure discretized into cells with a uniform spacing of 10 m. The 2-D acquisition geometry for parameterization of the direct modeling consists of 176 sources with an interval of 40 m and 150 geophones along a 2500 m straight line, with intervals of 10 m, with the first geophone at 100 m from the source. The true velocity model with three layers, with velocities of 1500 m/s (water), 2000 m/s, and 2500 m/s, was compared with the results of the transit time tomography without regularization using regularization methods. The true model was compared to the tomographic results without and with regularization employing different regularization parameters (λ). For $\lambda = 10^{-1}$, the residual converges to model that differs significantly from the real one. For $\lambda = 10^{-2}$, we observe numerical instability, and no convergence occurs for up to 40 iterations. Regularization parameter (λ) smaller than 10^{-3} guides to residuals around $6.\ 10^{-7}$. Convergence with more incredible velocity (in fewer iterations) occurs for the λ values of 10^{-3} and 10^{-7}. It is concluded from this work that: better results of structure definition and few distortions are reached whenever the regularization is applied; the Berryman regularization presented faster convergence with improvement in the velocity model; the sensitivity test of the λ parameters show how much a wrong choice of λ can distort the geological structures.