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Bayesian determination of the uncertainty in the travel time inversion

M. Majdanski (1), R.W. Hobbs (2)

(1) Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland,

(2) Department of Earth Sciences, Durham University, UK,

(mmajd@igf.fuw.edu.pl / Fax: +48-22-6915915)

Seismic travel times tomography is commonly used to invert travel time data into a velocity/depth model. Both the error due to the bandlimited noisey data and model parameterisation creates uncertanty in the resultant model, so as with any scientific result, it should be presented with an uncertainty estimation. The most common methods for travel time inversion are analysis of ray density coverage, checkerboard or sensitivity tests. All of these give us a qualitative estimation of the uncertainty.

We propose a Bayesian based analysis as an appropriate method to determine a quantitative estimation of the uncertainty. We use the Metropolis-Hastings algorithm to generate a Markov chain which can then be analysed to determine the level to which the data supports the given result. We demonstrate the algorithm using real data in a 2D joint inversion of travel times from refracted and reflected waves. Even for relatively simple models with a small number of parameters this analysis is time consuming to assure sufficient steps to give robust posterior statistics. As the number of parameter increases the likelihood function quickly looses its ability to guide the Markov chain but this can be partly addressed by providing additional prior information to the Metropolis-Hastings algorithm. We compared our final uncertainty estimation against that obtained by averaging results from mulitple inversion runs where the input travel time data had been statistically perturbed to represent the estimated precision of each pick. We conclude that the latter method gives a minimum uncertainty estimate compared with our Bayesian based analysis.