First break tomography parametrization for near surface modeling

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Abstract

Turning ray tomography provides a measurement of the subsurface layers over the length of the layout and is the most appropriate for strong velocity variations (Epili et al., 2001). Therefore, a tomographic inversion update loop based on direct and refracted energy arrival-time is the most accurate technique as a solution to build a reliable velocity model for lateral varying velocity near-surface problems (Zhenwu et al., 2009). First-arrival times (also known as first-breaks) recorded on seismic reflection data are considered as input.

In this paper the analysis of how decisive parameters (e.g. cell size, and model depth) help to define the tomographic inversion as an appropriate tool for near-surface velocity model building are discussed. Other publications (Zhu et al., 2008) consider to compute static corrections from the estimated near-surface velocity model (tomostatics) as the tool which defines the reliability of the model. In this case the accuracy of the model is verified by the misfit between observed and estimated arrival-times, and near-surface anomalies distribution.

Introduction

Tomographic inversion has the capability to work with any kind of seismic propagation mode (Jones, 2010). Refracted energy is the one considered in this case, since it propagates mostly through the near-surface. An initial velocity model discretized into cells is iteratively updated. In each update iteration, rays are traced into the current model generating estimated first-breaks which are compared with the picked ones (Zhu et al., 1992). When this misfit decreases to an acceptable value, a reliable velocity model has been built. Figure 1 describes the stages of the velocity update loop.

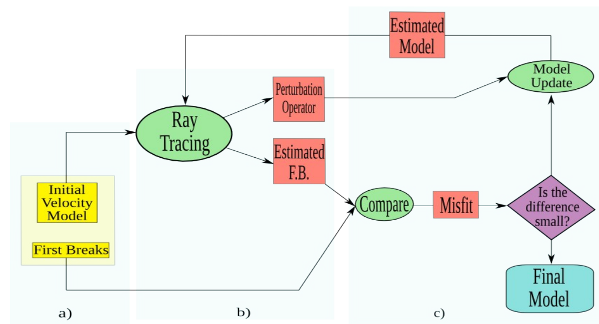

Figure 1 *Tomographic update loop: a) First-break picking and initial velocity model, b) Ray tracing, c) Model update*

Stage 1. Input data

- First-breaks: The observed arrival time must be consistently picked on the data set, considering the direct and refracted energy observed along the offsets. First-breaks represents the energy which mainly travels in the near-surface. Figure 2.

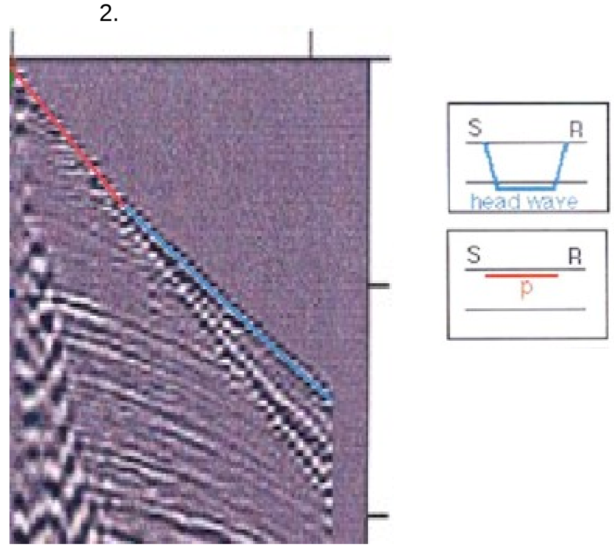

Figure 2 *Tomographic update loop: a) First-break picking and initial velocity model, b) Ray tracing, c) Model update*

- Initial velocity model: An appropriate initial velocity model increases the convergence rate throughout the update loop. Velocity model extension and discretization criteria (model's cell size) are defined according to the target depth and receiver station interval (*RSI*). A vertical velocity (Figure 3) gradient may be used as initial model. However, a velocity model estimated by other refraction techniques (e.g. generalized reciprocal method, generalized linear inversion) might be considered as initial model (Russell 1989).

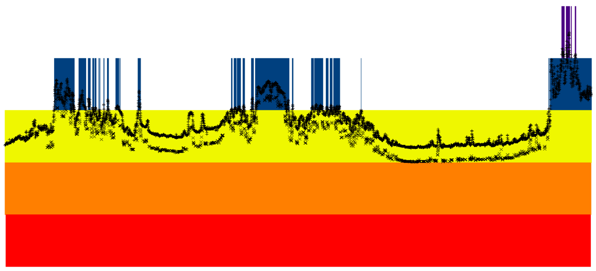

Figure 3 *Initial velocity model. First velocity 2000m/s, depth 200m, last velocity 6000m/s. Cell size 100m².*

Stage 2. Ray-tracing

Ray-tracing is performed in each update iteration considering the position of source-receiver pairs in the survey. This procedure provides estimated first-breaks and a perturbation operator, which links velocity changes to changes in first-breaks (Bishop et al., 1984). Turning-ray tracing is used due to its capability to properly reproduce energy propagation in the near-surface (Stefani, 1995).

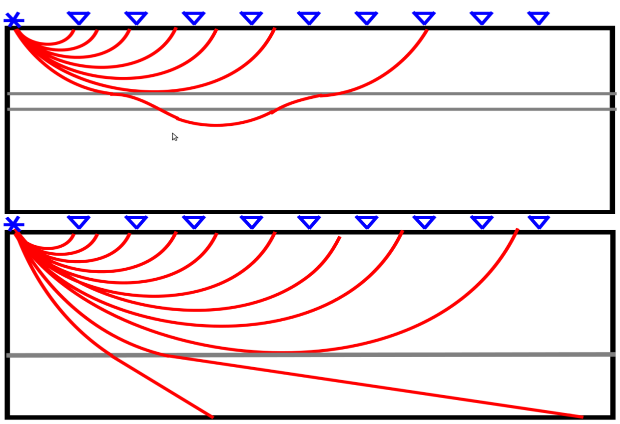

Figure 4 *Ray-tracing a long a layer velocity model. Ray-path trajectory depends on velocity variation. Model depth will affect ray trajectory and fold.*

Stage 3. Velocity model update

Tomographic inversion is computed for each model sample (cell) to update its velocity value. The misfit between observed and estimated arrival times Δt is iteratively back-projected, considering the perturbation operator S which is defined by the ray-paths inside the model sample. The updated velocity sample ΔM is given by *(1)*. Ray density W is used as weight to updated values**,** the more rays crossing a cell, the more accurate our velocity estimation will be (Lo et al., 1994).

$$\Delta M = \frac{1}{W}\left(S\Delta t\right) \quad (1)$$

Results and conclusions

In order to define the best parameters for tomographic inversion for geological complex models, an initial model defined by a vertical velocity gradient was submitted to different cell size and model depth values tests. Three cell size values (8x, 4x, and 2x *RSI*) and two depth values (10% and 5% from the maximum offset) were tested. Each test model was submitted to the same number of update loop iterations. The results showed that the bigger the cell and the depth, the smaller the convergence rate and shorter its computation time would be. The optimal result is achieved by iteratively reducing the cell size whenever the model misfit reaches stationarity. Figure 5.

A future work, might consist of updating an initial model estimated by other refraction techniques and the application of the resulting model to compute static corrections.

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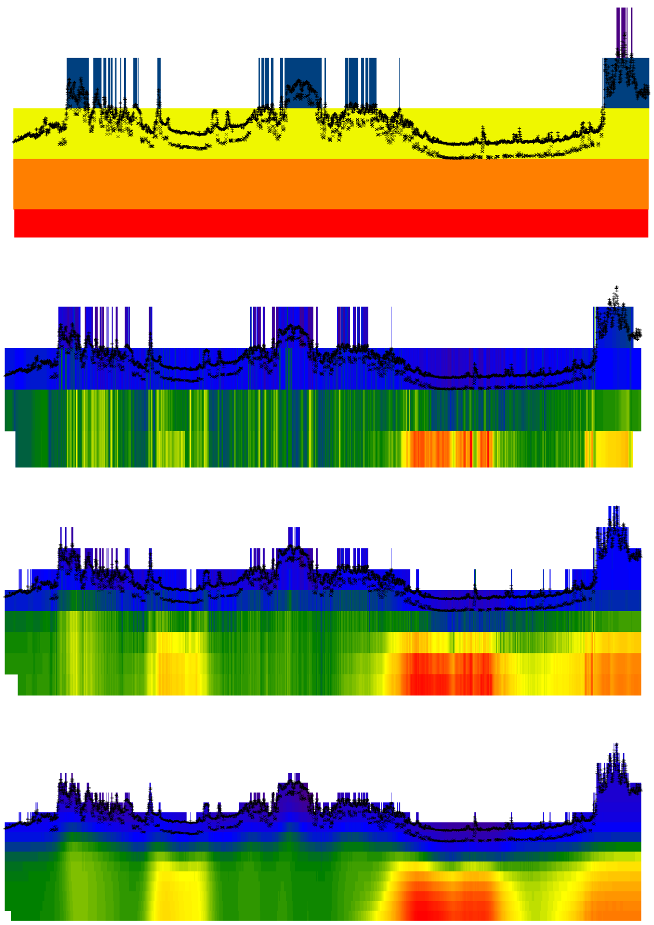

Figure 5 *Velocity model update. Figures represents the different update iterations .*