

Incorporating reflection data into refraction statics solution

Bernie Law and Daniel Trad

CREWES – University of Calgary

Summary

Near surface models from refraction inversion contain several types of errors, which are partially compensated later in the data flow by reflection residual statics. In this work, we modify the dataflow to automatically include feedback information from reflection statics from stack-power maximization. We modify GLI by adding model and data weights computed from the long wavelength components of surface consistent residual statics. By using an iterative inversion, these weights allow us to update the near surface velocity model and to reject first arrival picks that do not fit the updated model. In this non-linear optimization work flow the refraction model is derived from maximizing the coherence of the reflection energy and minimizing the misfit between model arrival times and the recorded first arrival times. This approach can alleviate inherent limitations in shallow refraction data by using coherent reflection data.

Introduction

Refracted first arrivals from seismic reflection surveys have been used to compute near surface velocity model for initial static correction for most land seismic data processing. Without these initial statics corrections, subsequent reflection velocity analysis and residual statics computation can be compromised. However, refraction statics corrections often contain errors caused by the quality of the refraction data, numerical errors of the refraction solution and the inability of the refraction algorithm to model the actual physical properties of the near surface. This can result in unsatisfactory statics corrections and reflection images. These problems are often revealed on CDP stack sections, and are typically addressed by revising refraction algorithm parameters and constraints and by surface consistent residual statics using deeper reflection data. Ronen and Claerbout (1985) demonstrated that surface-consistent residual statics can be estimated by stack-power maximization. Statics estimation is effectively a velocity analysis of the near surface (Ronen and Claerbout, 1985); however, surface-consistent residual statics derived from more coherent and better sampled reflection data are not used in refraction inversion algorithms. Surface-consistent residual statics corrects for the three refraction errors caused by the refraction data, numerical errors of the model and the complexity of the near surface. In this paper, a refraction inversion work flow utilizing stack-power maximization to estimate the refraction data error, ϵ_d , and model error, ϵ_m , for improved near surface velocity model and refraction statics corrections will be discussed.

Theory and Method

Refraction solution can be cast as the inversion of near surface velocity model parameters \mathbf{m} using first arrival time picks \mathbf{d} and forward modeling operator \mathbf{L} :

$$\mathbf{d} = \mathbf{Lm} \quad (1)$$

The model parameters \mathbf{m} can be computed by minimizing the objective function \mathbf{J} :

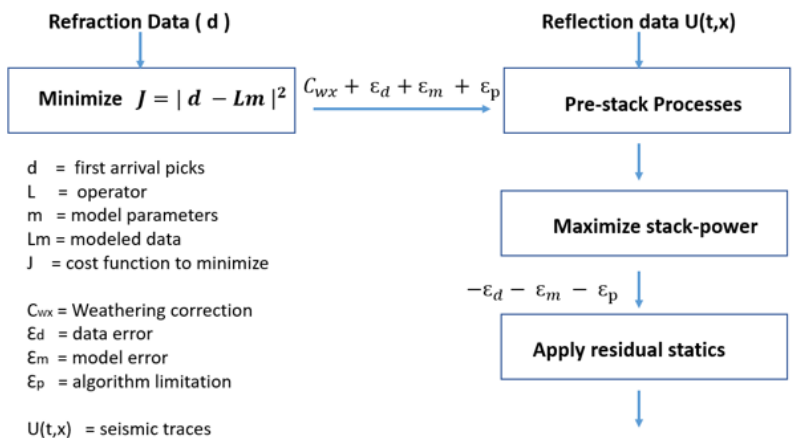
$$\mathbf{J} = \|\mathbf{d} - \mathbf{Lm}\|^2 \quad (2)$$

Errors in the refraction solution arise when the modeling operator \mathbf{L} is unable to model the data or the data are compromised because of near surface complexity. These errors often manifest as surface

consistent residual statics in the subsequent processing steps as shown in figure 1a. In the proposed non-linear optimization work flow as shown in figure 1b we add the model weight \mathbf{W}_m and data weight \mathbf{W}_d to the cost function of the inversion problem:

$$J = || \mathbf{W}_d \mathbf{d} - \mathbf{W}_d \mathbf{L} \mathbf{W}_m \mathbf{m} ||^2 \quad (3)$$

a) Conventional refraction and reflection statics processing flow



b) non-linear optimization of near surface velocity model using reflection data

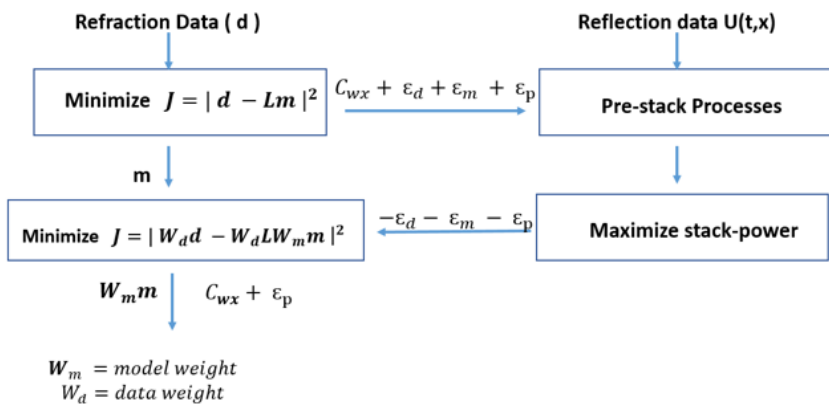


Figure 1 Conventional refraction statics processing flow versus non-linear optimization refraction statics processing flow.

We modify the GLI algorithm (Hampson and Russell 1984) to include \mathbf{W}_m and \mathbf{W}_d . \mathbf{W}_m corrects for slowness and thickness errors and is computed from \mathbf{E} , the long wavelength components of the surface consistent residual statics. \mathbf{W}_d corrects for data errors and is computed from the misfit between \mathbf{d} and $\mathbf{L} \mathbf{W}_m \mathbf{m}$.

$$\mathbf{W}_m \text{ (slowness)} = 1 - 0.5 * E_i / (Z_i P_i) \quad (4)$$

$$\mathbf{W}_m \text{ (thickness)} = 1 + 0.5 * E_i / T_i \quad (5)$$

where: $E_i = E Z_i / \text{Total thickness}$

$Z_i = \text{thickness for layer } i$

$P_i = \text{slowness for layer } i$

$$T_i = Z_i / V_r - Z_i P_i$$

V_r = replacement velocity

Example

2D line 2008-SC-01 acquired near Spring Coulee, Alberta was used to test the proposed refraction statics processing flow. To impose a data limitation on the GLI algorithm we decimated the first arrival times picks by 75% using only every 4th shot points. Refraction statics correction computed from the initial GLI solution was applied to the seismic data prior to surface-consistent residual statics using the stack-power maximization algorithm. Long wavelength components of the surface-consistent residual statics were used to compute the W_m and W_d matrix for the next GLI iterations. Figure 2 compares GLI solution and CDP stack from conventional refraction statics processing flow and the proposed refraction statics processing flow using feedbacks from stack-power maximization. As shown in figure 2d, CDP stack from the new GLI solution shows significant uplifts in coherence.

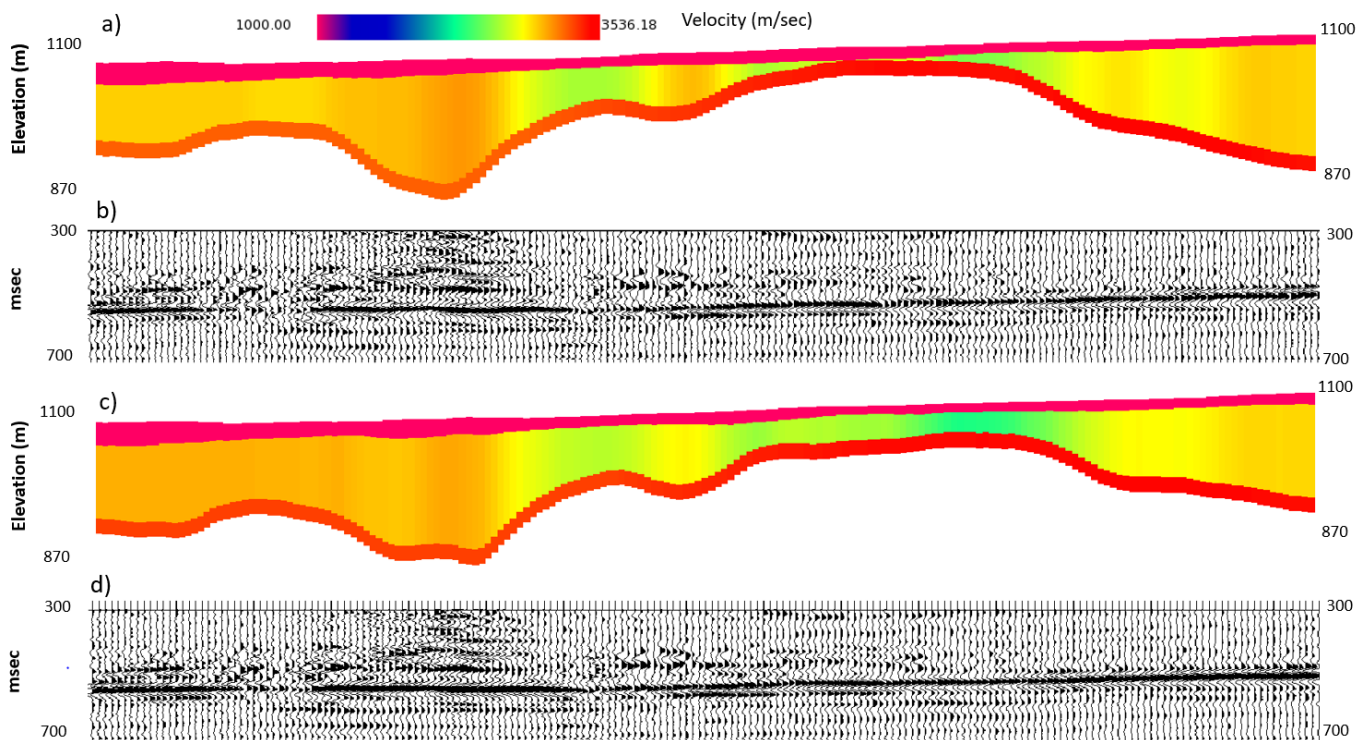


Figure 2: a) Initial GLI solution b) CDP stack after refraction correction from initial GLI solution c) GLI solution from non-linear optimization refraction statics processing flow. d) CDP stack after new refraction correction from new GLI solution.

Conclusions

The refraction statics processing flow and test results we showed in this study demonstrated how feedbacks from surface consistent reflection residual statics can be used to regularize the refraction inversion in both model and data space. Tests done in this study used GLI for refraction analysis and stack-power maximization for reflection residual statics solution. However, this technique can also be applied to

refraction tomography or other model based refraction method, as well as other surface-consistent reflection residual statics algorithms.

Acknowledgements

The work was funded by CREWES industrial sponsors and NSERC (Natural Science and Engineering Research Council of Canada) through the grant CRDPJ 46119-13.

References

Claerbout,J.,1992,Earth Sounding Analysis: Processing versus Inversion: Stanford University

Hampson, D., and Russell, B., 1984, First break interpretation using generalized linear inversion: Journal of the Canadian Society of Exploration Geophysicists, 20, 40-54

Ronen,J. And Claerbout,J., 1985, Surface-consistent residual statics estimation by stack-power maximization: Geophysics,50, 2759-2767