Multisource early-arrival waveform inversion of crosswell data

Gaurav Dutta, King Abdullah University of Science and Technology, Saudi Arabia

CSIM Center for Subsurface Imaging and Fluid Modeling

King Abdullah University of Science and Technology KAUST

1. Introduction

I propose a multisource early-arrival waveform inversion method for efficient and robust waveform inversion of crosswell data. Numerical results on the Friendswood crosswell data show an order of magnitude improvement in computational efficiency at every iteration of the inversion. CIGs and comparison with a sonic well log validate the fidelity of the proposed method.

2. Theory of multisource early-arrival waveform inversion.

- Objective function:

$$\epsilon = \frac{1}{2}\sum_{\omega}\sum_{\mathbf{s}}\sum_{\mathbf{g}}\left\|P^{pred}(\mathbf{g},\mathbf{s}) - P^{obs}(\mathbf{g},\mathbf{s})\right\|^2$$

- Misfit gradient for standard FWI:

$$\gamma(\mathbf{x}) = \sum_{\omega} S(\mathbf{x},\omega)R^*(\mathbf{x},\omega)$$

- Phase-encoding and windowing the CSGs:

$$\hat{S}(\mathbf{x},\omega) = \sum_{j=1}^{N} P_j(\omega)W_j(\omega)S_j(\mathbf{x},\omega),$$

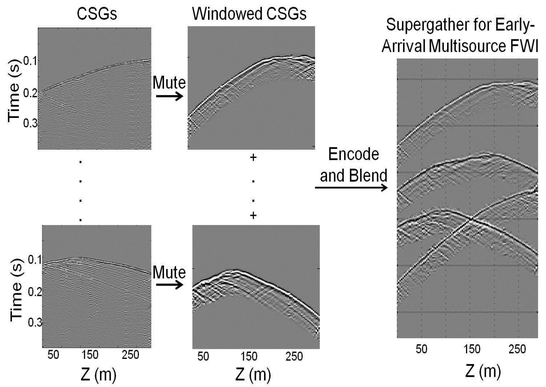
$$\hat{R}(\mathbf{x},\omega) = \sum_{j=1}^{N} P_j(\omega)W_j(\omega)R_j(\mathbf{x},\omega).$$

- New gradient:

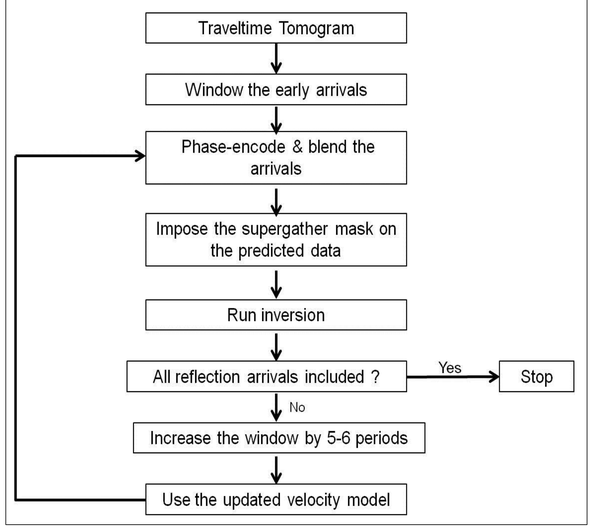
$$\hat{\gamma}(\mathbf{x}) = \sum_{j=1}^{N}\sum_{\omega}\left|P_j(\omega)\right|^2\left|W_j(\omega)\right|^2 S_j(\mathbf{x},\omega)\,R_j{}^*(\mathbf{x},\omega) + \sum_{j\neq k}^{N}\sum_{k=1}^{N}\sum_{\omega} P_j(\omega)P_k{}^*(\omega)W_j(\omega)W_k{}^*(\omega)\,S_j(\mathbf{x},\omega)\,R_k{}^*(\mathbf{x},\omega)$$

Crosstalk noise

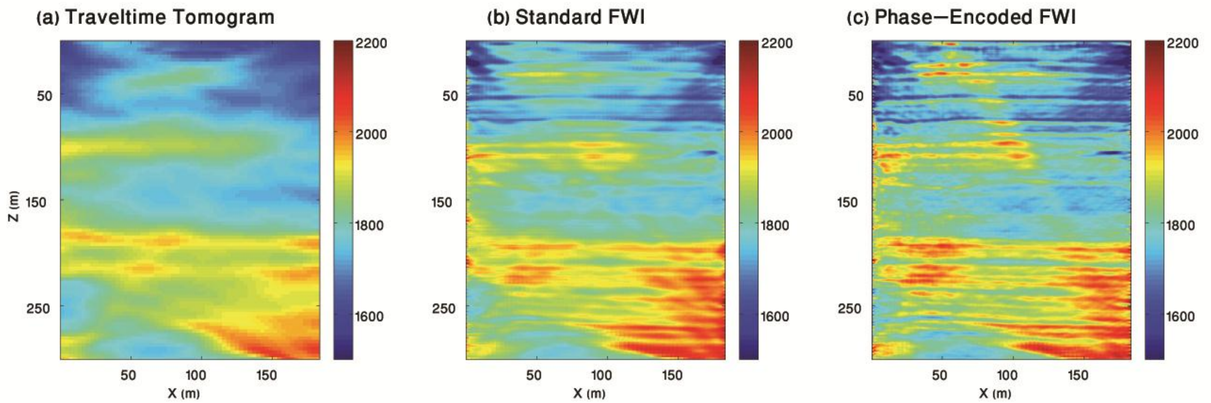
3. Phase-encoding of the early-arrivals



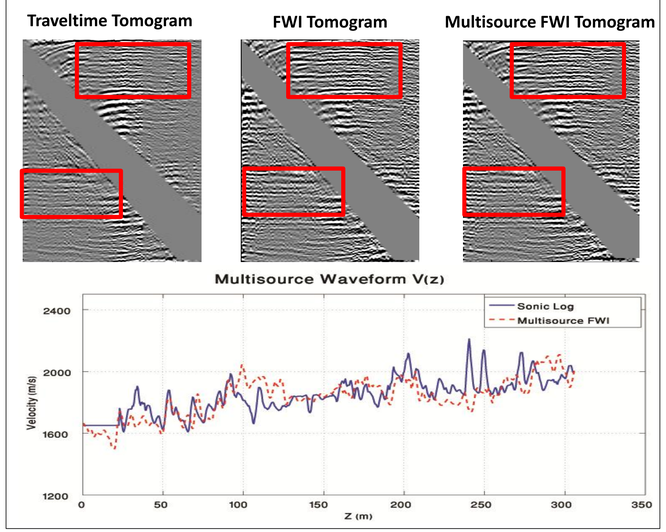
4. Inversion Workflow



5. Waveform Inversion Results



6. CIGs and Well Log Comparison



7. Conclusions

- An efficient and robust phase-encoded early-arrival waveform inversion method was presented.
- A cost savings of ***one order*** of magnitude was obtained without significant loss in accuracy.
- The method can be used for efficient waveform inversion of 3D VSP data and for statics estimation from land data by windowing out the early-arrivals.