Strategies for the efficient implementation of QFWI

Scott Keating* and Kris Innanen
*scott.keating@ucalgary.ca

QFWI and cross-talk

QFWI

- Full waveform inversion (FWI) is a powerful technique for recovering subsurface properties from seismic data.
- FWI is usually used to recover P-wave velocity only.
- In QFWI, quality factor Q, which characterizes attenuation and dispersion is also recovered.

Cross-talk

- Cross-talk occurs when physically distinct variables are confused in the inversion.
- Numerical optimization strategies affect cross-talk.
- Methods which consider more second derivative information better reduce cross-talk.

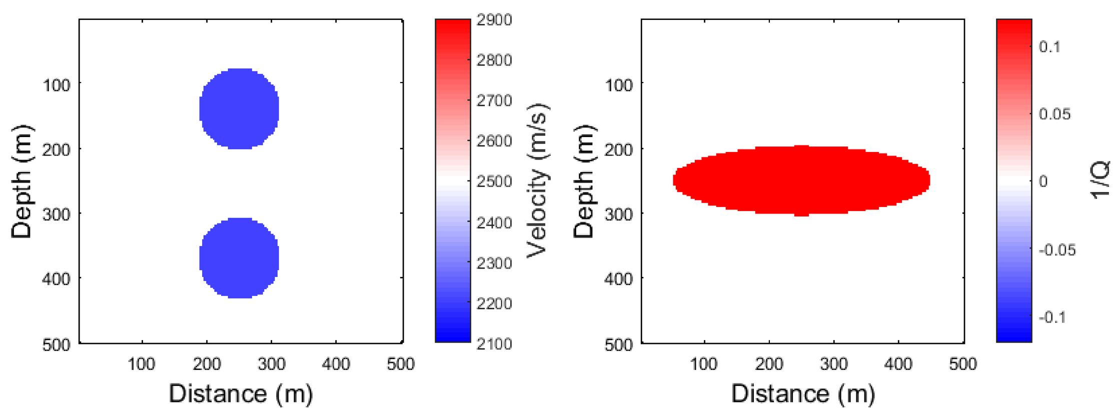

FIG. 1. True model used in QFWI examples.

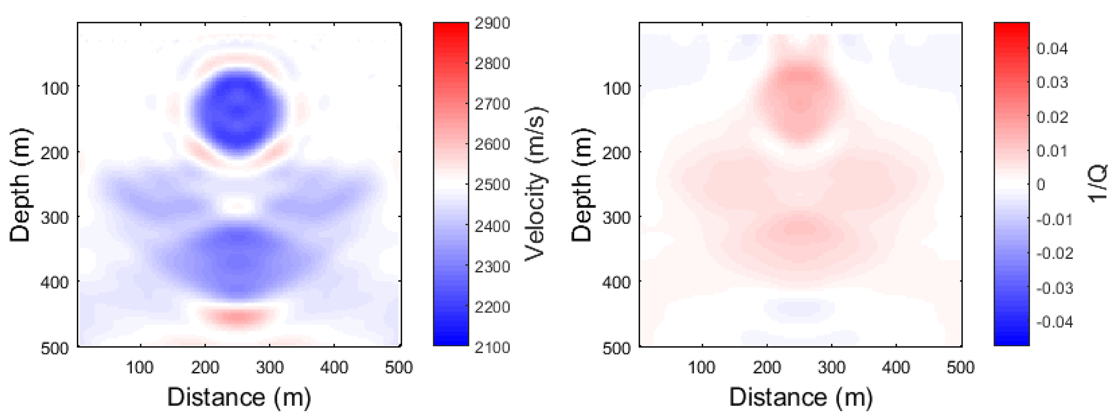

FIG. 2. QFWI result using steepest-descent optimization. Severe cross-talk limits recovery of both velocity and Q.

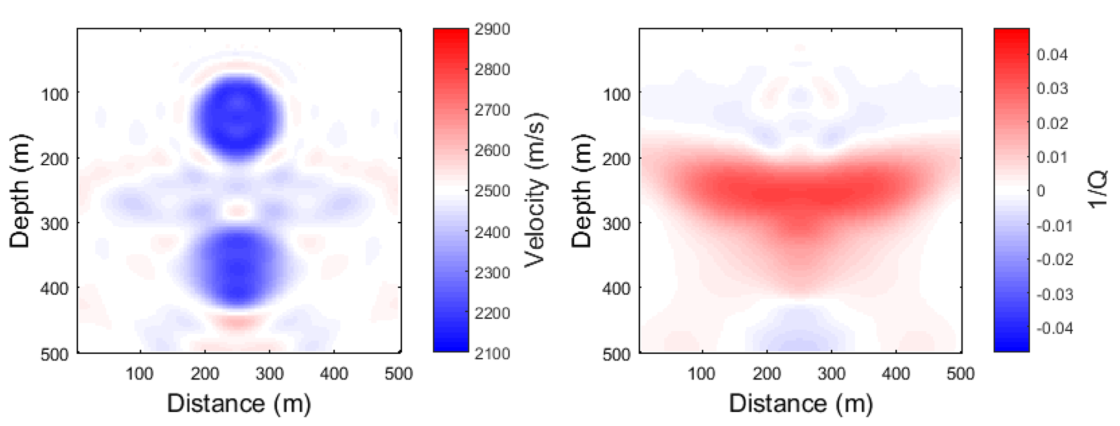

FIG. 3. QFWI result using truncated Newton optimization. By considering second order derivative information, cross-talk can be dramatically reduced.

- Unfortunately, the second derivatives are difficult to compute and store, due to the very high dimensionality of the problem.

Re-parameterizing

Changing the inverted model resolution

- More effective methods can be brought to bear by reducing the number of variables in the inversion.
- Model resolution can be adapted based on frequencies considered.
- More powerful methods can be used when there are few variables.
- This allows for cross-talk reduction on long-wavelength scales.

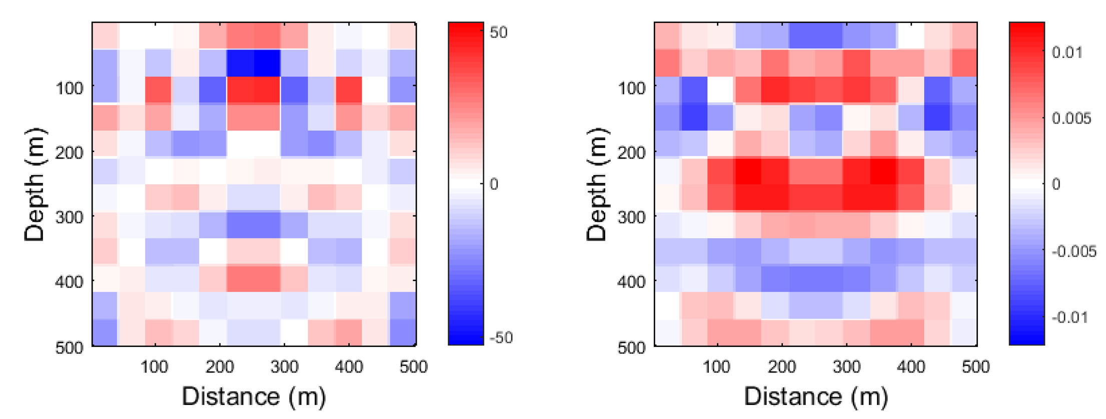

FIG. 4. Calculated model update for squared slowness(left) and reciprocal Q (right) at 1-7Hz frequency band (unscaled).

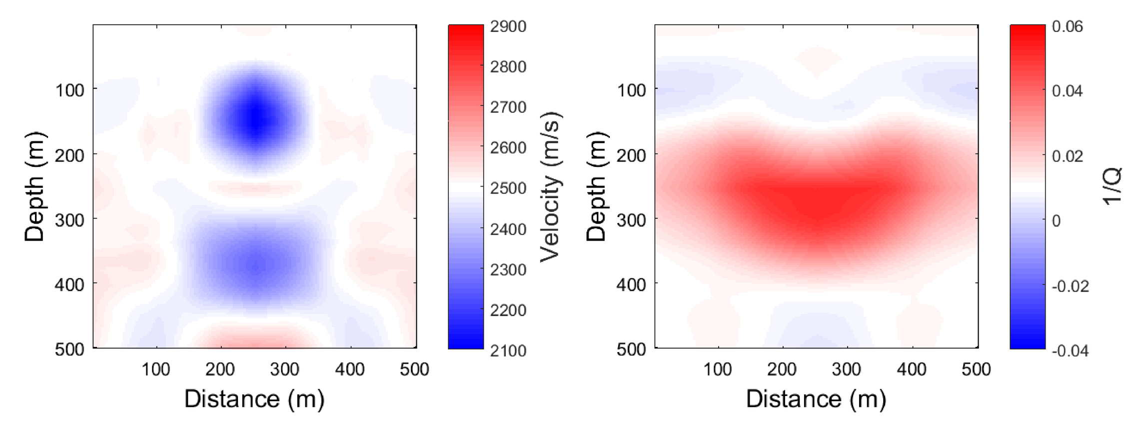

FIG. 5. QFWI result using Newton optimization with frequencies up to 7Hz.

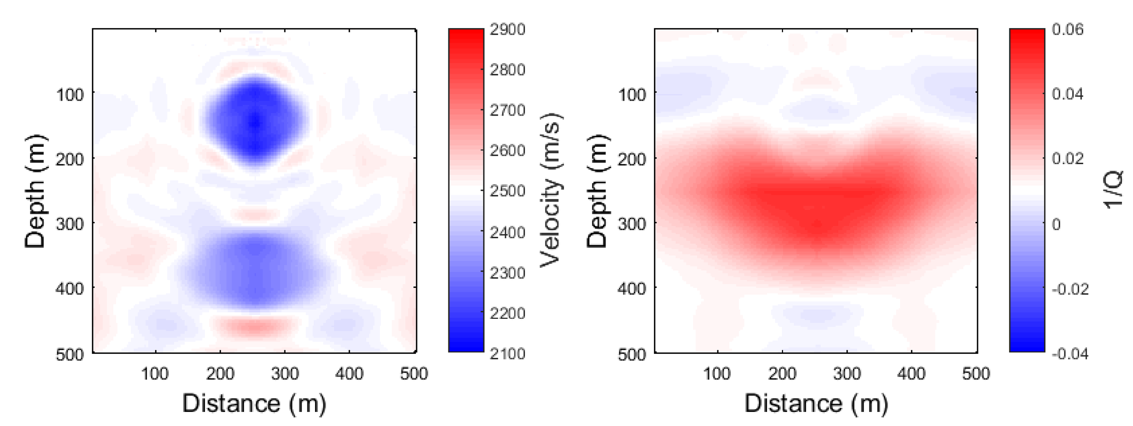

FIG. 6. QFWI result using steepest-descent optimization, starting with model in Figure 5. Compare to figure 2.

- Computational savings should be achievable using coarser parameterizations with other optimization techniques as well.

Approximating the Hessian

- Quasi-Newton methods can also reduce cross-talk by considering an approximation of the second derivatives (Hessian matrix).
- Coarse approximations to the Hessian can be used to initialize Quasi-Newton methods.
- The Hessian is more easily approximated than its inverse, suggesting the use of the Davidon-Fletcher-Powell (DFP) method.

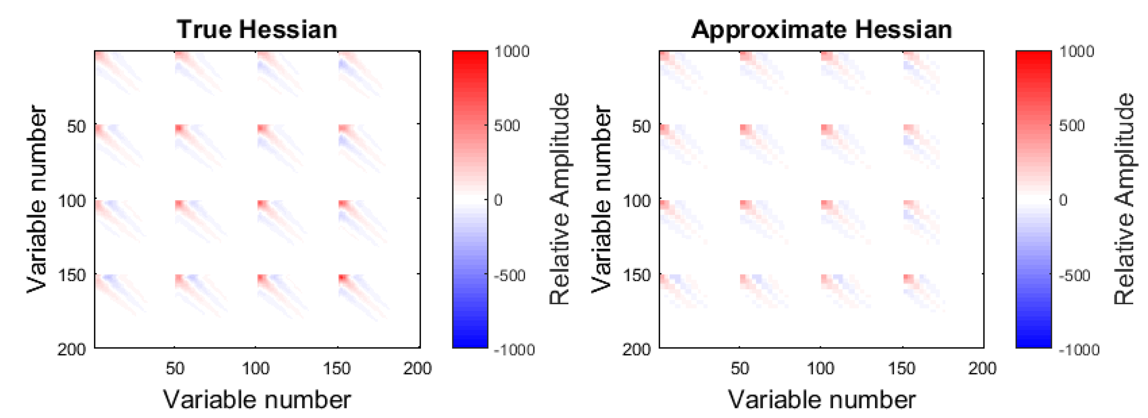

FIG. 7. Low resolution approximation to the Hessian. These matrices are close in a least-squares sense.

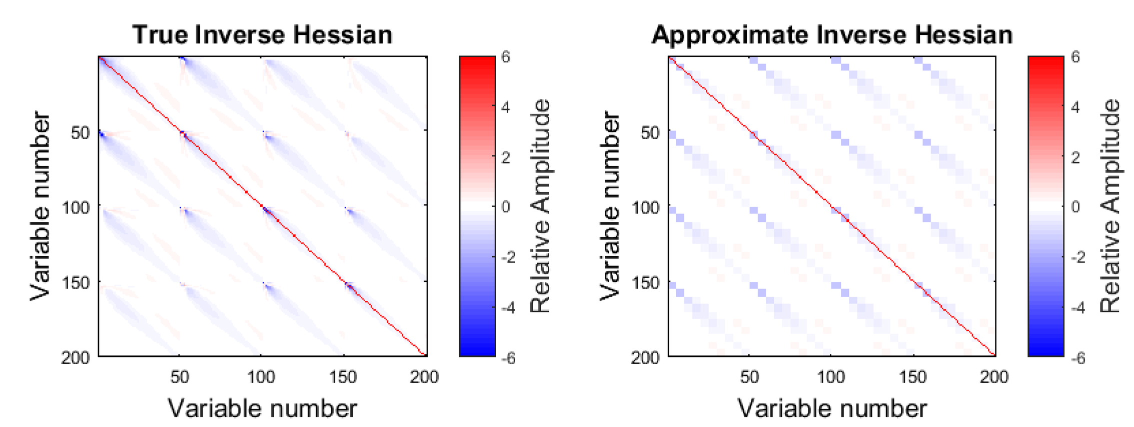

FIG. 8. Low resolution approximation to the inverse of the Hessian. These matrices are far apart in a least-squares sense.

Summary

- Numerical optimization costs can be dramatically reduced in FWI by considering fewer model variables.
- This allows for cross-talk effects, which confuse velocity data residuals with Q data residuals, to be severely reduced on long-wavelength scales.

Acknowledgments

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