Comparison between RTM gradient and PSPI gradient in the process of FWI

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Introduction

Full waveform inversion (FWI) can be described as an iterative cycle of four steps. 1) Generation of synthetic seismic data (modelled shots) from a smoothed initial model and obtain the difference among observed and modelled shots (data residuals). 2) Migration of the data residual (using the current velocity model) and stack. This step produces the gradient. 3) Scale the gradient in order to create a velocity update. 4) Add the velocity update to the current velocity model to obtain an inverted model. We start another cycle by using the new velocity model. This work is focused in the second step of the cycle. We compare the standard FWI gradient to the PSPI gradient. The PSPI and RTM gradients were scaled by applying the well calibration technique.

RTM vs PSPI

Migration response

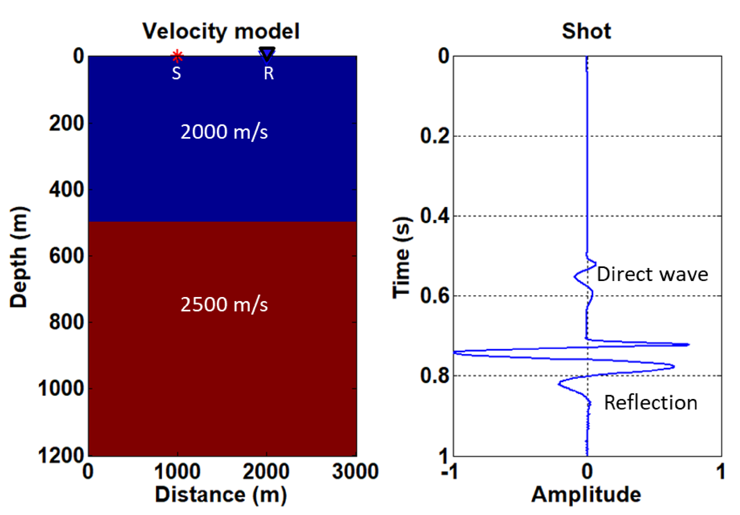


FIG. 1. Seismic trace with 1000-m offset generated by finite-difference modelling through a single interface model.

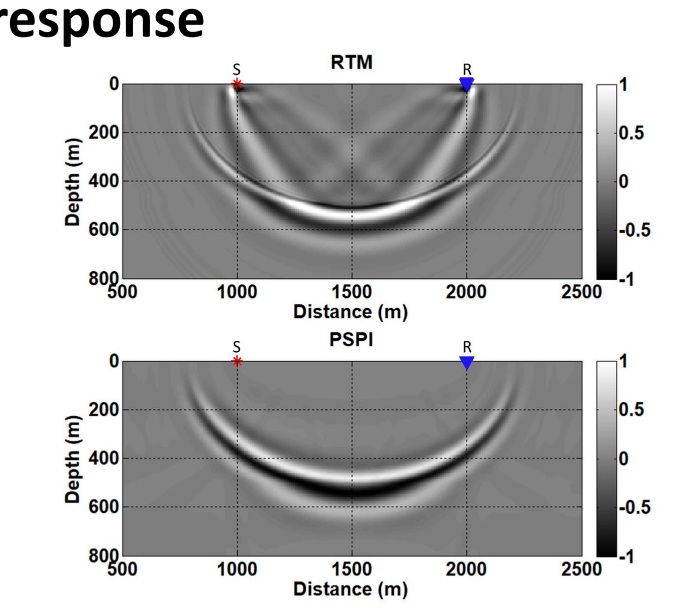


FIG. 2. PSPI and RTM applied to the 1000-m offset trace (Cross-correlation imaging condition).

Cross-correlation and deconvolution imaging conditions

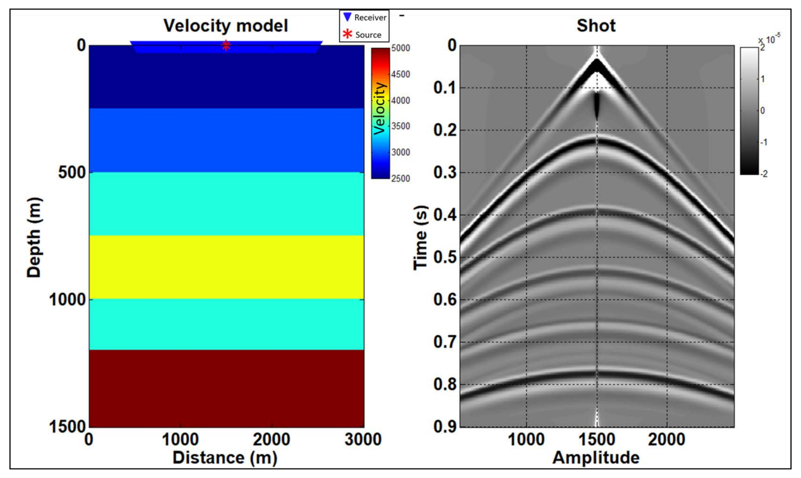


FIG. 3. Horizontal layered model used to generate the shot to the RHS. This shot was migrated with RTM and PSPI to compare imaging conditions.

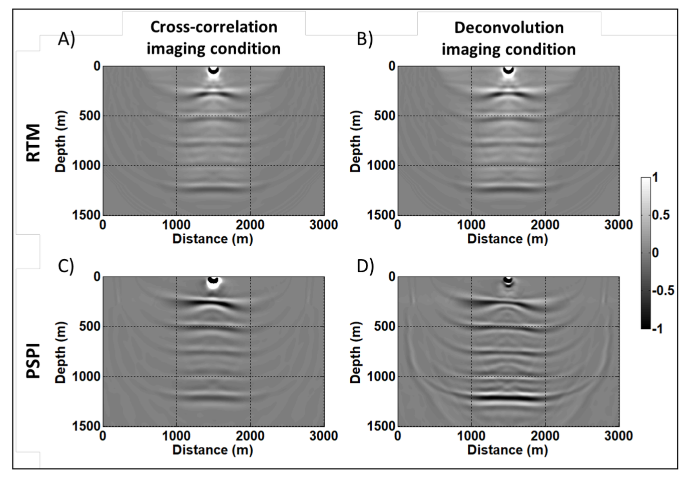


FIG. 4. Cross-correlation and deconvolution imaging conditions for RTM and PSPI applied to the shot of figure 3.

Inversion methodology

True model

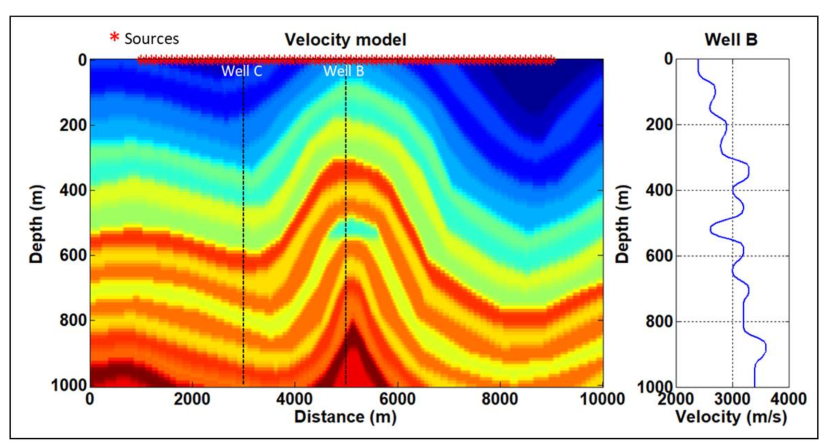


FIG. 5. Velocity model to be solved.

"Observed shots"

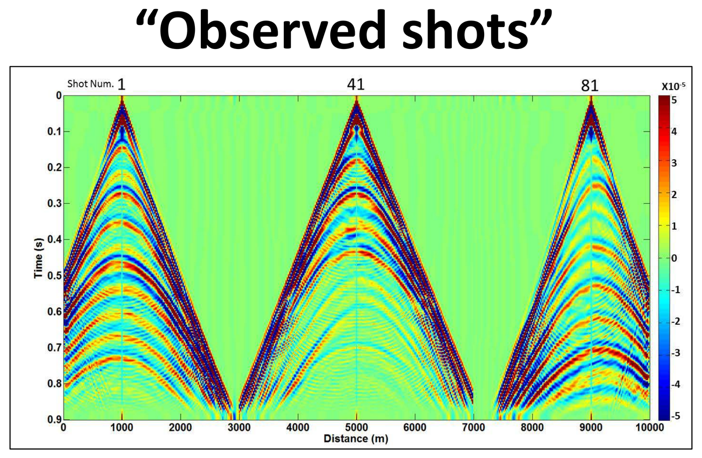


FIG. 6. Example of the synthetic seismic shots to be considered the observed data in the inversion

First iteration

Initial velocity model

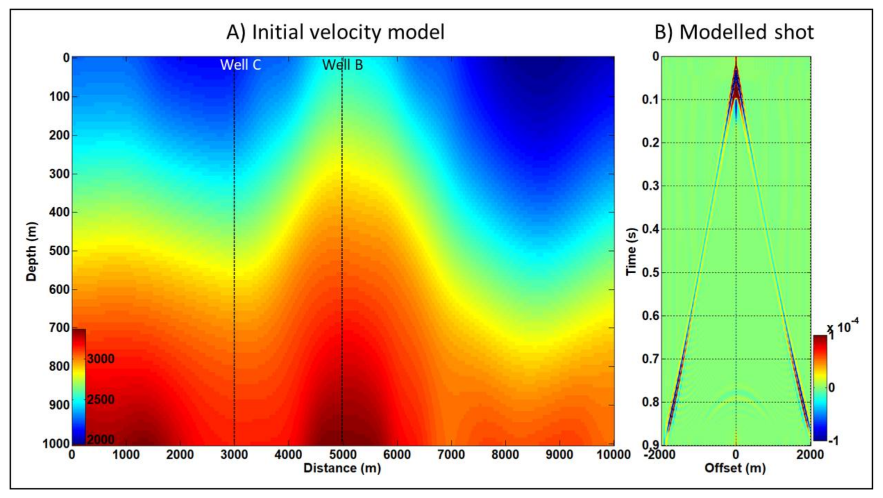


FIG. 7. {A) Initial velocity model. B) Synthetic shot modelled by finite difference through the initial velocity model.

Gradients

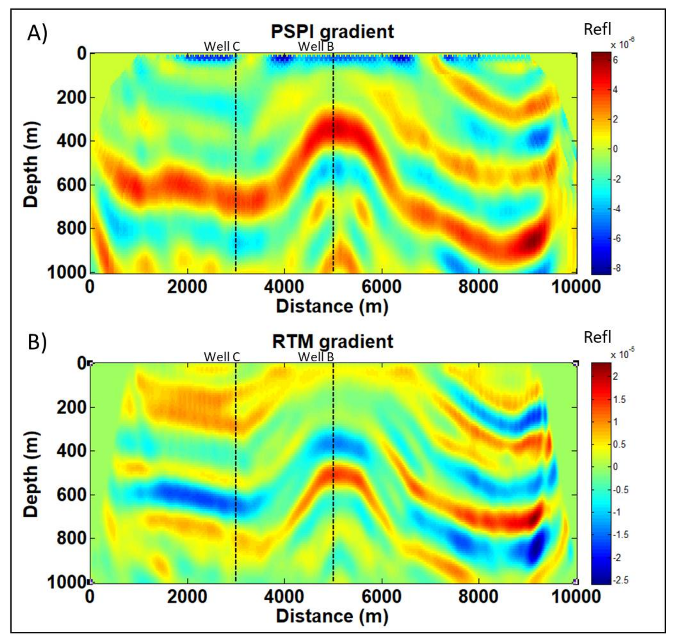


FIG. 8. A) PSPI gradient. B) RTM gradient.

Velocity updates

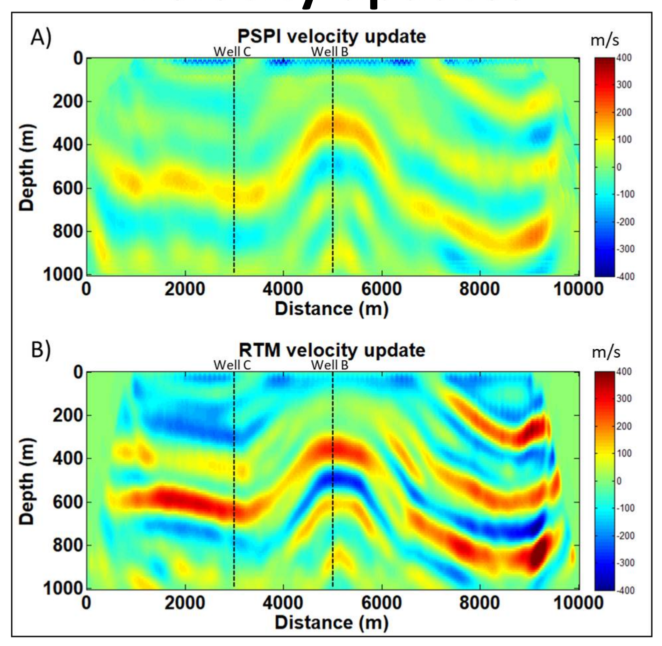


FIG. 9. . A) PSPI velocity update. B) RTM velocity update.

Inverted models

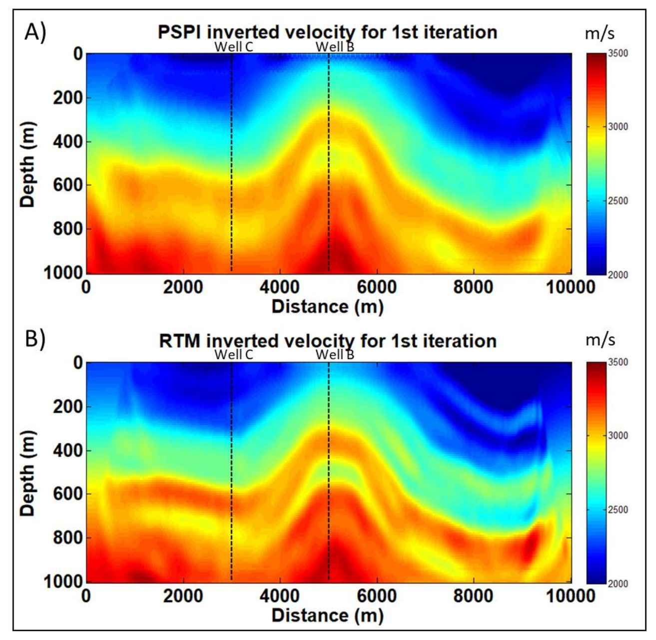
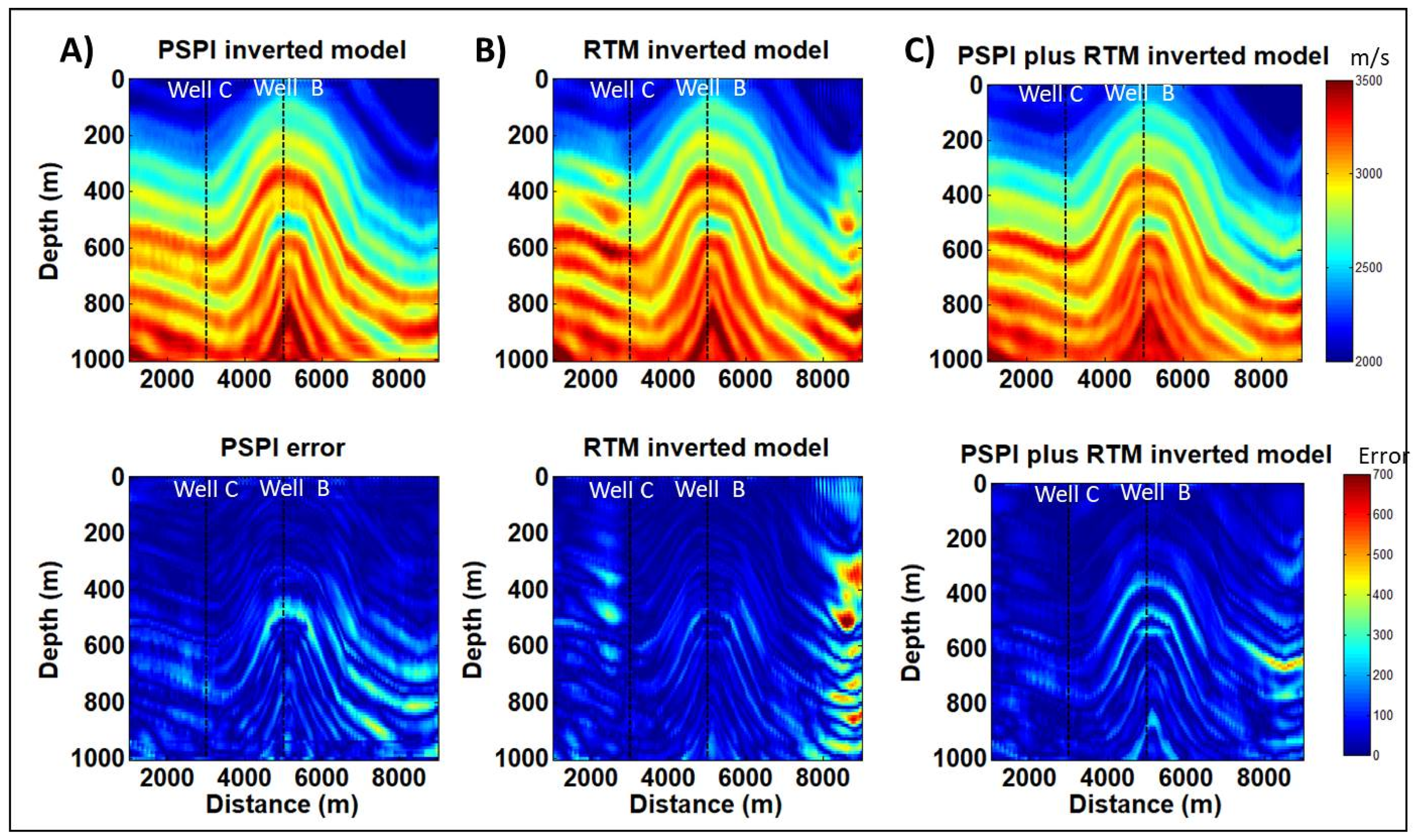


FIG. 10. Inverted velocity model for A) PSPI and B) RTM.

Results

Final inverted models



Error in final models

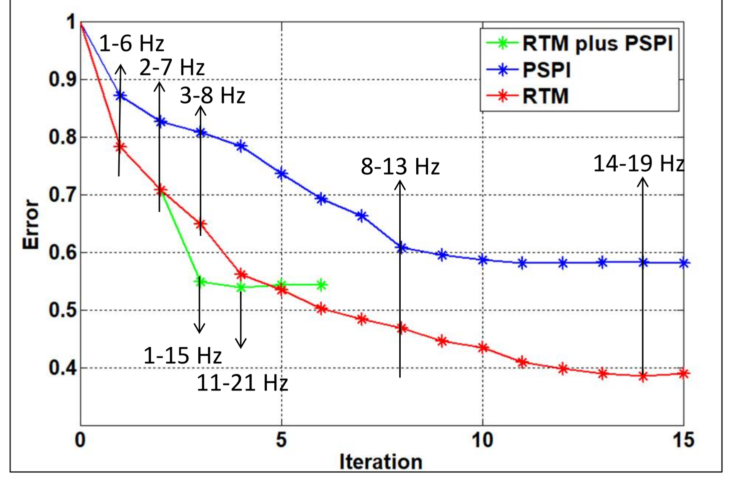
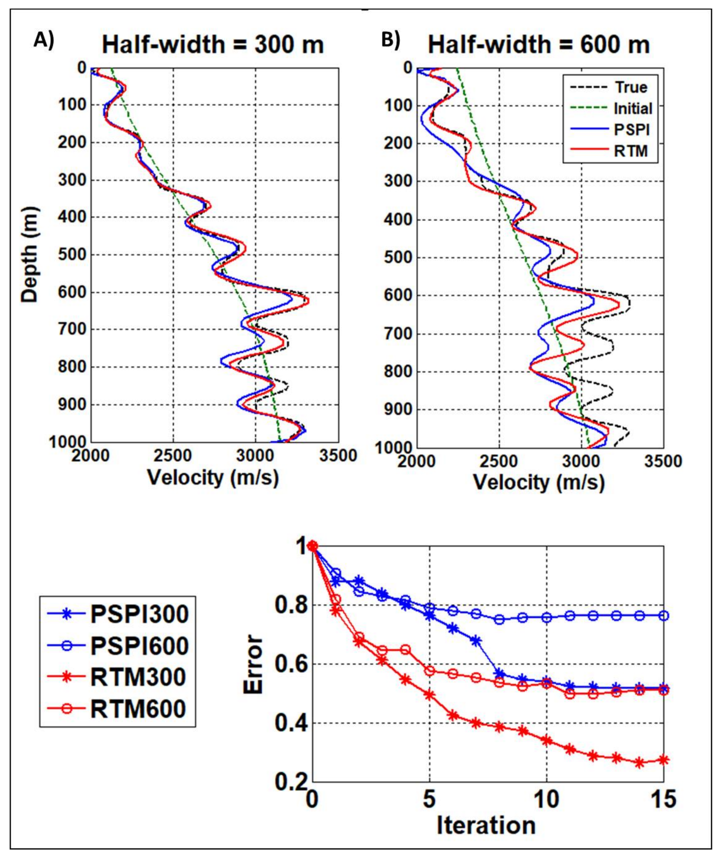


FIG. 15. The hybrid inversion produces a superior result than PSPI alone with only 6 iterations. However, the result is not as good as the one obtained by using RTM alone in 15 iterations.

Fig. 16. Error in inverted model for PSPI, RTM and the combination of both of them.

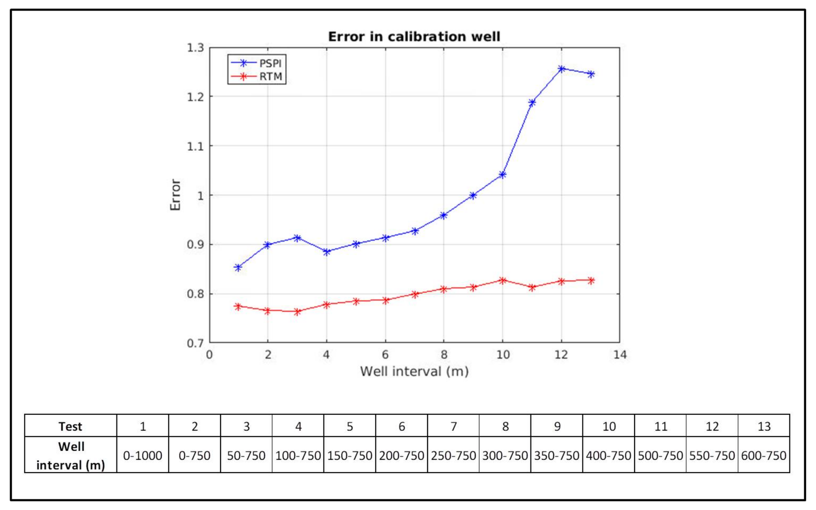
Sensitivity to initial model

FIG. 13. A) Gaussian smoother A) half-width = 300 m and B) half-width = 600 m. PSPI drastically underperforms with a smoother initial velocity



Sensitivity to well interval coverage

FIG. 14. PSPI is very sensitive to the well interval coverage, while RTM is quite stable. First iteration (1 – 6 Hz).



Conclusions

RTM is capable to manage all the arrivals in the wavefield, including primaries and multiples. PSPI can handle only reflections. The FWI gradient is commonly obtained by applying RTM to the data residuals. We showed that PSPI is also suitable to produce the gradient; however, it is more sensitive to the initial model and the well interval coverage used for the calibration, this characteristic will limit is applicability. RTM has the capability of recovering long-wavelength information; therefore, it is less sensitive than PSPI to a smoother initial model. The calibration of the RTM gradient with well information showed to be quite stable with smaller well interval coverages. RTM produced the smaller errors across the model and a superior result inside the full-fold and fully migrated zone. RTM showed to be more sensitive to the seismic coverage than PSPI. A hybrid inversion by using both methods is feasible and will save computational time, providing that we have enough well coverage to calibrate the PSPI gradient. A migration of one shot with RTM took 6 times longer than PSPI.

Acknowledgements

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References

Margrave, G. F., Innanen, K., & Yedlin, M., 2012, *A Perspective on Full Waveform Inversion* : CREWES Research Report, 24.