IMMI's performance with different maximum offsets, source intervals and random noise

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Introduction

IMMI stands for iterative modeling migration inversion. It was introduced by Margrave et al. (2012), and was thought as an alternative to accomplish full wave form inversion (FWI) by using standard processing tools. The core of FWI is summarized in Equation 1.

$$\delta v(x,z) = \lambda \nabla_v \phi_k(x,z,w) = \lambda \int \sum_{s,r} \omega^2 \hat{\Psi}_s(x,z,\omega)\delta\hat{\Psi}^*_{r(s),k}(x,z,\omega)d\omega \qquad (1)$$

The gradient of the objective function $\nabla_v \emptyset_k$ is obtained by correlating the time inverse residuals $\delta\hat{\Psi}_{r(s)}$ propagated into the medium with the source field $\hat{\Psi}_s$ propagated into the medium. This is a two-way wave migration. The gradient gives the update direction and needs to be scaled by λ to be converted into a velocity perturbation δv . λ is commonly obtained by a line search method. IMMI proposes that we can use any depth migration method to obtain the gradient and the incorporation of well information to scale it. Furthermore, we use a deconvolution imaging condition that works as a gain correction. We evaluate the sensitivity of the inversion to the maximum offset and source interval in the presence of random noise.

Inversion performance

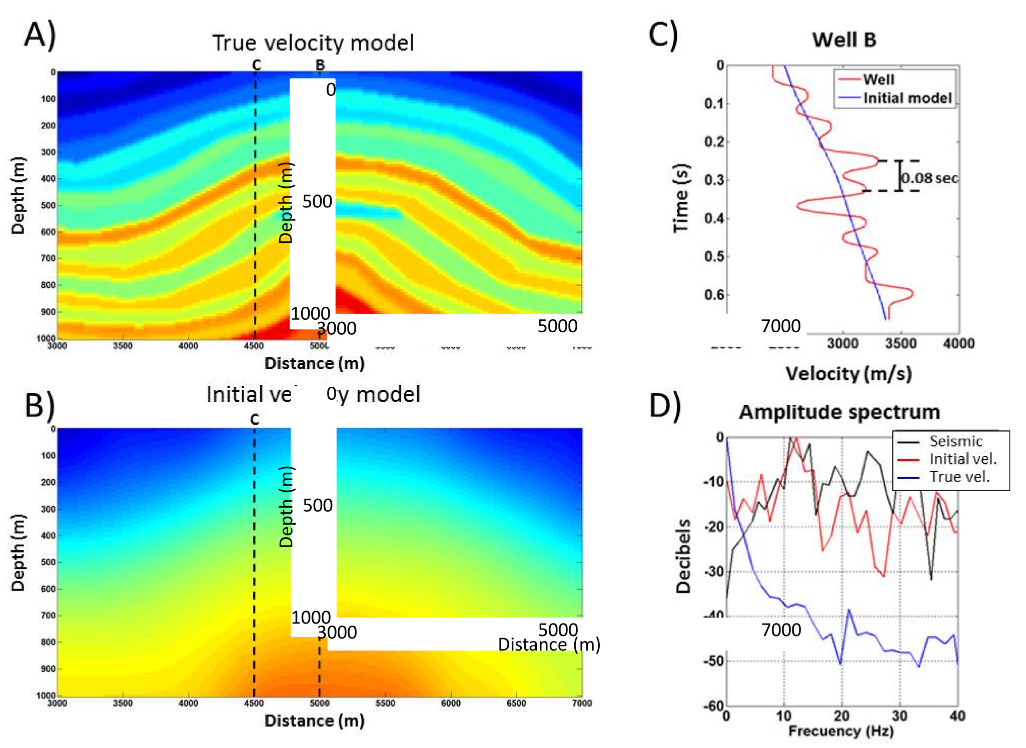

FIG. 1. A) True model. B) Initial model. C) Comparison between true and initial model in well B. D) Amplitude spectra of seismic, true and initial models.

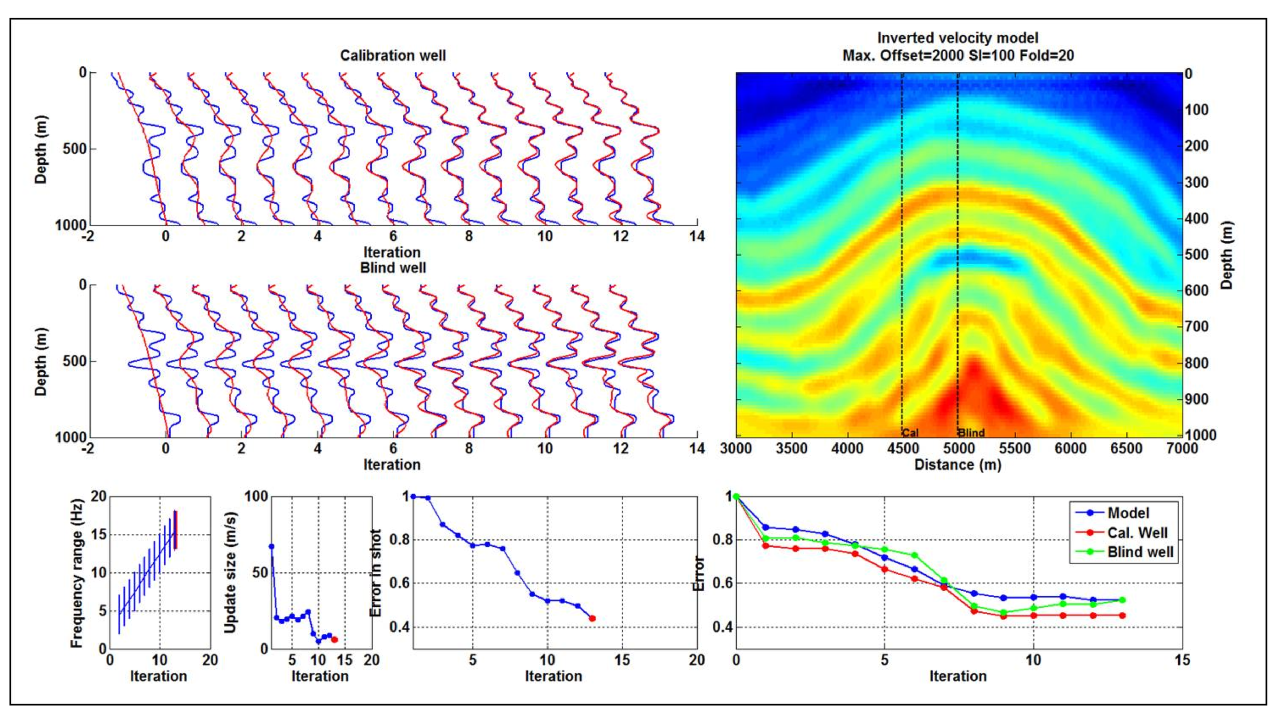

FIG. 6. Inversion performance.

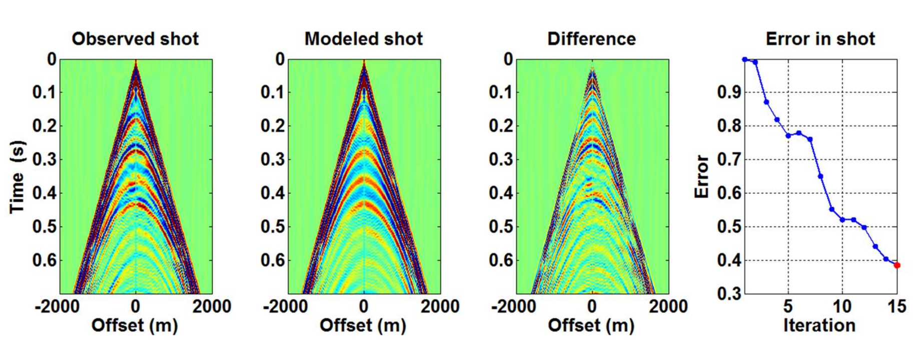

FIG. 7. Modeled shot and data residual for the 15th iteration.

Data analysis and results

Varying maximum offset

We compare the result of the inversion by using four different maximum offsets: 500, 1000, 1500 and 2000 m (Table 1).

Table 1. Varying maximum offset.

RI (m)	SI (m)	Max offset (m)	Fold	Channels	Number of shots
10	100	500	5	101	81
10	100	1000	10	201	81
10	100	1500	15	301	81
10	100	2000	20	401	81

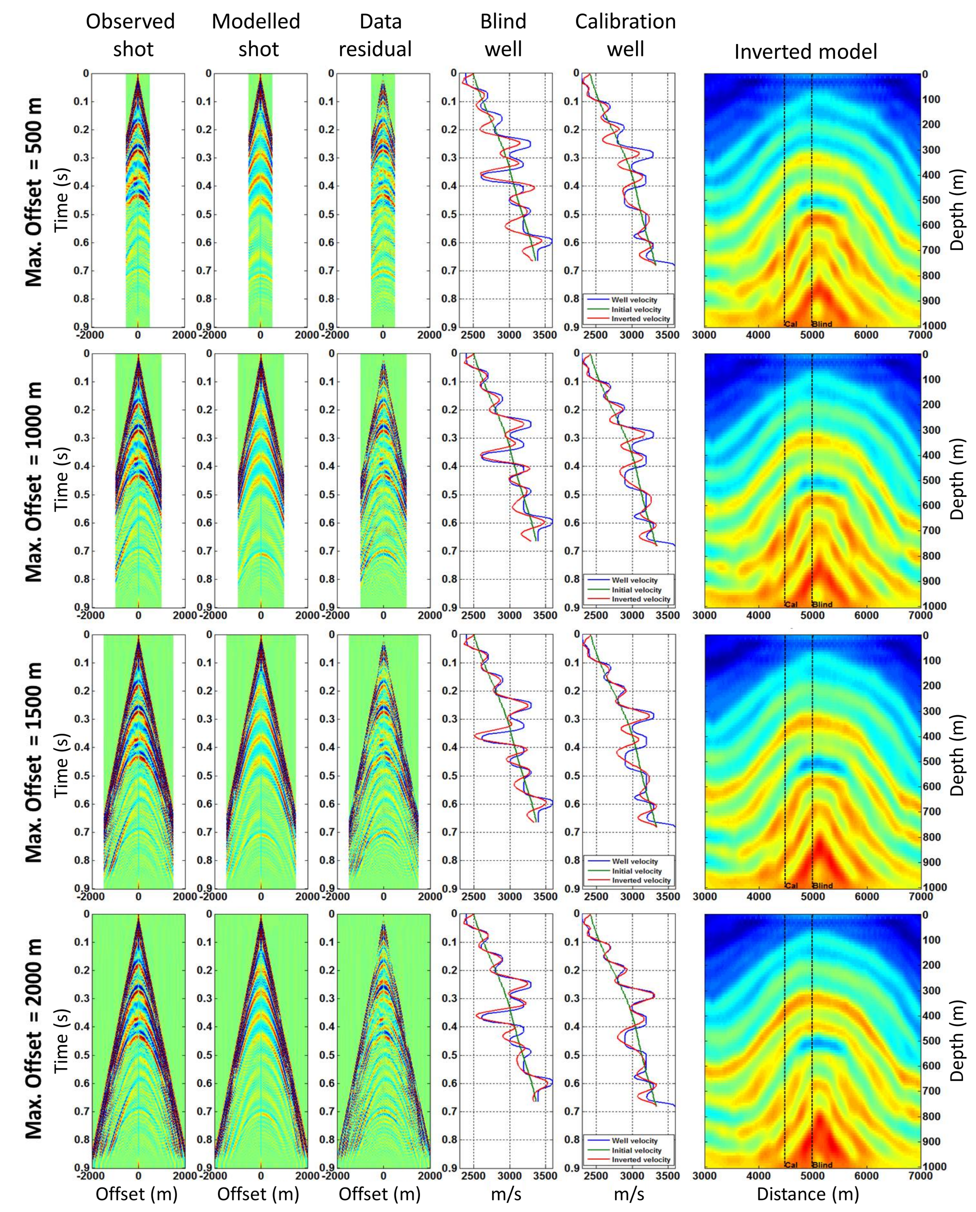

Fig. 8. Inversion performance with maximum offsets of 500, 1000, 1500 and 2000 m. No noise was added.

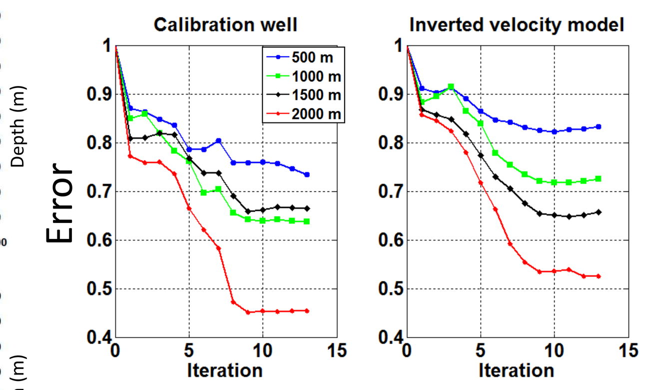

Fig. 9. Error when varying maximum offset.

The gradient is optimally scaled in the well location and produces the best velocity update and the smallest error. The result tends to improve as we use larger offsets.

Varying maximum offset plus random noise (S/N=6)

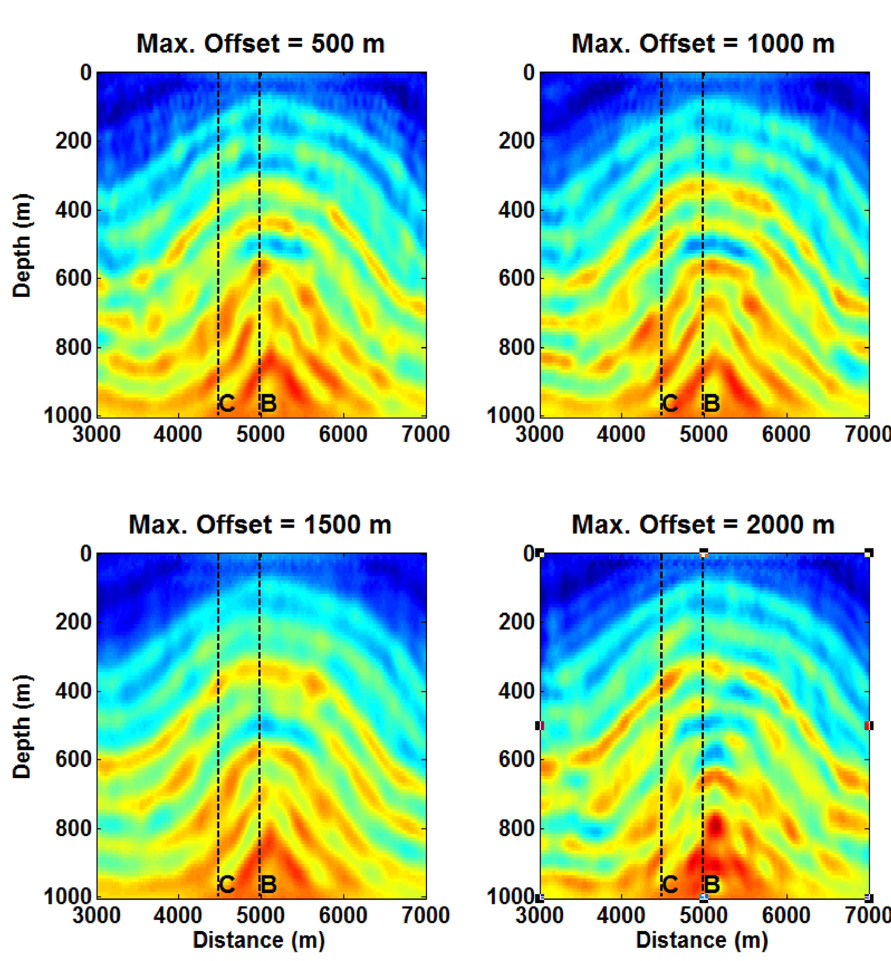

Fig. 10. Effect of random noise (S/N=6) in the inversion performance with maximum offsets of 500, 1000, 1500 and 2000 m. S/N = 6. Iteration = 13.

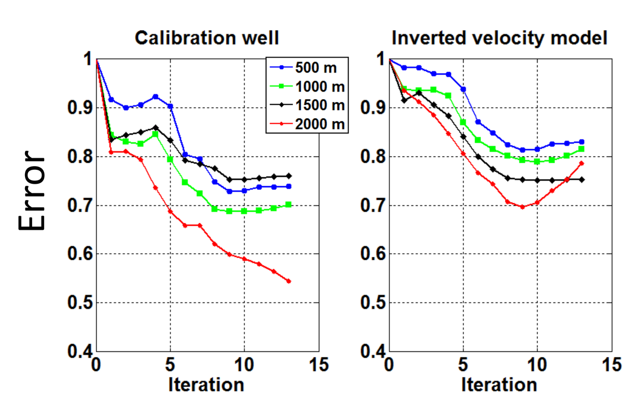

Fig. 11. Error when varying maximum offset with and without noise

When we increase the maximum offset we also augment the total fold, which contributes to improve the signal to noise ratio. Larger offsets provide smaller errors.

Varying source interval plus noise

We used four different source intervals for this experiment: 250, 100, 50 and 20 m. The total fold varies as shown in Table 2. The maximum offset was kept at 2000 m and random noise was added (S/N=6).

Table 1. Varying source interval.

RI (m)	SI (m)	Max offset (m)	Fold	Channels	Number of shots
10	20	2000	100	401	401
10	50	2000	40	401	161
10	100	2000	20	401	81
10	250	2000	8	401	33

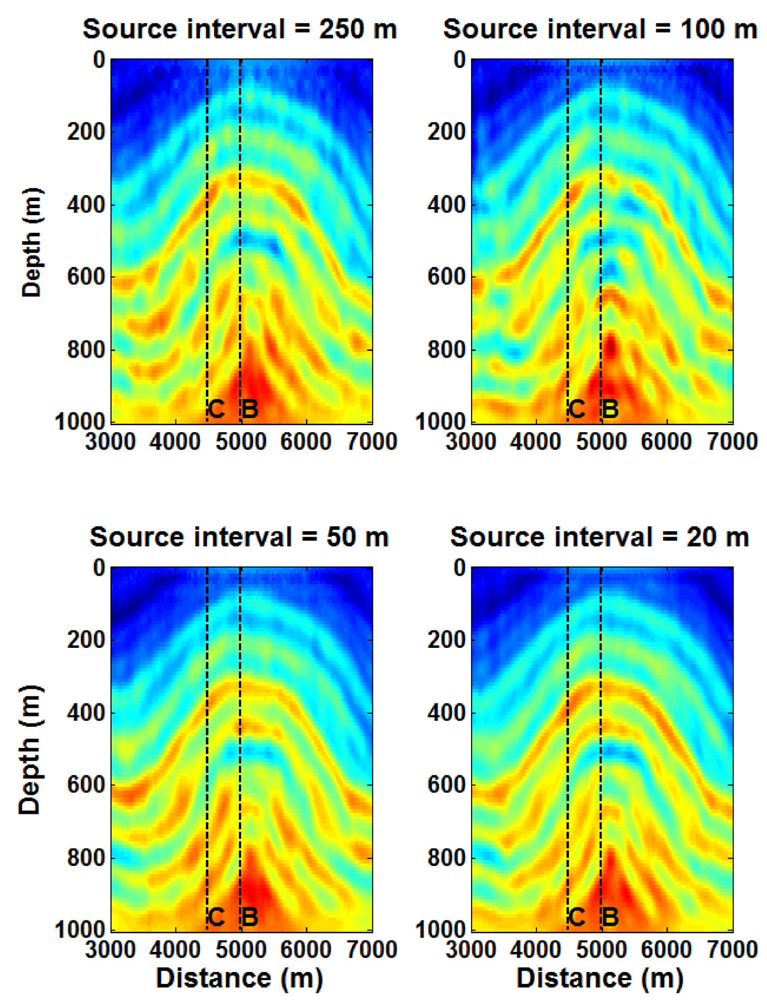

Fig. 12. Effect of random noise (S/N=6) in the inversion performance with source intervals of 250, 100, 50 and 20. Iteration =13 .

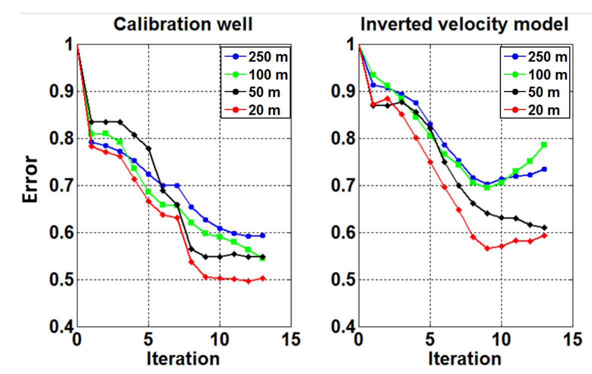

Fig. 11. Error when varying source interval with noise.

The features of the model are better defined with small source intervals of 50 and 20 m. The increment of fold, produced by smaller shot intervals and larger offsets, plays an important role for the improvement of the inversion.

Conclusions

IMMI's approach for FWI is able to find the velocity model of the subsurface. Depth migration methods other than RTM are suitable for obtaining the gradient in the minimization scheme of FWI. Well calibration provides an useful scaling of the gradient. The inversion is strongly influenced by random noise and seismic acquisition parameters. Offsets as twice the maximum target depth, favorably contributed to the inversion in this example. Large offsets and small source interval increase the fold, which improve the performance of the inversion in the presence of noise.

Acknowledgements

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References

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