IMMI: the role of well calibration in the context of high geological complexity

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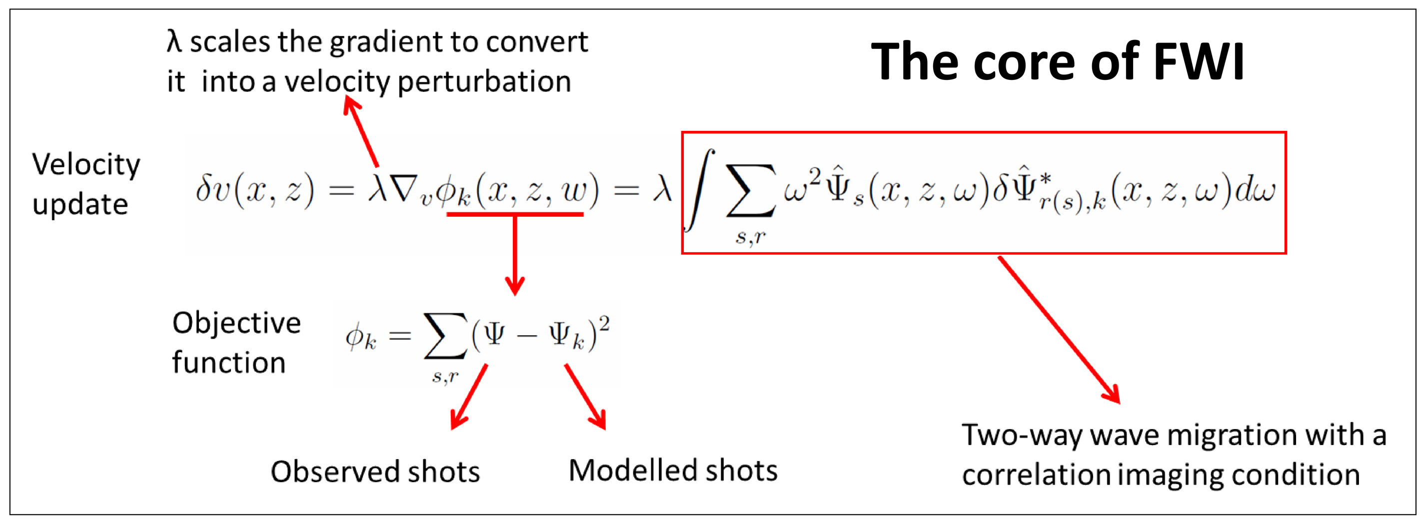
Introduction

- IMMI was introduced by Margrave et al. (2012).
- Stands for iterative, modelling, migration and inversion.
- Aims incorporating techniques of standard processing methodology into the FWI process.
- IMMI's approach proposes the use of any depth migration method and the use of well validation and data validation in FWI.
- We used PSPI migration with a deconvolution imaging condition to obtain the gradient and well velocity to scale the gradient.



Inversion process

1st iteration

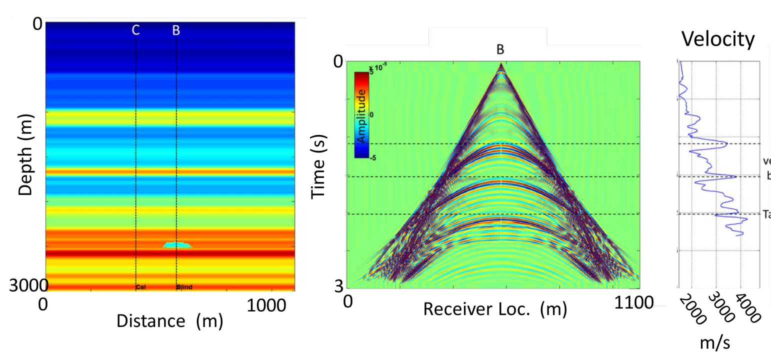


FIG. 1. True model and observed shots.

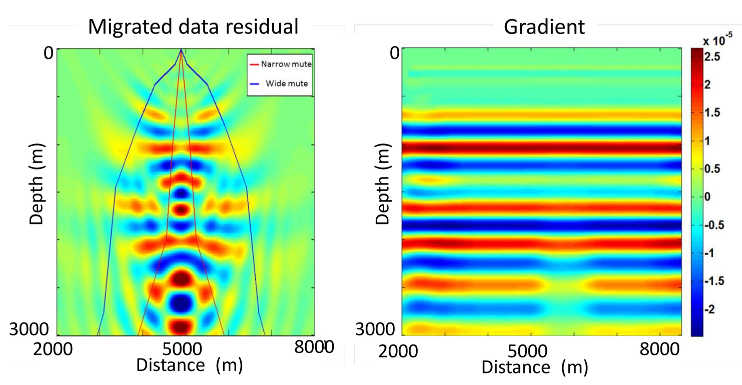


FIG. 4. Data residual migration and construction of the gradient .

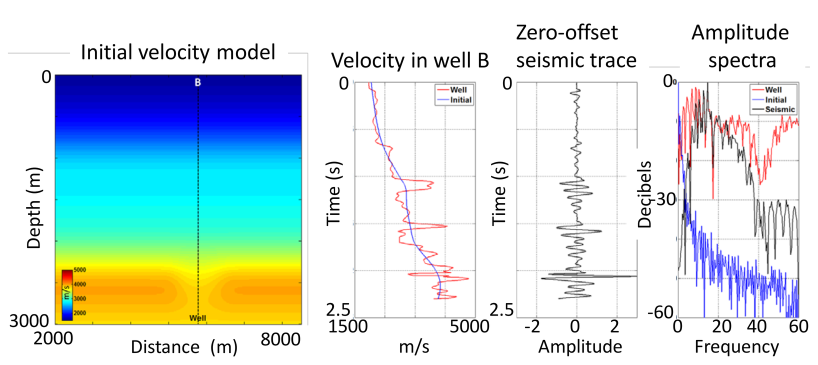


FIG. 2. Initial velocity model.

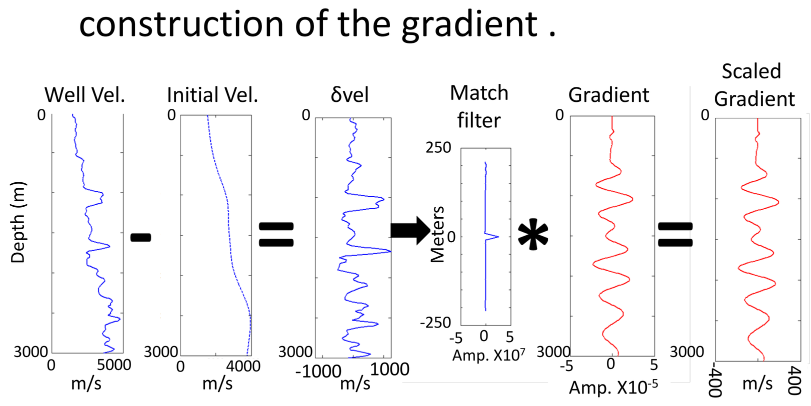


FIG. 5. Well C was used for scaling the gradient.

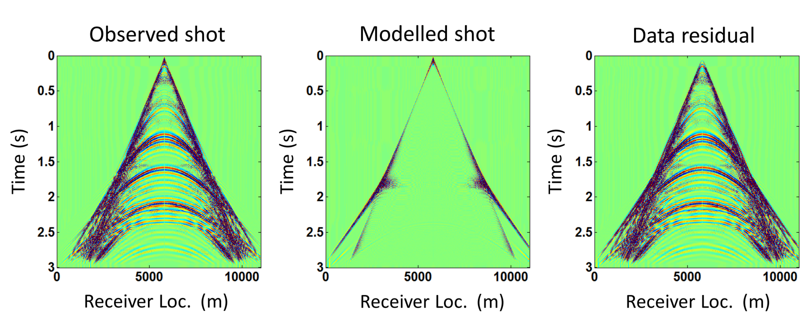


FIG. 3. The data residual is the difference between the observed and modelled shots.

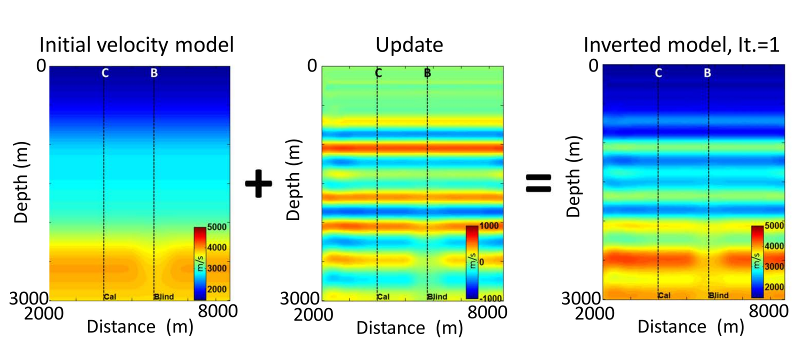


FIG. 6. Updating the current velocity model.

More iterations

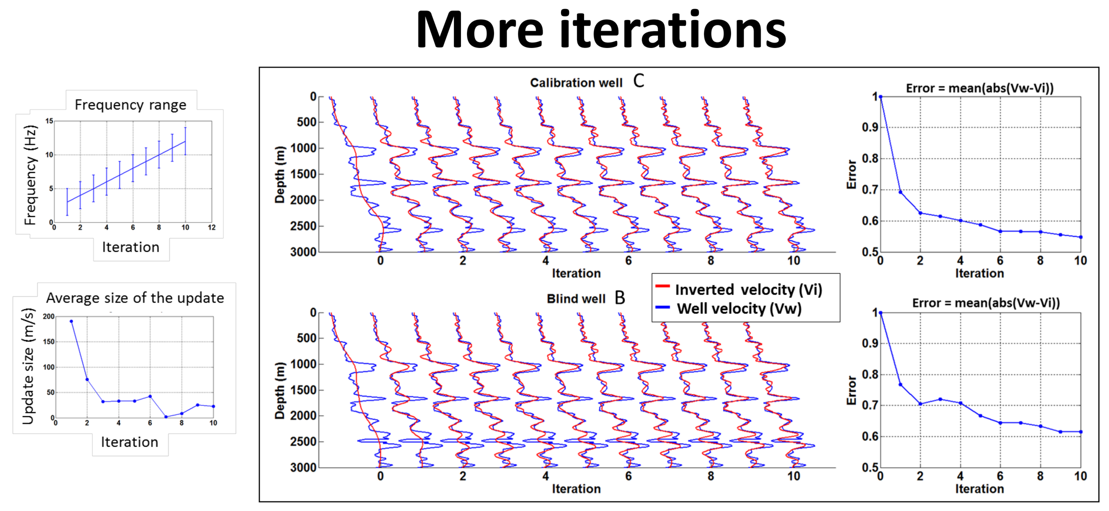


FIG. 7. Evolution of the inverted velocity in the calibration and blind wells. We increased the frequency range 1 Hz each iteration starting with 1-5 Hz.

More complex geology

We evaluated the performance of the well calibration technique in three different geological models (figure 8). The first model is constituted by horizontal layers with a low velocity stratigraphic target at a depth of 2500 m. The second one is a modification of the Marmousi model, where the normal faults were substituted by folded layers, producing moderate lateral velocity variations above the target. The complete Marmousi model was used for the third case.

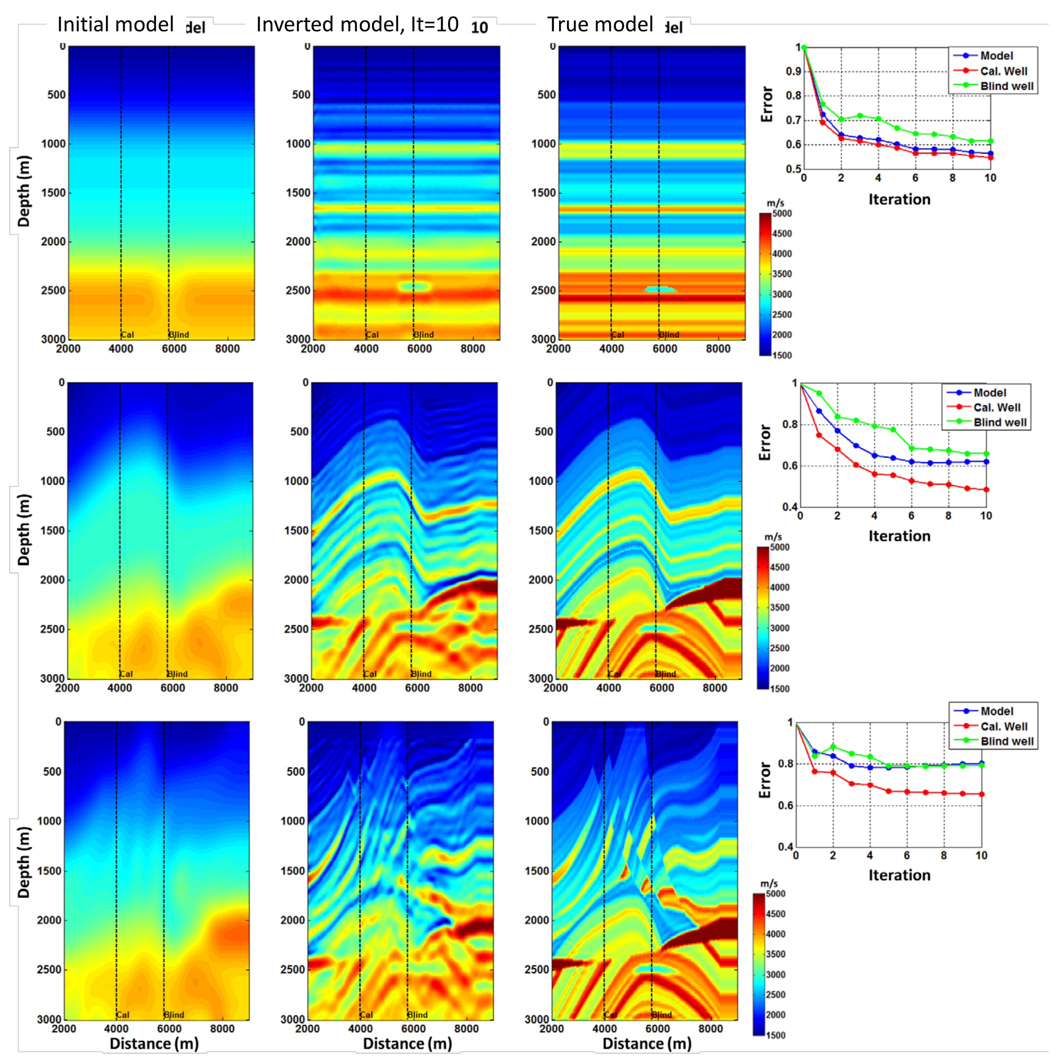


Fig. 8. Inverted models for three different geological setting (from less no more geological complexity). There are consistently low errors in the well calibration location for the three cases. Well calibration satisfactorily performs in the presence of moderate lateral velocity changes such as in Model 1 and 2. When we have strong lateral velocity variation (Model 3), well calibration is still able to produce a reasonable scale that allows recovering the main futures of the model.

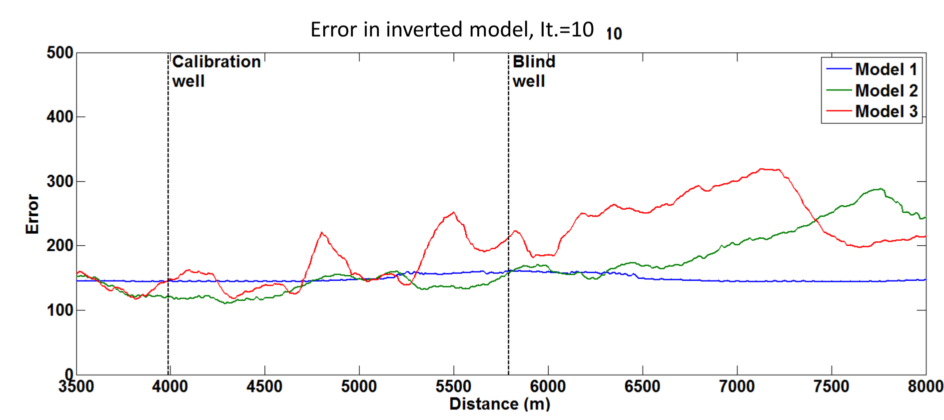


Fig. 9. Comparison of the spatial distribution error for Model 1, 2 and 3. There are consistently low errors in the vicinity of the well calibration location, even in the most complex settings. As the complexity increases to the right of Model 3, the error also rises.

What if we had a calibration well in each model location

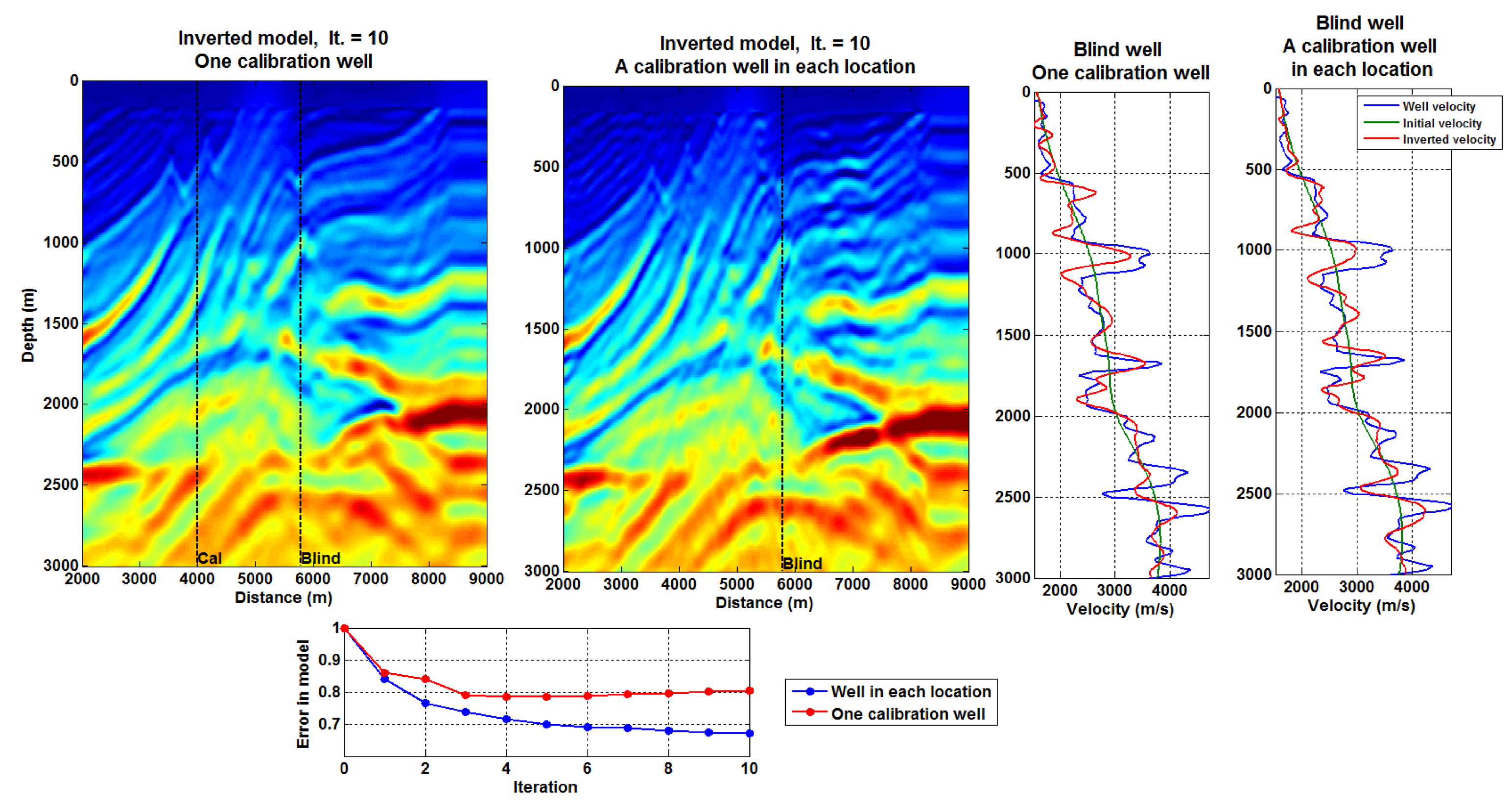


Fig. 10. Model 3: One calibration well vs Calibration wells in each single location. The high velocity body and the reservoir are better defined. The velocity in the target is better inverted.

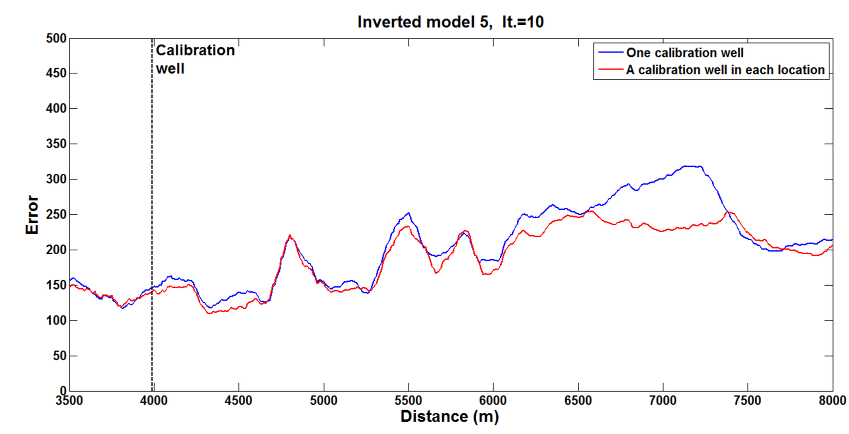


Fig. 11. Horizontal distribution of the error in Model 3. One calibration well vs Calibration wells in each single location.

Why a single well produces a similar result that the case where we have a well calibration in each location?

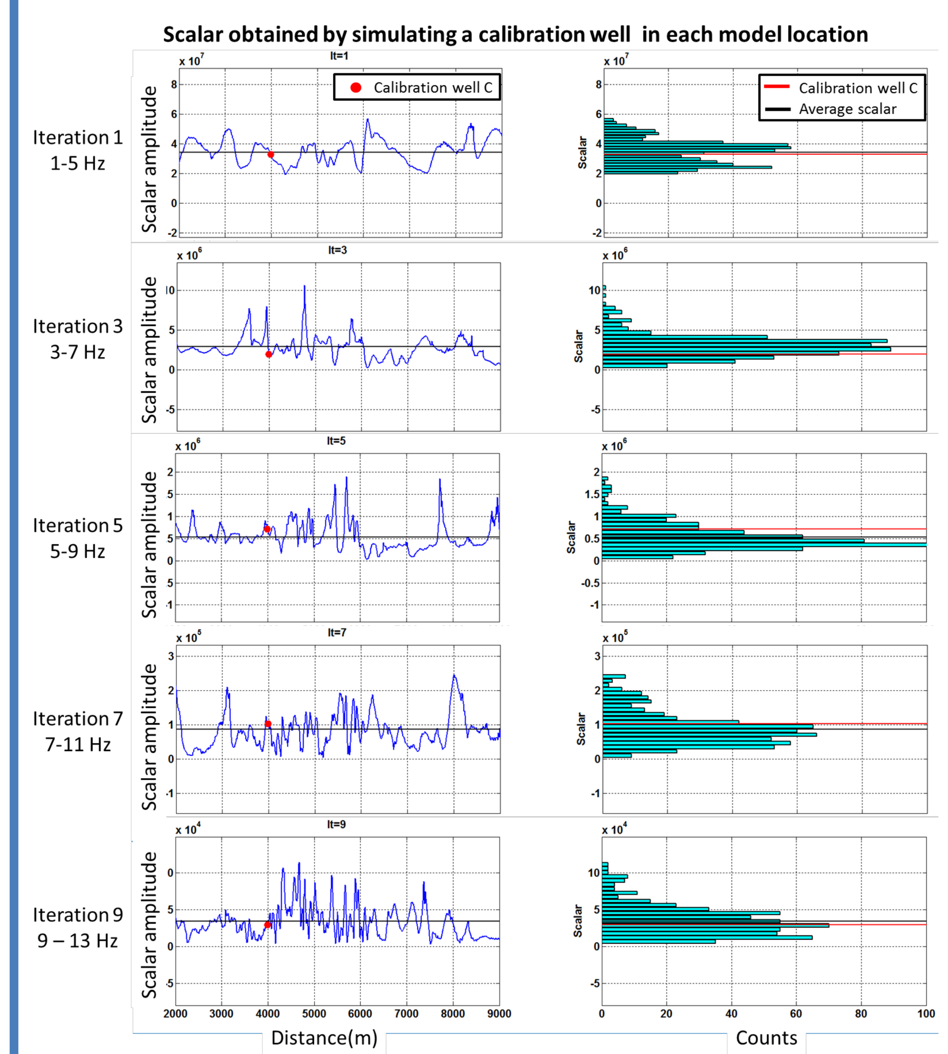


Fig. 11. Scalar variation across the section for several iterations. A single well will provide an acceptable calibration if it is close to this dominant scalar values.

Conclusions

- The gradient, calculated with an one-way wave migration method (PSPI) with a deconvolution imaging condition, points to the right direction to minimize the objective function in the FWI scheme.
- A scalar, estimated with well information, calibrates the gradient and produces suitable velocity perturbations to update the model. This was confirmed by the consistently low error in the well location even for the most geological complex model.
- Well calibration satisfactorily performs in the presence of moderate lateral velocity changes (Model 1 and 2).
- Well calibration can be used in strong lateral velocity contexts, providing that the well is representative of the geology of the area of interest.

Acknowledgements

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References

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

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