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A Real-data Example of Automatic Migration Velocity Analysis with Extended Images in the Presence of Multiples

W. Mulder* (Shell GSI BV & Delft University of Technology),

SUMMARY

Migration velocity analysis for the two-way wave equation based on focusing extended migration images at zero subsurface offset are sensitive to the presence of multiples. Even after thorough multiple suppression, remnant multiple energy can lead to conflicting events that will focus at different velocities, one for the primary and another for the multiple. An automatic algorithm will produce a velocity in between these two. If the multiples are mainly caused by the presence of a water layer, a bias of the algorithm towards higher velocities may help. Here, an application of this approach to a marine data is presented and the result is compared to a well log.

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Migration velocity analysis for the two-way wave equation based on focusing extended migration images at zero subsurface offset are sensitive to the presence of multiples. Even after thorough multiple suppression, remnant multiple energy can lead to conflicting events that will focus at different velocities, one for the primary and another for the multiple. An automatic algorithm will produce a velocity in between these two. If the multiples are mainly caused by the presence of a water layer, a bias of the algorithm towards higher velocities may help. Here, an application of this approach to a marine data is presented and the result is compared to a well log.

Introduction

Shen et al. 2003 proposed the use of differential semblance optimization on extended subsurface migration images. In the classic migration approach, the forward wavefield from a shot and time-reversed wavefield from the receivers are correlated. Extended images are obtained by shifting these wavefield over some distance, a subsurface offset, before correlation. In the correct velocity model, the extended image should have events focused at zero subsurface offset.

Method

If the classic migration image in 2D in the frequency domain is given by $\sum_{s,r(s),\omega} \omega^2 p_s^*(x,z,\omega)\, q_{r(s)}(x,z,\omega)$, with p_s the forward wavefield from source s and $q_{r(s)}$ the reverse-time field from the receivers $r(s)$, then an extended image for a horizontal subsurface shift h_x is defined as $R(x,z;h_x,h_z{=}0) = \sum_{s,r(s),\omega} \omega^2 p_s^*(x-\frac{1}{2}h_x,z,\omega)\, q_{r(s)}(x+\frac{1}{2}h_x,z,\omega)$. The velocity model is determined by maximization of the cost function $J = \frac{1}{2}\sum_{x,z,h_x} W(x,z)\,\eta(h_x)\,|\Xi_x R(x,z;h_x,0)|^2$, with dip and spatial low-cut filter Ξ_x, spatial weighting W and subsurface offset weighting function $\eta(h_x) = [1+(h_x/l_x)^2]^{-p}$, p around 1 and a length scale l_x of the order of the size of the Fresnel zone (Mulder 2012). With multiples, a bias can be introduced by replacing h_x in $\eta(h_x)$ with $\min(0,h_x)+b\max(0,h_x)$ and setting $b > 1$ if surface offsets are positive and higher velocities are favoured (Mulder and Van Leeuwen 2008).

Results

The method was applied to a marine seismic line, courtesy of Saga Petroleum A.S., now part of Statoil. The data were acquired above the Haltenbanken terrace, offshore Norway, where the sea bottom is fairly hard. The direct arrival through the sea water as well as multiple reflections were removed with the method described by Verschuur and Berkhout (1997). The coordinates in that paper were changed here, with x replaced by $(17200 - x)$ m, to have positive surface offsets. Figure 1 shows results after 20 iterations with an L-BFGS optimization algorithm. A section of the extended image at $x = 5.15$ km shows focusing of some events around zero subsurface offset h_x, but other events are not focused at all. With an asymmetric offset weighting function the results in Figure 2 were obtained, where now most of the high-velocity events are focused. Figure 3 displays velocity profiles along a well, where the reconstructed velocities are represented by cubic splines to impose some smoothness. The shallower part appears to have been improved by the bias.

Conclusion

Migration velocity analysis is highly sensitive to the presence of multiples, as demonstrated by a real-data example. A bias towards higher velocities improved the result in that case.

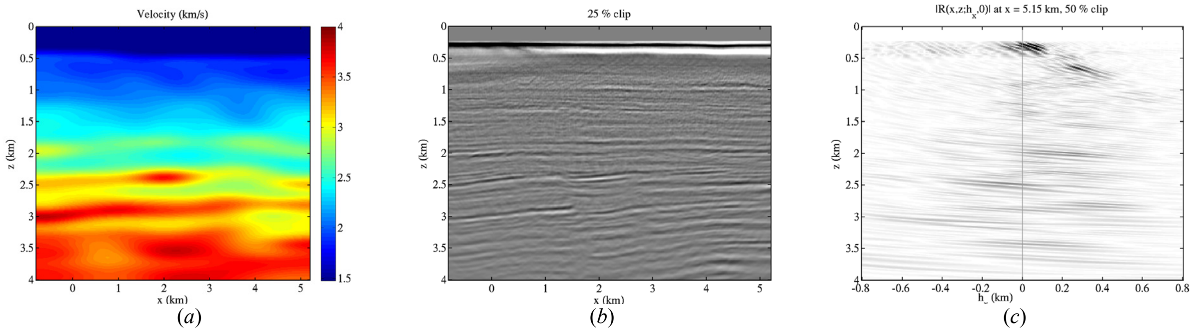

Figure 1 *(a) Velocity model after 20 iterations, (b) corresponding migration image and (c) amplitudes of the extended image at x = 5.15 km.*

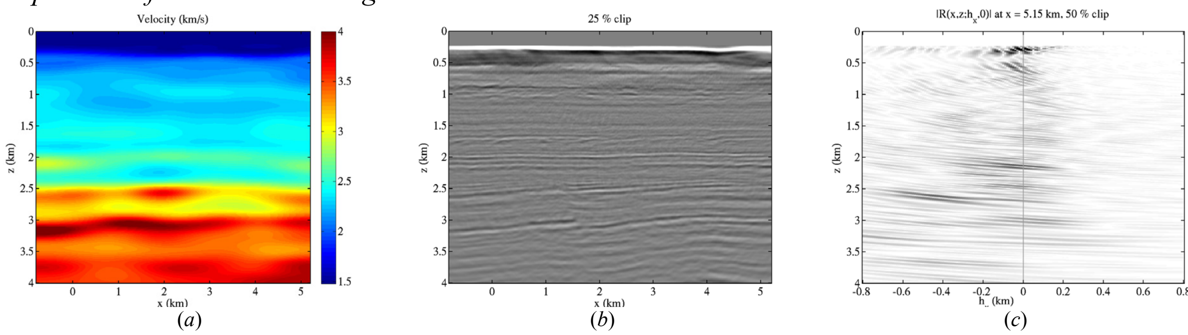

Figure 2 *(a) Velocity model after 20 iterations, using a bias towards higher velocities in the cost functional, (b) corresponding migration image and (c) amplitudes of the extended image at x = 5.15 km. The migration image is improved around 1 km depth.*

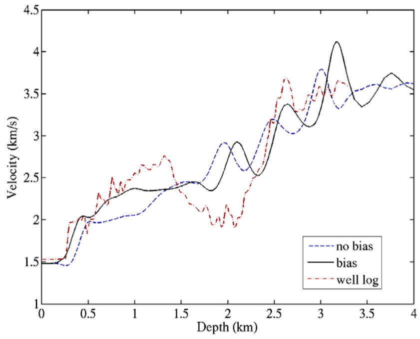

Figure 3 *Velocity at a lateral position of –475 m obtained without (blue dashed line) and with a bias (black drawn line) in the penalizing weighting function, compared to a velocity model based on a well log (red dot-dashed line) taken from the thesis by van Wijngaarden (1998).*

Acknowledgements

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References

Mulder, W.A. and van Leeuwen, T. [2008] Automatic migration velocity analysis and multiples. *SEG Technical Program Expanded Abstracts*, **27**(1), 3128-3132.

Mulder, W.A. [2012] Subsurface offset behaviour in velocity analysis with extended reflectivity images. *74th EAGE Conference & Exhibition*, Extended Abstracts, W019.

Shen, P., Symes, W.W. and Stolk, C.C. [2003] Differential semblance velocity analysis by wave equation migration. *SEG Technical Program Expanded Abstracts*, **22**(1), 2132-2135.

Van Wijngaarden, A.J. [1998] Imaging and characterization of angle-dependent seismic reflection data. *PhD thesis*, Delft University of Technology.

Verschuur, D.J. and Berkhout, A.J. [1997] Estimation of multiple scattering by iterative inversion, Part II: Practical aspects and examples. *Geophysics,* **62**(5), 1596-1611.