Land surface-related multiple attenuation based on wave-equation deconvolution

Gordon Poole, Brandon Li, Mattia Miorali, Keith Mills and John Tickle (CGG)*

Summary

Free-surface multiple prediction of land data is challenging due to the unknown downward reflecting free-surface combined with poorly sampled recording of the shallow multiple generators. We use a wave-equation deconvolution approach to derive an image of the shallow multiple generators using the multiple periodicity. The image is then used to model multiples which are subsequently subtracted from the input data. The approach adjusts to variations in the shallow subsurface and the multiple model requires minimal adaptation.

Introduction

Traditional free-surface multiple prediction approaches such as SRME (Berkhout and Verschuur, 1997) require multiple generators to be recorded as primaries, along with knowledge of the upper reflecting surface. For marine data, the upper reflecting surface may be approximated by the horizontal water-air interface, and long-period multiple generators are typically well recorded as primaries. For shallow water data sets, short-period multiple generators may have not been recorded at small enough reflection angles. In this case, they may be approximated by a Green's function (Wang et al., 2011) or through use of deconvolution-based approaches (Biersteker, 2001). For land data, a non-horizontal topography combined with an unknown and complex weathering layer reflecting surface means that the upper generator is not well known. In addition, land acquisition geometries typically result in shallow multiple generating layers being insufficiently well recorded as primaries. For this reason, deconvolution-based approaches are heavily used, but many surface-consistent approaches are 1D and do not fully respect the kinematic variations of reflection timings with propagation angle.

Method

We propose the use of a wave-equation deconvolution-based multiple prediction approach (Poole, 2019) for land data. The method involves two steps. The first step derives a least-squares reflectivity image of the shallow subsurface based on the periodicity of the multiples in the recorded data. The reflectivity image is akin to a time-space domain deconvolution operator but expressed as a depth domain image. In the second step, the image is used to predict multiples based on the approach of Pica et al. (2005). The resulting multiple prediction has high accuracy in terms of timing and amplitude, requiring only mild adaptive subtraction.

Results

The data example comes from a 2300 km^2 data set acquired in Algeria in 2019/2020 with a 210 × 30 m receiver spread and a 30 × 30 m shot density, resulting in a trace density of approximately 6 million traces/km^2 (Li et al., 2021). Prior to demultiple, these data were processed through denoise, statics corrections, and velocity analysis. The denoise flow addressed both random and coherent noise while retaining primary and multiple signals.

Wave-equation deconvolution imaging operated in the receiver domain and was run to 600 m depth. Figure 1a shows a migrated inline from primary imaging. The image is broken up due to the lack of short offsets and lacks lateral continuity. The same inline from wave-equation deconvolution, Figure 1b, exhibits an improvement in spatial continuity and a reduction of the acquisition footprint.

The wave-equation deconvolution image was used as input to the method of Pica et al. (2005), after which the corresponding predicted multiples were mildly adapted from the input data. Figure 2 compares near angle stack results of migrated data before and after the proposed demultiple approach, along with well synthetic QC. The results show a significant reduction in the level of reverberating short-period multiples, resulting in a good match with the well synthetic. The stack shows how the intermittent nature of the multiples, due to the variable near-surface, has been respected by the multiple modeling process, which results in improved lateral consistency of the section after demultiple.

Conclusions

We have demonstrated the effectiveness of wave-equation deconvolution-based imaging and a multiple modeling approach for land data. The approach derives a representation of the multiple generators in the image domain based on the periodicity of the multiples in the input data. The resulting image is used to predict multiples, which are then subtracted from the input data. The real data example shows a significant reduction in the level of reverberating multiples and an improved tie with the well synthetic.

Acknowledgments

We thank In Amenas JVGas (an association of Sonatrach, BP, and Equinor) and CGG for their permission to publish this paper.

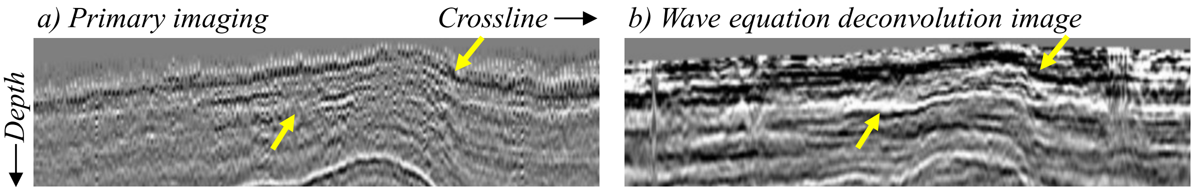

Figure 1) Inline comparison of: a) Primary imaging and b) Imaging from wave-equation deconvolution.

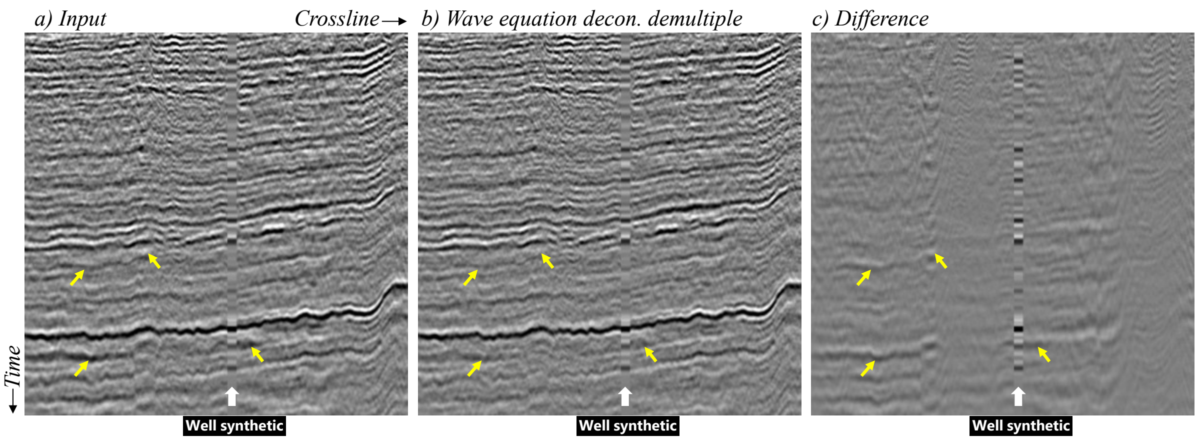

Figure 2) Near angle stack comparing: a) Before demultiple, b) After wave-equation deconvolution based demultiple, and c) Difference.

10.1190/image2022-3744945.1

References

Berkhout, A. J., and D. J. Verschuur, 1997, Estimation of multiple scattering by iterative inversion, Part I: Theoretical considerations: Geophysics, **62**, no. 5, 1586–1595, doi: https://doi.org/10.1190/1.1444261.

Biersteker, J., 2001, MAGIC: Shell's surface multiple attenuation technique: 71st Annual International Meeting, SEG, Expanded Abstracts, doi: https://doi.org/10.1190/1.1816335.

Li, B., M. Miorali, K. Mills, and G. Poole, 2021, 3D surface related multiple attenuation for land data using least- squares multiple imaging: PESGB PETEX Conference, Extended Abstracts.

Pica, A., G. Poulain, B. David, M. Magesan, S. Baldock, T. Weisser, P. Hugonnet, and P. Herrmann, 2005, 3D surface-related multiple modeling, principles and results: 75th Annual International Meeting, SEG, Expanded Abstracts, 2080–2084, doi: https://doi.org/10.1190/1.2148121.

Poole, G., 2019, Shallow water surface related multiple attenuation using multi-sailline 3D deconvolution imaging: 81st EAGE Conference and Exhibition, Extended Abstracts, Tu R01 05, doi: https://doi.org/10.3997/2214-4609.201900781.

Wang, P., H. Jin, S. Xu, and Y. Zhang, 2011, Model-based water-layer demultiple: 81st Annual International Meeting, SEG, Expanded Abstracts, 3551–3555, doi: https://doi.org/10.1190/1.3627937.