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Broadband Acquisition, Deblending and Imaging Employing Dispersed Source Arrays

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SUMMARY

During the last few years the importance of recording, processing and interpreting a wider range of frequencies has been highlighted with numerous field acquisition examples and case studies. A great effort has been dedicated in the recording of low as well as high frequencies for obtaining high resolution images. The ability to reduce the seismic wavelet's side lobes by recording lower frequencies and at the same time the increase of bandwidth has been proven as the main advantage of recording broadband data. The land seismic data used in this paper was acquired in Saudi Arabia by using an acquisition configuration based on a variation of the dispersed source arrays concept (Berkhout, 2012). During this seismic experiment we were sweeping three different frequency bands, namely, 1.5 to 8 Hz, 6.5 to 54 Hz and 50 to 87 Hz and with various sweep lengths, (Kim and Tsingas, 2014). In order to increase productivity the data were continuously recorded in a blended mode. In this study we outline a novel seismic acquisition survey which aimed for the optimum and efficient recording of broadband data without sacrificing data quality and we demonstrate the methodology employed for optimum broadband processing in terms of deblending, Full Waveform Inversion (FWI) and Reverse Time Migration (RTM) technologies.

Introduction

During the last few years the importance of recording, processing and interpreting a wider range of frequencies has been highlighted with numerous field acquisition examples and case studies. A great effort has been dedicated in the recording of low as well as high frequencies for obtaining high resolution images. The ability to reduce the seismic wavelet's side lobes by recording lower frequencies and at the same time the increase of bandwidth has been proven as the main advantage of recording broadband data. The land seismic data used in this paper was acquired in Saudi Arabia by using an acquisition configuration based on a variation of the dispersed source arrays concept (Berkhout, 2012). During this seismic experiment we were sweeping three different frequency bands, namely, 1.5 to 8 Hz, 6.5 to 54 Hz and 50 to 87 Hz and with various sweep lengths, (Kim and Tsingas, 2014). In order to increase productivity the data were continuously recorded in a blended mode. In this study we outline a novel seismic acquisition survey which aimed for the optimum and efficient recording of broadband data without sacrificing data quality and we demonstrate the methodology employed for optimum broadband processing in terms of deblending, Full Waveform Inversion (FWI) and Reverse Time Migration (RTM) technologies.

Deblending, Full Waveform Inversion (FWI) and Reverse Time Migration (RTM)

The individual blended shot records for the different frequency bands and sweep lengths were processed in order to reduce the crosstalk noise generated between the different sources. Figure 1, illustrates the proposed workflow used for the deblending application which was applied in various data domains. It is applied by a combination of multi-directional median filter and a sparse radon inversion.

The proposed workflow is divided into two parts. Part 1 mitigates the blending noise by applying the modified multi-stage median and radon filters and the sparse radon inversion which results in 'Output 1' in Figure 1. Part 2 is a restorative procedure for signal leakage in the de-noising process, which leads to 'Output 2' as depicted in Figure 1.
The different processes are applied to various data domains according to the blended noise characteristics. The first is the crosstalk noise removing part, which is implemented in Shot, CMP, and Offset domains and the second is the reconstruction of a residual signal via Radon sparse inversion in the Offset domain.

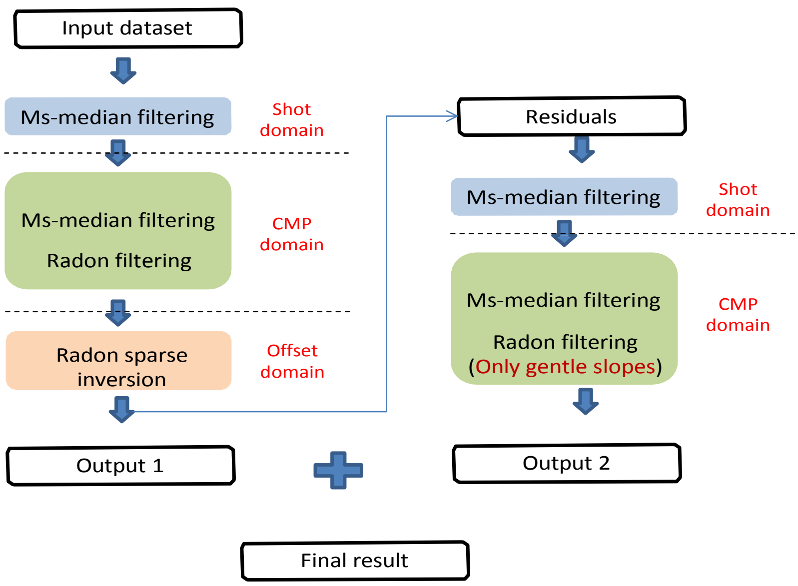
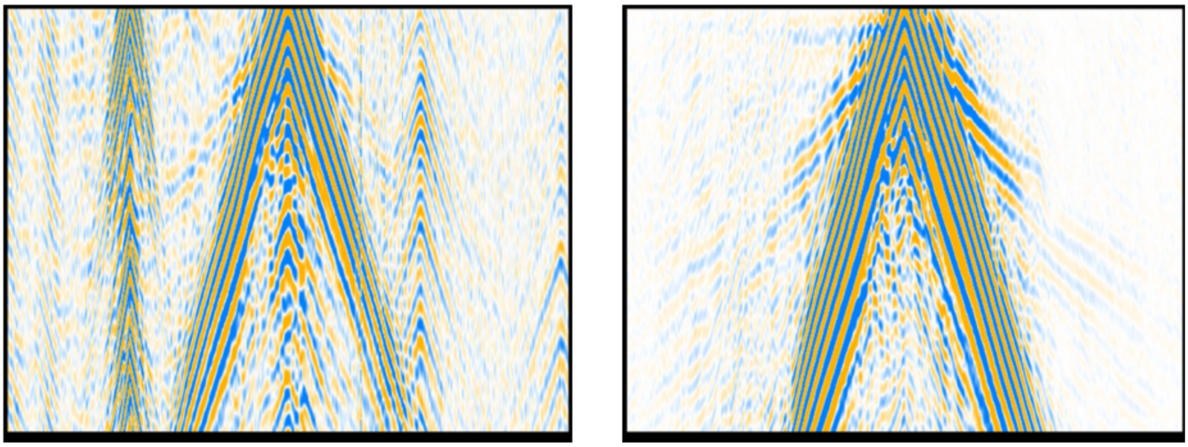


Figure 1 *Illustrates a typical workflow used to apply deblending in various data domains. It is applied by a combination of multi-directional median filter and sparse radon inversion.*

Numerical examples

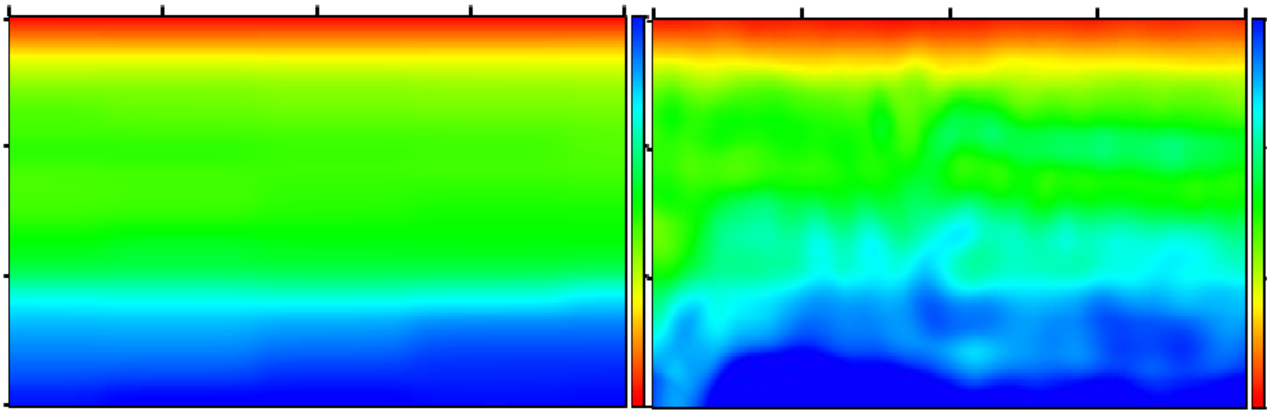
Figures 2a and 2b, show an example of blended and deblended shot gathers, respectively, after the application of the deblending workflow for the low frequency bandwidth data.



(a) (b)

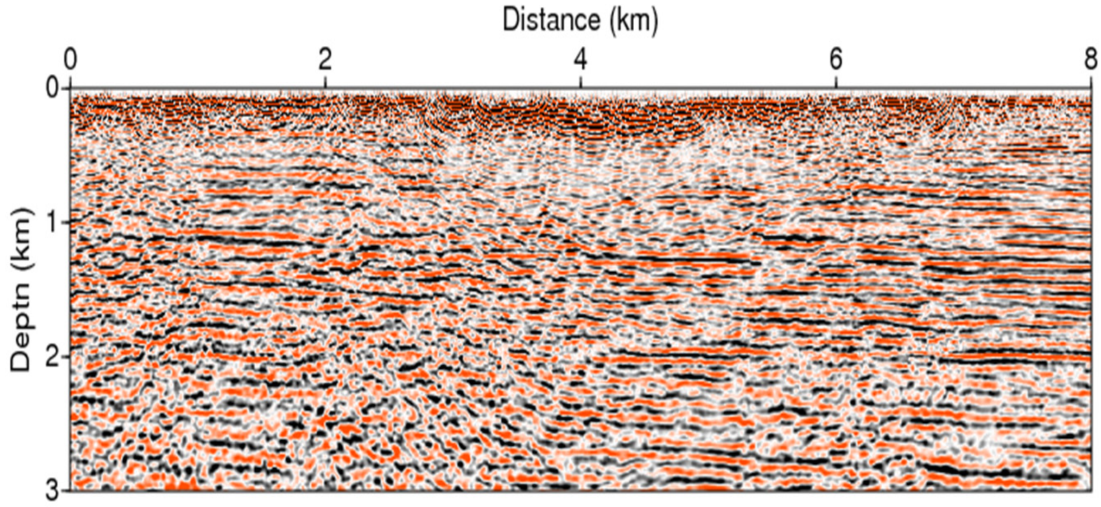
Figure 2 *(a) A low frequency bandwidth (1.5 to 8Hz) blended shot gather. (b) The corresponding deblended shot gather.*

Figure 3a show the initial velocity model employed for the FWI application. In order to assure convergence and avoid local minima during the inversion due to crosstalk generated noise, we used the low bandwidth (i.e., 1.5 to 8 Hz) deblended data. Figure 3b, depicts the final velocity model which was obtained by the FWI algorithm.

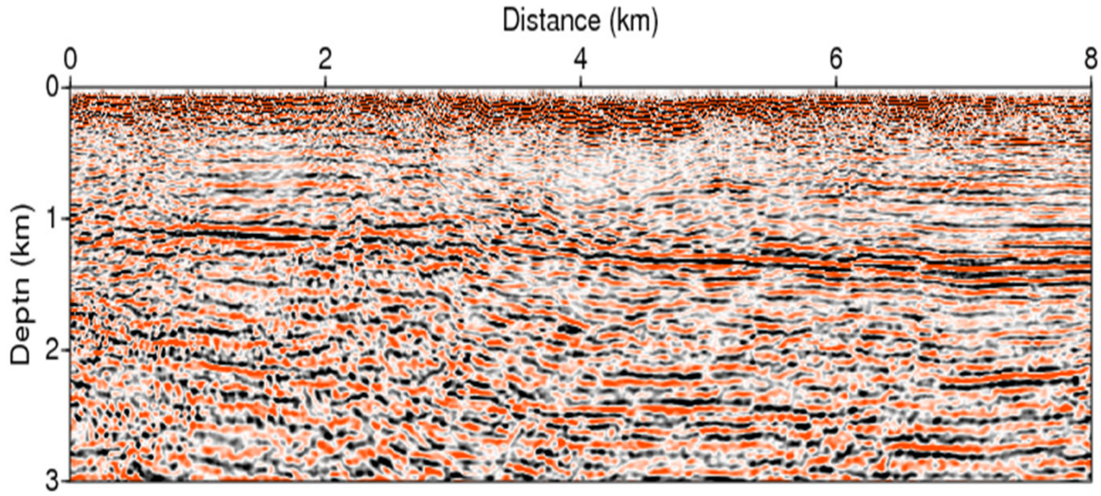


(a) (b)

Figure 3 *(a) Initial velocity model employed for the FWI. (b) Final velocity model obtained from FWI and using the deblended low bandwidth data (1.5 to 8Hz).*



(a)



(b)

Figure 4 *(a) RTM image obtained by using the initial velocity model shown in Figure 3(a).*
(b) RTM image obtained by using the final velocity model shown in Figure 3(b).

Figure 4a depicts an RTM section obtained using the middle bandwidth (6.5 to 54 Hz) and the final velocity model as depicted in Figure 3b. The amount of crosstalk and blended noise in the input data affects significantly the final RTM depth images. However, after applying the deblending procedure (as depicted in Figure 1), we obtained a remarkably cleaner depth section as is illustrated in Figure 4b.

Conclusion

We have presented an unconstrained and inhomogeneous blended field seismic survey for acquiring optimum broadband data. By implementing this type of blended acquisition we have established a procedure to employ narrow seismic frequency band sources fit for purpose for optimum field acquisition. We have also demonstrated the ability to perform various processing operations in order to obtain high resolution depth images and thus we have mitigated the effect of crosstalk noise between blended seismic sources.

Acknowledgments

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References

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