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A comparison of different 3D inversion approaches for deblending OBN data

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Abstract

High-dimensional (3D) FK*x*K*y* inversion is believed to enhance sparsity in the transformed domain, leading to improved deblending performance for simultaneous source data. While this approach has been demonstrated using streamer data, its application to Ocean Bottom Node (OBN) data remains less frequently explored. In this paper, we present two field data examples that clearly demonstrate the advantages of full-3D inversion over semi-3D approaches in promoting sparsity within the Fourier domain. Despite the potential for irregularities introduced in the additional cross-shotline direction, our results show that enhanced sparsity more than compensates for this, resulting in superior deblending outcomes.

Introduction

Inversion-based iterative methods have been widely used in deblending simultaneous source data to get a deblended model as if it were acquired with no interference (Abma et al., 2015 and Amin et al., 2021). A sparsity-promoting transformation is normally used in the inversion to help pick signals over noise as coherent events have larger amplitude than incoherent blending noise in the transformed domain. So, to have high-fidelity deblending, it is crucial to find a transformation by which high sparsity is achieved to the extent that it is easy to separate signals from noise.

In practice, several approaches are taken to improve sparsity in the transformed domain. Normal Moveout (NMO) or horizon flattening are used to flatten data and push up sparsity (Kumar et al., 2023). Sophisticated transformations such as Tau-P, Wavelet and Curvelet transformation are used to achieve high sparsity (Akerberg et al. 2008, Peng et al., 2006 and Qu et al., 2016). High dimension Fourier transformation (3D) and L1 Norm is another way to further boost sparsity while keeping the runtime at a practical level.

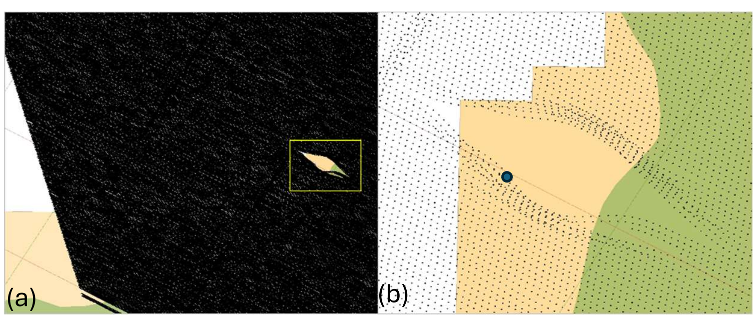

Figure 1: (a) **Project A** shooting geometry. (b) Closeup at the yellow box in (a). The blue dot marks a shotline at the nearest offset and it is right next to a void area.

As many examples have shown that 3D FKxKy transformation helps achieve high quality deblended model in deblending streamer data (Sun et al., 2022 and Chen et al., 2024), its power is not well demonstrated with OBN data (Kumar and Hampson 2020). For OBN data, deblending is performed in receiver domain, where the two horizontal dimensions are shotline and cross-shotline. On one hand having cross-shotline as the third dimension where blending noise is not coherent helps improve sparsity and therefore help deblending; on the other hand, the irregularity in cross-shotline direction may spread the energy across the spectrum and compromise the sparsity leading to suboptimal deblending result. This imperfect third dimension poses a dilemma in using full-3D Fourier transformation in OBN deblending. We use two field data examples hereby to clarify that full-3D inversion is clearly better than semi-3D in promoting sparsity despite the irregularity in the cross-shotline direction. Nonuniform FFT may be a better choice in honoring the FK spectrum. It is practically formidable, however, due to its computational cost.

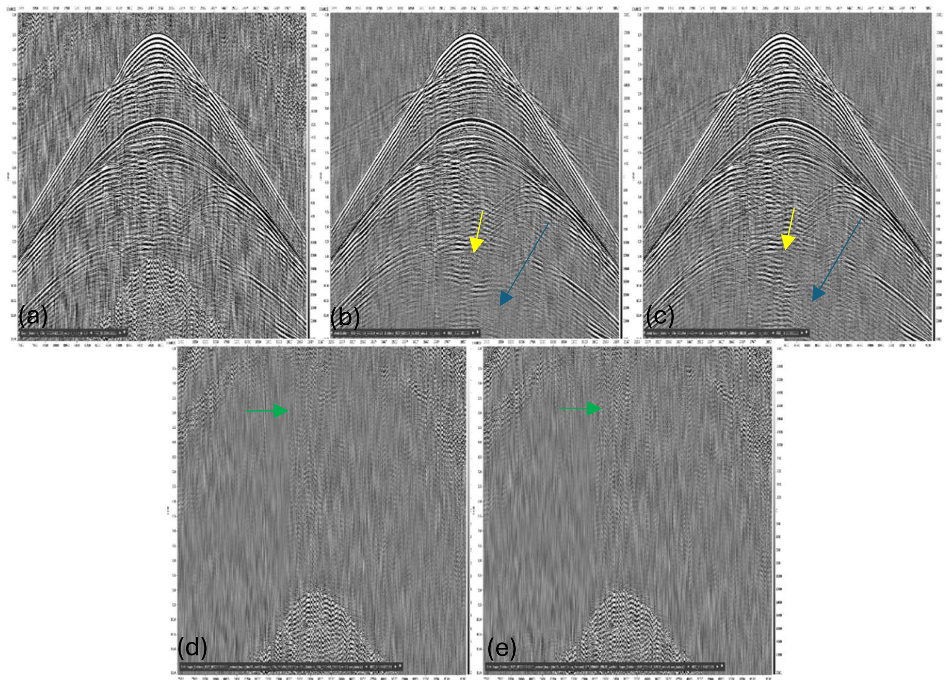

Figure 2: The sequence at the nearest offset in **Project A**. (a) Input (b) Deblended model with semi-3D method (c) Deblended model with full 3D method (d) Difference between input and semi-3D result (e) Difference between input and full 3D result.

Methodology

Semi-3D and full-3D Fourier transformation are used as sparsity-promoting domain in the frame of Iterative Shrinkage Thresholding Algorithm (ISTA) (Sun et al., 2022). The FKxKy components are thresholded to make the models for the next iteration.

The semi-3D method performs thresholding on each acquisition sequences. In the cross-shotline direction, therefore, the number of samples is just the number of sources. So, only few samples are available and therefore it is called semi-3D. The advantage of this method is that irregularity can be largely ignored as we only work on a single sequence. Memory requirement is lower, and runtime is much lower compared with full-3D method.

The full-3D method performs thresholding on the whole receiver gather, window by window. Therefore, in the cross-shotline direction, the number of samples is determined by the size of the window specified. The data is organized by first shotlines and then shots; the shotlines are aligned by their physical locations. The advantage is that the third dimension is fully used and promoted sparsity may overcompensate the energy spread-out due to irregularity in this dimension.

The horizontal windows are 17 by 17 for the full-3D method; whereas, 41 by 3 for the semi-3D method. Runtime for full-3D is 8 times larger due to high memory requirement.

Results

Project A is acquired in the Santos Basin, Brazil. Single shooting vessel with triple guns (flip-flop-flap) is used in the acquisition. Shotline spacing is 48 m and shot interval is 17.333 m.

Both methods are applied to this data, and we compare the results as follows. In Figure 1, we show the shooting geometry. The shotline marked by a blue dot at the lower edge of the acquisition hole is the one with the nearest offset and the corresponding sequence is shown in Figure 2.

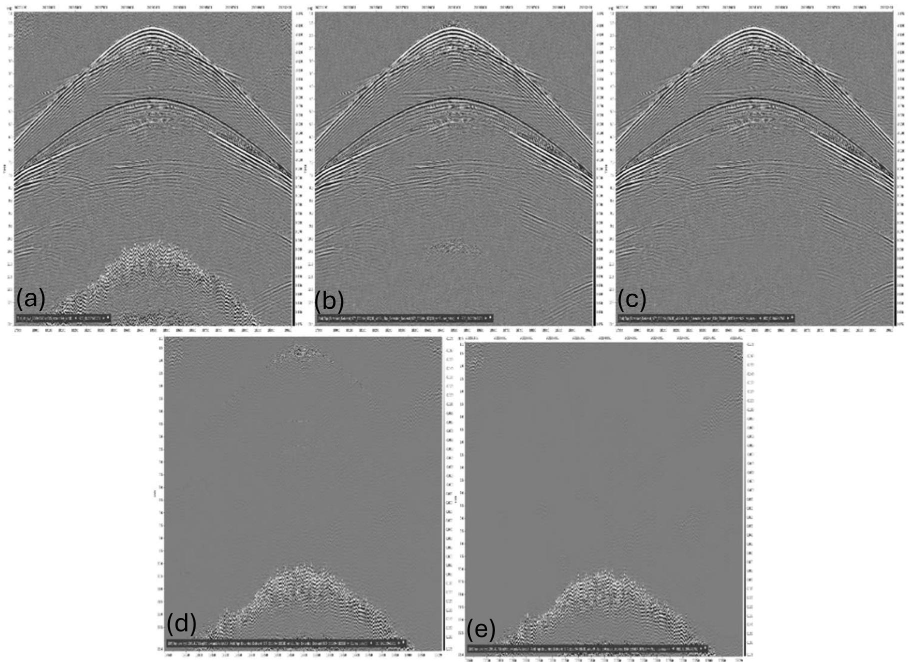

Figure 3: The sequence at the nearest offset in **Project B**. (a) Input (b) Semi-3D deblended model (c) full-3D deblended model (d) Difference between input and semi-3D result (e) Difference between input and full-3D result.

One would think this is a shotline that full-3D method might be challenged as there is a hole in the cross-shotline direction and strong irregularity at the edge of the hole. However, as in Figure 2, the full-3D method demonstrates its effectiveness and robustness through recovering the subtle events covered by the strong apex blending noise. Marked by the blue arrows, the full-3D method recovers more events; marked by yellow arrows, it doesn't have the high frequency blending noise seen in semi-3D model; and marked by green arrows in the difference figures, it removes more blending noise and preserves more primary signal.

Project B is also acquired in the Santos Basin offshore Brazil using single vessel with triple source (flip-flop-flap). The shot point interval is 16.67 m and the shotline spacing is 50 m.

In Figure 3, the deblending results of a shotline at the nearest offset with both methods applied are compared. The difference is clearly pronounced in both the deblended model and difference. Basically, full-3D does a much better job in modeling the apex area correctly without leaving high frequency blending noise.

Conclusions

We implemented two different FKxKy transformation schemes within the ISTA framework, namely, semi-3D and full-3D FKxKy transformation. They are applied to two different 3D OBN datasets acquired in the Santos Basin, Brazil.

It is clearly demonstrated that the full-3D method has an edge in capturing the apex with high accuracy over semi-3D and therefore removing the corresponding blending noise, which in turn helps preserve the weak and subtle events underneath the strong blending noise.

Acknowledgments

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