Seismic blending and deblending in 3D

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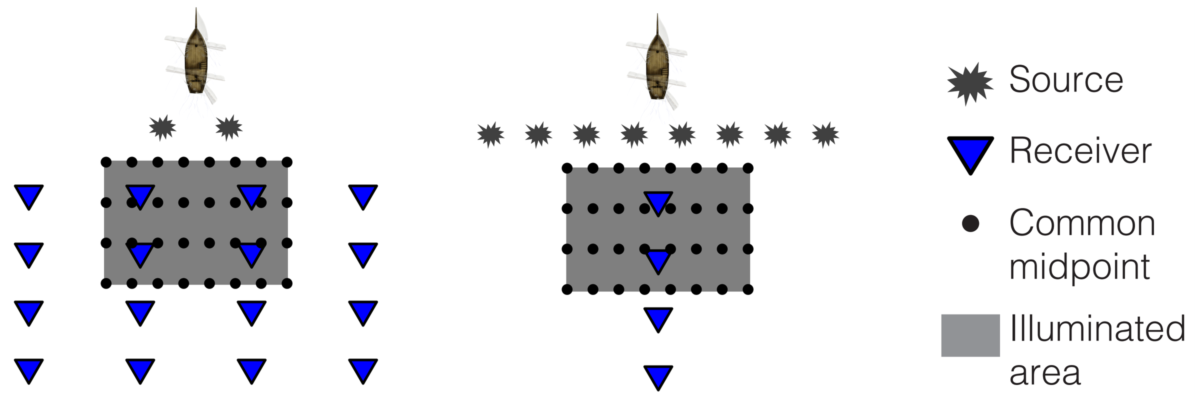
Advantage of (3D) blended acquisition?

We propose 3D blending for marine acquisition by blending sources in the crossline direction. This acquisition set-up allows to improve the source sampling in the crossline direction without requiring extra sail lines. In consequence the data quality is improved and/or the acquisition costs are reduced.

Blended acquisition set-up (3D)

Figure 1a shows a conventional acquisition design. The seismic vessel tows two sources and four streamers. The firing-time delay between the two sources is sufficiently long to avoid an overlap of the recorded seismic responses. The grey area indicates the midpoint coverage.

We propose the so-called crossline-source array in the center that uses multiple crossline sources. In this example we chose eight crossline sources and a single streamer. Thus, the crossline-source array covers the same area as the conventional acquisition design. In order to achieve a small inline and crossline source sampling while maintining an acceptable vessel speed the crossline sources are fired in a blended fashion. We optimized the firing-time delays between the blended sources (by optimal randomization) to facilitate the deblending.



1a) Conventional acquisition design

1b) Blended crossline-source array

Deblending method

Our 3D deblending method is derived from the 2D deblending method by Mahdad et al. (2011).

<u>2D Deblending</u>

1) *Pseudo-deblending*:
The blended data are copied and time-shifted. In a common-receiver gather of the pseudo-deblended data the signal of the aligned sources is coherent while the interfering sources are incoherent.

2) *Coherency constraint*:
The blending noise is attenuated in the f-k_x domain.

3) *Sparsity constraint*:
The blending noise is estimated by applying thresholding in the x-t domain.

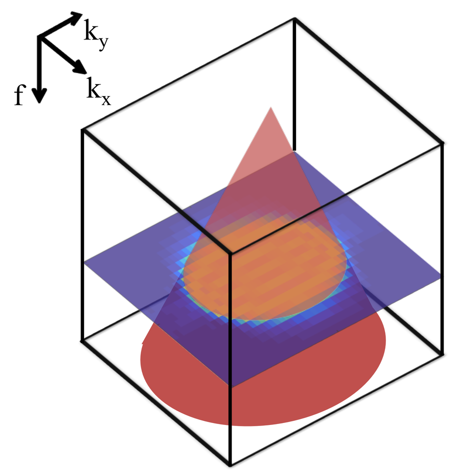
4) *Noise subtraction*:
The blending noise is subtracted from the pseudo-deblended data.

Iterate

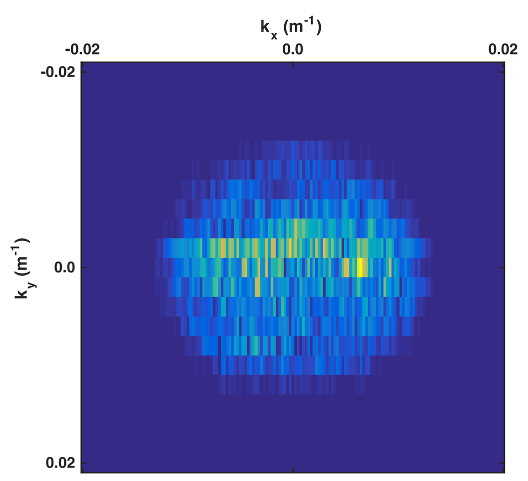
<u>3D Deblending</u>

We extended the deblending method of Mahdad et al. (2011) by using a 3D coherency filter in the f-k_x-k_y domain (see 2a). The 2D signal cone becomes a 3D cone. The unblended data in 2a and 2b illustrate that the coherent signal indeed maps in a 3D cone the f-k_x-k_y domain.

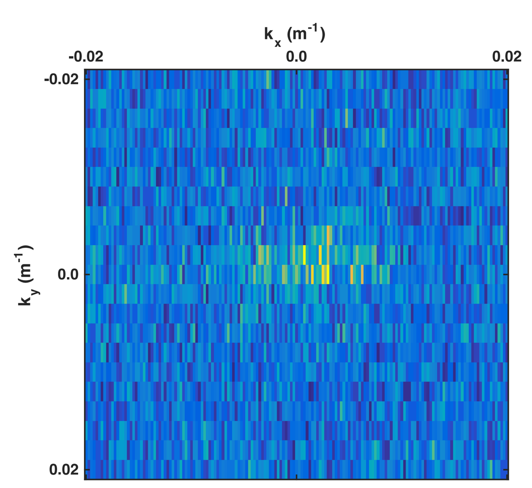
The 3D coherency filter suppresses the blending noise in the pseudo-deblended data (see 2c) more efficiently than a 2D filter. Figure 2d compares the 2D coherency filter (grey) with the 3D coherency filter (white) in the k_x-k_y domain. Since the 3D filter (white) is smaller than the 2D filter (grey) it suppresses the blending noise more efficiently. Reinicke (2015) demonstrated that the 3D coherency filter enhances the deblending result.



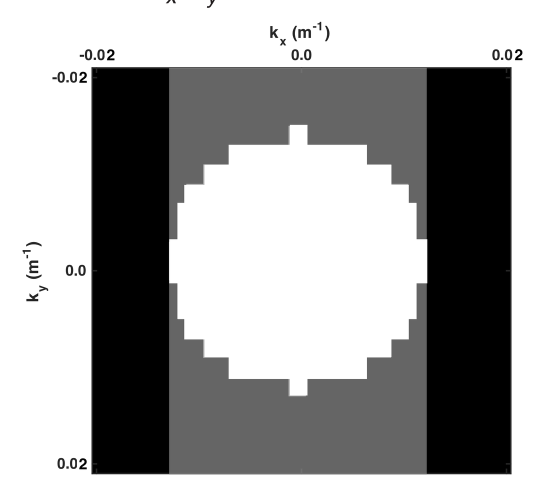
2a) 3D f-k_x-k_y cone



2b) Unblended data slice in the k_x-k_y domain



2c) Pseudo-deblended data slice in the k_x-k_y domain

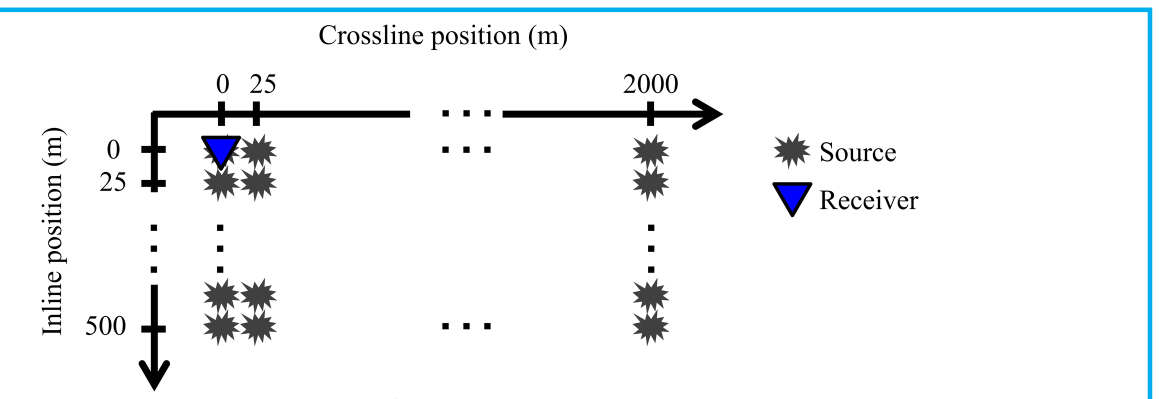


2d) 2D and 3D coherency filter in the k_x-k_y domain in grey and white respectively

Results on complex synthetic data

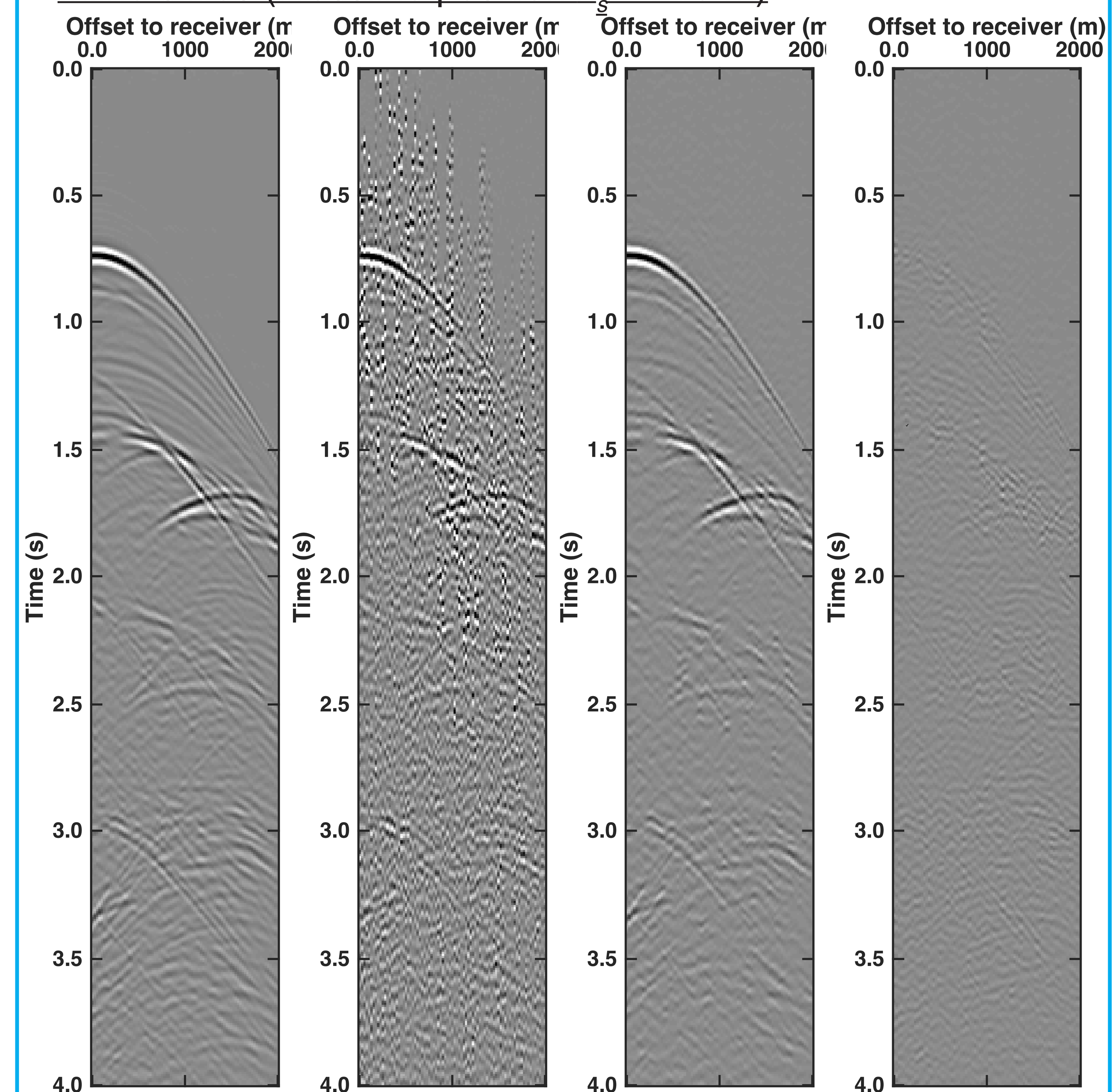
The data example is extracted from an unblended SEG SEAM dataset. The data are modelled with a source grid of 21 sources along the crossline direction and 81 sources along the inline direction (see Figure 3). The source spacing is 25 m in both directions. Since the presented deblending method is applied in the common-receiver domain it is sufficient to consider a single receiver position; we consider the one that is placed in the left upper corner of the source grid.

The sources are fired crossline-wise, i.e. first all sources of crossline one are fired, next, all sources of crossline two, etc. The 21 shots within each crossline are numerically blended in three seismic experiments, i.e. there are seven shots per experiment. The firing-time delays between the blended shots are optimized according to Reinicke (2015). Figure 4 shows an inline slice of the (a) unblended, (b) pseudo-deblended, and (c) deblended receiver gathers at the inline position x_s = 250 m. Figure 4d illustrates the misfit between unblended and deblended data.



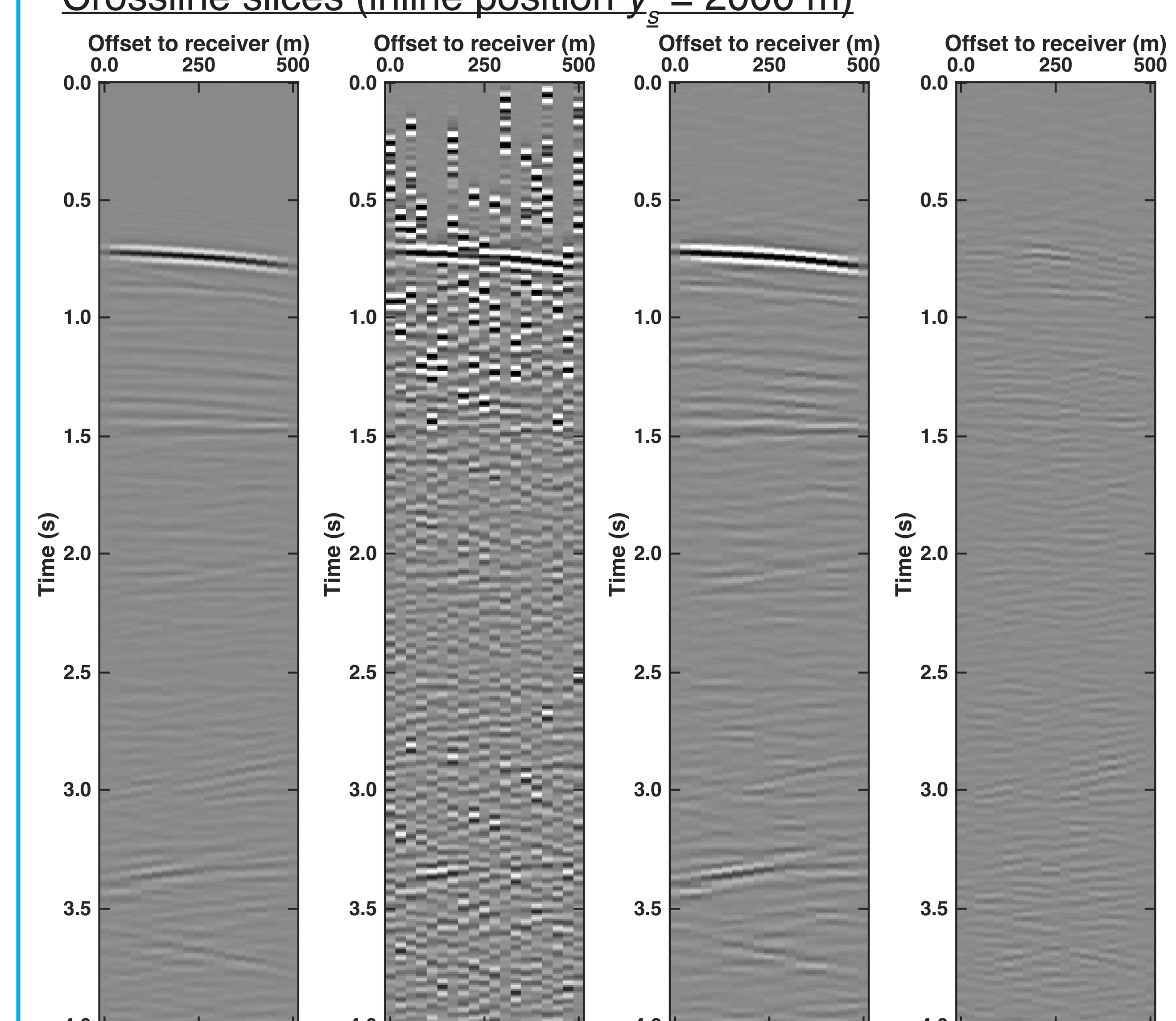
3) Source grid

<u>Inline slices (crossline position x_s = 250 m)</u>



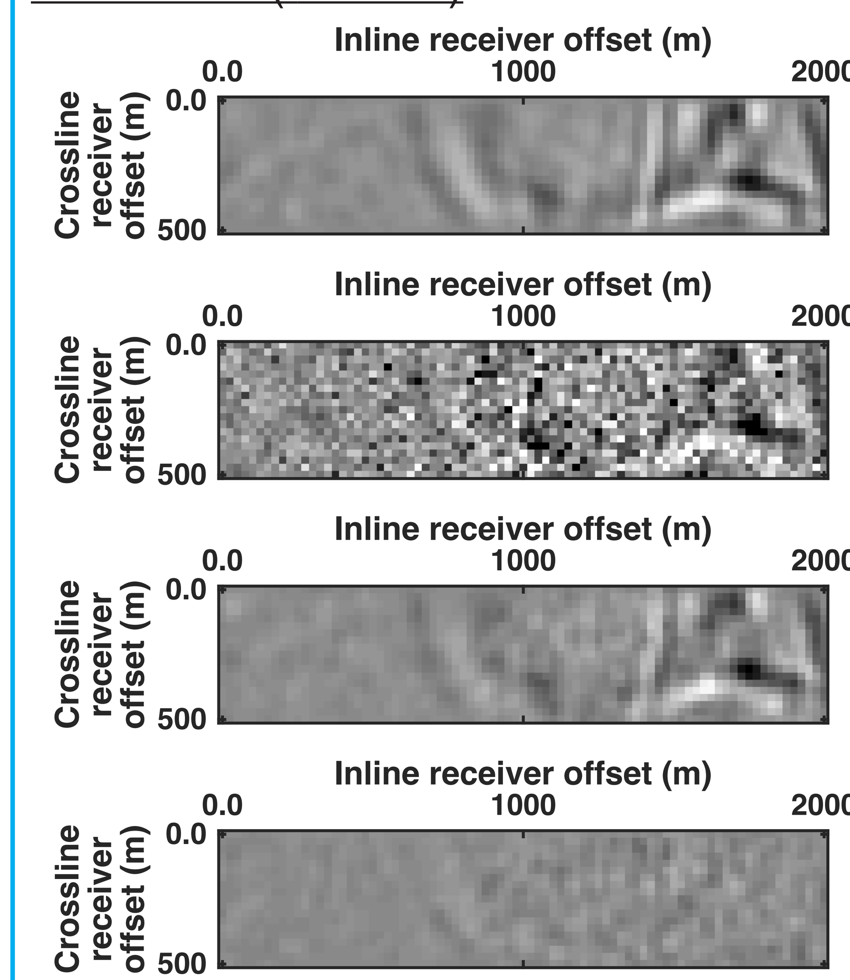
4a) Unblended **4b)** Pseudo-deblended **4c)** Deblended **4d)** Misfit

<u>Crossline slices (inline position y_s = 2000 m)</u>



5a) Unblended **5b)** Pseudo-deblended **5c)** Deblended **5d)** Misfit

<u>Time slices (t = 1.8 s)</u>



6a) Unblended

6b) Pseudo-deblended

6c) Deblended

6d) Misfit

In analogy Figure 5 illustrates crossline slices at the inline position ys = 2000 m. Figure 6 displays time slices through t = 1.8 s of the data. A comparison of the unblended and deblended data demonstrates the strength of the 3D deblending method. The quality factor (a measure similar to SNR, Ibrahim and Sacchi, 2015) is used to rate the deblending performance of our method on the SEAM data with 14.2 dB, a very good result.

Conclusions

We have successfully demonstrated deblending in the case of a numerically blended crossline-source array configuration, using the SEAM data. The good deblending results demonstrate the feasibility of blending and deblending in 3D.

The benefit of 3D blended acquisition is two-folded; it enhances the data quality and reduces the acquisition costs. The presented 3D deblending method takes advantage of a coherency constraint of the data in the f-k_x-k_y domain, in contrast to 2D deblending methods, which only use coherency constraints in the f-k_x domain.

References

Mahdad A., Doulgeris P., and Blacquiere G., *Separation of blended data by iterative estimation and subtraction of blending interference noise*, Geophysics, vol. 76, no. 3, pp. Q9–Q17, 2011.

Ibrahim A. and Sacchi M. D., *Fast simultaneous seismic source separation using Stolt migration and demigration operators.*, researchgate.net, 2015.

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